Center Report From JMA

Recent updates of JMA's NWP system development

- New HPCs launch (Mar. 2023 and Mar. 2024)
  - NAPS (Numerical Analysis and Prediction System) 10 -> NAPS11s, NAPS11
    - NAPS11s : Specialized for predicting MCS (Mesoscale Convective Systems)
    - NAPS11 : Implements all other functions
- Upgrades of the regional NWPs (Mar.2024)
  - Introduction of SSP-RK scheme in HE-VI time integration (Kimura et al. 2024, WGNE Blue Book).
  - Assimilation of ground-based microwave radiometer data (Nakamura et al. 2024, WGNE Blue Book)
- Research on machine learning based models

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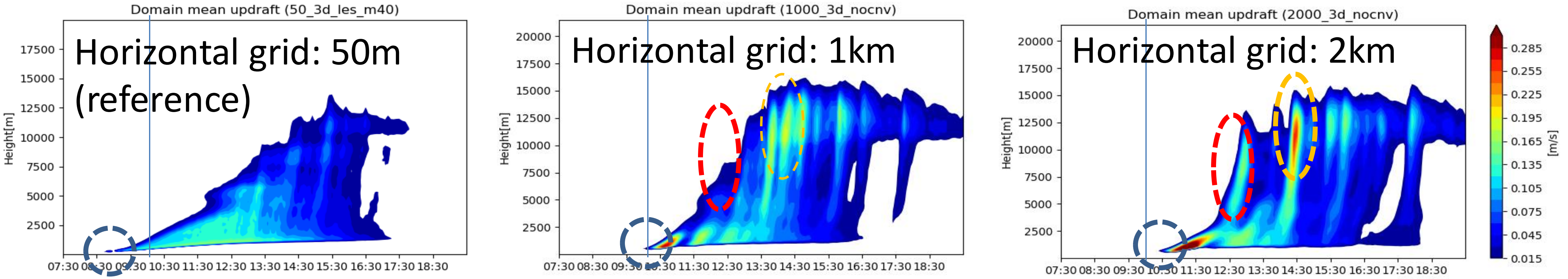
NAPS11s

- Operational March 2023
  - Contract w/ Fujitsu
- Two PRIMEHPC FX1000's
  - A64fx processor
- Spec per each subsystem
  - Peak 14.27 petaflop/s
  - Power 904.72 kW
- HBM2 memory
  - 1024 GB/s/node
  - 2x effective performance of NAPS10

Located in Fujitsu facility, unlike previous NAPS supercomputers

Development of improve horizontal resolution from 2km to 1km

- On NAPS11s, resolution improvement of LFM (the JMA's finest mesh regional model) is planned in Mar. 2026.
- Ideal experiment and NWP case studies (incl. feasibility studies on Supercomputer Fugaku) showed that the 1kmLFM represented better MCS than the 2km LFM, but issues still exists:
  - Mitigation of slow convective initiation and the rapid transition from shallow to deep convection
  - Mitigation of excessive deep convection
- Toward further improvement, vertical transport processes associated with convection will be a key.



Time-height cross sections of regionally averaged convective updraft from the ideal experiment of cumulus convection proposed by Grabowski et al. (2006).

NAPS11

- Operational March 2024
  - Contract w/ Fujitsu
- Two PRIMERGY CX2550 M7
  - Intel Xeon CPU Max 9480
- Spec per each subsystem
  - Peak 3.295 petaflop/s
  - Power 438.03 kW
- HBM2e memory
  - 3280 GB/s/node
  - 2x effective performance of NAPS10
- Additional GPU cluster on cloud
  - 48x NVIDIA A100 80GiB SXM

NAP11, located on the premiss of JMA

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Introduction of SSP-RK scheme in HE-VI time integration

- ASUCA, a regional non-hydrostatic model used in the JMA's regional NWPs (Ishida et al. 2022), employed a HE-VI (Horizontally Explicit Vertically Implicit) method for solving fast modes such as acoustic waves.
  - Combined with the Wicker and Skamarock (2002)'s third-order Runge-Kutta scheme (RK3)
- For solving the fast modes (less meteorologically important waves) with higher computational stability and efficiency, a Strong Stability Preserving Runge-Kutta scheme (Shu and Osher 1998; SSP-RK) was implemented in the HE-VI method.

