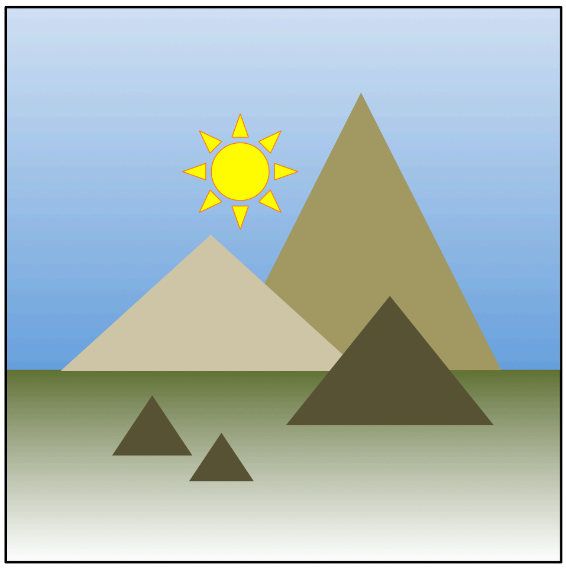
Desktop Exploration of Remote Terrain



User Guide for Version 1.0 Beta

TABLE OF CONTENTS

Introduction

Desktop Exploration of Remote Terrain (DERT) is a scientific simulation application for exploring large Digital Terrain Models (DTM) of our world and other planets of the solar system in 3D. It aids in understanding topography and spatial relationships of terrain features, as well as performing simple analysis tasks relevant to the planetary science community. DERT employs an interactive virtual world for 3D visualization and navigation, and also provides features for simulating lighting and shadows, display of multiple surface layers, color maps, landmarks, measurement, and terrain profiling.

DTMs are constructed from imagery acquired by satellites and other remote sensing platforms. They can be found on websites such as the NASA Planetary Data System, the USGS Earth Explorer, and the HiRISE site at the University of Arizona, among others. A DTM consists of layers of co-registered imagery that are spatially referenced to a body, usually a Digital Elevation Model (DEM) and one or more orthoimages. These layers are typically very large raster files, and in order to facilitate rendering performance, they are preprocessed into a multi-resolution data structure called a *Landscape*. DERT ingests the landscape and creates a virtual world, adding lighting and other elements.

A landscape is a directory holding the set of raster layers, each layer stored as a subdirectory containing a multi-resolution tiled image pyramid. Using the pyramid tiles, DERT creates a 3D mesh from an elevation layer created from a DEM and drapes orthoimage layers on the mesh. As the user moves the viewpoint, DERT renders close terrain with higher resolution tiles and far terrain with lower resolution tiles. See the section on *LayerFactory* to learn more about layers and how to build a landscape.

With DERT, a desktop explorer can:

- View a remote landscape in 3D.
- Place landmarks at interesting locations.
- Measure the distance between landmarks.

- Simulate the sunlight and shadows for the region.
- View elevation color maps blended with orthoimage layers.
- Place a camera with a synthetic a view of the terrain in the landscape.

System Requirements

The primary platform for DERT is Apple Mac OS X 10.8 or later, but it is also available for Linux Red Hat 6. It requires a 64-bit architecture, the Java 6 JRE or later, and OpenGL 2 or later. For the examples in this user guide, we will use a relatively small landscape called Victoria Crater. You should have at least 200 MB of disk space available and at least 2 GB of RAM.

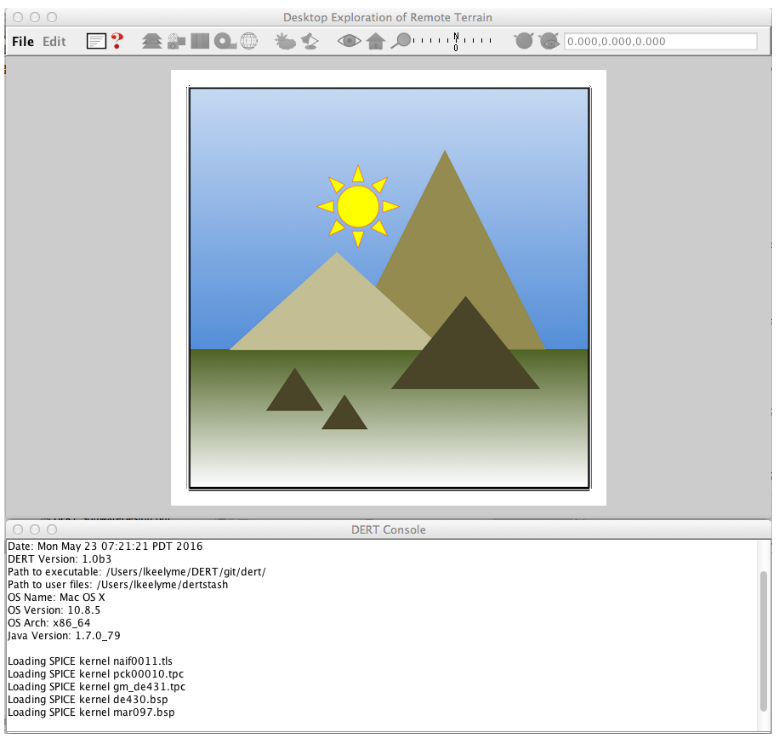
DERT uses the left, middle, and right mouse buttons and the mouse scroll wheel. A 3-button mouse is recommended. The Mac track pad can be configured to use all but the middle mouse button in Apple System Preferences and works with a little practice. See *Appendix A* for instructions.

Installing the Geospatial Data Abstraction Library (GDAL) is recommended. It can be downloaded from www.gdal.org.

Getting Started

Download the DERT application and VictoriaCrater zip files and unzip both. Place the resulting installation directory anywhere you wish but keep its contents intact. The path to the DERT installation directory should not contain any spaces. Do not remove or rearrange any of its files. You may edit the *dert* script to set the path to Java and/or change the memory allocation. See the file called *README.txt* in the installation directory for instructions. To start DERT, run the dert command in the installation directory on the command line. Mac users with Java 1.7 or later set as their default JRE may double-click on the dert icon to run the application.

The main DERT window will appear on your screen. A directory called *dertstash* will be created in your home directory the first time DERT is invoked. This directory contains session information and the log file.



DERT main window and console

The console is shown here positioned below the main window. Messages from DERT are displayed here during your session. This information is also logged to the *dert.log* file in the dertstash directory.

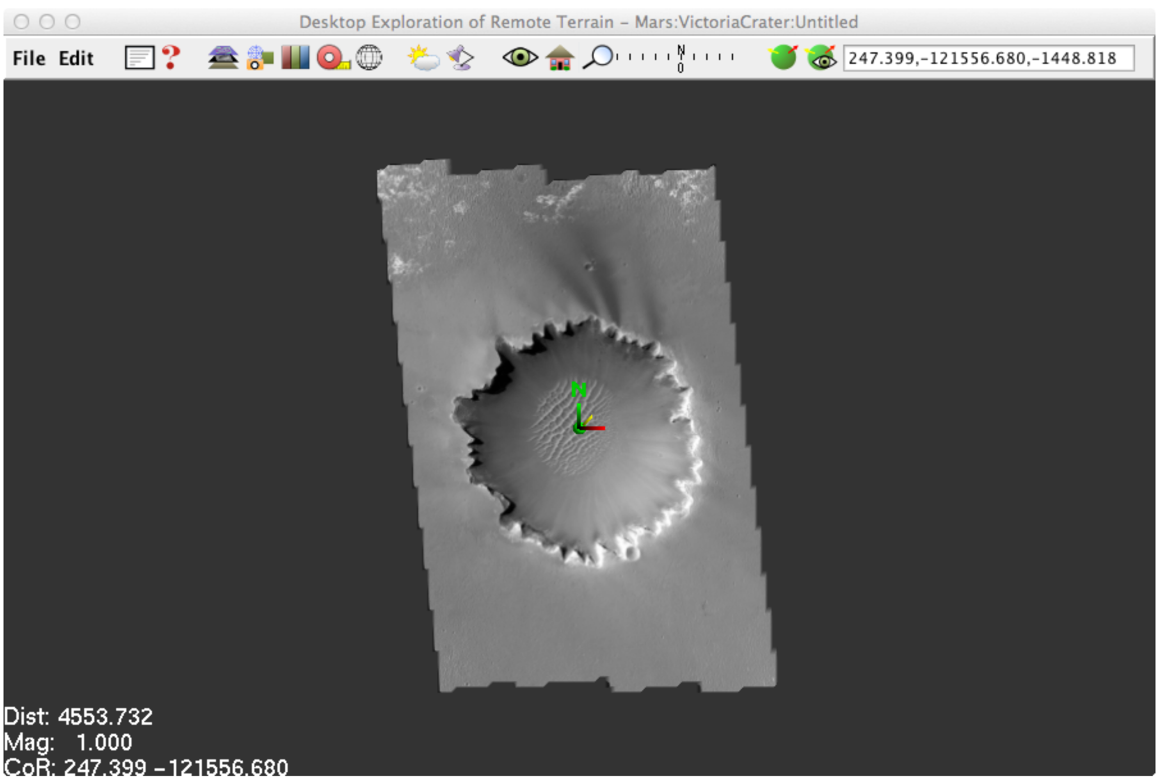
A number of preferences are kept in the file called *dert.properties*. See README.txt to find the location of this file. The format of dert.properties is “key=value”. To set a preference for a given key, change the associated value.

View a Virtual World

Next, you need to load a landscape. At the top of the DERT main window you will see 2 menus: *File* and *Edit*.

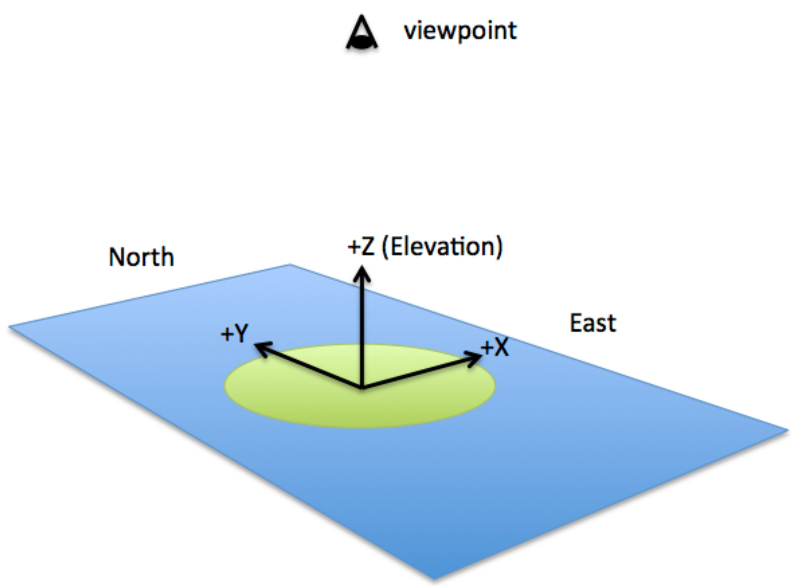
Example 1: View a Landscape

1. Select *File>Open Landscape* and a file dialog will appear.
2. Browse to and select *VictoriaCrater* in the dialog. Landscapes are indicated with the icon .
3. Press *New Configuration*. The dialog will disappear and a view of Victoria Crater will appear in the DERT main window. NOTE: double-clicking on *VictoriaCrater* will also create a new configuration.



The Victoria Crater landscape from the default viewpoint

The DERT main window displays the virtual world containing the Victoria Crater landscape in the *worldview*. The viewpoint starts out in the default position: overhead and looking down at the center of the landscape with North up and East to the right. A three-pronged crosshair, the center of rotation (CoR) crosshair, appears in the middle of the view. The prongs represent the 3 axes of the virtual world. The large green N indicates north (+Y), the red axis points east (+X), and the blue axis points up (+Z).



Default (overhead) viewpoint

DERT uses the projection from the original raster files. If the data are not projected (in longitude/latitude), DERT applies an equirectangular projection. Coordinates may be displayed in meters or longitude and latitude (degrees).

Toolbar

Once a landscape is loaded, the menus and buttons in the toolbar along the top of the window will be fully enabled. Here is a quick synopsis of each control's function.

- ***File***: A menu for accessing file operations in DERT.
- ***Edit***: A menu for general editing tasks concerning the worldview, and undo.
-  ***Console***: Open the console view.
-  ***Help***: Open the help view.
-  ***Surface***: Edit the landscape surface and layers.

- ***Map Elements***: Open a view for adding, removing, and editing landscape map elements.
- ***Color Bars***: Open a view displaying the color maps currently in use.
- ***Tape***: Enable/disable the tape measure.
- ***Graticule***: Toggle display of Lon/Lat (degrees) or projected (meters) coordinates.
- ***Lighting***: Edit the light and shadow settings.
- / ***Light position***: This icon represents the lighting type (artificial or solar) and opens a window used for positioning the light.
- ***Viewpoint***: Open a view of the viewpoint list and for changing viewpoint properties.
- ***Reset***: Set the viewpoint to the default (overhead) position.
- ***Zoom***: When enabled, the mouse scroll wheel will change the magnification instead of the distance from viewpoint to the center of rotation.
- Compass showing the current bearing of the viewpoint in degrees (0-360) from North.
- ***Marble View***: View landscape properties at the current marble location.
- ***Seek Marble***: Move the viewpoint close to the marble.
- 246.893,-121556.174,-1448.818 Marble location field showing the current position of the marble. To change the marble location, enter a new position and hit return. You may enter just two coordinates and the elevation will be provided.

Hover the cursor over a control to view a reminder of its function.

The Current Viewpoint

Now that you have a virtual world, you may traverse it by changing the viewpoint. Navigating in a 3D application can take some practice. If you get lost, press *reset* in the toolbar and the viewpoint will move to the default position.

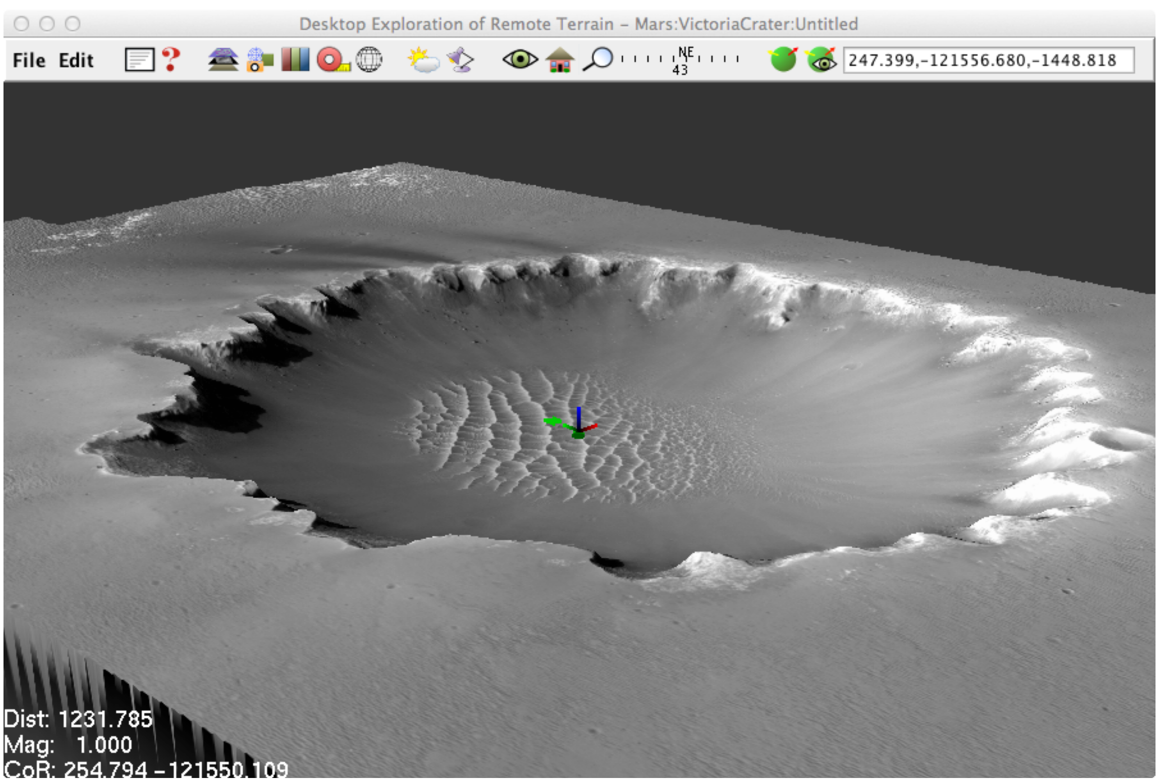
DERT uses several mouse movements to control the viewpoint location. Drag the cursor with the left mouse button pressed down to translate the viewpoint in the plane of the landscape. Given enough momentum, the viewpoint will continue to move after you release the mouse, and then slow to a stop. Press any mouse button down to stop the motion. Drag the cursor with the right mouse button down to rotate the viewpoint about the CoR. Drag the cursor with the middle button down to translate the viewpoint in the plane of the screen. Roll the mouse scroll wheel to dolly the viewpoint away from or towards the CoR. The mouse scroll direction may be set in dert.properties. In summary:

- To ***translate in the plane of the landscape***, drag with the *left* mouse button pressed.
- To ***translate in the plane of the screen***, drag with the *middle* mouse button pressed.
- To ***rotate***, drag with the *right* mouse button pressed.
- To ***dolly or zoom***, roll the *scroll wheel.*

For small single steps of rotation, press the arrow keys. Each step rotates 0.25 degree. Hold down the control key while translating or rotating with the mouse to reduce the speed.

