Nonhydrostatic Icosahedral Atmospheric Model (NICAM) studies on the supercomputer Fugaku: Challenges and next directions

Satoh Masaki*, Chihiro Kodama, Hisashi Yashiro,
Tomoki Miyakawa, Yohei Yamada, Woosub Roh
(*Atmosphere and Ocean Research Institute, University of Tokyo)

Agu Fall Meeting 2021, 12-16 December m x x
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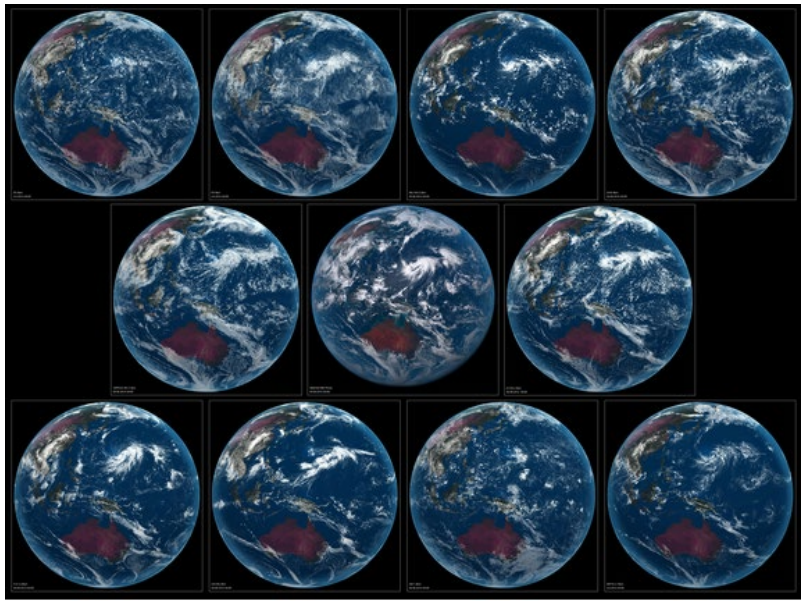
A43D - High-Resolution Earth System Modeling on Large Supercomputers
Friday, 17 December 2021, 03:45 - 05:00 JST
Convention Center - Room 278-279
https://www.agu.org/Events/Meetings/Fall-Meeting-2022

DYAMOND: DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains https://www.esiwace.eu/services/dyamond

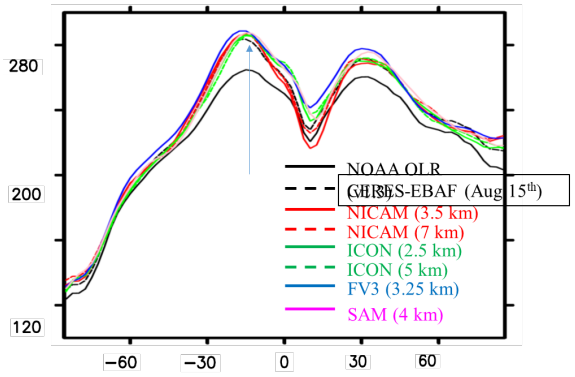
- The first inter-comparison of global storm resolving models (less than 5 km).
- Start on Aug. 1, 2016, simulate 40 days
- DKRZ and ESiWACE provide support and space of data storage (2PB)
- Project term: Oct. 2017 (idea), Nov. 2017 (protocol), about one year most models had submitted the simulation.



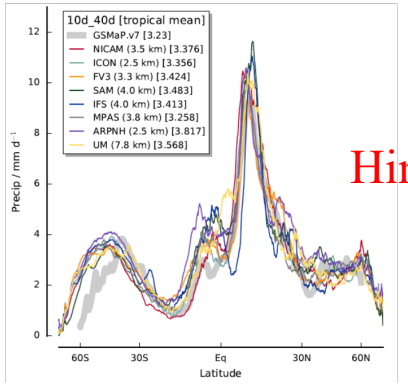
Robustness and Uncertainties of the DYAMOND results

- All models look good cloud distribution compared to Himawari, OLR, and precipitation.
- Meso-scale structure captured globally (Arnold et al. 2020)
- However, a lot of variability exists for vertical structure of clouds.
- Tropical cyclones statistics are within similar range, but very different structure (Judt et al. 2020, in review)
- Cloud evaluations using various observations are on-going (Roh and Satoh, 2020, in prep.)

