Satellite Data Applications in Atmospheric Monitoring

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Sep 2008 Graz, Austria

Why: Atmospheric Monitoring

Atmosphere - a mixture of different trace gases maintains earth's temperature at the average level. Due to human activities like deforestation, fossil and biomass burning, industrialization, rice fields, etc the naturally occurring levels of these gases are altering by putting different pollutants into it, resulting in rising temperature , global warming and regional cooling. Impacts due to change in temperature include frequent landslides, floods and cyclones, sea level rise, increase in rapid melting of glaciers, less efficiency in removal of pollutants, etc.

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Conti--

- To understand how the earth’s climate is changing it is critical to understand each mechanism that causes warming or cooling in the atmosphere

- Aerosol and other pollutants act as Atmospheric forcing scattering, reflecting and absorbing the radiation coming into or going out of the earth's atmosphere

Atmospheric Pollutants

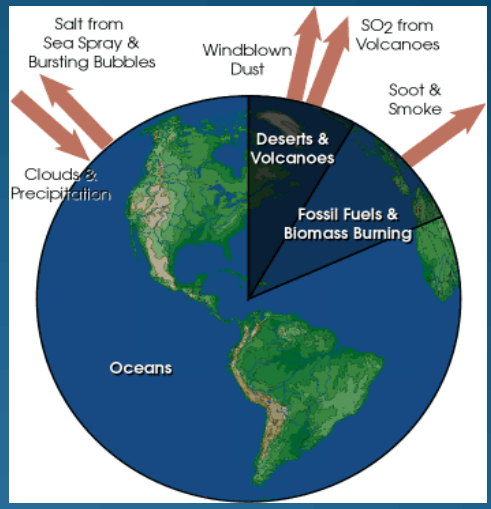
Gaseous Pollutants

- SOx
- NOx
- CO
- CO2
- VOC

Aerosols

Atmospheric Aerosols

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



Examples:

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

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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
- Trace Metals

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Aerosols - Effects

- Climate
- Visibility
- Health
- Hydrology
- Nutrient source

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Natural Aerosols

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Man-Made Aerosols

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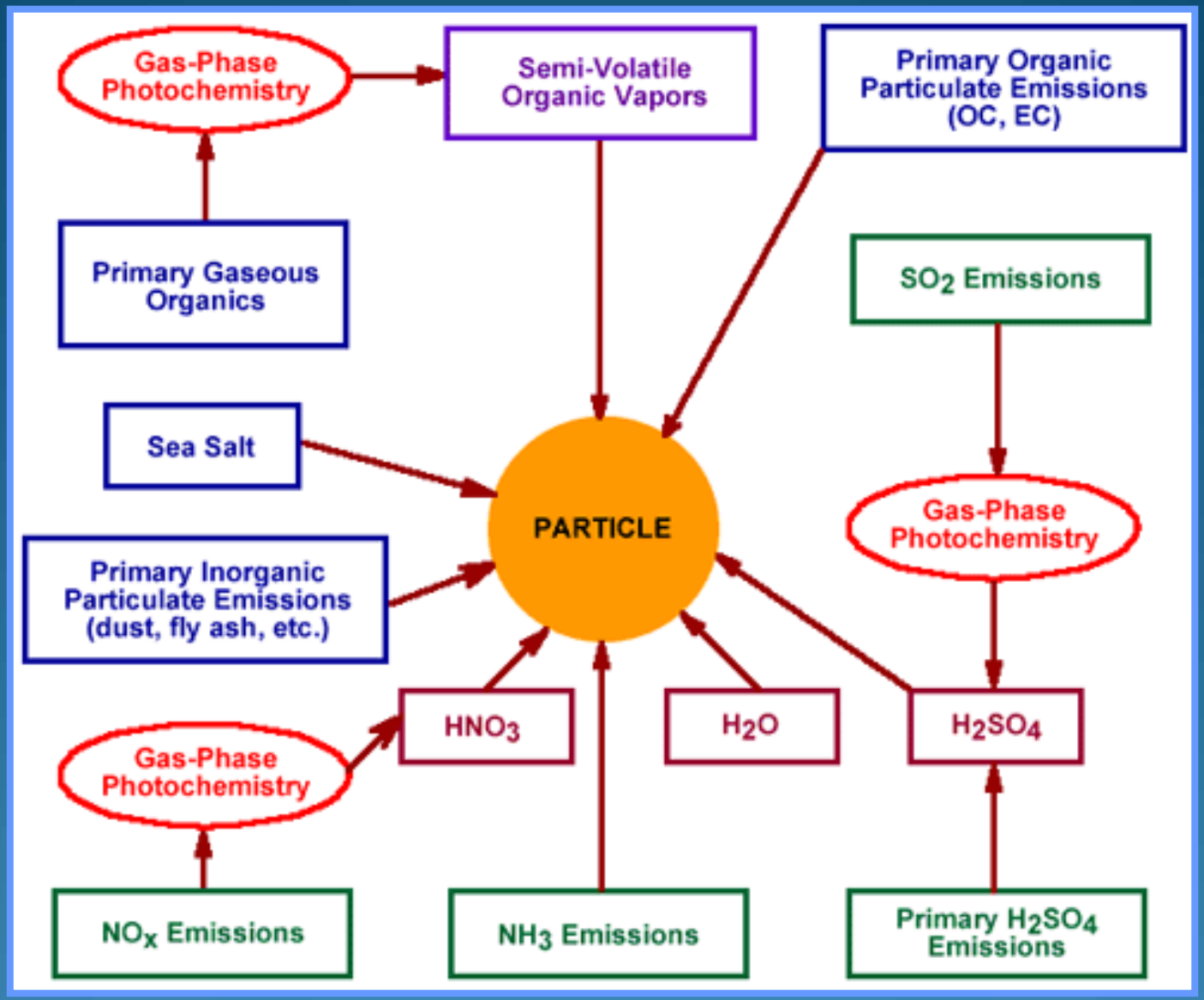
Atmospheric Aerosol Chemistry

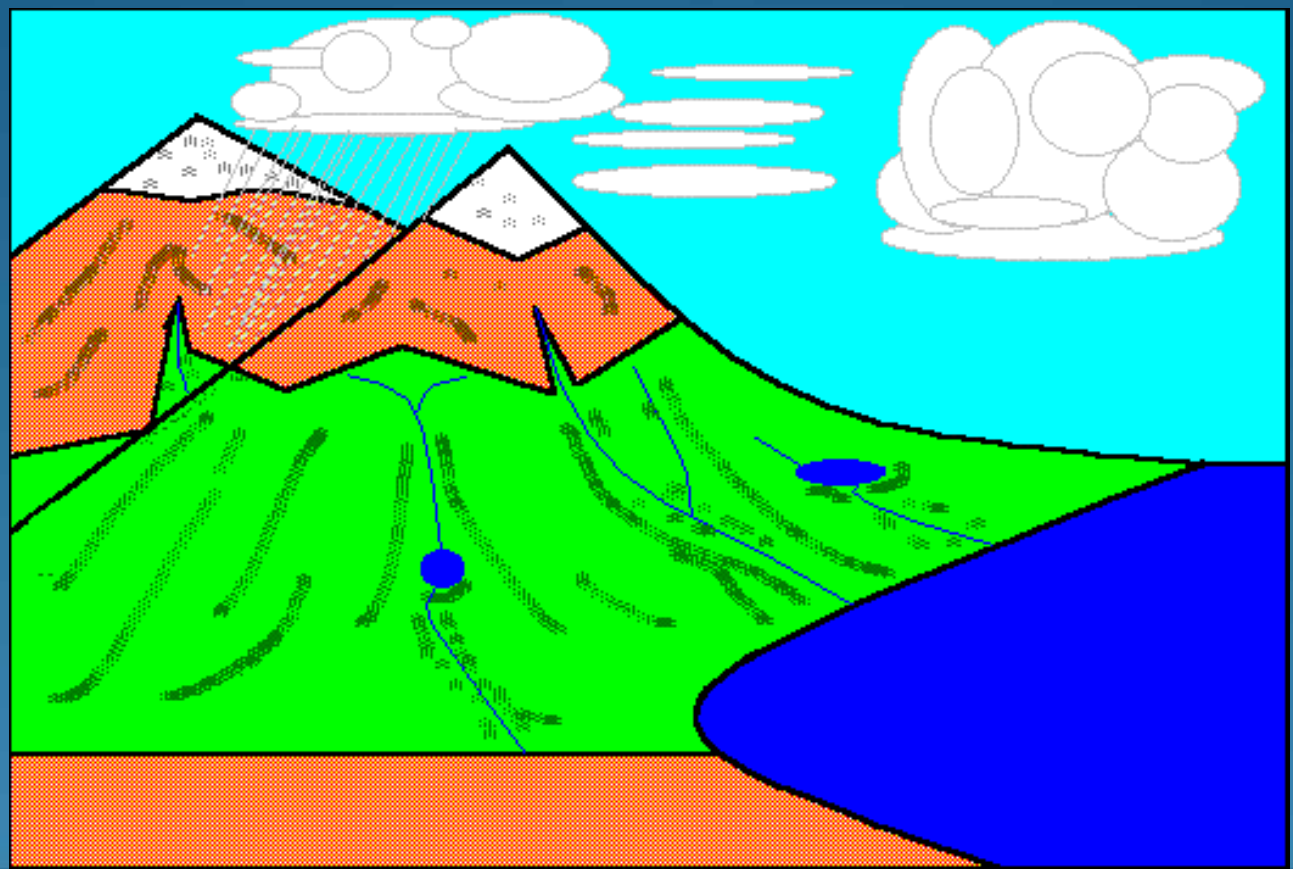


Aerosols and Hydrological Cycle

Increased aerosols

↓

Weak Hydrological Cycle



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Aerosols & Climate

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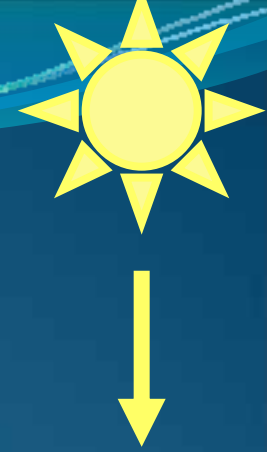
Direct Effect



TOP OF THE ATMOSPHERE

INCREASE IN REFLECTANCE

Short Wave Radiation

$\lambda < 4\mu m$

SCATTERING & ABSORPTION

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

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Indirect Effect

More Aerosols

More Cloud Droplets

More Sunlight Will Be Reflected.

Net Result:

- Reduction In Solar Radiation at the Surface
- Last Longer Clouds and Cooling

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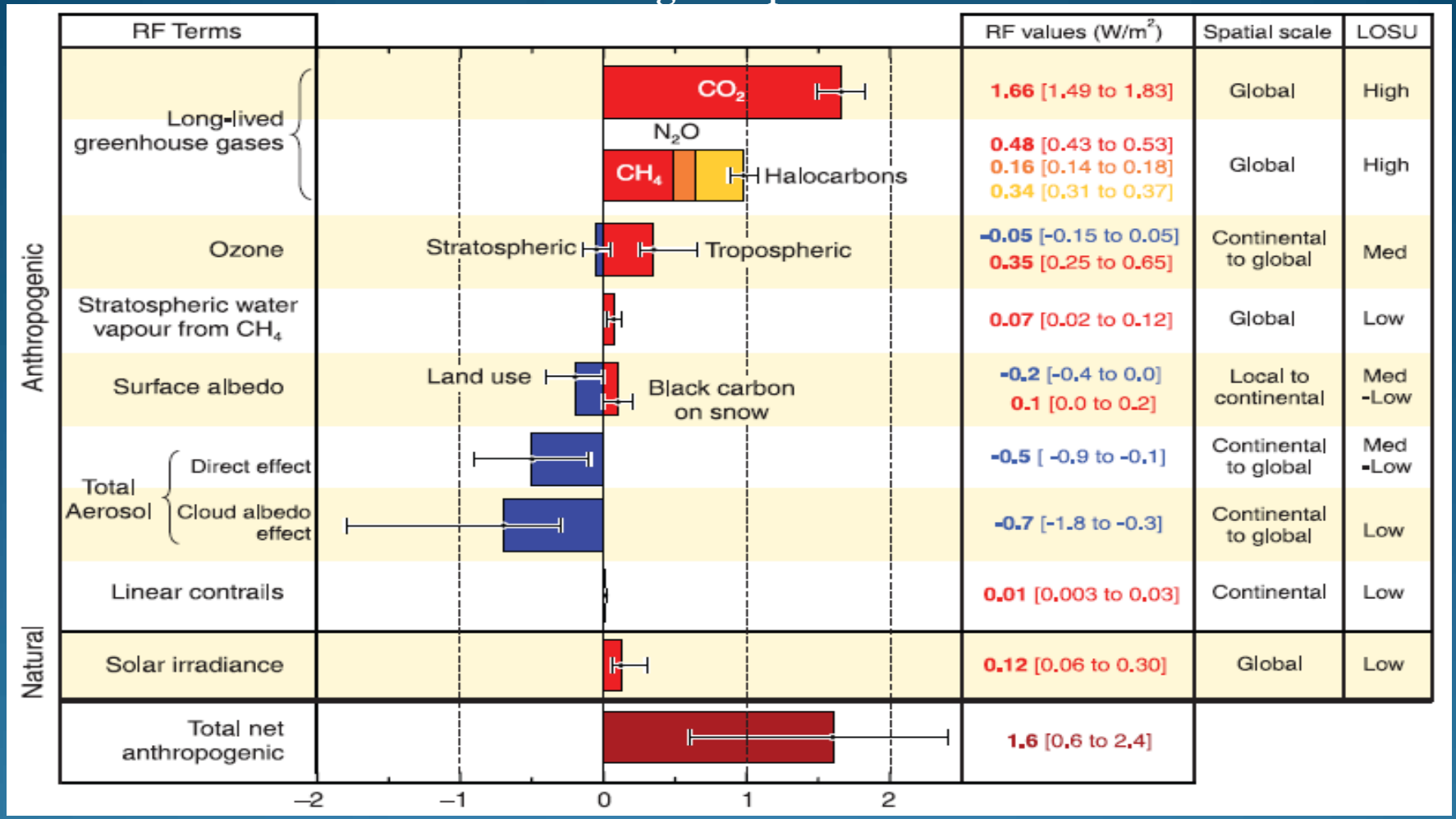
The Global Mean Radiative Forcing of the Climate System for (Year 2005, Relative to 1750 : IPCC)

Radiative Forcing Components



Level of scientific understanding

Satellite & Ground-based Atmospheric Monitoring in Pakistan

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

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MODIS-Derived Aerosol Optical Thickness

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Aqua Satellite

Sun

Aerosol Optical Thickness :Basis

Column Satellite Measurement

Ozone

Multiple MODIS bands are utilized to derive aerosol properties

0.47, 0.55, 0.65, 0.86, 1.24, 1.64, and 2.13 μm

10X10 km^2 Res.

10km

Rayleigh Scattering

Water vapor + other gases (absorption)

$$AOT\ (\tau) = \int \beta_{ext}\, dz$$

Particle size
Composition
Water uptake
Vertical Distribution

Aerosol

Surface

Point Measurement PM2.5 mass

Satellite retrieval issues - inversion (e.g. aerosol model, background).

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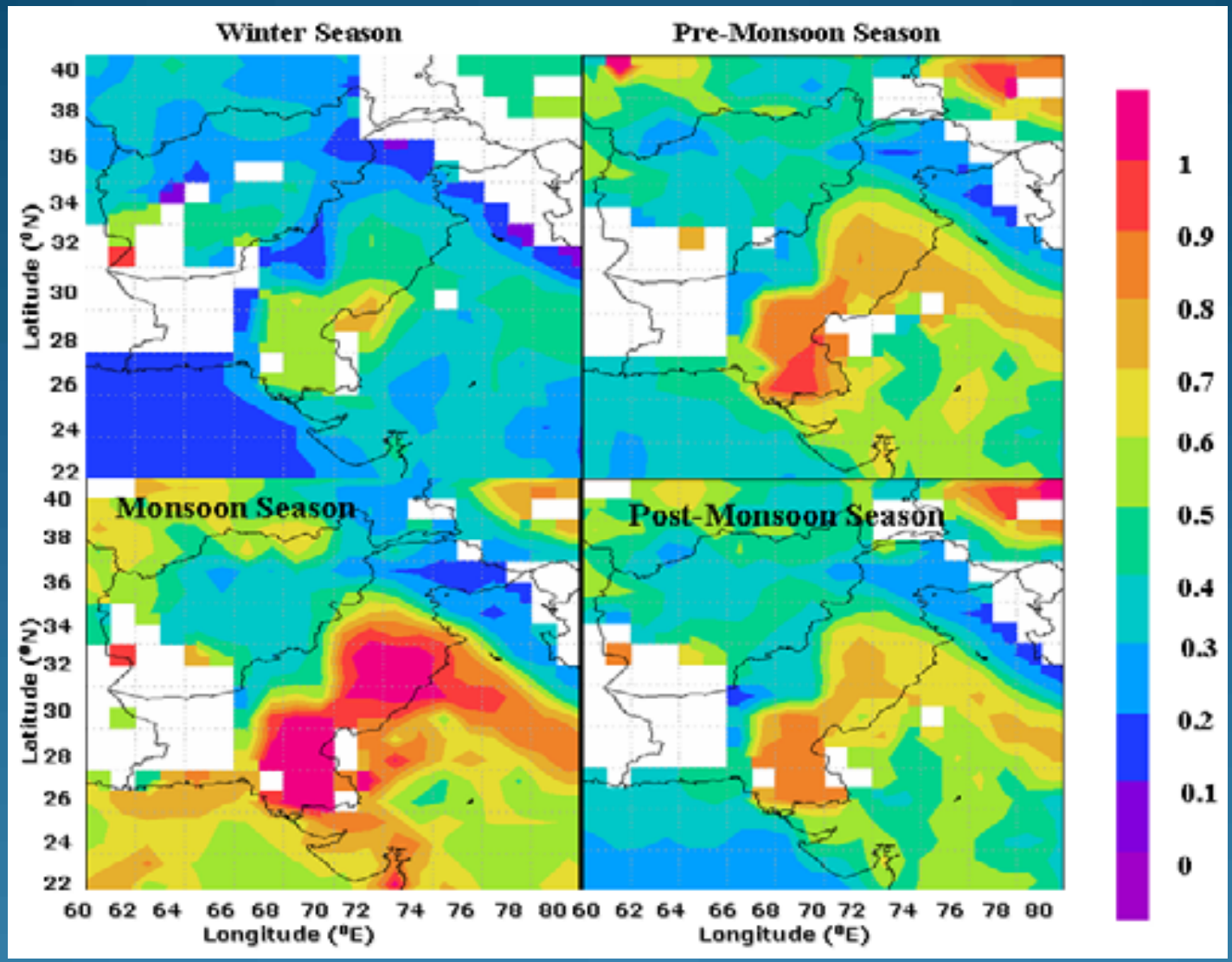
Seasonal Study of AOT for the period (2000-07)



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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°N and minimum above this latitude

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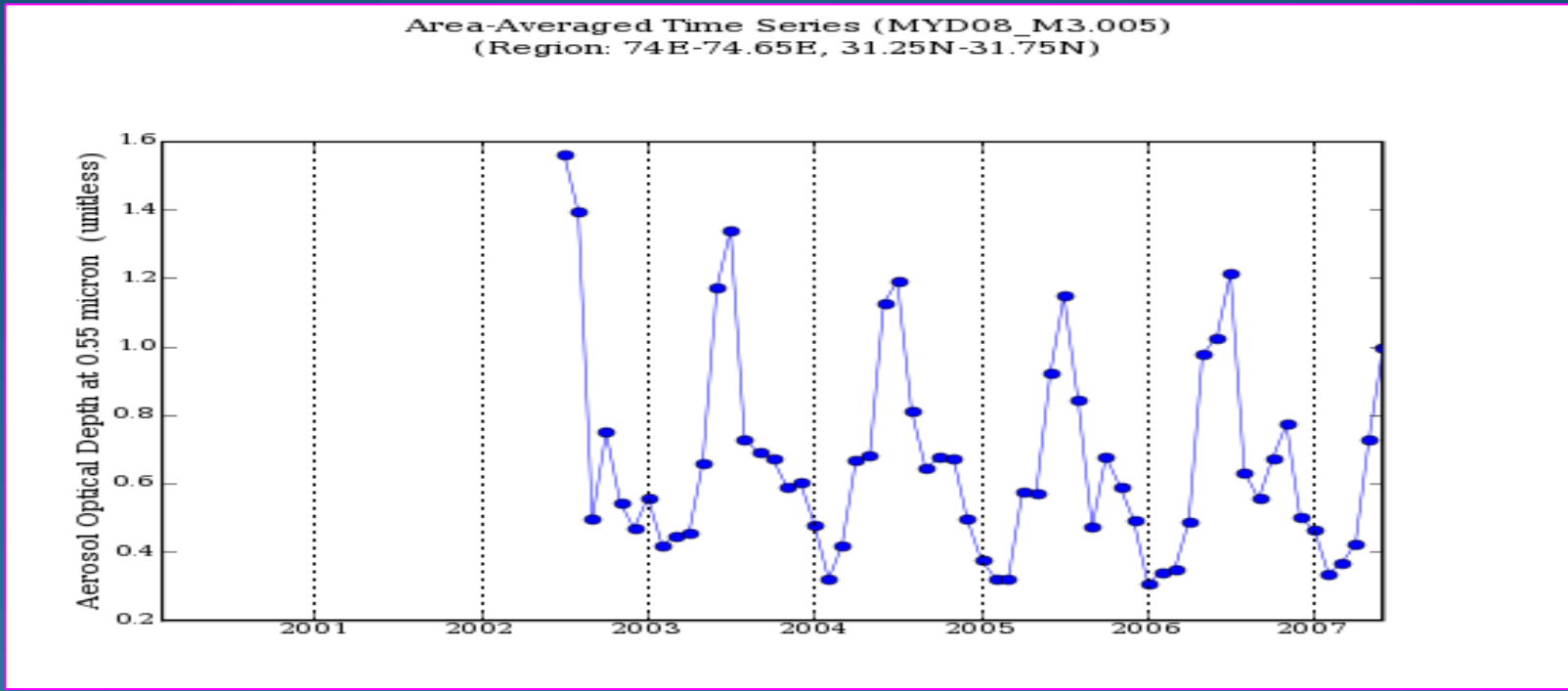
MODIS- Derived AOT (Lahore)

