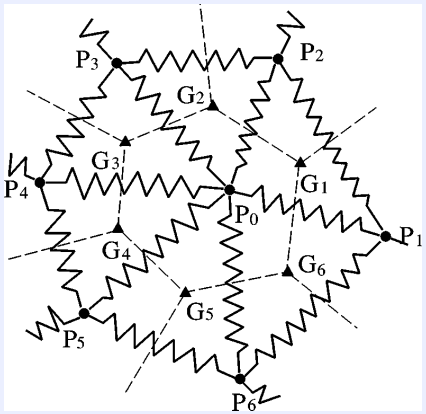
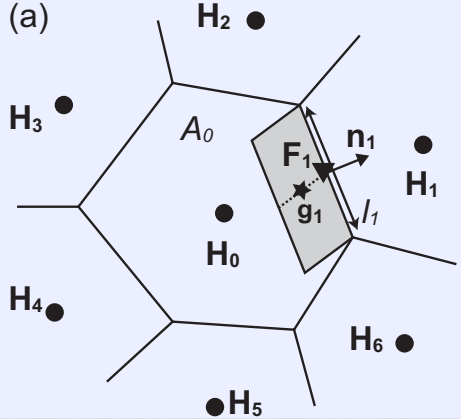
Recent activities of the NICAM group and our science targets on K-computer

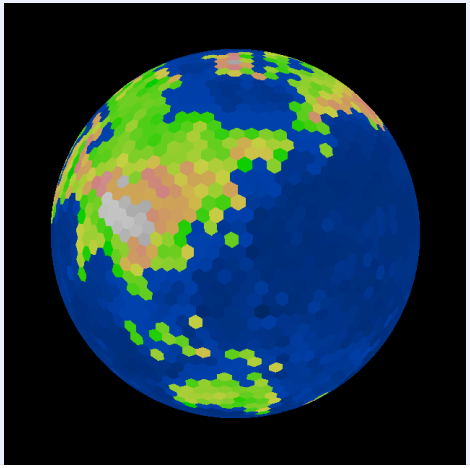
Hiroaki Miura (Univ. of Tokyo)
Masaki Satoh (Univ. of Tokyo)

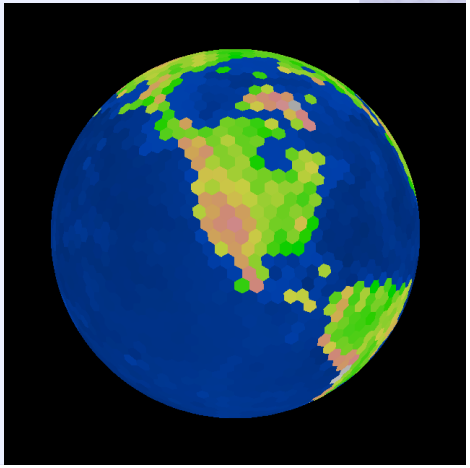
What's NICAM?

- Nonhydrostatic ICosahedral Atmosphere Model
- A global cloud-resolving model
- Icosahedral grid optimized by the spring-dynamics
  - Tomita et al. (2001, 2002)
- A mass, momentum, and total energy conserving scheme
  - Satoh (2002, 2003)
- An upwind-biased transport
  - Miura (2007), Niwa et al. (2010)



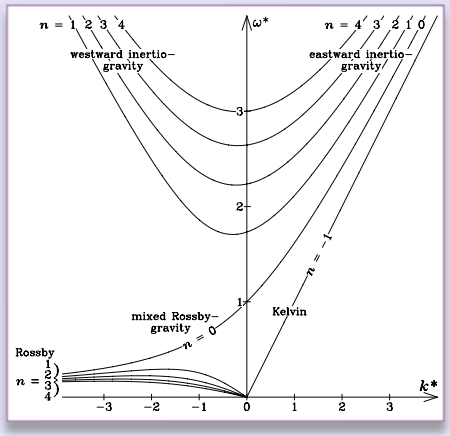






Matsuno's dream

(NIES Web site)



Matsuno (1966)
(Fig. 2 of Kiladis et al. 2009)

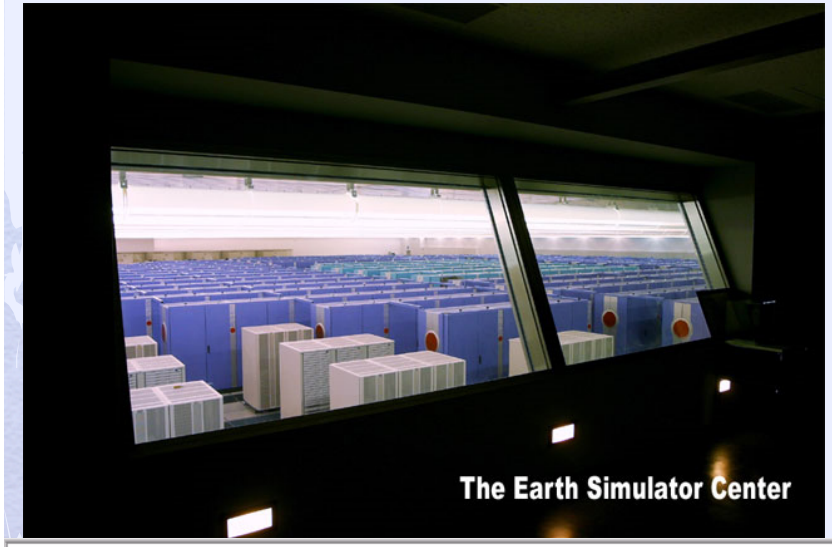
Spontaneous behavior of clouds

- Global circulation model
- dx < 10 km
- no cumulus parameterization

M. Satoh (U. Tokyo)

H. Tomita (AICS, Riken, Kobe)

The Earth Simulator



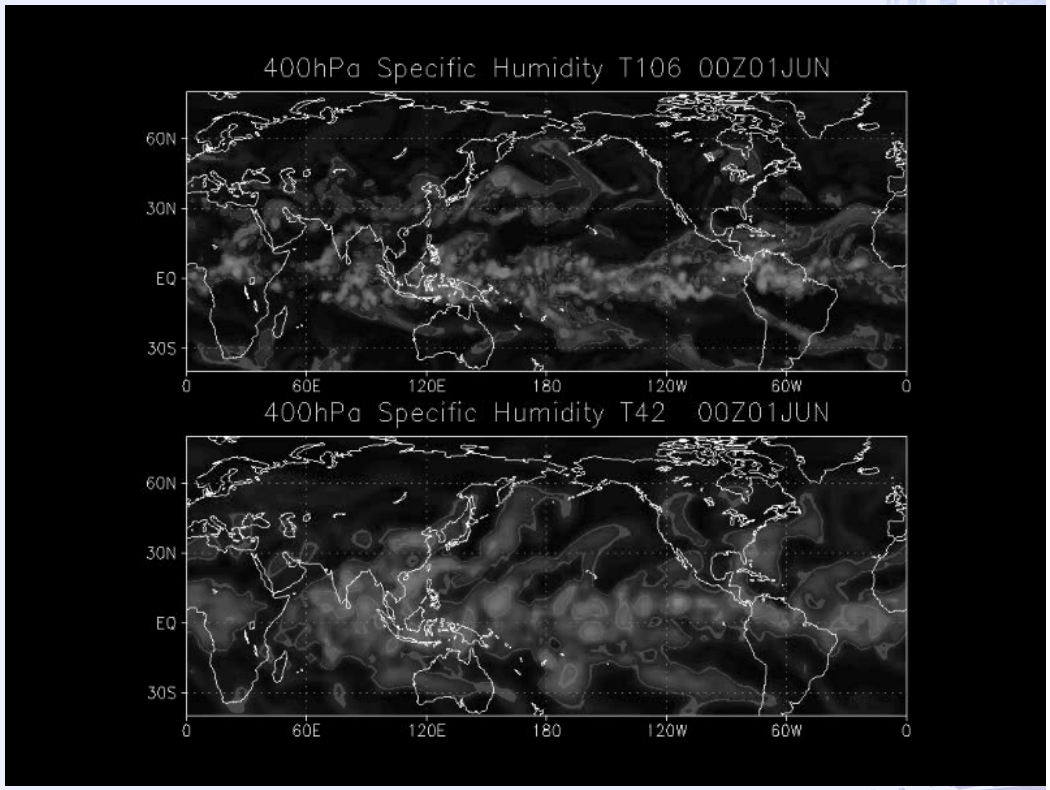
TOP500 List for November 2002

R_{max} and R_{peak} values are in GFlops. For more details about other fields, please click on the button "Explanation of the Fields"

DETAILS EXPLANATION OF THE FIELDS

Rank	Manufacturer Computer/Proce	R_{max} R_{peak}	Installation Site Country/Year
1	**NEC** Earth-Simulator/ 5120	**35860.00** 40960.00	Earth Simulator Center Japan/2002
2	**Hewlett-Packard** ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096	**7727.00** 10240.00	Los Alamos National Laboratory USA/2002
3	**Hewlett-Packard** ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096	**7727.00** 10240.00	Los Alamos National Laboratory USA/2002
4	**IBM** ASCI White, SP Power3 375 MHz/ 8192	**7226.00** 12288.00	Lawrence Livermore National Laboratory USA/2000
5	**Linux NetworX** MCR Linux Cluster Xeon 2.4 GHz - Quadrics/ 2304	**5694.00** 11060.00	Lawrence Livermore National Laboratory USA/2002

dx~110 km MIROC model



dx~250 km

Back to 2000~2002

- Spectral method would not be efficient.
  - High-resolution
  - Massive parallel machines
- Only one icosahedral grid model
  - Z-grid (Heikes and Randall 1995)
- Poisson solver would not work.
- Arakawa C-grid on hexagons? (Nicovic et al. 2002)
- Discontinuous Galerkin?
- O(km) grid was “cloud-resolving”.

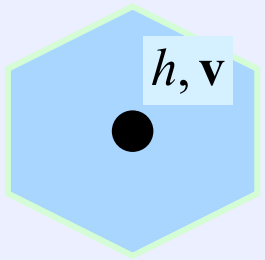
We know

- ECMWF spectral model is fast for ~T4000 on parallel machines.
- Multi-grid method is efficient for more than 80,000 cores (CSU).
- Thuburn et al. (2009) and Gassmann (2012)
- SE or DG is a choice.
- O(km) gird is not enough.

Dynamics

Highest priority on efficiency and conservation

- Icosahedral grid (hexagonal/pentagonal cells)
- Arakawa A-grid arrangement
  - No Poisson solver
- Finite-volume method
- Minimum stencils
  - 2^{nd}-order centered spatial discretizations



Governing equations	**Fully compressible non-hydrostatic system**
Spatial discretization **Horizontal grid configuration** **Vertical grid configuration** **Topography**	**Finite Volume Method (Tomita et al. 2001,2002)** **Icosahedral grid** **Lorenz grid** **Terrain-following coordinate**
Conservation	**Total mass, total energy (Satoh 2002,2003)**
Temporal scheme	**Slow mode － explicit scheme （RK2, RK3）** **Fast mode － Horizontal Explicit Vertical Implicit scheme**
Advection scheme	**Conservative and monotonic** **Miura (2007), Niwa et al.(2011)**

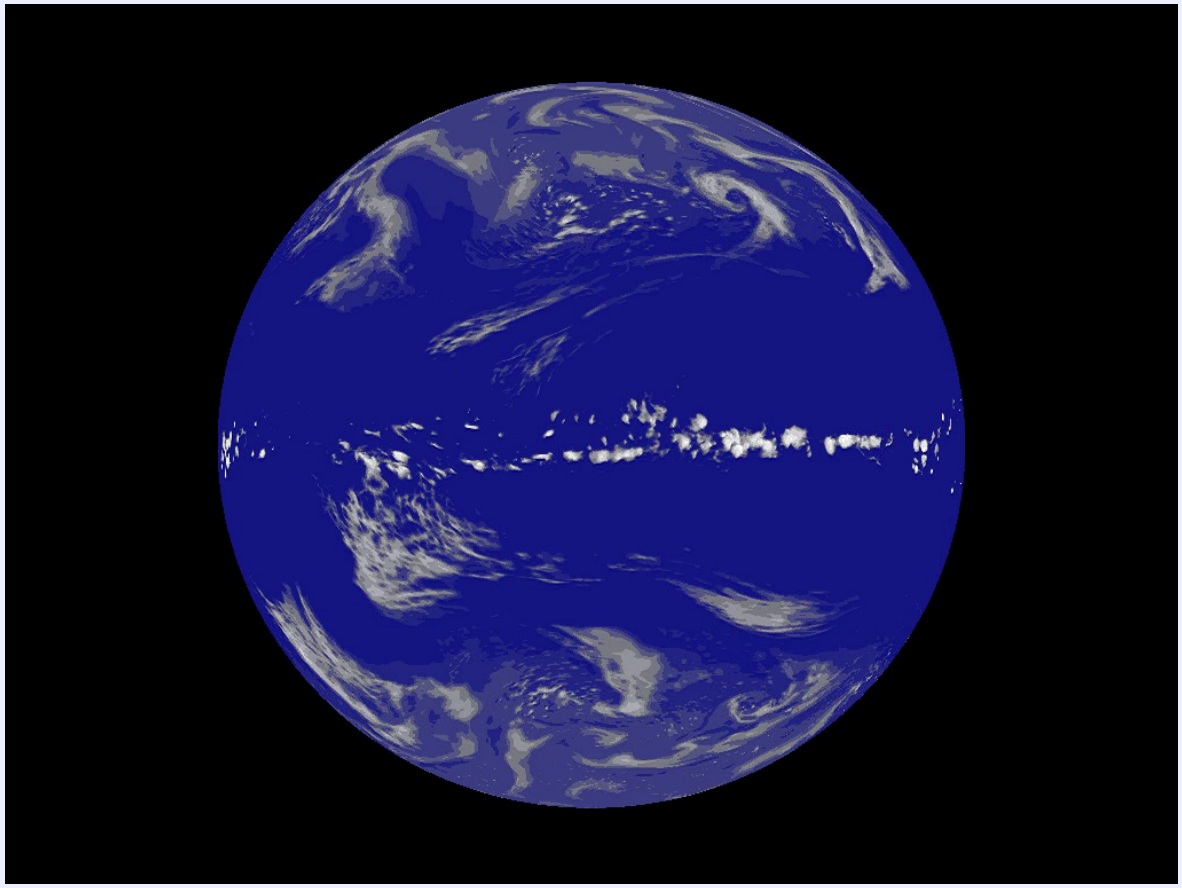
Physics

Turbulence, surface flux	MYNN(Nakanishi and Niino 2004; Mellor & Yamada 2,2.5,3) Louis(1979), Uno et al.(1995) Moon et al. (2007)
Radiation	MSTRNX (Sekiguchi and Nakajima, 2008)
Cloud physics	Kessler Grabowski(1998) Lin et al.(1983) NSW6(Tomita 2008) NDW6(Seiki et al. 2011) WSM3-6 (Hong et al. 2004)
Subgrid convection	Prognostic AS Kuo, Chikira (Chikira and Sugiyama 2010) Tiedtke (1989)
Land and sea processes	Mixed layer/bucket MATSIRO (Takata et al. 2003)

