A
Project Report
On
"Development of software for the visualization of the earth's atmospheric parameters using satellite data and ground based observations"

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ABSTRACT

Ozone is naturally present gas in the atmosphere. It is one the most active absorbers of ultra-violet (UV) radiation, and thus is the most important gas for the existence of life. Temperature, Aerosol, Carbon Dioxide and other atmospheric constituents are strongly associated with each other and have their imprint on dynamics, radiation and chemistry of the Earth's atmosphere. In this work we have carried out a substantial study of the above mentioned atmospheric parameters.

In our project work entitled "**Development of software for the visualization of the earth's atmospheric parameters using satellite data and ground based observation**."**,** parameters like Atmospheric Ozone, Temperature, Atmospheric Aerosols, etc. have been studied using different instruments and different satellites. It includes observations from SABER (Sounding of the Atmosphere using Broadband Emission Radiometry), TOMS (Total Ozone Mapping Spectrometer) and OMI (Ozone Monitoring Instrument), covering various regions and places across the globe. SABER is one of the key instruments onboard TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite. TOMS and OMI are onboard the satellites Earth Probe and NASA Aura respectively. Along with that, observations from ground based instruments – MICROTOPS II, UV Biometer and LIDAR (Light Detection And Ranging) have also been studied over the regions of Ahmedabad and Mount Abu.

We have developed a very user friendly application for visualization and scientific study of various atmospheric parameters using HDF/NetCDF files available from the satellites and observations recorded from the ground based instruments MICROTOPS II, UV Biometer and LIDAR. Using this application any user can visualize the concentrations of Atmospheric Ozone, Temperature, Atmospheric Aerosols, etc. across any location. User can choose any type of observation, either ground based or satellite based, and can select parameters and locations for which graph is to be plotted. User can either choose a location marker or specific latitude and longitude directly from google maps.

In this application the user can generate various types of graphs depending on their specific requirements such as Daily, Monthly, Yearly or Inter Yearly time period over desired location for selected parameters.

ACKNOWLEDGEMENT

To learn new things is an opportunity, but a chance given to implement what you have learnt is a bigger opportunity. Development and evolution of this project has been a never ending source of both challenges and joy to me. Satisfaction and euphoria that accompanies the successful completion of my project would be incomplete without the mention of the people and organization that made it possible, whose support rewarded my efforts with success.

It has been a great honor for me to undertake a project assignment at one of the most prestigious institutes – **Physical Research Laboratory, Ahmedabad.** I have been fortunate enough to work in Space and Atmospheric Sciences Division at PRL. This allowed me to collaborate with many researchers. I am happy to have learnt about many new technologies and theories of pure science and the innovative way of carrying out research at PRL.

I am deeply honored and thankful beyond words to **Dr. Som Kumar Sharma** under whom I endeavored this project. His constant guidance and willingness to share his vast knowledge made me understand the project in greater depth and helped me to complete assigned task.

I express my special thanks to **Prof. Parth Shah,** head of Information Technology department CSPIT, Changa for encouraging and inspiring us to carry out the project. we would also like to thank our guide, Assistant Professor **Mr. Sagar Patel** for his expert guidance, encouragement and valuable suggestions at every step.

I am thankful to the Director and Dean of PRL for providing me the opportunity to learn a great deal in this esteemed institution.

I would also like to acknowledge the help and support provided by staff of PRL's Computer Center, Library and other members who directly or indirectly, helped me during course of this project at PRL.

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1.INTRODUCTION

1.1 PROJECT SUMMARY

“Development of software for visualization of earth’s atmospheric parameters and ground based observations”. The primary function of this project is to display scientific data retrieved from satellites in user friendly format so that even layman user can understand it easily. A secondary function is to display the observations taken from ground based instruments – MICROTOPS II, LIDAR (Light Detection and Ranging) and UV Biometer – across the regions of Ahmedabad and Mount Abu.

The important parameters are Total column Ozone, Total column Aerosol, Water Vapor, etc. for which data can be observed. Through this application one can easily come to know about the atmospheric conditions of any location across the globe at any point of time in the past. It also allows the user to generate various types of graphs based on requirements. Any layman user can use this application.

1.2 PURPOSE

- Ozone is a naturally occurring atmospheric gas and is one of the lifesaving gas in the atmosphere as it absorbs the most harmful UV-B radiation coming from sun.
- The percentage Ozone in atmosphere is ~0.000004% by volume which makes up 0.6ppm of atmosphere, out of which 10% is present in troposphere region (~0 km to ~12 km) while remaining 90% is present in stratospheric region (~12 km to 50 km).
- Ozone at the concentration of 100 ppb can easily be detected by people and can cause damage in mucous and respiratory tissues in plants and animals making it a respiratory hazard, but it plays a very important to study about it globally to understand various geophysical processes and their impact on humans.
- Atmospheric temperature is a measure of temperature at different levels of the earth’s atmosphere. In the Earth’s atmosphere, temperature varies greatly at

different heights relative to the Earth's surface. Thus, it is necessary to observe the temperature change at various locations across the globe.

- To develop a user friendly application that displays visually the parameters like atmospheric ozone, temperature, aerosol from HDF/NetCDF format files across any location of the globe.
- It also allows the user to save the data retrieved in ASCII format.
- To develop a user friendly application that displays visually the parameters like total column ozone, water vapor and aerosol optical thickness observed from the ground based instrument MICROTOPS II across the regions of ahmedabad and mount abu.
- To develop a user friendly application that displays visually the amount of UV radiation reaching the surface observed from the ground based instrument UV biometer across the region of ahmedabad.
- The project also helps to view the vertical profile of atmospheric parameters with the help of ground based instrument namely LIDAR (Light Detection And Ranging) across the regions of Ahmedabad and Mount Abu.

1.3 OBJECTIVE

Technical Objective

- Data mining of scientific data, extracting quantitative and qualitative information and to decimate it in various user friendly graphical format.

Scientific Objective

- Software is designed so that the user can easily view, generate and get the information over desired location of interest over the globe. This application also provides the facility of making various kinds of graphs depicting many atmospheric parameters.

- This work provides very comprehensive, visual outputs of Earth's atmospheric parameters and one can further study association between different parameters at various latitude and longitude.
- This product can also pave path for validating and improving models for further prediction of the vital atmospheric parameters.

1.4. SCOPE

The atmospheric profile is very useful to generate comprehensive scenario of Total Column Ozone, Atmospheric Water Vapor, Temperature, etc. variability. In this application the user can generate graphs for the following specific requirements:

- For single day, single month, single year and multiple years plotted graphs, where places can be chosen directly from google map or by providing the latitude and longitude explicitly.
- Graphs can also be generated to display the latitudinal and longitudinal variation of the selected parameter in the atmosphere for the selected location and date range.
- To have qualitative gross information of atmospheric parameters, contour plots can be generated.
- Graphs can also be generated for the data of ground based instruments such as MICROTOPS II, LIDAR and UV Biometer for various parameters observed for many days.
- In this way we can decimate quantitative and gross information. Information is plotted using Satellite and Ground based observations.

1.5. TECHNOLOGY AND LITERATURE REVIEW

1.5.1. Technology

HTML

HTML stands for Hyper Text Markup Language. It is the markup language created for developing web pages and web applications. Web browsers receive HTML documents from a web server or from local storage and render them into multimedia web pages. HTML describes the structure of a web page semantically and originally included cues for the appearance of the document.

HTML markup consists of several key components, including those called tags, character-based data types, character references and entity references. HTML tags most commonly come in pairs like <h1> and </h1>, although some represent empty elements and so are unpaired, for example <img>. The first tag in such a pair is the start tag, and the second is the end tag. Another important component is the HTML document type declaration, which triggers standards mode rendering. The current latest version of HTML is HTML5

File name extension	.html or .htm
Internet media type	text/html
Developed by	W3C and WHATWG
Initial release	1993
Latest release	2016
Type of format	Document file format
Extended from	SGML
Extended to	XHTML

Table 1 HTML Specification

Figure 1 HMTL Logo

CSS

Cascading Style sheet is more commonly referred as CSS is used for describing the presentation of a document written in a markup language. Although most often used to set the visual style of web pages and user interfaces written in HTML and XHTML, the language can be applied to any XML document. Along with HTML and JavaScript, CSS is a cornerstone technology used by most websites to create visually engaging web pages, user interfaces for web applications, and user interfaces for many mobile applications.

CSS has a simple syntax and uses a number of English keywords to specify the names of various style properties. A style sheet consists of a list of rules. Each rule or rule-set consists of one or more selectors, and a declaration block. There have been different versions of Cascading Style Sheet like CSS 1, CSS 2, CSS 2.1 and the latest being CSS 3.

Filename extension	.css
Internet media type	text/css
Developed by	Hakon Wium, Lie Bert Bos, World Wide Web Consortium
Initial release	1996
Type of format	Style Sheet Language

Table 2 CSS Specifications

Figure 2 CSS Logo

Javascript

JavaScript often abbreviated as JS, is a high-level, dynamic, weakly typed, prototype-based, multi-paradigm, and interpreted programming language. Alongside HTML and CSS, JavaScript is one of the three core technologies of World Wide Web content production. It is used to make webpages interactive and provide online programs, including video games. The majority of websites employ it, and all modern web browsers support it without the need for plug-ins by means of a built-in JavaScript engine.

In December 1995, soon after releasing JavaScript for browsers, Netscape introduced an implementation of the language for server-side scripting with Netscape Enterprise Server.Since the mid-2000s, additional server-side JavaScript implementations have been introduced, such as Node.js in 2009.

Although it was developed under the name Mocha, the language was officially called LiveScript when it first shipped in beta releases of Netscape Navigator 2.0 in September 1995, but it was renamed JavaScript when it was deployed in the Netscape Navigator 2.0 beta 3 in December. The final choice of name caused confusion, giving the impression that the language was a spin-off of the Java programming language, and the choice has been characterized as a marketing ploy by Netscape to give JavaScript the cachet of what was then the new Web programming language.

Filename extensions	.js
Internet media type	application/javascript or text/javascript
Paradigm	Multi-paradigm as in object-oriented, imperative, functional, event-driven
Developed by	Netscape Communications Corporation, Mozilla Foundation, Ecma International
Initial release	1995
Latest stable release	2017
Type of format	Scripting language

Table 3 Javascript Specifications

Figure 3 Javascript Logo

Electron

Electron Electron formerly also known as Atom Shell is an open-source framework created by Cheng Zhao, and now developed by GitHub. It allows for the development of desktop GUI applications using front and back end components originally developed for web applications: Node.js runtime for the backend and Chromium for the frontend. Electron is the main GUI framework behind several notable open-source projects including GitHub's Atom and Microsoft's Visual Studio Code source code editors, the Tidal music streaming service desktop application and the Light Table IDE, in addition to the freeware desktop client for the Discord chat service.

A basic Electron app consists of three files: package.json (metadata), main.js (code) and index.html (graphical user interface). The framework is provided by the Electron executable file (electron.exe on Windows, electron.app on macOS, and electron on Linux). Developers wishing to add branding and custom icons can rename and/or edit the Electron executable file. The most important file in the Electron file is package.json. It keeps information about the package.

Developed by	GitHub
Initial release	2013
Latest stable release	2018
Written in	C++, JavaScript, Objective-C++, Python and Objective-C
Operating systems	Windows, Linux and macOS
Platforms	x86, x86-64, ARM

Table 4 Electron Specifications

Figure 4 Electron Logo

Node JS

Node.js is an open-source, cross-platform JavaScript run-time environment for executing JavaScript code server-side. Historically, JavaScript was used primarily for client-side scripting, in which scripts written in JavaScript are embedded in a webpage's HTML, to be run client-side by a JavaScript engine in the user's web browser. Node.js enables JavaScript to be used for server-side scripting, and runs scripts server-side to produce dynamic web page content before the page is sent to the user's web browser. Consequently, Node.js has become one of the foundational elements of the "JavaScript everywhere" paradigm, allowing web application development to unify around a single programming language, rather than rely on a different language for writing server side scripts.

Though .js is the conventional filename extension for JavaScript code, the name "Node.js" does not refer to a particular file in this context and is merely the name of the product. Node.js has an event-driven architecture capable of asynchronous I/O. These design choices aim to optimize throughput and scalability in Web applications with many input/output operations, as well as for real-time web applications.

Developers	Node.js Developers, Joyent, contributors
Initial release	2009
Latest stable release	2018
Written in	C, C++, JavaScript
Operating system	Linux, macOS, Solaris, FreeBSD, OpenBSD, Microsoft Windows (older versions require Cygwin), webOS, NonStop OS
Type	Event-driven networking

Table 5 Node specifications

Figure 5 Node js Logo

Plotly.js

Plotly.js is one of the best free to use javascript libraries to create variety of responsive, interactive and functionality-rich charts and graphs. It offers a lot of features that make worth using it. Plotly.js is based on a declarative, open-source JSON schema that attempts to describe every physical aspect of any scientific chart. With this approach, the role of plotly.js is simple: plotly.js takes the JSON specification of a chart and produces it as an interactive visualization. It is a high-level declarative library built on top of d3.js and stack.gl. plotly.js ships with 20 chart types, including 3D charts, statistical graphs, and SVG maps. plotly.js abstracts the types of statistical and scientific charts that you would find in packages like matplotlib, ggplot2, or MATLAB. plotly.js charts are described declaratively as JSON objects. Every aspect of the charts, such as colors, grid lines, and the legend, has a corresponding set of JSON attributes. Most plotly graphs are drawn with SVG. This offers great compatibility across browsers and publication-quality vector image export. Unfortunately, there are inherent performance limitations with the number of SVG elements that you can draw in the DOM. plotly.js uses stack.gl for high performance 2D and 3D charting. plotly.js charts are shipped with zoom, pan, hover, and click interactions. Click-and-drag to zoom into a region, double-click to autoscale, click on legend items to toggle traces. All of these events are also exposed in the API.

Couchbase Server

Couchbase Server is a NoSQL document database for interactive web applications. It has a flexible data model, is easily scalable, provides consistent high performance and is “always-on,” meaning it can serve application data 24 hours, 7 days a week.

Couchbase benefits

- Flexible data model: The other advantage in a flexible, document-based data model is that it is well suited to representing real world items and how you want to represent them. JSON documents support nested structures, as well as fields representing relationships between items which enable you to realistically represent objects in your application.
- Easy Scalability: It is easy to scale your application with Couchbase Server, both within a cluster of servers and between clusters at different data centers. You can add instances of Couchbase Server to address increases in users and application data without any interruptions or changes in your application code. With a single click of a button, you can rapidly grow your cluster of Couchbase Servers to handle additional work and keep data evenly distributed.
- Consistent high performance: Couchbase Server is designed for massively concurrent data use and consistent high throughput. It provides consistent sub-millisecond response times which help ensure an enjoyable experience for users of your application. By providing consistent, high data throughput, Couchbase Server enables you to support more users with less servers. The server also automatically spreads workload across all servers to maintain consistent performance and reduce bottlenecks at any given server in a cluster.
- Always Online: Couchbase Server provides consistent sub-millisecond response times which help ensure an enjoyable experience for users of your application. By providing consistent, high data throughput, Couchbase Server enables you to support more users with less servers. The server also automatically spreads workload across all servers to maintain consistent performance and reduce bottlenecks at any given server in a cluster.

Figure 6 CouchDB Logo

NoSQL databases are characterized by their ability to store data without first requiring one to define a database schema. In Couchbase Server, you can store data as key-value pairs or JSON documents. Data does not need to confirm to a rigid, pre-defined schema from the perspective of the database management system. Due to this schema-less nature, Couchbase Server supports a scale out approach to growth, increasing data and I/O capacity by adding more servers to a cluster; and without any change to application software. In contrast, relational database management systems scale up by adding more capacity including CPU, memory and disk to accommodate growth.

1.5.2 Literature Review

What is atmosphere?

An atmosphere (from Greek (atmos), meaning 'vapor', and (sphaira), meaning 'sphere') is a layer of gases surrounding a planet or other material body, that is held in place by the gravity of that body. Every celestial body in the universe has their own atmospheric structure and a unique amalgamation of gases in it. The Earth is the only life sustaining planet in the Universe behind which the composition of the Earth’s atmosphere plays a crucial role.

How the Earth’s atmosphere is different from others?

The Earth is often described as being in the ‘Goldilock’ zone (or Habitable Zone) because it is at a distance from the Sun which is not too hot and not too cold for life, and for our atmosphere.

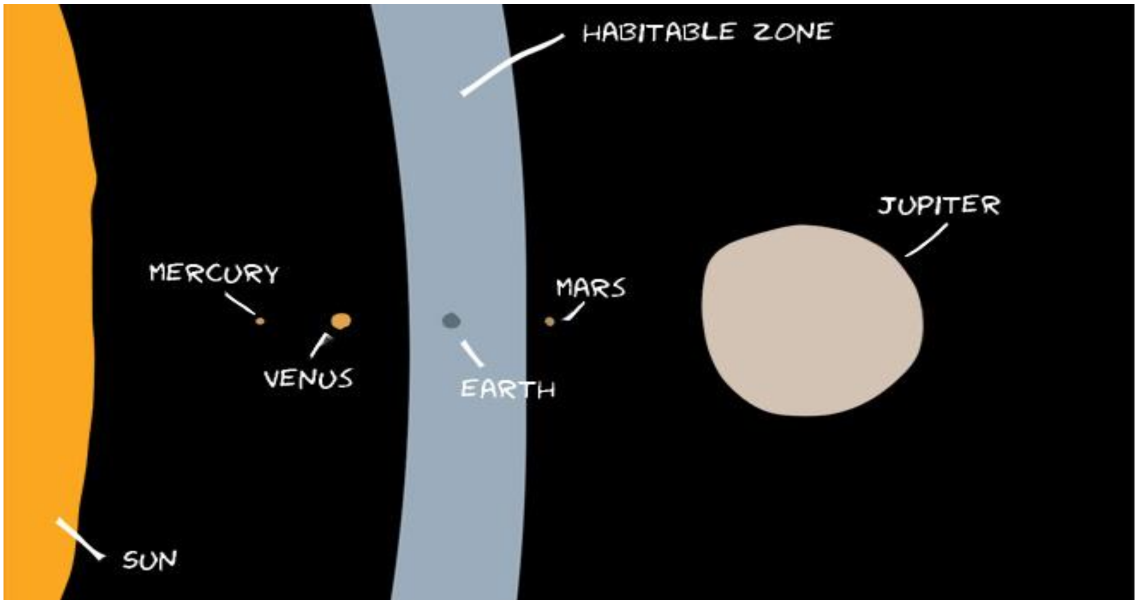

Figure 7 Goldilock Zone

On the Earth, the amount of energy coming in from the Sun and being lost to space is about the same, meaning that the planet can stay at a constant temperature. Our atmosphere, although started due to emission of gases from volcanoes has changed over the years by the presence of life, and photosynthesis producing oxygen to the level it is now.

Composition of the Earth's Atmosphere

The atmosphere of Earth is the layer of gases, commonly known as "AIR", that surrounds the planet Earth and is retained by Earth's gravity. The atmosphere of Earth protects life on Earth by creating pressure allowing for liquid water to exist on the Earth's surface, absorbing ultraviolet solar radiation, warming the surface through greenhouse effect and reducing temperature extremes between day and night.

By volume, dry air contains 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapor, on average around 1% at sea level and 0.4% over the entire atmosphere. Air content and atmospheric pressure vary at different layers, and air suitable for use in photosynthesis by terrestrial plants and breathing of terrestrial animals is found only in Earth's troposphere.

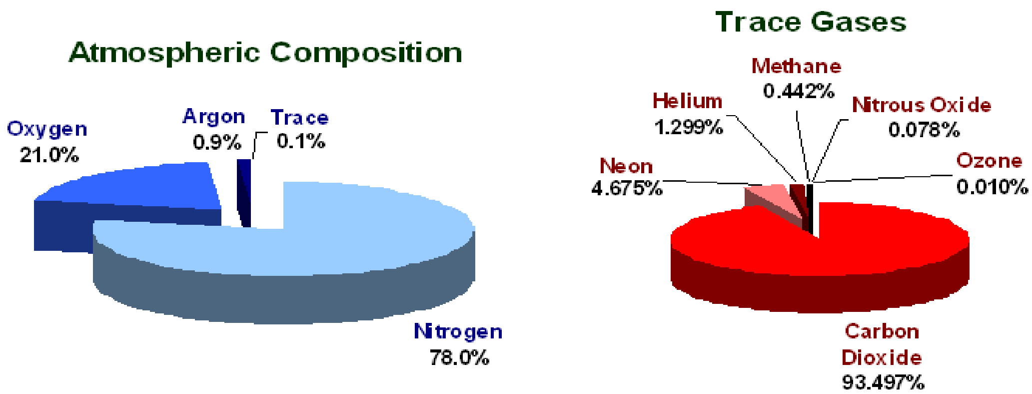

Figure 8 Atmospheric Composition

The atmosphere has a mass of about 5.15×1018 kg, three quarters of which is within about 11 km of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space. The Kármán line, at 100 km is often used as the border between the atmosphere and outer space.

Nomenclature of Earth's Atmosphere

Earth's atmosphere can be basically classified into 5 layers as follows:

- Troposphere (0-12 km)
- Stratosphere (12-50 km)
- Mesosphere (50-80 km)
- Thermosphere (80-700 km)
- Exosphere (700-10,000 km)

Troposphere

Troposphere is the lowest part of the atmosphere and is closer to the earth and extends about 8 km above the poles and 18 km over the equator. It is the densest part of the atmosphere which contains almost all the water vapor, clouds and precipitation. Temperature decreases gradually with height in troposphere. Troposphere means region of turning and mixing and is so named because of vigorous air currents within the layer.

The troposphere is bounded at the top by tropopause whose altitude varies considerably depending on location, type of weather systems, latitude etc. The temperature and altitude of the tropopause at a given location can vary rapidly depending on the prevalent weather systems.

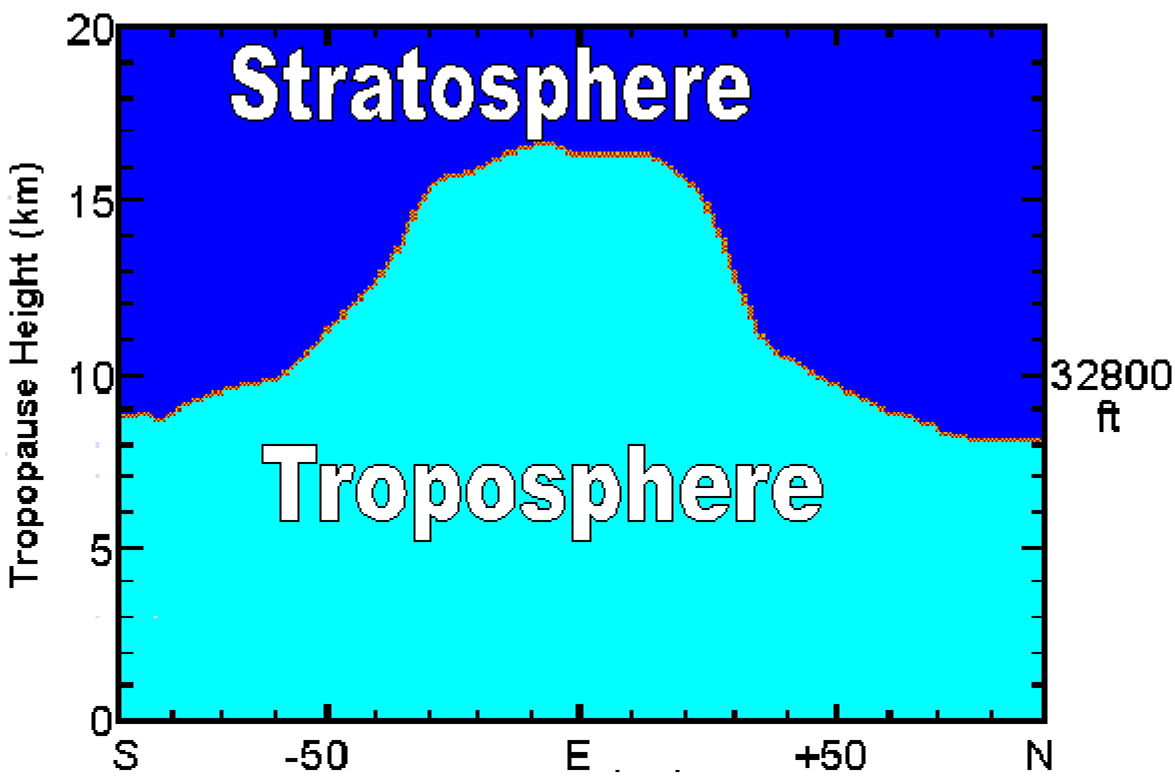

Figure 9 Tropopause

The tropopause may be considered as the base of large inversion layer, i.e. the stratosphere, which inhibits vertical mixing. Consequently there are often significant concentration gradients across tropopause. For example, the concentration of water vapor which results largely from evaporation from the Earth’s surface decreases distinctly above the tropopause while ozone concentration increases noticeably. The moist ozone-poor tropospheric air does not mix much with the dry ozone-rich stratospheric air.

Stratosphere

The stratosphere is second major stratum in the atmosphere. It resides above the tropopause upto 50 km. The air temperature in the stratosphere increases gradually around 273 K at the stratopause which is marked by the reversal in the temperature trend. Because the air temperature in the stratosphere increases with the altitude, it does not cause convection and has a stabilizing effect on atmospheric conditions in the region and confines turbulence to the troposphere. As a water vapor content within the stratosphere is very low, ozone plays the major role in regulating the thermal regime of this layer because temperature increases with ozone concentration. Solar energy is converted into kinetic energy when ozone molecules absorb ultraviolet radiation, resulting in heating of stratosphere.

The vertical temperature gradient in the stratosphere strongly inhibits vertical mixing, in contrast to the situation in troposphere. From about 20-32 km there is usually a near-isothermal layer, whereas the temperature above rises with height. The stability of stratosphere results in a strongly layered structure in which thin layers of aerosol can persist for a long time. The small concentrations of water vapor mean that latent heat release or condensation becomes unimportant, so weather and clouds are rare. However, mother-of-pearl clouds are sometimes seen at altitudes of 20-30 km.

Figure 10 Mother-of-perl Clouds

The stratosphere is a region of intense interactions among radiative, dynamical and chemical processes in which horizontal mixing of gaseous components proceeds much more rapidly than vertical mixing. The stratosphere is warmer than the upper troposphere, primarily because of a stratospheric ozone layer that absorbs solar ultraviolet radiation.

The chemical composition of the stratosphere is generally similar to that of the troposphere with some exceptions, the most notable of which are ozone and water vapor. The stratosphere is relatively dry. However, it is rich in ozone as it is the main region of ozone production. Ozone absorbs ultraviolet radiation from the sun and with the low densities present at stratospheric altitudes, this absorption is an efficient mechanism of transferring kinetic energy to a relatively small number of molecules due to which the air temperature becomes high. Ozone in the upper stratosphere therefore acts as a heat resource. The upper limit of stratosphere is called stratopause, which occurs at an altitude of 50-55 km, the level at which temperatures tends to increase with height.

Mesosphere

The mesosphere is the third layer from the Earth's surface extending from 50 to 80 km is known by its characteristic of decreasing temperatures with increasing altitude, reaching about 180 K at 80 km. The concentrations of ozone and water vapor in the mesosphere are negligible which leads to lower temperatures. Its chemical composition is fairly uniform and pressures are very low. The mesopause which separates mesosphere form thermosphere is a region where temperature trend changes direction. The mesopause is the level at which the lowest atmospheric temperatures are usually found.Middle atmosphere is the region lying between troposphere and thermosphere which extends approximately from 10-100 km which comprises of stratosphere and mesosphere.

Thermosphere

The thermosphere is the fourth layer of the Earth's atmosphere and a region of high temperatures above mesosphere. It includes the ionosphere and extends out to several hundred kilometers. The temperature ranges from 500-2000 K and densities are very low. The thermosphere is the part of heterosphere which does not have a constant chemical composition with increasing altitude.

At an altitude of 100-200 km, the major atmospheric components are still nitrogen and oxygen, although at this high altitude gas molecules are widely separated. Auroras normally occur in this region between 90-160 km.

Figure 11 Auroras in thermosphere

The thermopause is the level at which the temperature stops rising with height. Its height depends on the solar activities and is located between 240-500 km altitude.

Exosphere

The exosphere is the outermost layer of our atmosphere. “Exo” means outside and it is the very edge of our atmosphere. This layer separates the rest of the atmosphere from outer space. It’s about 10,000 kilometers thick. That’s almost as wide as Earth itself. The exosphere has gases like hydrogen and helium, but they are very spread out. There is a lot of empty space in between. There is no air to breathe, and it’s very cold in the exosphere.

The exosphere is the transitional zone between the Earth’s atmosphere and interplanetary space.

Temperature structure of Earth’s Atmosphere

Temperature is proportional to the average kinetic energy of an air molecule. From gas kinetic theory, absolute temperature (K) is obtained from equation :

$$\frac{4\mathrm{kT}}{\pi} = \frac{1}{2}Mv^2$$

T = Temperature

k = Boltzmann’s constant (1.3807×10^{-23} kg m^2 s^{-2} K^{-1} $molecule^{-1}$)

M= Average mass of 1 air molecule (4.8096×10^{-26} kg $molecule^{-1}$)

v= Average thermal velocity of air molecule

The temperature profile of the Earth trends as shown in the figure below :

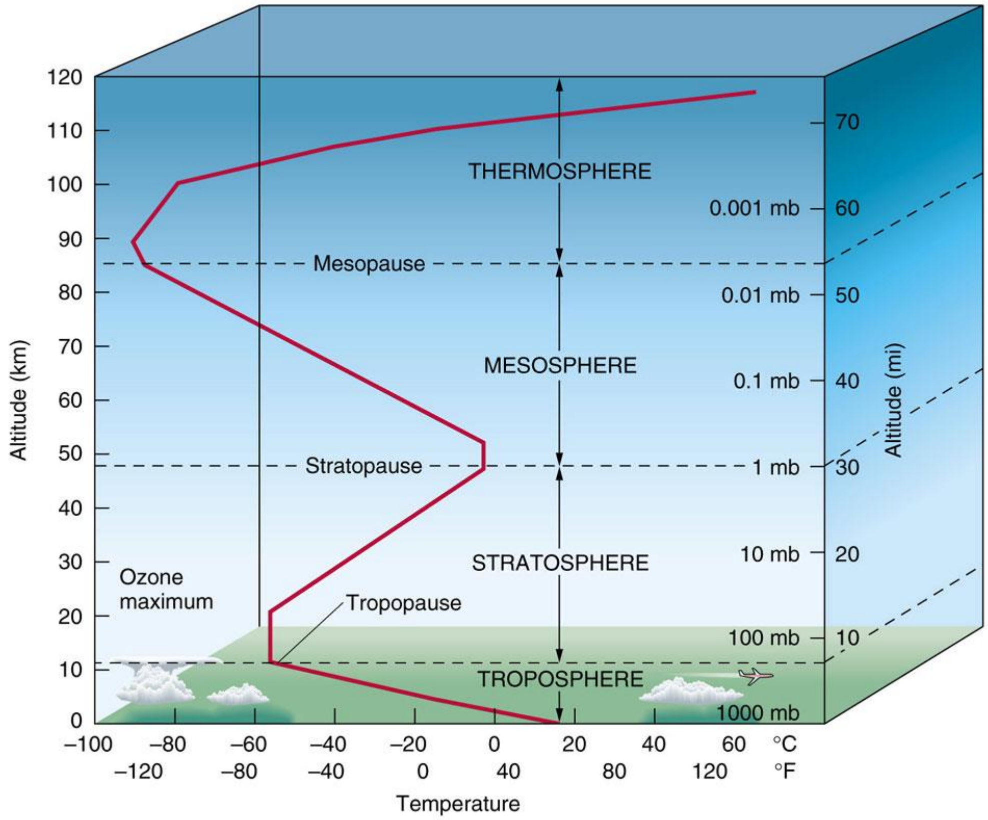

Figure 12 Temperature Profile

Temperature in different layers varies greatly and there are various reasons behind such non uniformity.

