Omega Prediction - A Clue for Flood and Weather Forecaster with Sufficient Lead Time for Disaster Managers; A Case Study of Urban Flooding in the City of Hyderabad

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Abstract

Urban flooding is a serious challenge for disaster managers. The urban flooding in the city of Hyderabad during the year 2003 has been discussed in this study. The prevalence of the positive value of vertical velocity (omega) at a specific region at least three days earlier is the indication of the onset of the severe weather system. The positive omega value has been developed five days earlier of the urban flooding in Hyderabad during 2003. It is very difficult to assess the track of the low pressure system (LPS) at the time of its generation in the Bay of Bengal; the positive value of omega at a particular region provides the indication of the approaching LPS. To validate the omega value, the other mega floods of Pakistan have been studied. The omega value for the mega floods of 1989, 1992 and 2010 have been observed with sufficient lead time for the onset of the severe weather system. By studying the other meteorological parameters along with the omega value, an attempt has been made to set the criteria for onset of severe weather or flood early warning to save the lives and properties of the nation. The tropical low pressure system merges with the seasonal low, developed at southern Pakistan, causes the moisture laded flow from Arabian Sea into southern Sindh. The causes and meteorological conditions developed during the urban flooding in Hyderabad during July 2003 have been discussed in detail. The hydro meteorologists, disaster managers and policy makers may use the omega value as a tool for flood early warning system.

Key Words: Urban flooding, Hyderabad, Meteorological conditions, Omega value, Flood early warning.

Introduction

Hyderabad is located at latitude 25.367 °N and longitude 68.367 °E. It is on the east bank of the Indus River and is roughly 150 kilometers away from Karachi. It has an elevation of 13 m (43 feet) and is the 2nd largest city in Sindh, 8th largest in Pakistan whereas 209th largest city of the world with respect to population. It has population estimates to 1,732,693 as of census 2017 (Pakistan Bureau of Statistics, 2017). Hyderabad has an extreme climate. The days are hot and dry usually going up to extreme highs of 48 °C whilst the nights are cool and breezy. The winds that blow usually bring along clouds of dust and people prefer staying indoors in the daytime, while the breeze that blows at night is pleasant and clean (Hyderabad climate, encyclopedia)**.** In recent years Hyderabad has seen spells of heavy downpour. In 2003, Hyderabad received 211 mm of rain in the month of July. The years 2006, 2007, 2008 and 2009 saw close contenders to this recorded rain with death toll estimated in hundreds all together. In this study we will discuss a particular case of Hyderabad city for urban flooding. A case study of the year 2003 for the month of July will be discussed. Most floods during monsoon season are the result of concentrated spells of heavy rainfall. The main cause of rainfall over this area is monsoon depressions which periodically form in the Bay of Bengal and move westwards or northwestwards along the monsoon trough and finally merge in the heat low over Sindh and Baluchistan. Mostly urban flooding occurs during monsoon season in this region while a tropical depression merges with the seasonal low causing generation of strong southwest flow within the lower troposphere along southeastern Sindh and adjoining Punjab. Prior to its merger into seasonal low, the tropical low-pressure system causes widespread precipitation over the Sindh and the Punjab. The depression usually after moving up to Madhya Paradesh and southeast Rajasthan curves towards north and northeast finally finishing up at the Himalayas. During westward movement of the depression, heavy rainfall occurs in the southeastern sector of the depression.

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A flood is a situation in which water temporarily covers land where it normally doesn't. In the Himalayan mountainous areas floods are frequently triggered by rainfall in the region under the influence of a monsoon climate and this is responsible for a variety of human and environmental impacts. A flood is hazard that can occur in Pakistan and rest of the world brings misery to those that live in the area. They can cause loss of life and property and often cause a great disruption of daily life. Floods all over the world cause enormous damages every year like economic damages, damage to the natural environment and damage to national heritage sites. The causes of urban flooding have been discussed in the schematic figure 1(Gupta, et al, 2010).

