CLIMATE CONUNDRUMS: HEAT RISE, DUST STORMS AND DESERTIFICATION

DR S. D. ATTRI
Dy Director General of Meteorology
India Meteorological Department, MoES, GOI, New Delhi
sdattri@gmail.com; sd.attri@imd.gov.in
3 out of every 4 hectares of land altered from their natural states & the productivity of about 1 in every 4 hectares of land is declining.

Poor land health is on the rise impacting 3.2 b people in the world.

Land degradation working in tandem with climate change and biodiversity loss may force up to 700 m people to migrate by 2050.

Focus on the over 1.3 billion people who rely directly on land to survive and suffer the most land degradation and drought.

Changes like rise in ocean temp., acidification & diminished capacity to absorb heat and carbon is happening. Rising warming level may gradually affect upper-ocean mixing, nutrient supply and cycling of carbon through marine life

The changes could take anywhere between 30 to 100 years to manifest. The ph levels of the oceans have already dropped from 8.2 to 8.1 and could further go down to 7.8.

Target-Land degradation neutral by 2030 and restore 2 billion ha of degraded land
Economic loss US$330 billion; 97% from extreme weather damage

Disaster risk is growing due to unplanned urbanization, persistent poverty and ecosystem degradation.

Insurance industry suffered losses of US$135 billion in 2018 - highest in 40 yrs.
Cyclone - 2 seasons
• 7500 km long coastline

Drought
• 68% net sown area in 116 dist.

Forest Fire
• 44 M ha (~65%: Deciduous) of India’s 67.5 M ha (total) forest cover is prone to forest fires

Earthquake
• 55% of area in Seismic Zone III-IV-V

Flood
• 40 M ha flooding

Heavy Rainfall and Flash Floods
• Two monsoon seasons

Landslide
• Himalayas and Western Ghats
• Mostly rainfall induced - 6 - 7 major landslide events Each monsoon,

Thunderstorms
• Most parts of country vulnerable

(NATURAL HAZARDS IN INDIA LEADING TO DISASTERS
(Image Courtesy: ISRO)

Heat Wave/Cold Wave
• Same areas affected in different seasons
EXTREME WEATHER EVENTS

Winter (Jan-Feb): Western Disturbances, Cold Wave, Fog


Monsoon (Jun-Sep): Southwest Monsoon Circulation, Monsoon Disturbances

Post-Monsoon (Oct-Dec): Northeast Monsoon, Cyclonic Disturbances

- Heavy rains
- Cyclone
- Hailstorm
- Dry spells
- Drought
- Heat wave
- Frost
- Cold wave
- Ice storms
- Pest and diseases incidence on crop and livestock.
FWCC 1979 (Scientific Knowledge)
‘Climate Variability and Change as an issue of concern worldwide ’
➢ IPCC

Development policy

SWCC 1990
Political Awareness
‘More momentum to address Climate Variability and Change’
➢ GCOS
➢ UNFCCC

WCC-3 (31 Aug-4 Sept. 2009)
Societal services
‘Climate prediction and information for decision-making
➢ GFCS
• Observation & Monitoring
• Climate Research & Modeling
• Climate Services & Information System
• Climate Services Application Programme
Temperature and CO₂ concentration in the atmosphere over the past 400,000 years (from the Vostok ice core)

**CO₂ concentration, ppmv**

400,000  350,000  300,000  250,000  200,000  150,000  100,000  50,000  0

Year before present (present = 1950)

**Temperature change from present, °C**

-10°C  -8°C  -6°C  -4°C  -2°C  0°C  2°C  4°C  6°C  8°C  10°C

400,000  350,000  300,000  250,000  200,000  150,000  100,000  50,000  0

Year before present (present = 1950)

Observed change in average surface temperature 1901–2012

IPCC, 2013
### WARMEST YEARS (1880–2018)

