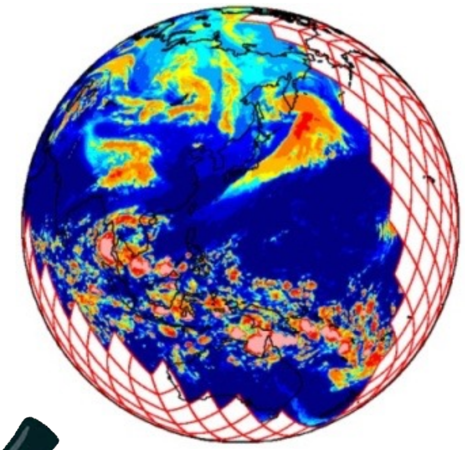
WCRP Workshop on Future of Climate Modelling, Day2

”Model Improvement”



Tomoki Miyakawa

AORI, The University of Tokyo

Many sub- 5 km mesh models available now (13～ atmos., 4 coupled)

Tomoki Miyakawa, Daniel Klocke, Florian Ziemen, Julia Duras, Ludovic Auger, Ron McTaggart-Cowan, William Putman, Peter Dueben, Thomas Rackow, Falko Judt, Crolyn Reynolds, Tamaki Suematsu, Luca Harris, Marat Khairoutdinov, Peter Caldwell, Pier Luigi Vidale, Nils Wedi, Claudia Stephan, Rene Redler, Christopher Ryutaro Terai, Benoit Vanniere, Jian Li, Yi Zhang, Masaki Satoh, Bjorn Stevens

DYAMOND2 models, IWP+LWP visualized by Florian Ziemen, DKRZ

Supercomputers and key NICAM simulations

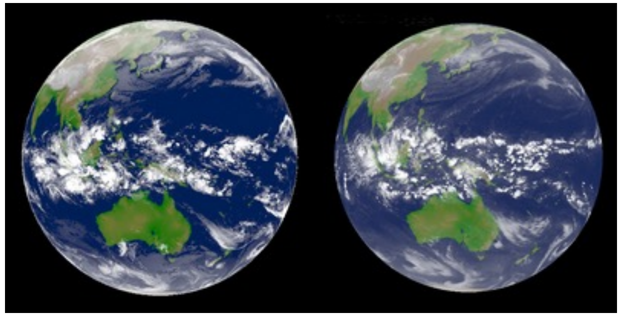
| ES1 (40 TFlops) | K computer (10 PFlops) | OFP (25 PFlops) | Fugaku (488/977 PFlops for DP/SP)

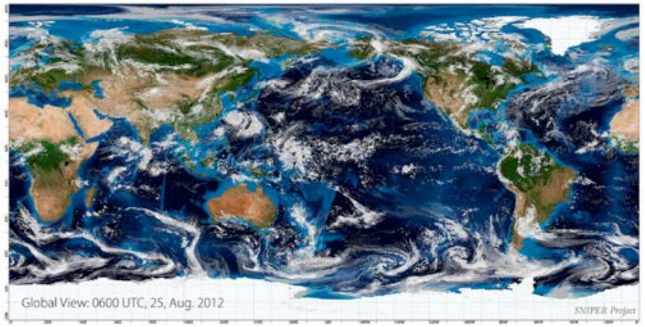
02 05 07 11 12 13 14 15 16 17 19 20 21 ongoing