Wicker and Skamarock(2002)	SSP-RK(3,2)
$f^{(1)} = f^n + \frac{\Delta t}{3}\phi\left(f^n\right)$	$f^{(1)} = f^n + \frac{\Delta t}{2}\phi\left(f^n\right)$
$f^{(2)} = f^n + \frac{\Delta t}{2}\phi\left(f^{(1)}\right)$	$f^{(2)} = f^n + \frac{\Delta t}{2}\phi\left(f^{(1)}\right)$
$f^{n+1} = f^n + \Delta t\phi\left(f^{(2)}\right)$	$f^{n+1} = \frac{1}{3}f^n + \frac{2}{3}f^{(2)} + \frac{\Delta t}{3}\phi\left(f^{(2)}\right)$

Introduction of SSP-RK scheme in HE-VI time integration

- Our linear stability analysis using a one-dimensional shallow water system has clarified that SSP-RK combined with HE-VI provides higher computational stability than RK3.
- Not only the simplified linear system, but also in the non-linear three-dimensional systems using ASUCA, we empirically confirmed that SSP-RK is stable with larger Courant numbers than RK3.
- These results suggest that SSP-RK enables employment of larger time-step for HE-VI.

$$\frac{\partial u}{\partial t} = -g\frac{\partial h}{\partial x},$$
$$\frac{\partial h}{\partial t} = -H\frac{\partial u}{\partial x}.$$

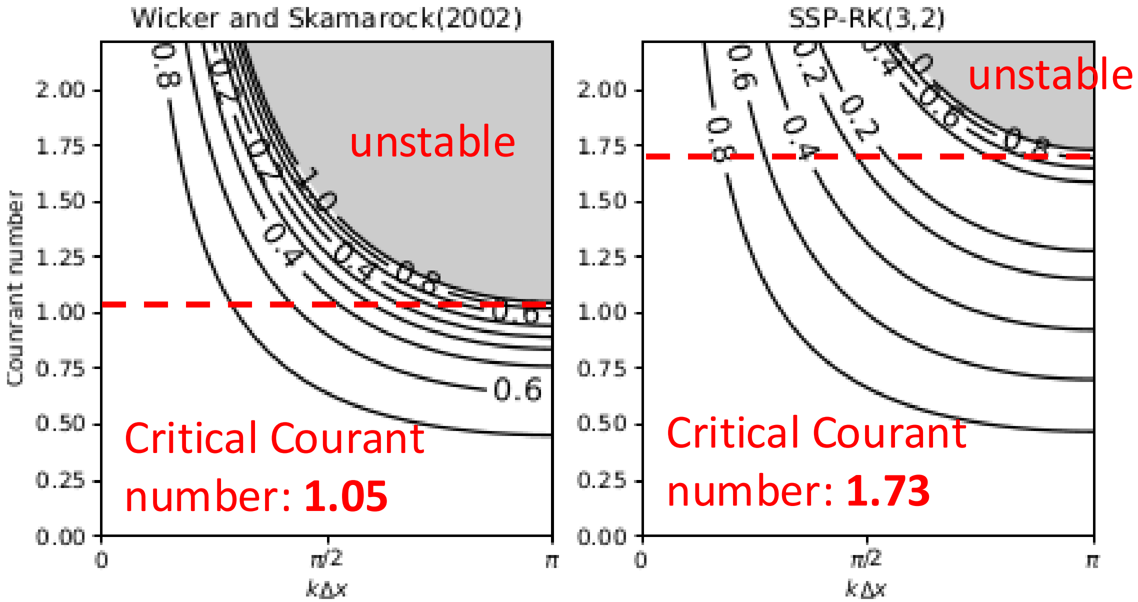
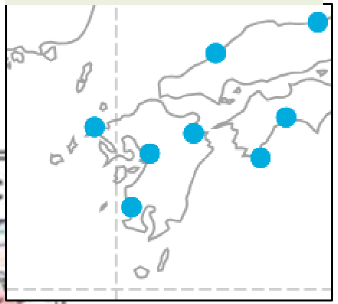


Figure 2: Amplification factors of WS02 (left) and SSP-RK(3,2) (right). The horizontal and vertical axes are $k\Delta x$ and Cr, respectively. Regions with amplification factors larger than unity (i.e., where numerical solutions are unstable) are shaded.