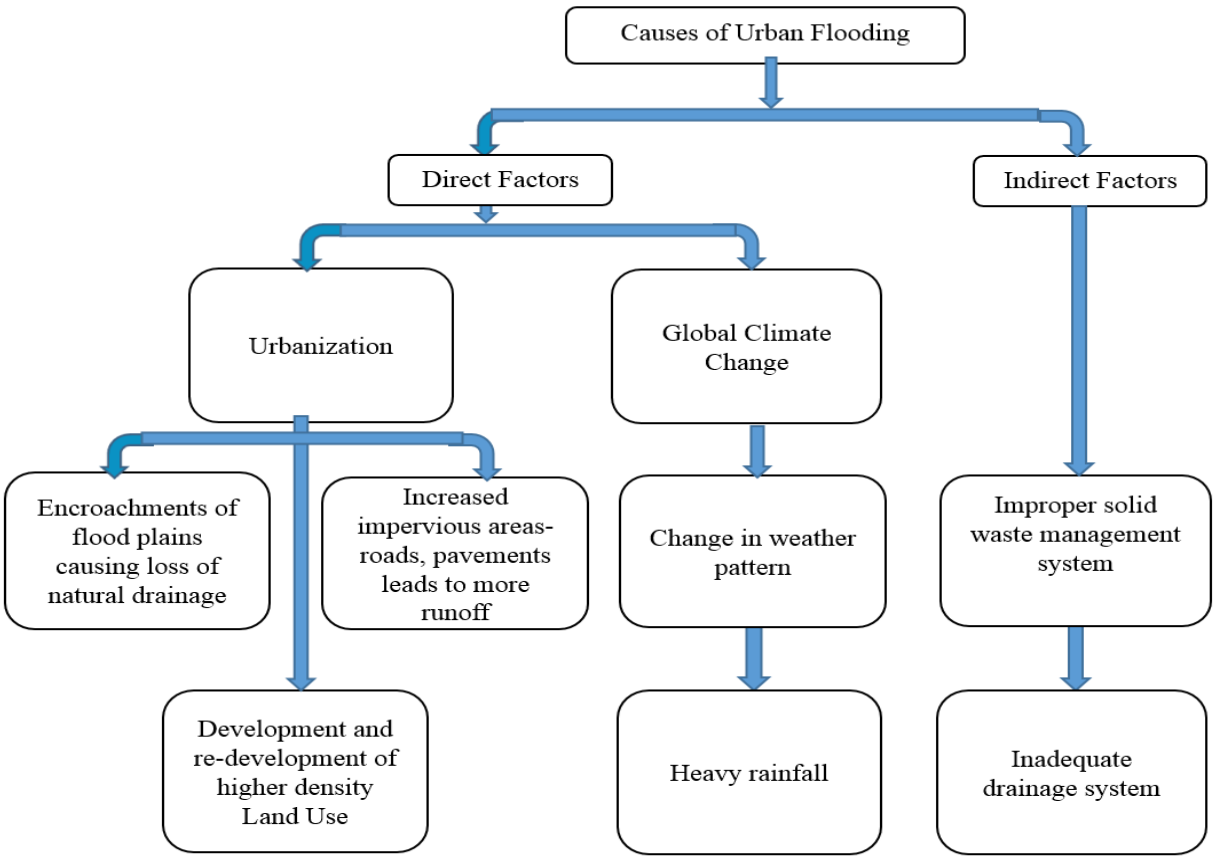

Figure 1: Causes of urban flooding.

The wetted winters and heavier summer showers are expected to put more pressure on urban drainage. The climate models predict that winter rainfall will increase by 20-30 % by the 2080s such an increase could lead to a much larger (up to 200 %) increase in flood risk.

Movement of the Tropical Depression

The rain spell from July 24 to July 30, 2003 has been selected for study in the city of Hyderabad. Total rainfall recorded in this spell was 211 mm. The occurrence of the weather and rain along the track of the approaching Low pressure system (LPS) is a usual phenomenon. The amount of rain and the extent of the precipitation region in this situation are related to the intensity and coverage of the LPS. This can be judged by its vertical extent and its areal spread. During the monsoon season 2003 the LPS upon reaching Rajasthan continues to move westward to reach lower Sindh causing heavy rain under its direct effect. At this point the LPS fall under the grip of a westerly wave moving along the Northern latitudes and recurve towards north to merge into the seasonal low. The low then cause strong southwest currents from the Arabian Sea extending up to 700 mb or more. The moisture laded maritime flow from the Arabian Sea causes the heavy monsoon rains, which causes floods under the intensified seasonal low condition (Flood Forecast bulletin, 2003).

