Ozone Monitoring Over India

भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

Ozone Measurement in IMD

- The first Columnar Ozone Observations were made in 1928-29 at Kodaikanal as part of Dobson's worldwide Total Ozone Measurements.
- IMD acquired first Dobson Spectrophotometer in 1940 and regular observations are available from 1957.
- Development of Indian Ozone sonde by Instrument division of IMD in 1964. Vertical Ozone profiles using indigenous balloon-borne ozone-sondes were observed fortnightly at 4 stations including Maitri.
- IMD's National Ozone Centre at New Delhi is designated as Secondary Regional Ozone Centre for Regional Association II (Asia) of the World Meteorological Organisation.
- The centre maintains and controls a network of ozone monitoring stations including Maitri (Antarctica).
- Total ozone is measured with Dobson/Brewer Ozone Spectrophotometer from five locations including Maitri (Antarctica).

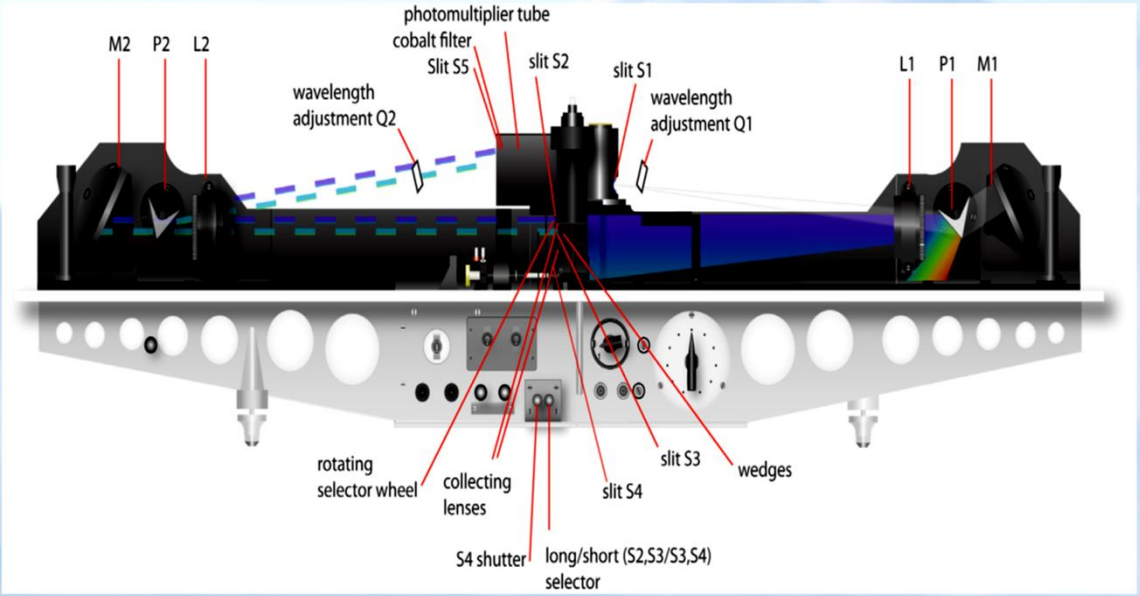
Total Columnar Ozone Measurements in IMD

- The first Columnar Ozone Observations in India were made in 1928-29 at Kodaikanal as part of Dobson's worldwide Total Ozone Measurements.
- IMD acquired first Dobson Spectrophotometer in 1940.

S. No.	Name of Station	Lat.	Long.	Instrument Type & S. No.	Frequency of Obsn.	Since when
1.	Srinagar	34^0 05' N	74^0 50' E	Dobson 10	6/day	Nov. 1955
2.	New Delhi	28^0 35' N	77^0 12' E	Dobson 36	6/day	Jan. 1955
3.	New Delhi	28^0 35' N	77^0 12' E	Brewer 089	Continuous	Aug. 1994
4.	Varanasi	25^0 18' N	83^0 01' E	Dobson 55	6/day	Dec. 1963
5.	Pune	18^0 32' N	73^0 51' E	Dobson 39	6/day	Mar. 1973
6.	Kodaikanal	10^0 14' N	77^0 28' E	Dobson 45	6/day	July 1957
7.	Kodaikanal	10^0 14' N	77^0 28' E	Brewer 094	Continuous	May 1994
8.	Maitri (Antarctica)	70^0 48' S	11^0 42' E	Brewer 153	Continuous	July 1999
9.	New Delhi	National Standard		Dobson 112	Since April 1969	

Total Columnar Ozone Measurements in IMD

- IMD is collaborating at both the national and international levels through international inter-comparison of instruments.
- IMD's National Ozone Centre at New Delhi is designated as Secondary Regional Ozone Centre for Regional Association II (Asia) of the World Meteorological Organization.
- National Standard Donson is inter-compared with world standard in international inter-comparisons held at Belsk (1974), Boulder (1977), Melbourne (1984) and Japan (1996 & 2006).



Dobson Spectrophotometer

Brewer Spectrophotometer

Measurement of Total Column Ozone by Dobson Spectrophotometer

WMO Calibration Campaign, 2019
Irene, South Africa

- IMD is taking measurements of total column ozone by Dobson Spectrophotometer at two stations e.g. New Delhi and Varanasi.

- The Brewer spectrophotometer measures ozone based on the same technique as the Dobson instrument.

Techniques for Measuring Atmospheric Ozone

The following parameters of ozone are being measured at IMD stations:

- Surface Ozone Measurement using UV Ozone Analyzer
- Surface Ozone Measurement using Electrochemical Concentration Cell (ECC)
- Total Columnar Ozone using Dobson / Brewer Spectrophotometer
- Vertical Distribution of Ozone using Electrochemical Ozone-sonde.

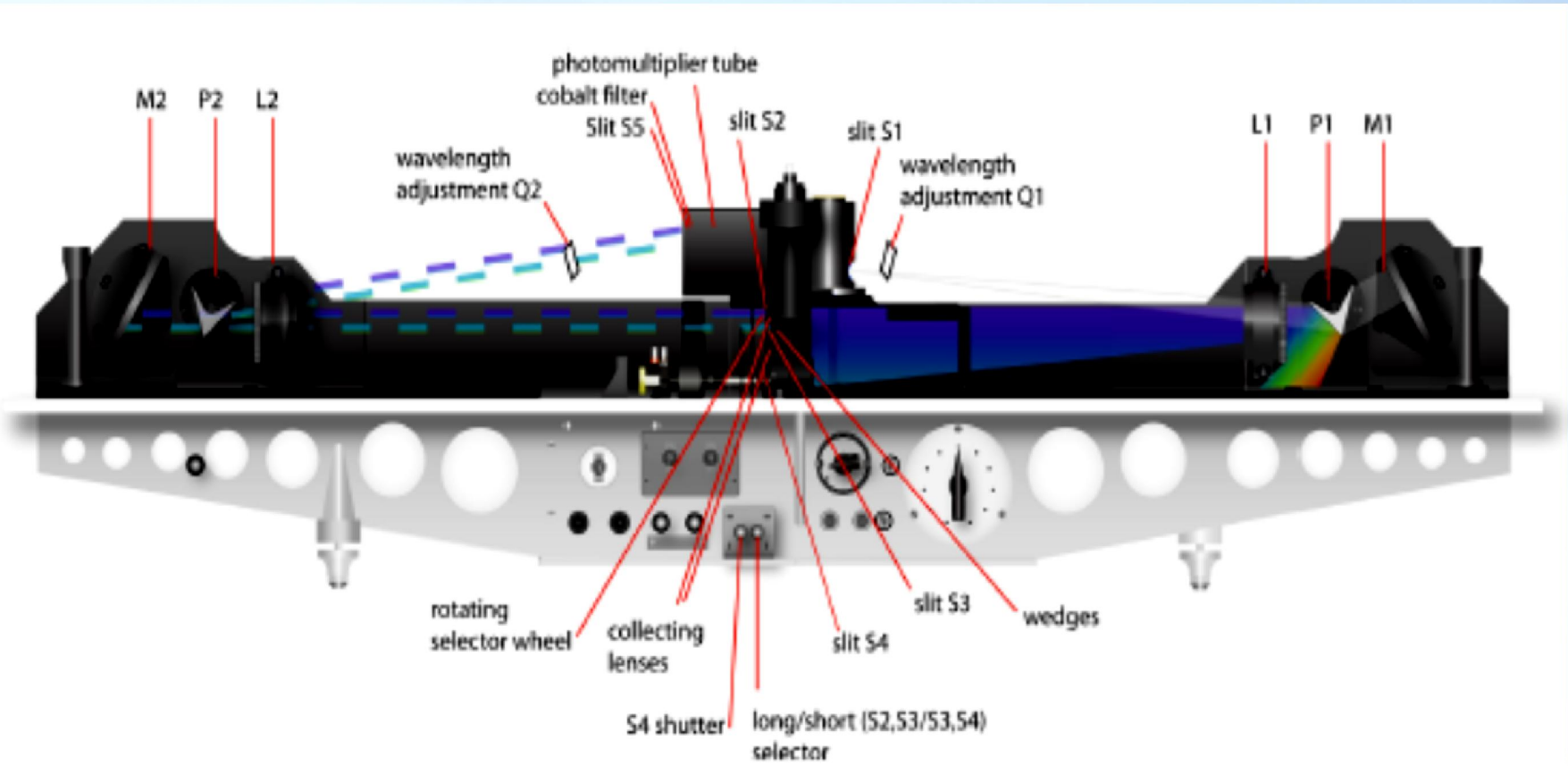
Measurement of Total Column Ozone by Dobson Spectrophotometer

- IMD is taking measurements of total ozone by Dobson Spectrophotometer at two stations e.g. New Delhi and Varanasi.

- The Dobson Spectrometer measures the total ozone by measuring the relative intensity of the dangerous UVB radiation that reaches the Earth and comparing it to that of UVA radiation at ground level. If all of the ozone were removed from the atmosphere, the amount of UVB radiation would equal the amount of UVA radiation on the ground.

- As ozone does exist in the atmosphere, the Dobson Spectrometer can use the ratio between UVA and UVB radiation on the ground to determine how much ozone is present in the upper atmosphere to absorb the UVC radiation.

The ratio is determined by turning the R-dial, which can be rotated a full 300°, on the instrument. The spectrometer compares two different wavelength intensities, UVB (305 nm) and UVA (325 nm), in order to calculate the amount of ozone. When turned, the R-dial filters and blocks out the light of the UVC wavelength until the intensity of the two wavelengths of light are equal. The ratio of the two wavelengths at incidence can be deduced once the filtered intensities are the same. The results are measured in Dobson Units.



Measurement of Total Column Ozone by Brewer Spectrophotometer

IMD was taking measurements of total ozone by Brewer Spectrophotometer at two stations e.g. New Delhi and Kodaikanal.

The Brewer spectrophotometer measures ozone based on the same technique as the Dobson instrument.

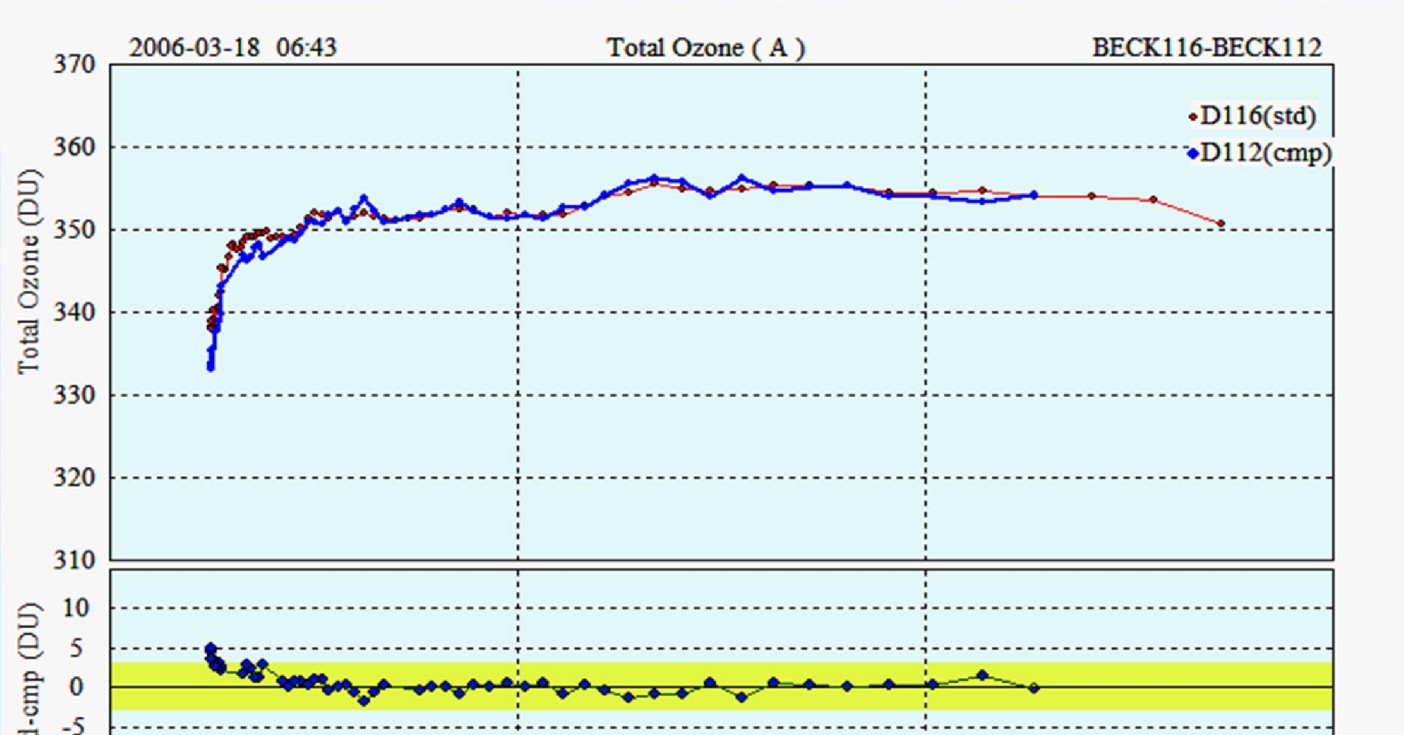
Unlike the Dobson instrument, however, the Brewer spectrophotometer is completely automated and can be programmed by a laptop computer to make measurements at any given time during the day.

The absolute accuracy for a total ozone measurement made by a well calibrated Brewer instrument is estimated to be +/- 2.0%.

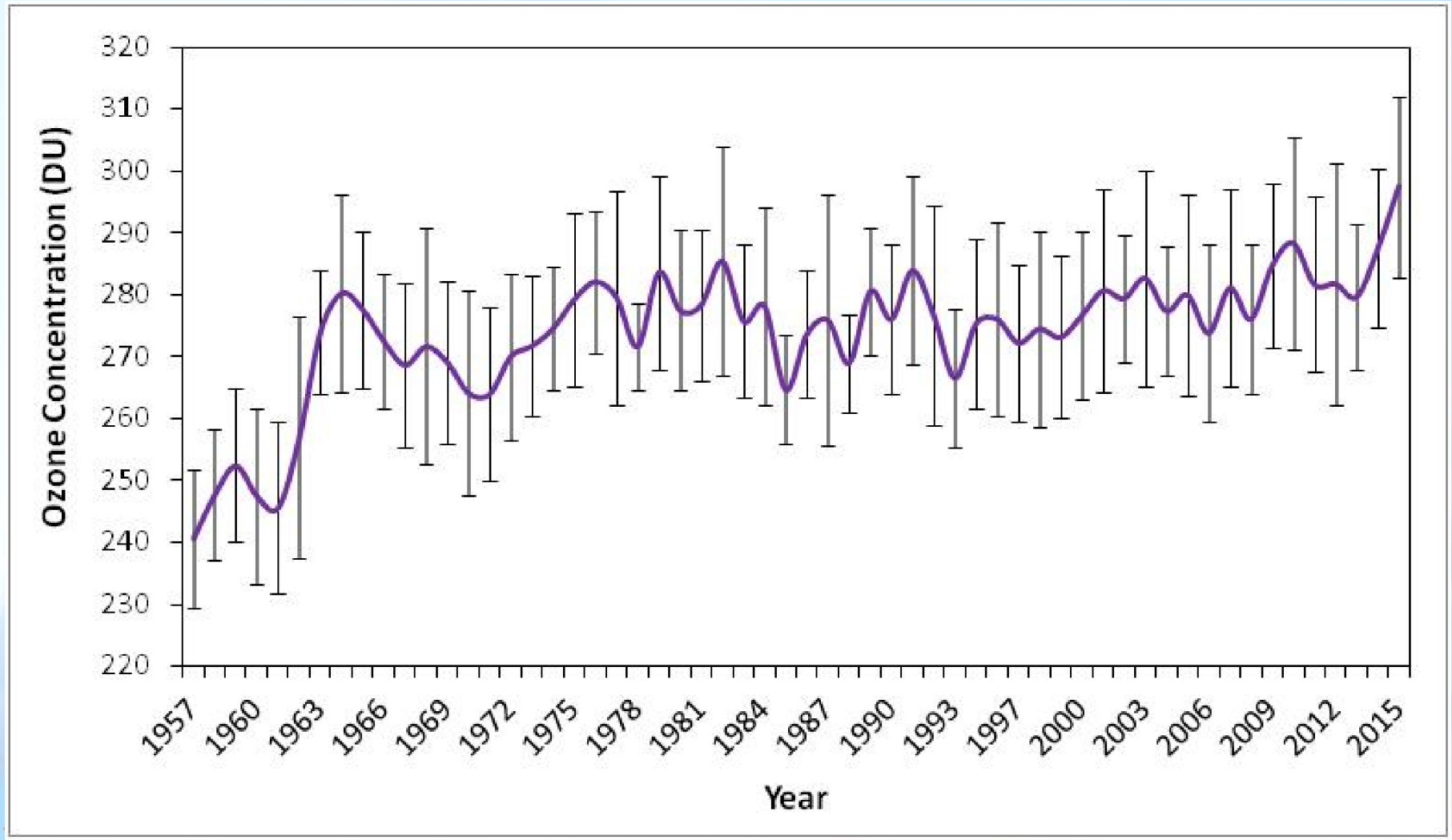
Calibration of IMD's Dobson Spectrophotometer

