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Impact of QuikSCAT derived wind fields in a mesoscale non-hydrostatic model

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सार – वायुमंडलीय प्राचलों पर मेसोस्केल निदर्शों को उच्च–विभेदन आँकड़ों की आवश्यकता होती है। क्विकस्केट अत्यधिक उच्च क्षैतिज विभेदन वाले भूमंडलीय महासागरों में पवनों के क्षैतिज अवयव उपलब्ध कराता है। इस शोध पत्र में, गैर–जलस्थैतिक मेसोस्केल निदर्श परिसंचरण की आरंभिक स्थिति में सुधार के लिए क्विकस्केट व्युत्पन्न पवन क्षेत्रों का उपयोग किया गया है। क्विकस्केट आँकडों सहित और उनके बिना भूमंडलीय आँकड़ों का उपयोग करके आरंभिक स्थिति की तुलना से महत्वपूर्ण मेसोस्केल परिसंचरण लक्षणों को शामिल करने के लाभों का पता चला है। पवन परिसंचरण पूर्वानुमान को ध्यान में रखते हुए, क्विकस्केट आँकड़ों के बिना कंट्रोल रन द्वारा किए गए आरंभिक स्थिति के उपयोग से अत्यंत कमजोर निम्न दाब क्षेत्र का पता चला है। इसके विपरीत, क्विकस्केट आँकड़ें वाले प्रायोगिक रन से इसका 48 घंटे तक पुर्वानुमान लगाया जा सकता है, जो प्रेक्षित परिसंचरण के अनुरूप रहा।

ABSTRACT. Mesoscale models need high-resolution data on atmospheric parameters. QuikSCAT provides the horizontal components of winds over the global ocean with a very high horizontal resolution. In this paper, QuikSCAT derived wind fields have been used to improve the initial state of mesoscale circulation in a non-hydrostatic mesoscale model. The comparison of initial state using global data with and without QuikSCAT data has clearly identified the benefits of addition of important mesoscale circulation features. Considering the wind circulation forecast, the control run that used the initial state without QuikSCAT data predict very weak low pressure area. In contrast, the experimental run with QuikSCAT data could forecast it up to 48 hours in a way that agreed well with the observed circulation.

Key words – Mesoscale Model (MM), National Centre for Environmental Prediction (NCEP), Special Sensor Microwave Imager (SSM/I), National Centre for Atmospheric Research (NCAR), Remote sensing.

1. Introduction

During pre and post monsoon seasons a number of tropical cyclones form over the head Bay of Bengal and move towards the Indian subcontinent. Torrential rainfall, strong winds and storm surges along with the high tides cause disaster along the coast of Bangladesh and east coast of India. A timely forecast of the tropical cyclone is of great importance, as it may help to avoid a great loss of lives and huge damages.

A high-resolution mesoscale model is a useful tool for prediction of tropical cyclone movement. Problem regarding the use of mesoscale model is to get high-density initial state. Presently almost all the mesoscale models get their initial state from the global Analysis field (*e.g.* NCEP, ECMWF or NCMRWF). This global field gets interpolated from coarse resolution to mesoscale. The interpolated fields may not represent the actual mesoscale feature. Therefore, additional data assimilation has to be done to get realistic mesoscale simulations. The asynoptic data (wind, moisture and temperature profile) from microwave remote sensing is most useful for mesoscale assimilation.

In this paper an effort has been made to assimilate the asynoptic data (QuikSCAT derived wind fields) in a mesoscale model. QuikSCAT provides zonal and meridional component of the winds at surface with a very high horizontal resolution.

2. Model

In the present study we use a well-studied mesoscale model, namely MM5. MM5 is the latest version of the mesoscale model originally developed by Anthes and Warner (1978) known as Fifth Generation NCAR/ Penn State Mesoscale Model (MM5). This non-hydrostatic version employs reference pressure as basis for terrain – following vertical coordinate and the fully compressible

