FLOODS IN SOUTHWESTERN SRI LANKA IN MAY 2017

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Orographic Rains Induced by a Cyclonic Storm in the Bay of Bengal triggered the Floods in Southwestern Sri Lanka in May 2017

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Abstract: *Studies of the floods, landslides and mudslides around Ratnapura, Galle, Kegalle and Matara Districts around 24-26 May 2017 have not reported on its meteorological drivers. The heavy rainfalls was coincident with a storm in the Bay of Bengal that formed before the 20th and intensified to a cyclone by the 28th. The cyclogenesis took place around 1000 km to the East of Sri Lanka and it slowly tracked Northward. Sri Lanka experienced intense winds from the 14th onwards due to the long-range impact of this storm. Such rapid wind can interact with the topography to lead to intense orographic rainfall in the windward slopes of the mountain.*

Here, we analyze the rainfall, the cyclone track, wind fields, the topography, and satellite imageries and show that the precise dates and the locations of the heavy rainfall on the 24-26th and find that these are consistent with what is expected from the orographic rainfall mechanism induced by the wind field of a remote cyclone located in the Bay of Bengal. The wind was dramatically increased from the North-Westerly direction on the 14th of May and stayed high till May 31. The peak rainfall on the 24-26th was on South-western mountain slopes located on slopes that give unimpeded channels for westerlies. For the 24th to 26th, the regions that experienced peak rainfall were situated on the north-western slopes of the mountains which were not impeded by the wind field. The majority of deaths and inundation were reported from such sub-districts on these slopes or that which received its streamflow.

Keywords: ***Landslide, Flood, precipitation, cyclone Mora.***

1. Introduction

Floods, landslides and cyclones are common and critical disasters in Sri Lanka are frequently triggered by meteorological antecedent (Zubair et al., 2006). The impacts of remotely passing cyclones too can have an impact on places with suitably oriented topography as happened on December 26, 2003 in the Ratnapura area landslides which led to 260 fatalities (Zubair, 2004). The hills of Sri Lanka have a consistent diurnal and seasonal variation (Zubair, 2002). Unusual wind along with unusual rainfall in places that do not experience it in the past can trigger landslides and mudslides.

Floods and mudslides of large magnitude occurred in Ratnapura areas were reported on 25/26-05-2017 inundating several villages. 575,618 people (147,927 families) were affected in total; 213 deaths were reported due to the floods – by district the fatalities were Ratnapura -86, Kalutara -66, Matara -31, Galle -16 (DMC, 2017).

The details of spatial and temporal distribution of rainfall that led to the landslides and floods for this region have not been reported on so far. Moreover, if we can identify the mechanisms that lead to enhanced rainfall in certain locations, we can use that information to make landslide warnings more specific and accurate.

- *Floods and mudslides*

Factors that lead to floods include obstruction of waterways, deforestation, buildings on flood plains and river margins. Rainfall was the immediate trigger and the rainfall for May 2017 has been a historical peak exceeding 400 mm in a day.

- *General rainfall and wind patterns in the South Western hill slopes*

The Inter-Tropical Convergence zone is overhead in May. During May the heaviest rainfall is large scale and due to the associated zonal cloud bands. The wind during May over Sri Lanka is usually Westerly and modest (Gadgil et al, 2011, Zubair, 1998, 2002)

- *Orographic Rainfall*

Air may be forced to rise when land barriers such as mountain ranges lie in the path of extensive air masses. The ideal conditions are when winds off a warm ocean meet a relatively continuous mountain range close to the coast, at right angles (Zubair, 1999). There is orographic augmentation of rainfall in the mountain slopes 10-20 km to the windward side – the western slopes see augmentation from May to September and the eastern slopes from December to February.

- *Storm / Cyclone Mora*

Low wind shear and warm sea surface conditions in late May 2017 favoured the development of cyclonic storms. Observations & satellite imagery indicated that a depression had formed over central Bay of Bengal in the previous week and this intensified to cyclone status by 0530 of 28th May, 2017 with its eye at 14.0º N and 88.5 ºE. (RSMC, 2017)

This paper describes the spatial and temporal evolution of rainfall in this region, examines the topography and wind circulation to examine its consistency with a theory of augmentation of rainfall through the orographic rainfall mechanism.

