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

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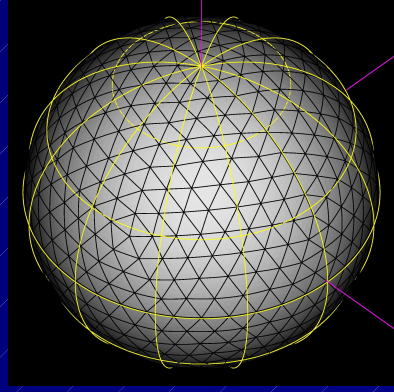
Dec 31, 2006 (after 6 days)

IR image (MTSAT-1R)

3.5km-mesh Exp.
Miura et al. (2007, Science)

Overview



Icosahedral grid system over globe

- 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

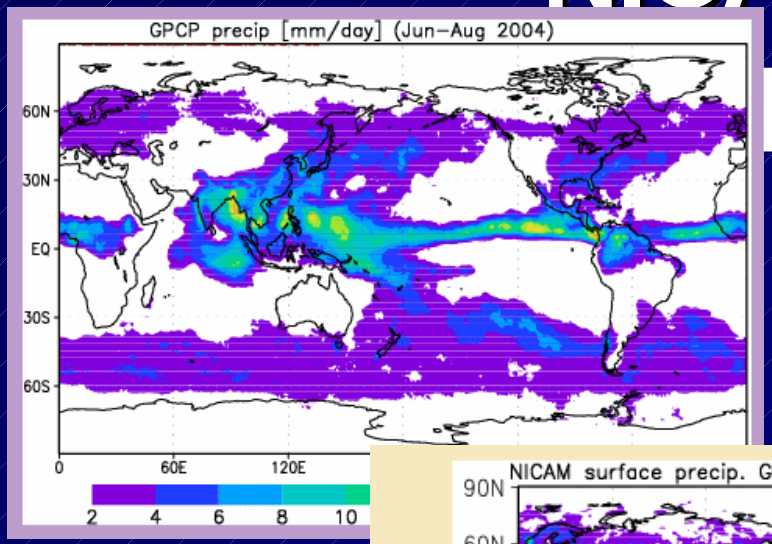
- Contents
  - Possible cause of excessive precipi. over tropics of NICAM
  - Change of amplitude of precipi from 14-km mesh to 7-km mesh
- Major Interests
  - How the difference of horizontal resolution affects on precipi. intensity in GCRM study?
    - Necessary to understand the cause of model biases
    - 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 × 8prosessors × of the Earth Simulator

