Satellite & Ground-based Aerosol Monitoring
in
Pakistan

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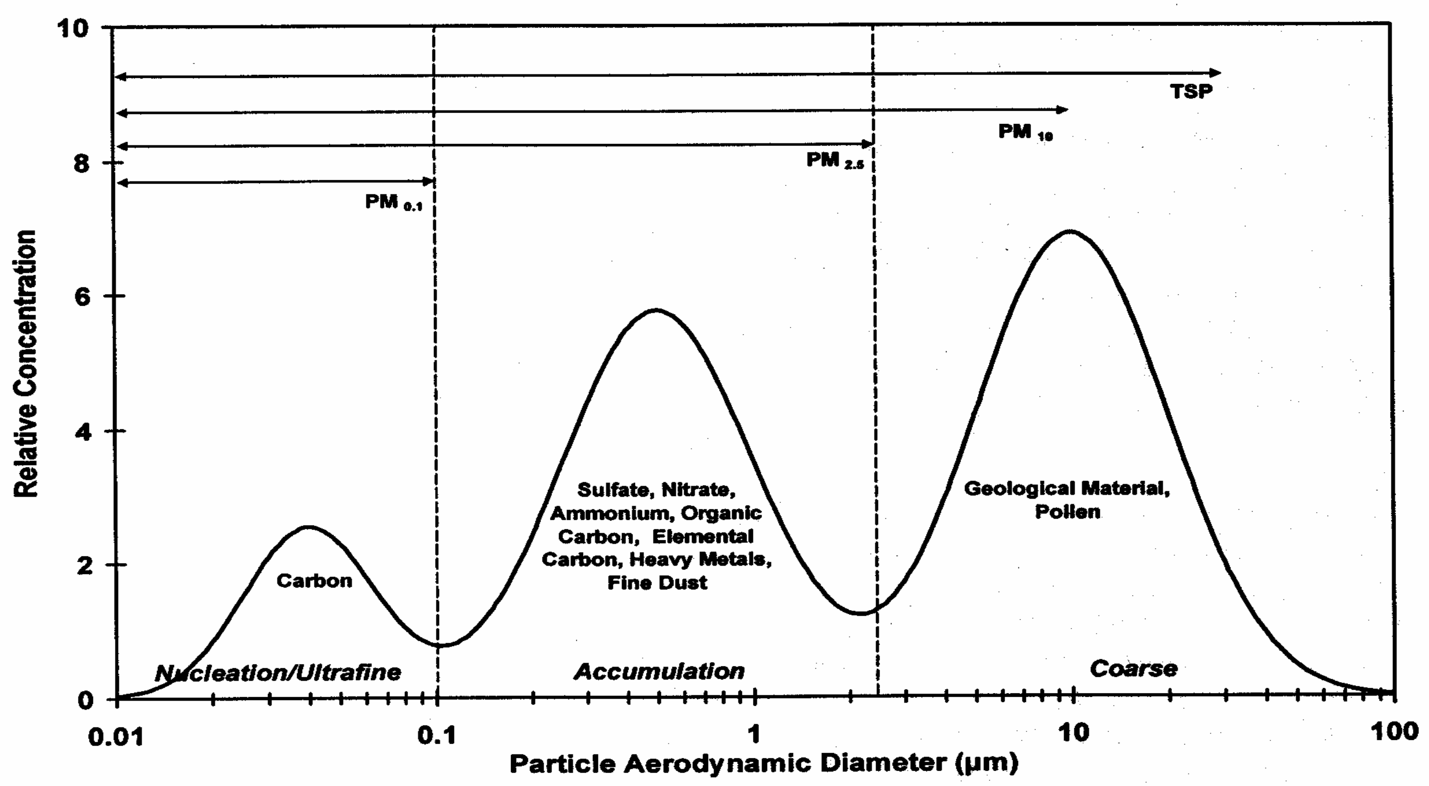
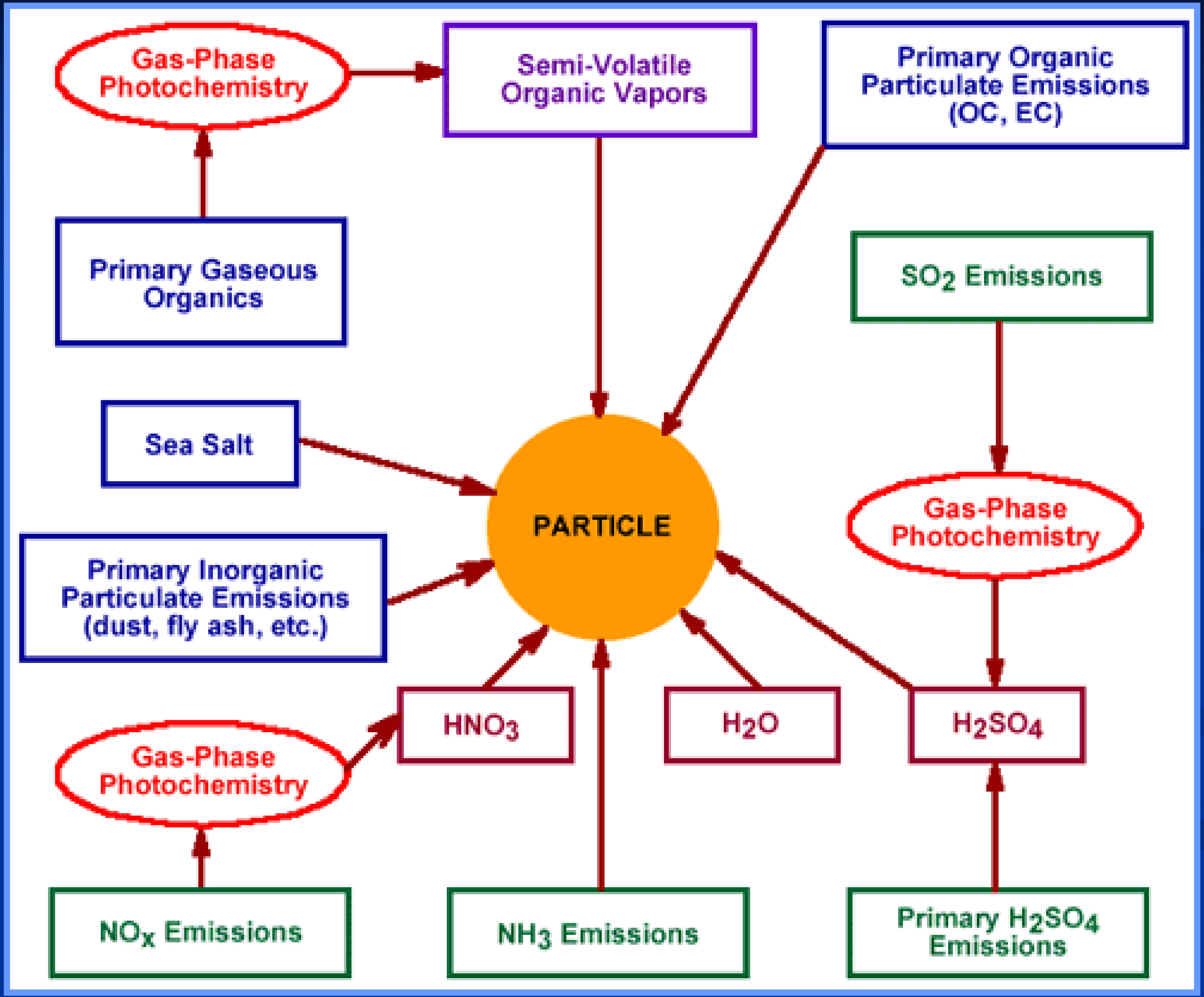
Introduction

Atmospheric Aerosols

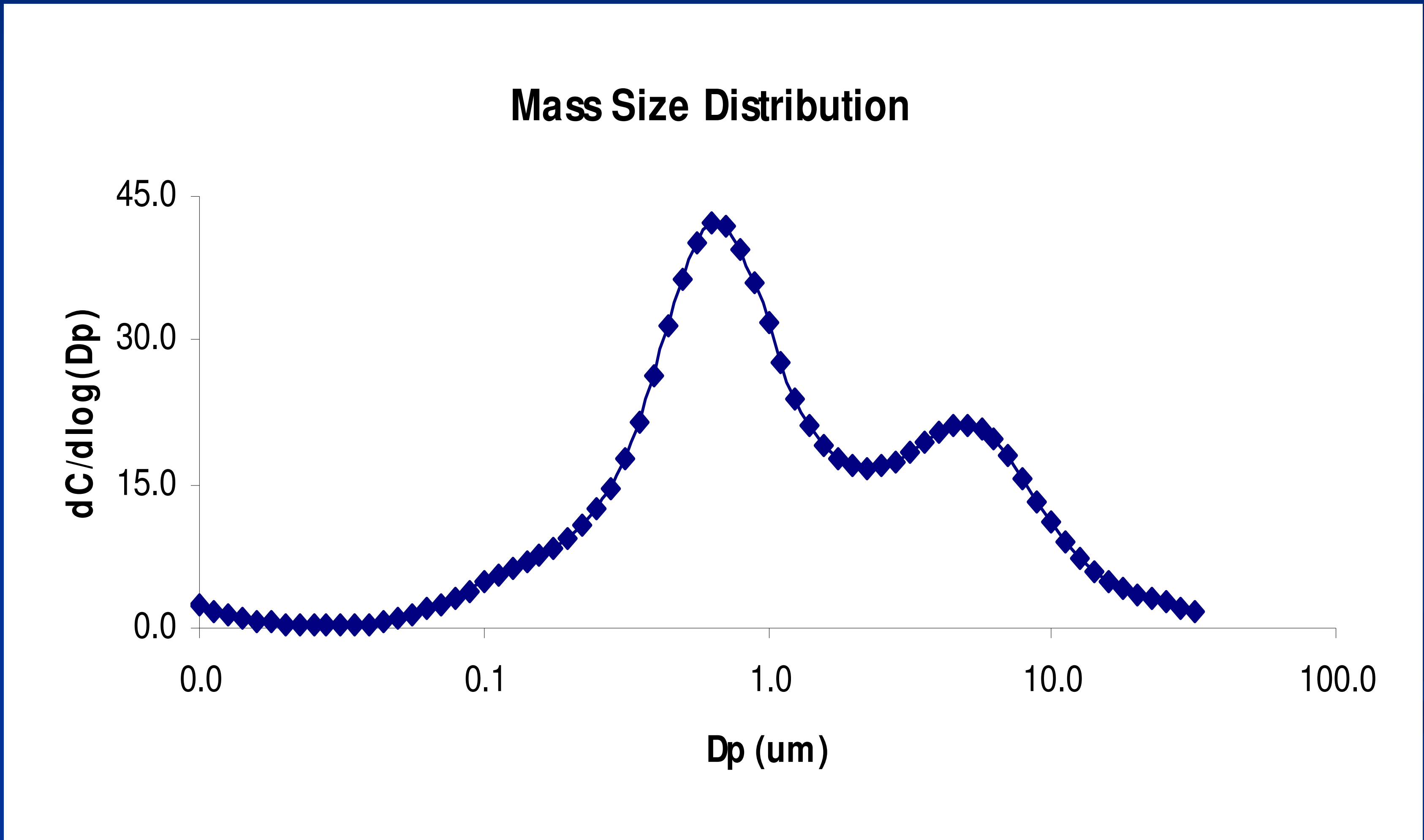
Atmospheric particle diameters can range from nanometers (10^{-9}) to a hundred micrometers or four orders of magnitude.



Atmospheric Aerosol Chemistry



Size Distribution of Aerosol Mass Concentration on Hazy Day



Chemical Composition of Fine Particles

- Organic Carbon
- Black Carbon
- Sulfate
- Nitrate
- Trace Metals Such as Lead, etc

What is Black Carbon

- It is graphitic,
- It is insoluble in water
- Chemically Inert
- Absorbs Sunlight
- Absorbs Moisture in presence of Sulfates

Atmospheric Aerosols

A chemically complex and dynamic mixture of solid, liquid and gases

- Sea salt
- Soil (wind blown dust)
- Combustion–generated particles
- Photochemicaly produced particles

Atmospheric Aerosols

Aerosol have different shapes and composition and they can contain some combination of:

- Inorganic ions
- Elemental carbon (black soot)
- Various trace elements
- Crustal compounds
- Organic coumpounds
- Biological matter

Sources of Aerosols

Sources of Aerosols

Anthropogenic

- Industrial processes
- Food cooking
- Biomass burning
- Traffic

Natural

- Sea-salt
- Dust storm

Natural Aerosols

Natural Aerosols contain

Soil Dust- Produced from dust storm
Sea Salt

Volcanic Dust- Produced as a result of Volcanic eruption & Oceanic Sulphates

Man Made Aerosols

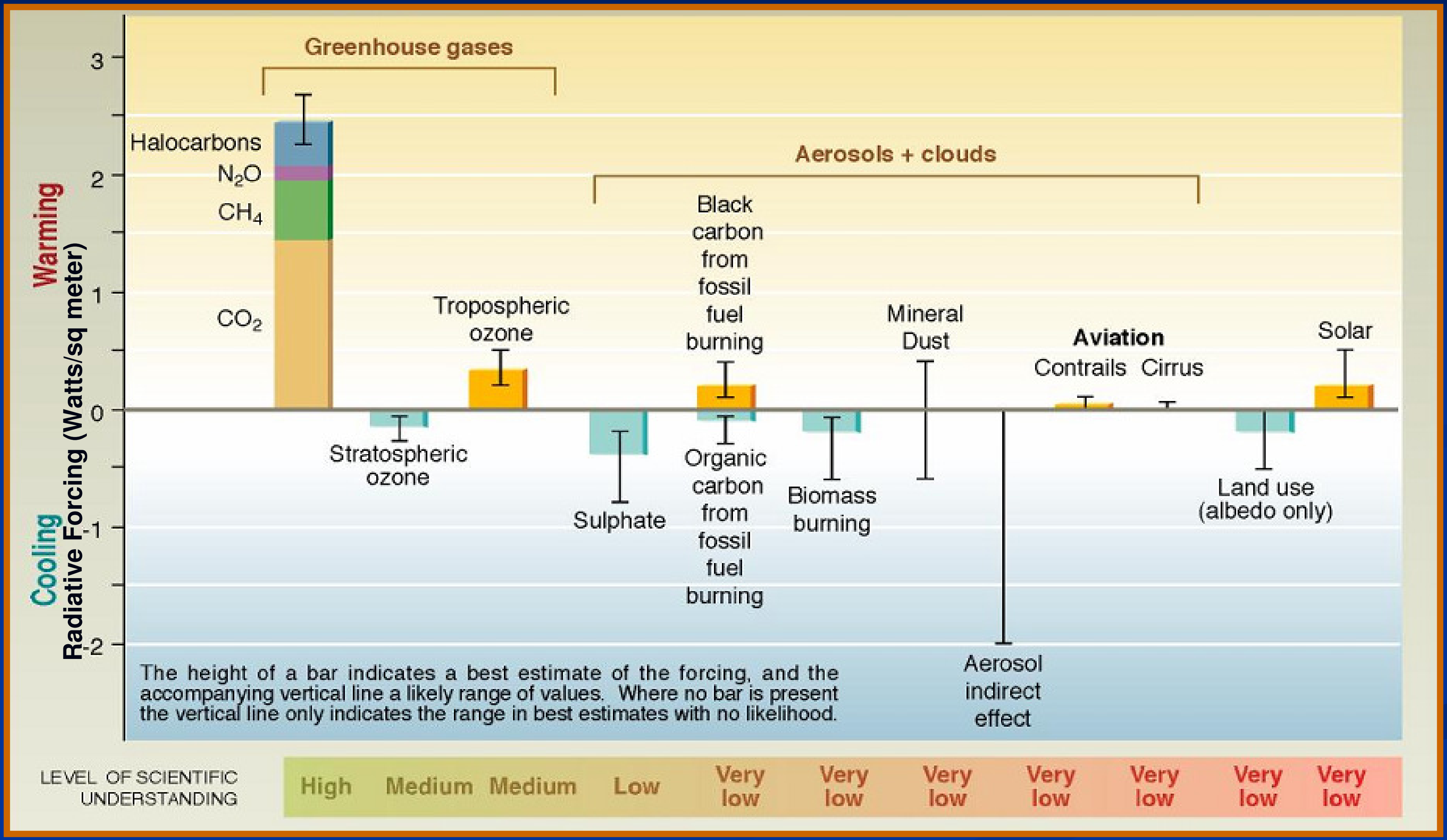
Man Made Aerosols contain

- Industrial Sulphates
  Black carbon & Organic particles
- During Fossil burning SO2 is emitted which converts to sulfate in the atmosphere
- During Biomass burning elemental and organic carbon are emitted.

Why to study: ----

- Concentration and their chemical composition are critical to air quality
- To understand how earth's climate is changing it is critical to understand each mechanism that causes warming or cooling in the atmosphere
- Both aerosol and cloud act as Atmospheric forcing scattering, reflecting and absorbing the radiation coming into or going out of the earth's atmosphere
- Understanding the properties and concentration of aerosols and their relationship to aerosols on global and regional scales

The Global Mean Radiative Forcing of the Climate System for (Year 2000, Relative to 1750 : IPCC)



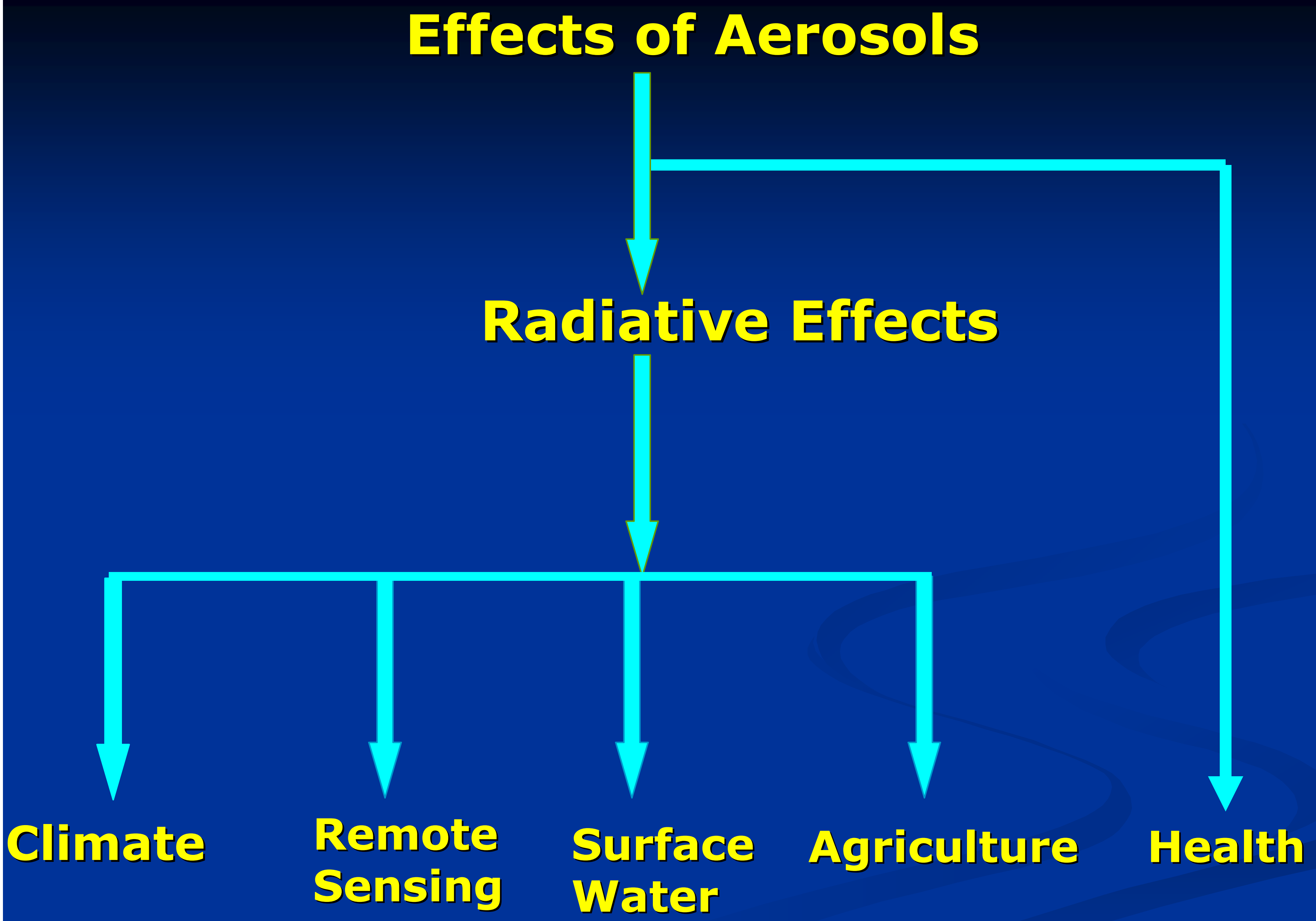
As per IPCC report the average temperature of the atmosphere has increased resulting in global warming causing abrupt melting of snow, Floods, increase in frequency of cyclone, etc the other thing which is the result of increased concentration of aerosols is the cooling Effect. Cooling Effect has many impacts comparable to Global warming. Aerosols can have regional as well as global impact on climate Aerosols play an important role in all problems connected with air pollution, ranging from very local effects and human health problems to regional problems such as acid deposition and eutrophication up to continental and global questions such as stratospheric ozone loss and climate change.

The role of aerosol particles in atmospheric processes is extremely important in climate research.The increased concentration of aerosols cause cooling effect by scattering and reflecting the solar radiation affecting agriculture through photosynthesis, hydrological cycle and monsoons.

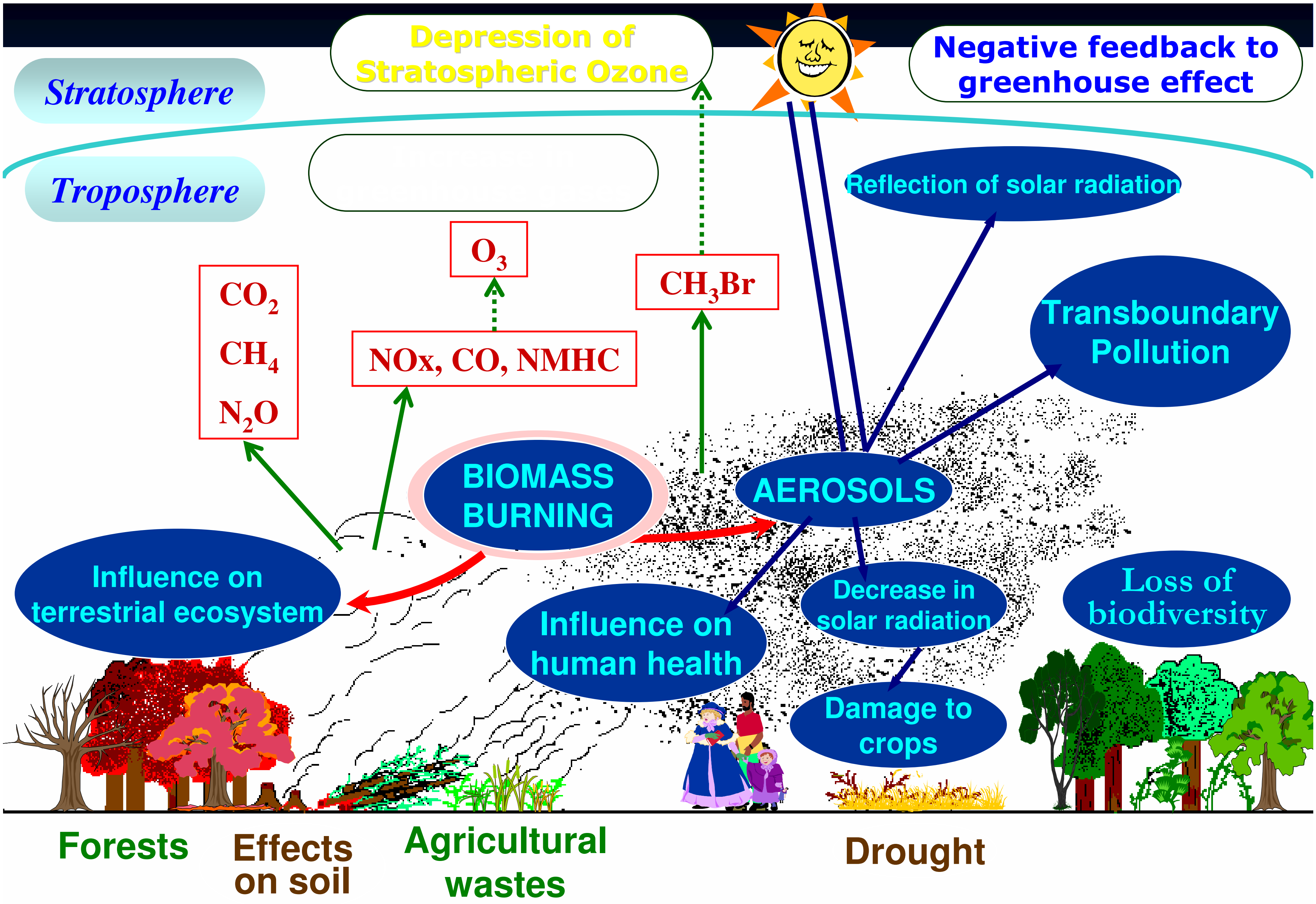
Other effects include Dimming, SST, Less Efficiency of Clouds to produce rain, Monsoons, rain formation, weather forecasting, bio-geochemical cycling as well as remote sensing of the reflectance and texture of ground and other surfaces. For this reason, systematic studies are undertaken now in order to retrieve global as well as regional distributions of aerosols.

To understand how the Earth's climate is changing, it is critical to understand each mechanism that causes warming or cooling in the atmosphere. Each process that changes the balance of radiation coming into and going out of the Earth-atmosphere system is known as atmospheric forcing.

Both aerosols and clouds act as atmospheric forcing.Therefore, it is necessary to study these parameters and its effects on earth's Radiation Budget.

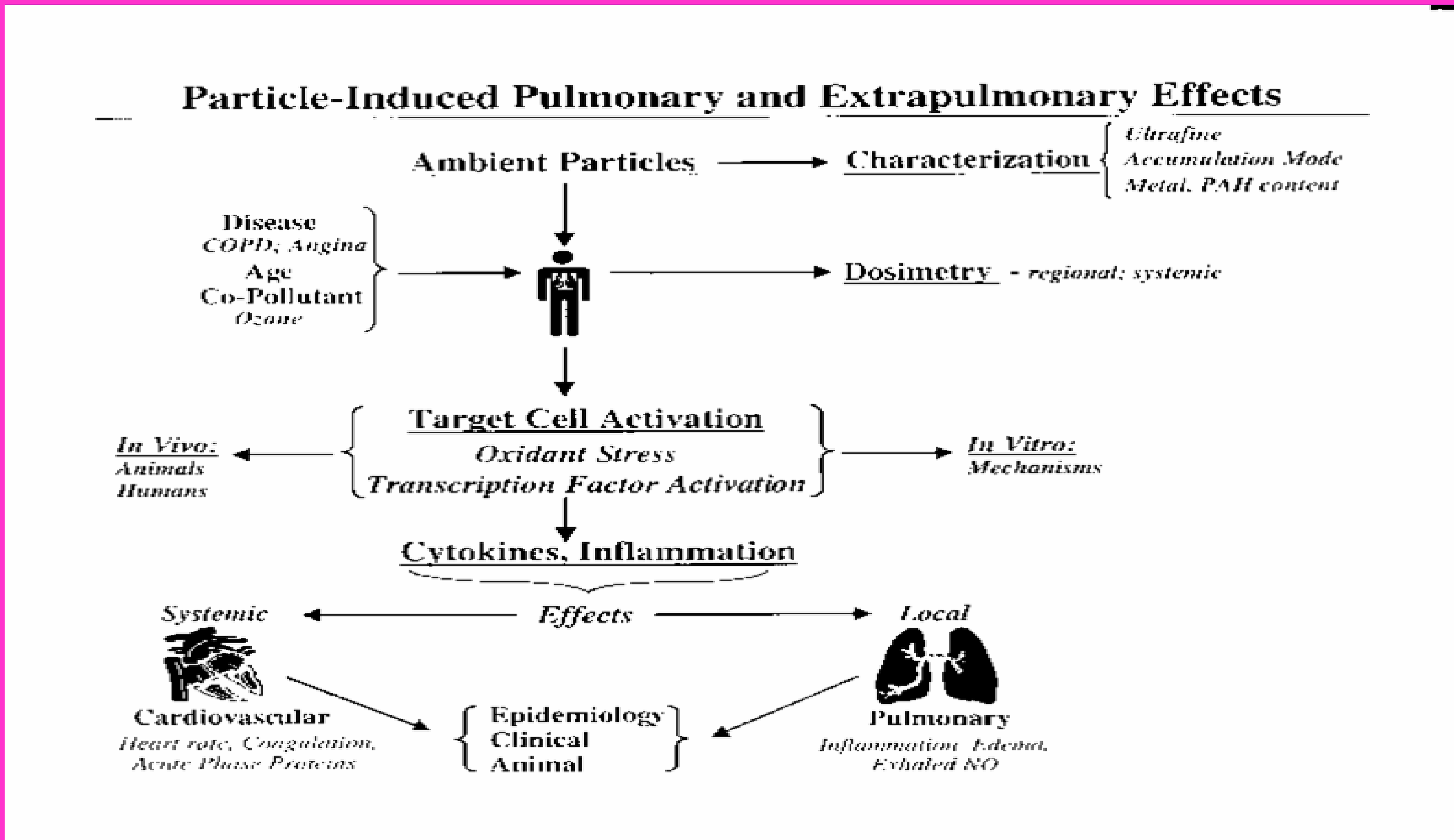

Effects of Aerosols
Radiative Effects
Climate
Remote Sensing
Surface Water
Agriculture
Health

This slide shows some chain effects of Aerosols, Radiative effects on Climate,Remote Sensing and Agriculture and particle effects on Health.In aerosols filled atmosphere radiations coming from sun are reflected back to space and no information can be acquired about the object which is to be remotely sensed.In case of Agriculture as sunlight is one of the basic requirements for the process of Photosynthesis through which plants prepare their food is also affected in concentration of aerosols.Human health is affected through lung diseases.



