Extent of climate change over India and its projected impact on Indian Agriculture

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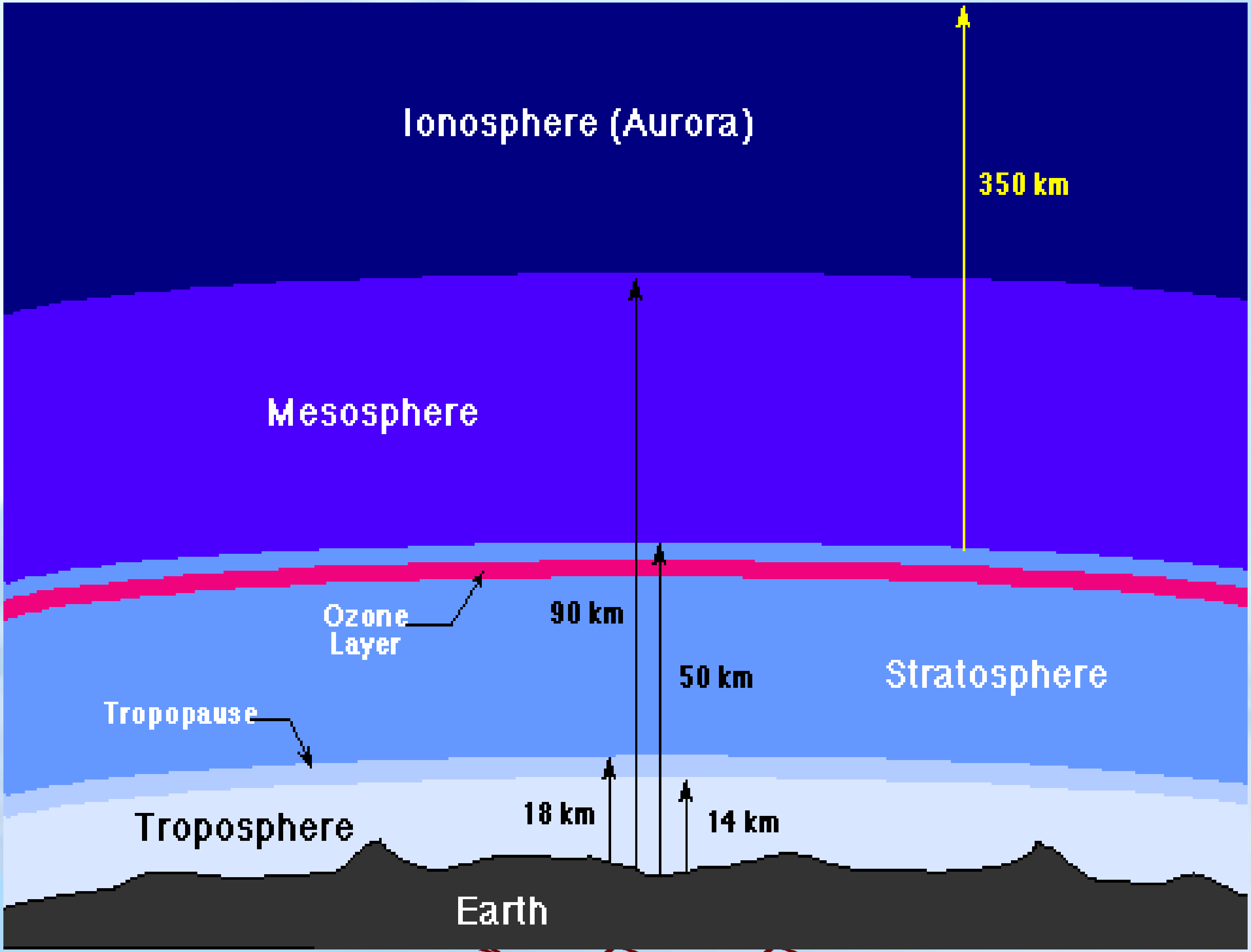
Outline of the presentation

- Global Warming
- Climate change - Implications of Global Warming
- Climate change scenario in India with special reference to Kerala
- Impact of climate change on Indian Agriculture

Global Warming

Layers of the atmosphere



Composition of the Atmosphere

- Nitrogen : 78.08 %

  Oxygen : 20.95 %

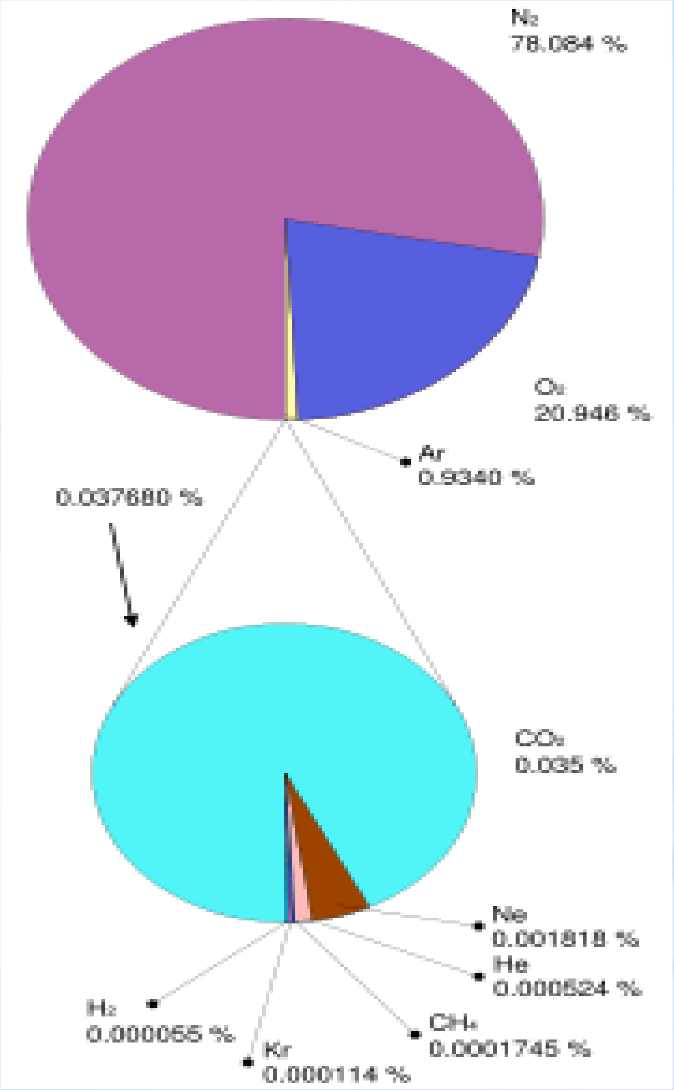
  CO_2 : 0.03 %
- Other gases :

  Neon, Helium, Krypton, Xenon, Hydrogen, Methane, Nitrous oxide
- Variable gases:

  Water vapour 0-3 %

  Ozone 0-0.07 ppm (ground)

  0.1-0.2 ppm(20-30 km)



Importance of CO_2 and Water vapour

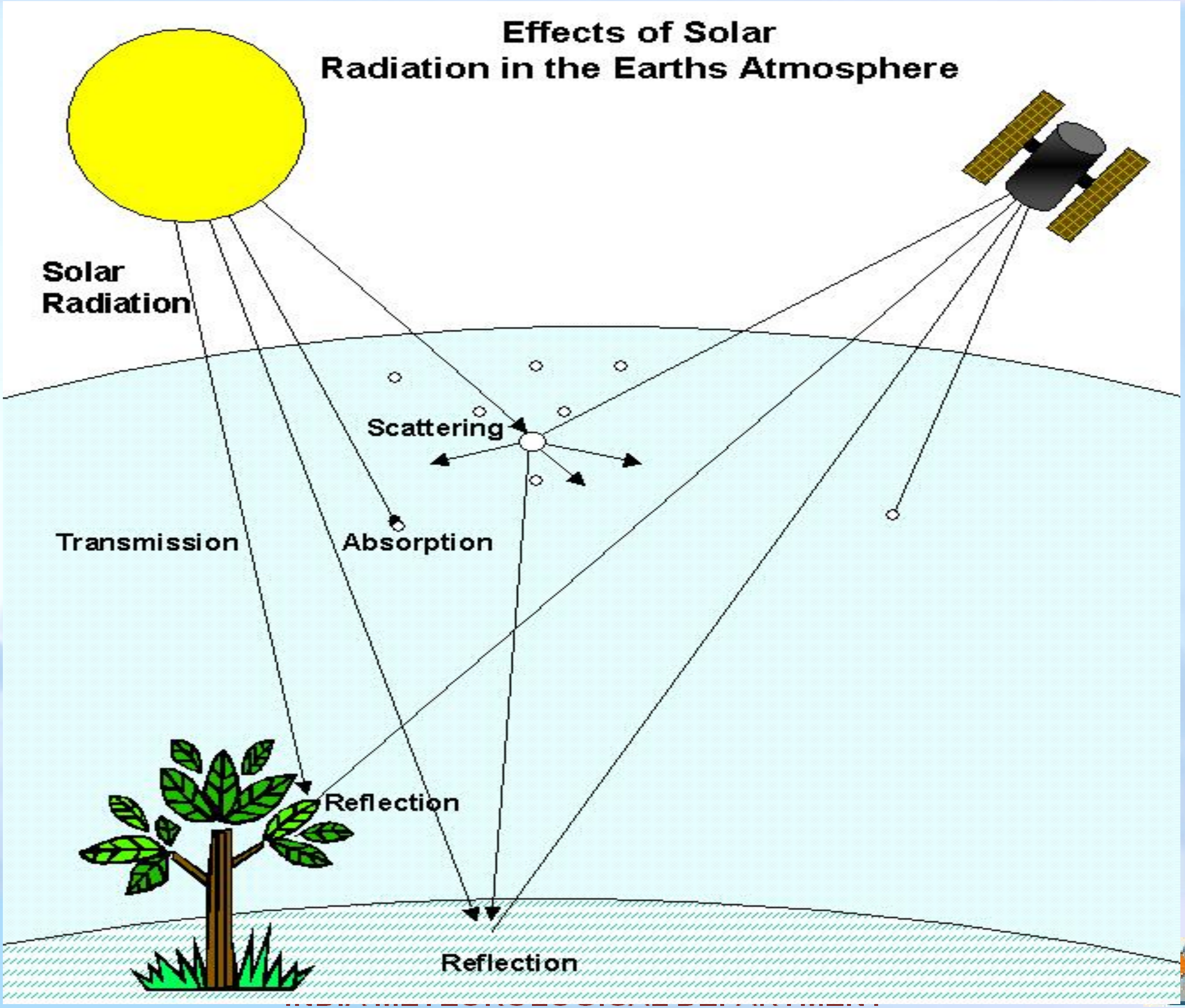
- Presence of water vapour in the atmosphere eventually leads to its condensation.
- Formation of clouds and finally precipitation
- CO_2 plays an important role in the radiation budget of the earth.

Solar radiation

- Temperature of Sun : 6000 °K
- Sun radiates as a black body
- Wave length of maximum emission (λ_m)
  (Wien's law) : 2897 / 6000
  : 0.5μ
- Solar constant : 2.00 cal/cm^2/min for earth

Insolation

- The incoming solar radiation varies with latitude, season, time of the day.
- The daily solar radiation received at a location is called insolation.
- Given latitude and time, the undepleted insolation can be derived mathematically.
- Scattering depletes insolation
- Presence of clouds also modifies the solar radiation substantially.


Effects of Solar
Radiation in the Earths Atmosphere
Solar
Radiation
Scattering
Transmission
Absorption
Reflection
Reflection

Terrestrial Radiation

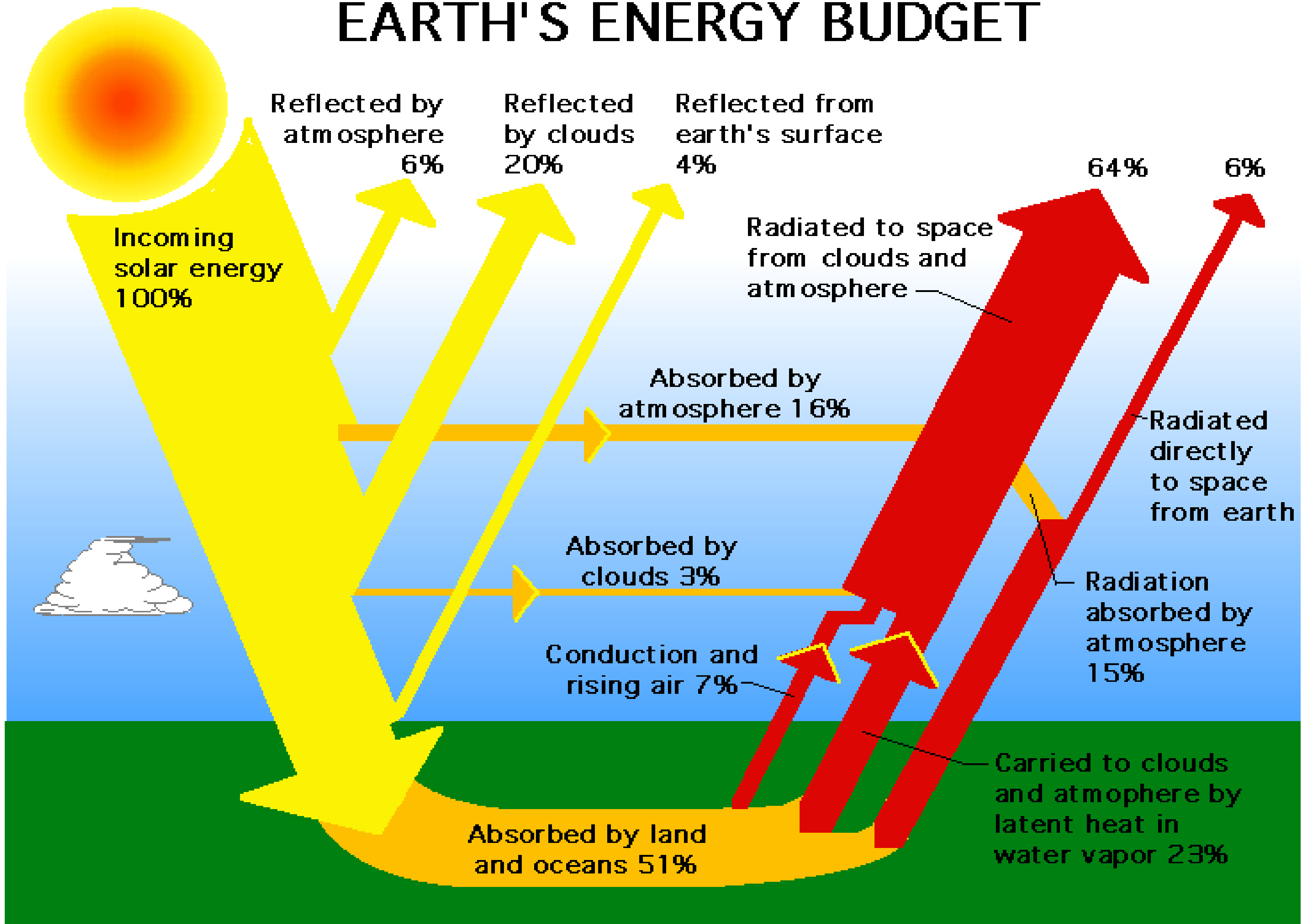
- If we take the mean temperature of earth as 15°C (288°K), $\lambda_m \approx 10\mu$ which is much higher than λ_m for solar radiation (0.5μ).

- This leads to water vapour, CO_2 and O_3 playing important roles in terrestrial radiation.

- CO_2 absorbs terrestrial radiation in the w.l band of 13.5-17μ

- H_2O absorbs terrestrial radiation in 5-8μ

EARTH'S ENERGY BUDGET

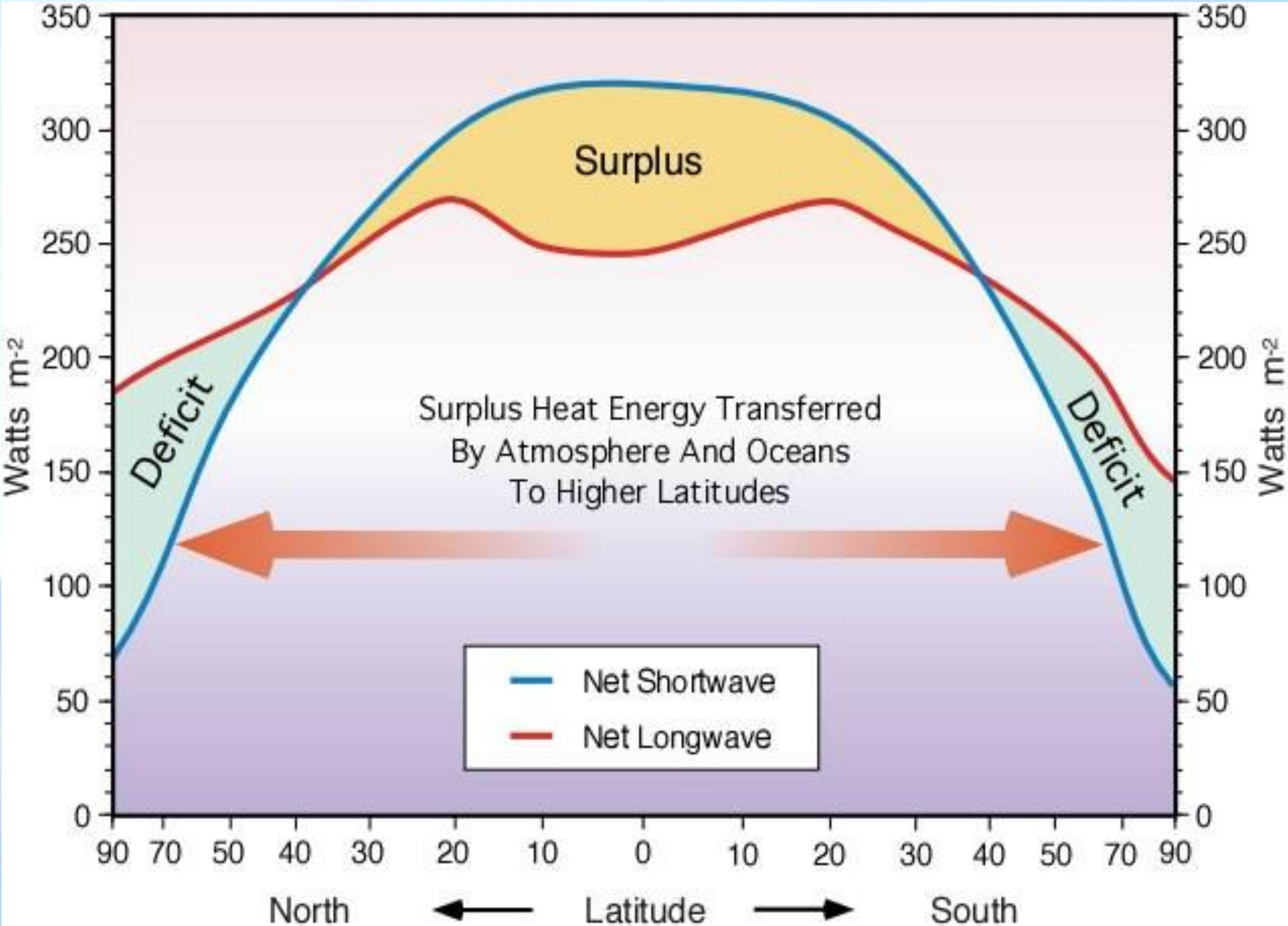


Mean annual heat balance of the earth

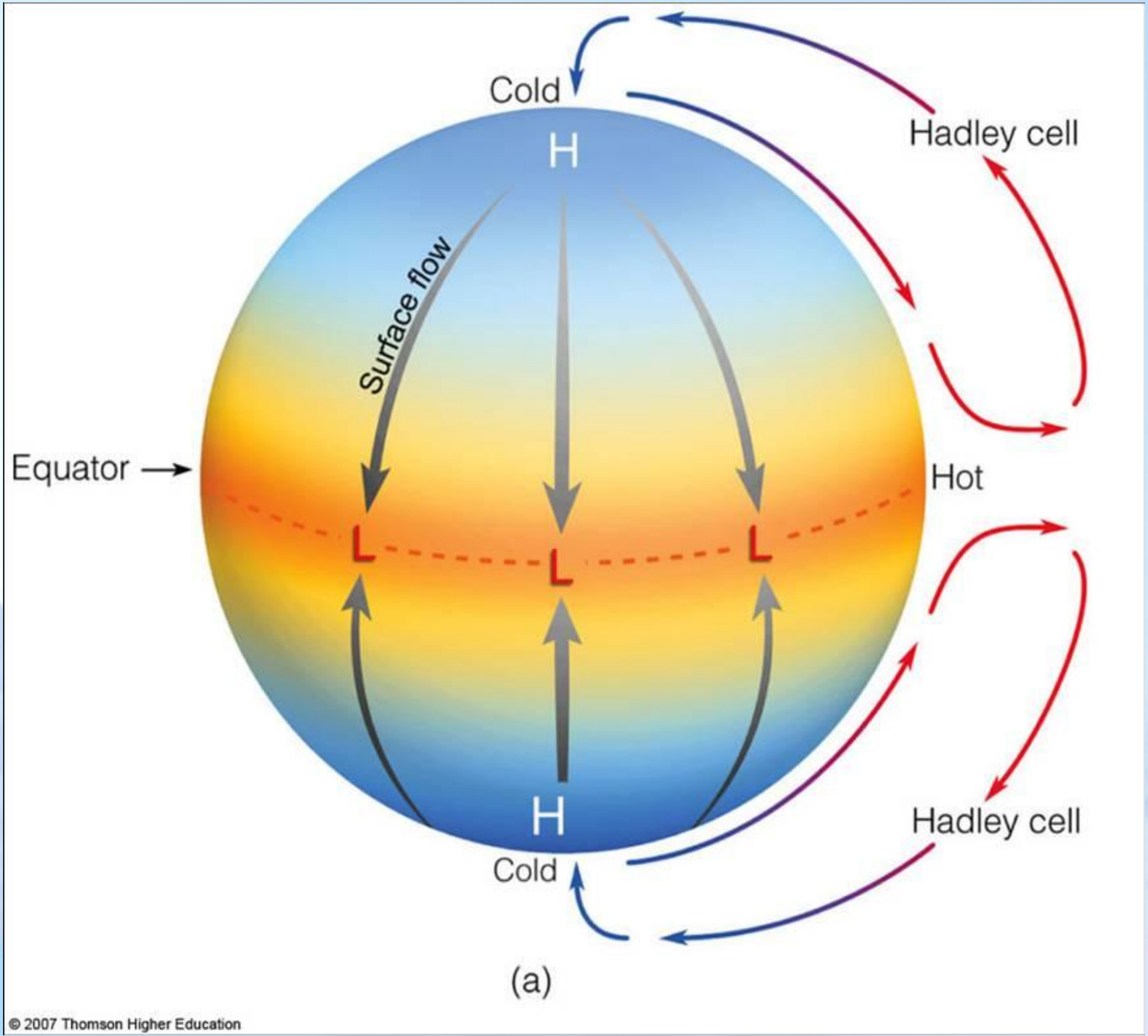
- The earth is supposed to maintain a long term heat balance with no trend in the mean temperature of earth / atmosphere.