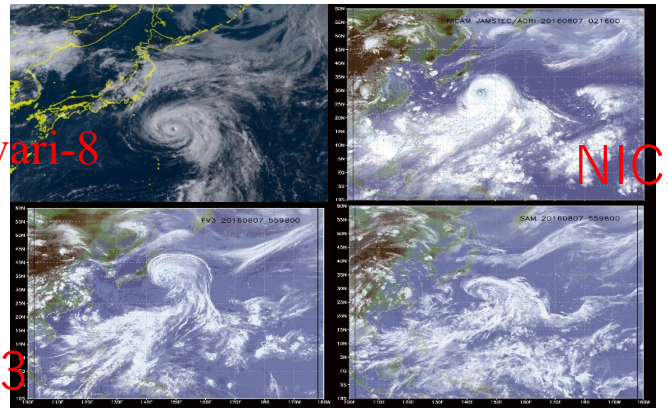
Zonal mean OLR



Zonal mean precipitation

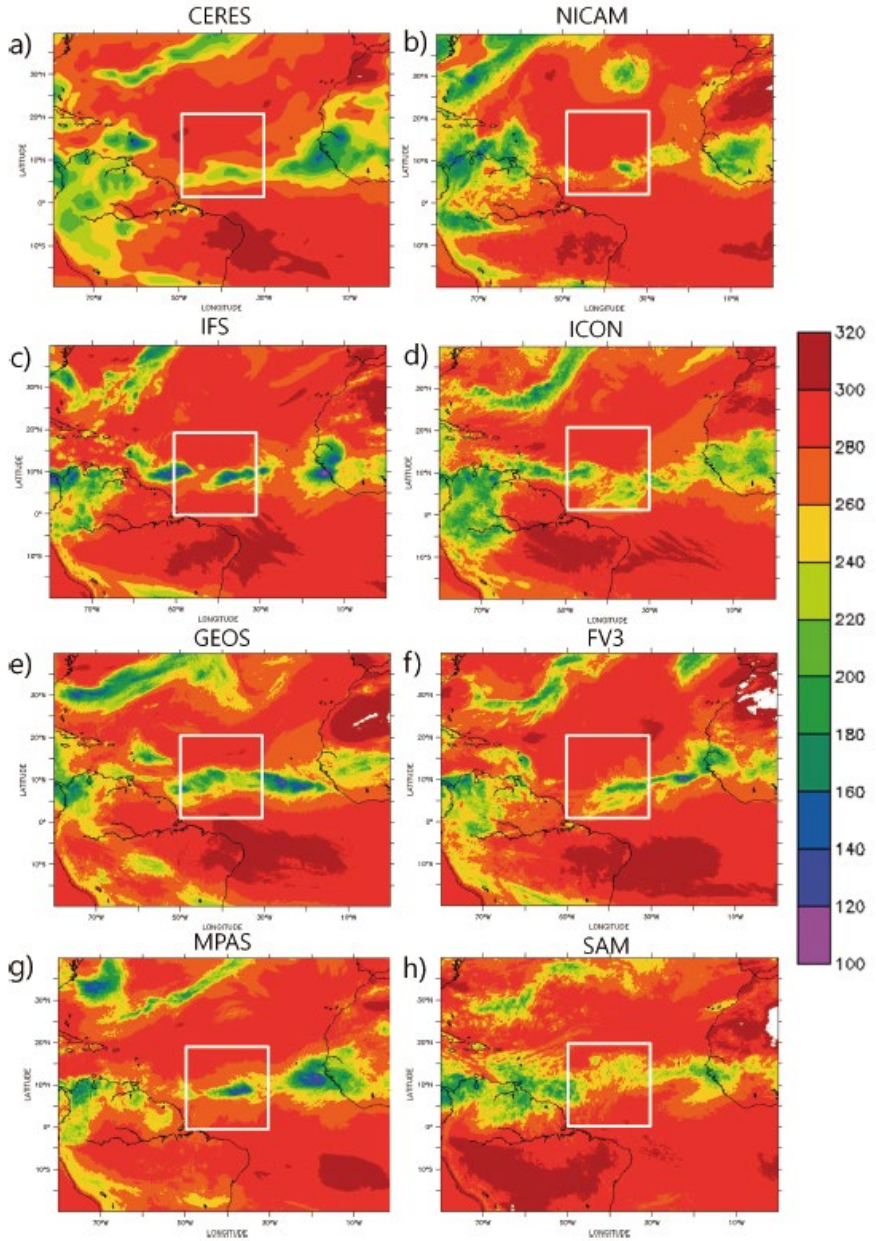


A snapshot for Tropical cyclone OMAIS

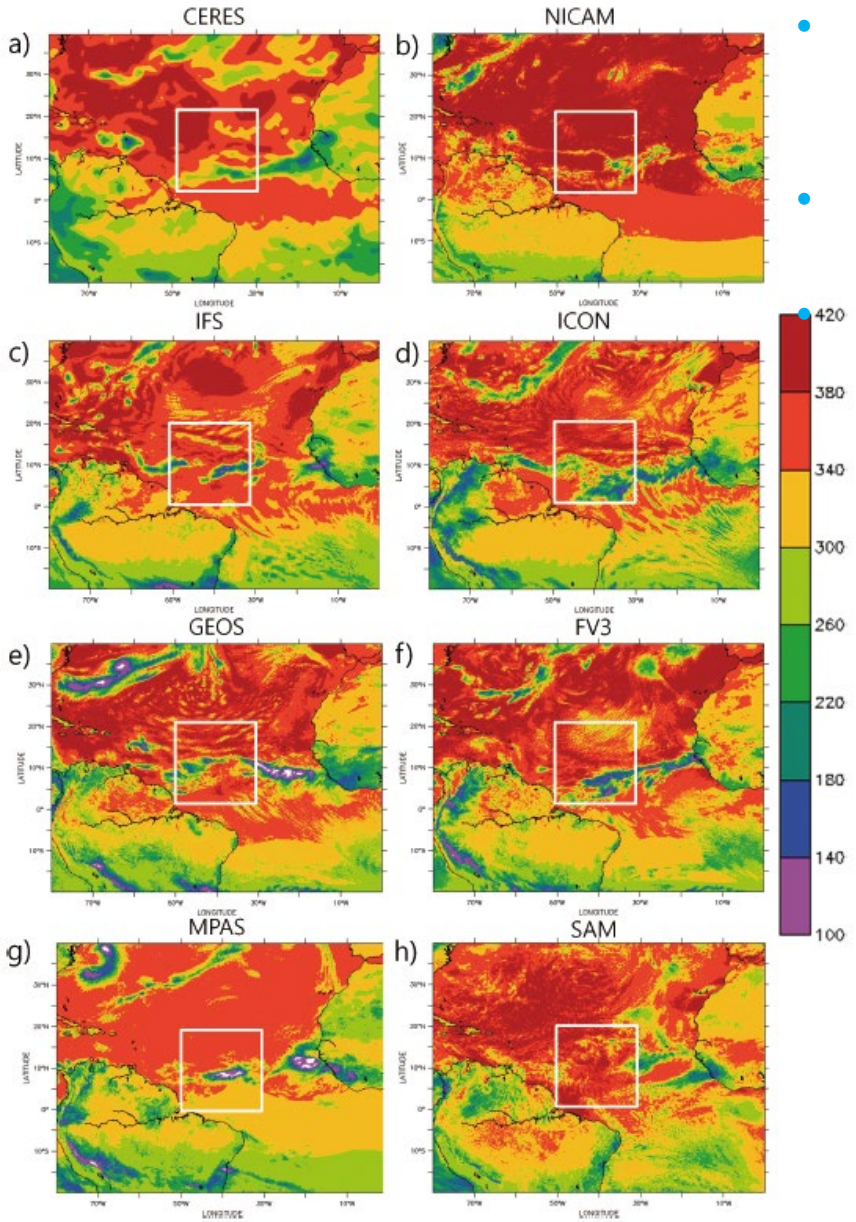


- DYAMOND summary paper: Stevens et al., 2019, PEPS https://doi.org/10.1186/s40645-019-0304-z
- JMSJ DYAMOND Special edition: J. Meteor. Soc. Japan