Evaluation of the Benefits and Risks of Human Solar Radiation Exposure Within Cities

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Evaluation of the Benefits and Risks of Human Solar Radiation Exposure Within Cities

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by

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Under the joint supervision of

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Declaration

I declare that this written submission represents my ideas in my own words and where others ideas and words have been included. I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/facts/source in my submission. I understand that any violation of the above will be caused for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Place: IIT Kharagpur

Date: 30th April, 2019 (Chitransh Atre)

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Abstract

The albedo of the earth's surface is the ratio between spectral irradiance reflected by the ground to all directions and global irradiance. The earth's surface can also influence the incident radiation due to its albedo, because reflected radiation can be scattered back from the atmosphere and thus increase the incident radiation. Simulation for the sun’s UV radiance and irradiance in region ranging UV (250 nm – 400 nm wavelength) concerning diurnal, seasonal and geographic variability for several locations e.g. in Berlin with different solar zenith angles and times. Albedo is taken for the different surfaces like grass, concrete, snow (fresh and old), sand, water, vegetation etc. Assuming that the surfaces behave like a Lambertian surface. Later on, the calculation of exposure time will be calculated for getting the sufficient vitamin-D and also the future levels of UV calculated due to the variation of the clouds and clothing behavior of human and their impacts. Also, the solar UV radiation variation due to the different types of clouds is calculated and compared.

Keywords: UV radiance and irradiance, Albedo

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List of Abbreviations

SZA – Solar zenith angle

IDL - Interactive data language

UV-A - Near UV (315–400 nm)

UV-B - Middle UV (280–315 nm)

UV-C - Far UV (100–280 nm)

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Chapter -1
Introduction

1.1 EM radiation

Electromagnetic radiation (EMR) is energy that can travel through the vacuum and through space. Whenever an electric charge oscillates or is accelerated, an electric and magnetic field propagates outward from it. In a vacuum, EMR travels at the speed of light.

EMR exhibits a wave-like behavior as it travels through space and the wavelength and frequency are related through the speed of light. Electromagnetic waves can be classified according to their various wavelengths/frequencies and this classification is known as the electromagnetic spectrum.

1.2 UV spectrum

Sunlight is the main source of UV rays. Ultraviolet (UV) designates a band of the electromagnetic spectrum with wavelength from 100 nm to 400 nm, shorter than that of visible light but longer than X-rays. UV radiation is present in sunlight, and contributes about 10% of the total light output of the Sun. It is also produced by electric arcs and specialized lights, such as mercury-vapor lamps, tanning lamps, and black lights.

1.3 Types of UV radiation

There are 3 main types of UV rays:

- UV-A rays age skin cells and can damage their DNA. These rays are linked to long-term skin damage such as wrinkles, but they are also thought to play a role in some skin cancers. Most tanning beds give off large amounts of UVA, which has been found to increase skin cancer risk.

- UV-B rays have slightly more energy than UVA rays. They can damage skin cells' DNA directly, and are the main rays that cause sunburns. They are also thought to cause most skin cancers.
- UV-C rays have more energy than the other types of UV rays, but they don't get through our atmosphere and are not in sunlight. They are not normally a cause of skin cancer.

Both UVA and UVB rays can damage skin and cause skin cancer. UVB rays are a more potent cause of at least some skin cancers, but based on what's known today, there are no safe UV rays. These divisions were made arbitrarily at the Second International Congress of Light in 1932 (Diffey 2002b).

Name	Wavelength (nm)	Notes
Ultraviolet A	315–400	Long-wave, black light, not absorbed by the ozone layer: soft UV
Ultraviolet B	280–315	Medium-wave, mostly absorbed by the ozone layer: intermediate UV
Ultraviolet C	100–280	Short-wave, germicidal, completely absorbed by the ozone layer and atmosphere: hard UV

Table 1.1: Classification of UV radiation

1.4 Effects due to UV radiation

Suntan and sunburn are familiar effects of over-exposure of the skin to UV, along with higher risk of skin cancer. Living things on dry land would be severely damaged by ultraviolet radiation from the Sun if most of it were not filtered out by the Earth's atmosphere. The UV spectrum thus has effects both beneficial and harmful to human health. Exposure to ultraviolet (UV) radiation is a major risk factor for most skin cancers. However, over ninety percent of vitamin D3 in a person's diet is produced through exposure to sunlight (Holick 2003b).

Even though UV rays make up only a very small portion of the sun's rays, they are the main cause of the sun's damaging effects on the skin. UV rays damage the DNA of skin cells. Skin cancers start when this damage affects the DNA of genes that control skin cell growth.

1.5 Variation in UV radiation at earth's surface

The strength of the UV rays reaching the ground depends on a number of factors, such as:

- Time of day: UV rays are strongest between 10 am and 4 pm.
- Season of the year: UV rays are stronger during spring and summer months. This is less of a factor near the equator.
- Distance from the equator (latitude): UV exposure goes down as you get further from the equator.
- Altitude: More UV rays reach the ground at higher elevations.
- Cloud cover: The effect of clouds can vary. Sometimes cloud cover blocks some UV from the sun and lowers UV exposure, while some types of clouds can reflect UV and can increase UV exposure. What is important to know is that UV rays can get through, even on a cloudy day.
- Reflection off surfaces: UV rays can bounce off surfaces like water, sand, snow, pavement, or grass, leading to an increase in UV exposure.

The amount of UV exposure a person gets depends on the strength of the rays, the length of time the skin is exposed, and whether the skin is protected with clothing or sunscreen.

1.6 Albedo

The amount of energy that is reflected by a surface is determined by the reflectivity of that surface, called the albedo. A high albedo means the surface reflects the majority of the radiation that hits it and absorbs the rest. A low albedo means a surface reflects a small amount of the incoming radiation and absorbs the rest. For instance, fresh snow reflects up to 95% of the incoming radiation. Therefore, fresh snow has a high albedo of .95. By contrast, water reflects about 10% of the incoming radiation, resulting in a low albedo of .10. Since 30% of the sun's energy is reflected by the entire earth, the earth has an average albedo of .30.

1.7 Cloud

Clouds cause more variability in surface UV radiation than all other geophysical variables. For most locations, the variability of clouds limits the ability to detect long-term changes in surface erythemal irradiance due to other causes such as ozone (den Outer et al., 2005; Glandorf et al., 2005). Different cloud types have significantly different effects on the intensity and angular distribution of surface UV radiation. A thin layer of clouds reduces the direct component of surface radiation and generally enhances the diffuse component, leading to a different angular distribution. A thicker cloud layer blocks the direct component leaving only the diffuse component.

Research Objectives

- Simulation of UV radiance due to the surface albedo on human within the city i.e. due to the ground surface reflectivity for different solar zenith angles and times.
- To study the variability of vitamin-D in human body with clothing behavior conditions and different types of surfaces.
- Calculation of the sun exposure time to get the sufficient vitamin-D in different seasons.
- UV radiance variation due to different types of the clouds.

Chapter-2

Literature Review

Beneficial biological effects due to UV radiation

Too much sun causes sunburn and too little results in a vitamin deficiency. Then we looked at physiological relationships to estimate the exposure times to sunlight that optimise human health, as a function of the widely used UV Index (UVI). The target we used for vitamin-D production was 1000 IU (international units).

Geographic location

a. **Altitude**
b. **Latitude and Longitude**
c. **Seasonal variation**

Seasons in Germany

Germany's climate is moderate and has generally no longer periods of cold or hot weather. Northwestern and coastal Germany have a maritime influenced climate which is characterized by warm summers and mild cloudy winters. Most areas on the country's North Sea coast have midwinter temperatures about 1.5°C or even higher. Farther inland, the climate is continental, marked by greater seasonal variations in temperature, with warmer summers and colder winters. Temperature extremes between night and day and summer and winter are considerably less in the north than in the south. During January, the coldest month, the average temperature is about 1.5°C in the north and about -2°C in the south. In July, the warmest month, it is cooler in the north than in the south. The northern coastal region has July temperatures averaging between 16°C and 18°C; at some locations in the south, the average is almost 20°C or even slightly higher.

German Spring: March, April, May

German Summer: June, July, August

German Autumn: September, October, November

German Winter: December, January, February

Earth-to-Sun Distance

The intensity of solar radiation just outside the Earth's atmosphere at all wavelengths is proportional to the inverse square of the distance between the Earth and the sun. During its annual elliptical orbit around the sun, the Earth is closest to the sun in early January and farthest from the sun in early July. The difference in the intensity of solar radiation between the January maximum and the July minimum is nearly 7% at all wavelengths. This asymmetry has consequences for the geographical distribution of UV radiation, since the maximum occurs during summer in the southern hemisphere and winter in the northern hemisphere, whereas, the minimum occurs during winter in the southern hemisphere and summer in the northern hemisphere. In addition, UV radiation in the southern hemisphere is enhanced by smaller total column ozone.

