CLIMATE CHANGE SCIENCE -

Indian programmes

AVM (Dr.) Ajit Tyagi

Director General of Meteorology

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INDIA METEOROLOGICAL DEPARTMENT

CLIMATE CHANGE SCIENCE

Climate Monitoring

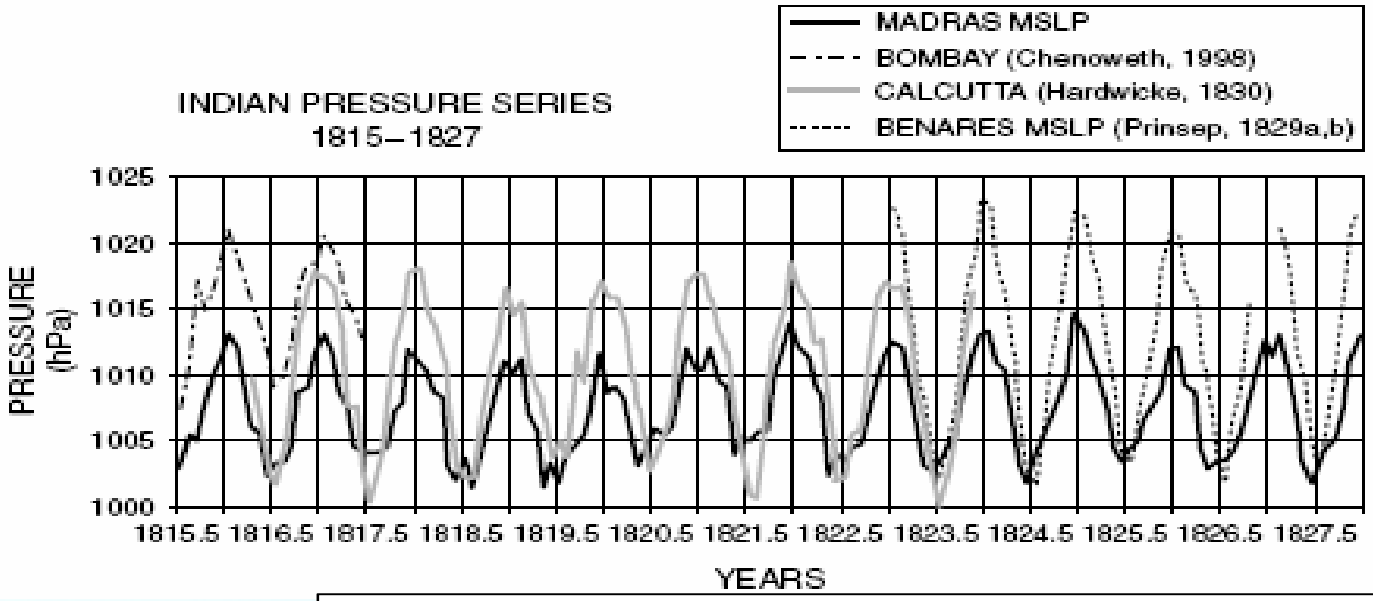
- Climate Change Detection

Climate Modelling

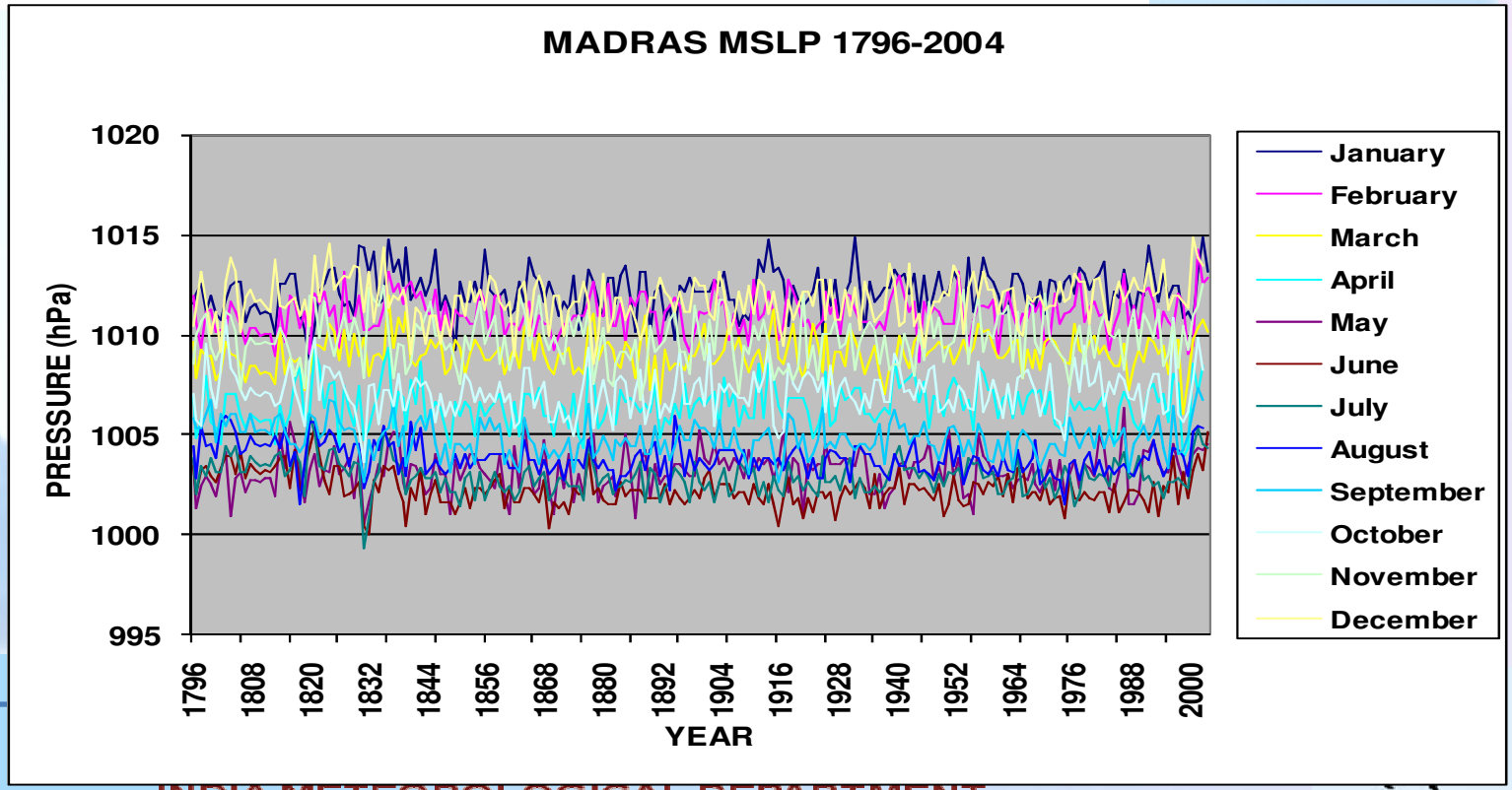
- Climate Prediction

History of Weather & Climate Services In India

- India Meteorological Department (IMD) set up in 1875
- The possibilities of climate change as a result of massive land use changes viz. deforestation and agriculture, was first recognized in IMD as early as in 1885.



More than 100 stations are operative since mid 19th Century



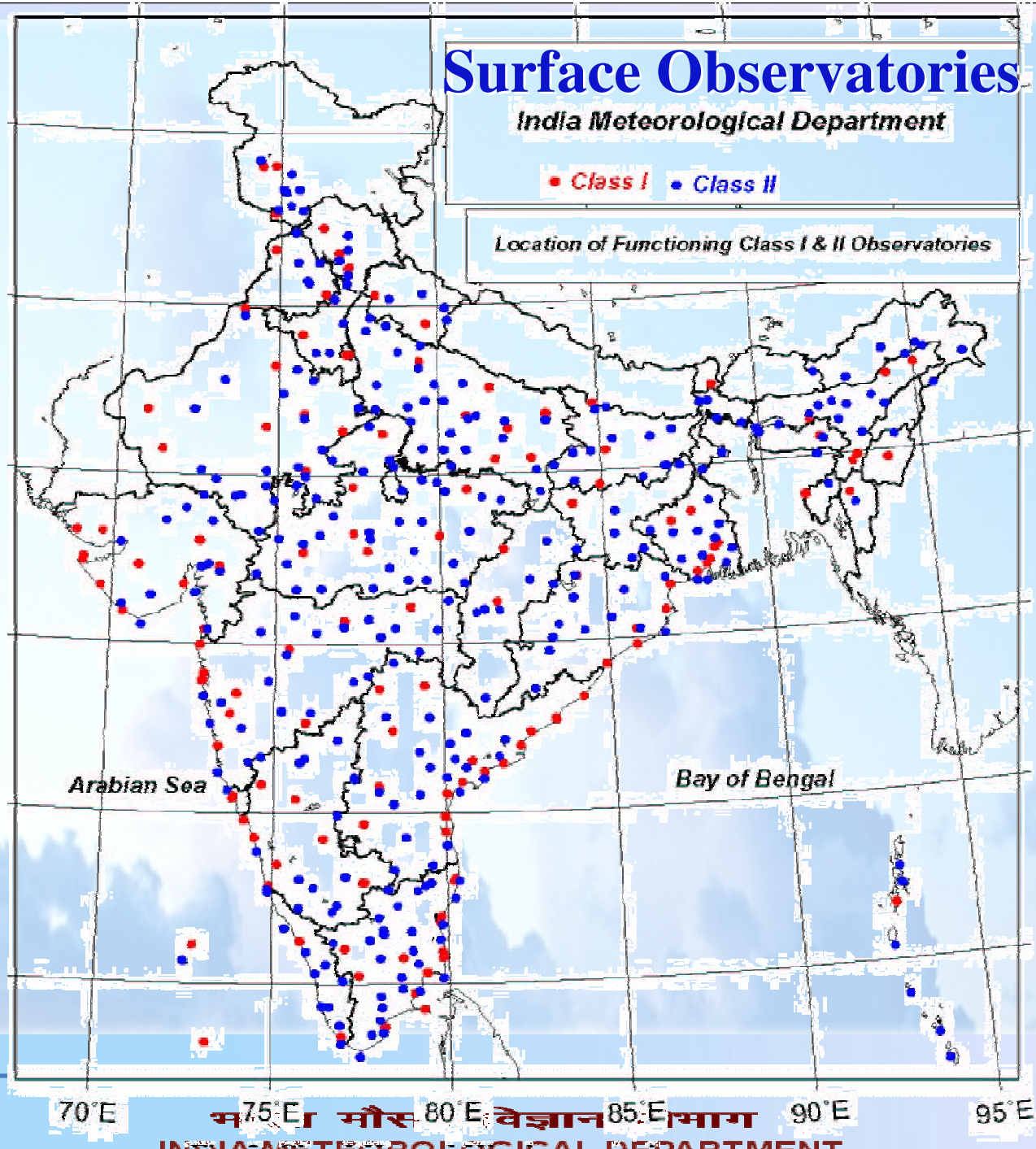
❖Need forObservations

❖Inherent uncertainties in our understanding of Climate Change give rise to diverse perceptions of its impact in different Sectors.

❖The need of the hour is to build adequate observational infrastructure and predictive capability

Observing Systems

Surface Observatories



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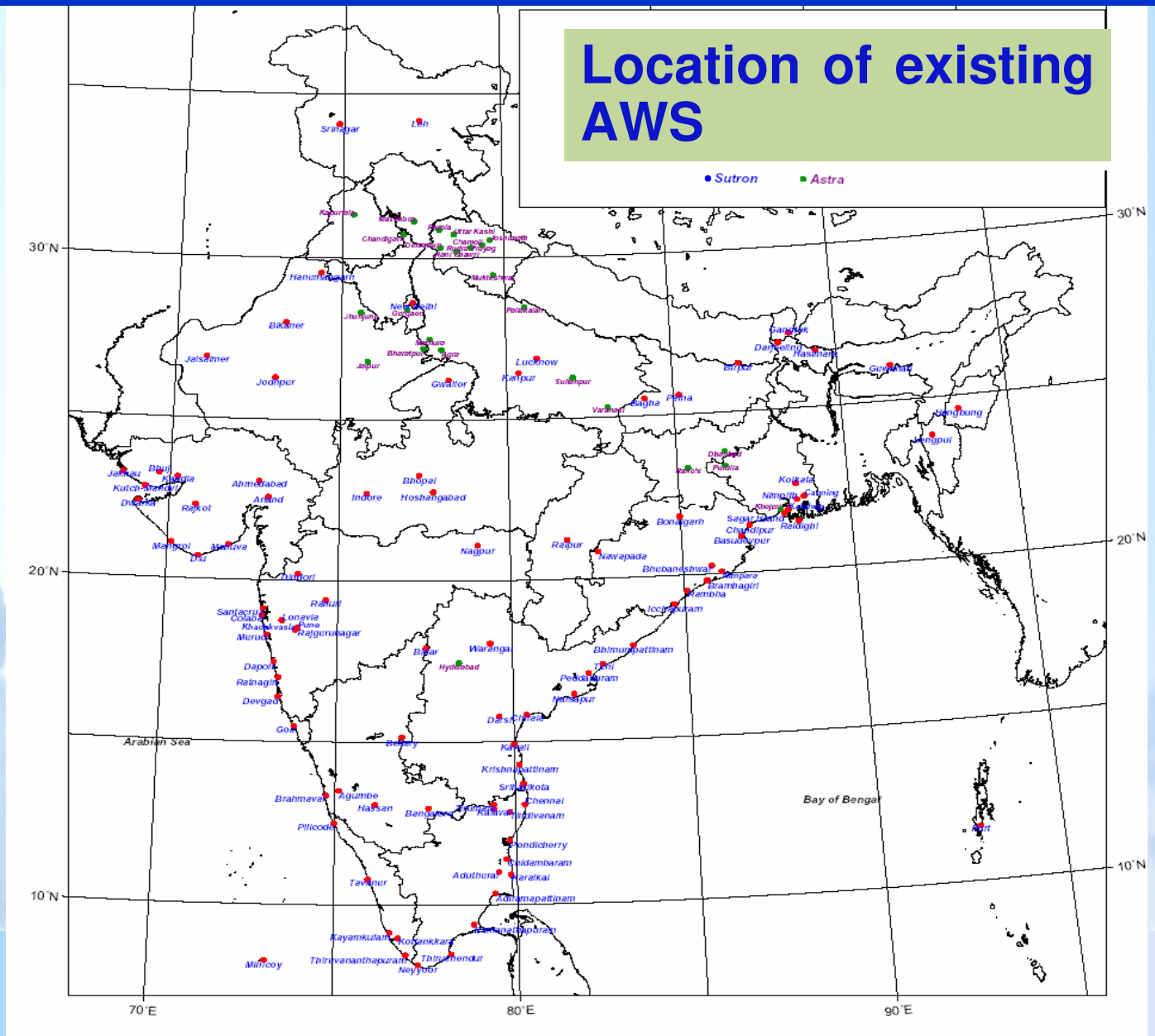
Automatic Weather Station