https://jmsj.metsoc.jp/special_issues_editions/DYAMOND.html

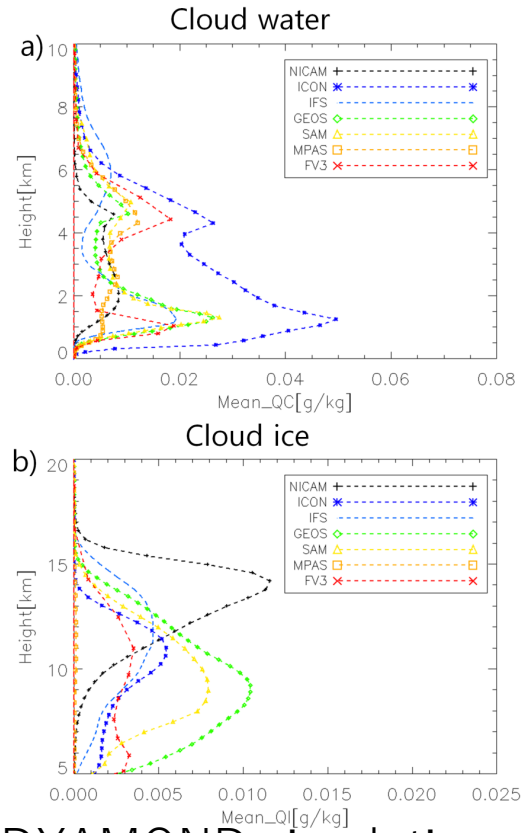
OLR on 11 August 2016



Net Shortwave Outgoing Radiation on 11 August 2016



- **The domain averaged OLR is relatively similar across the models**
- **The NSR shows large differences among the models.**
- **Vertical profiles of hydrometeors are divergent.**