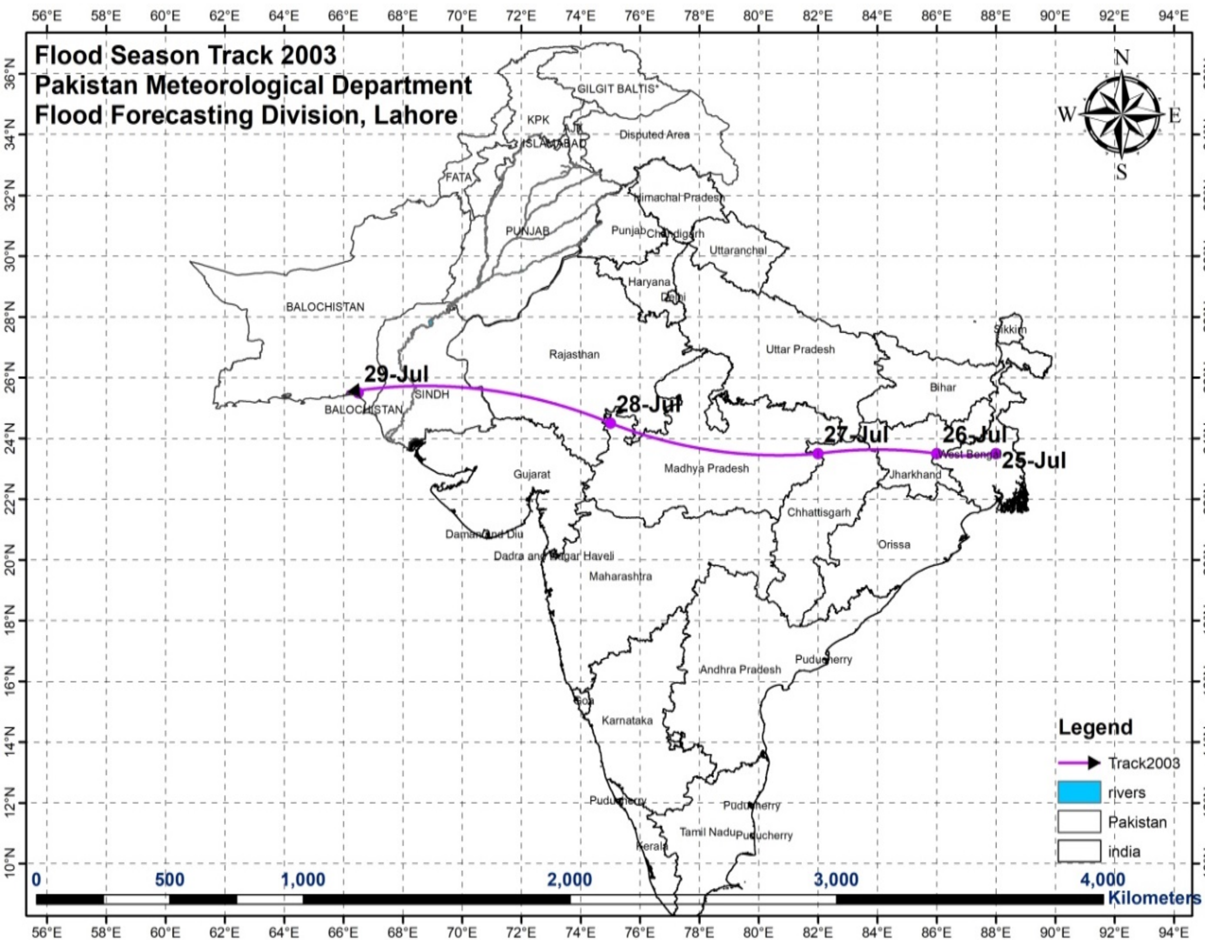

Figure 2: Shows the track of monsoon depression from Bay of Bengal to southern Sindh during the month of July, 2003

The LPS had been seen first on the coast of east Bengal on 25th July, 2003. On 26th July it further moved Northwestwards. On 27th July it moved westwards and reached over Eastern Madhya Paradesh. At this stage it intensified in to depression. The depression was strongly reflected even at 500mb level. It continued to move along west to arrive over the boundary of Rajasthan on 28th July, 2003. Upon reaching Rajasthan it further moved to reach lower Sindh causing rain under its direct effect. At this point the LPS fall under the grip of westerly wave to move along the west of northwestwards to merge in to the seasonal low. The low causes strong southwest currents from Arabian Sea extending up to 700 Mb level. The moisture laded maritime flow from Arabian Sea causes the monsoon rains which cause flood under intensified seasonal low condition. On 29th July the LPS located on southeastern Baluchistan with its intensity reduced to one closed isobar and weakened in to monsoon low.

Rainfall Distribution

The rainfall spell lasted from July 27 – July 30; 2003.The rainfall mainly confined to southern Sindh as shown in the isohyetal map. There were repeated rainfall spells over the region during three days. The daily rainfall data of July 24 – July 27, 2003 used in this study, acquired from Pakistan Meteorological Department (NMCC, PMD). The seasonal spell of July 2003, was mainly caused by an approaching monsoon low, which finally dissipated on July 29, 2003, and by the passage of westerly wave in the North. The shifting of seasonal low towards Iran also caused influx of moisture over lower Sindh along with coastal Mekran. Consequently, heavy to very heavy rain occurred over Lasbela district and lower half of Sindh province. The rainfall maxima exceeding 200 mm was observed around Lasbela and coastal Sindh. (Flood Forecast bulletin, 2003)