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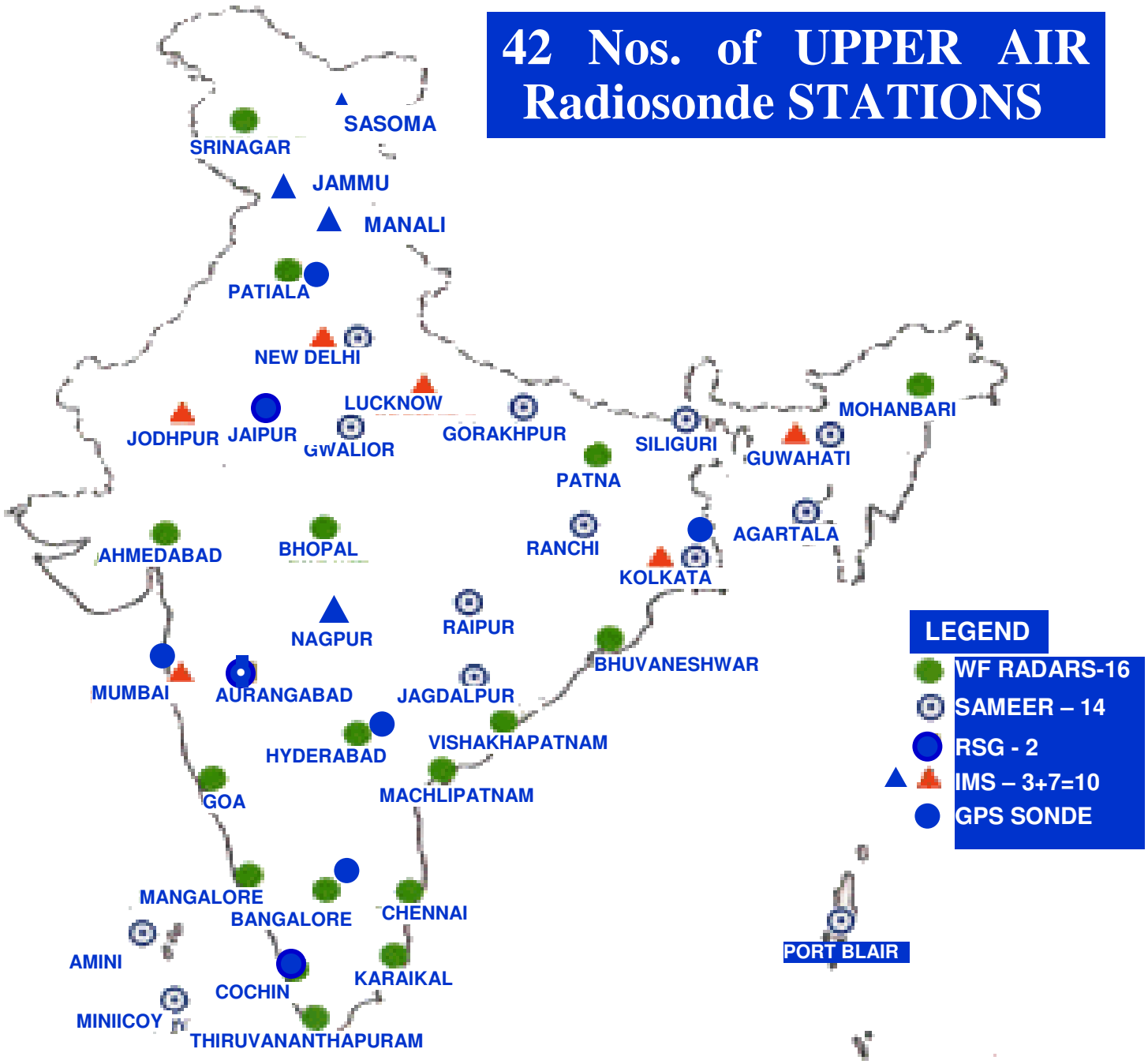
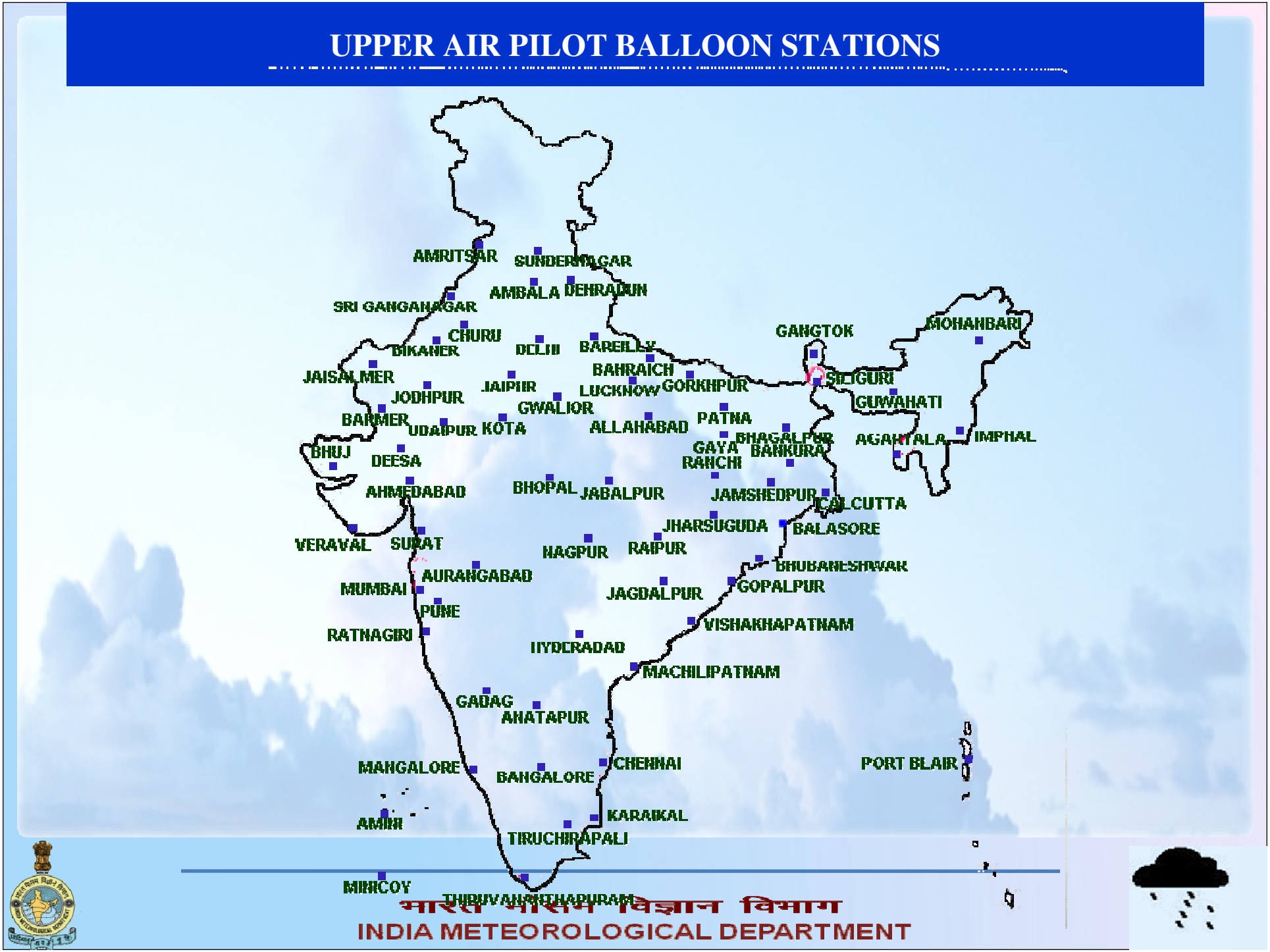
42 Nos. of UPPER AIR Radiosonde STATIONS



UPPER AIR PILOT BALLOON STATIONS



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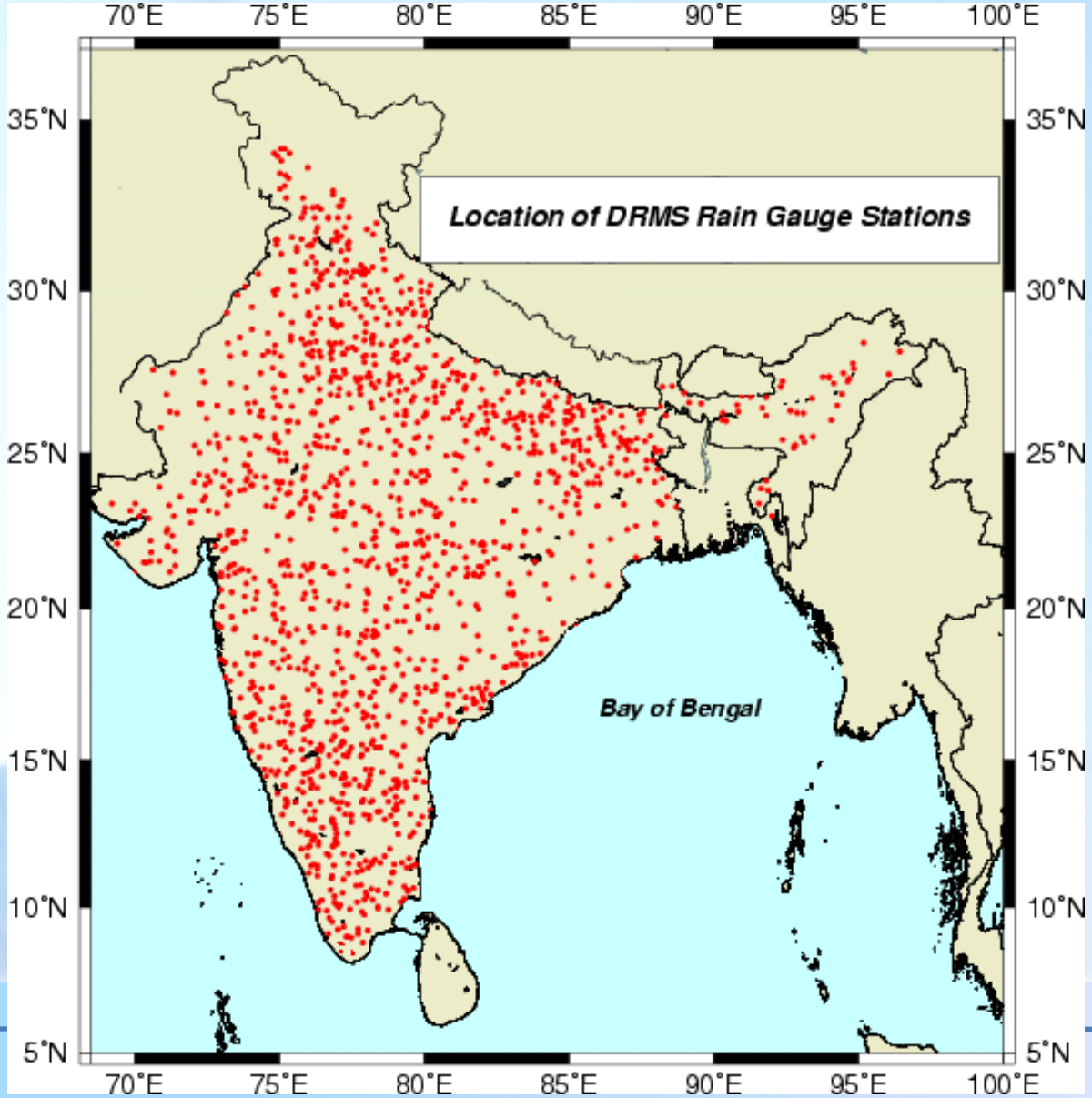
Rainfall Network: 2500 stations

District wise Rainfall Monitoring Scheme (DRMS)



