Comparative Analysis of Clear and All Sky Infrared Radiations from top of the Atmosphere

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Abstract:

This study examine and analyze the amount of infrared radiations from top of the atmosphere using the NASA CERES Ordering tool data and other techniques. These radiations are responsible for the excessive heat waves in the upper atmosphere. Collected the data from the website with the help of NASA satellite named EBAF 4.2. The data barred into clear and all-sky monthly data. Used panoply software first to convert the NC file to CSV which is readable for excel. Then mark the maximum values and average of months and do the graphical analysis after the daily data conversion which is provide the information of the graph starting and ending and the difference between the values of all-sky and clear sky. In the end, concluded that the hotter years have higher IR flux values at that upper atmosphere just like 2014 and some other years, and these affected due to some major factors that discussed, such as cloud cover, surface temperature, greenhouse gas variations etc. Clouds that are present in the higher altitude known as the cirrus clouds absorb incoming radiation. The earth varying temperature controlled by incoming and outgoing radiations and another factor is greenhouse gas variation in the surface temperature.

Keywords: Infrared Radiations, All and Clear Sky, Upper Atmosphere, IR comparative analysis, Top of the atmosphere.

Introduction:

The earth's energy balance depends upon the interchange between incoming and outgoing solar radiation and infrared radiation respectively [1]. Solar radiation is invisible ultraviolet light radiation that heats [2]. When the ultraviolet radiation gets absorb by the surface of the earth, it emits infrared radiation in return [3]. Some of the emitted infrared radiation emitted back to the space the rest gets absorbed by the greenhouse gasses present in the environment [4]. These greenhouse gasses are the heating catalyst of the environment as they capture the infrared radiation causing the increase in the earth's overall atmosphere [5].

The first and most important motivation to study and analyze infrared radiation at the top of the atmosphere is that it allows us to monitor climate change effectively and can keep an extensive track of the earth's energy budget [6]. This data aids in the future understanding of climate change, how and at what percentage the global temperature rises, and for evaluating the effectiveness of climate changed mitigation strategies [7]. The second motivation for studying Infrared radiation allow us to analyze the absorption of infrared radiation by the greenhouse gasses at the top of the atmosphere, the study of the role of greenhouse gases helps to understand how these unchained gasses play a crucial role in trapping the infrared radiation and completely influencing the earth's climate by heating the atmosphere. [8] TOA infrared measurements help to see various aspects of the earth's system, which deemed invisible to the human eye [9]. Studying the infrared radiation at the top of the atmosphere is crucial for remote sensing as the measurements from the TOA Infrared radiation and the building block for remote sensing techniques used to monitor several earth's systems, such as cloud cover, land surface, and ocean surface temperature [10].

Analyzing and understanding the top of the atmosphere (TOA) infrared radiation is so much more than a simple data collection [11]. Rather than it's a powerful tool, which, aside from the diagnosis of severe environmental change, helps scientists form better, more efficient models for understanding the environment [12]. The analysis of infrared radiation helps to understand the complexities of the processes that govern the entire earth's energy balance [13].

This study delves into the intensity of the top of the atmosphere infrared radiation, essentially measuring the total amount of infrared radiation escaping Earth. This analysis involves measurements of the overall radiation emitted from the top of the atmosphere [14]. Studying the different variations in intensity and can identify the change in earth's energy balance [15]. Earth's energy balance is the complex interplay between incoming and outgoing radiation [16]. Various other factors including cloud cover, surface temperature, etc [17]. However, influence this energy balance [18]. Clouds play a rather significant role in the regulation of the day-to-day earth's energy budget [19]. These fluffy beings act like a comfortable cover or a blanket and trap the starry outgoing infrared radiation [20]. Clouds that are present in the higher altitude known as the cirrus clouds absorb incoming solar radiation [21]. The earth varying temperature controlled by the amount and type of incoming and outgoing infrared radiation [22]. In this study, investigate the intricate relationship between the ever-changing earth's surface temperatures and the infrared radiation at the top of the atmosphere [23].

The main purpose of this study is to gain comprehensive insight into the relationship between TOA infrared radiation and its influence on the drastically changing climate [24]. Through this project, aim to understand how climate change influenced [25]. The aim to estimate the total energy flow in an earth system, quantifying the earth's energy budget [26]. To get that insight analyzed the change in the top of the atmosphere infrared radiation, which will help to understand the sheer energy imbalance that feeds the global warming [27]. By getting a deep insight into how earth responds to factors such as cloud cover, and greenhouse gas variation in the surface temperature and can help develop better, more accurate models to predict future climate changes events [28]. Then further implement strategies to fight climate change and accurately monitor top of the atmosphere infrared radiation.

Methodology:

The aim of this study is to investigate weather and climate patterns over a span of ten years, our endeavors use the phenomena of infrared radiative fluxes to determine the incoming and outgoing heat. Analyze the data from the NASA clouds and earth's radiant energy system (CERES) website. The data focuses on all-sky and clear-sky conditions at the top of the atmosphere. After analyzing both datasets extensively and comparing them and hope to identify the potential change in cloud cover and their impact on radiative fluxes.

The data acquired for this study is from NASA's clouds and earth's radiant energy system Ordering tool. Upon accessing the website and navigated to the data product page and selected the "EBAF-TOA and surface (Ed. 4.2) product this data set provided us with the information needed for both the atmospheric and surface radiative fluxes. To obtain our data presented with a set of required parameters to select from, these parameters specified the time range, longitude, latitude, temporal, and spatial resolution. To obtain our data in the rawest form the selected parameters for data retrieval were:

- Time range: 10 years (2013-2022)
- Spatial Coverage: Global (longitude: 90° W to 90° E, Latitude: 0° to 360°)
- Temporal resolution: Monthly mean
- Spatial resolution: to specified

After providing the specified parameter, the website required us to provide an email address and initiate the data download process. After downloading, the data might still require some altercations and may need to be re-downloaded, and after confirming that the data is to our satisfaction, it will require an order for further analysis.

The data downloaded is likely stirred in the Net CDF (NC format, which is a specialized file format most commonly known for its use in scientific research data. Even though the NC format is widely acceptable and known, and also known to efficiently store a large number of multi-dimensional data, the NC format renders itself useless when used for spreadsheet or data analysis software. Hence, to facilitate analysis and proper visualization of our data and need to convert the NC file into a much more convenient and readable comma- separated value (CVS) format. This conversion process converts the data into a table-like structure, in which each row showcase a data point and each column represents a variable. Each value separated by a comma, this format makes the data much more readable and importable, making it easier to read by various software tools.

To unlock the hidden insights within the NC file, employ the panoply software. This standard chapter excels in converting the scientific data formats Net CDF (NC) into a rather user/software-friendly comma- separated values (CSV) format, the specific format used by this study was Panoply Win-5.0.10. Ensuring compatibility is crucial before diving into the conversion process, with the help of panoply specific system requirements:

- Java runtime environment (JRE): a minimum Java 11Java installed on the computer system where panoply is. This environment provides us with the essential libraries for panoply to function correctly.

