

# ‘Hidden in the Havoc’ Hydrological Solutions and the Need for Innovative Studies into Extreme Events.

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**Abstract:** *Managing water resources is a very complex and difficult exercise, because demand for water is always on the increase, while its distribution and availability is uneven, coupled with a lot of unpredictable variations. Often times managing the vagaries of water becomes a dangerous exercise too. Extreme water events like floods, thunder storms and avalanches may even cause danger to the lives of those involved in the management of the same, besides the victims themselves. Moreover it is extremely strange and interesting to note that the havoc created by those extreme events resulting from wild and unpredictable changes in the state and flow of water, consistently carry hidden solutions to the problem of managing those events. This peculiar phenomenon being unique only to water related havocs, calls-for mechanisms that will keep a full record of each extreme event for a later exploration for finding those solutions.*

## Introduction

As an introduction to this phenomenon, let us examine a typical example that points to the vital and pivotal importance of keeping reliable data records of those extreme events for unearthing the hidden solutions with in them. The extreme event under consideration is a thunder storm which develops in a few hours and causes severe damage to human life and property. But the information (data) how the lightning flashes i.e.; the direction of the flash of light that occurs during these flash floods in association with the thunders, holds the key to finding solutions as discussed below.

## 1. Thunder Storms, Flash Floods and Now-Casting:

Flash floods are the most common natural disaster in the United States, and because of their unpredictability they're the leading weather-related cause of death for Americans. They usually arrive with little or no warning, but a Tel Aviv University

researcher is able to predict where and when they will occur - using lightning. Prof. Colin Price, coordinator of the international "Flash Project" and head of the Geophysics and Planetary Physics Department at Tel Aviv University, studied the link between lightning and subsequent flash floods. The three-year study included scientists from five European countries, and its results are adopted by weather forecasting agencies around the world. The goal is to develop an early warning system for people in the path of a flood. Flash floods are different from normal floods, which are often the product of melting snow. Flash floods are short-lived and dump a lot of rain. Using the radiation emitted from lightning flashes, a warning system was developed, that can give adequate warning to the public- and save lives, by way of sending messages to cell phones, RSS feeds, GPS units and other devices to warn people in the path of a flash flood and avert disaster [1].



**Figure.1- Lightning Flash before the Flood**

A wild lightning storm passes overhead with bolts hitting the foothills, revealing a link between lightning and subsequent flash floods.

## 2. Flash Flood Warnings:

Unlike normal floods which arrive slowly and with more warning, flash floods are particularly dangerous because they happen so quickly, developing from thunderstorms that form in a matter of hours. By measuring the radiation emitted by lightning, researchers can pinpoint the most intense

thunderstorms, and the resulting rainfall can be located and tracked.

“Now-casting,” is predicting what conditions will be in the next few hours, as against, “forecasting” which is predicting what conditions will be in a day or two in advance. Now casting is critical.

By observing the real-time lightning data, Tel Aviv University researchers could see where storms will travel over a period of a few hours, and can warn people in the path of the flood of impending danger. The U.S. National Lightning Detection Network could easily apply the results of the Flash research. This is a tool for the future, and it will be even more exciting, when continuous real-time detection of lightning activity is available from satellites. That data will be used to predict floods anywhere.” The U.S. also has geostationary satellites with lightning trackers that will take a picture every 15 minutes from 36,000 kilometers above the earth.

The FLASH project focused on using lightning observations to better understand and predict convective storms that result in flash floods. For the analysis of these storms lightning data from the ZEUS network were used together with satellite derived rainfall estimates in order to understand the storm development and electrification. In addition, these case studies were simulated using mesoscale meteorological models to better understand the meteorological and synoptic conditions leading up to these intense storms. Tools for short term predictions (now-casts) of intense convection across the Mediterranean and Europe, and long term forecasts (a few days) of the likelihood of intense convection were developed. While flash floods and intense thunderstorms cannot be prevented as the climate changes, long-range regional lightning networks can supply valuable data, in real time, for warning.

