Why Floods Occurs Over Tamil Nadu Coast?

Jayesh Phadtare*
PhD student, Indian Institute of Science, Bengaluru
Email: phadtare@iisc.ac.in

The annual arrival of monsoons over India is one of the robust meteorological phenomena over the Earth. However, we also face its capricious behavior during its stay. This year there were 1,400 deaths reported in India due to floods during monsoon. In the month of August, the southwest monsoon unleashed its fury over Kerala where widespread heavy rainfall and flooding brought the entire state to a standstill. About 483 people died due to rains. In November 2015, Kerala's neighboring state Tamil Nadu suffered the same fate during the northeast monsoon. Around 500 deaths and Rs.20,000 cr. economic losses were reported in Tamil Nadu then. On 1 December 2015, a weather station in Chennai recorded 494mm of rainfall within 24hrs. This was 'once-in-a century' rainstorm. On the very next day, Chennai was declared as 'disaster zone' by the state government. Armed forces and the NDRF teams were deployed for relief and rescue operations. The scale of this operation was one of the largest in the recent times.

With the frequent occurrences of catastrophic floods, following questions are raised: Are we able to predict floods? Are they due to climate change? And how should we prepare for them? Satisfactory answers to these questions will come only when we understand the underlying meteorological mechanisms of floods. Here the word 'flood' refers to the heavy/extreme rainfall, and not to the surface inundation. However, note that the former is often the cause of the latter. As far as the weather prediction is concerned, modern-day computer models are doing a decent job to predict flood events, thanks to the advancements in the satellite and computing technology. A computer weather model is a set of mathematical equations. These equations – laws of fluid

* Mr. Jayesh Phadtare, Ph.D. Scholar from Indian Institute of Science, Bengaluru, is pursuing his research on "Cloud Dynamics." His popular science story entitled "Why Floods Occur over Tamil Nadu Coast?" has been selected for AWSAR Award

mechanics, thermodynamics, and radiation – govern the evolution of entities, such as, temperature, pressure, winds, water vapor. So, if we know these quantities at time t1, by solving these equations we can predict the state of these quantities at time t2. Satellites and ground weather stations do the job of recoding the quantities at time t1. Then by running a computer model we can predict the quantities at time t2. However, although we understand the above laws/equations when considered individually, a weather phenomenon couples these laws and evolves in a far more complicated manner which we still don't understand completely. Thus, without an exact understanding of the working of real world weather that leads to the events at time t2, we are still using these models like a 'black box'. Further improvements in the models and better comprehensions of their forecasts will happen only when we understand our weather systems well. Part of my PhD research at the Indian Institute of Science is to understand the dynamics of storms using satellites and computer models. I have studied the storm that resulted in the record-breaking rainfall on 1 December 2015 over Chennai mentioned before in the article. The study was published by the American Meteorological Society in *Monthly Weather Review.*

During winter monsoon, many tropical depressions form over the Bay of Bengal and move westwards towards Indian peninsula. They give heavy rainfall over the east coast during their passage. Rainfall accumulations of 100-200mm in a day are normal over Chennai due to these depressions. The study first identifies that the unprecedented flood over Chennai on 1 December 2015 was due to the storm-clouds being stationary over Chennai for about two days. By performing computer simulations of the event, the study proposes a mechanism by which this happens.

Chennai is located right over the east coast, and the Eastern Ghats (EG) are about 200km inland. In the winter monsoon, winds blow from east towards the EG. The study says that when these winds arrive over the Indian peninsula, their fate is decided by the kinetic energy (wind speed) they possess. If winds are strong, they might have enough energy to climb the EG mountains. If winds are weak they get blocked by the mountains (imagine someone throwing a stone up in the air; the greater the throwing speed, the higher the height reached). In latter case, winds are

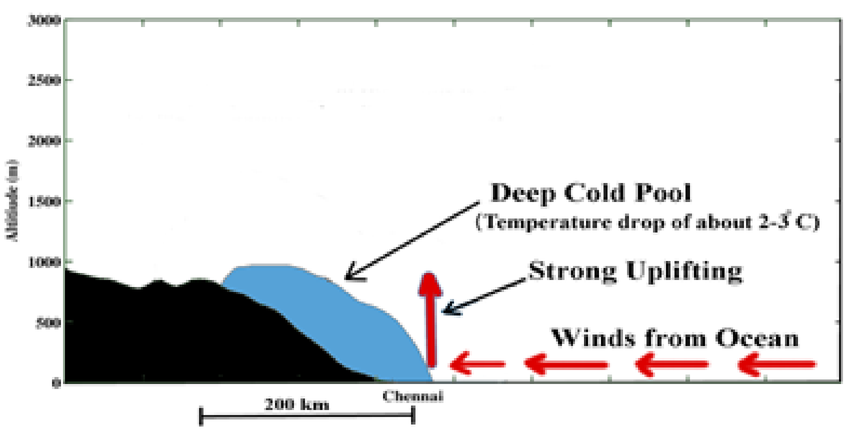

Figure 1: *Schematic of cold pool piling and uplifting of warm air*

deflected; they flow around the mountains. Further, if raining clouds also approach east coast with these winds, the raindrops evaporate by absorbing heat from the surrounding air while falling down from the clouds. The evaporation cools the surrounding air. This cold air lying over the ground and below the cloud-base is known as ‘cold pool’. The cold pool is denser than the surrounding air, so winds need to exert more force over the cold pool to lift it over the mountains. If winds are weak, cold pool will flow against the winds and will get disorganised. With stronger winds, the cold pool is pushed towards the mountains by the winds; if winds are very strong, cold pool will be carried over the mountains by the winds. At a critical wind speed (around 10m/s), cold pool can’t flow over the mountains, but remains organised. It starts accumulating along the mountain slopes and backward towards the coast, very similar to the river water when blocked by a dam. A pile of cold air is steadily held against the mountain by the winds. This pile can be as tall as the mountain itself (figure 1).

