Boreal-summer multiscale intra-seasonal variability in NICAM: current status and future strategy

Kazuyoshi Oouchi[1], Akira T. Noda[1], Masaki Satoh[1,2], Hirofumi Tomita[1], Tomoe Nasuno[1], Hiroshi Taniguchi, [1] Yohei Yamada[1], Mikiko Ikeda[1], Ryo Oonishi[1], and Observation Team[1] (Kunio Yoneyama, Ryuuichi Shirooka, Shuuichi Mori, Hiroyuki Yamada, and Mikiko Fujita) (1.Research Institute for Global Change, JAMSTEC; 2. Atmosphere-Ocean Research Institute, the University of Tokyo, JAPAN)

Introduction

■ Monsoon/ISV research with GCRM

Boreal summer is a challenging season to predict in the conventional atmospheric models. This study uses global cloud-resolving model NICAM (Satoh et al. 2008; Tomita and Satoh 2004) to assess performance of NICAM in simulating multi-scale weather events ranging from diurnal to intra-seasonal time scales in the monsoon-prone region.

1. Linkage between Intra-seasonal variability and tropical cyclone
2. performance of GCRM in simulating boreal summer monsoon-related weather phenomena, thereby assess potential predictability of them with GCRM ⬅ **This presentation**

[References on the boreal-summer experiments]
1 Oouchi et al. 2009a
2 Oouchi et al. 2009b
3 Noda et al. 2010: (turbulent boundary-layer scheme; low clouds)

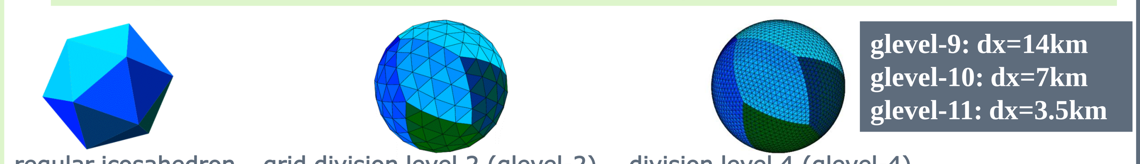
■ Advantages of GCRM (NICAM)

-Reduction of uncertainties in representing organization of cumulus clouds with the benefit from direct calculation of lifecycle of clouds based on cloud physics (Satoh et al., 2008, Tomita and Satoh, 2004)

-Reasonable representation of the Madden-Julian Oscillation (Miura et al. 2007) and associated equatorial disturbances (Nasuno et al. 2009) including tropical cyclogenesis (Fudeyasu et al. 2008)

■ NICAM dynamical core

- Quasi-uniform horizontal grid: Icosahedral grid
- Non-hydrostatic equation system: a new conservative scheme:suitable for long term simulation (Satoh, 2002, 2003)



regular icosahedron   grid division level 2 (glevel-2)   division level 4 (glevel-4)

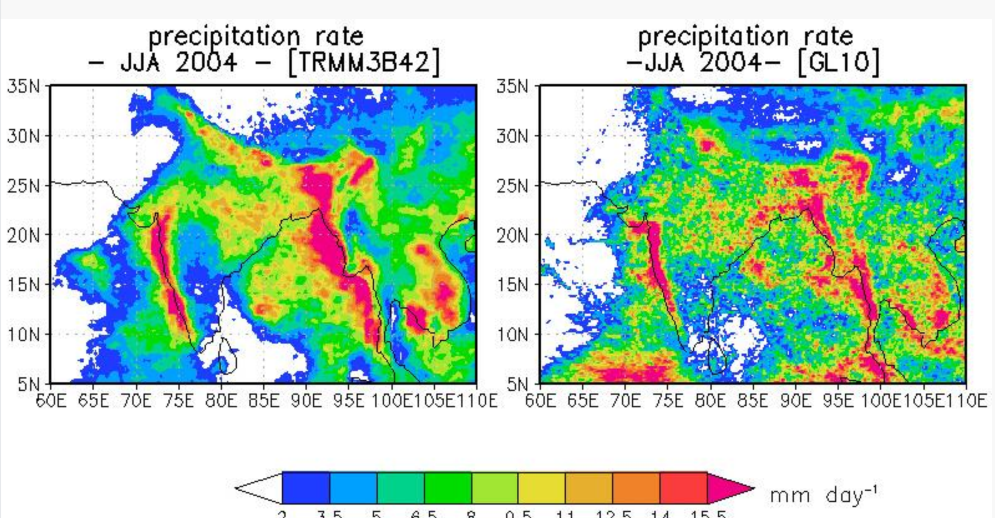
■ Experimental design of boreal summer runs

