Rhine-Waal University of Applied Sciences
Faculty Communication and Environment

Interdisciplinary Project

Scientific Visualization and Animation

Project documentation
WS 2018/ 2019

Interdisciplinary Project 17
Prof. Dr. Frank Zimmer, Nicolas Fischöder

Kamp-Lintfort, February 8th, 2019

Table of contents

1 Introduction

The given task was to create an animation showing the future development of the sun and the earth. The animation should start at the current time and end at the point of time, where the Sun as we know it today, ceases to exist and transitions into a planetary nebula. The simulation should show the transition of the Sun from its current status, to its increase in luminosity and size, to becoming a red giant, a white dwarf, and finally a planetary nebula. In addition, changes caused by that on the earth should be shown in the simulation.

The task stated above was the content of an interdisciplinary project, where students from different study programs work together on the same project. Each bachelor degree student of the Rhine-Waal University of applied sciences chooses and participates in a interdisciplinary project in the fifth semester. The participants of this interdisciplinary project are predominantly students from 'Medien und Kommunikationsinformatik', but also from the courses of 'E-Government', 'Communication and Information Engineering', 'Digital Media' and 'Environment and Energy'. The diverse backgrounds were taken as an invitation to split the participants into two teams; One for research and one for graphics. The research team was responsible for finding the relevant data and presenting it to the graphics team to discuss together what happens, what is important to animate, how detailed it should be and what elements needed further research. The graphics team used the open source Blender program to create the individual elements and later on put them together in scenes.

2 Project Management

Antonio Sarcevic was voted as project lead on the 08.11.2018. A discord server was created to ensure that everyone in the group can communicate with each other. Trello is used as a kanban board to organize incoming tasks and multiple Google Drive files were created to track progress of the team and record the time spend on the project.

2.1 Choosing a communication platform

The goal is to work on a task as a team. For that, it is highly important to have a platform where everyone is able to participate. Before selecting a platform, it is important to think about the features that the platform requires.

The following features are needed:

- Free to use
- Intuitive installation, configuration and usage under Windows, macOS and Linux
- Textchat and voicechat (+ Screenshare)

- Creation of different text channels (and categories) to keep everyting organized
- (Free app for Android and iOS)

After a short discussion we find a platform that features all the required functions and is already used by some of the members of the team: Discord. Discord is an "'all-in-one voice and text chat [...] that's free, secure, and works on both your desktop and phone.'" (Source: https://discordapp.com/, Last opened: 10.11.2018, 1:45pm)

2.1.1 Installation of Discord

The installation of Discord is on all platforms the same. First, the user needs to download the installer from https://discordapp.com/download. After that the installer needs to be started. Discord will install and configure all required settings on its own. The last step to take is to create an account at https://discordapp.com/ so the user can log into the client. After that, Discord can be used in its full extent.

2.1.2 Configuration of the Discord server

One of the main features of Discord are servers. After the installation of the Discord client, it is possible to create a new server or join an existing server. In our case we create a new server that is primarily used for the communication about the interdisciplinary project.

Figure 1: Creating a Discord Server

The server requires different text channels to organize the general communication. For that, the channels "'general'", "'meetings'" and "'documentation'" are created. As the tasks have been split within the group, two more main categories were created. They were named "'Research'" and "'Graphics'".

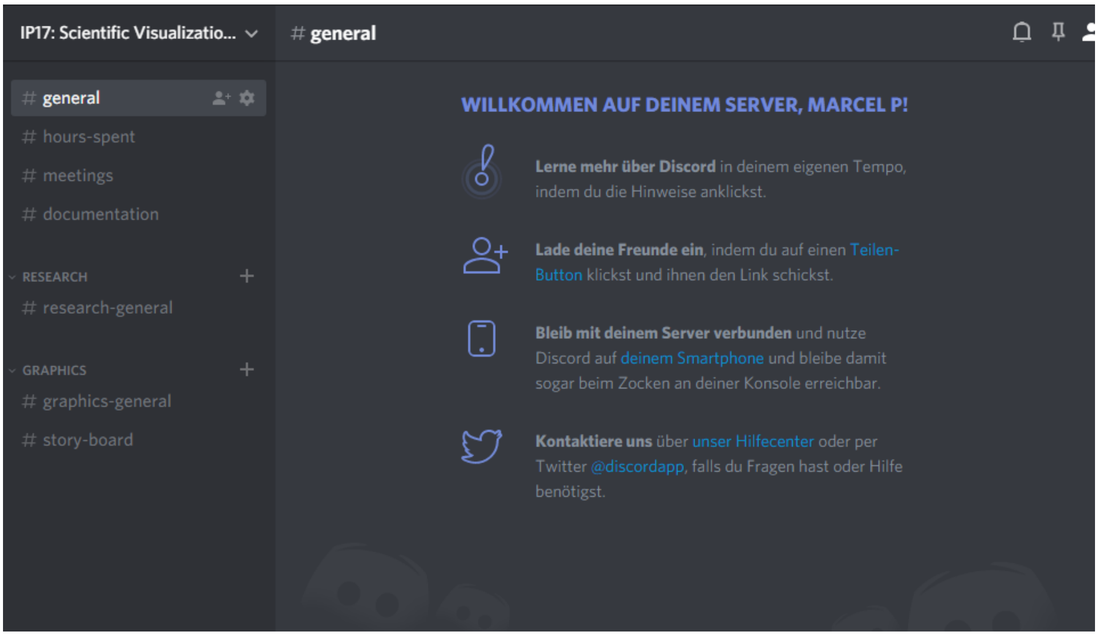

Figure 2: Screenshot of the Discord Server

At the end the participants of the project need to be invited into the server using an invite-link. After the people joined the server the clients have been sorted into different groups/ roles:

- Projectmanager
- Research
  - Space
  - On-Earth
- Graphics
  - Space
  - On-Earth
- Premiere Pro

2.2 Using the online kanban board Trello

In order to distribute the work packages accordingly, it was decided to use a Kanban Board. In past projects, the Trello platform has proven successful, so it was decided to use on this project as a tool for controlling work packages.

2.2.1 Creation of the basic structure

For the basic structure the following categories were chosen:

Product Backlog

Here you will find all open (planned) work packages

To Do (Sprint)

All work packages that must be completed within the current sprint are located here.

In Progress (Sprint)

This contains all work packages that are currently being processed in the current sprint.

Done (Sprint)

Located here are all work packages that were completed during the sprint but not yet discussed during a meeting.

Done

Located here are all work packages that have been completed and discussed during a meeting.

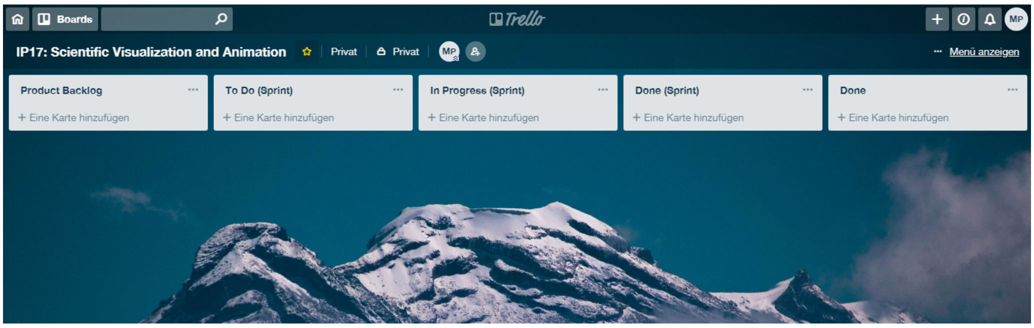

Figure 3: Trello board basic structure.

2.2.2 Creating the first work packages

The concept of Trello (and Kanban) is based on creating work packages which are then labelled and place into different categories according to their status. For this purpose, the first (general) work packages are created and assigned to the corresponding project subgroups. All newly created work packages are labelled "Product Backlog" and sorted into the appropriate category according to the development of the project.

In addition, tasks which will be completed by the upcoming meeting are added to the "To Do (Sprint)" list, .

2.3 Creation of a Google Spreadsheet to record the required time

In order to be effectively track the work steps and to summarize them in the final documentation, a spreadsheet was created to record the required working time per sprint, per participant in the group.

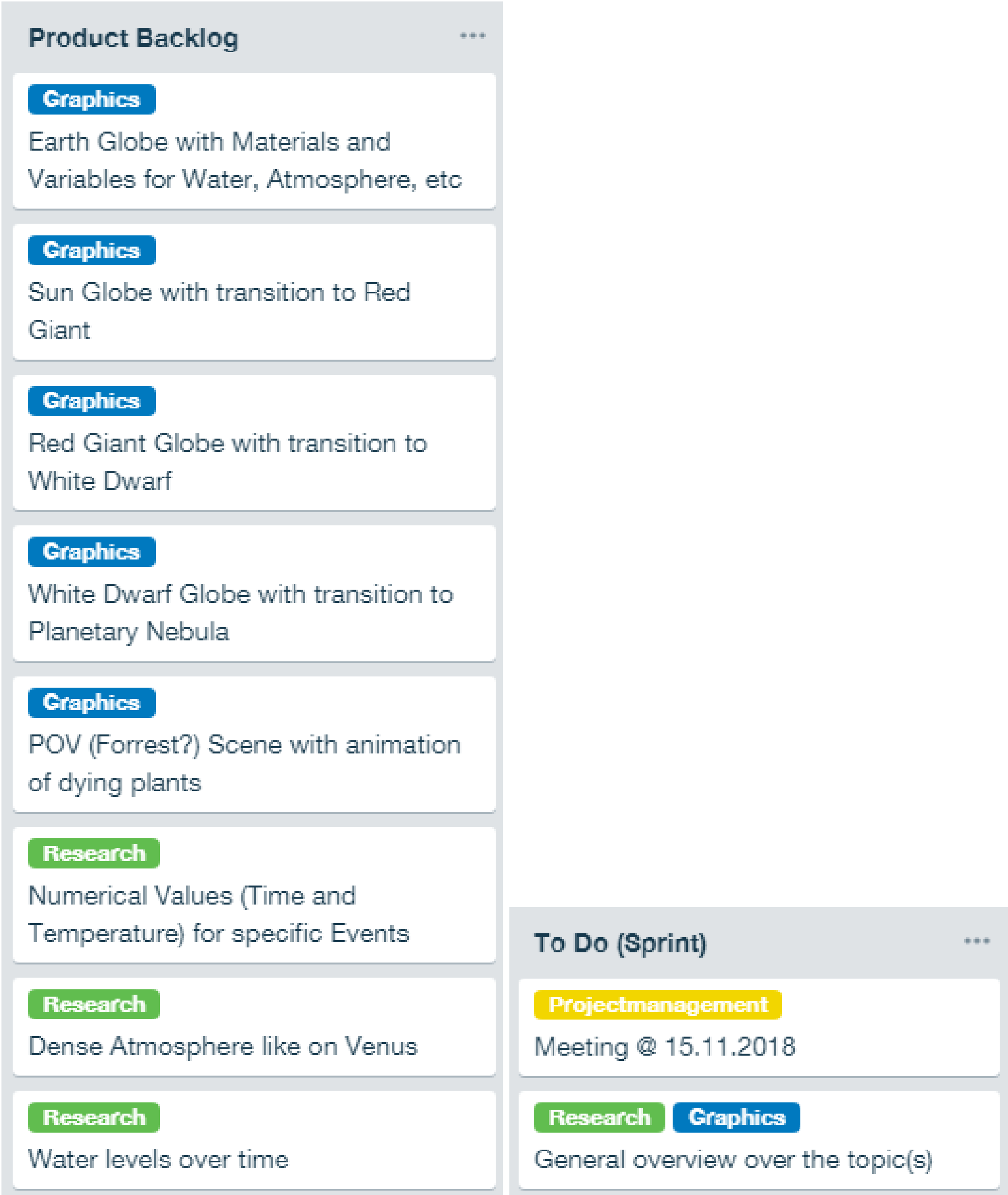

Figure 4: Trello-Board, first work packages in the "Product Backlog" and the "To Do (Sprint)".

Team Member	Total	11.10.2018 - 17.10.2018	18.10.2018- 24.10.2018	25.10.2018 - 31.10.2018	01.11.2018 - 07.11.2018	08.11.2018 - 14.11.2018
Angela	0					
Anna B.	0					
Anna K.	0					
Antonio Sarcevic	17	4		4	4	5
Daniel A.	0					
Dustin Koschmann	16	4		4	4	4
Laura	0					
Leonie	0					
Lucas Osten	0					
Majda Suljanovic	16	4		4	4	4
Marcel Paturej	16	4		4	4	4
Max	0					
Mike	0					
Panagiotis Tsitsos	16	4		4	4	4
Sebastian Golks	0					

Figure 5: Google Table "'IP17: Hours spend"'.

Once the file was created, the link was sent to the group participants, who were asked to enter their working times, as otherwise the project manager would not have the necessary information on attendance and activity for all of the participants.

3 Blender

Blender is a free and open source 3D graphics software with the features to create models, animations, visual effects and simulations. The biggest advantage is that there is a large online community with many tutorials and forums to help new Blender users to get started. Moreover, there are multiple unofficial builds that can be used if a specific feature is required.

3.1 Cycles renderer

The 'cycles renderer' is a physically-based renderer (PBR), that is an included component in Unity. Cycles has two features that are extremely helpful for the project. The first feature is the GPU renderer, which significantly improved the time required to export a frame. The second useful feature is the node editor that can be used to customize the details of a texture.
To use the cycles renderer you need to switch from the default option "Blender Render" to "Cycles Render" in the drop-down box located at the top of the program. This enables further settings. Next, it is recommended to switch the render device from "CPU" to "GPU Compute", as rendering using the CPU is usually slower than the GPU device. If it is grayed out, you have to open the "User Preferences" (Ctrl+ALT+U), switch to the tab "System" and set the "Cycles Compute Device" from "None" to "CUDA" and select your GPU.

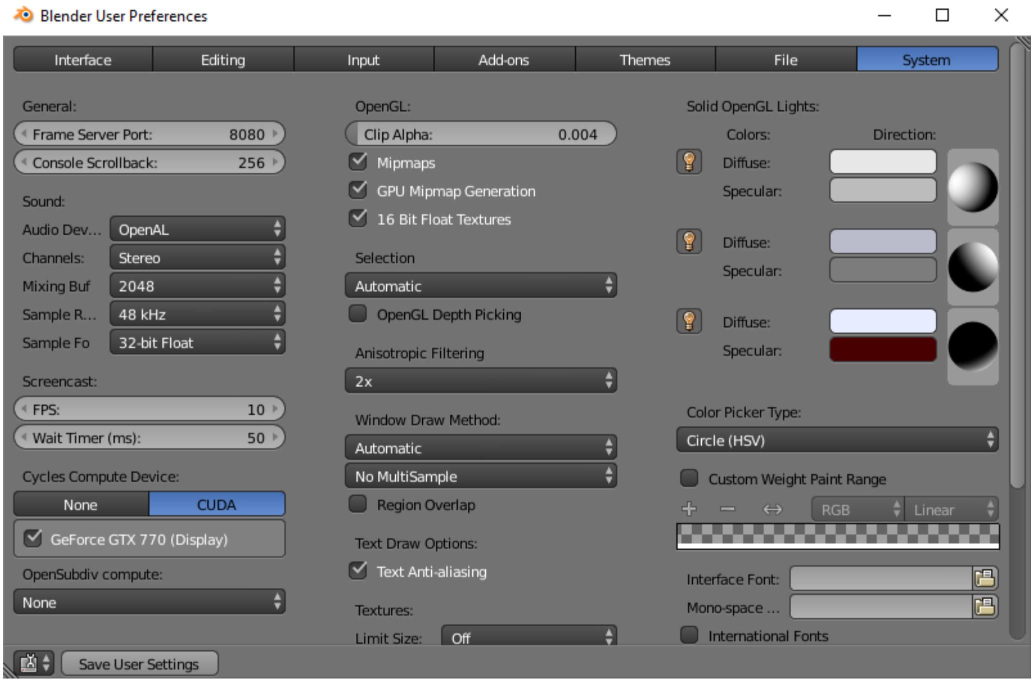

Figure 6: Configure Blender (Cycles renderer) GPU Compute Device

3.2 Introduction into Blender

During the course of the interdisciplinary project, meetings were held at regular two-week intervals, with some extra meetings scheduled in-between. During these meetings, the students were introduced to the Blender software, and provided with some basic tutorials on how to use. The goal of these tutorials was to get a feeling for creating a first fictitious model of a globe with the help of the Blender node editor and to exchange it with real continents and oceans towards the end of the introduction.

4 Summary of the simulation

The simulation starts in the present-day with a fly-by of the earth showing the actual state of the planet. The Sun can be seen in the background. As time progresses, the greenhouse effect get stronger, and the climate on earth becomes more extreme. This is animated by a close-up of Earth's surface showing strong rain and forest fires as examples of these conditions. The shift of the climate zones is visualized in the next scene from a viewpoint in space which shows the climate zones enlarging towards the poles. By 2050 the arctic and antarctic are expected to be ice free in summer. To represent this visually, the next scene is a split screen. One half shows a close up of melting ice, viewed from Earth's surface, and the other half shows Earth from space to visualize the rising sea levels. As the luminosity of the Sun increases, the surface water of the Earth heats up and starts to boil and evaporate. This occurs around 1 billion years in the future. The evaporation of the water leads to further reactions in the atmosphere that change its composition. This results in a dense, Venus-like atmosphere which is shown from space. Eventually, the loss of Earth's magnetic field leads to the loss of its atmosphere, leaving a brownish planet. For the next part of the simulation the focus shifts to the sun, which continues to grow in size and change colour. It progresses from white, to orange, and then to red while also increasing in luminosity. This all occurs as the sun progresses to a red giant. It continues to undergo various changes, including helium ignition and eventually hydrogen-exhaustion, as it progresses toward the end of the asymptotic-giant-branch, whereupon its core collapses into itself and becomes a white dwarf. While this is happening, its outer layers float away into space and form a planetary nebula, made visible with the help of radiation emitted by the white dwarf.

5 Storyboard

Before initial research had begun, a simple storyboard was created to help visualize an overview of the project as well as to begin an exchange in the group as to what key points needed to be visualized, and how to best represent them. The first draft of the storyboard was created using free stock photos and altering them with photo editing software to achieve the desired look. Color changes were achieved by selecting the desired area to isolate, or selecting a specific color range, and then altering the color by either adjusting the color balance or using the replace color option if available. For the magma effect on the earth, a lava texture was placed on the layer above the earth and cut to the be the same shape as the earth. The layer was then set to overlay and some erasing of key areas was done to get the desired look.

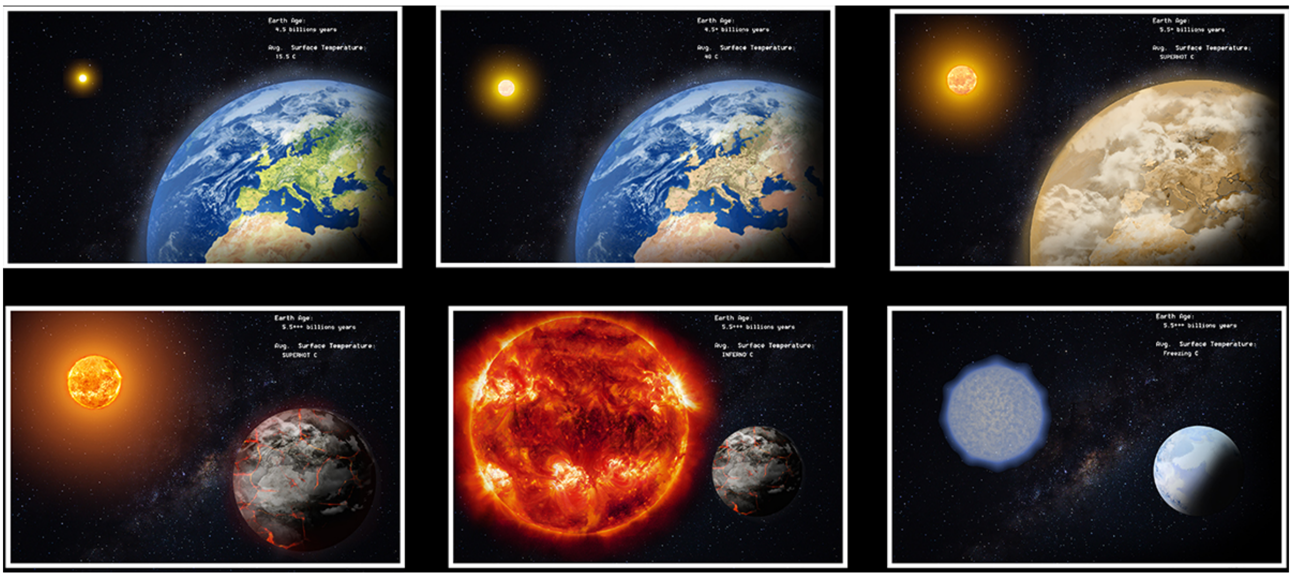

Figure 7: First draft of storyboard

After research had been completed, a final storyboard was created to document the timeline of the animations and highlight key points, allowing the graphics team to easily visualize what needed to be modelled, and how the changes of the earth and sun would appear. As was done in the first version, photo manipulation was used to visualize the project, and to keep the ideas as clear as possible and close to what the final product would resemble. Fire and steam effects were created using free Photoshop brushes found on brusheezy.com and altering their opacity to generate the desired effect. Some further research needed to be conducted, in order to fill-in visual gaps. This made the final version of the storyboard as clear as possible for the graphics team. After the visual elements of the storyboard were confirmed by the research team as correct, time frames were calculated for each scene and important dates added to give an idea of how fast transitions should occur.

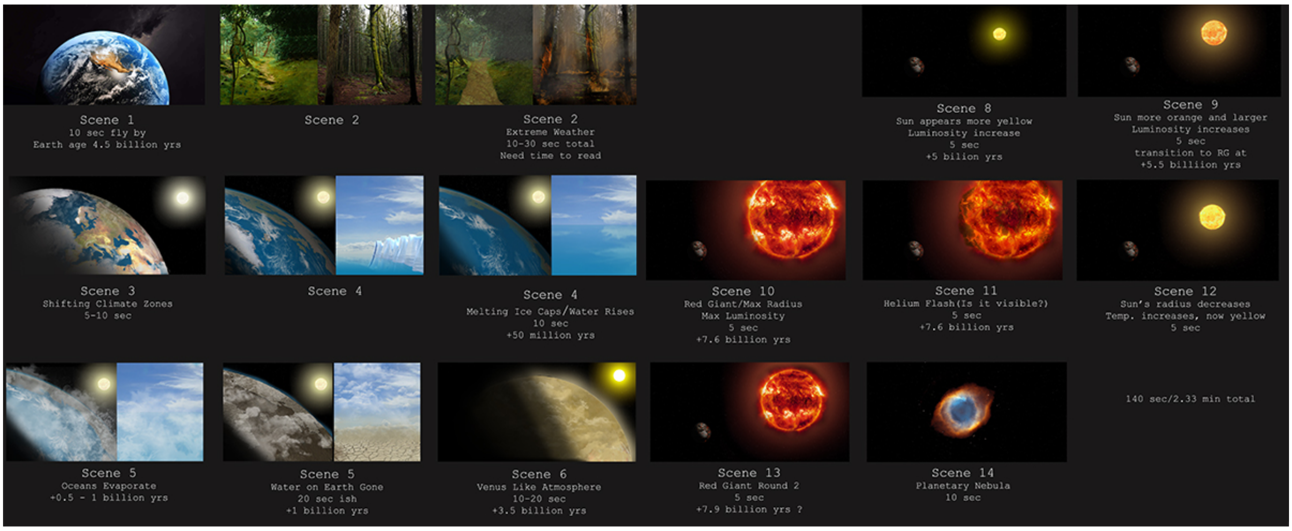

Figure 8: Final storyboard

6 Scene 1: Intro

For the first Scene, the earth is shown in its current state as a camera sweeps around the planet.

6.1 Research

The scene's starting point is set in 2018 where the earth is roughly 4.5 billion years old and has a average surface temperature of 15 °C. Global greenhouse gas emissions have lead to a man-made climate change, which is on the verge of determining the future development of the planet. The Sun is roughly 4.6 billion years old, shines at a luminosity of 1°L and has a surface temperature of 5778 °K. The scene is supposed to work as an introduction to the project and therefore shows the initial state of the Earth and the Sun to give the watcher a reference image. The scene shows no changes on Sun or Earth. The short time frame was chosen, because the scene is only supposed to give an overview of the initial conditions, before the visible changes begin to occur.

6.2 Animation

Based on the tutorial, we arrived at a good-looking non-modular earth. The nodes and settings must be edited to get a modular version, where we can tweak and adjust different values and textures for our task. The first step is figuring out exactly what we want to modify and how it should be done. We decided to use node-based 3D animation, so that these nodes could be used for further modifications.

6.2.1 Working in Blender

The upcoming explanation presupposes that you are familiar with the basic Blender settings and that you have at least some experience. The basic components and compositing settings are from a tutorial. We used the tutorial as a base and carried on adding features to our scene.

6.2.2 How to create the Earth and what to consider

At first, it should be mentioned, that the majority of the project participants had never used blender before, so a lot of trial and error was necessary. The first step was to look up some tutorials or any guides based on the task. We also went back and forth between blender Internal and cycles because we found out, that we could produce similar quality with less render time. However, we finally decided to stick with cycles because of the fantastic node features. The tutorial we decided to start working with had the following features:

- An easy texture mapping for spheres
- A way to use maps to make more convincing materials
- Possibilities to create a realistic sun flare entirely in Blender

It also showed us how to add glow, color grading and a warp effect in the compositor. We wanted a model of the earth that is cinematic, realistic, and has the following properties:

- Spectacular oceans
- Volumetric clouds
- Atmospheric effects such as a Rayleigh Scattering and halos
- Real displacement if close-up on mountains
- Looks good from any angle or distance
- fast to render

Creating a planet in Blender is not difficult, however, making a modular and visually-appealing planet is difficult. Therefore it's important to plan properly in order to ensure the planet fits your project or future work. By following the tutorial, we realised that we can achieve a good-looking Earth with a good base-setup, that we can use to create the scene we want. If you don't want to start from scratch, it's highly recommended to follow the tutorial. The first step is figuring out what we need and what do we want to change. We decided to use different Earth textures and less compositing, in order to avoid a sci-fi looking earth, as our task requires a realistic-looking model.

The first step after finishing the tutorial is to switch to the Node editor and click the red marked button to access the compositing nodes.

Figure 9: Compositing Node-editor.

Open the red marked node by selecting it and using the TAB-key on your keyboard to go into the node (You can also use the same key to get out of the node). The node structure is based of the tutorial, making use of the optional feature that allows one to group (or un-group) nodes. It's recommended to group nodes if you plan to use a specific node structure several times. You can label and colour them for better organisation.

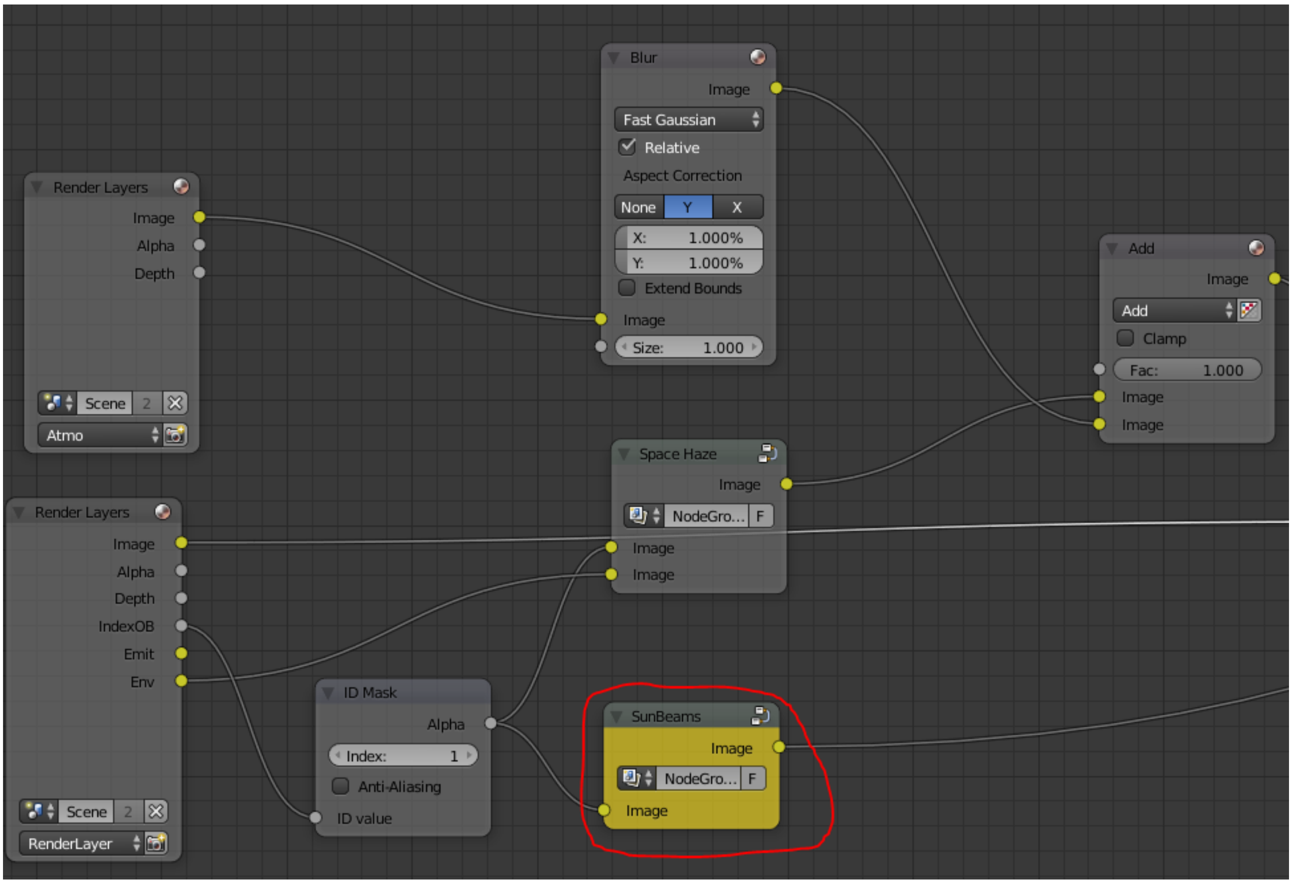

Figure 10: Compositing nodes.

The next step is to adjust the Sun Beams-node's 'Ray length' to a lower value, so that the Sun won't be too unrealistic. This makes the beams smaller. It is important to be aware that the changes are only visible in a rendered frame. You can disable the earth, clouds and atmosphere objects in order to improve the render time, as well as by rendering only a single test-frame to gauge the sun emission. By putting it into the "Backdrop", you can see the render result behind your compositing nodes. This is the fastest way of comparing values for this node and is highly recommended if time is a priority.

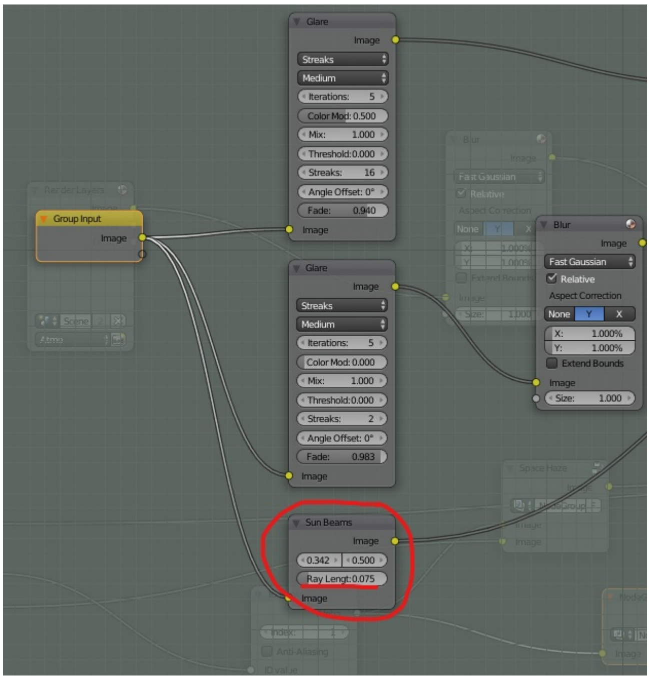

Figure 11: Compositing Sun Beams.

The last step is to change the colour settings for the compositing of the atmosphere. Open the node shown in the picture by pressing the TAB-key and adjust all three colour wheels for a good-looking atmosphere.

If you want to compare render results quickly, one can use the aforementioned method. Enable the Atmosphere, put the render result in the Backdrop and start rendering a frame.

After adjusting the values in the compositing nodes, switch back to your regular node tree on the earth object.

At this point, changes are made to lights on the earth surface. It was decided to subtract the lights from the texture with the clouds. By doing this, the clouds cover the lights on the dark side of the planet and it gives a much more realistic look in the fly-by.

To execute this, one only needs to add an "Image Texture" node and load the cloud texture into it. Set the colours to "Non-Color-Data" and switch the flat settings to sphere. Be sure to connect it to your "Generated" connection of the original "Texture Coordinate" node, as shown in the tutorial. Now add a "Mix-RGB" node and set it to subtract. Plug the clouds into the "Fac" and the lights texture into "Color1" also, change "Color2" to white. The Outcome "Color" is plugged into the "Light Control" node.

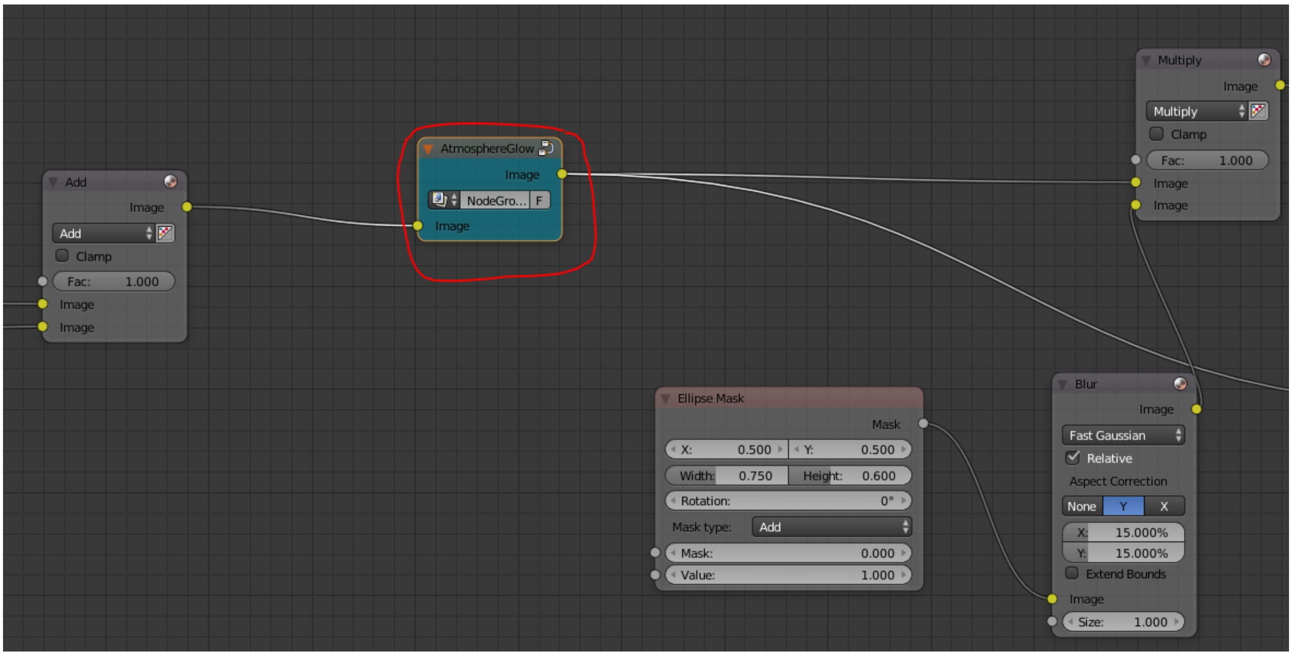

Figure 12: Compositing Atmosphere.

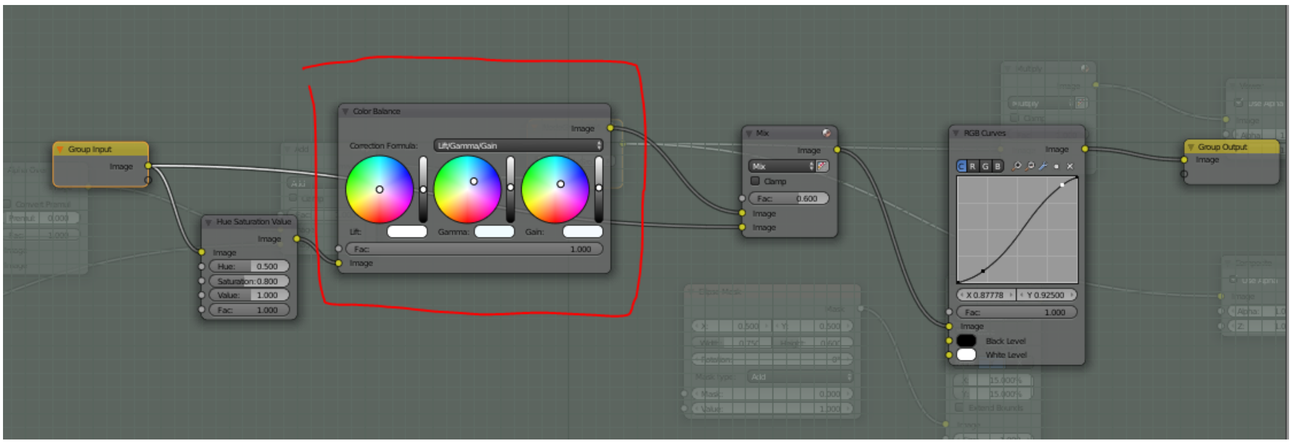

Figure 13: Compositing Atmosphere colour.

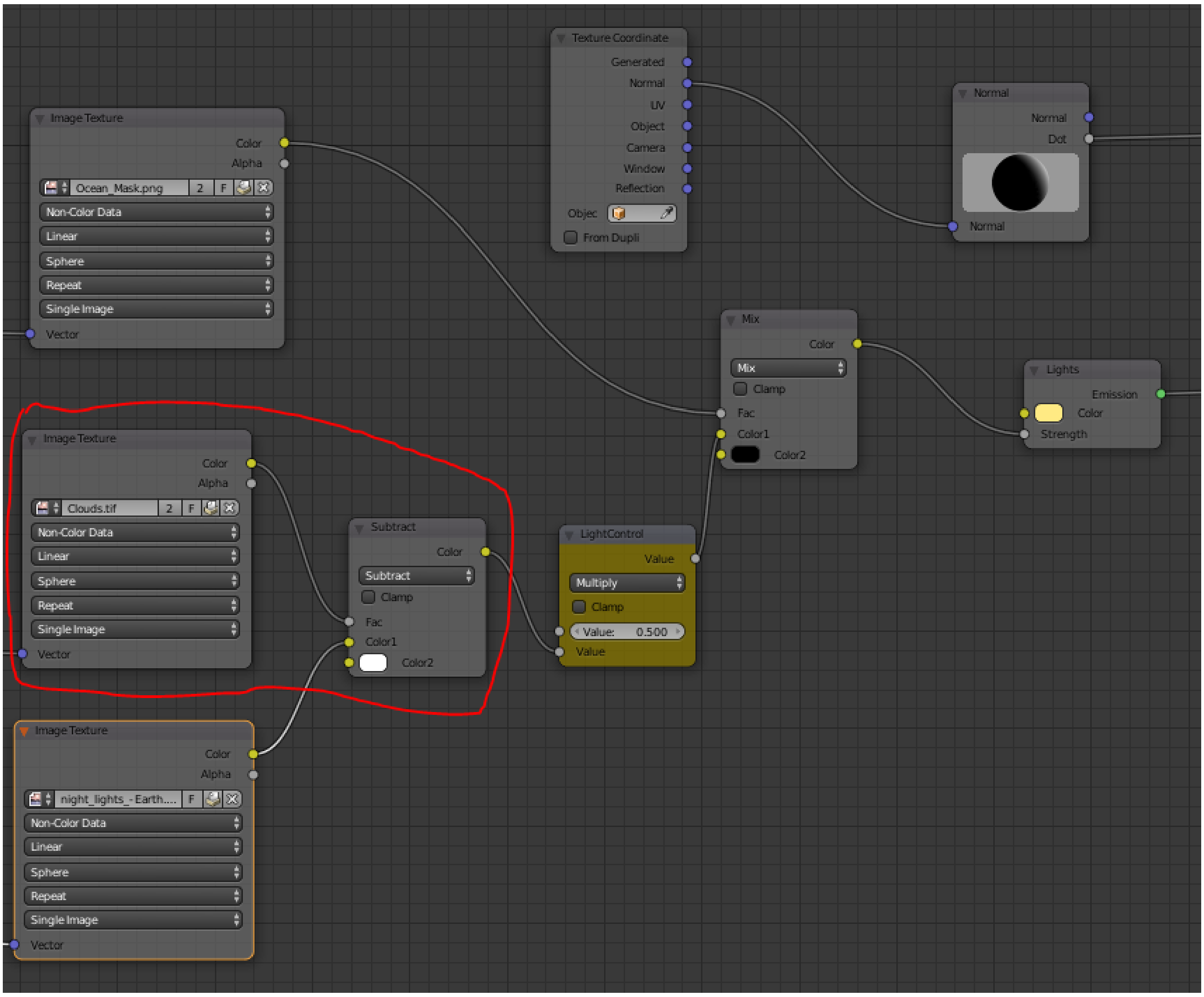

Figure 14: Lights adjustment.

If you haven't coloured and labelled yours it might look slightly different.

6.2.3 Camera

To start our animation, it was decided to use a 180° tracking shot. The first step is to set the length of the animation. By changing the viewed screen to "Timeline" you can access and set up a frame range for an animation. Since we decided to run our animations on 24 Frames per second and planned the whole animation length around 24 Frames per second, we set it to 312 Frames.This means this segment of animation is 13 seconds long, with some extra time in the end for cutting and transitions.

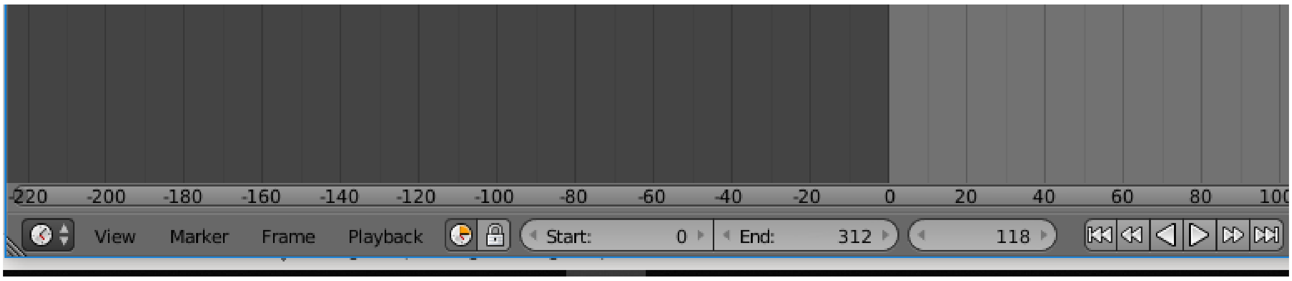

Figure 15: Frame Settings.

The next step is creating a path that the camera should follow, for the tracking shot. Switch into the solid mode of the 3D-viewer and press the TAB-Key to get into the edit mode. After that, create a Bezier-circle and shape it into a form for the tracking shot. Shaping is done by adding connections, pressing the E-Key and dragging the outer connection-points. Once the circular shape resembles the desired path for the tracking shot, connect the camera to the Bezier-circle and set the focus on the earth sphere. To set a focus, select the camera, hold the shift-key and select the object you want to focus on; In our case it's the earth sphere. Now press ctrl-T and chose the option "Track to constraint". Now the camera is fixed on your sphere you can move both objects around as much as you like; The camera will be always fixed on the Earth. If you want to cut the connection between the objects, select both objects, press alt-T and choose the option "Clear Track".

One must connect the camera to the Bezier-circle for it to follow the path. Select the camera first, then the Bezier-circle, press ctrl-P and select "Follow path". Repeating the same action with alt-P gives you the option to "Clear Parent" to unfollow the path again. Since the camera becomes a child of the Bezier-circle, if you move the circle, it too will move.

You can move the camera on its own, by selecting it. It's recommended to set the focus length and the camera size for an optimal shot of the scene. The clipping distance is the distance your camera will see objects in, every object placed outside the clipping range is not shown in the animation or rendered frame.

The last step is to enable the path animation, so the camera knows that it is following the circle in a specific frame range. Select the Object circle and open the circle settings in the option panel. It's recommended to change the resolution settings of the circle, to ensure that the path is smooth. A

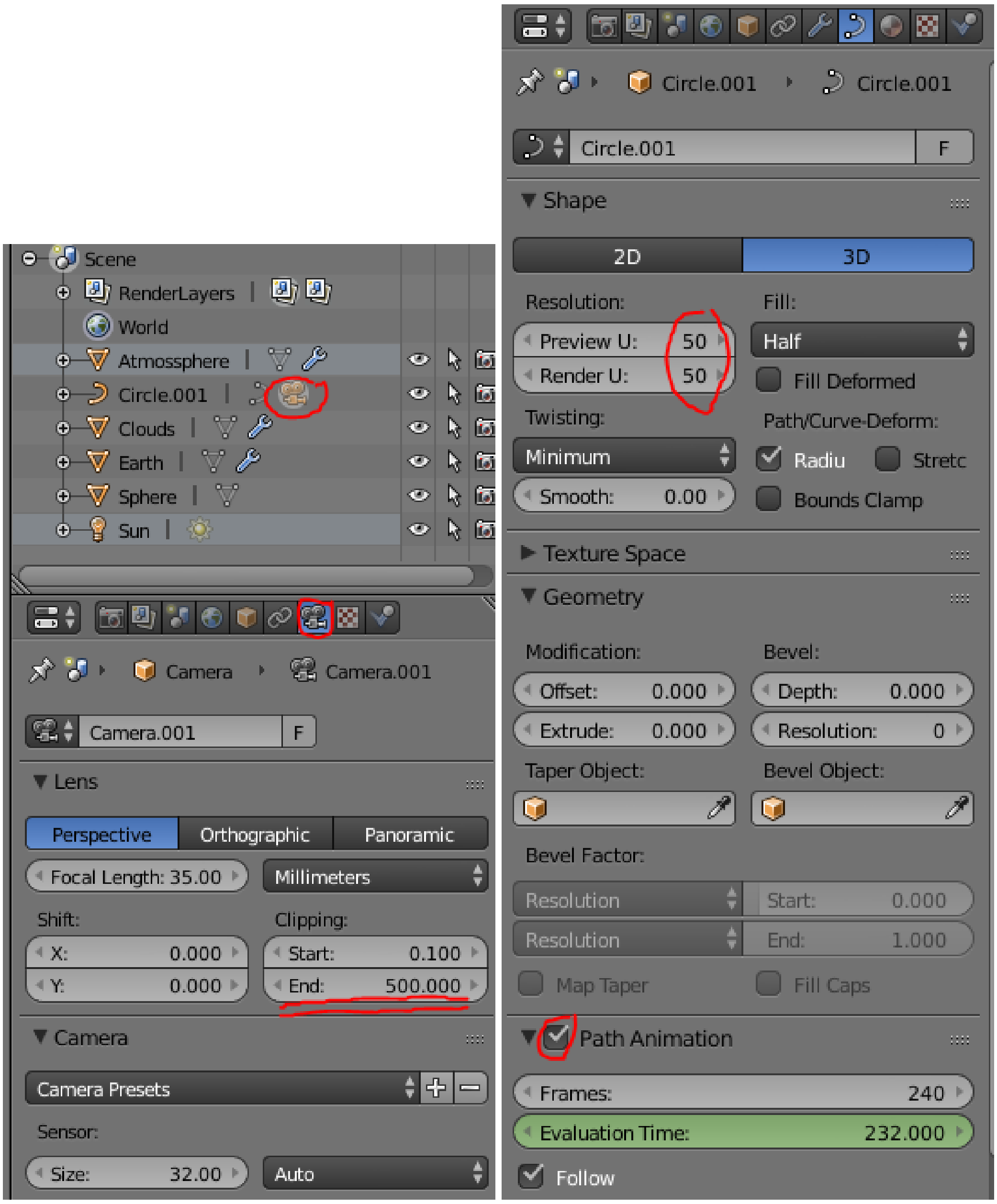

Figure 16: Left: Camera Settings. Right: Circle Settings.

"Preview U" and "Render U" of 50 should give you a much smoother camera movement as a result. Lastly, enable the "Path Animation" setting and set the Frames to the target length of your animation. We choose 240 frames, because the tracking shot should be around 10 seconds long. The whole animation scene is 312 frames, we added some more frames after the tracking shot to have a static view in the end and to have some space for cutting.

If you followed the tutorial as well as the changes recommended thus far, the result should be a very similar scene. Keep in mind one can always tweak values and change textures and colours, to achieve an different outcome more suited to your task.

7 Scene 2: extreme weather conditions

In the second scene, two forests are shown in different climate zones. One forest gets flooded while the other ignites.

7.1 Research

Scene two shows extreme weather conditions in the near future as an example of the consequences of man-made climate change. The scene only brings the animation to roughly 2035, however in reality, the events depicted are already occurring to some degree in 2018, and will intensify in the future. This scene is shown early in the video to emphasise this fact. The changes will further intensify due to the growth, and increased output of the Sun. As examples for extreme weather conditions, it was decided to juxtapose a heavy rainfall event and a forest fire. These are only two of many changes in weather that occur as the Earth warms. These particular two weather conditions were chosen for two main reasons. Firstly, rain and fire are commonly seen as opposites, thus reflecting the extreme nature of changing weather conditions when viewed on a global scale. Secondly, these conditions are familiar to the general public, making them easy to show, and understand in a short sequence. One can already observe these changes by observing the increased frequency at which natural catastrophes have occurred over the course of the past few years. Massive wildfires were seen in the U.S.A and Australia in 2018, as well as an increased number of floods in various regions around the globe. These effects are shown early in the animation to emphasize that they are already occurring, however in reality, they continue to amplify in frequency and intensity beyond the timespan covered in this scene.

7.2 Animation

For this scene, a number of objects were created and then compiled into two different forest scenes. One blender scene for the burning forest and another one for the rainforest that gets flooded.

7.2.1 Creating ivy

Creating the ivy was one of the easiest tasks in this scene. Blender offers a Add On named "Add Curve: Ivy Gen". The user only has to activate it under User Preferences -> Add Ons. With this tool you adjust position the 3D-Cursor and select the object where the ivy should grow. Then press Shift + A and select "Add Ivy to Mesh" under the Curves tab. Finally, change the settings that appear on the left of the screen.

The most important settings are:

Max Ivy Length: The maximum length of the Ivy measured in Blender Units.

Ivy Size: The overall size of the Ivy. Here the User must be careful, because a large value lets the ivy sink into the object.

Branching Probability: The probability that a new branch gets created. With a value of 0.05 there is a 5 percent Chance of a new branch.

Ivy Branch Size: This is the thickness of the branches.

Ivy Leaf Size: The size of a single leaf.

Leaf Probability: The chance that a new leaf gets created.

As soon the user is satisfied with the look of the ivy, the textures can be added. The easiest way is to use the nodes from the tree textures of the leaves and the branch and change the image texture of the leaves to an ivy one.

7.2.2 Creating bushes

Create the trunk and branches

Another simple object to create is the bush. There is an Add On in the User Preferences called "Add Curve: Sapling Tree Gen". Once activated the user can press Shift + A –> Curves –> Sapling Tree Gen. A very simple tree should appear on the screen. To create a bush the following options are helpful:

In the Branch Spitting Tab:

Levels: This value sets the number of levels of branches. One is only the trunk, two is the trunk plus the first branches and so on. For the bush, value 2 was used, as for a bush, another level of branches is unnecessary.

Trunk Height: This is the height at which the first branches appear. Because we are creating a bush, set this value to 0.

In the Branch Growth Tab:

Lengths: The first value under the Length section is the overall height of the bush. A value around 0.3 should work fine. The second value defines the length of the second level of the branches. Here a number of around 0.8 is appropriate.

Down Angle: In this section it's possible to change the angle of the branches. For a realistic look change the second value to around 110, making the branches bend slightly upwards.

Curvature and Back Curvature: Now the middle and the end of the branches must bend upwards. To reach this goal, change the second value of these two settings to approximately -30 and - 15.

In the Branch Radius Tab:

Check the box "Bevel" to create a realistic looking trunk. Initially the thickness is too high, so change the Radius Scale to around 0.25 and the Bevel Resolution to a value between 20 and 25.

In the Branch Growth Tab:

Use the option "Use Armature" and change the Armature Levels to 3 to get a few more options for later in the animation. It's important to check the box add Mesh. Only when this option is selected, is it possible to add the branches later on.

In the Animation Tab:

To make a quick animation of the branch movement select Armature Animation. For the forest scene this animation is way too fast. So set the Animation Speed to a value of around 0.3. The next step is to adjust the Wind settings. Some good values here are:

- Overall Wind Strength: 0.5 - 0.6
- Wind Gust strength: 0.3 - 0.35
- Wind Gust Frequency: 0.08

The rest of the values are fine.

These are the most important settings to create the bush without the leaves, however there are many more options that the user can change to adjust the look. Here the best way is to play around with different options and values and find a look which suits the specific requirements.

Add the leaves

Now we have a bush without leaves. The next step is to copy a branch from the already-created tree and add it into the scene. Select the tree mesh object and add a particle system. The type must be changed to 'Hair' and the advanced options should be enabled. The Number of Hairs (the amount of leaf branches added) was changed to 900 and the hair size to approximately 1500. This can be varied by personal preferences. The last important step is to go to the Render Options in the particle system and switch to object. Now an option called 'Dupli Group' should appear. Select the copied branch there and the leaves should appear. The size of the leaves can be changed with by adjusting the 'Size' value. These changes are visible when the user switches to the 'Object' option. This value is responsible for the size of the branch. For this scene a number of 0.170 was fine. Because the animation is auto-generated and the bushes in this scene are only in the background, there are no other adjustments needed and the object is ready to use.

7.2.3 Creating tree trunks

These steps two were used twice to create the small and the big trunk in this scene. To create the tree trunks, select the cube that appears at the start and press tab to go into the edit mode. Then press Alt + M and select 'merge at center'. Now the cube should disappear. The next step is to add a skin modifier. The user can now extrude the object by pressing E, allowing one to form the basic shape of the tree by generating new meshes at every edge of the object. To create a smoother surface, there is a modifier called subdivision surface. For the trunks two of these modifiers were used. The first one was moved on top of the modifier list while the other was positioned after the skin modifier. The last step to a smooth surface is to use the checkbox "Smooth shading" at the skin modifier. With ctrl + A the radius of the vertex can be changed so that the thickness of the roots and the trunk can be adjusted. When the form of the trunk looked acceptable, pre-made nodes for tree bark were applied and adjusted . These adjustments ensure that not every piece of tree bark looks the identical. At first the object must be unwrapped. This works by splitting the screen and select UV/Image Editor. The next step is to open the image of the bark that gets used, hover over the side of the screen with the 3D-View and press TAB to get into the edit mode again. Select all with A and press U -> Unwrap. Now we can see what part of the object gets positioned where on the Texture. Nodes designed for the ground were used to add a moss texture on the trunk. This was mixed with the bark textures of the tree, created for this scene by Max and Marcel. These added nodes are explained in the chapter Ccreating Ground". The nodes for the moss and the tree bark are joined together with a mix shader. To get a good distribution of texture, you can use a noise node combined with 'RGB Curves' instead of using the „geometry node“ that was needed for the terrain. They can be used as the factor of the mix shader. Try out different values in the noise to find a good-looking result. Because the scene needs a lot of different trees you can use this object with different textures. This way it's possible to use this tree trunk multiple times without the viewer noticing that it's the same object, so long as a good position and rotation angle are used.

7.2.4 Creating grass

For this object, the Add On „Import-Export: Import Images as Planes“ was used. This is a helpful tool that allows one to create a plane with an already-implemented texture. The first step is to delete everything in the scene. Then press Shift + A Mesh Images at Planes. A menu should appear where the user can add a texture. Use a texture of a single blade of grass and select it. Before clicking on Import Images as Planes there are a few options at the left side that must be changed. At first switch the Material Settings to „diffuse“. Then in the Texture Settings check the box „Use Alpha“ and change the option to Premultiplied. Now that everything has the right options selected click on „Import Images as Planes" and it shows up in the scene. The plane must be repositioned. The best way of doing this is to switch into a detailed top view. (Press 7 followed by 5 on the numpad). Now the object can be moved to the center by holding shift and use the green arrow to move it up. The next step is to go into the edit mode and subdivide the plane by pressing R and scroll up the middle mouse button until there are 5 to 6 squares. After that rotate the plane upwards until it's vertical with the x-axis. For a more realistic view, turn on proportional editing and select the highest points of the plane. It's now possible to use R to rotate parts of the grass blade until it achieves a more realistic form. When the first blade is ready, turn off the proportional editing and set the pivot point to the 3D Cursor. Shift + D followed by R, duplicates the blades, and they can be rotated around the selected pivot point. This step must be repeated 4 or 5 times. The single blades of grass can be edited to appear different by using proportional editing again. When the user is satisfied with the result, he must select everything, duplicate it and scale it down. Finally, rotate the smaller group of grass and change the form at will. With the grass now created, there are just a few more nodes to add for the color and light settings. Because of the settings that were made when importing the texture as plane, nodes already exist that can remove the parts of the plane without texture. The nodes are created with the following setup:

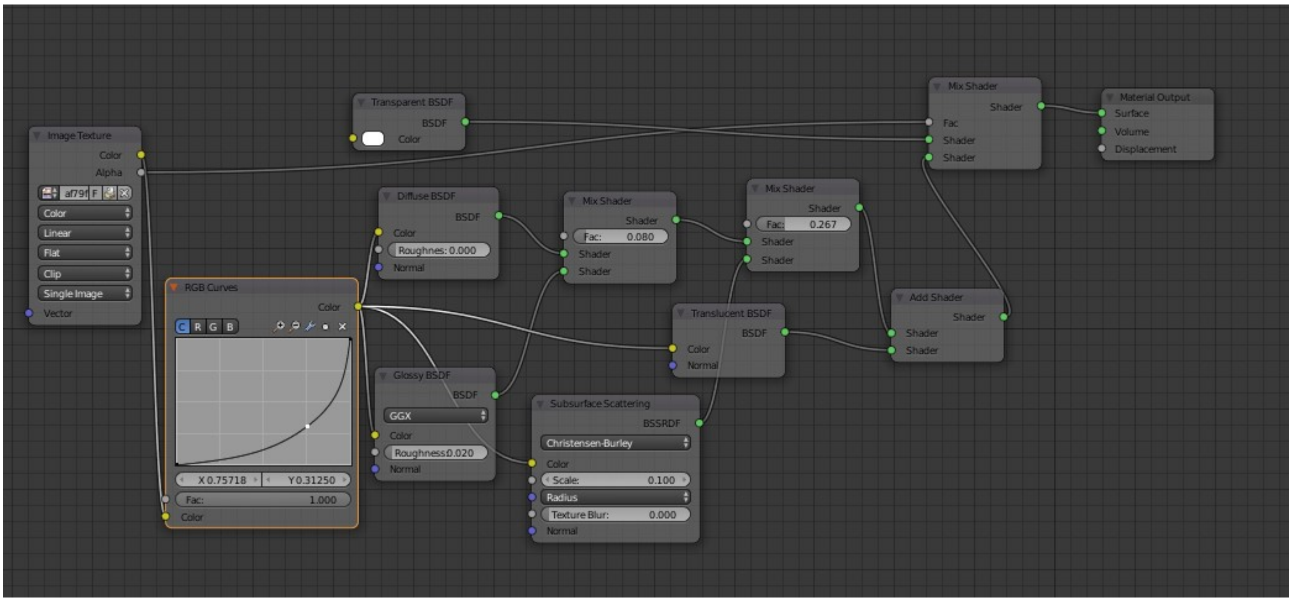

Figure 17: Node setup grass

The user can change the color of the grass using the RGB Curves. The other nodes change how lights interacts with the object. Especially with the Glossy BSDF (which changes the glossiness of the object) and the Subsurface Scattering Node. This node simulates how light looks when it enters an organic object like this blade of grass.

7.2.4.1 Creating a wet look

For the rain-forest scene the ferns and rocks had to look wet and glossy. The task is to find a combination of nodes that looks like rain on a surface. One way to simulate this is the following addition to the already created nodes of the ferns and rocks:

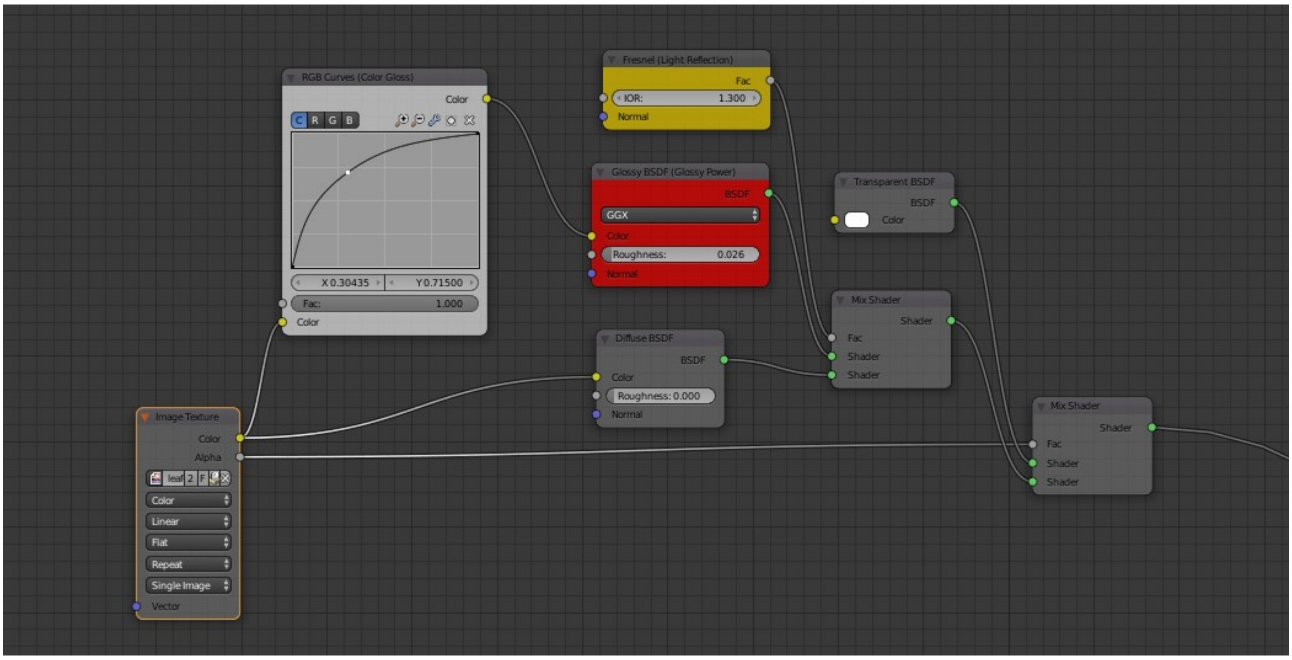

Figure 18: Node setup wet look 1

With the RGB Curves it's possible to adjust the Color of the added gloss. The power of this gloss is set in the Glossy BSDF Node (red). Note the Fresnel Node(yellow) which is responsible for the amount of light an object can reflect. These nodes will be connected with the old nodes of the ferns or rocks with a Mix Shader. The Mix Shader gets plugged into the Surface of the Material output.

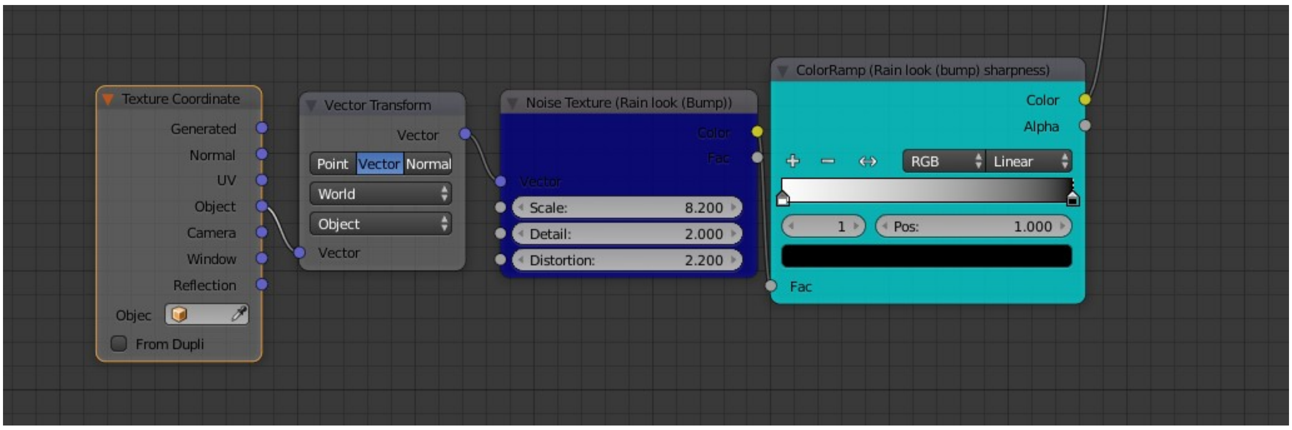

Figure 19: Node setup wet look 1

The two important nodes here are the noise texture (which creates the form of bumps that simulate rain drops or wet surfaces), and the 'Color Ramp' (which decides how sharp the drops will look). These nodes will be connected to the displacement of the material output. The values used in these

Nodes created one of the wet ferns. The other objects which look wet have different values but the same setup.

7.2.5 Creating the ground

To create the ground a simple plane is needed. First it must be scaled up to the desired size. The object is then subdivided into around 4000 squares. It is now possible to make a realistic ground, using the sculpt mode. The most useful tools for this task are the smooth, crease, inflate/deflate and SculptDraw brushes. When the result of the sculpting looks good, adjust the texture with the correct nodes. The node setup consists of two main parts. The first one is for the grass parts of the terrain.

