Challenges in the prediction of Extreme events in a Climate Change Scenarios

"The Future of Weather, Climate and Water across Generations."
World Meteorological Day
23 March 2023

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23 March 2023

India Climate and Energy Modelling Forum (ICEMF)

OUTLINE

- RECENT SEVERE WEATHER EVENTS
- UNDERSTANDING CLIMATE CHANGE
- SCIENTIFIC UNDERSTANDING
  - RISE IN TEMPERATURE
  - IMPACT FROM ATMOSPHERIC MOISTURE
  - EXTREME RAINFALL (MONSOON, MOISTURE, MOUNTAIN)
  - SEA SURFACE TEMPERATURE, RAINFALL & CYCLONE
- SUSTAINABLE LIVING IS THE WAY FORWARD
- BETTER PREPAREDNESS,ADAPATION AND MITIGATION

Over 7 lakh deaths in India per year linked to climate change: Lancet study

"A Scene From A Nature Documentary!" — Unexpected Thundershowers, Stormy Winds Stun Delhi on May 30

Heatwave reduced India's wheat crop yield by 10 to 30% this year: Report

Reported By: Aditi Gupta
New Delhi • Updated: May 23, 2022, 11:55 PM(IST)

WORLD ›

Nearly 100 dead in Africa with Freddy set to become longest-lasting tropical cyclone on record

Experts predict more cyclones, thunderstorms in future

49 degrees in Delhi, flash floods in some region. Experts warn of climate change

Heatwaves claimed over 17,000 lives in 50 years in India: Study

Heatwave is one of the extreme weather events (EWE). In 50 years (1971-2019) EWE killed 1,41,308 people. Of this, 17,362 people were killed due to heatwave -- a little over 12 percent of the total deaths recorded, the study said.

33 dead as strong winds, rains lash Bihar

BY Team MP 22 May 2022 12:15 AM

India to get heat waves this year after hottest February on record

Intensity of severe cyclonic storms increasing in North Indian Ocean region: Study

'Extreme weather events will become more frequent and intense'

Assam Floods: Death Count Reaches 30, Over 5.61 Lakh People Affected

WILDLIFE & BIODIVERSITY

Frequent extreme weather events may lead to decline in Olive Ridley turtle population: Experts

Global warming may affect gender-ratio of Olive Ridley turtles

Source: News Articles

In 60 yrs, 268 extreme rainfall events, more than 69k deaths

Cyclone Nisarga: Rare storm in decades pounds India's west coast

Over 100,000 people, including coronavirus patients, moved to safety as rare cyclonic storm lashes Mumbai and suburbs.

As Earth warms up, expect intense, extreme rain leading to more flash floods

hey often lead to flash

CLIMATE CHANGE

Run for cover: 100 days, 44 storms, 16 states, 423 deaths

An unprecedented storm season challenges India's scientific community

NEXT COVERAGE >

Odisha is India's 'bolt capital'with 9 lakh strikes

TNN | Updated: Sep 2, 2019, 17:04 IST

A-

News / India / Hyderabad Rains LIVE Updates: 70 have died across Telangana in rain-related incidents, says CM

Hyderabad Rains LIVE Updates: 70 have died across Telangana in rain-related incidents, says CM

Freak weather to rise in India over two decades, cataclysmic fallout likely by 2040

Scientists from across government and independent agencies say India is projected to experience a temperature rise of 1.5 degrees by 2040 if measures are not taken to curb greenhouse gas emissions.

Can We Survive Extreme Heat?

Humans have never lived on a planet this hot, and we're totally unprepared for what's to come

Flood-battered Kerala on edge

75% districts in India vulnerable to climate crisis, face risk of floods: Report

CLIMATE CHANGE

Changing character of cyclones

Fani teaches us that the future is even more risked and even more unpredictable than we imagined. It is time we woke up to this reality

Extreme weather, strong signs of global warming marked 2018: United Nations

Rainfall in Kerala in August was 96% above the long-term average, resulting to deluge

NEWS / INDIA NEWS / Uttarakhand's Most Disaster-Related Deaths In 2021

Uttarakhand's most disaster-related deaths in 2021

Gaurav Talwar / TNN / Oct 24, 2021, 02:46 IST

HOW CLIMATE CHANGE PLAYED OUT IN 2018

SEA LEVELS RISE
Global Mean Sea Level for 2018 was around 3.7 millimetres higher than in 2017, and the highest on record

OCEAN ACIDIFICATION
In the past decade, the oceans absorbed around 30% of anthropogenic CO2 emissions. Absorbed CO2 reacts with seawater and changes the pH of the ocean. This process is known as ocean acidification, which can affect the ability of marine organisms

ETING ARCTIC ICE
ea-ice extent was well

$4.3 bn
The WMO report identified the floods in Kerala as one of the main indicators of extreme weather events due to climate change, leading to economic losses of $4.3 billion

belov and v the fi The (losing over

Alarming trends

Key indicators like sea level rise, glacier loss paint a stark picture

HIGHEST ON RECORD

3.7mm Rise in global mean sea level recorded in 2018

KERALA AS AN EXAMPLE

The report underlined last year's extreme global weather events, including the August floods in Kerala

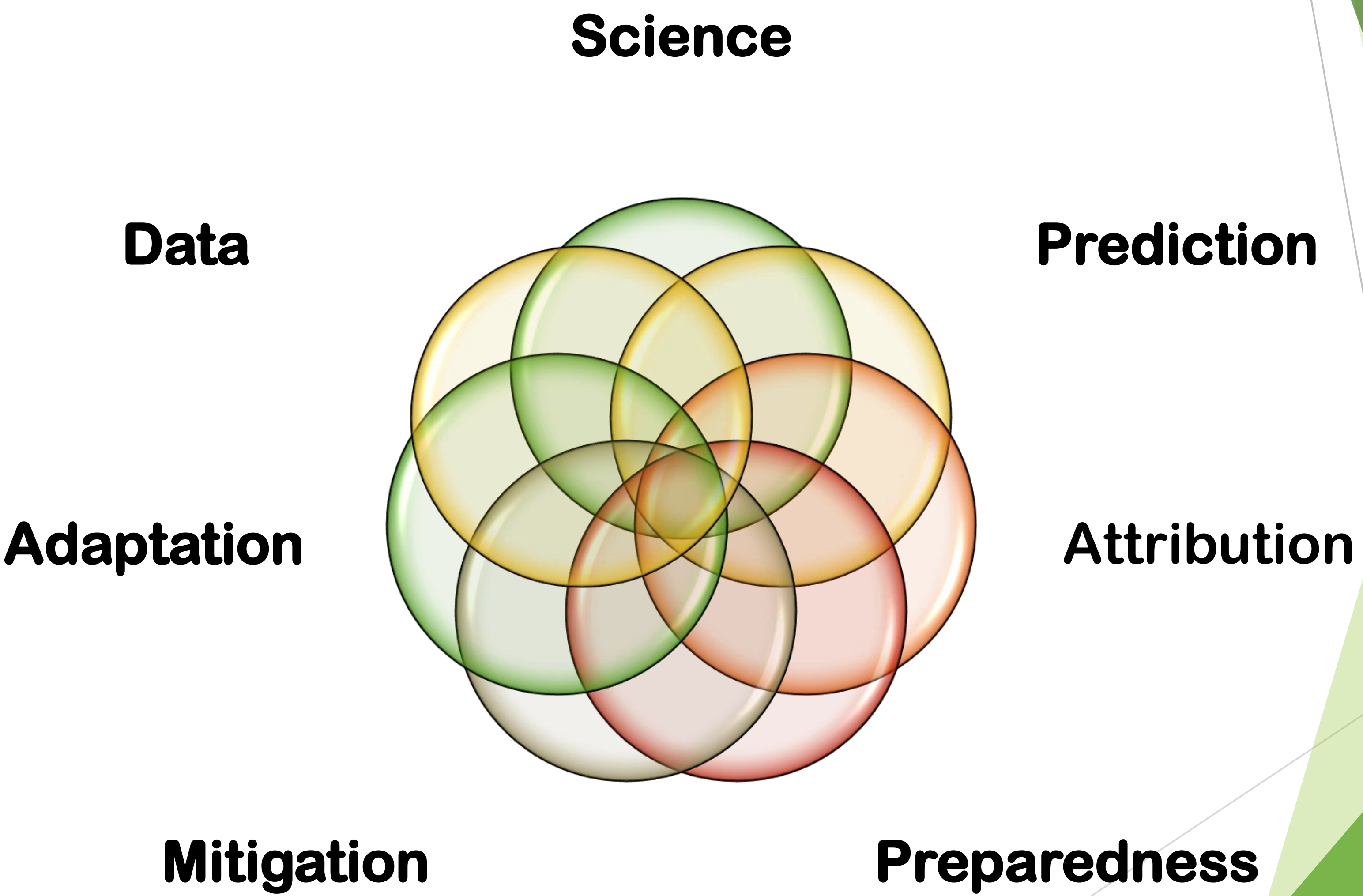
Houses Damaged, Vehicles Washed Away After Cloud Burst In Jammu And Kashmir's Poonch

A cloud burst hit upper reaches of Dingla area, resulting in flash floods and damage to a few houses and roads, they said.

Cities | Press Trust of India | Updated: June 06, 2020 9:02 am IST

Source: News Articles

Major Components of Climate Change



Climate

Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. (IPCC)

The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation and wind.

Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change and Variability

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean or variability of its properties, and that persists for an extended period, typically decades or longer.

Climate change *may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.*

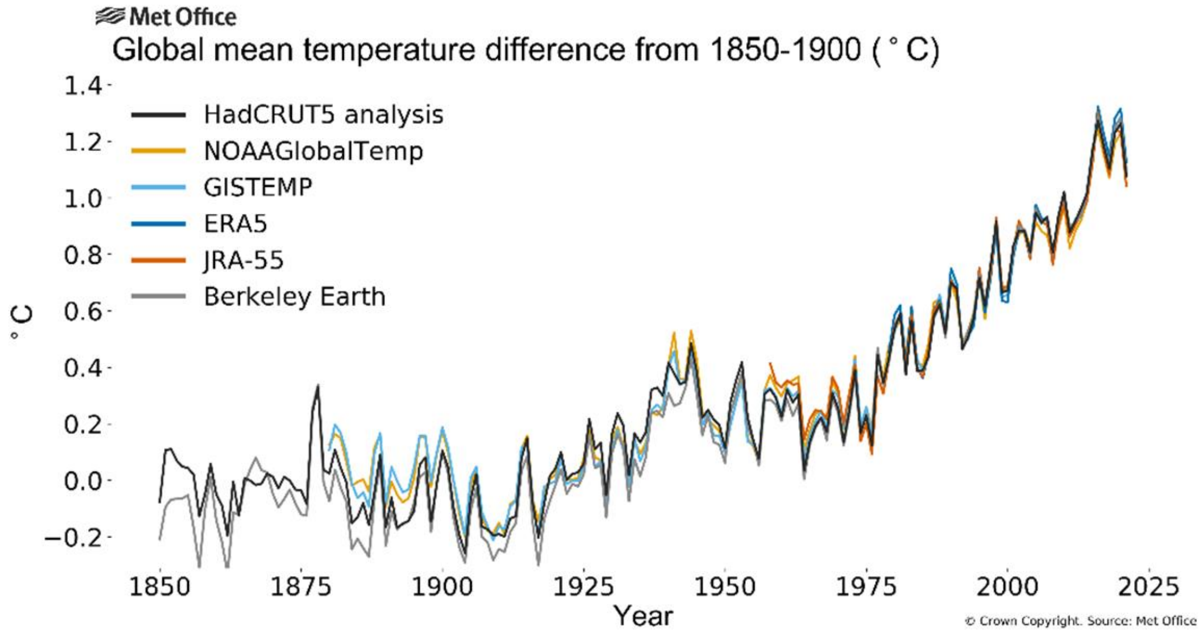
Climate change refers to **significant changes in global temperature, precipitation, wind patterns and other key indicators.**

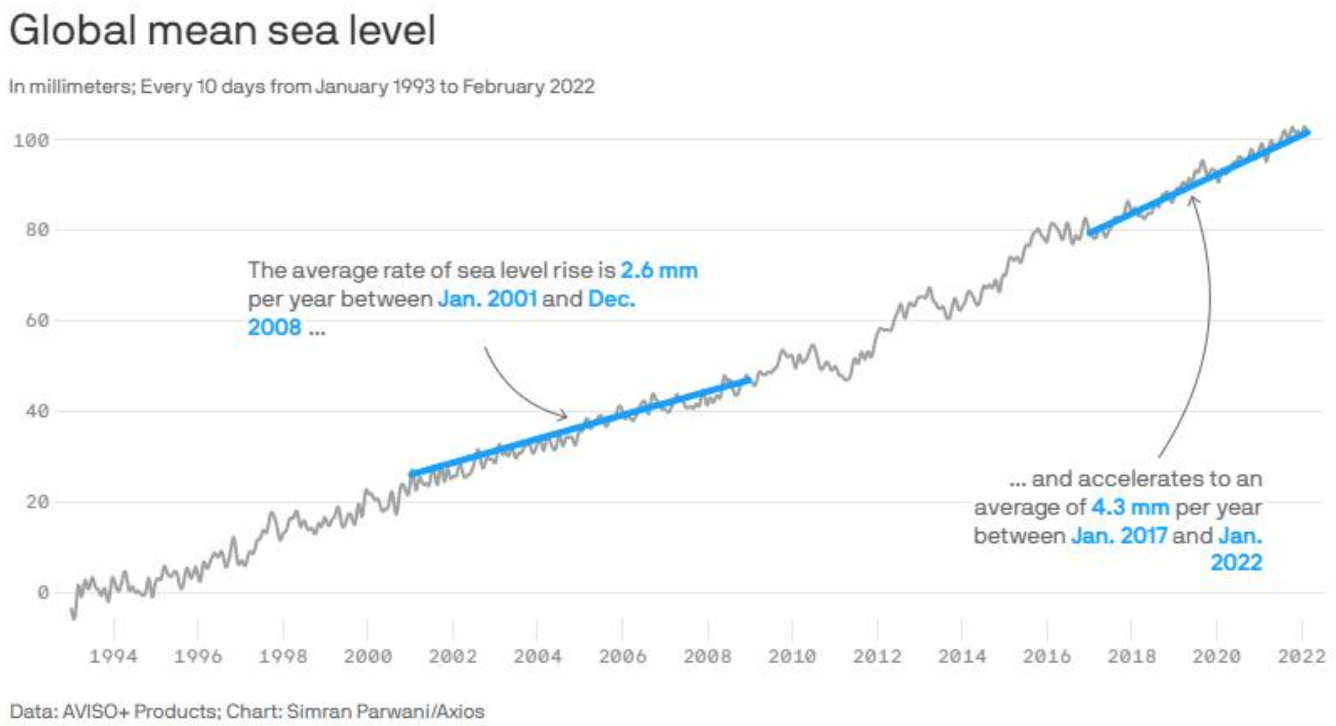
Climate change and Variability

*United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: **'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'**.*

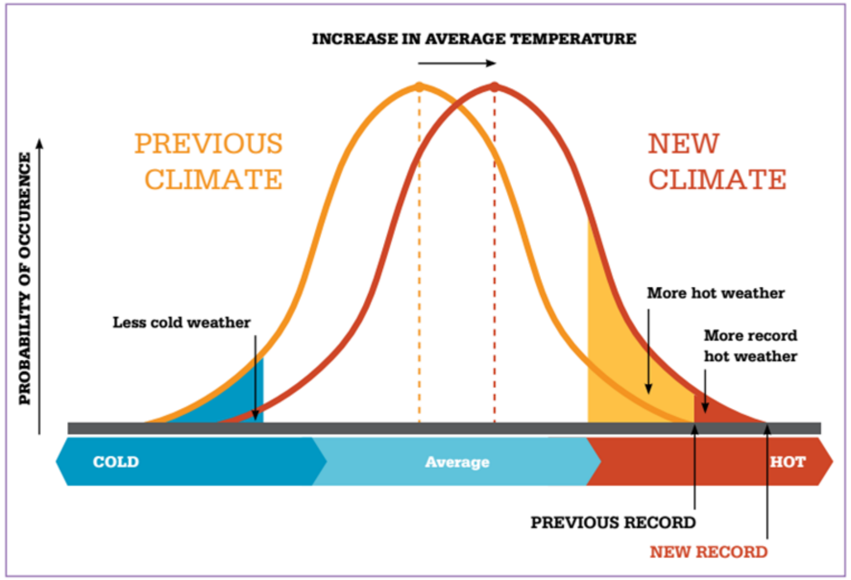
The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate variability refers to variations beyond individual weather events in the mean state and other statistics of the climate (such as standard deviations, the occurrence of extremes, etc.) on all spatial and temporal scales.

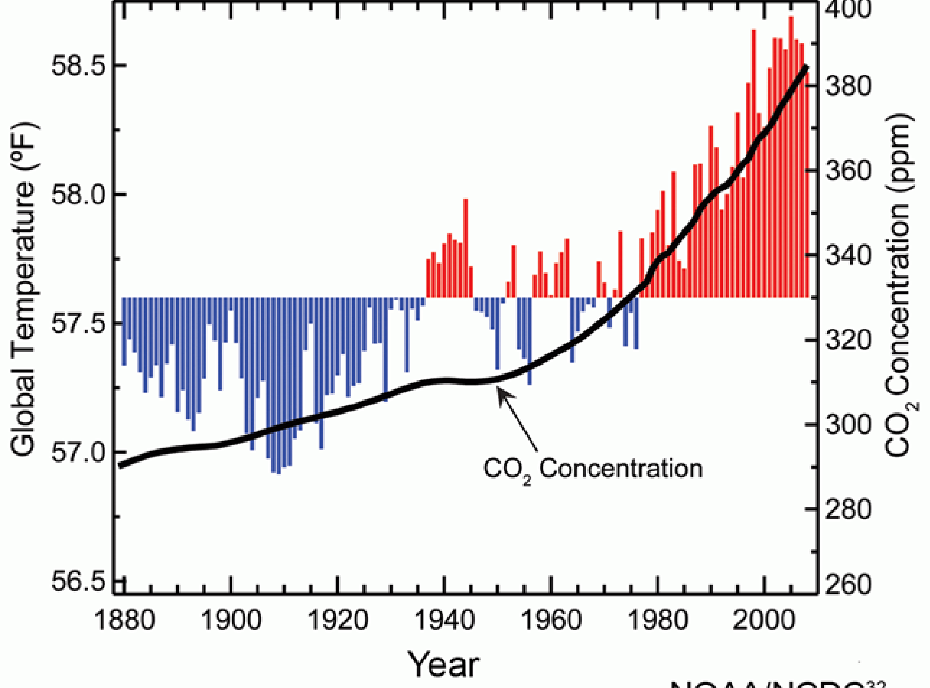

Met Office
Global mean temperature difference from 1850-1900 (°C)
HadCRUT5 analysis
NOAAGlobalTemp
GISTEMP
ERA5
JRA-55
Berkeley Earth
°C
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
1850
1875
1900
1925
1950
1975
2000
2025
Year
© Crown Copyright. Source: Met Office


Global mean sea level
In millimeters; Every 10 days from January 1993 to February 2022
100
80
60
40
20
0
The average rate of sea level rise is 2.6 mm per year between Jan. 2001 and Dec. 2008 ...
... and accelerates to an average of 4.3 mm per year between Jan. 2017 and Jan. 2022
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Data: AVISO+ Products; Chart: Simran Parwani/Axios

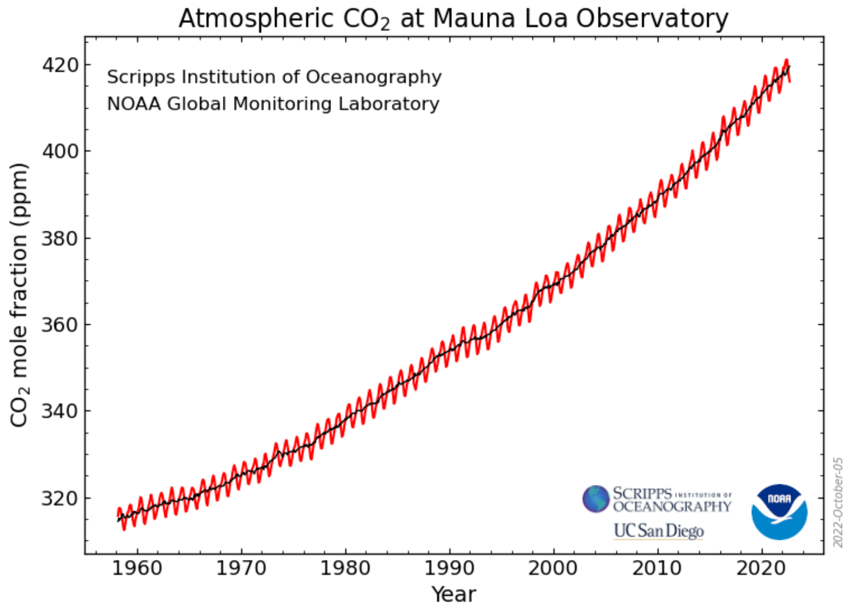
CO2

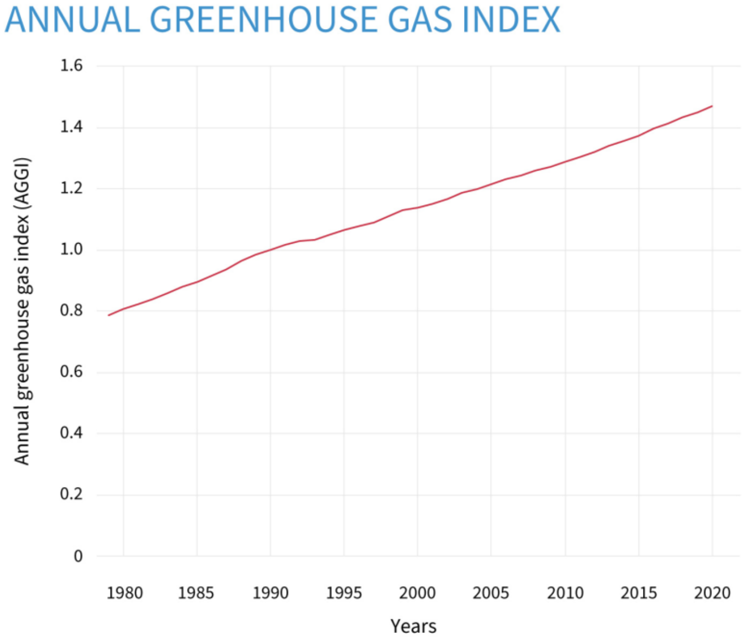


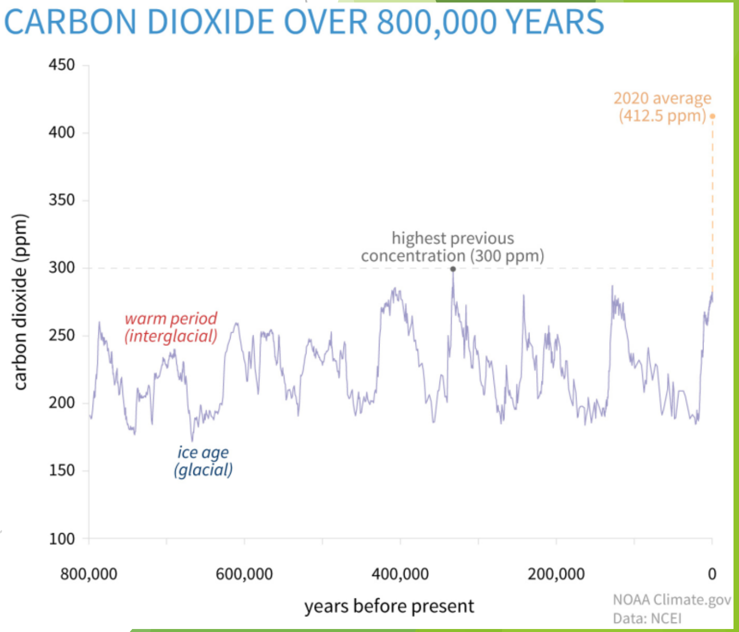
IPCC



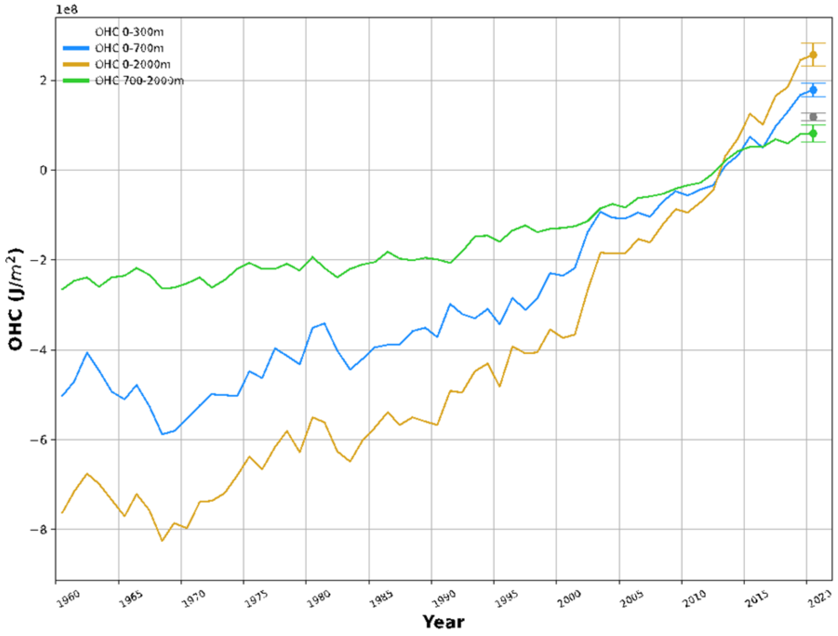
NOAA/NCDC[32]