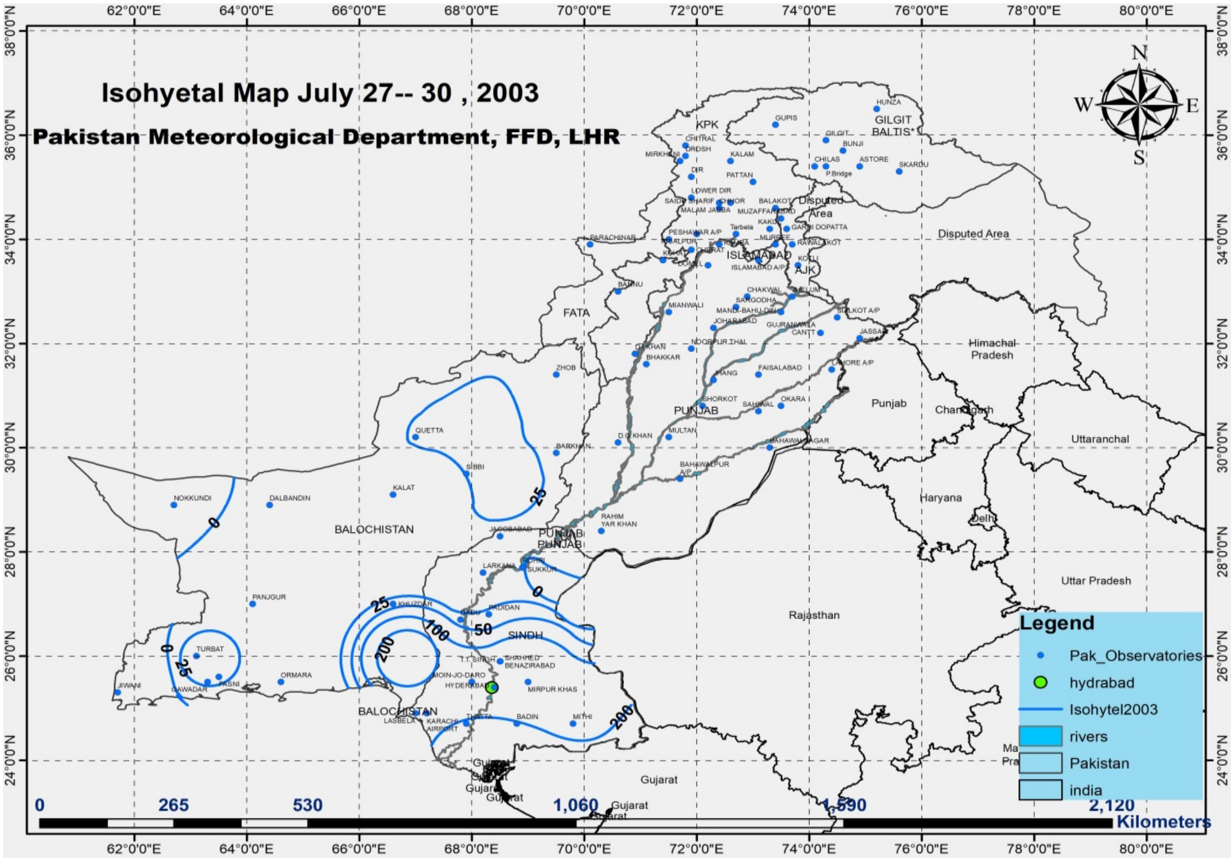

Figure 3: Isohyetal Map of Pakistan for the period of July 27-30, 2003 shows the concentration of rainfall over southern Sindh.

Results and Discussions

The weather charts of different pressure levels depict movement of High Pressure System (HPS) and Low Pressure System (LPS). The weather charts of 850 mb, 700 mb and 500 mb (NOAA, ESRL PSD) clearly indicate the presence of LPS at all these three levels on July 28, 2003. On the next day on July 29, 2003 the weather system is also present on all of these levels which show the strength of the system. The heavy monsoon currents from Arabian Sea are reaching Punjab and Sindh up to 500 mb level above the mean sea level. The LPS has reached Arabian Sea with its trough extending northeastwards. The LPS merges with the seasonal low that lies over Baluchistan. The HPS lies over north of the country which confined the LPS to remain in southern parts of the country. The situation is favorable for moisture feeding from Arabian Sea to the lower parts of the country. The maritime flow is likely to produce heavy to very heavy rain in southern parts of the LPS. Consequently, the southern Sindh received very heavy rain during the spell. The surface weather chart (shown in the figure 4) depicts the position of the seasonal low, monsoonal depression and Tibetan high. The seasonal low at this stage merges with the LPS. This intensified LPS, causes the moisture laded maritime flow from the Arabian Sea to southern parts of Sindh. The Subtropical high act as a steering force which moves the LPS under its direct effect i.e. if it moves northeastwards the LPS also moves in like direction and vice versa.

The LPS reached at southern Sindh while the HPS lies over northern parts of the country as shown in figure 5, which restricts the LPS to remain in southern parts of the country. The situation is favorable for moisture feeding from Arabian Sea to the lower parts of the country. The spatial extent of the LPS has enhanced in next day as shown in figure 6. The HPS has moved further away in the northeastward from the country.

The situation is more favorable for moisture fetching from the Arabian Sea. The southern Sindh received heavy rainfall.