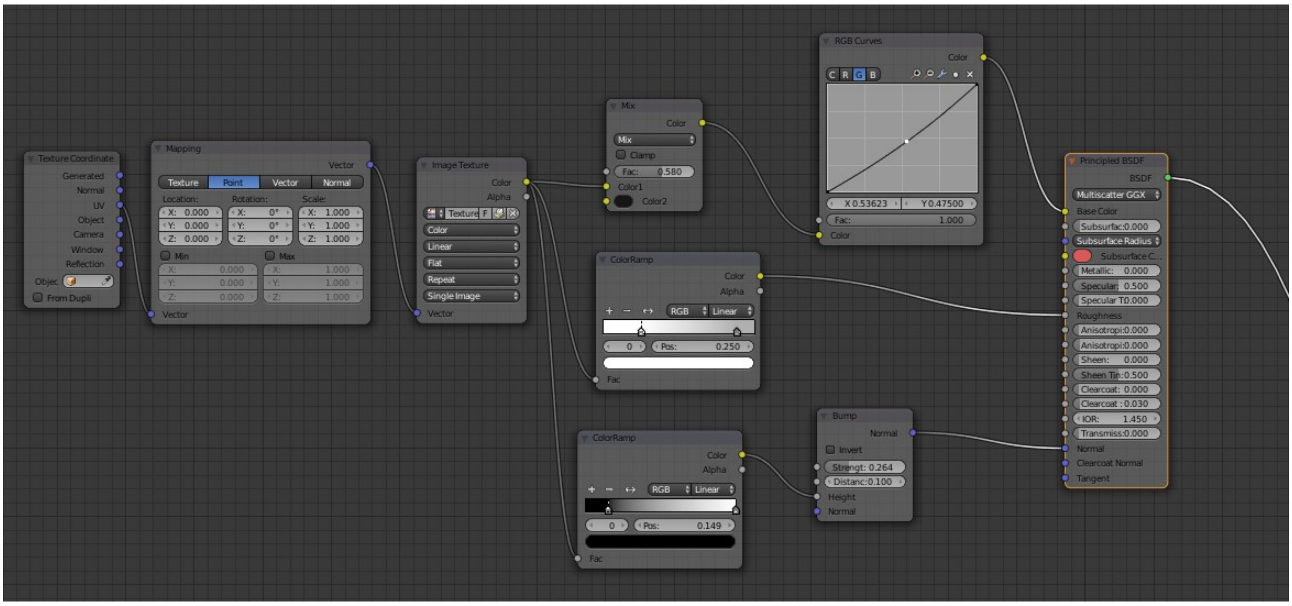

Figure 20: Node setup terrain 1

Find a suitable grass or moss texture and insert it into the Image Texture node. The color can be changed with the RGB Curve. The Color ramp that connects with the roughness of the principled shader is for the glossiness. The second one replaces the height map. This means it creates a bump for a realistic look.

The second part of the setup is for the mud or dirt texture. If the user can find a 3D-Scan he can use the following nodes, otherwise just copy the previous setup and change the values slightly.

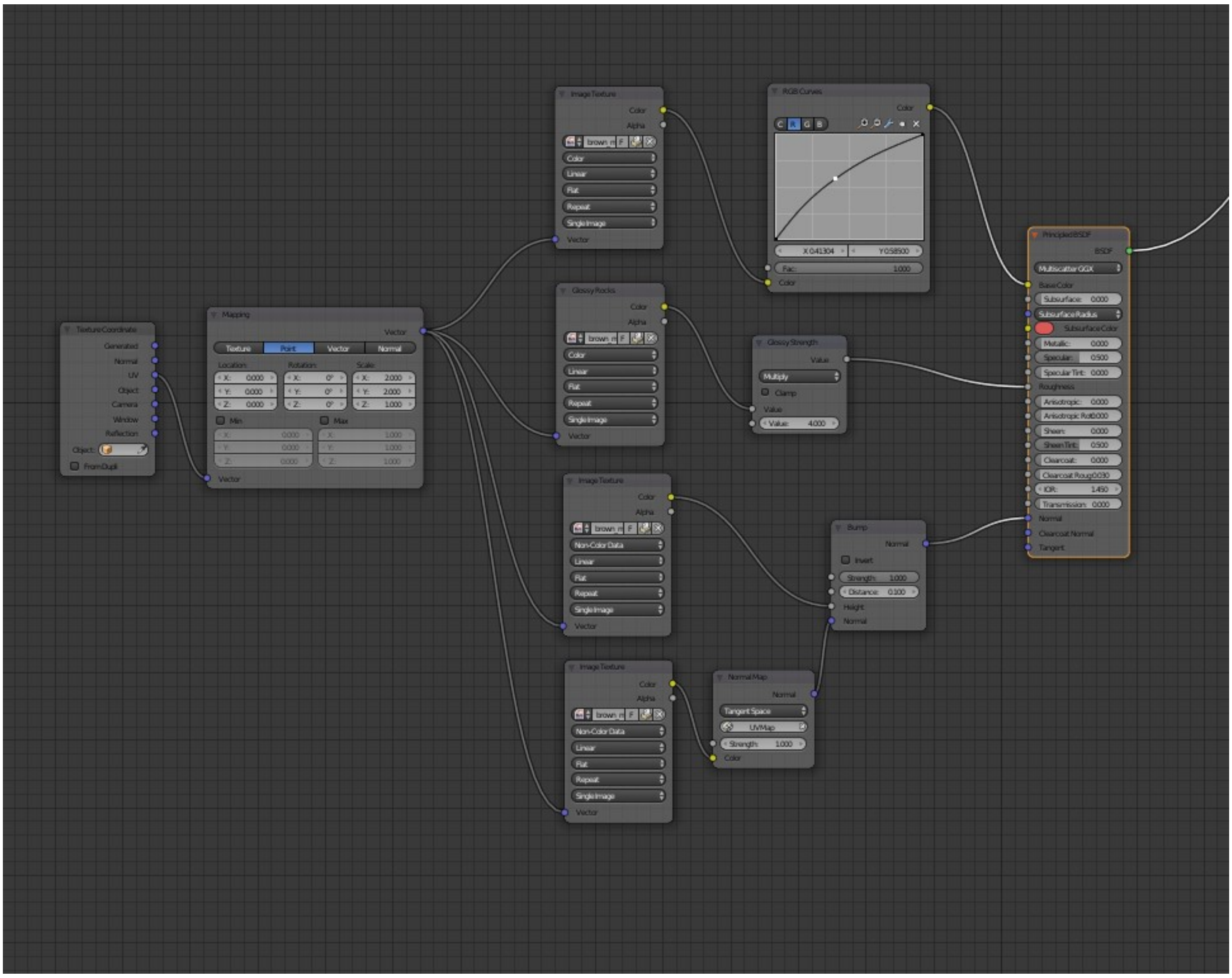

Figure 21: Node setup terrain 2

Here the details for the 3D-look come from the different picture modes. It's ideal if the user can find fitting textures, because they look much better and are more appropriately detailed. Here are sample images of one Texture with different picture modes:

Figure 22: Samples 3D Textures

The two principled shaders are connected into a mix shader. For the distribution of the two textures, use a geometry node. If the pointiness of it gets combined with a color ramp and used as the factor of the previous mix shader, the higher points of the terrain get one texture while the lower ground gets the other one.

7.2.6 Creating ferns

To get ferns like the ones in this scene, appropriate textures are important. The best result can be attained by using three different leaves of the same plant like in these images.

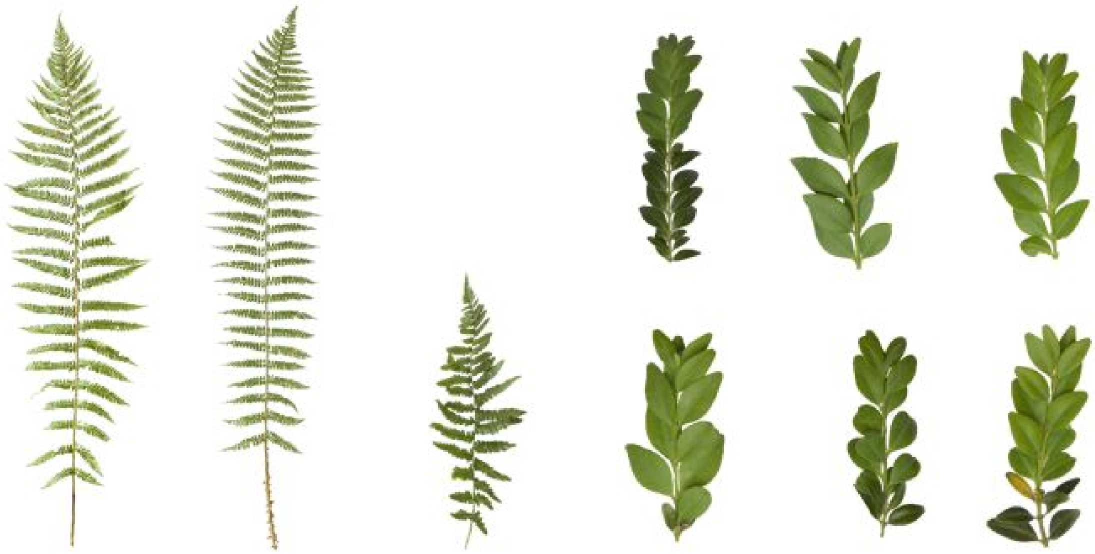

Figure 23: Fern leaves

At first the user needs to create a single leaf. Press Shift + A and create a plane. To move the object press 7 to go into top view, then move it up until the base is at the x-axis. Because the leaves aren't square, switch into edit mode and select the top corners. Press G + Y to extend the plane in y direction until its around 8 squares long in the blender grid. To get more flexibility in the object it needs to get subdivided into around 8 parts. Press Ctrl + R and scroll the mousewheel up until there are 7 lines. The next step is to create the basic form of the leaf. To do this, go into the proportional editing mode and select sharp. Select the edges that need to be scaled and press S followed by X. The circle that appears shows how much of the object will be scaled. The size can be in-/decreased with the mousewheel. This forms the shape of a leaf like in the picture below.

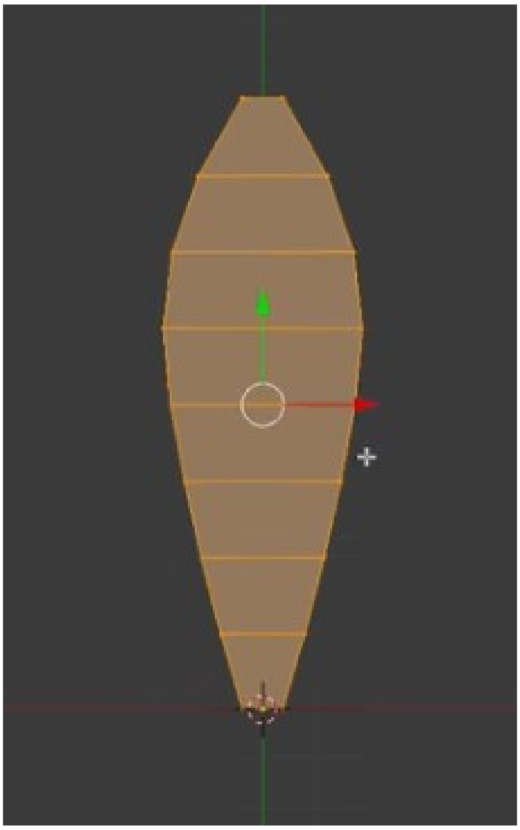

Figure 24: Modeling a leaf

The plane is then subdivided along the y-axis. Afterwards the three top and bottom points have to be selected and moved downwards in sideview (Numpad 3) to get a good form. If all looks fine, select everything and move the bottom of the plane to the center. The last step of creating the basic form of a single leaf is to select all points in the middle and move them down slightly. The result should look like this:

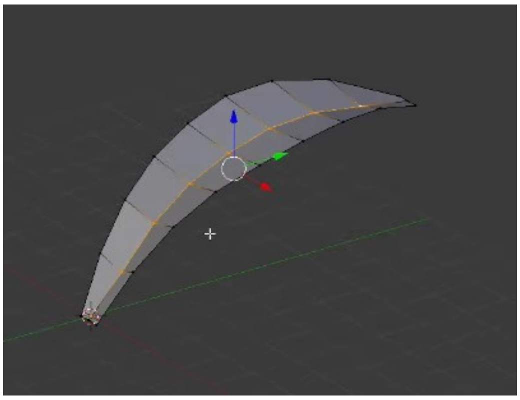

Figure 25: Shaping a leaf

The ferns in this scene have a tree-level of leaves and each one is smaller than the one above. Because of this the plane needs to be duplicated, rotated downwards and downscaled two times. Put all objects in a different layer by selecting one, pressing M and choosing the desired layer. Now create an empty object in each layer and add an array modifier. The number of leaves at each level of the plant can now be adjusted with the 'count' value of the array. Currently the new objects are created side by side, so check the box Object Offset and select to be created empty. Now a rotation around the z-Axis and a variation of the scale of the empty object will create a realistic layer of leaves.

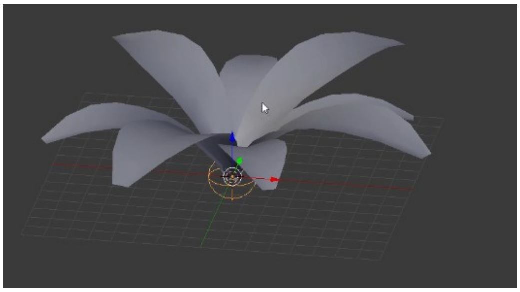

Figure 26: Layering the leafs

Now the basic form of the fern has been created. The next step is to apply the texture and the node setup. To do so, split the screen and switch one side to UV/Image Editor. In this window insert the texture of the three leaves and unwrap the object of every layer on the picture. With the help of proportional editing it's possible to adjust the shape of the object to the image. The next part is setting up the nodes. Create a material and apply it to all three leaves and create the following nodes:

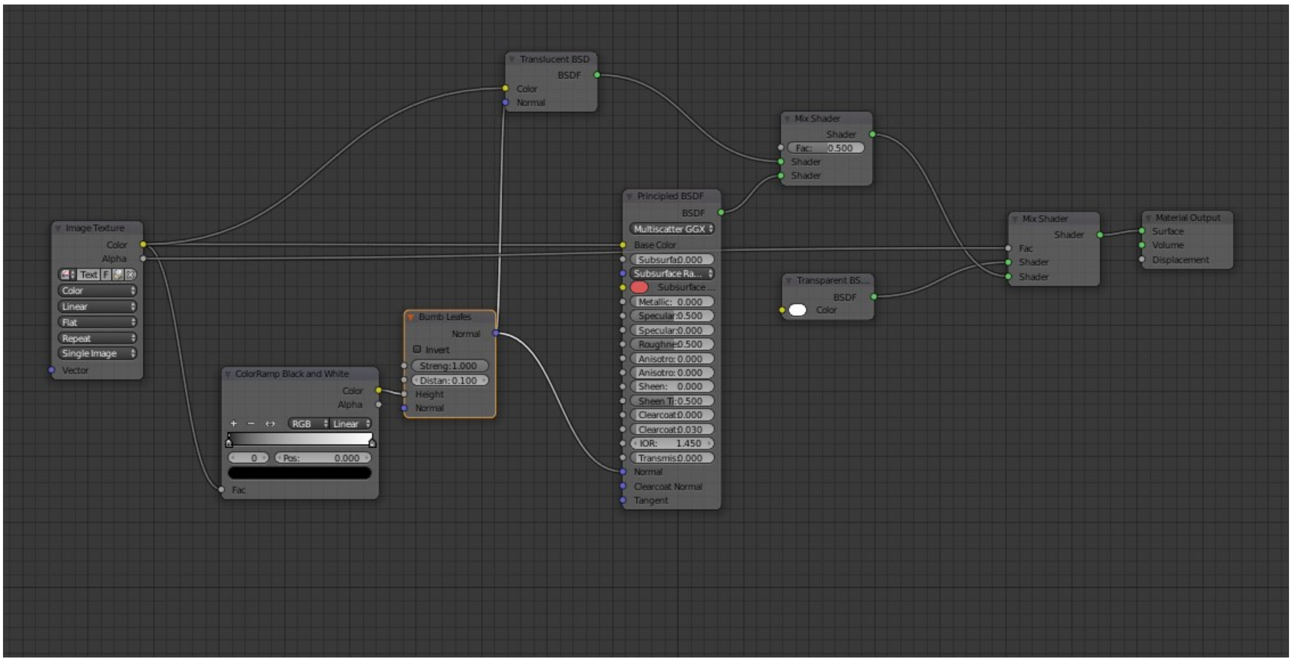

Figure 27: Node setup ferns

In this simple set-up, the bump is responsible for the "3D-Look". The translucent BSDF lets the light shine through the object. The transparent shader removes the part of the plane without texture.

Therefore it needs the alpha from the texture as the factor. Select all three parts of the plant, duplicate, and move it to another layer. Make sure to apply the array modifier in this layer before making it a single object with CTRL + J. Now the fern is essentially ready to be inserted into the scene. The only thing the user can do is to rotate or deform some leaves for a better look. Example of one final fern:

Figure 28: Finished fern

7.2.7 Creating rocks

To create the rocks, we start by using a icosphere. On the left side set the subdivisions to one. Now switch to the sculpting mode and enable Dyntopo in the options that appear. Under the Dyntopo Tab is an option called relative Details that have to be changed into constant details. Now its possible to form the icosphere with brushes like the SculptDraw at will. When satisfied with the shape of the rocks, only the nodes for the texture are still needed. The setup is the following:

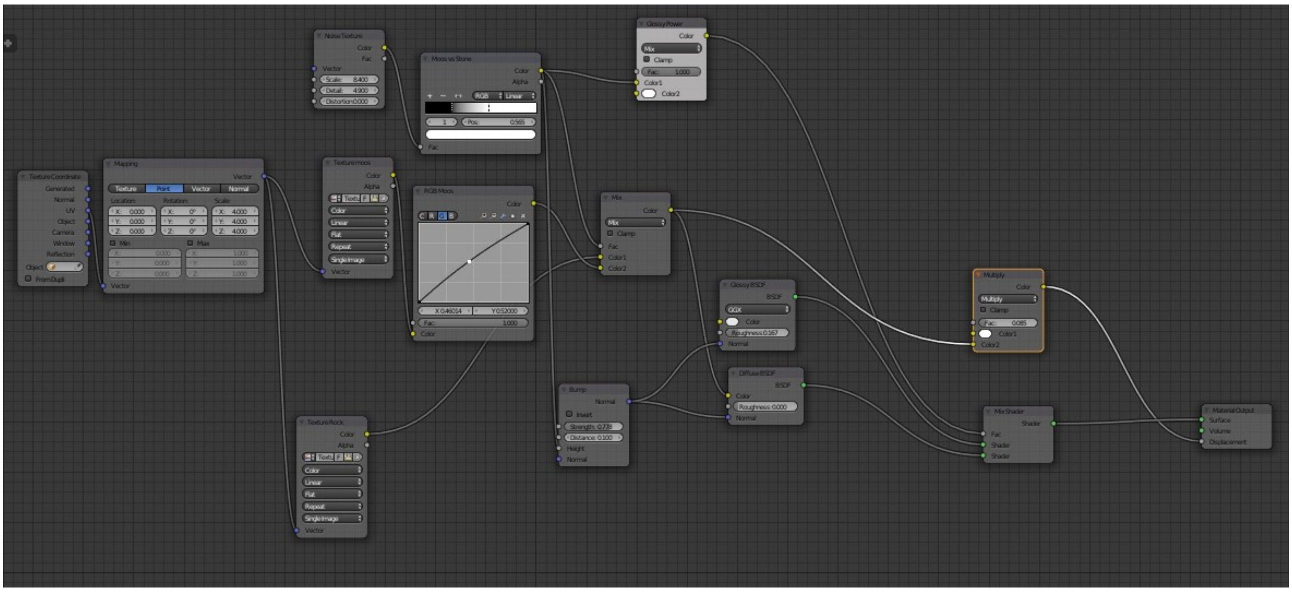

Figure 29: Node setup rocks

Here a rock and a moss texture are used. These two get plugged into a color mix node with a noise as factor. If the user wants to change the color, an RGB Curve like the one in the picture(RGB Moss) can be used. The rest of the nodes are mostly for the bumps and glossiness, and work the same as in the nodes for all the other objects.

7.2.8 Creating trees by hand

The aim is to create a tree that is as realistic as possible. It is useful to make it possible to modify the tree (as well as the leaves and branches) later without much effort so that the tree can be used for different scenes (and environments).
Before the actual modelling of the tree begins, the image of a real tree is integrated into the background, which can be used for orientation during the modelling. This makes it possible to pay attention to realistically running branches and leaf groups.

Figure 30: Template of the tree to be created.

In order to insert this image as a template, check the "Background Images" box in the settings menu (open with the "N" key) and then select an appropriate image using the "Open" button and the subsequent dialog box. After pasting, the scene is prepared to start modelling.

7.2.8.1 Creating the tree stump

The skin modifier is used to create the tree trunk. This requires a single vertex at the beginning. To get this vertex, first create a cube (SHIFT+A -> Mesh -> Cube), then switch to edit mode (TAB) and merge the vertices in the middle of the cube (ALT+M -> "At Center"). The modifier tab of the object is then called and a skin modifier must be added.

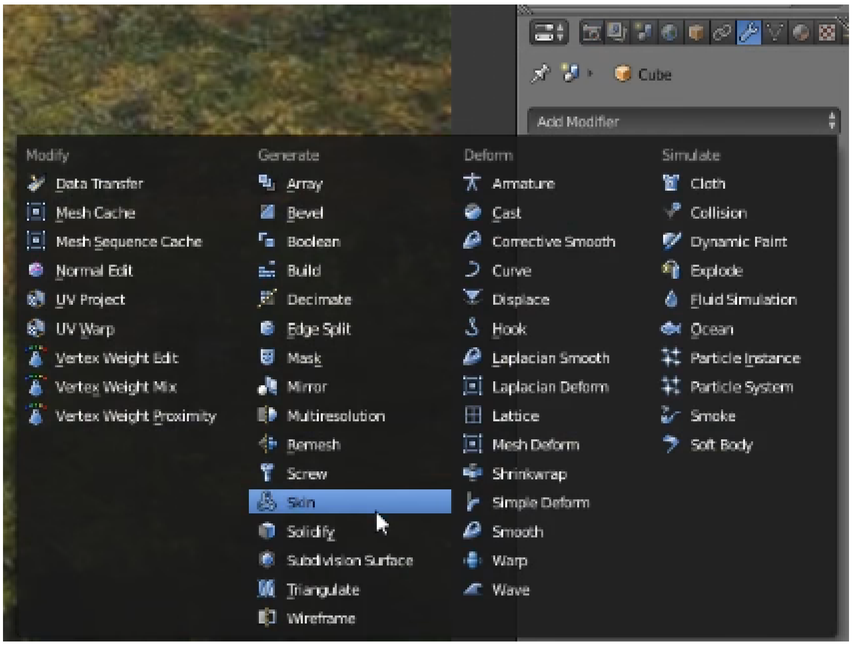

Figure 31: Add the skin modifier to the tree trunk.

Now you can see another cube, which consists of the skin modifier. Since a Cube is not the most suitable form for creating a tree trunk, a "Subdivision-Surface-Modifier" is added now (In Object-Mode: CTRL+2). Now you have a round structure with which you can model a tree trunk.

If you are now in edit mode and have selected the object, you can adjust the tree trunk accordingly by pressing the E (= extrusion) key. This should look something like this.

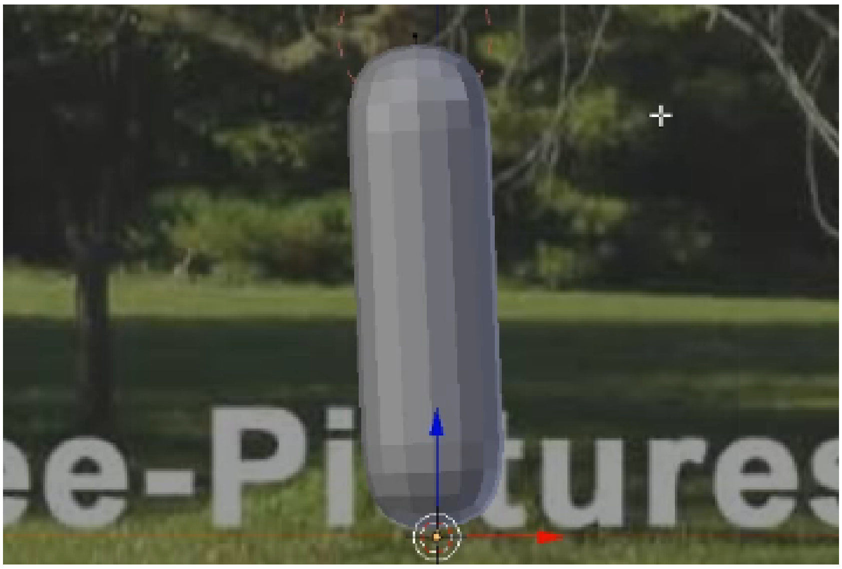

Figure 32: Extrusion of the trunk-object.

The root of the tree (marked by the orange dotted border at the top of the object) must be on the opposite side of the tree. This is done via the modifier menu of the object. Click the "Mark Root" button of the skin modifier, causing the marker to slide to the bottom of the object.

Reduce the width of the tree trunk and deform it a bit, as a tree trunk becomes narrower and narrower towards the top. To do this, CTRL+A is used in edit mode to reduce the width accordingly so that the modelled tree trunk resembles that of the template.

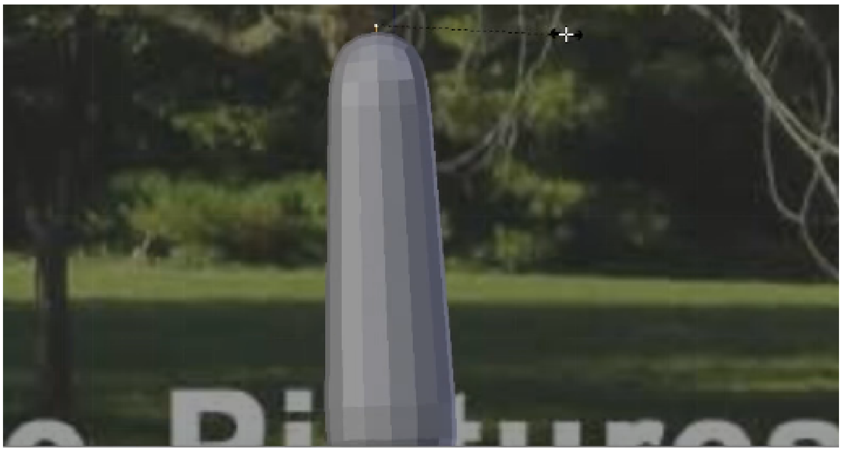

Figure 33: Resize the trunk object.

If the tree trunk does not lie well enough above the template, you can change the alignment of the tree trunk. To do this, adjust the position of the upper point with the key G in the edit mode. Subdivide the structure into several subareas. This makes it possible not only to move or change the tree trunk statically, but also to give the tree trunk a more realistic structure. To do this, select the point on the opposite side (with SHIFT+R-Click), as well as the top point and select the "Subdivide" option by pressing the W key. Afterwards there is another point in the middle of the tree trunk which can be manipulated independently of the other points. Now select the new point in the middle, press the G key and drag the point further down, so that the lower surface now looks like a tree base (root base).

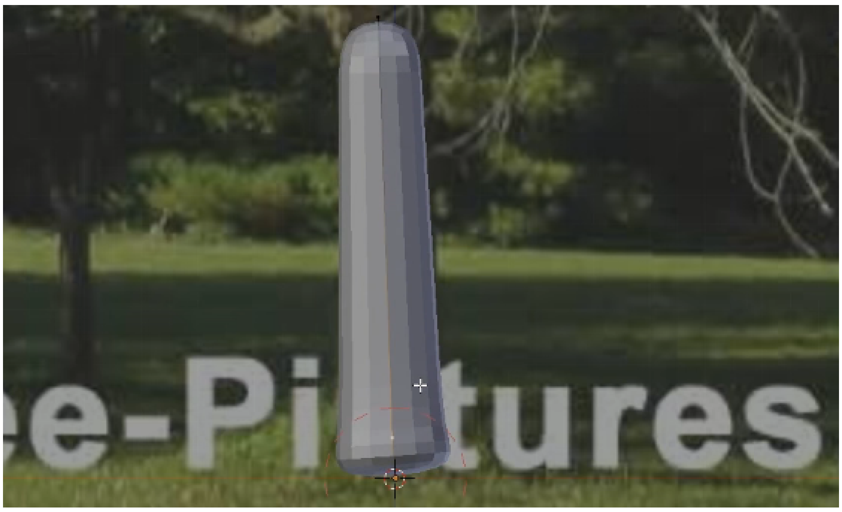

Figure 34: Pull middle trunk point down.

It is possible to extrude the tree further at any point. Next, select the upper point of the tree trunk and press E (= extrude). Pull the tree trunk up (or along the branches in the template) to further shape the tree. It is important that you always set a point at which the branches are divided. This simply ensures that the tree can be modelled freely. At the end the result should look like this:

Figure 35: Final trunk setup.

Since the tree was modeled from only one perspective, it is correspondingly (unrealistically) narrow. To correct this, you first change to a perspective from which you can give the tree a certain depth.

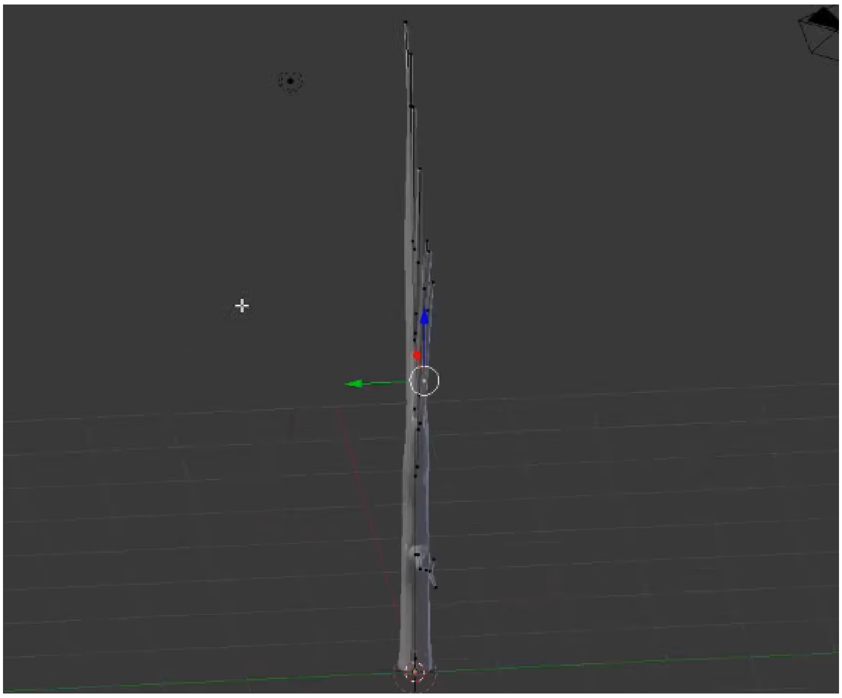

Figure 36: Final trunk setup (flat). Stand: 30.01.2019

Now you can select the individual points of the tree trunk (or branches) and manipulate them with the visible arrows. It is recommended to activate the function "Proportional Edit"[1] so that the movement of the points is proportional and the branches of the tree move realistically. The amount of proportional editing can be increased or decreased by scrolling with the mouse wheel.

If the tree is now modelled according to the ideas, an Amature must be created. This creates the so-called bones of the tree, which later become particularly helpful in the creation of an animation. To create this amature, simply click on this option in the Blender UI:

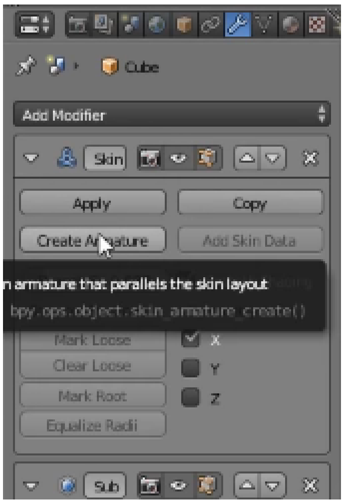

Figure 37: Create an Amature for the trunk.

To see the result of the creation of the Amature, you can switch to the Wireframe View (pressing the Z key in Object Mode). You should be able to see the orange bones of the tree highlighted.

If you now switch to the pose mode, you can change the individual positions (or rotations) of the branches. However, this change only has a very static effect on a branch and this is too unrealistic. Therefore it makes sense to regard the bones of the tree as B-bones, through which one can integrate a mutually influencing movement into the branches. At the beginning the corresponding B-Bone option must be activated in the Amature settings of the tree trunk:

[1] https://docs.blender.org/manual/en/latest/editors/3dview/object/editing/transform/control/proportional_edit.html

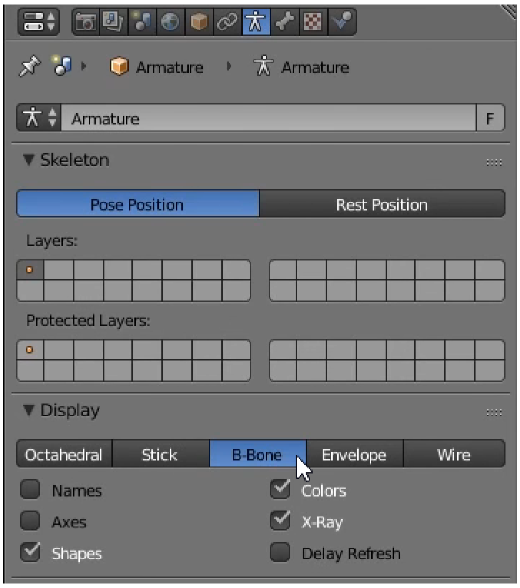

Figure 38: Enable the B-Bone settings for the Amature.

Now some so-called IK constraints have to be created and configured, which guarantee the animation of the tree. First you select one end of a branch in the edit mode and use SHIFT+D to create a duplicate of the bone.

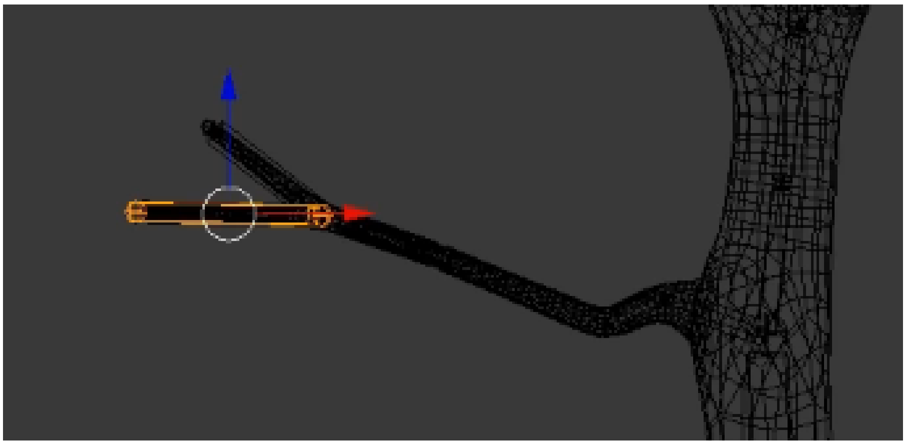

Figure 39: Duplicate a bone to make it an IK-Bone.

Then press the W key to call up the "Specials" and select the "Switch Direction" option. Then (if the settings window is not open, press N to open it) and rename the node. It is recommended to add the suffix ".IK" to the bone name to make it easier to find it again. Then select the (old) bone below (not the new IK bone) and switch to Pose mode. Now create a bone constraint in the constraint tab via the corresponding button:

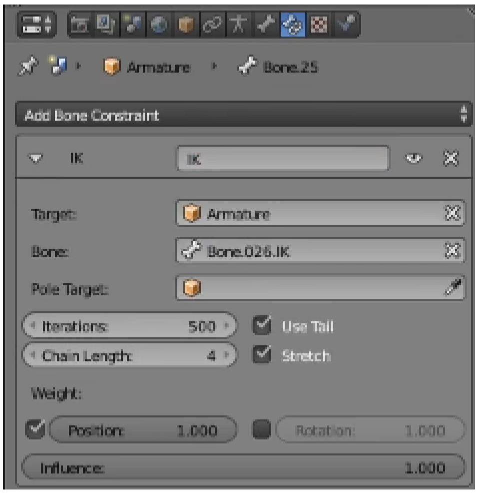

Figure 40: Create a Bone-Contraint.

As "Target" you choose the "Amature" and as "Bone" you choose the previously created IK-Bone. Now a value must be selected for "Chain Length" so that the stitched line in the preview goes from the selected branch to the main tree trunk (in our case "4"). If you now select the IK bone and press the G key in Pose mode, the entire branch moves realistically. If you now create animations, you only have to animate the IK-Bone so that the branches move to e.g. wind.

This process can then be repeated for each branch of the tree. The more IK-Bones you create, the better you can animate the tree. In addition (if no animation is desired) the tree can be changed much more easily with this method in order to achieve a variation in a forest.

7.2.8.2 Creating branches

The creation of the branches is similar to the creation of the tree trunk. A skin modifier is also used here to create a branch structure, which is then applied to the tree trunk. In addition, the insertion of a background image is omitted here, since the course of branches is relatively random and can therefore be freely modelled. The creation of an IK bone at the end of the branches is also avoided, since this will have a negative influence on the render time and the variation of the branches is not achieved by manipulating the individual bones, but by creating three or more different branches.

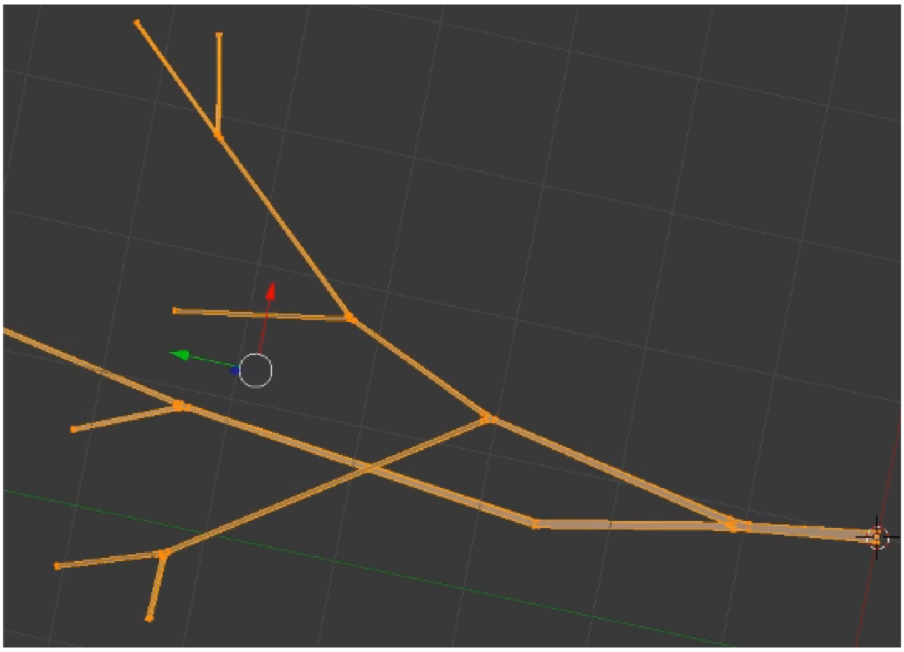

Figure 41: Model of the first branch.

When modelling the branches, care should be taken to ensure that a branch is always much thinner than the tree trunk. Furthermore, it must also be ensured that the branches must also be modelled on all axes so that the structure does not appear too flat.

Creating the leaves

When creating the sheets, the add-on "Import-Export: Import Images as Planes" is used. This must be activated (if not already done) via the "Blender User Preferences" in the "Add-ons" tab.

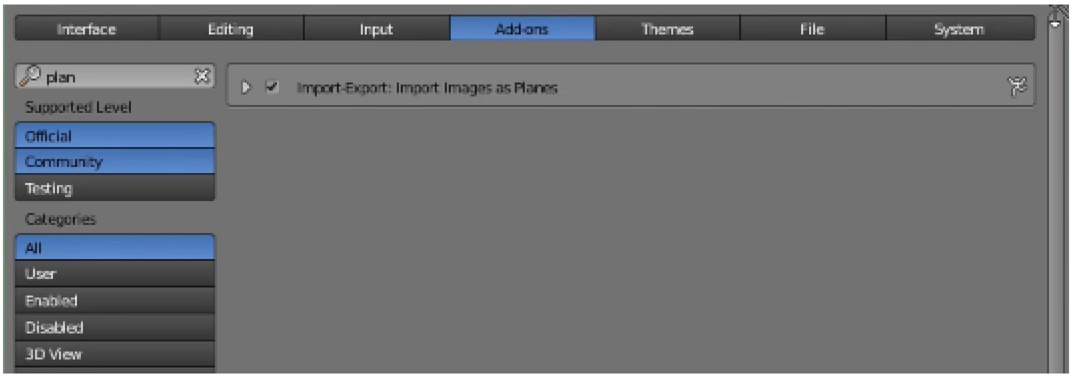

Figure 42: Enable the add-on "Import-Export: Import Images as Planes".

With this you are able to import photos or pictures of real sheets as planes and model them afterwards.

Before you insert the sheet, make sure that you have selected the Cycles Render rather than the Blender Render engine. This provides the required functions for the creation of the sheets.

Now you can select the option "Images as Planes" in "Mesh" via the key combination SHIFT+A.

Then your dialog window will open where you can select the file you want to import. However, before importing the file, the "Use Alpha" setting in the selection dialog must be changed from "Straight" to "Premultiplied". This gives the leaves a more beautiful appearance. The desired file can then be imported.

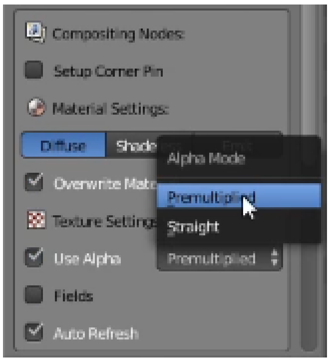

Figure 43: Change the "Use Alpha" value from "Straight" to "Premultiplied".

You can now start adapting the sheet. It is important to move the leaf in edit mode so that the origin point is on the lower side of the leaf (at the petiole). Next, add some more structure to the sheet file by pressing the W key in edit mode and selecting the "Subdivide" option. You can then move the various subitems of the file up and down to give the sheet a certain depth. The sharp edges can be removed in Object Mode by clicking on "Shading -> Smooth" in the Tools. Now the sheet should look like this:

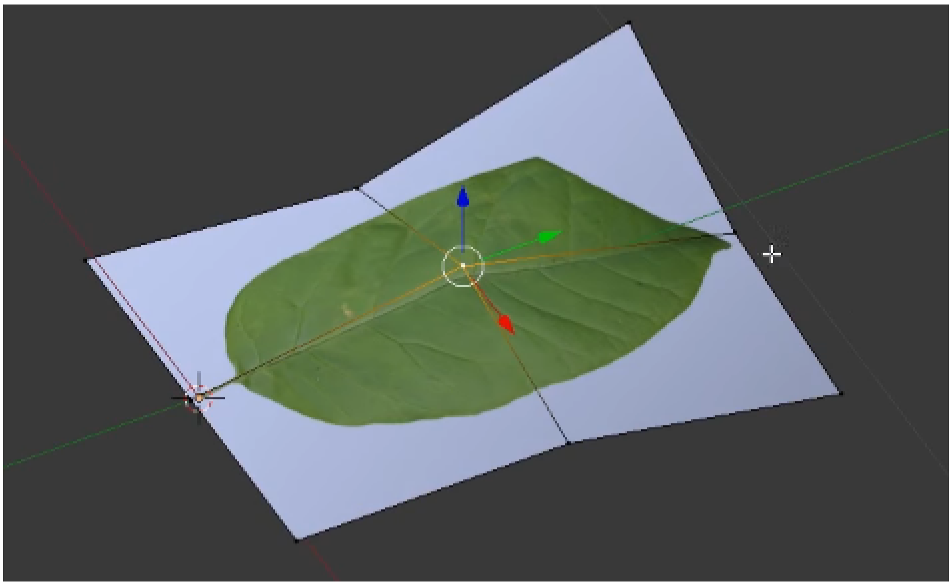

Figure 44: Leaves now have a 3d optic.

In order to give the leaf texture a more realistic look, adjust some settings in the node editor. It should be noted that some settings will have little effect on the final texture, but will have some effect on the render time. Therefore you have to decide (depending on the use-case of the tree) how detailed the texture should be.

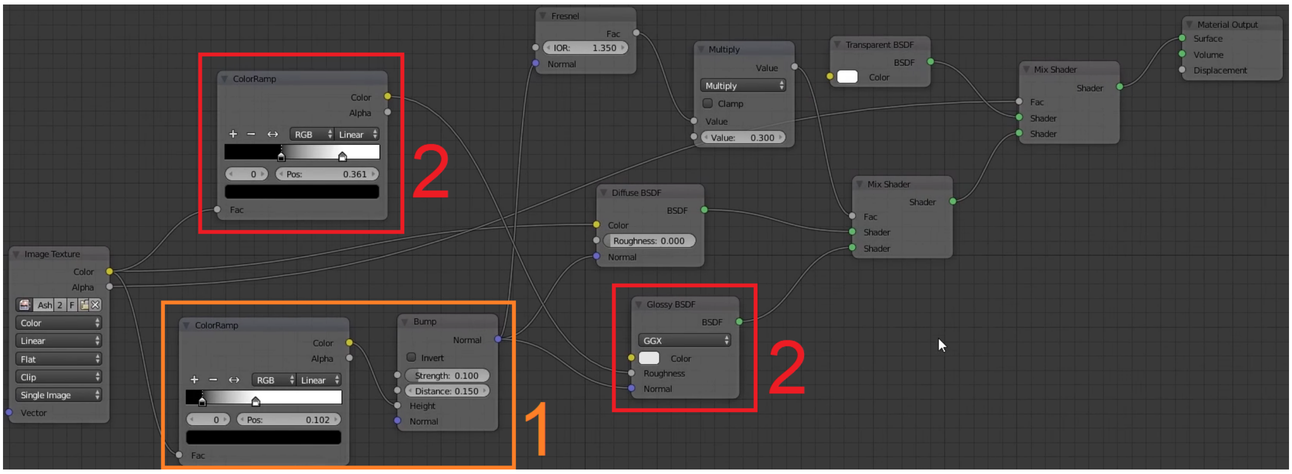

Figure 45: Nodes of the leaves.

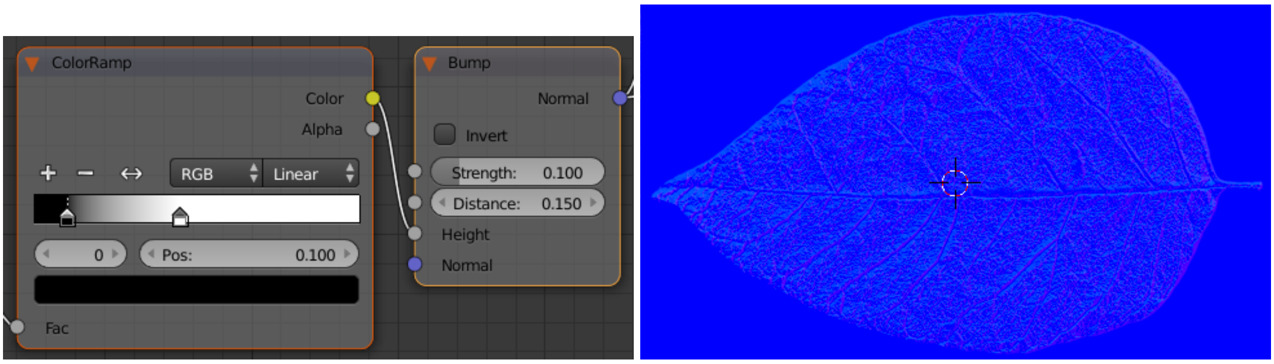

Figure 46: 1. Adding a bump to the leaves along the leaf veins.

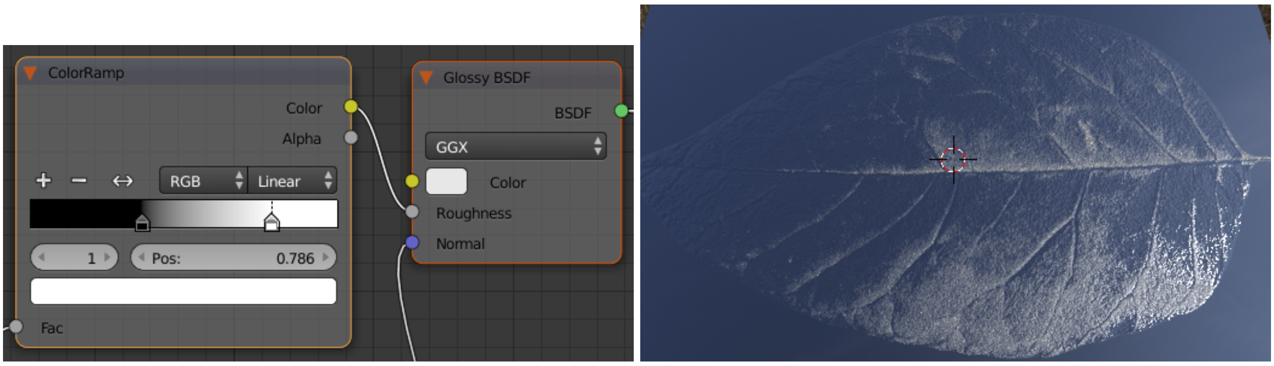

Figure 47: 2. Adding a glossy shader to the leaves.

Since the realistic look of the blade has now only been applied to the top of the blade, the same must be reapplied to the bottom of the blade. For this all nodes of the sheet are marked and duplicated with SHIFT+D. Then the field "Invert" should be selected for the duplicated bump node, as the bumps must now be opposite to the upper side. Then the texture of the sheet in the Image Texture node is changed and the last two Mix Shaders on the front and back are connected according to the following graphic.

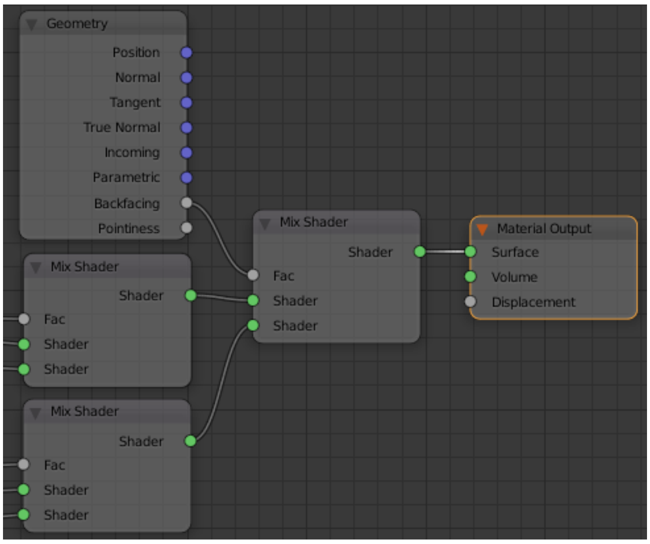

Figure 48: Connecting both Mix Shaders from the two sides of the leaf.

Now, when you have finished designing the leaves, you should put them together into groups. The reason for this is that leaves on trees also do not grow individually, but hang in groups of several different leaves. Therefore the individual sheets are marked and duplicated with SHIFT+D. These are then joined together optically so that they touch each other on the petiole. Of course, it is also possible to scale the leaves so that they appear more different and thus create a certain variation in the tree.

Figure 49: Grouping up leaves for more variety.

Now all (in our case) three leaf types and groups have to be marked and merged to one group by means of CTRL+G. The group should be clearly named so that it is easier to find later. To do this, enter the name "Leaves" in the input field that appears.

Figure 50: Grouping up leaves for more variety.

Putting leaves on branches

The leaves can be applied to the branches as a particle system. To do this, it is defined in advance where more leaves are to appear and where fewer leaves are to be placed according to nature. Therefore a weight-paint-map is created. The branch is selected and the view is changed to "Weight Paint Mode". The weight paint is then reinforced further up the branches so that more leaves appear there. The result should look something like this:

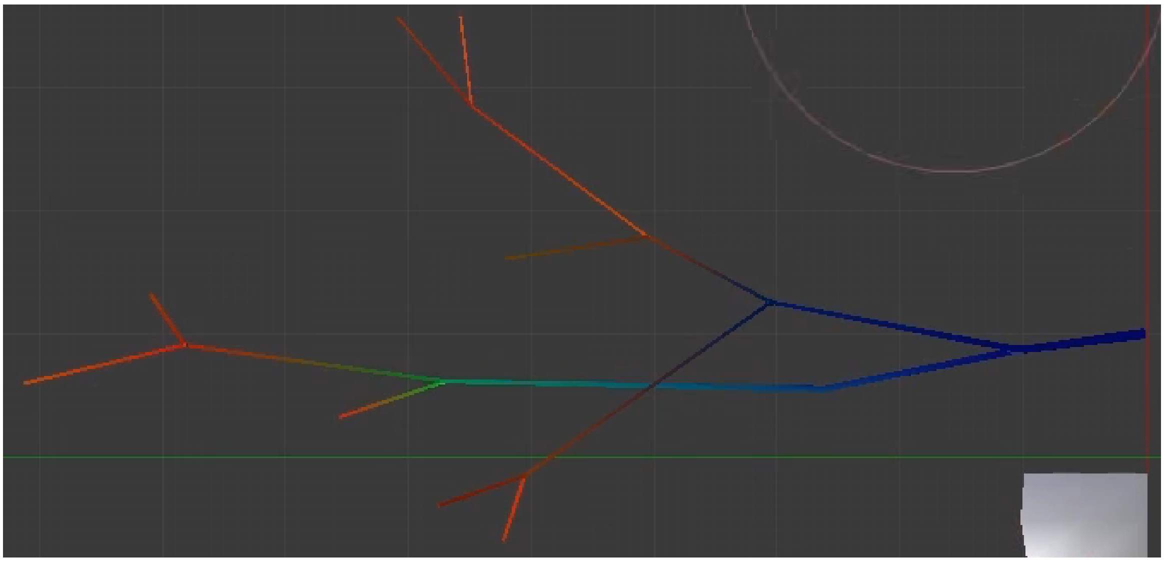

Figure 51: Creating a weight map for the branches.

Now a particle system must be applied to the branch. This particle system must be of the "Hair" type. In addition, a check mark must be placed at "Advanced" in order to be able to make all settings. To apply the leaves as particles on the branch, select the option "Group" for "Render" and select the previously created "Leaves" for "Dupli Group". Finally, the option "Group" must be selected as "Density" for "Vertex Groups". Then the sheets are placed according to the previous grouping and weight map. Now other values can be freely manipulated to meet the requirements. For example, the rotation or size of the particles can be changed. Since the particle system is linked to the previously created leaves, any changes to the leaves are now automatically transferred to the particle system. This is especially helpful if the rotation of the leaves is not correct on the branch. All you have to do is rotate the leaves and the change will be applied automatically.

In the end, the branches should look like this:

Figure 52: Branches with leaves as a particle system.

Putting branches in the tree

The leaves still need to be inserted onto the tree trunk. The same procedure is used as for the leaves and branches. First you have to create a weight-map for the tree trunk, so that the branches should only appear in the intended places. At the end the weight-map of the tree trunk should look like this:

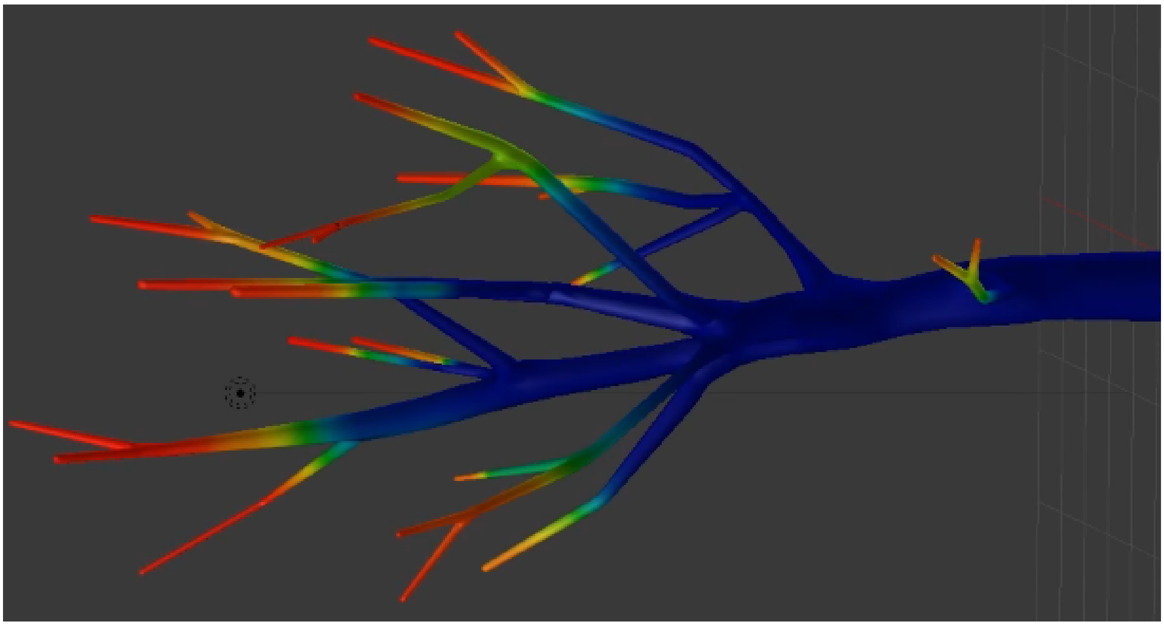

Figure 53: Trunk with weight-map.

Before the branches can be applied to the tree trunk as a particle system, the particle system of the branch must first be converted to a fixed object. To do this, select the branch (together with the particle system), change to the "Modifier" tab and click on "Convert" at "ParticleSystem". After that, the old particle system in the just converted object has to be removed by switching to the "Particle System" tab and clicking on the delete button.

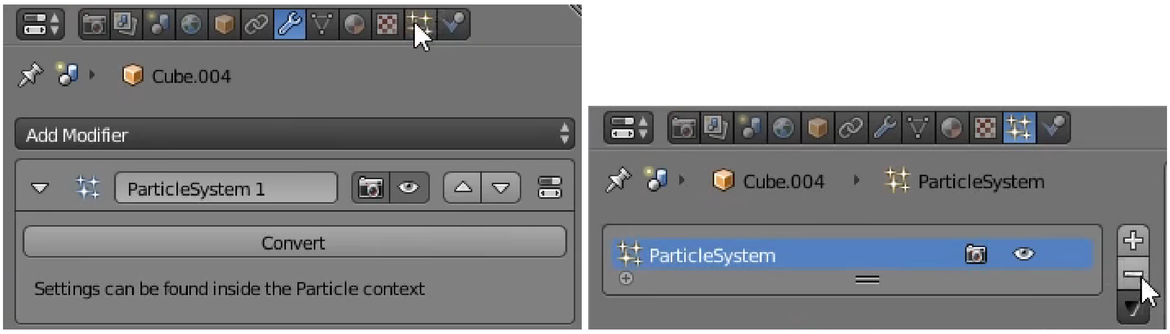

Figure 54: (1) Convert the particles to an object and (2) remove the old particle system.

Directly after deleting the old particle system, the key combination CTRL+J must now be used to join the elements.

Now all branches are marked again and a new group is created with CTRL+G. Now you can rename this group to "Braches", so that this group can be used later.

Subsequently a particle system can be created on the tree trunk (with the same settings as for the branches), "Branches" is selected as "Dupli Group" and the weight map created before is selected as "Density" of the "Vertex Groups". After that, the branches should appear on the tree according to the weight-map. Now you can (again) freely adjust the arrangement of the particle system so that the tree looks appropriate.

Figure 55: Added branches to the tree.

7.2.8.3 Tree texture

Finally, the tree trunk must be given a texture. First, a tree trunk texture is opened in Blender, which is then applied to the tree trunk. Then the entire tree trunk is marked in edit mode and with the U key and a click on "Smart UV Project" the tree is projected onto the texture.

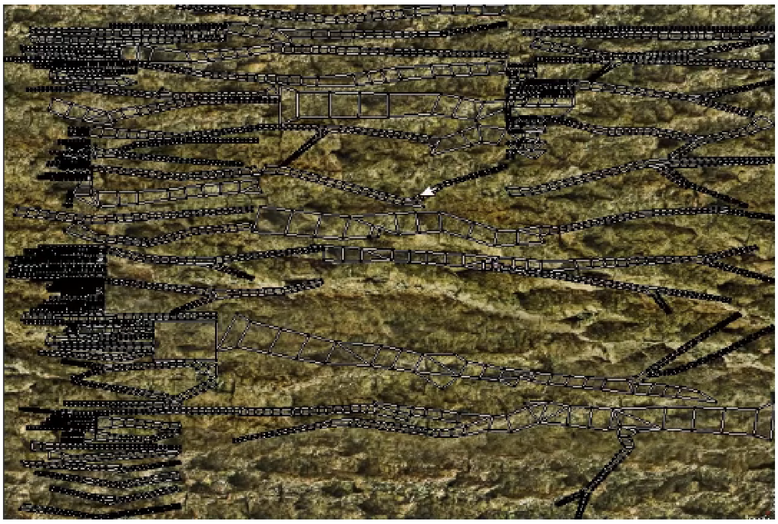

Figure 56: Projected trunk on wood texture.

Now, above all, the parts of the projection that run against the stream of texture have to be adjusted manually, otherwise they will look bad.

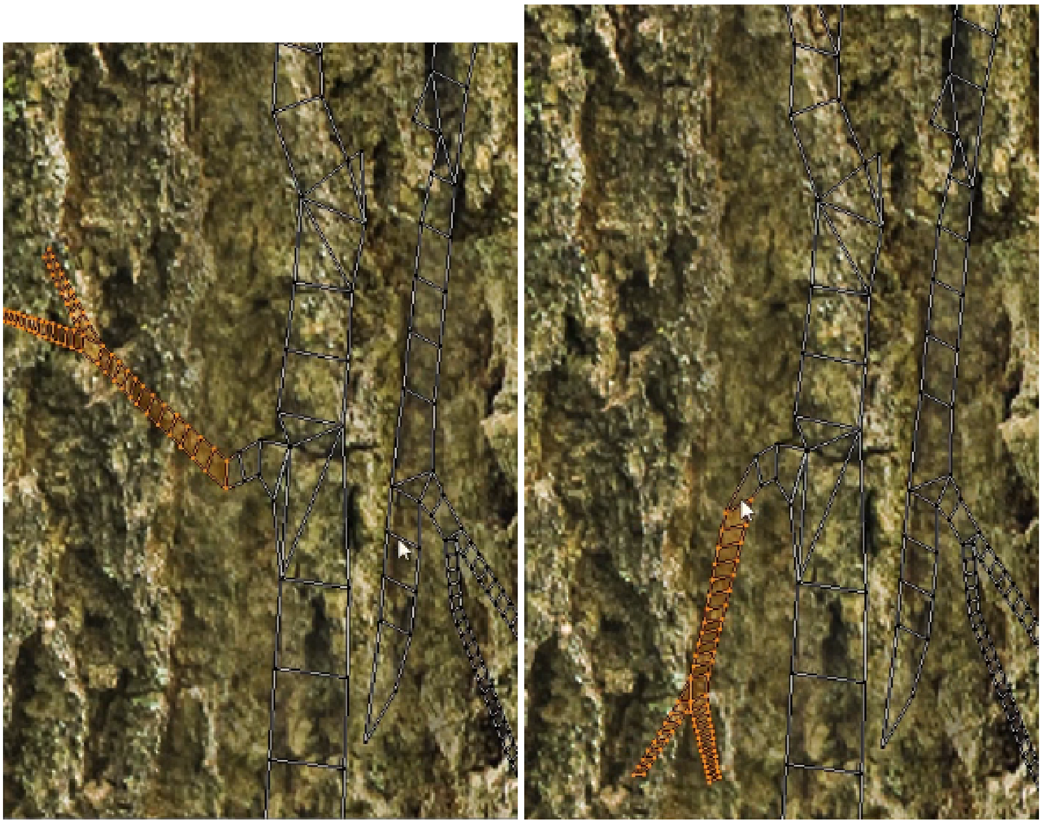

Figure 57: (1) Before correction, (2) after correction.

The same must then be done for each template of branches on the tree. Since the branches are a particle system, changes to the templates are transferred directly to the tree trunk.

Then you switch to the Node Editor, where you insert a texture for the tree trunk. First, a "Texture Coordinate" node is created, which is connected to the "Image Texture" by a "Mapping" node. Now we have to adjust for Scale so that the texture of the tree trunk is correctly scaled.

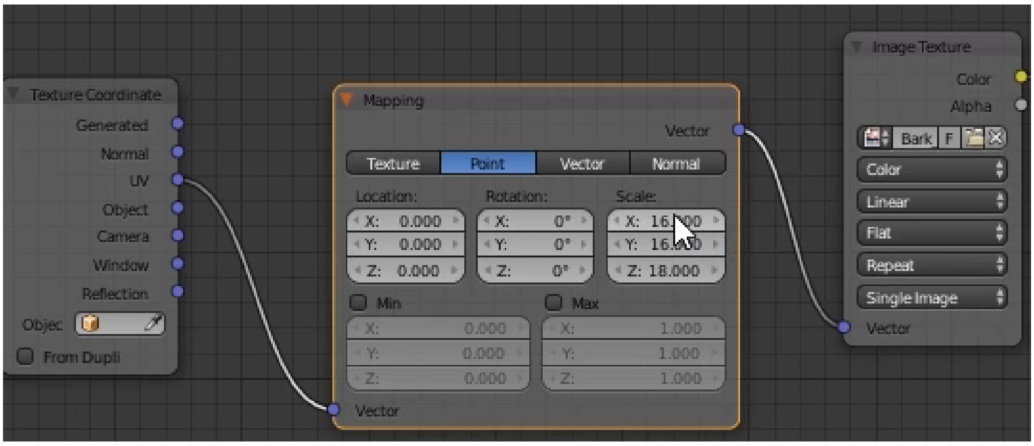

Figure 58: Texturing the trunk with a bark texture.

The result should look something like this:

Figure 59: Rendered view of the trunk with an applied bark.

Now the same settings for texturing the tree trunk are applied to the branches of the tree. The result is a tree with animable and changeable branches.

7.2.9 Modular Tree creation

The modular tree creation Add-on is one way to create trees in blender. To download the Add-on just follow the link [2] and download the latest version as zip.

