"Model Improvement"

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Many sub-5 km mesh models available now (13~ atmos., 4 coupled)
Supercomputers and key NICAM simulations

<table>
<thead>
<tr>
<th>ES1 (40 TFlops)</th>
<th>K computer (10 PFlops)</th>
<th>OFP (25 PFlops)</th>
<th>Fugaku (488/977 PFlops for DP/SP)</th>
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<tbody>
<tr>
<td>02 05 07</td>
<td>11 12 13 14 15 16 17 19</td>
<td>20 21 ongoing</td>
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~day

<table>
<thead>
<tr>
<th>3.5km(APE)</th>
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<th>7km 10ens (Athena)</th>
<th>14km 54ens NICOCO</th>
<th>14km 1600ens</th>
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<tr>
<td>870m</td>
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~clim.

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<tr>
<th>14km 30yr</th>
<th>CMIP6</th>
<th>3.5km 10yr</th>
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Miura et al. (2007) Science
Miyamoto et al. (2013) GRL
Kodama et al. (2015) JMSJ
Stevens et al. (2019) PEPS

slide by courtesy of Kodama
High resolution climate simulation

NICAM-AMIP 30 years (14 km)
HighResMIP 100 years

Resolution
Super-high resolution
Global 870m mesh

Complexity
Global cloud & ocean eddy resolving coupled simulation
NICAM+COCO MJO experiment

Duration
Computer resources with good computational efficiency

Ensemble size
Large Ensemble
NICAM-LETKF
1000 ensemble
Data assimilation

Miyakawa et al. (2017, GRL)
Weather/climate studies with K computer & Fugaku
slide by courtesy of Satoh

Kodama et al. (2015 JMSJ; 2020 GMD)

Miyamoto et al. (2013, GRL)

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)
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)

Full coupling with Ocean

NICOCO - COCO

Thx to Yashiro

Masunaga et al.

NICAM-COCO (NICOCO) vs COCO forced by reanalysis

Ocean bias due to coupling

Uncertainty & resolution dependency of cloud microphysics

(a) Mean vertical velocity 700hPa

(b) Mean updraft velocity 700 hPa

[m/s]

[×10^3 m/s]

mean w (w > 0) larger for 3.5 km

Miyakawa and Miura 2019

similar tropical mean w

(d) Cloud ice 200 hPa

[m/kg]

[×10^-3 kg/kg]

more cloud ice survive in 3.5 km

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