Yearwise **AOT (2001-07)**

Region (31.25 - 31.75N, 74 - 74.65 E)



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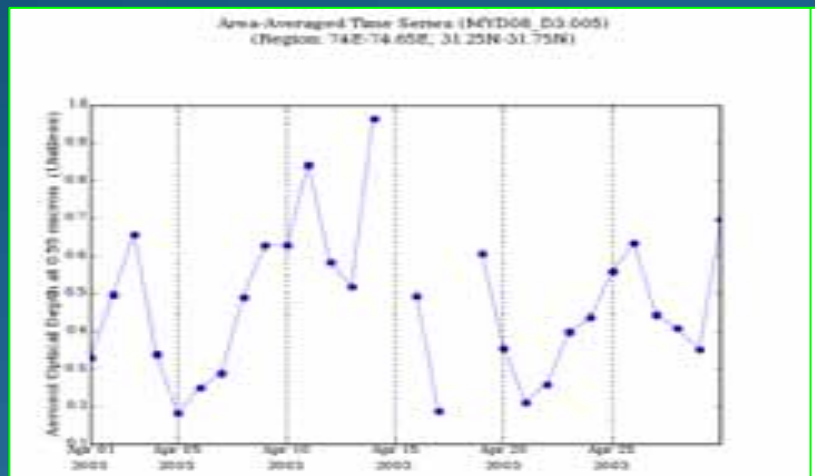
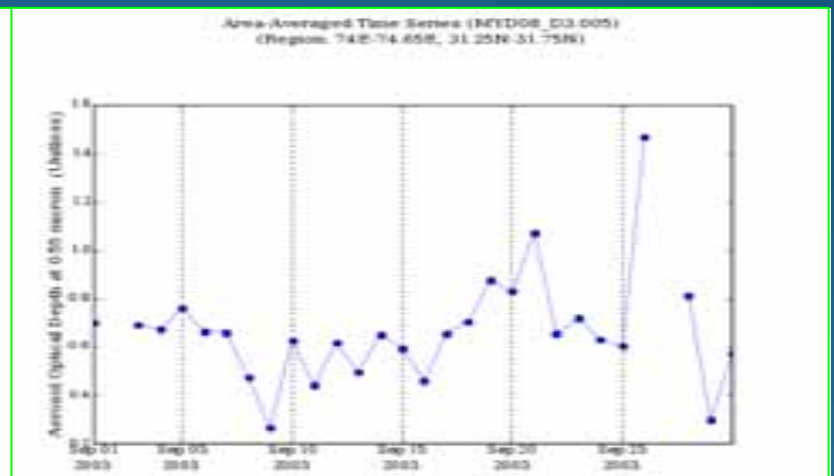
Monthly **AOT**

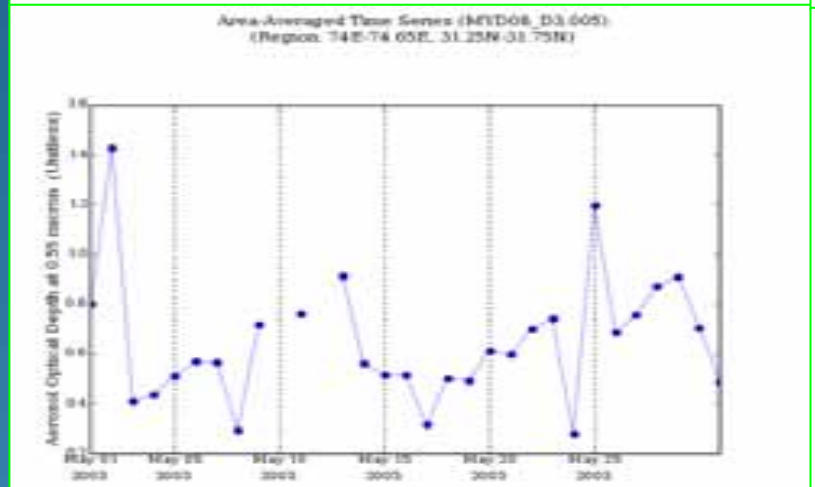
Region (31.25 - 31.75N, 74 - 74.65 E)

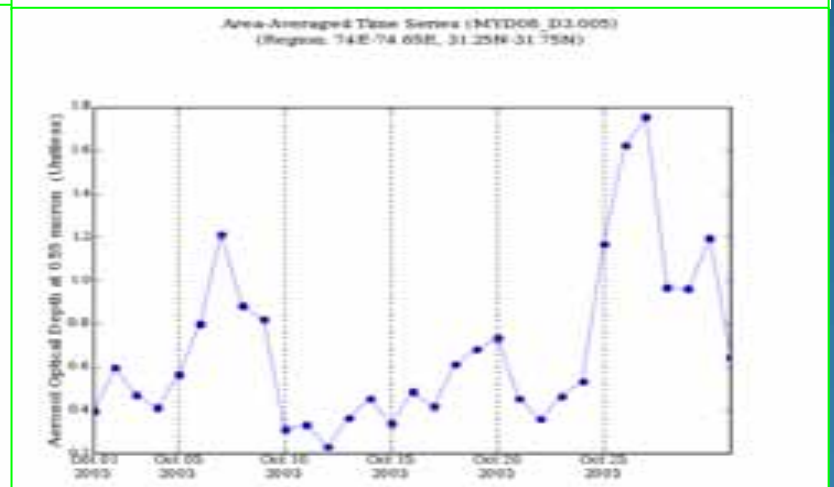
(April-May) 2003

(Sep-Oct) 2003









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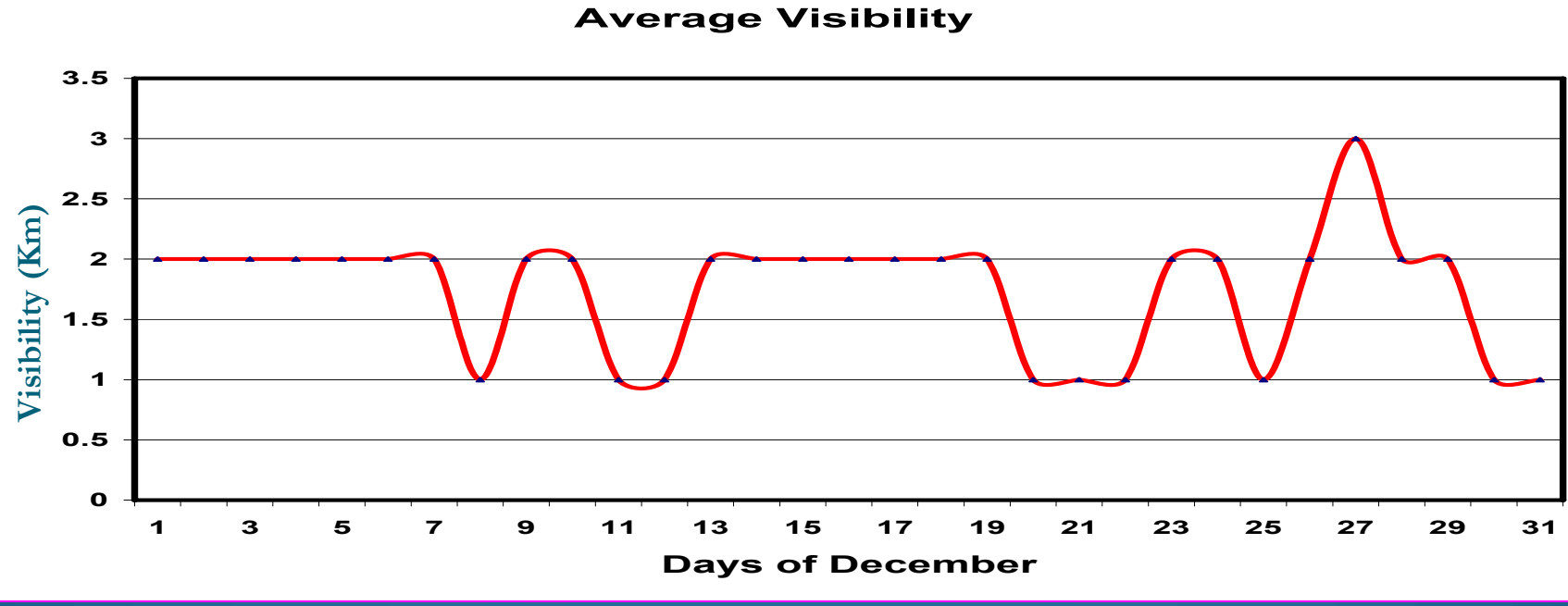
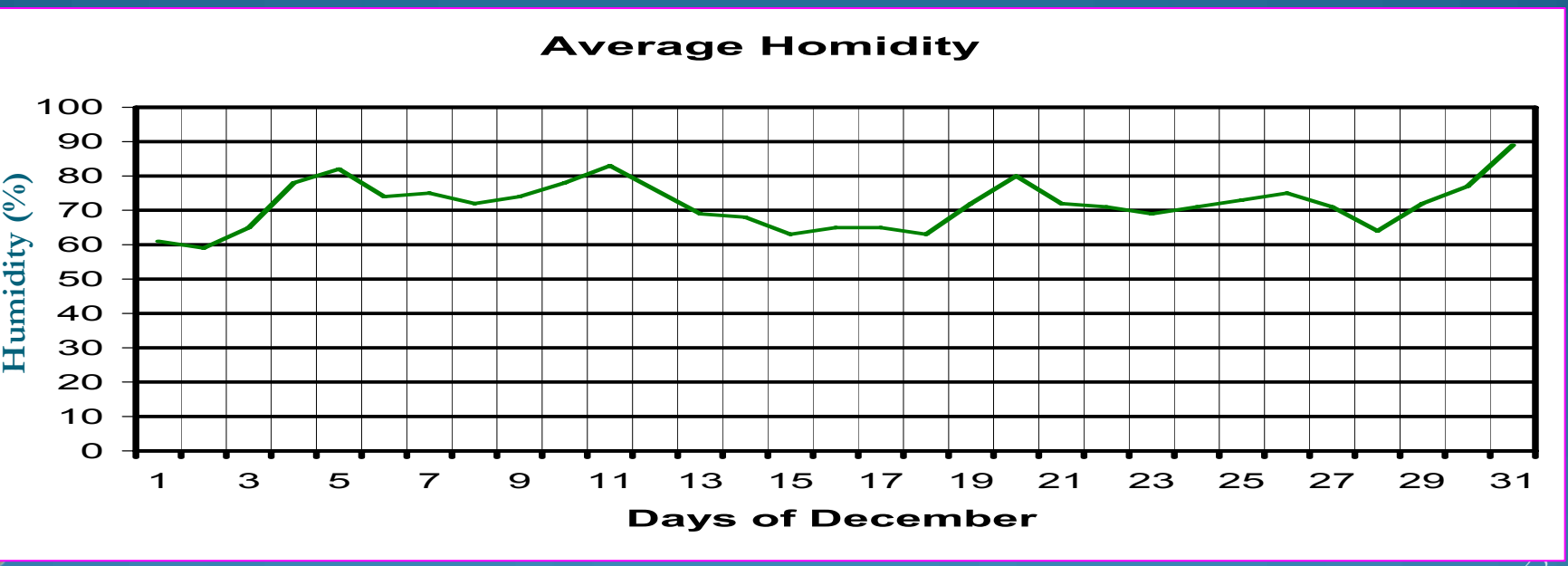

Average Visibility
Visibility (Km)
3.5
3
2.5
2
1.5
1
0.5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Days of December


Average Homidity
Humidity (%)
100
90
80
70
60
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Days of December

AOT Through Sunphotometers (Karachi & Lahore)

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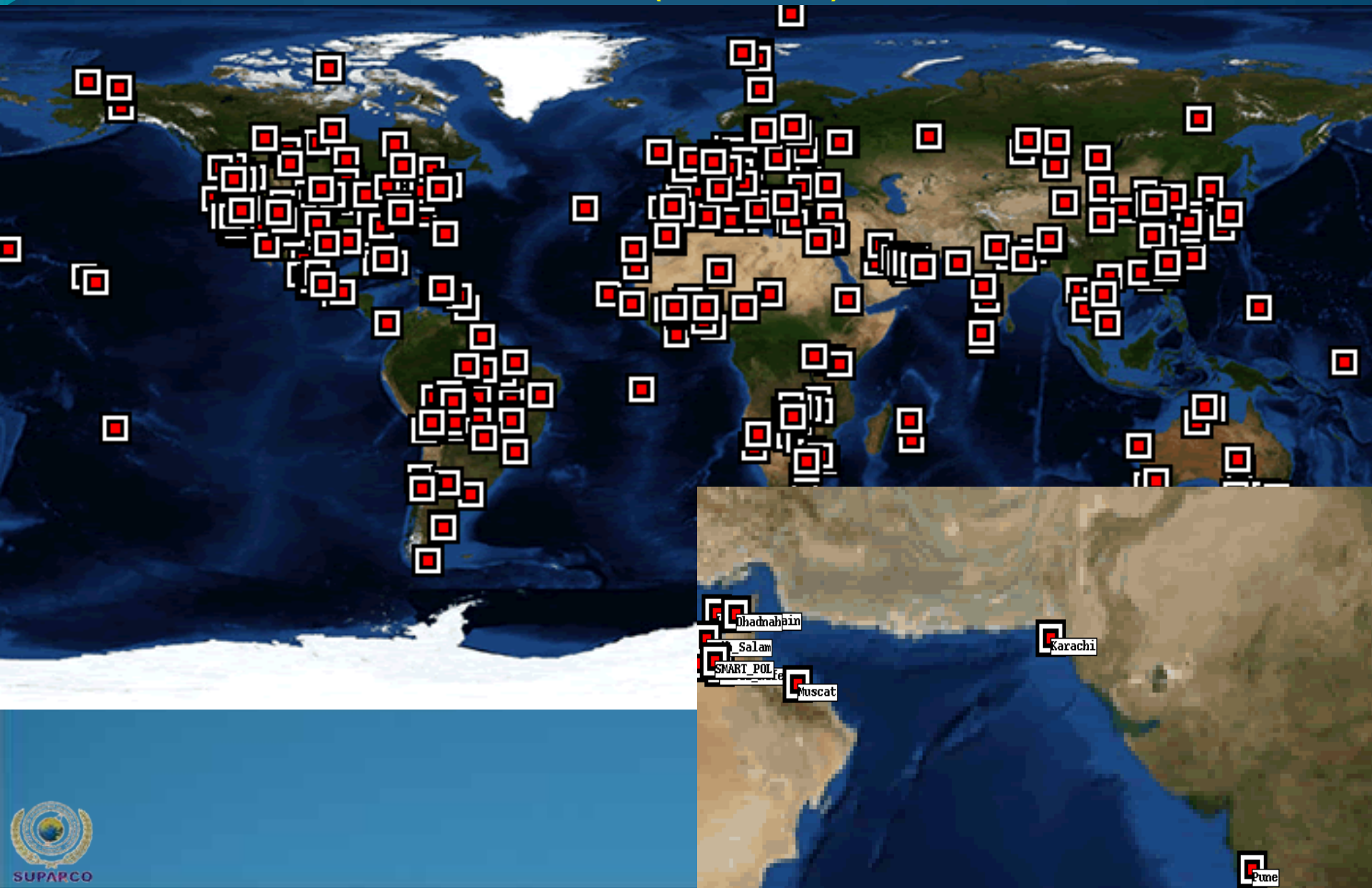
International Participation Program

Worldwide Aerosol Robotic Network (AERONET)



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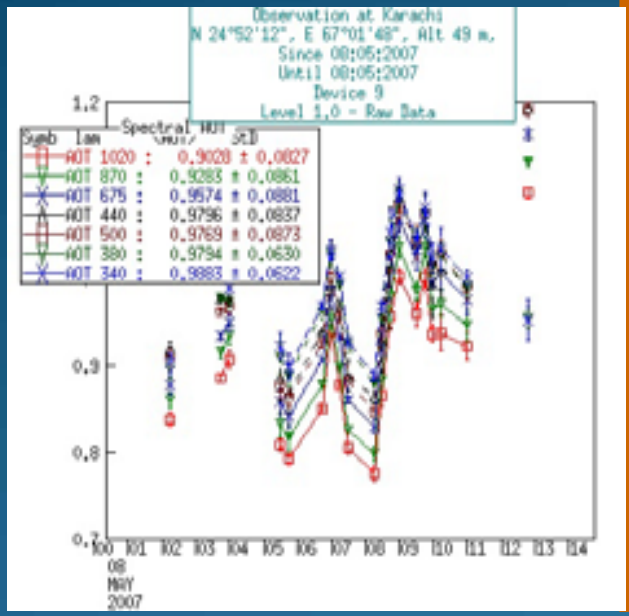

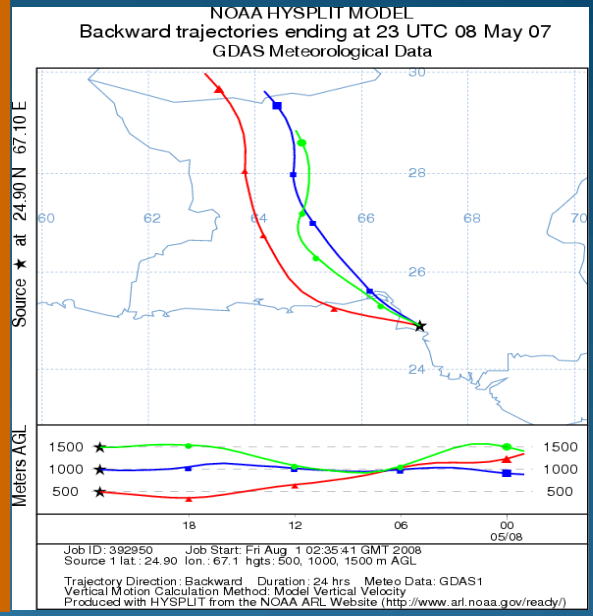

May 8, 2007 Terra true color image of regional dust transport over S. Pakistan. The plot on the right shows the highly variable AOD as measured in several spectral wavelengths by an AERONET station in Karachi as the dust is transported over the city.

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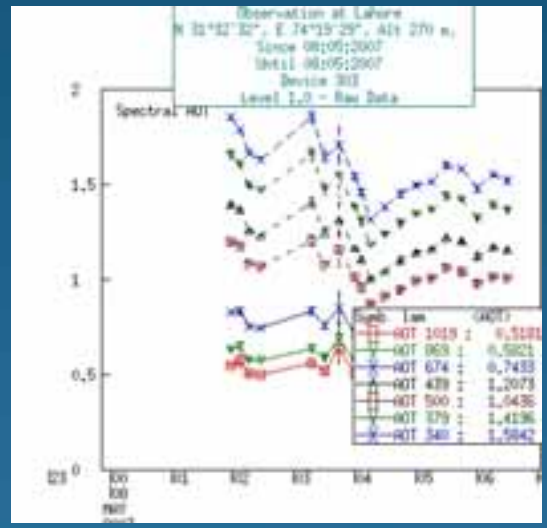

Centered over Lahore on May 8th, 2007 shows regional haze south of the mountains. Right is the AOD trace that exceeded 1.0 in the shorter wavelengths, which is not uncommon.

