ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop
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Updating EarthCARE synthetic data using the global 220-m mesh simulation

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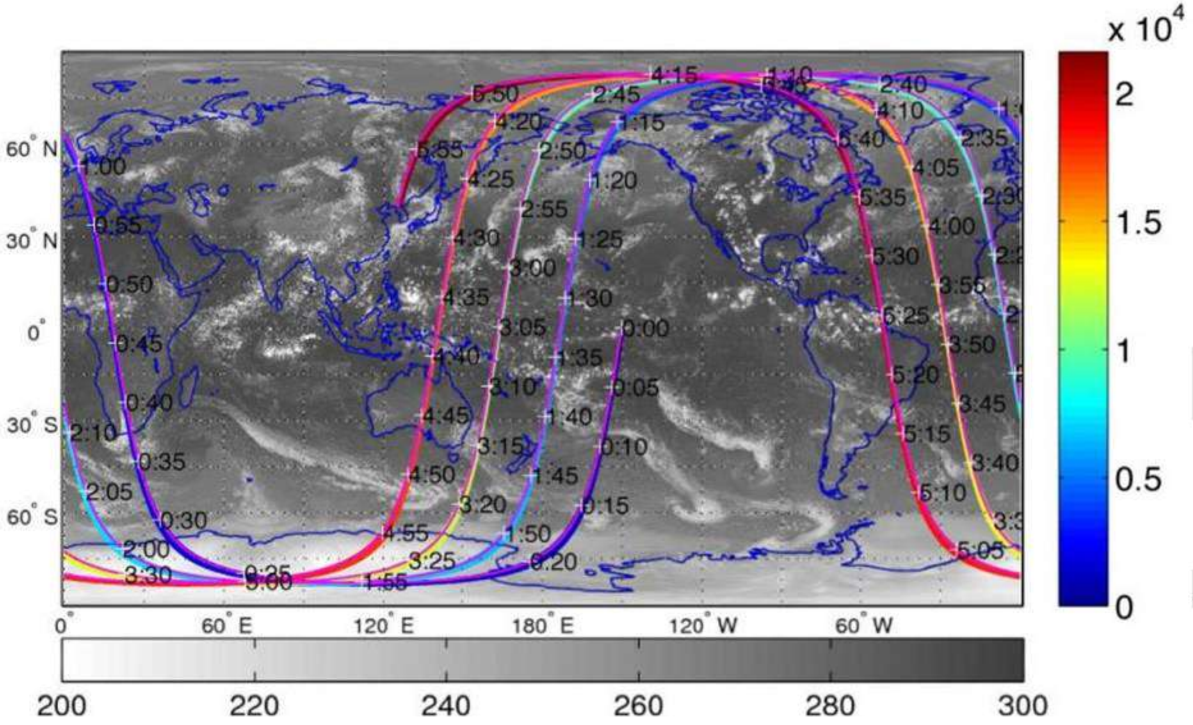
EarthCARE synthetic data

Roh, W., Satoh, M., Hashino, T., Matsugishi, S., Nasuno, T., Kubota, T. (2023)
Introduction to EarthCARE synthetic data using a global storm-resolving simulation.
Atmos. Meas. Tech., 16, 3331–3344, https://doi.org/10.5194/amt-16-3331-2023

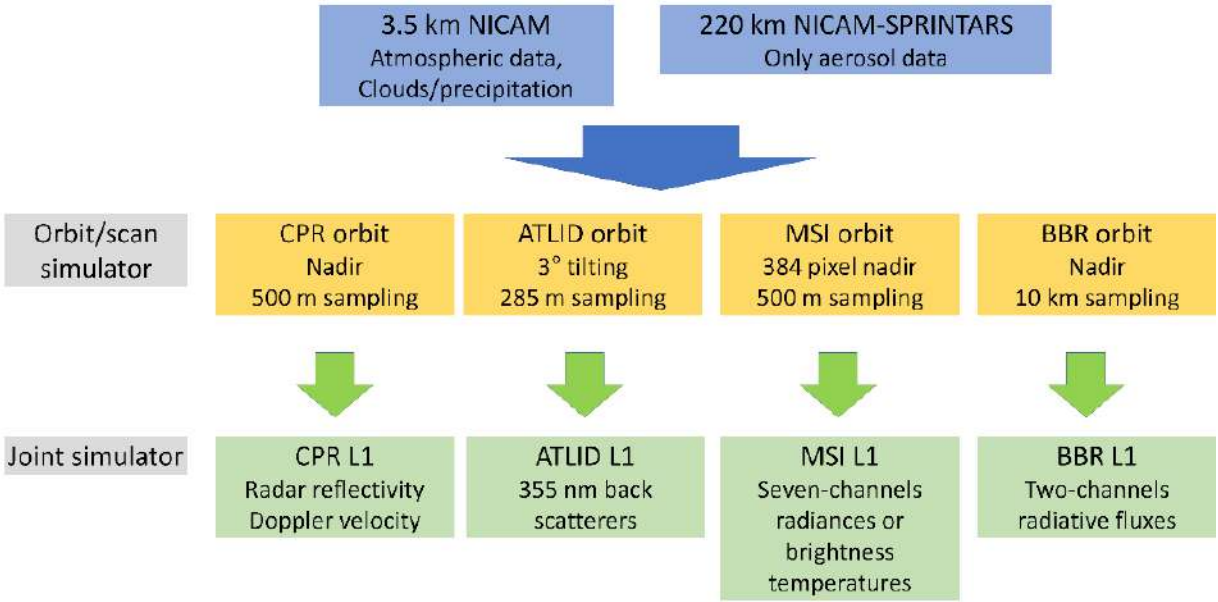
- The global storm-resolving simulation, the 3.5km-mesh NICAM (Nonhydrostatic Icosahedral Atmospheric Model) data, was used to simulate EarthCARE-like data using J-Sim (the Joint Simulator for Satellite Sensor).
- Recently, we conducted the 220m-mesh NICAM simulation using Fugaku, Japan's flagship supercomputer.
- The global 220m-mesh data simulates CPR-like signals, including Doppler velocity.
- We discuss how this updated EarthCARE synthetic data, such as a reference to the Global Storm-Resolving Model Intercomparison called DYAMOND, is useful.

Data is available at the Zendo server https://doi.org/10.5281/zenodo.7835229 (Roh et al. 2023)

EarthCARE synthetic data



The 3.5km-mesh NICAM simulation with simulated tracks and swath of the EarthCARE satellite. The black/white contour is the 11 μm brightness temperature (K). Colors indicate the time from the starting point (00:00Z) in seconds.

