# NUMERICAL SIMULATION OF A BAY OF BENGAL TROPICAL CYCLONE: A COMPARISON OF THE RESULTS FROM EXPERIMENTS WITH JRA-25 AND NCEP REANALYSIS FIELDS

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## INTRODUCTION

Tropical cyclones are known for their devastation and damage all over the world. Prediction of the intensification and the movement of the tropical cyclones is important for planning and disaster management. Numerical models based on well defined dynamical and physical processes provide quantitative weather prediction. Numerical modeling studies of tropical cyclones are being continuously attempted since 1960s to understand the physical and dynamical mechanisms of tropical cyclone development and movement. With the developments in atmospheric modeling and computer technology, mesoscale atmospheric models with non-hydrostatic dynamics are currently being used for tropical cyclone studies. As of short range weather prediction, numerical prediction of tropical cyclones is dependent on the accuracy of the initial conditions provided for the model integration. Numerical models require specification of the initial state of the atmosphere (i.e.) of the 3-D fields of wind, pressure/ geopotential, temperature and humidity in addition to the 2-D fields of surface pressure, sea surface temperature, land surface characteristics and topography. These data are to be prescribed at the grid points of the model domain as per the chosen horizontal and vertical resolutions. Since observations are not available at the required grid points of the model domain, they are interpolated using an objective analysis procedure. This was the method adopted till the global reanalysis fields have become available. The first global reanalysis were provided by NCEP/NCAR (NCEP-RA) for the period starting from 1948 (Kalnay et al, 1996). These data are available at a horizontal resolution of 2.5° latitude/ longitude. ECMWF have produced global reanalysis fields for the 15 year period from 1979 to 1993 with a resolution of 200 km (Gibson et al, 1997) and then second reanalysis for the 45 years from September 1957 to August 2002 at a higher resolution of about 120 km (Uppala et al, 2005). The JRA-25 (Japanese 25-year) Reanalysis data at a resolution of 120 km for the period from 1979-2004 have become available recently (Onogi et al 2007). These data facilitated their application for numerical models in lieu of objective analysis to produce the gridded initial fields.

In the present study numerical prediction experiments of an intense tropical cyclone over North Indian Ocean have been made with NCAR MM5 model with the initial conditions taken from NCEP-RA and JRA-25 global reanalysis fields. The model predicted intensification and movement of the tropical cyclone with the two different data sets have been compared to discuss the relative merits of the utilization of NCEP-RA and JRA-25 data.

## DESCRIPTION OF THE MODEL, DATA AND THE CASE STUDY

NCAR MM5, a non-hydrostatic primitive equation model, developed by Pennsylvania State University (PSU)/ National Center for Atmospheric Research (NCAR), has versatility to choose the domain region of interest; horizontal resolution; interactive nested domains and with various options to choose parameterization schemes for convection, planetary boundary layer (PBL), explicit moisture; radiation and soil processes (Grell et al, 1994). For the present study, the model is designed to have two interactive nested domains with horizontal resolutions at 90 and 30 km covering the Bay of Bengal and neighborhood region as shown in Figure 1. The model is integrated for 120 hours starting from 0000 UTC 25 October 1999.

The initial conditions for the two model domains were taken from JRA-25 and NCEP-RA global fields available at 1.25 and 2.5 degree resolution respectively corresponding to 0000 UTC 25 October 1999. The model landuse has 13 categories as per USGS classification and the model topography for the two domains were interpolated from the USGS topography data at 30´ and 10´ resolutions. Time varying lateral boundary conditions were derived at every 6 hr interval during the period 0000 UTC of 25 October to 0000 UTC of 30 October, 1999. The intensity and the position of the Orissa super cyclone are taken from the reports of the IMD (India Meteorological Department, 2000) for comparison with the model results.