- Integration period: June 1st to August 31st 2004
- Initial condition: NCEP final analysis
- Horizontal resolution: 14- or 7-km mesh without cumulus parameterization
- Vertical layers: 40 layers (model top at 38-km)
- Boundary layer scheme: (Noda et al. 2010) based on MYNN (Niino and Nakanishi,2004)
- Cloud Microphysics: 2 solid categories (Grabowski, 1998)
- Land-surface: Bucket scheme
- Sea surface temperature: prescribed (daily interpolated from Raynolds OI weekly SST)
- Radiation scheme: MSTRN-X (Sekiguchi and Nakajima, 2008)

Boreal summer monsoon simulation 2004

Oouchi et al. (2009b)

■ Mean precipitation rate (June-July-August)

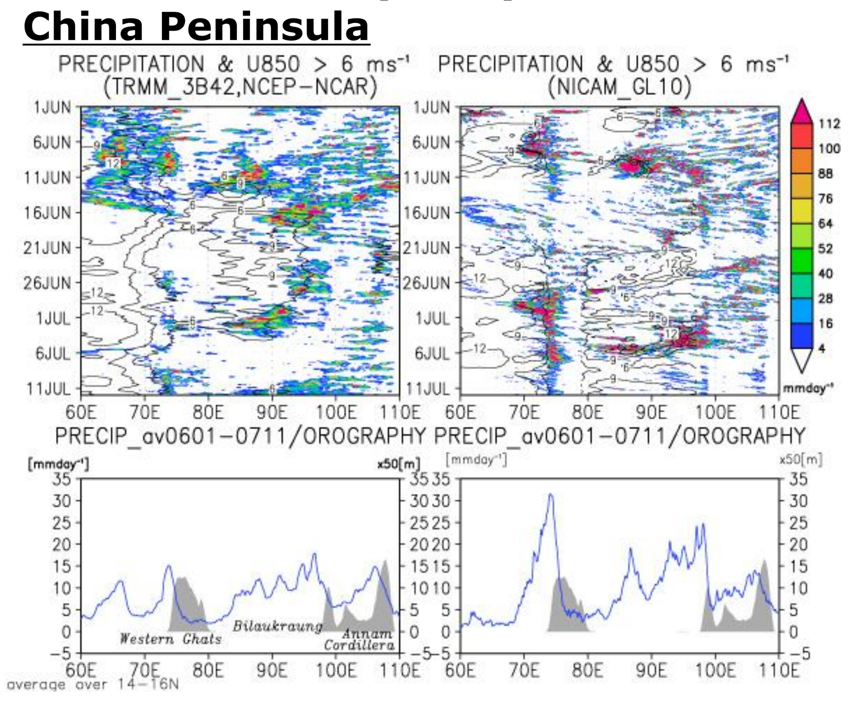


(left) Observed and (right) simulated precipitation rate over the Indo-China monsoon region as June–July–August average (in units of mm day^{-1}). The observed precipitation is from TRMM_3B42, and the simulation is for 7km-mesh run

The 7-km model simulates successfully most of the local maxima of summer precipitation organized in narrow strips on the west slope of the western Ghats range, Himalayan foothills, the Arakan Yoma highlands, and the Annamite range.