- In the annual heat balance, there is
  - a surplus of heat in the tropics,
  - balance in the sub mid latitudes and
  - deficit in the high and mid latitudes.

- Transport of surplus heat from the tropics to higher latitudes - by oceans and atmospheric general circulation



Surplus
Deficit
Deficit
Surplus Heat Energy Transferred
By Atmosphere And Oceans
To Higher Latitudes
Net Shortwave
Net Longwave
Watts m-2
Watts m-2
350
300
250
200
150
100
50
0
90 70 50 40 30 20 10 0 10 20 30 40 50 70 90
North
Latitude
South

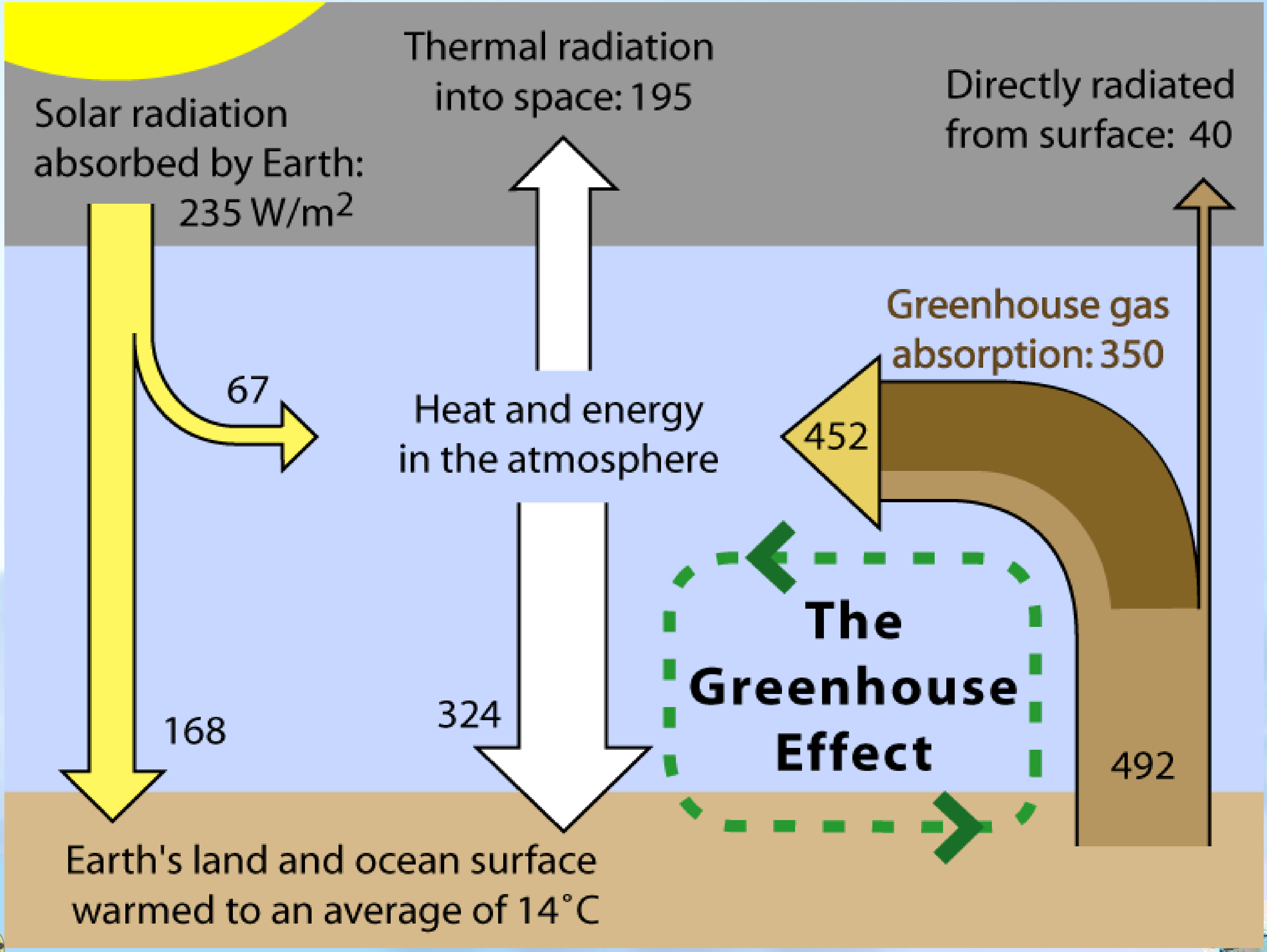

Cold
H
Hadley cell
Surface flow
Equator
Hot
L
L
L
H
Cold
Hadley cell
(a)
© 2007 Thomson Higher Education

Green House effect

Green House

- A green house permits most of the short wave (visible)radiation to pass through but reflects back part of the long wave (IR)radiation

- Earth's atmosphere also acts like a green house, CO_2 and water vapour acting like the glass top


Solar radiation
absorbed by Earth:
235 W/m2
Thermal radiation
into space: 195
Directly radiated
from surface: 40
Greenhouse gas
absorption: 350
67
Heat and energy
in the atmosphere
452
The
Greenhouse
Effect
324
168
492
Earth's land and ocean surface
warmed to an average of 14˚C

Major Green House gases in the atmosphere

Water vapour	:	36-70%
$C0_2$	:	9-26%
Methane	:	4-9%
Ozone	:	3-7%

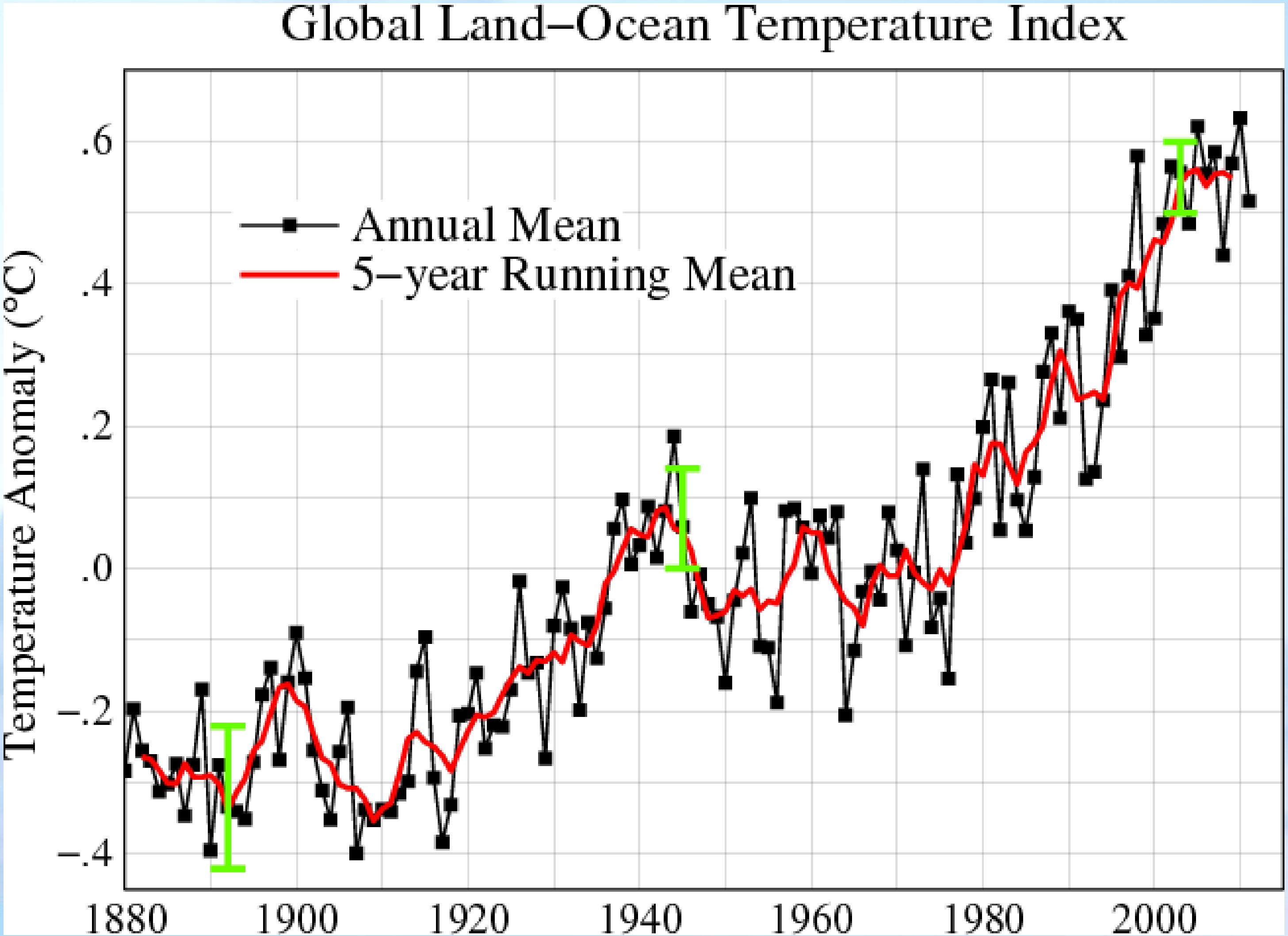
Global Warming

- Global warming refers to the temporal increase in the average surface temperature of the earth and oceans.

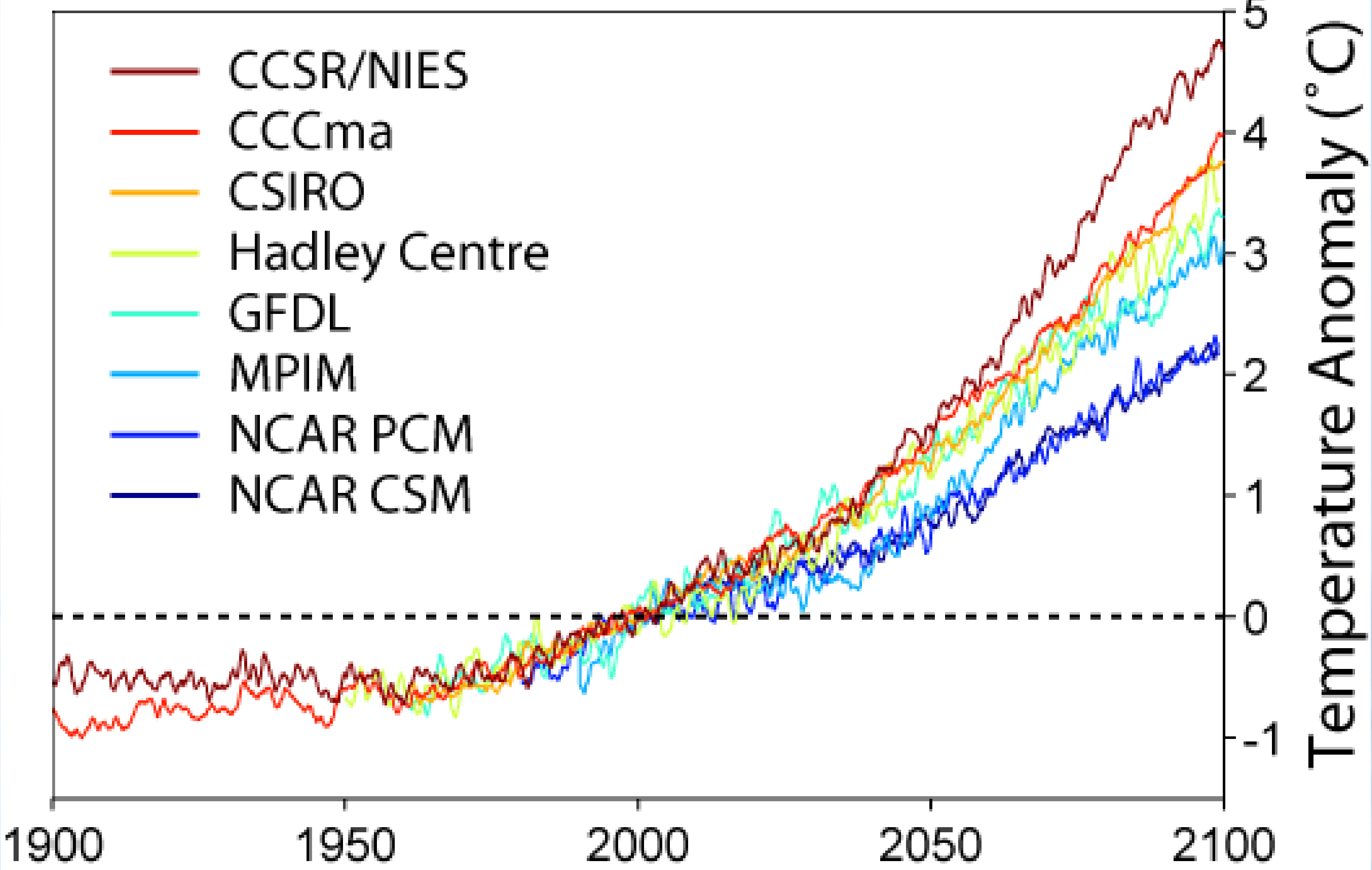
- Increase has been in the order of nearly 0.74°C during the past century.

- Since 1980, the mean global temperature has been steadily rising from an anomaly of 0°C to nearly 0.4-0.45°C as of now.

Global mean surface temperature anomaly 1880 - 2010



Global Warming Projections



Reasons attributed to Global Warming

- Increase in CO_2 concentration in the atmosphere and the consequent Green house effect

- Increase of methane
- Unsustainable development
- Increase in automobiles, air conditioning

Human activities responsible for release of Green House gases in the atmosphere

- $C0_2$

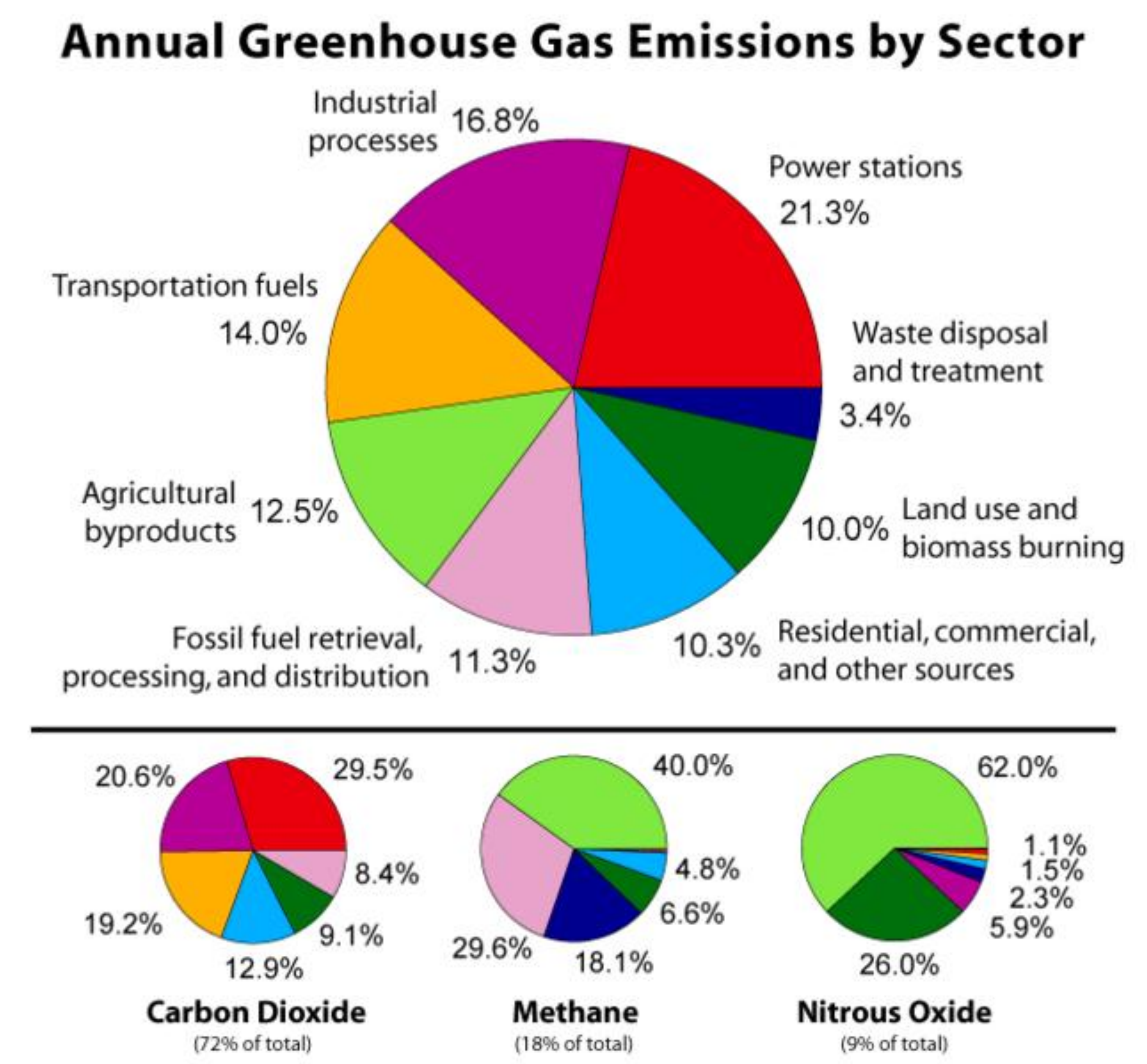
  from

  1. power plants where fossil fuels such as coal are burnt
  2. Emitted by automobiles,

     aeroplanes

- Methane

  Rice plants / fields release methane

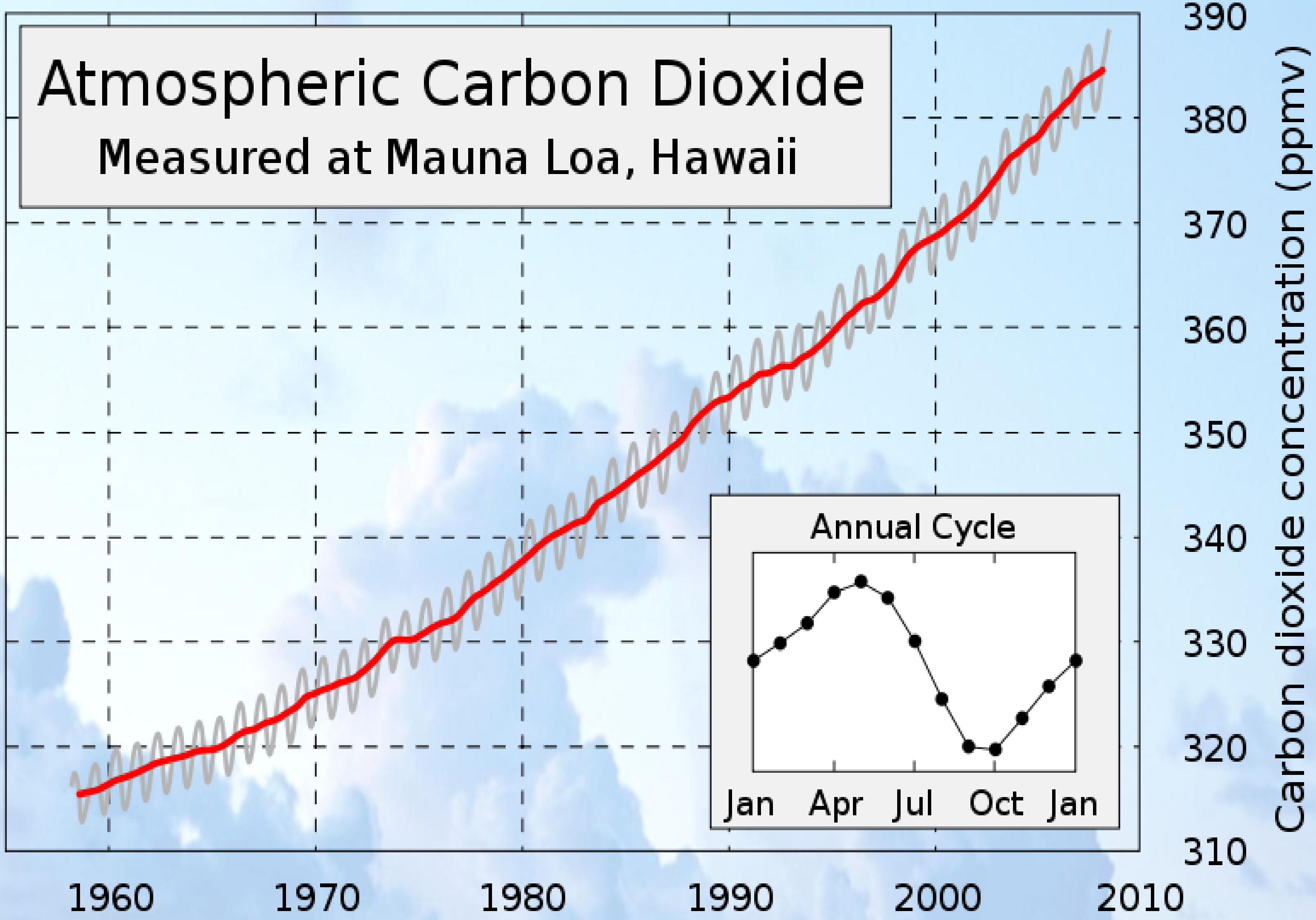


Annual Greenhouse Gas Emissions by Sector
Industrial processes 16.8%
Power stations 21.3%
Transportation fuels 14.0%
Waste disposal and treatment 3.4%
Agricultural byproducts 12.5%
10.0% Land use and biomass burning
Fossil fuel retrieval, processing, and distribution 11.3%
10.3% Residential, commercial, and other sources
20.6%
29.5%
8.4%
19.2%
9.1%
12.9%
Carbon Dioxide
(72% of total)
40.0%
4.8%
6.6%
29.6%
18.1%
Methane
(18% of total)
62.0%
1.1%
1.5%
2.3%
5.9%
26.0%
Nitrous Oxide
(9% of total)

