NICAM:
A global cloud-system-resolving model

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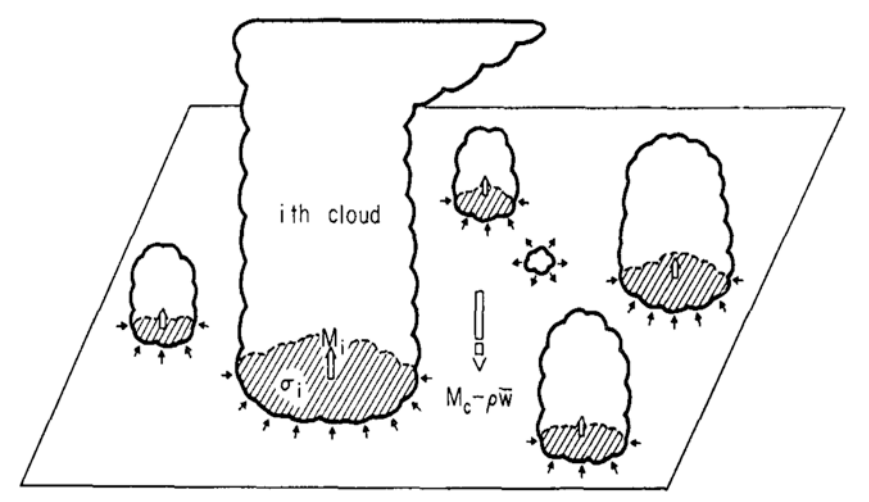
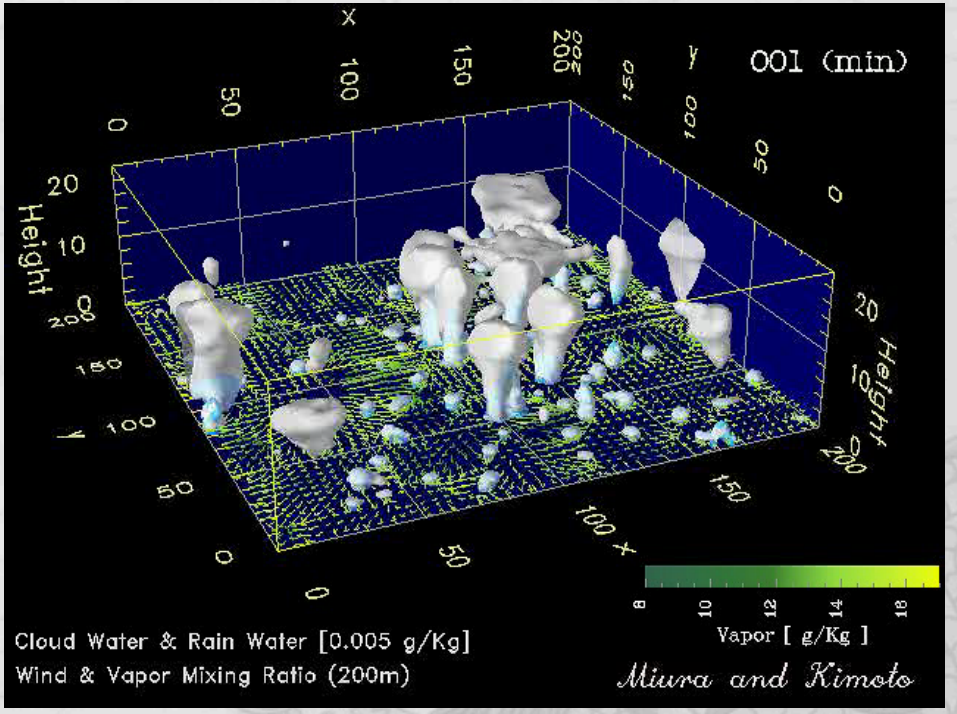
Ryuji Yoshida (AICS, Riken, Kobe)
Tomoki Ohno (University of Tokyo)