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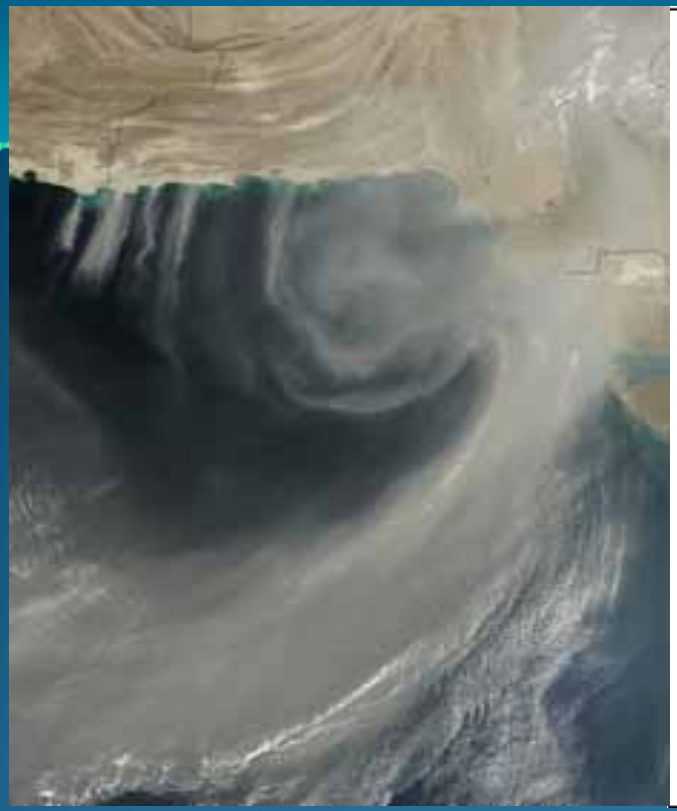

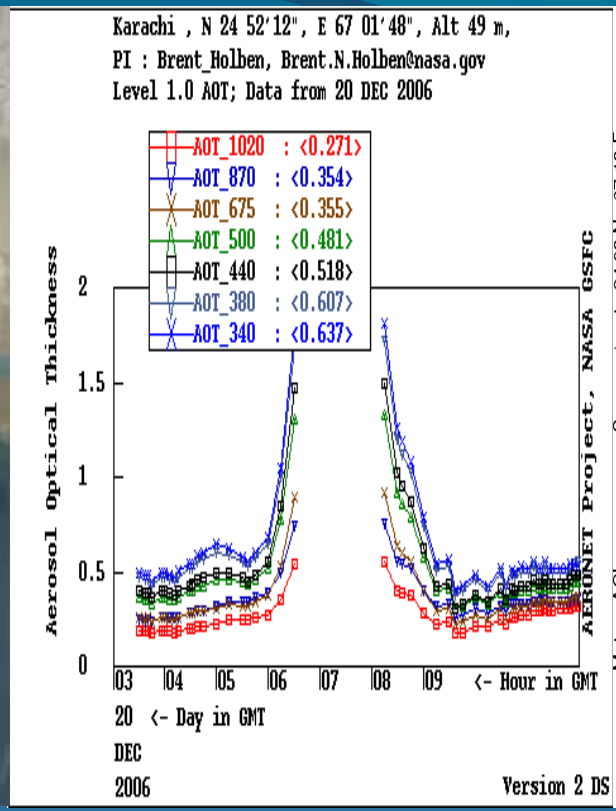

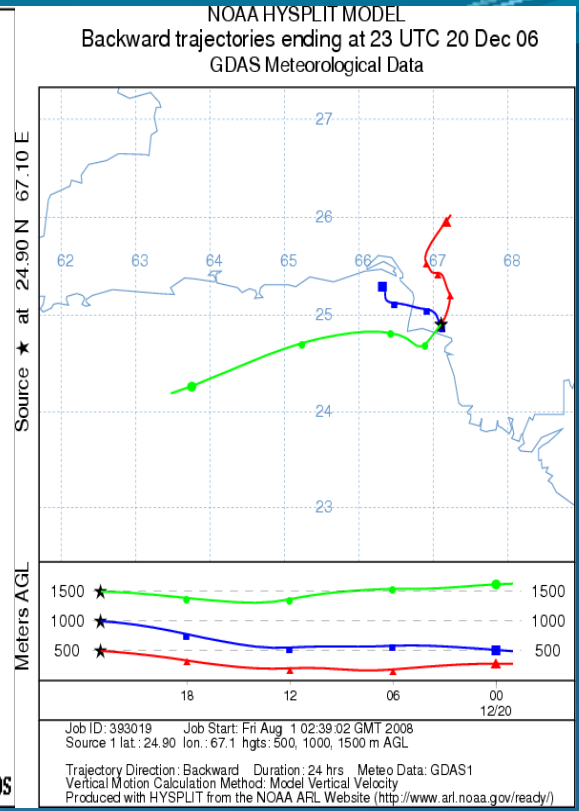

Dec 20, 2006 Terra true color image of regional dust transport over coast of Pakistan. The plot on the right shows the highly variable AOT from 0.271 to 0.637 as measured in spectral wavelength ranges from 340nm to 1020nm by an AERONET station in Karachi as the dust is transported over the city

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Dust Storm Image (22 Feb 2008)

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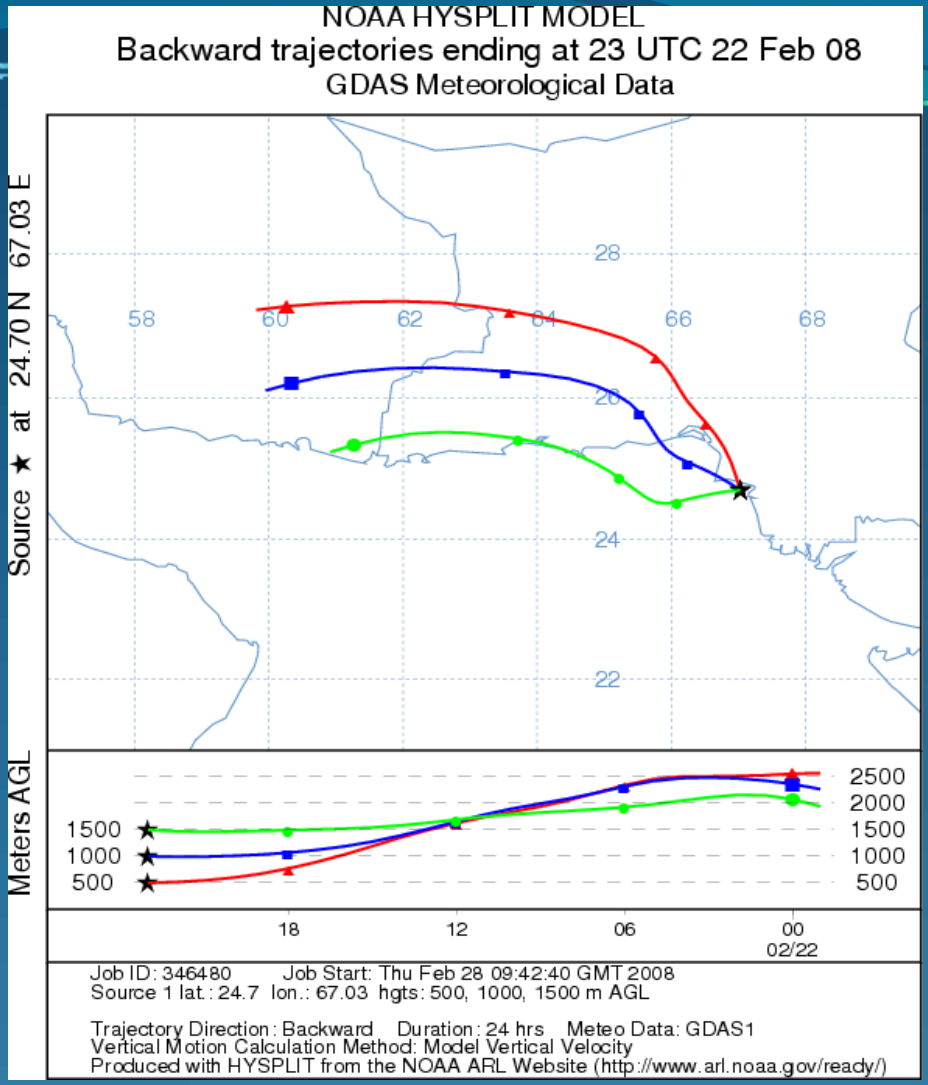
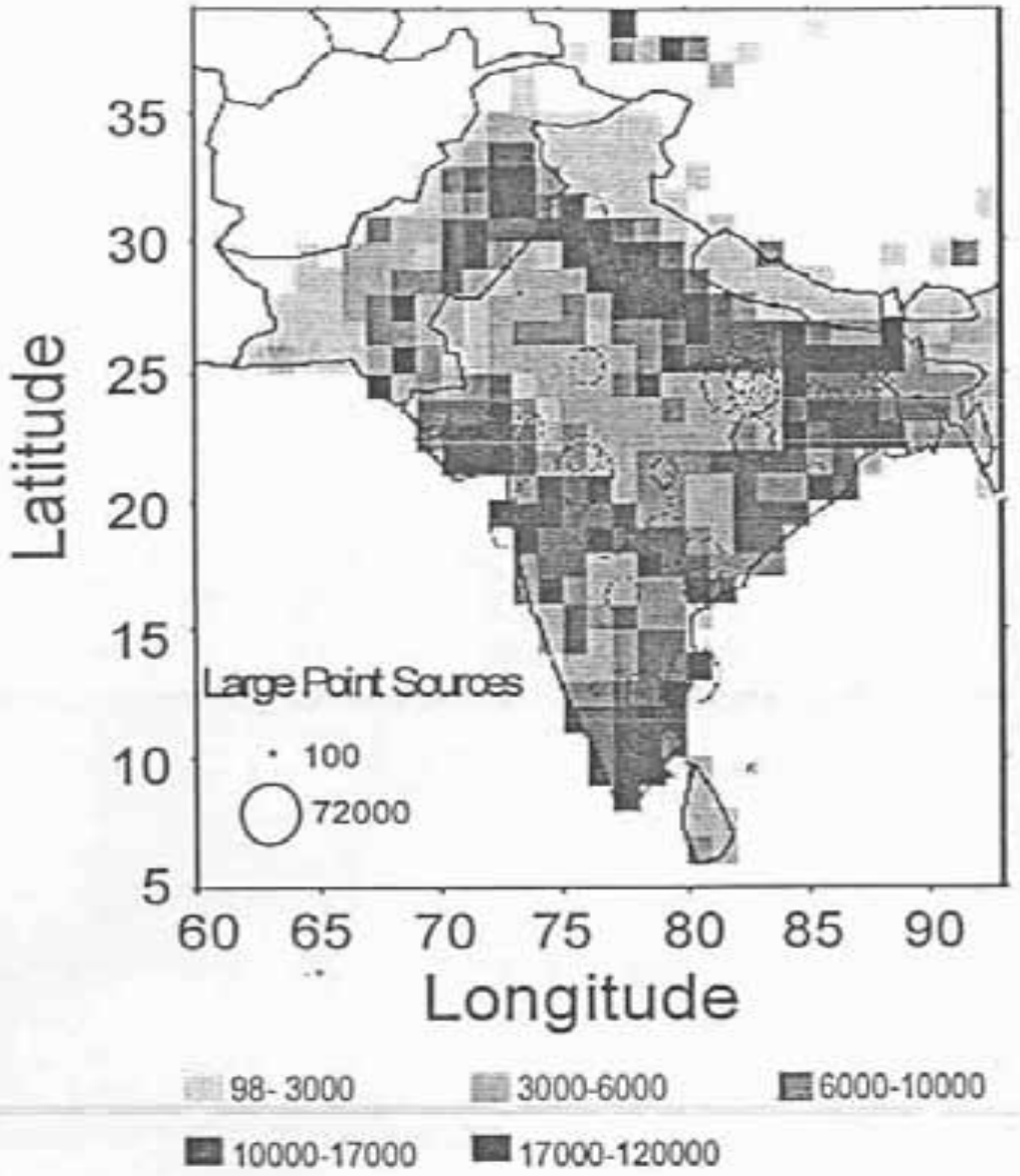


	Average	Maximum	Minimum
Temperature	26 C	30 C	21C
Humidity	50	94	10

Wind Speed	11km/hr
Maximum Wind Speed	26 km/hr
Visibility	3.2 km

Fog Study
(Lahore)



Regional SO_2 emissions in 10^3 Kg SO_2/year on a 1° x 1° grid in India and Pakistan, (G. Carmichael, personal communication, 1999). Circles represent large point sources.

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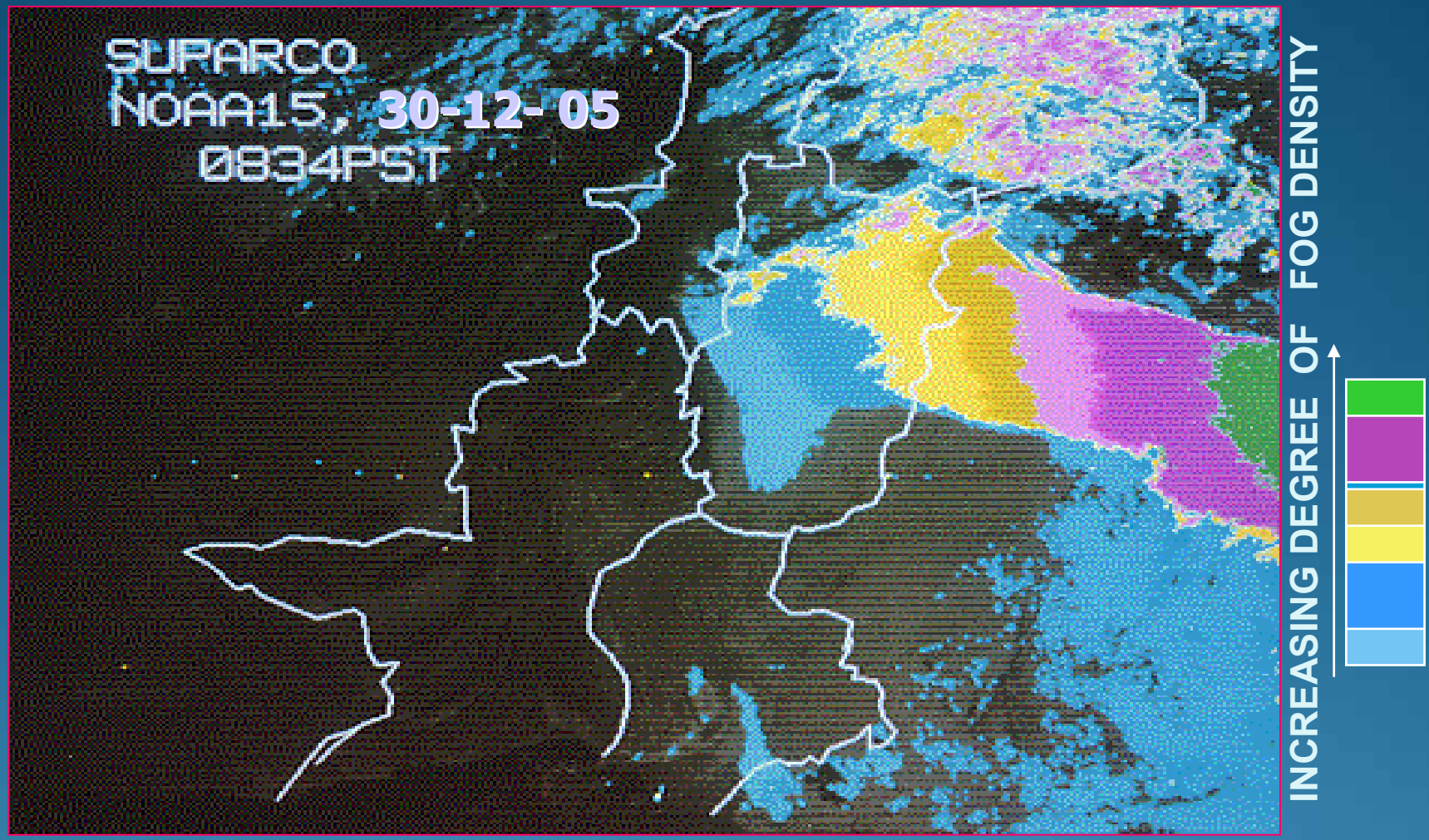
SATELLITE IMAGE OF FOG



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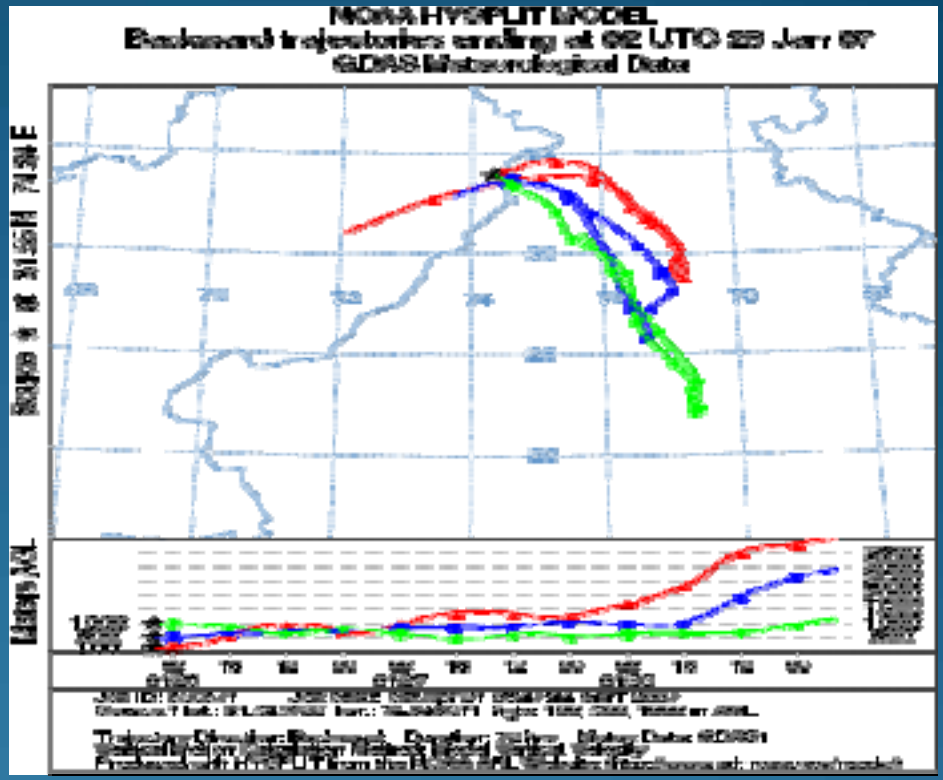
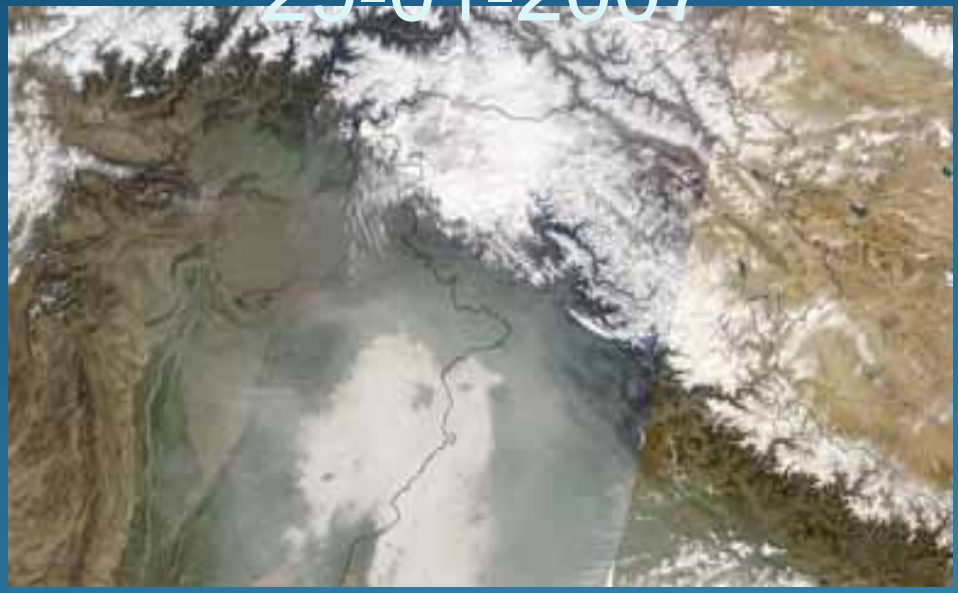
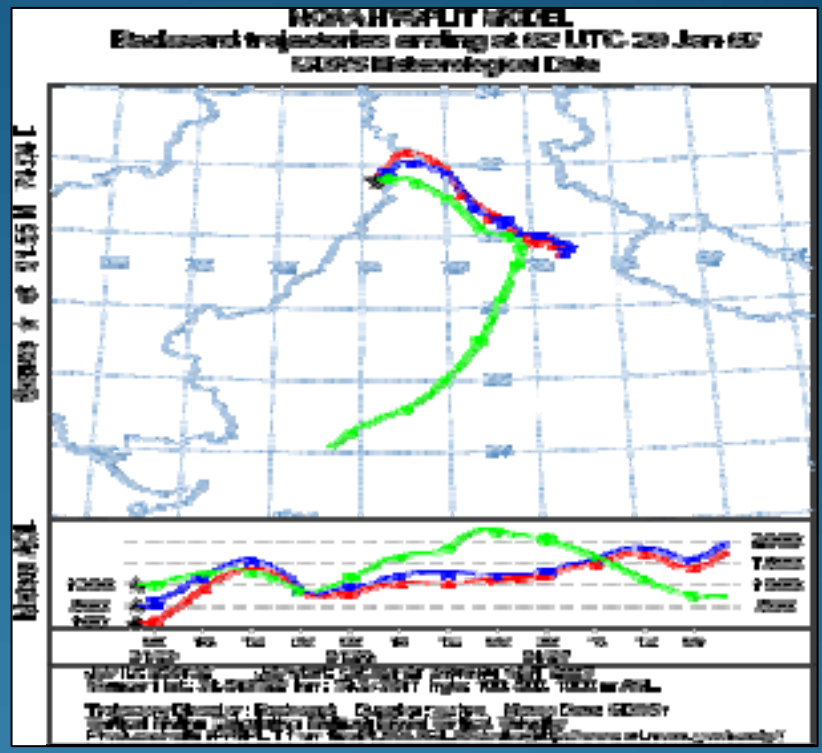
MODIS Terra 28-01-2007



MODIS Terra 29-01-2007





Satellite Monitoring of Black Carbon (BC) (Column Optical Depth) (Pakistan)

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What is Black Carbon

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

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Why to Monitor Black Carbon (BC)

Incomplete combustion of fossil and bio fuels

- Black Carbon aerosols absorb solar radiation and are the second largest contributor to global warming after greenhouse gases.
- On a global basis BC contributes ~ 0.5 Wm^{-2} radiative forcing
- BC has regional climatic impacts such as decrease in agricultural productivity
- BC affects local air quality