The results of 2006 Inter-comparison of Dobson Spectrophotometer no.112 are as follows :

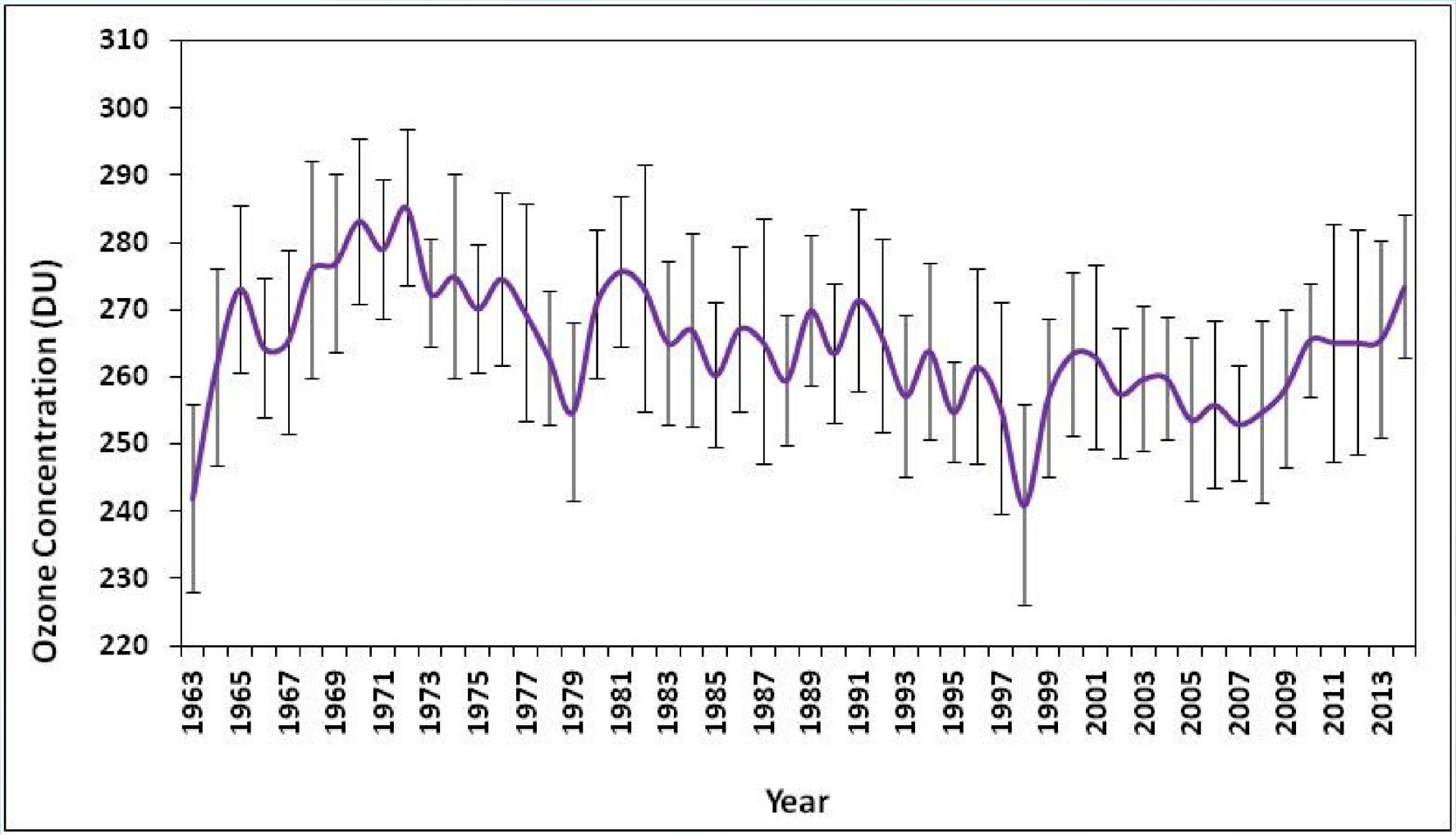
- Initial calibration results have showen that the d-Nad value shown an average + 0.2 % error in calculated ozone value, mu = 1 to 3, Total ozone=300 D.U.
- Final inter-comparison shows average difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.1% in total ozone.



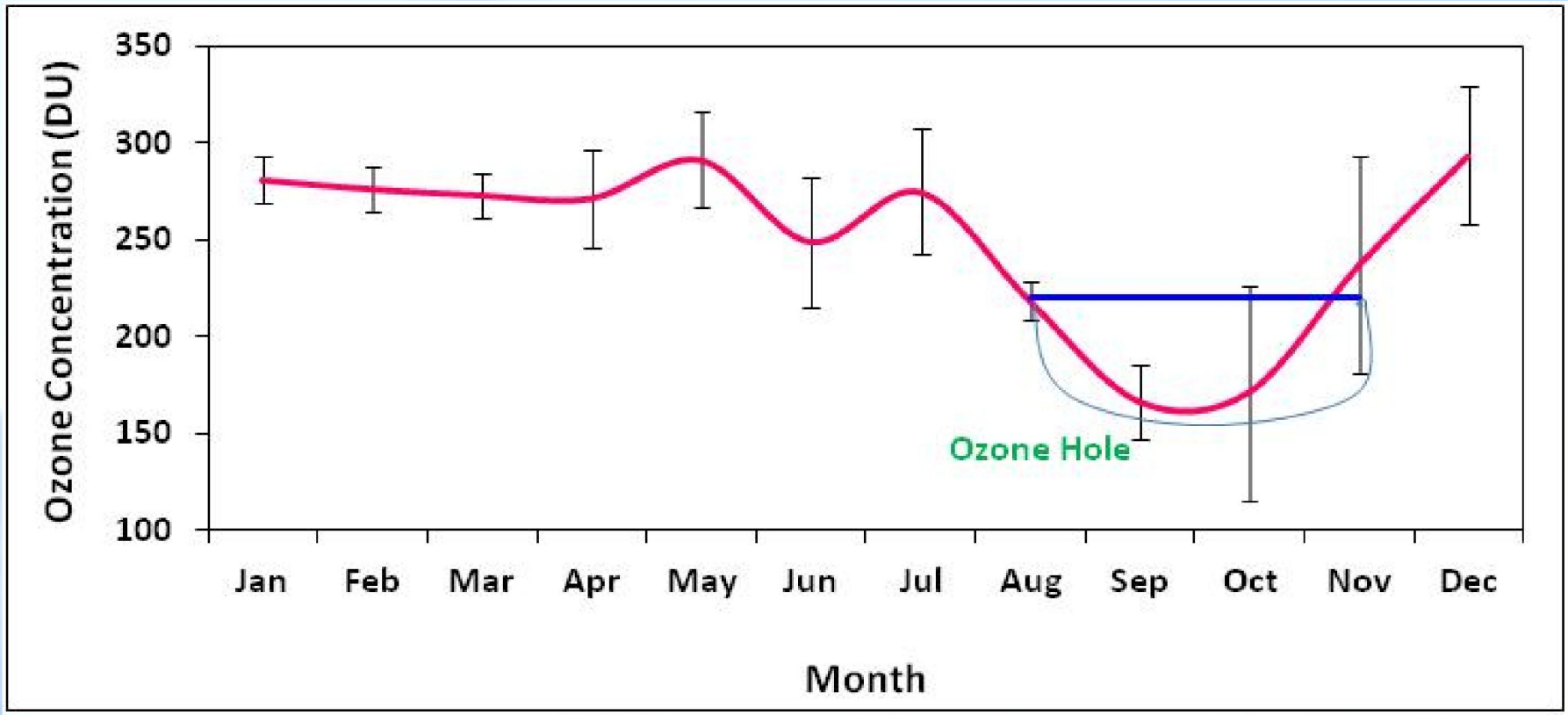
Variation of Yearly Averaged Total Columnar Ozone Concentration at Delhi (1957 - 2015)



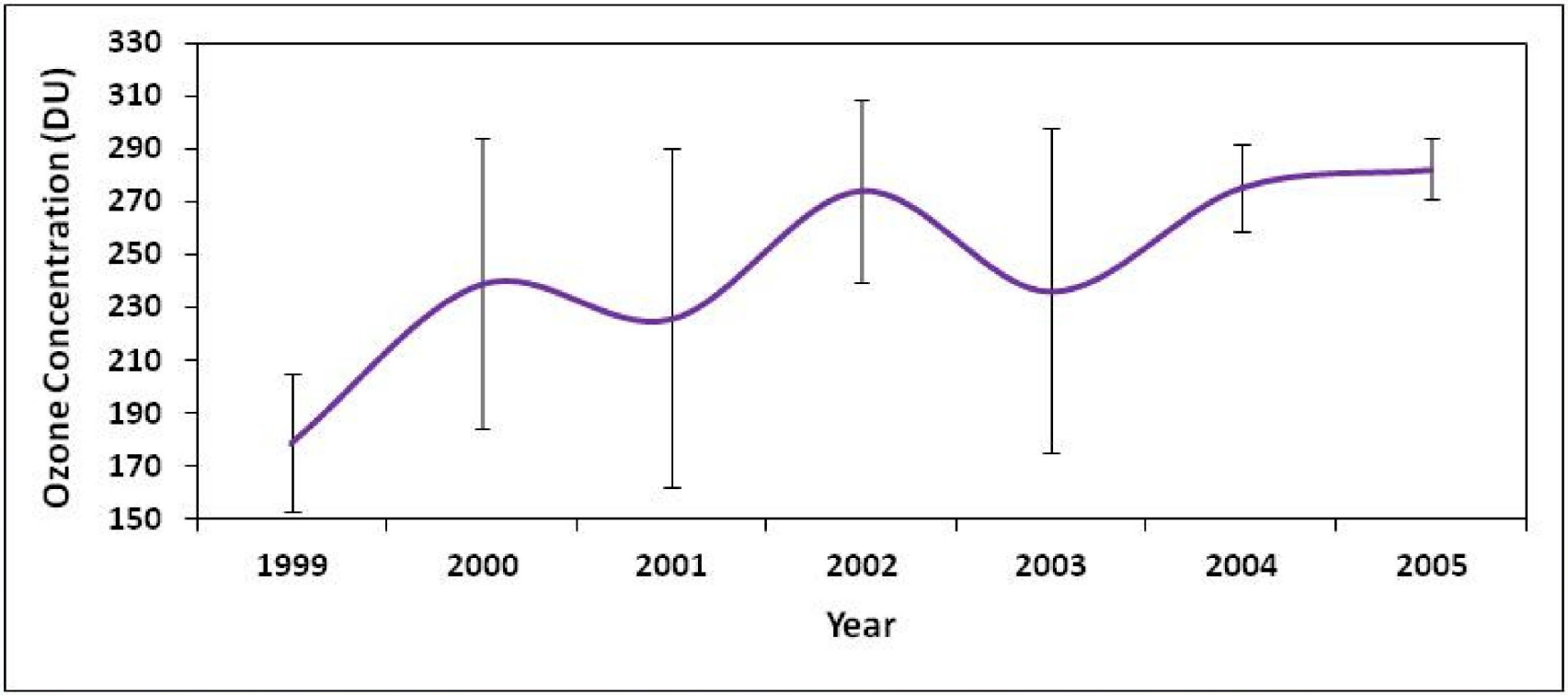
Variation of Yearly Averaged Concentration of Total Columnar Ozone at Varanasi (1963 - 2014)



Variation of Monthly Averaged Concentration of Total Columnar Ozone at Maitri, Antarctica (1999 - 2005)



Variation of Yearly Averaged Concentration of Total Columnar Ozone at Maitri, Antartica (1999 - 2005)



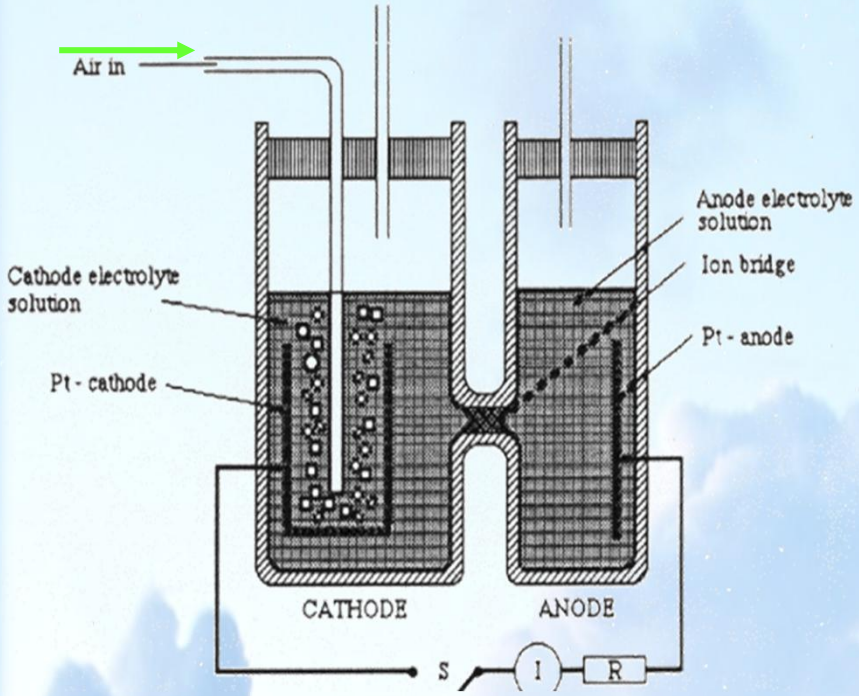
Surface Ozone Measurement in IMD

- Surface ozone measurements using electrochemical method had recorded continuously at 7 stations
    - Srinagar,
    - Pune,
    - Nagpur,
    - New Delhi,
    - Kodaikanal,
    - Trivandrum and
    - Maitri
- IMD had also installed Serinus 10 Surface UV Ozone Analyzers at nine locations e.g. New Delhi, Pune, Nagpur, Kodaikanal, Guwahati, Portblair, Ranichouri, Thiruvananthpuram, Antarctica and Varanasi.

Significant Values of Surface Ozone

- Average concentrations range from almost 0 ppb to over 150 ppb depending on time of year and geographic location.
- In extremely polluted conditions ozone can reach 200 ppb and more.
- Levels of surface ozone exceeding 80 ppb for 8 hours or longer are considered harmful for most living things.
- Increases often occur in urban and industrial areas during summer.