Example 2: Create an Oblique View

1. Press *reset* to place the viewpoint at the default position.
2. Place the cursor inside the bottom left corner of the screen.
3. Press the right button down on the terrain. Drag the mouse up and right to rotate the scene to an oblique view. The toolbar compass should change to indicate the current bearing.
4. Roll the mouse scroll wheel to move the viewpoint closer to the landscape.
5. Press the left mouse button down and drag to move the viewpoint along the plane of the landscape.



Oblique view of Victoria Crater landscape

Note that the CoR crosshair always remains at the center of the rotation. At the end of each movement the crosshair elevation is updated. To hide/show the crosshair, select *Edit>Show Center of Rotation Crosshair*.

Viewpoint information is displayed in a text overlay located in the bottom left corner of the worldview. This overlay shows the distance from the viewpoint to the CoR, the current magnification, and the location of the CoR.

Example 3: Set the Center of Rotation

1. Right-click with the mouse at the desired location and select *set center of rotation* from the context menu. The scene will center on the new location.
2. Place the cursor at a different location and single-click with the center mouse button. The scene will center on the new location.

DERT defaults to dolly mode. In this mode, the scroll wheel moves the viewpoint in and out from the center. You may also use magnification to enlarge the scene. Activate this mode by pressing *zoom* in the toolbar. In this mode, scroll wheel movement will change the camera frustum for a true zoom instead of changing the location of the viewpoint. NOTE: The current magnification value is still applied even when you leave zoom mode.

While in dolly mode the viewpoint passes through objects in the scene and may run into clipping planes. In zoom mode this doesn't occur but there may be some distortion at extreme magnification levels. Only dolly mode causes the landscape tile resolution to change. Resetting the viewpoint will restore magnification to 1.

Example 4: Using Zoom Mode

1. Press *zoom* to change the mode. A check mark will appear in the icon to indicate the mode is enabled.
2. Roll the scroll wheel to change magnification. The scene will change.
3. Press *reset* to set the magnification back to 1.0 and press the *zoom* again (the checkmark disappears) to disable zoom mode.

Moving Objects and Terrain Following

Objects in DERT do not move in space, they must be dragged along a surface. This gives the user a point of reference for positioning. Sometimes you don't want an object to follow the terrain. You may move objects in the plane of the screen by holding the shift key down while dragging.

Example 5: Moving an Object

1. Right-click on the landscape surface to bring up the context menu and select *Add>3D Figure*. A red box will appear at the point where you clicked.
2. With the cursor over the box, hold the left mouse down until the cursor turns to a hand and the box highlights.

3. Drag the cursor. The box will move with it, following the terrain.
4. Release the mouse button. The cursor returns to the default arrow and the box stops moving.
5. Rotate the scene a little. And move the box again.
6. Move the box around on the dunes at the bottom of the crater. You will see it hop sometimes. This is because it has reached the top of the dune and moves to the next piece of ground under the cursor.
7. Hold the shift key down and drag the box. It will raise or lower along the screen plane. Rotate the scene to view the box floating above the terrain.

Exiting and Configurations

When you exit DERT, you will be asked if you would like to save the current configuration with the landscape. A configuration retains the state of the current DERT session including the viewpoint and the location and size of the worldview, among other settings. Once a landscape is open, you may save or create a new configuration from the File menu. You may also delete configurations from the File menu as well as open recent ones. Abort your exit from DERT by pressing *Cancel* when prompted to save a configuration.

NOTE: Closing the DERT main window with the window close button will produce the same behavior. However, using the Apple application menu “Quit” item will not. It simply closes DERT without prompting to save the current session. Your current session will be lost.

Example 6: Saving and Restoring a Configuration

1. Select *File*>*Exit* to quit DERT and the configuration prompt will appear.
2. Press *Yes* and a name prompt will appear.
3. Enter a name and press *OK*.
4. Start DERT.
5. Select *File*>*Open Landscape* and the file dialog will appear. Navigate to and select the VictoriaCrater pyramid. You will see your configuration appear in the list at the bottom of the dialog.
6. Select your configuration and press *Open*. DERT will open the landscape with the same viewpoint and window location.
7. Exit DERT. Select *No* when prompted to save the configuration.
8. Start DERT.
9. Select *File*>*Open Recent Configuration*>VictoriaCrater:*your config name* and DERT will open the landscape with the same viewpoint and window location.
10. Exit DERT. Select *No* when prompted to save the configuration.
11. Start DERT.
12. Select *File*>*Delete Configuration*. A file dialog will appear.
13. Navigate to and select the VictoriaCrater pyramid and your configuration will appear in the list at the bottom.

14. Select your configuration and press *OK*.
15. Press *OK* in the confirmation dialog. The configuration is deleted.

Worldview

Viewpoint List

To see detailed viewpoint information, open the viewpoint view by pressing the viewpoint button in the toolbar. At the right, this view displays the current viewpoint location, the direction it is looking, the azimuth and elevation (pan, tilt) of the direction, the distance from the center of rotation, the altitude above ground level, the magnification (zoom) scale factor, and the location of the center of rotation. You may edit all but the center of rotation directly.

On the left side of the viewpoint view DERT maintains a list of interesting viewpoints. You may add and remove viewpoints, change directly to a viewpoint, and go to the previous or next viewpoint in the list.

Additionally, you can make a “fly through” animation from your list of viewpoints. In the fly through, the camera moves to each viewpoint, interpolating frames between. Each viewpoint provides a key frame for the animation. Select the number of “in between” frames and the time between each frame. Optionally, you may ask DERT to loop through the animation repeatedly. To fly along a path, see the section on the *Path* tool for instructions.

Example 7: The Viewpoint List

1. In the viewpoint view, press *Add* to add the current viewpoint to the list.
2. Enter a viewpoint name and press *OK*. Your name will appear in the list.
3. Move the viewpoint with the mouse.
4. Repeat steps 1-4 several times to add multiple viewpoints to the list.
5. Select an entry in the list to change directly to the viewpoint.
6. Select one of the names in the list and then press *Delete* to remove the viewpoint. You will be prompted for confirmation.
7. Press the right and left arrows at the top of the list to step through the viewpoints.

Example 8: Fly the Viewpoint List

1. Press *Fly List* and a dialog will appear.
2. Press the *Play* button and DERT will play through the list with 10 *in between* frames for each two *key* frames (viewpoints).
3. Check the loop box and press *Apply*.
4. Press *Play* and the animation will continuously loop.
5. Press the *Pause* button and the animation will pause. Press *Play* and the animation will continue.
6. Press the *Stop* button to stop the loop.
7. Change the *Milliseconds Per Frame* field and press *Apply*.
8. Press *Play*. The animation will proceed at a different rate than before.

The Green Marble

The green marble indicates the location of the last selected point in the landscape. There are two arrows that emerge from the marble. The yellow one points to the main light. The red one represents the direction of the surface normal at the marble location. A view called the Marble view provides further information concerning the landscape at the marble location including:

- The location in projected coordinates (meters) and unprojected coordinates (Lon/Lat degrees).
- The surface normal vector at the marble.
- The direction vector to the main light source.
- The elevation (meters).
- The slope (angle of surface normal with horizontal).
- The aspect (azimuth of surface normal).

Example 9: The Green Marble

1. Press the marble button in the toolbar. The Marble view will appear.
2. With the left mouse button, single-click at an interesting point in the landscape. The green marble will appear at the picked point and the contents of the marble view will change. Additionally, the marble field at the top of the main window will change to the selected location.
3. Copy the contents of the marble field.
4. Single-click in the scene to move the marble.
5. Paste the saved contents into the marble field and press return. The marble moves back to the original position.
6. Press the marble seek button in the toolbar. The viewpoint moves to view the marble. The marble may be buried in the terrain (new tiles may be loaded when the viewpoint moves closer).

The Tape Measure

The tape measure is a rubber band tool for measuring distances and slopes. Press the tape toggle in the toolbar to enable it. In addition to distance, it reports slope, azimuth, and elevation change.

Example 10: Using the Tape Measure

1. Press the tape measure button in the toolbar. The cursor will change to a crosshair and the tape measure window will appear.
2. Single-click with the left mouse button on one side of the crater. A blue ball will appear at the point and a red rubber band with a second white ball will

be attached to the cursor. The coordinates at the cursor and the distance, slope, and azimuth of the line are updated as the cursor moves.

3. Single-click again with the left mouse button on the other side of the crater. The rubber band detaches and the window stops updating.
4. Single-click with the left mouse. The anchor moves to the new point and the rubber band is attached to the cursor as before.
5. Rotate the scene with the right mouse button. The rubber band remains attached while the scene rotates.
6. Single-click again with the left mouse to detach the rubber band.
7. Press the tape measure button or close the window. The tape measure and window disappear.

DERT uses a z-buffer to simulate the location of the terrain and the tape measure will be obscured. Sometimes it is helpful to be able to see the full tape measure no matter where it is lying in the terrain. Set the property *TapeMeasure.ZBuffer* to *false* to enable this feature.

Background Color

The background color can be changed to one of 3 preset colors for Earth, Moon, or Mars or to a custom color. Colors are entered via a color chooser. The preset and default backgrounds may be specified in *dert.properties*.

Example 11: Background Color

1. Select *Edit>Change Background Color*. The Background Color dialog will appear showing the current background color.
2. Select *MarsSky* from the Predefined menu and then press *OK*. The worldview background color changes.
3. Select *Edit>Change Background Color*.
4. Press the *Color* button. A color chooser appears.
5. Select a color and press *OK*. Then *OK* in the background color dialog. The background changes again.

Stereo Viewing

For landscapes with gray surfaces, view the virtual world in anaglyph stereo. Red/cyan glasses are required. You may adjust the focal distance and eye separation (units are meters) for comfort.

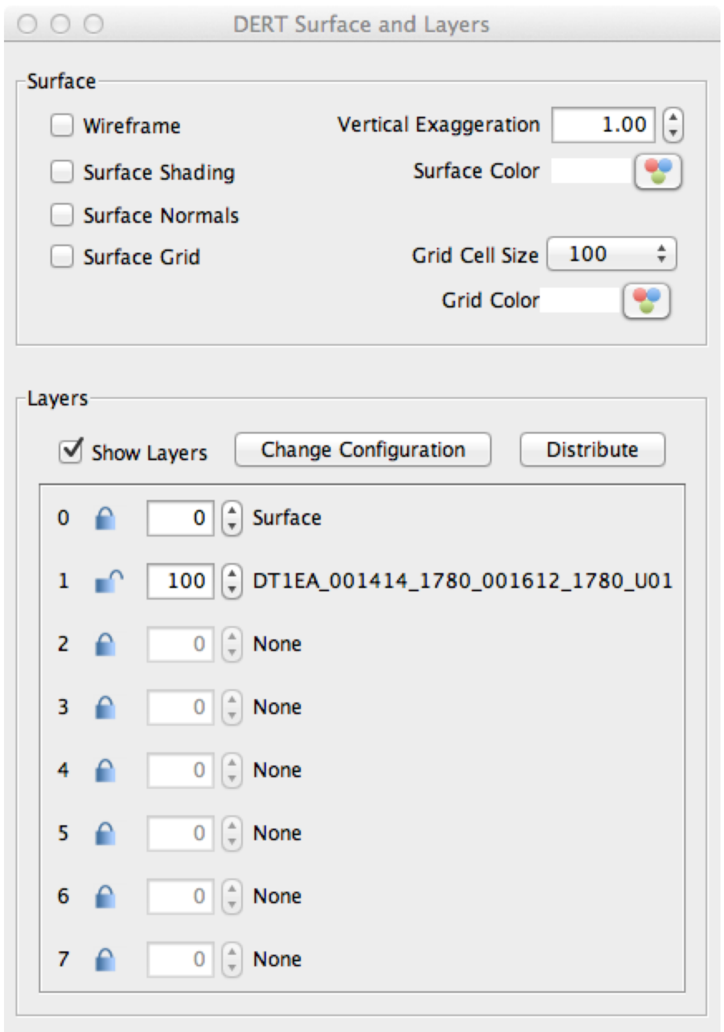
Example 12: Stereo Viewing

1. Select *Edit>Stereo* to change the viewing mode to anaglyph stereo. A dialog will appear.
2. Select *Stereo* and press *OK*. The view will change to anaglyph.

3. Select *Edit>Stereo* again and adjust the focal distance and eye separation.
4. Press *OK*. The color separation should change.
5. Open the dialog again, unselect *Stereo* and press *OK* to switch back to normal rendering.

Surface and Layers

The landscape contains an elevation layer and one or more image layers. The elevation layer is a special case and is visualized as a surface mesh whereas the other layers are draped on that mesh. There are a number of terrain configuration options that are accessed through the Surface and Layers view. To open this view, press the surface and layers button in the toolbar.



Surface and Layers view

Surface

The surface of the landscape is the 3D mesh that was created from the elevation layer of the DTM. It is typically rendered as a solid but can also be displayed as a wireframe. Normally, the image layers draped on the mesh provide all of the coloring and shading for the landscape. However, if there are no image layers, the surface can provide the shading as well as the color.

The Z coordinate of each vertex in the mesh represents the height of one pixel in the elevation layer. Exaggerated Z-axis scaling of the surface mesh enhances the visibility of terrain relief. The surface normal vector for each cell of the mesh can be displayed as an arrow.

Additionally, DERT provides a grid that covers the entire surface. It is draped like an image layer resulting in grid lines that follow the terrain. The cell size and color of this grid may be changed. The units of the grid are the same as the DEM.

