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Research Article

AN EPISODE OF CONVECTIVE HEAVY RAINFALL OVER TAMILNADU AND KERALA: OBSERVATIONAL STUDY

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ABSTRACT
A case study of convective heavy precipitation on 5th April, 2005 over southern peninsula is diagnosed with surface and upper air circulation features with the help of Satellite and model reanalysis data. During April month this type of precipitation was peculiar in various respects as it may be boon for agriculture and ground water resources and activity if Inter Tropical Convergence Zone (ITCZ). The rainfall departure for the above said week over south peninsula was about 300 % from normal.

Key Words: *Low level Circulation (LLC), ITCZ, divergence and MODIS*

INTRODUCTION
A mesoscale circulation (L~100 km) associated with surface heat and moisture flux is responsible for initiation of deep and moist convection over the area (latitude 05.0 N – latitude 15.0 N and longitude 75.0 E – longitude 80.0 E). The unusual rainfall occurred on 05-04-2005 over Tamilnadu region, may be due the overall structure of surface moisture gradient zone in which surface air interactions play an important to role in maintaining deep convection. In this case convergence at lower levels which was associated with moist convection can be one of the important mechanisms of thermodynamic instability in the atmosphere. Heating and moistening the atmospheric boundary layer; combined with radiative cooling at the top of the troposphere this creates instability in the atmosphere. During conditional instability the saturated air is unstable and dry air is stable and a small perturbation may cause large changes in this case. Atmospheric processes are characterized by long-range spatial and temporal correlation, and by corresponding structure on a wide range of scales (Bodenschatz et al, 2010). The list of these scales has a gap, however, from a few km (a few minutes) to 1,000 km (a few days), spanning the so-called mesoscale, and it is in this gap that the following arguments are most likely to be relevant. Mostly heavy rainfall occurs by mesoscale convective systems (Zisper, 1982) under certain synoptic scale environmental conditions, like in the vicinity of subtropical ridge (Lee et al, 1988).

Inter tropical convergence zone (ITCZ) remains around 5° N in the month of April and some times cyclone vortices form in the region of ITCZ and move from East to West and effect the southern peninsula giving good amount of rainfall. Rainfall variability over the region has been the subject of investigation, due in part of the importance of rain fed agriculture in the region, the arid to semi- arid nature of the climate, and the high degree of interannual and interdecadal variability over the region. It is well known that the most of the rainfall occur during this season is mainly due to convective instability of the atmosphere (Ganesan et. al, 2001). The tropics provide a unique opportunity for short term predictions, because the circulation and temperature patterns of various layers of the atmosphere respond rapidly to changes in the atmospheric conditions. Over many parts of Tamilnadu, Karnataka, and Andhra Pradesh, exceptional stresses on water resources have led to rain harvesting as a means of intercepting flows that may otherwise be "lost" as runoff to the ocean, and put them to immediate beneficial use (Palanisani et. al, 2002). While attractive in the short-term, intensive rain harvesting over long periods of time has the potential to seriously impact groundwater levels, aquatic habitats, and sediment supplies. This rainfall event is said to be abnormal because these areas are situated in the rain shadow of the Western Ghats, large areas of TamilNadu, Karnataka, and Andhra Pradesh receive limited rainfall. Also, because of the hot climate, evaporation rates from these areas are very high. Thus, the quantities of rainfall as well as the quantity of water transferred as evaporation and transpiration are beyond human control. Surface water that flows in streams plays an extremely important role in transporting sediments and nutrients, as well as sustaining the habitats of many plants and animals, collectively referred to as ecosystems. Water that infiltrates underground partly remains in the soil, sustaining plant life, and partly remains below the water table in the form of groundwater. This groundwater feeds natural springs and the wells that supply our domestic, agricultural, and industrial needs. This rainfall was the boon over that area because the condition of groundwater reservoir is improved tremendously because these areas is markedly shallow, with limited water holding capacity, and the quantity of water in the reservoir is vulnerable to seasonal fluctuations in rainfall. Secondly it was good for many dam those can built to divert water for irrigation, flood control and other purposes. The heavy rainfall events sometimes are associated with locally modified atmospheric instabilities, Jayaram (1965) suggest the objective method of forecasting the heavy rainfall events. An analytical study of rainfall pattern over Chennai by Natarajan et. al, 2004 observed that the rainfall pattern over Chennai area have mainly three distinct patterns in which 15-20 percent of total rainfall occurred in during April to September. The above case is abnormal in the sense that the rainfall observed in Tamilnadu and Kerala was highest during last 16 years. Sometimes the unusual rainfall very useful to the economy and ecosystems those are intimately interlinked.