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

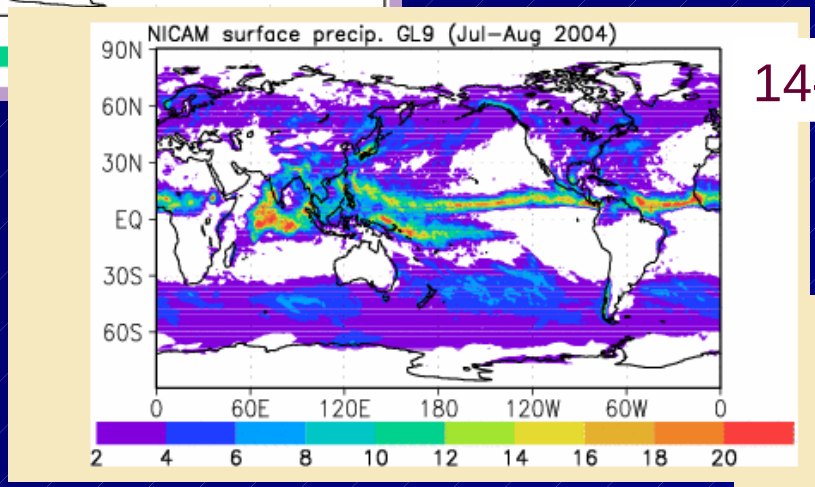
Surface Precipi.
~NICAM vs. GPCP~



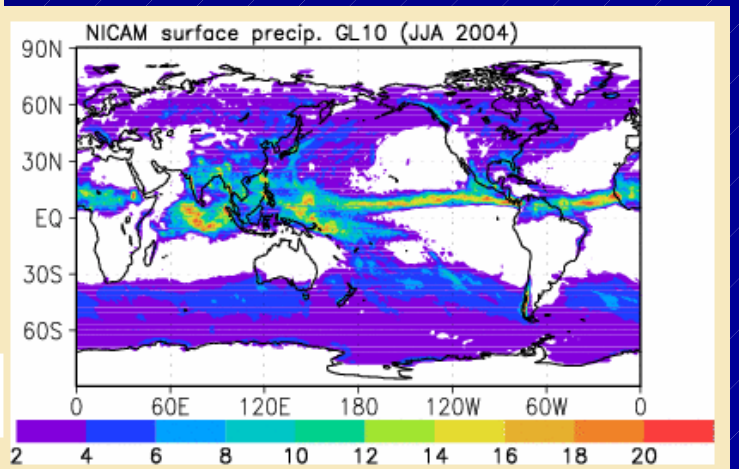
GPCP

Similar distribution of precipi. in space

Agree well with the obs.
Roughly, similar results in 7km and 14km runs



14-km mesh



7-km mesh

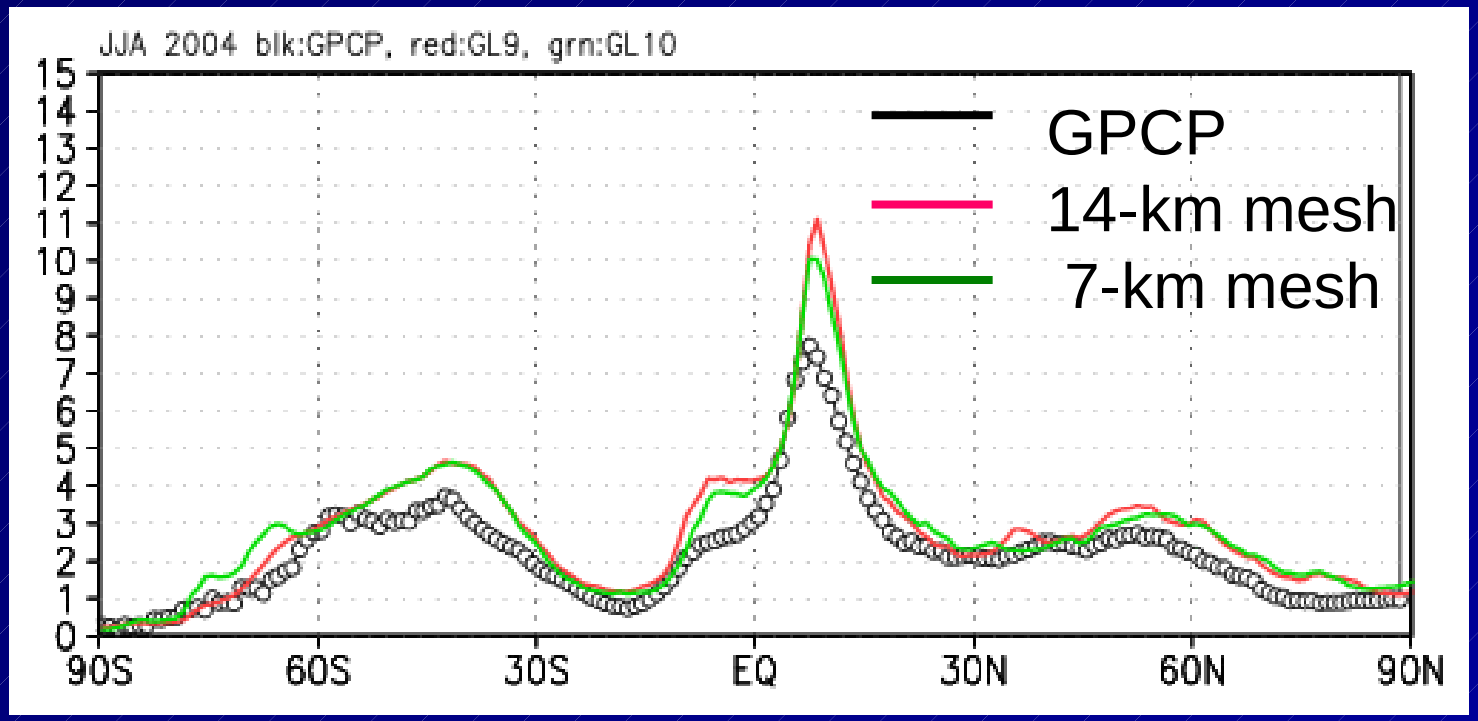
Surface Precipi.
NICAM vs. GPCP