Electrochemical Conductivity Cell (ECC)



Idea:

Titration of ozone in a potassium iodide (KI) solution according the redox reaction:

$$2\ KI + O_3 + H_2O \rightarrow I_2 + O_2 + 2\ KOH$$

Measurement of "free" iodine (I_2) in electrochemical reaction cell(s). The iodine makes contact with a platinum cathode and is reduced back to iodide ions by the uptake of 2 electrons per molecule of iodine:

$$I_2 + 2\ e^- \text{ on Pt} \rightarrow 2\ I^- \quad \text{[cathode reaction]}$$

- The electrical current generated is proportional to the mass flow of ozone through the cell
- Continuous operation through pumping of air through the solution

Applications: Measurement of vertical O_3 distribution up to the stratosphere, Surface O_3

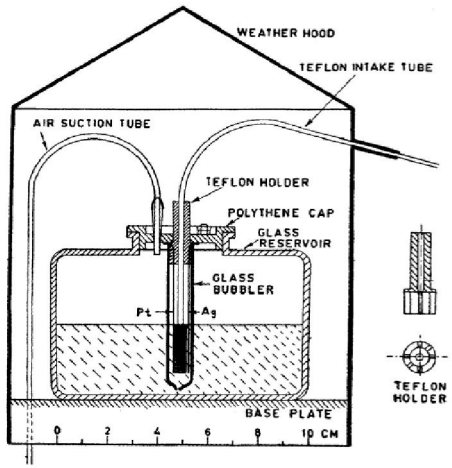
Problems: Interference by SO_2 (1:1 negative) and NO_2 (5-10% positive)

- Solution preparation has large impact on measurement accuracy
- Pump efficiency is reduced at high altitudes

The ozone recording system consists of a modified bubbler sensor, a suitable miniature pump, a network for supplying a polarizing potential to the bubbler and a recorder capable of full scale deflection for a current of 2uA. The recorder is calibrated by a micro ampere current source. From the record, the Ozone current in μA is determined and the partial pressure P of Ozone is calculated from the formula :

$$P(\mu\ mb) = 4.31 \times 10^{-3}\ i\ .T.t$$

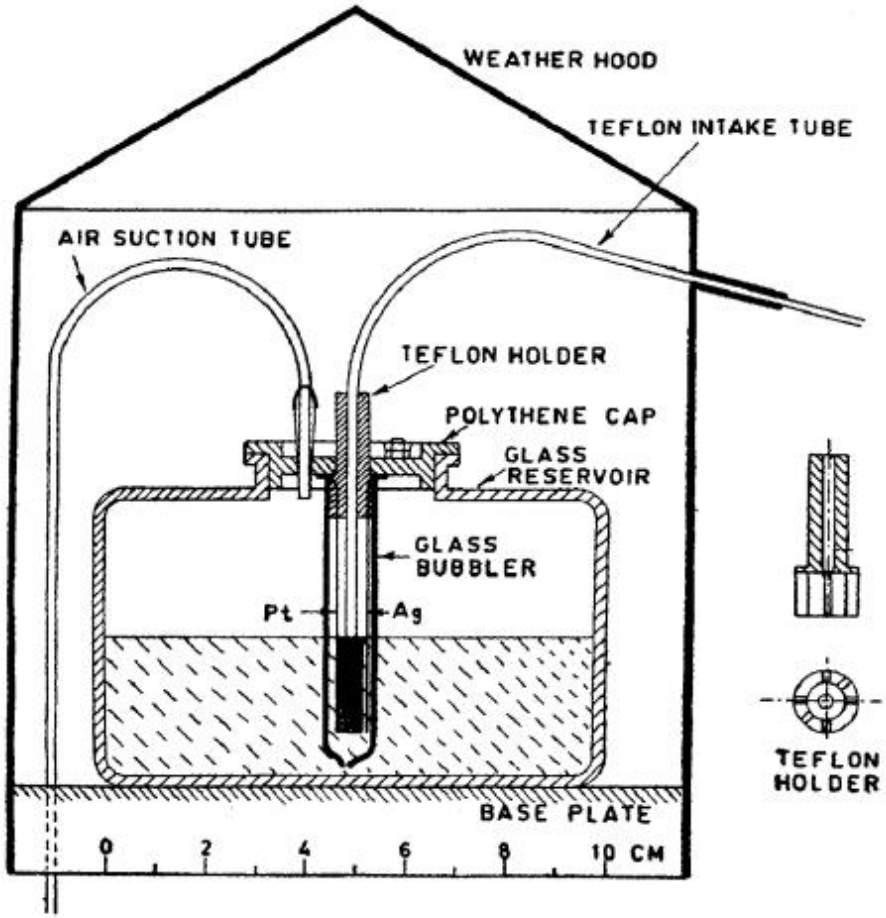
Where i is the ozone sensor current in mA, T is the temperature of the air in Kelvin and t is time in seconds for pumping 100 ml of air. The system has a response time of few seconds and has a resolution capability of 0.1 part of Ozone per 100 million parts of air. The overall accuracy is about 5 %.



Surface Ozone Sensor

S. No.	Name of Station	Lat.	Long.	since when
1.	New Delhi	28° 35'N	77° 12'E	1972
2.	Pune	18° 32'N	73° 51'E	1971
3.	Kodaikanal	10° 14'N	77° 28'E	1976
4.	Thiruvananthapuram	08° 20'N	76° 57'E	1973
5.	Nagpur	21° 04'N	79° 02'E	1978
6.	Srinagar	34° 05'N	74° 50'E	1981
7.	Dakshin Gangotri	70° 03'S	12° 00'E	1986-89
8.	Maitri	70° 48'S	11° 42'E	1990

Surface Ozone using IMD ECC method



Surface Ozone Sensor

Surface Ozone using IMD ECC method

1) Ozone Glass Sensor (modified bubbler sensor)
2) Miniature pump
3) Ozone Amplifier
4) Data logger

Maintenance

- Preparation of KI solution – Once every month
- Pump Maintenance
- Data Logger

KI Solution: 1 gm KI in 1000 cc double distilled water.

The buffers 1.26 gm of Na2HPO4.2H20 and 2.6 gm of NaH2PO4.2H20 are added to keep the pH within tolerable limit

Routine Operation: Sensor

- Normally the sensor will not require any attention for about 15 days.
- The solution has to be added when the level goes below the limits indicated on the bottle.
- For replenishing the solution, remove the lid and pour the solution, gently until the original level is reached.

Routine Operation: pump and motor

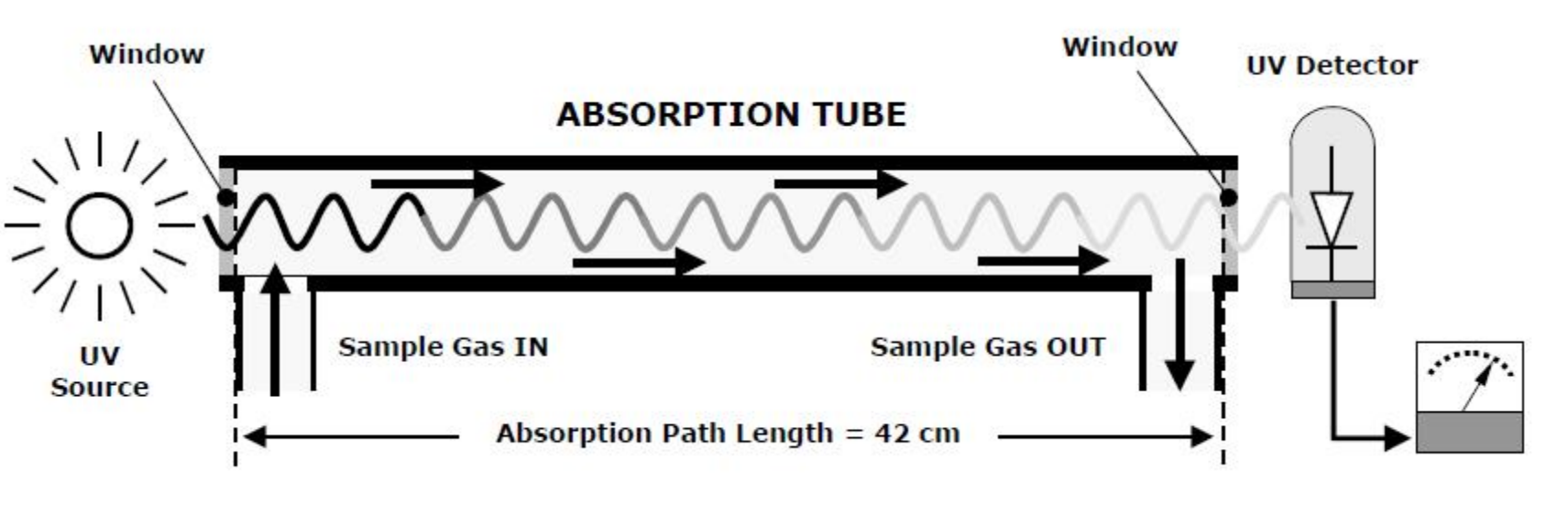
- The pump has to be oiled once in a week with a few drops of SAE-30 lubricating oil.
- A thin layer of oil about 1 mm deep will be sufficient. The motor has to be oiled once a week.
- Receptacles are provided on the sides of the motor for oil. Fill the receptacles with 3-in-1 oil.

Surface Ozone Measurements by UV Absorption Method

IMD had installed Serinus 10 Surface UV Ozone Analyzers at ten locations e.g. New Delhi, Pune, Nagpur, Kodaikanal, Guwahati, Portblair, Ranichouri, Thiruvananthpuram, Antarctica and Varanasi. The UV photometer determines the concentration of Ozone (O_3) in a sample gas at ambient pressure by detecting the absorption of UV radiation in a glass absorption tube. The Serinus 10 ozone analyzer follows these principles and measurement techniques:

- Ozone shows strong absorption of UV light at 254 nm
- Sample air is passed into the glass absorption tube (measurement cell)
- Within the measurement cell a single beam of UV radiation passes through the sample and is absorbed by the Ozone (O_3)
- The solar blind vacuum photodiode detects any UV that is not absorbed
- The strength of the UV signal being detected is proportional to the amount of UV light being absorbed by Ozone (O_3)
- The Serinus 10 ozone analyzer uses the Beer-Lambert relationship to calculate the ozone concentration

Surface Ozone analyzer
UV Absorption Ozone Analyzer



- **UV photometer determines ozone concentration by measuring the attenuation of light due to ozone in the absorption cell.**
- **Absorption wavelength is 254 nm.**
- **The concentration of ozone is directly related to the absorbance.**

Problem – other gases absorb at 254 nm.

Solution: Add a reference cycle to the sample cycle - use a manganese dioxide scrubber to selectively remove ozone from the sample gas, measure absorbance due to interferants, and subtract interferants from sample cycle.

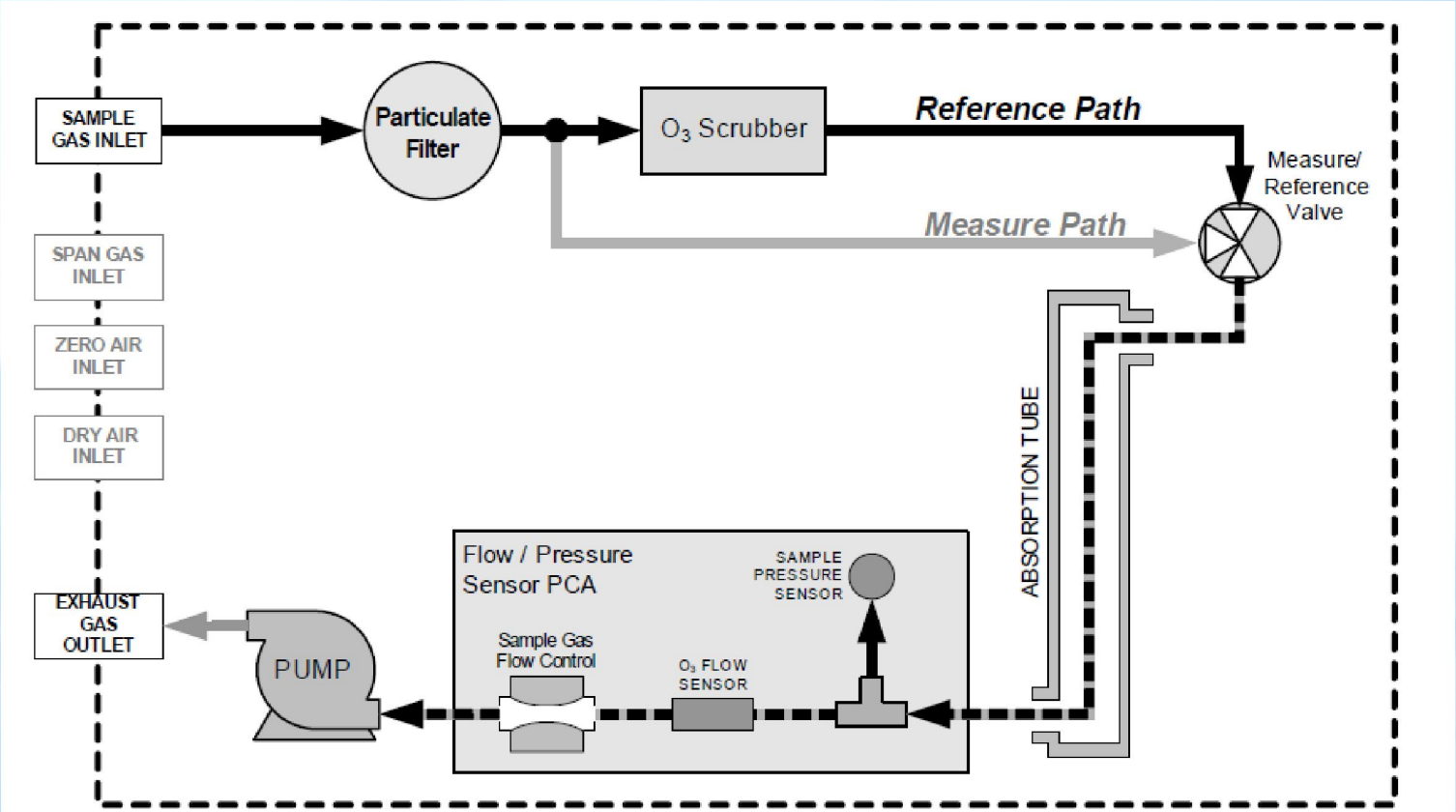
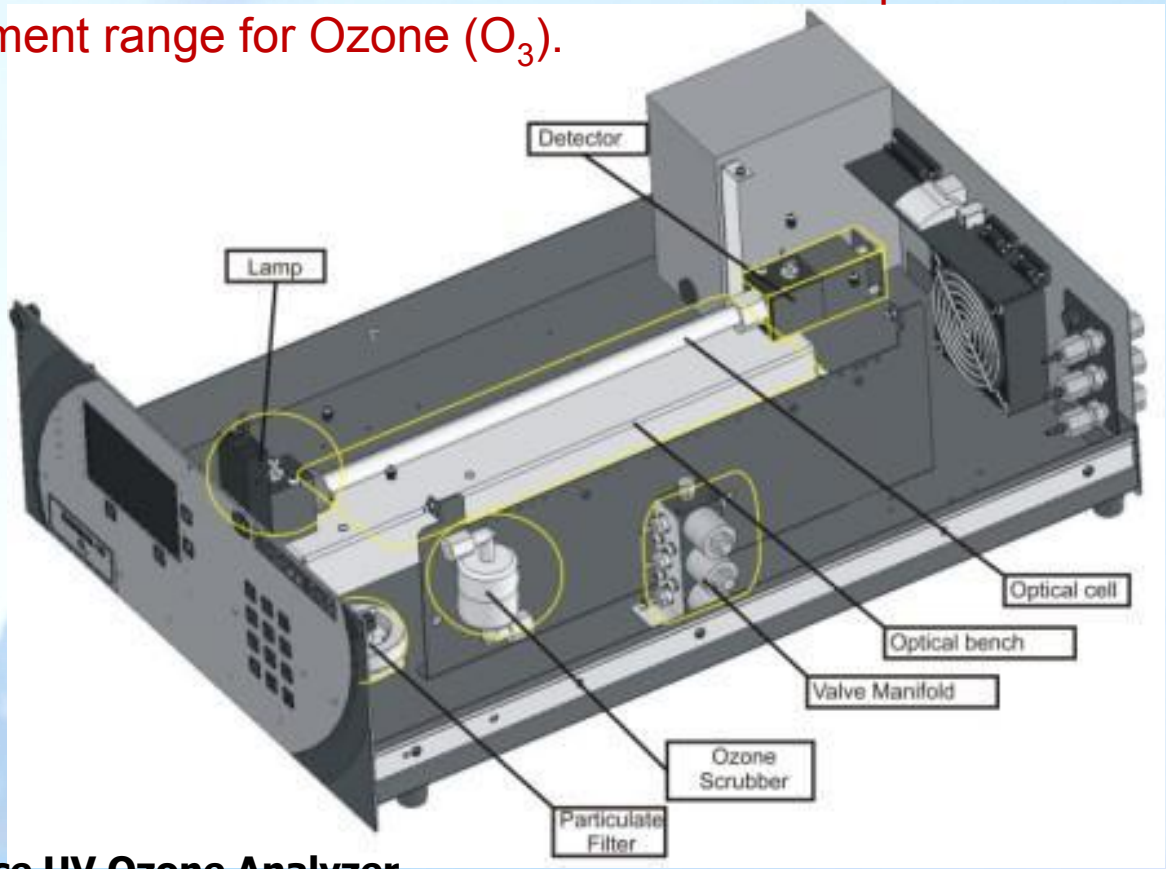


Figure 11-2: Reference / Measurement Gas Cycle

- The Serinus 10 Ozone analyzer has a sensitivity of 0.5 ppb in the range of 0 - 20 ppm.
- The Ozone (O_3) concentration is automatically corrected for gas temperature and pressure changes and referenced to 0°C, 20°C or 25°C at 1 atmosphere. This allows the Serinus 10 to sample in the most common measurement range for Ozone (O_3).



Serinus 10 Surface UV Ozone Analyzer

Siting Requirements

- Because O_3 is a reactive gas, measurements in many locations are required to define its spatial and temporal variations.
- Near sources of industrial pollution or biomass burning, O_3 concentrations are generally elevated due to photochemical production.
- At sites more remote from these primarily anthropogenic influences, background measurements may be representative of broad geographic regions.
- The elevation of a site may be an important factor in determining the type of measurement obtained. For example, stations located at high elevation mountain sites are frequently representative of the free troposphere.
- At boundary layer sites in marine environments, photochemical losses usually dominate while stations downwind of pollution sources will measure higher values of O_3.