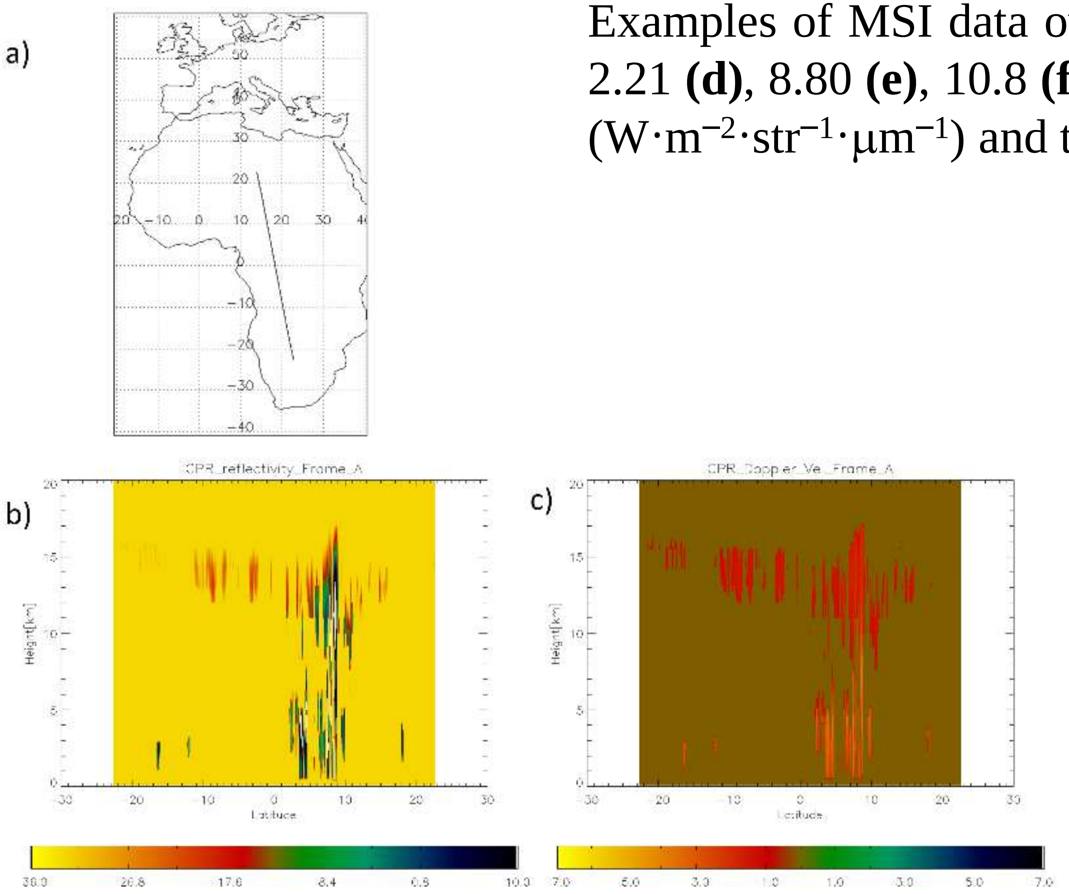


Flowchart for production of JAXA L1 data

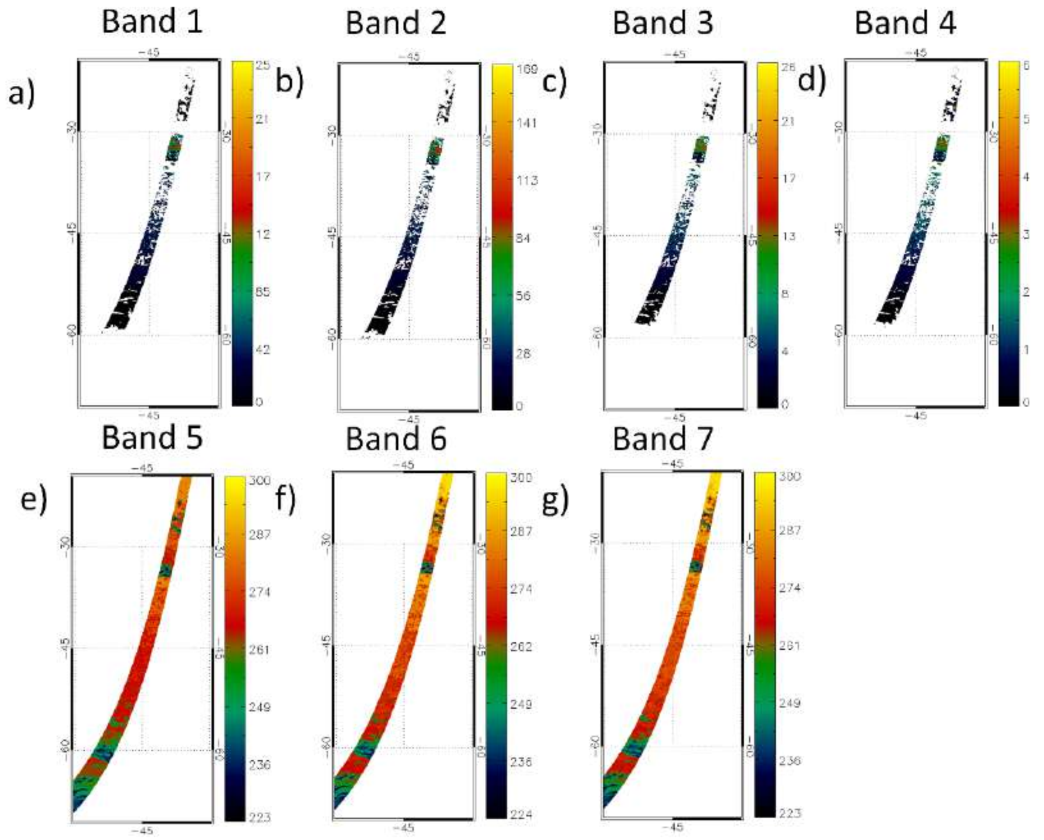
Roh et al. (2023, AMT)

EarthCARE synthetic data

Examples of MSI data over the ocean for seven channels at 0.67 **(a)**, 0.865 **(b)**, 1.65 **(c)**, 2.21 **(d)**, 8.80 **(e)**, 10.8 **(f),** and 12.0 μm **(g)**. The contours of the upper panels are radiance (W·m^{-2}·str^{-1}·μm^{-1}) and those in the bottom panels are temperatures (K).



Examples of CPR data over the African continent **(a)**, with radar reflectivities **(b)** and Doppler velocities **(c)**.

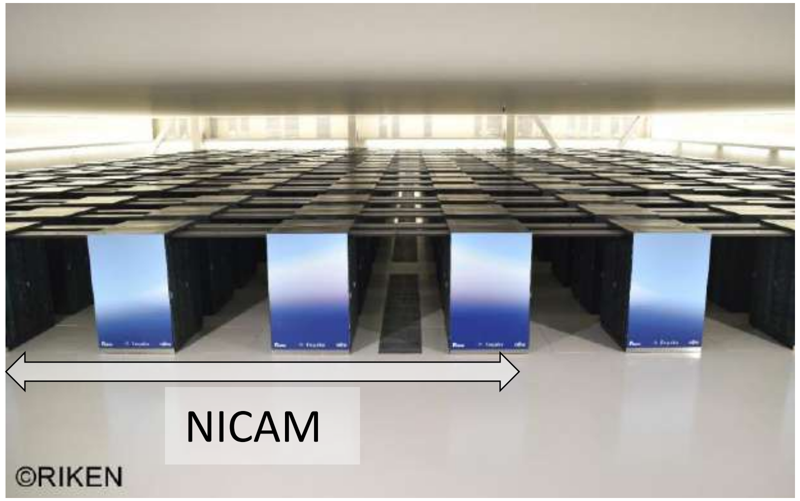


Roh et al. (2023, AMT)

The global highest-resolution (dx=220m) simulation

Satoh, M., Matsugishi, S., 2023: Toward global large eddy simulations. Gekkan Kaiyo, , Vol. 55, No. 4, 172-179, https://doi.org/10.15083/0002007328 (in Japanese)

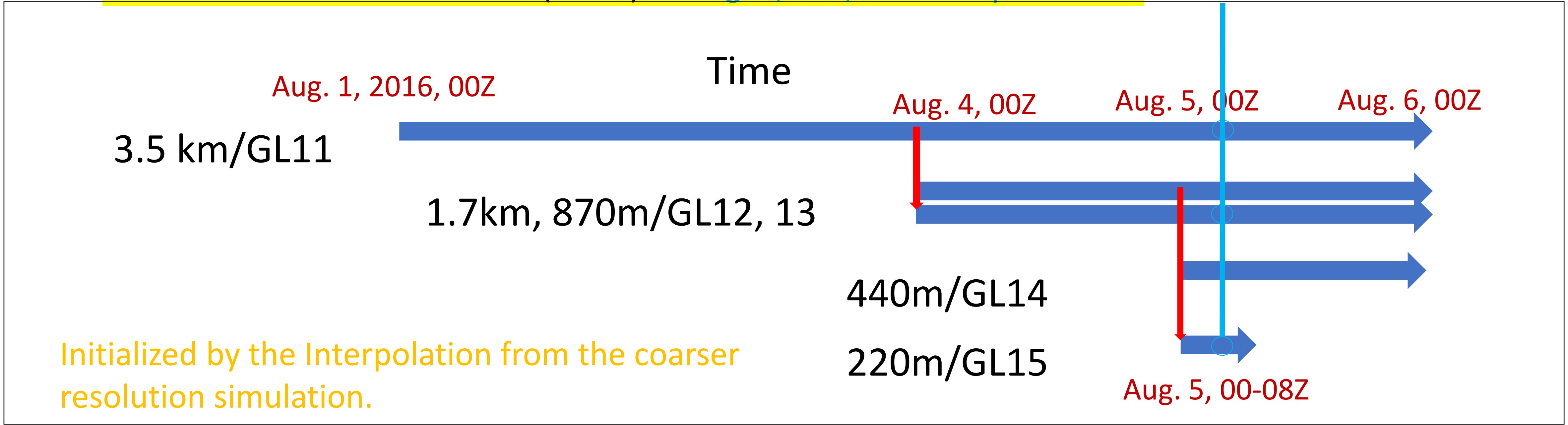
- The global highest-resolution (dx=220m) simulation is valuable to knowing the capability of reproducing a realistic atmosphere and the computational performance.
- The global 220-m simulation tends to resolve "large eddies" related to deep convection and is referred to as "Global Large Eddy Simulation (GLES)" for deep convective motions.
- This simulation will be a basis for the more popular "global KM-scale "(global storm-resolving) simulations, and a reference to the intercomparison of the global storm-resolving models (called DYAMOND) for evaluation using the EarthCARE and EC-TOOC observations (June-October 2024).