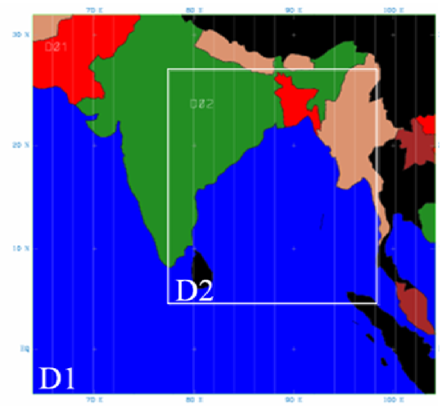

Figure 1: Model domains with 90 and 30 km resolution

Orissa super cyclone (OSC) is the most intense cyclone occurred over the North Indian Ocean during the past century. The life cycle of this cyclone is about 7 days i.e. from 25 -31 October 1999. This system was identified as a low pressure at 99102500, intensified to attain the strength of a very severe cyclonic storm at 99102718 and of super cyclone (with estimated central surface pressure of 912 hPa and wind speed of 140 knots) at 99102818. The system consistently moved westnorthwestward throughout its life cycle and had its landfall near Paradip (20.5 N, 86 E) around 99102903.

**RESULTS**

Two numerical prediction experiments were performed with NCAR MM5 model to predict the development and movement of the Orissa super cyclone taken up as a case study. For both the experiments, the model domain and the choice of the parameterization schemes are same but differ only in the specification of the initial and lateral boundary conditions taken from JRA-25 and NCEP-RA fields. The model was integrated for 120 hours starting from 00UTC of 25 October 1999. The model predicted intensity in terms of CSLP (central sea level pressure) and maximum wind and the track positions are compared with IMD reports. The results are briefly presented as follows.

The model predicted track positions from the two experiments along with the IMD reports are shown in Figure 2. The numerical experiment with JRA-25 produces very good track prediction up to 72 hours and then the predicted movement deviates slightly towards right of the observed track. The vector track errors (Figure 2) are less than 70 km up to 72 hours and then slowly increase to 150 km in 96 hr and 200 km at 120 hours. Correspondingly the experiment with NCEP-RA shows deviation right from the beginning, first towards right up to about 24 hours and then towards left of the observed track with the vector errors consistently increasing (i.e.) with errors of 150 km at 36 hours increasing to 200 km at 60 hours, 350 km in 96 hours and 490 km at 120 hours. This clearly demonstrates the superiority of the JRA-25 reanalysis fields in the specification of not only the initial vortex but also the large scale environmental fields surrounding the vortex region.

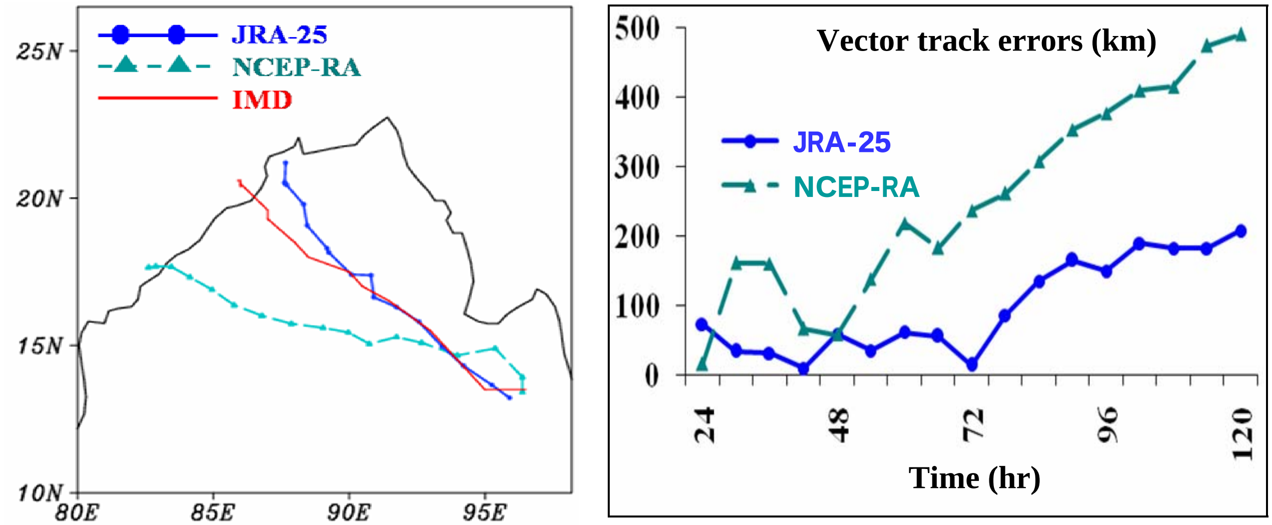


Figure 2. Model predicted track positions along with IMD estimates (left) and vector track errors (right) at different times of prediction

