Impact of Reanalysis Forcing Data – NCEP-FNL, NASA-MERRA and ECMWF-ERA Interim on Tropical Cyclone Forecasts: An Analysis over the North Indian Ocean

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Introduction

Numerical models continue to show improvements in tropical cyclone (TC) track and intensity predictions. These improvements are due to an enhanced comprehension of the processes and data assimilation procedures. The success of these models is still heavily dependent on initial and boundary conditions such as that provided from reanalysis products. Because of the differences in procedures, numerics, and resolution, each reanalysis datasets can have a different impact on the model performance, in different regions.

Study Objective

This study seeks to investigate the impact of boundary forcing data provided by three reanalysis products on the TC simulations over the North Indian Ocean (NIO). The reanalysis products being tested are– National Centers for Environmental Prediction Final Analysis (NCEP-FNL), National Aeronautics and Space Administration Modern Era Retrospective-Analysis for Research and Applications (NASA-MERRA), and European Centre for Medium-Range Weather Forecasts-ERA Interim (ECMWF-ERA Interim).

Data and Methods

The atmospheric analysis data from NCEP and ECMWF is widely used in weather and climate research because of their spatial and temporal continuity. NASA's MERRA is a new analysis for the satellite era that uses a new version of Goddard Earth Observing System (GOES–5) data assimilation system.

NCEP – FNL: Grid resolution of 1.0° x 1.0° and 26 vertical levels prepared every 6 hours like NCEP-GFS but initialized an hour or so later.
ECMWF – ERA Interim: Spatial resolution of 0.75° x 0.75° and 60 vertical levels prepared every 6 hours. Uses most in-situ and satellite data used in NWP, including satellite radiances.
NASA – MERRA: Spatial resolution of 0.5° x 0.667° and 72 vertical levels. This reanalysis significantly improves in precipitation and water vapor climatology over older reanalyses.

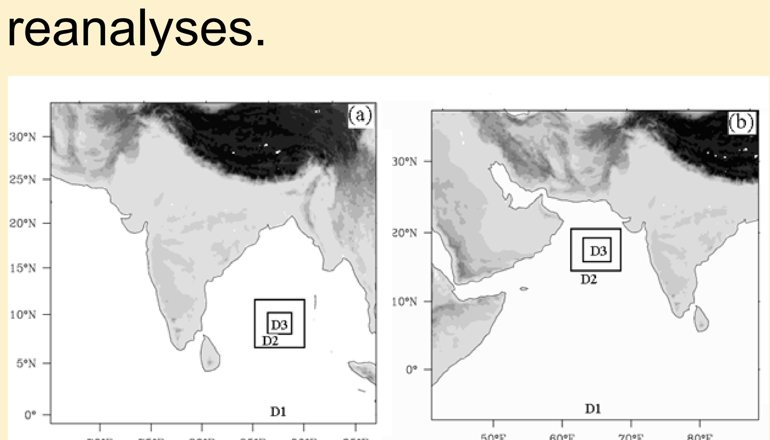

Fig 1: Configured domain D1 for storms over (a) Bay of Bengal and (b) Arabian Sea. The domains D2 and D3 are storm centered.

Model Used: Advanced Hurricane WRF (AHW)

Domain Resolution: 12km:4km:1.33km with inner two domains (D2, D3) as movable nests and storm centered.

TCs studied: Laila (2010), Jal (2010), Nargis (2008) and Sidr (2007) over Bay of Bengal (BOB) and Phet (2010), Phyan (2009) and Gonu (2007) over Arabian Sea (AS).