Parameterization



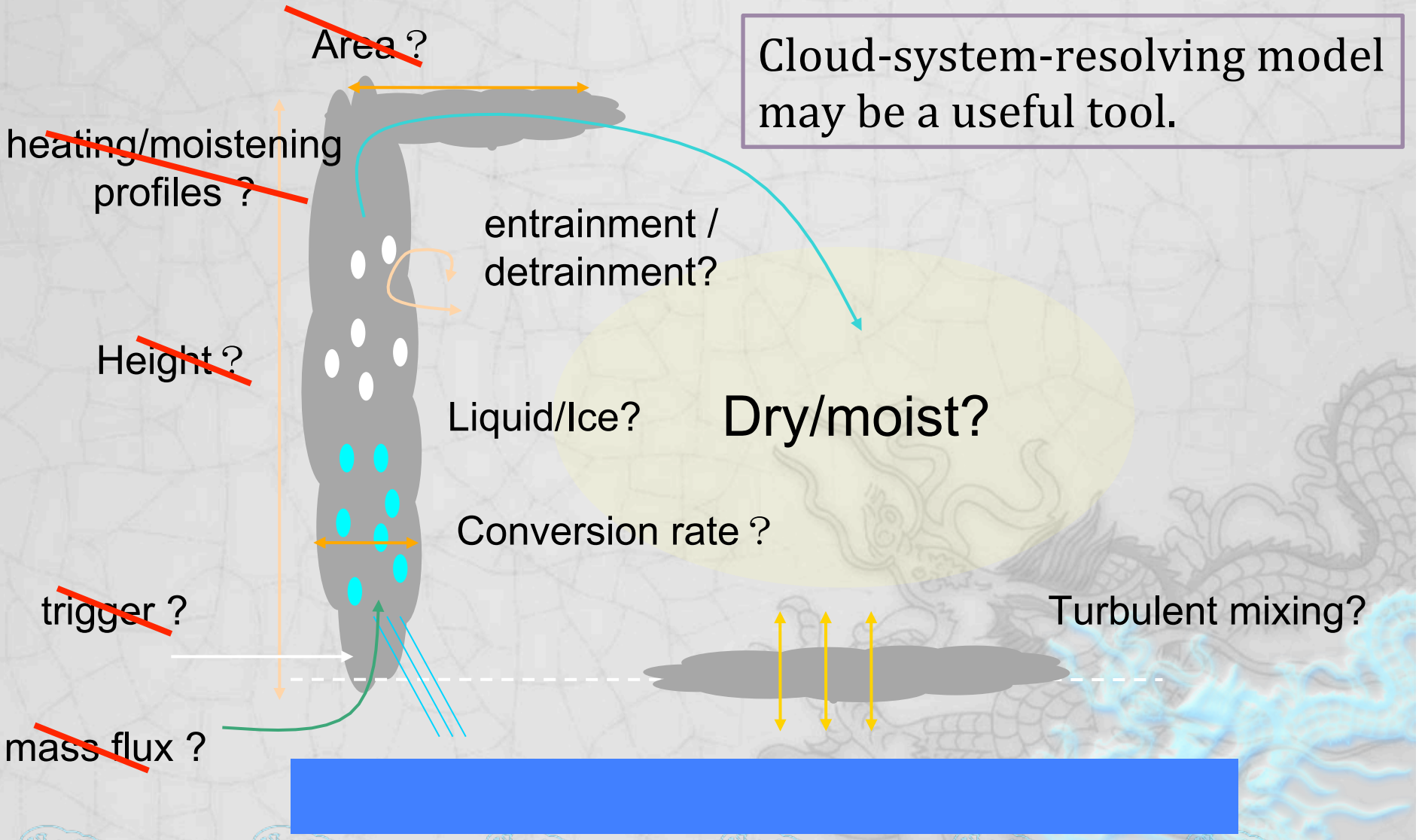
Arakawa and Schubert (1974)



Cloud parameterizations are valuable to test our understandings.

Cloud parameterization deadlock (Randall et al. 2003)

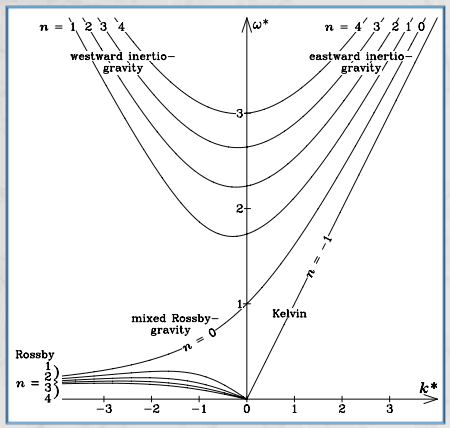
Uncertainties



Cloud-system-resolving model may be a useful tool.

Dr. Matsuno's dream

(NIES Web site)



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

Spontaneous behavior of clouds

- Explicit scale interactions
- Global model of 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

It was estimated that the finest grid spacing would be dx~10km.