The model over-predicts the precipitation over the Indian Ocean. By design, the prescribed SST method does not capture the observed negative correlation between SST and rainfall over warm oceans with weak SST gradients [Wang et al., 2004; Krishna Kumar et al., 2005]. The lack of oceanic feedback may be a source of the precipitation bias.

■ Multi-scale precipitation: across the Indian subcontinent, Bay of Bengal, and Indo-China Peninsula



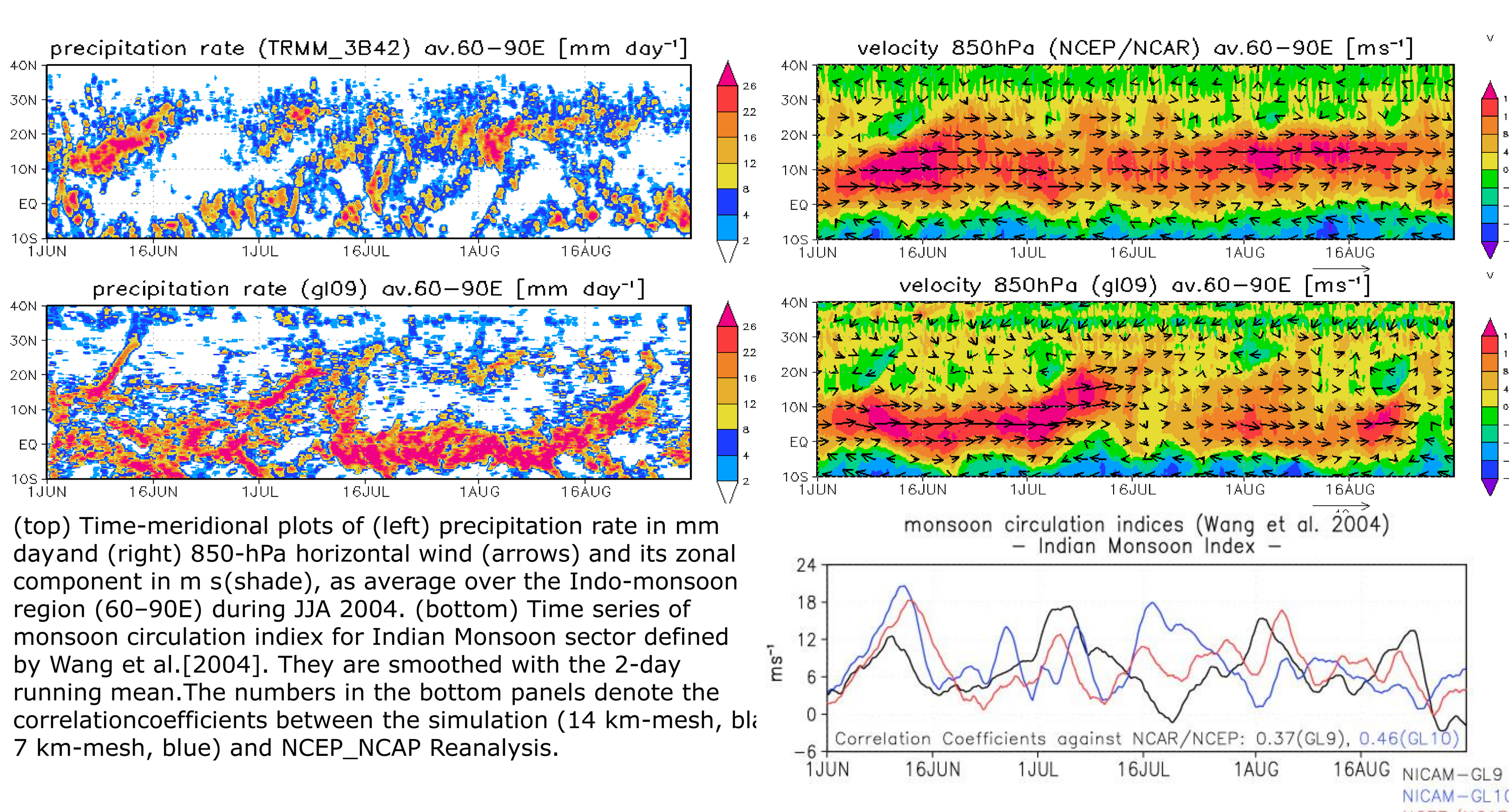
precipitation displays conspicuous diurnal cycle both in TRMM observations and NICAM simulation. The diurnal cycle is the most evident over the land area of the Indo-China peninsula (98–108E), and to a lesser degree, in regions west of the coastal mountains (70–75E and 95–100E).

