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Points to be discussed

- Climatic parameters and health
- Extreme weathers over India
- Climate Change and its implication on human health
- Effect of climate on health (brief review of literatures)
- Air and Water pollutions and health
- Prospect of Climate Services in Health Sector over India
  - Climate Information
  - Climate Forecasts
  - Action Plans
- Summary
GFCS Priorities

In the first four years give priority to:

- Agriculture
- Disaster risk reduction
- Water
- Health
- Energy
Climate-Health

The day-to-day health outcomes of human being are most likely to be affected by climate variability and climate change because they are associated with weather and/or climate variables:

- temperature-related morbidity and mortality;
- health effects of extreme weather events (storms, tornadoes, hurricanes, and precipitation extremes);
- air-pollution-related health effects;
- water- and food borne diseases; and
- vector borne diseases.
Climate and Health

Human exposures

- Regional weather changes
  - Heat waves
  - Extreme weather
  - Temperature
  - Precipitation
  - Humidity

Health effects

- Temperature-related illness and death
- Extreme weather-related health effects
- Air pollution-related health effects
- Water and food-borne diseases
- Effects of food and water shortages
- Effects of population displacement
- Vector-borne diseases

Location and Normal movement of weather System in India

ML: Monsoon low
MTC: Mid-tropospheric cyclone
C: Cyclone
TS: Thunderstorm
OV: Onset Vortex

Western Disturbance
Fog

Off-shore vortices

Easterly wave
Indian Southwest Monsoon (June to September)

Mean % of Heavy rainfall days
Mean % of Very heavy rainfall days

JJAS mean rainfall (cm)
Monsoons (Drought and Floods)
Variations of the Monsoon Trough over the Indian region associated with the active and break spells
AISMR inter-annual and Intra-seasonal variability during JJAS (1901-2014)

**Mean = 89 cm**
**CV ≈ 10.0%**

**Percentage dep. of AISMR (1901-2014)**

**Daily RF (1988)**
**Average (1951-2000)**

**Daily RF (2002)**
**Average (1951-2000)**
Pre-monsoon (MAM) and Post monsoon Tropical Cyclone (OND); 1951-2014
Winter Tmax Climatology (March, April, May, June)
Thunderstorms

(Tyagi, 2007)
Effects of climate on health

1. Weather extremes (heavy rains, floods, and disasters)
   - endanger health as well as destroy property and livelihoods.
   - 600,000 died due to weather-related natural disasters in the 1990s
   - some 95% of which took place in developing countries.

2. CO$_2$ and other greenhouse gases
   - Increased by more than 30% since pre-industrial times,
   - trapping more heat in the lower atmosphere.
   - deaths in extreme high temperatures
   - Changing patterns of infectious diseases.
3. Intense short-term fluctuations
   - heat stress (hyperthermia) or extreme cold (hypothermia)
   - Increased death rates from heart and respiratory diseases.

4. Rising sea levels
   - Outcome of global warming
   - Floods can directly cause injury and death
   - Increase risks of infection (water and vector-borne diseases)
   - Population displacement could increase tensions and potentially the risks of conflict.
5. More variable rainfall patterns causing:

A. *Water scarcity*
   - already affects four out of every 10 people globally
   - Increase the risk of household water contamination, causing illnesses.

B. *Reduced crop yield*
   - Malnutrition
   - Impoverishment
Climate Change
Probability of extreme weather events
**Background**: Frequency of different rainfall (R) events during monsoon season (June to September) over India during 1951 to 2005.

\[ y = -0.0966x + 208.79 \]
\[ R^2 = 0.0114 \]


**Average frequency**

(a) Category-i, JJAS
\[ y = -0.0033x + 5.2894 \]
\[ R^2 = 0.0059 \]

(b) Category-ii, JJAS
\[ y = -0.0033x + 5.2894 \]
\[ R^2 = 0.0059 \]

(c) Category-iii, JJAS
\[ y = 0.006x + 0.7892 \]
\[ R^2 = 0.143 \]

(a) Category-i with ‘R’ ≤ 64.4 mm in a day,
(b) Category-ii with 64.4 < ‘R’ ≤ 124.4 mm in a day &
(c) Category-iii with ‘R’ > 124.4 mm in a day.

