Climate change impacts and Vulnerability Assessment for Odisha

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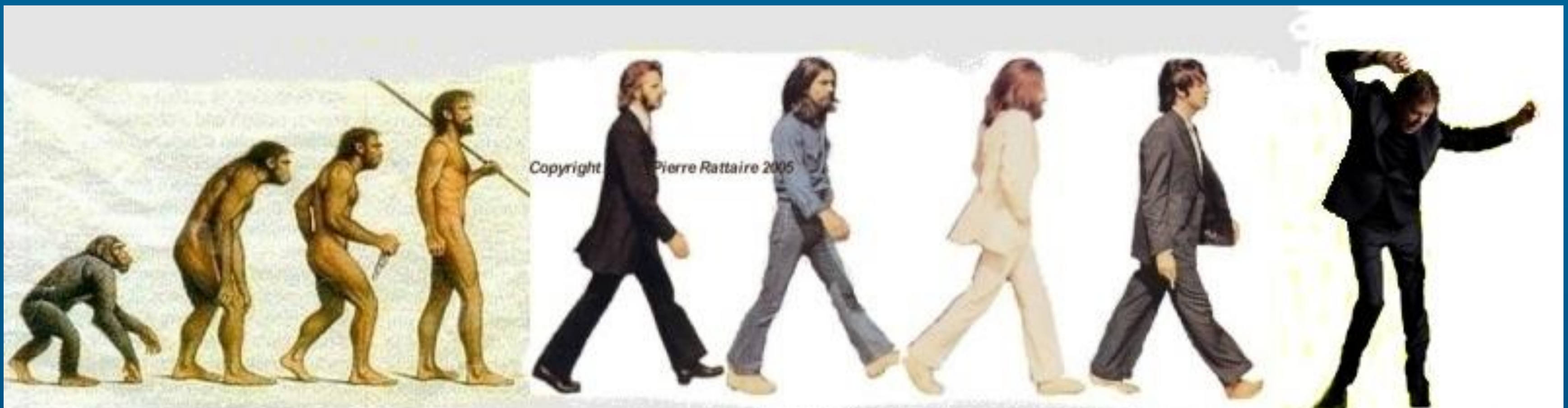
OUTLINE

- Introduction
- Forcing behind climate change(Natural & Anthropogenic)
- Observational evidence for climate change: at global and regional scales
- Assessment of vulnerability in Odisha:
  - Tropical Cyclone
  - Flood & drought
  - Heatwave
  - Coastal erosion
- Future climate and possible impacts(India & Odisha)
- Climate resilient actions

INTRODUCTION

- Climate change reduces resilience of and increases the human vulnerability
- Those with least resources have least capacity to adapt and are most vulnerable.
- Climate change brings loss in functional biodiversity and pose threat to food security
- Extreme weather events, a manifestation of climate change, significantly increases the human suffering due to loss of life and property

CLIMATE CHANGE AND DEVELOPMENT

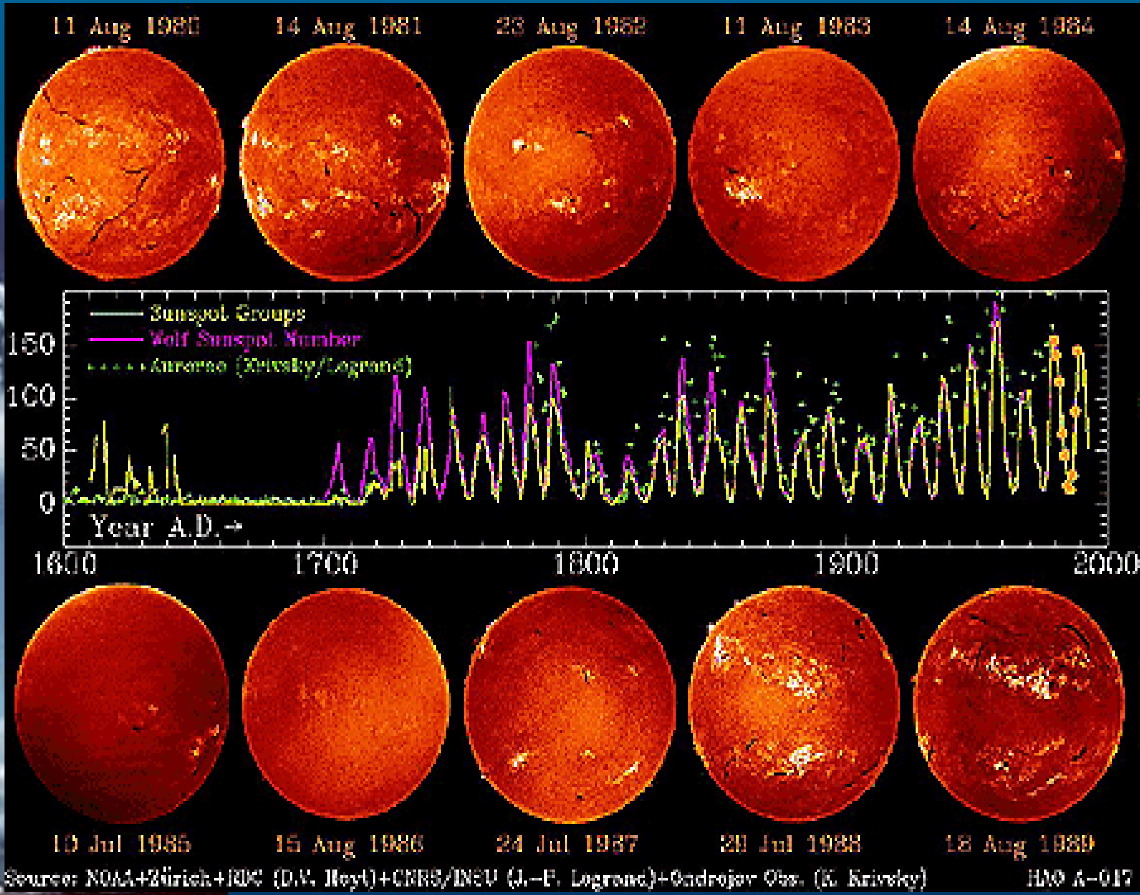


A Journey from the late Pleistocene to the Subsequent Holocene and present(past 800,000 years to present)

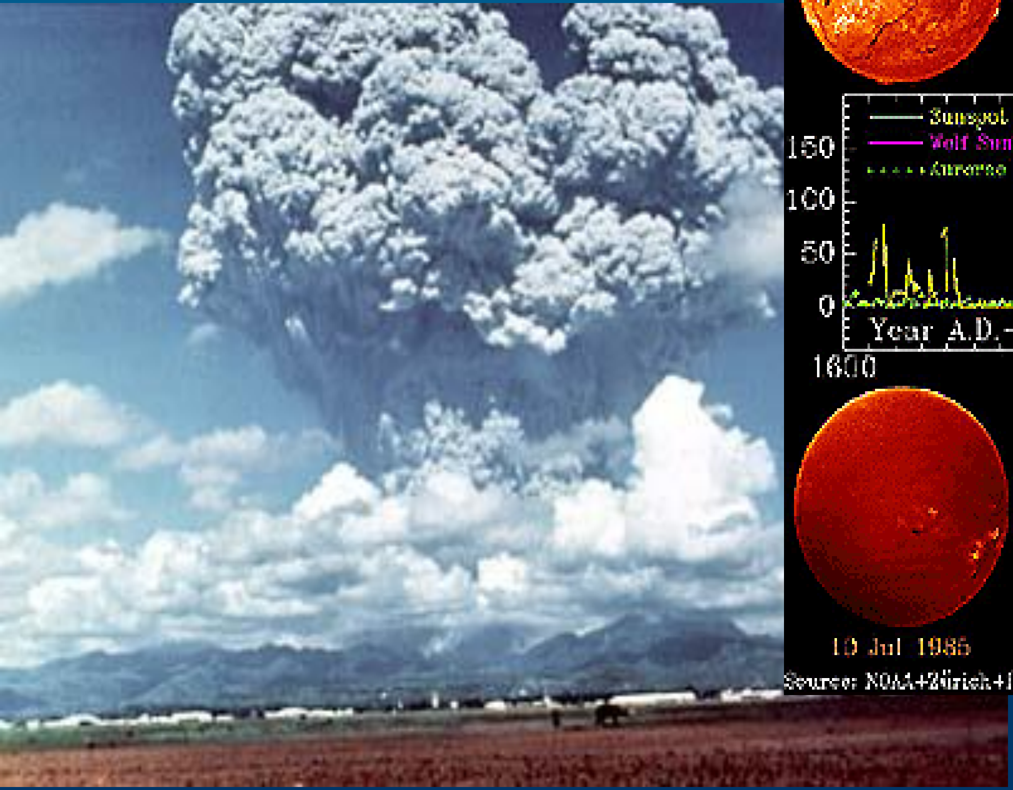
Climate change associated with global warming may put our journey in the reverse gear

Natural causes of climate change

Variation’s in the Sun’s output

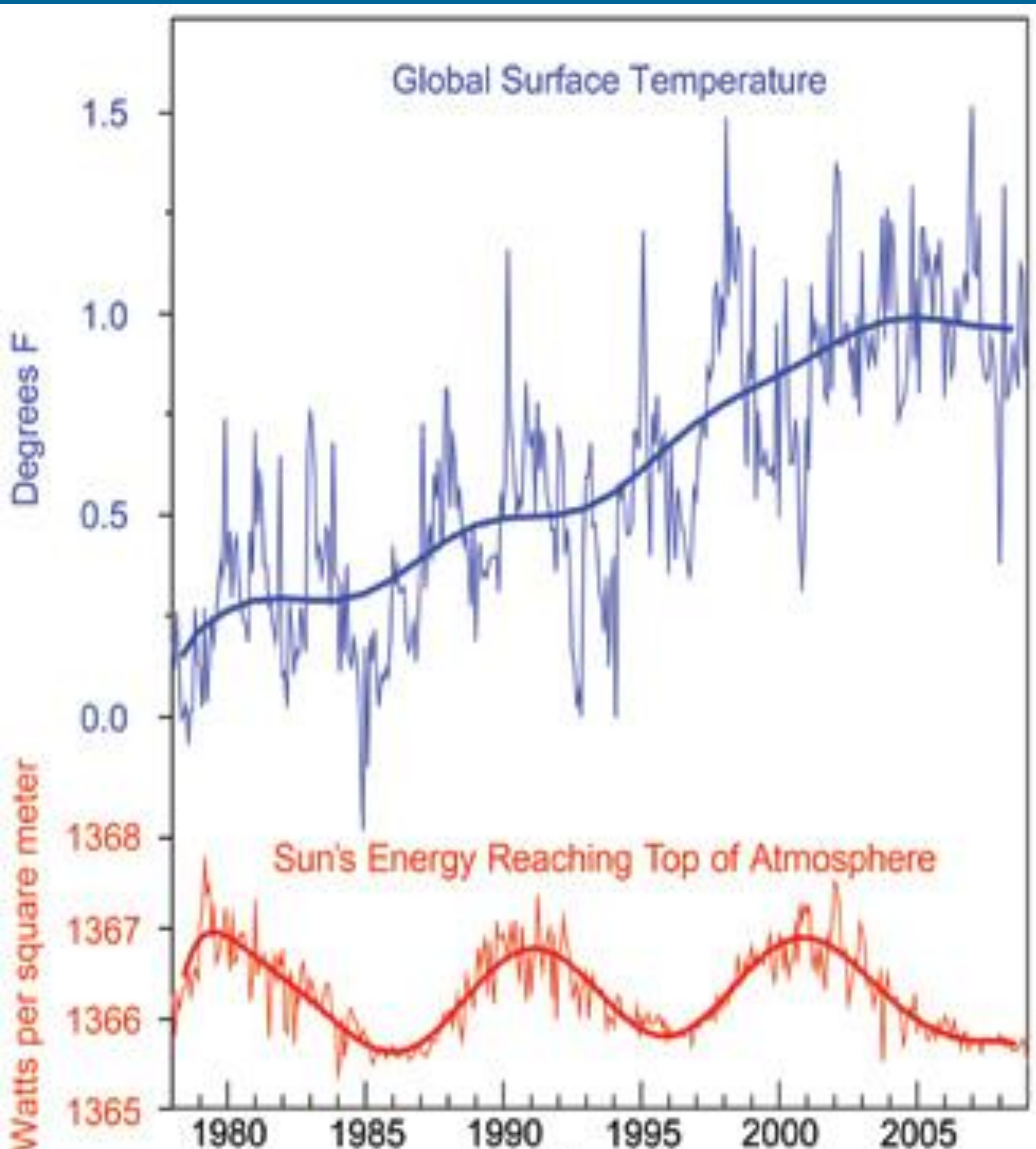


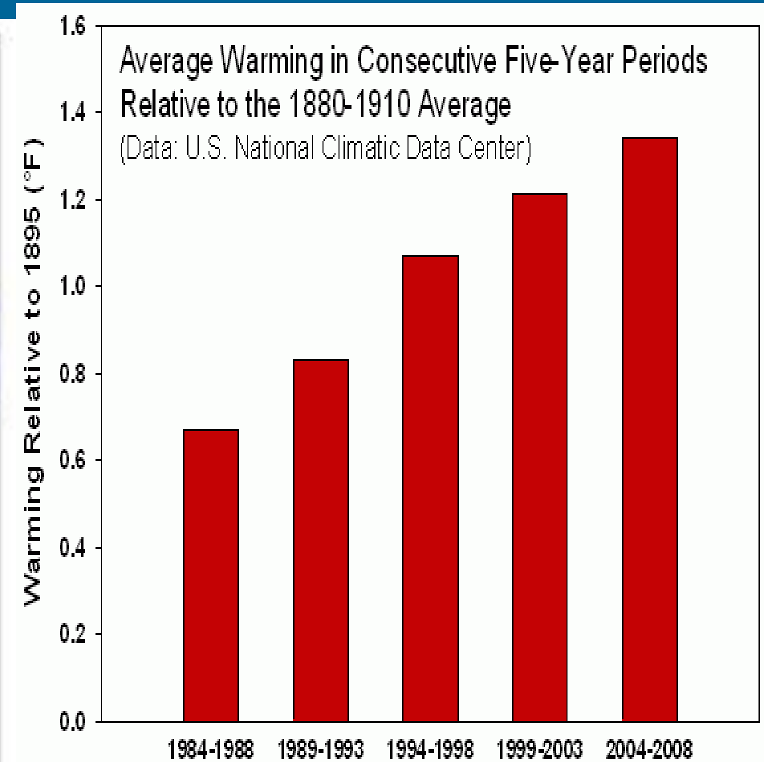
Volcanoes



Long term natural climate changes are likely driven by Earth's orbit changes

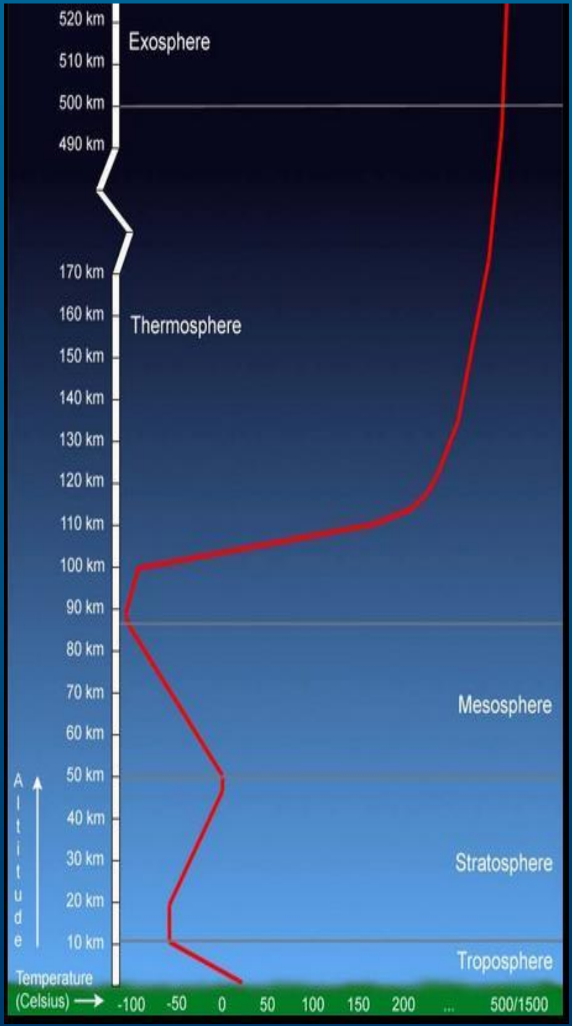
SUN & GLOBAL WARMING: A MISCONCEPTION

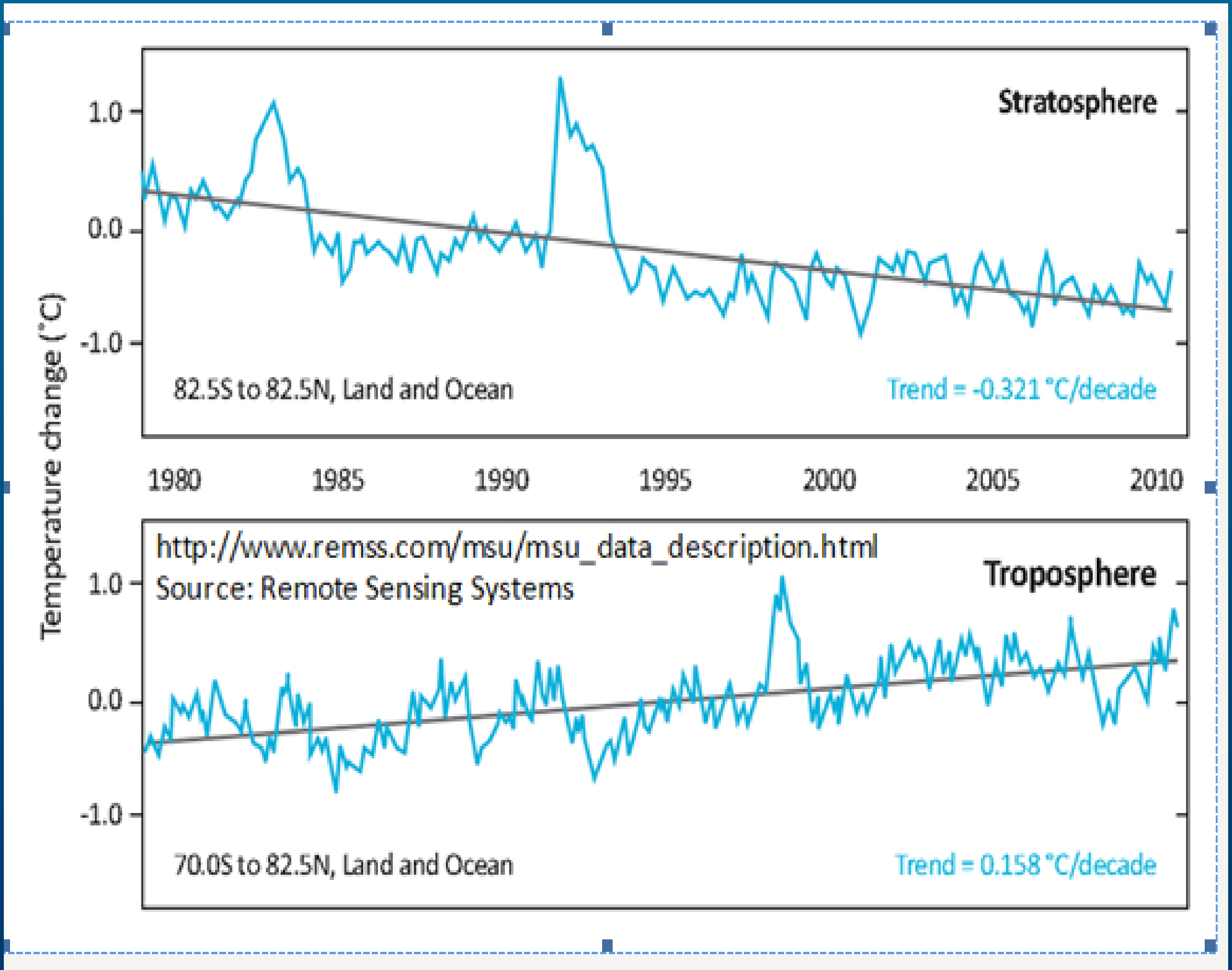




Satellite observations show the well known 11 year solar cycle, during which the amount of sunlight reaching the earth's surface varies by 0.1 % only. This cycle causes the global temperature to fluctuate up and down by about 0.2º F , which is much less than the present rate of observed warming of 1º F in the last 50 years(Prof. Bill Chmeides, Duke University)

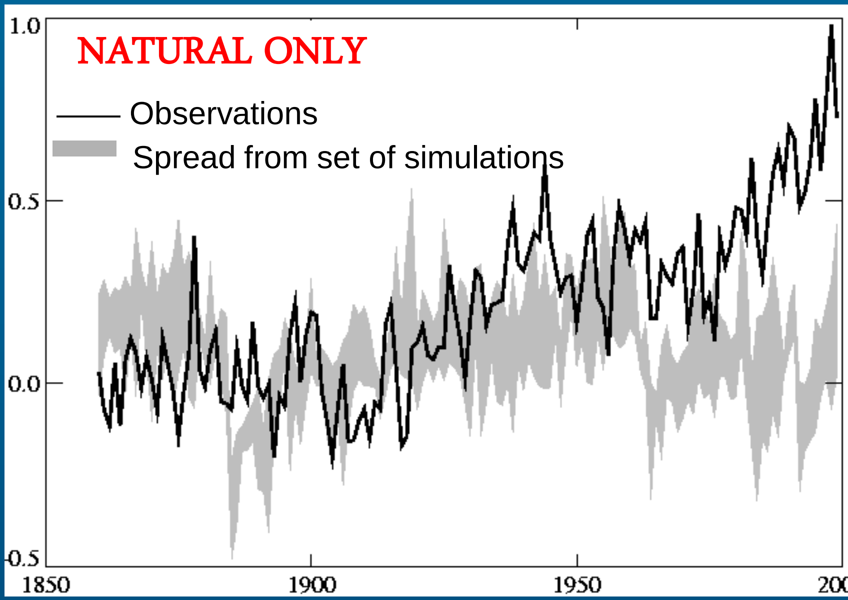
TROPOSPHERE vs STRATOSPHERE: OPPOSITE TEMPERATURE TREND

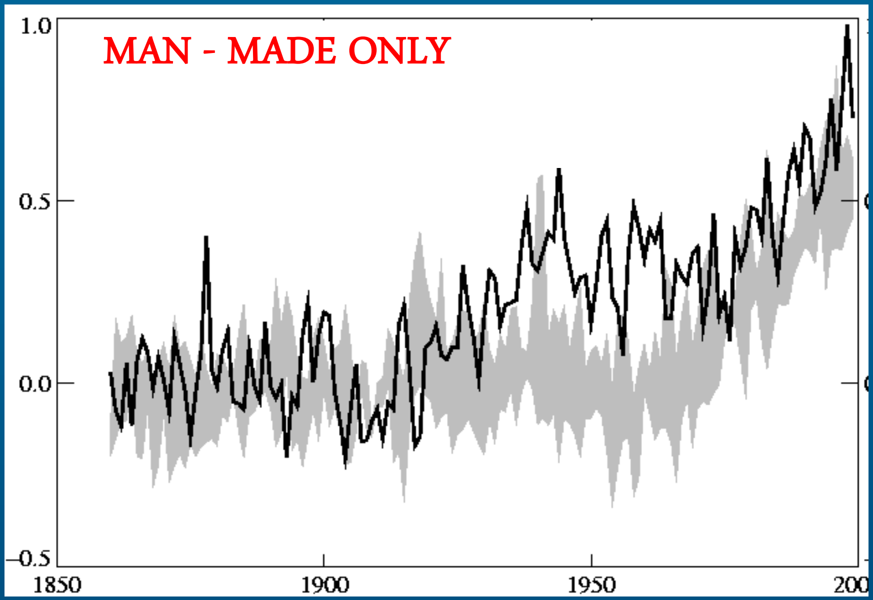


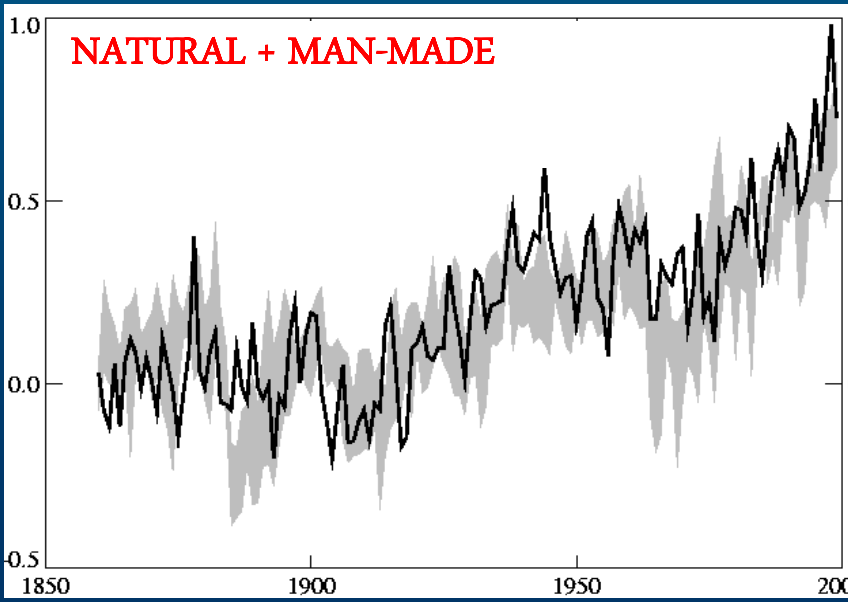


The Earth's average surface temperature has increased by 1.4°F (0.8°C) since the early years of the 20th century. Global average temperature shows rise with the rate of 0.67 degree centigrade for 100 years between 1891 and 2008. (IPCC,AR5,2013)

RECENT WARMING: OBSERVATIONS AND SIMULATIONS







"Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentration" *(IPCC 2013)*

Anthropogenic Climate Change

Anthropogenic climate change is a result of increasing concentrations of greenhouse gases in the atmosphere:

(a) Carbon-dioxide (CO_2)

(b) Methane (CH_4)

(c) Nitrous Oxide (N_2O)

(d) Chlorofluro carbons

Each of these gases are released in the atmosphere due to our actions in

Industries

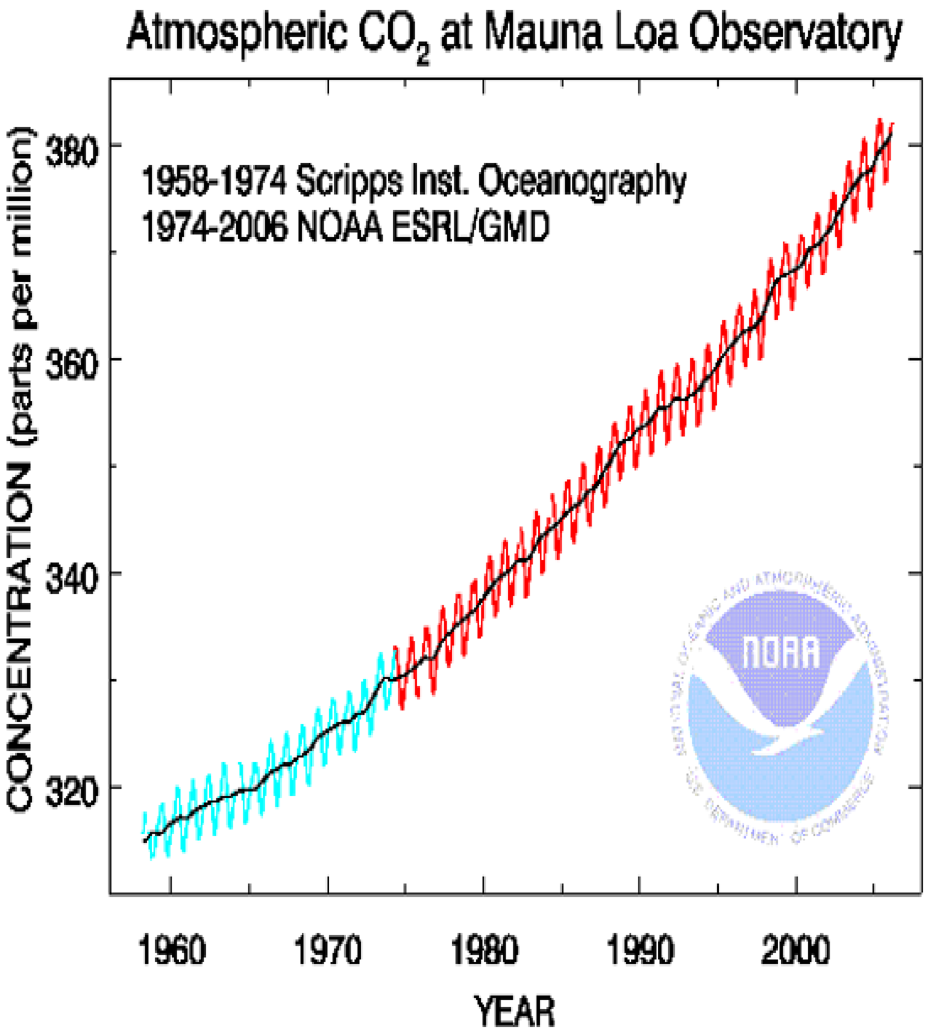
Transportation

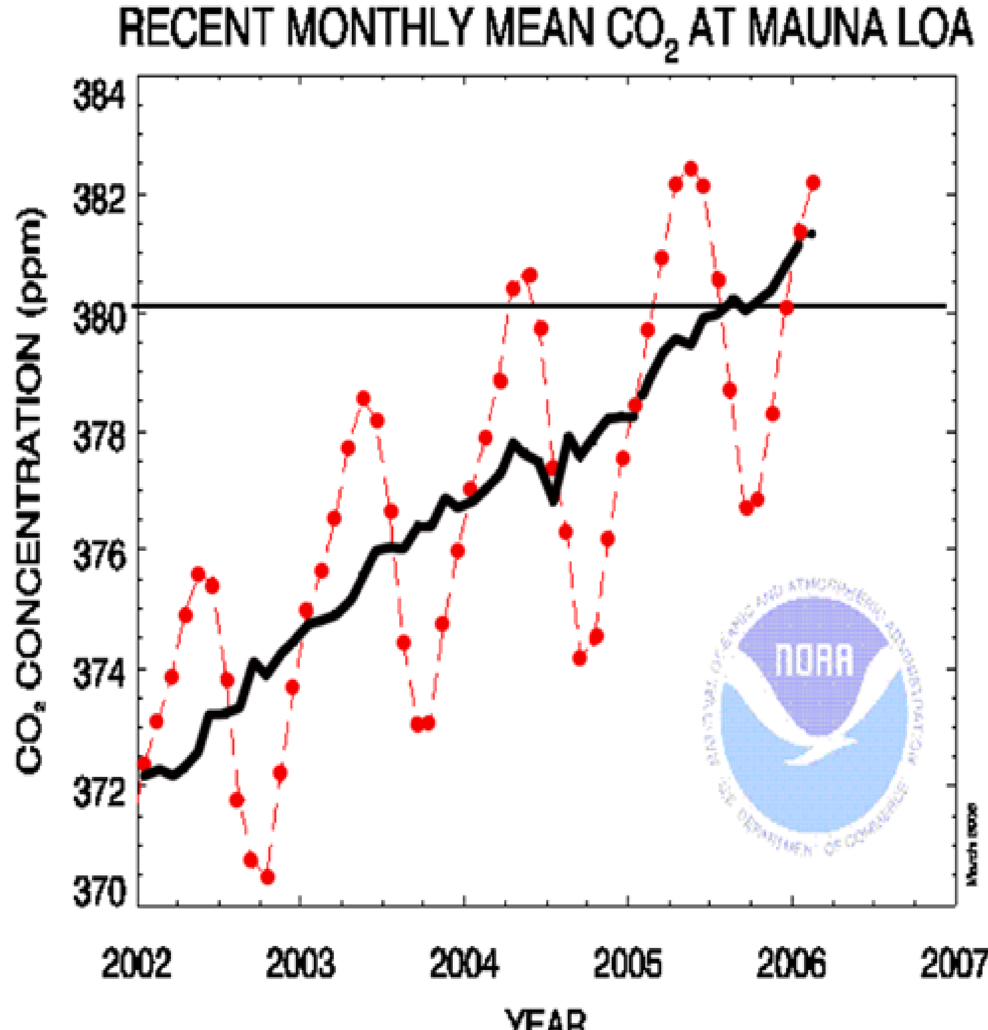
Agriculture

Domestic activity and Lifestyle issues

Modern life style is supported by large energy inputs and material resources producing huge waste