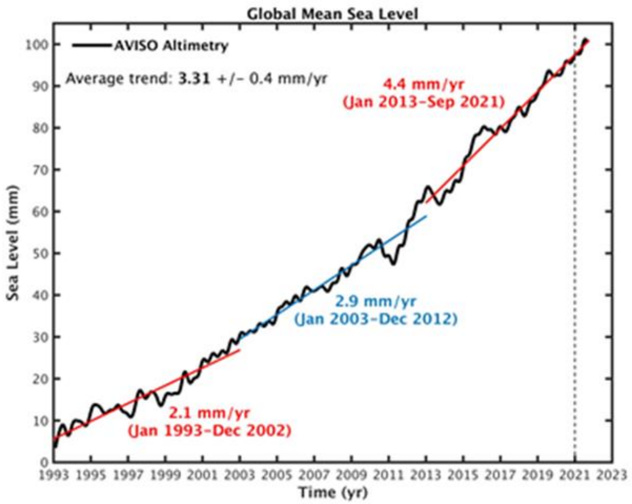


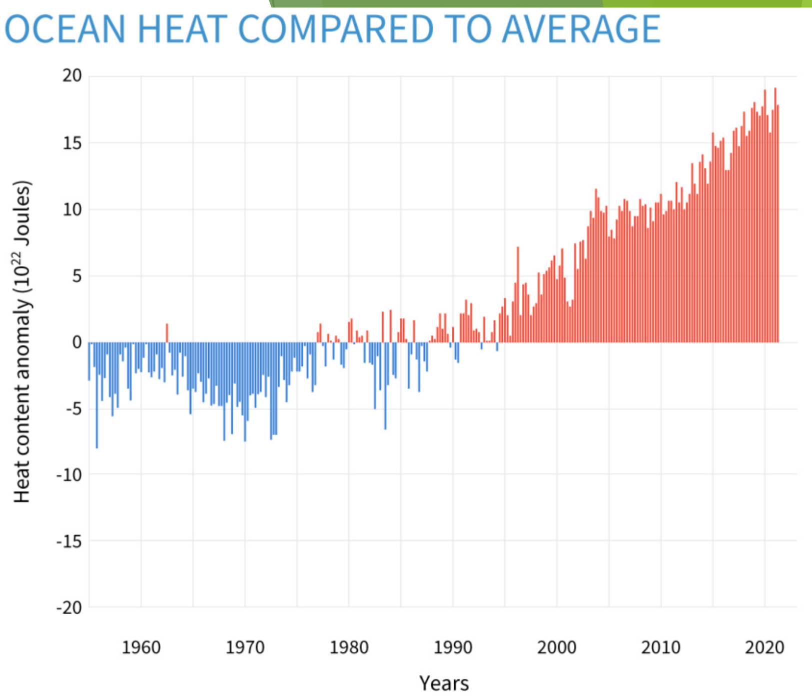


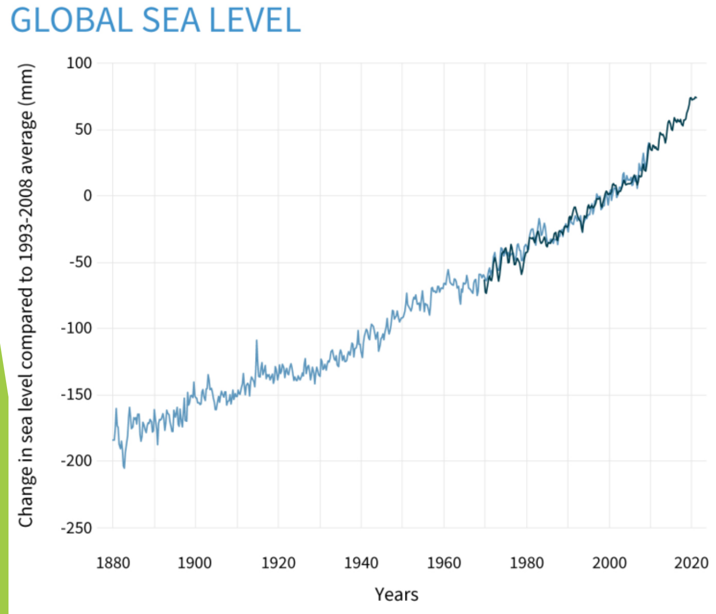


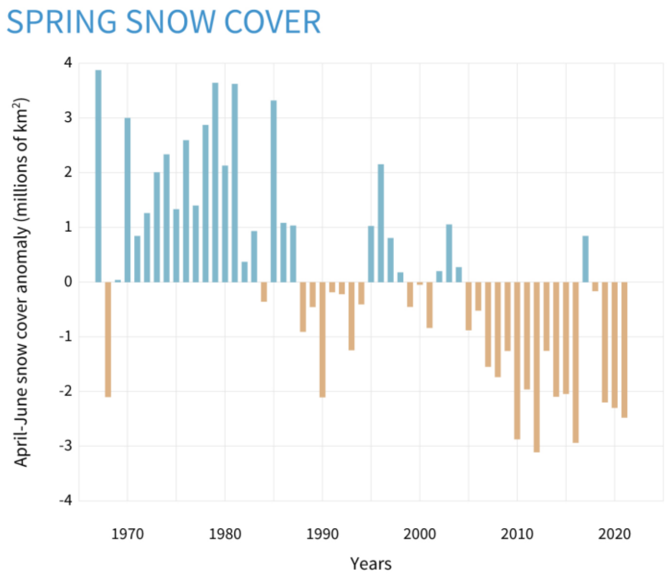
Ocean/Sea Ice Parameters

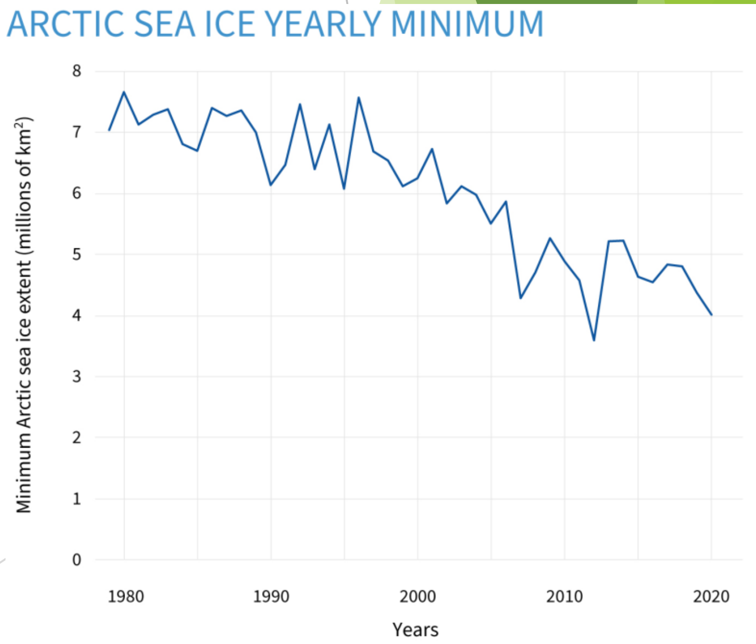




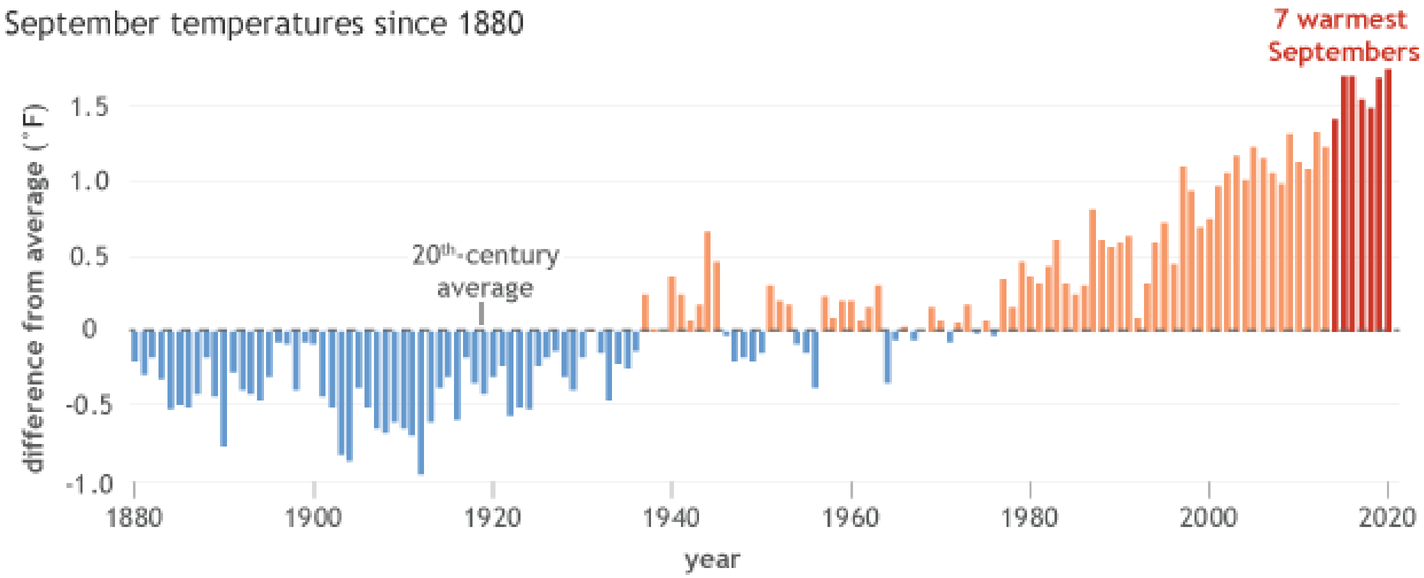




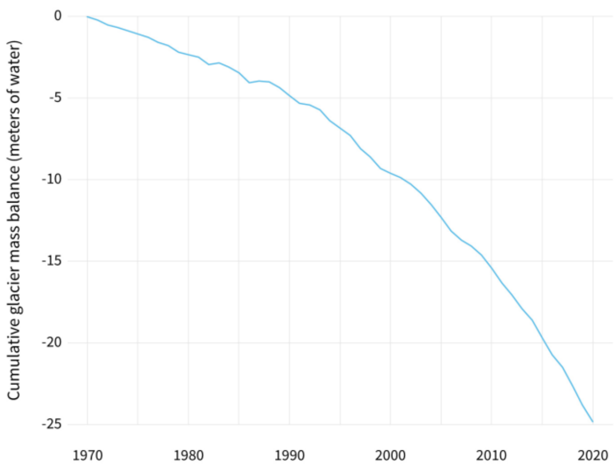




Source: NOAA,climate.gov

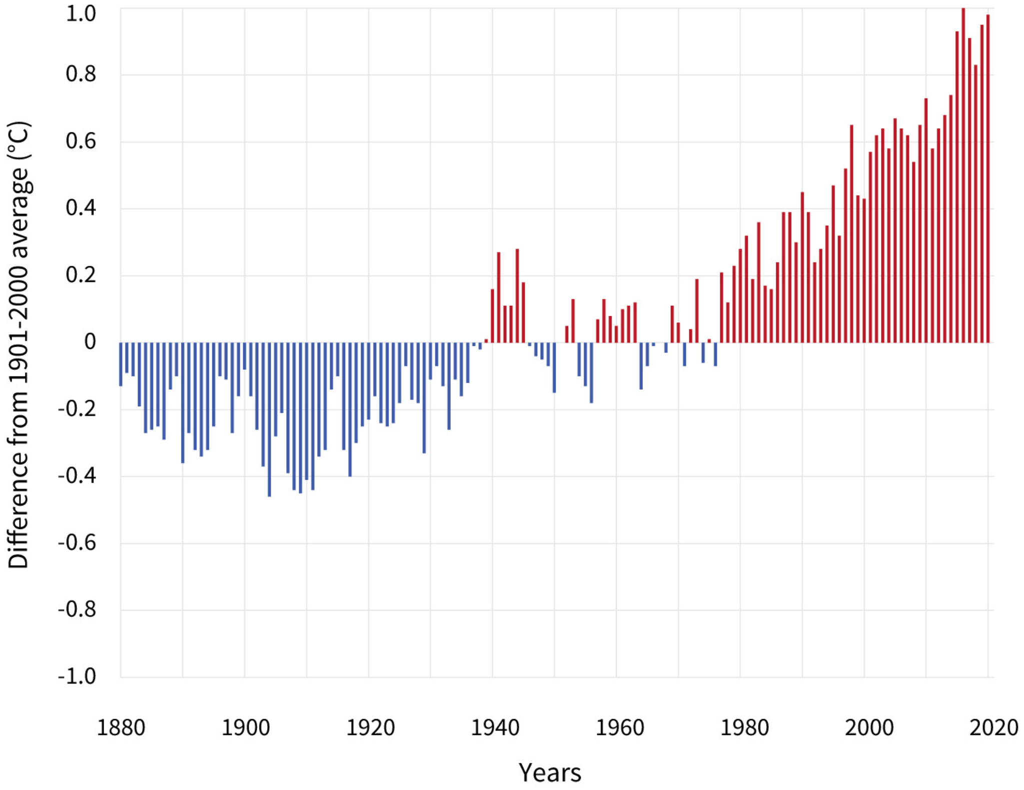


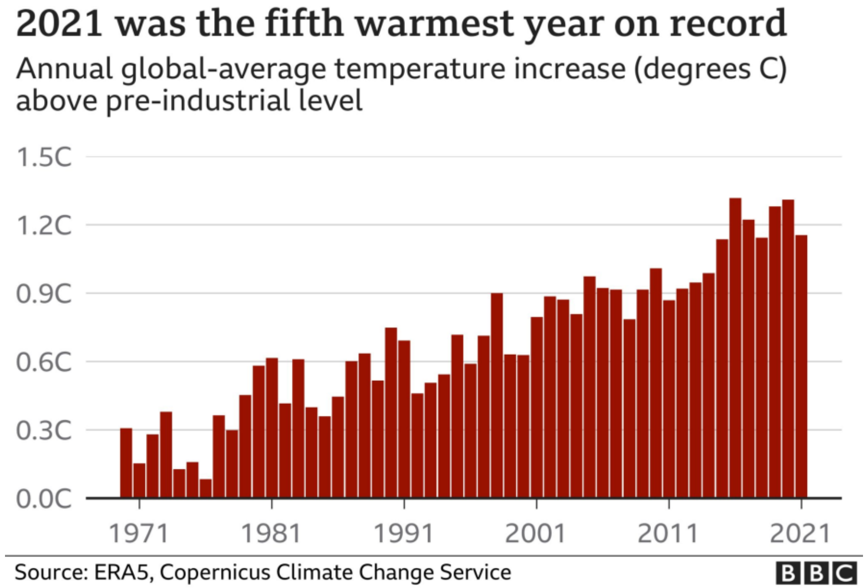
GLACIER MASS BALANCE (YEARLY)



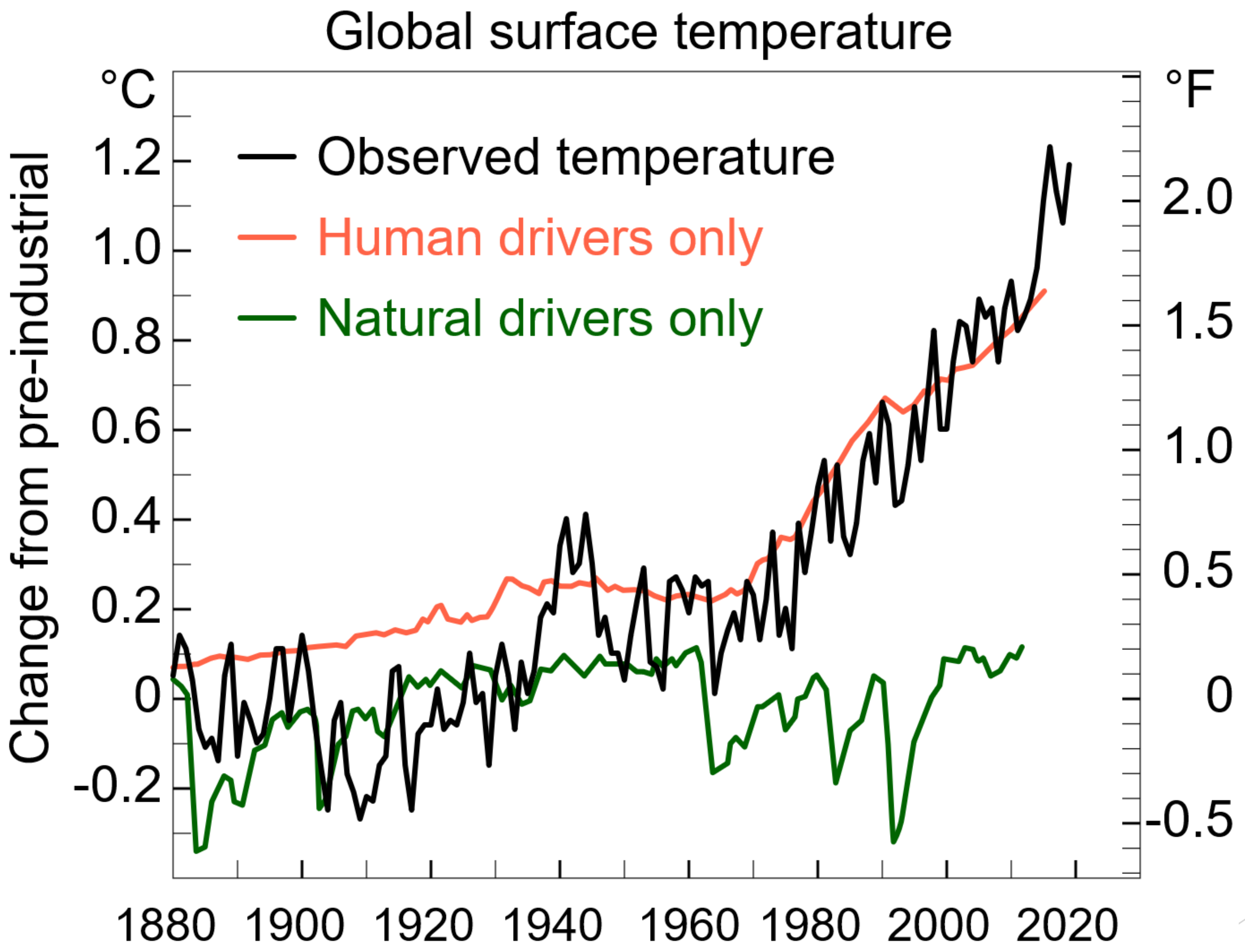
The global temperature differences from average for all Septembers since 1880. September 2020 was the warmest September on record and the seven warmest Septembers have occurred in the last seven years. Source: Climate.gov

GLOBAL AVERAGE SURFACE TEMPERATURE





Increase in Surface Temperature



Observed temperature from NASA vs the 1850–1900 average used by the IPCC as a pre-industrial baseline. The primary driver for increased global temperatures in the industrial era is human activity, with natural forces adding variability

Extreme Event

A weather or climate event that is rare at a particular place (and, sometimes, time of year) including, for example, heat waves, cold waves, heavy rains, periods of drought and flooding, and severe storms.

Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than a particular percentile (e.g., 1st, 5th, 10th, 90th, 95th, 99th) of a probability density function estimated from observations expressed as departures from daily or monthly means. (IPCC)

Severe weather events

- Landfalls of Hurricanes/Cyclones/Typhoons
- Intense Heat Waves and Hot Days
- Precipitation extremes
- Temperature extremes (Heat and Cold Waves)
- Long and Severe Droughts
- Intense thunder and lightning
- Floods (Coastal, Urban)
- Change is Monsoon Systems
- Wildfires, Dust storms
- Lightning, Storm Surge
- Land Slides
- Others (windstorms, blizzards, Wild Fires etc.)

COST OF EXTREME WEATHER EVENTS AND SUSTAINABLE DEVELOPMENT

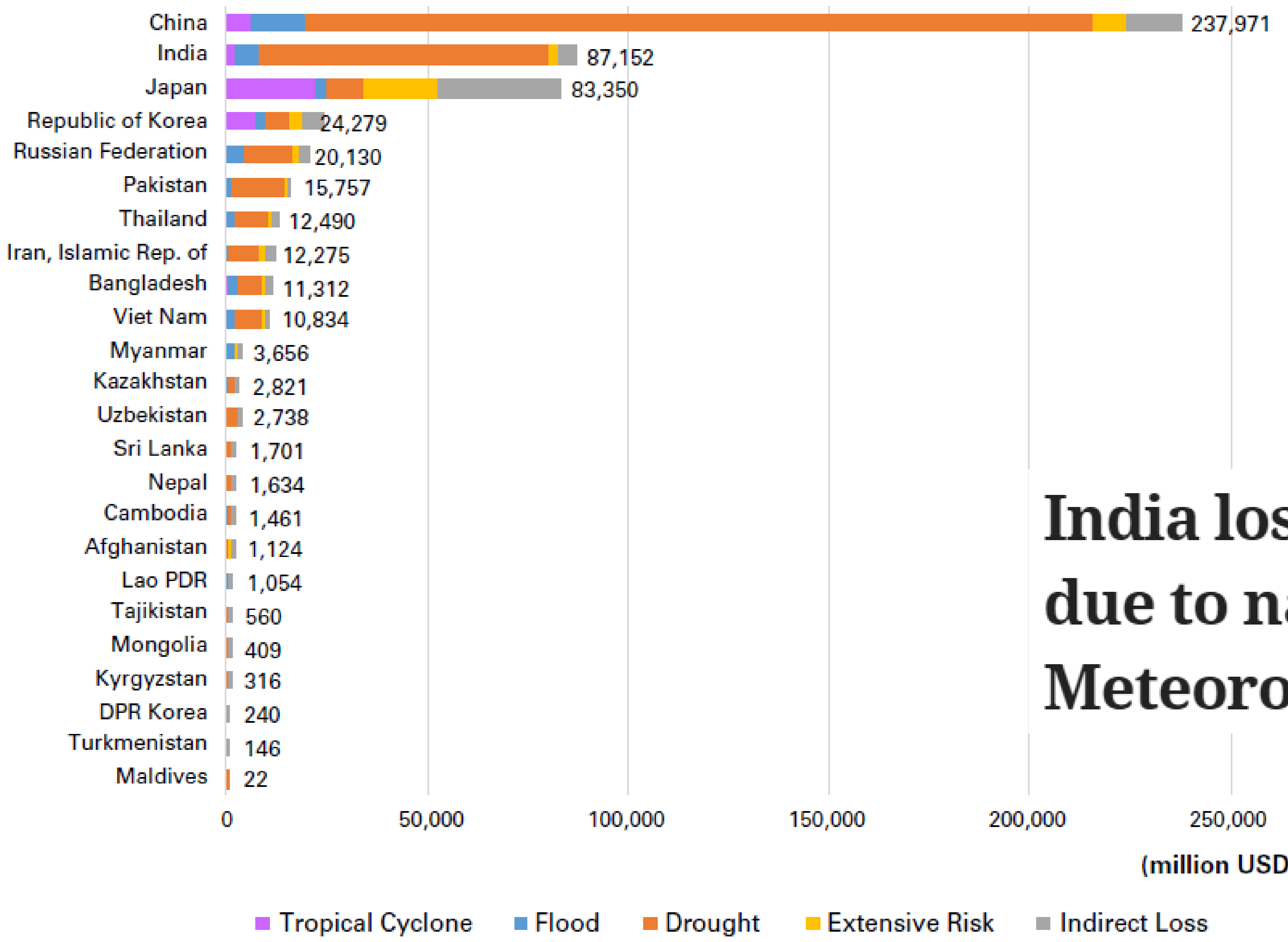
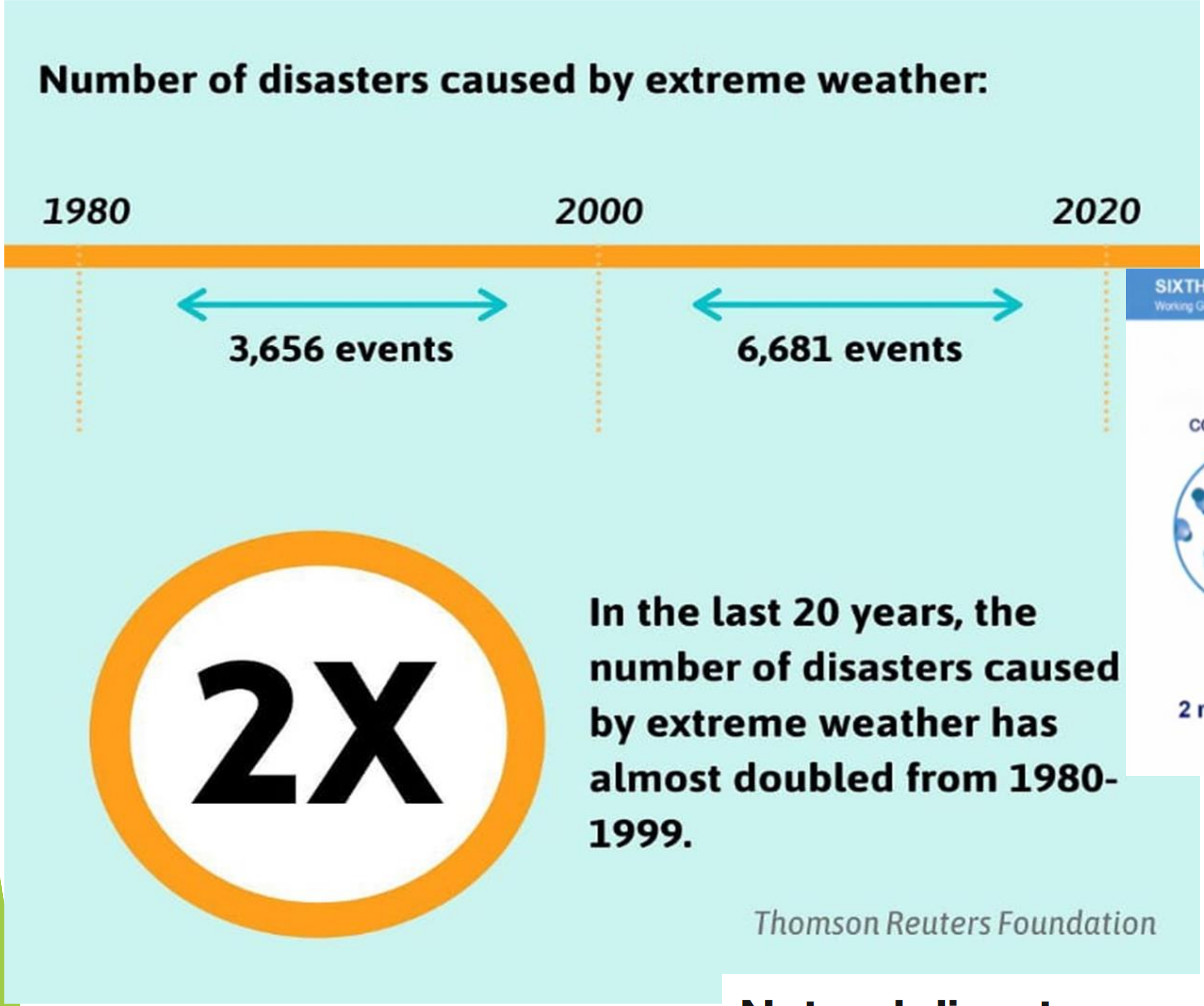
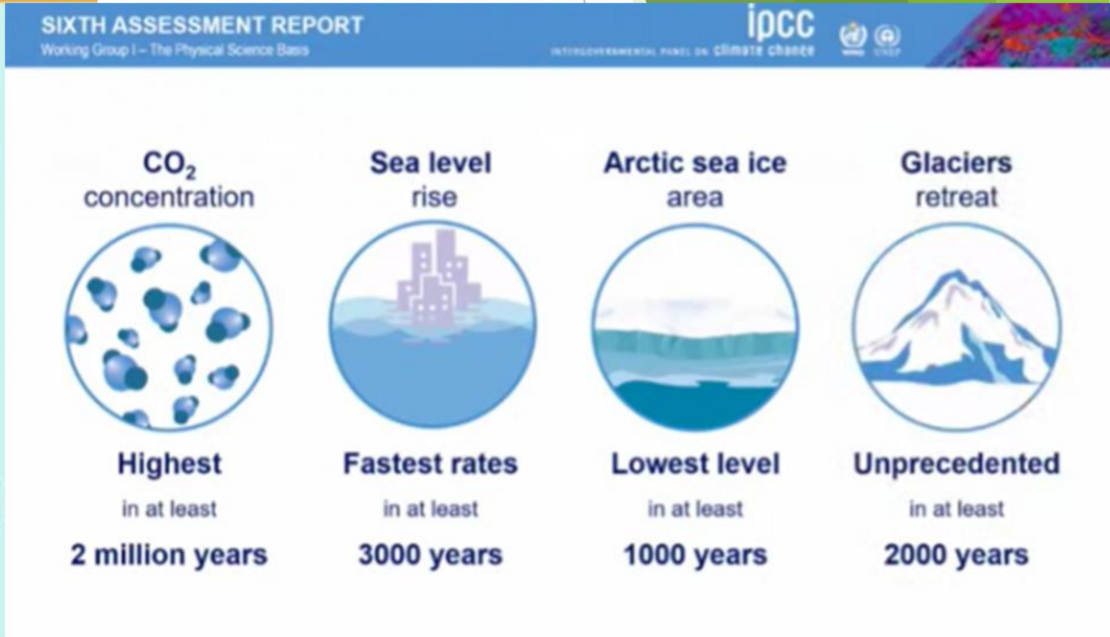


Figure 20. Total AAL from climate-related hazards in Asia. Data sourced from ESCAP, 2021: The Risk and Resilience Portal. Note: Data unavailable for Bahrain; Bhutan; Hong Kong, China; Iraq; Kuwait; Macao, China; Oman; Qatar; Saudi Arabia; United Arab Emirates; and Yemen.