Supplementary Networks

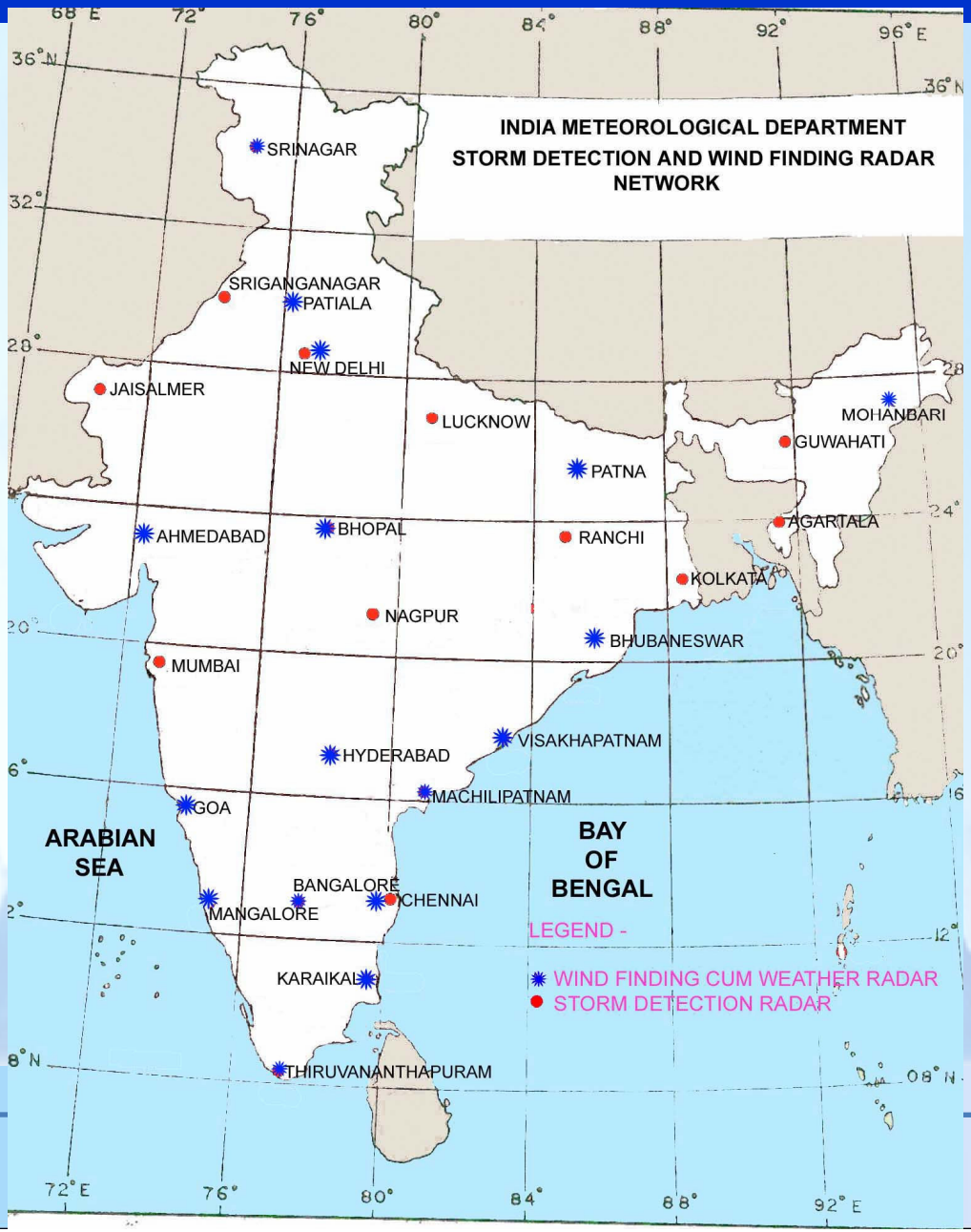
Aviation

Water Resources

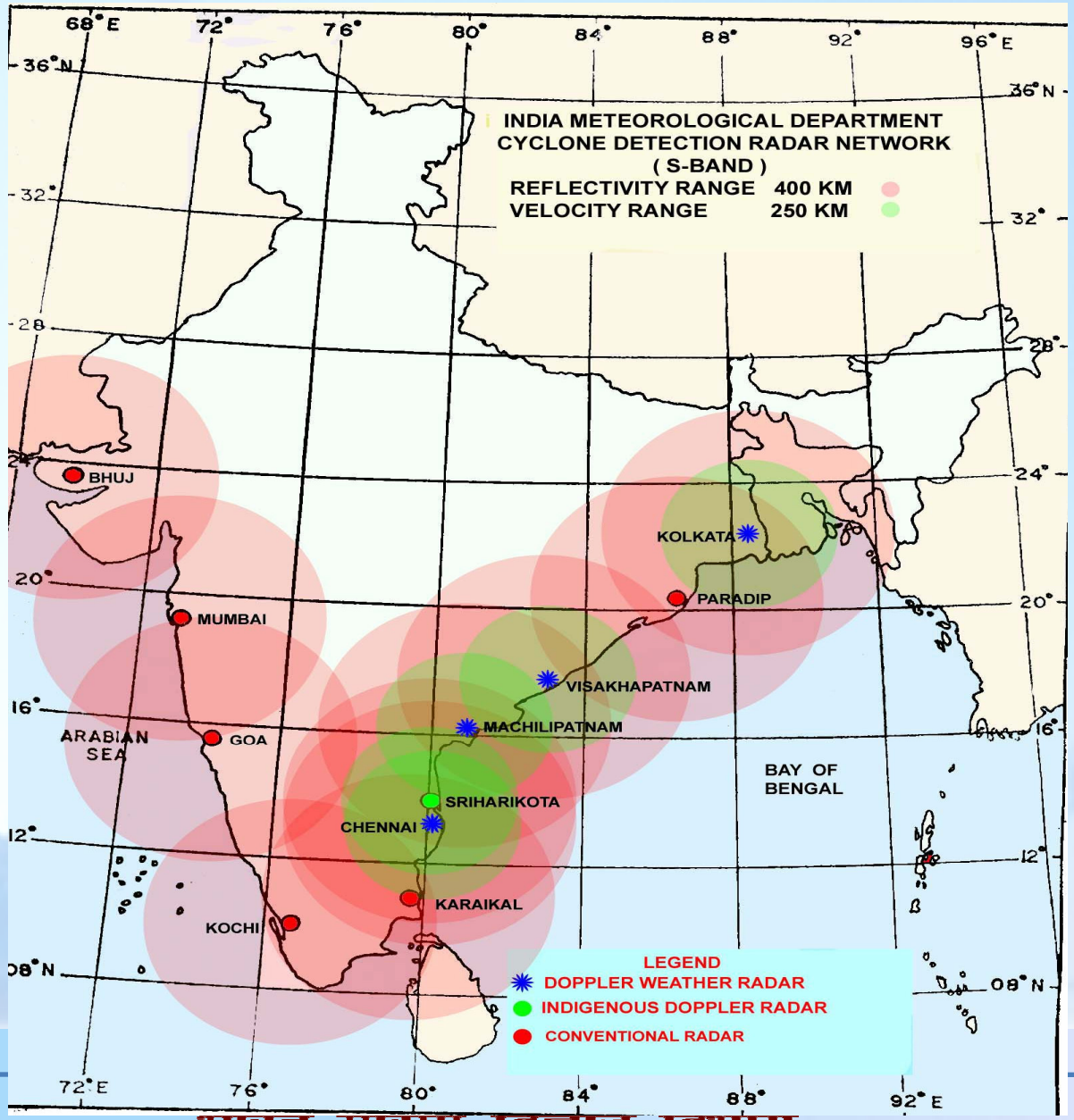
Agriculture:

- Agro meteorological Observatories
- Soil Moisture Recording Stations
- Dew-fall Recording Stations
- Evapotranspiration Stations

Wind Finding and STORM detection RADARS



Cyclone Detection Radar Network



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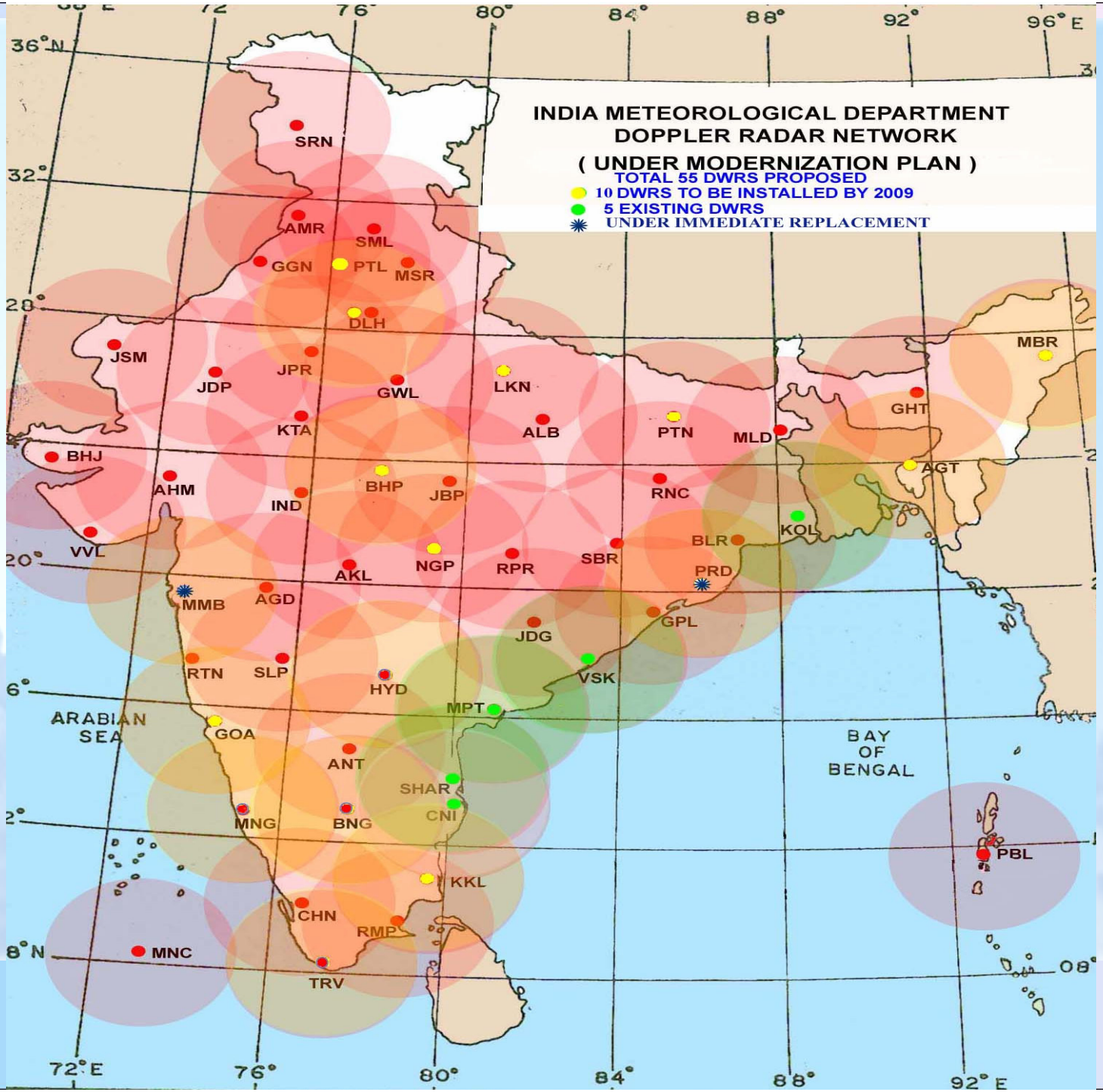

INDIA METEOROLOGICAL DEPARTMENT
DOPPLER RADAR NETWORK
(UNDER MODERNIZATION PLAN)
TOTAL 55 DWRS PROPOSED
10 DWRS TO BE INSTALLED BY 2009
5 EXISTING DWRS
UNDER IMMEDIATE REPLACEMENT
SRN
AMR
SML
GGN
PTL
MSR
DLH
JSM
JPR
JDP
GWL
LKN
MBR
GHT
KTA
ALB
PTN
MLD
BHJ
AGT
AHM
BHP
JBP
RNC
IND
KOL
VVL
BLR
SBR
AKL
NGP
RPR
PRD
MMB
AGD
GPL
JDG
RTN
SLP
VSK
HYD
MPT
ARABIAN SEA
GOA
BAY OF BENGAL
ANT
SHAR
CNI
MNG
BNG
PBL
KKL
CHN
RMP
MNC
TRV
36°N
32°
28°
20°
8°N
72°E
76°
80°
84°
88°
92°
96° E

INSAT Series of Meteorological Satellites

1. **KALPANA-1**

   main operational Satellite

2. **INSAT-3A**

   standby satellite

3. **INSAT-3C**

   used for Dissemination System

4. **Future Satellites**

   INSAT 3D, Meghatropiques, Oceansat

Existing Environmental Network

Ozone Stations

Column Ozone (1957)	6
Vertical Ozone Profile (1971)	3
Surface Ozone (1971)	5

Global Atmosphere Watch (1973)

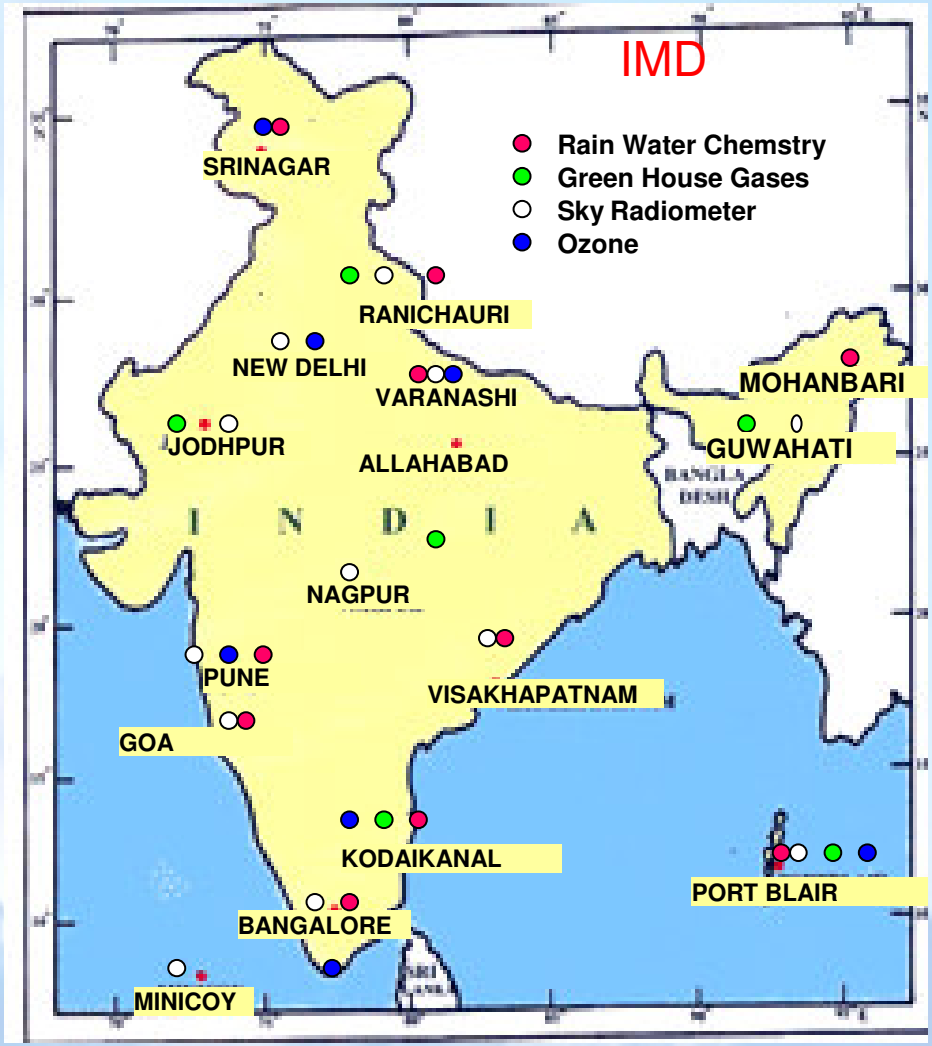
Precipitation Chemistry	10
Atmospheric attenuation	10
Aerosol Chemical Characterisation (1982)	2