### 3. Now casting:

Modern observing systems such as Doppler weather Radars continuously scan the whole sky. Radar pictures are repeated every few minutes and thus keep tracking the movement of clouds, Both cyclonic storms and severe thunderstorms are very effectively tracked by radars. This kind of prediction is a valid one for only few hours and is called Now casting. Being an extrapolation of the observation itself, it is highly accurate. Now casting is a term coined in 1980s by UK Met Office scientist Professor Keith Browning [2].

It is extensively used in Economics also. In meteorology it became a significant product after very short range NWP techniques were added to the observational component. This extended the range of prediction to 3-6 hours. Meteorologists have developed Numerical Weather Prediction models (NWP) that can be used to make forecasts of the hydrological system. Research done in the

Netherlands showed that a combination of rain gauge and radar data gave the best results. This increases the trustworthiness and accuracy of data [3].

Now casting implies the short term (up to 3 h) forecasting of heavy rainfall events. Using the ZEUS ground-based lightning detection network and the Warning Decision Support System – Integrated Information (WDSS-II) software, a now casting ability over the Mediterranean region was developed. Thousands of thunderstorms were used in developing the final now casting algorithm. Now casts are provided for 30, 60, 90 and 120 min lead time. The algorithm first clusters the lightning flashes into thunderstorm cells. Every 15 min these clusters are recalculated and motion vectors estimated for each thunderstorm cluster. The storms are then propagated forward in time with updates to the motion vectors every 15 min. This method has been implemented for the use in real time now casting and is used to automatically seek and track areas of thunderstorm risk according to lightning intensity. These predictions are data intensive and clearly show the vital importance of event information in real time and on all possible concerned parameters. The point to note is that, before the flash project, the importance of observing the radiation emitted from lightning flashes is hardly realized and appreciated. But that has now become a must record to be maintained [4].

This leads us to the only logical conclusion that for managing the water resources the **HIS** (Hydrological Information System) should include all possible parameters of Water, including those that are not currently used are also observed and data generated for future possible usefulness. Therefore **the design of HIS** should be inclusive and comprehensive and should be guided by connected National policies and practices. **HIS** should reflect and serve present projects as well as future needs of possible innovations. Present actions in putting suitable futuristic observation networks in place, is essential, as data will not be useful unless it is generated over longer periods of time. Similar data intensive extreme events like the devastating 2009 Kurnool floods that occurred in A.P. state, in India, needs a similar data built up for future preparedness to avert recurrence of such large scale damages.

### 4. Global Water Partnerships:

Water information is both inevitable and critical to resolving water problems almost anywhere in the world, simply because water operates with-in the water cycle, which is a global phenomenon.

But the impacts of water scarcity are often felt locally and gradually, therefore response of governments is often fragmented and weak. This means that the responsibility to address shared risks

arising from the unsustainable management of water increasingly falls on the local stakeholders. In many ways this makes sense, as the risks facing the local community, businesses and ecosystems are often unique and require local knowledge and insight to tackle them. As a consequence, local problems are usually best solved by local stakeholders working together to deliver meaningful change on the ground.

Water is truly a global problem. However, the factors that contribute to the issue, such as local climate and geography, are often unique to a specific region or country. To tackle this issue therefore requires an approach that can harness the scale and expertise of global organizations, whilst enabling specific local water issues to be identified and for local stakeholders to be drawn together to address them. The local water challenges are usually best solved in partnership with NGOs, local governments, communities and other local businesses.

Global Water Partnership, aims to prove the business case for private sector engagement in promoting the sustainable management of water resources. The partnership seeks to share the lessons learnt throughout the business's global operations with other stakeholders to promote better water stewardship. The fundamental concept underpinning the partnership is that a lack of water security presents risks that are shared by the business, other water users, ecosystems and governments. The partnership follows an innovative and participatory approach to sustainably manage water resources.