- The simulation was conducted by using Supercomputer “Fugaku” (R-CCS, RIKEN, Kobe)
- 81,920 nodes, 3,932,160 cores, 2.3 PB Memory (This is > 50% of the total 158,976 nodes).
- Mixed precision version NICAM (Nakano et al. 2017)
  327,680 MPI + 12 OMP
- Data size (a variable per a step): 2D: 40GB; 3D:3TB (without compression)

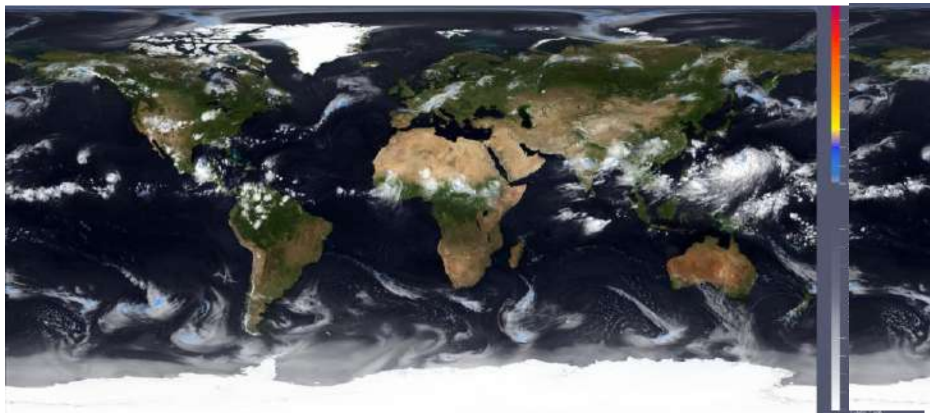
Model settings of NICAM

- Horizontal resolution: dx = 3.5km, 1.7km. 870m, 440m, 220m (GL11, 12, 13, 14, 15)
- Vertical level: 78 (dz = 400m in Troposphere)
- Time step: dt = 10, 6, 3, 1.5, 0.75 s for 3.5/1.7/0.87/0.44/0.22 km, respectively
- Integration: Aug. 2016, the DYAMOND-summer condition
- Turbulence scheme: sub km is “Grayzone”: MYNN (Nakanishi & Nino 2004) with Gray zone extension (Ito et al. 2015), Smagorinsky; Cloud microphysics: Single moment 6 category (Tomita 2008; Roh & Satoh 2014); Radiation: MSTRNX(Sekiguchi & Nakajima 2008)
- The EarthCARE CPR/ATLID data is made by 3.5km, 870m, and 220m-mesh NICAM data and the Joint Simulator for Satellite Sensors (J-SIM).at Aug. 5, 06Z, 2016 snapshot data

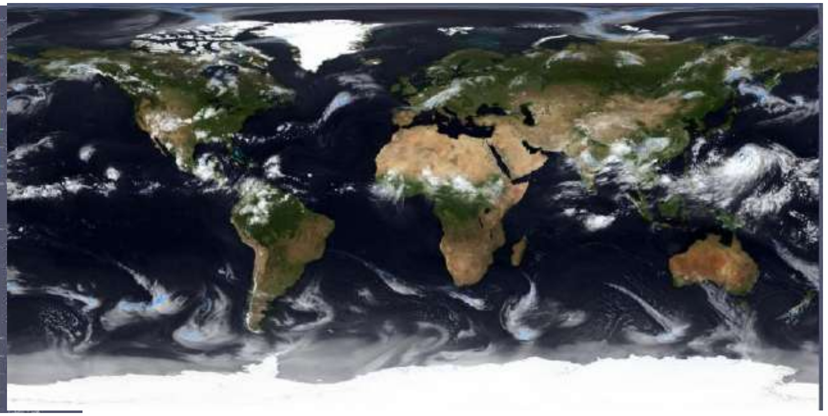


OLR/Precipitation (Smagorinsky)

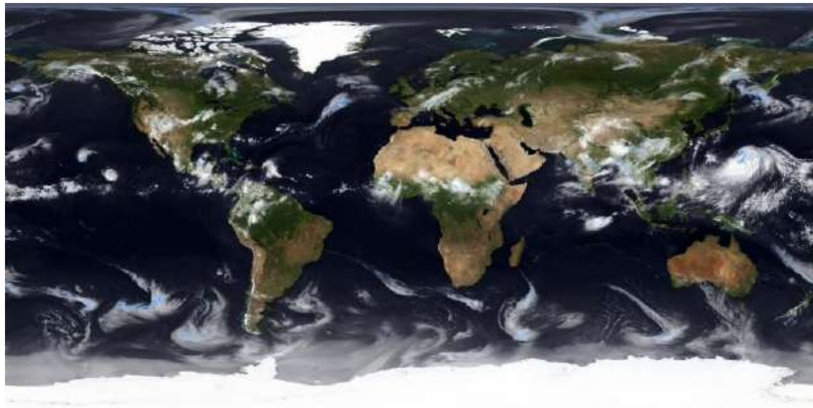
3.5km (GL11)



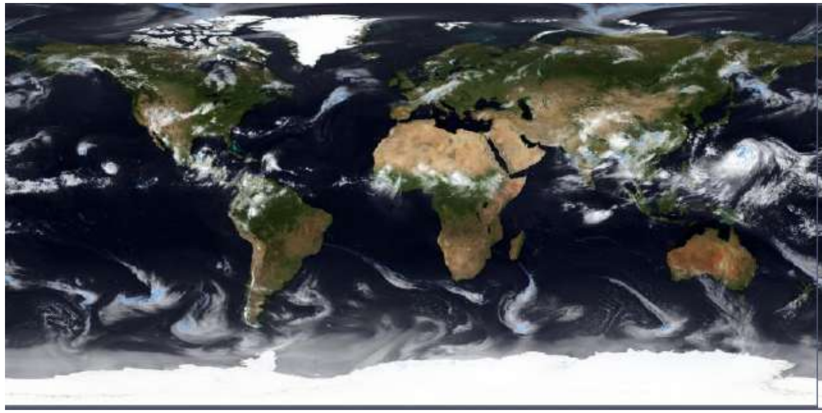
1.7km (GL12)



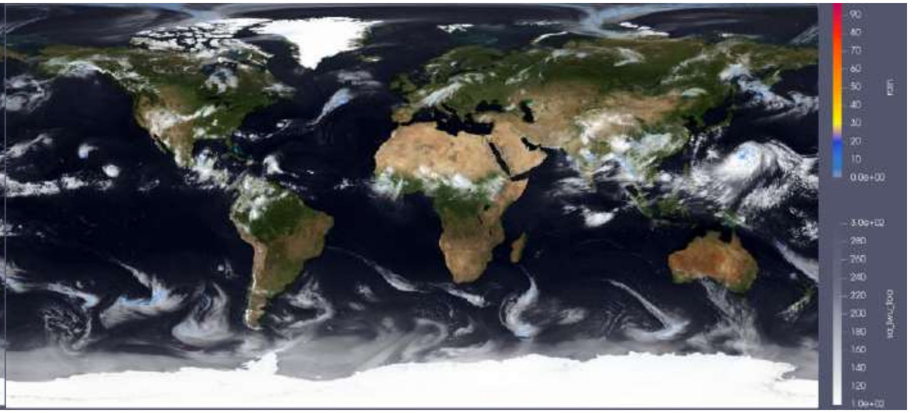
0.87km GL13



440 m (GL14)



220 m (GL15)

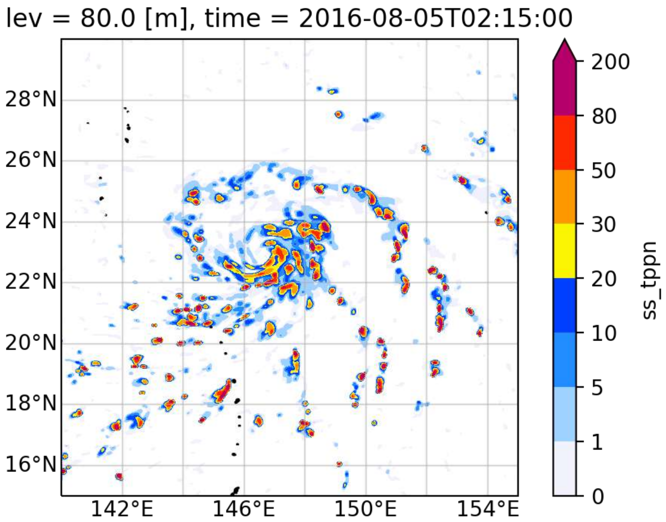


Aug. 5, 02Z, 2016

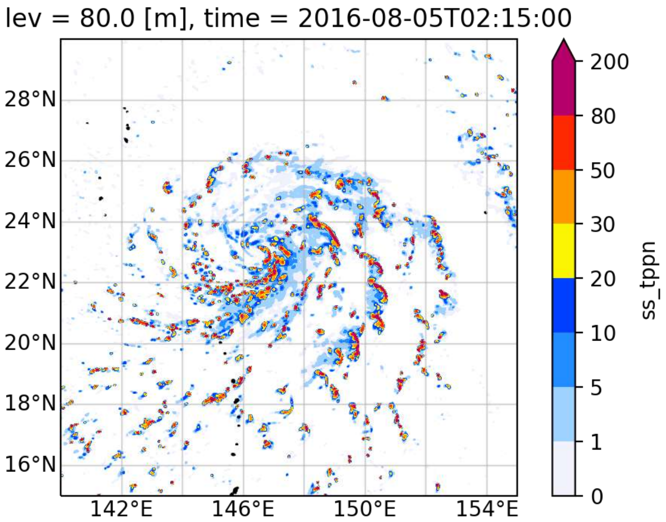
Background topography is NASA Blue Marble