Influence of Large-Scale Biomass Burning on the Global Environment

Health Effects of Airborne Particles

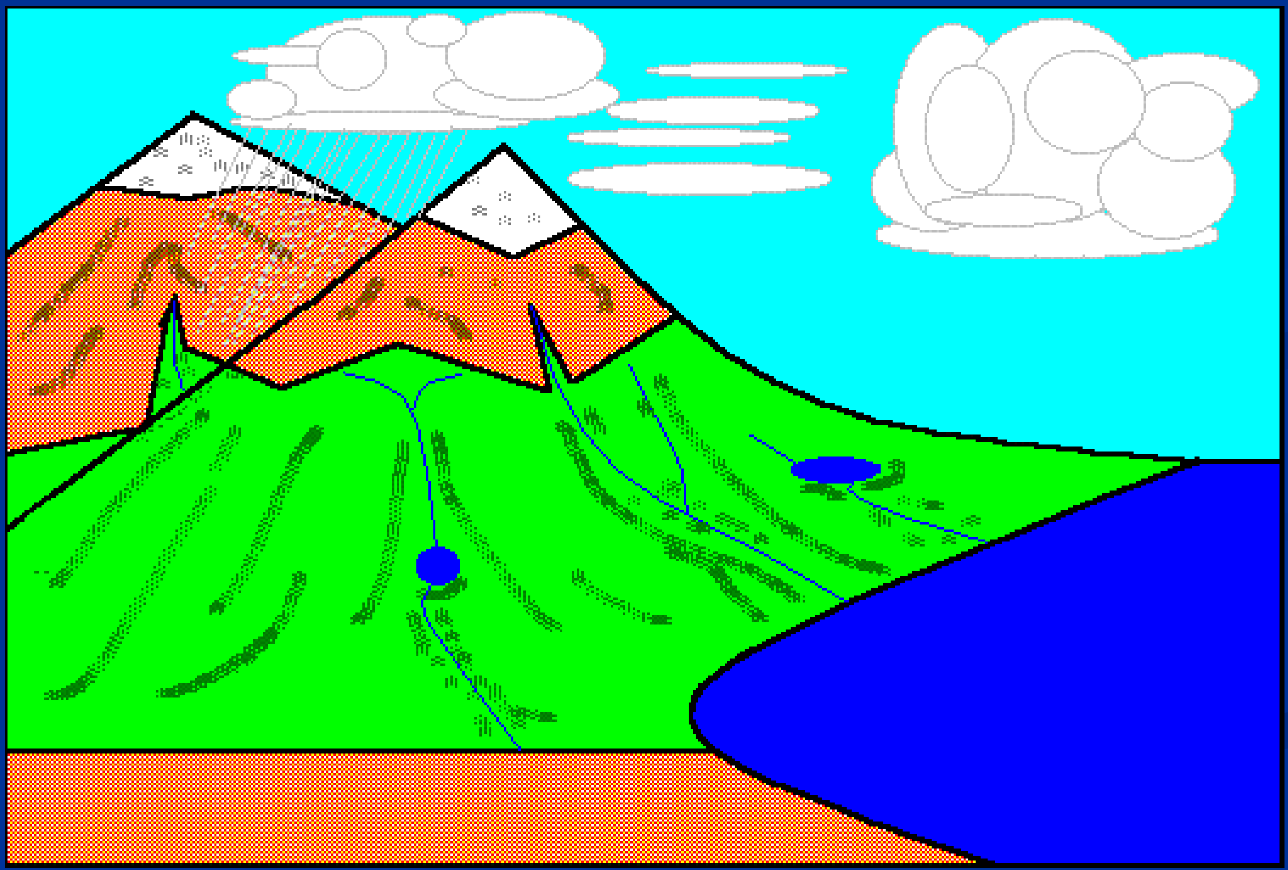


Aerosols and Hydrological Cycle

Increased aerosols

⇩

Weak Hydrological Cycle



Increase in aerosol will weaken the hydrological cycle. Because most aerosol can be washed from the atmosphere by natural processes, their lifetimes in the atmosphere generally are short (perhaps two weeks). This means they can have regional as well as global impact on climate. Therefore the impact (cooling) of excess atmospheric aerosol will be felt predominantly in the Northern Hemisphere, most notably in regions of high emission such as southeast Asia. These regional changes could lead to weakening of the hydrological cycle and reduce the availability and quality of fresh water.
When sunlight heats the ocean as part of the hydrological cycle, water escapes into the atmosphere and falls out as rain. Aerosol pollutants are cutting down the sunlight reaching the ocean and weakening the hydrological cycle.

If aerosol pollutants lead to reduce rain and snowfall, it could directly affect the refilling of the world's major stores of freshwater, including lakes, groundwater supplies, glaciers and high elevation snow pack.
This is not only warning about the role aerosols are playing on the regional and global water cycle, but also suggests that aerosol pollution increases the solar heating of the atmosphere, and reduces the solar heating of the surface of the planet. The researchers say these effects may be comparable to the global warming effects of greenhouse gases

Aerosols & Climate

Direct Effect

TOP OF THE ATMOSPHERE

INCREASE IN REFLECTANCE

SCATTERING & ABSORPTION

Short Wave Radiation

$$\lambda < 4\mu m$$

SURFACE

REDUCTION OF SOLAR RADIATION

NET RESULT:- Reduction In Solar Radiation At The Surface. Increase or Decrease In Reflected Radiation at the Top of the Atmosphere

AEROSOL EFFECTS ON CLIMATE

Direct Effects

This diagram shows direct effects of aerosols on Climate: How much light pass through the Atmosphere and how much is reflected back.

- All these things Depend on size distribution and index of refraction of the particles, as well as albedo of the underlying surface
- Aerosols scatter and absorb visible and infrared radiation causing warming or cooling
- As the radiation coming from sun are slowed down, they are absorbed and consequently reflection is decreased.

More Aerosols

⇩

More Cloud Droplets

⇩

More Sunlight Will Be Reflected.

Net Result:

- Reduction In Solar Radiation at the Surface
- Last Longer Clouds and Cooling (Ramanathan et al: 2001)

Last Longer Clouds

Increase in aerosol increases the droplet number concentration in clouds, which increases cloud extent and leads to global cooling. If the amount of water available for condensation in the cloud is not changed, this means that there will be more smaller drops, which are less likely to grow to sufficient size to fall out as precipitation and making clouds last longer, again contributing to cooling. For two reasons, therefore, - cooling of the surface because of increased reflection of solar energy, and reduced efficiency of clouds to produce rain

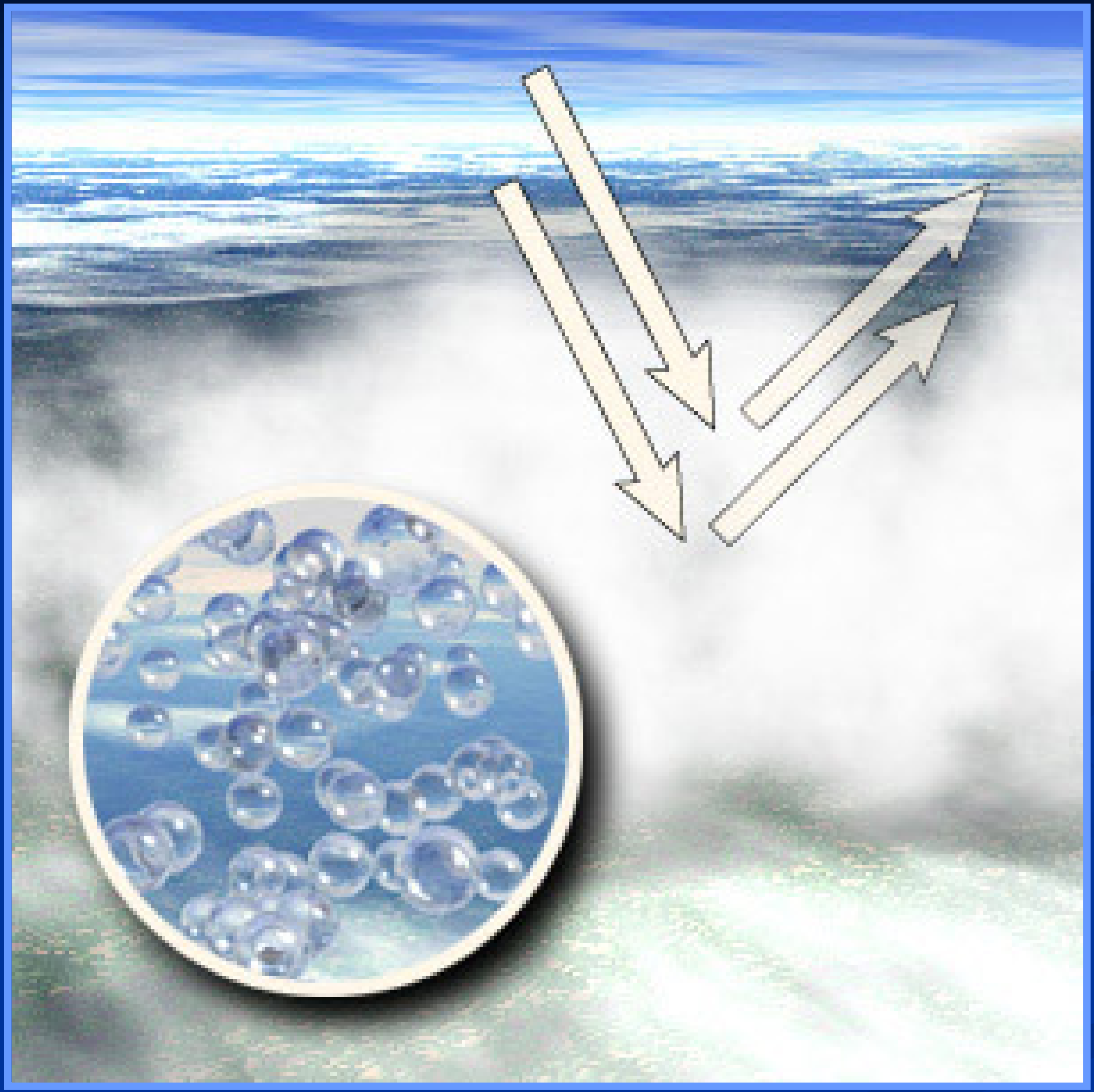
Indirect Effects

In Indirect effect aerosols affect clouds by (a) increasing drop concentration and optical depth and (b) by reducing drop size making the clouds more stable and of lower potential to produce rain. This effect extends the lifetime of the clouds and modifies ground wetness

- CCN influence cloud optical and microphysical properties
- Possible effects include changes in earth's albedo and changes in hydrological cycle.
- Smoke Can Reduce Photosynthesis And Diminution Of UV-B Radiation.

Aerosol Concentration

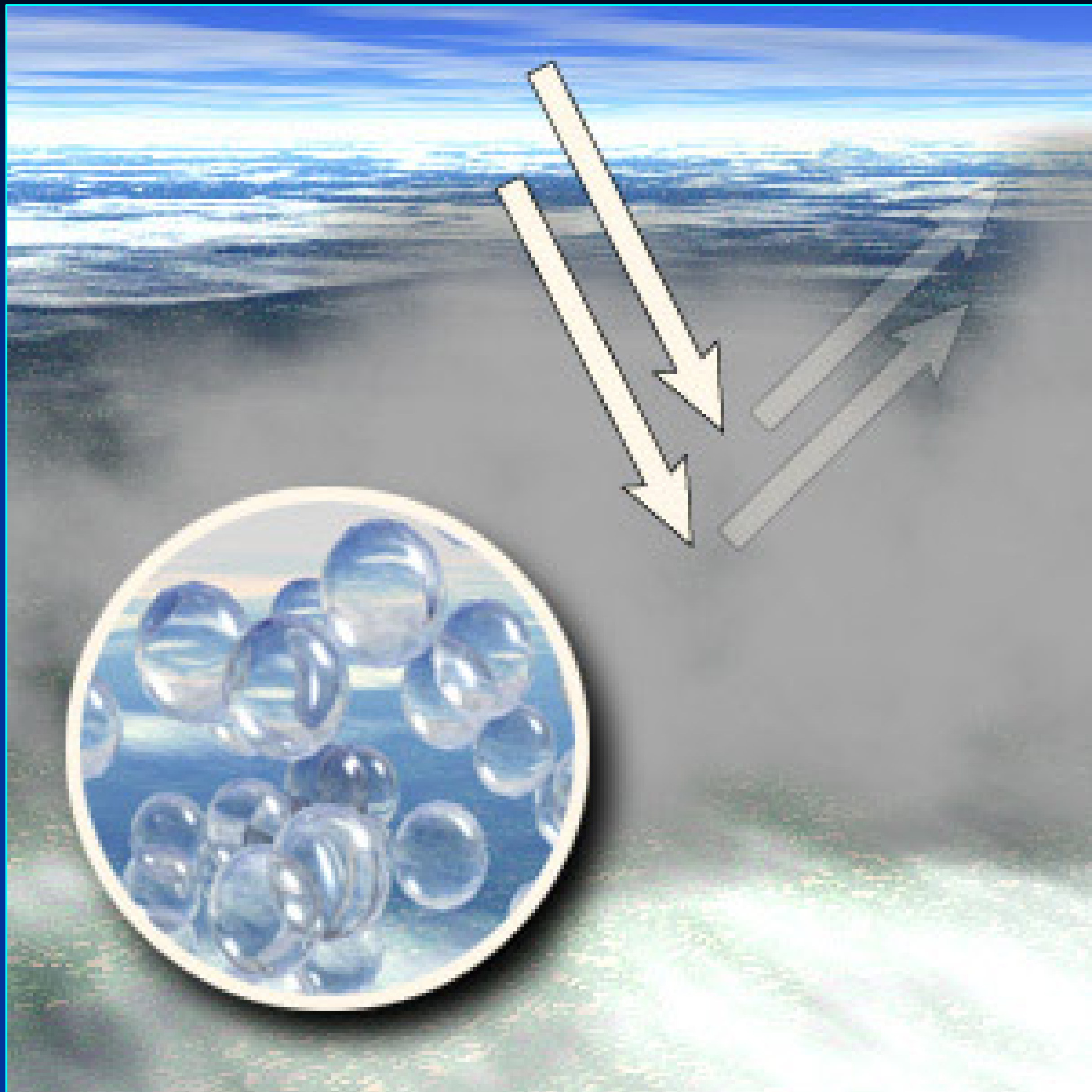
High



This slide shows:

The High Aerosol Concentration in clouds provide the Nucleation Points necessary for the formation of many small liquid water droplets. About 90% of visible radiation (Light) are reflected back to space by such clouds without reaching earth's surface.

Low



On the other hand as shown in the slide:

These are clouds with low aerosol concentration and a few large droplets. These clouds do not scatter and reflect light well and, allow much of the sun’s light to pass through and reach the surface of earth.

Particle Type

Conti--

Hygroscopic Particles

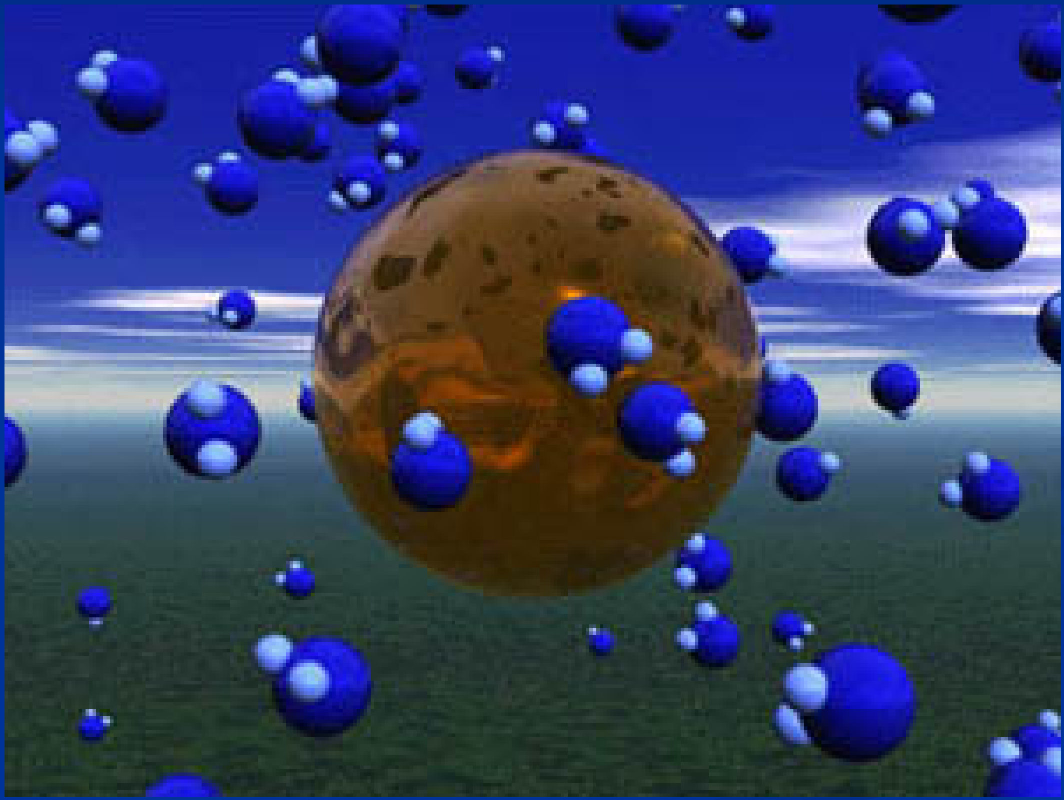
Conti--

HYGROSCOPIC PARTICLES

WATER ATTRACTING PARTICLES

These particles have an affinity or attraction for water. Consist of particles such as sea salt and common table salt. Even, when the relative humidity is considerably less than 100 percent water vapors condense on these particles. On humid days, Everyone would have observed that it is difficult to pour salt from the shaker because of condensation of water vapors on the salt crystals, sticking them together.

Hydrophobic Particles



Conti--

HYDROPHOBIC PARTICLES

WATER REPLELLING PARTICLES

Consist of particles such as oils and Teflon.These nuclei resist condensation even when the relative humidity is greater than 100 percent.

Measurement Capability

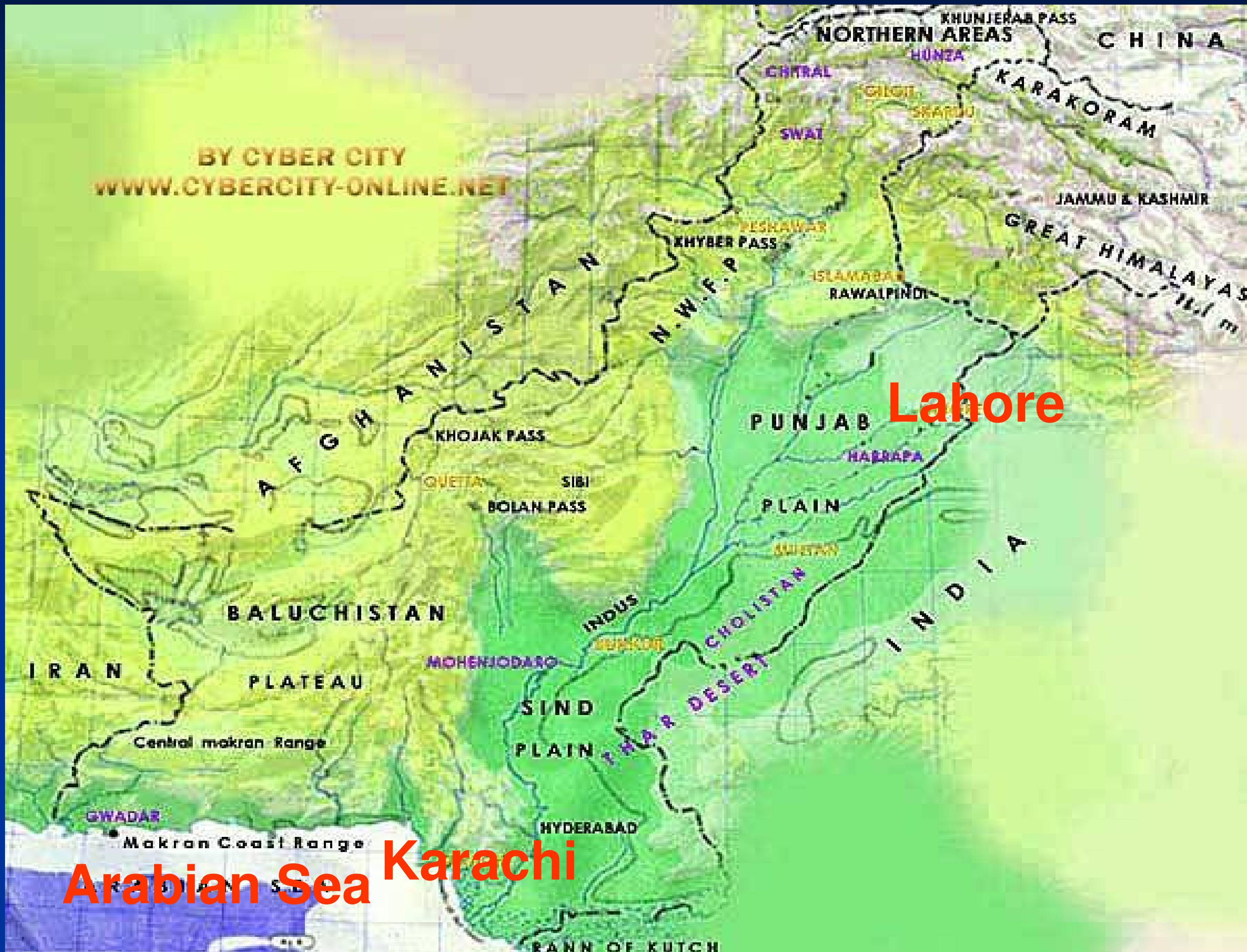
- Moderate resolution Imaging Spectroradiometer (MODIS) onboard Aqua and TERRA Satellites

- AERONET
- Other ground based facilities

Conti--

Study of Aerosol in Pakistan

MODIS-Derived Study of Aerosol Optical Thickness

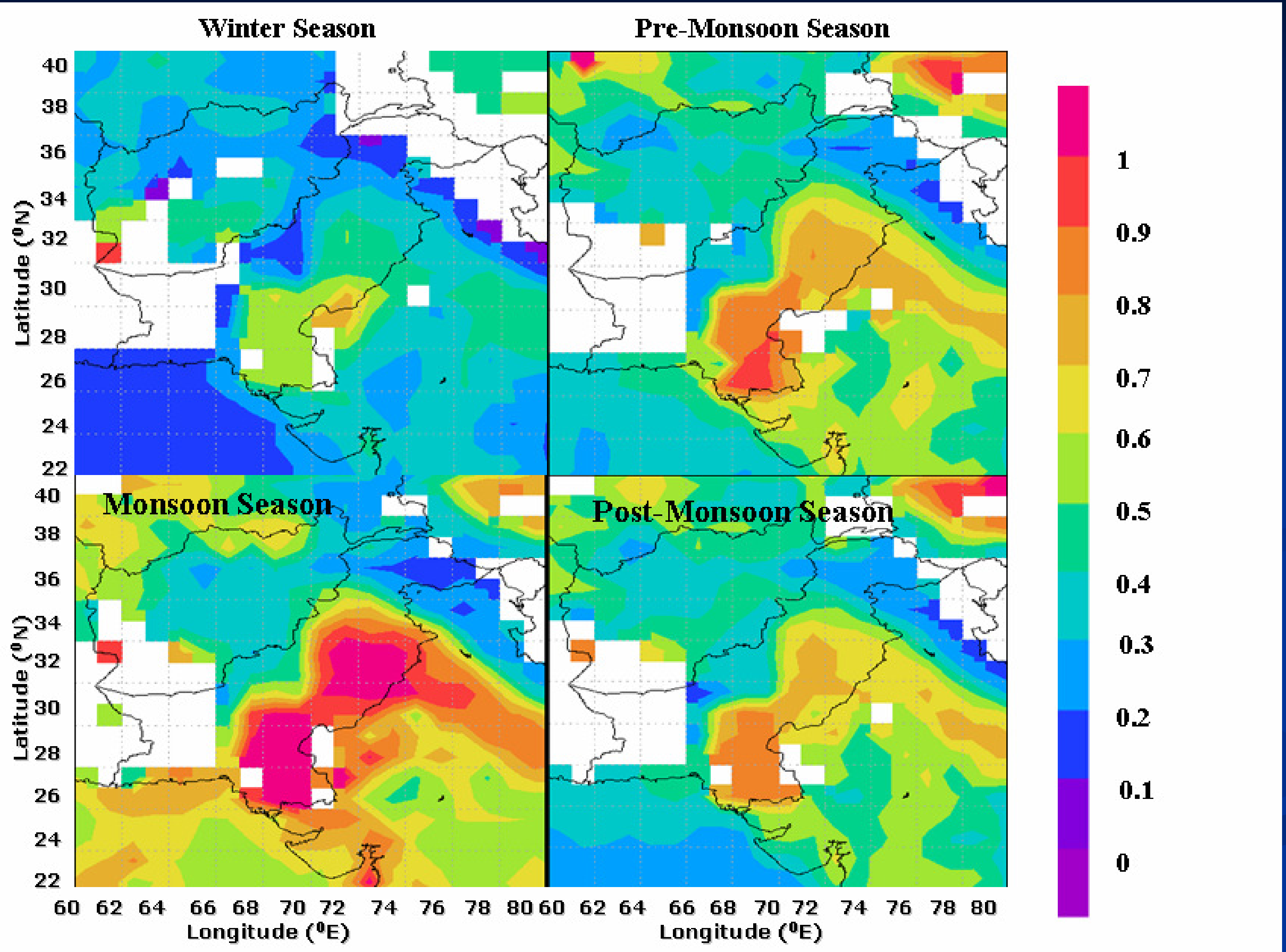


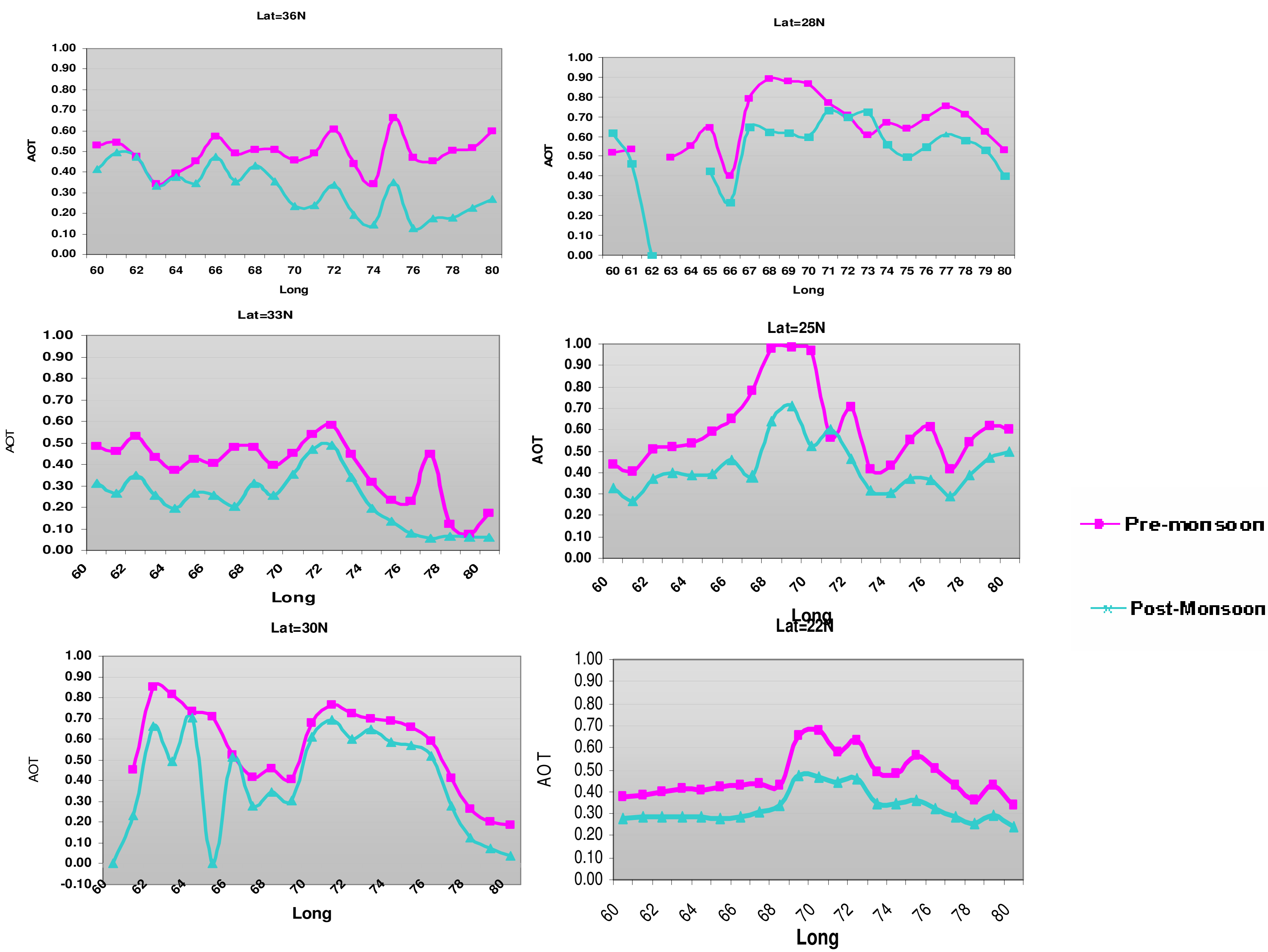
BY CYBER CITY
WWW.CYBERCITY-ONLINE.NET
KHUNJERAB PASS
NORTHERN AREAS
CHINA
HUNZA
CHITRAL
GILGIT
SKARDU
KARAKORAM
SWAT
JAMMU & KASHMIR
PESHAWAR
KHYBER PASS
GREAT HIMALAYAS
ISLAMABAD
RAWALPINDI
N.W.F.P
AFGHANISTAN
Lahore
PUNJAB
HARRAPA
KHOJAK PASS
QUETTA
SIBI
BOLAN PASS
PLAIN
MULTAN
INDIA
BALUCHISTAN
INDUS
CHOLISTAN
SUKKUR
IRAN
MOHENJODARO
PLATEAU
THAR DESERT
SIND
PLAIN
Central makran Range
GWADAR
Makran Coast Range
HYDERABAD
Karachi
Arabian Sea
RANN OF KUTCH