Slab ocean

Aquaplanet

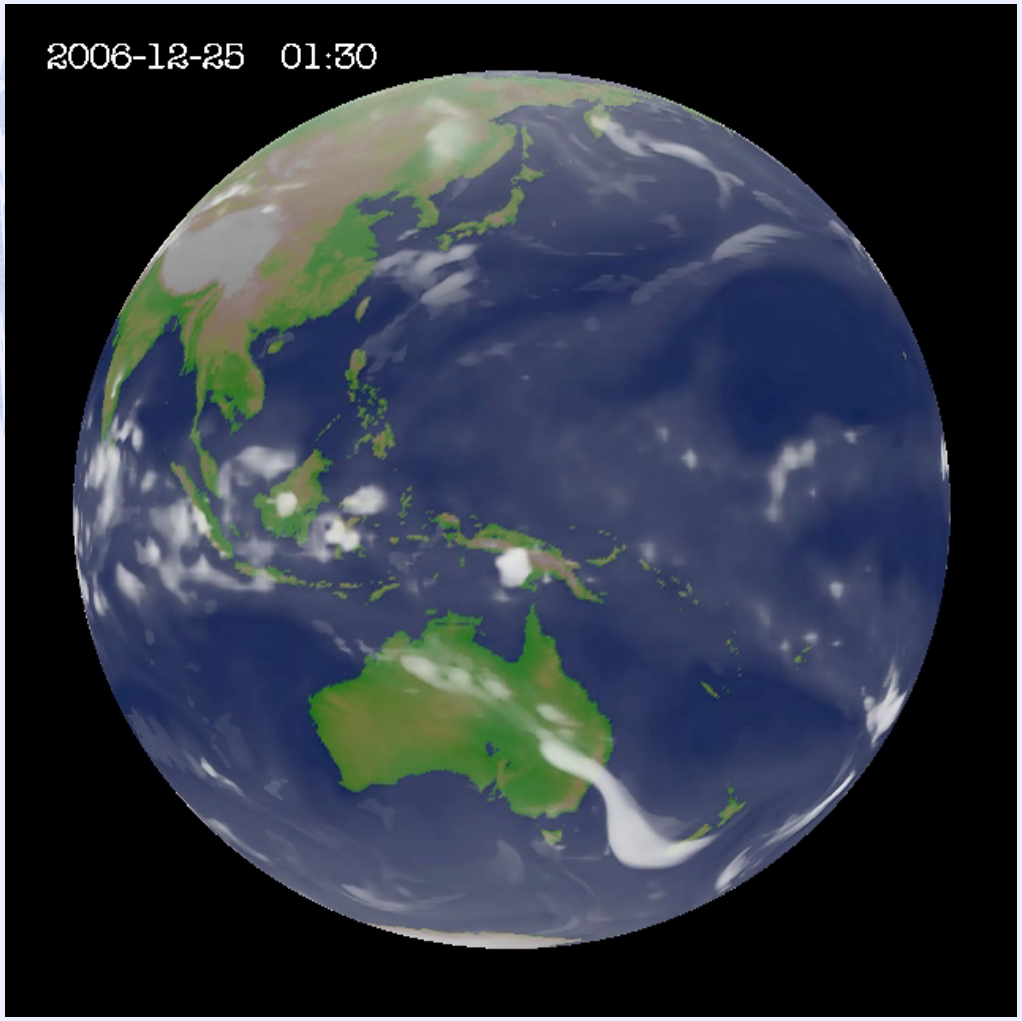
Tomita et al. (2005)



CRM framework can simulate spontaneous organization of clouds if it is used over the globe.

MJO

Miura et al. (2007)

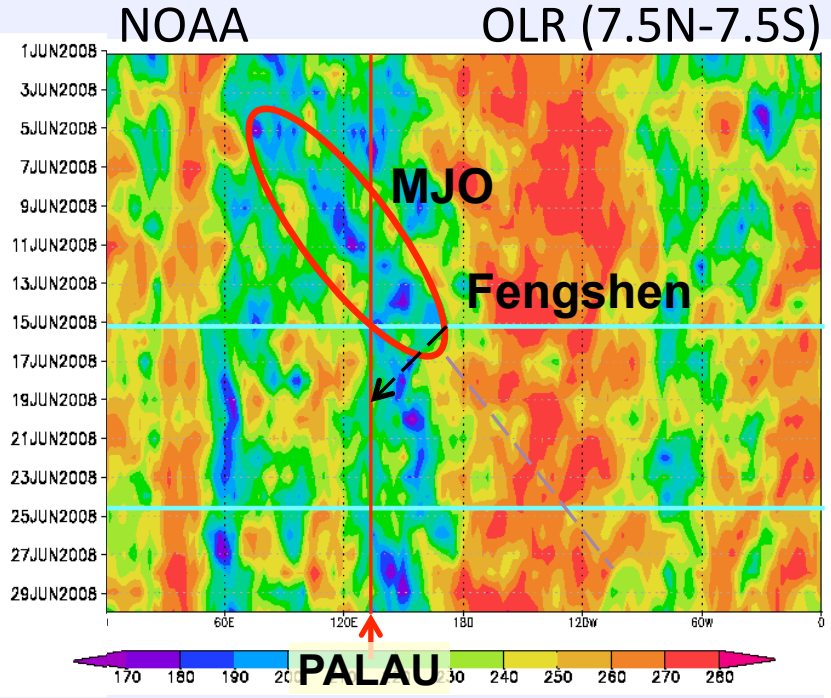


Cloud systems in GCRMs possibly have some reality.

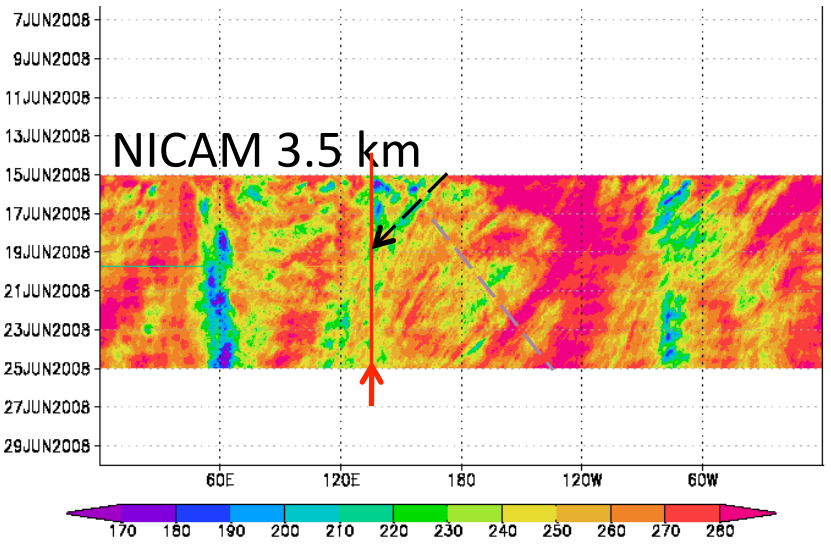
What followed?

- Typhoon Fengshen (YOTC)
- Satellite simulator
- Comparison with ECMWF IFS (the Athena project)
- Comparison with JMA GSM

Global cloud-resolving simulation of YOTC period #1



Nasuno et al. (to be submitted)
Yamada et al. (to be submitted)



Horizontal grid spacing: **14 km, 3.5 km**

Vertical domain: 0 m ~ 38,000 m (40-levels)

Integration: **10 days from 00UTC 15 Jun 2008**

Initial data: **ECMWF YOTC Operational data**

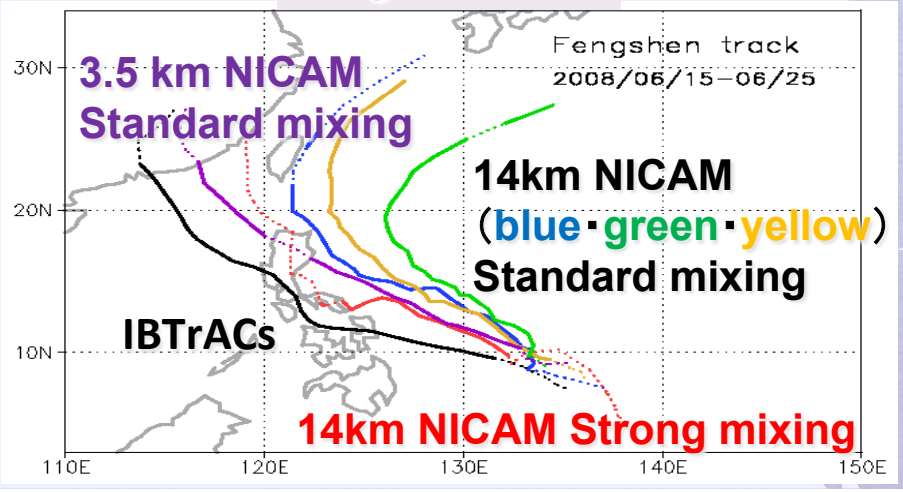
NCEP final analysis (land surface, SST)

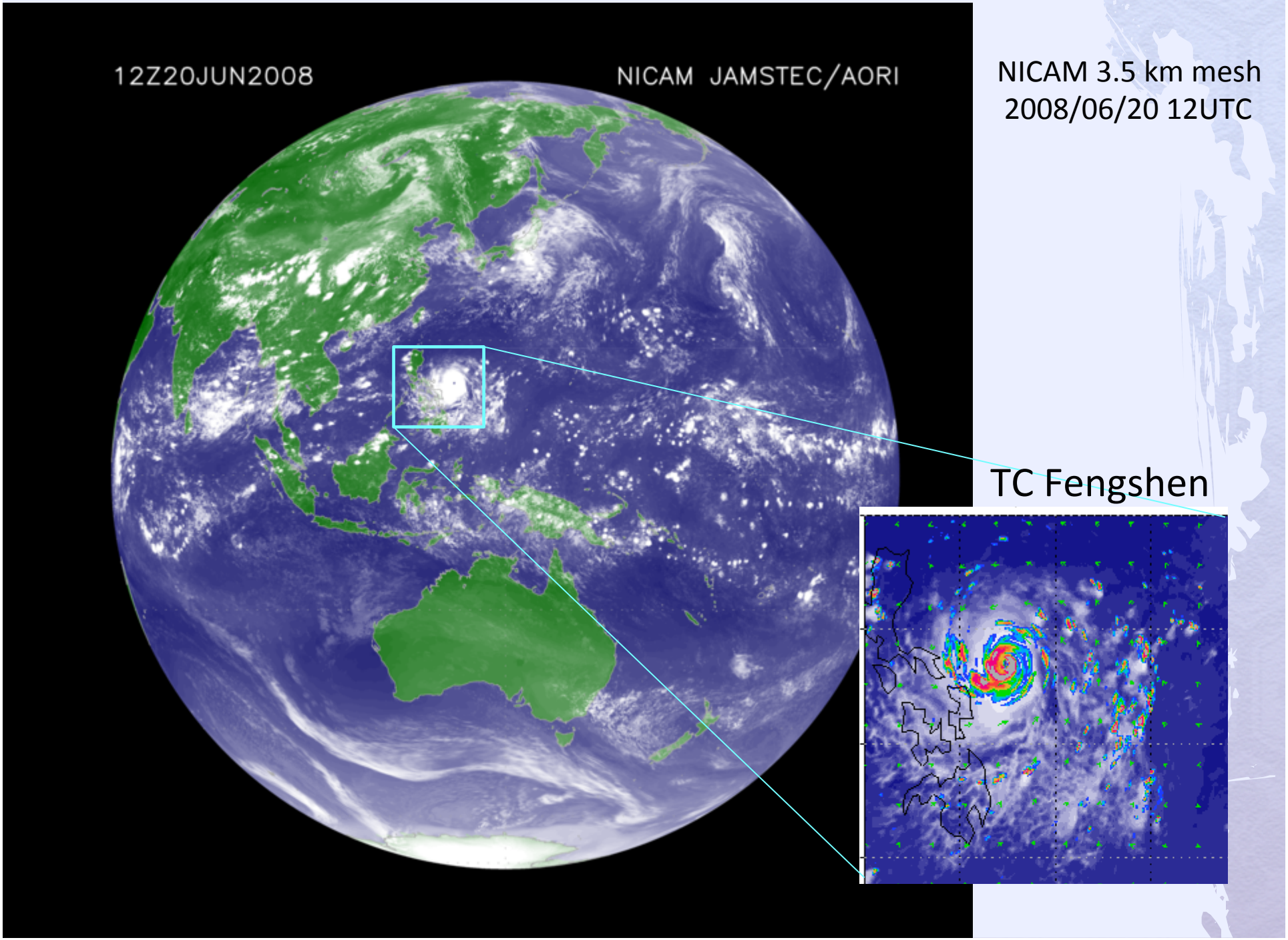
Boundary conditions: **slab ocean**

(nudging to Reynolds weekly SST)