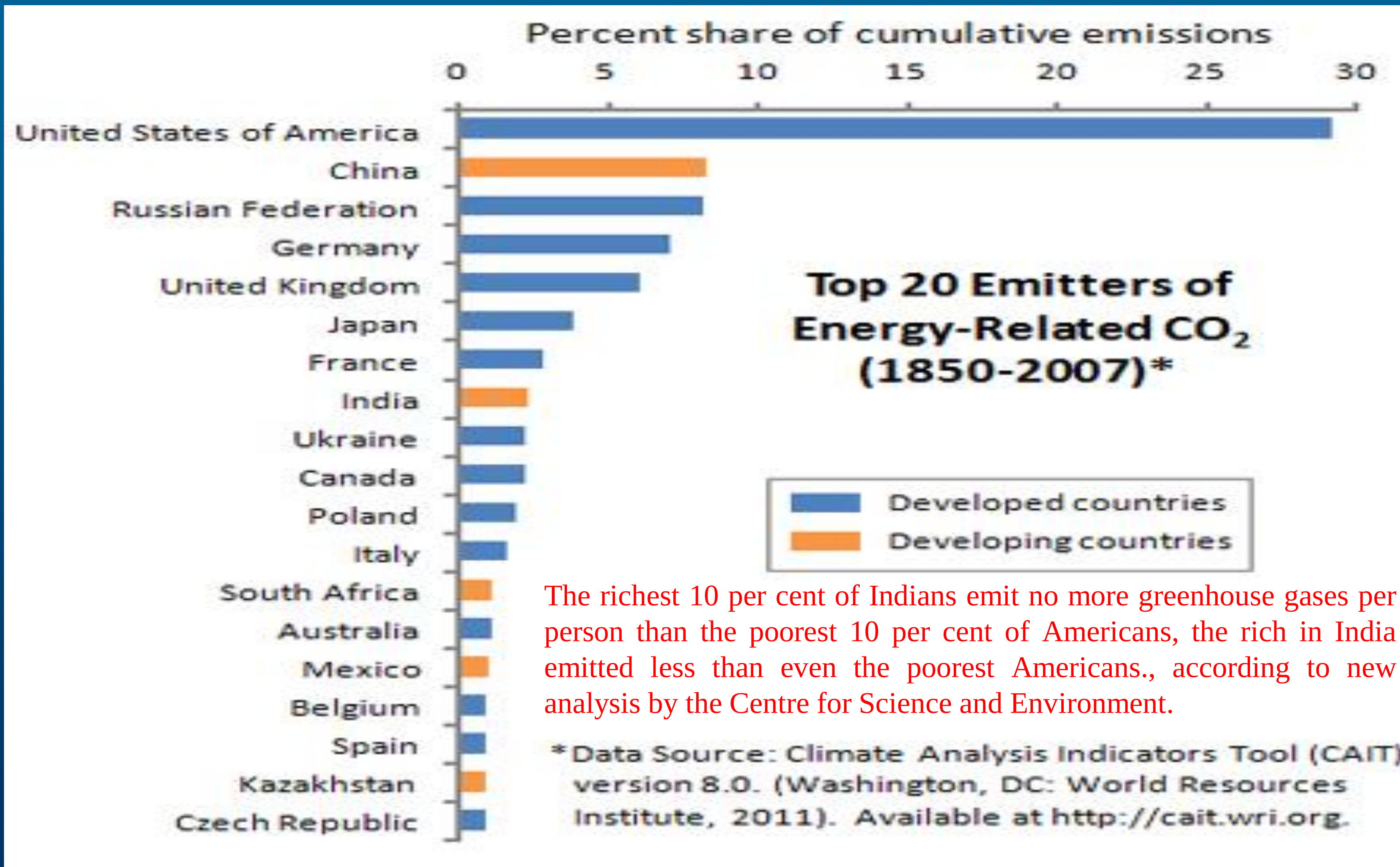
Atmospheric CO_2 measurements





CO_2 EMISSION: DEVELOPED vs DEVELOPING COUNTRIES

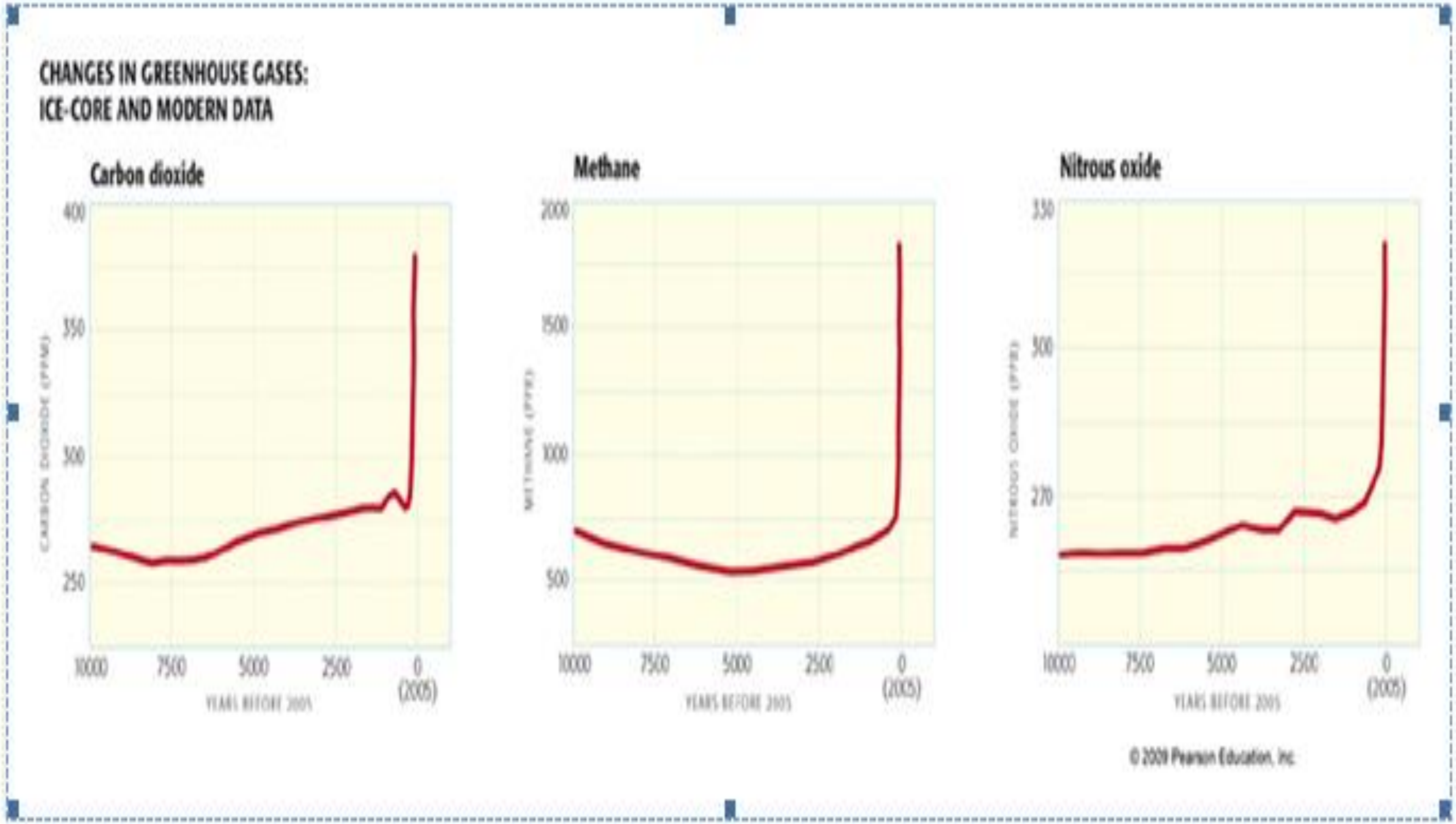
Just four countries account for half and 17 countries account for 80 percent of historic energy-related emissions. Only five developing countries rank among the top 20 emitters of cumulative CO_2.



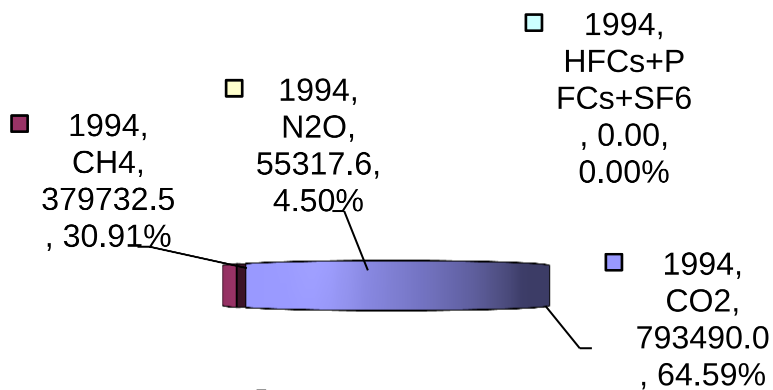
The richest 10 per cent of Indians emit no more greenhouse gases per person than the poorest 10 per cent of Americans, the rich in India emitted less than even the poorest Americans., according to new analysis by the Centre for Science and Environment.

Increase in GHG are human induced:

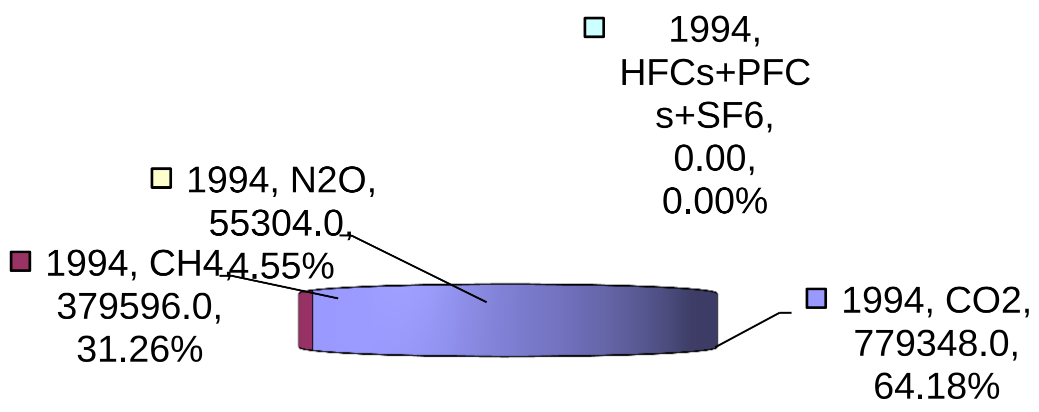
First, CO_2, methane, and nitrous oxide concentrations were stable for **thousands of years**. Suddenly, they began to rise like a rocket around 200 years ago, about the time that humans began to engage in very large-scale agriculture and industry



GHG Profile: India

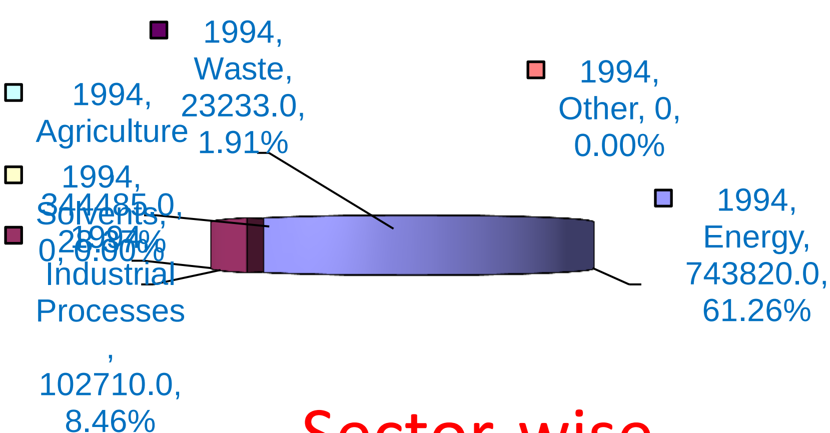


With LULUCF



Without LULUCF

Source: UN Climate change Secretariat



Sector-wise

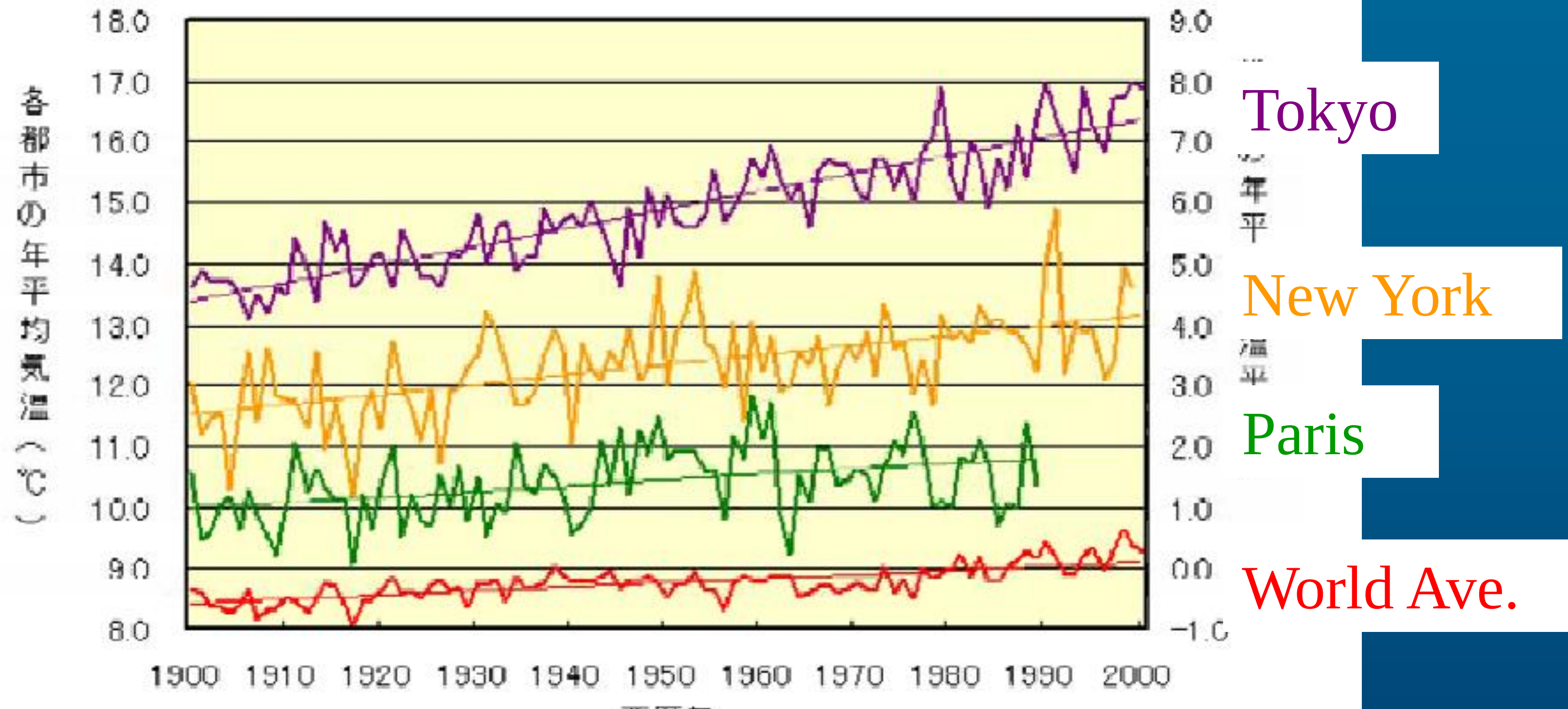
Land-use change can be a factor in CO_2 atmospheric concentration, and is thus a contributor to climate change. IPCC estimates that land-use change (e.g. conversion of forest into agricultural land) contributes a net 1.6 ± 0.8 Gt carbon per year to the atmosphere. For comparison, the major source of CO_2, namely emissions from fossil fuel combustion and cement production amount to 6.3 ± 0.6 Gt carbon per year

Warmest month and warmest year globally

Warmest months on record, through 2010			
Month	**Warmest**	**Anomaly**	
Jan	2007	+ 0.81°C	+ 1.46°F
Feb	1998	+ 0.83°C	+ 1.49°F
Mar	2010	+ 0.77°C	+ 1.39°F
Apr	2010	+ 0.73°C	+ 1.31°F
May	2010	+ 0.69°C	+ 1.24°F
Jun	2005	+ 0.66°C	+ 1.19°F
Jul	1998	+ 0.70°C	+ 1.26°F
Aug	1998	+ 0.67°C	+ 1.21°F
Sep	2005	+ 0.66°C	+ 1.19°F
Oct	2003	+ 0.71°C	+ 1.28°F
Nov	2004	+ 0.72°C	+ 1.30°F
Dec	2006	+ 0.73°C	+ 1.31°F

Rank	Year	Difference (°F) vs. 20th century
1	2005	1.12
2	**2010**	**1.12**
3	1998	1.08
4	2003	1.04
	2002	1.04
6	2006	1.01
7	2009	1.01
8	2007	0.99
9	2004	0.97
10	2001	0.94
11	2008	0.86
12	1997	0.86
13	1999	0.76
14	1995	0.74
15	2000	0.70

Urban warming during the last century



by JMA

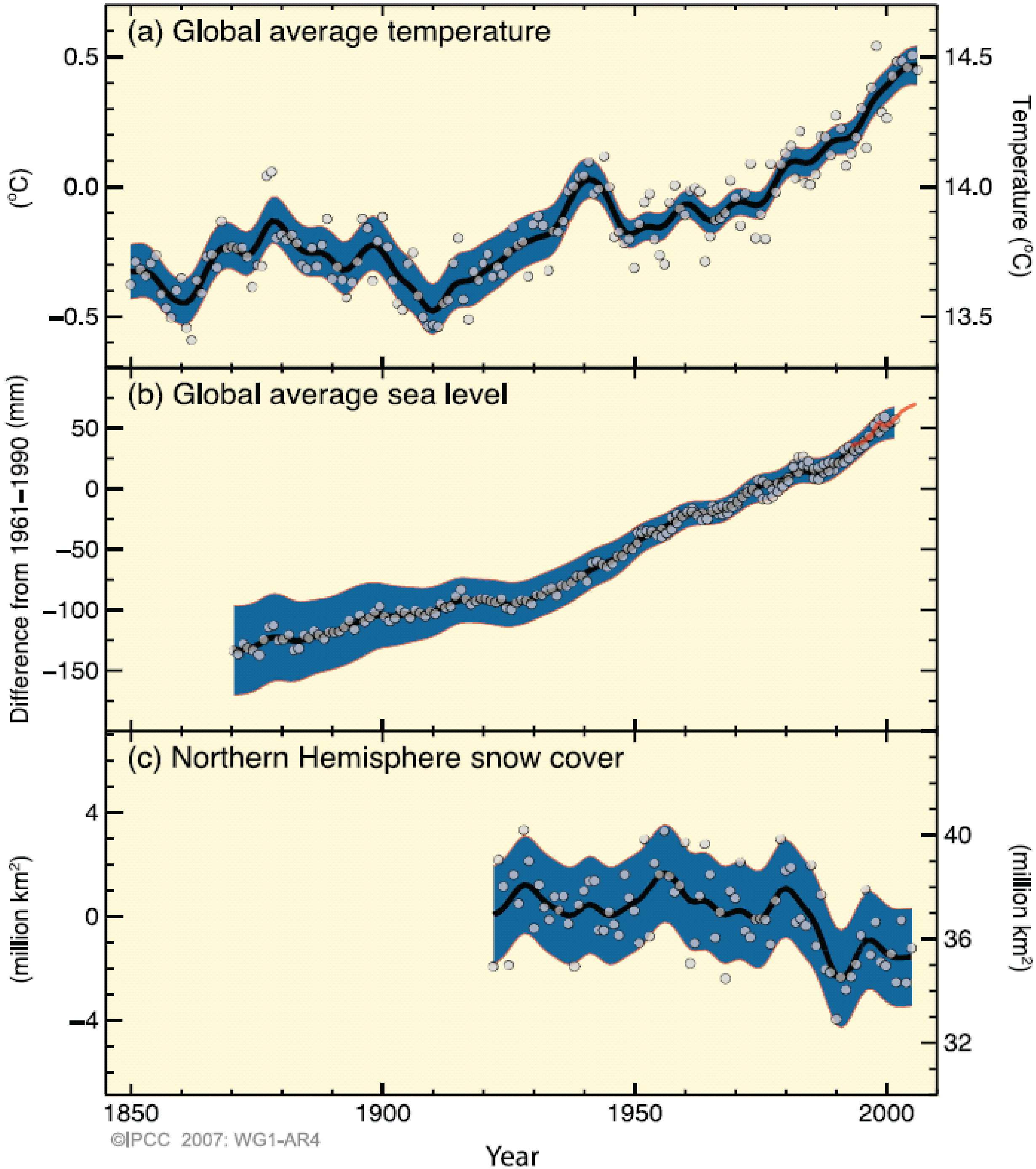
Temperature rise during the last century in Japan

Not urbanized area	0.2ºC
Small cities	1.0ºC
Average of big cities	2.5ºC
Tokyo	3.0ºC

（by JMA and Junsei Kondo）

CLIMATE CHANGE IMPACTS OBSERVED

- Both maximum and minimum average daily temperatures are increasing, but minimum temperatures are increasing at a faster rate than maximum temperatures.
- It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia.
- The average temperature of the global ocean has increased to depths of at least 3000 m and the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes sea water to expand, contributing to sea level rise, absorption of carbon dioxide by sea water make the sea water acidic due to formation of carbonic acid. An average pH reduction of 0.1 is recorded so far.
- Major carbon sink now releasing carbon dioxide: Southern ocean, the earth's carbon sink absorb about half of all human carbon emissions. With the southern ocean reaching its saturation point more carbon dioxide will stay in our atmosphere.
- Soils are becoming hydrophobic: Would cause more flooding and erosion, enhanced transfer of nutrients and agricultural chemicals to the ground water, reduced plant growth and productivity.

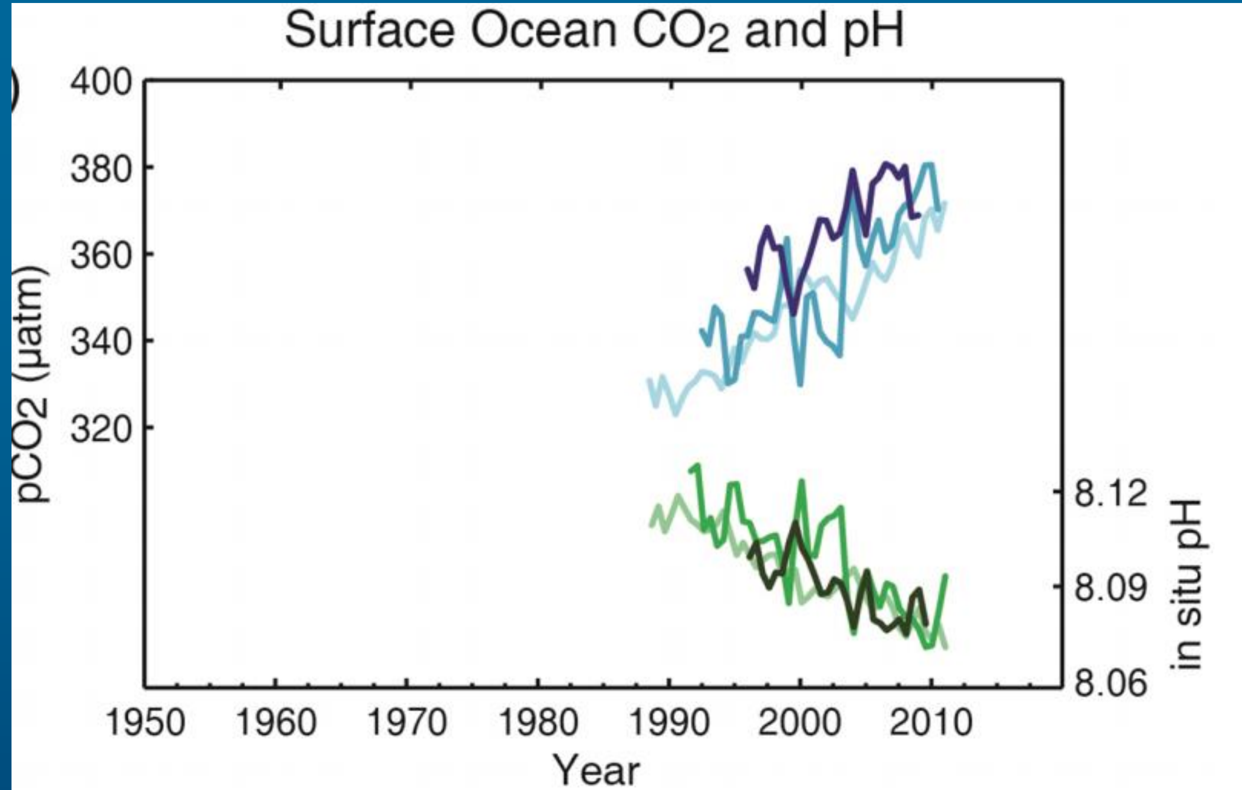


Observed changes in (a) global average surface temperature; (b) global average sea level from tide gauge and satellite data and (c) Northern Hemisphere snow cover for March-April. All differences are relative to corresponding averages for the period 1961-1990. Smoothed curves represent decadal averaged values while circles show yearly values. The shaded areas are the uncertainty intervals estimated form comprehensive analysis of known uncertainties (a and b) and from the time series (c) (IPCC, 2007)

- Global average temperature shows rise with the rate of 0.67 degree in centigrade for 100 years between 1891 and 2008.
- Global average sea level has risen since 1961 at an average rate of 1.8mm/yr and since 1993 at 3.1mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets.

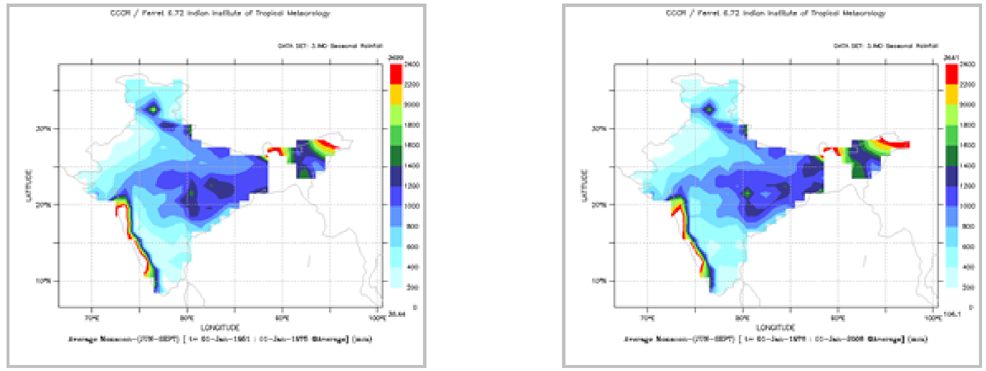
➢Ocean acidification is quantified by decreases in pH .

➢The pH of ocean surface water has decreased by 0.1 since the beginning of the industrial era (high confidence), corresponding to a 26% increase in hydrogen ion concentration.

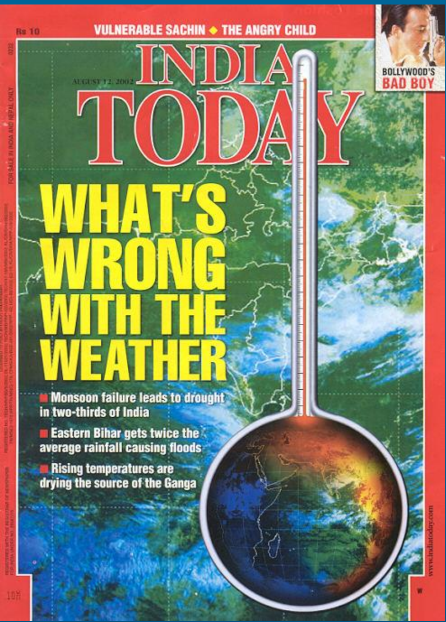


Partial pressure of dissolved CO 2 at the ocean surface (blue curves) and in situ pH (green curves), a measure of the acidity of ocean water. Measurements are from three stations from the Atlantic (29°10′N, 15°30 ′W – dark blue/dark green; 31°40′N, 64°10 ′W – blue/green) and the Pacific Oceans (22°45 ′N, 158°00′W − light blue/light green)

Summer monsoon rainfall features of the Pre 1975 and Post 1975 Period



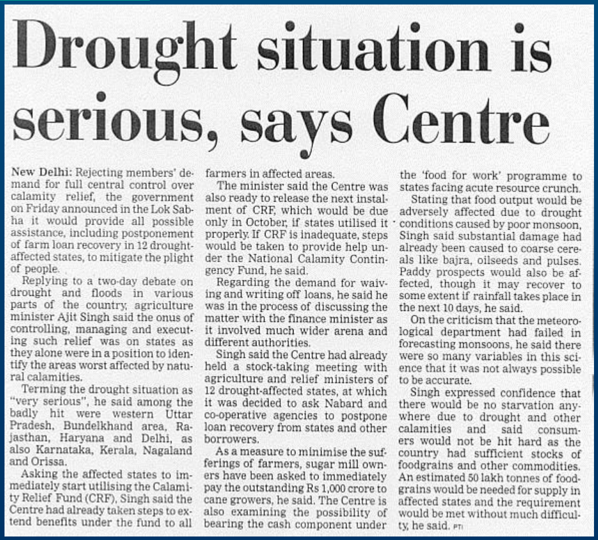
Rainfall decreased over Western ghat but increased over central region of India



2002 & 2009 Drought in India

Many states in state of worry over late rains

A farmer shows the state of his paddy that has dried up due to insufficient rain and water supply in Gidder village of Punjab.



Drought situation is serious, says Centre

New Delhi: Rejecting members' demand for full central control over calamity relief, the government on Friday announced in the Lok Sabha it would provide all possible assistance, including postponement of farm loan recovery in 12 drought-affected states, to mitigate the plight of people.

Replying to a two-day debate on drought and floods in various parts of the country, agriculture minister Ajit Singh said the onus of controlling, managing and executing such relief was on states as they alone were in a position to identify the areas worst affected by natural calamities.

Terming the drought situation as "very serious", he said among the badly hit were western Uttar Pradesh, Bundelkhand area, Rajasthan, Haryana and Delhi, as also Karnataka, Kerala, Nagaland and Orissa.

Asking the affected states to immediately start utilising the Calamity Relief Fund (CRF), Singh said the Centre had already taken steps to extend benefits under the fund to all farmers in affected areas.

The minister said the Centre was also ready to release the next instalment of CRF, which would be due only in October, if states utilised it properly. If CRF is inadequate, steps would be taken to provide help under the National Calamity Contingency Fund, he said.

Regarding the demand for waiving and writing off loans, he said he was in the process of discussing the matter with the finance minister as it involved much wider arena and different authorities.

Singh said the Centre had already held a stock-taking meeting with agriculture and relief ministers of 12 drought-affected states, at which it was decided to ask Nabard and co-operative agencies to postpone loan recovery from states and other borrowers.

As a measure to minimise the sufferings of farmers, sugar mill owners have been asked to immediately pay the outstanding Rs 1,000 crore to cane growers, he said. The Centre is also examining the possibility of bearing the cash component under the 'food for work' programme to states facing acute resource crunch.

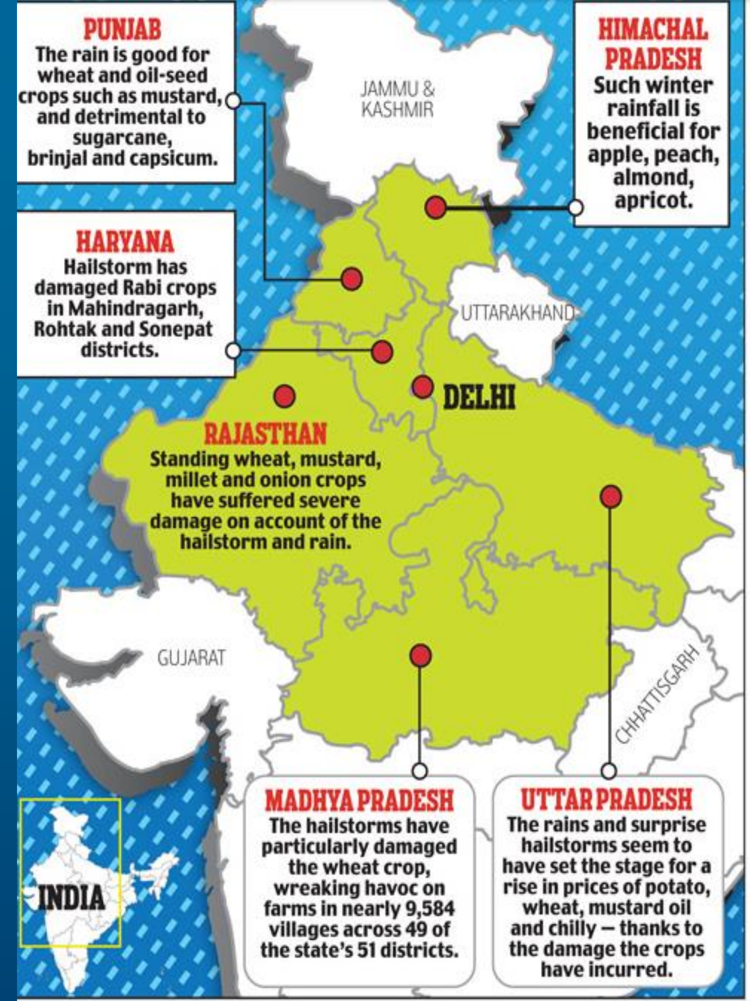
Stating that food output would be adversely affected due to drought conditions caused by poor monsoon, Singh said substantial damage had already been caused to coarse cereals like bajra, oilseeds and pulses. Paddy prospects would also be affected, though it may recover to some extent if rainfall takes place in the next 10 days, he said.