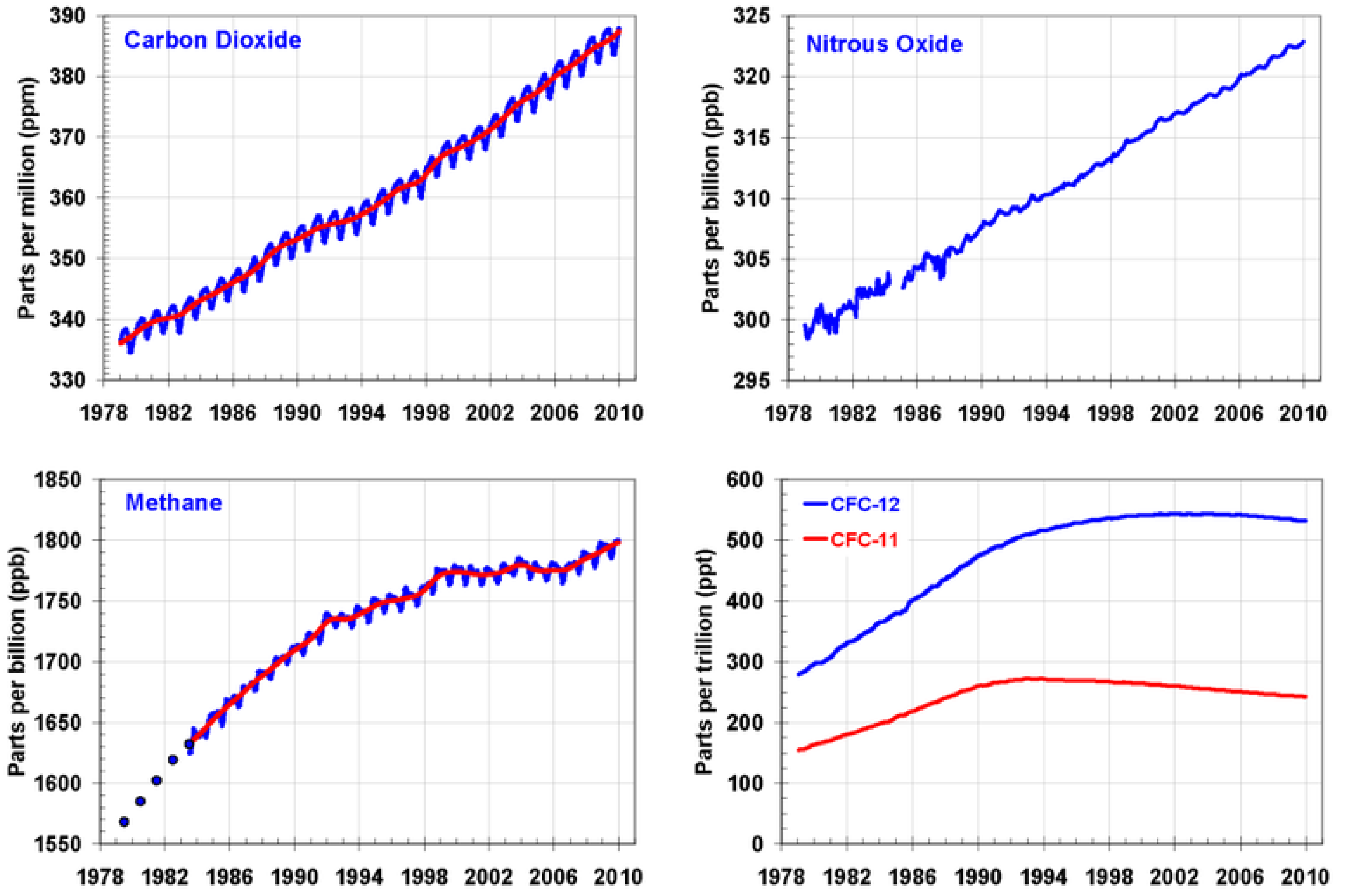
Increasing concentration of CO_2 in the atmosphere

- CO_2 –increase from 1750 till now (in parts per million)

In 1750	280
1994	358
2003	370
Nov 2009	386
2010	390
2011	392
Apr 2012	396
end of 21st century (projected)	500



Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Annual Cycle
Jan
Apr
Jul
Oct
Jan
390
380
370
360
350
340
330
320
310
Carbon dioxide concentration (ppmv)
1960
1970
1980
1990
2000
2010


Carbon Dioxide
Parts per million (ppm)
390
380
370
360
350
340
330
1978 1982 1986 1990 1994 1998 2002 2006 2010
Nitrous Oxide
Parts per billion (ppb)
325
320
315
310
305
300
295
1978 1982 1986 1990 1994 1998 2002 2006 2010
Methane
Parts per billion (ppb)
1850
1800
1750
1700
1650
1600
1550
1978 1982 1986 1990 1994 1998 2002 2006 2010
CFC-12
CFC-11
Parts per trillion (ppt)
600
500
400
300
200
100
0
1978 1982 1986 1990 1994 1998 2002 2006 2010

CO_2 emission by various countries (2010)

Country	Annual CO2 emission (in thousands of metric tons)	Percentage of global total	Per capita (metric tons) during 2007	Per capita (metric tons) during 2010
World	33508901	100%		
China	8240958	24.6%	4.9	6.2
USA	5492170	16.4%	18.9	17.6
India	2069738	6.2%	1.4	1.7
Russia	1688688	5.0%	10.8	11.8
Japan	1138432	3.4%		8.9

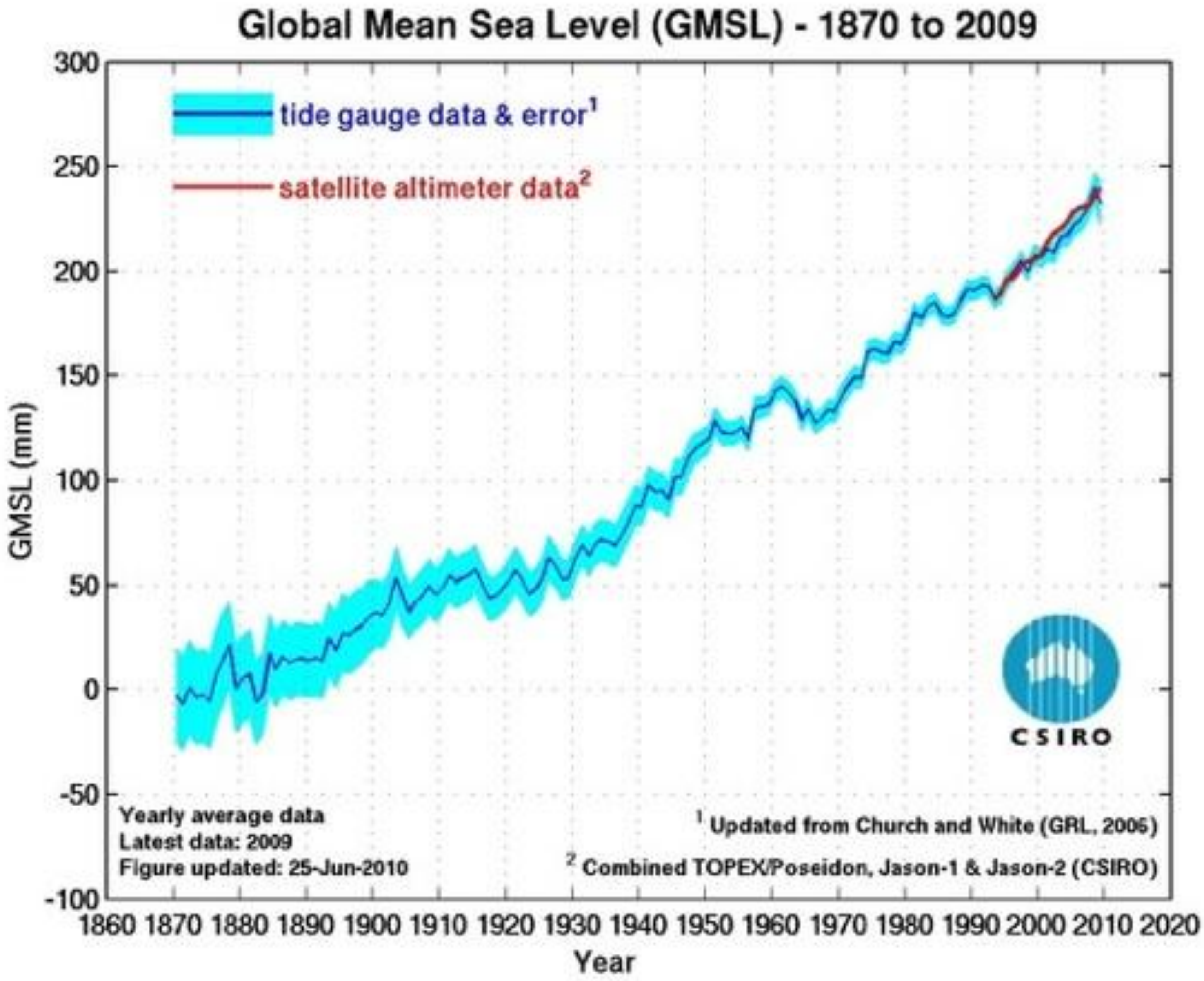
Implications of Global warming – Climate changes

Implications (projected)

- Even if emission of CO_2 could be curtailed totally today, the present concentration itself is so high, the gas could stay up in the atmosphere for another 200 years.
- Depletion of Ozone in the upper troposphere
- Certain changes in the climate system, such as, melting of ice sheets and major changes in the ocean circulation pattern likely to take place in 21st century would be irreversible.

Implications contd…

- Rise in sea level
- Increase in the occurrence of extreme weather events –
- Changes in precipitation patterns
- Retreat of glaciers
- Warmer summers and milder winters


Global Mean Sea Level (GMSL) - 1870 to 2009
tide gauge data & error[1]
satellite altimeter data[2]
GMSL (mm)
300
250
200
150
100
50
0
-50
-100
1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
Year
CSIRO
Yearly average data
Latest data: 2009
Figure updated: 25-Jun-2010
[1] Updated from Church and White (GRL, 2006)
[2] Combined TOPEX/Poseidon, Jason-1 & Jason-2 (CSIRO)

Documented implications of global warming (WMO)

- Rise of global mean sea level by 10-20cm
- Decrease of sea ice by 10-15%
- Decline of Arctic sea ice thickness by nearly 40%
- Retreat of mountain glaciers.
- Increase in frequency of extreme weather events such as floods, tropical cyclones and droughts in recent years.

Documented implications of global warming (WMO) contd…

- Doubling of hydro meteorological disasters over the globe during the last decade which included the strongest El Nino of the century in 1997-98 that affected 11 crore people and cost the global economy nearly US $100 billion.

- Winters milder and summers harsher in several countries.

WMO projections for future climatic events based on comprehensive climate models

- Increase of global mean temperature by 1.4-5.8°C by 2100

- Increase in sea level by 9-88 cm from the 1990 level by 2100
  IPCC projections 1990-2100 : 110-770mm
  Mean value of 0.7mm per year

- More hot days and heat waves, increase in heat index

- Decrease in cold waves and frost days

WMO projections for future climatic events (contd…)

- Increase in the occurrence of extreme weather events –
- Increase in precipitation extremes, viz., floods and droughts.
- Retreat of glaciers
- Warmer summers and milder winters

Impact of projected climatic changes

- Effect of potential rise in surface temp: would speed up hydrological cycle – severe consequences for ecosystems and human populations.
- 4-7 % increase in global mean evaporation and precipitation rates (doubling of CO_2 level and a few deg rise in global mean temp).
- Regional effects on water balance; some areas wetter, some drier.
- Greater and longer periods of summer dryness induced by lower soil moisture content & higher evaporation rates in mid-latitudes of Northern hemisphere

Impact of projected climatic changes (contd…)

- General reduction in potential crop yield in most tropical and sub tropical regions.
- Decrease in winter rainfall of Australia, Central America and Southern Africa
- Increased risk of coastal flooding and erosion, drinking water salinisation

Some positive impacts…

- Increase of crop yield in mid latitude countries
- Increase of precipitation by 5-10% over higher latitudes
- Reduced winter mortality in extra tropics.
- In the Arctic, there will be more running and standing water, thinner and reduced ice cover.

Feed back mechanism of increase in SST

Positive feed back

- Increase in SST ⇒ Increased evaporation and increase in water vapour which is a Green House gas will lead to further warming

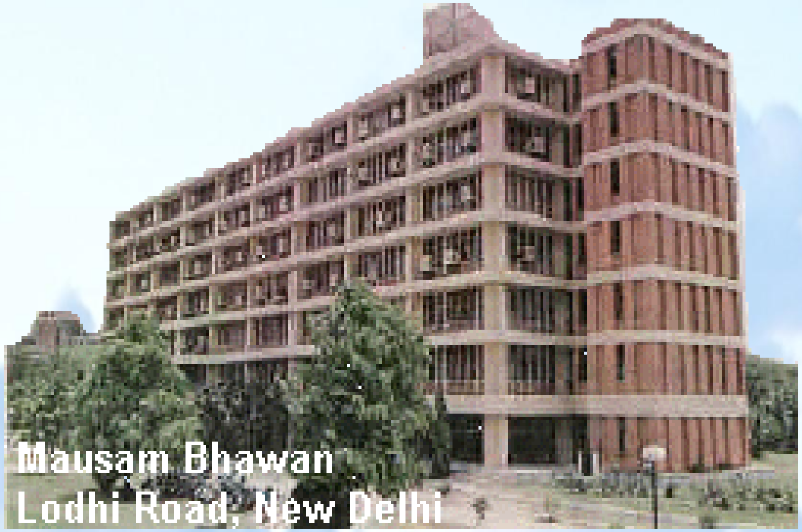
Negative feed back

- If increase in water vapour could lead to increased clouding and a consequent decrease in insolation, then, it would perhaps lead to cooling of the atmosphere

Climate Change- Indian Scenario

- India is currently the 3-rd largest emitter of green house gases in the world (6.2%).
- Persistent increase in emissions in the last decade
- Surface temperatures have shown some increase in recent years.

India Meteorological Department



- Established in 1875 India Meteorological Department (IMD) is the oldest scientific institution of India and is one of its premier scientific institutions.
- IMD is the National Meteorological Service and the principal Government Agency in matters relating to Meteorology & Seismology.
- Functions under Ministry of Earth Sciences

Regional Meteorological Centre, Chennai established in 1945.

IMD - Climate studies

- ❖ Systematic archival of observed atmospheric parameters is made at National Data Centre, IMD Pune
- ❖ Climate related studies are undertaken at National Climate Centre, IMD, Pune
- ❖ Radiation, ozone, aerosol studies undertaken
- ❖ Antarctic climate studies undertaken

Observational Organisation of IMD

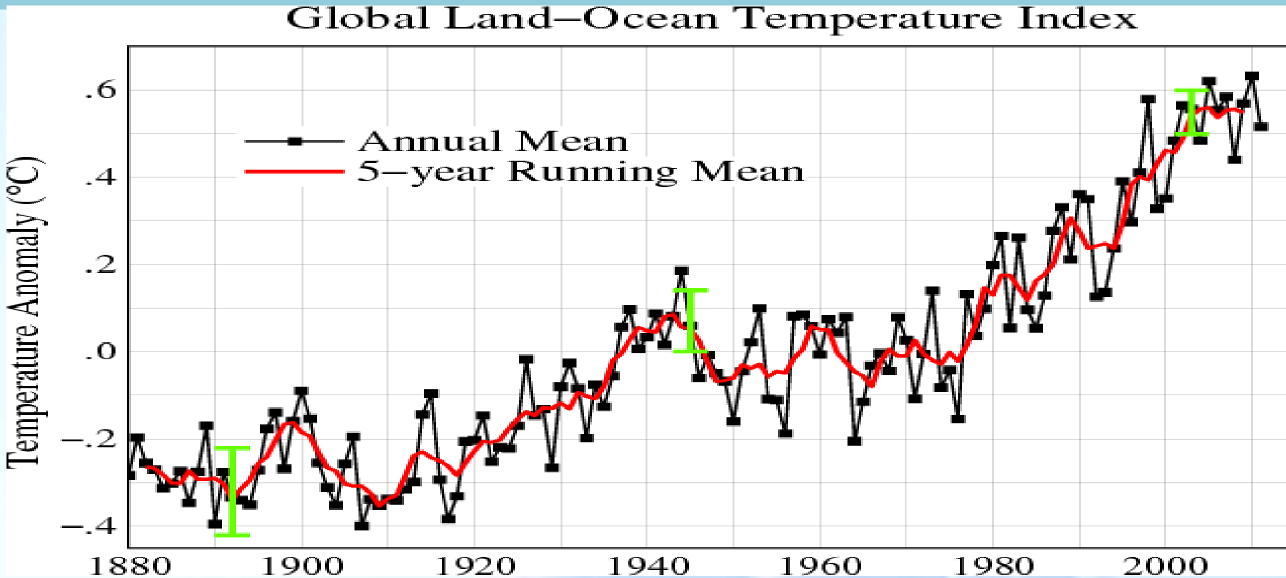
S.No.	Type of Observatories	Number
1	Surface Observatories	552
2	Pilot Balloon Observatories	62
3	RS/RW Observatories	39
4	Aerodrome Met. Offices (AMO)	18
5	Aerodrome Met. Stations (AMS)	51
6	Storm Detection Radar Stations	17
7	Cyclone Detection Radar Stations	10
8	High Wind Recording Stations	22
9	Stations for receiving cloud pictures from satellites	10
10	Automatic Weather Staions	>1350
11	Hydrometeorological Observatories	633
12	i) Non-departmental raingauge stations: a) Reporting b) Non-Reporting ii) Non-departmental Glaciological Observatories (Non-reporting)	 7941 4959 37
13	Agrometeorological Observatories	238
14	Evaporation Stations	238
15	Evapotranspiration Stations	42
16	Seismological Observatories	51
17	Ozone related Observatories	14
18	Radiation Observatories	54
19	Atmospheric Electricity Oservatories	4
20	Pollution and Climatological Observatories	25
21	Ships of the Indian Voluntary Observing Fleet	184
22	Soil Moisture Recording Stations	43
23	Dew-fall Recording Stations	76

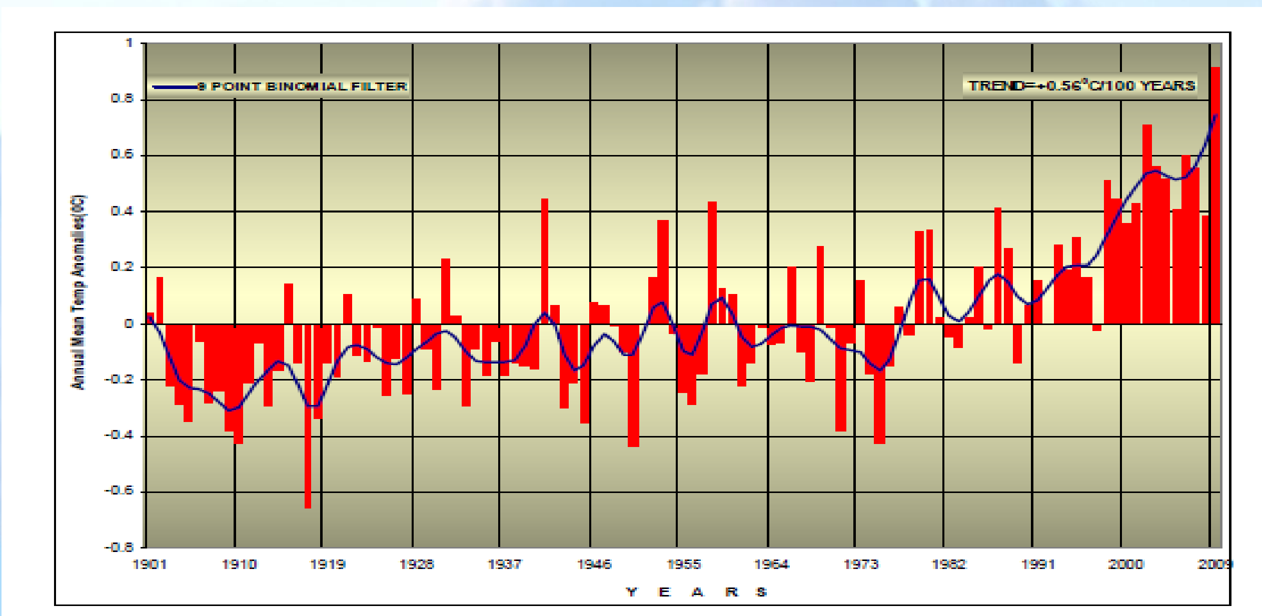
Observational network under Regl. Met. Centre, Chennai