Radiation Stations (1952)

Pyranometers	45
Pyrgeometers	10
Total radiometers	10
Pyrheliometers	10
UV-A, B (2007)	45

New Thrust areas in Environmental Monitoring

- **Greenhouse Gases & Aerosols – Radiative Forcing**
- **PPT Chemistry - Acid rain threats**
- **Ozone - Health Impacts & crop damage**
- **Environmental Impact Assessment – siting of industries, regulation of emissions**
- **Air Quality Forecasting**



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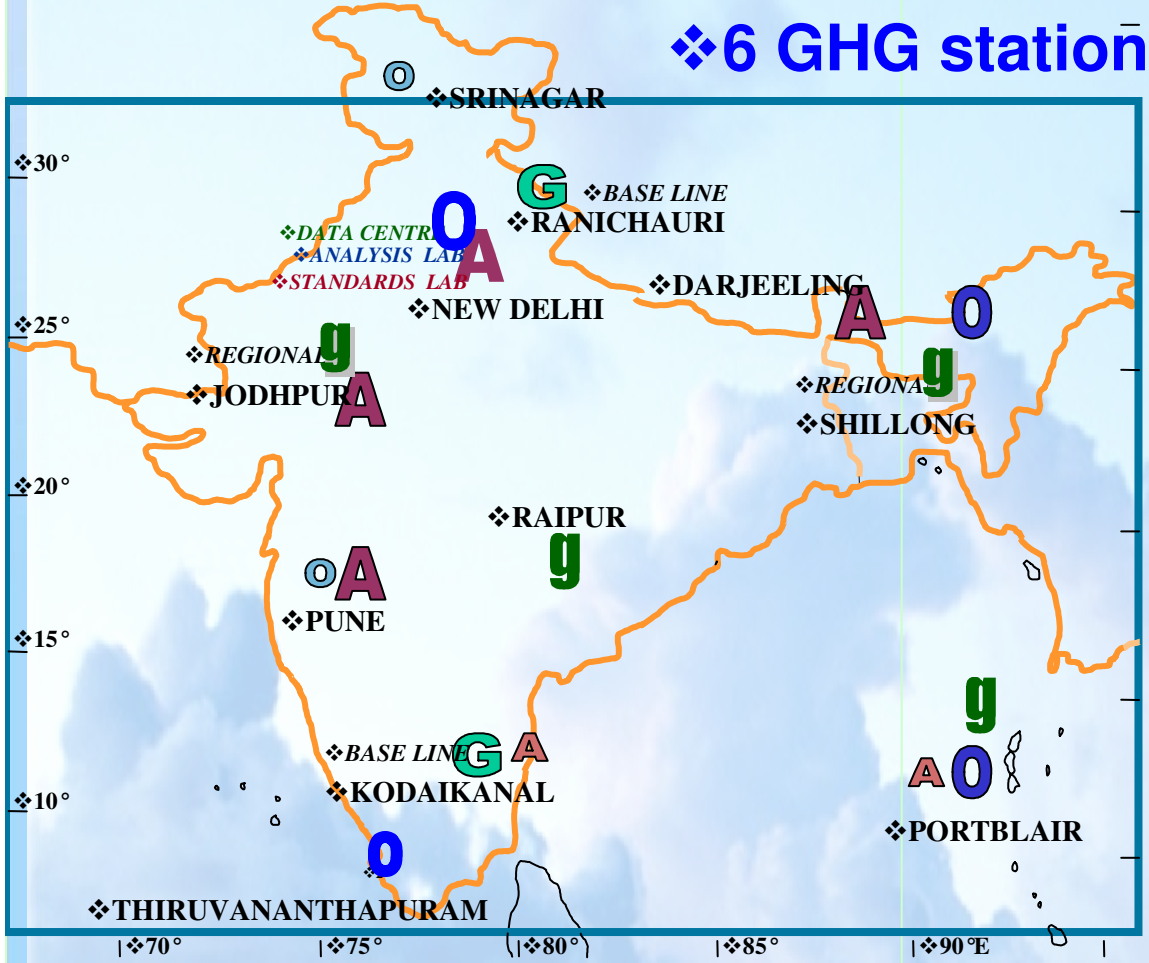
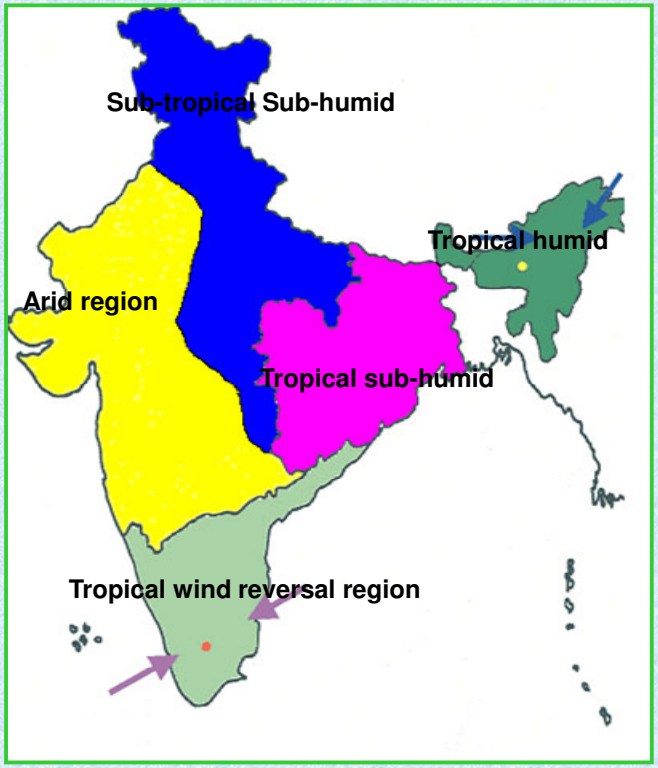
❖CLIMATE MONITORING NETWORK

❖6 GHG stations



CREM-DOMAIN



❖AEROSOL ❖OZONE ❖GHG EMISSION ❖FLUX

❖GREENHOUSE GAS (Baseline)

❖GREENHOUSE GAS (Grab sampling)

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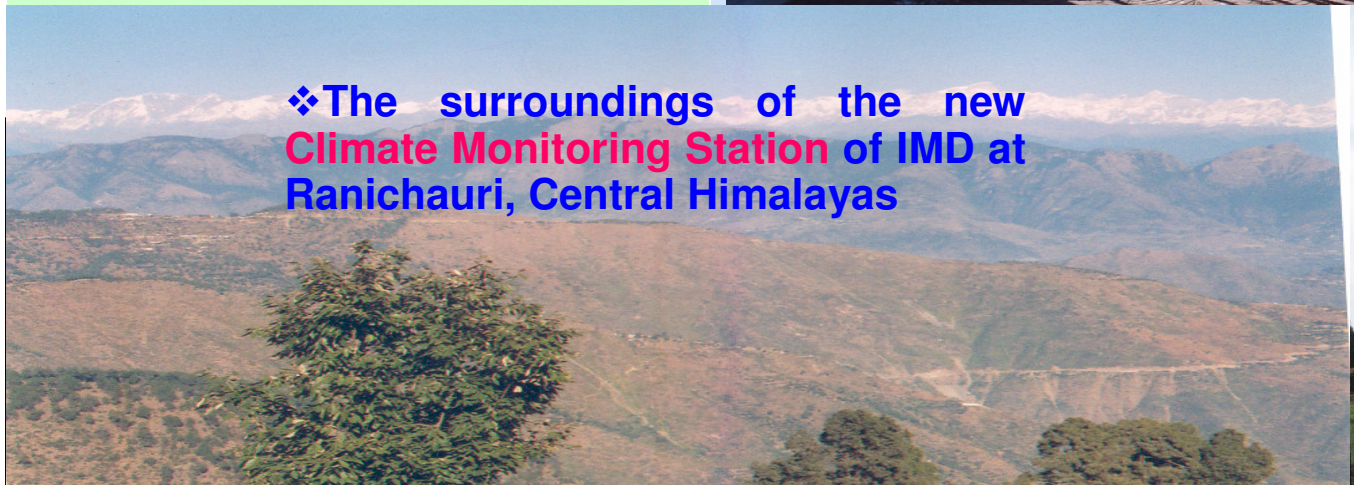
❖RANICHAURI OBSERVATORY

❖(2000m)

- **Greenhouse Gases**
- **Aerosols- Radiative properties**
- **Air Quality-SO_2, NOx, pH**
- **Meteorology**



❖The surroundings of the new Climate Monitoring Station of IMD at Ranichauri, Central Himalayas

CLIMATE CHANGE MONITORING NEEDS

- Detection and attribution
- Understanding regionally important climate issues – monsoon system, aerosols, land-surface interactions, ice-albedo, water vapor, cloud feedback processes
- Assessments of Vulnerability & Impacts
- Inputs for adaptation strategies
- Mitigation actions eg. renewable energy potential, building design etc

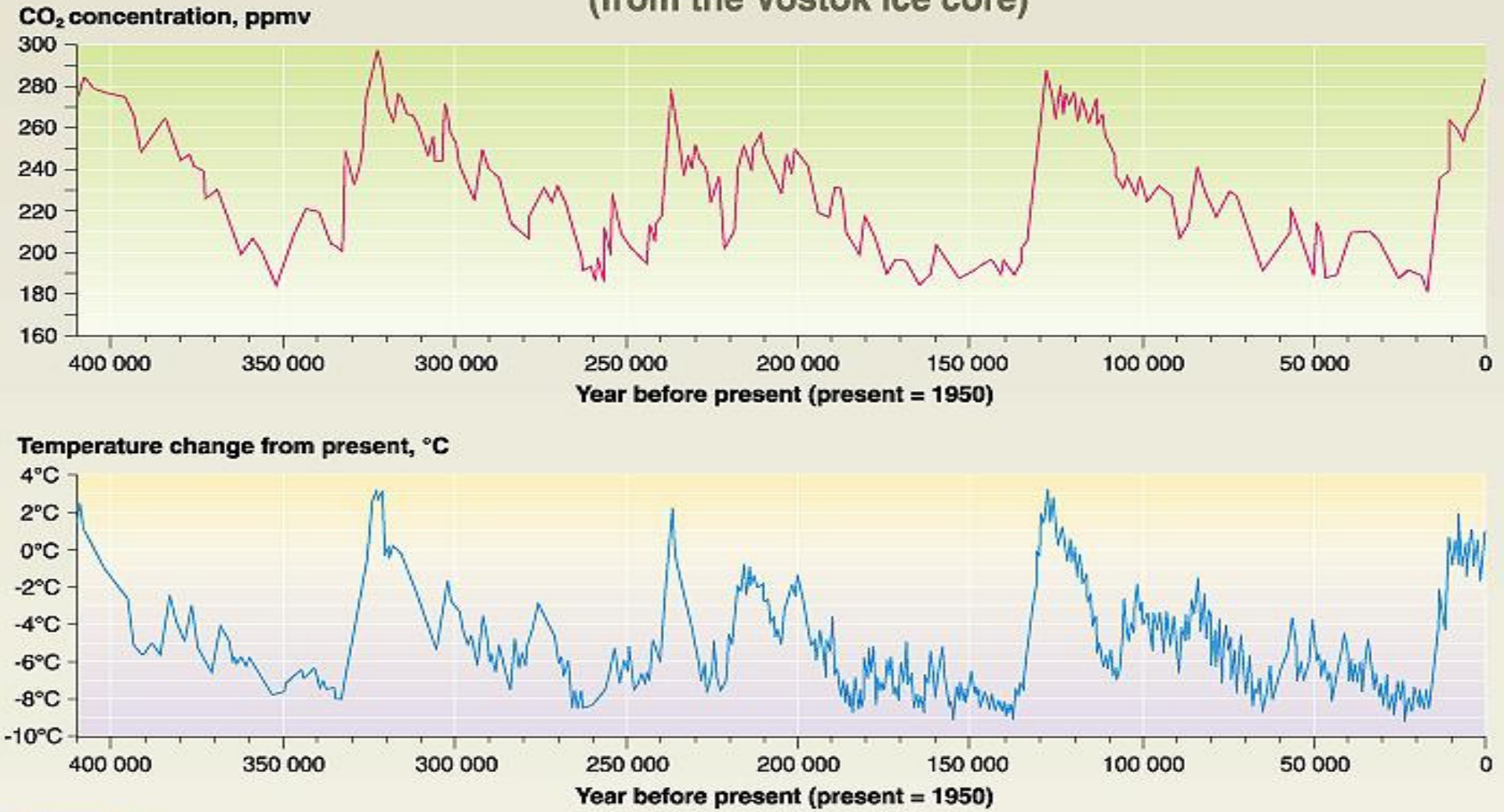
DETECTION

OF

CLIMATE

CHANGE

Temperature and CO_2 concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)



GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

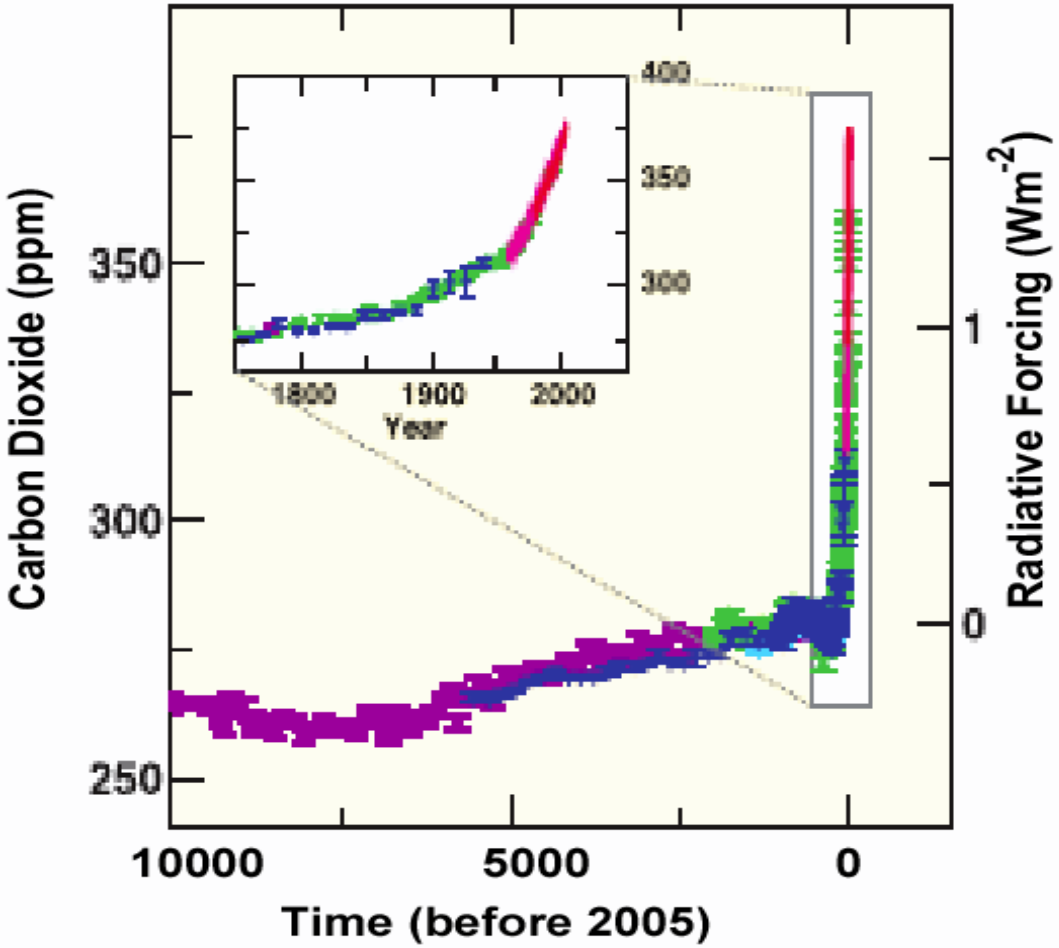
Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

Human contribution to climate change

Global atmospheric concentrations of greenhouse gases **increased markedly as result of human activities**

In 2005 concentration of CO_2 **exceeded by far the natural range** over the last 650,000 years

Changes in CO_2 from ice core and modern data



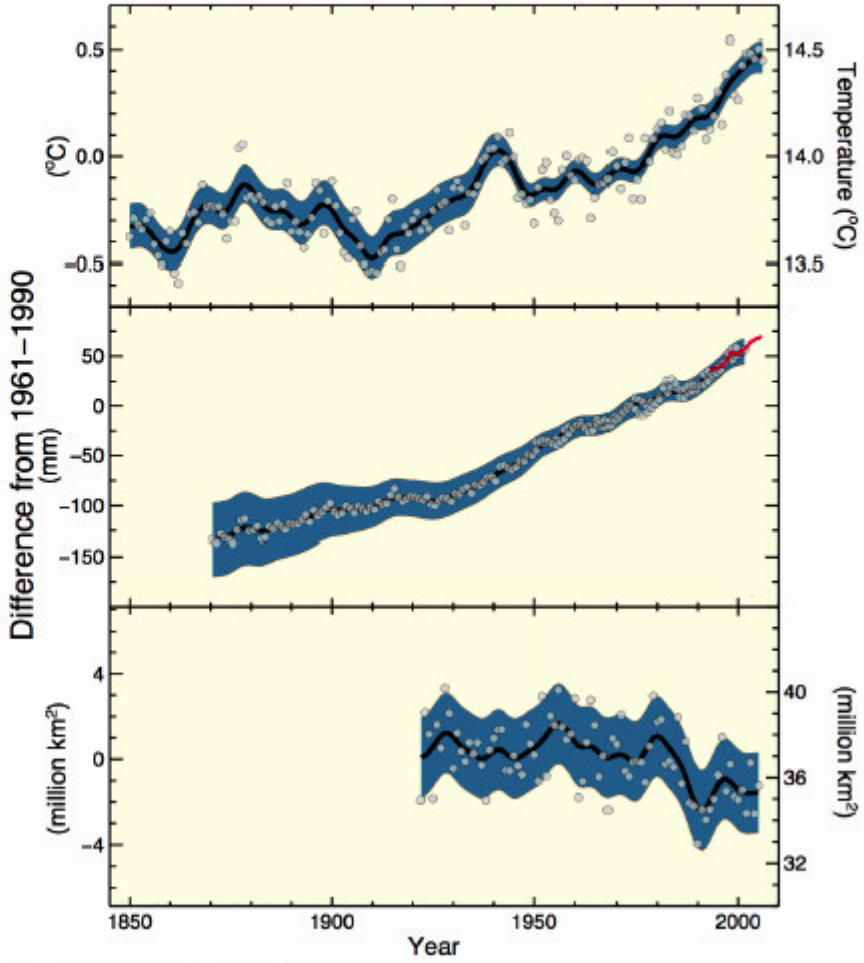
Direct observations of recent climate change

Global average temperature

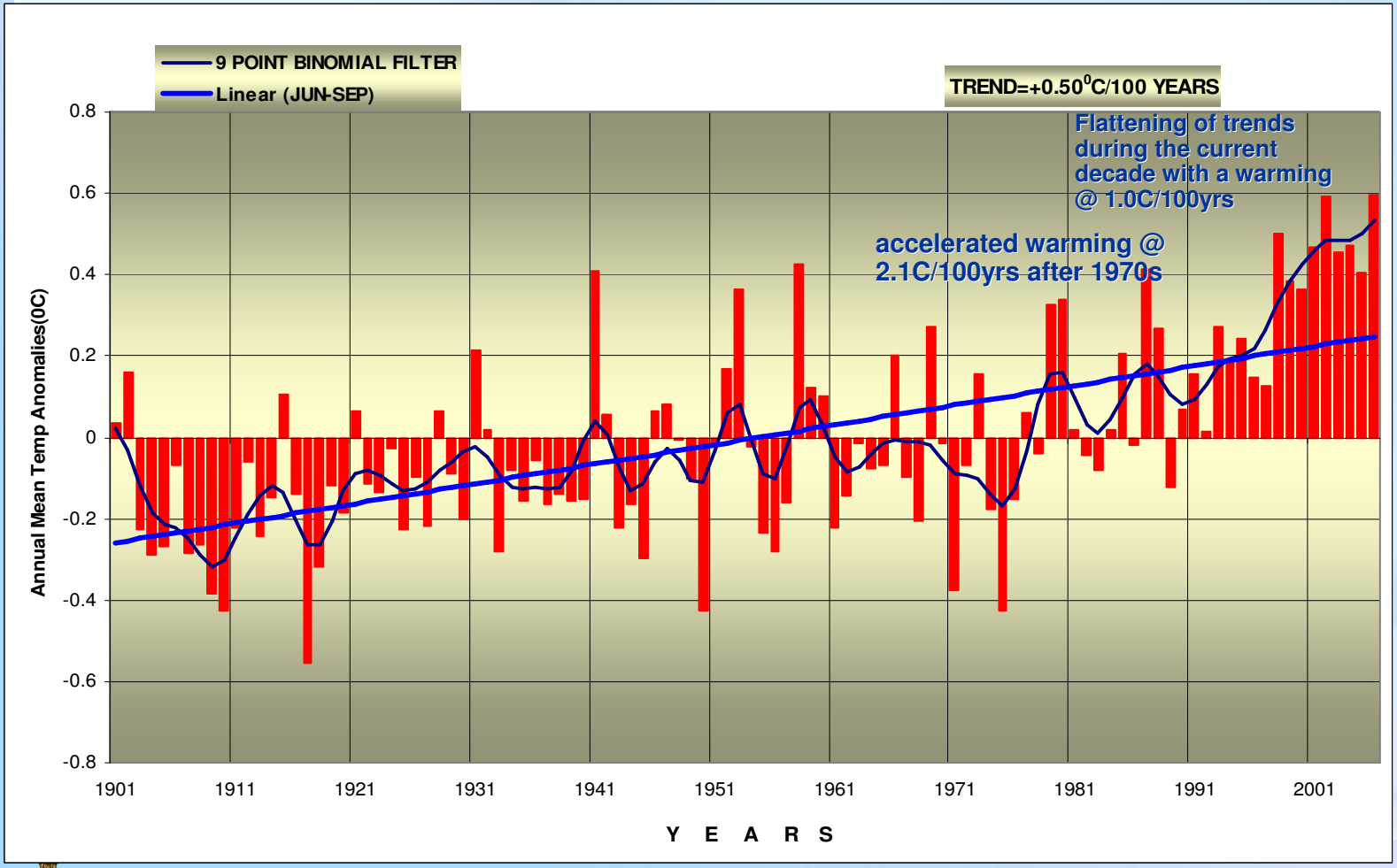
Global average sea level

Northern hemisphere snow cover

Changes in temperature, sea level and northern hemisphere snow cover



ANNUAL MEAN TEMPERATURE ANOMALIES OVER INDIA (1901-2008)



