Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Analysis Of The Temporal Changes Of Earth Outgoing Longwave Radiation (Olr) Over India

Tejas Turakhia[a], Sani Patel[b], Tejas V. Shah[c], Deepali H. Shah[c]

[a]*Research Scholar, Gujarat Technological University (GTU), Ahmedabad, Gujarat, India*
[b]*St. Xavier's College, Ahmedabad, Gujarat, India*
[c]*Instrumentation and Control Engineering Department, Gujarat Technological University (GTU),Ahmedabad, Gujarat, India*

Outgoing Longwave Radiation (OLR) is an important climatological parameter used in climate research related to energy balance. Aerosols and particulate matter like PM2.5 and PM10 also effect the radiation balance in the atmosphere. There is a complex relationship between PM2.5 and OLR, however OLR can be used to indirectly estimate PM2.5, and this make it necessary to understand its spatial and temporal variation. In this current study changes of OLR have been analyzed over Indian region using INSAT-3D for the year 2019. Five different land covers like Forest, Urban, Desert, Snow, Costal were covered to understand the variation of OLR. Our observation shows that as season move from winter to summer the value of OLR increases with temperature, while during the late dry seasons it decreases and during monsoon it shows minimum value. It is also observed that water body has higher OLR value as compared to land and snow surfaces, while urban areas show high values during winter. A diurnal analysis of all the months shows similar pattern for each season, with lower OLR values at midnight hours (1-2) and high values in morning (7-10). The results help in identify and analysis hotspots for regional OLR emissions over study area.

Keywords— Outgoing Longwave Radiation (OLR), INSAT-3D, Seasonal Variation

1. INTRODUCTION

Earth's climate is determined by the ERB (Earth Radiation Budget). For a climate equilibrium, the gain of energy from ASR (Absorbed Solar Radiation) is in balance with the loss of energy through Outgoing Longwave Radiation (OLR). OLR or radiative flux leaving the earth-atmosphere system in the infrared (IR) region of the electromagnetic spectrum in a very broad wavelength ranging from 4 to 100 µm. It is one important component of the Earth's energy equilibrium, and studying its temporal and spatial variations is climatically important.

OLR can be varied with air pollution and pollutants do have some effect on the radiation budget. Increased concentrations of greenhouse gases, such as CO_2, reduce the amount of outgoing longwave radiation to space, which in turn leads to energy retention in the Earth's atmosphere [1]. This process contributes to the trapping of longwave radiation, which can cause the Earth to warm [1]. The downward longwave radiation (DLR) is highly correlated with surface air temperature and water vapor, as well as particulate matter [2]. This correlation suggests that air pollution, which can lead to the formation of particulate matter like PM2.5, can impact the Earth's OLR [3]. The Earth's climate is closely linked to the flow of energy in and out of the Earth-atmosphere. At equilibrium, the OLR and the reflected shortwave radiation (RSW) at the top of the atmosphere (TOA) are related. Changes in the Earth's climate, such as the El Niño phenomenon, can affect the OLR [11]. The atmosphere grows moister because warmer air can hold more water vapor, which absorbs more shortwave radiation. This process lessens the amount of shortwave radiation that bounces back into space, leading to more effective longwave radiation shedding by the Earth, which cancels out the longwave-trapping effects of CO_2. [4]

PM2.5 can affect the longwave radiation balance of the atmosphere. The backward scattering efficiency of particles with a diameter less than 5 μm can lead to the scattering of thermal radiation back from the atmosphere, decreasing the thermal emission going out to space. This can cause a warming effect, as the atmosphere displays positive radiative forcing due to thermal radiation absorption by PM2.5. Aerosols can scatter and absorb longwave radiation, leading to a reduction in the amount of OLR that escapes to space [5]. This effect can cause a warming of the atmosphere, as the trapped energy is retained in the Earth's system. Studies have been conducted to quantify the longwave radiative effects of aerosols, including AOD. For example, one study used CERES observations to quantify the longwave radiative effect of the cloud-aerosol transition zone [6]. Another study found that the total aerosol optical depth can contribute to the longwave radiative forcing of the Indian Ocean tropospheric aerosol [7].