CLICK HERE FOR LARGER MAP
Tajikistan
Uzbekistan
HINDU KUSH
China
Northern Areas
Turkmenistan
Kabul River
Kabul
200 mi
200 km
Khyber Pass
Peshawar
Islamabad
Jammu and Kashmir
©GraphicMaps.com
Afghanistan
Gujrat
Indus River
Lahore
Zhob
Hazarganji Chiltan N.P.
Quetta
Multan
Chenab River
Bahawalpur
Nok Kundi
Delhi
Pakistan
Baluchistan Plateau
Iran
Mashkai River
Kirthar N.P.
Sukkur
India
Hingol N.P.
Indus River
Gwadar
Ormara
Hyderabad
Karachi
Arabian Sea
Mouths of the Indus
TROPIC OF CANCER
PAKISTAN
LOW / HILLS / MOUNTAINS


Uzbekistan
Tajikistan
Turkmenistan
China
Afghanistan
Islamabad
Lahore
Pakistan
Iran
India
Karachi
Arabian
Sea

Seasonal Study of AOT for the period (2005-06)





Lat=36N
Lat=28N
Lat=33N
Lat=25N
Lat=30N
Lat=22N
AOT
Long
Pre-monsoon
Post-Monsoon

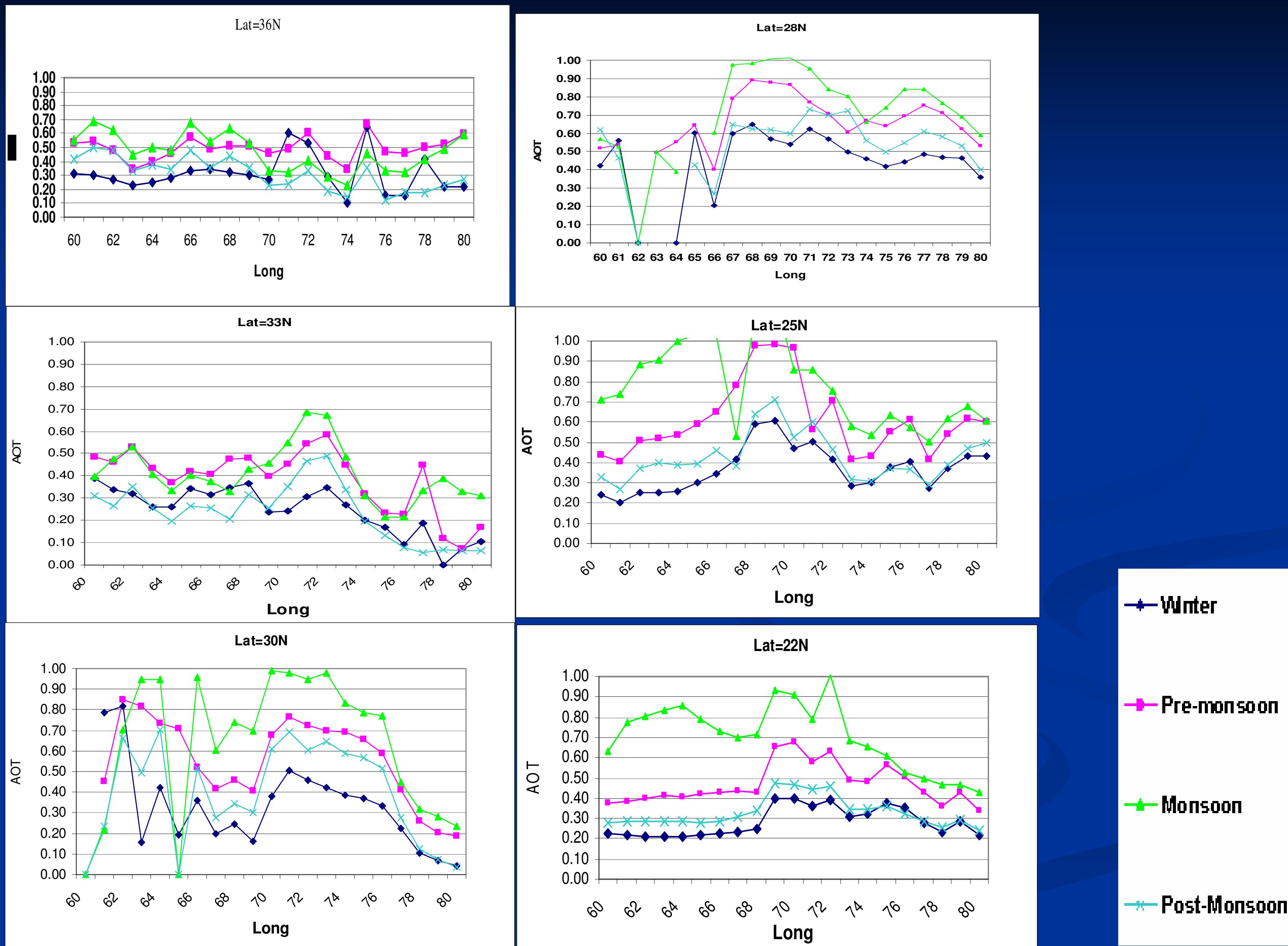
Seasonal Study of AOT

Study of AOT in pre and post-monsoon seasons at different latitudes by taking averages for the years from 2000 to 2006 shows that its maximum value almost remained in the pre-Monsoon season at all latitudes but at 25N it reached 0.9-1.0

Latitudinal Study of AOT

Maximum value remains below latitude 30^{o}N and minimum above this latitude

Seasonal Variation of AOT (0.55 um) over Pakistan (2000-06)

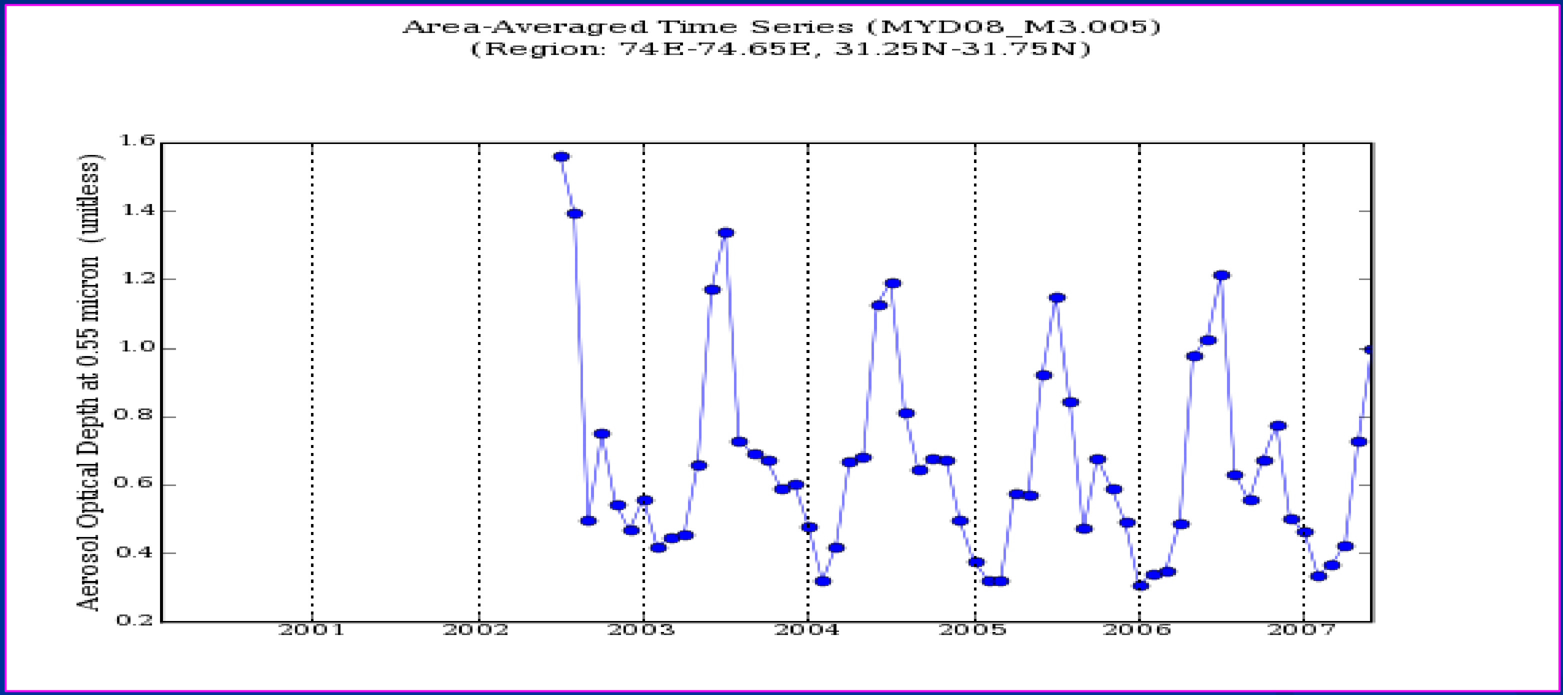


MODIS- Derived AOT

Region (31.25 - 31.75^{0}N, 74 - 74.65^0 E)

Yearwise **AOT (2001-07)**

Region (31.25 - 31.75^{0}N, 74 - 74.65^0 E)



Monthly **AOT**

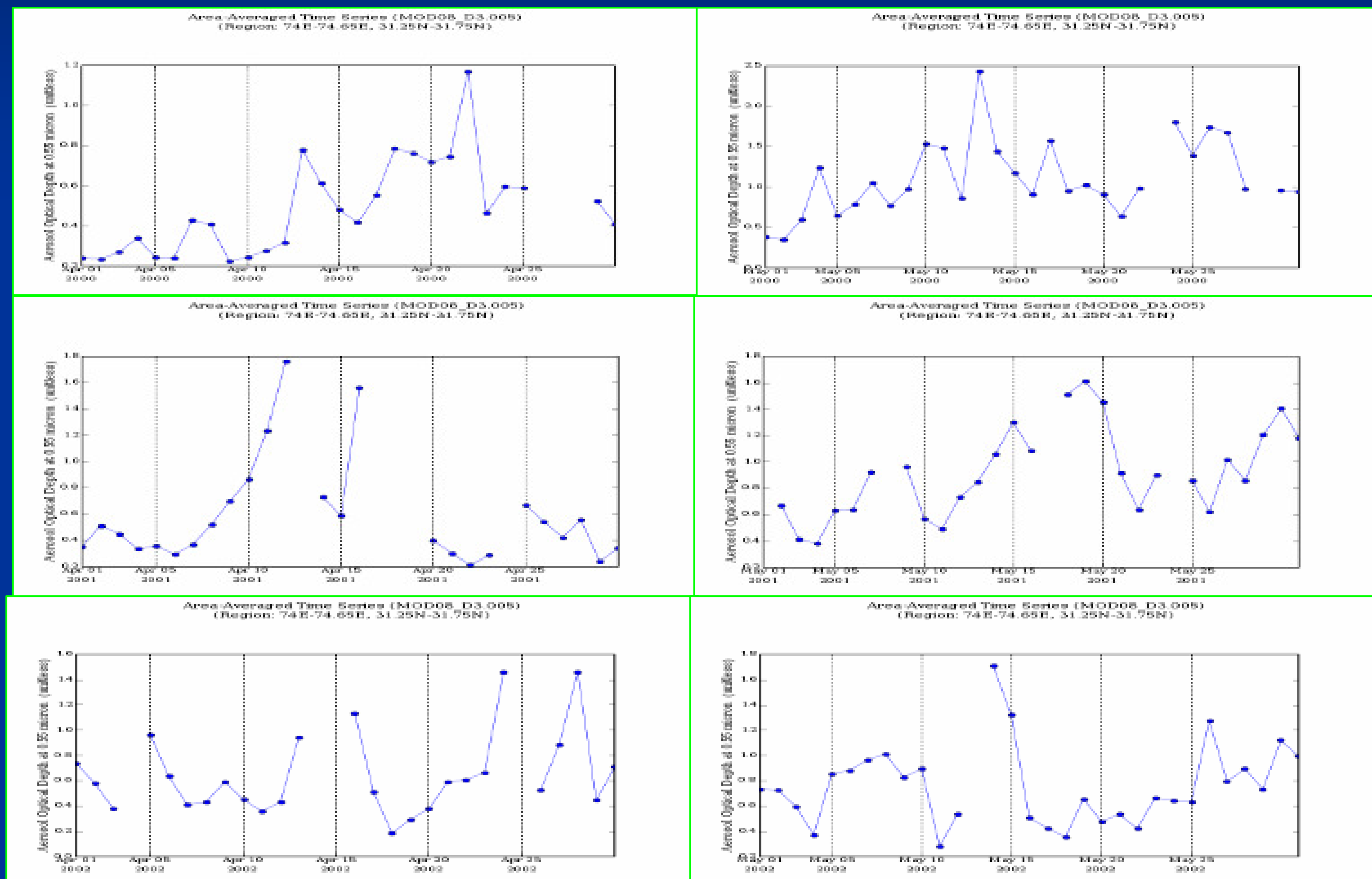
Region (31.25 - 31.75^{0}N, 74 - 74.65^0 E)

April | **May**

2000

2001

2002

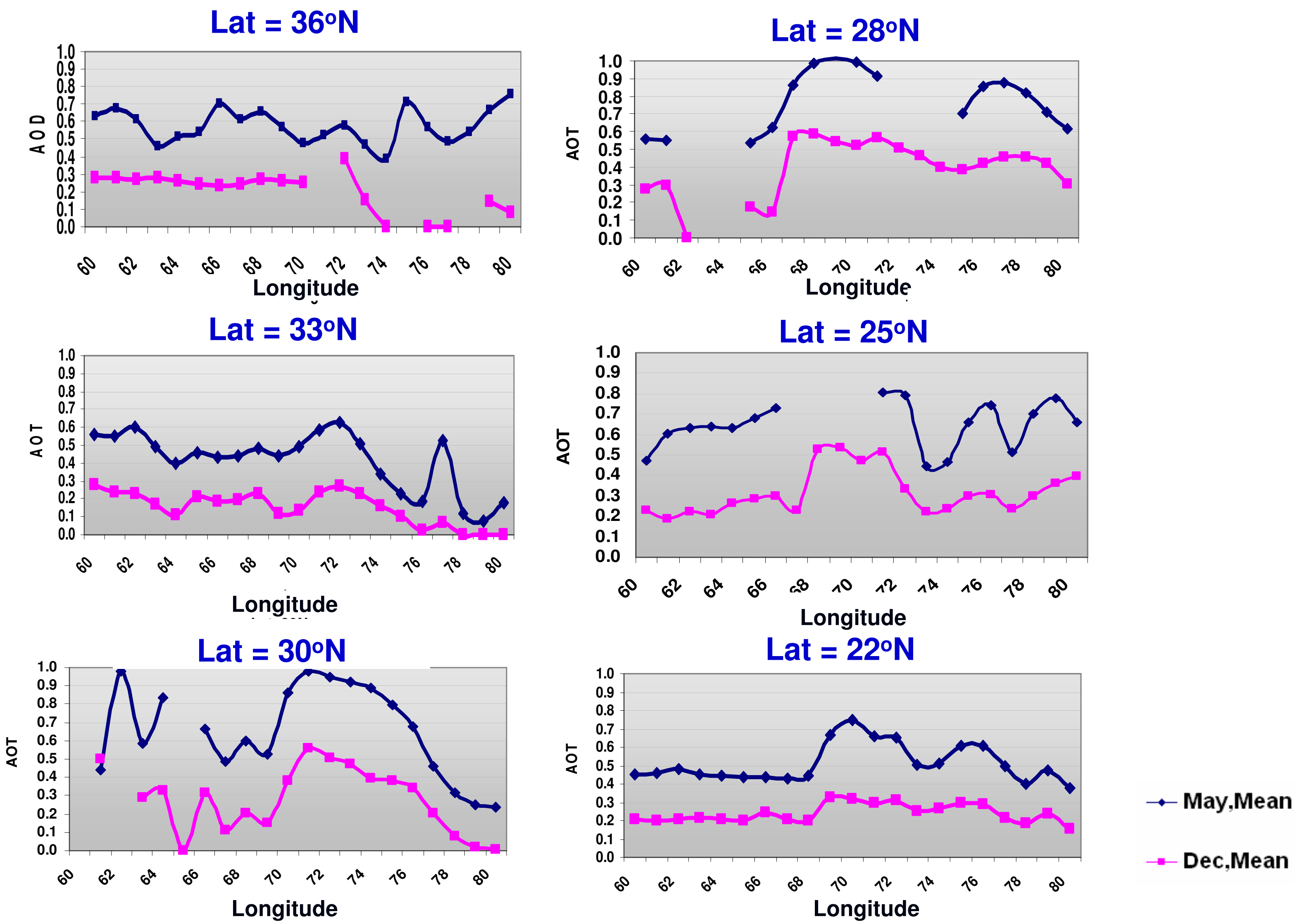


Seasonal Study of AOT

Seasonal study of AOT in different seasons at all latitudes by taking averages for the years from 2000 to 2006 shows that its maximum value almost remained maximum in the Monsoon season with value of about 0.6-0.8 and minimum value remained in winter season with value of about 0.2-0.3. In other seasons of Pre-monsoon and post-monsoon its values are in the range: 0.4-0.5.

Latitudinal Study of AOT

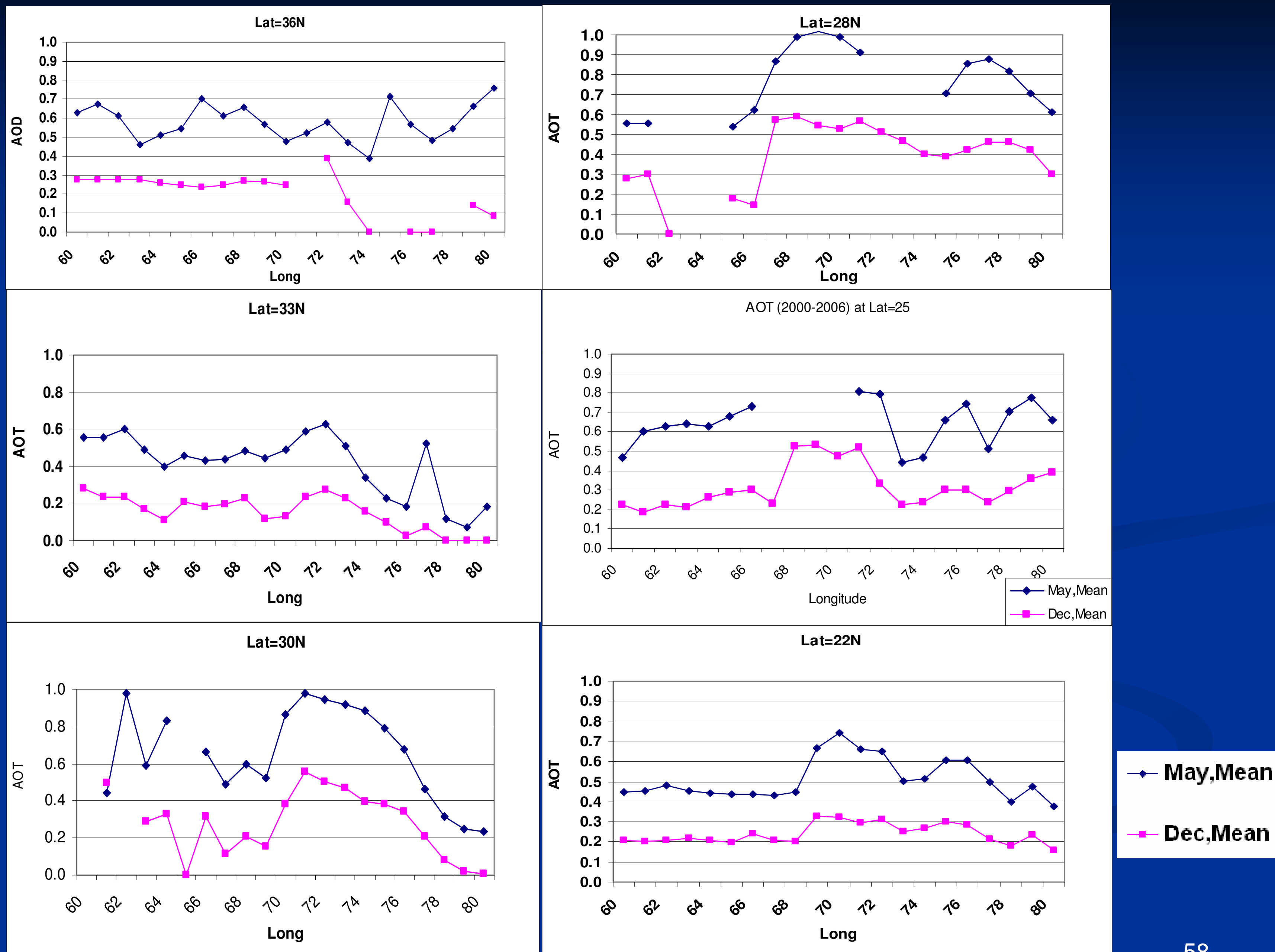
Maximum value remains below latitude 30^{o}N and minimum above this latitude



AOT (May, December)

Study of AOT in the months of May and December shows that at all latitudes it was maximum in May (0.5-0.8) and minimum in December

AOT (2000-2006) over Pakistan

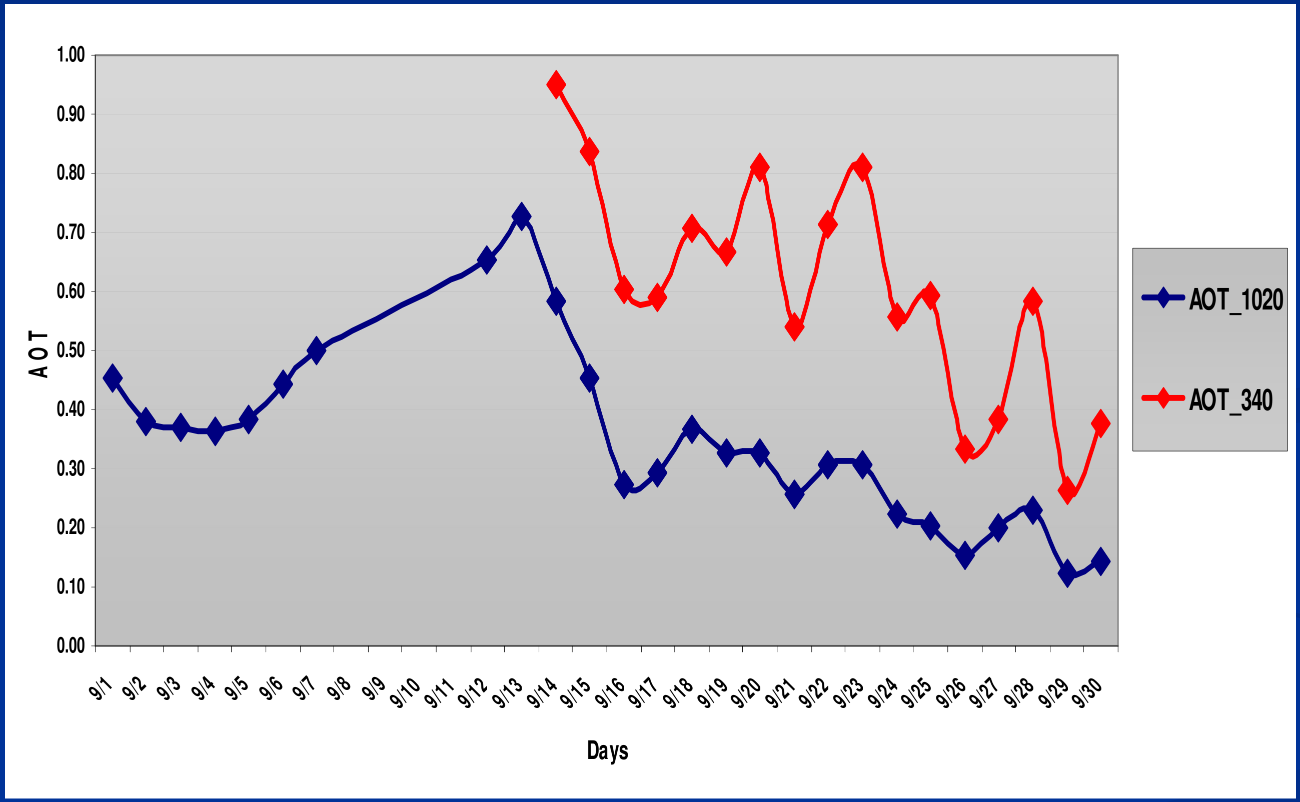


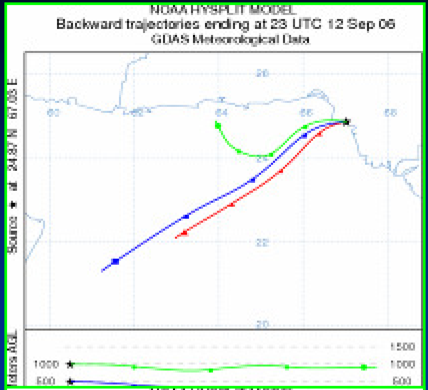
Ground-based Study of AOT Through Sunphotometers