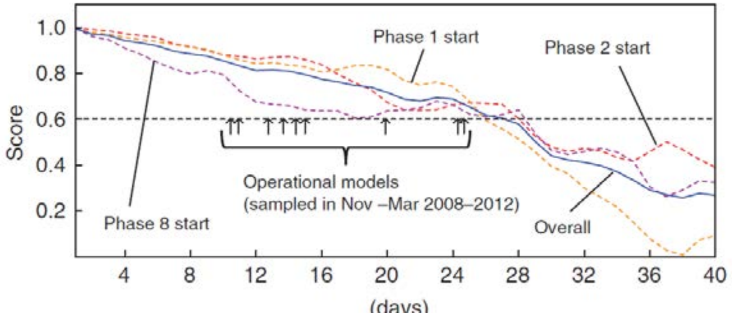
~day: | 870m

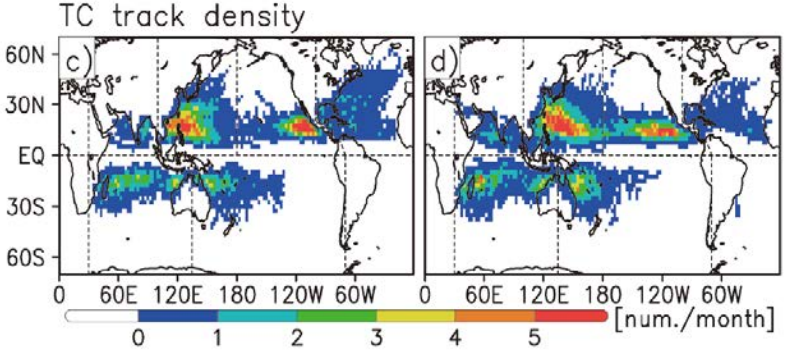
~S2S: | 3.5km(APE) | 3.5km | 7km 10ens (Athena) | 14km 54ens | 14km 54ens NICOCO | DYAMOND | 3.5km LETKF 1024ens | 14km 1600ens | 3.5km NICOCO | DYAMOND2

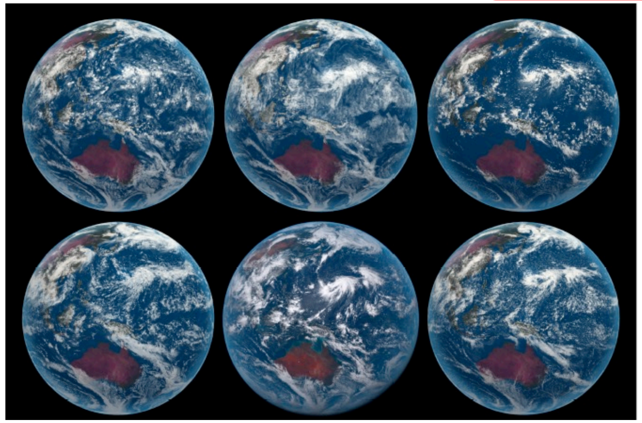
~clim.: | 14km 30yr | CMIP6 | 3.5km 10yr











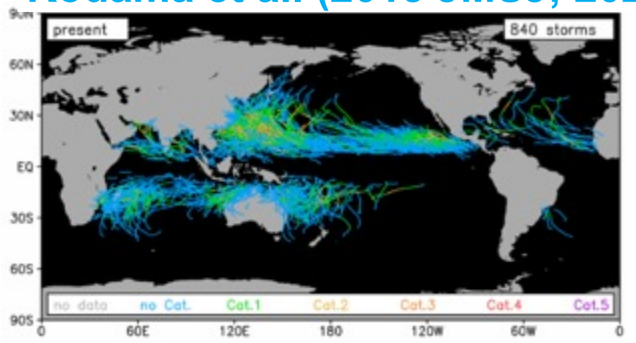
Miura et al. (2007) Science
Miyamoto et al. (2013) GRL
Miyakawa et al. (2014) Nature Comm.
Kodama et al. (2015) JMSJ
Stevens et al. (2019) PEPS