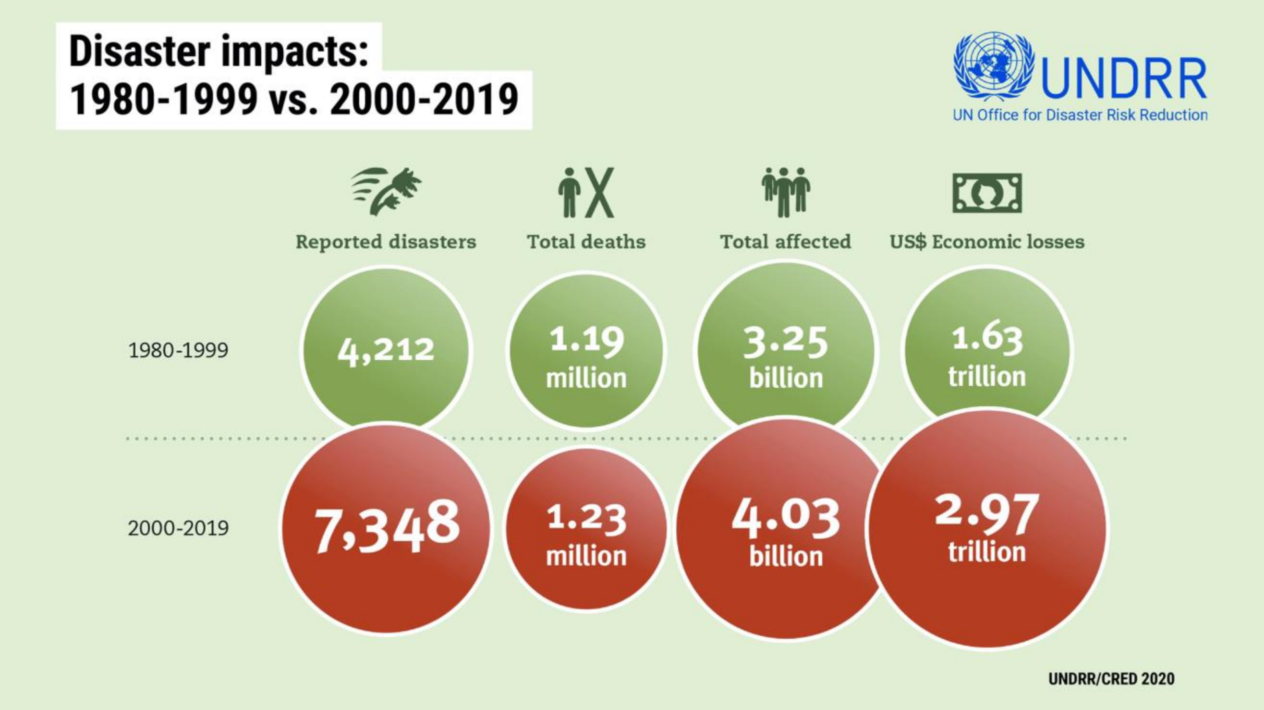
India lost Rs 65 lakh crore in 2020 due to natural disasters, says World Meteorological Organization

WMO State of Climate in Asia 2020

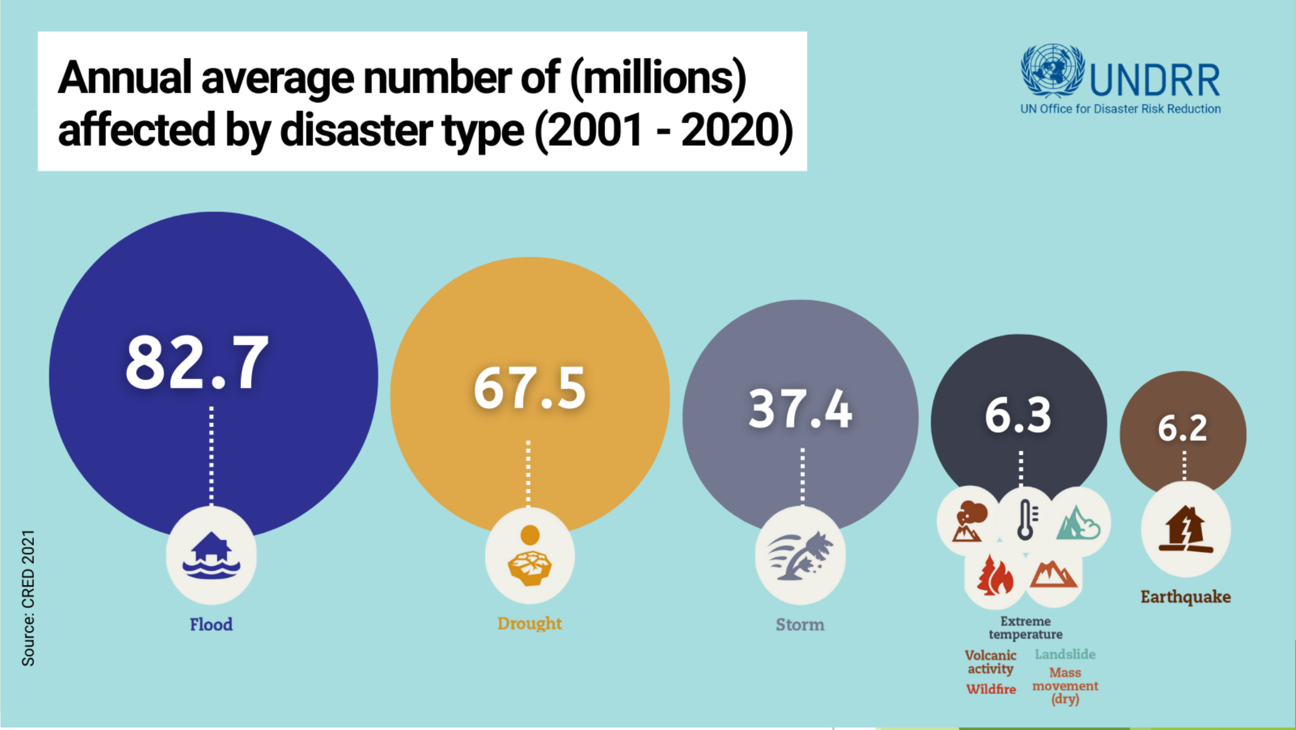




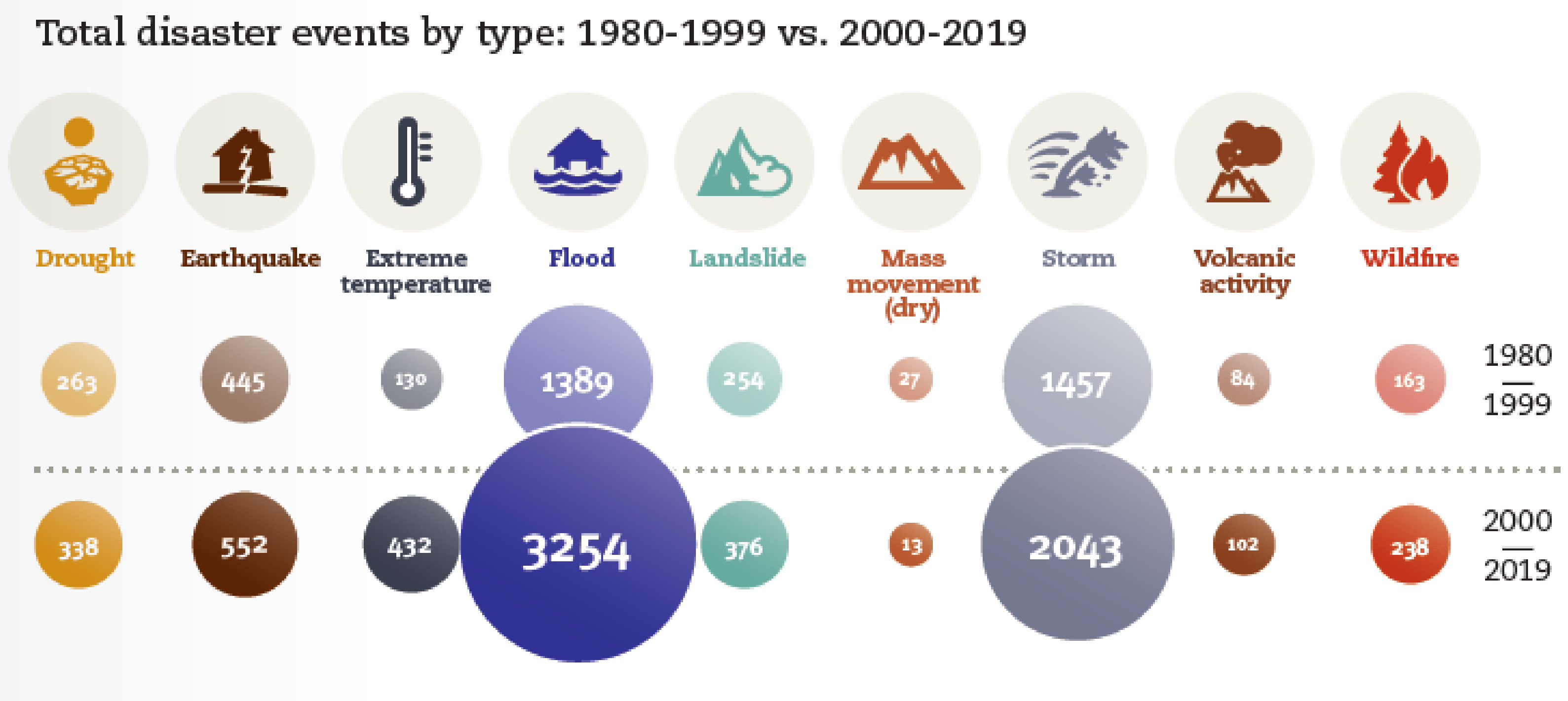
Natural disasters are occurring more frequently with increased ferocity, UN says



Disaster impacts:
1980-1999 vs. 2000-2019
UNDRR
UN Office for Disaster Risk Reduction
Reported disasters
Total deaths
Total affected
US$ Economic losses
1980-1999
4,212
1.19 million
3.25 billion
1.63 trillion
2000-2019
7,348
1.23 million
4.03 billion
2.97 trillion
UNDRR/CRED 2020



Annual average number of (millions) affected by disaster type (2001 - 2020)
UNDRR
UN Office for Disaster Risk Reduction
82.7
Flood
67.5
Drought
37.4
Storm
6.3
Extreme temperature
Volcanic activity
Landslide
Wildfire
Mass movement (dry)
6.2
Earthquake
Source: CRED 2021

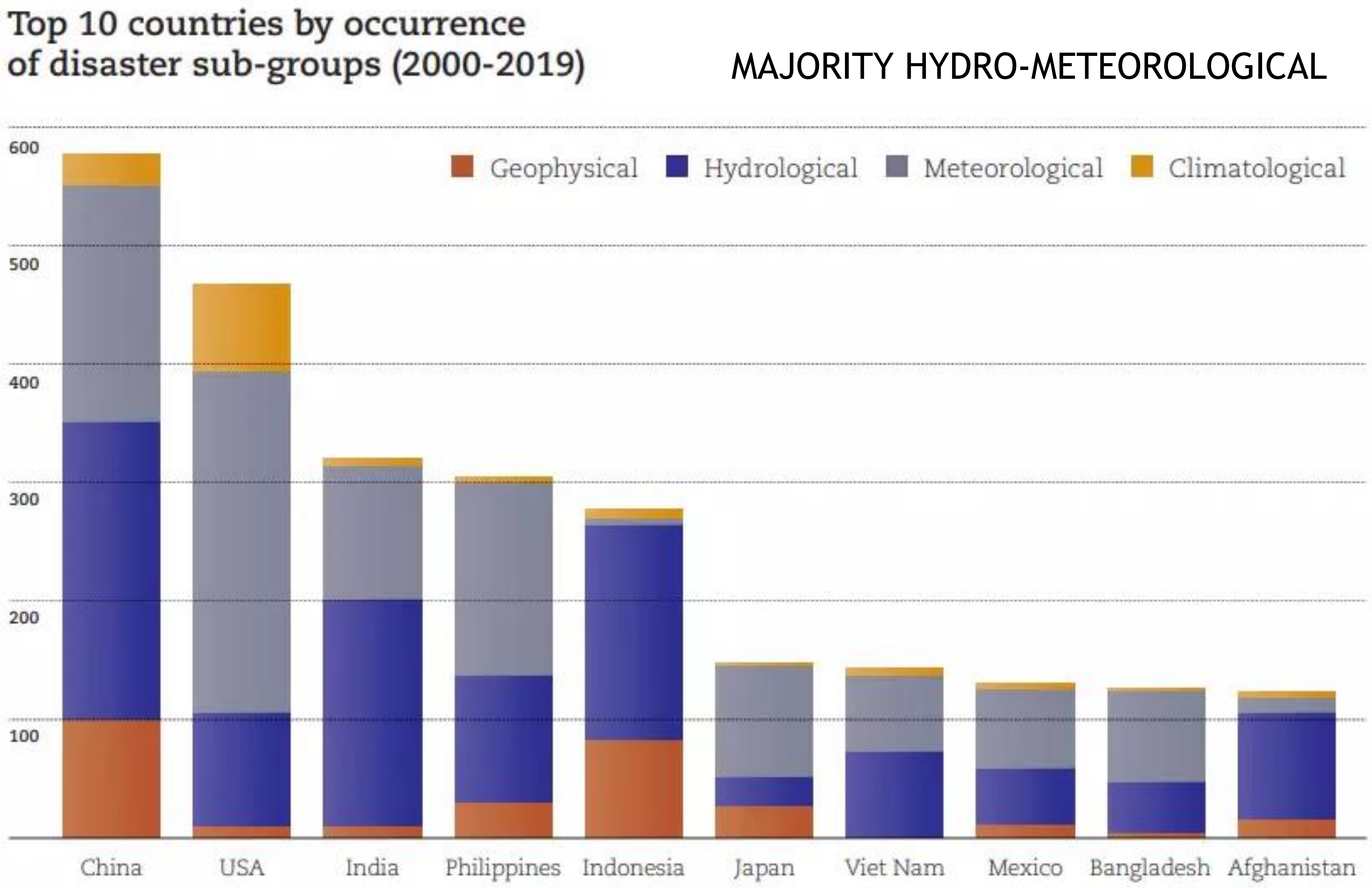


Total disaster events by type: 1980-1999 vs. 2000-2019
Drought
Earthquake
Extreme temperature
Flood
Landslide
Mass movement (dry)
Storm
Volcanic activity
Wildfire
263
445
130
1389
254
27
1457
84
163
1980 — 1999
338
552
432
3254
376
13
2043
102
238
2000 — 2019


10-year event
Frequency and increase in intensity of extreme temperature event that occurred once in 10 years on average in a climate without human influence
Future global warming levels
1850-1900
Present 1 °C
1.5 °C
2 °C
4 °C
FREQUENCY per 10 years
Once
now likely occurs 2.8 times (1.8 - 3.2)
will likely occur 4.1 times (2.8 - 4.7)
will likely occur 5.6 times (3.8 - 6.0)
will likely occur 9.4 times (8.3 - 9.6)
INTENSITY increase
+6 °C
+5 °C
+4 °C
+3 °C
+2 °C
+1 °C
0 °C
+1.2 °C hotter
+1.9 °C hotter
+2.6 °C hotter
+5.1 °C hotter
50-year event
Frequency and increase in intensity of extreme temperature event that occurred once in 50 years on average in a climate without human influence
Future global warming levels
1850-1900
Present 1 °C
1.5 °C
2 °C
4 °C
FREQUENCY per 50 years
Once
now likely occurs 4.8 times (2.3 - 6.4)
will likely occur 8.6 times (4.3 - 10.7)
will likely occur 13.9 times (6.9 - 16.6)
will likely occur 39.2 times (27.0 - 41.4)
INTENSITY increase
+6 °C
+5 °C
+4 °C
+3 °C
+2 °C
+1 °C
0 °C
+1.2 °C hotter
+2.0 °C hotter
+2.7 °C hotter
+5.3 °C hotter
Heavy precipitation over land
10-year event
Frequency and increase in intensity of heavy 1-day precipitation event that occurred once in 10 years on average in a climate without human influence
Future global warming levels
1850-1900
Present 1 °C
1.5 °C
2 °C
4 °C
FREQUENCY per 10 years
Once
now likely occurs 1.3 times (1.2 - 1.4)
will likely occur 1.5 times (1.4 - 1.7)
will likely occur 1.7 times (1.6 - 2.0)
will likely occur 2.7 times (2.3 - 3.6)
INTENSITY increase
+40%
+30%
+20%
+10%
0%
+6.7% wetter
+10.5% wetter
+14.0% wetter
+30.2% wetter
Agricultural & ecological droughts in drying regions
10-year event
Frequency and increase in intensity of an agricultural and ecological drought event that occurred once in 10 years on average across drying regions in a climate without human influence
Future global warming levels
1850-1900
Present 1 °C
1.5 °C
2 °C
4 °C
FREQUENCY per 10 years
Once
now likely occurs 1.7 times (0.7 - 4.1)
will likely occur 2.0 times (1.0 - 5.1)
will likely occur 2.4 times (1.3 - 5.8)
will likely occur 4.1 times (1.7 - 7.2)
INTENSITY increase
+2 sd
+1 sd
0 sd
+0.3 sd drier
+0.5 sd drier
+0.6 sd drier
+1.0 sd drier

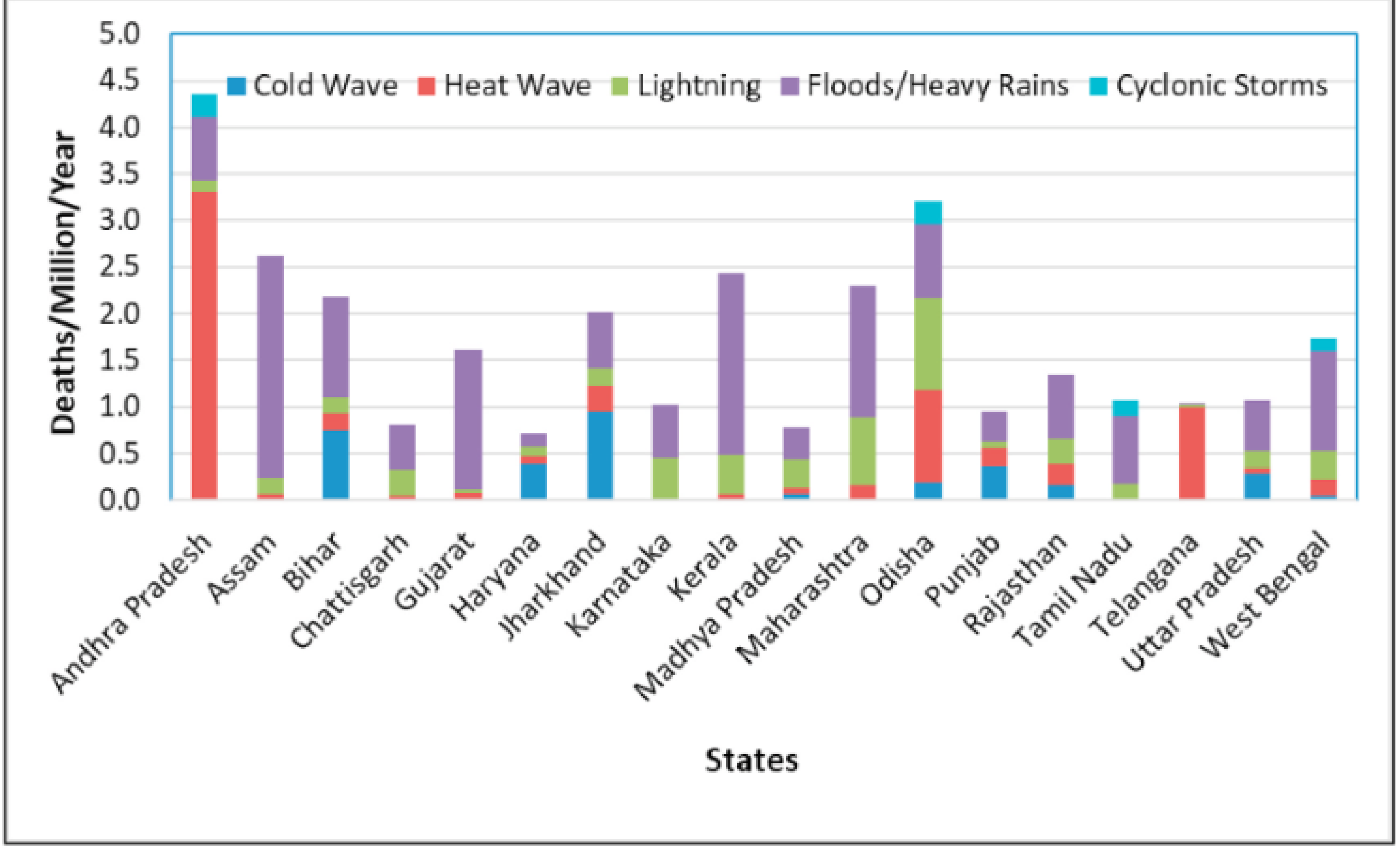
Source: IPCC

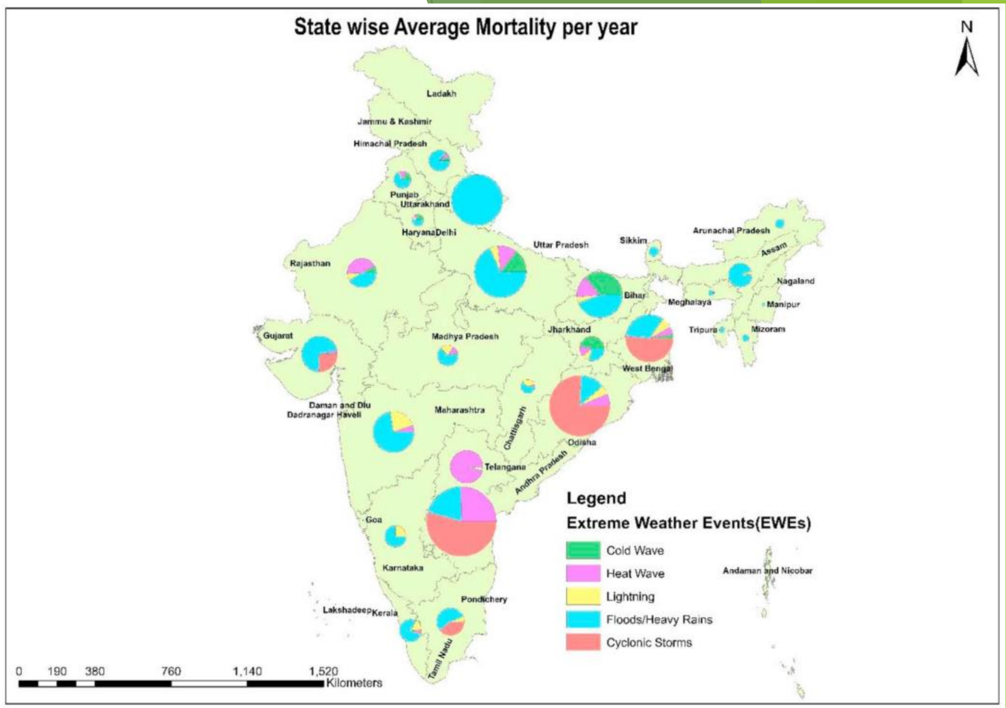
MAJORITY HYDRO-METEOROLOGICAL



8 out of the 10 most disaster-affected countries are in Asia. These events cost $2.97 trillion in economic losses with 8 out of the 10 most-affected countries in Asia.

Image: United Nations Office for Disaster Risk Reduction





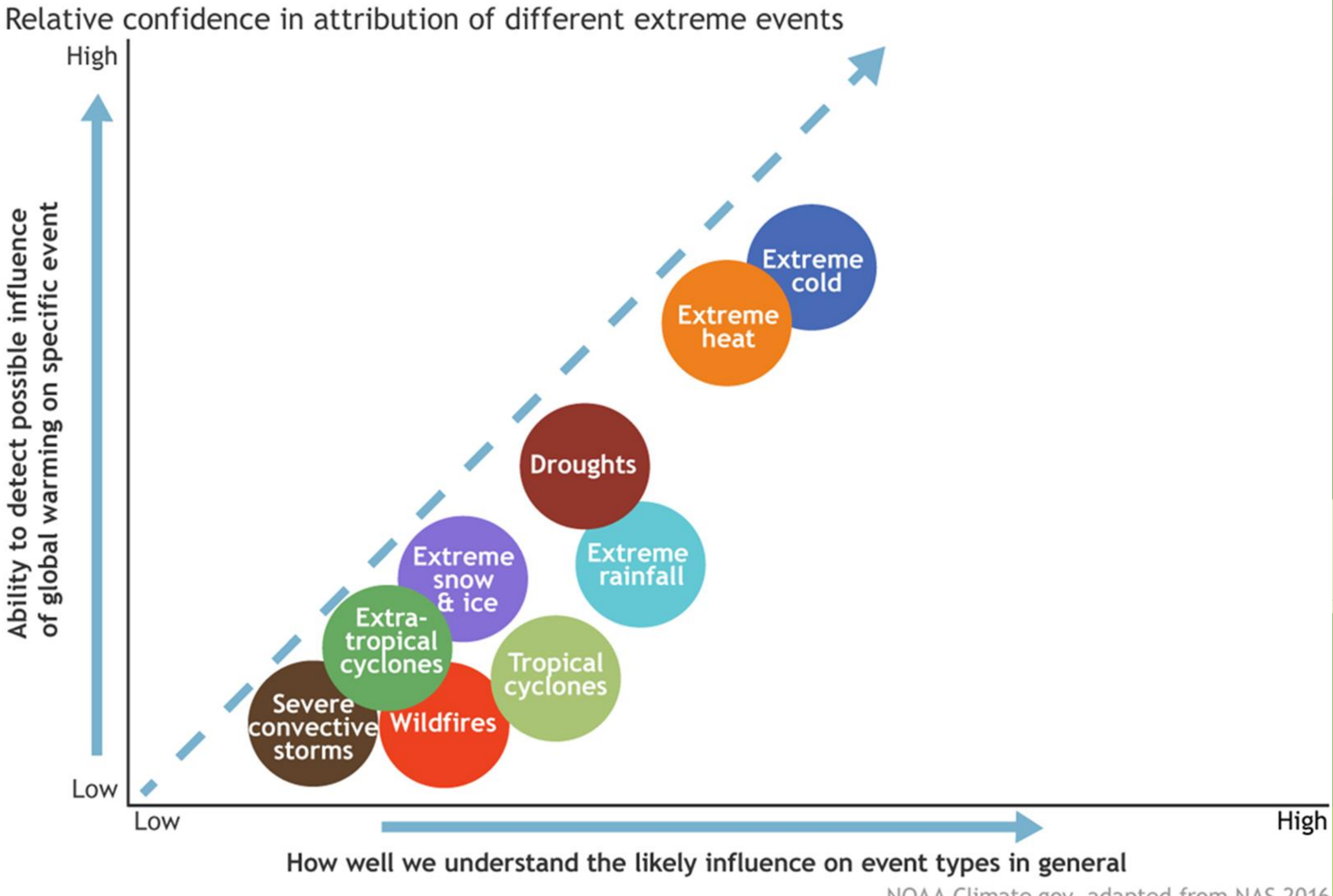
Total Mortality (1970–2019) wise top 5 states for each extreme weather event.