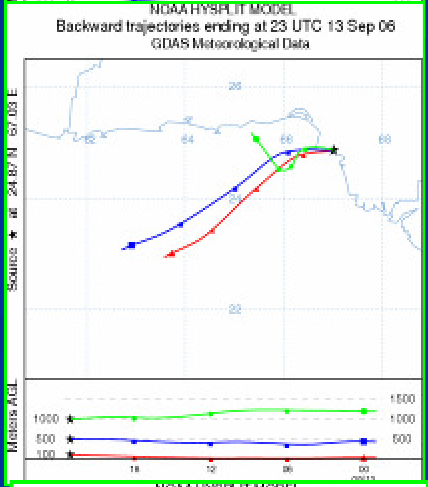
(Karachi)

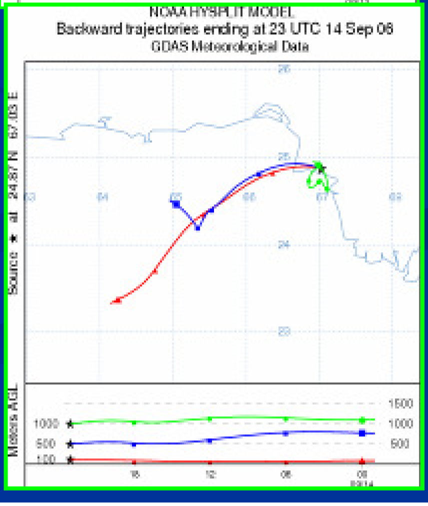
Backward Trajectory

Sep 2006

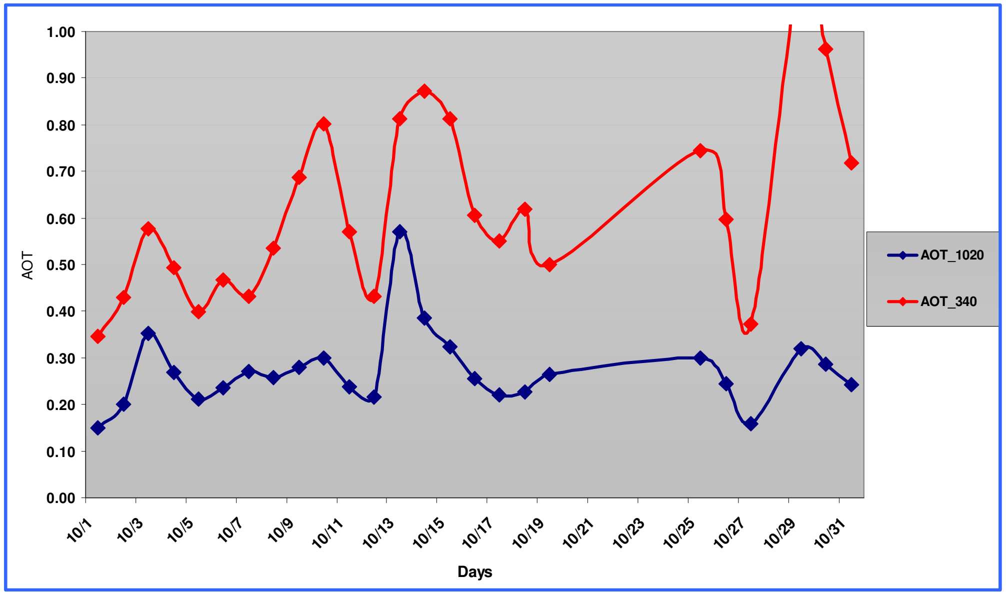




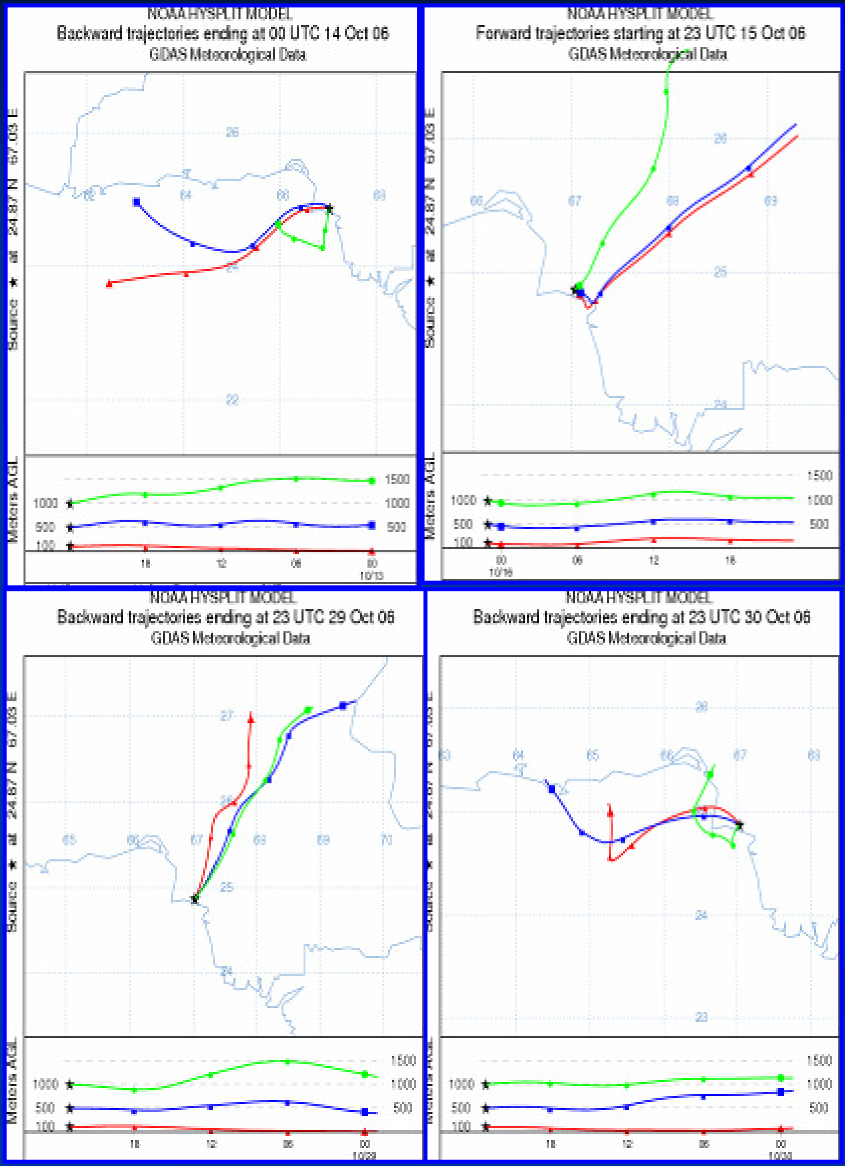




October 2006

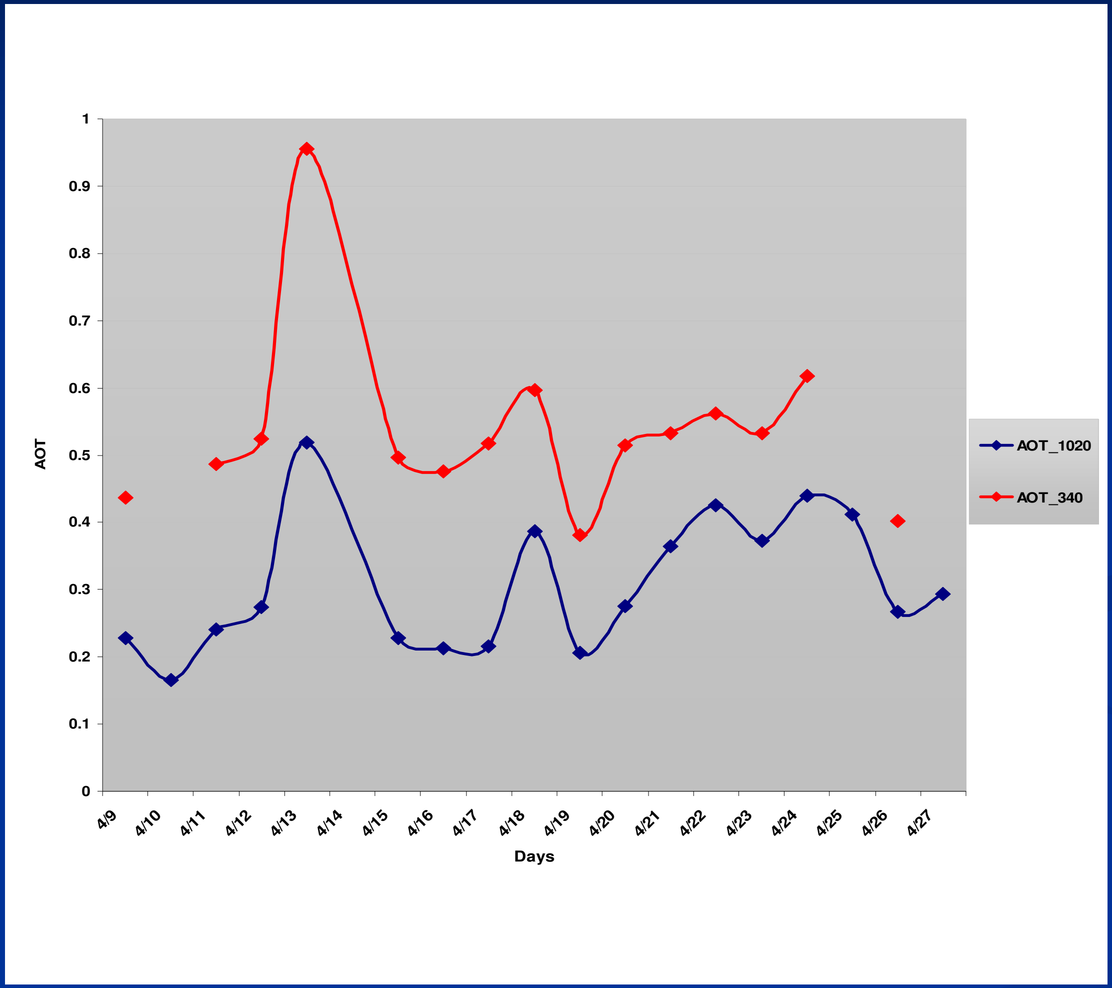


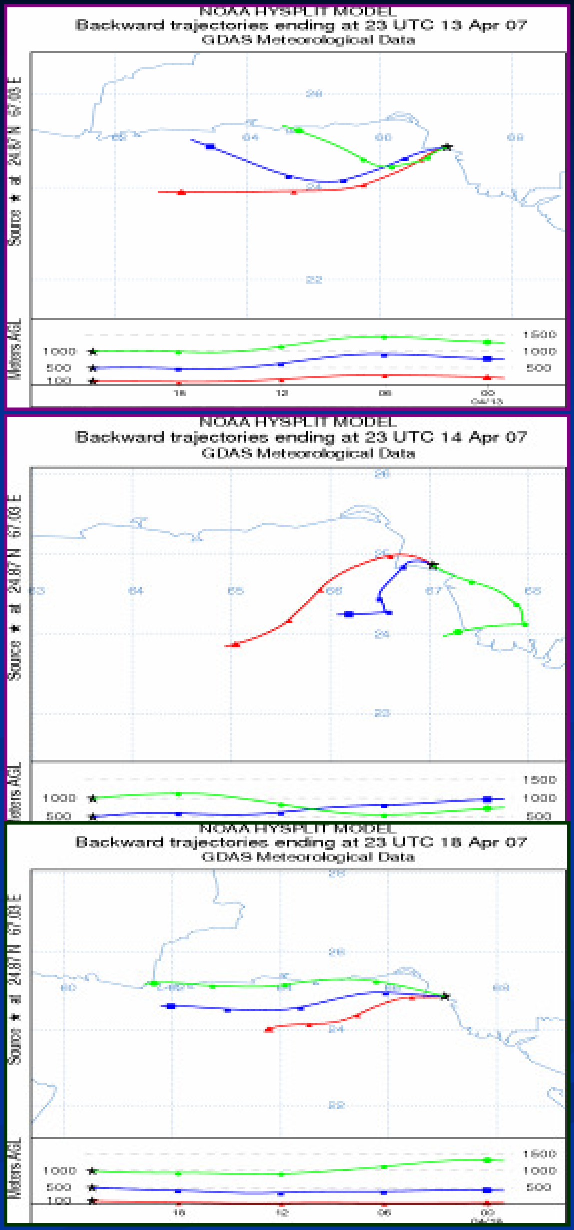
Backward Trajectory



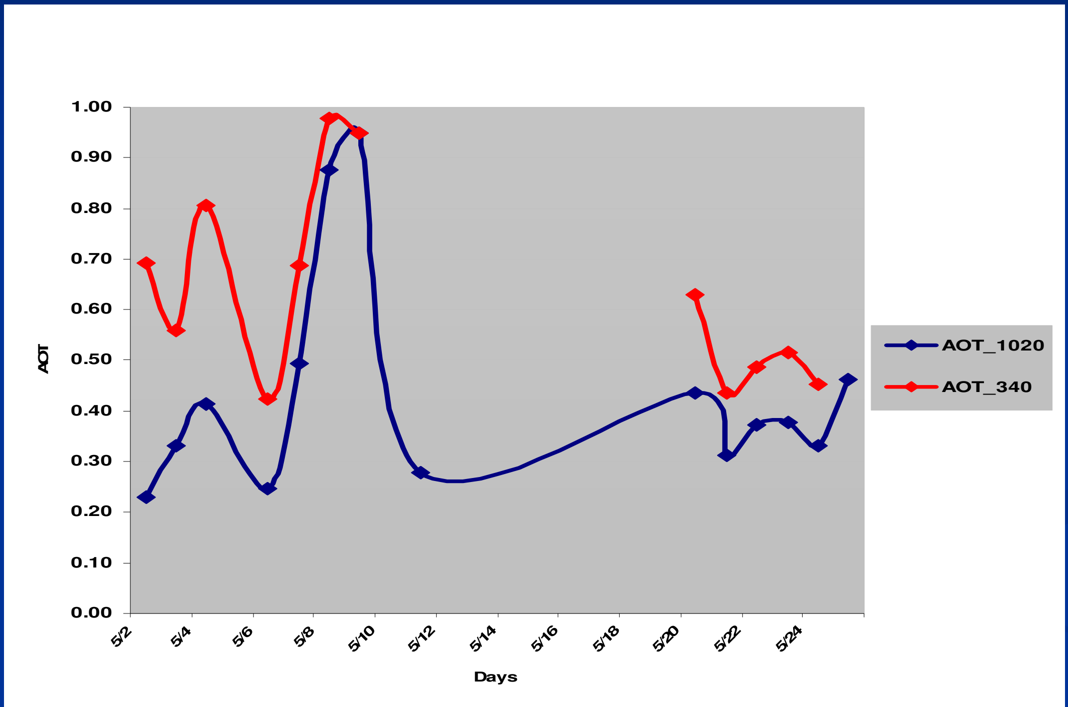
Backward Trajectory

April 2007

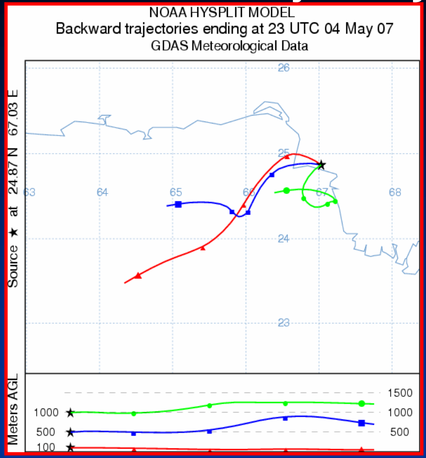


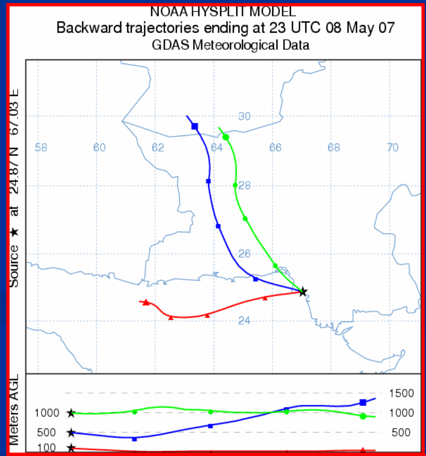


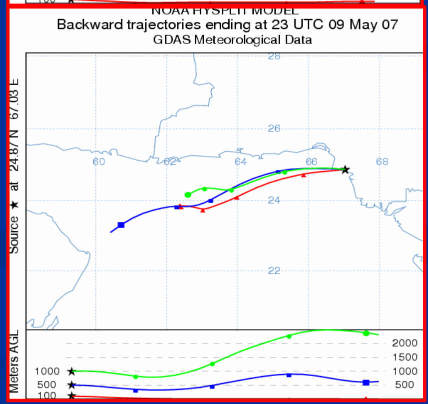
May 2007



Backward Trajectory







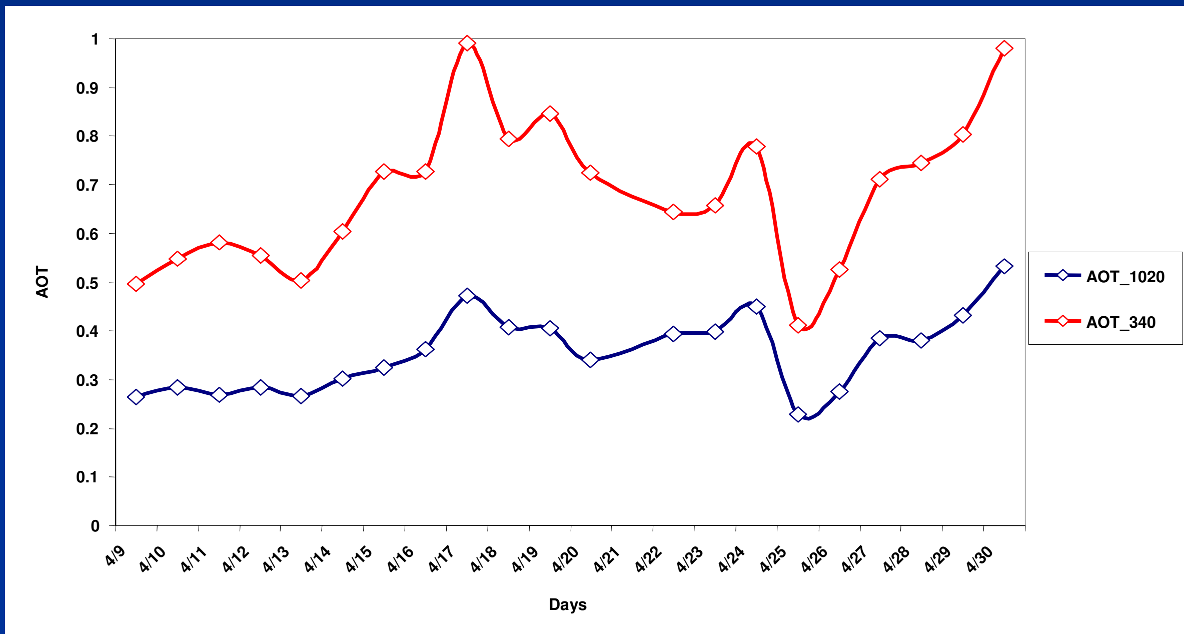
Analysis-Karachi

Months	Maximum *(nanometer)*	Minimum *(nanometer)*	Backward Trajectory Pattern
Apr	340,380,440 (0.27-0.95)	1020,870 (0.16-0.57)	West, South
May	340,380,440,500 (0.33-0.98)	1020,870,675 (0.22-0.97)	North-west, West
Sep	340,380,500 (0.21-0.99)	1020,870 (0.16-0.78)	South-west
Oct	340,380,440 (0.27-0.95)	1020,870,675 (0.15-0.64)	South-west, North-east

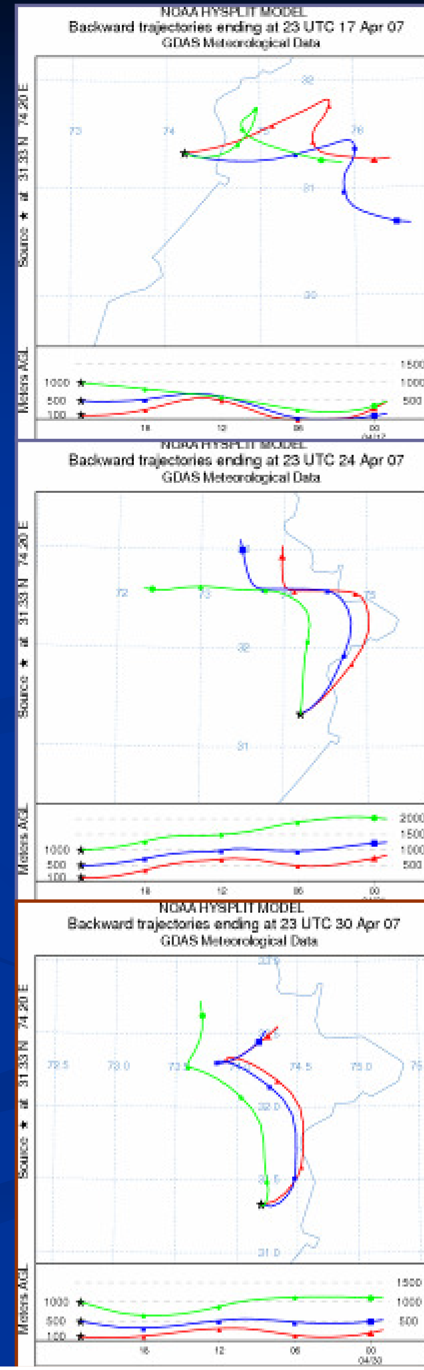
As shown from the analysis table on the previous slide ; study of aerosol concentration over Karachi as derived from sunphotometer installed at SUPARCO, Karachi shows that maximum concentration in the range of upto 0.98 was that of particles of size 340 nm and minimum was that of the size 1020 nm. From the backward trajectory pattern it is clear that in the months from Oct-Dec the transport of particles is either from South-west or North-east means either oceanic sulphates or due to emission in the north eastern or dust. In all other months the transport is from south-west

AOT and Backward Trajectory
- Lahore

April 2007



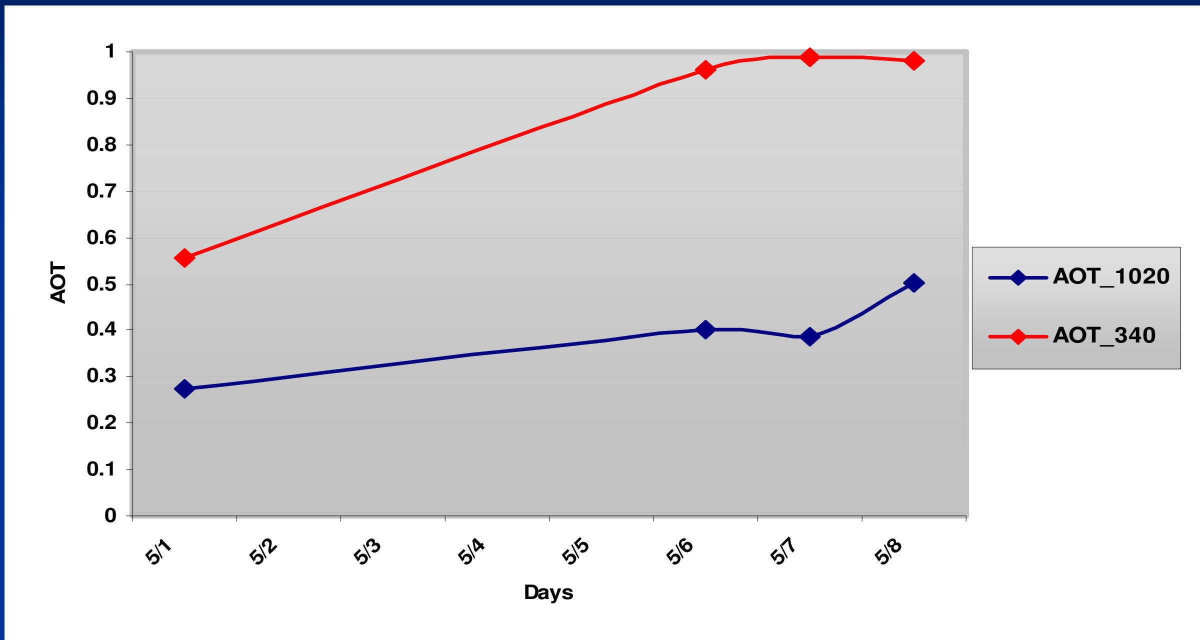
Backward Trajectory



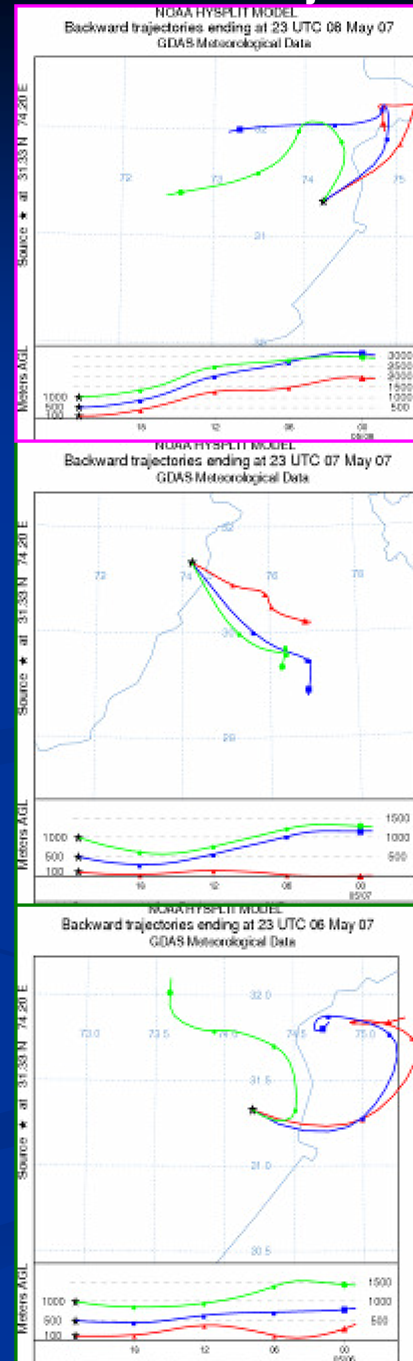
Analysis-Lahore

Months	Maximum (nm)	Minimum (nm)	Backward Trajectory Pattern
Apr	340,380,440 (0.42-0.99)	1020,870 (0.23-0.64)	North-east
May	340,380,440,500 (0.41-0.99)	1020,870 (0.27-0.57)	North-east, South-east

May 2007



Backward Trajectory



Monthly **AOT**

Region (31.25 - 31.75^{0}N, 74 - 74.65^0 E)

