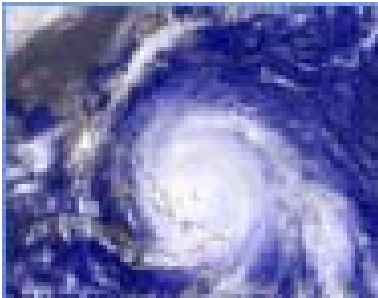


**Foreshadowing the tracks of tropical  
depressions and cyclonic storms and  
understanding their thermodynamical  
structure over Bay of Bengal and Arabian sea  
using TOVS and ATOVS data**



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# Conventional vis-à-vis Satellite soundings

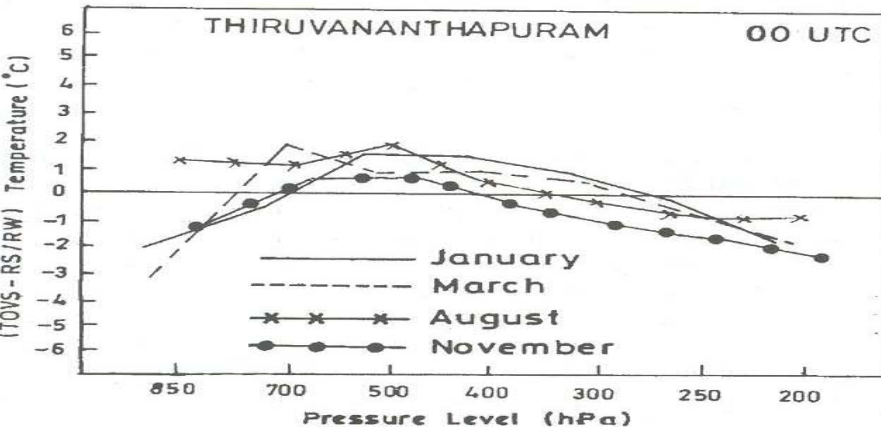
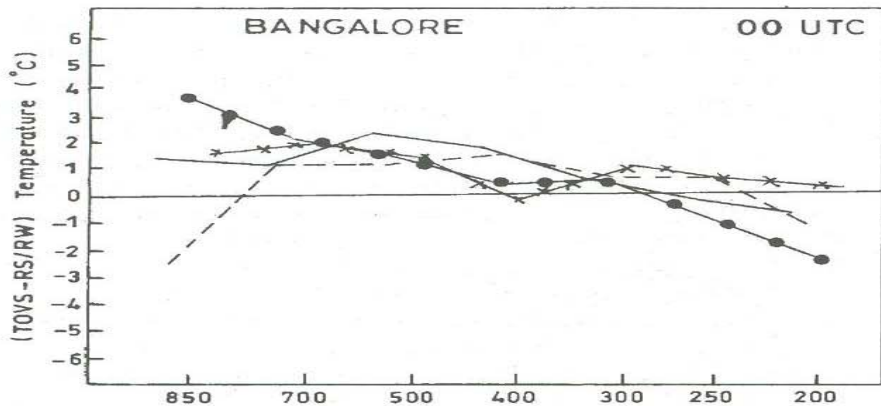
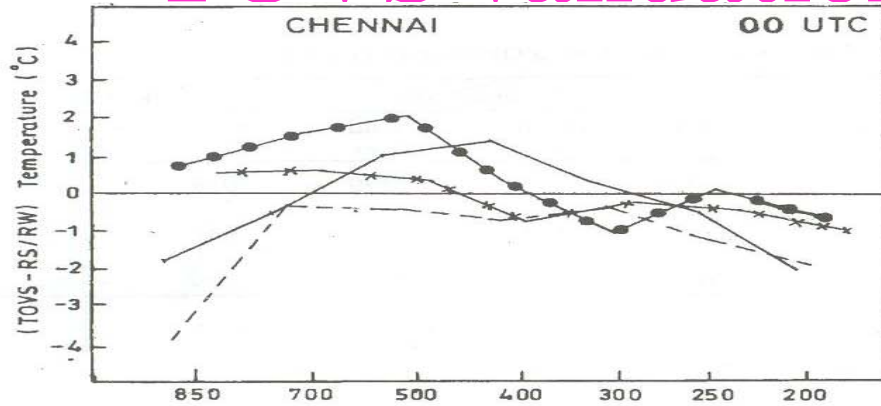
## Deficiencies in Conventional soundings

- **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



❖ 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 ( $\pm 100\text{km}$ ,  $\pm 2$  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 °C and g.p.m less than 100m during 1996-'98.**

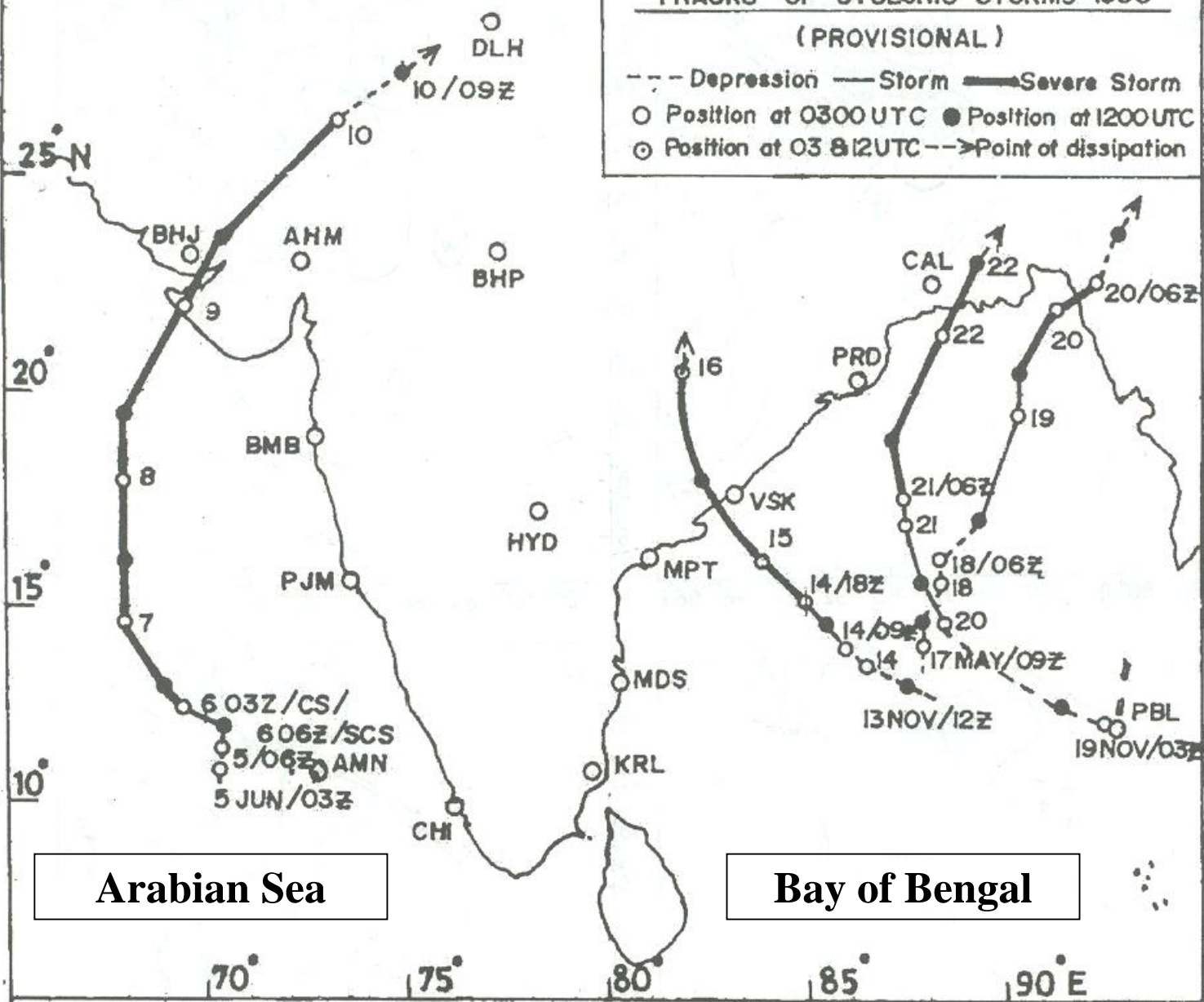
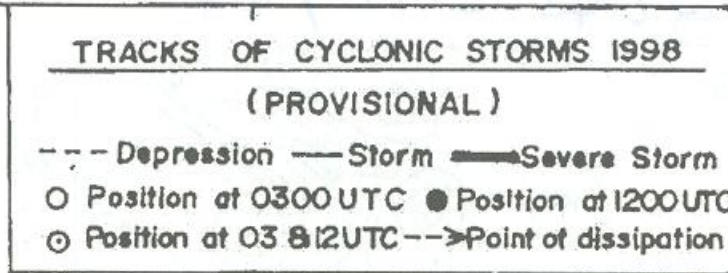
Mean temperature bias (Satellite – RadioSonde)