- Readme file: Panoply is contained somewhere in the zipped folder which should include the original readme file. This original document is a valuable source that provides instruction and important information regarding the software.
- Software file: The zipped folder is typically comprised of the following components:
- Panoply.exe: this executable file that launches the panoply application.
- Jars folder (Sub-directory): This folder features the application code essential for panoply's functionality.
- Java_11 readme file (optional): Some versions may feature a separate readme file specifically designed to address the Java 11 requirements.

After all the mentioned requirements met, we proceed with the conversion, which consists of multiple steps such as:

- Launch the software
- Select the desired NC file containing your data
- While opening the file, the Panoply displays all the parameters we previously selected during the data acquisition.
- Start the conversion process, transforming the data from the NC file into a much-readable CSV file. Converting raw data into an easily accessible and readable file.

This conversion paves the way for the in-depth exploration and visualization of our data, ultimately enabling further analysis so that can extract crucial insight into the weather, climate change, and possible future trends.

Following the conversion of our previous NC file into a user-friendly CSV file, we further explore the raw data within the file. Explorations lead to conclusions:

- Temporal resolution: Initial observation led to a revelation of the monthly means temporal resolution for our data. Each data point represents the average value for a specific for the span of a ten-year acquisition period. As a result, the dataset confines a total of 120 months, which corresponds to a ten-year frame.
- Data Volume and Structure: The volume of data amounts to a total 212720 rows within the CSV file. A closer examination revealed a fascinating structure within the data, the data

showed a recurring pattern where every 180 rows corresponds to a single month following a blank row.

- Spatial Resolution: The presence of 360 columns within the CSV file directly reflects the chosen longitudinal range: - 90° to 90°, which was chosen during the data acquisition process. This coverage is across the entire longitudinal spectrum providing a valuable global perspective for analysis.
- Daily reading and temporal granularity: After sorting out data month wise, further delve into the data distribution within each month to determine the temporal resolution within these monthly segments. Considering have 180 rows representing a single month, assuming an average of 30 days a month, this translates the data into six readings captured throughout the day:

After this observation, to gain a deeper insight into the data granularity on a daily timescale, calculate the time interval between consecutive measurements. Within the six daily readings, it can easily extrapolate a 4-hour time interval between each data point.

- Consistent data structure: After careful observation, concluded that the dataset has a rather consistent structure for both the clear-sky and all-sky. Each dataset exhibits a monthly, measurement arrangement with a consistent 4-hour interval between each diurnal reading with each month. The ending of each month's reading (after 180 readings) followed by a blank row, which serves as a clear unambiguous indicator of the transition between months.

After gaining a comprehensive understanding of the data structure and can further delve into the process of sorting said dataset. Sorting the data is a crucial step as it helps pave the way for a smoother further in-depth analysis and informative visualization. A sorted data will help form a better understanding of the data ultimately enabling to extract valuable information stored with the data.

Following the detailed exploration from the section above (section 3.4), utilize Microsoft Excel to organize both datasets; the all-sky and clear-sky. This process more commonly known as data wrangling, data wrangling involves sorting and manipulating data to facilitate according to the needs of the research work.

- Temporal sorting: focus on the temporal dimension, specifically reconstructing the time series within the month. As mentioned in the section above each month confines 180 data points which correspond to six readings per day with 4-hour intervals between each reading. Now after gaining this insight and assigned timestamps to each data point assuming the starting time of reading to be midnight subsequent 4-hour intervals (4:00 AM, 8:00 AM, 12:00 PM, 4:00 PM, AND 8:00 PM) with this assumption can proceed to ensure a consistent time series for the dataset throughout the 10 years.
- Aggregating daily data: after reconstructing the time series, further aggregate the data. Focus is to simply the data as much as so that can perform analysis by obtaining a single representative value for each day. By taking the aggregate of all six diurnal readings for 120 months, reduced the data volume while simultaneously preserving the essential daily trends. This aggregate helps make data more readable and manageable.
- Visualizing trends: After data aggregation, we proceed to visualize the data and construct a 10-year for both all-sky and clear-sky datasets. These charts will help visualize the variation in the chosen variable over the entire 10-year timeframe. For further comparative analysis, create another set of charts specifically to compare the all-sky and clear-sky data. With this comparative analysis, the aim to identify potential relationships and discrepancies within the all-sky and clear-sky conditions.

Results and discussion:

Figure 1 shows the behavior of ten years data for all sky Infrared radiations from top of the atmosphere against IR radiative Fluxes and the days of the year. This analysis examines the ten years (2013-2022) of regional data across the globe on earth's surface infrared (IR) radiative fluxes that emitted toward space. The data reveal a consistent annual cycle, with the starting and ending points of each IR flux value perfectly aligned. However, throughout this cycle, there are fluctuations caused by various factors affecting the radiative fluxes at the top of the atmosphere (TOA). As previously discussed, several global and regional factors come into play when study the influence on net IR flux at TOA in all-sky conditions (which includes both all and clear skies). These factors broadly categorized as:

- Radiative transfer process: Depending on the type and concentration of the aerosol they scattered incoming radiations and reemit both solar and IR radiation (warming). Clouds can trap and reflect outgoing fluxes that influence the overall atmosphere.
- Earth's surface properties: Variations in the surface and its temperature, emissivity, and land cover can influence the overall outgoing flux.
- Understanding the flux fluctuation: The observed fluctuation in IR fluxes data likely represents the combined influence of these factors. Periods with higher IR flux may indicate conditions where factors enhance outgoing. Conversely, periods of lower IR flux may suggest conditions favoring factors that trap outgoing radiation.

Similarly, if the net impact of factors affecting IR radiation flux decreases this will decrease IR fluxes as well, again this happens because factors that decrease IR fluxes cancel out the effect of the factors that increase the IR fluxes.

Figure 2 shows the behavior of ten years data for clear sky infrared radiations against IR radiative fluxes and the days of the year. This analysis examines the ten years (2013-2022) of regional data across the globe on earth's surface infrared radiative fluxes that emitted toward space. The data reveal a consistent annual cycle, with the starting and ending points of each IR flux value perfectly aligned. However, throughout this cycle, there are fluctuations caused by various factors affecting the radiative fluxes at the top of the atmosphere (TOA).The data is spread in consistent yearly patterns where the starting and ending values round back to the same values showcasing cyclical trends about seasonal variation. In these ten years, observed fluctuations throughout the year caused by various factors affecting IR fluxes at TOA Factors discussed above come into play when we are examining global net data and can help explain large-scale trends, factors such as solar activity, etc.

Regional factors: These factors have a rather localized impact and can cause fluctuation within the year wise cycle e.g. monsoon season etc. The net effect on IR fluxes are the combined regional and global factors can influence and increase IR fluxes outweigh the effect of factors that decrease them in turn the net result is a substantial increase in IR radiation. Where, the combined regional and global factors that can influence and decrease IR fluxes outweigh the effect of factors that increase them in turn the net result is a substantial decrease in IR radiation.