Example 13: Surface Options

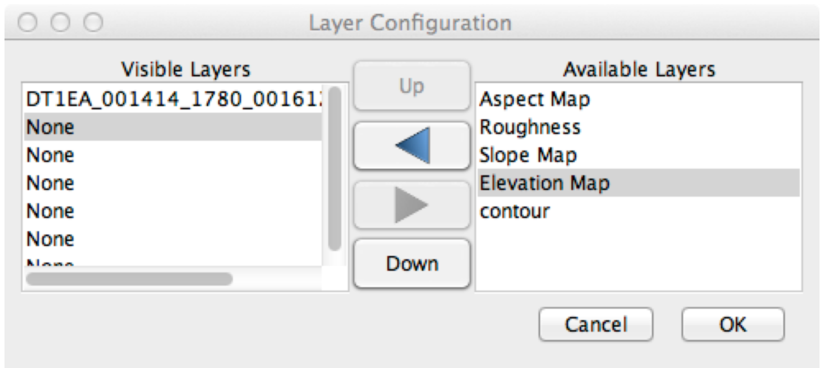
1. Press the surface and layers button. The Surface and Layers view appears.
2. Select the *Wireframe* checkbox. The landscape is drawn in wireframe.
3. Unselect the checkbox. The landscape returns to solid.
4. Select the *Surface Normals* checkbox. The surface normal vector at each mesh cell is displayed as a red arrow.
5. Unselect the checkbox. The surface normal arrows disappear.
6. Change the value in the *Vertical Exaggeration* field. The landscape stretches vertically.
7. Set the vertical exaggeration back to 1. The landscape returns to normal.
8. Select the *Surface Grid* checkbox. The grid appears.
9. Change the grid cell size. The grid changes.
10. Press the *Color* button for the grid. A color chooser appears.
11. Select a color and press *OK*. The grid color changes.
12. Unselect the *Surface Grid* checkbox. The grid disappears.
13. Unselect the *Show Layers* checkbox in the Layers section. Only the surface is displayed.
14. Press the *Color* button for the Surface Color. A color chooser appears.
15. Set the color and press *OK*. The surface changes to the color.
16. Select the *Surface Shading* checkbox. The landscape will display shading from the surface. To see this better, open the artificial light positioning view and adjust the elevation of the light (see below).
17. Unselect the *Surface Shading* checkbox, reset the surface color to white and select the *Show Layers* checkbox.

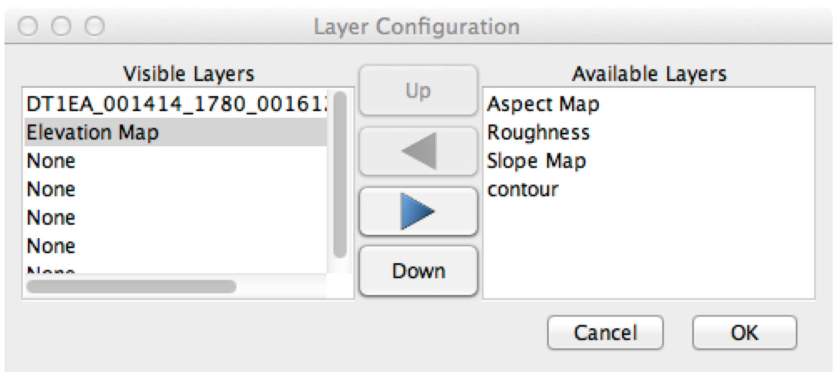
Layers

As seen in the above example, layers may be turned off so that only the surface is shown. The *Show Layers* button in the layers section is available for this purpose.

Image layers are draped on the surface of the 3D grid. These layers include the image layers in the landscape directory as well as special elevation derivatives and viewsheds. Elevation derivatives are layers derived from the elevation layer and include an elevation color contour, a slope map, and an aspect map. See the section on the *Camera* tool for a discussion of viewsheds.

You may have up to 7 layers displayed simultaneously. Layers are shown in the layer list and are configured with the Layer Configuration dialog.





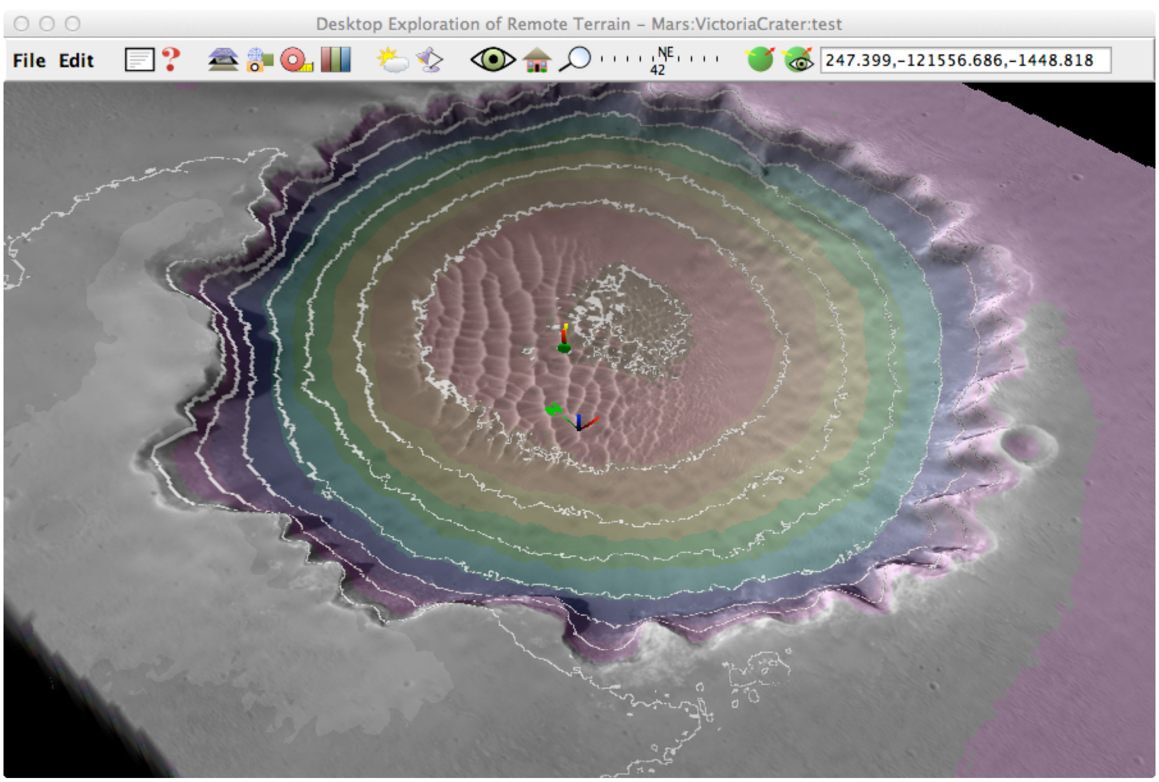
Top: default configuration with second layer and Elevation Map selected. Bottom: after pressing the left arrow, the Elevation Map is configured for the second layer.

The first layer must be an orthoimage. The default is the first orthoimage layer in the landscape occurring alphabetically by name. The other layers may be an orthoimage, an elevation derivative, or an instrument footprint/viewshed. Any layer may be absent. To change a layer, select it in the left column and then select the desired file in the right column. Press the *left arrow* to add the new layer to the configuration. Press the *Up* and *Down* buttons to change the order of the layers in the left column.

DERT will automatically adjust the blending of multiple layers at each pixel. The contribution of the layer is the number, the *blend factor*, at the left of the layer name showing the percentage of the color the layer contributes. The range of the blend factor is 0-100. When the blend factor of an unlocked layer is changed, the values of all other unlocked layers adjust. Pressing the lock icon next to the blend factor will remove that layer from auto-adjustment. Additionally, changes to it will not affect the other layers. Press the lock icon again to unlock the layer. NOTE: Layers created from vector files such as contours are overlays and are added in locked mode. Press *Distribute* to distribute the blend factors equally across all unlocked layers.

Example 14: Layer Selection

1. Press the *Change Configuration* button to open the layer configuration dialog.
2. Select the second layer in the left list.
3. Select Elevation Map in the right list and press the *left arrow*.
4. Press *OK*. You will see a color contour overlay of the elevation.
5. In the layers section, press the up or down arrows or type in a value to change the contribution of a layer. The other layer will adjust automatically.
6. Select the lock icon on the first layer.
7. Change the value of the blend factor in the second layer. The other layer does not auto-adjust.
8. Select the first layer lock icon again to unlock it and click once on an arrow. The blend factor values will be distributed between the layers.
9. Press the *Change Configuration* button again.
10. Change layer 3 to contour. Press *OK*. A contour map appears on the landscape.
11. Adjust the blend factors for the layers.

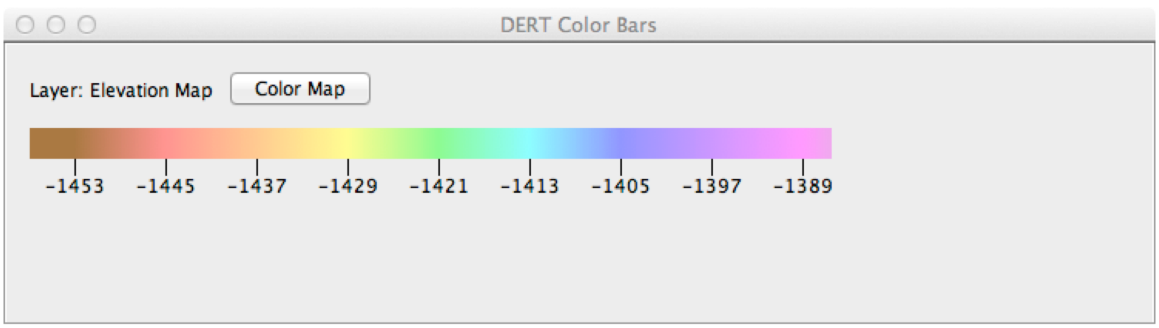


Victoria Crater with orthoimage, elevation color map, and contour layers.

Derivative layers use color maps. Color bars for those maps may be displayed by pressing the color bar button in the toolbar. The color maps are maintained as text files in the *colormap* subdirectory of the DERT installation directory. These files can be edited and new ones added and removed. They have a format consistent with those of GDAL. A gradient option is available if you wish the color map to make a gradual change from one color to the next.

Example 15: Color Map

1. Press the Color Bar button in the tool bar to show the elevation color map. The Color Bar view appears.
2. Press the *Color Map* button for the Elevation Map layer color bar. The Color Map Settings dialog appears.
3. Select *Gradient*. The color map is shaded gradually between colors.
4. Lower the *Maximum* value in the color map settings dialog. The color contours change in the scene as the range narrows.
5. Press *Default*. The contours return to the original setting.



Color Bar View with gradient color map.

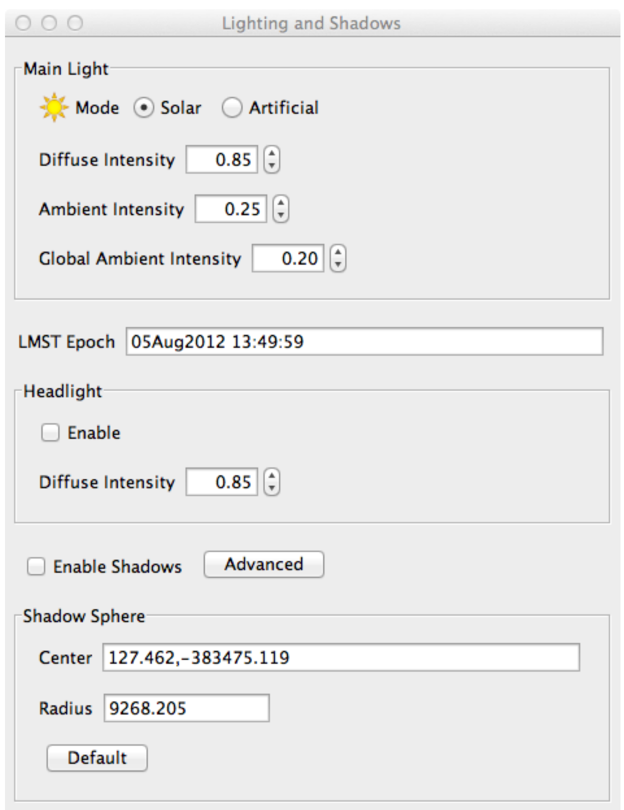
Lighting and Shadows

Lighting

DERT provides a single main light and an optional headlight. The headlight is attached to the viewpoint and always shines in the direction of the center of rotation. The main light has two modes: solar and artificial. In solar mode the position of the light is determined by the Sun's position at a given time. In artificial mode, the user positions the light by manipulating its azimuth (rotation about the Z axis) and elevation (rotation about the X axis). In both cases, a disk is drawn in the scene to represent the light source.

You may also change the diffuse (directed) and ambient (bounced and scattered) intensities of the main light. These values range from 0-1 where 1 is saturated. The global ambient intensity is the amount of ambient background lighting. This is mostly useful when the orthoimage is transparent or absent.

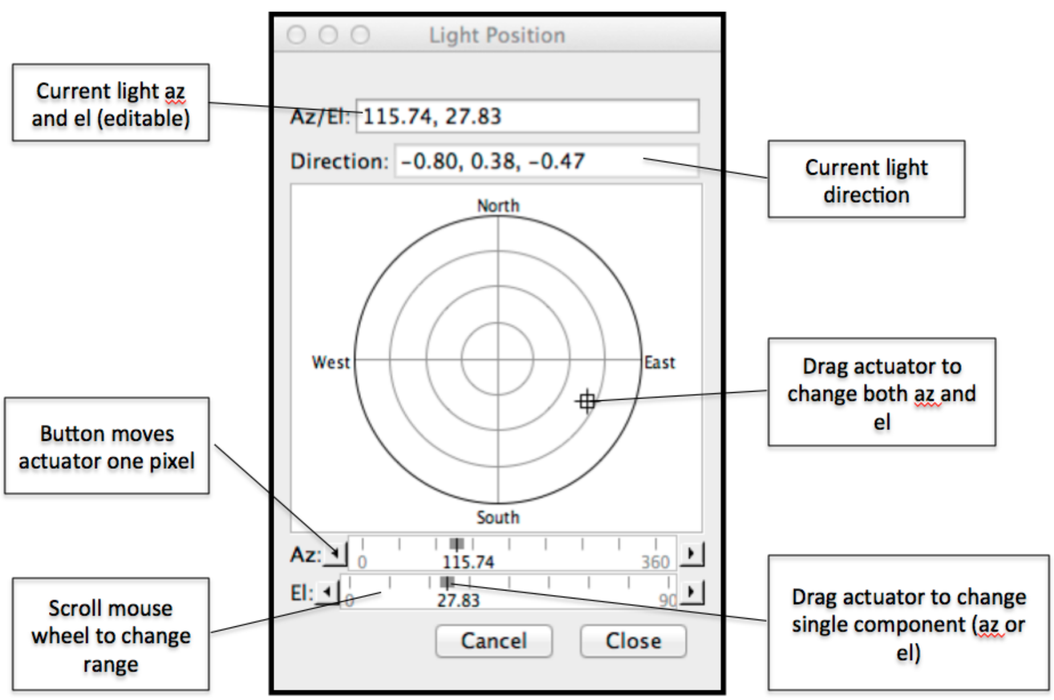
Additionally, this view allows you to configure the headlight. The headlight diffuse intensity is treated the same way as the main light. The headlight does not affect terrain that is shaded with orthoimages. It will highlight the surface and 3D figures.



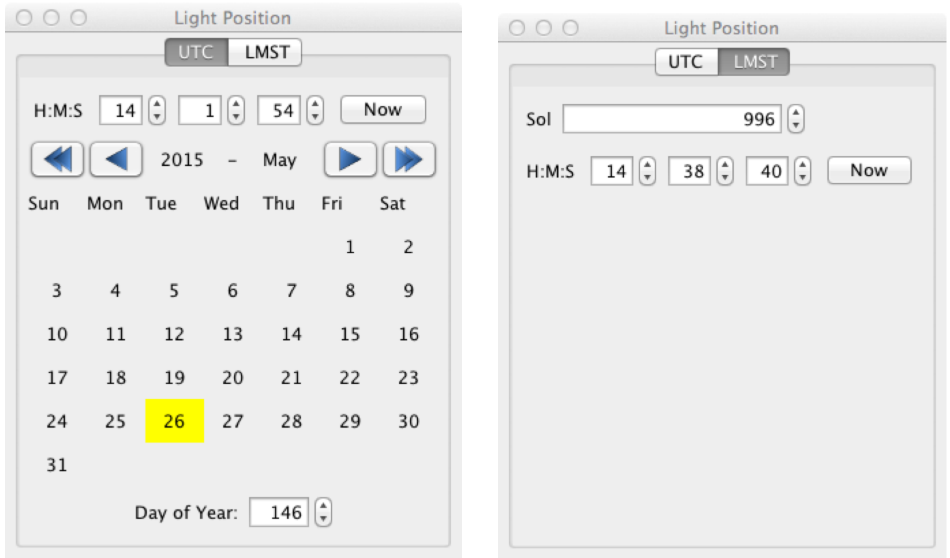
Example 16: Light Settings

1. Press the lighting and shadows button in the toolbar. The lighting view will appear.
2. Change the main light mode by pressing one of the two mode buttons in the Main Light section. The light mode icon will change.
3. Right-click with the mouse on the landscape and select *Add>3D Figure* from the context menu. You will see a red box at the location where you clicked.
4. Change the diffuse, ambient, and global intensities of the main light. You will see the affect on the figure.
5. Select the enable checkbox in the headlight section. The headlight will come on.
6. Adjust the intensity of the headlight.