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

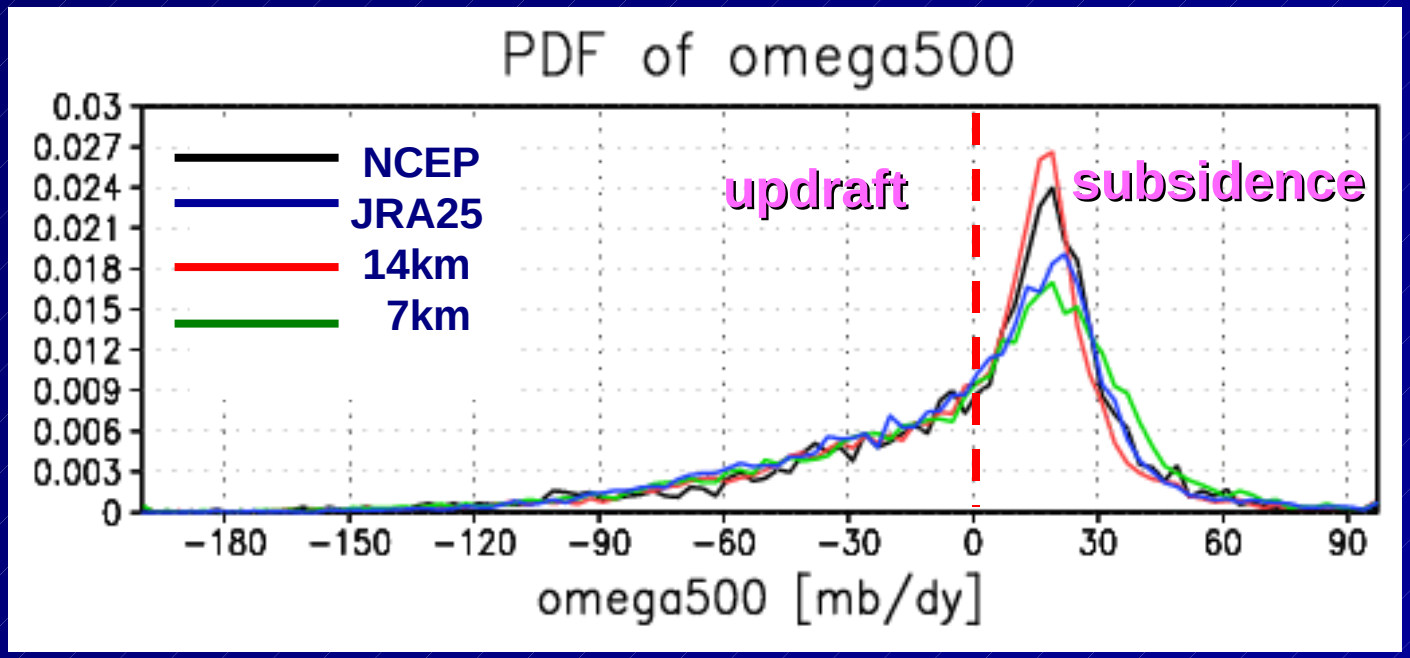


Excessive precipi.
□ PDF of Omega500~

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

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)

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



Excessive precipi.

□ ω □ @ □ 500hPa~

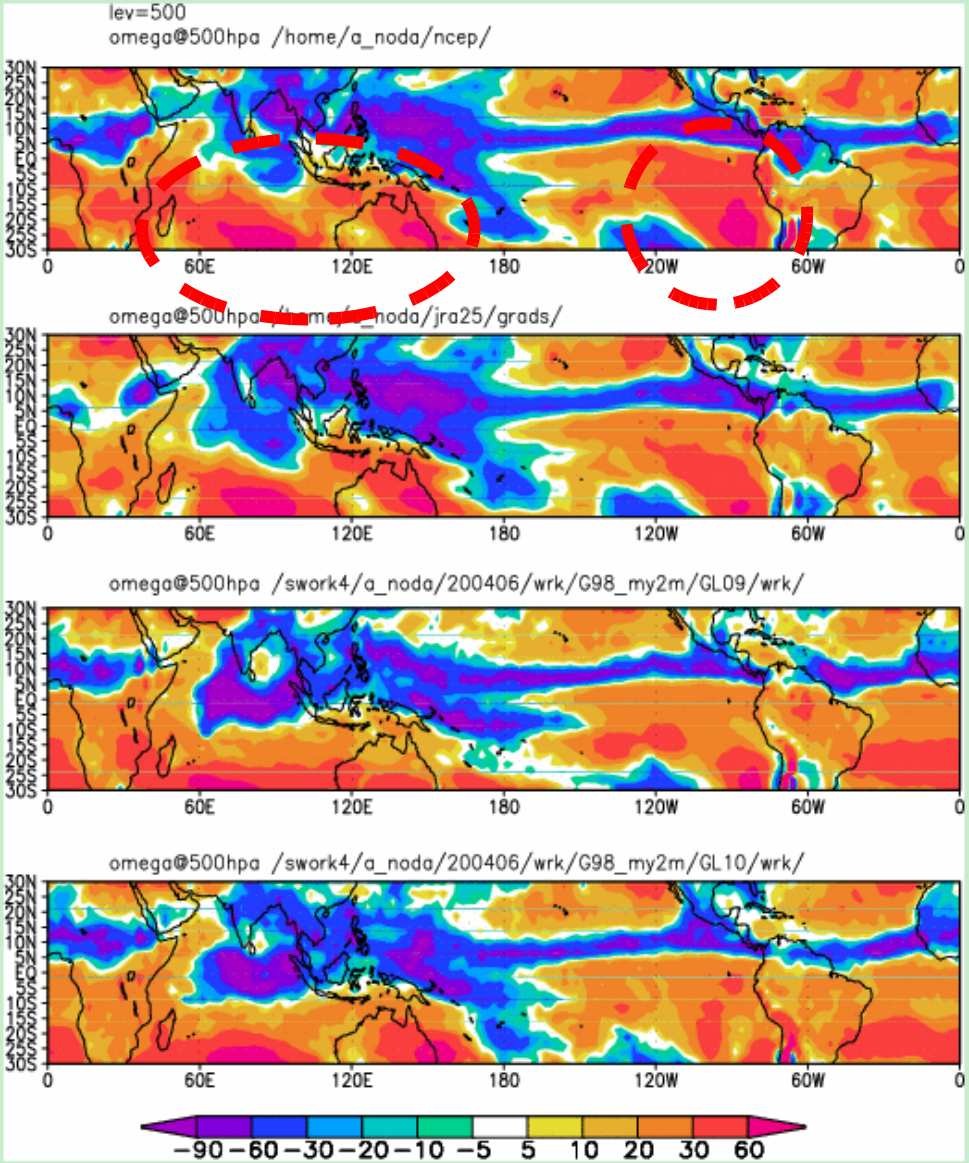
※JJA 2004 30S~30N
Compared in 2.5 deg. resolution