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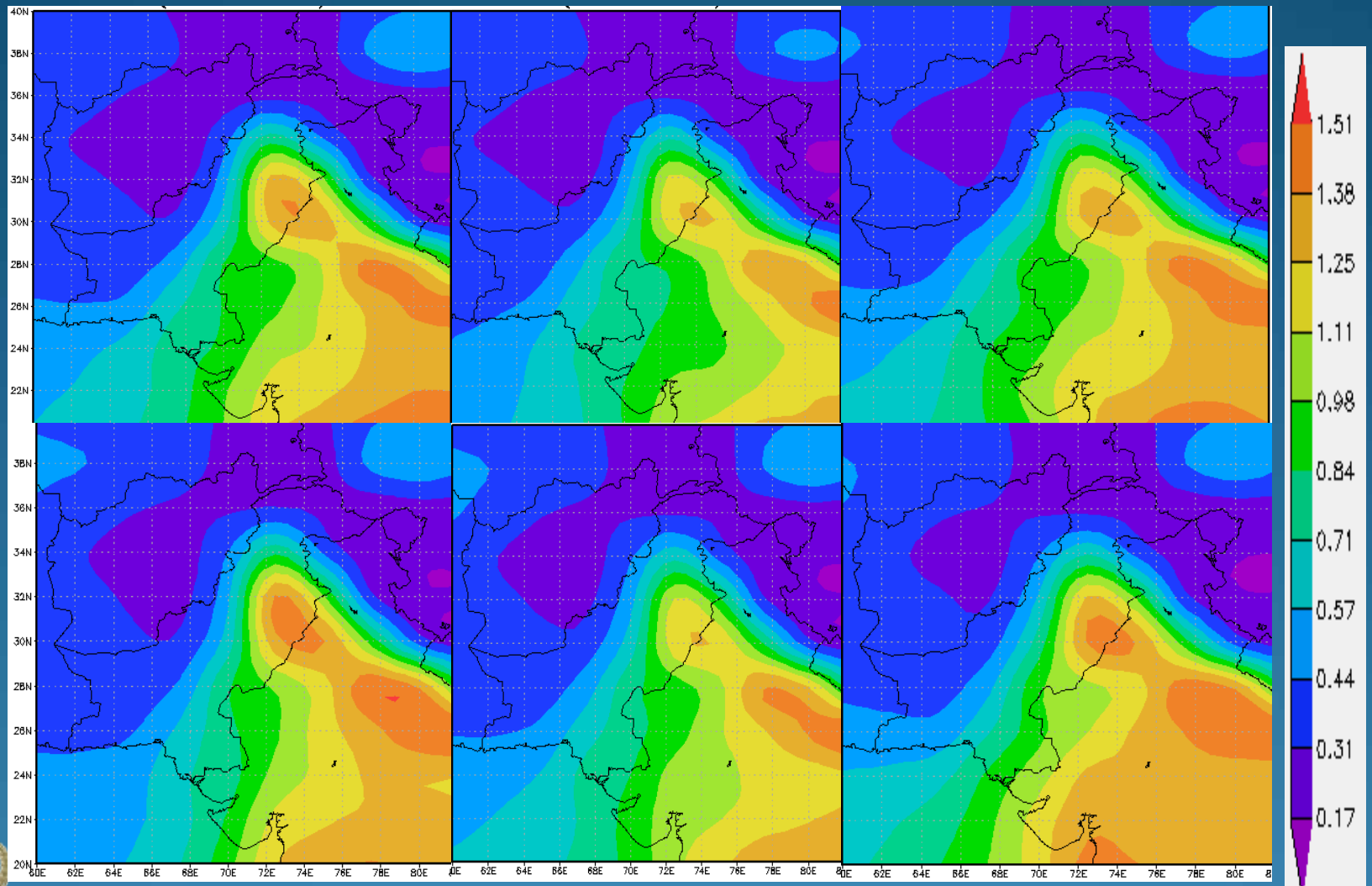
BC: Column Optical Depth {(10^{-2}) Unitless}

(Winter Season)

Dec 2000-Feb2001 | Dec 2001-Feb2002 | Dec 2002-Feb2003



Dec 2003-Feb2004 | Dec 2004-Feb2005 | Dec 2005-Feb2006

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Satellite-based Daily Black Carbon Column Optical Depth (Lahore)

Ground-based Black Carbon Concentration (Lahore)

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Size Distribution of Carbonaceous Aerosols at Lahore, Pakistan

Size (μm)	BC %
< 0.5	77
0.5 – 1.0	87
1.0 – 1.5	92
1.5 – 3.0	96
3.0 – 7.2	98
7.2 - 10	100

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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

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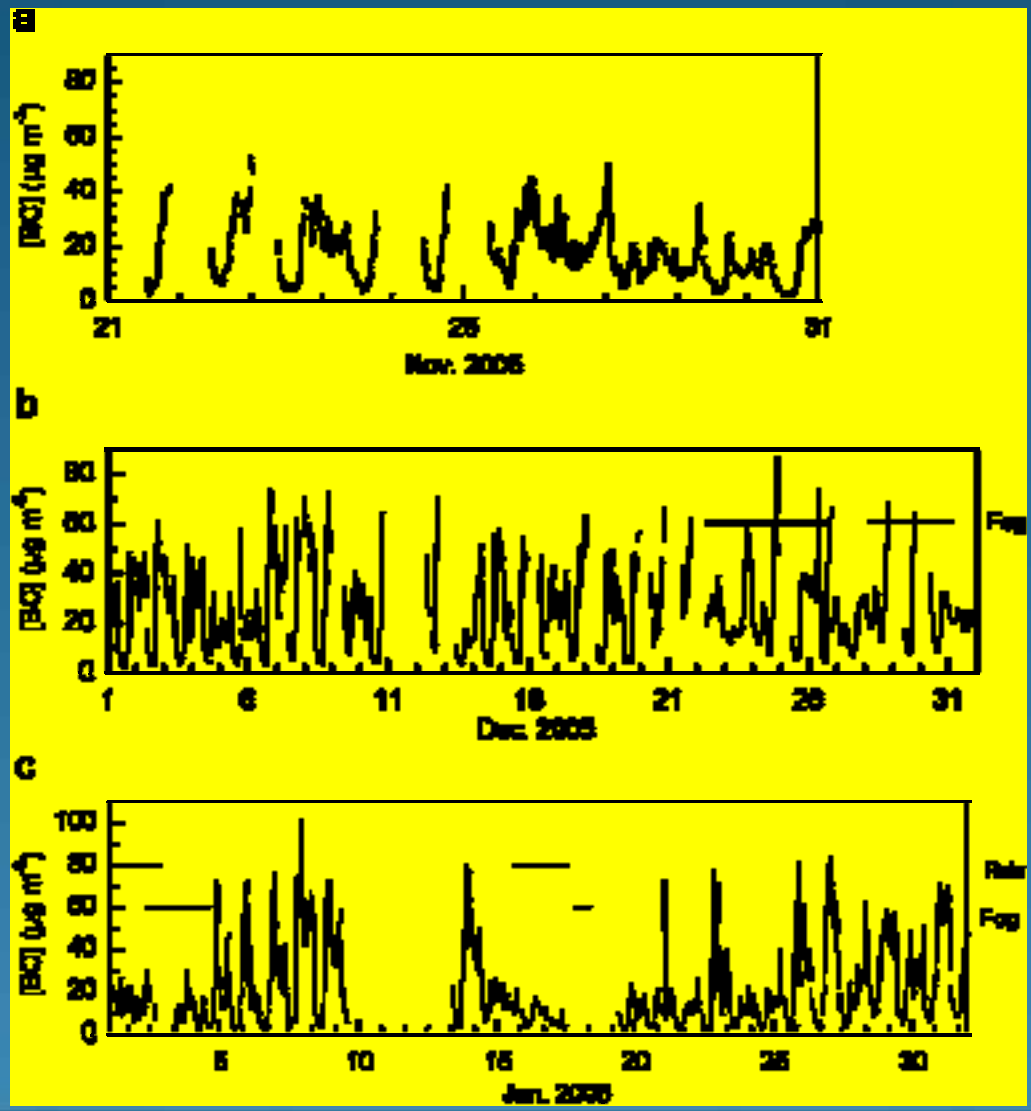
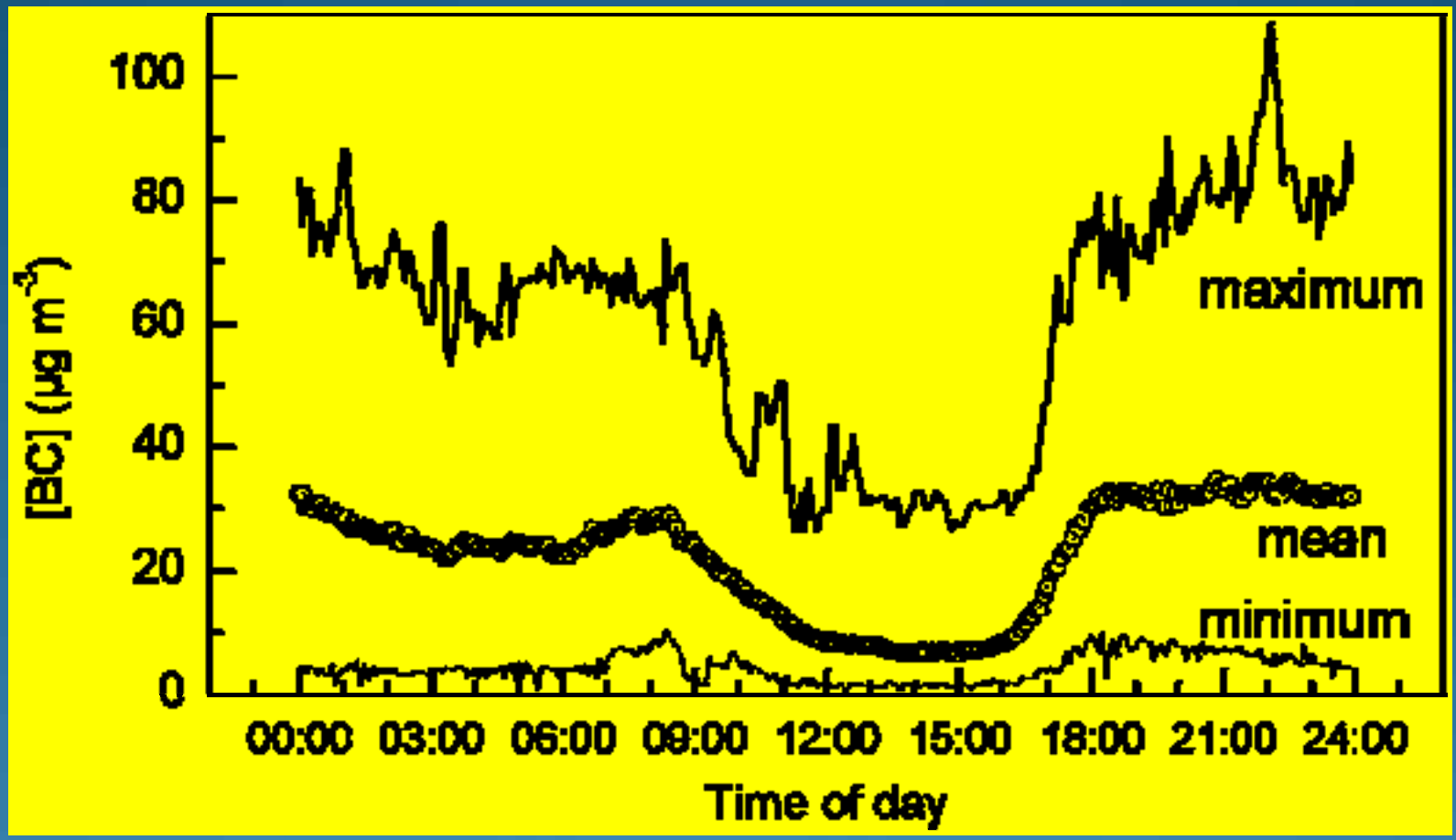
Time series plot of 5-min Aethalometer [BC] measured during November 2005 through January 2006 at Lahore, Pakistan. The horizontal bars mark periods with either rain or fog.



Time series plots of 5-min [BC] averaged over the entire 72-day study period, along with the maximum and minimum concentrations.



Concentrations (ug/m3) 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
Lahore	2005	17.6
Mexico City	1997	5.8
New York	2002	<2
London	1995	2.3
Paris	1984-85	3.8

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Ground-based Study of $PM_{2.5}$ Lahore

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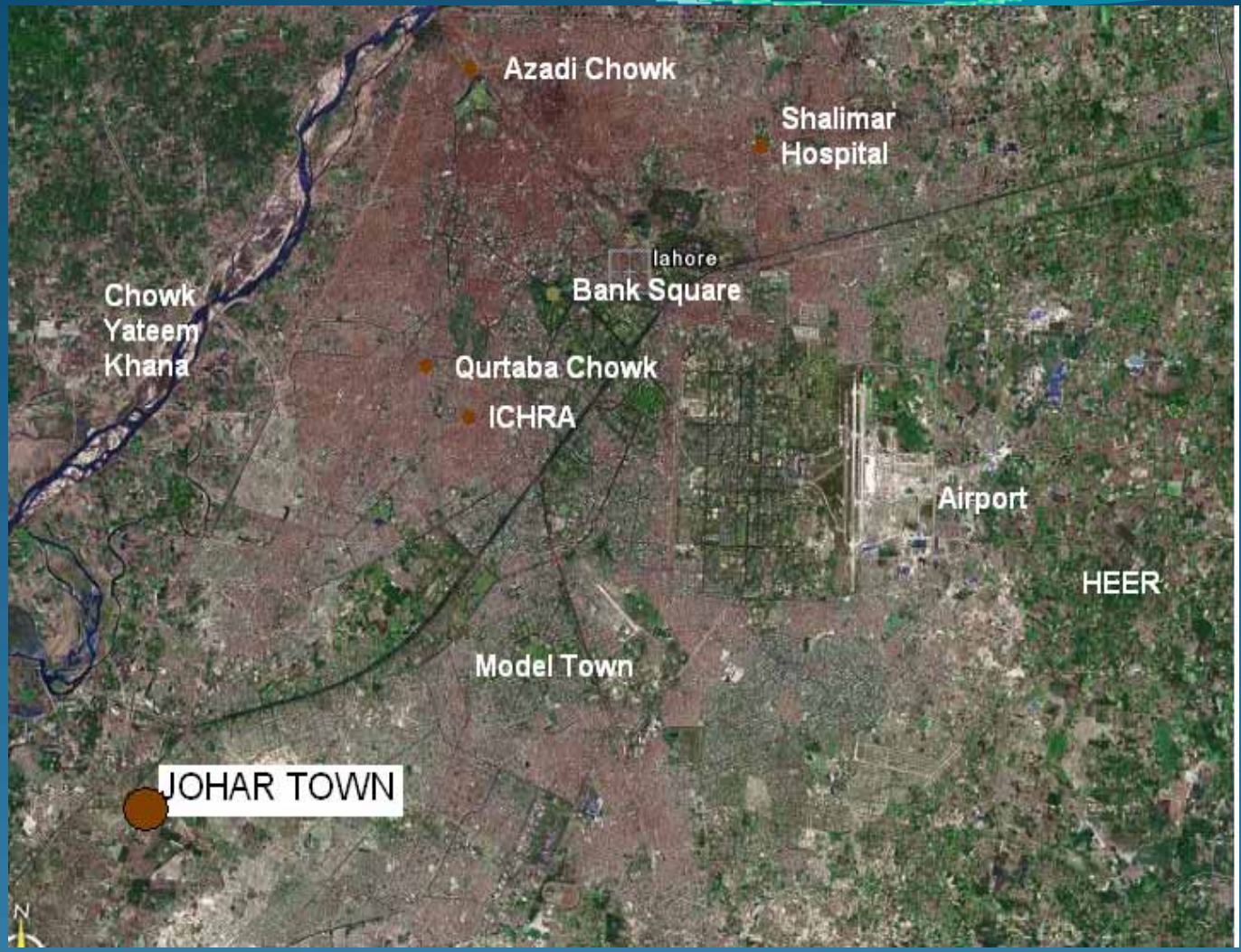

Location of Sampling Site (Johar Town), a residential area downwind to the city of Lahore

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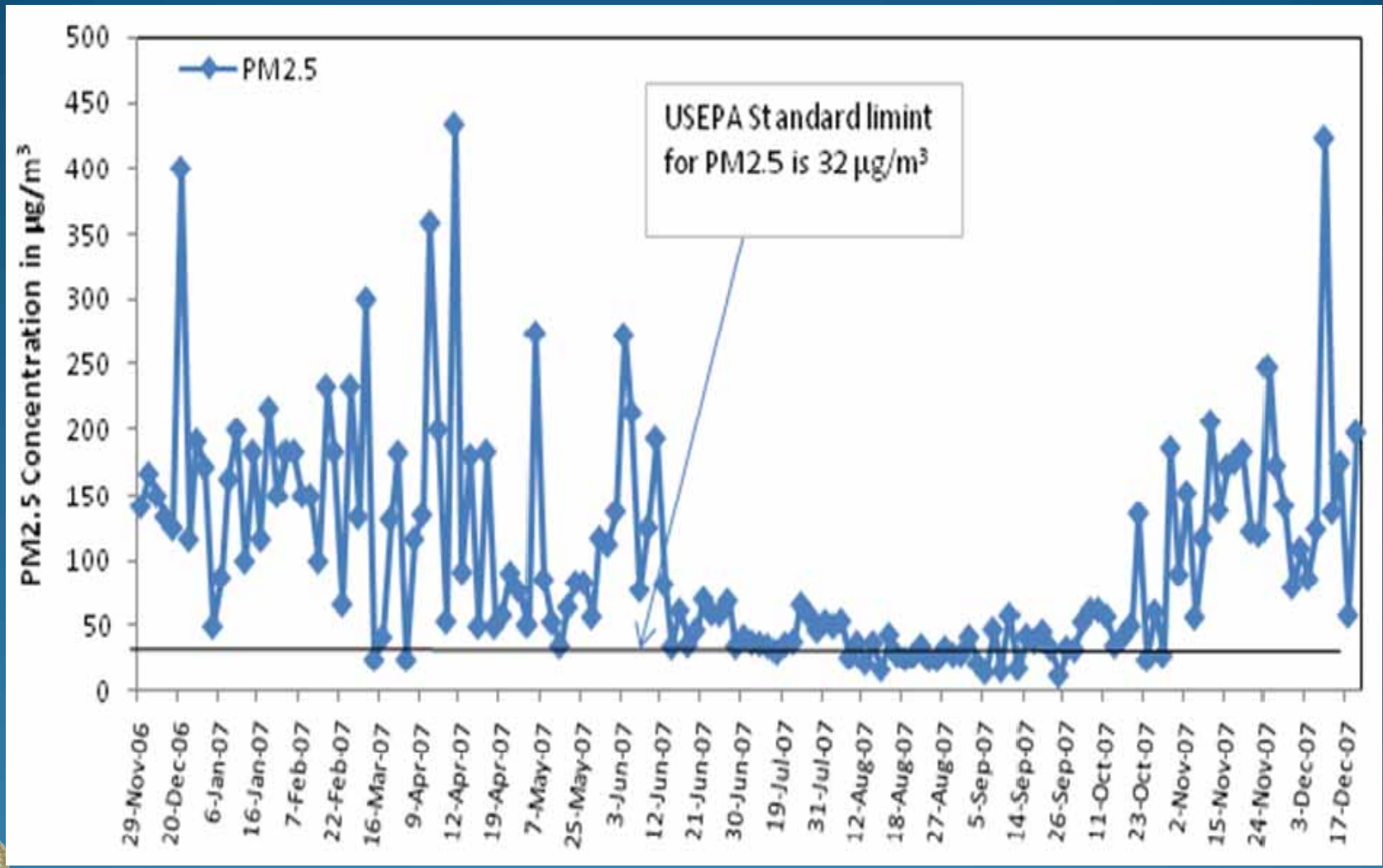
PM2.5 Concentration Variations from Nov. 2006 to Dec. 2007



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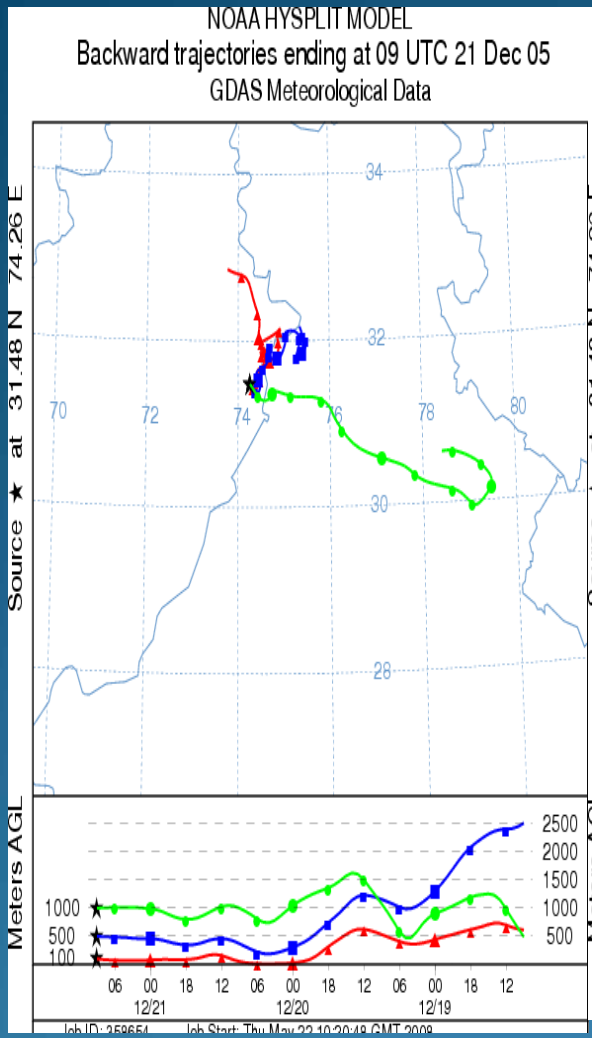
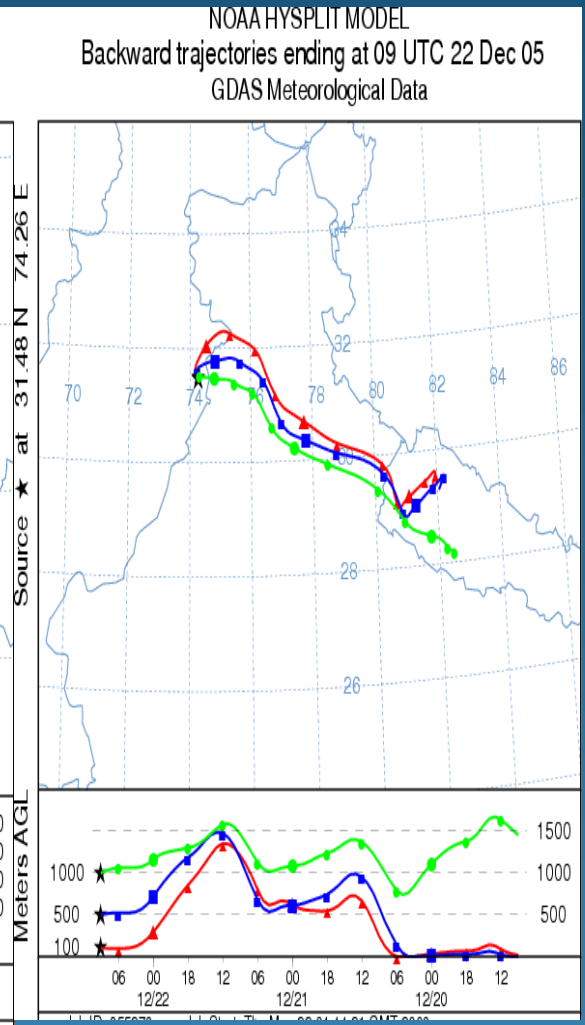
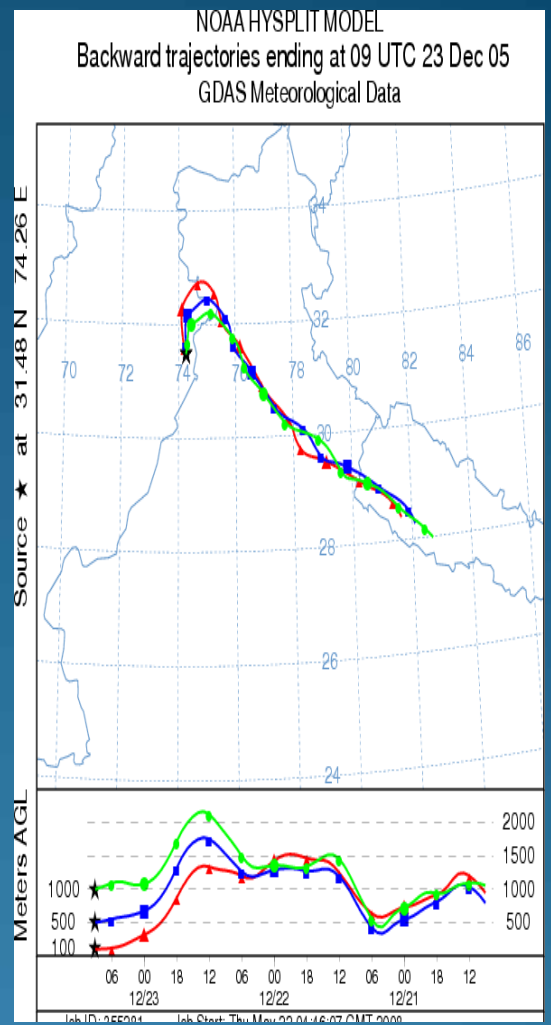

