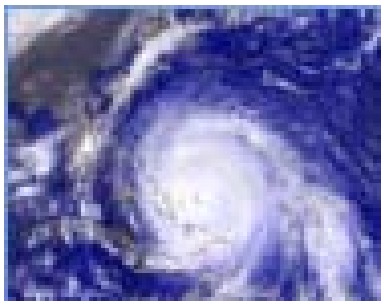
Foreshadowing the tracks of tropical depressions and cyclonic storms and understanding their thermodynamical structure over Bay of Bengal and Arabian sea using TOVS and ATOVS data



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Conventional vis-à-vis Satellite soundings

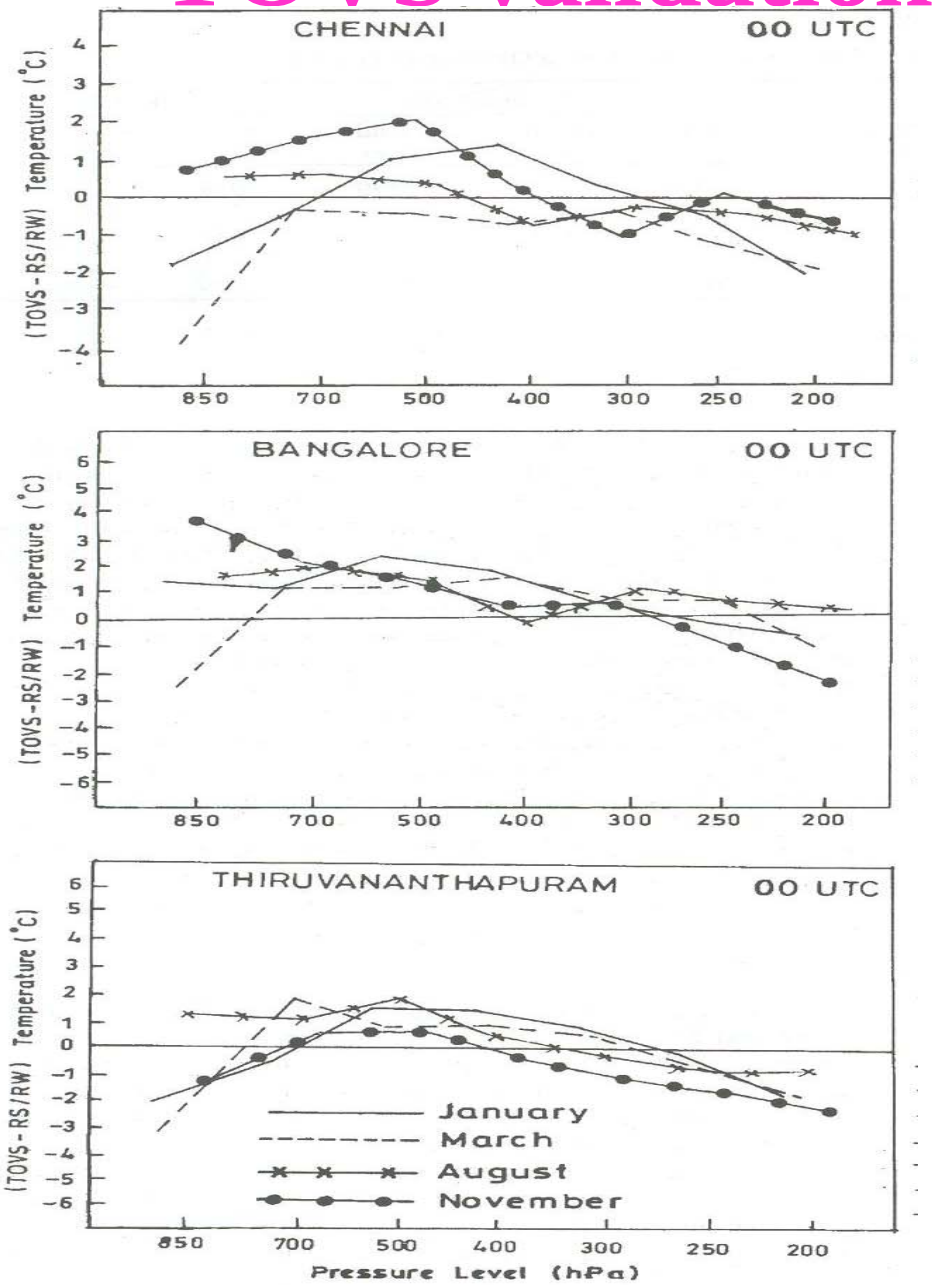
Deficiencies in Conventional soundings

- **Radio sonde data has inherent errors (both instrumental and radiation related).**
- **Different types of Radio Sonde instruments are used throughout the world (inter-comparison is difficult).**
- **Irregular coverage of the earth's surface and practically no data over oceanic and inaccessible areas ➔ *optimum interpolation/ objective analysis needed for use in NWP.***

Advantages of Satellite soundings

- **Cover land and ocean alike.**
- **Frequent observation / measurement through satellites are possible in comparison to twice a day Radio sonde observations.**
- **Spatial accuracy is far better than the conventional soundings.**

TOVS validation at IMD, Chennai



Mean temperature bias (Satellite – RadioSonde)

- **HRPT Direct Readout Ground Station at IMD, Chennai used one step physical retrieval to solve the Radiative Transfer Equation (RTE) during 1996-1998.**
- **Initial guess has been obtained from**

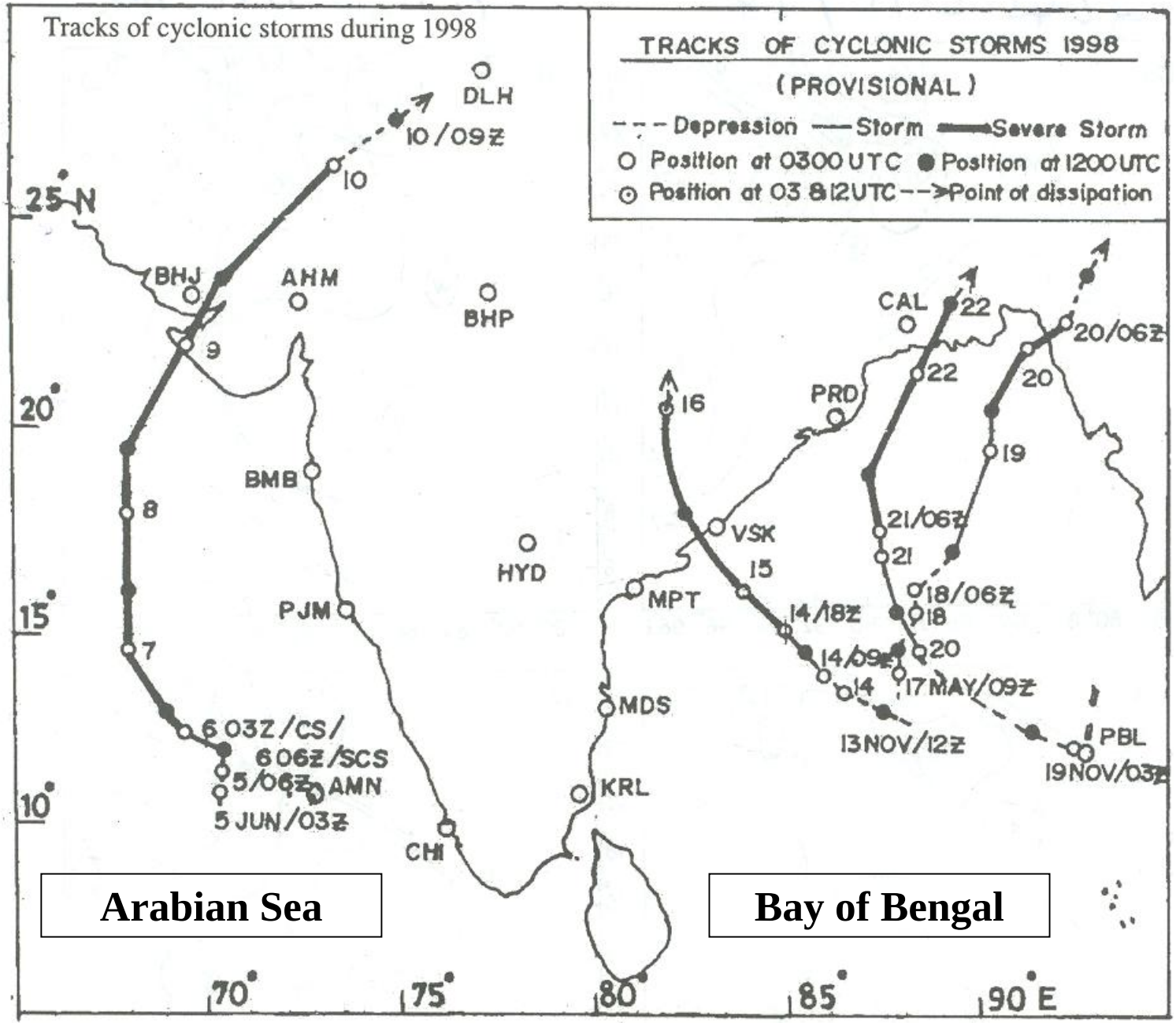
  (i) climatology

  (ii) regression estimates using stratospheric level HIRS channels and MSU channels which are mostly unaffected by clouds.
- **Validation of upper air temperature, dew point, was carried out as a matter of routine with collocated (± 100km , ± 2 hours between soundings) Indian RS / RW stations for 00 and 12UTC.**
- **Temperature between 700 and 400 hPa agrees well with RS/RW within a root mean squared bias of 2.5 ^{o}C and g.p.m less than 100m during 1996-'98.**