[2]https://github.com/MaximeHerpin/modular_tree/releases

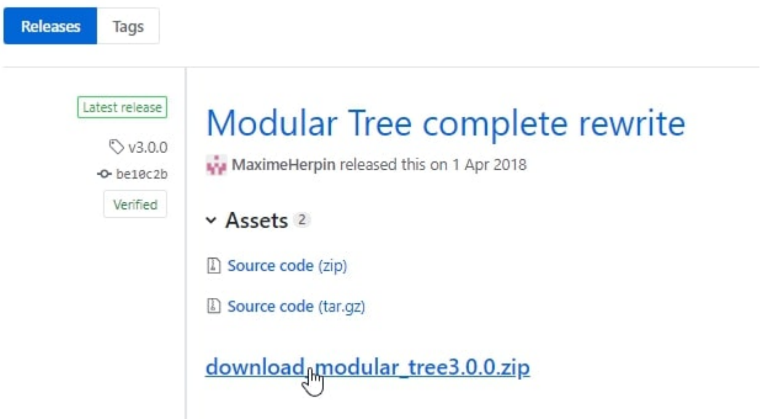

Figure 60: Download Add-on

To install the Add-on open the User preference window. One way to open it is with the shortcut Ctrl + Alt + U. The other way is to click on files User preferences. After that click on the Add-ons tab and select install Add-on from file at the bottom.

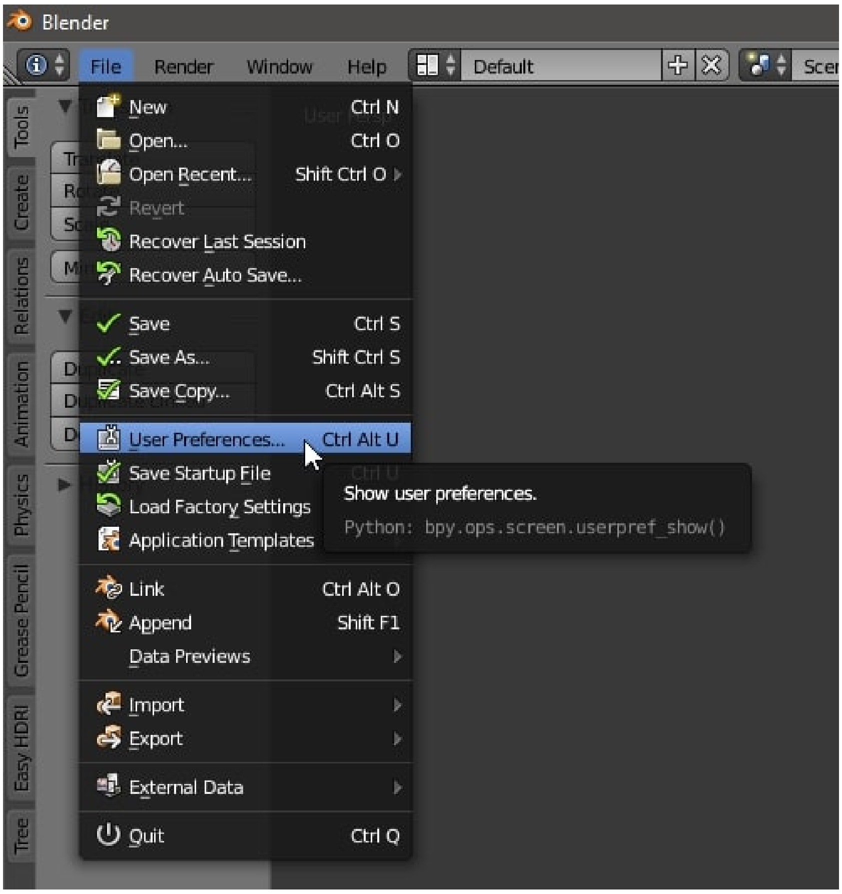

Figure 61: Install Add-on

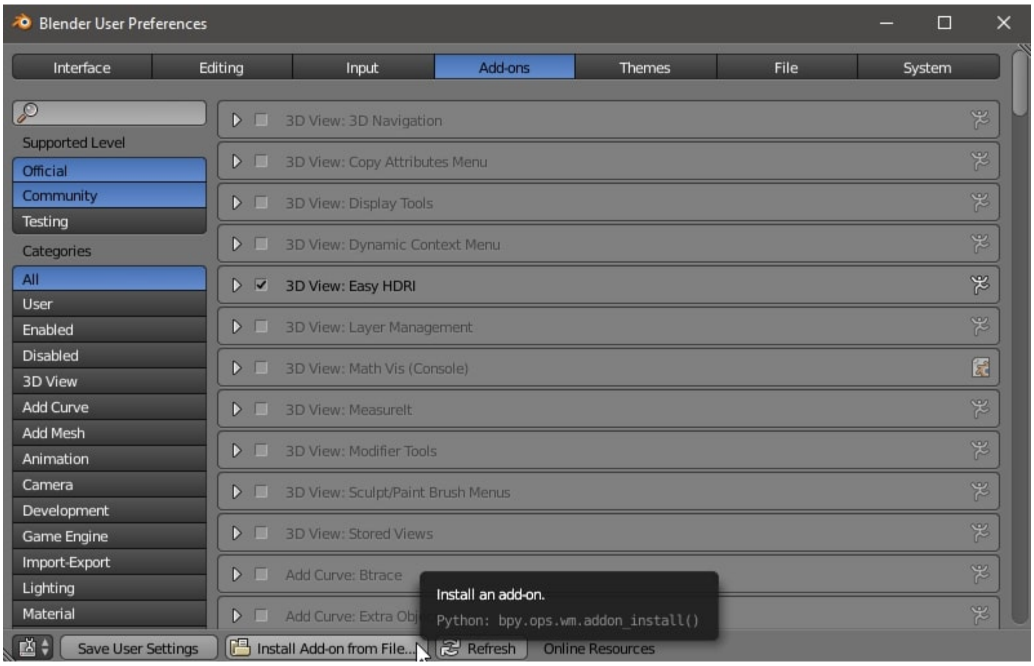

Figure 62: Install Add-on

Now select the downloaded zip file and confirm at the top right. After that check the checkbox from the Add-on and save the user settings so the next time blender starts the Add-on is enabled.

7.2.9.1 Tree creation

The modular tree creation Add-on comes with its own node system to create trees with. A new symbol can be found in the node editor on the bottom.

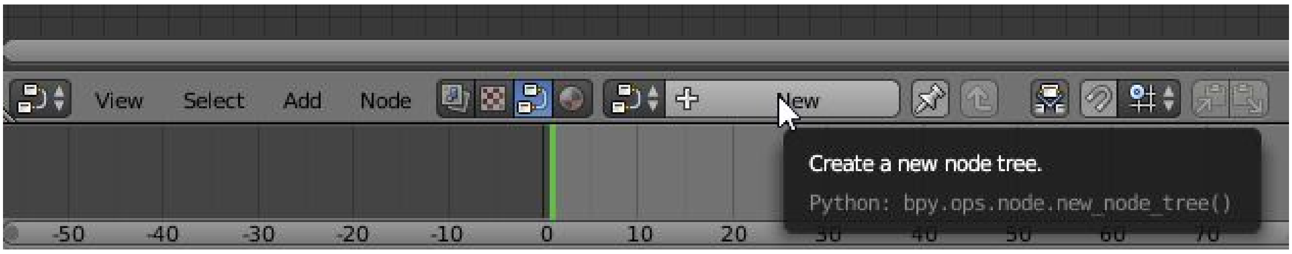

Figure 63: Node Editor

To create a new tree click on the new symbol and on new after that. Name the tree accordingl. To create a tree with the node system, one requires an input node, a tree function node and a output node. To add one of those nodes simply click shift + A.

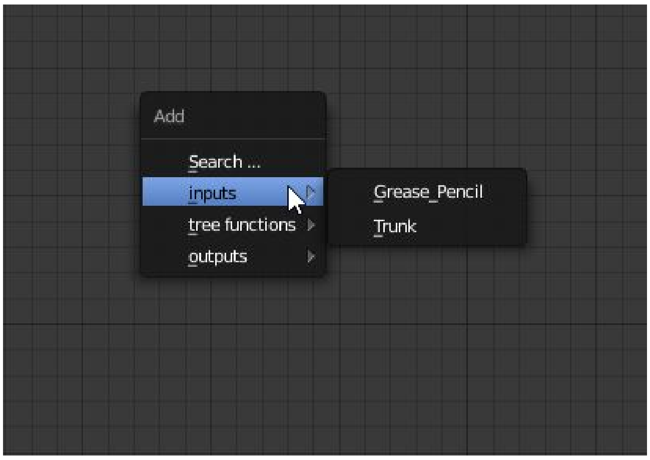

Figure 64: Create tree nodes

There are two options under inputs. The first option is to create a trunk out of a grease pencil drawing or to use a trunk node. In this case a trunk node will be used. The trunk alone cant be displayed without a tree function and an output. The next step is to add those two nodes. After that connect the nodes like this:

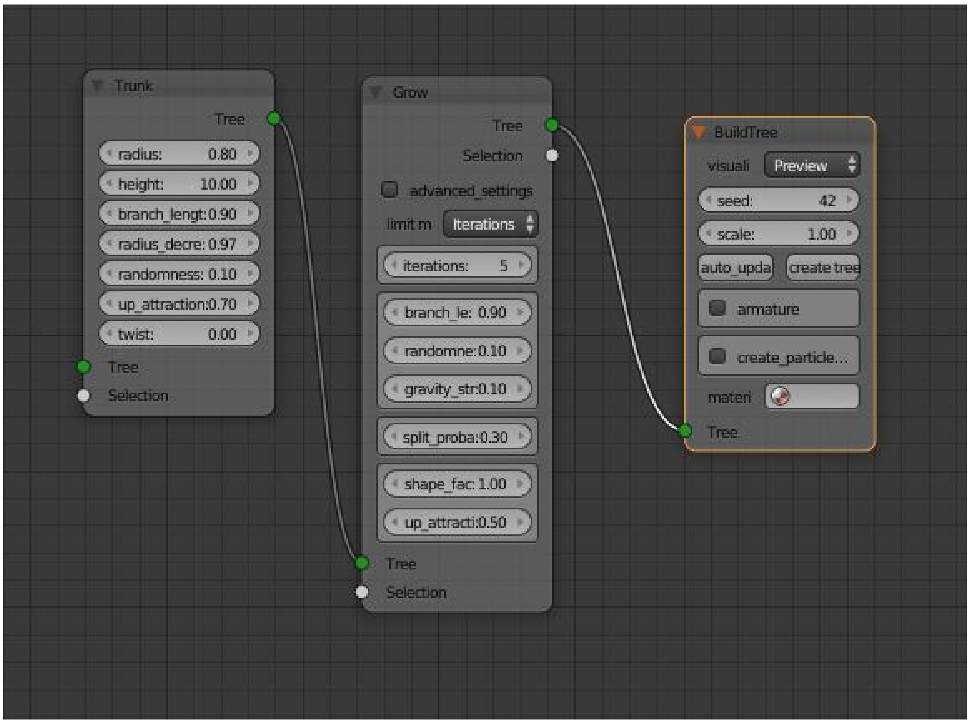

Figure 65: Connect tree nodes

Now with the three main nodes connected the tree can be displayed in the 3D View. Simply click on create tree on the output node. To shape the tree use the grow and split nodes in between the input and the output node. There are two settings you can use in the grow node "radius" and "irritations". More information about the grow nodes can be found in the documentation of the Add-on. After the tree is shaped choose the detail level in the output node and change "preview" to "final". The amateur option will give the tree bones so it can interact with wind later on. For the leafs the particle option will be used. Simply type in the maximum radius that the particle system can spawn within and create the tree. The next step is to create twigs and to assign them to the particle system.

Create a new layer for the twigs to keep the scene organized. To create a twig click on make twig under the tree tab on the left side. This will spawn a twig which can be modified with the options on the left side.

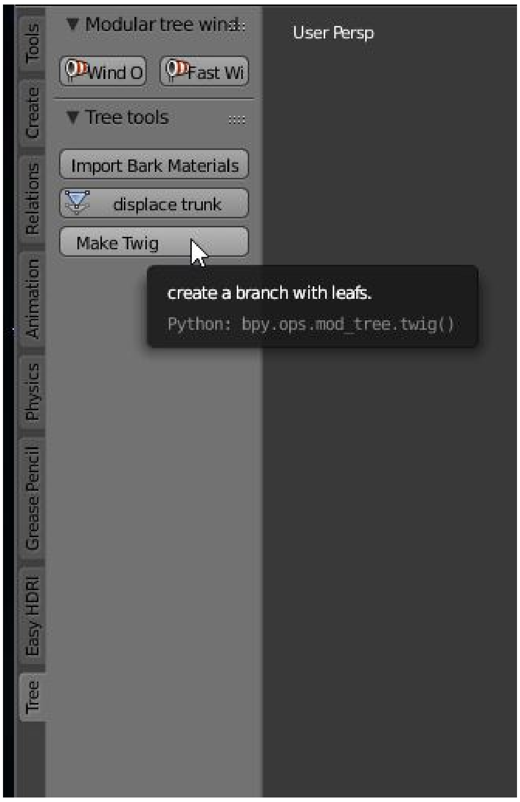

Figure 66: Create twig

Create different twigs and place them next to each other in the same layer. Create one and move it slightly to the side then create another one and so on. A number of four twigs is usually enough to have sufficient randomness in the tree. Select all twigs and group them with Ctrl + G. Name the group twigs and go back to the layer where the tree is.

To assign the twigs to the particle system click on tree leaves emitter on the scene and go to particle options. On the bottom click on group and select the twigs group. Select pick random and change the size and random size to have a variety of twigs.

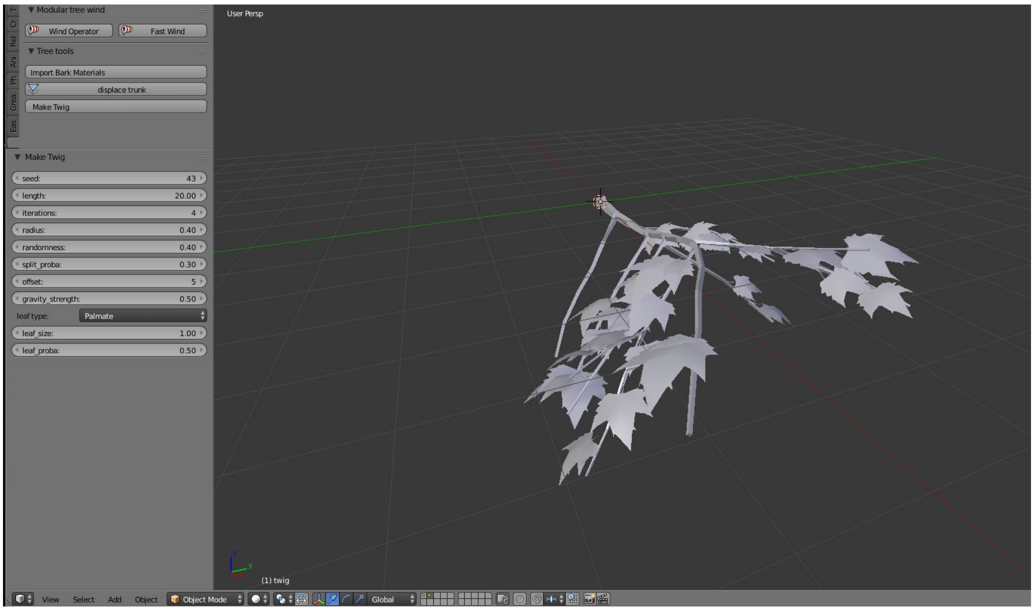

Figure 67: modify twigs

Figure 68: Group twigs

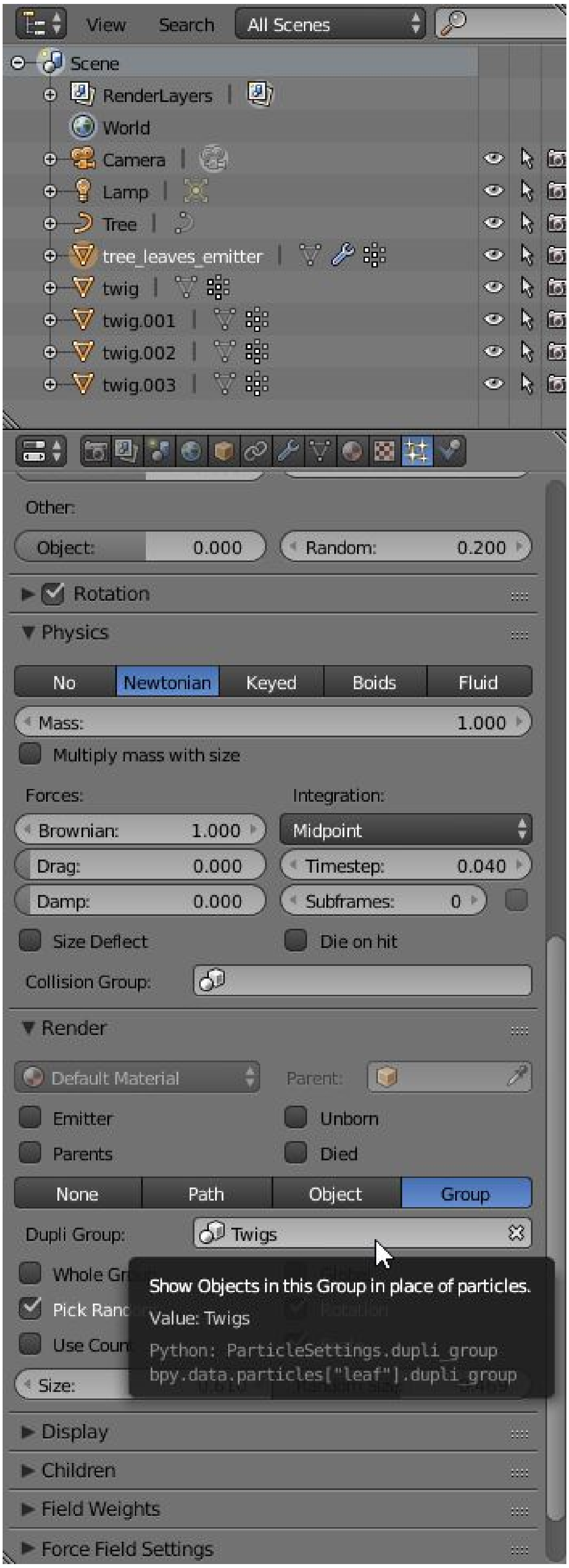

Figure 69: Select particle system

These are the main steps to create a tree with the modular tree creation Add-on. To give the tree a nice texture simply use the material created in the first tree guide of this document or use the textures which come with this Add-on by simply clicking under tree and import bark materials.

Figure 70: Import bark materials

7.2.9.2 Creating a large scale forest that is render friendly

Different kinds of high-quality trees can be created with the two methods listed above. Since the trees use many resources it is very computationally intensive to render those. Another method was used to populate the forest with more trees so that the rendering would not take as long while yielding the same result. This method consists of two main steps. The first step is to setup a Scene which will later be used to create different 2D images of different trees. The images will be later used to create a 3d effect of the 2d tree so it is less resource intensive. The second big step is to place the 2d trees in the scene. For this step a hair particle system will be used. To start with the first step create a new scene and set it up with the following settings.

7.2.9.3 Setting up the tree

First of all some settings must be selected. Click on scene edit on the right side and change the view option under color management, from default to filmic and the contrast from none to Medium high.

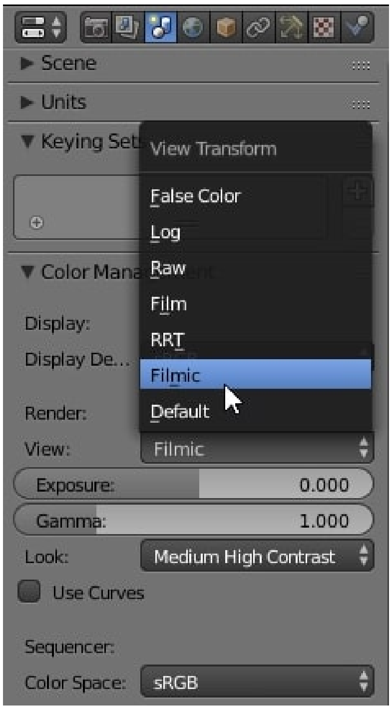

Figure 71: Change scene

First of all set blender to cycles render. Under render settings the following settings need to be selected:

- Change the resolution to 2048x2048 and just set that only one frame will be rendered.
- Set the percentage scale for the render resolution has to 100 percent
- Go to Film and check the transparent option
- The render samples have to be set to 64

Set up the scene a little bit by first deleting the cube and the lamp which spawn after a new scene is created. Then add a plane with shift + a and scale it up with s. Now select the plane and go to object settings. Under cycle settings disable the ray visibility for the camera so the objects will still interact with the plane but the plane is invisible for the camera if the image gets rendered. Insert a previously-created tree into the scene and place it in the center. Now press shift + A on the scene, select an area lamp and place the light over the tree. Scale the light with S. The strength of the lamp should be set to 2000. The option can be found in the lamp settings. The world background should be set to the color white with a strength of 2. The next step is to select the trunk and change the pass index to 1 so later on a black and white mask of the trunk can be created. The option can be found under the object settings –> Relations –> Pass Index.

Set up the camera by selecting it and resetting the rotation and position. Simply use the shortcut alt + R for the rotation and alt + G for the position. With a press on numpad3 and numpad5 a side view gets activated. Now rotate the camera 90 degrees. Use R for this or simply type in 90 in the cameras x rotation. Move the camera in front of the tree and set the camera under the camera settings to orthographic instead of perspective. Scale the orthographic scale up if needed. With numpad0 the camera view gets activated. With a press on G the camera can be moved. Align the camera so there is no free space between the bottom of the camera and the bottom of the trunk. With Ctrl + b the render size can be set. Simply draw a rectangle over the tree. Now it is time to create different kind of pictures e.g. a normal image, a black and white mask, a normal map and a volume picture of the tree that is currently in the scene. This scene will be used later for different kind of trees so the settings above need to be done one time only and the scene can be reused multiple times. The scene should look like this.

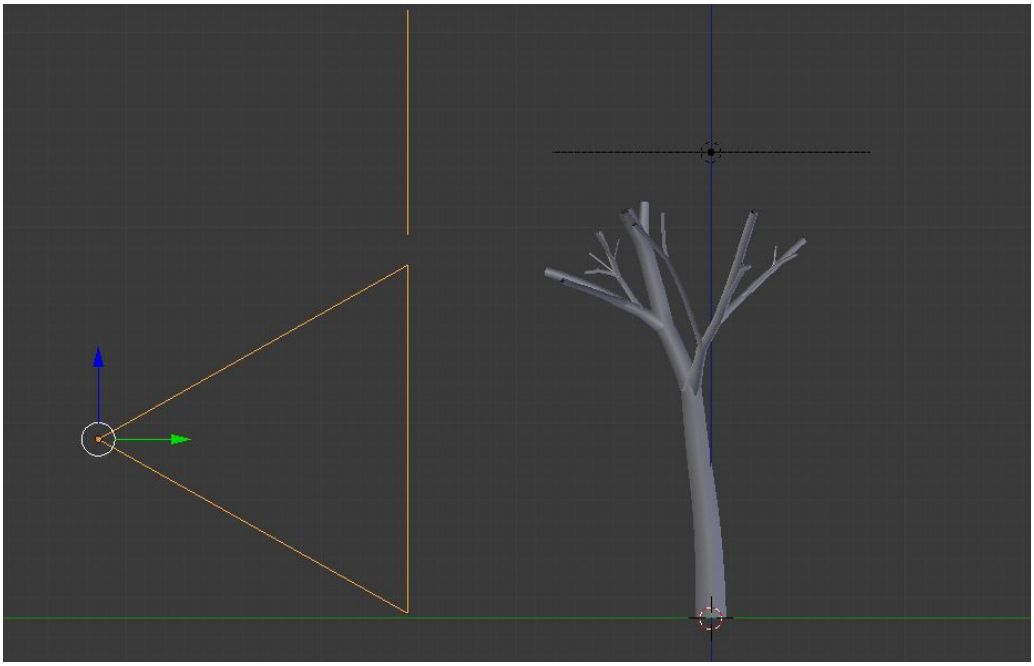

Figure 72: Scene view with a tree without leafs

Now it is time to render the image. Once rendering is done, save the image with f3. Name this image 'color image'. On the left side set the color to RGBA and for the color depth select 8. After the first image is saved go back to the rendered image and change the combine setting on the bottom to indexOB. Now the trunk should be white. Hit f3 again to save the image. In this case chose BW on the left and name the image mask. Now a normal map of the tree has to be created. For this, change the cycles render back to blender render and go to the render settings on the right. Under Anti-Aliasing click on 16 and activate Full sample. Press N in the 3D view so a sidebar will appear on the right. Go to Display and check the only render check box. The last setting that has to be done is under shading. Enable Matcap and select the normal mapping texture.

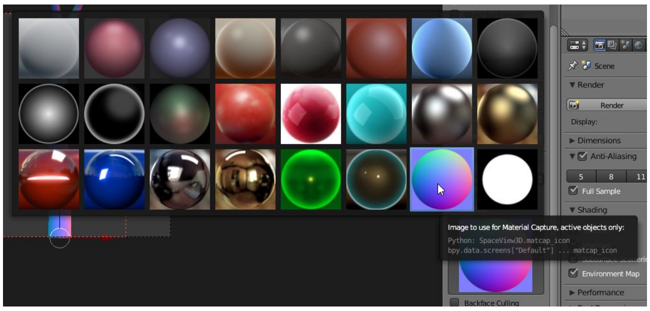

Figure 73: Select normal map matcap

Now select the second icon from the right on the bottom bar (the openGL render button) and render the normal map image. Change the shading option in the render settings from sky to transparent to get a transparent background. Now render the image again and select RGB on the left side and name the image normal map. Go to another layer now and create a cube with shift + A. Scale it up with S so it fills the entire render box. On the toolbar on the left go to tools –> edit and click on smooth shading. Now render the image with the openGL button again. Select RGB on the left and name the image volume normal.

This scene can be saved now and used for every other tree. This scene will be used to create pictures for different kinds of trees to use in the particle system in the next step.

7.2.9.4 Create particle system as large forest

In the second step a new scene will be created where the 2d tress are going to be placed in. First delete the cube and the lamp again which spawn if a new scene is created. Now create a plane and switch to the edit mode with tab. Now move the plane one blender unit away by holding Ctrl and using the arrows in the 3D View.

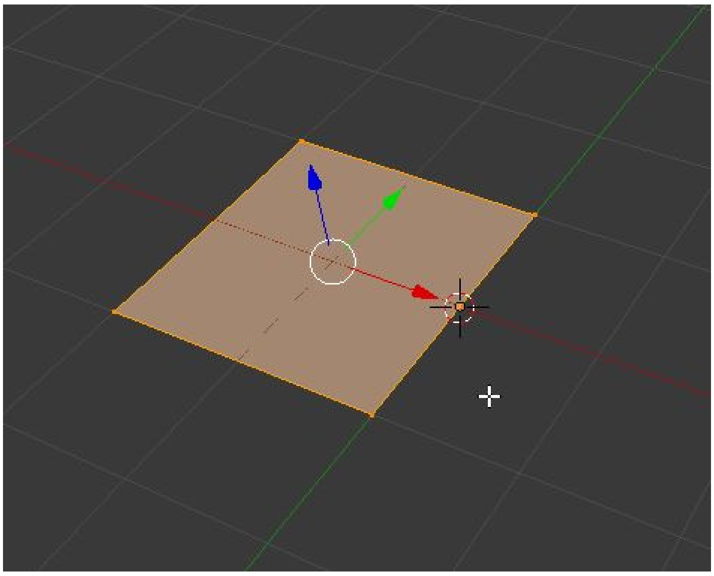

Figure 74: Move Plane one blender unit

Now switch back to object mode and rotate the plane 90 degrees up so the centre point is on the bottom.

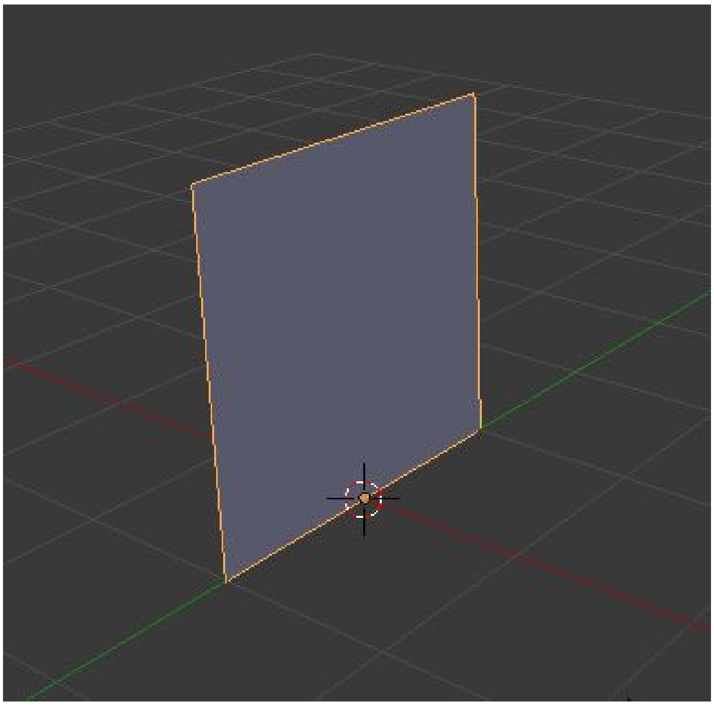

Figure 75: Rotate plane

After that press Ctrl + A and apply the rotation. Change the settings to filmic again like in the previous scene also add another plane and scale it up as a ground.

Change the settings to filmic again like in the previous scene. Add a sun and let it look at the plane. Before creating the different nodes needed to combine the previously created pictures, switch to edit mode, press U and unwrap the plane.

Now a whole node system is created to join the different types of images (such as the color image, the normal map, the mask image and the volume image) together to create a 3d effect of a 2D tree. The images combined will react to light in a way a normal 3D tree would do but in fact they are 2D and less resource intensive in case of rendering but still look good.

First of all create a new node and add four image textures. These are for the color image,the normal map,the volume map and the mask image. There will be three main sections later on on for a random color for the trees, one for the translucent effect and one for the normal mapping. The nodes look like this.

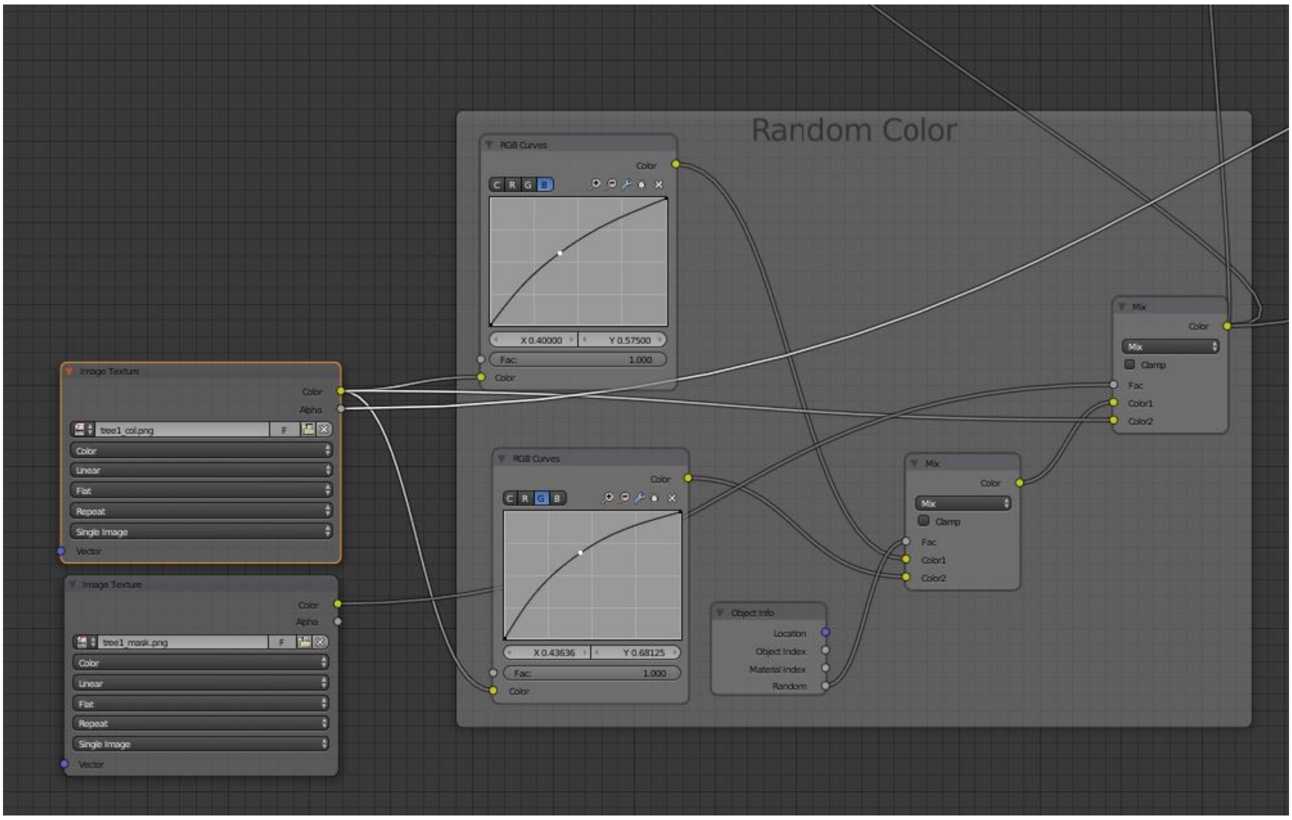

Figure 76: Random color label

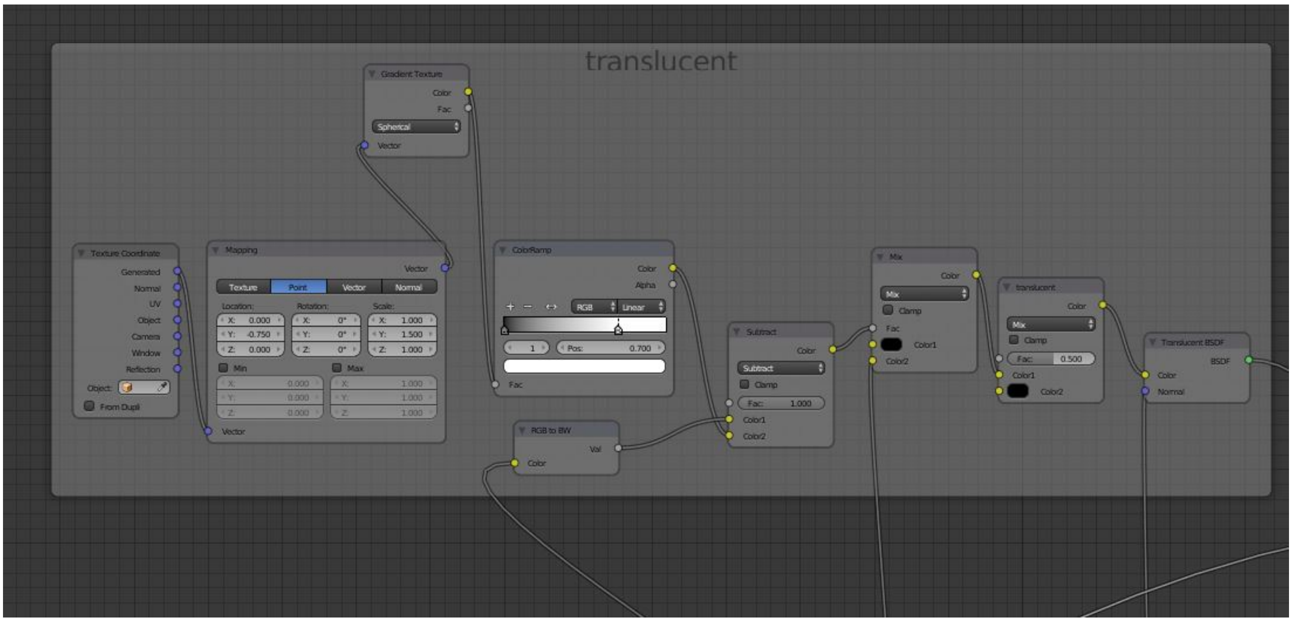

Figure 77: Translucent label

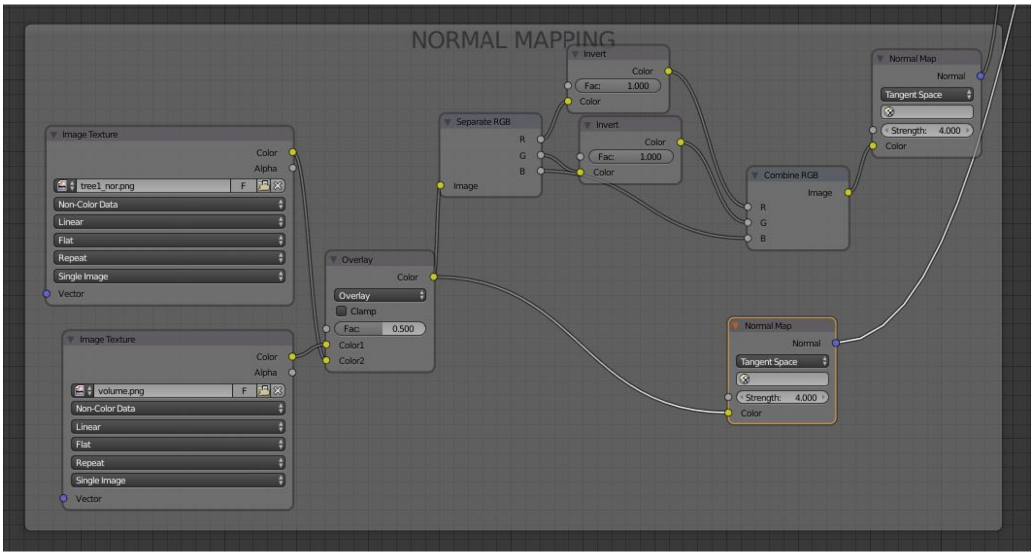

Figure 78: Normal mapping label

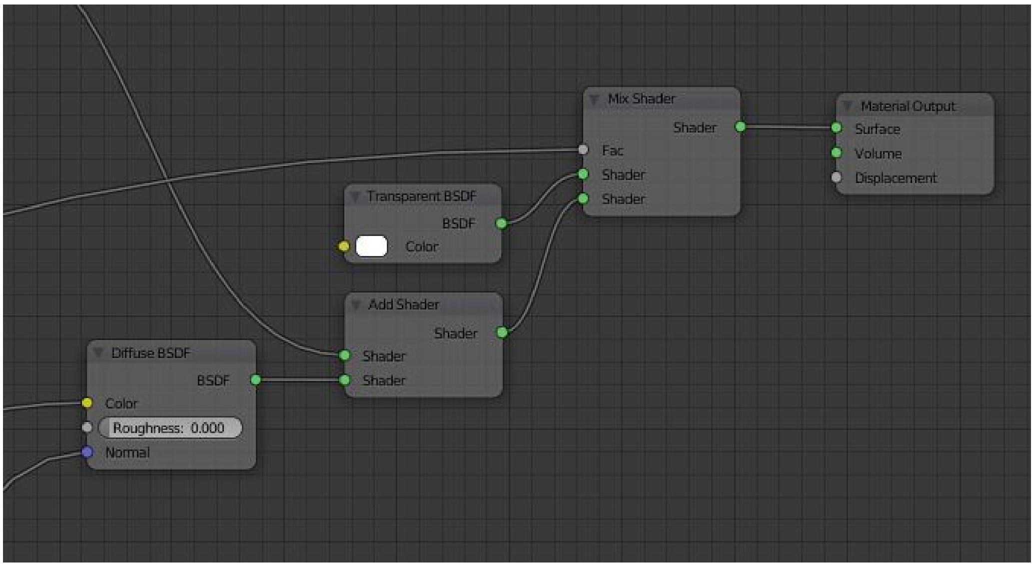

Figure 79: Output nodes

Connect the last mix output of the random color label with the RGB to BW node from the translucent label. Then connect the output of the last mix from the random color label with the second color of the first mix of the translucent label.

The upper normal map output from the normal mapping label has to be connected to the last node of the translucent BSDF node in the translucent label. The below output of the normal map from the normal mapping label goes to the diffuse BSDF node outside the labels. Connect it with the normal slot. The last mix node from the random color label goes to the color slot of the diffuse BSDF. The output of the translucent label goes to the first add shader slot outside the labels. The alpha channel of the color image will be used in the fac slot of the mix shader node which comes before the material output node.

The whole node system looks like this.

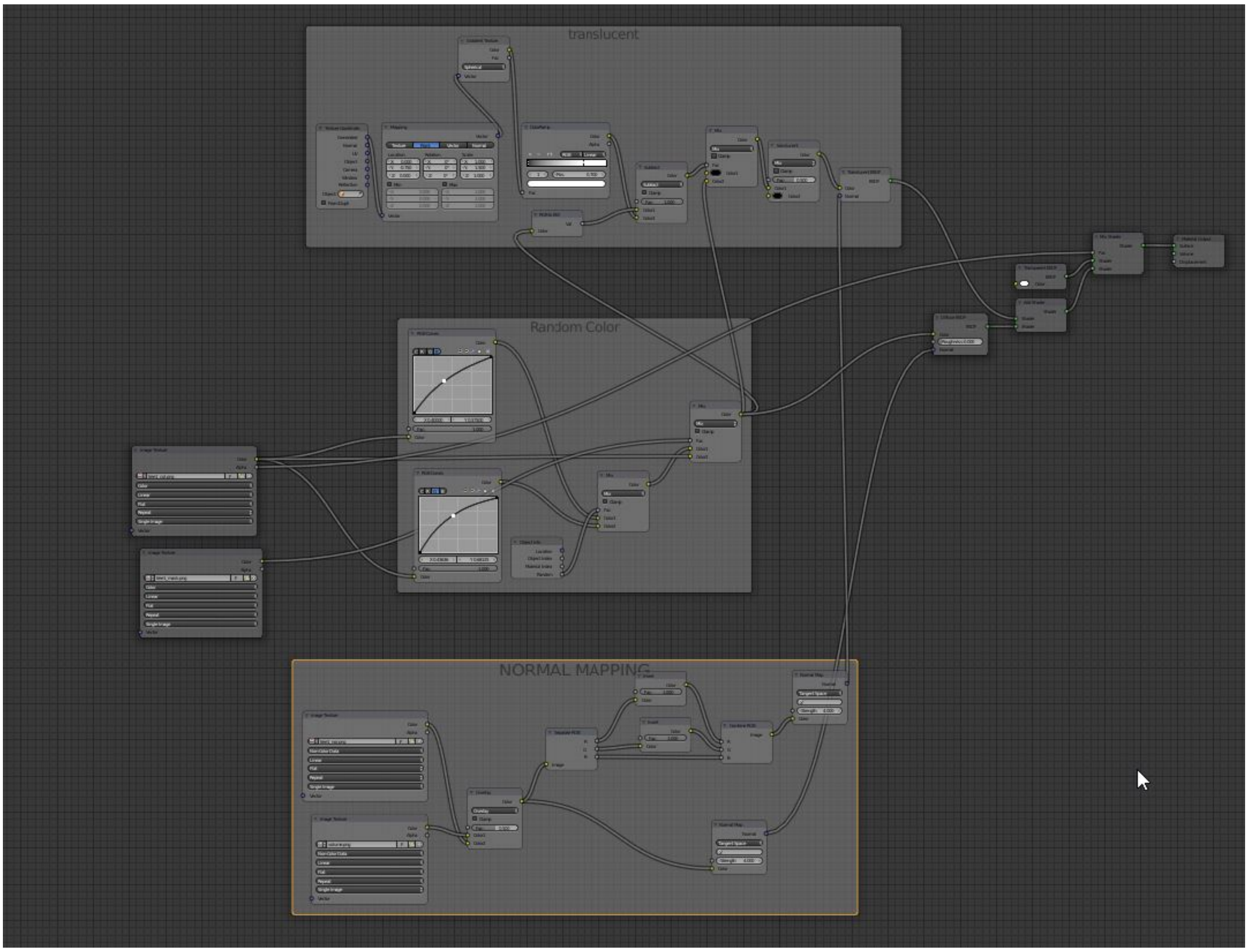

Figure 80: Whole nodes

After the nodes are created it is time to align the planes to the camera. This way they follow the rotation and movement so the camera always looks at the front of the plane, maintaining the 3D effect. Select the plain, go to the constrain option, select 'track to' and choose the camera. Constrain the plane either to X or -X, depending on the rotation the plane has in the current scene. Next add another object constraint and limit the rotation of the X and Y axes so the plane will only rotate to the left and right instead of up and down.

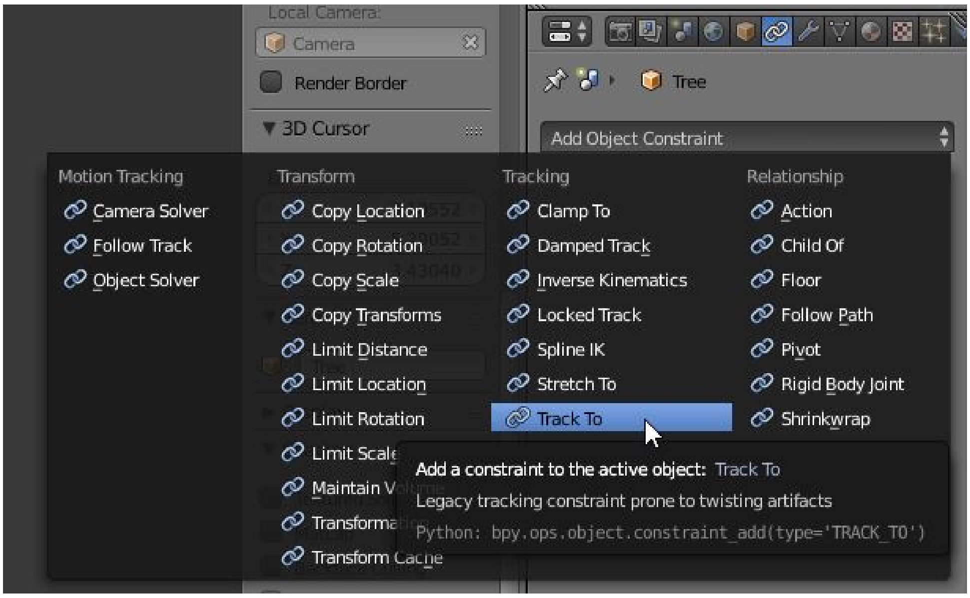

Figure 81: Track to camera

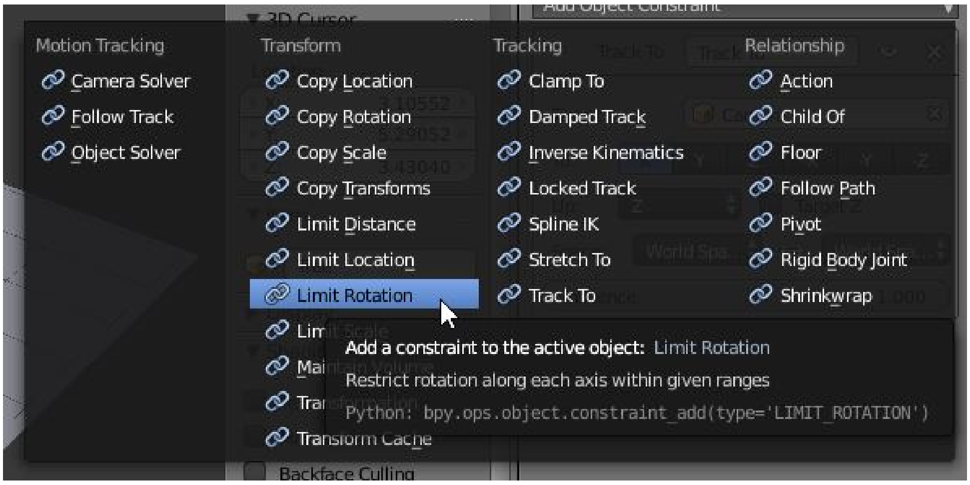

Figure 82: Choose limit rotation

Figure 83: Limit rotation X and Y axes

To add different kind of trees just create a new plane, copy the nodes and change the image textures with the images of another tree. After creating some trees to get a set of trees, group the planes together.

The next step is to select the big plane which represents the ground to create a hair particle system on which the different planes with the different trees will later spawn on. Select the ground go to the particle system option and add a new particle system. Give the particle system a name, change the type to hair and enable the advanced options. Go to render in the particle system options, click on group and select the tree group. Check the rotation check box so all spawned trees will have their origin rotation which is the camera. Under physics the size and the random size can be adjusted so the trees will have different sizes. To spawn more or less trees simply change the emission number.

To decide where trees spawn, simply select the plain, go with tab to edit mode, press W and click on subdivide. Subdivide the plane four times and go back to the object mode. Now go to the weight paint mode and draw on the plain where trees should spawn. Now the particle system will spawn only on the areas trees.

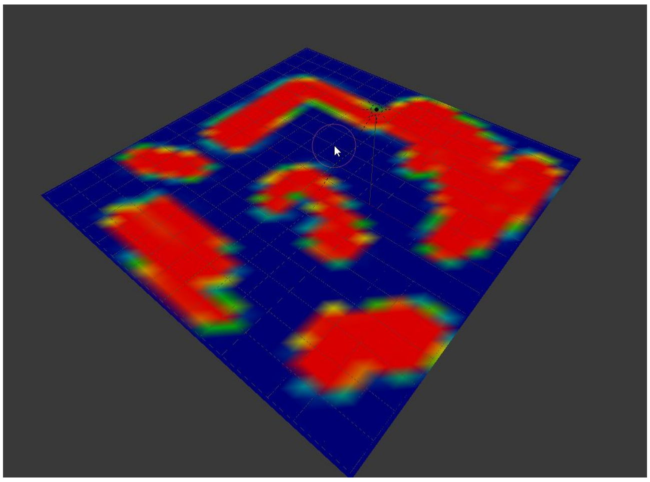

Figure 84: Weight paint

7.2.10 Creating the Background

To create the background the user must use the composite mode. Here it's possible to create a node setup that is used after a frame of the scene in the default mode is rendered. At the beginning it's necessary to render a single frame. It's important that the background is transparent. After this is done, switch into the composite mode and select use nodes and Backdrop. Two nodes should appear. The goal is to use the rendered image as a part of the background. This way everything looks more realistic and uniform. Since there are some parts which are still transparent, the user needs a hdri picture to fill them. In this case a hdri picture of a forest is certainly the best choice.

Now the following node setup is needed:

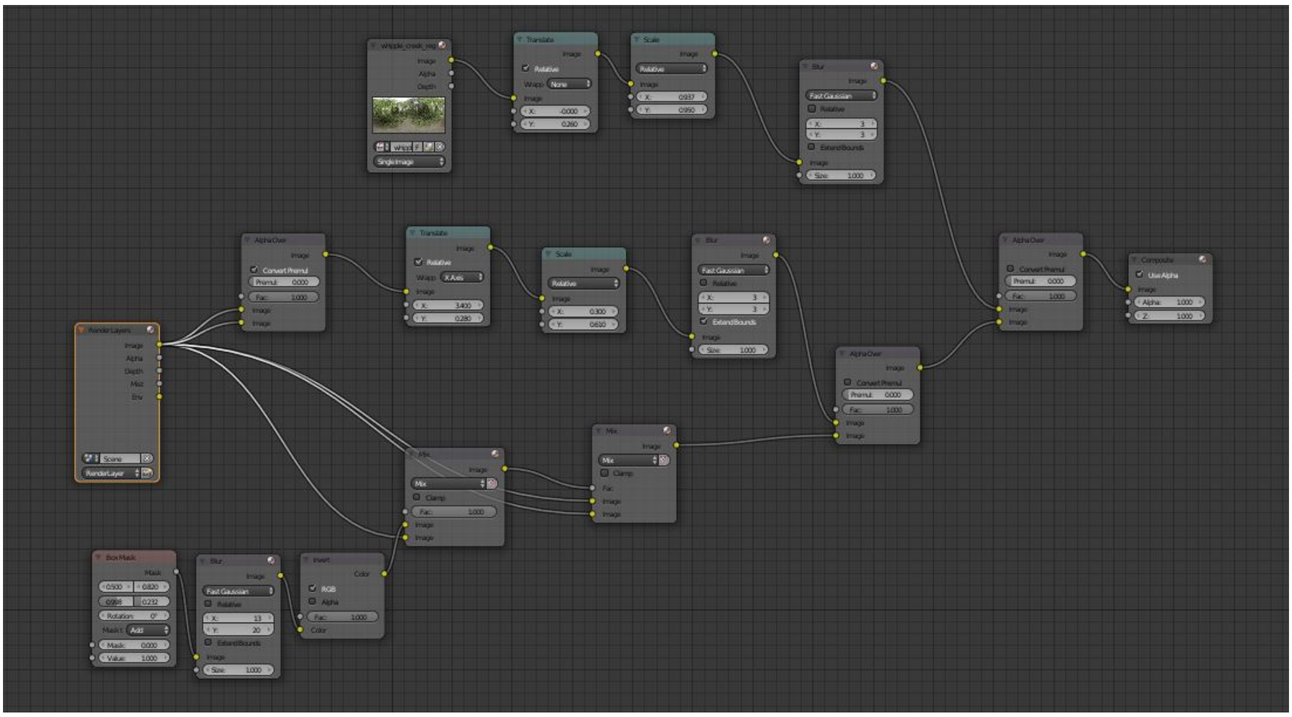

Figure 85: Complete node setup Background

This is the complete setup. The most important nodes for implementing changes are the ones in the next picture.

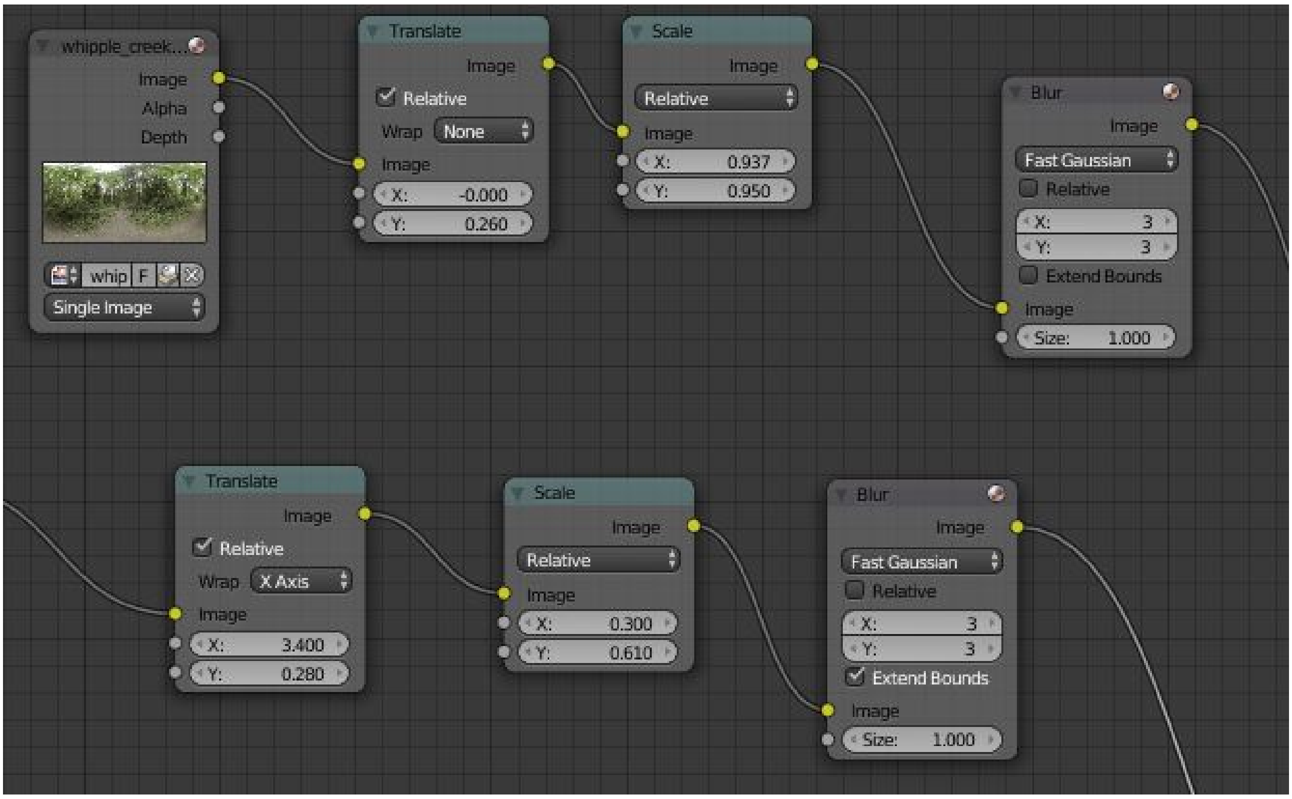

Figure 86: Composition: important nodes for changes

The four nodes on top are the ones that are used to implement the hdri picture. The other nodes are for the rendered frame that is used for the background. For a realistic look the parts in the back should be a little bit blurry. The user can adjust it by increasing the value of both of the blur nodes. The other nodes are used to scale and position the background. It's important to use the option warp: x-Axis in the translate node on the bottom. With this option the rendered frame repeats itself around the x-axis when it gets scaled down. The rest is just a lot of experimenting with the position of the pictures. Find a result that looks good and make a few test renders to see which settings give the best outcome.

The last step is to check if compositing is activated under post processing in the render tab. If every step is followed correctly the finished result could look like this one:

Figure 87: Final render

7.2.11 Rainforest

Rain with wet ground

Rain was modelled to create the effect of a wet ground. First two planes and an icosphere are needed. In this case the ground plane and the upper plane have the same size so that the rain will cover the whole ground.

The upper plane has a particle system with rain droplets. The rain droplet is an icosphere with a material. First the subdivisions of the sphere are set to one and the shading is set to smooth. The material output has a node named “Principled BSDF” as the surface where just the transmission is changed to 1 and IOR to 1.33.

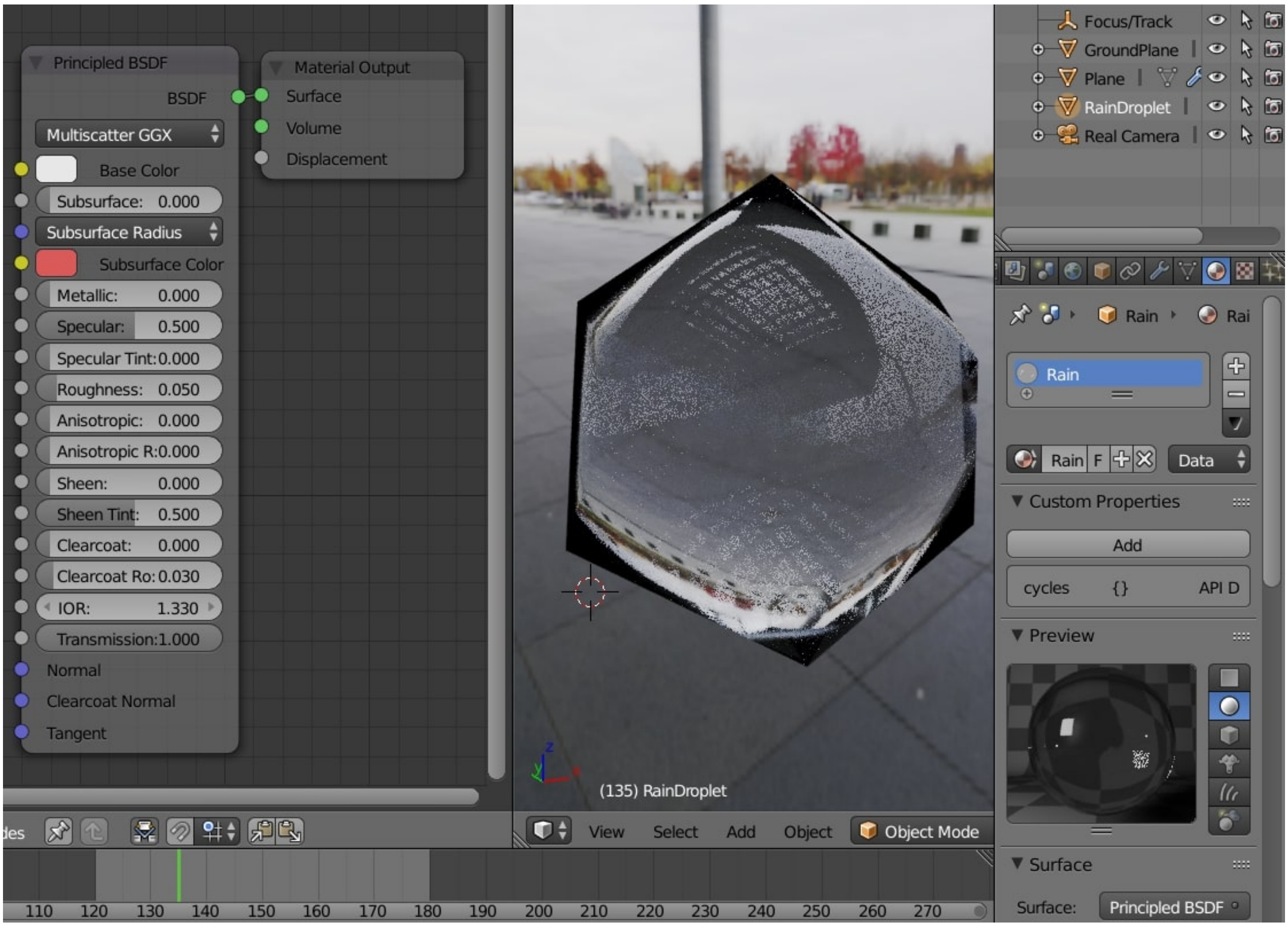

Figure 88: Icosphere material

To use the icosphere as a rain droplet the upper plane needs a particle system.

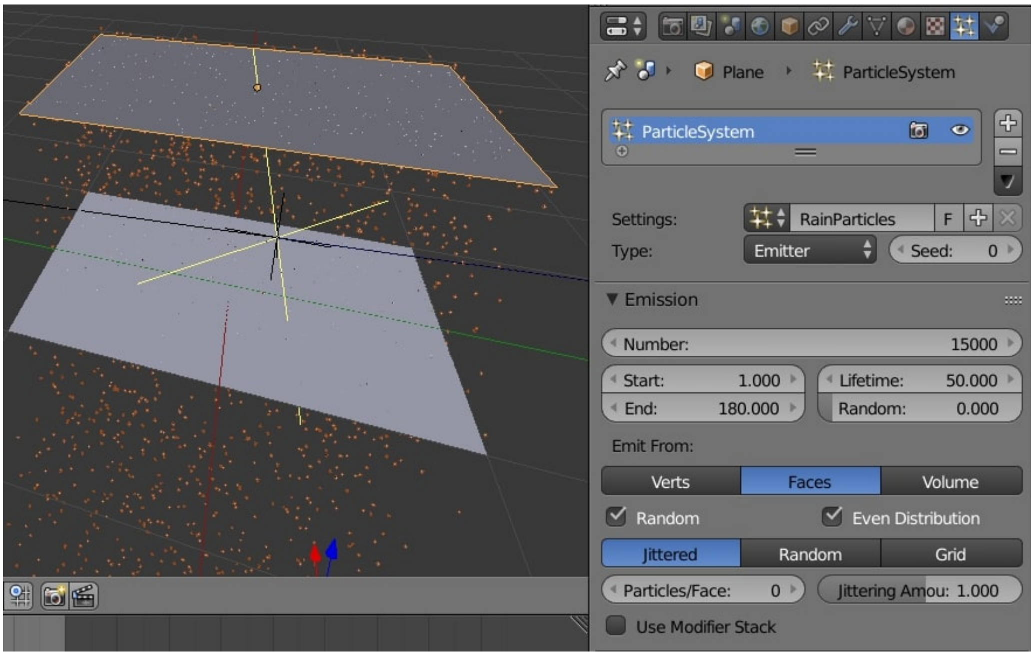

Figure 89: Particle System for rain

It is set to “Emitter” and the emission has a lifetime of 50. Under the tab “Render” the “Dupli Object” is set as the icosphere object named “RainDroplet” and has a random size of 0.5.

For now it is raining however the ground is not getting wet. The bottom plane has also a standard principled BSDF material set with a texture and maps. The important thing now is to generate a wetmap to fill the material with “wetness”.

To generate this, a map of the rain drops falling through or on the plane is needed.

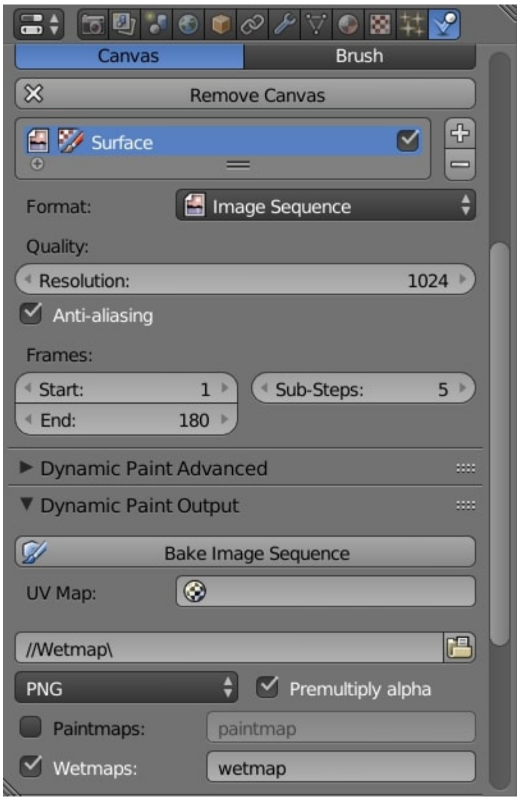

Figure 90: Blender Physics: Canvas of type surface

Under the physics tab of the ground plane “Dynamic Paint” has to be enabled and set to a canvas with the format “Image Sequence”. It behaves like a canvas that is being painted on by the rain drops falling through the plane. The Resolution is 1024 and the sub-steps are set to five. Under “Dynamic Paint Output” the images are baked and saved.