Figure 3 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2013. After analyzing the 2013 data for both all-sky and clear-sky conditions and have observed significant fluctuation, especially in clear-sky data and observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky & clear-sky data appeared on nearly the same day. Notably, the lowest minimum value in all-sky data recorded this year in 10-year data. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. In fact, for month 8 in clear sky data, based the decision on the upward & downward direction of the graph due to high-level fluctuation. Notably, all-sky is showing a decreasing trend in the majority of months leading to the lowest minimum value in 10 years.

Figure 4 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2014. After analyzing the data of 2014 for all-sky and clear-sky conditions, observed significant fluctuation, especially in clear-sky data and observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky & clear-sky data appeared on nearly the same day. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. Few months in clear sky data have high levels of fluctuation due to this we have more than two trends in those months.

Figure 5 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2015. After analyzing the data of 2015 for both all-sky and clear-sky conditions, and observed significant fluctuation, especially in clear-sky data and observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky & clear-sky data appeared on nearly the same day. Monthly data analysis shows an interesting trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. Few months in clear sky data have insane levels of fluctuation due to this we have decided trend based on graph direction.

Figure 6 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2016. After analyzing the 2016 data for both all-sky and clear-sky conditions, observed significant fluctuation, especially in clear-sky date, also observed that the max value for all-sky appeared earlier than clear sky. However, the minimum value for all-sky and clear-sky data appeared on the nearly same day. Notably, the highest maximum value in all-sky data recorded this year in the 10-year data. The highest maximum & minimum value in clear sky data recorded in this year in the 10-year data. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. In fact, for many months in clear sky data, Decision based on the upward & downward direction of the graph due to high-level fluctuation. Notably, all-sky is showing an increasing trend in the majority of months leading to the highest max value in 10 years. Notably, clear shows show an increasing trend in the majority of months leading to the highest max value in 10 years, also there is a lesser overall decrease in values leading to the highest value in 10 years.

Figure 7 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2017. After analyzing the data of 2017 for both all-sky and clear-sky conditions observed significant fluctuation, especially in clear-sky data. Also observed that the max value for all-sky appeared earlier than clear sky. However, the minimum value for all-sky and clear-sky data appeared on nearly the same day. Monthly data analysis shows an interesting trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. Lot of months in clear sky data have immense levels of fluctuation due to this decided trend based on graph direction.

Figure 8 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2018.After analyzing the 2018 data for both all sky and clear sky observed significant fluctuation especially in clear-sky data. Also observed that max value for all-sky appeared earlier than clear sky. However, min value for all-sky and clear-sky data it appeared on nearly same day. Monthly data analysis shows an interesting trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. In fact, few months in clear sky data has high level of fluctuation due to this we have decided trend on the basis of graph direction.

Figure 9 shows the comparison of clear and all sky infrared radiations for the year 2019. After analyzing the 2019 data for both all-sky and clear-sky conditions, observed significant fluctuation, especially in clear-sky data. Also observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky and clear-sky data appeared on nearly the same day. Notably, the lowest maximum value in all-sky data recorded this year in the 10-year data. The lowest maximum in clear sky data recorded in this year in the 10-year data. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. A few months in clear sky data, the decision based on the upward & downward direction of the graph due to high-level fluctuation. Notably, all-sky is showing a decreasing trend in the majority of months leading to the lowest max value in 10 years. Clear-sky is showing a decreasing trend in the majority of months leading to the lowest max value in 10 years.

Figure 10 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2020. After analyzing the data of 2020 for all-sky & clear-sky conditions, observed significant fluctuation, especially in clear-sky data. Also observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky & clear-sky data appeared on nearly the same day. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation, in fact in clear-sky data there we a few months where we can see an immense level of fluctuation.

Figure 11 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2021. After analyzing the 2021 data for both all-sky and clear-sky conditions, observed significant fluctuation, especially in clear-sky data. Also observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky and clear-sky data appeared on nearly the same day. Notably, the highest minimum value in all-sky data recorded in this year in the 10-year data. The lowest minimum value in clear sky data recorded in this year in the 10-year data. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation. Notably, all-sky is showing a decreasing trend mix with an increasing trend in the majority of months leading to the highest value in 10 years. Notably, clear-sky is showing a decreasing trend in the majority of months leading to the lowest in value in 10 years.

Figure 12 shows the comparison of clear and all sky infrared radiations from top of the atmosphere for the year 2022. After analyzing the data of 2022 for both all-sky & clear-sky conditions, observed significant fluctuation, especially in clear-sky data. Also observed that the max value for all-sky appeared earlier than the clear sky. However, the minimum value for all-sky & clear-sky data appeared on nearly the same day. Monthly data analysis shows a surprising trend. While the all-sky data reveals less fluctuation, clear-sky data reveals a significant amount of fluctuation.

Conclusion:

In this study, by comparing the data of all sky and clear sky for ten years (2013-2022), concluded that there are lot of fluctuations in clear sky data as can see from the graph as well as from the analysis there are so many variations in values of clear sky data as compared to all sky data. From the graph as well as from the analysis that the fluctuation in all-sky data is less than in clear-sky data. The reason for so many fluctuations in all-sky data is due to the absence of the cloud parameter in clear-sky data. As a cloud can absorb or radiate radiation so cloud parameter can called as balancing act in this data. In clear sky data, this parameter is absent so the radiation has so many fluctuations in clear sky than all sky. In few months of clear sky data does not have a clear as its trend cannot be told because of so many fluctuations its trend has been told by seeing the direction of whether the graph is going upward or downward. The highest value for all sky from 2014-2018 appears in the first half of the year while the max value or clear sky appears in the second half of the year. While from 2019 to 2022 these highest values for all skies shift from the first half of the year to the second half of the year while the highest value for clear skies remains in the second half of the year. The primary cause of this trend is that, whereas clear-sky infrared radiation mostly depends on surface temperature, all-sky infrared radiation is highly impacted by cloud cover, humidity, and atmospheric conditions. The all-sky infrared maximum's transition from the first half (2014–2018) to the second half (2019–2022) points to a shift in the seasonal pattern of cloud cover, which could be brought on by climate variability, delayed rainy seasons, and shifting weather systems. It also noticed that for all sky and clear sky data, the graphs from 2019 to 2022 have more decreasing trend than the graphs from 2013 –2018. It seen that during 2019-2022 graphs are more going in a downward direction than in an upward direction, this is also the reason that our highest value shifted to the second half of the year for all-sky data. If talk about the minimum value, it stays in the first half of the year for all-sky & clear-sky for ten-year data (2013-2022). For the clear sky, during performing analysis that graphs of the month showing almost clear trend from 2019-2022 there were less than in this duration that has not clear trend and trend decided on direction of the graph even the fluctuation was less in values in this duration for clear sky as well as all sky. This data also shows that from 2019 values are mostly decreasing for both data that is why get the lowest value after 2019 and the highest value before 2019. So, in conclusion, noticed that there are lot of fluctuations in clear sky data and less fluctuation in all-sky data that why have a clear trend in all-sky data than in clear sky data. Clear sky infrared data fluctuates because it reacts directly to surface warming and cooling, which can cause abrupt changes in a short amount of time.