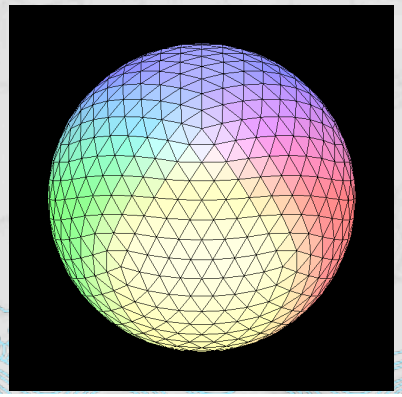
In early 2000s, O(km) was called as “cloud-resolving”.

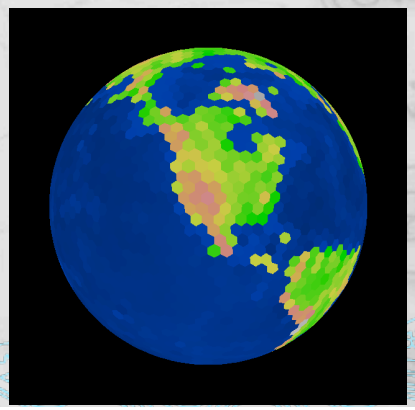
For O(km)

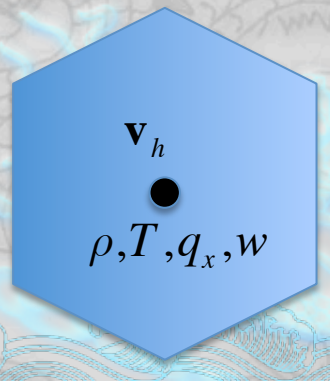
"as simple as possible"

Highest priority was on the computational efficiency on the ES.

- Icosahedral grid (hexagonal/pentagonal cells)
- Arakawa A-grid
  - NO Poisson solver
- Finite-volume
  - Conservation of mass, moisture etc. in long simulations
- Minimum stencils
  - 2nd-order centered spatial discretizations







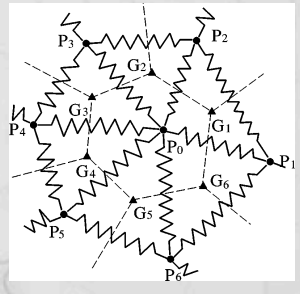
Except for the use of the icosahedral grid, NICAM follows a standard of the cloud-resolving models in early 2000s.

- Full compressible equation system
- Three-stage Runge-Kutta time stepping
- Sound waves
  - Explicit horizontally
    - Split-explicit w/ divergence damping
  - Implicit vertically
- Terrain-following height coordinate
- Linear/non-linear diffusion (horizontal)
- Rayleigh damping (vertical)

We deeply appreciate the preceding experiences of JMA, CSU and NCAR.

Some originalities

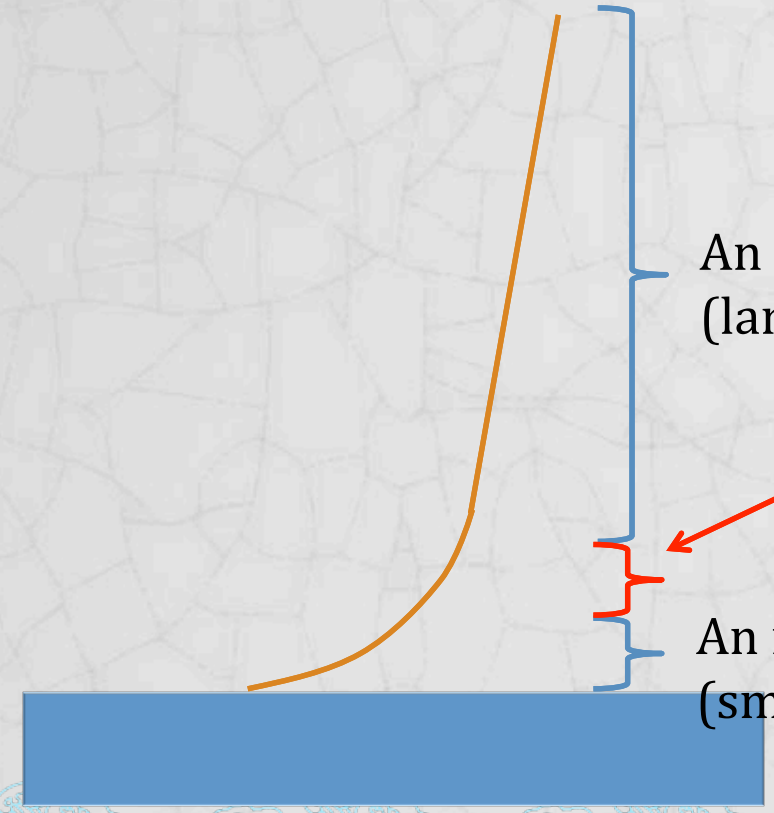
- Satoh (2002,2003)
  - Prediction of the total energy, instead of (pot.) temperature
- Tomita et al. (2001)
  - The first momentum form model on the icosahedral mesh
- Tomita et al. (2002)
  - The spring dynamics for better accuracy
- Tomita and Satoh (2004)
  - The first non-hydrostatic core on the icosahedral mesh
  - Deep and shallow configurations
  - Some test cases of dry dynamics
- Miura (2007)
  - Easy implementation of the piecewise linear advection (w/ the lux limiter of Thubern 1995,1996)