<table>
<thead>
<tr>
<th>Year</th>
<th>Anomaly in respect of the 1981–2010 average (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>+0.56</td>
</tr>
<tr>
<td>2017</td>
<td>+0.46</td>
</tr>
<tr>
<td>2015</td>
<td>+0.45</td>
</tr>
<tr>
<td>2014</td>
<td>+0.30</td>
</tr>
<tr>
<td>2013</td>
<td>+0.24</td>
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<tr>
<td>2010</td>
<td>+0.28</td>
</tr>
<tr>
<td>2009</td>
<td>+0.22</td>
</tr>
<tr>
<td>2006</td>
<td>+0.22</td>
</tr>
<tr>
<td>1998</td>
<td>+0.21</td>
</tr>
</tbody>
</table>

- **2006-2015:** 0.86°C
- **2009-2018:** 0.93°C
- **2014-2018:** 1.04°C

(Above the pre-industrial baseline: 1850-1900)

[IPCC1.5 (2018)]

- 18 out of 19 warmest years on record in the 21st century
- 2001-2010 as the warmest decade on record.
Proportion of heavy rainfalls: increasing in most land areas
Areas sensitive to desertification (yellow)
Probability of Moderate Severe Drought (1901-2000)

Thunderstorm (Per year) Hailstorm (in 100 years)

Tornado prone areas
OBSERVED TEMPERATURE TREND OVER INDIA
(1901-2018)

Winter: 0.72°C
Pre-monsoon: 0.61°C
Monsoon: 0.35°C
Post Monsoon: 0.81°C

Trend: 0.60°C / 100 years
ANNUAL MAXIMUM TEMPERATURE ANOMALIES
(1901-2018)
(BASED ON 1961-1990 AVERAGE)

Annual Max Temp Anomalies(0C)

TREND = +1.050°C/100 YEARS

9 POINT BINOMIAL FILTER

Meteotological Department of India
ANNUAL MINIMUM TEMPERATURE ANOMALIES (1901-2018)
(BASED ON 1961-1990 AVERAGE)

Annual Min Temp Anomalies(°C)

TREND = +0.160°C/100 YEARS

9 POINT BINOMIAL FILTER

YEARS


0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6

-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2

YEAR

INDIA METEOROLOGICAL DEPARTMENT
Spatial Variation of mean annual Temperature Changes in last century

Spatial Variation in the linear trend of air temperature (in °C/100 years) over the country.
# BREAK IN MONSSON

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>NUMBER OF BREAK DAYS DURING</th>
<th>JULY</th>
<th>AUGUST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>01-10</td>
<td>11-20</td>
</tr>
<tr>
<td>1888-1917</td>
<td></td>
<td>46</td>
<td>49</td>
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<tr>
<td>1918-1947</td>
<td></td>
<td>14</td>
<td>36</td>
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<td></td>
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<tr>
<td>1948-1977</td>
<td></td>
<td>22</td>
<td>44</td>
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<td></td>
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<tr>
<td>1978-2003</td>
<td></td>
<td>23</td>
<td>32</td>
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</tr>
</tbody>
</table>
Heat waves in India (per year)

- Less than 500
- About 580
- About 670

### HEAT / COLD WAVE

**Heat Wave**

When maximum temperature of a station reaches $\geq 40^\circ\text{C}$ for plains and $\geq 30^\circ\text{C}$ for hilly regions.

(a) Based on Departure from normal

- **Heat Wave**: Maximum Temperature Departure from normal 4.5°C to 6.4°C.
- **Severe Heat Wave**: Maximum Temperature Departure from normal $\geq 6.5^\circ\text{C}$

(b) Based on Actual maximum temperature

- **Heat Wave**: When actual maximum temperature $\geq 45^\circ\text{C}$.
- **Severe Heat Wave**: When actual maximum temperature $\geq 47^\circ\text{C}$

(c) Criteria for heat wave for coastal stations

When maximum temperature departure is $> 4.5^\circ\text{C}$ from normal. Heat Wave may be described provided maximum temperature $\geq 37^\circ\text{C}$

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**Warm Night**

When maximum temperature remains 40°C

- **Warm Night**: When minimum temperature departure 4.5°C to 6.4°C.
- **Severe Warm Night**: When minimum temperature departure $> 6.4^\circ\text{C}$.