# Mid-tropospheric warmness vis-à-vis cyclone track

- Soundings from reconnaissance flights revealed that mid-tropospheric warmness due to altostratus outflow protrudes at least 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

Tracks of cyclonic storms during 1998



Arabian Sea

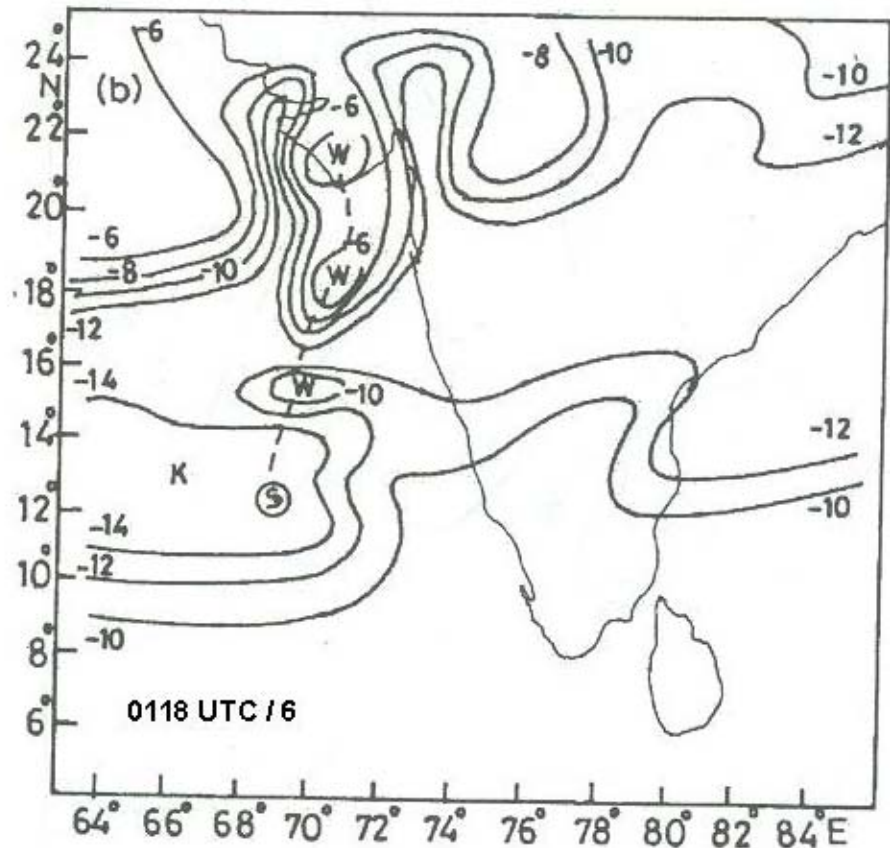
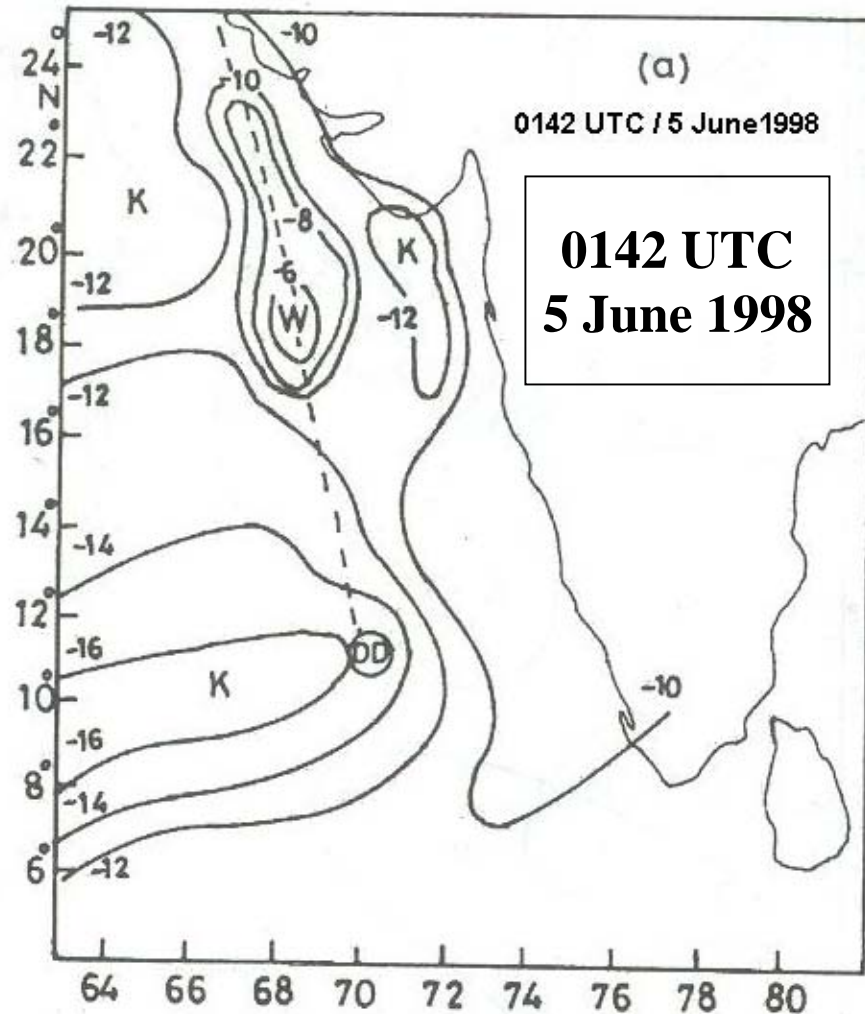
Bay of Bengal

← 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) 5-10 June 1998\_Arabian Sea.. 700-400hPa mean temp

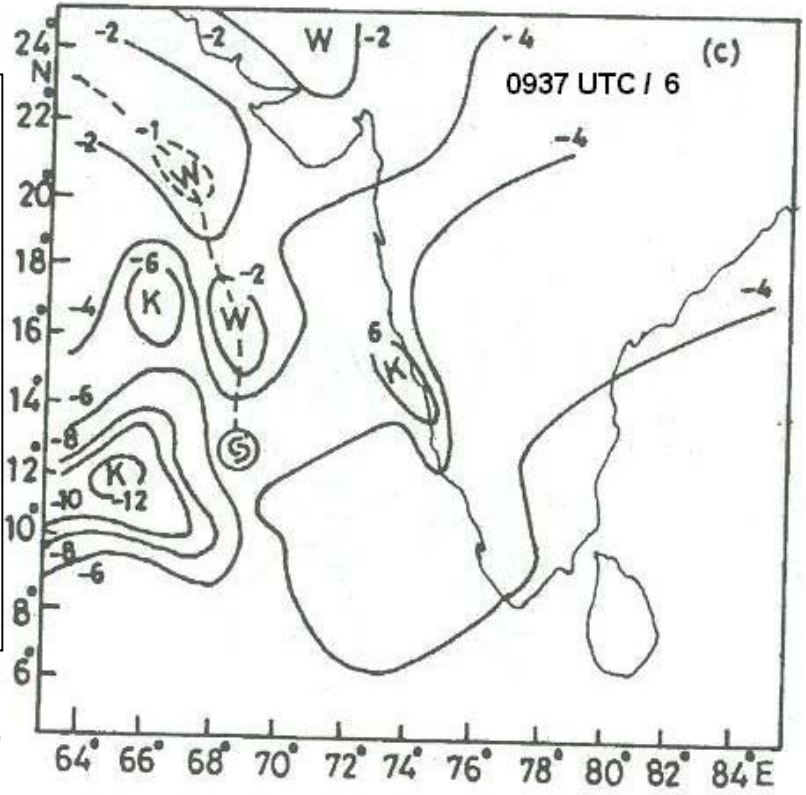


**0118 UTC / 6 June 1998**

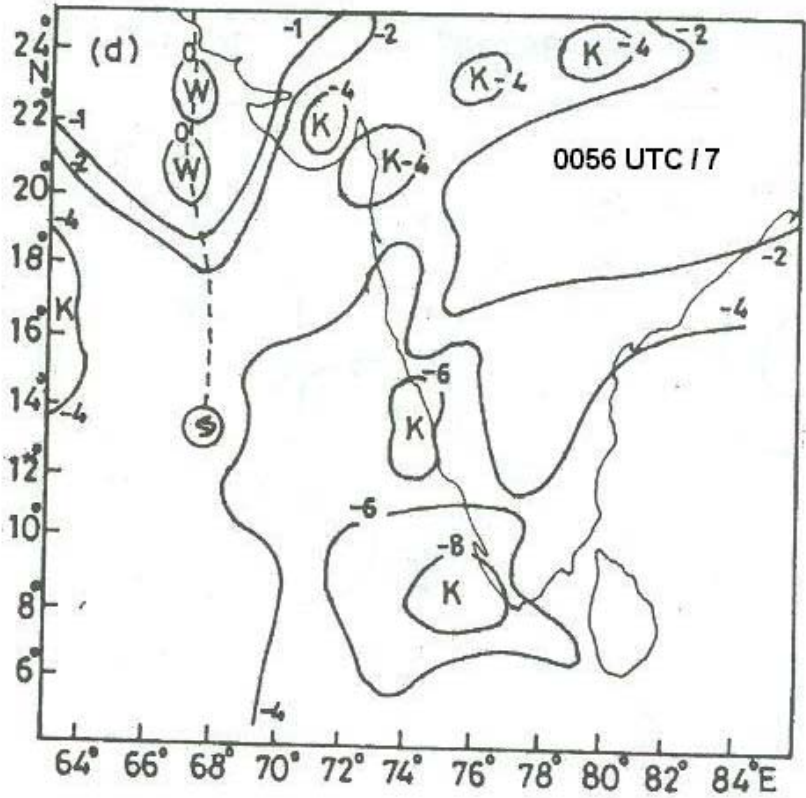
*Mid-tropospheric (700-400 hPa) warmth protrudes northwards suggesting the storm's Northward movement.*