Positioning the Light



View for positioning artificial light



View for positioning solar light. Left: UTC. Right: LMST.

Example 17: Artificial Light Position

1. Set the lighting mode to artificial in the lighting and shadows view.
2. Right-click on the landscape to invoke the context menu.
3. Select Add>3D Figure. A red box will appear.
4. Press the light position button in the toolbar. The artificial light position panel will appear.
5. Drag the crosshair to the outer edge of the circles. The lighting will change on the box and the yellow arrow on the marble will move.
6. Drag the puck in the Az and El fields. The crosshair will move and the Az/El and direction fields will change.
7. Type a new value into the Az/El field and hit return. The crosshair will move to the new position.

Example 18: Solar Light Position - UTC

1. Set the lighting mode to solar in the lighting and shadows view.
2. Right-click on the landscape to invoke the context menu.
3. Select Add>3D Figure. A red box will appear.
4. Press the light position button in the toolbar. The solar light position panel will appear.
5. Select UTC. A calendar will appear.
6. Press the single arrow buttons to change the month and the double arrow buttons to change the year.
7. Press the Now button to set the time and date to the current time and date.
8. Press the up and down buttons on the hour field and the yellow arrow on the marble will move as well as the disk representing the sun.

Example 19: Solar Light Position - LMST

1. Set the lighting mode to solar in the lighting and shadows view.
2. Enter the LMST epoch (the default is found in dert.properties).
3. Right-click on the landscape to invoke the context menu.
4. Select Add>3D Figure. A red box will appear.
5. Press the light position button in the toolbar. The solar light position panel will appear.
6. Press the LMST tab. The LMST panel will appear.
7. Press the Now button to set the time and date to the current time and date.
8. Press the up and down buttons on the hour and sol fields and the yellow arrow on the marble will move as well as the disk representing the sun.

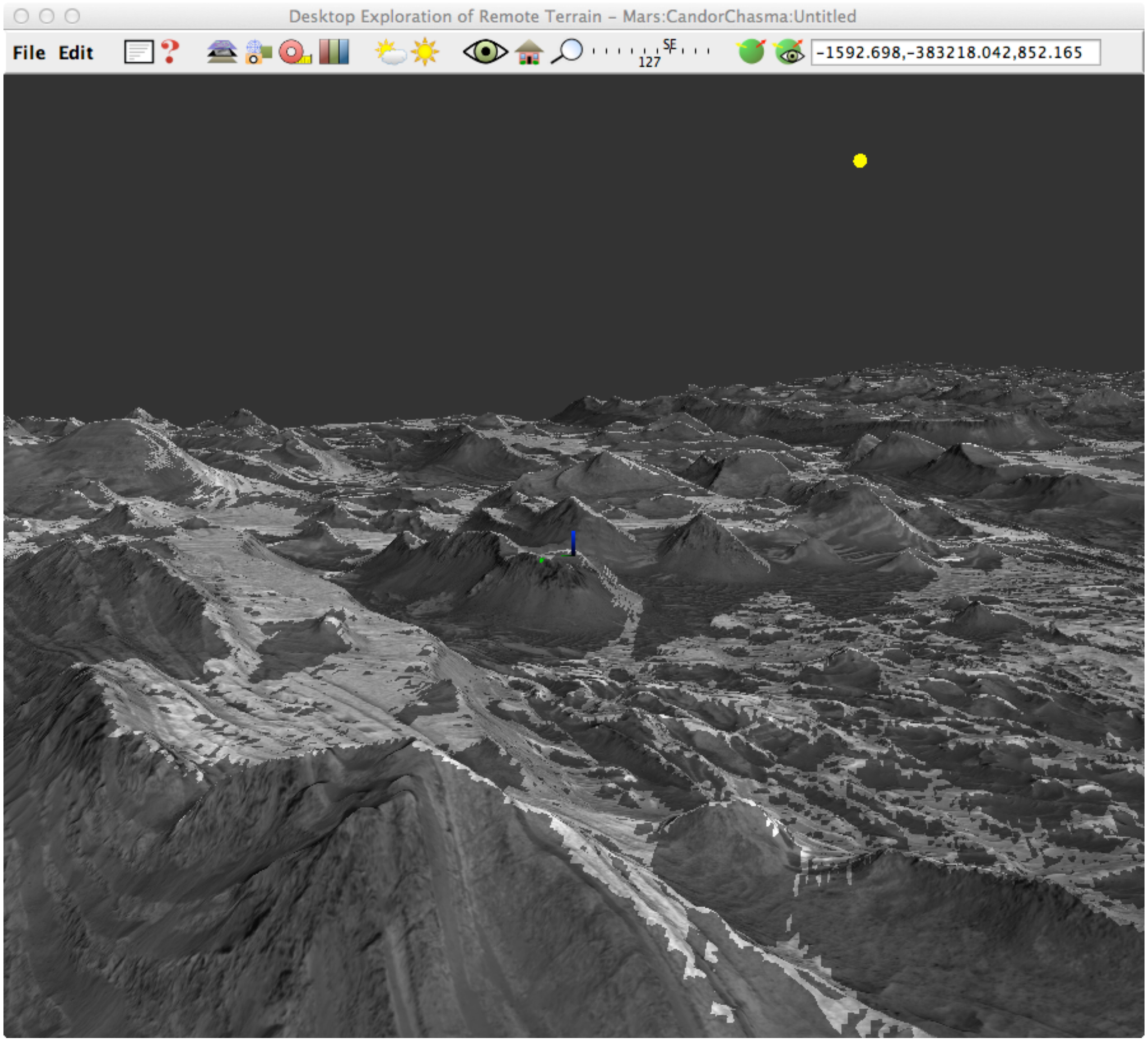
Shadows

DERT provides shadows with a technique called *shadow mapping*. The shadow sphere is the volume where the shadow is applied. All objects within the sphere are subject to shadowing. Anything outside the sphere will not be shadowed nor contribute to shadows. A shadow map is an image, and reducing the radius of the shadow sphere will increase the resolution of the shadow map. The default sphere is the full landscape. Edit the sphere center and radius in the lighting and shadows view and hit return to enter the changes. NOTE: The sphere center point is used to calculate the light direction vector.

The *Advanced* shadow options allow you to set some parameters for the shadow map. Normally, they are not needed but may be helpful in correcting shadow artifacts.

Example 20: Setting Shadows

1. Select Enable Shadows in the lighting and shadows view. Depending on the position of the light, shadows will appear in the scene.
2. Open the light position view.
3. Move the light close to the horizon. The shadows will move.
4. Copy the location from the marble field to the shadow sphere center.
5. Set the shadow sphere radius to 100.
6. Hit return. The shadow area shrinks to the smaller region and the shadow resolution increases.
7. Press Default. The default shadow sphere values appear.
8. Hit return. The shadows fill the entire landscape.
9. Unselect the Enable Shadows checkbox. The shadows disappear.



Shadows in Candor Chasma.

This feature may not be entirely accurate on large projected landscapes from small bodies such as the Moon as the curvature of the body contributes to the location of the shadows. Using the shadow sphere can help in these cases.

You may see the following or similar message in the DERT log:

CSPICE_N0065: CSPICE.spkpos: SPICE(SPKINSUFFDATA): [spkpos_c --> SPKPOS --> SPKEZP --> SPKSSB --> SPKGEO] Insufficient ephemeris data has been loaded to compute the state of ### (*body name*) relative to 0 (SOLAR SYSTEM BARYCENTER) at the ephemeris epoch *dateandtime*.

It is possible that you haven't loaded the required spk file for your body. See the NAIF website at http://naif.jpl.nasa.gov for instructions. The general rule is that you must add a kernel file for each body. See http://naif.jpl.nasa.gov/pub/naif/generic_kernels/spk/satellites/AAREADME_Satellite_SPKs for more information.

Map Elements

Map Elements are objects added to the scene to aid in viewing and exploring the landscape or to indicate an interesting feature. All map elements use elevation from the landscape as the third (Z) component of their location. DERT provides 3 types of map elements, *Landmarks*, *Tools*, and *LineSets*:

- **Landmarks**: objects that mark a place in the landscape.
    - A ***Placemark*** is an icon representing a location. It has no depth and does not produce a shadow. It always faces forward and its size changes so that it always appears to be the same regardless of the distance from the viewpoint.
    - A ***Figure*** is a three dimensional object representing a location and will produce a shadow. Its size is fixed or changes with the viewpoint. Additionally, the figure's orientation may be adjusted.
    - A ***Billboard*** is a user specified image placed in the scene. It always faces forward and its size may be fixed or change with the viewpoint. The billboard image may be opened in the default image viewer for the platform.
- **Tools**: objects used to measure or otherwise explore the landscape.
    - A ***Path*** tool is a sequence of waypoints representing a path or region and is used for measuring distance, surface area, and volume.
    - A ***Plane*** tool is a plane defined by 3 points located on the terrain surface. This tool provides an elevation difference map as well as strike and dip.
    - A ***Cartesian Grid*** is a configurable rectangular grid.
    - A ***Radial Grid*** is a grid of concentric circles.
    - A ***Camera*** provides a separate view of the virtual world in a seen through a camera placed somewhere in the landscape. Camera properties are defined in a file found in the camera subdirectory of the DERT installation directory. The field of view is articulated in azimuth and elevation.
    - A ***Profile*** tool provides an interactive transection line in the landscape with an associated graph of elevation.
- **LineSets**: objects created from GeoJSON vector files (created from ArcGIS shape files with GDAL)
    - A LineSet is displayed in the scene as a set of line segments using elevation as the Z coordinate.

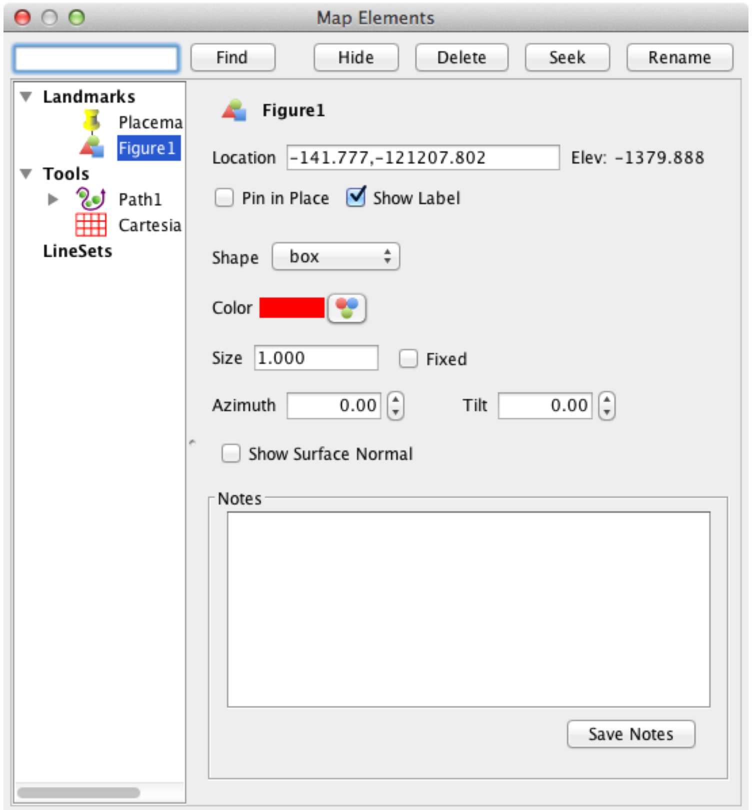
Landmarks and tools are added to the scene via the context menu. They may be dragged along the terrain surface with the left mouse button. Hold the shift key down to drag it in the plane of the computer screen. Use *Edit>Undo*, and *Edit>Redo* to undo/redo landmark and tool moves. NOTE: For Path and Profile you may only drag points, not the line or polygon. Right-click on a map element to invoke its context menu. Here you may hide or delete the map element, or view its annotation.

Example 21: Adding and Positioning a Map Element in the scene

1. Right-click with the mouse on the landscape and select Add>Placemark. A yellow pushpin will appear at the point where you clicked.
2. Position the cursor over the pushpin and press the left mouse button down until you see the cursor change to a hand.
3. Continue pressing down and drag the pushpin. It will follow the terrain.
4. Release the mouse button to stop dragging. The pushpin remains at its position.
5. Select Edit>Undo Move Placemark1. The pushpin returns to its original position.
6. Select Edit>Redo Move Placemark1. The pushpin moves back to the last position.
7. Hold the shift key down and drag the pushpin again. It moves in the plane of the screen instead of along the terrain.
8. Right-click on the pushpin to invoke its context menu.
9. Select Placemark0 notes from the menu. A window for displaying notes appears.
10. Close the window.
11. Select Delete Placemark1 from the menu. A confirmation prompt appears.
12. Press OK. The pushpin disappears.
13. Select Edit>Undo Delete Placemark1. The pushpin reappears.
14. Select Hide Placemark1 from the menu. The pushpin disappears.
15. Select Edit>Undo Hide Placemark1. The pushpin reappears.
16. Translate or rotate the view away from the pushpin. Right-click with the mouse and select *Place Here*. A selection of map elements will appear. Select Placemark1 and press *OK*. The pushpin will move to the new location.

Map Element Editing

In addition to the context menu, all types of map elements may be added to the scene and edited via the Map Elements view. Press the map elements button in the toolbar to open it. The view displays the current set of map elements in the list to the left, each under one of the categories of Landmarks, Tools, and LineSets. To bring up the main panel for the category, select the category in the list (Landmarks, for example). This panel will allow you to add a map element from that category. Once added, the map element will appear in the list. Selecting it will allow you to edit, hide, delete, seek, and rename the element. Changes will take place immediately. Other functions include hiding or showing all map elements of the category and setting preferences. Additionally, for Landmarks, you may save a list of landmarks to a file in comma separated value format.



MapElements View

To search for a specific map element by name, enter a string in the field at the top of the view and press the Find button. The first map element with a name containing the string will be highlighted.

Each map element carries an annotation. You may edit and save it in the map elements view.

Example 22: Add a Map Element with the MapElements View

1. Select the map element category from the list, one of Landmarks, Tools, or LineSets. The category panel will appear.
2. Press the *Add* button for the desired map element type. The type panel will appear. For all but LineSet, a new instance of the map element type will appear at the green marble location. Path and Profile are special cases. See their sections below for more information.

Example 23: Hide/Show Map Element Label (all types except LineSet)

1. Open the panel for the map element.
2. Select the desired map element from the list.
3. Unselect the *Show Label* checkbox. The map element label will disappear.
4. Select the *Show Label* checkbox. The label will reappear.
5. NOTE: For grids this switch applies to axis numbers.

Example 24: Change Color (all types except Billboard)

1. Open the panel for the map element.
2. Press the *Color* button. A color chooser will appear.
3. Select a color and press *OK*. The color chooser will disappear and the map element color will change.

Example 25: Pin a Map Element (all types but LineSet)

1. Open the panel for the map element.
2. Select the Pin in Place checkbox.
3. Try to drag the map element. It doesn't move.
4. Unselect the Pin in Place checkbox.
5. Try to drag the map element again. It moves now.