The observed increase in westerly winds over the Bay of Bengal persists from 16 June to 5 July, but rainfall is concentrated on three synoptic "events" around 16 June, 26 June, and 2 July, indicative of the importance of synoptic-scale systems. Orographic lift can be a factor enhancing the synoptic system-induced rainfall. The simulation also captures such synoptic-scale precipitation systems.

The intraseasonal oscillation (ISO) modulates the diurnal cycle over the Indo-china region; it controls not only its amplitude but its propagation direction. The observed diurnal cycle is strong, and propagates westward during the first part of June (wet phase of ISO), but it weakens and propagates eastward during the second part of June (dry phase of ISO).The westward/eastward propagation is apparently initiated from Annam Cordillera/Bilaukraung. The model simulates these two features of ISO modulation quite well. The simulated westward/eastward propagations seem to be embedded in the low-level (700 hPa) easterly/westerly regions (not shown).

(top) Hovmoller representation of precipitation rate (mm day^{-1}, shaded) and zonal velocity (contoured for 6, 9 and 12 ms1) for the average over 14–16N, for TRMM_3B42 (precipitation) and NCEP/NCAR Reanalysis (zonal velocity), and 7km-mesh run. The plot period spans from 1 June to 11 July. (bottom) Precipitation amount averaged over the period (blue lines), and the orography (elevation 50 m; grey) that is constructed by the spatial smoothing of the global digital elevation model GTOPO30 from the U.S. Geological Survey.

■ Northward migration of precipitation and velocity (850hPa) and Indian Monsoon Index



(top) Time-meridional plots of (left) precipitation rate in mm dayand (right) 850-hPa horizontal wind (arrows) and its zonal component in m s(shade), as average over the Indo-monsoon region (60–90E) during JJA 2004. (bottom) Time series of monsoon circulation indices for Indian Monsoon sector defined by Wang et al.[2004]. They are smoothed with the 2-day running mean.The numbers in the bottom panels denote the correlationcoefficients between the simulation (14 km-mesh, bl 7 km-mesh, blue) and NCEP_NCAP Reanalysis.

Monsoon is also characterized by the northward migration of precipitation ISO [Fu and Wang, 2004; Rajendran and Kitoh, 2006]. Figure (top) illustrates this phenomenon in time-meridional sections of precipitation and 850 hPa velocity (vector) and its zonal component (shade). The 7-km mesh run predicts the strength of the Indian monsoon trough quite well up to 40 days (1 June to 10 July), although more ensemble members are necessary to conclude robustness of the result. The observed northward migration of the precipitation area is simulated in early June to mid-July, but becomes unclear thereafter in the simulations.

To investigate the monsoon evolution, the time series of Indian Monsoon Index by Wang et al. [2004] is compared with observations in the bottom panel. The index provides measures to track dynamical features of the regional monsoon subsystems. Remarkably, IMI is high (enhanced monsoon trough) during the first part of June and low (weakened monsoon trough) in the second half of June. The model thus captures both the wet and dry spells well, although its sensitivity to initial conditions remains to be seen.

■ Summary and Issues

- This study focuses on the results from the first boreal summer (2004) seasonal-long GCRM simulations, in an attempt to simulate complex multi-scale interaction among the monsoon-related precipitation and circulation.