MATERIALS AND METHODS

The rainfall and geostationary satellite imagery data is taken from India Meteorological Department (IMD) Lodi Road New Delhi. The National Centre of Environmental Prediction (NCEP) reanalysis data along with Meteosat -7 derived wind products from Cooperative Institute of Meteorological Science Studies (CIMSS), University of Wisconsin, Madison, USA also utilized in the study. HYDRA software tool for the analysis of MODIS satellite data (collected from NOAA website) and upper air sounding data from University of Wyoming for the convection as well as thermodynamic indices is utilized in this study.

RESULTS AND DISCUSSION

Satellite derived upper air divergence field

Atmospheric motion vector (AMVs) derived from a sequence of triplets of Meteosat -7 geostationary winds can be used to diagnose the Low Level Circulation (LLC) activity. Water vapor winds are most representative of the upper levels (400 mb and above) moisture in the upper troposphere. During the time of LLC the ITCZ was also in active phase and a continuous moisture supply generate an area of convergence in lower levels which was supported by upper level divergence field. The convection area over southern peninsula was encapsulated with sufficient amount of upper level divergence field (Fig 1). The system feedback mechanism enclosed the convective area quasi stationary which results the heavy rainfall over that area. Normally during the month of April this type of precipitation is rare but is of utmost importance for agriculture and drinking water planning.

MODIS data analysis of convection zone

Moderate resolution Infrared Spectroradiometer (MODIS) has 36 spectral bands with 250 m to 1 km resolution. Fig (2 &3) shows the band 31 imagery in Infrared region along with organization of clouds on 5th April 2005 at 0720 UTC time. The transact line over the area between dry region to cloudy region shows the temperature distribution (300 K -180 K). This difference shows the area of availability of deep to intense convection which was later responsible to unusual rainfall over southern peninsula of India. The results presented have been derived from HYDRA software developed by CIMSS of university of Wisconsin, Madison, USA.

Kalpana -1 Satellite imageries analysis

On 1st and 2nd April 2005, the convective cloud mass observed over Bay of Bengal south of 12 N. On 3rd to 5th April there was intense cloud mass over Tamilnadu and Kerala in association with Low Level

Circulation (LLC) at 0.9 Km above mean sea level (ASL) and trough in easterlies at 3.1 Km ASL. Maximum convection was observed over Tamilnadu and Kerala on 5th April 2005 (Fig. 4).

On 7th April 2005 (Fig. 5), there was maximum convective cloud mass over Tamilnadu and Kerala. On 8th there was maximum convective cloud mass over Tamilnadu and adjoining southwest bay. A circular convective cloud cluster was also observed over Lakasdeep and adjoining southeast Arabian Sea. On 9th convection was confined over north Tamilnadu but due to pre monsoon thunder storm activities Tamilnadu and Kerala were covered by convective cloud mass (12 UTC imagery). On 10th April convective clouds were confined over north Kerala but in the afternoon both the states were covered by convective cloud mass. After 10th there were convective clouds over Kerala in association with pre monsoon thunderstorm activities during evening hours.

Synoptic history

There was extended low-pressure area over Tamilnadu with associated cyclonic circulation (CYCIR) extending up to mid troposphere (0.9 and 3.1 Km). On 2nd April 2005 low pressure persist and LLC at 0.9 Km ASL and a trough in easterlies over Tamilnadu coast at 3.1 Km. ASL. The above system moved westwards and observed as an upper air cyclonic circulation over north Kerala and adjoining area with trough in easterlies along Tamilnadu coast at 3.1 Km ASL. On 4th April 2005, there were two troughs on mean sea level chart one over southwest bay and another over southeast Arabian Sea with circulation at 0.9 Km over southeast Arabian Sea.