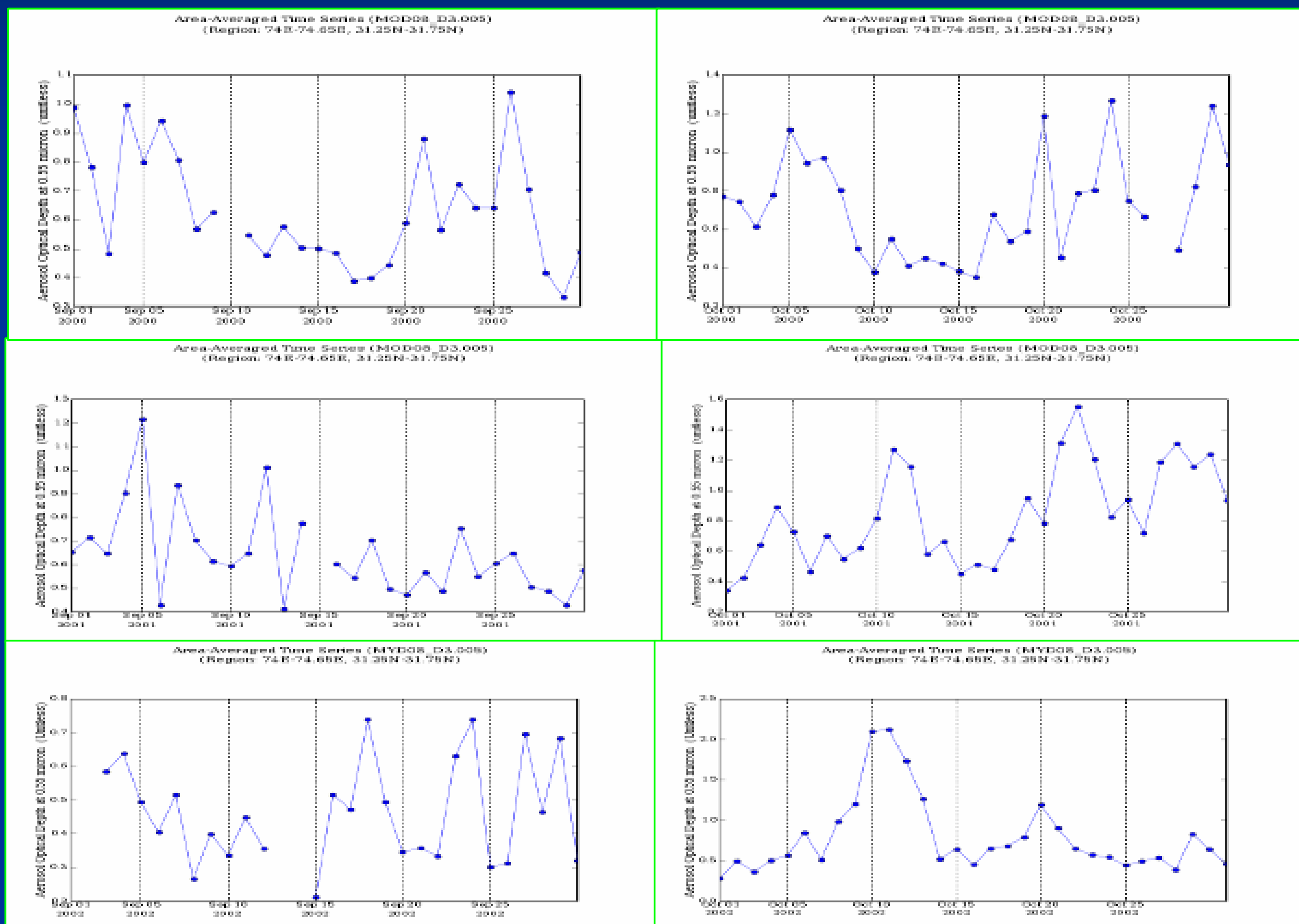
Septempber

October

2000

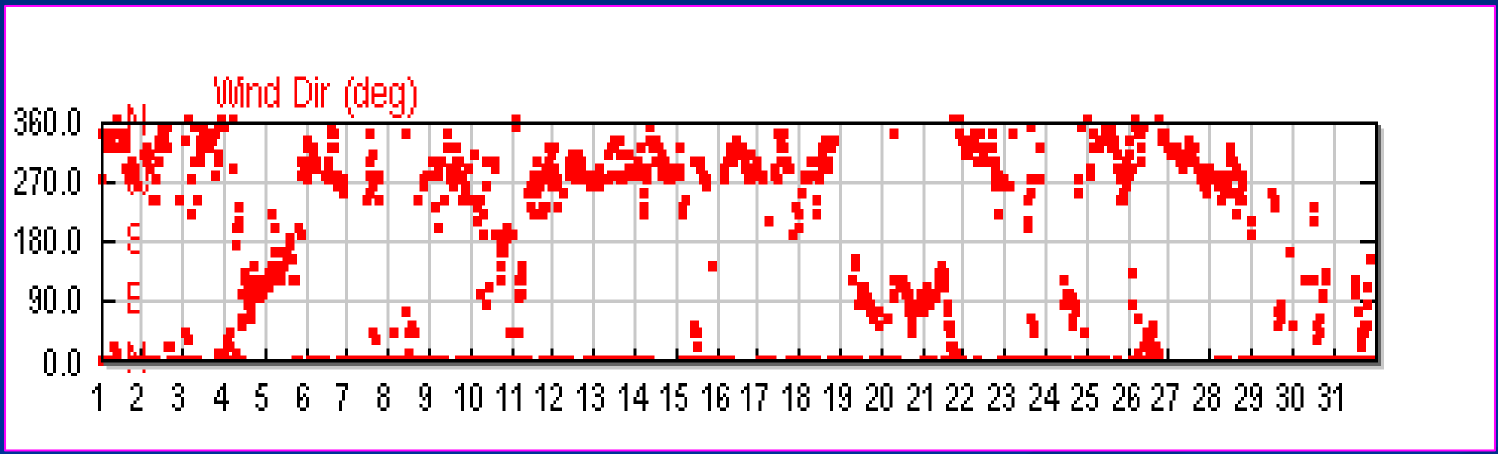
2001

2002

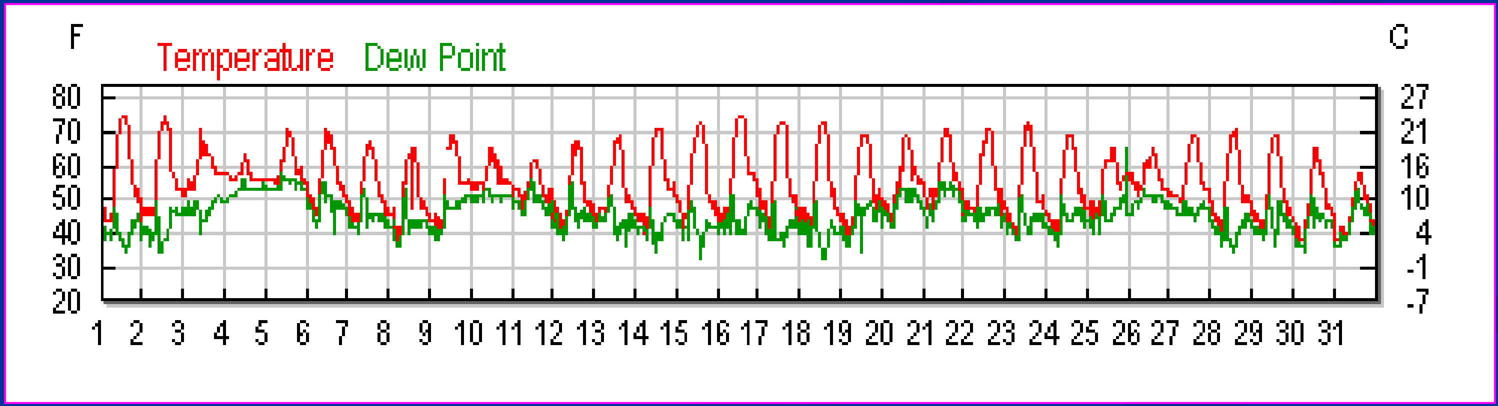


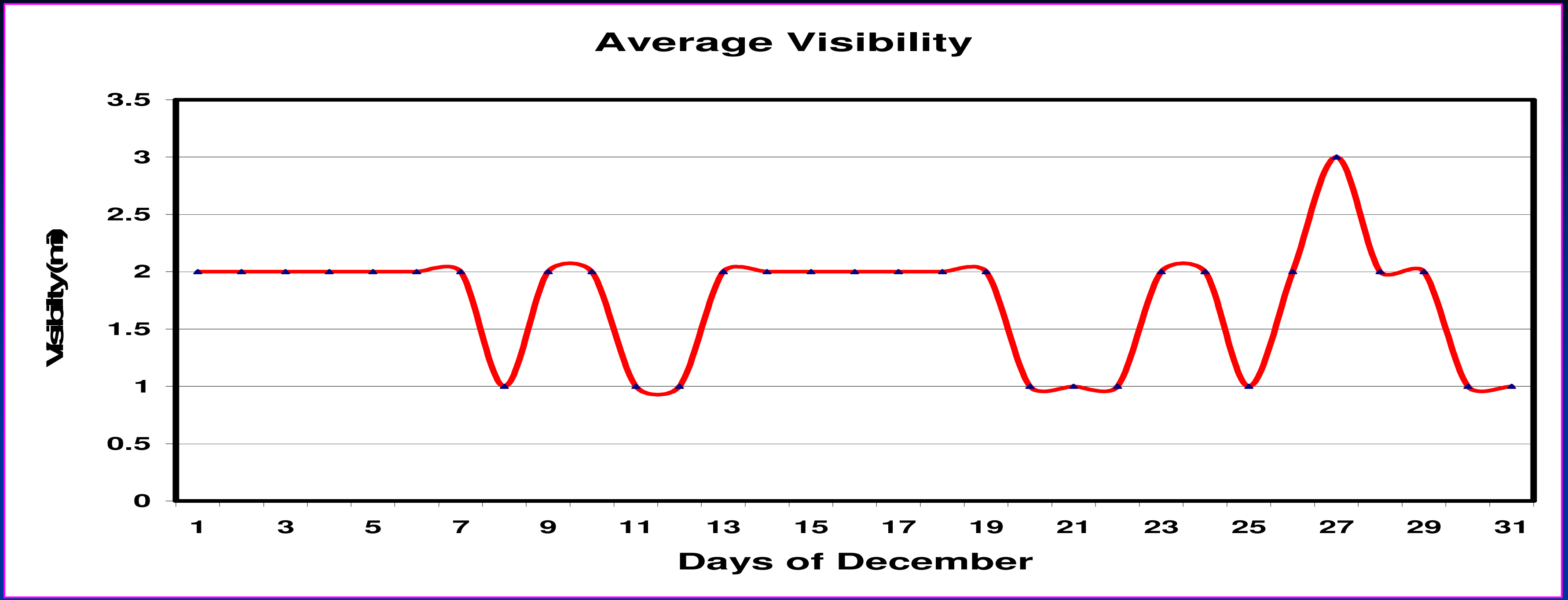
Wind Direction & Temperature (Dew)

Region (31.25 - 31.75^{0}N, 74 - 74.65^0 E)

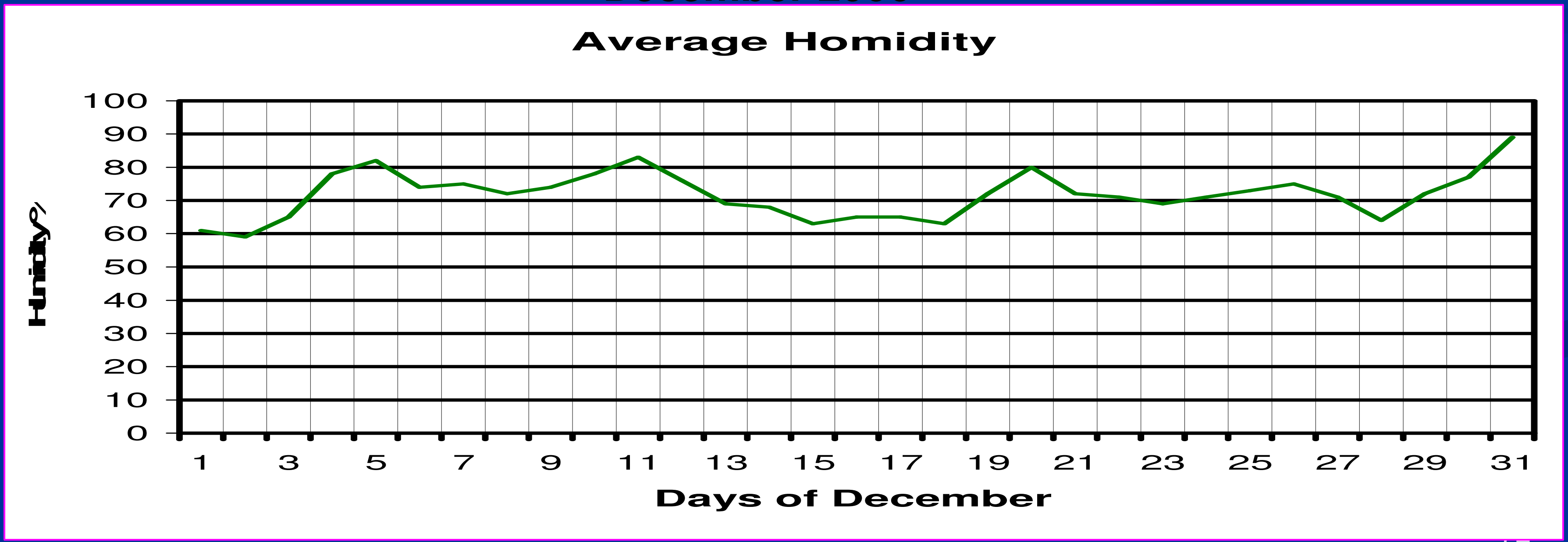


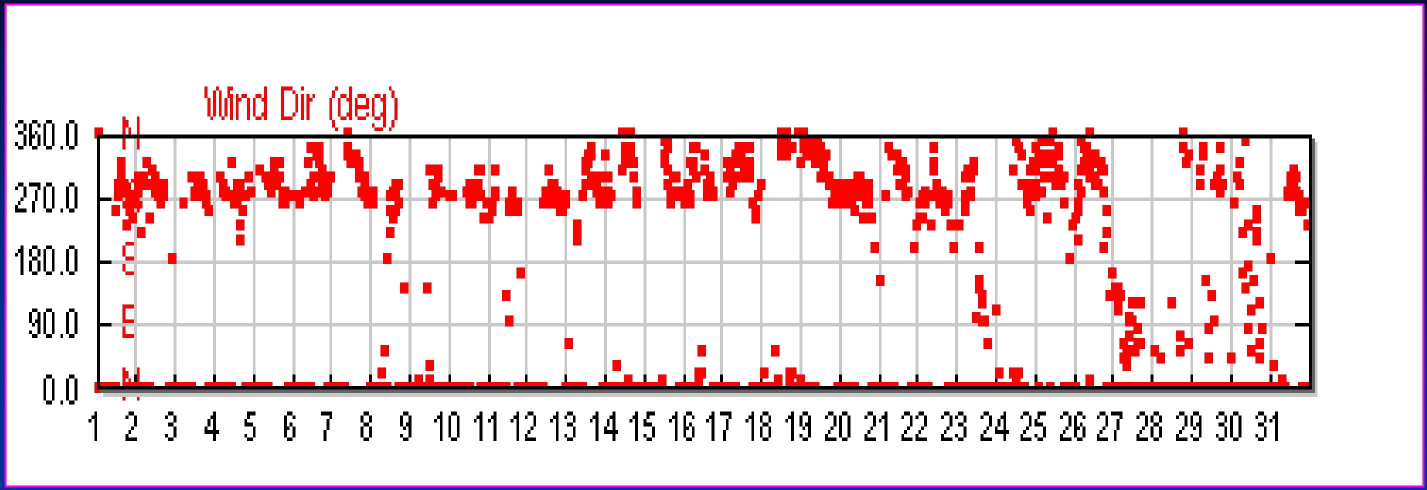
December 2006



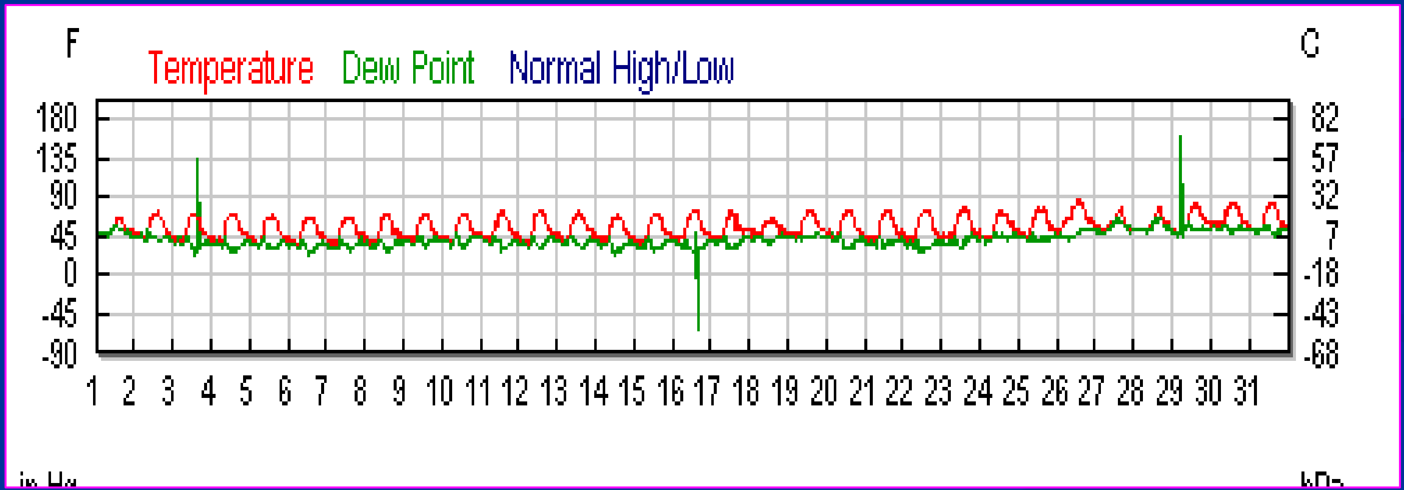


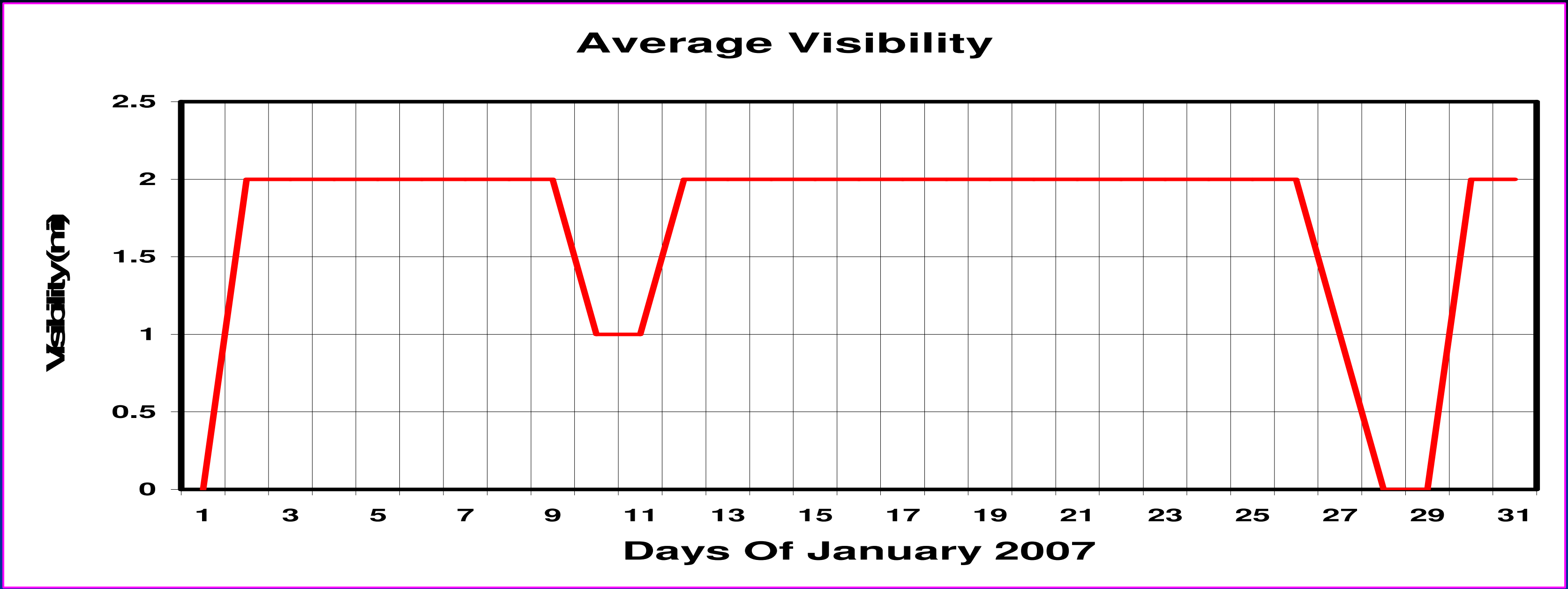
December 2006



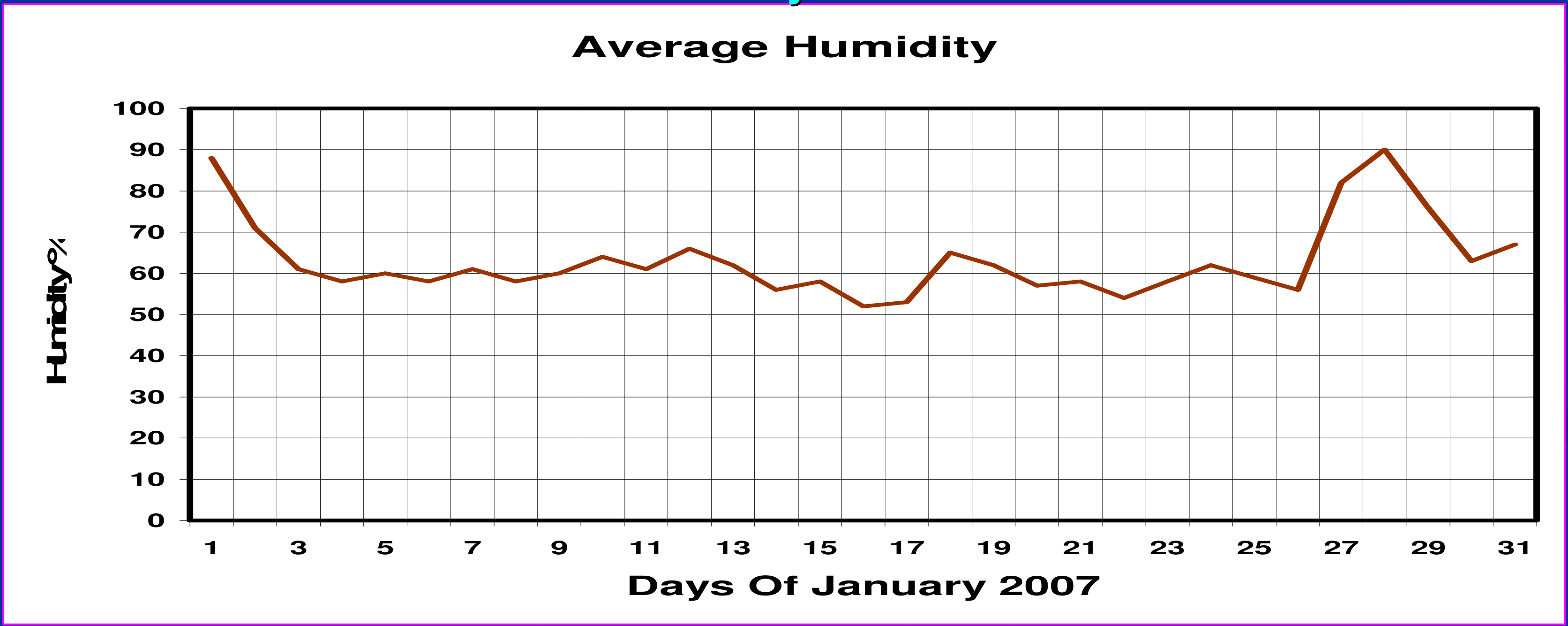


January 2007

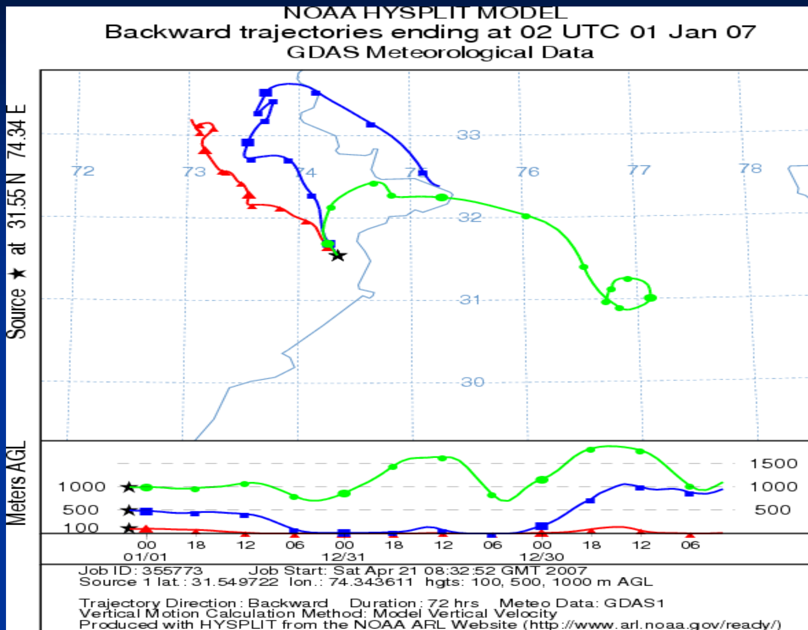


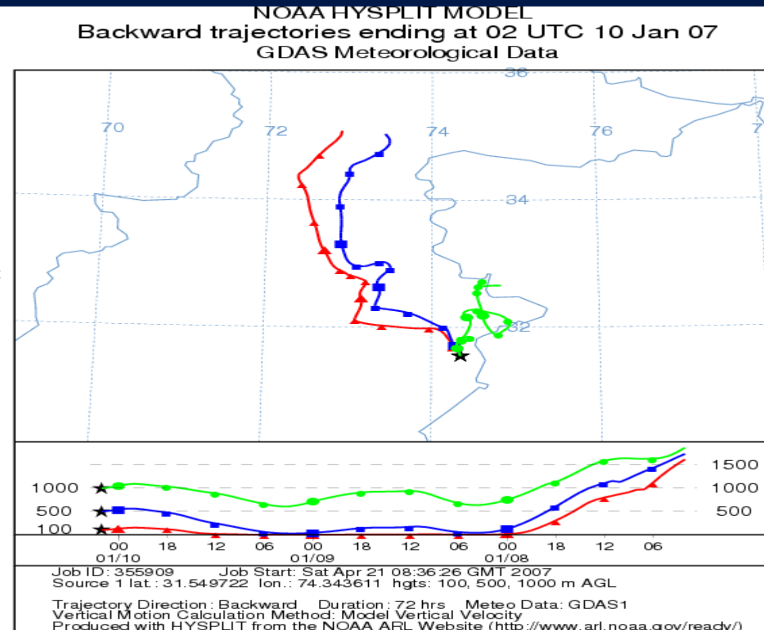


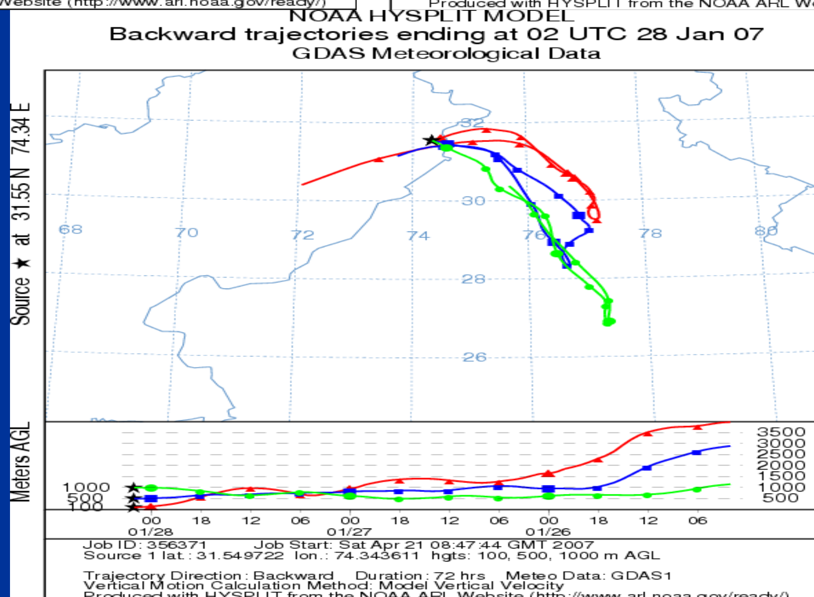
January 2007



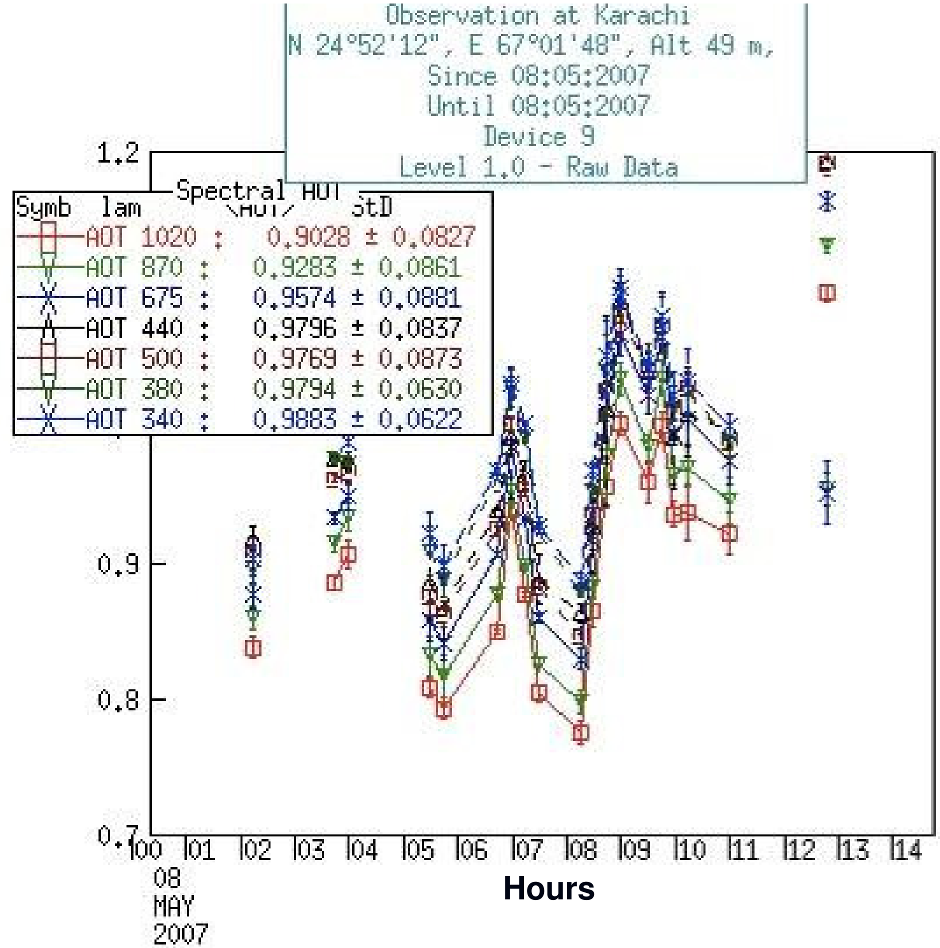
Back Air Trajectory at Lahore
January 2007