NCEP

JRA25

14km

7km



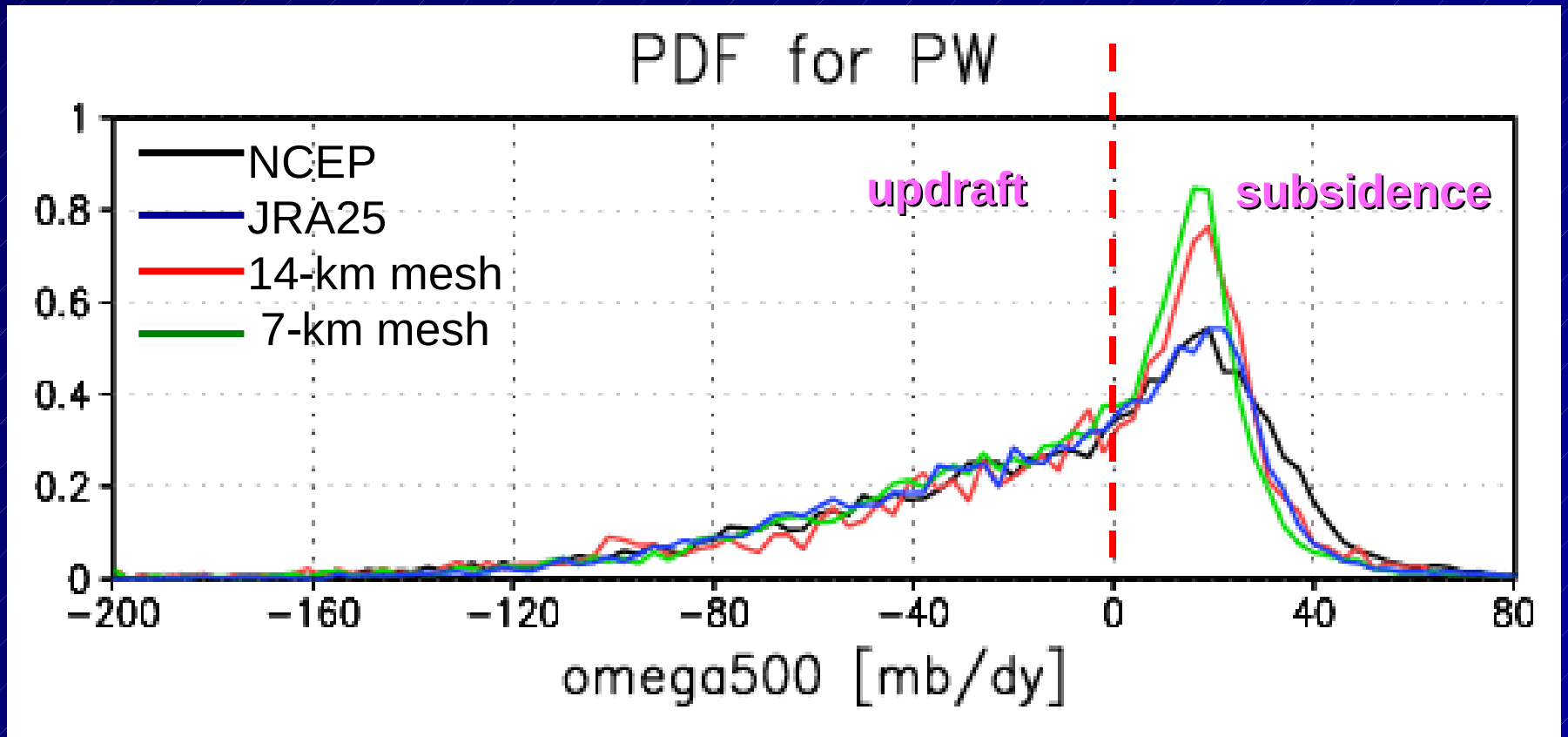
Example of weaker subsidence

Remarkable differences appeared in off the coastal regions and Indian ocean

Excessive precipi.
□ PDF of Precipitable Water~

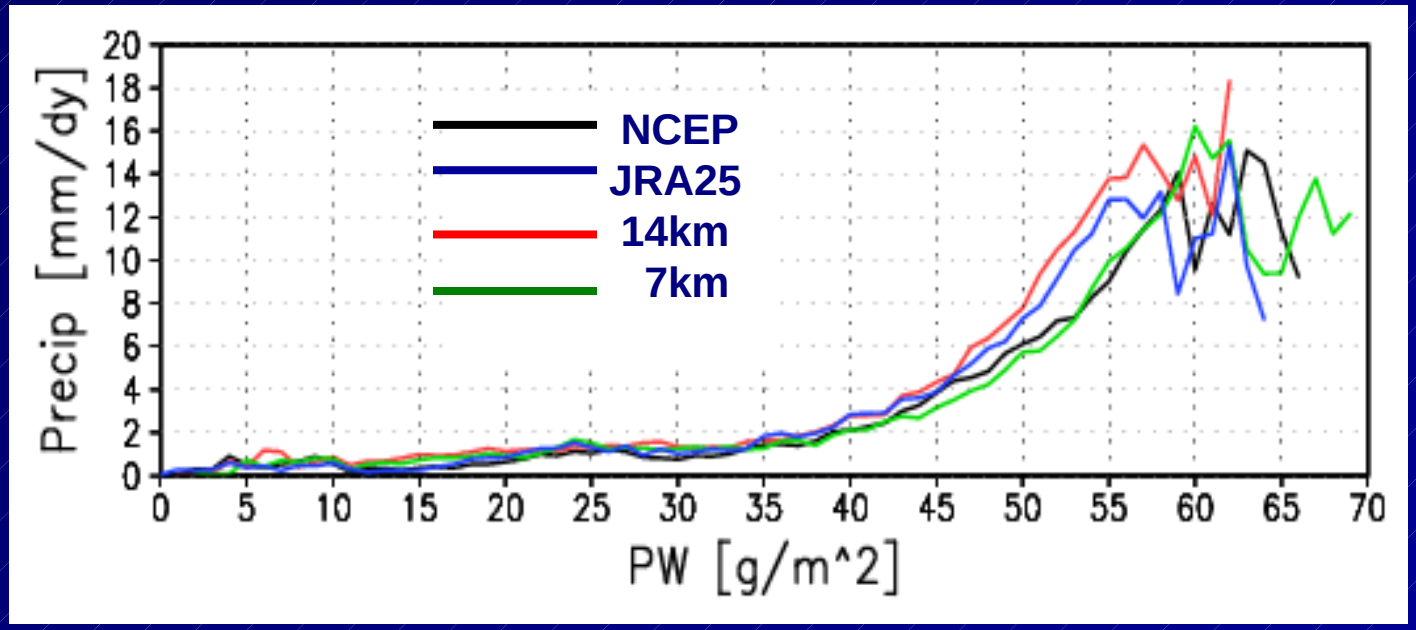