The outgoing longwave radiation is a component of the earth's radiation budget and a radiation flux that can explain the overall status of the global atmospheric system. Since it changes frequently by the surface temperature, water vapor, and cloud cover. OLR is a key climatological parameter used in climate research related to energy balance. It is considered particularly critical for the cloud-radiation interaction and is used for the development or improvement of a parameterization model for surface-atmosphere relations. Moreover, it is used as a key factor in the survey of the changes in cloud distribution, precipitation, and ecosystems. A distribution of low TOA OLRs (i.e., 240 Wm^{-2} or less) indicates convective activity and is useful for identifying the location of a tropical monsoons. The theory of Anthropogenic Global Warming (AGW) postulates that Greenhouse gases (GHG) emissions would cause a decrease of OLR at top of the atmosphere for a given global average surface temperature[8]. This OLR reduction would cause an energy imbalance with the incoming solar radiation resulting in a “forcing”. Hence, the more incoming energy than out-going energy is leading an increase in global temperatures. This elevation in temperatures cause an increase the OLR values until the radiation balance is restored. The earth radiation balance has been of concern to atmospheric scientists and observed by earth-orbiting satellites since the mid-1960s. The diurnal variation of the OLR is modulated by the response of the climate system to the variation of Incoming shortwave radiation (ISR) on diurnal time scale and is affected by a combination of factors: humidity of different heights in the atmosphere, amount of cloud and surface temperature, etc.

There is limited information on the direct estimation of PM2.5 using outgoing longwave radiation (OLR). However, some studies have investigated the relationship between PM2.5 and OLR, which can be used to indirectly estimate PM2.5. For example, one study employed an empirical parameterization to calculate OLR from PM2.5, with a normalized mean bias of -
0.09 [18]. Another study found that backward scattering efficiency of particles with a diameter less than 5 μm can lead to the scattering of thermal radiation back from the atmosphere, decreasing the thermal emission going out to space, which can cause a warming effect [19]. These studies suggest that there may be a relationship between PM2.5 and OLR, but further research is needed to establish a direct estimation method.

The OLR spatiotemporal variations and distributions from satellite data were used in several studies for different regions, which provide information and evidence for its traces and sources in the atmosphere. The aim of this research to analyze the regional, seasonal and annual hotspots emissions, and monthly distribution of OLR and evaluate its long term-trends over India using INSAT-3D data for the year 2019. The results help in identify and analysis hotspots for regional OLR emissions over study area. The OLR satellite data were also analyzed over urban, costal, forest, snow and desert area over India. The monthly mean OLR were generated using programming to analyze its distribution for the study area.

2. DATA AND METHODOLOGY

2.1. Data Acquisition

This research has been carried out for 12 months data from January 2019 to December 2019. The INSAT-3D datasets have been used for this research. The OLR every 30 min products data from the IMAGER sensors onboard INSAT-3D Satellite were used to analyze and understand the variability of OLR over different parts of India. The IMAGER is one of several instruments aboard ISRO's INSAT-3D platform at a 35,786 Km -altitude, Geostationary Orbit, was launched on 25 July 2013. Its global coverage due is 6000 × 6000 km^2 Continues scanning, and spatial resolution is 4 km. The information about the satellite and data are provided in Table 1.

Table 1. Data Information

Satellite Name	**INSAT 3D**
Product Name	Outgoing Longwave Radiation(OLR)
Product Sensor	IMAGER

Product Band and Channels	TIR 1 & TIR 2 & WV Channels
Product Wavelength	TIR 1 = 10.3 to 11.3 µm TIR 2 = 11.5 to 12.5 µm
Resolution	4 km
Data Availability Frequency	Every 30 Min Data Available

2.2. Study area and Methodology

As one of the South Asia countries, India extends between (6˚90`N and 37˚7`N) latitude and between (66˚ 20`E and 100º 90`E) longitude with total area is 3.287 million Km^2. Five locations were selected of different land covers in India like Urban, Coastal, Forest, Desert and Snow. The details of the locations are provided in Table 2. The data is first collected for the database from which different regions data is extracted and averaged out after removing the outliers. The monthly and seasonal patten is also generated. The MOSDAC portal provides every 30 min data of 1/3 Globe in Geotiff format. After extracting data, the OLR variation of different area like Forest, Urban, Desert, Snow, Costal is analyzed.