Example 26: Change Map Element Size (only Landmarks and Grids)

1. Open the panel for the map element.
2. Change the value in the *Size* field (use *Cell Size* for Cartesian grid or *Distance* for radial grid).
3. Press return. The map element changes size.
4. NOTE: Most map elements are view dependent. That is, they change size as the viewpoint changes to remain visible. The Figure allows you to turn that behavior off by selecting the checkbox labeled "Fixed".

Example 27: Change Map Element Icon or Shape (only Placemarks and 3D Figures)

1. Open the panel for the map element.
2. Select a different icon for a Placemark or a different shape for a Figure from the associated menu. The map element changes.

Example 28: Edit a Map Element Annotation

1. Open the panel for the map element.
2. Type your text into the *Notes* field.
3. Press *Save Notes*.
4. Click on the map element in the worldview with the right mouse button to invoke the context menu.
5. Select *Notes* from the menu*.* The new notes appear in a window.

Example 29: Change Map Element Location (all but LineSet)

1. Open the panel for the map element.
2. Change the *Location* field and press return. The map element moves to the new location. For Path, you must change the location of the waypoints. For Profile, there are two location fields. One for each end point.
3. Select *Edit>Undo Move*. The map element moves back to the original position.
4. Select *Edit>Redo Move*. The map element moves to the new position.

Example 30: Hide/Show a Map Element

1. Select a map element from the list.
2. Press *Hide*. The map element will disappear.
3. Press *Show*. The map element will reappear.

Example 31: Seek to a Map Element

1. Select a map element from the list.
2. Press *Seek*. The viewpoint will move to a close-up position for the map element.

Example 32: Rename a Map Element

1. Select a map element from the list.
2. Press *Rename*. The name prompt will appear.
3. Enter a new name and press *OK*. The map element label will change.

In addition to those previously described, each map element has other special features. These are accessed through the map element panel.

3D Figure

- Change the orientation of the figure with the *Azimuth* or *Tilt* fields.
- Show the red surface normal arrow by selecting the *Show Surface Normal* checkbox.

Grids

- In a Cartesian grid, change number of *Columns* and *Rows* with the respective fields in the panel. Columns or rows will be added or subtracted.
- For a radial grid change the rings field. New rings will be added or subtracted.
- Display N, S, E, and W compass indicators in the radial grid by selecting the *Compass Rose* checkbox.

Billboard

- Use the *Browse* button to open a file dialog and navigate to a new image file.
- Press *Open Image* to display the image in the platform image viewer.

Path

The Path tool consists of a list of waypoints, each represented by an icon. The waypoints are listed under the path entry in the map element list. You may add a path either via the context menu in the worldview or through the Map Elements view.

The Path provides some simple statistics regarding the area it encircles. The sampled statistics are retrieved from the highest resolution landscape tiles at a sampling interval that corresponds to the pixel scale. Depending on the size of the Path, calculating the statistics can take some time so it is not automatic.

View the list of waypoints by clicking on the small triangle next to the path in the tool list. Select a waypoint to display its location and elevation. Press *Add Points* to add points directly after this waypoint.

Example 33: Create a Path

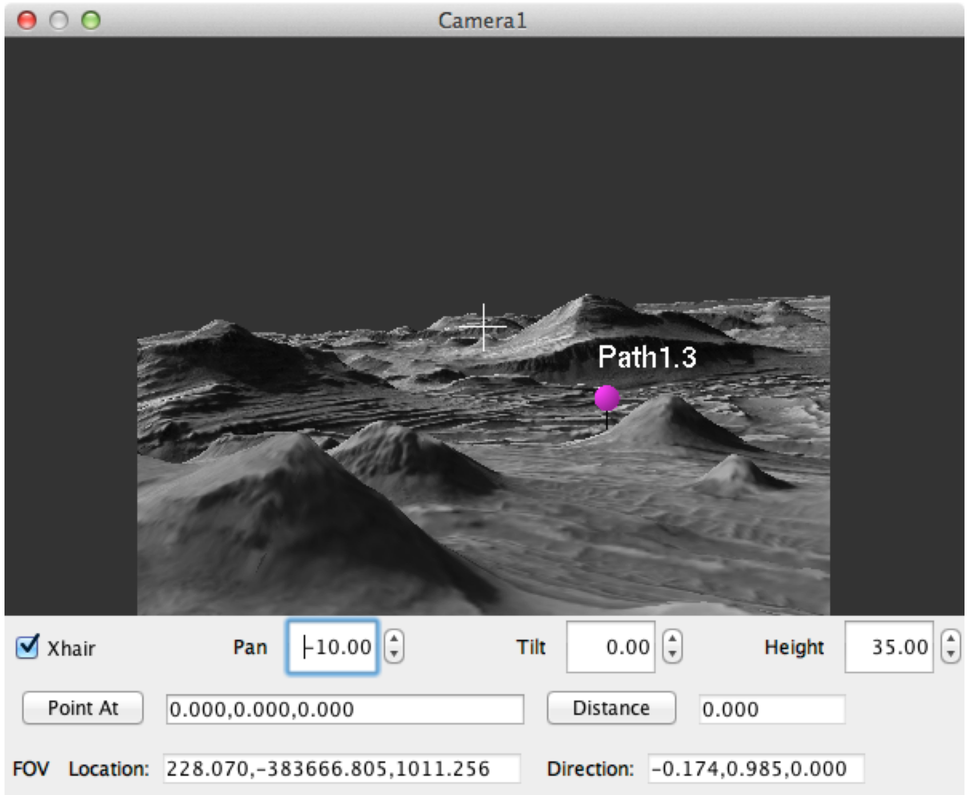
1. Open the Map Elements panel and select Tools from the list.
2. Press the Add button for Path. The cursor changes to a crosshair. A single waypoint will appear at the green marble as well as a prompt for more waypoints.
3. Single-click in the worldview with the left mouse button at each desired waypoint position. Keep in mind you can move them later so they don't need to be perfectly placed.
4. Right-click and select *Path Complete* from the context menu to exit waypoint entry mode. The cursor returns to an arrow.
5. Select the Path in the map elements list.
6. Press *Add Points*. The becomes a crosshair again.
7. Single-click a few more times. The new waypoints are added to the beginning of the path waypoint list.
8. Right-click and select *Path Complete*.
9. Select the second waypoint in the list.
10. Press Add Points. The cursor changes.
11. The waypoints added this time appear after the selected waypoint.
12. Right-click and select *Path Complete*.

Other Path features include:

- Unselect the *Show Waypoints* checkbox to hide the waypoint icons.
- Using the type menu, change the path to display a line between waypoints or a polygon.
- Use the label menu to select the label contents.
- Press *Save As CSV* to save waypoint locations to a file formatted as comma separated values.
- Press *Statistics* to view stats for the path.
- Press the *Refresh* button in the statistics view to recalculate after a waypoint is moved.
- DERT uses a z-buffer to simulate the terrain and parts of the path can be obscured. Unselect the *ZBuffer* check box to disable this feature and view the entire path object.

Camera

A new camera will open a view displaying the virtual world from its location. You may add a camera via the context menu or from the Map Elements panel. With the panel, the camera will appear at the location of the green marble. You will see the inside of the marble in the new view. Single-click in the worldview to move the marble.



View through the lens of a Camera tool.

The camera view control panel provides controls for changing camera pan (North is zero), tilt (horizontal is zero), and height. Additionally, you may point the camera at a location or find the distance to the object at the center of the view.

Example 34: Point a Camera

1. Create a new camera. The camera view will open.
2. Single-click on the landscape to move the marble.
3. Copy the coordinates from the marble location field.
4. Paste the coordinates in the field next to *Point At* in the camera view.
5. Press *Point At*. The marble will appear in the camera view.
6. Select the camera in the Map Elements view to display its panel.
7. Select Show Frustum in the camera panel. The camera frustum will appear.
8. Select Show Line to LookAt Point. A line will be drawn to the point the camera is centered on.

The location and direction of the camera field of view (FoV) is available at the bottom of the view. The location is in the same coordinate system as the landscape. These two values may be used with other software.

To see the camera footprint or viewshed on the landscape, configure it as a layer.

Example 35: Camera Footprint and Viewshed

1. Create a camera.
2. Open the Surface and Layers view.
3. Press *Change*.
4. Move the camera footprint to the second layer.
5. Press *OK*. The footprint of the camera will be visible on the landscape.
6. Press *Change* again.
7. Move the camera viewshed to the second layer.
8. Press *OK*.
9. The footprint will change to a viewshed.
10. Drag the camera. The viewshed will move and change with it.

Profile

The Profile tool provides an interactive transection line in the landscape with an associated graph of elevation. You may add a profile via the context menu or the map elements view.

Example 36: Add a Profile

1. In the tools panel, add a profile. A new graph view will appear on top of the DERT main window.
2. Move the widow aside and resize it. In the worldview, two paddles will appear at the green marble.
3. With the left mouse button, press a paddle and drag it along the terrain.
4. Drag the second paddle with the left mouse button. A graph line will appear in the graph view.
5. Single-click in the graph view with the left mouse button to display the picked point at the top.

Press *Save as CSV* in the profile map element panel to save the graph to a file in comma separated value format.

Plane

The Plane tool provides an interactive plane in the landscape with an associated map of elevation difference from the plane to the underlying terrain. You may add a plane via the context menu or the map elements view.

Example 37: Add a Plane

1. In the tools panel, add a plane. In the worldview, three paddles will appear at the green marble.
2. With the left mouse button, press a paddle and drag it along the terrain.

3. Drag the second paddle with the left mouse button. A plane will appear in the worldview. A solid line representing the strike is drawn on the plane. A dashed line represents the dip.
4. The locations of the three paddles define the plane.
5. In the plane panel of the map elements view, scale the plane along the dip and strike axes.
6. Press *Diff Map* to display the elevation difference map and other plane details.
7. Move the cursor in the difference map to display the point underneath. Single-click in the difference map with the left mouse button to move the green marble in the scene.
8. Use the mouse wheel to zoom the map image and drag the image with the left mouse button.

Due to performance issues, the difference map is not automatically recalculated each time a paddle is moved. Press the refresh button to recalculate. The elevation difference is calculated from the highest resolution landscape tiles at the pixel scale resolution of the tile. The size of the plane is limited by the amount of available RAM.

LineSet

Example 38: Add a LineSet

1. Open the LineSets panel in the Map Elements view.
2. Press *Browse*. A file dialog will appear.
3. Navigate to the VictoriaCrater pyramid directory and select contour.json.
4. Press *Choose*. A set of contour lines will appear in the worldview.

Map Element Preferences

Map element preference can be set in the Landmarks, Tools, and LineSets panels of the Map Elements View.

LayerFactory

Introduction

LayerFactory is a tool for building the layers for the terrain visualized in DERT. A set of layers, each represented by a multi-resolution tiled image pyramid is stored in a specialized directory called a *landscape*. These layers, a height map or an orthoimage for example, are geo-referenced and displayed together. The height map provides a 3D mesh on which the orthoimages are draped. Data sets used by LayerFactory can be found at the NASA Planetary Data System (PDS), USGS Earth Explorer, and USGS National Map Viewer as well as other sites.

A landscape contains a ".landscape" file to indicate its purpose. The pyramid that represents a layer employs a data structure called a *quad-tree*. A *quad-tree* is a series of levels, each with a greater number of tiles, covering the same physical space. Each tile is in a separate file housed in a hierarchical directory structure. Metadata for the layer is located in a properties file in the top layer directory. Tiles are PNG format. All tiles have the same number of pixels. As the level increases, a tile covers less physical space, but there are more tiles. As the level increases a pixel covers a smaller area. Each level represents a different resolution of the layer and has 4 times the number of tiles as its parent. The lowest resolution level (0) consists of only one tile, level 1 has four tiles, level 2 has 16, etc. Each tile knows about the 4 tiles of higher resolution in the next level that covers its area. These are considered to be the tile's "children". When the camera comes closer to a tile, the children replace the parent in the scene, providing more detail. When the camera moves away, the parent returns, reducing the overhead of drawing unseen detail.

There are two types of layers: elevation and image. The elevation layer provides the 3D mesh derived from a height map, and image layers are orthoimages that are draped on the mesh. Tiles are rectangular in shape (not necessarily square) and are on the order of 128 x 128 pixels in size. The number of pixels on a side of an elevation tile is 2^n+1. The extra row and column are used to stitch the tile to its neighbor. DERT uses bilinear interpolation when scaling tiles, avoiding pixelation and providing a smoother transition between tile edges. This means that the image layers display best when image tile dimensions are 4 or greater times the elevation tile dimensions. For example, if an elevation tile width is 128 pixels, an image layer tile width should be at least 512 pixels.

File Requirements

There are a wide variety of geo-referenced file formats. Currently, LayerFactory supports only the commonly found NASA PDS (.img) and GeoTIFF (.gtif, .tif, .tiff,

.gtiff) formats. GeoTIFF is loaded via libtiff. Other formats can be converted to GeoTIFF with GDAL (www.gdal.org). Here are some additional requirements:

1. The DEM and orthoimage files must cover the same physical area. Corner locations should be identical. These values can be listed with gdalinfo. The raster type may be AREA or POINT as long as both files are the same (see note below).
2. Each dimension of the orthoimage file (width and height) must be a power of 2 multiple of the corresponding DEM file dimension. For example, if the DEM dimensions are 100 x 200, the orthoimage must be 100 x 200, 200 x 400, 400 x 800, etc. This is dictated by the quad tree structure of the pyramid. See the section called *Preparing Files for Tiling* for an example of using GDAL to crop and resample a DEM and orthoimage.
3. LayerFactory relies heavily on the metadata included in the geo-referenced file. This metadata must therefore be accurate. For example, if you are using Mars files and they are not projected, make sure the datum in the file is not defined for Earth.
4. DERT does not currently handle floating-point or 16 bit gray image layers. LayerFactory converts these files to unsigned byte. It must use the minimum and maximum pixel values to determine the range for the gray byte quantities. If these values are not available they will be calculated, significantly extending the time required to construct the landscape.
5. Only one value may represent missing or "no data" values (not, for example, all negative values). This value must be specified in the metadata or as a parameter to the LayerFactory application.
6. LayerFactory uses memory-mapped files. You will need at least 2 times the disk space that a data file currently occupies.
7. GeoTIFF files with more than one scan line per row are not currently supported.
8. Linear units other than meters are not currently supported.

Error Management

To minimize error, the DERT quad-tree scales by the integer 2. Starting with the full size of the original image, each level going up the pyramid is one quarter the size as the dimensions are cut in half. Therefore the baseline DEMs and orthoimages must have dimensions that are a power of 2. To avoid distortion, LayerFactory adds a margin of missing values to the edges of the data set to take its dimensions to a power of 2. The missing value is NaN for elevation data sets and 0 for image data sets.

Each level is averaged from the full size original data set. A mean value is calculated from the portion of the original that a pixel represents.

Raster Type

The GeoTIFF specification lists two raster types: *Area* and *Point*. The PDS format is typically *Point*. See http://www.remotesensing.org/geotiff/spec/geotiff2.5.html#2.5.2 for an explanation. For our purposes, the difference is in the tie point value. It is offset by ½ pixel between the two types. Be sure to specify the raster type in the –mo parameter when converting a PDS file to a TIFF format with gdal_translate. For example, to convert a PDS file to a TIFF file:

gdal_translate –mo "AREA_OR_POINT=Point" image.IMG image.TIF

Preparing Files for Tiling

The DEM and orthoimage must cover the same physical area. You will get a better landscape if you use an orthoimage with dimensions that are at least 4 times the size of the DEM. Use the GDAL utilities to super-sample your orthoimage. Additionally, each dimension of the orthoimage file (width and height) must be a power of 2 multiple of the corresponding DEM file dimension. GDAL utilities gdal_translate and gdalwarp may be used to modify files that don't meet these requirements. For example, the following steps can be used to prepare files dem.tif and img.tif for input to LayerFactory.