2. Methodology

2.1 Data

- *Surface observed rainfall and wind speed data*
  Daily rainfall data for May 16th-30th of 2017, from Badalgama, Ellagawa, Millakanda, Pitabeddara, Putupaula, Ratnapura, Tawalama and Urawa are from the Department of Irrigation and daily rainfall and wind speed data for Colombo, Ratmalana, Ratnapura and Galle are from the Department of Meteorology.
- *Satellite observed rainfall estimates and wind speeds*
  Gridded daily rainfall estimates at a grid size of 10 km is available from the National Oceanic and Atmospheric Administration (NOAA) /Climate Prediction Center (CPC). We use IRI/FECT tool that estimates data for Sri Lanka.
- *Regional Wind Field*s were obtained from National Centers for Environmental Prediction-National Center for Atmospheric Research Reanalyses (NCEP-NCAR), National Aeronautics and Space Administration (NASA) worldwind project (Worldwind.arc.nasa.gov, 2017)
- *The track of cyclone Mora* was obtained from Regional Specialized Meteorological Centre (RSMC, 2017) and augmented by our analysis of wind fields.
- *Topography* was obtained from United States Geological Survey (USGS).

2.2 Methodology

- *Quality Control of Surface Data*
  Data from the 12 stations was compared with those in the neighbourhood and satellite rainfall estimates. Some suspect date were eliminated.
- *Identification of Slopes of Incidence and Rainfall Observations* – the slopes of the topography was identified from news-reports and spatial analysis.

- *Comparison of Windfields and Rainfall* in a few locations were done from estimates from the worldwind project and from the NCEP-NCAR.

3. Results and Discussion

3.1 Geography of Affected Locations

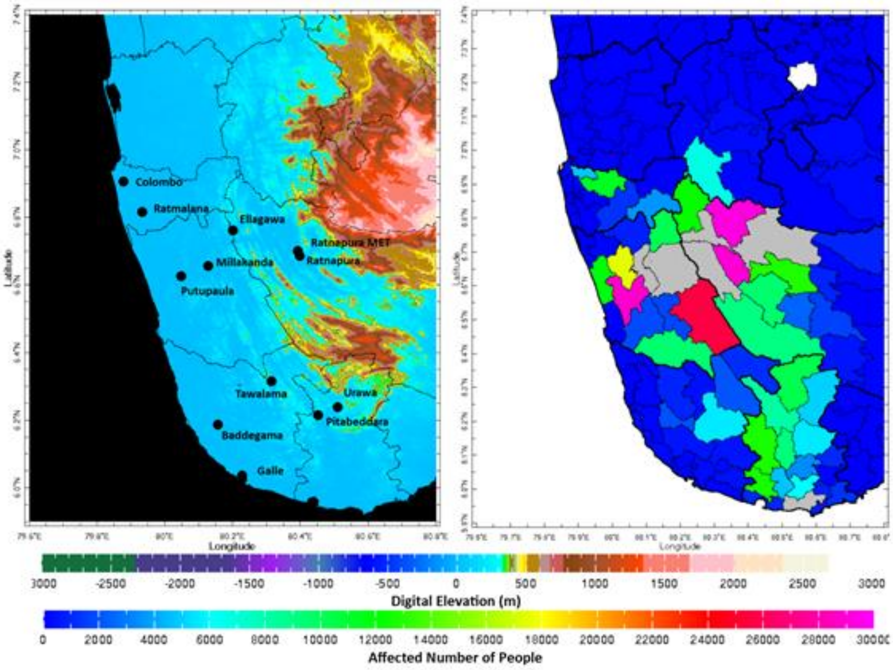


Figure-1. (left) Topography map of the region mapped from USGS 30 second resolution DEM and (right) the Affected number of people by DSD.

The major floods and mudslides too place on the steeper north-west-west facing mountain slopes near the steep Adams Peak (2243 m a.s.l) and Gonagala mountain (Gonagala mountain 1358 m a.s.l near Pitabeddara and Urawa) complexes (Figure 1). There is unimpeded access to winds from the North-West in this region.

3.2 Rainfall Observations

The aggregate rainfall for 11-20 May reached 120-150 mm in the western half of Sri Lanka in the following dekad (21-31 May), there continued to be additional rainfall of over 400 mm in the Ratnapura, Kalutara, Galle and Matara districts while other neighboring districts had lesser rainfall (Figure 2).