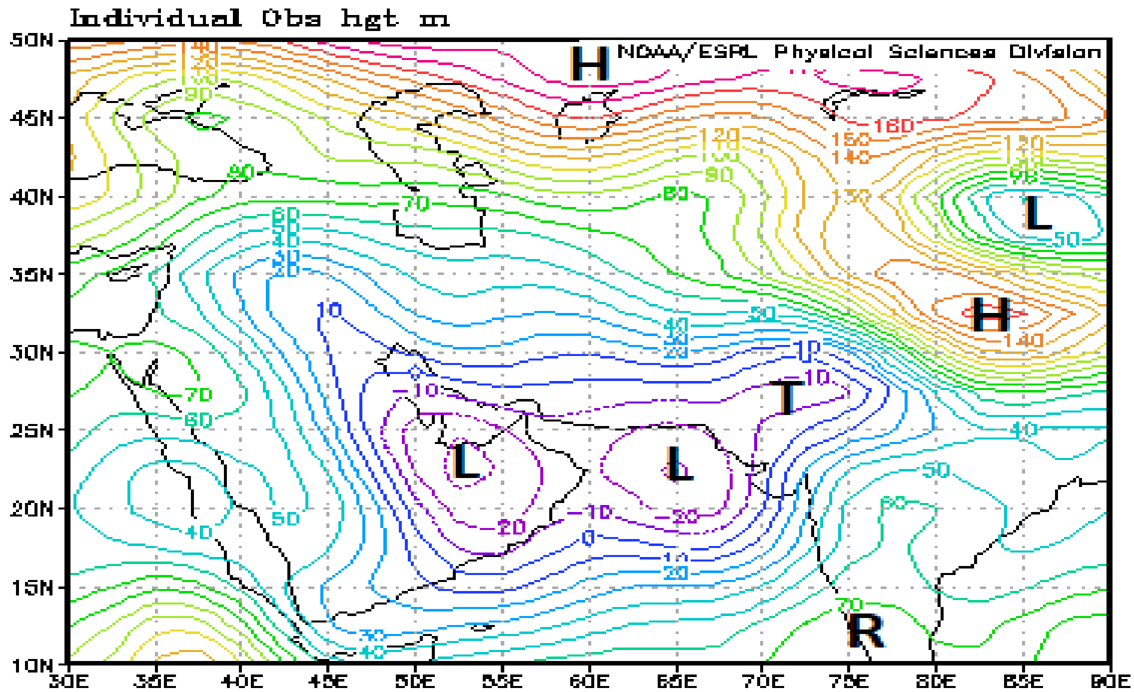

Figure 1: The surface weather chart depicts the position of the seasonal low, monsoonal depression and Tibetan high. The seasonal low at this stage merges with the LPS. (level 1000 mb; July 29, 2003 at 00 Z)

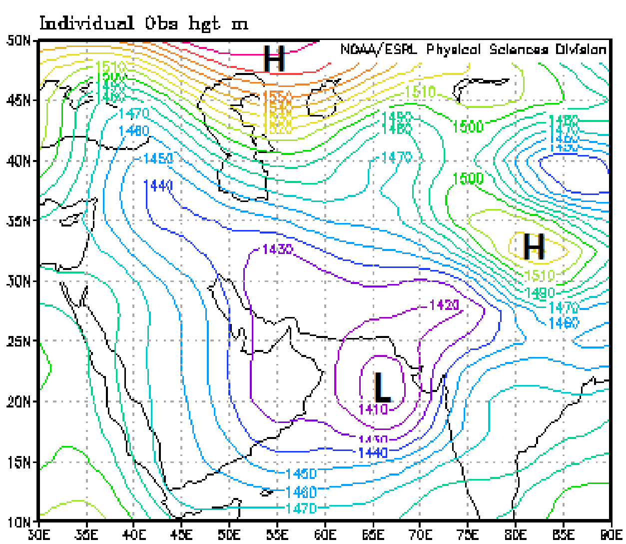

Figure 5: The LPS lies over southern Sindh while the HPS is over northern parts of the country. The situation is favorable for moisture sucking from Arabian Sea. (Level 850 mb; July 29, 2003 at 00 Z)

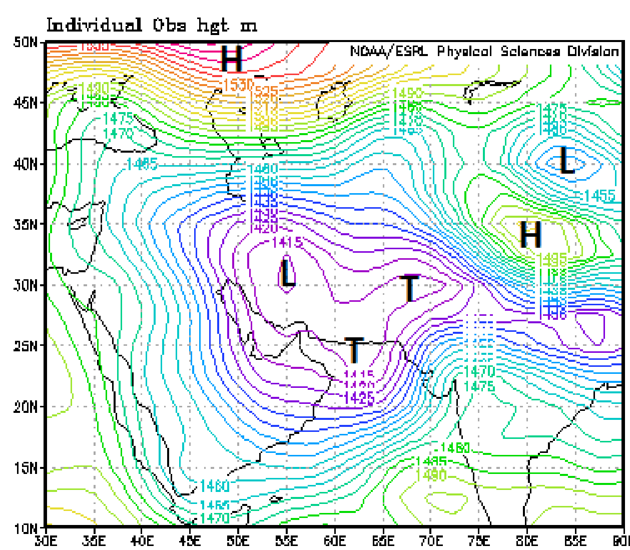

Figure 6: On next day the spatial extent of the LPS has extended. The HPS has moved further away in the northeastwards direction from the country. (level 850 mb; July 30, 2003 at 00 Z)

The position of the LPS at this height is same as that of 850 mb as shown in the figure 7. The system is strong enough to fetch enough moisture from the Arabian Sea. The meteorological situation is favorable for heavy rainfall in southern Sindh. A ridge lies over northern parts of the country tending to move northeastward. On next day, the position of the LPS is almost same but its trough extended eastwards pushing the ridge northwards as shown in the figure 8. The system is still strong to compel the moisture from Arabian Sea to southern Sindh. The moisture laded winds are favorable for heavy to very heavy rains in Sindh. The monsoon currents hardly reaches at the height of 700 mb and the system is considered very strong if the currents are present at this level. The system looks stationary at this height on July 29 and July 30. The situation is favorable for heavy downpour.