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**Cold Wave**

When minimum temperature of a station $\leq 10^\circ\text{C}$ for plains and $\leq 0^\circ\text{C}$ for hilly regions.

(a) Based on departure

- **Cold Wave**: Minimum Temperature Departure from normal -4.5°C to -6.4°C.
- **Severe Cold Wave**: Minimum Temperature Departure from normal $\geq -6.5^\circ\text{C}$

(b) Based on actual Minimum Temperature (for Plains only)

- **Cold Wave**: When Minimum Temperature is $\leq 4.0^\circ\text{C}$
- **Severe Cold Wave**: When Minimum Temperature is $\leq 2.0^\circ\text{C}$

(c) For Coastal Stations

When Minimum Temperature departure is $\leq -4.5^\circ\text{C}$ or actual Minimum Temperature is $\leq 15^\circ\text{C}$

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**Cold Day**

When minimum temperature of a station $\leq 10^\circ\text{C}$ for plains and $\leq 0^\circ\text{C}$ for hilly regions

Based on departure

- **Cold Day**: Maximum Temperature Departure from normal -4.5°C to -6.4°C.
- **Severe Cold Day**: Maximum Temperature Departure from normal $\leq -6.5^\circ\text{C}$

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**INDIA METEOROLOGICAL DEPARTMENT**
Sea Surface Temperature Variations in the Indian Ocean

Arabian Sea

Bay of Bengal

Sea Surface Temperature (°C)

SIGNIFICANT DECREASING TREND IN ANNUAL FREQUENCY OF CYCLONIC STORMS OVER THE NORTH INDIAN OCEAN (1891-2006)

\[
y = -0.0183x + 6.3291
\]

\[
R^2 = 0.1031
\]
Trend in sub-divisional rainfall data (increase/ decrease in rainfall in mm) for different seasons (1901-2003).
1901-2018: 23 drought years (16 El Niño)
13 excess years (6 La Niña)
Low & Moderate events

Heavy events
(>10cm)

Goswami et al. 2006,
Science, 314, 1442

V. Heavy events
(>15cm)
Figure 5: State level annual mean temperature trends.
Figure 7: State level annual rainfall trends.
Expected Future Change in Monsoon Rainfall and Annual Surface Temp for 2020’s, 2050’s and 2080’s under A1B scenario in AR5

Rainfall

Temp

Krishna Kumar et al, 2009
Projections of extremes in rainfall (2041-2060)

- Overall decrease in the number of rainy days over a major part of the country.
- Decrease in the western and central part of the country (by more than 15 days).
- Foothills of Himalayas and in northeast India the number of rainy days is found to increase by 5–10 days.

- Increase in the rainfall intensity by 1–4 mm/day,
- Northwest India - the rainfall intensities decrease by 1 mm/day
- Increase in the highest 1-day rainfall over a major part - may be up to 20 cm/day

(Source: IITM)
• The SDS-WAS established in 2007- a joint WWRP and GAW activity in response to the interest of 40 WMO member countries to improve capabilities for more reliable sand and dust storm forecasts
• The WMO SDS-WAS has been established with the objective to develop, refine and provide monitoring and prediction products that are useful in reducing the adverse impacts of SDS and to assess numerous impacts of the SDS process on society, climate and environment

SDS-WAS Asian Node (hosted by China)
SDS-WAS Northern Africa-Middle East-Europe Node (hosted by Spain)
SDS-WAS Americas Node (hosted by Bermudas)
Dust storm events observed from MODIS along with the air mass back-trajectories at (a) New Delhi, (b) Jodhpur during 19–23 March 2012.

