Indian Meteorological Society, Chennai Chapter
Newsletter Vol.14, Issue No.1, June 2012

Contents

From the Chairman's Desk...

Dear members of IMS Chennai chapter and readers of Breeze,

I am happy to release the chapter's news letter Breeze, Vol.14 No. 1 of 2012. I am optimistic that the current issue which contains a number of informative articles may quench the scientific thirst of the members and readers of Breeze. I request the members to contribute for the ensuing issue of Breeze likely to be released sometime during December 2012 / January 2013.

I wish to inform you that as a sequel of seminars on non-conventional energy sources organized by our chapter, we have organized a half-a-day seminar on 27th June 2012 A/N. Solar energy and Ocean energy have been covered in that seminar. Prof A. Mani of IIT Madras, Chennai delivered a lecture on *'Thermal applications of solar energy'* and Prof. S.A. Sannasi Raj of IIT Madras, Chennai gave a talk on *'Ocean energy potential in India'*. The seminar was well attended by an audience of more than 100 in number from Students to Senior Scientists / Professors. An abstract of talk delivered by Prof. S.A. Sannasi Raj has been included in this issue for the benefit of members / readers, especially for those who could not attend the seminar.

Our chapter in collaboration with SRM University, Kattankulathur is going to conduct the ensuing International Tropical Meteorology Symposium (INTROMET) series during 27-30 August 2013. The tentative focal theme of the INTROMET-2013 would be **Monsoons – Observations, Prediction and Sustainability**. A formal announcement and first call letter for inviting papers will be sent/released/put on website(s) shortly. Members are requested to prepare high quality papers for presentation in the INTROMET-2013 which is likely to be attended by internationally acclaimed researchers / scientists in the field of monsoon meteorology.

With best regards
R. Suresh
Chairman, IMS Chennai Chapter.
16 August 2012, Chennai

Membership details of IMS-Chennai Chapter (as on June 2012)
Life Members: 145; Ordinary Members: 15; Total : 160

Those who wish to become members of IMS, Chennai Chapter may please mail to
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OCEAN ENERGY POTENTIAL IN INDIA

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An everlasting increasing energy demand-supply gap in India has put tremendous pressure on our energy development program. The availability of energy resources further shows non-uniform growth due to various factors that include social and political reasons in addition to the primary reason of limited reserves of coal and fossil fuels. At present, it is of mandatory requirement to focus on the development of technologies to extract energy from both conventional and non-conventional energy sources. An optimal utilization of generated energy through proper management of demand sector is the need of the hour in our country. Further, there are tremendous scope for decentralizing the energy systems, in particular on renewable sources. For example, the recent peak demand in Tamilnadu has been resolved by some extent from the wind mills and most of those are being managed independently.

On an interesting note, our country has sufficient renewable energy resources viz. solar energy, wind energy, biomass and hydro. These are also widely distributed across the country. Even off late, the poorly given attention is on the energy potential available in the Ocean. Some facts about the geography of ocean: Indian geographic area is 3.29 million sq km and India's Exclusive Economic Zone (EEZ) is 2.1 million sq km with the Indian coastline stretching more than 7,500 km including mainland and islands. The Indian Ocean is the third largest body of water in the world covering about 20 per cent of the earth's water surface. Indian Ocean's energy potential comprises of Ocean Thermal Energy Conversion (OTEC) potential 180,000 MW, Wave Energy potential about 40,000 MW and Tidal Energy Potential about 9,000 MW.

The average wave potential along the Indian coast is around 5-10 kW/m. With a coastline of approximately 7500 km, a ten percent utilization would mean a resource of 3750 –7500 MW, and more importantly distributed across the wider region. The Indian wave energy program started in 1983 at the Institute of Technology Madras (IITM) under the sponsorship of the then Department of Ocean Development, Government of India. Initial research was conducted on three types of device: double float system, single float vertical system and the oscillating water column (OWC). The OWC was chosen as a viable device for Indian conditions. The development activities have thus since concentrated on this type. A 150 kW pilot OWC was built onto the breakwater of the Vizhinjam Fisheries Harbor, near Trivandrum (Kerala), and commissioned in October 1991 by National Institute of Ocean Technology, Chennai. It has demonstrated that energy from a random source such as waves can be harnessed as electrical energy and exported via the local grid. Even though, the present status is not commercially viable, the proven technology would be much useful when the need arises.

The OTEC (Ocean Thermal Energy Conversion) technology uses the water temperature difference at the surface (at about 290 C) and at a depth of 1,100 meters (at about 70 C) to produce electricity. This kind of non-polluting renewable energy source is appropriate for power-starved nation like India. Though it is capital intensive now, improvements in technology and higher rated plants can bring down the unit cost considerably. India's OTEC resource potential is estimated at around 180,000 MW. Conceptual studies on OTEC plants are being underway and the same concept has already been extended to successful installation of desalination plants in Lakshadweep islands. For the mainland, the cost of power generation for plants upwards of 25 MW is expected to be comparable to fossil fuel units. But for islands, an OTEC power plant of any size is cheaper than the conventional generation units. The economics is one of the governing deciding factors for the choice of OTEC power plant. Advanced studies made thus far on thermal cycle and heat exchangers have brought promising results of far improved efficiency of OTEC system as a whole. From our scientists successful demonstration, OTEC is valuable not only in power generating, but in achieving additional objectives such as desalination. We have successful desalination plants in our islands.

According to Ministry of Non conventional Energy Sources, Government of India, India has a combined tidal potential of 9,000 MW in Gulf of Kutch, Sundarbans and Gulf of Khambhat. Two estuaries on the west coast, Gulf of Khambhat and Gulf of Kutch in Gujarat have large tidal potential. Gulf of Kutch potential is estimated to be 900 MW with an annual output of 1.6 TWh. The potential of Gulf of Khambhat is about 7000 MW by enclosing a basin area of 1970 sq-km and the annual output is estimated to be 15 TWh. Along the east coast, Sunderbans in West Bengal is a potential site. 20 MW power estimated in regions of Dungaduani, Belladonna Creek & Pitts Creek in Sunderbans will lead to the near future tidal power plant.

The typical magnitude of ocean current along the Indian sub-continent is much smaller and there is no feasibility for the extraction of energy from ocean currents. However, ample opportunities exist to install tidal current mill at the tide dominant locations discussed earlier. The implementation of small tidal current mill is very much similar to wind mill and hence, a lot of scope exists for the participation of non-governmental agencies in the power sector.

India has good know-how and technical knowledge in many commercially viable Ocean Energy technologies. However, the infrastructure for large scale development and deployment are not available in comparison to conventional forms of energy which were developed over a number of years. The natural advantage available to conventional energy due to its high level of maturity in all spectrums of its development and its widely accepted usage, is not available to Ocean Energy technologies. We need a judicious mix of large scale and small scale installation and production of Ocean Energy depending upon the technology and usage and its applications. In remote areas and rural locations, the decentralization of power sector focusing on Ocean Energy would be a viable option in the near future.

WERE 2009 AND 2010 THE WARMEST YEARS IN INDIA SINCE 1901? IF SO WHAT IS THE SIGNIFICANCE?

by

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1. Warmest years

The India Meteorological Department (IMD) announced in 2010 that 2009 was the warmest year in India since 1901 (Attri and Tyagi, 2010).. Again in 2011 it was stated that 2010 was the warmest since 1901 (IMD, 2011). The annual mean temperature for the country as a whole is estimated to have risen by 0.56ºC over the period. This agrees with the widespread perception that the world is warming.

What was the basis for this assessment? The IMD has utilised the records of about 210 surface observatories (including those at major cities) all over India and computed the average of the daily maximum and minimum temperatures at each station. Data have been gridded and weighted average of all grid values has been calculated for the country as a whole. While this is a straightforward process there are certain limitations of the data which need to be considered, as the likely errors in the data could be larger than the "expected" warming due to any climate change.

2. Changes in Land Use

Over the period of more than a century many land use changes have evidently taken place all over the country. The changes in urban areas may be in the form of new structures which can contribute radiation or alter wind circulation. In other areas there can be changes such as development of irrigated lands, change in farming practices, drying up or filling up of water bodies and removal of vegetation. These changes affect the radiation balance, evaporation, soil moisture and wind flow. The observed increase in temperature can have a component due to land use change and a component due to changes in atmospheric composition and it will be difficult to separate the two.

It is interesting to note that the Inter-Governmental Panel on Climate Change (IPCC) (IPCC, 2012) has recently redefined climate change as "*A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use*". This is different from the previous definition. IPCC states "This definition differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change is defined as: "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability*."

The IMD (Attri and Tyagi, 2010) is therefore correct in listing the trend under "**Climate Change Scenario**". However the land use changes in each area and their impact will depend on many factors (meteorological as well as socio-economic) and will be widely different in different areas. Hence the temperature changes may not be compatible among all the stations or the particular station's own data of earlier decades. An average of the temperatures for the whole country is therefore unlikely to be a good measure of climate change.