EWE	States (arranged mortality wise, in descending order)
Cold wave	Bihar, Uttar Pradesh, Jharkhand, West Bengal, Rajasthan
Heat Wave	Andhra Pradesh, Rajasthan, Uttar Pradesh, Bihar, Odisha
Floods	Uttar Pradesh, Maharashtra, Uttarakhand, Andhra Pradesh, Bihar
Lightning	Maharashtra, Odisha, West Bengal, Karnataka, Madhya Pradesh
Tropical Cyclone	Odisha, Andhra Pradesh, West Bengal, Gujarat, Tamil Nadu
Total	Andhra Pradesh, Odisha, Uttar Pradesh, West Bengal, Bihar

Floods and tropical cyclones contribute almost 75 percent to the total mortalities per year due to Extreme Weather Events (EWE). Followed by Heat Wave and Lightning.

States like Odisha, Andhra Pradesh, Assam, Bihar, Kerala, and Maharashtra, with high populations, had the maximum mortality rates due to EWEs in the last two decades.

Ray et al. 2021


Relative confidence in attribution of different extreme events
High
Low
Ability to detect possible influence of global warming on specific event
Low
High
How well we understand the likely influence on event types in general
Extreme cold
Extreme heat
Droughts
Extreme rainfall
Extreme snow & ice
Extra-tropical cyclones
Tropical cyclones
Severe convective storms
Wildfires

Cyclones in NIO

- Asani (2022) –SCS
- Yaas (2021) –VSCS
- Amphan (2020) –SuCS
- Fani (2019) –ESCS
- Bulbul(2019) –VSCS

- Taukate (2021) –ESCS
- Nisarga (2020) – SCS
- Jawad (2021)– SCS–Winter
- Gulab–Saheen ((2021) –Monsoon

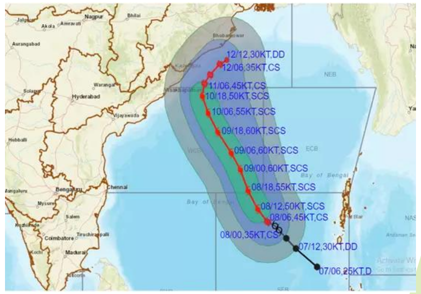
Key Features

Every year pre-monsoon
Intense storms
Landfall over India
Rapid intensification
Unseasonal storms
Recurving storm
Lots of Rainfall
Sustenance after landfall
Quick variability in track/intensity

Case of Asani (2022)

1May-9May (10Days)
Simulations 4 cycles per day (40)
30 models per simulations (1200)
About 4 major centers (4800)

Suppose to cross Odisha Coast
Ended up in AP coast



Source: IMD

TROPICAL CYCLONE FANI (2019)

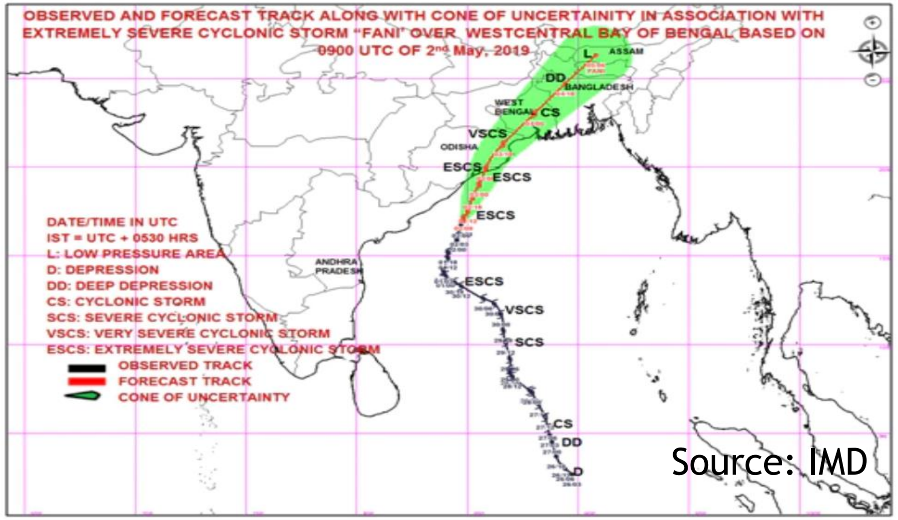
In the past (1891-2017) **only 14 severe tropical cyclones were formed in April over the Bay of Bengal** and only one storm crossed the Indian mainland.

Cyclone Fani is the second storm forming in April and crossing the mainland. The last time it happened was Cyclone Nargis that devastated Myanmar in 2008.11 Days and Crossed about 13,500kms.

The system maintained the cyclonic storm intensity for almost 21 hours even after landfall till 0000 UTC.

The peak MSW of the cyclone was **200 - 210 kmph (115 knots) gusting to 230 kmph during 0900 UTC to 2100 UTC.**

The system crossed Odisha coast close to Puri with maximum sustained wind speed of 175-185 kmph (100 knots) gusting to **205 kmph between 0800 to 1000 hrs IST of 03 May, 2019**.

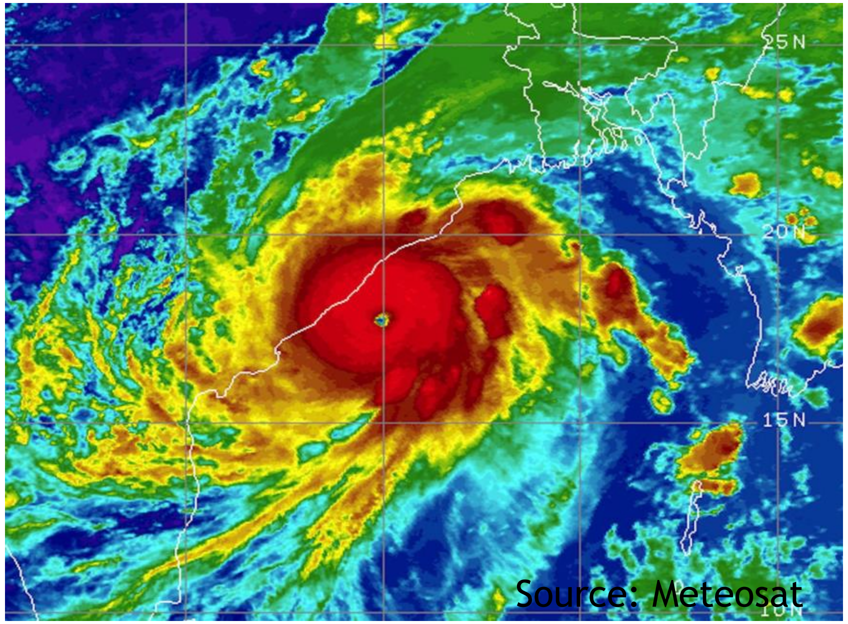


Source: IMD

It developed near the equator (near 2.70N and 88.70E). **Genesis of the cyclonic disturbance in such a lower latitude is very rare,** last such activity was observed over the north Indian Ocean in January, 2005.

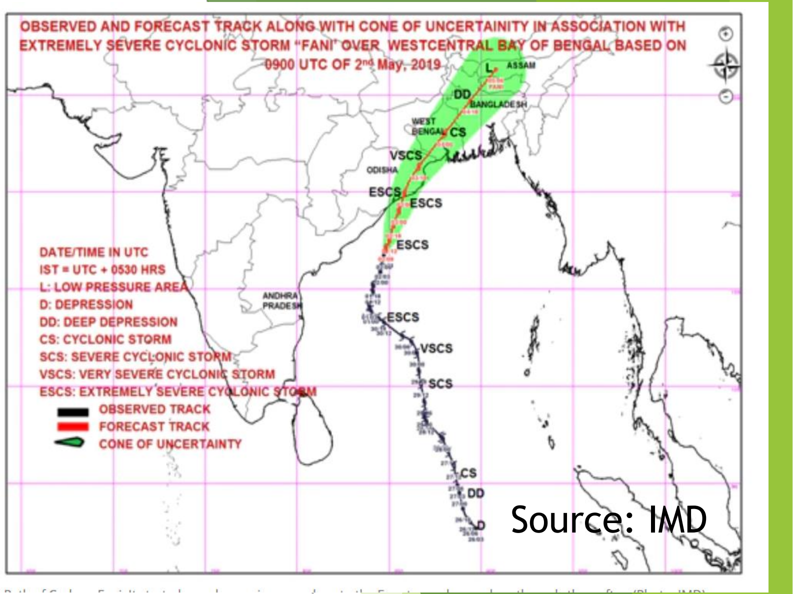
It was the most intense cyclone to cross Odisha coast after **Phailin in 2013 which crossed coast with a maximum** sustained wind speed of 215 kmph.

EXTREME SEVERE TROPICAL CYCLONE FANI (2019)



Cyclone Fani is one of the **rarest of rare summer cyclones to hit Odisha in 43 years**. It is also one of three to hit in the last 150 years.

Rapid intensification during 29th afternoon to 30th April evening over westcentral Bay of Bengal with increase in maximum sustained wind speed (MSW) from 45 knots (**84 KPH) at 1430** IST of 29 to 95 knots (**175KPH**) at 2030 IST of 30 April.

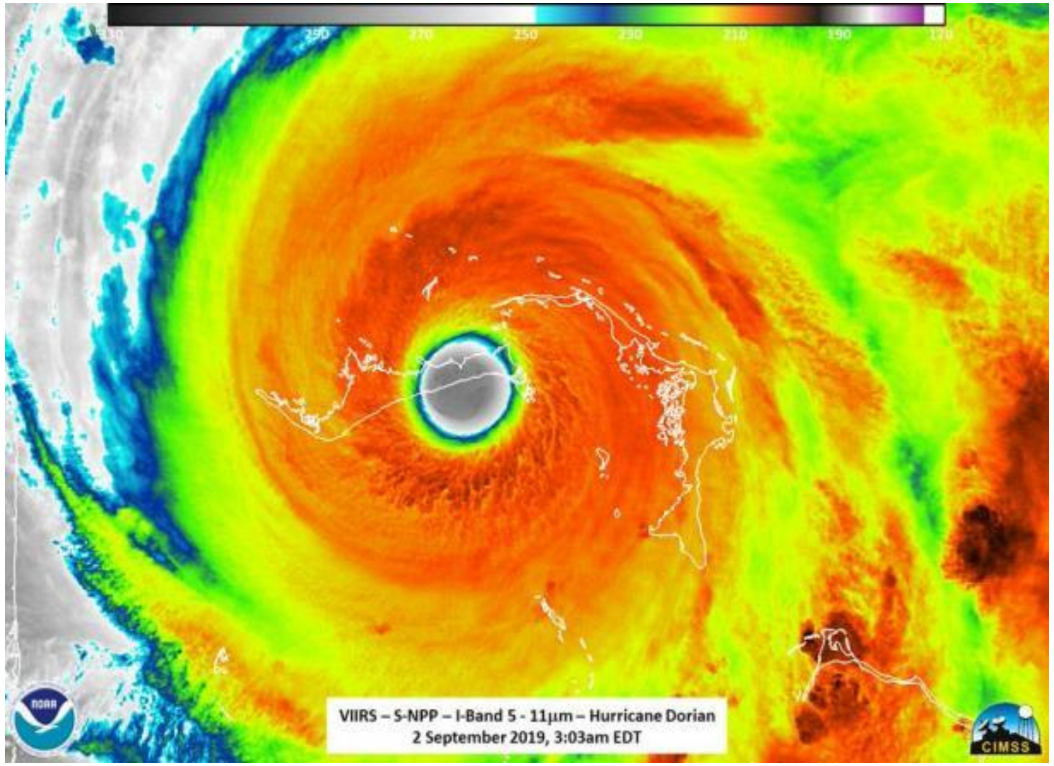


Traversing for nearly 10 days over the sea (Longest Track 3030Km) allowed Fani to gather such strength that it is now classified as an **Extremely Severe Cyclone.** (Cyclones generally 4~7 days).

Between **1965 and 2017**, India was hit by **145 cyclonic storms** that were classified as severe, very severe, extremely severe and super cyclonic storm. Of these, **only seven (5 per cent) were in April and 27 (18 per cent) in May.**

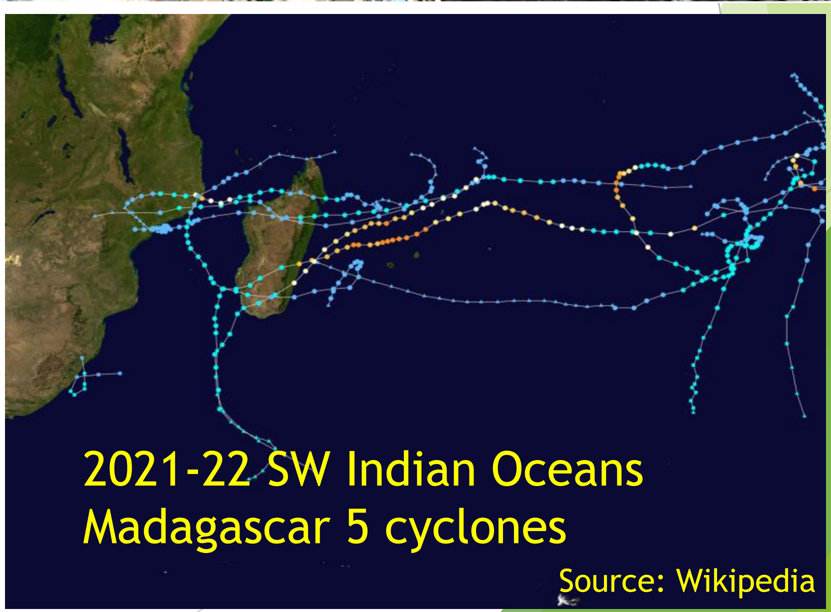
Pre-monsoon Land Falling cyclone ~200 km/h. (**Seventh highest** among cyclones to have originated from the Northern Indian Ocean)

2020 and 2021, **Amphan (Supercyclone),** Tauktae (ECSC), Yaas (VSCS), **Nisarga (SCS, strongest storm to hit MH)** and Nivar (SCS) formed in Bay of Bengal/Arabian Sea—made landfall, causing immense destruction.

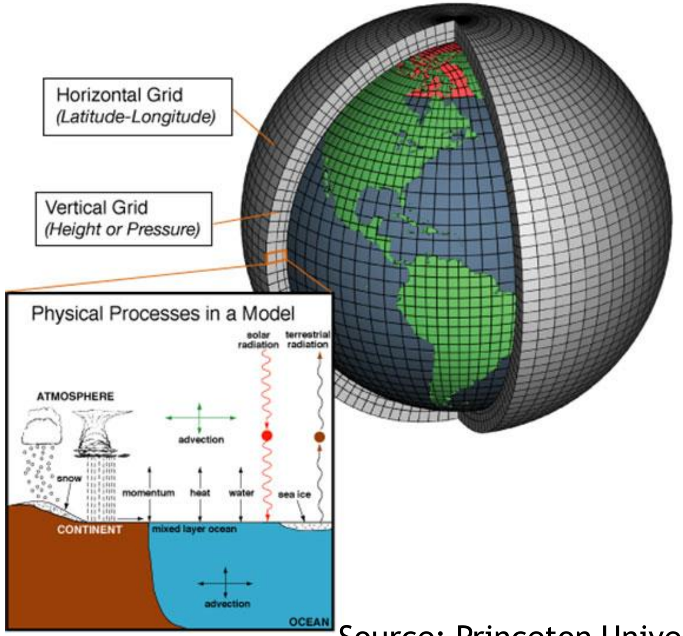


Hurricane Dorian (2019) Destroyed Bahamas

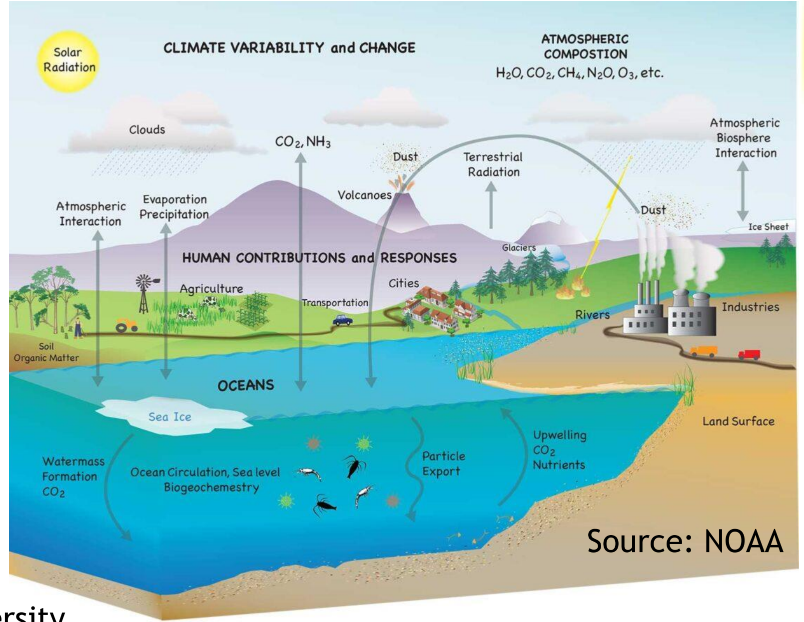
Dorian had maximum sustained winds of **185 mph (297 km/h), and brought a storm surge of 18 to 23 feet (5.5 to 7 meters)** above normal tide levels. Dorian **remained stationary (48hrs),** thus exacerbating the impacts of the hazards – wind, rain, waves and storm surge. Satellite and aerial images showed unprecedented flooding and destruction in the worst affected islands - Abaco and Grand Bahama. **Official 45 deaths** and many missing.



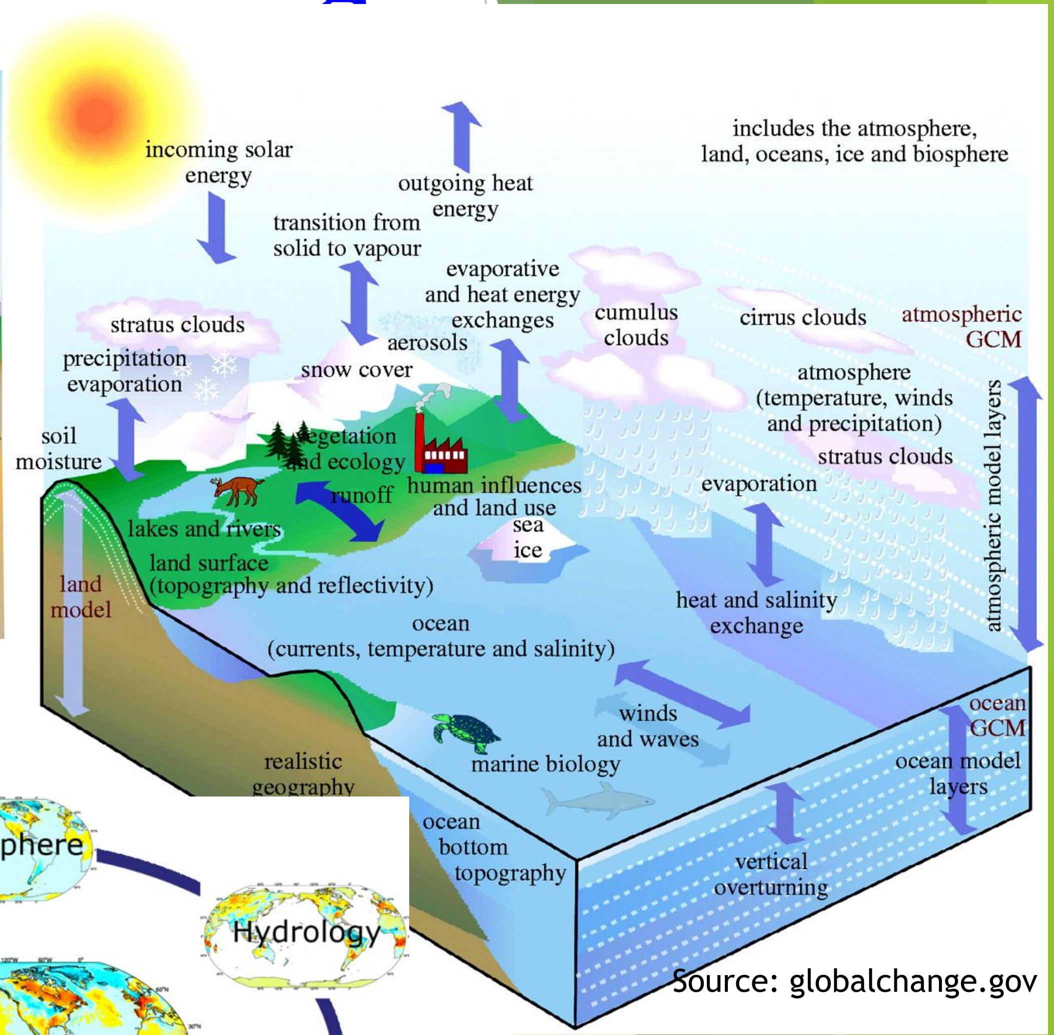
Earth System (Climate) Modeling



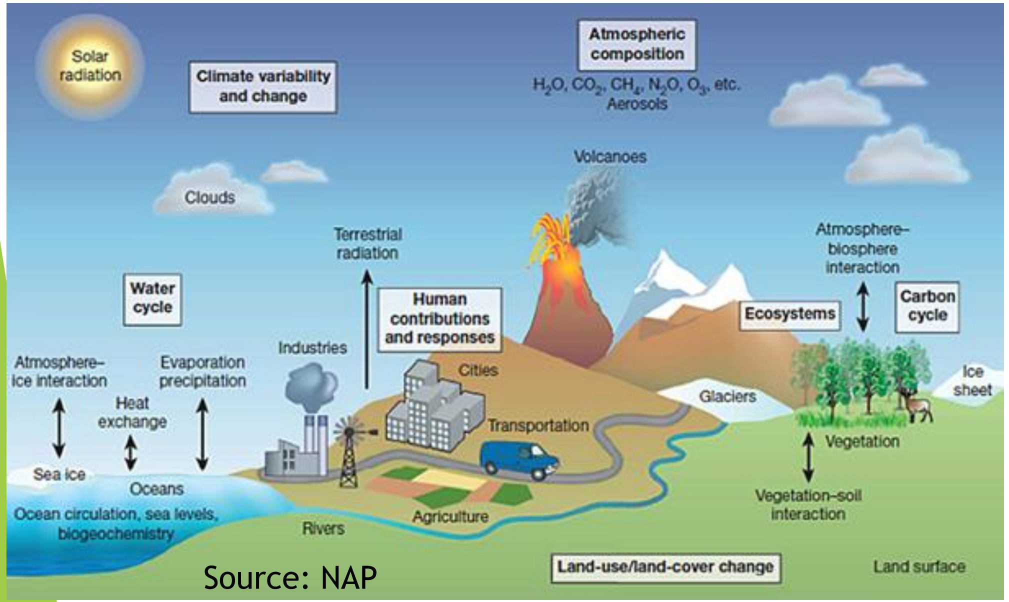
Source: Princeton University



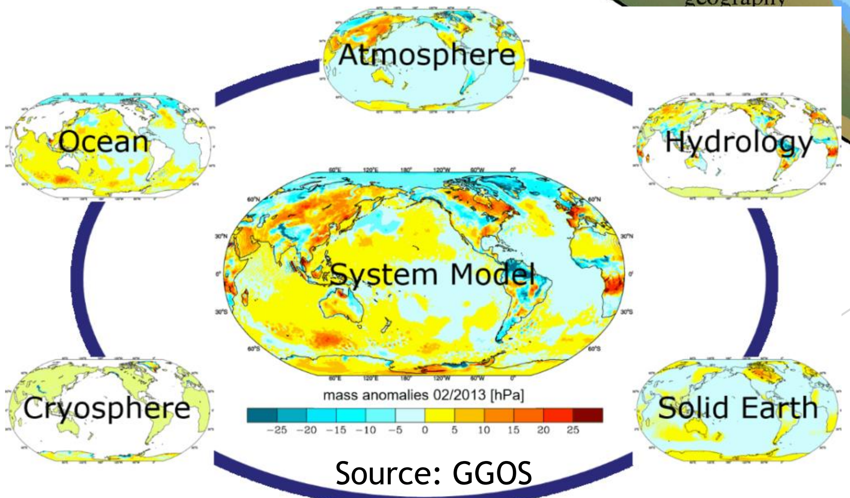
Source: NOAA



Source: globalchange.gov



Source: NAP



Source: GGOS

Rise in Temperature

SCIENTIFIC REPORTS

OPEN

Decadal surface temperature trends in India based on a new high-resolution data set

Received: 3 November 2017
Accepted: 6 April 2018
Published online: 10 May 2018

Robert S. Ross[1], T. N. Krishnamurti[1], Sandeep Pattnaik[2] & D. S. Pai[3]

A new comprehensive surface temperature data set for India is used to document changes in Indian temperature over seven decades, in order to examine the patterns and possible effects of global warming. The data set is subdivided into pre-monsoon, monsoon, and post-monsoon categories in order to study the temperature patterns in each of these periods. When the decade means in maximum, minimum and daily mean temperature for the 2000s are compared to those of the 1950s, a consistent pattern of warming is found over northwestern and southern India, and a pattern of cooling is seen in a broad zone anchored over northeastern India and extending southwestward across central India. These patterns are explained by the presence of a large region of anthropogenic brown haze over India and adjacent ocean regions. These aerosols absorb solar radiation, leading to warming of the haze layer over northeastern and central India and to cooling of the surface air beneath. The heated air rises and then sinks to the north and south of the haze region over northwestern and southern India, warming the air by compression as it sinks in those regions. The possible impact of these temperature patterns on Indian agriculture is considered.

The motivation for this study came from examination of all-India surface mean temperature anomalies for the period 1901–2016 shown in the supplementary information section of this paper as Fig. S1. These reveal an unmistakable rapid rise in Indian surface temperatures, particularly since about 1980, as seen in annual, winter, pre-monsoon, monsoon, and post-monsoon period depictions.

There has been great interest in India in recent decades concerning extreme values of temperature that have been observed, particularly during the warmest part of the year in April and May, the period preceding the onset of the summer monsoon. Such observations are consistent with global trends in temperature. The Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report[1] reported that warming of the global climate system is unequivocal and this warming has accelerated since the 1950s. Each of the last three decades has been successively warmer at the earth's surface than any prior decade based on records extending back to 1850. Globally averaged temperature for the land and ocean regions combined has shown an increase of 0.85C since 1880.

Recent research[2] has pointed out how climate change poses many challenges to growth and development in South Asia. India, for example, is more vulnerable to climate change because its agricultural system must feed 17.5% of the world's population with only 2.4% of the land and 4% of the water resources of the planet. A mid-range projection of climate change for the period 2020–2039 indicates a crop yield reduction of 4.5–9% depending on the magnitude and distribution of the warming. Clearly it is extremely important to understand the patterns of long-term temperature change across India so that informed decisions can be made with respect to the demands on agricultural production.

In the current study, a new comprehensive temperature data set, unprecedented in both the number of observation stations involved and in its high horizontal resolution, has been used to document changes in Indian surface temperature over nearly seven decades, in order to examine the patterns and possible effects of global warming. This important new information on temperature trends across India has the potential to make significant contributions to future planning in the country, particularly for the agricultural system.