No cumulus parameterization?

An analogy

Approximate solution of the boundary layer problem



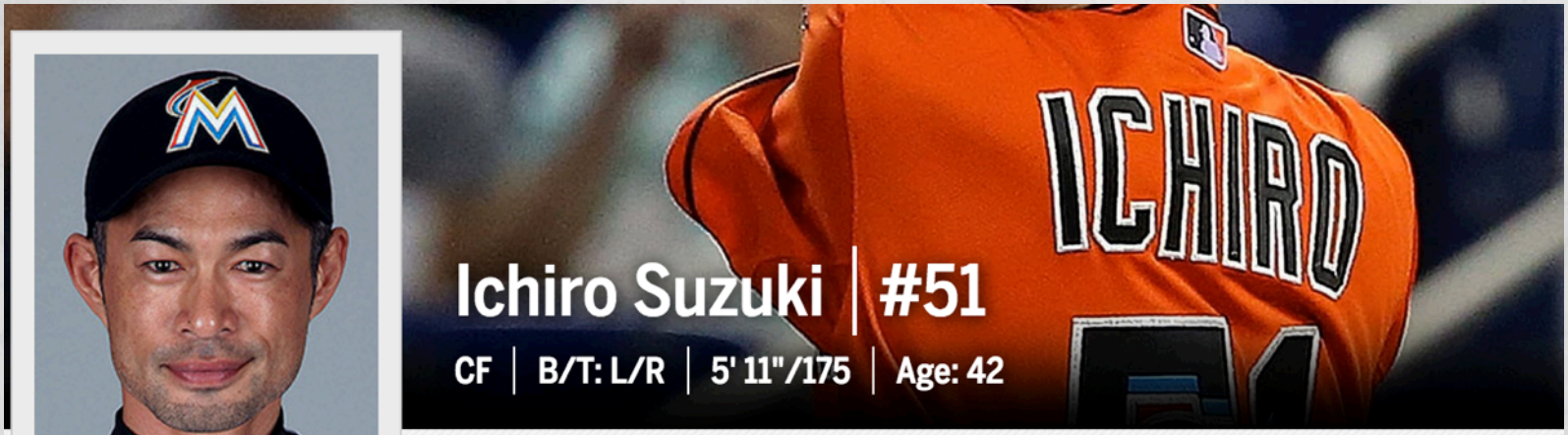
Which is better between the internal and external solutions?

An external solution
(larger spatial scale)

A solution is constituted by matching the internal and external solutions.

An internal solution
(smaller spatial scale)

Ichiro Suzuki



Summary

Ichiro Suzuki
Pronunciation: EE-chee-roh soo-ZOO-kee
Born: 10/22/1973 in Kasugai, Japan
High School: Aikoudai Meiden, Aichi, Japan
Debut: April 2, 2001

Year	AB	R	H
2016 Stats	99	13	31
MLB Career Stats	9461	1361	2966

http://m.mlb.com/player/400085/ichiro-suzuki

NICAM is NOT like Ichiro.