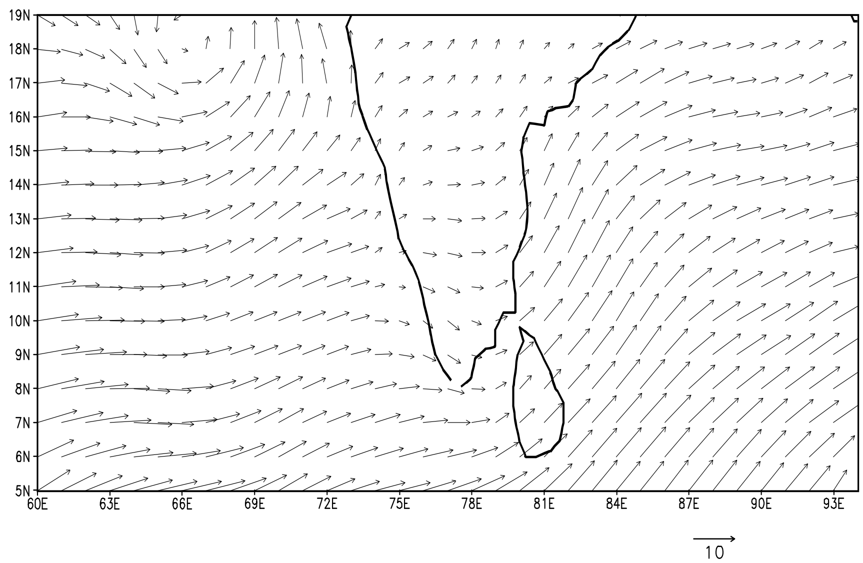

Fig. 1. Initial 850 hPa wind fields at 0000 GMT of 11 October 2001

system of equations. In combination with multiple-nest capability, a four–dimensional data assimilation technique and a variety of physics options, makes the model capable of simulation on any scale, limited only by data resolution, quality and computer resources. The model was run with 30 km horizontal resolutions with a single domain. Twenty-three unevenly spaced full-sigma levels were used in the vertical, with the maximum resolution in the boundary layer. Thirty minutes averaged terrain/landuse data were interpolated to the 30 km model grids. The domain used the explicit moisture scheme by Dudhia (1989) including ice-phase microphysics below 0°C. Grell (1993) parameterization scheme was applied for cumulus convection. The planetary boundary layer was parameterized using the non-local scheme (Hong and Pan, 1966). The radiation effects (Dudhia, 1989) due to cloud were considered.

The initial condition was generated for 30 km resolutions by interpolating the NCEP/NCAR global analysis at 75 km resolutions to the model grid. The same model forecasts for every 6 hours were linearly interpolated in time in order to provide the lateral boundary conditions. The boundary condition is relaxation type in which the four points nearest to boundaries are relaxed towards specified values that are interpolated in time between the analysis times.

3. Data used

Beside NCEP global fields, the QuikSCAT derived surface winds fields (for 11 October 2001) and SSM/I measured rain rate during 12 October 2001 were used. NASA's Quick Scatterometer (QuikSCAT) was launched on 19 June 1999 and is at the altitude of about 800 km (500 miles) above earth. The SeaWinds on QuikSCAT mission is a "quick recovery" mission to fill the gap created by the loss of data from NASA scatterometer (NSCAT) onboard ADEOS. The SeaWinds instrument on the QuikSCAT satellite is specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over earth's oceans. The antenna radiates at a frequency of 13.4 Ghz across broad regions of surface. The instrument collects data over ocean, in a continuous 1,800 – kilometer – wide band, making approximately 400,000 measurements and covering 90% of the earth's surface in one day. It gives wind-speed measurements of 3 to 20 m/s, with an accuracy of 2m/s and direction, with a accuracy of 20 degree. The horizontal resolution is about 25 kilometer.

The Defence Meteorological Satellite Project (DMSP) series of satellites of US Air force, starting from F8, carried on board a four frequency 7 channel linearly polarized passive microwave radiometer, called SSM/I, which measures atmospheric, oceanic and terrain brightness temperatures at 19.3, 22.2, 37.0 and 85.5 GHz. All frequencies are received in dual polarization (V and H) except 22.2 GHz (only V). The SSM/I instrument has a swath of 1400 km. It does a conical scanning while looking aft ward at an angle of about 45° from the zenith. The spatial resolution is about 55 km for 19.3 GHz and 18 km for 85.5 GHz channels. The SSM/I is used for estimating cloud liquid water, water vapour, wind speed and rainfall.