Table 2. Locations

Location Type	**Coordinates**
Urban (Ahmedabad)	23.0274 N , 72.5175 E
Coastal (Sundarban)	21.9497 N, 89.1833 E
Forest (Eravikulam National Park)	10.1356 N, 77.0597 E
Desert (Thar Dessert)	27.4695 N, 70.6217 E
Snow (Mount Everest)	27.9881 N, 86.9250 E

3. RESULTS AND DISCUSSION

Figure 1 represented the average monthly OLR from January 2019 – December 2019 for all our five selected locations; Urban, Desert, Costal, Snow and forest. The value of OLR varies with seasonal fluctuations that depends strongly upon weather condition. The data shows that the snow region has the least outgoing radiation while the urban region is showing maximum values during winter. In the months of summer and post monsoon the desert region dominates with values around 320 W/m^2. Seasonal pattern is observed in all locations, however the pattern is less observed in snowy region.

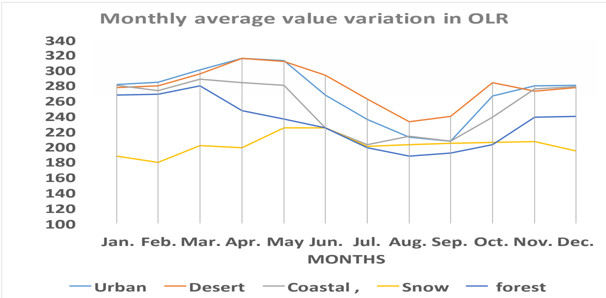


Figure 1. The average monthly OLR variation of year 2019 for Urban, Desert, Costal, Snow, Forest Regions.