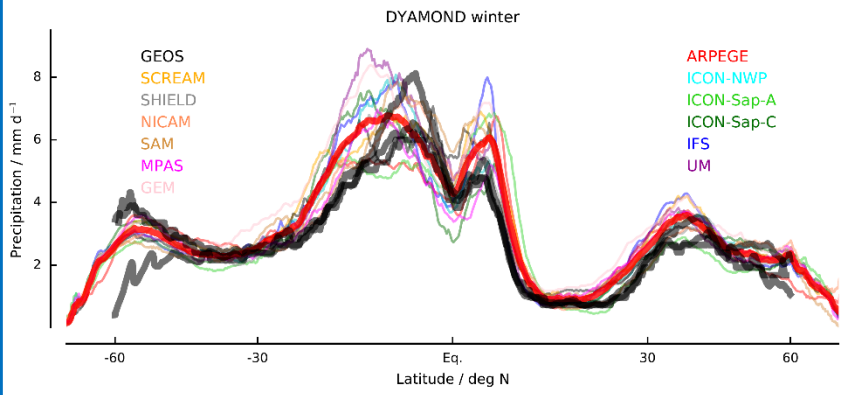


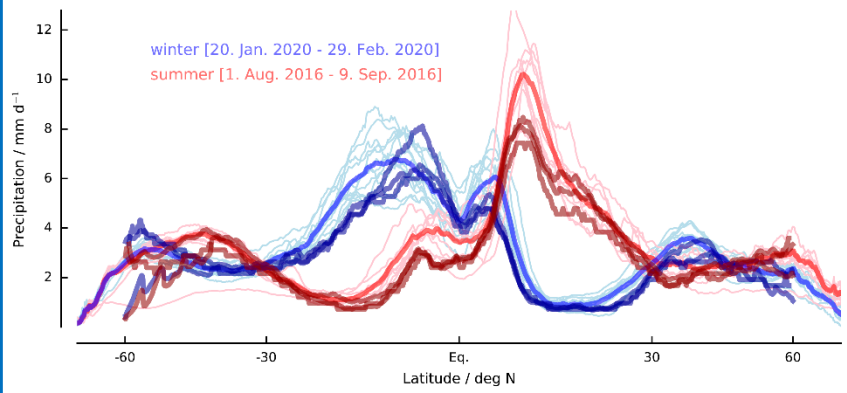
Roh, W., Satoh, M., Hohenegger, C. (2021) Intercomparison of cloud properties in DYAMOND simulations over the Atlantic Ocean. J. Meteorol. Soc. Japan, https://doi.org/10.2151/jmsj.2021-070

NICAM related activities as a Global Storm-Resolving Model

DYAMOND winter simulations (T. Miyakawa)

- dx<5km
- 40 days integration: **20 January – 1 March 2020**
- Atmosphere-only (NICAM), AO-coupled model (NICOCO)

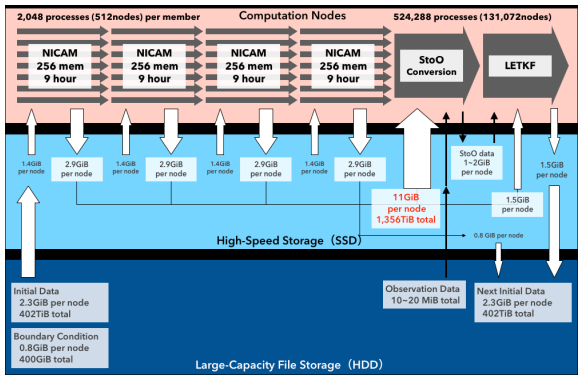


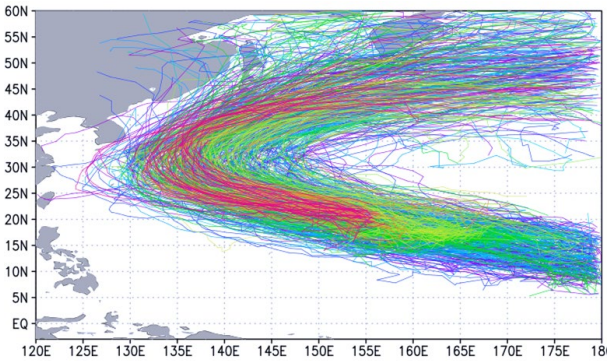


Model	Resolution	Grid	Coupled
ARPEGE-nh	2.5	spec	no
GEM	0.045deg	y-y	no
GEOS	1.5	sphere3	no
GEOS	3	sphere3	no
GEOS	6	sphere3	yes
ICON-NWP	2.5	ico	no
ICON-NWP	5	ico	no
ICON-Sap	5	ico	no
ICON-Sap	5	ico	yes
IFS-NEMO	4	spec	yes
IFS-NEMO	9	spec	yes
IFS-FESOM2	4	spec	yes
IFS-NH	4	spec	no
MPAS	3.75		1D
NEPTUNE			yes
NICAM	3.5	ico	no
NICOCO	?	ico	yes
SHIELD (FV3)	3	sphere3	no
SAM	4	I-I	??
SCREAM	3	sphere3	no
SCREAM	3.25	sphere3	yes
UM	4.8	I-I	no

Super-ensemble simulations "Fugaku" supercomp.