[1]Department of Earth, Ocean and Atmospheric Science, Florida State University, Tallahassee, FL, 32306, USA. [2]School of Earth, Ocean and Climate Sciences, Indian Institute of Technology, Bhubaneswar, Odisha, 751013, India. [3]Indian Meteorological Department, Pune, Maharashtra, 411005, India. T. N. Krishnamurti is deceased. Correspondence and requests for materials should be addressed to R.S.R. (email: rross@fsu.edu)

India Science Wire

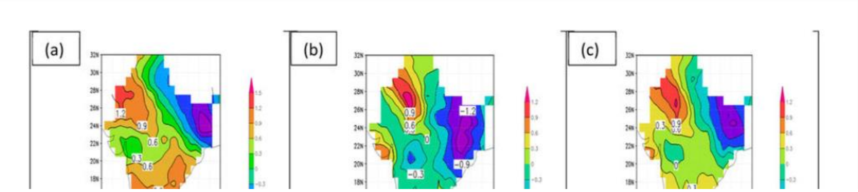
Latest S&T News from India

Home > Category > Indian Science News

India is warming rapidly

Tweet

By Dinesh C Sharma   New Delhi,Tuesday, May 15,2018



CLIMATE CHANGE

India has warmed rapidly in the past 70 years: study

Global warming is manifesting itself over parts of India in the maximum temperatures observed during the warm pre-monsoon period

NEXT NEWS >

By Dinesh C Sharma
Last Updated: Wednesday 16 May 2018

Source: Down to Earth

Science

Rising temperature: India is warming up rapidly

Dinesh C Sharma | New Delhi | Updated on May 15, 2018 | Published on May 15, 2018

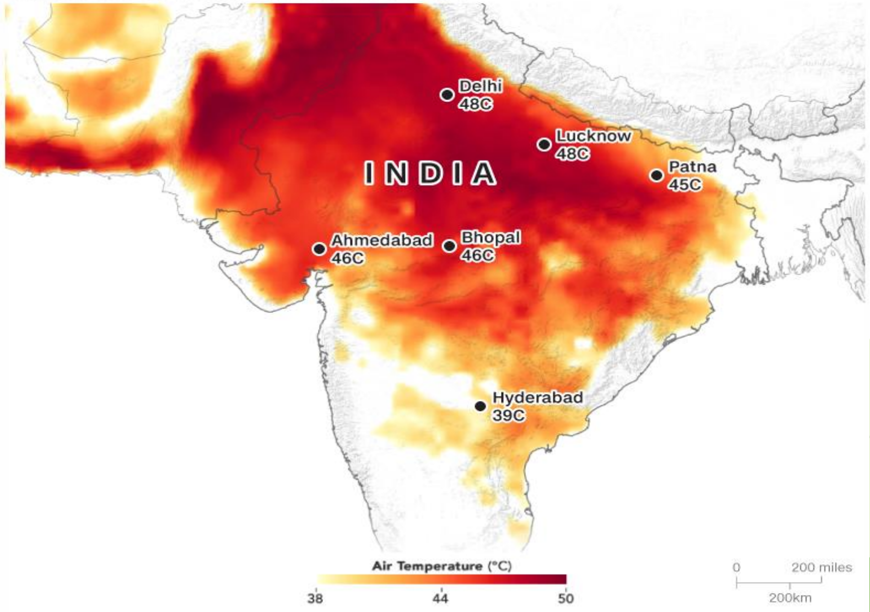
A representational picture - Reuters

A new study on climate change in India has confirmed a rapid rise in surface temperatures in the past 70 years.

The study calculated temperature rise in terms of change occurring from decade to decade, using

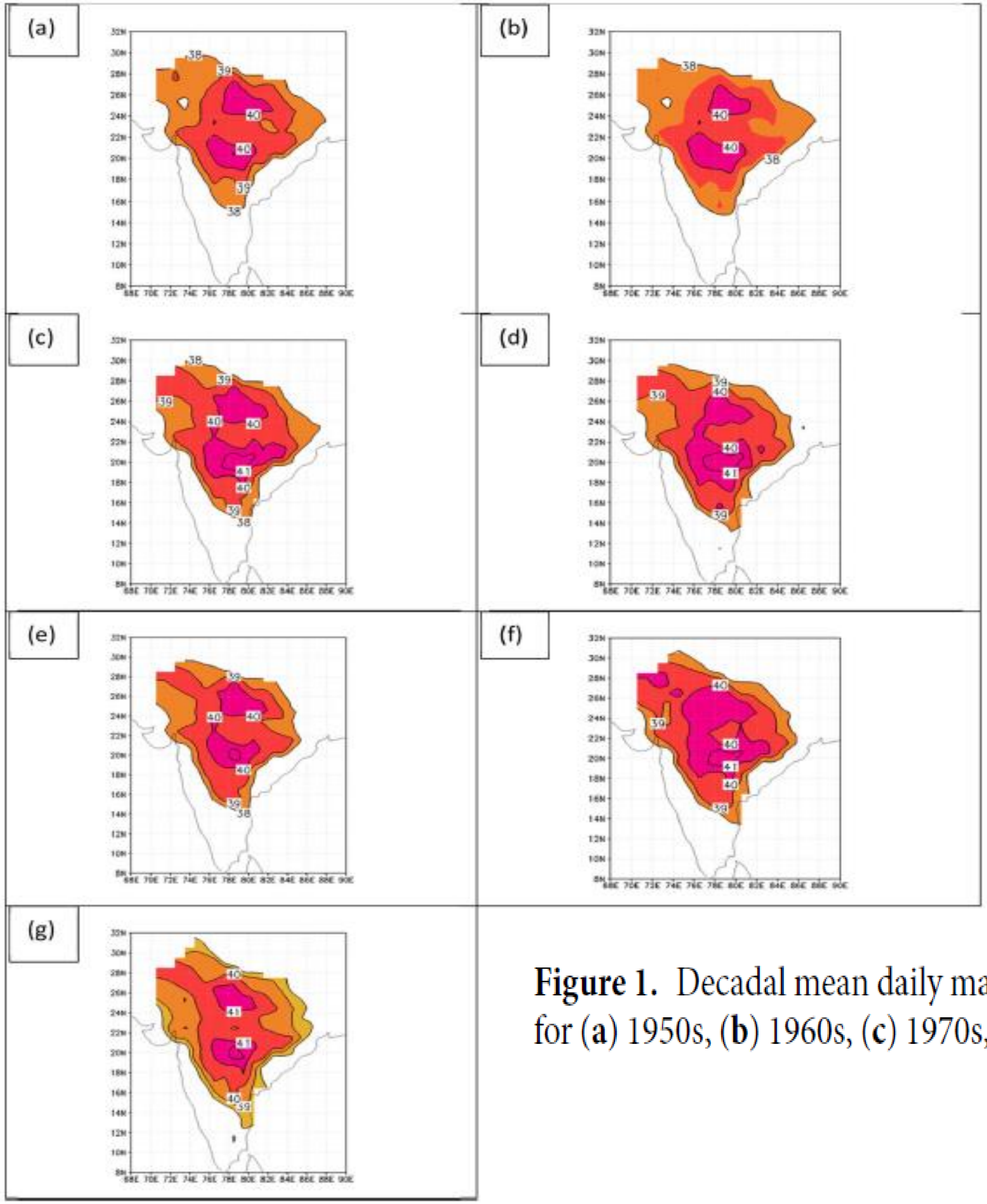
Source: Hindu

India scorches in heat wave



Source: June 10, 2019. NASA Earth Observatory image by Joshua Stevens, using GEOS-5 data from the Global Modeling and Assimilation Office at NASA GSFC

1 APRIL – 31 MAY (MAX T)



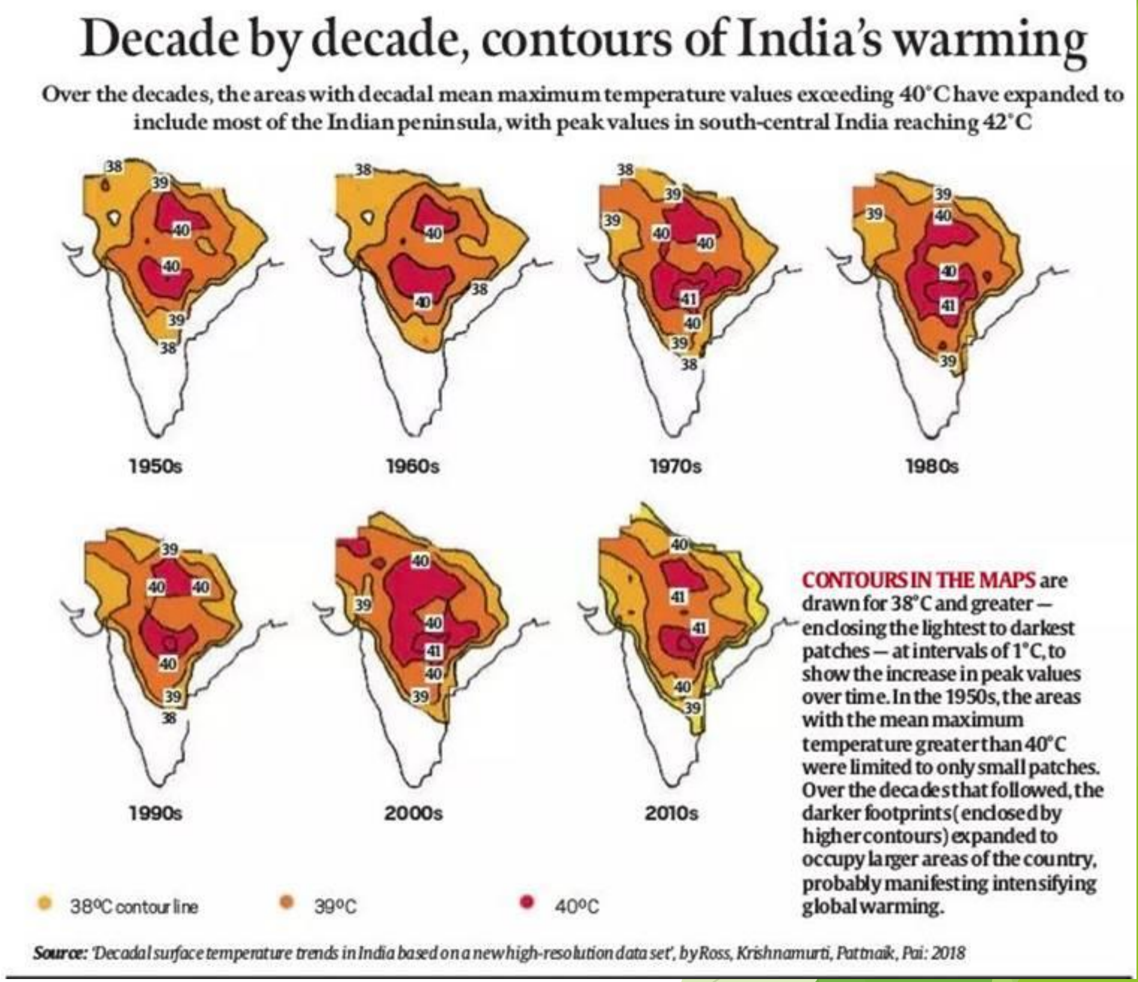
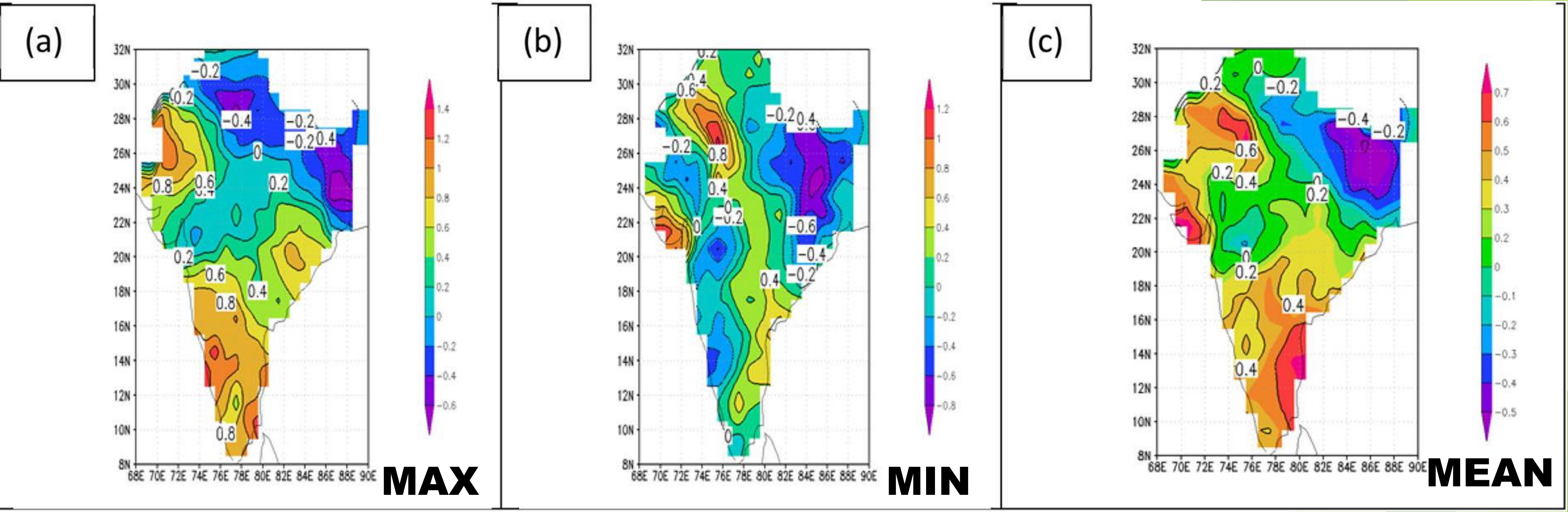


Figure 1. Decadal mean daily maximum temperature for the period April 1 to May 31. The decades shown are for (**a**) 1950s, (**b**) 1960s, (**c**) 1970s, (**d**) 1980s, (**e**) 1990s, (**f**) 2000s, and (**g**) 2010s.



WINTER
1 JAN – 31 MAR
2000s minus 1950s

Research Article

Spatiotemporal patterns of surface temperature over western Odisha and eastern Chhattisgarh

Keval Maniar[1] · Sandeep Pattnaik[1]

- Examines daily max/mini Temperature (i.e., March, April and May) for 30 years (i.e., 1988–2017) using ERA 12 km data.
- Results suggest that the daily maximum, minimum and mean temperature over the study region increase at **the rate of 0.006 °C, 0.012 °C and 0.017 °C per year, respectively.**
- **Alarmingly, frequency and intensity of warm night have increased, whereas frequency and intensity of cold nights** have decreased over the years.
- Raigarh in Chhattisgarh has the highest increasing trend of warm night frequency (0.13 times/year) followed by Jharsuguda, Sundargarh and Sambalpur in Odisha.
- **Sundargarh has the highest increasing trend of warm day (night) intensity ~ 0.065 days/year (~ 0.07 days/year)**

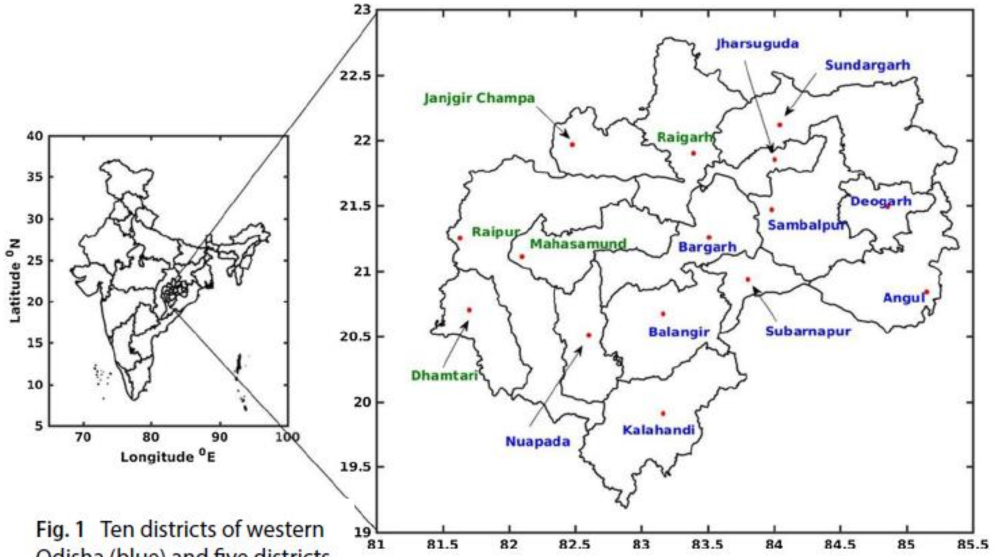


Fig. 1 Ten districts of western Odisha (blue) and five districts of eastern Chhattisgarh (green)

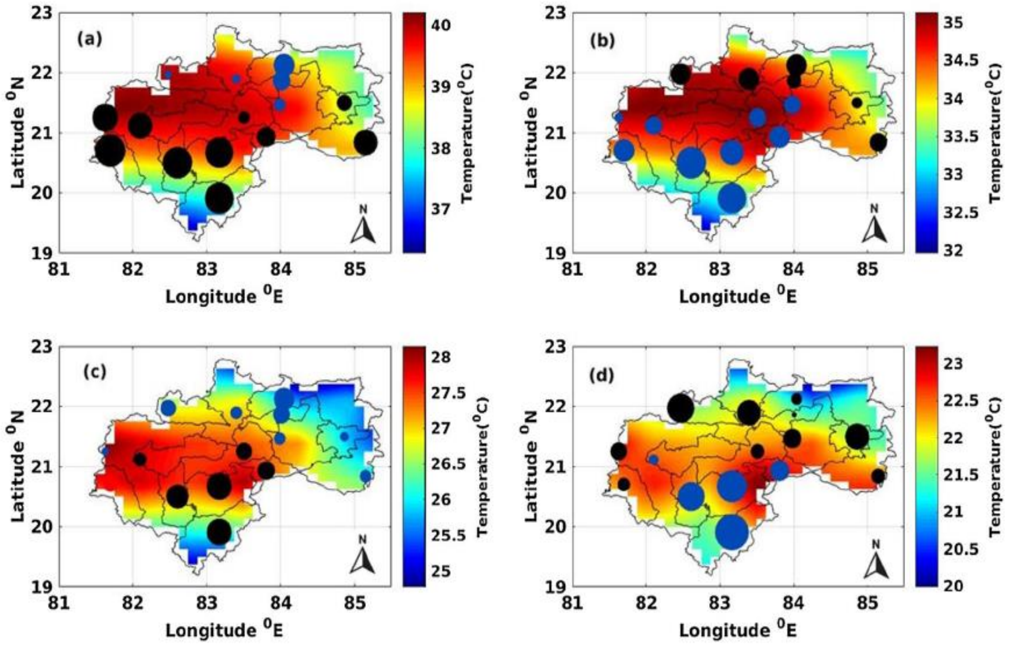


Fig. 7 Intensity trend variation positive (blue) and negative (black) of the **a** warm days, **b** cold days, **c** warm nights, **d** cold nights; the color shows the respective percentile temperature values. Size of the circle indicates the quantitative value of the trend

Impact of Atmospheric Moisture on Monsoon Depressions

Climate change may increase rainfall intensity in India: Report

Photo: Mint

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Ramifications of Atmospheric Humidity on Monsoon Depressions over the Indian Subcontinent

Received: 29 January 2018
Accepted: 22 June 2018
Published online: 02 July 2018

Himadri Baisya, Sandeep Pattnaik, Vivekananda Hazra, Anshul Sisodiya & Deepika Rai

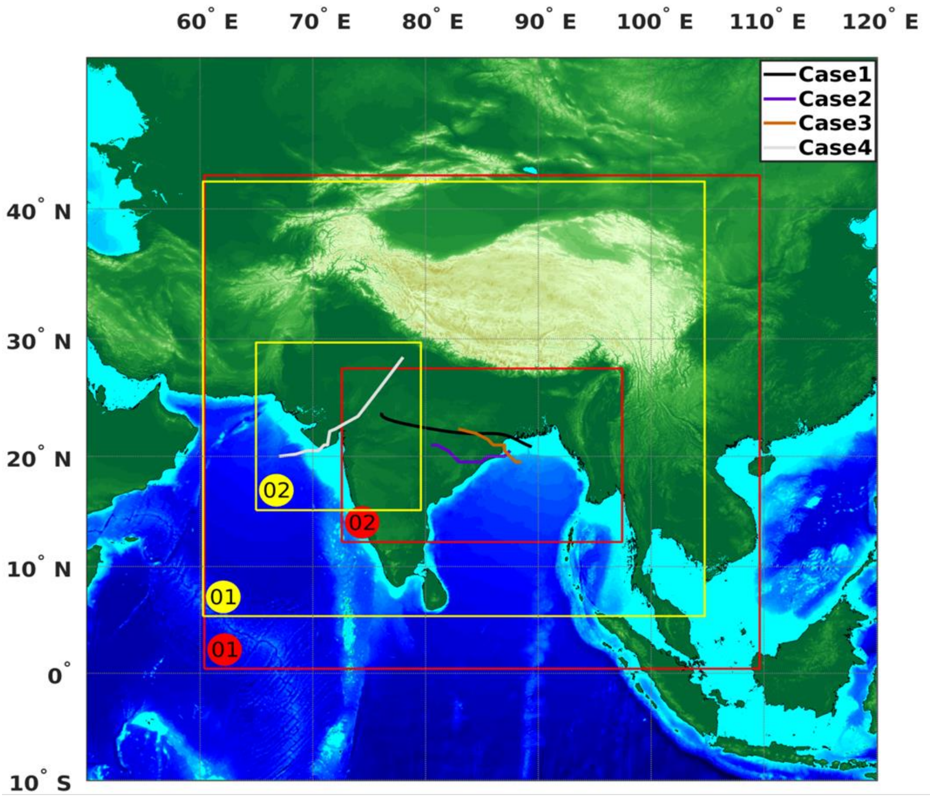
In this study, a comprehensive investigation is carried out to examine the sensitivity of tropospheric relative humidity (RH) on monsoon depressions (MDs) under a changing climate regime through surrogate climate change approach over the Indian region. Composite analysis of four MDs show a persistent warming (RH2+) and cooling (RH2−) throughout the troposphere in the sensitivity experiments. In-depth analysis of a MD over the Arabian Sea (AS) exhibits sustained warming for RH2+, which is accredited to 2.6% increase in stratiform clouds accounting for 13% increment in heating, whereas 5% increment in convective clouds hardly contribute to total heating. Frozen hydrometeors (graupel and snow) are speculated to be the major contributors to this heating. Stratiform clouds showed greater sensitivity to RH perturbations in the lower troposphere (1000–750 hPa), albeit very less sensitivity for convective clouds, both in the lower and mid-troposphere (700–500 hPa). Precipitation is enhanced in a moist situation (RH2+) owing to positive feedbacks induced by moisture influx and precipitation efficiency, while negative feedbacks suppressed precipitation in a dry troposphere (RH2−). In a nutshell, it is inferred that under moist (dry) situations, it is highly likely that intense (weak) MDs will occur in the near future over the Indian region.

In an ever-changing climate with a consistently increasing trend in the global mean temperature, it is apparent that the water holding capacity of the atmosphere will increase at a rate governed by the Clausius-Clapeyron (CC, ~7% $°C^{-1}$) relationship[1,2]. Global land and ocean temperatures in 2016 set a record by overshooting the 1981–2010 average by 0.45° and 0.56 °C respectively, and as a consequence specific humidity (SH) peaked, reaching a record high well above the long-term average[3]. Further, RH is projected to remain nearly constant with an increase in SH. The differential heating of land and ocean has been attributed for a small decrease in the near-surface RH over most land areas with exceptions over parts of Africa and the Indian subcontinent[4]. Dai[5] documented similar trends from *in situ* observations (1975–2005) with exceptions over the central and eastern United States, India, and western China with RH increase ranging from 0.5–2% $decade^{-1}$. It is inferred that this change is a result of increased RH coupled with moderate warming and enhanced low-level clouds during the analysis period.

The earth's radiation budget is significantly affected by the presence of water vapor, owing to the absorption of radiation that contributes to changes in the water vapor feedback[6–8]. A 10% increase in RH in the upper troposphere led to ~1.4 Wm^{-2} of radiative forcings[9]. It is found that, if RH distribution is specified instead of absolute humidity, water vapor feedback to climate sensitivity doubled and the atmosphere took twice the time to reach radiative convective equilibrium[10]. Further, studies demonstrated that in Deep Convective Systems (DCS), the convective cores bear the heavy precipitation with widespread rain in the stratiform region; the non-precipitating anvil canopy is dominant in the atmospheric radiation budget due to their sheer spatial coverage[11]. DCS that last more than 6 hours have 50% more mid-tropospheric RH compared to short-lived systems, whereas, a dry mid-tropospheric profile can lead to suppressed deep convection in favor of a shallow convective regime[12,13]. It was also found that an improved RH at the initial time in the model can bring better skills of MDs rainfall predictability (up to day 2) over the Indian region[14].