# 5-10 June 1998\_Arabian Sea.. 700-400hPa mean temp..contd.

0937 UTC / 6 June 1998

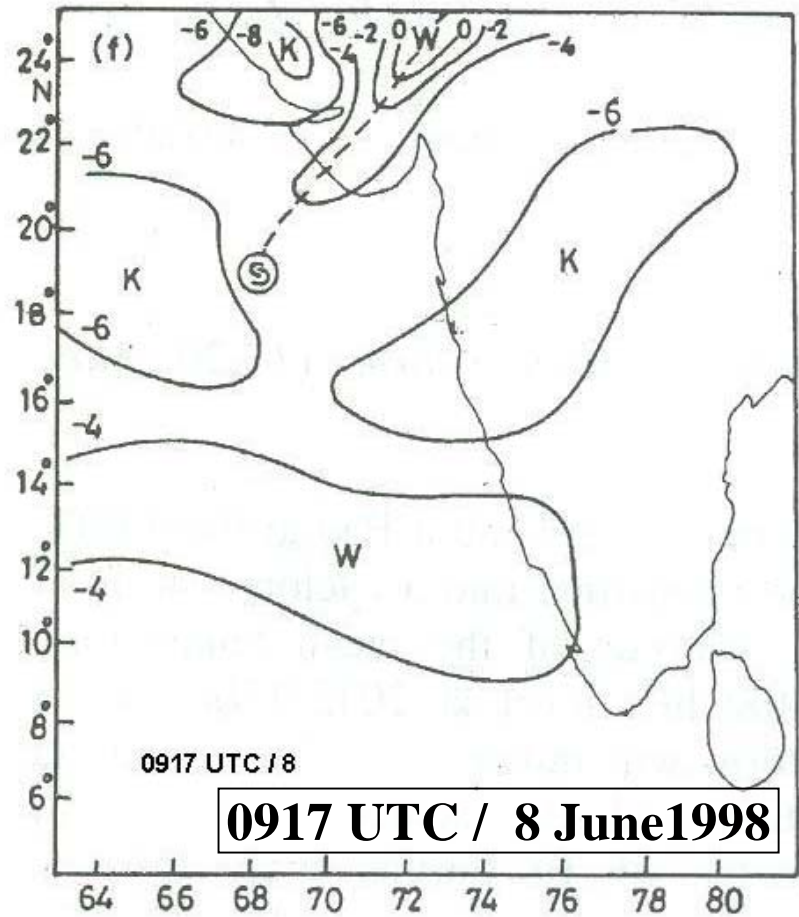
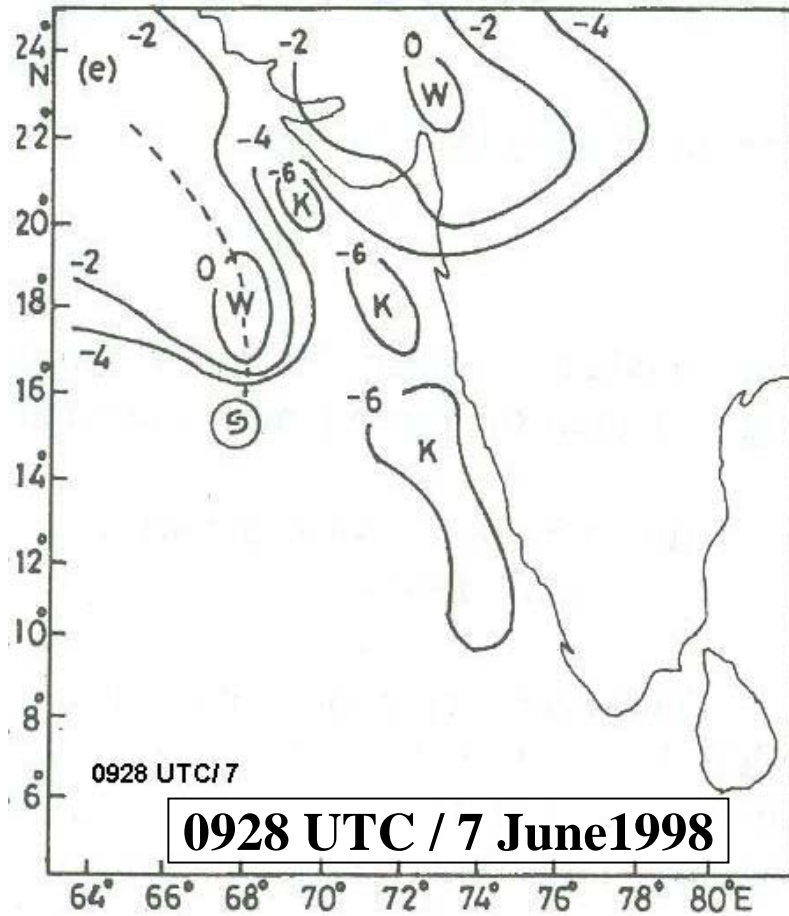


0056 UTC / 7 June 1998



- 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.

# 5-10 June 1998 \_ Arabian Sea.. 700-400hPa mean temp..contd.

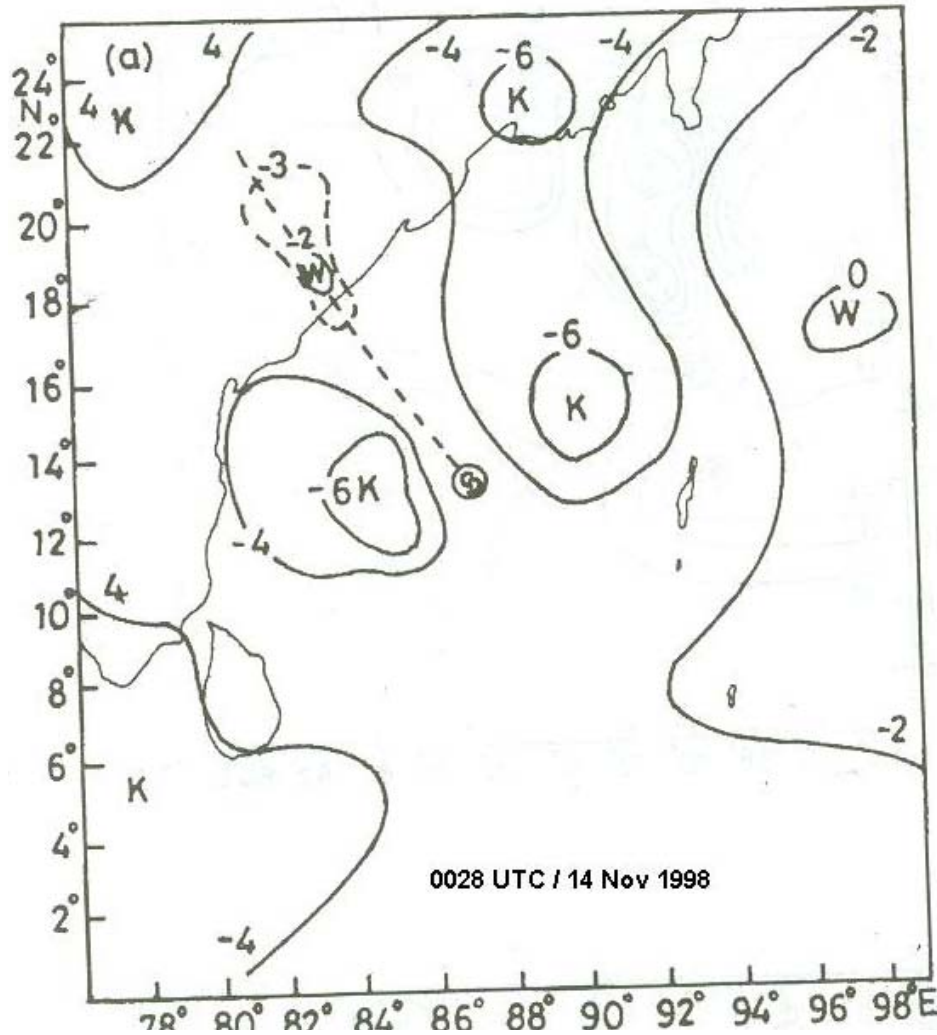


•Recurvature (movement towards NE) has been well captured by the 700-400 hPa mid-tropospheric warmth at 0915 UTC, at least 5 hours in advance.