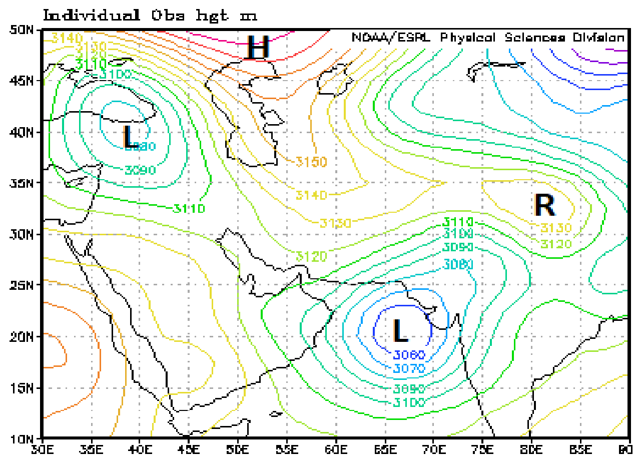

Figure 7: The meteorological situation is favorable for heavy rainfall in southern Sindh. The position of the LPS at this height is same as that of 850 mb.
(level 700 mb; July 29, 2003 at 00 Z)

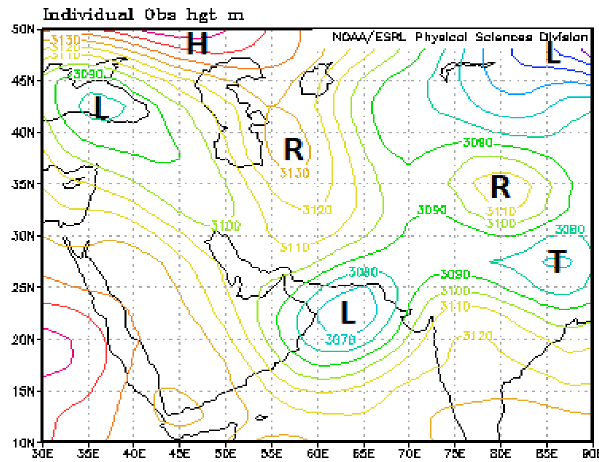

Figure 8: On next day, the position of the LPS is almost same but its trough extended to eastwards pushing the ridge northwards.
(level 700 mb; July 30, 2003 at 00 Z)

The LPS is located at the same spatial coordinates as that of the 850 mb and 700 mb which indicates strengthening of the weather system as shown in the figure 9. The HPS has moved southwards with its ridge extending southeastwards. The position of the LPS provides good chances of heavy to very heavy rain in southern parts of the country. On the next day, as shown in figure 10, the position of the LPS is almost the same. The HPS from north and ridge from east and southeast has confined the LPS to remain at the previous day position. However, by making way for maritime flow in southern Sindh, the meteorological situation is favorable for heavy to very heavy rain. The region around the Lasbela district received more than 200 mm rain in a couple of days as shown in the isohyetal map in the figure 3. The pressure level 500 mb provides clear indication to the westerly weather system. The ridge of the system is located over Afghanistan and adjoining areas of Pakistan.

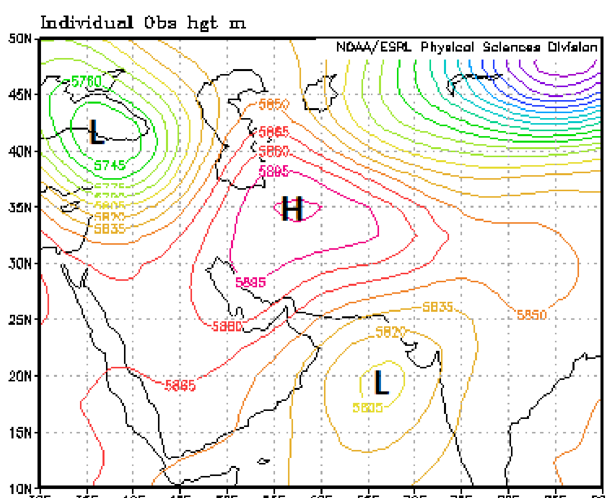

Figure 9: The LPS has the same spatial coordinates as that of the 850 mb and 700 mb. The position of the LPS provides the good chances of very heavy rain.
(Level 500 mb; July 29, 2003 at 00 Z)

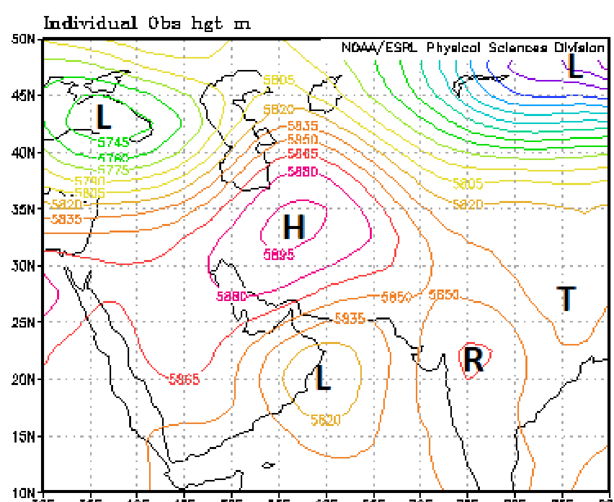

Figure 10: On the next day, the position of the LPS is almost same. The meteorological situation is favorable for heavy to very heavy rain.
(Level 500 mb; July 30, 2003 at 00 Z)