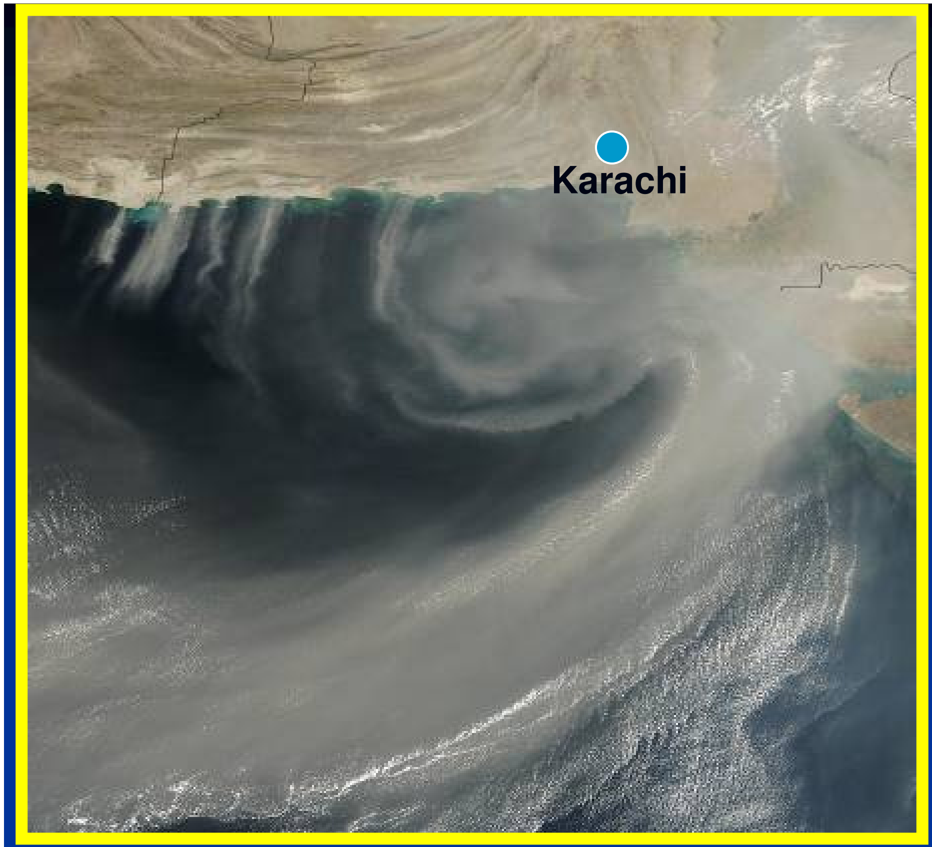


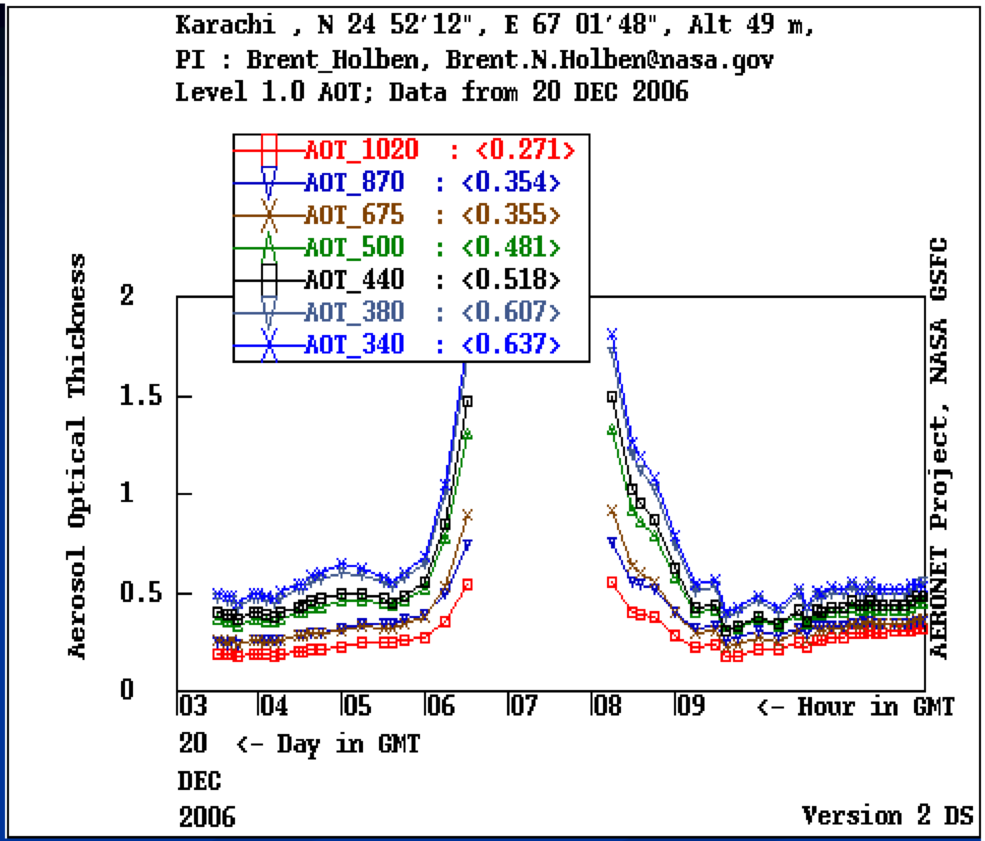


Dust Storms



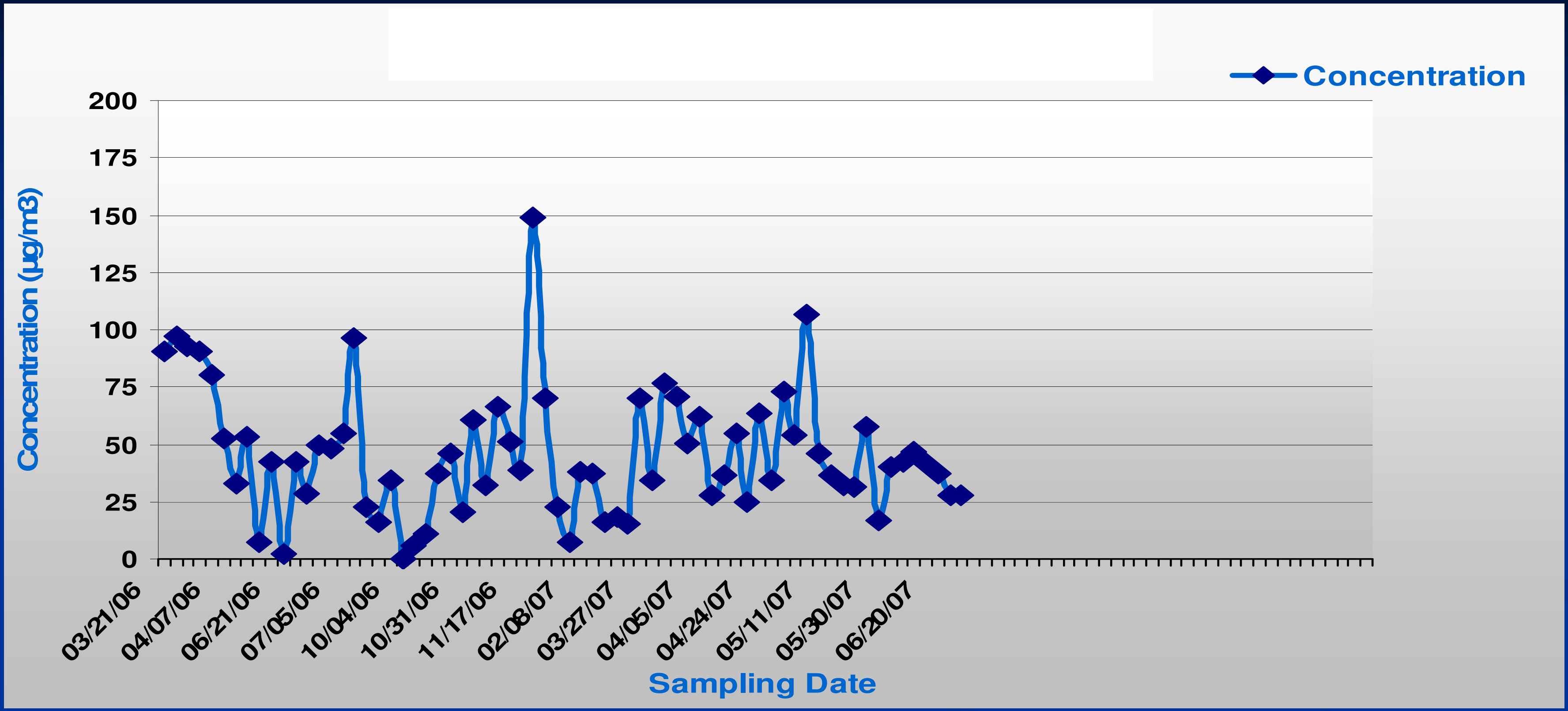
May 8, 2007 Terra true color image of regional dust transport over S. Pakistan. The plot on the right shows the highly variable AOD as measured in several spectral wavelengths by an AERONET station in Karachi as the dust is transported over the city.



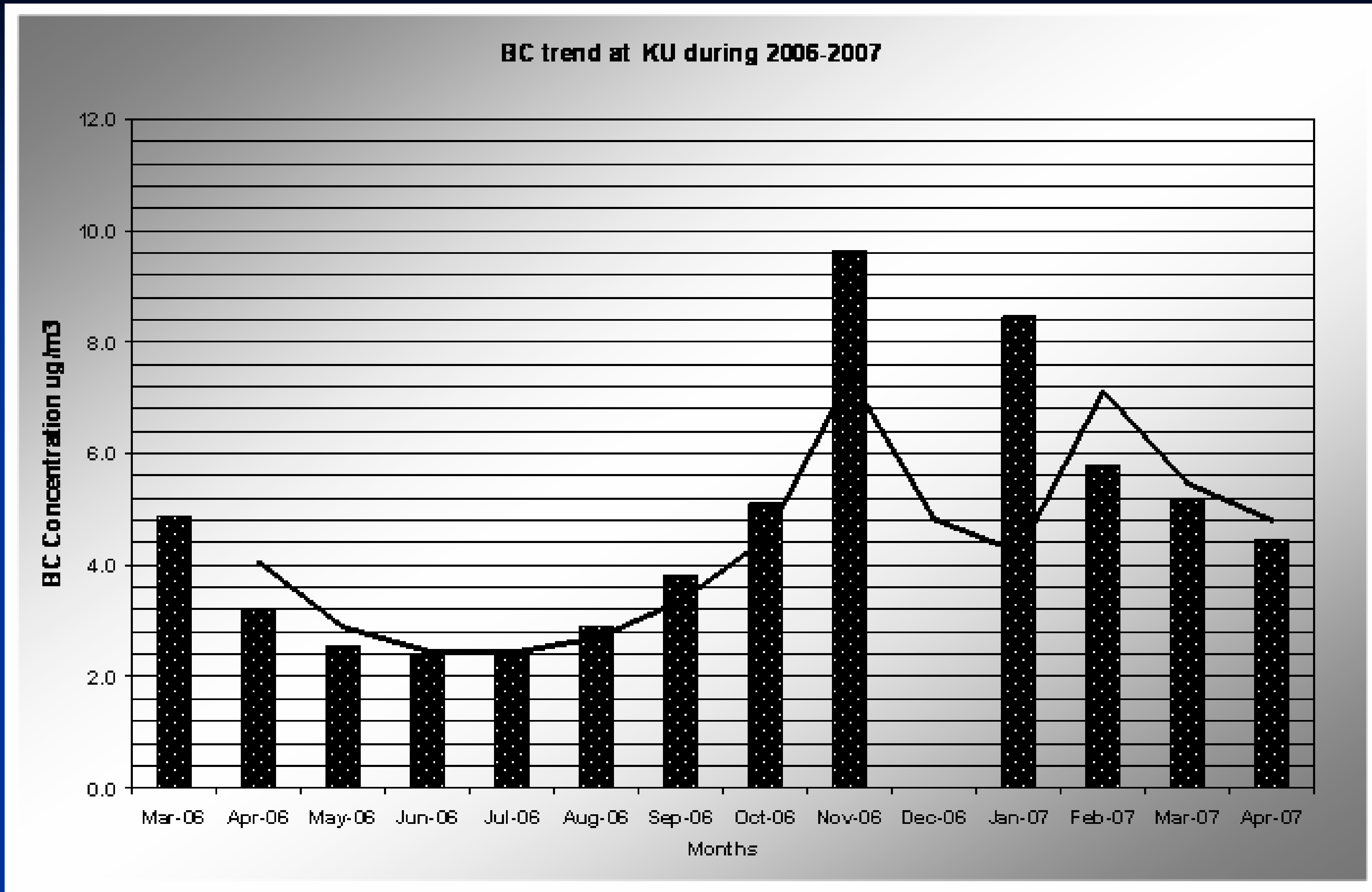


Dec 20, 2006 Terra true color image of regional dust transport over coast of Pakistan. The plot on the right shows the highly variable AOT from 0.271 to 0.637 as measured in spectral wavelength ranges from 340nm to 1020nm by an AERONET station in Karachi as the dust is transported over the city

Black Carbon Aerosols in Urban Areas



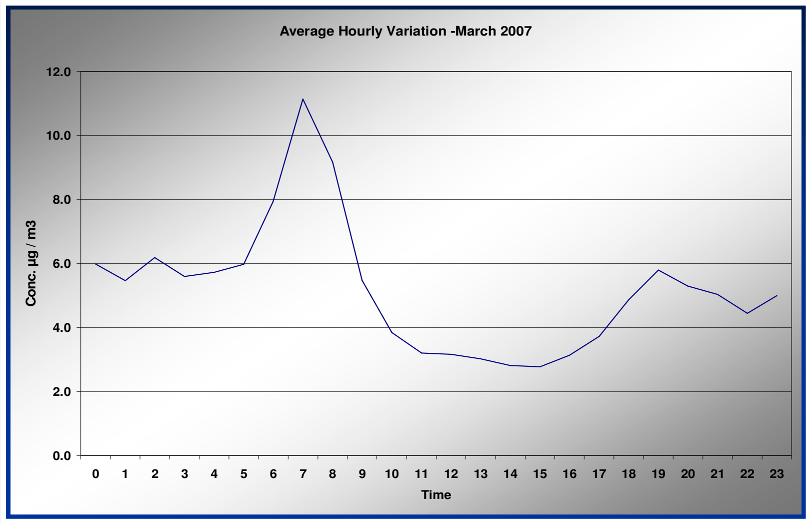
PM2.5 Concentration at Karachi

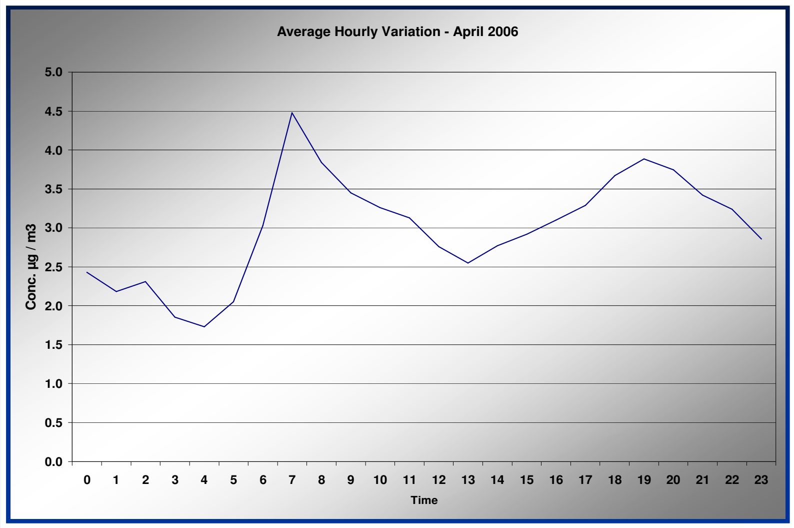


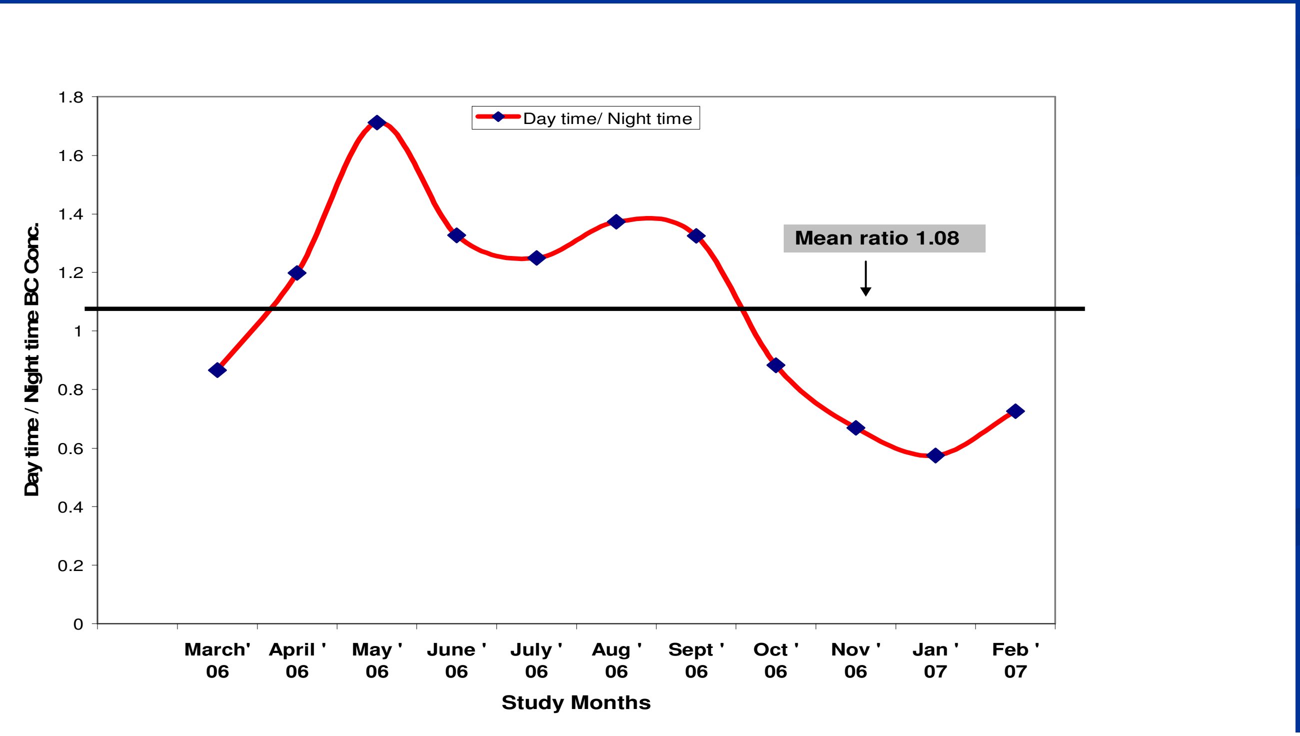
Variations of Black Carbon in Karachi, Pakistan

Karachi (24.53°N, 67.01°E) which is an urban city, study of Black carbon (BC) aerosols was carried out out from March 2006 to April 2007 through Aethalometer in four cycles: summer (March-June), monsoon (July-August), post monsoon (September-October) and winter (November-February). Seasonal and diurnal variations of BC in relation to changes in the regional meteorological conditions and local boundary layer characteristics have been studied in every month. Also, wind data was studied to assess the direction and speed of wind transporting BC particles. Wind speed was divided in to four classes; Calm, Low (4-7m/s), High (7-11m/s) and very high (>11m/s). The data collected during (March 2006 to February 2007) indicated that average BC concentration in this period was 4.27µg/m3 at Karachi. During winter season, average BC concentration was maximum (about 40% more than annual mean), mainly due to prevailing meteorological conditions like low wind speeds and low ventilation coefficients; as well as due to the transport of BC from north-east regions of Karachi. Minimum BC concentration was observed during monsoon season i.e. 2.69µg/m3 (about 37% less than average period mean), which could be attributed to the wash-out effects due to precipitation as well as due to southwesterly high speed winds coming from marine areas. Diurnal variation of BC showed two peaks, one in morning and another in the afternoon, which are mostly related to the daily changes in the local boundary layer. However, the intensity of local traffic emissions could have impact on the magnitude of these peaks.

Hourly Variation of BC & Day/Night Concentration Ratio







Concentration (µg/m^3) of Black Carbon at Lahore

Nov 27	11.4	45	21.4
Nov 28	4.8	52.4	14.3
Nov 29	1.5	40.4	10.8
Nov 30	1.7	34.7	12
Dec 01	2.1	57.9	20.9
Dec 02	3.1	68.7	26.3
Dec 03	2.2	56.7	21.4
Dec 04	3.3	51.4	19.5
Dec 05	3.1	57.6	15.9
Dec 06	2.1	76.3	20.7

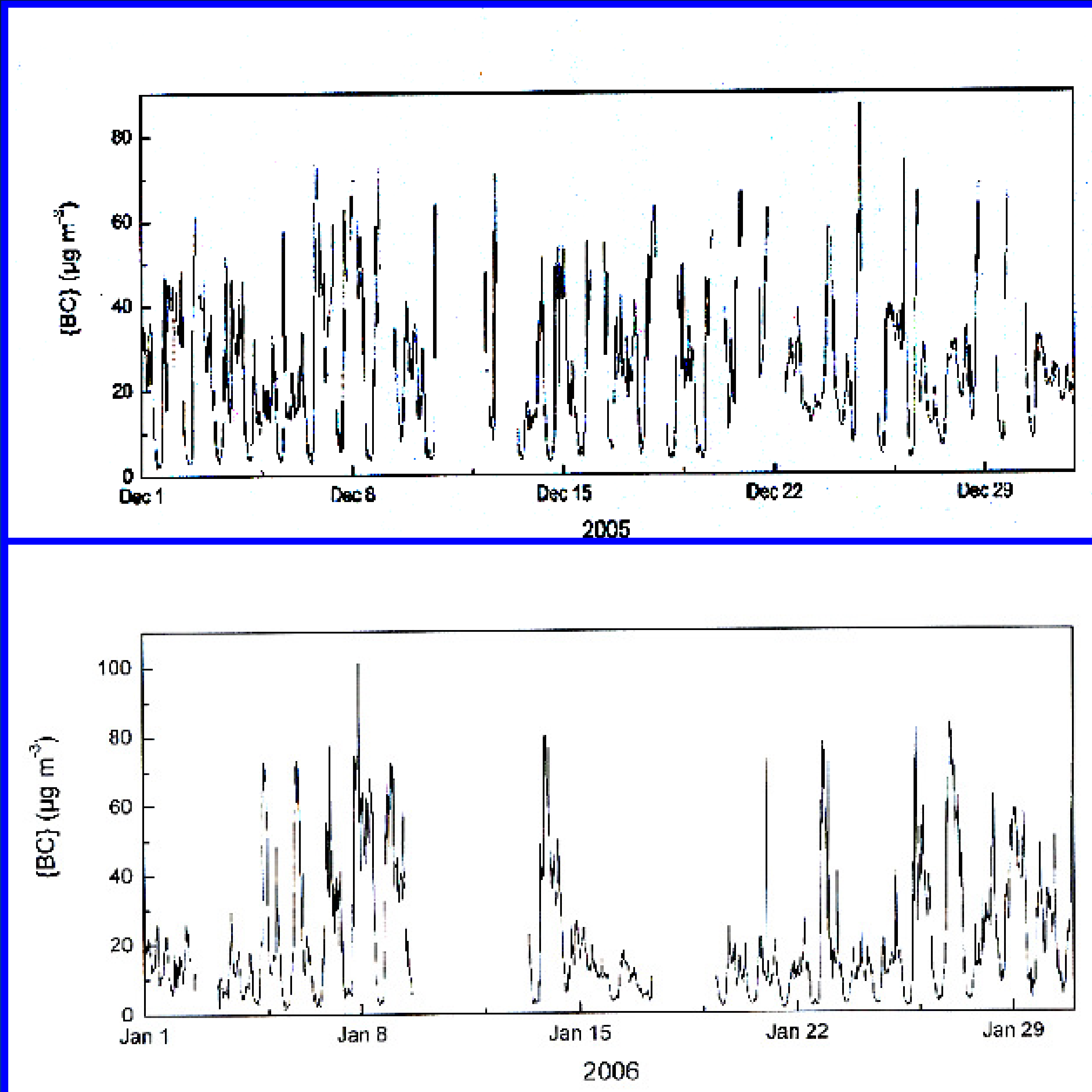
Size Distribution of Carbonaceous Aerosols at Lahore, Pakistan

Size (µm)	BC %	OC %
< 0.5	77	32
0.5 – 1.0	87	57
1.0 – 1.5	92	73
1.5 – 3.0	96	84
3.0 – 7.2	98	95
7.2 - 10	100	100