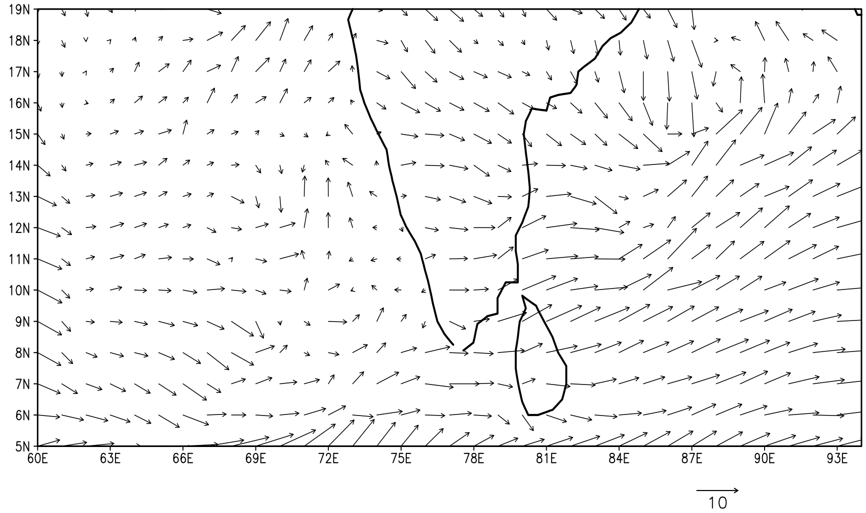

Fig. 2. 48 hrs simulation of 850 hPa wind fields valid at 0000 GMT of 13 October 2001, control run

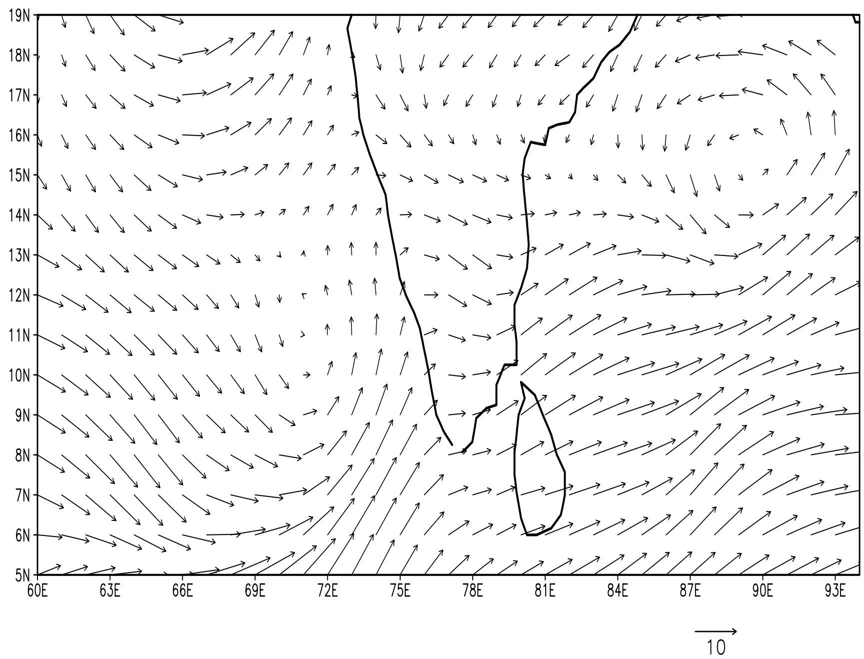

Fig. 3. NCEP analyzed 850 hPa wind fields valid at 0000 GMT of 13 October 2001

4. Results

A major problem in the use of numerical models in operational cyclone forecasting is absence of observational data out in the sea-area where cyclone develops. Due to these paucities in oceanic observations, cyclones are not well represented in initial analysis for running a forecast model. The poor initial analysis brings large error in the skill of forecast model. On 13 October, 2001 a low-pressure system, which ultimately intensified to a cyclonic storm was present in Bay of Bengal.