Mid-tropospheric warmness vis-à-vis cyclone track

- ***Soundings from reconnaissance flights revealed that*** **mid-tropospheric warmness due to altostratus outflow protrudes atleast 400 km ahead of the cyclonic storm** ***(Simpson, 1954, Proc. UNESCO symp. on typhoons, Tokyo, p129-150).***
- **700-400 hPa warmness protrudes as far ahead as 400 to 700 km and 3 to 12 hrs ahead of the movement of storms over Bay of Bengal and Arabian sea** ***(Suresh and Rengarajan, 2002, Mausam, 53, 2, p215-224).***
- **To work out the 700-400 hPa layer mean temperature and to verify the protrusion of warm tongue, TOVS data are inevitable, more specifically over the oceanic area.**
- **Despite the scan geometry limitations (cyclonic fury left undetected / unnoticed between two consecutive passes), TOVS / ATOVS data help to identify pre-cursor(s) to foreshadow storm's movement.**

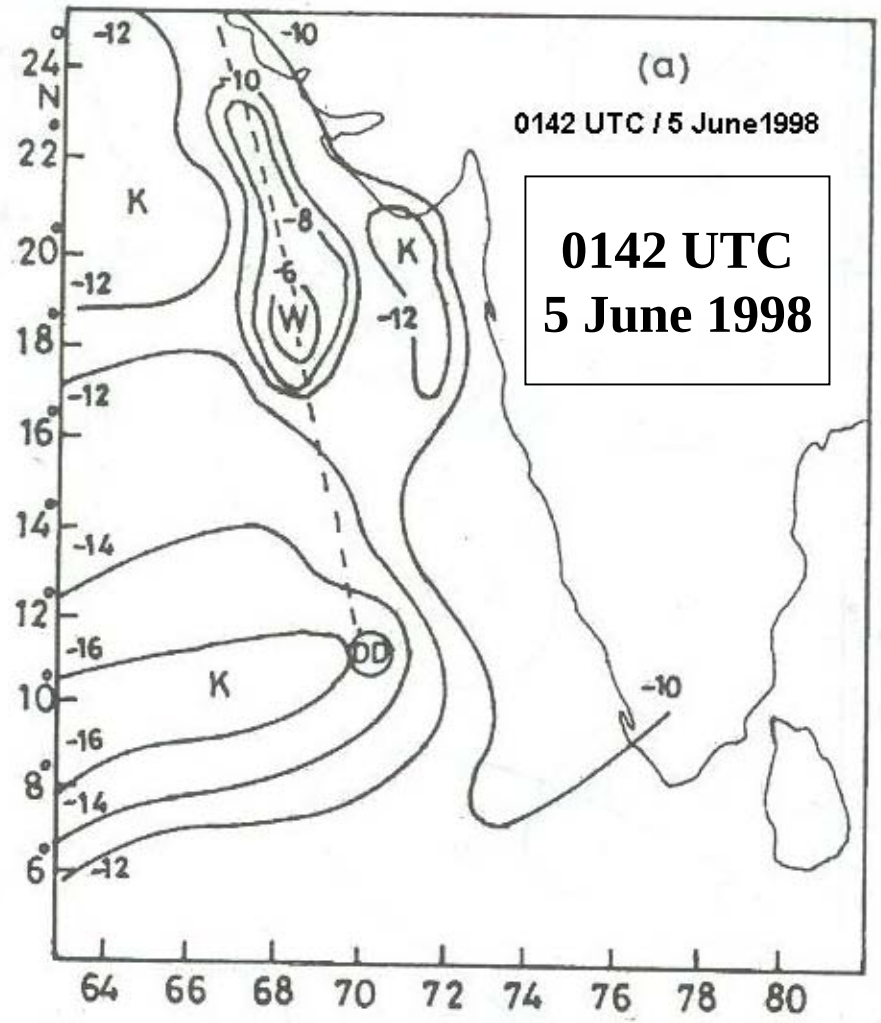
Tracks of cyclonic storms.. 1998

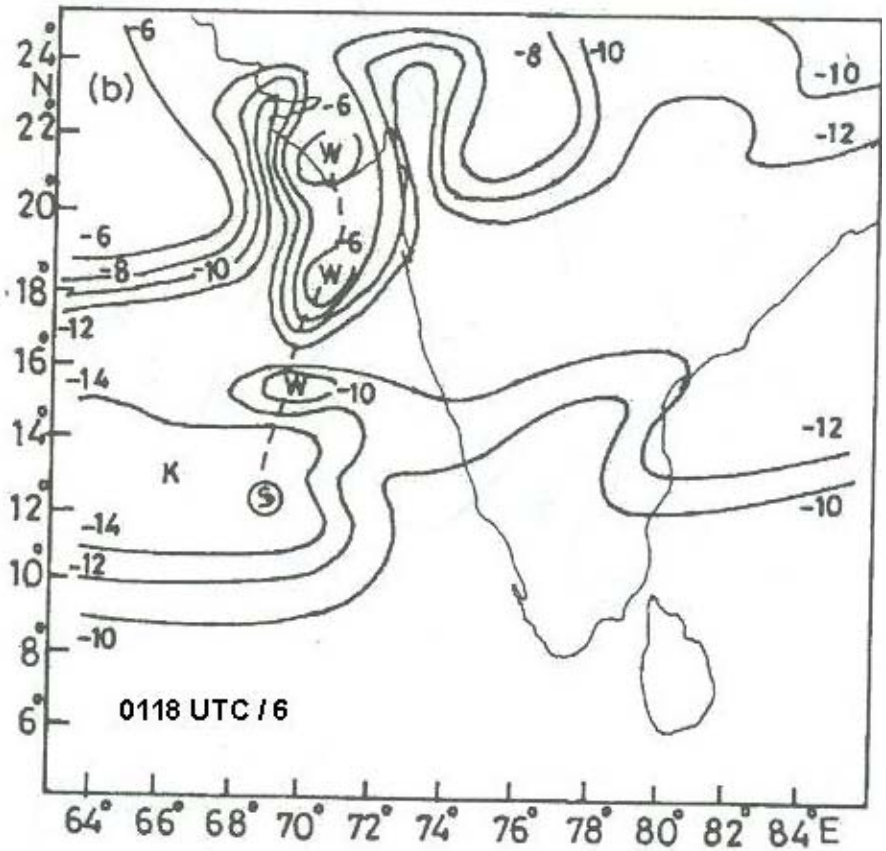


←Cyclone tracks of 1998 as finalised by IMD.

- **Analyses of some of the cyclones of 1998 are presented here.**
- **Analyses of cyclones during 2002 and 2003 & a rare southward moving cyclone of 1996 are also presented.**