QA/QC

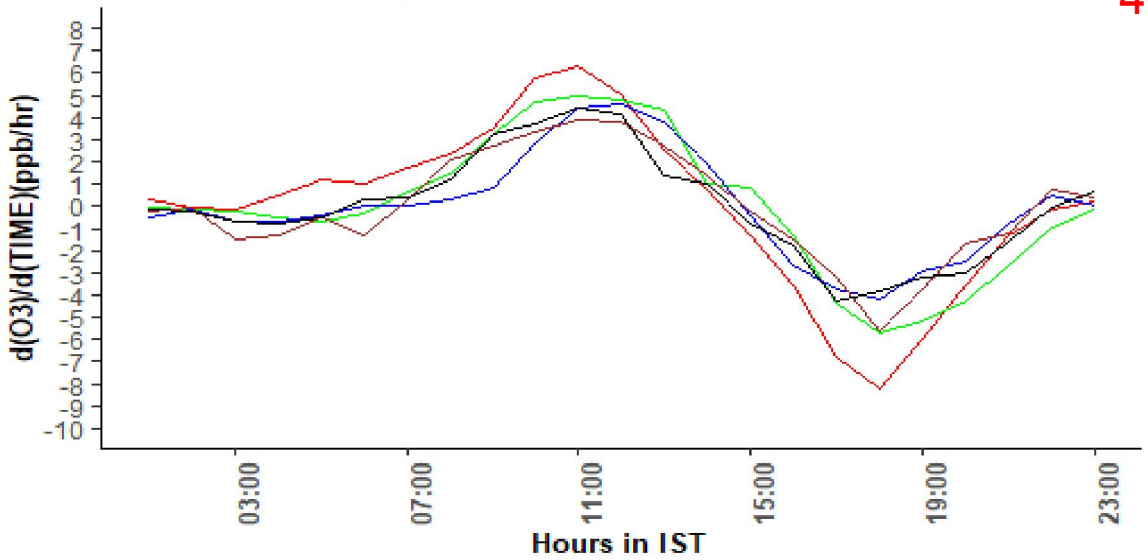
- On a daily to weekly schedule, the instrument is given a "zero" check by sampling air with ozone removed to determine the zero level of the instrument.

- A "span" concentration can also be provided to the instrument to check its operation.

- All data should be routinely inspected by the trained operator in order to flag erroneous measurements.

Average Rate of Change of Ozone

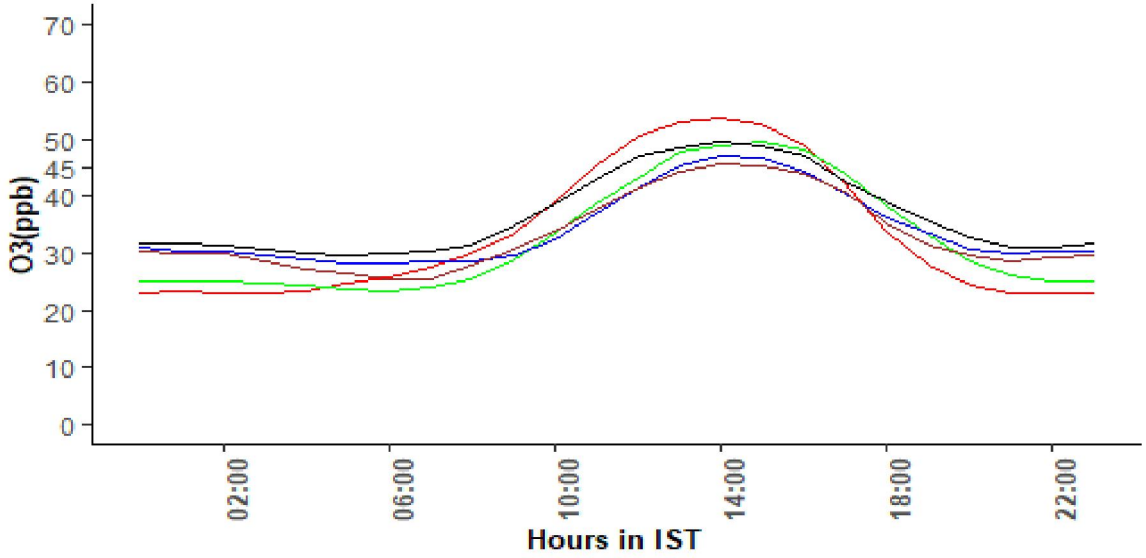
4.16 ppbh^{-1} and -4.48 ppbh^{-1}



IMD.LODI.ROAD
IGI.AIRPORT.PALAM
CRRI.MATHURA.ROAD
NCMRWF.NOIDA
CV.RAMAN.DHEERPUR

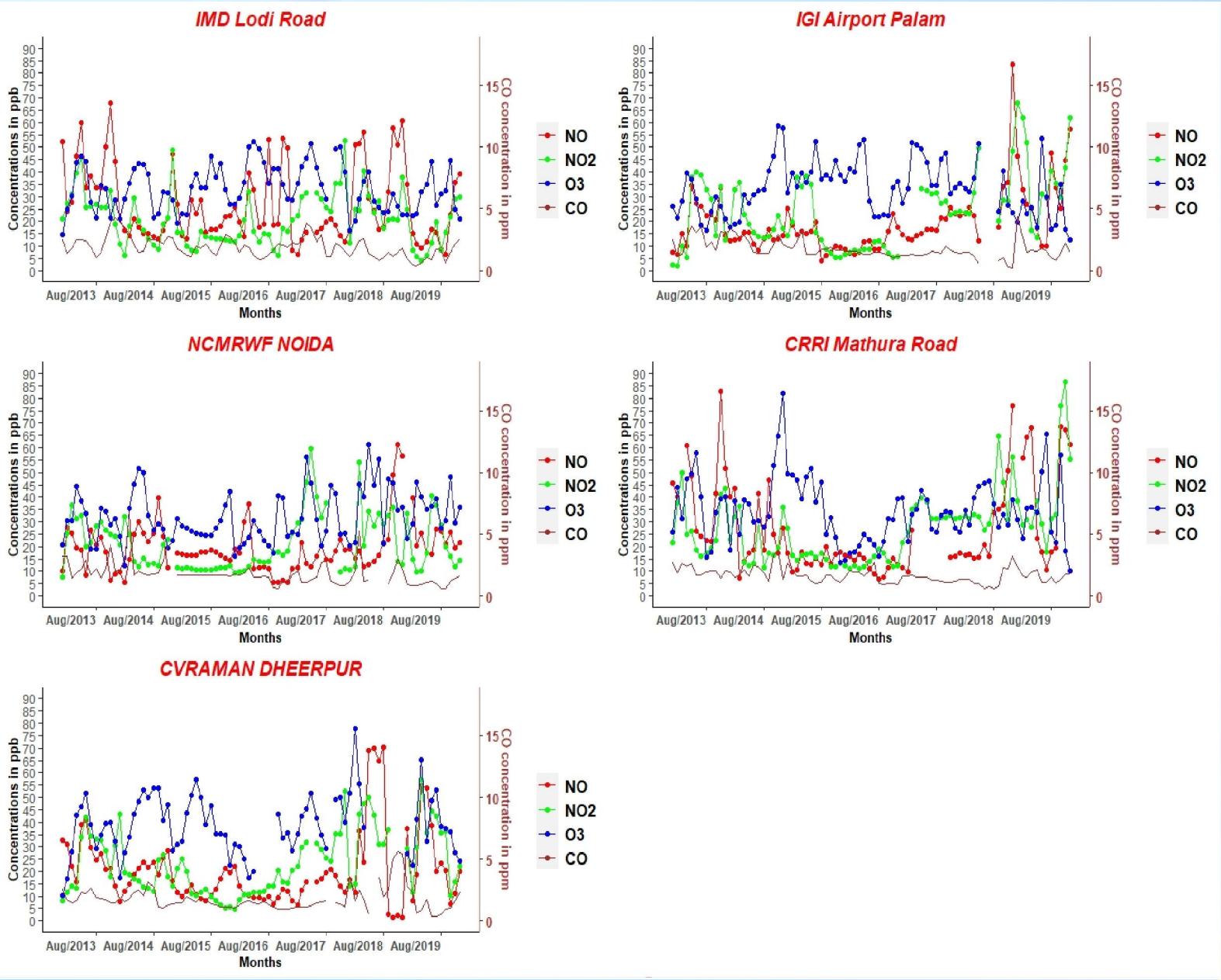
Diurnal Variation of Ozone

Data Period : 2013 - 2019

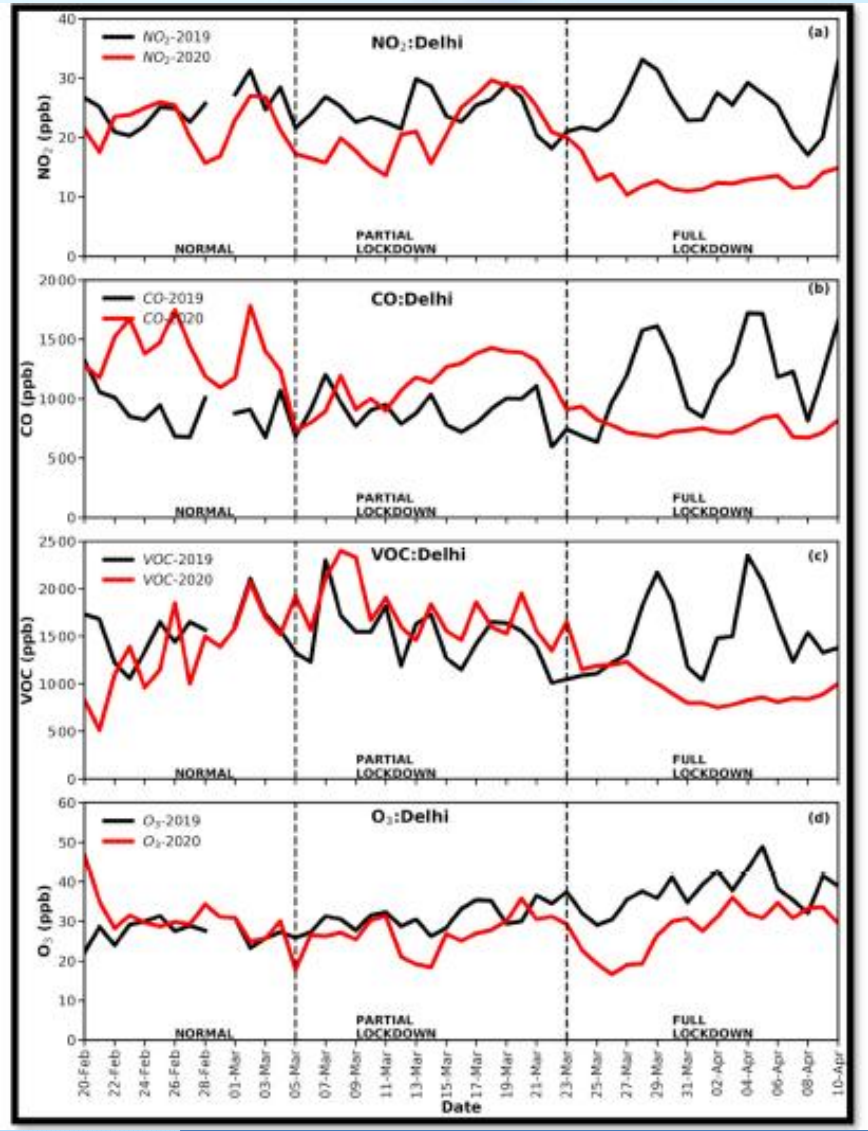


IMD.LODI.ROAD
IGI.AIRPORT.PALAM
CRRI.MATHURA.ROAD
NCMRWF.NOIDA
CV.RAMAN.DHEERPUR

Variation of monthly averaged concentration of NO, NO_2, O_3 and CO in Delhi



Anomalous behaviour of ozone under COVID-19 and explicit diagnosis of O3-NOx-VOCs mechanism (A. Rathod et. al., 2021)



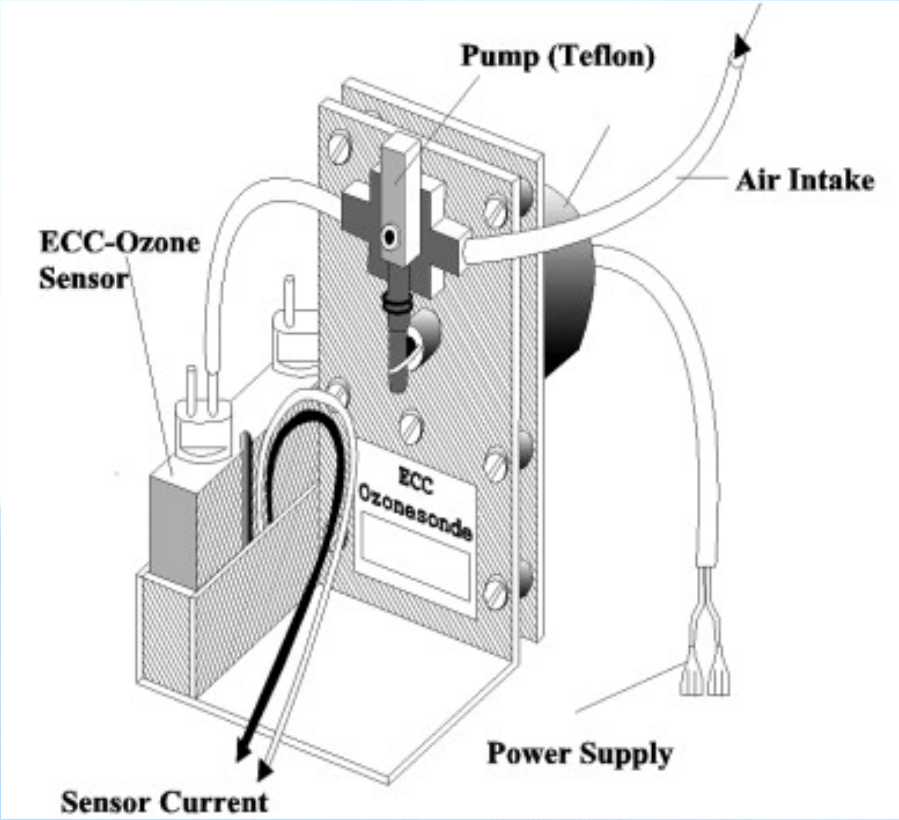
Percentage change in O_3, NO_2, CO, and VOCs during Partial Lockdown and Full Lockdown as compared to normal period

Percentage Change/ Pollutant	O_3	NO_2	CO	VOC
After w.r.t. Before (Full Lockdown)	- 3 %	-41 %	-39 %	-39 %
Full lockdown w.r.t. Partial Lockdown	3 %	-40 %	-34 %	-46 %
Full Lockdown w.r.t to Normal	-7 %	-42 %	-44 %	-31 %

Measurement of Vertical Distribution of Ozone (Ozone Sonde)

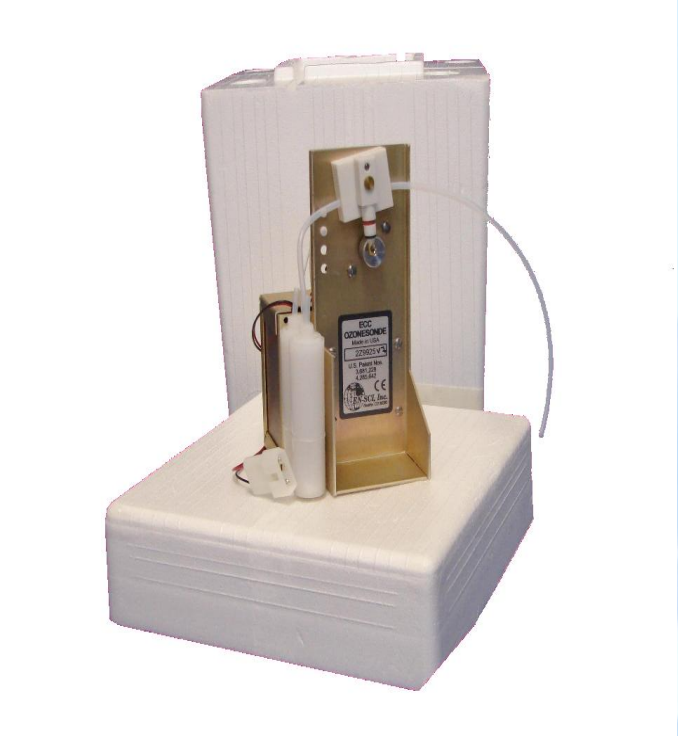
- Vertical ozone profiles using balloon-borne ozone-sondes are observed fortnightly at New Delhi.
- The ozone-radiosonde is a lightweight, balloon-borne instrument that is mated to a conventional meteorological radiosonde.
- As the balloon carrying the instrument package ascends through the atmosphere, the ozone-radiosonde telemeters to a ground receiving station information on ozone and standard meteorological quantities such as pressure, temperature and humidity.
- The balloon will ascend to altitudes of about 115,000 feet (35 km) or about 3 hPa before it bursts.
- The heart of the ozone-radiosonde is an electrochemical concentration cell (ECC) that senses ozone as is reacts with a dilute solution of potassium iodide to produce a weak electrical current proportional to the ozone concentration of the sampled air.
- Ozonesondes are composed of an ozone sensor, a battery, a small gas pump, and some electronic circuit boards.
- The ozone sensor, an electrochemical concentration cell (ECC), consists of two small chambers containing solutions of potassium iodide (KI).