Starting at 0000 GMT of 11 October 2001, a 48 hrs simulation was carried without scatterometer data. Fig. 1 shows initial flow at 850 hPa. In Fig. 1 the absence of convergent flow in Bay of Bengal is noted. A well-marked low-pressure area is present in the Arabian Sea. In Fig. 2 (48 hrs) convergent flow is observed in Bay of

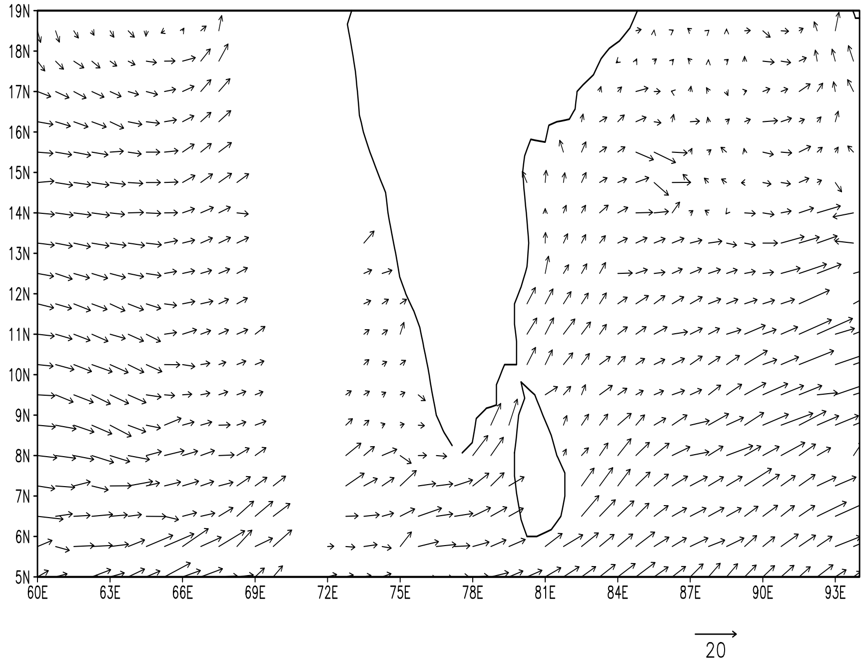

Fig. 4. QuikSCAT derived wind field on 11 October 2001

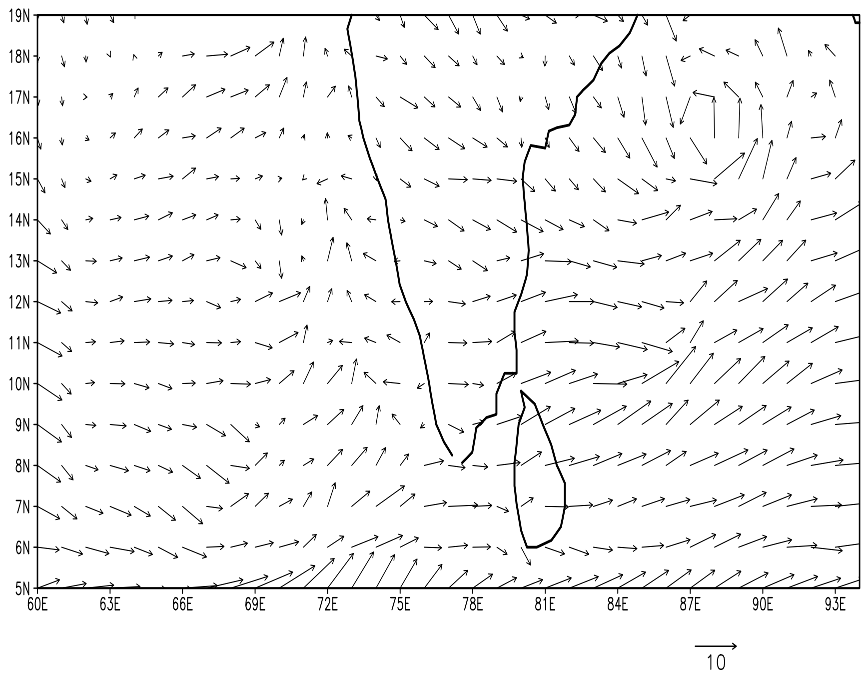

Fig. 5. 48 hrs simulation of 850 hPa wind fields valid at 0000 GMT of 13 October 2001, assimilation run

Bengal. In the Arabian Sea the low-pressure area gets disappeared at 0000 GMT of 13 October 2001. The model simulated convergent flow is compared with the analysis. Fig. 2 shows that the model has generated a vortex. Fig. 3 shows the analyzed wind field at 0000 GMT of 13 October 2001. In analyzed field a well-marked low