Solar zenith angle and solar azimuthal angle

Atmospheric gases absorb very little UV-A radiation. Atmospheric oxygen and ozone absorb all UV-C radiation and prevent it from reaching the troposphere and the Earth's surface. Downwelling surface UV radiation is also enhanced by increased surface albedo, which returns radiation upwards to the atmosphere where it is partially scattered back to the ground. In general, the albedo of most surfaces for UV radiation is about 4% (Surface ultraviolet radiation J.B. Kerr & V.E. Fioletov**)**. Also, if clouds are present below a high-altitude observation site, the effects of increased albedo from clouds become important (McKenzie et al., 2001a).

Solar radiation is important for nearly all studies regarding the Earth's geophysical properties and biological activities.

Solar Zenith Angle

For a particular site at the Earth's surface, the solar zenith angle (sza) is readily calculated and depends on latitude, time of day, and season. Surface UV irradiance falling on a horizontal surface decreases with increasing sza. This decrease has two causes. First, the irradiance falling on a horizontal surface at the Earth's surface is proportional to the cosine of the sza. Several trace atmospheric gases absorb solar radiation at UVB wavelengths. The most significant absorber is stratospheric ozone, which allows less than 3% of erythemal radiation to reach the lower troposphere and the Earth's surface.

Albedo and reflectivity

The intensity of radiation falling on a horizontal sensor can be enhanced with an increase in the reflectivity of the Earth's surface, even when the Earth's surface is not in the sensor's view. This is the result of additional radiation being scattered upwards to the atmosphere where it is partially scattered back to the ground. For water and most land surfaces the albedo is generally quite low (<5%) in the UV (e.g., Webb et al., 2004; Wendisch et al., 2004) and the UV ocean albedo is typically higher than the land albedo (Herman and Celarier, 1997). Sand surfaces can have higher albedo (Parisi et al., 2003). In general, spatial differences in land use (e.g., urban, agricultural, forest, etc.) have little optical effect on surface UV radiation. The situation is more complicated when both snow and clouds are present (Krotkov et al., 2001).

Only UV-B radiation enables vitamin D formation. The intensity of UV-B radiation is the crucial factor for the endogenous vitamin D synthesis: at too low levels, the endogenous vitamin D synthesis comes to a halt. This is the situation in Germany during wintertime. If the UV-B radiation is high – in spring, summer and autumn - a sufficient quantity of endogenous vitamin D is synthesized in a short time.

No extra sun exposure is needed for vitamin D synthesis. Based on current scientific knowledge, sufficient vitamin D synthesis is achieved when exposing the face, hands, and arms uncovered and without sunscreen to half of the minimum erythemal UV dose (0.5 MED) two to three times a week, i.e. half the time it would usually take for unprotected skin to develop a sunburn (see also "acute damage to the skin"). In purely mathematical terms, this would correspond to about 12 minutes of exposure to high erythemal UV radiation (UV index 7) for people with skin type II. According to scientific studies, longer exposure will not lead to more vitamin D synthesis, but will only increase the risk of UV-related health damage.

The vitamin D blood serum level decreases in winter. Due to the low UV-B radiation in winter (October to March in Germany), a reduction of vitamin D levels in the blood serum can occur even with a balanced diet. Vitamin D reservoirs formed during summer contribute to the vitamin D supply in winter. From the spring, the vitamin D reservoirs depleted during the winter months can be easily replenished.

Vitamin D deficiency and risk groups. Groups at particularly high risk of vitamin D deficiency are people with certain chronic diseases for example of the liver, kidneys and the gastrointestinal tract. But also, people with lacking or insufficient sun exposure, such as immobile elderly people, people with a dark skin type living in Germany or traditionally veiled people are at risk.

Vitamin- D: -

Two sources are important for our vitamin D supply: In addition to the body's own vitamin D formation in the skin with the help of sunlight (UVB radiation in a range of 219-315nm), vitamin D-rich foods should be mentioned.

- 90 percent skin formation due to UVB radiation
- 10 percent intake via the food

Here it becomes clear how important sufficient UVB irradiation is for optimal supply of vitamin D. However, in our latitudes, the sun is not sufficient, especially in the months of October to March, to ensure adequate vitamin D formation. In addition, the modern way of life (frequent stay in closed rooms or car, lunch break in the canteen) regularly causes us to spend less time under the open sky and in the sun - the body's own vitamin D synthesis is stalled. In addition, the use of sunscreens or creams with SPF is common today. Even a sun protection factor of 10, which is contained in many day creams, inhibits vitamin D production by 90 percent!

Assumption

Lambertian reflectance is the property that defines an ideal "matte" or diffusely reflecting surface. The apparent brightness of a Lambertian surface to an observer is the same regardless of the observer's angle of view. More technically, the surface's luminance is isotropic, and the luminous intensity obeys Lambert's cosine law.

Lambert's cosine law

In optics, Lambert's cosine law says that the radiant intensity or luminous intensity observed from an ideal diffusely reflecting surface or ideal diffuse radiator is directly proportional to the cosine of the angle θ between the direction of the incident light and the surface normal. The law is also known as the cosine emission law or Lambert's emission law. A surface which obeys Lambert's law is said to be Lambertian, and exhibits Lambertian reflectance. Such a surface has the same radiance when viewed from any angle. This means, for example, that to the human eye it has the same apparent brightness (or luminance). It has the same radiance because, although the emitted power from a given area element is reduced by the cosine of the emission angle, the actual area of the surface visible to the viewer is increased by a corresponding amount (1/cosine). Or equivalently, a remote sensor with a constant solid viewing angle (or "IFOV") will perceive a larger source area with decreasing emission angles, but observe less emitted power per unit source area: these two effects compensate each other and hence the observed radiance is independent from emission angle. Therefore, its radiance (power per unit solid angle per unit projected source area) is the same.

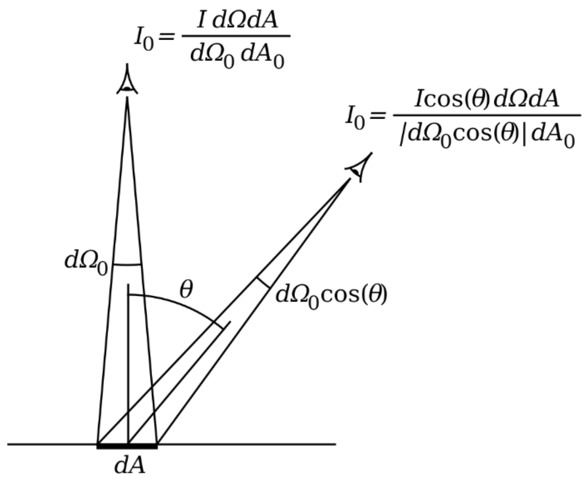

Fig 2.1: Observed intensity (photons/(s-m^2-sr)) for a normal and off-normal observer

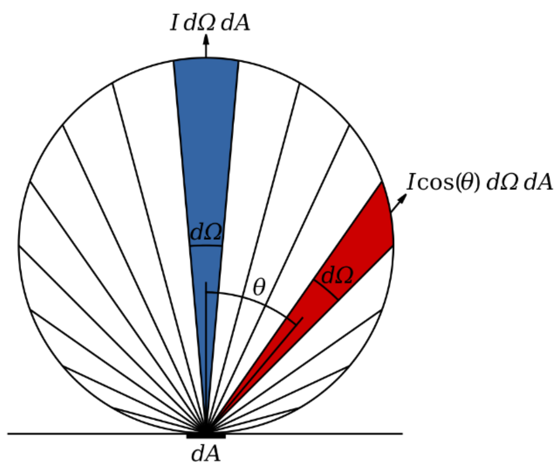

Fig 2.2: Emission rate (photons/s) in a normal and off-normal direction

The situation for a Lambertian surface (emitting or scattering) is illustrated in Figures 1 and 2. For conceptual clarity we will think in terms of photons rather than energy or luminous energy. The wedges in the circle each represent an equal angle dΩ, of an arbitrarily chosen size, and for a Lambertian surface, the number of photons per second emitted into each wedge is proportional to the area of the wedge.

The length of each wedge is the product of the diameter of the circle and cos(θ). The maximum rate of photon emission per unit solid angle is along the normal, and diminishes to zero for θ = 90°. In mathematical terms, the radiance along the normal is I photons/(s·m2·sr) and the number of photons per second emitted into the vertical wedge is I dΩ dA. The number of photons per second emitted into the wedge at angle θ is I cos(θ) dΩ dA.

Chapter-3

Data and Methodology

Region of Study

The region for the study named 'Ernst Reuter Platz' which is located in Berlin, Germany having coordinates latitude = 52° 51' N and longitude = 13° 31' E.

