1. INTRODUCTION:

Very Severe Cyclonic Storm Nargis, the deadliest named tropical cyclone (TC) in the North Indian Ocean Basin, devastated Burma (Myanmar) in May 2008, causing tremendous damage and numerous fatalities. An increased lead time in the prediction of TC Nargis would have increased the warning time and may therefore have saved lives and reduced economic damage. Recent advances in high-resolution global models and supercomputers have shown the potential for improving TC track and intensity forecasts, presumably by improving multi-scale simulations. The key but challenging questions to be answered include: (1) if and how realistic, in terms of timing, location and TC general structure, the GMM can simulate TC genesis and (2) under what conditions can the model extend the lead time of TC genesis forecasts. In this study, we focus on genesis prediction for TCs in the Indian Ocean with the GMM. Preliminary simulations show that the initial formation and intensity variations of TC Nargis can be realistically predicted at a lead time of up to 5 days. Global high-resolution simulations using real data suggest that the accurate representations of a westerly wind burst and an equatorial trough, associated with monsoon circulations and/or a Madden-Julian Oscillation (MJO), is important for predicting the formation of this kind of TC.

2.THE MODEL and NUMERICAL APPROACH:

The GMM, previously called the high-resolution finite-volume GCM (fvGCM), has three major components: (1) finite-volume dynamics, (2) NCAR CCM3 physics, and (3) the NCAR Community Land model (e.g., Lin 2004; Atlas et al. 2005; Shen et al. 2006a). Dynamic initial conditions (ICs) and sea surface temperature (SST) are derived from the GFS T382 (~ 35km) analysis data and 1° optimum interpolation SSTs from the National Centers for Environmental Prediction (NCEP). No vortex initialization (e.g., bogusing) scheme is applied in the initial fields. Our previous studies with more than sixty 5-day runs have shown the global mesoscale model with disabled cumulus parameterizations (CPs) was able to produce remarkable forecasts of track and intensity associated with intense Atlantic hurricanes in 2004 and 2005. Realistic TC vertical structures (e.g., Katrina) were also simulated, including maximum horizontal winds near the top of the boundary layer, a narrow eyewall, and an elevated warm core (e.g., Shen et al. 2006a,b).

Tropical Cyclogenesis Revealed in Global Mesoscale Simulations: Very Severe Cyclonic Storm Nargis (2008) B.-W. Shen (UMCP/ESSIC) and W.-K. Tao (NASA/GSFC)

3. RESULTS:







Figure 1: Satellite images over the Indian Ocean (panel a-b) and simulated 850 hpa winds (panel c) in late April 2008. (a) TCs Durga and Rosie south of a westerly wind burst/jet (WWB) at 0100 UTC 22 April. (b) When the WWB moved northward, TC Nargis formed at 1200 UTC 27 April 2008.

(c) Global high-resolution simulations initialized at 00Z April 22 show that the formation of TC Nargis can be predicted with a lead time of up to 5 days.



<u>Figure 2:</u> Time-longitude diagrams of average zonal winds from 22 to 29 April showing the northward movement of the WWB. Top panels: NCEP reanalysis at 2.5x2.5 degree resolution. (a-c) 850 hpa zonal winds averaged over (-5S,0), (0,5N), and (5N,10N), respectively. Average 200 hpa zonal winds are shown in (d-f). Bottom panels: model simulations.



Figure 3: The equatorial trough and monsoon lateral

panels): Timelongitude diagrams of moisture transport at 850 and 500 hpa and surface

moisture and latent

heat fluxes.

circulations. Top panels: zonal winds. Bottom panels: meridian winds. This figure shows favorite condictions for TC formation, as suggested by McBride and Zehr (1981).

Talbe 2: Favorable environmental conditions *Figure 5 (right*

•(Leading edge of) the WWB (fig. 2) •(North of) the equatorial trough (fig. 3) •Enhanced monsoonal circulation (fig. 3) •Zero wind shear line (fig. 3) •A good upper-level outflow (fig. 4) •Anti-cyclonic wind shear (200 - 850 hPa, fig. 4) •Low- and middle-level moistening (fig. 5) •Surface fluxes (fig. 5)

-25 -20 -15 -10 -5

Table 1: TC NargisFast Facts

 deadliest named cyclone in the North Indian Ocean Basin •formation: at 04/27 03Z (a depression by the IMD); at 04/27 2Z (TC 01B by the JTWC)

•Life Cycle: 04/27-05/03, 2008 •intensity (CAT 4): MSLP ~962

•Impact: damage ~ \$10 billion; fatalities ~ 134.000

•Affected areas: Myanmar (Burma), Bangladesh, India, Srilanka



Figure 4: Vertical wind shear between 200 and 850 hpa. NCEP reanalysis data (top panels). Model simulations at 78h, 102h, and 126h of integration, respectively (bottom panels).





Nargis

Figure 6: 7-day forecasts of TC Nargis: formation, intensity, and vertical strucure. Intensity evolution from 108 to 144h of simulation (top). Vertical structure of winds and temperature anomalies (e.g, warm core) at 132h of integration.

4. CONCLUDING REMARKS:

To answer the questions in the introduction, we need to address the following question: to what level of accuracy in terms of timing and location can a high resolution global model simulate TC genesis. In typical hurricane climate studies with coarse resolution GCMs, TC genesis on a monthly or seasonal scale in 6 major basins is the focus. In this study, we simulate TC genesis at a lead time of 3-5 days with position errors of 100-250 km, which is close to the typical grid spacing in climate models.

Our simulations support the hypothesis that the occurrence of the westerly wind burst associated with the large-scale equatorial trough and/or MJO appears to dictate the location and timing for TC genesis. Our results also suggest that in addition to the WWB's strength, accurate simulations of its northward movement (i.e., propagation within an equatorial trough) is equally important for accurately predicting the impact of large-scale flows on regional mesoscale weather events (e.g., TCs) as compared to the accurate simulation of a WWB's longitudinal propagation (e.g., associated with an MJO). Several numerical experiments (e.g., higher resolution, different options in the physics parameterizations) confirm the above findings.

The current trend is to understand TC inter-annual variability and the impact of climate change (e.g., the doubling of CO2) on long-term TC activity. This study provides a baseline for extending short-term hurricane forecasts toward long-term hurricane climate studies (Bengtsoon et al., 2007a,b). To understand and improve simulations of the initiation, intensification, and northward (eastward) movement of the monsoon trough (the MJO) in long-term (seasonal and inter-annual) model integrations, improved representations of cloud-scale moist processes are crucial. We plan to address this topic by combining the strengths of both the global mesoscale model and the multiscale modeling framework (e.g., Tao et al. 2008), which recently showed promising 30-day MJO simulations.

References (selected) and Notes:

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