- NICAM-LETKF dx=3.5km, #1000 (H. Yashiro) SC20, Gordon Bell Finalist
- Typhoon predictability #1000, 1month, dx=14km (Y. Yamada)

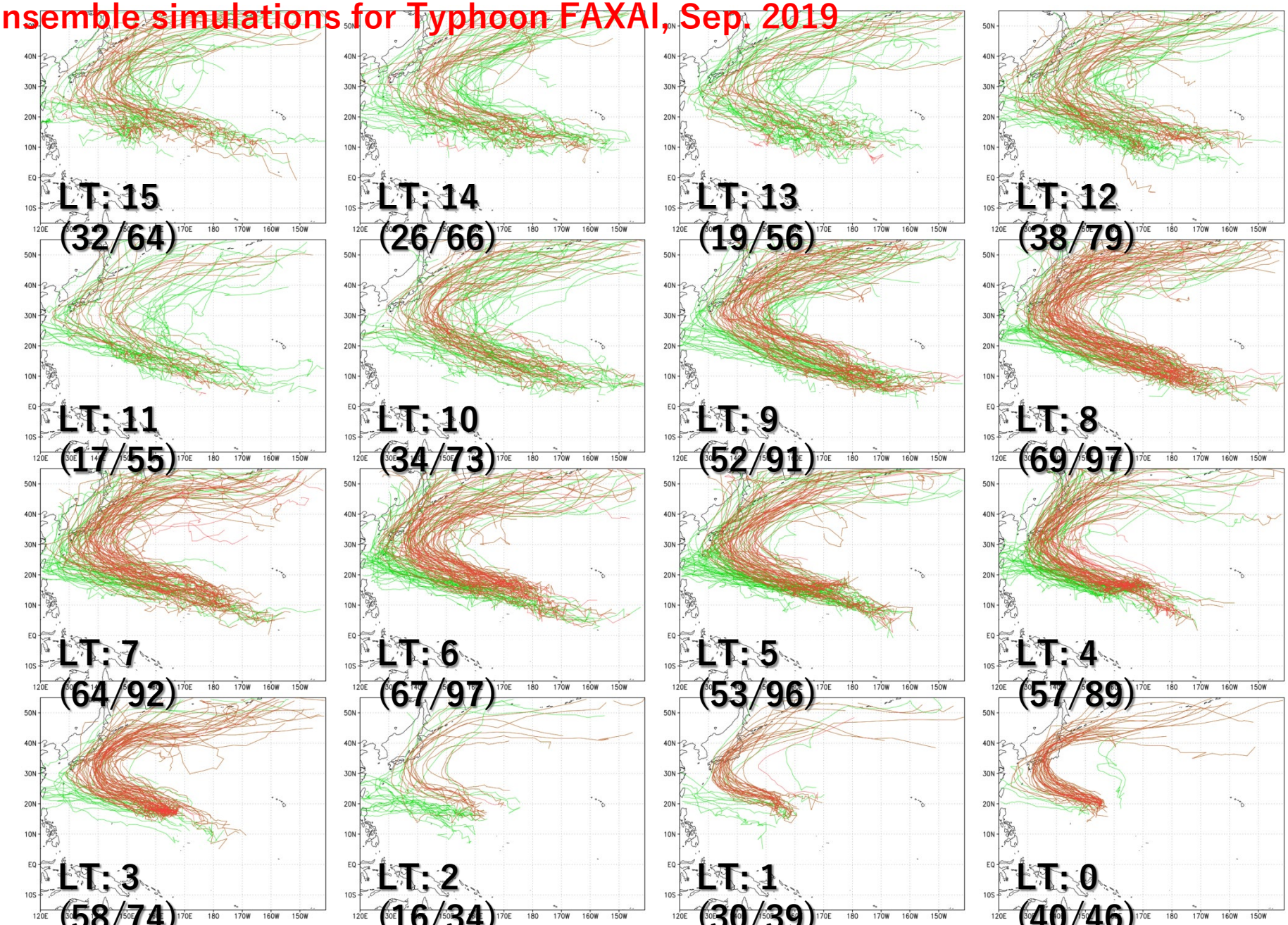




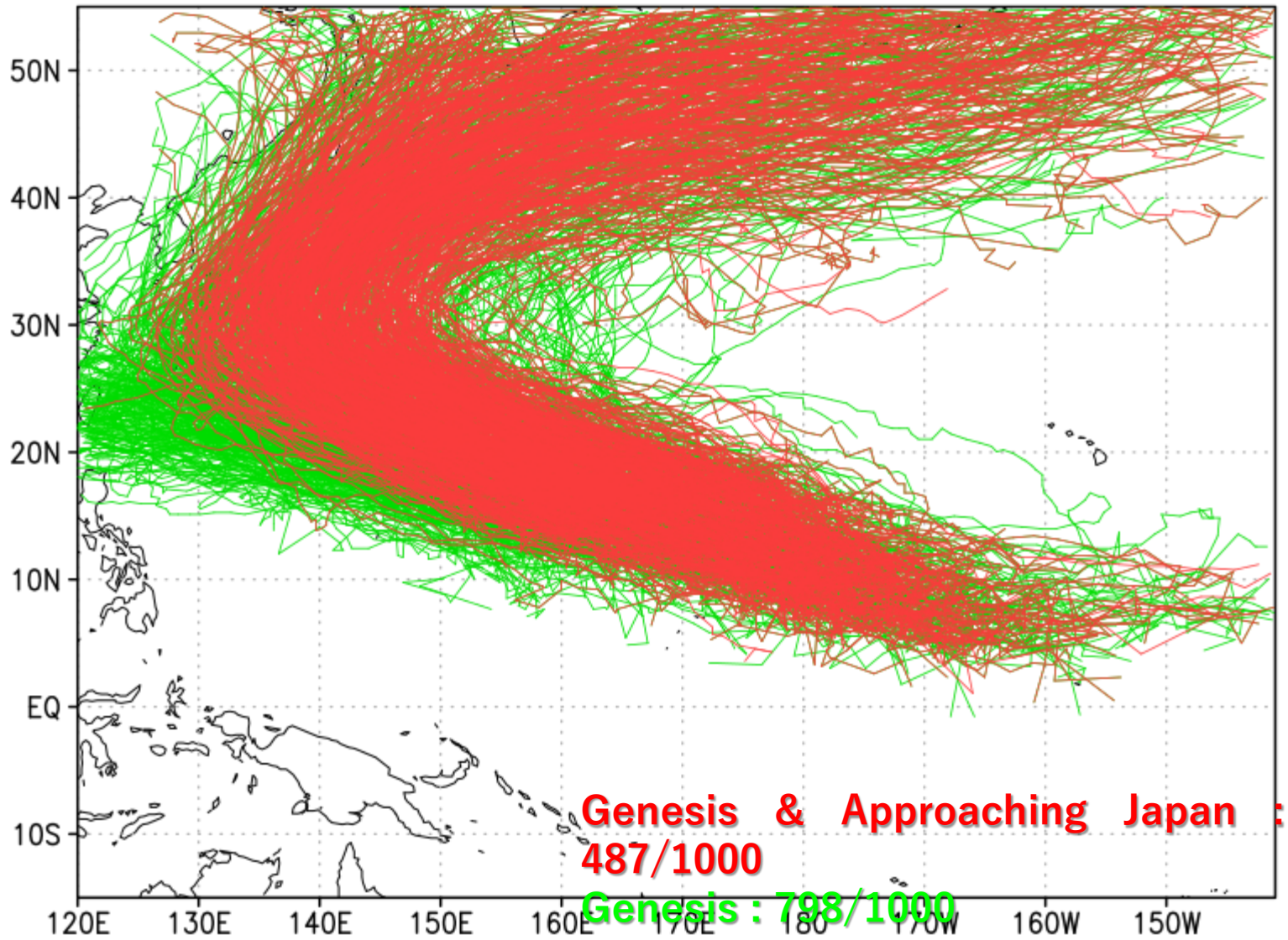
Next step activities

- Collaboration with satellites: EarthCARE (2023) etc.
- Global LES: dx=220m global on Fugaku (2022)
- Evaluation of cloud microphysics: ULTIMATE (2020)
- Typhoonshot: dx~1km (2022)

NICAM 1000-ensemble simulations for Typhoon FAXAI, Sep. 2019



Red lines: tracks of TC which satisfies conditions: position and timing of genesis and approaching Japan of Faxai
Green lines: tracks of TC which satisfies conditions: position and timing of genesis of Faxai



Red lines: tracks of TC which satisfies conditions: position and timing of genesis and approaching Japan of Faxai