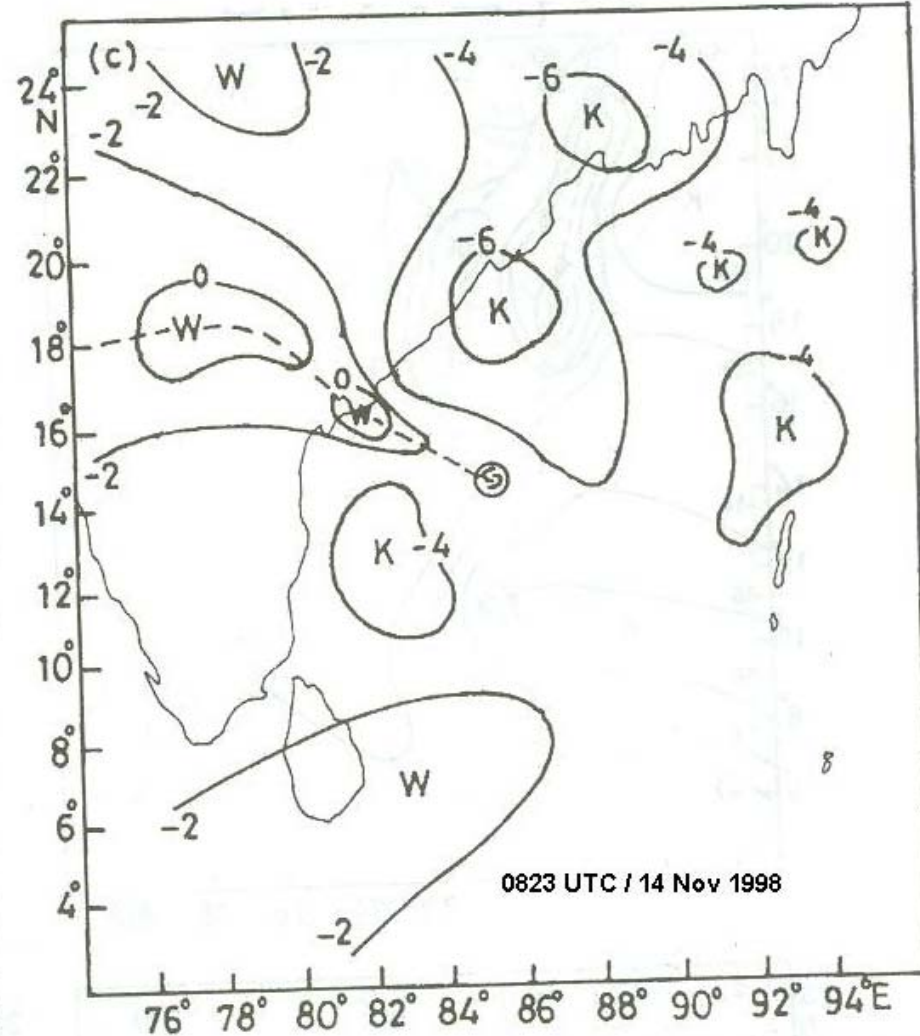
**•The storm's landfall was also clearly indicated.**