Precipitation (snapshot) Smagorinsky

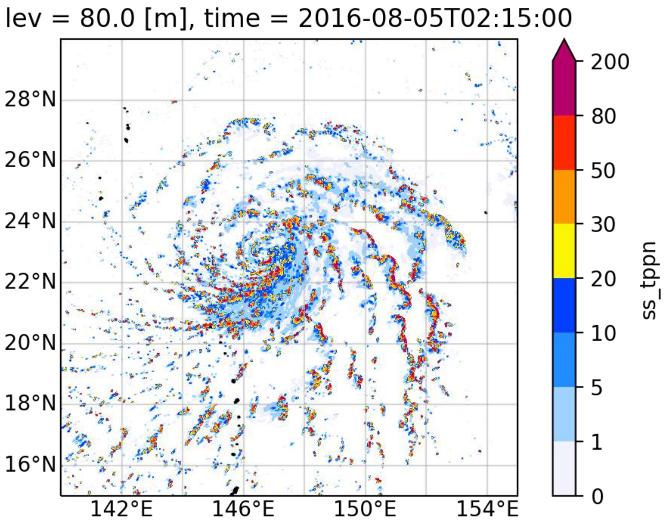
3.5km (GL11)



1.7km (GL12)



0.87km GL13



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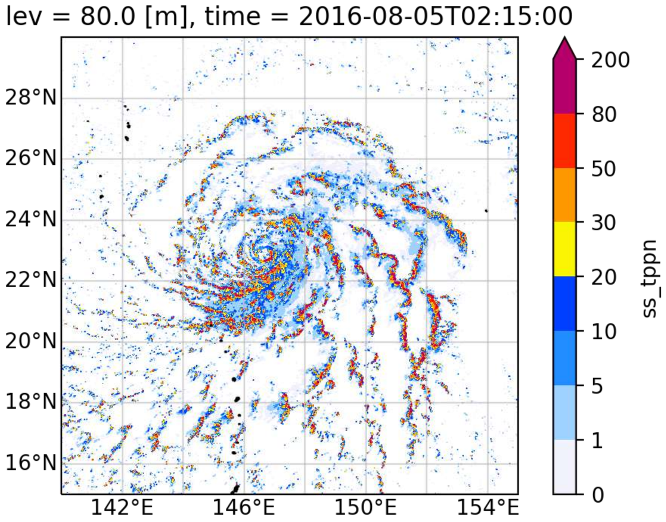
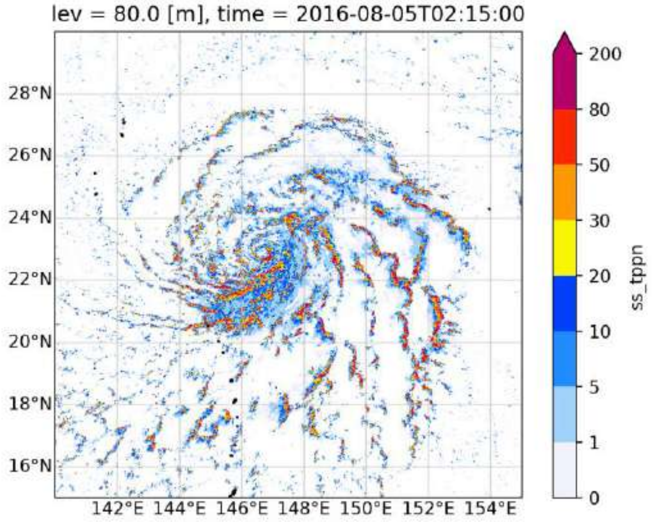
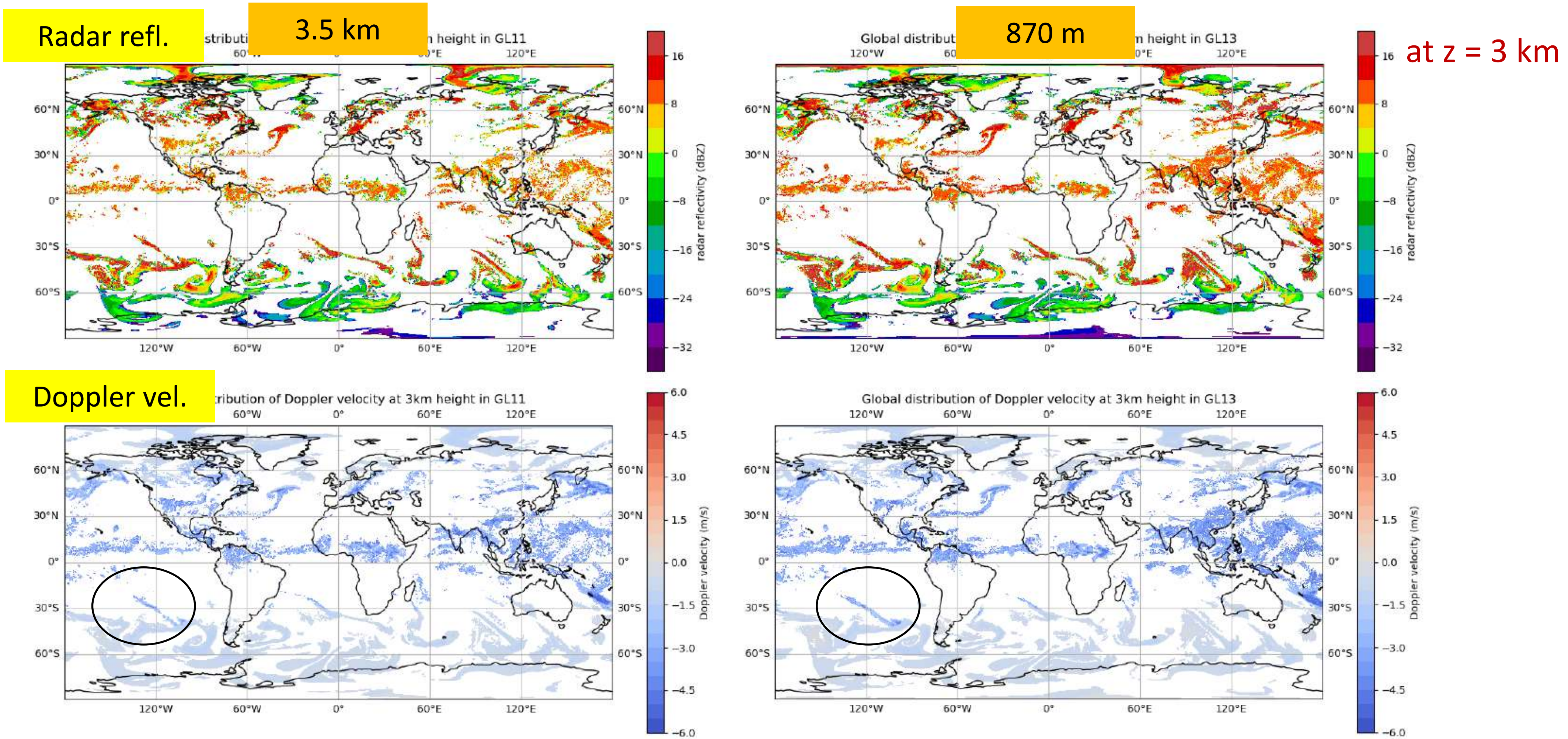


220 m (GL15)