On the criticism that the meteorological department had failed in forecasting monsoons, he said there were so many variables in this science that it was not always possible to be accurate.

Singh expressed confidence that there would be no starvation anywhere due to drought and other calamities and said consumers would not be hit hard as the country had sufficient stocks of foodgrains and other commodities. An estimated 50 lakh tonnes of foodgrains would be needed for supply in affected states and the requirement would be met without much difficulty, he said. PTI

Hail outburst damages crops, casts shadow on Rabi harvest

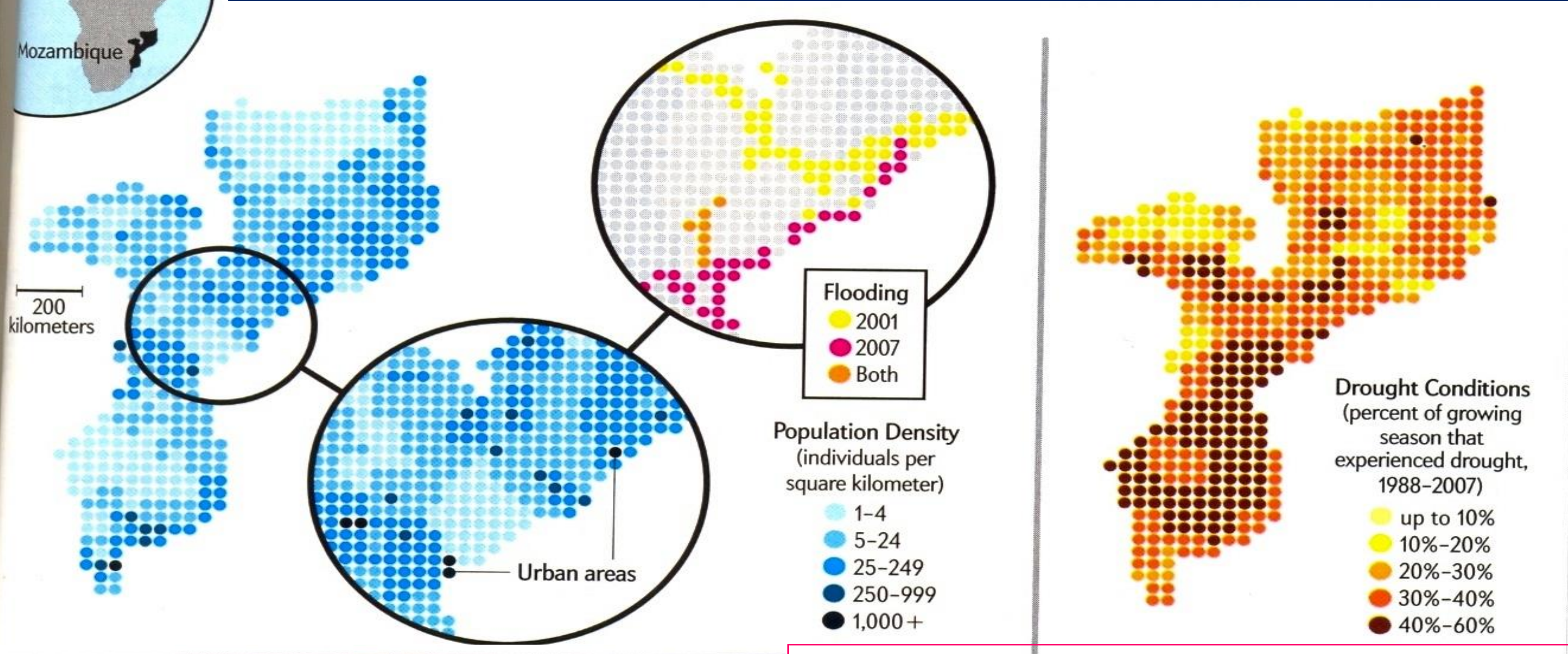
27 Feb-4, March, 2014



The unseasonal spell of rain and hail brought a flood of worry for farmers across North India, having wreaked havoc on Rabi crops right on the threshold of spring.

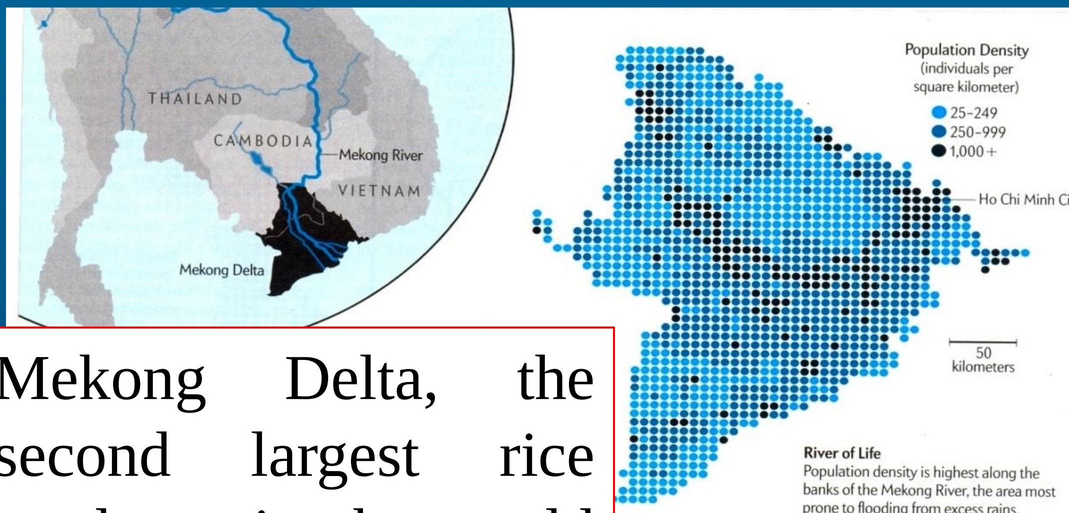
CLIMATE CHANGE INDUCED MIGRATION

(Mozambique is simultaneously hit by drought and flood in many years)



Permanent migration of many families in Mozambique due to severe and frequent floods while the droughts have severely affected food production, Situation is equally bad in Bangladesh

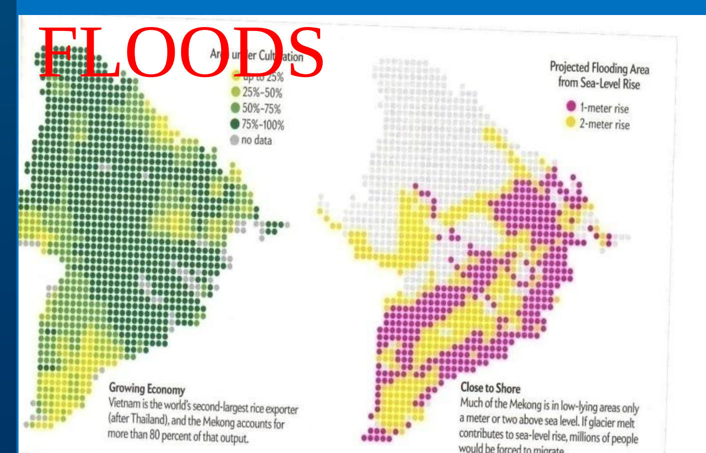
CLIMATE CHANGE INDUCED MIGRATION (Mekong Delta in Vietnam is in Peril)

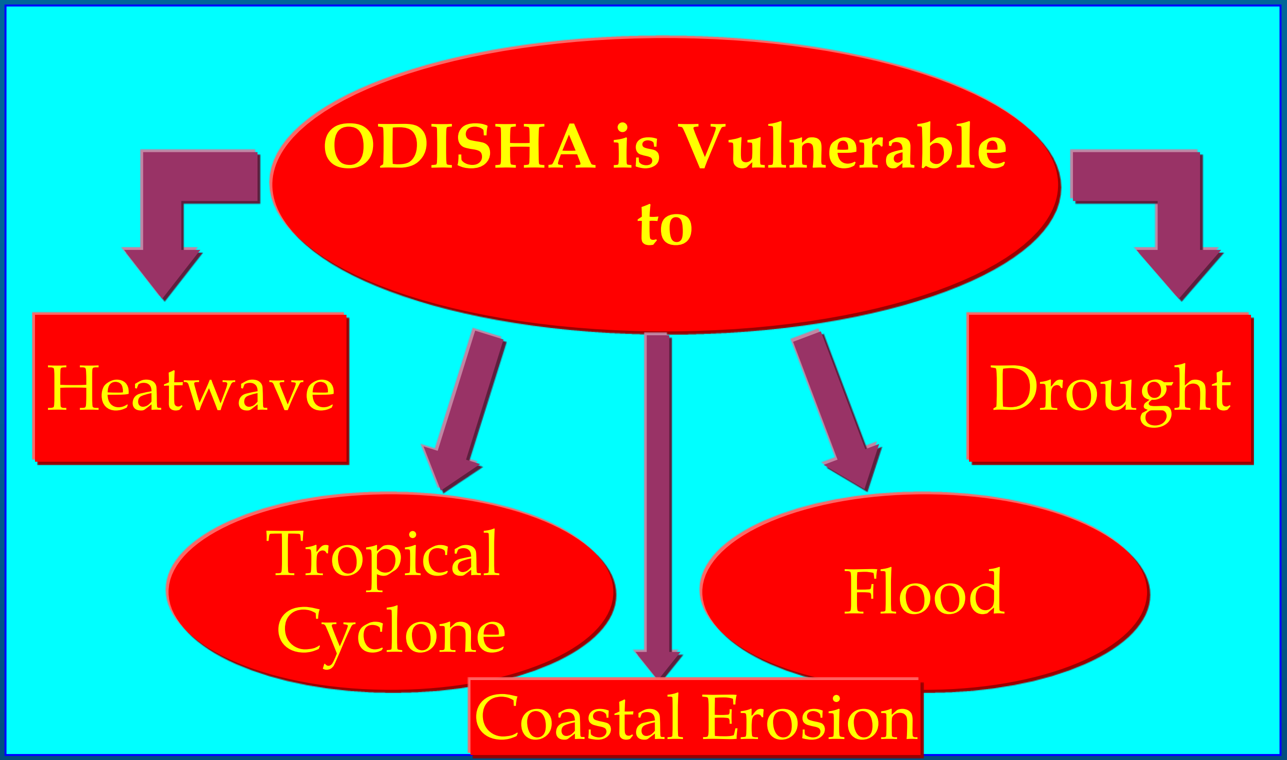


Mekong Delta, the second largest rice producer in the world is in peril because of severe and frequent flooding. The region is highly vulnerable to sea level rise. 1m rise would displace 7 million people.

1-2m rise in sea level and associated coastal flooding would displace about 80% of Vietnam population by 2020

LIVING WITH FLOODS





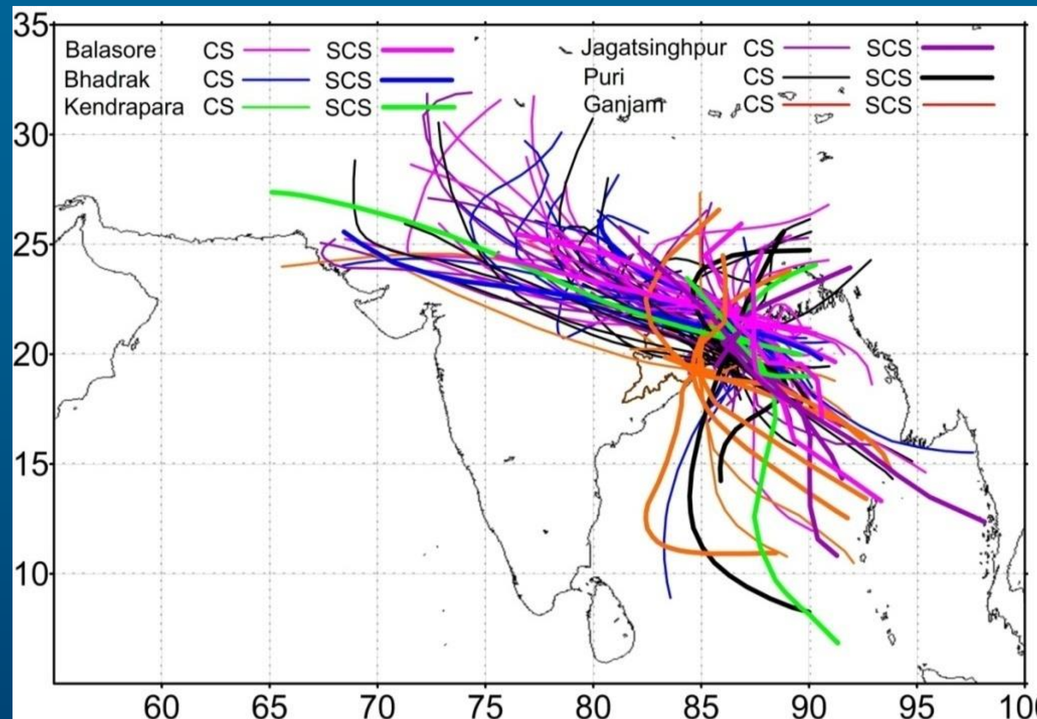
ODISHA: A State frequently prone to natural disasters

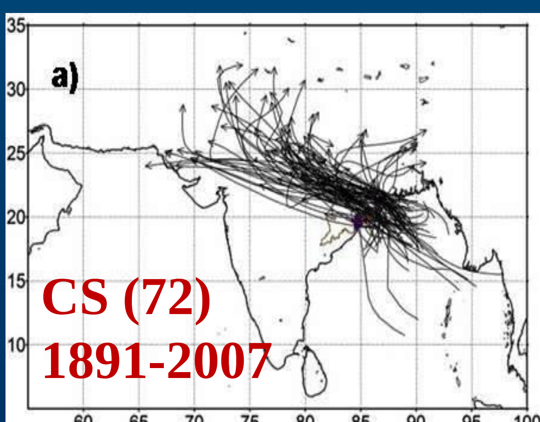
Cyclonic Storms (1891-2007) *Depression and Deep Depression*: 280 *Cyclonic storms*: 72 *Severe Cyclonic Storms, Very Severe Cyclonic Storms/ Super cyclone*: 20	Drought (1975-1996):23 Floods/Heavy rains (1975-1996): 88 Heat wave (1975-1996): 13	Thunderstorms Tornado (1975-1996): 54 Hail Storm (1975-1996): 55 Gale (1975-1996): 24 Squall (1975-1996): 15

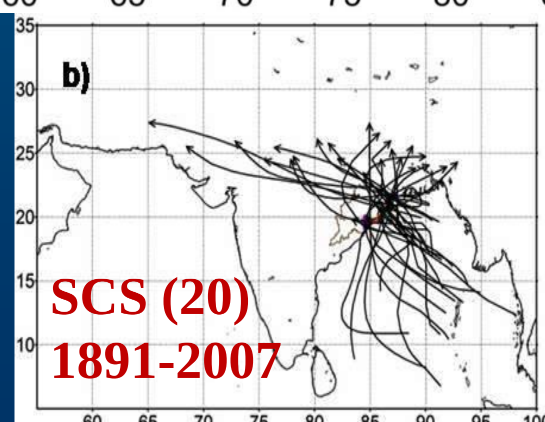
CLIMATOLOGY OF TROPICAL CYCLONES ALONG THE ODISHA COAST

Number of D/CS/SCS crossing the six coastal districts of Odisha (1891-2007)

Districts	Coastline (in km)	D	CS	SCS
Ganjam	63.25	22	6	5
Puri	138	56	17	2
Jagatsinghpur	61.38	33	12	3
Kendrapara	79.43	41	7	4
Bhadrak	49.36	27	7	2
Balasore	88.64	101	23	4
Total	480	280	72	20

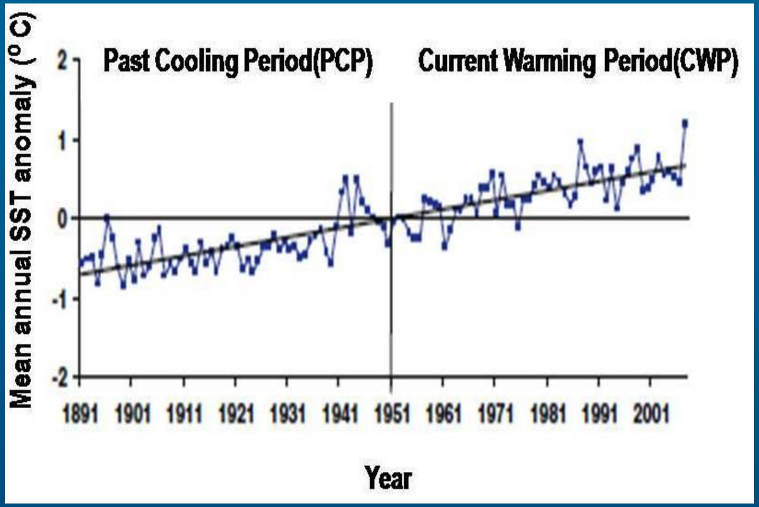






CLIMATE CHANGE IMPACTS ON TROPICAL CYCLONE CLIMATOLOGY ALONG THE ODISHA COAST

1891-1950→ Past Cooling Period (PCP)
1951-2007→ Current Warming Period (CWP)



(Mohanty et al. 2012)

PCP

Intensity	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
CS	0	0	0	0	1	11	15	13	10	3	2	0	55
SCS	0	0	0	0	2	1	2	1	1	2	0	0	9
TOTAL	0	0	0	0	3	12	17	14	11	5	2	0	64

CWP

Intensity	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
CS	0	0	0	0	0	2	1	4	7	2	1	0	17
SCS	0	0	0	0	2	0	0	1	1	6	1	0	11
TOTAL	0	0	0	0	2	2	1	5	8	8	2	0	28

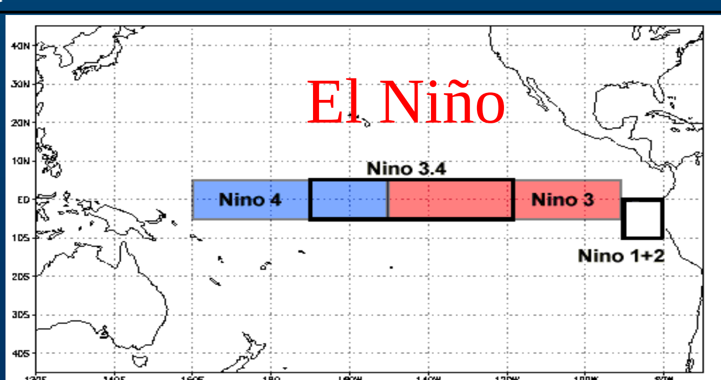
Extreme Value Analysis of TCs in return periods

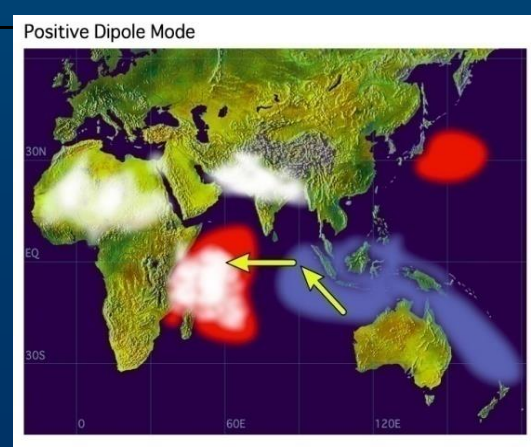
	Wind speed (Knots) in the States along east coast of India			
Return Period	West Bengal	Odisha	Andhra Pradesh	Tamilnadu
10 years	65	80	90	80
20 years	85	102	112	93
30 years	96	118	123	106
50 years	112	130	141	116

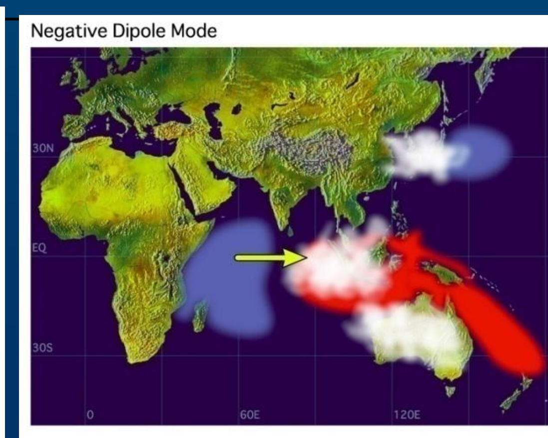
CLIMATE CHANGE IMPACTS ON TROPICAL CYCLONE FREQUENCY ALONG THE ODISHA COAST

(the boldface numbers indicate the frequency of cyclone landfall)

States	El Niño			La Niña			Neutral ENSO			+ve IOD			–ve IOD			No IOD		
	TCs	CS	SCS	TCs	CS	SCS	TCs	CS	SCS	TCs	CS	SCS	TCs	CS	SCS	TCs	CS	SCS
Tamilnadu	17	10	7	13	4	9	20	9	11	8	4	4	9	1	8	33	18	15
	0.4	**0.24**	**0.16**	**0.39**	**0.12**	**0.27**	**0.47**	**0.21**	**0.26**	**0.44**	**0.22**	**0.22**	**0.53**	**0.06**	**0.47**	**0.4**	**0.22**	**0.18**
Andhra Pradesh	24	14	10	24	19	5	25	13	12	11	3	8	14	10	4	48	33	15
	0.57	**0.33**	**0.24**	**0.73**	**0.57**	**0.16**	**0.59**	**0.31**	**0.28**	**0.61**	**0.17**	**0.44**	**0.82**	**0.59**	**0.23**	**0.58**	**0.4**	**0.18**
Odisha	24	20	4	38	28	10	30	24	6	9	6	3	16	10	6	67	56	11
	0.57	**0.47**	**0.1**	**1.15**	**0.84**	**0.31**	**0.71**	**0.57**	**0.14**	**0.5**	**0.33**	**0.17**	**0.94**	**0.58**	**0.36**	**0.82**	**0.68**	**0.14**
West Bengal	15	9	6	15	5	10	13	8	5	2	1	1	7	3	4	34	18	16
	0.36	**0.21**	**0.15**	**0.45**	**0.15**	**0.3**	**0.31**	**0.19**	**0.12**	**0.1**	**0.05**	**0.05**	**0.41**	**0.17**	**0.24**	**0.41**	**0.22**	**0.19**



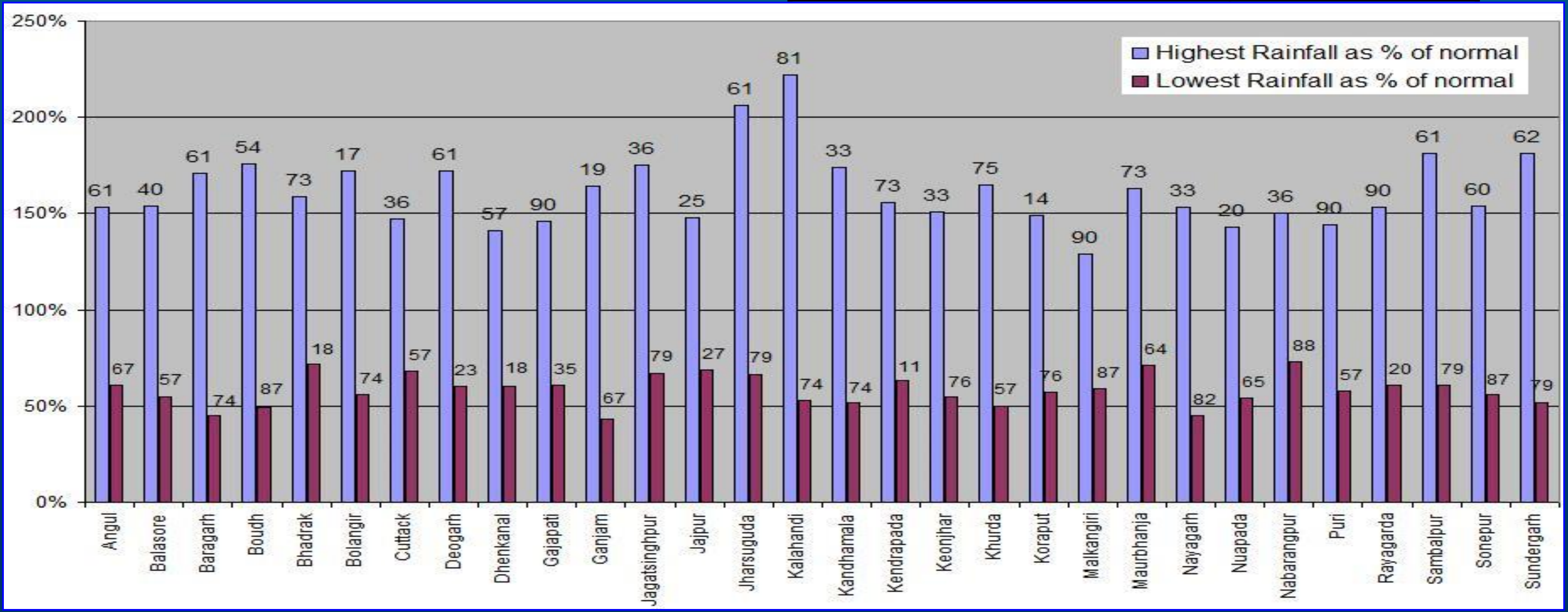




ODISHA RAINFALL(Mean annual rainfall: 145 cm)

Coefficient of variation of rainfall	
Annual	19-29%
Pre monsoon	40-80%
SW monsoon	17-30%
Post monsoon	58-130%
Winter	90-170%

Contribution of the seasonal rainfall to the total annual rainfall	
SW Monsoon (JJAS)	79%
Winter (DJF)	3%
Pre-monsoon (MAM)	8%
Post-monsoon (ON)	10%



Drought & Excessive rainfall Conditions

Moderate drought: If rainfall deficit is between 25-50% of the normal

Severe drought: If the rainfall deficit is more than 50% of the normal

Districts	Number of drought year(1901-1990)	Frequency of drought(%)	Districts	Number of drought year(1901-1990)	Frequency of drought(%)	Districts	Number of drought year(1901-1990)	Frequency of drought(%)
Angul	10	12	Ganjam	7	8	Malkanagiri	6	13
Balasore	7	9	Jagatsinghapur	1	2	Mayurbhanja	2	3
Baragarh	8	11	Jajpur	3	5	Nayagarh	3	5
Boudh	4	9	Jharsuguda	4	6	Nuapada	7	11
Bhadrak	3	3	Kandhamala	5	6	Nabarangapur	2	5
Bolangir	2	3	Kalahandi	7	12	Puri	4	5
Cuttack	3	3	Kendrapara	6	10	Rayagada	4	6
Deogarh	5	11	Keonjhar	9	12	Sambalpur	6	7
Dhenkanal	2	3	Khurda	4	5	Sonepur	12	18
Gajapati	2	3	Koraput	5	7	Sundargarh	5	8

Excessive Rainfall (Annual rainfall of 125% or more of the normal)

Districts	Average annual (Normal) rainfall (mm)	Successive Years of excessive Rainfall	Heaviest rainfall record in 24 hours (year within bracket)
Angul	1401.9	1960-61	339.0 (1991)
Balasore	1592.0	1940-41,1960-61	479.3 (1943)
Baragarh	1367.3	1936-37,1963-64	368.3 (1939)
Boudh	1623.1	1939-40,1954-55-56	395.0 (1936)
Bhadrak	1427.9	1955-56	514.6 (1879)
Bolangir	1289.8	1917-18-19,1985-86	325.8 (1958)
Cuttack	1424.3	1955-56	416.8 (1934)
Deogarh	1582.5	-	330.2 (1943)
Dhankanal	1428.8	1956-57	305.0 (1991)
Gajapati	1403.3	-	319.2 (1990)
Ganjam	1276.2	-	445.0 (1990)
Jagatsinghpur	1514.6	1916-17,1936-37	498.6 (1889)
Jajpur	1559.9	1985-86	350.0 (1992)
Jarsuguda	1362.8	1933-34,1936-37,1960-61	350.0 (1925)

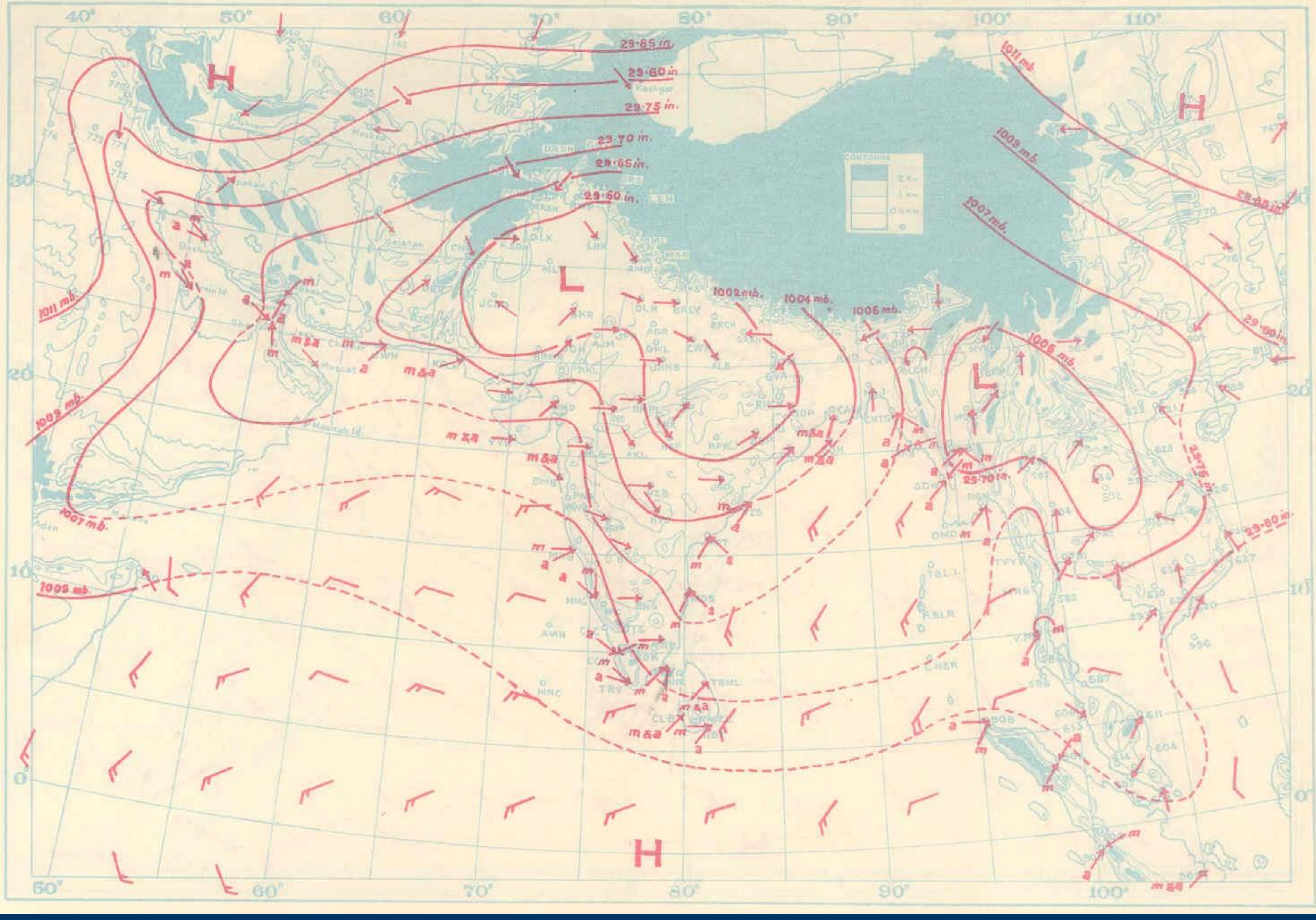
Excessive Rainfall (Annual rainfall of 125% or more of the normal)