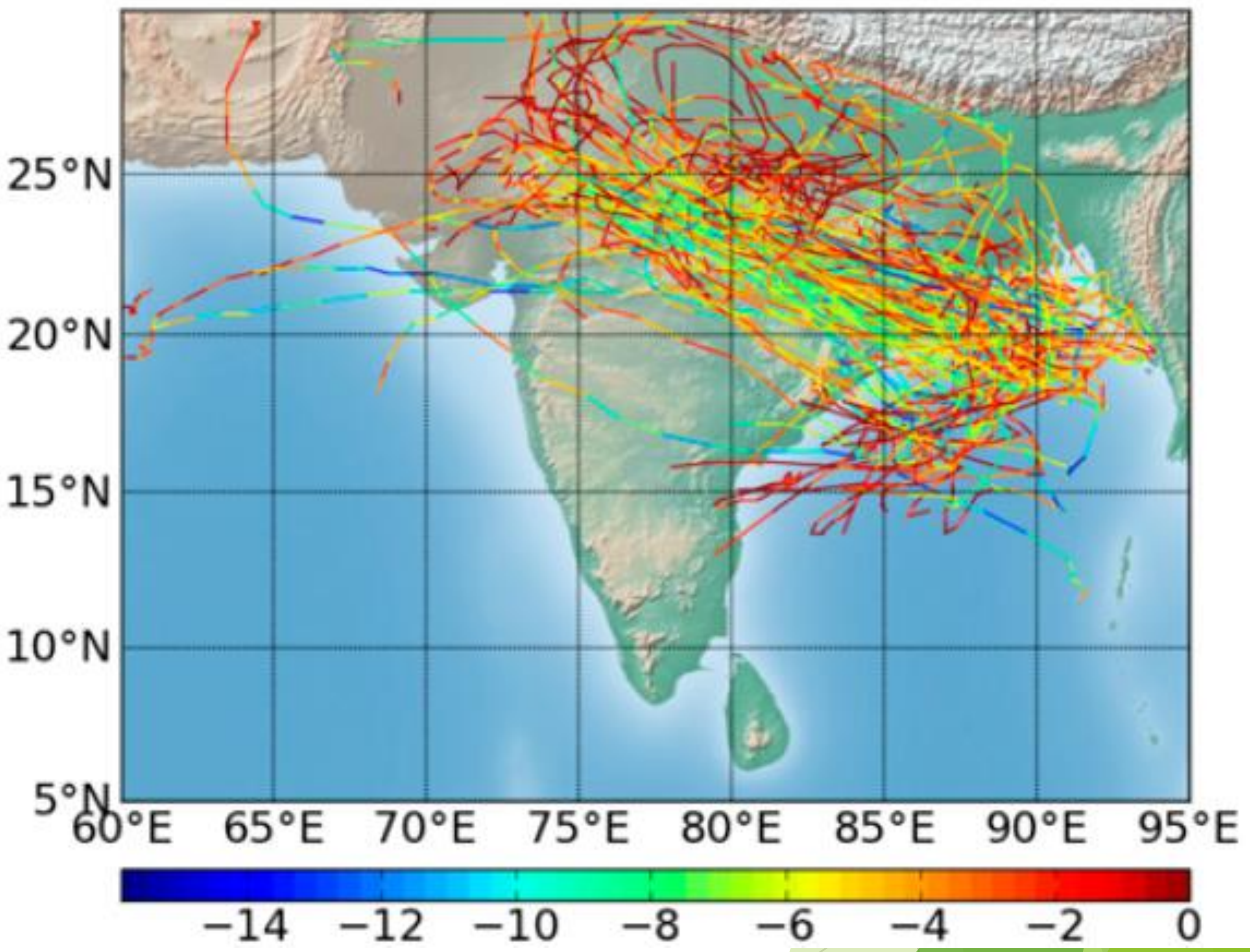
Over the Indian subcontinent, the summer monsoon accounts for ~80% of annual precipitation which is crucial for an agrarian society like India[15]. On an average, out of ~14 low-pressure systems that develop during the monsoon season, about 50% develop into depressions[16]. Some concerns have been cited in recent literature regarding a decreasing trend in the number of monsoon depressions due to a decline in the mid-tropospheric RH and moisture flux convergence, weakening the low-level jet[17–20]. Recent studies have also cautioned the use

School of Earth, Ocean, and Climate Sciences, Indian Institute of Technology Bhubaneswar, Odisha, India. Correspondence and requests for materials should be addressed to S.P. (email: spt@iitbbs.ac.in)



Monsoon Low Pressure Systems

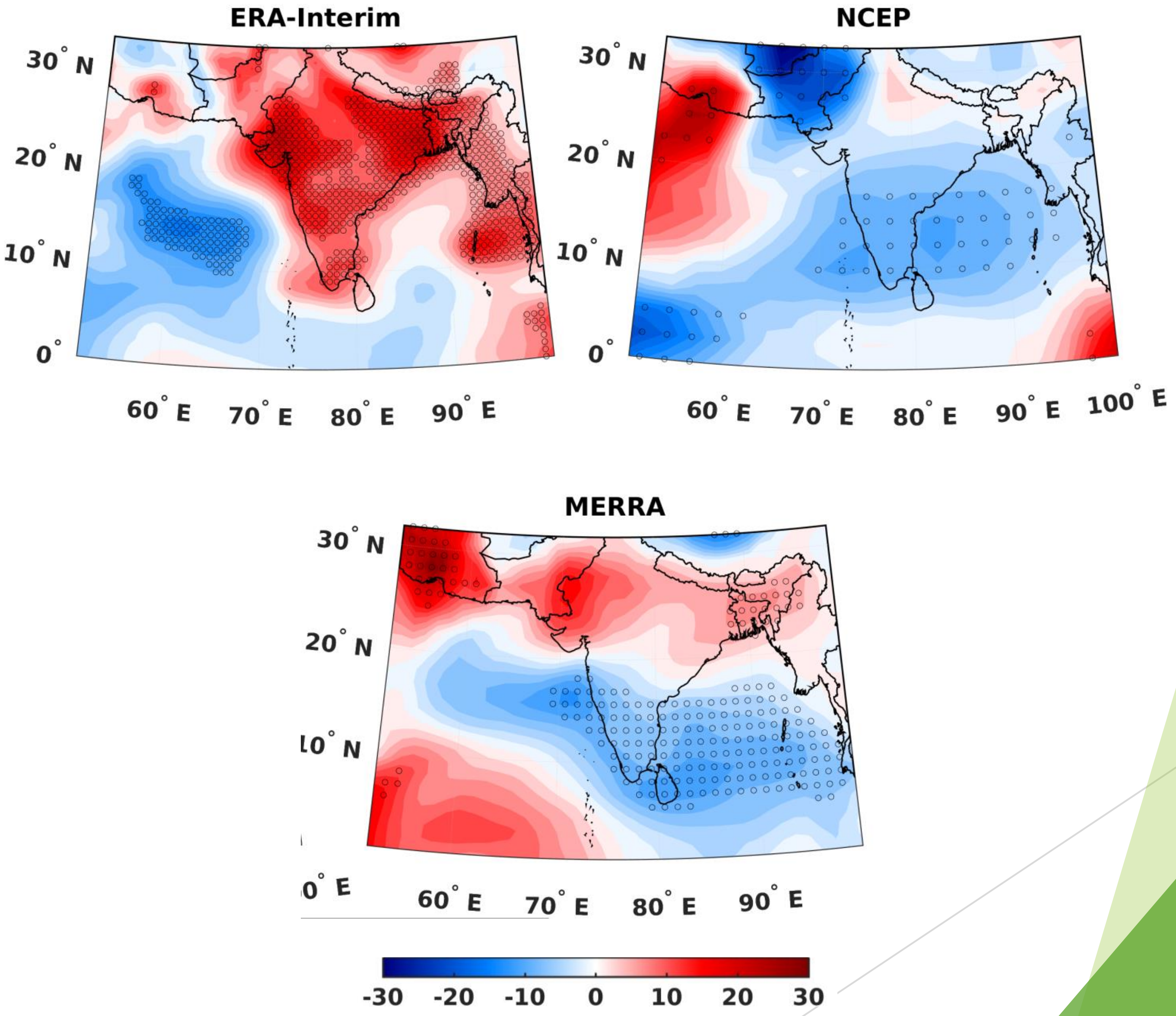
Depressions, Deep Depressions



Tracks of low pressure systems formed during the JJAS monsoon season. (Hunt 2016)

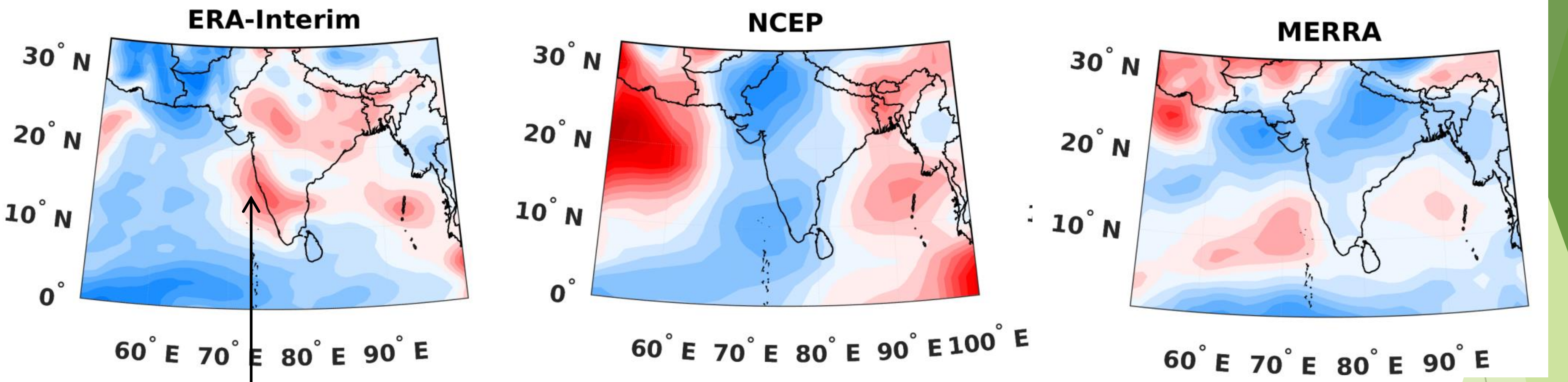
Long Term Trend in RH (1979-2017)

- Overall increase in RH is seen in ERA-I and is statistically significant at 95% confidence level.
- NCEP showing a decreasing trend over the Indian subcontinent.
- MERRA is showing an increasing trend over the Gangetic plain, but statistically insignificant.

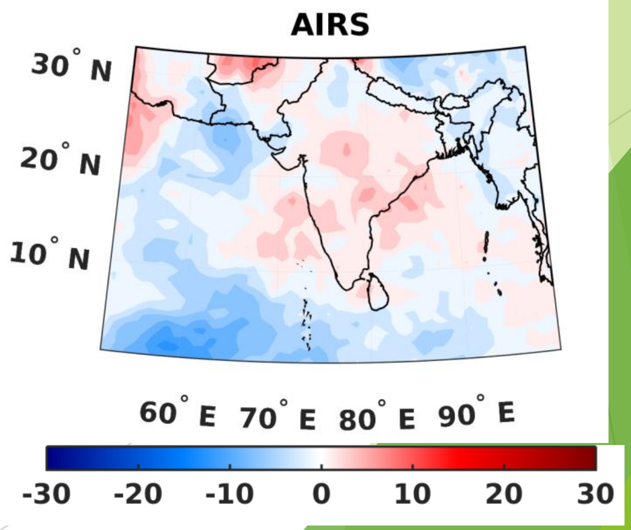


Change in RH (%) JJAS

Change in mid-tropospheric RH (700-500 hPa) from 2003-2017

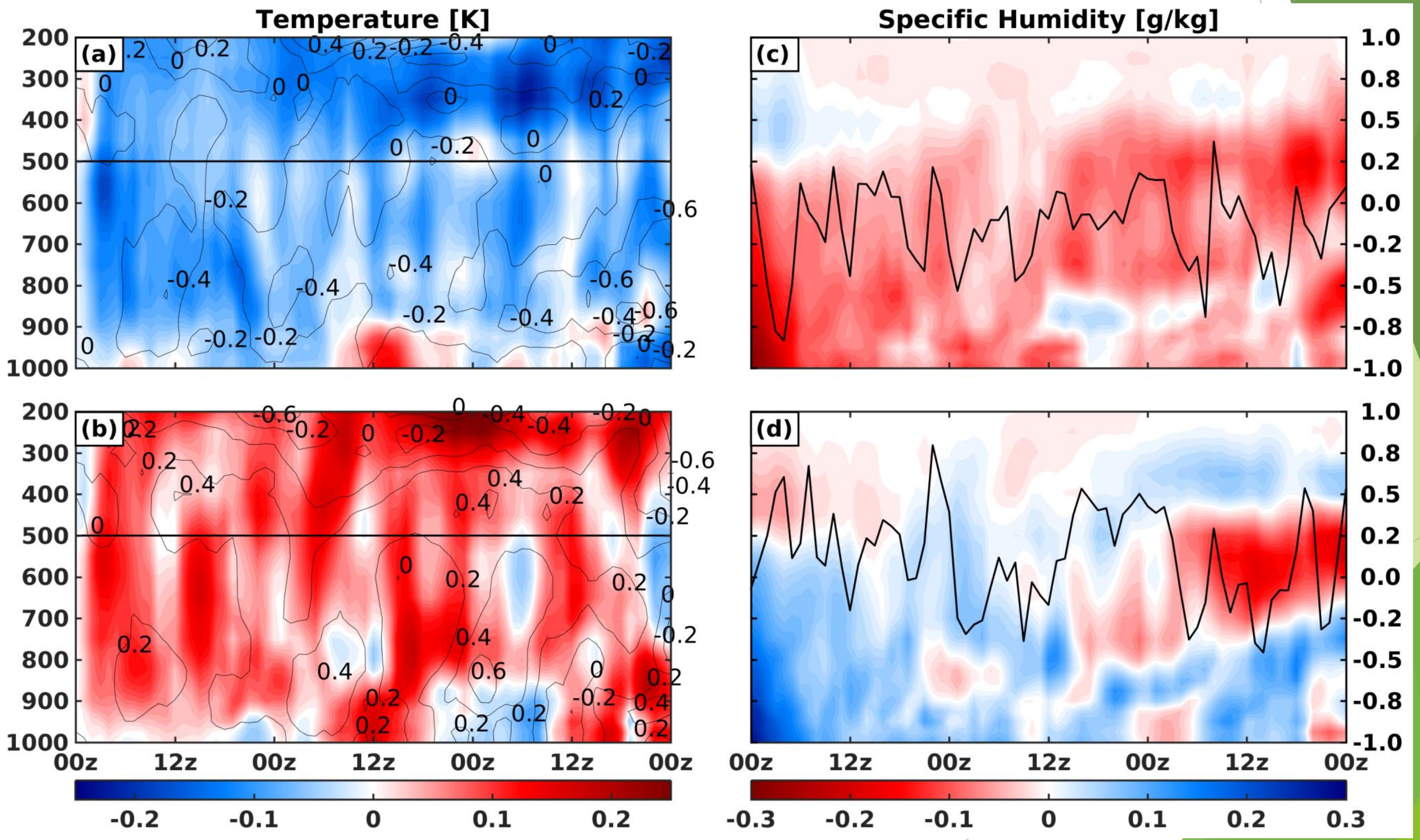


Only ERA-I is showing skill amongst the datasets



Modern-Era Retrospective analysis for Research and Applications (MERRA), NASA/European Reanalysis (ERA), National Centre for Environmental Prediction, NOAA, Atmospheric Infrared Sounder (AIRS),NASA

Temperature and Humidity



Cloud Sensitivity

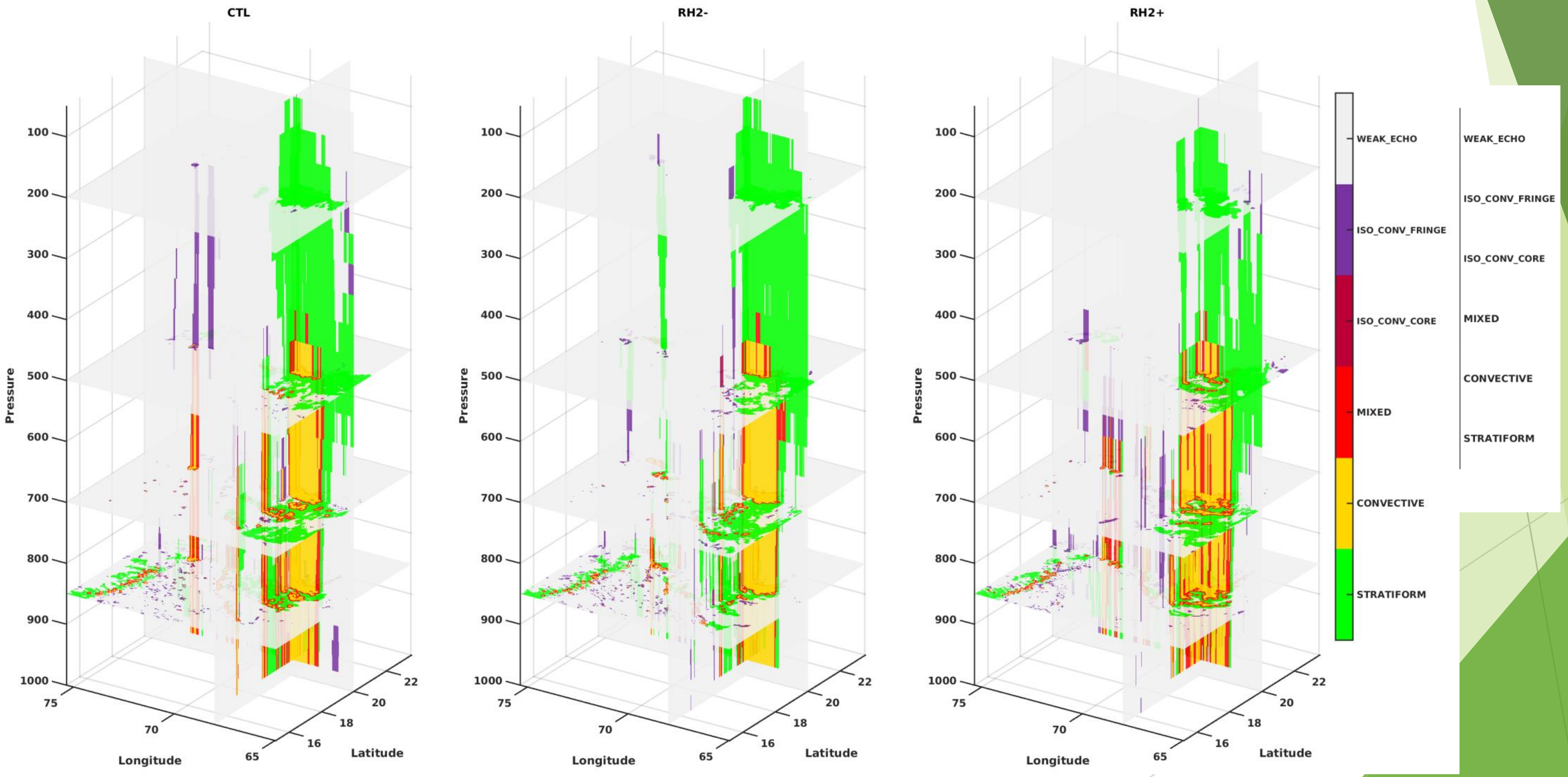
Level wise correlations are computed between cloud coverage and VEF to ascertain which part of the troposphere responds the most to RH perturbations for a domain bounded by 66˚E–77˚E longitude and 18˚N–27˚N latitude.

RH2-				
	Lower (1000 - 750 hPa)		Mid (700 - 500 hPa)	
	Stratiform	Convective	Stratiform	Convective
Correlation	0.62	0.71	0.32	0.69
RH2+				
Correlation	0.80	0.74	0.25	0.67

- **Lower tropospheric RH perturbations show higher sensitivity towards stratiform clouds.**
- **Convective clouds are not much affected both in the lower, as well as in the mid-troposphere.**

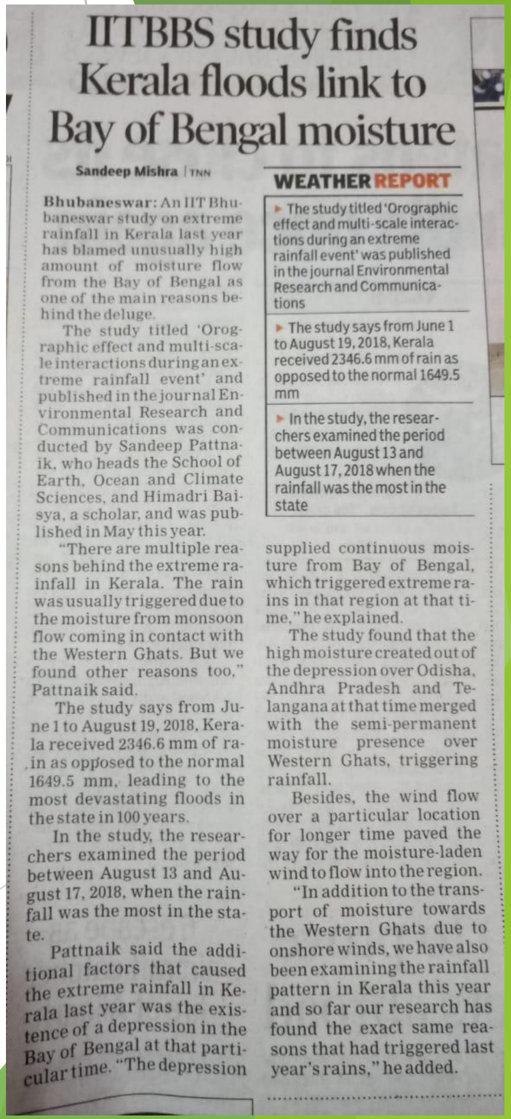
Rain Type Algorithm

Cloud categories shown for a time instant.



Extreme Rainfall

Multiscale interactions (Land Surface, Orography, Moisture incursions) (Kerala 2018, 2019,2021)



IITBBS study finds Kerala floods link to Bay of Bengal moisture

Sandeep Mishra | TNN

Bhubaneswar: An IIT Bhubaneswar study on extreme rainfall in Kerala last year has blamed unusually high amount of moisture flow from the Bay of Bengal as one of the main reasons behind the deluge.

The study titled 'Orographic effect and multi-scale interactions during an extreme rainfall event' and published in the journal Environmental Research and Communications was conducted by Sandeep Pattnaik, who heads the School of Earth, Ocean and Climate Sciences, and Himadri Baisya, a scholar, and was published in May this year.

"There are multiple reasons behind the extreme rainfall in Kerala. The rain was usually triggered due to the moisture from monsoon flow coming in contact with the Western Ghats. But we found other reasons too," Pattnaik said.

The study says from June 1 to August 19, 2018, Kerala received 2346.6 mm of rain as opposed to the normal 1649.5 mm, leading to the most devastating floods in the state in 100 years.

In the study, the researchers examined the period between August 13 and August 17, 2018, when the rainfall was the most in the state.

Pattnaik said the additional factors that caused the extreme rainfall in Kerala last year was the existence of a depression in the Bay of Bengal at that particular time. "The depression supplied continuous moisture from Bay of Bengal, which triggered extreme rains in that region at that time," he explained.

The study found that the high moisture created out of the depression over Odisha, Andhra Pradesh and Telangana at that time merged with the semi-permanent moisture presence over Western Ghats, triggering rainfall.

Besides, the wind flow over a particular location for longer time paved the way for the moisture-laden wind to flow into the region.

"In addition to the transport of moisture towards the Western Ghats due to onshore winds, we have also been examining the rainfall pattern in Kerala this year and so far our research has found the exact same reasons that had triggered last year's rains," he added.

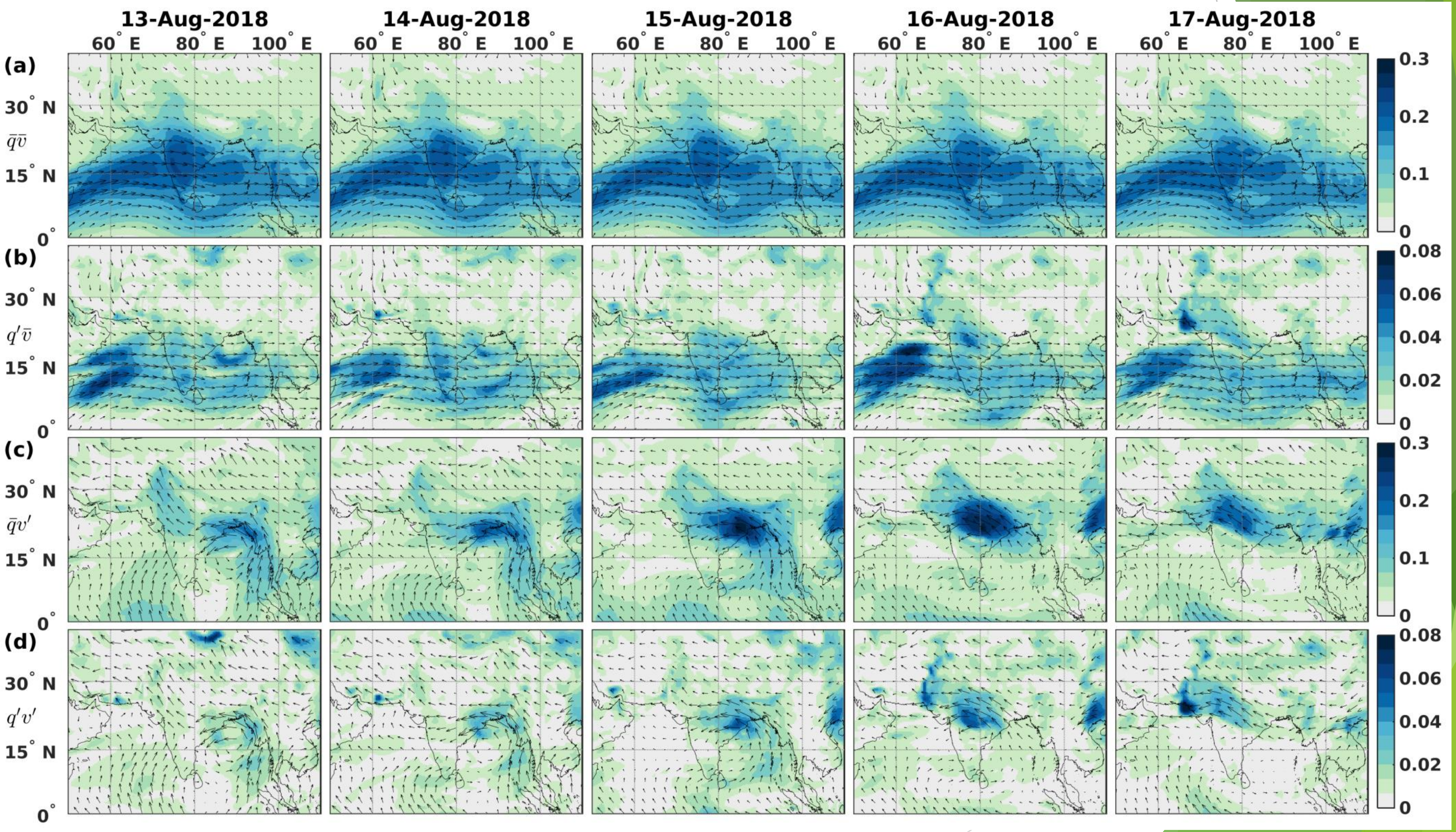
WEATHER REPORT

- The study titled 'Orographic effect and multi-scale interactions during an extreme rainfall event' was published in the journal Environmental Research and Communications
- The study says from June 1 to August 19, 2018, Kerala received 2346.6 mm of rain as opposed to the normal 1649.5 mm
- In the study, the researchers examined the period between August 13 and August 17, 2018 when the rainfall was the most in the state

WMO also underlined the extreme weather events experienced all over the world in 2018, including the severe flooding in Kerala in August 2018, which led to economic losses estimated at $4.3 billion. Over 480 deaths.

Rainfall in Kerala in August was 96% above the long-term average. Weekly totals for the 9-15 and 16-22 August periods were 258% and 218% above average, respectively.