slide by courtesy of Kodama

Weather/climate studies with K computer & Fugaku

slide by courtesy of Satoh

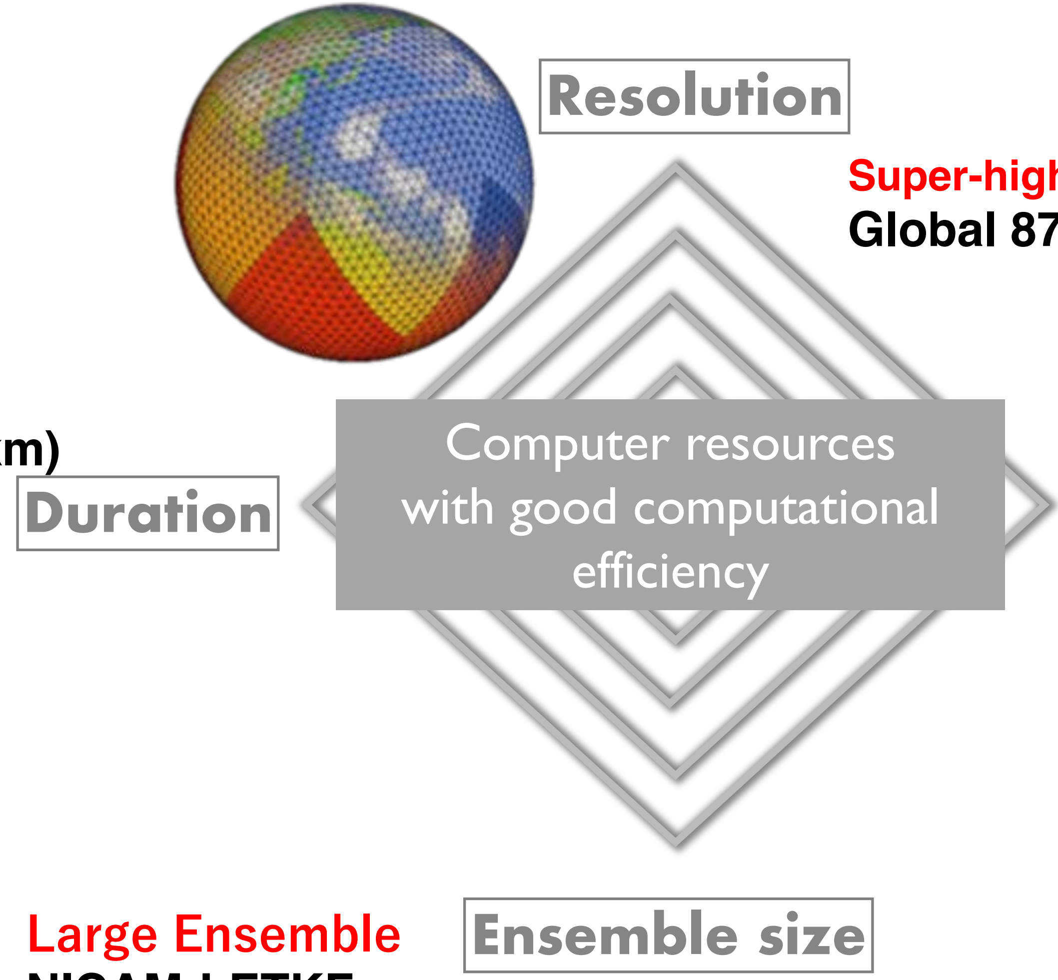
Kodama et al. (2015 JMSJ; 2020 GMD)



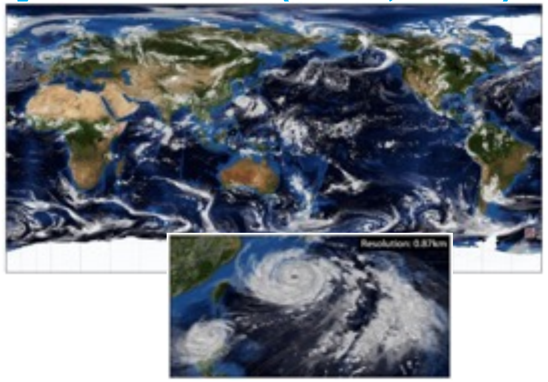
High resolution climate simulation

NICAM-AMIP 30 years (14 km)

HighResMIP 100 years



Miyamoto et al.(2013, GRL)