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Figure 1: Ten years data of All Sky Infrared radiations from top of the atmosphere

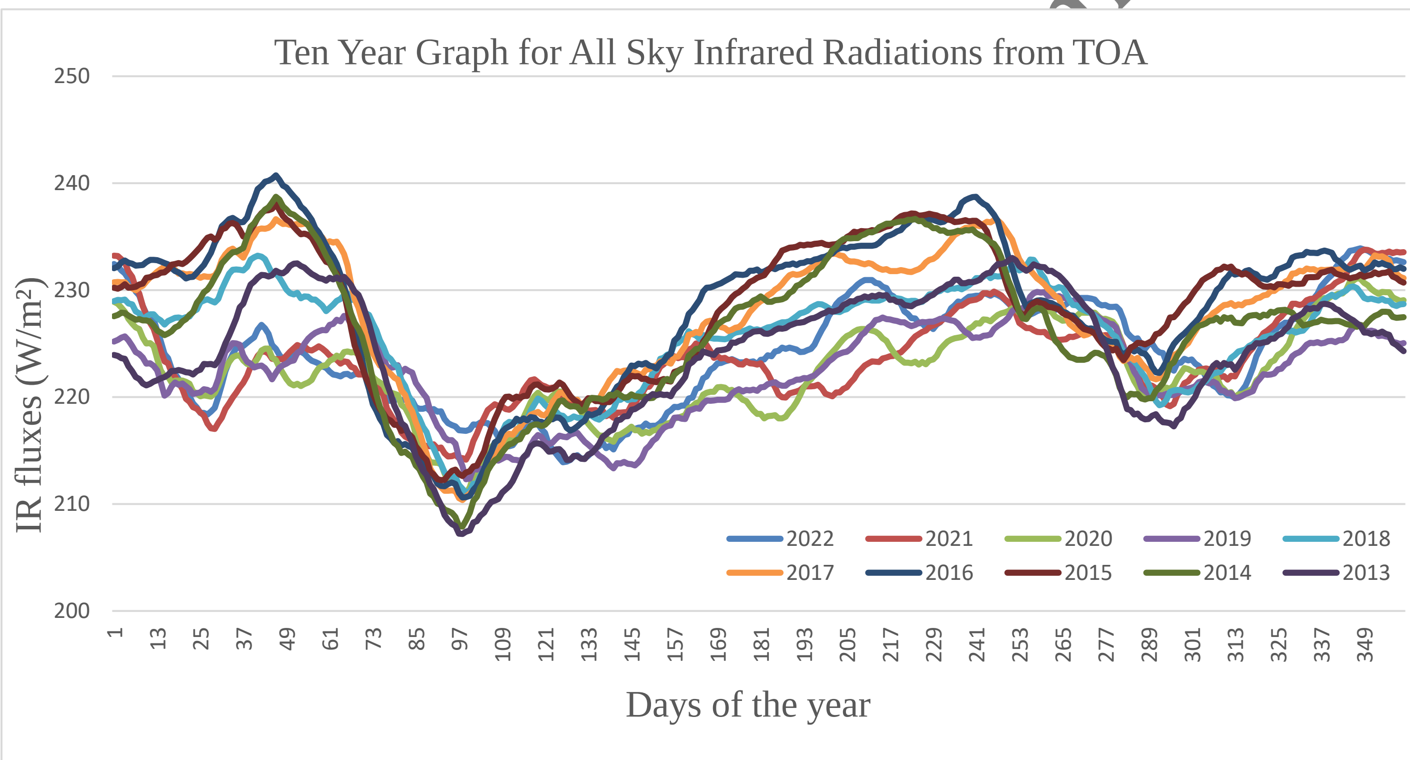

Figure 2: Ten years data of Clear Sky Infrared radiations from top of the atmosphere