On 6th and 8th April 2005, we observed the system as a low-pressure area over southeast Arabia Sea with associated CYCIR in the lower troposphere then it became less marked. Another system over southwest bay and adjoining parts of Tamilnadu was observed in the lower troposphere, which moved westwards and remained over Tamilnadu and Kerala up to 10th April 2005.

During first fortnight of April 2005, Tamilnadu and Kerala reported significant rainfall amounts and Rayalseema and South Interior Karnataka and Coastal Karnataka reported moderate to heavy rain. These rainfall figures were very important for these areas. During pre-monsoon season Kerala is predominant for pre-monsoon thunderstorm activities, but Tamilnadu fall in rain shadow area.

NCEP reanalysis data field

National centre for Environmental Prediction (NCEP) reanalysis data is a potential source for examining the past or nearly recent events. The meridional velocity field represents the potential of moisture potential and its possible movement. This in turn is the momentum flux of moisture distribution over the area. Fig (6) shows the meridional distribution of velocity filed and have sufficient uplift potential to sustain the moisture over the wide spread area. Similarly, the Omega vertical velocity filed represents the triggering potential of moist convection over the southern peninsula with negative buoyancy. Fig (7) shows the vertical velocity filed over the area having sufficient triggering up thrust to make the saturated air aloft stable as compared to the dry and unsaturated air below. This generates the conditional instability over the area. This increase the ITCZ activity and positive feedback of moisture over the area which enhance the moisture transport. Fig (8) shows the outgoing long wave radiation filed in clear sky, which is proxy of convection over the area. It is the energy flux in watt/m2 and its low value indicates the convection is available derive the LLC engine. The area of low value of proxy flux is the most representative of sustained moisture over the area, which further responsible for rainfall over the area. There is good inverse correlation in rainfall activity and rainfall. Similarly, vertically integrated total precipitable water filed can also be used a parameter of rainfall activity. It seems a direct relation with rainfall over the area provided the sufficient triggering mechanism is available over the area. Fig (9) suggests the sufficient amount of integrated precipitation water (~ 40 - 45 mm) availability over the area. The above fields are having forecasting potential also as model generated the forecast in short range (1-3 days) and as well as medium range (3-10 days).

Thermodynamic Indices

The possible values of thermodynamic indices along with their thunderstorm possibilities are given below. These indices are based on global observations. Results may vary as per the regional or local

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behavior of the weather events. The Convective Inhibition Energy (CINE) if it is zero then there will not be any inversion of the energy and all available energy will be utilized in building up the convection. As the value of CINE increases (negative order) then the possibility of capping inversion increases and it inhibits the CAPE activity. Table (1) below shows there is a sustained and significant convection was present around Chennai area which was responsible for the significant amount of rain observed over the area.

Table 1: Chennai Upper –air observations (01 -06 April 2005) Station id =43279 (13.0 N, 80.13 E):

Date	Identifier	0000 UTC	1200 UTC
01-04-2005	CAPE (J/kg)	279.78	1911.78
	CINE (J/Kg)	-00.61	-06.94
	Lifted Index	-01.28	05.97
	K index	05.90	16.50
	Precipitable Water (mm)	67.39	31.06
02-04-2005	CAPE (J/kg)		1533.42
	CINE (J/Kg)		-08.96
	Lifted Index		-03.67
	K index		14.30
	Precipitable Water (mm)		36.82
03-04-2005	CAPE (J/kg)	168.82	381.34
	CINE (J/Kg)	-26.56	-80.72
	Lifted Index	-01.58	-01.83
	K index	29.90	37.10
	Precipitable Water (mm)	45.10	49.99
04-04-2005	CAPE (J/kg)	3906.81	1357.20
	CINE (J/Kg)	-00.21	-02.42
	Lifted Index	-06.60	-04.44
	K index	37.00	35.30
	Precipitable Water (mm)	55.55	57.07
05-04-2005	CAPE (J/kg)	637.72	170.39
	CINE (J/Kg)	00.00	-01.17
	Lifted Index	-05.52	-01.83
	K index	39.80	
	Precipitable Water (mm)	58.05	41.68
06-04-2005	CAPE (J/kg)	754.67	482.30
	CINE (J/Kg)	-0.10	-12.23
	Lifted Index	-04.10	-03.67
	K index	34.00	23.00
	Precipitable Water (mm)	53.69	47.34