(A) 5-10June1998_Arabian Sea.. 700-400hPa mean temp

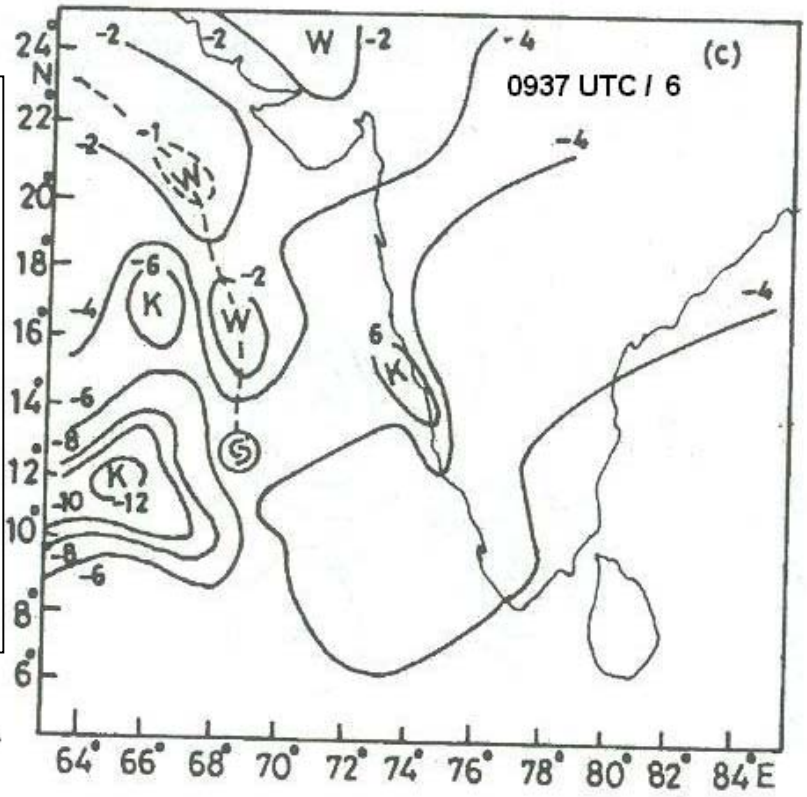


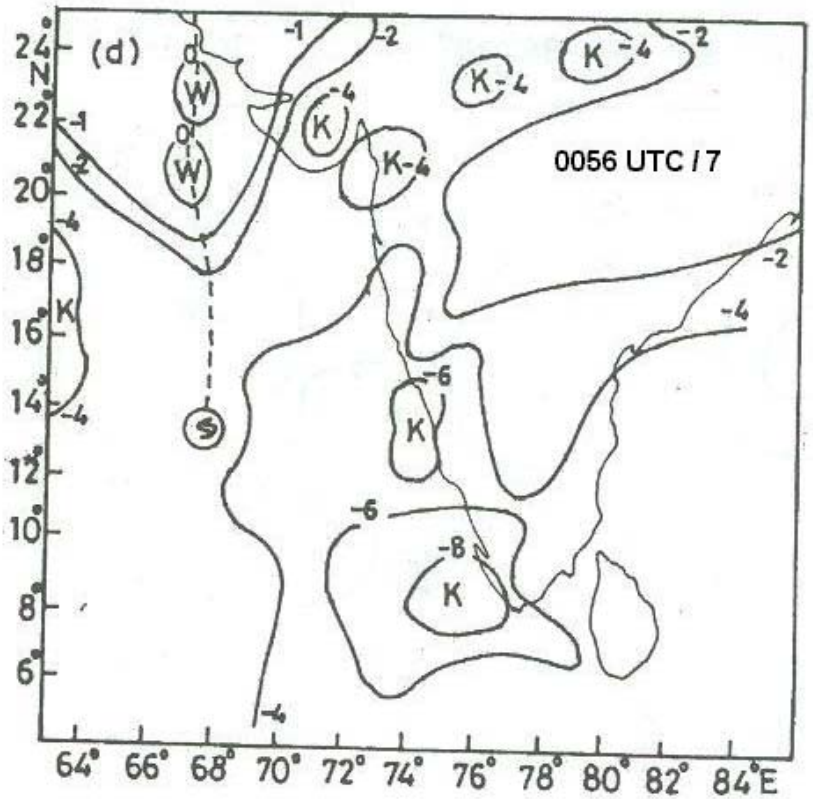


Mid-tropospheric (700-400 hPa) warmness protrudes northwards suggesting the storm's Northward movement.

5-10June1998_Arabian Sea.. 700-400hPa mean temp..contd.

0937 UTC / 6 June 1998

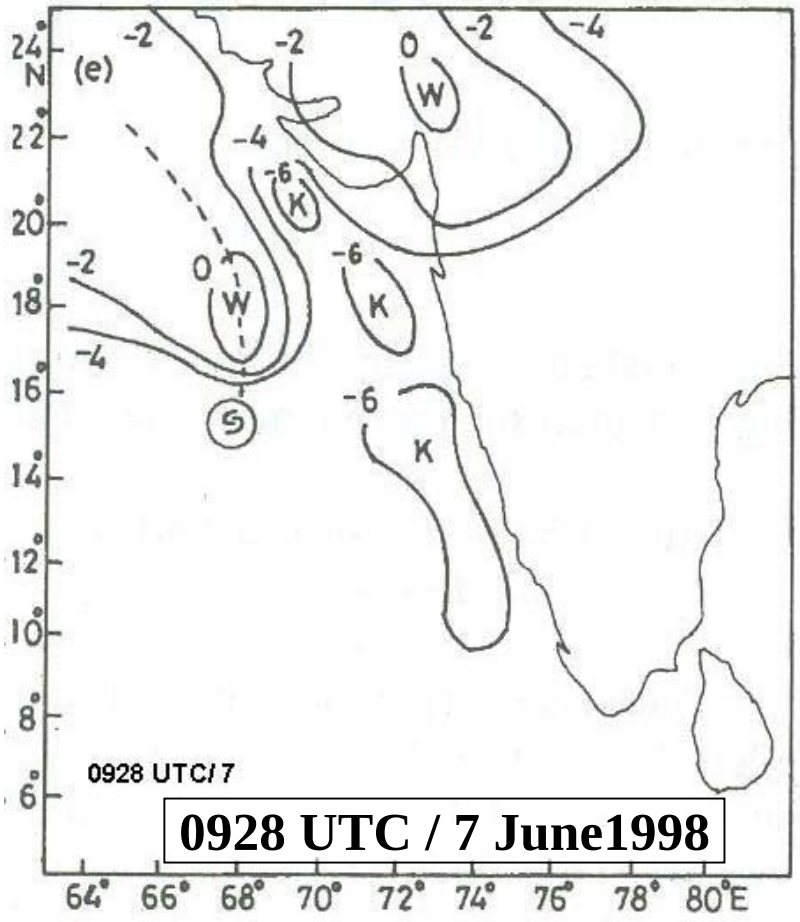




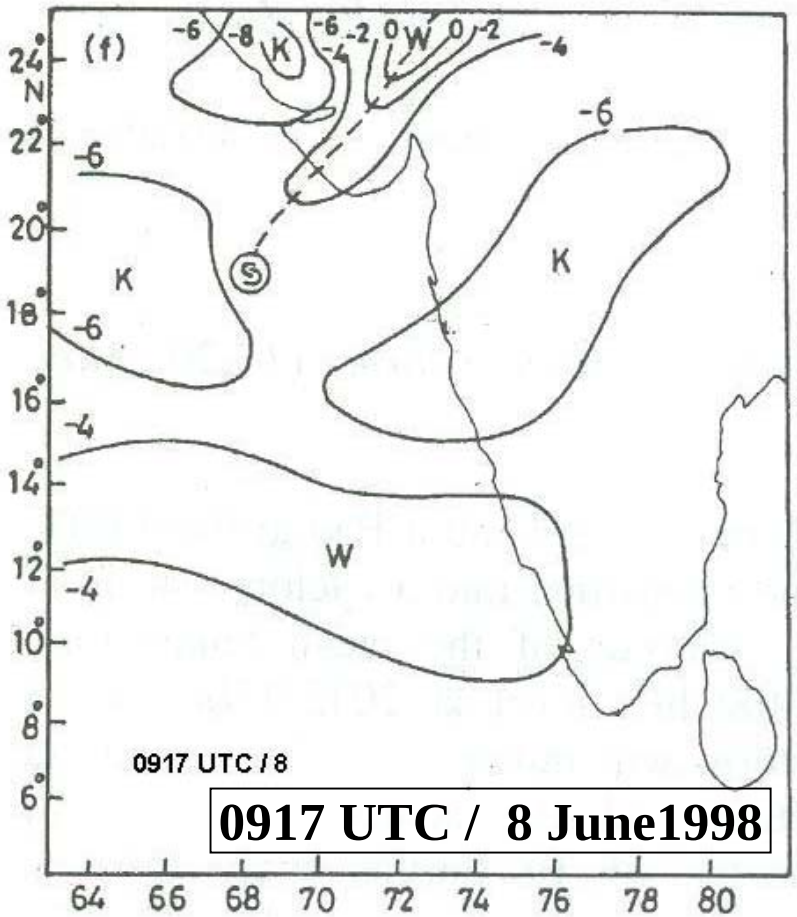
0056 UTC / 7 June 1998

- **The 700-400 hPa mean layer TOVS temperature analyses showed the northward movement of the storm, right from its genesis. This is quite in agreement with actual track of the storm.**
- **The warm tongue extended as far as 800-1000 km ahead of the storm and showed a lead time of more than 36 hours.**

5-10June1998_Arabian Sea.. 700-400hPa mean temp..contd.