The ozone sensor is connected to a meteorological radiosonde. This radiosonde transmits values of air temperature, air pressure, relative humidity, detector current, detector temperature, and pump speed to a ground receiving station. The air containing the ozone sample is pumped through a solution which is oxidized by this ozone producing an electrical current. The electrical current is proportional to the flow of ozone. By knowing the flow (pump speed), the ozone concentration can be deduced. The result is an ozone partial pressure vertical profile.



Schematic of an electrochemical concentration cell (ECC) Ozone sonde

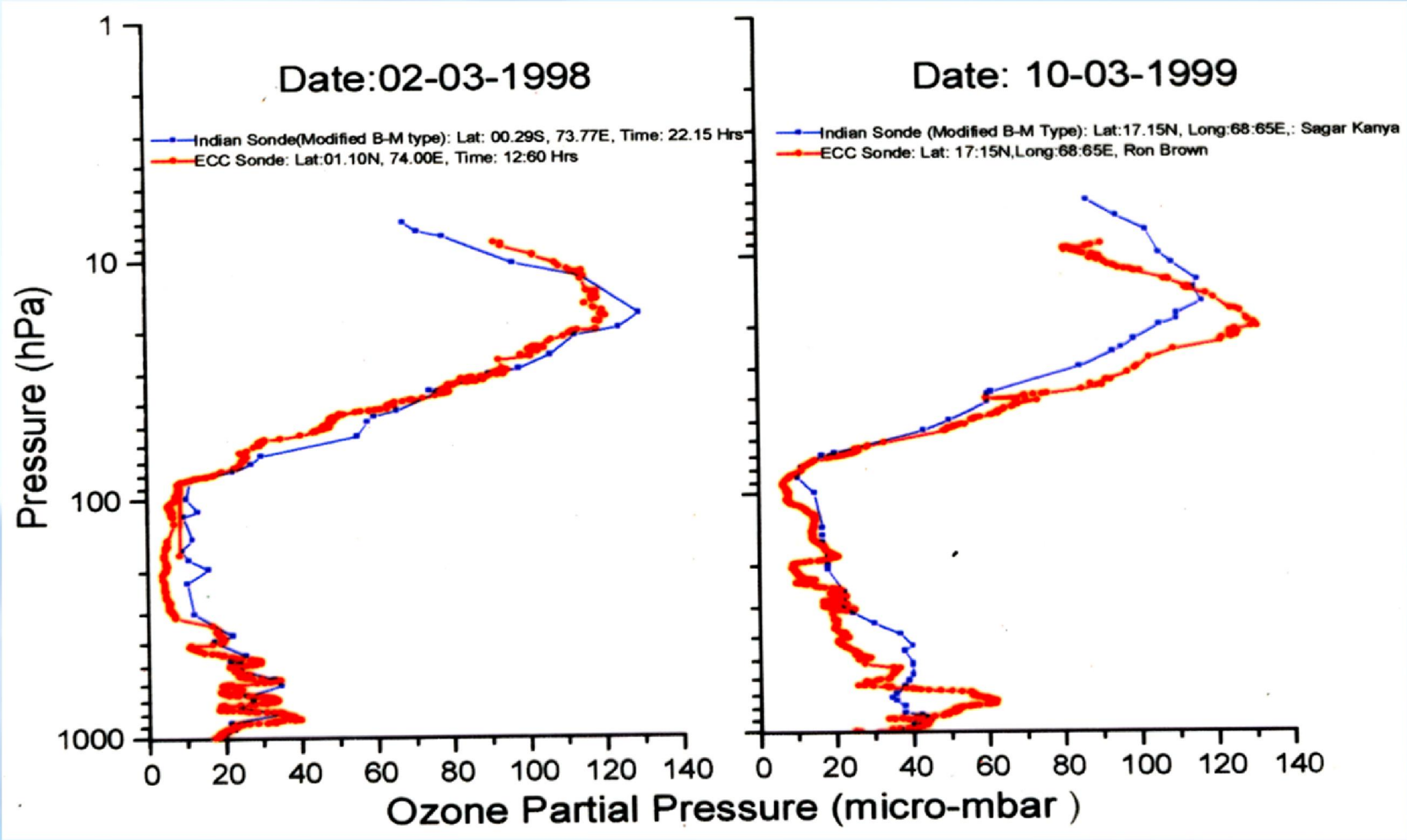
ELECTRO CHEMICAL METHOD:



(i)

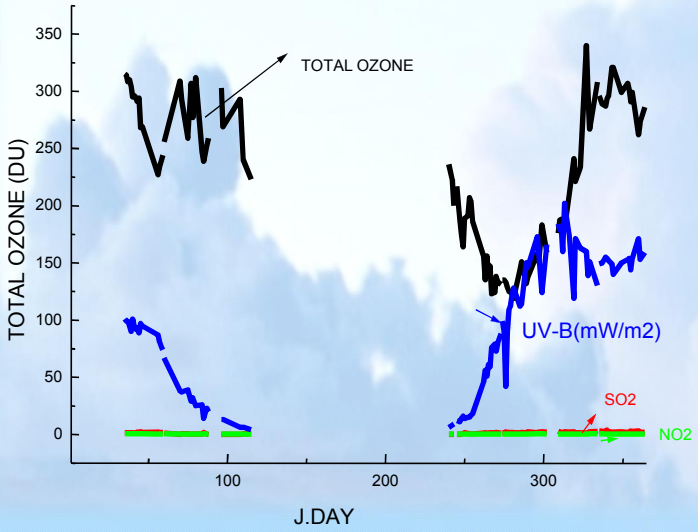
(ii)

Comparison of IMD's Ozone sonde with ECC sonde during INDOX – 1999 experiment



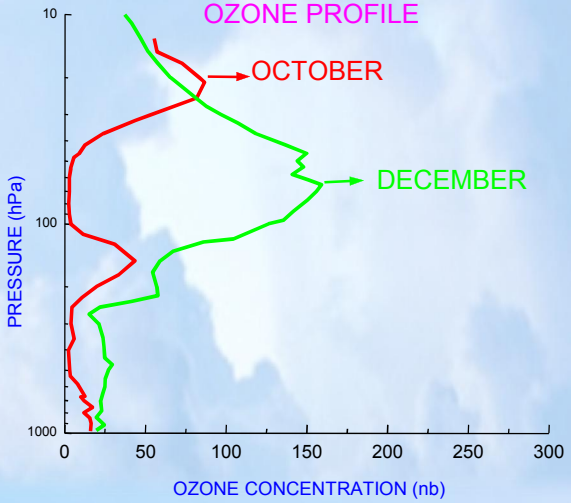
BREWER OZONE SPECTROPHOTOMETER AT MAITRI (ANTARCTICA)

MAITRI: BREWER DATA



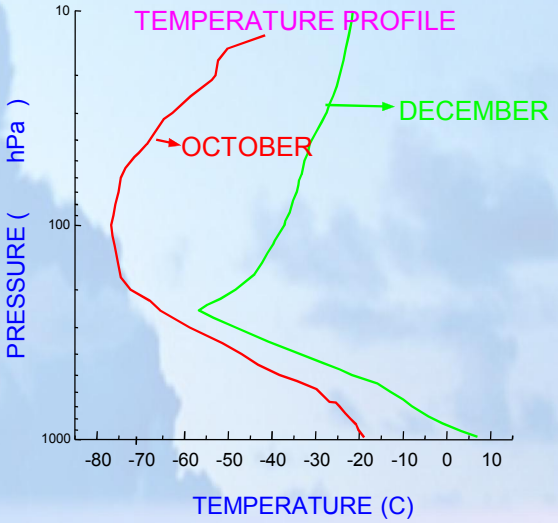
MAITRI

OZONE PROFILE



MAITRI

TEMPERATURE PROFILE



भारत मौसम विज्ञान विभाग

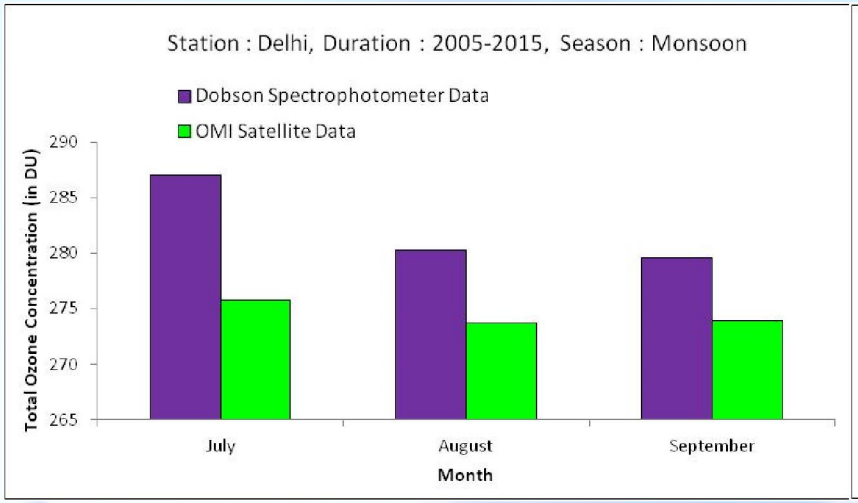
INDIA METEOROLOGICAL DEPARTMENT

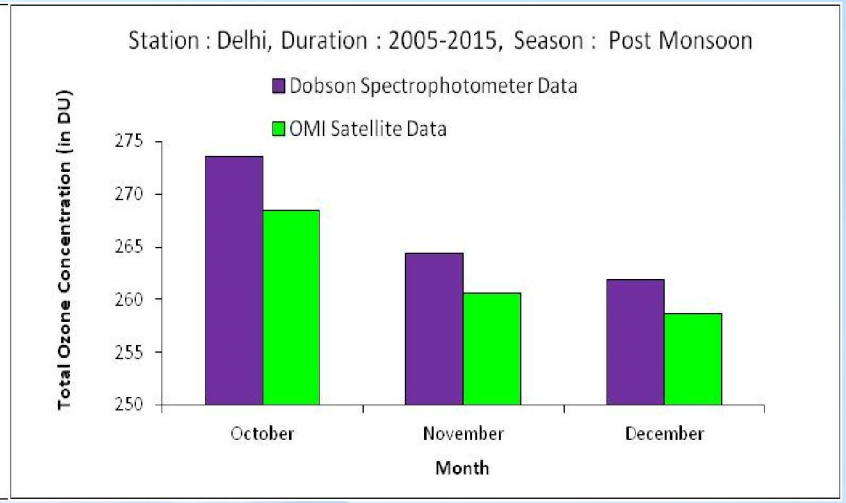
❖ Satellite Measurements

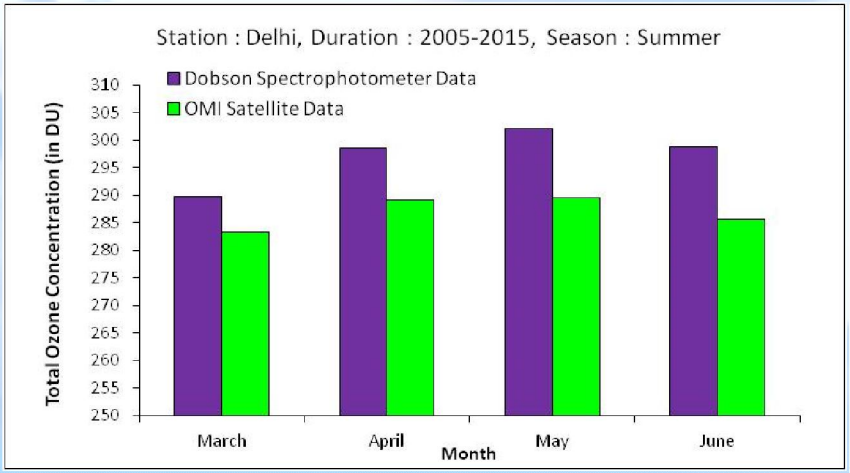
Satellites measure ozone over the entire globe every day, providing comprehensive data. In orbit, satellites are capable of observing the atmosphere in all types of weather, and over the most remote regions on Earth.

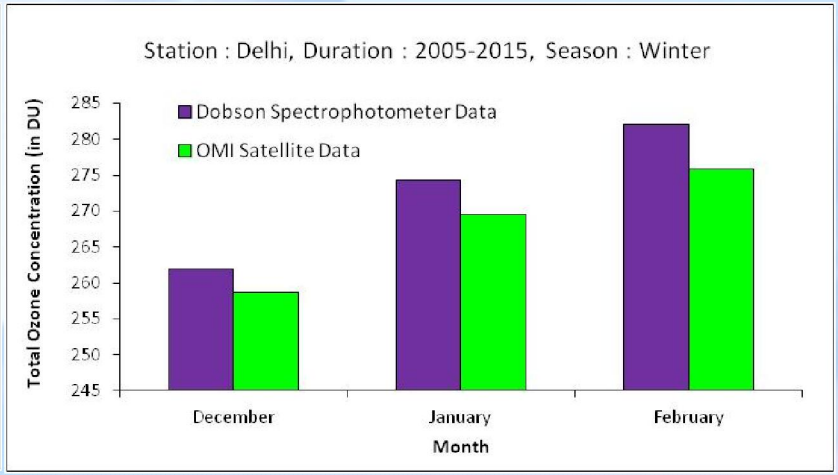
They are capable of measuring total ozone levels, ozone profiles, and elements of atmospheric chemistry. In the mid-1980s wide-ranging ozone depletion over the Antarctic was first recognized from satellite data.

Ten Yearly Averaged Total Ozone Concentration at Delhi during 2005 – 2015 : A Comparative Representation

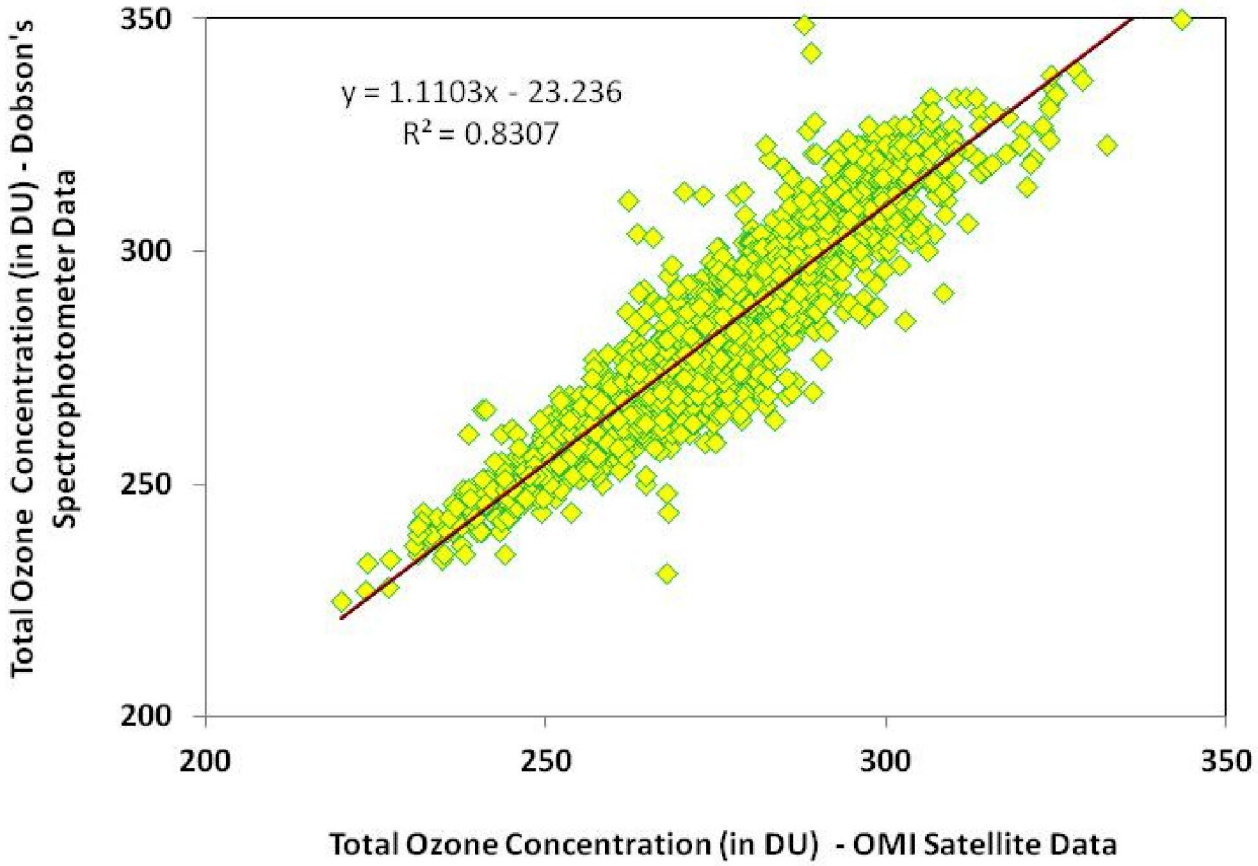








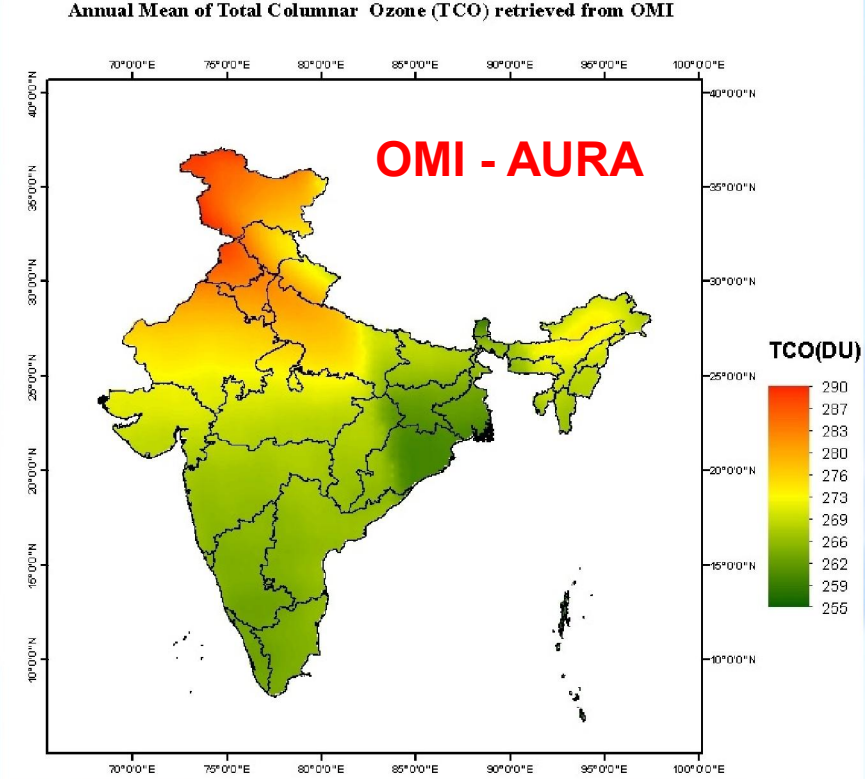
Correlation between Dobson Spectrophotometer's data and OMI Satellite Observations over Delhi (2005 – 2015)