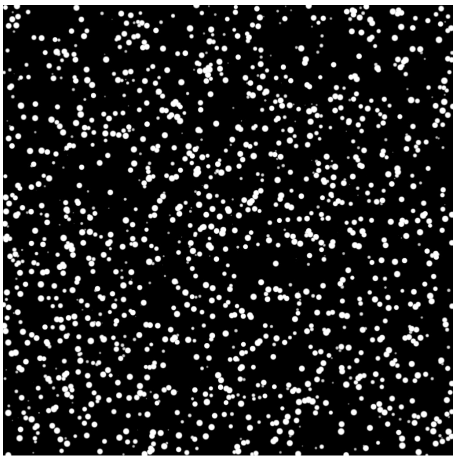

Figure 91: Wetmap

The white dots correspond to wet dots on the material. Additionally these dots can be made even more realistic by adding sprinkles. Now the images can be used to put wetness on the material. Thus the base color and the roughness of the principled BSDF have to be manipulated by the white color.

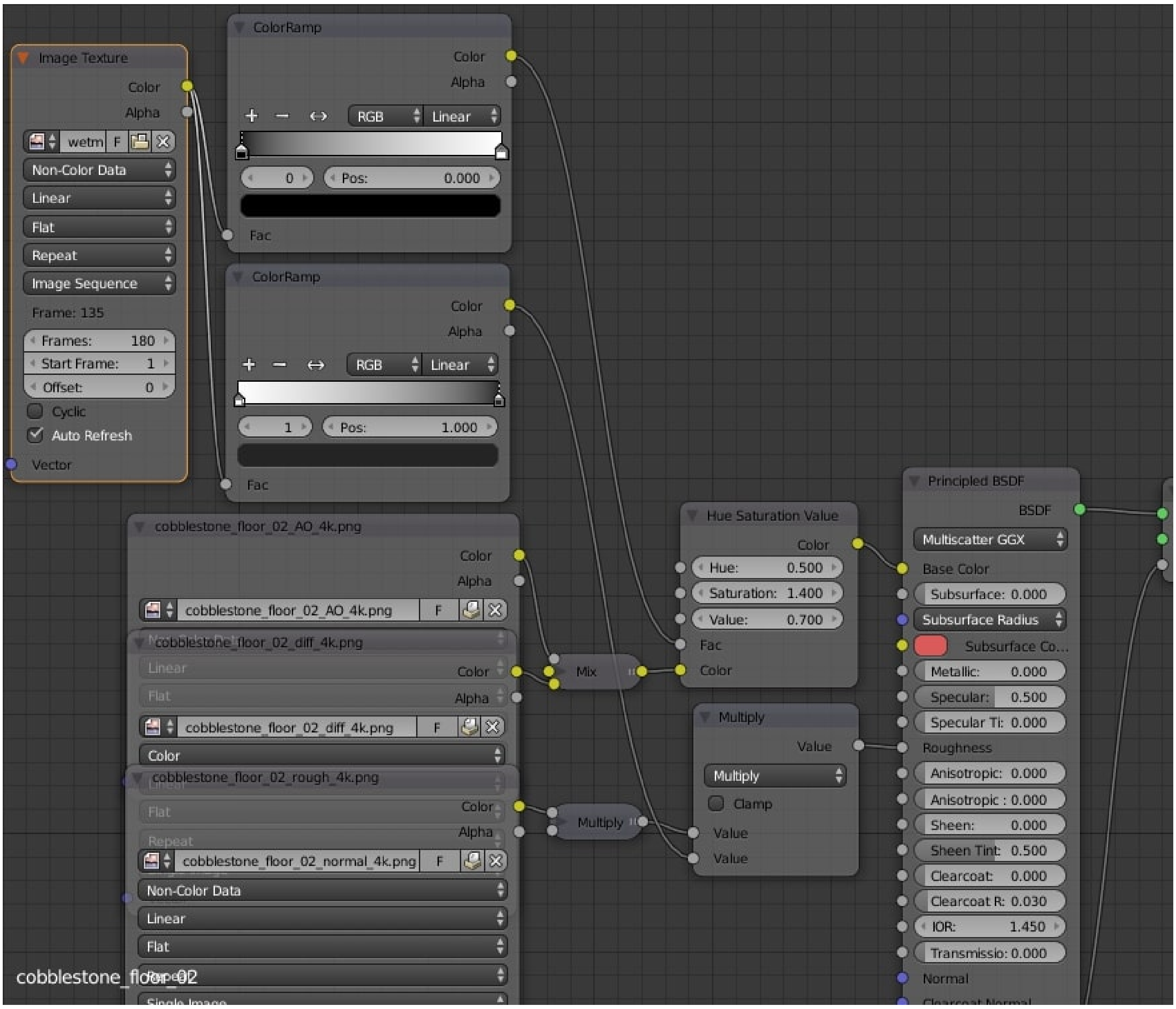

Figure 92: Principled BSDF Material with Wetmap

The screenshot shows that the images are used as image textures. The color values can also be changed by the color ramps. The bottom color ramp is flipped to fit the colors of the normal map and is responsible for the placement. Furthermore the upper ramp is used to get that wet reflective look. The finished ground looks like the picture below.

Figure 93: Rendered wet ground from rainparticles

Afterwards it was decided to not paint the rainforest ground this way because it is already wet and will not be a close up. Instead there should be puddles which react to the falling rain.

7.2.11.1 Rain with puddles

The composition of the scene is the same as in the chapter before: 7.2.2.1.1 Rain with wet ground. An upper plane containing a particle system that uses the icosphere rain droplet.

The bottom plane will be now the water puddle and also act like a canvas. This time the surface type is waves. The speed is set to 1.5, Damping to 0.1, Spring to 0.1 and Smoothness to 1. The influence scale is set to 0.6 and defines how hard the waves are displayed.

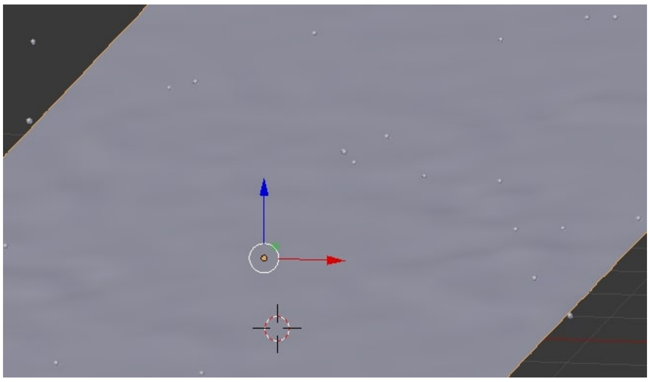

Figure 94: Waveseffect on a plane

The screenshot shows how the drops effect the plane. It has the same principled BSDF material as the rain droplet. The transmission can be set lower to simulate dirty water. The base color should then be changed to a brown color.

To look like puddles the plane is set into the ground plane.

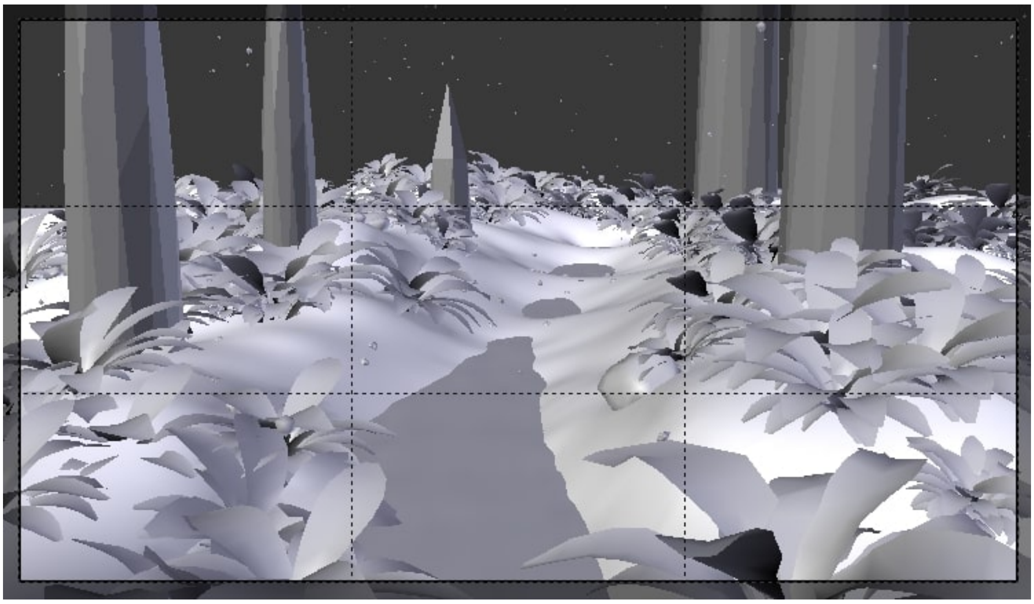

Figure 95: Puddle in ground

Additional in the camera settings the shutter under “Motion Blur” is set to 0.4 to simulate the motion of falling drops.

Figure 96: Motion blur with raindrops

7.2.11.2 Ground or forest floor

The ground is a plane modified by hand in sculpt mode. The material is made with nodes with textures from texturehaven.com.

The material output surface uses a principled BSDF node where specular is set to 0.2.

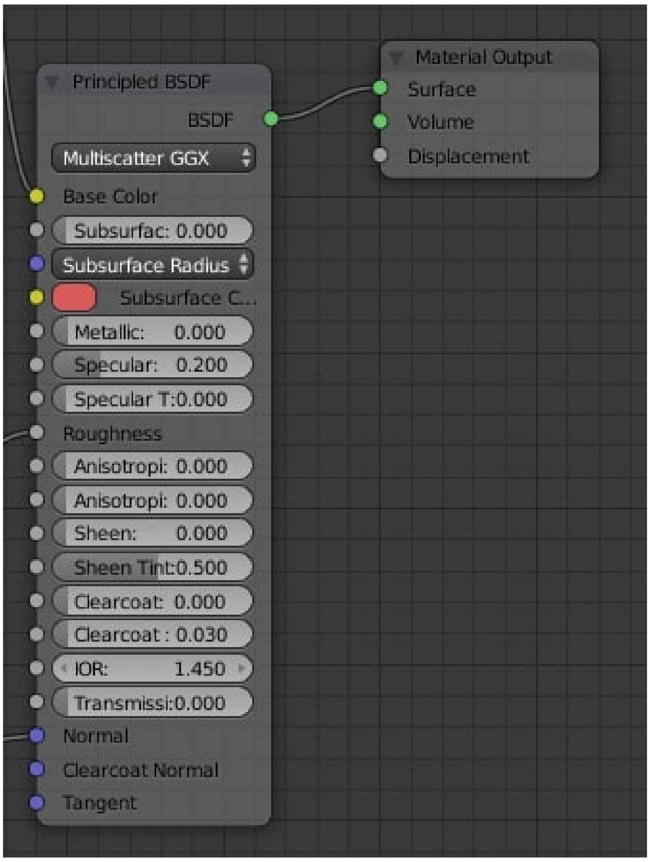

Figure 97: Principled BSDF material on the rainforest ground

A color ramp followed by a hue saturation value node is used for the base color. The color ramp changes the factor.

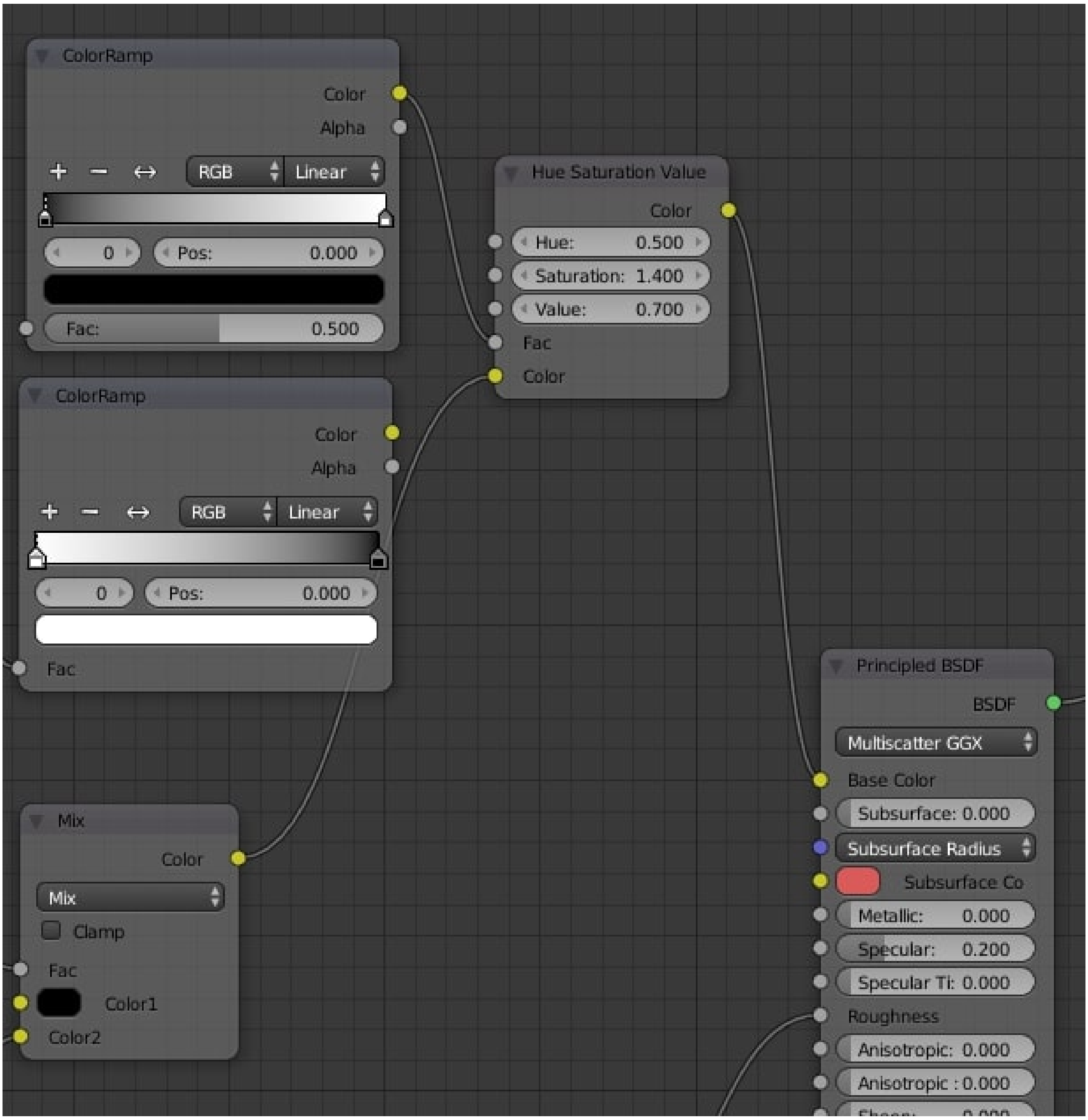

Figure 98: Rainforest ground: Color ramp and Hue Saturation Value node

The mix node is based on the ambient occlusion map above and the diff texture.

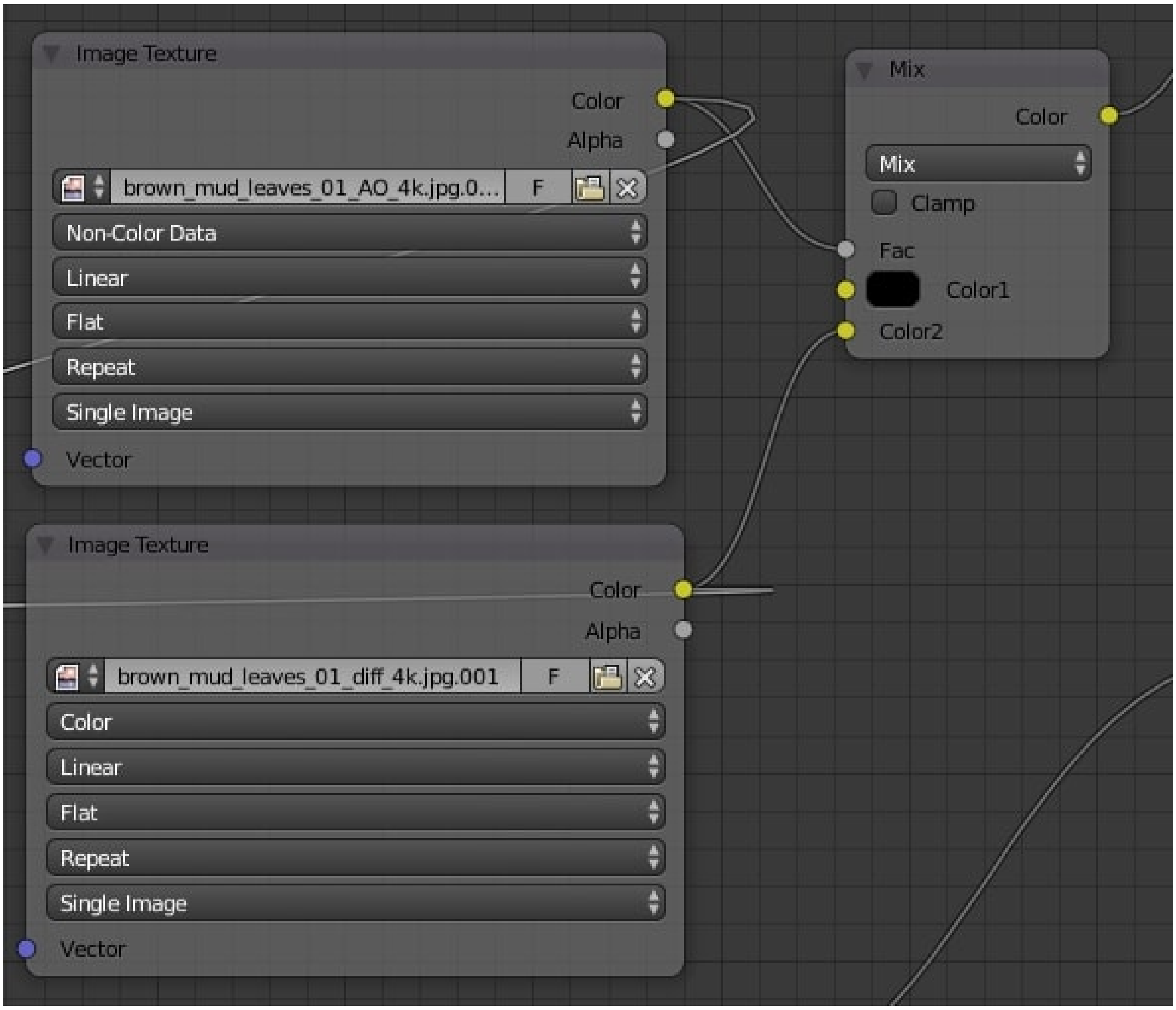

Figure 99: Rainforest ground: Mix node

The roughness uses the rough map, followed by an invert node with a value of 1.

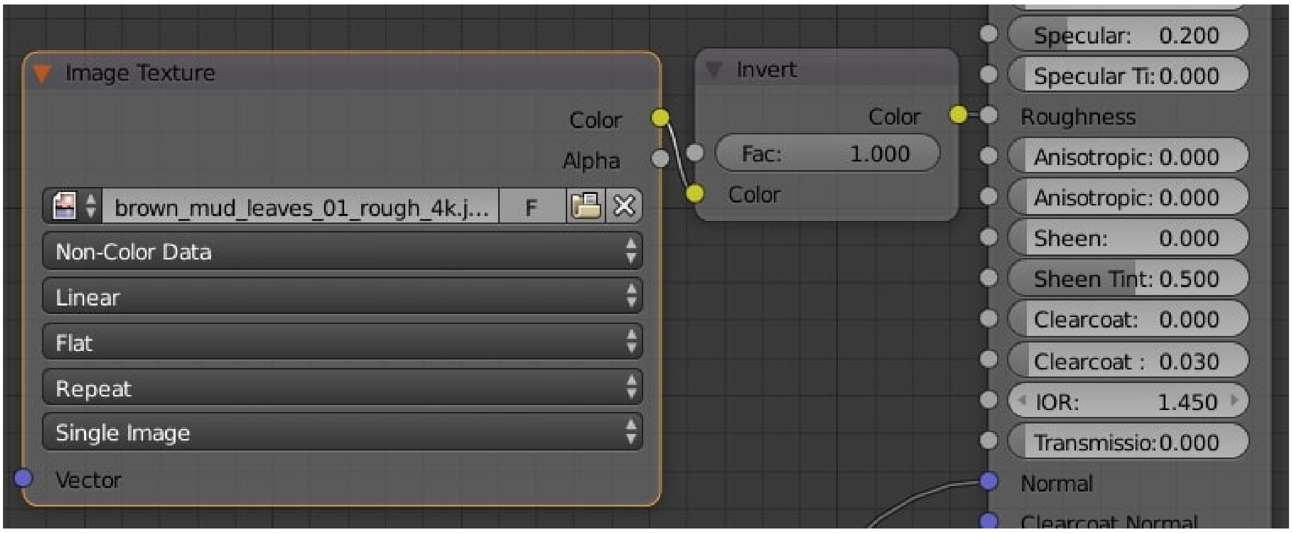

Figure 100: Rainforest ground: Rough map

Last a normal map is used and converted for the normal input.

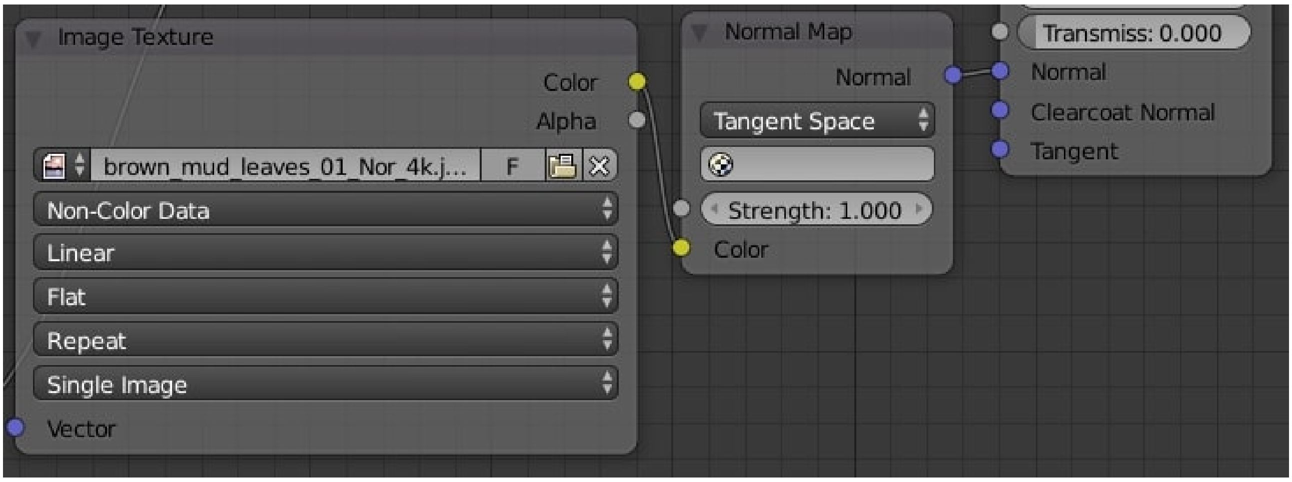

Figure 101: Rainforest ground: Normal map

Combined the material of the ground looks like in the picture shown below. It also has a glossy finish to display a wet look because of the rain.

Figure 102: Rainforest ground

7.2.11.3 Placement of grass, plants and rocks

The ground plane uses particle systems of the type hair to place the grass, plant and rock objects randomly on given paths.

In weight paint mode the paths are painted as vertex groups:

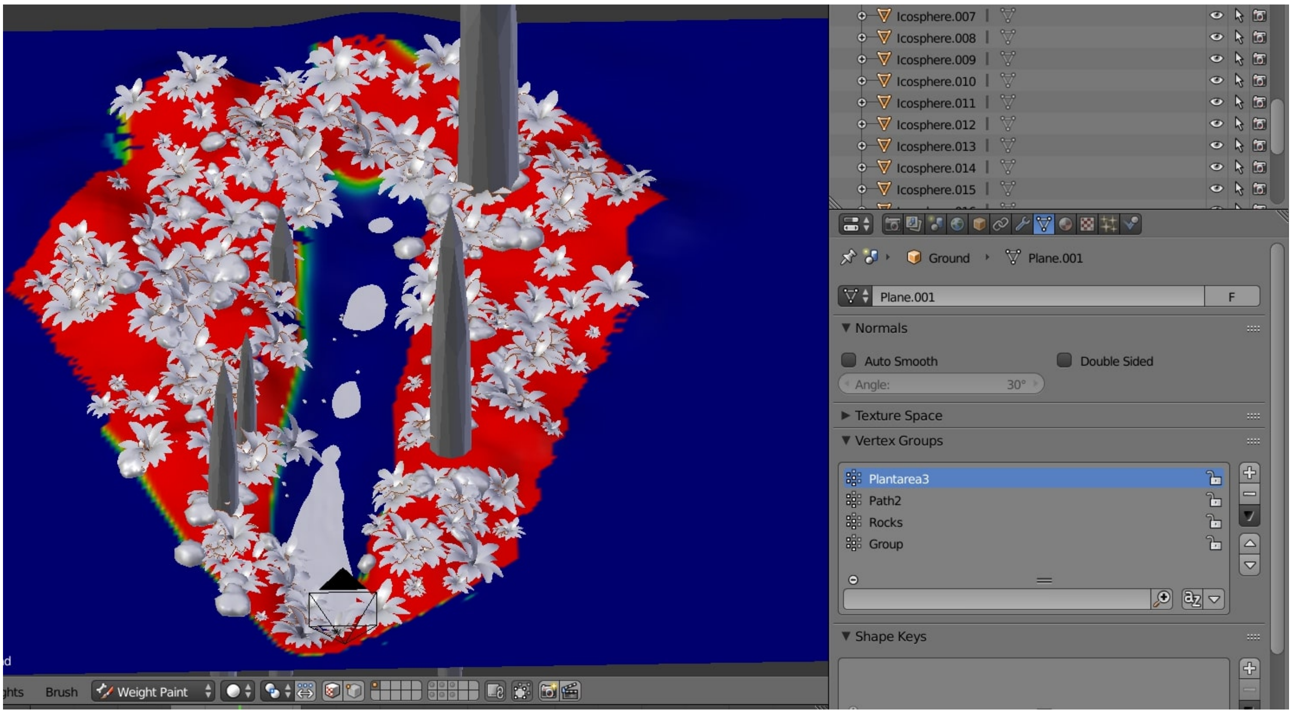

Figure 103: Weight paint on the rainforest ground

This example shows the area where the plants should be:

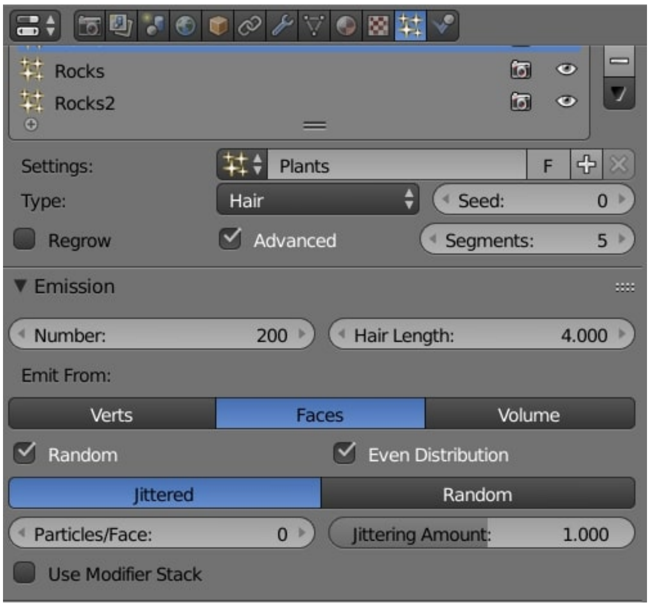

Figure 104: Particle system: Hair

The number defines how many objects are placed.

Under render the Dupli Group sets the group of the objects to be shown.

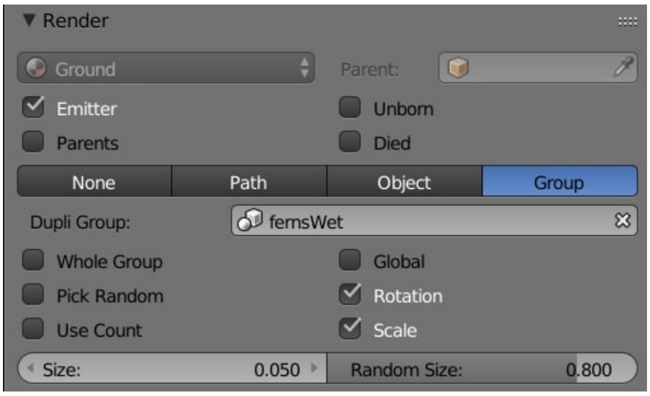

Figure 105: Particle system: Render

For that the objects (e.g. all rocks) have to be in one group.

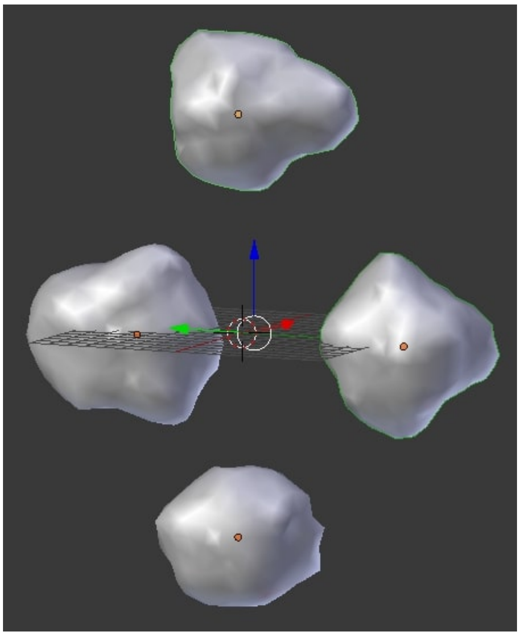

Figure 106: Grouped rocks

Furthermore the size can be adjusted randomly by the particle system if activated. In this case it is set to 0.8. Repeat the steps for every group.

7.2.11.4 Depth of Field

To make the scene look more realistic and to not have a sharp cut from the ground and background, depth of field is set.

Figure 107: Depth of field settings

To have control over the blur use an empty coordinate object and place it where the focus should be. Thus can easily move the focus. These were the best settings after adjusting for the scene.

The empty object is set in front of the camera.

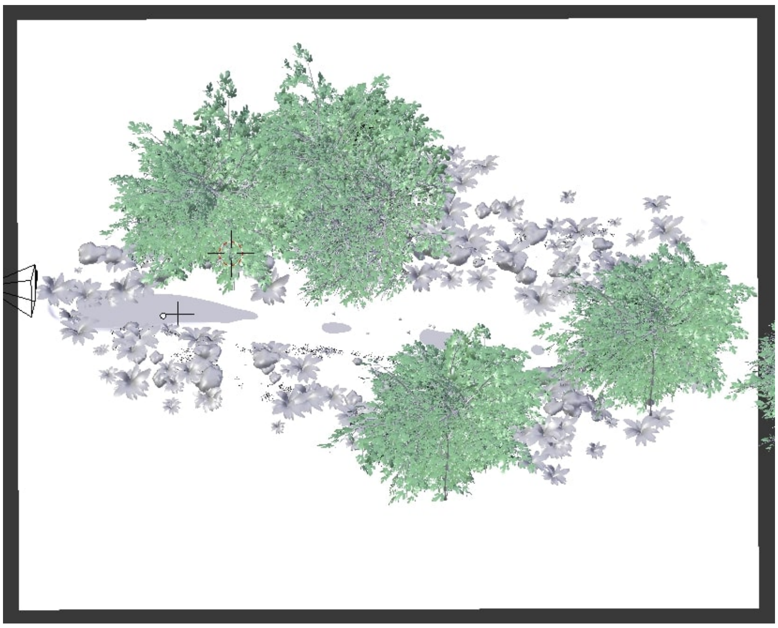

Figure 108: Placement of the empty object

This is the final render picture:

Figure 109: Final render picture

7.2.12 Creating fire for the burning forest

Start by creating a cube and resize it to the extent of your surface for the fire domain. Expand the cube's z-axis a bit further to the height of the trees. By pressing Z you can change to the wireframe view and look through the cube.
Next while having the cube selected, open the physics tab and select smoke. A new tab will open and select 'Domain'. Change the settings of the Domain accordingly:

Divisions: 48
Density: -0.001
Temp. Diff.: 0.1
Scale: 1.0
Vorticity: 4.0

Check the boxes for Smoke Adaptive Domain and Smoke High Resolution.

7.2.12.1 Set the fire location

To create the fire select the Surface in Object Mode and change to Weight Paint. Here you can easily draw where you want your fire to be. To have a more realistic Fire we are going to start off with a fire right in front of the camera view.
To do so draw a circular shape like in the picture.

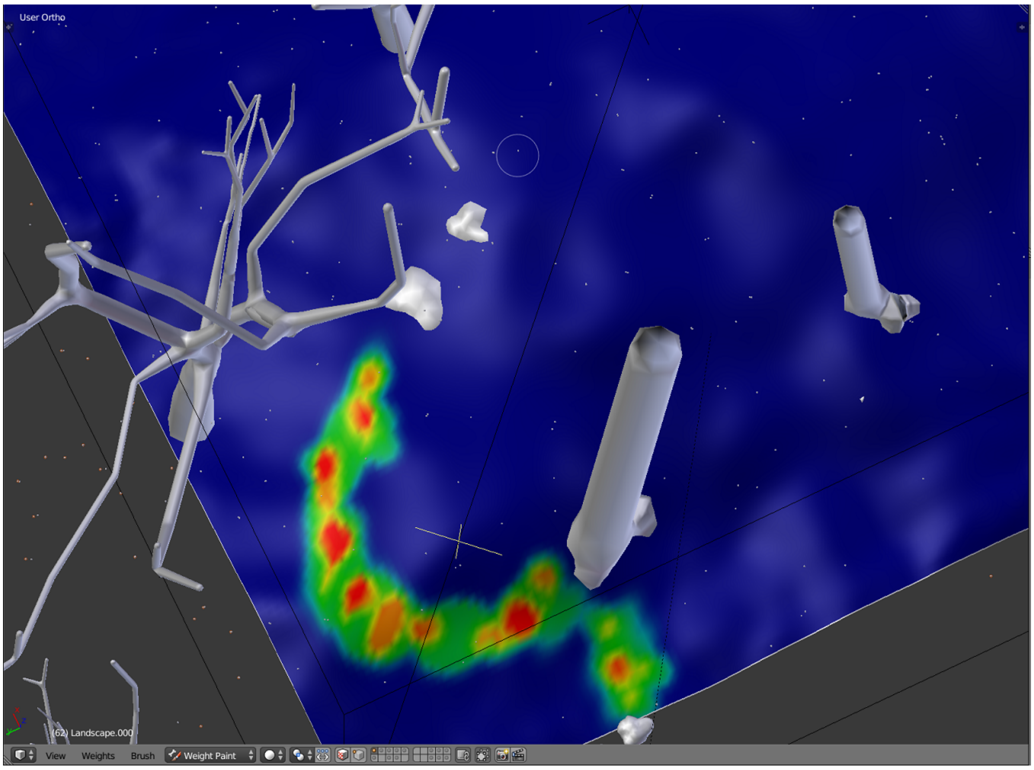

Figure 110: Weight Paint - Fire foreground

The flames of this fire won't be as high as the other flames that's why we have to put it in a separate vertex group. In the right tab of blender switch to the object Data. Here you can see your vertex groups. Press plus to create a new vertex group. To make it easier for yourself you can rename the vertex group to something like 'vertex fire front'.

Now switch back into object mode and switch to the physics tab. In the Smoke Flow Advanced tab select the vertex group you just created.

In this tab you can only assign one vertex group so you have to duplicate the surface and do the same procedure again. This time before creating the new vertex group you have to delete the 'vertex fire front' group. The new vertex group will have higher flames and will be more in the background. Make sure you paint all visible parts of the surface. To do so you can switch into the camera view by pressing 0. The result should look something like the picture.

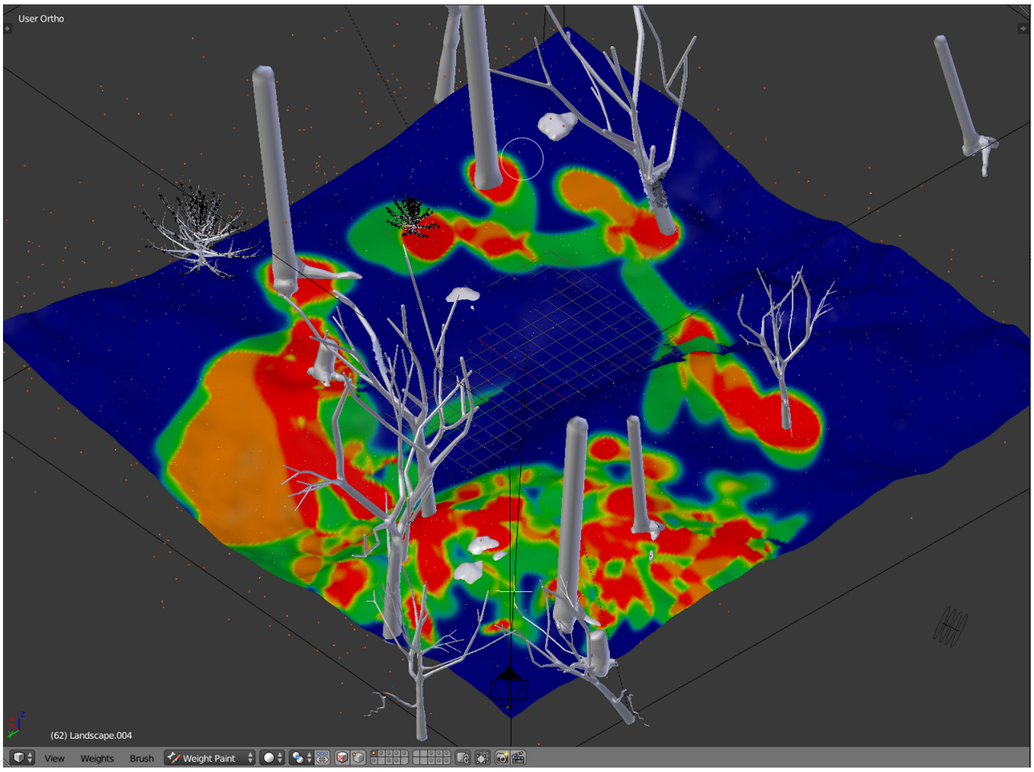

Figure 111: Weight Paint - Fire background

Now change into the physics tab of your duplicated surface and select the newly created vertex group. You have to change the physics settings of both surfaces accordingly to have a realistic fire.

Fire front:

Flow type: Fire

Absolute density: checked

Surface: 1.5

Flame Rate: 0.15

Volume: 0.0

Fire back:

Flow type: Fire

Absolute density: checked

Surface: 1.5

Flame Rate: 0.65

Volume: 0.0

You can change the height of the flames by adjusting the flame rate.

7.2.12.2 Creating the fire material

For the next step open a new window next to your view. Switch this window to the node editor. In your 3D-View, select your fire domain, change into the material tab and create a new material by pressing plus. In your node editor you will see two automatically created nodes. Delete the 'Diffuse BSDF', because we won't need it right now.
To easily create the correct nodes just press SHIFT + A and select search. You can just type in the name of the node you need and blender creates it for you.
Start by creating an Attribute node and change the name field to 'density'. It is important to spell it correctly otherwise blender won't display the fire correctly.
Create a ColorRamp next to the Attribute node and connect the 'Fac' of the Attribute node with the 'Fac' of the ColorRamp. In the ColorRamp you want to have a gradient transition from black to white as this will be the color of the smoke. You will get the best results with the following settings.
5 color stops.

first stop	second stop	third stop
position: 0.00	position: 0.121	position: 0.823
color (hex): 000000	color (hex): 898989	color (hex): BCBCBC

forth stop	fifth stop
position: 0.918	position: 1.00
color (hex): B2B2B2	color (hex): FFFFFF

For the next step, add a Math node after the ColorRamp, change it to multiply and connnect the 'color' of the ColorRamp to the 'Value' of the Math node. Set the 'Value' of the Math node to '4.000' and add a Volume Absorption Node and a Volume Scatter node. Now connect the 'Value' of the Math node with the Density of the two nodes. After that you just need to add an Add Shader and connect the last two nodes to the Add Shader node. This completes the Smoke, but of course the fire needs some nodes too. To have a better usability you can put a frame around your nodes by pressing B to and select all nodes with your mouse and then press CTRL + J.
To set up the fire start just like before by adding an Attribute node. This time set the name to 'flame' and again double check the spelling.
After that add two ColorRamps. The top ColorRamp will set the color of the flames so connect the 'Fac' of the Attribute node to the 'Fac' of the ColorRamp. Do the same with the bottom ColorRamp.
You will get the best results with the following settings.

First ColorRamp:

first stop	second stop	third stop
position: 0.084	position: 0.283	position: 0.333
color (hex): 000000	color (hex): 943600	color (hex): 7C3000
alpha: 0.8	alpha: 0.8	alpha: 1.0
forth stop	fifth stop	sixth stop
position: 0.349	position: 0.530	position: 0.644
color (hex): 993000	color (hex): FFC464	color (hex): 661900
alpha: 1.0	alpha: 1.0	alpha: 1.0

Second ColorRamp:

first stop	second stop	third stop
position: 0.084	position: 0.283	position: 0.333
color (hex): 000000	color (hex): 9F9F9F	color (hex): FFFFFF
alpha: 0.0	alpha: 1.0	alpha: 1.0
forth stop	fifth stop	sixth stop
position: 0.349	position: 0.530	position: 0.644
color (hex): 993000	color (hex): FFC464	color (hex): 000000
alpha: 1.0	alpha: 1.0	alpha: 0.0

With the colors set add a Math node behind the bottom ColorRamp and change it to multiply. Set the 'Value' to 5 and connect the 'Color' of the ColorRamp with the 'Value' of the Math node.

To conclude the fire part of the nodes add an Emission node and connect the 'Color' of the upper ColorRamp with the 'Color' of the Emission node and the 'Value' of the Math node to the 'Strength' of the Emission node. Optionally you can add another frame around the nodes for the fire.

You should still have the Material Output node that blender automatically added when you created a new material. Add an Add Shader node infront of that node and connect the 'Shader' of the last node from the smoke frame to the upper 'Shader' socket and the 'Emission' of the last node from the fire frame to the bottom 'Shader' socket. As a last step you just have to connect the 'Shader' from this Add Shader node to the 'Volume' socket of the Material Output.

In the end your Node Editor should look like the picture below.

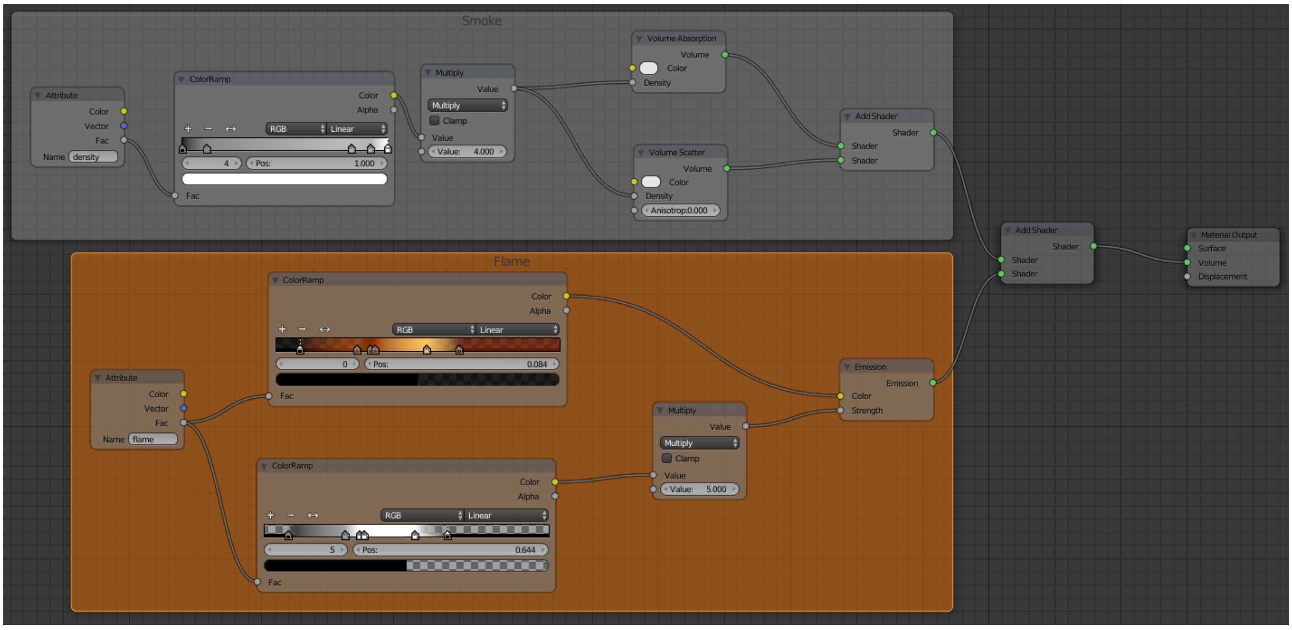

Figure 112: Fire Nodes

7.2.12.3 Ash Particles

Creating the body

Change into another layer to create the Ash-Body. Do so by selecting an empty field in the layers tab right next to the transformation orientation – mostly set to 'Global'. Create an ecosphere in the new Layer.

Nodes

Create a new Material for the sphere and open a new window for the node editor. Select the Sphere and create a group by pressing CTRL + G.
Start with deleting the Diffuse BSDF node and leave the Material Output for now. Add a Glossy BSDF node, switch it to 'GGX' and set the 'Roughness' to '0.35'. Add an Emission node below that, set the 'strength' to 1.0 and add a Mix Shader node behind that. Now connect the BSDF and the Emission to the Mix Shader and set the 'Fac' to 0.9. With this you can change the glossiness of the Particle.
Add a Translucent BSDF node under the Mix Shader node, add another Mix Shader node and connect the 'BSDF' from the Translucent node to the bottom Shader of the Mix Shader and the Shader of the first Mix Shader to the top Shader of the second Mix Shader. Then set the 'Fac' of the second Mix Shader to 0.2.
To complete it just connect the Shader of the last Mix Shader with the Surface of the automatically created Material Output.

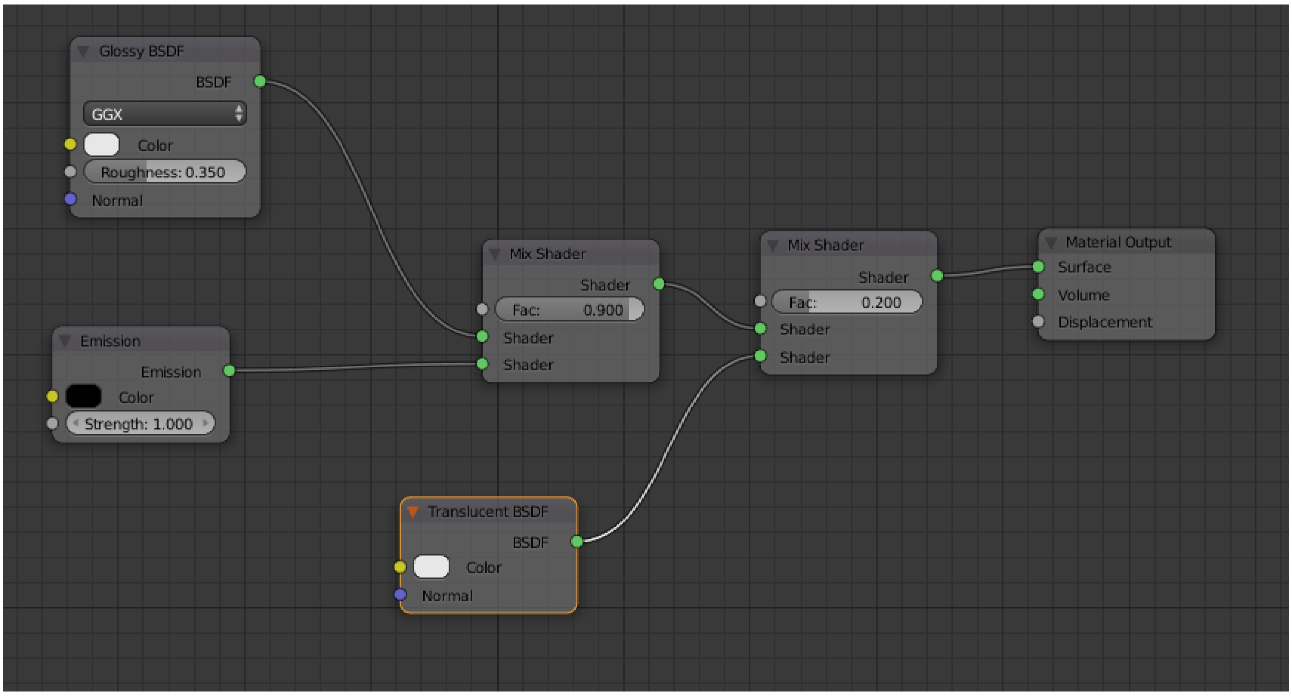

Figure 113: Ash Nodes

Emitting the Particles

Select the Surface in Object Mode and switch to the Particle tab. Create a new particle system by pressing +.

Change the type to Emitter and in the 'render' tab select 'Group' and select your newly created group in the field just below. To have a more realistic distribution of the particles regarding the size you can increase the 'Random' to 1 to have different sized particles.

In the Emission tab change the Number of particles to 15000 and the Lifetime to 50. Check the boxes for Random and Even Distribution.

7.2.12.4 Compositing the Scene

When every object is created the user can put the whole scene together. At first choose a camera angle. For a good-looking result it should not be to high. Now append every object into a different layer. Now it's possible to copy the single objects to the layer where the terrain is and arrange them on the ground. When the result looks good the last step is to create a realistic background. For the grass its possible to use a vertex group and the weight paint mode. This method is described in the rain forest. The ferns are placed like this.

7.2.12.5 Animation

Animate the ferns and grass

To animate the ferns, we use a displace modifier. Select the object and add it at the right side of the screen (tool sign). Choose a strength of 0.1 and click on the right button in the texture setting. In this menu it's important to change the type to clouds and the size to 1. Otherwise the movement would be too strong and the leaves wouldn't look realistic anymore. The second change here is to activate the ramp under the color tab and pull both pointers closer together.

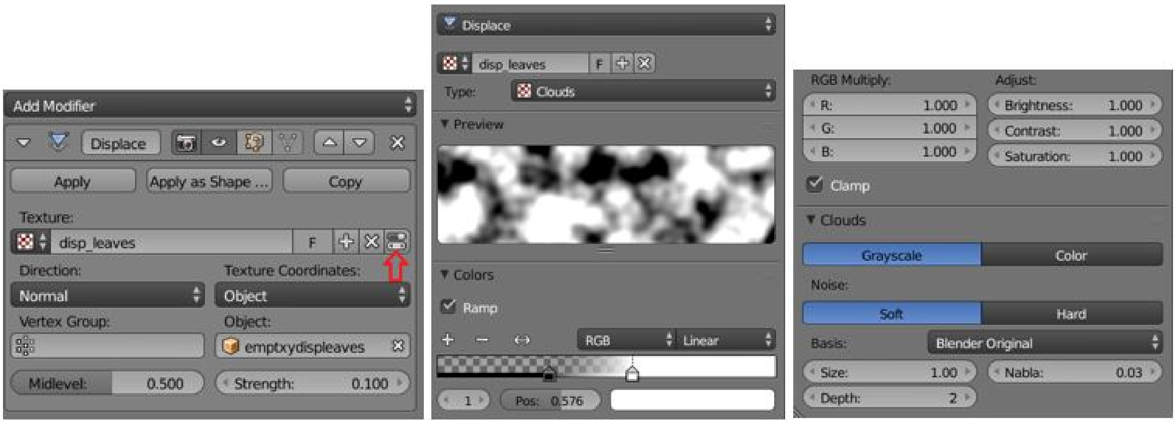

Figure 114: Displace modifier setup

To get an automatic movement the user needs to create an empty object. The next step is to divide the screen into two parts. Select graph editor in one of them. Now a keyframe is needed, so select the empty object and press i -> location. In the graph editor the x, y and z location should appear. Select one axis and press n to open the properties window. Under the modifier tab we choose noise. The last step in the graph editor is to use the right noise value in every axis. For the ferns some good numbers should be: Scale: 60 – 80 Strength: 2 When it is implemented change the phase of all three noise modifiers so that the graphs are looking different.

This empty object needs to be attached to our fern. Go back to the fern object and in the modifier tab change the texture coordinates type to object and select the empty.

These steps can be repeated with the grass to get the same movement. The user should play a little bit with the values to find a result that looks good.

The tree animation

For the trees in front the same modifier for the ferns can be used for the leaves. The only change is to switch the cloud size to 2 and the strength to 0.02. To get a little more movement its possible to add a wave modifier. First add a new vertex group to the branches and switch to weight paint. Use

Alt + Left Mousebutton to create a color gradient. The end of the branch should still be dark blue. In the modifier options we can select this new vertex group so that the end of the branch doesn't move anymore. To let the wave move upside down, press Ctrl + A and select rotation. The movement is still too steady. Because of this choose the empty object for the displace modifier also here under texture coordinate. I used the following values for a nice animation. Offset: -100

Speed: 0.03 Height: 0.10 Width: 3 Narrowness: 0.2 I would recommend using the displace modifier only for the trees in the front. There is also a possibility to add a forcefield. Here the best ones are wind or turbulence, but often the result doesn't look good or work at all. It's also possible that the wind or turbulence affect other objects in a bad way. If it don't work or less movement doesn't bother just leave it without the force field.

8 Scene 3: shifting climate zones

Scene 3 shows the climate zones getting extremer from a space view.

8.1 Research

The purpose of scene three is to show how an increase in Earth's temperatures will affect the planet's climate zones, as opposed to only certain weather conditions. The temperature rise leads to higher evaporation along the equator and an enhanced scale and force of the Hadley Cells. In the end this leads to all climate zones in the norther hemisphere to shift further north and all zones in the southern hemisphere to shift towards the south pole. Since accurate predictions of exactly how these climate zones will shift were not able to be found, the decision was made to look at current man-made climate zone data and extrapolate it to warming due to the Sun.

During the last years the Earths' climate has changed a lot: some countries suffer from anomalous heat, other ones from harsh and snowy winters, which are unusual for such places. Scientists talk about global climate change, which includes the increase in the average annual temperature. In the result, the glaciers melt and the sea level rises. In addition to this, natural systems become unbalanced, leading to precipitation pattern change, temperature anomalies and the extreme events frequency increase (hurricanes, floods, droughts etc.). One of the weightiest effects of climate warming is likely to be the melting of glaciers and rising sea levels. Millions of people on the coast will die from frequent floods or be forced to move, UN analysts predict. According to experts, sea level rise in the 21st century will be up to 1 m (in the 20th century - 0.1-0.2 m). In this case, lowlands, coastal areas and small islands will be the most vulnerable. It is not news that the Earth has always experienced changes in climate, but they have occurred as a consequence of natural changes. During the last decades because of the human interference the weather conditions started to change more dramatically. An easy example could be higher greenhouse gases concentration in the atmosphere, including CO2, which is now helping to produce a warmer climate in the Arctic. Measurements show that temperatures have risen throughout the world, and that the average temperatures in the Arctic in the last 100 years have risen twice as rapidly as they have elsewhere in the world. The reason for this is complex feedback loops between the atmosphere, the oceans and the ice. It is therefore difficult to predict how quickly the changes will take place, but they have so far occurred more rapidly than most scientists expected. But the climate is changing not only in the Arctic, but on the whole earth; world's climate zones are changing in considerable and measurable ways. It is difficult to say exactly how and when will the climate change, but the scientists already have some predictions based on their researches. The researchers the Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder, led the study concerning this matter. The team sought to determine whether ecosystems might undergo "runaway climate-zone shifts" above a certain temperature threshold. The team combined data from 13 model simulations using global mean temperature and precipitation to estimate past and future regional climate shifts between 1900 and 2098. Under one modelling scenario, the pace of climate-zone change nearly doubles by the end of this century and about one-fifth of Earth's land area undergoes a climate shift. The study predicts that polar climates will shrink whereas arid regions will expand. Large swathes of Earth will switch from cool summers to hotter summers. And at low latitudes, mountainous regions will shift climate zones earlier than nearby low-altitude areas. The link between climate change and natural disasters has been proved by American scientists who have found traces of warming in the study of tropical cyclones in the Pacific ocean, unusually high summer temperatures in Europe, China, South Korea and Argentina, as well as forest fires in the us state of California. Climate change has also served as a catalyst for drought in Africa and the middle East, snowstorms in Nepal, and torrential rains that have caused flooding in Canada and New Zealand. Let us also look at some changes that have already happened. To start with, the tropics are getting bigger at 30 miles per decade. About a decade ago, scientists first noticed that this dry belt seemed to be getting bigger. The dry edges of the tropics are expanding as the subtropics push both north and south, bringing ever-drier weather to places including the Mediterranean. Meanwhile, the smaller equatorial region with heavy rains is actually contracting. Since satellite records started in the late 1970s, the edges of the tropics have been moving at about 0.2-0.3 degrees of latitude per decade (in both the north and the south). The change is already dramatic in some areas — the average over 30 years is about a degree of latitude, or approximately 70 miles, but in some spots the dry expansion is larger. The result is that the boundary between where it's getting wetter and where it's getting drier is pushing farther north, making even countries as far north as Germany and Britain drier. Secondly, the Sahara desert has gotten 10 percent bigger since 1920. Across most of the Sahara the change is on the order of tens of miles over the study period, but in other spots it's far more dramatic: Libya has gone from being mostly not desert in 1920, to mostly desert in 2013, as the line there has advanced a shocking 500 miles or so in winter months. Lake Chad, which sits on the southern edge of the Sahara, shrank dramatically from 9,600 square miles in the 1970s to less than 770 square miles in the 1990s, in part due to reduced rainfall in the Sahel, the dry region just to the south of the Sahara. Thirdly, the 100th meridian has shifted 140 miles east. Climate scientist Richard Seager of the Lamont–Doherty Earth Observatory of Columbia University and colleagues published papers showing the transition is on the move. The reasons for the existence of the line are many: the Rocky Mountains force the wet air blowing in from the Pacific to rain out before the winds reach the plains; Atlantic storms and winds from the Gulf of Mexico bring moisture to the east. Now things are changing. Rainfall has not changed much in the northern plains, but rising temperatures are increasing evaporation from the soil and drying things out. Meanwhile, rainfall is diminishing further south due to shifts in wind patterns. In total, that seems to have moved the line about 140 miles eastward since 1980, Seager calculated. The shift seen so far might be due to natural variability, he says, but it's in line with what we expect to keep happening because of climate change. And it will keep moving east as the planet keeps warming. In addition to this, the permafrost line has moved 80 miles north in 50 years in parts of Canada. As the planet warms, the Arctic is feeling it the most: Temperatures in northern regions are rising at about twice the global average. That's having a huge impact on the region's permafrost, ground that typically stays frozen all year round. As the line delineating an average temperature of 0 degrees Celsius moves north, so too does the permafrost line. The future looks similarly dire. One study predicts that by 2100, the area covered by permafrost might shrink from nearly 4 million square miles to less than 0.4 million; most of Alaska and the southern tip of Greenland would be permafrost-free. The impacts are expected to be huge on both a local and global level. Right now, permafrost acts like cement, keeping the ground firm and impermeable to water. As it thaws, buildings and infrastructure collapse. In the northern Russian city of Norilsk, buildings are already tilting, cracking, and becoming condemned. In Bethel, Alaska, roads are buckling and homes collapsing. Many of the Arctic's uncountable small lakes will also drain away.

8.2 Animation

Animating the changes of the climate zones was one of the most challenging parts in the project. It's hard to define a specific way to animate climate changes without making it too unrealistic. It was decided to divide the Earth's surface into four big climate zones. The changes are based on scientific predictions and do not show a 100 percent accurate outcome, they more likely show an extreme version of what to expect for better visualization and to emphasize the problem of climatic changes.

8.2.1 Working in Blender

The base blender file we are working with is a copy of scene 1. We will modify the node system and keep adding different nodes to it. The following description is only for the climate zones and their connections. You might see nodes that are connected to the climate nodes that you haven't got yet.

They get added in other scenes it's up to you to add those now or later into the project. For a better understanding the climate zones are put into boxes and they are labelled. It is optional, but highly recommended, so you always know the climate zone you are currently working with. The animation is made with key-frames while our camera remains stationary.

8.2.2 New earth texture

The new earth textures are four masks to map our climate zones, they are individual made and created from the ocean water mask.

8.2.3 Shifting climate zones

To give you a short preview what you can expect from this following description, you can see the final structure for the climate zones. Keep in mind that all climate zones are designed in a very similar way and you basically only use the same node groups for all four zones. The only differences are the connections, those are a result of trying out and playing with values. It is important to know that each climate zones get its own texture and its own colours. The colours get mixed and spread by "Noise Textures" and "Voronoi Textures" in connection with a "ColorRamp". The set colours are also an outcome of trying out and finding an accurate level of change without looking to unrealistic.

The first step you must do is create the "Image Textures" for the scene, you need the basic earth texture node from the tutorial and 5 new texture nodes. One of them is a texture of a completely dry earth surface. The dry earth texture and the 4 climate zones are made in Photoshop and completely custom. After adding the 5 "Image Texture" nodes load the dry earth texture and all 4 climate zones. Set all four climate "Image Texture" nodes to "Non-Color-Data" and change "Flat" to "Sphere". For the dry earth texture, you need to set it to "Color" and "Sphere". Connect the vector of each "Image Texture" node to the "Generated" connection dot of the original "Texture Coordinate" node.

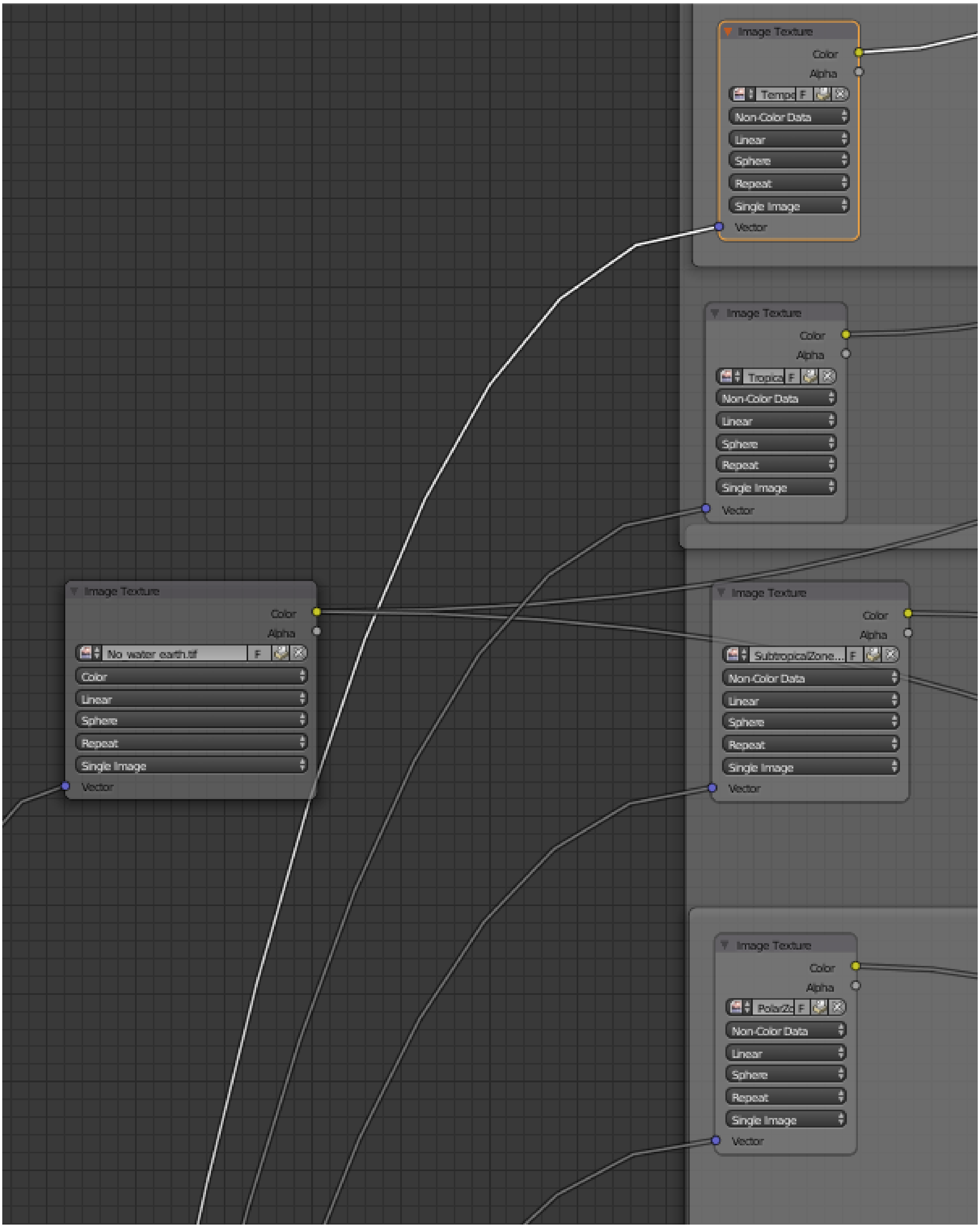

Figure 115: Texture Images.

The first climate zone is the Temperate zone. We know based on our research that we can expect that the Temperate zone is getting hotter and dryer. Based on that information we want to create a good-looking surface and climate change visible from space. You can start organizing the zones and label them with pressing the keys ctrl-J, this allows you to frame the zones without setting up a group structure. Its more a visual and helpful tool for the designer then a functional grouping structure. You can name the Frame by labelling it and add as many new nodes into the frame as you want. It is also possible to have a frame in a frame if you want to have sub-labels to work with. Please setup the climate zones like it is shown in *Figure 117* below, after you have done that, we will continue with explaining the structure and what nodes are connected from somewhere else.

