WRF Modeling of the Madden-Julian Oscillation during AMIE/DYNAMO field campaign

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Background

- The Madden-Julian Oscillation (MJO) is the dominant component of the intraseasonal variability in the tropical atmosphere. Past studies have shown the challenge and limitations of global general circulation models in representing MJO structures.
- To improve model predictability and our understanding for MJO, a regional mesoscale model – NASA Unified WRF (NU-WRF) is introduced in this study for higher resolution simulations.

Model Configuration

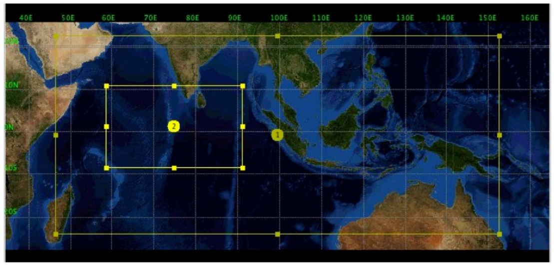

Figure 1. Model integration domain for MC3E forecast. The box marked '2' outlines the moving inner domain of 9 km resolution.

Table 1. Model configuration

	WRF
Dynamic core	WRF-ARW
Domain	1 moving nested domain
Horizontal resolution (km)	27 km, 9 km
Vertical levels	40
Microphysics parameterization	Goddard 3-ice graupel
Radiation	Goddard
Cumulus parameterization	GD for the 27 km domain

The forecast uses ECMWF Interim Reanalysis (ERA-interim) to provide initial and boundary conditions, which has 0.7 degree horizontal resolution and are provided every 3 hours. The model also uses ERA-interim data to nudge the moisture field.

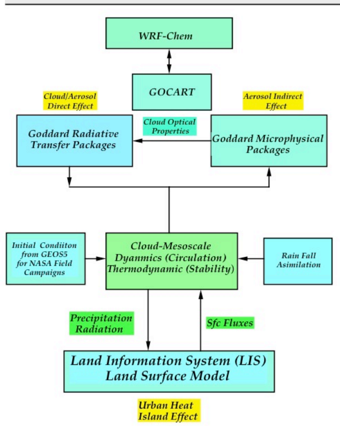

Figure 2. Schematic diagram for NASA NU-WRF modeling framework in Goddard, blue boxes are NASA physical packages.

Satellite Observation

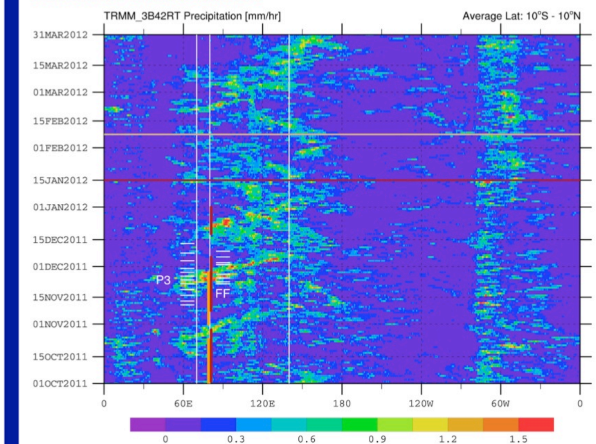

Figure 3: Time-longitude of TRMM rainfall (3B42RT) during the DYNAMO field campaign. The two straight white lines at 70 and 80˚E mark roughly the longitudinal range of the DYNAMO sounding/radar arrays. The vertical line to the right marks roughly the longitude of the ARM Manus site. The purple horizontal line marks the end of Intensive Observing Period (IOP). The pink line marks the end of the DYNAMO observations at Addu Atoll, Maldives. The vertical orange lines mark the on-station dates of R/V Mirai and the vertical purple lines mark the on-station dates of R/V Revelle. Small horizontal tick-marks indicate the dates of aircraft (P3 and FF) missions.