0928 UTC / 7 June1998

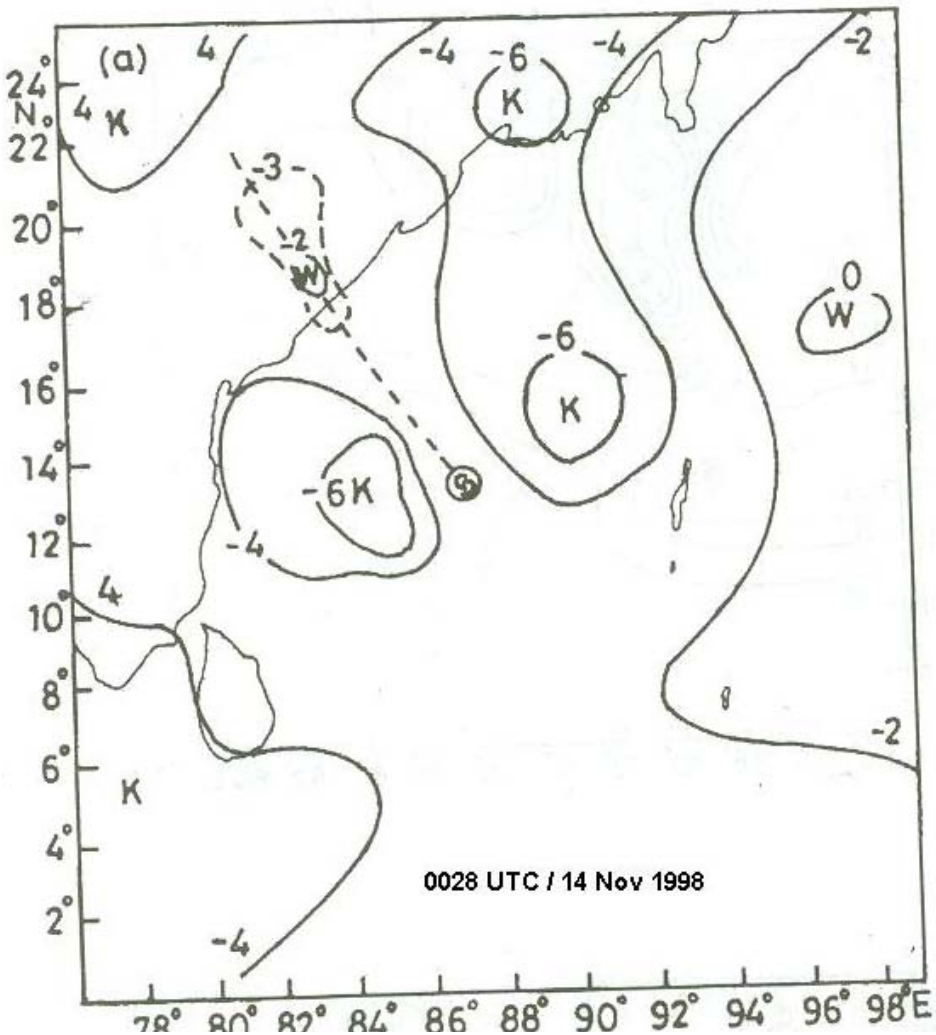


0917 UTC / 8 June1998

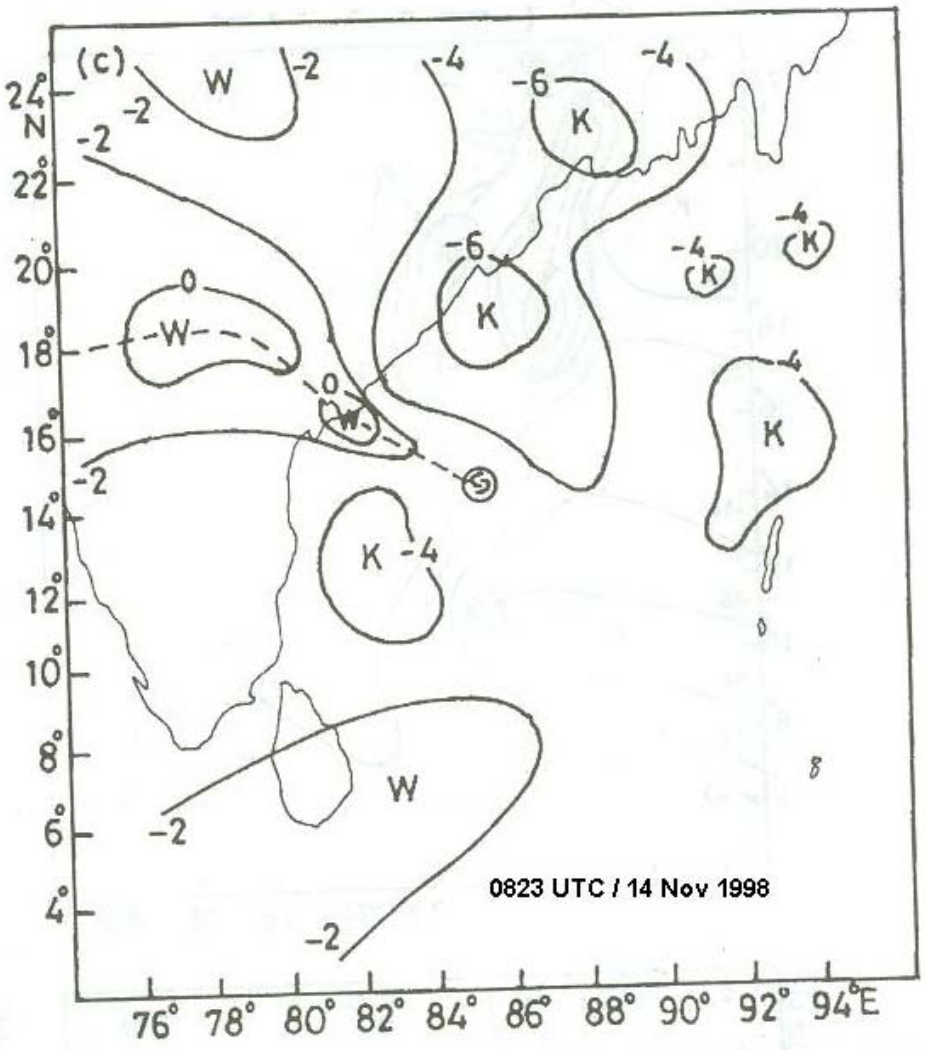
- *Recurvature (movement towards NE) has been well captured by the 700-400 hPa mid-tropospheric warmness at 0915 UTC, atleast 5 hours in advance*.

- **The storm's landfall was also clearly indicated.**

(B) 14-16 Nov1998_Bay Cyclone.. 700-400hPa mean temp



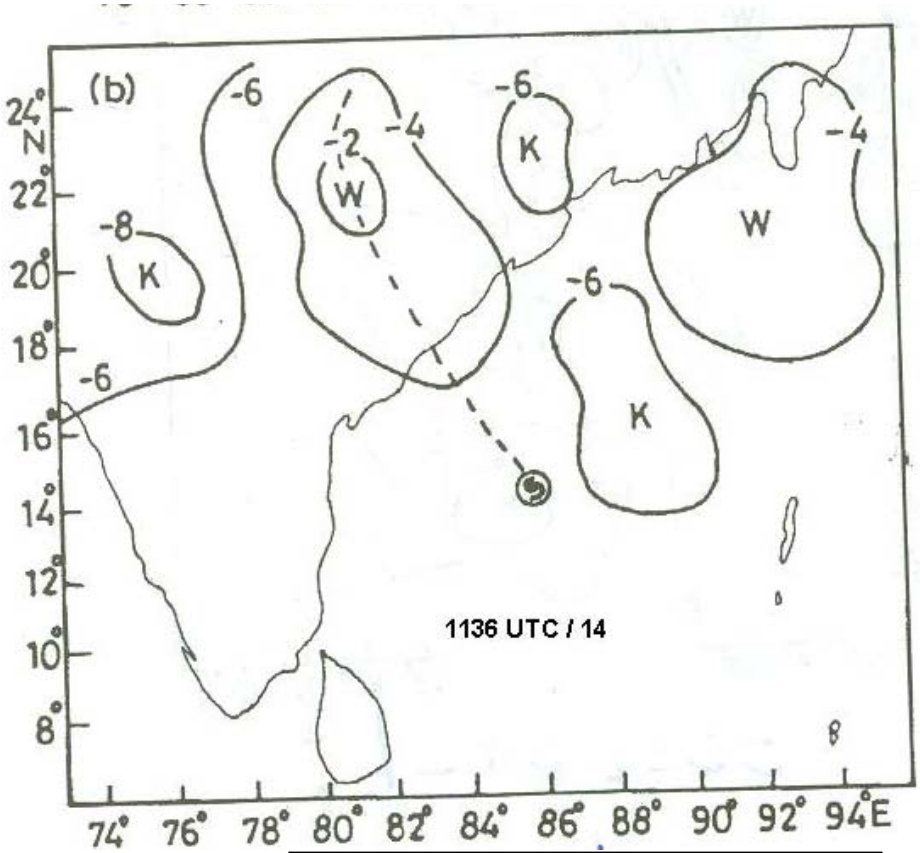
0028 UTC/ 14 Nov 1998



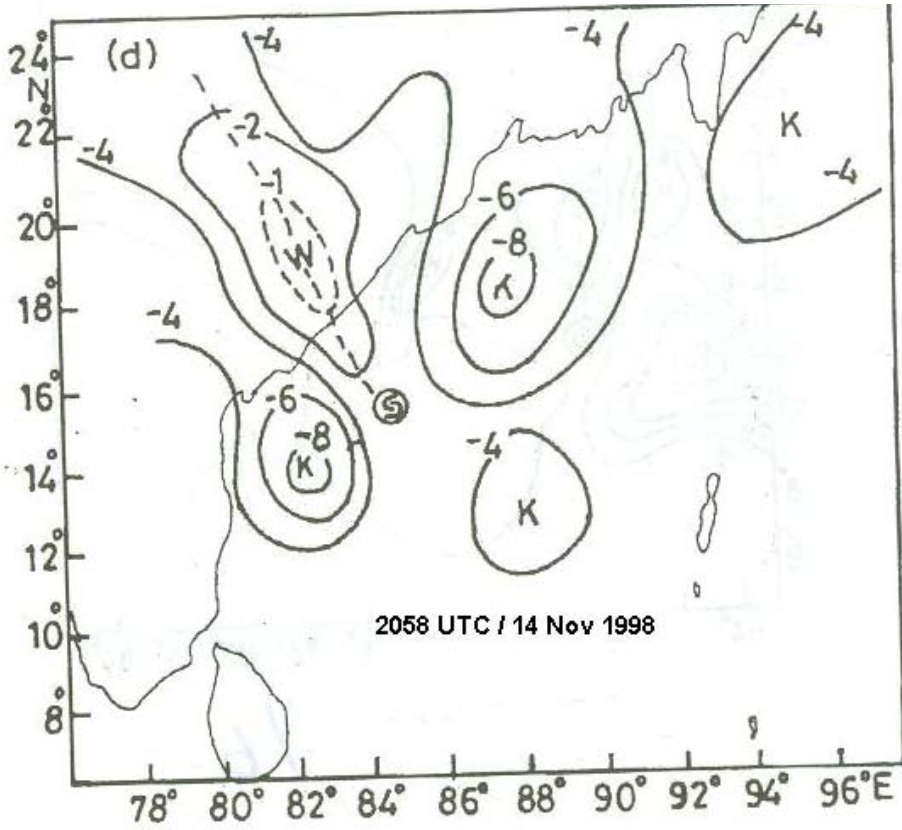
0823 UTC/ 14 Nov 1998

Warmness (though localised) could be captured at 0028 UTC / 14 Nov 1998 TOVS data. Warm tongue is clearly identified at 0823 UTC / 14 Nov 1998.