First in the troposphere temperature on average decreases with increasing altitude. The average rate of temperature decrease in free troposphere is 6.5 K km^{-1}. The temperature decrease in the free troposphere with increasing altitude is because pressure decreases with increasing altitude and air expands with it. For a parcel of air to expand kinetic energy must be converted to work. The resulting loss of kinetic energy causes temperature to decrease. The tropopause is formally defined by the World Meteorological Organization (WMO) as the lowest altitude at which the lapse rate decreases to 2 K km^{-1}. The temperature of tropopause also depends on the water vapor as it absorbs the Earth's infrared radiation preventing some of it from reaching tropopause.

Moving on to the stratosphere, the increase in temperature with increase in height is because O_3 and O_2 in the stratosphere absorb the sun's UV radiation and emit infrared radiation heating the region. Approximately 90% of ozone molecules reside in the stratosphere while remaining most are in troposphere. The process of ozone formation and destruction takes place by the photolysis reactions and the whole cycle is known as Chapman cycle. Peak ozone density occurs at 25-32 km in which sufficient radiation encounters sufficient oxygen density.

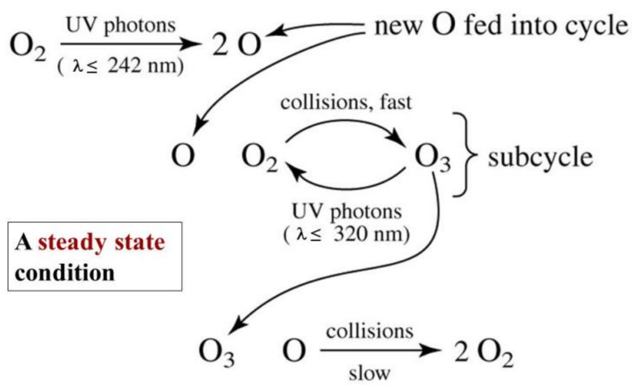

Figure 13 Ozone Cycle

Coming to the third layer of the atmosphere, in the mesosphere temperature decreases with increase in height for the same reason as they do in troposphere. Ozone densities are too low for ozone to absorb radiation and affect the temperatures in the mesosphere.

Finally talking about the temperature increase in the thermosphere with rise in altitude, it is because of the molecular oxygen and nitrogen absorbs very short wavelengths of radiation in this region. Air in the thermosphere would not feel hot to the skin because it contains fewer gas molecules but each gas molecule in thermosphere is highly energized and so the average temperature is high.

Boundary Layer

Boundary layer (300-5000 m) is the portion of troposphere influenced by earth's surface and responds to surface forcings with a time scale of about an hour or less. The free troposphere is affected by the boundary layer but on a larger time scale.

Temperature varies significantly in boundary layer during the day between day and night. Temperatures in boundary layer depends on various factors like specific heat, radiation, mechanical turbulence, advection, thermal turbulence, etc.

During day time boundary layer is characterised by surface layer, convective mixed layer and an entrainment zone.

Surface layer: The surface layer is a region of strong wind shear that comprises the bottom 10% of the boundary layer that is 30-500 m.

Convective mixed layer : In the surface layer strong temperature gradient is caused by rapid solar heating. The temperature gradient is so strong that surface layer is unstably stratified and air adjacent to the ground moves up buoyantly to mixed layer. The mixed layer is neutrally stratified, thus parcels of air can mix up or down.

Entrainment zone : Thermals originating in the surface or mixed layer cannot easily penetrate through the inversion. Thus the inversion layer is entrainment zone.
Other features of daytime boundary layer include cloud layer and a region under it known as sub cloud layer. A cloud is formed if rising rising in a thermal cools sufficiently. During night the surface cools radiatively. Cooling at the top of the surface layer cools bottom of the mixed layer, increasing the stability of the bottom layer at its base. The portion of mixed layer that is stable at night is known as stable (nocturnal) boundary layer. The remaining portion which stays neutrally stratified is residual layer.

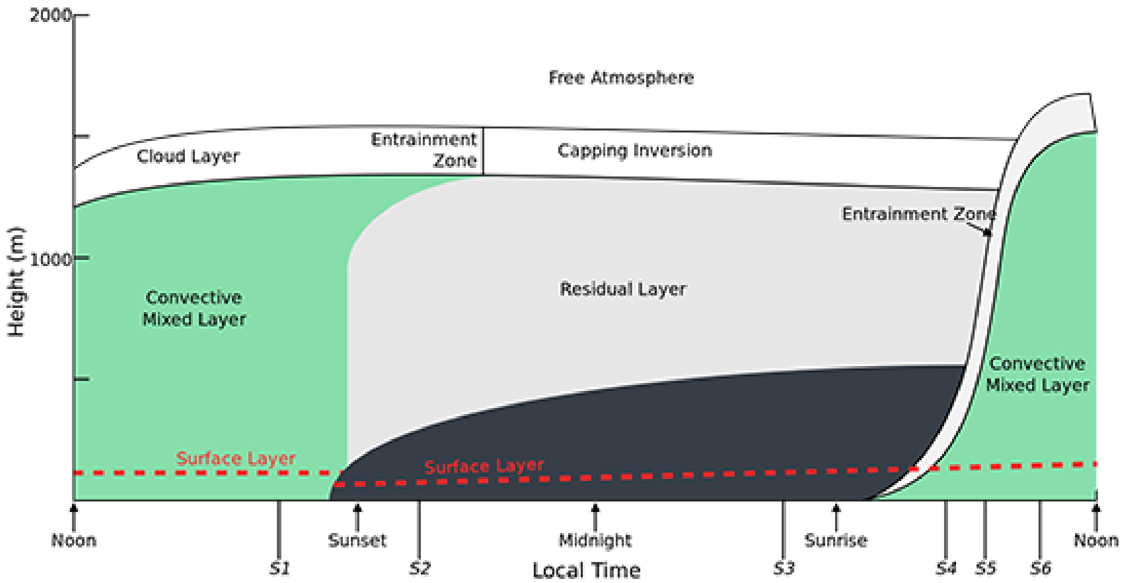

Figure 14 Boundary Layer

Density

Air density is the mass of air per unit volume of air. Since atmospheric mass is concentrated near the surface, air density is highest near the surface. 50% of atmospheric mass lies between sea level and 5.5 km. The density varies with altitude by following trend :

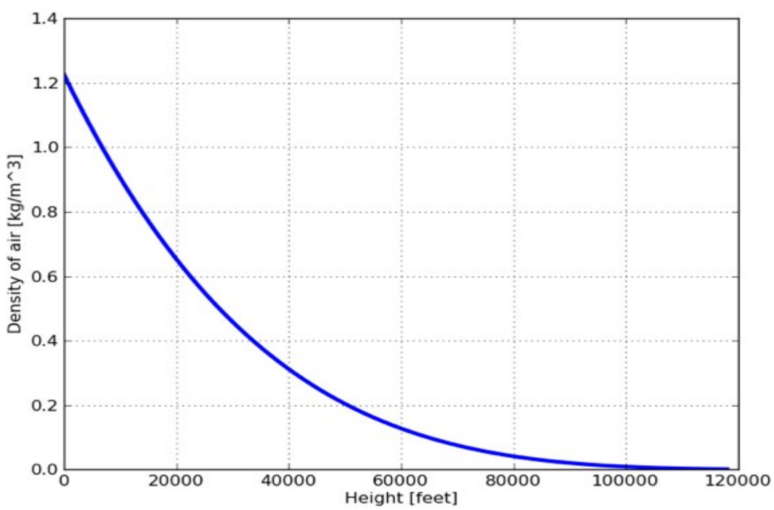

Figure 15 Density Profile

Pressure

The mean atmospheric pressure at a planet's surface is the total atmospheric force divided by the total surface area. It is given by :

$$P_0 = \frac{Mg}{4\pi R^2}$$

M = mass

g = gravity

R = Radius of the planet

One standard atmosphere on the Earth is defined as 101325 Pa (Pascal or N m^{-2}). Pressure decreases exponentially with increment in altitude. Pressure decreases by 1 mb (millibar) every 8 m of altitude. (1 mb = 10^2 Pa, 1 atm = 1 bar = 1013.25 mb)

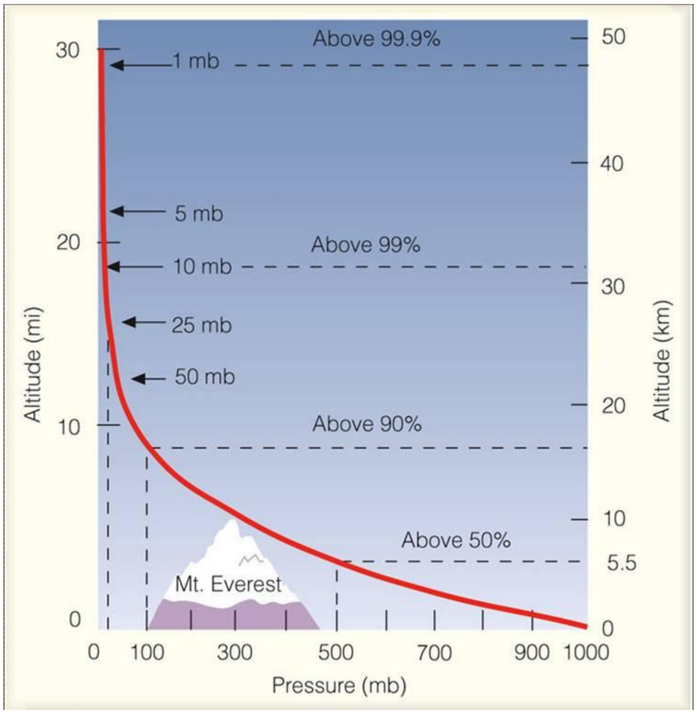

Figure 16 Pressure

Hydrostatic Equilibrium in Atmosphere

In the atmosphere the pressure of the air decreases with increasing altitude. This pressure causes an upward force called the pressure gradient force. The force of gravity balances this out keeping the atmosphere bound to the Earth and maintaining pressure differences with altitude. This state of atmosphere is known as hydrostatic equilibrium.

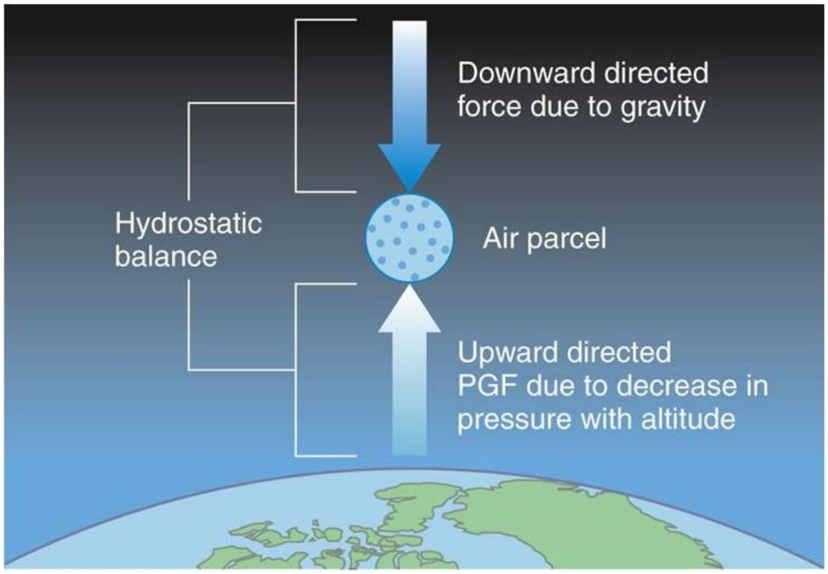

Figure 17 Hydrostatic Equilibrium

The hydrostatic equation is the formal expression of hydrostatic equilibrium. Consider an air mass lying between heights z and z+dz. The vertical pressure gradient acting on air mass is $\frac{\partial p}{\partial z}$. The weight of the air mass per unit is ρg. Under hydrostatic equilibrium the vertical pressure gradient force (buoyancy force) is balanced by the body force. The hydrostatic equation can be written as :

$$\frac{\partial p}{\partial z} = -\rho g$$

p = Pressure

z = geometrical height

ρ = density

g = gravity

Ozone

Ozone (trioxygen, O_3) plays a significant part in the chemistry of the Earth's atmosphere even though it is a minor species in terms of abundance. If all the ozone of atmosphere were collected and compressed in to 1 atm (atmospheric) pressure it would occupy a column about 3 mm (millimeter) tall.

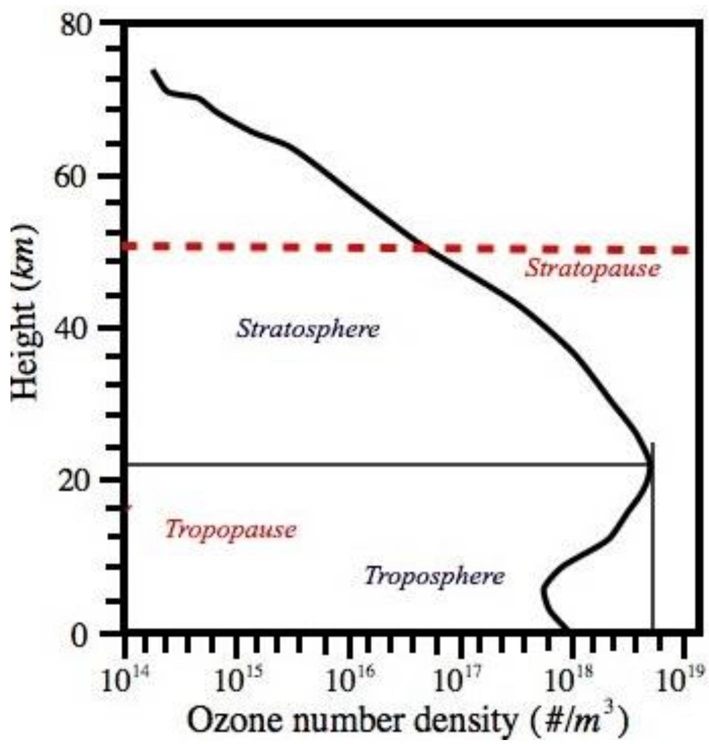

Figure 18 Ozone Number Density

Ozone concentrations are sharply dependent on altitude. The above graph clearly shows that maximum ozone lies in the stratosphere.

The relationship between absorption spectrum of ozone and protection of living systems from the full intensity of solar UV radiation is outstanding. The macromolecules such as proteins and nucleic acids, that are characteristics of a living cell, are damaged by radiation of wavelength shorter than 290 nm. O_2 filters out UV radiation with wavelength < 230 nm. The only species in atmosphere capable of attenuating the Sun's radiation of wavelength > 230 nm is ozone. Ozone has an unusually strong absorption at critical wavelengths of 230-290 nm so it is an effective filter despite of lower concentration.

Ozone is formed in the atmosphere from molecular oxygen, the necessary energy supplied by the absorption of UV radiation. Ozone needed as an ultraviolet filter to protect life, itself is dependent on atmospheric oxygen. Loss of ozone is regulated by chemistry involving some other trace gases of atmosphere such as oxides of nitrogen which are themselves at least partly of biological origin. Biological processes thus influence both generation and destruction of ozone. Ozone is a endothermic substance so the reactions involving ozone are often exothermic.

Scale Height

Scale height is a distance over which a quantity decreases by a factor of e (~2.72). For planetary atmospheres scale height is the increase in altitude for which the pressure decreases by a factor of e. The scale height remains constant for a particular temperature. It can be calculated by :

$$H = \frac{kT}{Mg} \qquad \text{or} \qquad H = \frac{RT}{Mg}$$

k = Boltzmann's constant

M = mean mass of molecule

g = gravity

T = mean atmospheric temperature in Kelvin (250 K)

R = Gas constant

m = mean molecular mass of one atmospheric particle

The pressure at a given altitude is a result of the weight of the overlying atmosphere. If at a height z the atmosphere has density ρ and pressure P, then moving upwards at a infinitely small height dz will decrease the pressure by amount dP, equal to the weight of a layer of atmosphere of thickness dz

$$\frac{dp}{dz} = -\rho g$$

Using the equation of state for an ideal gas of mean molecular mass M at temperature T, the density can be expressed as :

$$\rho = \frac{MP}{kT}$$

Merging above two equations we get $\frac{dp}{P} = -\frac{dz}{H}$ which will not change till temperature does. Thus integrating this equation on both sides and assuming where P_0 is the pressure at height z = 0, we get :

$$P = P_0 \exp\left(-\frac{z}{H}\right)$$

This clearly shows pressure decreasing exponentially with increase in height.

Instruments

Different measurement techniques with various spatial coverage, vertical and temporal resolution, as well as a detection limits and costs are used to measure water vapor content and temperature in atmosphere. A wide range of instruments are available to measure atmospheric parameters, we use ground based instruments and satellites to measure atmospheric parameters in this project.

Meteorological Satellites

The weather satellite is a type of satellite that is primarily used to monitor the weather and climate of the Earth. Meteorological satellites see more than cloud and cloud systems. City lights, fires, effects of pollution, auroras, sand and dust storms, snow cover, ice mapping, boundaries of oceanic currents, energy flows and other types of environmental information are collected using them. Each meteorological satellite is designed to use one of two different classes of orbit: geostationary and polar orbiting.

Geostationary

Geostationary weather satellites orbit the earth above equator at altitudes of 35,880 km. At this altitude, one orbit takes 24 hours, the same length of time as the requires to rotate once on its axis. Because of this orbit, they remain stationary with respect to the rotating earth and thus can record or transmit images of the entire hemisphere below continuously with their visible-light and infrared sensors.

Polar Orbiting

Polar orbiting weather satellites circle the earth at an altitude of 850 km (530 miles) in a north to south (or vice versa) path, passing over the poles in their continuous flight. Polar satellites are in sun-synchronous orbits, which means they are able to observe any place on earth and will view every location twice each day with the same general lighting conditions due to the near-constant local solar time. Polar orbiting weather satellites offer a much better resolution than their geostationary counterparts due to their closeness to earth.

Satellites Measuring Ozone

Satellites measure ozone over the entire globe every day, providing comprehensive data. In orbit, satellites are capable of observing the atmosphere in all types of weather, and over the most remote regions on the Earth. They are capable of measuring total ozone levels, ozone profiles, and elements of atmospheric chemistry. In the mid-1980s wide-ranging ozone depletion over the Antarctic was first recognized from satellite data. Two instruments which are widely used for the measurement of ozone using satellite are SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) and TOMS (Total Ozone Mapping Spectrometer).

SABER (Sounding of the Atmosphere using Broadband Emission Radiometry)

Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument is one of four instruments on NASA’s TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite. Primary goal of the SABER experiment is to provide the data needed to advance our understanding of fundamental processes governing the energetics, chemistry, dynamics, and transport in the mesosphere and lower thermosphere. SABER accomplishes this with global measurements of the atmosphere using 10-channel broadband limb-scanning infrared radiometer covering the spectral range from 1.27 µm to 17 µm. These measurements are used to provide vertical profiles of kinetic temperature, pressure, geopotential height, volume mixing ratios for the trace species O_3, CO_2, H_2O, [O], and [H], volume emission rates for 5.3 µm NO, 2.1 µm OH, and 1.27 µm O_2 (1µ), cooling and heating rates for many CO_2, O_3, and O_2 bands, and chemical heating rates for 7 important reactions.

SABER is Polar orbiting satellite located approximately 625 km above the sea level around earth. It provides Temperature and Ozone measurements reported at 44 different pressure/altitude since 2002. SABER measures ozone using two independent techniques at different wavelength.

9.6 µm	**1.27 µm**
Ozone directly measured from emission of ozone molecule	Ozone concentration inferred from emission of molecule oxygen day glow
Measures from 15 to 100 km	Measures from 50 to 105 km
Day and Night measurement	Day Measurement

Table 6 Wavelength for ozone measurement (SABER)

Key Experiment Features

SABER System	Key Spacecraft Characteristics
Mass: 65.6 kg Electric Power: 76.5 W Data Rate: 4 kbps Dimensions: 77 x 104 x 63 cm Heater Power: 11.0 watts Altitude Resolution: 10 km to 180 km Limb Vertical Sampling Interval: 0.4 km Build by: Space Dynamics Laboratory, Utah state Univ. Lifetime: >2 Years	Launch Date: Dec. 7th, 2001 at 7:07 a.m. PST Launch Site: Vandenberg AFB, CA Total Spacecraft weight: 660 kg Spacecraft Size: Mid-Lite class Launch vehicle: Boeing Delta II 7920-10 Medium Expendable Launch Vehicle (Co-manifest with Jason-1 Spacecraft) Launch Dimensions: Right cylinder 80.9 inches in diameter and 108 inches in height Orbital Altitude: 625 km Circular (+/- 25 km) Orbital Inclination: 74.1 degrees(+/- 0.1 degree) Nodal Regression Rate: 720 degrees per year

Table 7 SABER Details

The instrument telescope is a Cassegrain design with a picket-fence tuning fork chopper at the first focus, and a clam shell re-images to focus the image on the focal plane. The telescope has been designed to reject stray light from the earth and atmosphere outside the instrument instantaneous field-of-view (IFOV). The baffle assembly contains a single axis scan mirror which permits the 2km vertical IFOV of each detector to be scanned from the earth to a 400 km tangent height. Accurate vertical registration of tangent height of data in the atmosphere is achieved by analysis of the 14.9 µm CO_2 channels. Telescope and baffle assembly are cooled to 240 K by a dedicated radiator. The focal plane assembly, consisting of a filter array, a detector array, and a Lyot stop is cooled to 75 K by a miniature cryogenic refrigerator. The detector array contains discrete HgCdTe, InSb, and InGaAs detectors. The conductive heat load on the refrigerator is minimized by a support system that thermally isolates the focal plane assembly from the telescope. The telescope is supported and thermally isolated from the instrument base plate by a glass composite structure. The cryogenic refrigerator and electronics heat loads are dissipated to space by the plate radiator. Instrument responsively drifts due to changes in telescope and focal plane base temperatures as well as other causes are corrected by an in-flight calibration system.

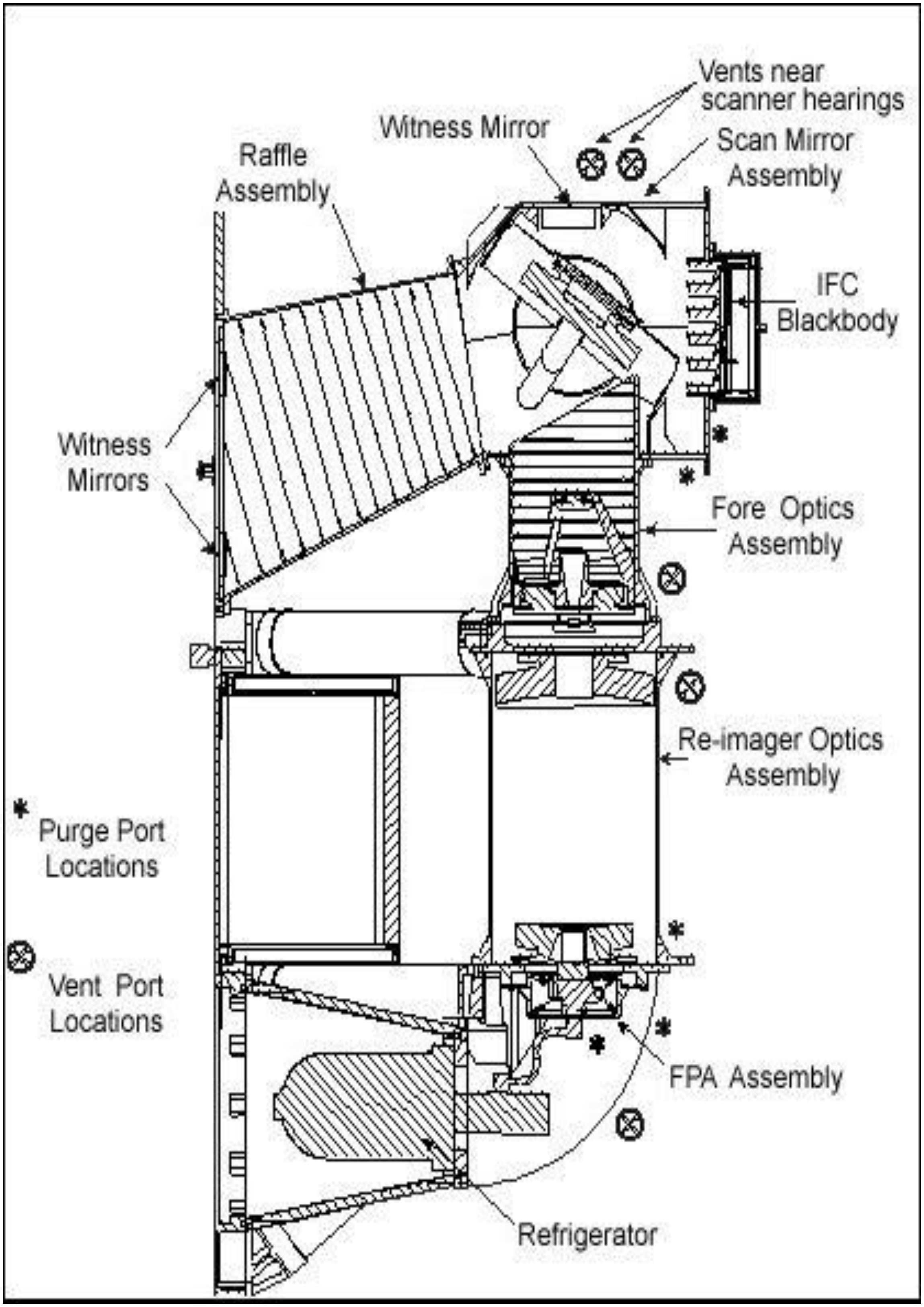

Figure 19 Cross section view of SABER

Total Ozone Mapping Spectrometer (TOMS)

Total Ozone Mapping Spectrometer (TOMS) is a satellite instrument for measuring ozone values. It has been flown on NASA-satellites. Of the five TOMS instruments which were built, four entered successfully into the orbit. Nimbus-7 and Meteor-3 provided global measurements of total column ozone on a daily basis and together provide a complete data set of daily ozone from November 1978 to December 1994. After an eighteen-month period when the program had no on-orbit capability, ADEOS TOMS was launched on August 17, 1996 and provided data until the satellite which housed it lost power on June 29, 1997. Earth probe TOMS was launched on July 2, 1996 to provide supplemental measurements, but was boosted to a higher orbit to replace the failed ADEOS. The only total failure in the series was Quick TOMS-satellite, which was launched on September 21, 2001 but did not achieve an orbit. The transmitter for the earth probe TOMS failed on December 2, 2006. Since January 1, 2006 data from the Ozone Monitoring instrument (OMI) has replaced earth probe TOMS.

The TOMS instrument is the second generation backscatter UV ozone sounder, TOMS can measure “total column ozone” - the total amount of ozone in a column of air from earth’s surface to the top of atmosphere under all daytime observing and geophysical conditions. TOMS observation covered the near UV region of the electromagnetic spectrum, where sunlight is absorbed only partially by ozone.

TOMS measures total column ozone by absorbing both incoming solar radiation and backscattered UV radiation at 6 wavelengths, “Backscattered” radiation is solar radiation that has penetrated to the earth and is scattered by the air molecule and clouds back through stratosphere to the satellite sensor. Along that path a fraction of UV is absorbed by Ozone. By comparing amount of backscattered radiations to the observations of incoming solar energy at identical wavelength, scientist can calculate earth’s albedo, the ratio of light reflected by earth compared to that it receives. Changes in albedo at the selected wavelength can be used to derive amount of ozone above the surface. TOMS makes 35 measurements every 8 seconds, each covering 30 to 125 miles wide on the ground using 6 different wavelengths ranging from 308.6 nm to 360.0 nm.

6 wavelengths that TOMS absorb for ozone measurement are:

Bands	**Wavelength**	**Comments**
Band 6	308.6 nm	Absorbed at greater or lesser extend by ozone
Band 5	312.5 nm	Absorbed at greater or lesser extend by ozone
Band 4	317.5 nm	Absorbed at greater or lesser extend by ozone
Band 3	322.3 nm	Absorbed at greater or lesser extend by ozone
Band 2	331.2 nm	Used to assess the reflectivity
Band 1	360.0 nm	Used to assess the reflectivity

Table 8 Wavelengths of TOMS for ozone measurement

Configuration and Function of Sensor

Toms consists of optical subsystem, electrical subsystem and driving subsystem.