# (B) 14-16 Nov1998\_Bay Cyclone.. 700-400hPa mean temp



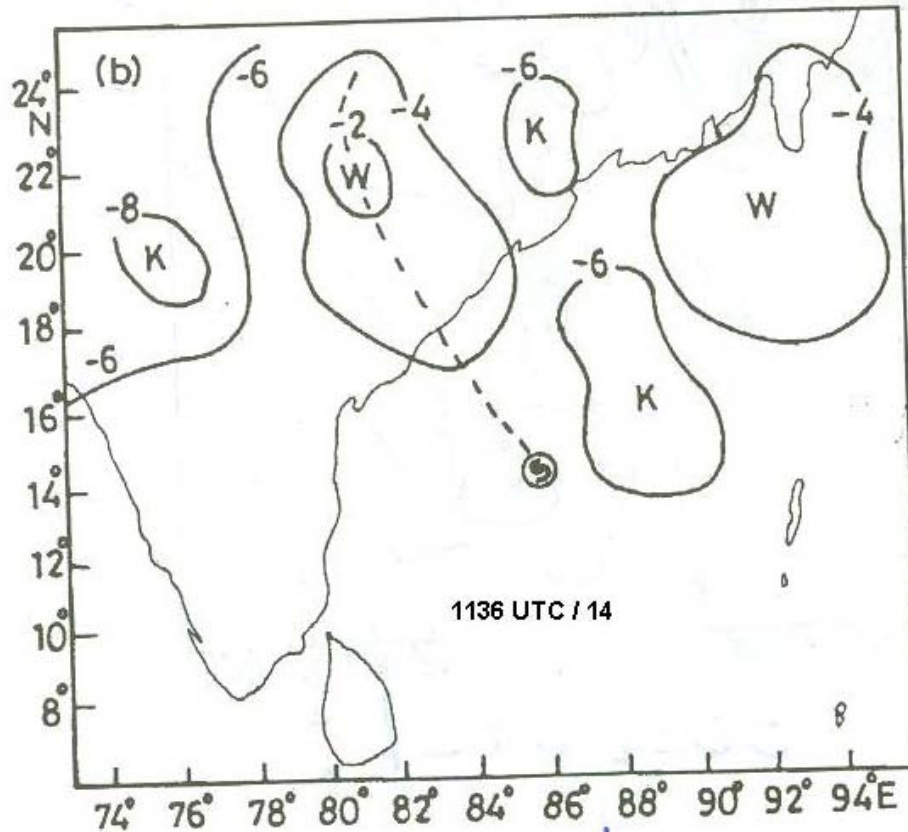
0028 UTC/ 14 Nov 1998



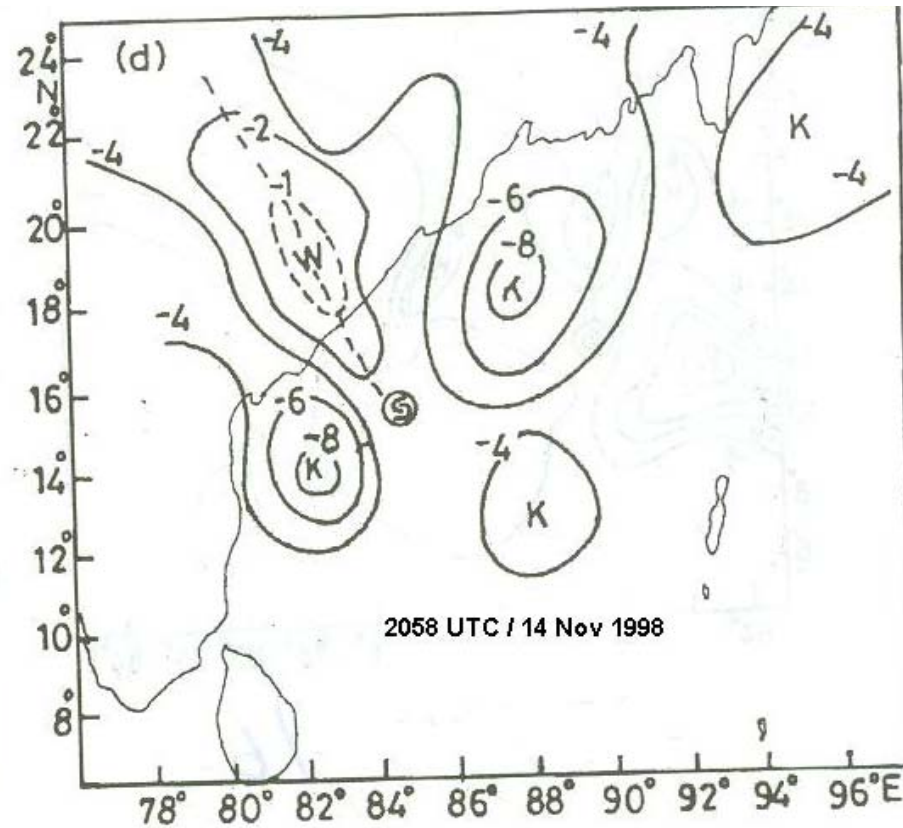
0823 UTC/ 14 Nov 1998

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

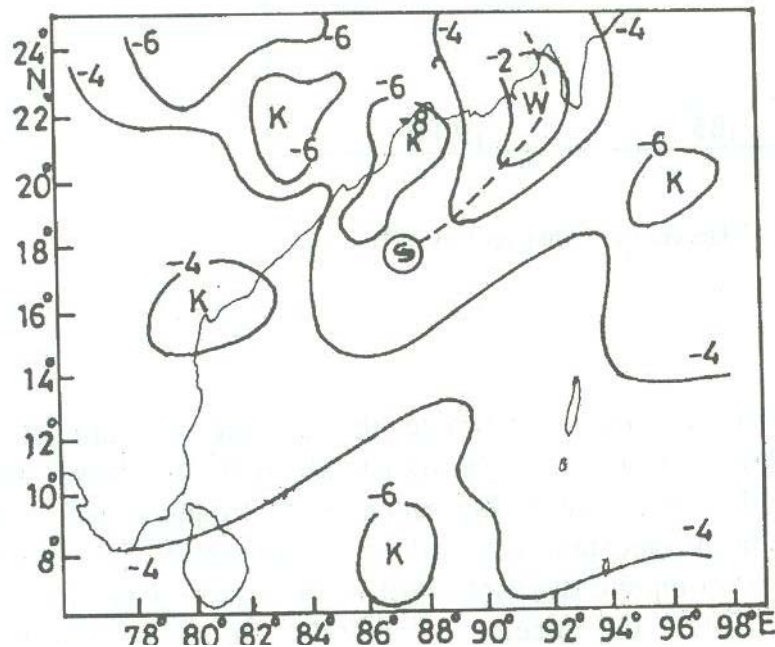
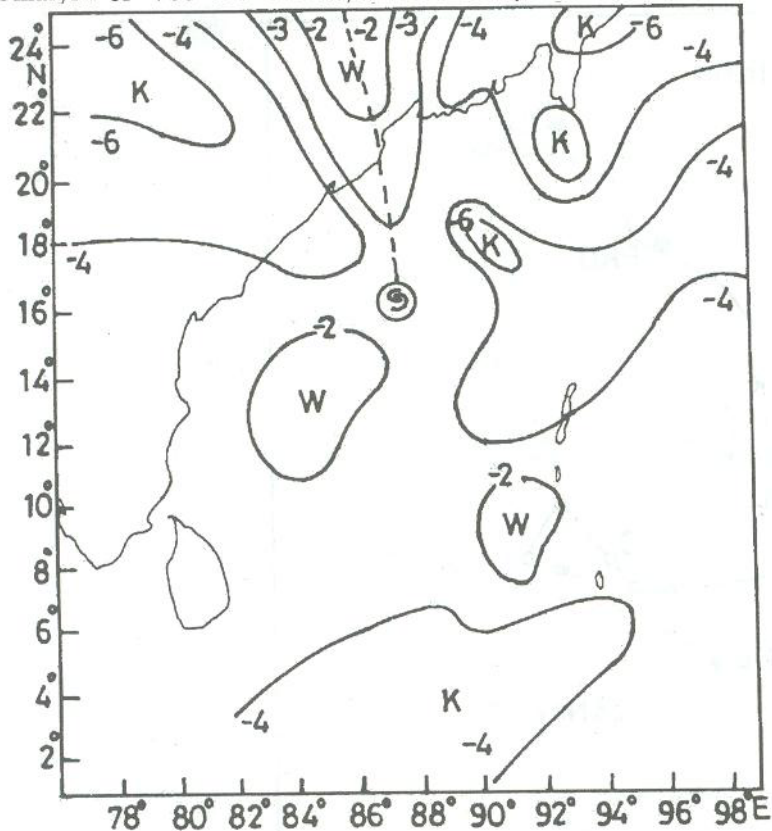


2058 UTC/ 14 Nov 1998

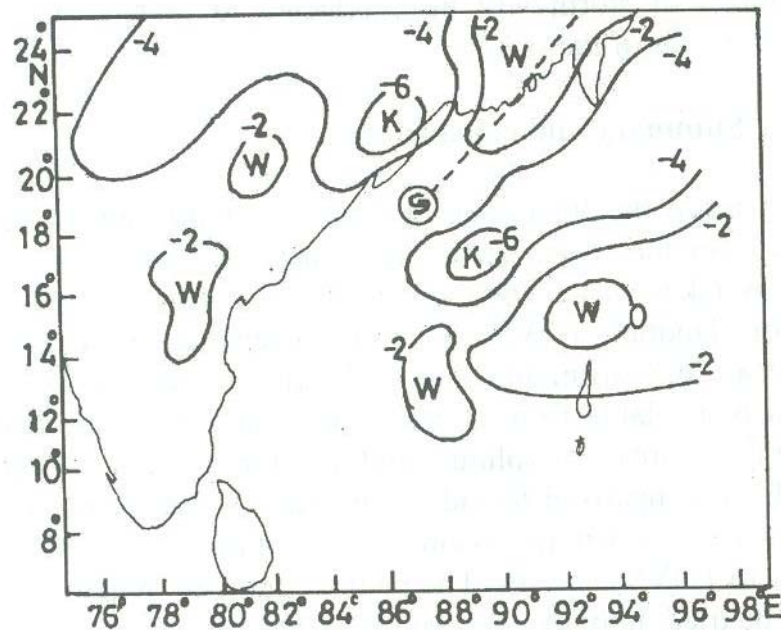
*Clear cut warmness separated by colder areas on either side indicated the storm's NWward movement and its landfall close to Visakhapatnam.* The land fall was predicted within 30 km from the actual track of the cyclone.

# (C) 19-22Nov1998\_Bay Cyclone.. 700-400hPa mean temp

Analysis of 700-400 hPa layer mean temperature 19-22Nov1998



0844  
UTC / 21  
Nov  
1998.

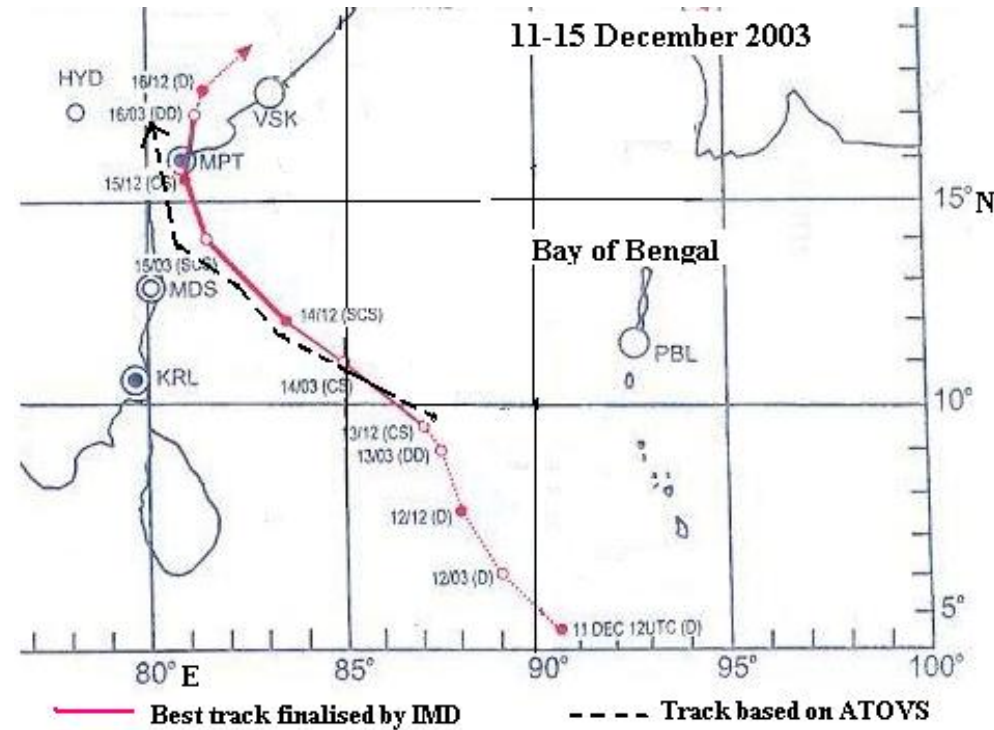
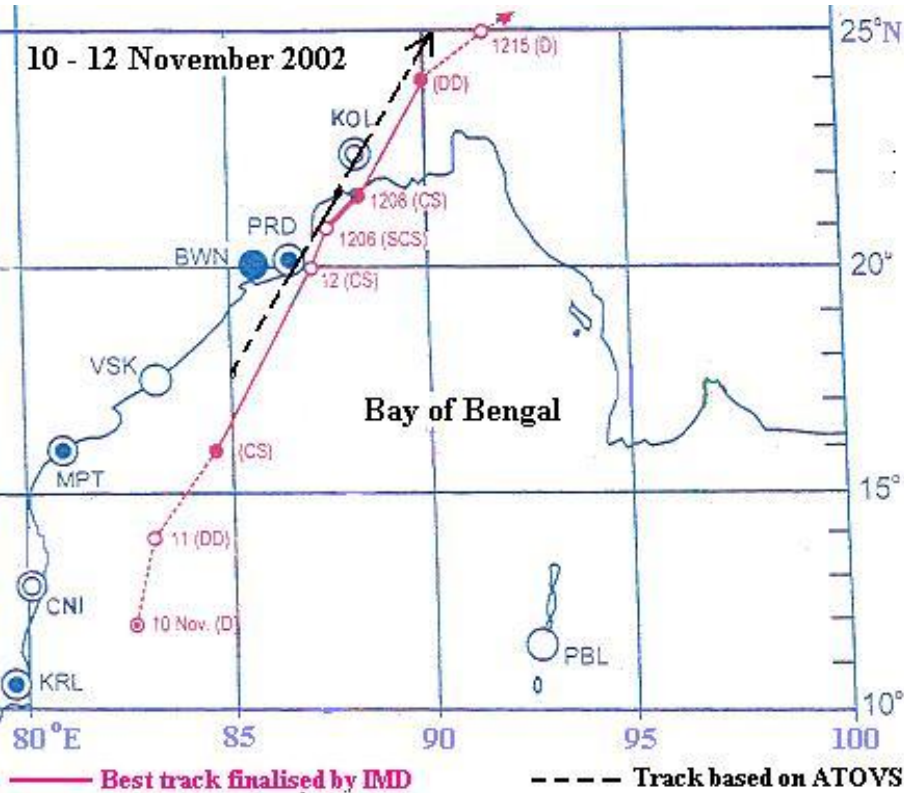


