



**Very Severe Cyclonic Storm “Ockhi” over Bay of Bengal
(29 November–06 December 2017): A Report**

1. Prevalent Condition over Bay of Bengal prior to genesis of cyclone, Ockhi

- Due to active inter-tropical convergence zone (ITCZ) and associated meso-scale convection, the trough in easterly winds or low pressure systems developed over the southern part of Bay of Bengal and moved westwards causing rainfall activity over the southern peninsular India in regular intervals.
- In this scenario, a low pressure area formed over Andaman Sea on 22nd Nov. under the influence of a remnant upper air cyclonic circulation from Gulf of Thailand. It lay over southeast and adjoining eastcentral Bay of Bengal on 23rd, central part of south Bay of Bengal on 24th, southwest bay and adjoining equatorial Indian Ocean on 25th, southwest bay and adjoining southeast Sri Lanka on 26th. It weakened and lay as a trough of low over southeast Arabian sea and adjoining Maldives on 27th and over southeast Arabian Sea and adjoining Lakshadweep Maldives on 28th Nov. 2017. It then moved away westwards and became less marked.
- **Rainfall due to this low pressure system:** It caused scattered heavy to very heavy rainfall over Tamil Nadu on 26th Nov and Kerala received isolated heavy rainfall on 26th and 27th.
- It is to mention that there was no remnant of any circulation system moving from Gulf of Thailand that intensified near Sri Lanka and later became cyclone, Ockhi over Comorin Sea.

2. Genesis of Cyclone, Ockhi:

- A fresh low pressure area formed over southwest Bay of Bengal and adjoining areas of south Sri Lanka & equatorial Indian Ocean in the forenoon (0830 IST) of 28th November. It became a well marked low pressure area in the early morning (0530 IST) of 29th over the same region.
- Under favourable environmental conditions, it concentrated into a Depression over southwest Bay of Bengal off southeast Sri Lanka coast in the forenoon (0830 IST) of 29th Nov. Moving westwards, it crossed Sri Lanka coast after some time. Continuing it's westward movement, it emerged into Comorin area in the evening (1730 IST) of 29th and intensified into a Deep Depression (DD) in the early hours (0230 IST) of 30th. It further moved northwestwards and intensified into a Cyclonic Storm (CS) in the forenoon (0830 IST) of 30th Nov. over the Comorin area.

3. Movement and Intensification of cyclone, Ockhi

- There was rapid intensification of Ockhi during its genesis stage, as it intensified into a CS at 0830 IST of 30th, after its genesis as a depression at 0830 IST of 29th (within 24 hrs). It intensified from deep depression into a cyclonic storm over Comorin area within six hours.
- While moving west-northwestwards, Ockhi further intensified into a Severe Cyclonic Storm (SCS) over Lakshadweep area in the early morning (0530 IST) of 01st Dec. and

Very Severe Cyclonic Storm (VSCS) over southeast (SE) Arabian Sea to the west of Lakshadweep in the afternoon(1430 IST) of 01st Dec.

- It then moved northwestwards and reached its peak intensity of 150-160 kmph gusting to 180 kmph in the afternoon (1430 IST) of 2nd Dec with lowest central pressure of 976 hecta Pascal (hPa). It moved north-northwestwards for some time and then north-northeastwards and maintained its intensity till early morning of 03rd Dec. It then continued to move north-northeastwards and weakened gradually.
- It crossed South coast of Gujarat between Surat and Dahanu as a well marked low around early morning (0530 IST) of 6th Dec.

4. Realised Heavy Rainfall

- It caused isolated heavy rainfall over south Tamil Nadu on 28th and 29th and scattered heavy to very heavy rainfall and isolated extremely heavy rainfall over south Tamil Nadu on 30th Nov. and 1st & 2nd Dec.
- It caused isolated heavy rainfall over south Kerala on 29th Nov. and 1st Dec. and heavy to very heavy rainfall on 30th Nov.
- It caused heavy to very heavy rainfall over Lakshadweep on 01st and 2nd Dec.
- There was heavy rainfall over north coastal Maharashtra and adjoining south coastal Gujarat on 5th Dec.
- There was no heavy rainfall over Tamil Nadu on 27th, over Kerala on 28th.
- It clearly indicates the occurrence of two separate spells of heavy rainfall over Tamil Nadu and Kerala in association with a low pressure system and cyclone, Ockhi

The observed track of the system during 29th November- 6th December is presented in **Fig.1**. Typical satellite imagery and radar imagery from DWR Kochi of the system are presented in **Fig.2**.

5. Salient Features:

The salient features of the system were as follows:

- i. This was the fourth cyclonic storm developing over Comorin Sea (south of Kerala and Tamil Nadu and west of Sri Lanka). However, cyclone, Ockhi did not cross Tamil Nadu and Kerala coast and moved across Lakshadweep Islands. Previously two cyclones in 1912 and another in 1925 developed over Comorin Area (**Fig.3**). All these cyclones affected south Kerala and south Tamil Nadu. However the cyclone during 19-21 Nov. 1912 moved across south Tamil Nadu and Kerala on 19th Nov. and the cyclone during 6-10 Nov. 1925 crossed north Kerala coast on 10th Nov. Other cyclone in 1912 skirted Kerala coast.
- ii. Thus, it was a rare cyclone with rapid intensification in genesis stage. It intensified from deep depression into a cyclonic storm over Comorin area within six hours.
- iii. Ockhi had a clockwise recurving track. The track length of the cyclone was 2538 km.
- iv. The 12 hour average translational speed of the cyclone was 15.0 kmph.
- v. The life period of cyclone was 162 hours (6 days & 18 hours) against long period average of 4.7 days for very severe cyclonic storm over north Indian Ocean.