Districts	Average annual (Normal) rainfall (mm)	Successive Years of excessive Rainfall	Heaviest rainfall record in 24 hours
Kalahandi	1330.5	1910-11,1955-56-57	344.1 (1967)
Kandhamala	1427.9	1925-26	331.0 (1991)
Kendrapara	1556.0	-	401.8 (1925)
Keonjhar	1487.7	-	343.4 (1941)
Khurda	1408.4	1973-74-75	325.0 (1974)
Koraput	1567.2	-	546.1 (1931)
Malkanagiri	1667.6	-	306.3 (1907)
Mayurbhanja	1630.6	1940-41, 1977-78	467.4 (1973)
Nayagarh	1354.3	-	273.1 (1945)
Nuapara	1286.4	1919-20	279.4 (1917)
Nabarangapur	1569.5	-	350.0 (1973)
Puri	1408.8	1946-47	480.1 (1862)
Rayagada	1285.9	1916-17	355.6 (1890)
Sambalapur	1495.7	1907-08,1919-20,1960-61	581.9 (1982)
Sonepur	1418.5	1917-18,1932-33,1985-86	365.5 (1918)
Sundargarh	1422.4	1919-20,1961-62	333.5 (1920)

Origin of Heat Wave

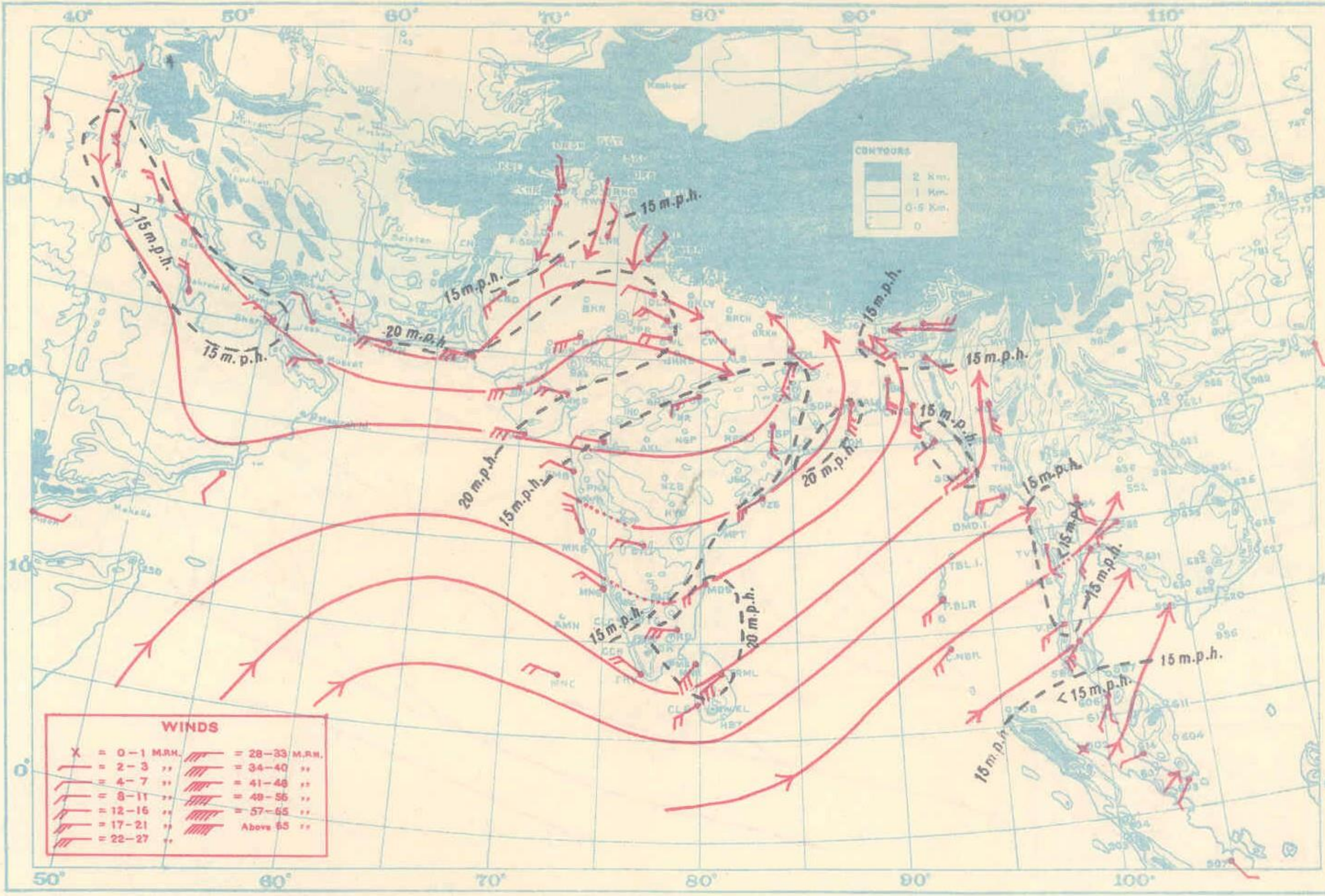
- Heat wave due to advection
  - **Advection of heat from northwest India due to stronger westerly to northwesterly wind.**
  - **Large amplitude anticyclonic flow (thickness of atmosphere above normal) and dry adiabatic lapse rate helps in thermal advection.**
- Heat wave in situ
  - **Weak/ delayed onset of sea breeze.**
  - **Less cloudiness and less relative humidity are favourable for heat wave.**

Mean pressure & Prevailing Wind - MAY

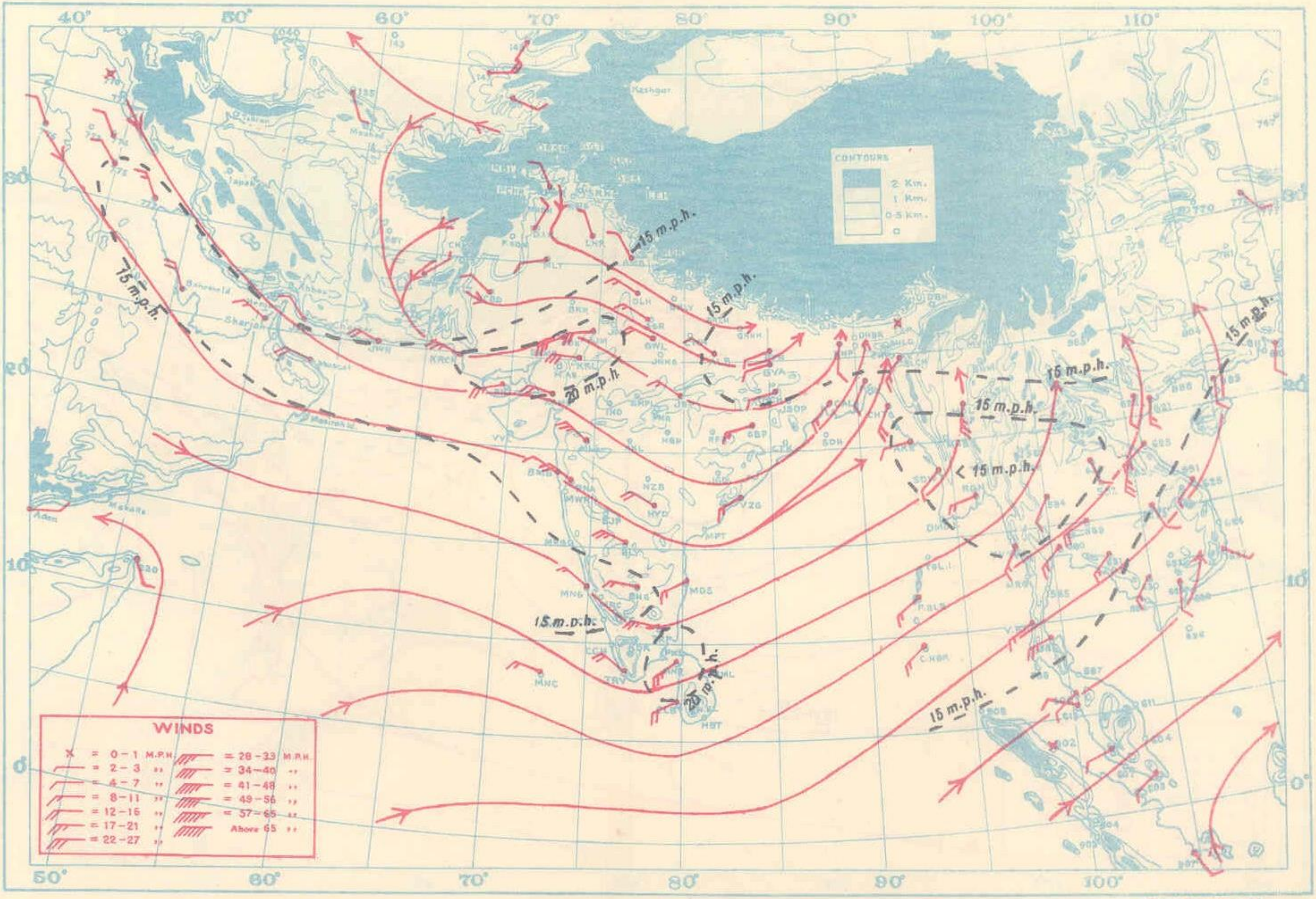


UPPER WINDS (0.5 km) – MAY

MAY — 0·5 Km. / 1,600 Ft. a.s.l.

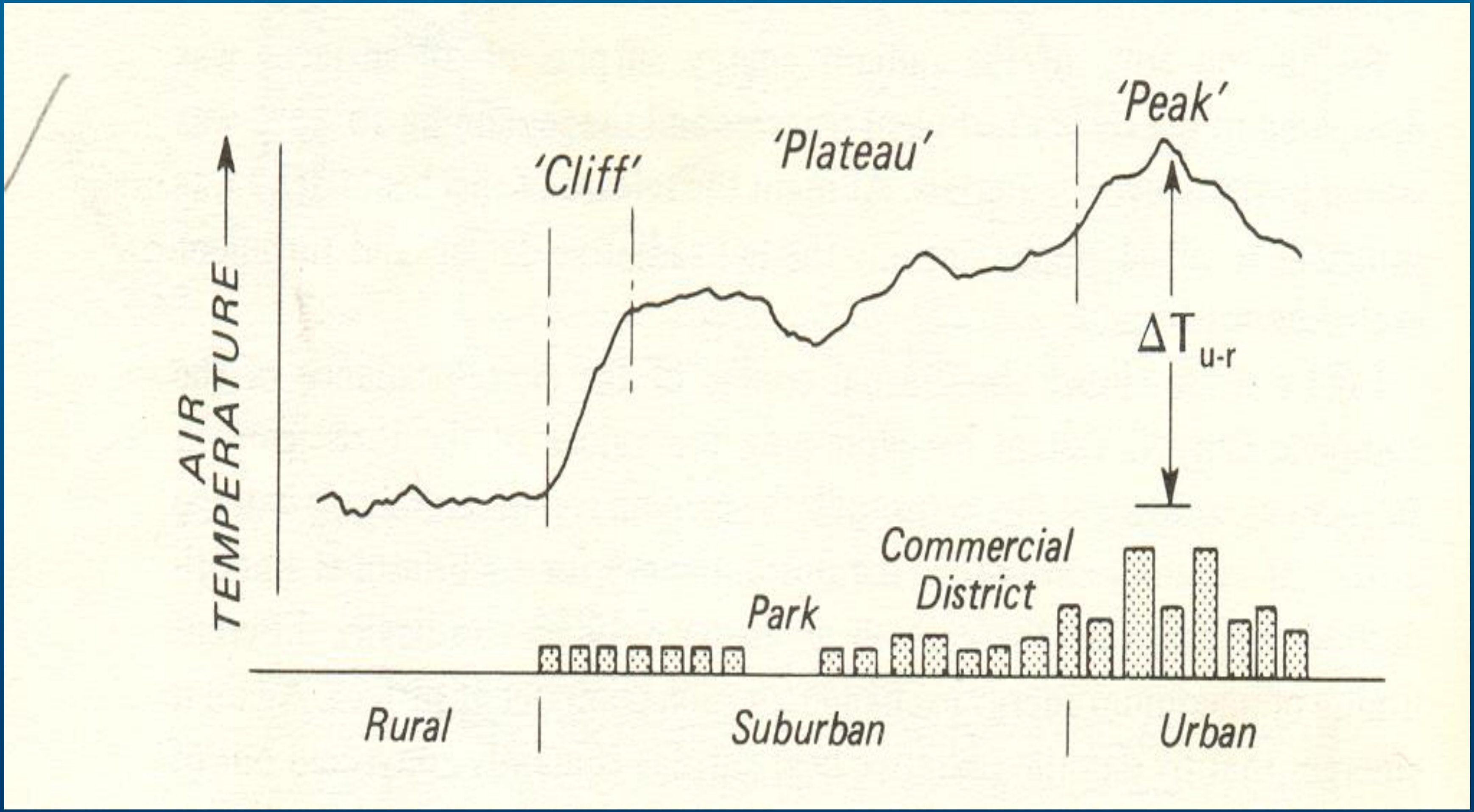


UPPER WINDS (1.0 km) – MAY



Resultant direction and force of wind with stream lines. Broken black lines indicate average speed (Irrespective of direction).

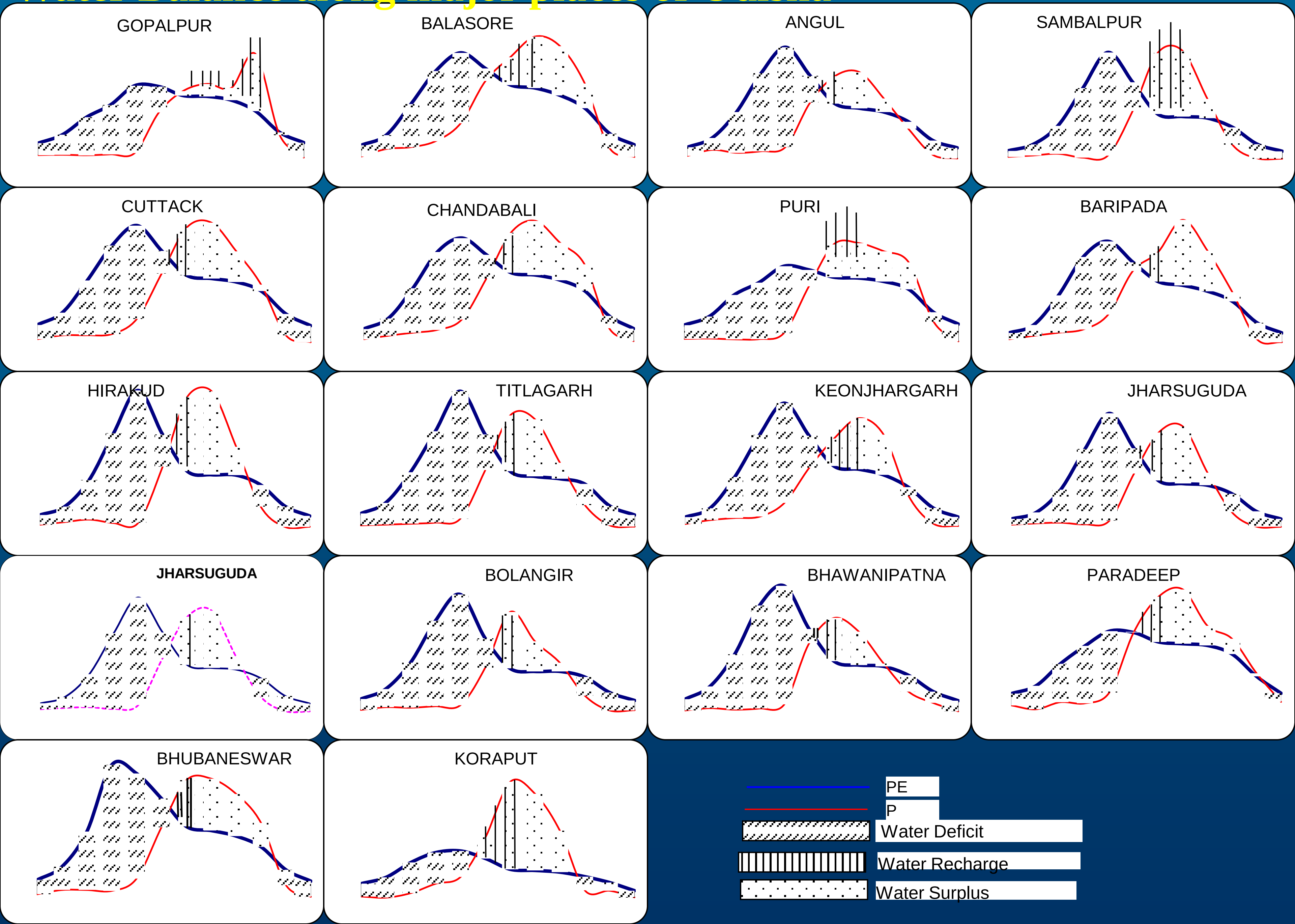
Urban Heat Island



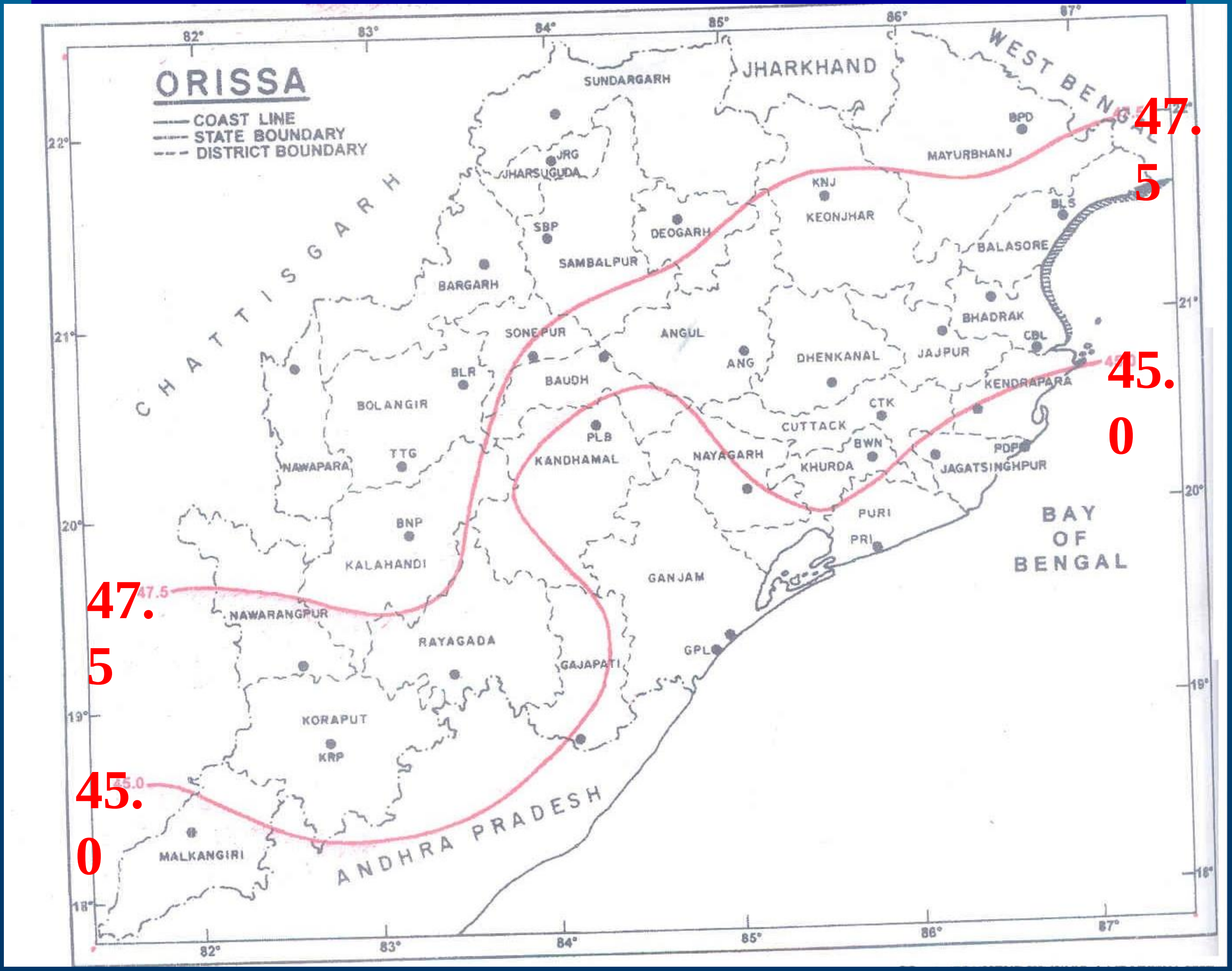
Causes of Urban heat Island

Sl. No.	Effect	Mechanism
1	Increased counter radiation	Absorption of LWR up and emission by pollutants
2	Decreased net long-wave radiation	Increase in atmospheric pollutant levels
3	Greater day time heat storage	Thermal properties of construction materials
4	Decreased evaporation	Removal of vegetation and surface waterprofing
5	Decreased sensible heat loss	Reduced wind speed

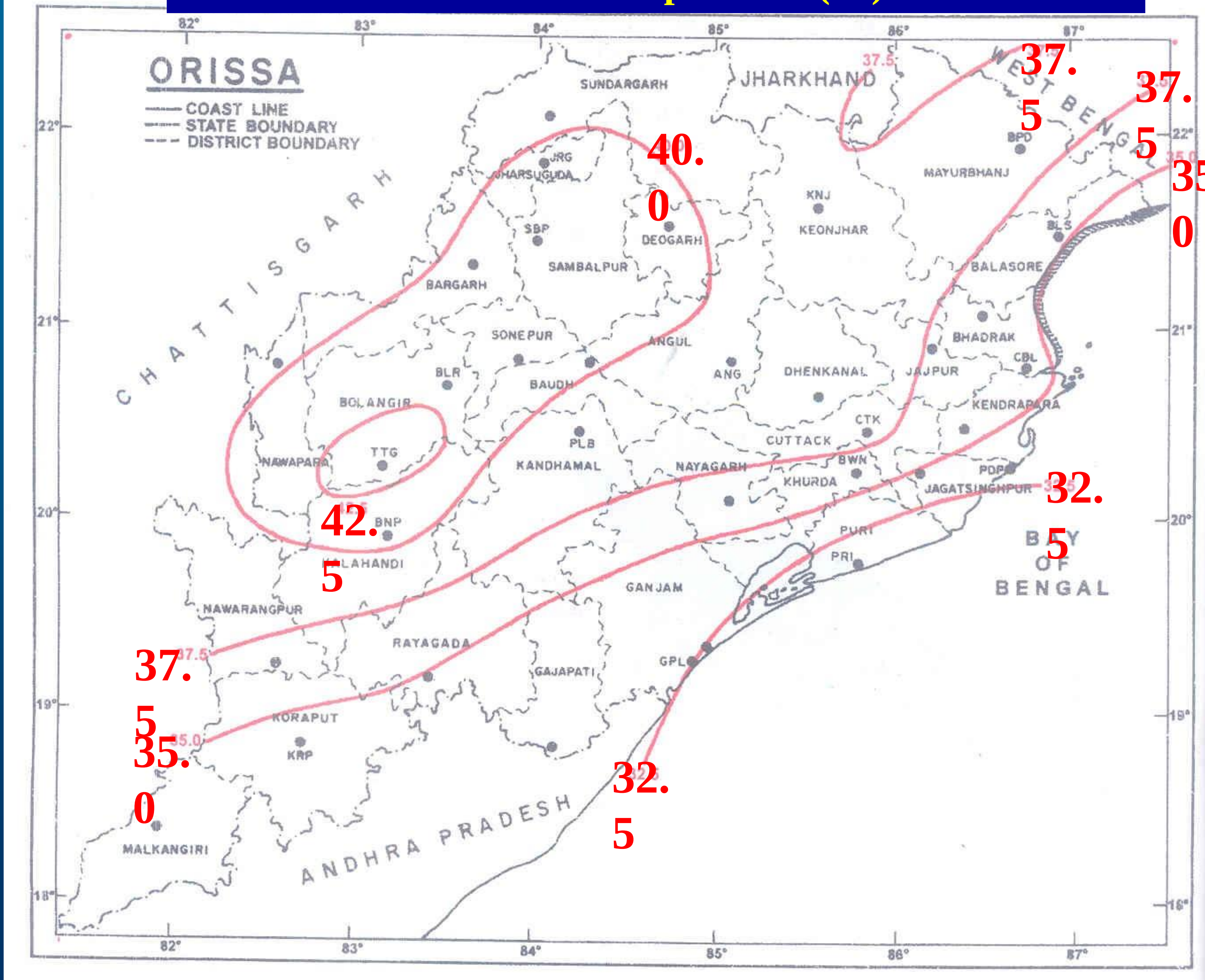
Water Balance along major places of Odisha



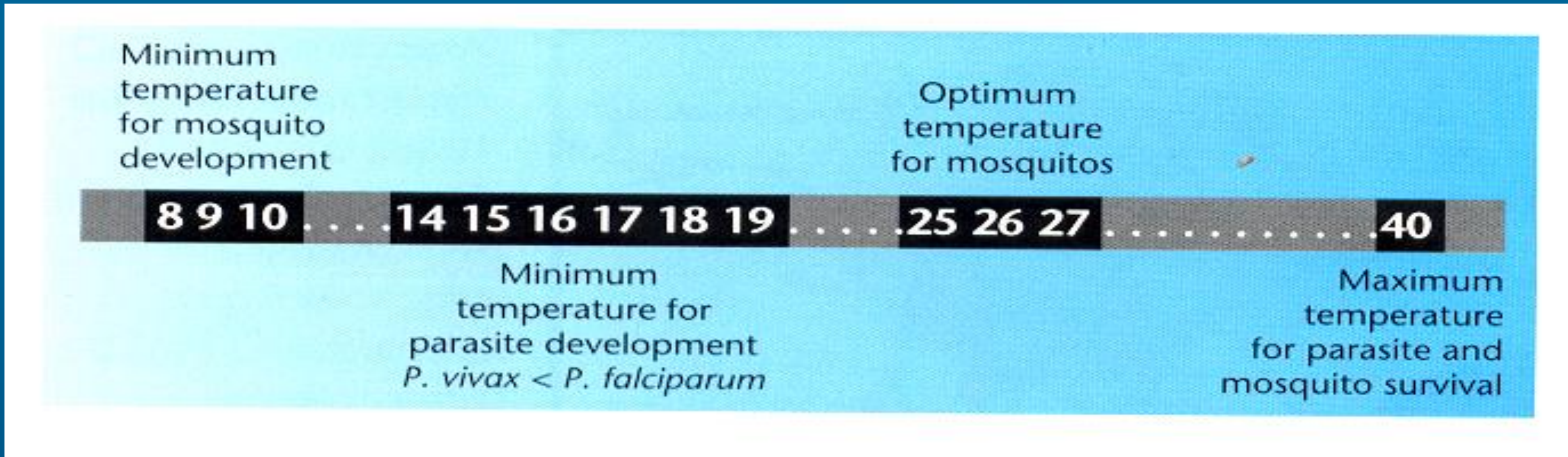
Highest Maximum Temperature (⁰C) Ever Recorded



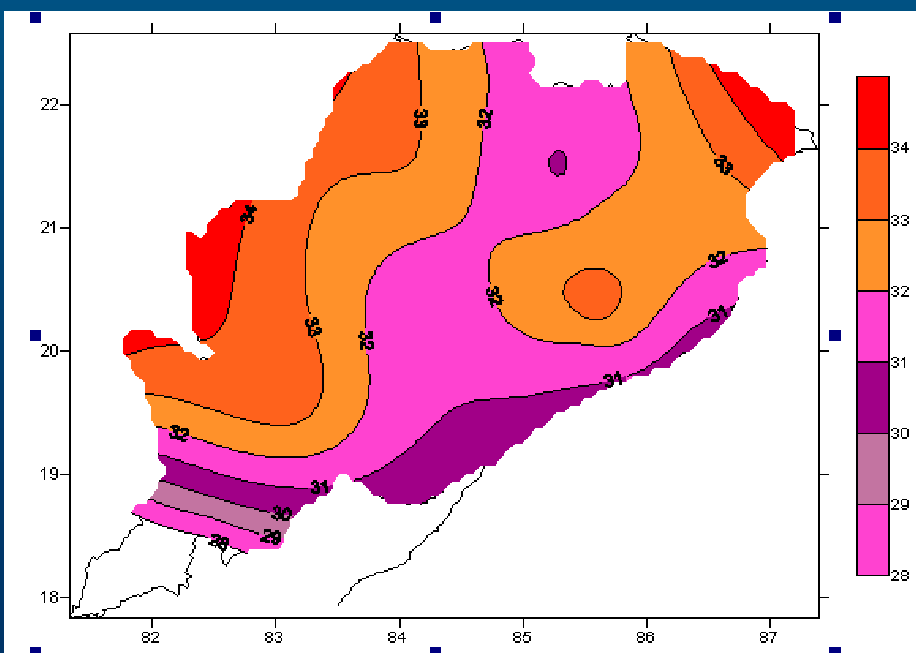
Mean Maximum Temperature (^{0}C) - MAY



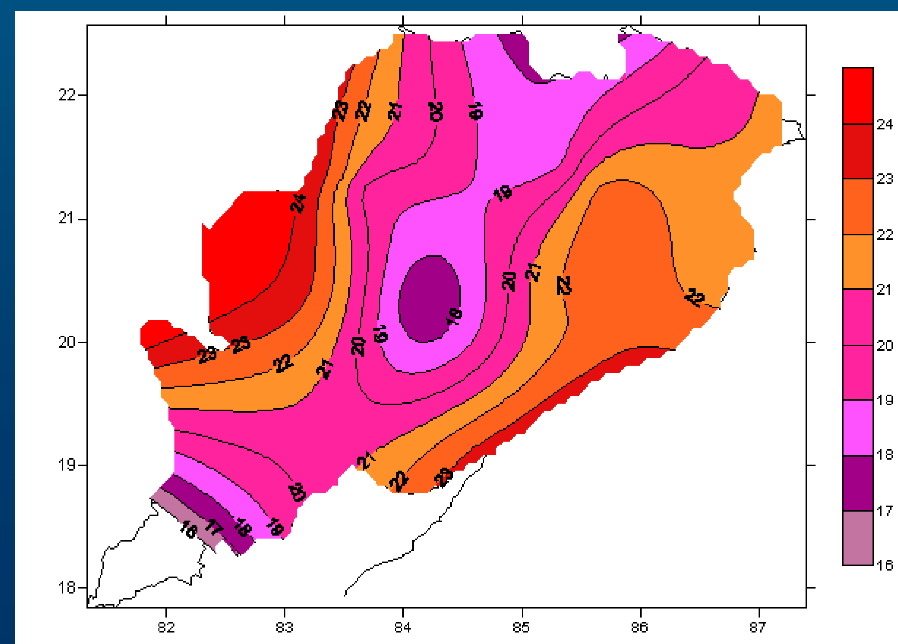
Critical temperatures (^{0} C) for malaria transmissions



Mean Annual Maximum Temperature (^{0}C)



Mean Annual Minimum Temperature (^{0}C)



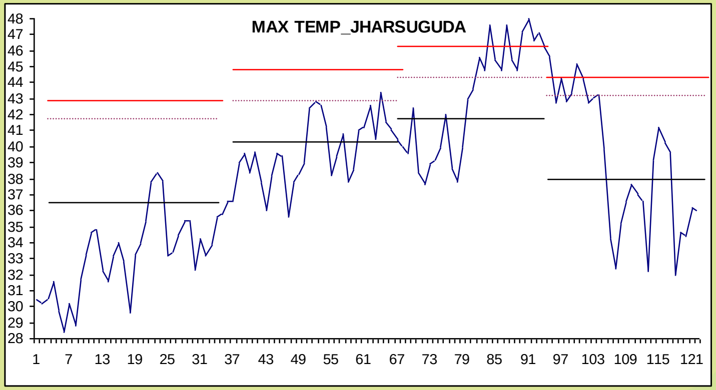
I M D Definition of Heat Wave

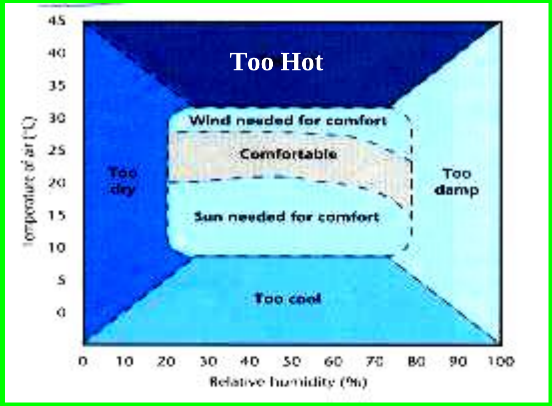
Places where the normal maximum temperature is more than 40 0 C:

- Day Temperature > 3 – 4 0C above normal: **Heat Wave**
- Day Temperature ≥ 5 0C above normal: **Sever Heat Wave**

Places where the normal maximum temperature is less than 40 0 C:

- Day Temperature > 5 – 6 0C above normal: Mod. **Heat Wave**
- Day Temperature > 6 0C above normal: **Sever Heat Wave**





Apparent Temperature

The ambient temperature adjusted for variations in vapour pressure above or below some base value and is expressed as a function of Temperature, humidity and wind speed)

AT = $-2.653+(0.994\ T_a)+(0.0153\ T_d)^2$

16- 25 ^{0}C – Mild conditions :

Clothing thickness (7.64-0.20 mm)

Skin thermal resistance (0.0387 $m^2\ K\ w^{-1}$)

Skin Moisture resistance (0.0521 $m^2\ K\ w^{-1}$)

25- 50 ^{0}C – Severe conditions :

Clothing thickness (0.00 mm)

Skin thermal resistance (0.0377-0.0229 $m^2\ K\ w^{-1}$)

Skin Moisture resistance (0.0446-0.0037 $m^2\ K\ w^{-1}$)

Extreme danger | Danger | Extreme caution | Caution

Heat Index *is how hot the heat-humidity combination makes it feel.*

RELATIVE HUMIDITY (PERCENT)

AIR TEMPERATURE (DEGREES FAHRENHEIT)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125																				
135	120	128																			
130	117	122	131																		
125	111	116	123	131	141																
120	107	111	116	123	130	139	148														
115	103	107	111	115	120	127	135	143	151												
110	99	102	105	108	112	117	123	130	137	143	150										
105	95	97	100	102	105	109	113	118	123	129	135	142	149								
100	91	93	95	97	99	101	104	107	110	115	120	126	132	138	144						
95	87	88	90	91	93	94	96	98	101	104	107	110	114	119	124	130	136				
90	83	84	85	86	87	88	90	91	93	95	96	98	100	102	106	109	113	117	122		
85	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	95	97	99	102	105	108
80	73	74	75	76	77	77	78	79	79	80	81	81	82	83	85	86	86	87	88	89	91
75	69	69	70	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	79	80
70	64	64	65	65	66	66	67	67	68	68	69	69	70	70	70	71	71	71	71	71	72

Heat Index: heat-humidity combination make the condition dangerous

Thermo-Hygrometric Index

THI = $T_{max} - [(0.55 - 0.0055\ RH\%)(T_{max} - 14.5)]\ ^0C$

Mortality and Morbidity depends on Complex thermo-hygrometric Index (*Tseletidaki et al, 1995*)

THI > 28.5 is usually associated with discomfort.