14-16 Nov1998_Bay Cyclone.. 700-400hPa mean temp..contd.



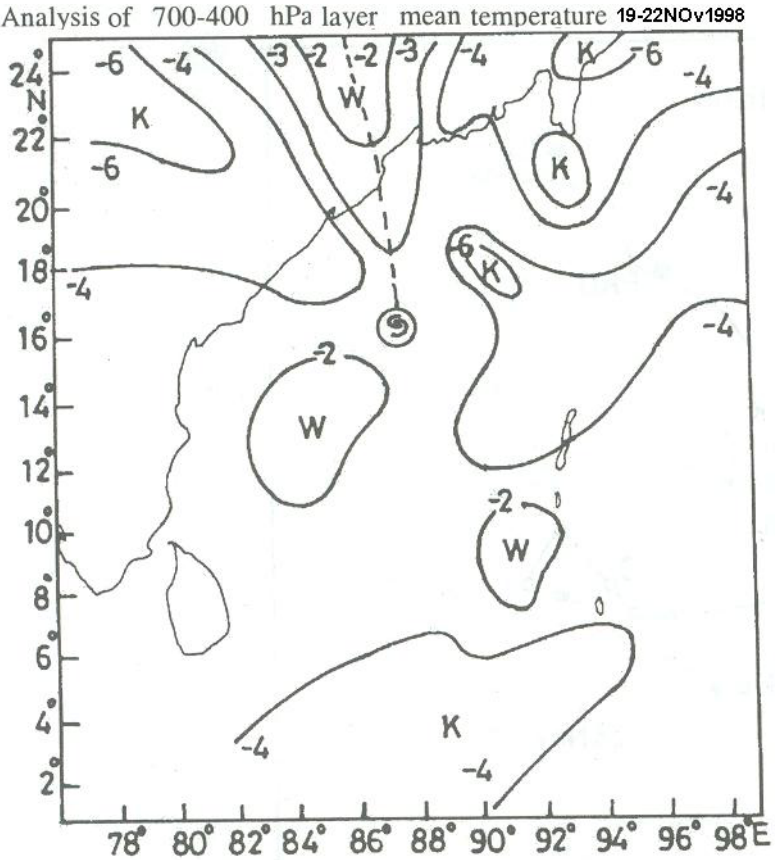
1136 UTC/ 14 Nov 1998



2058 UTC/ 14 Nov 1998

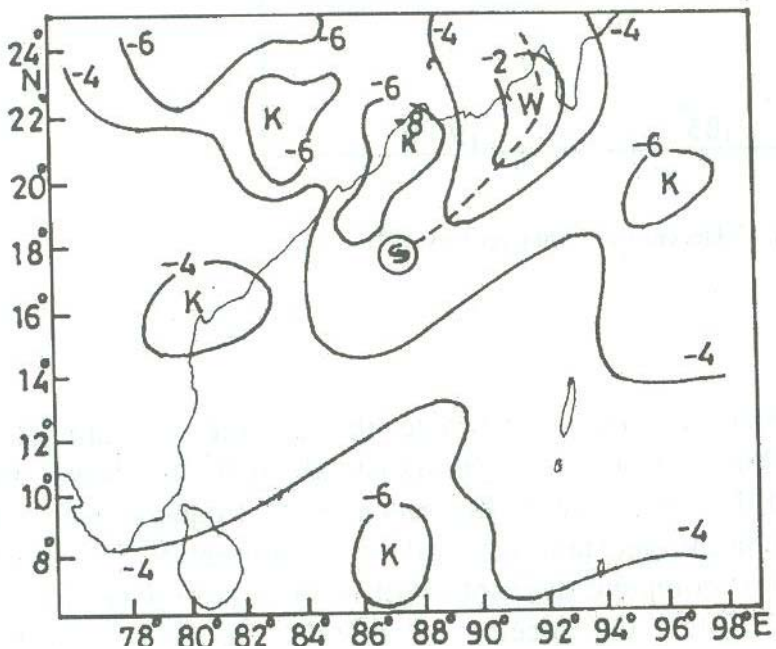
***Clear cut warmness separated by colder areas on either side indicated the storm's NWward movement and its landfall close to Visakhapatnam*. The land fall was predicted within 30 km from the actual track of the cyclone.**