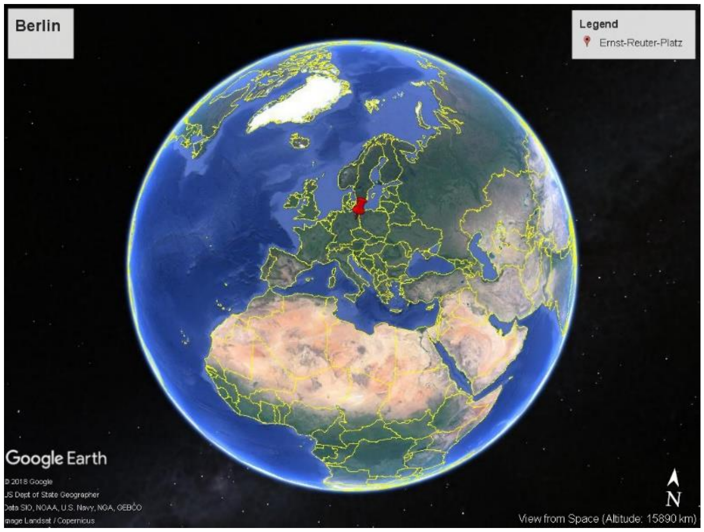

Fig 3.1: It shows the region of study. (Berlin)
Source: Google earth image

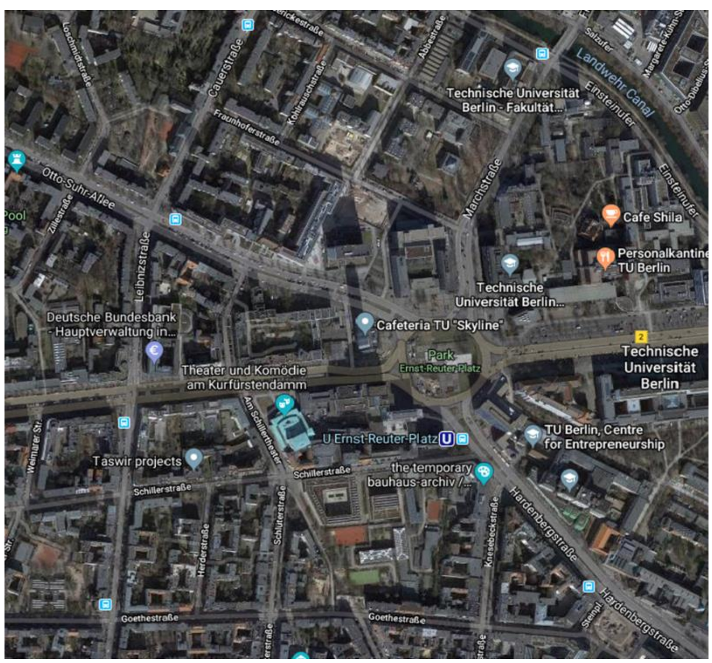

Fig 3.2: Satellite image of Ernst- Reuter Platz, Berlin

Classification of my study of UV radiation exposure is done on the basis of some of the factors that affects the exposure in the different seasons and chose some particular dates in a year which are important in astronomical studies. Considering the usual average timing for going a person outside in the exposure are the morning time i.e. around 8:00 A.M. to 9:00 A.M. for going to work or offices, then for having lunch, the time which is found suitable for this study is from 12:00 O'clock to 1:00 P.M. generally. And then coming back from the office from 4:30 P.M. to 5:30 P.M. in the working days (Monday to Friday).

The most important timing is when the solar exposure becomes highest in a day which is usually around 12:00 O'clock when the sun is at its highest position. But there are many other factors as mentioned in the introduction part of which some decreases the exposure and some may increase the exposure like clouds or types of reflecting surface. My study covers the UV radiation exposure on humans after striking with the different surfaces which include natural surfaces as well as artificial surfaces (made by humans).

Selection of particular dates:

1.) March Equinox: The March equinox may be taken to mark the beginning of spring and the end of winter in the Northern Hemisphere. In general, this happens on the date 21 March according to Gregorian calendar. On this day, the night and day are nearly same length. The March equinox marks the moment the Sun crosses the celestial equator – the imaginary line in the sky above the Earth's equator – from south to north. This happens on March 19, 20, or 21 every year. The March equinox is often used by astronomers to measure a tropical year.
2.) Summer Solstice: The summer solstice, also known as midsummer, occurs when one of the Earth's poles has its maximum tilt toward the Sun. The Sun travels the longest path through the sky, and that day therefore has the most daylight. Because of this situation, we get the highest solar radiation exposure in the month of June on 21st.
3.) September equinox: The September equinox is the moment when the Sun appears to cross the celestial equator, heading southward. Due to differences between the

calendar year and the tropical year, the September equinox can occur at any time from the 21st to the 24th day of September.

4.) Winter solstice: When this axis leans towards the sun, it's summer in the northern hemisphere and winter in the south. This is reversed as the earth continues on its orbit until the axis becomes tilted away from the sun. During the winter solstice, the earth's axis is tilted at its furthest point from the sun. This means that, for us in the northern hemisphere, the sun is at its lowest point in the sky. It's also the shortest day of the year - and the longest night. On the day 21^{st} December, the nights are longer than the day. We can assume that the solar exposure will be minimum because in winters, the sun appears for very less duration in Germany.

In reference to the article "A Novel Method to Calculate Solar UV Exposure Relevant to Vitamin D Production in Humans", considering that the minimum amount of International Units (IU) required for the sufficient vitamin-D production in the human body is 1000 IU for a day.

Albedo Values

Table 3.1 shows the albedo values from the different types of surfaces which is taken for this study. The highest value of albedo is for snow which is fresh and equal to 0.77. Although the other surfaces have less albedo ranges but even these less values can impact on the human health and cannot be neglected.

Table 3.1: Albedo from the different surfaces

Surface Type	Albedo Range
Concrete	0.1 to 0.2
Snow (fresh)	~ 0.77
Snow (aged)	~ 0.41
Sand	0.02 – 0.12
Vegetation	0.01 – 0.04
Asphalt	0.07

Cloud Data

Table 3.2: Cloud information which shows the type of cloud on a selected date and the cloud cover. Where, St- Startus, Sc- Stratocumulus, Cu- Cumulus, Ci- Cirrus, As- Altostartus, Cc- Cirrocumulus, Cb- Cumulonimbus, Ac- Altocumulus.

Date	Time (UTC)	Type of cloud	Height (m.)	Cloud Cover (overall)(x/8)
March 2015				
1	12	Sc	600	
		Cu	510	6
2	13	Cu	1050	
	14	Cb	750	
		Cu	1200	6
3	12	Ci	7500	
		Cu	900	7
	13	Cu	840	
		As	3600	8
7	12	Ac	3900	
		Ci	9000	5
9	11	St	390	
		Ci	7500	4
16	12	Sc	390	
		Cu		7
17	12	Cc	10500	7
21	12	St	270	
		Sc	720	7
	14	Cb	600	
		Sc	1140	7
23	12	Cs	900	7
29	12	St	300	
		Sc	450	
		Ns	870	8

Apr-15				
1	13	Cb	540	
		Cu	900	
		Ci	8400	7
7	12	Sc	1140	
		As	5100	8
12	12	Cu	840	
		Ci	8400	7
13	12	Cu	720	7
14	12	Cu	1050	
		Cs	7200	
		Ci	9000	7
24	12	Ac	3000	
		Ci	8100	7
25	12	Sc	1020	
		Ac	3300	8

Table 3 shows the information regarding the types of cloud present on a particular date. In this study, we have selected the dates in which a unique type of cloud is present in the atmosphere. It also gives the information about the cloud cover and the time. We have the radiation data only for March and April month of 2015, that's why we have taken the cloud data for the respective months.

Here's a list of some of the most common cloud types in the sky:

Clouds are given different names based on their shape and their height in the sky. Some clouds are near the ground. Others are almost as high as jet planes fly. Some are puffy like cotton. Others are grey and uniform.

The highest clouds in the atmosphere are cirrocumulus, cirrus, and cirrostratus. Cumulonimbus clouds can also grow to be very high. Mid-level clouds include altocumulus and altostratus. The lowest clouds in the atmosphere are stratus, cumulus, and stratocumulus.

Cirrocumulus clouds are small rounded puffs that usually appear in long rows high in the sky. Cirrocumulus are usually white, but sometimes appear grey. They are the same size or smaller than the width of your littlest finger when you hold up your hand at arm's length. When these clouds cover a lot of the sky, they can look like the scales of a fish, which is it is called a "mackerel sky.” Cirrocumulus are common in winter and indicate fair, but cold, weather.