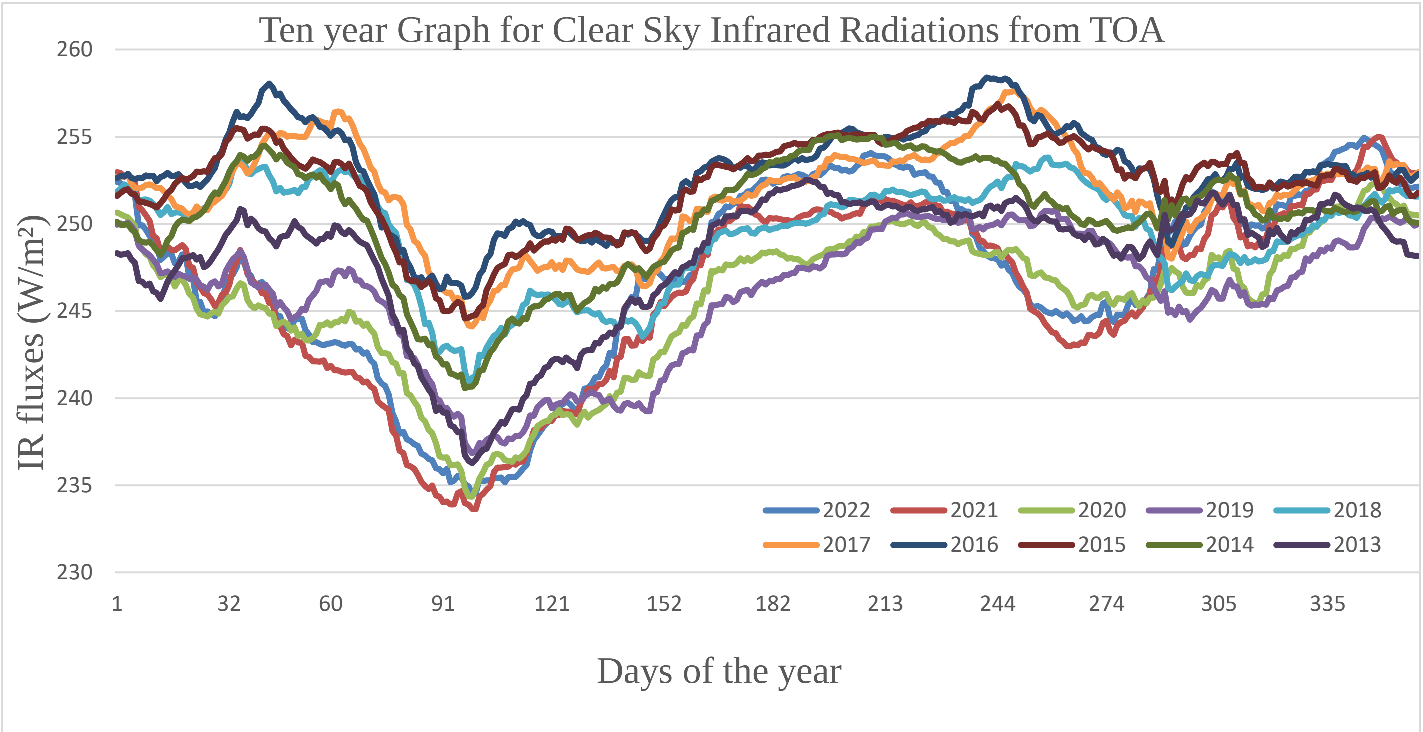

Figure 3: Comparison of Clear and All sky Infrared Radiations for the year 2013

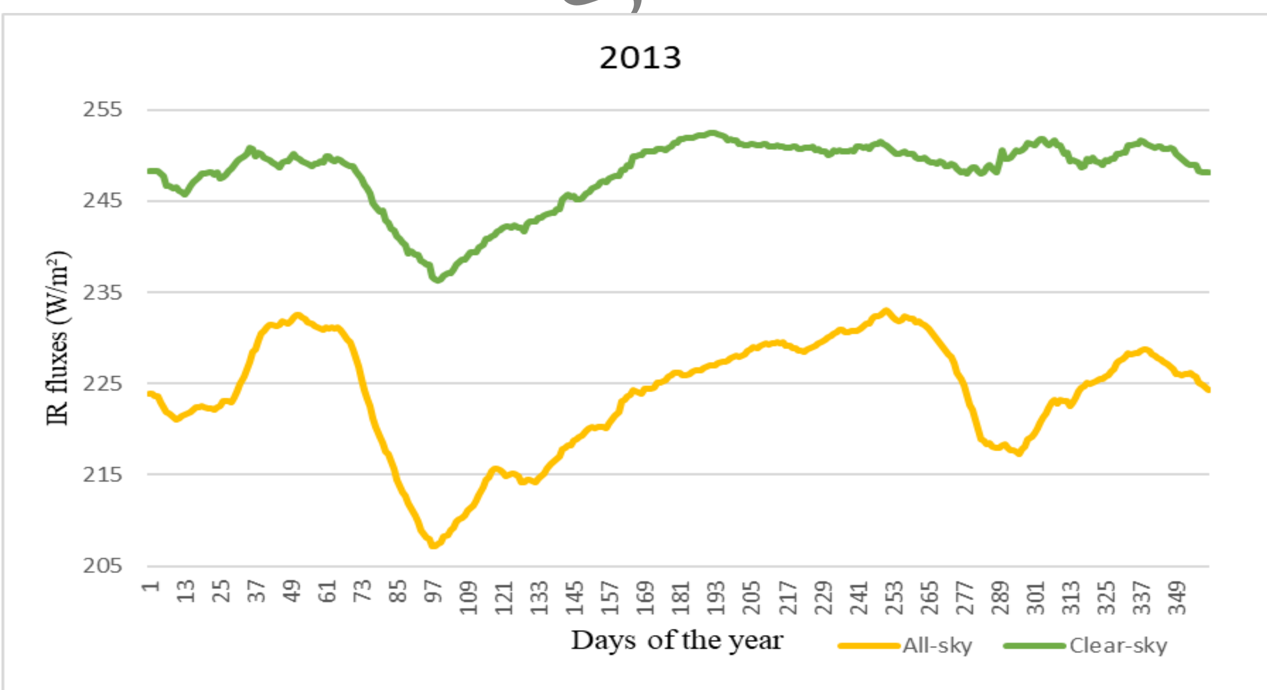

Figure 4: Comparison of Clear and All sky Infrared Radiations for the year 2014

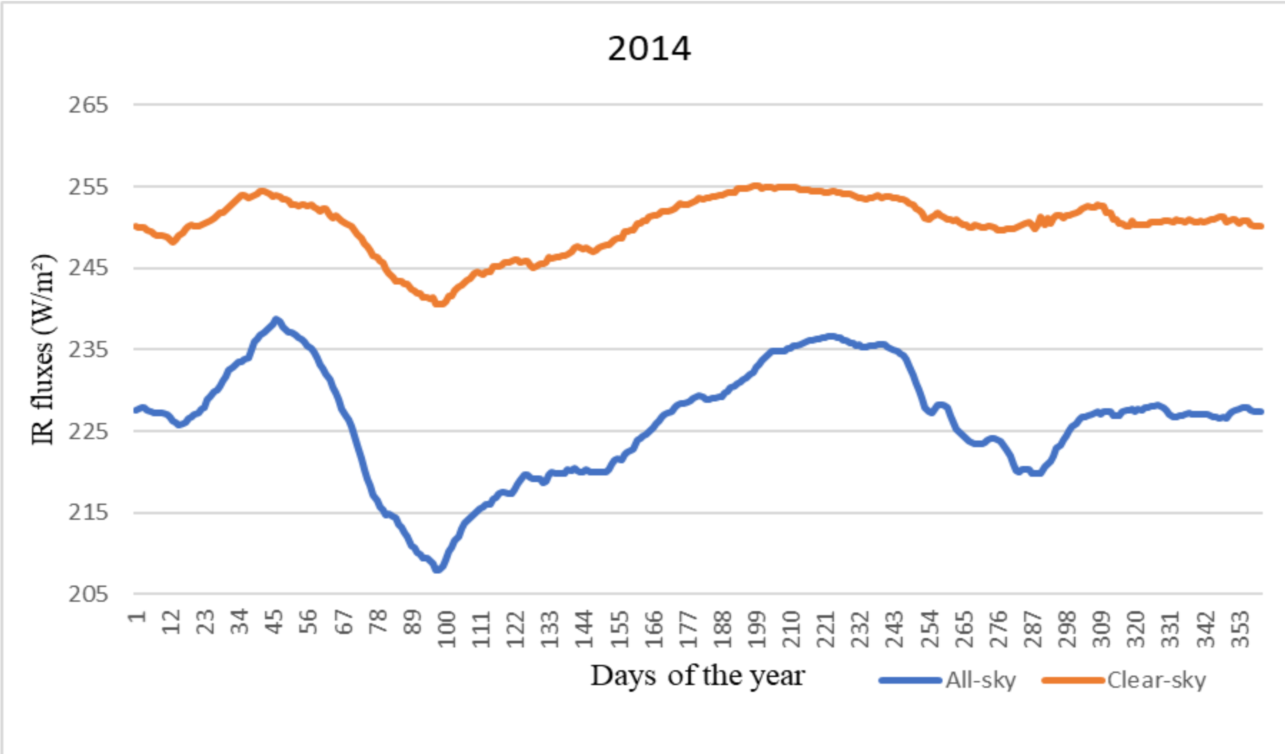