※JJA 2004 30S~30N
Compared in 2.5 deg. resolution

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. □

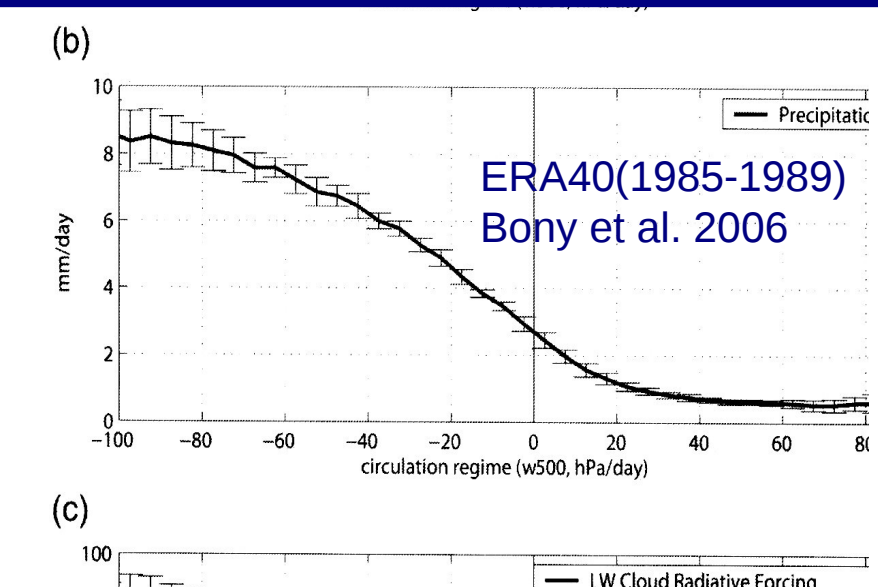
No systematic bias in PW that can explain the excessive precipi. in NICAM