Munenori Kawasaki

MLB.com SCORES NEWS VIDEO STATS STANDINGS SCHEDULE PLAYERS VOTE TICKETS APPS SHO

Now Reading: MLB News

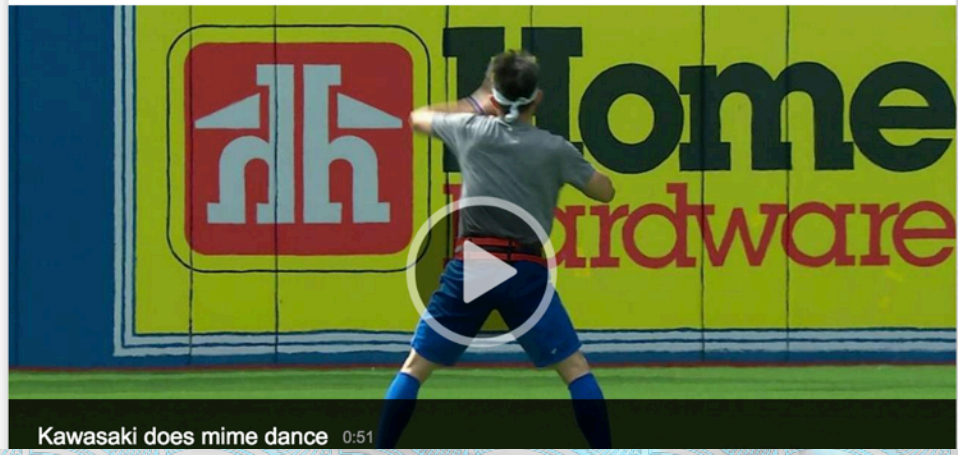
Munenori Kawasaki

Born: 6/3/1981 in Kagoshima, Japan

Year

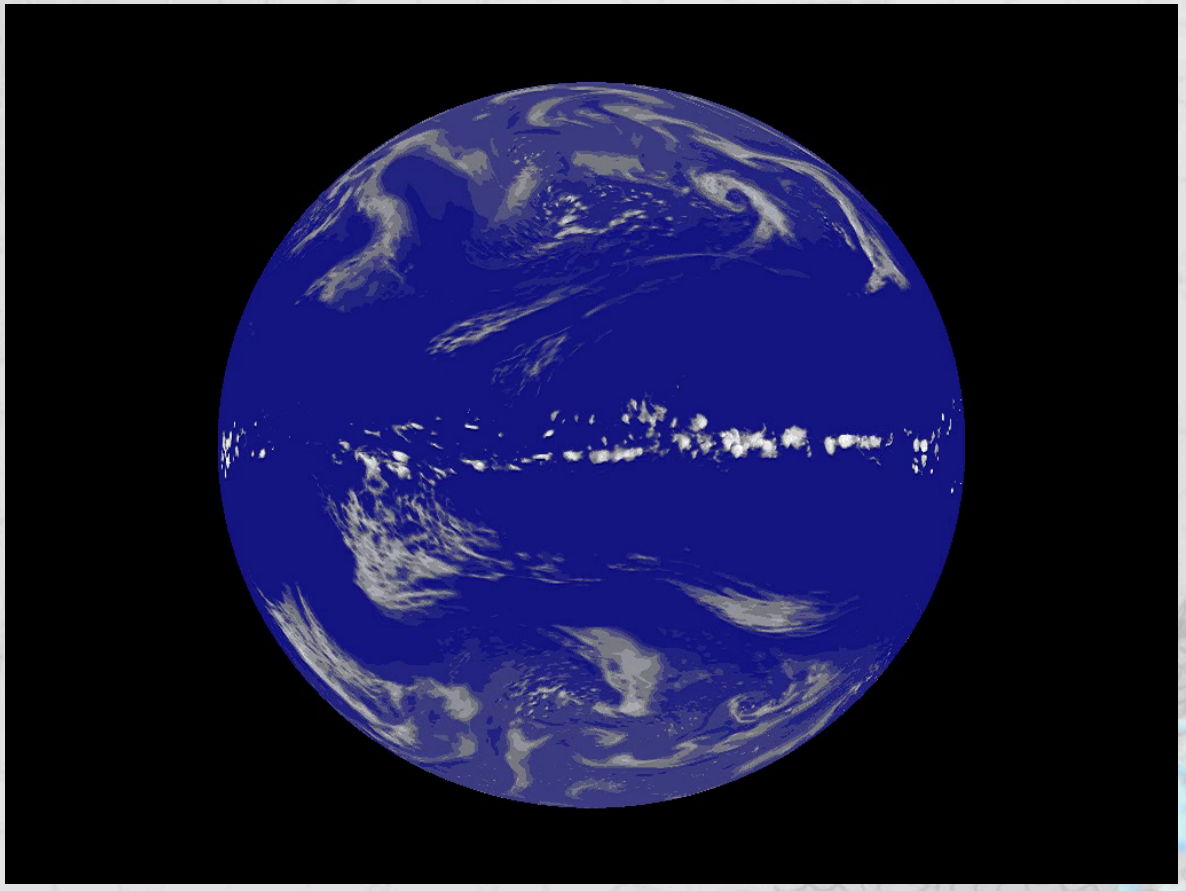
Recalling Munenori's best Blue Jays moments