The model predicted intensity, in terms of CSLP and maximum wind associated with the tropical cyclone, for the two experiments are compared with IMD estimates for validation (Figure 3a). The numerical experiment with JRA-25 predicts gradual deepening up to about 48 hours attaining 985 hPa, and then rapidly deepens to attain a CSLP of 960 hPa at 78 hours and then little variation indicating the attainment of the mature stage. Correspondingly the experiment with NCEP-RA has pre- deepening up to 54 hours attaining CSLP of 989 hPa, then deepens to reach 965 hPa at 90 hours and slowly gets filled up. It is to be noted that though JRA-25 has an initial CSLP of 1000 hPa and NCEP-RA has 1005 hPa, the model predicted CSLP coincides with IMD estimates at 12 hours and produces the deepening period between 48 hours and 96 hours nearly agreeing with the observations. However both the experiments could not predict the observed intensity of the cyclone i.e., the CSLP of 912 hPa.

The time variation of the model predicted maximum wind (Figure 3b) shows that the experiment with JRA-25 has an initial strength of 20 m/s which weakens slightly during the first 12 hours and then gradually increases up to 48 hours followed by rapid intensification attaining a maximum strength of 55 m/s at 96 hours. Correspondingly the experiment with NCEP-RA shows intensification up to 24 hours, then remains constant up to 48 hours and then rapidly increases to attain a maximum of 50 m/s at 90 hours. Though neither of the two experiments produce the observed intensity of the cyclone, experiment with JRA-25 produces slightly stronger cyclone but the time of attainment of maximum wind in both the experiments nearly coincide with IMD reports. It is to be noted that in the experiment with JRA-25, the cyclonic vortex strength decreases during the first 12 hours and then undergoes intensification as indicated by slight increase of CSLP and decrease of maximum wind. This may be due to the adjustment of vortex circulation to the large scale environment as JRA-25 incorporate assimilation of TCR wind data.

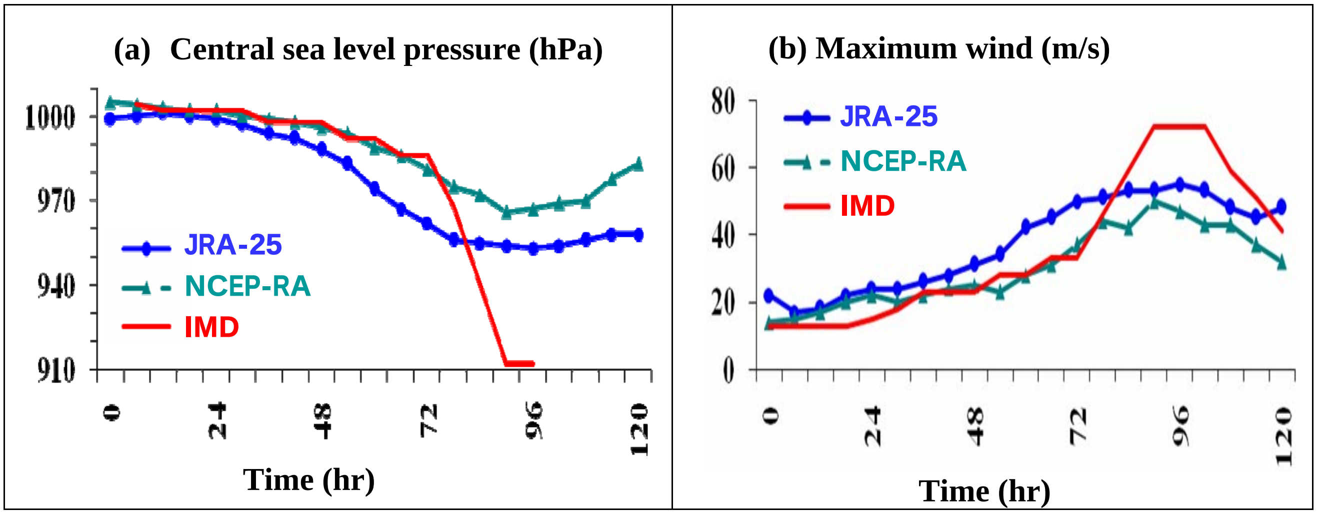


Figure 3. Time variation of (a) central sea level pressure (hPa) and (b) maximum wind (m/s) from the experiments with JRA-25 and NCEP-RA along with IMD estimates.