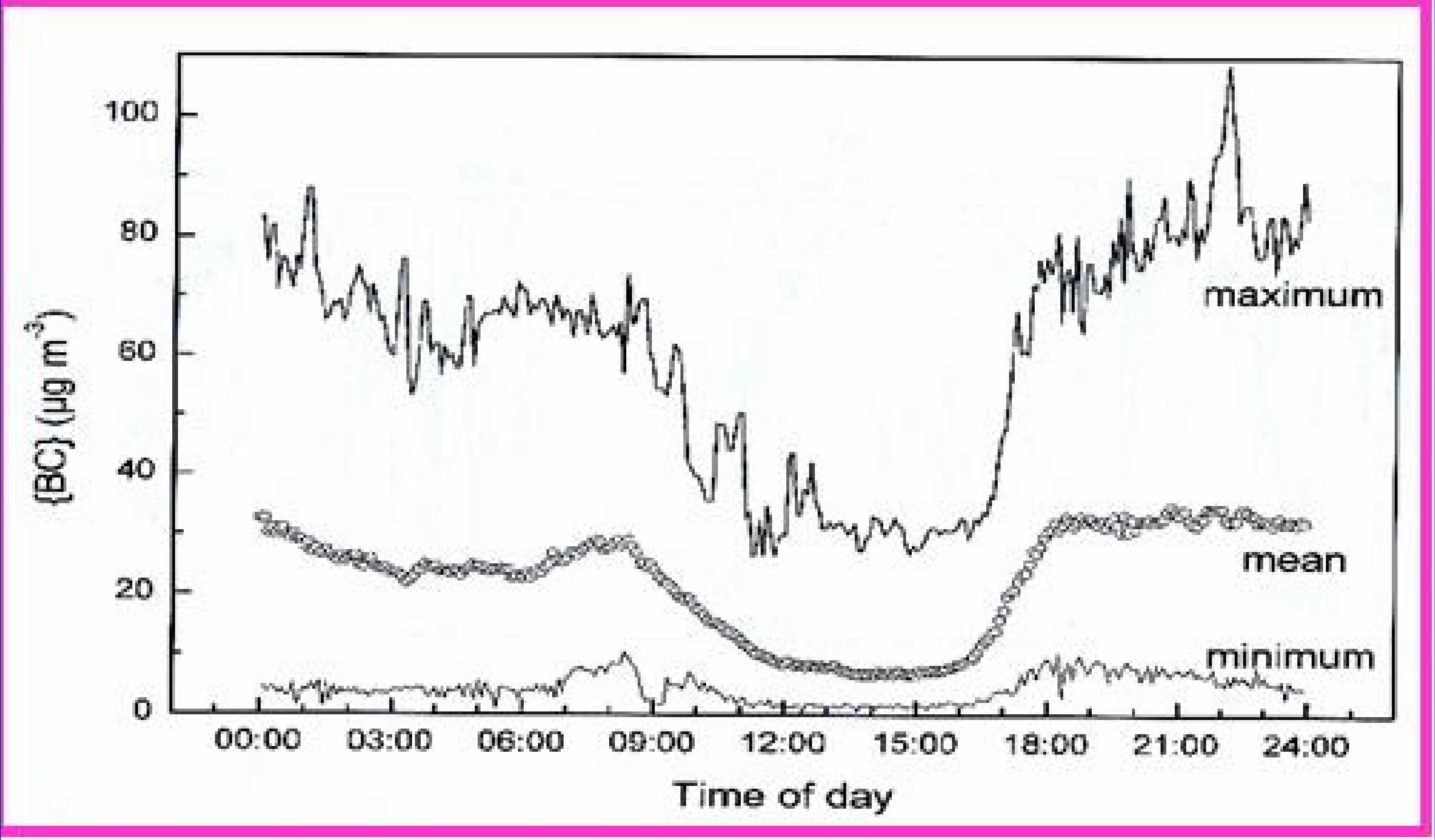
Concentration (μg/m^3) of black carbon at Lahore

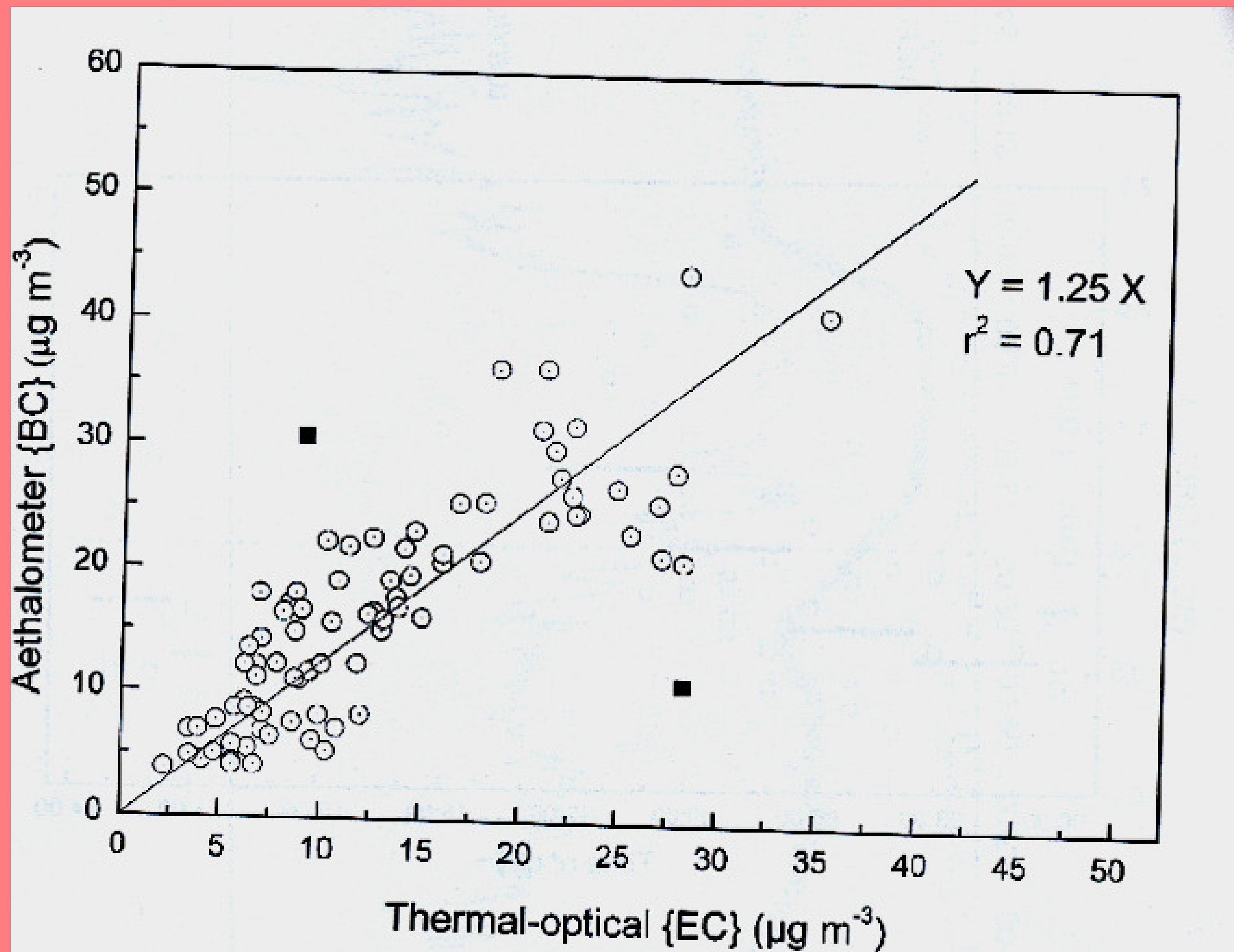
Date (2005)	Min.BC	Max. BC	Avg. BC
Nov 21	1.6	46.1	14.3
Nov 22	6	54.4	18.2
Nov 23	3.7	52.8	15.8
Nov 24	4.4	38.3	16.5
Nov 25	3.2	55.2	12.1
Nov 26	4.7	58.8	21.2

Daily Concentrations of BC at Lahore

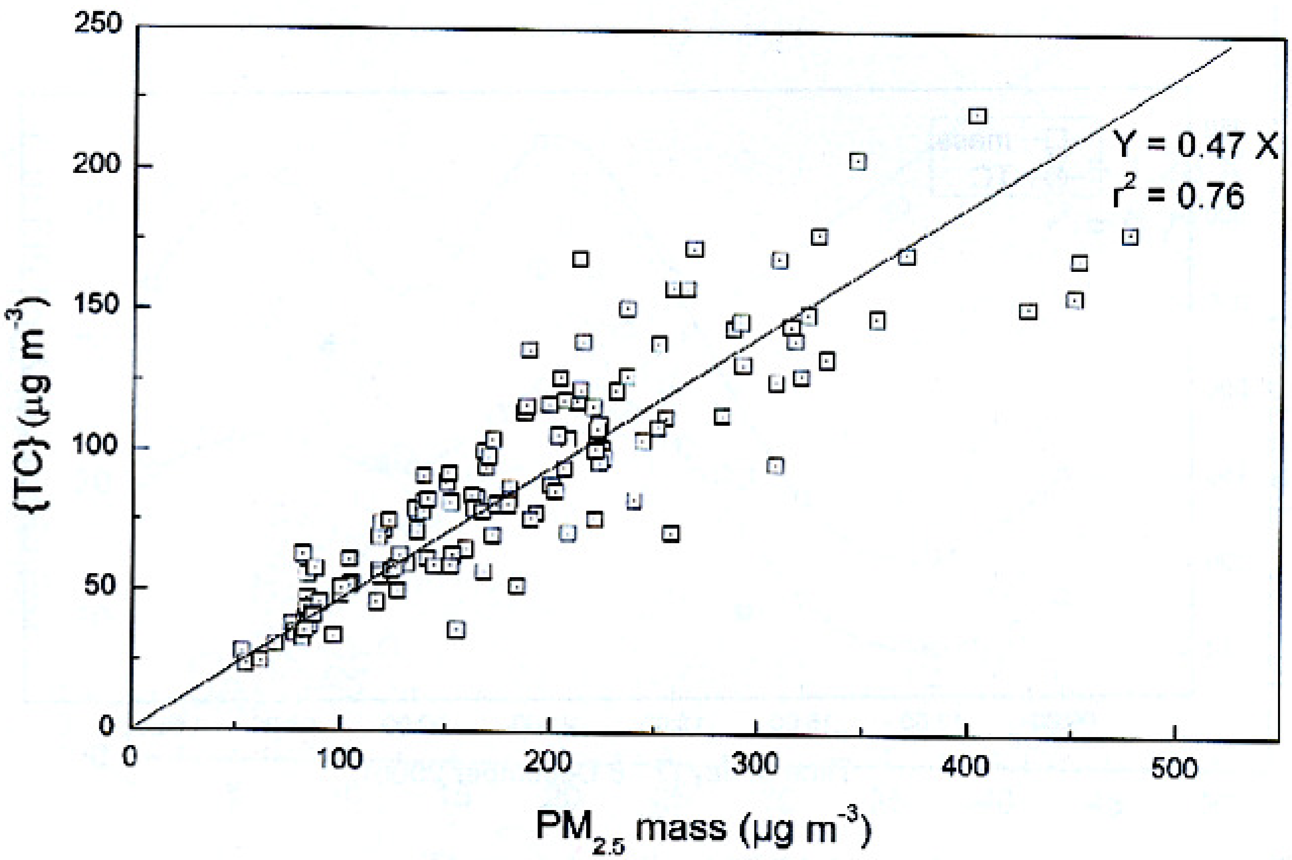


Hourly Concentrations of BC Dec. 2005

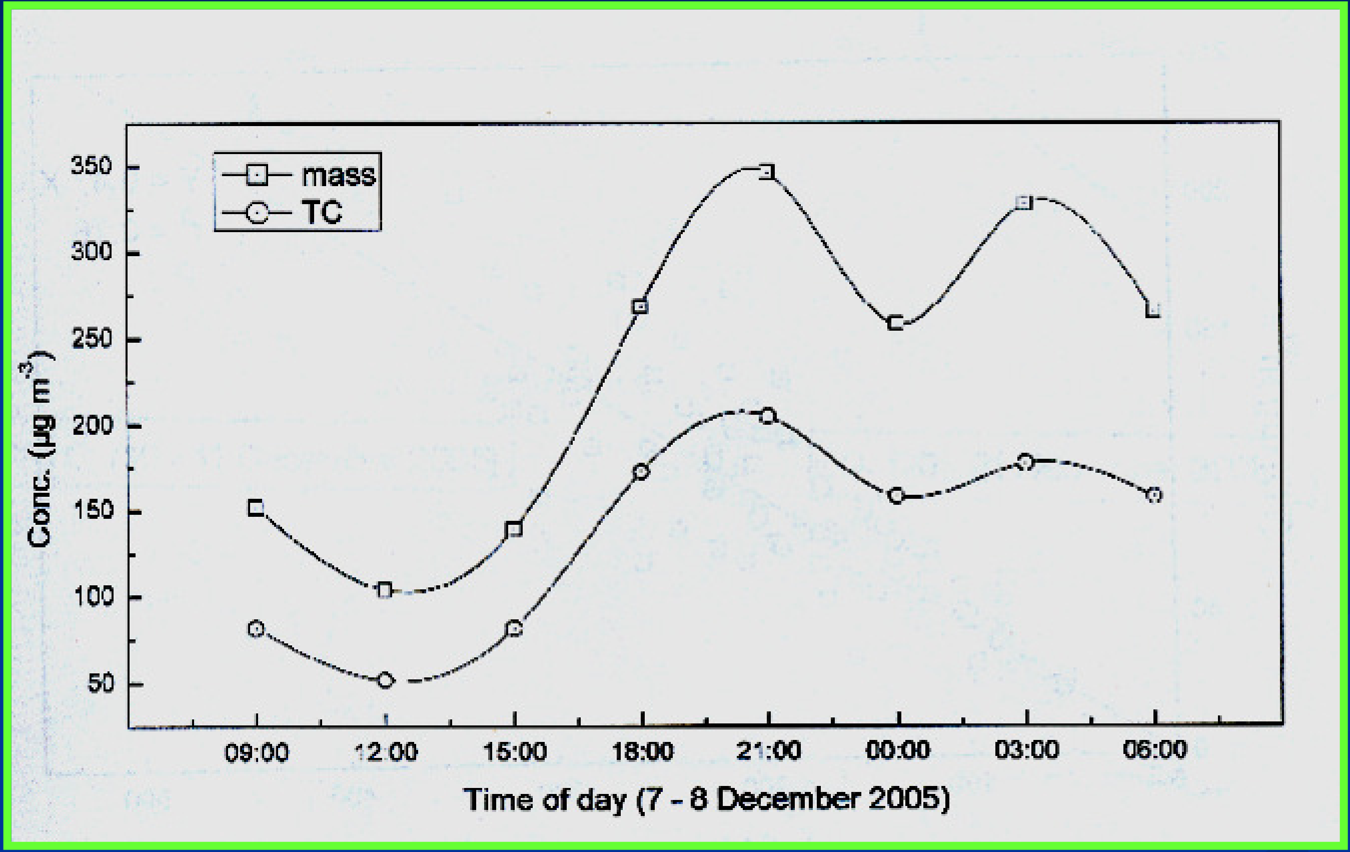


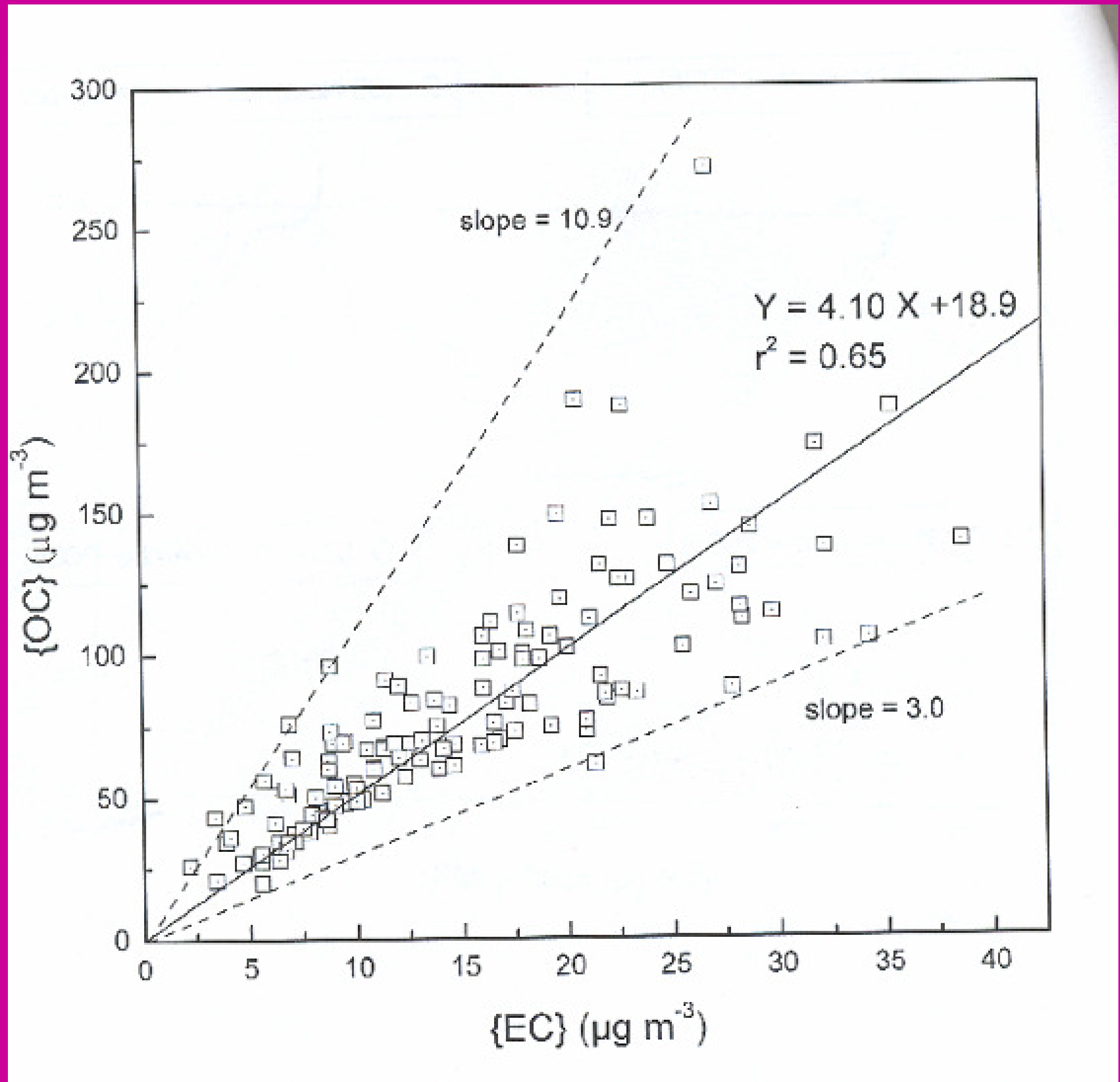


Aethalometer {BC} (µg m-3)
Thermal-optical {EC} (µg m-3)
Y = 1.25 X
r2 = 0.71
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50

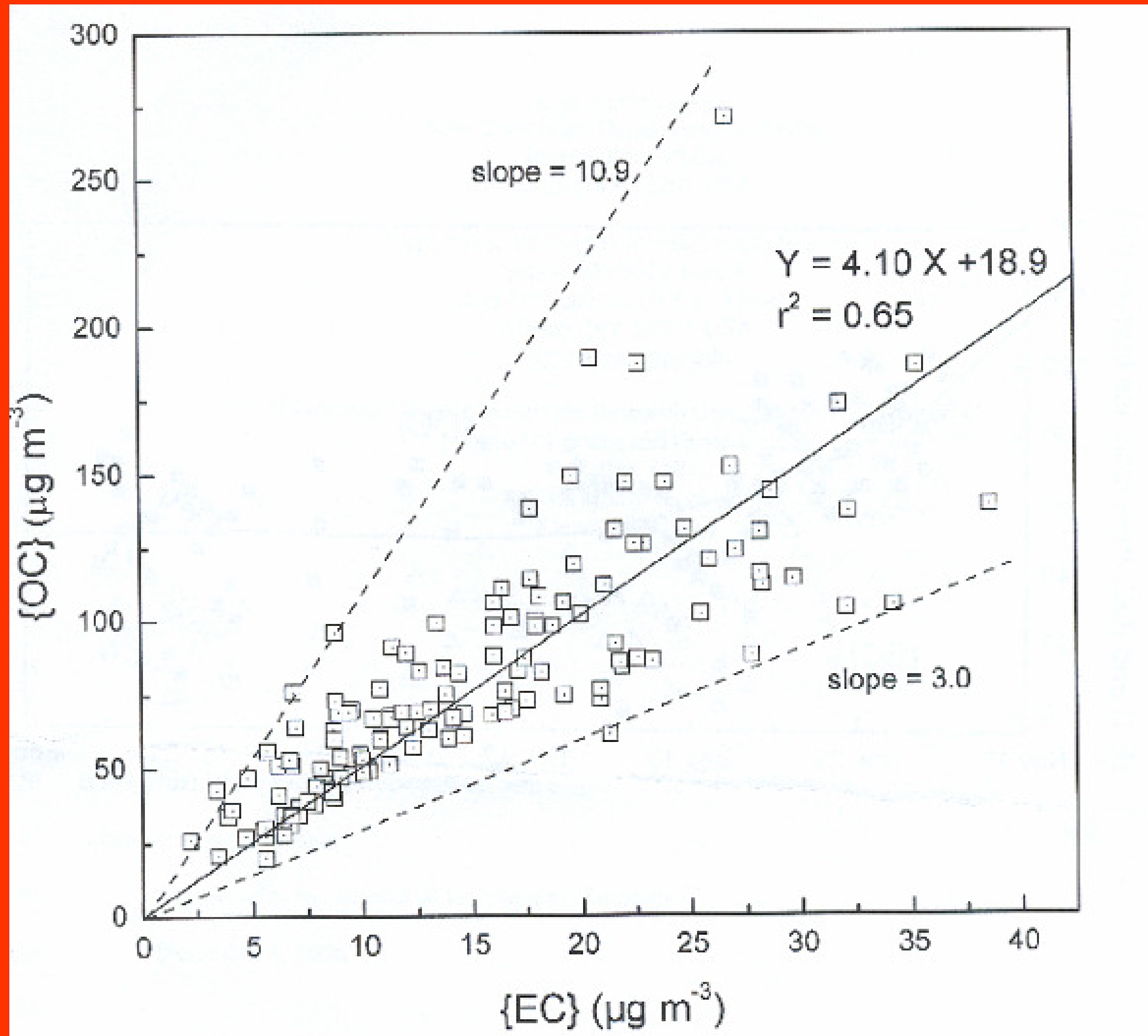


250
200
150
100
50
0
{TC} (µg m-3)
0
100
200
300
400
500
PM2.5 mass (µg m-3)
Y = 0.47 X
r2 = 0.76

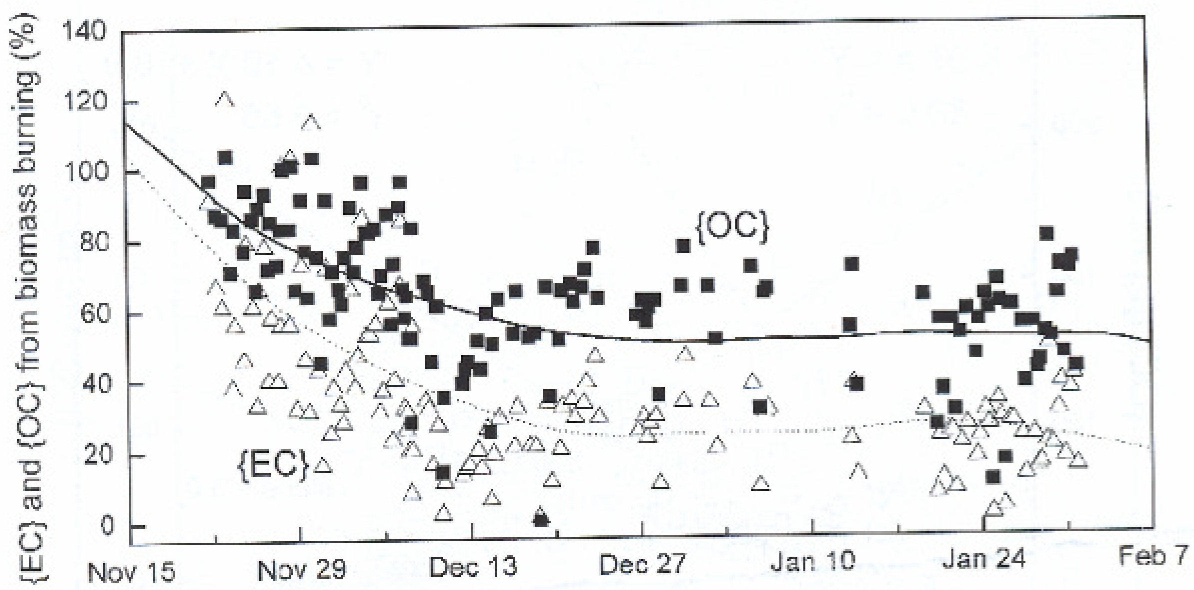

mass
TC
Conc. (µg m-3)
350
300
250
200
150
100
50
09:00
12:00
15:00
18:00
21:00
00:00
03:00
06:00
Time of day (7 - 8 December 2005)



300
250
200
150
100
50
0
{OC} (µg m-3)
slope = 10.9
Y = 4.10 X +18.9
r2 = 0.65
slope = 3.0
0
5
10
15
20
25
30
35
40
{EC} (µg m-3)



300
250
200
150
100
50
0
{OC} (µg m-3)
slope = 10.9
Y = 4.10 X +18.9
r2 = 0.65
slope = 3.0
0
5
10
15
20
25
30
35
40
{EC} (µg m-3)



{EC} and {OC} from biomass burning (%)
140
120
100
80
60
40
20
0
Nov 15
Nov 29
Dec 13
Dec 27
Jan 10
Jan 24
Feb 7
{OC}
{EC}

Concentrations ($\mu g/m^3$) of Black Carbon in Metropolitan Areas

City	Year	Black Carbon
Beijing	1999-2000	8.5
Shanghai	1999-2000	6.0
Hong Kong	1998-2002	4.2
Tokyo	1998-1999	5.4
Mumbai	1999	12.6
Dhaka	2001	22
Karachi	2006	5.5
Lahore	2005	17.6
Mexico City	1997	5.8
New York	2002	<2
London	1995	2.3
Paris	1984-85	3.8

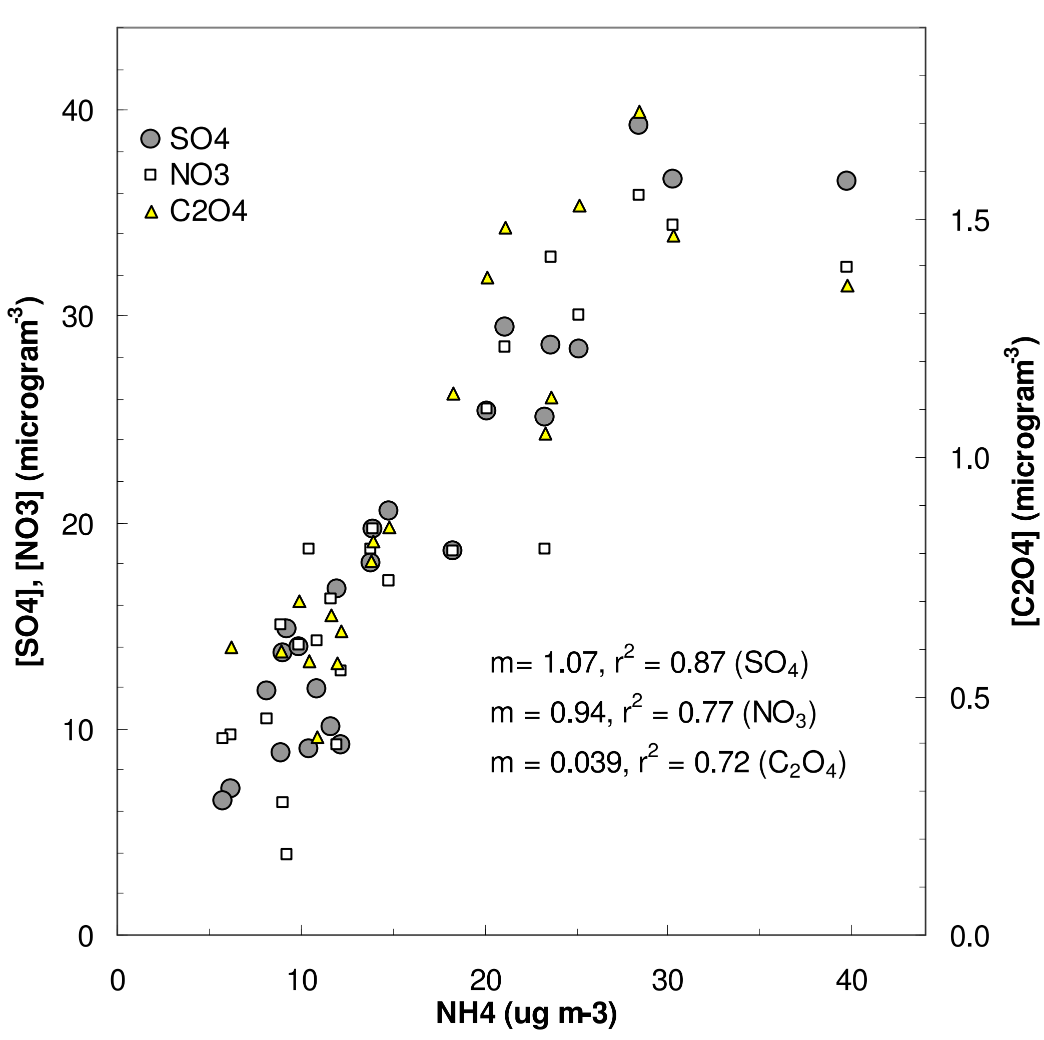
Composite Gas Mixing Ratio & Ionic Concentrations in Lahore ($PM_{2.5}$)