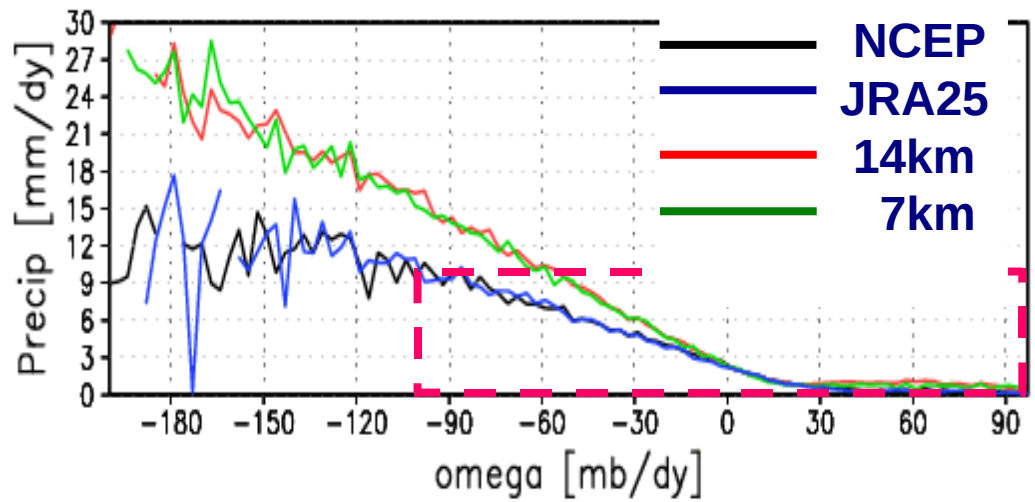


Excessive Precipi.
□ Precipi. vs. Omega500 □

□ 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 preicpi. is intrinsic characteristics in the model,
and may be difficult to expect to reduce the bias solely by using more higher resolution

ω500 vs. Precipi.



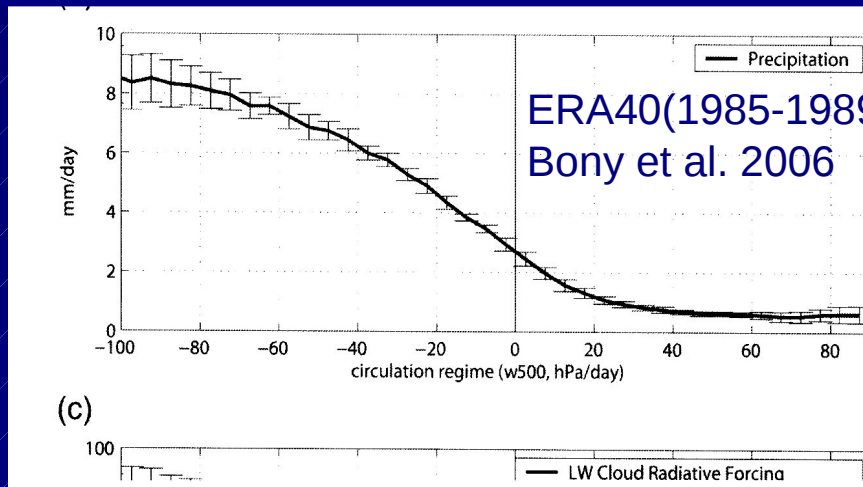


Excessive Precipi.
□ Precipi. Efficiency □

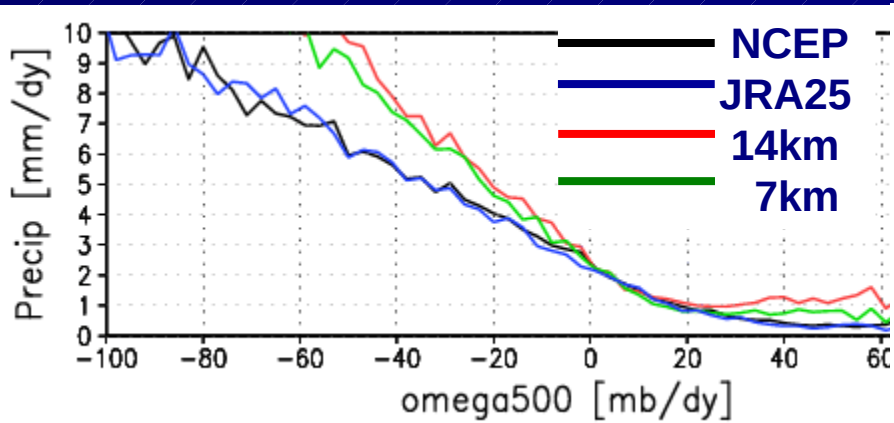
Does the relation □ between ω500 & Precipi. becomes better if ω500 in correspondence with precipi. would be reproduced more accurately?