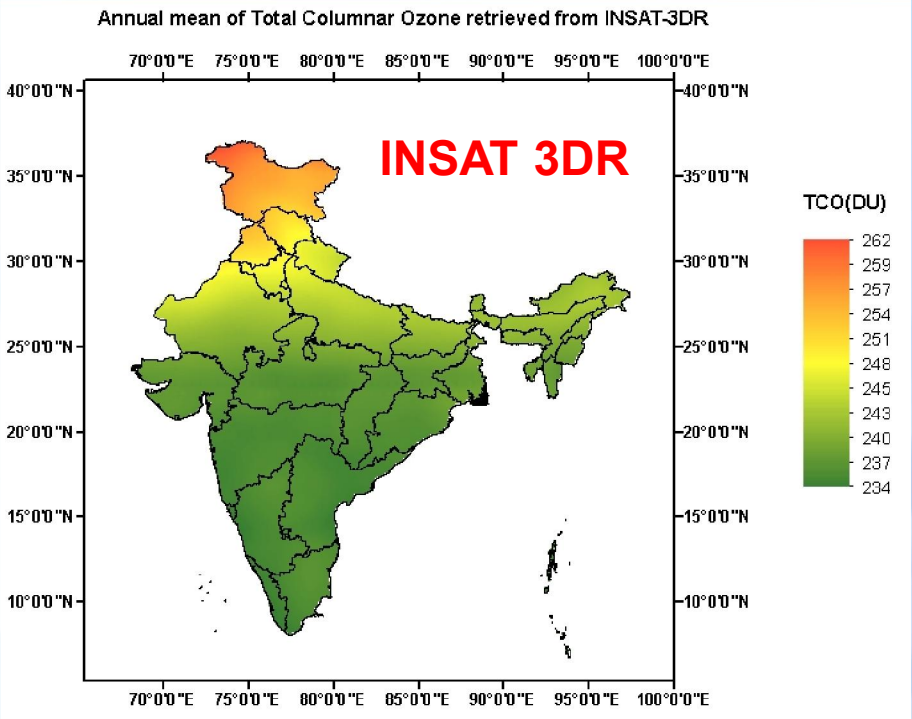


Strong correlations of 0.92 is found between OMI-TOMS and Dobson total columnar ozone. Overall, there is good agreement between OMI-TOMS and Dobson observations over Delhi.

Satellite Measurements

Year : 2020





What can We do?

- Keep your automobile well tuned and maintained.
- Carpool, use mass transit, walk, bicycle, and/or reduce driving, especially on hot summer days.
- During the summer, fill your gas tank during the cooler evening hours.
- Make sure your car's tires are properly inflated and your wheels are aligned.
- Seal containers of household cleaners, workshop chemicals and solvents, and garden chemicals to prevent VOC from evaporating into the air. Dispose of them properly.


THIS IS THE SOLUTION WE'VE DEVISED FOR DEALING WITH THE FLOODING CAUSED BY CLIMATE CHANGE.
Chris Madden

Thank You

Measurement: Principle

The surface ozone detector makes use of the wet electrochemical bubbler Sensor for the detection of ozone.

Air from the atmosphere is drawn through Potassium Iodide solution in which two electrodes of platinum and silver are dipped. The ozone in the air reacts with Potassium Iodide liberating free iodide according to the reaction.

$$2KI + H_2O + O_3 \longrightarrow 2KOH + O_2 + I_2$$

At the cathode the free iodine is reduced to iodide:

$$I_2 + 2e \longrightarrow 2I$$

And at the anode the iodine is formed

$$2I - 2e \longrightarrow I_2$$

Measurement: Principle

Since silver is used as the anode the iodine combines with Ag to form AgI which precipitates out of the solution thereby effectively preventing the iodine from recirculation .Thus every molecule of ozone that reacts with the solution liberates two iodine atoms which in turn results in a flow of two electrons in the external circuit.

Assuming this stoichiometric reaction, let

i be the resulting current in microamperes,

T is temperature in ^{0}K of the air containing ozone and

t is the time in seconds for bubbling 100ml of air.

Measurement: Principle

We can drive an expression for the partial pressure of ozone in the air as follows:

$$\text{i micro amp} = i \times 10^{-6} \text{ coulomb /sec}$$

$$= ix10^{-6} \text{ coulomb/sec}$$

$$1.062 \times 10^{-19}$$

Since charge of an electron e = 1.062×10^{-19} coulomb.

For every molecule of ozone 2 electrons flow in the bubbler and hence a current of 1 microampere corresponds to:

$$i \times 10^{-6} \quad \text{molecules of ozone / sec}$$

$$2x\ 1.062 \times 10^{-19}$$

Measurement: Principle

Say No_3

This is contained in 100ml/t of air. The total number of molecules sampled per seconds (say N_T) at normal temperature is

$$= (100/t) \times 2.687 \times 10^{19} (273/t)$$

Where the number of molecules per ml of air (Loschmitt'number L) = 2.687×10^{19}.

Therefore the partial pressure of ozone p (micromillibar) = $(No_3/ N_T) \times 1013.2 \times 10^6$

Where standard pressure = 1013.2 mb.

Substituting for No_3 and N_T from above

P (micro mb) = 4.31×10^{-3} i T t.

In the principle, the electrochemical method is absolute. Two electrons per ozone molecule entering the bubbler solution contribute to the ozone current and absolute values of ozone can be obtained if necessary precautions are taken.

Instrumentation

The surface ozone recording system consists of

- **Bubbler ozone sensor**
- **Suction pump for drawing atmospheric air through the bubbler.**
- **An amplifier for the current and**
- **Data logger**

Installation: GI pipe, Weather hood and Sensor

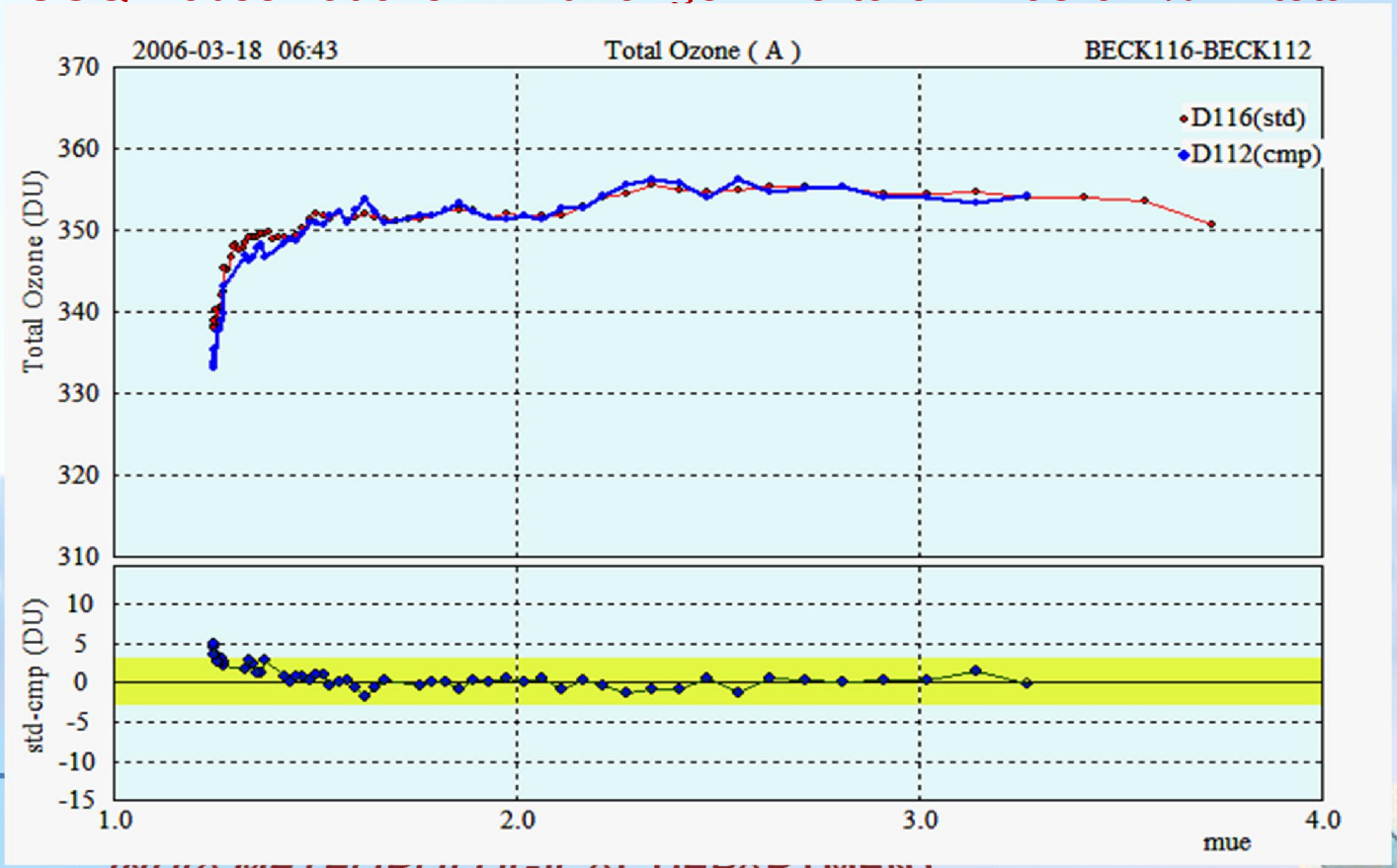
Fix the GI pipe support for the equipment either to the parapet wall by clamps or to the ground grouted in concrete. Fix the weather hood , Lay the rubber / plastic tube and twin core shielded cable from the top of the pillar to the recording room. Whenever the tube and cable are going over the ground it should be enclosed in a polythene tube and buried underground.

Place the sensor inside the weather hood and connect the red wire to Platinum and black to Silver electrodes of the twin core shielded cable through the connectors.

Calibration of IMD's Dobson Spectrophotometer

The results of 2006 Inter-comparison of Dobson Spectrophotometer no.112 are as follows :

- Initial calibration results have showen that the d-Nad value shown an average + 0.2 % error in calculated ozone value, mu = 1 to 3, Total ozone=300 D.U.
- Final inter-comparison shows average difference against the standard for ADDSGQP observations in mu range 1.15 to 3.2 was 0.1% in total ozone.

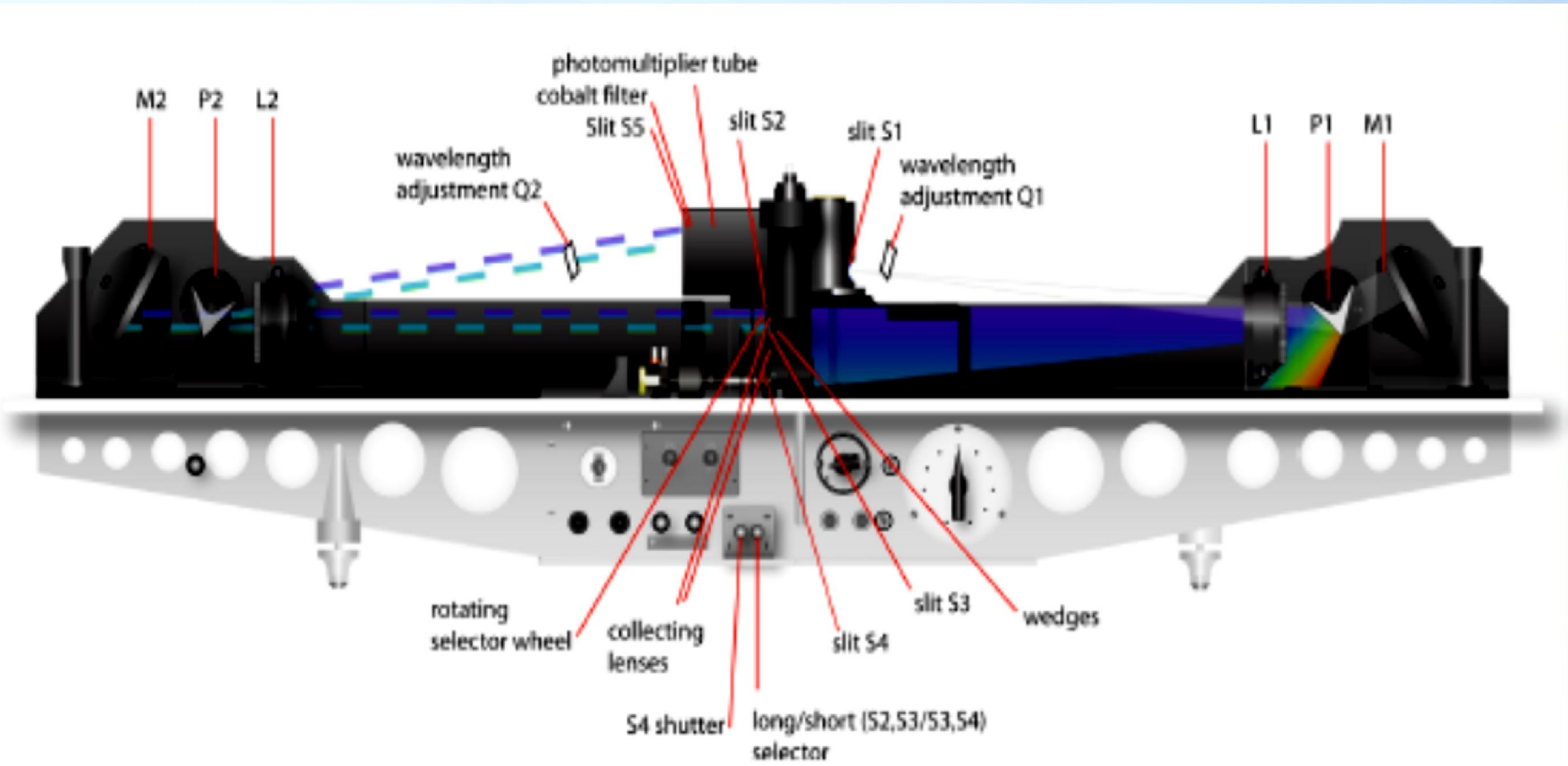


Measurement of Total Column Ozone by Dobson Spectrophotometer

- The Dobson Spectrometer measures the total ozone by measuring the relative intensity of the dangerous UVB radiation that reaches the Earth and comparing it to that of UVA radiation at ground level. If all of the ozone were removed from the atmosphere, the amount of UVB radiation would equal the amount of UVA radiation on the ground.

- As ozone does exist in the atmosphere, the Dobson Spectrometer can use the ratio between UVA and UVB radiation on the ground to determine how much ozone is present in the upper atmosphere to absorb the UVC radiation.

The ratio is determined by turning the R-dial, which can be rotated a full 300°, on the instrument. The spectrometer compares two different wavelength intensities, UVB (305 nm) and UVA (325 nm), in order to calculate the amount of ozone. When turned, the R-dial filters and blocks out the light of the UVC wavelength until the intensity of the two wavelengths of light are equal. The ratio of the two wavelengths at incidence can be deduced once the filtered intensities are the same. The results are measured in Dobson Units.



Measurement of Total Column Ozone by Brewer Spectrophotometer

IMD was taking measurements of total ozone by Brewer Spectrophotometer at two stations e.g. New Delhi and Kodaikanal.