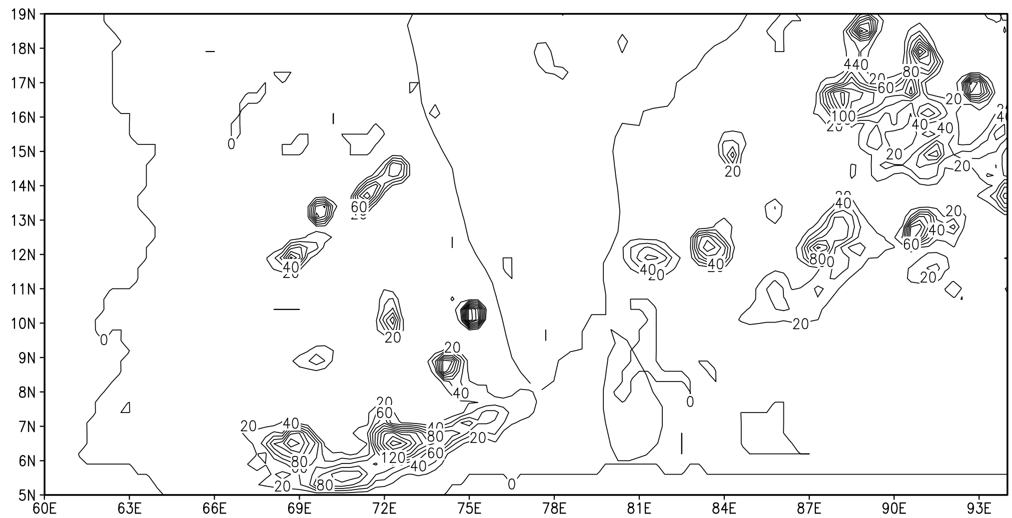

Fig. 6. Last 24 hrs accumulated rainfall (mm) valid at 0000 GMT of 13 October 2001, control run

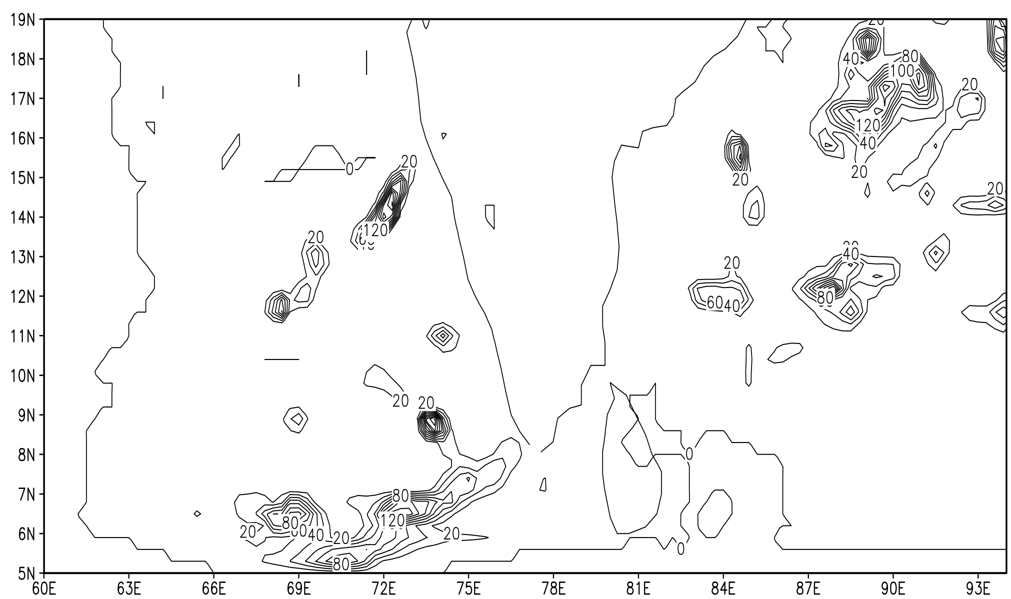

Fig. 7. Last 24 hrs accumulated rainfall (mm) valid at 0000 GMT of 13 October 2001, assimilation run

pressure with a closed circulation is present. While in case of simulation the vortex is very weak (only a convergent flow).

The same simulation is done again where the initial condition has been improved by addition of QuikSCAT derived winds (assimilation run) on 11 October 2001. Fig. 4 shows the QuikSCAT derived winds during 11 October 2001. A low-pressure area is well seen over Arabian Sea. Over North Bay of Bengal wind shear is seen. Fig. 5 shows the 48 hrs simulation of resulting circulation at 850 hPa. The circulation in Bay of Bengal gets improved in comparison to the control run. Now the low-pressure area is well presented in the simulation, which was just a convergent flow in the control run. A slight difference is there in the position. The predicted vortex is present toward the west of the observed position. The circulation over Bay of Bengal is very close to observed circulation in assimilation experiment.