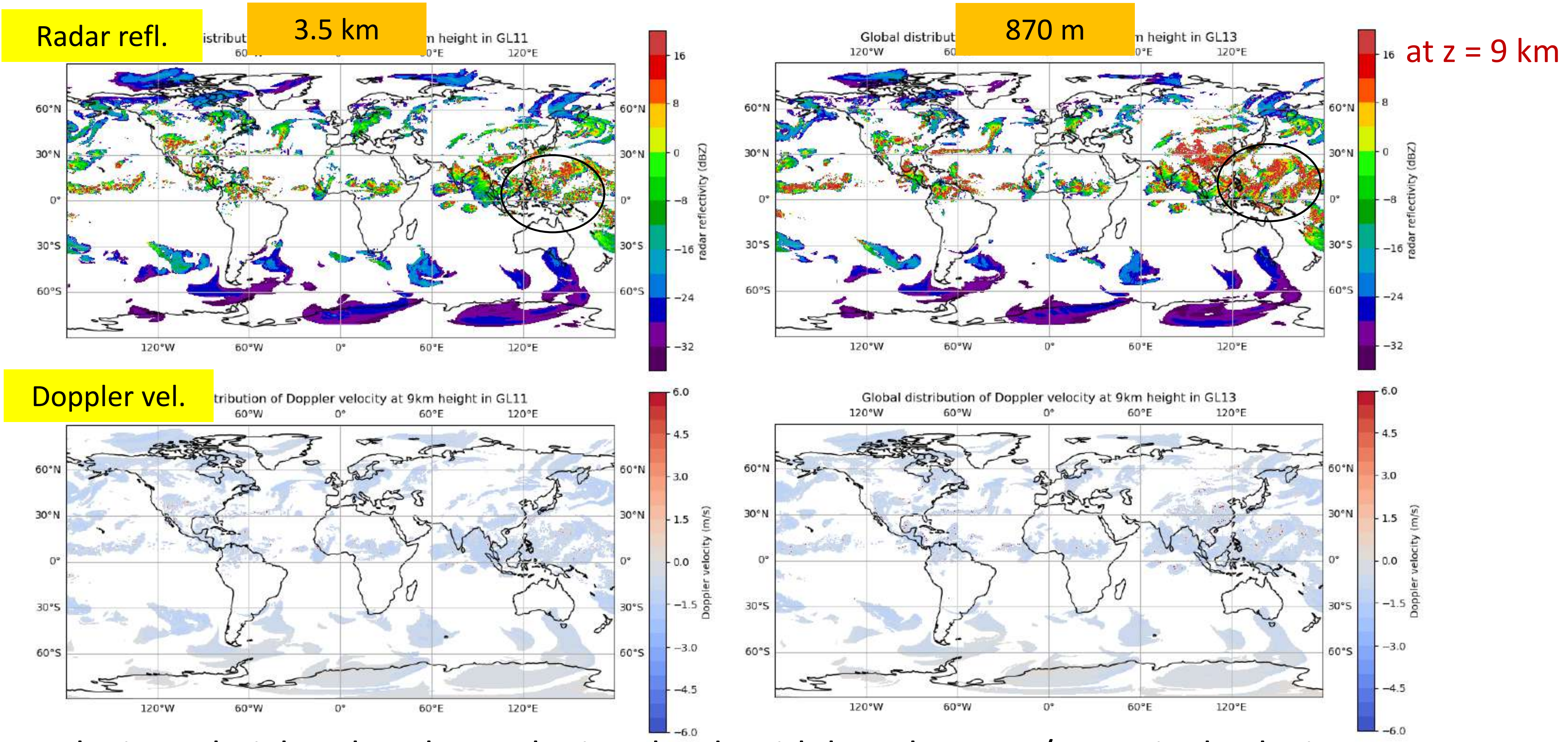


Global views of the EarthCARE-like CPR using the NICAM 3.5km and 870m-mesh simulations based on Mellor–Yamada–Nakanishi–Niino (MYNN) scheme



- Comparison between the two NICAM simulations with 3.5km and 870m horizontal meshes.
- Doppler velocity can be used to clearly distinguish rain from snow at high latitudes.
- Precipitation from Doppler velocity is also apparent because it has less impact from wet attenuation.

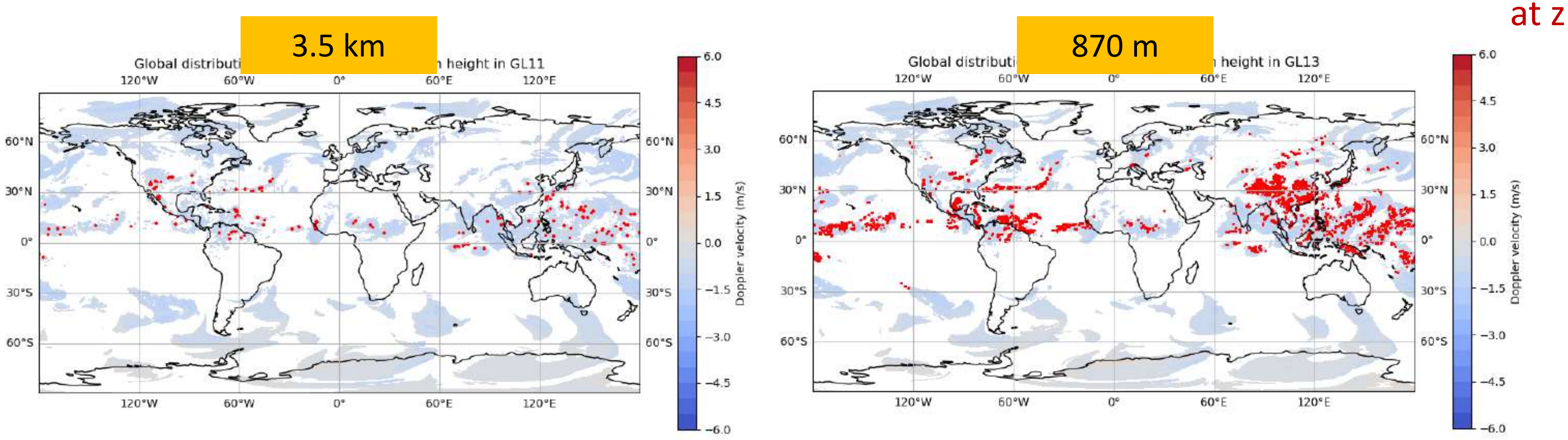
Global views of the EarthCARE-like CPR using the NICAM 3.5km and 870m-mesh simulations based on Mellor–Yamada–Nakanishi–Niino (MYNN) scheme



- The Doppler velocity at height 9 km shows the ice clouds with less than 2 m/s terminal velocity.
- The 870m simulation shows high clouds with larger radar reflectivity than the 3.5 km resolution experiment.

Upward Doppler velocity (> 3m/s) for the improvement of unfolding method: Normalized Frequency of Doppler velocity

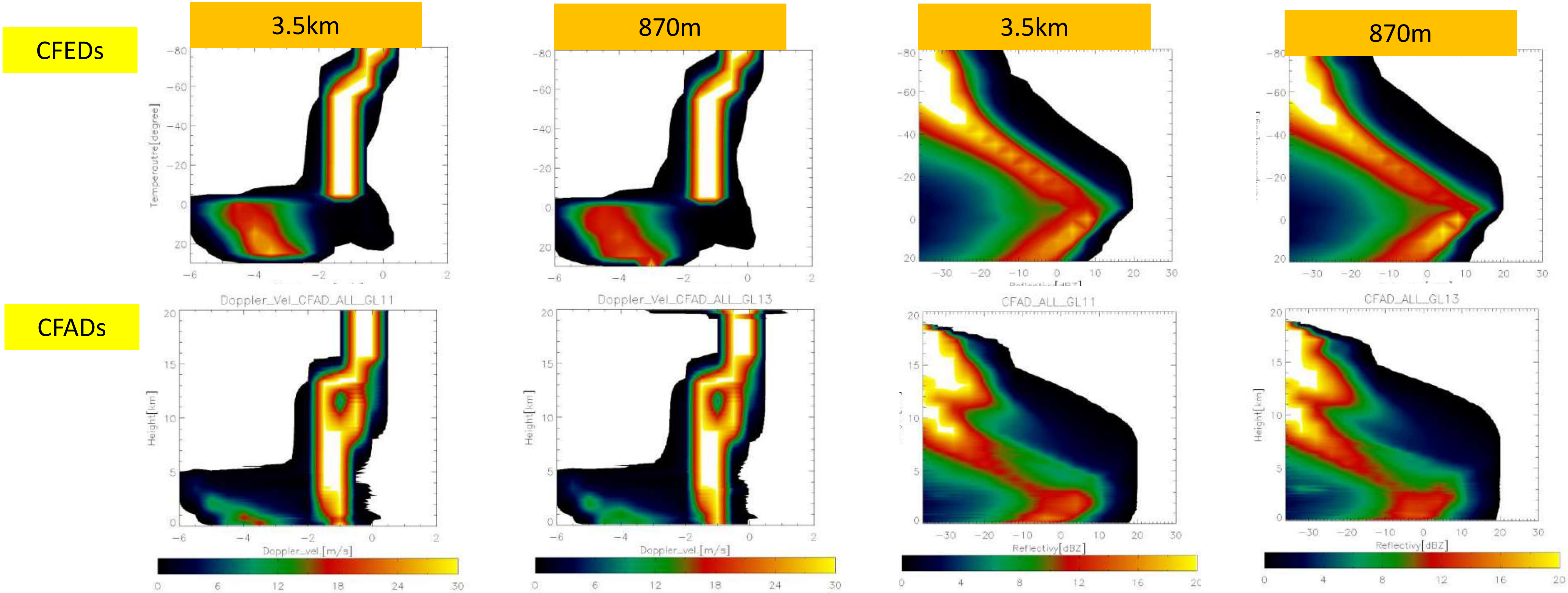
at z = 9 km



The red points are for > 3 m/s: 3.5 km: 0.0015% vs 870 m: 0.0042%.

