National Aeronautics and Space Administration

Predicting the Formation of Tropical Cyclone Nargis (2008) with the NASA High-Resolution Global Model and Supercomputers

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1. INTRODUCTION:

Very Severe Cyclonic Storm Nargis (Figure 1), the deadliest named tropical cyclone (TC) in the North Indian Ocean Basin, devastated Burma (Myanmar) in May 2008, causing tremendous damage and numerous fatalities (Table 1). 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. Over the past several decades, TC track forecasts have been steadily improving, but intensity and genesis forecasts have lagged behind (Figure 2). Recent advances in high-resolution global models and supercomputers at NASA have shown the potential for improving TC track and intensity forecasts, presumably by improving multi-scale simulations (e.g., Shen et al. 2006a,b,c; Shen et al., 2007, in preparation). In this study, we focus on genesis prediction for TC Nargis with a high-resolution global model.

Table 1: TC Nargis Fast Facts

- Deadliest named cyclone in the North Indian Ocean Basin
- Short lifecycle: from 04/27 03Z (by the IMD) or 04/27 12Z (by the JTWC) to 05/03, 2008
- Very intense with an MSLP of 962 hPa and peak winds of 135 mph (~ CAT 4)
- High-Impact: damage ~ $10 billion; fatalities ~ 134,000
- Affected areas: Myanmar (Burma), India Bangladesh, Sri Lanka

2.THE NASA GLOBAL MODEL & SUPERCOMPUTERS

The NASA high-resolution global model (aka the finite-volume general circulation model, 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). The fvGCM at high resolutions (e.g., 1/12 and 1/8 degree) was deployed on the NASA Columbia supercomputer, producing remarkable forecasts of intense hurricanes in 2004 and 2005. A brief summary on this work is presented in Shen et al. (2008).

The Columbia supercomputer with (in late 2004): (1) 20 SGI Altix superclusters, each with 512 CPUs; (2) 10,240 Intel Itanium II CPUs; (3) 20 TB total memory with 1 TB of memory per 512 CPUs (Biswas et al., 2007).

3. RESULTS:

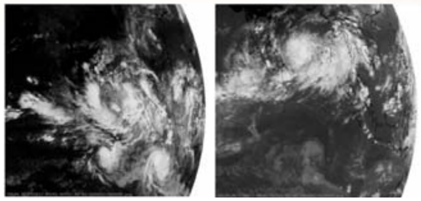


***Figure 1**: Satellite images over the Indian Ocean in late April 2008. (a) tropical cyclones Durga and Rosie south of a westerly wind burst/jet (WWB) at 0000 UTC, 22 April; (b) When the WWB moved northward, TC Nargis formed at 1200 UTC, 27 April 2008.*

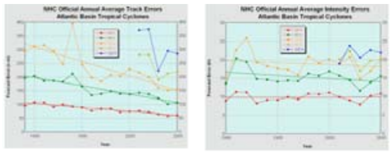


***Figure 2**: Progress of track (left) and intensity (right) forecasts made by the National Hurricane Center during the past 15 years.*

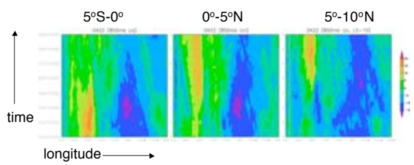


***Figure 3**: Northward movement of the westerly wind burst, as shown in time-longitude diagrams of average zonal winds from 22 to 29 April. Panels (from left to right) are 850 hPa zonal winds averaged over (5°S,0°), (0,5°N), and (5°N,10°N), respectively.*

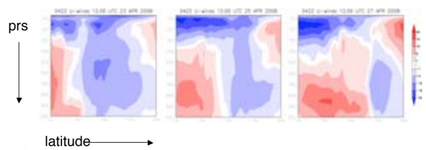


***Figure 4**: Monsoon lateral circulations and equatorial trough as shown in zonal winds. This figure shows favorite conditions for TC formation: low-level (upper-level) cyclonic (anti-cyclonic) circulation.*