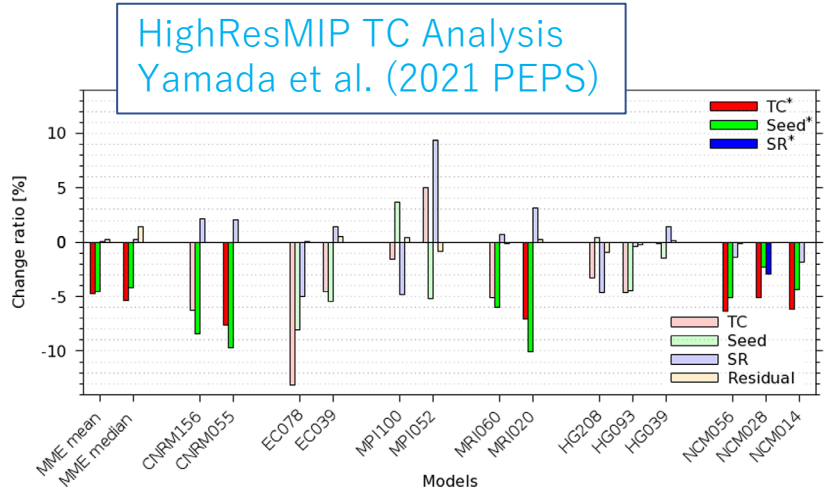
Climate studies with NICAM

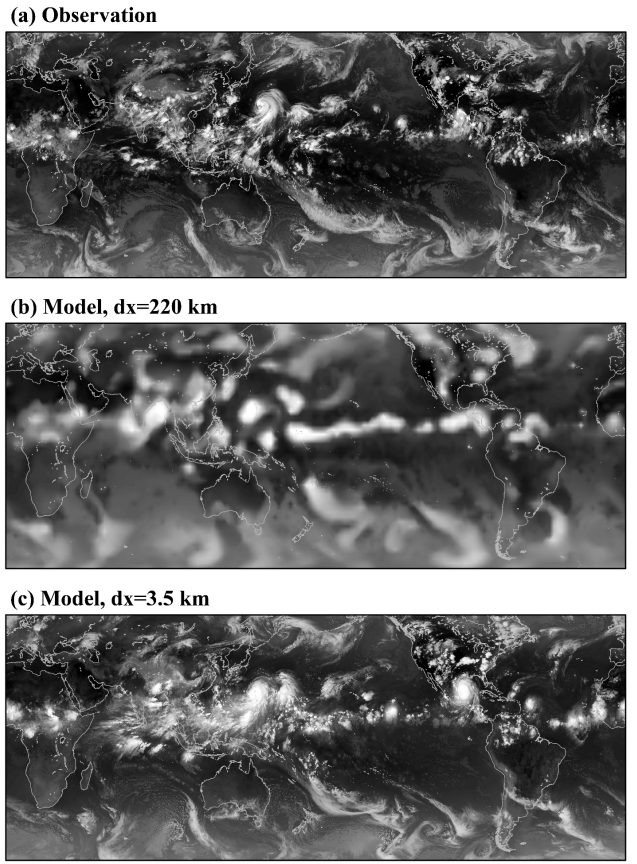
- **Recent climate analysis with NICAM (inc. HighResMIP)**
  - Tropical cyclone (Yamada et al. 2021 PEPS; Roberts et al. 2020 GRL)
  - Monsoon precipitation (Takahashi et al. 2020 JC; Na et al. 2021 JGR)
  - High cloud response (Ohno et al. 2021 GRL; Chen et al. in revision)

- **Model development & tuning for climate bias reduction**
  - Continuous effort to reduce mean state biases (e.g. cloud & precipitation, surface air temperature) (Kodama et al. 2021 GMD)
  - Recent update on cloud microphysics (Seiki and Roh 2020 JAS; Roh et al. 2020 JAS; Noda et al. 2021 JGR)
  - Importance of turbulence scheme in high-cloud response to warming (Ohno et al. 2020 JMSJ)
  - Parameter tunings to realistically simulate both mean state and disturbances (e.g. MJO) : Lessons from DYAMOND1/2 and more

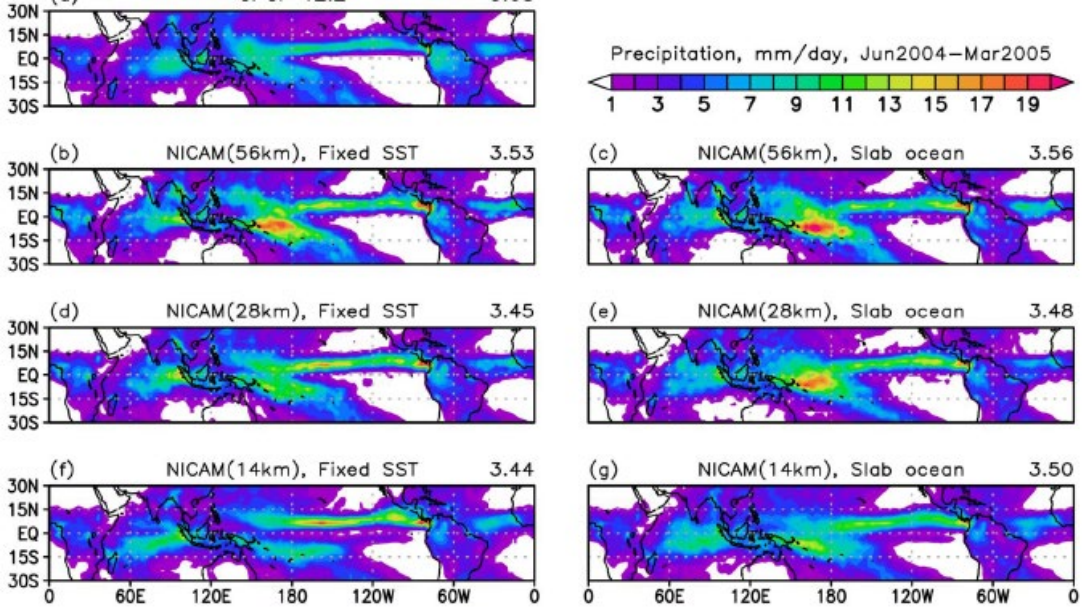
- **On-going**
  - Global cloud-resolving (3.5 km) climate (~10yr) simulation
  - Ocean-coupled 14 km climate simulation
  - 14 km large-ensemble time-slice simulation