➢ Fengshen formed on **17 Jun 2008**

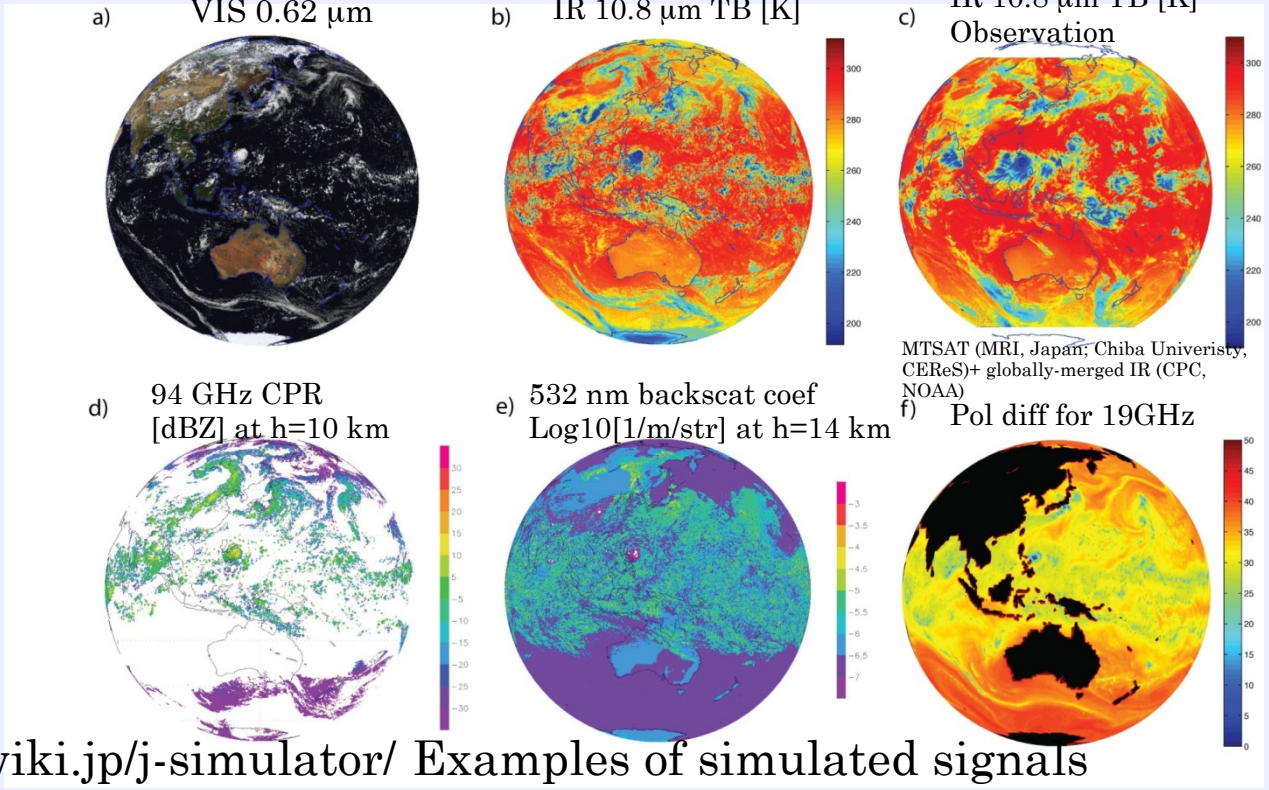
Fengshen track




12Z20JUN2008
NICAM JAMSTEC/AORI
NICAM 3.5 km mesh
2008/06/20 12UTC
TC Fengshen

J-simulator (Joint Simulator for Satellite Sensors) by T. Hashino and the EarthCARE team

- Simulate EarthCARE (2014) from CRM outputs.
- Satellite Data Simulator Unit (SDSU)
  Masunaga et al. (2010, BAMS)
- Extension by NASA/Goddard with Goddard-SDSU
  (T. Matsui and NASA GPM team)

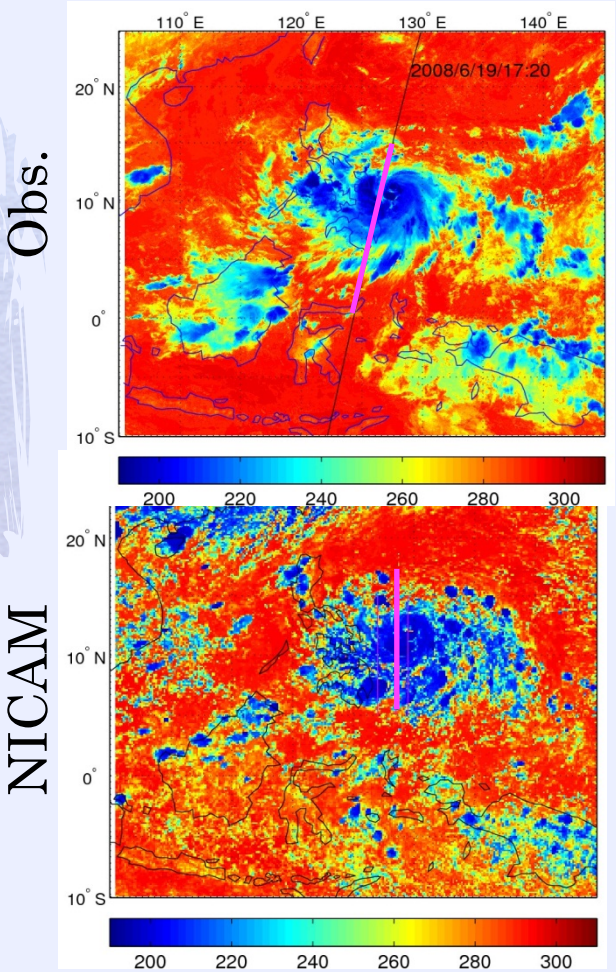


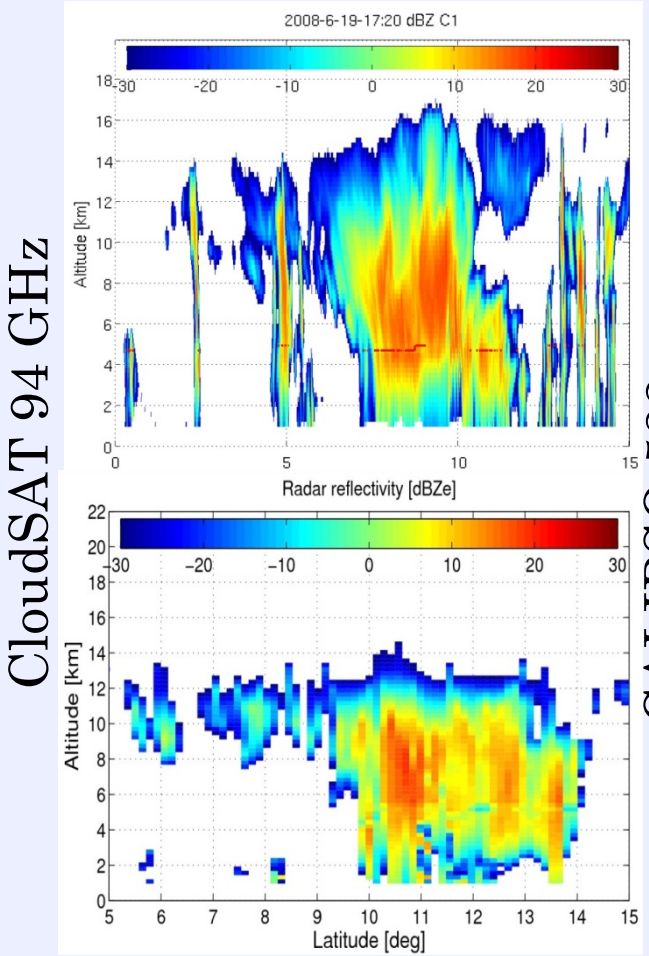
Joint Simulator for Satellite Sensors J-Simulator

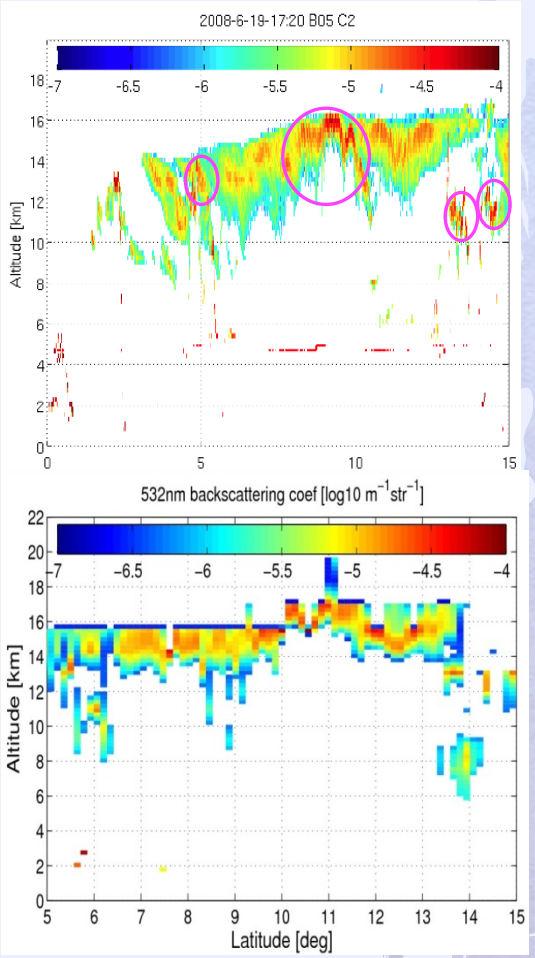
http://www22.atwiki.jp/j-simulator/ Examples of simulated signals

Example: Tropical Cyclone

MTSAT IR T_b (10.8 μm)







OBS:

- Bright band exists.
- High β_{532} above convective cores.
- Overlap regions of C1 and C2 mask exist.