(C) 19-22Nov1998_Bay Cyclone.. 700-400hPa mean temp

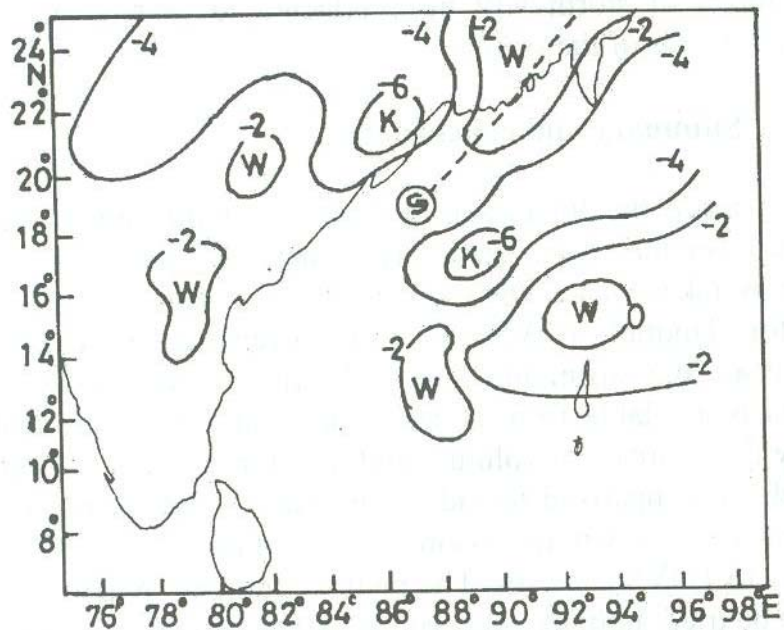


2335 UTC / 20 Nov 1998

***Storm's movement, recurvature and landfall was predicted well*.**

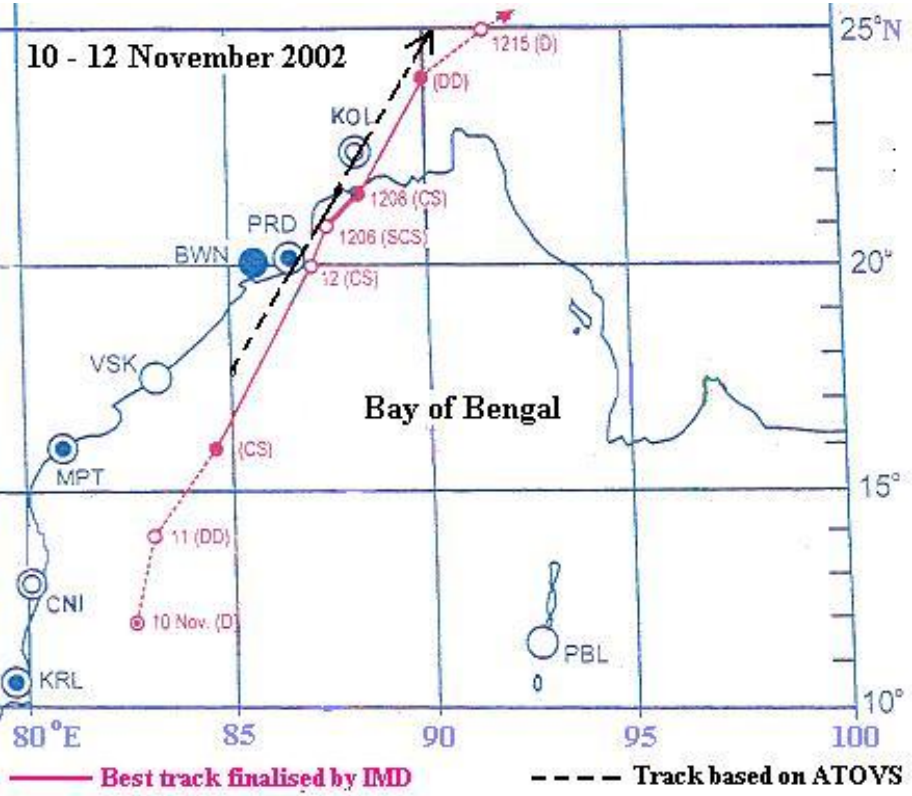


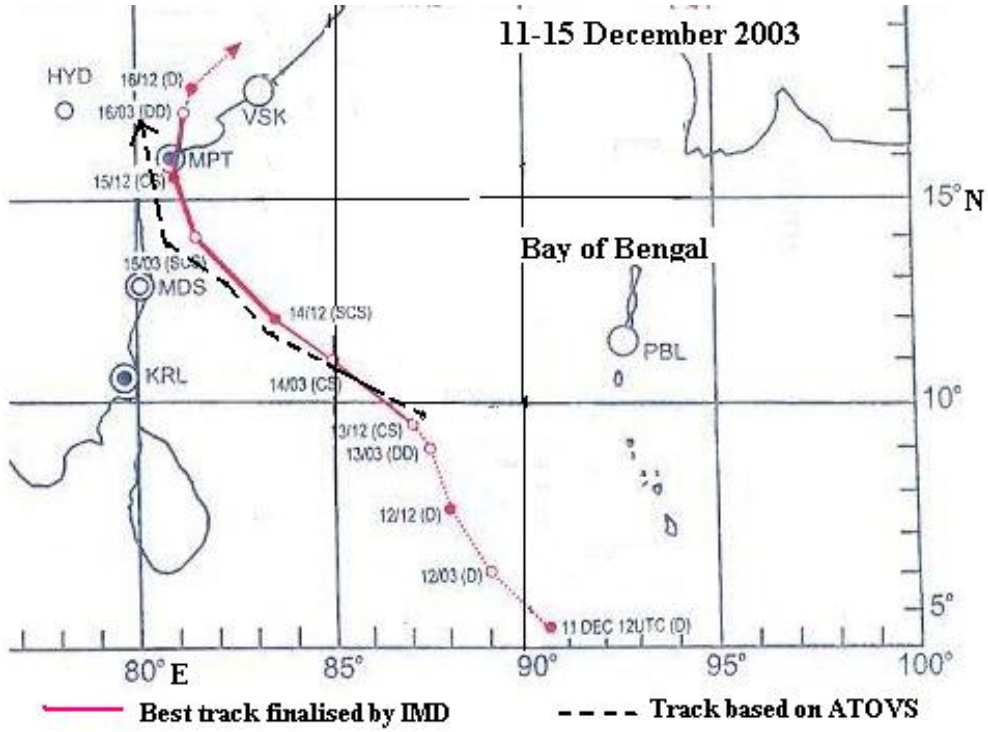
0844 UTC / 21 Nov 1998.



1223 UTC / 21 Nov 1998.

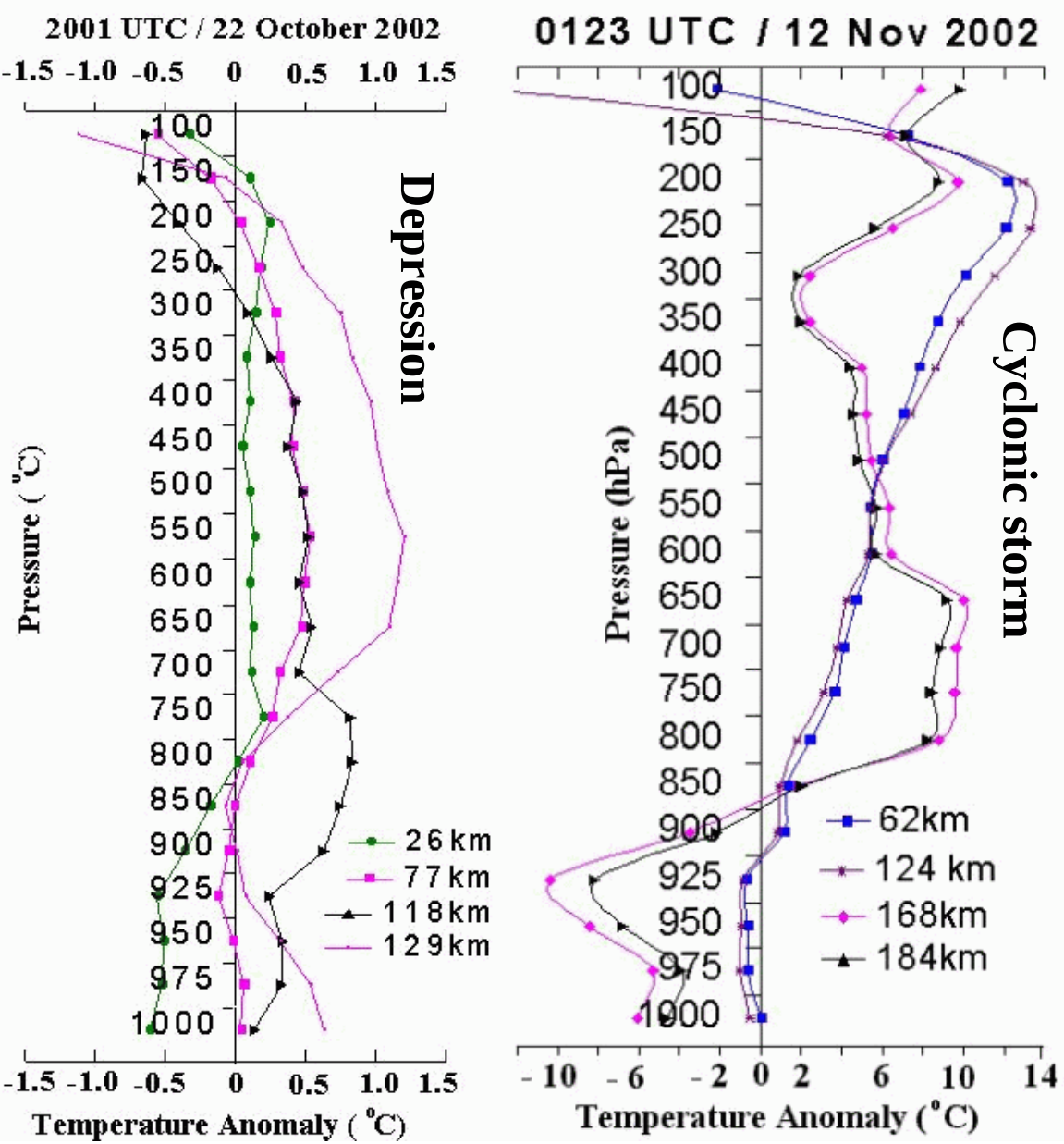
Storms during 2002 & 2003





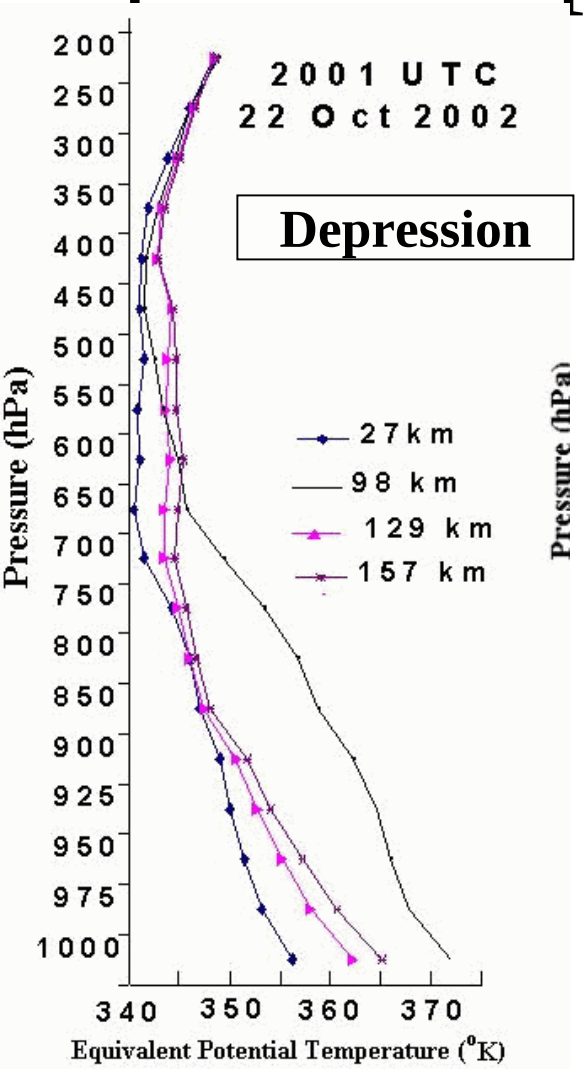
- **The tracks of the cyclonic storms based on ATOVS data (black dotted line) are in close agreement with the storm track finalised by IMD (red solid line).**
- **The land fall was predicted within 30 km for both the storms.**
- **The protrusion of mid-tropospheric warmness has been tested for one more depression also during 22-23 October 2002 (not shown here).**