Type of Observatory	AP	KAR	KER	TN	Total
Surface (dept)	8	9	10	16	53
Surface (non-dept)	19	18	7	24	68
Pilot Balloon	4	3	3	3	13
RS-RW	3	2	3	2	10
RS-RW (GPS)	2	0	2	1	5
RS-RW Radiosonde only			1		1
Hydromet	10	8	2	2	22
Raingauges (reporting	179	310	59	191	739
Raingauges(non-reporting,	535	971	73	289	1868
Seismic	2	1	2	3	8
Ozone monitoring			1	1	2
Radiation monitoring	3	3	3	3	12
Evaporation measurements	7	4	4	11	26
Dew measurements	2	2	2	1	7
Aviation CWO	4	3	4	6	17
Aeronautical FO	1	1	1	1	4
Storm detection radar	1	1	0	1	3
Doppler Weather Radar	4	0	0	1	5
Cyclone Detection Radar	0	0	1	1	2
BAPMON stations	1	0	1	1	3
CWDS	80	5	5	58	148
AWS	35	26	16	28	105

Temperature

Mean temperature over India during 1901-2009 (bottom) and Global Land – Ocean temperature Index 1880-2006 (top)





All India annual Max & Min temp anomalies for the period 1901-2009 (Source: Climate Profile of India, IMD, 2010)

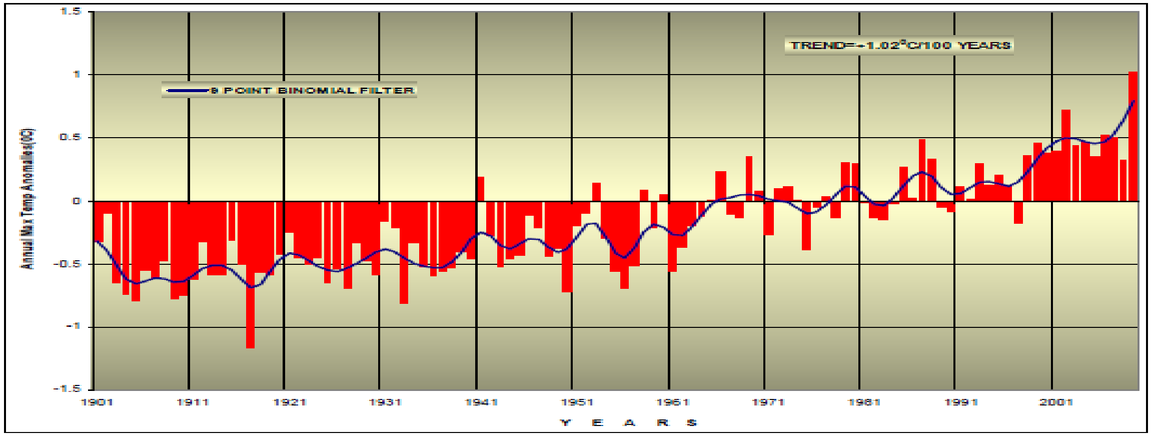


Fig 5: All India annual maximum temperature anomalies for the period 1901-2009 (based on 1961-1990 average) shown as vertical bars

(The solid blue curve show sub-decadal time scale variations smoothed with a binomial filter)

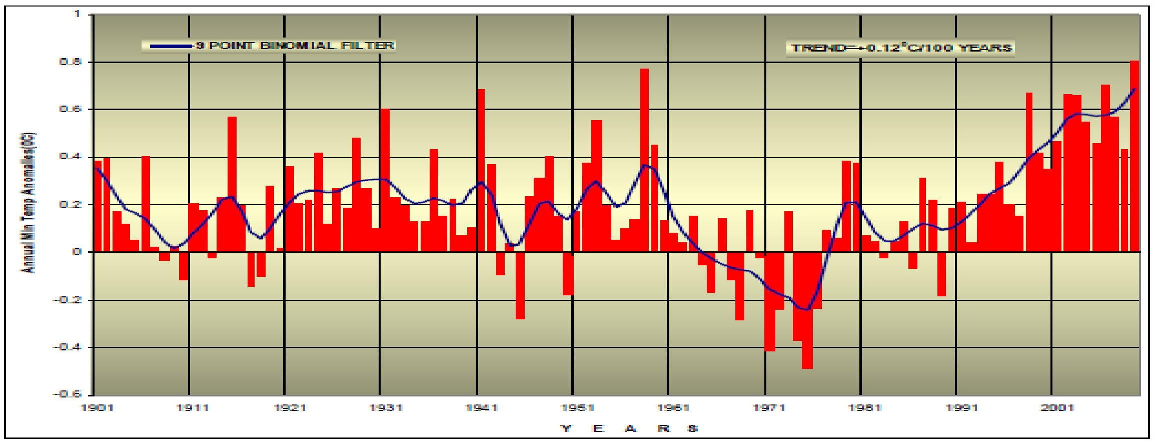


Fig 6: All India annual minimum temperature anomalies for the period 1901-2009 (based on 1961-1990 average) shown as vertical bars

(The solid blue curve show sub-decadal time scale variations smoothed with a binomial filter)

Seasonal temperature trends
(Source: Climate Profile of India, IMD, 2010)

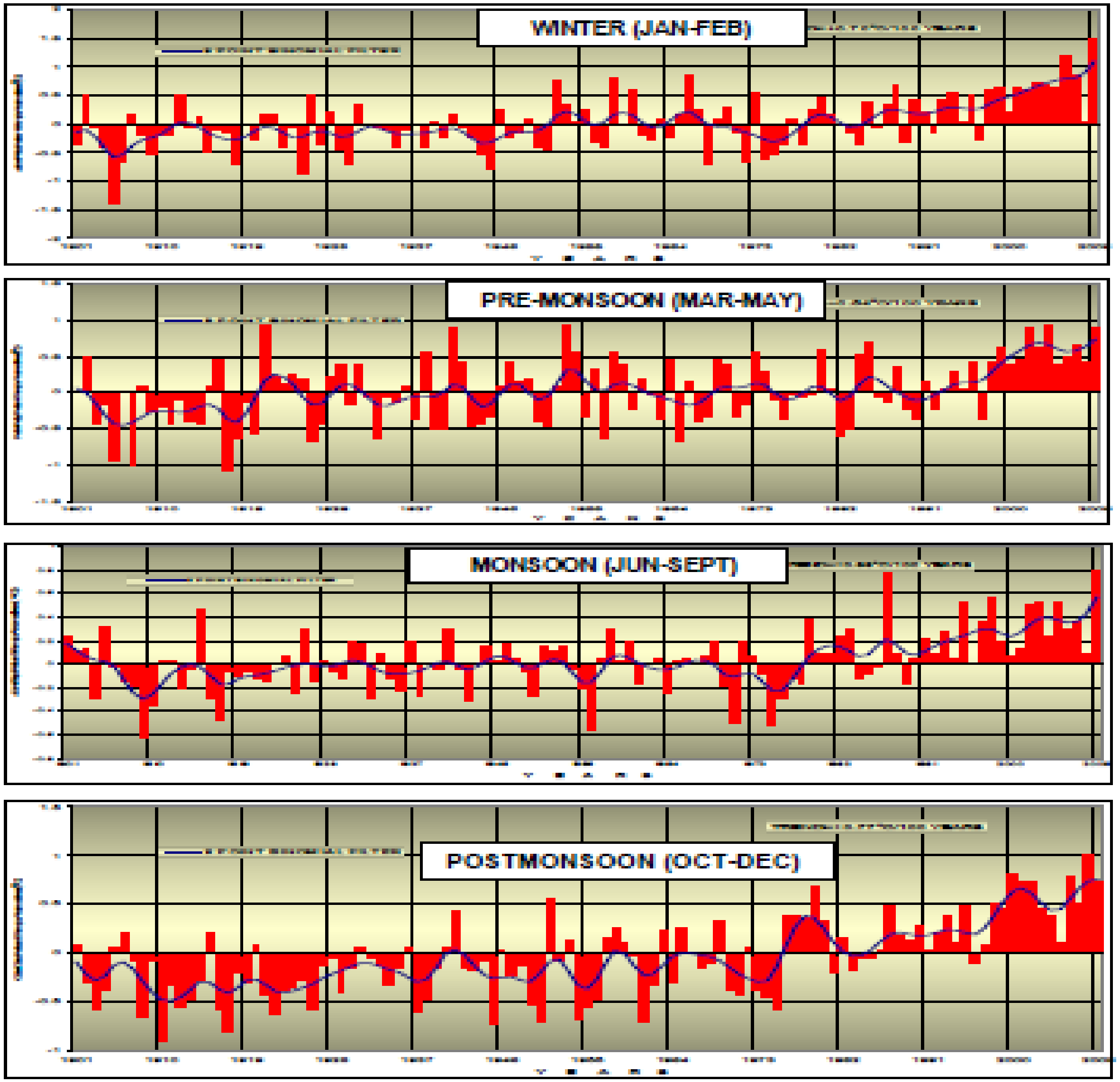


Fig 8: All India Mean Temperature Anomalies for the four seasons for the period 1901-2009 (based on 1961-1990 average)

Temp trends over India …

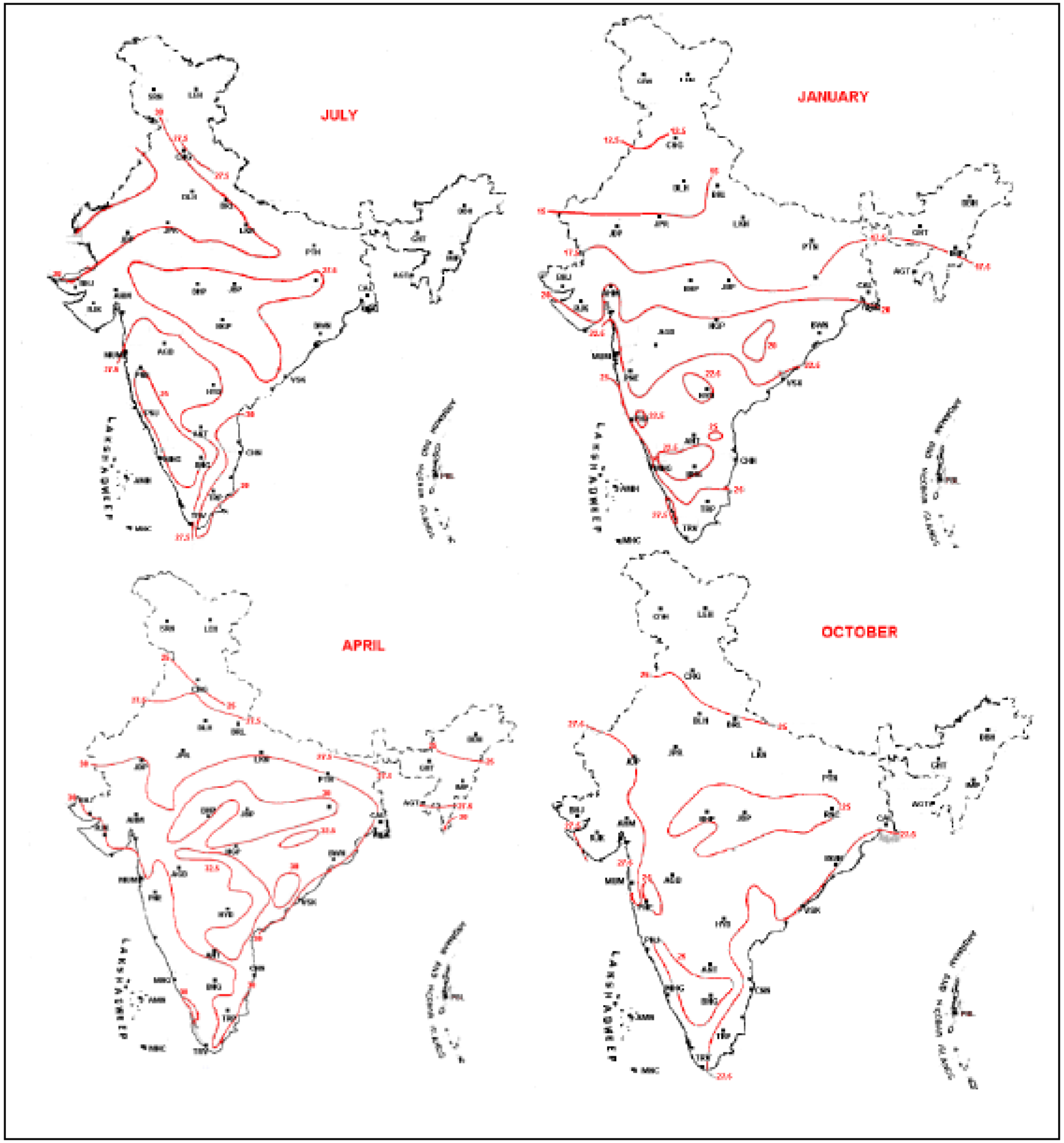
- Indian temperature anomalies are negative for most of the years prior to 1960 and positive in the post 1960 period.

- Since 1991 they are substantially positive and the profile is similar to the Global temperature index indicating the presence of signal on global climate change in India.

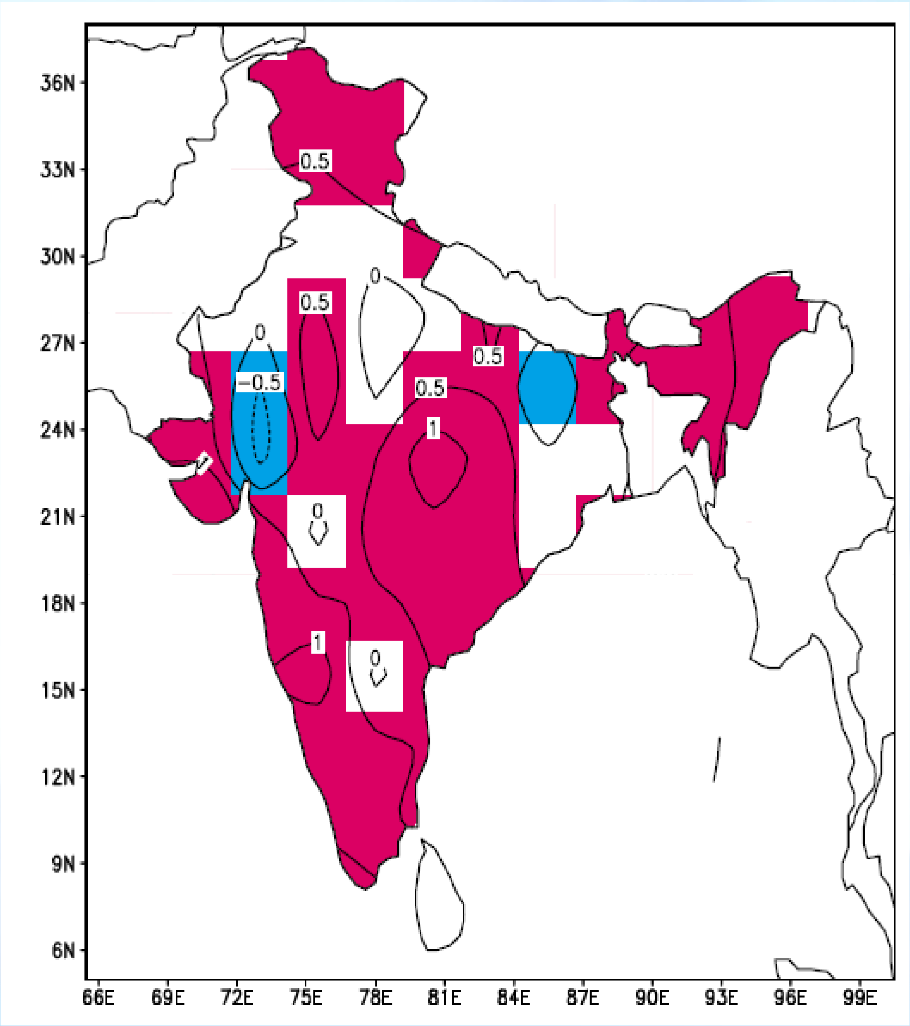
- The temperature rise has been in the order of 0.2 – 0.4°C.

- Temperature rise as manifested over India could be partly due to urban heat island effect as most of the observatories of IMD are situated in towns and cities.

Seasonal temperature distribution
(Source: Climate Profile of India, IMD, 2010)



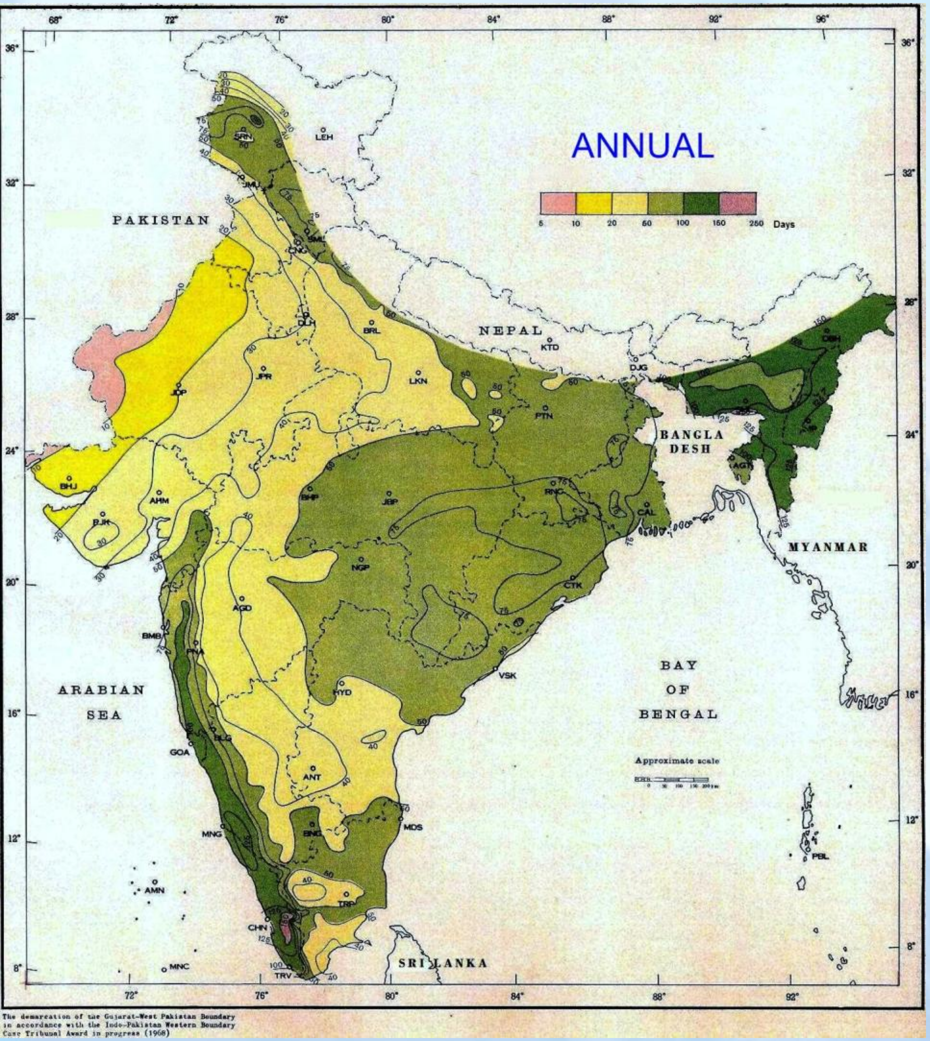
Spatial Pattern of Trend (deg c/100 years) in Mean Annual Temp Anomalies (1901-2009) Significant trends - shaded (red: warming, blue: cooling)

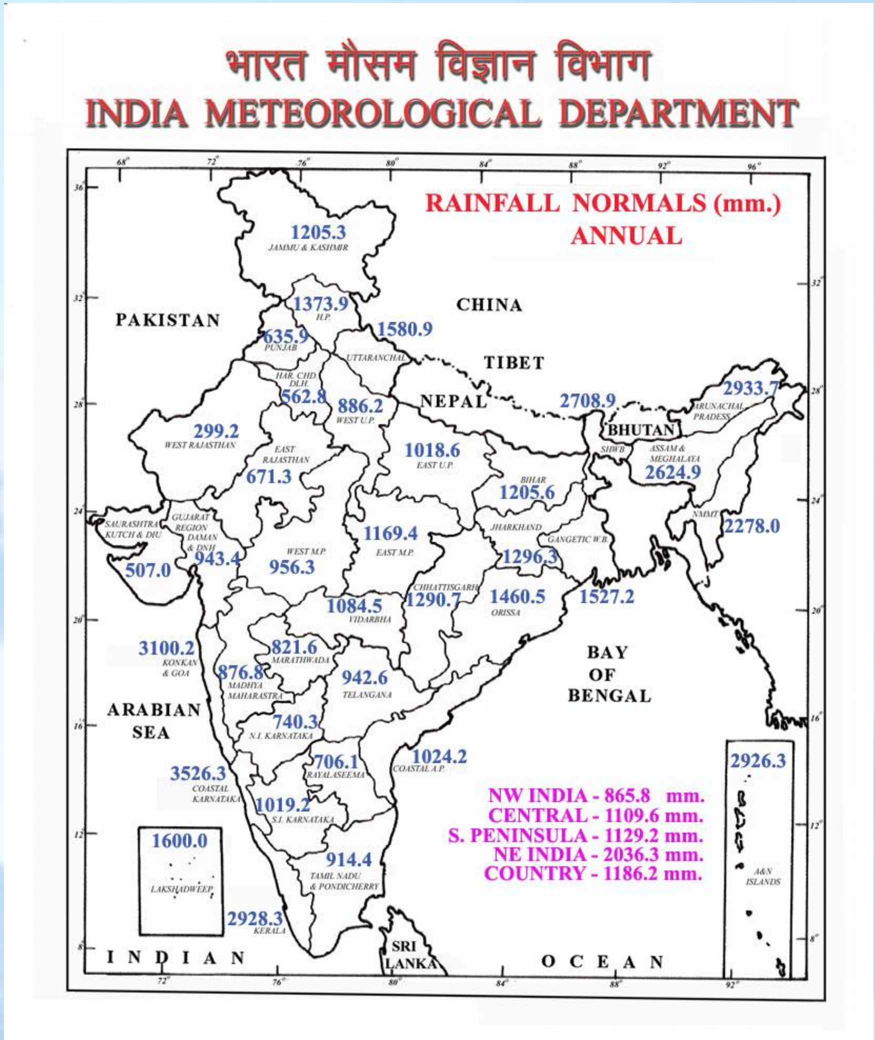


- ❖ In most of the regions there is warming trend save for two regions one over North Gujarat and other over Eastern UP.