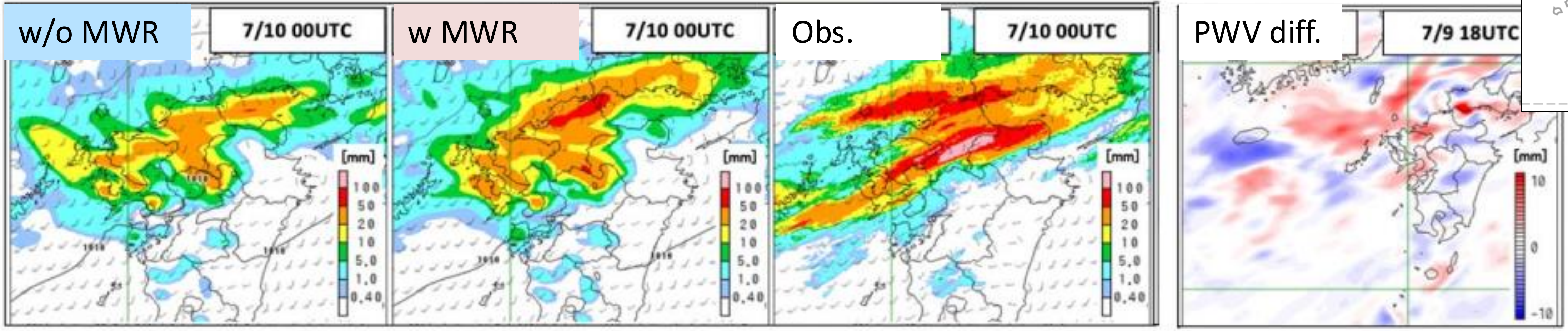
Assimilation of ground-based microwave radiometer data

- MCS: Important targets for JMA’s NWP systems (as stated in the JMA NWP strategic plan)
- JMA started to assimilate precipitable water vapor (PWV) retrieved from the ground-based microwave radiometers (MWRs) adopted in western Japan for water vapor monitoring.
- In a case below, ongoing assimilation of MWR modified PWV distribution around MCSs and improved precipitation forecasts.

MWR sites



Three hour accumulated precipitation [mm] valid for 00UTC 10 Jul. 2023
Forecast lead time : 6hr



NAKAMURA Yuki, YOSHIMOTO Koichi and YAMAMOTO Kentaro

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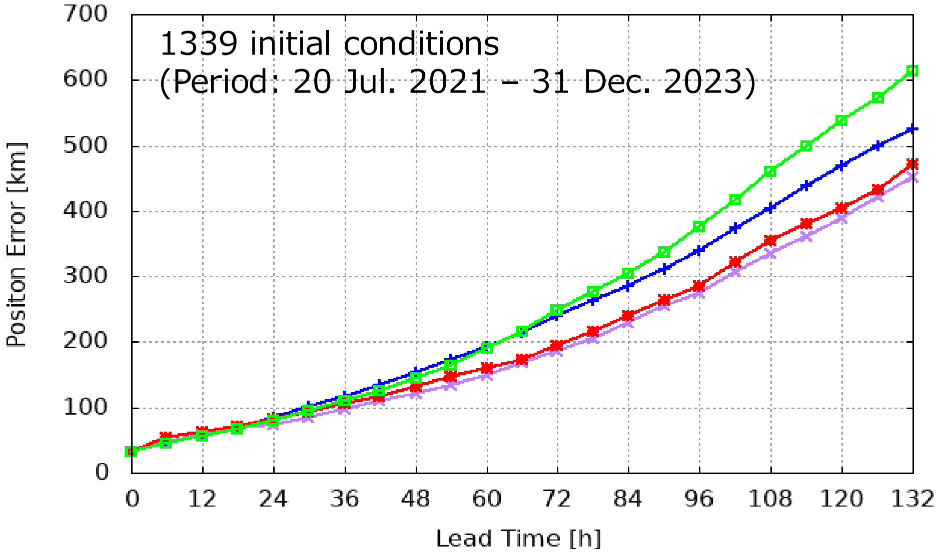
Research on Machine Learning-based models