Example 40: Aligning DEM and Orthoimage Boundaries

1. Enter gdalinfo dem.tif on the command line to reveal:

   ```
   Corner Coordinates:
   Upper Left  (  -31420.000,  112740.000) ( 15d34'22.27"W, 86d 8'30.64"S)
   Lower Left  (  -31420.000,  102340.000) ( 17d 4' 2.33"W, 86d28'14.45"S)
   Upper Right (  -22020.000,  112740.000) ( 11d 3' 6.07"W, 86d12'47.52"S)
   Lower Right (  -22020.000,  102340.000) ( 12d 8'34.52"W, 86d32'55.85"S)
   ```

2. Enter gdalinfo img.tif on the command line to reveal:

   ```
   Corner Coordinates:
   Upper Left  (  -31406.000,  112740.000) ( 15d33'58.50"W, 86d 8'31.09"S)
   Lower Left  (  -31406.000,  102340.000) ( 17d 3'36.55"W, 86d28'14.94"S)
   Upper Right (  -22012.000,  112740.000) ( 11d 2'51.97"W, 86d12'47.70"S)
   Lower Right (  -22012.000,  102340.000) ( 12d 8'19.11"W, 86d32'56.05"S)
   ```

3. The corner coordinates are the physical boundaries of the file. We want to crop both files to the intersection of these two boundaries. Using the upper left and lower right coordinates of each file the intersection comes out to be:

Upper Left (-31406, 112740)
Lower Right (-22020, 102340)

4. Crop dem.tif with gdal_translate to the intersection.

   ```
   gdal_translate –projwin -31406 112740 -22020 102340 dem.tif dem_cropped.tif
   ```

5. Crop img.tif with gdal_translate to the intersection.

   ```
   gdal_translate –projwin -31406 112740 -22020 102340 img.tif img_cropped.tif
   ```

6. Enter `gdalinfo dem_cropped.tif` to find the width, height, and pixel size of dem_cropped.tif.

   Size is 469, 520
   Pixel Size = (20.000000000000000,-20.000000000000000)

7. Enter `gdalinfo img_cropped.tif` to find the width, height, and pixel size of img_cropped.tif.

   Size is 4693, 5200
   Pixel Size = (2.000000000000000,-2.000000000000000)

8. The dimensions (width and height) of img_cropped.tif should be a power of 2 times that of dem_cropped.tif. Currently it is 10 times (20/2 = 10). Resampling dem_cropped.tif to a pixel size of 16 will make the dimensions of img_cropped.tif 8 times the size of dem_cropped.tif and 8 is a power of 2. The scale factor for the resampled file will be 20/16 so the new width will be 588 and the new height will be 650.

9. Use gdalwarp to resample dem_cropped.tif.

   ```
   gdalwarp –r bilinear –ts 588 650 dem_cropped.tif dem_cropped_16.tif
   ```

10. We now have an orthoimage that is 8 times the size of the DEM. Run LayerFactory using a tile size of 128 for dem_cropped_16.tif and a tile size of 1024 (8x128) for img_cropped.tif.

Unprojected Data

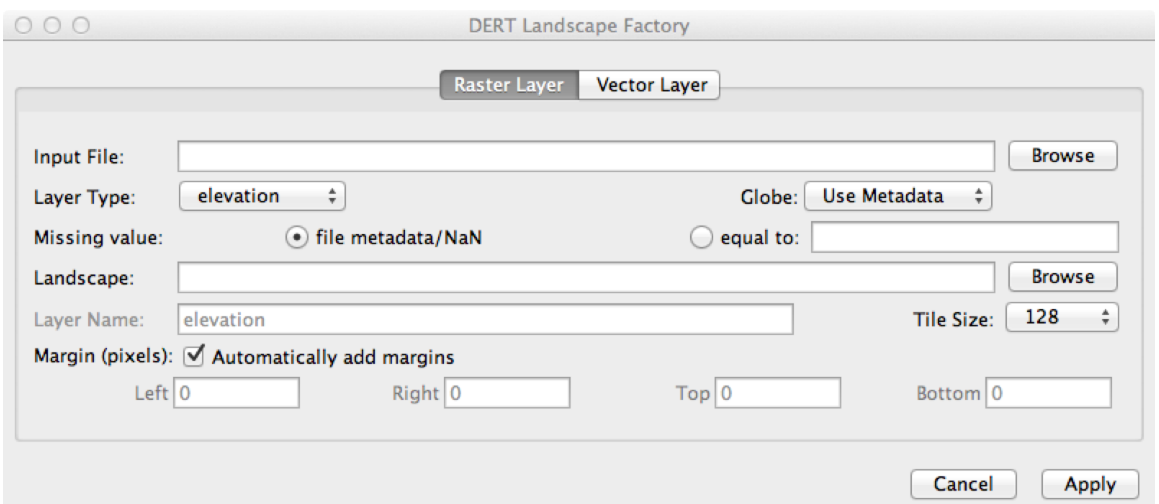
LayerFactory does not alter the projection of the landscape. If it is not already, you may want to consider projecting your data. DERT is not a virtual globe and to visualize an unprojected height map, it must be converted to 3D Cartesian coordinates. As this technique adds significant complications, it has not yet been implemented. DERT will "project" an unprojected landscape in the following manner:

1. Project the upper left and lower right corners to obtain tie points using polar stereographic projection if the latitude > 85 or < -85, or equirectangular projection otherwise. This calculation is carried out via the Proj.4 projection library.
2. Divide the range between the upper left and lower right by the number of pixels in the corresponding dimension to get the pixel scale.

Parameters

LayerFactory has a number of optional and required command line parameters. If the required parameters are not provided, a user interface will appear.

Raster Layer



This panel is for building one layer of a Landscape pyramid. The area underneath the window title displays messages for the user. It will update with status once the pyramid build is underway.

Input File: This is the DEM or orthoimage to use for the pyramid. It should be in PDS or GeoTIFF format.

Layer Type: Describes the type of layer to create. Select one of *elevation* (for a DEM), *colorimage* (for an RGB orthoimage), or *grayimage* (for a gray scale orthoimage). In DERT, image layers will be draped on the DEM and displayed with no modifications.

Globe: Select the planet or moon for this layer. This selection will override any file metadata. The default is in the dert.properties file.

Missing value: This field designates how to handle missing or no-data values. Select *file metadata/NaN* to use whatever is found in the input file metadata or NaN values. Select *equal to* and enter a number if the value is not found in the metadata.

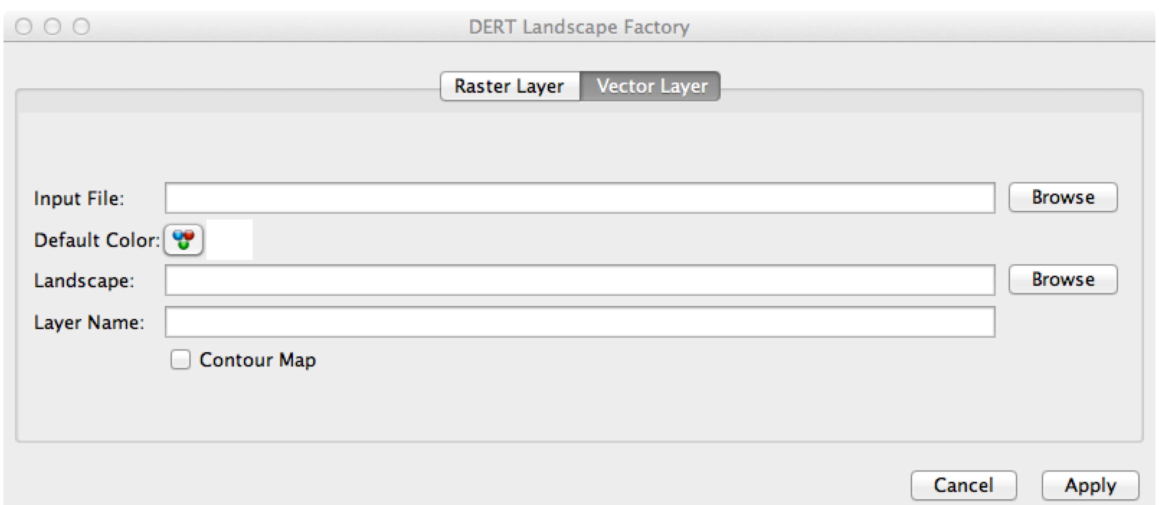
Landscape: Enter the landscape path here. To create a new Landscape, select *Browse*, then *New Landscape* in the dialog. You may also specify an empty directory for a new landscape. LayerFactory will add the .landscape file.

Layer Name: Enter the name of the layer subdirectory in the Landscape.

Tile Size: Select the length of the longest edge of the tiles.

Margin: Normally, *Automatically add margins* should be checked. If you are building a sub-pyramid uncheck this button and provide the margin to be added to each edge of the pyramid.

Vector Layer



The vector layer tab provides the option to generate a multi-resolution image pyramid from a file in GeoJSON format.

Input File: This is the GeoJSON vector file to use for the pyramid.

Default Color: Select a color to use if there is none in the file.

Landscape: The landscape directory.

Layer Name: The name of this layer. This name will be used for the layer subdirectory in the landscape directory.

Contour Map: Check this if the file is a contour map generated by GDAL.

Command Line Execution

To invoke LayerFactory on the command line, enter:

layerfactory *parameters*

The following parameters are required:

-landscape =*landscape directory path*
-file=*input file path*
-type=*layer type (for raster only)*
-tilesize=*tile size*

The following parameters are optional:

-globe=*globe name (default Earth if not in metadata)*
-missing=*missing value (default NaN for DEM, 0 for image if not in metadata)*
-leftmargin=*number of pixels to fill left edge*
-rightmargin=*number of pixels to fill right edge*
-bottommargin=*number of pixels to fill bottom edge*
-topmargin=*number of pixels to fill top edge*
-name=*layer name*
-color=*vector color (either r,g,b or r,g,b,a)*
-contourmap *indicates a contour map file generated by GDAL*

Creating a Sub-pyramid

One pyramid can be added to another as a sub-pyramid. The edges of the sub-pyramid must match the neighboring tiles in the pyramid. For the elevation layer, if adjacent tiles are to the bottom or right a one-pixel margin must be provided at the highest resolution. More pixels must be provided for the averaging process. The number of extra pixels for the width is *paddedWidth/tileWidth* where the *paddedWidth* is the width of the raster expanded to the nearest power of 2. The number of extra pixels for the height is *paddedHeight/tileHeight* where the *paddedHeight* is the height of the raster expanded to the nearest power of 2. A image layer will have 3 times the extra pixels. These extra pixels must be included in the margins specified in Landscape Factory.

Layer File Format

A Landscape is a directory that contains one or more layers. It must also contain a ".landscape" file to be identified as a Landscape. This file is a Java properties file with a date and the login name of last user who wrote it. LayerFactory rewrites the .landscape file each time a layer is written in the landscape.

Each layer is a subdirectory consisting of a pyramid of tiles. The top level of a pyramid will contain a file called layer.properties. This file contains the metadata for the layer including projection, size, etc. Each tile is in binary format.

In addition to the layers, a landscape may have a dert subdirectory, created by DERT itself. This subdirectory contains information useful to DERT including configurations and user supplied color maps and instruments. Its directory structure is:

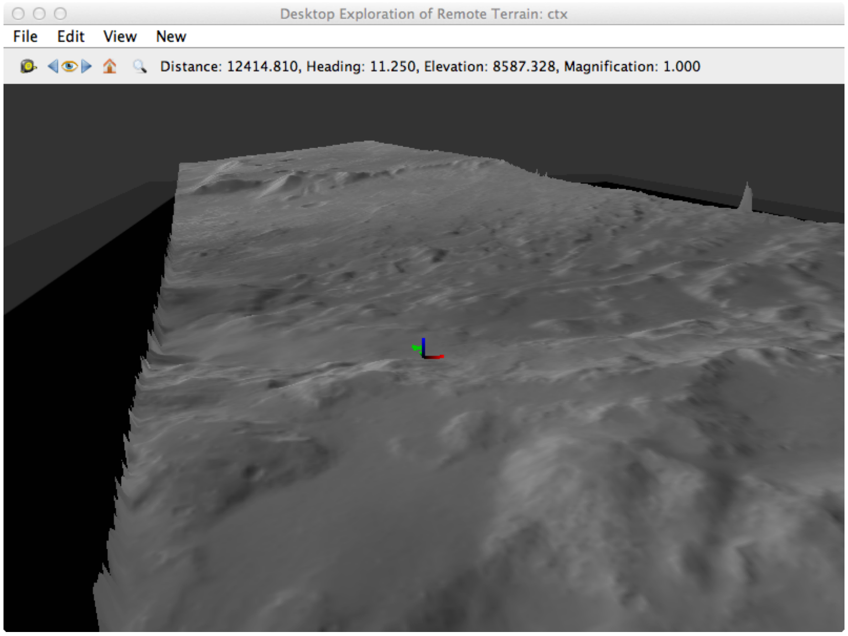
- colormap (directory for user supplied color maps)
- config*R* (directory for configurations written by DERT, R indicates the release)
- camera (directory for user supplied camera property files

Examples

This section provides examples of creating landscapes from various data products available online. NOTE: these examples are for demonstration purposes only and may not be perfectly accurate.

You will need GDAL to prepare the data for some of these examples. Use gdalinfo to print out the metadata for your files. Everything you need to know should be in the metadata.

Example 41: MRO CTX Eberswalde



This example uses files P17_007481_1544+P19_008272_1545-DEM.tif and P17_007481_1544+P19_008272_1545-DRG.tif. Provided courtesy of Malin Space Science Systems.

1. Create a directory for the landscape called *ctx*.

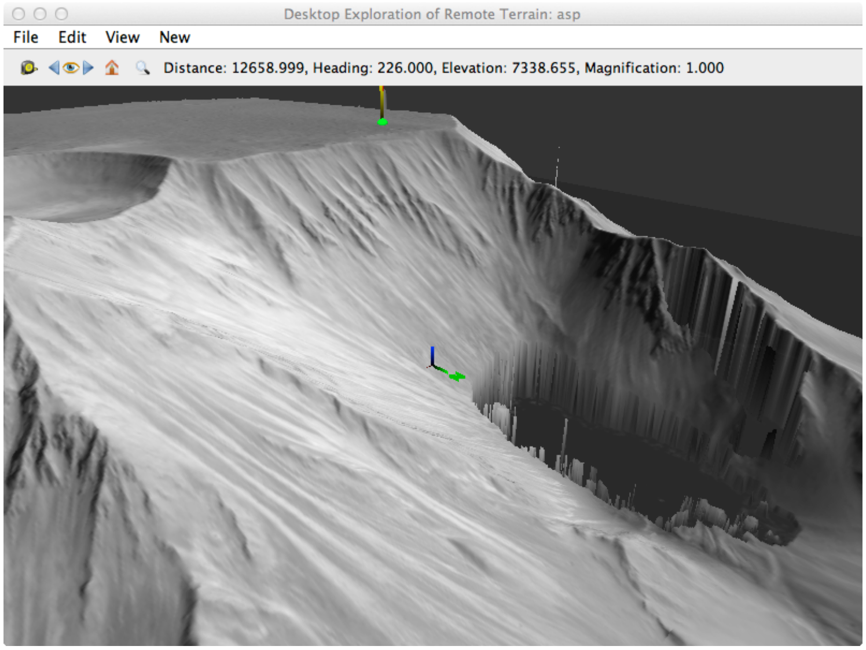
2. Run layerfactory with the following parameters:

   -layer=elevation
   -file= P17_007481_1544+P19_008272_1545-DEM.tif
   -landscape =*yourpath*/ctx
   -tilesize=128
   –globe=mars

3. Run layerfactory again for the gray orthoimage with the parameters:

   -layer=grayimage
   -file= P17_007481_1544+P19_008272_1545-DRG.tif
   -landscape =*yourpath*/ctx
   -tilesize=128
   –globe=mars

Example 42: Ames Stereo Pipeline Mars DEM and DRG



This example uses files out-DEM.tif and out-DRG.tif created by the Ames Stereo Pipeline.