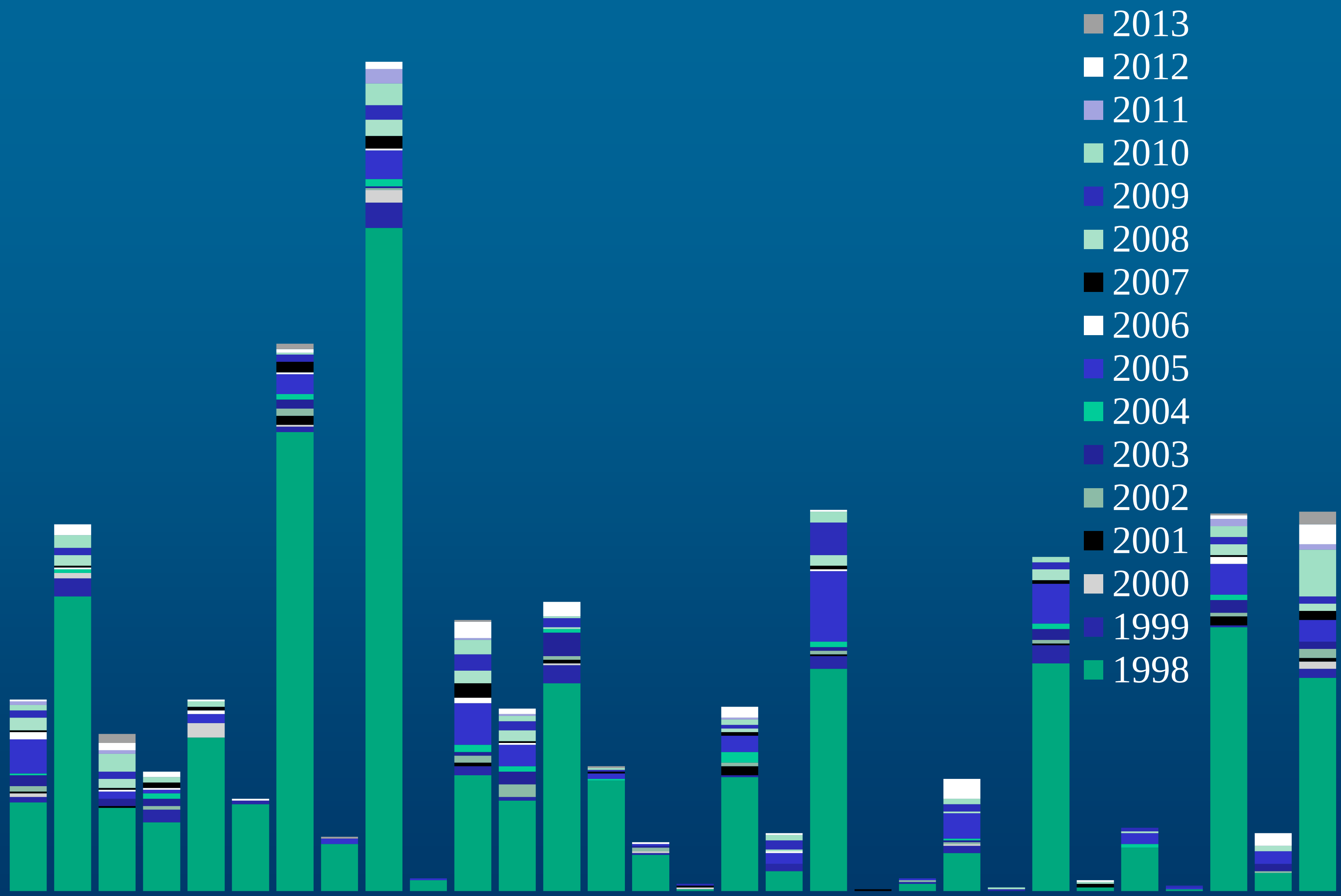
Duration of Heat spells in different stations in Odisha during 1998-2008.

STN	Mean frequency of heat wave spells											
	1998			2000			2005			2008		
	a	b	c	a	b	c	a	b	c	a	b	c
ANGUL	5	1	1	1	0	0	2	1	1	2	1	0
BARIPADA	-	-	-	0	1	0	1	3	0	*	*	*
BOLANGIR	-	-	-	4	1	1	0	0	1	0	1	0
BHUBANESWAR	2	2	0	*	*	*	0	2	1	1	0	0
BHABANIPATNA	-	-	-	-	-	-	-	-	-	2	1	1
BALASORE	0	0	1	*	*	*	3	1	0	*	*	*
CUTTACK	2	1	0	*	*	*	2	3	0	1	0	0
CHANDABALI	1	3	0	1	0	0	3	1	1	1	0	0
GOPALPUR	-	-	-	1	0	0	2	0	0	*	*	*
HIRAKUD	-	-	-	-	-	-	-	-	-	*	*	*
JHARSUGUDA	2	1	1	1	2	0	1	0	2	*	*	*
KEONJHAR	0	0	1	*	*	*	1	1	1	*	*	*
KORAPUT	-	-	-	-	-	-	2	2	4	1	1	1
PARADIP	*	*	*	1	0	0	2	0	0	*	*	*
PURI	*	*	*	*	*	*	*	*	*	*	*	*
PHLBANI	-	-	-	*	*	*	1	3	0	-	-	-
SAMBALPUR	0	3	0	1	0	0	0	3	0	*	*	*
SUNDARGARH	*	*	*	2	2	1	*	*	*	*	*	*
TITILAGARH	0	0	2	0	1	0	2	1	3	*	*	*

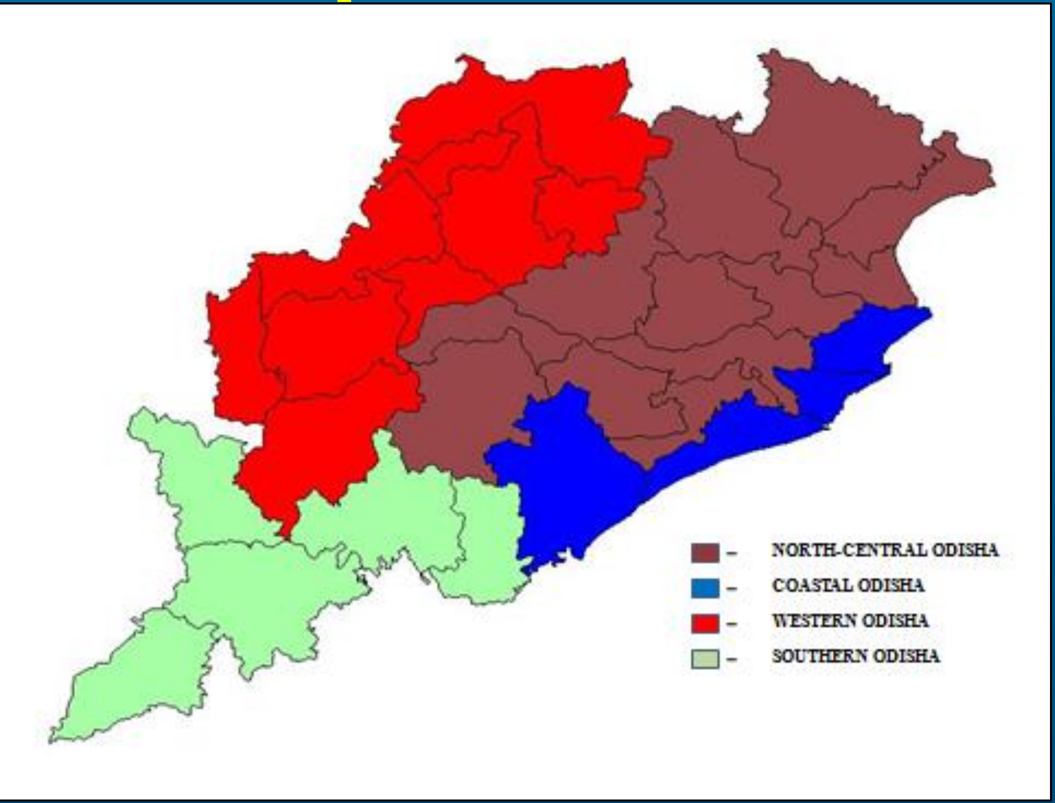
(-) represents not available
(*) represents no heat spell

a. Mean frequency of heat wave spells of duration < 2 days.
b. Mean frequency of heat wave spells of duration = 2-5 days.
c. Mean frequency of heat wave spells of duration > 5 days.

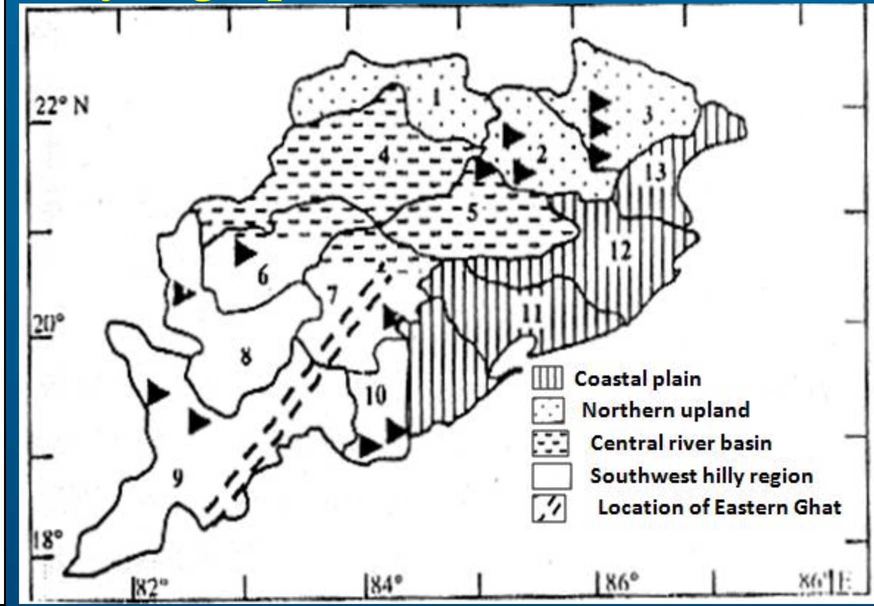
District wise mortality during 1998-2013



Different Temperature Zones in Odisha and their temperature ranges



Physiographic features of Odisha



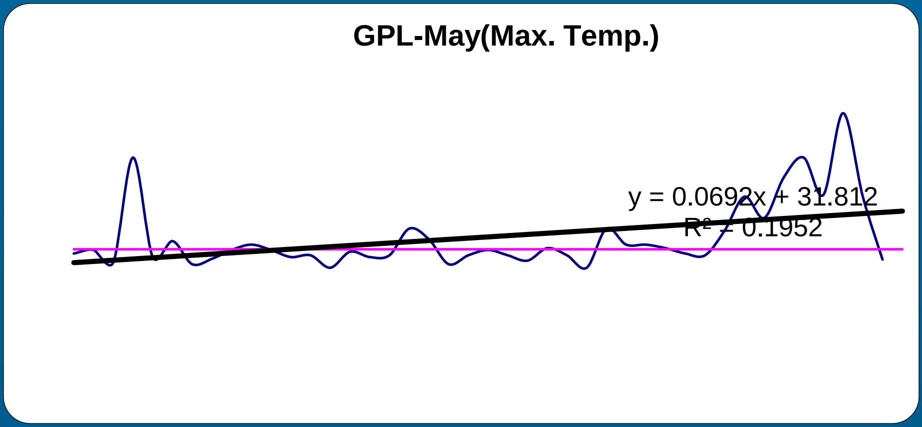
- **Coastal Odisha: >=35^0 C < 39^{0}C** (Gopalpur, Paradeep, Puri)
- **North-Central Odisha: >=42^{0}C < 44.5^{0}C** (Balasore, Cuttack, Baripada, Phulabani, Keonjhar, Chandbali, Bhubaneswar)
- **Western Odisha: >=44.5^{0}C <= 48^{0}C** (Titilagarh, Bhawanipatna, Jharsuguda, Bolangir, Anugul, Sambalpur, Sundergarh, Hirakuda)
- **Southern Odisha: >39^{0}C <=40^{0}C** (Koraput)

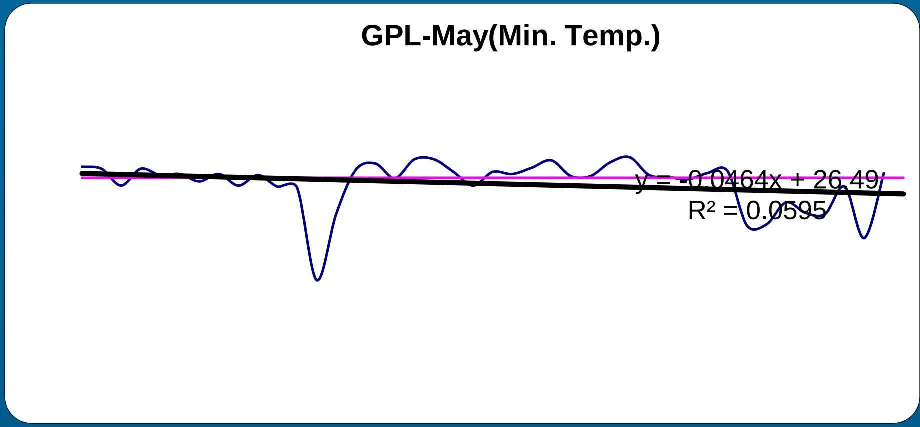
Heat spell and mortality in different temperature zones of Odisha

Year/Station	Coastal Stations		North Central station		Western station		Southern stations	
	Number of mortality	Number of heat spells	Number of mortality	Number of heat spells	Number of mortality	Number of heat spells	Number of mortality	Number of heat spells
1998	138	3	736	14	446	17	0	NA
1999	7	1	38	23	5	30	0	NA
2000	0	2	9	2	19	12	0	NA
2001	2	3	6	2	6	7	0	NA
2002	11	7	7	7	7	16	0	NA
2003	9	1	8	14	14	16	0	NA
2004	9	4	11	20	5	14	0	4
2005	41	4	70	28	50	17	0	8
2006	4	3	5	8	12	8	0	2
2007	9	2	11	6	7	13	1	2
2008	14	0	20	3	13	8	0	3
Total	244	30	921	127	584	158	1	19

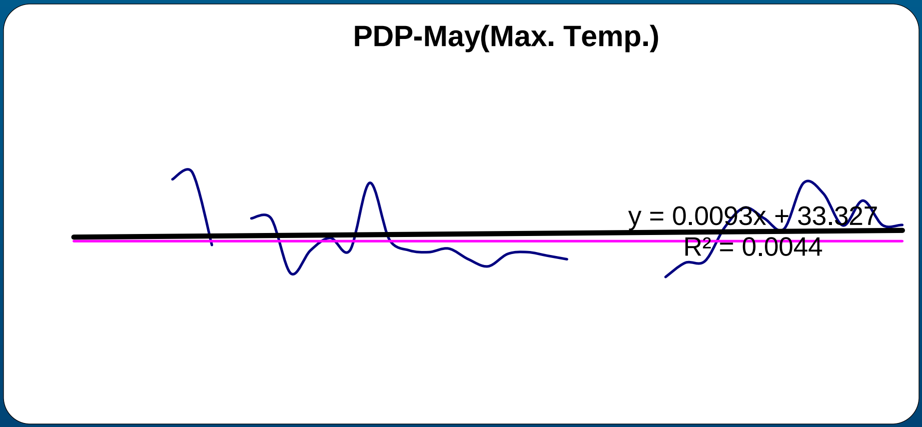
Comparison of Max. and Min. Temperature trends along Coastal Odisha during May

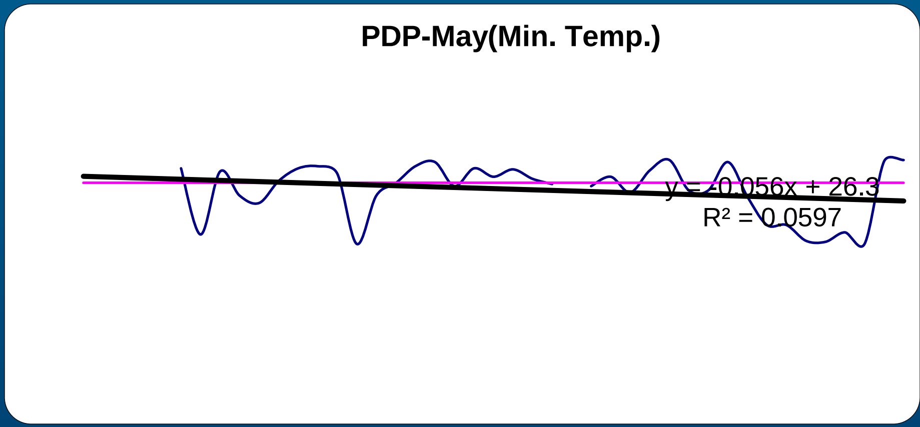
GOPALPUR



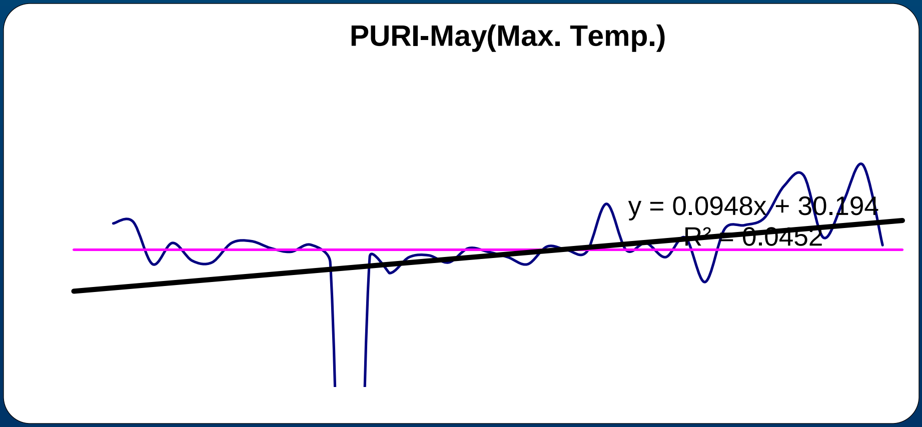


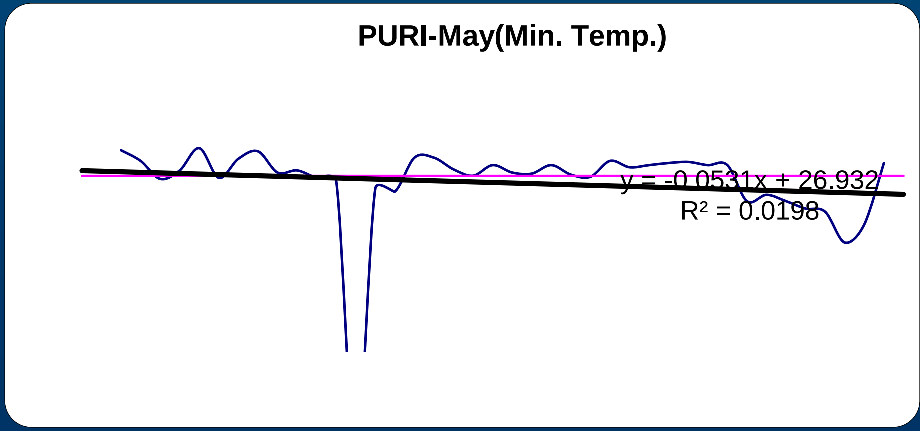
PARADIP





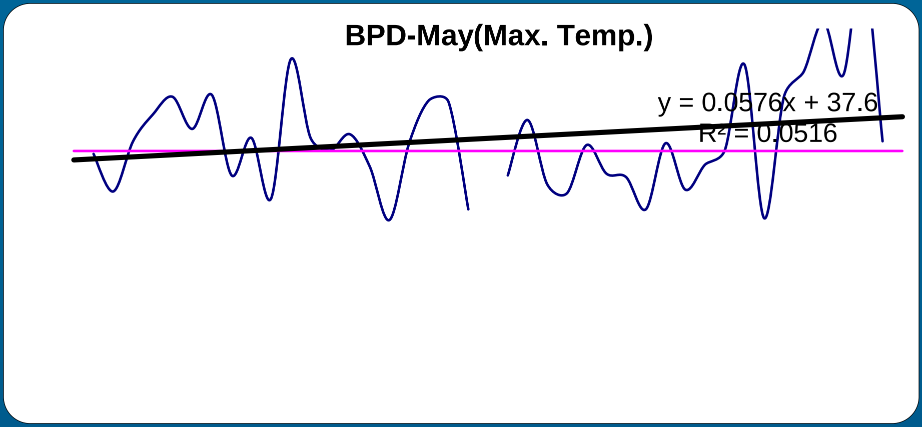
PURI

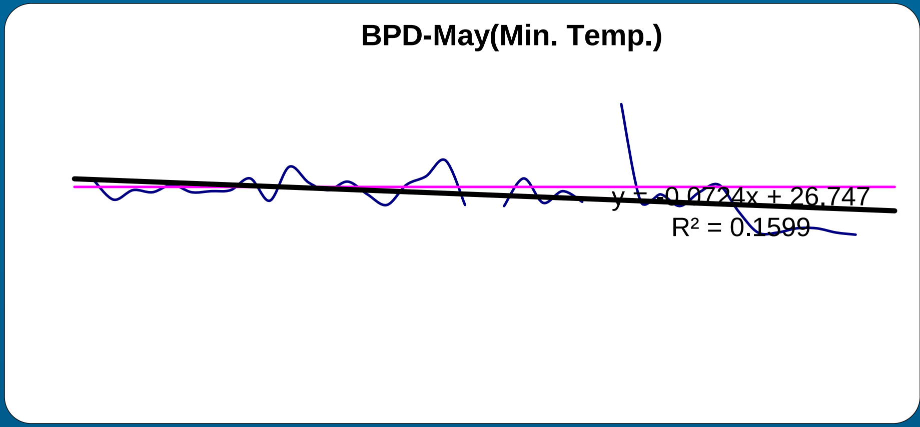




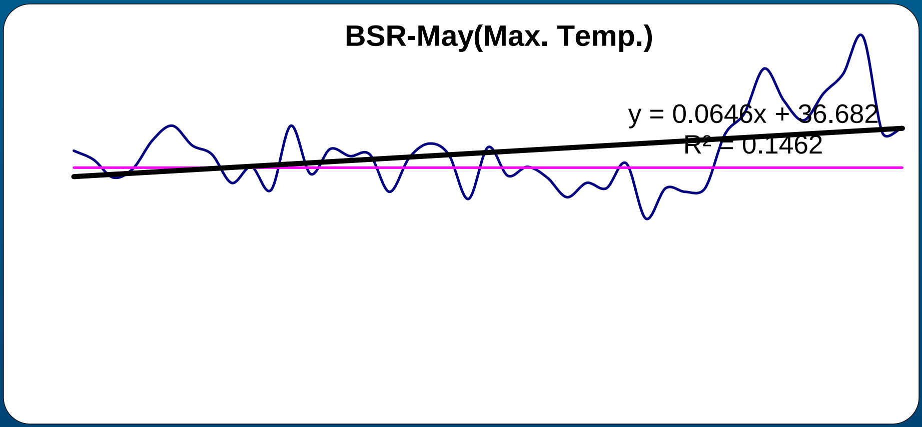
Comparison of Max. and Min. Temperature trends along North Central Odisha during May

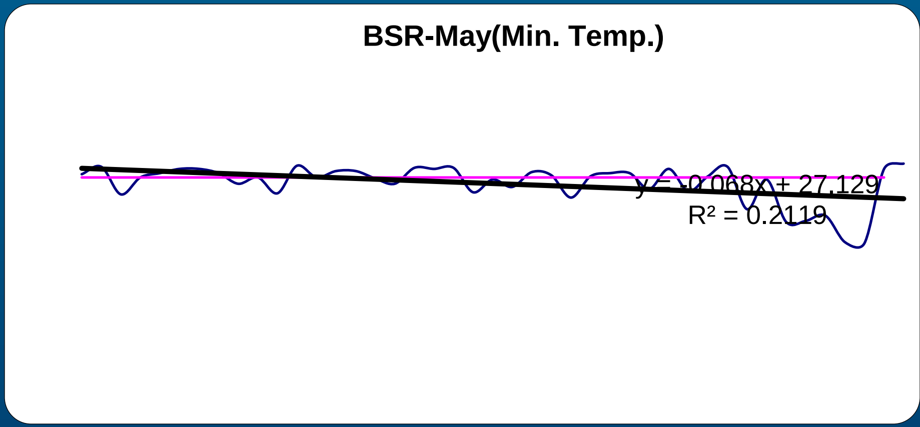
BARIPADA



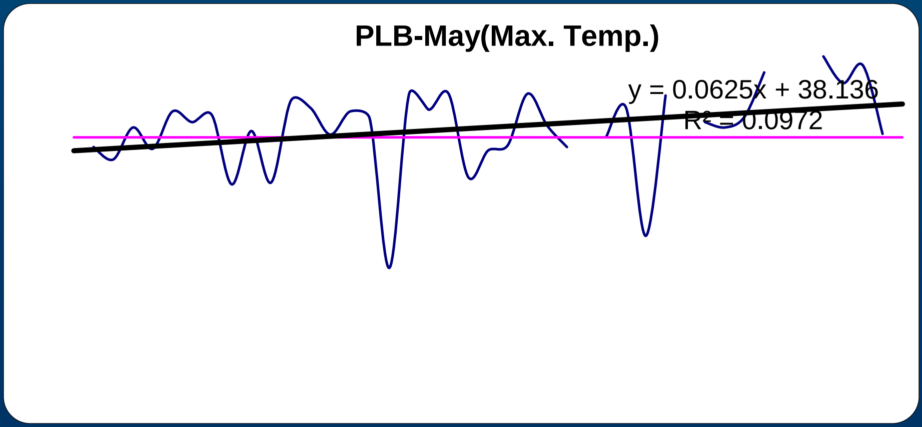


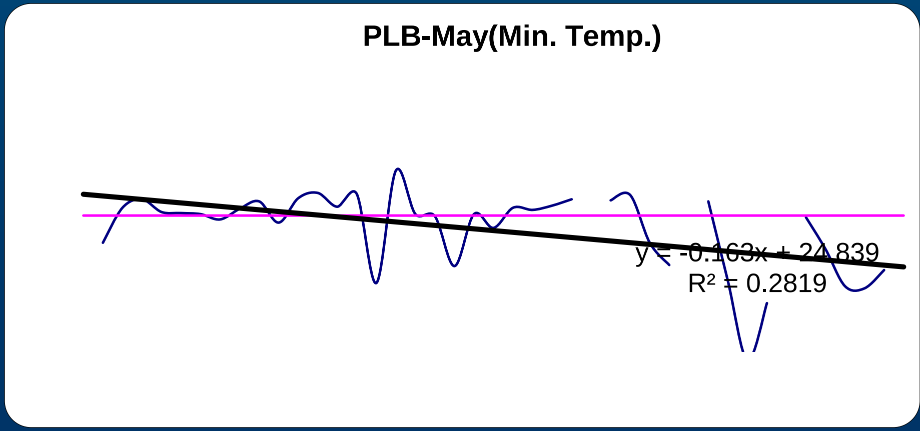
BHUBANESWAR





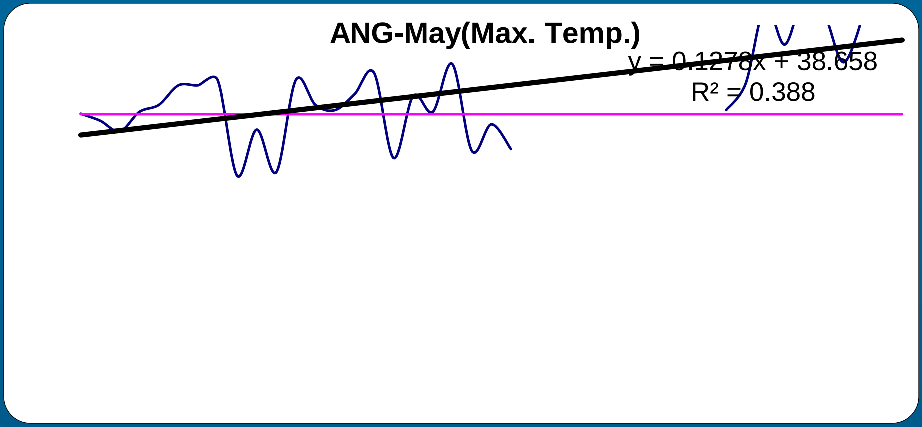
PHULBANI

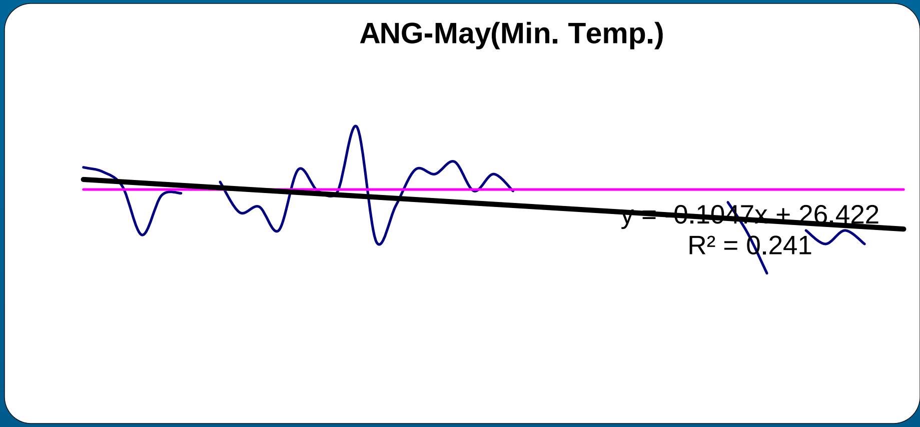




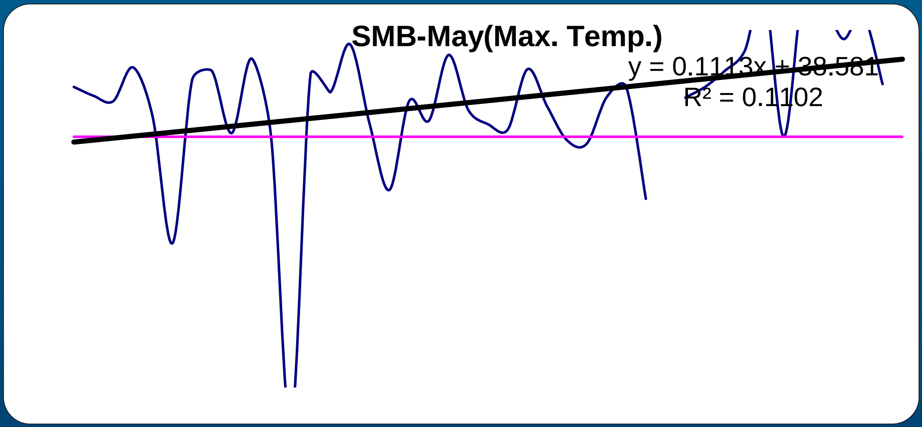
Comparison of Max. and Min. Temperature trends along Western Odisha during May