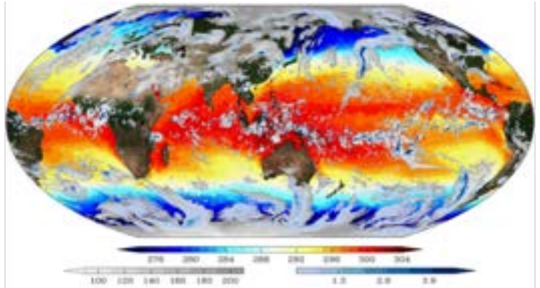


Super-high resolution

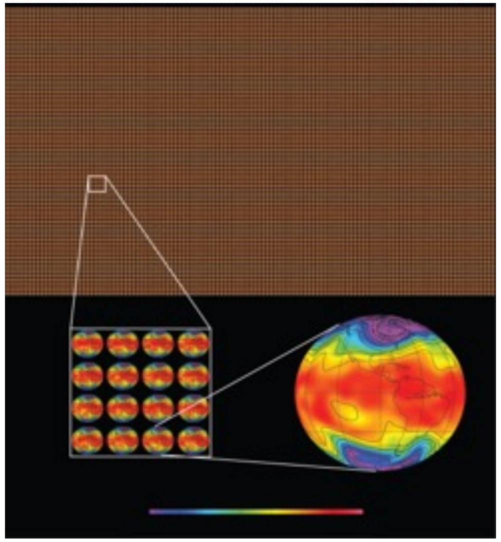
Global 870m mesh

Global cloud & ocean eddy resolving coupled simulation

NICAM+COCO MJO experiment



Miyakawa et al. (2017, GRL)



Large Ensemble

NICAM-LETKF

1000 ensemble

Data assimilation

Miyoshi et al. (2015, Computer)

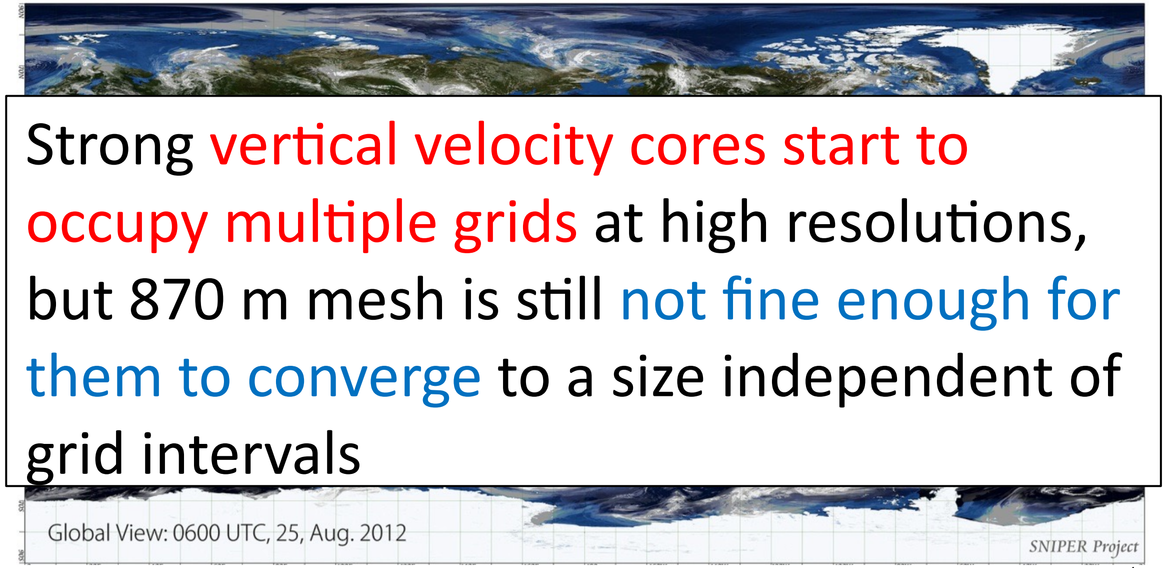
What does global km-scale resolution buy us?

What target is scientifically interesting, computationally feasible, and socially relevant?