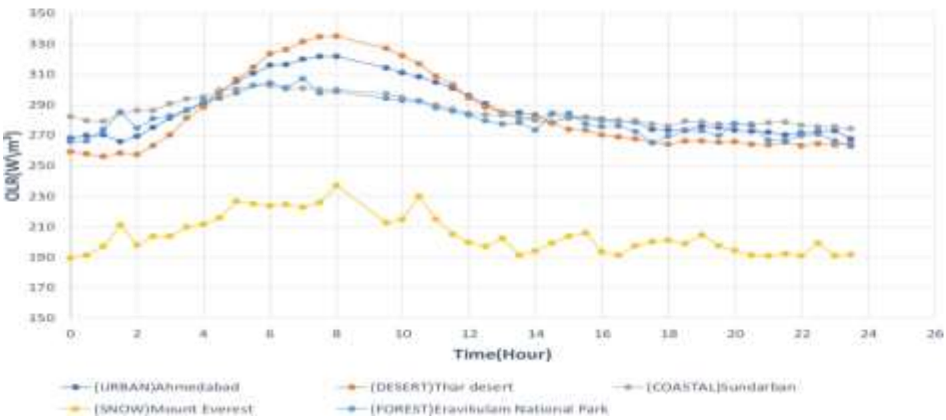
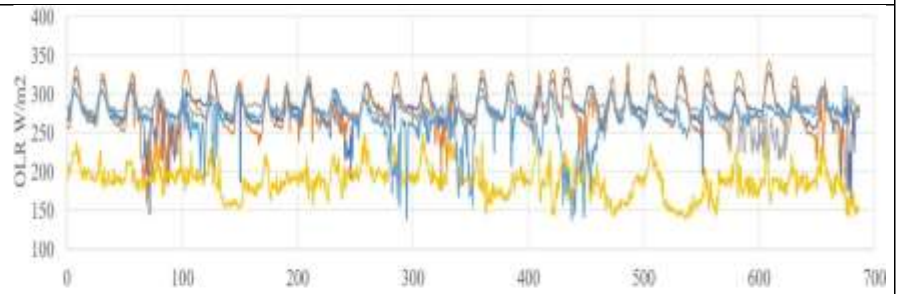
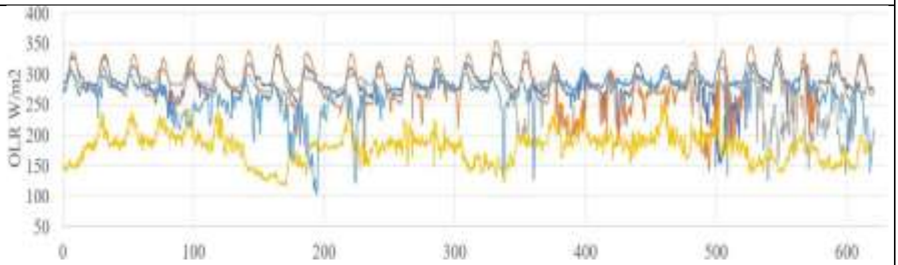
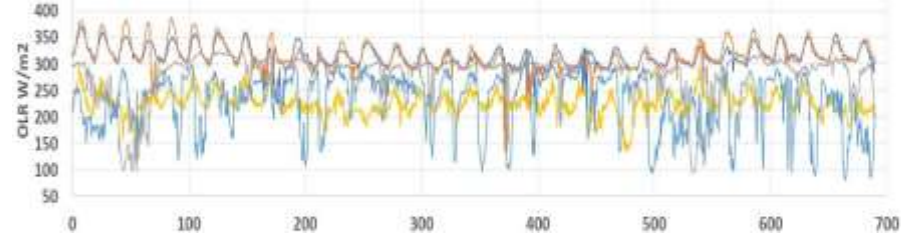
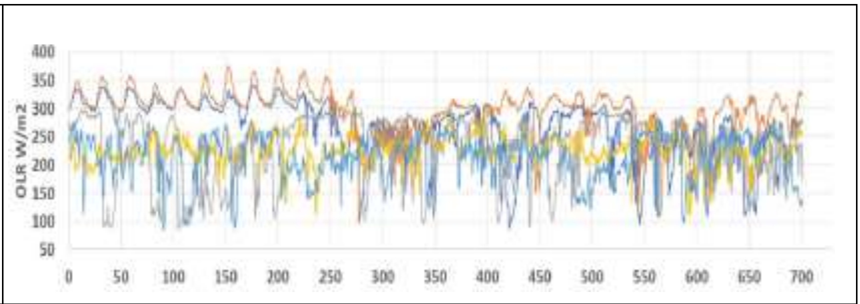
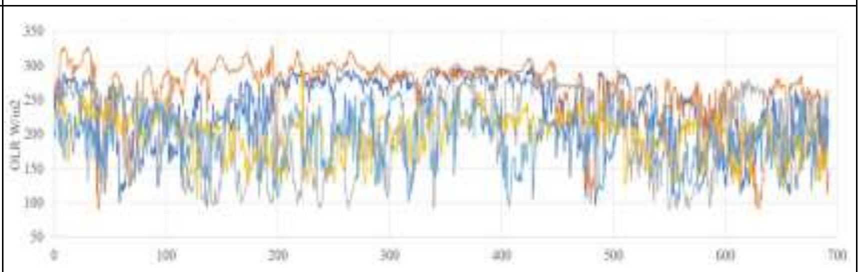
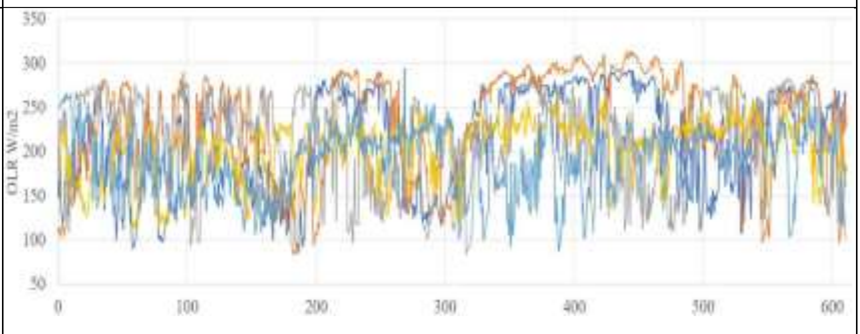
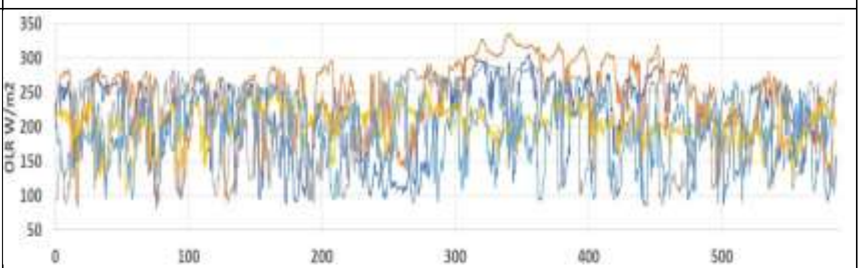
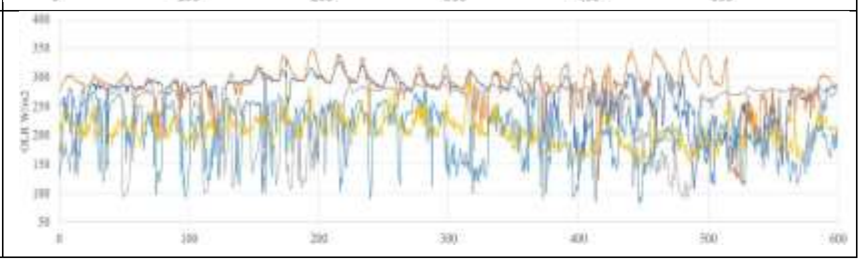