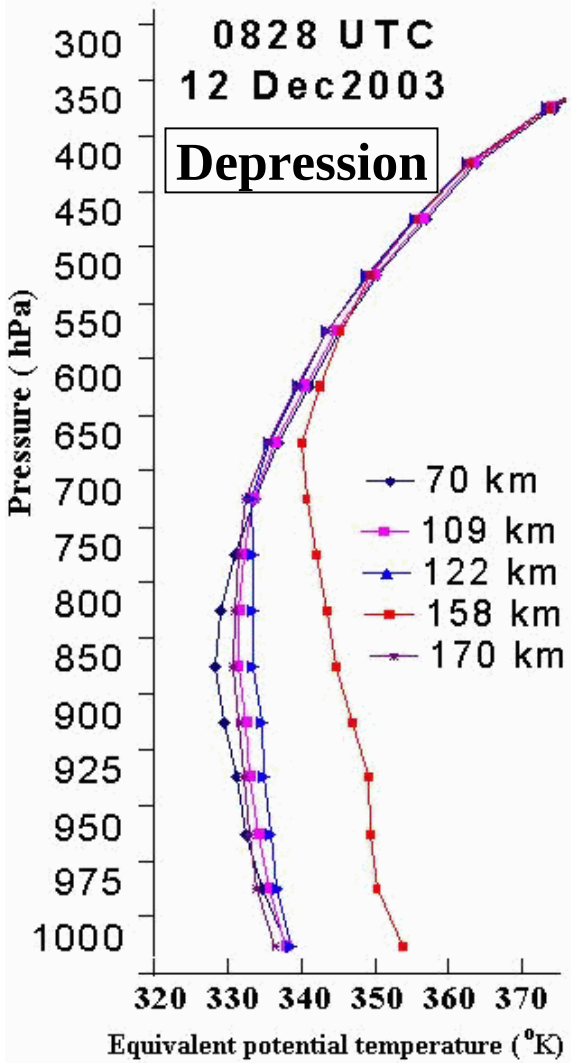
Vertical cross section of Temperature anomalies

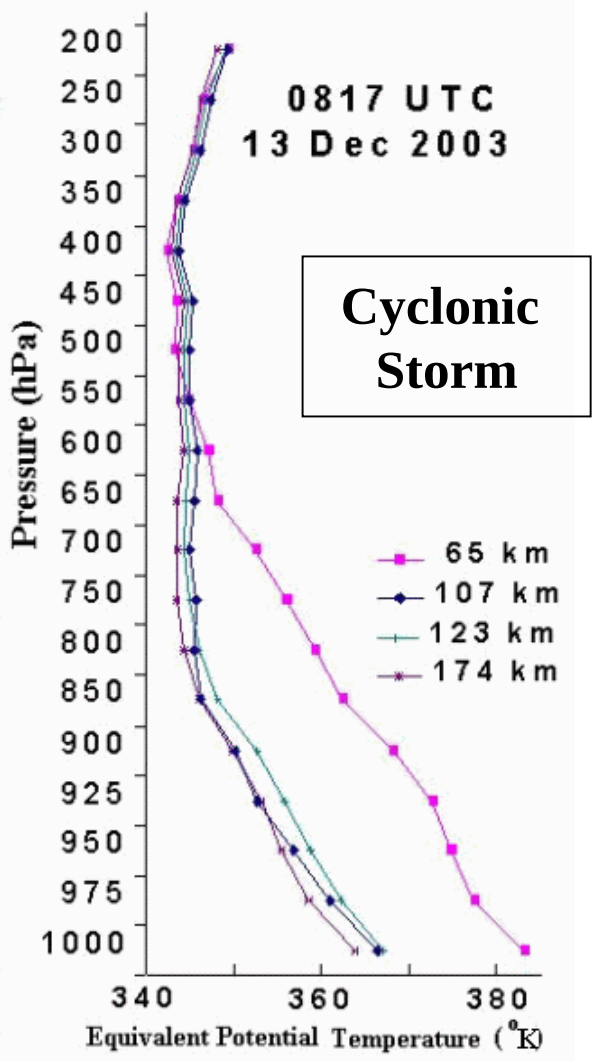


- The core of the tropical cyclone is warmer by 7.0 to 13.0°C than the surrounding areas (beyond 500-600 km from the storm centre) at upper tropospheric levels (250 - 200 hPa).
- A maximum warmness of 13.3 °C was observed at 250 hPa on 0123 UTC of November 12, 2002.
- No significant warming in the upper tropospheric level could be seen *in the depression stage* of the weather systems.

Equivalent potential temperature profile

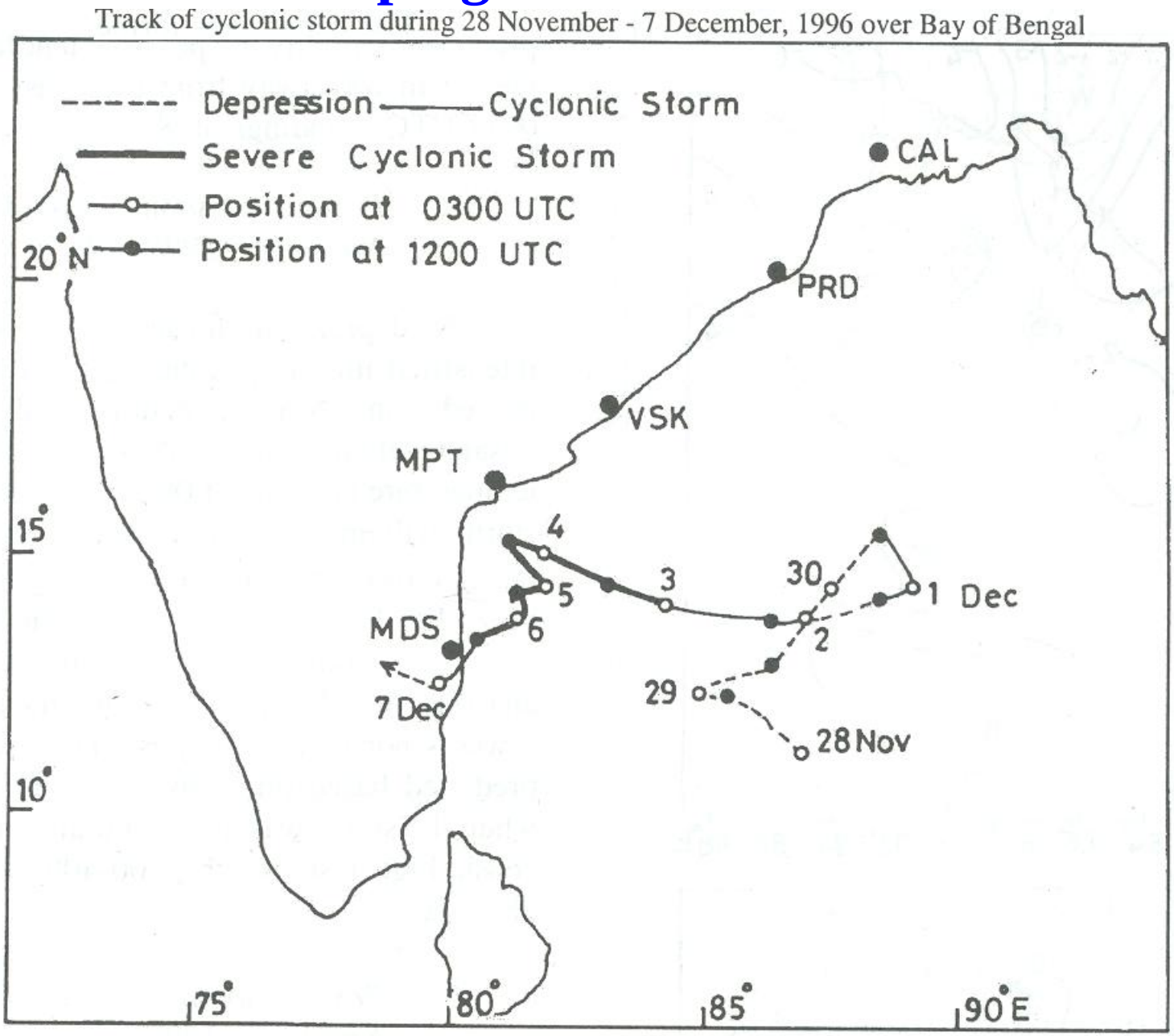






- **Due to closeness to the coast and large convective instability, depression on 22Oct2002 might have rained out before intensifying into a cyclone.**
- **Due to weak convective instability in the depression stage and long sea travel, depression on 12 Dec2003 intensified into a storm.**