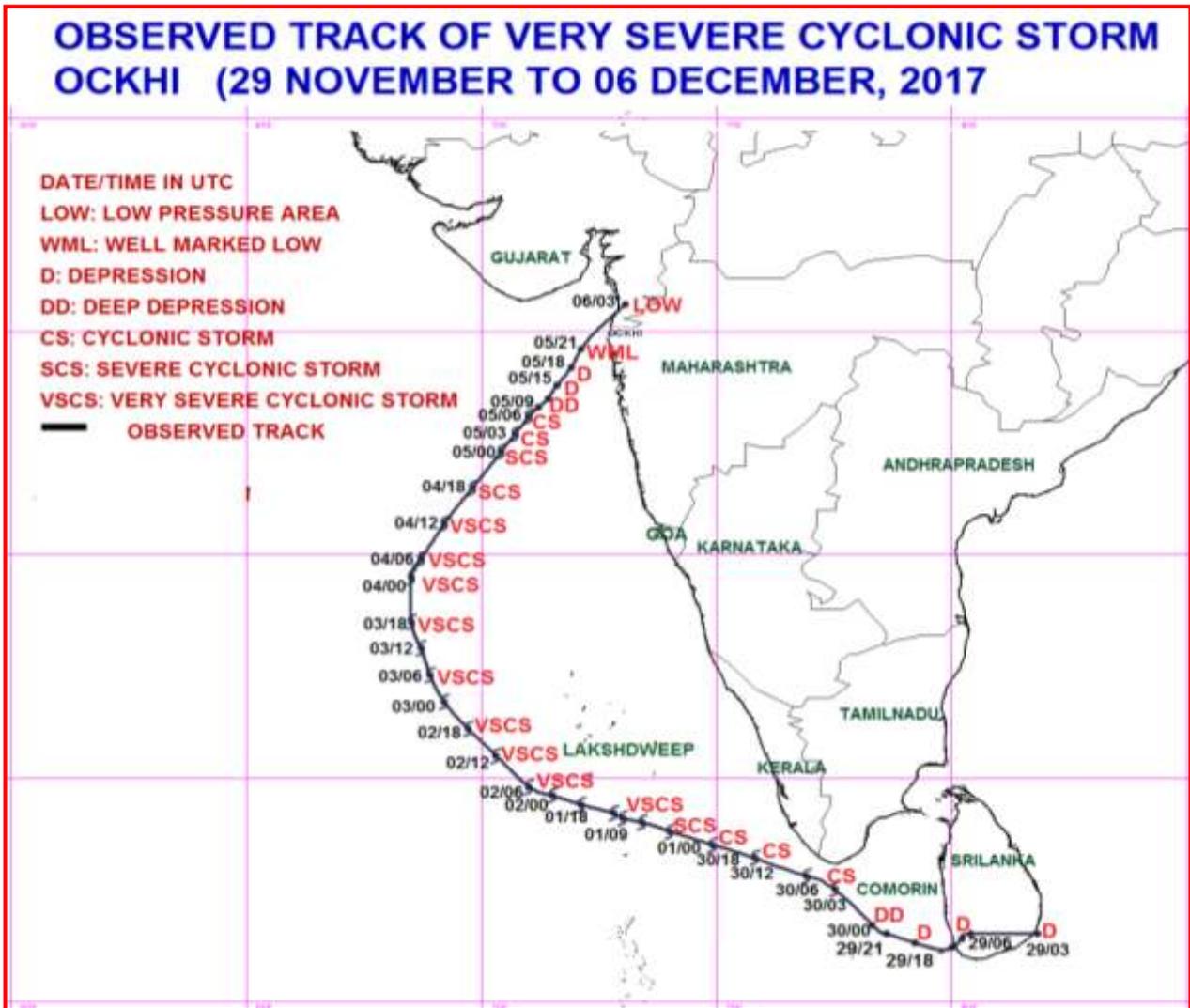


Fig.1: Observed track of VSCS Ockhi (29 Nov.–06 Dec, 2017) over Bay of Bengal

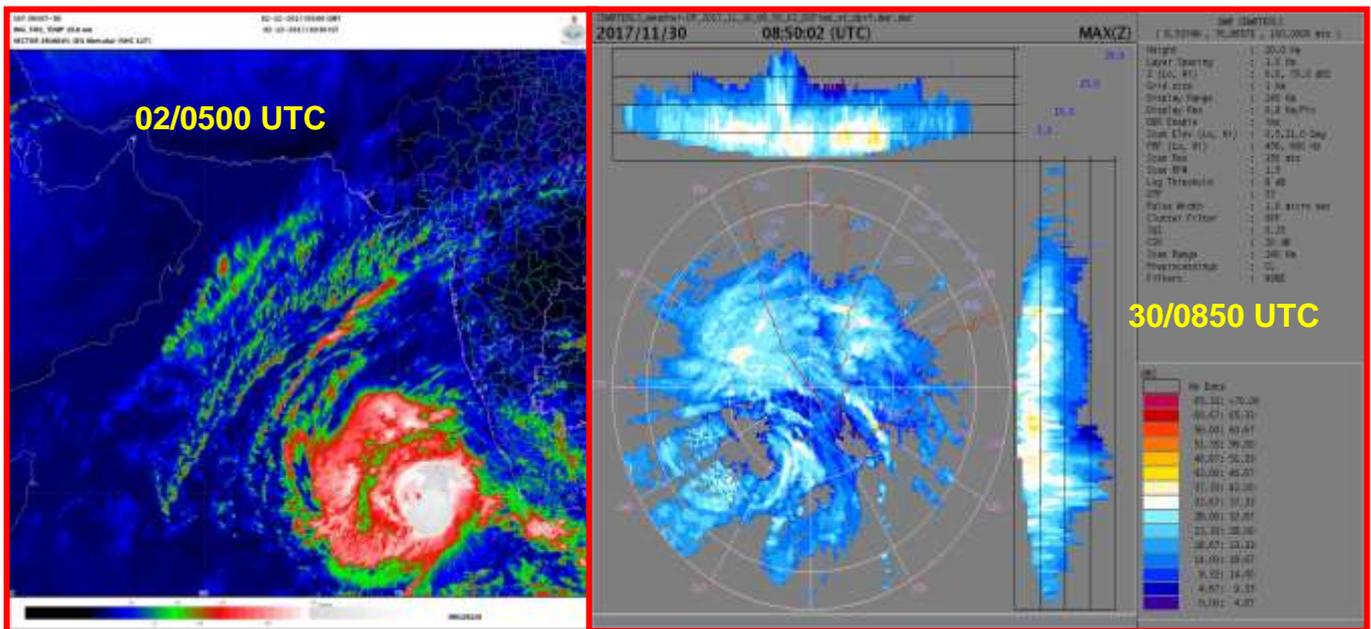