Cirrus clouds are made of ice crystals and look like long, thin, wispy white streamers high in the sky. They are commonly known as "mare's tails" because they are shaped like the tail of a horse. Cirrus clouds are often seen during fair weather. But if they build up larger over time and are followed by cirrostratus clouds, there may be a warm front on the way.

Cirrostratus clouds are high, thin sheet-like thin clouds that usually cover the entire sky. The clouds are so thin that the Sun or moon can sometimes shine through and appear to have a halo as light hits the ice crystals and bends. The halo is the width of your hand held at arm's length. Cirrostratus clouds usually come 12 to 24 hours before a rain or snowstorm.

Cumulonimbus clouds also have vertical growth and can grow up to 10 km high. At this height, high winds will flatten the top of the cloud out into an anvil-like shape. Cumulonimbus clouds are thunderstorm clouds and are associated with heavy rain, snow, hail, lightning, and sometimes tornadoes.

Altocumulus clouds are mid-level, greyish-white with one part darker than the other. Altocumulus clouds usually form in groups and are about one kilometre thick. Altocumulus clouds are about as wide as your thumb when you hold up your hand at arm's length. If you see altocumulus clouds on a warm, humid morning, there might be a thunderstorm by late afternoon.

Altostratus clouds are mid-level, grey or blue-grey clouds that usually covers the whole sky. The Sun or moon may shine through an altostratus cloud, but will appear watery or fuzzy. If you see altostratus clouds, a storm with continuous rain or snow might be on its way. Occasionally, rain falls from an altostratus cloud. If the rain hits the ground, then the cloud has become a nimbostratus.

Stratus clouds are low and have a uniform grey in colour and can cover most or all of the sky. Stratus clouds can look like a fog that doesn't reach the ground. Light mist or drizzle is sometimes falling when stratus clouds are in the sky.

Cumulus clouds have vertical growth. They are puffy white or light grey clouds that look like floating cotton balls. Cumulus clouds have sharp outlines and a flat base at a height of 1000m. They are generally about one-kilometre wide which is about the size of your fist or larger when you hold up your hand at arm's length to look at the cloud. Cumulus clouds can be associated with fair or stormy weather. Watch for rain showers when the cloud's tops look like cauliflower heads.

Stratocumulus clouds are low, lumpy, and grey. Sometimes they line up in rows and other times they spread out. Only light rain (usually drizzle) falls from stratocumulus clouds. To distinguish between a stratocumulus and an altocumulus cloud, point your hand toward the cloud. If the cloud is about the size of your fist, then it is stratocumulus.

Chapter – 4

Results and Discussions

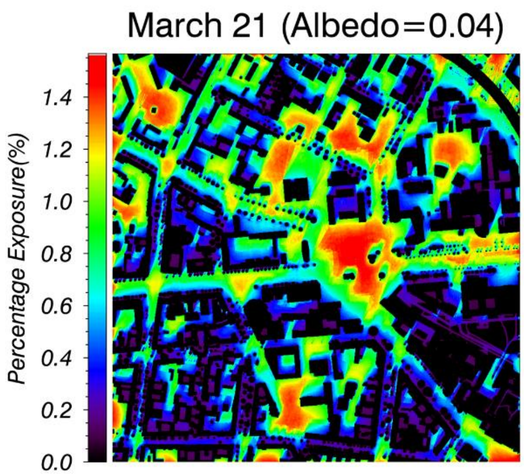

Fig. 4.1: Exposure percentage on 21st March with albedo value 0.04

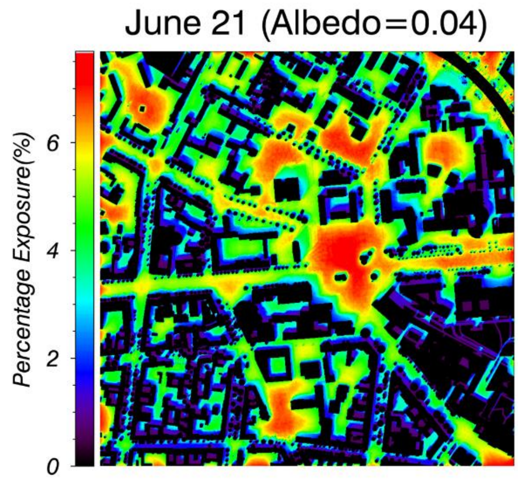

Fig. 4.2: Exposure percentage on 21st June with albedo value 0.04

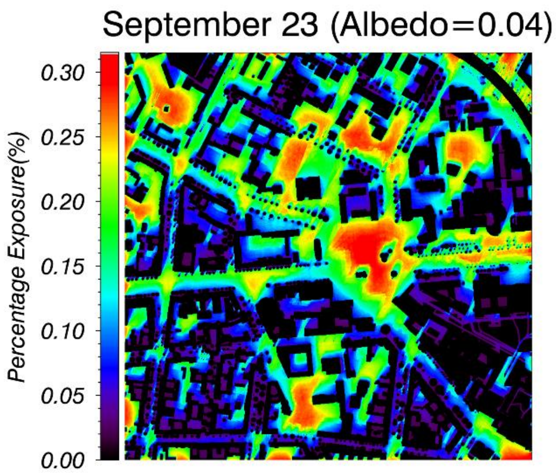

Fig. 4.3: Exposure percentage on 23rd September with albedo value 0.04

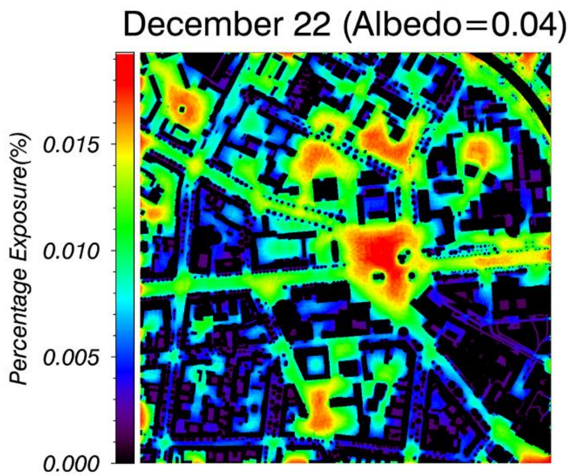

Fig. 4.4: Exposure percentage on 22nd December with albedo value 0.04

In the above figure, the albedo is taken as 0.04 which is of vegetation. The solar UV radiations are striking to the vegetation surface and then falling on the human body. Fig. 4.1 is generated for March 21 and for 1200 hrs to 1300 hrs. The plot shows the exposure percentage within 1 hour of time. When human stands or walks on the red colour region, he will get the exposure percentage of above 1.4 which is more than sufficient because we have taken 1000 IU as reference to get the sufficient vitamin-D in a day. Here, to get the sufficient vitamin-D production, one needs to get exposure percentage of 1. If human is getting exposure percentage of less than 1, then there will be deficiency of vitamin-D in the human body and then he should spend some more time in sun. However, if he stands or walks on the region of yellow, he will get 1.2 exposure percentage. In this plot, the black colour is the roof top so there will be no exposure in black region. Further over green colour and sky-blue colour, human is getting exposure percentage of around 1 and 0.8 which fulfils the requirement of vitamin-D in a day. This is the season of spring so not much radiation is absorbed.

In Fig. 4.2, the plot is made for June 21 which is the summer season in the year. Also, it is the hottest day throughout the year. Therefore, the solar UV radiation will be very high on this day. If any person walks on the red region area, majorly red colour is in the central part of the plot, he will get the exposure percentage of above 6 which is very high and may be harmful for the humans as it can develop skin related diseases. In this case, human should stand walk in the region where the colour is blue. For that he needs to find the shades.

Fig. 4.3 shows the exposure percentage on September 23 which lies in the season of autumn in which human is getting less percentage exposure e.g. around 0.30 is the maximum if he remains in the red colour region. People need to spend more time to get approximately 4 times exposure as they are getting in this case.

In Fig. 4.4, the plot is made for December 22 which is in the winter season. 22^{nd} December is the shortest day throughout the year. So, the sun will be seen for very less time in Germany. Therefore, the solar radiation exposure will be very less and we are not able to develop sufficient vitamin-D in our body. Hence vitamin-D deficiency occurs in the winter season. Also, the people wear fully covered clothes to whole body except the face in winter season preventing from cold. This decreases the area of exposure to the radiation.

