Seasonal-scale experiments with a Global-cloud model - Resolution Dependency in a 7-km and 14-km mesh Experiments -

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and NICAM developing members

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IR image (MTSAT-1R)

3.5km-mesh Exp.

Miura et al. (2007, Science)
Overview

NICAM (Nonhydrostatic Icosahedral Atmospheric Model) has been conducted week-to one-month-long experiments
- To investigate relatively short-term tropical disturbances to date

Seasonal-change experiment by global 14-km & 7-km meshes
- Ongoing studies
  - MJO events (Oouchi et al. 2009, SOLA)
  - Monsoon circulation (Oouchi et al. GRL in press)
  - Genesis mechanism and climatology of tropical cyclones
  - Cloud climatology (Noda et al. Atmos.Res. in press)
- Boreal summer (JJA) of 2004
  - Record typhoon landfalls in Japan (10 Typhoons in the year)
  - Clear MJO signals
  - Inter-model Comparison with the CLIVAR
Focus of this talk

Contents

- Possible cause of excessive precipi. over tropics of NICAM
- Change of amplitude of precipi from 14-km mesh to 7-km mesh

Major Interests

- How the difference of horizontal resolution affects on precipi. intensity in GCRM study?
  - Necessary to understand the cause of model biases
  - The most significant advantage of GCRM is to omit ambiguity raised by a cumulus parameterization
  - Can we expect that the biases will decrease with horizontal resolution?
  - If not, what physical process is responsible?
### Experimental Design

※About 11 hrs for a 10-day integration by 80nodes of 8processors of the Earth Simulator

<table>
<thead>
<tr>
<th>Initialization</th>
<th>NCEP Global analysis on 00Z Jun 1, 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nudging</td>
<td>Not used</td>
</tr>
<tr>
<td>Bottom boundary</td>
<td>Bucket model and NOAA Weekly Reynolds SST</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>14km &amp; 7km (2 experiments)</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>80m 2.9km (Stretched)</td>
</tr>
<tr>
<td>Cloud</td>
<td>Cloud microphysics by Grabowski et al. (1998) (Predicting cloud condensates and diagnosing into liquid and ice phases)</td>
</tr>
<tr>
<td>Turbulence</td>
<td>Improved version of Mellor-Yamada Level 2 with subgrid-scale condensation (Nakanishi &amp; Niino 2006; Mellor and Yamada 1982) ※But not producing a partial cloud</td>
</tr>
<tr>
<td>Surface turbulent flux</td>
<td>Bulk parameterization by Louis (1979)</td>
</tr>
<tr>
<td>Radiation</td>
<td>MSTRNX (Nakajima et al. 2001; Sekiguchi 2004)</td>
</tr>
<tr>
<td>Integration period</td>
<td>June 1st − August 31st (for 7-km mesh)</td>
</tr>
<tr>
<td></td>
<td>June 1st − November 7th (for 14-km mesh) (but analyze during JJA)</td>
</tr>
<tr>
<td>Aerosol process</td>
<td>Not used (but optionally available in NICAM)</td>
</tr>
</tbody>
</table>
Surface Precipi.
~NICAM vs. GPCP~

Similar distribution of precipi. in space

Agree well with the obs.
Roughly, similar results in 7km and 14km runs
Surface Precipi.  
NICAM vs. GPCP

Why a positive bias in the tropics?

Possible causes:
1. Too strong vertical velocity (convections)?
2. Too much precipitable water?
3. Physical process?

※JJA 2004
Compared in 1 deg. resolution

Positive bias in precipi.
Somewhat reduced in 7km-mesh

[Graph showing precipitation differences between GPCP and NICAM for 14-km and 7-km meshes]
Excessive precipi.

PDF of Omega500~

Agree well with reanalysis data in updraft region
→ The error of the updraft is not the primary cause of the excessive precipi.
(But, modeled subsidence is weaker than that in reanalysis data, showing a lack of strong subsidence)

※ JJA 2004 30S~30N
Compared in 2.5 deg. resolution

<table>
<thead>
<tr>
<th></th>
<th>NCEP</th>
<th>JRA</th>
<th>14km</th>
<th>7km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frac. of Updraft</td>
<td>0.60</td>
<td>0.58</td>
<td>0.62</td>
<td>0.61</td>
</tr>
<tr>
<td>Frac. of Downdraft</td>
<td>0.40</td>
<td>0.42</td>
<td>0.38</td>
<td>0.39</td>
</tr>
</tbody>
</table>

PDF of omega500

Frac. of Updraft: NCEP 0.60, JRA 0.58, 14km 0.62, 7km 0.61
Frac. of Downdraft: NCEP 0.40, JRA 0.42, 14km 0.38, 7km 0.39

Omega500 [mb/dy]
Excessive precipi.

Example of weaker subsidence

Remarkable differences appeared in off the coastal regions and Indian ocean

※JJA 2004 30S~30N
Compared in 2.5 deg. resolution

NCEP

JRA25

14km

7km
Agree well with NCEP in updraft region
The error of precipitable water is also not the primary cause of the excessive precipi.
Excessive Precipi.

Precipitable Water vs.Precipi.

No systematic bias in PW that can explain the excessive precipi. in NICAM.
Excessive Precipi.

Precipi. vs. Omega500

- NCEP and JRA25 agree with ERA40
- Much stronger precipi. against each omega value in both 7km and 14km results
- Few differences in 7-km and 14-km results
  - Excessive precipi. is intrinsic characteristics in the model, and may be difficult to expect to reduce the bias solely by using more higher resolution

\[ \omega_{500} \text{ vs. Precipi.} \]

ERA40(1985-1989)  
Bony et al. 2006
Excessive Precipi.  

Precipi. Efficiency  

Does the relation between \( \omega_{500} \) & Precipi. becomes better if \( \omega_{500} \) in correspondence with precipi. would be reproduced more accurately?

- The relation (curve) much closer to reanalysis results if replacing with \( \omega_{500} \) of reanalysis
- The model overestimates response of \( \omega \) to precipi.
- Excessive precipi. would be reduced if revising, e.g., cloud physics process, i.e., Relation between precipi. and vertical velocity (Precipitation Efficiency) (may change of autoconversion rate play a role?)

※Ranges of x- and y-axes are all the same
Decrease of Max. Precipi. in 7-km mesh against 14-km mesh
Mean meridional circulation \([10^{10} \text{ kg s}^{-1}]\) in JJA

14-km mesh

7-km mesh

Diff. (7km-14km)

Hadley circulation in 7-km becomes wider, and amplitude of the vertical velocity weaker than in 14-km mesh

Figure by C.Kodama
Summary

~Dependency on Horizontal resolution (7km and 14km meshes)~

Positive biases of precipi. in 7-km and 14-km meshes
- tied strongly with a stronger response of precipi. to vertical velocity
  - Possibility of intrinsic nature within model physics
  - May difficult to expect to reduce solely by further improving horizontal resolution

Excessive precipi. reduced (~1mm/dy) in 7-km mesh
- because vertical velocity associated with the Hadley circulation in 7-km mesh is somewhat weaker than in 14-km mesh (~O(10^{-3} hPa/dy))
- yielding weaker precipi. in 7-km mesh
  - under the same relation of ω500 and precipi. (i.e., precipitation efficiency)

- Need further investigation about whether 7-km mesh is more accurate than 14-km in terms of precipi. intensity
  - Which mesh model is more realistic (or consistent with mode ensembles) in terms of the Hadley circulation (e.g., intensity and width)?