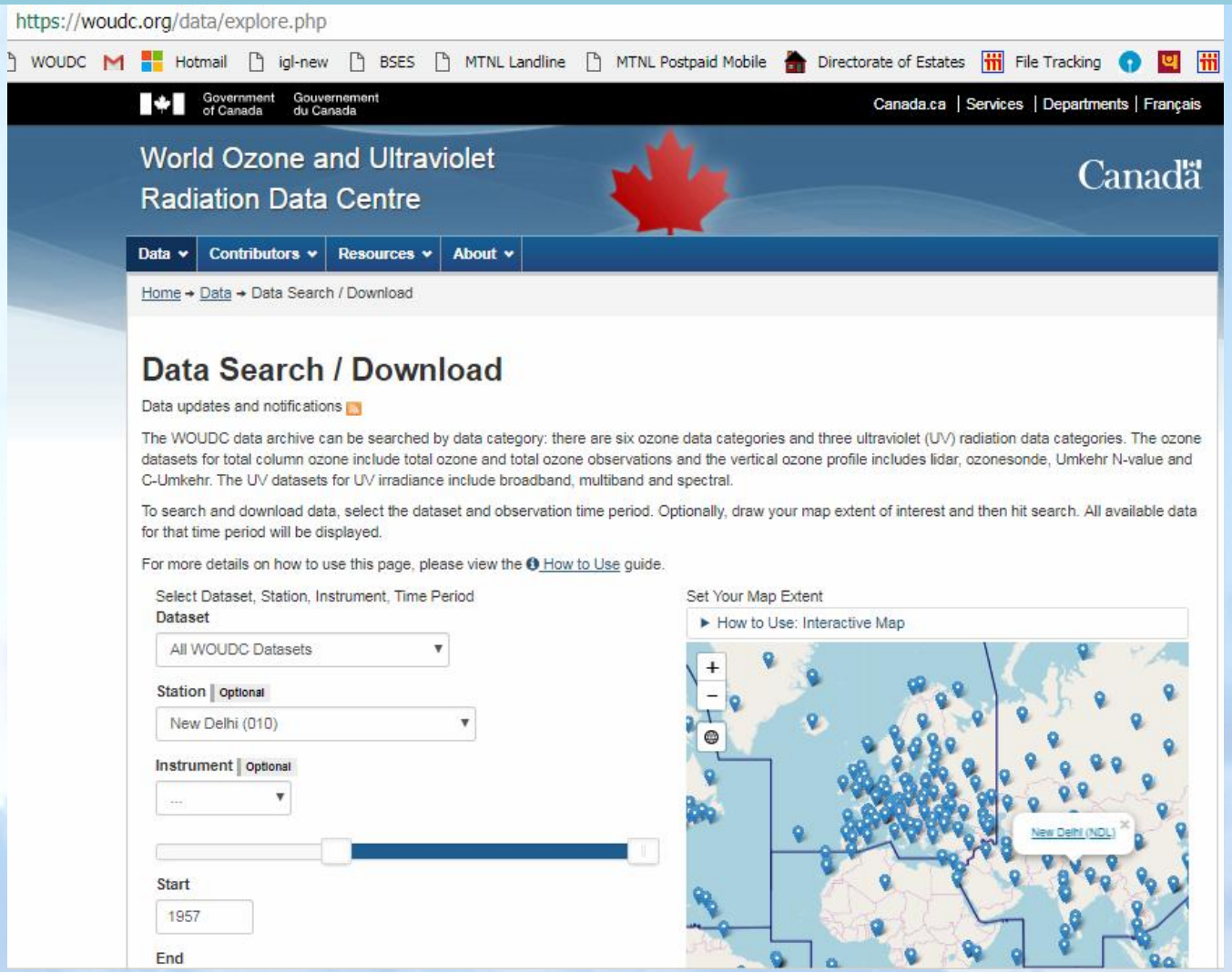
The Brewer spectrophotometer measures ozone based on the same technique as the Dobson instrument.

Unlike the Dobson instrument, however, the Brewer spectrophotometer is completely automated and can be programmed by a laptop computer to make measurements at any given time during the day.

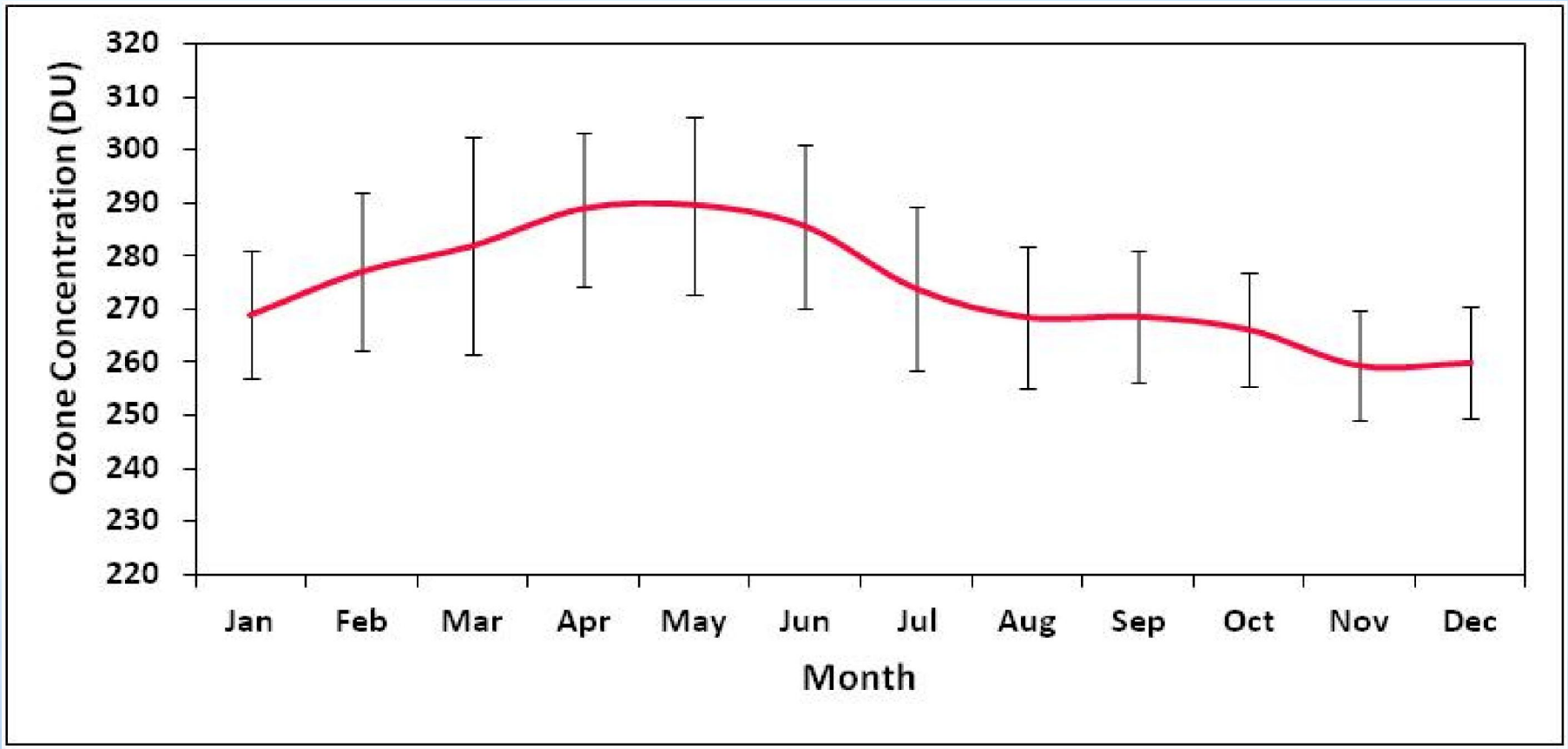
The absolute accuracy for a total ozone measurement made by a well calibrated Brewer instrument is estimated to be +/- 2.0%.

Ozone Measurement in IMD

- Ozone data is being regularly sent to World Ozone Data Centre, Canada for archival. The data is available in the internet on: http://www.woudc.org.



Variation of Monthly Averaged Concentration of Total Columnar Ozone at Delhi (1957 - 2015)



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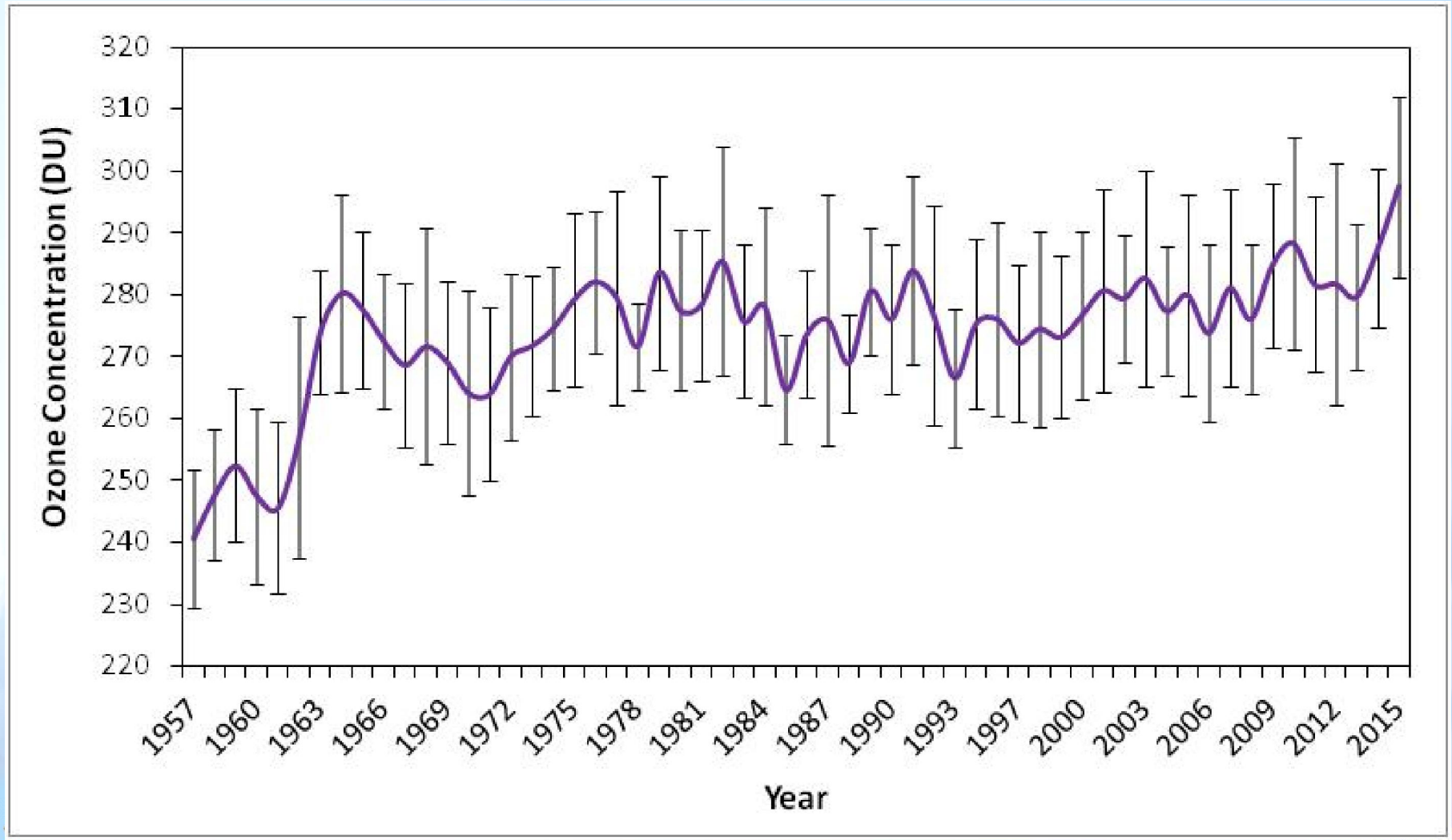
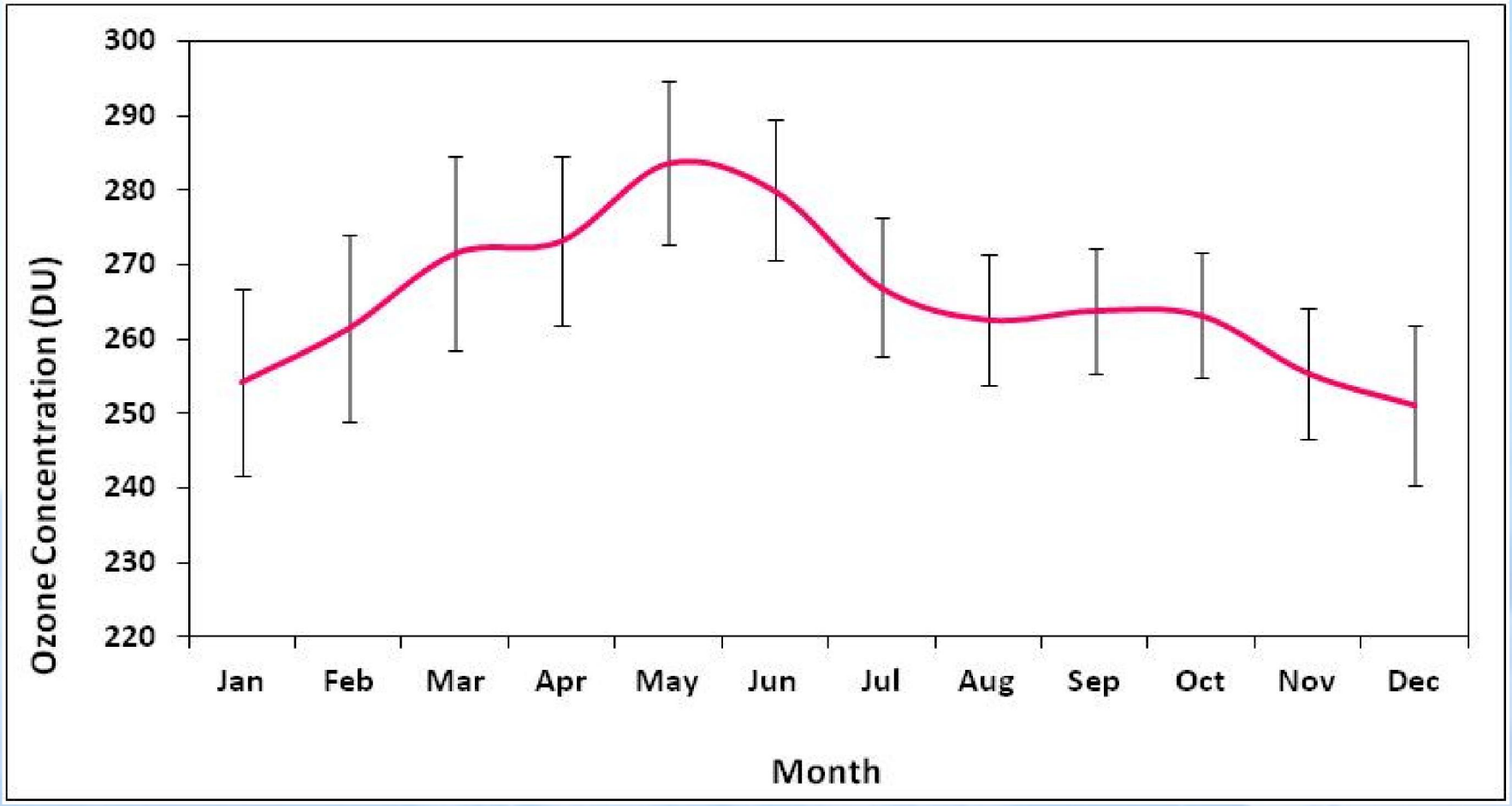


Variation of Monthly Averaged Concentration of Total Columnar Ozone at Varanasi (1963 - 2014)