Fig.2: Typical satellite and Radar imagery from DWR Thiruvananthapuram of VSCS Ockhi.

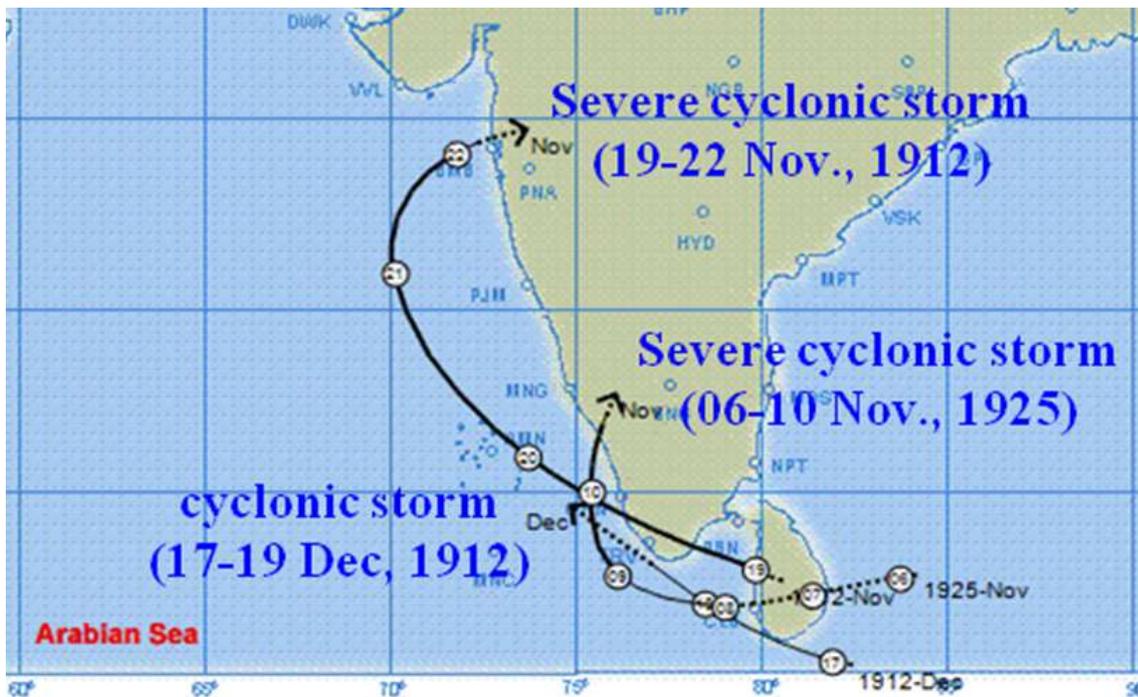


Fig.3: Climatological tracks of cyclones affecting Kerala and Kanyakumari during 1891-2016.