- To keep pace with the rapid progress of ML-based (data-driven) models, and understand their feasibility for JMA operations, JMA has recently started an investigation into ML models.
  - Investigation of available existing ML models such as FourCastNet, Pangu-Weather and GraphCast : to catch-up the current progress of ML models
    - Experiments using ML models initialized with JMA's operational global analysis
    - Fine-tuning using JMA's operational global analysis data
  - Construction of a small ML model from scratch : to be familiarized with ML model development

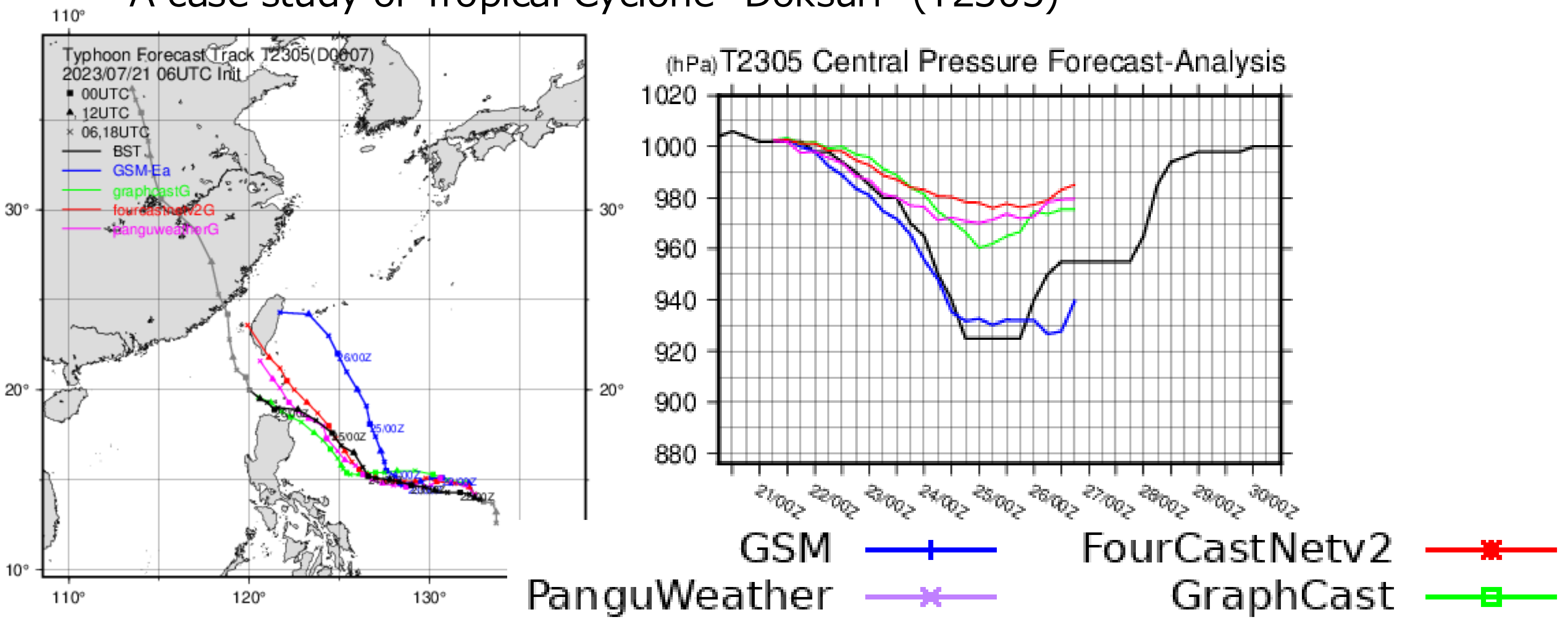
TC Verification

- Several ML models <u>initialized from the JMA's operational global analysis</u> improved TC position errors by 20% against GSM (JMA's Global Spectral Model) at T+72hr
  - Better: Pangu-Weather and FourCastNetv2, Worse: GraphCast