Moisture Transport



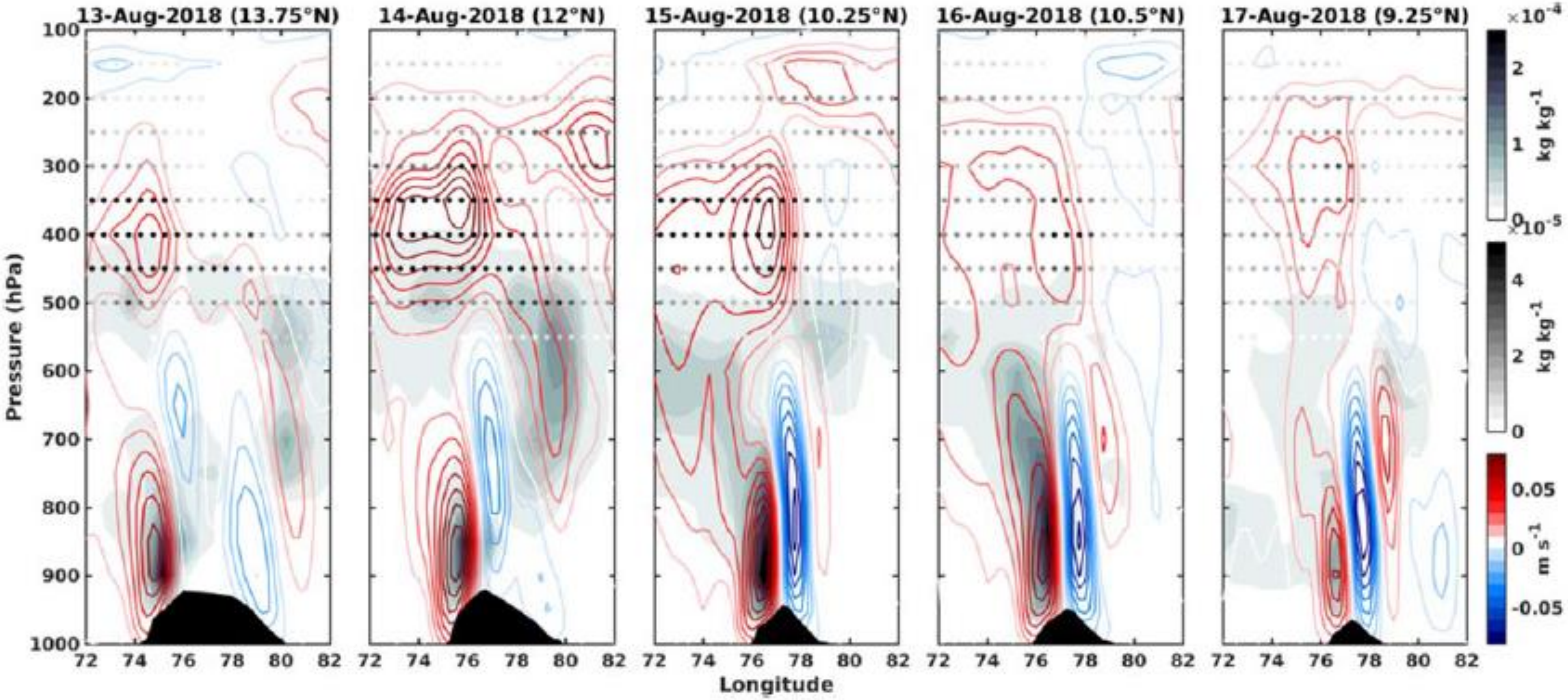
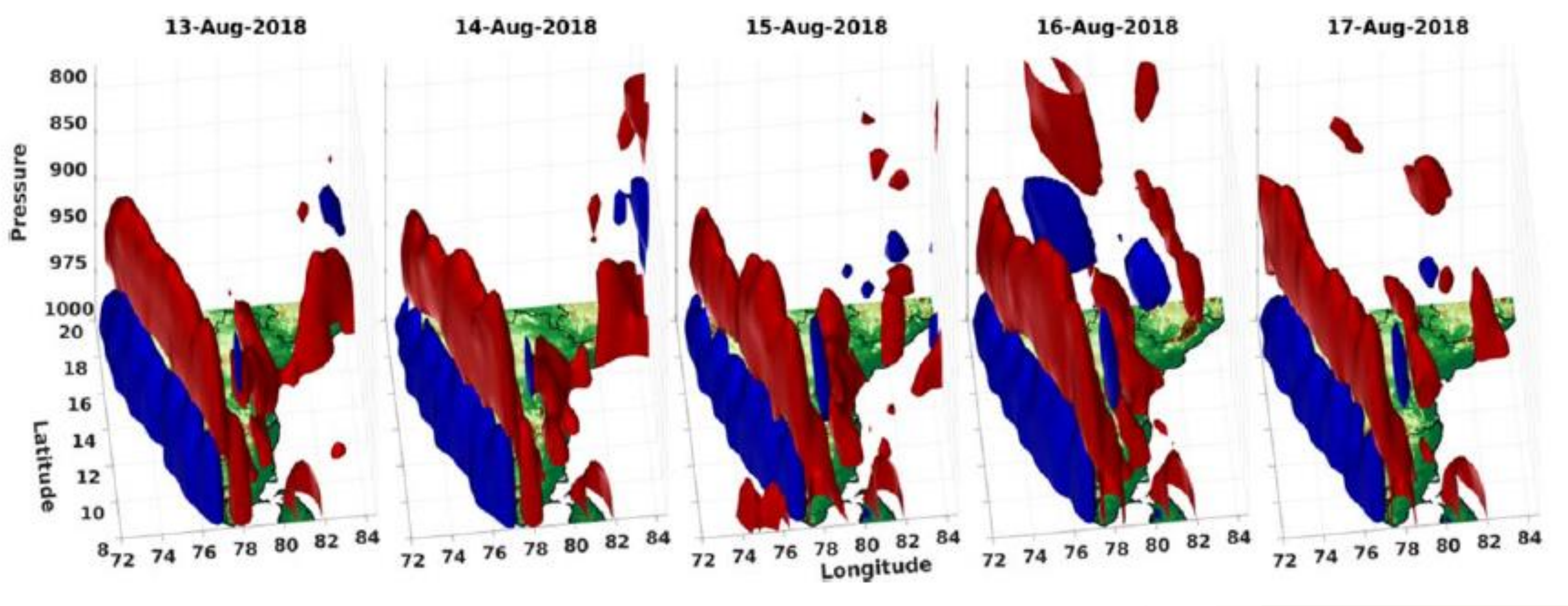


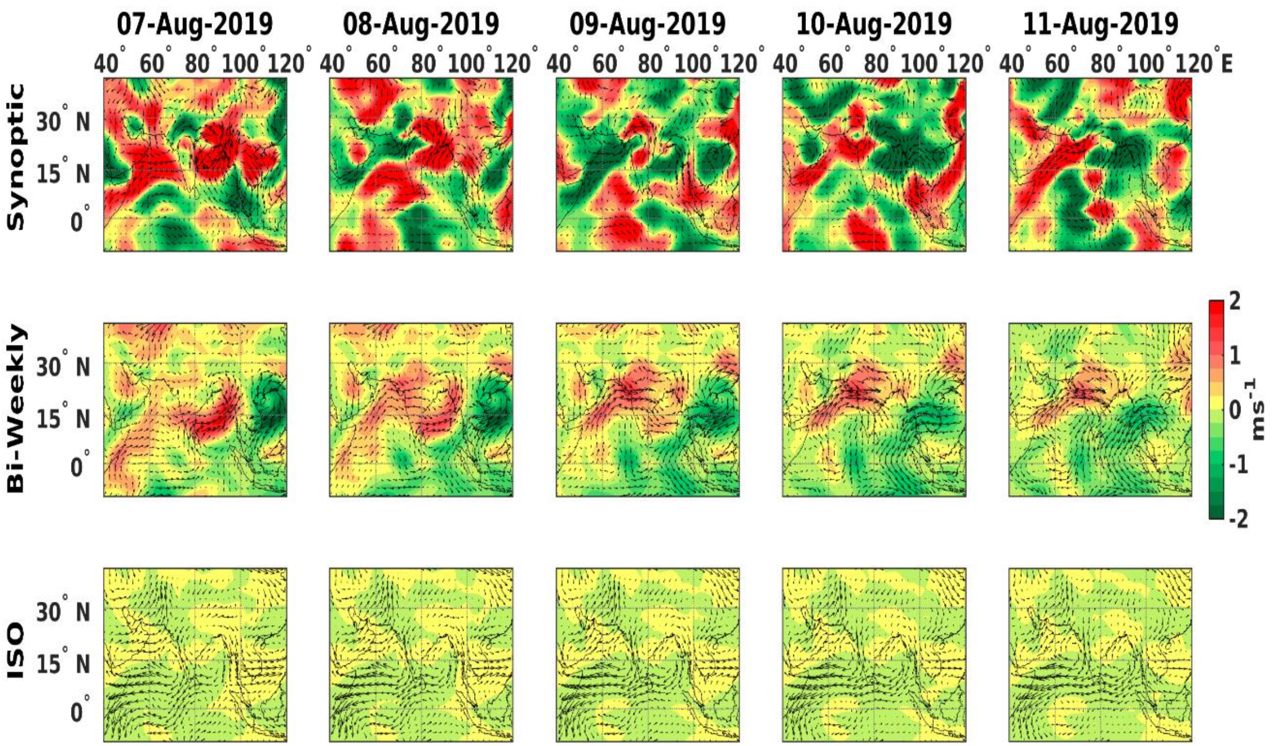
Figure 2. Daily averaged cloud liquid water (shaded, top colorbar) and cloud ice water (dotted, middle colorbar) overlaid with vertical velocity (contours, bottom colorbar). The cross sectional orography is shaded black starting from 1000 hPa. Units in Kg Kg^{-1} for cloud parameters and in m s^{-1} for vertical velocity.

Moisture Flux Convergence Towers

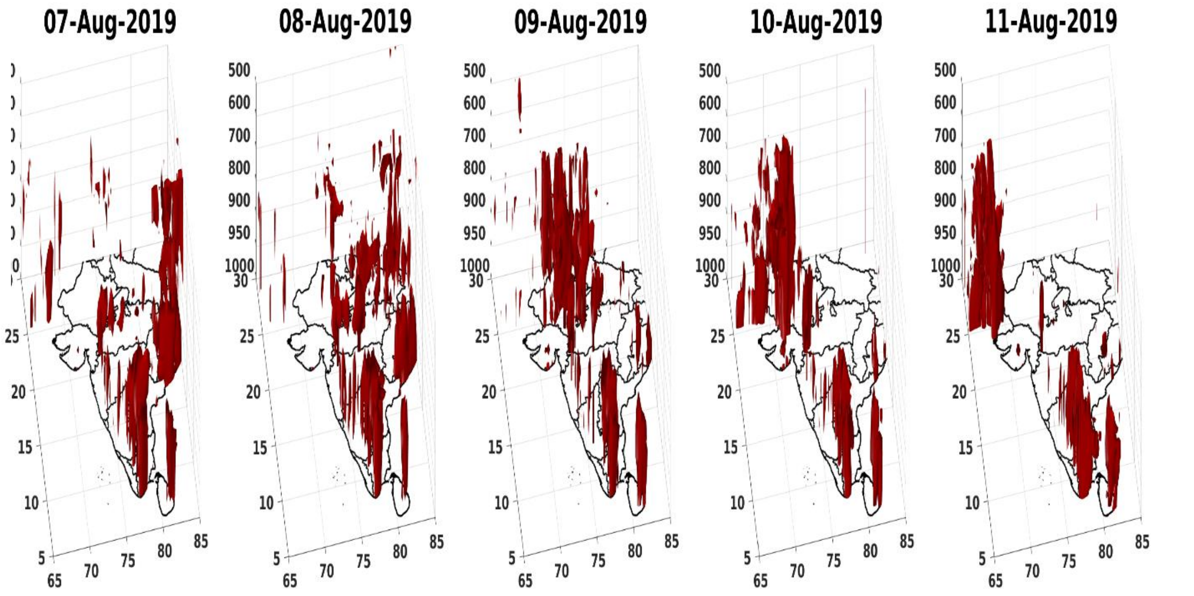


Isosurfaces of MFC shown for values 2.5×10^{-5} (red) and -5×10^{-5} (blue).

2019 Kerala Rainfall Event

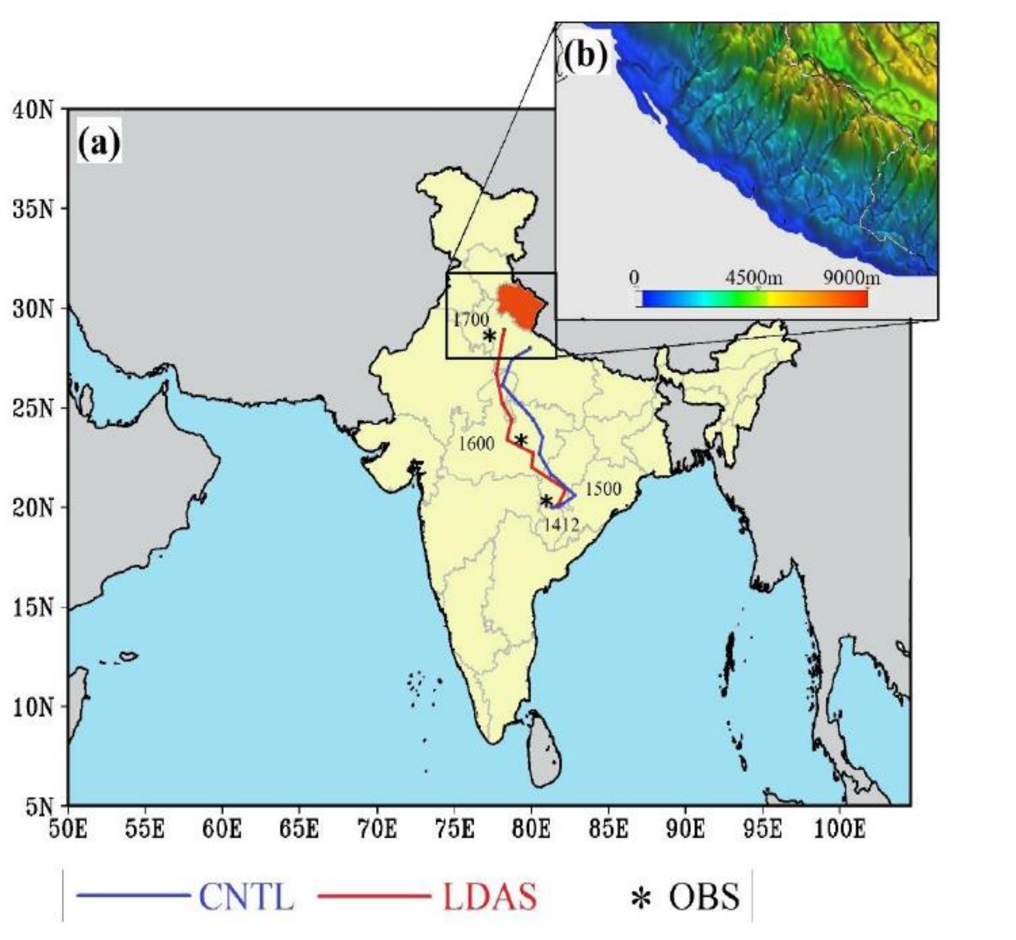


Influence of BoB MDs

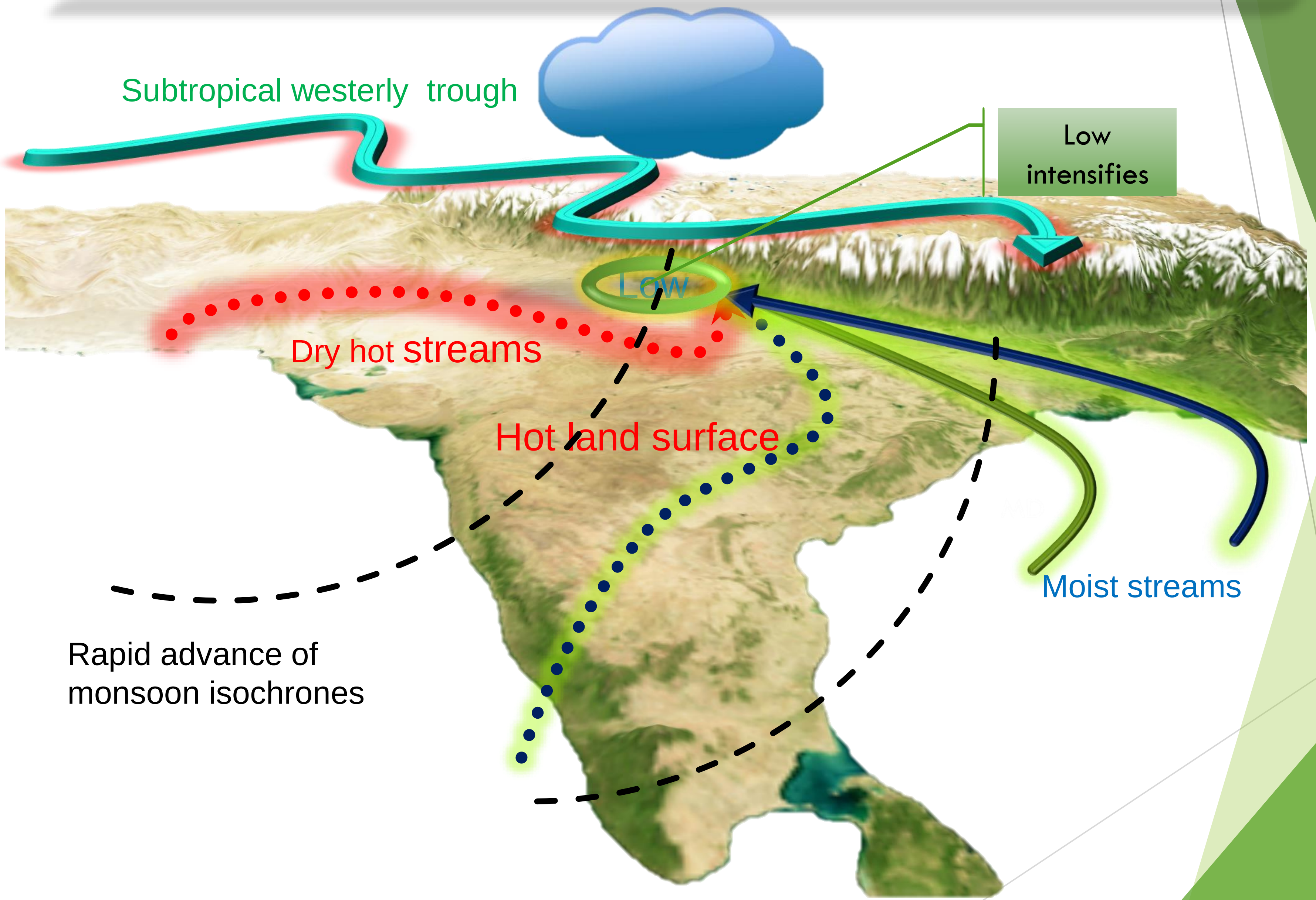


Synoptic: 3–7 days
Bi – Weekly: 10–20 days
ISO: 30–60 days

Role of land state in a high resolution mesoscale model for simulating the Uttarakhand heavy rainfall event over India



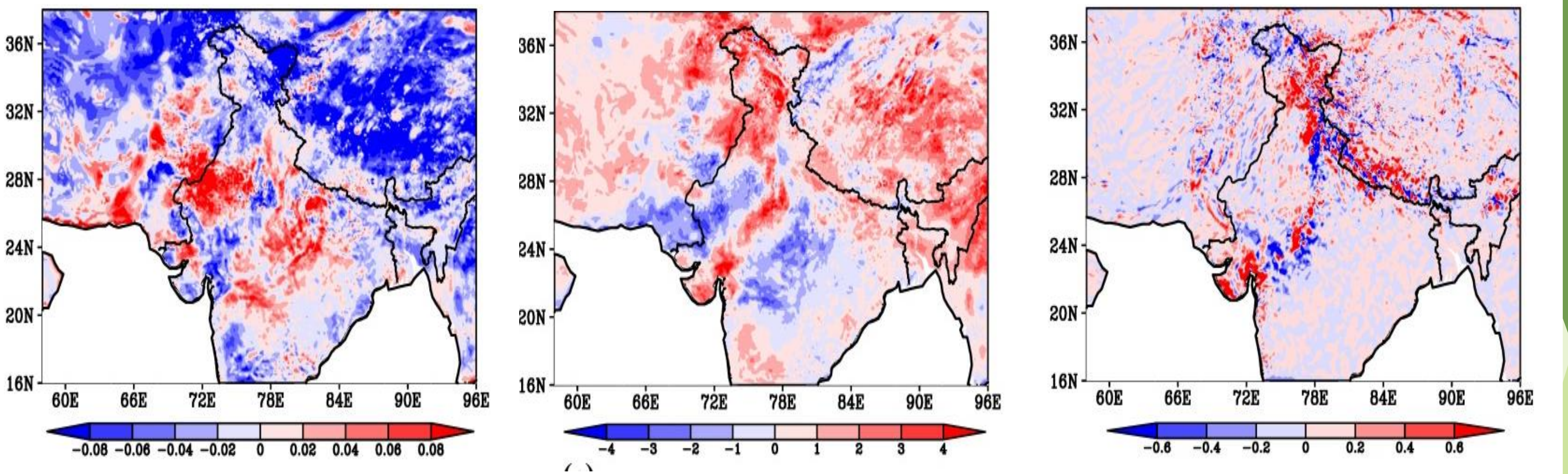
Synoptic features of Uttaknhand heavy rainfall event



IMD, 2013

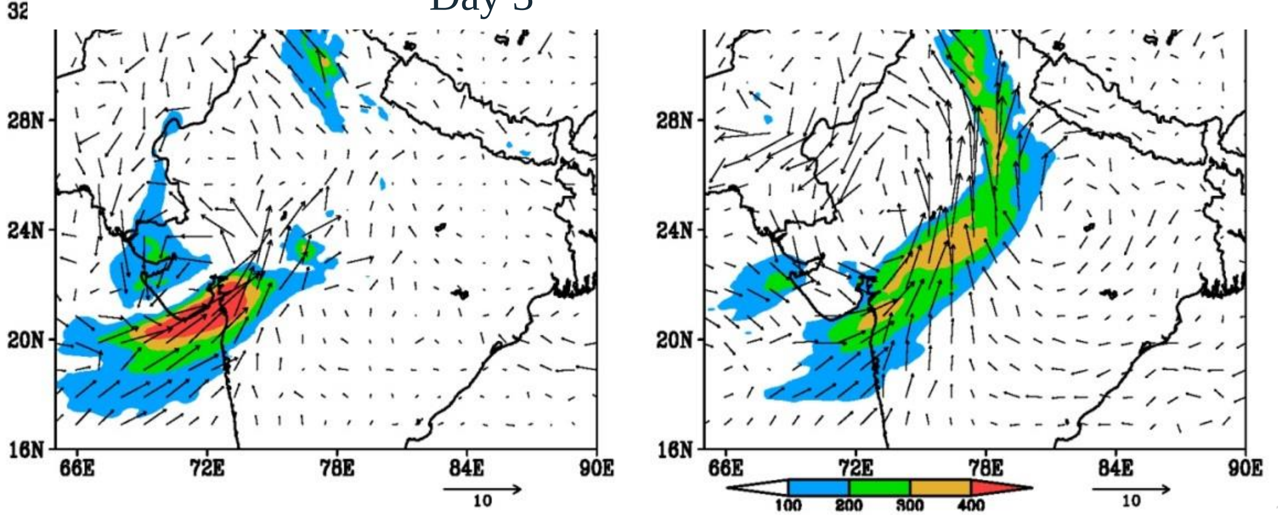
Difference between LDAS and CNTL (LDAS-CNTL)

Soil moisture | Soil temperature | Vertical velocity



Day 2

Day 3

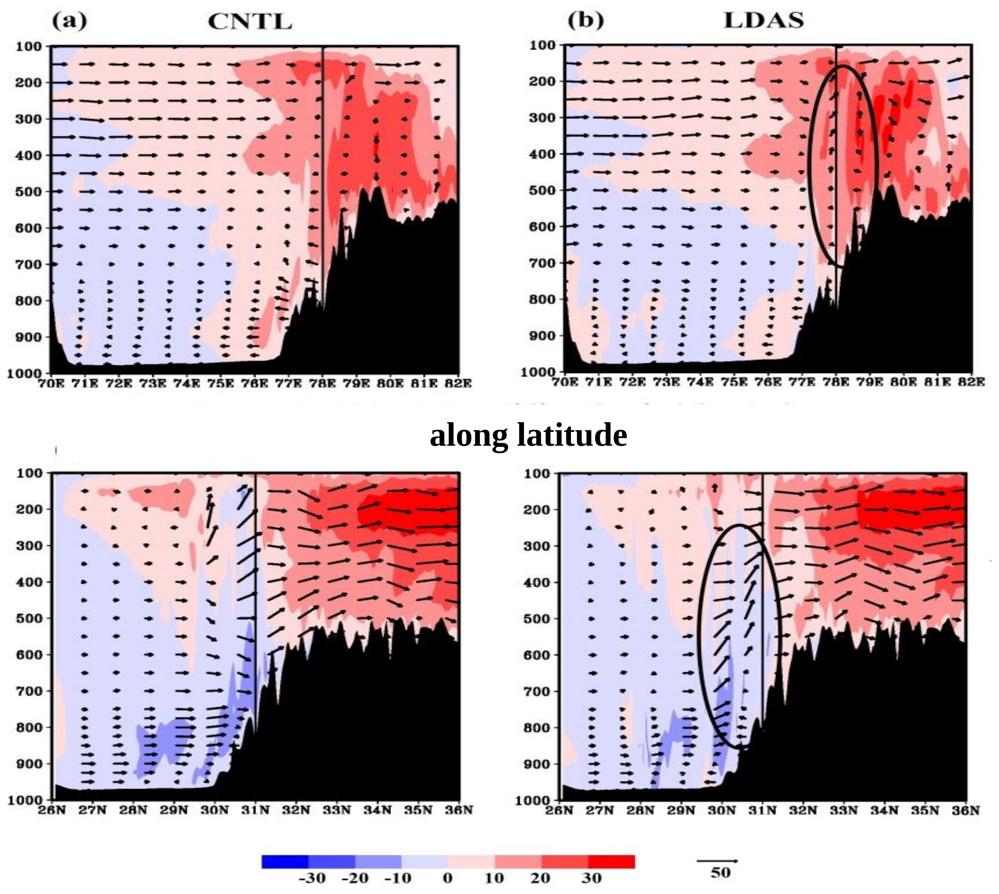


(Guillod et al. 2015) suggests that the contrast in soil conditions, especially SM will induce local circulations and can generate vertical motions along the regions of strong discontinuity in SM

vertically integrated moisture transport (kg $m^{-1}s^{-1}$; shaded)
850 hPa wind vector

Meridional wind (shaded) and zonal wind (vector)

along longitude



- Vertical black line: center of heavy rainfall region
- Thick black elliptic : region of high orographic vertical upliftment
- Vertical velocity is magnified to an order of 10

✓ Complex Interactions

Monsoon

Moisture

Mountain

Role of Sea Surface Temperature

Sensitivity of tropical cyclone characteristics to the radial distribution of sea surface temperature