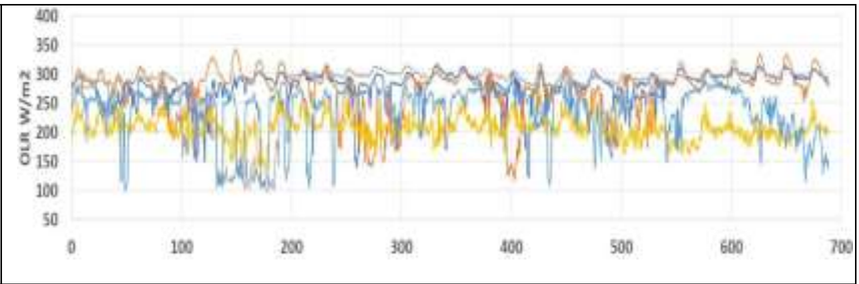
Figure 2. The Diurnal variation of OLR year 2019 for Urban, Desert, Costal, Snow, Forest Regions.

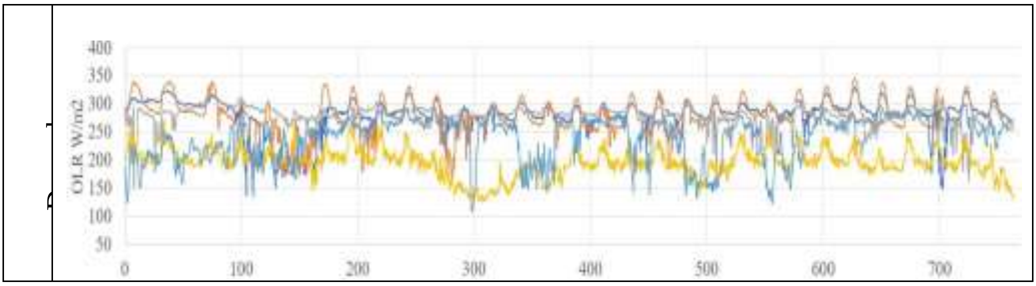
Table 3. Data plots of OLR for different locations (as specified in Table 2), the legend is same as in Figure 2

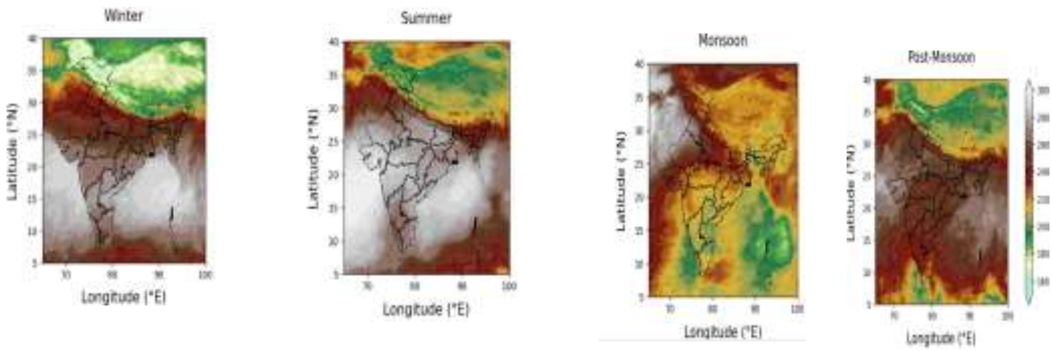
<table>
<tr><td colspan="2">Data</td></tr>
<tr><td>January</td><td>
</td></tr>
<tr><td>February</td><td>
</td></tr>
<tr><td>March</td><td></td></tr>
<tr><td>April</td><td></td></tr>
</table>

May	 OLR W/m2 400 350 300 250 200 150 100 50 0 100 200 300 400 500 600 700

	OLR W/m2 400 350 300 250 200 150 100 50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
	OLR W/m2 350 300 250 200 150 100 50 0 100 200 300 400 500 600 700
	OLR W/m2 350 300 250 200 150 100 50 0 100 200 300 400 500 600
	OLR W/m2 350 300 250 200 150 100 50 0 100 200 300 400 500
	OLR W/m2 0 100 200 300 400 500 600


OLR W/m2
400
350
300
250
200
150
100
50
0
100
200
300
400
500
600
700





(a) (b) (c) (d)

Figure 3: Seasonal variation of OLR variation for year 2019. (a) Winter – December, January and February (b) Summer – March to May (c) Monsoon – June to September and (d) Post – Monsoon – October and November

As shown in above maps as we go winter to summer the value of OLR was going increase when the temperature andsunshine days increase, also absence of cloudy days in middle part of India and also some part of north India. During the late dry seasons the OLR decrease and in during the monsoon this value going too low in all over the India which is shown in below figure.