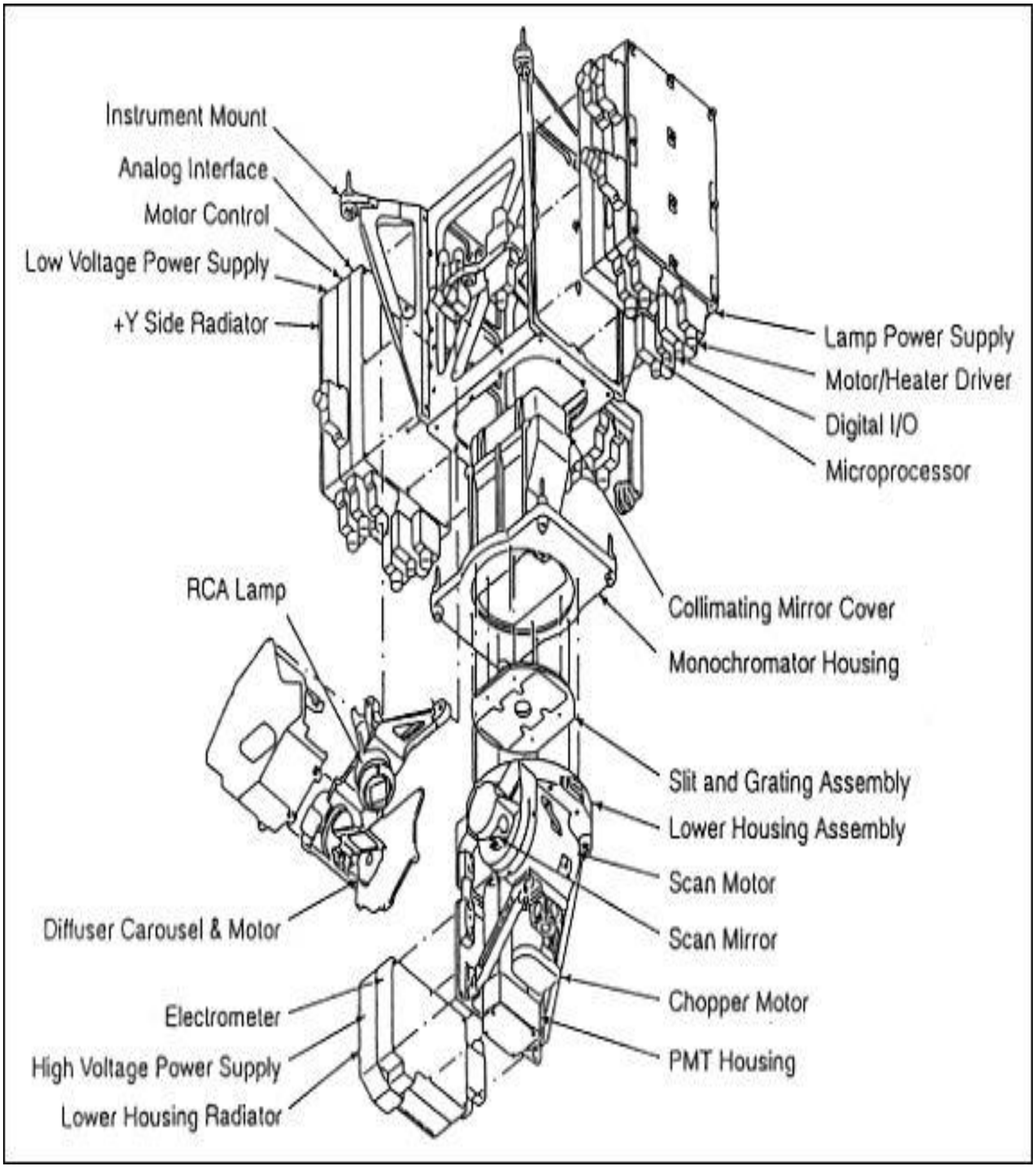

Figure 20 TOMS Cross-section View

TOMS Overview

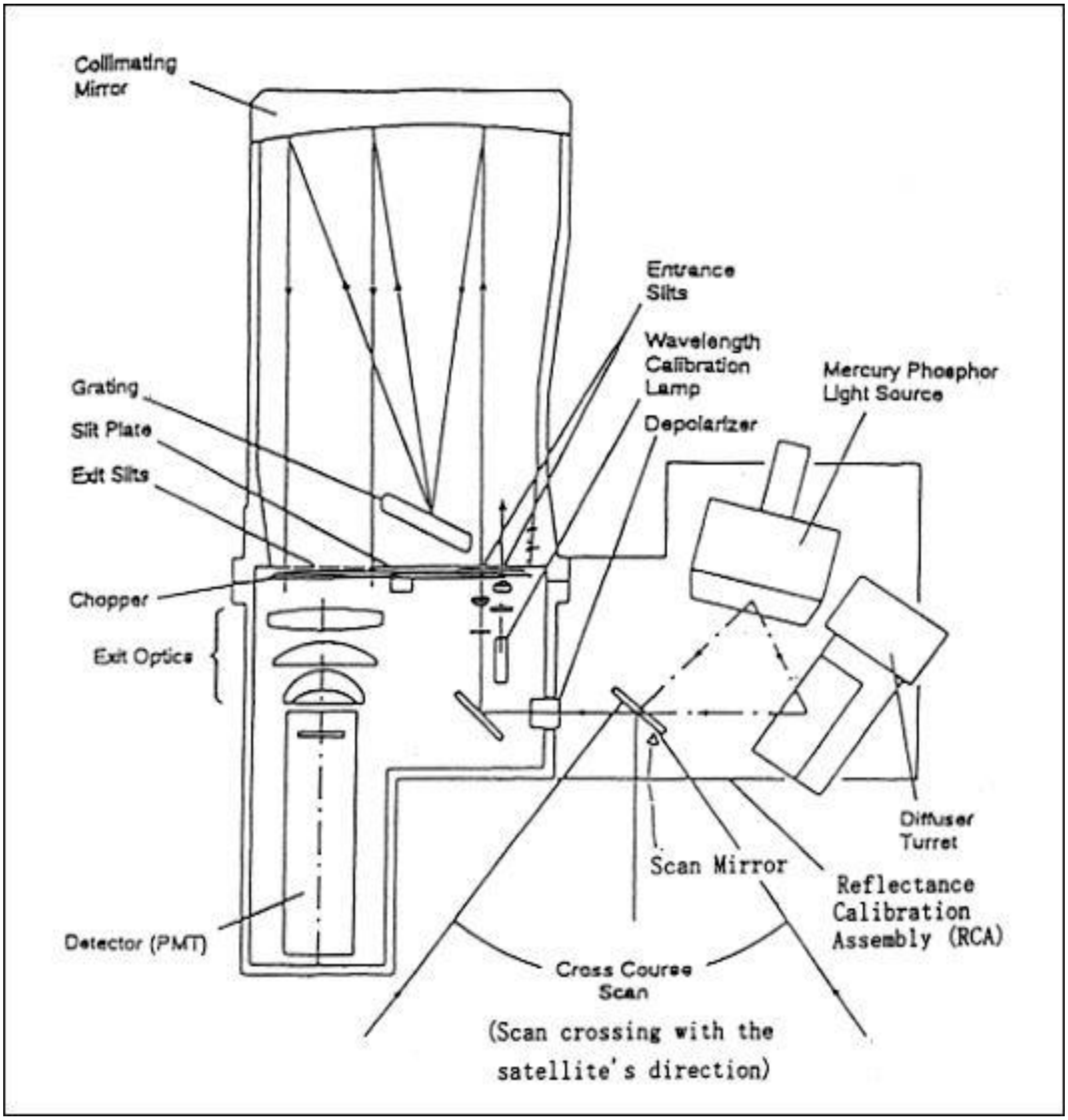

Figure 21 TOMS Optical System

TOMS Optical System

The scan mirror observes the earth target along cross track direction, and first focuses sunlight on the right side of a collimator. The spectrum, using holographic grating, is focused on the other side of the collimator and converted to the electrical signals via optoelectronic amplifier in the focal plane. Each spectrum is focused on the focal plane via slit plates and chopper. The TOMS observation data will be calibrated by using one of three diffusers. The alternative use is to evaluate degradation of the diffuser by solar radiation. TOMS can also calibrate by using mercury phosphor and wavelength calibration is made by using a reflectance calibrator.

Ozone Monitoring Instrument (OMI)

The **Ozone Monitoring Instrument** (**OMI**) is on board the NASA Aura. OMI can distinguish between aerosol types, such as smoke, dust, and sulfates, and can measure cloud pressure and coverage, which provide data to derive tropospheric ozone. OMI follows in the heritage of TOMS, SBUV, GOME, SCIAMACHY, and GOMOS. It is a wide-field-imaging spectrometer with a 114° across-track viewing angle range that provides a 2600 km wide swath, enabling measurements with a daily global coverage. OMI is continuing the TOMS record for total ozone and other atmospheric parameters related to ozone chemistry and climate.

The OMI project is a cooperation between the Netherlands Agency for Aerospace Programmes (NIVR), the Finnish Meteorological Institute (FMI) and the National Aeronautics and Space Agency (NASA).The OMI project was carried out under the direction of the NIVR and financed by the Ministries of Economic Affairs, Transport and Public Works and the Ministry of Education and Science. The instrument was built by Dutch Space in cooperation with Netherlands Organization for Applied Scientific Research Science and Industry and SRON Netherlands Institute for Space Research. The Finnish industry supplied the electronics. The scientific part of the OMI project is managed by KNMI (principal investigator Prof. Dr. P . F. Levelt), in close co-operation with NASA and the Finnish Meteorological Institute.

OMI Parameter

The instrument observes Earth's backscattered radiation with a wide-field telescope feeding two imaging grating spectrometers. Each spectrometer employs a CCD detector.

Onboard calibration includes a white light source, LEDs, and a multi-surface solar-calibration diffuser. A depolarizer removes the polarization from the backscattered radiation.

Item	**Parameter**
Visible	350 - 500 nm
UV	UV-1, 270 - 314 nm, UV-2 306 - 380 nm
Spectral resolution	1.0 - 0.45 nm FWHM
Spectral sampling	2 - 3 for FWHM
Telescope FOV	114 (2600 km on ground)
IFOV	3 km, binned to 13 x 24 km
Detector	CCD: 780 x 576 (spectral x spatial)px
Mass	65 kg
Duty cycle	60 minutes on daylight side
Power	66 watts
Data rate	0.8 Mbps (average)

Table 9 OMI Configuration

Ground based instruments

MICROTOPS II

The **MICROTOPS II** is a hand-held multi-band sunphotometer capable of measuring the total ozone column and optionally the water vapor column (also called precipitable water) as well as aerosol optical thickness at 1020nm.

Figure 22 MICROTOPS Ozonometer

Principle Of Operation

The instrument is equipped with five (5) accurately aligned optical collimators, capable of a full field view of 2.5°. Internal baffles are also integrated into the device to eliminate internal reflections. Each channel is fitted with a narrow-band interference filter and a photodiode suitable for the particular wavelength range. The collimators are encapsulated in a cast aluminum optical block for stability. A sun target and pointing assembly is permanently attached to the optical block and laser-aligned to ensure accurate alignment with the optical channels. When the image of the sun is centered in the bull’s-eye of the sun target, all optical channels are oriented directly at the solar disk. A small amount of circumsolar radiation is also captured, but it makes little contribution to the signal. Radiation captured by the collimator and bandpass filters radiate onto the photodiodes, producing an electrical current that is proportional to the radiant power intercepted by the photodiodes. These signals are first amplified and then converted to a digital signal by a high resolution A/D converter. The signals from the photodiodes are processed in series. However, with 20 conversions per second, the results can be treated as if the photodiodes were read simultaneously.

The ozone layer, a concentration of 3-atom oxygen molecules in the stratosphere, is essential to life on Earth. Short wavelengths of ultraviolet radiation are much more readily absorbed by ozone than the longer wavelengths in the same UV bandwidth. This means that the amount of ozone between the observer and the Sun is proportional to the ratio of two wavelengths of the Sun’s ultraviolet radiation. MICROTOPS II uses that relationship to derive the Total Ozone Column (the equivalent thickness of pure ozone layer at standard pressure and temperature) from measurements of 3 wavelengths in the UV region. Similarly, as in the traditional Dobson instrument, the measurement at an additional 3rd wavelength enables a correction for particulate scattering and stray light. The precipitable water column is determined based on measurements at 936 nm (water absorption peak) and 1020nm (no absorption by water). The aerosol optical thickness at 1020nm is calculated based on the extraterrestrial radiation at that wavelength, corrected for the sun-earth distance, and the ground level measurement of the radiation at 1020 nm.

Major Features

- High accuracy: High grade filters are embedded in a solid cast aluminum housing that assures accurate, stable optical alignment. Low noise electronics and a 20 bit A/D converter ensure high linearity, resolution and dynamic range.

- Ease of use: No computer knowledge is necessary to take measurements. Once the geographical coordinates of the measurement site are entered, just aim the meter at the sun, align the image of the sun with the bull's-eye and push the button. In seconds the result will be displayed on the LCD.

- Portability: A small hand-held device is all you need to take measurements. No additional computer is necessary.

- Computer interface: A serial interface allows for the transfer of data and remote control of the instrument from any computer. Simple text protocol makes the process easy and dependable. Specialized data management software is available as an option.

- GPS interface: MICROTOPS II understands the NMEA 0183 communication protocol and can be linked directly to a handheld GPS receiver via serial cable. The GPS receiver is optional.

- Instantaneous results: The ozone and total water vapor calculation algorithms are programmed in the MICROTOPS II and the results of all stored scans can be conveniently viewed on the LCD. The raw data is also stored to allow retrospective adjustments of calibration constants.

- Non-volatile memory: The raw data collected by MICROTOPS II, as well as calculated results are stored in non-volatile memory. Each data point is annotated with date, time, site coordinates, solar angle, altitude, pressure and temperature.

- Low cost: By implementing the latest technology, instrument cost has been brought below that of comparable ozonometers, without sacrificing accuracy or features.

Ground Based Rayleigh LIDAR

A Nd-YAG laser based Rayleigh Lidar was set up at Guru Shikhar, Mount Abu (24.5^{o} N, 72.7^{o} E, altitude 1.7 km) by the Physical Research Laboratory to study the temperature structure in the altitude region of 30-75 km at tropical latitudes. Temperature profiles are derived from relative density measurements, following the method described by Hauchecorne & Channin (1980). Photon counts are averaged over one hour (2 hour during the later phase) in time and 480 m in altitude.

LIDAR System	Specifications
Laser	
Type	Nd:YAG(581C-10 Quantel, France)
Average Power	4.4 W at 532 nm
Energy Pulse	440 mJ at 532 nm
Pulse repetition rate	10 Hz (maximum)
Pulse width	7 ns
Beam divergence	0.6 mrad

Telescope	
Telescope type	Cassegrain
Effective focal length	737 cm
Diameter (primary mirror)	90 cm
Diameter (secondary mirror)	25 cm
Field of view	1 mrad
Power aperture product	2.6 Wm^2
Optics	
Interference filter	
Central wavelength	532 nm
Filter bandwidth	1 nm
Transmission	20%
Photomultiplier	9813 A (electron tubes, UK)
Mode of operation	Photon counting mode
Dark counts	~300 counts/s at 20 °C
Signal Processor	
Type	SR430 Stanford Research System, USA
Bin width	640 ns (~96 m)

Table 10 Specifications of PRL's Rayleigh LIDAR

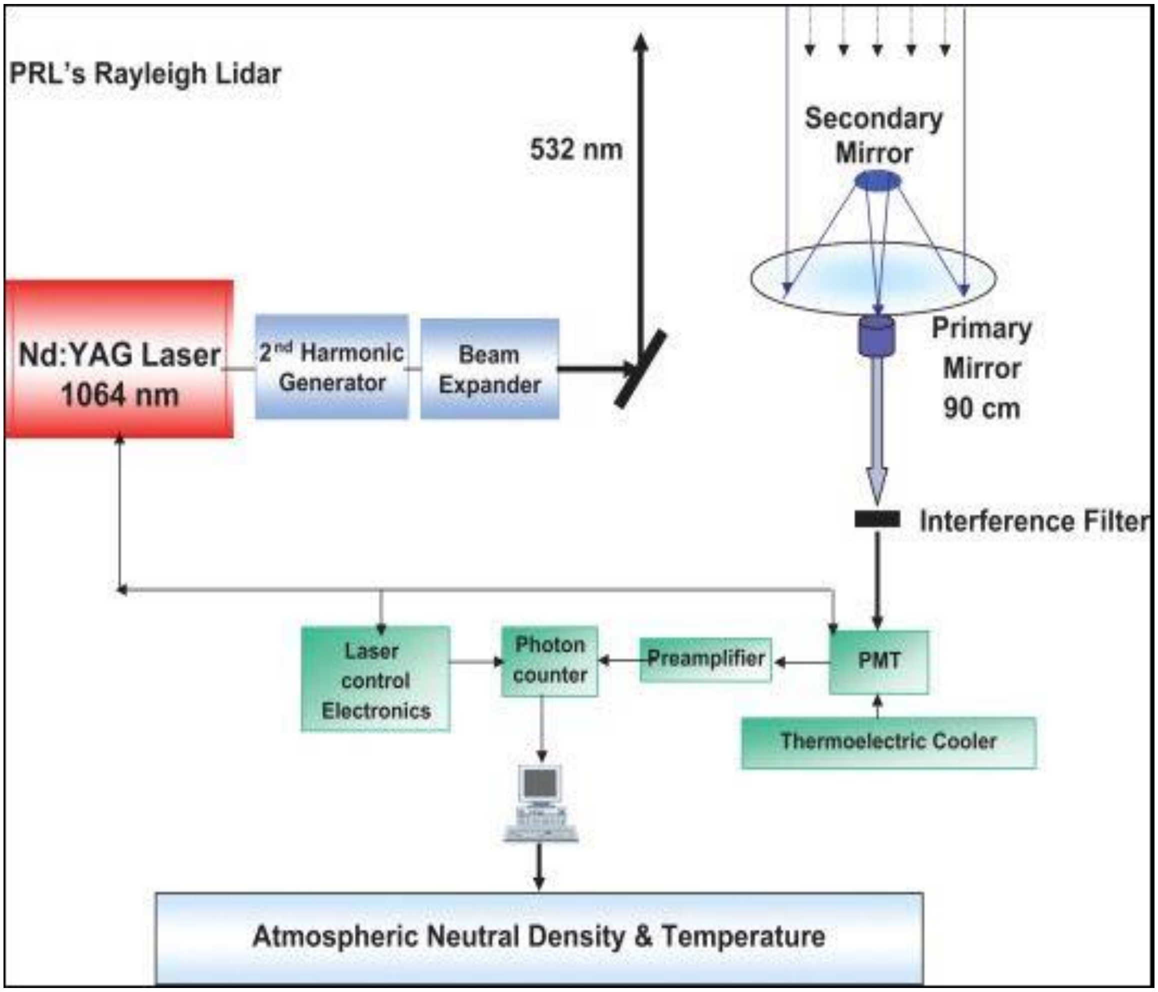

Figure 23 Block Diagram of PRL's Rayleigh LIDAR

Ground Based Raman LIDAR

The Raman Lidar is an active, one of the best ground-based, laser remote-sensing instrument that provides height- and time-resolved measurements of water-vapor mixing ratio, temperature, aerosol, cloud optical properties and other atmospheric parameters in altitude range from 0 to ~25 km. The Raman Lidar operates in the UV and is sensitive to both molecular and aerosol backscatter.

Raman Lidar works on the Raman Scattering principle according to which when highly coherent laser beam collides with the particle in the atmosphere waves of different wavelength get scattered. The wavelengths for some of the atmospheric components are predefined for instance if the beam of 532 nm get scattered from the particle and generates the wave of 408 nm or 355 nm then those waves will be emitted from nitrogen molecule and water molecule in atmosphere respectively

Principle:

- Send intense pulsed laser light into the sky.
- Observe/Receive carefully,what comes back.
- Learn about physical and chemical properties of atmosphere.
- Get height resolved profiles of the designated parameters.

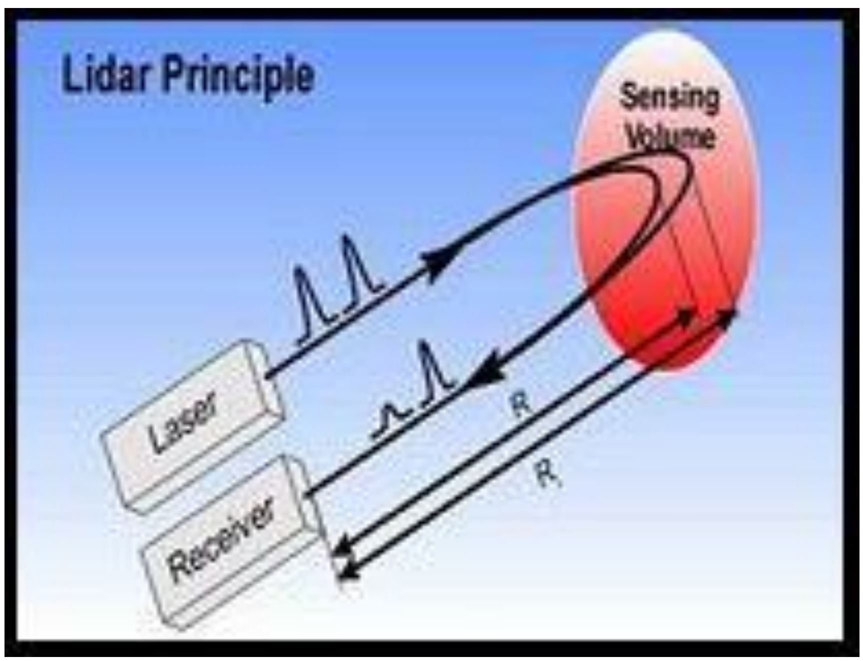

Figure 24 LIDAR Principle

Measurements

- Direct: Vertical distribution of neutral atmospheric species in the lower and middle atmosphere, clouds, water vapor, aerosols etc.

- Indirect: Temperature, humidity etc.

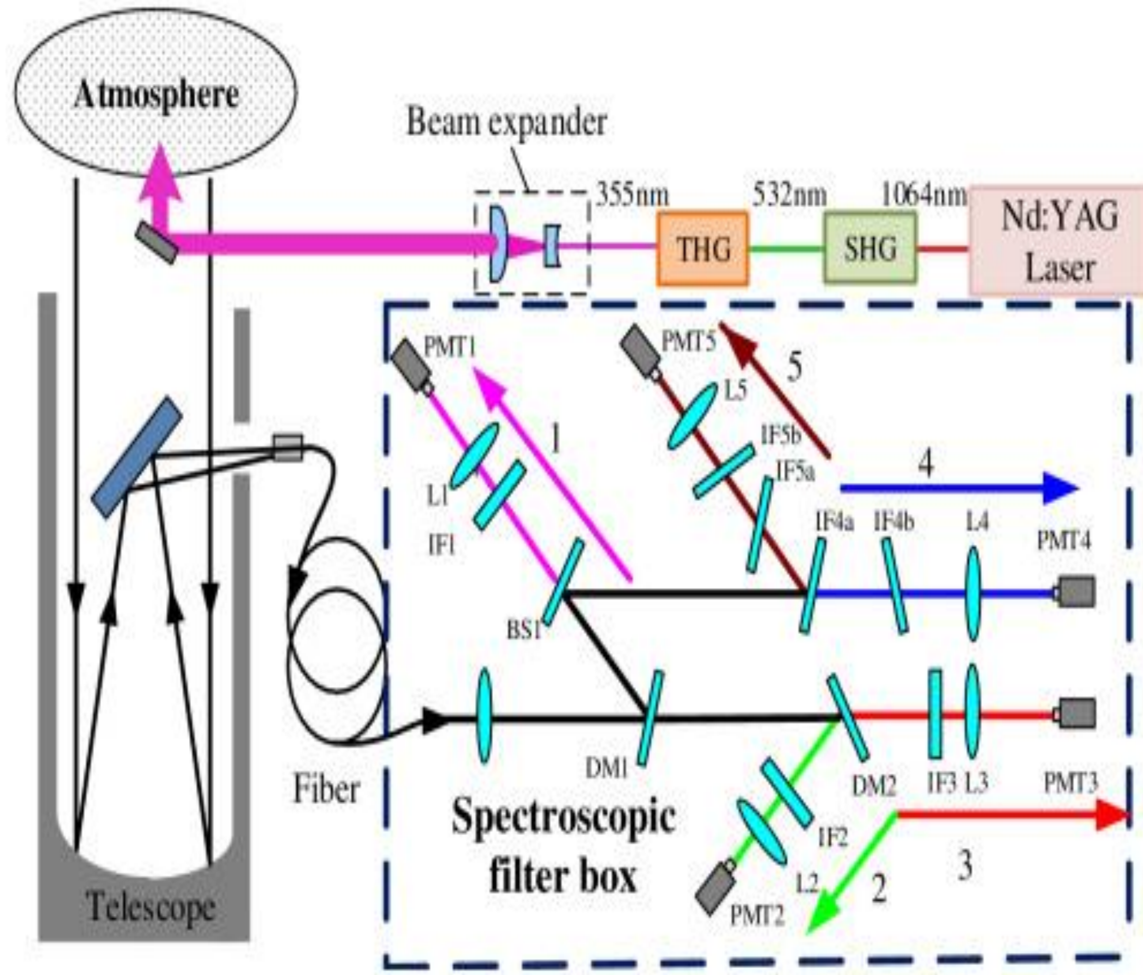

Figure 25 Block diagram of PRL's Raman LIDAR

Products:

The different products that can be obtained from the LIDAR are particle backscatter, particle extinction, depolarization ratio, LIDAR ratio, temperature, aerosol optical depth and water vapor mixing ratio. The combination of particle backscatter measured at three wavelengths, particle extinction measured at two wavelengths, and particle depolarization ratio will also give information of their types.

Satellite Data File Formats:

Hierarchical Data Format (HDF)

What is HDF?

At its lowest level HDF (Hierarchical Data Format) is a physical file format for storing scientific data. At its highest level, HDF is a collection of utilities and applications for manipulating, viewing, and analyzing data in HDF files. Between these levels, HDF is a software library that provides high-level APIs and a low-level interface.

HDF and HDF5 are two different products. HDF is a data format first developed in 1980s and currently in release 4.x (HDF release 4.x). HDF5 is a new data format first released in Beta in 1998 and designed to better meet the ever-increasing demands of scientific computing and to take better advantage of the ever-increasing capabilities of computing systems. HDF5 is currently in release 1.x (HDF5 release 1.x). HDF5 is completely new Hierarchical Data Format product consisting of a data format specification and a supporting library implementation.

HDF5 File Organization:

HDF5 file is a container for storing a variety of scientific data and is composed of two primary types of objects: groups and datasets.

- HDF5 group: A grouping structure containing zero or more HDF5 objects, together with supporting metadata.
- HDF5 dataset: A multidimensional array of data elements, together with supporting metadata.

Any HDF5 group or dataset may have an associated attribute list. HDF5 attribute is a user defined HDF5 structure that provides extra information about HDF5 object. Working with groups and datasets is similar in many ways to working with directories and files in UNIX. As with UNIX directories and files, HDF5 object in a HDF5 file is often referred to by its full path name (also called an absolute path name).

Why HDF5?

HDF5 is designed to address some of the limitations of older HDF product and to address current and anticipated requirements of modern systems and applications. HDF5 ia a unique technology suite that makes possible the management of extremely large and complex data collections. The HDF5 technology suite includes:

- A versatile data model that can be represent very complex data objects and a wide variety of metadata.
- A completely portable file format with no limit on number or size of data objects in the collection.
- A software library that runs on a range of computational platforms, from laptops to massively parallel systems, and implements a high-level API with C, C++, Fortran 90, and Java interfaces.
- A rich set of integrated performance features that allow for access time and storage space optimizations.
- Tools and applications for managing, manipulating, viewing, and analyzing data in the collection.

HDF5 Tools and Applications:

Following is a list of few HDF5 Tools and Software.

- HDF5 utilities: Tools included with the HDF5 collection.
- HDF view: A visual tool for browsing and editing HDF4 and HDF5 files.
- HDF Java Products: All of the HDF java products, including HDF view and HDF Java wrappers.
- H5check: A tool to check validity of HDF5 files.
- H4-H5 conversion software: A library and tools for converting to and from HDF4 and HDF5.

- HDF web-browser plug-in (windows): Extends a web browser to display HDF4 and HDF5 files.
- 3rd party applications: User applications that read/ write HDF5 files.

Network Common Data Format (NetCDF)

What is NetCDF?

NetCDF (Network Common Data Format) is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. The data format is "self-describing". This means that there is a header which describes the layout of the rest of the file, in particular the data arrays, as well as arbitrary file metadata in the form of name/value attributes.

NetCDF data is:

- Self-Describing: A NetCDF file includes information about the data it contains.
- Portable: A NetCDF file can be accessed by computers with different ways of sorting integers, characters, and floating-point numbers.
- Direct-access: A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- Appendable: Data may be appended to a properly structured NetCDF file without copying the dataset or redefining its structure.
- Sharable: One writer and multiple readers may simultaneously access the same NetCDF file.
- Archival: Access to all earlier forms of NetCDF data will be supported by current and future versions of the software.

Why NetCDF?

NetCDF access has been implemented in about half of Unidata software, so fat, and it is planned that such commonality will extend across all Unidata applications in order to:

- Facilitate the use of common datasets by distinct applications.
- Permit datasets to be transported between or shared by dissimilar computers transparently, i.e., without translation.
- Reduce the programming effort usually spent interpreting formats.
- Reduce errors arising from misinterpreting data andancillary data.
- Facilitate using output from one application as input to another.

NetCDF Applications:

It is commonly used in climatology and meteorology applications(e.g., weather forecasting, climate change) and GIS applications. It is an input/output format for many GIS applications, and for general scientific data exchange. A wide range of application software has been written which makes use of NetCDF files. These range from command line utilities to graphical visualization packages.

- A commonly used set of UNIX command line utilities for NetCDF files is the NetCDF operators (NCO) suite, which provide a range of commands for manipulation and analysis of NetCDF files including basic record concatenating, slicing and averaging.
- NC Browse is a generic NetCDF file viewer that includes Java graphics, animations and 3D visualizations for a wide range of NetCDF file conversions.
- The NCAR Command Language is used to analyze and visualize data in NetCDF files(among other formats).

- Ferret is an interactive computer visualization and analysis environment designed to meet the needs of oceanographers and meteorologists analyzing large and complex gridded data sets.

NetCDF/HDF5 Comparison:

- One of the goals of NetCDF is to support efficient access to small subsets of large datasets. To support this goal, NetCDF uses direct access rather than sequential access. This can be much more efficient when the order in which data is read is different from order in which it was written, or when it must be read in different order for different applications. The use of HDF5 as a data format adds significant overhead in metadata operations, less so in data access operations.
- HDF supports n-dimensional datasets and each element in the dataset may itself be a complex object. Relational databases offer excellent support for queries based on field matching, but are not well-suited for sequentially processing all records in the database or for subsetting the data based on coordinate-style lookup.
- NetCDF does not support compression directly but use of HDF5 allows interface for compression.

2. PROJECT MANAGEMENT

2.1.PROJECT PLANNING

2.1.1 Project Development Approach and Justification

The development of application follows the agile model.