Tropical Cyclones

ANDHRA PRADISH

TAMIL NADU

India Meteorological Department
Flood prone areas

Floods

Drought
Global Warming Impacts on Climate and Risk Factors

- **Storms, cyclones**: More extreme weather events.
- **Heat waves**: More frequent, more intense, and longer.
- **Air pollution**: Increase in levels of ground ozone, more allergens.
- **Rapid glacier melting**: Landslides, flash floods, and reduced water availability.
- **Disturbed rainfall patterns**: More droughts, more extreme precipitation events, floods, and disrupted water supply.
- **Warmer temperatures**: Warmer minima.
- **Sea-level rise**: Inundation, saltwater intrusion, loss of land.
Health impact of climate change associated with increasing frequency of extreme weather are diverse, global and probably irreversible over human time scales

First, these hazards range from increased risks of extreme weather, such as fatal heat waves, floods and storms, potentially more serious effects on infectious disease dynamics, shifts to long-term drought conditions in many regions.

Second, the health impacts of climate change are potentially huge. Many important global killers are highly sensitive to climatic conditions. Malaria, diarrhoea and protein-energy malnutrition together cause more than 3 million deaths each year (WHO 2004).

Third, these risks are inequitable, in that the greenhouse gases that cause climate change originate mainly from developed countries, but the health risks are concentrated in the poorest nations, which have contributed least to the problem (Patz et al., 2005).

Finally, many of the projected impacts on health are avoidable, through a combination of public health interventions in the short term, support for adaptation measures in health-related sectors such as agriculture and water management, and a long-term strategy to reduce human impacts on climate.
### Air pollution and Health

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Health Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPM</td>
<td>Damage of lungs, bronchitis and asthma.</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>Acid rain, damage to lungs, eye and skin.</td>
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<tr>
<td>NO$_x$</td>
<td>Form Smog damage to respiratory system and eye irritation.</td>
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<tr>
<td>CO</td>
<td>Toxic causes blood poisoning.</td>
</tr>
<tr>
<td>HC</td>
<td>Cancer.</td>
</tr>
<tr>
<td>Pb</td>
<td>Nervous system slow down ad brain development is retarded; slow reaction time.</td>
</tr>
</tbody>
</table>

Human activities such as burning of fossil fuels in vehicles, power plants, and various industrial processes also generate significant amounts of aerosols.

**Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function, and lung cancer**
Water quality, and health

- About 70% to 80% of water-borne diseases in India are caused due to contamination of surface and ground water by the discharge of untreated/partially treated sewage and industrial effluents into water bodies.

- The World Health Organization (WHO) estimates 21% of communicable diseases in India are water related (WHO 2002). Of these diseases, diarrhoea alone killed lakhs of Indians in 1999.

- The highest mortality from diarrhoea is in children under the age of five. It is so alarming that water pollution induced morbidity and mortality rate is very high.

- Pollution drives need for more expansive & expensive water and cause of rising cost of water supply which going higher day by day due to unabated urbanization.
Climate Change and Health over the Mountain regions
Glacier Mass Balance

Himalayan glaciers are shrinking more rapidly than anywhere else on the globe

Dyurgerov and Meier, 2005
Rapid Glacier Melting = Less Freshwater
Changes in the ice and snow cover of the Shrong Himal glacier, Nepal, over a 26-year period (1978 to 2004).
The Temperature Increases Faster on High Altitude

Liu and Chen, 2000
Glacial Lake Outburst Flood

- Excess melt water leads to Glacial Lake Outburst Flood (GLOF) or “mountain tsunami”
- In 2007, two hundred glacial lakes in the Himalayas were at risk of bursting

Photo: Nare glacier GLOF hits Pangboche village, Nepal, 1977
More Water Borne Diseases

- In 2005, diarrhoeal diseases accounted for 20.1% of deaths in children less than five years.