Source:[http://www.weather.uwyo.edu/upperair/sounding.html]

Rainfall analysis

The rainfall that occurred during the week ending 06 April 2005 and 13 April 2005 made the seasonal rainfall for the period 31st March to 13 April 2005 large excess at Rayalseema, Kerala, Tamilnadu and Pondicherry while it was excess in South Interior Karnataka and Coastal Karnataka. The rainfall realized during the fortnight 31st Match to 13th April 2005 have been tabulated in Table 3. It can be seen that percentage departure from normal was in excess of 100 %. In regard to Tamilnadu and Pondicherry Meteorological subdivision; the rainfall recorded during the above period is highest since 1990.

Concluding remarks

The low level circulation over southern peninsula and supported by ITCZ activity can be seen in satellite imageries in advance. Additionally NCEP reanalysis and MODIS data ensures the potential of convection and availability of the moisture in mid and upper troposphere. Such type of monitoring and forecasting of the weather events are very important in management and planning of agriculture activities over the region. As in this case the departure of rainfall of the April week is more than 100 % and during this time the demand of fresh water is also a major issue. So, with the help of satellite imageries, derived products, upper air observations and model analysis field can justify the utility of the forecast and timely management of available resources.

Table 2(a): K Index with Thunderstorm occurrence Probability

K- Index	Thunderstorm Probability
Less than 15-20	20 %
21- 25	20 - 40 %
26- 30	40- 60%
31- 35	60 - 80%
36 - 40	80 - 90 %
> 40	Near 100 %

Table 2(b): LI and SI conditions for different probabilities of thunderstorms occurrence

LI	Possibilities
-2 to 0	Showers probable, some thunderstorm.
-5 to -3	Moderate indication of sever thunderstorm (forecast thunderstorm)
<-6	Strong indication of sever thunderstorm (thunderstorm forecast)

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Table 2(c): Conventional Available Potential Energy (CAPE) and its significance

APE (Joule / kg)	Significance
300 -1000	Weak Thunderstorm Activity
1000 - 2000	Moderate Thunderstorm Activity
2500 - more	Severe Thunderstorm Activity

Table 3: **Rainfall for the week ending 06-04-2005 and 13-04-2005**

S.No	Meteorological sub-divisions	Week ending (6-4-05)		Week ending (13-4-05)	
		Actual	Normal	Actual	Normal
1	Tamilnadu and Pondicherry	59.3	8.1	46.9	9.5
2	Kerala	62.1	19.7	71.1	29.7
3	South Interior Karnataka	9.9	5.9	24.4	7.5
4	Costal Karnataka	8.5	3.6	9.7	4.1
5	Rayalaseema	9.3	2.5	5.7	2.7