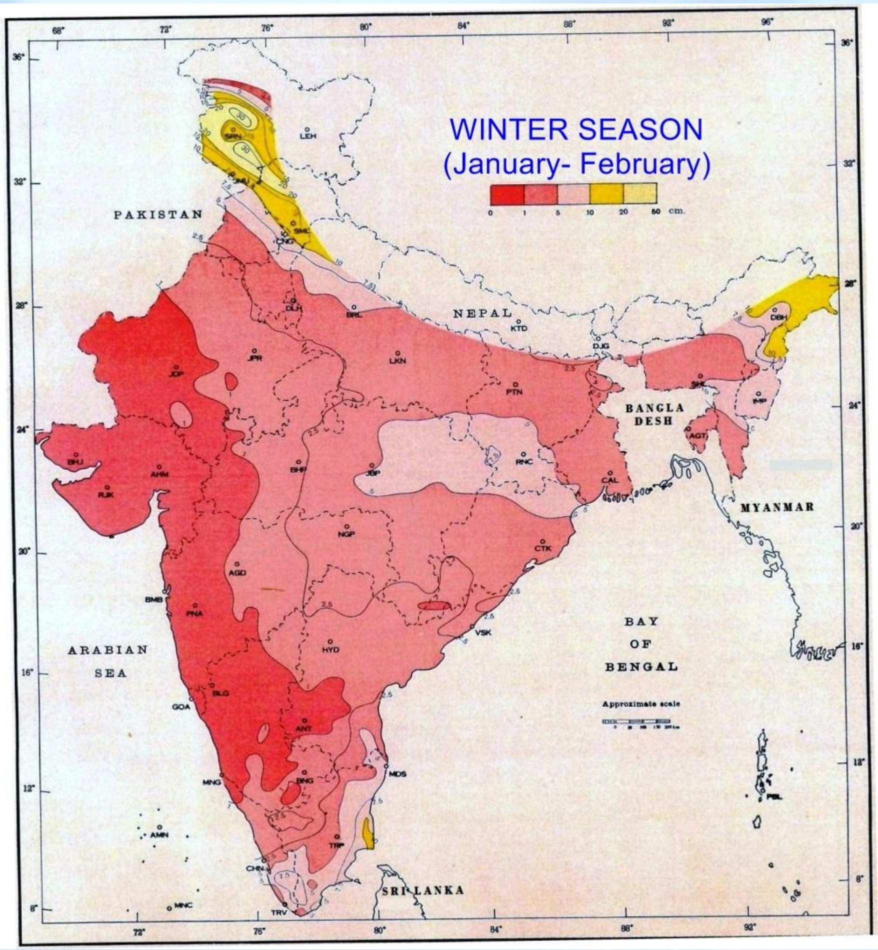
Annual / Seasonal rainfall trends

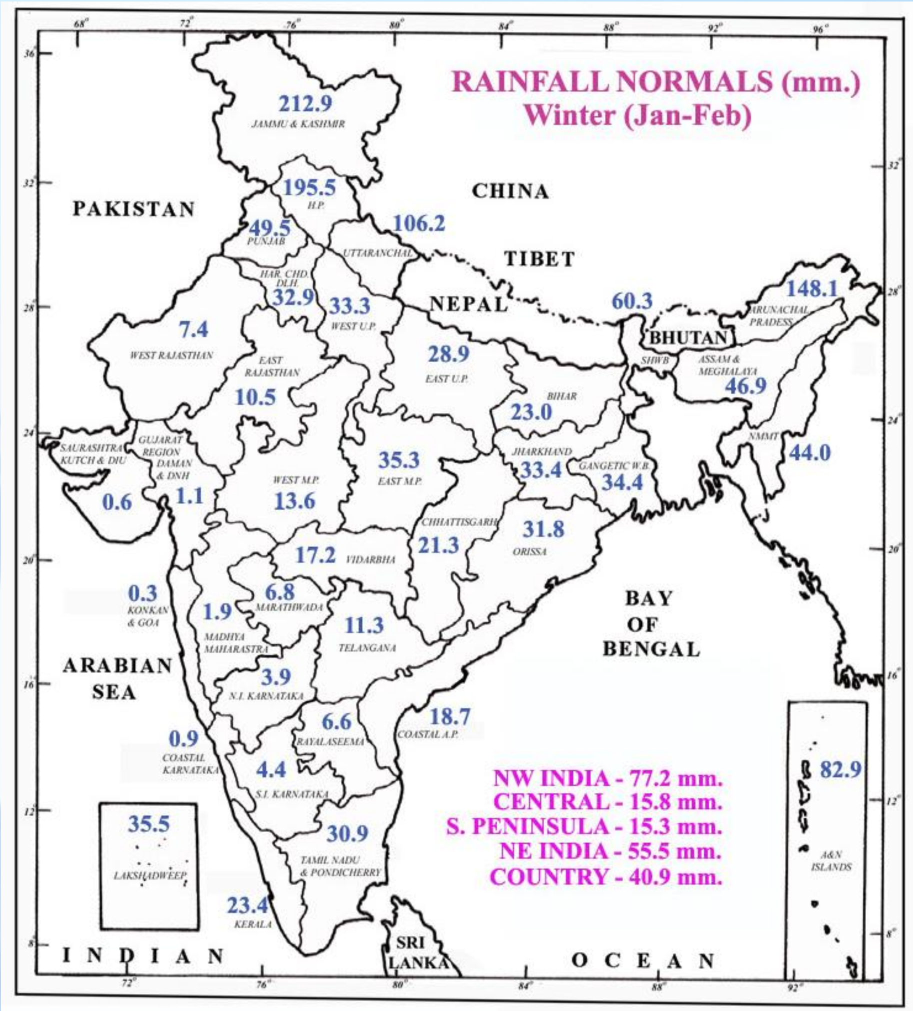
Annual normal rainfall – spatial distribution & sub divisional normals



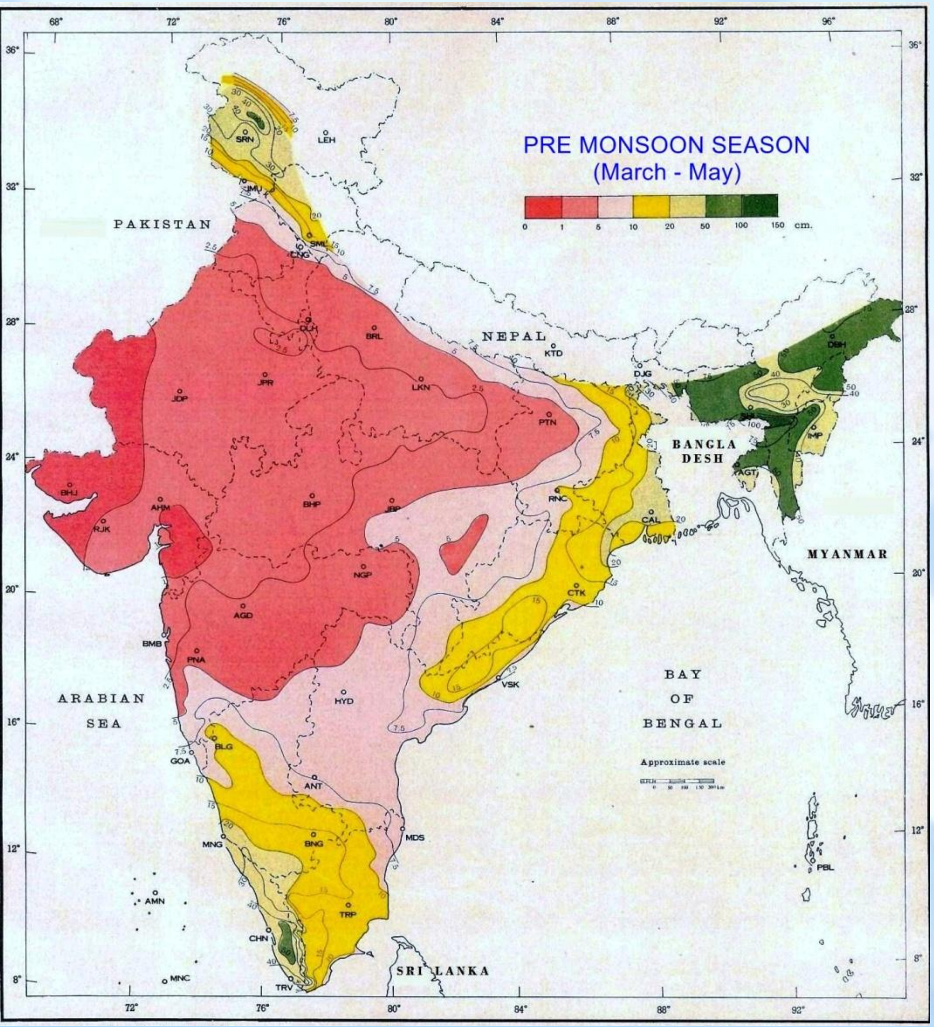


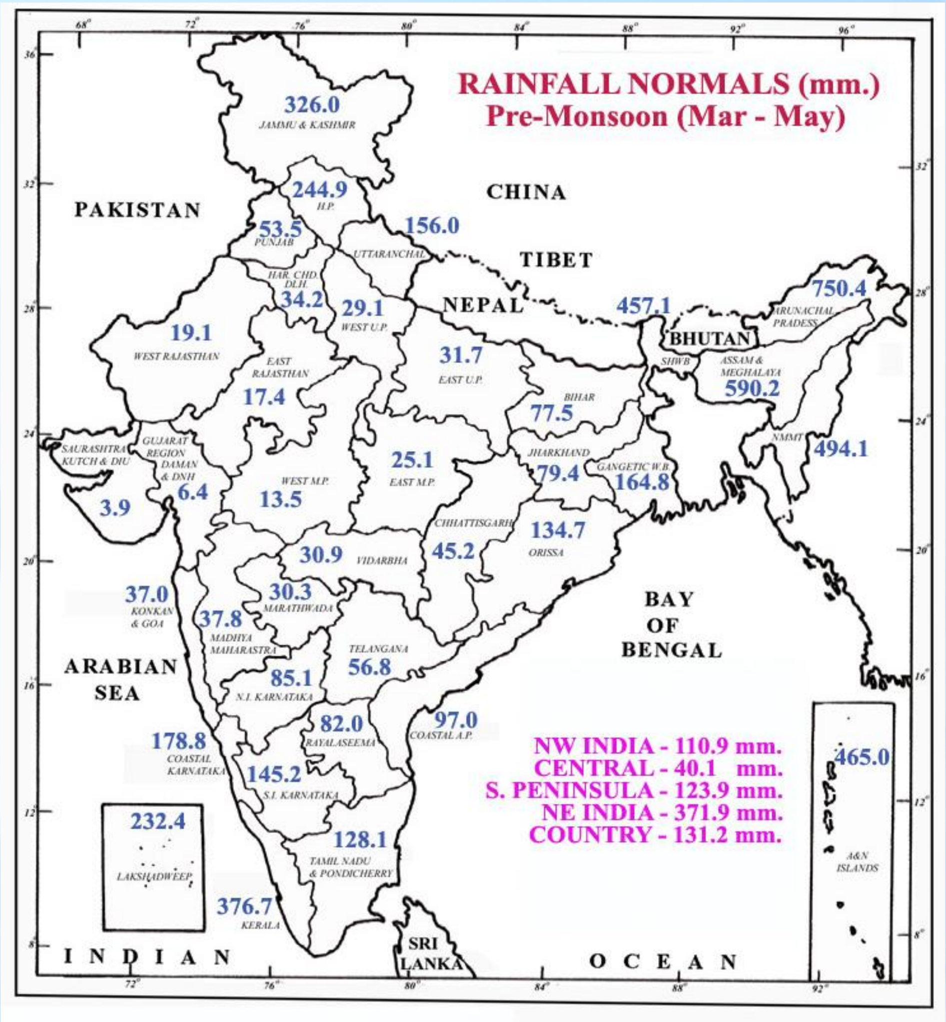
Winter seasonal (Jan-Feb) normal rainfall – spatial distribution & sub divisional normals



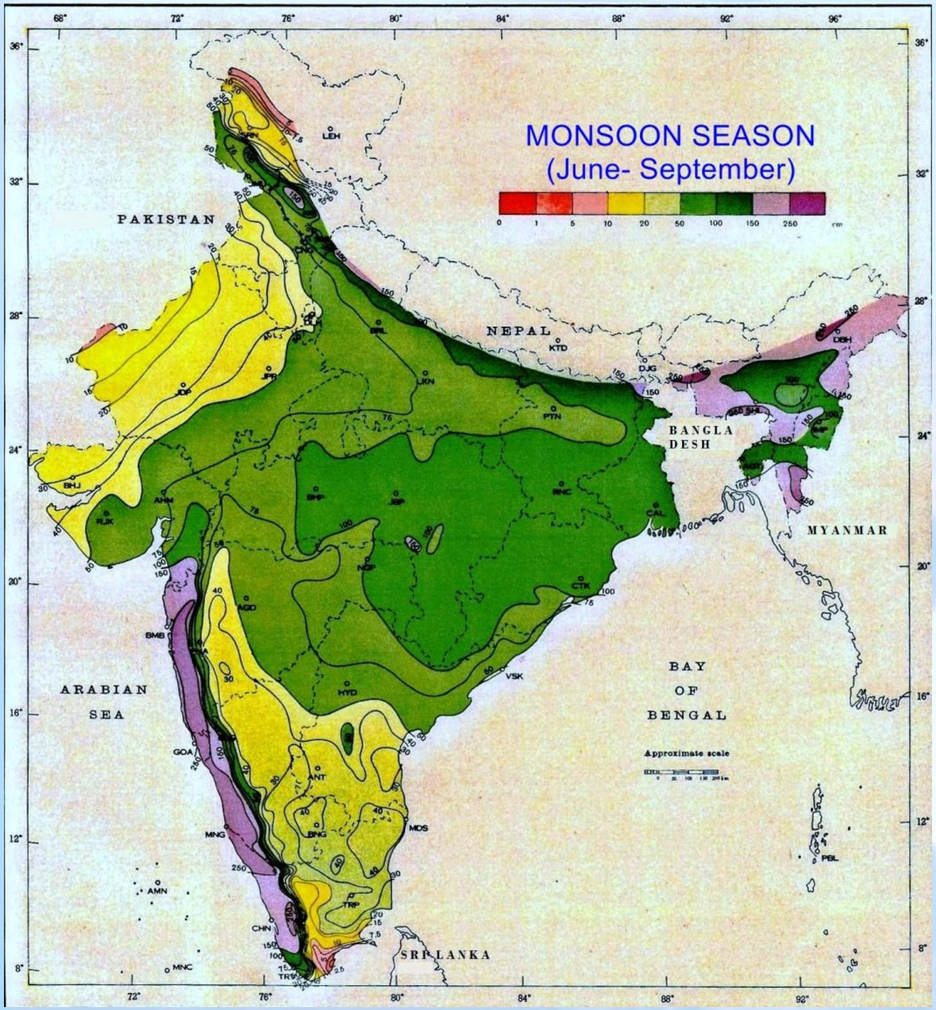


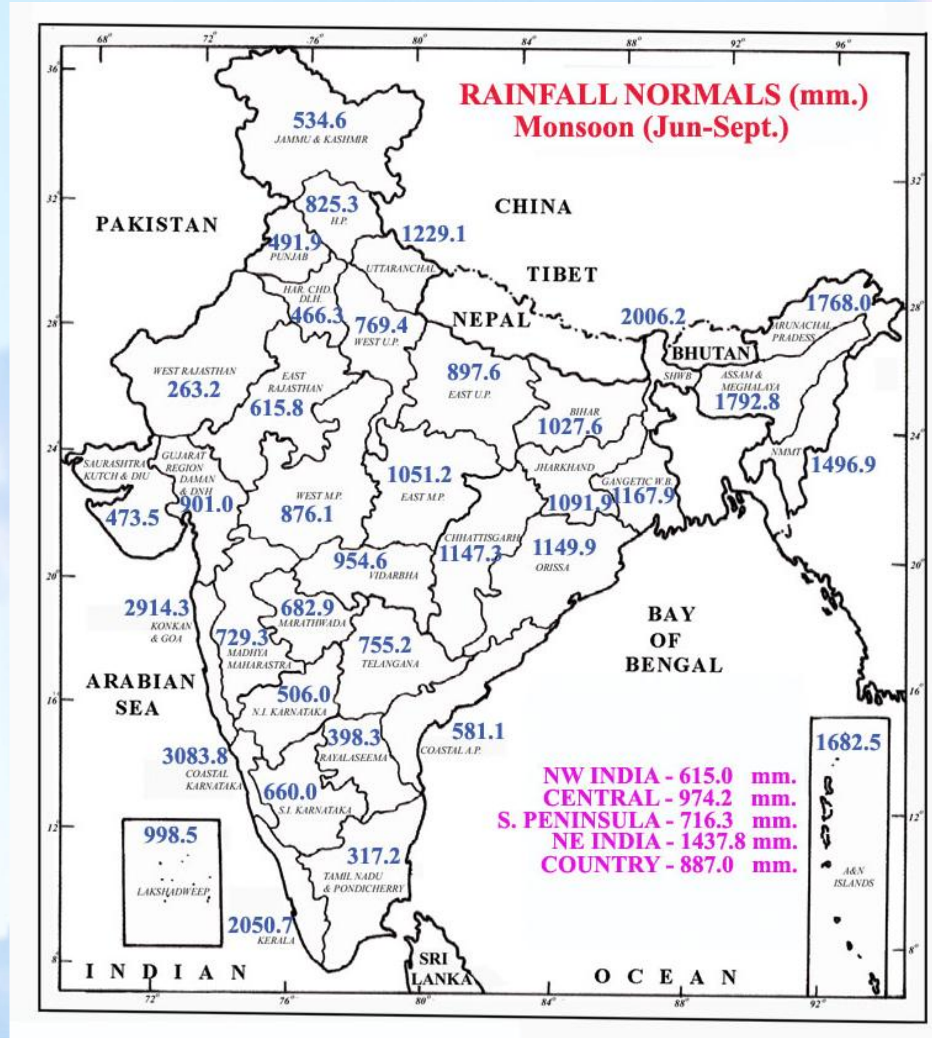
Pre-monsoon seasonal (Mar-May) normal rainfall – spatial distribution & sub divisional normals