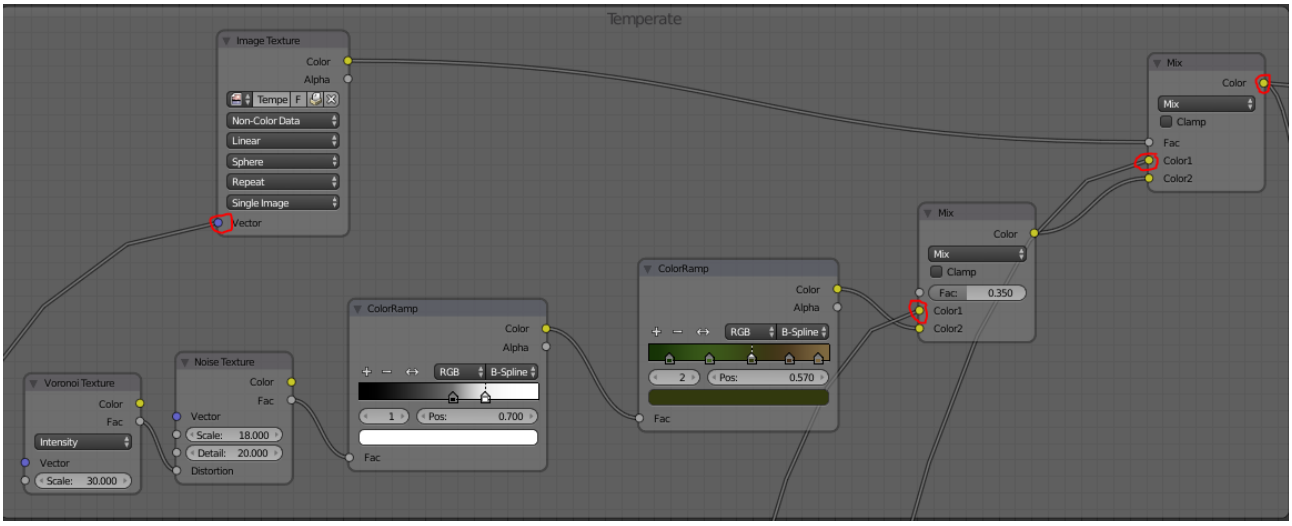

Figure 116: Temperate climate zone.

The structures of the climate zones are always the same and just differ in values and colour pattern. So, you might as well setup all the other climate zones the same way as you did before and just adjust the values and colours later. The distribution is done by a "Voronoi Texture" and "Noise Texture" in combination with a black and white "ColorRamp" to spread the different colours and give the zone a realistic look. The colouring itself is a combination of a "ColorRamp" mixed with the original earth texture. You can add more colours by pressing the "+" on the "ColorRamp" and changing the colour below. We choose the switch both "ColorRamp" to the "B-Spline" setting to get a nicer and smoother colour gradient. The red marked connection is the connection of the original earth texture. To mix both together we use a regular "MixRGB" node. You want to set the "Fac" value to about 0.35, since we want some more of the new colours and only some spots with the original texture.

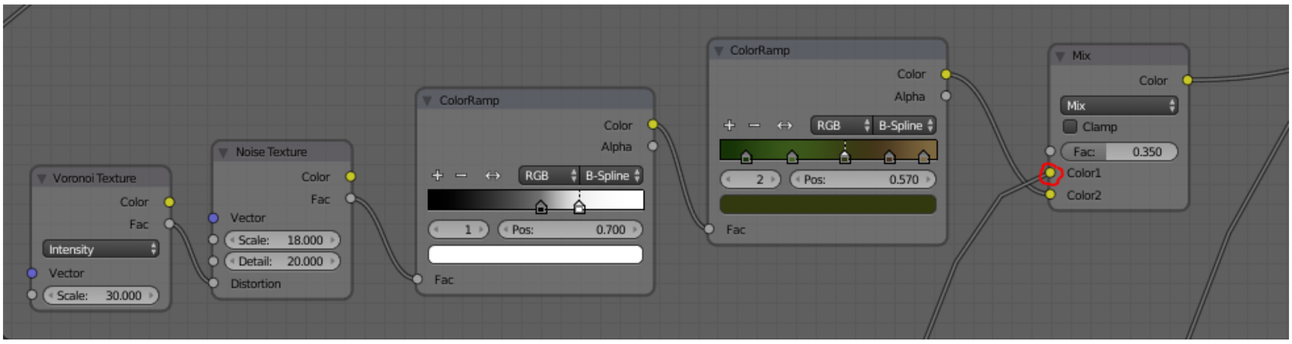

Figure 117: Colour Temperate zone.

After the setup of the colours we need to setup the climate zones itself and connect the mask. We are doing it just by connecting the "Color" from the colour mixer with a new mixer on "Color2" and the mask "Image Texture" node in the "Fac" connection. You also want to connect the original earth texture with "Color1". The final three nodes should look like shown in the picture below, the connection from the final Mixer is shown later.

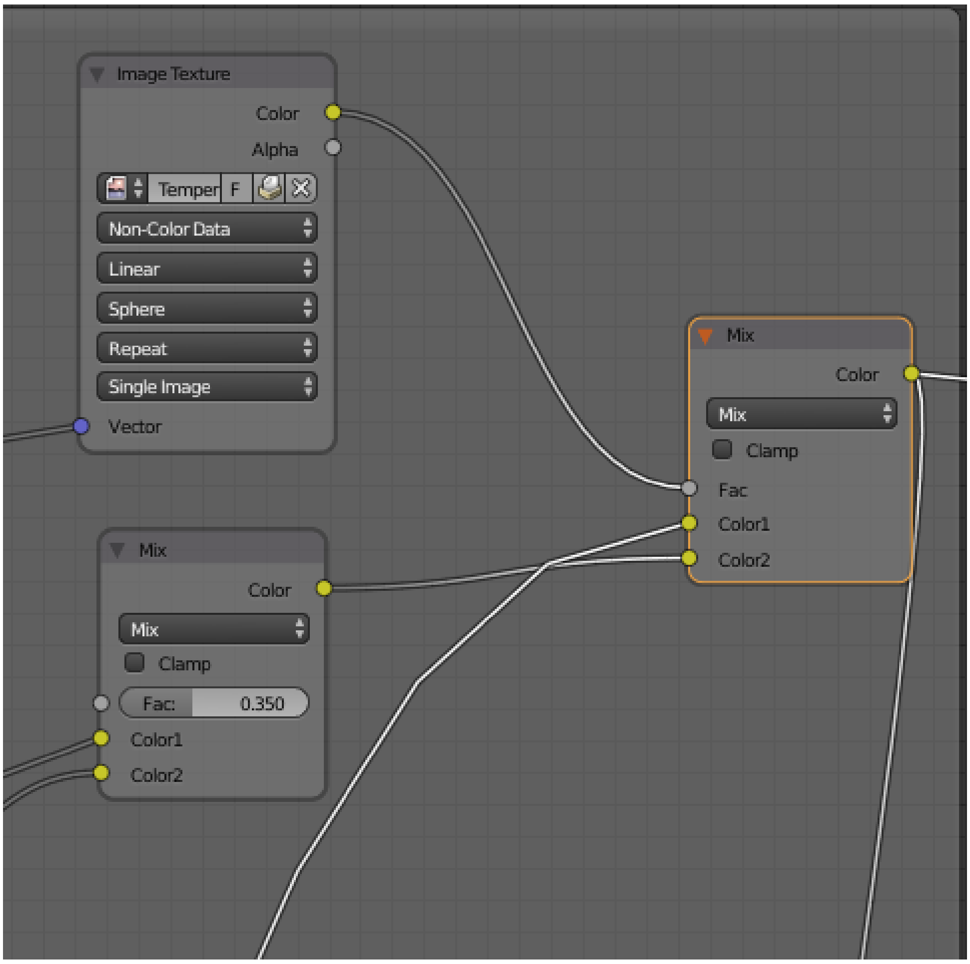

Figure 118: Mask Temperate zone.

If you did setup all the other climate zones the same way, we now just need to adjust values and colours. Also, we need to make some connections and switch up some of the original textures for a more realistic outcome. The second zone we want to adjust is the Tropical zone. Now we need some more green and sand colours and we want to mix the colours with the dry earth texture.

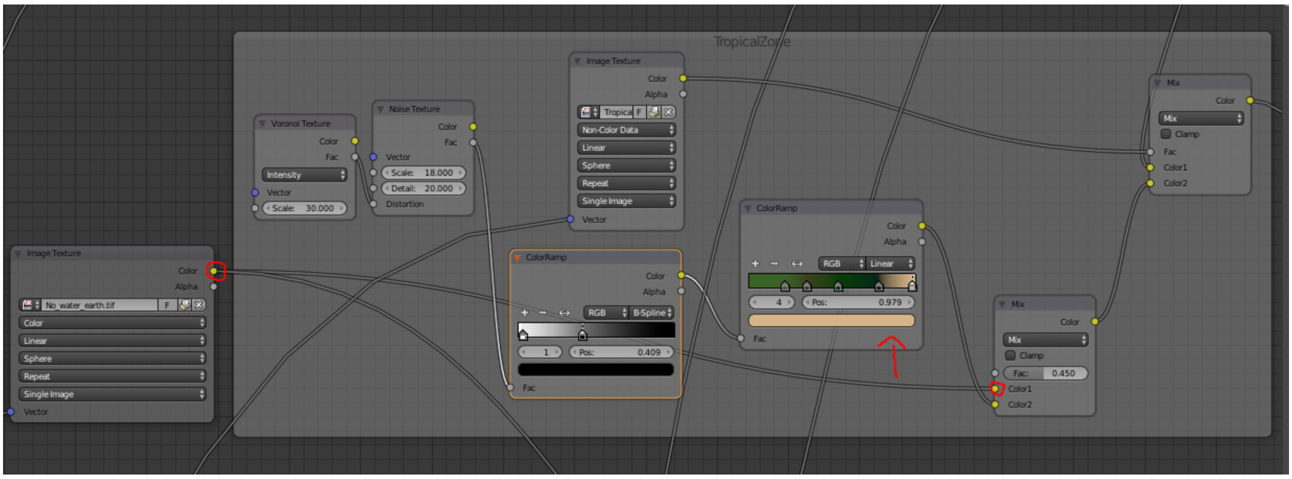

Figure 119: Colour Tropical zone.

The most important thing is the connection between the first and the second climate zone. This connection is needed for later, so it is possible to animate the whole climate on the earth surface with just one slider. All you need to do is connect the last mixer of the climate zone before with the “Color1” of the last “MixRGB” node of the following zone. By doing that you slowly layer the masks on top of the original earth texture and only the water of the original texture remains.

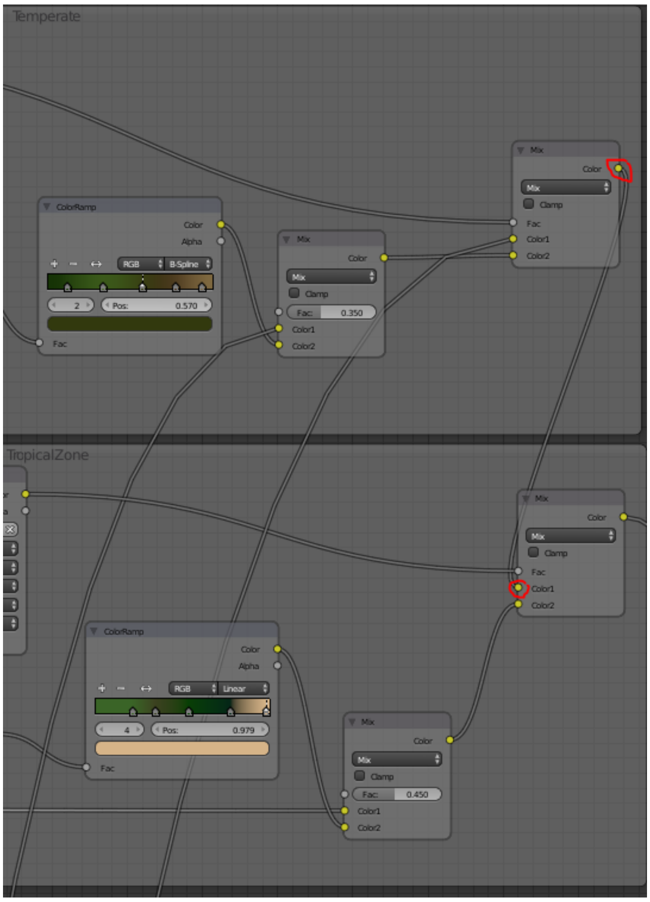

Figure 120: Connection between zone.

You want to repeat the connection between the different zones until you are done with the last zone. The Subtropical zone is also connected to the dry earth texture, for a more realistic setup and the colour gradient is adjusted for the zone.

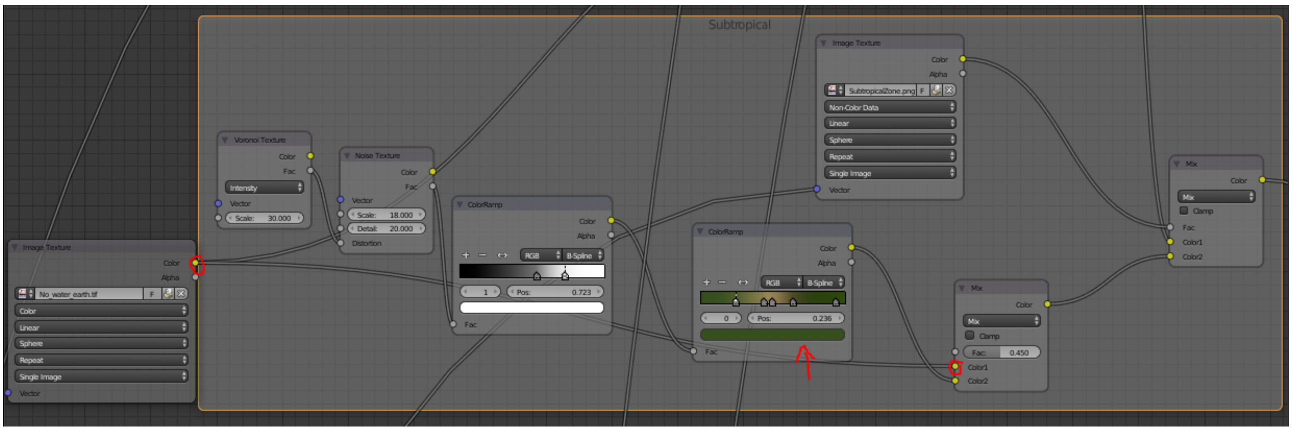

Figure 121: Colour Subtropical zone.

The Last zone is the Polar Zone, again we adjusted the colour gradient and this time we mixed it with the original earth texture for better fitting colours.

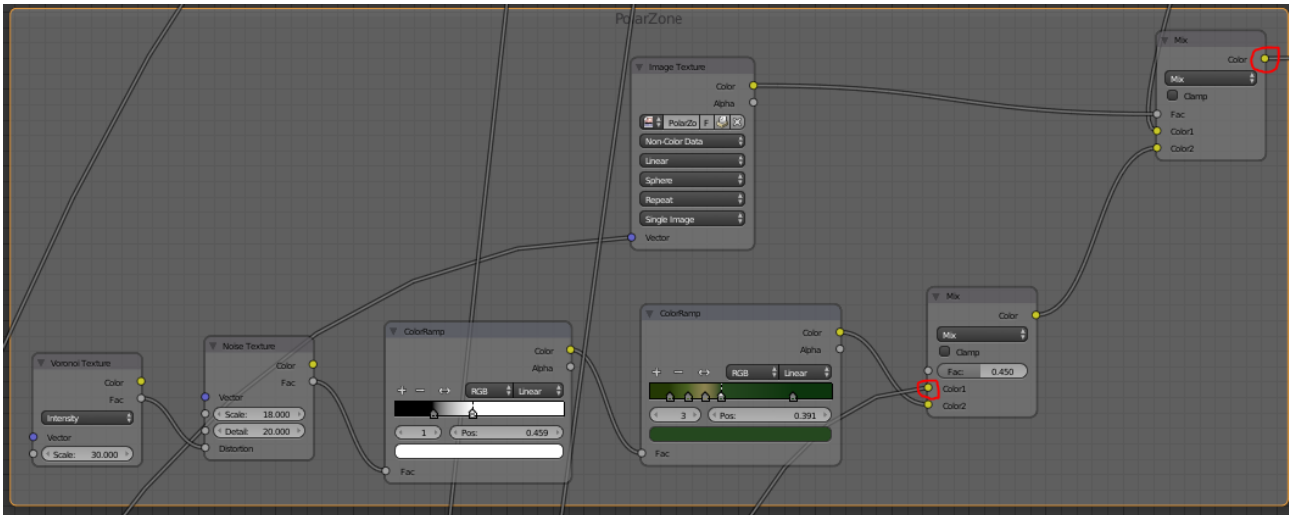

Figure 122: Colour Polar zone.

The special thing about the last mixer is, that it is plugged into a new “MixRGB” node, this is the final “MixRGB” node to adjust our climate with. This node sits between the original earth texture node and the new climate system and the “Diffuse BSDF” node from the tutorial. Adjusting the value of the “Fac” on this node allows you to switch between the original earth texture in “Color2” and the new climate changed textures in “Color1”.

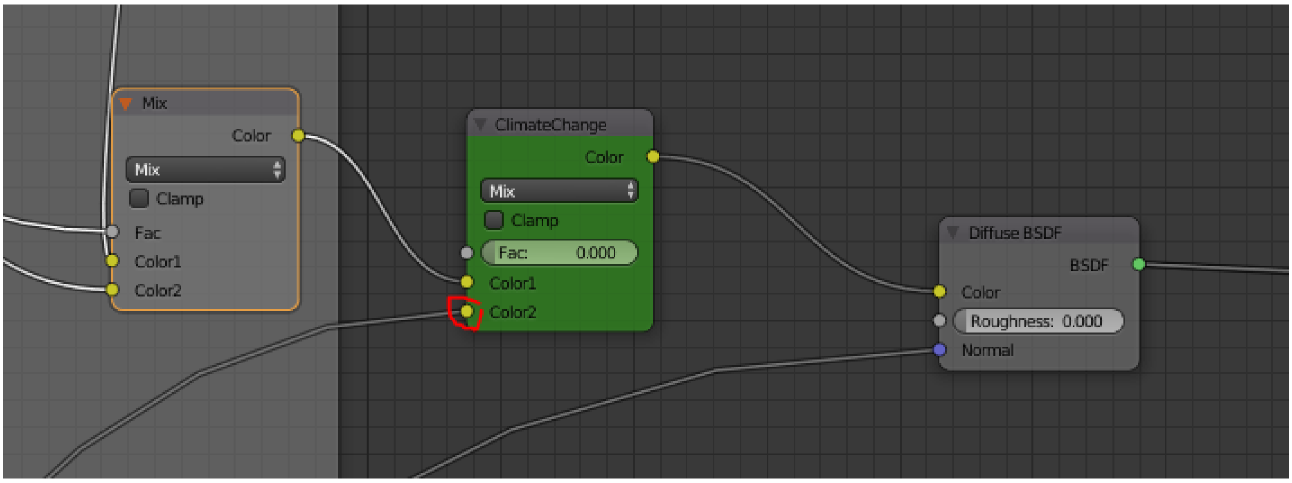

Figure 123: Final mixer “Climate-Change”.

8.2.4 Camera and animation

The camera in this scene is static and is focused on Europe, Africa and parts of Asia. We choose this camera angle to show a high diversity of climate zones and to show our connection towards Europe because we live there. The biggest changes are closer to the Mediterranean Sea, that’s why we decided to point the camera on it. To fixate a camera on an object you must setup a camera adjusts the settings and set a focus on the sphere of the earth with pressing ctrl+P. Using the axial arrows for the camera allows you to position it in the right way while focused on the earth. By pressing the

Num0 - key you can switch into to camera view to see its current point of view. In this Scene we only need to setup the frame range for the animation and setup and record two key-frames. The only value we want to change in our animation is the “Fac” of the “Climate Change” Mixer we want to switch from 1.0 to 0.0. The Frame range is 0 to 312 Frames like in the other scene and it runs on 24 FPS. The yellow lines in the timeline are key-frames, those will start or end your animations.

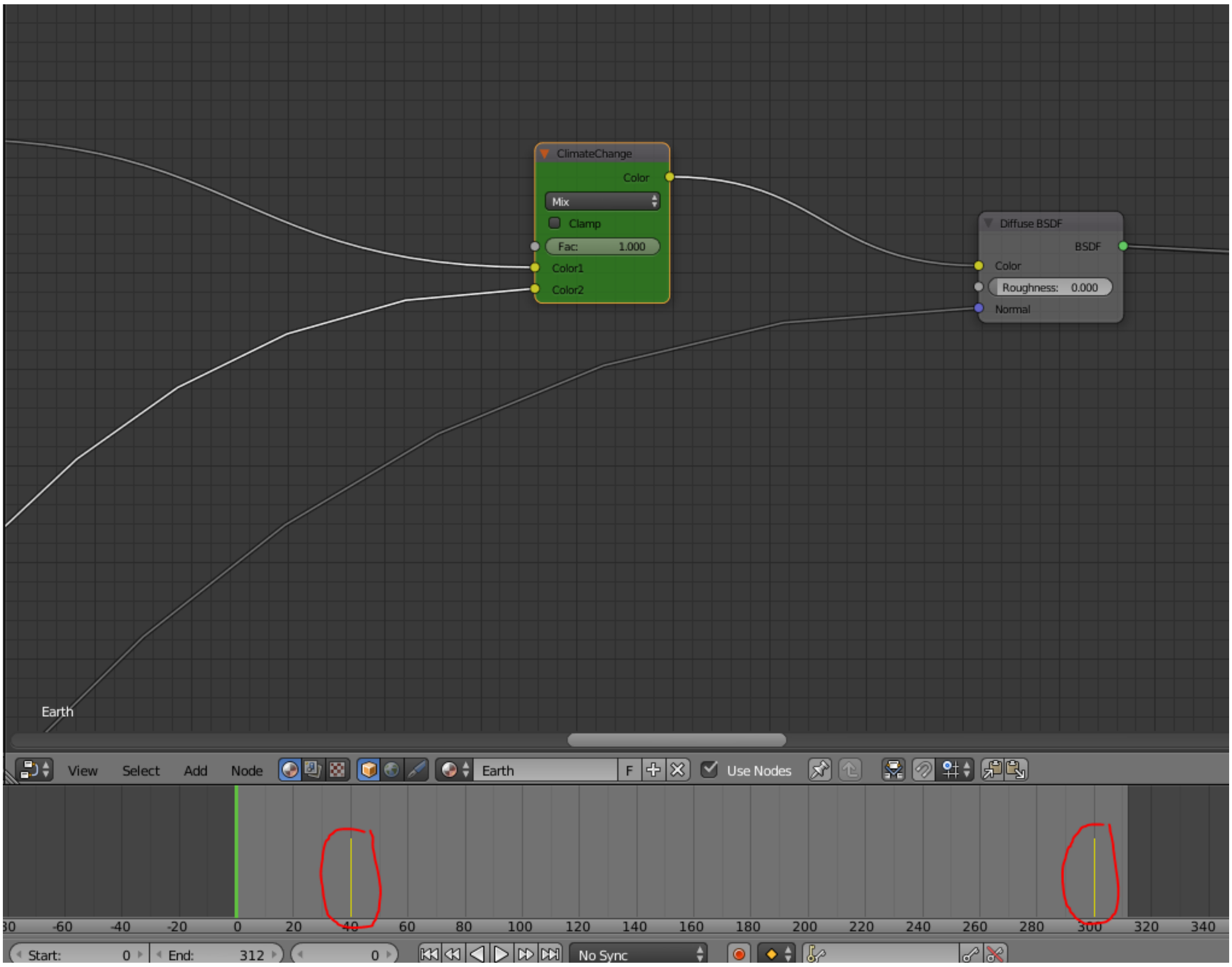

Figure 124: Animation Frame Setup and Key-frames.

You can add key-frames by moving your timeline to the wished frame to start from and then hover over the value you like to change in our case the “Fac” and press “ i “ blender will setup a key-frame in the current selected frame. Move to the frame you want to end your animation and repeat. Now you have two separate key-frames, the next step is to record the changes you want to make during this time frame.

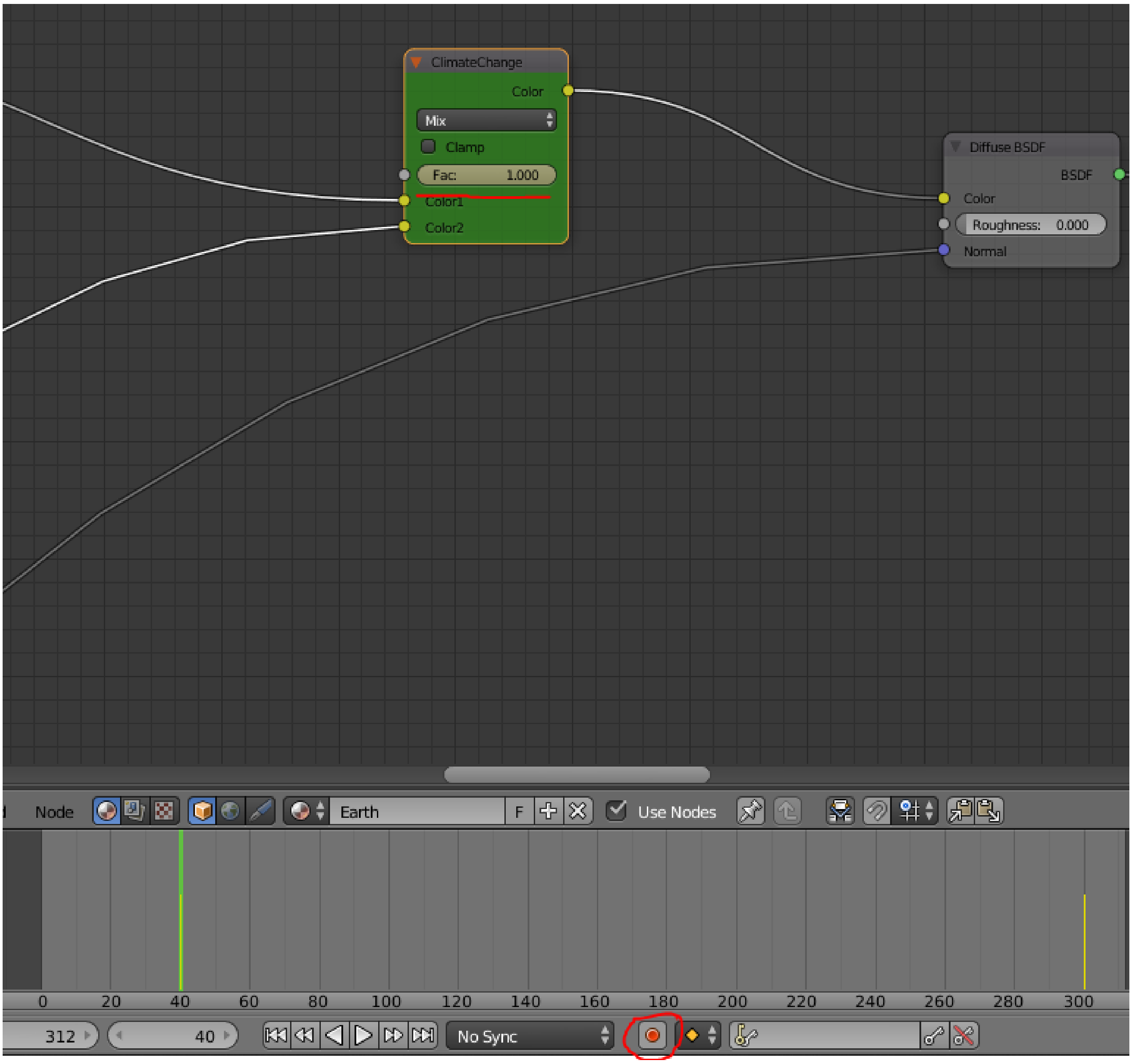

Figure 125: Recording.

You can record actions by clicking on the red dot down below next to the “No Sync” setting. Toggle the record and move the slider from 40 frames to 300 frames in the timeline, then change the value of the “Fac” slider in the nodes to 0. Stop the recording by pressing the red dot again. You can check if its works by simply moving the green bar with your left mouse button between the two key-frames. The value should now change between 1.0 and 0.0 within the key-frame range of 260 frames.

9 Scene 4: melting ice caps, sea levels rising

Scene 4 shows the melting of the polar ice caps and the rising sea levels caused by the melting. This is shown in one on-earth close-up view and a space view.

9.1 Research

By 2050 the Arctic may experience ice-free summers, which last for three months. But since ice floats in the sea, the water does not directly raise the sea level. 50 years later Greenland and the Arctic are completely melted and Greenland’s ice will already add another 7m to the increasing sea level, which also pushes the tides. By the year 7050-12018 the earth will be ice-free, meaning that the more than 24 million cubic meters of ice on Earth, including the massive amounts of ice from Antarctica, will be melted and raise the sea level by 68.5 meters. In 0.5-1 billion years from now, the runaway greenhouse effect leads to boiling of oceans until the oceans are gone by the end of the 1 billion years.

In the following it is described what happens to the different continents when the sea level rises by 68.5 meters: South East: The Mediterranean Sea spills into the Black Sea and the Caspian Sea, while Odessa and Istanbul are drowned. Meanwhile, the Adriatic Sea grows north erasing Venice. Rome, Marseilles and Barcelona will suffer from the Mediterranean Sea. In the north St. Petersburg and Helsinki will be plunged by Baltic Sea. 55 percent of the Netherlands will lie below sea level by that time but will be better off than Denmark, Stockholm, and Copenhagen considering that they will be gone. For the United Kingdom, it is estimated that London and Dublin will be flooded.

Asia: Already 0.9m of added sea level would eliminate up to 1300 km2 of Indian Subcontinent including Namibia, Calcutta and Bangladesh. In South East Asia Bangkok, Singapore and Hong Kong will be drown. In Japan, the sea level would rise 10-20 times faster than the global average.

South America: The regions around Lima, Rio de Janeiro and Buenos Aires would disappear under the water.

Australia: The water penetrates from ground building huge liquid area around Adelaide.

USA: The west of the coastline cities gets slammed. The Gulf of California will stretch north towards San Diego. San Francisco will be flooded by the Central Valley. Seattle and Portland will become islands and the Gulf of Mexico will disappear. Furthermore, it is predicted that Florida, NY, Boston and DC will be gone.

9.1.1 Atmosphere changes

The Sun is halfway through its main-sequence phase, which already has started 5 billion years ago, during which nuclear fusion reactions in its core fuse hydrogen into helium. With every second, approximately 5 million tons of matter are converted into energy inside the core of the Sun, generating solar radiation and neutrinos. The Sun is slowly getting hotter and hotter as a main sequence star, since the atoms of the helium inside the core occupy less volume than the hydrogen atoms, which were fused. For this reason, the core of the Sun is shrinking, enabling the outer layers to shift closer to the center and face a more powerful and significant gravitational force. The amount of greenhouse gases increases in Earth's atmosphere and, as a result, it leads to melting ice caps.

9.2 Animation: Close-Up View

Antonio Sarcevic was responsible for creating the close-up view of Scene 4 in Blender. The steps needed to create this scene include finding and editing a fitting HDRI, creating an ocean plane with fitting settings and material, sculpting ice sheets and creating an ice material, creating an iceberg using Add-ons and animating the whole scene using keyframes.

9.2.1 HDRI

For this Scene, an HDRI Image is used for the sky and clouds in the background. After finding a mostly fitting HDRI online[3], it still had to be edited to make it work for our scene. Opening up the HDRI in a raster graphics editor (here Photoshop was used) lets you edit the image directly. Use a selection tool to select the ocean from the HDRI because we don't need it since we will add an animated ocean in Blender. Use a color picker to pick a fitting color to replace the ocean with. Choose a color near the horizon. To create a smooth transition from the sky to the missing ocean, select the gradient tool and choose a gradient between the chosen color and transparent. Zoom near the horizon and apply a gradient from where the ocean starts, to where the clouds start to be visible. Hold shift to make the gradient perfectly horizontal.

Save this image as a ".hdr"-File. Create a new Blender scene to insert the HDRI into. Important: at the top of the window set the Renderer to Cycles Render. In the Properties window select the World tab. Under Surface click the Use Nodes button. Open a Node Editor window and from the toolbar at the bottom select the World icon. Add an Environment Texture node by clicking Add from the bottom toolbar, then Texture and then Environment Texture. Connect the Color parameter from the Environment Texture node to the Color parameter from the Background node. Click the Open button and select the edited Texture. Rotating the HDRI is possible using a Mapping node connected to the Vector property of the Environment Texture node.

[3] https://cgi.tutsplus.com/articles/freebie-8-awesome-ocean-hdris%2D%2Dcg-5684

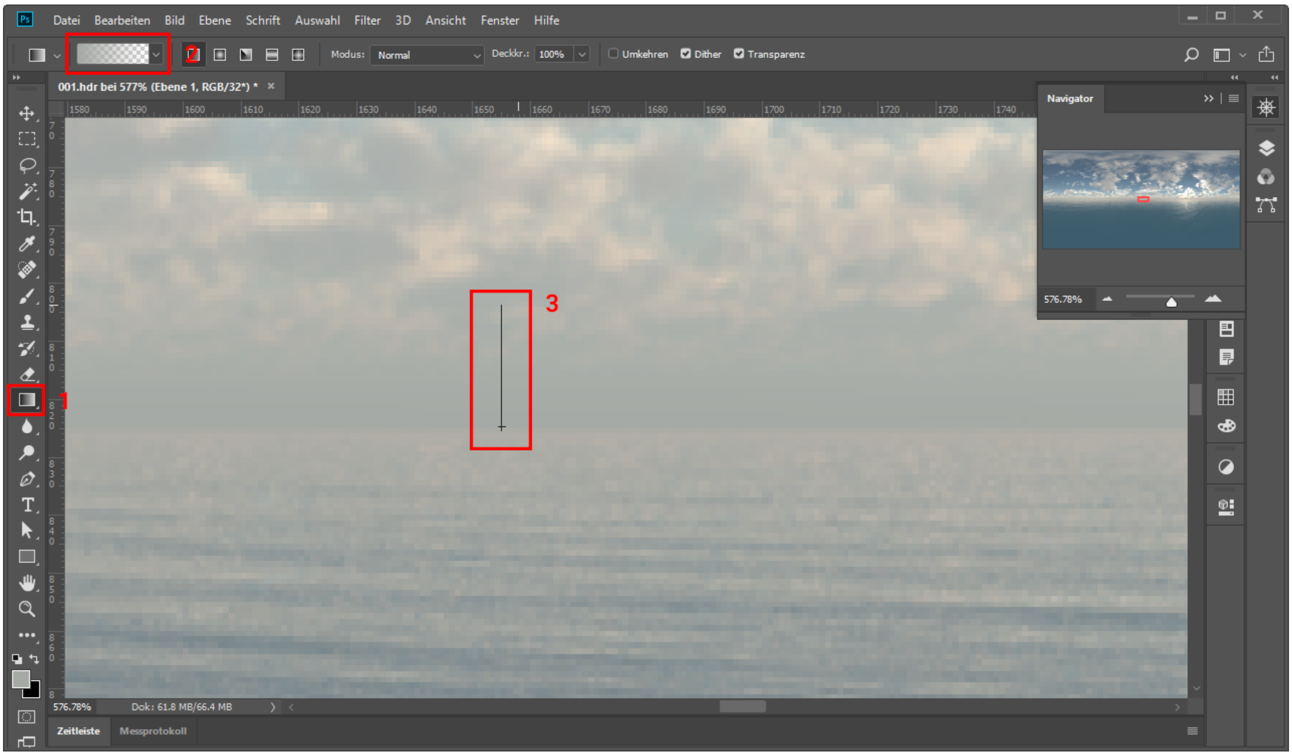

Figure 126: Create the gradient to replace the ocean in the HDRI. (1) Select the gradient tool. (2) Select a gradient from the picked color to transparent. (3) Click and drag from the ocean to the start of the clouds in the image.

To set up the camera select the Camera from the Outliner to edit its properties. In the 3D Viewport change the Location on the right-hand side to 0, -50, 10 and the Rotation to 90°, 0°, 0°. The Scaling can be set to 200, 200, 200 to get a better view of what the camera sees. Under the Properties window, select the Data tab and set the Clipping to Start at 1 and End at 240.

9.2.2 Ocean

Start by adding a plane into the scene. To create a plane use the 3D Viewport in Object Mode and select Plane from the Create tab in the left-hand menu. The location can be changed in the right-hand menu of the 3D Viewport (press N to open it, if it isn't open) and was set to -75, 0, 0. Rename the Plane to Ocean in the Outliner window.

After creating the plane, open the Modifiers tab in the Properties window. Click Add Modifier and select Ocean under Simulate. This opens up a range of options. First, make the ocean bigger by setting both Repeat X and Repeat Y to 4. Set the Resolution to 12 the Choppiness to 1.5. Alignment is set to 1. One can press the Bake Ocean button to bake the ocean for faster working later. Also important is to check the Generate Foam box and put in a name like "Foam" for the Foam Data Layer Name.

To create a material for the ocean plane, go to the Material tab in the Properties window and click New. Name the material Ocean and open up a Node Editor window to edit the material. To create a

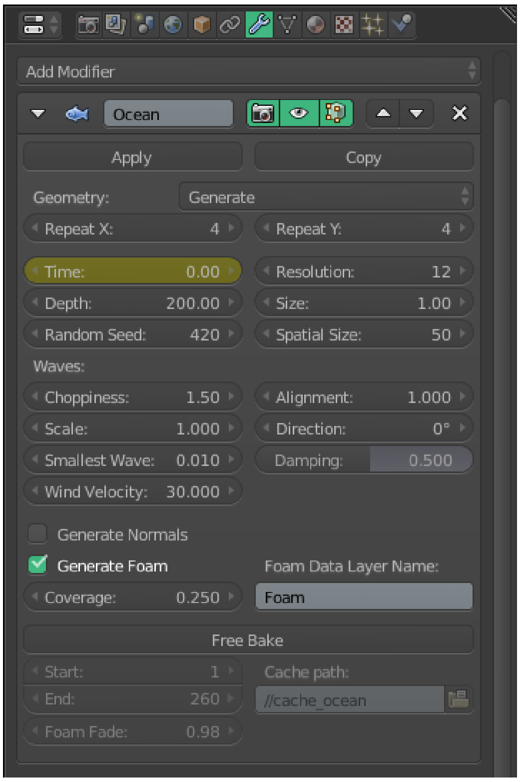

Figure 127: Ocean Modifier settings for Scene 4.

node press CTRL and A and click Search to search for the node names given. First, a Glass BSDF is added and set to Bleckmann with a dark blue color (HEX #052031). The roughness is set to 0 and the IOR is set to 1.45. Then a new Glossy BSDF is added with a light blue color (HEX #96D5FF). These both get plugged into a Mix Shader node with a factor of 0.2. Below, create a new Attribute node with the name you set in the Foam Data Layer Name before. This gets plugged into a Diffuse BSDF node with a Roughness of 1. The Mix Shader from above and the Diffuse BSDF from below both get plugged into an Add Shader node and this Add Shader node gets plugged into the Surface input of the Material Output node. Recreate this material by using CTRL and A to add the nodes and copy the values from the image.

9.2.3 Ice sheets

Start by creating a Cube in the Create tab of the Object Mode inside the 3D Viewport. Scale the Cube to a desired size of the ice sheet. Use the Numpad 0 key on the keyboard to view the scene from the camera's perspective and determine a good location and size for the ice sheet. You can also rotate the cube to make the scene more varied. Rename the Cube to Ice in the Outliner window. Disable the Ocean layer by pressing the little eye icon in the Outliner so you can view your work better. Next, press the Numpad Comma / Period key to focus the camera on the cube.

To give the ice some shape, one can add another cube to carve out some parts of the original cube to give it some shape. After adding another cube, scaling it larger on the Z axis than the original cube

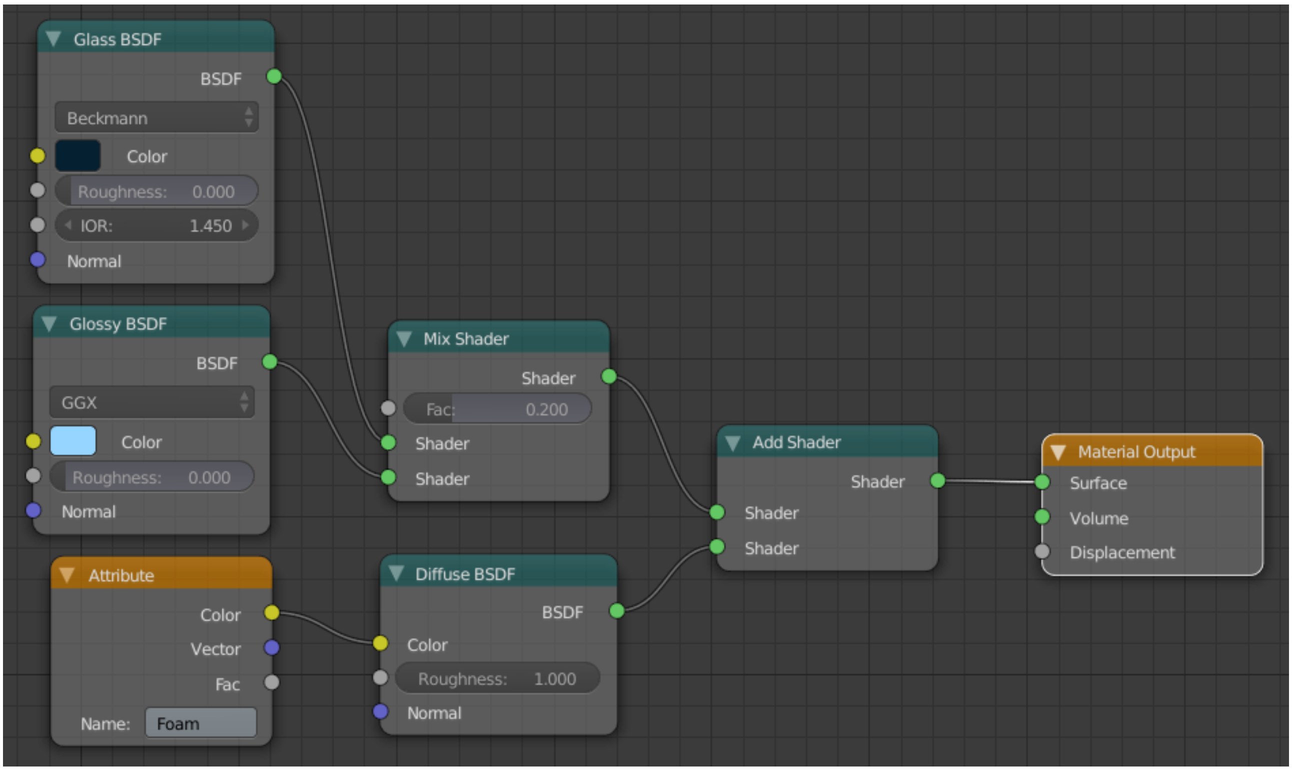

Figure 128: The finished ocean material.

and placing it where it should carve the ice select the original ice cube again.

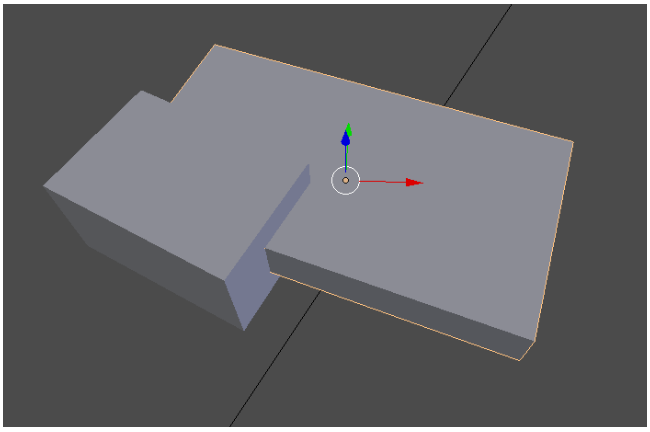

Figure 129: Shaping the ice by placing a new cube to carve the ice cube.

With the ice cube selected go to the Modifiers tab in the Properties window, click Add Modifier and select Boolean under the Generative section. Under object select the newly made Ice block that we placed to carve the ice then under Operation set it to Difference and press Apply. Then go ahead and delete the new block.

One can repeat this progress to make unique shapes for the ice base. Then go to into the Sculpt Mode in the 3D Viewport and in the right-hand menu of the 3D Viewport select Matcap under Shading. In the left-hand menu of the 3D Viewport select the Scrape/Peaks tool and set the Radius to a desired size and the Strength to 1. Under Stroke set the Spacing to 1%. Under Curve select the flat curve

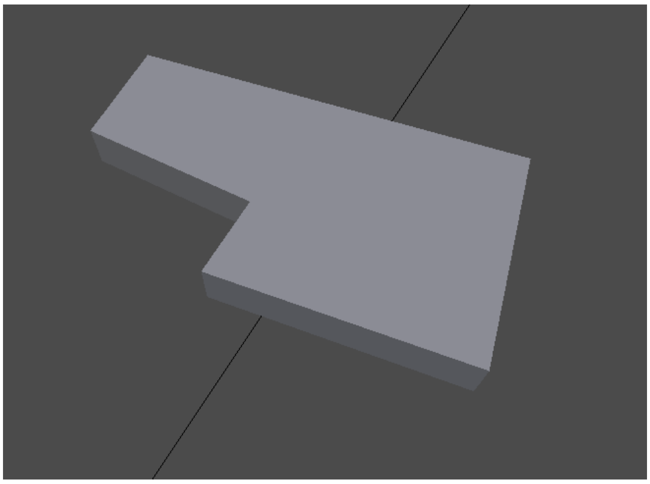

Figure 130: Carved ice sheet base.

(the last button under the graph view). And be sure to have a checkbox in the Dyntopo setting. Also uncheck every axis in the Symmetry/Lock feature. Then go ahead and hold your left mouse button and move it over the edges of the ice base to shape it into a desired model. Experiment with different radii and camera views to get different results. Scrape the ice sheet base into a general ice shape. Smooth out the corners and give it the desired look. Use Ctrl + Z to undo undesired changes. This part requires a lot of trial and error. If you want to add material to work with use the Blob or Clay tool to add more material. You can use the Smooth tool to fix mistakes or generally smooth the surface more, but a more "edged" look is more desirable.

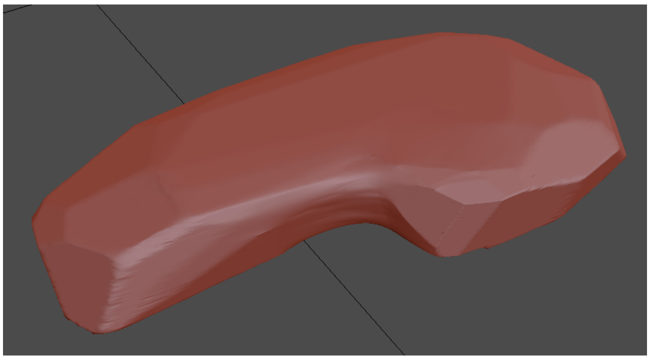

Figure 131: Finished result of the sculpting process.

Apply sculpting the object, leave Sculpt Mode and go back to Object Mode. After creating several ice sheets with different sizes and shapes, place them in the scene, copy and rotate some to fill the lower half of the ocean. Matcap can be also disabled now. To finish up the ice sheet, one should decrease the complexity of the mesh. To do this go to the Property window and select the Modifier tab. Click on Add Modifier and select the Decimate modifier. Lower the ratio until the Faces reach a number between about 100 and 1000.

Create a new material like described above. Name it Ice and add a Texture Coordinate node. Plug the Object output into a Separate XYZ node. Plug the Z output into a Math node and set it to Add and set the other value to 2. This output gets plugged into a Gradient Texture node set to Linear. This output gets plugged into an Invert node and this output gets plugged into a Bright Contrast node with a Bright of 0.4 and Contrast set to 0. Go back to the Texture Coordinate node and plug the Generated output into a new Noise Texture node with Scale set to 50, Detail set to 16 and Distortion set to 0. The Color output gets plugged into a Bright Contrast node with a Bright of -0.2 and Contrast of 0.7. The last Bright Contrast node gets plugged into the Color 2 of a MixRGB node and the Bright Contrast form before gets plugged into the Fac of the same MixRGB node. The Color1 of the MixRGB gets set to a greyish blue (HEX #9BA6BC). This MixRGB node gets plugged into a Glossy BSDF with a roughness of 0.2. Go below and create a Fresnel node with IOR of 1.45. Create two Subsurface Scattering nodes with one being blueish almost white (HEX #D9EDFF) and the other a more vibrant blue (HEX #007EB7). Create a Mix Shader node and plug the Fresnel Fac into the Fac of Mix Shader and the Subsurface Scattering in both Shader inputs of the Mix Shader. This last Mix Shader and the Glossy BSDF from above both get plugged into an Add Shader and this gets plugged into the Surface input of the Material Output.

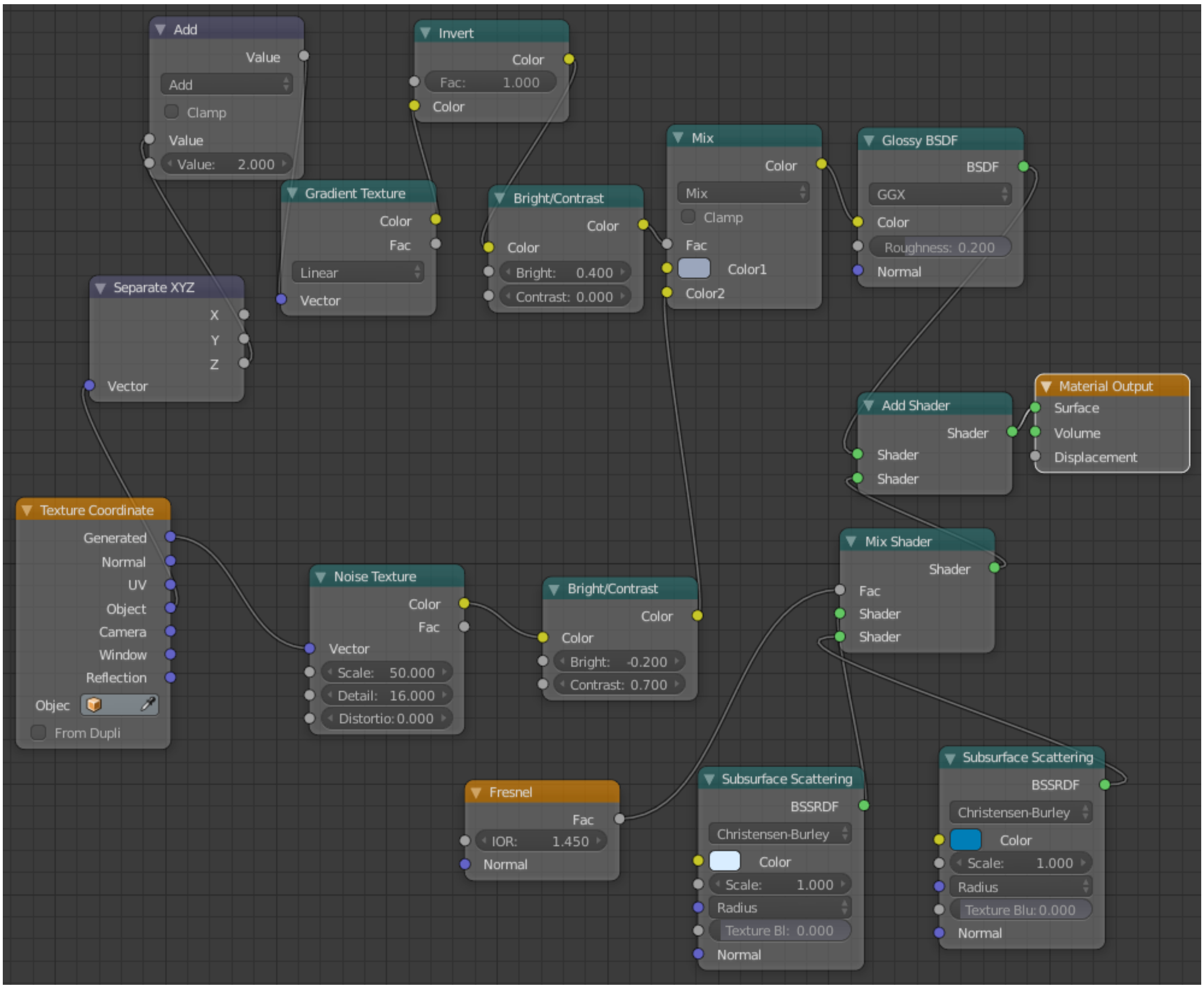

Figure 132: The finished Ice Material.

9.2.4 Iceberg

In the background an iceberg will be added. To generate a mountain structure we will use a Blender Add-on. To enable the plugin go to File then User Preferences then select the Add-ons tab. Search for “Landscape” and check the box next to “Add Mesh: A.N.T.Landscape” and click Save User Settings.

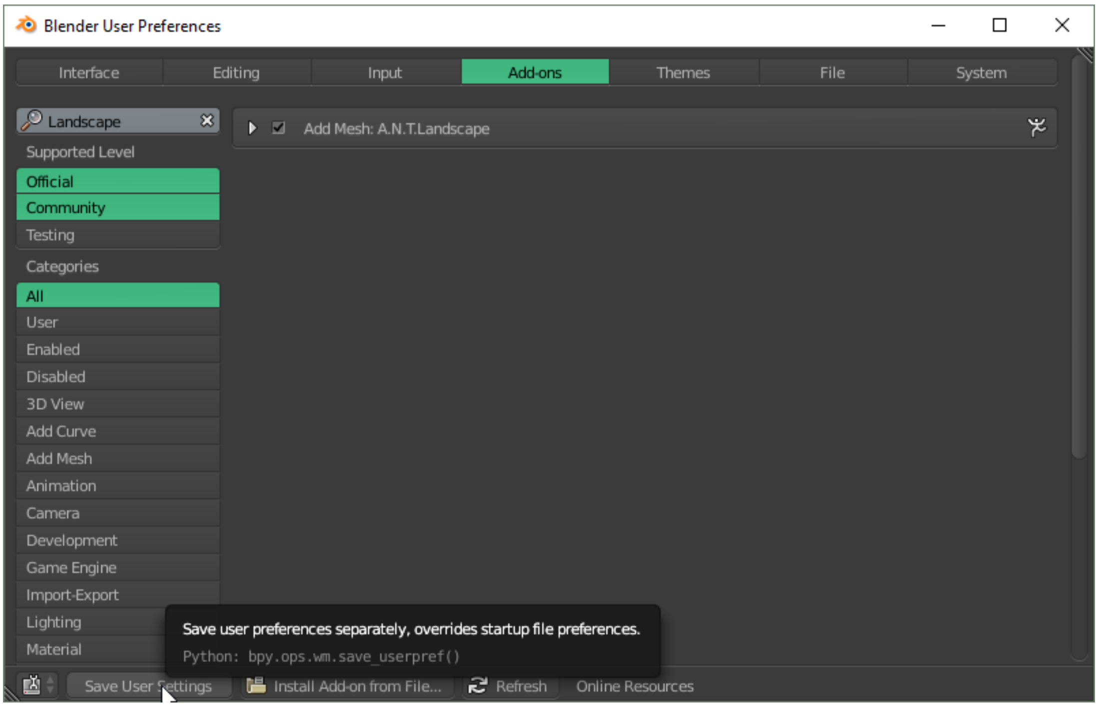

Figure 133: Enable the Add-on “Add Mesh: A.N.T.Landscape” and Save User Settings.

After enabling the add-on there will be a new option under the Create tab of the Object Mode. Below the Add Primitive section there is a Landscape section with a Landscape button. Click the button to add a new landscape. On the left hand side there also will be a new section at the bottom (or press the little plus icon if it is missing) called “Another Noise Tool - Landscape”. This section contains all the settings for the newly added landscape mesh. Use the Mesh Size X and Mesh Size Y to scale it to the desired size. Under Noise Settings select Slick Rock as a Noise Type. To make the mountains bigger set the Maximum and Height to a larger value under the Displace Settings. To decrease the amount of pointy mountains set the Noise Size to a higher value. The Offset X/Y and Size X/Y of the Noise Settings can be manipulated to create different effects. Play around with the settings until there is a desired result. Add the ice material used in the ice sheets.

This part of the scene is based off the beginning of the Tutorial “Blender Tutorial- Create Realistic Mountains Free”[4]. View this video for further details.

[4] https://youtu.be/qSafYNQrodk

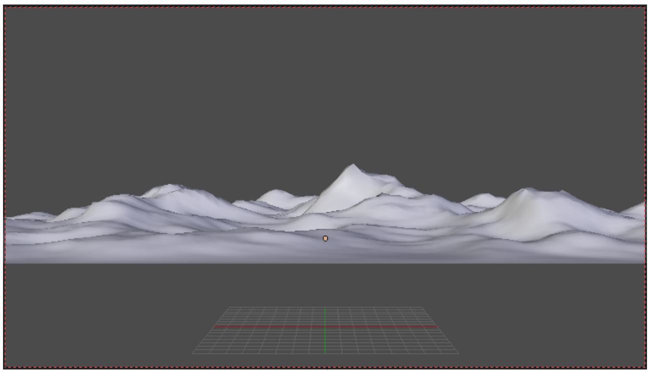

Figure 134: Finished iceberg.

9.2.5 Keyframe animation

First set the total length of the animation. Open up the Render tab inside the Property window and under Dimensions set the Resolution to X: 1920 and Y: 1080. Under Frame Range set the Start Frame to 1 and End Frame to 260.

Next up is animating the ocean. Note the Time parameter inside the Ocean Modifier. This needs to be animated for the ocean to simulate movement. To add a keyframe, be sure that in the Timeline the Current Frame is set to 0, then hover over the Time parameter of the Ocean modifier and press the I key on the keyboard. Then go to the last frame of the animation and set the Time to 20 and press I again. To animate the ocean level rising create a keyframe on the Location of the Ocean plane at Time 10. Go to the end of the animation, rise up the ocean as much as you like and create another keyframe on the Location. Opening the Graph Viewer allows the user to set curves for the animations. To create a smooth slow-then-fast rising water, adjust the curves in the Graph Viewer.

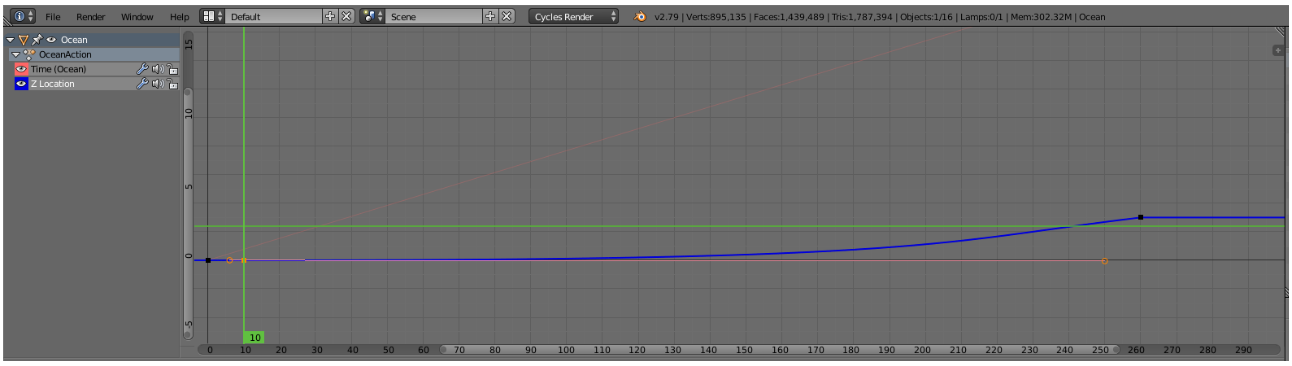

Figure 135: Graph Viewer allows the user to adjust the animations.

To animate all the ice sheets and the iceberg go to Time 10, select them all from the Outliner with Shift held down, then head to the 3D View and click Object from the bottom toolbar, then Animation, then Insert Keyframe and then select Scaling. Then go to the end of the animation and change the scale of all objects to 0 by holding ALT while clicking on Scale Z and typing in 0. Then add another keyframe through Object, Animation, Insert Keyframe and then Scaling.

9.3 Animation: Space View

The animation is quite simple and based on switching textures. To get the effect of rising water without adding bump or height to the water, we must simulate flooding for areas close to the sea level such as Denmark or the Netherlands. We use a basic combination of “Image Texture” nodes and “Mix-RGB” nodes to switch earth textures. By switching the “Ocean-Water-Mask” we can overwrite landmass with water, so we get a nice flooding effect in areas close to the ocean. The animation is done with keyframes and by adjusting the values of certain “Mix-RGB” nodes.

Make sure that you delete all keyframes from your duplicated file. Search all objects look in the timeline at 40 and 260 frames and delete every keyframe made for the other animation by hovering over it and pressing alt- i. Also keep the end settings of the former scene as your starting point for the new scene.

Working in Blender

To complete this task, it is recommended to finish all the scenes before and to know the basic node structure. Since all scenes are related to each other, it is hard to decide what nodes to add in advance or what to ignore. It’s better if you add all nodes you see in the other scenes and add the connections later. The scenes 3,4 and 5 are all made in one node tree, that makes them quite special and there are multiple connections between their nodes.

9.3.1 Connecting textures for rising water levels

Since you want to simulate the decreasing ice all over the planet and the rising water, you need to switch the “Ocean-Water-Mask” and the “Earth Texture”. The new mask texture is modified in Photoshop and the earth texture without ice caps is provided by the “NASA”. It is important to notice, that this scene is related to the scenes before and will switch up connections, because we want to keep the climate change that we created before in place.

First you must create an additional “Image Texture” node for the mask and the earth texture. Set them up like their equivalent and connect them to the “Generated” connection of the “Texture Coordinate” node. Now put the “Ocean_Mask_flooded” texture in the mask texture image and the “Earth_Flooded” texture into the image texture for the texture. Add two “MixRGB” mixer behind both node groups and plug the flooded textures into “Color1” and the original textures into “Color2”. Increase the value of both mixers to 1.0 and add an invert node behind the “Ocean_water_mark” mixer. Connect the mixer “Color” with the invert “Color” and set the invert to a value of 1.0.

Using this setup allows you to switch between textures within an animation and it is a very simple solution. As you can see in picture 1 there are a lot of paths leaving from the mixers and the invert nodes. The connections of the earth texture mixer are the same connections you had before for the

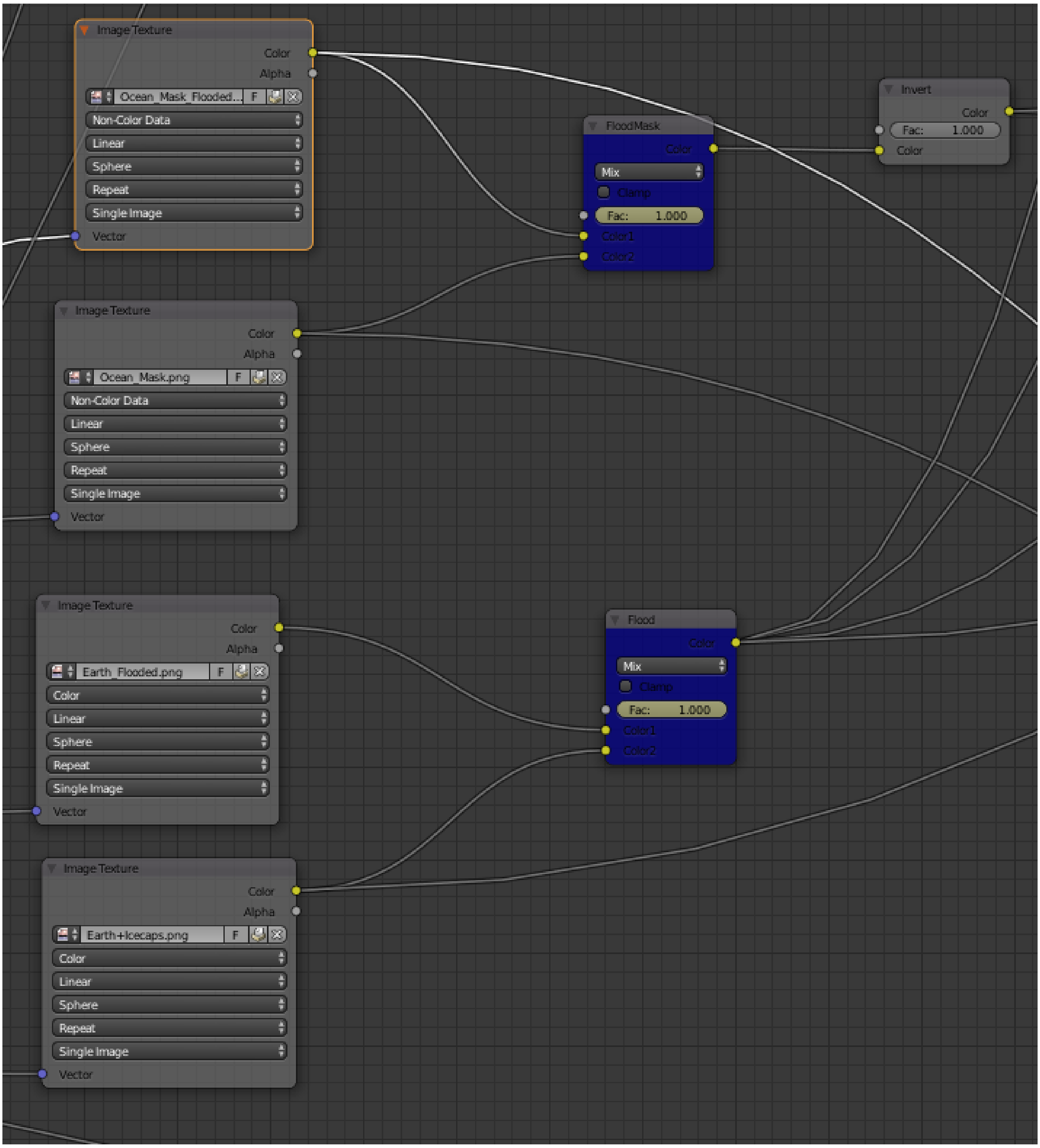

Figure 136: Overview Image Textures.

original earth texture. Two are connected to the mixers in the “Temperate” zone frame and one is connected to the colour mixer in the “Polar” zone frame. The fourth connection is used for a second mixer after the “ClimateChange” mixer. This allows one to keep the climate change and to animate the increasing water levels and decreasing ice caps at the same time.