Track and Intensity

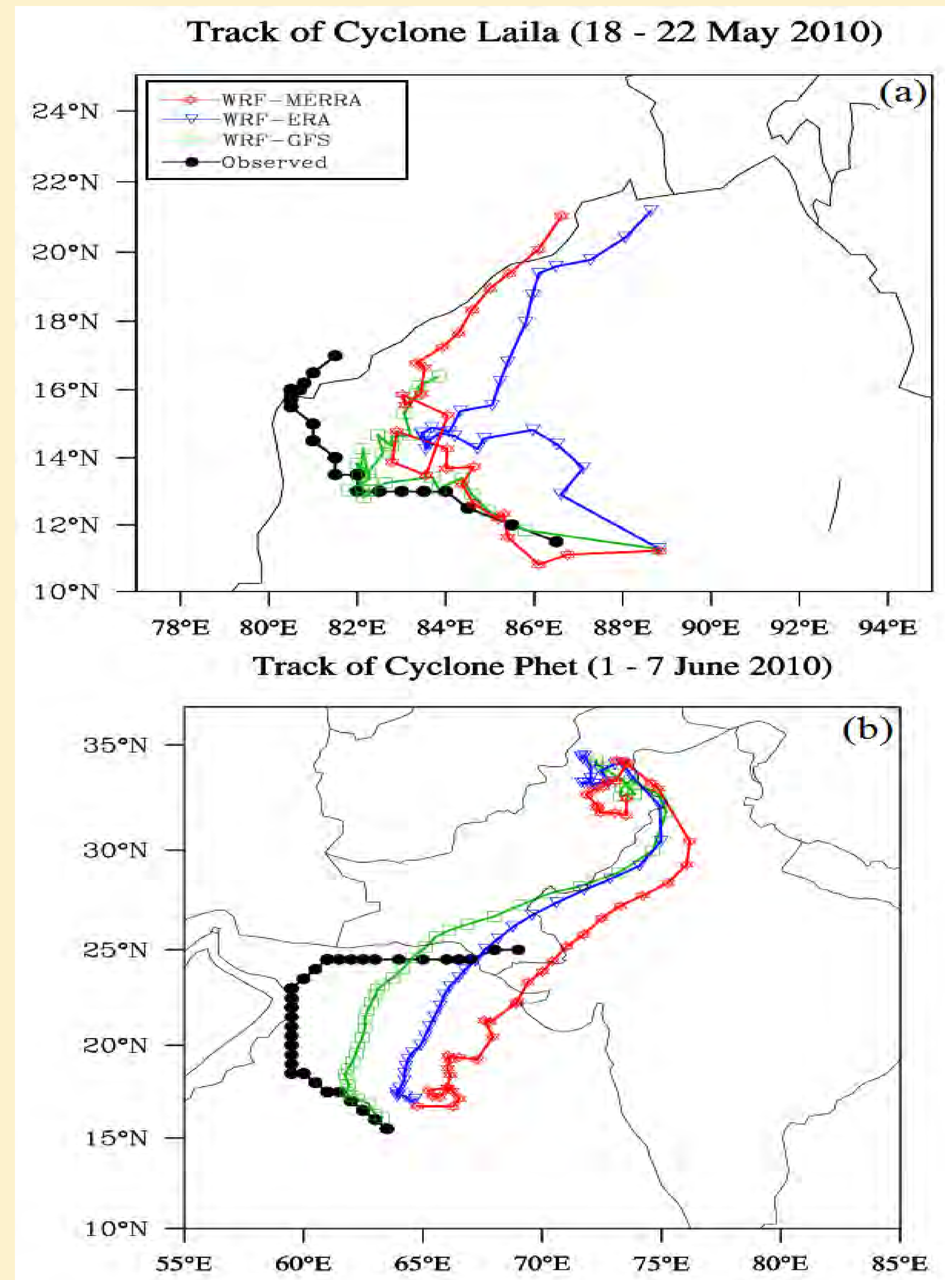

Fig 2: Cyclone tracks for (a) Laila and (b) Phet

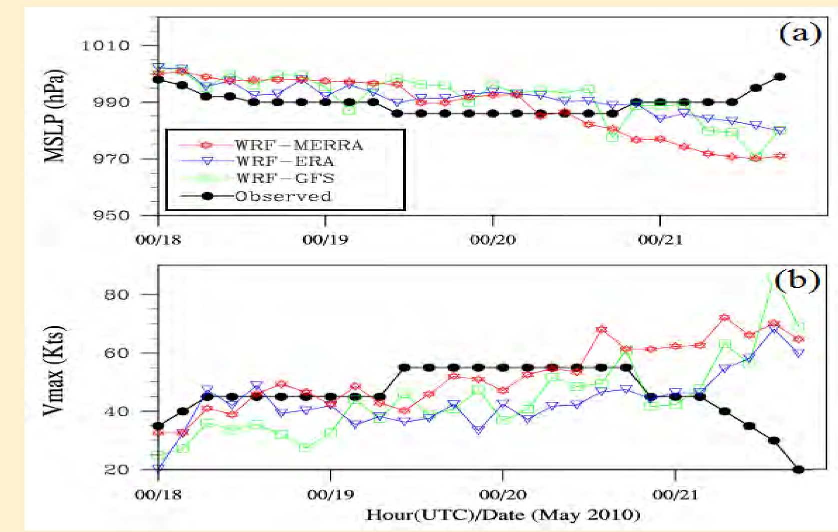

Fig 3: (a) MSLP and (b)V_{max} for Laila