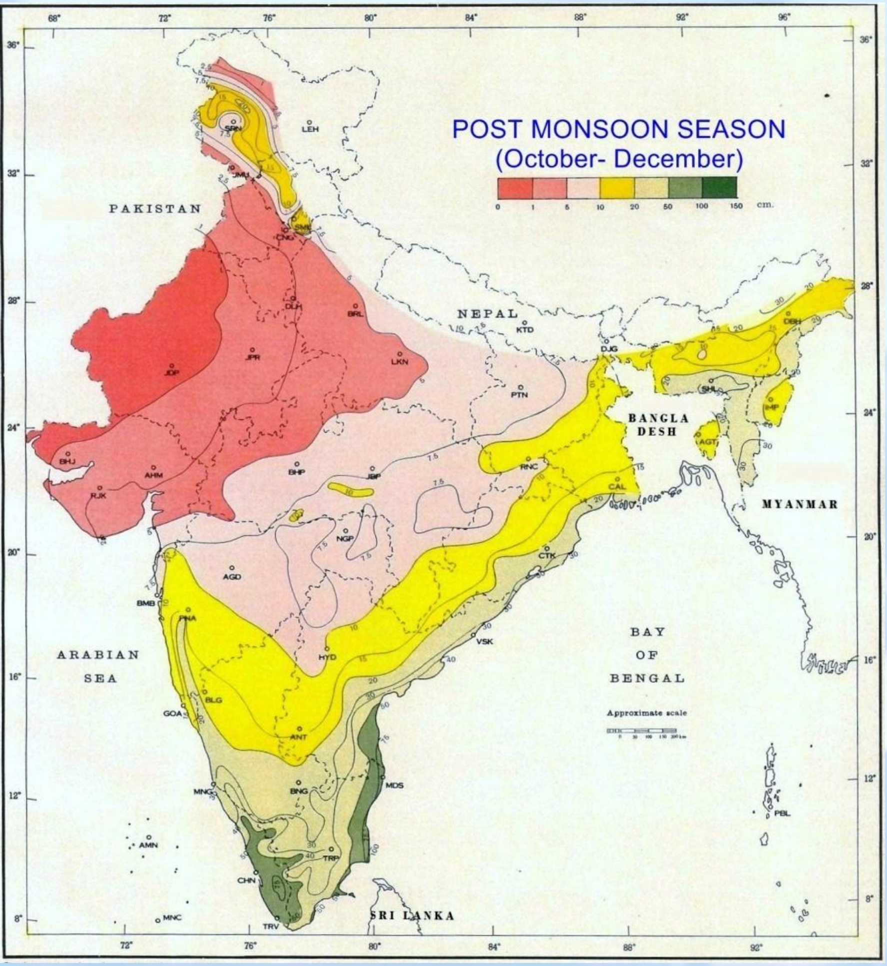


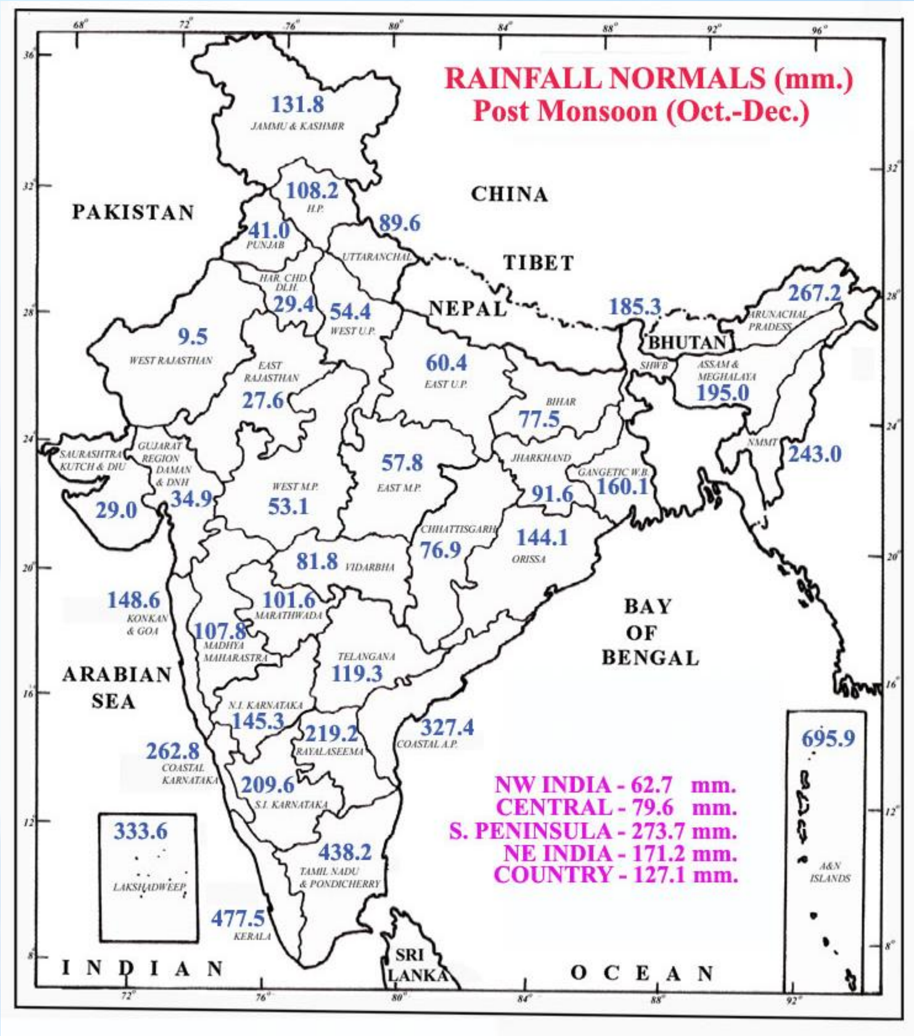
SW Monsoon seasonal (Jun-Sep) normal rainfall – spatial distribution & sub divisional normals



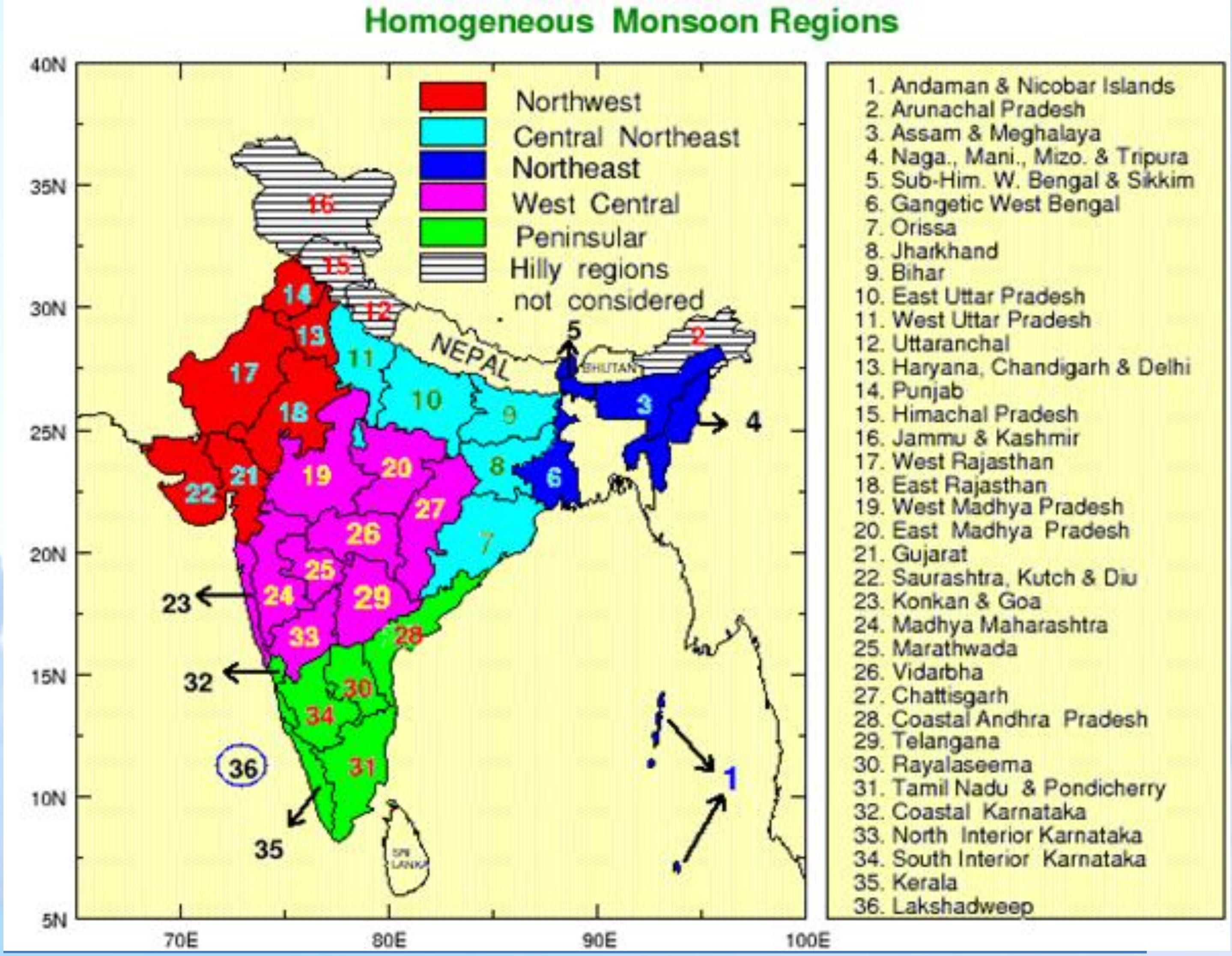


NE Monsoon seasonal (Oct-Dec) normal rainfall – spatial distribution & sub divisional normals





Rainfall


Homogeneous Monsoon Regions
Northwest
Central Northeast
Northeast
West Central
Peninsular
Hilly regions not considered
40N
35N
30N
25N
20N
15N
10N
5N
70E
80E
90E
100E
NEPAL
BHUTAN
SRI LANKA
1. Andaman & Nicobar Islands
2. Arunachal Pradesh
3. Assam & Meghalaya
4. Naga., Mani., Mizo. & Tripura
5. Sub-Him. W. Bengal & Sikkim
6. Gangetic West Bengal
7. Orissa
8. Jharkhand
9. Bihar
10. East Uttar Pradesh
11. West Uttar Pradesh
12. Uttaranchal
13. Haryana, Chandigarh & Delhi
14. Punjab
15. Himachal Pradesh
16. Jammu & Kashmir
17. West Rajasthan
18. East Rajasthan
19. West Madhya Pradesh
20. East Madhya Pradesh
21. Gujarat
22. Saurashtra, Kutch & Diu
23. Konkan & Goa
24. Madhya Maharashtra
25. Marathwada
26. Vidarbha
27. Chattisgarh
28. Coastal Andhra Pradesh
29. Telangana
30. Rayalaseema
31. Tamil Nadu & Pondicherry
32. Coastal Karnataka
33. North Interior Karnataka
34. South Interior Karnataka
35. Kerala
36. Lakshadweep

Trend in annual rainfall of 30 met subdivisions of India during 1871-2011

S. No.	Sub division	Mean (mm)	CV%	CC	t value	Change for 10 years(mm)
1	Assam &M-laya	2337.3	11.6	-0.15	-1.8	-9.9
2	NMMT	1980.8	12.6	-0.19	-2.3*	-11.5
3	SHWB & Sikkim	2503.0	13.2	-0.01	-0.2	-1.0
4	Gangetic WB	1542.1	15.3	0.17	2.0*	9.5
5	Orissa	1481.6	13.3	-0.03	-0.4	-1.6
6	Jharkhand	1341.6	14.8	-0.05	-0.6	-2.6
7	Bihar	1223.9	17.8	-0.04	-0.5	-2.2
8	East Uttar Pradesh	1022.2	20.6	-0.07	-0.8	-3.5
9	West Uttar Pradesh	874.7	20.5	-0.05	-0.5	-2.0
10	Haryana	556.9	25.8	0.11	1.3	3.8
11	Punjab	637.7	27.9	0.14	1.7	6.1
12	West Rajasthan	295.6	37.2	0.06	0.8	1.7
13	East Rajasthan	685.7	25.0	-0.07	-0.8	-3.0
14	West MP	941.0	18.8	-0.07	-0.8	-3.0
15	East MP	1252.3	16.6	-0.20	-2.4 *	-10.1
16	Gujarat	910.3	30.0	-0.01	-0.2	-0.9
17	Saurashtra & Kutch	477.4	42.1	0.09	1.1	4.7
18	Konkan & Goa	2538.8	18.9	0.17	2.0*	20.1
19	M Maharashtra	739.8	19.5	0.04	0.5	1.4
20	Marathwada	831.2	26.1	0.03	0.3	1.5
21	Vidarbha	1084.2	18.8	-0.08	-0.9	-4.0
22	Chattisgarh	1353.3	17.0	-0.27	-3.3**	-15.4
23	Coastal AP	981.7	20.1	0.15	1.7	7.0
24	Telangana	888.4	21.3	0.13	1.5	6.0
25	Rayalaseema	722.3	22.3	0.14	1.7	5.6
26	TNadu&Puduchery	930.9	16.0	0.11	1.3	3.9
27	Coastal Karnataka	3278.0	16.4	0.18	2.1*	23.1
28	NI Karnataka	833.7	17.9	0.10	1.1	3.5
29	SI Karnataka	883.9	17.0	0.06	0.7	2.0
30	Kerala	2827.7	14.6	-0.01	-0.1	-0.5
	India	1087.1	9.3	-0.03	-0.4	-0.8

Spatial Seasonal Rainfall trends

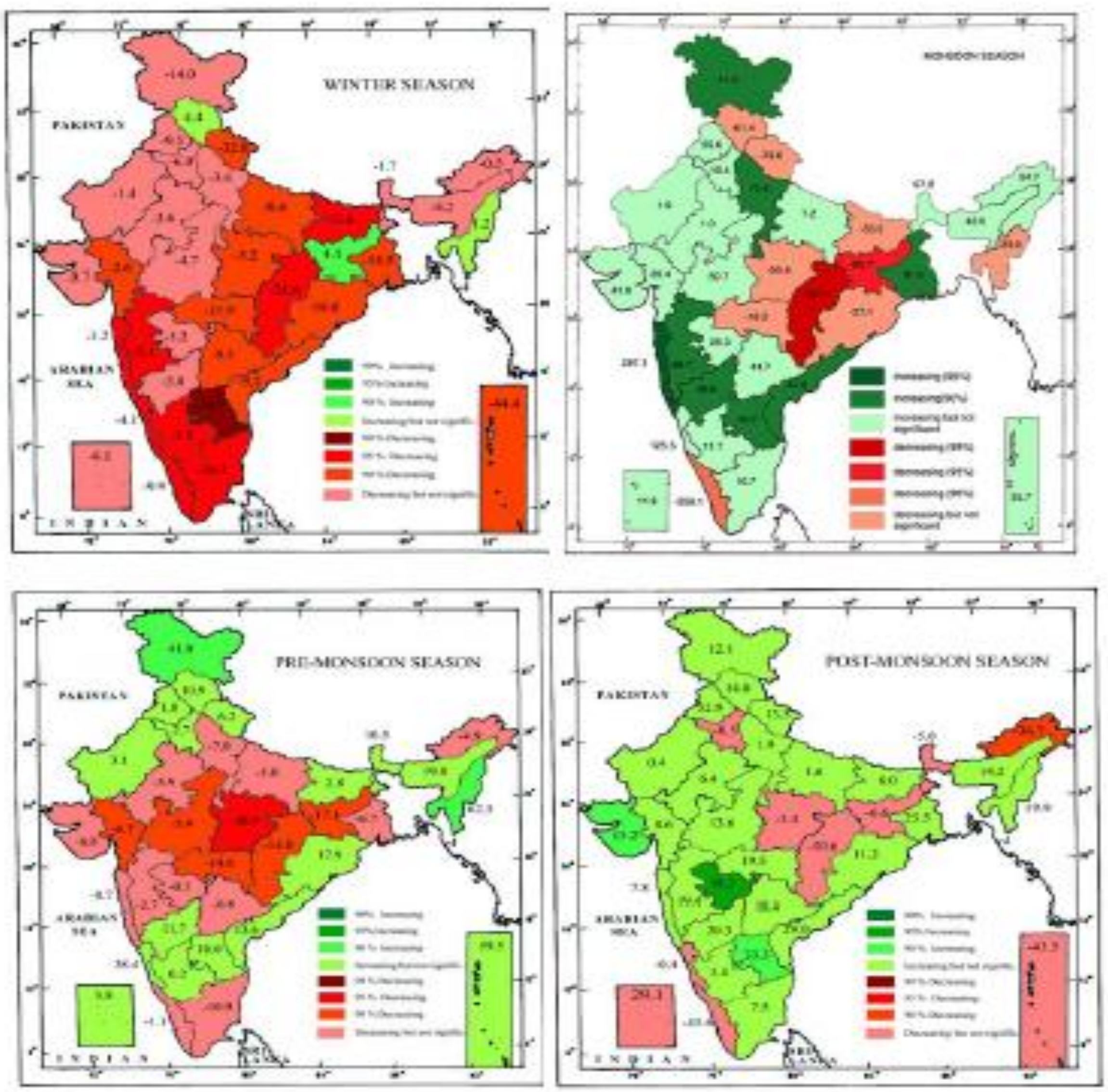


Fig 10: Trend in sub- divisional rainfall data (increase/decrease in rainfall in mm) for different seasons season (1901-2003). Different levels of significance are shaded with colors.

Green: increasing trend
Red: decreasing trend

4 shades: 1%, 5%, 10% LS & Not sig

Spatial Monthly Rainfall trends during SWM season

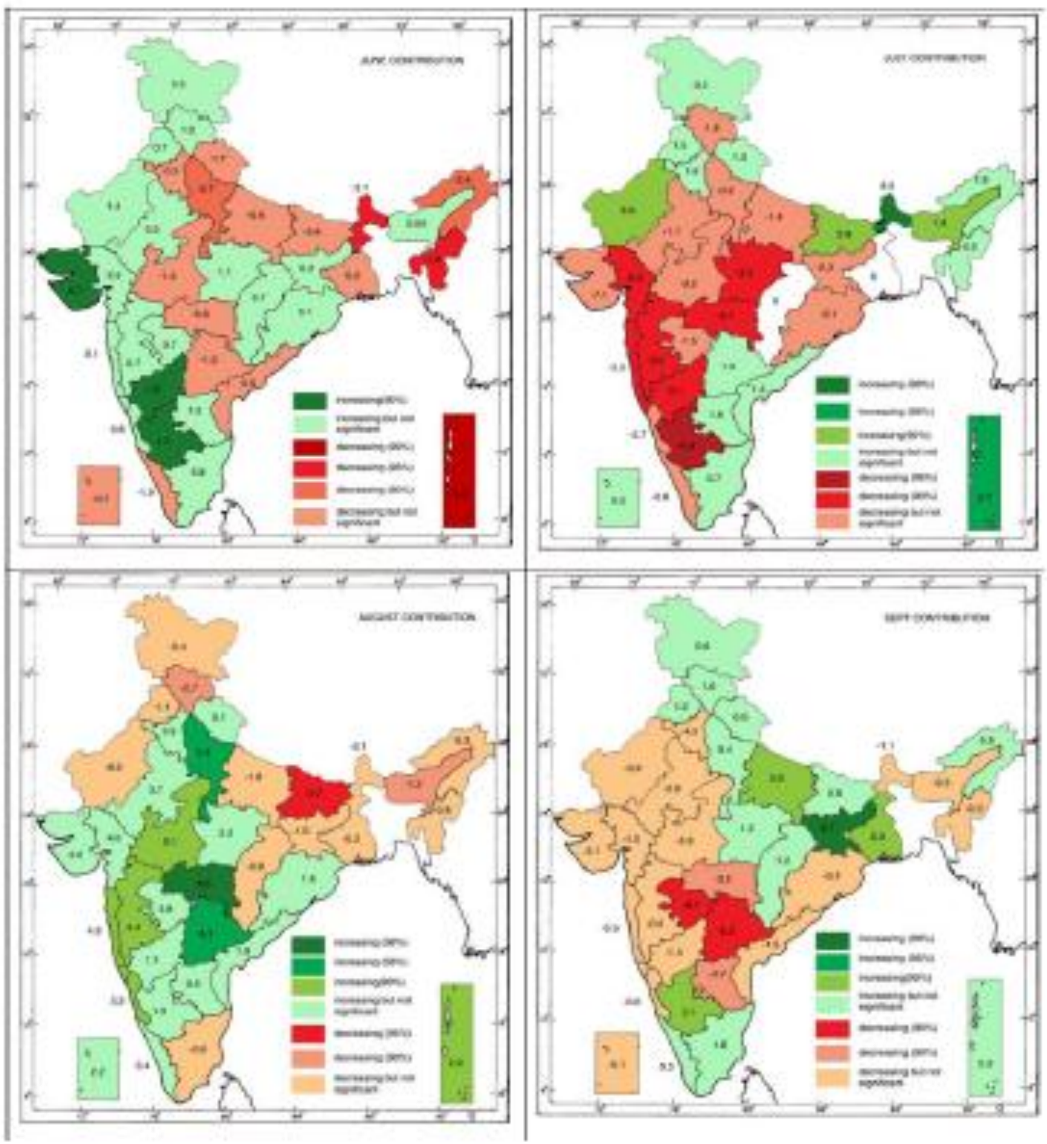
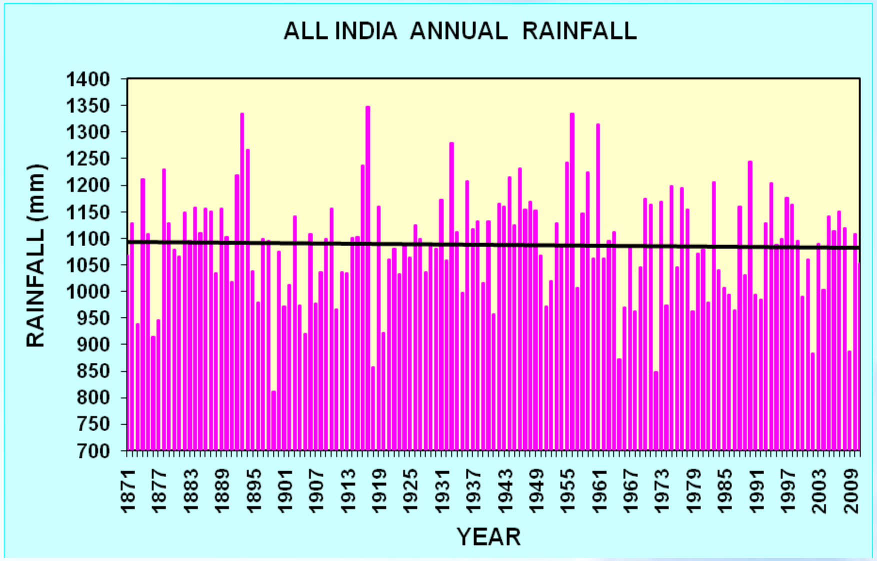


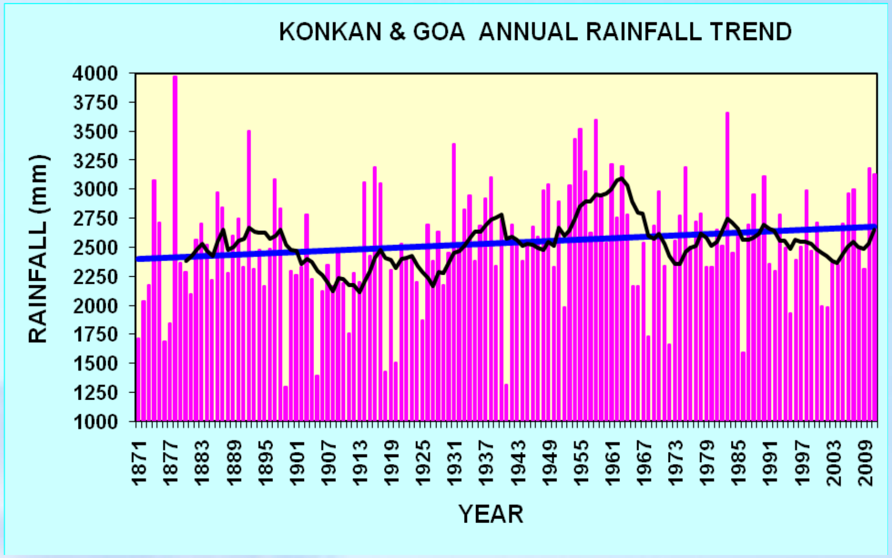
Fig 11: Trend in sub-divisional rainfall data of monsoon months (Increase/Decrease in rainfall in percentage) to annual rainfall (1901-2003).