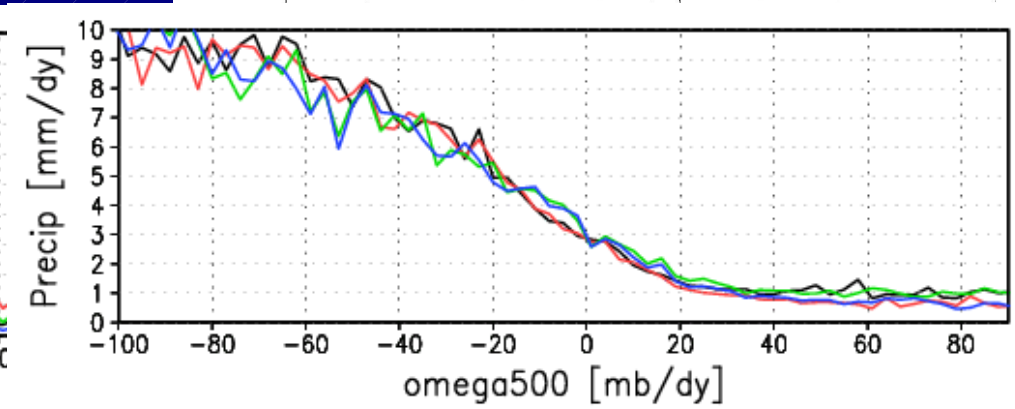
□ The relation (curve) much closer to reanalysis results if replacing with ω500 of reanalysis
→ The model overestimates response of ω to precipi.
→ Excessive precipi. would be reduced if revising, e.g., cloud physics process, i.e., Relation between precipi. and vertical velocity (Precipitation Efficiency) □ (may change of autoconversion rate play a role?)