- Cross track errors before curvature, a well-known common bias in NWP models, are not clearly found in ML models.
- Intensification of TCs are weaker in ML models.
- Verif. with the WGNE format could be possible in future.

TC Position errors
over the Western North Pacific



A case study of Tropical Cyclone "Doksuri" (T2305)



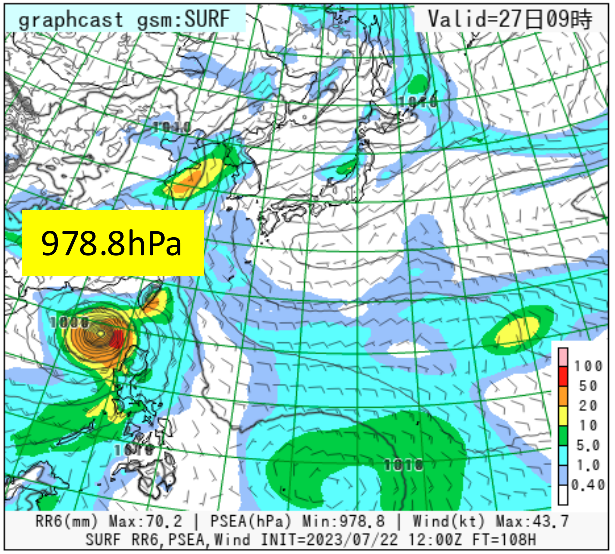
YONEHARA Hitoshi, TANOSHITA Jun-ichi and TERAUCHI Shumpei

Preliminary results of fine-tuning using JMA's own analysis

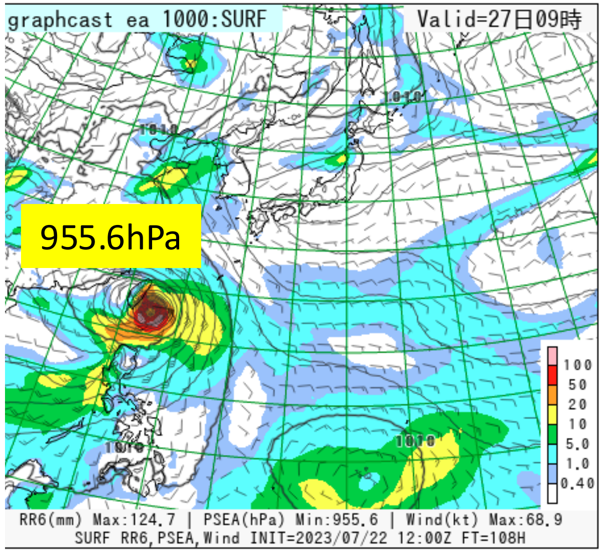
- Fine-tuning, additional two-years training, for GraphCast using the JMA's operational global analysis has been carried out.
- The fine-tuned GraphCast forecasted more similar fields to GSM
- A case study showed that the fine-tuned GraphCast represented deeper TC (not all TC cases).