NICAM:

- Bright band exists.
- Low cloud top for C1, but high for C2.
- Few overlap regions of C1 and C2 mask exist

The Athena Project

COLA, ECMWF, JAMSTEC, University of Tokyo, NICS, Cray

List of experiments

NICAM 7km
dt=30sec

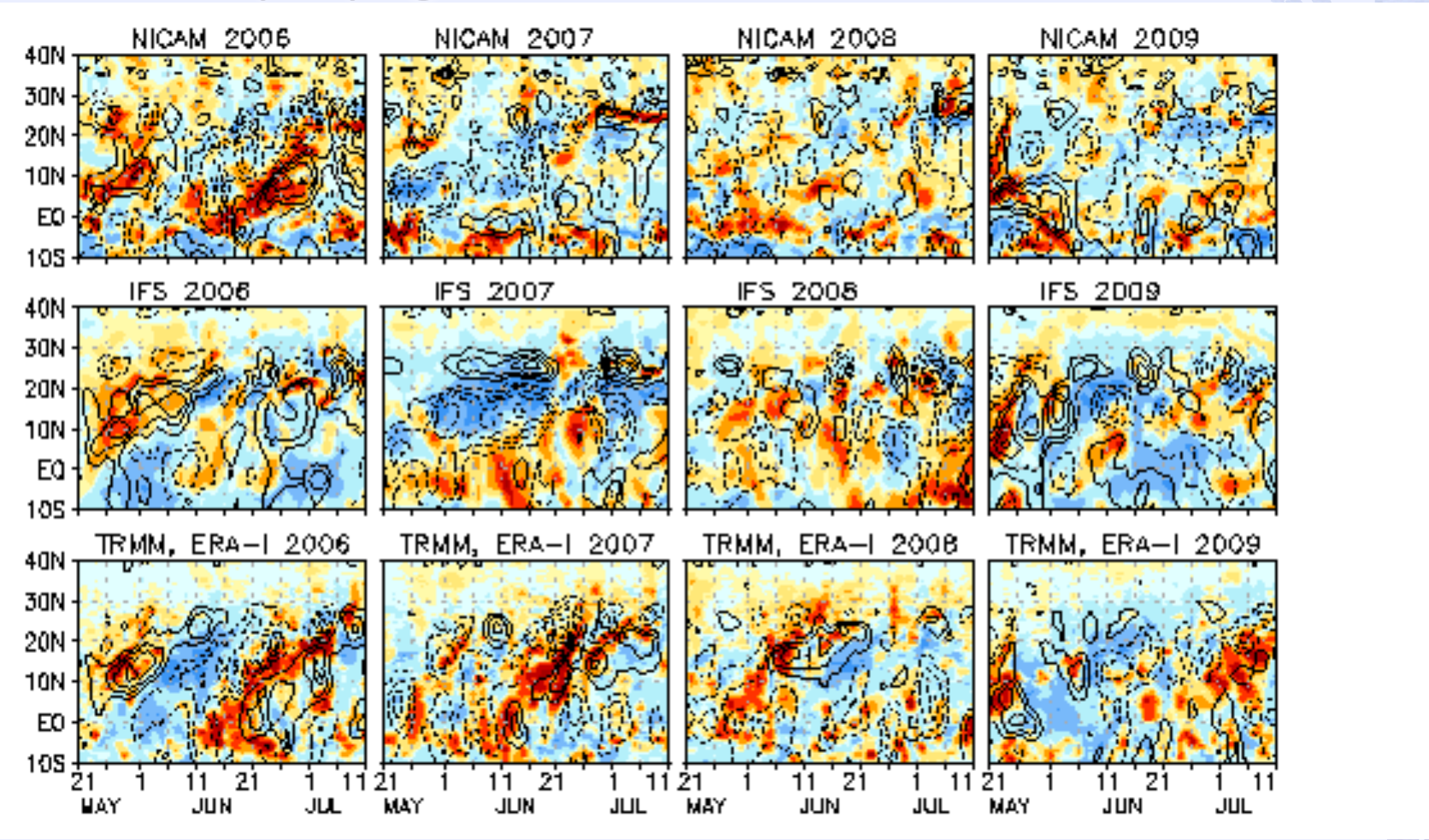
Model/Exp.	Resolution	# Cases	Period	Notes
NICAM / Hindcasts	7 km	8	103 days	21 May - 30 Aug 2001 - 2009
IFS / Hindcasts	125 km 39 km 16 km	48	395 days	1 Nov - 30 Nov (following year) 1960 - 2007
IFS / Hindcasts	10 km	20		1 Nov - 30 Nov (following year) 1989 - 2007
IFS / Hindcasts	125 km 39 km 16 km 10 km	9	103 days	21 May - 30 Aug 2001 - 2009 NICAM analogs
IFS / Summer Ensembles	39 km 16 km	6	132 days	21 se
IFS / Winter Ensembles	39 km 16 km	6	151 days	1 se
IFS / AMIP	39 km 16 km	1	47 years	1961 - 2007
IFS / Time Slice	39 km 16 km	1	47 years	2071 - 2117

IFS 10km
dt=450sec

http://wxmaps.org/athena/home/

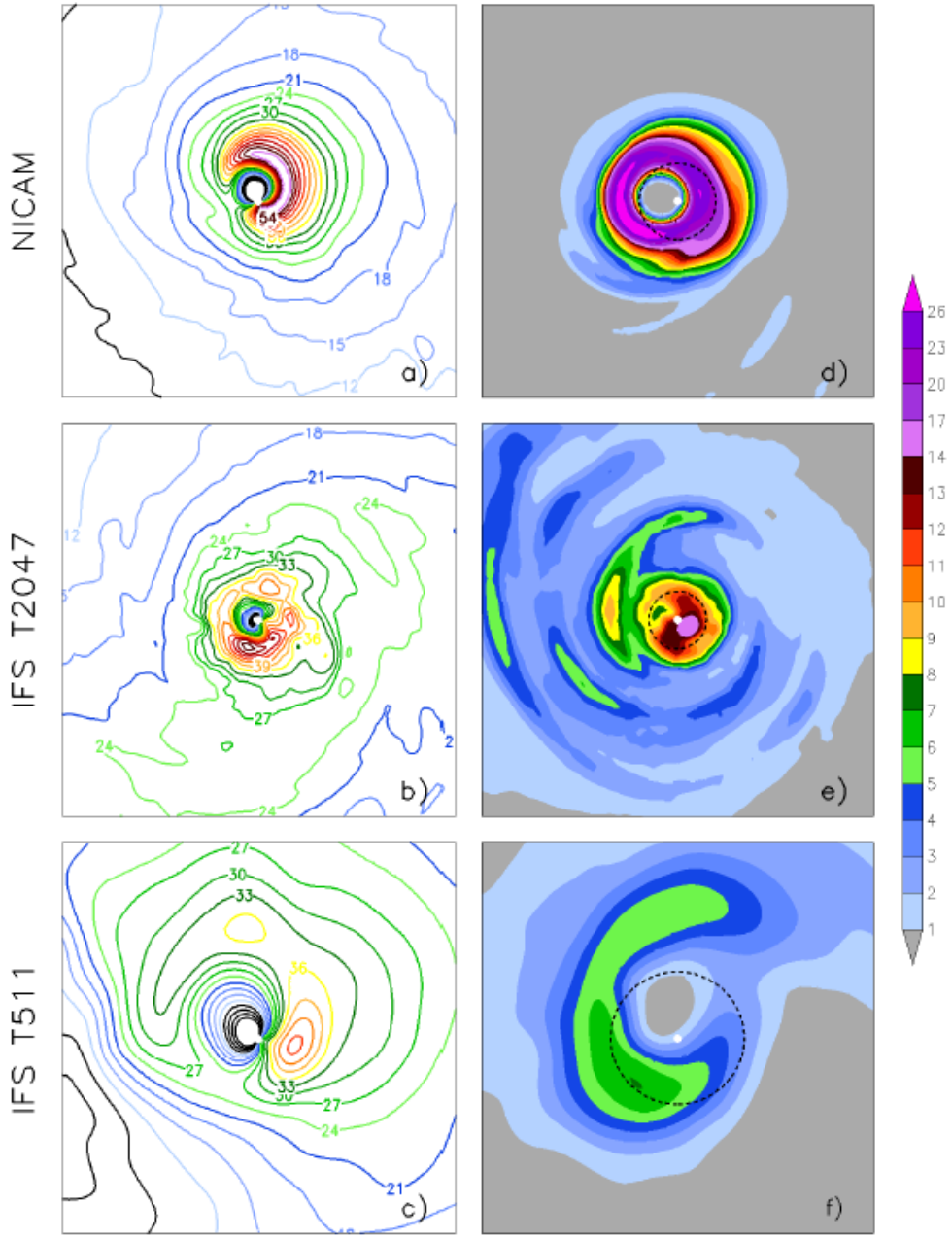
Kinter et al.(2011,submitted)

Northward propagation of ISV in the Indian ocean



Time-latitude sections of anomalous 60-90E average surface precipitation (color) and zonal wind at 850 hPa (contour lines in the initial 52 days of NICAM (top) and IFS (middle) simulations in comparison with TRMM–3B42 and ERA–Interim data (bottom). The anomalies from the 8-year average (Fig. 2) are plotted. Contour intervals for zonal wind are 2 m s^{-1}(solid: positive, broken: negative). Zero contour lines are omitted.

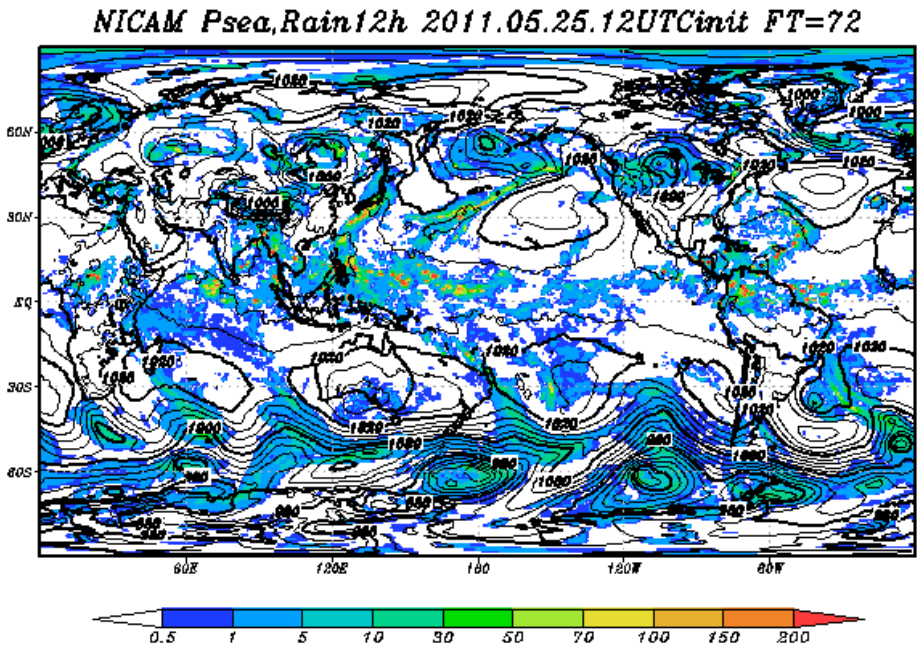
Most intensive Tropical cyclone structure

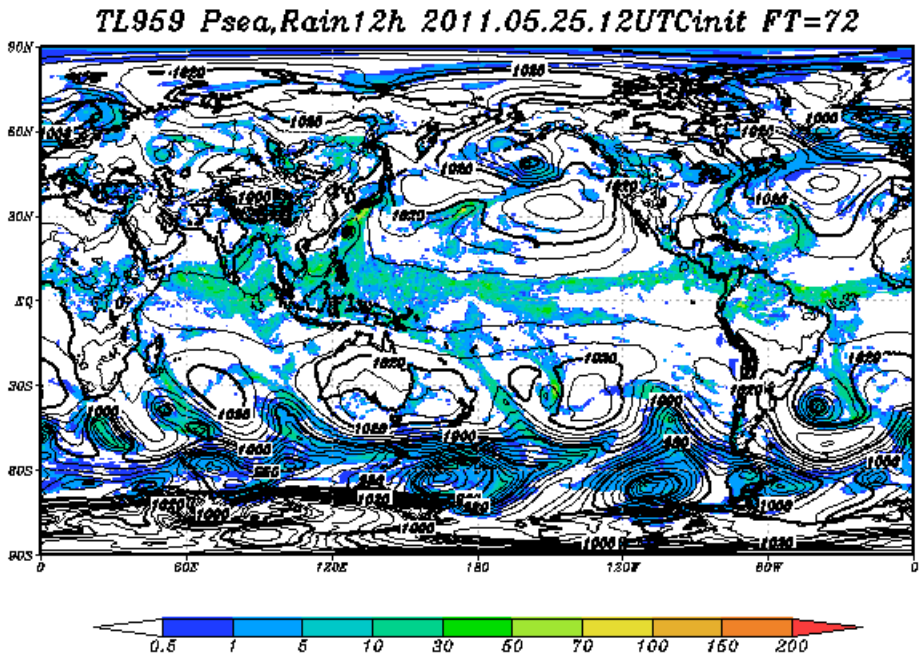


Distributions of 10m tangential wind (left panels; m s^-1) and total column liquid water and ice (TCLWI; right panels; kg m^-2) for the most intense TCs at the peak of their intensity from the NICAM simulation (panels a and d, labeled “NICAM”), the IFS 10---km simulation (panels b and e, labeled “T2047”), the IFS 39km simulation (panels c and f, labeled “T159”), respectively. Radius is 2°Contour interval is 3 m s^1 for wind Dashed black contours in panels d, e and f show the radius of maximum winds for each case with respect to the center of the storm determined from the location of maximum vorticity at 925 hPa (1000 hPa for the IFS cases).

Kinter et al.(2011)

NICAM and JMA-GSM (HITACHI SR11000)





- NICAM dx=28km
  - 10nodes
  - 150min for 72h forecast
    (~25min if 60 nodes)
  - dt=150sec

- JMA-GSM dx=20km
  - 60 nodes
  - 25min for 84h forecast
  - dt=10min (600sec)

What's next?

K-computer (AICS, Riken, Kobe)

TOP500 List - June 2012 (1-100)

R_{max} and **R_{peak}** values are in TFlops. For more details about other fields, check the TOP500 description.

Power data in KW for entire system

next

Rank	Site	Computer/Year Vendor	Cores	R_{max}	R_{peak}	Power
1	DOE/NNSA/LLNL United States	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom / 2011 IBM	1572864	16324.75	20132.66	7890.0
2	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect / 2011 Fujitsu	705024	10510.00	11280.38	12659.9

Priority use from 30 July, 2012

Formal operation from September, 2012

CINDY/DYNAMO

An observation campaign operated by JAMSTEC.

The joint project with DYNAMO.

What's New?

