Advancing Climate Simulations with EarthCARE Observations: Intercomparison Frameworks and Model Improvement Initiatives

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2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
17 – 20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

Introduction

ECOMIP: EarthCARE-ORCESTRA Model Intercomparison Project

- ECOMIP is a model intercomparison and model evaluation project using observations from EarthCARE and from the tropical Atlantic field experiment ORCESTRA.
- It is open to any modelling institute that wishes to take part. As an unfunded collaboration the work is carried out on a best-effort basis. The methods and collaborations developed as part of this project will hopefully lead on to a wider endeavour to improve models exploiting EarthCARE data.

coordinated by Masaki Satoh (University of Tokyo, satoh at aori.u-tokyo.ac.jp) and Robin Hogan (ECMWF, robin.hogan at ecmwf.int).

https://www.earthcarescience.net/projects/ecomip

ECOMIP

EarthCARE-ORCESTRA Model Intercomparison Project

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Experimental protocol

Simulations

Two simulation types are envisaged:

1. **48-hour forecasts** initialized at midnight every day between 00 UTC on 9 August 2024 and 00 UTC on 29 September (52 start dates). Comparison with EarthCARE and between models would be carried out on the second day of each forecast. Optionally, to evaluate the degradation of forecasts as a function of lead time, longer simulations may be carried out but still initialized each day. Operational NWP centres may wish to simply provide their operational forecasts for the period.
2. **A free-running simulation** initialized at 00 UTC on 1 August 2024 and running until the end of September.

Since high resolution simulations are computationally intensive, some models may not be able to simulate the entire period, in which case the dates corresponding to the most interesting ORCESTRA case studies should be prioritized. The 18 dates with HALO aircraft flights are listed here. The most interesting of these in terms of deep convection are the following:

- 18 August
- 22 August
- 27 August
- 3 September: a golden case in terms of observations from EarthCARE, the HALO aircraft and the Meteor ship
- 19 September

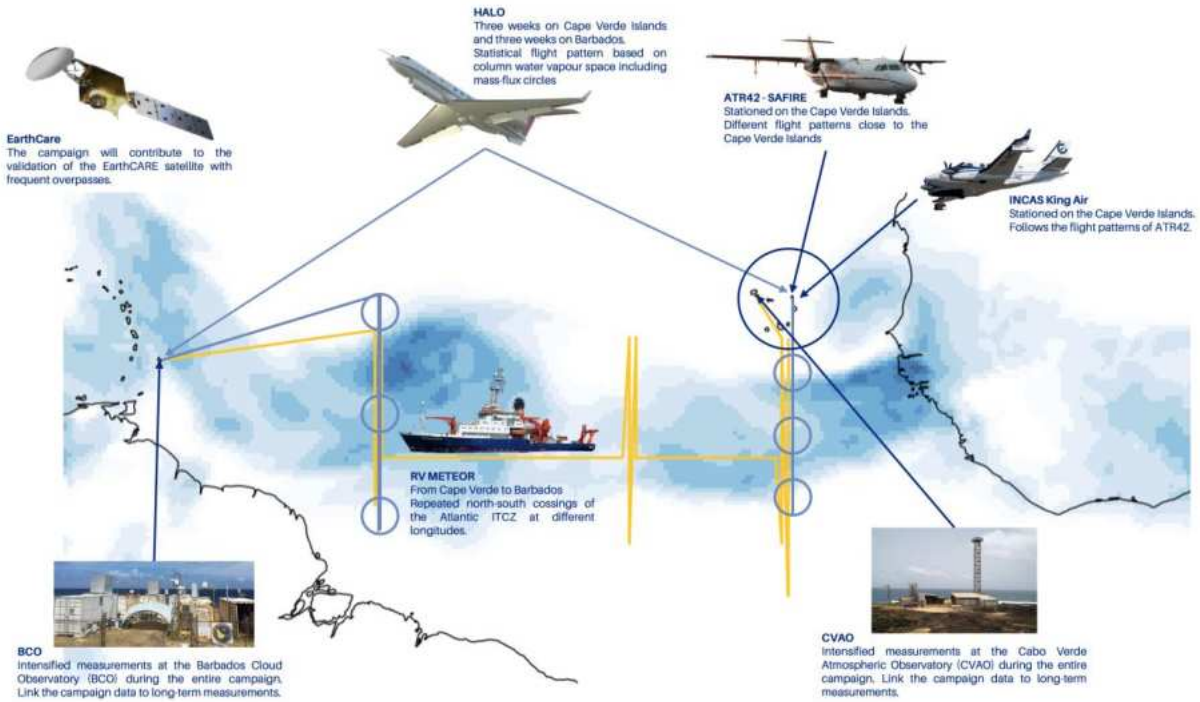
Note that the simulations themselves should be initialized at the beginning of the previous day.