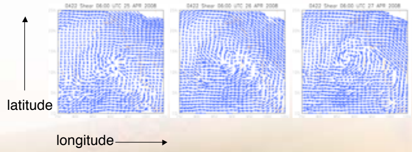
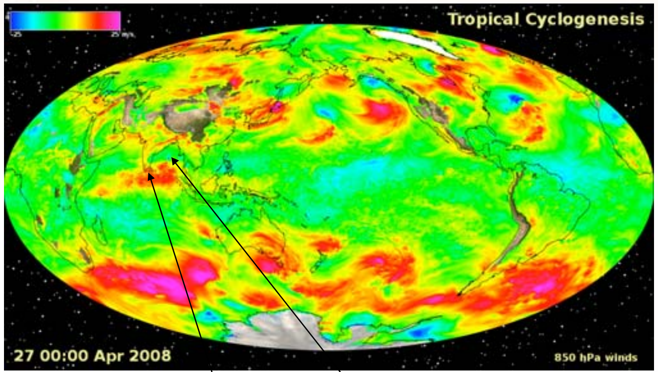


***Figure 5**: Vertical wind shear between 200 and 850 hPa. Model simulations at 78h, 102h, and 126h of integration, respectively.*



Westerly Wind Burst (WWB) TC Nargis **(indicated by the easterly winds in blue)**

Formation of TC Nargis from 120h simulations of zonal winds at 850 hPa.

Table 2: Favorable Environmental Conditions

- (Leading edge of) the westerly wind burst (WWB, Figure 3)
- Enhanced monsoonal circulation, (North of) the equatorial trough (Figure 4)
- Zero wind shear line (Figure 4)
- A good upper-level outflow, Anti-cyclonic wind shear (200 - 850 hPa, Figure 5)
- Low- and middle-level moistening, surface fluxes (Figure 6)

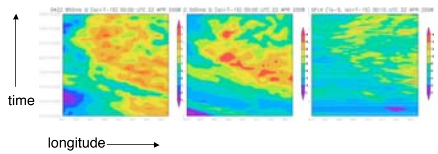


***Figure 6** : Time-longitude diagrams of moisture transport at 850 and 500 hPa and surface moisture fluxes.*

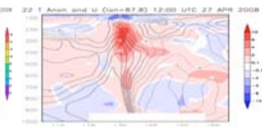


***Figure 7**: Vertical structure of winds and temperature anomalies (e.g., a warm core) at 132h of integration.*

4. DISCUSSION:

Our global high-resolution simulations using real data show that the initial formation and intensity variations of TC Nargis can be realistically predicted at a lead time of up to 5 days (Figure 8). Experiments also 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. Favorable factors for the formation and intensification of TC Nargis are summarized in Table 2.

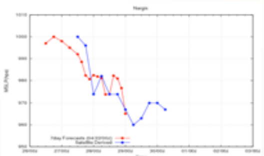


***Figure 8**: Intensity evolution of TC Nargis from 108 to 144h of integrations (red) in a 7-day simulation, as compared to the satellite derived intensity (blue).*

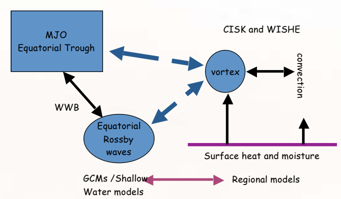


***Figure 9**: Unified view of TC formation, including modulation by large-scale flows (e.g., MJO), Rossby wave accumulation, vortex dynamics (e.g., vortex merger), and interaction between mesoscale vortices, surface fluxes and convection (e.g., Shen et al., 2007, in revision).*

5. CONCLUDING REMARKS:

When the NASA Columbia supercomputer came into operation in late 2004, its computing power enabled the deployment of the fvGCM at very high resolution. While the high-resolution fvGCM has previously shown a potential for improving forecasts of TC track and intensity, its capability in predicting the formation of TCs (e.g., in the Indian Ocean) is now investigated with a unified view (Figure 9) in which both modulations by large-scale flows (e.g., monsoonal circulation) and interactions with small-scale convection and surface fluxes are important. This study could provide a baseline for extending short-term TC forecasts toward long-term TC climate studies to understand TC inter-annual variability and the impact of climate change (e.g., the doubling of CO2) on TC activity. We plan to address this topic by combining the strengths of both the high-resolution global model and the multi-scale modeling framework (e.g., Tao et al., 2008), which recently showed promising extended-range (~30-day) simulations of large-scale flows such as MJOs and African Easterly Waves (see the demo by Shen and Tao, 2008). As NASA's new supercomputer (called Pleiades) becomes available this year, our preliminary benchmark shows that a 1/4-degree seasonal simulation only takes about 3.7 wall-time hours when 960 cores are used, which makes it feasible to perform real-time seasonal predictions.

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