A case of tropical cyclone "DOKSURI" (T2305)
Valid time 00UTC 27 Jul. 2023, Forecast lead time: T+108hr

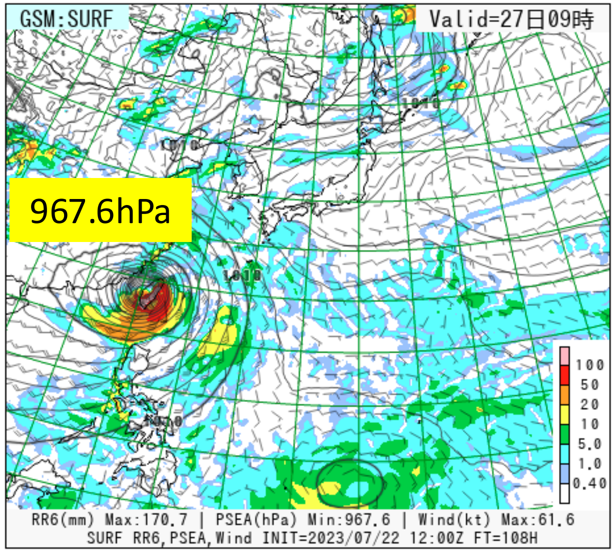
GraphCast



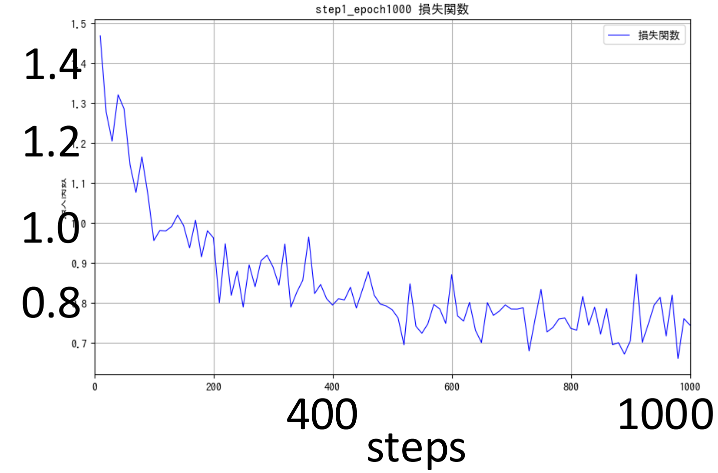
Fine-tuned GraphCast



GSM



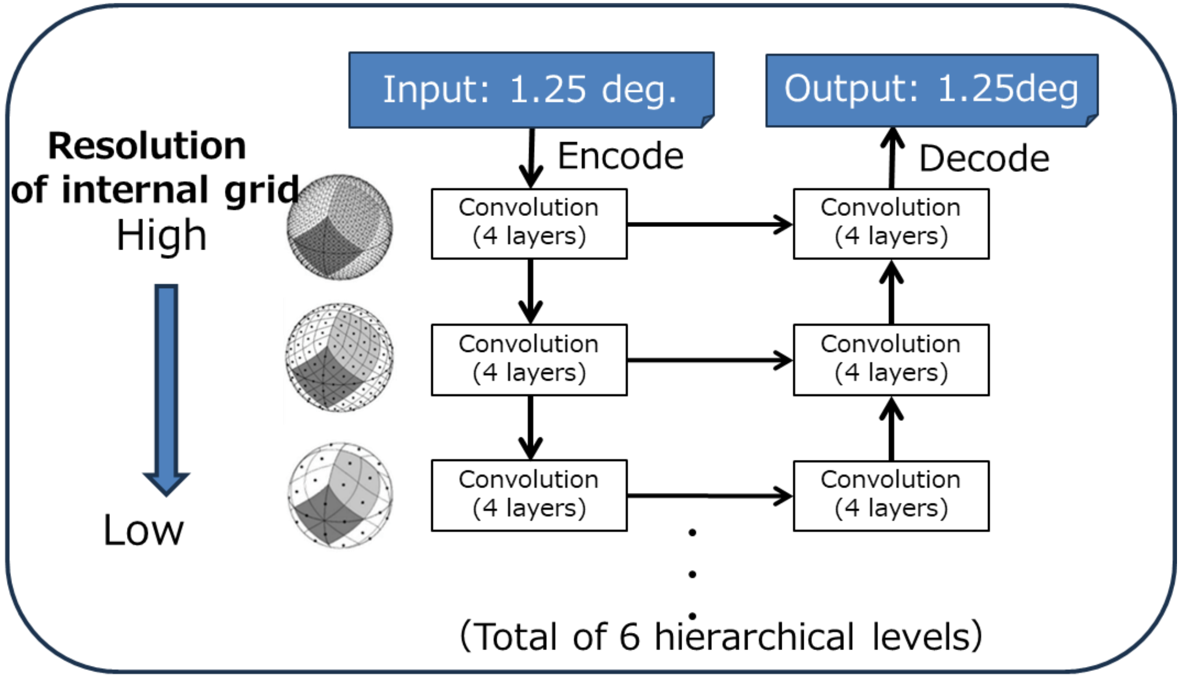
Loss function



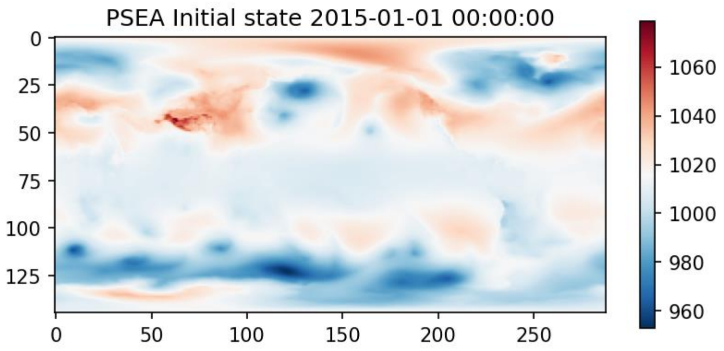
TANOSHITA Jun-ichi and YONEHARA Hitoshi

Writing a low-res ML-based global prediction model

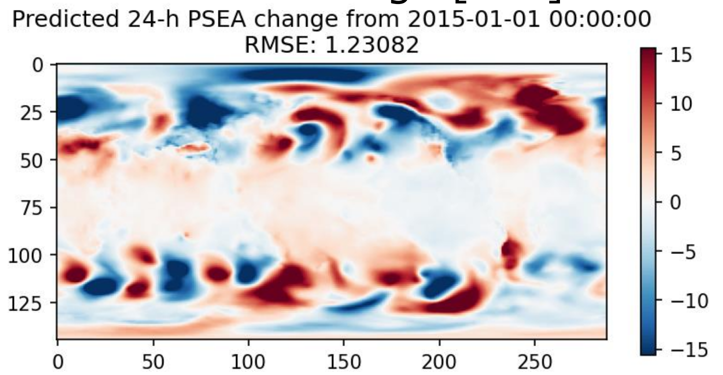
- **Objective:**
  Writing and training a compact global AI weather model using Graph Neural Network following Keisler (2022) as an exercise