3. Deterioration of Exposure Conditions

In case an observatory site is changed, IMD has procedures to compare observations at the new and old sites for ensuring compatibility. But the change in exposure conditions at the same site is difficult to quantify or correct for. In major cities such as Mumbai and Kolkata where the observatories are surrounded by newly developed roads and buildings, the changes are large and the observatory exposure is drastically affected. In addition to the changes in radiation fluxes and wind flow, even the instruments could have been shadowed in some cases.

It is not often possible to shift the observatory to a more open and representative site to overcome this problem. As different stations are differently affected the computed country average will be affected.

4. Heat island effect

The heat island effect in cities is well-known. A study organised by the present author at Chennai (Jayanthi , 1991) in the 1980s showed heat island effects of up to 4ºC in some pockets in the minimum temperature epoch in winter. The effect on maximum temperature may be expected to be smaller. The result indicates that the heat island effect is much larger than any increase which may be expected due to climate change. There may also be effects of changes in local wind circulations due to urban development or due to increasing air pollution. Such an effect will bias the country average.

5. Maximum and minimum temperatures

Maximum and minimum temperatures may be affected differently by land use changes or the heat island effect. Hence an average of the maximum and minimum temperatures may not bring out the correct change over time if any.

6. Network Selection

The basis of selection of the 210 stations for the computation of trend is not clear. Presumably the departmentally manned observatories with long period records which can be expected to have been set up originally with good exposure and yield more reliable data have been selected. Presumably there has been no change in type of instrumentation or observing practices at these stations. These need to be verified.

The USA has a Historical Climate Network consisting of a subset of stations of the National Weather Service for Climate change analysis. But even this is said to have several stations with unsatisfactory exposures (Davey and Pielke, 2005). More recently a U.S. Climate Reference Network (CRN) has been established (Vose et al., 2005). The IMD also maintains a network of 10 Global Atmosphere Watch stations (GAW, formerly Background Air Pollution Monitoring Network or BAPMoN) as per WMO protocols and standards (Attri and Tyagi 2010). These may perhaps have a record which has not been significantly affected by the above effects but these stations are available only from 1974. They are few in number and widely different in geographical distribution and in topographic characteristics. Hence they may also not be representative of the country. The optimum station density network for assessing trends may need to be determined (See e.g. Voss and Menne, 2004).

7. Correction of data

Evidently while assessing long-term trends the impact of these effects has to be minimised. How is this to be done?

The stations to be included in the analysis can be reviewed to exclude those which are affected by significant heat island effect or exposure deterioration. A station by station check is necessary to exclude those which have poor or non-standard exposures or are unrepresentative in other respects. Techniques for "homogeneity adjustments" have been suggested (e.g. Easterling et al., 1996). Another method suggested is to use temperature anomalies instead of the temperatures themselves because temperature anomalies are expected to be much more geographically coherent than actual temperatures (Peterson, 2006).The anomaly time series is derived by subtracting the mean temperature from a base period. Such corrections need to be effected before announcing to the public the rise in the temperatures.

8. Significance and interpretation of temperature trends

How to interpret the trends corrected as suggested and use the information?

There is a widespread view among scientists that near-surface temperature is not the most reliable metric to assess climate change. Other parameters such as ocean heat content have been suggested as most of the energy received by the earth is stored in the oceans (e.g. Ellis et al. 1978). Publishing a temperature trend without interpreting it may cause the public to derive wrong conclusions. For example the public and the media often state and feel during every summer that the current summer is hotter than any they experienced earlier. They interpret this as climate change. This perception is in most cases not correct.

As discussed earlier, whether the observed trend is due to land use change or change in atmospheric composition, it is to be considered as climate change. But the actions to be taken to minimise the trend will be different in the two cases. The meteorological community should be able to advise decision-makers about measures to be taken in the two cases. Any information which goes to users should put these issues in proper perspective.

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ROLE OF TELESCOPIC METEOROLOGICAL TOWER IN WEATHER MONITORING – A REVIEW

by
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Introduction

A weather station is a facility, either on land or sea, with instruments and equipment for observing atmospheric conditions to provide information for weather forecasts and to study the weather and climate. The measurements taken include temperature, barometric pressure, humidity, wind speed, wind direction, and precipitation amounts. Wind measurements are taken as free of other obstructions as possible, while temperature and humidity measurements are kept free from direct solar radiation. The atmosphere is the medium in which air pollutants can be transported away from the source. For a given source strength, its actions govern the length of time, the frequency and the concentration to which any receptor will be exposed. On the other hand, meteorology plays only a limited part in the control of elimination of air pollution. The degree to which air pollutants discharged from various sources concentrate in a particular area depends largely on meteorological conditions. Micrometeorology is a branch of meteorology which deals with the atmospheric phenomenon and the processes at the lower end of the spectrum of atmospheric scales, which are variously characterized as microscale, small-scale, or local-scale processes. The scope of micrometeorology is further limited to only those phenomena which originate in and are dominated by the shallow layer of frictional influence adjoining the earth's surface, commonly known as the atmospheric boundary layer or the planetary boundary layer. A 16m tall telescopic meteorological tower has been installed in SRM University with multi-level sensors and data logger. The entire system was commissioned on 10th July 2009. The data is used in real-time by IGCAR for its radiological environmental safety applications.

Study Area

Study area of the project is Potheri Village (12˚ 48' N to 12˚ 49' N and 80˚ 02' E to 80˚ 03' E). Potheri is one of the villages in Kancheepuram District, Tamil Nadu. It is situated near NH 45, about 40 km away from Chennai City. The tower was installed near medical canteen which is an open area (Figure 1).

Types of Sensors in Automatic Weather Station (AWS)

The sensors used on an AWS are the heart and soul of the system. Therefore a great deal of care should be taken when choosing sensors appropriate to the user's requirements. The Bureau's standard AWSs use sensors to monitor temperature, humidity, wind speed and direction, pressure and rainfall. Various advanced sensors are available for specialised applications. The components of telescopic tower are capacitive bead for measuring temperature, anemometer for measuring wind speed, wind vane for measuring wind direction, aneroid sensor for measuring pressure and in some cases a humicap thin film capacitor for measuring relative humidity.

Fig .1 Location of meteorological tower

Mast

The standard mast heights used with automatic weather stations are 2, 3, 10 and 30 meters. Other sizes are available, but typically these sizes have been used as standards for differing applications.

Mode of Operation

The NRG Symphonie data logger is an internet ready, ultra-low power microprocessor-controlled data logging system specifically designed for the wind energy industry. The Symphonie logger has a fixed averaging interval of 10 minutes. Each of the 12 channels' averages, standard deviations, minimum and maximum values are calculated from continuous 2 second data samples. Data intervals are calculated every 10 minutes, time stamped with the beginning time of each interval and written to the Multimedia Card (MMC) at the top of each hour.

Data Collection from Meteorological Tower

Meteorological data was collected by the sensors installed on the tower. The wind speed and direction are measured using anemometers for the wind speed, and wind vanes for the direction. These sensors were usually positioned at four heights on the tower, with four anemometers at each height, and one vane (Table 1). For the past few years we are regularly collecting the data and using the same for student projects and analysis. Presently the tower gives the basic meteorological parameters averaged for every 10 minutes. We are planning to display the data in real time (online). As a part of this work we have updated the data through group mail to avoid manual transferring the data from memory card to the system. We are planning to upgrade the tower with air quality monitoring instruments and sensors, so that it can be used along with weather data. This is more useful to the weather community and students of SRM University.

Table1: Measurement details of the tower system

Parameter	Sensor	Level	Unit	Sampling and averaging interval
Wind speed	Cup anemometer	2m, 4m, 8m, 16m	m/s	**10s and 1 hr**
Wind Direction	Wind vane	2m, 16m	Deg., zero to North	**-- do --**
Air temperature	Stevenson screen with Resistance thermometer	1.6m, 10m	Deg Celsius	**-- do --**
Rel. Humidity	Capacitance sensor	1.6m	%	**-- do --**
Air pressure	Aneroid capacitance sensor	1.6m	mb	**-- do --**
Rainfall	Tipping bucket	0.5m	mm/h	**Per hr**

Table 2a Average, standard deviation, maximum values of wind speed Aug 2010–Mar 2011

Month → / Wind speed (m/s)	Aug 2010	Sep 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011
Average (2 m)	0.897	0.792	0.824	0.815	0.924	1.08	0.8	0.68
Average (4 m)	0.916	1.080	1.119	1.076	1.239	1.37	1.17	1.06
Average (8 m)	1.443	1.326	1.257	1.209	1.324	1.41	1.27	1.18
Average (16 m)	1.798	1.857	1.696	1.672	1.716	1.79	1.67	1.63
Standard deviation (2 m)	0.549	0.449	0.507	0.634	0.701	0.91	0.6	0.35
Standard deviation (4 m)	0.689	0.644	0.653	0.797	0.846	1.03	0.76	0.66
Standard deviation (8 m)	0.874	0.841	0.783	0.941	0.952	1.11	0.87	0.77
Standard deviation (16 m)	1.076	1.065	0.941	1.134	1.048	1.16	1.03	1.02
Maximum (2 m)	3.13	3.15	3.07	3.98	3.83	4.53	4.12	2.23
Maximum (4 m)	3.77	3.72	3.80	4.78	4.72	5.08	4.67	2.77
Maximum (8 m)	4.38	4.52	4.72	5.35	5.08	5.25	4.83	3.37
Maximum (16 m)	5.75	5.97	6.03	6.28	5.67	5.53	4.58	4.83