1223 UTC  
/ 21 Nov  
1998.

2335 UTC / 20 Nov 1998

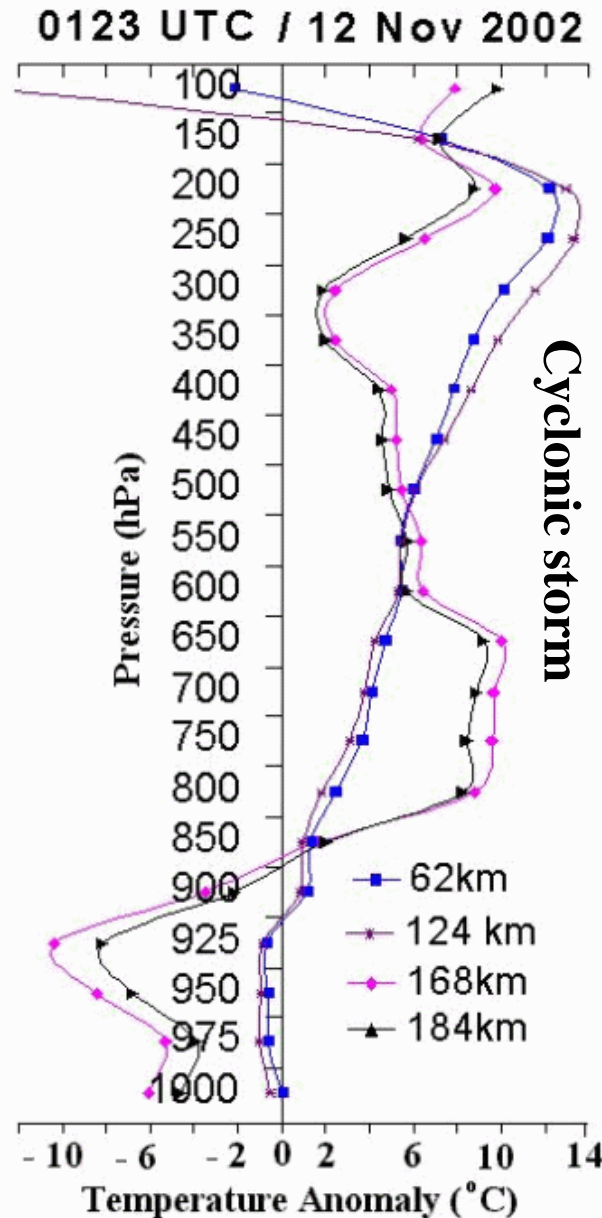
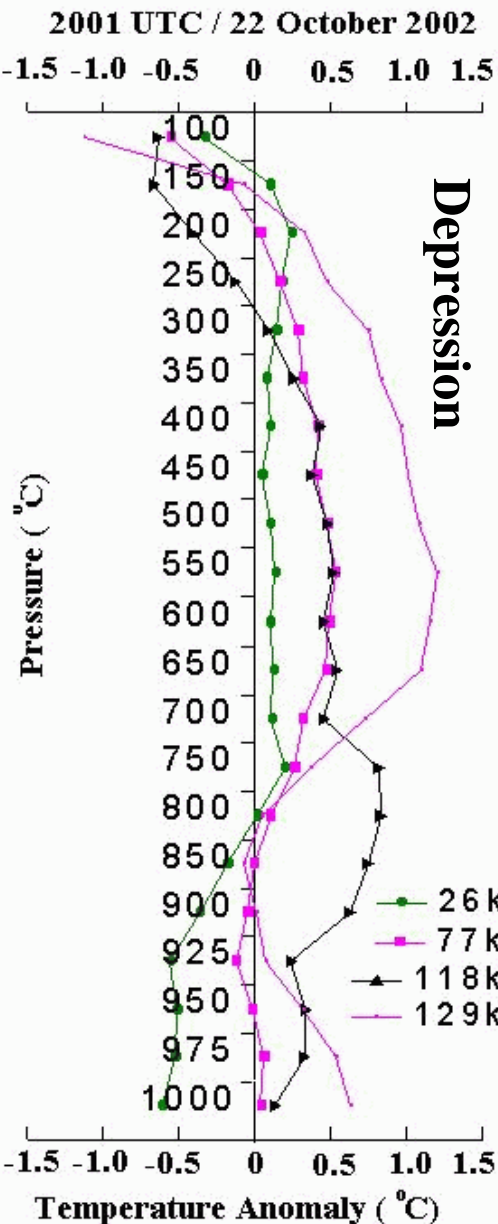
Storm's movement,  
recurvature and landfall  
was predicted well.

# Storms during 2002 & 2003



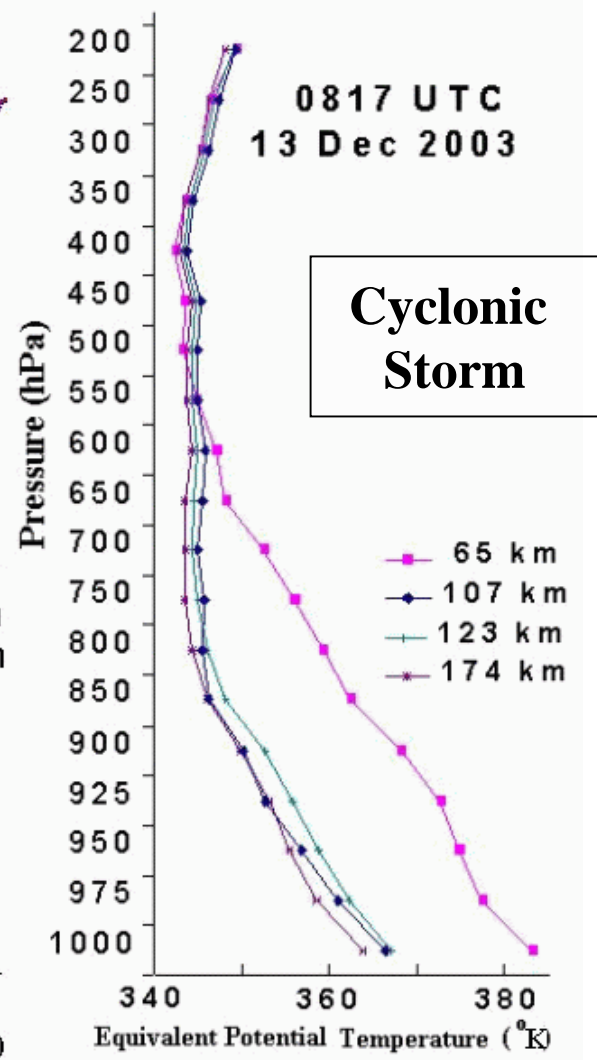
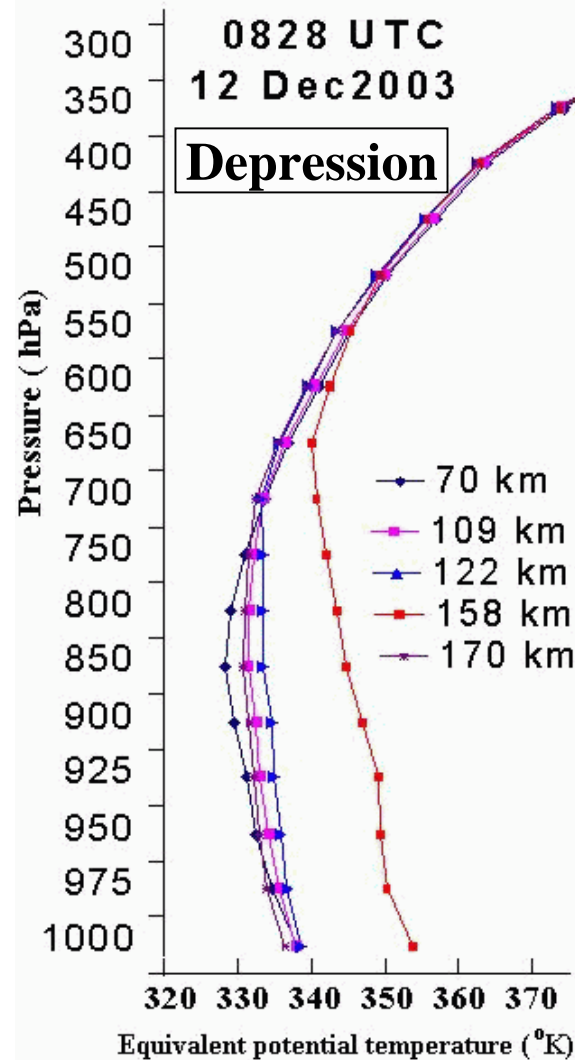
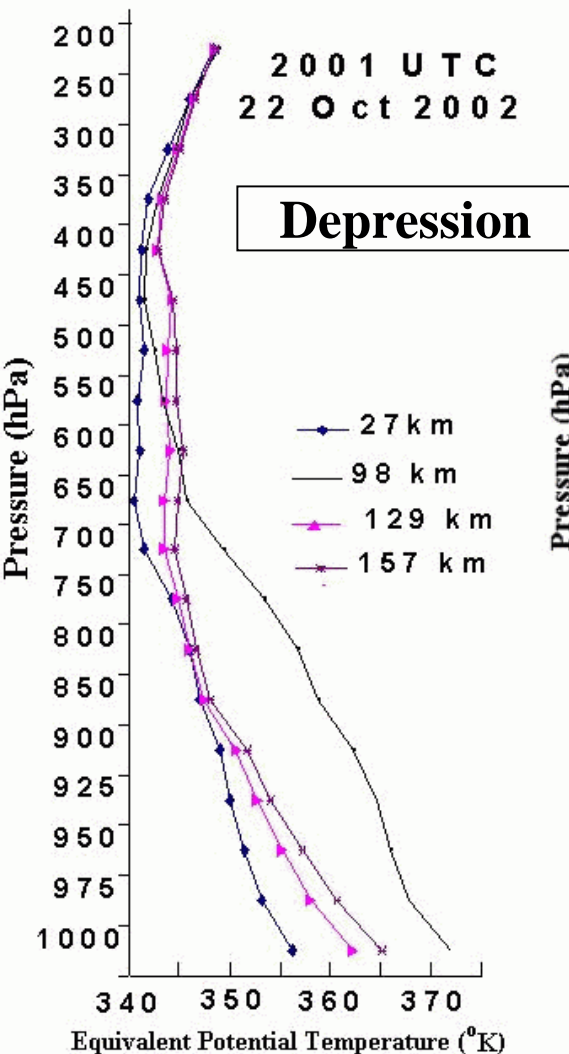
- The tracks of the cyclonic storms based on ATOVS data (black dotted line) are in close agreement with the storm track finalised by IMD (red solid line).
- The land fall was predicted within 30 km for both the storms.
- The protrusion of mid-tropospheric warmness has been tested for one more depression 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 $^{\circ}\text{C}$  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  $^{\circ}\text{C}$  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.

