JAMSTEC 2009 Research-Report (20 Apr. 2010)

Global Cloud Resolving Model Simulations toward Numerical Weather Forecasting in the Tropics (JST, CREST)

Masaki Satoh, Hirofumi Tomita, Tomoe Nasuno, Shin-ichi Iga, Akira T. Noda, Kazuyoshi Oouchi, Hiroshi Taniguchi, Yohei Yamada, Chihiro Kodama
(Global Cloud-Resolving Modeling Research Team, Advanced Atmosphere-Ocean-Land Modeling Program, RIGC, JAMSTEC)

1 Introduction

■ Importance of Weather Forecasting in the Tropics

Well-organized cumulus cloud clusters generate and decay in the tropics. Their behaviors affect an weather system in the eastern Asia e directly and indirectly.

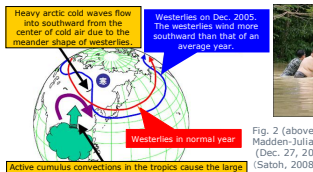


Fig. 1: A schematic overview of atmosphere on Dec. 2005. The Japanese archipelago is experiencing record heavy snowfall on Dec. 2005.

Fig. 2 (above): Floods in Malaysia due to Madden-Julian Oscillation (MJO) (Dec. 27, 2006). Courtesy of Jiji Press Ltd. (Satoh, 2008).
Fig. 3 (right): Damage situation of Myanmar cyclone Nargis (above: May 7, 2008; below: May 3, 2002) (from NASA Hurricanes web-site: http://www.nasa.gov/mission_pages/hurricanes/archives/2008/h2008_nargis.html)

■ Importance of the study on TC by GCRM

- Difficulties in predictions for cyclogenesis and typhoon tracking
  - Many operational numerical prediction models cannot reproduce the development from tropical disturbances of cloud clusters to tropical cyclone.
  - In current status, some operational models use the typhoon bogus (artificial seeds of typhoon) in order to emphasize the prediction of typhoon tracking after observed cyclogenesis.
  - Pointed out several factors:
    - Uncertainties by using cumulus parameterization with statistical closure of cumulus convections
    - Difficulties in reproducing the intra-seasonal factors (ex. MJO, monsoon onset) related to initial disturbances which are need for TC genesis (right).

- Advantages of GCRM
  - Reduction of uncertainties for the treatment of cumulous clouds is expected by direct calculation of lifecycle of clouds based on cloud physics .
  - Enhanced predictability of the MJO in the simulation would result in improvements in the predictability of TC genesis.

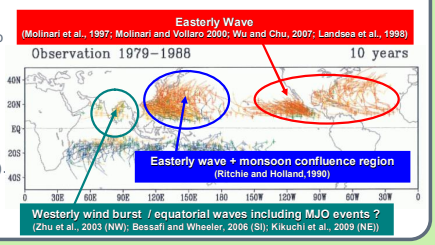


Fig. 6: Best tracks of tropical cyclones from 1979 to 1988 (Oouchi et al. 2006). Intra-seasonal factors which is thought as factors of cyclogenesis are also shown.

2 Global Cloud Resolving Model: NICAM

■ Advantage of Global Cloud Resolving Model

Progress in advancing weather/climate prediction has been hampered by the difficulties involved in handling a cloud unresolved in the model resolution and the uncertainties involved in using cumulus parameterization in a subgrid-scale of conventional general circulation models (GCMs), since behaviors of GCMs crucially depend on specific implementations of cumulus parameterization.

The global cloud resolving simulation in which cumulus convection in the atmosphere is directly resolved with a few km horizontal mesh over the global domain is succeeded by our group for the first time using the Earth Simulator.

A newly developed Global Cloud Resolving Model (GCRM), called NICAM, overcomes the difficulties in existing atmospheric global models where cumulus convection is not resolved and is represented in parameterized forms.

This research project promotes development of NICAM by aiming that NICAM is practically used as a next generation weather forecasting and climate prediction model. Toward this goal, we concentrate on improvements of representation of convective-precipitation systems in the tropics and the Asian monsoon region, which directly affects meteorology around Japan.