Table 2b Average, standard deviation, maximum and minimum values of temperature Aug 2010–Mar 2011

Month → / Temperature (deg C)	Aug 2010	Sep 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	Mar 2011
Average (2 m)	29.21	29.31	29.04	27.52	25.22	25.58	26.42	28.34
Average (10 m)	28.37	28.42	28.21	26.67	24.51	24.81	25.55	27.38
Standard deviation (2 m)	2.98	2.75	2.88	2.83	2.62	3.23	3.59	4.03
Standard deviation (10 m)	2.72	2.38	2.60	2.51	2.39	2.83	3.03	3.42
Maximum (2 m)	36.77	36.40	36.43	35.68	33.25	32.55	34.38	38.35
Maximum (10 m)	35.62	34.97	34.87	34.20	31.68	30.92	32.18	36.58
Minimum (2 m)	24.10	23.93	24.12	20.63	19.63	19.45	19.42	21.05
Minimum (10 m)	23.27	23.27	23.40	20.08	19.28	18.92	18.98	20.63

Results and Discussion

Temperature and wind data were taken and correlation was done. The variation in wind speed is high for all the months, with the standard deviation close to the mean (Table 2a). The wind speeds reduced at the lower levels consistently for all the months. The maximum wind speeds at all levels remained more or less constant from August through October. They were the highest in November and again reduced in December. The wind speeds increased again in January and started reducing in February. This pattern follows the monsoonal trend of the region. The temperatures at the two levels also remained almost the same till October, and then saw a gradual decline (Table 2b). The temperatures again started increasing by February, after the end of the monsoon season in January. The average temperatures at 2 m were higher than those at 10 m by almost a degree, due to the influence of the land surface.

Correlations were calculated between wind and temperature (Table 3). The correlation coefficient is the normalized measure of the strength of the linear relationship between variables. It is interesting to note that in the non-monsoon months the correlation was high at all levels and it decreased towards the monsoon season. There was no correlation in November and December, and the correlation between wind and temperature started to turn negative in December. However, from January the correlation between wind and temperature again increased (Figure 2).

Table 3 Correlation between wind and temperature

	Wind and temperature 2 m	Wind 16 m and temperature 10 m
Aug 2010	0.482	0.460
Sep 2010	0.397	0.244
Oct 2010	0.336	0.265
Nov 2010	0.111	0.093
Dec 2010	0.112	-0.006
Jan 2011	0.451	0.451
Feb 2011	0.467	0.574
Mar 2011	0.734	0.662

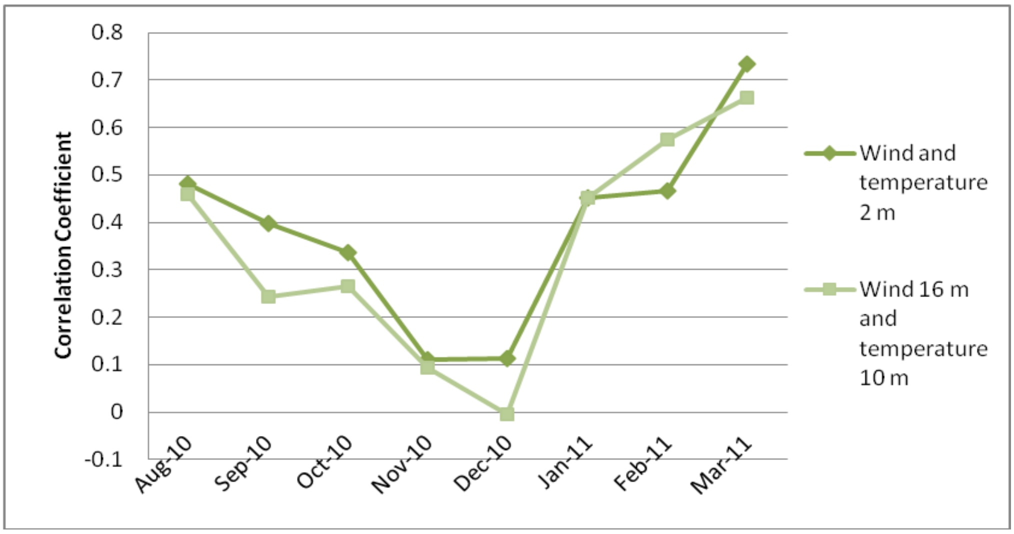

Figure 2 Correlation between wind and temperature

It is clear from above that the average wind speeds were the highest in January and lowest in March. The temperatures were the lowest in December and January, corresponding to the monsoon season, and then increased. The average and maximum temperatures at 2 m were higher than those at 10 m by almost a degree, due to the influence of the land surface. In all the month there is positive correlation except in the month of December due to influence of seasonal change and depression.

Conclusion

The importance of data from AWS installed for operational weather analysis and forecasting, especially during adverse weather conditions cannot be overemphasised. These inputs help the weather forecaster to correctly assess the intensity and predict the landfall of the system especially at the local scales.

Acknowledgement

It is our duty to acknowledge the Director, IGCAR, Kalpakkam and the scientists of Radiological Safety Division for their continuous support for installation of tower and the Director (E&T) and HOD, Department of Civil Engineering of SRM University for their support and encouragement in executing this work.

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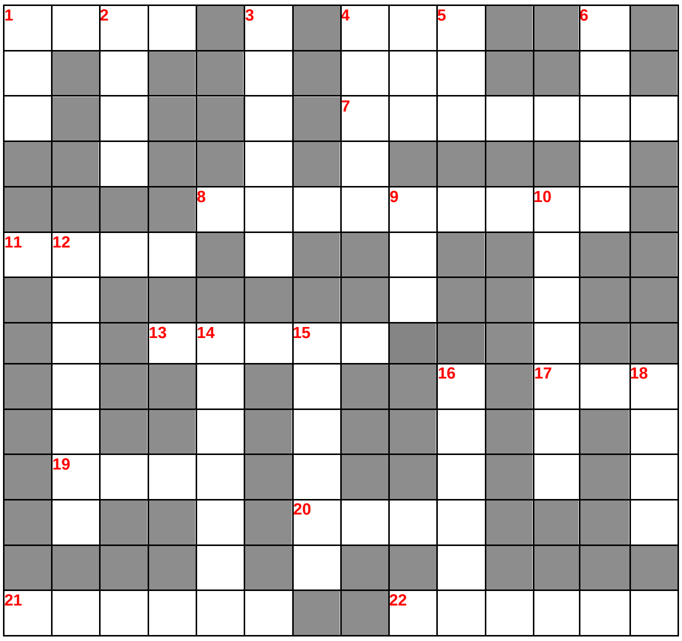
Weather Puzzle



Across

1 - hydrometeor
4 - if isolated means one or two places, scattered implies ---
7 - fluid discharge
8 - curl the velocity
11 - an episode of pressure swing in tropical pacific
13 - derived from Greek Okeanos
17 - drops of condensation
19 - top layer of earth surface
20 - more datum
21 - high at Atlantic
22 - solar hot spots

Down

1 - acronym for runway visibility
2 - acronym for trades meet
3 - storm penetrating Arab lands
4 - mathematically first order discontinuity
5 - not yet dry
6 - solar aura is Great
9 - rink surface for hockey
10 - rumbling after electric discharge
12 - what will happen in next few hours?
14 - revolving system in torrid zone
15 - indicates degree of reflection
16 - brief violent wind storm
18 - air motion

S.R.Ramanan

SATELLITE-BASED AUTOMATIC RAIN GAUGE STATIONS OF INDIA METEOROLOGICAL DEPARTMENT

by

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Globally, the process of augmentation of the national surface observational network to obtain data from meteorologically unrepresented locations has gained importance in the recent decades. In order to have a spatially denser and technologically state-of-art automated unmanned observational network on par with other countries, Automatic Weather Stations(AWS) and Automatic Rain Gauge stations(ARGs) are being installed all over India under the modernisation programme of India Meteorological Department(IMD). Typically, data from the AWS and ARG are considered as representative of the 3 km radial area around them. Already, around 675 AWS are functional. Sensor for measurement of rainfall is the tipping bucket rain gauge and is interfaced with all the 1350 satellite-based ARGs proposed under Phase I. Sensors for air temperature, relative humidity and rainfall are available in 500 ARGs. The installation and commissioning of ARGs under Phase I is expected to be completed by the end of year 2012. Regional Meteorological Centre, India Meteorological Department, Chennai is the nodal office which coordinates the installations in the southern peninsular India where 209 ARGs have been planned. Tamil Nadu and Puducherry will have 75 ARGs out of which 10 have been already commissioned in and around the Greater Chennai metropolitan city. Work of installation of ARGs has commenced in other nearby districts of Tamil Nadu. 50 are planned in Karnataka, 54 in Andhra Pradesh and 30 in Kerala. Installation work is almost completed in Kerala.