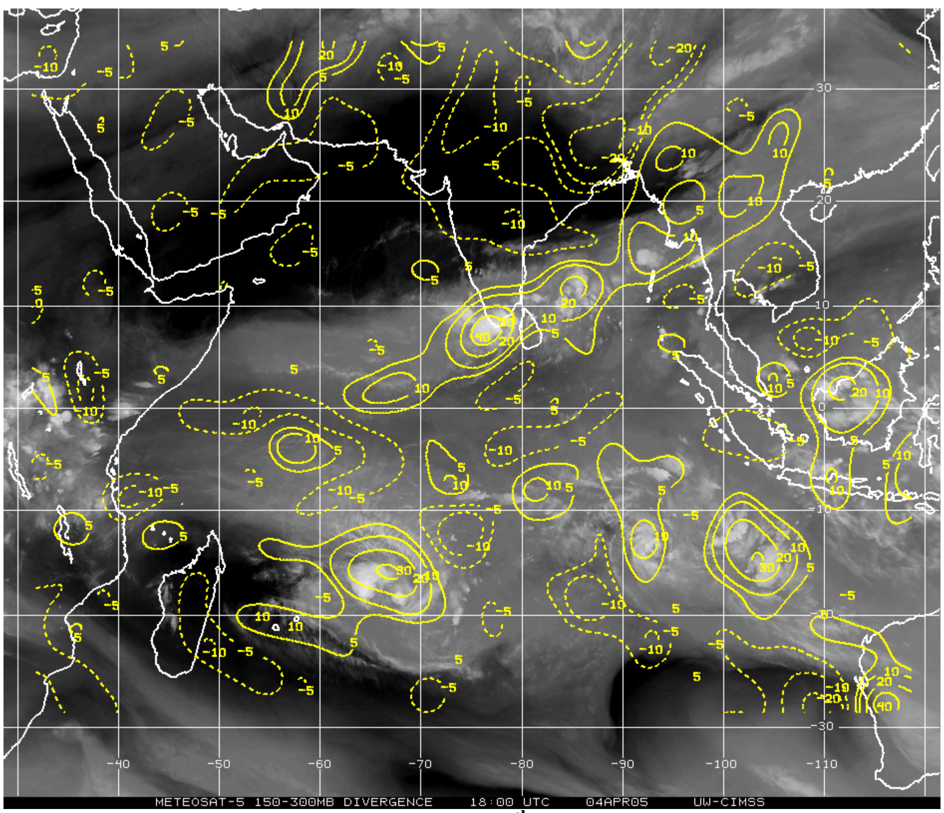

Figure 1: 150-300 mb Divergence 1800 UTC 4th April 2005

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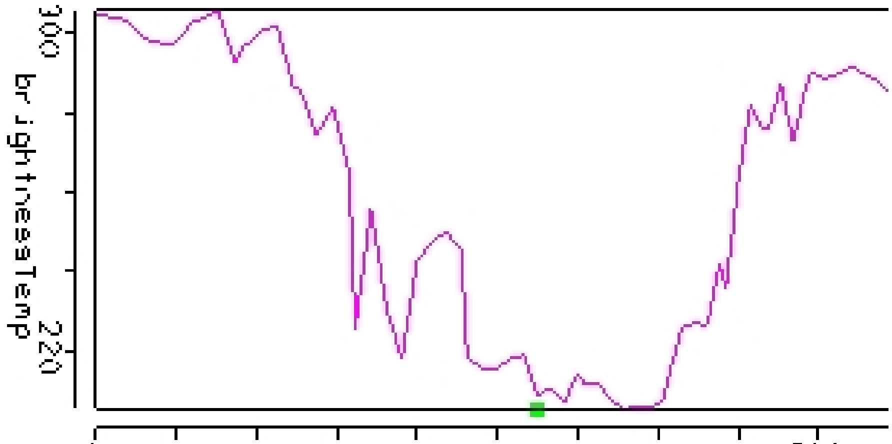

Figure 2: Transact divides the convection and temperature ranges (200 K -300 K)