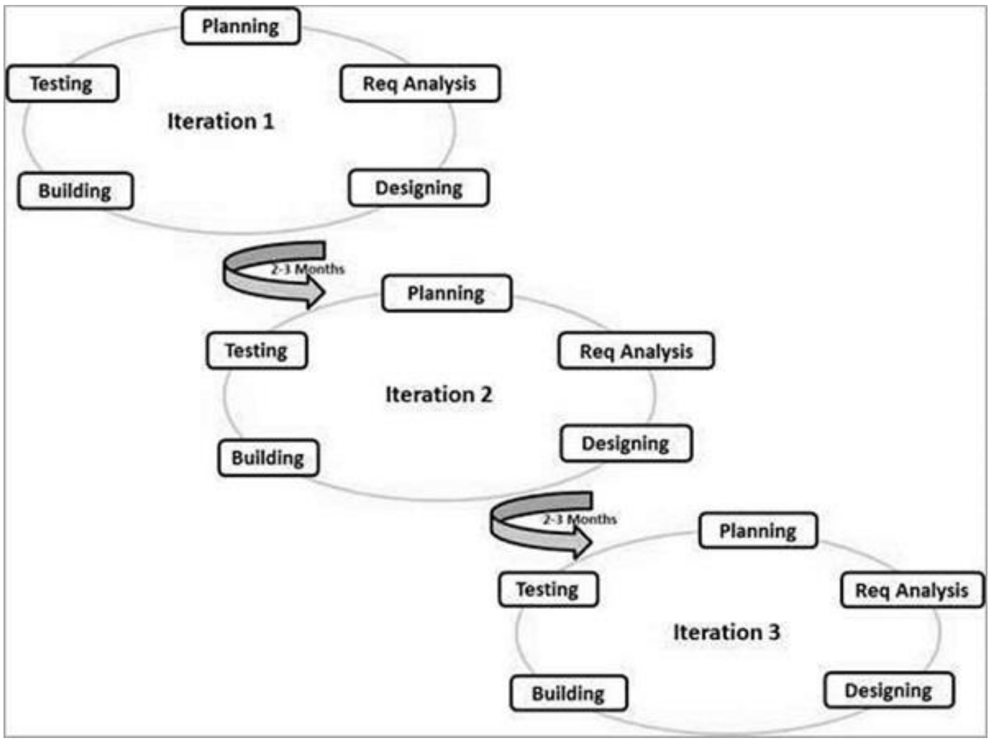

Figure 26 Project Devlopment Approach

Agile model believes that every project needs to be handled differently and the existing methods need to be tailored to best suit the project requirements. In Agile, the tasks are divided to time boxes (small time frames) to deliver specific features for a release.

Iterative approach is taken and working software build is delivered after each iteration. Each build is incremental in terms of features; the final build holds all the features required by the customer.

Following are the Agile Manifesto principles –

- **Individuals and interactions**

In Agile development, self-organization and motivation are important, as are interactions like co-location and pair programming.

- **Working software**

Demo working software is considered the best means of communication with the customers to understand their requirements, instead of just depending on documentation.

- **Customer collaboration**

As the requirements cannot be gathered completely in the beginning of the project due to various factors, continuous customer interaction is very important to get proper product requirements.

- **Responding to change**

Agile Development is focused on quick responses to change and continuous development.

2.1.2 Project Effort and Time, Cost Estimation

- In managing any project the whole plan of the project is made before its actual implementation. The plan of the project helps team to work as per the schedule and helps to successfully complete the project.
- To plan a project the main requirements that are calculated are cost, duration, effort, scheduling, man power, resource allocation, risk management etc.
- Proper planning was made initially with the team so that the factors affecting do not cause much interference.
- The effort and duration involved were calculated in the COCOMO model which utilized semidetached type of model for calculation. Proper management of the whole project was done in order to compensate with the duration was less than

estimated. The cost involved was only on the resources and the other charges like paying the developers was not involved as trainees made it. Looking closely at details and listening to outside sources of information was vital to the success of project. Most of the project failure could be because of human error or system error and vise versa. But the project was handled in amuch proper way.

- Thus, the whole project was very feasible. The risk management was also handled as issues were encountered during the designing and testing phase of project.

2.1.3 Roles and Responsibilities

To keep project smooth – going a proper team structure has to be maintained. This project involved MIXED CONTROL TEAM STRUCTURE.

This structure helps to do ego less programming and work where each member is free to give his own suggestions. Each one can easily interact with each other and give own views on the project development. Finally project manager approves decision, as he is experienced one. Also, the readings from ground based instruments – MICROTOPS OZONOMETER was to be taken carefully as instrument was too sensitive to handle. It was effectively done under the presence and the guidance of project manager.

As only two members were involved in the team,each of them had to perform all the task as coder, tester, developer, designer, etc. as the project proceeded through its different phases. This helped oneself to develop all kinds of skills in all the phases and complete the whole project very effectively.

2.1.4 Group Dependencies

The team structure depends on the management style of the organization, the number of people in the team, their skill levels and the problem difficulty. Considering all these points our team organization was Democratic Decentralized, in which there is no team leader. Both of the members worked effectively at the same level. Decisions on the problems were made by the group consensus.communication amongst the team members was horizontal and very helpful. Project manager also guided us in very straight forward and effective manner.

2.2.PROJECT SCHEDULING

Name	Begin date	End date	Resources
Visualization software	26/1/18	27/4/18	
Feasibility Study	26/1/18	2/2/18	Theses, internet, PC
Requirement Gathering	5/2/18	2/3/18	Theses, internet, PC
Requirement Analysis	5/3/18	14/3/18	Theses, internet, PC
Design Phase	15/3/18	29/3/18	
Learning basics	15/3/18	21/3/18	Theses, internet, PC
GUI Design	22/3/18	26/3/18	14ce028, Theses, internet, PC
Database design	27/3/18	29/3/18	14it038, 14ce028, Theses, internet, PC
Coding phase	30/3/18	12/4/18	
Satellite Data	30/3/18	5/4/18	14ce028,14it138, Theses, internet, PC
Groundbased Data	6/4/18	12/4/18	14ce028,14it138, Theses, internet, PC
Testing	13/4/18	24/4/18	
Unit Testing	13/4/18	16/4/18	14ce028,14it138, Theses, internet, PC
Integration Testing	17/4/18	19/4/18	14ce028,14it138, Theses, internet, PC
System Testing	20/4/18	24/4/18	14ce028,14it138, Theses, internet, PC
Documentation	25/4/18	27/4/18	14ce028, 14it138, thesis, internet etc

Figure 27 Gantt chart

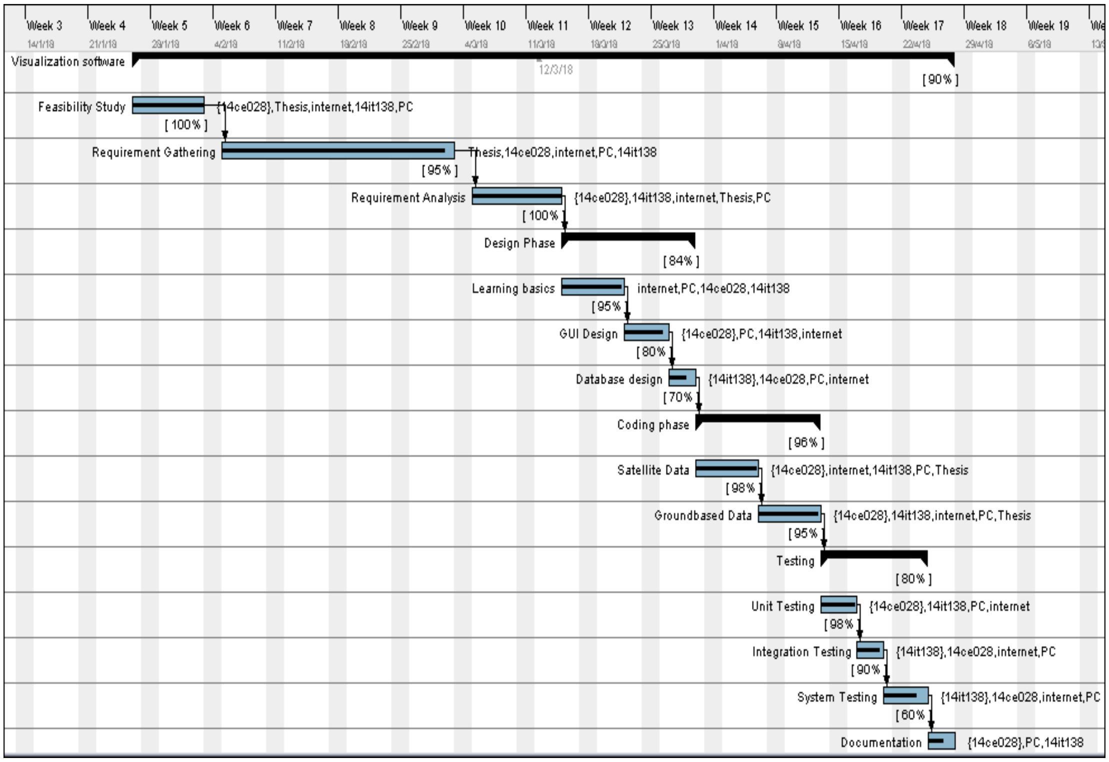

Figure 28 Gantt Chart

3. SYSTEM REQUIREMENTS STUDY

3.1. USER CHARACTERISTICS

User may be a research person, student or any other person related to organization.The user should know basics of atmosphere and measurement units of the Temperature, Atmospheric Water Vapor as well as other important parameters. The user should also know about the basics of satellites and ground based instruments that are used for observation of different parameters at various places. User should be able to understand basics of graphs of the observations and should be able to compare change easily for various parameters. User with these characteristics is able to use application efficiently.

3.2. HARDWARE AND SOFTWARE REQUIREMENTS

- RAM: 4.00 GB;
- Processor: Intel Core i5 CPU @ 3.20 GHz
- Operating System: Windows 7 Enterprise
- System type: 64-bit operating system; Graphics: Intel HD Graphics
- Input Device : Mouse, Keyboard
- Any web browser which support Js.

3.3. ASSUMPTIONS AND DEPENDENCIES

Assumptions:

- User must have basic knowledge about atmospheric units of various parameters and information regarding the type of data available from different satellites (i.e., SABER provides vertical profile of ozone in terms of ozone mixing ratio while OMI and TOMS provide total column ozone in Dobson unit).

Dependencies:

- This system is depended upon user’s valid selection criteria.
- If user inputs are not desired by application, then application would simply display error message.
- If data of ground based instruments used, is not available for the selected parameters or provided date range, then an error message will be displayed.

4. SYSTEM ANALYSIS

4.1. STUDY OF CURRENT SYSTEM

A pre – requirement of investigation was prepared which revealed the exact amount of efforts required in people – person months, the cost that would be incurred, the risks and the mitigating factors. Different parameters were taken into consideration while considering the cost factor incurred in the project:

Hardware cost: This cost is taken care of by PRL.

Software cost: All the software licenses were either freewares or bought by PRL.

Software analysis and requirements definition

After doing a preliminary investigation the following functional and non – functional requirements were found and a SRS (System Requirements Specification) was prepared. Based on the SRS we decided to follow agile for system development. Changes were also added lately and based upon that design phase was reiterated and tested correctly over and again.

A software process model is a simplified abstract representation of a software process which is presented from a particular perspective. A process model for software engineering is chosen based on nature of project and application, the methods and tools to be used, and the controls and deliverables that are required.

4.2. PROBLEM AND WEAKNESSES OF CURRENT SYSTEM

The present system does not have any major weaknesses and problems associated with it. Minor weaknesses of the system are as follows:
Current system "Giovanni" is a web – based Application of NASA that provides the data visualization of all the parameters of the satellites launched by NASA, but it has some of the limitations such as:

- Giovanni does not provide the information of the instrument SABER.
- Giovanni does not have support of google maps for selection of latitude and longitude of the location. User had to explicitly specify it.
- Giovanni is only limited to satellite instruments and does not support the data files from the ground based instrument such as MICROTOPS – II, LIDAR or UV Biometer.

4.3. REQUIREMENTS OF NEW SYSTEM

4.3.1. Functional Requirements

This sub section presents the identified requirements for the project. Intitially, general requirements that pertain to the whole system are given. Where possible, subsequent requirements have been demarcated based on their relevance to the user of the system.

R1 PLOT DATA

Description: Using this module, system allows user to plot any kind of plot based on requirements filled by user. If the user provides invalid input, validations are being checked and alert boxes are popped up.

R1.1: PLOT SATELLITE DATA

Description: To plot the satellite data, form details such as satellite name, parameters selected, location, date range and the type of graph are entered. Data is processed and required action is performed.

State: The index page is opened.

Input: Satellite name, parameter, location, date range and type of graph.

Output: Selected graph based on inputs provided.

Processing: The inputs provided by the user would be redirected and MATLAB (or plotly.js) instance is created where the satellite data are read and graph is calculated. On the basis of that output is shown on HTML page.

R1.2: PLOT GROUND BASED DATA

Description: To plot ground based data, form details such as instrument name, parameter selected, location, date range and wavelength are entered. Data is processed and required action is performed.

State: The index page is open in browser.

Input: Instrument name, parameter, location, date range, wavelength and type of graph.

Output: Selected graph based on inputs provided.

Processing: Inputs provided by user would be retrieved and based on that application will find the files from the system and thus after locating them would display the relevant output to the output HTML page.

4.3.2. Non Functional Requirements

- **Reliability**

  This application delivers reliable output to the end user in terms of calculation and efficient output.

- **Robustness**

  This application provides robustness which means that the software handles error gracefully, without failure. Error message is displayed in case of undesired input by user.

- **Usability**

  The system provides user friendly interface, so that any user can use it without any difficulty.

- **Availability**

The application will be take some time to get loaded when opening it firstly.

4.4. FEASIBILITY STUDY

4.4.1. Does the system contribute to the overall objectives of the organization?

Yes, " Development of software for the visualization of the earth's atmospheric parameters using satellite data and ground based observations." contribute to the overall objectives of the organization .

4.4.2. Can the system be implemented using the current technology and within the given cost and schedule constraints?

Since, our project has a long time span , however, it will get finished at the end of month june. As far as technical constraint is concerned, we have used HTML, CSS, javascript, plotly.js, couchbase server(No SQL DB).

4.4.3. Can the system be integrated with other systems which are already in place?

Yes, application can be easily integrated with other systems .

4.5. ACTIVITY/PROCESS IN NEW SYSTEM

PLOT SATELLITE DATA

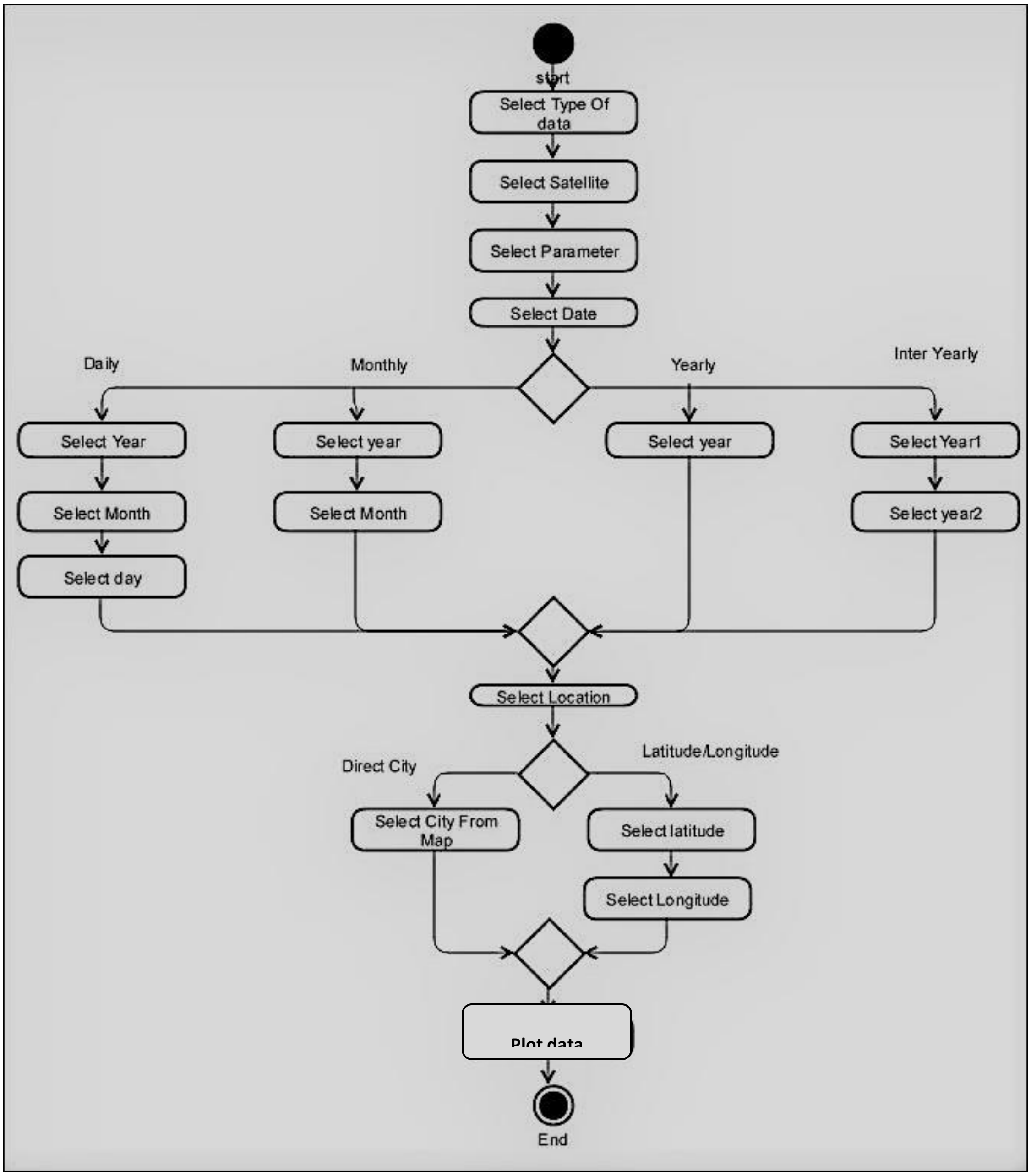

Figure 29 Plot satellite data

PLOT GROUND BASED LIDAR DATA

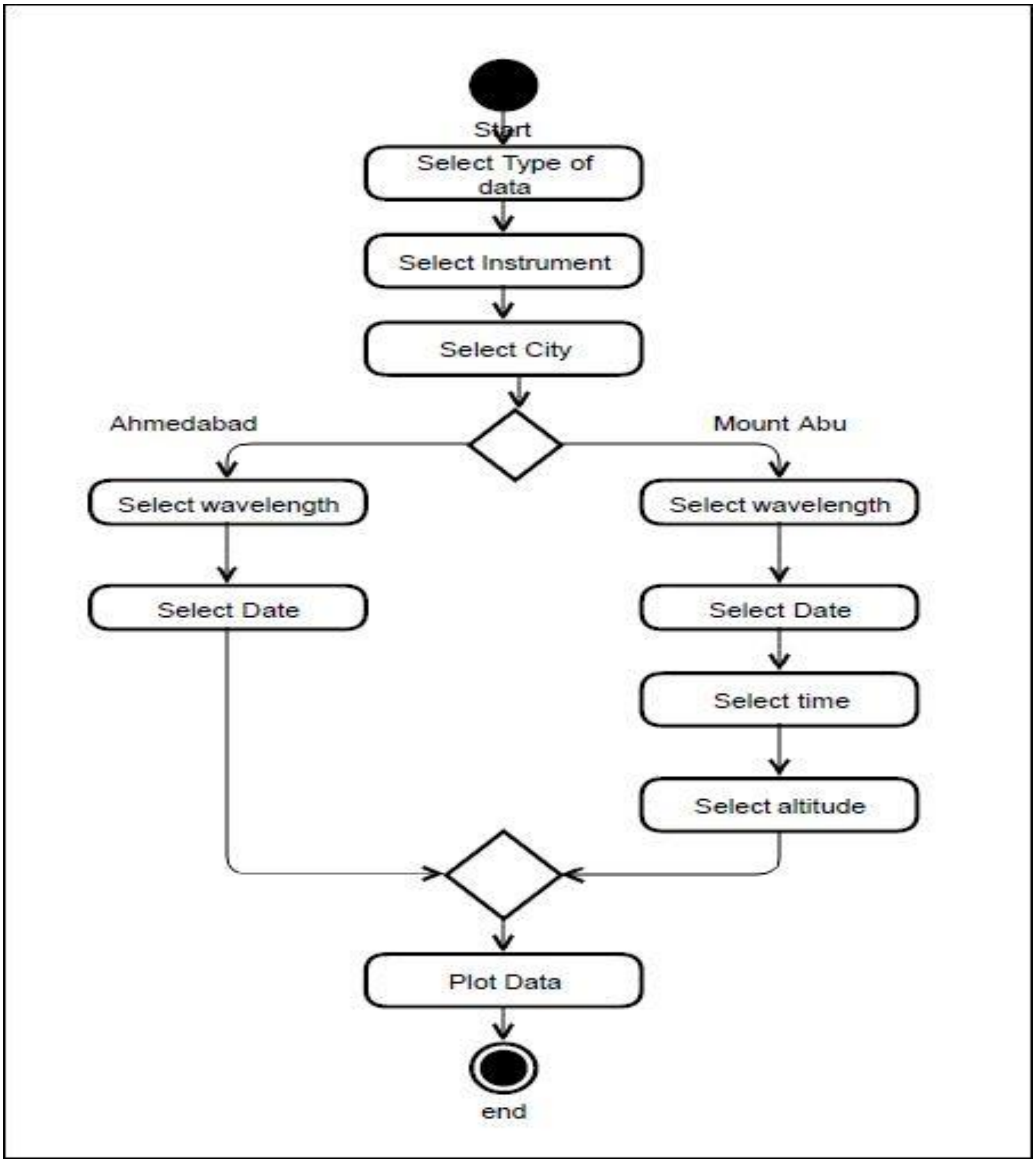

Figure 30 Ground Based LIDAR Data Activity

4.6. FEATURES OF NEW SYSTEM

The newly developed system will have many different features which are not available in the current system such as:

- It will support HDF and NetCDF data format for data obtained from satellites.
- It allows user to select the latitude and longitude of the location by just clicking on the Google map or else for well known places direct markers are provided.
- It allows user to plot multiple plot concurrently so that one can easily measure spatial and temporal variation of the parameters.
- It allows user to view the information in the form of line plot or contour plot.
- Ground based information is also supported in the system along with the satellite data.

4.7. USE CASE DIAGRAM

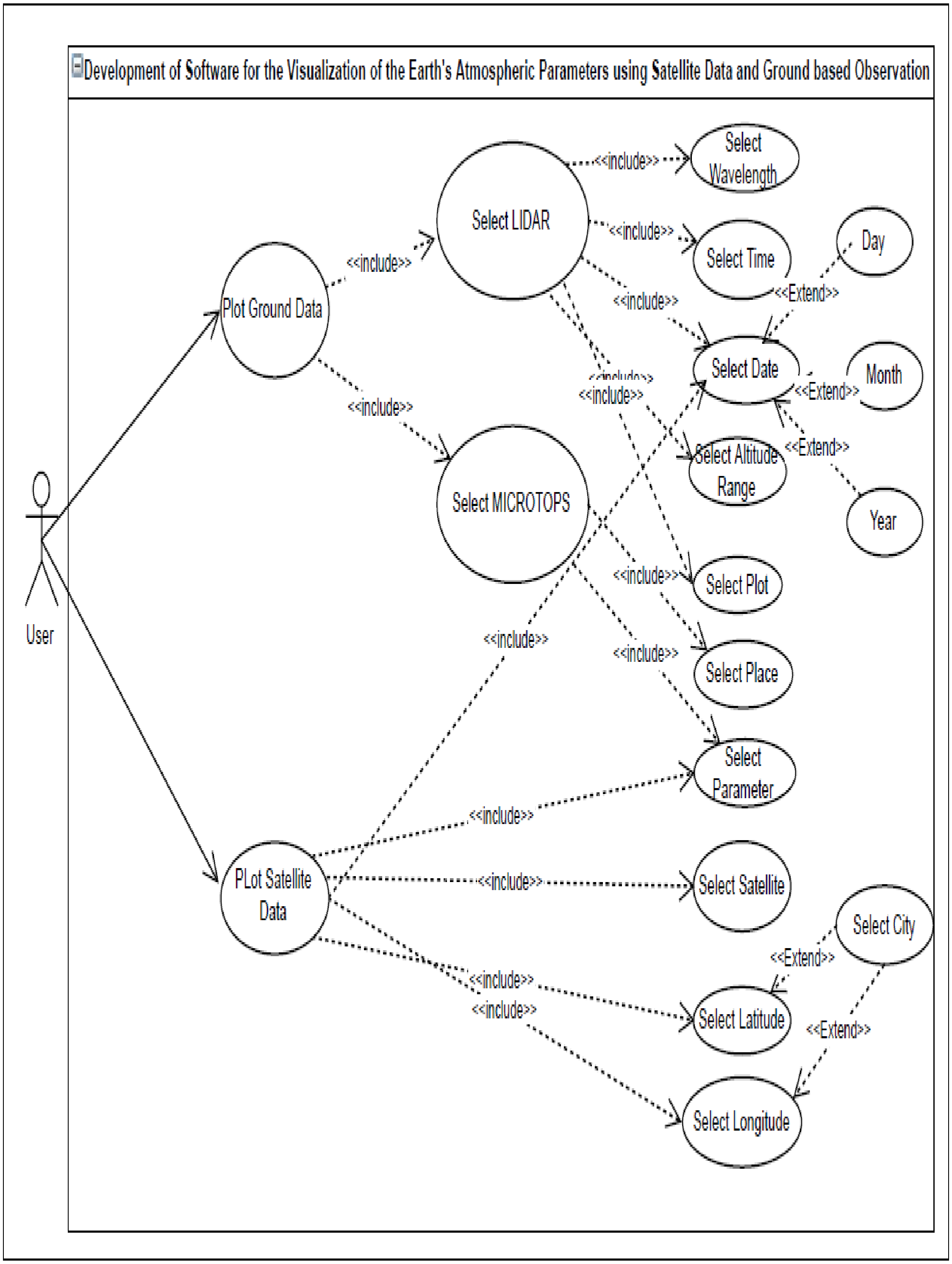

Figure 31 UseCase Diagram

4.8 CLASS DIAGRAM

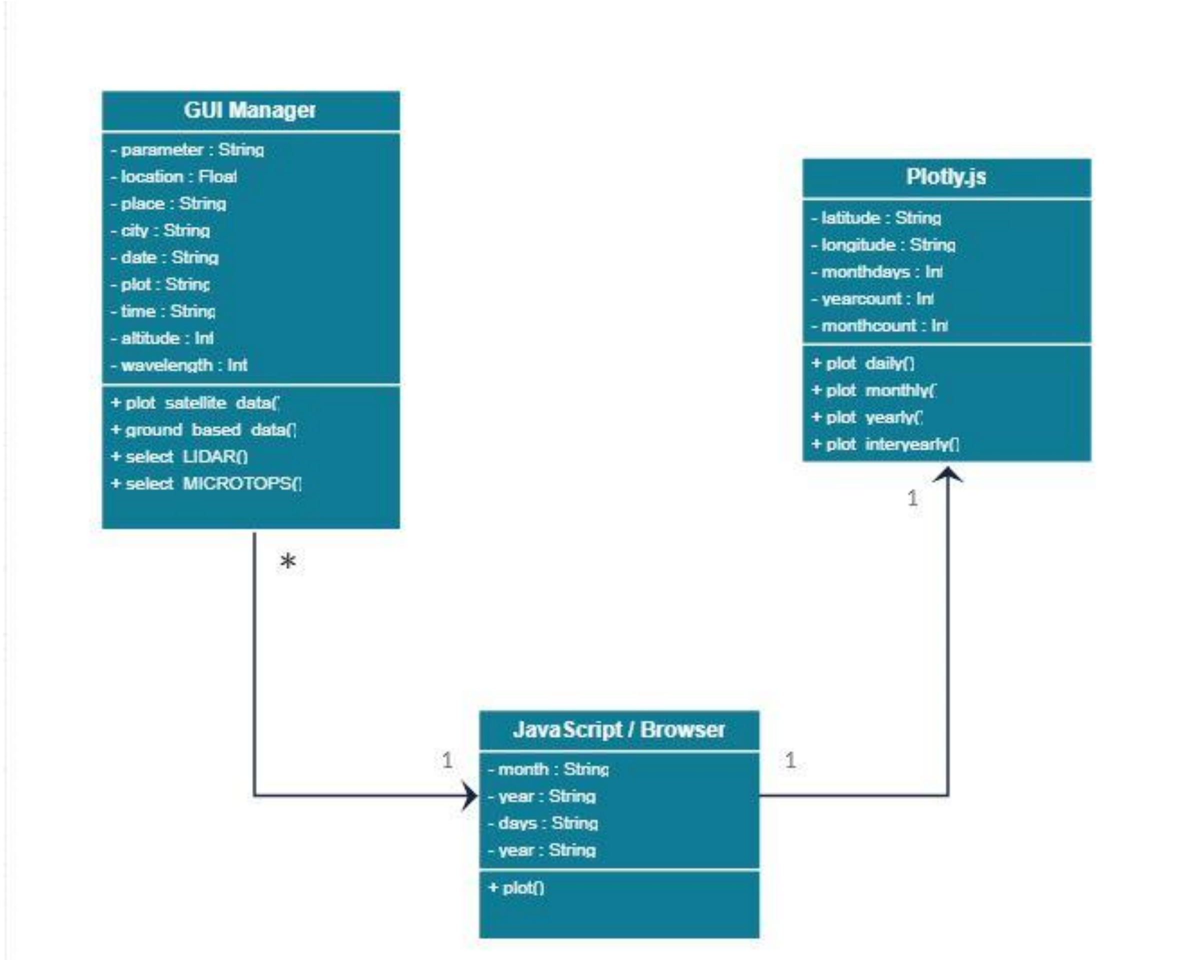

Figure 32 Class Diagram

4.9. SEQUENCE DIAGRAM

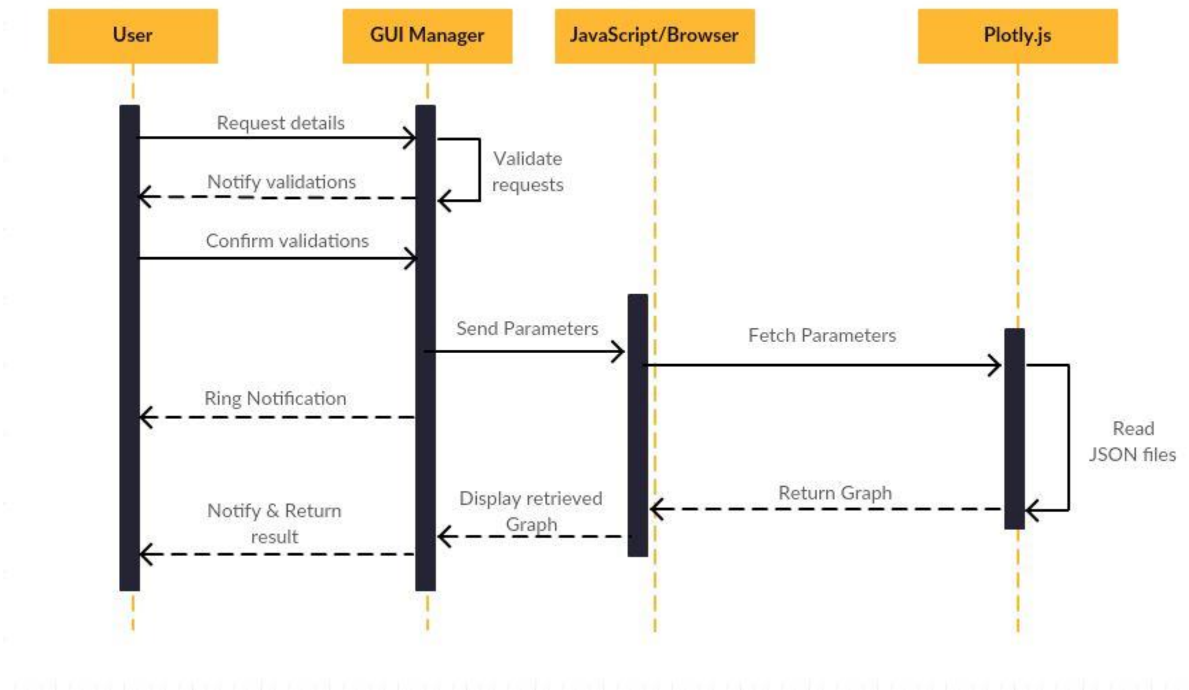

Figure 33 Sequence Diagram

4.10. LIST MAIN MODULES OF NEW SYSTEM

Plot Satellite Data: Using this module user can plot SABER, TOMS, OMI, MetData satellite data for various parameters.