Toronto fan favorite leaves legacy of laughs



Aquaplanet

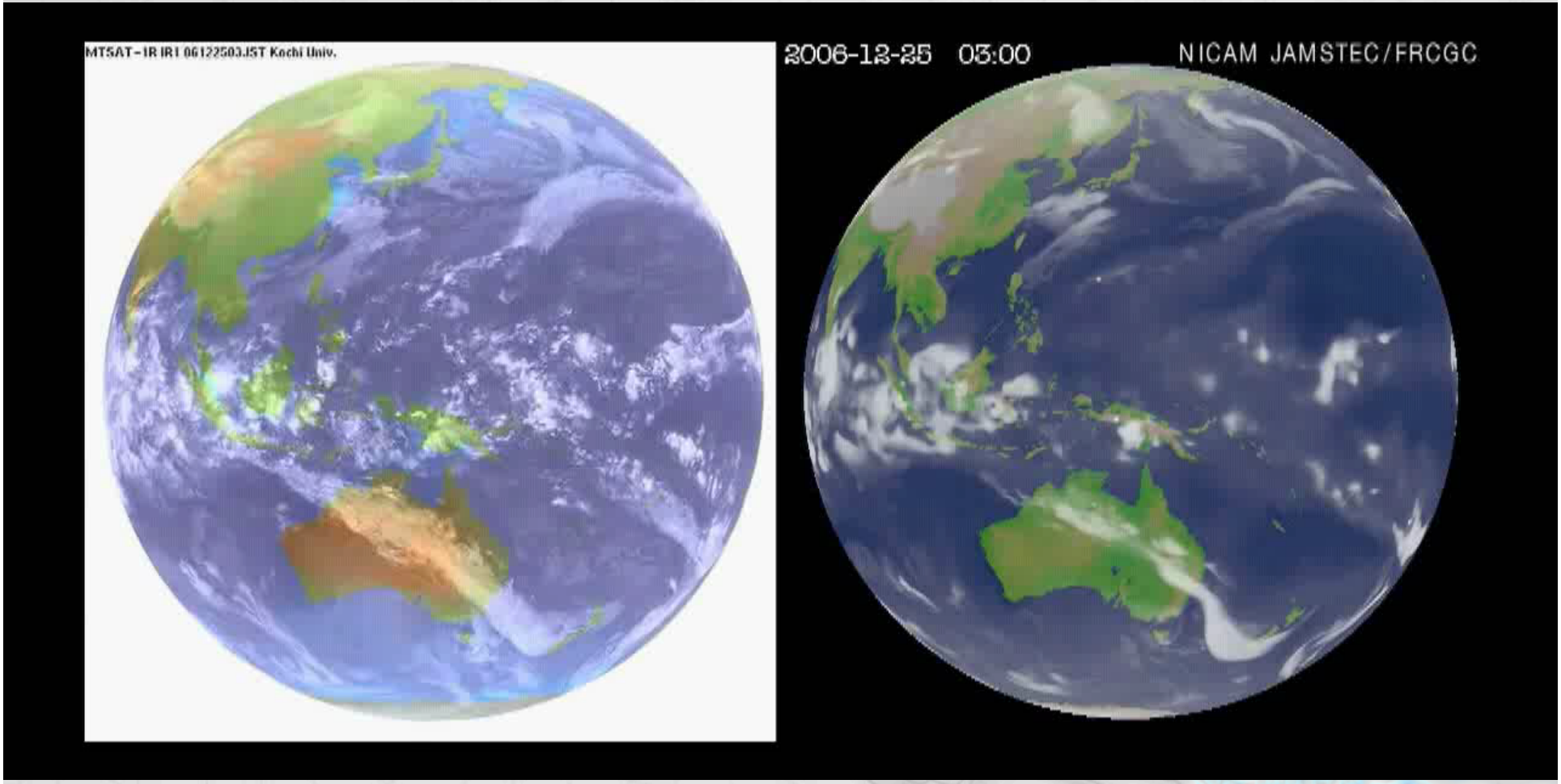
Tomita et al. (2005,Geophys. Res. Lett.)



CSRM framework can reproduce hierarchical cloud organization spontaneously.

Madden-Julian Oscillation

Miura et al. (2007,Science)



Cloud systems in GCRMs possibly have some reality.