NOAA HYSPLIT MODEL
Backward trajectories ending at 09 UTC 21 Dec 05
GDAS Meteorological Data
Source ★ at 31.48 N 74.26 E
Meters AGL
12/21
12/20
12/19


NOAA HYSPLIT MODEL
Backward trajectories ending at 09 UTC 22 Dec 05
GDAS Meteorological Data
Source ★ at 31.48 N 74.26 E
Meters AGL
12/22
12/21
12/20


NOAA HYSPLIT MODEL
Backward trajectories ending at 09 UTC 23 Dec 05
GDAS Meteorological Data
Source ★ at 31.48 N 74.26 E
Meters AGL
12/23
12/22
12/21

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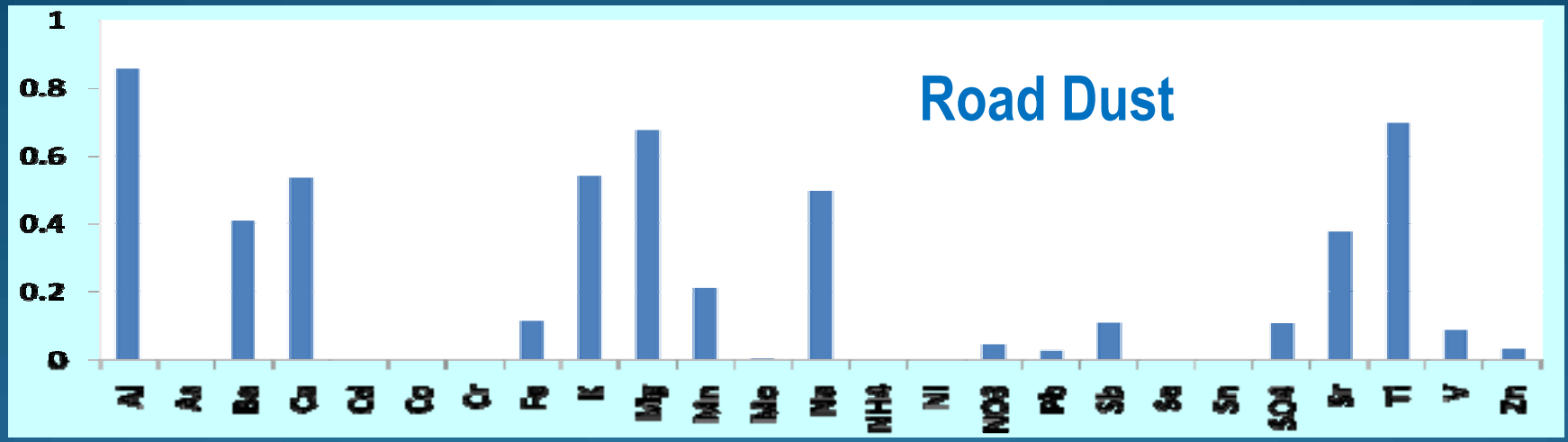
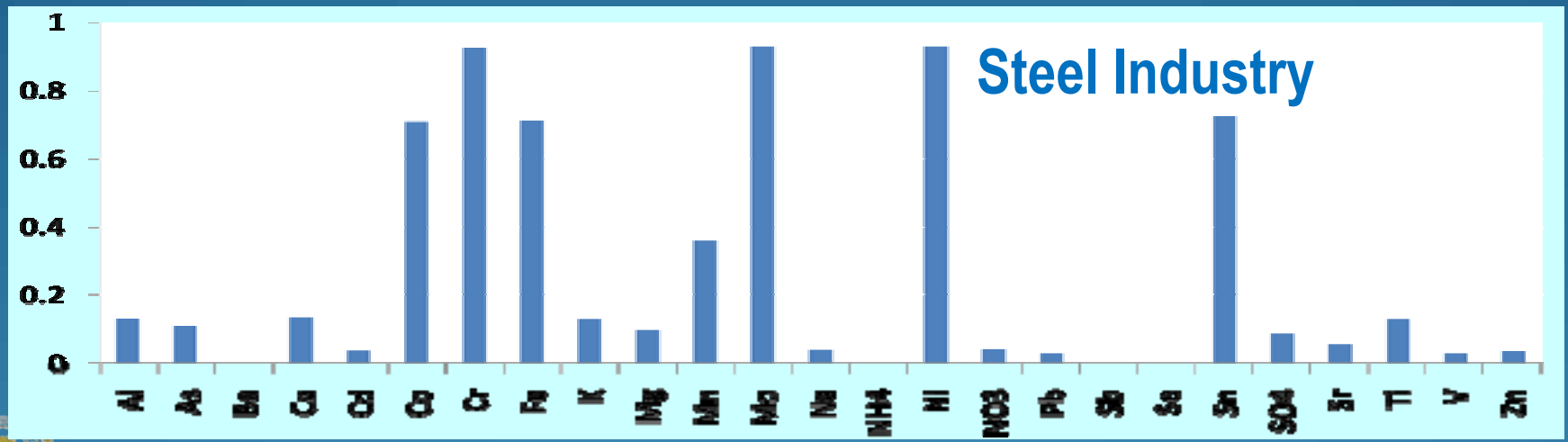
Source Profiles, Lahore





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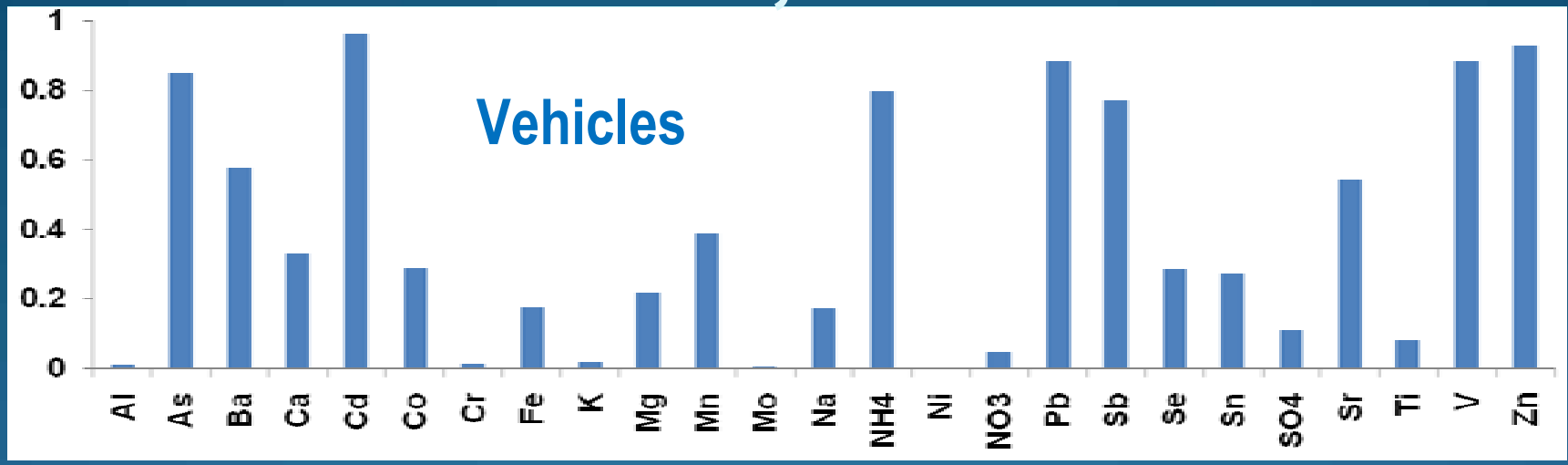
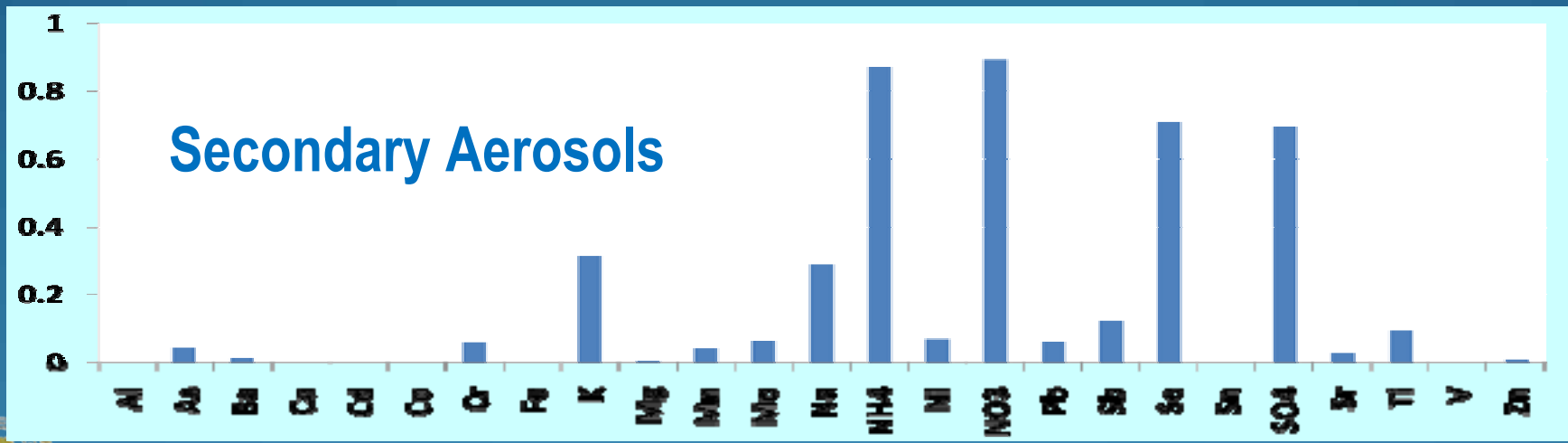
Source Profiles, Lahore Cont'd





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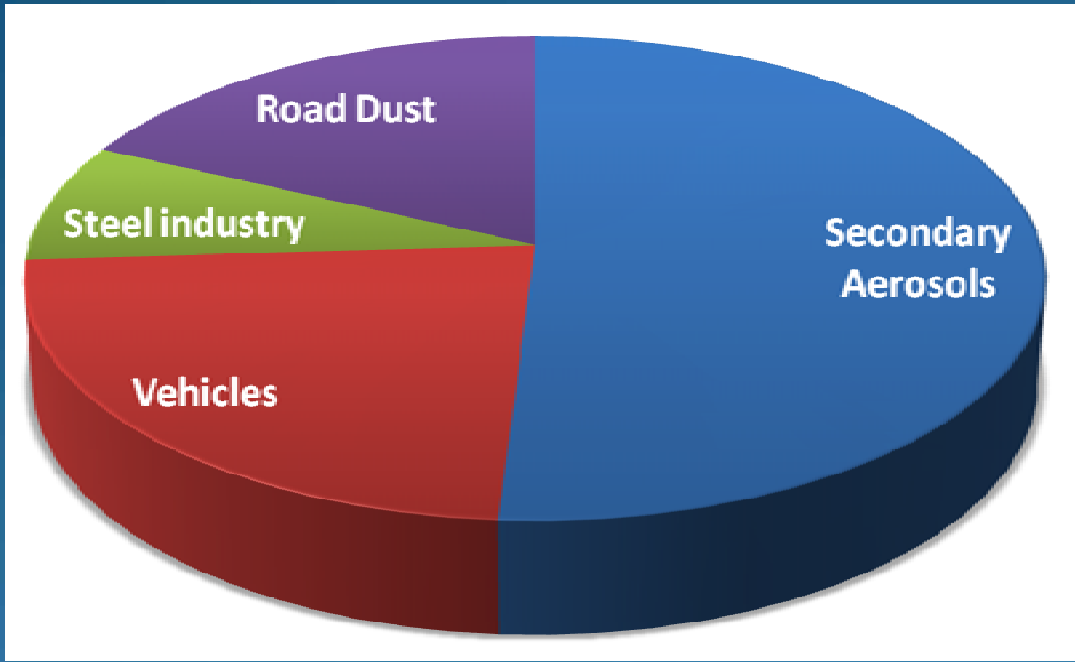
Source Apportionment Lahore



- Secondary Aerosols (51%)
- Vehicles (23%)
- Steel industry (8%)
- Road Dust (18%)

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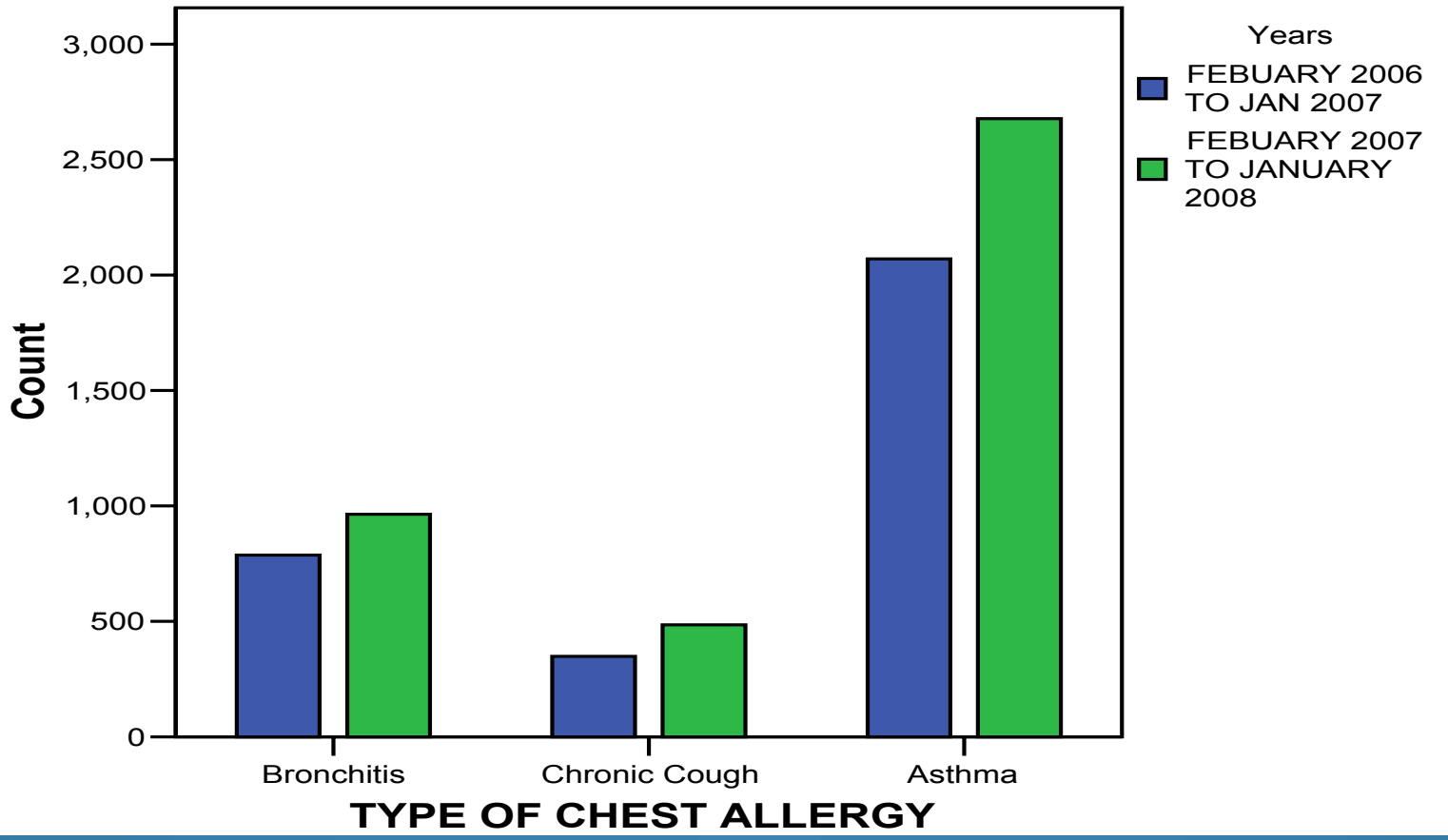
COMPARASION OF CHEST ALLERGIES CASES DURING FEB 2006 TO JAN 2007 & FEBUARY 2007 TO JAN 2008



* Health data of Jinnah Hospital Lahore

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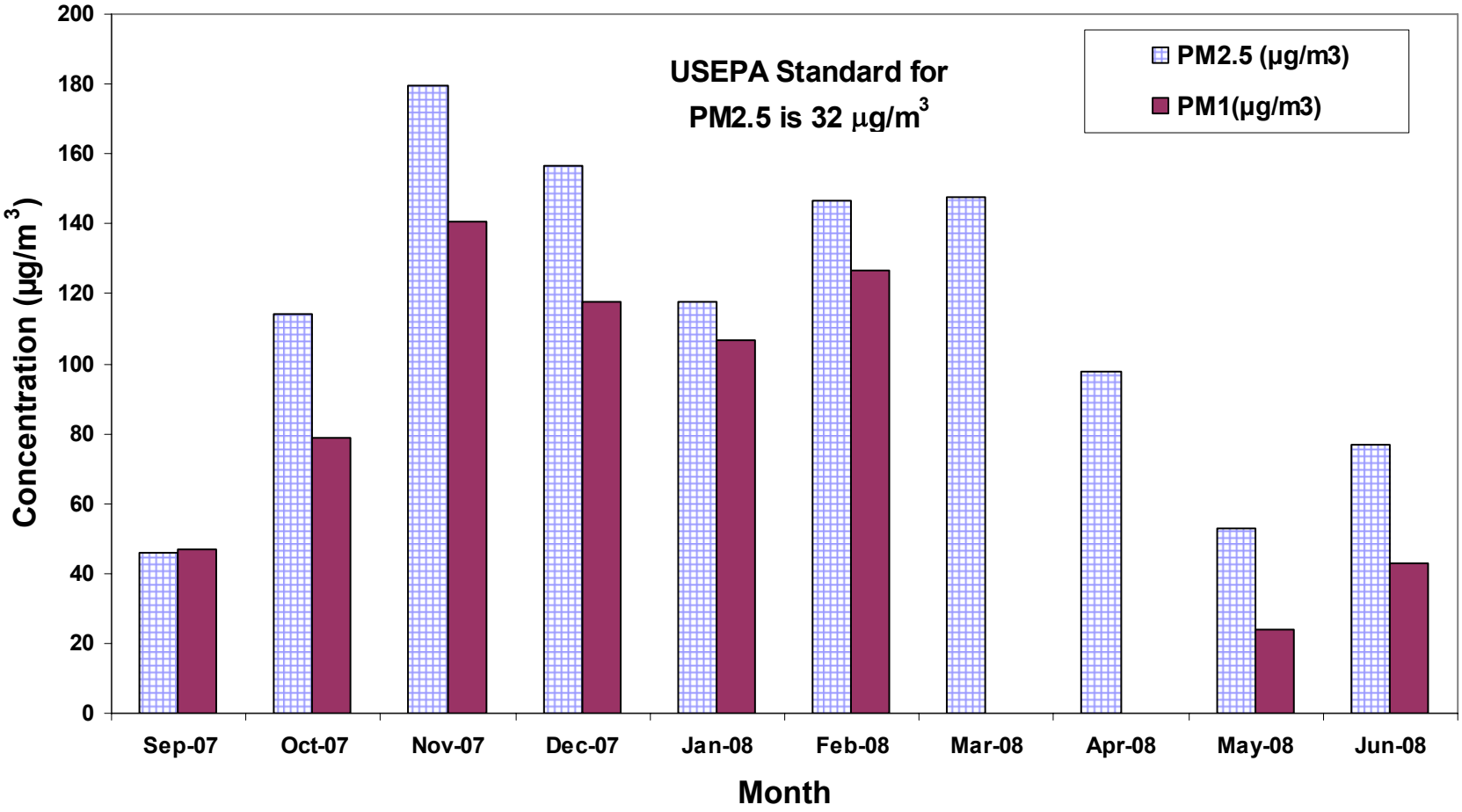
Groun-based Study of Black Carbon and Particulate Matter (Karachi)

Comparison of PM_1 & $PM_{2.5}$ data at SUPARCO HQs Karachi



Conclusion

- **Satellite-based measurements give full coverage of the study area**
- **Due to certain limitations like resolution, atmospheric effect, satellite measurements are not well agreed with ground data**

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Glacier Depletion in Tibetan Plateau-Climate Change Perspective