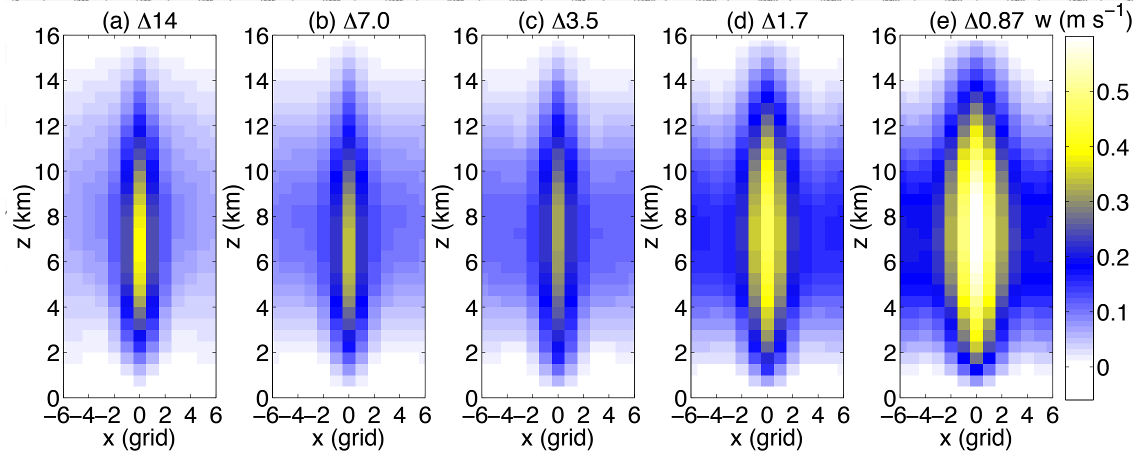
What are the main model issues that need to be resolved to achieve that target?

< What does global km-scale resolution buy us? >

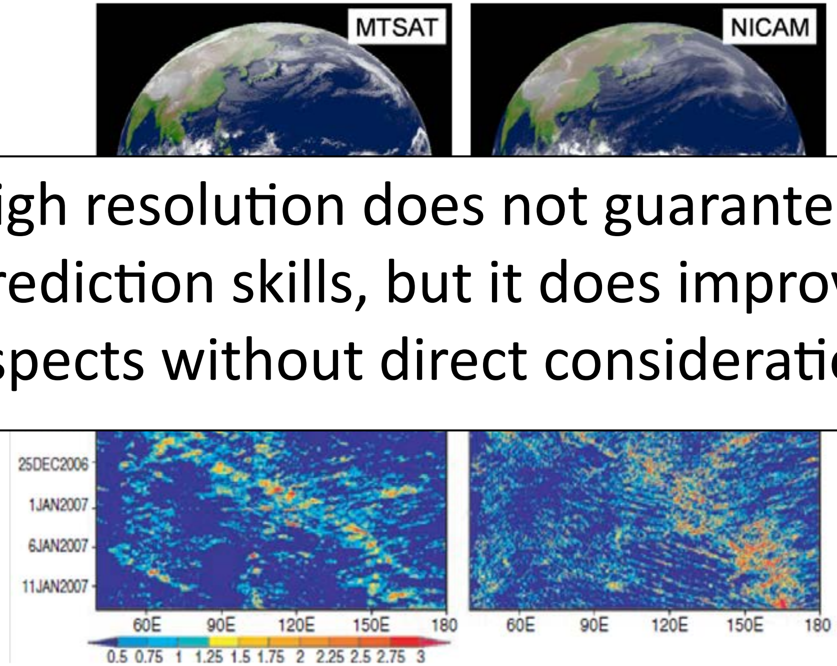
Miyamoto et al. (2013,GRL)



Strong vertical velocity cores start to occupy multiple grids at high resolutions, but 870 m mesh is still not fine enough for them to converge to a size independent of grid intervals



Radius-height cross sections for composites of vertical velocity w (14 km mesh to 870 m mesh)



High resolution does not guarantee better prediction skills, but it does improve many aspects without direct consideration.

Early success on MJO simulation by NICAM Miura et al. 2007, *Science*

Explicit representation naturally allowed convection to be sensitive to environmental relative humidity.

GCMs became successful after implementing schemes that consider such effect (e.g., Bechtold 2008)

< What target is scientifically interesting, computationally feasible, and socially relevant? >

Recently, HPC machines are getting bigger, but individual CPUs not much faster.