K-computer (AICS, Riken, Kobe)

RANK	SITE	SYSTEM	CORES	RMAX (TFLOP/S)	RPEAK (TFLOP/S)	POWER (KW)
1	National Super Computer Center in Guangzhou China	**Tianhe-2 (MilkyWay-2)** - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P NUDT	3,120,000	33,862.7	54,902.4	17,808
2	DOE/SC/Oak Ridge National Laboratory United States	**Titan** - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x Cray Inc.	560,640	17,590.0	27,112.5	8,209
3	DOE/NNSA/LLNL United States	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1,572,864	17,173.2	20,132.7	7,890
4	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect Fujitsu	705,024	10,510.0	11,280.4	12,660

"as simple as possible" again

No major changes in dynamics and physics

One big reason is that
we did not have enough resources.

Late 2000s: The Earth Simulator

dx~3.5 km: 1 year project

1 month for 1 week simulation

1~2 months for data conversion and data transfer

3~6 months for data analysis

data size ~ 10TB

Early 2010s: K computer

dx < 1km: project of 2 years or more

1 month for a few days simulation

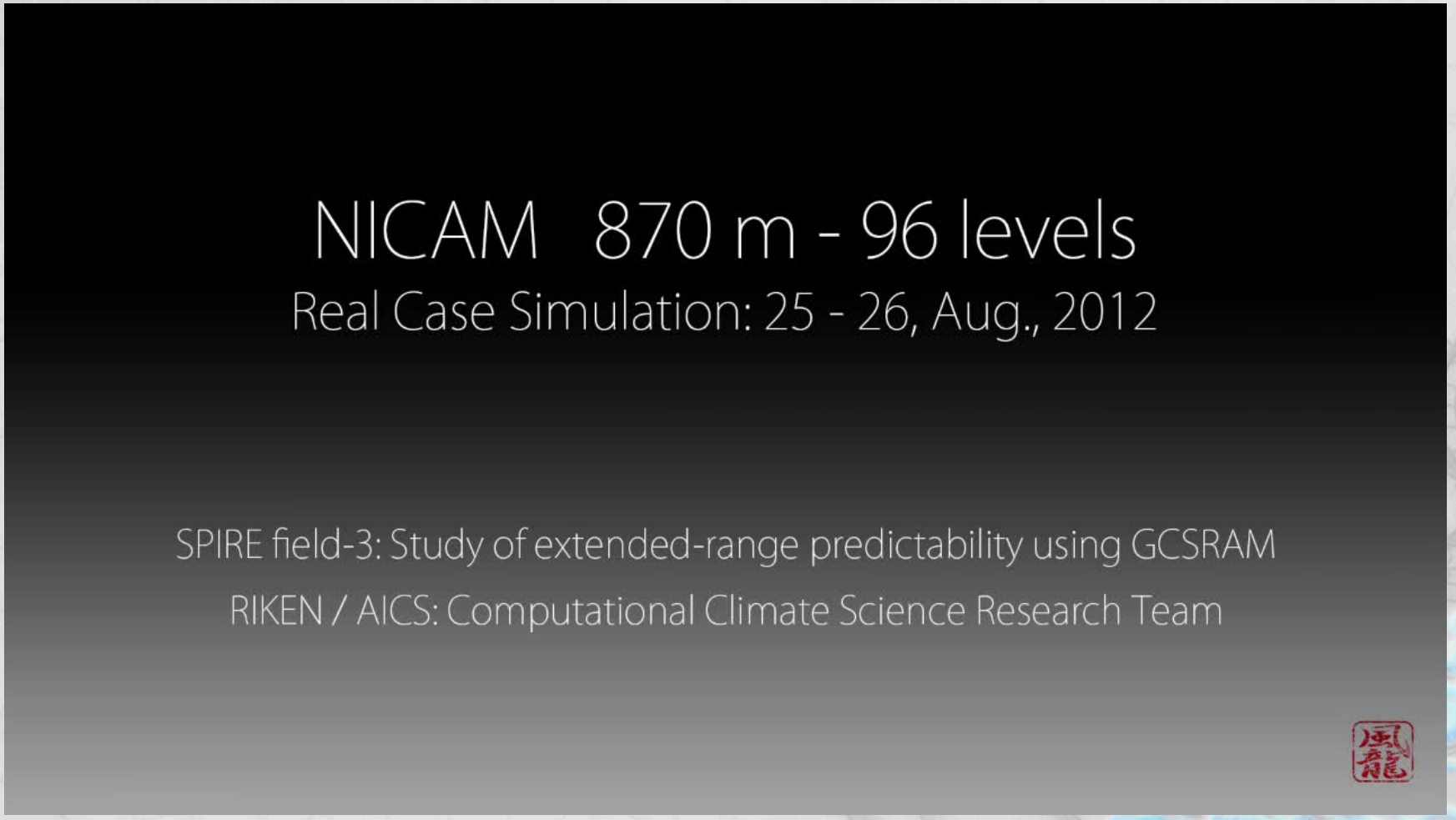
1 year for full conversion of data

years for data analysis

data size ~ 1 PB

dx~870 m simulation

Miyamoto et al. (2013,Geophys. Res. Lett.)