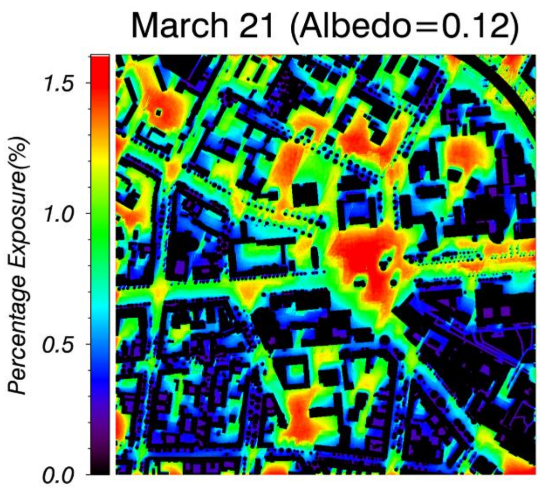

Fig. 4.5: Exposure percentage on 21st March with albedo value 0.12

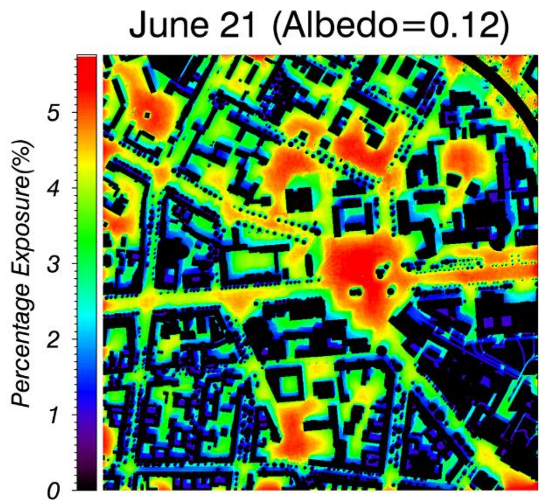

Fig. 4.6: Exposure percentage on 21st June with albedo value 0.12

From Fig. 4.5 to Fig. 4.8, all are plotted for the albedo value of 0.12 which is for the surfaces like sand. If we compare the plots on 21 march for vegetation and sand, we find more exposure from the sand surface because there is higher albedo for sand. Although the difference is not so large but if we select to walk on the sand, it will be better for the vitamin-D production in our body. Most of the region near the buildings are blue in colour. The reason behind that is there are shades near the buildings, therefore the solar radiation reaches there in less quantity.

If we compare the Fig. 4.6 and Fig. 4.7, there are dark blue regions more in Fig. 4.7 because it's a season of autumn and there is season of summer in the Fig. 4.6. So, the solar light will be spread in most of the corner areas and more places will be exposed to radiation.

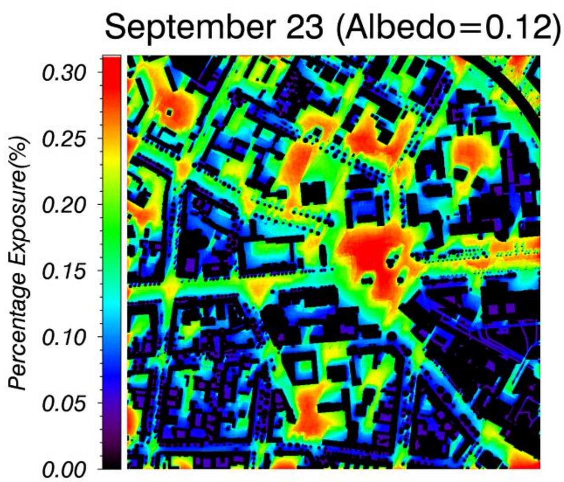

Fig. 4.7: Exposure percentage on 23rd September with albedo value 0.12

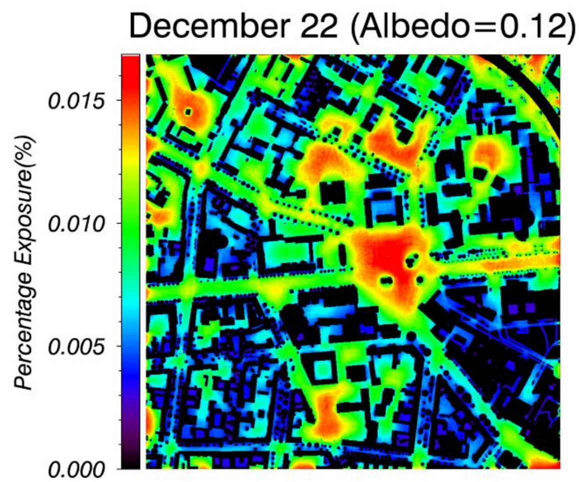

Fig. 4.8: Exposure percentage on 22nd December with albedo value 0.12

In Fig. 4.8, there is very less radiation exposure and its about 0.015 exposure percentage which is highly lesser than as we get in all other seasons. To compensate the deficiency caused due to less UB radiation absorption, we have to spend more time outside in the red color region in winter season.

If we compare the Fig. 4.5 and Fig. 4.7, we don't find much difference in the shadings near by the buildings and trees because these are the season of equinoxes i.e. March and September. On dates 21 March and 23 September, the time of day and night will be equal. Hence the solar exposure and zenith angle will be nearly same.

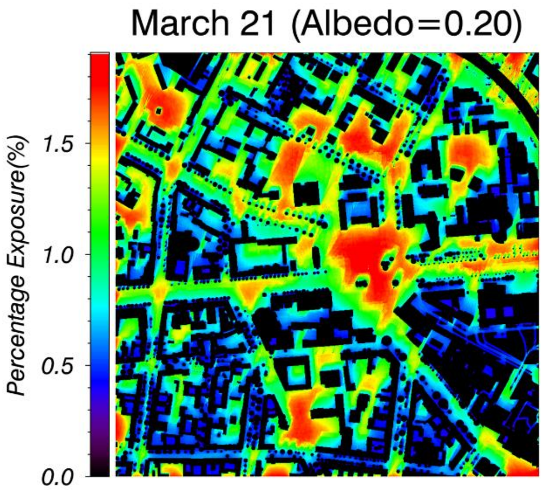

Fig. 4.9 Exposure percentage on 21st March with albedo value 0.20

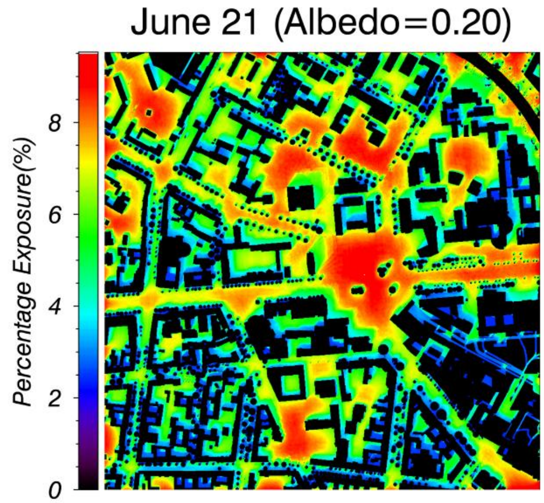

Fig. 4.10: Exposure percentage on 21st June with albedo value 0.20

Fig. 4.9 and Fig. 4.10 are plotted for albedo value 0.20 which is for the concrete surface. As the value of albedo is more, the reflected radiation will be more and hence we get more vitamin-D production in the human body. In Fig. 4.10, the value of exposure percentage is nearly around 9 in the red areas which is very high and harmful for the human skin. And also, in the summer time, people wear short clothes and loose clothes. The exposure to the radiation will be more and only half hour remaining outside can be dangerous.

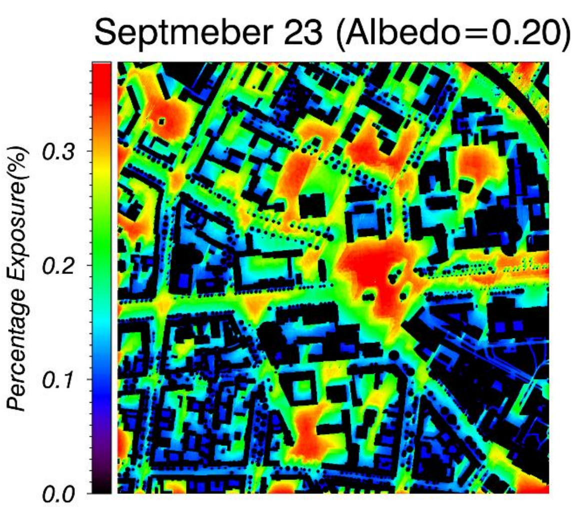

Fig. 4.11: Exposure percentage on 23rd September with albedo value 0.20

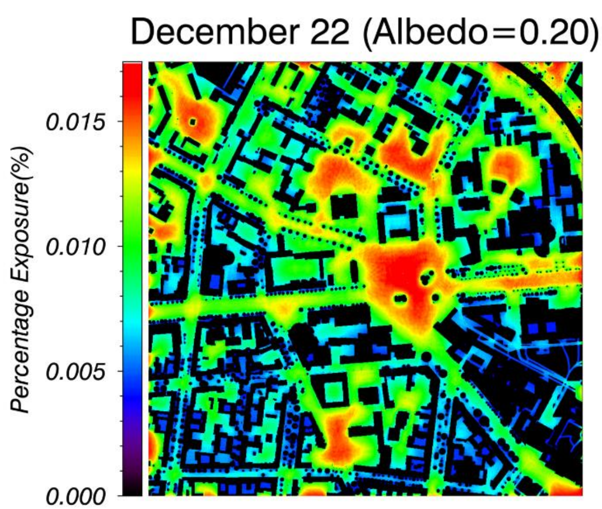

Fig. 4.12: Exposure percentage on 22nd December with albedo value 0.20

Fig. 4.11 and Fig. 4.12 are also for the concrete surface and autumn and winter season respectively. On September 23, the maximum exposure percentage is nearly around 0.40 that means to achieve sufficient vitamin-D condition, we have to stay outside in the sun exposure about 2-3 times as of now in this situation. For Fig. 4.12, the exposure is similar as for sand surface. There is not so big difference because of the very less sun radiation in the season of winter.