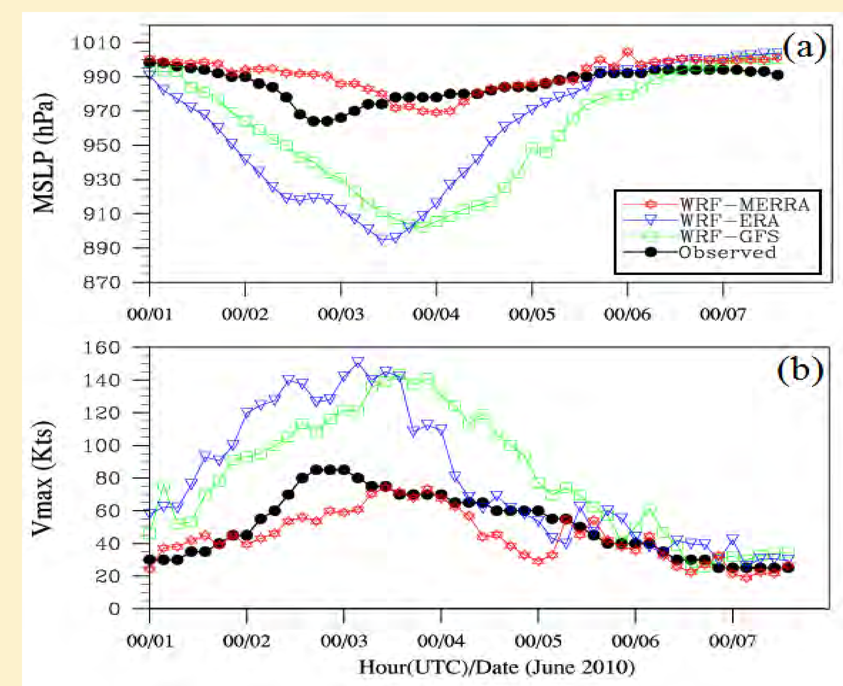

Fig 4: (a) MSLP and (b)V_{max} for Phet

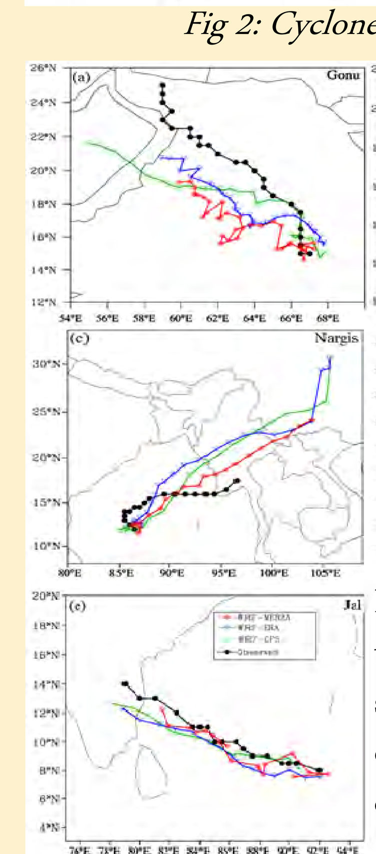

Figure 5: Observed track and model simulated tracks for other mentioned cyclone cases