Vertical lifting of the air mass started a few days earlier to create a surface low and low tropospheric vortex resulting in northwards extension of the seasonal low 2003 (Majeed, A. et al., 2006). This situation caused the heavy rainfall over south Sindh from 27th July, 2003 and onwards as indicated in the isohyetal map shown in figure 3. The area of the maximum omega values is also superimposed upon the surface chart of 29th July, 2003. Another positive indicator of the formulation of the lower tropospheric cyclonic vortex over southern Sindh is the creation of the centre of vertical lifting of the air mass wherein the positive values of the vertical component of the wind field is shown centered over southern Sindh, which approximately corresponds with the centre of the positive omega (vertical velocity) values at 850 mb level of 28th July. The positive value of omega can be seen over southern Sindh which causes the heavy rain in the region on July 29, 2003 as shown in the figure 11. The positive value of omega was observed four to five days earlier than the start of the rainfall. Flood peaks occurred at Mangla and Marala during the period from 29th of July to 01st of August 1989. Marala received three repeated peaks starting from 28th to 30th July 1989. River was flowing at around one hundred thousand cusecs up to 28th when rain started to cause first peak of about 200,000 cusecs. The base flow did not fall below 1.5 hundred thousand cusecs when the second peak arrived to raise the flow to 200,000 cusecs. The third major peak occurred towards the midday of 30th, which amounted to about 360,000 cusecs, and continued for about 15 – 20 hours. At Mangla two peaks of 180,000 and 240,000 cusecs occurred with a gap of 24 hours. The most significant peak is the one received at Tarbela, in which case the river started to rise from 28th onwards. A peak of more than 5 hundred thousand cusecs occurred on 1200 hours of 31st July. Consequently the peak carried tremendous volume amounting to 6.5 MAF. The positive value of omega developed over north and northeastern Pakistan on July 27, 1989 which make basis for heavy rainfall in the region as shown in figure 12. The flood peak of magnitude extremely high flood having value 510000 cusecs was observed at Tarbela on July 31, 1989.

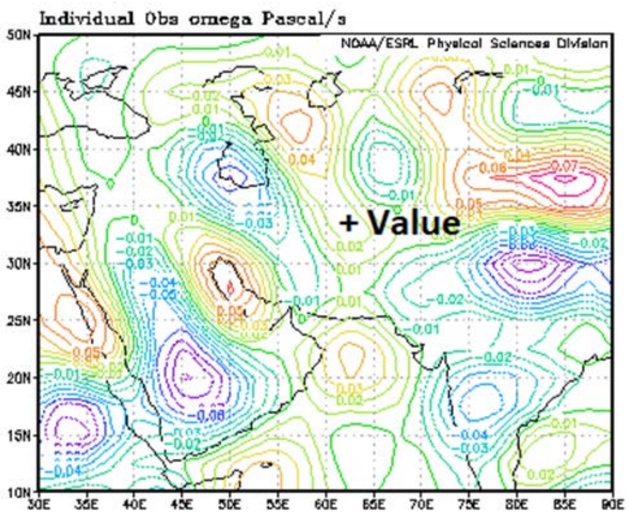

Figure 11: The positive value of omega can be seen over southern Sindh which causes the heavy rain in the region on July 29, 2003.
(level 850 mb; July 24, 2003 at 00 Z)

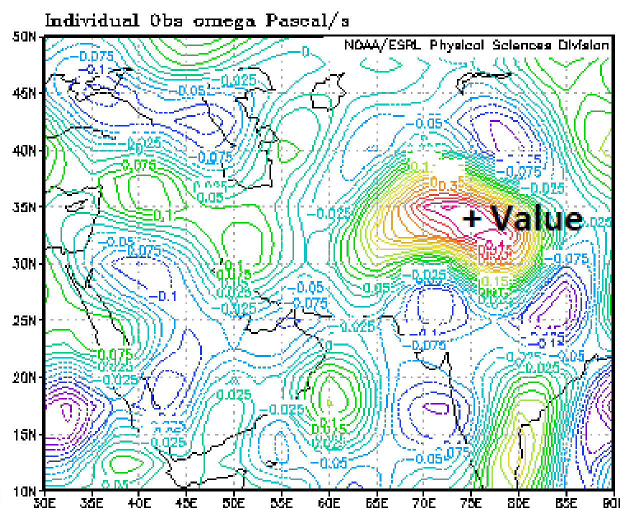

Figure 12: The positive value of omega developed over north and northeastern Pakistan on July 27, 1989 which make basis for heavy rainfall in the region.
(level 850 mb; July 27, 1989 at 00 Z)