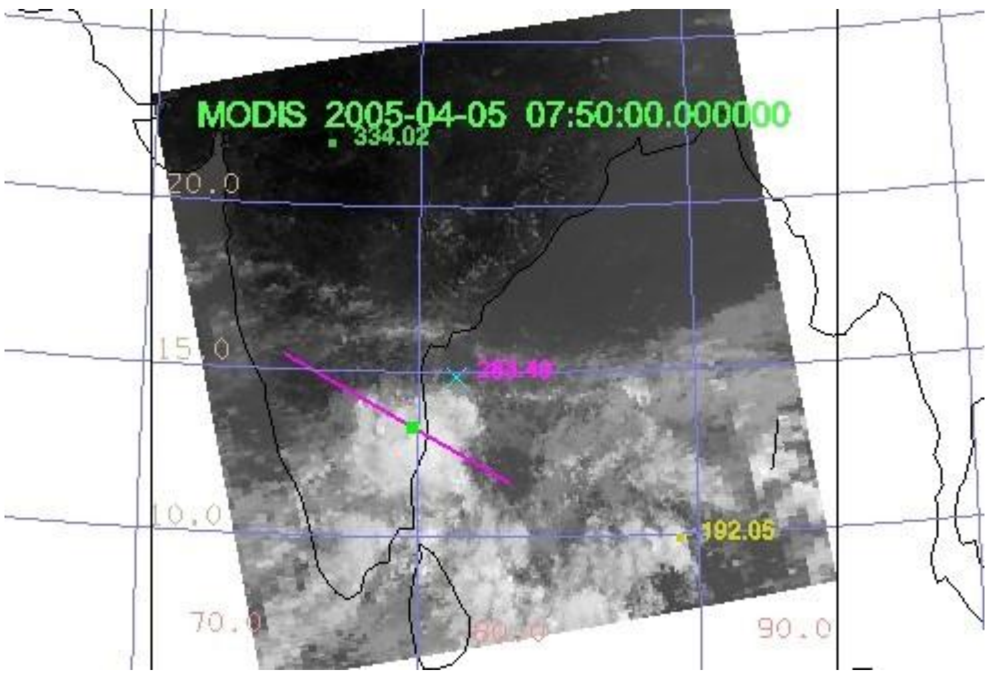

Figure 3: MODIS satellite data coverage at 0750 UTC on 5th April 2005
(Source: modis.gsfc.nasa.gov/data)

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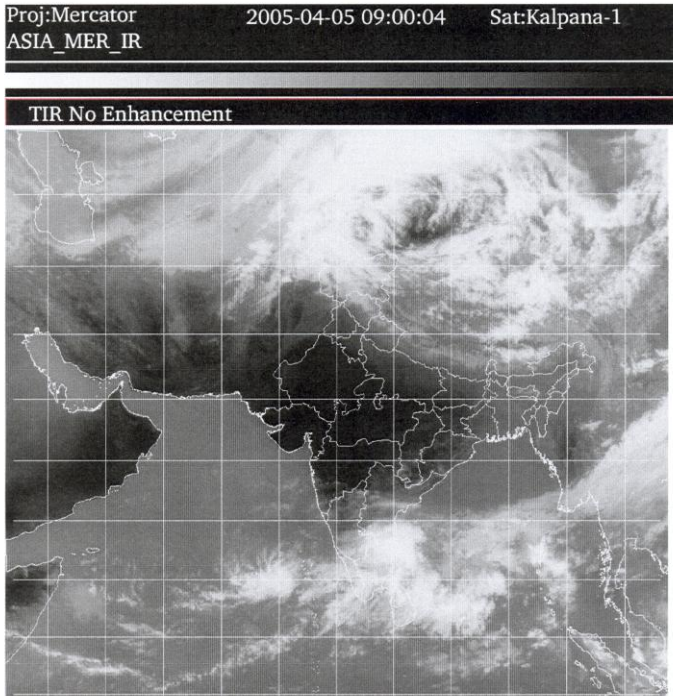

Figure 4: Infrared Imagery of 09 UTC 05 April 2005, indicating circulation in the cloud field over Tamilnadu and adjoining Bay and another circulation in the cloud field over southeast bay also seen.

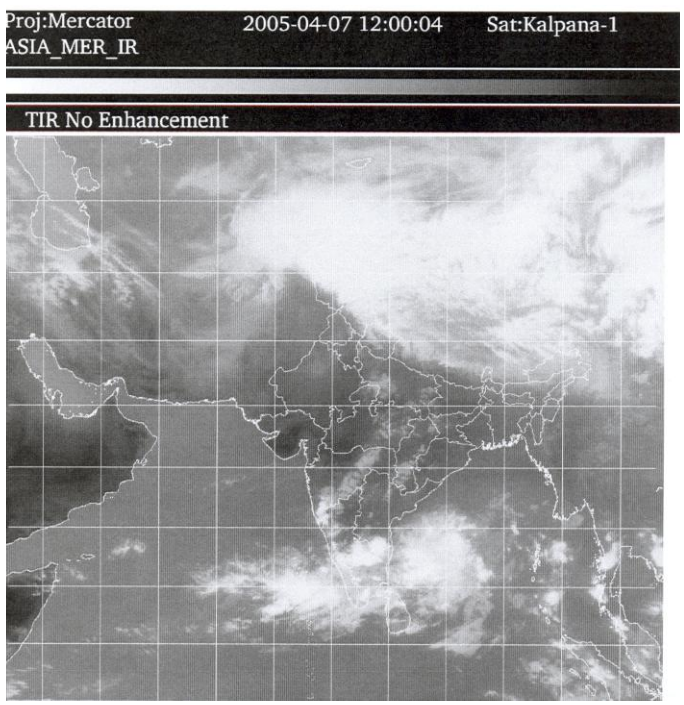

Figure 5: Infrared Imagery of 12 UTC 07 April 2005, indicating circulation in the cloud Sea field over southwest bay and another circulation in the cloud field over southeast Arabian and intense to very intense convection over Tamilnadu and Kerala due to wind shear.