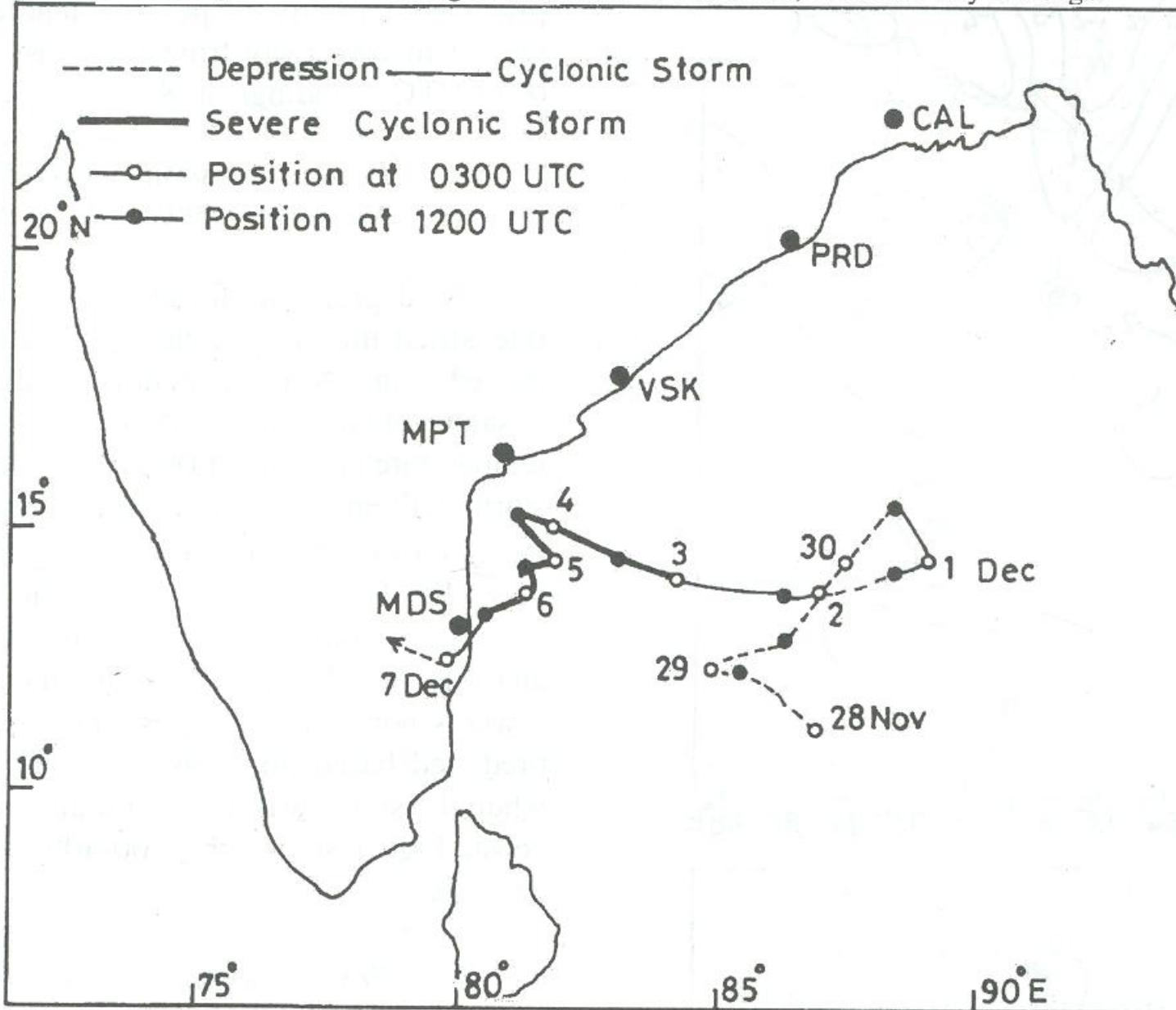
# Equivalent potential temperature profile



- **Due to closeness to the coast and large convective instability, depression on 22 Oct 2002 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 Dec 2003 intensified into a storm.**