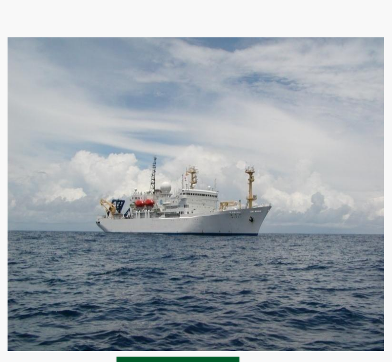
- Our study identifies a number of strengths and weaknesses of NICAM. NICAM exhibits an encouraging simulation results of intraseasonal variability of the Indian monsoon up to 40-days (June to early July), and the representation of local precipitation features, especially those anchored by mountain ranges —features poorly reproduced in conventional GCMs [Xie et al., 2006]. Precipitation there involves a unique diurnal cycle, especially over Indo-China. The good performance of NICAM in simulating monsoon convection should come from improved representation of interaction among moisture, circulation and topography in GCRM.

- A weakness of the model is the over-prediction of precipitation over the Indian Ocean, a common problem for state-of-the-art conventional atmospheric GCMs [Wang et al., 2004]. The problem can have the same root as in conventional atmospheric GCMs from the prescription of SST as the bottom boundary condition. By design, the prescribed SST method does not capture the observed negative correlation between SST and rainfall over warm oceans with weak SST gradients The lack of oceanic feedback may be a source of precipitation bias, which in turn affects ISO and seasonal variations of monsoon [Goswami,1998; Krishnan et al., 2006]. We are working to understand impact of ocean-atmosphere interaction on monsoon-related features.

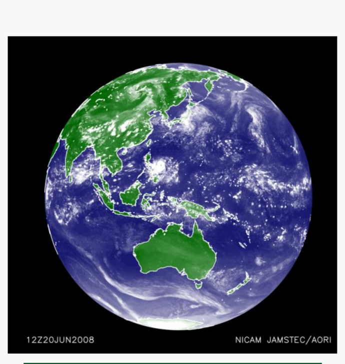
Fusion of Observation and GCRM Modeling

Toward CINDY2011/DYNAMO

-NICAM quasi real-time forecast for a coordinated observation project, PALAU 2010-



MIRAI



NICAM snapshot

Acknowledgements The simulations were performed on the Earth Simulator/JAMSTEC, under the framework of the Innovative Program of Climate Change Projection for the 21st century (KAKUSHIN) project funded by Ministry of Education, Culture, Sports, Science and Technology. The authors thank J.-X. Fu, B. Wang, S.-P. Xie, H.-G. Takahashi, T. Yasunari, T. Matsuno, Y. Wang, and Y. Kajikawa for discussions.

■ OBSERVATION

CINDY2011/DYNAMO

WCRP CLIVAR

Objectives

The aim of the experiment is to collect in-situ atmospheric and oceanic data to study the intraseasonal variability in the equatorial Indian Ocean, with focus on the initiation process of convection in the Madden-Julian oscillation (MJO), by constructing a long-time (over intraseasonal period) and wide-areal observation network with ships, land-based sites, and a mooring array as a multi-national effort. Key scientific objectives are set to reveal 1) the evolution of heating profile associated with the MJO, 2) relationship between meso-scale convective systems and equatorial waves, and 3) relationship between convective activity and sea surface conditions.

Background

CINDY2011 can be regarded as a follow-up project of MISMO, which took place in the central equatorial Indian Ocean from late October to early December 2006.

Contact: Dr. Kunio Yoneyama (yoneyamak@jamstec.go.jp)
CINDY2011 URL: http://www.jamstec.go.jp/iorgc/cindy/

■ CINDY2011 and DYNAMO are the endorsed projects by WCRP/CLIVAR.