6. Monitoring and Prediction:

The cyclone was monitored & predicted continuously by India Meteorological Department (IMD) since genesis of low pressure area over southwest BOB on 28th November. At the genesis stage, the system was monitored mainly with satellite observations from INSAT 3D, 3DR and Kalpana along with available ships & buoy observations. The system was also monitored by Doppler Weather Radar Chennai, Thiruvananthapuram, Karaikal, Goa, Mumbai and Kochi. Various national and international NWP models and dynamical-statistical models were utilized to predict the genesis, track and intensity of the cyclone. Tropical Cyclone Module, the digitized forecasting system of IMD was utilized for analysis and comparison of various models guidance, decision making process and warning product generation. IMD issued regular bulletins to WMO/ESCAP Panel member countries including Sri Lanka and Maldives, National & State Disaster Management Agencies, general public and media since inception of the system over BOB.

7. Forecast and Warning Performance:

7.1. Genesis Forecast

- The first information regarding formation of depression during next 48-72 hours (i.e. 29th onwards) was issued on 28th November in the Tropical Weather Outlook issued at 1200 hours IST. The system developed into a depression in the forenoon of 29th.
- In the first bulletin based on 1150 IST of 29th Nov, IMD, New Delhi indicated the west-northwestward movement of system and its emergence into Comorin area by 30th. It was also mentioned that the system would intensify further. The system emerged into

Comorin Area during night of 29th and intensified into Deep Depression in the early hrs (0230 IST) of 30th and into Cyclonic Storm in the forenoon (0830 IST) of 30th Nov. 2017.

7.2. Cyclone Warning

- As the deep depression after crossing over southern Sri Lanka unusually intensified into a cyclone Ockhi in 12 to 24 hrs from 29th November morning over Comorin Sea, the cyclone specific advisory was only issued from 30th Nov at 1155 hrs IST as per the protocol for south Tamil Nadu, South Kerala and Lakshadweep
- However, cyclone watch/alert could not be issued due to unusual rapid intensification over the Comorin Sea.
- It is quite different from cases of cyclone intensification that happens over central part of Bay of Bengal and Arabian Sea. In those cases, usual provision of issuing cyclone alert/watch normally exists as per SOP.
- In this case, cyclone warning was to be issued directly on 30th morning only to enhance already initiated actions taken by respective state Govt. based on the regular bulletins issued by IMD since 29th November forenoon.

7.3. Track Forecast

- The west northwestward movement towards Lakshadweep was predicted in the first bulletin itself issued at 0830 hrs IST of 29th Nov.
- The observed and forecast track with cone of uncertainty issued for (a) Kerala, Tamil Nadu, Lakshadweep and (b) Gujarat coast are shown in **Fig.4 and 5**.
- The track forecast error for 12, 24, 48 and 72 hrs lead period were 52.4, 77.2, 111.9 and 189.6 km respectively, which is significantly less than the average track forecast errors of 59.7, 97.2, 149.1 and 202.8 km during last five years (2012-16). The track forecast skill was about 45%, 61%, 76% and 69% for 12, 24, 48 and 72 hrs lead period respectively, which are higher than the long period average (LPA) during 2012-16 for 12 and 24 hrs lead period (**Fig.6**).