Seasonal Anomalies

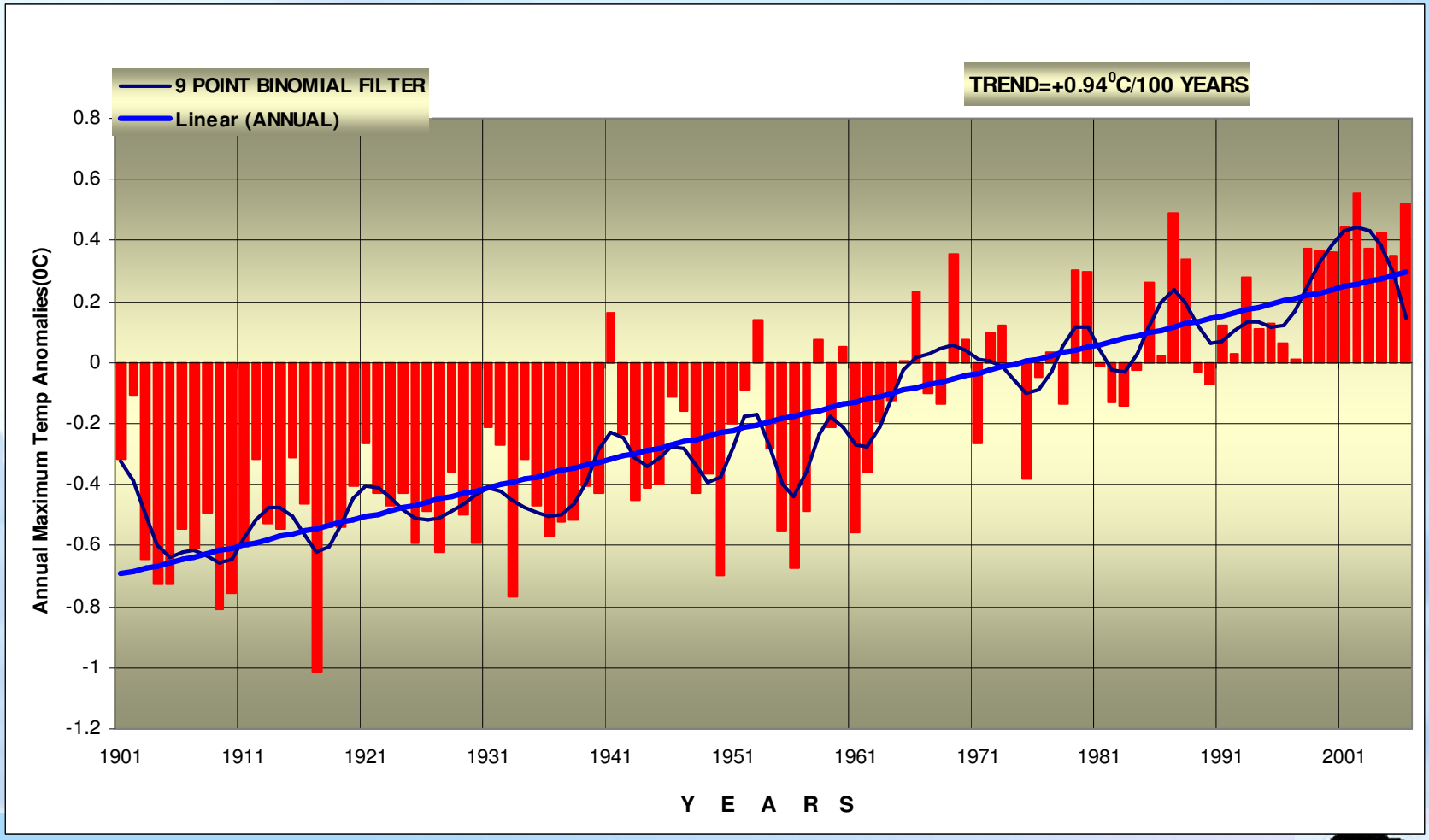
Post-monsoon - 0.7°C

Winter - 0.67°C

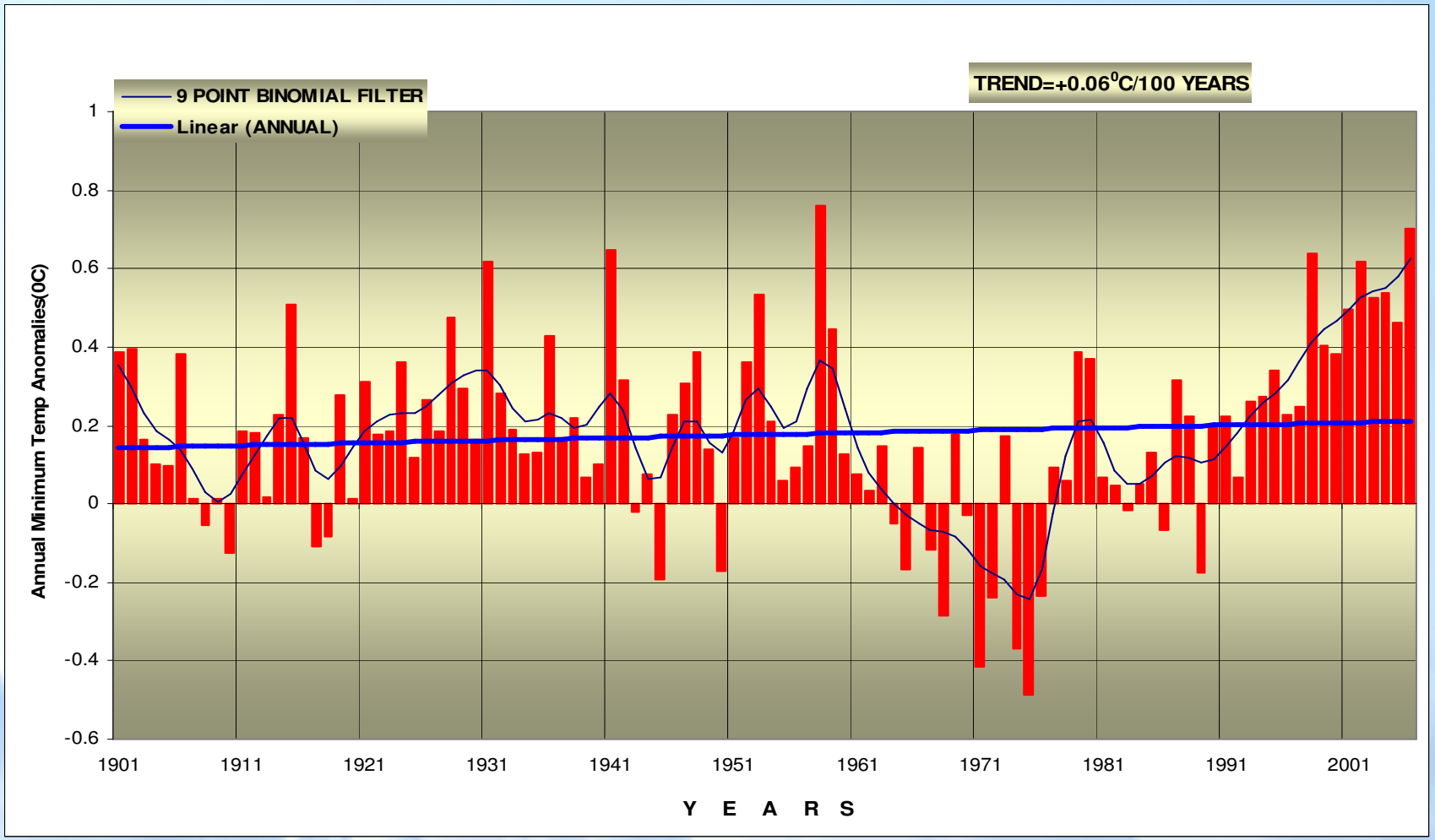
Pre-monsoon season- 0.50°C

Monsoon season- 0.30°C

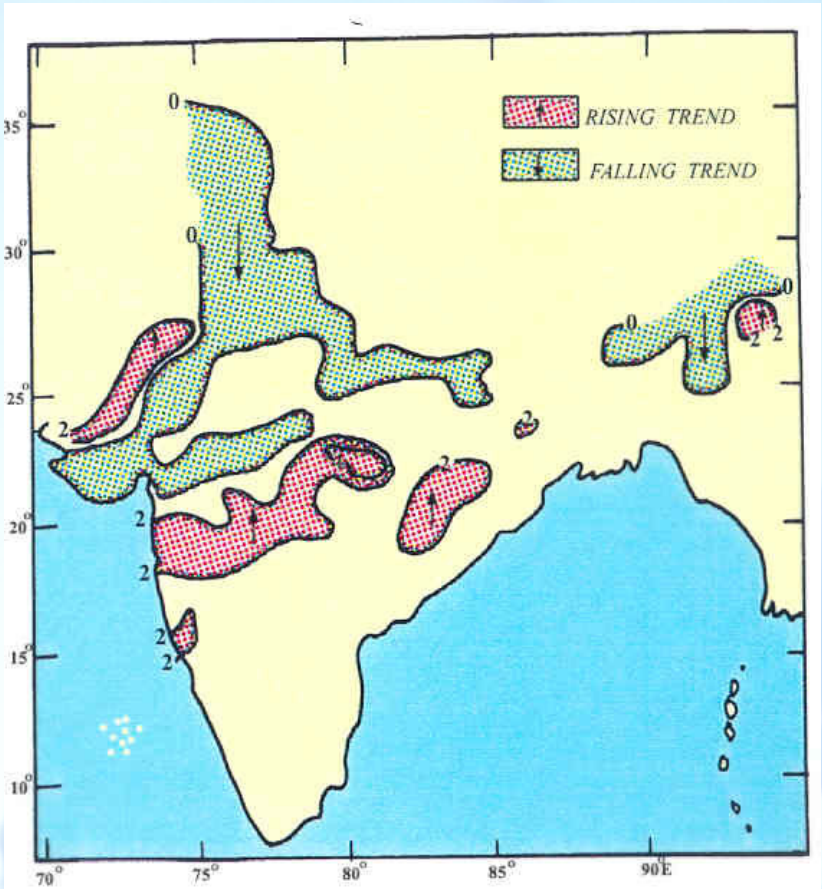
ANNUAL MAXIMUM TEMPERATURE ANOMALIES (1901-2008)



ANNUAL MINIMUM TEMPERATURE ANOMALIES (1901-2008)

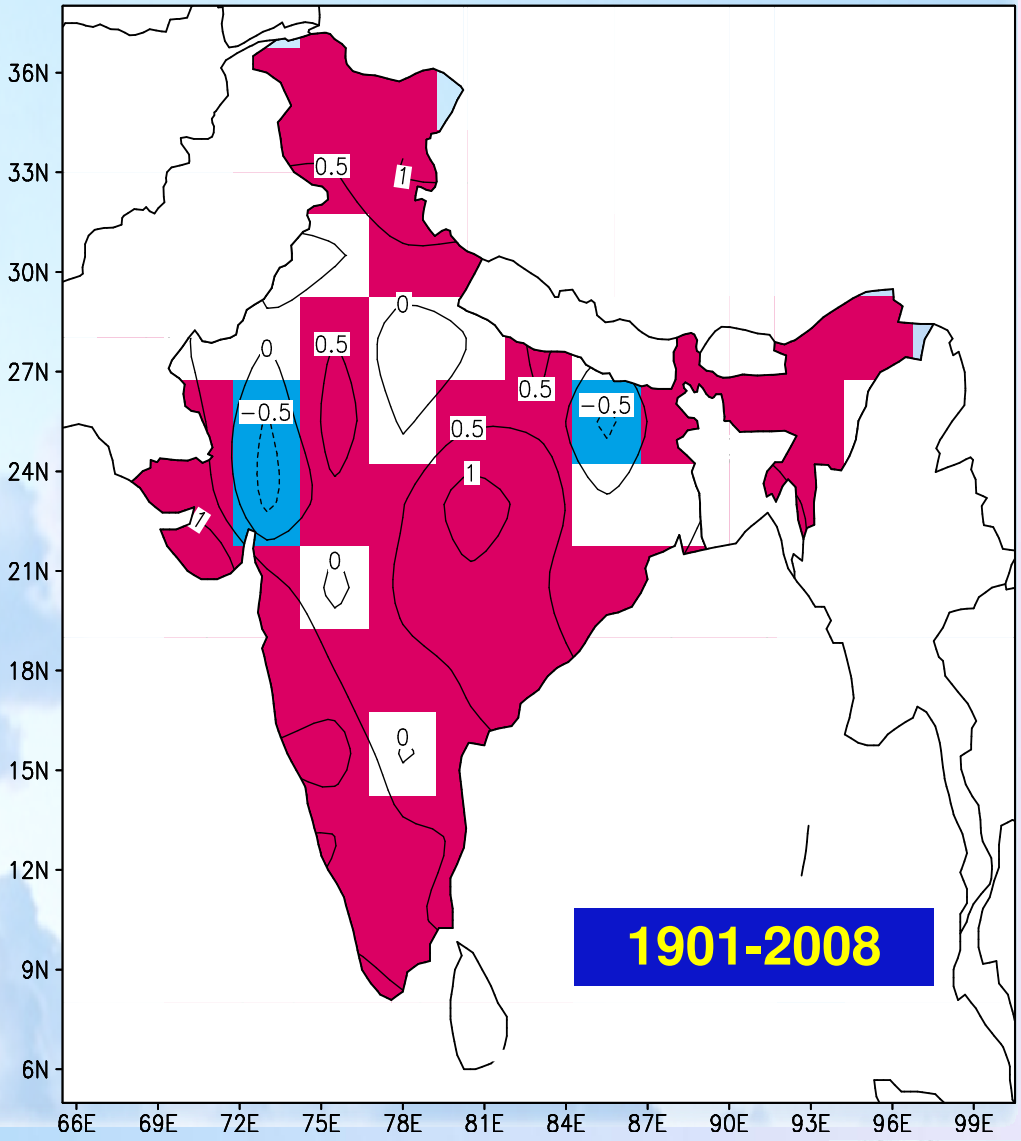


Spatial Variation of mean annual Temperature Changes in last century



1901-92

SPATIAL VARIATION IN THE LINEAR TREND OF AIR TEMPERATURE (IN °C/100 YEARS) OVER THE COUNTRY



1901-2008

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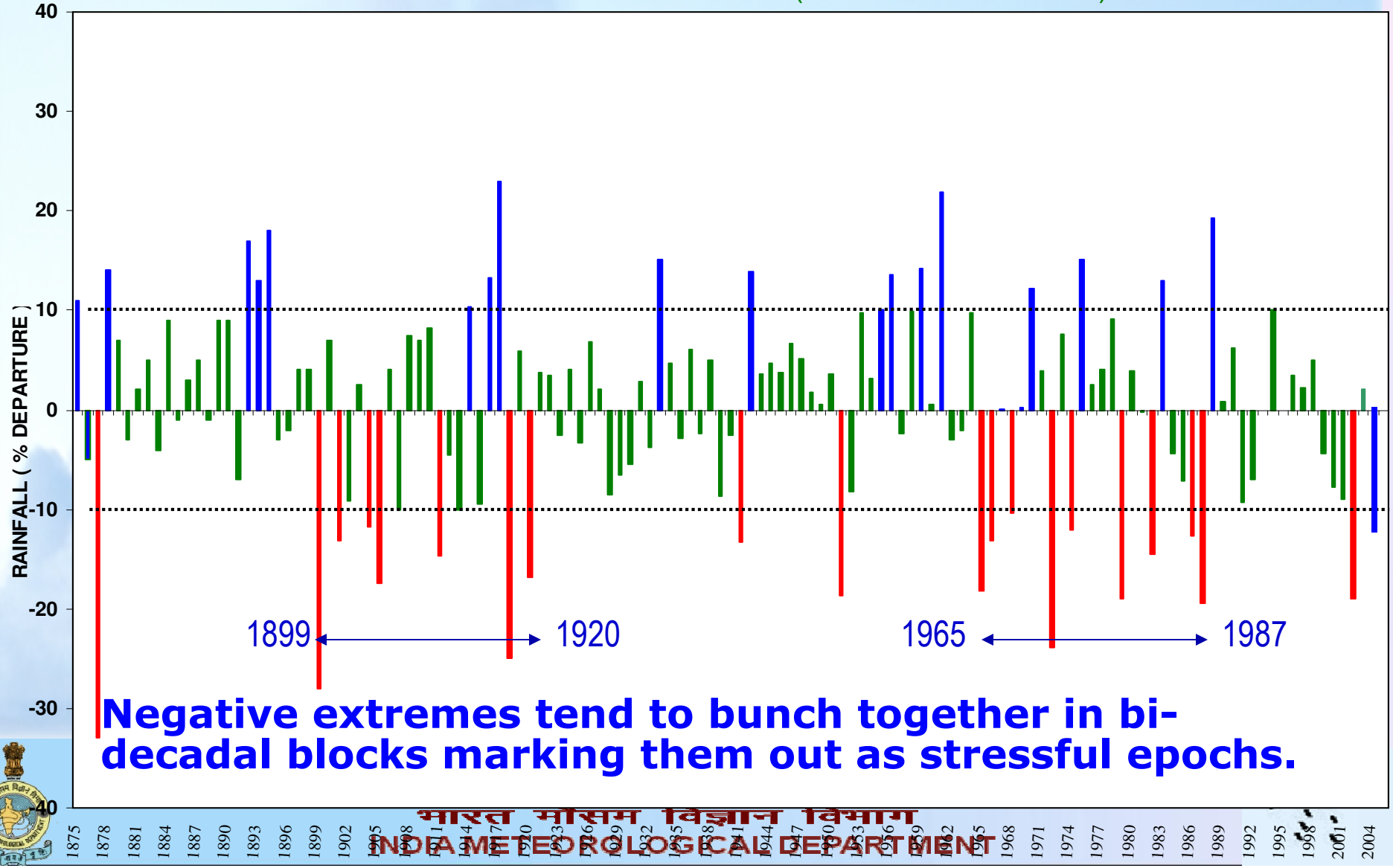
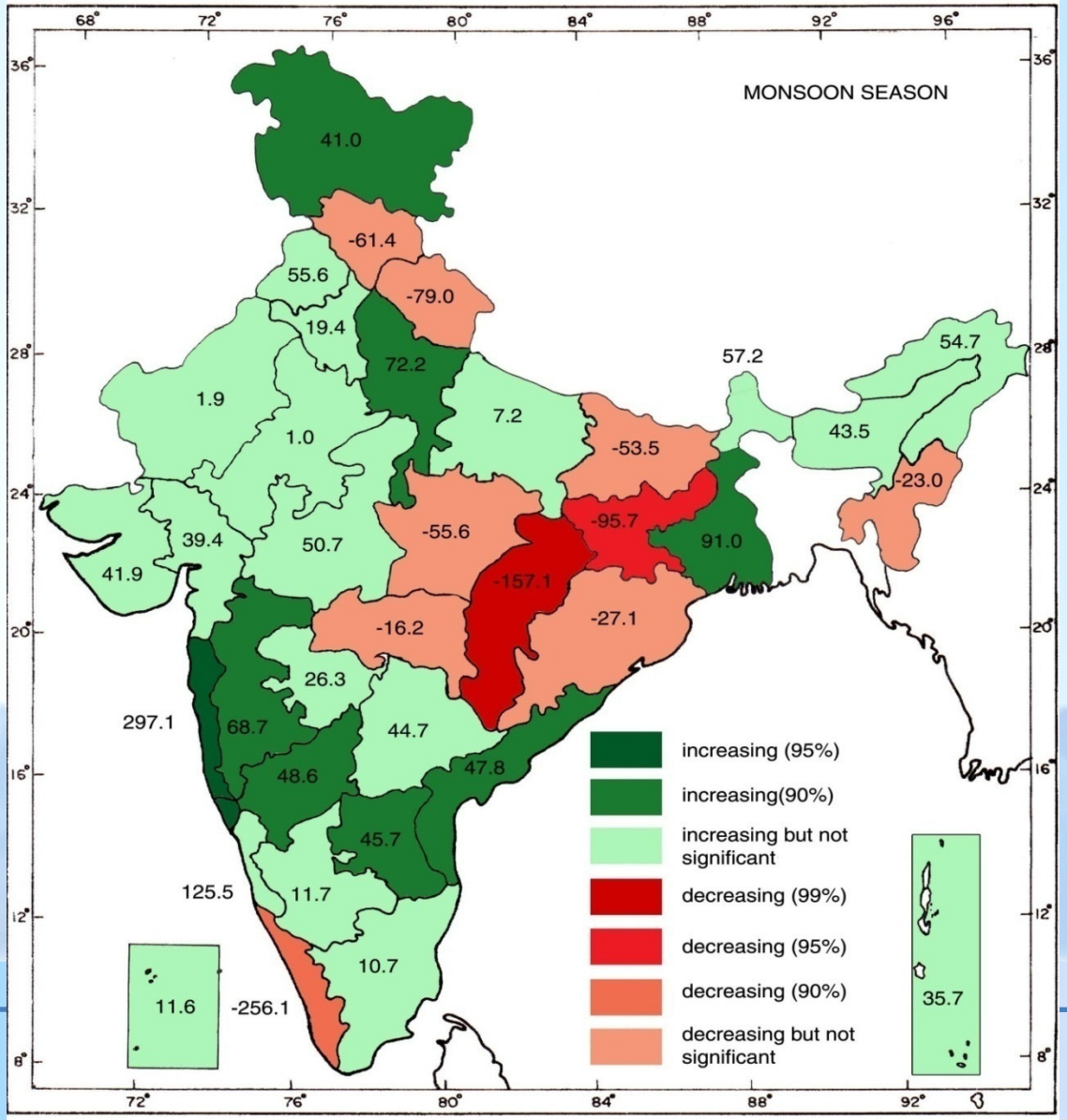
MONSOONS - A RELATIVELY REGULAR PHENOMENON INTERSPERSED WITH LARGE EXTREMES