Unlike fossil fuels, water has no substitutes or alternatives. The way that water is currently managed in many countries around the world is simply unsustainable, based on current projections and research, Global population growth is set to rise from 6.7 billion today to over 9 billion in 2050. This expansion in population will place a higher demand on resources available, particularly for agriculture and the provision of food. Currently, it is estimated that over 70% of global fresh-water withdrawals are used for this purpose. In some countries this can reach 90%.

A further complication is that freshwater is not distributed evenly across the globe - nine countries account for 60% of global freshwater - while within countries there are often significant variations in regional rainfall levels. If anything, the impact of climate change is likely to increase both variability and unpredictability. More than one-sixth of the world's population live in glacier or snowmelt-fed river basins and will be affected by the seasonal shift in stream flow, an increase in the ratio of winter to annual flows, and possibly the reduction in low flows caused by decreased glacier extent or snow water storage. At the same time, sea-level rises attributable to climate change will extend areas of Stalination of groundwater and estuaries, resulting in a decrease

in freshwater availability for humans and ecosystems in coastal areas. Semi-arid and arid areas - for example, around the Mediterranean, western USA and southern Africa - are particularly exposed to the impacts of climate change on freshwater. According to the UN's World Water Development Report, almost half the world's population will live in areas of high water stress by 2030 as a result of climate change. Shortage of water will also have a significant impact on the local ecology and biodiversity of an area. It is down to individual consumers and companies to take responsibility to use water more sustainably, and for governments to manage water resources appropriately within river basins.

One such typical extreme event is presented in the next topic, which deserves 'globalisation i.e., application of global information and co-operation for tackling a local problem', one that is a result of global climatic change and resulted in an unprecedented and unexpected disaster of massive scale, through foods caused by cumulonimbus clouds for the first time in the region of Kurnool of Andhra Pradesh, in India, in the year 2009 [5].

### **5. Kurnool Floods And The Inadequacy In Sharing Experience & Data (through Global Water Partnership):**

A similar case that deserves attention is a devastating unwarned havoc created by floods that occurred in Kurnool, AP, India in the year 2009. These floods high-light the importance of HIS Data with an increased parameter coverage and taking help from Global water information partnerships.

History was made at the Srisailem project on Saturday 3rd October, when the water level in the reservoir touched 896.5 feet, well above its full reservoir level (FRL) of 885 feet. This was the first time in the State that any irrigation project received inflow of water 11 feet above the FRL. Though this massive quantity of water threatened to wreak heavy destruction upstream in Kurnool district, the day was saved for people of the State as the inflows began dwindling. Unprecedented rains in North Karnataka on Thursday 1st October, flooded several districts, cutting off areas like Bijapur, Bagalkot and Bellary. Karwar for instance got 50 cm of rain in a single day. Locals called it the heaviest downpour in 50 years. The waters inundated the Krishna and Tungabhadra rivers and the Karnataka government released upto 8 lakh cusecs of water from the Almatti and Narayanpur dams, in a single day. From the last week of September, Andhra Pradesh was experiencing heavy rains, some areas got over 30 cm in a single day. This brought heavy inflows into major projects in Krishna Basin like Jurala, Srisailem, Nagarjunasagar, Prakasam Barrage and Sunkesula.