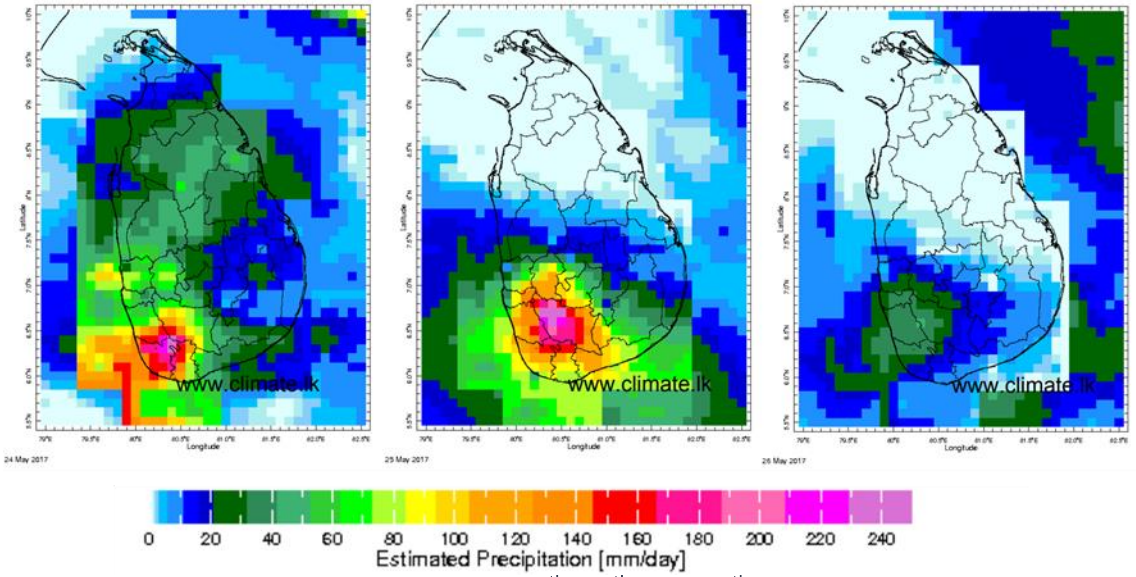


Figure-2. Daily rainfall estimations for 24th ,25th and 26th May 2017 for Sri Lanka

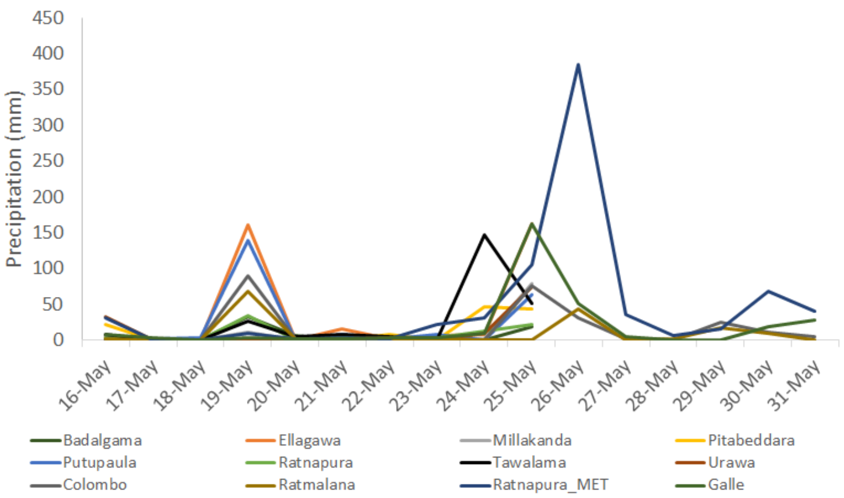
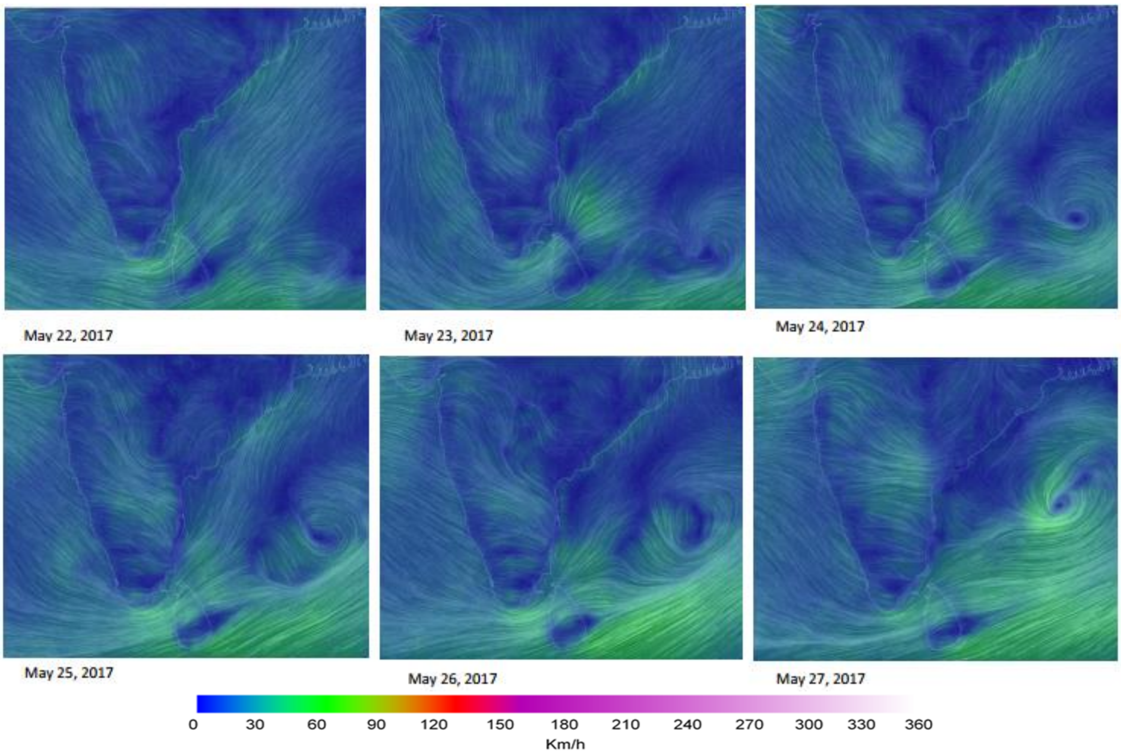