Glacier Monitoring Through Satellites

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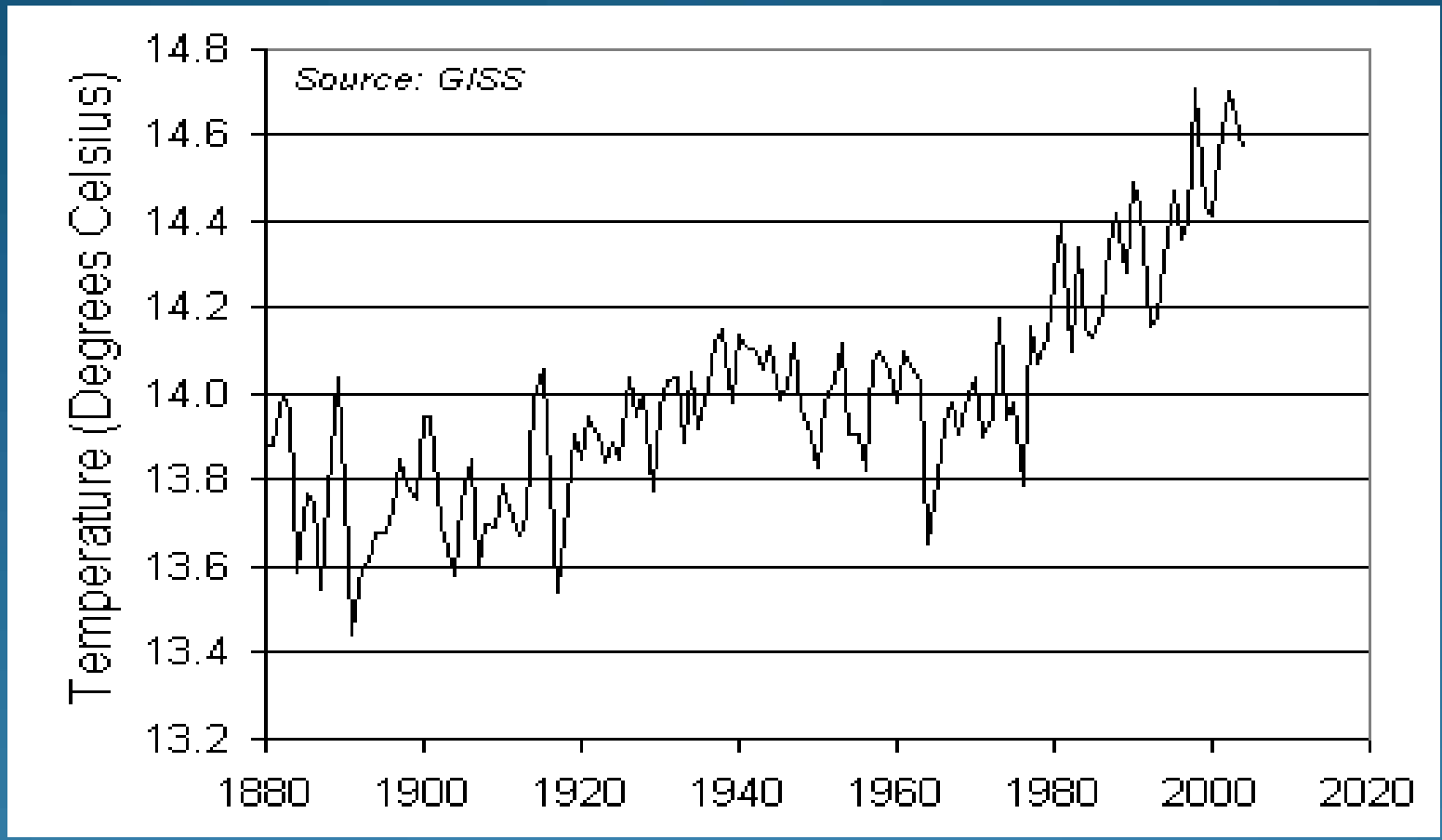
Global Temperature Rise



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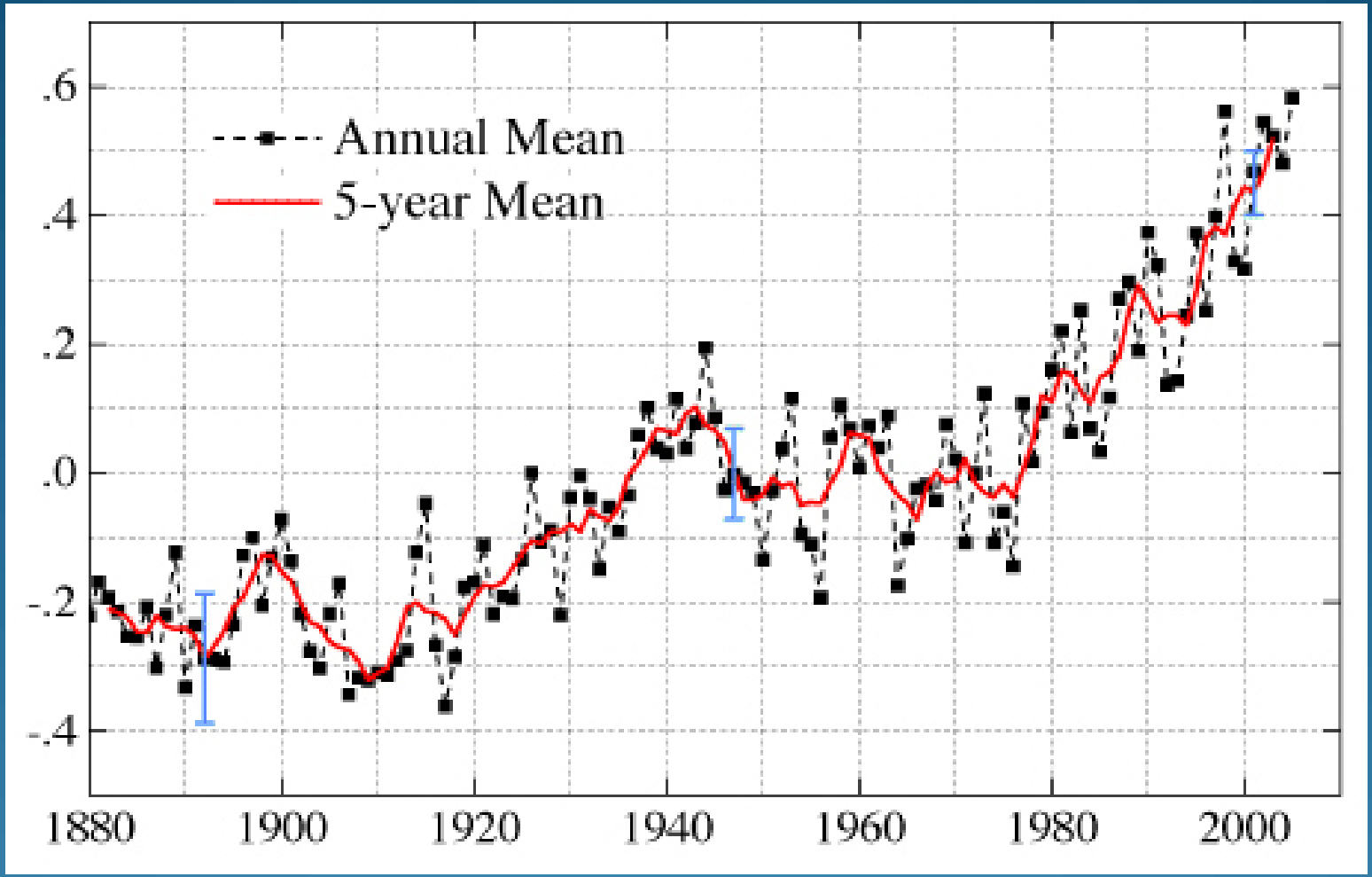
Global Temperature Rise



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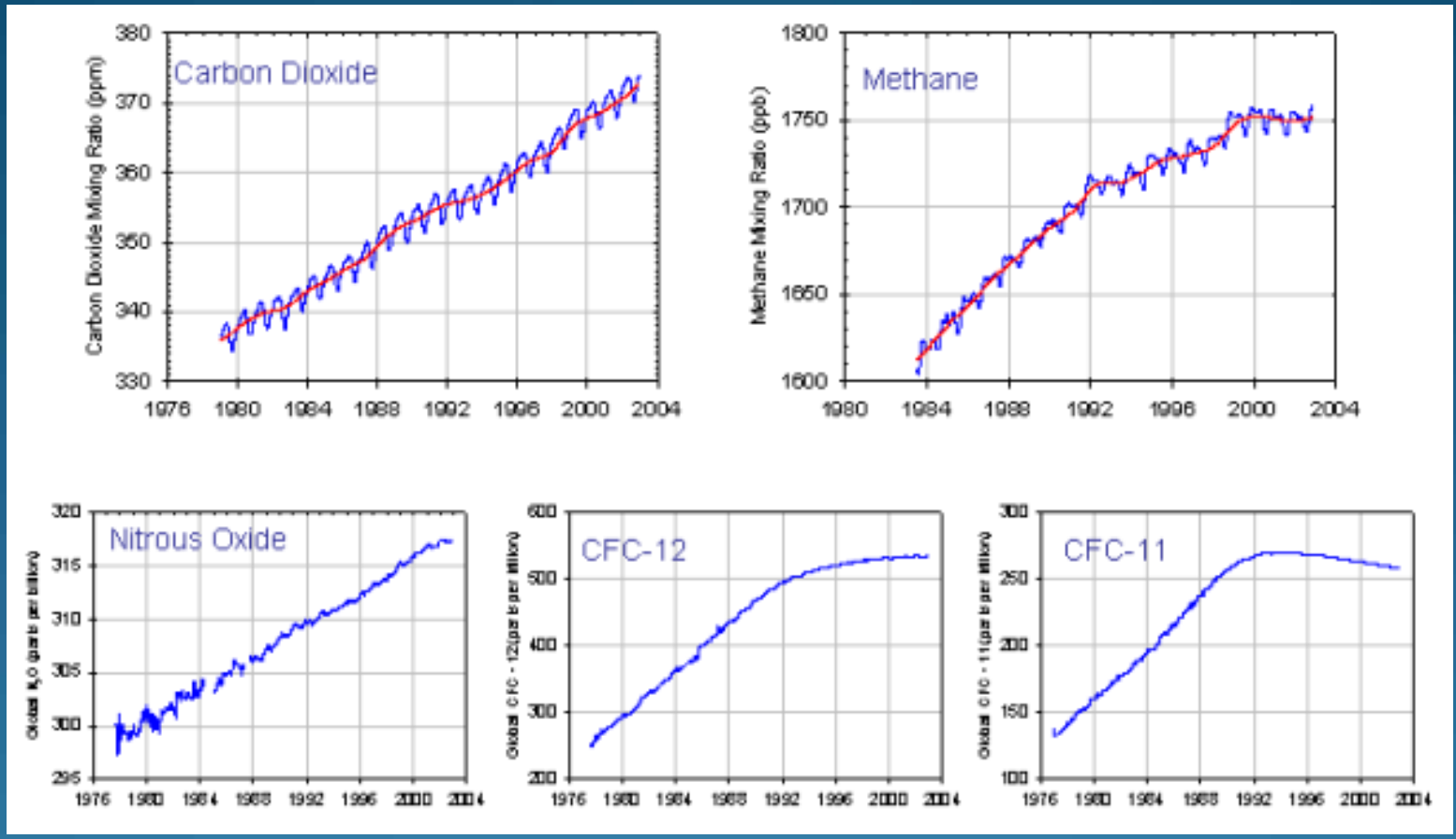
Global trends in major long-lived greenhouse gases through the year 2002



These five gases accounts for about 97% of the direct climate forcing by long lived greenhouse gas increases since 1750.

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Brief on Tibetan Plateau

- Tibetan Plateau is the most concentrated glacier centre in the low latitudes on earth with a total glacier area of 104,850 Km ^{2}
- Out of which Pakistan's share is 16933 Km ^{2}
- The glaciers supply 303.6 million cubic feet of water every year to Asian rivers, including Yangtze & Yellow Rivers in China, Ganga in India, Indus in Pakistan, Brahmaputra in Bangladesh & Burma's Irrawaddy

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Contd……

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- Glaciers in Tibetan Plateau form a unique water reservoir
- These glaciers are source of water for half of humanity of the world
- Civilization in these countries started along these rivers

Contd …….

66

- Glaciers in our region have been observed to be retreating possibly due to ‘Climate Change‘
- These are receding faster than in any other part of the world and may disappear during the next century if the present rate of retreating continues
- Population in these areas are dependent on the melt water for agriculture and allied activities

Contd ……

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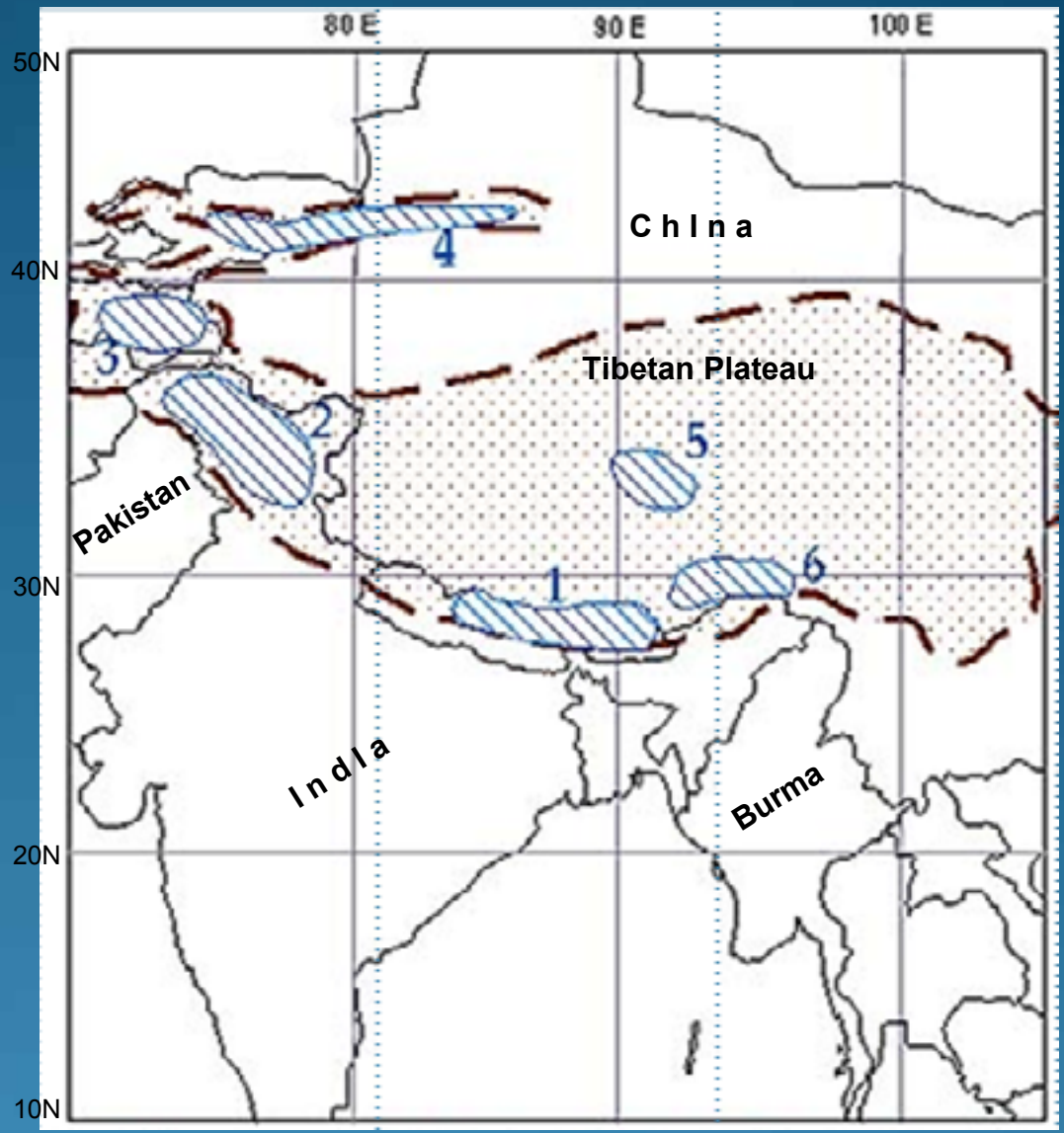
- Effects of increased glacier melt are both local and regional
- As glacial-melt continues, 40 percent of humanity in South Asia and China could be living with little drinking water
- Satellite observations enable to better understand the relationship b/w climate change & glaciers and to predict areas of future glacier changes

Map of Tibetan Plateau and Adjoining Areas

Tibetan Plateau

1. Eastern Himalaya
2. Western Himalaya/ Karakoram
3. Pamirs
4. Tien Shan
5. Tanggula Shan
6. Southern Tibetan Plateau



(Wake and Mayewski, 1996)

Glacier Distribution in Countries of the Tibetan Plateau

Country	Glacier area/km^2	Sources
China	49873	Liu Chaohai et at., 2000
India	23000	Kulkarni,A.V. and Buch, A.M., 1991
Pakistan	16933	http://www.pakembwaw.com.ol/SeePakistan.htm
Nepal	5322	Bajracharya, S.R. et al., 2002
Bhutan	1318	Bajracharya, S.R. et al., 2002
Sikkim	912	Hasnain, S.I., 2000
Tajikistan	7493	Liu Chaohai et al., 2000
Total	**104850**	

Ref: Yongping SHEN

Image of 20 November 2001 Shows Bhutan Glaciers turned into Glacial Lakes

Courtesy: American Geophysical Union

ASTER Image Shows Estimates of Gangotri (India) Glacier Retreat

Courtesy of Jesse Allen, Earth Observatory, USA

Scenario of Pakistan Glaciers

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Aerial View of Part of Glacier Region of Pakistan on 15 May 2006

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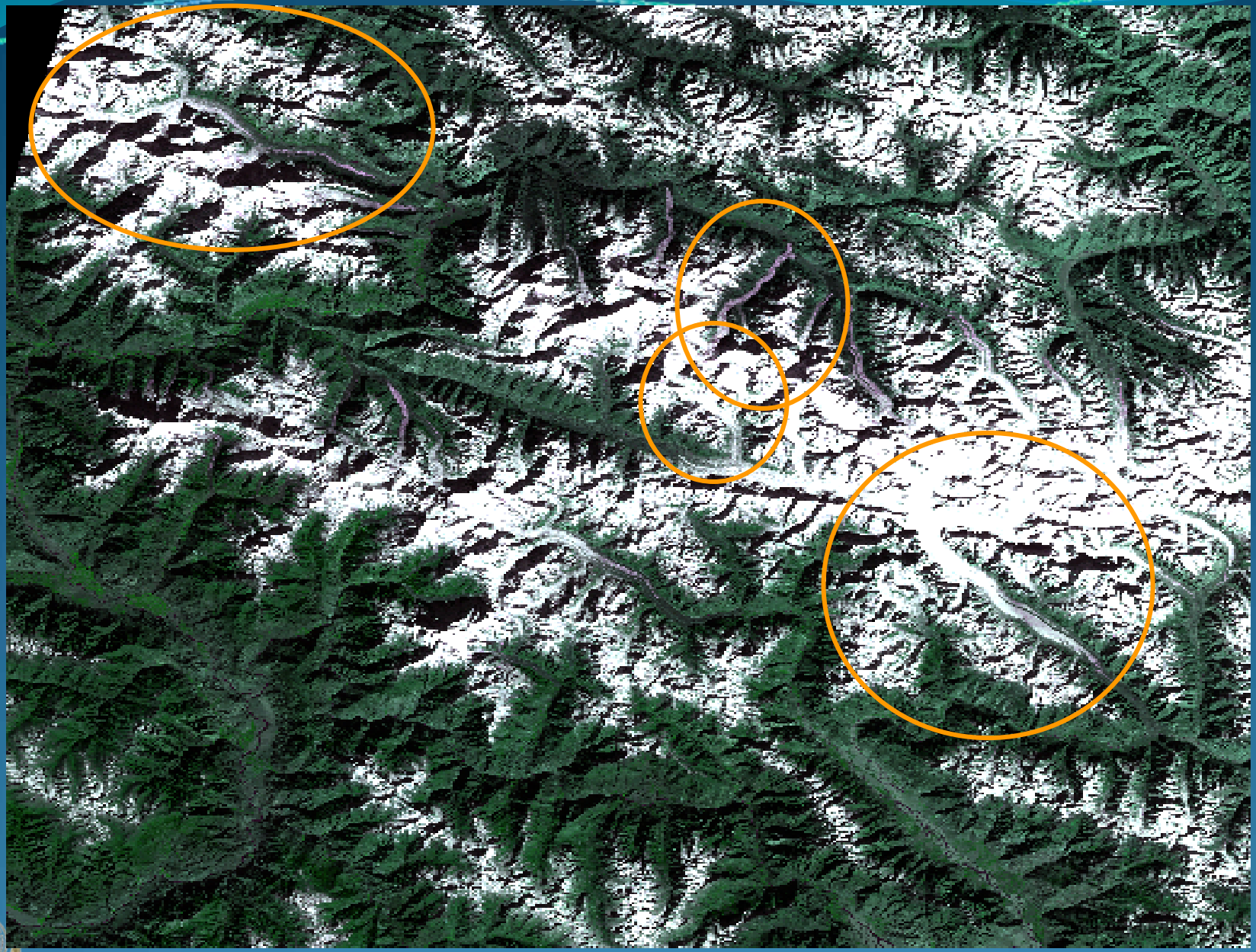
SUPARCO conducted study of following Glaciers