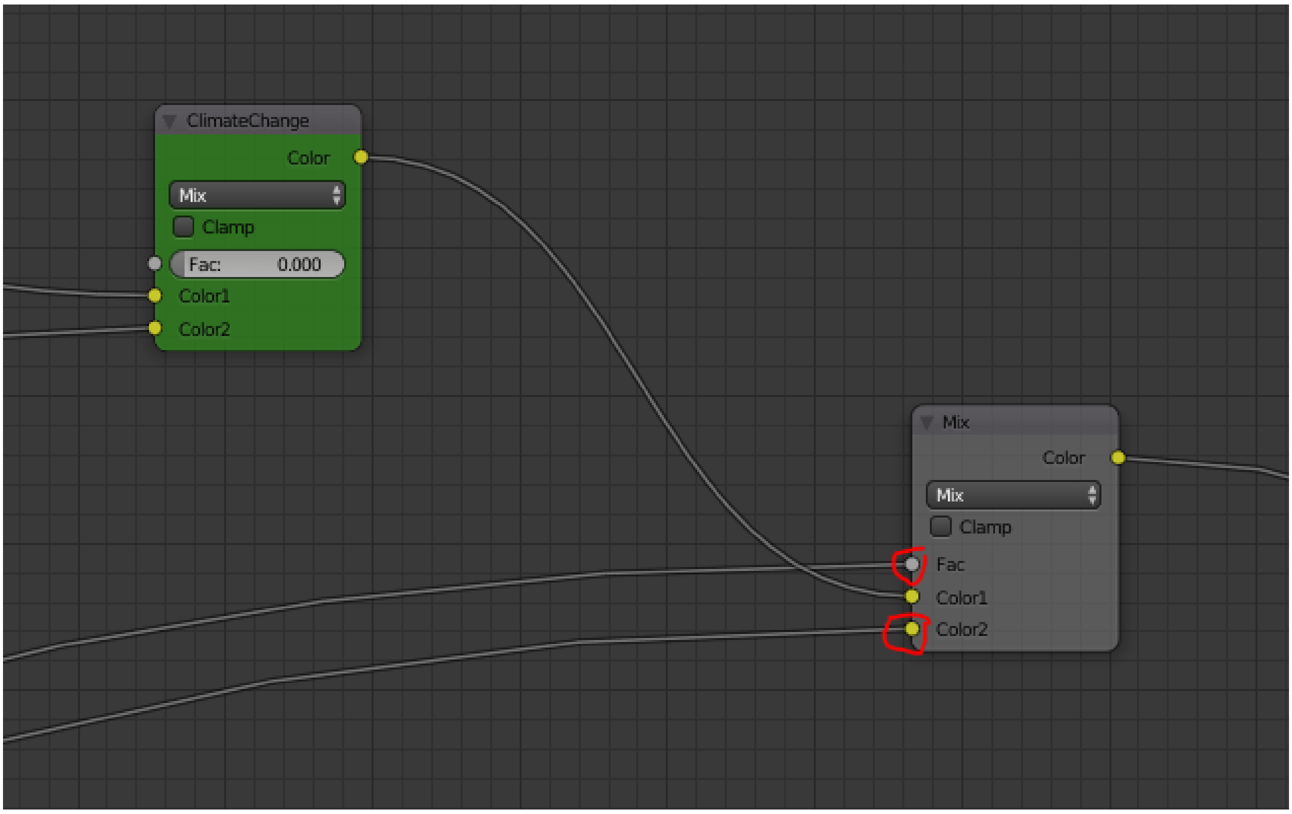

Figure 137: Water level and melting ice caps.

Add a “MixRGB” node and plug the “Color” of the “ClimateChange” node into “Color1” of the new mixer. Connect the “Color” from the invert node you created before right after the mask mixer with the “Fac” of the new mixer. Now plug the “Color” of the earth texture mixer into “Color2” of the new mixer. The “Color” of the new mixer goes into the “Color” of the “Diffuse BSDF”.

If you’ve done the tutorial, these shaders should be already there; If something looks different, please consider redoing the part of the tutorial, or add the nodes you need. The marked “Fac” of the “Mix Shader” should be empty or go directly to the original “Ocean_water_mask” you want to delete this connection and connect the “Fac” with the “Color” output of the inverter right after the mask mixer.

The final step would be adjusting the human lights on the earth to the new water mask and the new flooded areas.

Your lights are currently shown on the dark side of the planet and the Mixer right after the light control should have a connection to the original ocean water mask. This connection needs to be redone and adjusted to the new setup. By adding one “MixRGB” node and two invert nodes between the lights mixer and the new mask system, we can switch between the flooded and the regular ocean water mask for the lights on the earth.

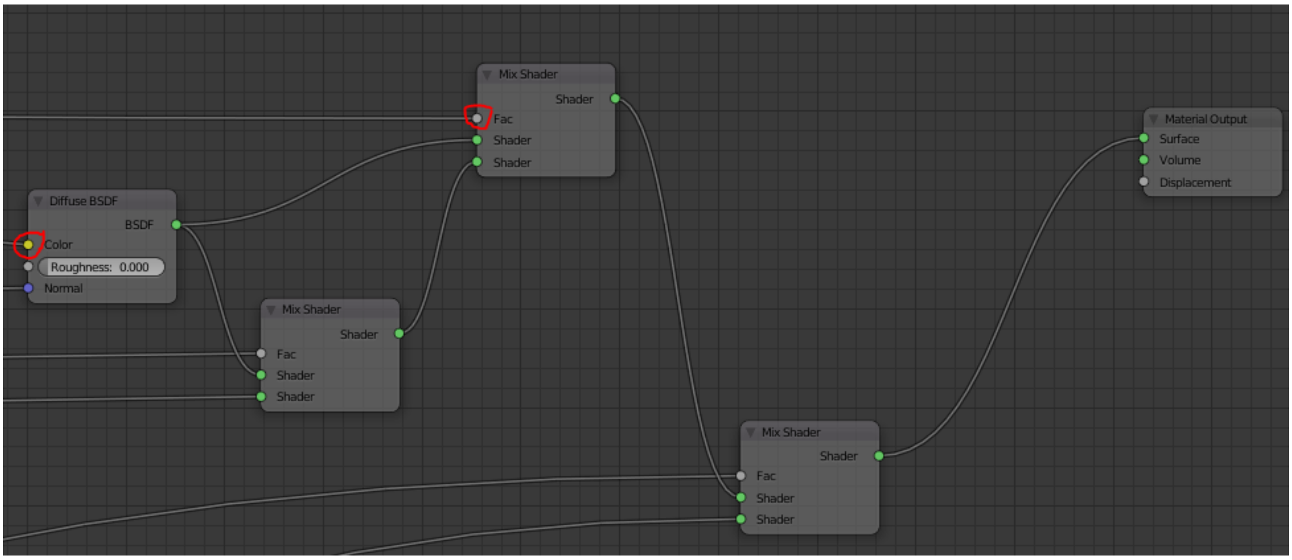

Figure 138: Shader setup.

The invert node connected to “Color1” of the mixer is connected to the “Color” output of the regular ocean water mask and the invert node connected to “Color2” of the mixer is connected to the flooded ocean water mask “Color” output.

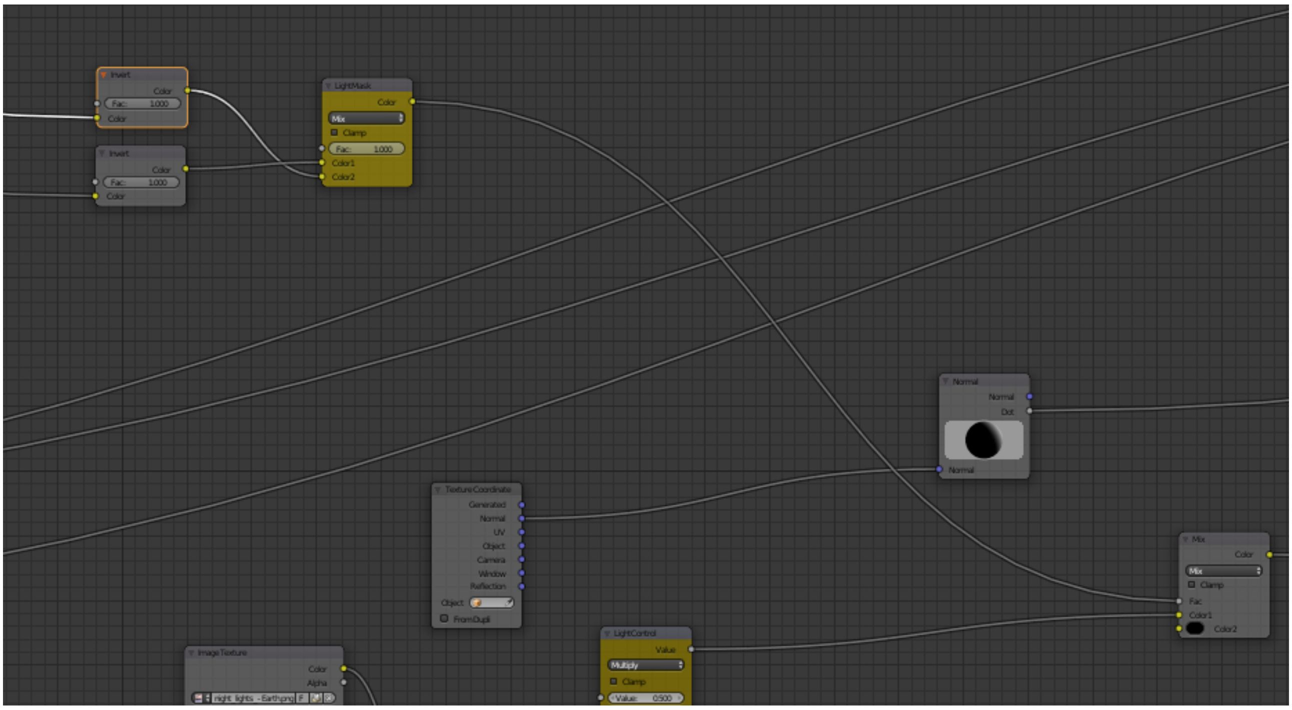

Figure 139: Light Mask flooded and regular.

9.3.2 Camera and animation

We decided to use a fixed camera position, to give the observer the best opportunity to analyse the changes during the animation. The camera is fixed on the “Mediterranean Sea” and shows parts of Europe and Africa. You can also see parts of the north pole.

The animation is done in 312 frames and at 24 frames per second. We use two keyframes on three different nodes. The change over time gets recorded by decreasing and increasing values of the "MixRGB" nodes.

The start keyframes are set at 20 frames for all three mixers. Hover your mouse over the "Fac" of the "MixRGB" node and press " i " to set a keyframe. Move your green timeline to frame 260 in the timeline and set three more keyframes on the same nodes. Go back to the 20-frame mark and set both "Image Texture" nodes to the value 1.0 and the mixer for the light mask to 0.0. Press the red record button and drag the green bar to frame 260. Change the values of the "Image Texture" nodes to 0.0 and the value of the light mask mixer to 1.0 and stop the recording.

Control the animation by dragging the green bar between start and end frame and check if the values are changing between 1.0 and 0.0. The animation is now done, and you can check in the rendered mode how it looks.

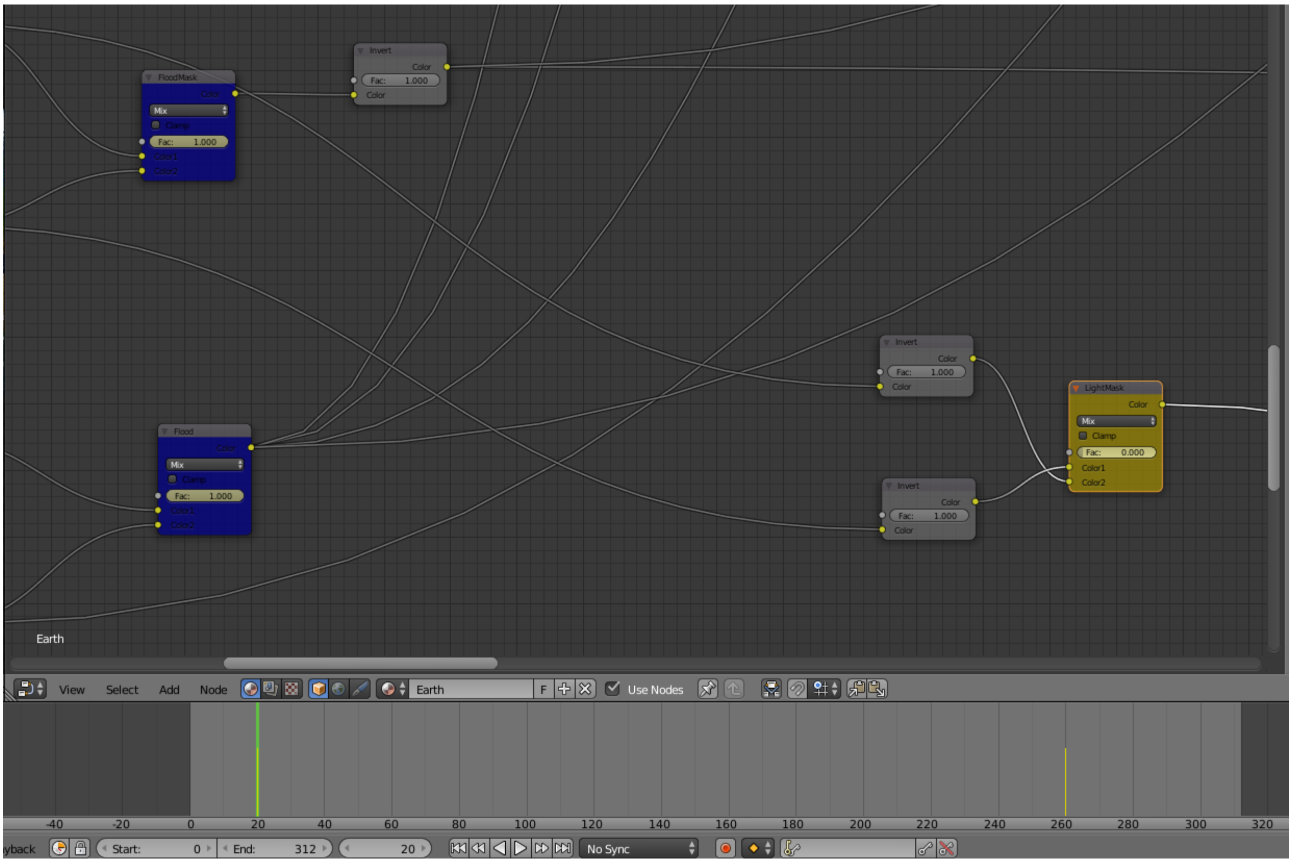

Figure 140: Animation Flooded, melting ice and light mask.

10 Scene 5: water boiling and evaporation

Scene 5 shows how the water gets heated to the point of boiling up completely. This is shown again in a close up view from earth and from space in a split screen.

10.1 Research

In scene five a split screen is used to show the water on Earth's surface boiling and finally evaporating. The split screen was used to make clear what is happening, by simultaneously showing the water evaporating in a close up and from a point in space. In the close up it can be seen, that the water starts to boil and evaporate. The space view additionally shows how the atmosphere gets thicker due to the increase in water vapour and also gives an overview about how an ocean-less earth will look. The water on the Earth will start to boil and evaporate in noticeable amounts in about one billion years, when the temperature on the surface reaches an average of 70°C. It is not clear how strong the actual evaporation of the water will be at the distinct points of time, Earth's water is already evaporating in the present day, but at a level where it is balanced out through condensation and rainfalls. With the temperature increasing, also the evaporation amount will increase, until it will not be balanced out by rain falls any longer. This will finally result in Earth losing its liquid surface water.

10.2 Animation: Close-Up View

Antonio Sarcevic was responsible for creating Scene 5 in Blender. This scene is based upon Scene 4 and uses the same Blender file. Boiling water is animated using a Displacement Modifier, vapor is faked using a video plane and the dry earth surface is modeled and textured.

10.2.1 Boiling water

Because this scene is based upon the previous one the work is done in the same Blender file. Start by going to the Render tab in the Property window and increasing the End Frame to 740. Then go to the last frame in the Timeline and select the Ocean plane in the Outliner. Under the Modifier tab there is the Time property, raise this to 60 and create a Keyframe by hovering over the Time and pressing I on the keyboard. Go to Frame 260 where the old end of the animation was and delete the old keyframe using ALT + I.

To create a boiling effect, a Displacement Modifier is used. Go under the Properties window with the Ocean selected and go to the Modifier tab. Click Add Modifier and select Displace. For a new Texture go to: add a new texture and give the texture a name like "Boiling". Go back to the Modifier tab and create a cloud texture. Go to frame 260 and set the Strength of the Displace modifier to 0 and create a keyframe. Then go to frame 300 and create another keyframe with a Strenght of 1.

10.2.2 Vapor Rising

The vapor simulation is based on the following video: smoke[5]. First go to the User Properties under the File menu and go to the Add-ons tab. Search for "Import Images as Planes", activate the checkbox

[5]https://www.videezy.com/fire-and-smoke/13093-dense-smoke-going-up-and-creating-white-swirls-slowly-in-4k

and click Save User Settings. Then in the 3D Viewport, click on Add, Mesh, click Images as Plane and search for the video in the file system. After the video plane is created, select it and set the X Rotation to 90°. Set the Location to 0.3,-48.1, 10 so, that the video plane covers the camera. Open up a Node Editor window to edit the Material of the video plane. Under Image Texture set the Start Frame to 260 and make sure Non-Color Data is selected in the first drop down. The Color output should go into the Diffuse BSDF and also to a ColorRamp that needs to be created. Set the white color stop of the ColorRamp to a Position of 0.5 and plug the Color output into the Factor input of the Mix Shader (The Transparent BSDF is connected to the first Shader slot of the Mix Shader and the Diffuse BSDF is connected to the second one). The black parts of the video should appear Transparent now. For the smoke fade-in, create a new Mix Shader after the last Mix shader and plug it into the second slot. Create a new Transparent BSDF and plug it into the first slot. Go to frame 260 and create a keyframe on the Factor of the last Mix Shader with a value of 0, then go to frame 300 and create a new keyframe with a value of 1. Fade the smoke out again at the end by creating a new keyframe at frame 650 and then a new keyframe with the value of 0 at the very end of the animation.

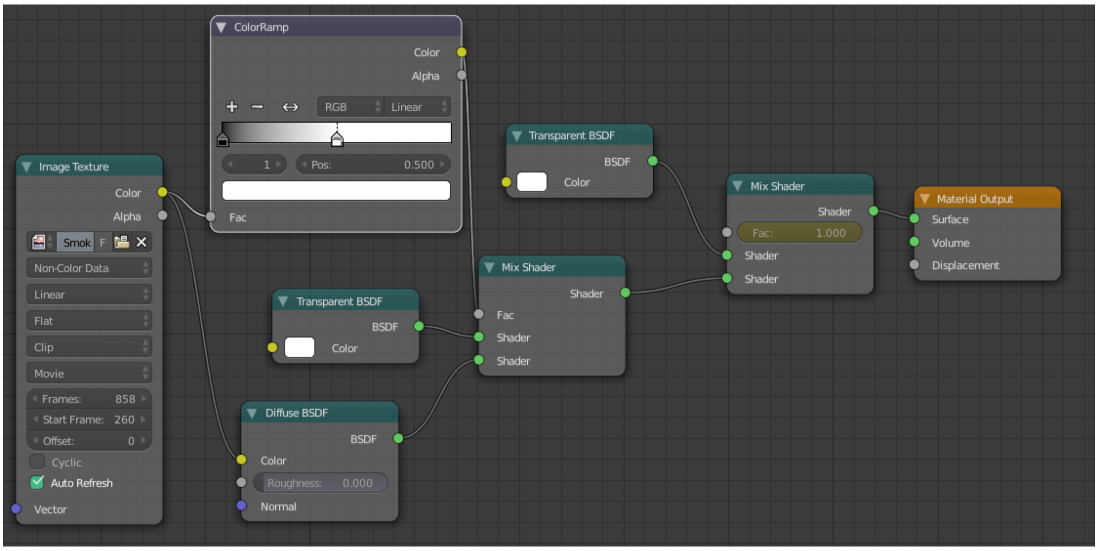

Figure 141: Finished Video Plane material with keyframes.

10.2.3 Dried out surface

The dried out desert is based on the Youtube tutorial "Desert Scene - Blender Tutorial"[6] but strongly simplified. A new Blender file is created to make creating the surface easier and faster. The finished objects will be transferred to the original Blender file. First, a new Plane with a Scale of 100, 100, 1 and a Location of 0, 75, 0 is created, then select the camera and use the same settings as in the Ocean scene. The clipping for the camera needs to be adjusted by heading to the Properties window with the camera selected, clicking on the Data tab and setting the Clipping to End 300. Select the new plane again and go into the Edit Mode of the 3D Viewport. Press the W key and click subdivide 5 times.

[6]https://www.youtube.com/watch?v=rmf6l0RN-Cc

Press A until all the edges are black (unselected) again and click on the Face select option in the bottom 3D Viewport toolbar. Press C and select all faces that are not inside the camera view. Press X and select Faces. To create background dunes, create a new Plane and set the Scale to 120, 50, 0 and the location to 0, 180, 0. Add a Multiresolution modifier in the Properties window and subdivide the plane inside the Edit Mode like the previous one a couple of times. Then go into the Sculpt mode and be sure that Symmetry/Lock is turned off again and select the Grab brush. Back in the Modifier, click on the Subdivide button, then grab the plane and form small dunes like in the screenshot.

Then, in the Multires modifier click on the subdivide button again. Now further details can be added in the Sclupt Mode with different tools. Go back to the Object Mode, then in the modifier increase the Preview value as high as it can and in the 3D Viewport go to the Tools tab of the left-hand menu and click on Shading: Smooth. Give the ground some detail by going into Edit Mode and enabling Proportional Editing and setting it to Connected in the bottom toolbar of the 3D viewport. Select some Vertices with C and grab them with G to give the ground some depth. Scroll to change the level of Proportional Editing and make sure the ground connects to the dunes in a believable way. Go back to Object Mode and select Smooth Shading under Tools.

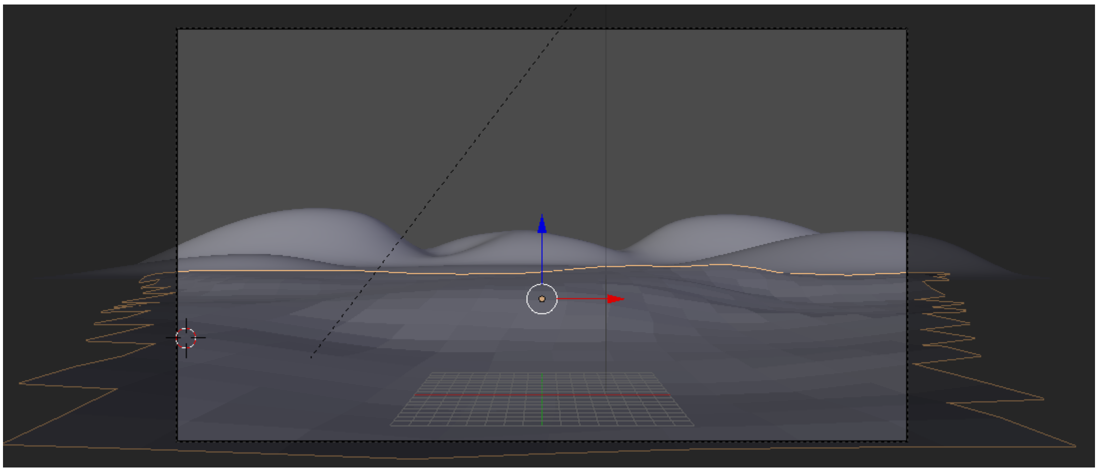

Figure 142: Sculpted dunes and ground layer with depth through Proportional Editing.

Next, the ground Material will be created. Select the ground plane in the Outliner and go to the Materials tab in the Properties window. Be sure you are in the Cycels Renderer at the very top of the Blender window and then click on New. Open a Node Editor window and delete the Diffuse BSDF. Create a PrincipeldBSDF node and connect BSDF to Surface of the Material Output. Create two Image Texture Nodes and connect one to the BaseColor of the PrincipeldBSDF node. The other one gets plugged into a new Math node set to Multiply and a Value of 10 and then this gets plugged into the Displacement input of the Material Output. Go ahead and download the free Ground Clay 002 material from Poliigon.com[7]. Put the GroundClay002_COL_VAR1_3K.jpg inside the first Image Texture node and the GroundClay002_DISP_3K.jpg inside the second Image Texture node. To map the texture to

[7]https://www.poliigon.com/texture/ground-clay-002

the mesh correctly go to the Edit Mode and press Numpad 7 to view the scene from the top. Press U and select Project From View. Add the Material to the dunes and repeat the process for the dunes. Now we prepare the surface ready for import. Go to the Modifier of the dunes again and click Apply. Then create a new Empty object in the Object Mode, place it at 0, 0, 0 and in the Outliner drag the dunes and the ground onto the Empty object. Rename the Empty object to "drySurface" Select all three Objects and press Ctrl + C. Go back into the original Blender file and press Ctrl + V to paste the Objects into the scene. Select the Empty object and move it to Location Z -20 so it doesn't appear above the water.

To finish the scene, Animate the water boiling down to the surface by raising the surface and the camera both at the same time. To do this go to frame 400 and create a Location keyframe for the camera, the video plane and the drySurface. Go to frame 720 and add new keyframes for both, raising the Z Location by 30 each.

10.3 Animation: Space View

To create the desired animation, one needs to finish all scenes beforehand. The best setup for this scene is to duplicate the whole file of scene 4 and remove all keyframes with alt+ i at 20 frames and 260 frames. After that we will begin with setting up the evaporation animation. Since you won't see any evaporation from space, the earth will just become cloudier and all signs of human existence like lights during the night will be gone.

Textures for the dried out earth surface are created for this scene

10.3.1 Earth Surface

The changes on the earth surface are drastic and very important, sadly we won't see all of them for the whole animation, because the planet will get covered in heavy clouds, because of the ocean's extreme evaporation. We will only add one more "MixRGB" node and animate a change of texture and lights will be animated to disappear.

You want to add a "MixRGB" node right before the "Diffuse BSDF" on the "Color" input. The "Color" output from the mixer that was attached before goes into the "Color1" of the new mixer. In "Color2" of the new mixer you must put in the dry earth texture. It's recommended to use the dry earth texture from the climate zones. One can choose to connect the existing texture or create a new "Texture Image" with the dry earth texture in it. It's always recommended to label the nodes you are working with, so you know what you can change in the node. We called our "MixRGB" node "EarthDryer" and coloured it in a fitting colour.

This is all you must do in this Object, and we will return, when the animations need to be done.

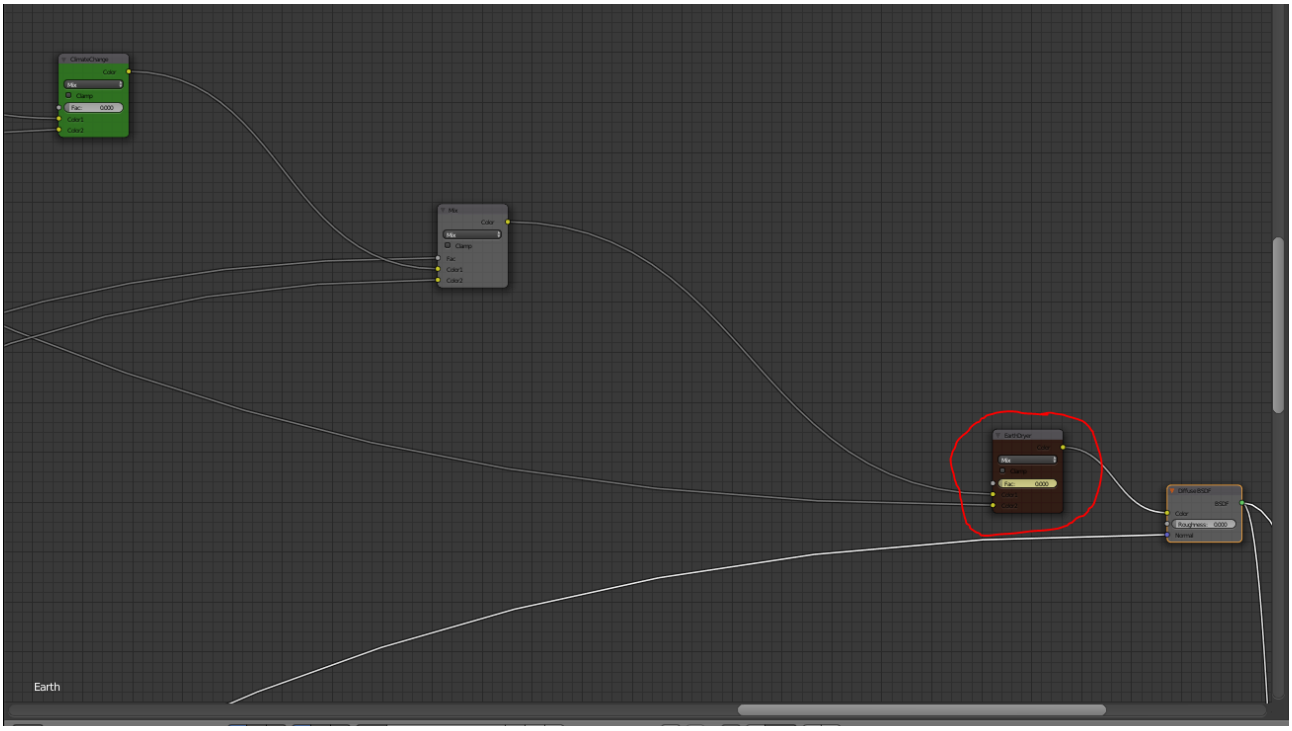

Figure 143: Earth drying out.

10.3.2 Clouds

You need to switch into the cloud object sphere and open the node tree. In this tree you should have a basic cloud setup with bumps from the tutorial. We will now start to add an additional cloud texture that is way heavier and different in colour.

This overview will show you what to expect and the changes we have done.

First thing you want to do, is to duplicate the clouds from the tutorial, so we have the same base setup. After that, put a “ColorRamp” between the “Image Texture” and the “Diffuse BSDF”. Add an additional slider to the colour ramp by hitting the “+” and put a grey colour in it. Setup the ramp like it is shown in the picture below. Switch out the “Clouds.tif” texture with the custom made “Heavy-Clouds.jpg” texture. Make sure you change the distance value of the “Bump” node to 10.0 and the colour of the “Transparent BSDF” to a slightly grey colour. For switching between the scenes, you need to add an additional “Mix Shader” and plug both Outputs of the “Mix Shader” into the new one. The new mixer output is connected to the input “Surface” of the “Material Output” node.

10.3.3 Camera and animation

The Camera remains in the Position it’s currently set. You should have the same camera setup, since it is a duplicated file you are working with. The animation is done in two objects, the earth and the clouds object. Like in every other scene we want to keep the 312 total frames and 24 frames per second. The start of our animation across the scene is at 40 frames. The end of the animations is at 260 frames, except for the light animation, this will end at 80 frames, because it is very unlikely that

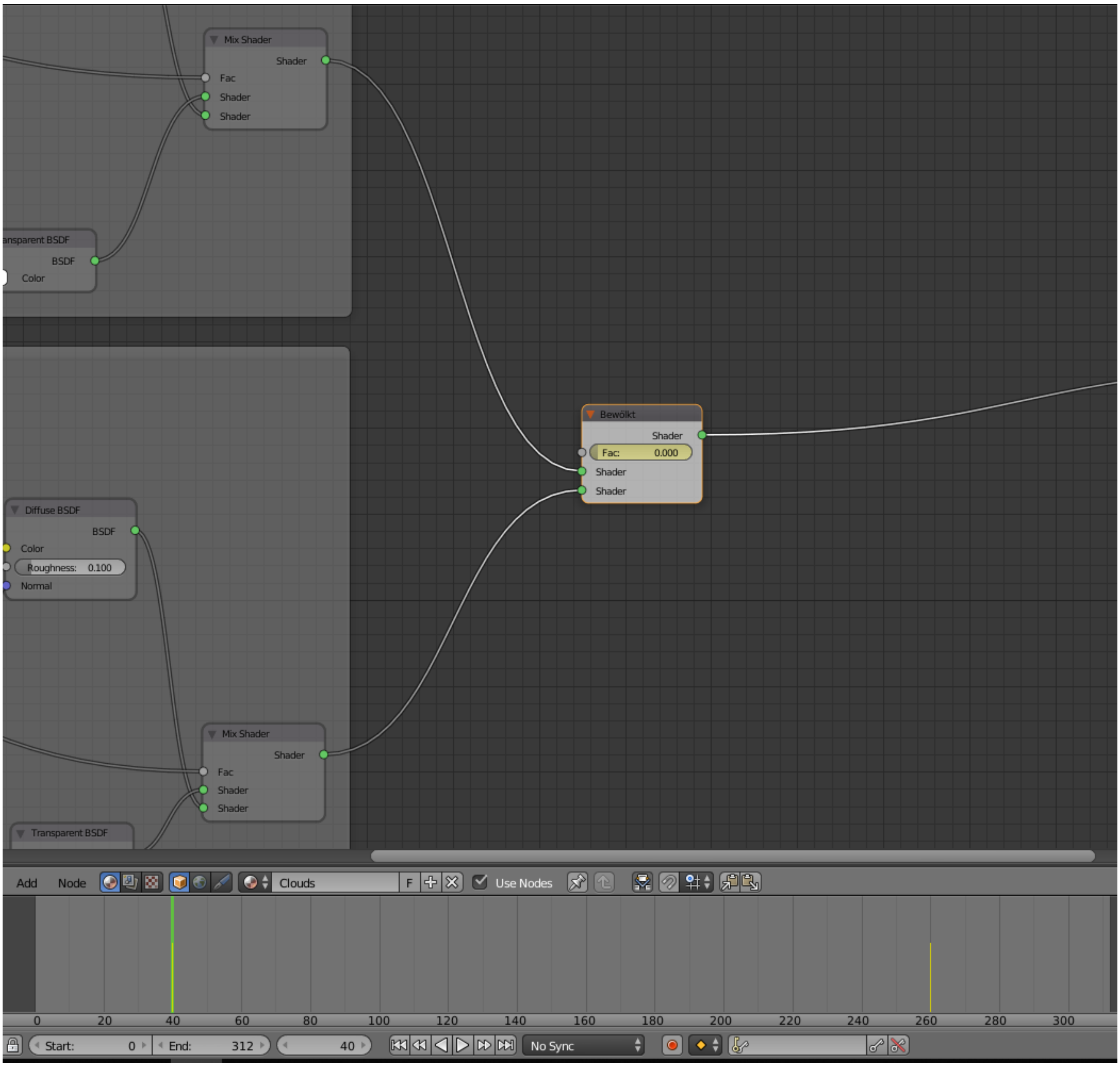

Figure 144: Overview clouds.

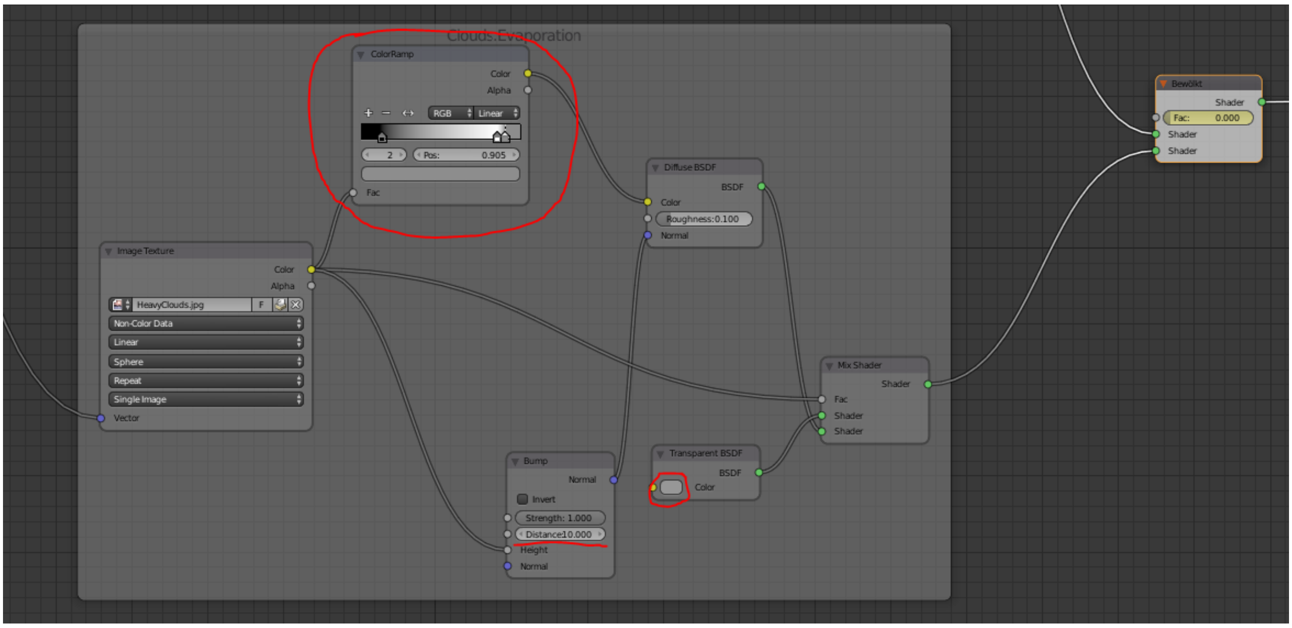

Figure 145: Setup Heavy Clouds.

life will exist on the planet anymore, when the oceans begin to dry out and evaporate. First, we will do the earth surface animations. Switch to the earth object and set two keyframes on the “Fac” of the “LightControl” node and the recently added “EarthDryer” node at 40 frames. Go to 80 frames and set a second keyframe for the “LightControl” node and set another keyframe on 260 for the “EarthDryer” node. Now select “LightControl” and press recording, go to 80 frames and set the value of “Fac” to 0.0 and stop the record.

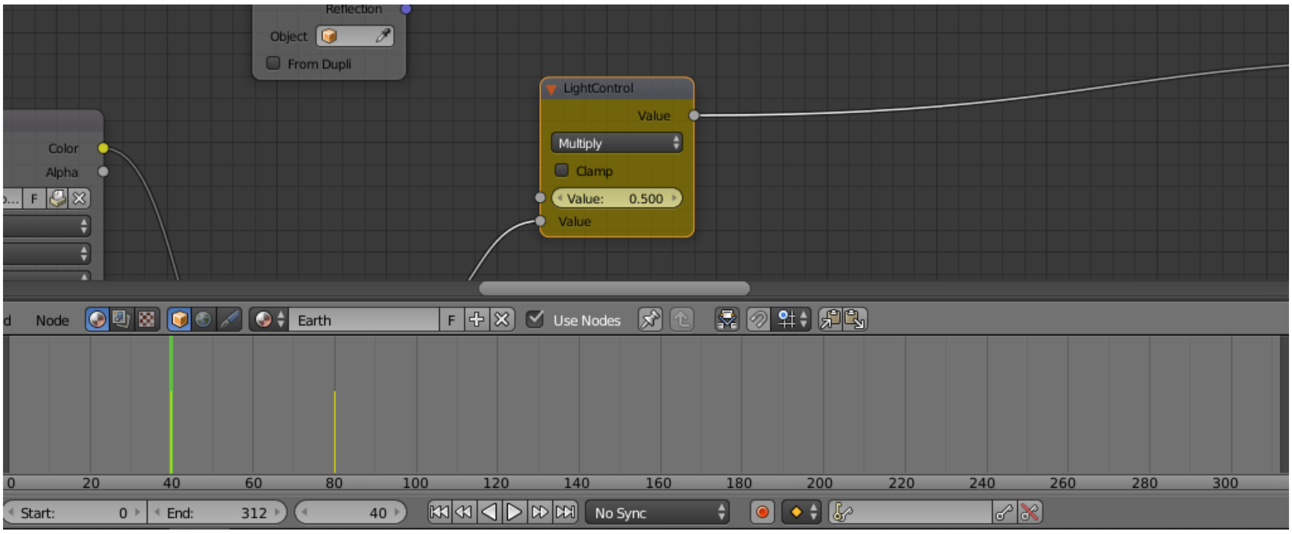

Figure 146: “LightControl” animation.

After that select the “EarthDryer”, start recording at 40 frames and switch to frame 260 and set the value of the “Fac” to 1.0 and stop it.

Now switch into the “Clouds” object in blender and set two keyframes on the final “MixShader” for the “Fac” value on 40 frames and 260 frames. Start recording, go to 260 frames and set the value to

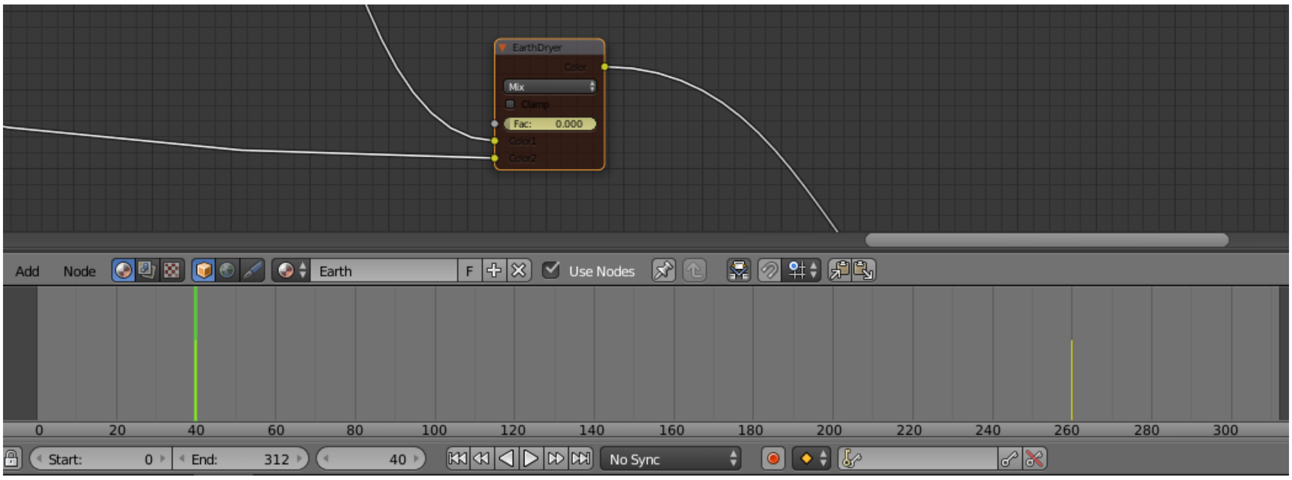

Figure 147: “EarthDryer” animation.

1.0 and stop the record. You should test your animation in the rendered mode and see if you like the colour of the clouds and the setup, if not change the values.

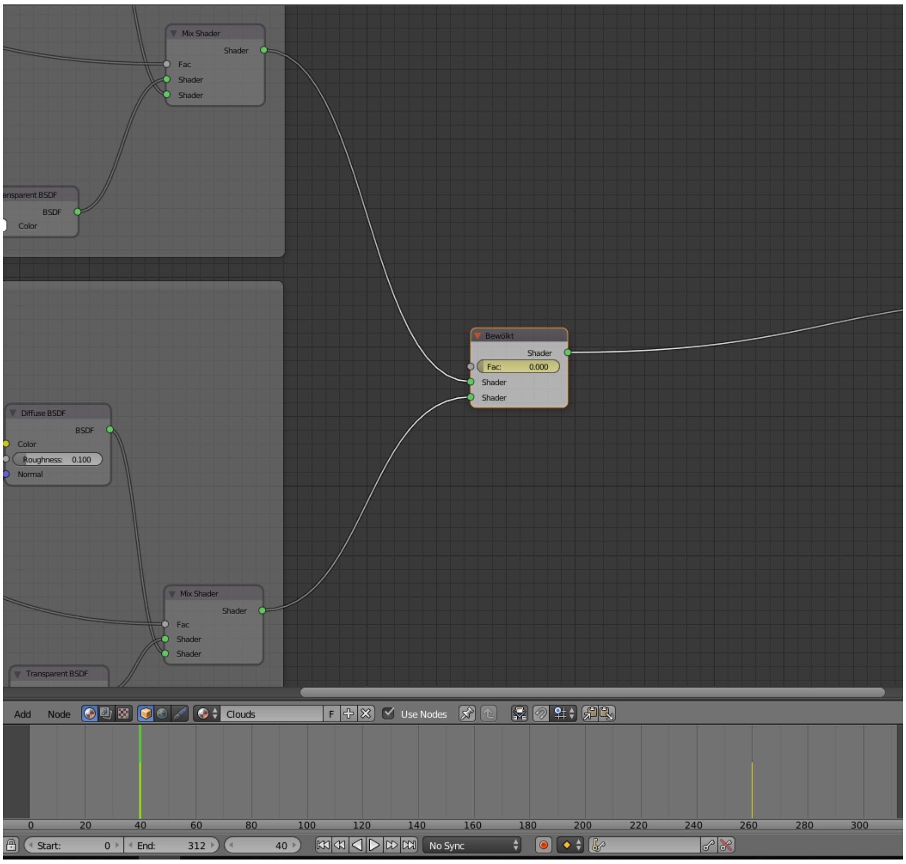

Figure 148: “Clouds” animation.

11 Scene 6: Venus-like atmosphere

Scene 6 shows the earth acquiring a Venus-like atmosphere. This is shown from a space view.

11.1 Research

In one billion years the luminosity of the Sun will be 10 percent higher than in the present day, as it moves along the main sequence time line. Growing brightness will influence an increase in the amount of heat the Earth receives from the Sun. The significant increase in heat from the Sun will lead to more water evaporating off the Earth's surface, where it will be held in the atmosphere instead. This changes the location of the habitable area near and around the Sun. The Earth's atmosphere behaves like a large greenhouse, resulting in serious problems like evaporation of the oceans and other water resources on the Earth. A tight carbon dioxide-rich atmosphere will catch all the Earths heat energy. The Sun, by this time, will already be sufficiently hot to make the Earth's oceans boil away, leaving the Earth as a burned-out planet full of ash. As the atmosphere fills and saturates with water in gas form, the water located in the highest parts of the atmosphere will be overwhelmed by light-energy from the Sun, which will split apart the molecules, allowing water to disappear as hydrogen and oxygen, eventually leaving the Earth fully dry without water. Later, in 1.5 billion years the Sun's rising luminosity causes its circumstellar habitable zone to move beyond the Earth's orbit.

11.1.1 Earth developments: Venus and Earth- What is alike?

Earth and Venus may seem like very different worlds, but they aren't. Next to Mercury and Mars, they are the only 'rocky' planets of the solar system. In particular, Earth and Venus, have roughly the same size, mass and are made from the same compounds. Whereas Venus has a mean radius of about 6,052 km and a mass of 4,867,500,000 quadrillion kg, Earth has a mean radius of 6,371 km and a mass 5,972,370,000 quadrillion kg. With regard to the volume, the two planets do not differ much. Venus has a Volume of 928.45 billion cubic km compared to Earth's 1083.21 billion; Venus possesses 0.866 as much volume as Earth. Venus and Earth have similar structures due to their composition. Earth's physical and chemical processes, result in different layers: The core, the mantel and the crust. The core consists of nickel and iron, the mantel and the outer crust of silicate, rock and minerals. Based on the knowledge about the similar size and density of Venus compared to Earth, it is safe to assume, that the internal structures of Venus are like Earth's. Derived from the fact that the two planets have been cooling about the same rate, the Venusian core is liquid as Earth's. The presumed difference between the both is that Venus does not have plate tectonics, which reduces the heat loss and prevents the planet from cooling. Besides this difference, Venus' core is not divided into an inner and outer core. The inner core of the Earth is thought to be solid, whereas the outer core is a low viscosity liquid. It is also assumed that the outer core rotates in the opposite direction as the planet, which drives the magnetic field. Since Venus has a lack of convection in its core, there is no dynamo effect and thus only a very weak magnetic field. It is assumed that the reason for this is the global resurfacing event that shut down plate tectonics, leading to reduced heat flux through the crust and resulting in an increasing mantle temperature. Lastly, reducing the heat flux from the core. Another difference between Venus and Earth is the distance at which they orbit the sun. Where Earth orbits the sun in 365 days with a distance of 149.6 million km in average, Venus orbits the sun in 225 days with an average distance of 108.2 million km. In short, Venus orbits closer to the Sun than the Earth. Besides that, Earth's axis is tilted by 25.5° Venus' by 2.64° towards the solar ecliptic.

These factors show that the early Earth and early Venus are very similar; Almost identical twins at their earliest stages. But now only parts of their internal structures seem to be similar, whereas from the outside they look like completely different worlds, as their history took different paths. However, it is expected, that Earth will catch up with Venus in the future and they will look alike again. Based on the assumption, the surface and the atmosphere of the earth are visualized in reference to Venus' current appearance in this simulation.

11.1.2 Features of Venus planet with the focus on the Atmosphere

Currently, Venus' atmosphere is over 100 times denser than Earths but has less than one percent water vapour. Since the surface rock temperature is about 600°C, liquid water does not exist. The atmosphere mainly consists of carbon dioxide, reduced gases, but has no free oxygen. The free oxygen formed by water/carbon dioxide in the top layers of the atmosphere would be consumed quickly by these reduced gases. In addition, the atmosphere has a significant content of hydrogen sulfide. Together with water molecules in the atmosphere, it yields a sulfuric acid mist/fog. So far, no life on Venus was detected, but it is possible that some form of life could live in the outer (cooler) layers of the atmosphere. Furthermore, Venus does not have a magnetic field, which can be due to the very slow retrograde rotation rate of Venus. The surface temperature is around 450°C and looking at the rotation rate compared to Earth' one day on Venus equals 243 days on Earth. The question is: Where did all the CO2 come from? From Earth's interior carbon dioxide bubbles up due to volcanic activity. Nevertheless, Earth's atmosphere at present contains only about 0.6 percent carbon dioxide by volume. It is known that the volcanic carbon dioxide gets fixed as carbonate rock by a combination of organic and inorganic processes. Then, it gets recycled via the plate tectonic process in which the ocean floor gets subducted beneath volcanic arcs. Since Venus does not have either ocean water or subduction zones at present all carbon dioxide accumulates in the atmosphere. Further, the extreme volcanism contributed to the dense carbon dioxide-rich atmosphere, and carbon that was earlier stored in seas and rocks changed its phase into gaseous form. Generally, the atmosphere consists of three layers: Below the cloud layer, in the lower atmosphere, 96.5 percent of carbon dioxide is present. The remaining percent is are nitrogen and sulfur dioxide. On top of that, in the cloud layer, carbon dioxide is also dominant, but also sulfur dioxide (solid, gaseous), water (solid, gaseous) and sulfuric acid (liquid state). The higher atmosphere is composed of 96 percent carbon dioxide and the rest Is nitrogen and carbon monoxide. Due to its composition, the atmosphere appears in a hellish, yellowish colour. Whereas sulfur dioxide is dominant in the surface, hence it appears in a reddish brown colour. In that sense, the same colours for the Earth's surface and atmosphere were used in the visualization.

11.1.3 Venus Surface

The thick atmosphere of Venus is heavier than that of any other planet, leading to a surface pressure 90 times than on Earth with a mean surface temperature of 463°C; The hottest planet in the solar system. As Venus suffers from the runaway greenhouse effect, which means its thick carbon dioxide-rich atmosphere traps the planet's heat energy, resulting in this blistering surface temperature. In addition, the thick hazy atmosphere hides the barren landscape. For the most part, Venus surface has massive volcanos, craters and ancient lava flows. From the surface, it also has lightning and thunder cracking down from the upper atmosphere. Without the super-hot temperatures, it would rain sulfuric acid, but the rain evaporates before reaching the ground.

In comparison, Earth surface is about 70.8 percent covered by oceans, lakes and rivers where the submerged surface has undersea volcanoes, mountains, oceanic trenches and submarine canyons. The uncovered land has different landforms, deserts, mountains, plains and plateaus. An essential point is that the surface undergoes reshaping since there are erosions and tectonic activity on the Earth. Whereas Venus' surface has been formed by volcanic activity. Venus has several times as many volcanoes as Earth (167 Volcanoes over 100km). Since Venus does not have plate tectonics, the surface does not recycle by subduction and is estimated to be 300-600 million years old. In contrast to that, Earth's surface is believed to be 100 million years old.

11.1.4 Shortcomings for application on earth

Though Earth and Venus were once so similar, they are different planets and this might also show in certain features. The system of planets is so complex that it is impossible to guarantee what happened on Venus will happen in the same way on Earth. In addition, there are still small differences in the mass, density and size between Venus and Earth which can influence the runaway greenhouse in an unknown manner. However, for simplicity reasons the visualization was created based on the known properties of Venus since there is no clear evidence on how Earth is going to look like.

11.2 Animation

To create a Venus-like atmosphere, we must adjust the clouds and the atmosphere glow in the project. It is recommended to duplicate the file of scene 5 and to work from there, since this will be the start for our scene 6 animation. Most important is that you delete all keyframes from your duplicated file. Search all objects, look in the timeline at 40, 80 and 260 frames and delete every keyframe made for the other animation by hovering over it and pressing alt- i. Also keep the end settings of the former scene as your starting point for the new scene.

We are using a custom made “HeavyClouds2” texture for a dense cloudy atmosphere like the Venus.

11.2.1 Coloring the Atmosphere

The first step is to duplicate the heavy cloud setup used in the cloud object. After that you must switch the texture in the “Image Texture” node to the “Heavy_clouds2” texture. Connect the “Image Texture” with the “Generated” output of the “Texture Coordinate”. Now adjust the colour in the “ColorRamp” to an orange colour gradient that looks like the Venus atmosphere. You can use the picture as an example. Change the value of “Distance” in the “Bump” node to 0.8.

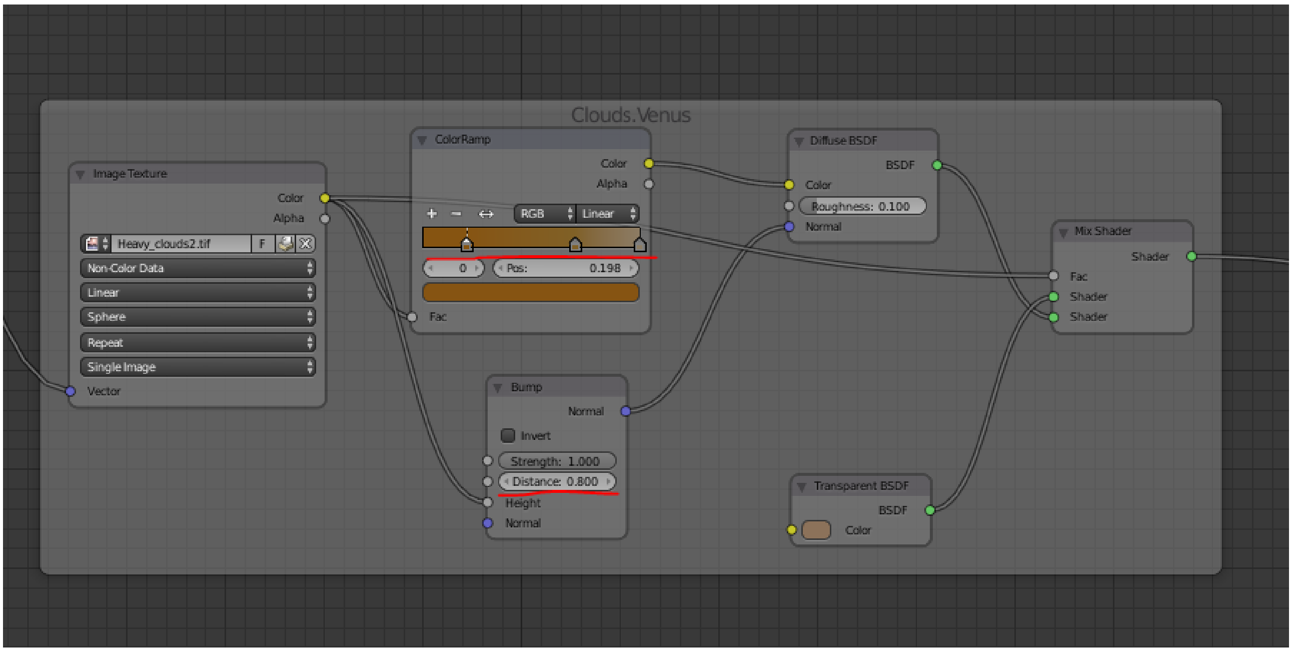

Figure 149: Colouring the Clouds.

Now you must add two “Mix Shader” nodes to be able to switch between Venus-like clouds and the regular high density clouds. The first mixer is connected to the regular clouds “Mix Shader” output and to the new “Mix Shader” of the Venus clouds. Since the inputs are named the same it is not important which inputs you plug the outputs into, the only thing you need to keep in mind for our later usage of this mixer is, we want to animate it as a switch between scenes, so it’s recommended to connect the Venus clouds to the bottom input and the original clouds to the top. Right after this mixer we want to put a new mixer between the “Material Output” node and the two “Mix Shader” nodes for switching between heavy clouds and regular clouds. Connect both outputs into the shader inputs like it is show in the picture and connect the new mixer to the material output “Surface” input.

Now you must switch over into the “Atmosphere” object in blender. You should have the regular setup from the tutorial. There is only one small addition to this setup and its for the colouring of the

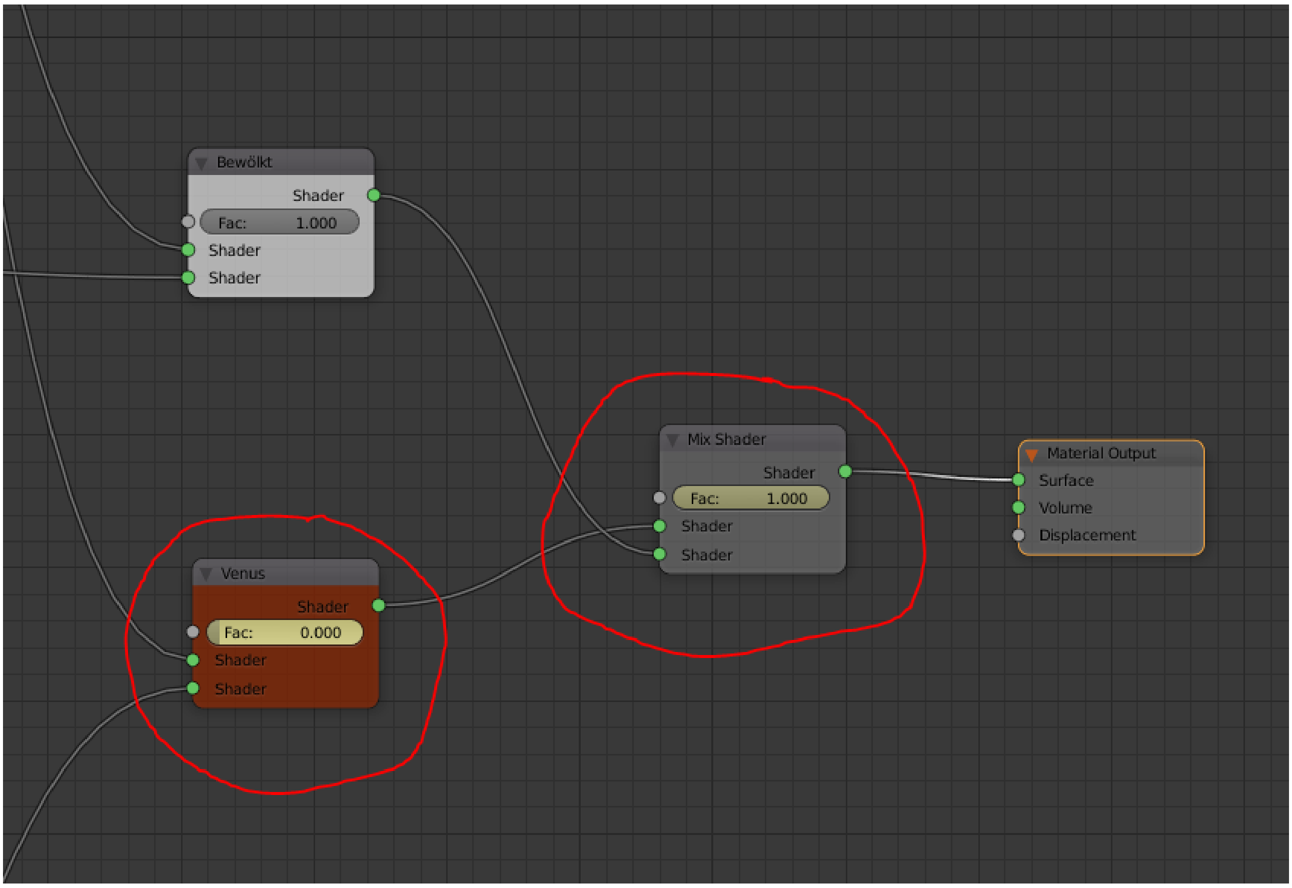

Figure 150: Switching Clouds.

atmosphere. We currently have a blue glowing atmosphere, but this will change as soon as the earth becomes a Venus-like planet.

To switch between colours, you need to add a “ColorRamp” in front of the “Diffuse BSDF” node and set up the two colours you want to switch between. Get the Blue colour of your atmosphere from the “Transparent BSDF” and assign it to the right slider. You can switch the “Transparent BSDF” colour to white after that. Now setup a new colour on in the left slider for your Venus like atmosphere. Connect the “Color” output of the “ColorRamp” to the “Color” input of the “Diffuse BSDF”.

11.2.2 Camera and animation

The Camera remains in the Position it’s currently set, you should have the same camera setup like in scene 5. The animation is done in two objects, the atmosphere and the clouds object. Like in every other scene we want to keep the 312 total frames and 24 frames per second. The start of our animation across the scene is at 40 frames and the end of the animations is at 260 frames. Since we are currently working in the atmosphere object, we can start with the animation of the atmosphere. Select the “ColorRamp” hover over the “Fac” and set a keyframe at 40 frames, go to 260 frames and set a second keyframe. Go back to 40 frames press recording and switch over to 260 frames and set the value of the “Fac” to 0 and stop the record.

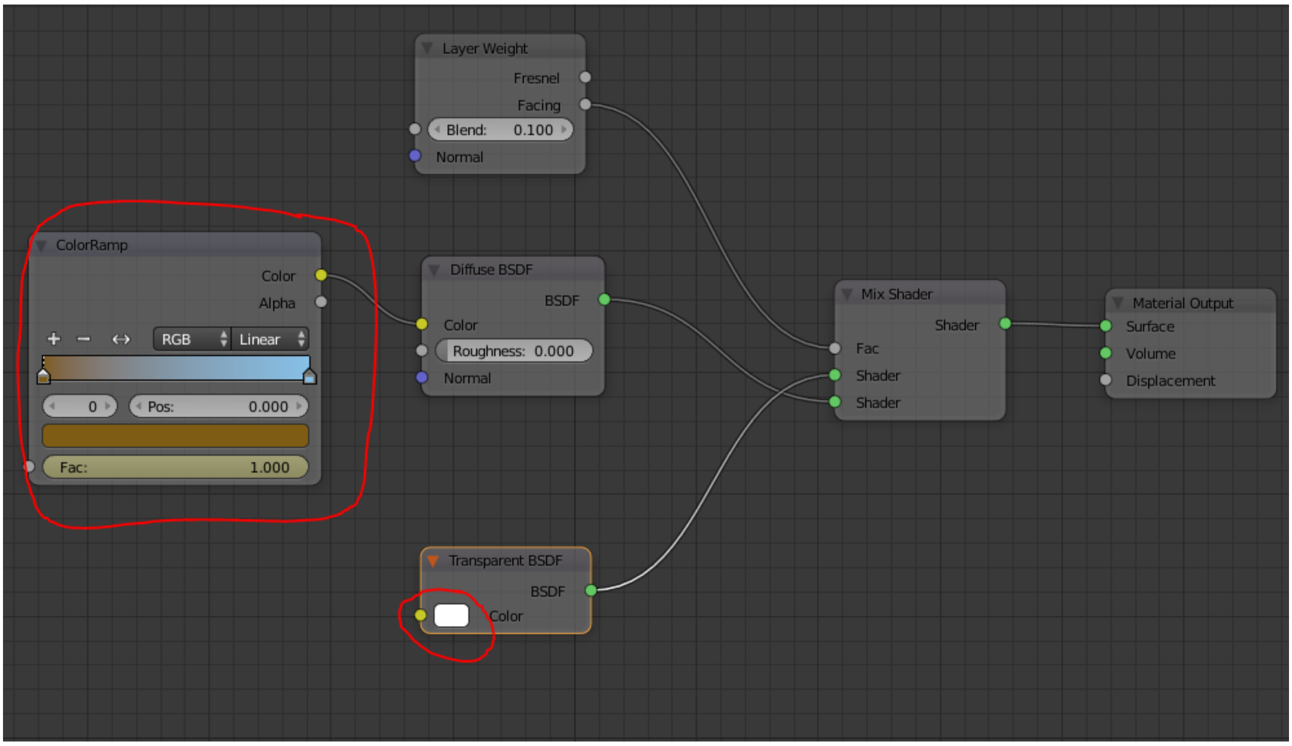

Figure 151: Atmosphere changes.

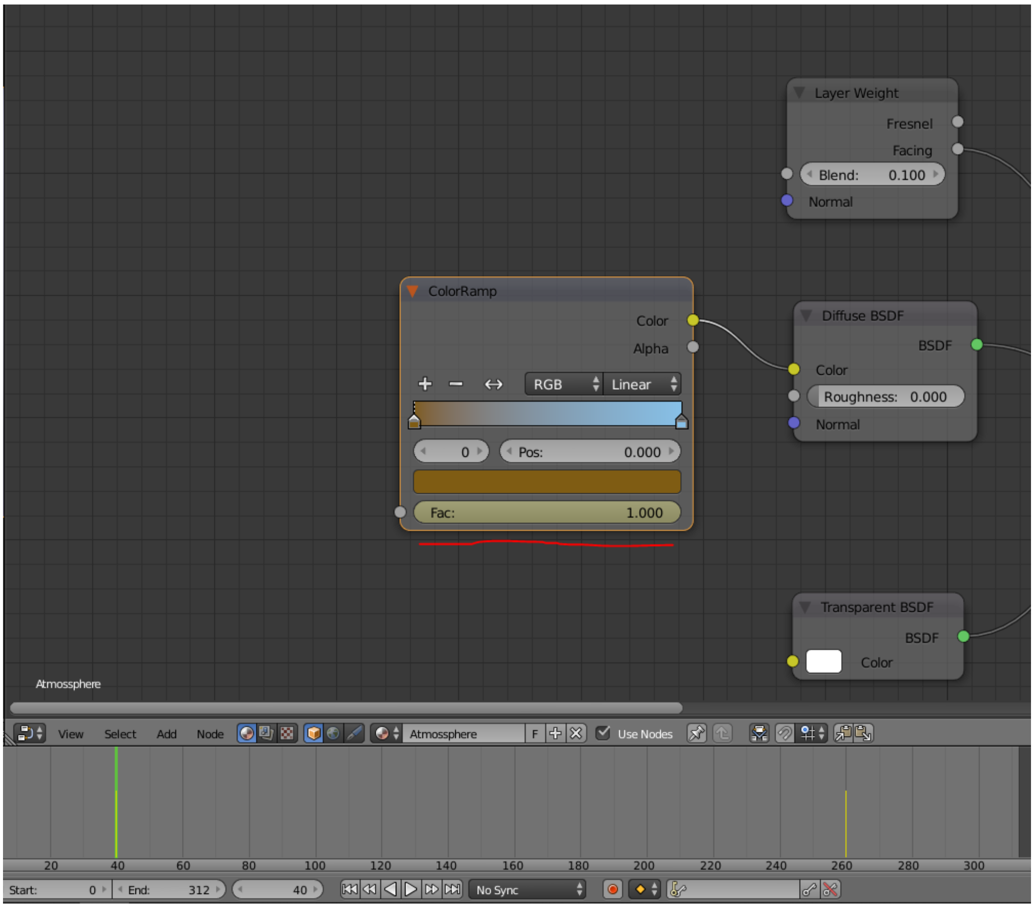

Figure 152: Atmosphere animation.