- Hagihara et al. (2021) introduced the unfolding method to reduce the Doppler errors, but this method also removes the signals associated with convection.
- We examined the upward Doppler velocity faster than 3 m/s.
- The normalized frequency is less than 0.1%.
- The frequencies of upward Doppler velocity faster than 3 m/s depend on the horizontal resolution.
- We will cooperate with Hagihara-san of NICT to improve the unfolding method.

Global contoured frequency by temperature diagram (CFEDs) and global contoured frequency by altitude diagrams (CFADs) of Doppler velocity & radar reflectivity



- When we examined the dependence of the horizontal resolution on the statistical analysis such as CFEDs and CFADs, the results were consistent between different resolutions.
- The simulations with higher resolution reproduced the higher cloud top and the higher frequency of riming particles.

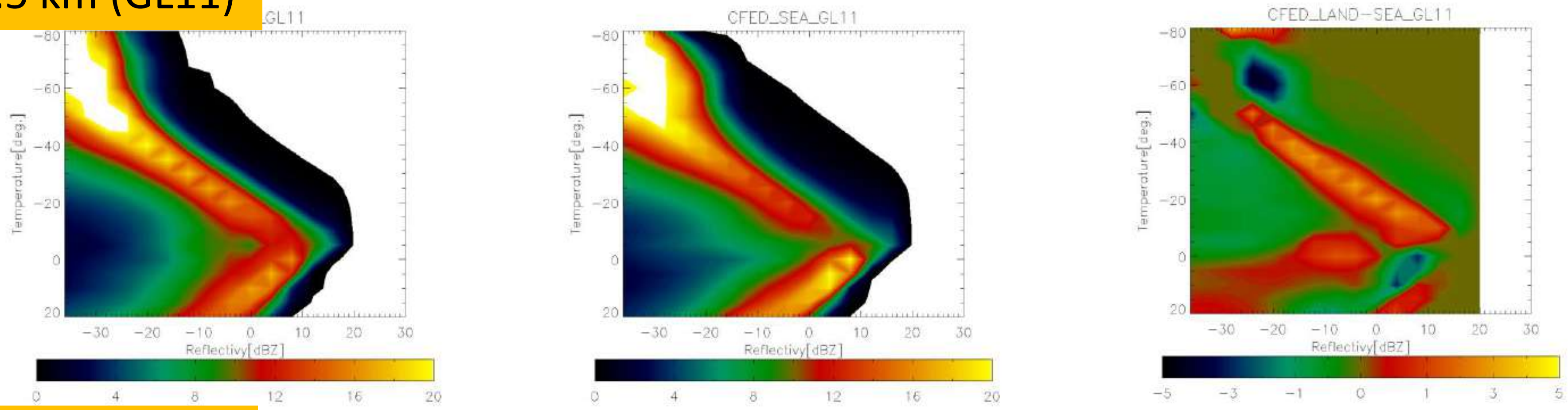
Contoured frequency by temperature diagram (CFEDs) for radar reflectivity between land and ocean

Land

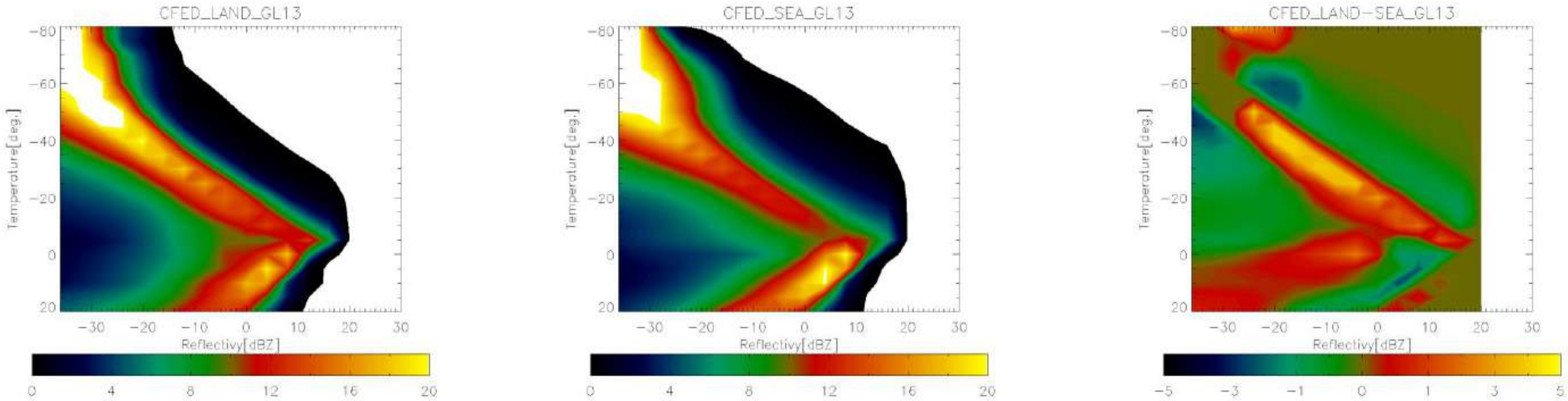
Ocean

Land - Ocean

3.5 km (GL11)



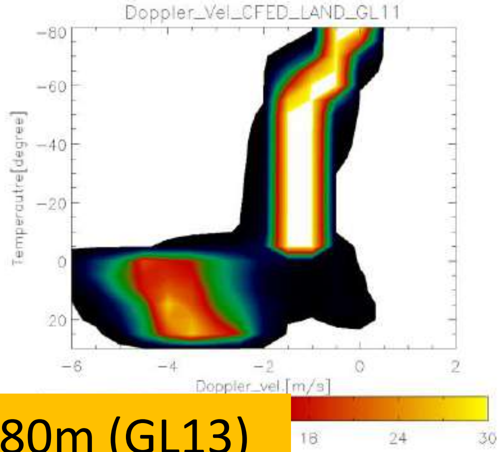
880m (GL13)

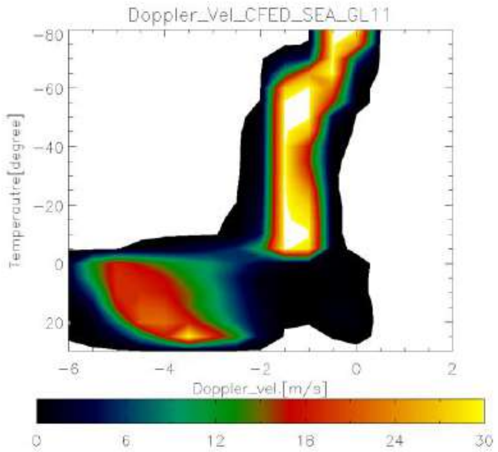


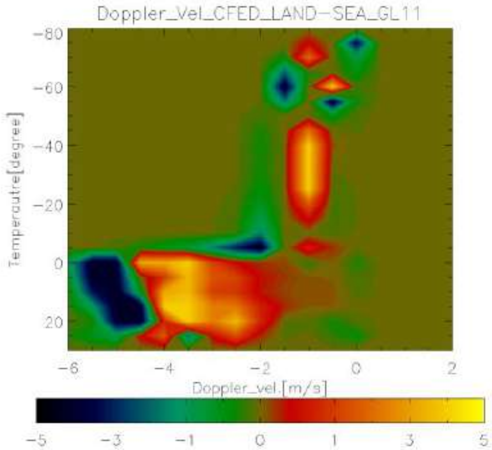
Contoured frequency by temperature diagram (CFEDs) for Doppler velocity between land and ocean