Figure 5: Comparison of Clear and All sky Infrared Radiations for the year 2015

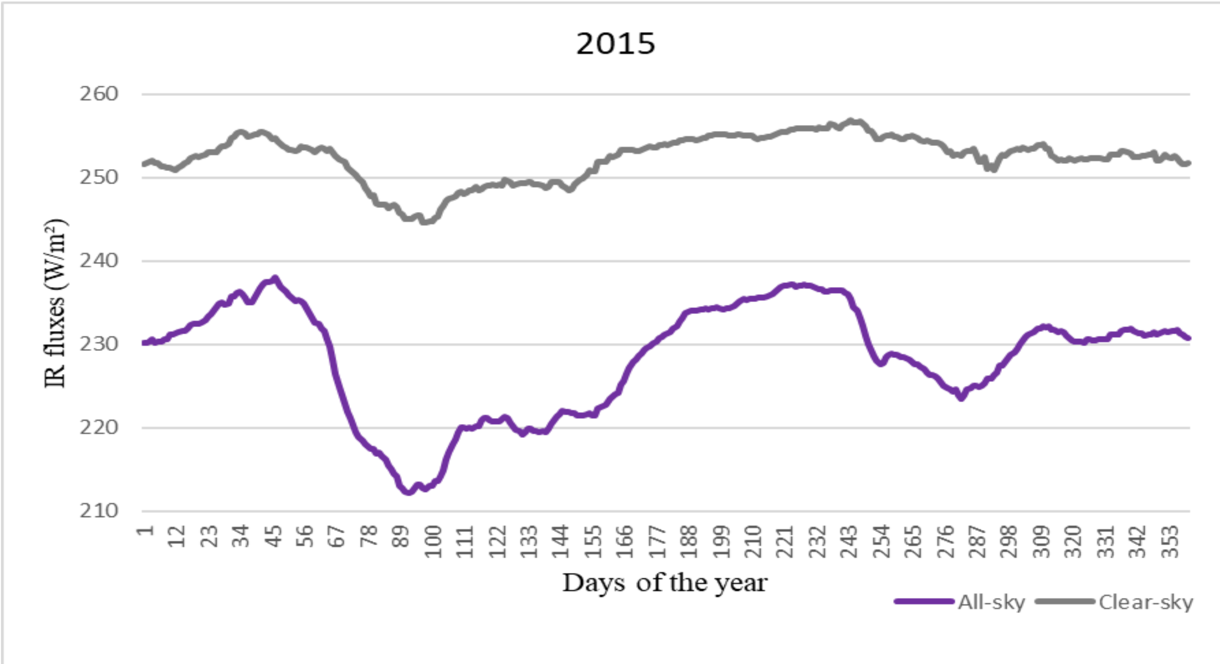

Figure 6: Comparison of Clear and All sky Infrared Radiations for the year 2016

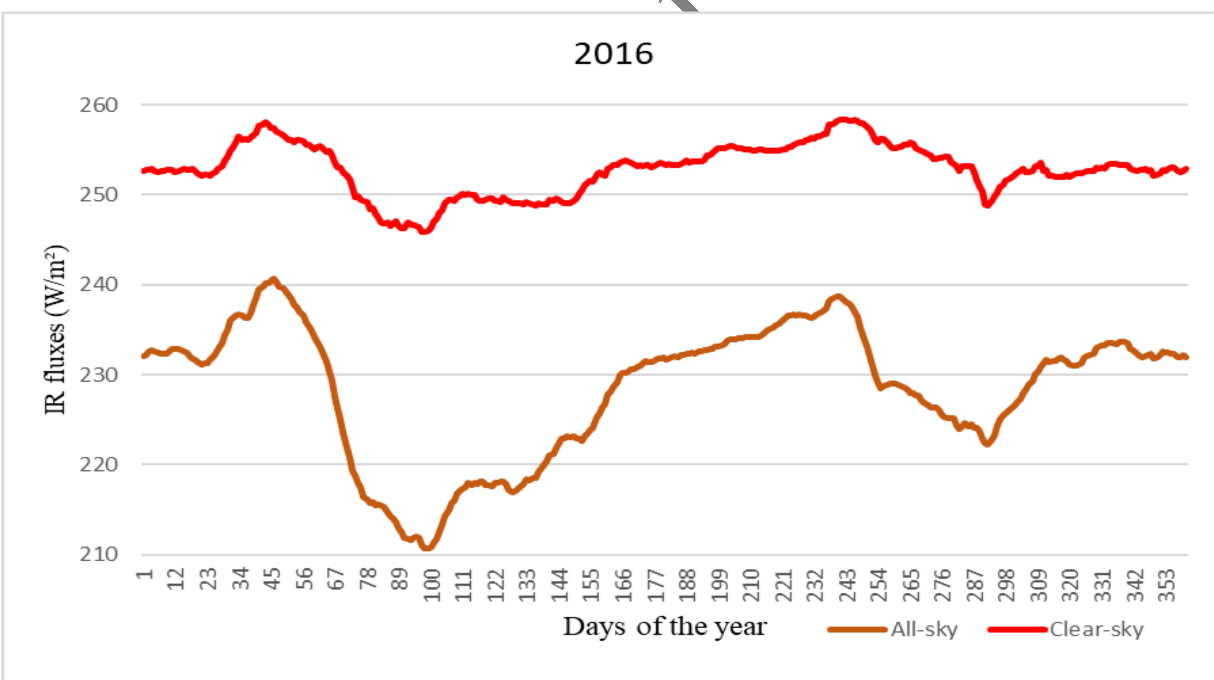

Figure 7: Comparison of Clear and All sky Infrared Radiations for the year 2017