All India SW Monsoon Rainfall (JUNE-SEPTEMBER)



Negative extremes tend to bunch together in bi-decadal blocks marking them out as stressful epochs.

TREND OF SOUTH-WEST MONSOON SEASON IN mm of RF (IN 100 YEARS)



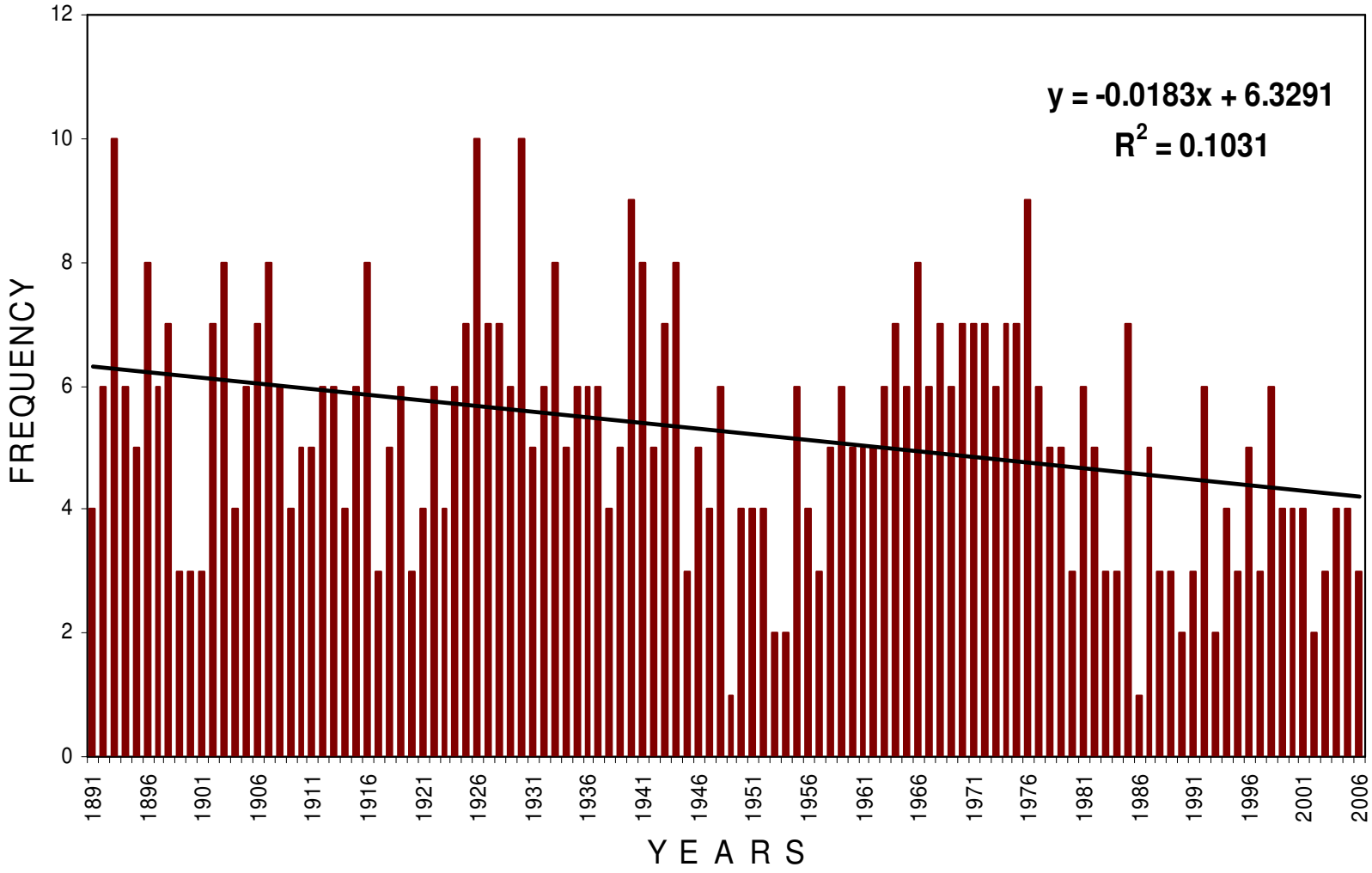
❖CLIMATE CHANGE ASSESSMENTS
❖EXTREME RAINFALL
❖(1901-2005)

- **Significant increasing trend of Extreme Rainfall events along the west coast and north Maharashtra**

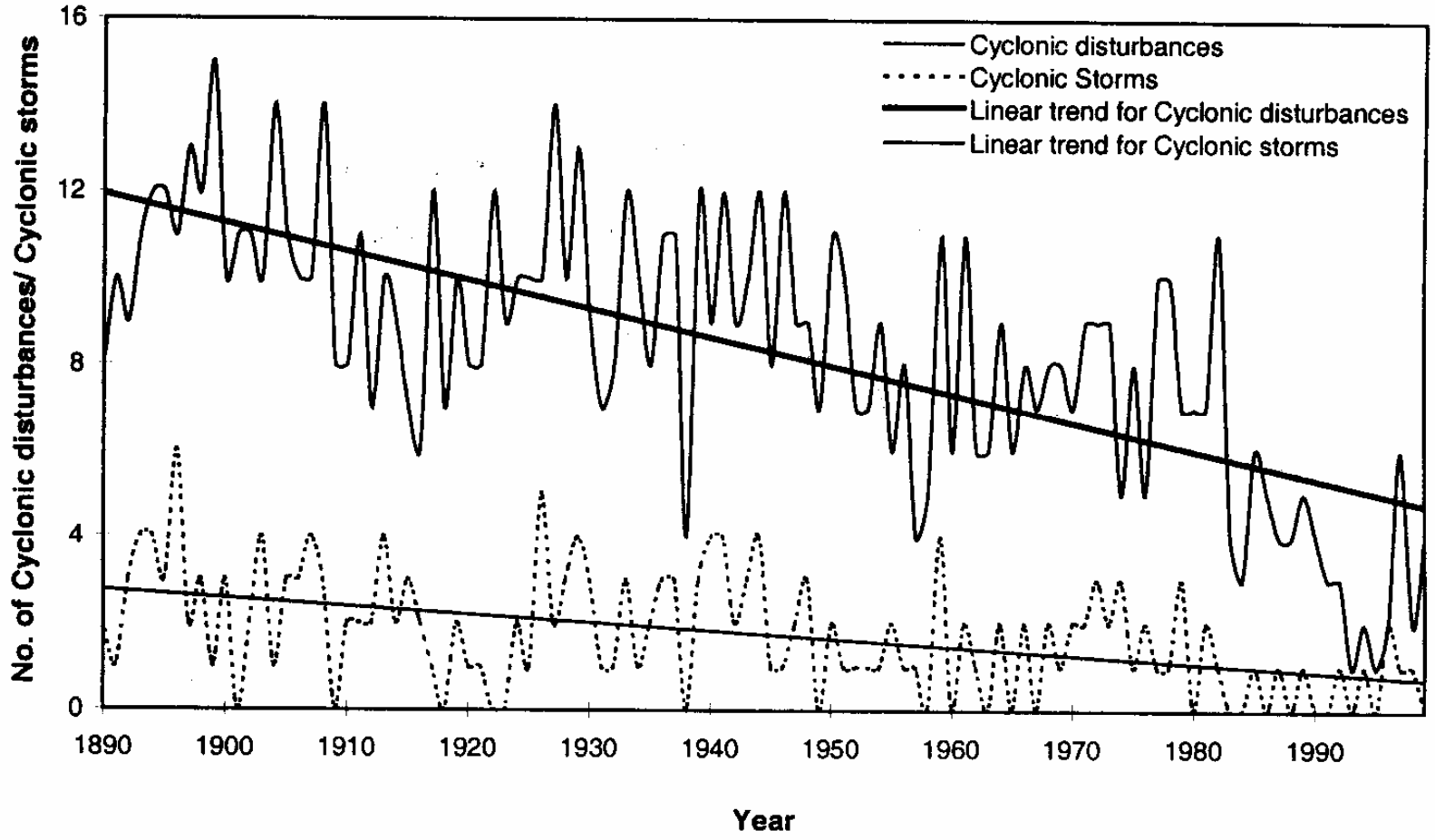
- **Hilly stations are however showing decreasing trends in extreme rainfall events**

SIGNIFICANT DECREASING TREND IN ANNUAL FREQUENCY OF CYCLONIC STORMS OVER THE NORTH INDIAN OCEAN

(1891-2006)



FREQUENCIES OF MONSOONAL CYCLONIC DISTURBANCES ALONGWITH THEIR TRENDS OVER NORTH INDIAN OCEAN DURING THE PERIOD 1890-1999 (O.P.SINGH, 2001)



❖ TROPICAL CYCLONE OVER THE NORTH ❖INDIAN OCEANS (1901-2006)

- Significant Decreasing trend of annual frequency of storms over north Indian Ocean
- Significant decreasing trend of depressions and storms over Bay of Bengal during the monsoon season.
- An increasing trend of storms over Bay of Bengal in May and November

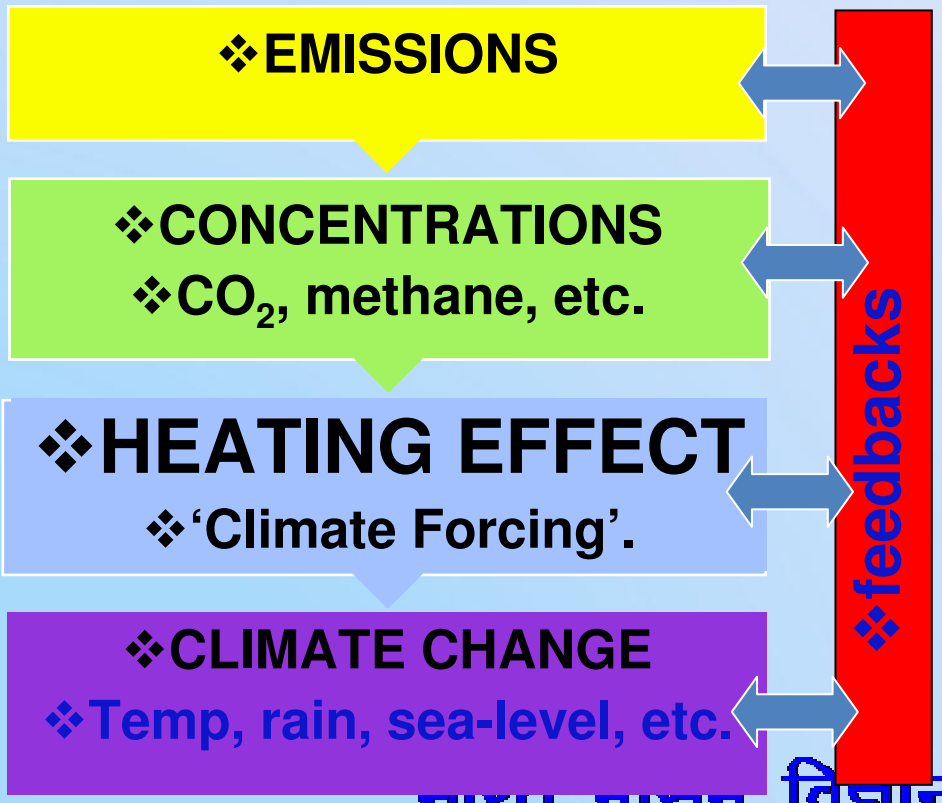
❖MARINE DATA OF NORTH INDIAN OCEAN

❖(1951-2005)

- A warming of the north Indian Ocean, an increase of Sea Surface Temperature by 0.6°C during the period.
- Cloud Cover over the equatorial Indian Ocean increased, but over Bay of Bengal decreasing trend.