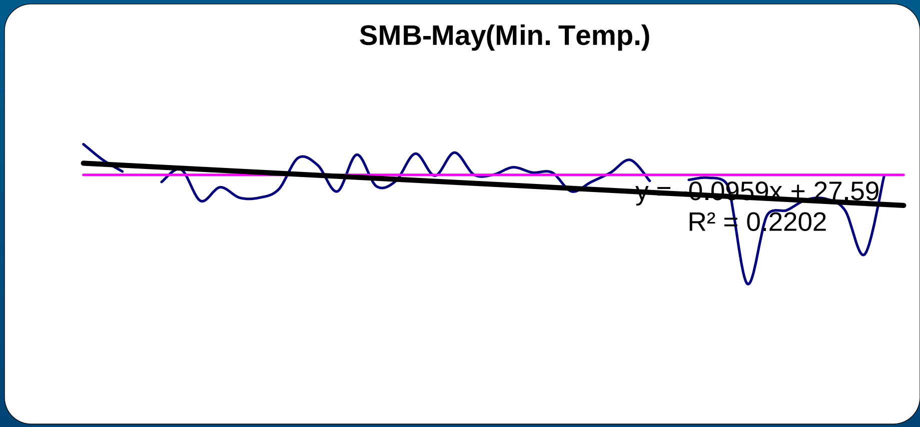
ANGUL



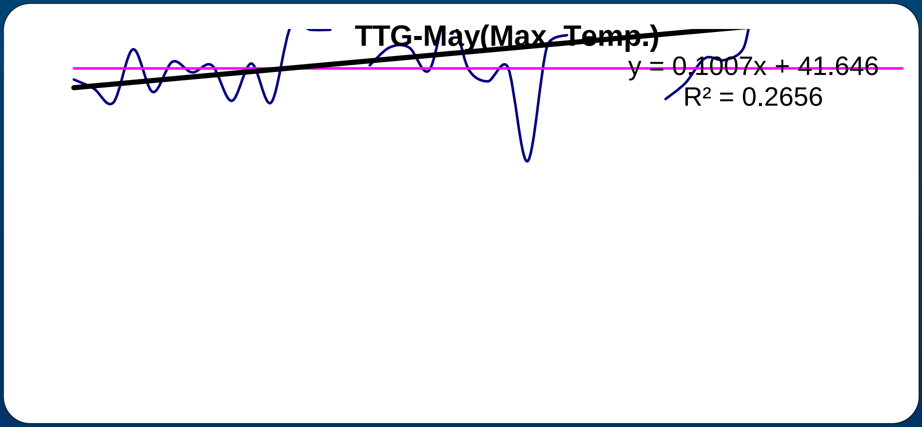


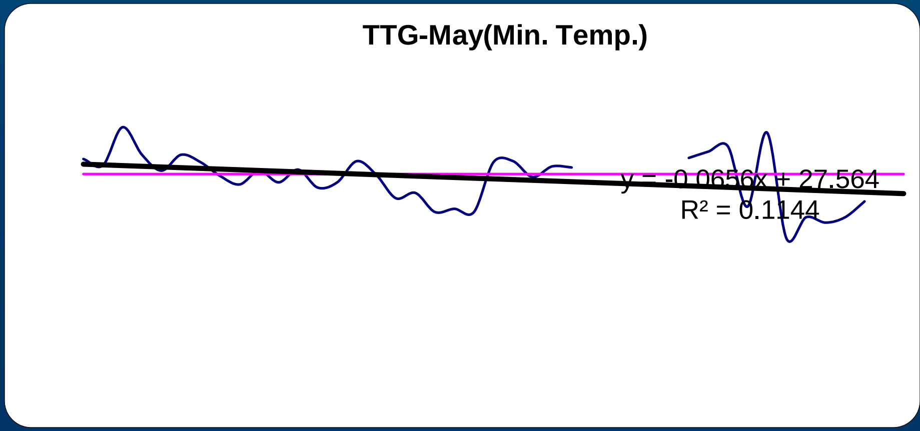
SAMBALPUR



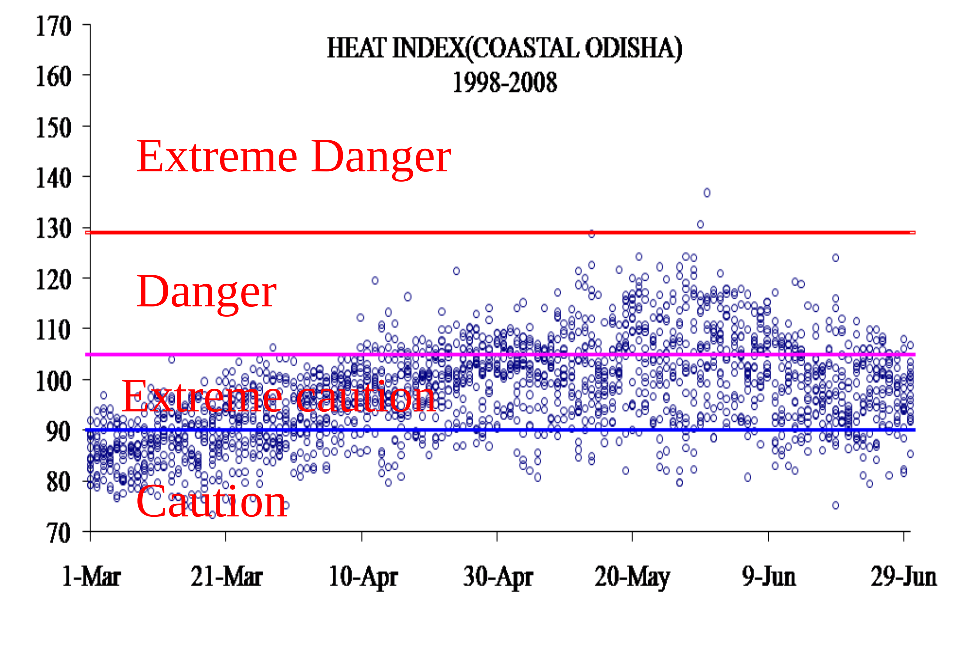


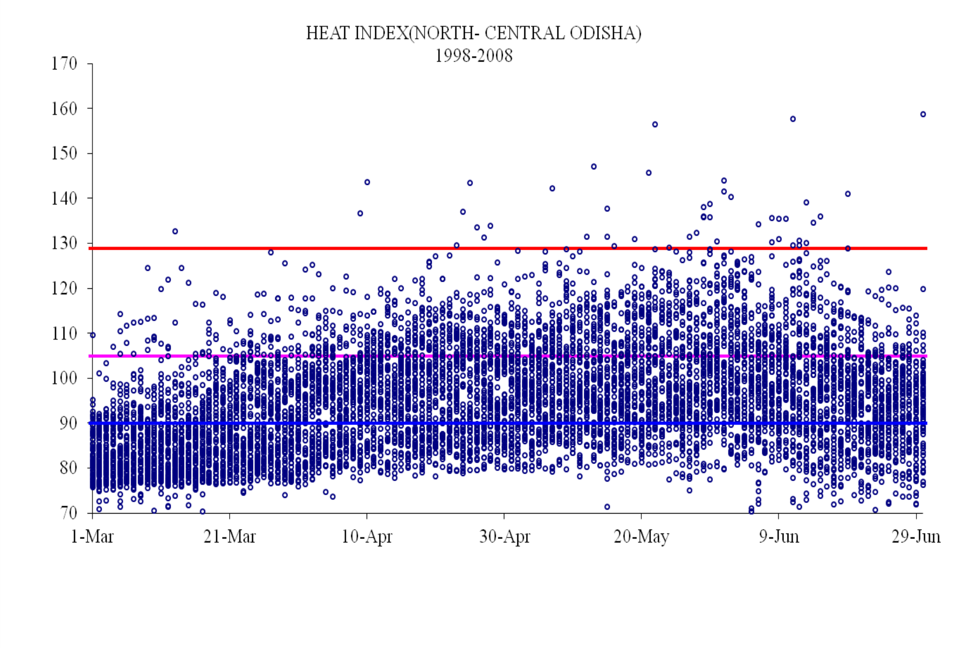
TITILAGARH

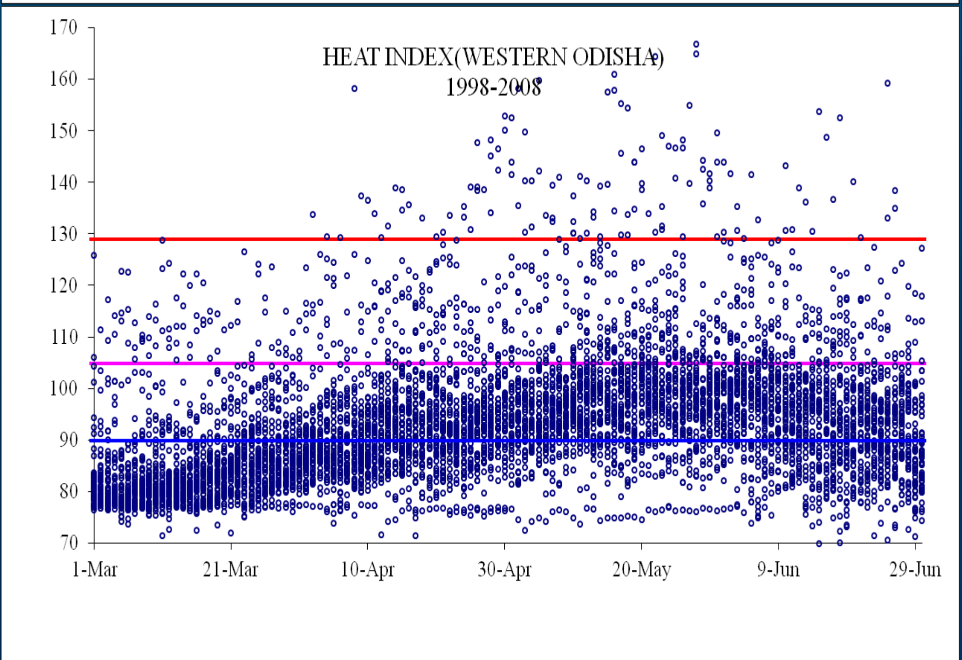


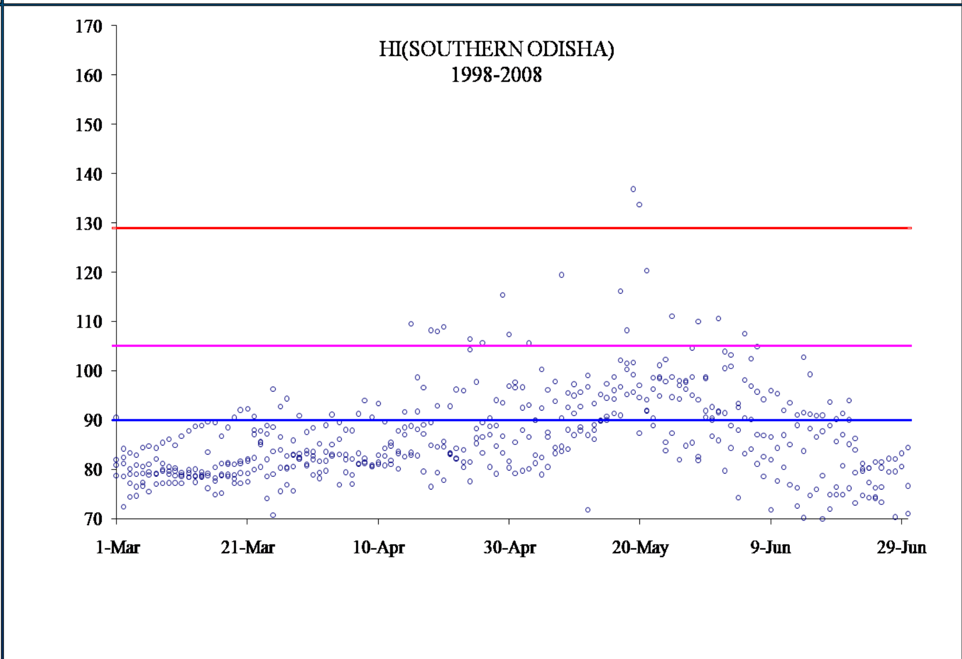


Heat Index for different Temperature Zones in Odisha during 1998-2008

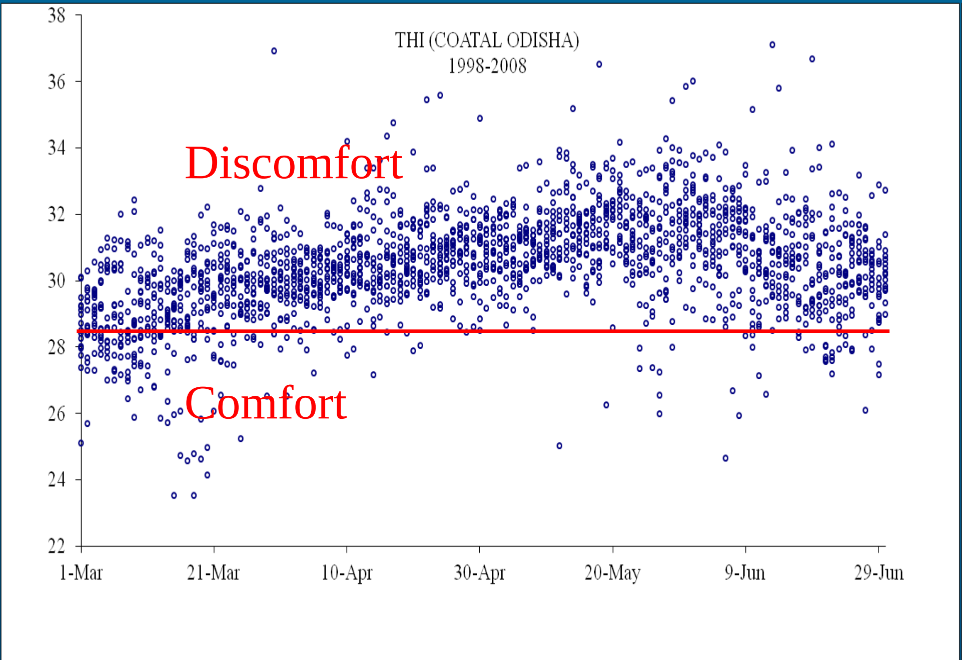


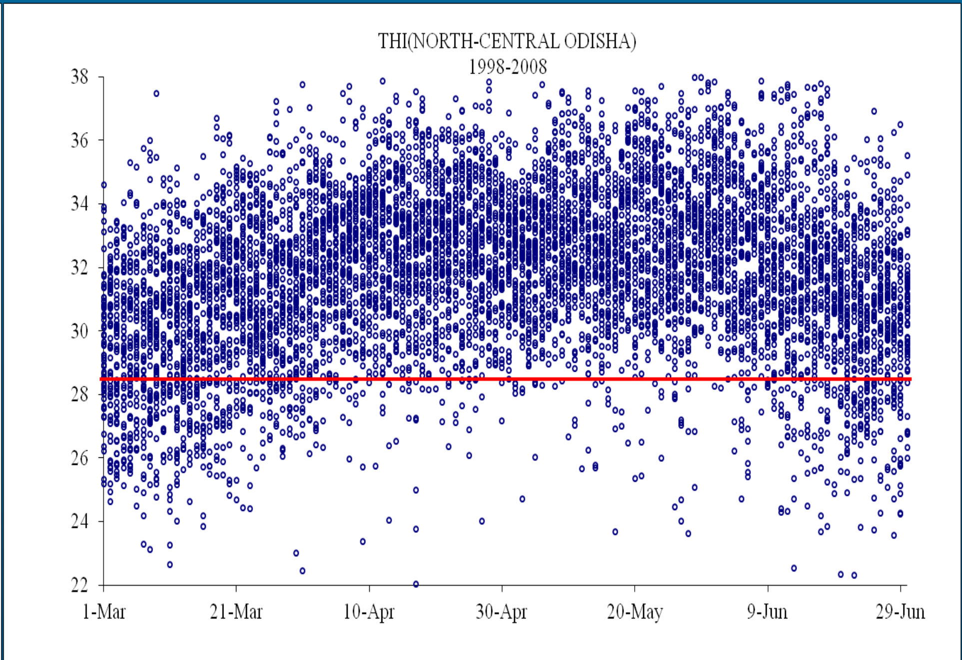


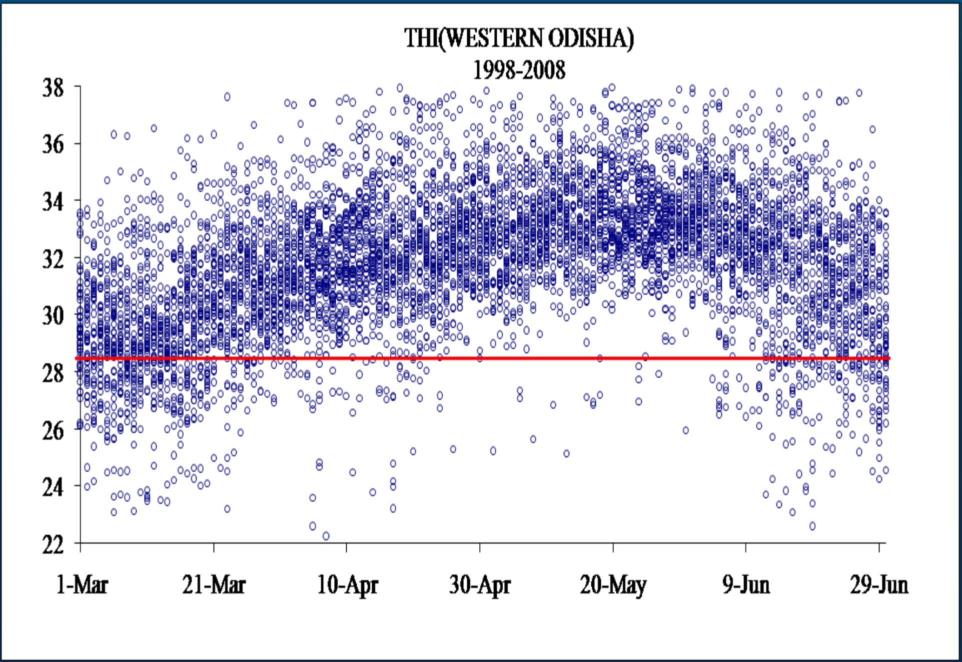


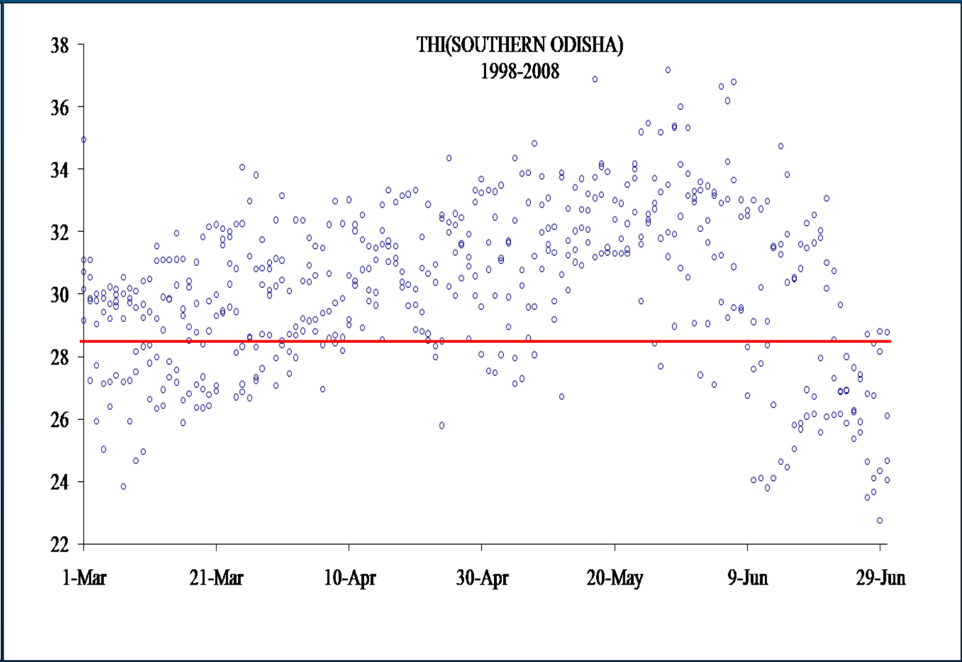


Thermo Hygrometric Index for different Temperature Zones in Odisha during 1998-2008

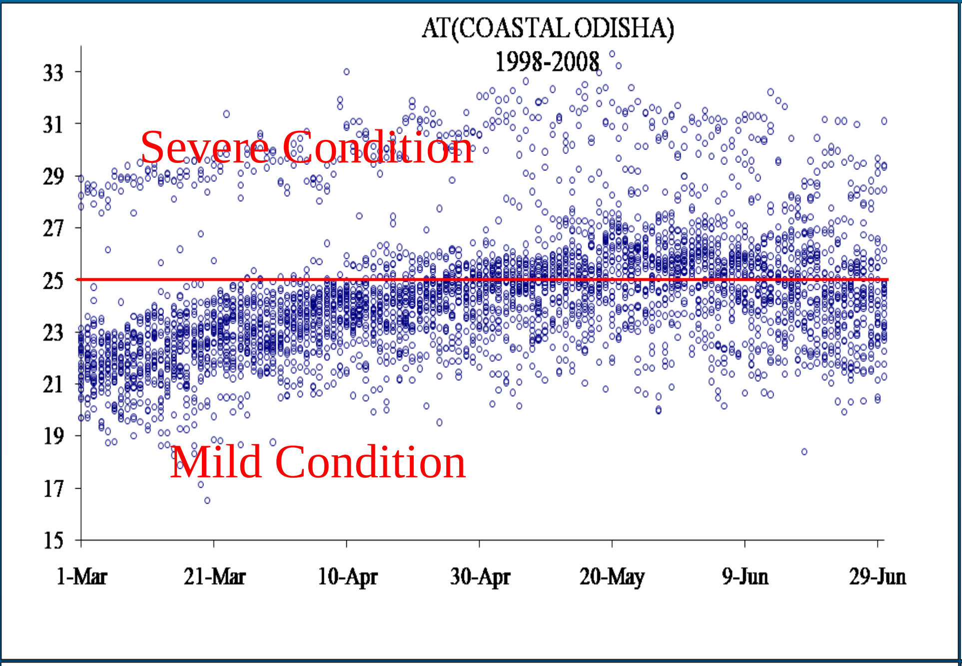


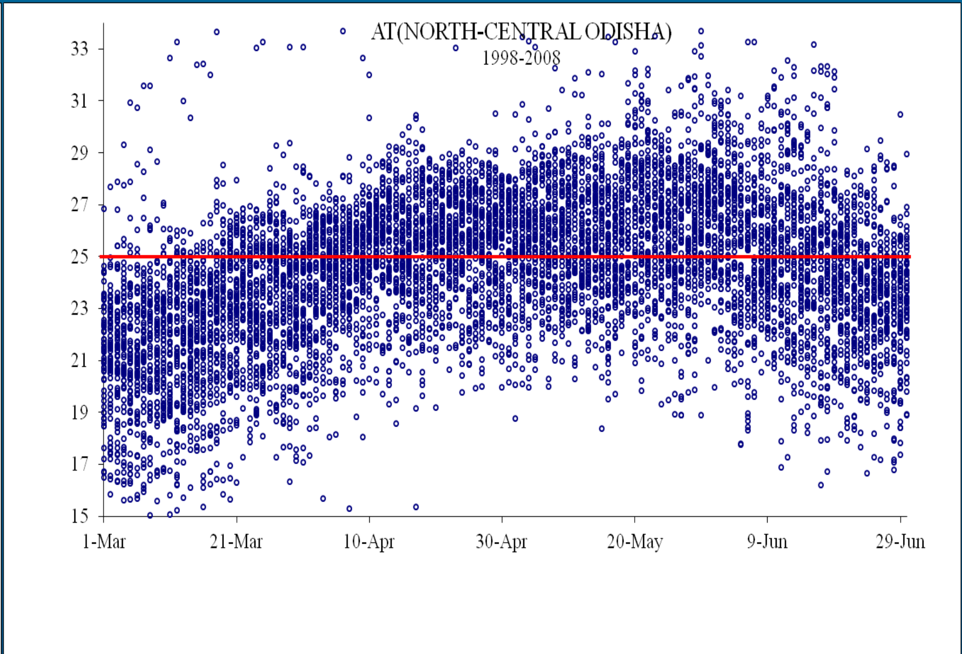


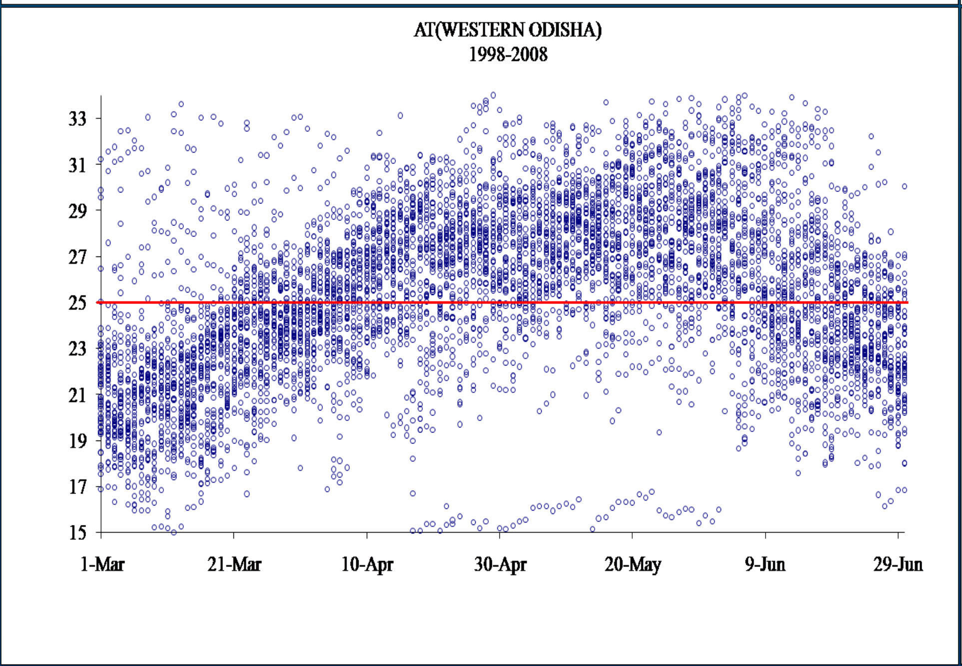


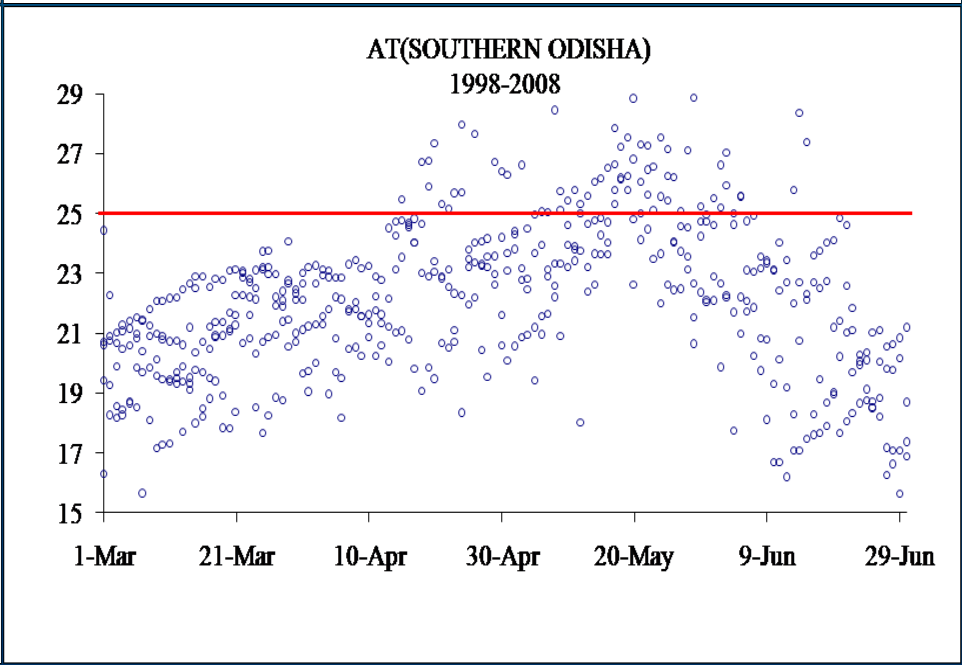


Apparent Temperature for different Temperature zones in Odisha during 1998-2008

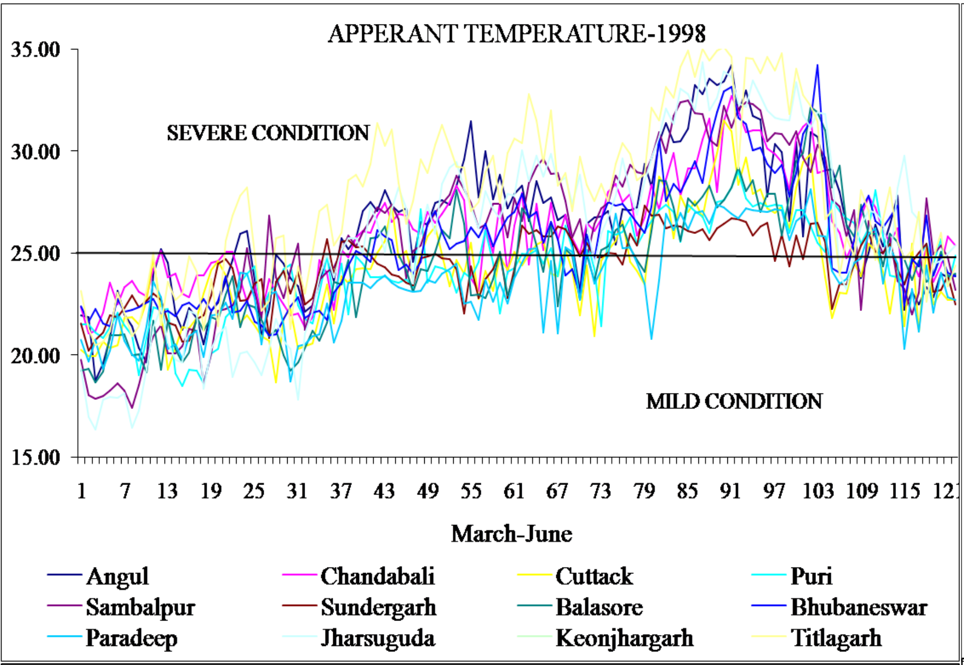


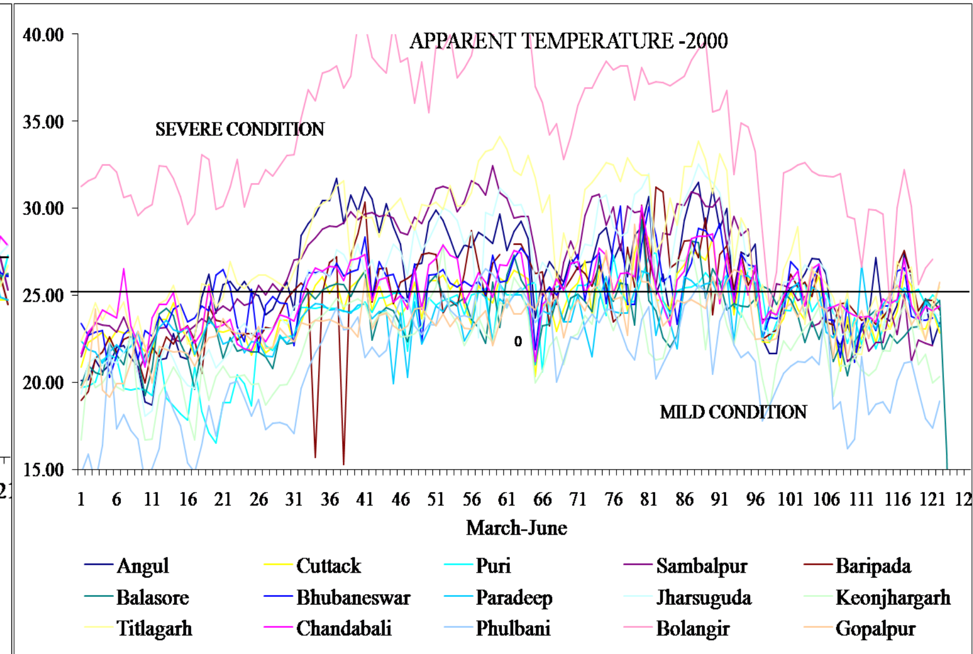


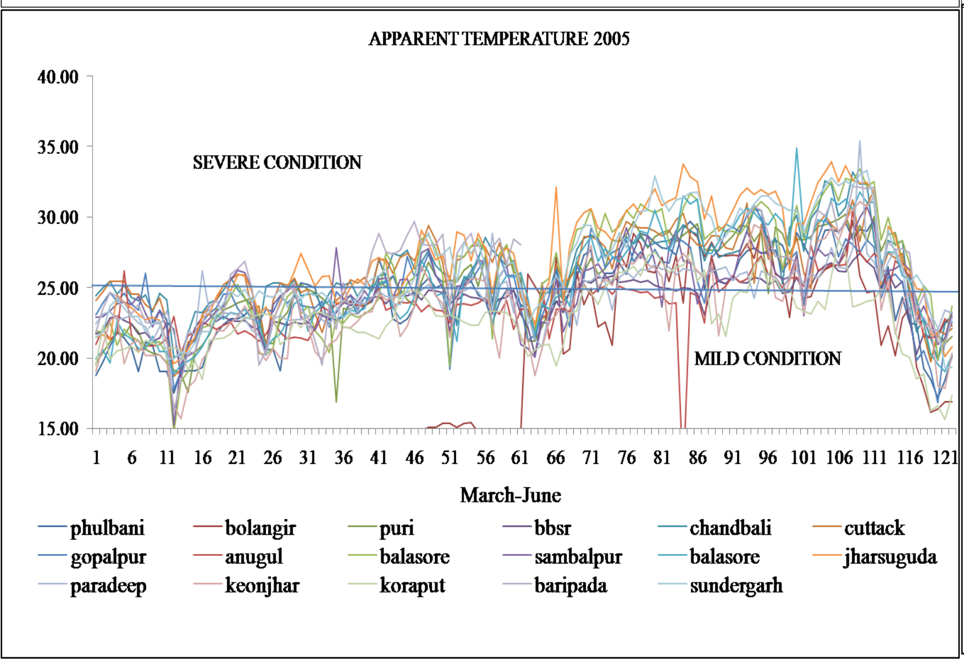


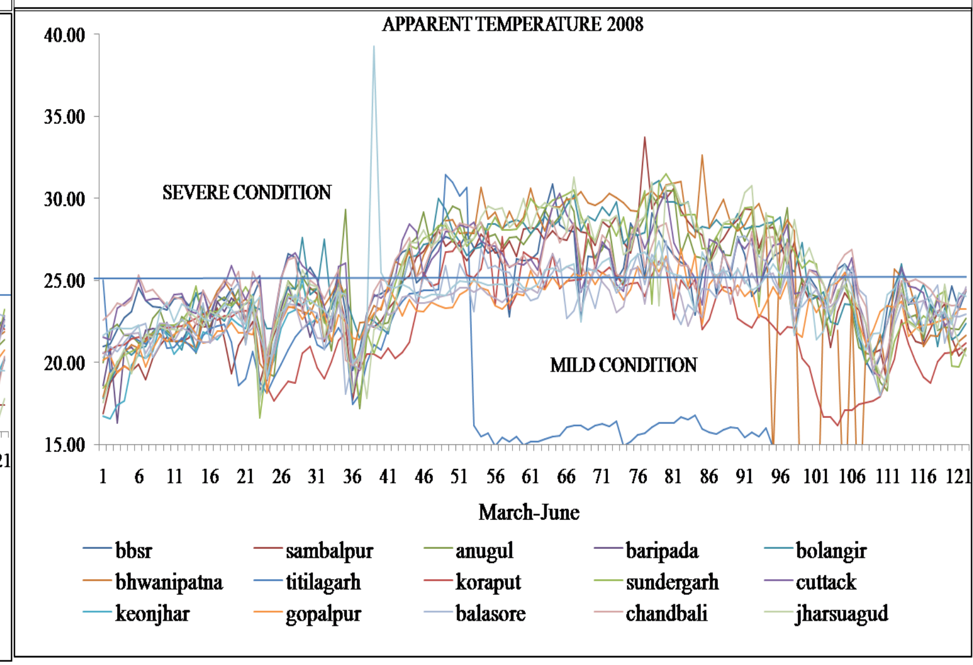


Apparent Temperature (^{0}C) for different stations in Odisha during March-June (1998-2008)