1. Create a directory for the landscape called *asp*.

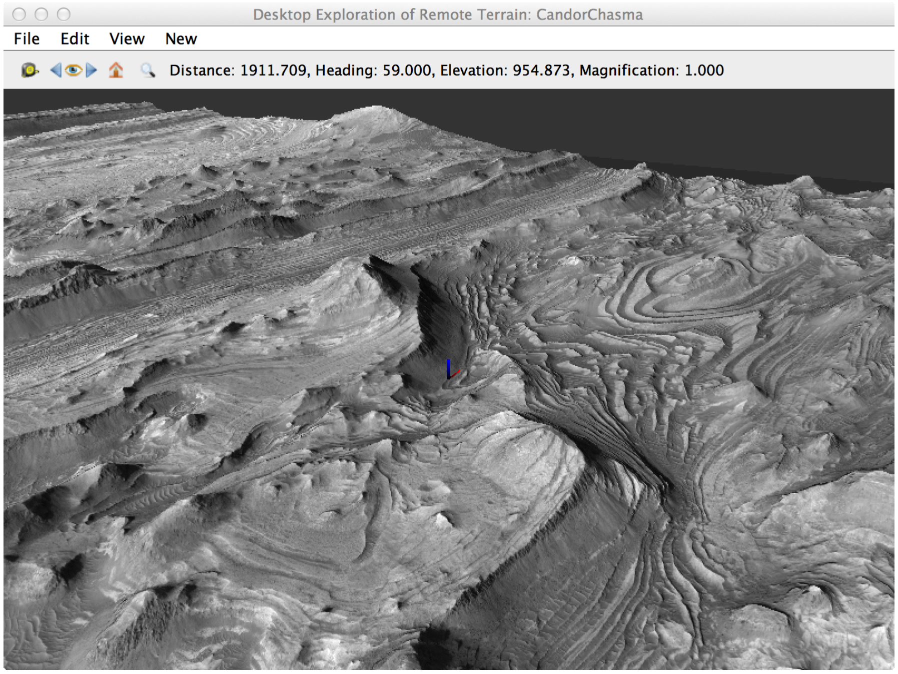
2. Run layerfactory with the following parameters:

    -layer=elevation
    -file= out-DEM.tif
    -landscape =*yourpath*/asp
    -tilesize=128
    –globe=mars
    –missing=-529

3. Run layerfactory again for the gray orthoimage with the parameters:

    -layer=grayimage
    -file= out-DRG.tif
    -landscape =*yourpath*/asp
    -tilesize=128
    –globe=mars
    –missing=-529

Example 43: MRO HiRISE DEM and Orthoimage of Candor Chasma



The Candor Chasma file can be found here: http://hirise.lpl.arizona.edu/dtm/dtm.php?ID=PSP_001918_1735.

1. Go to the HiRISE website and select "full directory listing" link.

2. Download DTEEC_001918_1735_001984_1735_U01.IMG. This is the DEM file.

3. Download PSP_001984_1735_RED_A_01_ORTHO.JP2 and the corresponding .LBL file. This is the orthoimage.

4. Convert the JP2 file to an IMG file with the free JP2_to_PDS utility. You can find it here: http://hirise.lpl.arizona.edu/tools/pds_jp2.php.

5. Create a pyramid directory called CandorChasma.

6. Run layerfactory with the following parameters:

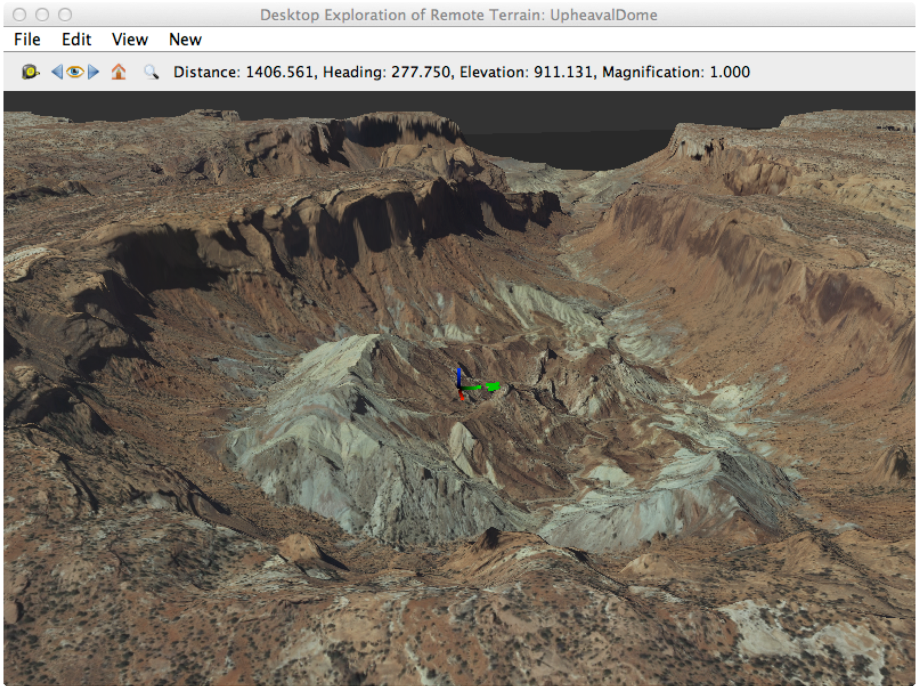
    -layer=elevation
    -file= DTEEC_001918_1735_001984_1735_U01.IMG
    -landscape =*yourpath*/CandorChasma
    -tilesize=128

7. Run layerfactory again for the gray orthoimage with the parameters;
    -layer=grayimage

-file= PSP_001984_1735_RED_A_01_ORTHO.IMG
-landscape =*yourpath*/CandorChasma
-tilesize=512

The orthoimage is 0.25 m/pixel whereas the DEM is only 1 m/pixel, hence the larger tile size.

Example 44: USGS DEM and Orthoimage of Upheaval Dome, Moab, Utah



USGS files can be found here: http://viewer.nationalmap.gov/viewer/.

1. Go to the USGS website and select *Download Data* at the top of the page.

2. Select *Click here to download by coordinate input* at the bottom of the popup.

3. Enter 38.47 for the top latitude, 38.41 for the bottom latitude, -109.974 for the West longitude, and -109.889 for the East longitude. Press *Draw Area*.

4. Select *Elevation* and *Orthoimagery* from the list in the popup. Click *Next*.

5. Select *Elevation* to open it. Select the check box next *National Elevation Data Set (1/3 arc second) IMG*.

6. Select *Orthoimagery* to open it. Select the check box next to the 0.25m color orthoimagery.

7. Select *Next*. Select *Checkout*. Enter your email address and select *place order*. You will get an email with a number of links to the data. Download all of the data (1 file for the DEM and 20 for the orthoimage). Unzip all the files and you will see directories. Keep all of the directories intact during processing.

8. Make a directory called *data* and one called *UpheavalDome*.

9. To convert the Erdas Imagine .img file to geotiff *cd* to *n39w110* and enter the command

   gdal_translate imgn39w110_13.img ../data/DEM.tif.

10. To convert the JPG2000 files, *cd* to each of the 20 directories and enter

    gdal_translate –mo=”AREA_OR_POINT=Point” filename.jp2 ../data/filename.tif.

11. Cd to data and use gdalwarp to stitch the orthoimages together. For example

    gdalwarp filename1.tif filename2.tif filename3.tif orthoimage.tif.

12. Crop the orthoimage.

    gdal_translate –strict –srcwin 4020 1990 22000 22000 UpheavalDome_DRG.tif

13. The DEM must be projected:
    a. Run gdalinfo on UpheavalDome_DRG.tif.
    b. Copy the WKT section to a file call proj.prf. This section starts with PROJCS and includes everything in the square brackets.
    c. Run gdalwarp to project the DEM and resample to 1 m pixels.

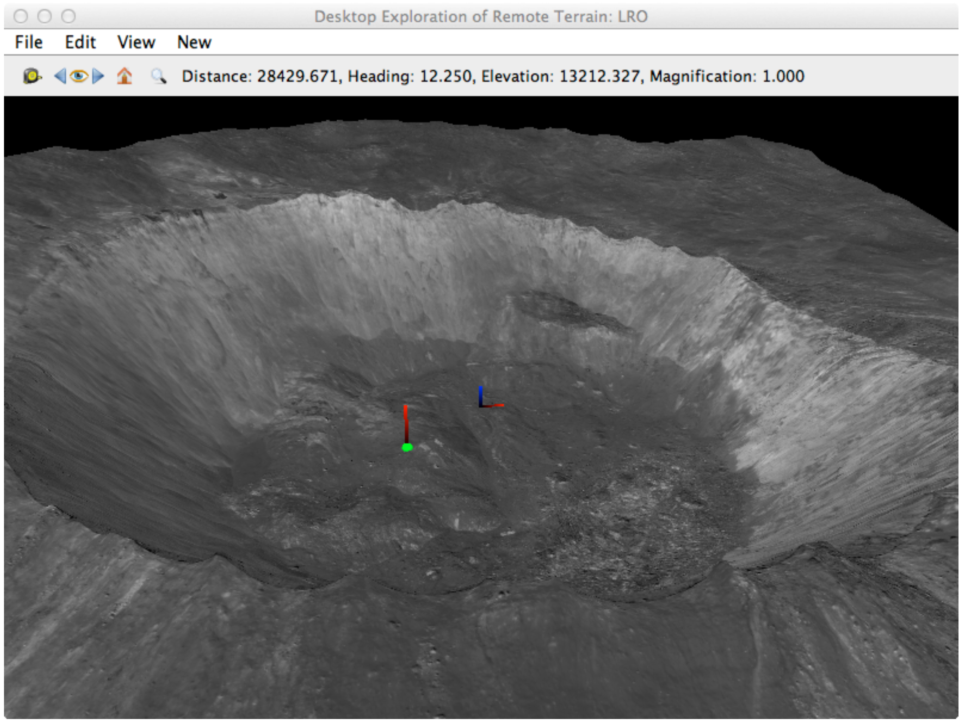
       gdalwarp -t_srs proj.prf -r bilinear –tr 1 1 DEM.tif DEM_Prj.tif

14. Crop DEM_Prj.tif to fit orthoimage.tif.

    gdal_translate –strict –srcwin 3962 60740 5500 5500 DEM_Prj.tif UpheavalDome_DEM.tif

15. Run layerfactory with the following parameters:
    –layer=elevation
    –file=UpheavalDome_DEM.tif
    –landscape =../UpheavalDome
    –tilesize=128
16. Run layerfactory again for the color orthoimage with the parameters:
    –layer=colorimage
    –file= UpheavalDome_DRG.tif
    –landscape =../UpheavalDome
    –tilesize=512

Example 45: LRO LOLA DEM and LROC Orthoimage



LOLA GDR (DEM) files can be found here: http://imbrium.mit.edu/DATA/LOLA_GDR/. LROC RDR files can be found here: http://lroc.sese.asu.edu/data/LRO-L-LROC-5-RDR-V1.0/LROLRC_2001/DATA/BDR/NAC_ROI/.

1. Go to the website and download NAC_ROI_GDANOBRUHIA_E102N3600.IMG, LDEM_1024_30N_45N_090_120.IMG, and LDEM_1024_30N_45N_090_120.LBL.

2. You will need to crop the LOLA file to fit the LROC file. You can do this with GDAL. Use the gdal_translate command to change the LOLA file format to TIFF.

   gdal_translate –mo=”AREA_OR_POINT=Point”
   LDEM_1024_30N_45N_090_120.LBL
   LDEM_1024_30N_45N_090_120.TIF

3. Use the *gdal_translate* command to crop the new TIFF file. For example:

   gdal_translate -strict -srcwin 11920 8333 2370 1844 -a_nodata none
   LDEM_1024_30N_45N_090_120.TIF LDEM_cropped.TIF

4. Use the gdalwarp command to resample the file to a larger number of pixels. You want the file size of the LROC image to be the same or an order of 2 larger than the LOLA file. For example:

   gdalwarp -r bilinear -ts 7885 7585 -srcnodata None LDEM_cropped.TIF LRO_DEM.TIF

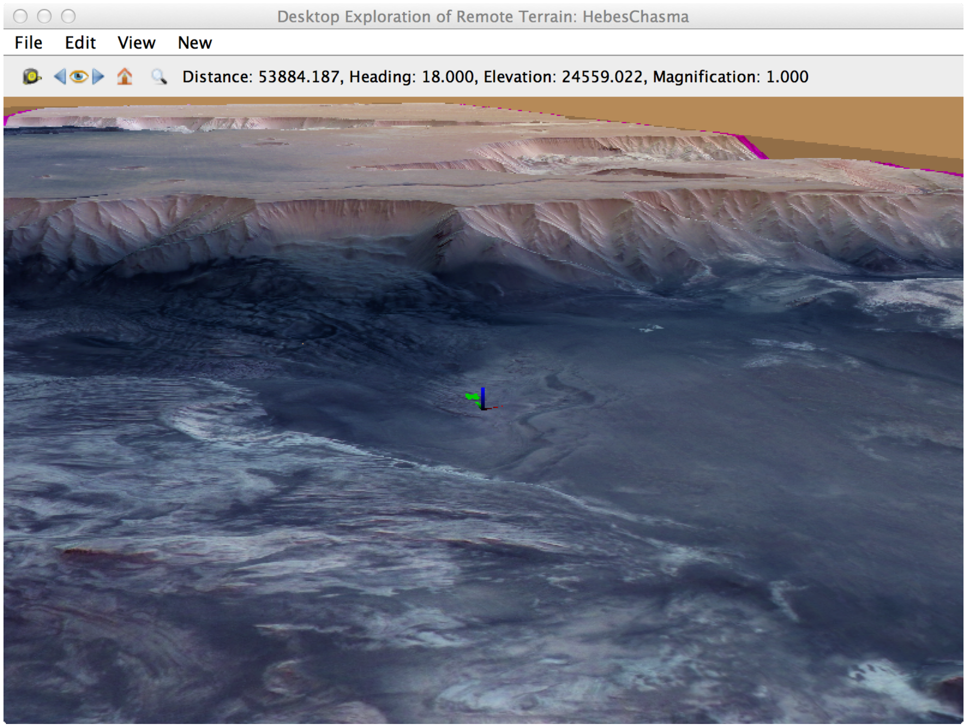
5. Create a pyramid directory called LRO. Run layerfactory with the following parameters:

   –layer=elevation
   –file=LRO_DEM.tif
   –landscape =LRO
   –tilesize=128
   -globe=moon

6. Run layerfactory again for the gray orthoimage with the parameters:

   –layer=grayimage
   –file= NAC_ROI_GDANOBRUHIA_E102N3600.IMG
   –landscape =LRO
   –tilesize=512
   -globe=moon

Example 46: Mars Express HRSC Hebes Chasma



HRSC files can be found here: http://hrscview.fu-berlin.de/cgi-bin/ion-p?page=entry2.ion. HRSC files are also stored on the PDS site at wustl.edu. Browse to Hebes Chasma and click on the image.

1. Click the Download Data Product link at the top left of the page.

2. Download the level 4 ND, RE, GR, BL, and DT products in PDS format.

3. Using *gdalinfo* you can determine that the ND (panchromatic) product is 4 times the resolution of the DT (DEM) product.

4. Make a color image (you may want to adjust the colors, see Appendix C):

   ```
   gdal_merge.py -separate H0360_0000_re4.IMG H0360_0000_gr4.IMG H0360_0000_bl4.IMG -o H0360_0000_rgb.tiff
   ```

5. Scale it to the ND resolution with bilinear resampling:
   ```
   gdalwarp -ts 10016 43576 -r bilinear H0360_0000_rgb.tiff H0360_0000_rgbx4.tiff
   ```

6. Sharpen with the panchromatic image using hsv_merge.py by Frank Warmerdam http://fwarmerdam.blogspot.com/2010/01/hsvmergepy.html:

./hsv_merge.py H0360_0000_rgbx4.tiff H0360_0000_nd4.tiff H0360_0000_color.tiff

7. Use the DT product for the elevation layer and the color product for the color image layer. Tile size for the color layer should be 4 times the elevation.