Pixel size must be reduced before rendering.

Ryuji Yoshida

NICAM 870 m - 96 levels

Real Case Simulation: 25 - 26, Aug., 2012

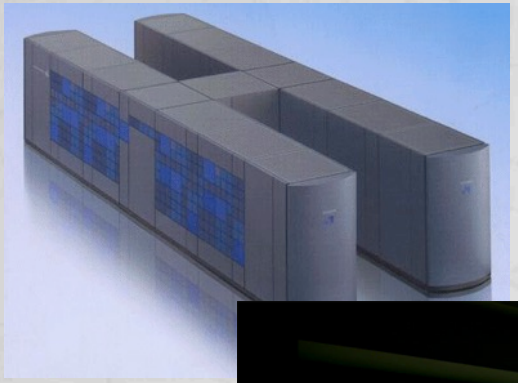
80K Monitor is needed.

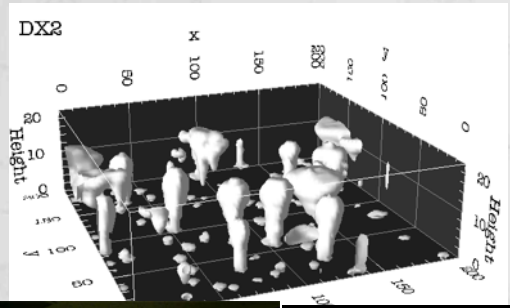
SPIRE field-3: Study of extended-range predictability using GCSRAM

RIKEN / AICS: Computational Climate Science Research Team

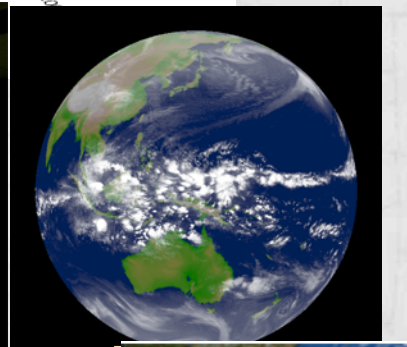
4K Monitor

8K Monitor




DX2
x
Height
Height


The Earth Simulator Center




京
京
K computer


Resolution: 0.87km

ExaFlops?

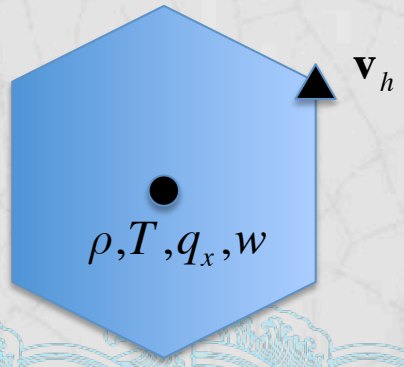
?

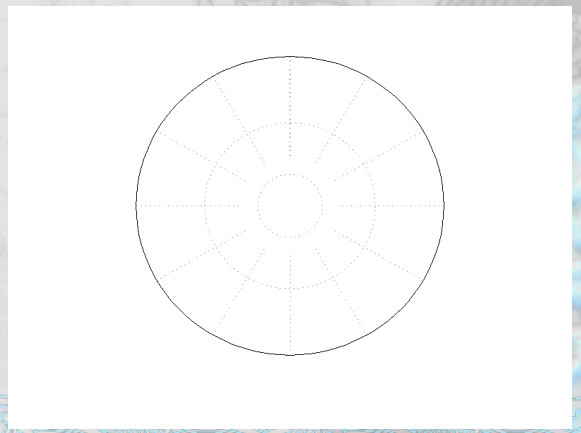
Recent progress

- Air-Sea coupling

Future updates of the dynamical core

- More accurate transport
  - Miura and Skamarock 2013, Miura 2013
- B-grid (or ZM-grid)
  - I might have eliminated the computational mode.





Height error Case 2 (Williamson et al. 1992))