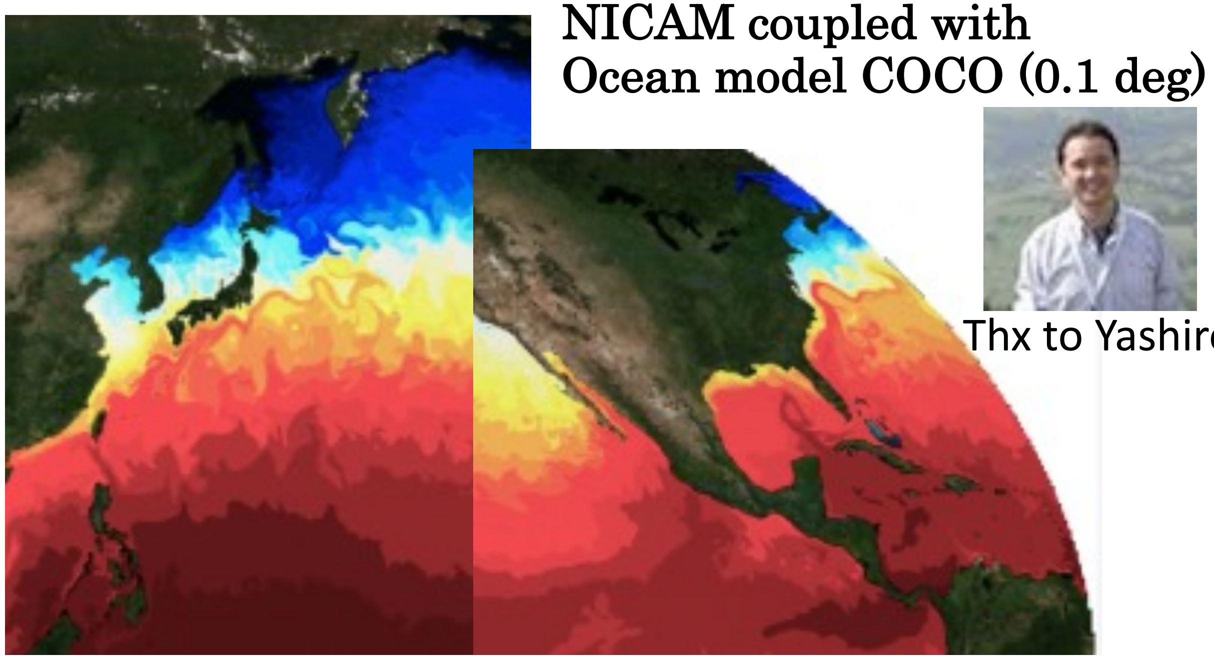
This means that it is more difficult to make simulations longer compared to making ensemble sizes larger, for global km-scale.

→ 20 member decadal simulation is much closer in reach than a single 100 year simulation

\+ shorter turn-around time for tests
scientific value of having a sizable spread
social demand for a "reliable" projection

→ Year ~ multi-decadal ensemble projection
would be the main target in the next 5+ years
(DYAMOND3?)

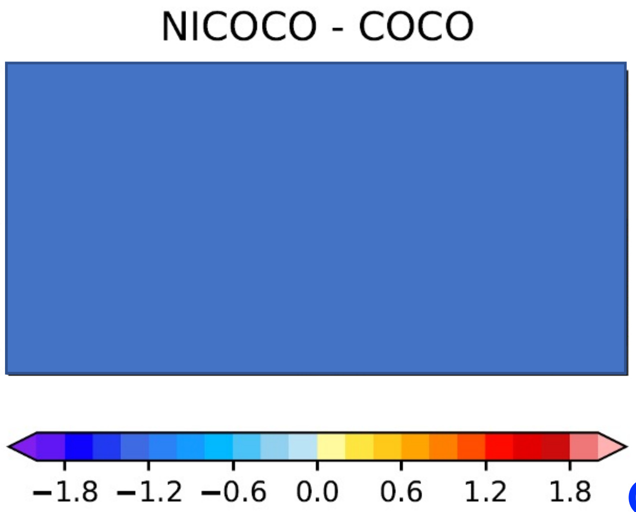
< What are the main model issues that need to be resolved to achieve that target? >



NICAM coupled with
Ocean model COCO (0.1 deg)