※Ranges of x- and y-axes are all the same

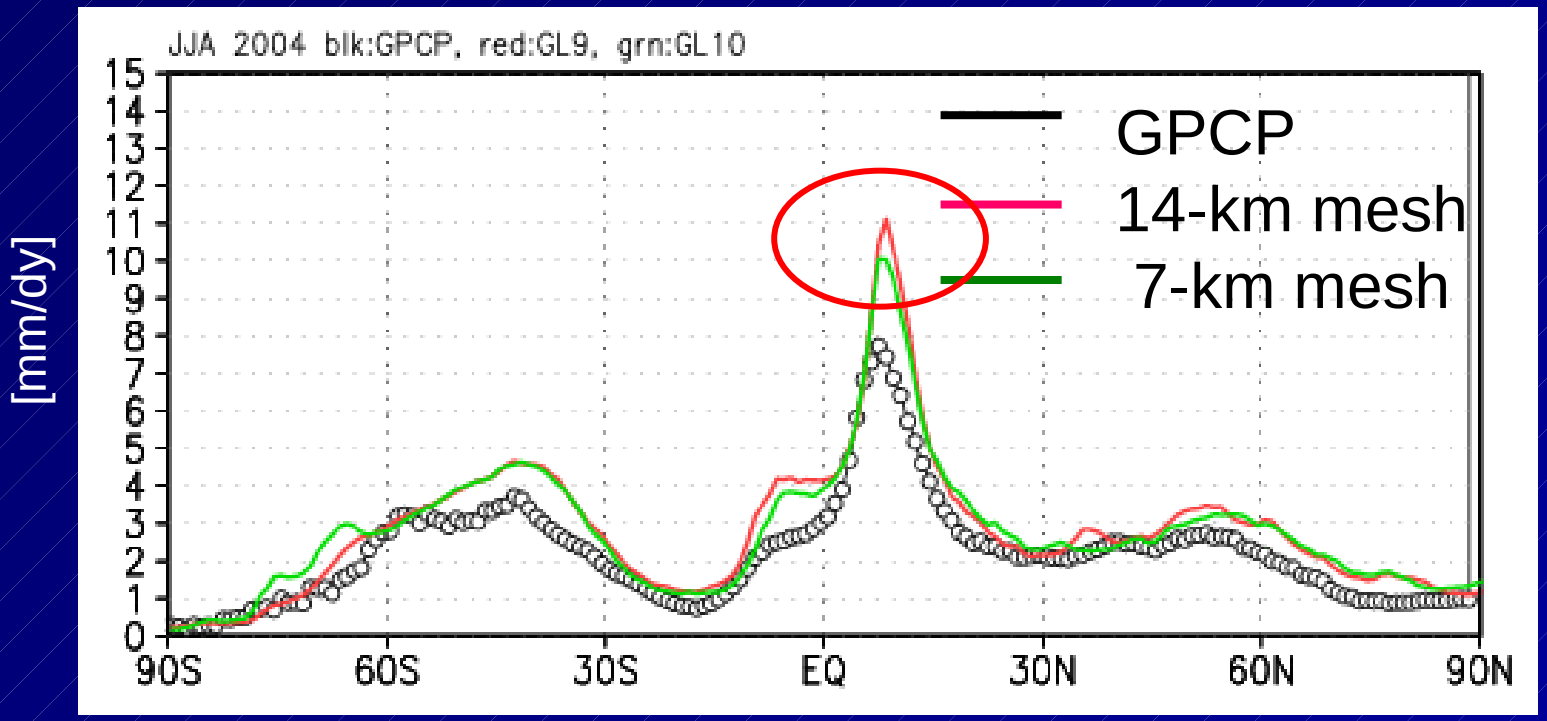


JRA25ω-Precipi(14km)
JRA25ω-Precipi(7km)
NCEPω-Precipi(14km)
NCEPω-Precipi(7km)





Decrease of Max. Precipi. in 7-km mesh against 14-km mesh



Mean meridional circulation [10^{10} kg s^{-1}] （JJA）

14-km mesh　　7-km mesh　　Diff.（7km-14km）

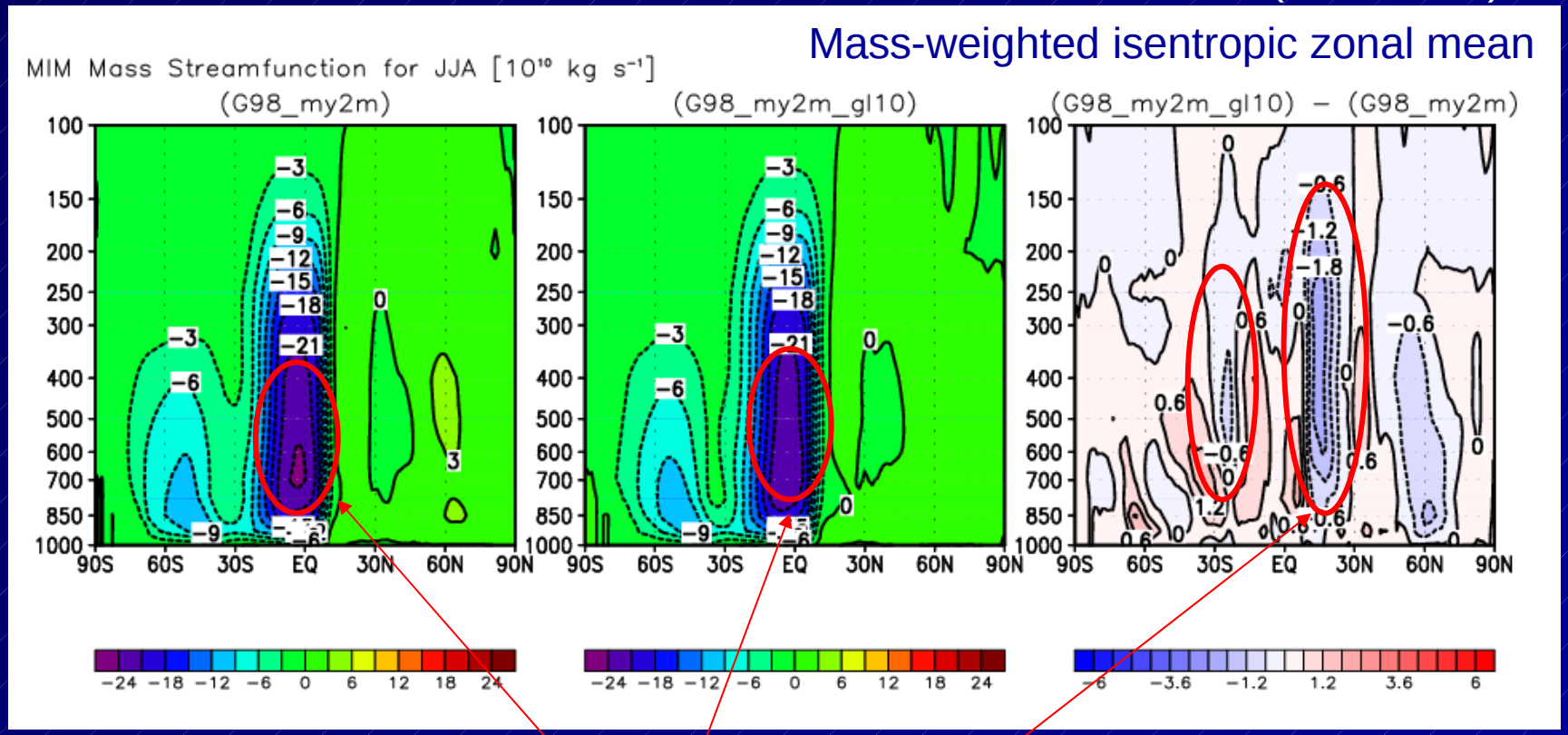


Figure by C.Kodama

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

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 preicipi. (i.e.,precipitation effiency)
  - 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)?