Type of samples		pH	$PM_{2.5}$	HCl	HNO_2	HNO_3	SO_2	$(COOH)_2$	NH_3	F^-	Cl^-	NO_3^-	SO_4^{2-}	$C_2O_4^{2-}$	Na+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
			Atmosphric concnetration (µg/m3)																
All sampling days	Mean	4.56	209	1.16	19.6	1.00	19.4	0.60	50.1	0.10	7.43	18.9	19.2	0.97	0.76	16.1	3.49	0.08	0.89
	SD	0.28	92.1	0.85	10.8	0.57	12.9	0.52	16.9	0.04	4.98	9.31	9.90	0.40	0.49	8.66	1.64	0.05	0.63
	Min	4.04	82.7	0.08	0.05	0.18	2.11	0.07	21.2	0.04	1.76	3.85	6.48	0.41	0.26	5.73	0.87	0.03	0.14
	Max	5.17	450	2.52	48.9	2.63	43.1	2.19	81.3	0.18	25.7	35.9	39.2	1.72	2.27	39.7	7.27	0.18	2.75
Fog episode	Mean	4.42	183	1.30	11.3	0.38	3.5	0.27	44.7	0.15	7.66	12.6	16.0	0.84	0.52	14.8	3.24	0.07	0.48
	SD	0.42	90.8	1.72	12.01	0.28	1.7	0.15	29.9	0.04	5.51	6.19	8.21	0.29	0.03	7.5	1.87		0.41
	Min	4.11	82.7	0.08	0.05	0.18	2.11	0.16	21.2	0.11	1.76	6.37	9.18	0.64	0.50	9.00	1.18		0.20
	Max	4.89	260	2.52	24.0	0.57	5.4	0.38	78.4	0.18	12.7	18.7	25.1	1.05	0.54	23.3	4.82		0.95
Clear-day	Mean	4.66	214	1.44	19.7	1.10	27.9	0.70	54.9	0.09	5.54	16.2	15.5	0.94	0.62	11.9	3.36	0.11	1.37
	SD	0.19	98.5	0.83	10.8	0.45	11.1	0.51	16.7	0.04	2.43	7.21	8.72	0.40	0.38	6.09	1.76	0.06	0.83
	Min	4.37	102	0.19	4.90	0.51	14.2	0.07	25.9	0.06	3.07	9.49	6.48	0.59	0.26	5.73	1.57	0.04	0.63
	Max	4.86	356	2.44	32.4	1.68	43.1	1.33	81.3	0.11	9.71	28.5	29.5	1.48	1.18	21.1	5.95	0.18	2.75
Clear night	Mean	4.61	211	1.08	21.8	1.34	19.1	0.95	51.9	0.11	6.49	23.7	23.4	1.05	1.25	18.5	3.79	0.04	0.58
	SD	0.23	78.0	0.94	4.30	0.90	5.45	0.85	5.23		3.77	8.94	10.6	0.55	0.73	7.78	1.33	0.01	0.20
	Min	4.37	151	0.25	17.3	0.58	11.4	0.29	45.7		3.73	14.2	11.9	0.41	0.30	10.9	2.85	0.03	0.29
	Max	4.88	330	2.13	27.6	2.63	24.3	2.19	58.9		12.8	35.9	39.2	1.72	2.27	28.4	6.02	0.05	0.75
	Clear- day/night	1.01	1.01	1.34	0.90	0.82	1.46	0.73	1.06	0.76	0.85	0.68	0.66	0.89	0.50	0.64	0.88	2.74	2.37
	Clear episode	4.64	213	1.26	20.7	1.22	23.5	0.82	53.4	0.10	6.01	20.0	19.4	0.99	0.93	15.17	3.6	0.07	0.97
	Clear/Fog episode	1.05	1.16	0.97	1.83	3.23	6.72	3.10	1.19	0.68	0.79	1.58	1.22	1.18	1.80	1.02	1.10	1.12	2.02

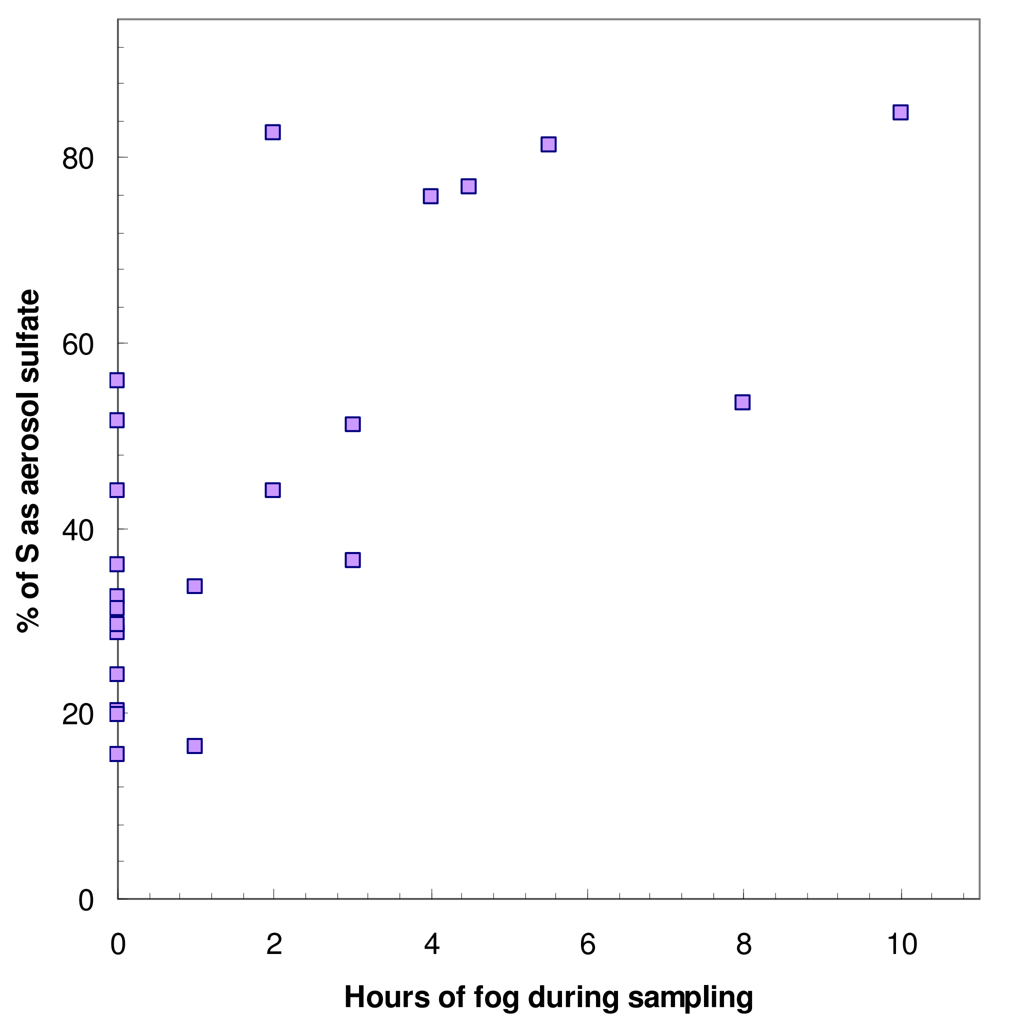
Gas Mixing Ratio & Ionic Concentration in $PM_{2.5}$ of Lahore & International Cities

Type of samples		$PM_{2.5}$	HCl	HNO2	HNO3	SO2	NH_3	Cl^-	NO_3^-	SO_4^{2-}	NH_4^+
		Atmosphric concnetration (µg/m3)									
Lahore (this study)	Mean	209	1.16	19.6	1.00	19.4	50.1	7.43	18.9	19.2	16.1
	Min	82.7-45	0.08-2.5	0.05-48.	0.18-2.63	2.11-43.	21.2-81.3	1.76-25.7	3.85-35.	6.48-39.	5.73-39.7
Daliao, Taiwan (Chiang et al., in manuscript)		55	1.84	3.59	2.00	19.0	18.0	1.20	6.45	12.57	6.09
Seoul, Korea (Lee et al., 1999)		57	NA	4.51	1.09	17.3	4.34	NA	6.0	8.7	4.19
Hong Kong (Pathak et al., 2003)		NA	NA	NA	NA	NA	NA	0.43	1.5	8.9	25.6
New York, USA (Bari et al., 2003)		15.7	0.45	3.22	1.30	26.0	2.78	NA	NA	3.89	
Eastern N Carolina, USA			0.74	0.26	0.15	2.99	10.5	0.32	0.548	3.25	1.102
(McCulloch et al., 1998)			0.32-3.51	0.14-1.18	0.15-0.16	0.2-41.8	(0.34-106	0.14-2.55	0.15-3.47	0.33-48.5	0.04-14.6
Nara, Japan		NA	1.66	1.46	1.61	4.32	2.43	1.12	2.09	4.27	1.7
(Matsumoto and Okita, 1998)			1.19-2.27	0.81-2.65	0.26-3.99	3.0-5.71	(1.36-3.24)				

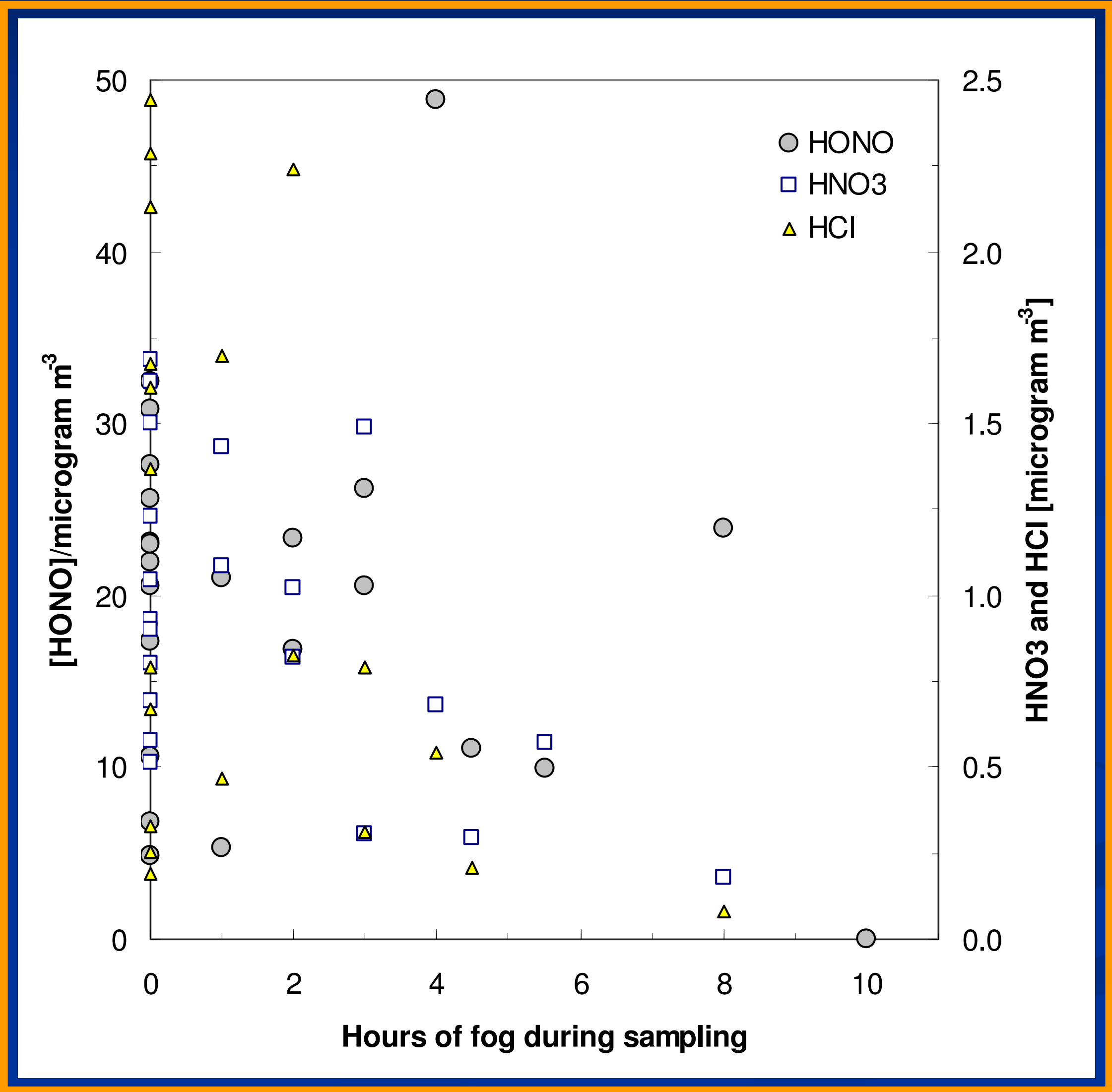
Existence of Ammonium in $PM_{2.5}$ as sulfate, nitrate and oxalate

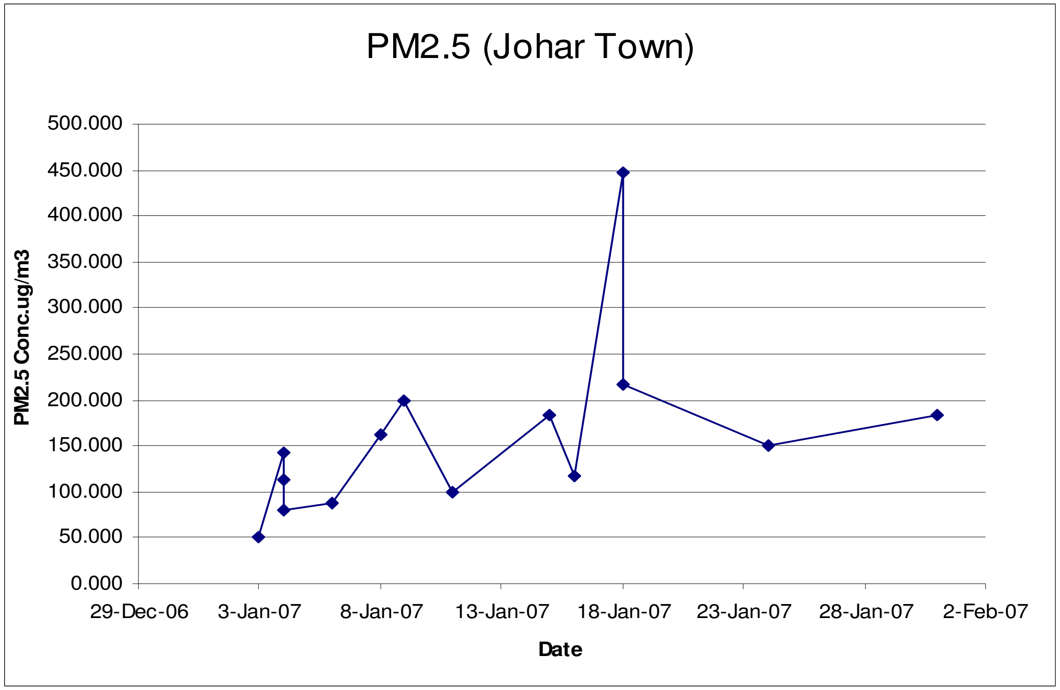


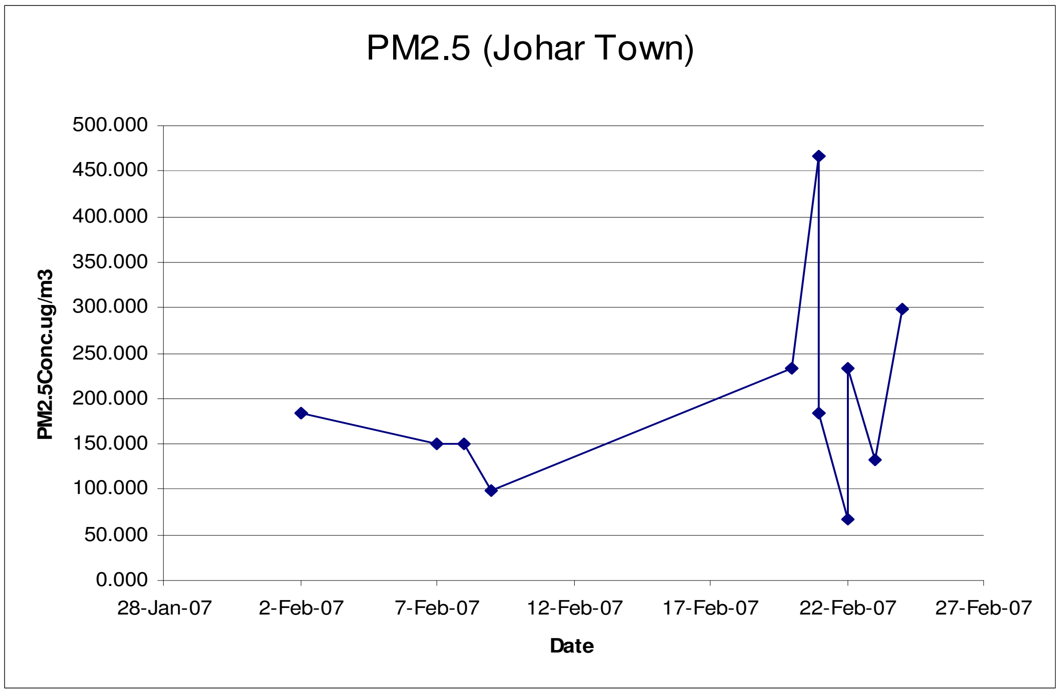
Percentage of sulfur present as aerosol as a function of number of hours of fog

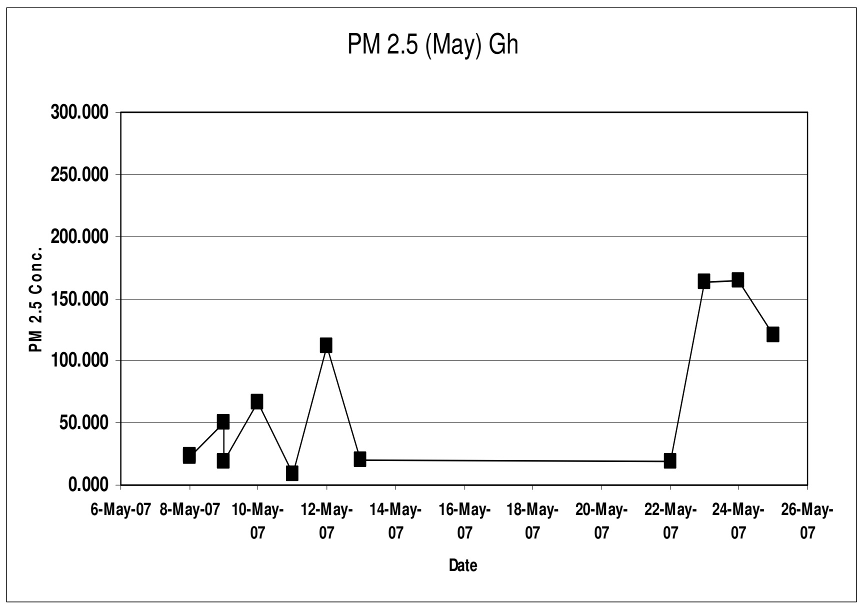


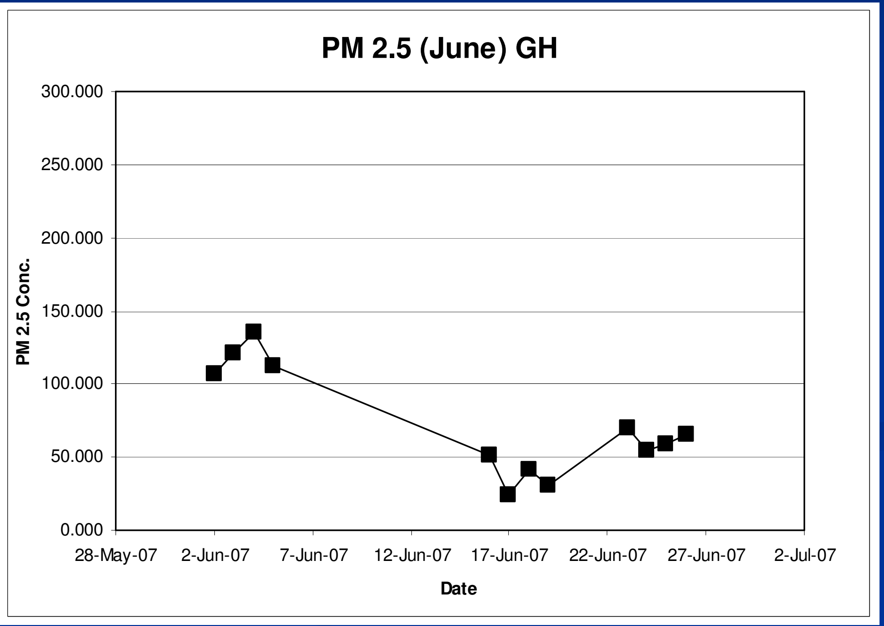
Acidic gas concentration as a function of duration of fog

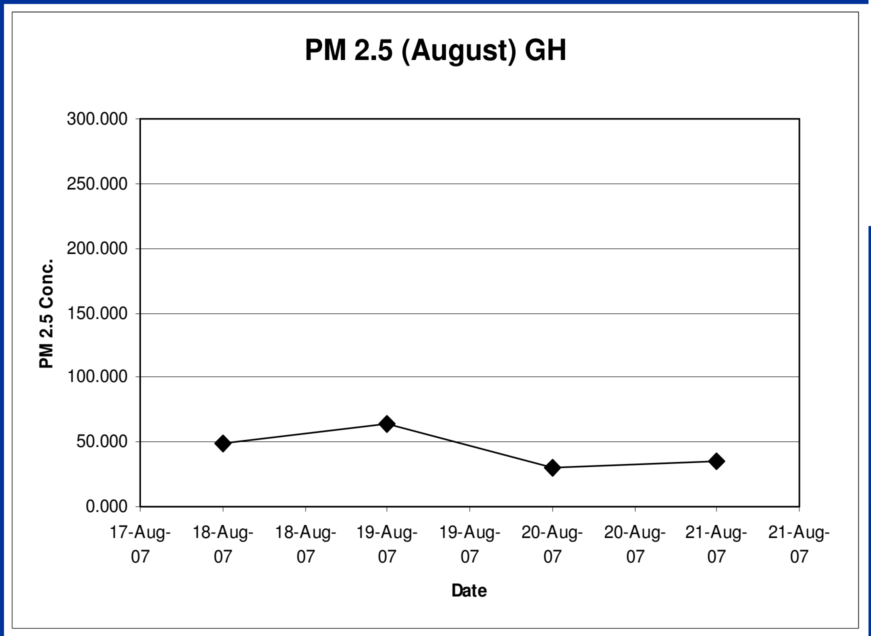


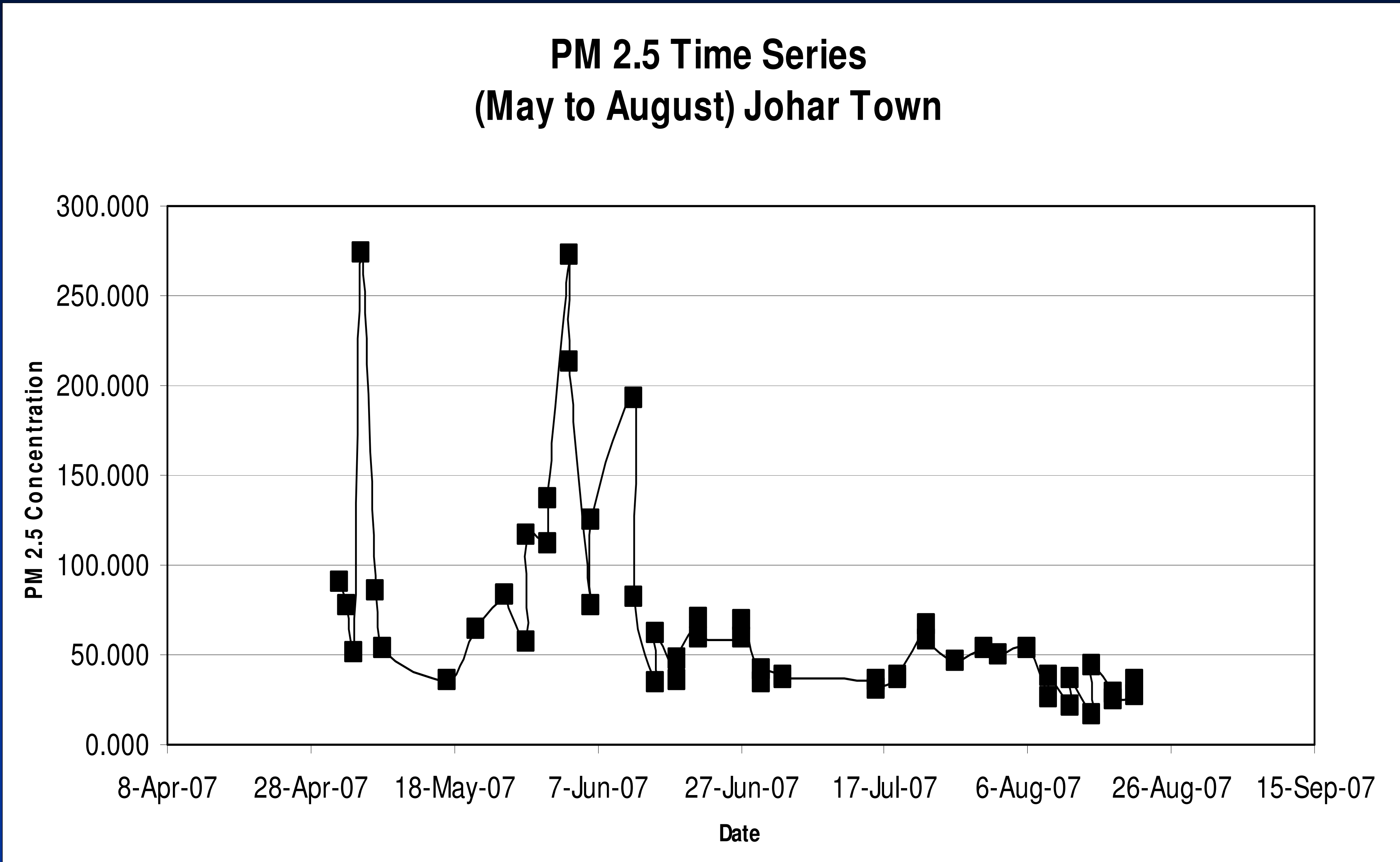

PM2.5 (Johar Town)
500.000
450.000
400.000
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM2.5 Conc.ug/m3
29-Dec-06
3-Jan-07
8-Jan-07
13-Jan-07
18-Jan-07
23-Jan-07
28-Jan-07
2-Feb-07
Date


PM2.5 (Johar Town)
500.000
450.000
400.000
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM2.5Conc.ug/m3
28-Jan-07
2-Feb-07
7-Feb-07
12-Feb-07
17-Feb-07
22-Feb-07
27-Feb-07
Date


PM 2.5 (May) Gh
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM 2.5 Conc.
6-May-07
8-May-07
10-May-07
12-May-07
14-May-07
16-May-07
18-May-07
20-May-07
22-May-07
24-May-07
26-May-07
Date


PM 2.5 (June) GH
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM 2.5 Conc.
28-May-07
2-Jun-07
7-Jun-07
12-Jun-07
17-Jun-07
22-Jun-07
27-Jun-07
2-Jul-07
Date


PM 2.5 (August) GH
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM 2.5 Conc.
17-Aug-07
18-Aug-07
18-Aug-07
19-Aug-07
19-Aug-07
20-Aug-07
20-Aug-07
21-Aug-07
21-Aug-07
Date


PM 2.5 Time Series
(May to August) Johar Town
300.000
250.000
200.000
150.000
100.000
50.000
0.000
PM 2.5 Concentration
8-Apr-07
28-Apr-07
18-May-07
7-Jun-07
27-Jun-07
17-Jul-07
6-Aug-07
26-Aug-07
15-Sep-07
Date

Conclusion

- Impact of Aerosols on monsoon rainfall in connection with the health impact of air polution provides a strong rationale for reducing air pollution in the developing nations
- As ground-based measurements are very limited in space & time & these particles get transported over long distance from their sources so both Satellite & ground-based Monitoring systems are required
- Encourage scientists & researchers for developing skills in the integrated use of remote sensing & in situ observation systems for Air Quality Monitoring
- Translation of technical data & products to tools that support decision-making related to societal needs by those who make these kinds of decisions
- Improve interactions between the technical elements & other aspects of societally-relevant decisions: social, economic, political, cultural

THANK YOU