Early on Friday 2nd October, reports started coming in of water levels rising dangerously in the border town of Mantralayam in Andhra Pradesh. By evening, the water level had crossed the danger mark in Srisaillam dam. In a single day on Friday, the reservoir had received over 25 lakh cusecs (2.5 Million cusecs) of water in 12 hours, whereas it is designed to get no more than 13.6 lakh cusecs. This is the probable maximum flood predicted once in 10,000 years. On Saturday 3rd October, the maximum water limit was crossed in Srisaillam, Jurala and Sunkesula projects causing inundation in many villages in the backwaters. Kurnool town and several villages in Kurnool, Mahbubnagar and Nalgonda districts were flooded. From the Srisaillam dam, the waters were flowing into Nagarjunasagar dam. On 4th October Sunday morning, 10.85 lakh cusecs were released to keep the masonry dam safe. The waters that reached Prakasam Barrage, Vijayawada in the coastal Krishna district on Monday have submerged hundreds of villages. Prakasam Barrage has never received such huge amounts of water in the last 100 years. It is the first time in history that the scale of floods has been so massive. This is known as PMF or possible maximum flood, which happens once in 10,000 years. Heavy discharge of water from the dam submerged two fishermen colonies alongside the river forcing 700 families to be evacuated to Sundipenta rehabilitation camps. Copious inflows from Jurala, Handri-Neeva, and Krishna river at one time put engineers to high tension as water began occasionally flowing above the 12th sluice gate (Sluice Serial No.1) of the dam even before it was opened. Water entered the main power-generation unit in the evening after the 12th sluice was also opened and partially damaging the 110MW X 7 power house. A continuous watch was put in place on downstream Nagarjunasagar Dam dynamics, controlling water outflow depending on inflow. Rain stopped on Saturday giving much needed relief to the people of Kurnool town. Water inflow came down to 14.22 lakh cusecs by 5 p.m. and outflow was 14.66 lakh cusecs filling the Nagarjunasagar dam downstream. The reservoir received over 20 lakh cusecs of water on Friday night and has discharged over 10 lakh cusecs and is likely to overflow by Saturday morning. Until Friday when Srisaillam received 8 lakh cusecs of water, the highest discharge from here was in 1998-99 when eight gates (4-11) were lifted and 7.36 lakh cusecs of water released downstream. The next highest discharge was 6.26 lakh cusecs in 2006-07.



**Figure 2 and 3. Srisaillam Dam Had Tilted But Regained Its Position**

The top portion of Srisaillam dam had tilted towards the downstream side by 4 mm on October 3 when an unprecedented inflow of 26 lakh cusecs, described as “maximum probable flood” in the Krishna that occurs once in 10,000 years, flowed into its reservoir. A preliminary inspection of the dam by engineers with reference to the parameters specified for dam safety has revealed the tilt reached a maximum of 8.8 mm on October 8 when water was discharged from the dam. This was the first time that the top tilted so much, although the dam design allows bending up to 20 mm, before it came back to its normal position.

Dam safety engineers found that the structure stood up well to the heavy uplift pressure caused by impounding of a massive quantity of water in the reservoir on October 3 when the level touched 896.5 ft, which is 11.5 ft higher than the full reservoir level.

Each square metre of the dam had to withstand the pressure of over 170 tonnes of water while the permitted level for Srisaillam is only 143 tonnes. Heavy pressure of the water threatened to lift up the structure but the latter countered it by its sheer weight and strength. Only 404 feet height of the massive dam is visible above the river bed, but a structure of equal height constitutes its foundation. This is its main strength and another engineering feature that enabled the dam to withstand the high flood was the curvature provided in its alignment. This dissipates the force unleashed by water onto the hillside. Engineers found that seepage in the galleries of the dam to be within the permissible limits.

Similarly, the readings of the basic parameters for judging the safety of a dam—tilt, uplift pressure and deflection have all been found within the safe limits in case of Nagarjuanasagar Dam also which handled its highest inflow of 15 lakh cusecs October 4th. Engineers were surprised that Nagarjuanasagar also stood up to the flood just as Srisailam did, even though it is built in a straight line across the river without a curvature.



**Figure.4 - Nagarjuanasagar Dam During Floods In October 2009.**

**6. The Cause:** A well-marked low pressure system with a center (lat 17.53°N/lon 84.56°E) had persisted off the coast of West central Bay of Bengal and adjoining central Coastal AP from 29th September through 2nd October 2009. The condensation heating maintains over the Bay in a strong way and cyclonic circulation with the associated sub-synoptic scale cells of low level. Record of extreme heavy rainfall events over AP., caused moisture convergence; it has extended vertically up to 500 hPa level and high level divergence is maintained at 200 hPa level. A deep convection associated with east-west trough from Southwest Bay to Amaravathi might have propagated the westward generation spells of heavy precipitation over study region. A heavy rainfall quantity of 21 cm was observed near Amaravathi station (16.15°N; 80.5°E) in Guntur district due to a meso- $\alpha$  low pressure system extended from the Bay of Bengal and widespread rainfall episodes were also appeared to many adjoining places in other three districts namely Mahaboob Nagar, Kurnool and Krishna in AP state simultaneously on 29<sup>th</sup> September. The rainy situation continued till 2<sup>nd</sup> October and caused