Now the transition between the colours of your atmosphere is animated. Switch to the clouds object and set two keyframes each on 40 frames for the “Fac” of both mixers the “Venus” mixer starts at 0 and the last mixer on 1. Also set a keyframe for both mixers on 260 frames. Press record on 40 frames and go to 260 frames and switch both values. The “Venus” mixer value to 1 and the other mixer value to 0, then stop the record.

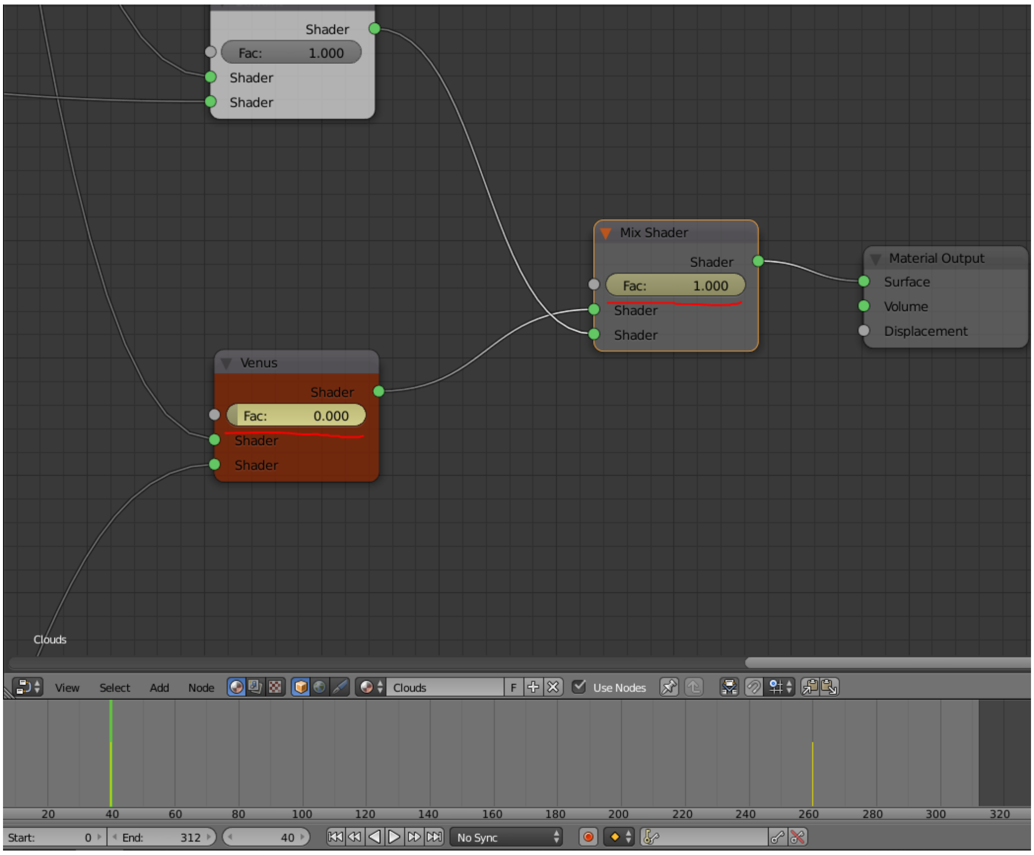

Figure 153: Clouds animation.

12 Scene 7: Atmosphere evaporation

In scene 7, the earth is shown losing its Venus-like atmosphere. This is also shown from a space view.

12.1 Research

Plate tectonics, the electromagnetic field and Earth’s atmosphere are linked and dependent on each other. Where the plate tectonics are essential for the mantel convention and drive the electromagnetic field, the electromagnetic field, in turn, is key to the atmosphere. Obviously, nobody can ever accurately predict the end of plate tectonics and researchers have come up with different plate tectonic death dates. A study (conducted 2016) using simplified computer simulation put the end date at five billion years. Whereas another paper (conducted 2008) suggests that plate tectonics are intermittent. Based on the evidence of the past plate tectonic activity, they predict the next pause will take place 350 million years from now. According to plate tectonics specialist Christopher Scotese from the University of Texas at Arlington, plate tectonics will come to a halt during the next one to two billion years, but before will be more active than currently. The reason is that the mantle heat flow diminishes and subduct faster, as the slabs become extremely cool and dense. Following Christopher Scotese's paper, for feasible argumentation reasons, it will be assumed that the plate tectonics come to a halt in the next one to two billion years. Then, the planet would cease to produce a magnetic field protecting it from the solar winds that would strip it of atmosphere assuming this to happen during the next 2.5 billion years.

12.1.1 The Magnetic Field and the Plate Tectonics

A bicycle dynamo moves magnets past each othe to induce current, which powers a light. On the flip-side, if there is a rotating electric current, it will create a magnetic field. Basically, this is transferable to the formation of the magnetic field of the earth. The magnetic field of the earth is created by the interaction between the magnetic minerals inside the earth with the earth' spin on its axis. The inner core of the earth consists of two parts: the Iron subcore at the very center and the surrounding electrical conductivity fluid subshell. The iron subcore produces heat by nuclear fusion reactions and gives its products to the fluid subshell. This process makes the bottom of the fluid subshell less dense than the top of the fluid subshell. This creates convection motions of the fluid which are twisted by earth's rotation and thus, the dynamo effect is generated.

The heat that is brought to the top of the subshell by convection is removed by the massive thermally conducting heatsink that is the inner core. A long-term stable convection is enabled by the more massive fluid core surrounding the inner core. Thus, plate tectonic, in particular subduction, is essential for the mantel convection. Studies on the Magnetic field, also provide evidence to the theory of plate tectonics. Magnetic minerals were discovered, like old layers of volcanic rock, which did not orient to Earth's current magnetic field. The inclination of the minerals, which is the angle of fossil magnets relative to the horizontal plane, helps to understand the link between the magnetic field and the plate tectonics. Therefore, important to notice is that rocks take on the magnetic signature of that particular location when the lava is still fluid. Finding magnetic minerals that are oriented differently to the current Earth's magnetic field supports the theory that continents shift in their position. Consequently, Earth's surface is a system of massive rock plates floating on the molten interior (the magma underneath), creating Earth's magnetic field, stretching between the north and south magnetic poles.

12.1.2 Why does Earth lose its Atmosphere?

As the movement of the plate tectonics stops and the outer core freezes, while the inner core continues to grow, the magnetic field can no longer be generated. Thus, the lighter gas will strip away from the atmosphere by collision with the constant stream of charged particles in the solar winds that would otherwise be deflected by the magnetic field.

The sun's natural wind is so powerful, it can easily rip gasses out of a planet's atmosphere until there is little gas left at all. Hence, without an electromagnetic field, Earth's atmosphere is left totally unprotected from solar winds, free to leak into space.

12.2 Animation

This animation is showing us the earth without clouds, atmosphere, water and remains of human civilization. It's the state of a dead earth and the sun reached already a very high luminosity. After this animation we will transition to the sun and show the changes of the sun, since the earth becomes a dry dead planet. The animation is done in all objects the earth, clouds and atmosphere object. There is only a small addition made to the clouds node tree.

12.2.1 Working in Blender

You want to make sure that you have scene 6 as a duplicated file for scene 7, so we can start at the end of scene 6 with our new scene. Most important is that you delete all keyframes from your duplicated file. Search all objects look in the timeline at 40 and 260 frames and delete every keyframe made for the other animation by hovering over it and pressing alt- i. Also keep the end settings of the former scene as your starting point for the new scene.

After you finished this step, go to the clouds object and add a "MixRGB" node between the "Diffuse BSDF" and the "Image Texture" node of the regular cloud setup. Connect the Output of the mixer to the "Height" input of the "Bump", to the "Color" input of the "Diffuse BSDF" and to the "Fac" of the "Mix Shader" node. Set "Color1" to black in the "MixRGB" node and connect "Color1" with the output "Color" of the "Image Texture" node. This setup allows you to completely remove the clouds from the planet, by simply overwriting them with black colour.

This is all you must add for this scene; All other parts are animated with existing nodes from previous scenes.

12.2.2 Camera and animation

The Camera remains in the Position its currently set, you should have the same camera setup like in scene 6. The animation is done in three objects, the atmosphere and the clouds and the earth object. Like in every other scene we want to keep the 312 total frames and 24 frames per second. The start of our animation across the scene is at 40 frames and the end of the animations is at 260 frames. The animation is done in keyframes and we want to get a clean dry earth texture without clouds and atmosphere as a result of our animation. The first step would be animating the removal of the clouds, our planet is at this stage covered in a Venus-like atmosphere with a high density of clouds and we want to remove that. We currently have the regular clouds texture when we decrease the "Fac" of the

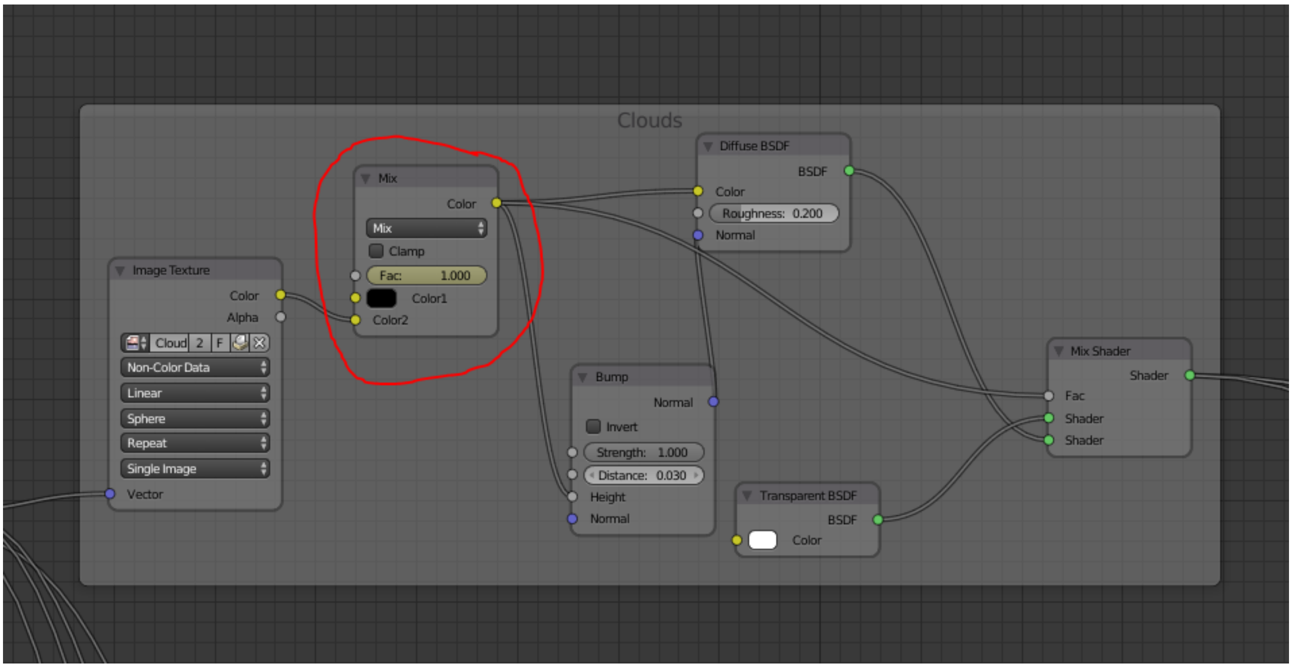

Figure 154: Clouds removal.

“Venus” mixer to 0, with the new mixer, we can remove them completely. Select the new mixer in the regular “Clouds” node frame and set a keyframe on 40 frames and 100 frames. Start recording and set the “Fac” of the mixer to 0 at 100 frames and stop the record.

Now go to the “Venus” mixer and set keyframes at 40 frames and 260 frames. Start recording and change the value of the mixer from 1 to 0 and stop recording.

Now switch into the atmosphere object and set keyframes on the “Blend” value of the “Layer Weight” node at 40 frames and 260 frames. Start recording and set the value at 260 to 0.0 and stop the record. This will totally remove the effect of the atmosphere.

The final step is opening the earth object and to change two values of a “GlossyBSDF” node that is connected to the “Mix shader” right behind the “Diffuse BSDF”. Check if the “EarthDryer” node is still set to 1.0 if not set it to 1.0, so you have the dry earth texture loaded. Select the “GlossyBSDF” and set keyframes for the “Roughness” value and the “Color” at 40 frames and 110 frames. Start recording and set the value of the “Roughness” to 0 at 110 frames and change the “Color” to black at 110 frames as well. This will completely remove the glossy effect we used in the tutorial, to give our water surface nice reflections.

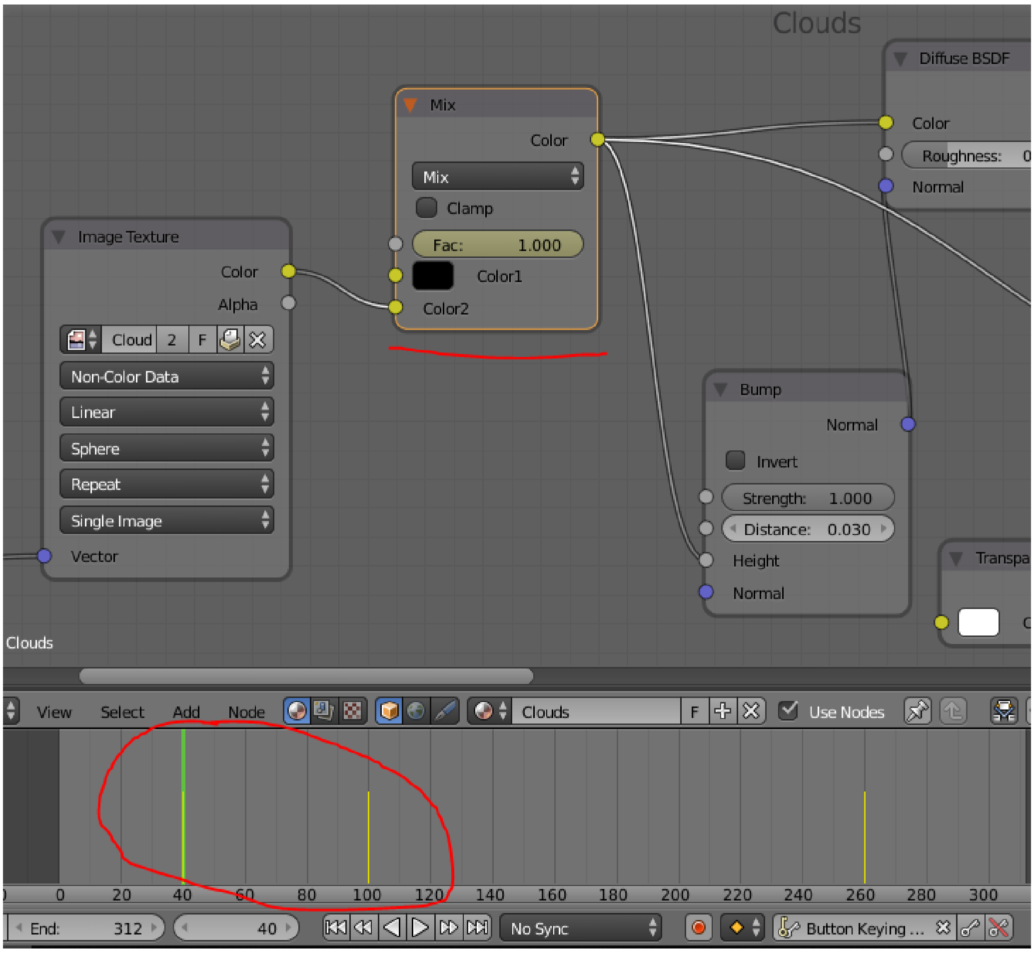

Figure 155: Animation remove regular clouds.

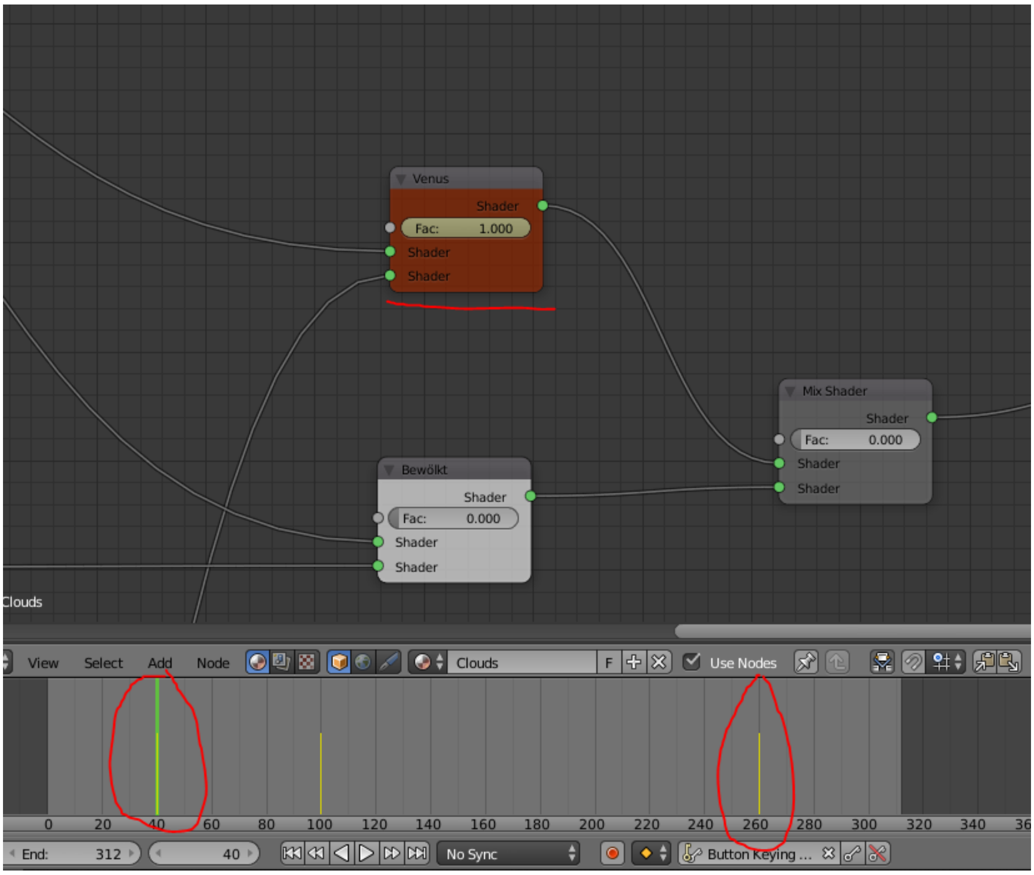

Figure 156: Animation remove Venus clouds.

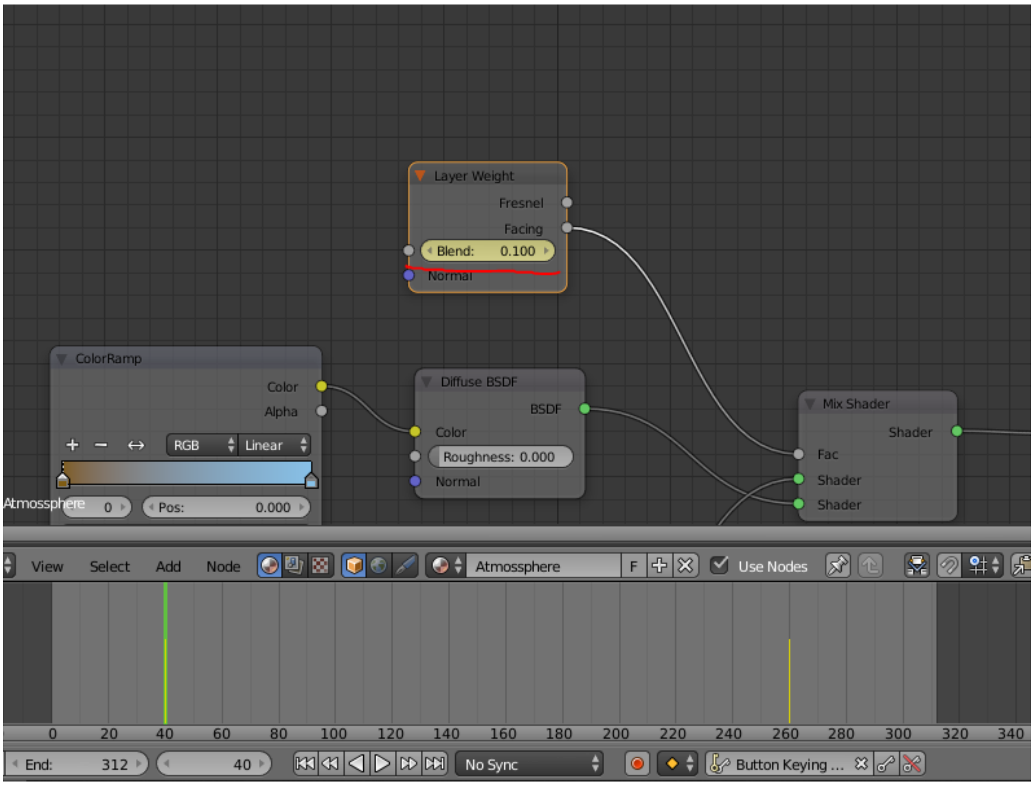

Figure 157: Animation remove atmosphere.

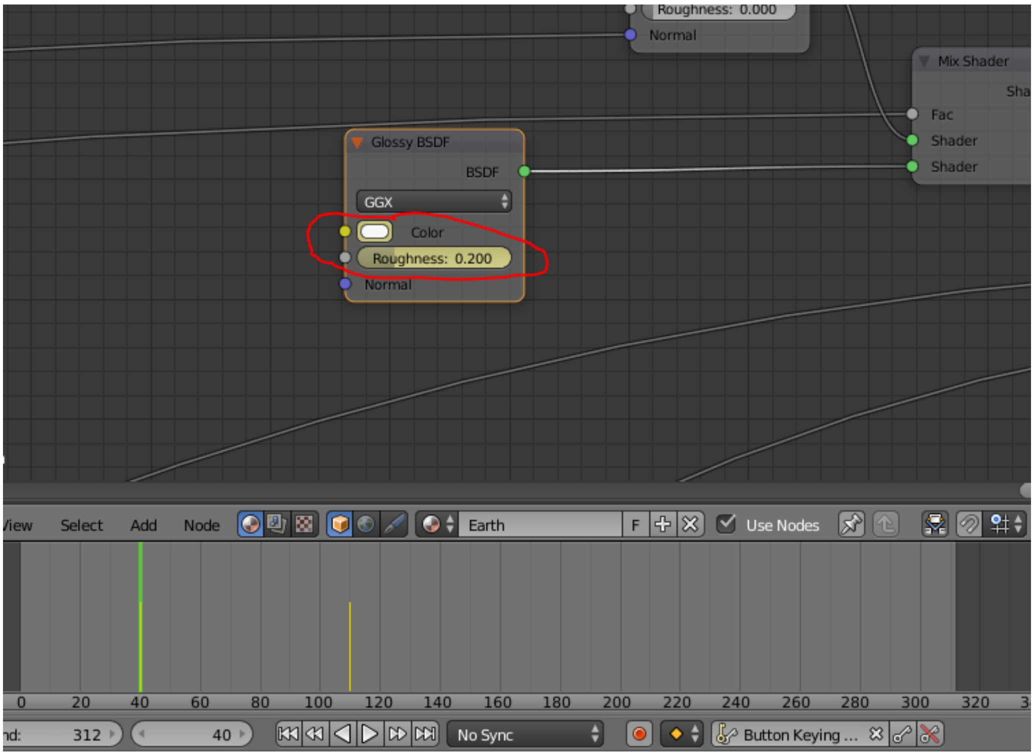

Figure 158: Glossy effect removed.

13 Scene 8: Sun, pre red giant

13.1 Research

In approximately 5.5 billion years, the sun will begin the helium-burning process, ending its time as a Main Sequence star and slowly turning into a Red Giant. That happens after the Sun moves from the Subgiant branch. This period of the Suns' transformation will last about 500 000 000 years and as a consequence the Sun will have a larger radius and an orange color, after that it will transform into the Red Giant.

13.1.1 Yellow Sun

The Sun – the heart of our solar system, the massive star located in the Milky Way galaxy that holds the solar system together. The Sun has a great influence on Earth's processes – the interactions drive the seasons, ocean currents, climate in general and much more different aspects. It is located 150 million km away from our planet. The whole solar system is formed from a giant, rotating cloud of gas and dust called a solar nebula around 4,5 billion years ago. As the nebula collapsed because of its overwhelming gravity, it spun faster and flattened into a disk. Most of the material was pulled toward the center to form our Sun, which accounts for 99.8 percent of the mass of the entire solar system. Like all the other stars, the Sun will end its existance since it will simply run out of energy. Right now the Sun has not come to the halfway phase through its lifetime and will last another billions of years till it becomes a white dwarf. It is important to mention that this ball of gas by mass is made of about 70.6 percent hydrogen and 27.4 percent helium. The Sun's enormous mass is held together by gravitational attraction, producing immense pressure and temperature at its core. The Sun has six regions: the core, the radiative zone, and the convective zone in the interior; the visible surface, called the photosphere; the chromosphere; and the outermost region, the corona. At the core, the temperature is about 15 million degrees Celsius. The surface of the Sun(the photosphere) is a 500-kilometer-thick region, from which most of the Sun's radiation escapes outward. This is not a solid surface like the surfaces of planets. Instead, this is the outer layer of the gassy star. After the first billion or so years, the sun's radius would increase by 6 percent, its luminosity increasing by 10-13 percent. It doesn't seem like a lot – but think about this. The current average surface temperature on Earth is about 15°C. This change in the sun in just a billion years (an eyeblink on astronomical timescales) would be enough to raise the Earth's average surface temperature to 33°C. At this point, all the polar ice caps will melt. Antarctica will be a much warmer place than it is today. These changes will trigger the moist greenhouse effect on the Earth that is similar to the runaway warming that turned Venus into the hellish environment during these times. As we move forward in time, it is worth to mention one caveat – we are assuming nothing major goes down in the solar system this entire time. If no major asteroids hit, if no gamma ray burst sterilizes the solar system, if nothing happens to the other planets like Neptune, or Jupiter (whose orbits and sizes keep us in line) then, the following is the best estimation of our progress. Obviously, 6 billion years is a long time, and these are very big ifs. Every second, 600 million tons of matter are converted into neutrinos, solar radiation, and roughly 4 x 1027 Watts of energy. However, this process cannot last forever since there is a finite amount of hydrogen in the core of the Sun. So far, the Sun has converted an estimated 100 times the mass of the Earth into helium and solar energy. As more hydrogen is converted into helium, the core continues to shrink, allowing the outer layers of the Sun to move closer to the center and experience a stronger gravitational force. This places more pressure on the core, which is resisted by a resulting increase in the rate at which fusion occurs. Basically, this means that as the Sun continues to expend hydrogen in its core, the fusion process speeds up and the output of the Sun increases. At present, this is leading to a 1 percent increase in luminosity every 100 million years, and a 30 percent increase over the course of the last 4.5 billion years.

13.1.2 Sun developments

The Sun will start to evolve so intensively and as a consequence it will stop to be a main-sequence star, getting bigger and progressing into a red giant. It is impossible for the main sequence process to last eternally, because there is a limited number of hydrogen in the core of the Sun. Temperatures grow with the contraction and, as a result, reach the stage where helium is able to fuse into carbon. The helium burning may be progressive or may start by an explosive flare. With the hydrogen stock devastated at its core, the Sun ends the main sequence and begins to evolve into a red giant. Even before the Sun becomes a red giant, the luminosity of the Sun will have nearly doubled, and Earth will receive as much sunlight as Venus receives today. The Sun's core will get heated and thick, therefore shrinking; however, the external part of the Sun will expand and grow.

13.2 Animation: Creating the Sun for scene 8 - 12

The sun was created in blender. The same model is used with animations in all scenes for the sun.

13.2.1 Noise texture and oil node

To create the basic texture/material for the sun it was first important to know how to create a procedural texture. To create a procedural texture something called "Oil" and "Noise Texture", which was taught in the beginning of the module, was used. The so called "Oil", which is used a lot throughout the project, consists of several noise textures. But to know how the "Oil" works, it is essential to have an idea of what a noise texture itself is. The noise texture in the Blender Cycles Renderer is, like the name noise suggests, a texture which is made of RGB colors in a random and noisy pattern. Computer generated random values most of the time mean it is pseudo random, so in this case it is also possible to use a seed to get the exact same pseudo random result every time. It also contains values for scale, detail and distortion so the texture can be easily modified at any time. The "Oil" texture is actually just a combination of more than one noise texture and some other nodes so that it looks even more random, the texture we created has a look that reminds of oil, so it was called oil. It is also used to modify other texture parts and make them oily and distorted in a specific way.

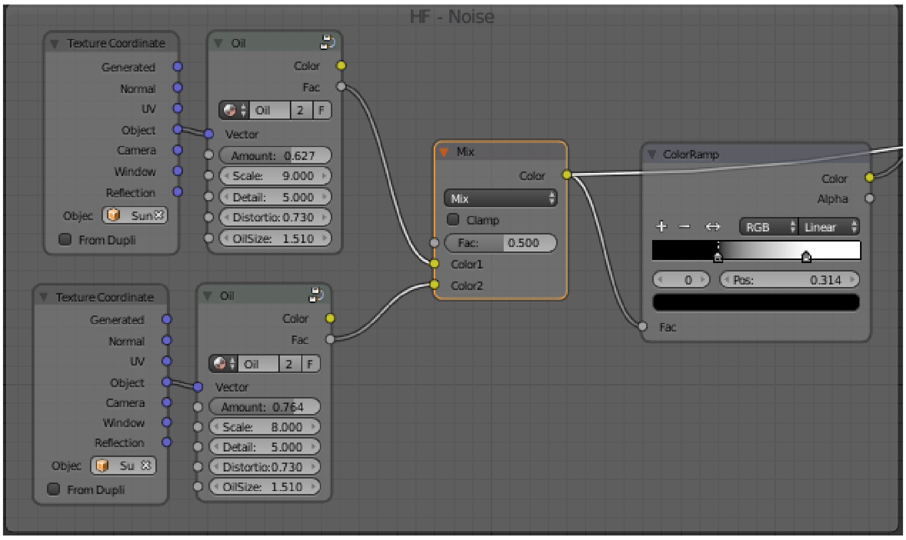

Figure 159: Node setup of the noise part

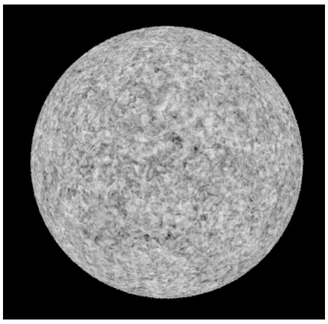

Figure 160: The created noise texture

13.2.2 Creating the sun

The sun is based on the sun video Guide from the Creative Shrimp Space VFX series but was extended and modified over the course of the project to fit the specific needs.

The first thing was to create a simple UV sphere in a decent resolution and set the shading to smooth to make it look like it is perfectly round. This was most of the “modeling” part for the sun sphere.

Sun surface material

After the modeling part was done, several oil texture nodes were used and their values adjusted to create the basic sun surface material. It was also important to note that a “ColorRamp” node was used at different points to give a grayscale version of the texture as well as to have better control over the contrast of the texture at different stages of the material. Other “VectorNoise” nodes, which are similar to the “Oil” nodes, are then connected to a “Voronoi Texture” which, like the noise texture, is random but has a different pattern and is created by the “Delaunay triangulation” which will not be discussed further since it is only used for creating a visually appealing result for the sun surface material. It is also important to make use of the “Node Wrangler” Blender add-on to see the result of the current node setup by pressing “CTRL” + “Shift” + “Left Click” on the node that has to be previewed.

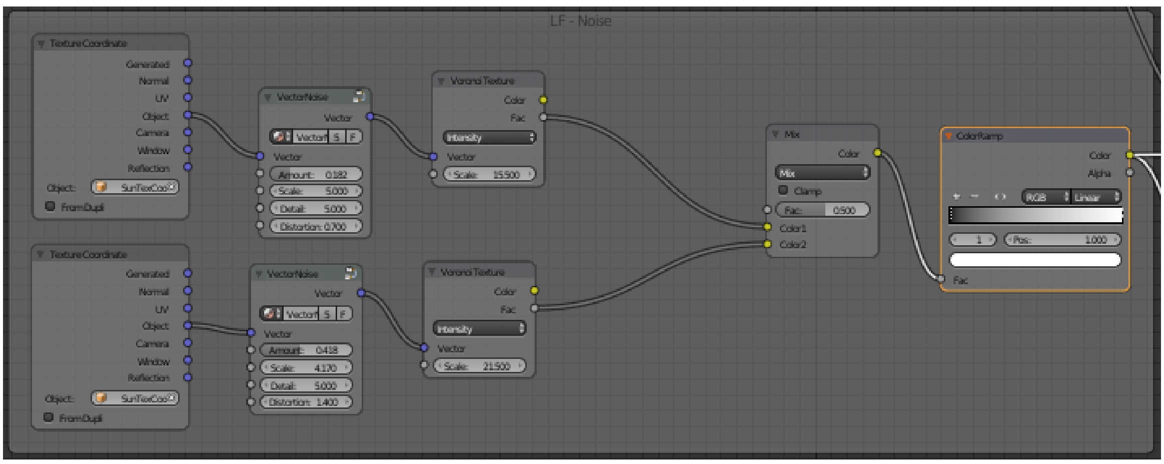

Figure 161: Node setup of the voronoi part

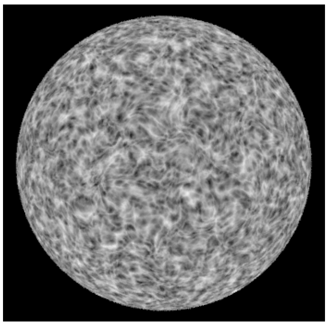

Figure 162: The created voronoi texture

Highlighting the edges

Different nodes were used to highlight the edges of the sun. Most important is the “Layer Weight” node which is connected to a “ColorRamp” and then a “Math Power” node. Giving these nodes the right values makes it so the sphere has a white outline towards the edge. It is then connected to the rest of the material.

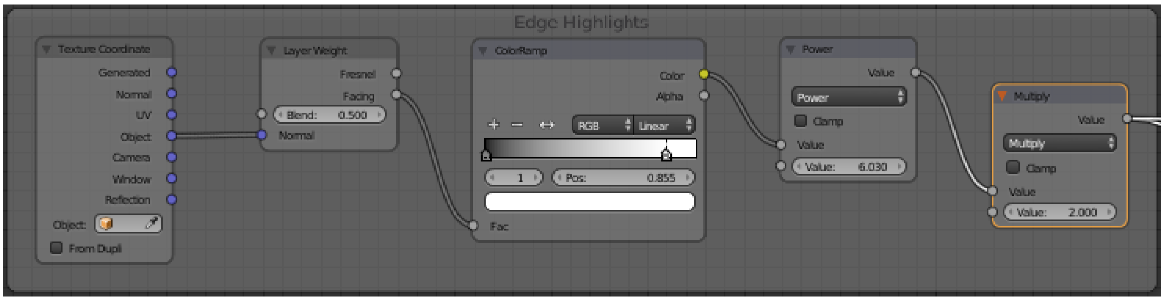

Figure 163: Node tree of the highlighted edge part

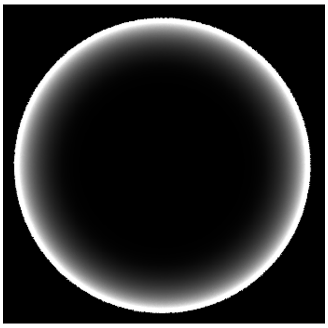

Figure 164: Edges which are later connected to the rest of the material

Combining parts of the material

To combine different parts of the material, like the noise, voronoi and edge highlight parts, a “Mix RGB” node is used most of the time. This node allows you to combine different color inputs. It is also possible to choose how to combine them, for example “Add” or “Multiply” two colors, depending on what fits best. Using this node makes it easy to combine only “masked” parts of a material stage with the main material. “Masked” in this case means only white/bright or black/gray values will be filled out by the rest of the material.

Bringing the material together

After creating each separate part of the material and combining them with “Mix RGB” nodes it is now possible to modify and tweak some parts of it. First an “RGB Curves” node is used to brighten up both of the noise and voronoi textures. To give it an even better look it is then connected to the “Factor” input of a “Mix RGB” node which is using dodge. Also connected to the same “Mix RGB” node is an “RGB” node to give the whole material a color. The RGB node has the possibility to change the color over different keyframes for the animation later on. Everything is then connected to an emission node which makes it so the material is emitting light and does not need an extra light source.

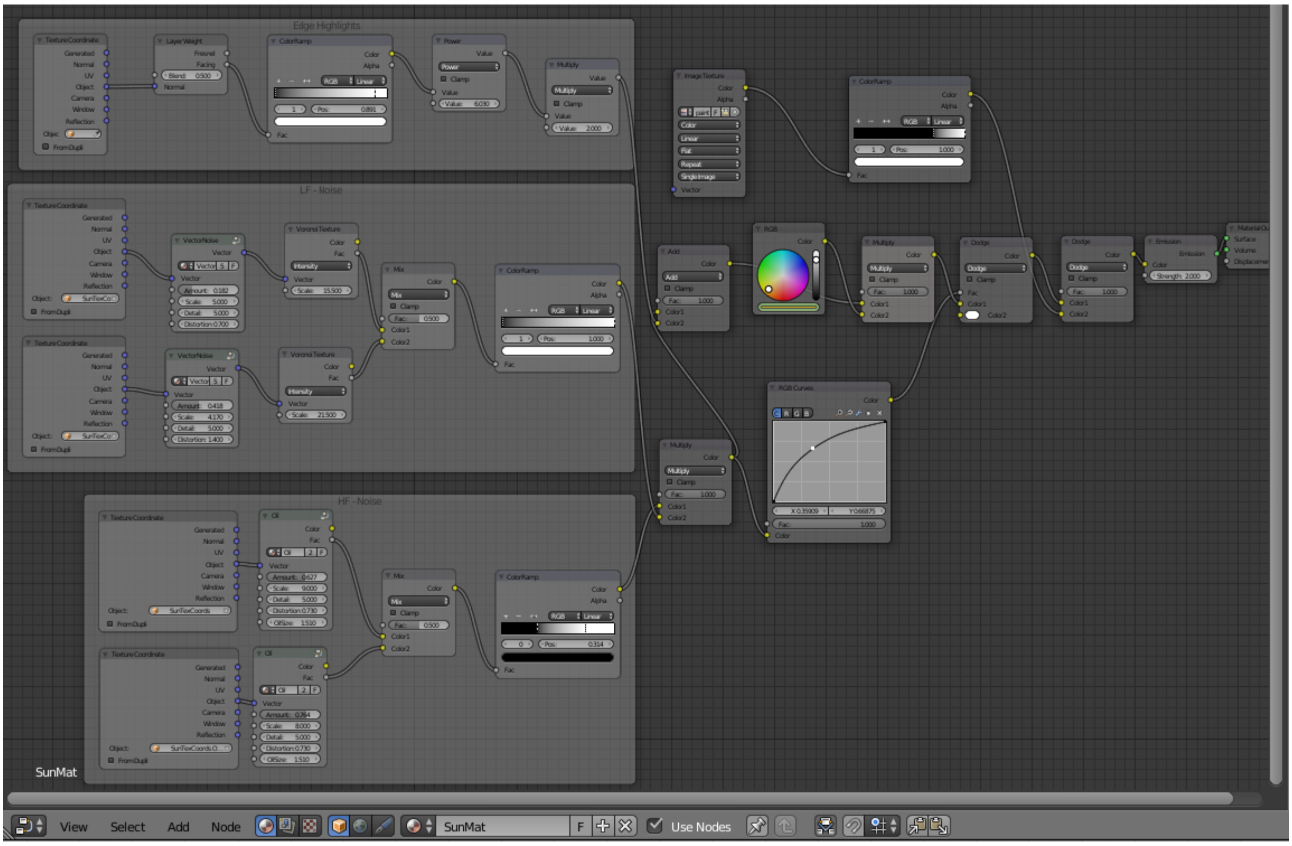

Figure 165: The whole node tree of the sun surface material

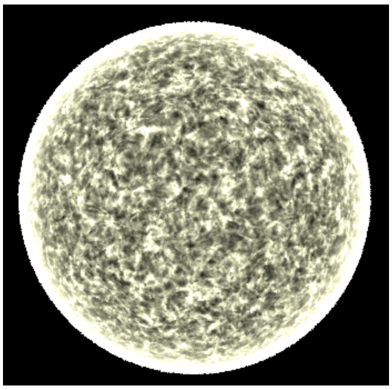

Figure 166: Material of the different node paths combined

Animating the sun surface material

Animating the material works by using the texture coordinates of a different object rather than the coordinates of the sphere object itself. This means when the object of which the texture coordinates are used is moved or scaled it moves the texture as well and gives the material the effect of an animated material. First an empty object is created next to the sun sphere. This can be any empty object, in this case it is a “Plain Axes” object. This is then copied again to have two empty objects next to each other.

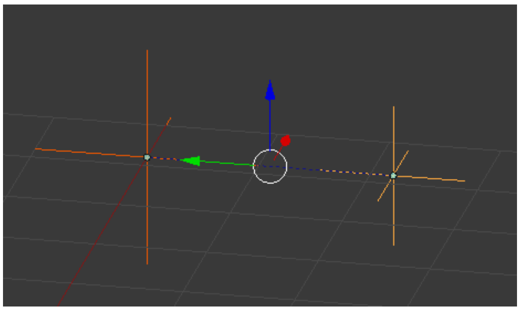

Figure 167: Both empty objects that have to move in different directions

One of the objects now needs to have the object constraint “Copy Location” with the target being the other empty object and only “Z” and “Invert” checked. Having done this allows both empty objects to move in the opposite direction if only one of them is moved.

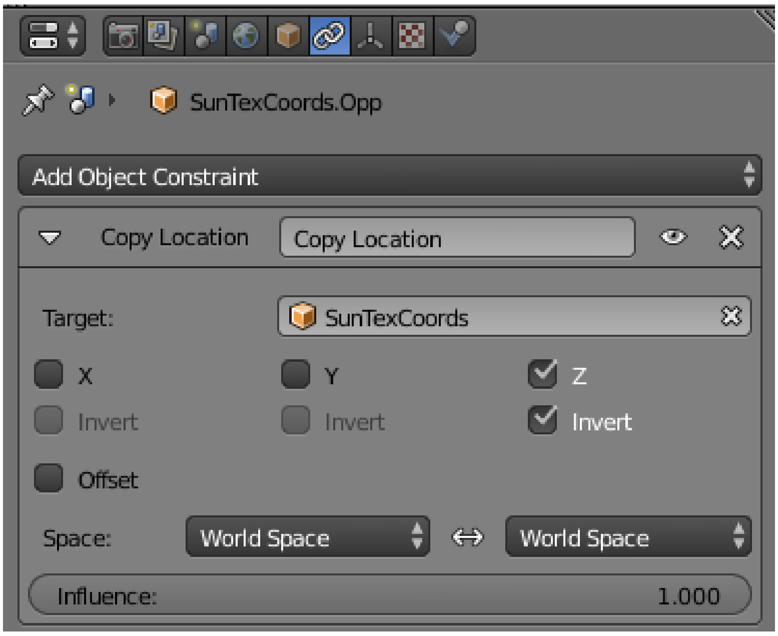

Figure 168: Object Constraints for one of the empty object

When these objects are now used for the texture coordinates and are moved around, it gives the material the great effect of the surface shifting in different directions. To do this the texture coordinates nodes of all the noise and voronoi parts have to use the “Object” output and have the recently created empty object selected, one for the first empty object and one for the other empty object.

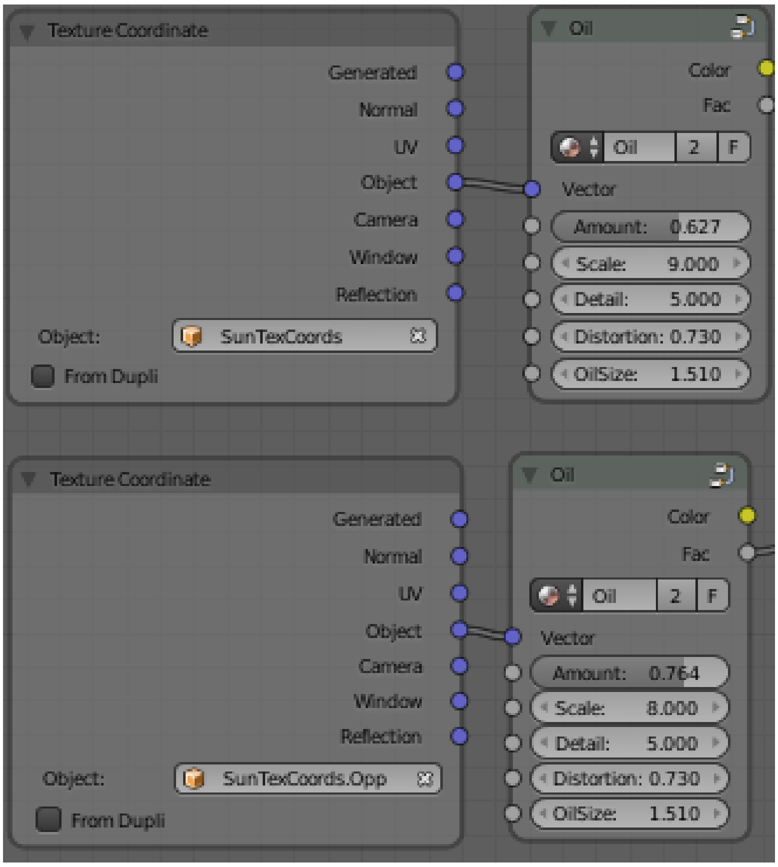

Figure 169: Texture Coordinates: "Object" is set to the respective empty object

By moving the empty objects and setting keyframes it is now possible to have the material animated. Changing the color over time is possible by selecting the RGB node, picking a color, setting a keyframe (i), moving the “Time Cursor” on the timeline, changing the color and setting another keyframe. It is important to have the cursor on the color area of the RGB node while pressing “i” to create a keyframe. A keyframe is indicated by a yellow outline of the color area.

Figure 170: RGB Node: The yellow outline indicates a set keyframe

13.2.3 Creating the corona

First a circle object with 64 or more vertices and about the same size as the sun is created. In edit mode it is then extruded and scaled outwards to create a round plane around the sun. Since the real sun has a visible corona from all sides the plane has to always rotate with the camera so it looks like it has a corona from all angles. To create this effect the object constraint “Copy Rotation” is used again. The target for this is the camera, X, Y and Z have to be checked and influence has to be at one. From the camera perspective the corona always looks in the direction of the camera.

UV unwrapping the object

To give the object a material which fits the round shape and can later be animated correctly, the corona has to be UV unwrapped. First a new window with the “UV Editor” has to be opened. Then, by going into edit mode, face mode, selecting all faces (One has to be “active” by highlighting it again) and pressing “U” > “Follow Active Quads” > OK. Now in the UV Editor everything is selected and put into the little area by scaling it on the x-axis (CTRL + S, X), so it fits perfectly.

Creating the basic corona material

A new material was created in the node editor. Then the voronoi parts from the sun surface material are copied and pasted into the corona material. Instead of using the Object coordinates in the “Texture Coordinate” nodes, the UV coordinates are used. Now, to make the material less stretched, the coordinates around the x-axis have to be increased. This is done by separating the UV vector by using a “Separate XYZ” node and multiplying the x-value with a “Math Multiply” node and subtracting from the y-value with a “Math Subtract” node. Finally the X, Y and Z values are combined again by a “Combine XYZ” node. This allows for a good control for the material, similar to the sun surface material, and can later be animated by changing the y-value. Changing the y-value of the texture is done by using the “Math” node of either “Add” or “Subtract”, which was created between the “Separate” and “Combine” nodes. Finally have both, the y-value and a new “Value” node connect to the “Math” node inputs. The material can now be animated by keyframing the “Value” node.

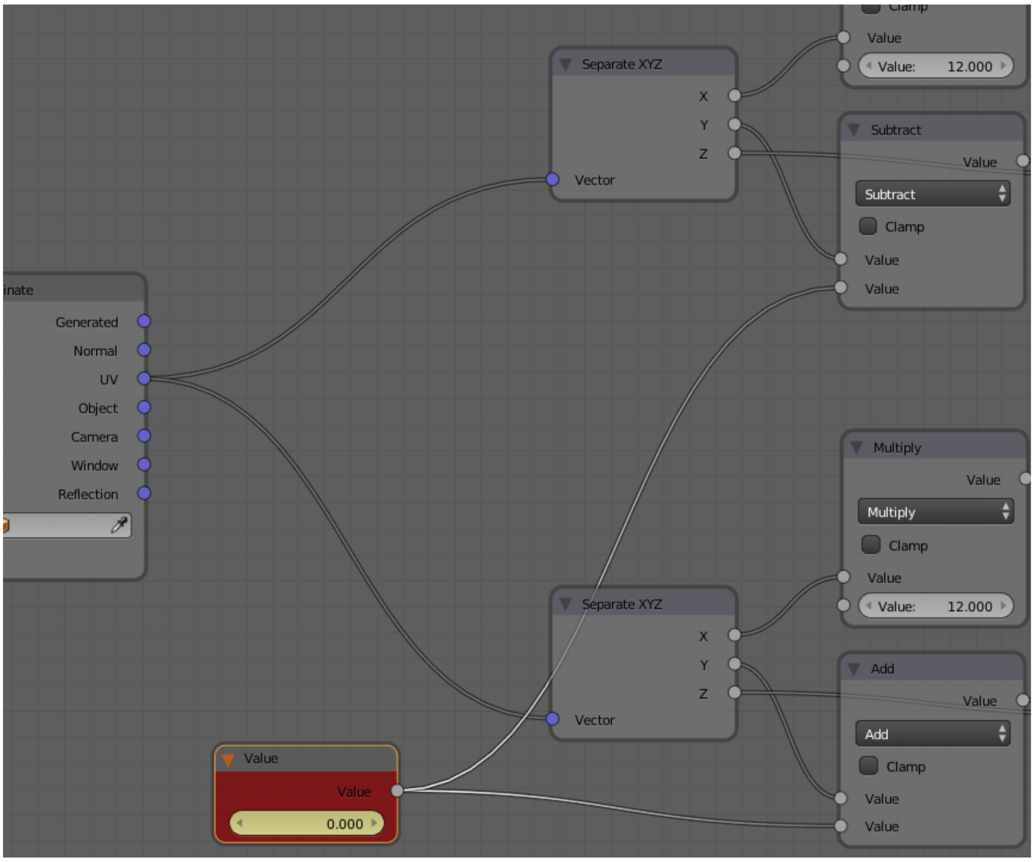

Figure 171: Node Editor: Keyframing the (Y-)value node to animate the material

Fading out the edges of the corona

To make the material fade out at the edges of the corona, a “Fade mask” has to be created. To create this mask, “Texture Coordinate”, “Mapping”, “Gradient Texture” and a “ColorRamp” nodes are used. The Mapping node allows one to shift the location, rotation and scale of the whole UV coordinates, in this case they have to be rotated by “90°” on the z-axis to have it align correctly. The UV coordinates might not be rotated the same way every time so there is a possibility that the rotation has to be “-90°” to work properly or has to be inverted using an “Invert” node. After rotating it the right way it is put into the “Gradient Texture” node which is set on “Linear” to make it fade outwards, then put into a “Math Power” node to adjust the amount of “fade” and finally put into the “ColorRamp” to tweak the thickness of the corona. To brighten up the material a bit, the whole part of the material is copied and pasted again and added on top of each other by using a “MixRgb Add” node and mixing the outputs.

Fixing the corona

Since the voronoi texture is random and not seamless when it is used this way, there is a point on the corona that looks like it has been cut off. To fix this issue, the exact position has to be “Vertex Painted” by using the “Vertex Paint” mode and painting the vertices that have this issue. After doing this, it is possible to create an “Input” > “Vertex Colors” > “Col” node and connect it to the rest of the material by using a “MixRGB Multiply” node and putting the “Fac” output of the Attribute node into a color input slot of the “MixRGB Multiply” node and connecting the rest of the material to the other color input. This now creates an empty space at the painted vertices which can now be filled by using another object. The corona can be copied and pasted at the exact same position and the faces which are not at the position where the issue occurs can be deleted so that only two faces are left. These faces now need to be vertex painted again but this time in the opposite way, black at the edges and white in the middle. Now that two planes are at the exact same position it creates something called “Z-fighting” which creates some artifacts because two objects want to be rendered at the same exact position. To prevent this, one object has to be moved slightly above or beyond the other object. At last the small object, consisting of two faces, now has the wrong UV coordinates, this has to be fixed in the UV editor, so that the two faces are aligned.

Combining the material parts

Similar to the sun surface material, the corona material has to have all parts of the node system combined. This is done by using “MixRGB” nodes most of the time and works exactly as explained in the sun surface material part.

13.2.4 Creating the sun flares

The sun flares are created by using a particle system and filling the sun surface with them. In this case the particle is made out of a simple plane, which is UV unwrapped by selecting the only face of the plane and pressing “U” > “Unwrap”. It is also scaled so it has the form of a trapezoid. To make the particles stick out from one side and not having only half of it stick out, the origin point of the plane has to be move close to the edge of it. To allow the particle to have some detail and make it able to be bent, the “Subdivision surface” modifier is added to it with the resolution of three and the mode “Simple”, the object also has to have smooth shading enabled. If needed the resolution can be increased easily by upping the values or to make it really smooth, adding another “Subdivision surface” modifier with the mode “Catmull-Clark” to it. To not have to model the plane itself, a “Displace” modifier is added and a new texture with the type “Clouds” was created. This makes it so the grayscale image of the “Clouds” “Displace” the plane in a random way to make it look interesting.

The particle has its own material which is made out of parts of the corona material, which are copied and pasted over into the sun flare material. The first part is the same as the corona material but instead of having two “VectorNoise” and “Voronoi” textures it only has one “Noise Texture”. It also has a fade out on the left and right edges as well as on the top which works almost the same as in the corona fade out part.

Animating the particles

Animating the movement of the particle is possible by making use of the already added “Displace” modifier, changing the “Texture Coordinates” from “Local” to “Object” and using an empty object, similar to the sun surface material animation, to make the clouds texture shift and therefore make the object move. To not make the whole object move and only make the top part of it move, it is possible to “Weight Paint” it so that the vertices that have to move, have a value of one and the rest either zero for no movement of something in between for slight movement. The values for the weight are indicated by the color of each vertice, while in weight paint mode and are either blue for the value 0 or red for the value 1. It is of course possible to have values in between which are for example green for the value 0.5.

Different particle styles

The basic particle can be copied to create various styles of it. One of the styles is bending the particle using the “Simple Deform” modifier. This allows the particle to be bent around an object, in this case an empty object, and have it be bent by 180° or however much is needed. Three different particles are then put together in a group by pressing “CTRL + G” and given a fitting name. This is used later to have one particle system use the particles from that group.

Adding the particles to the sun

Since the particles have to cover the Sun’s surface, the particle system is created on the main sun sphere. It is done by clicking the sun object, then under the “Particles” tab, create a new particle system. To have the sun flares stay static and not change position or disappear after time some setting have to be changed. The “Number” of particles is lowered to about 200-300 to not make it too cluttered, “Start” and “End” frames have to be 1, so the particles are there from the start frame, the “Lifetime” has to be long enough so they do not disappear after a certain frame when animated, “Velocity -> Normal” has to be 0 so the particles don’t move and “Field Weights -> Gravity” has to be 0 so the particles don’t fall down by gravity. To add the group of particles, which were created earlier, the group is added under the item “Render -> Group -> Dupli Group”, the size is then scaled up a bit to about 0.2 as well as the random size to about 0.5. To make the particles face in the right direction, in a 90° angle from the sun surface, the “Rotation” has to be enabled, the “Initial Orientation” has to be set to “Normal” and to make the rotation a bit more random, the “Phase Random” value can be increased. If the sun has to be scaled up and down in an animation, like it has to be in the current project, the used particle system type “Emitter” has to be changed to “Hair” and the values have to be changed accordingly to have a similar looking particle system as was created with the emitter type. To do this, the “Hair Length” is set to the value 10, the emitter for the group are still the sunflares group, the “Size” is set to 0.07 and “Random Size” to 0.0652. Making this change allows the sun object to be scaled up and down without having to fix the scale of the particles for each keyframe.

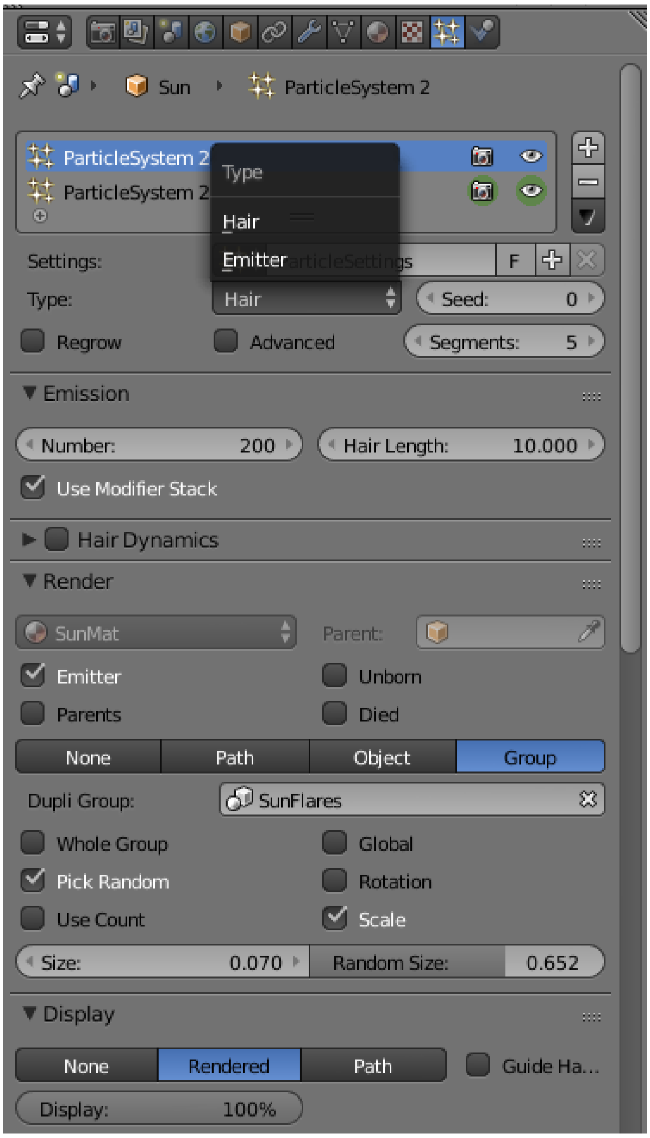

Figure 172: Particles: Changed type from Emitter to Hair and adjusted values

Problems creating solar flares

It is theoretically possible to animate solar flares and other eruptions by using blenders smoke- and particle simulation. Some attempts showed decent results by making particles or smoke follow along a path to make it look like it is shooting out of the surface of the sun. This is done by first creating a simple particle system and then creating a “Curve -> Bezier” which indicates the path, the particles should follow. Next, the curve is selected and under the “Physics” tab, “Force Field” is selected. The “Strength” value is then set to a negative value to make the force field attract the particles instead of forcing them away, also the “Shape” has to be set to “Curve” to change the whole curve to a force field. Finally customizing the speed and proportions is done by tweaking the “Strength” and “Flow” values.

Why it was not used in the final versions

To make the particle system look decent compared to the rest of the objects, it has to have a high number of particles, which take a lot of computational power. The number of particles have to be around 500.000 to a few million so that the particle simulation itself takes more effort than all the other parts of the animation. Another factor is the amount of crashes that occur while working with those high numbers which makes it almost impossible to work with it or makes it at least really irritating and sucks up a lot of time. The particles also have to have a material which, compared to the sun material, is almost as complex. It works by using the cycles node system as well but uses a lot of different nodes, specifically for particles, which takes a lot of time to learn. After trying a few days to get some nice effects done by using the particle system, it was decided against using it, since the result would not be worth the amount of work that would have to be put into it.

13.2.5 Preparing the objects for the animation

First of all, the earth object, which was used in the other scenes, has to be imported and the material values have to be adjusted in the node editor so the earth has no atmosphere, clouds or ocean. Then of all the objects have to have a realistic scale and distance. This is done by checking the actual size of the sun object, which is 2m in diameter and convert the size of the earth and the distance from the earth to the sun, based on the real world values, to fit the animation. Since the distance between the sun and earth objects are really large for “Blender” circumstances, the camera won’t be able to capture both objects, sun and earth, even if positioned so that both objects are in the line of sight. Fixing this problem is done by increasing the “Clipping End” distance for the camera object under the “Data” tab to 50km, just to be safe. The “Focal Length” is also set to 190mm to compensate for the large distance. Some objects have to be animated infinitely or loop, for example the material for the corona, which always moves in the same pattern, so that these objects don’t have to be animated manually for each keyframe. This is mostly the same for each object and is done in the “Graph Editor”. To animate a material, the object to which this material is assigned to, has to be selected. It also has to have two assigned keyframes of the node which has to be animated, for example “frame 0 = value 0 and frame 24 = value 4” and the node has to be selected. In the “Graph Editor” it is now possible to select and modify the graph for the keyframes of the selected node. To make it infinite (frame 48 = value 8, frame 72 = value 12, ...) the first keyframe has to be selected and under the “Modifiers” tab changed for “Before Mode” and “After Mode” from “No Cycles” to “Repeat with Offset” respectively. Infinite animations are done for the sun material, the corona material, the particle material, the earth rotation and a few other objects.

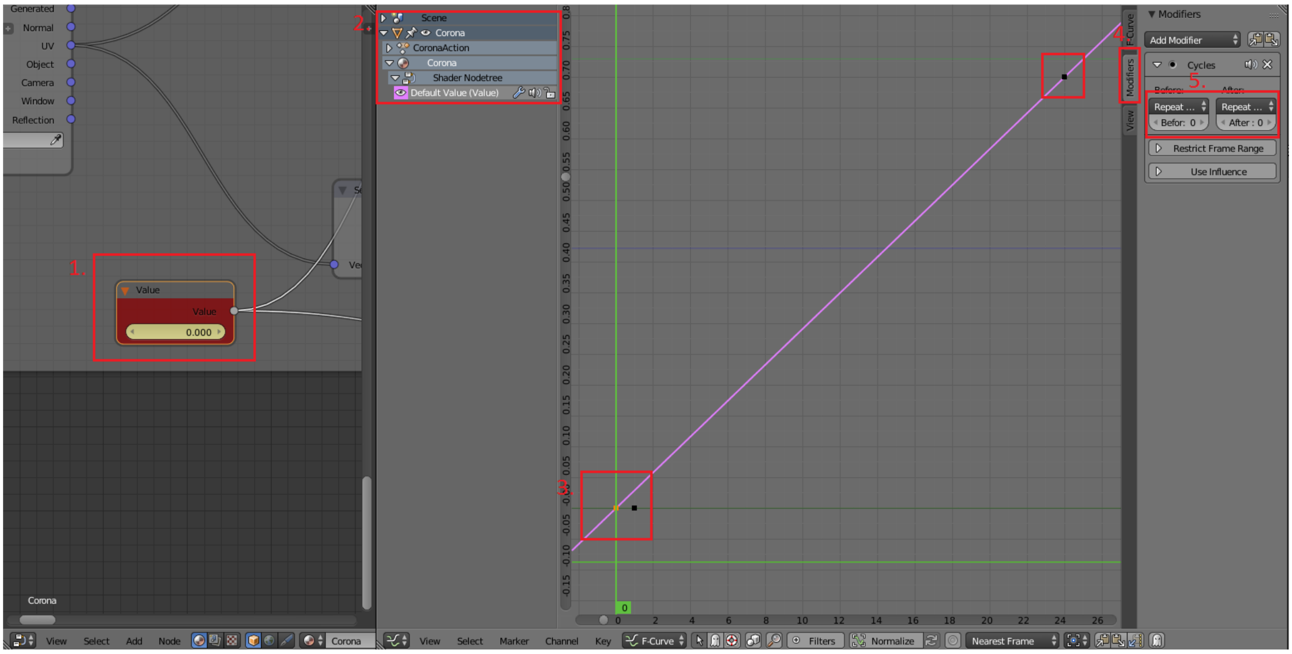

Figure 173: Graph Editor with repeated animation

Using the compositor

To make it possible for the viewer to see a change in luminosity, which is realistically not possible considering the strength of luminosity in the real scenario, the Blender compositor is used. It allows the user to create a node setup, similar to the material nodes, which post processes the rendered images afterwards. In this case a change in luminosity is created by overlapping the rendered image with a blurred outline of the objects to make it look like it is glowing. First of all, since the sun is the object that has to have the glow effect, the sun is selected and the material index is increased by clicking the "Materials" tab and setting the "Pass Index" to 1. Next the "Render Layers" tab is clicked and the "Material Index" box is checked. The object now has a separate render layer which can be used in the compositor.