Figure-3. Daily rainfall graph of May 2017 for weather stations in southwestern regions

On the 19th most stations show a spike in rainfall with Ellagawa and Putupaula regions receiving rainfall up to 160 mm and 140 mm respectively. On the 24th Tawalama region received rainfall up to 150 mm. 160 mm of rainfall was recorded in Galle and Ellagawa regions on the 25th - the Department of Meteorology station in Ratnapura recorded a rainfall up to 100 mm. The highest rainfall of 400 mm was recorded in the same station on the 26th. Note, Ratnapura is a hilly area and there is often differences among the stations as in this case – there is also often issues with calibration and observations of extremely high rainfall.

3.3 Cyclone Track and Wind Field



The cyclonic storm formed about 500 km East of Sri Lanka in the Bay of Bengal before the 22nd of May and tracked Northwards – in this period the winds over Sri Lanka were intensified and were from the South-West to South-West-West.

3.4 Time series of Wind Observations

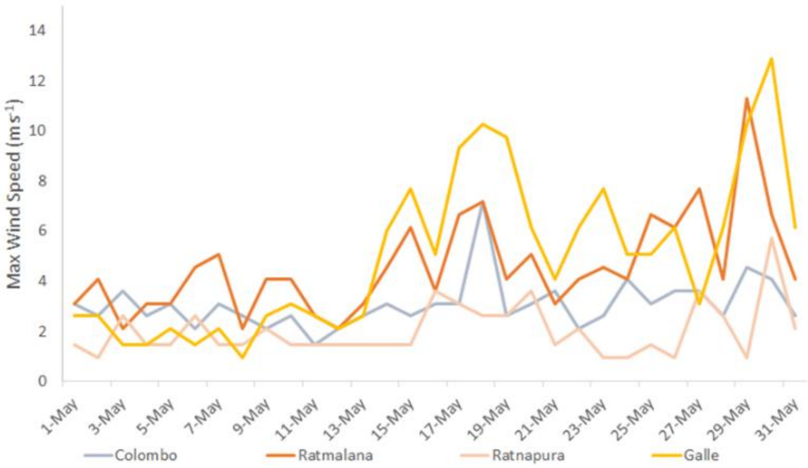


Figure-5. Daily Maximum Wind Speed graph for May for the Department of Meteorology stations in Southwestern Sri Lanka

Figure-4. Wind Pattern over Sri Lanka during 22nd-25th May – worldwind.arc.nasa.gov.

The wind speeds were high on the 14th of May onwards – after the 31st wind speeds dropped fractionally. The wind directions however were from the South-West on the 15th, West on the 16th and from South-West after the 18th. These changes in wind directions shall lead to augmentation of rainfall in areas that have Mountain slopes that are South-West facing.

4. Conclusions

Some of our findings were:

- The heavy rainfall in Sri Lanka was located in the region around where the floods and landslide occurred and were at a historical high.
- The cyclone led to extreme wind fields which were coincident with heavy rainfall.
- The wind directions and distribution of rainfall were consistent with a model of orographic augmentation on the Western facing slopes of the Adams peak and Gonagala mountain complex.
- The major human impacts of the cyclone were also on these South-West to South-West-West slopes.
- The reasons as to why there was no heavier rainfall in the other dates than the 24^{th} and 25^{th} from 14^{th} to 31^{st} were not conclusively determined. But such an absence was captured in climate models as well.

Detailed testing of the above inferences shall require mesoscale wind and rainfall modeling which we shall undertake in the future. Given the implication of the orographic rainfall augmentation, we can classify landslide risk based on the likelihood of wind directions and landslide hotspots based on climatology and weather models in the future. This shall be a vast improvement on early hazard warning at present.

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