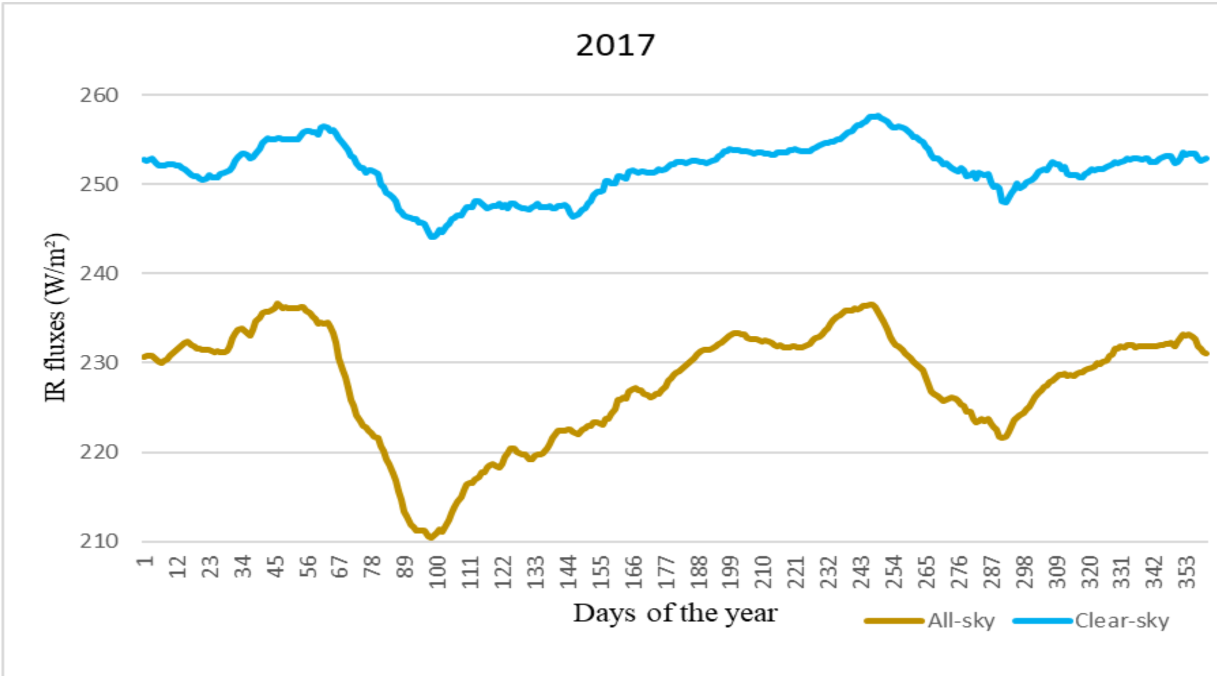

Figure 8: Comparison of Clear and All sky Infrared Radiations for the year 2018

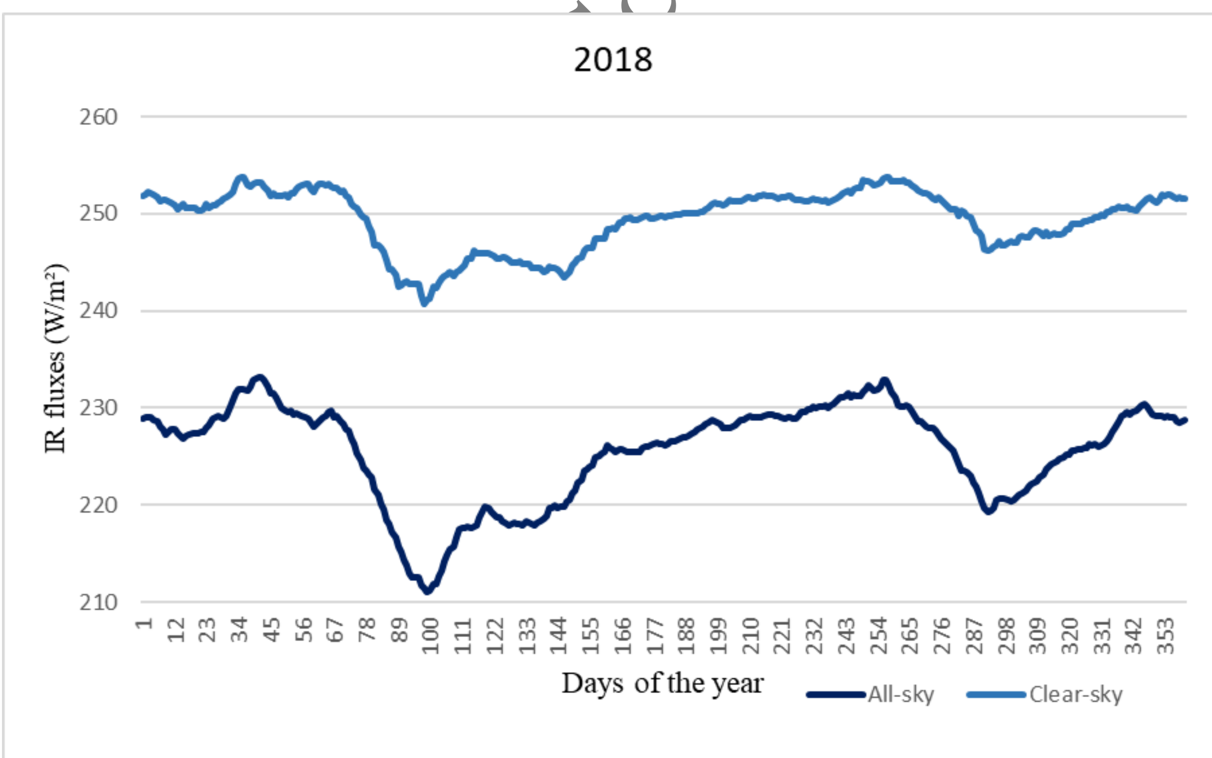

Figure 9: Comparison of Clear and All sky Infrared Radiations for the year 2019

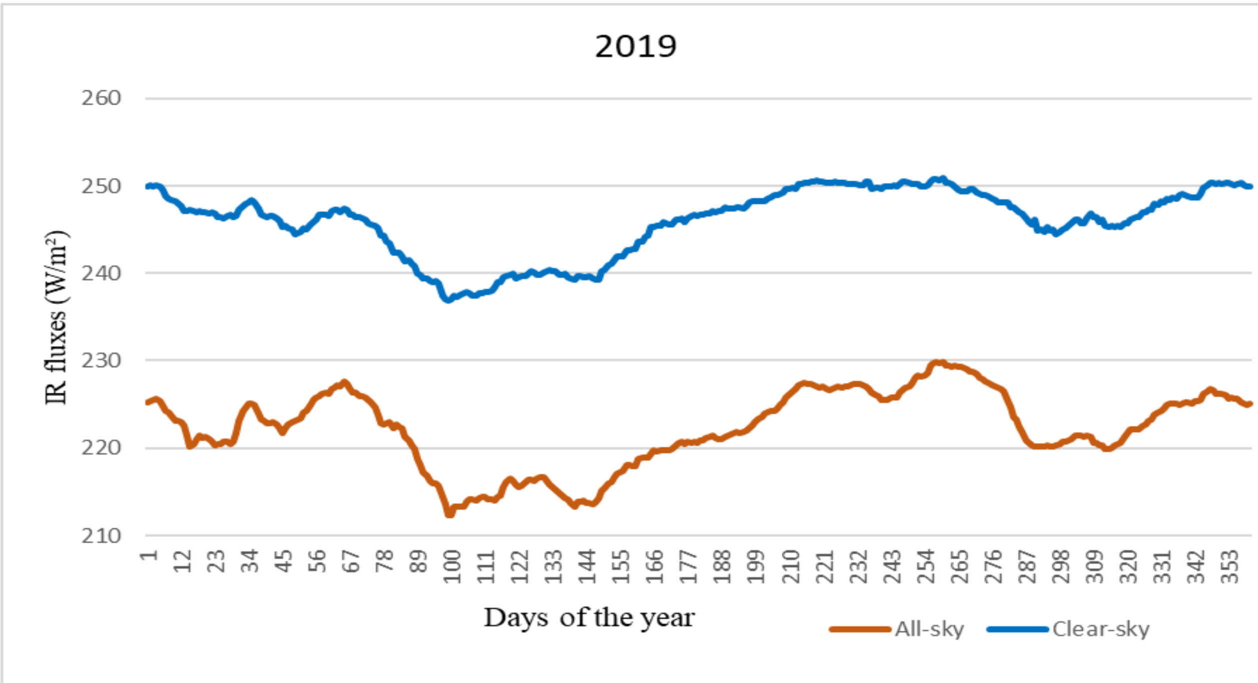