- Batura Glacier
- Biafo Glacier
- Yazghil Glacier
- Jutmau Glacier

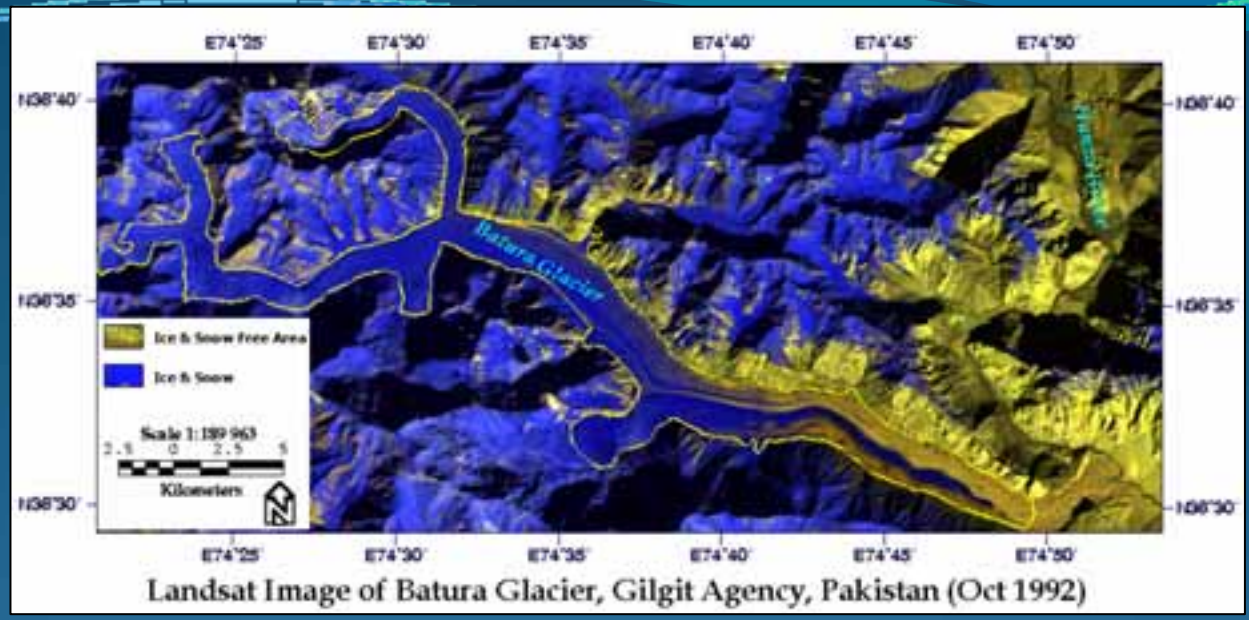
Yazghil Glacier



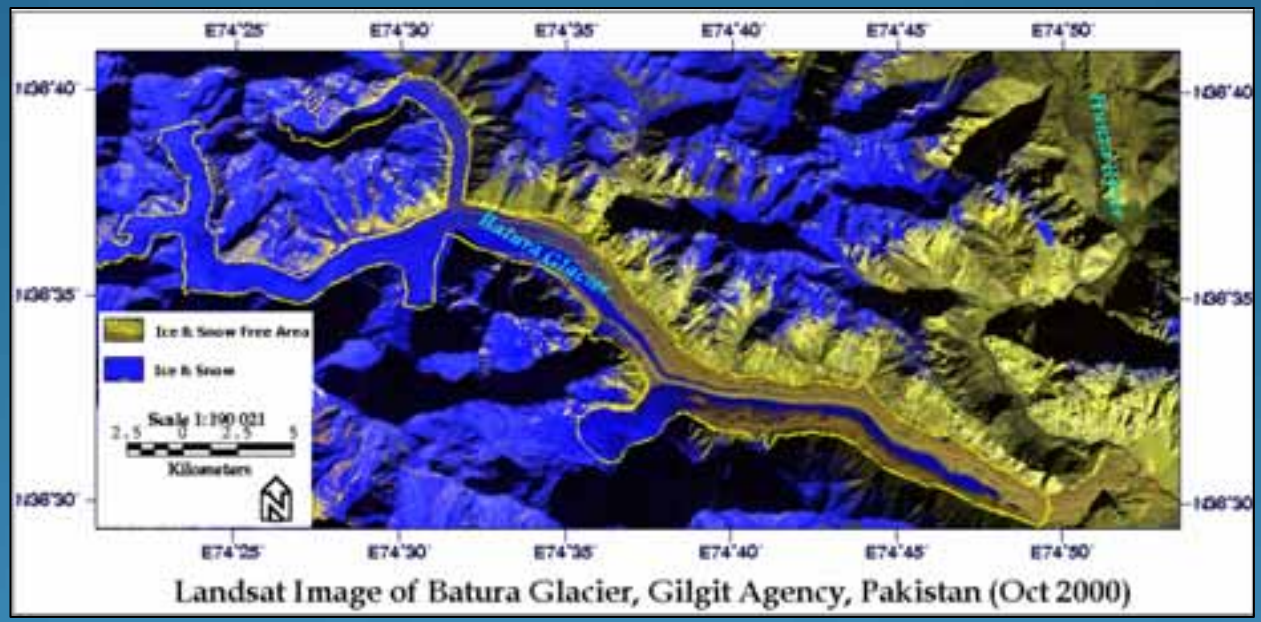
Batura Glacier

- It is one of the largest glaciers outside the polar region
- It lies in the north of Passu 7,500 meter above sea level
- It feeds River Hunza in northern Pakistan which flows west to east into the Indus River
- Temporal analysis of satellite images of Batura Glacier revealed that snow & ice covered and free areas in the year 1992 was 98 & 25 sq km respectively
- Whereas in the year 2000 snow & ice covered area reduced to 81 sq km, consequently increasing the ice free area to 42 sq km

Contd……



Landsat Image of Batura Glacier, Gilgit Agency, Pakistan (Oct 1992)



Landsat Image of Batura Glacier, Gilgit Agency, Pakistan (Oct 2000)

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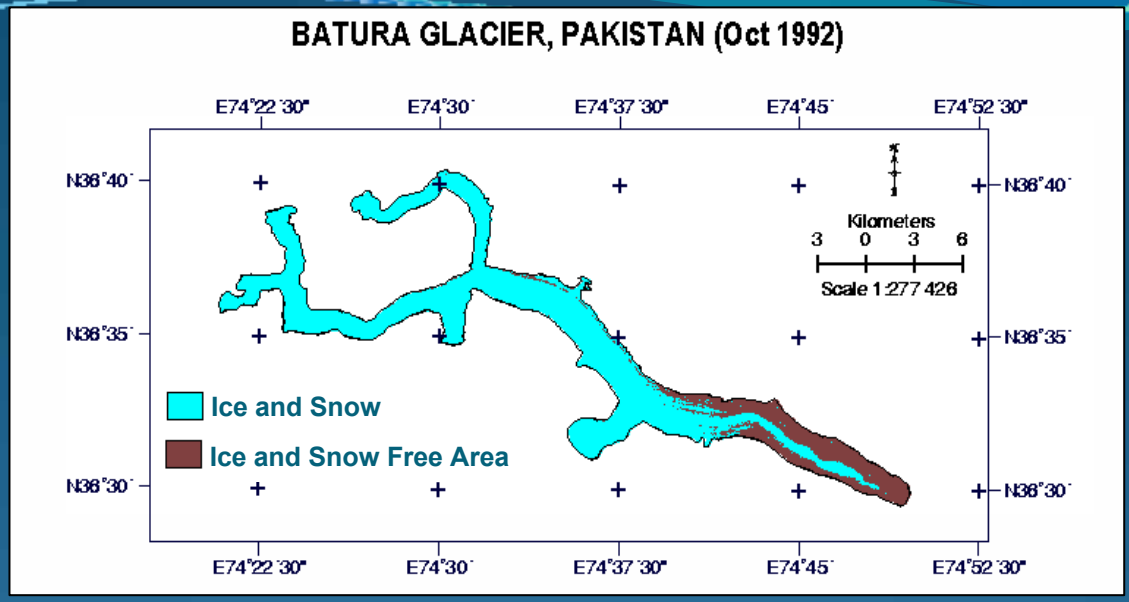
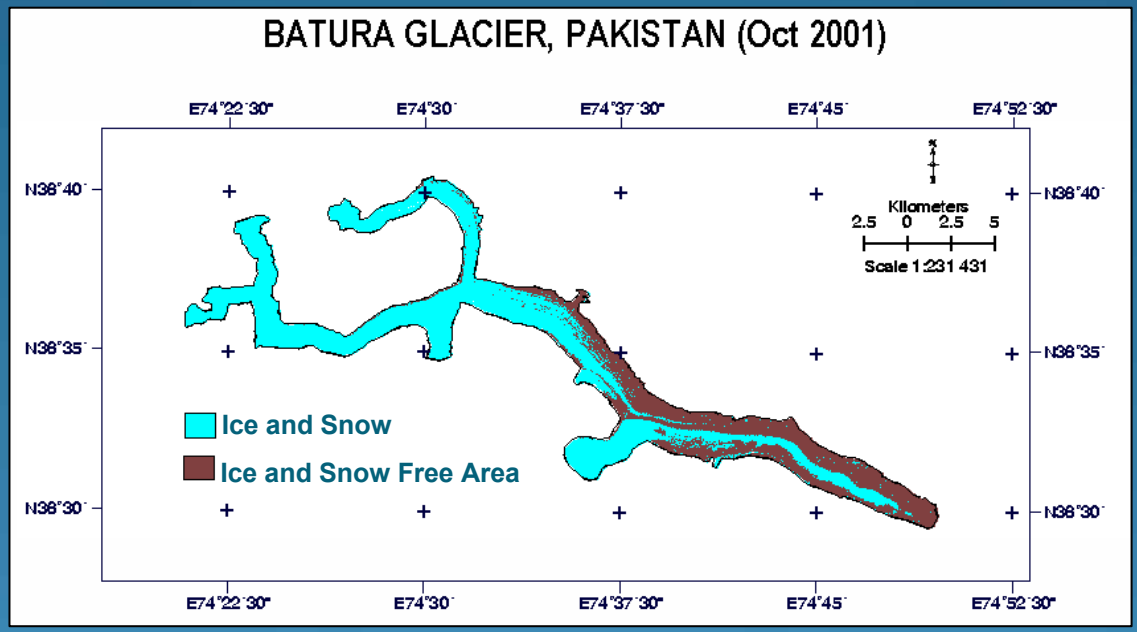

BATURA GLACIER, PAKISTAN (Oct 1992)
E74°22'30"
E74°30'
E74°37'30"
E74°45'
E74°52'30"
N38°40'
N38°35'
N38°30'
Kilometers
3 0 3 6
Scale 1:277 426
Ice and Snow
Ice and Snow Free Area

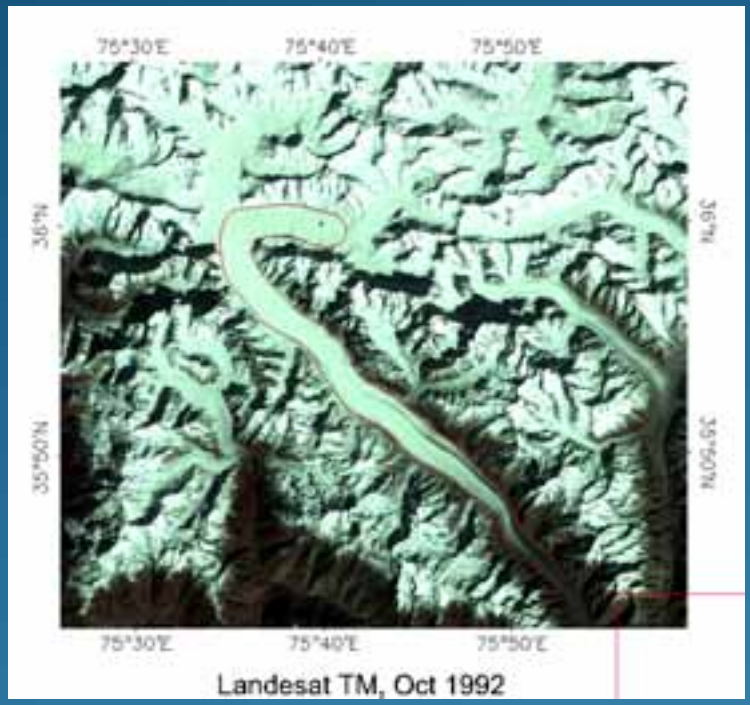

BATURA GLACIER, PAKISTAN (Oct 2001)
E74°22'30"
E74°30'
E74°37'30"
E74°45'
E74°52'30"
N38°40'
N38°35'
N38°30'
Kilometers
2.5 0 2.5 5
Scale 1:231 431
Ice and Snow
Ice and Snow Free Area

Biafo Glacier

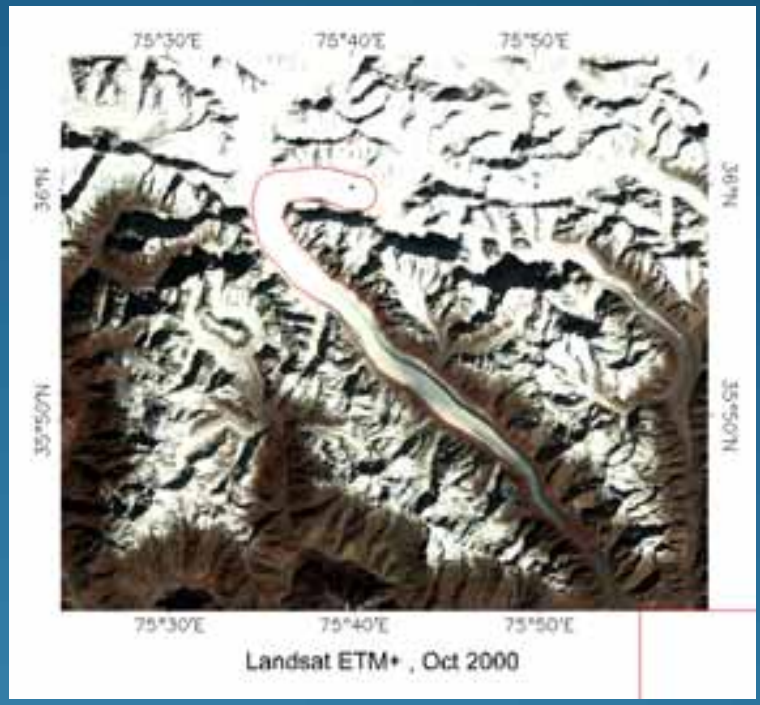
- It is the third largest glacier in the Karakoram and the fourth largest in Asia
- It lies on the south-facing slopes of the Karakoram Range in the Baltistan
- The main stream originating from this glacier is Barldu River flowing into the Shigar River, a tributary of the Indus River
- Temporal analysis of satellite images revealed that snow & ice covered and free areas in the year 1992 was 93.137 sq km and 21.959 sq km respectively
- Whereas in the year 2000 snow & ice covered area reduced to 84.622 sq km, consequently increasing the ice free area to 30.474sq km

Contd……

Satellite images of Biafo Glacier

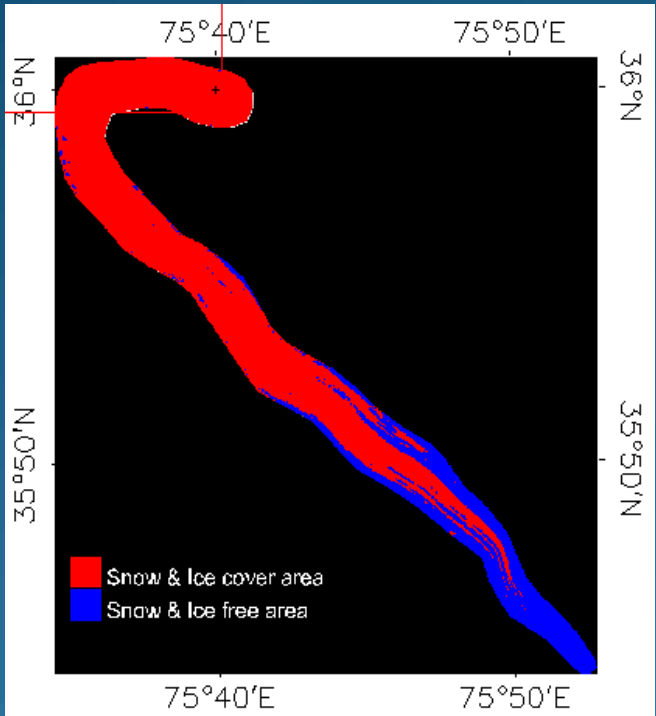


Landesat TM, Oct 1992

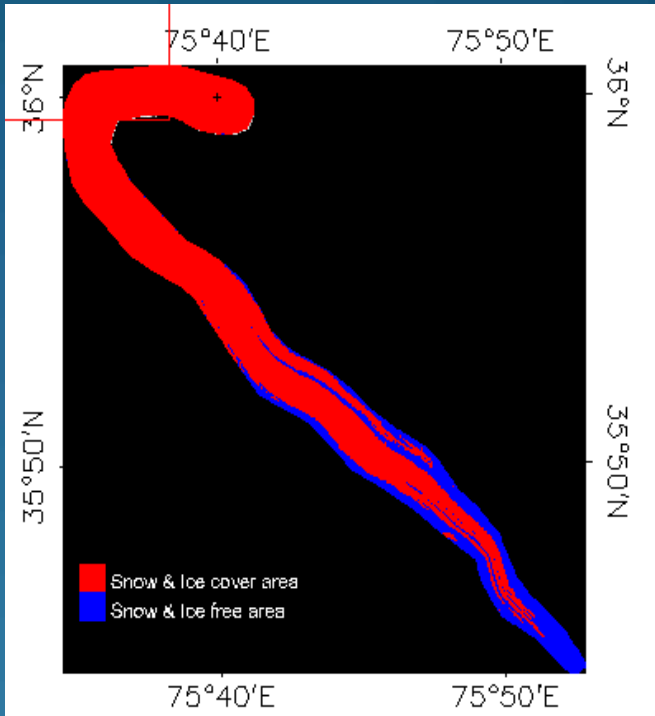


Landsat ETM+ , Oct 2000

Contd……



Landsat TM, Oct 1992
Classified Band ratio (TM3/TM5)



Landsat ETM+, Oct 2000
Classified Band ratio (ETM3/ETM5)

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Yazghil Glacier

- Yazghil Glacier lies in Hispar Muztagh, Karakoram Range, 7324 meter above sea level
- Temporal analysis of satellite images indicated slight decrease in the glacial area of 1.18 sq km during 1992 and 2007

Contd……

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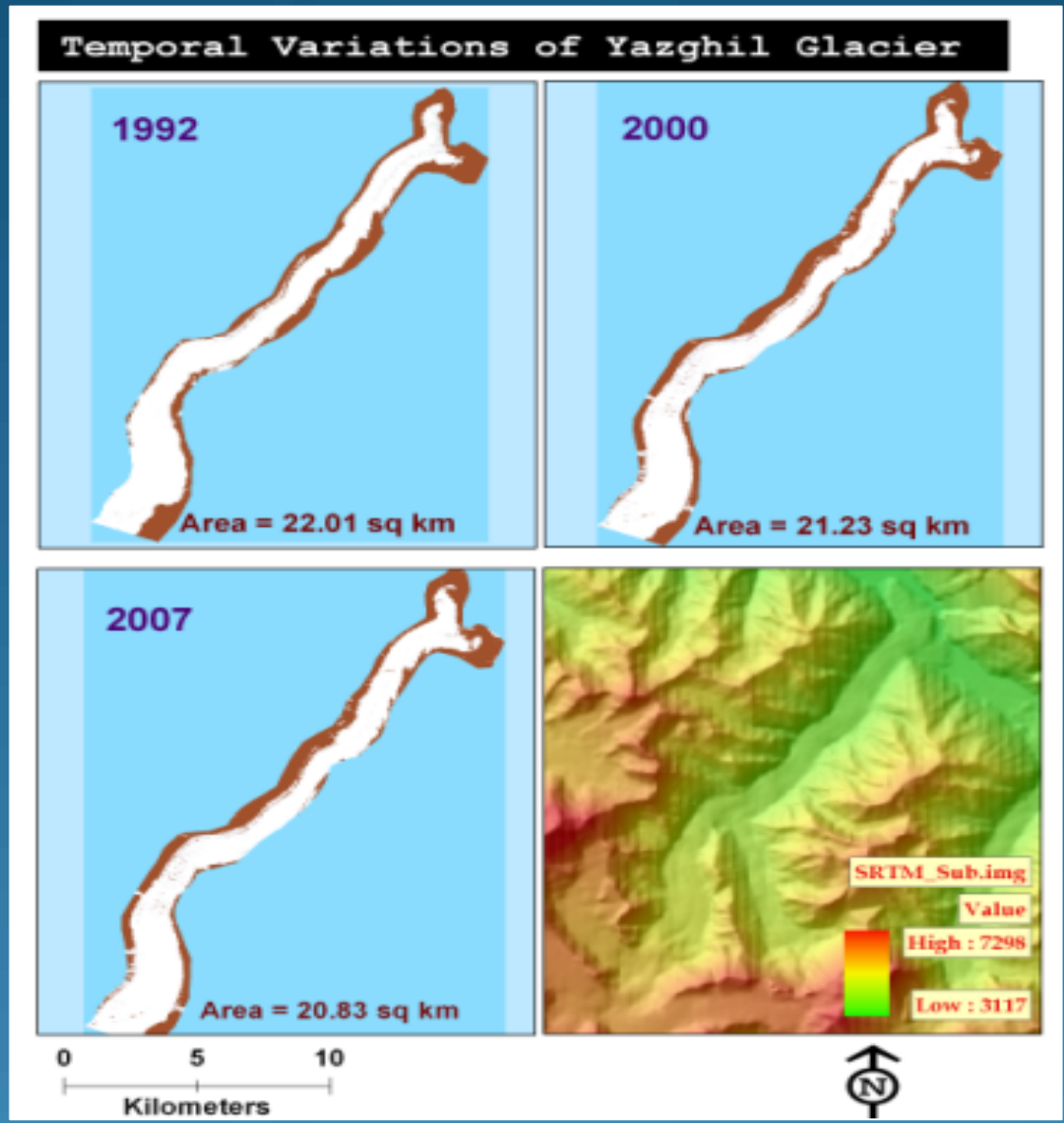
Yazghil Glacier



Jutmau Glacier

- Jutmau Glacier lies in the north of Hispar Glacier in Karakoram Range

- Temporal analysis of satellite images of Jutmau Glacier indicates that Jutmau glacier has lost glacial area of 6 sq km area during 1992 and 2007