The edge of the cold pool can reach hundreds of kilometer backward over the coast. Now, the warm and moist winds that arrive at the coast get uplifted by the cold (dense) air of cold pool. Thus, an invisible mountain of cold pool sits right over the coast, much ahead of the actual EG mountains.

The uplifting of warm and moist winds result in more cloud formation over the coast and the raindrops that fall out from clouds feed the cold air to the cold pool. Thus, as long as the winds supply the optimum amount of kinetic energy and moisture, the pile of cold pool can stand for several hours without getting diffused; and clouds rain continuously over the coast, inundating the surface below it. This is what happened on 1 December 2015 over Chennai. We have known the effect of Western Ghats (WG) on the west coast rainfall for centuries. This is the first study that relates the copious rainfall over the east coast to the EG. With this understanding of the underlying

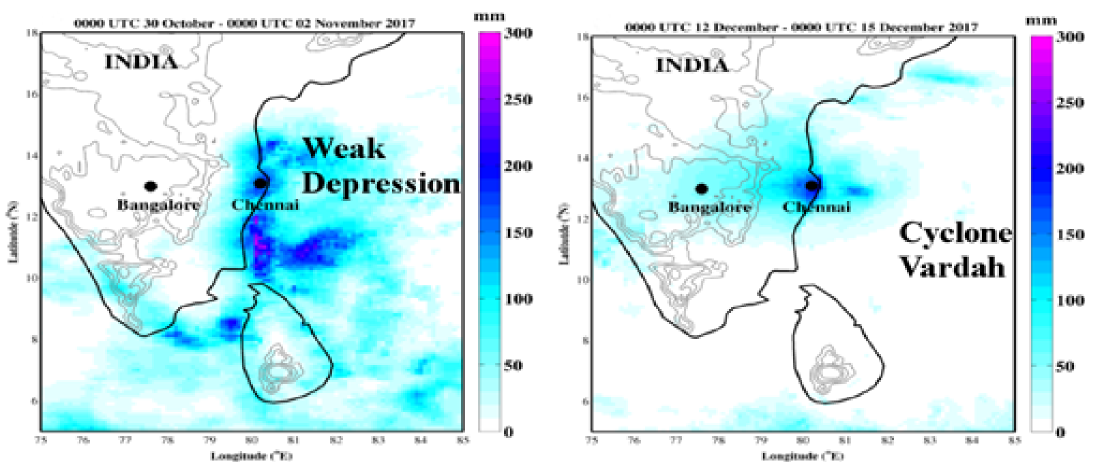

Figure 2:A *3-day rainfall accumulation from NASA’s GPM satellite. Left panel shows rainfall accumulation for weak depression that was stationary at the coast; right panel shows rainfall accumulation for tropical cyclone Vardah. The track of Vardah is shown in the inset figure.*

mechanism of storm stagnation, extreme rainfall over the coastal zone can be predicted with greater confidence. We can predict which weather systems will get stalled at the coast due to EG mountains and which will pass over the coast by climbing up the EG heights. According to the above theory, weaker cyclonic depressions can be blocked by the EG mountains whereas, strong cyclonic storms will cross the mountains. This answers the question of prediction asked before in this article.

Figure 2 shows a 3-day accumulation of rain for two cases – on the left, for the blocked weak depression (wind speed of about10 m/s) in October 2017 and, on the right, for very severe cyclonic storm 'Vardah' (wind speed of about 30-40m/s) in December 2016. The track ofVardah is also shown in the inset. It shows that in the first case, rainfall accumulation is high (reaching 300mm) over the coastal zone, whereas, over the EG and plateau there is no rainfall. In the second case, cyclone Vardah crossed the Indian peninsula; the rainfall for this case is less intense over the coast (reaching 200mm) than the previous case and more uniformly spread over the peninsula. This suggest that the weak depressions, if they get blocked by the EG mountains, can cause more severe local flooding than the full-blown cyclone. Therefore, we should not take them lightly and their development over the region should be followed seriously. The infrastructure developed in the coastal area should not only account for the impact of severe cyclones but also for the 2-3 day flooding due to stalled storms. An action plan should be chalked down for these flooding. Action plan designed for the cyclones may not entirely be applicable for the 2-3 day flooding event, considering the discrepancies in the wind speeds, the rainfall distribution, and the lead time available for preparation in these two systems.

As far as the question of climate change is concerned, a research should be undertaken to analyse how the storm-dynamics is getting affected by the warm temperatures,then we will have a more concrete physical evidence for it rather than just the stats. As far as science is concerned, proving a relation with statistics can be clever, but explaining the physical mechanism behind it is more satisfying!