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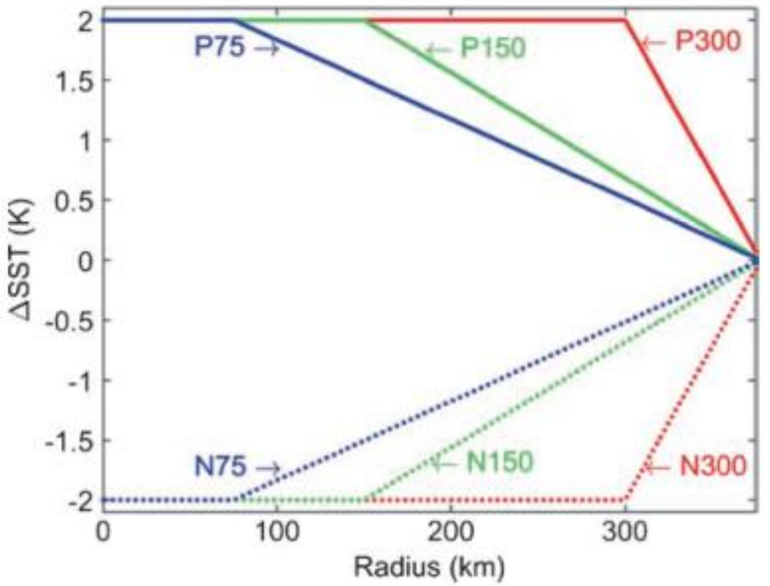
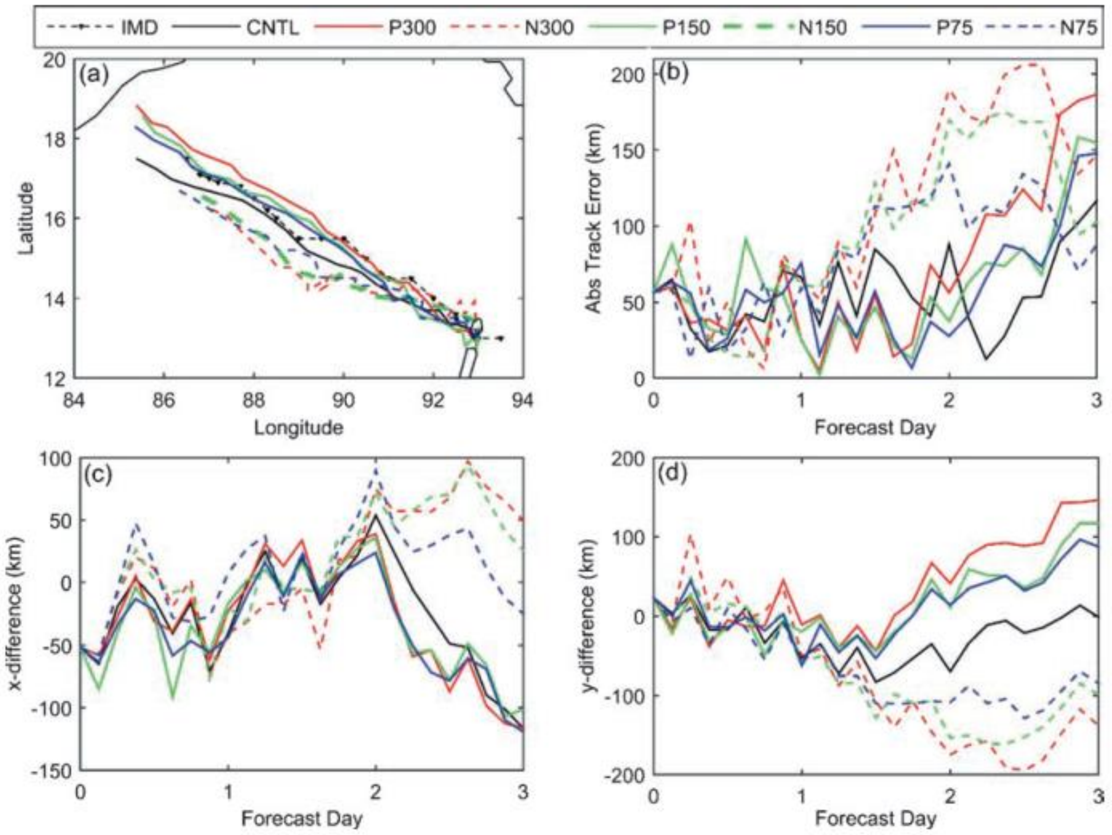
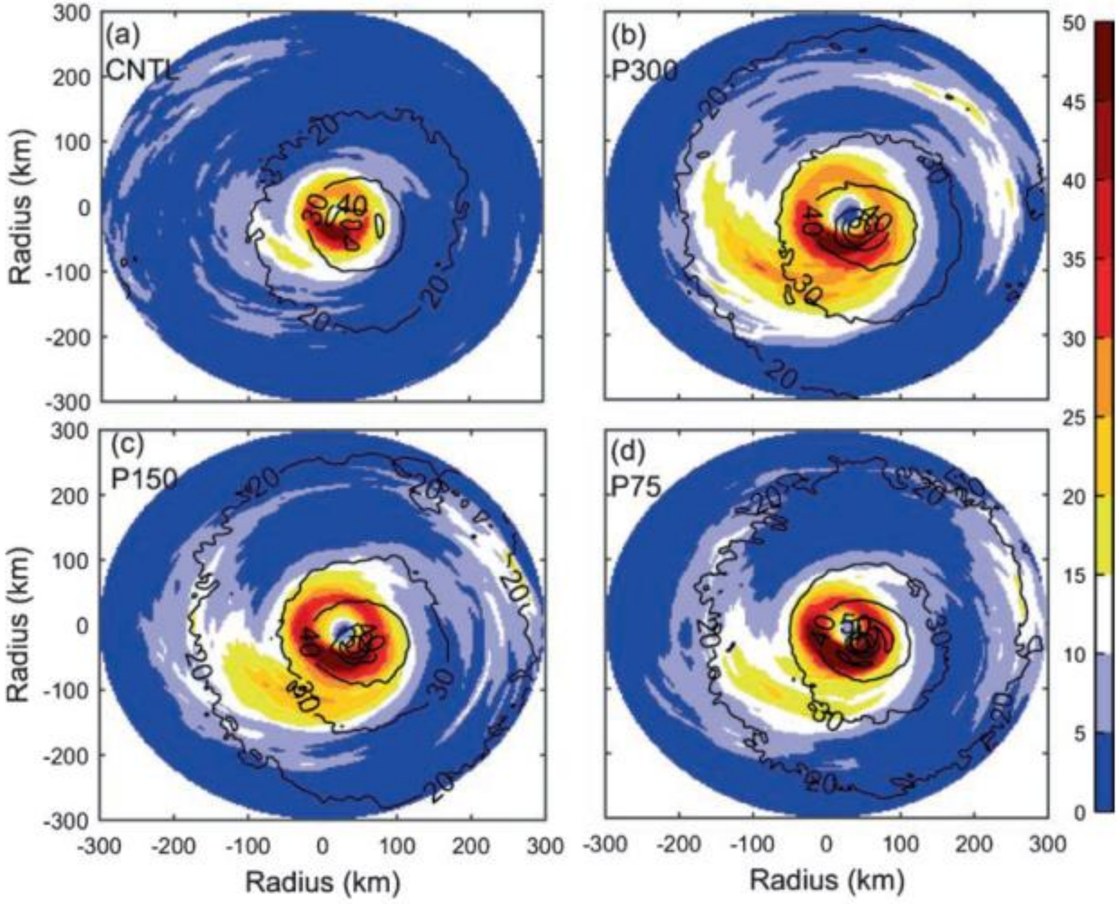


Figure 2. Distribution of SST anomaly for sensitivity experiments P300 (red, solid line), P150 (green, solid line), P75 (blue, solid line), N300 (red, dashed line), N150 (green, dashed line), and N75 (blue, dashed line). Radius represents the distance from the cyclone centre.

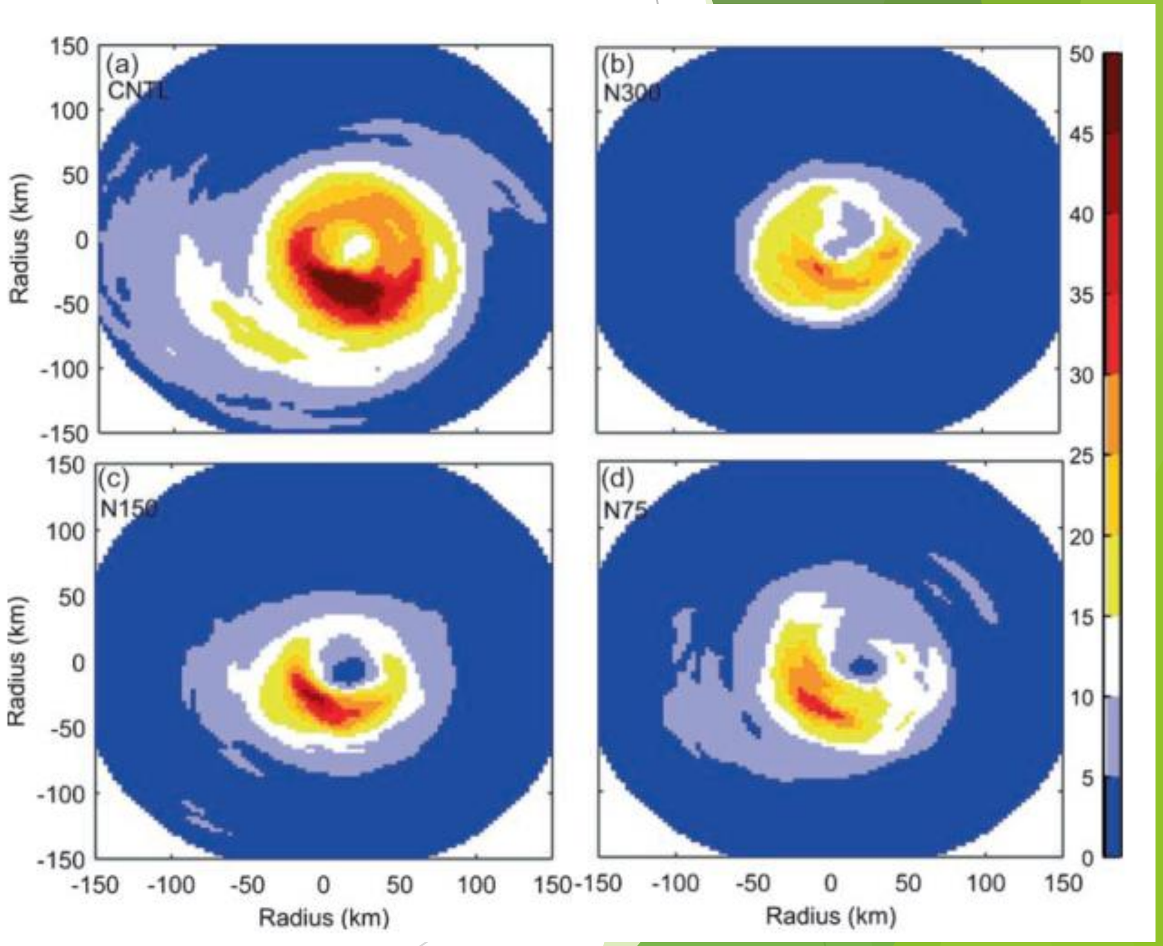


Rain Rate

SST+

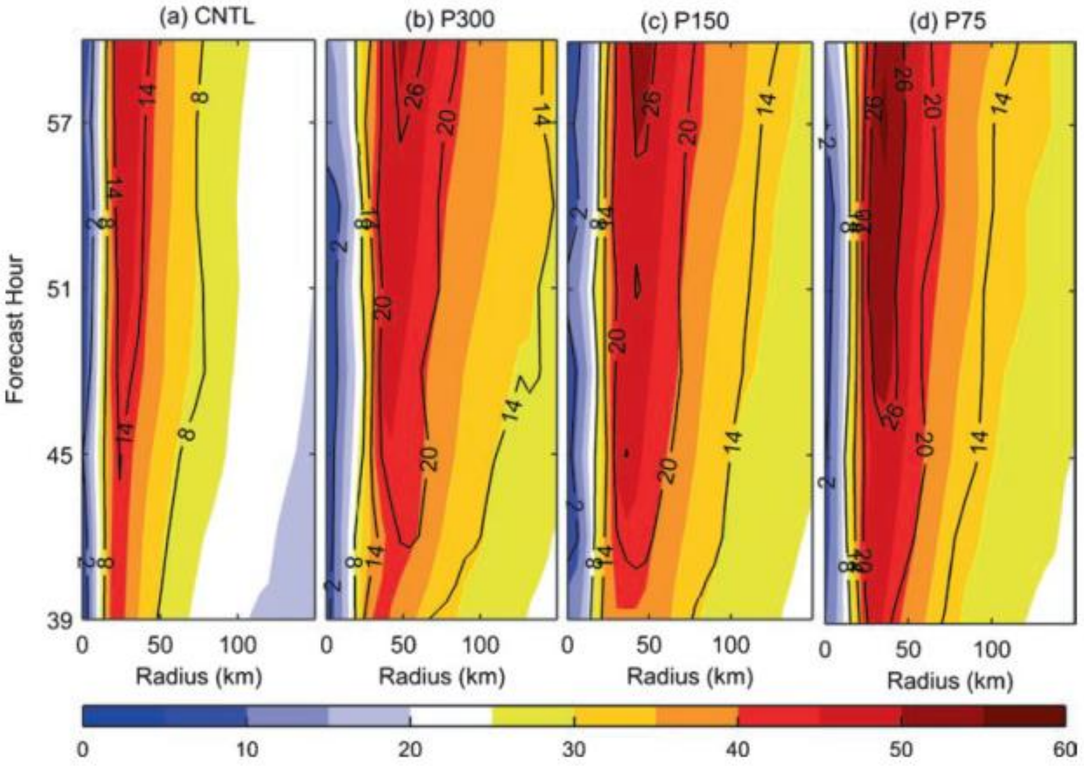


SST−

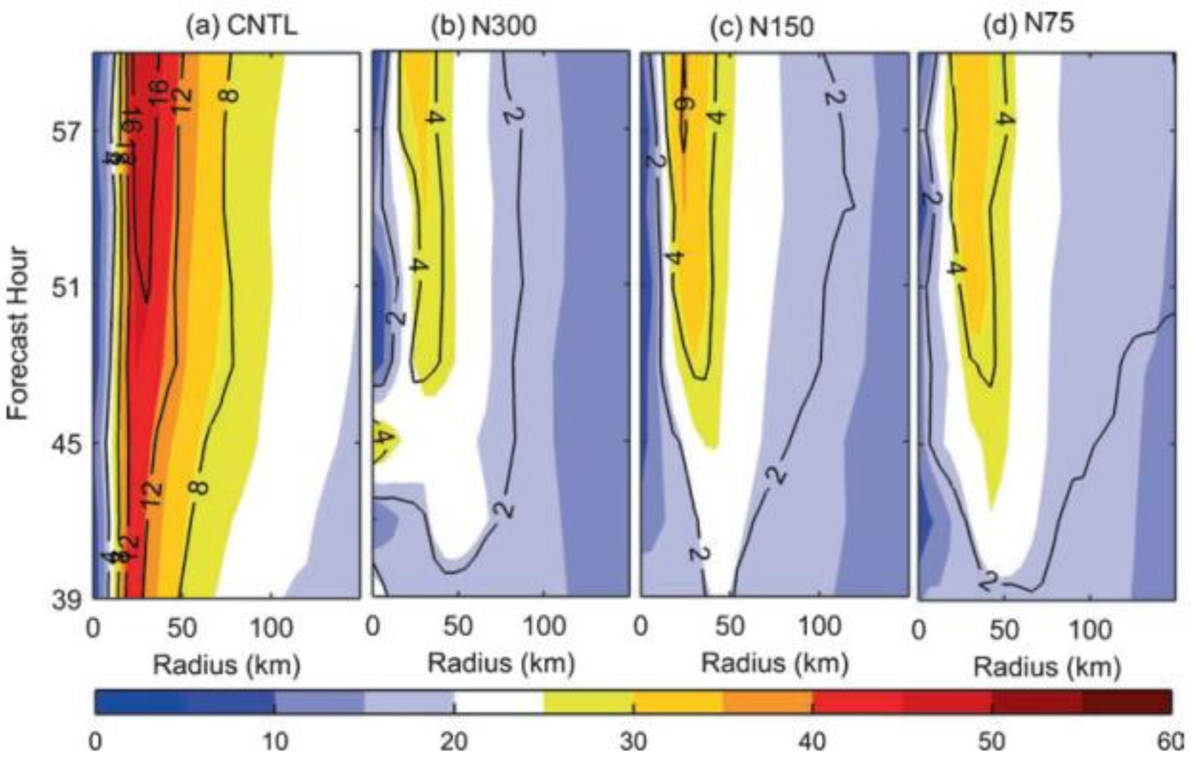


Wind Speed (m/s)

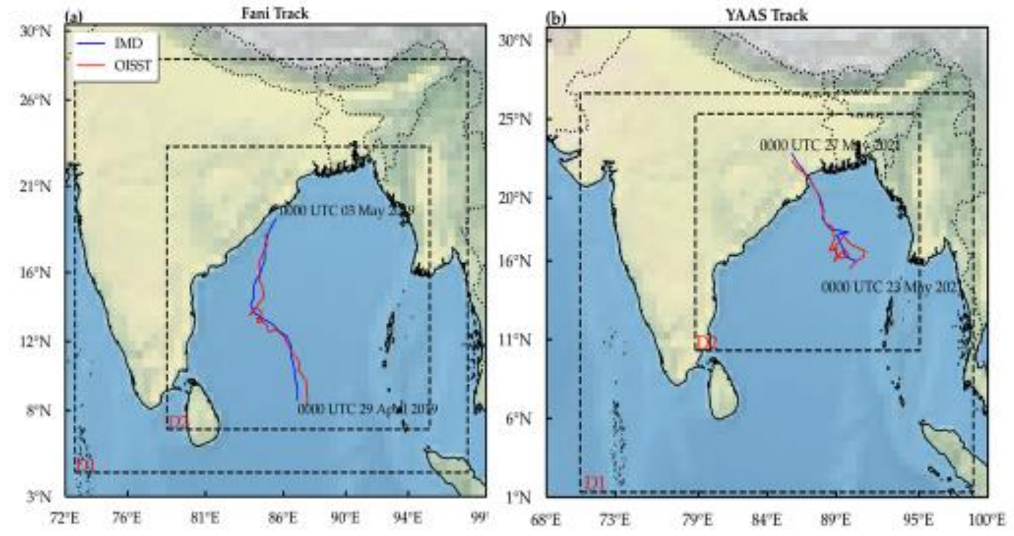
SST+

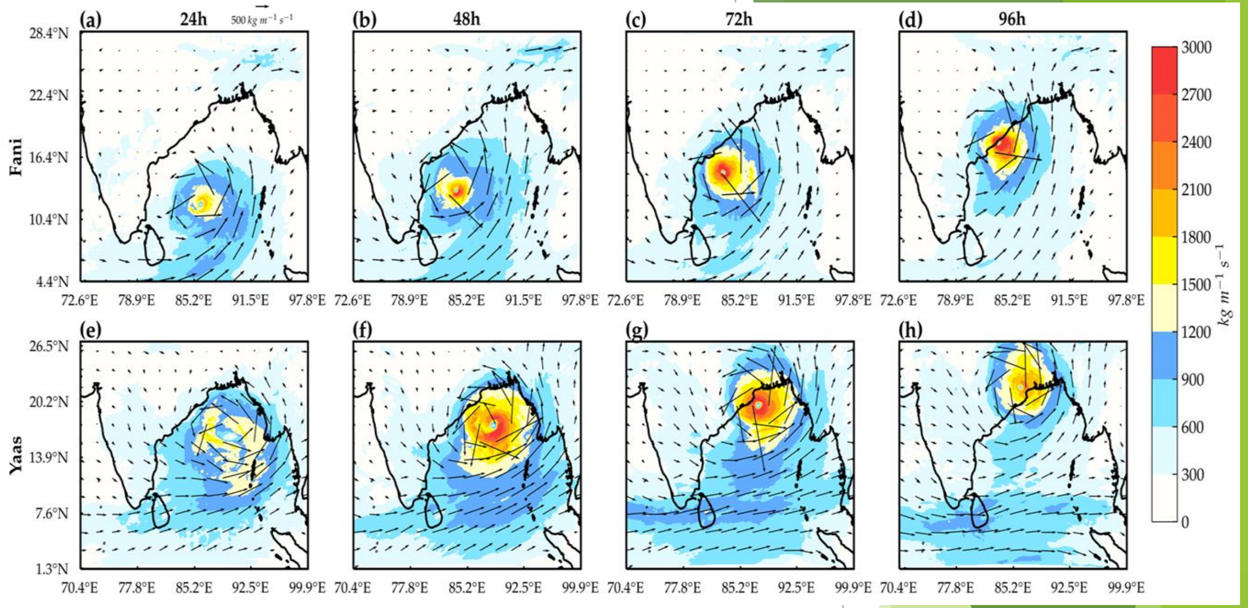


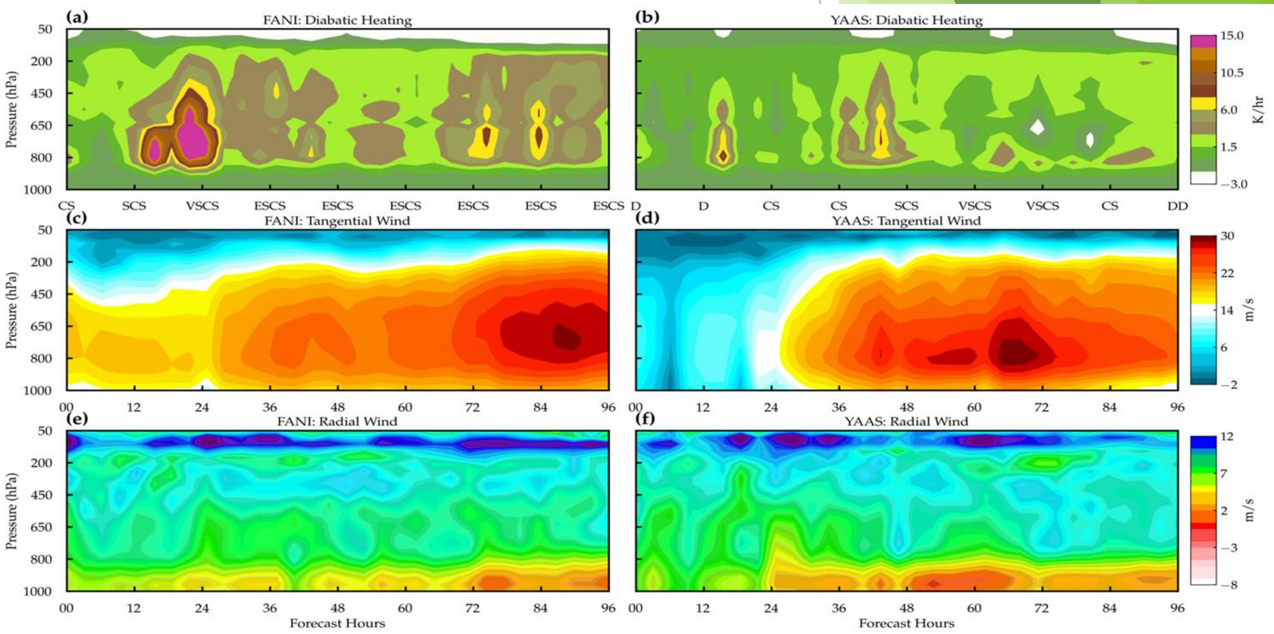
SST-



Role of Rainfall in Cyclone (Fani-2019 & Yaas-2020)







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Spatio-Temporal Variability of Pre-monsoon Convective Events and Associated Rainfall over the State of Odisha (India) in the Recent Decade

Tapajyoti Chakraborty, Sandeep Pattnaik, Vijay Vishwakarma & Himadri Baisya

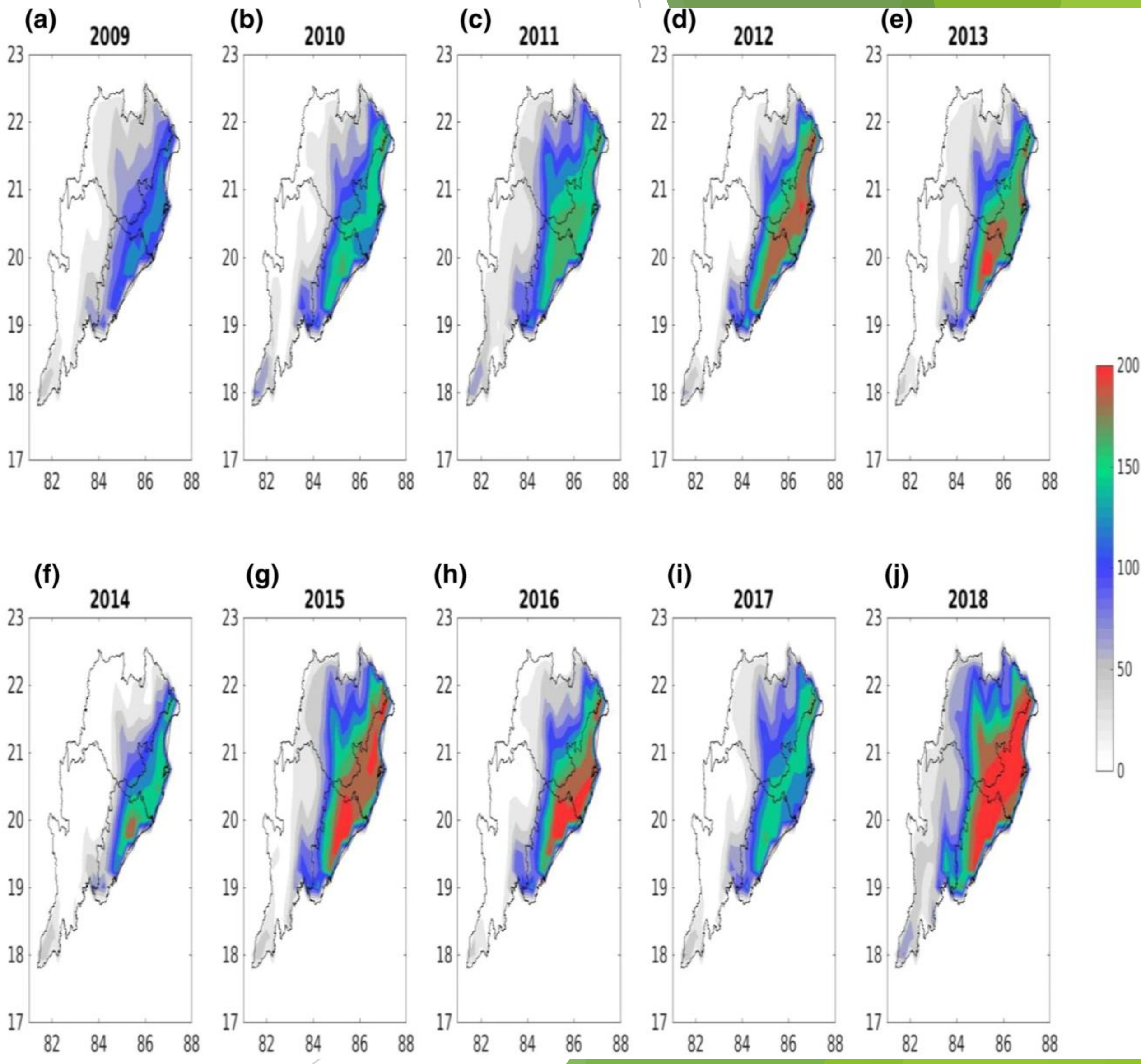
Pure and Applied Geophysics (2021) | Cite this article

The convective events (severe and moderate) show an increasing trend in recent years, with South Coastal Odisha (SCO) and North Coastal Odisha (NCO) showing the highest increase.

Maximum convective precipitation (CP) is experienced over NCO and adjacent eastern districts of North Interior Odisha (NIO).

There exists a strong temperature gradient between the western and eastern portions of the state.

Major factor attributing to these changes in noted due to anomalous land-sea contrast signatures.



New Challenges in Prediction

- **Pre-monsoon cyclones every years in BoB(NIO) Fani(2019), Amphan(2020), Yaas(2021), Asani(2022)Nisarga (2020),Tautkae (2021)**

- **Pre-monsoon intense cyclones making landfall over Indian region. Recurving nature of the cyclone and Unseasonal cyclones (Jawad 2021, Asani 2020)**

- **Prolonged Heat Wave, Unseasonal Rainfall and Distinct Variability in Monsoon Rainfall Pattern**

- **Monsoon cyclones (Gulab-5days over land-Shaheen cyclone landfall Oman, Cyclone Freddy has the longest duration of lifecycle 35days)**

- **Rapid Intensification** is highly challenging to forecast it accurately and do not provide adequate time to operational, policy makers, administrators, disaster and risk managers to initiate action (e.g. evacuation).

- **Cyclone Amphan intensified from a Category-1 cyclone (about 100 km/hr) to a Category-5 cyclone (about 250 km/hr) in less than 24 hours. Taukate Depression to Severe Cyclonic storm (SCS) in just 2days.**


1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY

Source: UN

Scope for Collaboration

Initial thoughts on collaborations

a. Climate Change and Renewal Energy Region Specific Approach
b. Future climate scenarios and extreme events with thrust on water

References

- Assessment Report Inter governmental panel for climate Change (IPCC)
- Baisya et al. (2018) Ramifications of Atmospheric Humidity on Monsoon Depressions over the Indian Subcontinent, Scientific Reports, Volume 8, Article number: 9927, https://www.nature.com/articles/s41598-018-28365-2
- Chakraborty et al. (2021) Spatio-Temporal Variability of Pre-monsoon Convective Events and Associated Rainfall over the State of Odisha (India) in the Recent Decade, Pure and Applied Geophysics, https://link.springer.com/article/10.1007/s00024-021-02886-w
- Decadal surface temperature trends in India based on a new high-resolution data set, Scientific Reports, 8, Article number: 7452 (2018), doi:10.1038/s41598-018-25347-2
- Hunt et al. 2016: On the structure and dynamics of Indian monsoon depressions. Monthly Weather Review, 144 (9). pp.33913416. ISSN 00270644, doi: https://doi.org/10.1175/MWRD150138.1
- Maniar et al. (2019) Spatiotemporal patterns of surface temperature over western Odisha and eastern Chhattisgarh, https://link.springer.com/content/pdf/10.1007/s42452-019-0986-2.pdf
- Rajesh et al. (2016) Role of land state in a high resolution mesoscale model for simulating the Uttarakhand heavy rainfall event over India, Journal of Earth System Science,125,3,475–498, doi:10.1007/s12040-016-0678-x
- Rai et al. (2016) Sensitivity of tropical cyclone characteristics to the radial distribution of sea surface temperature, Asia-Pacific Journal of Atmospheric Sciences, Volume 54, Issue 3, pp.473-488
- State of Climate in Asia 2020, World Meteorological Organization (WMO)

Thank you