The heavy rainfall event occurred over Jhelum catchment from 07-11 September, 1992 brought a huge devastating flood at Mangla. It gave very heavy rainfall in almost all the divisions of KPK, Northern areas of Punjab and Kashmir. Almost 1,000 people died and 3 million evacuated due to flooding in Punjab province caused by torrential rains. The positive value of omega developed over Pakistan on Sep 8, 1992 which make basis for heavy rainfall in the region as shown in figure 13. The extremely high flood peak of 1,090,000 cusecs was observed on Sep10, 1992 at Mangla. The positive value of omega was observed three days earlier than the start of the rainfall. The 2010 Pakistan floods, driven by unprecedented monsoon rain, began in late July in the Khyber Pakhtunkhwa, Sindh, Punjab and Baluchistan regions of

Pakistan and affected the Indus River Basin. Approximately one-fifth of Pakistan's total land area was underwater. The colossal devastation brought a total human death toll of 1,985 with 2,946 injured; affecting approximately 20 million people with over 100,000 square kilometers of area inundated by the flood waters including over 2.1 million hectares cultivated land. The overall damage was estimated at PKR 855 billion which is 5.8 percent of 2009/10 GDP. Floods submerged 69,000 Square kilometers of Pakistan's most fertile crop land, killed 200,000 livestock and washed away massive amounts of grain (NDMA Annual Report, 2010). The positive value of omega developed over north and northwestern Pakistan on July 27, 2010 which make basis for heavy rainfall in the region as shown in the figure 14. The peak of extremely high magnitude having value 832000 cusecs was observed at Tarbela on July 30, 2010 which means the positive value of omega was developed three days earlier.

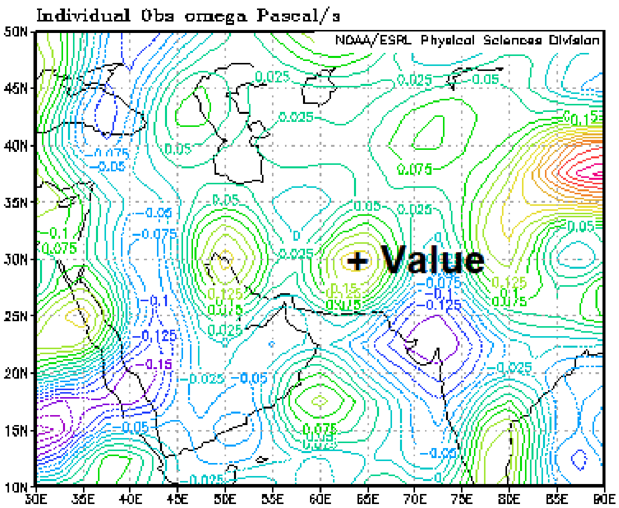

Figure 13: The positive value of omega developed over Pakistan on Sep 8, 1992 which make basis for heavy rainfall in the region.
(level 850 mb; Sep 8, 1992 at 00 Z)

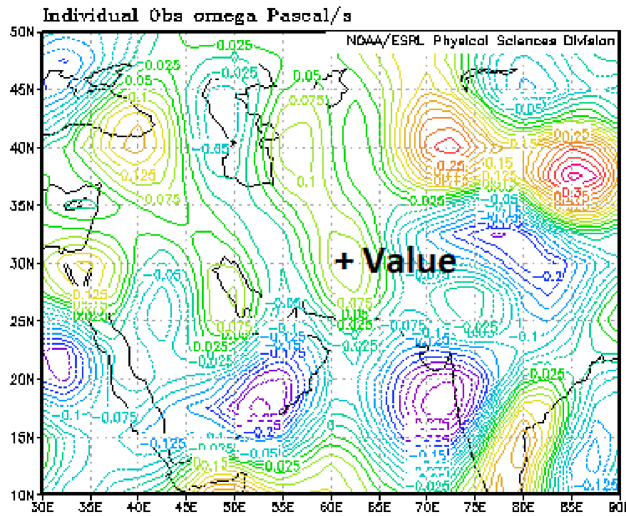

Figure 14: The positive value of omega developed over north and northwestern Pakistan on July 27, 2010 which make basis for heavy rainfall in the region.
(level 850 mb; July 27, 2010 at 00 Z)

Conclusion

The urban flooding is a serious issue which can be addressed by improving the lead time rainfall prediction system and the sewer system. The positive value of omega (vertical velocity) develops few days earlier than the start of the actual rainfall. This is the indication of the onset of the severe weather system. By making use of this value the disaster managers, policy makers and hydro meteorologists may issue forecasts and warnings with sufficient lead time. The region of high positive omega values shall be the region where the cyclonic vortex shall tend to form at the lower tropospheric levels causing the extension of the seasonal low to south/southeast. The merger of the monsoon depression or low into the seasonal low accentuates the urban flood situation. The weather system was strong as it maintained its vertical axis up to 500 mb. The present system was less tilted from ground to 500 mb, therefore, it was strong enough to produce heavy rainfall. The heavy rainfall will occur in the southwest sector of the LPS. The system causes strong southwest maritime flow from the Arabian Sea resulting in the heavy rainfall in the southern Sindh. The track of the LPS is strongly influenced by the position of the sub-tropical high (act as a steering force for the movement of the LPS) at the middle and upper tropospheric level. The southwards shift of the sub-tropical high shifts the depression southwards.

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