Photo credit: © Shehzad Noorani/Still Pictures
Climate and Health

Some Research Findings
Climate conditions affect the transmission of vector-borne diseases in 3 ways:

- Altering the distribution of vector species and their reproductive cycles;
- Influencing the reproduction of the pathogens within the vector organism, known as the external incubation period (EIP);
- Affecting human behaviors and activity.

Weather and Climate Affect the System in a Complex Fashion

- Impact of rain on larval habitats
- Impact of R.H. and temperature on adult survival
- Impact of temperature on host and vector winter survival
- Impact of temperature on larval growth and development

Today
Daily hospitalizations for diarrhoea, by daily temperature: Lima, Peru.
(Shaded region is 1997-98 El Niño event)


**Overall estimate from regression analysis:**
7% increase in daily cases per 1°C rise
Seasonal variations have been observed in coronary heart disease (CHD), cerebro-vascular disease and respiratory disease.

These are all characterized by a winter peak and summer trough in both the hemispheres.

In England and Wales, the winter peak in coronary and cerebro-vascular disease accounts for an additional 20,000 deaths per annum.

Effects of cold weather

Cold weather causes a spike in health problems:

- heart attacks;
- strokes;
- pneumonia;
- depression;
- worsening arthritis and increased accidents at home

Other ways an older person’s health is affected are:

- narrowing airways, making it harder to breathe;
- increasing the risk of respiratory infection;
- increasing blood pressure, an effect which can last for many hours;
- increasing the risk of blood clotting, which along with raised blood pressure increases the risk of heart attack or stroke.
Climate and Cholera

- A NICED study studied the pattern of cholera outbreaks during 1998–2006 in Kolkata, India, and Matlab, Bangladesh.

- The environmental dynamics data were analyzed with the objective of developing a prediction model for cholera.

- Rainfall, Sea surface temperature data were analyzed.

- The results of the study show that ocean and climate patterns are useful predictors of cholera epidemics.
Epidemiological and environmental dynamics for (A) Kolkata, India, and (B) Matlab, Bangladesh.

Constantin de Magny G et al. PNAS 2008;105:17676-17681
Climate and Malaria

- Higher positive correlation of association was found between malaria incidence and climatic variables (temperature, rainfall and humidity) in Uttaranchal, India*

- Malaria incidence has been positively correlated with rainfall†

*N Pemola Devi, R K Jauhari. Climatic variables and malaria incidence in Dehradun, Uttaranchal, India. Journal of vector borne diseases

†Gupta R. Correlation of rainfall with upsurge of malaria in Rajasthan. J Assoc Physicians India 1996
Climate change and Malaria

Figure 2. Trends of average monthly temperature, precipitation, relative humidity and malaria cases in India between the period 1970 and 2000.

Bhattacharya S, Sharma C, Dhiman RC, Mitra AP. Climate change and malaria in India. Current Science
Economic and Disease Burden of Dengue Illness in India

Donald S. Shepard, Yara A. Halasa, Brij Kishore Tyagi, S. Vivek Adhisht, Deoki Nandan, K. S. Karthiga, Vidya Chellaswamy, Mukul Gaba, Narendra K. Arora,* and the INCLEN Study Group†

Brandeis University, Waltham, Massachusetts; Centre for Research in Medical Entomology, Madurai, India; National Institute of Health and Family Welfare, New Delhi, India; INCLEN Trust International, New Delhi, India

Figure 1. Reported and adjusted number of clinically diagnosed dengue cases, 2006–2012. AF denotes adjustment factor.
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Fundamentals Section
Global environmental change
Climate epidemiology
Climate change attributable burden of disease
Modelling for future health impacts

Indian climatology in the context of human health
(D. R. Pattanaik and B. Muhopadhyay, 2012)

Evidence Section: climate extremes outcomes
Thermal stress
Climate disasters
Sea level rise

Evidence Section: climate sensitive diseases
Malnutrition
Vector-borne diseases
Diarrhoeal diseases
Respiratory diseases
Mental health
Emerging and re-emerging diseases

Applied Section
Geographic Information System
Resources and infrastructure
Lifestyle
Vulnerability and adaptation
Economic of scaling up
Health communication
Prospect of Climate Services in Health Sector over India

- Climate Information
- Climate Forecasts
- Action Plans
During 1998 more than 1000 people died over India due to scorching temperatures over Orissa, Coastal Andhra Pradesh, Rajasthan and Tamilnadu during May/June.