# Track of looping & southward movement 1996 cyclone

Track of cyclonic storm during 28 November - 7 December, 1996 over Bay of Bengal

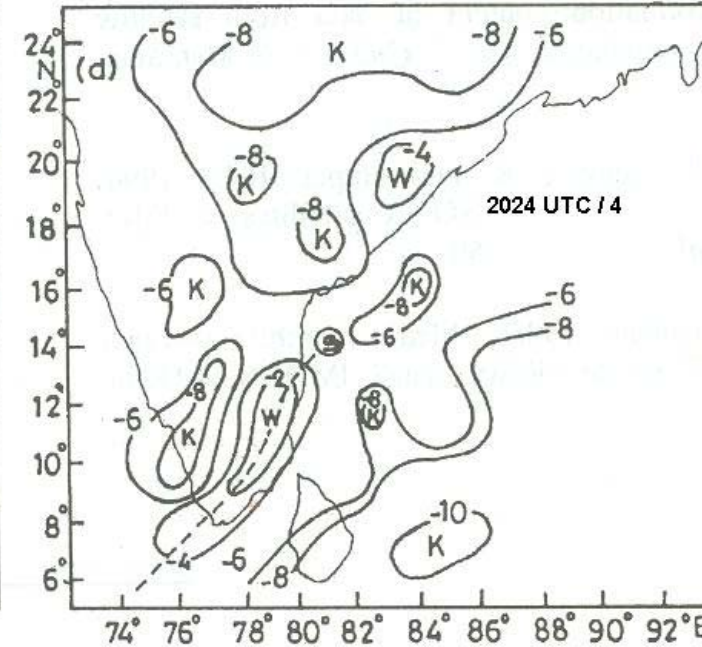
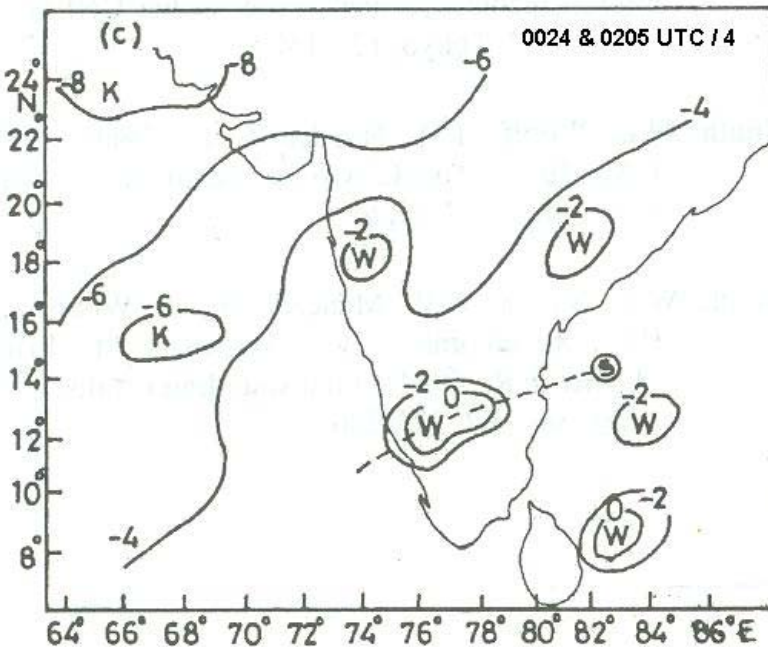
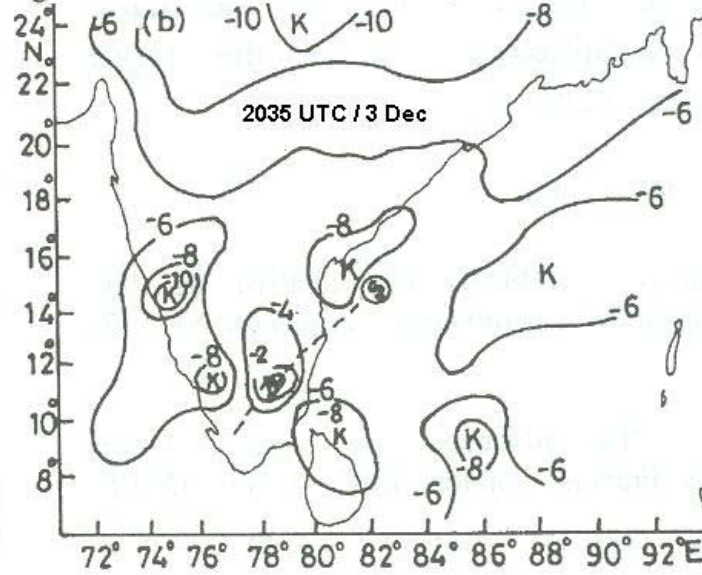
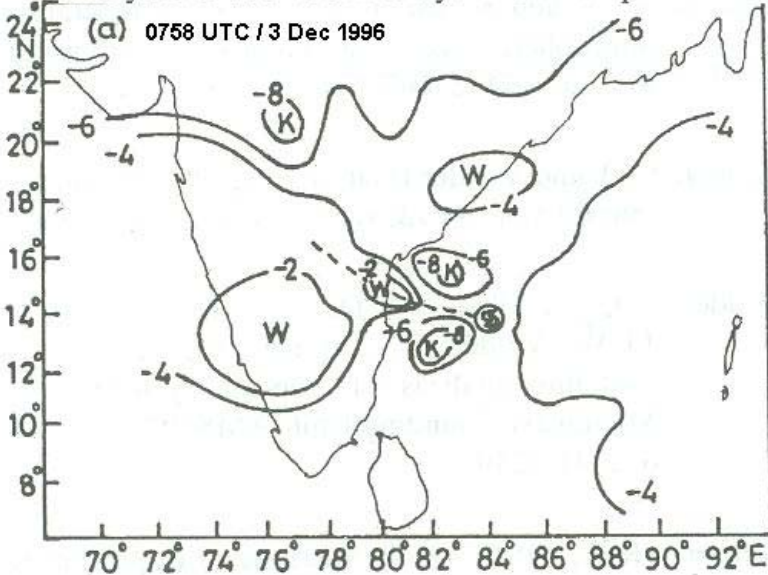


**TOVS data was available only from 3 Dec 1996 for analysis.**

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

# 28Nov-7Dec1996\_Bay Cyclone.. 700-400hPa mean temp

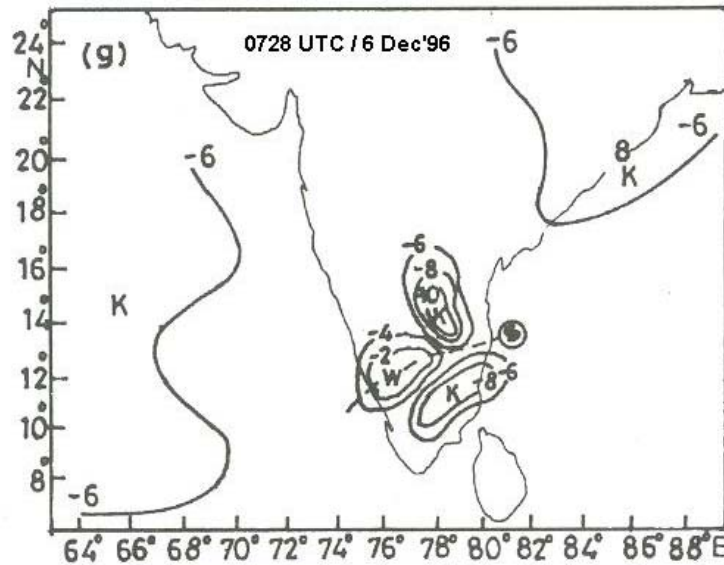
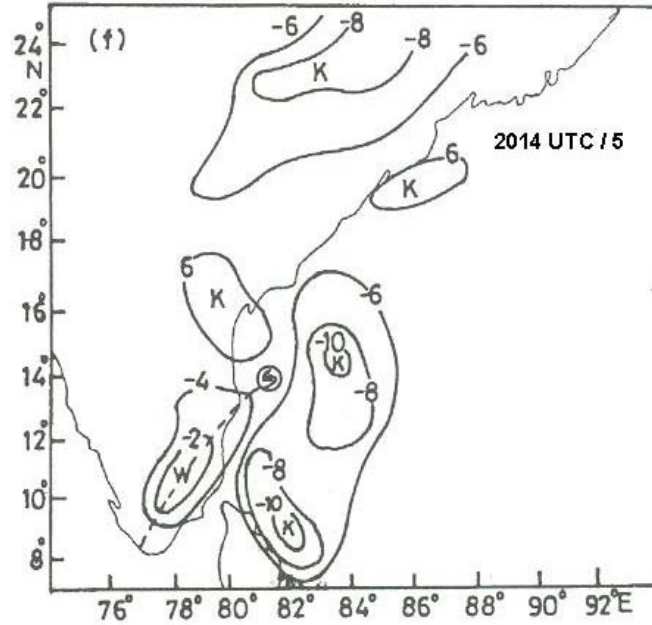
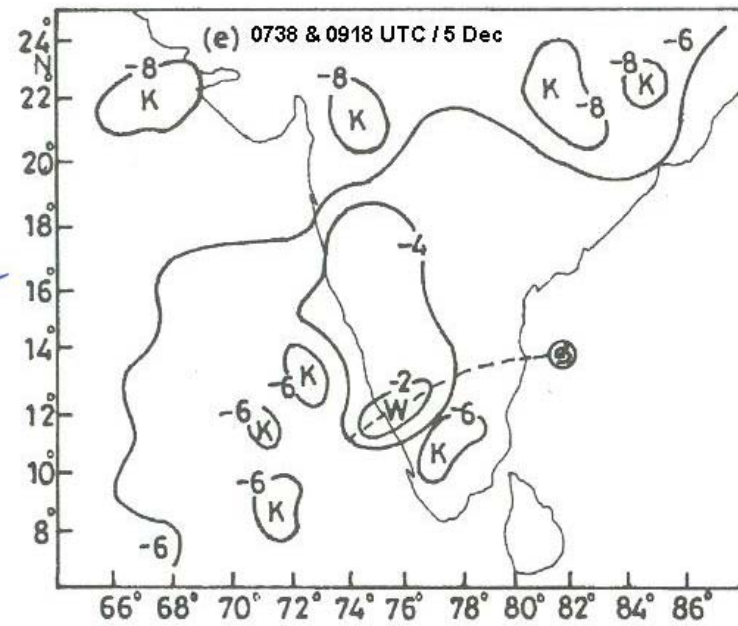
Analysis of 700-400 hPa layer mean temperature during 28 November - 7 December, 1996



*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 °C at upper tropospheric levels (250 - 200 hPa).**
- ✓ **A maximum warmness of 13.3 °C was observed at 250 hPa in a cyclone.**
- ✓ **Warm lower atmosphere and weak convective instability in the inflow regions ( $\approx$  150 – 200 km from the centre) may help to intensify the depression into a cyclonic storm.**

International TOVS Study Conference, 14<sup>th</sup>, ITSC-14, Beijing, China, 25-31 May 2005.  
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,  
Cooperative Institute for Meteorological Satellite Studies, 2005.