- Select various parameters.
- Select location directly from google maps.
- Select daily, monthly, yearly or inter yearly data range.
- Select plot type.
- Plot is generated.

Plot Ground based Data: Using this module, user can plot the data for various ground based instrument – MICROTOPS Ozonometer and LIDAR.

- Select various parameters.
- Select location from google maps.
- Select Range.
- Select wavelength.
- Select time range.

4.11. SELECTION OF HARDWARE AND SOFTWARE AND JUSTIFICATION

- Client machine should have windows OS with good internet connectivity and basic features.
- There is no other special requirement of hardware and software, only basic and minimum features are required.

5.SYSTEM DESIGN

5.1.SYSTEM APPLICATION DESIGN

5.1.1.Method Pseudo code

Below is pseudocode for plotting data values obtained from data files SABER instrument.

NOTE: Grid size 5 degree X 5 degree.

<u>Pseudocode for plotting satellite data:</u>

INITIALIZE latitude value, longitude value, Date Range, Plot name, Parameter value.

READ corresponding document from the bucket and create view and send it to plotly.js.

```
IF data available for corresponding request
        DISPLAY Plot.
ELSE
        Show error message.
END IF
```

<u>Pseudo code for plotting the ground data:</u>

```
INITIALIZE Location, Date Range, Time Range, Plot Name
SCAN bucket for document with specified location in Couch DB
        READ document corresponding to date and time
END SCAN
IF data available for corresponding request
        PLOT the data
ELSE
        Show error message
END IF
```

5.2.INPUT/OUTPUT AND INTERFACE DESIGN

User Home Page

Description: This is default home page which will be displayed first.

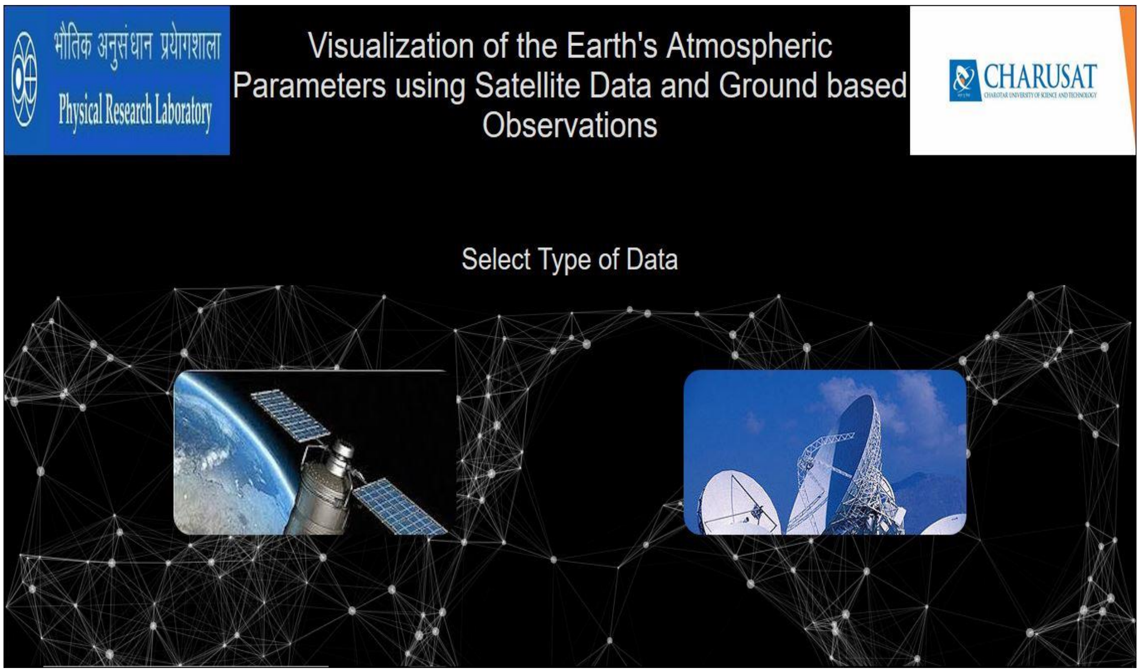

Figure 34 Application home page

User would be able to see his home page at the first glance. Now user can select either type of data. User can select either Satellite Data or Ground Data by clicking directly on respective images. On mouse hover user will be able to see respective names on images.

When user clicks on satellite data option, another webpage displaying the information about satellite will appear.

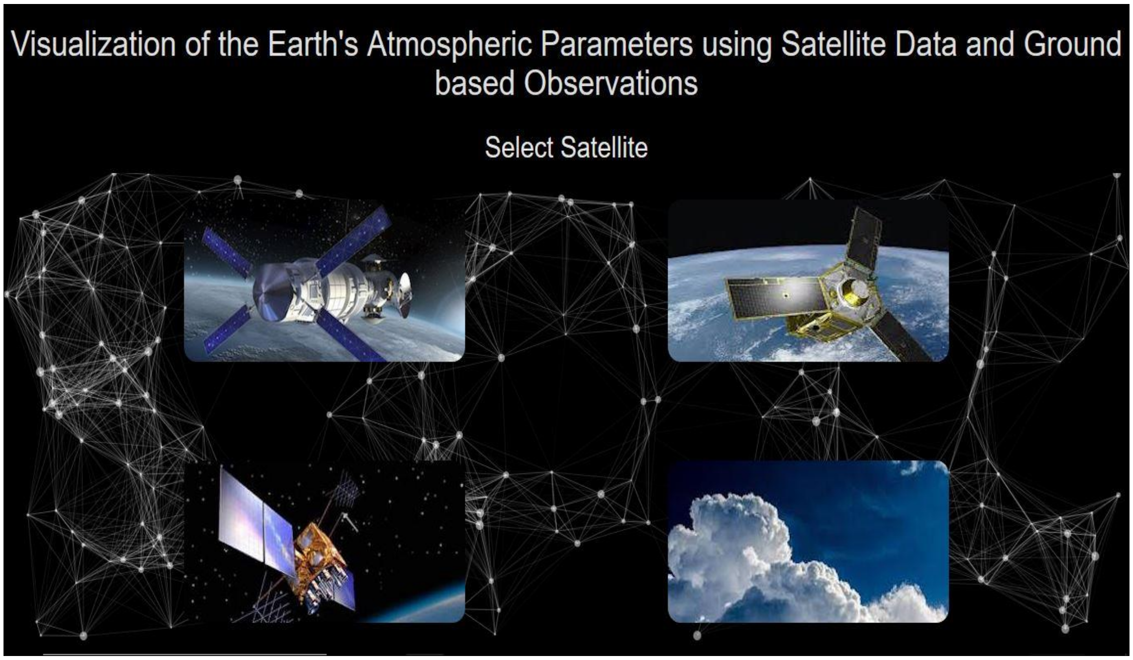

Figure 35 Select Satellite Option

After selecting satellite data option, user can see the multiple options provided. User can select either of satellites i.e., SABER, TOMS, OMI and MetData by clicking directly on the images. User will be able to see names on mouse hover over respective image.

When user clicks on the SABER Satellite option, the information about SABER Satellite is displayed where user is asked to input valid values for which data is to be retrieved.

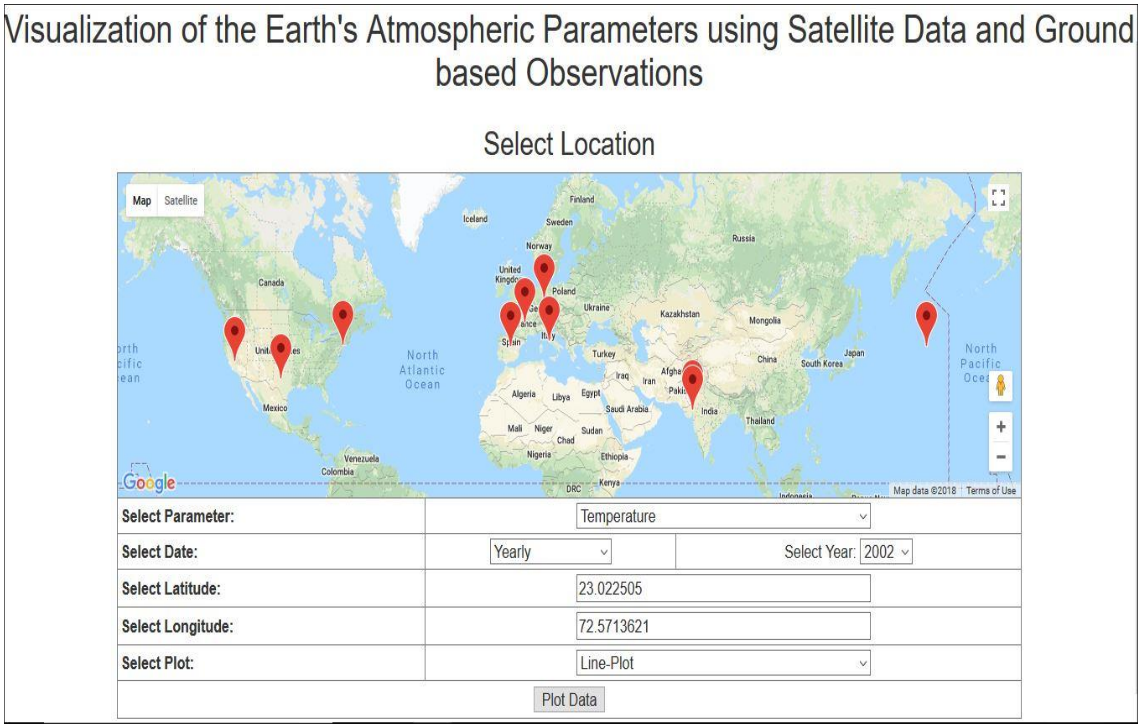

Figure 36 Data Input of SABER Satellite

The Select Parameter option, when clicked, displays the various parameters for which the data can be retrieved.

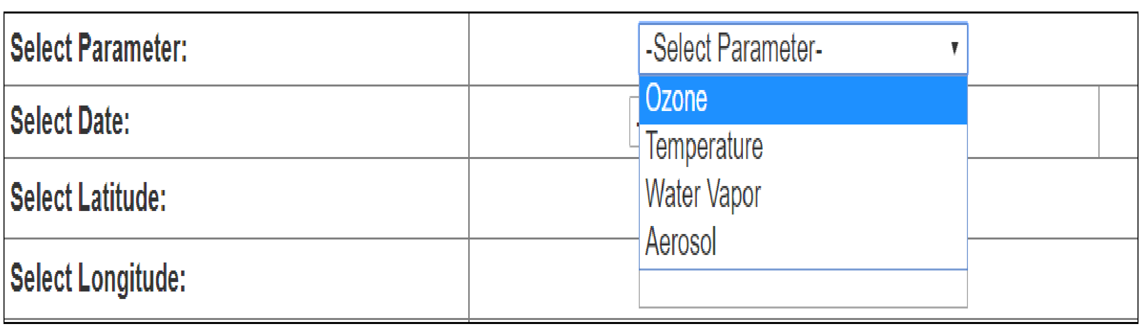

Figure 37 Select Parameter

User can fill input values as per requirements. If an user is not aware about the Latitude and Longitude values of any location, user can directly select location from the google maps.

The red markers displays the well-known places of the globe. If user selects any of those markers then name of that place and latitude-longitude of that place will be popped and these values will be directly filled in form.

Figure 38 Known Location Selected

For any new locations apart from these locations, user can enter latitude-longitude directly.User can also use zoom-in function inbuilt in google maps for selecting a location more accurately.

Figure 39 Zoomed-in Map

User can select date by choosing options from the drop-down i.e., Daily, Monthly, Yearly or Inter-Yearly.

For example:

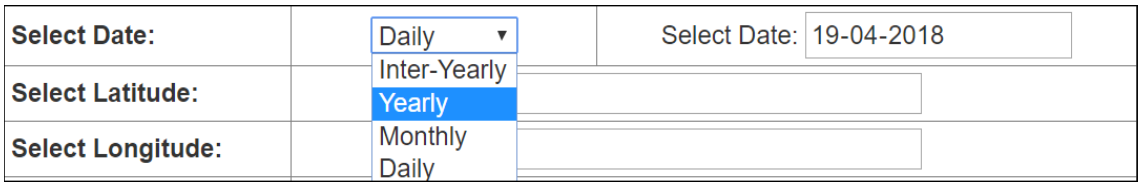

Figure 40 Select Date

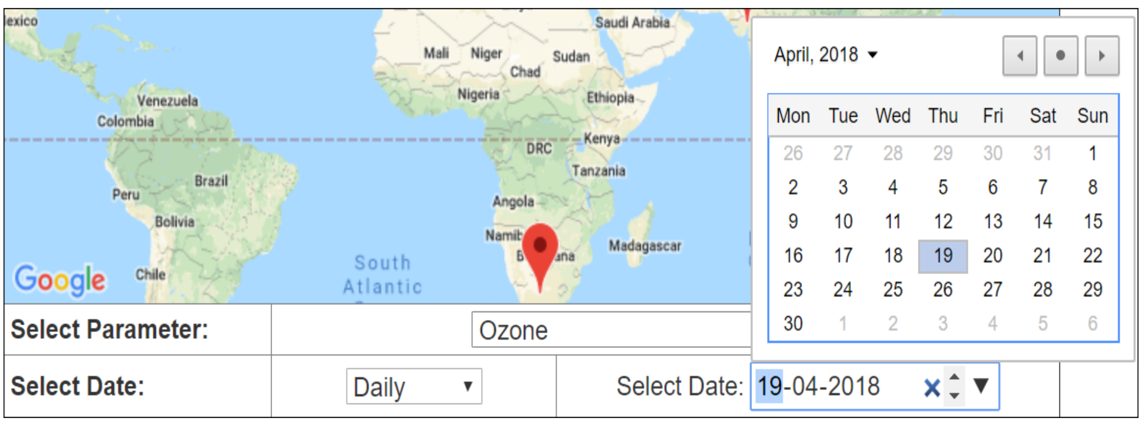

Figure 41 Select Date for daily data

User can select any one of the plot from the various options provided such as Line Plot and Contour plot.

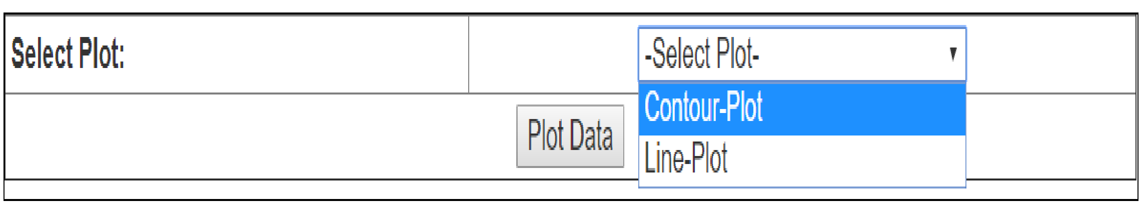

Figure 42 Select Plot

By providing valid input values – selection of parameter (Ozone), selection of date range (Yearly), selection of type of plot (Line Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

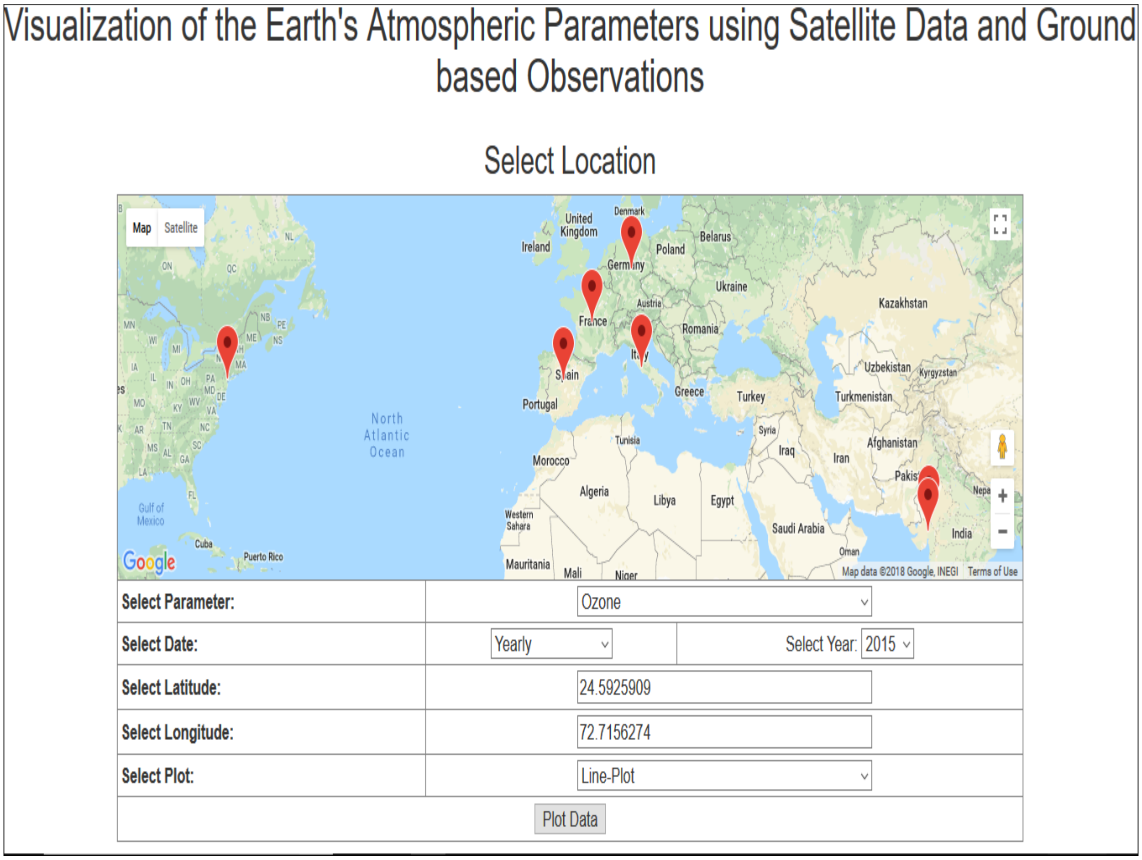

Figure 43 Filled input values for Ozone parameter, Yearly Date Range, Line-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

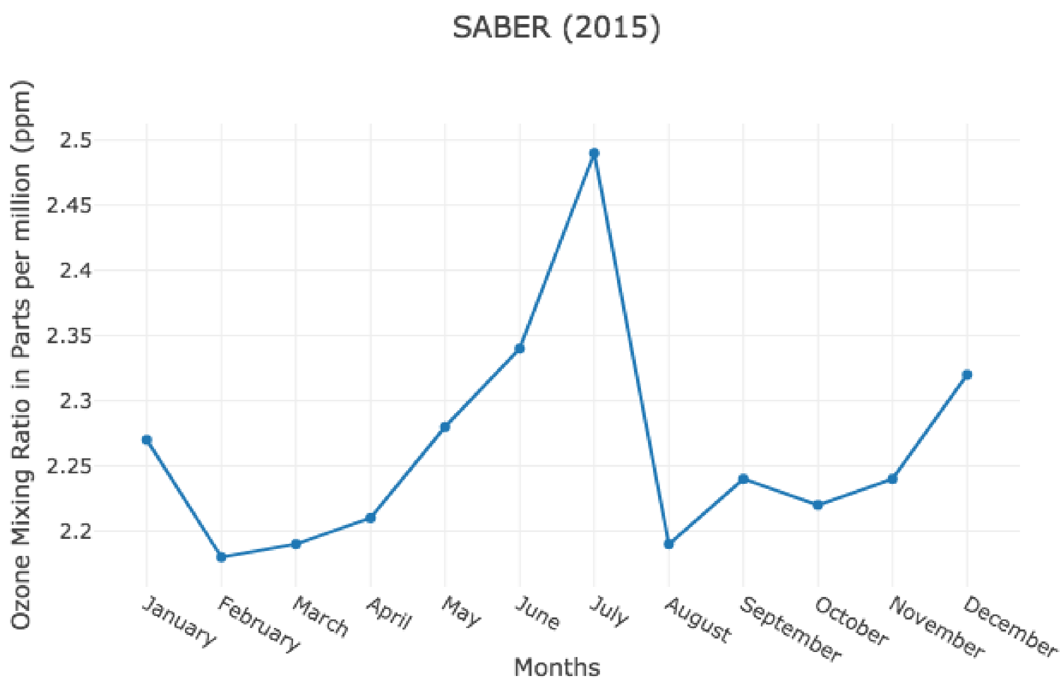

Figure 44 Output Graph for Ozone Parameter, Yearly Date Range, Line plot and Mount Abu Location

By providing valid input values – selection of parameter (Ozone), selection of date range (Yearly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

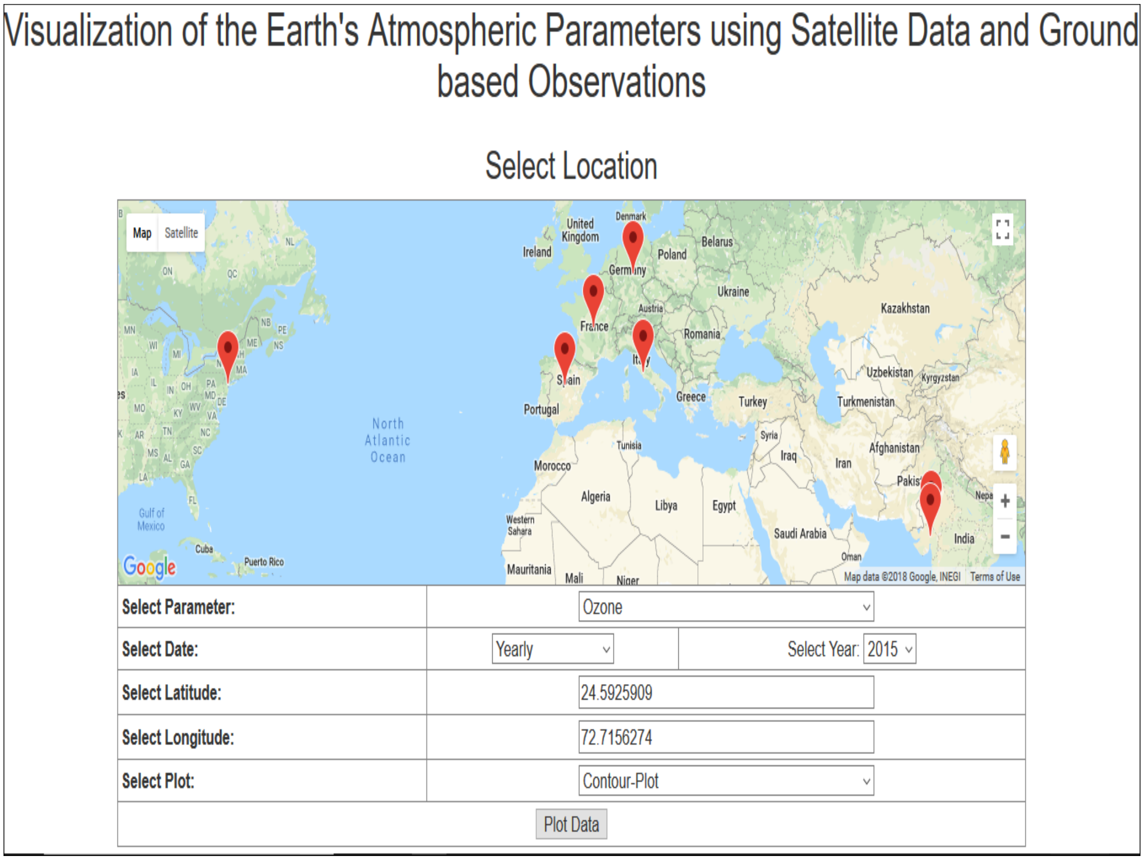

Figure 45 Filled input values for Ozone parameter, Yearly Date Range, contour-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

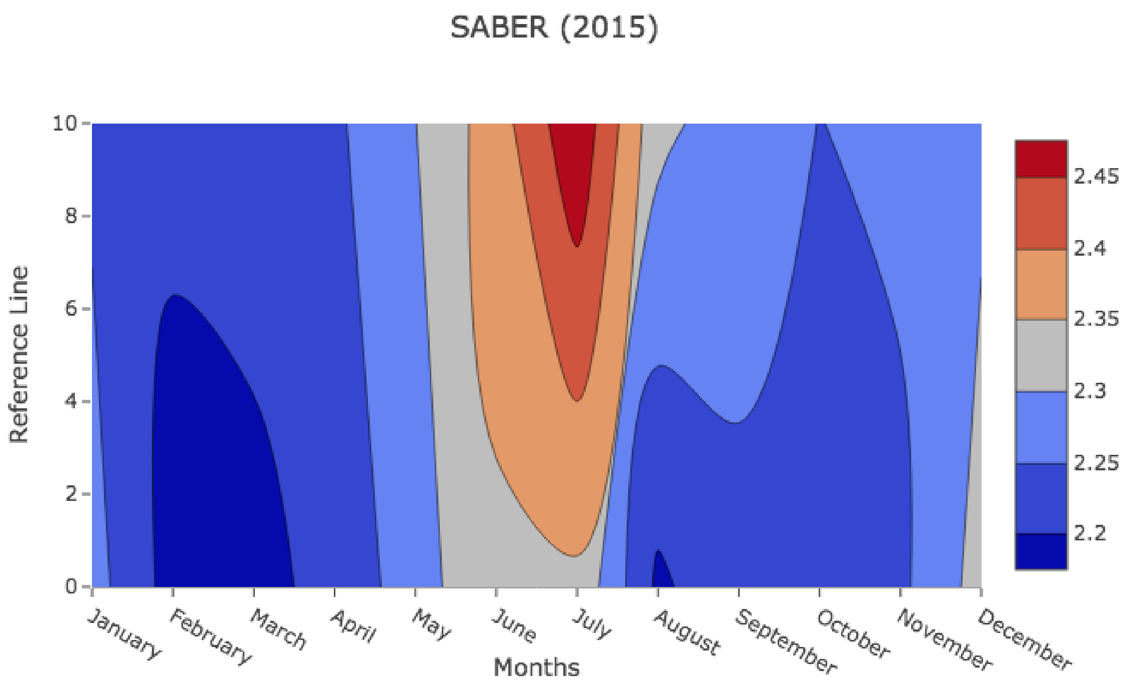

Figure 46 Output Graph for Ozone Parameter, Yearly Date Range, Contour plot and Mount Abu Location

By providing valid input values – selection of parameter (Temperature), selection of date range (Yearly), selection of type of plot (Line Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

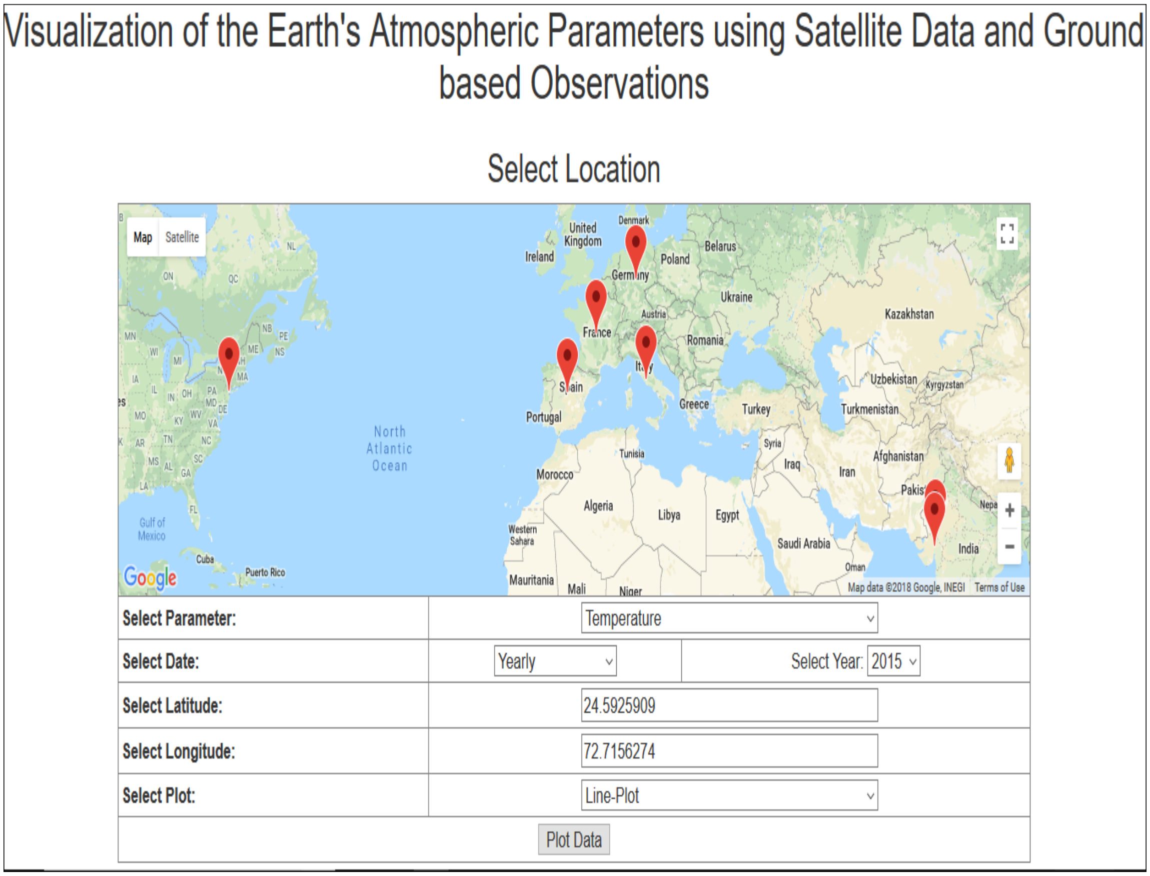

Figure 47 Filled input values for Temperature parameter, Yearly Date Range, Line-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