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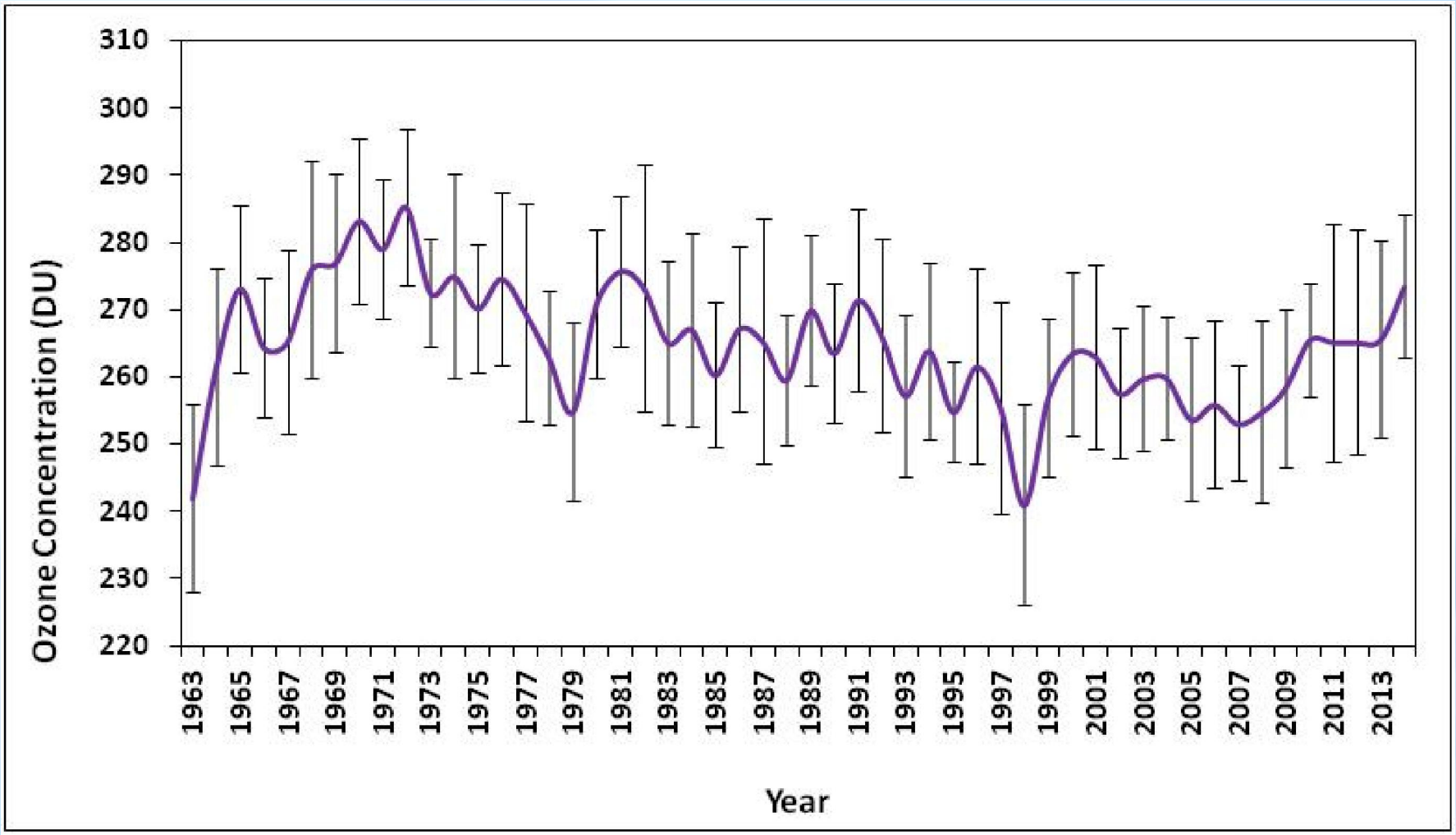
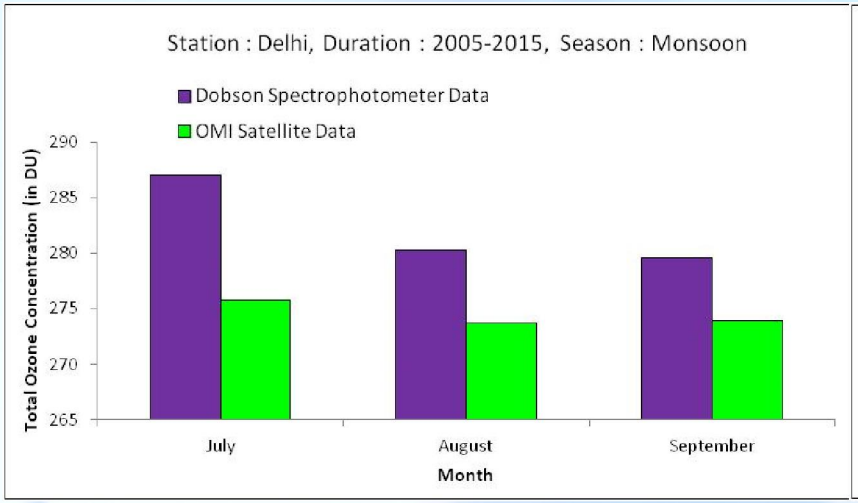
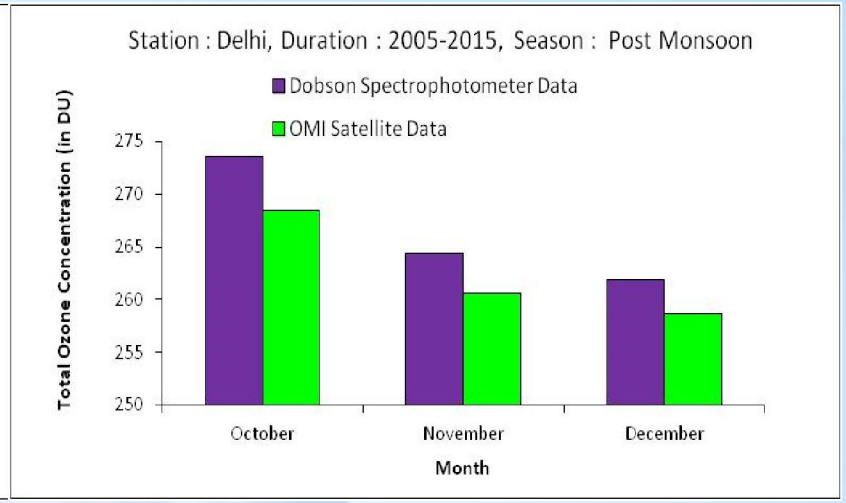
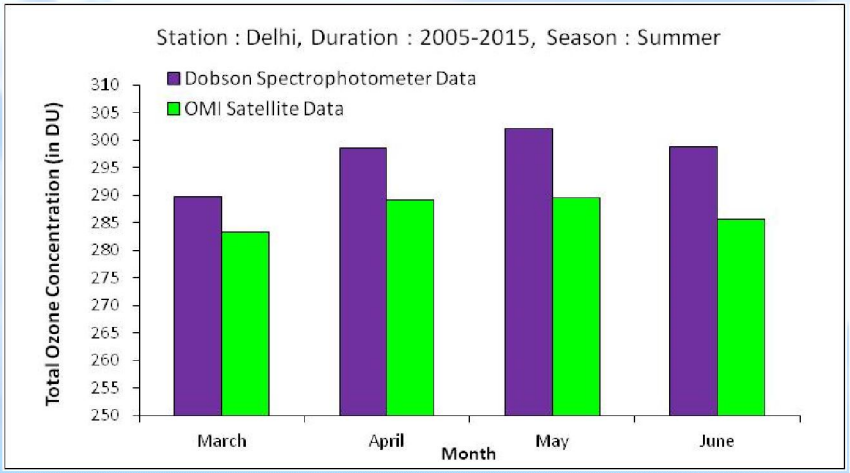
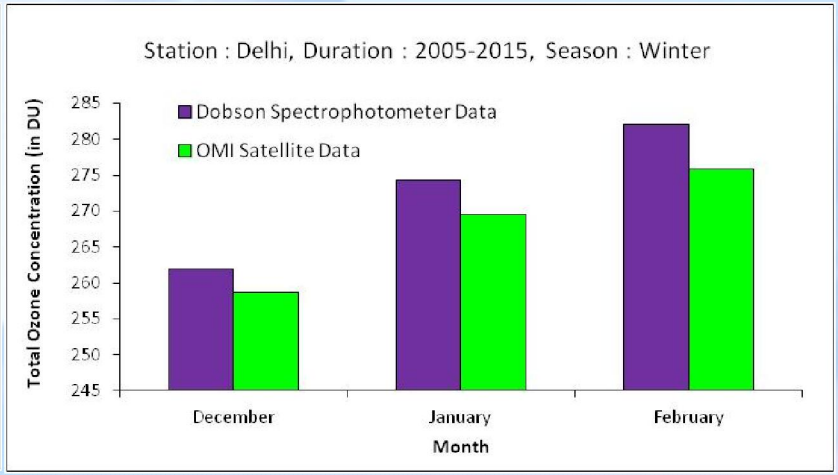


Ten Yearly Averaged Total Ozone Concentration at Delhi during 2005 – 2015 : A Comparative Representation





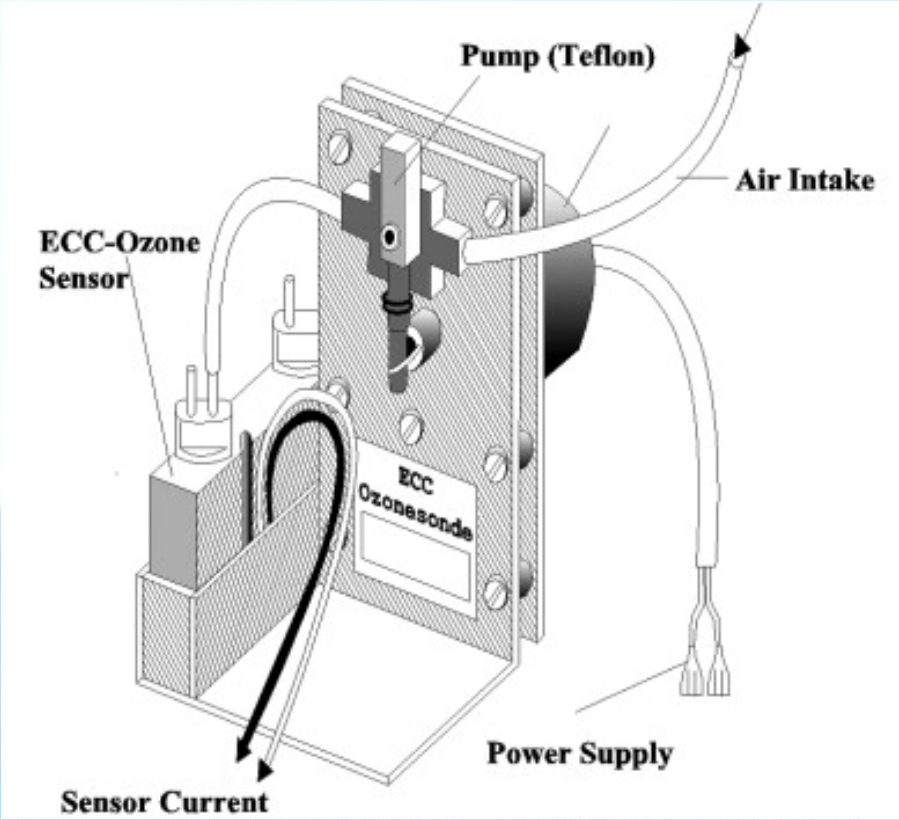




Measurement of Vertical Distribution of Ozone (Ozone Sonde)

- Vertical ozone profiles using balloon-borne ozone-sondes are observed fortnightly at New Delhi.
- The ozone-radiosonde is a lightweight, balloon-borne instrument that is mated to a conventional meteorological radiosonde.
- As the balloon carrying the instrument package ascends through the atmosphere, the ozone-radiosonde telemeters to a ground receiving station information on ozone and standard meteorological quantities such as pressure, temperature and humidity.
- The balloon will ascend to altitudes of about 115,000 feet (35 km) or about 3 hPa before it bursts.
- The heart of the ozone-radiosonde is an electrochemical concentration cell (ECC) that senses ozone as is reacts with a dilute solution of potassium iodide to produce a weak electrical current proportional to the ozone concentration of the sampled air.
- Ozonesondes are composed of an ozone sensor, a battery, a small gas pump, and some electronic circuit boards.
- The ozone sensor, an electrochemical concentration cell (ECC), consists of two small chambers containing solutions of potassium iodide (KI).

The ozone sensor is connected to a meteorological radiosonde. This radiosonde transmits values of air temperature, air pressure, relative humidity, detector current, detector temperature, and pump speed to a ground receiving station. The air containing the ozone sample is pumped through a solution which is oxidized by this ozone producing an electrical current. The electrical current is proportional to the flow of ozone. By knowing the flow (pump speed), the ozone concentration can be deduced. The result is an ozone partial pressure vertical profile.

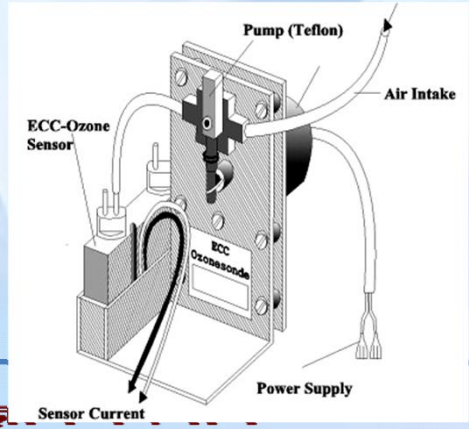


Schematic of an electrochemical concentration cell (ECC) Ozone sonde

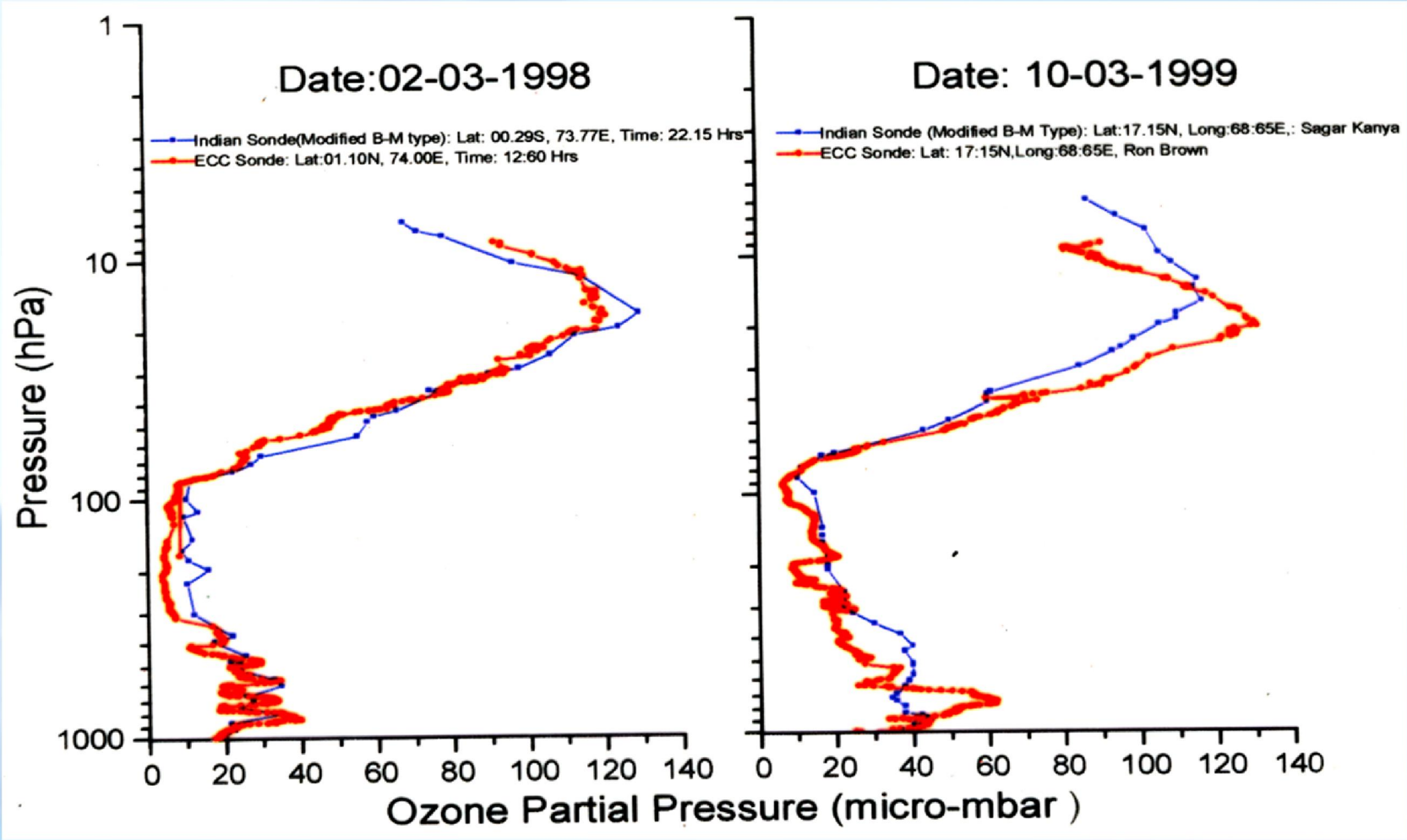
Vertical Distribution of Ozone Measurements in IMD

- Development of Indian Ozone sonde was done by Instrument division of IMD in 1964 (Sreedharan, 1968).
- Indian Ozone-sonde was intercompared in West Germany in 1970 and 1980, Canada in May 1991 and in Germany February 1996.

S. No.	Name of Station	Lat.	Long.	Frequency of Observation	Since when
1.	New Delhi	28^0 35’ N	77^0 12’ E	Fortnightly	1971
2.	Pune	18^0 32’ N	73^0 51’ E	Fortnightly	1971
3.	Thiruvananthapuram	08^0 29’ N	76^0 57’ E	Fortnightly	1971
4.	Maitri (Antarctica)	70^0 48’ S	11^0 42’ E	Weekly	1986-89
5.	Dakshin Gangotri	70^0 03’ S	12’ E	Weekly	1990



Comparison of IMD's Ozone sonde with ECC sonde during INDOX – 1999 experiment

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