● Rainfall significantly below normal for an extended period for several years (→ Drought)
● Degradation of land in arid, semi-arid, and dry sub-humid areas (→ Desertification)
● **Global warming** → rising temp → lower soil moisture → hinder condensation & rainfall → drop of water table → further drop of soil moisture → loss of vegetation cover (protection) → loss of organic matters → less cohesive soil → easy erosion by wind & water → desertification → climate change → land degradation → loss of vegetation → higher CO2 emissions → **global warming** → lower evaporanspiration → lower air humidity → less & infrequent rainfall .....  
● Temporary / high magnitude drought periods in semi-arid areas
Effects of desertification

Atmosphere
- local climate
  ↓ PPT
drought
- macro climate
global warming

Hydrosphere
- water cycle
  breaks down

Lithosphere
- loss of arable
  salinization
- land intensify the
  soil erosion

Biosphere
- extinction of
  plants & animals
  ↓ biodiversity

Upset the balance of ecosystem
Drought Management
• Prediction of land, atmospheric and Oceanic states at different scales to provide weather and climate forecast in different spatial and temporal range
  – Nowcasting (few hours)
  – Short range (1-2 days)
  – Medium range (3-10 days)
  – Extended Range (10-30 days)
  – Seasonal (Few months, e.g. Jun-Sep Monsoon)
  – Climate Scales

Spatial range : Location, Block, District, Meteorological Sub-division, River catchment, State and Homogeneous regions

➢ Early warning system on extreme events
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Forecast for</th>
<th>Region for which forecast issued</th>
<th>Issued in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Winter Season (Jan- March) Precipitation</td>
<td>Northwest India</td>
<td>December</td>
</tr>
<tr>
<td>2</td>
<td>Hot Weather Season Temperature (March to May) &amp; (April-June)</td>
<td>Subdivision wise</td>
<td>February &amp; March</td>
</tr>
<tr>
<td>3</td>
<td>SW Monsoon Season (June to September) Rainfall</td>
<td>Country as a whole</td>
<td>April</td>
</tr>
<tr>
<td>4</td>
<td>SW Monsoon Season (June to September) Rainfall</td>
<td>Country as a whole</td>
<td>June</td>
</tr>
<tr>
<td>5</td>
<td>South-West Monsoon Onset</td>
<td>Kerala</td>
<td>May</td>
</tr>
<tr>
<td>6</td>
<td>SW Monsoon Season (June to September) Rainfall</td>
<td>Four broad geographical regions: Northwest India, Northeast India, Central India and South Peninsula</td>
<td>June</td>
</tr>
<tr>
<td>7</td>
<td>SW Monsoon Monthly Rainfall for July and August</td>
<td>Country as a whole</td>
<td>June</td>
</tr>
<tr>
<td>8</td>
<td>SW Monsoon Second half of the Season (August- September) Rainfall</td>
<td>Country as a whole</td>
<td>July</td>
</tr>
<tr>
<td>9</td>
<td>September Rainfall</td>
<td>Country as a whole</td>
<td>August</td>
</tr>
<tr>
<td>10</td>
<td>NE Monsoon Season (October to December) Rainfall</td>
<td>South Peninsula</td>
<td>September</td>
</tr>
<tr>
<td>11</td>
<td>Cold Weather Season (December - February) Temperature</td>
<td>Subdivision wise</td>
<td>November</td>
</tr>
</tbody>
</table>
Monitoring and prediction of Land-Surface Fields

Daily Soil Moisture (%) 19 March for 2019 (ending at 0830 IST) for 60 cm depth

- Precipitation (mm)
- Max. temperature (°C)
- Min. temperature (°C)
- Mean temperature (°C)
- Runoff (mm)
- Soil moisture (mm)

March 19

India Meteorological Department
Big data enabling impact-based decision-making

- Data: signals, know nothing
- Information: useful, organized, structured
- Knowledge: contextual, synthesized, learning
- Wisdom: Understanding, integrated, actionable

Impact Based Forecasting
A dry spell is a short period, usually 4 weeks (upto 3 weeks in case of light soils), of low rainfall or no rainfall.