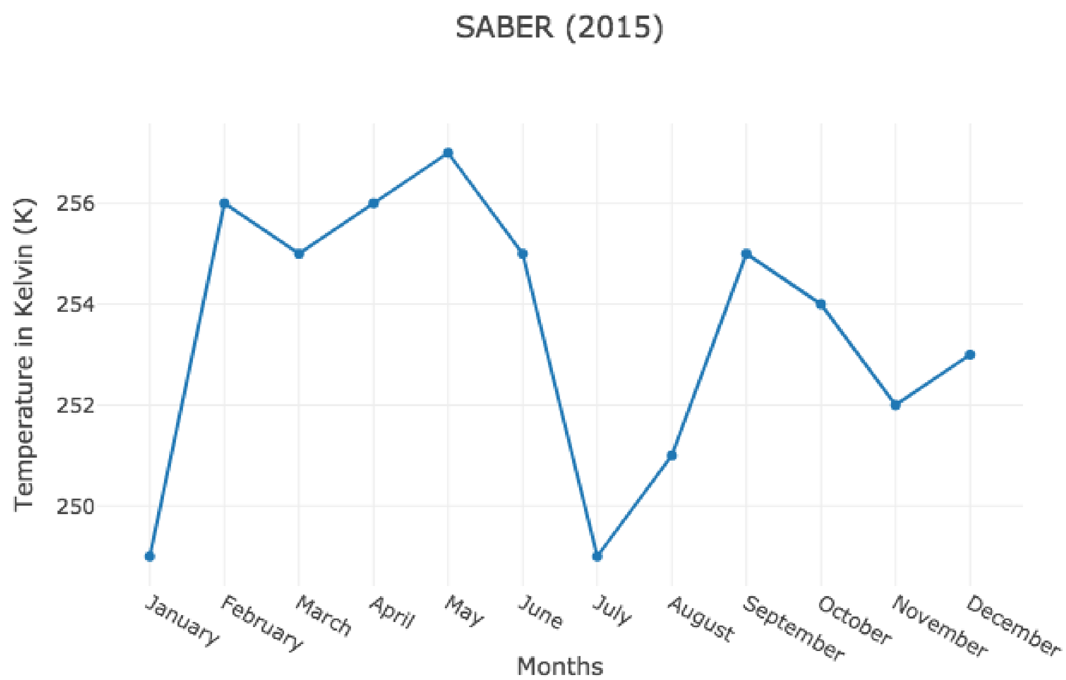

Figure 48 Output Graph for Temperature Parameter, Yearly Date Range, Line plot and Mount Abu Location

By providing valid input values – selection of parameter (Temperature), selection of date range (Yearly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

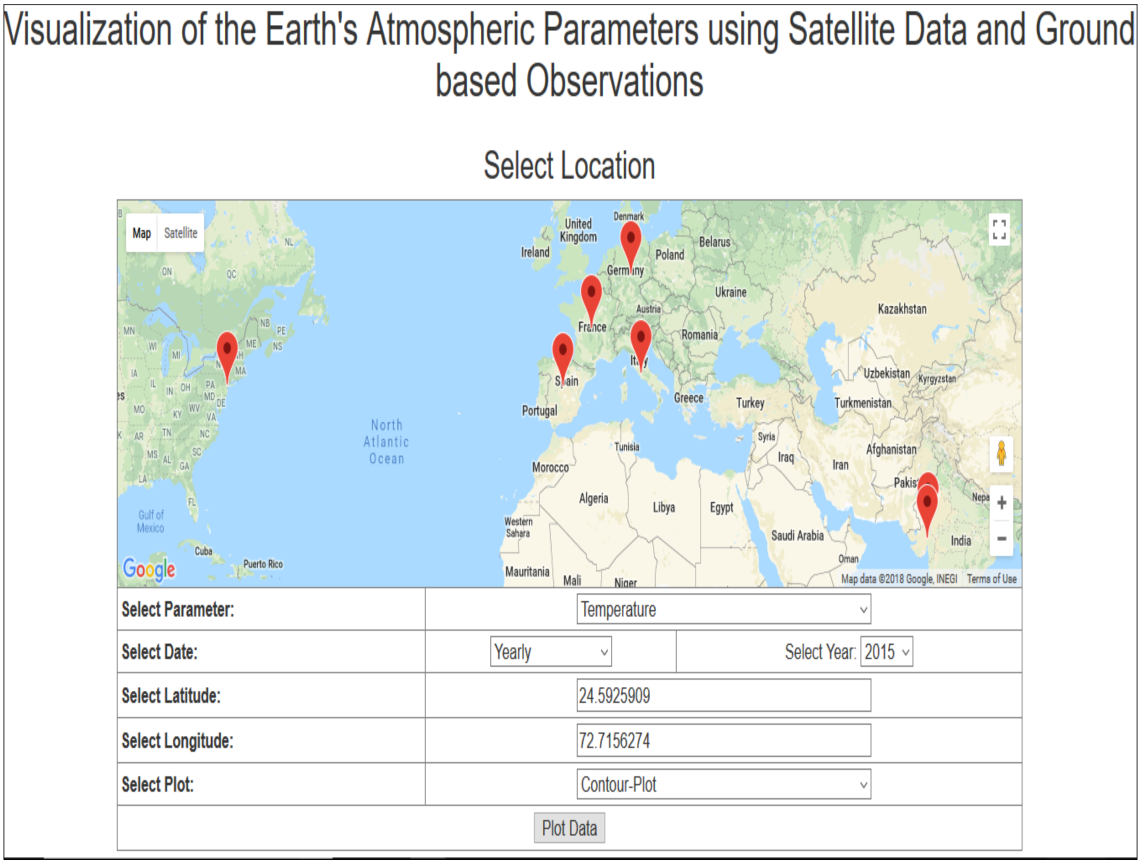

Figure 49 Filled input values for Temperature parameter, Yearly Date Range, Contour-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

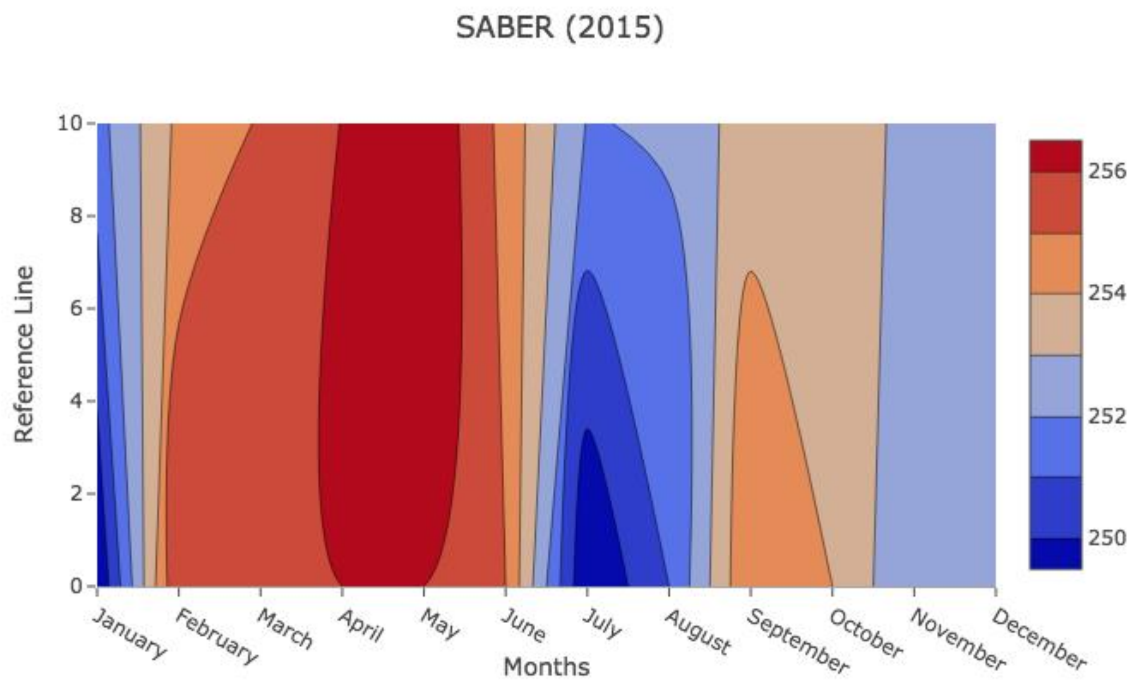

Figure 50 Output Graph for Temperature Parameter, Yearly Date Range, Contour plot and Mount Abu Location

By providing valid input values – selection of parameter (Temperature), selection of date range (Inter-Yearly), selection of type of plot (Line Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

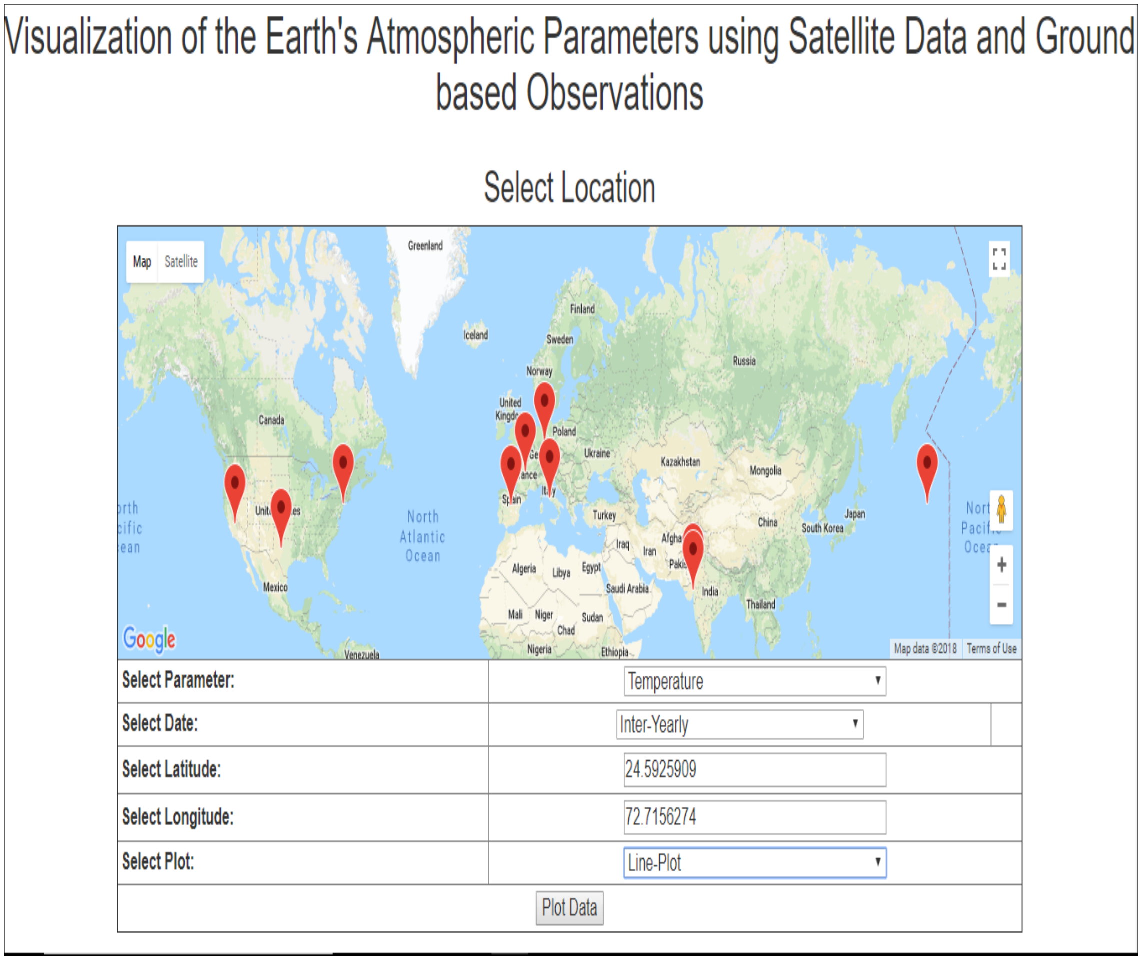

Figure 51 Filled input values for Temperature parameter, Inter-Yearly Date Range, Line-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

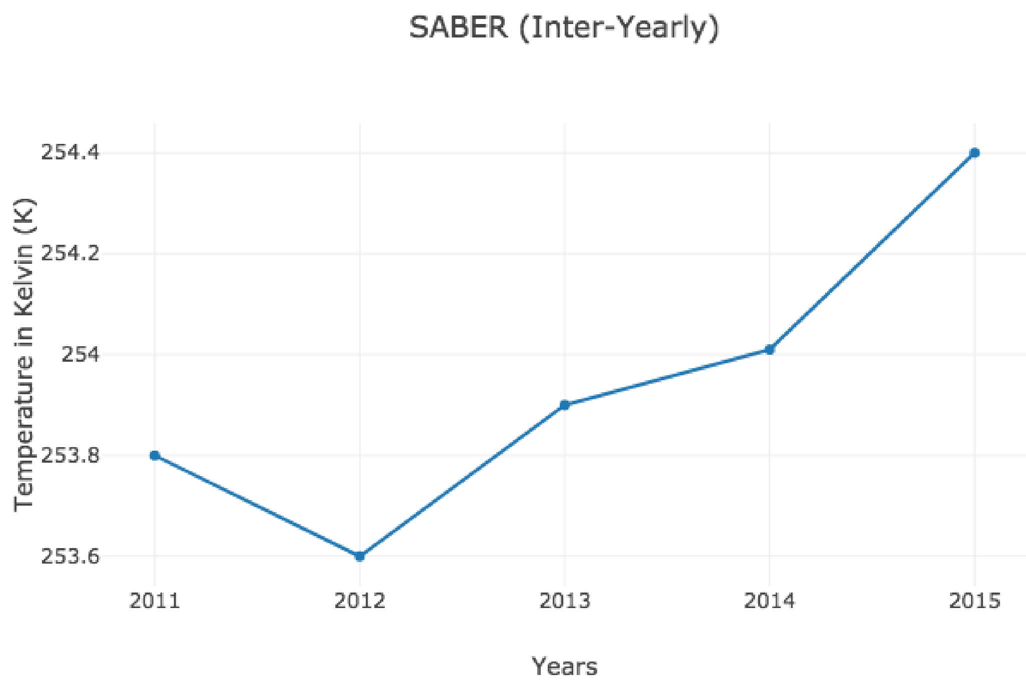

Figure 52 Output Graph for Temperature Parameter, Inter-Yearly Date Range, Line plot and Mount Abu Location

By providing valid input values – selection of parameter (Temperature), selection of date range (Inter-Yearly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Mount Abu) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

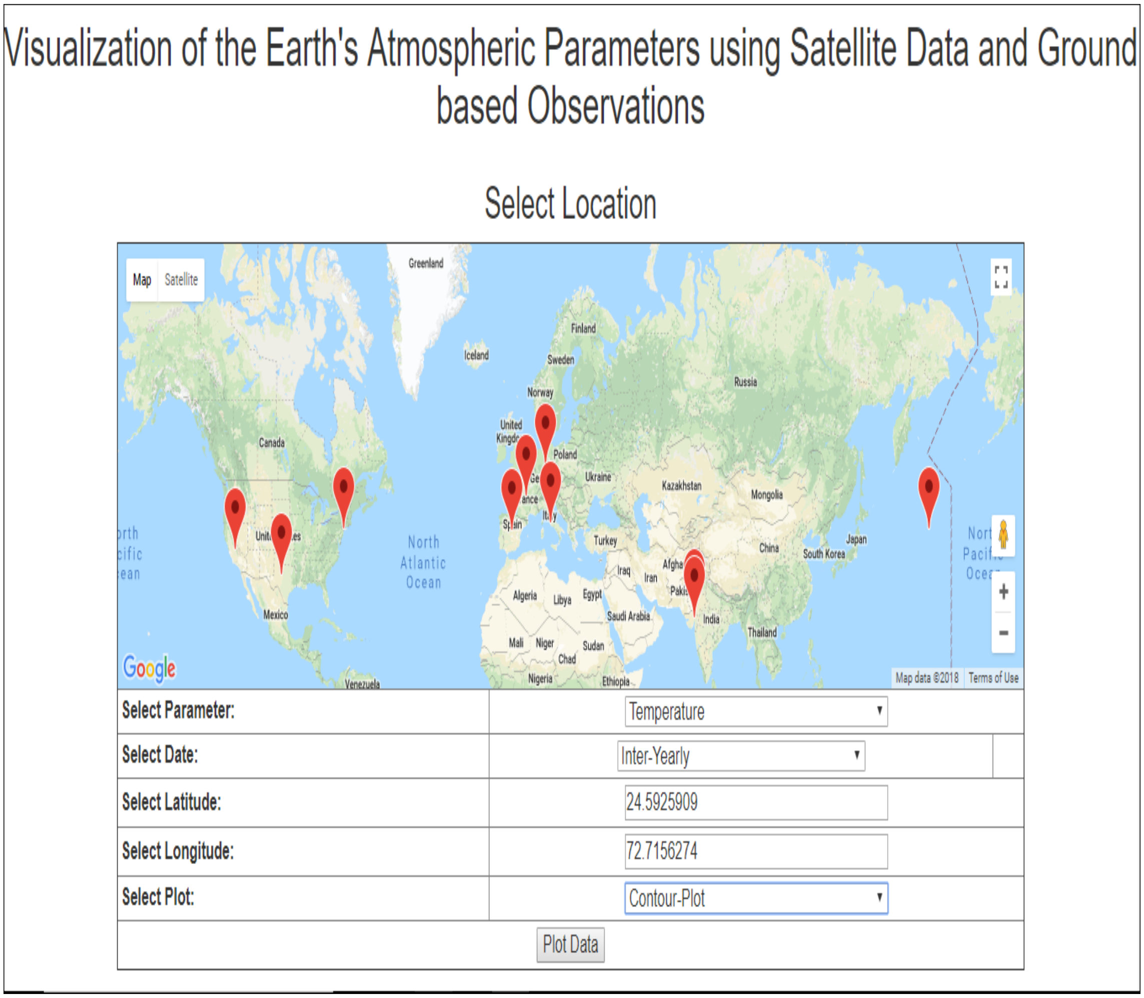

Figure 53 Filled input values for Temperature parameter, Inter-Yearly Date Range, Contour-plot and Mount Abu Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

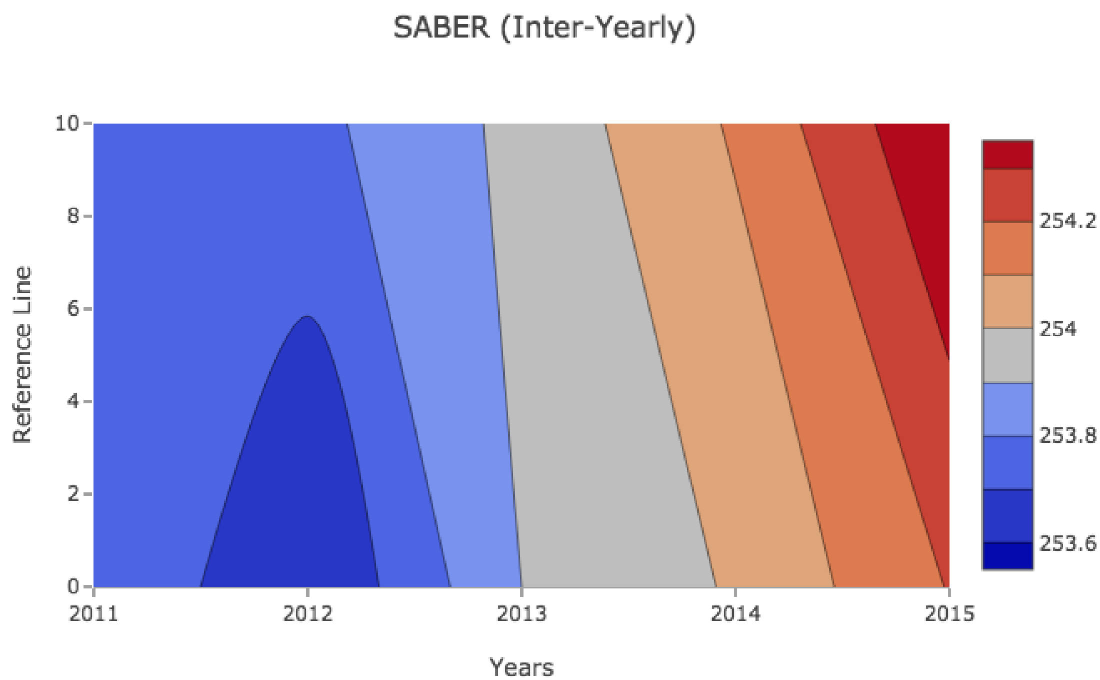

Figure 54 Output Graph for Temperature Parameter, Inter-Yearly Date Range, Contour plot and Mount Abu Location

When the user clicks on the TOMS Satellite option instead, the information about TOMS Satellite is displayed where the user is being asked to input the valid values for which the data is to be retrieved.

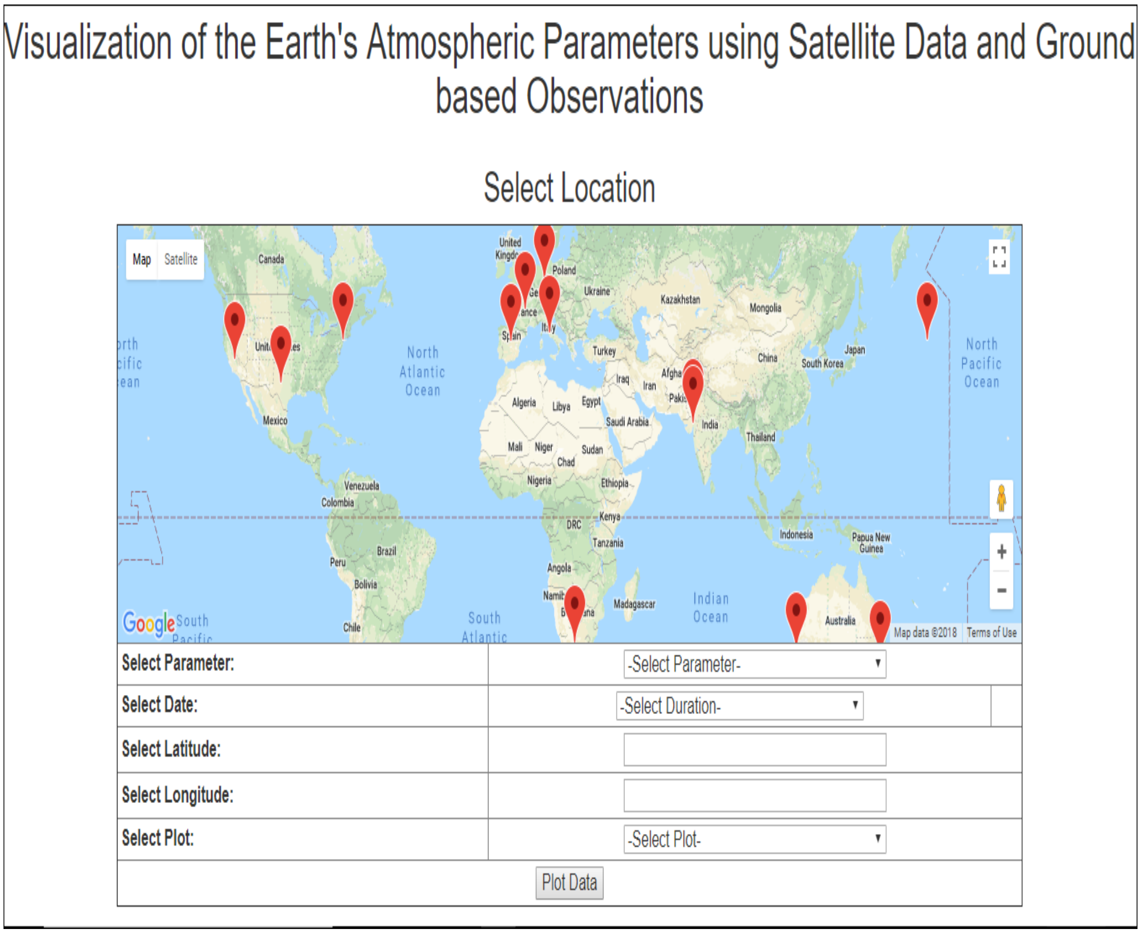

Figure 55 Form Data of TOMS Satellite

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Yearly), selection of type of plot (Line Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

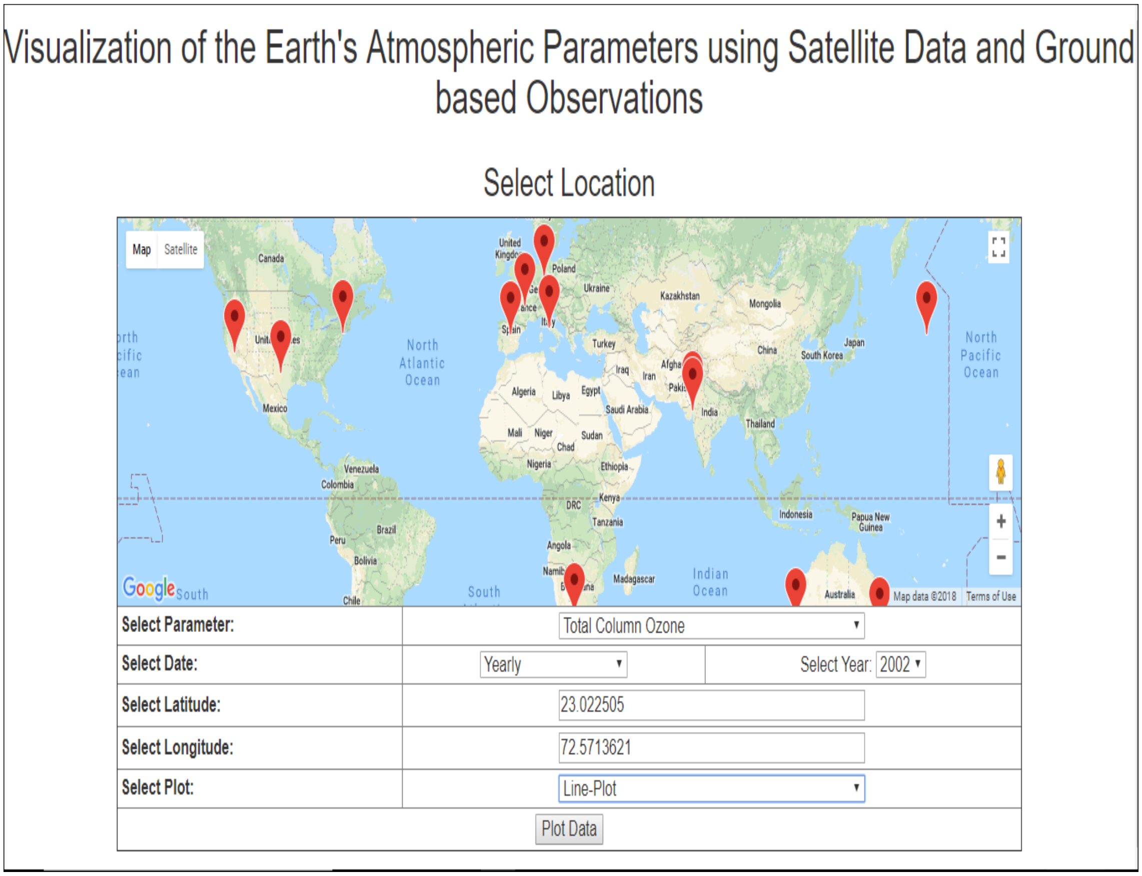

Figure 56 Filled input values for Total Column Ozone parameter, Yearly Date Range, Line-plot and Ahmedabad Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

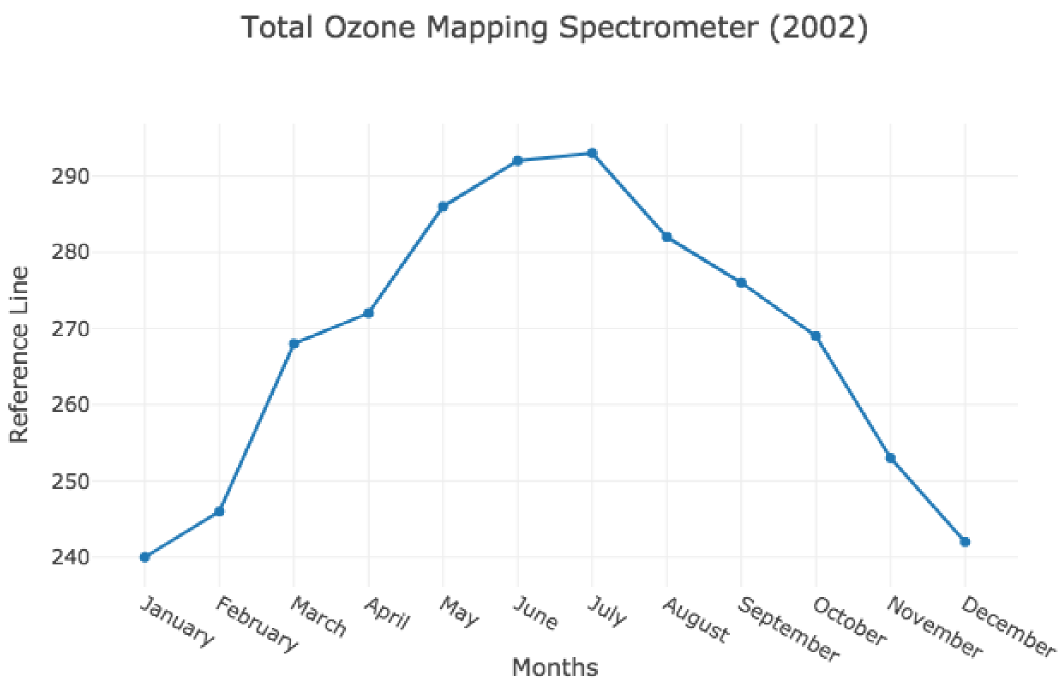

Figure 57 Output Graph for Total Column Ozone Parameter, Yearly Date Range, Line plot and Ahmedabad Location

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Yearly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

