The Kerala Floods: Was it Climate Change

K. J. Ramesh
INDIA METEOROLOGICAL DEPARTMENT
NEW DELHI-110003
kj.ramesh@nic.in
Changes in precipitation characteristics over India (1951–2015). (a) Observed changes (mm) in PPT\(_{\text{Total}}\), (b) PPT\(_{\text{Low}}\), and (c) PPT\(_{\text{High}}\). (d and e) Area averaged changes in or northwest India, NWI and north central India, NCI, and (f) area averaged changes in PPT\(_{\text{High}}\) in SI. All changes were estimated using the nonparametric trend test and Sen's method for the period of 1951–2016. Statistical significance was tested at 5% significance level and p value (in d–f) less than 0.05 indicates trends were significant.
Budget components (Precipitation, ET, and Total Runoff) from calibrated VIC model for 1980–2012 period for the monsoon season and annual time periods.
(A) Groundwater recharge (%) due to monsoon season rainfall,
(B) groundwater recharge due to other sources (canals, surface water bodies, irrigation return flow)
(C) state wise distribution of recharge during the monsoon season from rainfall and other sources, (D) state wise distribution of annual groundwater recharge due to different sources.
Data were obtained from CGWB.
Elevation ranges from -48 m below sea level to 750 m above mean sea level, with 35% area between 0-50 m, 39.82% are between 50-500 m, 18% of area above 500 m.
(a) Mean P for the monsoon season during the period of 1971–2000; (b) trend in P (mm yr⁻¹) during the period of 1901–47 estimated using the Mann–Kendall test; and (c) as in (b), but for the period of 1948–2012.
Indian Southwest Monsoon (June to September)

% of Heavy rainfall days

Mean % of Very heavy rainfall days
Frequency of Heavy Rainfall Events
June to September

Heavy Rainfall Events

HEAVY RF > 10 CM

Very HEAVY RF > 15 CM

Disaster and Climate Risk

Disaster risk is determined by the occurrence of a natural hazard (e.g., a cyclone), which may impact exposed populations and assets (e.g., houses located in the cyclone path). Vulnerability is the characteristic of the population or asset making it particularly susceptible to damaging effects (e.g., fragility of housing construction). Poorly planned development, poverty, environmental degradation and climate change are all drivers that can increase the magnitude of this interaction, leading to larger disasters.

Total loss and damage from hydro-meteorological disasters, by affected sector (1972–2013)

- **Economic Losses**
  - Social sectors: 71%
  - Infrastructure sectors: 5%

- **Physical Damages**
  - Social sectors: 32%
  - Infrastructure sectors: 31%
Multi-Hazard Vulnerability
Extreme Weather associated with South Asian weather systems

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

Off-shore vortices
Easterly wave
Western Disturbance
Fog
Numerical Weather Prediction (NWP) Modeling: Backbone for Forecasting and Warning Services

Models in 2018
- Ensemble Prediction Systems
  - GEFS (12km), UMEPS (9Km)
- Global Models
  - GFS (T1534), Unified
  - Regional Models
    - WRF, HWRF
- Nowcasting Tools
  - WRFSSII, ARPS Model
- Warnings Activities

By 2020:
- 1-3 km Regional multi-model prediction system, ocean-atmosphere-land surface coupled severe weather pred. systems,
- Parametric models and Expert systems – severe weather Warning up to 5-7 days, Forecast outlook up to 10-15 days.
India southwest Monsoon 2018 heavy rainfall warning skill (24, 48, 72, 96 & 120 hours)

Period of severe weather warning increased from 3 days to 5 days

Coded meteorological subdivision and district level impact based warning issued across India
WRF (3 km) Forecast & IMD observed Rainfall Analysis at 03 UTC 15-08-2018

OBSERVED (0.25x0.25 Deg.) RAINFALL ANALYSIS (mm)
on 03 UTC of 15-08-2018

IMD MESOSCALE MODEL (03 Km) 24 HOURLY RAINFALL (mm) FORECAST (24 hr)
based on 00 UTC of 14-08-2018 valid for 03 UTC of 15-08-2018

MESOSCALE MODEL (03 Km) 24 HOURLY RAINFALL (mm) FORECAST (48 hr)
Based on 00 UTC of 13-08-2018 valid for 03 UTC of 15-08-2018

IMD MESOSCALE MODEL (03 Km) 24 HOURLY RAINFALL (mm) FORECAST (72 hr)
based on 00 UTC of 12-08-2018 valid for 03 UTC of 15-08-2018
Rainfall over Kerala and associated large scale flooding

Rainfall over Kerala so far during southwest monsoon season 2018 (1st June to 20th August 2018) has been exceptionally high.