The 10 ARGs of the mesoscale network of Greater Chennai city are located in the premises of 1) Satyabhama University(which is the first ARG site commissioned on 29.3.2012), 2) PWD Taramani, 3) Hindustan University, 4) LMOIS Kolapakkam, 5) Poonamallee, 6) Chembarambakkam, 7) Puzhal, 8) KVK Kattupakkam, 9) HVF Avadi and 10) Anna University (10th and final ARG commissioned on 23.5.2012). The target of IMD under Phase I of the modernisation programme in having a denser network of ARGs in the urban context in major metropolitan cities to understand the spatial variability in rainfall, air temperature and relative humidity has been achieved. It is planned to have a minimum of four ARGs in each district and at least 10 more for the urban network under Phase II which may take at least two more years for the process to fructify. Site selection will be initiated shortly to identify more locations in every district to install ARGs.

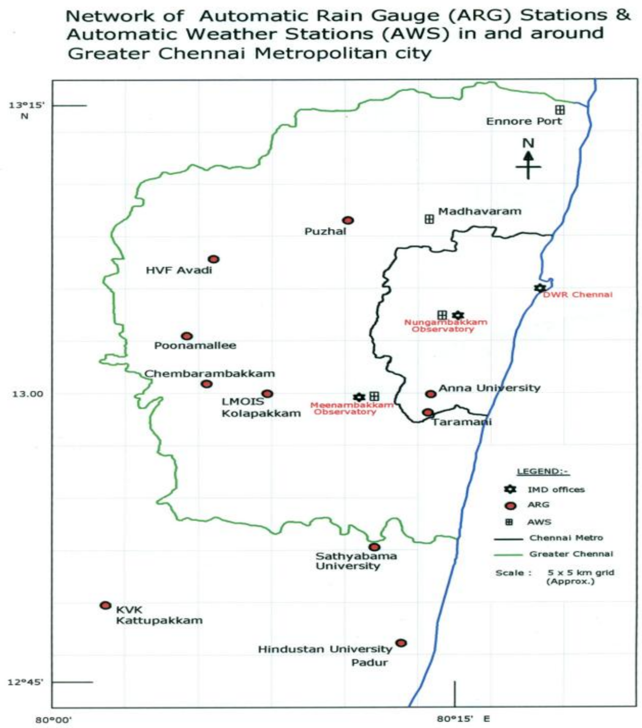

Fig.1 ARG and AWS network in the Greater Chennai metropolitan city.

In Chennai city, conventional surface weather observatories function at Nungambakkam and Meenambakkam. AWS are also installed in Nungambakkam, Meenambakkam, Madhavaram and Ennore Port. Along with the data from two conventional observatories, meteorological data from the four AWS and 10 metro ARGs will help in understanding the variability in rainfall, air temperature and relative humidity in the urban scenario. Fig.1 shows the spatial distribution of the 10 ARGs along with the existing AWS, surface observatories and the Doppler Weather Radar Facility, Chennai. Denser automated surface observational network for weather monitoring is now a reality, at least partially, though the requirement is not yet fully met.

Installation of an ARG requires a level site of area 5 m x 7 m with adequate meteorological exposure conditions. An ARG(as shown in Fig.2) will have a mast of 2.5 metres height, a transmitting antenna, datalogger enclosure, sensors and a 12V battery powered by a solar panel. The hourly data is transmitted at an uplink frequency of 402.76 MHz by means of a technique called Time Division Multiple Access (TDMA) to the geostationary satellite INSAT-3A which re-transmits the data in extended C-band frequency to the receiving earth station located at Pune. Each ARG has a unique time-stamping synchronised with the satellites of the Global Positioning System(GPS) so that data collision is avoided totally. The data in near-real time is available in the dedicated web site http://www.imdaws.com. In addition, the data is available to the forecasters through the AMSS (Automatic Message Switching System) and Global Telecommunication System (GTS) link. Educational and research institutions along with many government offices have evinced keen interest in having an ARG in their premises and provided valuable land for installation of ARGs. This sort of collaborative efforts will continue for Phase II as well. In this way, on the basis of mutual understanding and cooperation, the national project of IMD is being successfully implemented in a phased manner.

Fig.2 A typical ARG site at Krishi Vigyan Kendra, Kattupakkam

Preliminary analysis of temperature data from the urban network during the peak hot weather month of May 2012 indicates a distinct pattern in temperature variability, influenced by the micro-environmental factors like vegetative cover, vehicular traffic, suspended particulate matter, industrial activity, presence of water bodies like lakes in the locality. Ennore Port, due to industrial activity showed higher maximum temperatures during the last week of May 2012. At the same time, due to its proximity to the Bay of Bengal sea coast, onset of sea breeze in the afternoons brought down the evening temperatures considerably. ARG at Avadi, in the premises of Heavy Vehicles Factory, though comparatively located inland, recorded maximum temperatures almost equal to that of Ennore Port. Chembarambakkam, Puzhal and Madhavaram which have water bodies and higher vegetative cover in the vicinity have shown comparatively lower maximum temperatures. Analysis of more months of temperature data would help in arriving at conclusions which may depict consistency in the temporal and spatial variability.

IMPACTS OF SEA SURFACE TEMPERATURE ON CYCLONE DERIVED RAINFALL: A STUDY USING NUMERICAL WEATHER MODEL (WRF)

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1. Introduction

1.1 Sea Surface Temperature

Sea surface Temperature (SST) is the water temperature close to the surface of Sea. In practice, the exact meaning of surface varies according to the measurement method used. A statistical infrared radiometer indirectly measures the temperature of the very thin layer of about 10 micrometer thick of the ocean which leads to the phrase skin temperature. Because, Infrared radiations are emitted from thin layer, Microwave instrument measures sub skin temperature at about 1mm.

1.2 Measurement of SST

There are varieties of techniques for measuring this parameter. These can potentially yield different results. The earliest technique for measuring SST was dipping a thermometer into a bucket of water that was manually drawn from the sea surface. The first automated technique for determining SST was accomplished by measuring the temperature of water in the intake port of large ships. This measurement is not always consistent; however, as the depth of the water intake as well as exactly where the temperature is taken can vary from vessel to vessel. Probably the most exact and repeatable measurements come from fixed buoys where the depth of water temperature measurement is approximately 1 meter. Many different drifting buoys exist around the world that vary in design and the location of reliable temperature sensors

Since 1980, Satellites have been increasingly utilized to measure SST and have provided on enormous leap in the ability to view the spatial and temporal variation in SST. Satellite measurement of SST are far more consistent and in some cases, accurate than the in situ temperature measurements. The satellite measurement is made by sensing the ocean radiation in two or more wavelengths in the infrared part of the electromagnetic spectrum or other parts of the spectrum which can be empirically related to SST. These wavelengths are chosen because they are,

- Within the peak of the black body radiation expected from the earth,
- Able to transmit well through the atmosphere.

The satellite measured SST provides both a synoptic view of the ocean and a high frequency repeat views, allowing the examination of basin - wide upper ocean dynamics not possible with ships or buoys. The group for high resolution SST provides operational access to nearly all satellite Data sets in a common format and within six hours of acquisition by the satellite instruments. The National Oceanic Atmospheric Administration (NOAA) has been providing research quality SST data continuously since 1981. As of 2009, version five of the path finder project contains reprocessed global SST data from 1981 through April 2009 at 4 km resolution.

However there are several difficulties with Satellite based absolute SST measurements. First, in infrared remote sensing methodology the radiation emanates from the top ‘Skin ' of the ocean, approximately the top 0.01 mm or less. It may not represent the bulk temperature of the upper meter of ocean due to primarily to effects of solar surface heating in the day time, reflected radiation, as well as sensible heat loss and surface evaporation. All these factors make it somewhat difficult to compare to measurements from buoy or ship board methods, complicating ground truth efforts. Secondly, the Satellite cannot look through clouds, creating a “fair weather bias” in the long term trends of SST. Nonetheless, these difficulties are small compared to the benefits in understanding gained from Satellite SST estimates. However, some microwave techniques can measure SST and “See” through clouds.

1.3 SST and Tropical Cyclone (TC)

SST above 26.5°C is generally favorable for the formation and sustaining of tropical Cyclones. Generally higher the SST, stronger will be the storm. However, there are many factors affecting the strength of the storm. Remotely sensed SST can be used to detect the surface temperature signature due to hurricanes. In general SST cooling is observed after the passing of a hurricane primarily as the result of mixed layer deepening and surface heat losses. In some cases upwelling caused by a surface wind field divergence perhaps in conjunction with bathymetric effects can be a source of cooling.