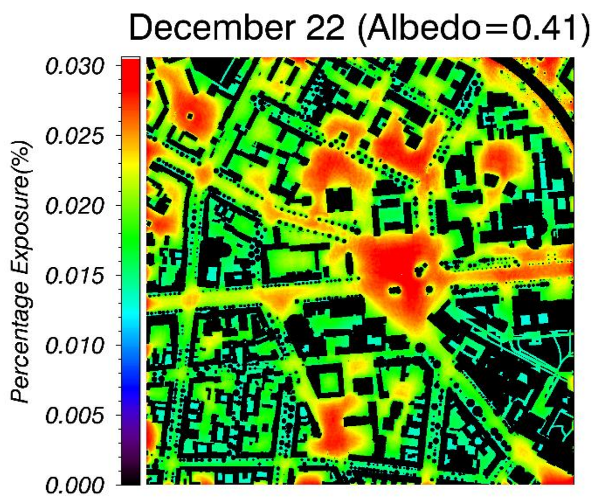

Fig. 4.13: Exposure percentage on 22st December with albedo value 0.41

Fig. 4.13 is plotted for December 22 and albedo value is 0.41 which is taken for aged snow. In Germany, snow fall occurs in the month of December. Assuming that whole area is covered with the snow, the exposure is calculated. Hence, we get double the exposure than we are getting on the sand surface or concrete surface. From this, we can conclude that in 1 hour, we are not getting sufficient vitamin-D in winter season. So, deficiency of vitamin-D will occur.

Comparisons

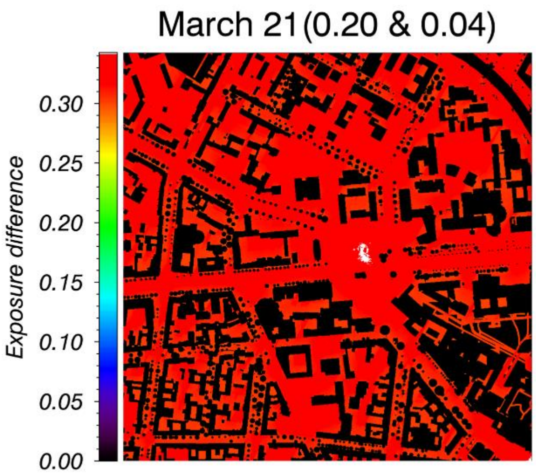

Fig. 4.14: Exposure difference between albedo value 0.20 and 0.04 on March 21

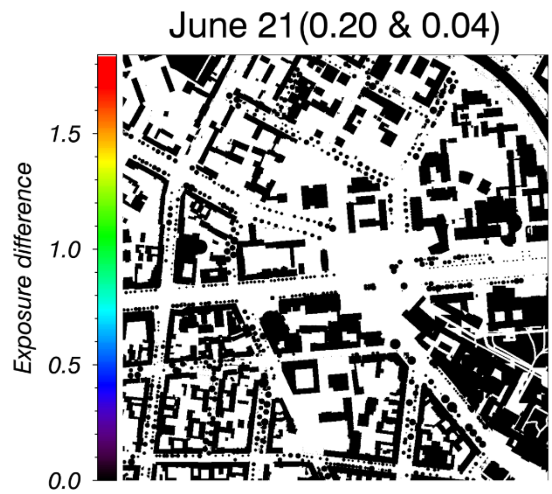

Fig. 4.15: Exposure difference between albedo value of 0.20 and 0.04 on June 21

Fig. 4.14, shows the difference between exposure for concrete and vegetation surfaces. The plot come out with red, black and little white color in the center part. It means that the area which is of red color gives us the difference of 0.35 units. There is little white at the center part of the figure which shows the highest value in the color bar. So, it is better to remain on the concrete surface rather than to remain at the vegetation surface.

Fig. 4.15, shows the difference between exposure for concrete and vegetation surfaces on June 21. The plot is in black and white color. Black color shows that there is no exposure because those are the roof tops. And white color shows the exposure difference of around 1.9. The white color is on the top most of color bar. It confirms that the value of exposure from concrete surface is always higher than that of vegetation surface.

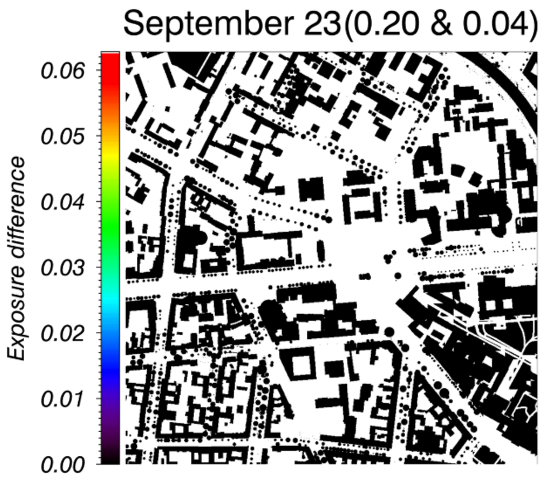

Fig. 4.16: Exposure difference between albedo value 0.20 and 0.04 on September 23

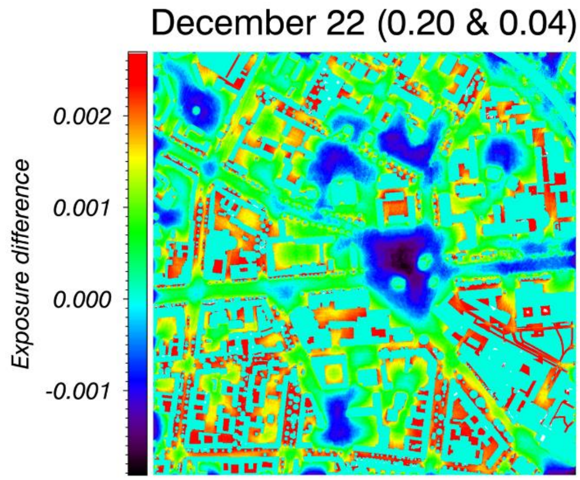

Fig. 4.17: Exposure difference between albedo value of 0.20 and 0.04 on December 22

Fig. 4.16 shows the exposure difference between concrete and vegetation surface on September 23. The white color depicts that we get 0.06 units more exposure than that of vegetation surface. But in Fig. 4.17 there are variations in the plot. In the blue color region, the difference is negative that means the exposure we are getting from the vegetation surface is more than that of the concrete surfaces. But in rest of the places except blue region, the exposure is more from concrete.