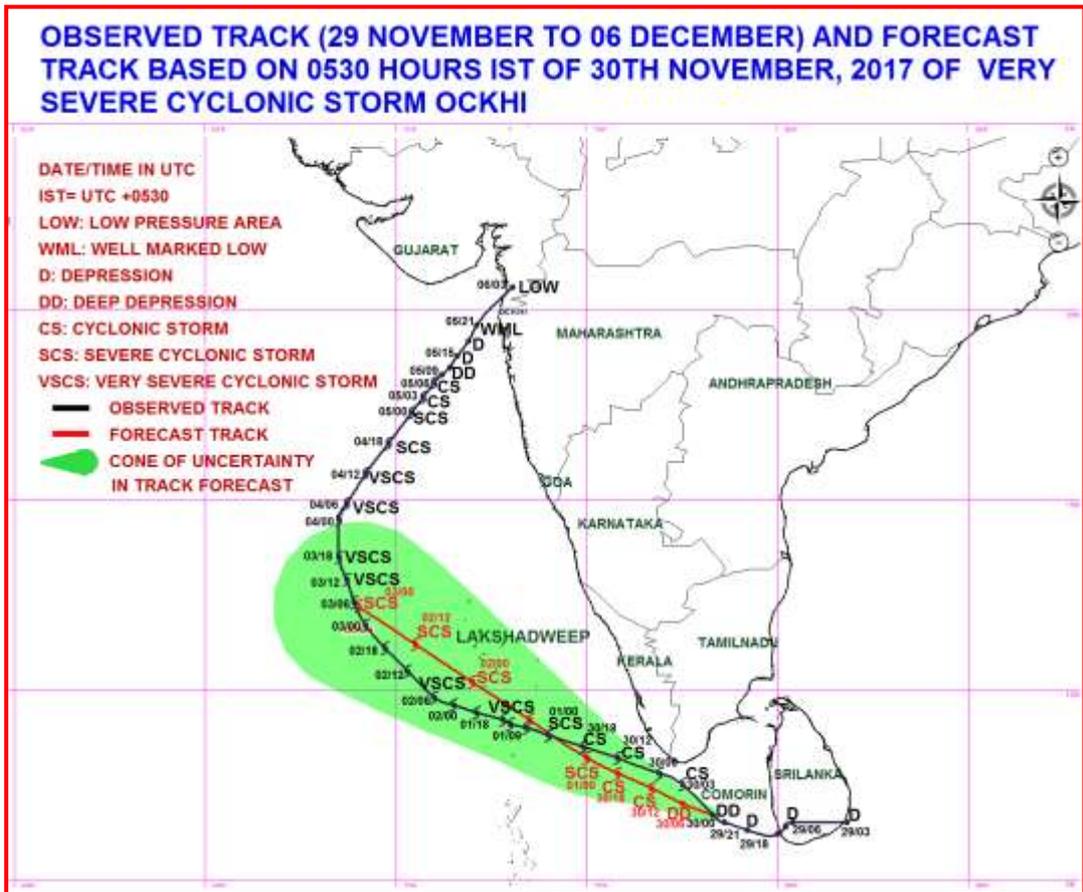


Fig.4: Observed and forecast track with cone of uncertainty issued for Kerala, Tamil Nadu, Lakshadweep

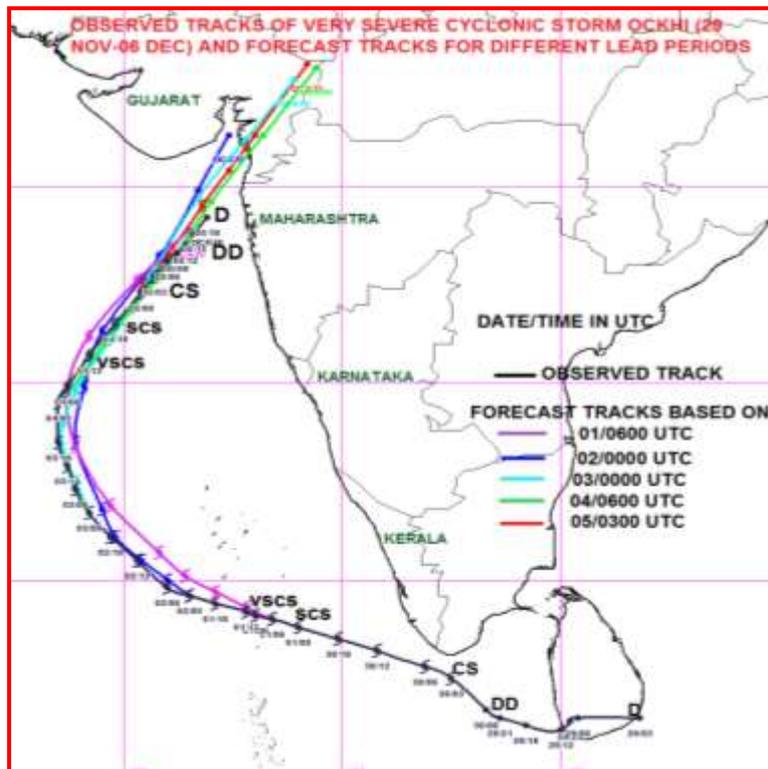


Fig.5: Typical graphical products displaying observed and forecast track for movement towards Gujarat coast