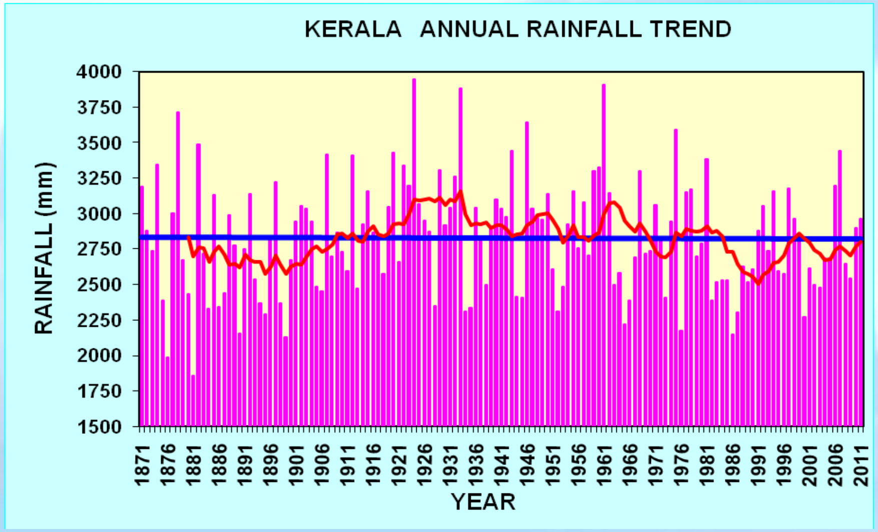
Green: increasing trend
Red: decreasing trend

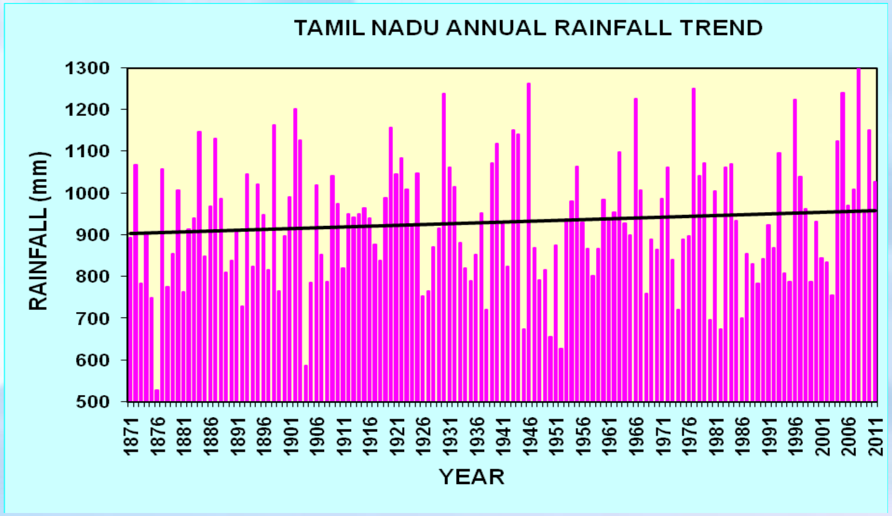
4 shades: 1%, 5%, 10% LS & Not sig

Some annual rainfall trends …









Trend in seasonal rainfall of Kerala during 1871-2011

S. No.	Season	Mean (mm)	CV%	CC	t value	Change for 10 years(mm)
1	JF	28.0	96.0	0.09	1.1	0.6
2	MAM	390.4	40.6	0.06	0.7	2.4
3	JJAS	1924.9	19.0	-0.12	-1.4	-10.9
4	OND	484.4	30.3	0.21	2.5*	7.5

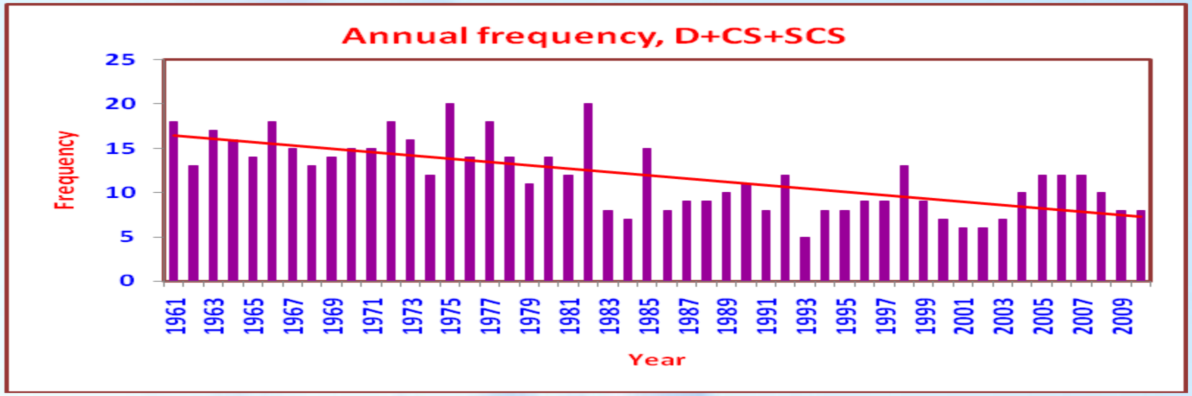
Annual mean rainfall of some stations of Kerala , TN and Karnataka based on the periods 1901-1950 and 1951-2000

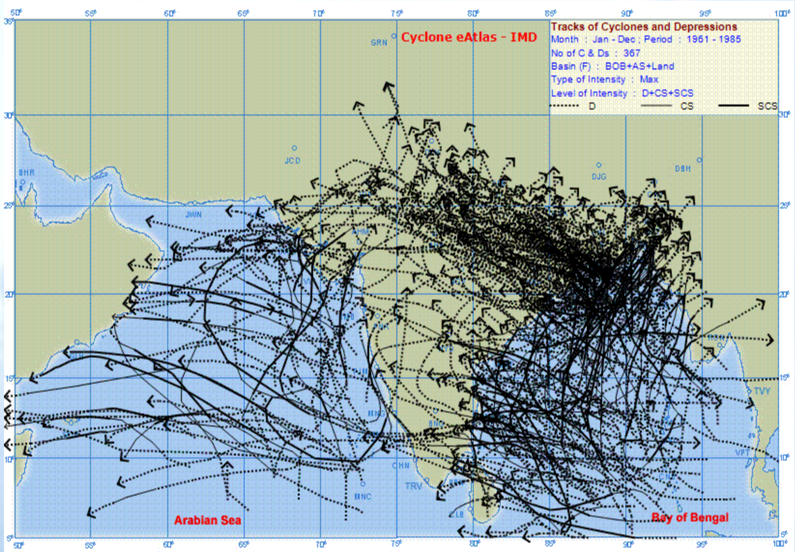
S.No	Station Name	State	Rainfall in mm		Difference
			1901-1950	1951-2000	
1	Thiruvananthapuram	Kerala	1812.1	1792.0	-20.1
2	Kollam	Kerala	2398.1	2357.8	-40.3
3	Alleppy	Kerala	3274.8	3006.1	-268.7
4	Kochi	Kerala	3046.6	3147.2	100.6
5	Calicut	Kerala	3178.1	3175.8	-2.3
6	Kannur	Kerala	3274.4	3256.2	-18.2
7	Kasargode	Kerala	3477.8	3631.3	153.5
8	Palghat	Kerala	2019.4	1999.1	-20.3
9	Munnar	Kerala	3815.9	3744.3	-71.6
10	Peermade	Kerala	5164.8	4427.7	-737.1
11	Punalur	Kerala	3159.4	2760.6	-398.8
12	Tirussur	Kerala	3096.4	3082.3	-14.1
13	Kottayam	Kerala	3261.5	2858.0	-403.5
14	Tiruvalla	Kerala	3093.0	2732.2	-360.8
15	Neyyattinkara	Kerala	1653.9	1622.6	-31.3
16	Pechipara	Tamil Nadu	2292.2	1990.2	-302.0
17	Kuzhithura	Tamil Nadu	1459.5	1326.5	-133.0
18	Chennai	Tamil Nadu	1285.6	1402.7	117.1
19	Madurai	Tamil Nadu	893.9	841.1	-52.8
20	Coimbatore	Tamil Nadu	614.2	613.8	-0.4
21	Mangalore	Karnataka	3397.9	3633.6	235.7
22	Bangalore	Karnataka	888.9	977.4	88.5
23	Karvar	Karnataka	3074.6	3238.7	164.1
24	Udipi	Karnataka	3739.1	3949.5	210.4

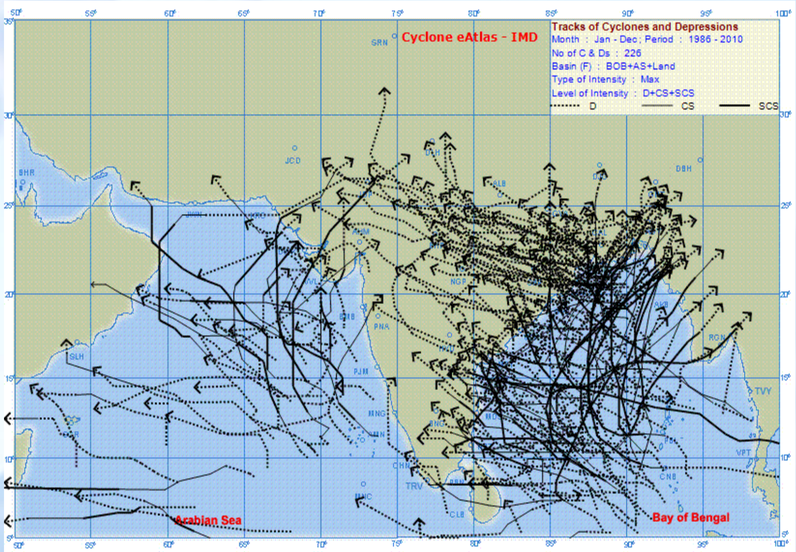
Trends in frequency of cyclones and depressions over Indian seas, 1961-2010

Season	Category	Mean	CC	*t* – value	Change in 10 years	Freq 1961-85	Freq 1985-2010
Annual (Jan-Dec)	D+CS+SCS	11.9	-0.67	6.6**	-1.86	367	226
Annual	SCS	3.0	-0.47	3.7**	-0.54	94	55
Jun-Sep	D+CS+SCS	5.5	-0.64	5.7**	-1.21	184	90

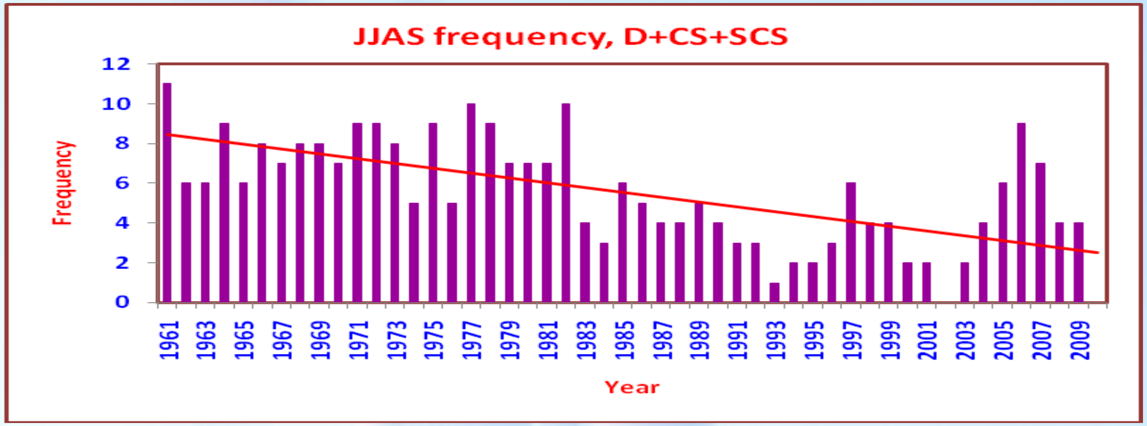
Trends in freq of C&Ds 1961-2010 Tracks of 1961-1985 & 1986-2010

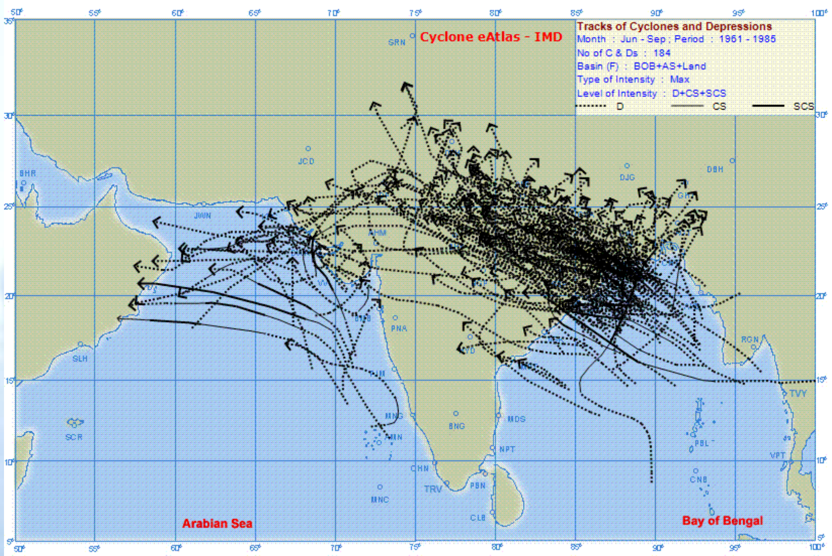


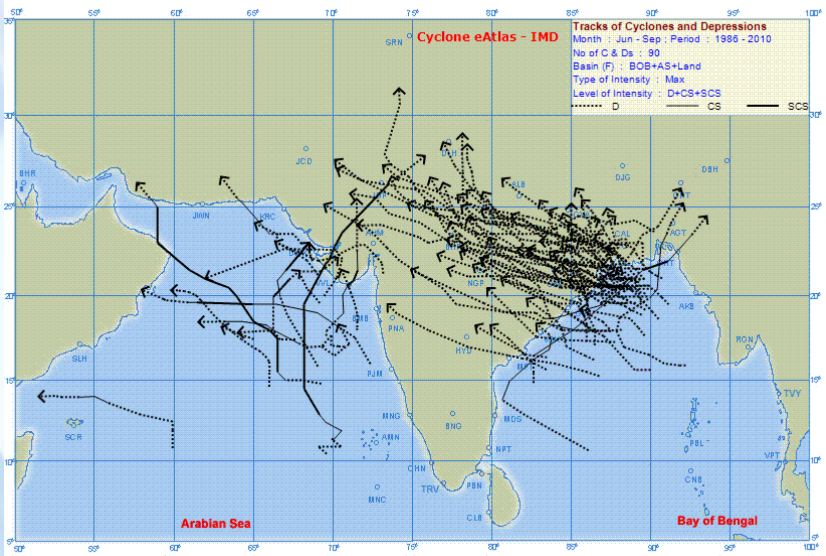




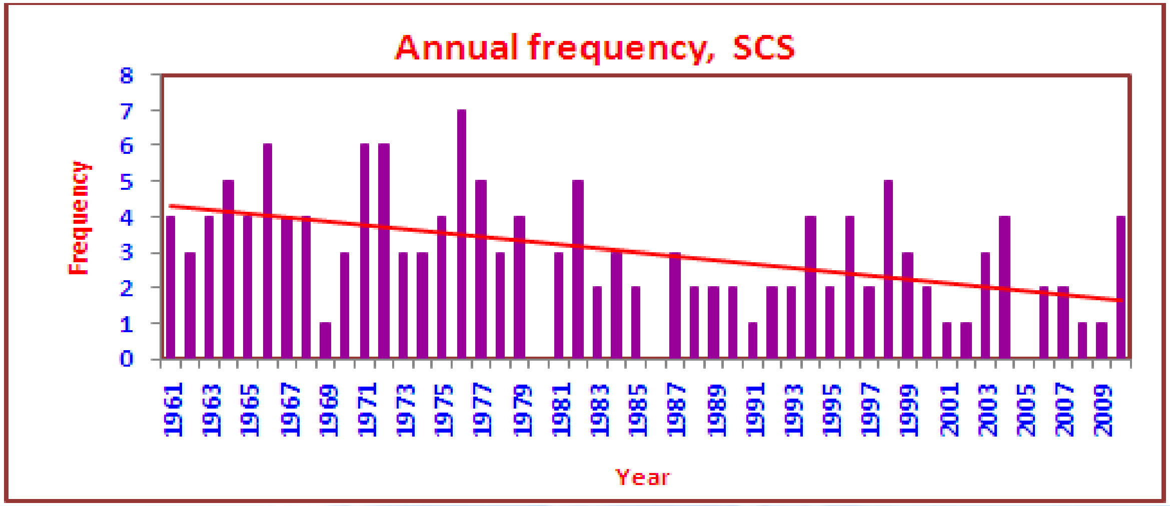
Trends in freq of C&Ds 1961-2010 Tracks of 1961-1985 & 1986-2010

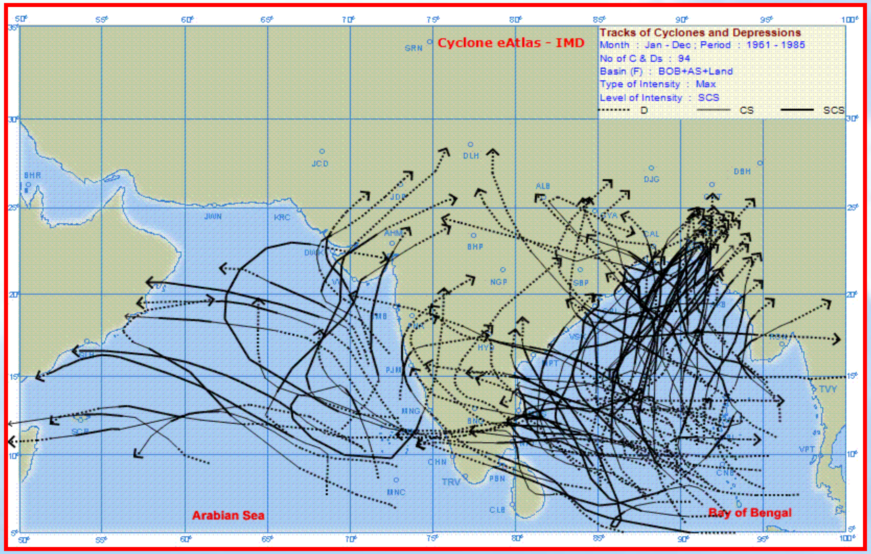


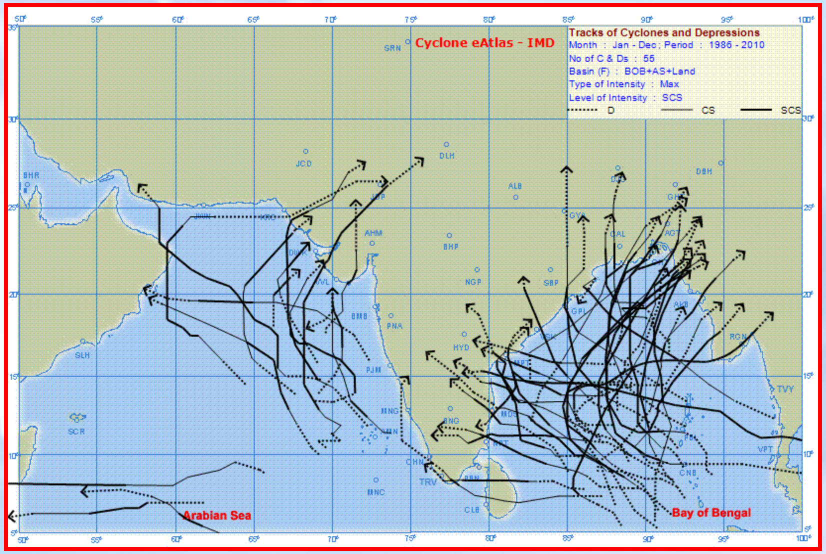




Trends in freq of SCS 1961-2010 Tracks of 1961-1985 & 1986-2010







Observation on Environment- Status in IMD

Global Atmospheric Watch stations

- A network of 10 GAW stations maintained by IMD since 1974.