1.4 Cyclone

In meteorology, a cyclone is an area of closed, circular fluid motion rotating in the same direction as the Earth. This is actually characterized by inward Spiraling wind that rotates counter clock wise in the Northern hemisphere of the Earth. Most large scale Cyclonic circulations are centered on areas of low atmospheric pressure.

While TC can produce extremely powerful winds and torrential rain, they are also able to produce high waves and damaging storm surge as well as spawning tornadoes. They developed over large bodies of warm water and loss their strength if they move over land. Because of this coastal regions can receive significant damage from a tropical cyclone, while inland regions are relatively safe from receiving strong winds. Heavy rains however can produce significant flooding inland and storm surges can produce significant flooding inland, and storm surges can produce extensive coastal flooding up to 40 km the coastal line.

Although their effects on human populations can be devastating, tropical cyclones can also relieve drought condition. They also carry heat and energy away from the tropics and transport it toward temperature latitudes, which make them an important part of the global atmospheric circulation mechanism. As a result, tropical cyclones help to maintain equilibrium in the Earth's troposphere, and to maintain a relatively stable and warm temperature worldwide.

1.5 Rainfall

Rain\fall reports during a cyclone passage are non uniform. The average rainfall in the passing tropical storm amounts to fairly common 500 mm. To the right from the direction of motion the precipitation area is larger and the rainfall more intense than to the left where the precipitation area abruptly fades at a distance of 60-70 km from the center. As tropical storm recurves toward higher latitude, the precipitation pattern can change abruptly and unpredictability.

2. Problem, Data and Methodology

2.1 Problem

Weather is the state of atmosphere at a particular place and time. It has several parameters like temperature, pressure, humidity, wind direction, wind speed etc. Temperature is the one of the major parameters of weather. General public wants to know in advance whether any heat wave or cold wave occur in the next 4-5 days. Peoples largely depend on the weather condition for planning their work. Thus creating a greater need for weather forecast, which help them to plan well in advance and make the most efficient and economic use of their labour and equipment. Reliable weather forecasting can be done based on available synoptic charts, satellite / RADAR inputs for coming two days. Reliable forecasts beyond two days can only be done based on numeric weather prediction models.

The Weather Research and Forecasting (WRF) Model is a next-generation meso scale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. It is proposed run the WRF model and generate five days forecast of intensity, rainfall associated with the cyclone, wind, temperature, humidity field during 'Nisha' Cyclone in the Bay of Bengal region. Also the model is run with additional input of SST data with the regular GFS model forecast output. The model outputs are compared to see the impact of Sea Surface Temperature over other physical parameters such as Rainfall, Temperature, RH ,Wind direction, Wind speed at 850 hPa and 200 hPa, Mean Sea level pressure, Temperature, Relative humidity, Convective Available Potential Energy (CAPE), etc.

2.2 Data

Here (i) the data of Global forecasting system (GFS) of National Centre for Environmental Prediction (NCEP), USA is used as input to the WRF model. The model forecast for 120 hours based on the 00UTC of 24.11.2008.

(ii) NOAA AVHRR real time gridded averaged Sea Surface Temperature. (http:polar.ncep.noaa.gov/sst/oper/changed_rtg_sst.html)

(iii) Tropical rainfall measuring mission (TRMM) Rainfall data (http:trmm-fc.gsfc.nasa.gov/index.html)

(iv) Nisha Cyclone Data (got from IMD Chennai)

2.3 Methodology

After downloading the main input for running WRF model, the 120 hour GFS forecast output at an interval of every 6 hours , the WRF model was run for 120 hours. The forecast outputs were generated. Again the model was run for 120 hours with SST as an additional input and 120 hours forecast outputs were generated. The forecast outputs were compared and discussed. The rainfall outputs were compared with TRMM data.

2.4 WRF Model forecast performance and verification

The programs executed to get the error difference of the outputs. The error measurements are presented in the form of tables and figures. The results are presented and discussed.

Study Area:

The domain selected is 75.03°E to 90.96° E and 2.09°S to 17.72°N. The area covering Tamil Nadu, Bay of Bengal region and parts of Indian ocean is chosen as our study area. The study area is given in Figure 3.1.

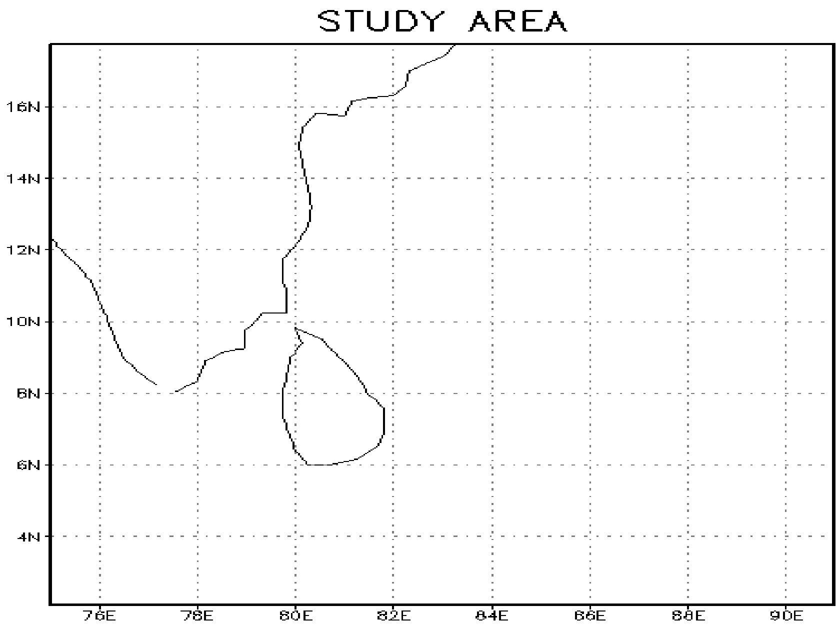


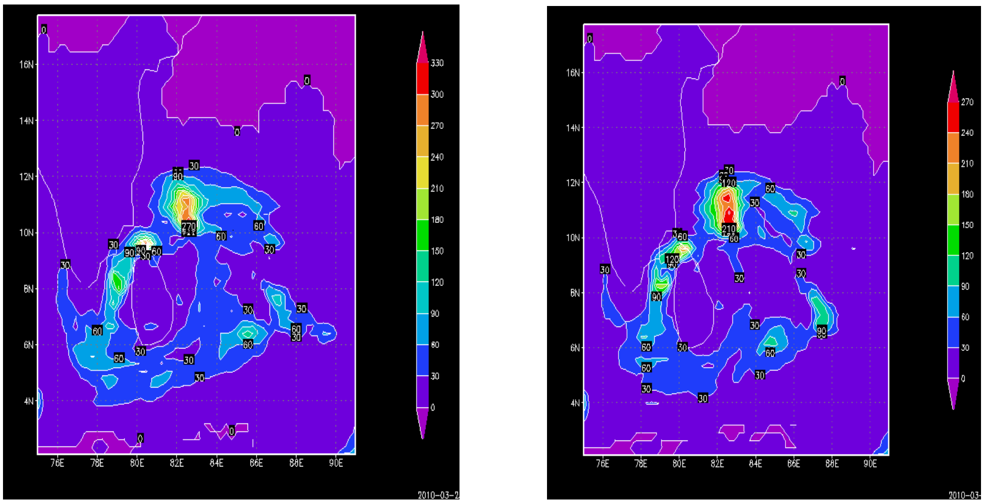
Fig. 3.1 Study area

3. Results and Discussion

3.1 Tropical cyclogenesis is the technical term describing the development and strengthening of a tropical cyclone in the atmosphere. Tropical cyclogenesis involves the development of a warm-core cyclone, due to significant convection in a favorable atmospheric environment. While six factors appear to be generally necessary, tropical cyclones may occasionally form without meeting all of the following conditions. In most situations, water temperatures of at least 26.5 °C (79.7 °F) are needed down to a depth of at least 50 meter (160 ft); waters of this temperature cause the overlying atmosphere to be unstable enough to sustain convection and thunderstorms. Another factor is rapid cooling with height, which allows the release of the heat of condensation that powers a tropical cyclone. High humidity is needed, especially in the lower-to-mid troposphere; when there is a great deal of moisture in the atmosphere, conditions are more favorable for disturbances to develop. Low amounts of wind shear are needed, as high shear is disruptive to the storm's circulation. Tropical cyclones generally need to form more than 555 kilo metres (345 mi) or 5 degrees of latitude away from the equator, allowing the