Contd ……

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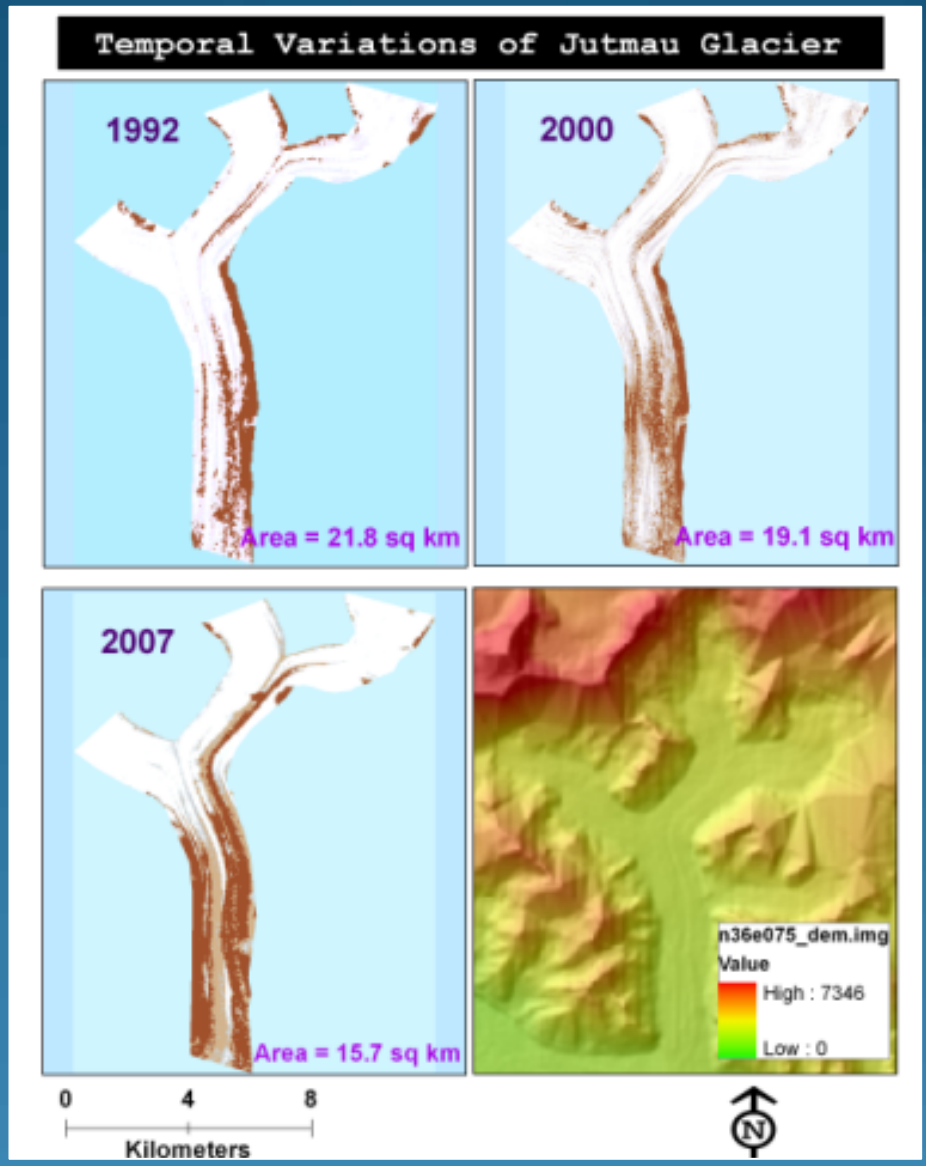
Jutmau Glacier



Snow Cover Mapping
using
MODIS and SPOT Images

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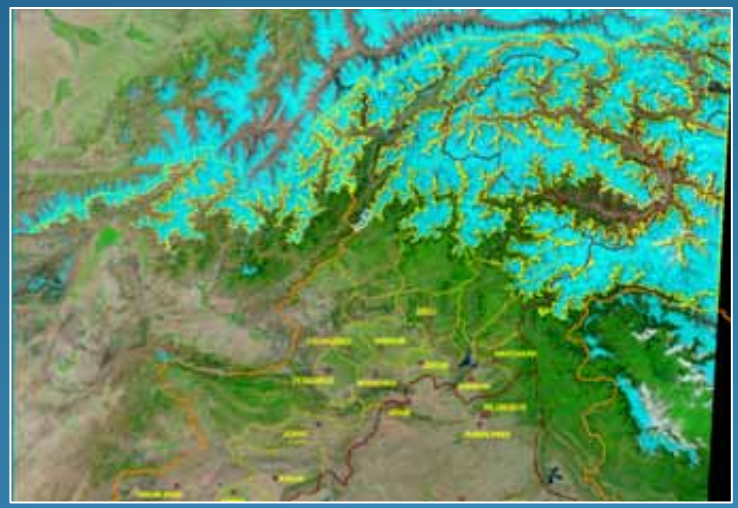
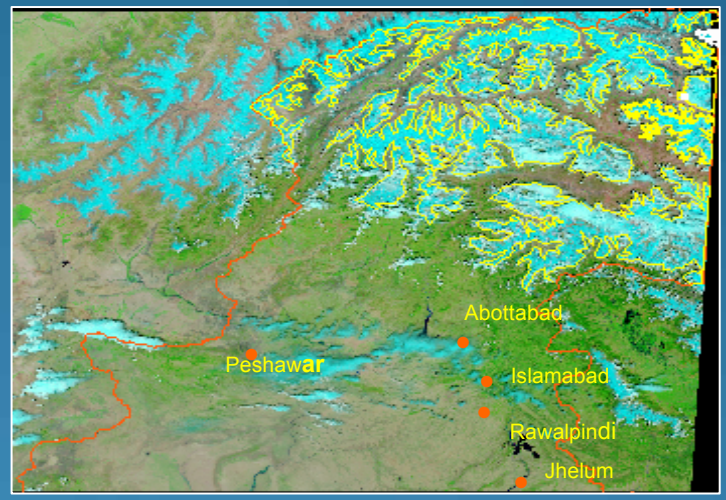
Quantitative analysis of temporary snow covered area in Northern area of Pakistan

10 May 2004, snow covered area is 57066 sq km

10 May 2005, snow covered area is 68420 sq km



10 May 2006, snow covered area is 59731 sq km



10 May 2007, snow covered area is 34820 sq km

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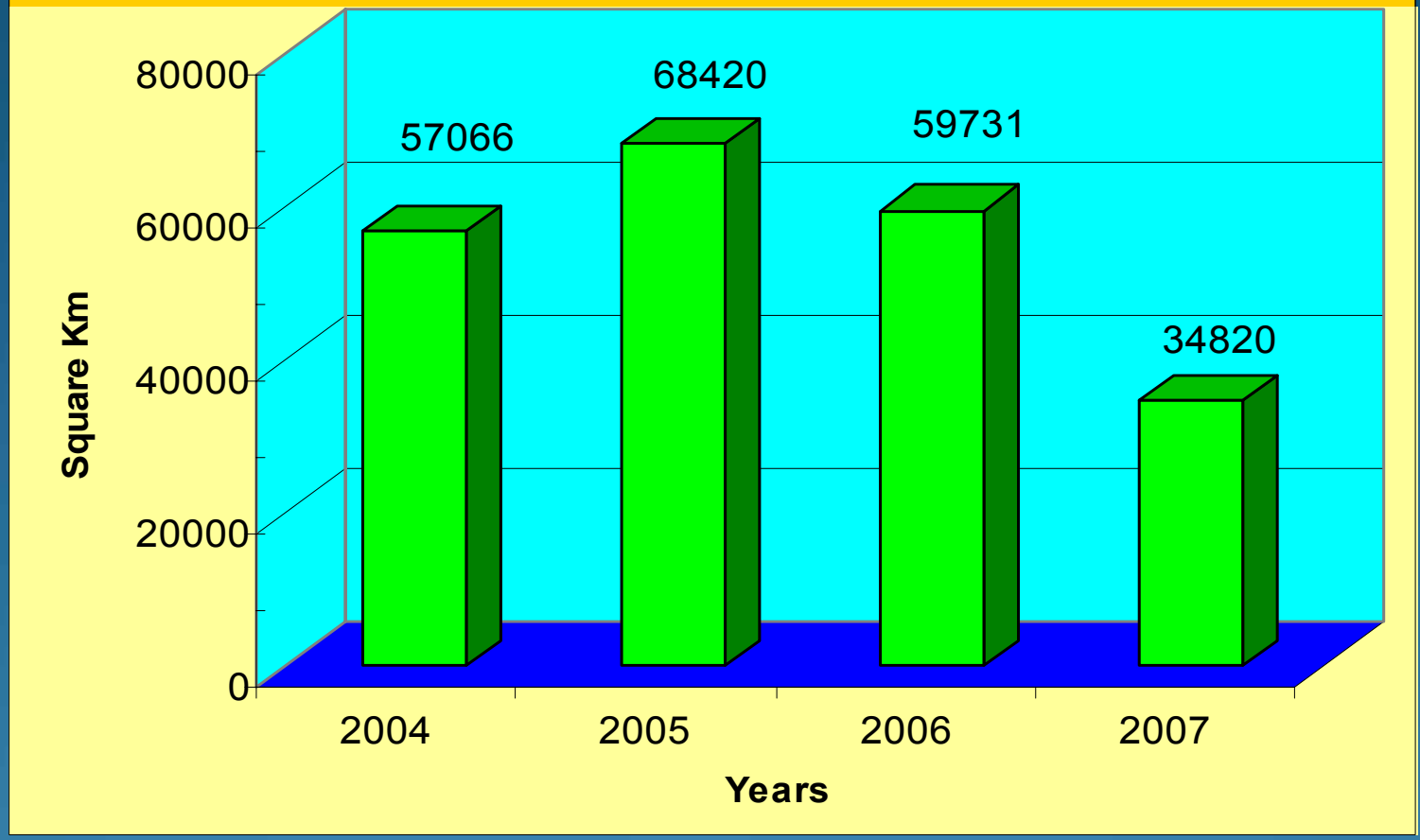
Snowcover Comparison For 10th May 2004, 2005, 2006 & 2007



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Snowmelt Due to Heat Wave

- Cold weather & heavy snowfall crippled Parts of Northern Pakistan & Afghanistan in Jan and Feb 2005
- The Region Experienced Heat Wave in June 2005(temperature was 40 to 50˚C)
- Snow-melt in the Region caused flood in Rive Swat, Kabul & ultimately River Indus

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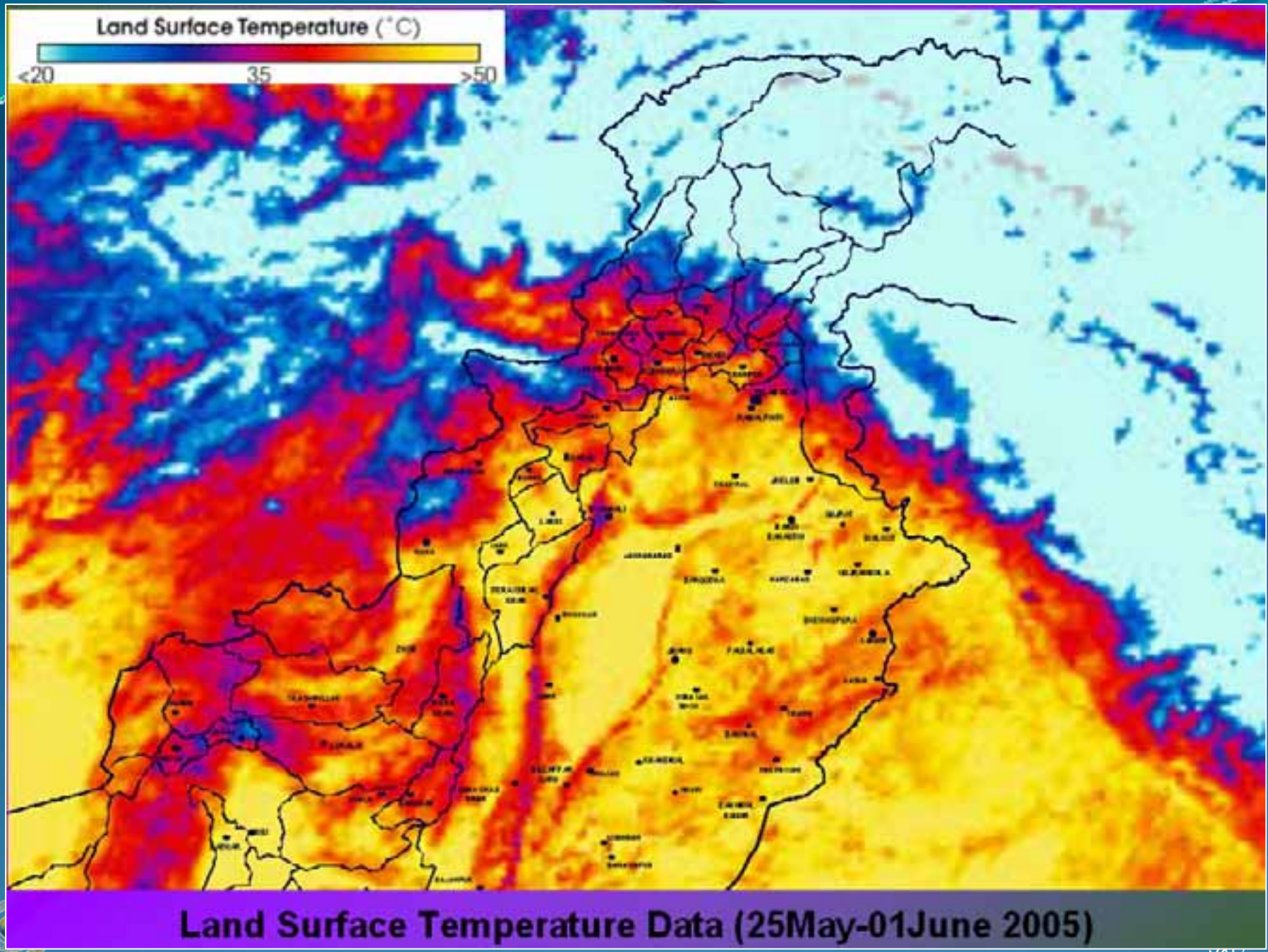

Land Surface Temperature Data (25May-01June 2005)

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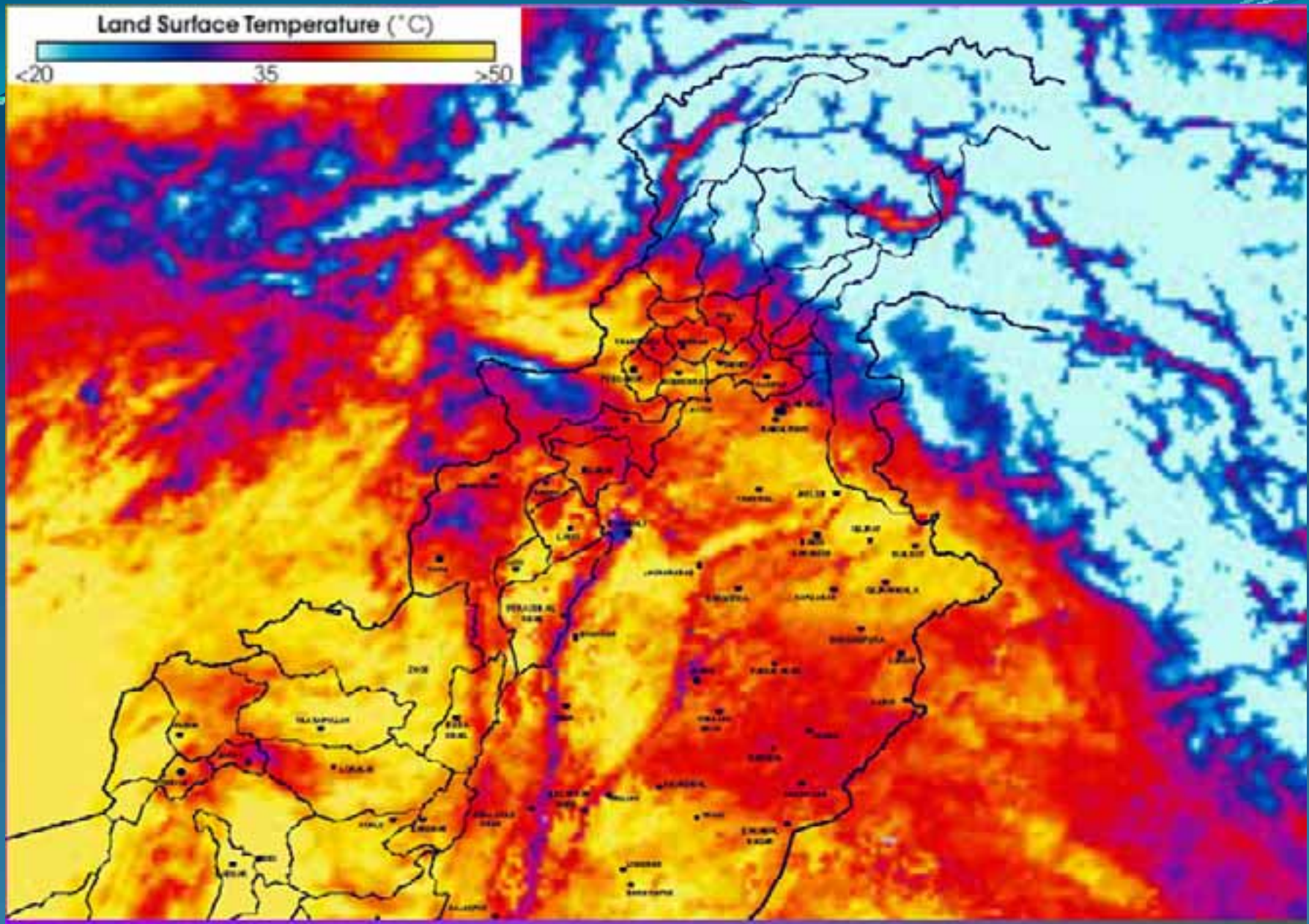

Land Surface Temperature Data (25May-01June 2004)

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SPOT Image Showing View of Pakistan Glacier

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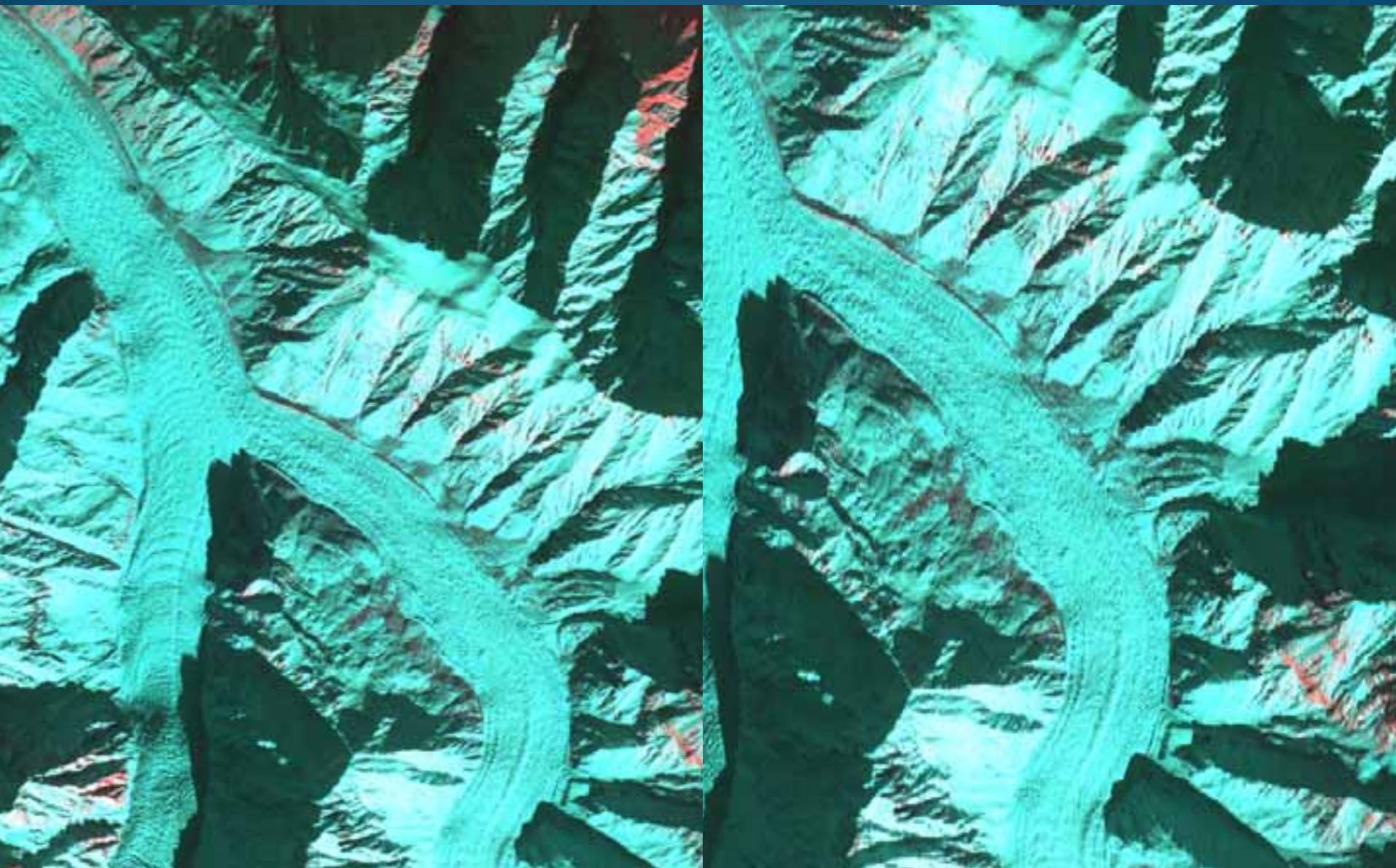
SPOT Image Showing View of Pakistan Glacier



Conclusion

- 20th century was a period of dramatic glacier retreat
- In the last 25 years +0.3°C warming caused temperatures rise
- Receding and wasting glaciers are signs of global climate change
- Due to glacier-melt there could be less amount of melt-water to sustain our agriculture and industrial activities

Contd……

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- Water tables would continue to fall and the gross per capita water availability would decline
- Pakistan's agriculture, consequently economy that depends mainly on water from glacier melt would be severely affected
- It is alarming that 40 percent of humanity living in South Asia and China could be living with little drinking water within 50 years

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Thank You