Kerala received 2377.1 mm against a normal of 1676.3 mm (above normal by 42%).

Rainfall over Kerala has been in general above normal throughout the season. The rainfall over Kerala during June, July and August (1-20 August) has been 15%, 18% and 156% above normal respectively.

Exceptionally high rainfall in August, 2018 so far has been due to two consecutive active spells, viz., 8th – 10th August and then during 14th – 17th August.

**vel Storage Scenario in reservoirs**

For this rainfall scenario, by the end of July, 2018, in all the major 35 odd reservoirs in Kerala, storage was close to the Full Reservoir Level (FRL) and had no buffer storage to accommodate heavy inflows from 8th August (source: Kerala State Electricity Board website, sldckerala.com/index.php?id=7).

Continued exceptionally heavy rainfall in August in the catchment areas had compelled the authorities to resort to heavy releases downstream into the rivers leading to widespread flooding. Taking an example of the largest reservoir of Kerala, according to State Load Despatch Centre (SLDC) of Kerala State Electricity Board website, the first water release from the largest Reservoir, Mullai reservoir was done on 10th August.

Water release continued thereafter with about 50-70 mcm per day till 14th August. However it picked up on 15th August to 390.5 mcm per day followed by 126 and 115 MCM per day on 16th and 17th August leading to devastating flood in downstream areas of the dam.
It may be mentioned that the highest excess rainfall during the season has been recorded over Idukki District (93% above normal) during the season (1 June-19 August). During the week ending 15th, 8th, 1st Aug., 25th and 18th July Idukki district recorded continuously excess rainfall (70%, 41%, 45%, 49% and 46% above normal respectively).

**Ivy rainfall Warning by IMD**

The Meteorological Centre, Thiruvananthapuram issued the heavy rainfall warnings at district level at least 2 to 3 days in advance of their occurrence on day to day basis. The warnings were issued to Chief Secretary, Addl. Chief Secretary (Revenue & Disaster Management), State Disaster Management Authority, State Emergency Operations Centre, District Collectors, Navy, Special Marine enforcement, press and electronic media.

**ansion of IMD, Thiruvananthapuram Activities**

Following the OCKHI cyclone impact, IMD has set up a Cyclone Warning Centre(CWC) at Thiruvananthapuram office that can fully take care of the special needs of the state, the neighbouring state of Karnataka and Islands of Lakshadweep.

Already, IMD, Thiruvananthapuram is working on improving the forecast customization and dissemination facilities. Apart from building cyclone warning services at Thiruvananthapuram, IMD will organize awareness and training workshop for the disaster management authorities and other stakeholders of Kerala.
Hydrological Study of August 2018 Kerala Floods using Remote Sensing, Modeling and Geospatial tools

Indian Institute of Remote Sensing
Indian Space Research Organization
The major Land Use and Land Cover (LULC) in Kerala is Plantation (22255 km², 58.23%), Deciduous and Evergreen Broad Leaf Forest (7849 km², 20.5%), and Shrubland/Grassland (4307 km², 11.27%) and Waterbody/Urban/Others (3806.5 km², 9.95%).

The major soil type of Kerala are Clay/Clay skeletal (31963 km², 83.83%), Loamy/Loamy skeletal (5339.20 km², 14%), small fractions of soil sandy. This high area under clayey soils result in high runoff potential during heavy rainfall in all major catchments of state.
Geological characteristics of Kerala and surrounding states