Land | Ocean | Land - Ocean

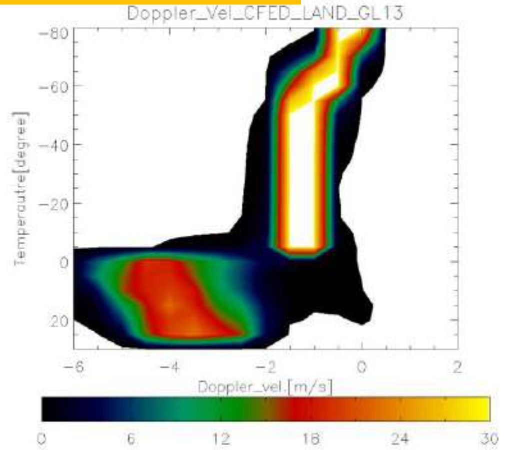
3.5 km (GL11)

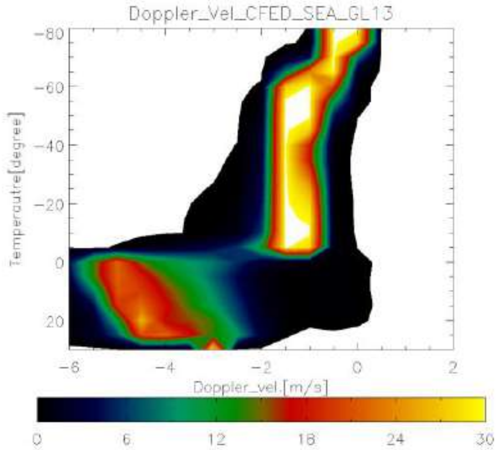


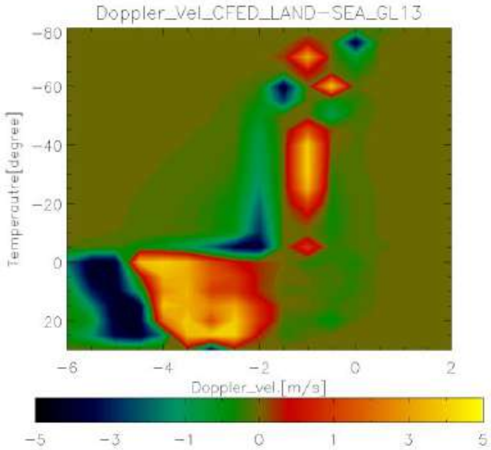




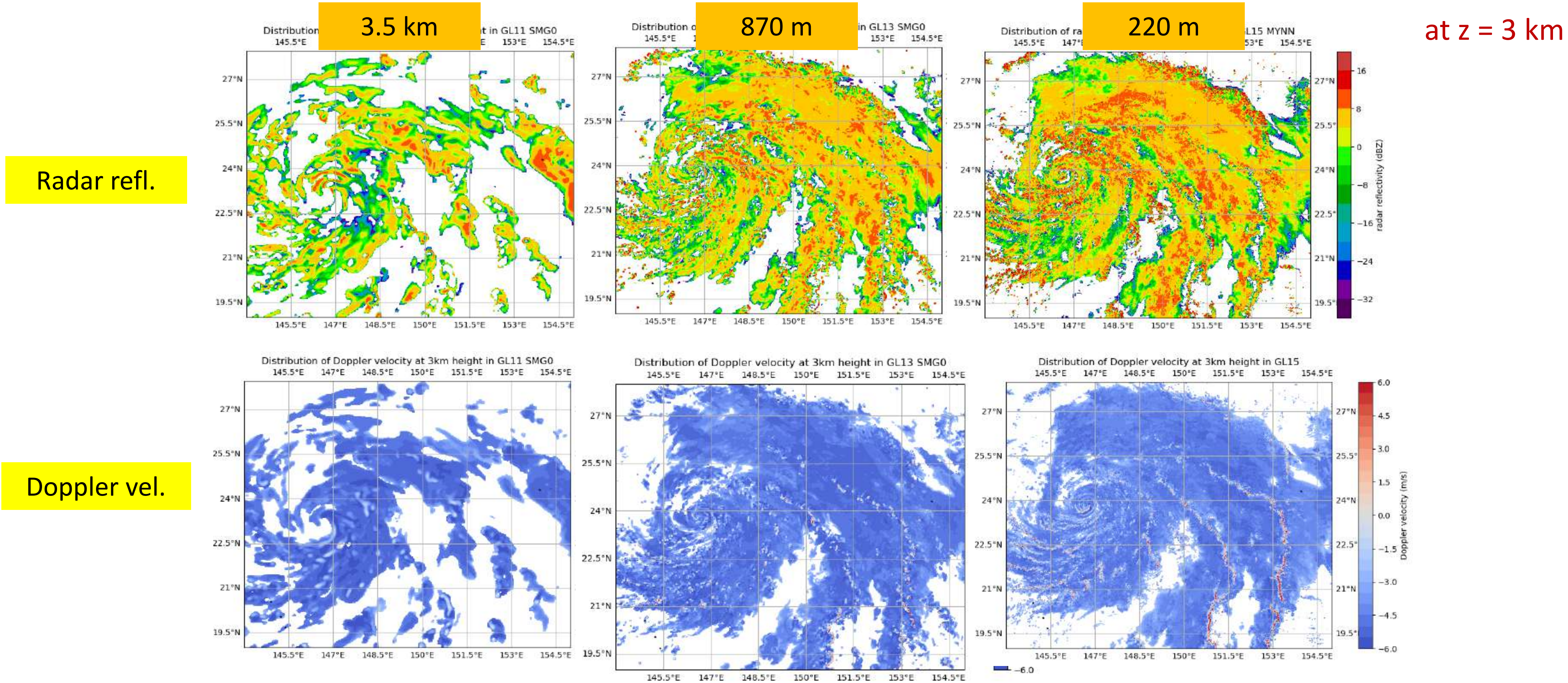
880m (GL13)







The resolution dependency for the global 220m, 870m, 3.5km-mesh simulations based on the Smagorinsky turbulence model
- Zoom-up of the tropical cyclone Omais

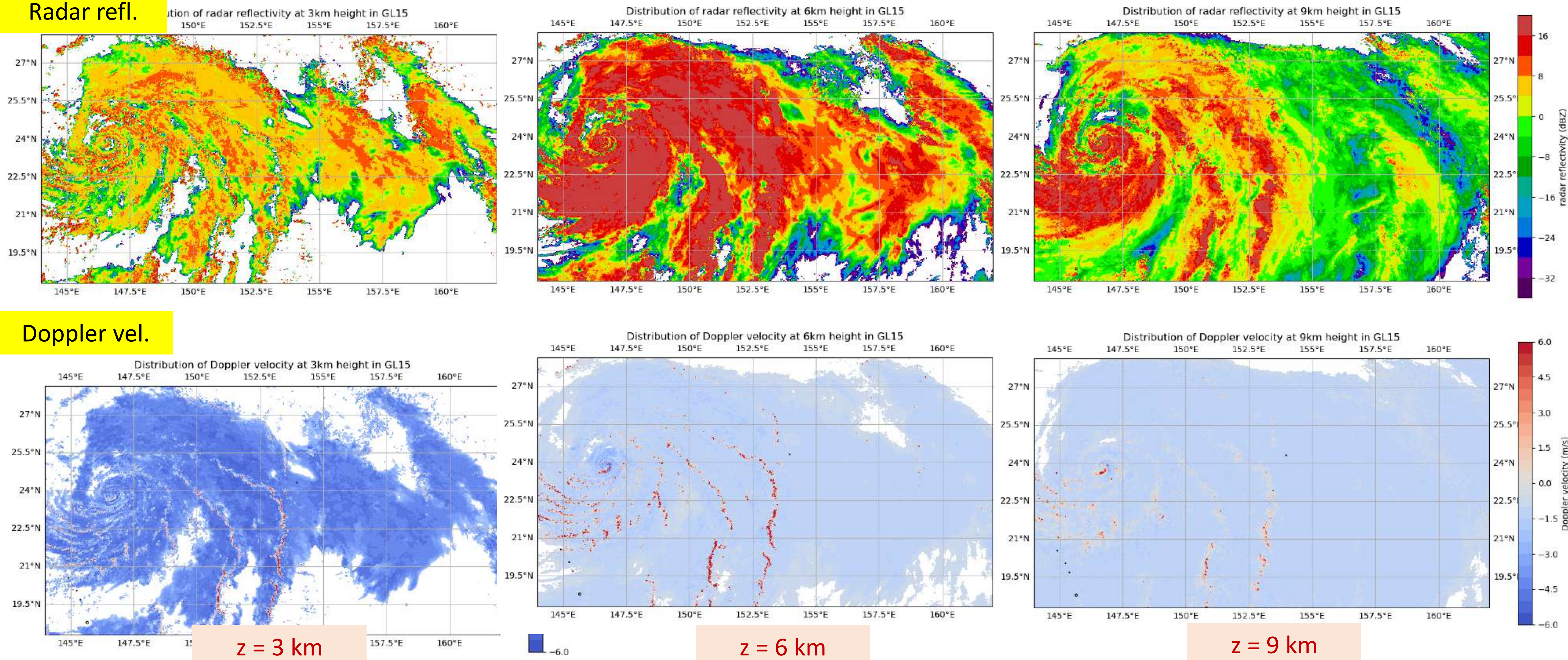


- The 220m-mesh simulation shows the convections clearly near the boundary layer.