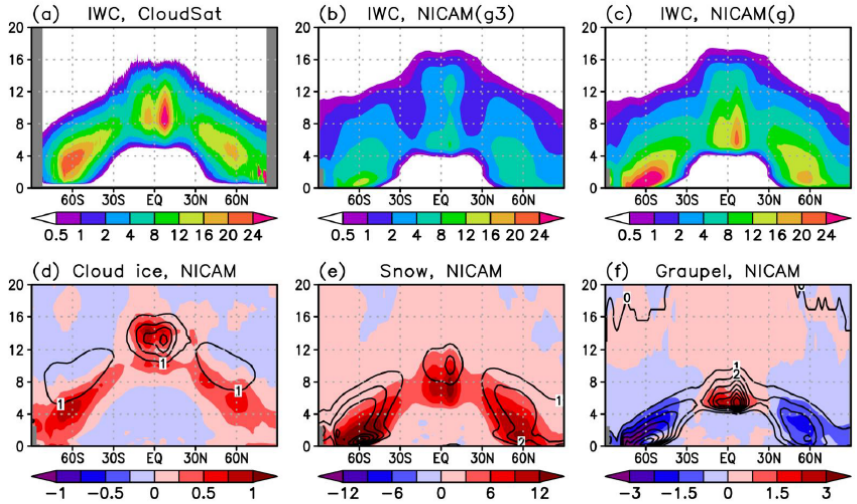
- **Prospect (~5ys)**
  - **DYAMOND-next: AO-coupled 30yrs: to collaborate with NextGEMS**



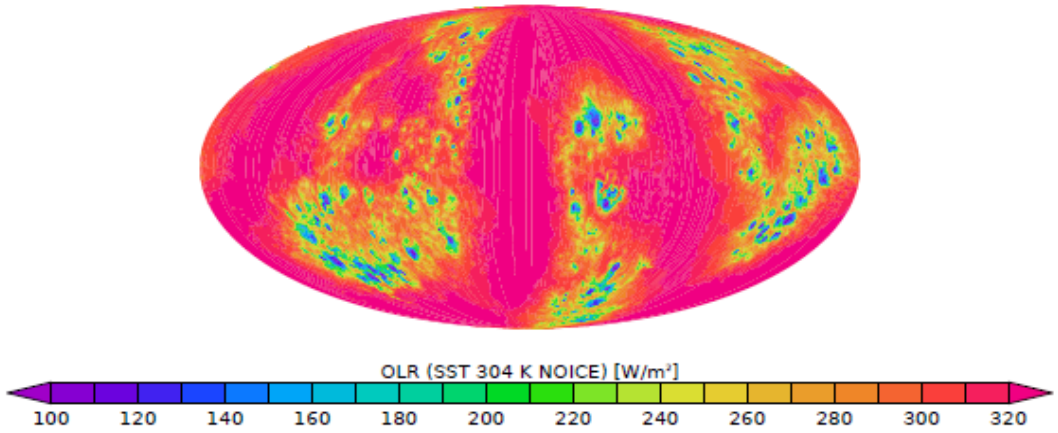


MJO/BSISO: NICAM@DYAMOND1 (Shibuya et al. 2021, JMSJ)

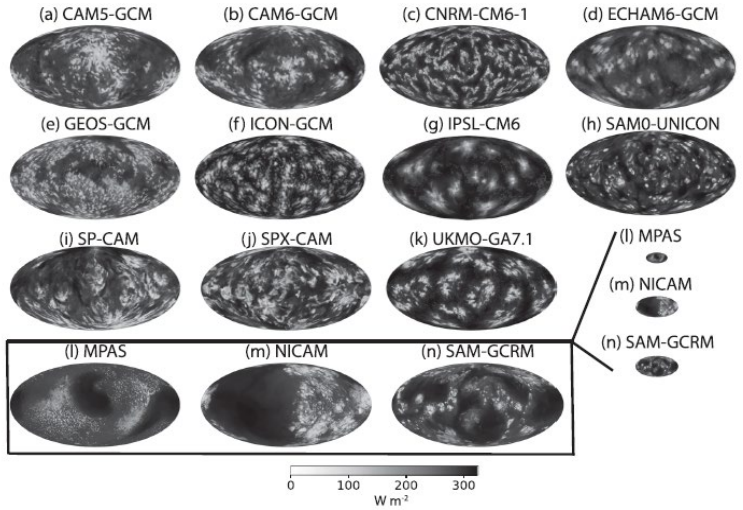




NICAM HighResMIP run (Kodama et al. 2020 GMD)



NICAM RCE (Ohno et al. 2020 JMSJ)



RCEMIP (Wing et al. 2020 JAMES)