Fig. 6 shows the 24 hrs accumulated rainfall (mm) in control run, valid at 0000 GMT of 13 October. The rainfall of the order of 100 mm is observed over low pressure in Bay of Bengal. While another band of heavy

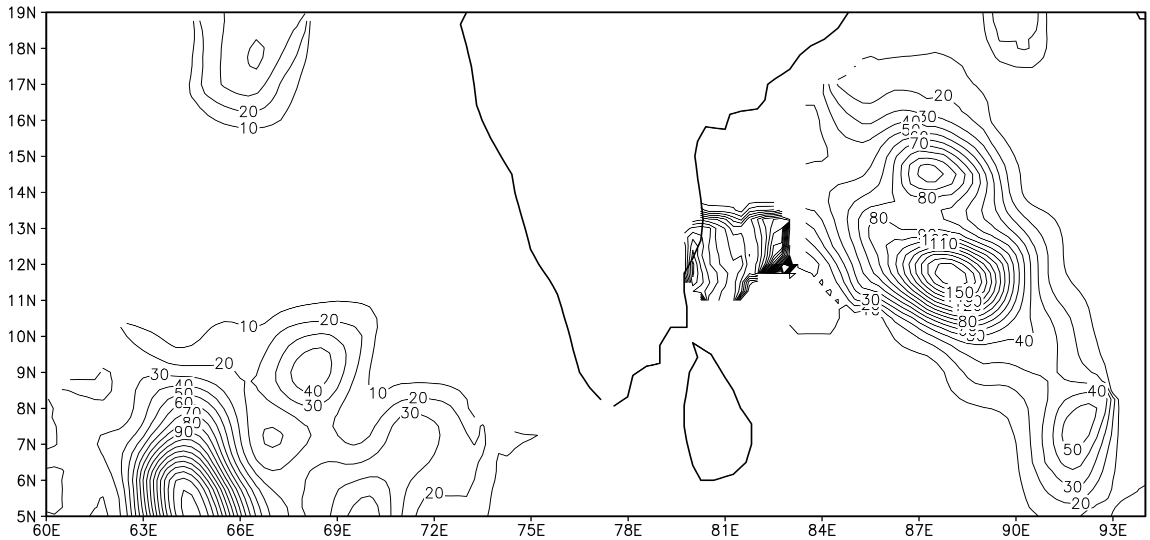

Fig. 8. Satellite observed last 24 hrs accumulated rainfall (mm) valid at 0000 GMT of 13 October 2001

rainfall (120 mm) is observed over the Arabian Sea. Fig. 7 shows the 24 hrs accumulated rainfall (mm) produced by assimilation run. The maximum rainfall over Bay of Bengal is of the order of 120-140 mm is observed. The rainfall in assimilation run is slightly more than control run. While over Arabian Sea both simulations show the equal rainfall.

The model predicted rainfall was compared with Satellite-measured rainfall. Fig. 8 shows the SSM/I measured last 24 hrs accumulated rainfall at 0000 GMT of 13 October 2001. In these Figures (6-8) maximum rainfall is seen over Bay of Bengal. Satellite measured rainfall is about 15 cm while model predicted rainfall is around 11 cm. Although the model shows one more pocket of high rainfall north part of Bay of Bengal, which is very week in the satellite, observed rainfall. This may be because the SSM /I measurements are on instantaneous basis (that is at the time of satellite pass). The rain rate might have been small at the time of pass. Over Arabian Sea there is a shift in the model simulated rainfall maxima. Satellite observation shows the rainfall maxima slightly towards the west of model-simulated rainfall. While the case of circulation is convincing, the case for rainfall is weak. Indeed, control run rain looks nearer to satellite observed rain, than assimilation run.

5. Conclusion

Assimilation of scatterometer derived sea surface wind data over Bay of Bengal cyclone has been carried out with in-built assimilation scheme of MM5 model. These winds have improved the circulation field in the initial data. Assimilation of QuikSCAT derived wind field has positive impact on vortex generation. Further assimilation of satellite and other local observed data is being attempted.

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