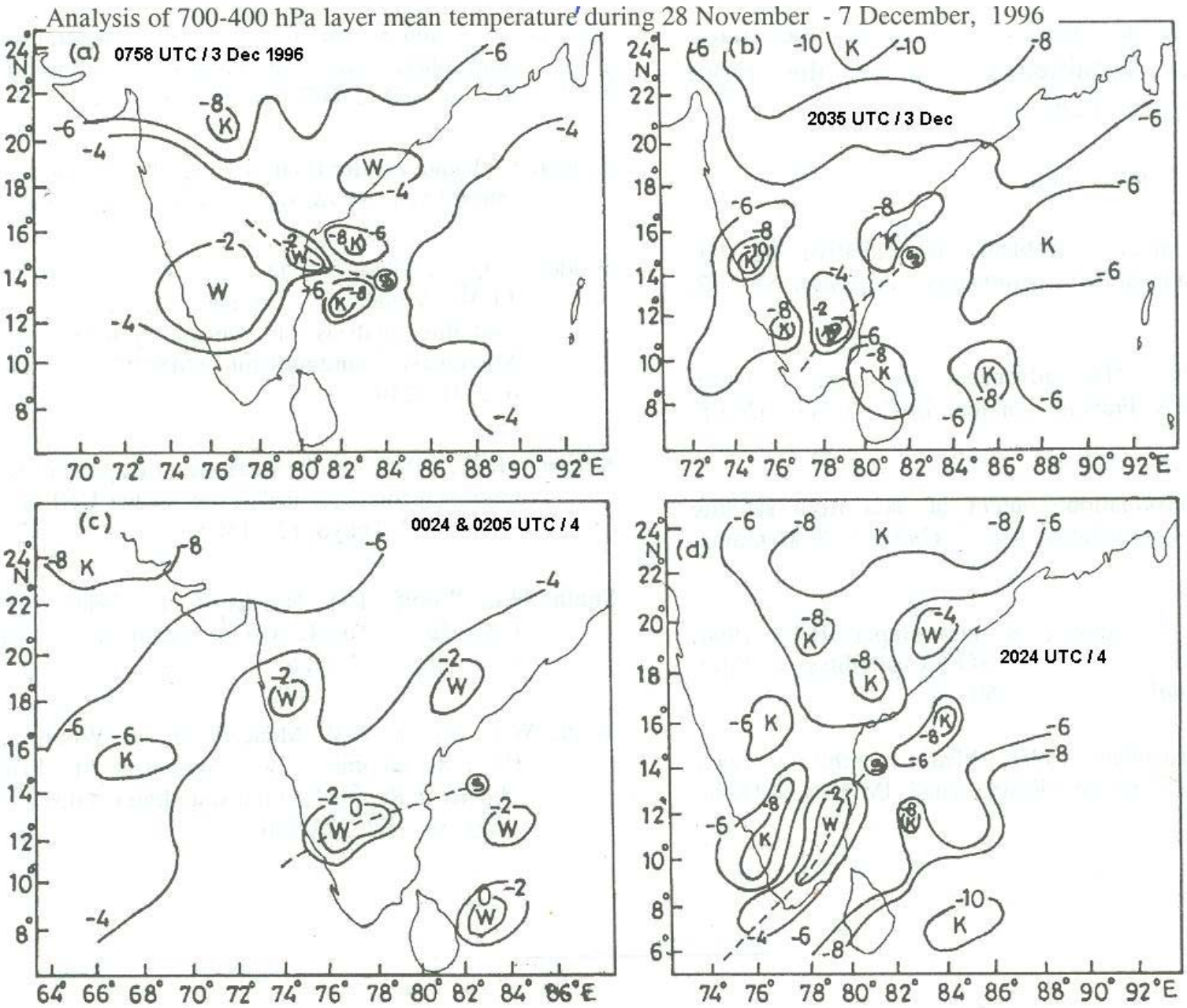
Track of looping & southward movement 1996 cyclone



TOVS data was available only from 3 Dec 1996 for analysis.

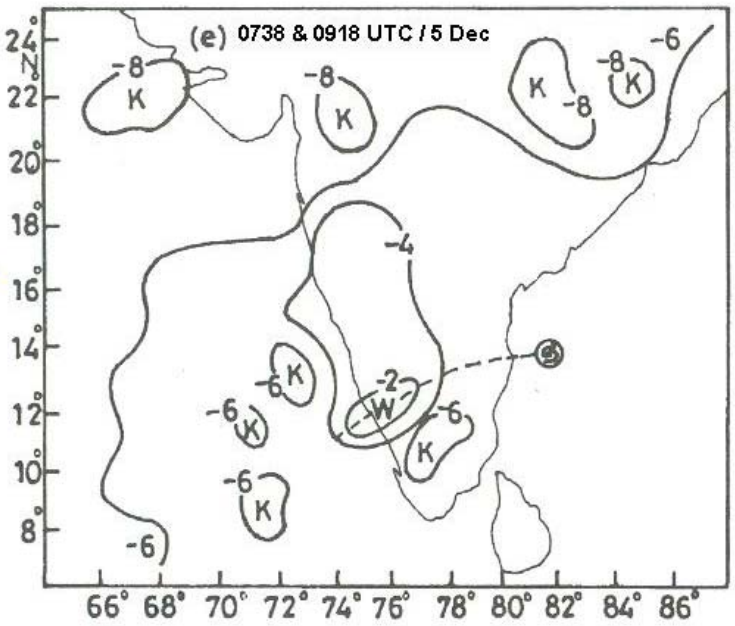
The very rare southward movement of a tropical cyclone has been captured well by the altostratus warming from 0758UTC/3rd .

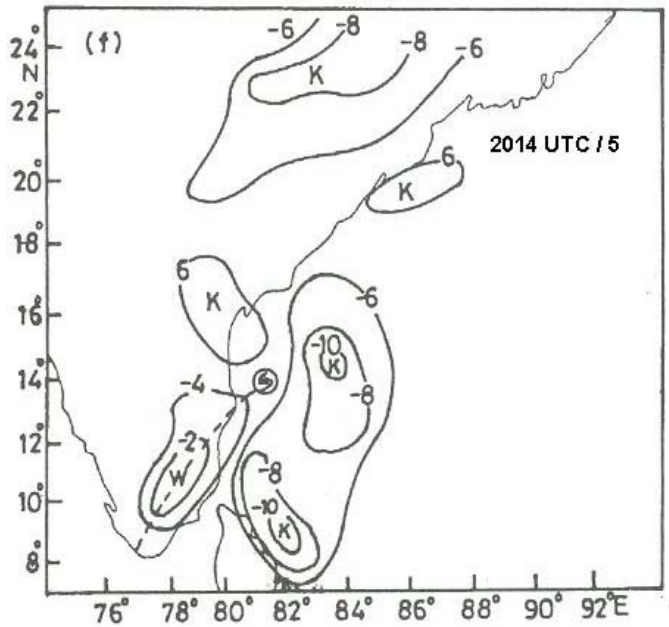
28Nov-7Dec1996_Bay Cyclone.. 700-400hPa mean temp

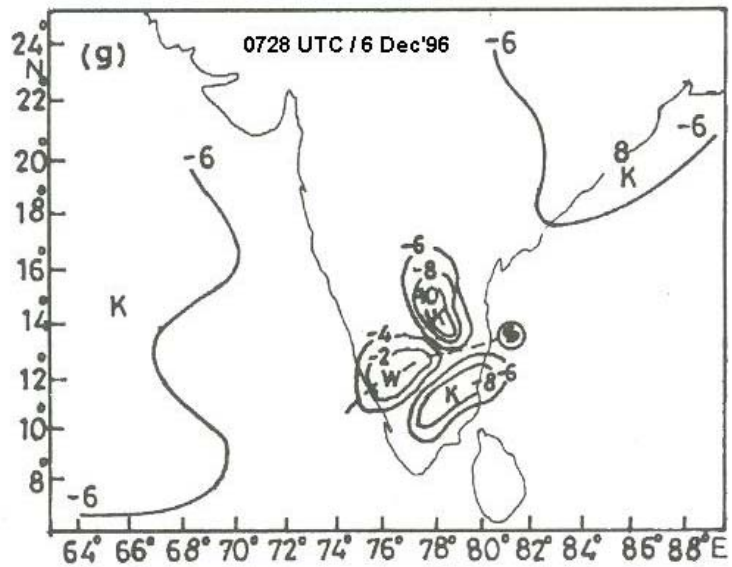


Southward travel of the storm had been captured well from 2035 UTC / 3rd Dec'96 **(more than 48hrs in advance). The storm was within 200 km range from the coast.**

28Nov-7Dec1996_Bay Cyclone..700-400hPa mean temp







Southward movement of the cyclonic storm as evident from the mid-tropospheric (700-400 hPa) warmness.

Summary

- ✓ **The mid-tropospheric warmness in the layer 700 - 400 hPa may be used as a tool to foreshadow the movement of tropical cyclonic disturbances.**
- ✓ **The method (based on 8 cyclonic disturbances) outlined in this paper can be tried, initially, as a parallel forecasting tool to assess its efficacy before operationalising the same.**
- ✓ **While no significant warming in the upper tropospheric level could be seen in the depression stage, the core of the tropical cyclone is warmer by 7.0 to 13.0 ^{o}C at upper tropospheric levels (250 - 200 hPa).**
- ✓ **A maximum warmness of 13.3 ^{o}C was observed at 250 hPa in a cyclone.**
- ✓ **Warm lower atmosphere and weak convective instability in the inflow regions (≈ 150 – 200 km from the centre) may help to intensify the depression into a cyclonic storm.**

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