CLIMATE PREDICTION

Predicting climate change



❖Scenarios from
❖population, energy,
❖economics models

❖Carbon cycle and
❖chemistry models

❖Gas properties

❖Coupled climate
❖models

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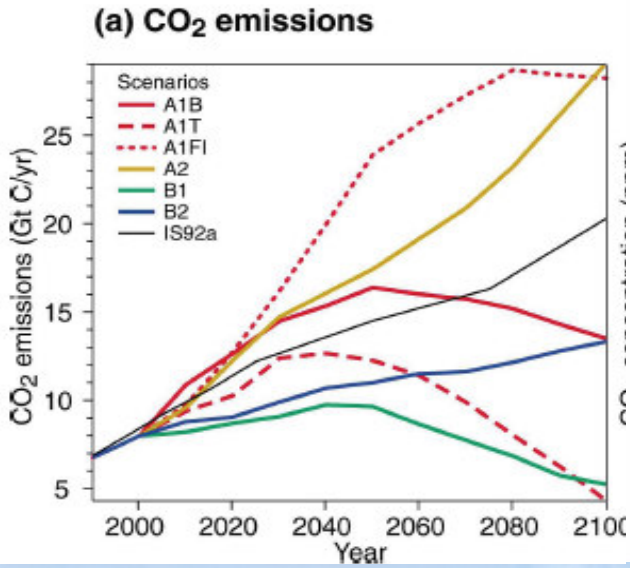
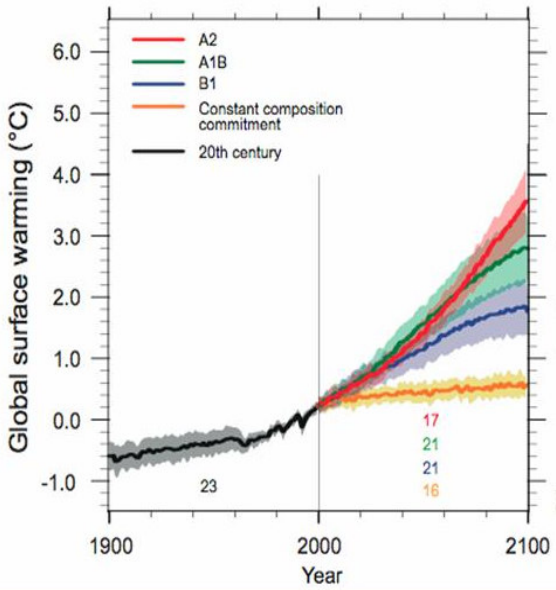
IPCC AR4 Simulations

- **Historical run: 20th Century simulation**
- **Future climate simulations (initial conditions from end of the 20th Century simulation):**

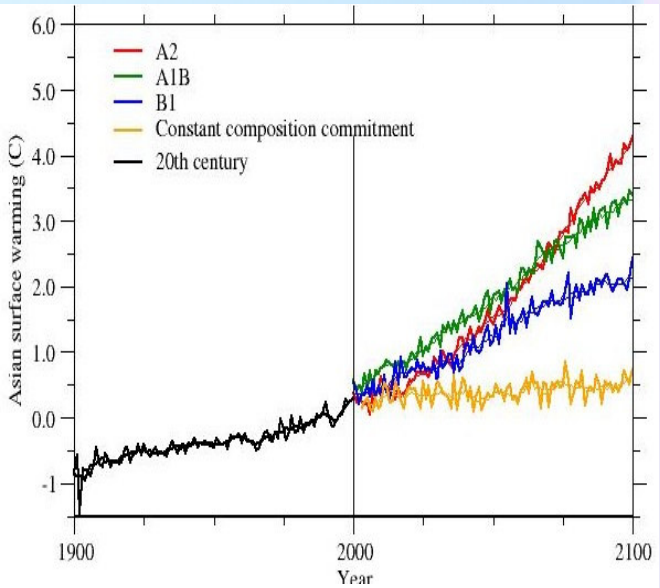
"Committed Climate Change": hold concentrations at year 2000



Global Mean



Indian Region



Major Outcomes of IPCC-AR4 Model Projections for India

- No significant change in monsoon rainfall until about 2050s and an increase in the order of 8-10% towards the end of 21st Century – biases and larger spread across models in the projected changes lead to lesser confidence
- Projected future increase in the monsoon rainfall appears to be caused by an increase in the total moisture content in the atmosphere rather than an increase in the strength of monsoon circulation
- A hint of ~10% increase in the variability of monsoon rainfall from the current levels in the future; possibility for the stretching of monsoon season with a substantial increase in the rainfall during May and Oct.
- Expected future changes in temperatures over India range from 1°C to 4°C for a range of IPCC GHG emission scenarios – lesser spread across models indicate higher confidence in the projected changes

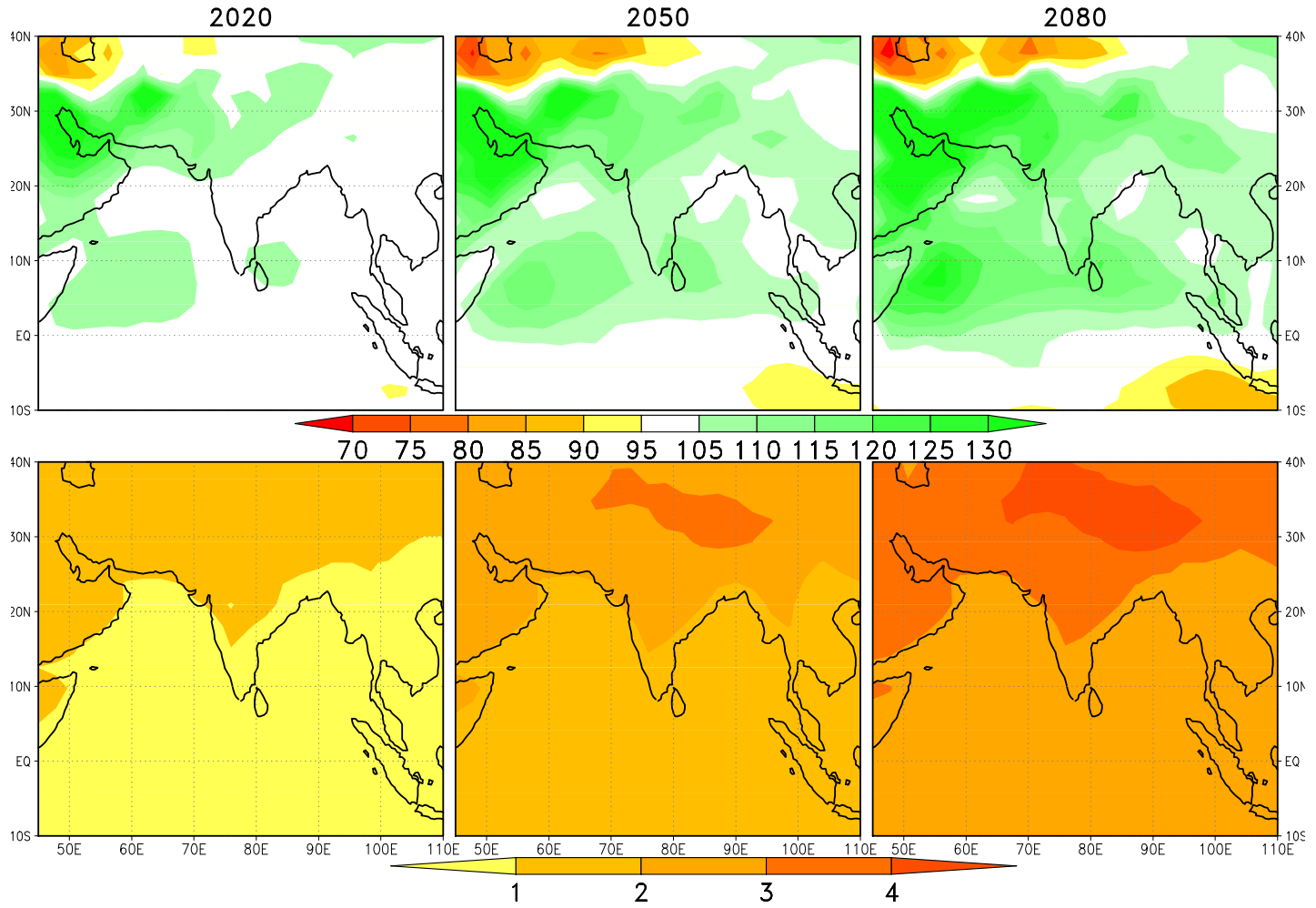
New experiments in AR5

- The QUMP (Quantified Uncertainties in Model Predictions) Project of IPCC provides for new Lateral Boundary Conditions from Global Runs for the purpose of Regional downscaling.
- 140 years of predictions for the Indian Region
- This new experiment provides for continuous year by year projection of climate parameters (rather than in discreet time slabs) to enable evaluation of sectoral impacts in a more meaningful way
- Experiments are currently underway to look at the following climatic features in the 140 year run
  - Monsoon onset dates
  - Intra-seasonal modes of variability
  - Frequency and Intensity of Cyclonic disturbances

Expected Future Change in Monsoon Rainfall and Annual Surface Temp for 2020's, 2050's and 2080's under A1B scenario in AR5

Rainfall

Temp



Krishna Kumar et al, 2009

Further insights emerging from high-resolution RCM based regional scenarios in AR5

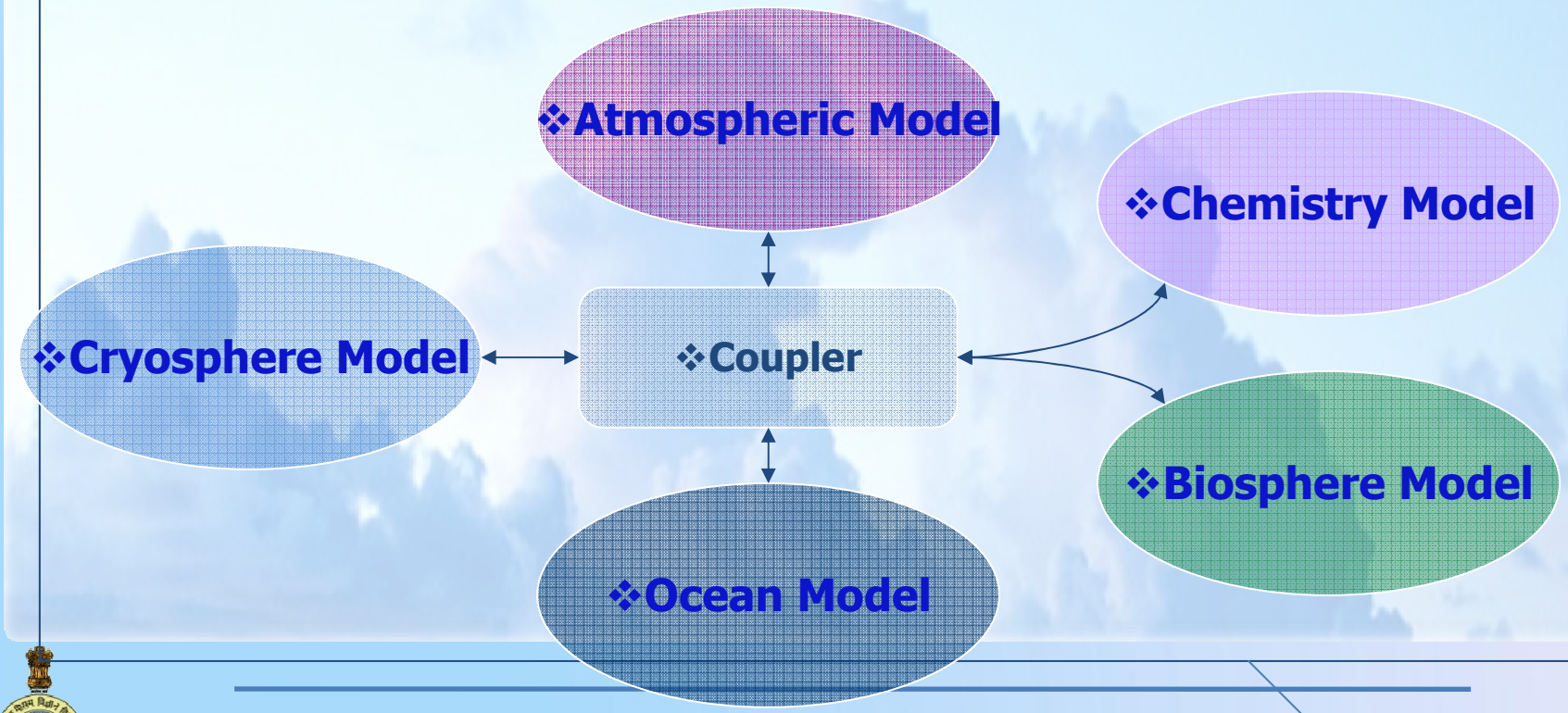
- Decrease in number of rainy days and increase in the intensity of rainfall on a given rainy day in the future
- Extremes in rainfall and temperature are showing an increase
- No significant change in the date of onset of monsoon but the variability of onset date appears to be higher in the future
- No significant change in the frequency of cyclonic storms/monsoon depressions but the intensity of storms seem to be higher by 10% in the future
- More simulations are needed to gain confidence in the projected future changes in the finer characteristics of monsoon

Climate services in India – Present and Future scenario

- National Climate Center at Pune (in the process of upgrading to South Asian Regional Climate Center)
- Diagnostic Bulletins are issued on Monthly and Seasonal assessments
- Current Empirical Seasonal LRF techniques are being revised
- Dynamical (AOGCM) and Dynamical - Stochastic approaches are being pursued
- Establishment of “Climate Change Research Center”
- “Indian Network of Climate Change Assessment” has been recently proposed

Climate modelling

❖ Coupled GCMs with biogeochemical cycles



Issues on which Scientific Consensus has not yet been arrived

- On the future projected strength of monsoon circulation and the quantum of rainfall
- Projected changes of sub-seasonal monsoon behavior (eg. Onset, ISOs, Monsoon Depressions, Extremes etc.) – Partly Limited by Resolution of CMIP3
- The response of ENSO to Global Warming
- The future strength of ENSO-Monsoon link

Current Gaps in Modeling/Observations

- Problems with the current generation of coupled models in simulating some features of mean monsoon and its interannual/decadal variability
- Large biases in the simulated ENSO characteristics and its tele-connection with Monsoon
- Role of Regional Aerosols on the Monsoon and their non-explicit inclusion in coupled simulations
- Large gaps in observations (both on land and ocean) leading to problems with modeling tropical convection, particularly over the monsoon region

Thank You