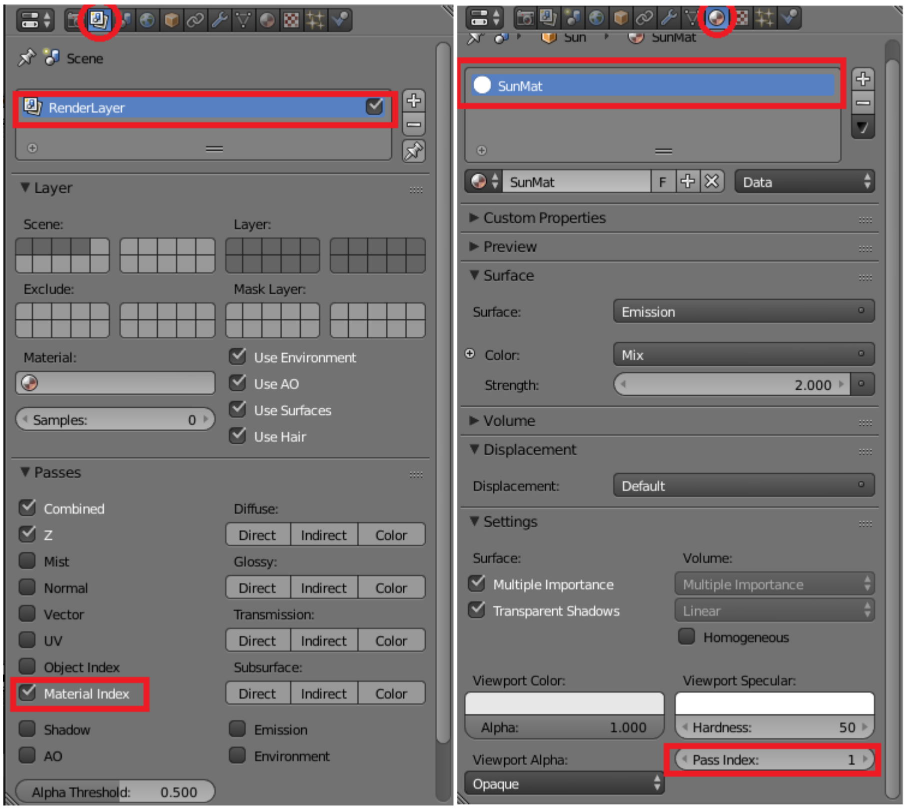

Figure 174: Render Layers/Materials tab to enable Material Index

The compositor is opened by switching to the "Node Editor" type and selecting the node tree type to "Compositor". Is is useful to check the "Backdrop" box and add a "Viewer" node as this allows a rendered image to be used as a background while changing the node setup and thus seeing the result of the post processing. The actual setup used for the glow is done by masking the sun object by using the just created index and the "ID Mask" node and adding a blur to it. It is then added on top of the rendered image. The "Blur" node is responsible for the glow in the X and Y coordinations, the "Mix" node is used for the amount of glow and the "Add" node with the separate color is used to create the white flashes in the later scenes. The last node has to be the "composite" node as this is the node for the final output. This compositor setup is simple, but effective as the user has a good control over the parameters of the luminosity.

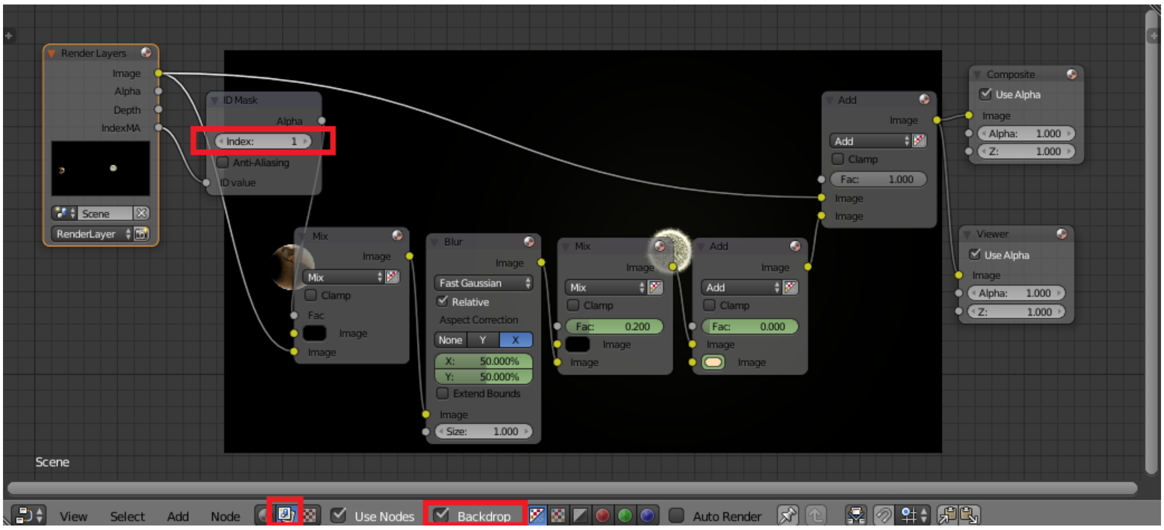

Figure 175: Particle System on the Sun: Left for startframe, right for endframe

13.2.6 Animation

Scene 8-12 are all in the same file and therefore have keyframes on the same Blender timeline. Scene 8 takes frame 0 to 200 and shows the sun and earth in relation. The camera is positioned so both objects are visible at the same time to give the viewer some way of recognizing the change in size of the sun. In the first few frames the camera is really close to the sun and zooms out. This is done by keyframing the camera position. The color of the sun is a mix of white and a bit of yellow which can be modified by changing sun surface material RGB node. After the camera is zoomed out so far that the earth is visible, the camera angle is changed slightly to make the look more appealing for the viewer. After frame 160 the sun starts to grow and the color changes to a bright yellow until frame 200. The scaling is also simply keyframed but the empty object, which is responsible for the position, rotation and scale of the sun material, also has to be scaled and moved accordingly to make the material look dynamic. Since the luminosity also changes the compositor has to have some values keyframed as well. This is done by going into the compositor node tree and hovering over the node and value that has to be changed. Then the frame is set to the preferred number and the values of the node can be changed and a keyframe can be set by using the "i"-Button on the keyboard. The yellow color indicates that the current frame has a set keyframe. All nodes values, material or compositor, are animated this way.

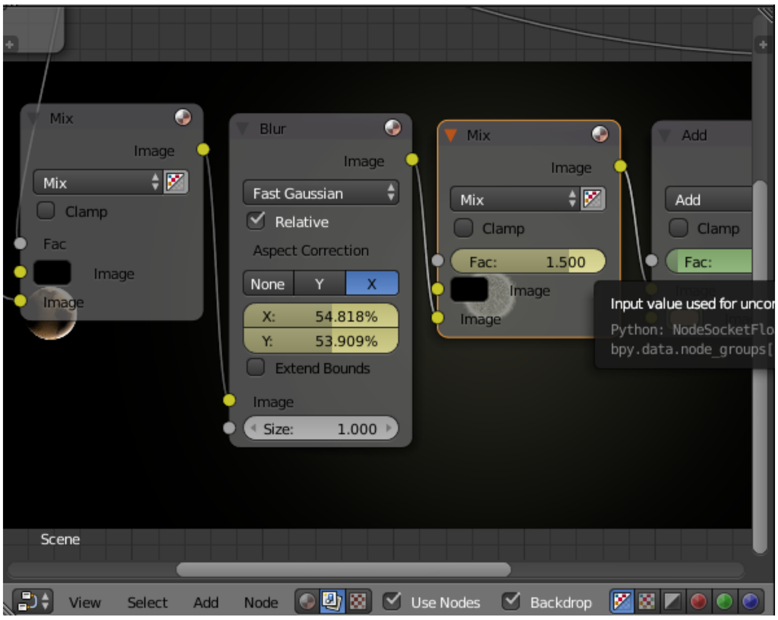

Figure 176: Set keyframes (yellow) in the compositor

14 Scene 9: red giant

14.1 Research

The information and data necessary for understanding what happens to the sun, and for deciding on the best way to visually represent these states and changes was obtained by reading through multiple research papers, literature (recommended by Professor Zimmer), websites, and watching presentations and documentaries online. A full list can be found at the end of this documentation. This information was inserted in chronological order into a shared spreadsheet that the entire team had access to. Columns existed for the following categories: Time, Solar Radiance, Solar Incidence, Temperature at Earth's surface, Temperature at Sun's surface, Luminosity, Size of Sun, Earth-Sun Distance, Colour, Physical appearance of Earth, Physical appearance of Sun and relevant notes for each entry. This allowed for the research team to store the information that they came across in a centralised location. When the graphic teams were working on their respective scenes, they were able to look at this spreadsheet and refer to the notes for an understanding of what was important to represent visually, as well establish the basis for a sequential timeline. For scene 9, this documentation summarises briefly what is happening with regards to the sun.

When the sun has reached the red giant stage (in around 7.09 Gyr from now), it's core has reached a density so high that the rate of hydrogen burning is hugely accelerated. This disruption in hydrostatic equilibrium has forced the Sun's outer layers further away from the core, leading to the huge increases in the solar radius, and the reddening in colour that is observed. [5] [4]

14.2 Animation

This scene goes up to frame 720 and starts with the sun increasing in size and luminosity as well as changing into a more orange color. The size is first increased to a scale of 10 and the luminosity is only increased slightly as it is otherwise not possible to show the further increase later on in the animation. After the first change in size and color, the camera zooms out again to make the sun fit the screen. The earth is now no longer visible as it is too small. Now that the earth is no longer visible, it is possible to not make it render anymore as it still takes up resources when rendering. This is done by setting a keyframe on the disabled render icon at the frame where it should no longer be rendered. The sun is now a red giant.

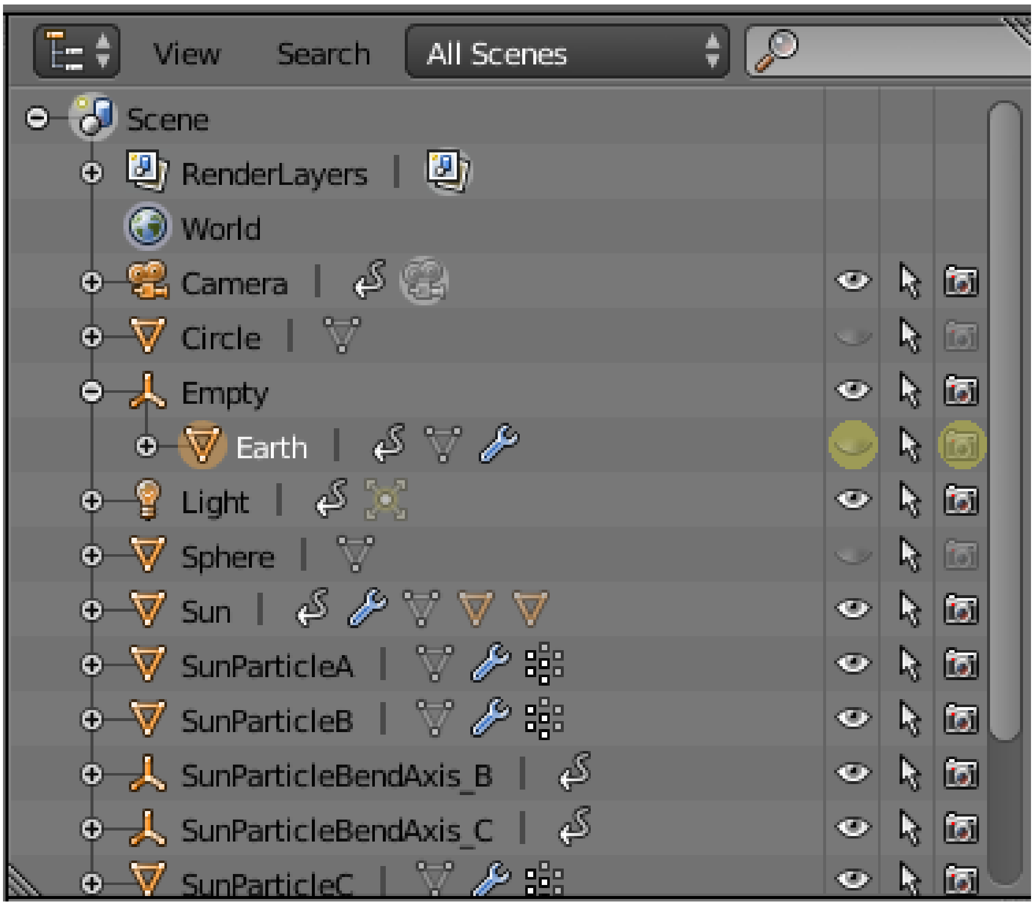

Figure 177: Disabled rendering for the earth object

15 Scene 10: helium flash

15.1 Research

Once enough helium has amassed in the core of the red giant, the pressure and temperature reaches a point at which the helium begins to ignite (in around 7.683 Gyr from now). This releases so much energy that the rate of helium burning increases, in turn releasing even more energy. This helium fusion begins to happen at such an intense rate that it is referred to as a 'helium flash'. Due to the internal balance of forces occurring within the sun, this flash is not visible externally (even though internal luminosities brighter than that of the entire milky way galaxy are reached). [8]

15.2 Animation

In this scene, which goes to frame 1180, the sun is scaled up to the value of 300 and the color is changed to an even darker red. The camera is zoomed out at some points to capture the whole sun. This might sometimes look, like the sun is shrinking again because the sun gets smaller in relation to the screen. To compensate for this look, the sun material was animated stronger while changing its real size and not so much, when the camera zooms out. When the Sun is close to its final scale of 300, a hair particle system of the sun is enabled to grow to make it look like it is releasing energy.

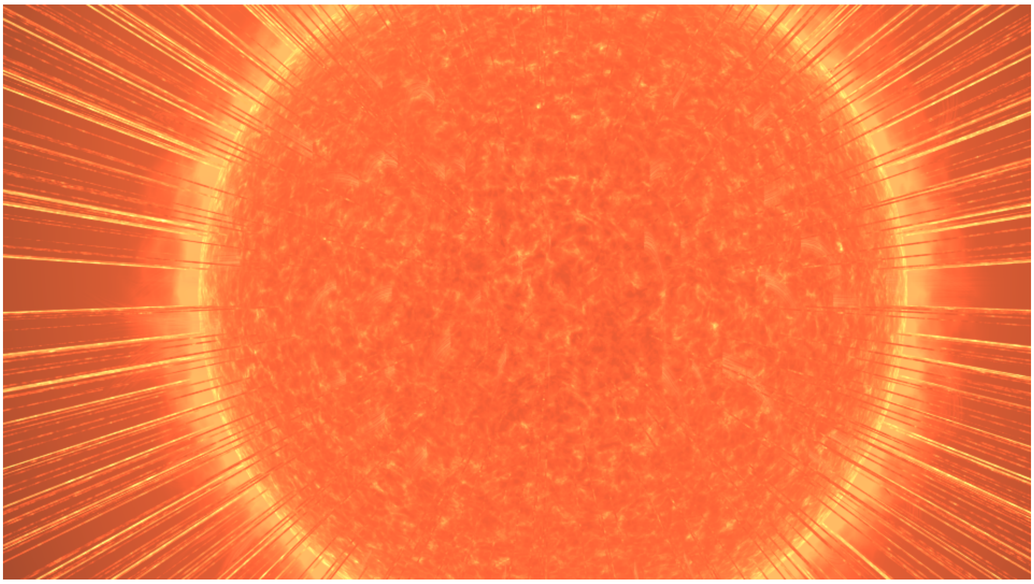

Figure 178: Rendered image of the Hair Particle System

It is done by creating a simple hair particle system on the sun object, setting the "Path End Timing" to 0 on the frame where the hair starts to grow and setting the "Path End Timing" to 1 as well as keyframing the disabled render icon on the frame where it is fully grown. The white flash is done in the compositor by using the "MixRGB Add" node and setting a keyframe on its "Fac" to 1 and changing the color to a desired one, in this case orange to white. The "Fac" value has to be set to 0 again to make it disappear after the flash.

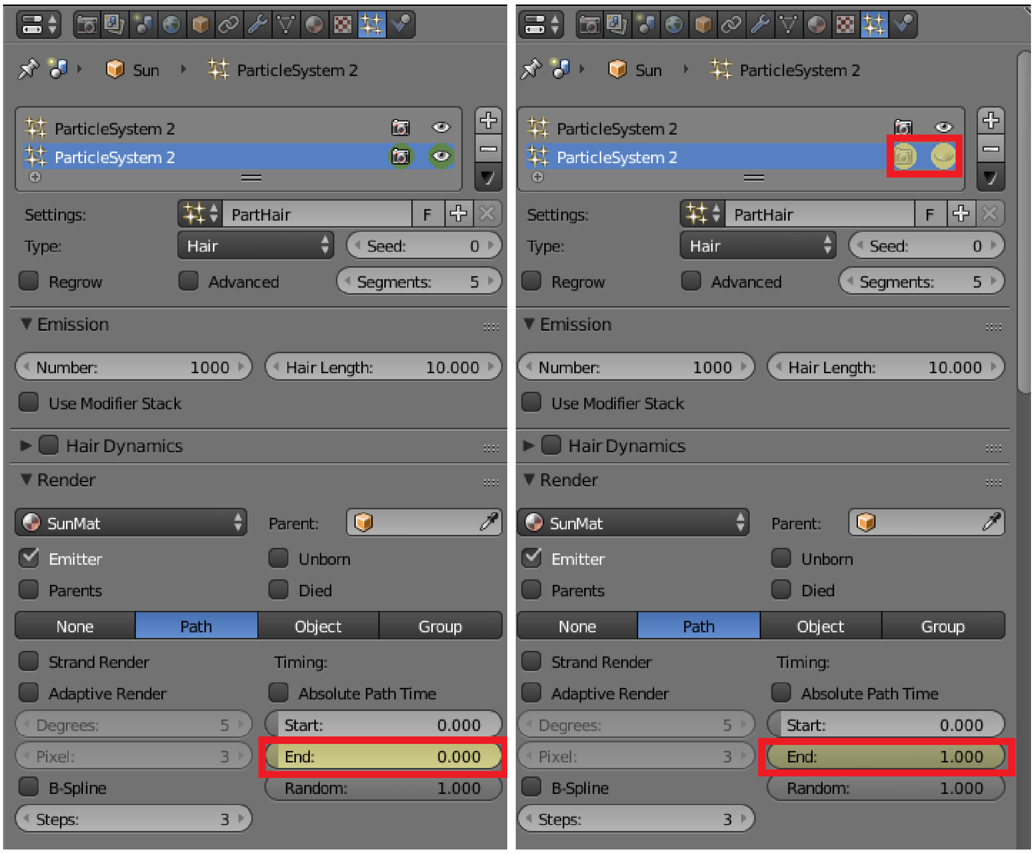

Figure 179: Particle System on the Sun: Left for startframe, right for endframe

16 Scene 11: yellow decreasing sun (Horizontal Branch)

16.1 Research

Due to the helium flash, huge amounts of heat are released and the degenerate core becomes highly dense but normal gas once again. This forces the core to expand significantly. This expansion of the core leads to cooling which leads to hydrogen shell fusion occurring at a decreased pressure, which in-turn leads to a reduction in energy output. Here it can be observed that the sun decreases in size and moves to a more yellow colour (in around 7.684 Gyr from now). At this stage it is thought the sun will be around 10 times the size of the current sun, and roughly 40 times brighter. These values are only around one fiftieth of what they will have reached during the peak of the Red Giant phase. [6] [3]

16.2 Animation

After the flash effect, the sun is scaled back to the value of 10 and the color is changed to yellow.

17 Scene 12: red giant 2.0 (AGB)

17.1 Research

During the early stages of this phase (around 7.795 Gyr from now), there is somewhat of a hydrostatic equilibrium between the gravitational forces and the fusion of both hydrogen and helium. Then, as hydrogen fuses to helium, this helium forms a layer around the core. Once this layer meets certain conditions, it ignites again in rapid burning flashes that head outwards, causing periodic disruptions to the outer hydrogen burning shells. Each time a helium flash occurs at this point, it consumes all the helium present. The hydrogen fusion soon creates more helium and eventually another flash will occur. These flashes are of huge luminosity. [3] [1]

17.2 Animation

The helium flashes (white flashes on the screen) are done by using the same method that was used for the first screen flash by using the compositor. The sun is now scaled up to 100 and down to 60 for the first flash and up to 200 and down to 60 for the next few flashes. The last flashes are all the same so it was only needed to create one flash and then copy the keyframes and paste them next to each other. They can then be modified individually. This is done in the "Dope Sheet" Editor where each keyframe for every object and node is listed and can be adjusted. It can also be used to select keyframes, copy/paste them (Shift + D) and move them next to the other keyframes on the timeline.

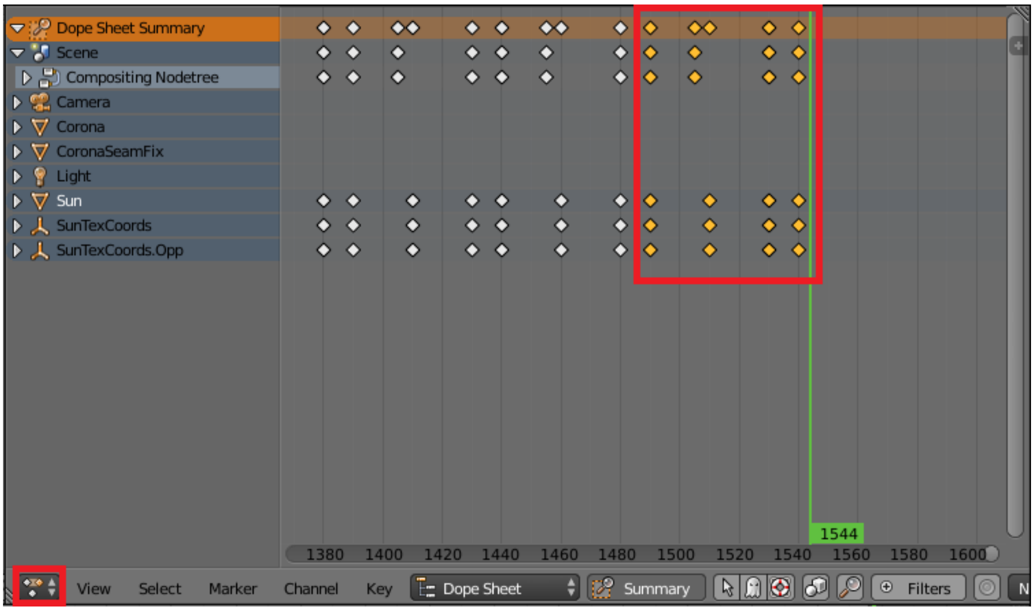

Figure 180: Blender Dope Sheed Editor with selected keyframes

18 Scene 13: planetary nebula

18.1 Research

Around 7.815446 Gyr from now, the rings of helium and hydrogen have essentially exhausted themselves, and huge floating clouds of gas have been 'kicked-off' by the sun. The dense core left in the middle that consists mainly of carbon, oxygen and other heavier elements, is now known as a white dwarf. It emits radiation at such an intensity that it makes the surrounding gas clouds glow in a variety of colours, known as a planetary nebula. [2] [7]

18.2 Animation

The defining features of a planetary nebula are its gaseous/smokey consistency and the rich color spectrum that they display. There are a few tutorials online that show how to create fly throughs of a nebula or how to create a static nebula background in blender. Unfortunately, there is not much to be found on how to model a planetary nebula as a whole in blender, however, there are plenty of tutorials to be found on how to model other space elements that can be used to help construct a planetary nebula. For this project two videos from Creative Shrimp Space VFX series, modeling Gas Clouds and Quasar, were instrumental in modeling the nebula's outside gas rings which will be covered in the appropriate section below.

18.2.1 Nebula Core

Planetary nebulas come in a variety of patterns but tend to have a spherical center surrounding a white dwarf. To create this center, start by clicking add>mesh>UV Sphere to create a new 3D sphere and then resize it to your desired scale by hitting S on your keyboard and dragging your mouse. Next go to the tool tab and click on smooth shading. Once that is complete go to the material tab, add a new material, and then open the node editor. Press Shift-S on your keyboard to bring up the add node selection and a Glow, Emission, Transparent BSDF, and 2 Mix Shaders. The glow node controls the strength of the spheres edges and the Transparent BSDF node softens the entire sphere so that we can achieve a more gaseous density for our core. Color and intensity can be changed in the emission node. Once all nodes are placed connect them as shown in the figure below with the final mix shader being connected to the material output.

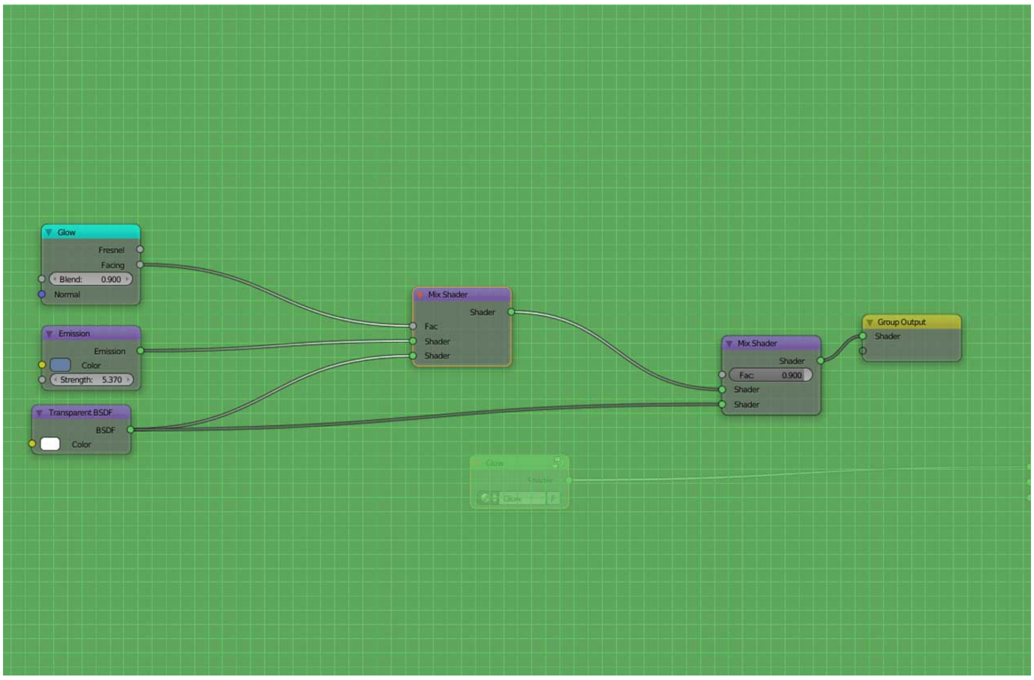

Figure 181: Blender Node settings: Sphere with edge glow

Now you should have a semi transparent sphere with soft edges but to make it look more gaseous we will add some smoke to the core. Create a second sphere smaller than the core and then open the physics tab on the far right of the screen. Under physics click on the button that says smoke and set it to flow. You will notice that a orange box has no appeared around your circle, this is the domain/container for your smoke. Resizing it will control how far the smoke can go and under the physics tab there is an option for border collision, this controls whether smoke can leak out of the domain vertically, everywhere, or not at all. For this project it was set to open to aid in the gaseous look.

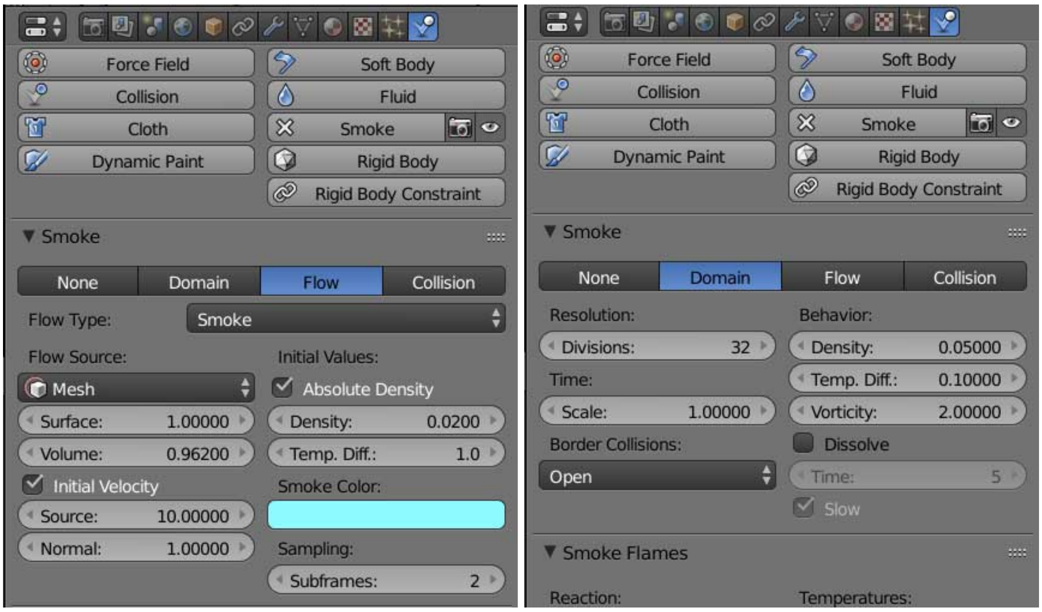

Figure 182: Belnder Smoke settings: Emission, and Domain settings

Create a third sphere that is equal to the core and under the physics tab click smoke again and set this sphere as Collision. This helps keeps the smoke in a spherical shape instead of flowing all over the scene. As a final step turn off rendering for the collision, domain, and smoke emitter by clicking the camera next to them in the scene tab, this keeps the objects from rendering in the scene so we only see the smoke.

18.2.2 Gas Clouds

For the following section, Creative Shrimp's video tutorials on gas clouds and quasars was followed to create the foundation on the planetary nebulas outer gas clouds. To start some gas cloud textures need to be created. The images used for this nebula were found on pixabay and edited in an image program such as GIMP and photoshop to have good composition and isolate only the parts needed for the model (i.e. using black to cover up any part of the image that was unwanted).

Once suitable images have been found click on add>mesh>cylinder in Blender and widen the cylinder by hitting S then Shift-Z dragging the mouse out. Tab into edit mode and select the top polygon. Press I to inset it and then shift R to repeat a few times, select all the top polygons so you have a circle, press D to duplicate, then G to move it above the cylinder, and finally P to create a new object out of it. The cylinder can be deleted as it will no longer be used. In the material tab, add a new material to this object and open the node editor

Delete the Diffuse shader and then insert an emission shader connecting it to the material output Surface socket. Add an Image Texture node and open your gas cloud texture, plug it into the emission shader color socket. The model now has to be unwrapped so that the image appears correctly on the model. Press tab, select all polygons and open the UV Image editor. Hold shift, press on one polygon to make it the active polygon, press U and select follow active quads, then ok. The image will now have to be rescaled to fit into the UV canvas using S+Y to scale it vertically and S+X for horizontal. Now return to the Node editor and add a Hue Saturation Value (changes the color of the image, 2 Translucent BSDF nodes, a mix shader, RGB Curves, Layer Weight, ColorRamp, and a Mix node. Connect them following the figure below.

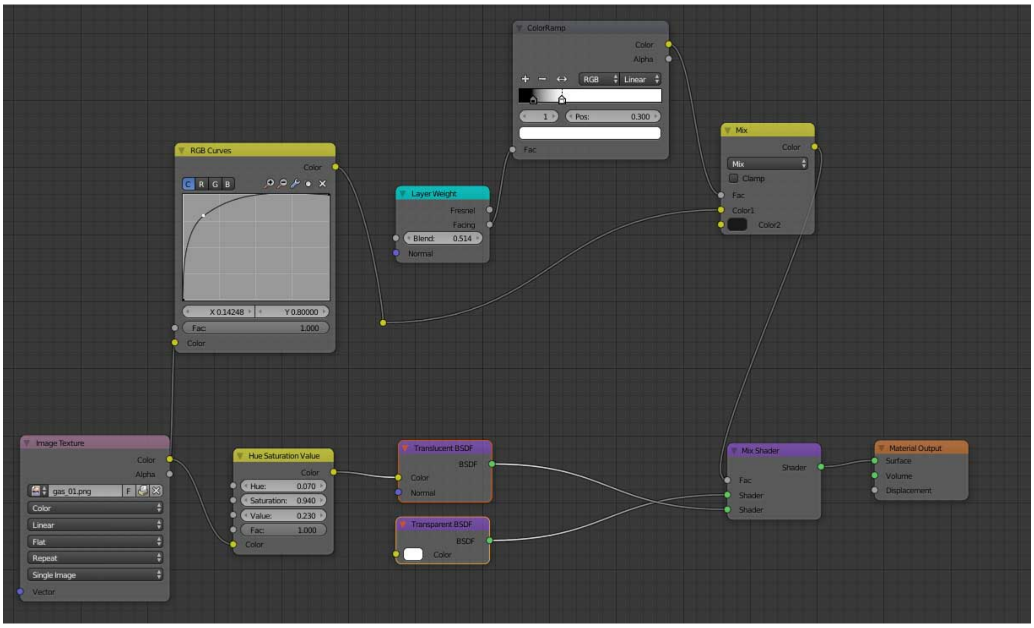

Figure 183: Blender Node settings: Gas cloud

Return to edit mode and enable proportional editing. Select the middle polygon and press G to move it up (press z to constrain it to that axis). For this project, the model was shaped to create a hat but the shape can be altered to create different patterns for the nebula. Duplicate this object and change the scale and rotation. The object can be duplicated again and replace the current image in the image texture field with a different image to create different patterns as well.

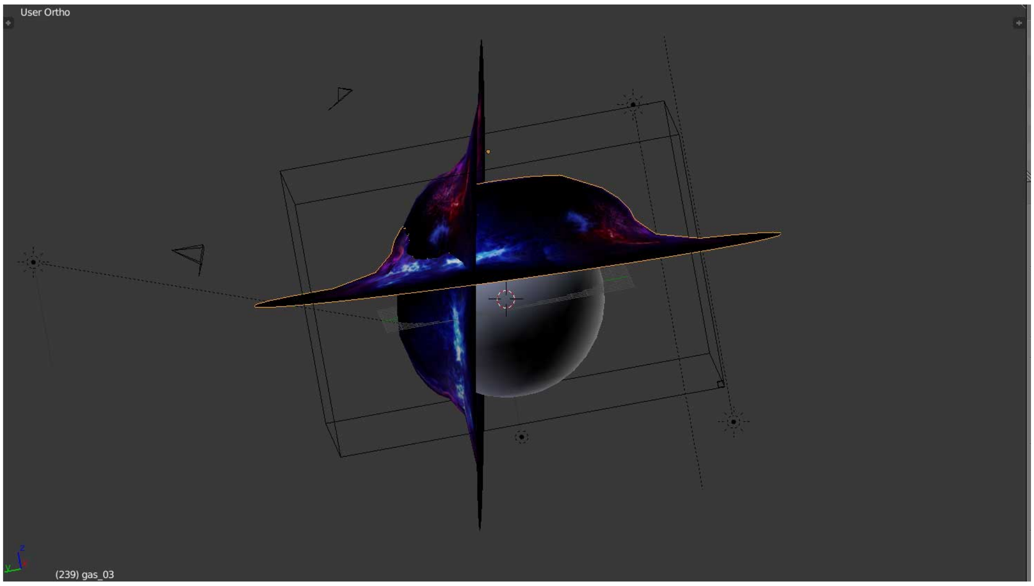

Figure 184: Blender model of nebula core with gas cloud models

(3D model of core with gas clouds)

18.2.3 Lighting and Camera Angle

After modeling all the pieces needed for the nebula, it is time to set up lighting and the camera to capture the nebula. Given the gaseous nature of the model, lighting and camera angle make a significant difference to the rendered end product of the nebula. In the above figure, one may note that several light sources have been placed underneath and above the nebula clouds. These light sources help bring out the colors/highlight certain areas of the gas clouds while rotating around the center. The color of the lights can also be adjusted to highlight certain colors in the clouds. For a static model, one might need perhaps two lights to highlight the needed areas but for an animated model and depending on how the gas clouds move, more might be necessary. Rotating the camera around and adjusting the settings (focal length, clipping, etc.) will also affect the appearance of the nebula, making some areas of the cloud more translucent or vanishing entirely. The lighting and camera angle should be adjusted until the desired look is found. For this project the camera was placed diagonally above the model with three sun lamps (one red, white, and blue) with a strength of 10 and one blue point light with a strength of 10000.

18.2.4 Animation

A planetary nebula is not static during its life, the gas clouds slowly rotate around the center and grow farther away with time, eventually leaving only a white dwarf behind. With the setup of the smoke simulator, some movement is already present in the model but rotation and dispersion is still needed. To start, select the first gas cloud and press shift + left arrow to go to the first frame of the animation. Press I and insert a keyframe for the current location, rotation, and scale. Once that is complete, move the animation timeline up a little by clicking ahead in the animation timeline. By pressing R on the keyboard rotate the gas cloud to the new desired state and press I + rotation + location to add a keyframe for its new position. At the same time the gas cloud can be scaled up a little to simulate it expanding away from the center, after you are done remember to set a keyframe for its new scale. Repeat this process till the end of the timeline and for all gas clouds models. If after rendering the animations one finds that the animation needs changes, keyframes can be deleted by right clicking on the point and deleting. However, a simpler solution would be to open up the dope sheet animator in the editor type. This allows you to see all your keyframes at once, giving you the option to drag and drop keyframes to a new place on the timeline instead of deleting and redoing every keyframe.

Figure 185: Blender model of nebula: Rendered

19 Rendering using Cycles Render

The module management does not make any precise specifications as to the quality of the final result. Therefore, during a meeting, all render settings that affect the final animation in resolution or frame rate are decided uniformly. The following settings are being used for the final animation:

Resolution	1920 x 1080
Frame Rate	24 fps
Output Format	PNG

19.1 Improve rendering speed

Regardless of the hardware resources available for rendering the animations, it is possible to increase the rendering speed so that less waiting time elapses overall. The possible settings are described in more detail below.

Resolution

The most obvious change, which has a positive influence on the render speed, is the resolution. A distinction must be made between the values X and Y and the quality setting (third setting). The values X and Y represent the final resolution of the animation. This has a direct influence on the format of the camera and should therefore be set to the value that the final animation should have. In our case the resolution is 1920px for X and 1080px for Y. The third setting is for the percentage gradation of the resolution. This value is ideal for testing render settings or the appearance of scenes by rendering with a lower percentage.

Frame Rate

Another simple way to reduce the render time for animations is to reduce the frame rate. If you select values of less than 24 fps for the animation, this ensures that the animation is no longer played smoothly, but that individual images are perceived. But a frame rate of less than 24 fps is a good way to test the effect of animations without rendering too many frames unnecessarily. This saves time and computing power.

Samples

A high number of "samples" ensures that there is no noise in the final animation. However, it also ensures that the rendering time goes up immensely. However, in most cases the number of samples is too high, so that sometimes no difference is visible.

When comparing the two images there is hardly any optical difference, but one render takes more than twice the time than the other. Therefore it is worthwhile to set the number of samples as low as possible, but at the same time to keep them as high as necessary in order to achieve the optimal render time and image quality.

To get the best sample size it is recommended to render the scene with the function "Progressive Refine" before starting the render the whole animation. This will render the scene Sample-by-sample and the result is in the output. This allows you to determine a value for the samples that gives a good average between noise-free result and low render time.

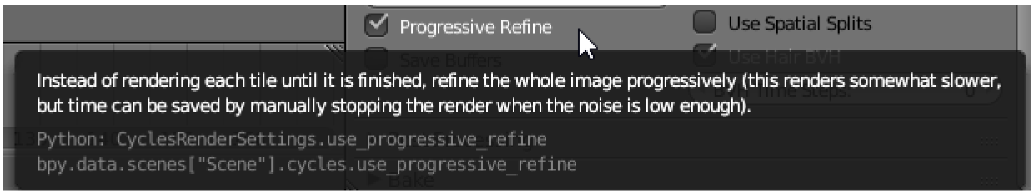

Figure 186: Rendering using the "Progressive Refine" option.

Bounces

"Bounces" means how often the light should bounce off objects in the scene. The higher the value, the more realistic the lighting conditions in the scene are, but it rarely makes sense to set the Max value higher than 5, since from this point on there are hardly any differences to be seen. The min value should be as small as possible. In our case, the default value of 3 is retained.

Tile Size

The "Tile Size" describes the size of the sub-sections to be rendered by the hardware. With this setting it is very important to distinguish between CPU and GPU rendering. If you use the CPU to render the scene, the "Tile Size" for X and Y should have the values 16 or 32. If you don't use the CPU, but a GPU to render the scene, a "Tile Size" for X and Y of about 256 or 128 is recommended. These values result from the experiments described in more detail in the section "Testing render speed with different devices".

19.1.1 Testing render speed with different devices

The rendering speed depends not only on the values you assign to the scene, but also on the hardware you use to render the animation. Some attempts are made in advance to find the best hardware for the respective scene.

GPU (GeForce 940MX + GeForce GTX 770)			**CPU** (Intel Core i7-7500U + Intel Core i7-3770K)		
Variable	**Value**	**Render Time**	**Variable**	**Value**	**Render Time**
Tile Size	256x256	189s	Tile Size	256x256	219s
Tile Size	**128x128**	**164s**	Tile Size	128x128	195s
Tile Size	64x64	215s	Tile Size	64x64	183s
Tile Size	32x32	498s	Tile Size	32x32	172s
Tile Size	16x16	1580s	**Tile Size**	**16x16**	**166s**

Figure 187: Comparing rendering speed with different tile sizes of (1) two GPUs and (2) two CPUs.

The result of the tests is that there are scenes that finish faster with CPU rendering than with GPU rendering. This must be tested individually with each scene in advance. Frequently, however, rendering with the GPU is much faster. The size of the tile size, on the other hand, provides a consistent result. Using the CPU rendering, a small tile size is much faster than a larger tile size. The values of the best render time vary between a tilesize of 16x16 or 32x32. If you use GPU rendering, a tilesize of 128x128 or 256x256 is the most efficient. Here the jumps of the render time are much higher and more serious if you vary the tile size.

19.2 Network-Rendering (using renderfarms)

Network rendering is a method of shifting the rendering process to two or more computers. Different software is used to differentiate between servers and clients. The servers are ready and waiting for a job from a client. When they receive this job, they begin rendering until they have rendered the specified areas of the image. They then return the result to the client, which saves it afterwards.

19.2.1 Local renderfarm at the University

In order to render the animation, it was decided to set up a local render farm at the Rhine-Waal University of Applied Sciences. About 50 computers (distributed over two rooms) are used. A standalone render server developed by the community is started on these computers, which then accepts render jobs via a Blender version (also modified by the community)[8].

[8]https://www.blender3darchitect.com/blender-cycles/distributed-network-rendering-cycles/

Figure 188: Renderfarm at the Rhein-Waal University of Applied Science.

Preparation

First all computers are started and the administrator user is logged in. This is important to ensure free communication via the network in which the computers are located. Subsequently, the Cycles server is installed on about ten computers, while a modified Blender version is installed on another computer (also in the same network). Now the cycles_server.exe files on the servers are started via the tool cmd.exe. Then the modified Blender version is started and the scene to be rendered is opened.

Connecting the Client to the Servers

To connect the client to the servers, the IP address of the computers in the network running the cycles_server.exe must be selected. Then the "Render Device" is set to "Network Render" at the client's blender. The IP addresses of the server computers are then listed separated by a semicolon into the available input field.

Starting the Render Process

Then click on "Render" or "Animation" to start the render process. First, the client connects to the servers and transmits all elements and objects of the scene that are relevant for rendering. ASubsequently, a square the size of the tilesize appears per CPU core or per GPU, which represents the position of the current render job.

Completing the Render Process

Finally, the rendering process finishes as with the official Blender versions. After the render process is finished, the client closes the connections to the servers again.

19.2.2 Third-party rendering services

There are a number of services that offer a render farm system. There are variants with costs, where you rent one or more servers, which then receive the render orders and process them. There are also a lot of free render farms where clients can also become servers and collect virtual currencies (or points) that can then be reinvested in projects to be rendered. This means that you first have to make your own computing power available to other users in order to collect points and later you can use these points to pay other users to render their own Blender projects.

SheepIt-Renderfarm

One provider of such a free render farm is SheepIt[9]. With SheepIt, users first download and run server software. Thus the own computer now receives orders from other users, which it processes. After some points have been collected, they can be redeemed on the website. For this you upload your own Blender file to be rendered and give the order to other servers in the farm. The project is rendered until all points are used up. After that you have to render for other users yourself once again.

A decisive disadvantage of this (and comparable) service is that the own project is transmitted to different (foreign) users. This can lead to data protection problems. Furthermore, the most recently rendered frames can be freely viewed on SheepIt on the website.

20 Editing

The editing will be done using Premiere Pro. The information bulletin overlay (such as text displayed that refers to what is happening with the earth or sun) will be done using After Effects. Both Premiere Pro and After Effects are part of the Adobe Creative Cloud. Many free tutorials on how to use this software can be found online.

21 Textures

Using textures in 3D modeling allows the user to quickly and easily show height details, color information, and surface textures for a model while keeping polygon counts and lighting calculations to a minimum. Certain elements of this project required the use of textures/images to show certain elements on the models, such as Earth, were textures were used to illustrate all the changes in water, landmass, and atmosphere. Texture maps for the earth as it appears presently were downloaded for free from solarsystemscope.com and shadedrelief.com,with the former also providing a Venus atmosphere texture which would be edited to be used as earth's heavy atmosphere after the oceans boil away.

[9] https://www.sheepit-renderfarm.com/

To show changes in earth's climate zones, a black and white map of the earth (white for landmass and black for water) was edited to isolate each of earth's climate zones and make an individual texture for each. This was achieved by first duplicating the original image 4 times (one for each climate zone) and then on one of the layers isolating the arctic zone using the lasso tool in photoshop to draw the borders. After that is complete, one can invert the selection and paint everything else black. This process can be repeated for each climate zone layer, a way of speeding up the process is to select the previous layers and delete those sections on the new layer so that there is less to deal with.

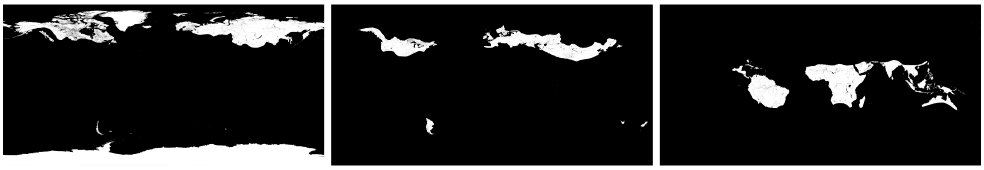

Figure 189: Textures: Polar Zone, Temperate zone, and Tropical Zone

Changes to water levels required the editing of two different textures, editing a black and white ocean mask and a normal colored image of the earth. Using online references to see what areas of the earth would flood, the ocean mask required only painting those areas black. Editing the color version was a bit more complicated as there are land masses underneath the ice caps that need to be considered and recolored. First step was to find an image of where there is a landmass underneath the ice so that it can be used as a point of reference as to what to delete. The easiest way of achieving this is to import the reference image into an image editing program with the colored earth texture. Go to the layer with the reference image and select with selection tool the ocean. Then with that selection activated, click on the layer with the texture you want to edit and fill the selection with the same shade of blue as the ocean in the image. Since there is no longer any ice, these new areas have to be recolored. Quick select the areas to have better control of what is being recolored and use the stamp tool to copy the colors/textures from the land around it so that it blends in with the rest of the image.

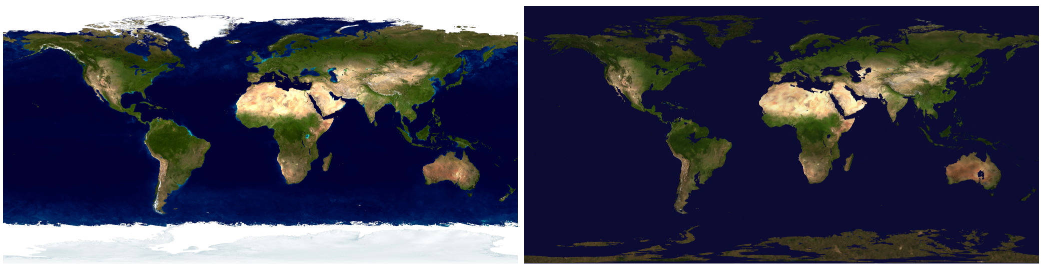

Figure 190: Textures: Earth with Ice caps, and Earth flooded

Cloud textures were altered using free cloud brushes found online and smudging the results to create a wispy look. For the venus like atmosphere that the earth poses after the oceans boiling away, a venus textures was downloaded from solarsystemscope.com and converted to black and white. The contrast was then increased so that the clouds would appear thicker in the blender file.

22 Summary and Conclusion

Overall it has to be said, that the main goal of developing a scientific animation about the future of the Sun and the Earth was reached. On the way to the goal a number of problems were encountered. Though most were able to be overcome, a few were not, and therein lie the shortcomings. The main difficulty of the research was the lack of unambiguous facts over the future of the Earth and Sun, due to the many varying scientific assumptions. These variances are exacerbated by the giant time spans that astrological science involves. For the animating itself, the largest problems were located within the forest scenes, which have a high complexity and therefore required a huge amount of time to render them. Hopefully in the future it will be possible to continue and improve the animation with the help of more reliable research sources and a higher computational power.

23 Attachment

Total Work Hours Spent

	Total	11.10.2018 - 17.10.2018	18.10.2018- 24.10.2018	25.10.2018 - 31.10.2018	01.11.2018 - 07.11.2018	08.11.2018 - 14.11.2018	15.11.2018 - 21.11.2018	22.11.2018 - 28.11.2018	29.11.2018 - 05.12.2018	06.12.2018 - 12.12.2018
Angela A.	73	4	3	4	4	7	3	4	5	9
Anna B.	73	4	3	4	4	7	3	4	5	9
Anna K.	118,5	4	2	4	5	6	11	10,5	4	5,5
Antonio S.	96	4	2	4	4	5	10	4	2	2
Daniel A.	118	4		6	4	5	14	16	8	11
Dustin K.	107	4	2	4	4	13	9	12	8	8
Laura C.	123	4	2	5	5	12	18	17	14	13
Leonie B.	117	4	3	4	5	13	18	7,5	5,5	9,25
Lucas O.	170,75	4	2	4	4	7	16,75	15	9	12
Majda S.	79	4	2	4	4	5	5	5	6	4
Marcel P.	113	4	1	4	4	5	11	5	4	2
Max L.	121	4		4	4	10	9,5	-	9	8
Michael D.	110,5	4	5	4	12	18	14	17	12	2,5
Panagiotis T.	77	4	2	4	4	4	5	5	4	6
Sebastian G.	161	4		4	4	8	10,5	-	7	5
Total	**1657,75**	**60**	**29**	**63**	**71**	**125**	**157,75**	**122**	**102,5**	**106,25**

	Total	13.12.2018 - 19.12.2018	20.12.2018 - 26.12.2018	27.12.2018 - 02.01.2019	03.01.2019 - 09.01.2019	10.01.2019 - 16.01.2019	17.01.2019 - 23.01.2019	24.01.2019 - 30.01.2019	31.01.2019 - 06.02.2019
Angela A.	73	7	-	-	2	8	5	4	4
Anna B.	73	7	-	-	2	8	5	4	4
Anna K.	118,5	7	5	6	18	9,5	13	3	5
Antonio S.	96	6	7	4	5	9,5	9	3	15,5
Daniel A.	118	10	-	-	7	8	12	13	
Dustin K.	107	5	-	-	4	6	12	4	12
Laura C.	123	6	4	2	4	8	9		
Leonie B.	117	11	2,5	5	8,75	8	5,5	3	4
Lucas O.	170,75	10	6	4	12	8	25	32	
Majda S.	79	9	-	5	5	8	4	5	4
Marcel P.	113	3	3	8	4,5	14,5	8	9	23
Max L.	121	9,5	-	6	13	17	22	5	
Michael D.	110,5	3	-	-	2	3	3	3	8
Panagiotis T.	77	5	2	6	7	7	4	5	3
Sebastian G.	161	12	11,5	2	29,5	37,5	21	5	
Total	**1657,75**	**110,5**	**41**	**48**	**123,75**	**160**	**157,5**	**98**	**82,5**

Work distribution

Daniel Angenendt, 21433, Medien- und Kommunikationsinformatik B.Sc.,

- Graphics
    - Scene 1: Intro (30 h spent)
    - Scene 3: shifting climate zones (40 h spent)
    - Scene 4: melting ice caps, sea levels rising (Space View) (10 h spent)
    - Scene 5: water boiling and evaporation (Space View) (10 h spent)
    - Scene 6: Venus like atmosphere (10 h spent)
    - Scene 7: Atmosphere evaporation (11 h spent)
- Documentation (8 h spent)

Angela Arzumanjan, 22197, Communication and Information Engineering B.Sc.,

- Research
    - Scene 4: melting ice caps, sea levels rising (7 h spent)
    - Scene 6: Venus like atmosphere (8 h spent)
    - Scene 9: red giant (12 h spent)
- Documentation (5 h spent)
- Space research for animation (65 h spent)
- Meetings (26 h spent)

Anna Bõstrajakova, 22198, Communication and Information Engineering B.Sc.,

- Research
    - Scene 3: shifting climate zones (9 h spent)
    - Scene 8: Sun, pre red giant (11 h spent)
- Documentation (6 h spent)
  (Research: Scene 3 and 8)
- Space and Earth research for animation (62 h spent)
- Meetings (26 h spent)

Leonie Bremer, 21050, Environment and Energy B.Sc.,

- Creating Poster (2 h spent)
- Research:
    - Scene 4: melting ice caps, sea levels rising (16 h spent)
    - Scene 6: Venus like atmosphere (24 h spent)
    - Scene 7: Atmosphere evaporation (25 h spent)
- Documentation (19 h spent)
- Putting final paper together (5 h spent)
- Meetings (26 h spent)

Laura Cosio, 22824, Digital Media M.A.,

- Graphics
    - Storyboard (28 h spent)
      (Research, Image Collection/Editing, Rough Draft, Creating Timeline, Final Version)
    - Textures (10 h spent)
      (Image collecting, Image editing, Blender test)
    - Sun/Blender practice (20 h spent)
      (1st version of sun (unused), modeling planet tutorials)
    - Scene 5: water boiling and evaporation (Space View) (6 h spent)

        (Flooding and atmosphere change)
    - Scene 13: planetary nebula (30 h spent)
      (Look for reference images, Tutorials, Setting up Gas core, Smoke, Create Gas clouds, Color correction, Animation)
- Meetings (29 h spent)
- Documentation (5 h spent)

Michael Delaney, 22293, Environment and Energy B.Sc.,
- Research
    - Solar (63.5 h spent)
    - Climate zone shift research (6 h spent)
    - Creating chronological spreadsheet of events between now and Sun's end.
      (Includes values for the following: Luminosity, Solar radius, Temperature at Sun's surface, Descriptions of the physical appearance of the solar surface at each stage, Detailed information on what is taking place within the sun at each stage, Timeframes for all events) (10 h spent)
- Editing poster (1 h spent)
- Cutting & Editing final animation (TBA)
- Documentation (8 h spent)
- Other administrative tasks (inc. meetings) (22 h spent)

Sebastian Golks, 21038, E-Government B.Sc.,
- Graphics (Scene 2: extreme weather conditions; burning forest)
    - Create ivy (2 h spent)
    - Create bush (4 h spent)
    - Create tree trunks (9 h spent)
    - Create grass (3 h spent)
    - Create wetlook (10 h spent)
    - Create ground (10.5 h spent)
    - Create rocks (7 h spent)
    - Create background (12 h spent)
    - Animations (26 h spent)
    - Composing Scene (27.5 h spent)
- Documentation (26 h spent)
- Meetings (24 h spent)

Anna Kopal, 21117, Environment and Energy B.Sc.,
- Creating Poster (29 h spent)
- Research:
    - Scene 1: Intro (7 h spent)
    - Scene 2: extreme weather conditions (9 h spent)
    - Scene 5: water boiling and evaporation (13,5 h spent)
- Documentation of own parts (11 h spent)
- Setup of final paper (16,5 h spent)
- Writing Introduction, Summary, Conclusion of final paper (6,5 h spent)
- Meetings (26 h spent)

Dustin Koschmann, 21130, Medien- und Kommunikationsinformatik B.Sc.,

- Meetings (22 h spent)
- Graphics:
    - Blender Training (20 h spent)
    - Creating the sun (12 h spent)
    - Scene 8: Sun, pre red giant (3 h spent)
    - Scene 9: red giant (2 h spent)
    - Scene 10: helium flash (3 h spent)
    - Scene 11: yellow decreasing sun (Horizontal Branch) (5 h spent)
    - Scene 12: red giant 2.0 (AGB) (8 h spent)
    - Compositor (10 h spent)
- Documentation (24 h spent)

Max Lietzau, 21040, E-Government B.Sc.,

- Research After Effects (19 h spent)

    (Animating Text, Setting Keyframes, Having 3D effects in a 2D picture, Keying)
- Graphics:
    - Create Ashes (16 h spent)
    - Create Tree (31 h spent)
    - Burning Tree (36 h spent)
- Documentation (19 h spent)

Lucas Osten, 21192, Medien- und Kommunikationsinformatik B.Sc.,

- Graphics
    - Scene 1: Intro (30 h spent)
    - Scene 3: shifting climate zones (40 h spent)
    - Scene 4: melting ice caps, sea levels rising (Space View) (10 h spent)
    - Scene 5: water boiling and evaporation (Space View) (10 h spent)
    - Scene 6: Venus like atmosphere (10 h spent)
    - Scene 7: Atmosphere evaporation (11 h spent)
- Documentation (60 h spent)

Marcel Paturej, 21129, Medien- und Kommunikationsinformatik B.Sc.,

- Project Management (5 h spent)

    (Setting up Trello, Setting up Overleaf (LaTeX) document for collaboration, Setting up Google Spreadsheet ("Hours spend"), Setting up Discord Server (channels and roles), Improve Google Drive folder structure)
- Participation in meetings (20 h spent)
- Blender Training (17 h spent)
- Poster Session (4 h spent)
- Documentation (30 h spent)

    (Discord, Trello, Blender, Tree, Rendering)
- Graphics:
    - Create animatable tree (9 h spent)
    - Create animatable grass (11.5 h spent)
    - Animation of water in Forest Scene (1 hour spent)
- Rendering Research, Testing and execution (≠ Render Time) (30 h spent)

(Network-Rendering, (Third-party) Renderfarms, Blender 2.8 Render-System, Improving speed and quality, Optimizing scenes for network rendering, Testing different render types on University PCs, Execution (+ control) the render process of the final animation)

Antonio Sarcevic, 21193, Medien- und Kommunikationsinformatik B.Sc.,

- Project Management (10 h spent)
- Graphics:
  - Scene 4: melting ice caps, sea levels rising (Close-Up) (35 h spent)
  - Scene 5: water boiling and evaporation (Close-Up) (15.5 h spent)
- Documentation (20 h spent)
- Rendering execution (≠ Render Time) (8 h spent)
- Meetings (+ preparation) (30 h spent)

Majda Suljanovic, 21139, Medien- und Kommunikationsinformatik B.Sc.,
(Some hours overlap due to parallel working)

- Graphics:
  - Fire (13,5 h spent)
  - Rain (4 h spent)
  - Scene 2: extreme weather conditions (Rainforest) (27,5 h spent)
- Documentation (6 h spent)
- Meetings (29 h spent)
- Blender Training (18 h spent)

Panagiotis Tsitsos, 21138, Medien- und Kommunikationsinformatik B.Sc.,

- Graphics:
  - Create Trees (12 h spent)
    (Modular Tree creation, Create different kind of Trees)
  - Create large scale forest (16 h spent)
    (Create Trees, Export Images of the trees, Create forest with render friendly trees 2D trees looking 3D)
  - Scene 2: extreme weather conditions (Rainforest) (8 h spent)
    (Import trees, Change textures)
- Documentation (9 h spent)
- Blender training (5 h spent)
- Meetings (27 h spent)

References

[1] Falk Herwig. AGB stars evolution & nucleosynthesis. In *Proceedings of International Symposium on Nuclear Astrophysics - Nuclei in the Cosmos - IX — PoS(NIC-IX)*. Sissa Medialab, dec 2010.

[2] Sun Kwok. Transition from red giants to planetary nebulae. In *Late Stages of Stellar Evolution*, pages 321–335. Springer Netherlands, 1987.

[3] Georges Michaud, Georges Alecian, and Jacques Richer. Horizontal-branch stars. In *Atomic Diffusion in Stars*, pages 217–233. Springer International Publishing, 2015.

[4] L. Piau, P. Kervella, S. Dib, and P. Hauschildt. Surface convection and red-giant radius measurements. *Astronomy & Astrophysics*, 526:A100, jan 2011.

[5] I.-Juliana Sackmann, Arnold I. Boothroyd, and Kathleen E. Kraemer. Our sun. III. present and future. *The Astrophysical Journal*, 418:457, nov 1993.

[6] E. Vassiliadis and P. R. Wood. Evolution of low- and intermediate-mass stars to the end of the asymptotic giant branch with mass loss. *The Astrophysical Journal*, 413:641, aug 1993.

[7] E. Vassiliadis and P. R. Wood. Post-asymptotic giant branch evolution of low- to intermediate-mass stars. *The Astrophysical Journal Supplement Series*, 92:125, may 1994.

[8] P. R. Wood and D. M. Zarro. Helium-shell flashing in low-mass stars and period changes in mira variables. *The Astrophysical Journal*, 247:247, jul 1981.

24 Sources

1. AgenZasBrothers. YouTube. March 24, 2011. Accessed January 10, 2019. https://www.youtube.com/watch?v=nipFueeCyyU.

2. AgenZasBrothers. YouTube. March 24, 2011. Accessed January 10, 2019. https://www.youtube.com/watch?v=3PbpfprO7XA.

3. Geek, CG. YouTube. January 20, 2017. Accessed January 10, 2019. https://www.youtube.com/watch?v=gQUO9yL2vYQ.

4. Guru, Blender. YouTube. January 20, 2015. Accessed January 10, 2019. https://www.youtube.com/watch?v=u-zK7Bu8cAI.

5. Pax, Sardi. YouTube. July 05, 2014. Accessed January 10, 2019. https://www.youtube.com/watch?v=lYTVOdcgyP8.

6. TutsByKai. YouTube. January 20, 2018. Accessed January 10, 2019. https://www.youtube.com/watch?v=jZPL_qRoRoY.
7. Wayward Art Company. YouTube. October 28, 2018. Accessed January 10, 2019. https://www.youtube.com/watch?v=hC36GPUcv-I
8. https://tass.ru/spec/climate
9. https://solarsystem.nasa.gov/solar-system/sun/in-depth/
10. https://solarsystem.nasa.gov/solar-system/sun/overview/
11. http://faculty.wcas.northwestern.edu/ infocom/The%20Website/end.html
12. https://www.creativeshrimp.com/spacevfx.html
13. https://www.brusheezy.com/
14. https://pixabay.com
15. https://e360.yale.edu/features/redrawing-the-map-how-the-worlds-climate-zones-are-shifting
16. https://www.evolving-science.com/space-stars/our-sun-may-turn-nebula-when-it-dies-new-study-00660
17. http://www.nat-geo.ru/universe/917393-khabbl-pokazal-kak-umret-solntse/
18. http://www.astronautica.ru/solnechnaya-sistema/planeta-zemlya/90.html
19. http://spacegid.com/diagramma-rassela-gertsshprunga.html#ixzz5ZZukFZmf
20. https://vesl.jpl.nasa.gov/sea-level/slr-gfm/
21. https://www.solarsystemscope.com/textures/
22. http://www.shadedrelief.com/natural3/pages/textures.html
23. https://ezproxy2.hsrw.eu:2280/content/pdf/10.1007%2F978-3-319-11388-3.pdf
24. https://www.nationalgeographic.com/environment/2018/11/climate-change-california-wildfire/
25. https://www.theguardian.com/australia-news/2018/dec/04/bushfires-tropics-queensland-terrifying-new-reality-cyclones-flooding
26. Barroso, Miguel. YouTube. May 21, 2013. Accessed January 11, 2019. https://www.youtube.com/watch?v=fPXdPnCoW0M.

27. Cookie, CG. YouTube. April 28, 2017. Accessed November 24, 2018. https://www.youtube.com/watch?v=PYHOV3bVIG0.

28. https://github.com/MaximeHerpin/modular_tree/wiki

29. yojigraphics. YouTube. September 30, 2018. https://youtu.be/4PEsSpz2LZA

30. Zacharias Reinhardt. YouTube. March 01, 2017. https://www.youtube.com/watch?v=BtUS8QTsVZA

31. Zacharias Reinhardt. YouTube. March 01, 2017. https://youtu.be/aLVodLos41Q

32. CG Geek. YouTube. January 20, 2017. Accessed November 18, 2018. https://www.youtube.com/watch?v=gQUO9yL2vYQ

33. Wayward Art Company. YouTube. May 28, 2018. Accessed November 26, 2018. https://www.youtube.com/watch?v=hC36GPUcv-I

34. Poliigon. YouTube. June 28, 2017. Accessed December 12, 2018. https://www.youtube.com/watch?v=aH6XPsEmozk.

35. Cookie, CG. YouTube. September 12, 2018. Accessed December 06, 2018. https://www.youtube.com/watch?v=zpgnNktugro.

36. Cookie, CG. YouTube. June 21, 2018. Accessed December 13, 2018. https://www.youtube.com/watch?v=rsy0mtIOb8A.

37. Wireheadking. YouTube. September 01, 2012. Accessed December 13, 2018. https://www.youtube.com/watch?v=39fyHYq4rFU.

38. Antoan Shiyachki. envatotuts. November 27, 2010. Accessed February 06, 2019. https://cgi.tutsplus.com/articles/freebie-8-awesome-ocean-hdris–cg-5684

39. CG Geek. YouTube. July 27, 2017. Accessed February 06, 2019. https://youtu.be/qSafYNQrodk

40. Videezy. Accessed February 06, 2019. https://www.videezy.com/fire-and-smoke/13093-dense-smoke-going-up-and-creating-white-swirls-slowly-in-4k

41. BEAM Studios. YouTube. June 29, 2018. Accessed February 06, 2019 https://www.youtube.com/watch?v=rmf6l0RN-Cc

42. Poliigon. Accessed February 06, 2019
https://www.poliigon.com/texture/ground-clay-002

43. Blender Guru. February, 2016. Accessed November 11, 2018.
https://www.blenderguru.com/tutorials/earth-cycles

44. Fictonal Reality User: Izac. November 26, 2018. Accessed December 10, 2018.
https://www.frealmedia.com/blog/tutorial-terraform-mars-in-blender

45. AgenZasBrothers.YouTube. January 9, 2011. Accessed November 16, 2018.
https://www.youtube.com/watch?v=4NLsE3j2hm0

46. NASA Visible Earth. Database Updated February 6, 2019. Accessed January 11 , 2019
https://visibleearth.nasa.gov/view_cat.php?categoryID=1484

List of Figures