Simulations

1) Precipitation

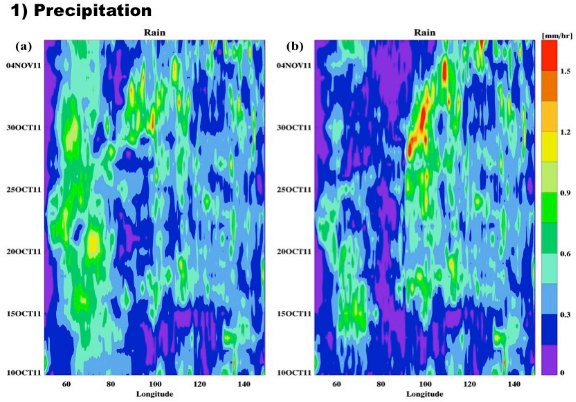

Figure 4. Time-longitude hourly precipitation from (a) NU-WRF simulation with 27 km resolution (no nested domain), and (b) NU-WRF simulation with prescribed moving domain (9 km resolution) during the first MJO event as marked in Figure 3.

Both simulations have captured the east-ward propagating mode for precipitation as the observations. The simulation with moving nested domain displays heavier precipitation than the one without nested domain (Figure 3).

2) Wind

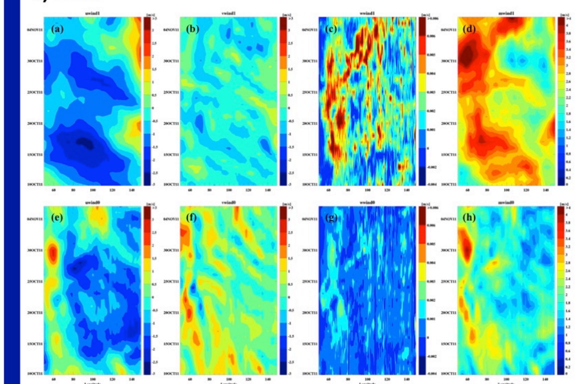

Figure 5. Same as Figure 4, but for the wind fields. (a)-(d) are averaged over mid- and upper- level winds, and (e)-(b) are averaged over lower-level. (a) and (e) are for u-wind component (positive for eastward), (b) and (f) are for v-wind component (positive for northward), (c) and (g) are for w-wind component (positive for upward), (d) and (h) are for horizontal wind magnitude.

The lower level u-wind (e), the vertical wind (c) and (g), and the horizontal wind magnitude (d) and (h) are associate with eastward propagating rainfall pattern. This feature is prominent in mid- and upper-level vertical wind and horizontal wind magnitude. Note that wind fields are not nudged in the model simulations.

3) OLR and Water Vapor

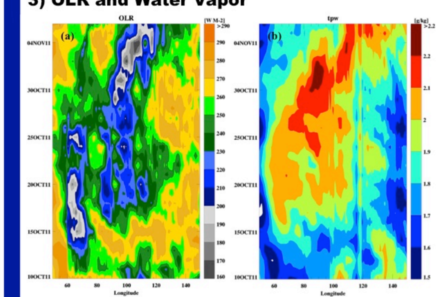

Figure 6. Same as Figure 4, but for (a) outgoing longwave and (b) column-averaged water vapor mixing ratio.

Both fields have displayed strong eastward propagating feature as shown in precipitation field (Figure 4)

Summary and Future Work

- WRF simulated rainfall have captured the key eastward propagating feature of MJO event in October 2011.
- The simulation with moving nested domain displays heavier precipitation which is more comparable to the satellite observation than the simulation without nested domain.
- The wind fields have also shown eastward propagating signals, such as lower level u-wind and vertical wind, which are likely the driven force for MJO systems.
- A series of model sensitivity tests will be carried out by Goddard Cumulus Ensemble model (GCE) to investigate key physical components, such as moisture advection, convective parameterization, and microphysics parameterization schemes. Field campaign datasets will be utilized for model validations and verifications.