In view of the above described results that the numerical experiment with the initial and time varying boundary conditions taken from JRA-25 has shown better simulation of the intensification and movement of the Orissa super cyclone, the differences in the initial conditions from JRA-25 and NCEP-RA are examined. The JRA-25 fields show slightly stronger tropical cyclone vortex at the initial time (i.e.) 00 UTC of 25 October 1999. The distribution of mean sea level pressure (Figure 4 a,b) show CSLP of 998 hPa in the JRA-25 as compared to 1004 hPa in NCEP-RA. This indicates the vortex as an intense low pressure system in the JRA-25 and closer to the observations as compared to the weak low pressure in the NCEP-RA. The wind field at 925 hPa (Figure 4 c,d) show stronger vortex with winds exceeding 16 m/s over a small region to the south of the centre with the radius of the maximum wind at about 300 km. Correspondingly NCEP-RA shows organized vortex with maximum wind strength of 8-16 m/s and with radius of maximum winds of about 400 km. This shows better representation of the magnitude of the cyclone vortex in the JRA-25 which may be due to the special features of JRA-25 to assimilate wind profiles around tropical cyclone (TCR) as reconstructed from the best track information. The vorticity at 925 hPa (Figure 4 e,f) shows the vortex to have stronger cyclonic vorticity in the JRA-25 with a magnitude of 12e-5 /s as compared to 8e-5 with the NCEP-RA. The cyclonic vorticity is noted to extend up to 200 hPa (Figure 5a) in both the data but with stronger intensity in the JRA-25 at all levels. A comparison of vertical profiles of the divergence at the respective locations of the surface maximum convergence show that the convergence at lower levels is nearly the same in both the fields, but the divergence at upper levels above 300 hPa divergence is stronger in the JRA-25 (Figure 5b). These differences clearly indicate a better specification of the vortex structure at the initial time in the JRA-25 reanalysis fields. The essential reason for the better representation of the initial vortex may be due to the impact of the assimilation of tropical cyclone retrieval wind data on the tropical cyclone representation in JRA-25 reanalysis. The impact is probably evident for the Bay of Bengal region where observations are sparse. This also demonstrates the superiority of JRA-25 to the NCEP-RA which did not have this kind of TCR wind assimilation.