- 2012.03.06: "Weather" page is updated("Satellite","In Situ","Reanalysis")
- 2012.01.31: Meeting information is updated
- 2012.01.10: MIRAI Cruise report is up (Main, Appendix A, Appendix B)
- 2011.12.26: Baruna Jaya III Cruise Report is up
- 2011.11.22: A report from Seychelles is available
- 2011.10.01: CINDY2011 Intensive Observing Period starts.
- 2011.08.15: Mirai departed Japan
- 2011.08.18: Mirai Operation Plan (revised)
- 2011.06.01: CINDY2011 Science Plan (revised)
- 2011.04.04: Release of CINDY2011 Official Logo

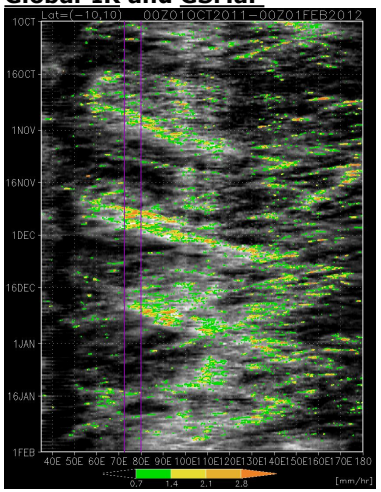
About CINDY2011

Background

Madden-Julian Oscillation (MJO), which is the dominant intraseasonal mode in the tropics, is known as a phenomenon which has a strong impact on not only the tropical climate but also the global climate through the interaction with El Nino, monsoon, tropical cyclone genesis, and so on.

CINDY2011 Summary

Global-IR and GSMaP



and more...

[RMM1,RMM2] phase space (by BOM)

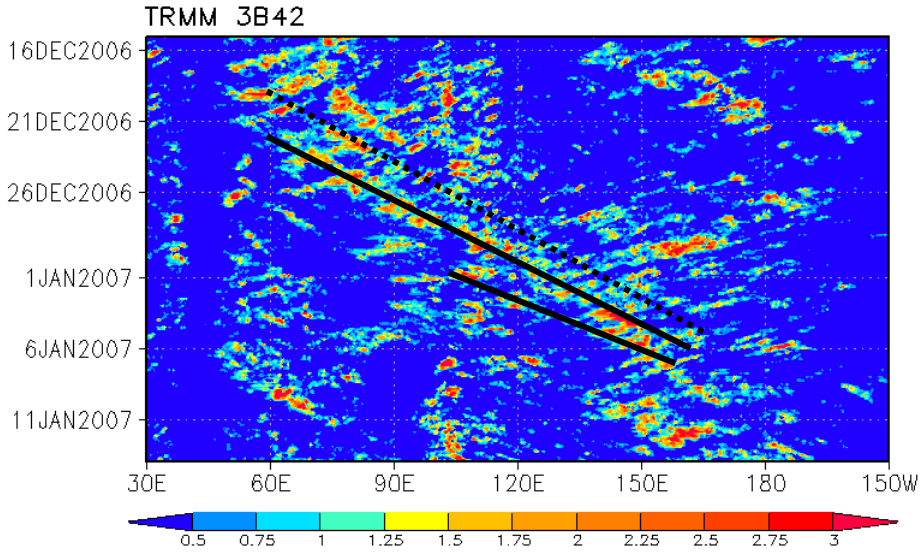
01OCT2011- 31JAN2012

OCT2011-
JAN2012
3 MJO events

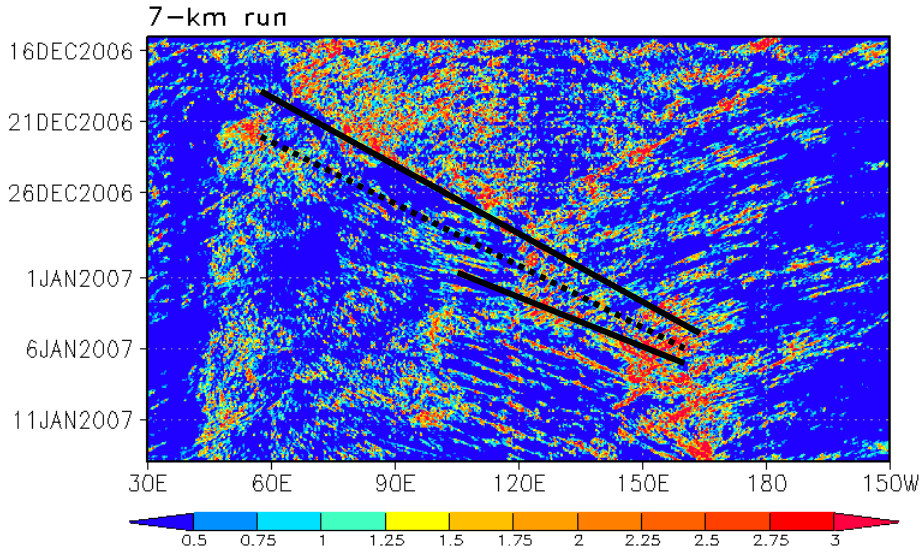
Eastward movement

Miura et al. (2007)

TRMM 3B42: average from 5S to 5N



NICAM: average from 5S to 5N



2006-12-15 to 2007-01-14

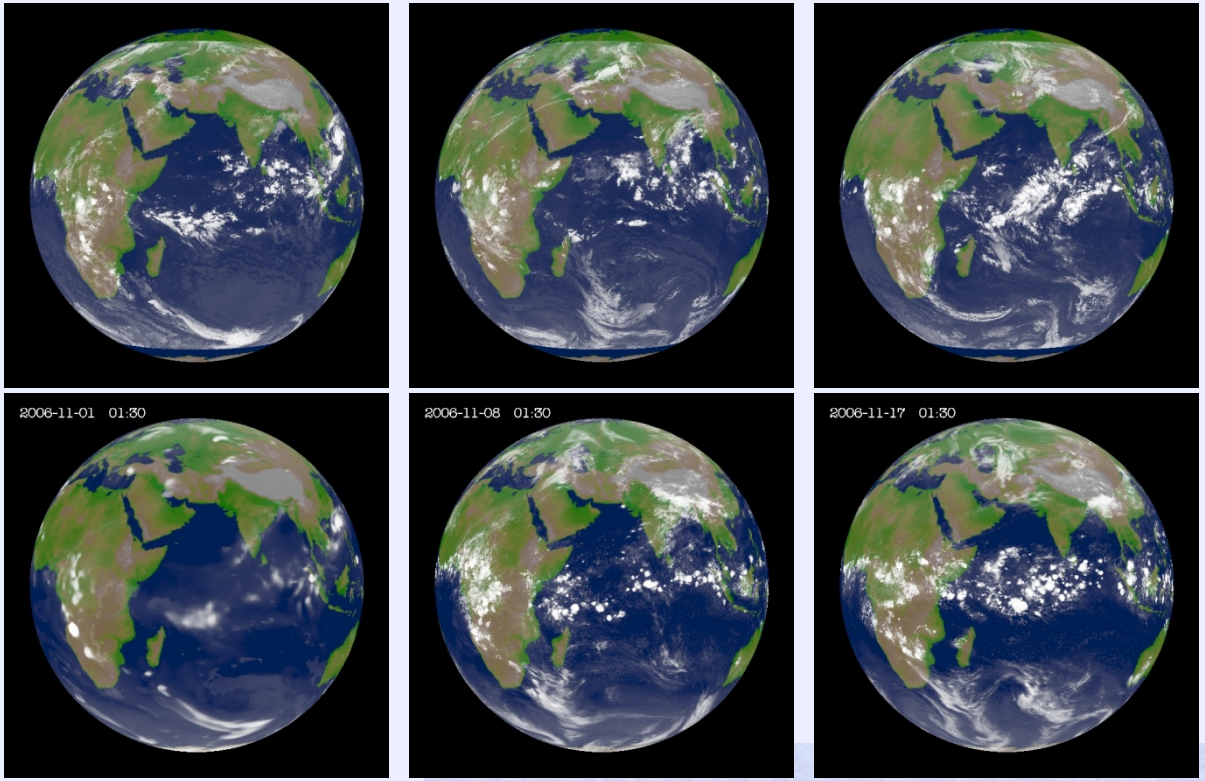
Onset

Miura et al. (2009)

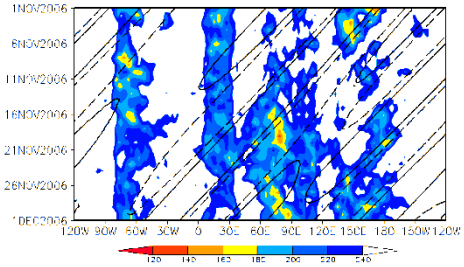
2006-11-01 to 2006-12-01

NCEP IR

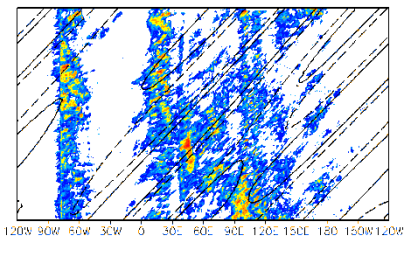
7-km run



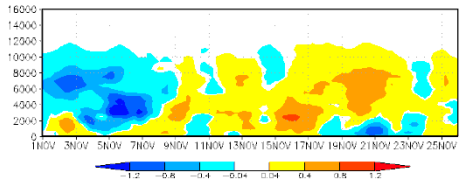
NOAA OLR



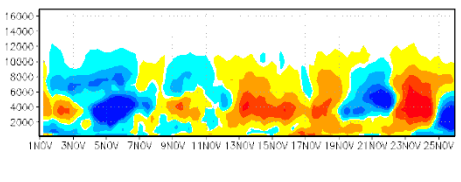
7-km run



MISMO qv'



7-km run

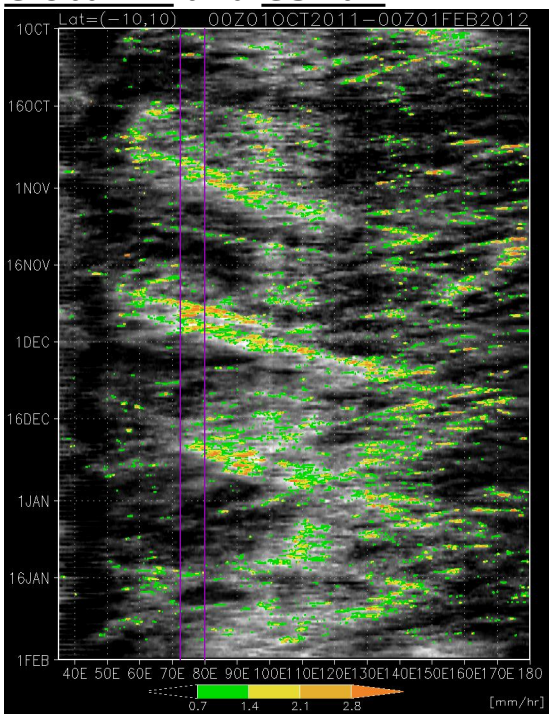


Challenges

- ✓ Slow eastward movement (Dec2006-JAN2007 case)
- ✓ Initiation (Nov2006 case)

CINDY2011 Summary

Global-IR and GSMaP



and more

(CINDY web page)

Cycle?

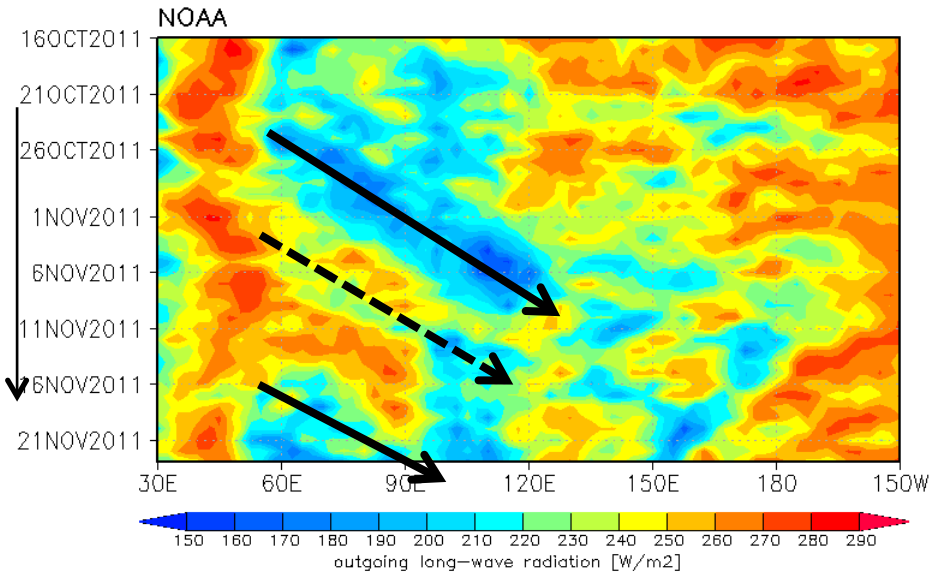
Robustness?