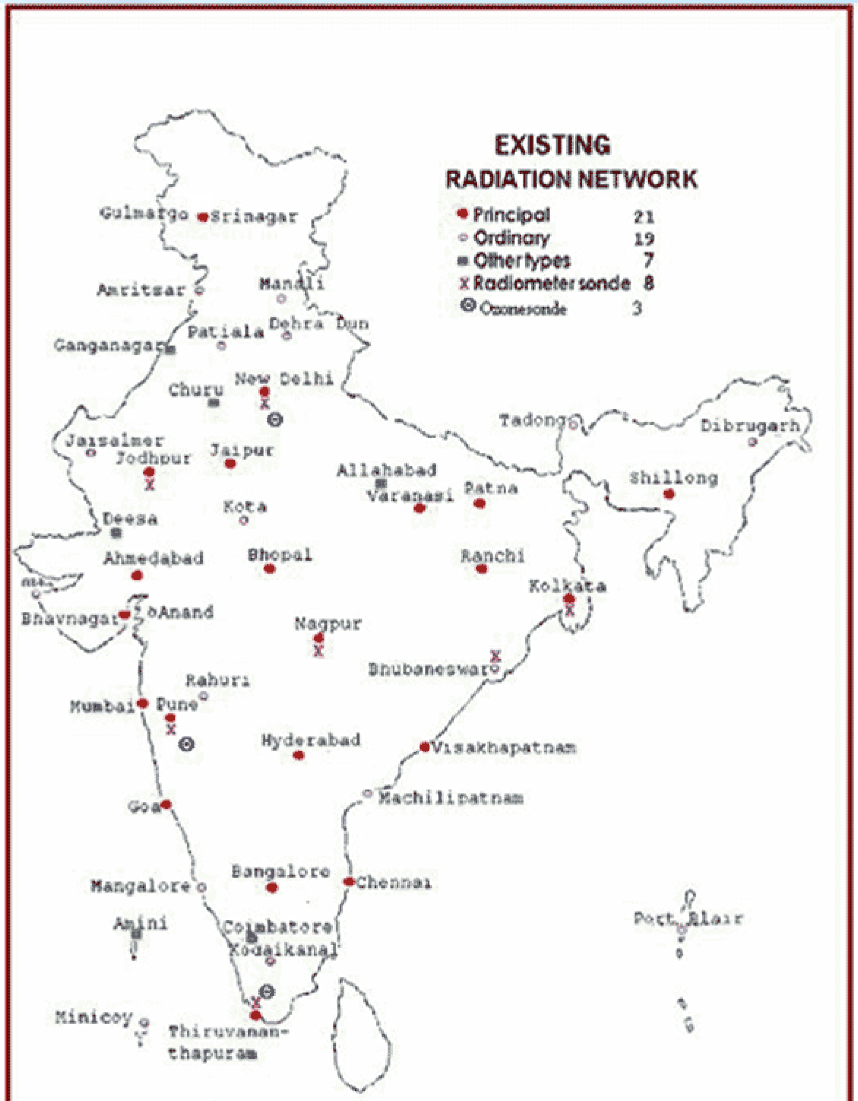
- Generates data/ info on exchange of trace materials between the atmosphere and earth's surface

- Mesures atmospheric turbidity and air quality measurements to quantify trends and acid rain threats.

- All GAW stations except Jodhpur indicate lowering trend of rainwater pH (increasing acidity)

- Sig increase in atm turbidity (indicator of aerosol concentration)

Radiation



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Radiation

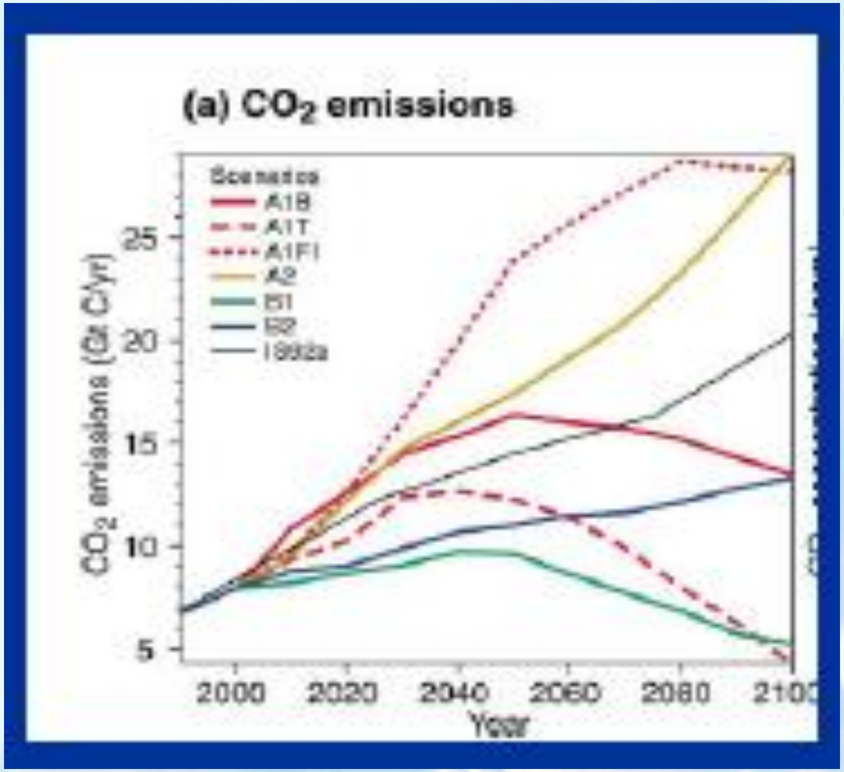
Long-term mean values and trend analyses of global irradiance (G), diffuse irradiance (D) and daily bright sunshine duration (S) in India under all sky conditions for 1971-2009. Trend values in bold are statistically significant.

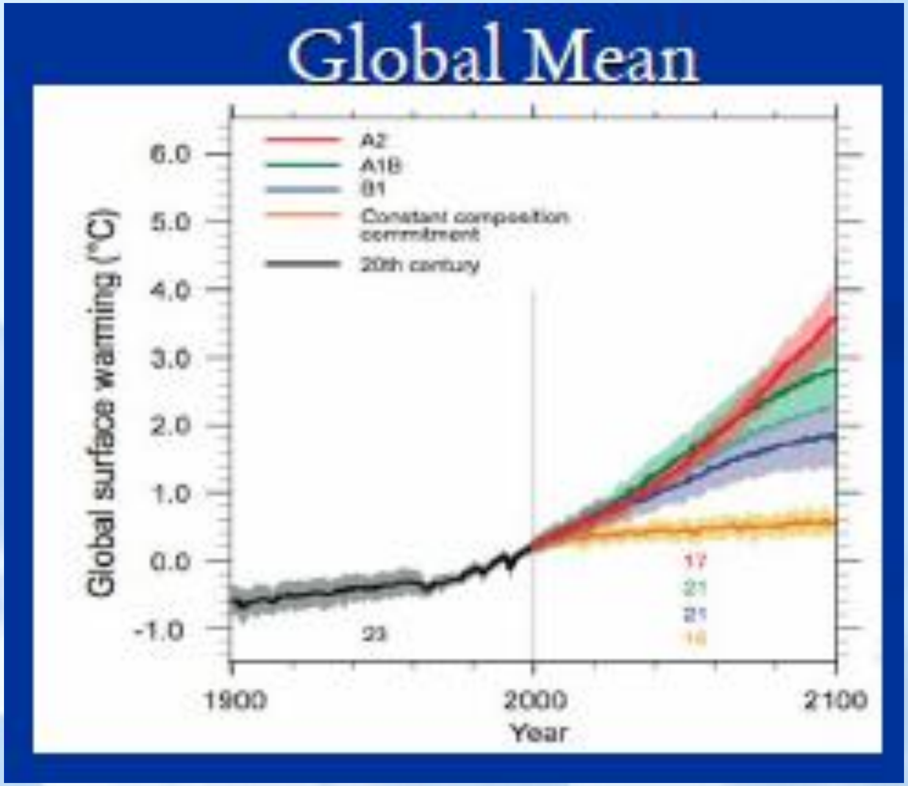
Station Name	Long-term Mean (Standard Deviation)			Trend (% per decade)		
	G (Wm^{-2})	D (Wm^{-2})	S (Hours)	G	D	S
Ahmedabad	226.2 (11.7)	87.6 (4.6)	8.2 (0.3)	**-3.3**	0.4	-1.3
Jodhpur	228.4 (12.1)	85.2 (5.2)	8.5 (0.4)	**-3.6**	0.8	0.0
Delhi	216.2 (10.2)	93.4 (3.8)	7.5 (0.7)	**-3.4**	0.4	**-6.3**
Kolkata	191.4 (10.5)	95.5 (5.0)	6.1 (0.6)	**-4.1**	-0.4	**-3.5**
Chennai	224.8 (7.7)	98.4 (6.8)	7.4 (0.4)	**-1.7**	**2.1**	**-3.6**
Mumbai	215.4 (8.5)	92.7 (4.9)	7.3 (0.4)	**-2.4**	**1.6**	-0.4
Nagpur	214.6 (7.1)	88.1 (4.8)	7.5 (0.5)	**-2.0**	**2.2**	**-2.4**
Pune	228.7 (8.6)	88.6 (3.5)	7.8 (0.4)	**-1.5**	-1.4	**-2.5**
Panjim	228.3 (12.2)	95.7 (5.1)	7.6 (0.4)	**-2.0**	**1.7**	**-2.8**
Shillong	191.0 (8.6)	90.6 (3.7)	5.7 (0.3)	-0.1	0.5	**-2.4**
Trivandrum	226.1 (11.4)	101.1 (3.6)	6.3 (0.4)	**-3.4**	0.8	**-3.0**
Visakhapatnam	218.5 (10.8)	94.3 (5.3)	7.2 (0.6)	**-3.9**	1.0	**-5.7**

Ozone studies

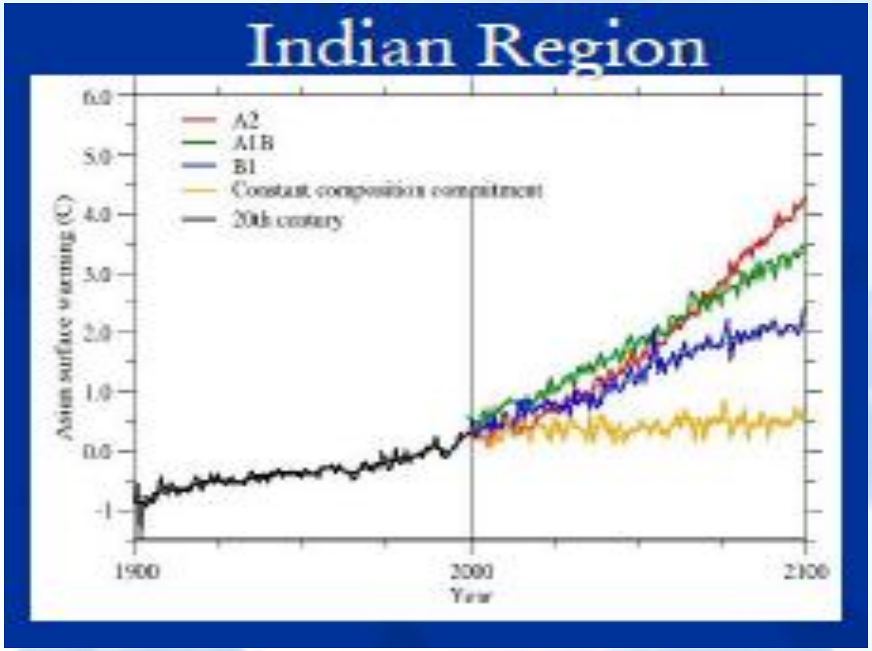
- Antarctic ozone studies (Maitri)
- From Equator to 20˚N, the troposphertic ozone concentration remains practically the same throughout the year.
- Total ozone observations are taken daily at Delhi, Varanasi, Pune and Srinagar.
- Vertical distribution of ozone is measured by balloon-borne ozonesonde (IMD-made) at fortnightly frequency at Delhi, Pune and TRV.
- Surface ozone measurement s are taken at Delhi, Nagpur, Pune, Kodaikanal, TRV
- Max ozone concentration of the order of 150μmb occurs at a height of 26-27 km over TRV, 25-26 km over Pune and 23-25 km over New Delhi.

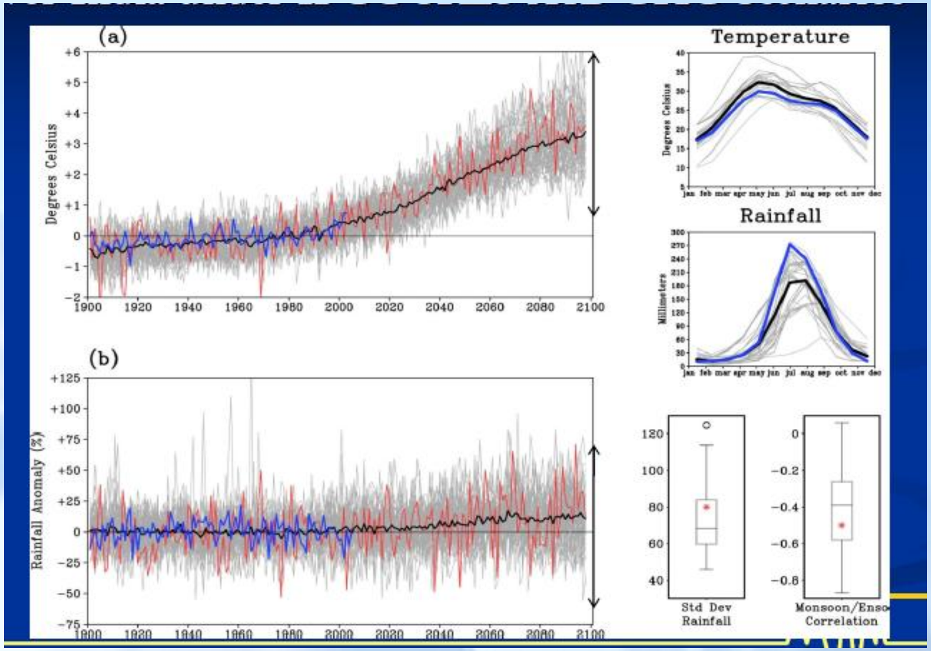
Climate change Projections
(4^{TH} Assessment Report – IPCC)





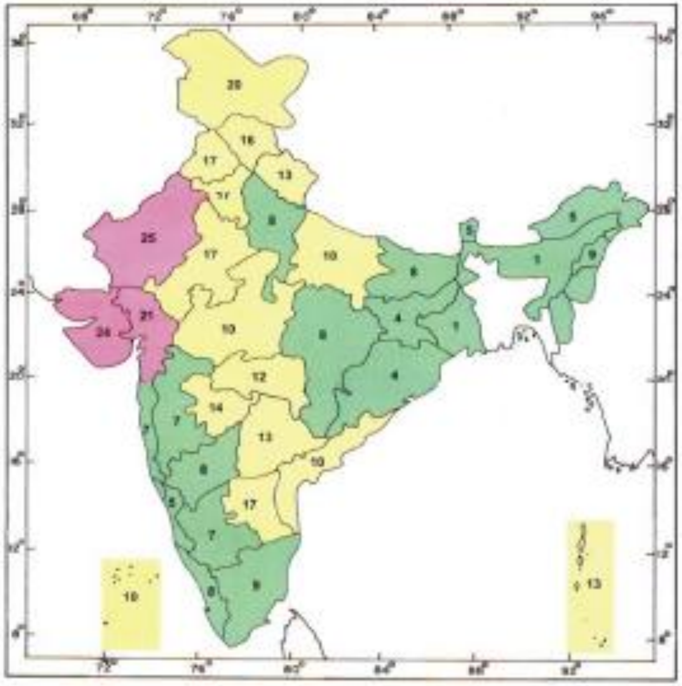
Climate change Projections for INDIA (4TH Assessment Report – IPCC)





Climate change Impact on Indian Agriculture

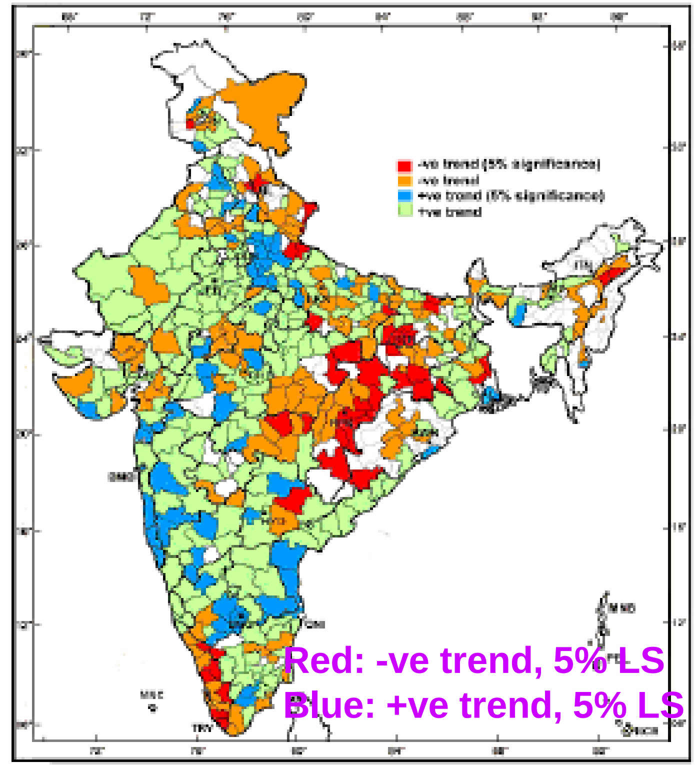
Probability of occurrence of drought (%) & District-wise Standardised precipitation Index (SPI) (Source: Climate profile of India, IMD, 2010)



PROBABILITY OF OCCURRENCE OF DROUGHT (%) AND DROUGHT PRONE AREAS 1875 - 2004

- CRONICALLY DROUGHT PRONE AREA (PROBABLITY OF OCCURRENCE OF DROUGHT MORE THAN 20%)
- FREQUENTLY DROUGHT PRONE AREA (PROBABLITY OF OCCURRENCE OF DROUGHT 10% TO 20%)
- LEAST DROUGHT PRONE AREA (PROBABILITY OF OCCURRENCE OF DROUGHT LESS THAN 10%)

Fig. 32: Probability of Occurrence of Drought and Drought Prone areas during 1875-2004



Red: -ve trend, 5% LS
Blue: +ve trend, 5% LS

Fig 35: Long-term linear trends in the district-wise SPI during the period 1901-2003

Impact on Indian Agriculture….

- Indian economy is basically agriculture oriented.
- The average food consumption in India is at present 550 gm per capita per day much lower than the figures of 980 gm and 2850 gm in China and USA resp.
- The present total production of food grains in the country is nearly 25 crore tons.
- India has been adding nearly 1.5 crore per year of population to its already large population which may not stabilise in the near future.
- Due to urbanisation and industrialisation, the total area of arable land has been decreasing.
- In India 60% of the total cropped area is rain fed and only remaining 40% is under irrigation.
- The dependence of Indian agriculture on climate, weather, rainfall and the timeliness of rainfall is substantial.

Impact on Indian Agriculture….

- ✓Estimating the effect of climate change on crop production is a difficult task due to the variety of crops, cropping systems and the levels of technology.
- ✓The two crop growing seasons in India are Kharif (June-September) and Rabi (October-November).
- ✓Detailed studies and simulations by agricultural experts suggest that increase of CO_2 in the atmosphere will increase the primary productivity of plants, but due to increase of temperature the productivity will decline.
- ✓The wheat crop could decrease by 600 $/m^2$ with every 1°C increase in mean temperatures.
- ✓A 2°C increase in mean air temperature could decrease rice yield by about 0.75 ton / hectare in high yield areas.
- ✓A 0.5°C increase in winter temperature would reduce wheat crop duration by 7 days and reduce yield by 0.45 ton/ hectare, i.e. by nearly 10%.

Impact on Indian Agriculture….

- Aggarwal (2009) projects that increase in CO_2 to 550 ppm will increase yields of rice, wheat and oil seeds by 10-20% but 1°C increase in mean temperature will reduce the yield by 3-7%.

- The loss will be much higher at higher temperatures, i.e. upto 10-40% by 2100.

- There could be some improvement in rabi, maize, sorghum, millets and coconut, less loss in potato, mustard and vegetables due to reduced frost.

- The loss of milk is estimated at 15 lakh tones. The apple production over Himachal Pradesh is expected to decrease evidently due to inadequate chilling.

Concluding remarks

- The scenario of significant climate change especially global warming is now well documented and the evidence incontrovertible.

- Regarding change in other crucial parameters such as rainfall and occurrence of cyclonic storms, there appears to be no clear signal over the Indian region.

- Projected climate change over India based on various models suggest steady increase in temperature and at a later stage slight increase of rainfall.

- The effect on agriculture is likely to be mixed.

- The increase in CO_2 initially favouring increase agricultural production but increase in temperature decreasing the same.

Concluding remarks …

- Considering that India has a very huge and rising population to feed, even a nominal persistent decrease in food production will lead to adverse consequences.

- Climatic change mitigation measures are frequently linked to the standard of living of masses and there is apprehension that stringent measures to curb warming will adversely impact on the poor of the developing countries.

- Obviously the situation is fluid and contradictory and calls for learned and measured responses based on scientific facts free from transnational political compulsions

Thank You