Thx to Yashiro

Full coupling with Ocean

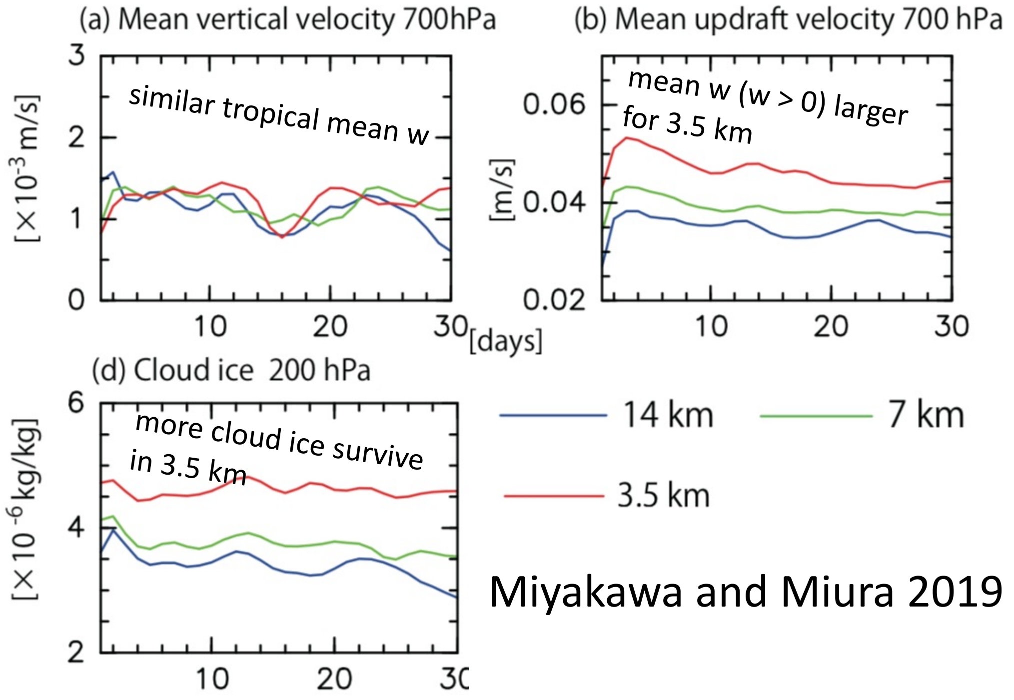


Masunaga et al.

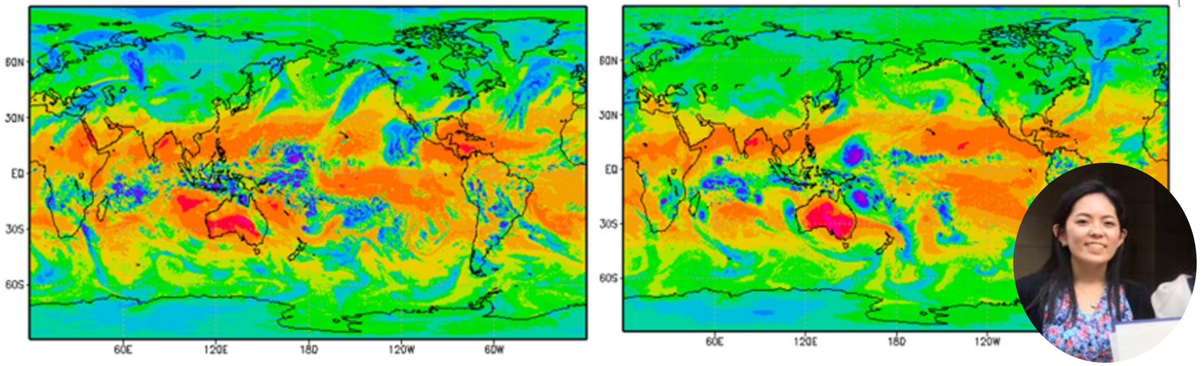
NICAM-COCO (NICOCO)
vs
COCO forced by reanalysis

Ocean bias due to coupling

Uncertainty & resolution dependency of cloud microphyisics



Miyakawa and Miura 2019



Suematsu 2021 Fugaku annual report (JPMXP1020351142)

What does global km-scale resolution buy us?

Finer details （but convection not fully resolved）
Possible model improvements without direct consideration

What target is scientifically interesting, computationally feasible, and socially relevant?

Year ～ multi-decadal ensemble projection
Extended range ensemble predictions of high-impact weathers（weeks～season scale）

What are the main model issues that need to be resolved to achieve that target?

Cloud microphysics, Ocean bias in coupled models
Coupled data assimilation