floods over above districts of AP state which lead to a death toll of 33 people and heavy crop loss. To quantify the above catastrophic monsoon heavy precipitation events a high resolution (9 km) Weather Research and Forecast (WRF-ARW) model is centered at Amaravathi station to simulate rainfall episodes over the study region.

This may be due to the fact that there is a difference in the updraft and downdraft cumulus congestus clouds associated with the low pressure system.



**Figure 5 . Cumulonimbus Clouds**

Cumulonimbus clouds are a type of cumulus cloud associated with thunder storms and heavy precipitation. They are also a variation of nimbus or precipitation bearing clouds. They are formed beneath 20,000 ft. and are relatively close to the ground. This is why they have so much moisture. Cumulonimbus clouds are also known as thunderheads due to their unique mushroom shape. These clouds often produce lightning in their heart. This is caused by ionized droplets in the clouds rubbing against each other. The static charge built up create lightning. Cumulonimbus clouds need warm and humid conditions to form. This gives them the moist warm updrafts needed to produce them. In some instances a Thunderhead with enough energy can develop into a super cell which can produce strong winds, flash floods, and a lot of lightning. Some can even become tornadoes given the right conditions.

Despite the heavy rainfall these clouds produce, the precipitation normally just lasts for around 20 minutes. This is because the clouds require not only a lot of energy to form but also expend a lot of energy. An overlooked result of Cumulonimbus clouds are flash floods. Cumulonimbus clouds form in the lower part of the troposphere, the layer of the atmosphere closest to the surface of the Earth. This region due to evaporation and the greenhouse effect produces a lot of the warm updrafts that make creation of cumulus and cumulonimbus clouds possible. The turbulence created by the friction between air and the surface of the Earth combined with stored heat from the sun helps to drive the majority of weather [6] .

## 7. Conclusion and Action Needed:

From the fore-going it becomes evident that climate change has a major role to play in bringing about such devastating extreme events. Therefore identifying those triggers which operate on a global platform is essential, but not possible, unless global water partnerships are established and kept operating on an interactive basis by monitoring them through some world-wide mission, such as the one under-taken by the WMO ('World Meteorological Organization'), called World Hydrological Cycle Observing System [7].

Water poses a continuous internal management challenge in the form of unpredictable variations in precipitation resulting in natural disasters or extreme events like floods or drought. The first step in managing those events is to read and record the events, in order to take precautionary and protective actions against their onslaughts. And that necessitates maintaining systematic records of Data of all the hydrologic processes that govern the movement and availability of water, in the shape of a 'Hydrological Information System (HIS)'. And after having put in place such a comprehensive 'HIS', it is also necessary to assess whether it is able to play its intended role in solving water management problems as desired, in order to reshape it as and when it needs to be. In India, the necessary first step had already been taken, that is, development of a comprehensive Hydrological Information System (HIS) which has now entered into its climactic phase III when it was approved by the Indian cabinet a few days ago on 6-4-16 with a total out-lay of Rs.3679.7674 crores [8] and it is now very important to ensure that the HIS being developed is made interactive with a global information system. Innovation is the key to handle problems relating to Water since it is a resource that is basic and vital for existence. A right recognition of this need is seen in the Indo-Israeli Mou signed recently [9], but further hydrological needs in the fields of water conservation, water use efficiency, waste water treatment and river rejuvenation, have to be identified Innovatively as done in Israel and then those 'HIN' have to be incorporated into the 'HIS' being developed at the earliest to collect pertinent data collected and kept ready for future use. This is the need of the hour and there is urgency in it.

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