A pilot run

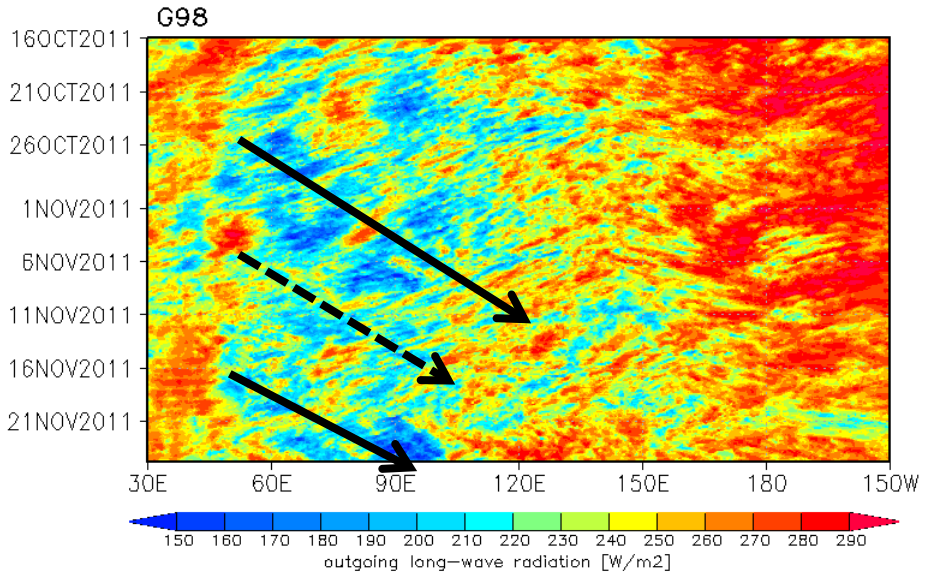
Settings very close to those of Miura et al. (2007) and Miura et al. (2009).

- The Earth Simulator
- Initial: October 16, 2011
- Duration: 40 days
- Initial data: interpolated from NCEP ds083.2
- Microphysics: Grabowski (1998)

OLR: NOAA



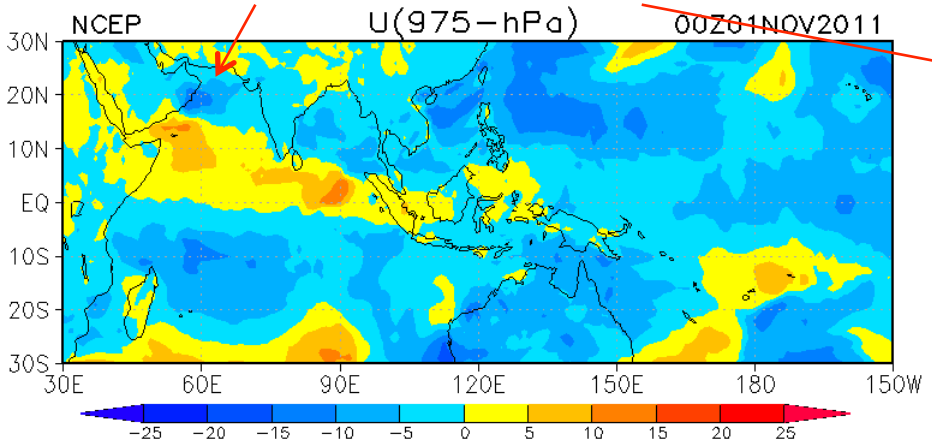
OLR: NICAM (14-km mesh)

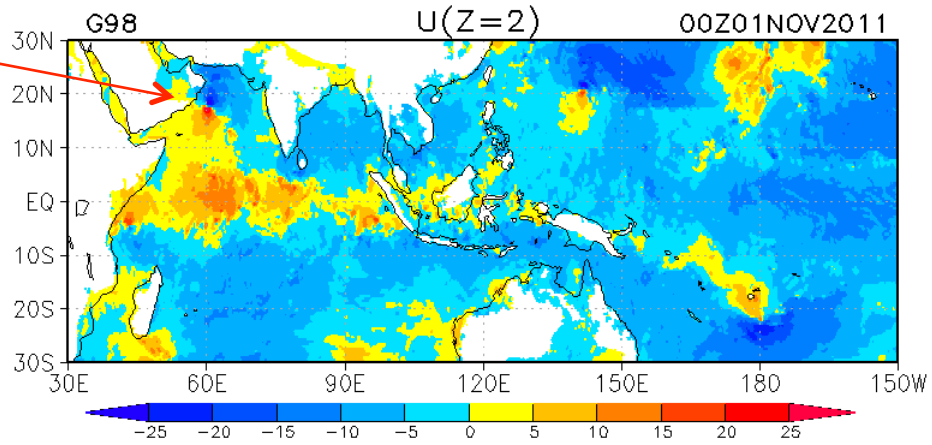


Day 17 (Nov 1, 2011)

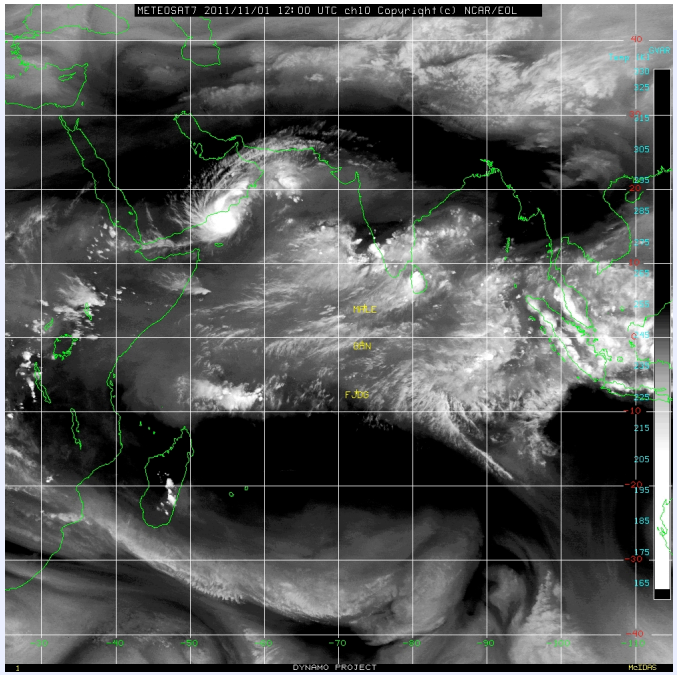
Tropical cyclone Keila

Zonal wind

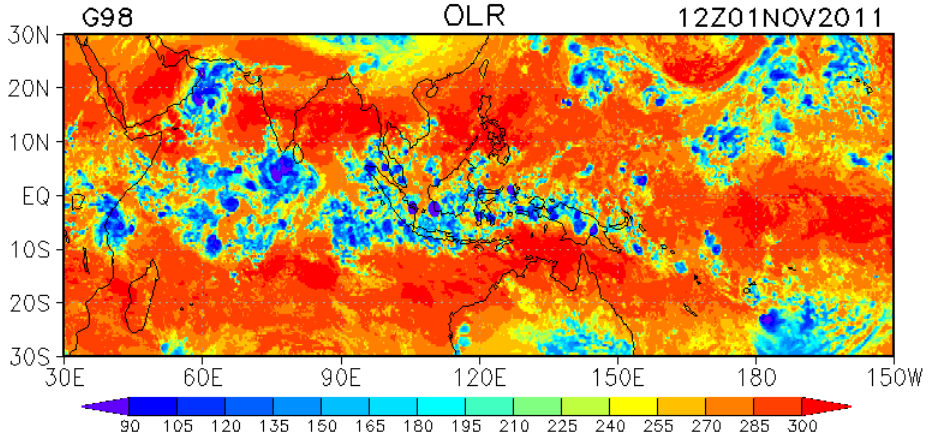




METEOSAT-7

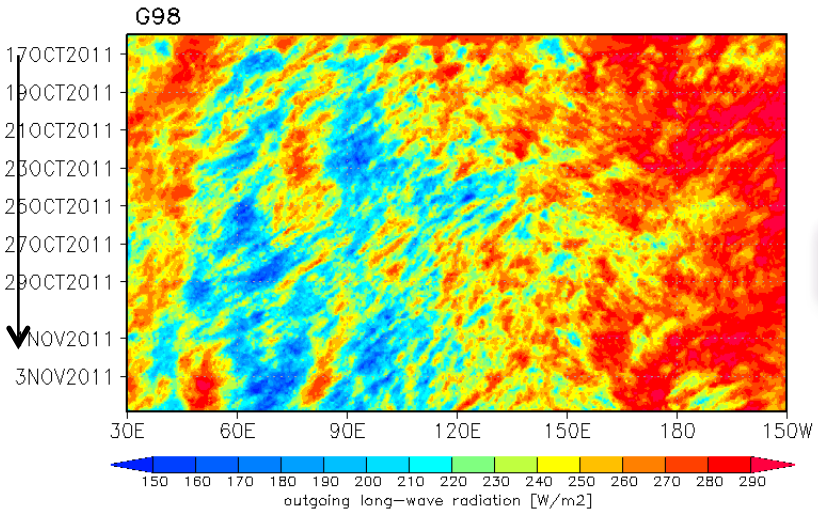


OLR: NICAM

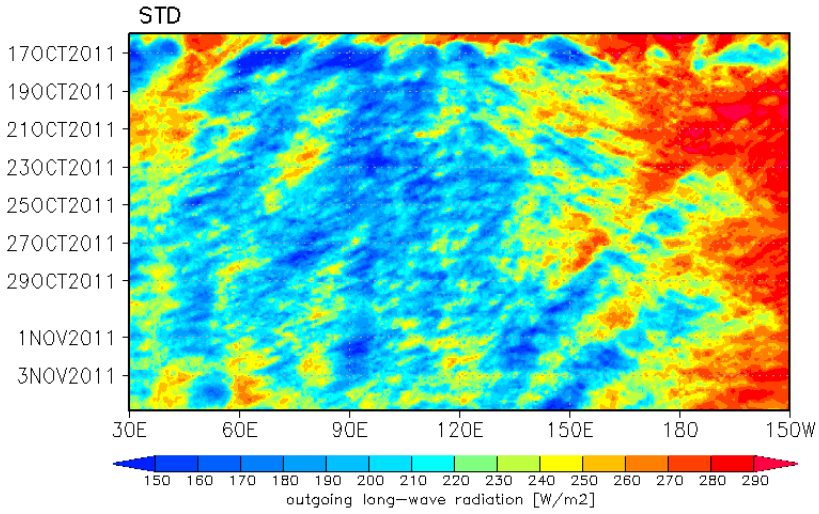


New physics

OLD



NEW



???

Something is wrong.

I tested by exchanging each old/new physics components.

Microphysics is responsible.

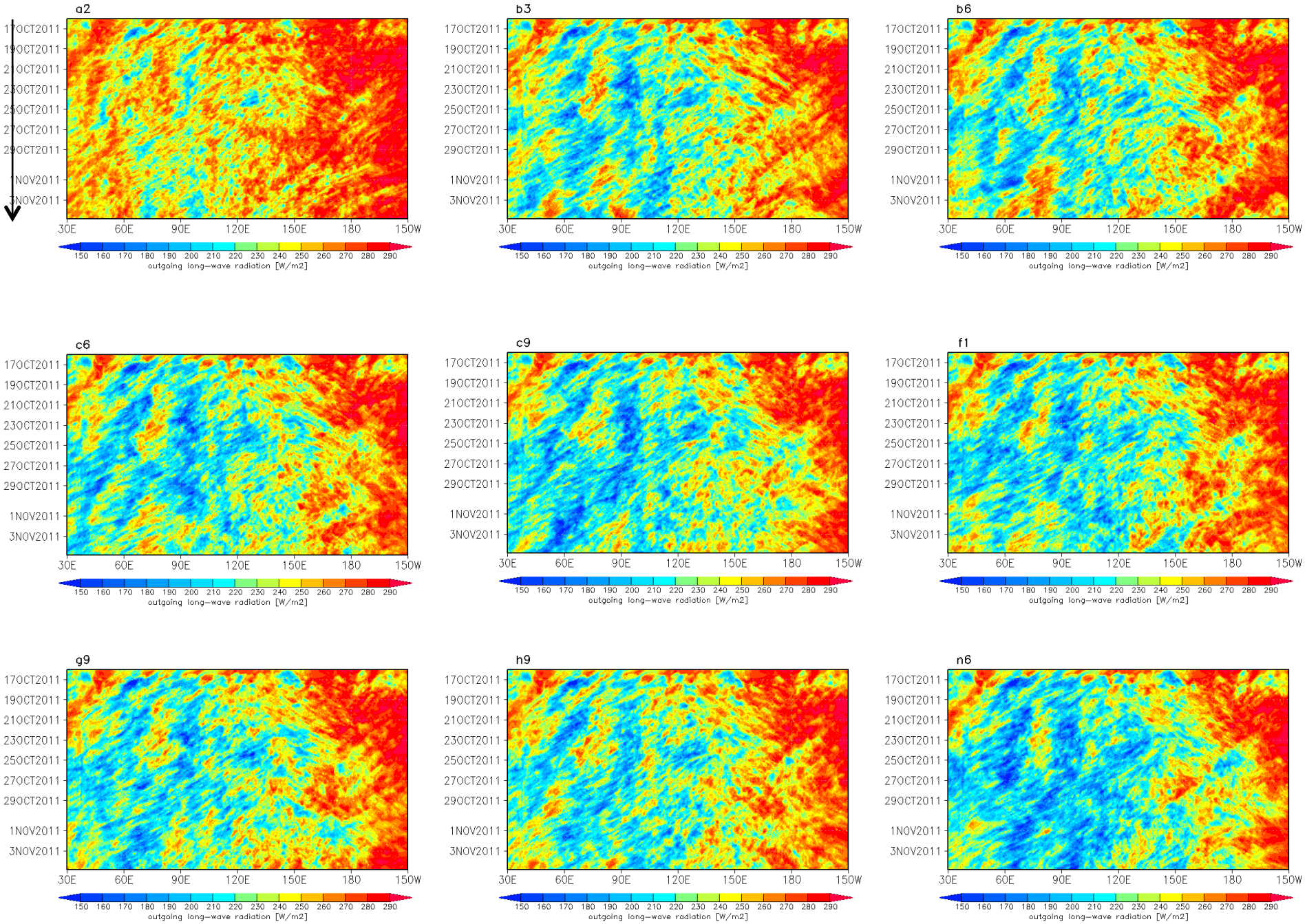
G98 (Grabowski 1998) → NSW6 (Lin type, Tomita 2008)

Tuning NSW6!