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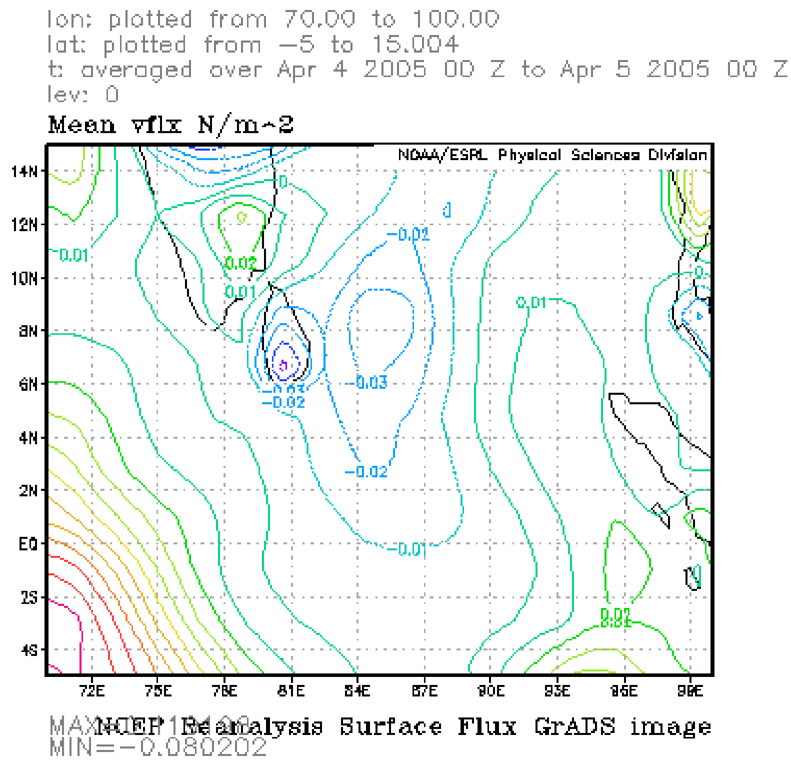

Figure 6: Mean meridional surface flux from NCEP reanalysis data

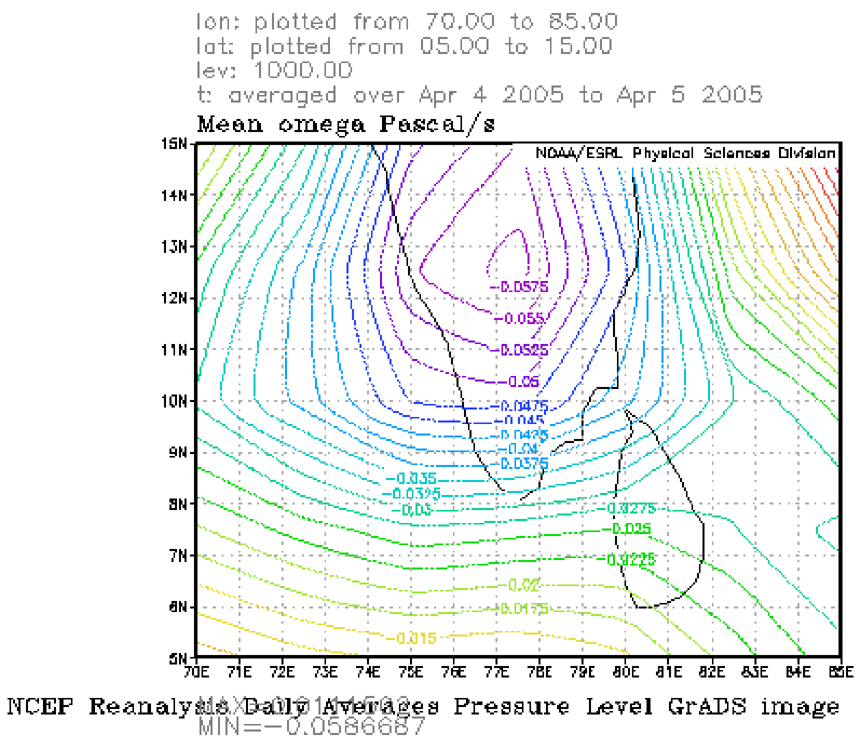

Figure 7: Mean omega vertical velocity (Pascal /sec) field from NCEP reanalysis data