Figure 10: Comparison of Clear and All sky Infrared Radiations for the year 2020

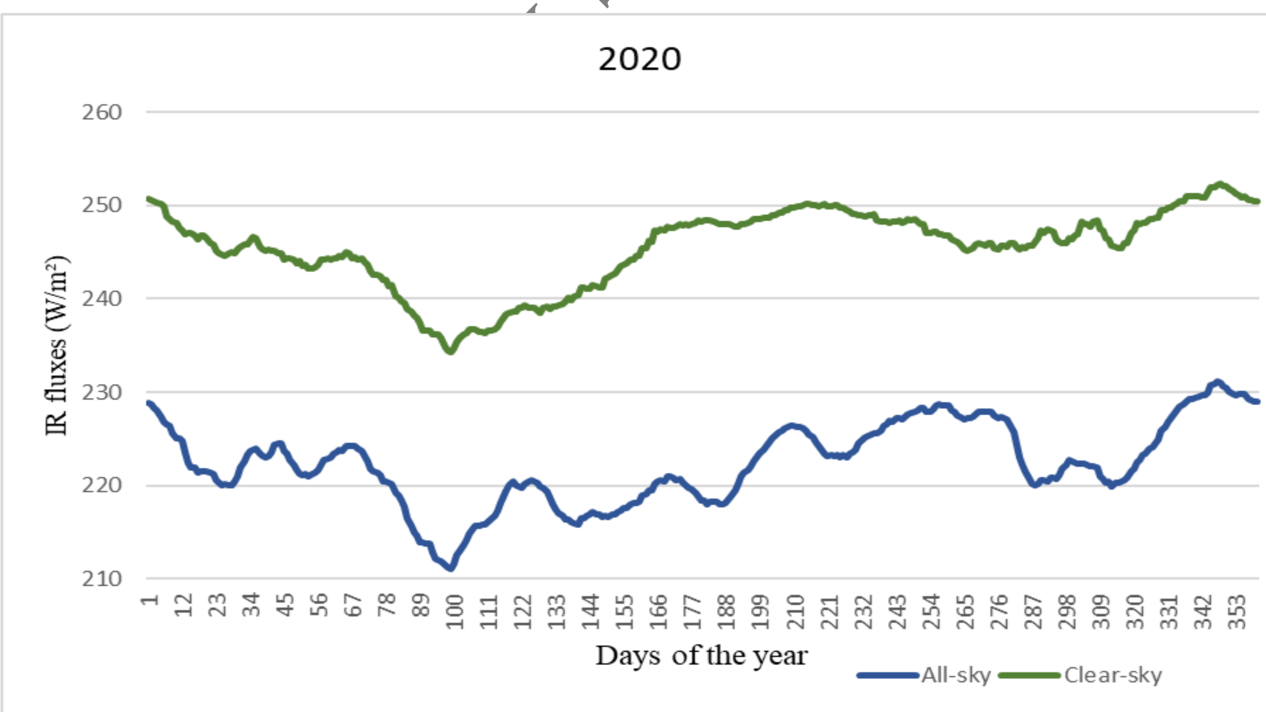

Figure 11: Comparison of Clear and All sky Infrared Radiations for the year 2021

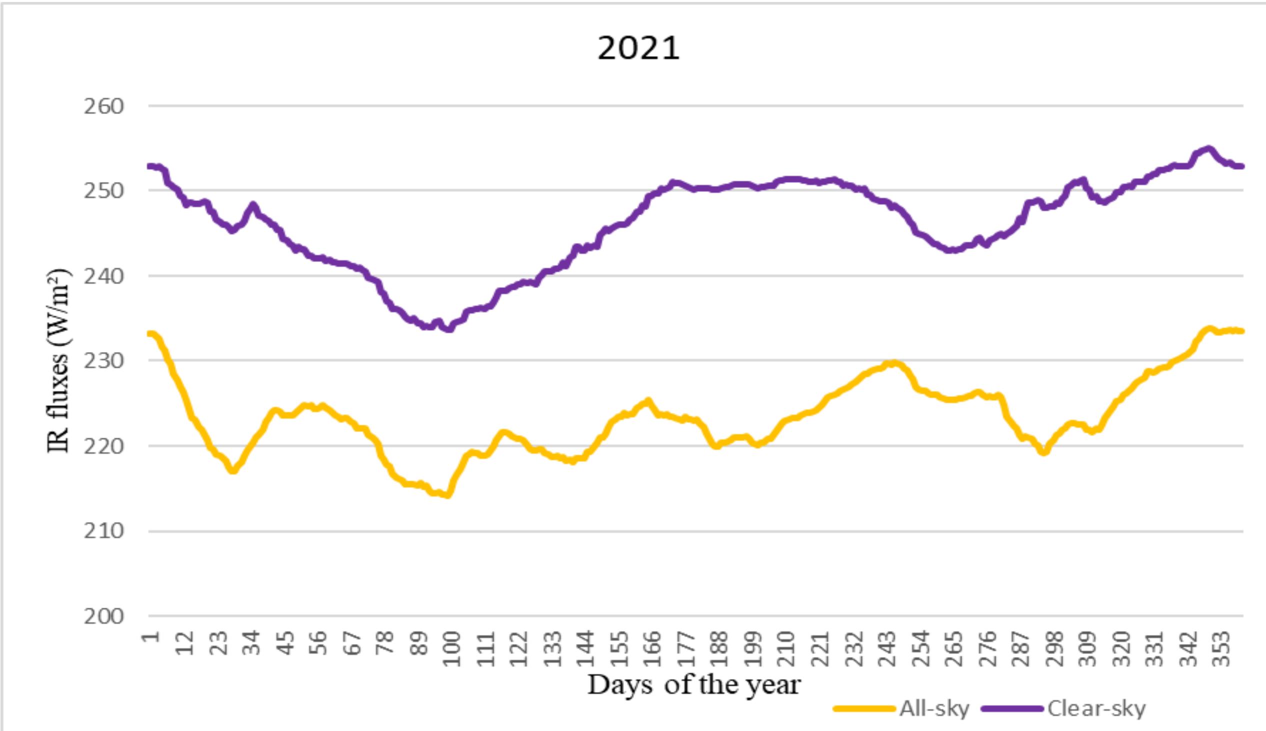

Figure 12: Comparison of Clear and All sky Infrared Radiations for the year 2022