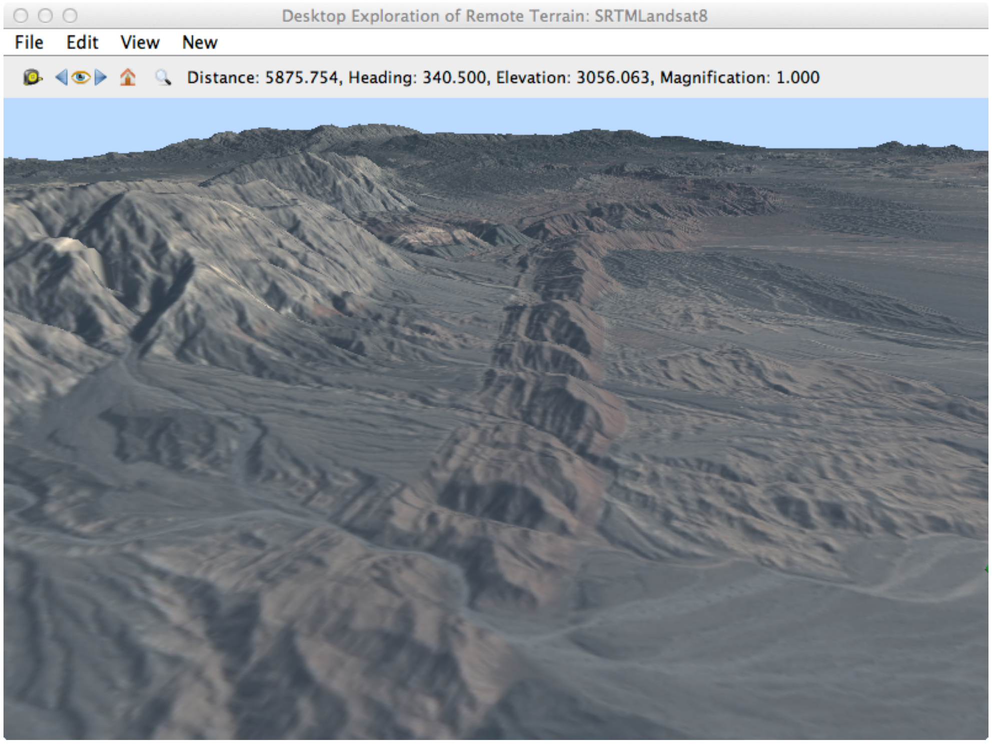
8. Create a pyramid directory called HebesChasma. Run layerfactory with the following parameters:

   –layer=elevation
   –file=H0360_0000_DT.IMG
   –landscape =HebesChasma
   –tilesize=128

9. Run layerfactory again for the color orthoimage with the parameters:

   –layer=colorimage
   –file= H0360_0000_color.tiff
   –landscape = HebesChasma
   –tilesize=512

Example 47: SRTM with Landsat 8 Andes Mountains



1. Go to the USGS EarthExplorer site http://earthexplorer.usgs.gov.

2. Select the Data Sets tab and then select SRTM under Digital Elevation and L8 OLI/TIRS under Landsat Archive.

3. Select the Search Criteria tab and then Add Coordinate. Enter -31 latitude and -69 longitude. Click Add. Click Results. This is an area in the Andes Mountains and only 3 arc data is available.

4. Select SRTM under Data Set and download image at coordinates -31, -68 as GeoTIFF format.

5. Select L8 OLI/TIRS under Data Set and download LC82320812013111LGN01 as GeoTIFF.

6. Untar the Landsat file and create a color ortho-image:

   gdal_translate -scale LC82320812013111LGN01_B4.TIF red.tiff

   gdal_translate -scale LC82320812013111LGN01_B3.TIF green.tiff

   gdal_translate -scale LC82320812013111LGN01_B2.TIF blue.tiff

gdal_translate -scale LC82320812013111LGN01_B8.TIF gray.tiff

gdal_merge.py -separate -ot Byte red.tiff green.tiff blue.tiff -o colorRGB.tiff

gdalwarp -ts 15321 14801 -r bilinear colorRGB.tiff colorRGBx2.tiff

./hsv_merge.py colorRGBx2.tiff gray.tiff colorRGBx2xp.tiff

7. Project the STRM data:

    a. Run gdalinfo on colorRGBx2xp.tiff.
    b. Copy the WKT section to a file call proj.prf. This section starts with PROJCS and includes everything in the square brackets.
    c. Run gdalwarp to project and rescale the DEM.

    gdalwarp -t_srs proj.prf -r bilinear -tr 60 60 s31_w069_3arc_v1.tif height.tiff

8. Crop the color image to fit the DEM.

    gdal_translate -projwin 499959.813 -3318739.183 596439.813 -3430099.183 colorRGBx2xp.tiff ortho.tiff

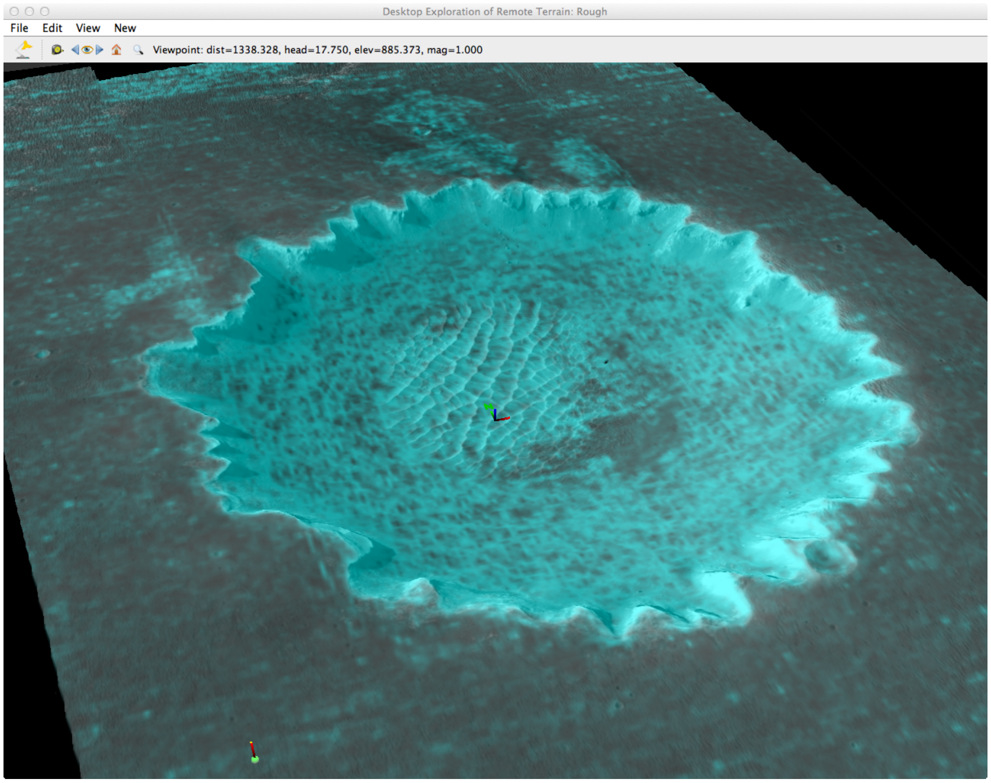
9. Create a pyramid directory called SRTMLandsat8. Run layerfactory with the following parameters:

    –layer=elevation
    –file=height.tiff
    –landscape = SRTMLandsat8
    –tilesize=128

10. Run layerfactory again for the color orthoimage with the parameters:

    –layer=colorimage
    –file= ortho.tiff
    –landscape = SRTMLandsat8
    –tilesize=512

Example 48: HiRISE Victoria Crater with Roughness Layer



Documentation for gdaldem can be found at http://www.gdal.org/gdaldem.html. HiRISE files for Victoria Crater can be found at http://www.uahirise.org/dtm/dtm.php?ID=PSP_001414_1780.

1. Go to the HiRISE website and select "full directory listing" link.

2. Download DTEEC_001414_1780_001612_1780_U01.IMG. This is the DEM file.

3. Download DT1EA_001414_1780_001612_1780_U01.JP2 and the corresponding .LBL file. This is the orthoimage.

4. Convert the JP2 file to an IMG file with the free JP2_to_PDS utility. You can find it here: http://hirise.lpl.arizona.edu/tools/pds_jp2.php.

5. Create a pyramid directory called VictoriaCrater.

6. Run layerfactory with the following parameters:

   -layer=elevation
   -file= DTEEC_001414_1780_001612_1780_U01.IMG

-landscape =*yourpath*/VictoriaCrater
-tilesize=128

7. Run layerfactory again for the gray orthoimage with the parameters:
   -layer=grayimage
   -file= DT1EA_001414_1780_001612_1780_U01.IMG
   -landscape =*yourpath*/VictoriaCrater
   -tilesize=512

   The orthoimage is 0.25 m/pixel whereas the DEM is only 1 m/pixel, hence the larger tile size.

8. Run the gdaldem command to create a roughness map:
   gdaldem roughness DTEEC_001414_1780_001612_1780_U01.IMG rough.tif

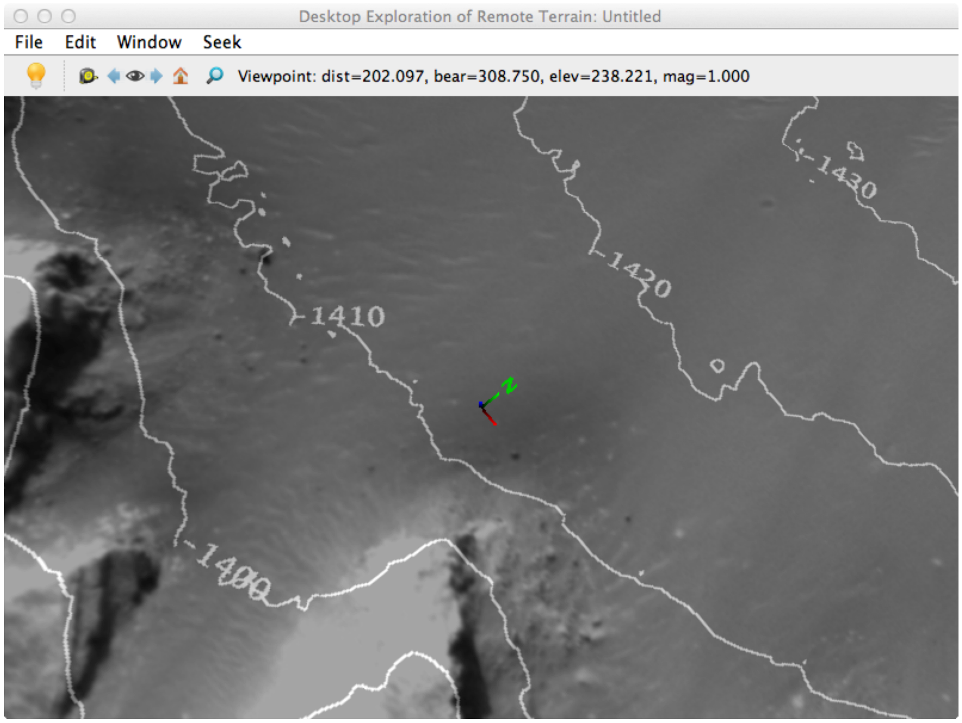
9. Run the gdalinfo command to get the mininimum and maximum roughness values:
   gdalinfo –stats rough.tif

10. Using the minimum and maximum values, create a color relief map from the roughness map and a color map. This color map (RoughColor.txt) contains the following lines:
    0 1 0 0 255
    1.0 0 255 255 255
    7.5 0 255 255 255
    nv 0 0 0 0

11. Use gdaldem to create the color relief map:
    gdaldem color-relief rough.tif RoughColor.txt Roughness.tif

12. Run layerfactory to create a Roughness layer with the parameters:
    -layer=colorimage
    -file=Roughness.tif
    -landscape=yourpath/VictoriaCrater
    -tilesize=128
    -layername=Roughness

Example 49: HiRISE Victoria Crater with Contour Map



Documentation for gdal_contour can be found at http://www.gdal.org/gdal_contour.html. HiRISE files for Victoria Crater can be found at http://www.uahirise.org/dtm/dtm.php?ID=PSP_001414_1780.

1. Go to the HiRISE website and select "full directory listing" link.

2. Download DTEEC_001414_1780_001612_1780_U01.IMG. This is the DEM file.

3. Download DT1EA_001414_1780_001612_1780_U01.JP2 and the corresponding .LBL file. This is the orthoimage.

4. Convert the JP2 file to an IMG file with the free JP2_to_PDS utility. You can find it here: http://hirise.lpl.arizona.edu/tools/pds_jp2.php.

5. Create a pyramid directory called VictoriaCrater.

6. Run layerfactory with the following parameters:

    -layer=elevation
    -file= DTEEC_001414_1780_001612_1780_U01.IMG
    -landscape =*yourpath*/VictoriaCrater
    -tilesize=128

7. Run layerfactory again for the gray orthoimage with the parameters:

    -layer=grayimage
    -file= DT1EA_001414_1780_001612_1780_U01.IMG
    -landscape =*yourpath*/VictoriaCrater
    -tilesize=512

    The orthoimage is 0.25 m/pixel whereas the DEM is only 1 m/pixel, hence the larger tile size.

8. Run the gdal_contour command to create the GeoJSON file contour.json:

    gdal_contour -a elev DTEEC_001414_1780_001612_1780_U01.TIF contour.json –f GeoJSON -i 10

9. Run layerfactory to make the contour map with the following parameters:

    -landscape= *yourpath*/VictoriaCrater
    -file=contour.json
    -contourmap

Appendices

Appendix A: Configuring the Mac Trackpad

- Open System Preferences.
- Select the trackpad icon.
- Disable "Tap to click".
- Enable "Secondary click".
- Close System Preferences.
- Use one finger for the left mouse button and two fingers for the right mouse button.
- Translate: press down with one finger until you hear a click, then drag.
- Rotate: press down with two fingers until you hear a click, then drag.
- Context menu: single-click with two fingers.
- Dolly or Zoom: swipe or drag (no click) with two fingers.

Appendix B: Create a Ground Plane

1. Find an existing DEM that you like and crop it.

```
gdal_translate –mo="AREA_OR_POINT=Point" –outsize 1024 1024
DTEEC_001414_1780_001612_1780_U01.IMG DEM.tif
```

2. Get the minimum and maximum elevation using gdalinfo.

```
gdalinfo –stats DEM.tif
```

3. Use gdal_translate to scale the elevation values to zero.

```
gdal_translate -scale -1452.89453125 -1373.3200683594 0 0 DEM.tif elevation.tif
```

4. Create a pyramid from the new DEM.

Appendix C: Adjust HRSC Colors

1. Convert the red and blue components from byte to floating point.

```
gdal_translate -ot Float32 H0360_0000_re4.IMG re4.tiff
gdal_translate -ot Float32 H0360_0000_bl4.IMG bl4.tiff
```

2. Scale the red and blue components from 0-255 to 0-1.

```
gdal_translate -scale 0 255 0 1 re4.tiff re4_01.tiff
gdal_translate -scale 0 255 0 1 bl4.tiff bl4_01.tiff
```

3. Scale the red and blue components exponentially.

```
gdal_translate -scale 0 1 -exponent 0.6 re4_01.tiff re4_scaled.tiff
gdal_translate -scale 0 1 -exponent 2.2 bl4_01.tiff bl4_scaled.tiff
```

4. Convert the red and blue components back to byte.

```
gdal_translate -ot Byte re4_scaled.tiff re4_256.tiff
gdal_translate -ot Byte bl4_scaled.tiff bl4_256.tiff
```

5. Create the RGB image file.

```
gdal_merge.py -separate re4_256.tiff H0360_0000_gr4.IMG bl4_256.tiff -o rgb.tiff
```