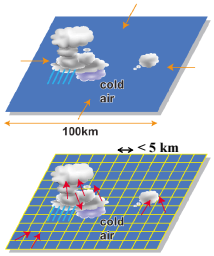


Fig. 4: Representation of cumulus clouds in the traditional low-resolution atmospheric model (upper) and in the high-resolution GCRM (bottom). Left panel shows cumulus clouds in the tropics viewed from space shuttle.

■ Nonhydrostatic ICosahedral Atmospheric Model: NICAM

- High-resolution General Circulation Model suitable for weather and climate predictions
- Global Cloud Resolving Model: grid interval less than 5 km
- Quasi-uniform horizontal grid: Icosahedral grid
- Non-hydrostatic equations system: a new conservative scheme: Suitable for long term simulation

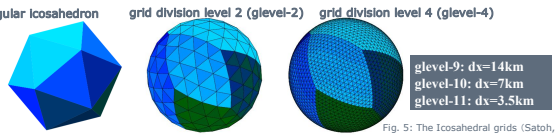
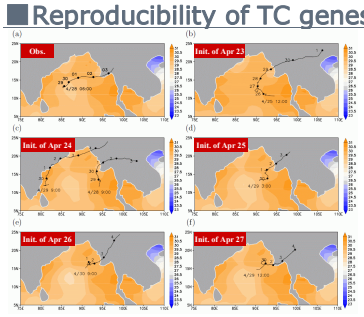


Fig. 5: The Icosahedral grids (Satoh, et al., 2008)

3 Ensemble simulation of cyclone Nargis (2008)

Taniguchi et al. (2010), in press of JMSJ.

■ Reproducibility of TC genesis and tracks



- Well reproduced cyclogenesis and tracks in the Bay of Bengal for all the simulation with initial days of April 23 to 27.
- Cyclogenesis occurs in high-SST area

Fig. 7: (a) Best track of cyclone Nargis (line) from the day of TC formation (27 April 2008), as obtained by the JTWC data center. (b–f) Tracks of simulated cyclones (lines). Color shading shows observed daily SST interpolated from weekly-averaged Reynolds-SST (°C) on the genesis day of observed cyclone Nargis (a) and the simulated cyclones (b–f). Solid circles with numbers show the day and position of each cyclone. Panels (b)–(f) show the results of simulations with initial time of 1200 UTC on 23–27 April 2008, respectively. In the simulations, no cyclone formed in the Bay of Bengal for initial days of 10 and 28 April 2008 (panels not shown).

■ Relationship between monsoon onset in the BoB and cyclogenesis of Nargis

- Zonal wind at 850 hPa (80E-100E Ave.) Lat.-Time
- Clouds and Precipitation (80E-100E Ave.) Lat.-Time

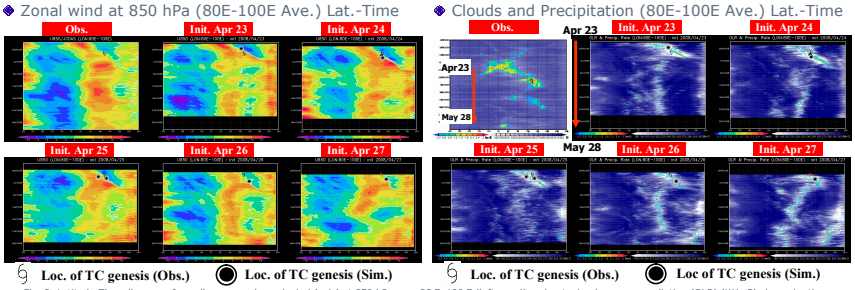


Fig. 8: Latitude-Time diagram of zonally averaged zonal wind (m/s) at 850 hPa over 80°E–100°E (left panel) and outgoing long-wave radiation (OLR) (W/m2) shown by the white-navy blue scale and surface precipitation rate (mm/h) shown by the rainbow color scale for values grater than 0.3 (mm/h) over 80°E–100°E (right panel), respectively.