4. CONCLUSION

In this study we have analyzed the OLR from the INSAT3D satellite and carried out detail analysis of daily variation and monthly variation of the OLR over the Indian region. We also mapped monthly average of all months over India. From this analysis we concluded following major points:

1) The value of OLR in all the region (Urban , Coastal , forest Desert , Snow) for one day are following the same pattern (no cloud cover situation).

2) It was also observed that all the region value of OLR were minimum at midnight and maximum in the early morning butnot at noon (no cloud cover situation).

3) Among Four of them(Urban , Coastal , forest, Desert) Desert had the minimum and maximum value of OLR at midnightand morning respectively.

4) It is observed that the value of OLR is least for snow compared to all other regions because of the low emissivity and moist ground (Low temperature)

5) From monthly analysis of OLR data we get when the cloudy atmosphere towards that region the value of OLR is decreasing to that region.

6) From monthly study we find that as we move from January to December (Or winter to summer and summer to monsoon) we get that the value of OLR is increase In summer and decrease in monsoon so we conclude that without the cloud the value of OLR is highest and with cloud the value of OLR is lowest (we are not sure that the value of the OLR is depend upon the thickness of cloud or not) so from this data we can say that the value of OLR can be affected by the cloudy atmosphere.

7) From the mapping of the Indian region, we find that the Water body shows high OLR value compare to land and snowsurfaces.

So, analysis of one-year INSAT3D OLR data revealed that weather conditions and topography are correlated and influence the OLR value. Monthly OLR distribution shows that maximum value at the middle part of the India throughout the year. The present study provides a preliminary investigation, however a thorough analysis involving more datasets pertaining to larger time duration is in progress.

5. ACKNOWLEDGMENT

The authors wish to thank the Indian space research organization (ISRO) for providing INSAT-3D satellite data.

6. REFERENCES

[1] J M Rajab , I S Abdulfattah, H A Mossa and S Y Sleeman, Spatial and Temporal Distributions of Outgoing Longwave Radiation over Iraq: 2007 – 2016. OP Conf. Series: Materials Science and Engineering (2018) 012030 doi:10.1088/1757-899X/454/1/012030

[2] Jake J G, Christine J C, Robert J G, Cyril J M, Peter G H, Jacqueline E R and Helen E B 2018 Insights into the diurnal cycle of global Earth outgoing radiation using a numerical weather prediction model Atmos. Chem. Phys. Discuss. 18 5129-5145

[3] Stephens G L, Li J, Wild M, Clayson C A, Loeb N, Kato S, L'Ecuyer T, Stackhouse Jr P W, Lebsock M and Andrews T2012 An update on Earth's energy balance in light of the latest global observations Nat. Geosci. 5 691-696

[4] Decadal Changes of Earth’s Outgoing Longwave Radiation, Steven Dewitte and Nicolas Clerbaux.

[5] Steven D and Nicolas C 2017 Measurement of the Earth Radiation Budget at the Top of the Atmosphere-A ReviewRemote Sens. 9 1143

[6] Saltykov M., Belolipetsky P., Hari R. E., Reid P. C., and Bartsev S 2017 Synchronous shifts in outgoing longwave radiation and their interpretation 15th International Conference on Environmental Science and Technology (Rhodes, Greece,31 August to 2 September 2017)

[7] Hai-Tien Lee , Andrew H, Arnold G and Robert G E 2004 The HIRS outgoing longwave radiation product from hybridpolar and geosynchronous satellite observations Adv. Space Res. 33 1120-1124.

[8] Aaron Donohoe, Kyle C. Armour, Angeline G. Pendergrass, and David S. Battisti, “Shortwave and longwave radiative contributions to global warming under increasing CO2”, Earth, Atmospheric, and Planetary sciences, November, 2014, 111 (47) 16700-16705. https://doi.org/10.1073/pnas.141219011