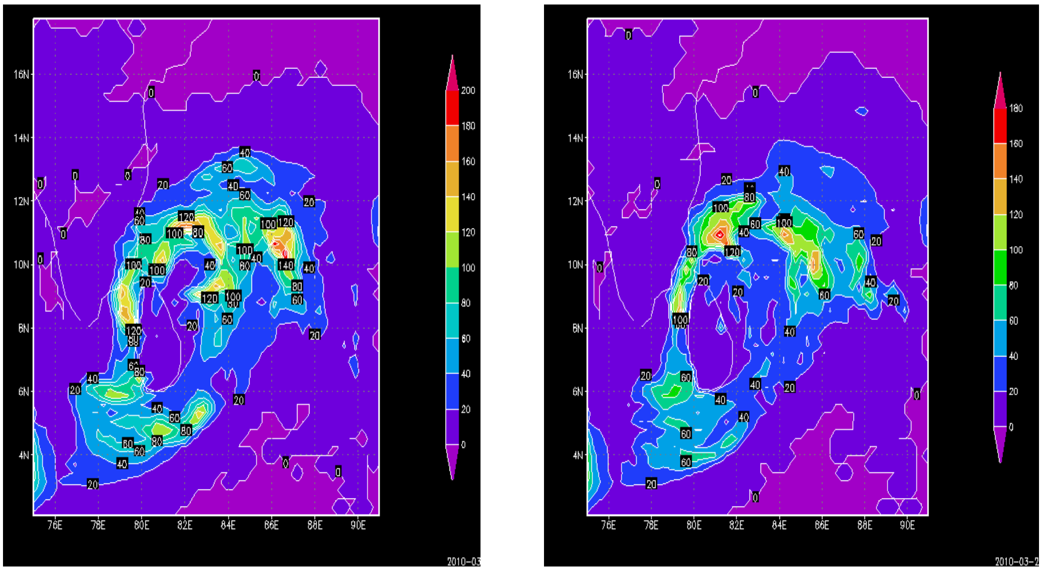
Coriolis Effect to deflect winds blowing towards the low pressure center and creating a circulation. Lastly, a formative tropical cyclone needs a pre-existing system of disturbed weather, although without a circulation no cyclonic development will take place.

Here in this study WRF model is run without ingesting SST data (MR1) and with ingesting SST data (MR2) in the model and the various output puts are presented and compared to see the impact of SST in the model output.



a) b)

Figure 3.1.1 Rainfall forecast for 25.11.2008: a) WRF model output without SST b) WRF model output with SST



a) b)

Figure 3.1.2 Rainfall forecast for 26.11.2008: a) WRF model output without SST b) WRF model output with SST

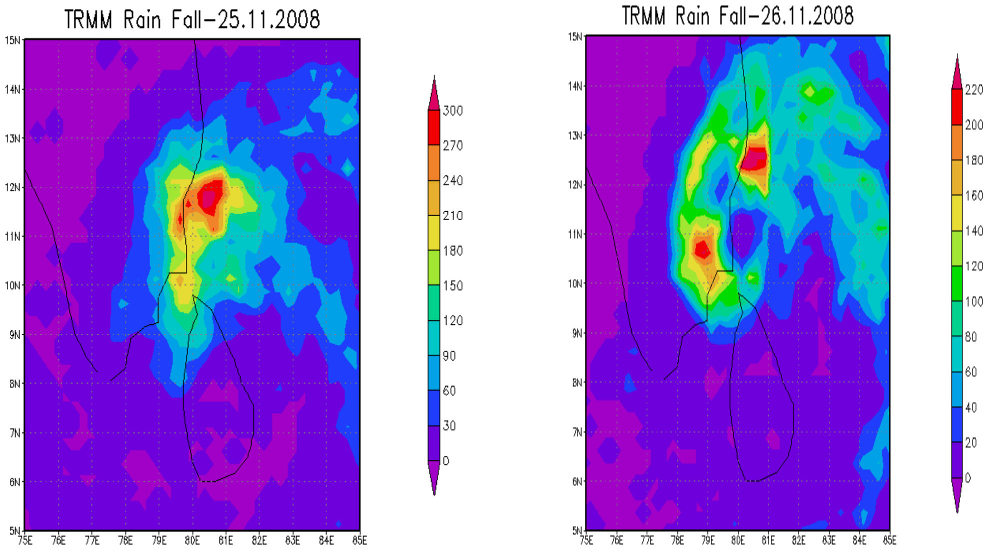


Figure 3.1.3 TRMM rainfall for 25th,26th November 2008

3.2 Rainfall

Figures 3.1.1 to 3.1.2 display the forecast rainfall pattern of 25th and 26th November 2008 by MR1 and MR2. Figure 3.1.3 display the TRMM rainfall pattern.

From the figures 3.1.1, it can be seen that 24 hour rainfall patterns forecasted by MR1 and MR2 are nearly same and almost matches the TRMM rainfall pattern as shown in the figure 3.1.3. The MR1 forecasts slightly lesser amount of rainfall than that by the MR2 forecasts. The highest 24 hour accumulated rainfall by MR1 is about 180cm and is seen near 11°N/ 81°E. The forecast rainfall pattern by MR2 shows two distinct areas of maximum rainfall and the highest rainfall is of the order of 20cm. Hence the ingestion of SST in the model makes the model to forecast slightly higher day1 rainfall.

Figure 3.1.2 shows the day 2 rainfall (26.11.2008) patterns as forecasted by MR1 and MR2. From the figure it can be seen that the rainfall patterns are similar but the intensity of rainfall are different. The highest rainfall forecasted by MR1 is about 33 cm as against a highest of 27cm forecasted by MR2. The zone of highest rainfall is nearly same and is near 11°N/82°E. Hence the ingestion of SST in the model makes the model to forecast slightly lower day 2 rainfall.

4. Summary and Conclusion

4.1 The primary objective of this study is to identify how SST impacts on Cyclone derived rainfall on WRF model. WRF model is run without ingesting SST data and with ingesting SST data and the model output of Rainfall has compared to see the effect of ingestion of SST. The model outputs are presented in pictorial form using GrADS and in tabular form.

4.2 The results are summarised as below.

(i) The highest 24 hour accumulated rainfall by MR1 is about 180cm and is seen near 11°N/ 81°E. The forecast rainfall pattern by MR2 shows two distinct areas of maximum rainfall and the highest rainfall is of the order of 20cm. Hence the ingestion of SST in the model makes the model to forecast slightly higher day1 rainfall. In The 48 hour forecast, the zone of highest rainfall is nearly same and is near 11°N/82°E. The ingestion of SST in the model makes the model to forecast slightly lower day2 rainfall.

The results shows SST impact on cyclone derived Rainfall. Hence this work shows that WRF model can be used to systematically identify the SST impact on Cyclone forecasting.

Solutions to the weather puzzle on page 12

1 R	A	2 I	N		3 H		4 F	E	5 W			6 G	
V		T			A		R		E			L	
R		C			B		7 O	U	T	F	L	O	W
		Z			O		N					R	
				8 V	O	R	T	9 I	C	I	10 T	Y	
11 E	12 N	S	O		B			C			H		
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21 A	Z	O	R	E	S			22 P	L	A	G	E	S

POST CYCLONE REVIEW ON TROPICAL CYCLONE "THANE'

by
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1. Formation of Cyclone

A depression formed over SouthEast Bay of Bengal on 25 December 2011 and lay centered about 1000 km SE of Chennai. It moved in north-north-west direction and intensified into deep depression (DD) on 26 December 2011. Later it became cyclonic storm (CS) "THANE'. It moved west-north-west ward and intensified into a severe cyclonic storm (SCS) and later became very severe cyclonic storm (VSCS) on the evening of 28 December 2011. It moved south-south-west ward and crossed east coast of Tamil Nadu between Puducherry and Cuddalore on the 30 December 2011 between 0530 to 0630 hrs IST .

DATE	TIME [IN UTC]	LOCATION LAT (ºN) / LON(ºE)	ESTIMATED CENTRAL PRESSURE [in hPa]		GRADE
			ECP	Pressure drop	
25.12.2011	1200	8.5 / 88.5	1000	3	D
26.12.2011	0000	9.5 /87.5	998	4	DD
26.12.2011	1800	11.0 / 87.5	996	7	CS
28.12.2011	0900	12.5 / 85.0	986	16	SCS
28.12.2011	1200	12.5 / 84.5	982	20	VSCS
29.12.2011	1200	12.0 / 81.3	972	30	VSCS
29.12.2011	1800	12.0 / 80.6	972	30	VSCS
30.12.2011	0000	11.8 / 79.9	972	30	VSCS
30.12.2011	0300	11.8 / 79.5	986	16	SCS
30.12.2011	0600	11.8 / 79.0	998	5	DD
30.12.2011	1200	11.8 /78.2	1000	3	D

On 31.12.2011, 0000 UTC, the system weakened into well marked low pressure and dissipated over North Kerala coast.

2. Post Cyclone Survey

As per Cyclone manual Chapter 11, No: 3 and as per the direction of DDGM, RMC Chennai a team headed by Shri. N.P.Mruthyunjaya and comprising of Shri. S.Gnanamurthy, Shri. M.V.Guhan and Shri. M.Srinivasan along with Shri. Kamalanathan, Staff car driver left from Chennai for post Cyclone survey on 31 December 2011 F/N.