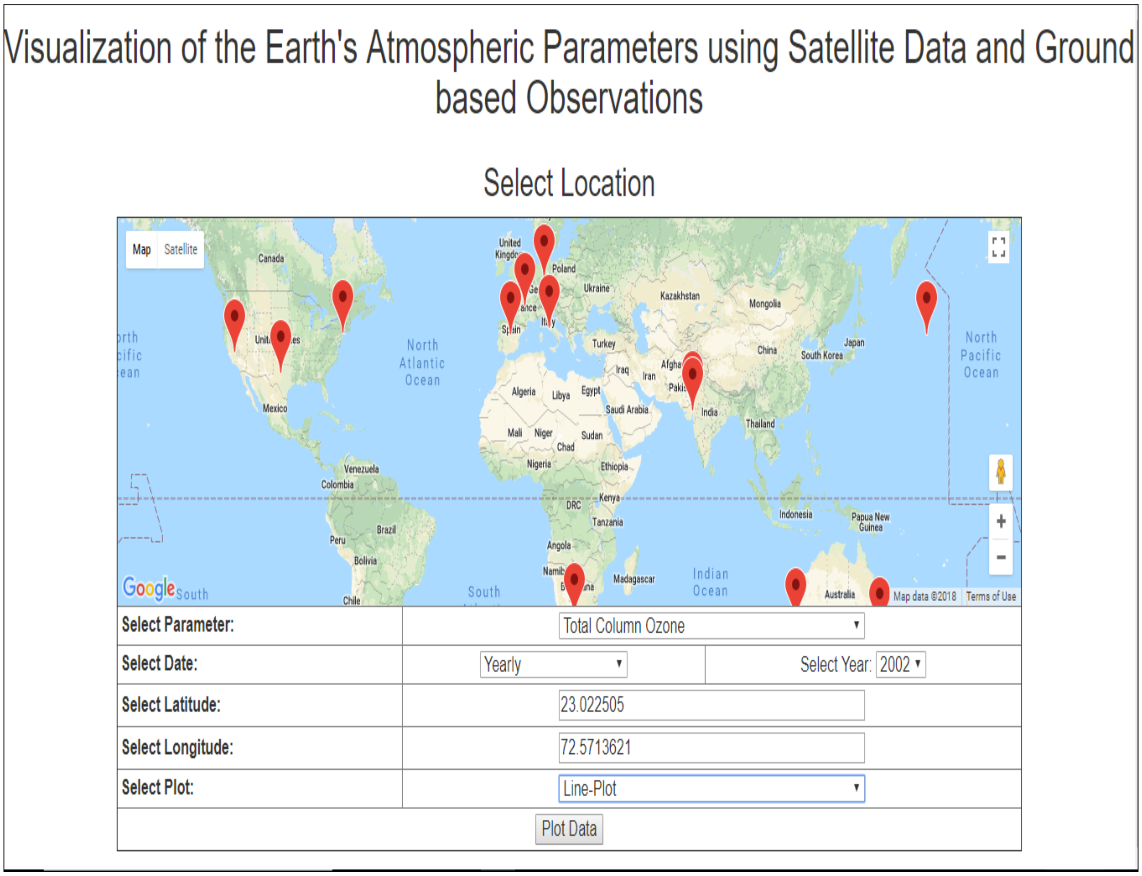

Figure 58 Filled input values for Total Column Ozone parameter, Yearly Date Range, Contour-plot and Ahmedabad Location

.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

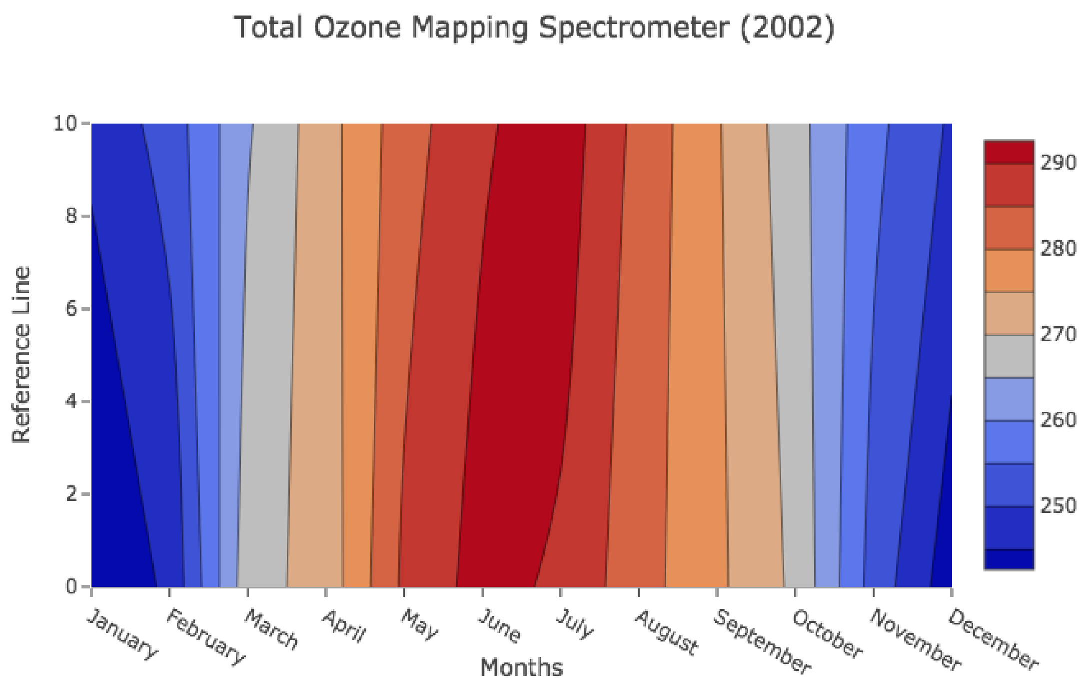

Figure 59 Output Graph for Total Column Ozone Parameter, Yearly Date Range, Contour plot and Ahmedabad Location

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Inter-Yearly), selection of type of plot (Line Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

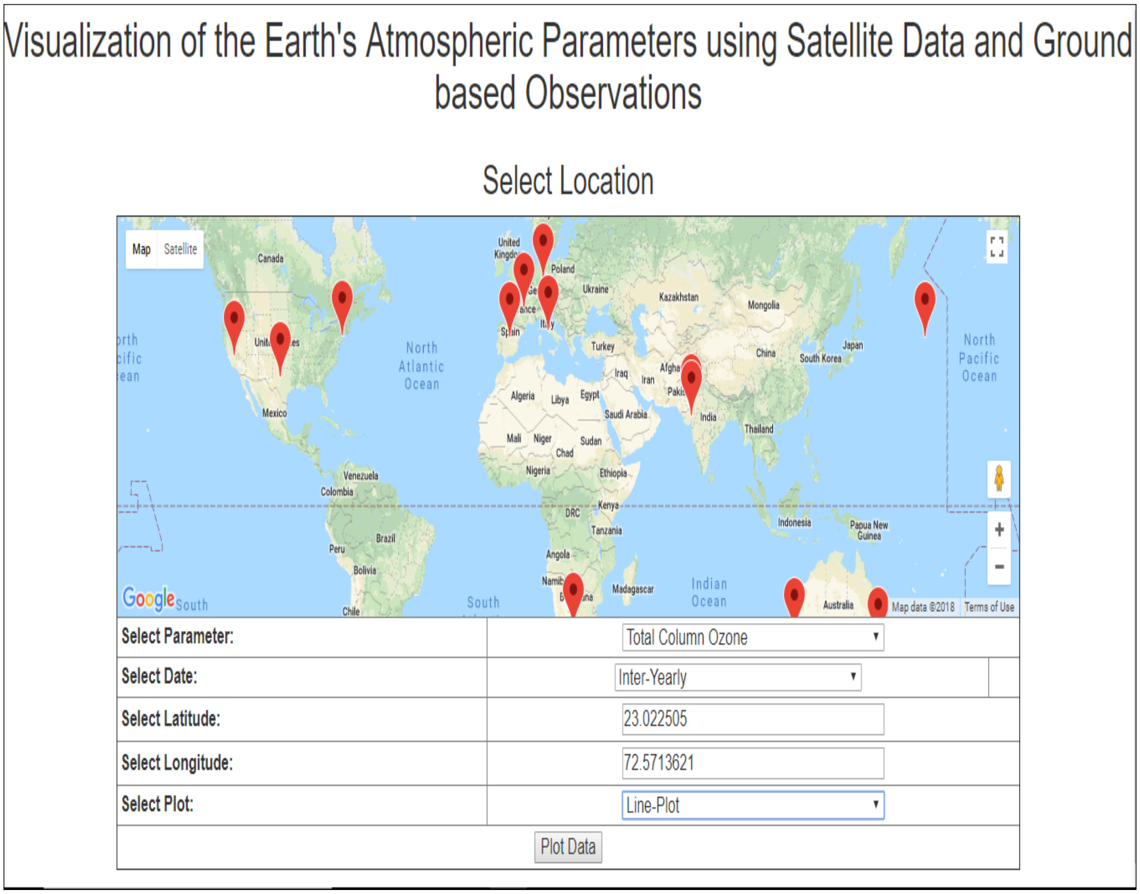

Figure 60 Filled input values for Total Column Ozone parameter, Inter-Yearly Date Range, Line-plot and Ahmedabad Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

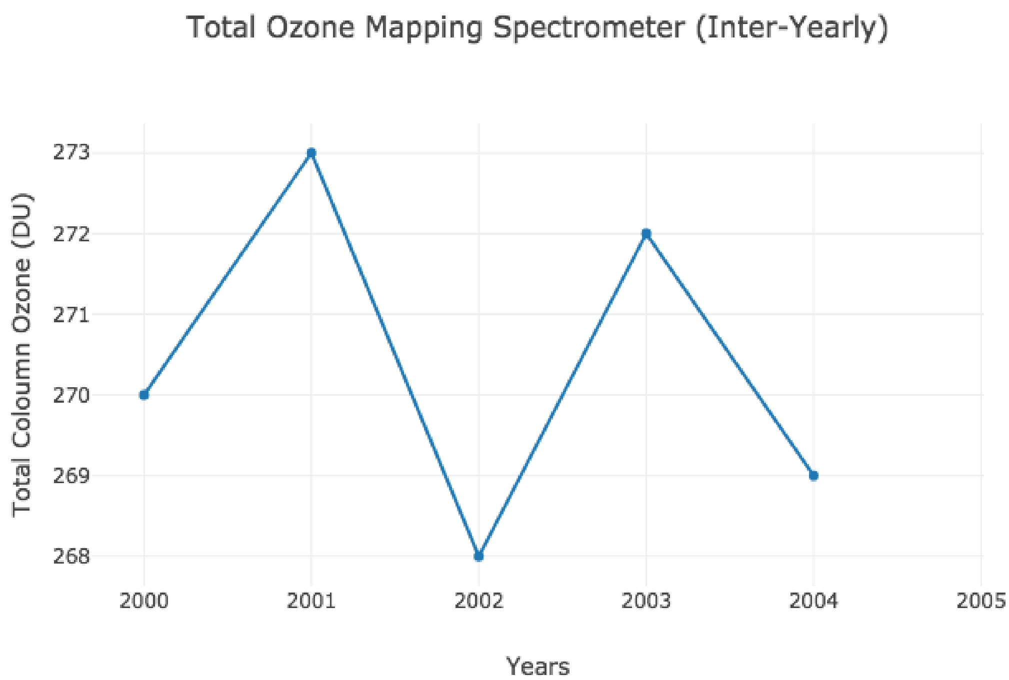

Figure 61 Output Graph for Total Column Ozone Parameter, Inter-Yearly Date Range, Line plot and Ahmedabad Location

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Inter-Yearly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

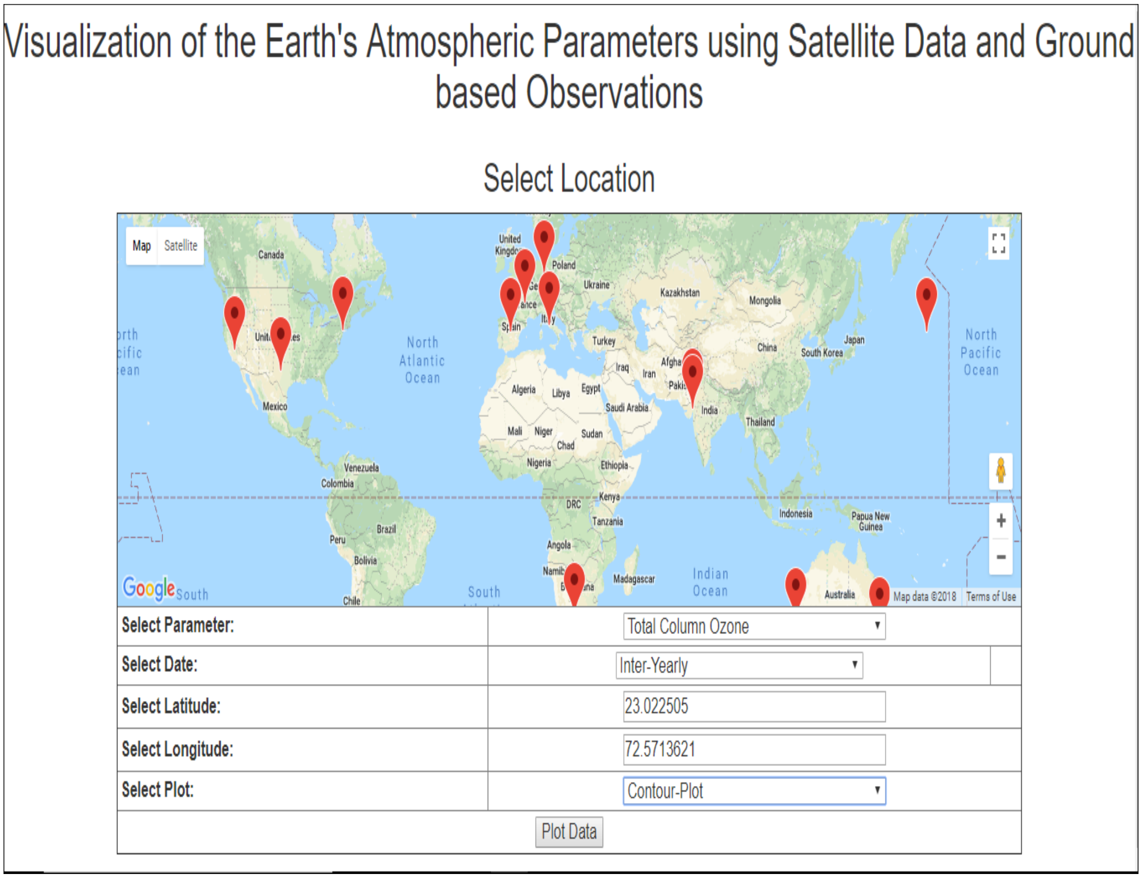

Figure 62 Filled input values for Total Column Ozone parameter, Inter-Yearly Date Range, Contour-plot and Ahmedabad Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

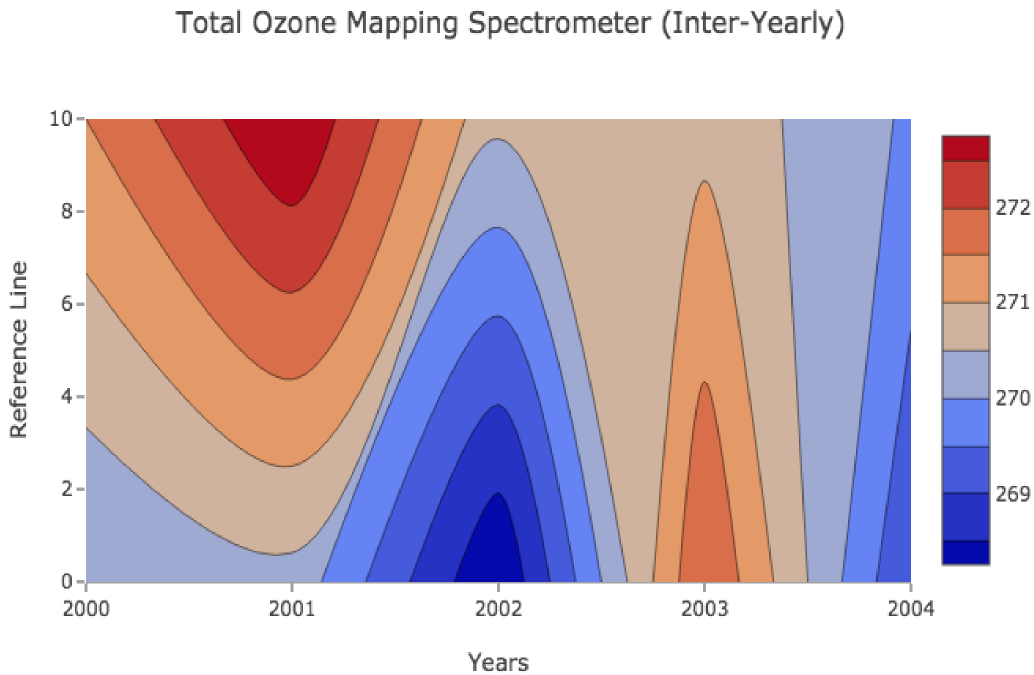

Figure 63 Output Graph for Total Column Ozone Parameter, Inter-Yearly Date Range, Contour plot and Ahmedabad Location

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Monthly), selection of type of plot (Line Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

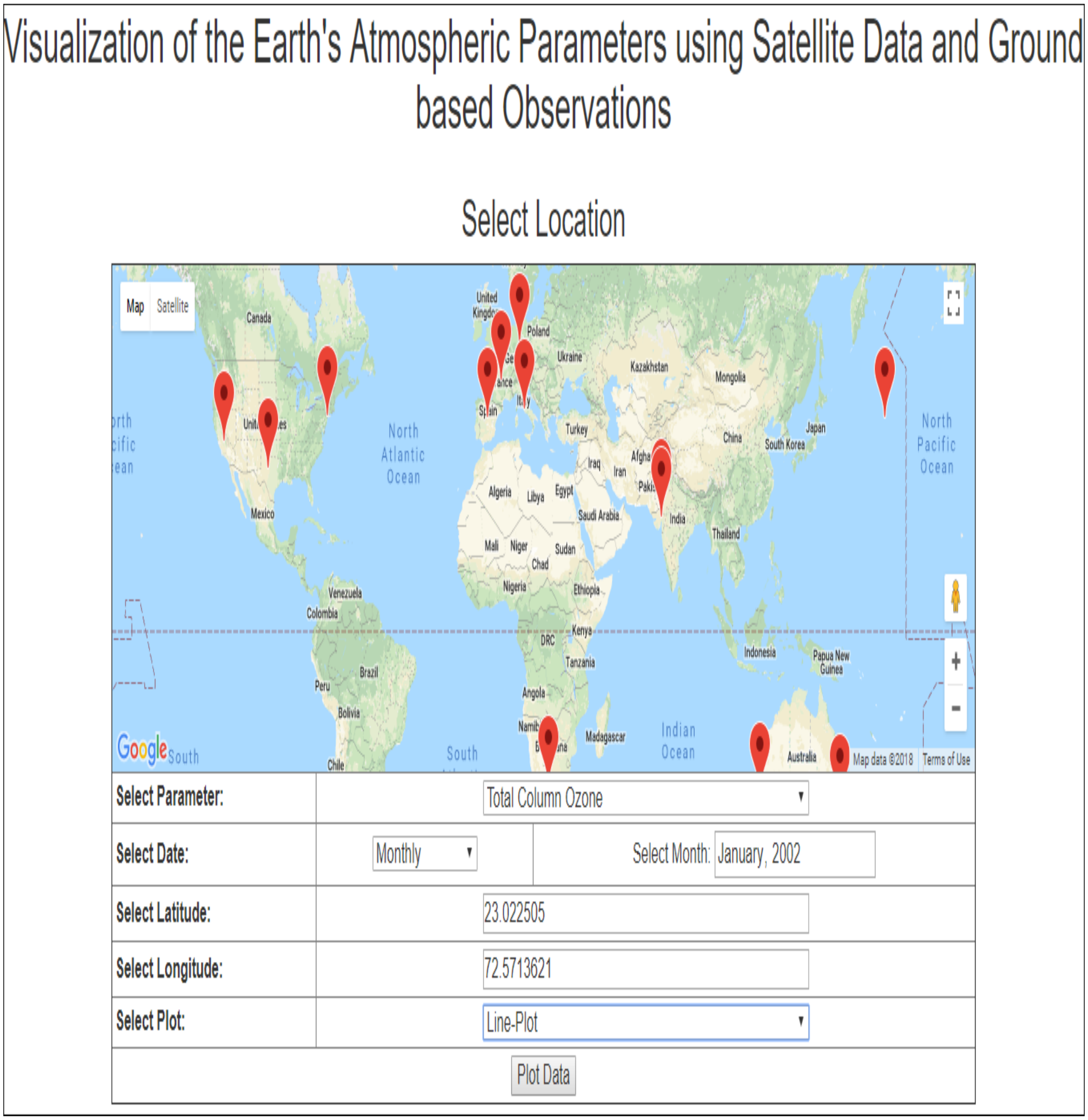

Figure 64 Filled input values for Total Column Ozone parameter, Monthly Date Range, Line-plot and Ahmedabad Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

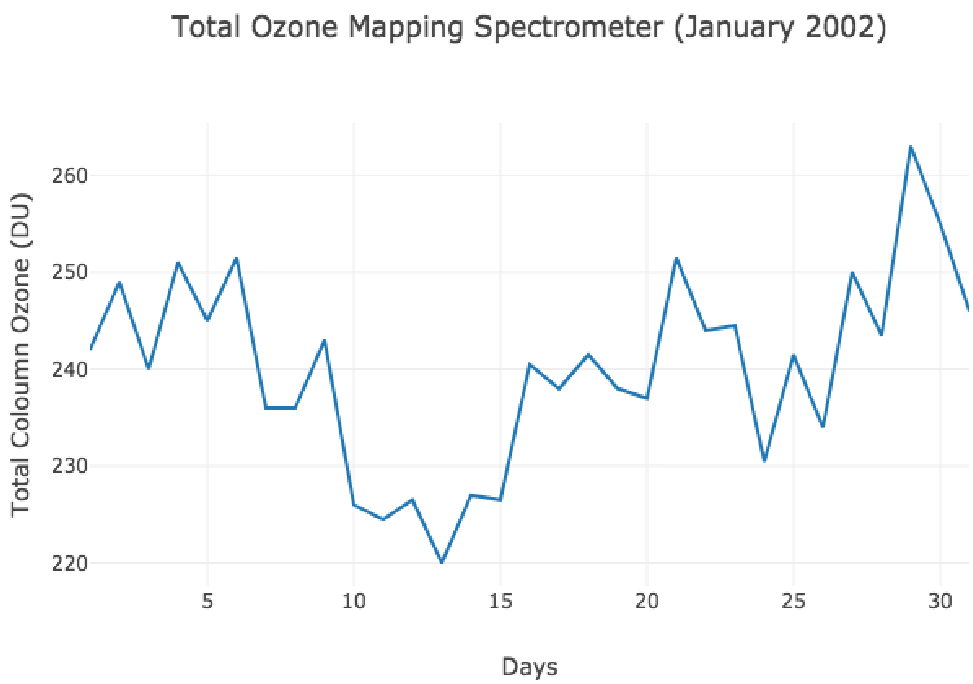

Figure 65 Output Graph for Total Column Ozone Parameter, Monthly Date Range, Line plot and Ahmedabad Location

By providing valid input values – selection of parameter (Total Column Ozone), selection of date range (Monthly), selection of type of plot (Contour Plot), and Selection of location from Google maps (Ahmedabad) which would directly fill up input boxes of Latitude and Longitude, the screen appears as follows.

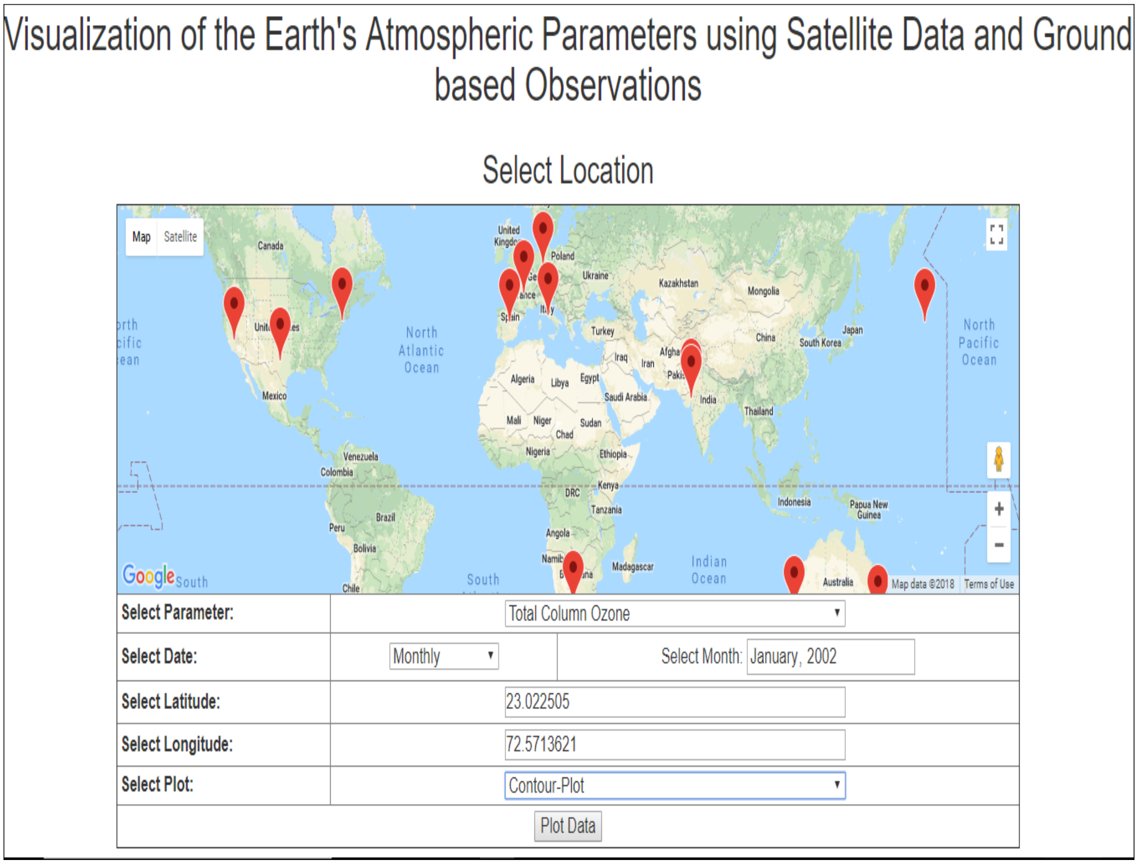

Figure 66 Filled input values for Total Column Ozone parameter, Monthly Date Range, Contour-plot and Ahmedabad Location.

Once the user clicks on the Plot Data button, system calculates and retrieves the data based on parameters filled by user and thus redirects output page.

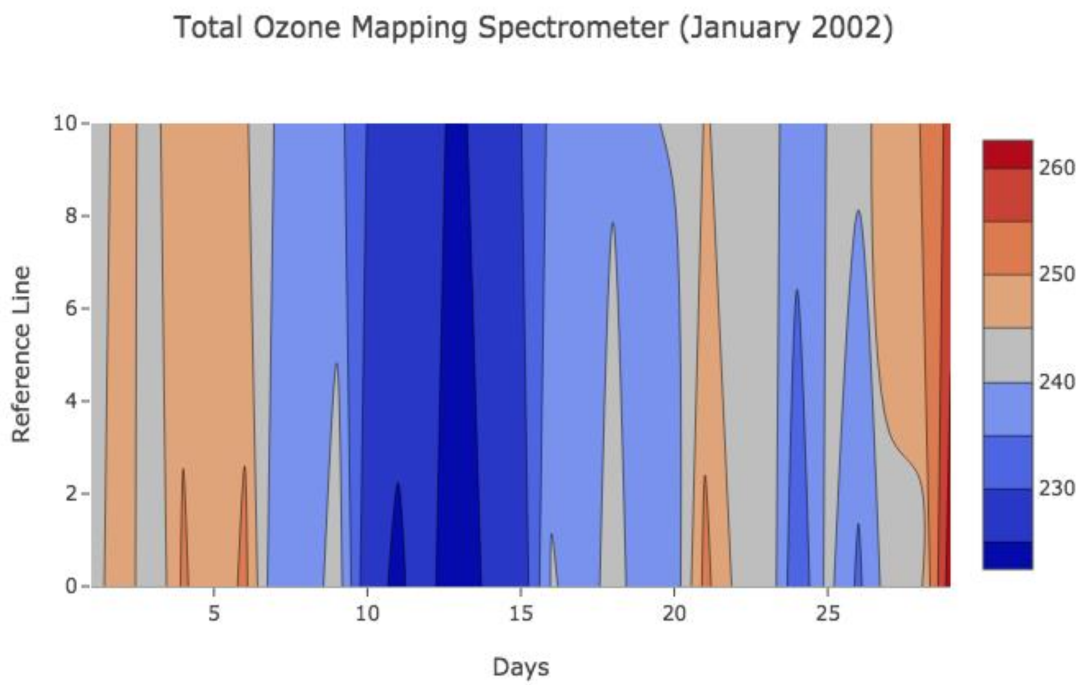

Figure 67 Output Graph for Total Column Ozone Parameter, Monthly Date Range, Contour plot and Ahmedabad Location

From the home page,if the user wishes to view the ground based data, then by directly clicking on image, user would enter ground based selector. On mouse hover user will be able to see names on respective images.