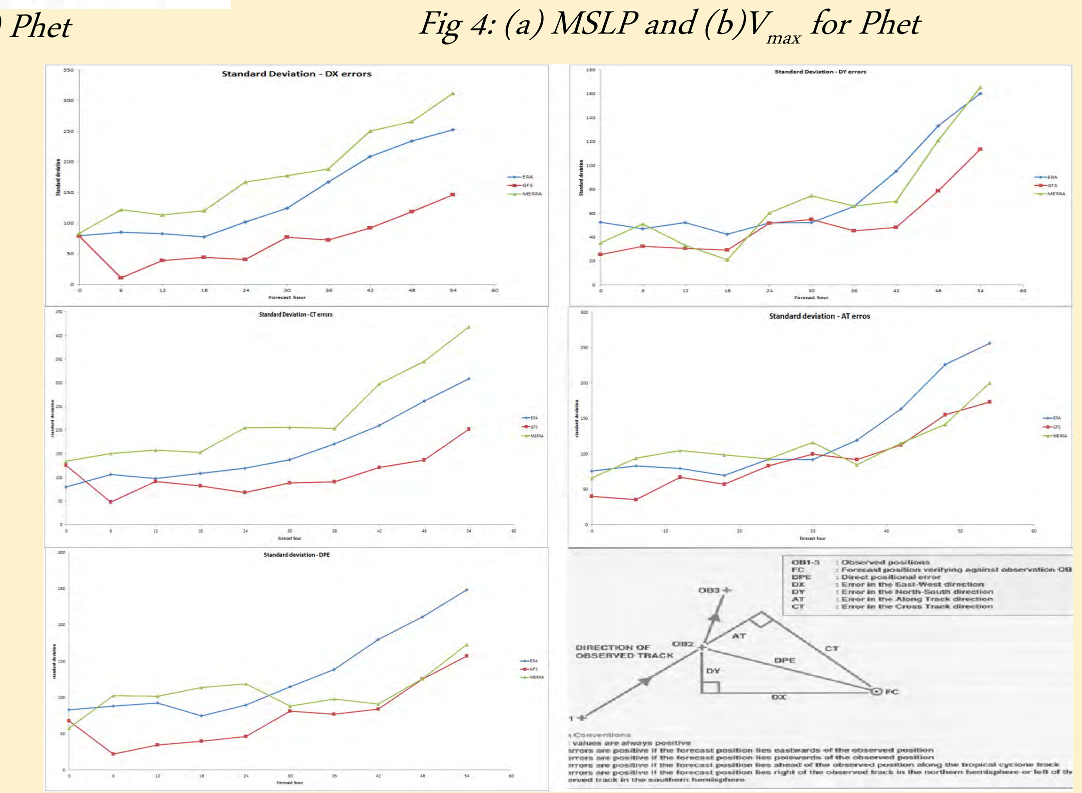

Fig 6: Standard deviation (SD) plots against observation data. Forecast hr. on x-axis and SD on y-axis