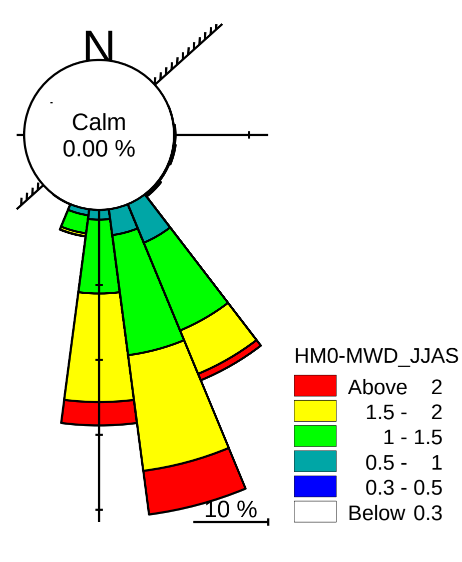


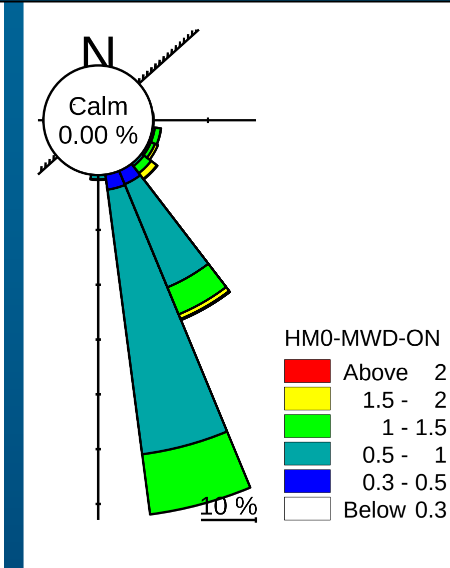


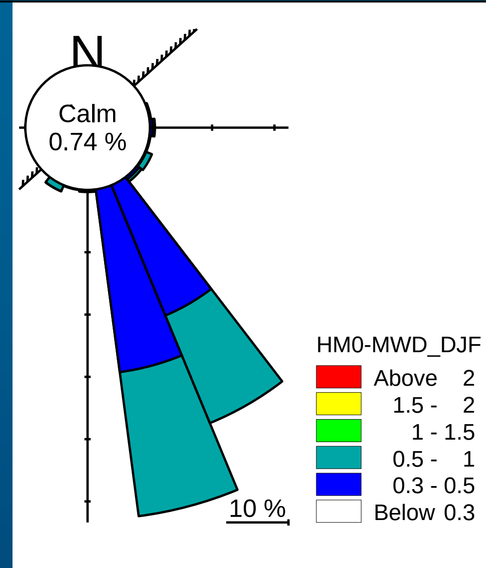
Wave Rider Buoy data collected during May 2008-June 2009 off Gopalpur

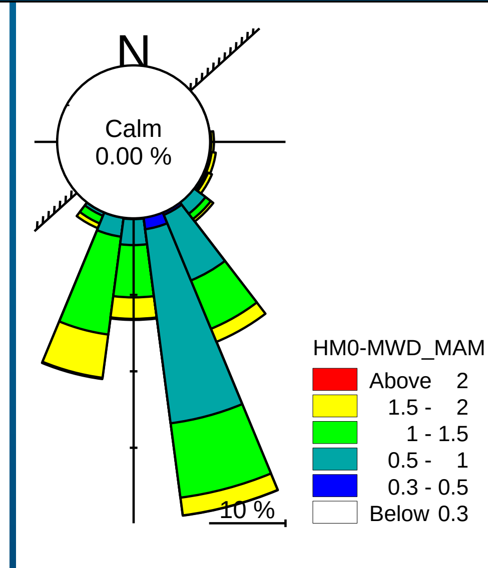
June-July-Aug.-Sept. High Energy	Oct.- Nov. Low. Energy	Dec.- Jan.- Feb. Very low Energy	Mar.- Apr.-May Moderate Energy

Significant Wave Height (m)

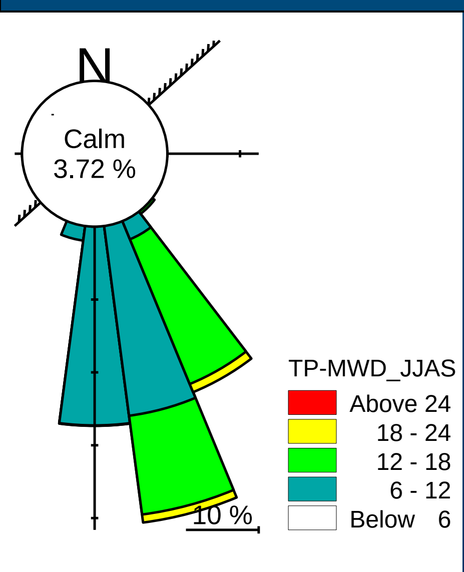


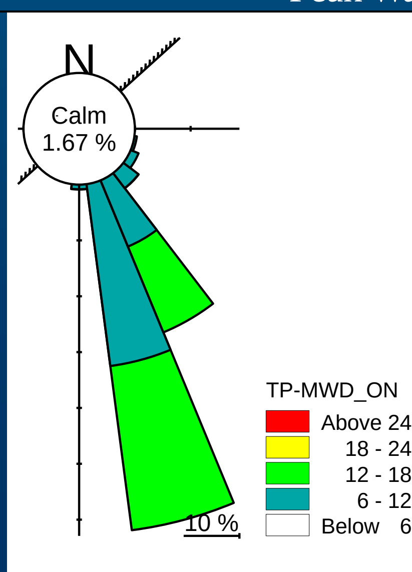


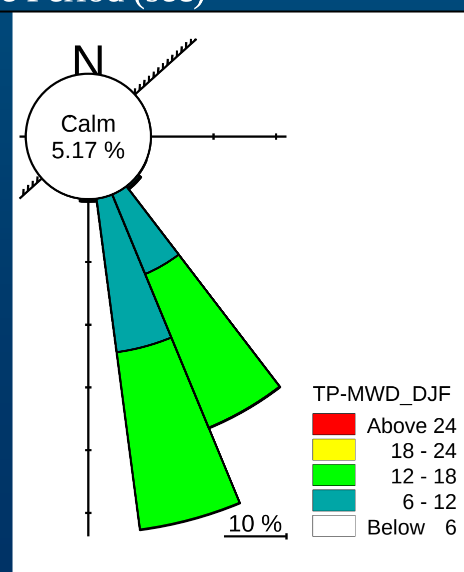


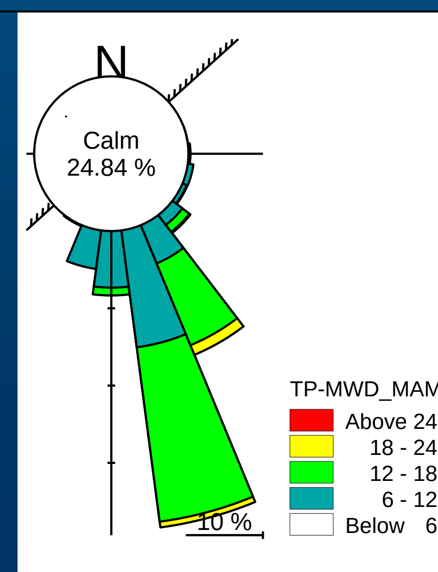


Peak Wave Period (sec)









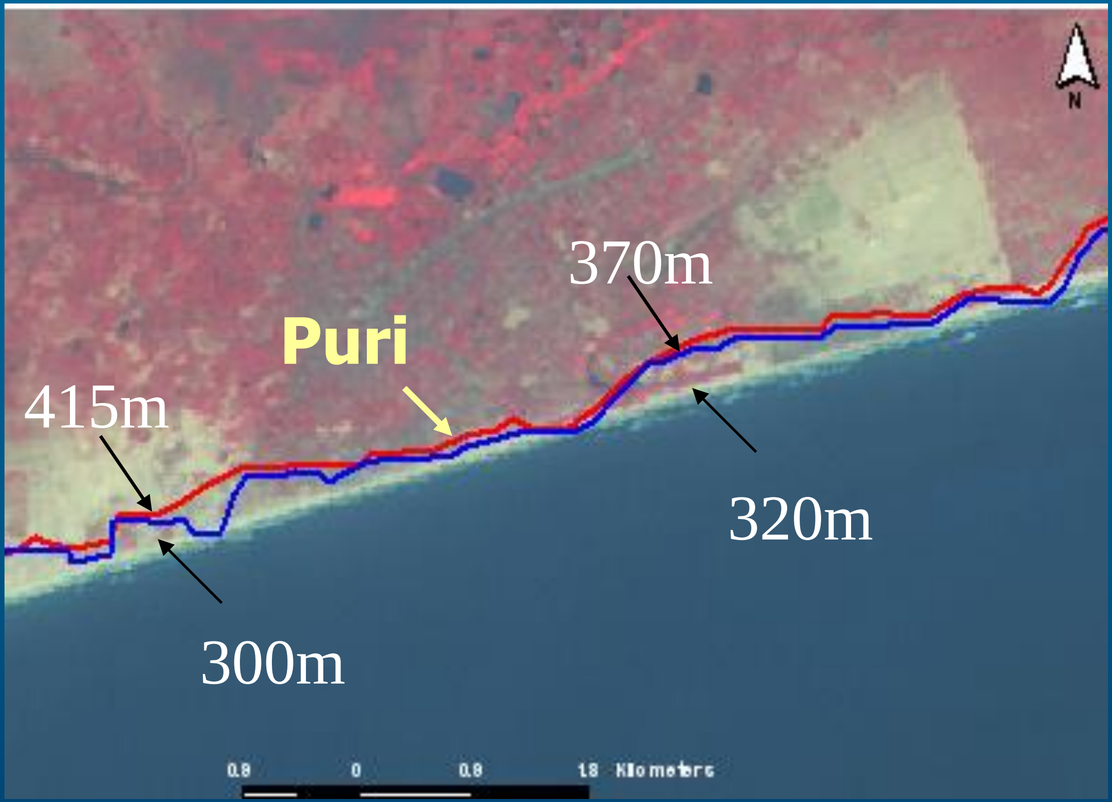
Erosion at Gopalpur tourist beach

IMPACT OF HIGH WAVES AT RUSHIKULYA TURTLE NESTING BEACH ON 13 MARCH 2009

Inundation of sea water due to high wave(2.3m) on 13th March,2009 and destruction of turtle eggs at the turtle nesting beach of Rushikulya rookery (world's one of the largest nesting beach for Olive Ridley sea turtle on East coast of India)

Prediction of tsunami inundation at N.Andaman using 2004 Sumatra source parameters

Orissa coast close to N.Andaman Tsunami source. 1941 Tsunami had no impacts



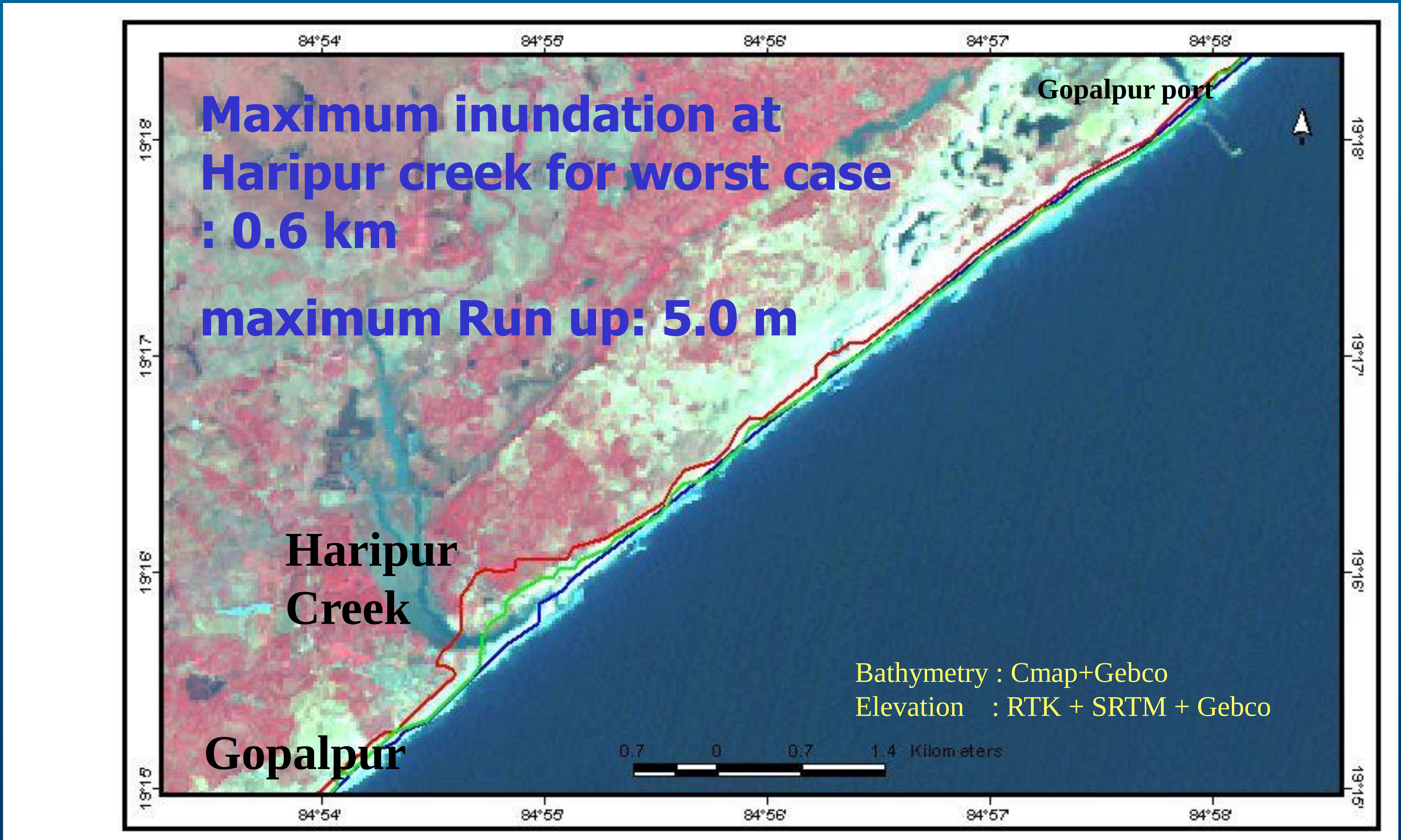
if tsunami occurs at N.Andaman at same magnitude as 2004

Date of Occurrence	: 26-Dec-2004
Tsunamigenic source	: Sumatra
Location	: 92.5 E, 12.1 N
EQ magnitude	: 9.3 Mw
Slip magnitude	: 15 m
Fault length	: 500 km
Fault width	: 150 km
Strike	: 345 deg.
Dip	: 15 deg.
Rake	: 90 deg.
Depth	: 20 km

Extent of Inundation without tide

Extent of Inundation with tide

Inundation at Gopalpur, Orissa



North Andman Source Sumatra Parameters (Worst scenario)
Sumatra : 26 December 2004 earthquake case
North Andaman: 26 June 1941 earthquake case

CLIMATE CHANGE **IS** HAPPENING……

…..AND ITS EFFECTS ARE LIKELY TO BE VERY PROFOUND AND WHAT WILL BE FUTURE CLIMATE AND ITS IMPACT

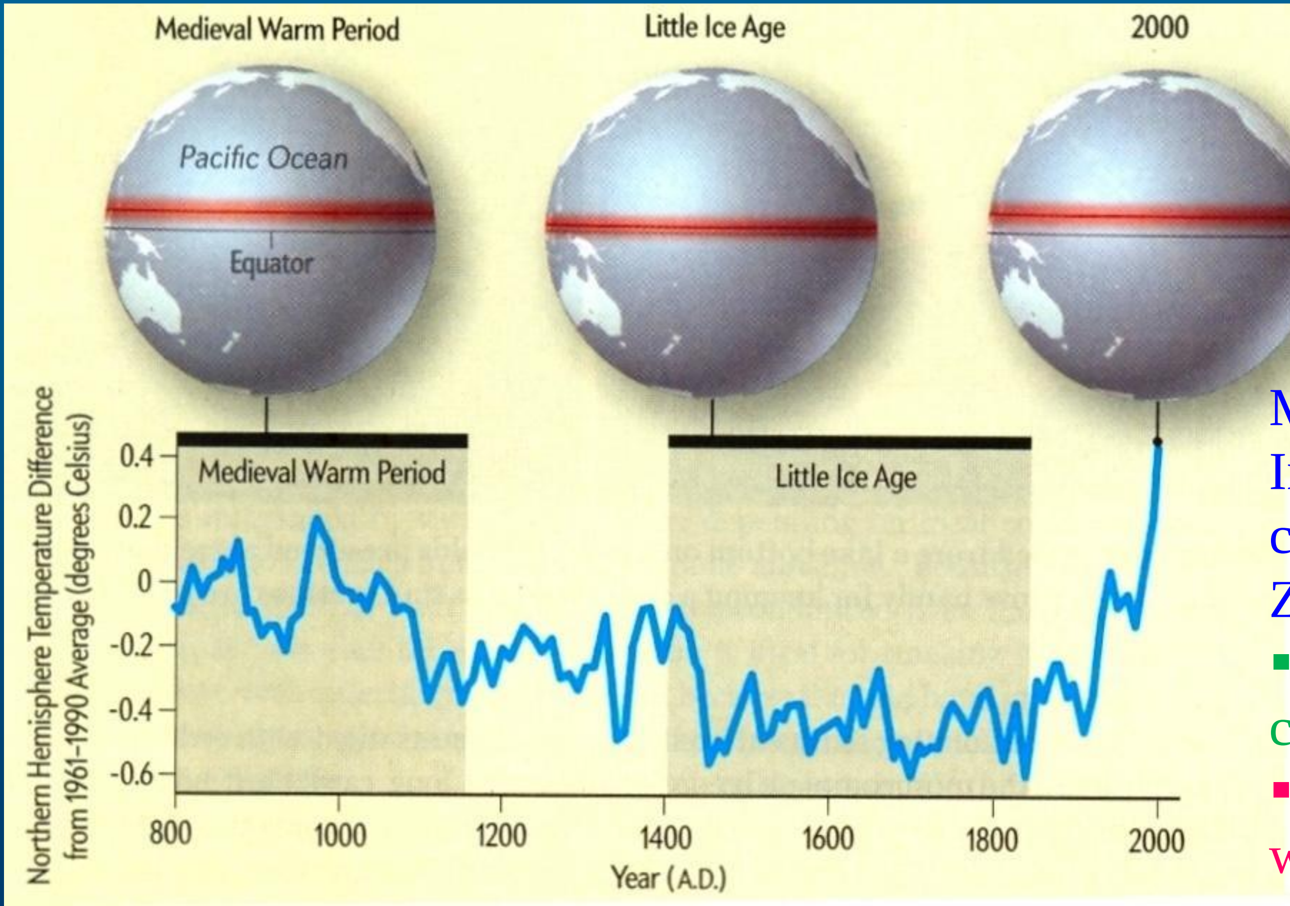
Climate changes over the next few decades are predicted to be <u>much</u> larger than we have seen so far…

*The war against **Global Warming** could be worse than that against **Global Terrorism***

THE DAY AFTER TOMORROW

We must avoid such a tomorrow. Therefore, we should understand the climate change, educate key policy-makers and the public about the causes and potential consequences of climate change and to assist the domestic and international communities in developing practical and effective solutions to this important environmental challenge.

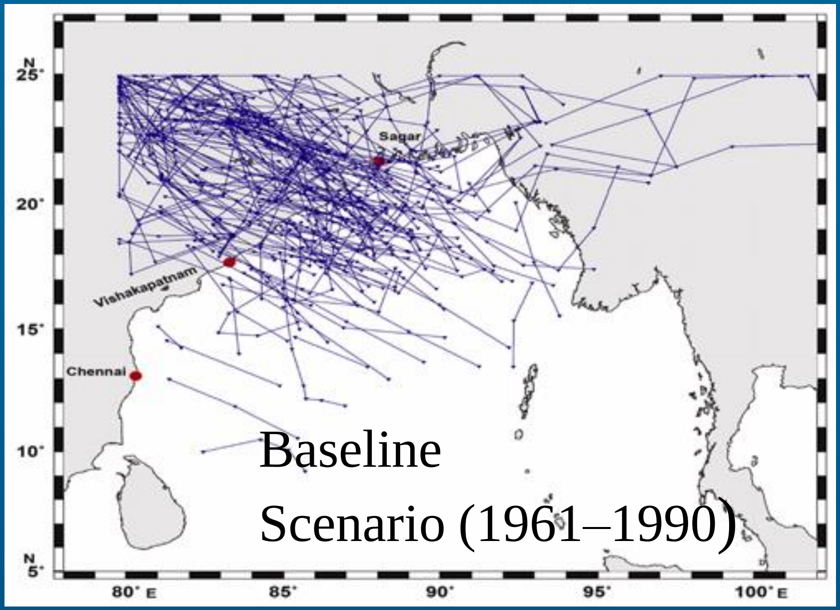
CLIMATE SWINGS : Medieval warm to little ice age, present and future

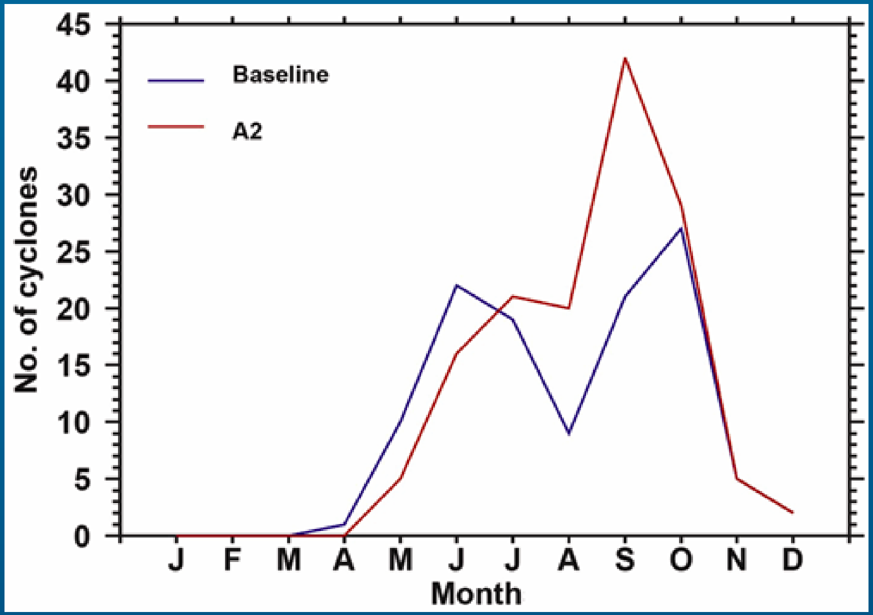


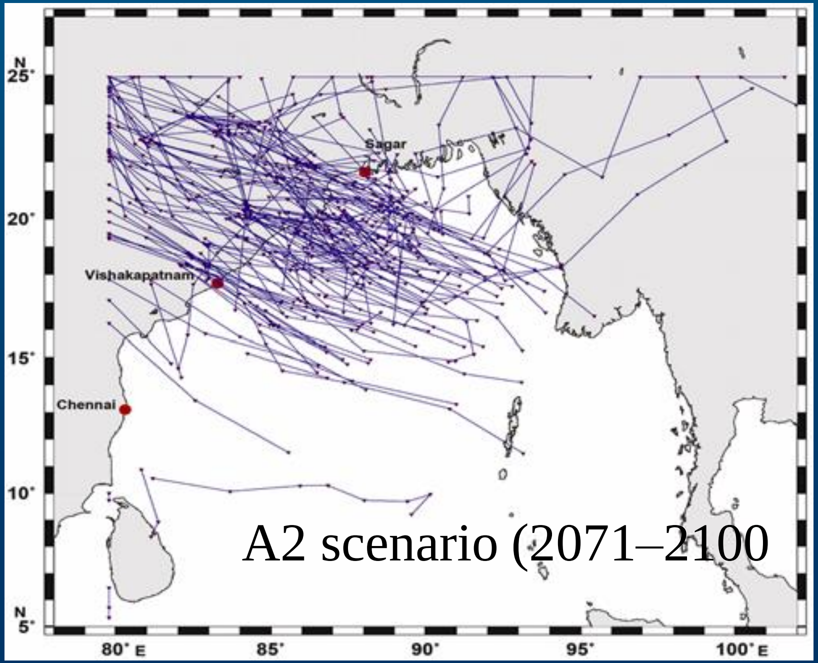
Meridional swing of Intertropical convergence Zone(ITCZ)

- southerly position-cool climate
- Northerly position-warm and wet climate

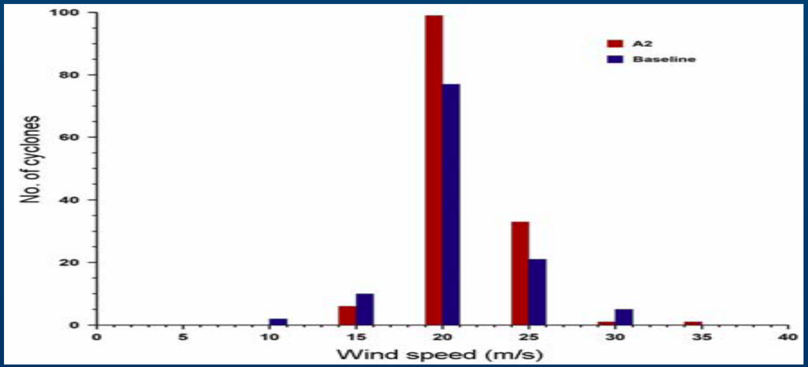
Implications: Millions of people near equator would experience dry condition, Crops like coffee, banana and tropical biodiversity would wither in places such as Ecuador, Colombia, northern Indonesia and Thailand. Serious drought in southwestern US. Locations near the band would experience high temperature and heavy rain. No idea yet on the frequency and intensity of hurricanes and monsoons



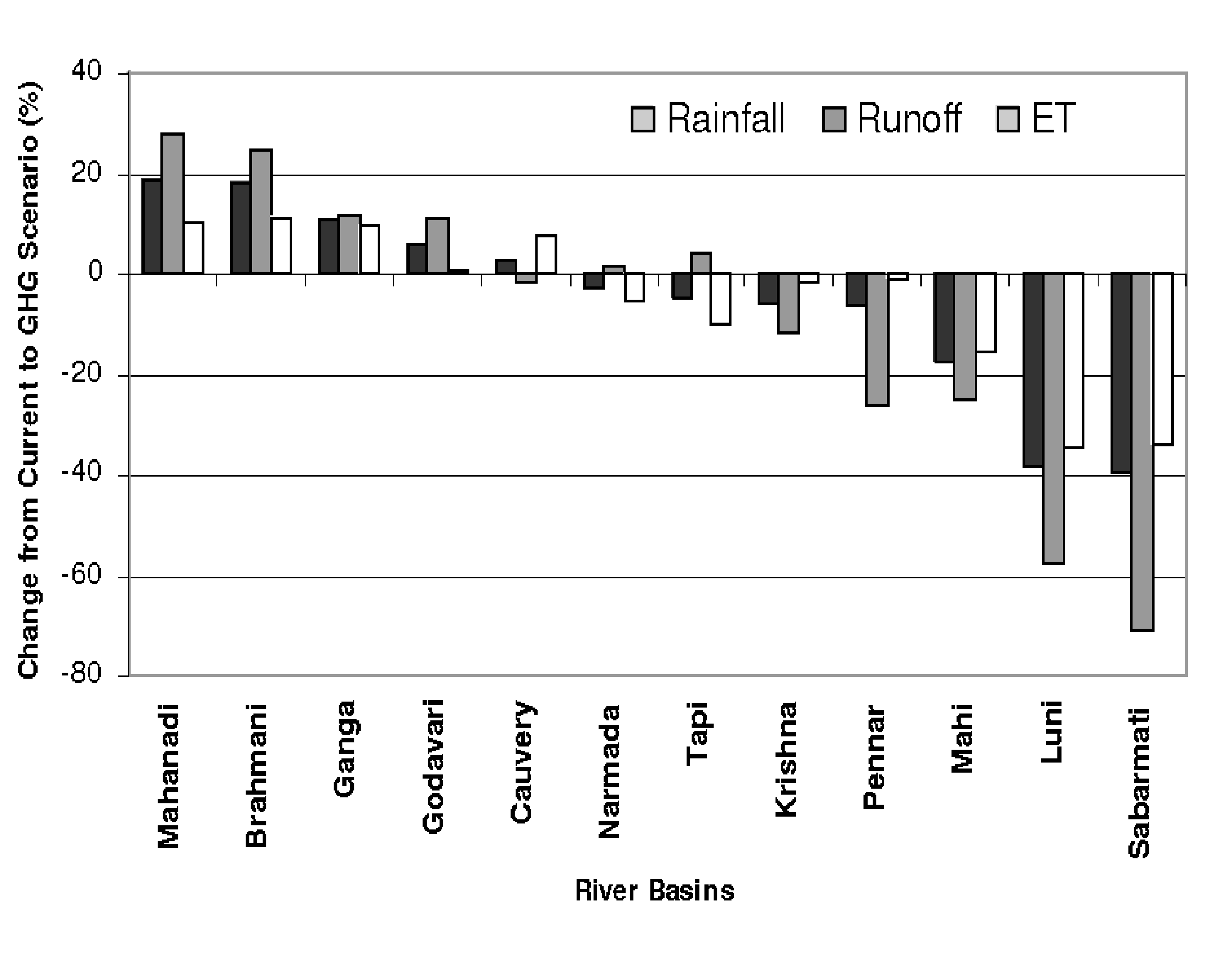




- The composite tracks of the cyclones for the baseline and A2 Scenarios do not show any significant difference
- The frequency of cyclones during the late monsoon season during the future (2071–2100) scenario is found to be much higher than that during the baseline scenario.
- Maximum wind speed indicates higher number of intense cyclones in the A2 scenario than that in the baseline scenario.