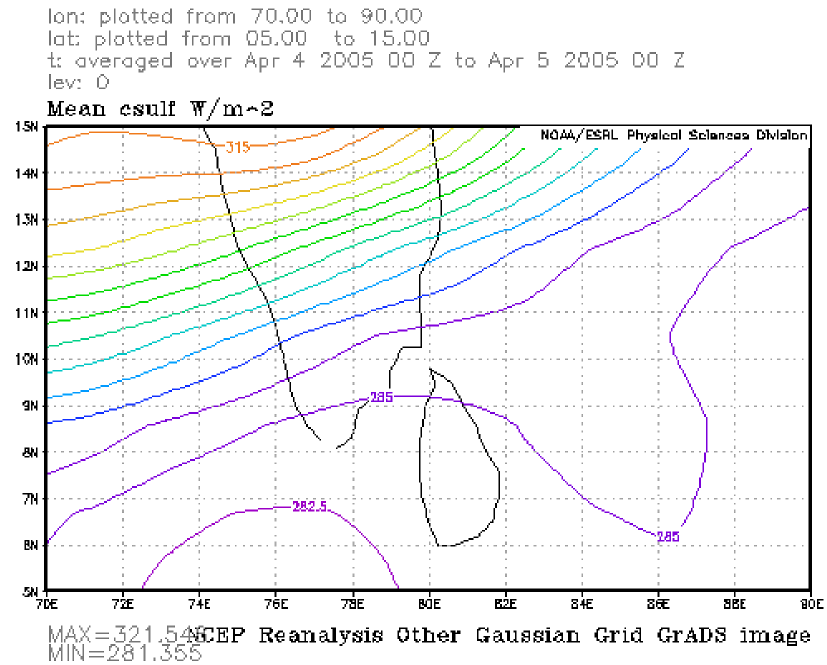

Figure 8: Mean outgoing clear sky radiation flux (watt/m2) from NCEP reanalysis data

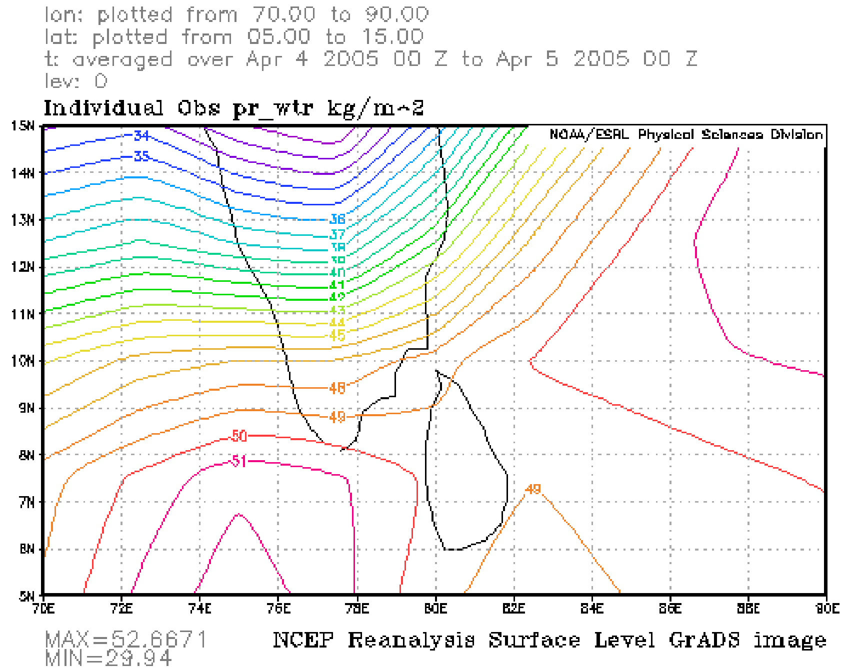

Figure 9: Integrated precipitable water over the circulation area from NCEP reanalysis data

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