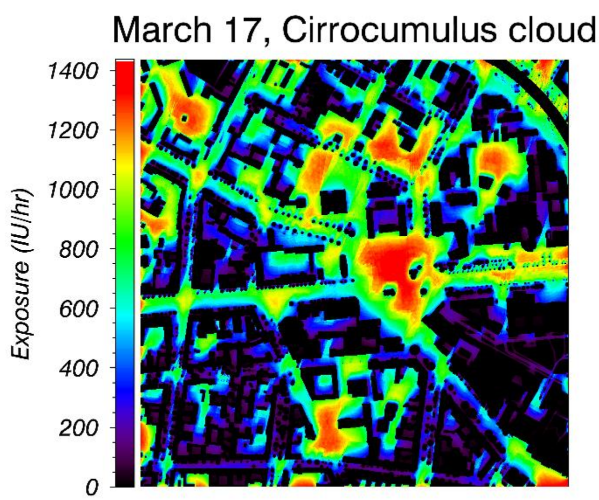

Fig. 4.18: Exposure on March 17 for Cirrocumulus cloud in an hour

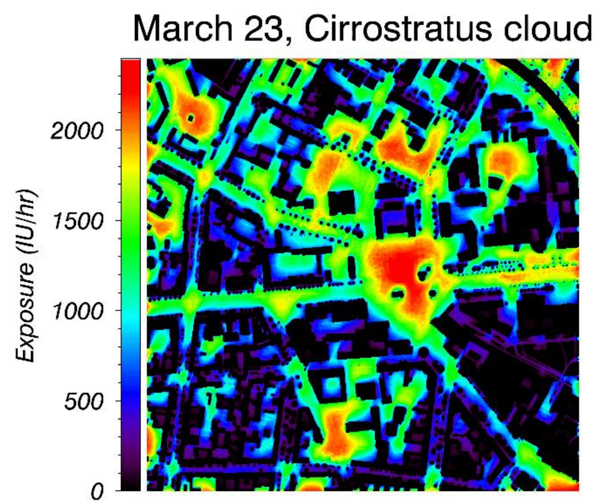

Fig. 4.19: Exposure on March 23 for Cirrostratus cloud in an hour

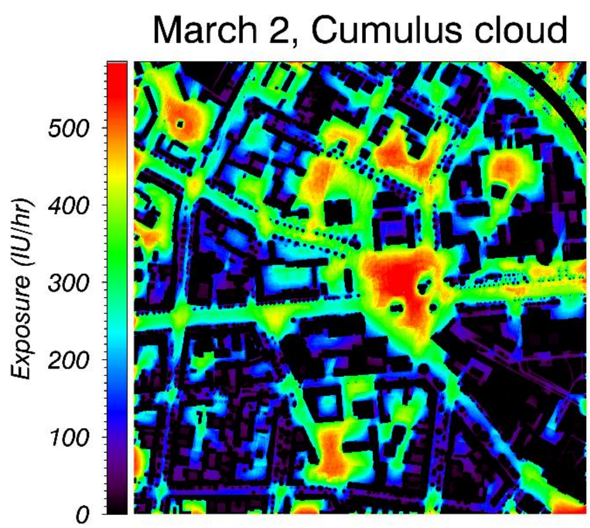

Fig. 4.20: Exposure on March 02 for Cumulus cloud in an hour

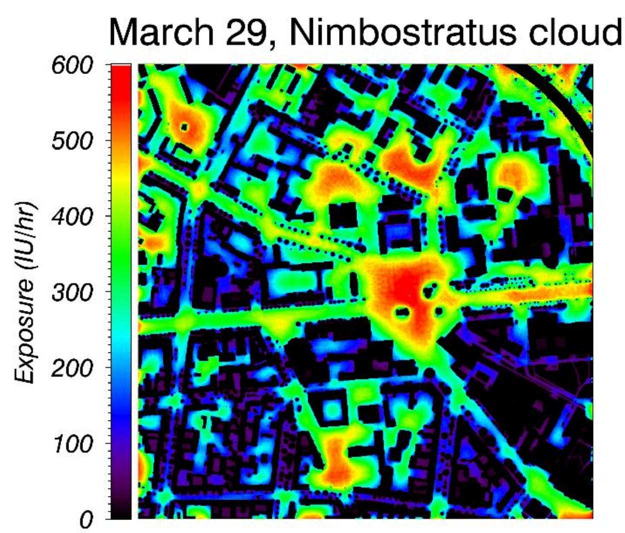

Fig. 4.21: Exposure on March 29 for Nimbostratus cloud in an hour

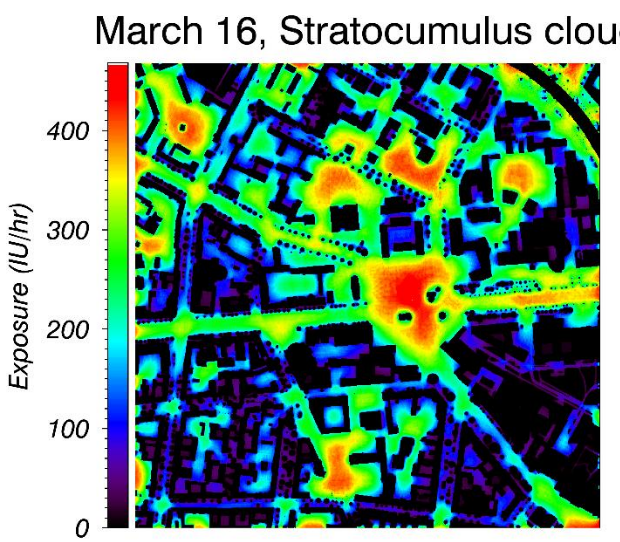

Fig. 4.22: Exposure on March 17 for Stratocumulus cloud in an hour

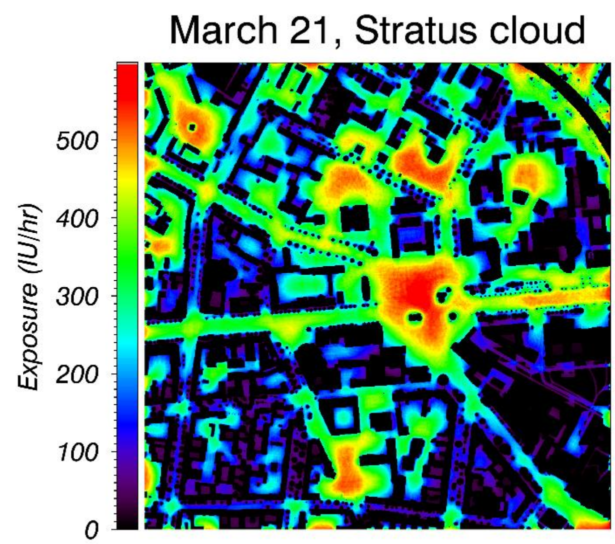

Fig. 4.23: Exposure on March 21 for Stratus cloud in an hour

Fig. 4.18 shows that the exposure on March 17, 2018. On that day Cirrocumulus clouds are present and the plot shows the exposure in International Units per hour. The considered time is from 12:00 hrs to 01:00 P.M. in daylight. From the figure its is shown that the exposure is very high around 1400 IU/hour.

Whereas in Fig. 4.19, the exposure is on 23 March and Cirrostratus clouds are present which gives the highest exposure amongst all types of clouds in this study.

If we compare Fig. 4.20 and Fig. 4.21, we can see Nimbostratus clouds are giving more UV radiation exposure than that of cumulus clouds on March 02.

Chapter 5

Conclusions and Future Scope

This thesis summaries the amount of time we should spent outside in the solar radiation to develop the sufficient vitamin-D in our body. There are mainly four selected dates which are in different seasons and on which the study has been done with changing in the clothing behavior. Therefore, we concluded that

- If we go outside in Berlin during the peak time of solar radiation i.e. from 12 O'clock to 1:00 P.M., we get higher exposure to UV radiation.
- In the month of December, we get very less exposure to the UV radiation due to the winter season, sun rarely can be seen directly. Therefore, there will be vitamin-D deficiency in winter season.
- In summer season, specially on 21st June, the sun remains at its highest peak and human will get extra exposure which can be harmful to health because to much of UV radiation causes skin diseases and even cancers.
- We are getting higher exposure if we walk or stand on snow or concrete surfaces rather than to remain on the sand or vegetation surfaces. Due to the higher albedo values of snow and concrete, we get higher exposure and which will be beneficial if there is winter season to get sufficient vitamin-D.
- If there is summer season, it is better to walk on vegetation or sand surfaces because these surfaces absorb most of the UV radiation and reflect very less UV radiations.