Similarly, in May 2003 a heat wave claimed over 1,600 lives throughout the country with some 1,200 dead in the state of Andhra Pradesh alone.

During 2005, India came under the grip of a severe heat wave towards the third week of June, and causing the deaths of a large number of people in the eastern parts of the country covering the state of Orissa and neighborhood.

2010 Heat Wave

Recent heat wave of 2015 (More than 2500 death)
The degree of discomfort that is felt during the hot weather period depends significantly on combined effect of the humidity of the air as well as the actual air temperature. The threshold ambient temperature at which, heat-related health complications varies greatly by location. However, in general, when summer temperatures increases to a value more than 40°C (about 104°F), incidences of heat-related illness such as heatstroke, hyperthermia, and dehydration increase dramatically. High humidity compounds the effects of high heat by reducing evaporation.
FORMULA FOR HEAT INDEX (HI)

- Ventilation rate: the amount of heat lost via exhaling, which depends on humidity
- Skin resistance to heat transfer: a function of activity, skin temperature, among others
- Skin resistance to moisture transfer: a function of the vapor-pressure difference across the skin (and, therefore, relative humidity), it decreases with increasing activity
- Surface resistance to heat transfer: as radiation and convection from the skin increases, this value decreases and
- Surface resistance to moisture transfer: similar to heat transfer resistance but also depends upon conditions in the boundary layer just above skin's surface

\[
HI = 16.923 + 1.85212 \times 10^{-1} \times T + 5.37941 \times RH - 1.00254 \times 10^{-1} \times T \times RH + 9.41695 \times 10^{-3} \times T^2 + 7.28898 \times 10^{-3} \times RH^2 + 3.45372 \times 10^{-4} \times T^2 \times RH - 8.14971 \times 10^{-4} \times T \times RH^3 + 1.02102 \times 10^{-5} \times T^2 \times RH^2 - 3.8646 \times 10^{-5} \times T^3 + 2.91583 \times 10^{-5} \times RH^3 + 1.42721 \times 10^{-6} \times T^3 \times RH + 1.97483 \times 10^{-7} \times T \times RH^3 - 2.18429 \times 10^{-8} \times T^3 \times RH^2 + 8.43296 \times 10^{-10} \times T^2 \times RH^3 - 4.81975 \times 10^{-11} \times T^3 \times RH^3
\]

where T is temperature in degrees Fahrenheit and RH is relative humidity in percent
Fig. 8: List of 41 districts considered for normal Heat Index calculation.
Mean and Max Heat Index (HI) Climatology over Bargarh (Orissa) District

Day starting from 1st January
Mean and Max Heat Index (HI) Climatology over Ganganagar (Rajasthan) District

Day starting from 1st January

Heat Index in (C)

- Mean HI
- Max HI
Mean and Max Heat Index (HI) Climatology over Nagpur (Maharashtra) District

Heat Index in (°C)

Day starting from 1st January
Average days per districts (out of 41)

Number of days with mean HI ≥30° and max HI ≥35°C

- Pune: 0
- JF: 1.6 (3%)
- MAM: 47.7 (52%)
- JJAS: 97.3 (80%)
- OND: 8.7 (9%)
- ANN: 155.2 (43%)

Number of days with mean HI ≥30° and max HI ≥45°C

- Pune: 0
- JF: 0.2 (0%)
- MAM: 33.7 (37%)
- JJAS: 54.3 (45%)
- OND: 2.8 (3%)
- ANN: 90.9 (25%)