■ Reproducibility of intra-seasonal factors related to cyclogenesis

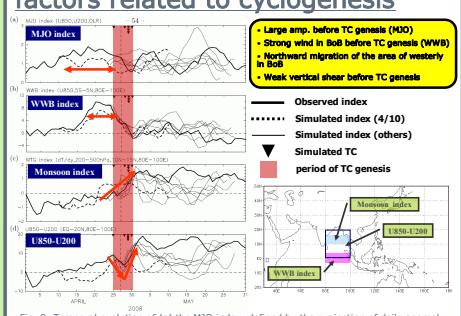


Fig. 9: Temporal evolution of (a) the MJO index, defined by the projection of daily anomaly data onto the multi-variable (U850,U200,OLR) EOFs; (b) the westerly wind burst (WWB) index, defined by the area-averaged zonal wind at 850 hPa in the area of 5°S–5°N and 80°E–100°E; (c) the monsoon onset index in the Bay of Bengal, defined by the area-averaged upper tropospheric (200–500 hPa) meridional temperature gradient in the area of 10°N–15°N and 80°E–100°E; and (d) vertical shear of zonal wind at 850 hPa and 200 hPa in the area of EQ–20°N and 80°E–100°E. Thick solid lines represent the observed index calculated by JMA/JCDAS (U850, U200) and NOAA (OLR, only (a) used) datasets. Thick dotted lines and thin solid lines indicate the simulated indices for initial days of 10 and 23–28 April 2008, respectively. The vertical dashed line shows the time of cyclone Nargis genesis. The timing of formation of simulated cyclones is indicated by solid inverted triangles.

■ MJO phase vs. TC genesis

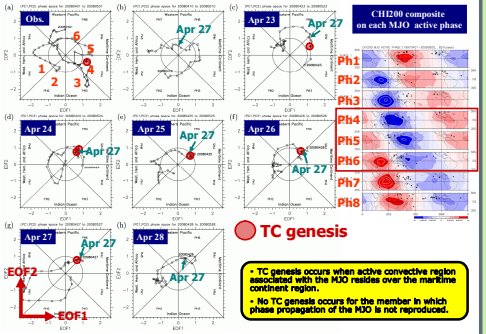


Fig. 10: PC1 and PC2 daily phase points (open circles) for the observed days (a) and simulated days (b–h) on the phase space. (a) Score calculated based on the observed (re-analysis) field. Thick and thin lines correspond to PCs during April and May 2008, respectively. (b)–(h) show the results of NICAM simulations with initial days of 10, 23, 24, 25, 26, 27, and 28 April 2008. Solid circles indicate the day on which cyclone Nargis formed (a) and the day of cyclone genesis in each simulation (c–h) (left panel) and composite diagram of velocity potential anomaly at 200-hPa in each MJO phase. Blue shadings are correspond to the active convective region associated with the MJO.

■ Reproducibility of Init. disturbances for TC genesis

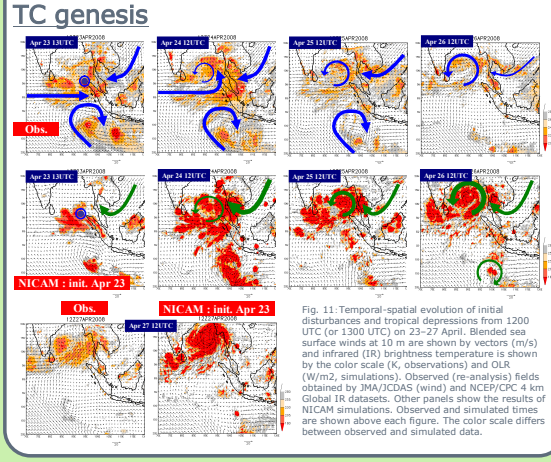


Fig. 11: Temporal-spatial evolution of initial disturbances and tropical depressions from 1200 UTC (or 1300 UTC) on 23–27 April. Blended sea surface winds at 10 m are shown by vectors (m/s) and infrared (IR) brightness temperature is shown by the color scale (K, observations) and OLR (W/m2, simulations). Observed (re-analysis) fields obtained by JMA/JCDAS (wind) and NCEP/CPC 4 km Global IR datasets. Other panels show the results of NICAM simulations. Observed and simulated times are shown above each figure. The color scale differs between observed and simulated data.