Note also that no CPR data were taken on 29 August and 22 September, and the CPR collection was incomplete for 28 and 30 August, and 2, 3, 12, 20, 21 and 23 September.

ORCESTRA: Organized Convection and EarthCARE Studies over the Tropical Atlantic

August-September, 2024

1. Determine the drivers of mesoscale organisation in the tropics and their impact on smallscale weather systems and the large scale circulation with a particular focus on the structure and variability of the Atlantic ITCZ
2. Serve as a benchmark for satellite remote sensing and a new generation of high resolution storm resolving models

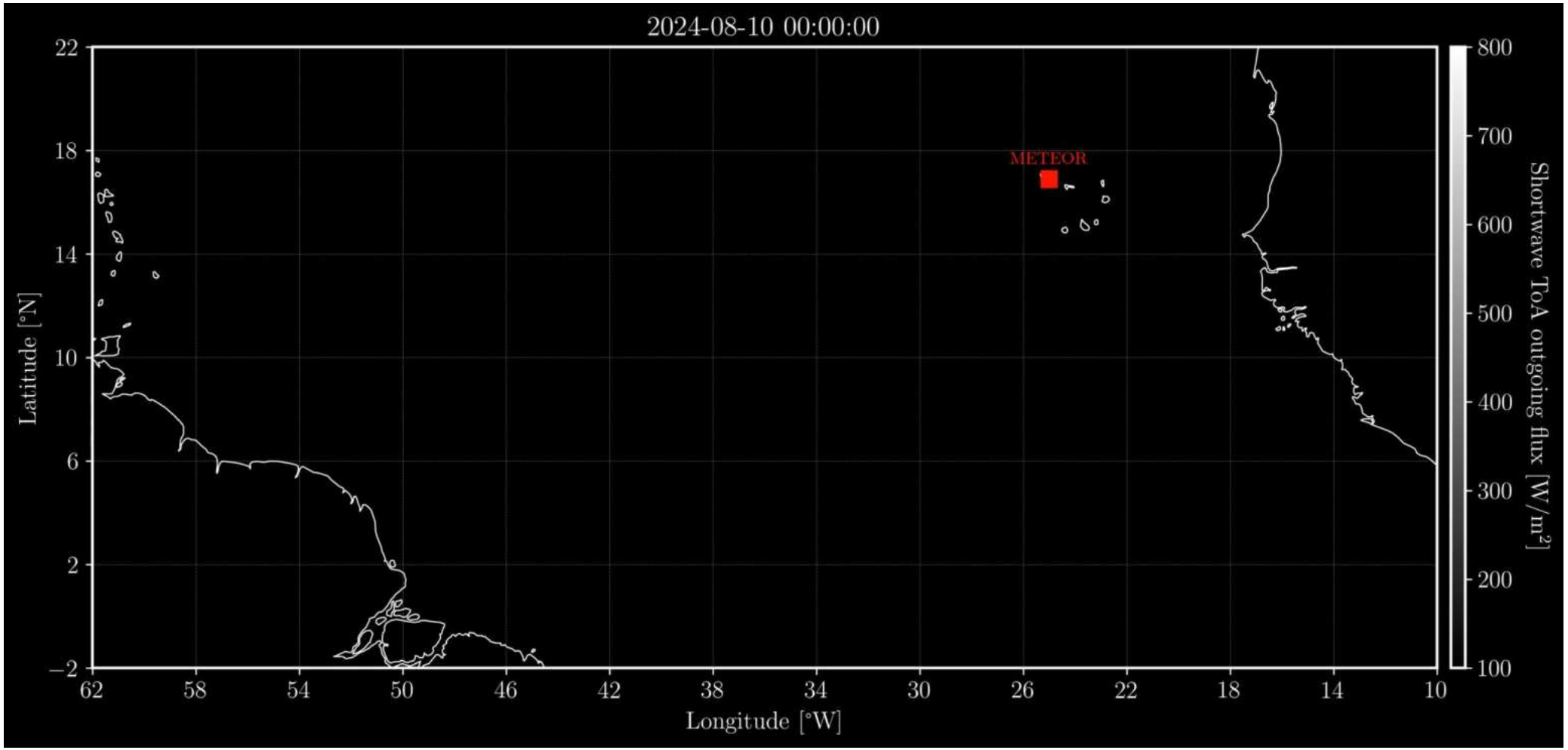


Sub-campaigns in ORCESTRA

- ORCESTRA unites several sub-campaigns under its roof.
- The campaign took place on the Cape Verde Islands, Barbados and all across the Atlantic Ocean from 10 August to 30 September, 2024.