Flood/Drought conditions in different river basins of India under climate change scenario

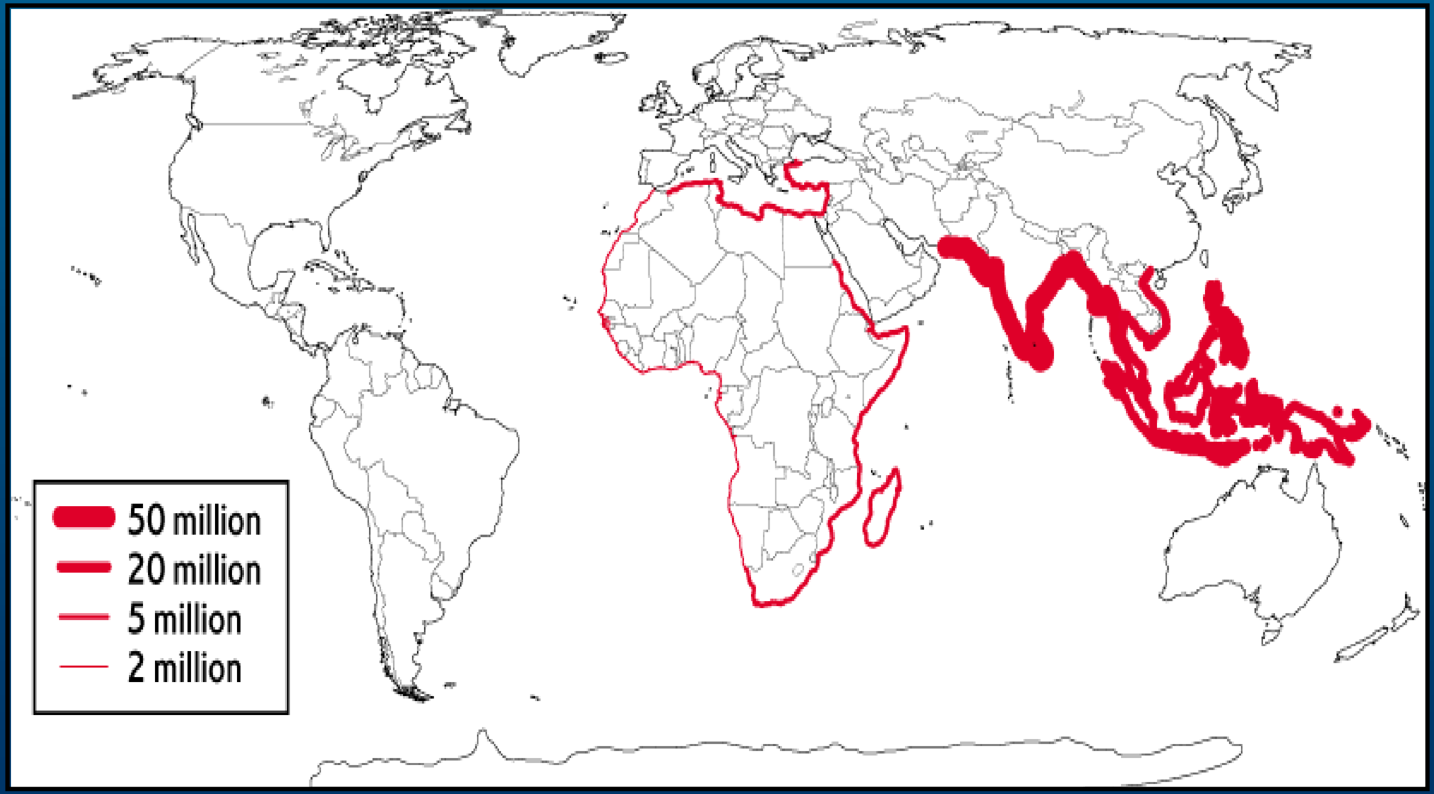


- Mahanadi and Bramhani River basins are expected to receive comparatively higher level of precipitation in future and a corresponding increase in evapotranspiration and water yield is also predicted.
- Increase in flood peak shall be detrimental to both life and property in these river basins

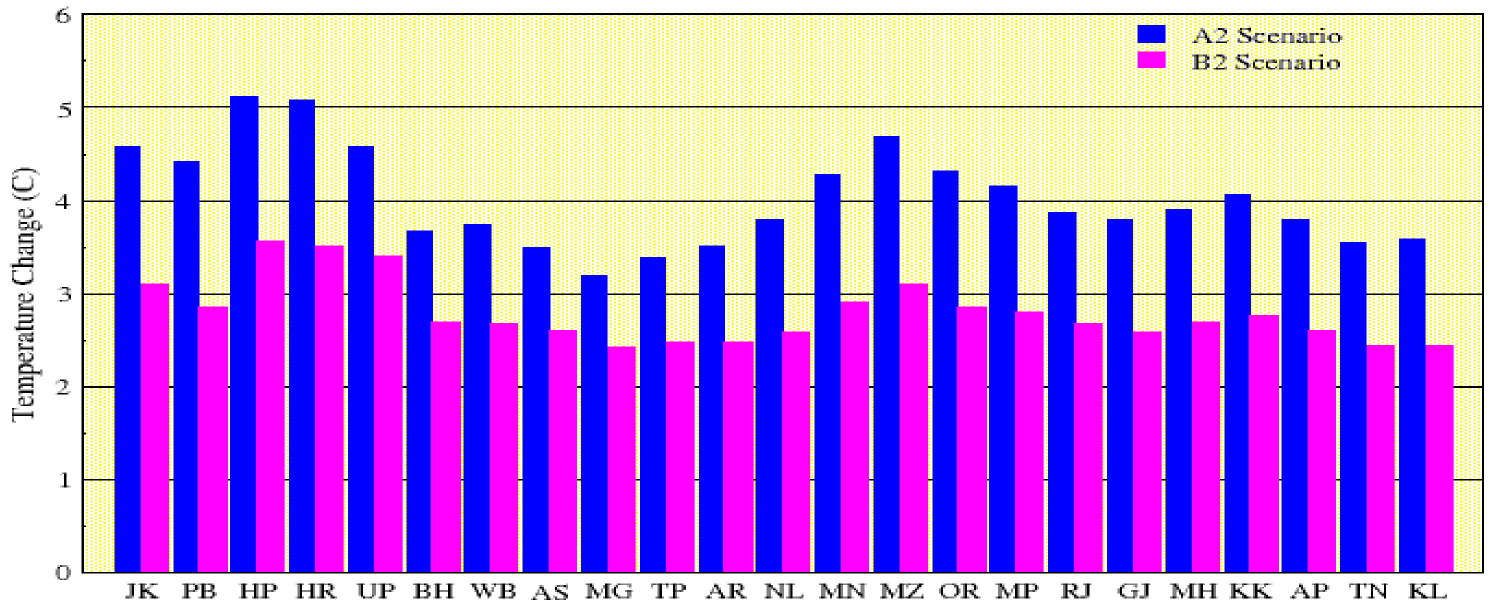
In many parts of the world, climate change may be disastrous……

ANNUAL NUMBER OF PEOPLE FLOODED

Change from the present day to the 2080s (unmitigated emissions)



Annual Temperature Scenarios for States of India, based on PRECIS, for 2071-2100



Source: IITM,Pune

Predicting crop yields in future climate

LINKING CROP WITH CLIMATE

CLIMATE CHANGE:

- Increase in air Temperature
- Increase in CO_2 content
- More evaporation and less precipitation
- Lowering of the water table

Autocatalytic component to global warming:

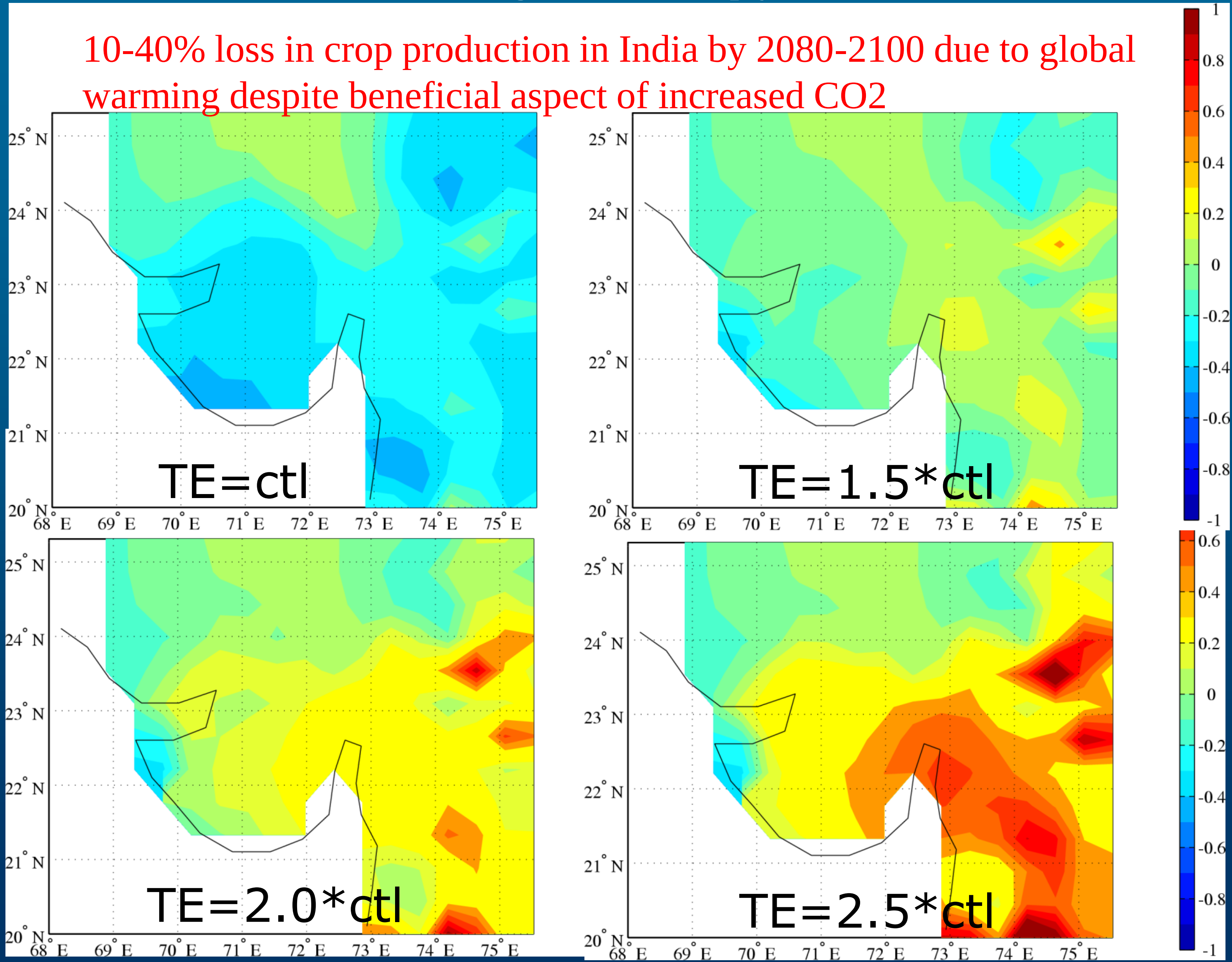
Photosynthesis and respiration of plants and microbes increase with temperature, especially in temperate latitudes. As respiration increases more with increased temperature than does photosynthesis, global warming is likely to increase the flux of carbon dioxide to the atmosphere which would constitute a positive feedback to global warming.

CROP RESPONSE:

- Accelerated crop development
- Reduction in the length of the effective growing season in the tropics
- Increase in the length of the effective growing season in areas where agricultural potential is currently limited by cold temperature stress
- CO2-induced increases in crop yields are much more probable in warm than in cool environments
- Increase in water stress, both by the root system and leaf
- What will happen to the over all productivity?

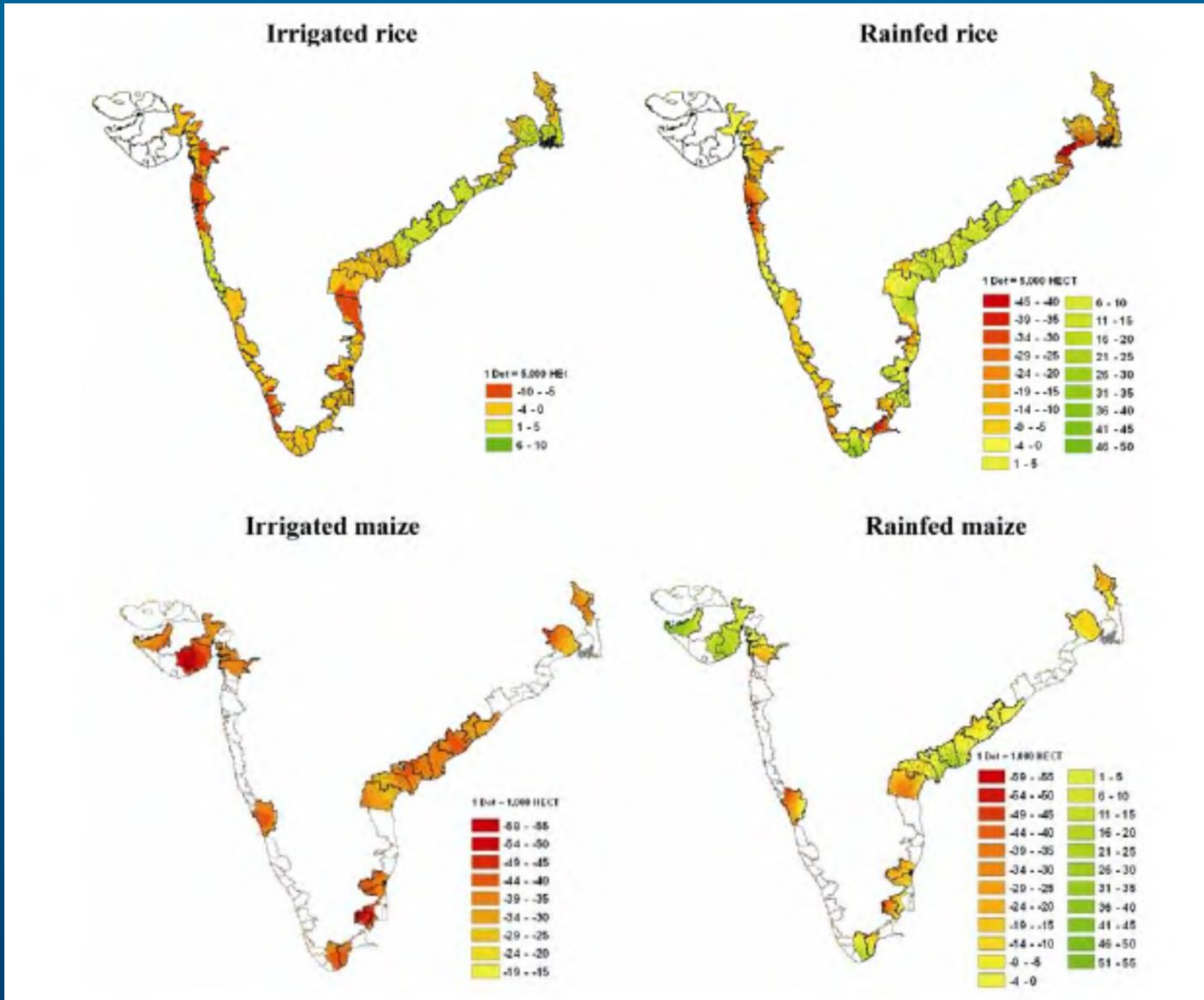
Effect of CO2 fertilisation on groundnut crop yields in future climates: 2080-2100

10-40% loss in crop production in India by 2080-2100 due to global warming despite beneficial aspect of increased CO2



Source:

Walker Institute University of Reading, UK



Percentage variation in rainfed and irrigated rice and maize along coastal zone of India during 2020-2050

- Yield of maize and sorghum, having c4 photosynthetic system, is likely to reduce by 50% due to climate change

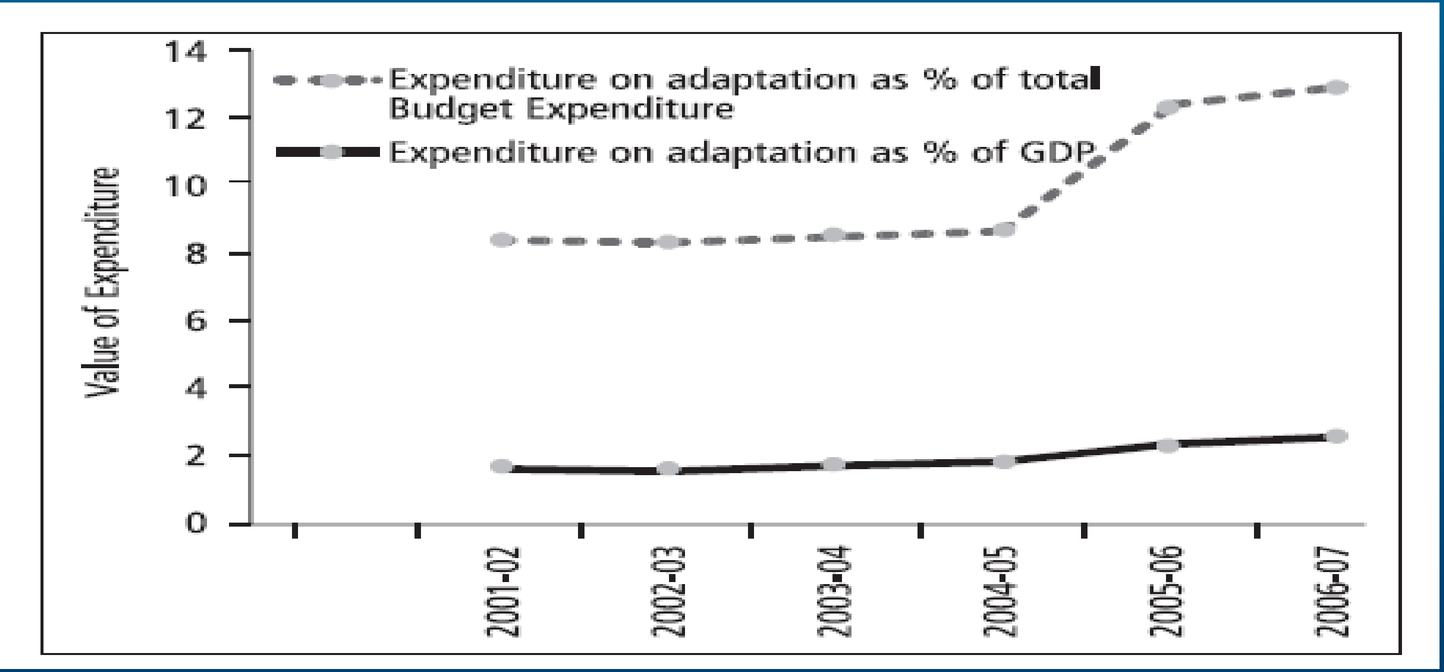
- Rice yields decrease 9% for each 1°C increase in seasonal average temperature

CLIMATE CHANGE AND AGRICULTURE IN ODISHA

- Odisha coast is projected to have less increase in temperature i.e. 1^{o} by 2020-2050.Irrigated rice yields are projected to increase by <5% in Odisha by 2020-2050 due to lesser increase in temperature.
- Rain fed rice yields are projected to increase by 15% along east coast and reduce by 20% along west coast.
- Irrigated maize crops are likely to have yield loss between 15-50% while rain fed maize shall have yield loss by 35%
- Kharif seasonal rainfall is projected to increase by 10%.
- Marginal increase in rainfall may not hamper the sunshine period in this region, providing ample scope for the plants to carry on photosynthetic process, thus benefiting the rice yield in elevated CO_2 conditions.

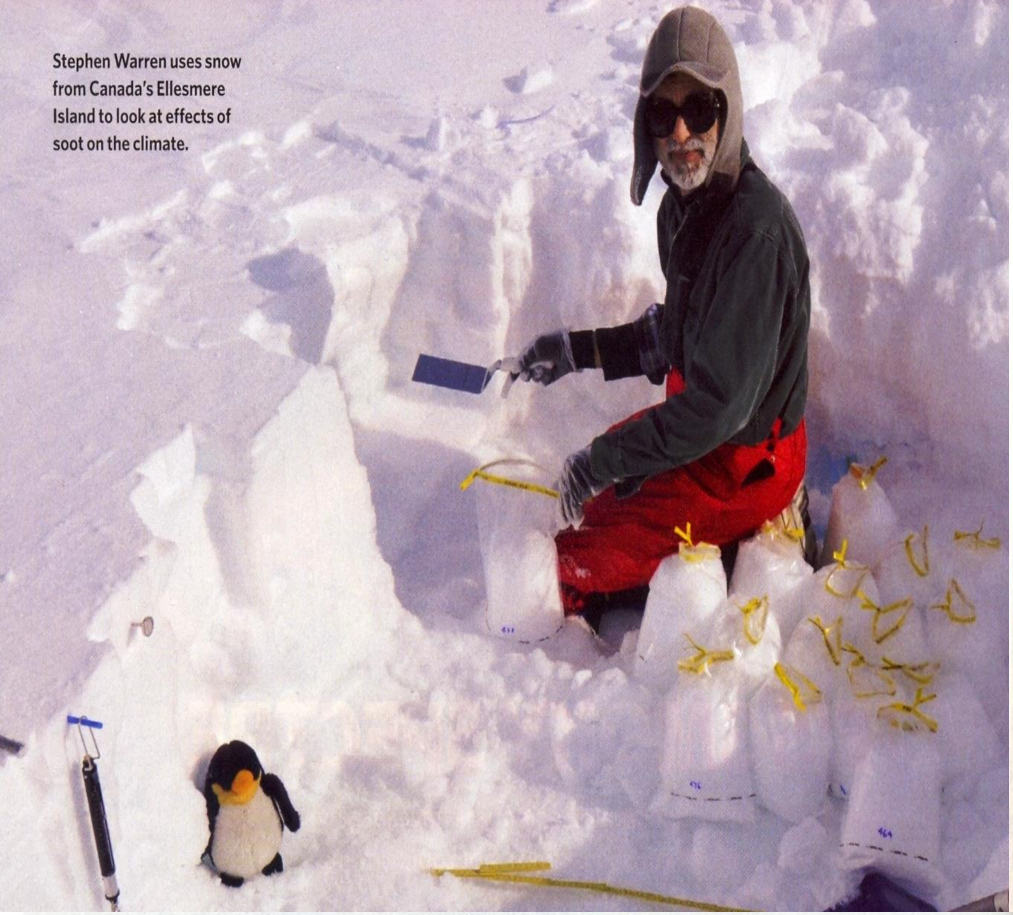
What needs to be done?

- The NAPCC, India aims to promote climate adaptation in agriculture through the development of climate-resilient crops, expansion of weather insurance mechanisms, and agricultural practices. As one of the eight missions under NAPCC



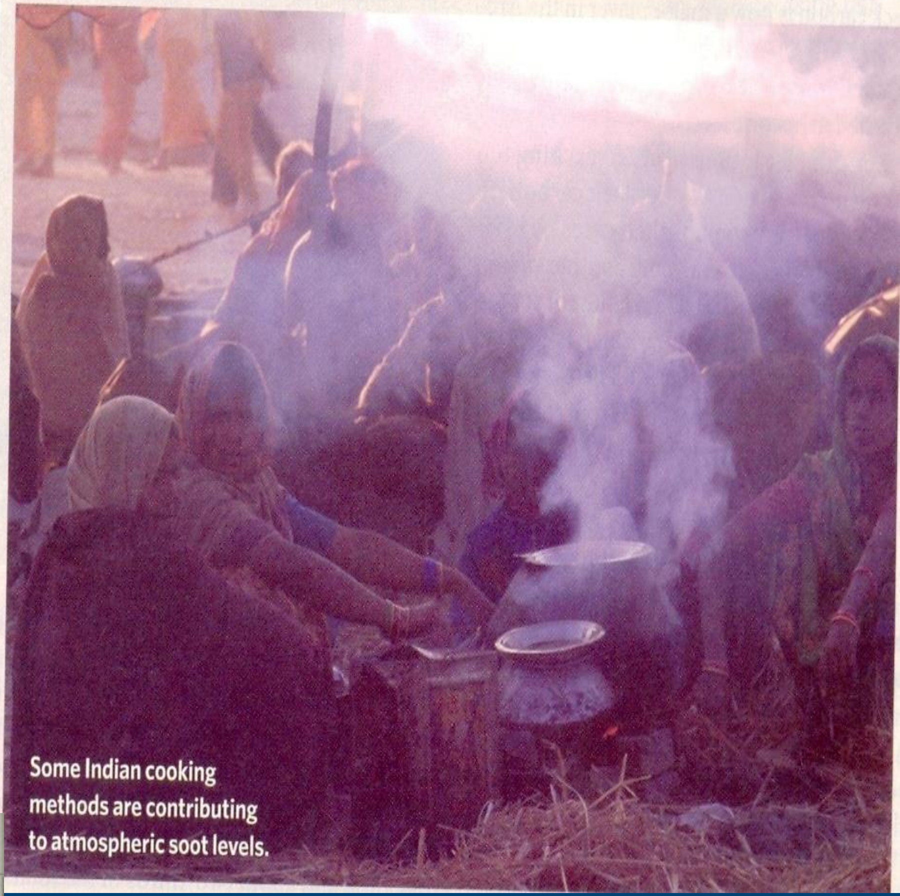
➢To rebuild food system, development of climate resilient crops and adaptation mechanisms should be aggressively followed

➢Use of sea water, a social resource, should be encouraged for extensive agro and aqua farming

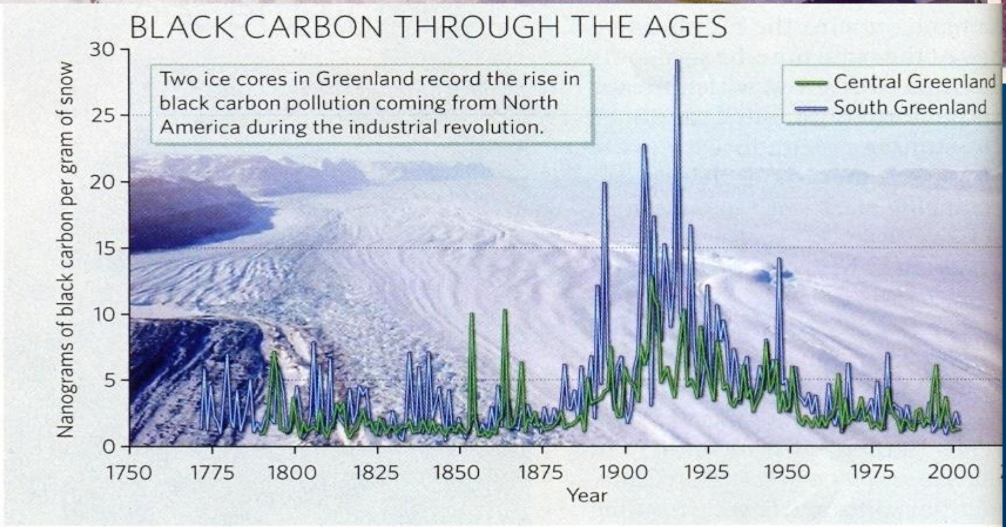


Stephen Warren uses snow from Canada's Ellesmere Island to look at effects of soot on the climate.

Stopping the soot



Some Indian cooking methods are contributing to atmospheric soot levels.



Quickest way to combat global warming is to reduce black carbon

Challenges in building Climate Change Resilience:

- Climate science and climate policy inhabit parallel words(Nature, 15 Dec, 2011) .
- Climate negotiations: a major exercise in diplomacy

- Adaptation to climate change is a challenge for all countries. From a global perspective, the adaptation challenge is probably greatest for developing countries. They are generally more vulnerable to climate change because their economies are more dependent on climate-sensitive sectors, such as agriculture, fishing, and tourism. With lower per capita incomes, weaker institutions, and limited access to technology, developing countries have less adaptive capacity.

- Food security for the developing countries is a serious challenge which can be addressed through convergence of climate science and policy involving both developed and developing nations.

- Strengthen international institutions and policy to protect the rights of those displaced by climate change.

HOW MUCH COAL IS BURNT TO GENERATE 1kWh ELECTRICITY

Thermal Energy Density of Coal = 24 Mega-Joules/Kg
= 6.67 kWh/Kg
(1kWh = 1 unit of electricity)

Although coal fired power plants are very efficient, they are still limited by the laws of thermodynamics. Only about 40% of thermal energy in coal is converted to electricity.

So, the electricity generated per Kg of coal = 0.40×6.67
= 2.67 kWh

How much coal is required to light a 100-watt (0.1kW) light bulb 8 hours a day for a year?

Energy in kilowatt-hours the light bulb uses per year = 0.1×8×365=292kWh

Coal required to light a 100-watt light bulb 8 hours a day for a year = 292/2.67=109Kg

CARBON FOOTPRINT

Measure of the impact human activities have on the environment in terms of the amount of GHG produced, measured in units of CO_2. A carbon footprint is often expressed as tons of CO_2 emitted usually on a yearly basis.

- Atomic Weight of C = 12,   Atomic Weight of O = 16
- Carbon combines with oxygen in the atmosphere during combustion producing CO_2 with molecular weight of 44 (12+16×2)
- Assume that coal has 50% carbon in it (by mass), 1 Kg of coal contains at least 0.5 Kg carbon
- CO_2 produced from burning **1 Kg of coal** (0.5 Kg carbon)

$$= (44/12) \times 0.5$$

$$= 1.83 \text{ Kg}$$

1 Kg of Coal $\xrightarrow{\textbf{combustion}}$ **1.83 Kg CO_2**

CO_2 produced from burning **109 Kg of coal** (0.5 Kg carbon)

= 1.83x109=199.5 kg **to light a 100-watt light bulb 8 hours a day for a year**

Climate Resilient Actions

- INVEST IN DEVELOPING POWER SAVING TECHNOLOGY RATHER THAN CREATING NEW POWER PLANTS

(Average consumption of electricity per day per household = 26 kWh, Amount of coal required daily to produce 26 kWh electricity = 9.7 Kg)

Total CO2 emission per household per day = 17.8 Kg

IMPROVING PUBLIC TRANSPORT SYSTEM is the essential need , which will reduce air pollution (SO_2, NOx, SPM) and greenhouse gas emission(A bus emits about 700g of CO_2 per km compared to 98g/km by a car, **a bus can replace 40 cars, which is equivalent to saving of CO_2 emission by about 3.2 Kg/km)**

SHIFT FROM COAL BASED ENERGY TO RENEWABLE ENERGY(solar, tide, wind etc.)

- CLIMATE AUDIT

WHAT YOU/WE CAN/SHOULD DO:

- **Dust your Tubelight & Bulbs.**
- **Turn off lights when not required.**
- **Buy the right wattage for your needs**
- **Keep Electrical Gadgets in efficient working conditions**
- **Avoid Room-heater through proper clothing**

- **Plan your building allowing free airflow and light to cut down use of fans and electric bulbs**
- **Use Day light hours to cut down light bills**
  Reduce garbage in the neighbourhood
- **Walking/cycling over short distances**
- **Use public transport**
- **Plant and adopt trees in your areas**

Say NO to Apples from Washington

And YES

Apples from Himachal Pradesh

We must protect the Earth

Apollo 12's Classic Earth Rise from Moon