- **Implementation:**
  Adopted a hierarchical structure like Lam et al. (2023) and Oskarsson et al. (2023)
  Input/Output : 1.25° horizontal resolution, 24-hour intervals, trained on 00UTC analysis only
- **Preliminary Validation:**
  - 24-hour forecast 500hPa height RMSE: 8.8m, showing some skill relative to persistence



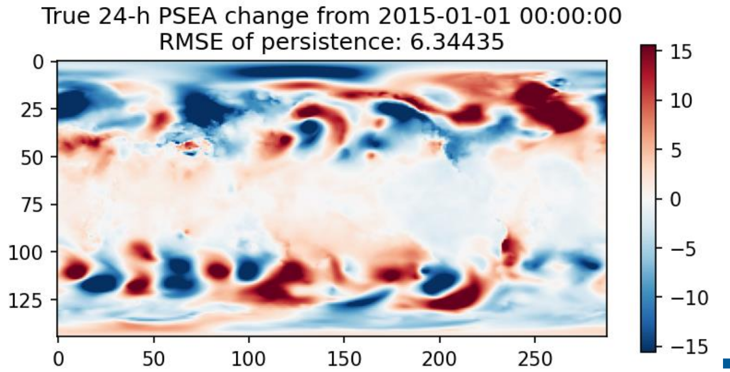
Initial Conditions
Input (PSEA)



AI Weather Model Output
24-hour change [hPa]



Analysis (JRA-3Q)
24-hour change [hPa]



YOSHIDA Takuma