Table:

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<th>Season</th>
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## Transmission Windows for Vector Borne Diseases

<table>
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<tr>
<th>State/union territory</th>
<th>District</th>
<th>Number of days with $\text{Tmax} \leq 35$; $\text{Tmin} \geq 20$; $\text{RH} \geq 55%$</th>
<th>Number of days with $25 \leq \text{T} \leq 30^\circ \text{C}$; $60 \leq \text{RH} \leq 80%$</th>
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<td>$\text{JF}$ $\text{MAM}$ $\text{JJAS}$ $\text{OND}$ $\text{ANN}$</td>
<td>$\text{JF}$ $\text{MAM}$ $\text{JJAS}$ $\text{OND}$ $\text{ANN}$</td>
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</table>

| Mean                        |                           | 4.1 7% 14.1 15% 88 72% 19.9 22% 126 35% | 4 7% 10.6 11% 48.2 39% 17.3 19% 80 22% |
Transmission Windows for Vector Borne Diseases

Number of days
with $T_{max} \leq 35$; $T_{min} \geq 20$; RH $\geq 55$

Number of days
with $25 \leq T \leq 30^\circ C$; $60 \leq RH \leq 80$

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<thead>
<tr>
<th>Season (annual)</th>
<th>Average no. of days</th>
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Pune
0 0 120 9 129 0 0 66 13 79
2009 June to September rainfall

Swine flu (H1N1), in India shocked into action during July–August 2009

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<th>S.NO.</th>
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<td>MADHYA M'RaASHTRA</td>
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<td>MARATHAWADA</td>
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<td>VIDARBHA</td>
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<th>WEEK ENDING ON</th>
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Climate Forecasts
Stagnation in monsoon progress can lead to Heat Wave
GFS model Forecast
Mean Heat Index and Max heat Index
based on 08 June 2005

10 Ensemble Members

- Pentad max HI forecast exceeding 43°C, 46°C, 49°C. Days 6-10 (Valid for 14-18 June, 2005).

- Probability of mean HI exceeding the value of 38°C for 2 days. Days 6-10 (Valid for 14-18 June, 2005).


- Probability of mean HI exceeding the value of 38°C for 2 days. Days 8-14 (Valid for 16-22 June, 2005).
Max heat Index for days 8-14 (16-22 June 2005)

Pattanaik et al., (2013)
Probability of mean Heat Index exceeding the value of $38^0C$ for 2 days

Pentad (14-18 June, 2005) $38^0C$ for 2 days

Weekly (16-22 June, 2005) $38^0C$ for 2 days
Cold Wave Forecasting (Based on 30 Dec, 2011)

Obs Tmin anom, 03-09 Jan, 2011

MME days 5-11 (03-09 Jan 2011)

Obs Tmin anom, 10-16 Jan, 2011

MME days 12-18 (10-16 Jan 2011)
Observed Heat Wave over Telangana and Odisha in May, 2015
MME Extended Range Forecast for Heat Wave of May, 2015 Over Telangana and Odisha

Forecast Tmax and Anomaly
(22-28 May 2015)

MME week 3 forecast Tmax based on 6th May, valid for 22-28 May, 2015

MME week 3 forecast Tmax anomaly based on 6th May, valid for 22-28 May, 2015
MME Extended Range Forecast for Heat Wave of May, 2015 Over Telangana and Odisha

Forecast Tmax and Anomaly (22-28 May 2015)

MME week 1 forecast Tmax based on 20th May, valid for 22-28 May, 2015

MME week 1 forecast Tmax anomaly based on 20th May, valid for 22-28 May, 2015
MoES (ESSO) institutions are already providing various weather and climate services like:

**IMD**
- operational weather forecasts up to medium range scale
- experimental extended range forecast system in collaboration with IITM
- a number of climate related products and data services

**NCMRWF**
- NWP model based forecasts upto next 10 days based on a suite of NWP models including Ensemble Prediction System (EPS)

**IITM**
- Extended to seasonal range weather forecasts
- Air Quality Monitoring and Prediction

**INCOIS**
- Wave and coastal inundation forecasts
Identify the weather dependent diseases and disorders for which climate-health services could be started in near future.