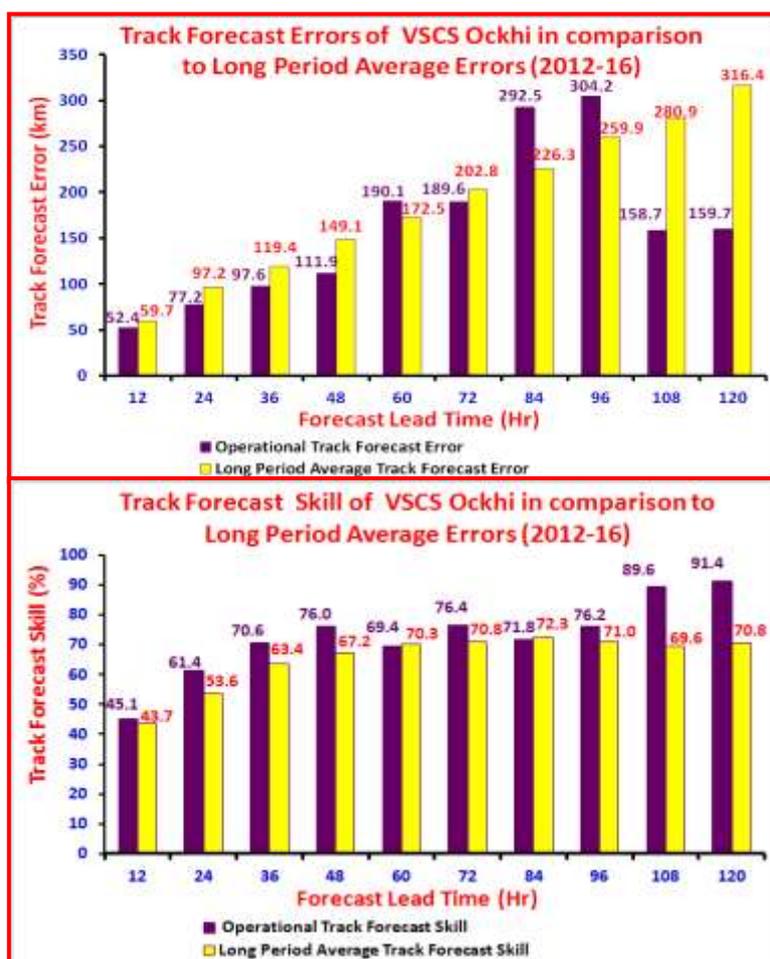


Fig.6: Track Forecast Errors and Skill of VSCS Ockhi

7.4. Intensity Forecast

- First wind warning for 45-55 kmph gusting to 65 kmph for south Kerala, south Karnataka and Lakshadweep was first issued at 1150 hrs IST of 29th November.
- It was increased gradually with expected intensification of the system
- Thiruvananthapuram recorded 62 kmph in gustiness at 1300 IST of 30th Nov. The threshold wind speed of 45 kmph was recorded over Thiruvananthapuram from 1230 IST of 30th Nov. Onwards (**Fig.7**).
- Maximum wind 120-130 kmph gusting to 145 kmph prevailed over northern parts of Lakshadweep
- First wind warning for 40-50 kmph gusting to 60 kmph for south Gujarat and north Maharashtra coast on 5th Dec. was first issued at 1700 hrs IST and 1930 hrs IST of 2nd Dec. The actual wind along these coasts has been 30-40 kmph.
- The absolute intensity (wind) forecast error for 12, 24, 48 and 72 hrs lead period were 5.4, 7.0, 13.5 and 16.4 knots against the LPA of 6.5, 10.7, 15.5 and 16.3 knots respectively. The skill in absolute intensity (wind) forecast for 12, 24, 48 and 72 hrs lead period was 26.6, 48.4, 61.0 and 75.7% against the LPA of 18.2, 35.2, 55.7 and 66.8% respectively. (**Fig.8**).

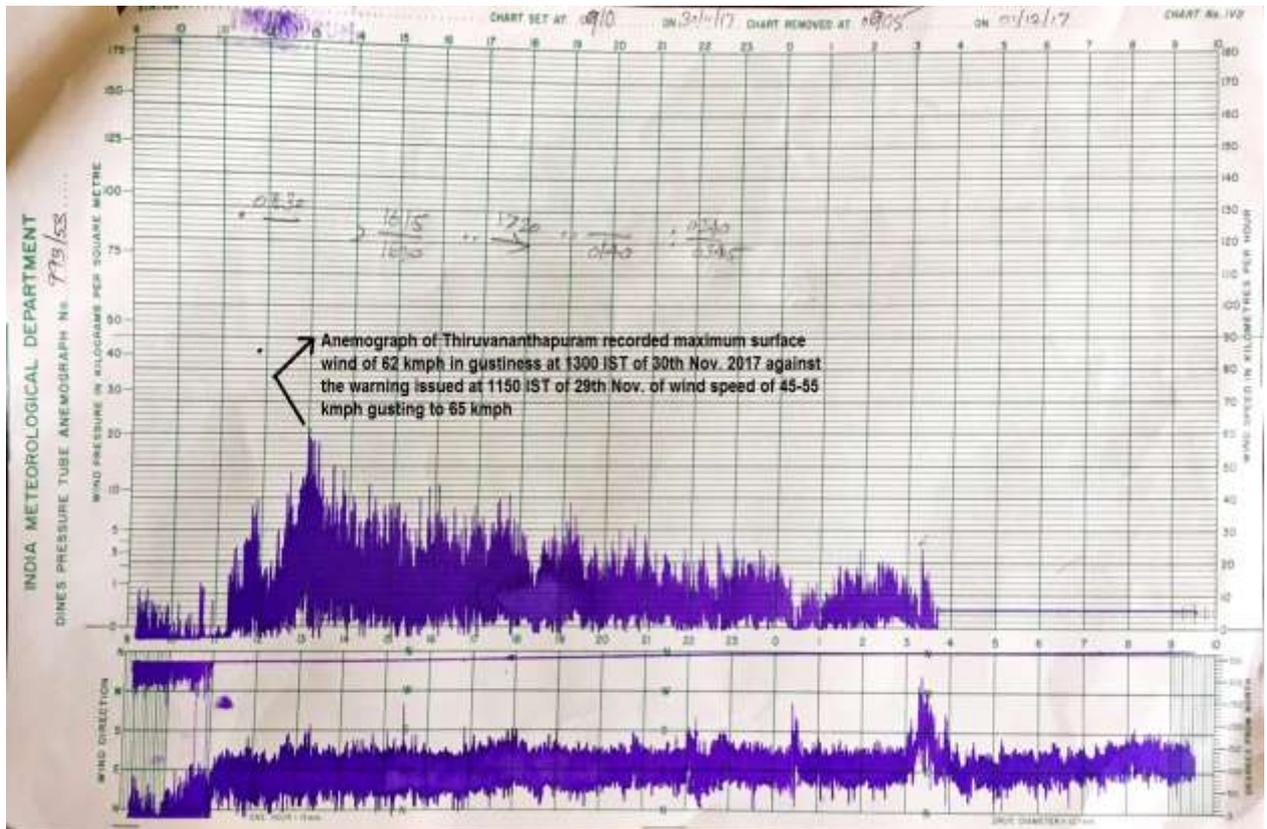


Fig.7 Anemograph record of 30th November over Thiruvananthapuram.