PV analysis and Rainfall representation for cyclone LAILA

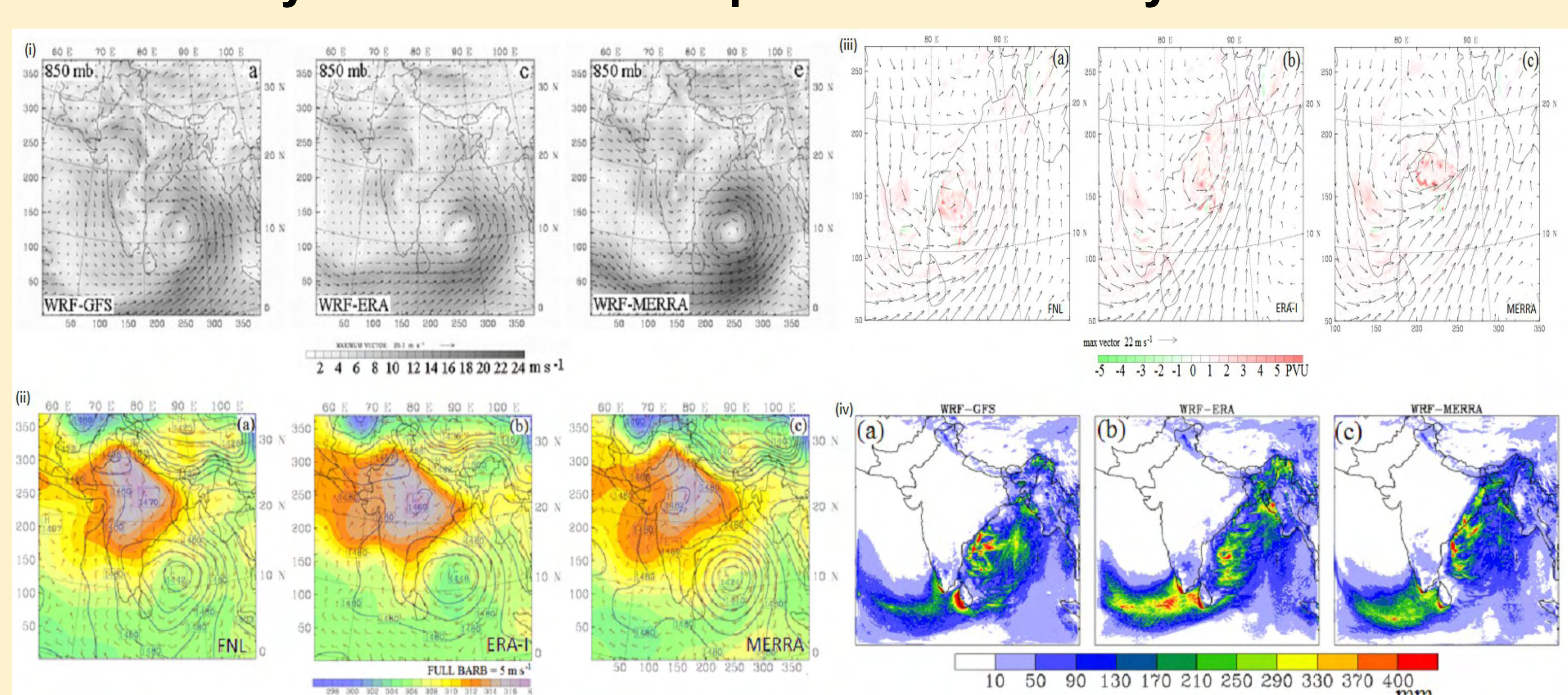

Fig 7: (i) 850mb level initial synoptic wind representation , (ii) 850 mb level geopotential height (contour) and geostrophic wind (wind barb) and potential temperature (shaded), (iii) 850 mb level horizontal wind vectors with potential vorticity (shaded) at 48 hours and (iv) Total accumulated rainfall (96 hours) for FNL, ERA-I and MERRA represented by (a), (b) and (c) respectively.

Results

- Initial state of synoptic wind is different in all the three forcing data especially in the wind speed magnitude.
- Vortex initialization in the model is also very different from each other in strength, position and shape.
- The vortex eye is clearer in MERRA at 850 mb level but is much weaker at 500 mb level compared to FNL and ERA-I.
- Track error analysis shows GFS does better than both MERRA and ERA-I with MERRA being the second best.
- MERRA based simulations were able to produce better MSLP and V_{max} for Laila and Phet. They remain very different for the first 48 hours of simulations but later converge. Intensity is generally over-predicted and GFS performs better than ERA-I and MERRA.
- Precipitation patterns differ, with MERRA producing less rainfall than GFS and ERA-I.
- No single reanalysis data emerges wholesome as each storm responds differently to each reanalysis data.

References

- Kalnay, E., et al., 1996: The NCEP/NCAR 40-year reanalysis project, *Bull. Am. Meteorol. Soc.*, 77(3), 437–471, doi:10.1175/1520-0477.
- Liu, Y., et al. 1997: A multi-scale numerical simulation of Hurricane Andrew (1992). Part I: Explicit simulation and verification, *Mon. Weather Rev*., 125, 3073 – 3093.
- Ma, L., et al., 2008: Evaluation of ERA-40, NCEP-1, NCEP-2 reanalysis air temperature with roundbased measurements in China, *J. Geophys. Res.*, 113, D15115, doi:10.1029/2007-JD009549.
- Simmons, A. J., and J. K. Gibson, 2000: The ERA-40 project plan, ERA- 40 Project Report Series No. 1, 63 pp., Eur. Cent. for Medium-Range Weather Forecasts, Reading, UK.

Acknowledgements

Study benefited from NSF CAREER (AGS-0847472, Dr. Anjuli Bamzai). The authors would also like to thank Dr. Michael Bosilovich/ NASA GMAO for MERRA related discussions.

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