- An unrealistic feature with the NEW physics
  - A larger amount of cloud ice remaining in the upper troposphere.
  - A higher stability in the upper troposphere.
- This possibly prohibited smaller-scale sporadic convection and enhanced stronger organized system localized near forcing.

FX10 (Univ. of Tokyo)

- mini K-computer
  - 1.13 Pflops
- Test period from April, 2012 to June 30.
- 20 hours to simulate 20 days with 14-km grid (320 nodes)
- More than 150 runs until now.


a2
b3
b6
c6
c9
f1
g9
h9
n6
17OCT2011
19OCT2011
21OCT2011
23OCT2011
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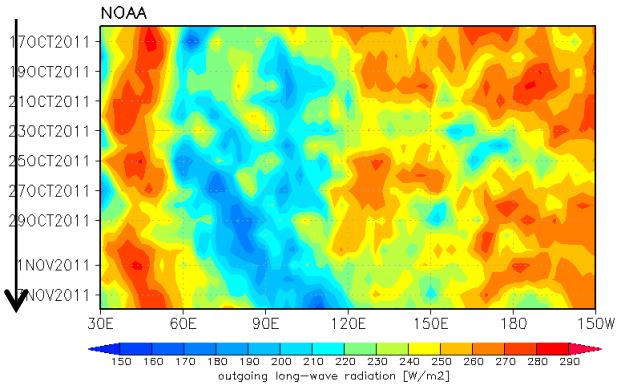
27OCT2011
29OCT2011
1NOV2011
3NOV2011
30E
60E
90E
120E
150E
180
150W
150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
outgoing long-wave radiation [W/m2]

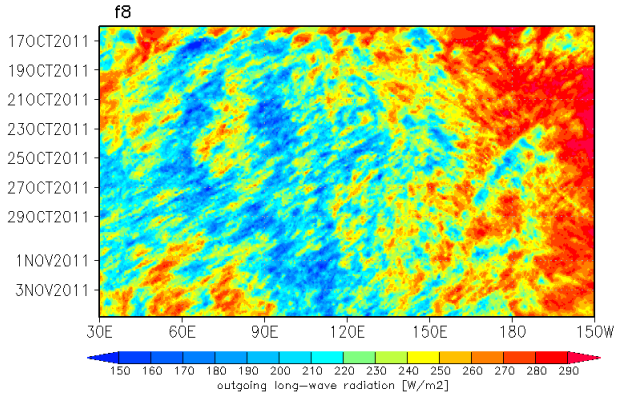
Systematic change?

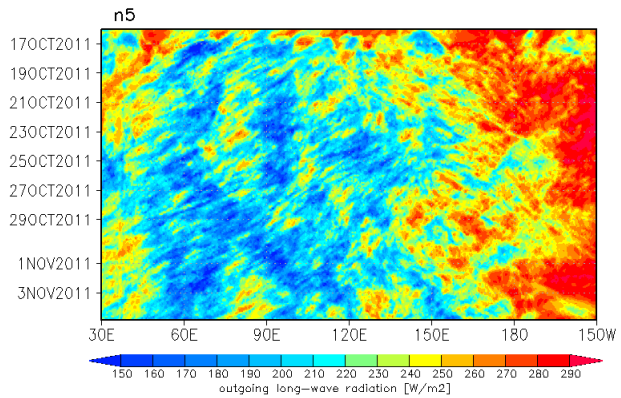
Enhancement of convection around Oct. 26: 150/150
Eastward movement was recovered.

NOAA OLR 10S-10N

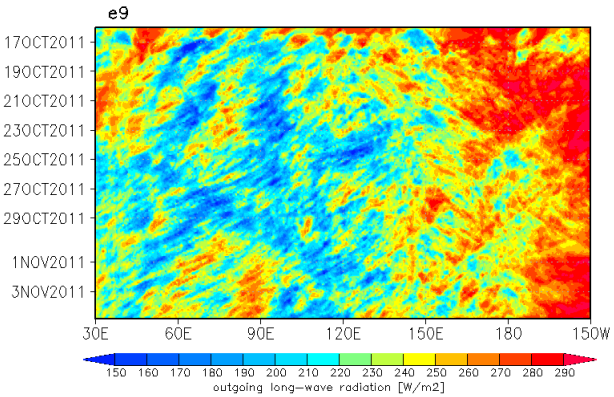


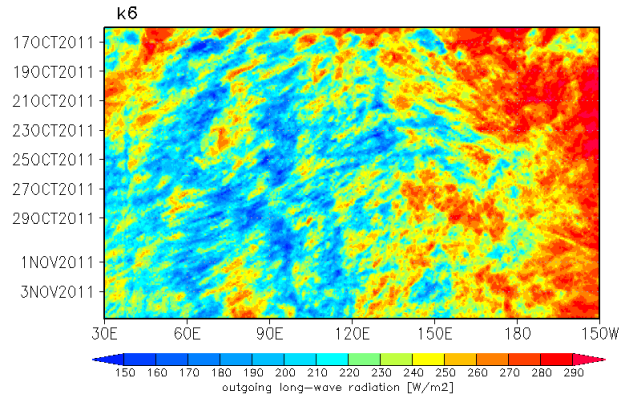
Slower

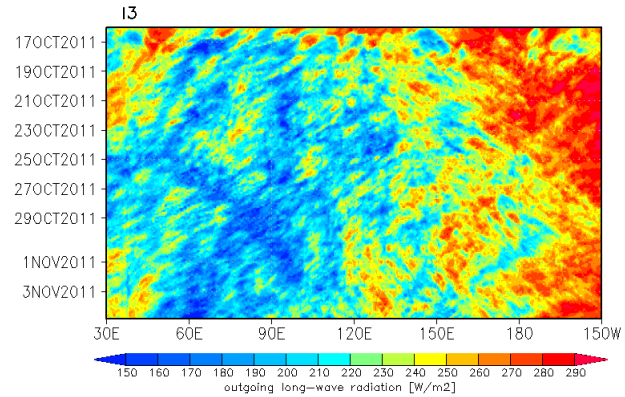




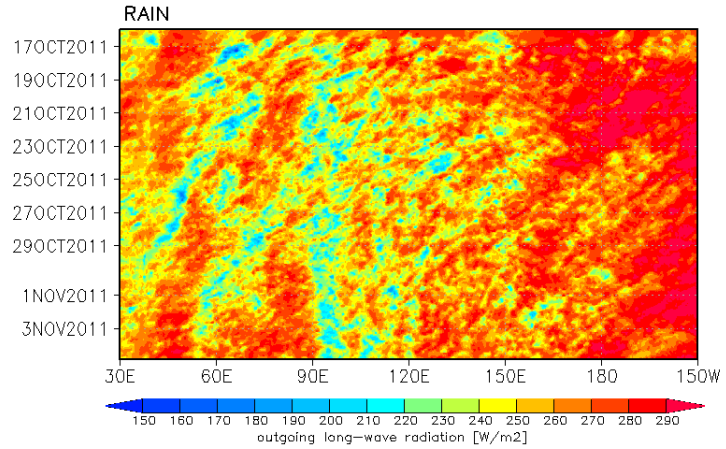
Faster

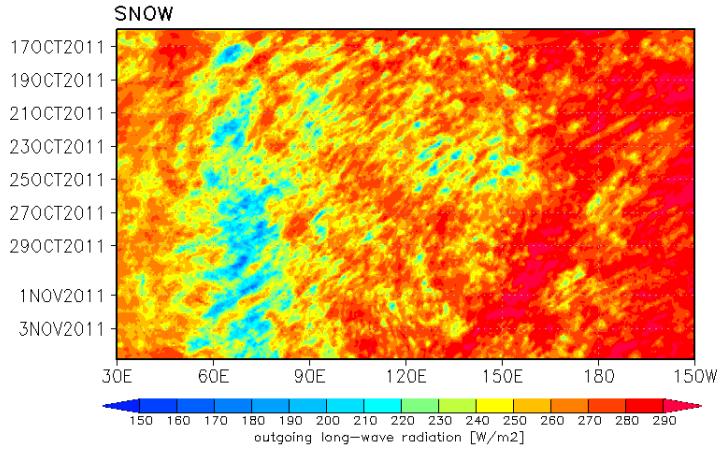


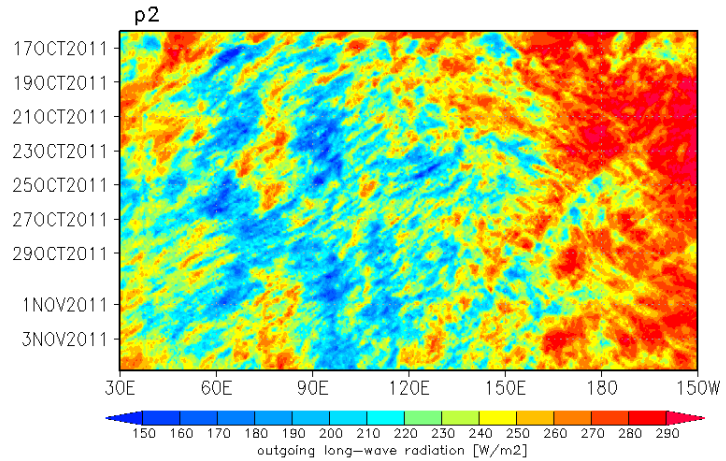


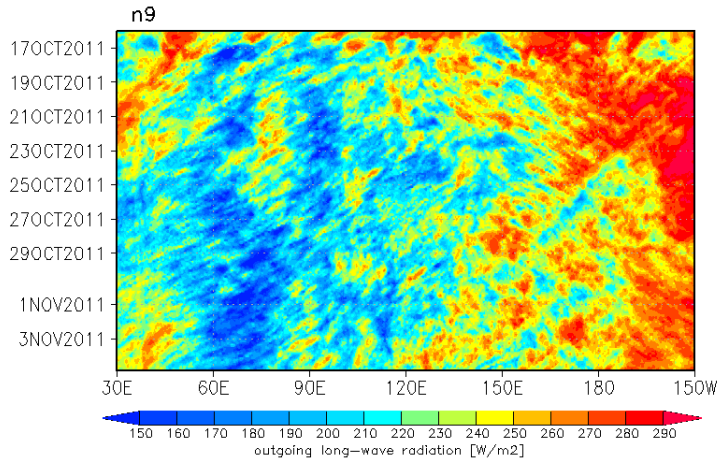


A kind of modes?