Thus, consecutive 3-4 weeks after the due date for the onset of monsoon with rainfall less than 50% of the normal in each of the weeks is defined as a Dry spell.

This indicator is important in that it quantifies the extent of intra-season rainfall variations which is so critical for the health of crops and maintenance of soil and hydrological regime.
Monitoring and Preparedness at Policy level

- Office of Prime Minister and other Ministers including Agriculture

- Crop Weather Watch Group (every Friday) by Ministry of Agriculture
  - Weather and climate
  - Water resources - reservoir position
  - Agriculture input and tools availability for enabling micro irrigation system
  - Credit availability
  - Insurance mechanism

- Provinces likely to be affected by deficient / excess rainfall forecast for coordination at province level to enhance action oriented preparedness.
INSTITUTIONAL MECHANISM FOR DROUGHT MONITORING

<table>
<thead>
<tr>
<th>Category</th>
<th>Institutions/ Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government of India</td>
<td>• Central Drought Relief Commissioner</td>
</tr>
<tr>
<td></td>
<td>• Crop Weather Watch Group</td>
</tr>
<tr>
<td>State Level</td>
<td>• State Drought Monitoring Centres</td>
</tr>
<tr>
<td>Scientific &amp; Support Organisations</td>
<td>• India Meteorological Department (IMD)</td>
</tr>
<tr>
<td></td>
<td>• Mahalanobis National Crop Forecast Centre (MNCFC)</td>
</tr>
<tr>
<td></td>
<td>• Central Research Institute for Dryland Agriculture (CRIDA)</td>
</tr>
<tr>
<td></td>
<td>• Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD &amp; GR)</td>
</tr>
<tr>
<td></td>
<td>• Indian Space Research Organisation (ISRO)</td>
</tr>
<tr>
<td></td>
<td>• State Remote Sensing Application Centres (SRSACs)</td>
</tr>
</tbody>
</table>

Drought Management Policy (2016)
District Level Agromet Advisory Service System

**IMD**
- Agro-climate level agro-met data

**130 AG.MET. FIELD UNITS**
- Preparation of District Wise Medium Range Weather Forecast by State Met Centre
- District-wise Agro-met data

**District Level Agencies (DAO/KVK/ATMA/NGOs)**
- Feedback analysis

**Farmers** (Through Media Agencies, IT Service, Personal Contact)
- Dissemination of District Level Agro-advisories

Expansion of Agromet Network at District level to support district (660) / block (6500) level advisory at KVKs with outreach to Panchyat level
95% of surveyed farmers experienced improved reliability of service in recent years.

The incremental profit due to AAS is assessed to be 10 to 25% of their net income.

The Annual Economic Profit of 24% of farmers cultivating 4-principal crops (wheat, paddy, sugarcane and cotton), after using AAS in 2010, was assessed at Rs. 38,463 Crs which raised to Rs. 42,000 Crs in 2015.

It (for 22-principal crops) has potential of generating net economic benefit up to Rs. 3.3 lakh Crs if AAS is fully utilized by 95.4 million farmer’s households.
IMD Agromet—Decision Support System

agromet.imd.gov.in

Automation of Location and Farming System specific Agromet Advisories

Modules in Use

- Forecast
  - District level
  - Block level
- Value added forecast
- Forecast Analysis
- Forecast verification
- Download
- Upload
- Access to Agromet Units

Overview

Central server: Data Processing and Visualization Interface

- Observed Weather Data
- Short SMS based on 5 days forecast
- WRF Forecast: 3 days (3 km)
- GFS Forecast: 4-10 days (12.5 km)

Products

- Daily Soil Moisture
  In Progress

- Populating agromet data
- Dynamic Crop Calendar
- Contingency plan linking
- Platform for automatic advisory preparation

Agricultural Information: Major Crop and cultivar information, Dynamic crop Calendar, Contingency, Crop health, Sources of Irrigation, Crowd sourcing

Forecast Analysis

Forecast verification

Forecast

Download

Upload

Access to Agromet Units
THANK YOU