<table>
<thead>
<tr>
<th>S. No</th>
<th>Basin name</th>
<th>Area (km²)</th>
<th>Total Drainage (km)</th>
<th>No. of sub-watersheds*</th>
<th>Mean Te (hours)**</th>
<th>No of major dams/reservoirs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Periyar</td>
<td>4276.91</td>
<td>527.16</td>
<td>47</td>
<td>6.92</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Pamba</td>
<td>2486.7</td>
<td>320.37</td>
<td>17</td>
<td>12.14</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>North Region</td>
<td>1008.4</td>
<td>114.73</td>
<td>11</td>
<td>11.21</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Muvattupuzha</td>
<td>1560.7</td>
<td>196.15</td>
<td>15</td>
<td>13.35</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Mannar</td>
<td>1234</td>
<td>155.83</td>
<td>7</td>
<td>20.48</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Kambini</td>
<td>6853</td>
<td>834.87</td>
<td>89</td>
<td>9.75</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Kadalundi</td>
<td>886.79</td>
<td>109.5</td>
<td>8</td>
<td>14.54</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Chaliyar</td>
<td>2915.73</td>
<td>329.93</td>
<td>37</td>
<td>7.16</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Chalakudy</td>
<td>1309.84</td>
<td>187.04</td>
<td>15</td>
<td>5.94</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Bharrathapuzha</td>
<td>5884.24</td>
<td>782.92</td>
<td>73</td>
<td>9.88</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>Kooroor</td>
<td>1045.28</td>
<td>107.15</td>
<td>14</td>
<td>10.69</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Puzhakal</td>
<td>1523.473</td>
<td>176.7</td>
<td>19</td>
<td>12.4</td>
<td>3</td>
</tr>
</tbody>
</table>

*The watersheds are delineated using SRTM-30 m DEM, and minimum watershed area threshold for defining a stream is given as 50 km². The derived drainages and number of sub-watersheds are based on this threshold. The total drainage length and number of sub-watersheds will increase if we decrease this threshold.

** The Time of concentration is calculated for each sub-watershed of each river basin with 50 km² area threshold and TR-55 method. The actual time of travel for entire basin.
Hydrological modelling (1-23 August 2018) using HEC-HMS

- All 12 major flood affected river basins are studied for detailed basin wise DEM based hydro data processing and virgin hydrological simulations using Hydrological Modelling System (HMS)
- IMD-GPM gridded data used as input met data, SCS method for loss, and SCS unit hydrograph as runoff transformation, Muskingum-Cunge as routing & constant monthly baseflow, in all basins simulations

The detailed hydrological modelling was done for Periyar basin with outlet at Alluru Manappuram Rail bridge, Periyar Nagar using HEC-HMS model.

- Basin has 47 sub-watersheds, with total area of 4276.9 km² and 527.16 km of drainages.
- Rainfall data from IMD product at 0.25 degree was used for simulating the river flows. Rainfall at various sub-watersheds and simulated river flood flow hydrographs are shown in figures. Two flood peaks are seen on 10 and 16 August 2018

---

Hydrological modelling for estimating potential flood flow hydrographs (1-23 August 2018) in major rivers of Kerala

The Northern Kerala river basins such Kambini and Puzhakal also received heavy rainfall during 7-10 and 14-10 Aug. 2010, which resulted in many landslides in upper catchments of Kerala and Karnataka, flooding along river and major flood inundation in Wayanad and Thrissur areas
Flood inundation mapping using hydrodynamic modelling – MIKE 11 HD model

- Hydrodynamic model was established for a Periyar river reach of 17.5 Km with upstream end at Cheruthoni dam using MIKE 11
- Simulation was carried out in steady state condition for discharge of 770 cumec generated after opening of 05 gates of the dam

Flood inundation d/s of Cheruthoni dam as simulated using MIKE 11
Flood inundation mapping using remote sensing data

Aug 09, 2018, Sentinel-1
Aug 21, 2018, Sentinel-1
Aug 22, 2018, Sentinel-2

Flood inundation maps from Sentinel-1, 2 data using Google Earth Engine & GIS tools
Pre-flood water body maps generated using...
Future Plans for Coastal Areas

Building multi-scale & multi-sensor networks for Long-term measurements of various environmental/terrestrial/marine/bio-geochemical/GHG variables at ge/regional/local/eco-system scales to capture vital signatures of the earth system response to climate variability and change

Comprehensive multi-institutional Program for Changing Water Cycle; thermal expansion Bay of Bengal and Arabian Sea; Sea Level Changes & coastal zone impacts; Engineering and Technical Solutions for Structural Safety of Coastal Investments

Id Earth System Model (ESM) to treat comprehensively the coupling of various sub-systems (ocean-atmosphere; land-atmosphere; cryosphere-atmosphere; biogeo-chemical cycles over ocean and land; aerosols-GHG-clouds-precipitation etc.) to improve our predictions of weather, climate, hazards, air quality and Environment

Expanding services in support of four key climate-sensitive sectors, including agriculture, water, health, Energy and climate and disaster risk management for rendering customized services for societal, environmental or economic benefits

Accelerating initiatives related to Capacity Building – for regular induction of skilled and specialized manpower
Thank you