The global 220m-mesh simulation (GLES) based on the Smagorinsky turbulence model - Zoom-up of the tropical cyclone Omais

Radar refl.

Doppler vel.



z = 3 km

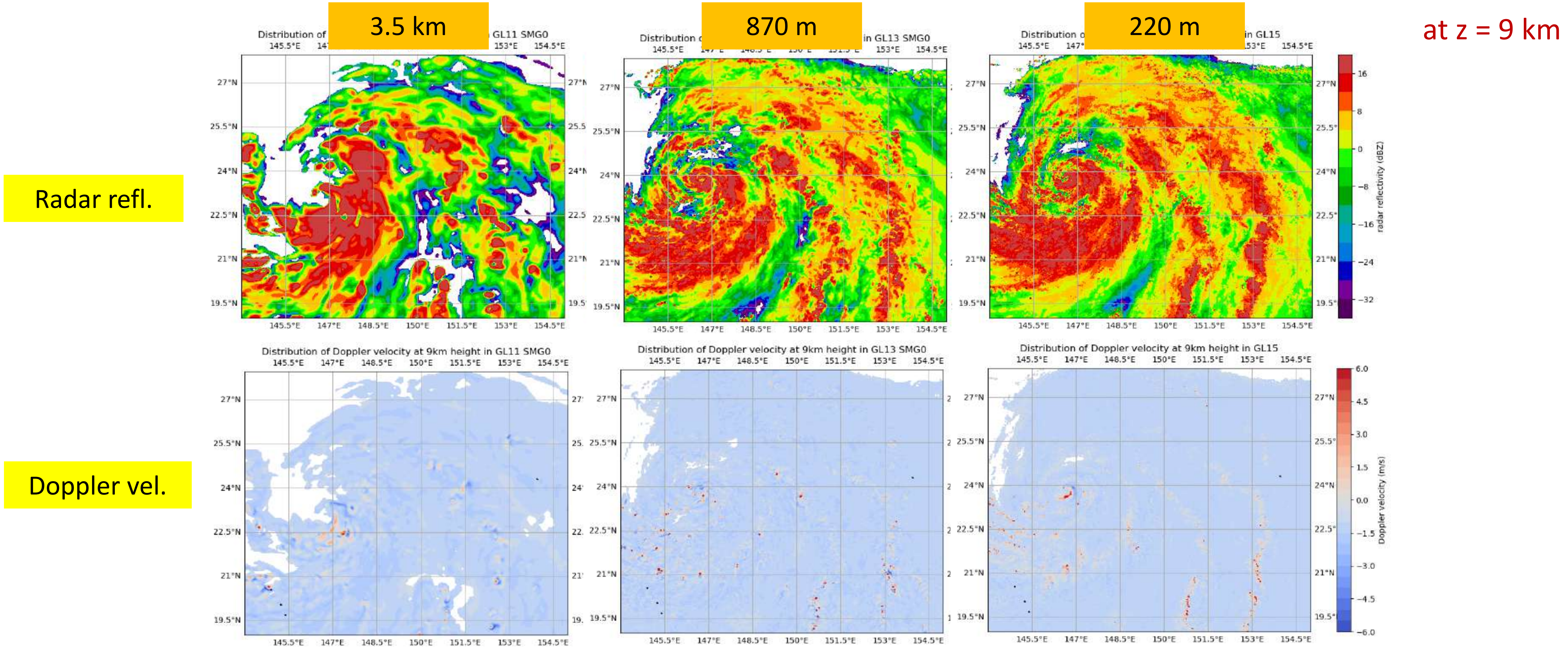
z = 6 km

z = 9 km

Summary

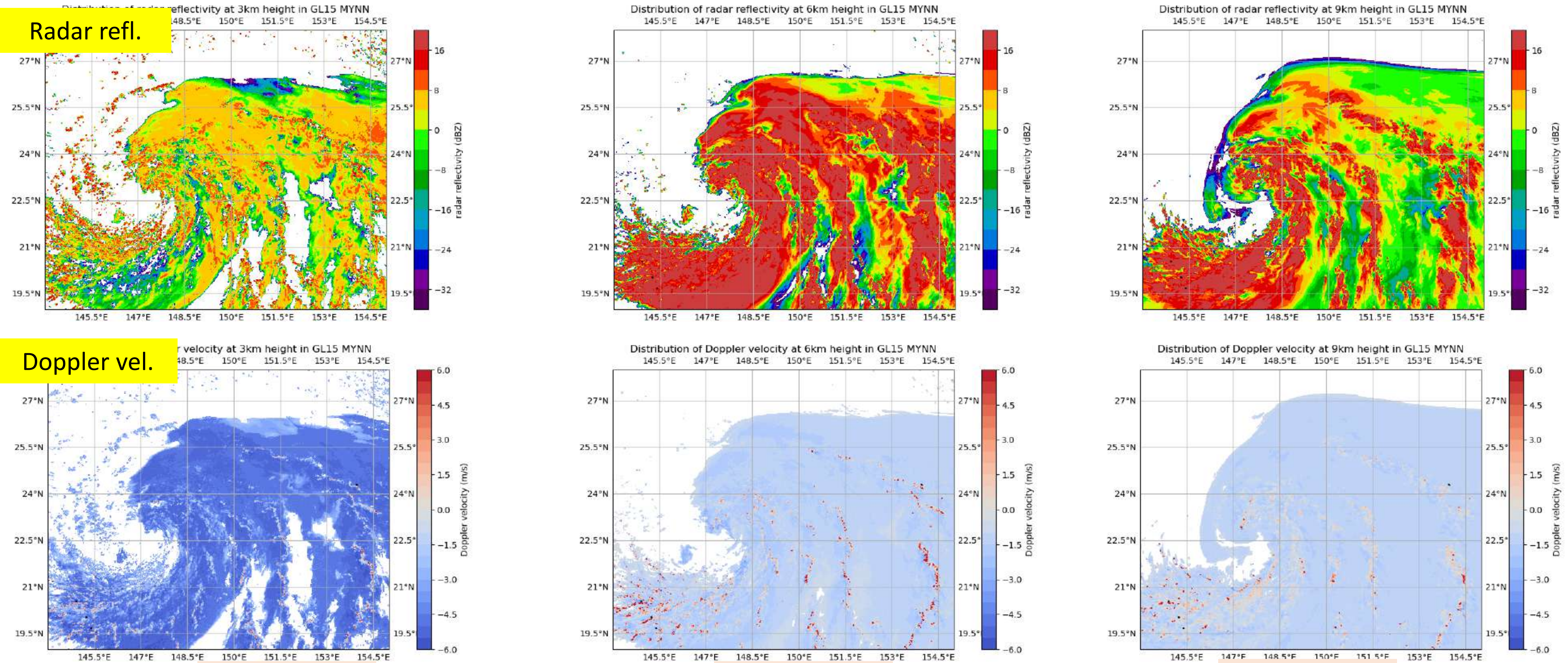
- Following the EarthCARE synthetic data by the 3.5km-mesh NICAM (Roh et al. 2023), we update the data by the global 220m-mesh NICAM simulation and the Joint Simulator for Satellite Sensors.
- We obtained global views and resolution dependency of the simulated Doppler velocity and radar reflectivity for CPR/EarthCARE.
- The Doppler velocity shows clear dependence on liquid/ice phase. The land and ocean difference is detected. Resolution dependency of the upward motion is quantified.
- The simulated data is to understand the characteristics of the non-uniform beam-filling effects and the interpretation of the EarthCARE observation.
- We plan to launch the intercomparison of the global storm-resolving models (GSRMs) for comparison/evaluation by the EarthCARE observation and the EC-TOOC (June-October 2024), i.e., a new DYAMOND-type intercomparison project. The present dataset will be a reference to the intercomparison.

The resolution dependency for the global 220m, 870m, 3.5km-mesh simulations based on the Smagorinsky turbulence model - Zoom-up of the tropical cyclone Omais



- The 220m-mesh simulation shows a more detailed structure than the GSRM (dx=3.5km).
- The 220m-mesh simulation reproduces the detailed structure of the tropical cyclone around the eyewall.
- The convection related to the eyewall shows more clearly in the GLES.

The global 220m-mesh simulation (GLES) based on the MYNN turbulence model - Zoom-up of the tropical cyclone Omais



z = 3 km

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