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Exposure Model

```
PRINT, 'Start exposure Modell:'
E_V = 1  ;Erythem=[0] oder VitaminD=[1]
restore, pfad+'\input\time1440.sav'
RESTORE, Pfad+'\input\Integrationswichtung_flux__ARRAY.sav'
FILE_MKDIR, Pfad+'Output\'+CASE_NAME+'\'

IF Shading_info eq 1 THEN BEGIN    ; 1 = mit Verschattung, 0 = keine
Verschattung
shading_FILE = FILE_SEARCH(PFAD+'\shading\', obstruction_file,
count=c_sh)
 PRINT, 'Read obstrcutiopn information:'
 restore, shading_FILE
 PRINT, 'Reading finished:'
 SHADE_XY = SIZE(obs, /Dimension)

 EXP_DATA=FLTARR(SHADE_XY(0),SHADE_XY(1))
 shading=DBLARR(72,19)+1
ENDIF ELSE BEGIN
  shading=DBLARR(72,19)+1
   shade_name='no_shading'
ENDELSE
```

```
PFUP=FLTARR(72,19)
clothing=STRARR(8)
clothing(0)= Pfad+'\input\3D_Modell\Golem1_Nackt__PFUP__PFDN.sav'
clothing(1)= Pfad+'\input\3D_Modell\Golem2_lHose_Tshirt__PFUP__PFDN.sav'
clothing(2)=
Pfad+'\input\3D_Modell\Golem3_gesicht_hals_Haende_frei__PFUP__PFDN.sav'
;clothing(3)=
Pfad+'\input\3D_Modell\Golem7_Gesicht_frei_Rolli_handfree__PFDN.sav'
;clothing(4)=
Pfad+'\input\3D_Modell\Golem6_Gesicht_frei_Bart_Rolli_handfree__PFDN.sav
'
clothing(5)=
Pfad+'\input\3D_Modell\Golem4.0_nur_gesicht_frei__PFUP__PFDN.sav'
;clothing(6)=
Pfad+'\input\3D_Modell\Golem4.1_Gesicht_frei_Rolli__PFDN.sav'
clothing(7)=
Pfad+'\input\3D_Modell\Golem5_Gesicht_frei_Bart_Rolli__PFUP__PFDN.sav'
RESTORE, clothing(Bekleidung)
```

```
;---- Simulaion aus Datensatz auswaehlen ----------
Start_H=STRMID(Startzeit,0,2)
Start_M=STRMID(Startzeit,2,2)
END_H=STRMID(ENDZEIT,0,2)
END_M=STRMID(ENDZEIT,2,2)

JUL_Start=JULDAY(month, day, year, Start_H, START_M, 0)
JUL_END  =JULDAY(month, day, year,   END_H,   END_M, 0)
TimeSteps=ROUND(( (JUL_END-JUL_Start)*24.*60 )+1)

SZAS      = FLTARR(TimeSteps)



;------ ausgewahlte Simulationen berechnen -----------------------------
--
FOR STEP=0,TimeSteps-1 DO BEGIN
  JUL_TIME = JUL_Start+(1.0D/24./60.)*STEP
        ;Solar_pos=solar_position(12.495479,41.894143, 0,0,0,0,0,0,
juldatetime=JUL_TIME)
Solar_pos=solar_position(Longitude, Latitude,
0,0,0,0,0,0,juldatetime=JUL_TIME)
 CALDAT, JUL_TIME, MOC, DAC, YEC, HOC, MIC
 SZAW=Solar_pos(0)
 SZAS(STEP)=SZAW
  IF SZAW LE 90 OR SZAW GE Kleinster_SZA_beiSimulationen THEN BEGIN
  ;PRINT,'calculating TimeStep: ',STEP ,'  (SZA = ', SZAW,')' ,
  FORMAT='(A,I3,A,I2,A)'
  IF SAA_in_south EQ 1 THEN SAA=180. ELSE SAA =Solar_pos(1)
  SZAW_inFile = SZAW-Kleinster_SZA_beiSimulationen


  ;------- Turn 3D-Modell into Viewing direction -----------------------
  PFDUMMY_temp=DBLARR(144,19)
        IF VIEW_to_SUN EQ 'YES' THEN StartPos_FLOAT = SAA/5. ELSE
      StartPos_FLOAT = Viewing_direction/5.
  SZA_IX=FINDGEN(19)
  AZI_IX=FINDGEN(72)+72-(StartPos_FLOAT)
  PFDUMMY_temp(0:71,*)  = PFDN
  PFDUMMY_temp(72:*,*)  = PFDN
  PFDN=interpolate(PFDUMMY_temp, AZI_IX, SZA_IX, /GRID)
  PFDUMMY_temp(0:71,*)  = PFUP
  PFDUMMY_temp(72:*,*)  = PFUP
  PFUP=interpolate(PFDUMMY_temp, AZI_IX, SZA_IX, /GRID)

  caldat, JUL_TIME, MONI, DAYI, YEARI, HOURI, MINI, SECONDI
        IN_ZEILE_X =   (WHERE(HOURI EQ time1440[0,*] AND MINI EQ
time1440[1,*] ,cwo))(0)
  ;PRINT, EXPO_DATA(0,0,IN_ZEILE_X)
  IF EXPO_DATA(0,0,IN_ZEILE_X) GE 0 THEN BEGIN
      Strahldichte_Array = EXPO_DATA(*,*,IN_ZEILE_X)
      ;Strahldichte_Array = radiance_weighted_Grid
      Strahldichte_Array_UP = FLTARR(72,19)
      edir_Messung = REFORM(direct_data(2,IN_ZEILE_X))
      IF edir_Messung LT 0 THEN edir_Messung = 0.
  ENDIF ELSE CONTINUE
```

```
IF Shading_info eq 1 THEN BEGIN
FOR grid_x = 0, shade_XY(0)-1 DO BEGIN
               PRINT,'calculating x-grid points: ',grid_x ,' / ',
    shade_XY(0)-1 , FORMAT='(A,I6,A,I6)'
     FOR grid_y = 0, shade_XY(0)-1 DO BEGIN
       shading10 = FLTARR(36,10)
       IF obs(grid_x,grid_y, 0) EQ 9 THEN Continue
                     FOR LAR=0,9 DO
          shading10(*,LAR)=obs(grid_x,grid_y,LAR*36:(LAR*36)+35)
       x_obssteps = FINDGEN(72)/2.
       y_obssteps = FINDGEN(19)/2.
       shading = interpolate(shading10,x_obssteps, y_obssteps, /GRID)

       DNW  = Strahldichte_Array    * PFDN * ARRAY * shading
       Down = Strahldichte_Array    * PFDN * shading
       UPW  = Strahldichte_Array_UP * PFUP * ARRAY

       DNW2 = TOTAL(DNW,2,/DOUBLE) ; Summe über die Zenitwinkel
       UPW2 = TOTAL(UPW,2,/DOUBLE) ; Summe über die Zenitwinkel
       Ex_DN = TOTAL(DNW2,1,/DOUBLE) ; " + Summe über die Azimutwinkel
       Ex_UP = TOTAL(UPW2,1,/DOUBLE) ; " + Summe über die Azimutwinkel



       IF SZAW LE 90 THEN BEGIN
          PFI=interpolate(PFDN,StartPos_FLOAT,SZAW/5.)
          SHI=shading(ROUND(SAA/5.), ROUND(SZAW/5.))
       ENDIF ELSE BEGIN
          PFI = 0
          SHI = 0
      ENDELSE
      IF SZAW eq 90 THEN SZA_DIR=89.99999 ELSE SZA_DIR=SZAW
      exp_direct = edir_Messung * PFI * SHI

                   EXP_DATA(grid_x, grid_y) = (Ex_DN + Ex_UP +
    exp_direct )*60./1000. *70.32D
   ENDFOR
ENDFOR
```

```
Pro stack_files
        CLOSE, /all
        PFAD = get_path()

       num = 0

       FILES = FILE_SEARCH(Pfad+'Output\June_summer_0.20(1200-1300)', '*.sav',
       count = nf)
       FNAME = TRANSPOSE(FILE_BASENAME(FILES,'.sav'))

       RESTORE, FILES(0)
       DATA = CREATE_STRUCT('Data_'+STRTRIM(STRING(0),2)+'', EXP_DATA)

       FOR i=1, nf-1 DO BEGIN

          RESTORE, FILES(i)
          COUNTER = 'Data_'+STRTRIM(STRING(i),2)+''
          DATA1 = CREATE_STRUCT(DATA[*], COUNTER, EXP_DATA)
          DATA = DATA1



          ;PRINT, 'Data'+STRTRIM(STRING(i),2)+''
          ;C[i,*,*]= EXP_DATA

       ENDFOR


             T= Data.(0)
            FOR i=1, nf-1 DO BEGIN

            T= T+ Data.(i)

       ENDFOR
            T= T/1000

             ;print, T
       SAVE, T, FILENAME=PFAD+'Output\June_summer_0.20(1200-1300)\stacked.sav'
                   im = IMAGE(T, RGB_TABLE=39,
            POSITION=[0.25,0.05,0.95,0.9],FONT_COLOR='Black', FONT_SIZE=24,
            TITLE='June 21 (Albedo=0.20)')
               im = COLORBAR(TARGET=im, ORIENTATION=1,
      POSITION=[0.22,0.05,0.25,0.9], TITLE='Percentage Exposure(%)')
       im.TEXTPOS = 0
       im.TICKDIR = 1
       im.BORDER_ON = 1
       im.COLOR = 'Black'
       im.FONT_STYLE = 'Italic'
       im.FONT_SIZE = 16
       im.Save, Pfad+'Output\June_summer_0.20(1200-1300)\stacked.bmp'

            ;T= DATA.Data_0+DATA.Data_1+DATA.Data_2


      STOP


END
```

```
Pro difference
 CLOSE, /all
 PFAD = get_path()

 ;input files
 file1= PFAD+'Output/stacked.sav'
 file2= PFAD+'Output/stacked.sav'

 ;file = FILE_SEARCH(PFAD+'Output/Test_march/', '*.sav')
 ;restoring the files
 RESTORE, FILENAME=file1
 data_file1 = T
 RESTORE, FILENAME=file2
 data_file2 = T
 difference1 = data_file1 - data_file2


              ;To save file and plot
```