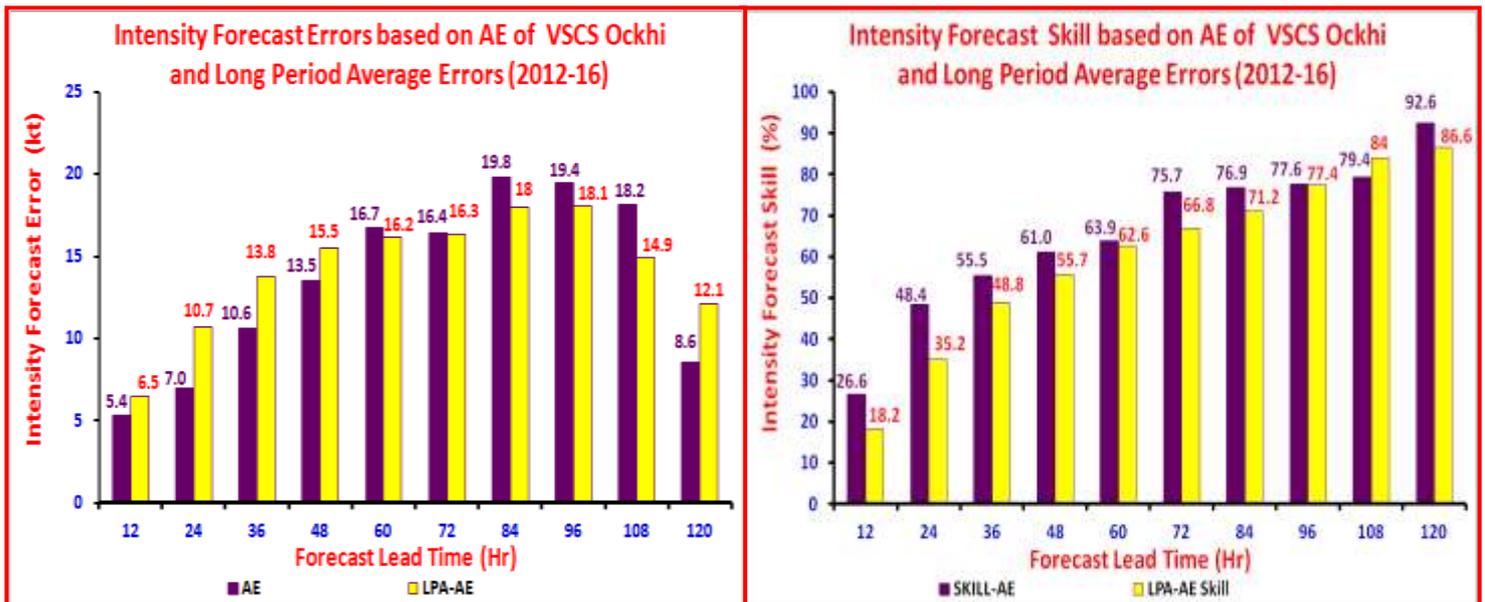


Fig. 8: Absolute Error (AE) of intensity forecast and skill of IMD for VSCS Ockhi

7.5. Heavy rainfall warning

- Heavy rainfall warning for south Kerala, south Tamil Nadu and Lakshadweep was first issued at around noon of 28th November for occurrence during next 72 hours.
- Heavy rainfall warning for south coastal Gujarat was first issued at 1700 hrs IST of 2nd December for occurrence on 5th December.

- Heavy rainfall warning for north coastal Maharashtra was first issued at 1330 hrs IST of 2nd December for occurrence from 4th night during subsequent 48 hours.
- It caused isolated heavy rainfall over south Tamil Nadu on 28th and 29th and scattered heavy to very heavy rainfall and isolated extremely heavy rainfall over south Tamil Nadu on 30th Nov. and 1st & 2nd Dec. It caused isolated heavy rainfall over south Kerala on 29th Nov. and 1st Dec. and heavy to very heavy rainfall on 30th Nov. It caused heavy to very heavy rainfall over Lakshadweep on 01st and 2nd Dec. There was heavy rainfall over north coastal Maharashtra and adjoining south coastal Gujarat on 5th Dec.

7.6. Storm Surge Warning

- First warning of storm surge of height about 1.0 m above astronomical tides likely to inundate low lying areas of Lakshadweep Islands was issued on 1700 hrs IST of 30th.

7.7. Fishermen Warning

- First warning for fishermen along and off south Tamil Nadu, south Kerala and Lakshadweep Islands not to venture into sea was issued at 1150 hrs IST of 29th November.
- First warning for fishermen along and off south Gujarat coast not to venture into sea was issued also at 1150 hrs IST of 2nd December and for north Maharashtra coast was issued at 1930 hrs IST of 2nd December.