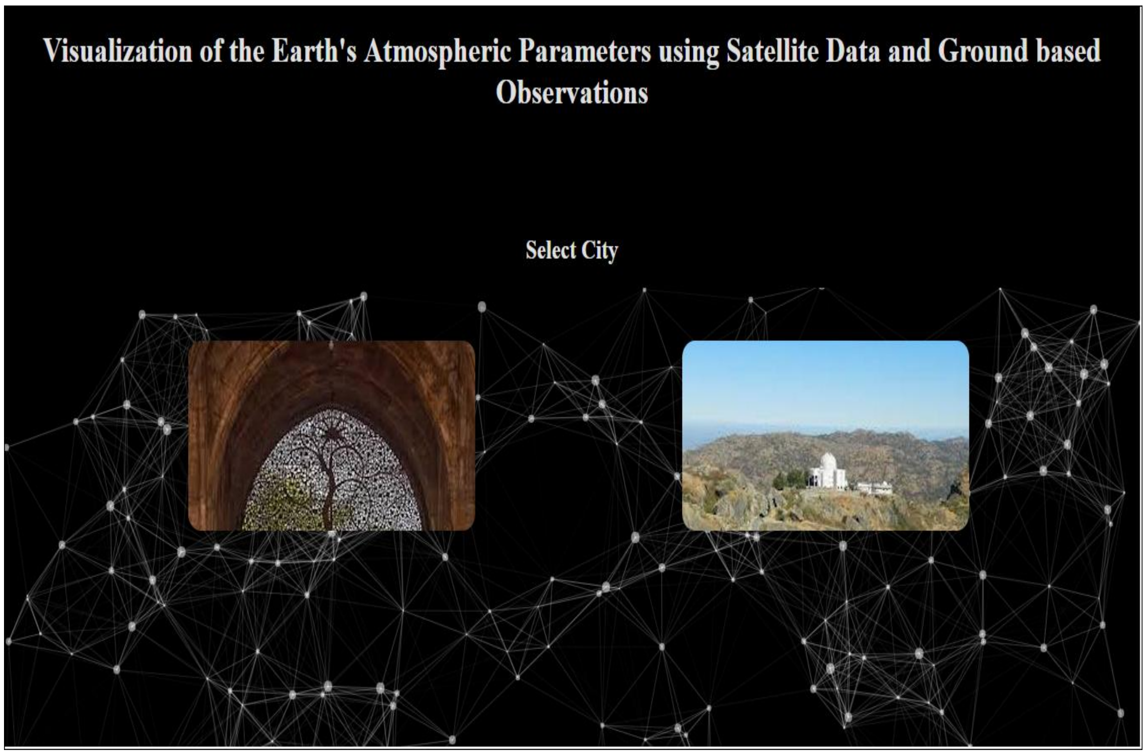

Figure 68 Ground Based City Option

User can select any city for which the data is required. The ground based instruments' data has been taken and observed at both the places namely Ahmedabad and Mount Abu. Thus either of the can be chosen and data can be retrieved. When user goes further selecting Ahmedabad city, further options for selecting instruments namely Raman Lidar, Microtops, UV Biometer are displayed.

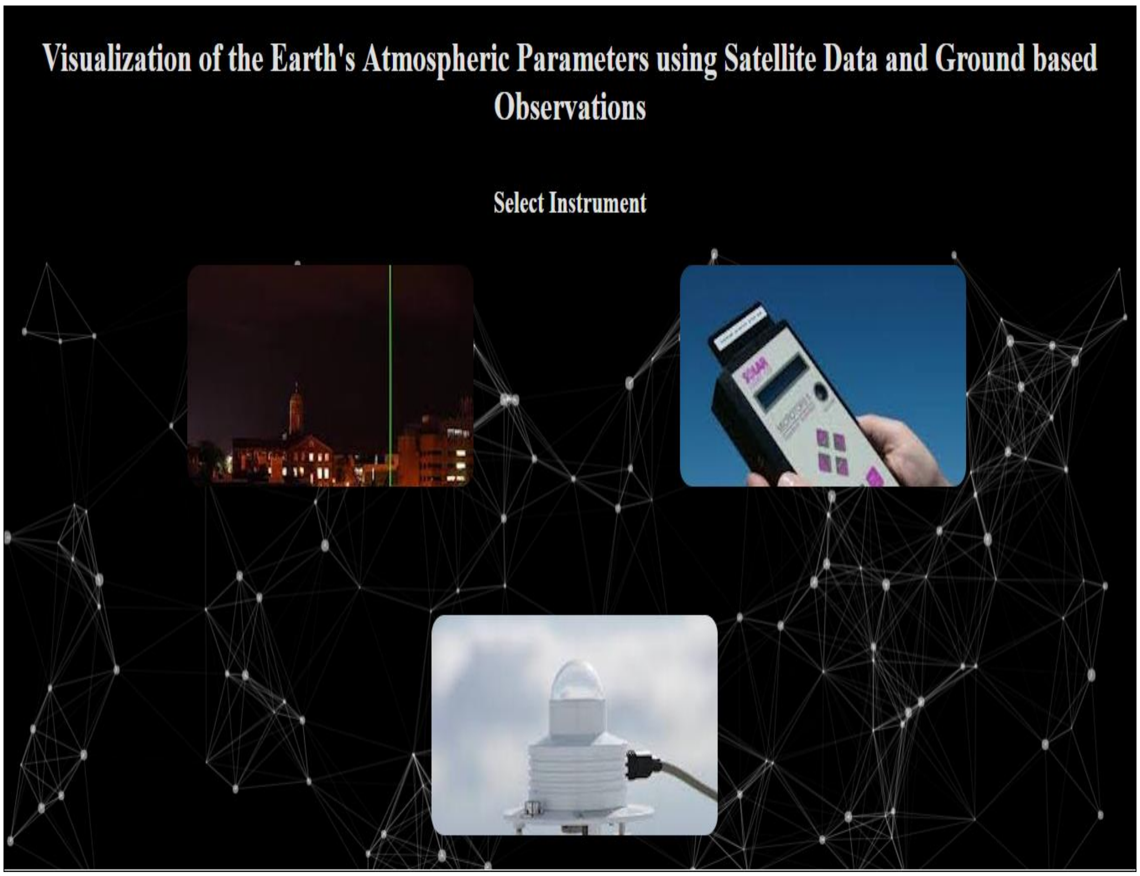

Figure 69 Instrument selection Option

To view PRL's Raman LIDAR, user clicks on image of respective instrument. The further options for the input values would be displayed based on which data would be retrieved.

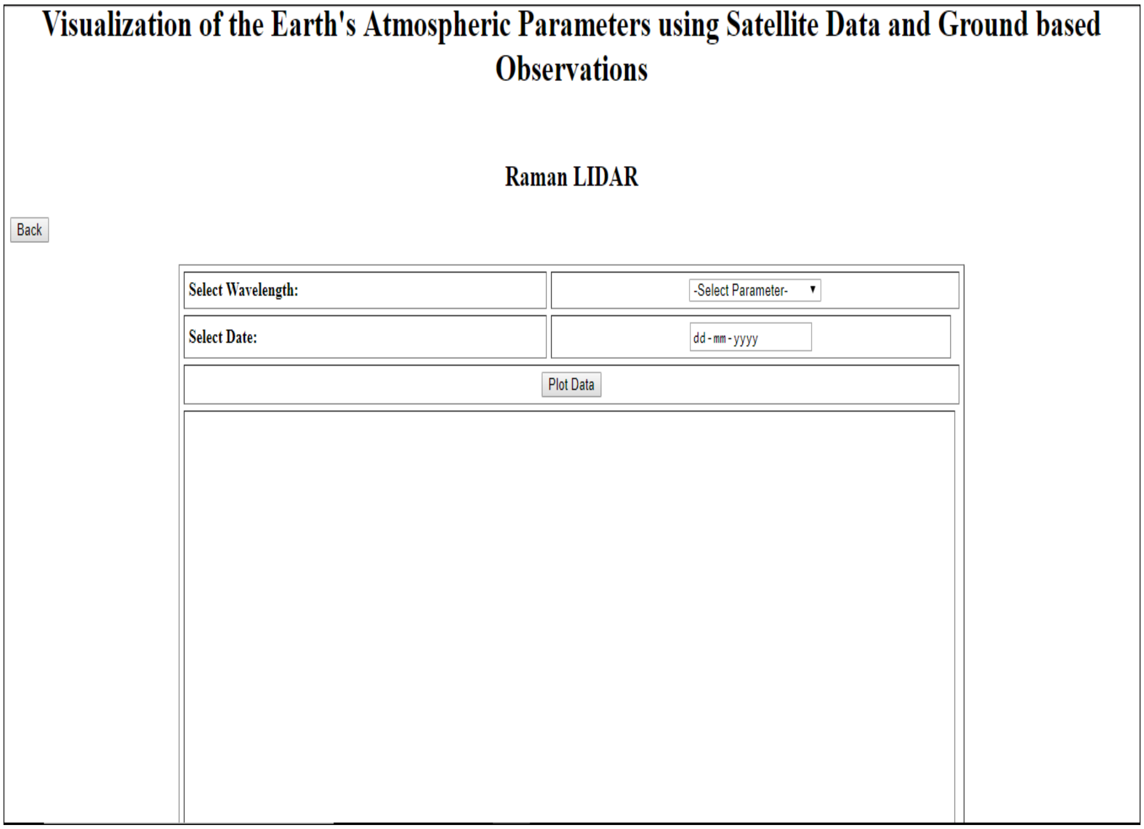

Figure 70 Form Data Input For RAMAN LIDAR

Date can be plotted at various wavelengths on various days as well.

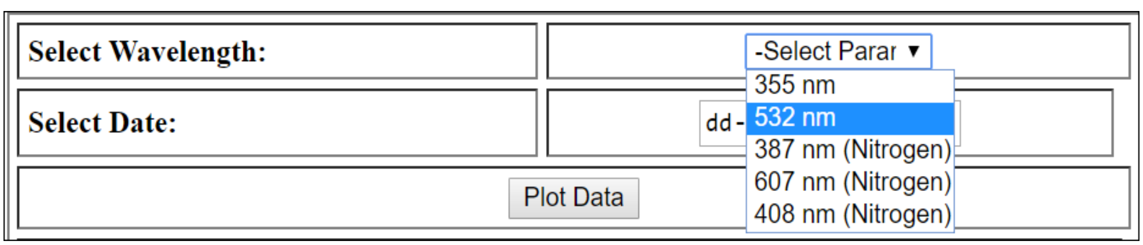

Figure 71 Wavelength selection, RAMAN LIDAR

Based on the valid input values by the user, system will try to calculate the data and would display the output graph in the box area within the same page.

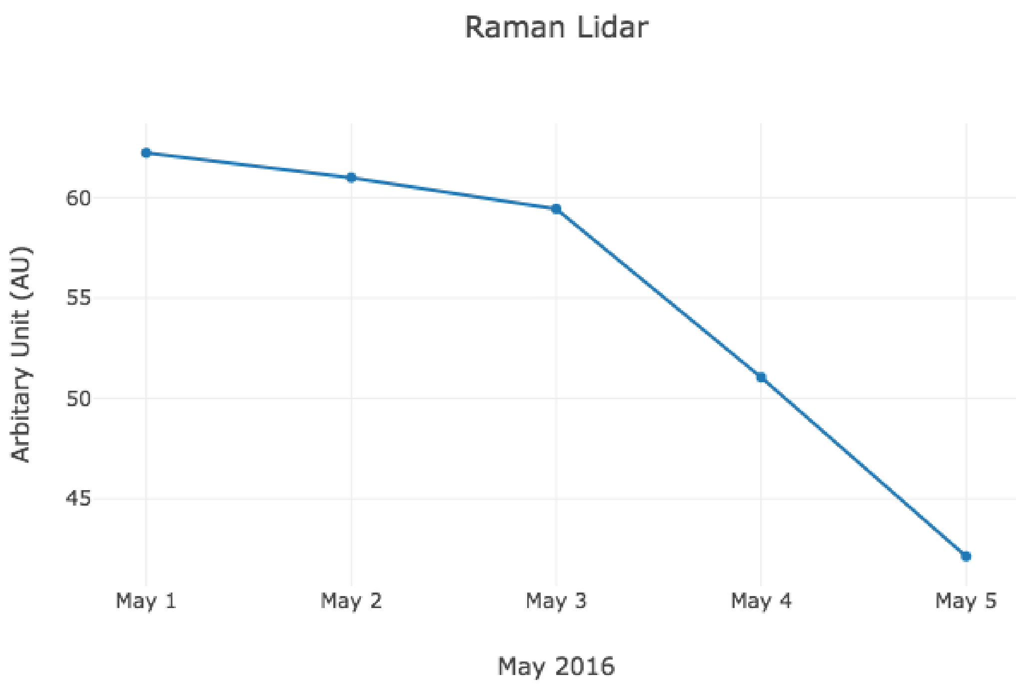

Figure 72 Output of RAMAN LIDAR

Similarly, from the data of MICROTOPS Ozonometer and UV Biometer graphs can plotted.

When user selects city Mount Abu instead of Ahmedabad, further options for selecting instruments Rayleigh LIDAR and Microtops are displayed which can be seen by mouse hover over images.

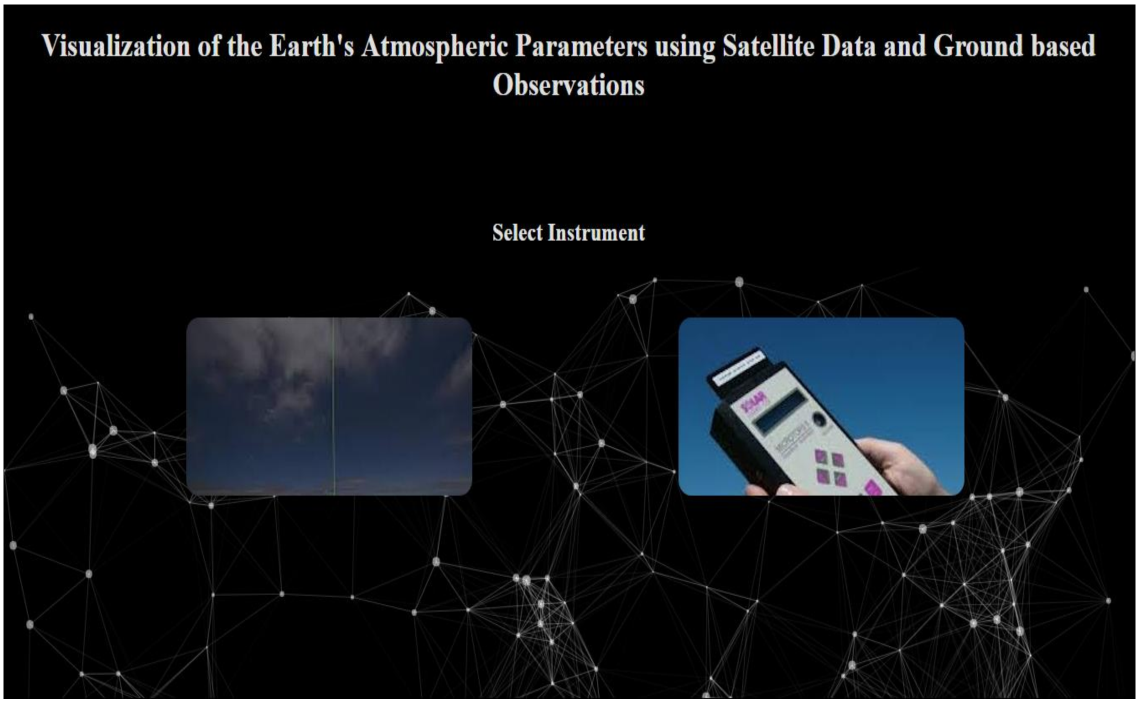

Figure 73 Instrument Selection Option

To view the data of PRL's Rayleigh LIDAR at Mount Abu, user clicks on image. Further options for the input values would be displayed based on which data would be retrieved.

Different kind of graphs can be generated based on the selection of different altitude ranges.Based on input values inserted, system would calculate the data to be retrieved and would display the output graph in the empty box within same page itself.

Similarly, we can plot graph for other ground based instrument MICROTOPS Ozonometer present at Mount Abu.

6. IMPLEMENTATION PLANNING

The right strategy for implementing this project is very critical to make it successful over a given period of time. The strategy should cover the people, information and the technology with broad view of the current status on these aspects in mind.

6.1. IMPLEMENTATION ENVIRONMENT

The System developed is totally on the server side which means that the user can just simply view the GUI and choose relevent options from it. It is very user friendly and one has not to worry about remembering any commands to perform various operations. User can use different operations to generate the desired graph.

Main purpose of this application is to give an user friendly GUI to end-uer such that any layman user can get information about any parameter at any location based on requirements.

Comparison between Single user and Multi User

Single User	Multi User
The major disadvantage is that when one user is accessing a system other user cannot use it.	More than one user can access a system paralleled.

Table 11 Single user and Multi User

GUI V/s Non GUI

- In GUI, multiple windows with different information can simultaneously be displayed on user screen. So user has flexibility to simultaneously interact with several related items at a time and can have access to different system information.

- Iconic information representation and symbolic information manipulation is possible in GUI.
- GUI usually supports command selection using an attractive and user friendly menu selection.
- In GUI, a pointing device such as mouse or light pen can be used for issuing commands.

6.2. PROGRAM/MODULES SPECIFICATION

The application package contains multiple program modules according to their function and the classification of these modules is vividly described below.

SABER

- Plot Satellite Data for SABER instrument: This enables the user to view the graphical format of the data obtained from SABER instrument in NetCDF format.

TOMS

- Plot Satellite Data for TOMS instrument: This enables the user to view the graphical format of the data obtained from TOMS instrument in NetCDF format.

OMI

- Plot Satellite Data for OMI instrument: This enables the user to view the graphical format of the data obtained from OMI instrument in NetCDF/HDF format.

Met Data

- Plot Satellite Data for Met Data instrument: This enables the user to view the graphical format of the data obtained from Met Data instrument in NetCDF format.

MICROTOPS – II

- Plot MICROTOPS – II Data: This enables the user to have visualization of the atmospheric parameter observed from ground using MICROTOPS – II along with the variation absorbed spatially (at. Mt. Abu) and temporally (at. Ahmedabad).

RAMAN LIDAR

- Plot RAMAN LIDAR Data: This enables the user to view photon counts with respect to altitude obtained from RAMAN LIDAR. We can also know about the signature and structure of a cloud present in the sky.

RAYLEIGH LIDAR

- Plot RAYLEIGH LIDAR Data: This enables the user to view photon counts with respect to altitude obtained from RAMAN LIDAR. We can also calculate various atmospheric parameters using photon counts such as temperature, humidity etc.

UV BIOMETER

- Plot UV Biometer Data: This enables the user to view the amount of UV Radiation reaching the surface of earth.

6.3. SECURITY FEATURES

As the system is made a user friendly system to help any layman user to retrieve information based upon requirements, the amount of security features are less and will be done in future enhancement. Security features of system are:

- User is not allowed to enter any invalid data.
- User is not able to change the data files retrieved from satellite.

6.4. CODING STANDARDS

The front end of the project is developed using HTML, CSS, Javascript, electron, Node js. Project “ Development of software for visualization of earth’s atmospheric parameters using satellite data and ground based observations” has fixed standards for designing the GUI and developing application.

Naming Convention and Standards

Your peer programmers have to understand the code you produce. A coding standard acts as the blueprint for all the team to decipher the code. Simplicity and clarity achieved by consistent coding saves you from common mistakes. If you revise your code after some time then it becomes easy to understand that code. It’s industry standard to follow a particular standard to being more quality in software.

- **Naming Conventions**
  - Use **camelCasing** for method arguments and local variables.
    - **Example**

```
public class UserLog
{
        public void Add(LogEvent logEvent)
        {
                Int itemCount = logEvent.Items.Count;
        }
}
```

  - Use **Hungarian** notation or any other type identification in identifiers
    - **Example**

```
// Correct
Int counter;
String name;

//avoid
```

Int iCounters;

String strName;

- Use **Screaming Caps** for constants or readonly variables
  - **Example**

```
// Correct
const string ShippingType = "DropShip";

//Avoid
const string SHIPPINGTYPE = "DropShip";
```

- Using **Abbreviations**. Exceptions: abbreviations commonly used as names, such as **Id, Xml, Ftp, Uri**
- Use **PascalCasing** for abbreviations 3 characters or more (2 chars are both uppercase)
  - **Example**

```
HtmlHelper htmlHelper;

FtpTransfer ftpTransfer;

UIControl uiControl;
```

- Use **Underscores** in identifiers. Exception: you can prefix private static variables with an underscore.
  - **Example**

```
//Correct
public DateTime clientAppointment;
public TimeSpan timeLeft;
//Avoid
Public DateTime client_Appointment;
Public TimeSpan time_Left;
//Exception
private DateTime _registrationDate;
```

7. TESTING

7.1. TESTING PLAN

The test plan describes the test environment and required test resources. It also provides measurable goals by which management can gauge testing. Furthermore, it facilitates communications within the test team, between the test team and the development team, and between the test team and management. It tells what to test.It has a dual function; it is used to identify the defects in program as well as is used to judge whether program is usable in practice or not. Thus software testing is used for validation and verification, which ensures that software confirms to its specifications and meet the needs of user.

Branch coverage:

It is a strategy, test cases are designed to make each branch condition assume either true or false values.

Conditional Coverage:

- In this kind of testing, test cases are designed in which each one of the Boolean expression have been evaluated to both true and false.
- The testing technique that is going to be used in project is black box testing, the expected inputs to the system are applied and only the outputs are checked.
- If the set of inputs that are provided to each module are not giving the output as per expected results from the module then the result of that testing is to be declared as failed. Moreover the bottom up integration of the modules is applied herein so that each module can be verified at the initial stage and if it is found that the independent module is perfectly alright, only then it is going to be integrated with other related modules, otherwise the module is checked

for flaws and then if it satisfies all specific requirements of the module, is integrated to other related mmodules to form and incorporate a system.

7.2. TESTING STRATEGY

Testing is the process of analyzing a software item to detect the differences between existing and required conditions and to evaluate the features of the software item. The Test Strategy decides how we are going to approach the testing in terms of people, tools, procedures and support. It tells how to test. Testability is one of the primary design goals for the Training Management .The following diagram from the Acceptance Test Engineering Guidance shows the testing layers.

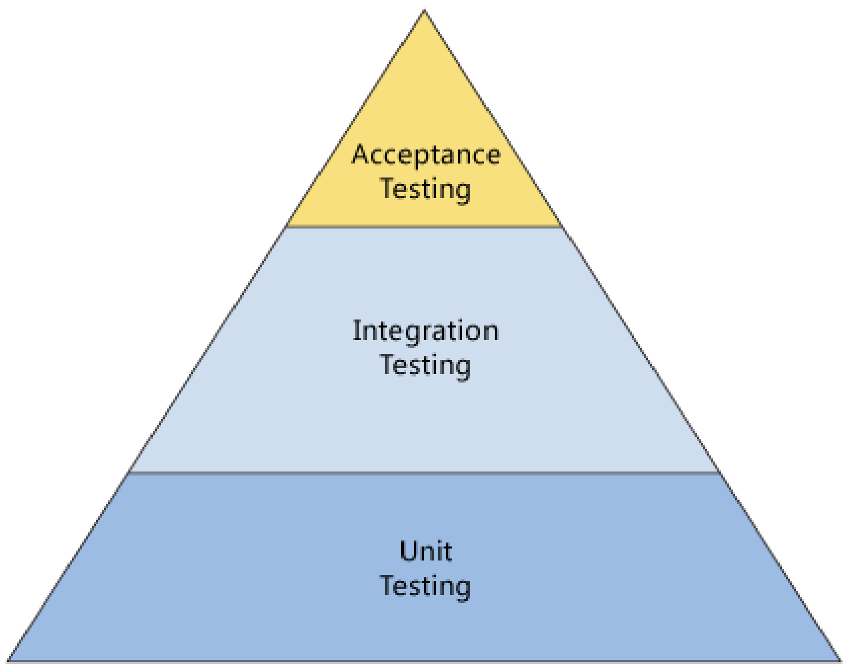

Figure 74 Testing Layers

Each type of test has a distinct purpose. They are the following:

Unit tests: Unit testing is usually done by developers. Unit tests isolate and verify discrete units of program logic. Isolation allows unit tests to run quickly, and developers can run unit tests frequently.

Integration tests: Integration tests differ from unit tests in that the code under test is not isolated. Integration tests are written by developers or testers. They run in a unit testing framework.

Acceptance tests: Acceptance tests consist of multiple steps that represent realistic usage scenarios of the application as a whole. These tests verify that an application meets the needs of the intended users. Their scope includes usability, functional correctness, and performance. Generally, test engineers create these tests.

7.3. TEST SUITES DESIGN

7.3.1. TEST CASES

Project Name	Atmospheric Ozone
Test Item	Front End Home Page

Function	Test Condition	Expected Result	Actual Result	Pass/Fail
Application				
Access to both	User selects any one out	User should be redirected to	Page redirects to	pass

data items	of two data items	selected page	selected page	

Project Name	Atmospheric Ozone
Test Item	Front End Home Page

Function	Test Condition	Expected Result	Actual Result	Pass/Fail
Application				
Access to all satellites	User selects any one out of four satellites	User should be redirected to respective satellite page	Page redirects to selected page	Pass

Project Name	Atmospheric Ozone
Test Item	SABER satellite Home page

Function	Test Condition	Expected Result	Actual Result	Pass/Fail
Application				
Select location from google maps	User clicks on google maps	Latitude and longitude of that location inserted in relative text box	Latitude and longitude of that location written in relative text box	Pass
Plot satellite data	User clicks on “plot data” button	Data for particular input values should be plotted through graph	Graph is displayed based in input values	Passs
Parameter not selected	User does not select any parameter	Alert box should pop up displaying parameter not selected	Alert box is displayed to select parameter	Pass
Select type of plot	User selects sny one type of plot to display data	Plot is selected and visual representation of the data in plot is displayed	Grpahical representationof data is created in the form of selected plot	Pass

Project title	Atmospheric Ozone
Test item	Toms satellite home page

Function	Test condition	Expected Result	Actual result	Pass/fail
Application				
Select location from google map	User clicks on google map	latitude and longitude of that location entered in relative text box	latitude and longitude written in relative text box	Pass
Plot satellite data	User clicks on plot data button	Data for particular value should be plotted	Graph is displayed based on input values	Pass
Parametetr not selected	User does not select parameter	Alert box should be popped up	Alert box is displayed	Pass
Select type of plot	User selects any one type of plot	Plot is selected and visual representation of data is displayed	Graph is displayed	Pass

Project name	Atmospheric ozone
Test item	Raman LIDAR home page

Function	Test condition	Expected result	Actual result	Pass/fa il
Application				
Access to all input values	User enters input and clicks submit	Output graph should be displayed	Output graph is displayed	Pass

Project name	Atmospheric ozone
Test item	Mount abu city home page

Function	Test condition	Expected result	Actual result	Pass/fail

Application				
Access to both the instruments	User selects any one out of two instruments	User should be redirected to respective instrument page	Page redirects to respective page	Pass

Project name	Atmospheric ozone
Test item	Mount abu LIDAR home page

Function	Test condition	Expected result	Actual result	Pass/fail
Application				
Access to all input values selection	User enters input and clicks submit	Page displays output graph	Output graph is displayed	Pass

8. CONCLUSION AND DISCUSSION

The project "Development of software for visualization of the Earth's atmospheric parameters using satellite data and ground based observations" is an user friendly application where any layman user can obtain data of atmospheric parameters like water vapor, temperature,total column ozone, etc. from four different satellites and take these observations in the graphical form for any date range as per requirement of user. The application also helps the userto view, observe and compare data acquired from ground based instruments across the regions of Ahmedabad and Mount Abu.

8.1. SELF ANALYSIS OF PROJECT VIABILITIES

- Graphical view of data created from satellite data files is completely dependent on the data file availability and selection of parameter.
- Provided the data set for any instrument of any satellite in any format may it be NetCDF/HDF, our project will analyze the dataset and provide accurate results.
- Project is capable of plotting inter-yearly plots for comparison of two or more than two years.
- Accuracy of algorithm is completely dependent on accuracy of data files.
- Project is so compatible that it runs on any windows platform.

8.2. PROBLEM ENCOUNTERED AND POSSIBLE SOLUTIONS

Since the project is not only limited to computer science as it primarily focuses on atmospheric science. There were many issues which we had encountered both related to computer science and atmospheric science.

- Due to lack of experience in new technologies used in project, we faced difficulty in interconnecting them.

- Working with satellite data files like NetCDF/HDF was confusing initially as wewere unable to understand the hierarchies in which the data is stored in those files, this problem was solved by reading the instruction files available with satellite's data files.
- We also faced the genuine huddle which anybody can face, that is presence of clouds while taking readings from grouundbased instruments like LIDAR due to which data recorded may not be much accurate.

8.3. SUMMARY OF PROJECT WORK

We have developed an application "Development of software for visualization of the Earth's atmospheric parameters using satellite data and ground based observations" at Physical Research Laboratory. Here, in this project we have used four satellite observations available in NetCDF/HDF format and four ground based instruments namely MICROTOPS – II Ozonometer, UV Biometer and two LIDAR's (RAMAN LIDAR and RAYLEIGH LIDAR) observations to extract atmospheric parameters. Using this application user can study different parameters like vertical profile of temperature, vertical distribution of ozone, atmospheric water vapor,total column ozone etc. User can choose any location in world where satellite or ground based data is available. In this application further provision has been made for user to select latitude and longitude directly from google map andthen can choose the day, month and year as per requirement from dropdown list provided in GUI. User can generate severaltypes of graph such as line plot, color coded contour plots etc. Furthermore, application is capable of providing user friendly, scientific and statistical view of atmospheric parameters observed by various ground based instruments and these alsocan be visually displayed through line plot, contour plot etc.

This application will be very useful for graphical visualization of various important atmospheric parameters over the globe and can be used for various scientific studies and for general use also. As concentration of stratospheric ozone directly affects the UV radiations reaching earth surface. One can have depth knowledge of stratospheric ozone concentration over any location ans then can decide accordingly about being in sun for longer periods. Similarly other atmospheric parameters can also be used for scientific and other useful purposes.

9. LIMITATION AND FUTURE ENHANCEMENT

Limitations

- The application is fit to run on any windows version. Other OS are not targeted and behavior of application is unknown.
- The application will not give output if data on certain days or for any of the events is not available as there may be no observations for that particular moment.
- The application for satellite instrument does not support if data is in some other format.
- Large amount of storage is required to store satellite data files as size of files is quite huge.

Future enhancement

- More data from satellite instruments can be added for having further insight and comprehensive view of earth's atmosphere.
- Oher types of plots such as surface plots, multiple contour plots etc can be generated to view data in different forms and formats.
- Support of other file formats to make application more versatile.
- It will be very good to provide these type of application with multilingual feature support for providing benefits to much wider user community.

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https://science.nasa.gov/missions/toms

[16] TOMS instrument,

https://disc.gsfc.nasa.gov/datasets/TOMSEPL3_V008/summary

[17] Aura Satellite,

https://www.nasa.gov/mission_pages/aura/main/index.html

[18] OMI Instrument,

https://aura.gsfc.nasa.gov/omi.html

[19] OMI Instrument,

https://disc.gsfc.nasa.gov/datasets/OMDOAO3Z_V003

Satellite Data Download Links

[20] SABER, http://saber.gats-inc.com/data.php

[21] TOMS,

https://disc.sci.gsfc.nasa.gov/datasets/TOMSEPL3_V008/summary?keywords=aerosol%20optical%20depth

[22] OMI,

https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/omi-nrt

ABBREVIATIONS

LIDAR	Light Detection And Ranging
TIMED	Thermosphere Ionosphere Mesosphere Energetics Dynamics
SABER	Sounding of Atmosphere using Broadband Emission Radiometry
TOMS	Total Ozone Mapping Spectrometer
OMI	Ozone Monitoring Instrument
NASA	National Aeronautics and Sapace Agency
HDF	Hierarchical Data Format
NetCDF	Network Common Data Format
COCOMO	Constructive Cost Model