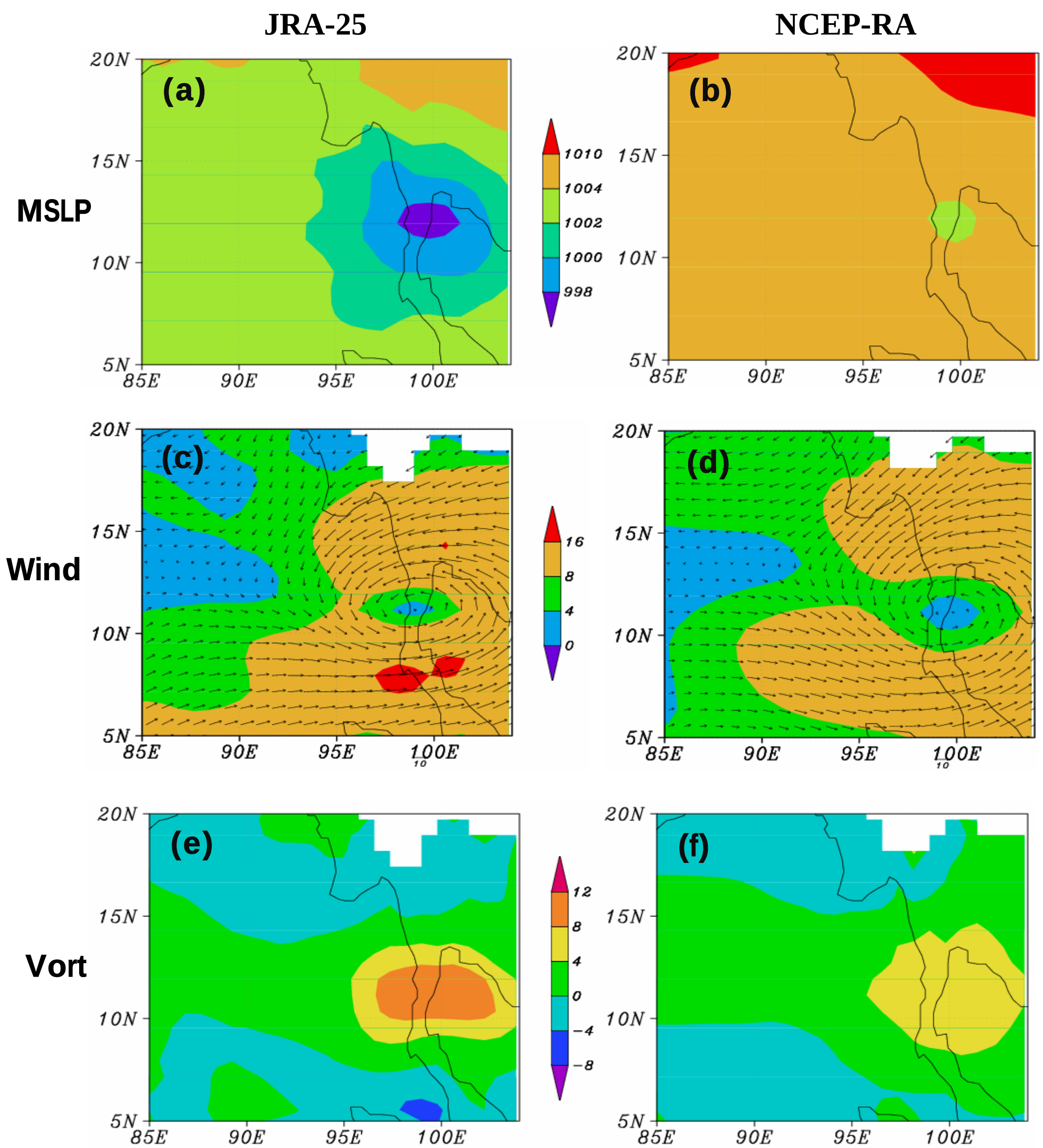


Figure 4. Horizontal distributions of (a,b) mean sea level pressure (hPa); (c,d) wind vectors and magnitude (m/s) and (e,f) vorticity (*1e-5) )/s) at the initial time of model integration (00 UTC of 25OCT1999) as derived from the JRA-25 (left panel) and NCEP-RA fields (right panel) .

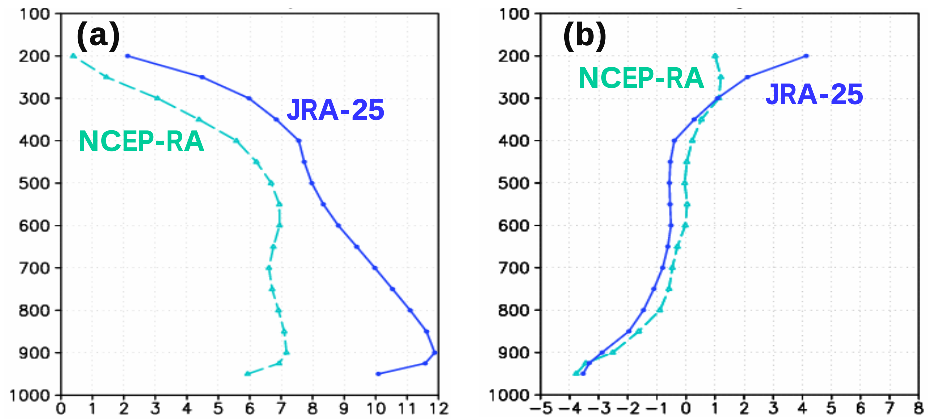


Figure 5: Vertical profile of (a) vorticity (*1e-5) (/s) and (b) divergence (*1e-5) (/s) at the locations of their maximum cyclonic vorticity/ convergence value at the 925 hPa level.

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