8. Warning Services

Bulletins issued by Cyclone Warning Division, New Delhi

- **Track, intensity and landfall forecast:** IMD continuously monitored, predicted and issued bulletins containing track, intensity, and landfall forecast upto 120 hrs or till the system weakened into a low pressure area. The above forecasts were issued from the stage of deep depression onwards along with the cone of uncertainty in the track forecast.
- **Cyclone structure forecast for shipping and coastal hazard management** The radius of maximum wind and radii of MSW ≥ 28 knots, ≥ 34 knots, ≥ 50 knots and ≥ 64 knots wind in four quadrants of cyclone was issued every six hourly giving forecast for different lead period.
- **Diagnostic and prognostic features of cyclone:** The prognostics and diagnostics of the systems were described in the RSMC bulletins and tropical cyclone advisory bulletins.
- **TC Vital:** Tropical cyclone vitals were prepared every six hourly from deep depression stage onwards and provided to various NWP modeling groups in India for generation/relocation of vortex in the model so as to improve the track and intensity forecast by the numerical models.

- **Tropical cyclone forecasts and adverse weather warning bulletins:** The tropical cyclone forecasts alongwith expected adverse weather like heavy rain, gale wind and storm surge were issued with every three hourly update during cyclone period to the central, state and district level disaster management agencies including MHA, NDRF, NDMA, Cabinet Secretariat, HQ Integrated Defence Staff, Doordarshan, All India Radio, Indian Railways, Indian Navy, IAF, concerned states like- Tamil Nadu, Kerala, Goa, Maharashtra, Karnataka, Gujarat, and Union Territory of Lakshadweep, Daman & Diu, Dadra Nagar Haveli. The bulletin also contained the suggested action for disaster managers and general public. These bulletins were also issued to Defence including Indian Navy & Indian Air Force.
- **Warning graphics:** The graphical display of the observed and forecast track with cone of uncertainty and the wind forecast for different quadrants were disseminated by email and uploaded in the RSMC, New Delhi website (<http://rsmcnewdelhi.imd.gov.in/>) regularly.
- **Warning and advisory through social media:** Daily updates were uploaded on face book and tweeter regularly during the life period of the system.
- **Press release and press briefing:** Press and electronic media were given daily updates since inception of system through press release, e-mail, website and SMS.
- **Warning and advisory for marine community:** The three/six hourly bulletins were issued by the cyclone warning division at New Delhi and cyclone warning centres of IMD at Chennai, Meteorological Centre, Thiruvananthapuram, Goa, Area Cyclone Warning Centre Mumbai and Cyclone Warning Centre Ahmedabad to ports, fishermen, coastal and high sea shipping community.
- **Advisory for international civil aviation :** The Tropical Cyclone Advisory Centre (TCAC) bulletin for international civil aviation were issued every six hourly to all meteorological watch offices in Asia Pacific region for issue of significant meteorological information (SIGMET). It was also sent to Aviation Disaster Risk Reduction (ADRR) centre of WMO at Hong Kong.

Statistics of bulletins issued by Cyclone Warning services of IMD in association with the very severe cyclonic storm Ockhi are given in **Table 1**

Table 1: Bulletins issued by Cyclone Warning Division, IMD, New Delhi

| S.N | Bulletin | No. of Bulletin | Issued to |
|-----|---|---------------------|---|
| 1 | National Bulletin | 54 | 1. IMD's website 2. FAX/ e-mail to Control Room, MHA and NDMA, Cabinet Secretariat, Minister of Sc. & Tech, Secretary MoES, DST, HQ Integrated Defence Staff, DG Doordarshan, All India Radio, DG-NDRF, Indian Railways, Indian Navy, IAF, Chief Secretary- Tamil Nadu, Kerala, Goa, Maharashtra, Karnataka, Gujarat, Administrator, Lakshadweep, Daman & Diu, Dadra Nagar Haveli. |
| 2 | RSMC Bulletin | 52 | 1. IMD's website 2. All WMO/ESCAP member countries through GTS and email. 3. Indian Navy, IAF by E-mail |
| 3 | Tropical Cyclone Advisory Centre Bulletin (Text & Graphics) | 23 | 1. Met Watch offices in Asia Pacific regions through GTS to issue Significant Meteorological information for International Civil Aviation 2. WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong through ftp 3. RSMC website |
| 4 | Tropical Cyclone Vital Statistics | 22 | Modelling group of IMD, National Centre for Medium Range Weather Forecasting Centre (NCMRWF), Indian National Centre for Ocean Information Services (INCOIS), Indian Institute of Technology (IIT) Delhi, IIT Bhubaneswar etc. |
| 5 | Bulletins through SMS | At least once a day | SMS through (i) IMD network for disaster managers at national level and concerned states (ii) Department of Electronics and Information Technology (iii) KISAAN Portal and (iv) INCOIS |
| 6 | Bulletins through Social Media | 11 | Cyclone Warnings were uploaded on Social networking sites like Face book and Tweeter since inception to weakening of system (every time when there was change in intensity). |
| 7 | Press Release | 10 | Disaster Managers and Media by email and uploaded on website |
| 8 | Press Briefings | | Regular |

9. Acknowledgement:

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