3. Methodology

It is decided to use non experimental, descriptive survey among the people to know the fact. Cross-sectional surveys were used to gather on hand information and ground truth about the storm and its effects. Questionnaires were asked to describe about the storm when it crossed their location. People surveyed were asked to narrate on the direction of wind, its approximate speed, the time of occurrence of the event, the lull period (if any) etc and were requested to provide data [if any]. The data collected were cross checked with nearest Meteorological Observatory, IMD, Part Time Observatory, IMD & private Automatic Weather Station records. The details from where data are obtained are also given below:

METEOROLOGICAL OBSERVATORY		AUTOMATIC WEATHER STATIONS [IMD]	PTO	AUTOMATIC WEATHER STATIONS [PRIVATE]
1	CHENNAI [8 Routine Observation + hourly data]	MAILAM [Hourly obsn] [NW of Puducherry]	PARENGIPETTAI South of Cuddalore [03 & 12 Z]	M/S/ Chemfab Kalapet, North of Puducherry [Hourly]
2	PUDUCHERRY [8 Routine Observation + hourly data]	PUDUCHERRY [Hourly obsn]		M/S. SANMAR LTD, SIPCOT Cuddalore
3	CUDDALORE [8 Routine Observation + hourly data]	NEYVELI [Hourly obsn] [SW of Cuddalore]		Cuddalore Port Survey of India Tide gauge record
4	KARAIKAL [8 Routine Observation + hourly data]	CHIDAMBARAM [Hourly obsn] [SW of ***Parengipettai***]		Kurinjipadi [26km SW of ***Cuddalore*** TNAU AWS

The lowest pressure reported by different stations:

SN	STATION	SLP in hPa	TIME OF OCCURRENCE in IST	Location
1	CHENNAI	1005.1	30.12.2011 / 0515 hrs	North of Cuddalore
2	PUDUCHERRY	989.2	30.12.2011 / 0515 hrs	South of Chennai
3	**CUDDALORE**	**969.4**	**30.12.2011 / 0620 hrs**	**South of Puducherry**
4	KARAIKAL	999.0	30.12.2011 / 0430 hrs	South of Cuddalore

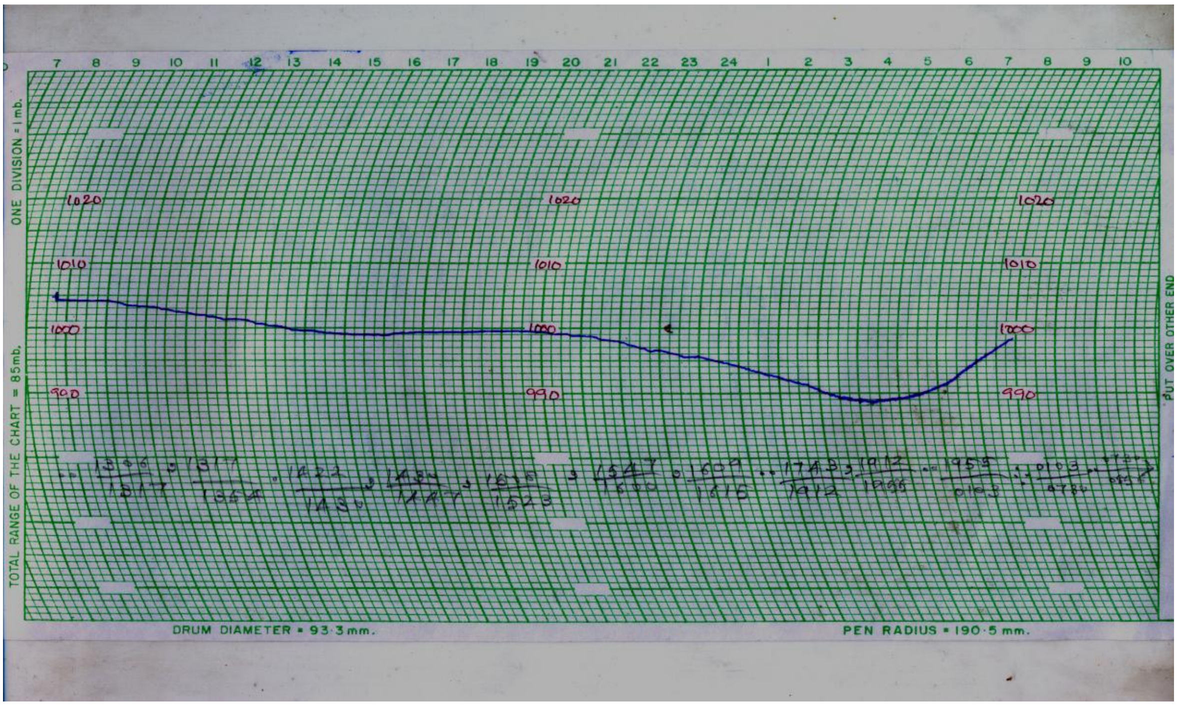

Fig.1. 29/30 Dec 2011 Puducherry barograph

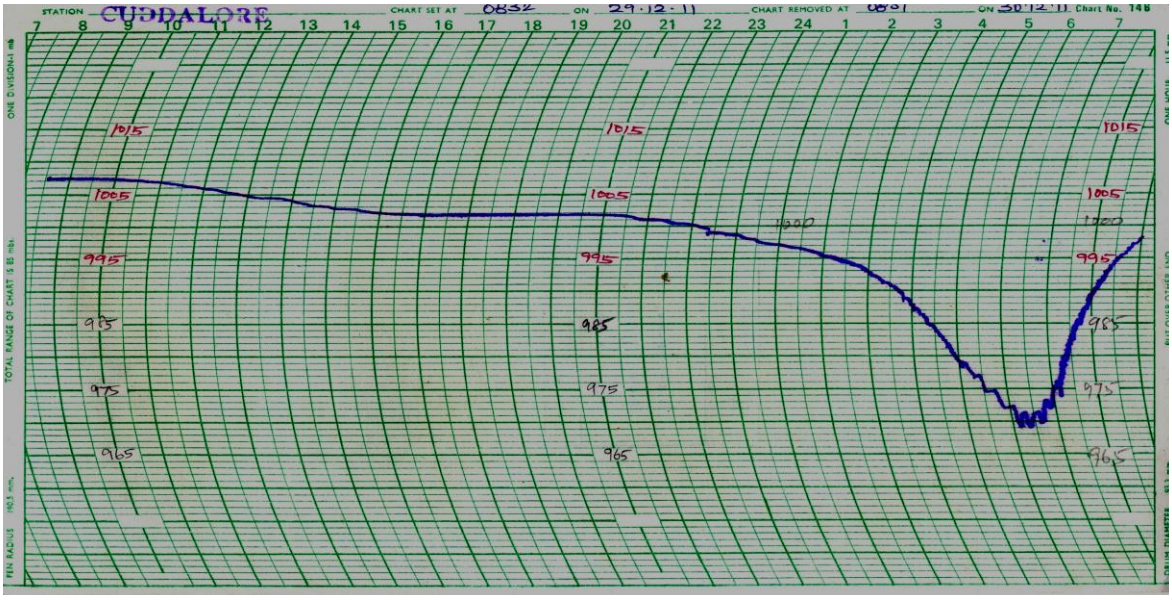

Fig.2. 29/30 Dec 2011 Cuddalore Barograph

30.12.2011:: Hourly pressure readings : Station Level Pressure in hPa

TIME in IST	MDS [hourly]	PDY [hourly]	CDL [hourly]	Neyveli [hourly]	Ppet [03&12Z]	CDM [hourly]	KKL [hourly]
0030	1005.7	996.3	998.2	998.5			1002.2
0130	1005.4	995.2	996.9	995.9			1001.4
0230	1005.4	993.4	994.7	994.5			1000.4
0330	1005.2	991.8	991.3	992.9			1000.3
0430	1005.2	989.4	984.3	990.2			999.0
0530	1005.6	989.3	976.4	987.1			1001.0
0630	1006.7	990.3	971.5	DNA*			1001.8
0730	1008.3	992.5	980.4	971.7			1004.4
0830	1009.6	997.2	994.8	972.4	1003.4		1006.2
0930	1010.1	1000.3	1002.1	DNA*			1007.4
1030	1010.4	1002.8	1004.5	997.7			1008.0
1130	1010.2	1004.1	1005.2	1001.2			1007.9
1230		1004.3	1005.9				
1330		1003.6	1005.9				
1430		1003.6	1005.9				
1530		1004.4	1005.9				

DNA: Data not available

30.12.2011:: Available Hourly wind direction and speed in knots.