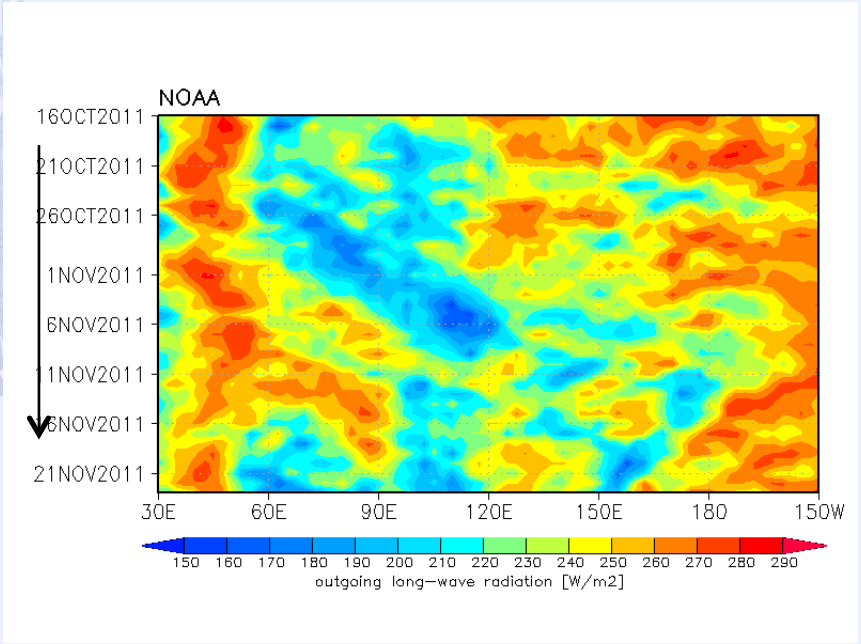




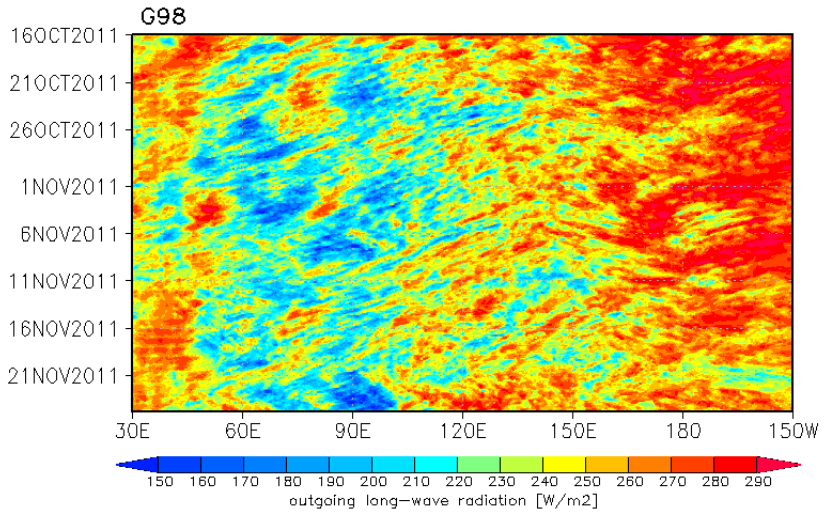


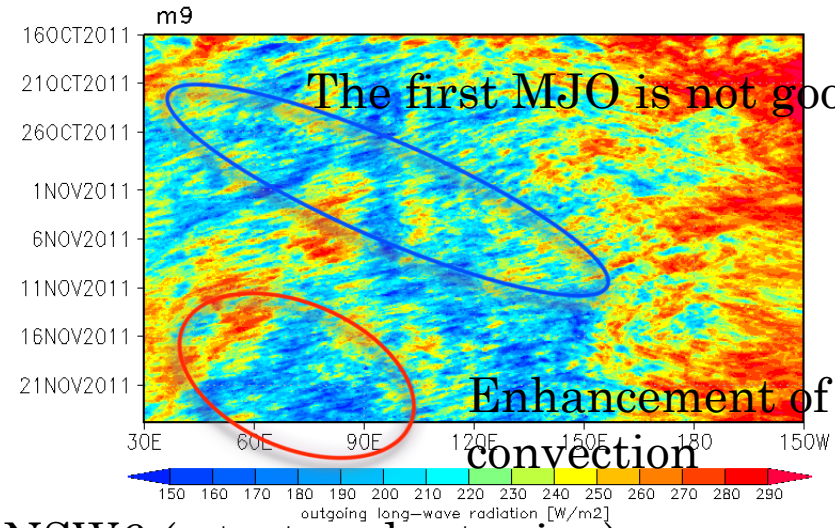
Systematic parameter sweep will be the next.

The second MJO in CINDY



G98





The first MJO is not good.

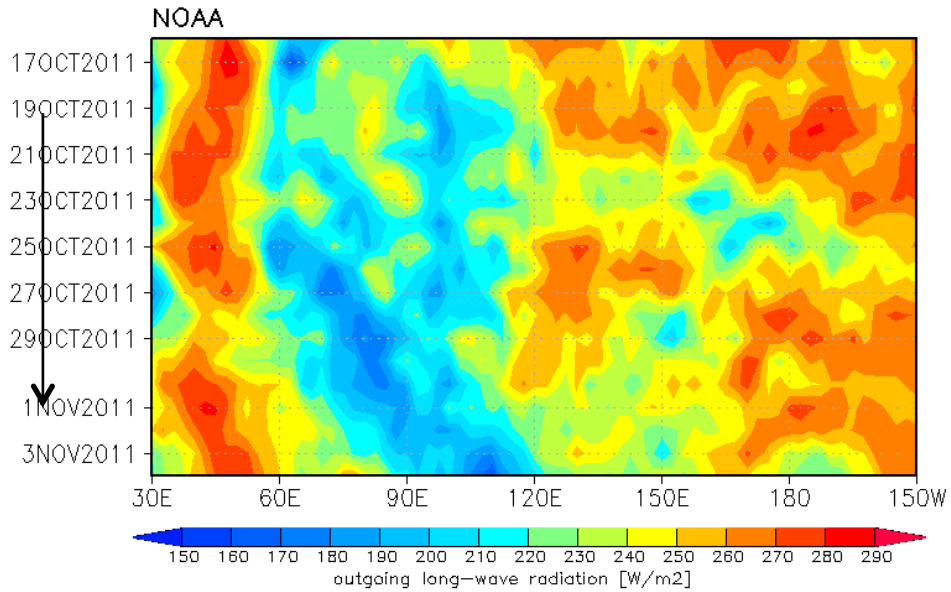
Enhancement of convection

NSW6 (a test under tuning)

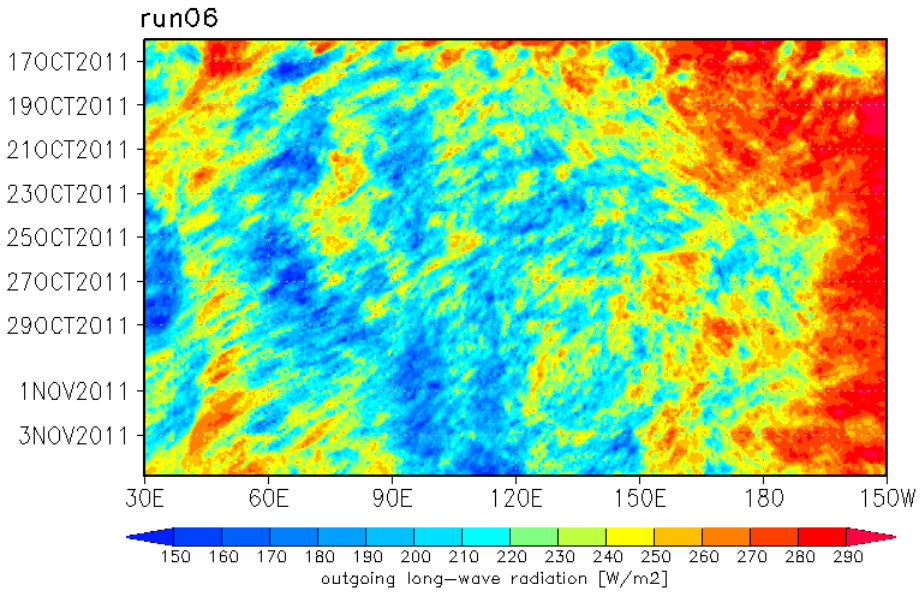
7-km run (very preliminary)

FX10 (mini K), 640 nodes, 40 hours

NOAA



Glevel-10 (7-km grid), 20-days



A good NSW6 for 14-km is also good for 7-km.

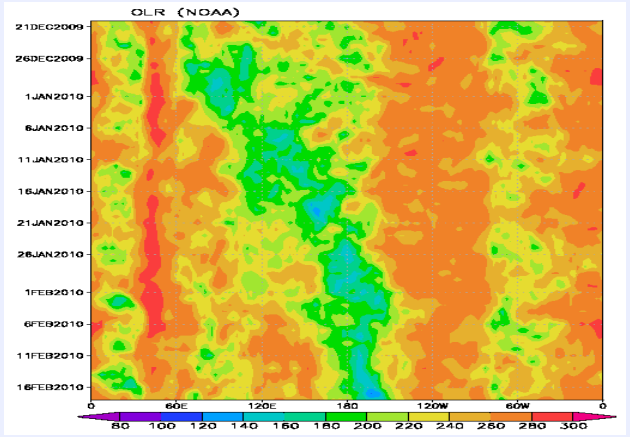
Another case

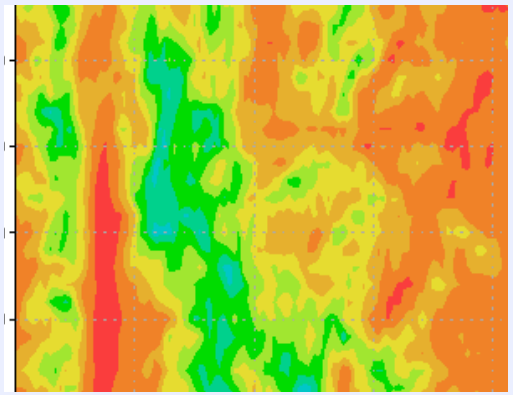
Dr. Miyakawa YOTC: Year of Tropical Convection

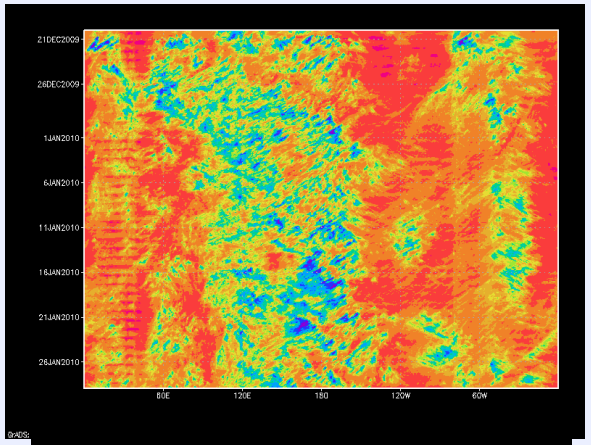
40-day simulation from Dec 20, 2009 / 20-day simulation from Oct 30, 2009.

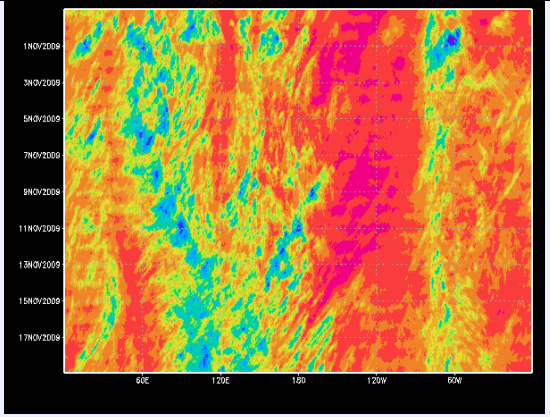
"corrected" NSW6 (with a "good" parameter set)

NOAA



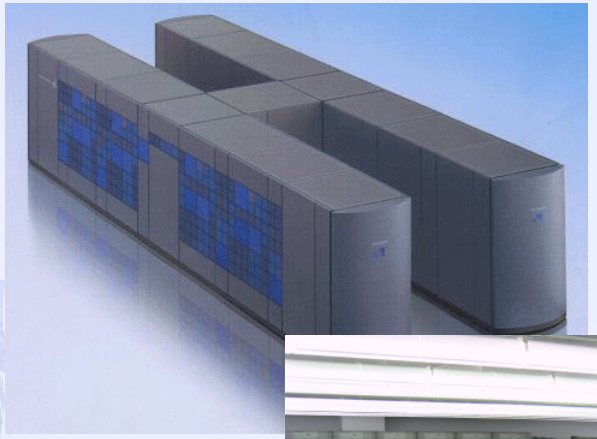


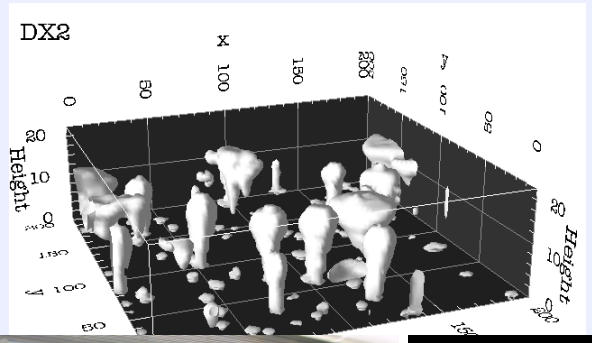


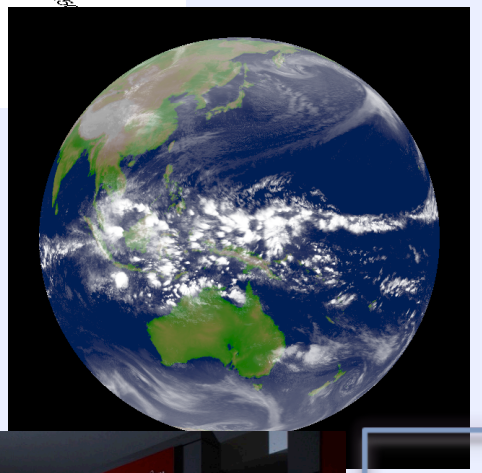


NICAM
dx~14 km

A good NSW6 for CINDY is also good for YOTC.




DX2
Height
Height




K computer
©RIKEN

?

Robustness?

Going beyond the case studies.

- Simulations of 30 pronounced MJO cases
- AMIP-like simulation longer than 10(20?) years

Dr. Tomoki Miyakawa is the main player.
NICAM team and I support him.

Summary

CINDY/DYNAMO runs are almost ready.

- Tuning of NSW6 is almost finished.
  - We can do something before going to ensemble runs.
- The first MJO event is recovered.
- The second MJO event is encouraging in two trials (G98, NSW6: 2/2).

MJO in NICAM is sensitive to microphysics.

- Grabowski's scheme produces good results in NICAM.
  - We were lucky in 2007, and should thank Grabowski (1998).
- Larger degrees of freedom are not always desirable.
- Systematic dependence on a few parameters?
  - Experiences to statistics.

K-computer

- 30 MJO cases (w/ ensembles) to test robustness of NICAM
  - Dec2006, CINDY/DYNAMO-1 and YOTCx2 (4/4)
- AMIP-like runs will follow.