Identify and provide the right weather/climate data, products and services on the temporal and spatial scales required for climate-health services.

Strengthen disease surveillance for improved case detection, which leads to useful climate-health services.

Discussions on pre-season coordination for strengthening the operational relationships between actors involved early case detection and early warning

Capacity building of local actors for strengthening the core knowledge and skills of those involved in weather-health services (Strengthening the awareness of early warning and forecasting tools and how to make appropriate programmatic decisions for improved system performance).
Building Public Awareness and Community Outreach

Initiating an Early Warning System and Inter-Agency Coordination

Capacity Building Among Health Care Professionals

Reducing Heat Exposure and Promoting Adaptive Measures
Color Signals for Heat Alert

The AMC will issue heat alerts, based on thresholds determined by the AMC, as an additional means of communication by using the following color signal system:

- **RED ALERT**: Extreme Heat Alert Day
- **ORANGE ALERT**: Heat Alert Day
- **YELLOW ALERT**: Hot Day
- **WHITE**: No Alert

Communication Plan When the AMC Nodal Officer Activates a Heat Alert

**TEMPERATURE FORECAST TRIGGERS ISSUANCE OF HEAT ALERT OR HEAT WARNING**

- **Gujarat State Disaster Mgmt Authority** notified
- **Gujarat State Surveillance Unit of IDSM** notified

**Non-Governmental Groups**
- PHFI/IIPH, 108 workers, AIDMI (All-India Disaster Mitigation Institute), Community health groups, and others to help reach the heat-vulnerable

**AMC Nodal Officer**
- Calls Heat Alert as an intervention
- via email, with phone call or fax to verify

**AMC Press Liaison** notified: Media outreach begins
- TV, Print, Radio alerts
- Posters & Pamphlets

**Promote Heat Hotline**
- Alert mobile, phone companies to send text msg

**School Board**
- Information to school students and potential change in summer holiday schedule

**Park, Zoo, Swimming**
- Extend hours

**Hospital**
- Link workers
  - Hospitals/ERs
  - Health center
  - Workers

**Labour**
- Provide water to workers
- Provide work shifts to cooler hours

**Water**
- Provide water to slum dwellers
- Limit non-essential water use

**Torrent Power**
- Maintain power to critical facilities/
  - vulnerable groups

**Transport Officer**
- Provide bus stops as sites of shade &
  - water distribution

**Religious groups/Library Board**
- Temples and libraries as cooling centers

**Information to students**
- Potential change in summer holiday schedule
India being a country with unique geographical conditions witnesses hydro-meteorological disasters throughout the year.

Health impact of climate change associated with increasing frequency of extreme weather are diverse, global and probably irreversible over human time scales.

Increased risks of extreme weather, such as fatal heat waves, floods and storms, potentially more serious effects on infectious disease dynamics.

The health impacts of climate change are potentially huge with developing countries are more vulnerable compared to developed countries.

Many of the projected impacts on health are avoidable, through a combination of public health interventions in the short term, support for adaptation measures in health-related sectors such as agriculture and water management, and a long-term strategy to reduce human impacts on climate.
The risk factor of climate-related diseases will depend on improved environmental sanitation, hygienic practice, and medical treatment facilities.

The problem is very complex and the climate scientist and health Practitioners need to work together (It has just started in India, whereas many countries have already move much ahead)

Action plans like (like Heat Action Plan in case of heat wave) with proper surveillance systems and up-to-date information on diseases is required for providing the best services in health sectors. A lack of these forced the developing countries like India into action during July-August 2009 to tackle the pandemic of swine flu (H1N1).
THANK YOU
Heat Action Plan

Deaths caused by heat waves in India

Till May 31

Quartz | qz.com

Data: Indian Meteorological Department's Annual Climate Reports