TIME in IST	MDS [hourly]	PDY [hourly]	CDL [hourly]	Neyi [hourly]	Ppet [03&12Z]	CDM	KKL [hourly]
0030	NNE/10	NW/25	NNW/20	NW/10			W/20
0130	NNE/10	NW/35	NW/20	NNW/10			W/20
0230	NNE/10	NW/35	NW/25	NNW/15			SW/20
0330	SE/10	NW/40	NNW/20	NNW/15			SW/15
0430	E/15	NW/65	NW/50	NW/20			**WSW/20**
0530	E/15	NE/70	NW/60	NW/20			**SW/25**
0630	SE/15	SE/50	NW/65	NW/30			**WSW/25**
0730	SE/15	SE/50	SE/75	NW/30			SW/20
0830	SE/05	SE/50	SSE/50	S/15	S/18		SW/15
0930	E/10	NE/05	SE/50	SSE/20			S/15
1030	NE/10		SE/20	SSE/15			S/10
1130	S/10			SE/05			S/20
1230							
1330							
1430							
1530							

3. Inferences

3.1. Kalapet: [Lat: 12º02' N / Log: 79º51' E] M/S. ChemFab alkali Chemicals, Kalapet has submitted meteorological records supporting to the maximum one minute sustained wind. The maximum wind speed recorded was 103 kmph at 0636 hrs IST on 30.12.2011 as per their records.

3.2. Puducherry: [Lat: 11º57' N / Log: 79º49' E] Puducherry people experienced and witnessed a large scale damage. Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt sheets and other sheets in poor condition peeled off roofs. The lowest pressure of 989.2 hPa recorded at Puducherry observatory was on 30.12.2011 at 0515 hrs IST.

3.3. Reddy Chavadi: [Lat: 11º50' N / Log: 79º47' E] it is a small village situated in Puducherry – Cuddalore State Highway. People narrated that before 0230 hrs IST winds were blowing from North Westerly direction. Later by 0400 hrs or so it turned to south easterly direction. Hence it is presumed that land fall has not occurred at this place.

3.4. Cuddalore: [Lat: 11º45' N / Log: 79º45' E] It is evident from the Barograph that lowest pressure occurred at 0620 hrs IST.[969.4 hPa]. Hence the system [VSCS] should have crossed the coast probably near SOUTH of Cuddalore. Innumerable trees were either broken off or uprooted. Many electrical poles and communication mast [Mobile tower, High mass light Post] were broken and damaged. Thatched / asphalt sheet / tile roof of houses were blown off. The Circus tented at Nehru ground Cuddalore, [near to Meteorological Observatory] underwent massive destruction including the fall of the giant wheel, dislocation of one ton mass to a distance of ten meter. Taking all into consideration it is evident that the wind force here was at serial number TEN on the Beaufort scale. (Ranging between 89-102 kmph)

Fig 3 Destructed circus, Nehru ground, Cuddalore

3.5. Kudigadu: [Lat: 11º41' N / Log: 79º45' E]. This small village is located nine km south of Cuddalore at National Highway 45A which runs between Cuddalore and Chidambaram. People here narrated that they experienced North Westerly wind for some time in the wee hours of 30.12.2011. After that there persisted a brief calm wind. There after they felt a strong Southerly wind from 0600 hrs to 0745 hrs IST. As per the people's version it may be presumed that the Cyclone has crossed coast anytime between 0630 to 0730 hrs. So it may be ascertained that the eye of the Cyclone might have crossed this place, or very close to this location.

3.6. Kambilimedu: [Lat: 11º37' N / Log: 79º44' E. This is also another small village situated on the NH 45A highway. People here narrated that they experienced WESTERLY winds of lesser force during 0230 hrs to 0500 hrs IST. They experienced calm wind during 0530 to 0630 hrs. Then a fierce SOUTHERLY wind has blown from

0645 hrs to 0930 hrs. When WESTERLY was indicated by the people then the system must be NORTH to this location. This perhaps is the location indicated by Chennai DWR. [Projected to surface location.]

Radar based Cyclone Bulletin

Date: 30th Dec. 2011 Time: 03:00 UTC
Name of reporting Radar Doppler Weather Radar, Chennai
Geo-coordinates of Radar 13.0728 N ; 80.2883 E
Name of Cyclone THANE
Main features visible at this time indicating: Eye crossed coast near Cuddalore at 01:47UTC
Centre Closed ill defined and narrow Eye along with supporting spiral bands visible. Vortex centre estimated to be near 11.64 N 79.5 E (Azimuth 207.8 deg. Range 180 km). Confidence very Good.

3.7 Neyveli: [Lat: 11º36’ N / Log: 79º29’E] Neyveli is situated just WEST of Kambilimedu. Neyveli reported a lower pressure 971.7 hPa at 0730 hrs IST and North Westerly/30Knots wind. There after Neyveli reported SOUTHERLY wind.

DATE / TIME (IST)	WIND DIRECTION	WIND SPEED [in knots]
30/0030 hrs	NW	10
30/0130 hrs	NNW	10
30/0230 hrs	NNW	15
30/0330 hrs	NNW	15
30/0430 hrs	NW	20
30/0530 hrs	NW	20
30/0630 hrs	NW	30
30/0730 hrs	NW	30
30/0830 hrs	S	15
30/0930 hrs	SSE	15

3.8. Kurunjipadi: [Lat: 11º33’ N / Log: 79º35’E] Kurinjipadi is situated 26 km SW of Cuddalore. TNAU AWS has recorded the following wind

DATE / TIME(IST)	WIND DIRECTION	WIND SPEED [in kmph]
30/0100 hrs	307	06
30/0200 hrs	307	06
30/0300 hrs	344	13
30/0400 hrs	312	12
30/0500 hrs	312	24
30/0600 hrs	315	37
30/0700 hrs	294	44
30/0800 hrs	220	69

Again it is evident from the WESTERLY winds blowing at 0700 hrs IST that the system has crossed coast just NORTHEAST of this place.

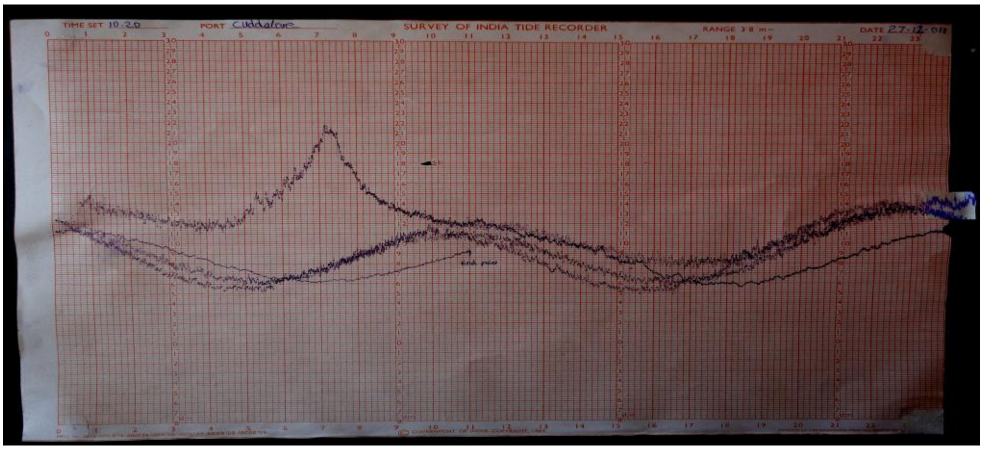

Fig.4. Tide gauge chart at Cuddalore Port from 27 to 30 Dec 2011.

4. Conclusion

1. It is a warm core wind generating tropical Cyclone. Hence there is no tilting.
2. The PGF is more in the Northern side [20hPa / 20 km] with more prominent closed isobars in the North Western sector of the system. i.e North & NW of Cuddalore and up to Puducherry. Less densely packed isobars from Cuddalore to Parengipettai in the southern direction of the system.
3. It moved in a West- Northwesterly direction
4. The fall of pressure on 30/0330 to 30/0630 hrs IST is [991.3-971.5 hPa] i.e.19.8 hPa/ 3 hour i.e the surface pressure decreased by 6.6 hPa per hour towards south during this period at Cuddalore
5. The lowest pressure 969.4 hPa recorded at Cuddalore on 30/0620 hrs IST. There after the pressure increased sharply and rapidly. The pressure depth would be around 24 hPa.
6. The Central Pressure might be 967 hPa and time of land fall may be around 30/0620 hrs IST or just after this time
7. The mean wind speed was around 60 kmph and maximum sustained wind was 104 kmph as per records obtained from M/S.Chemfab, Kalapet, Puducherry. However the observed wind (experienced wind in Beaufort scale) was around 120kmph.
8. In the north eastern sector of the system storm surge was at an average one meter high above the astronomical tide at Puducherry Port / Ennore Port. In Cuddalore the storm tide was only 0.9 meter above the normal astronomical tide as per records of tidal gauge of Survey of India located at this Port. Inundation here is only 15 meter.
9. Very heavy rainfall occurred at Puducherry only (15cm). However after landfall some stations to the west of Cuddalore recorded upto 18 cm of rainfall on 31.12.2011.
10. It induced a low in Arabian Sea and adjoining Comorin Sea and in down south also there was very heavy rainfall (> 12.5cm) in Kanyakumari and Tirunelveli district on 31.12.2011.

Keeping all above points it may be presumed that the most probable location where the system would have crossed the coast is at Thiyagavalli [[Lat: 11o.37’ N / Log: 79o.44’E] on 30.12.2011 between 0630 hrs IST to 0730 hrs IST.

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