■ MISMO project reference: Yoneyama, K., Y. Masumoto, Y. Kuroda, M. Katsumata, K. Mizuno, Y. N. Takayabu, M. Yoshizaki, A. Shareef, Y. Fujiyoshi, M. J. McPhaden, V. S. N. Murty, R. Shirooka, K. Yasunaga, H. Yamada, N. Sato, T. Ushiyama, Q. Moteki, A. Seiki, M. Fujita, K. Ando, H. Hase, I. Ueki, T. Horii, C. Yokoyama, and T. Miyakawa, 2008: MISMO field experiment in the equatorial Indian Ocean. Bull. Amer. Meteor. Soc., 89, 1889-1903, doi:10.1175/2008BAMS2519.1.

Prof. Masaki Satoh on MIRAI during PALAU 2010 cruise (photo by Dr. H. Yamada)

validation data

Collaboration & Synergy

forecast data

Acknowledgements to: All the crews, researchers, programs, sponsors involved in this project

■ MODEL – NICAM forecast among other potential model teams

Quasi real-time forecast in PALAU2010

a pilot feasibility study toward CINDY/DYNAMO

tropical cyclone/multi-scale tropical disturbances over the tropical north-western Pacific

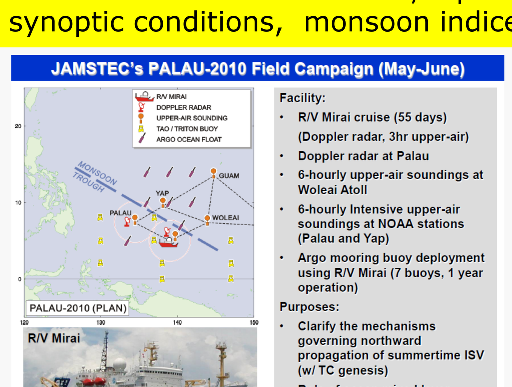
Aims

■ to establish closer collaboration between in-situ observation and modeling

■ to maximize the strength of global cloud-resolving that helps provide a first guess for expected atmospheric disturbances and multi-scale interaction during the limited in-situ observation period

Target disturbances to predict and metrics for tracing them

■ Madden-Julian oscillation, equatorial waves, meso-to-synoptic conditions, monsoon indices …



real-time forecast modeling team

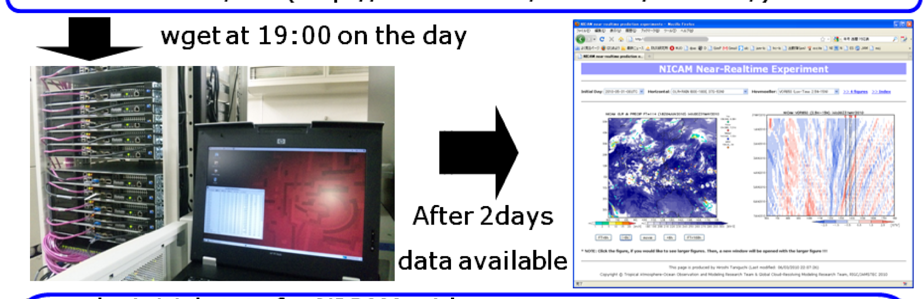
Source: Dr. H. Yamada

demonstration

Outline of 1-week prediction system by NICAM

initial data (ATM, LND, OCN) at 00UTC
NCEP/FNL (http://dss.ucar.edu/datasets/ds083.2/)

wget at 19:00 on the day



After 2days data available

1. make initial state for NICAM grids system
2. make ocean data for nudging
3. make configuration file for the run with above initial state
4. start run (7-day integration, 14km-stretch configuration; Tomita 2009)
   - multi-level: every 3hr (snapshot)
     - u, v, w, t, p, rho, qv, dh
   - single-level: every 1hr (average)
     - cldi, cldw, evap, olr, q2m, qr, slp, t2m,
     - t_sfc, tppn, u10m, v10m vap_atm

Region Stretch center: 136E,8N

calc. time:1.7 days

Next Generation Climate Model

Contact: Dr. Kazuyoshi Oouchi (k-ouchi@jamstec.go.jp) for the contents of the poster