Courtesy of Romain Fiévet & Bjorn Stevens (MPI-M)

The limited area simulations are performed with ICON-MPI at a horizontal resolution of 1.25km, and cover the (64W-8W,4S-24N)-area. Each daily run is initialized from the (day-7)-00h00 IFS analysis, and marched in times for 48h using the IFS forecast to update the lateral and surface boundary conditions.



A link the ORCESTRA limited-area simulations: https://orcestra-campaign.org/lam.html

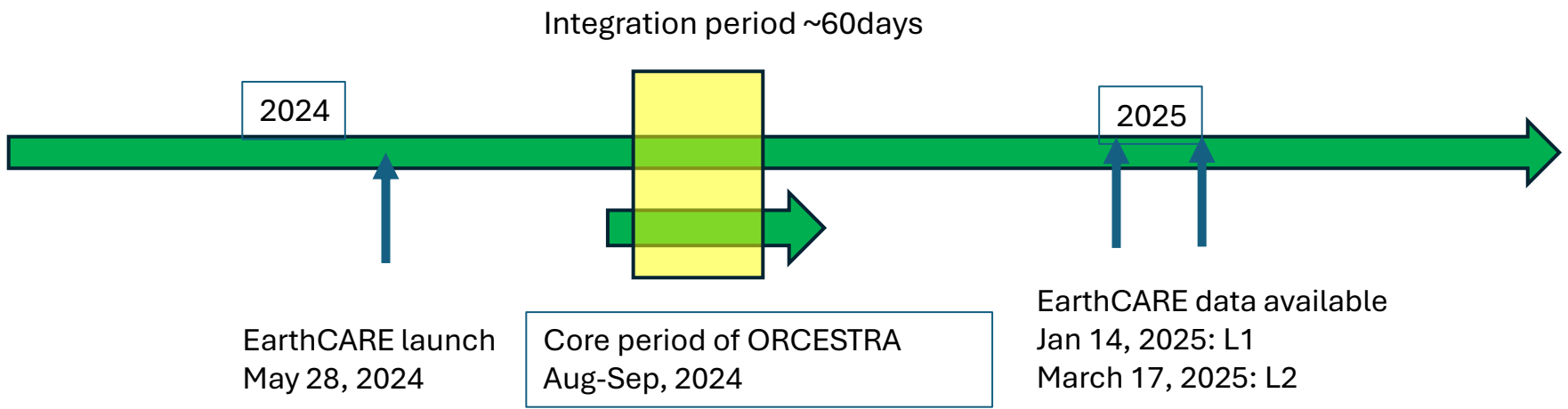
https://swift.dkrz.de/v1/dkrz_f765c92765f44c068725c0d08cc1e6c5/LAM-ORCESTRA/pathways-rsut_ZoomLvl2.mp4?temp_url_sig=4f025ecc86f6e54b92e61d164c410af1bcfb17ec&temp_url_expires=2026-09-25T09:58:50Z

The EarthCARE and ORCESTRA Intercomparison Project: ECOMIP

- Global storm-resolving simulations with dx < 5 km or any other regional and global models
  - Prerequisite: evaluations of EarthCARE with a satellite simulator, investigation of terminal velocity and Doppler velocity
  - Either an atmosphere-only or a coupled model
  - With an aerosol transfer model or not
- Two types of experiments
  - Case study: two days simulation (with one-day spin-up time): direct comparisons with observation data
  - 60 days simulation (with ten days spin-up time) : statistical analysis (like CFADs, CFEDs), evolutions of tropical disturbances
- Input data: ERA5 (or IFS-9km gpv)
  - Output data:

Case study: every 30-mins for 2D, every 30-mins for 3D

Statistical analysis: every 30-mins for 2D, every 3 or 6 hours for 3D



Output data

1.Model slices corresponding to each EarthCARE "frame", which is an eighth of an orbit. The Mini JSG files here define the times and locations of each frame in the ECOMIP period. The model data should be taken from the closest archiving time of the simulation and interpolated to the longitude and latitude grid from the JSG file, which is around 1-km resolution. The models own levels should be used in the vertical. One file per frame should be produced.

2.Three-dimensional model fields extracted over the Tropical Atlantic domain of ORCESTRA, bounded in longitude between 64° W and 8° W, and latitude between 4° S and 24° N. Ideally the output frequency would be 30 minutes for the 3D fields and 10 minutes for the 1D fields, but it is recognised that some models (and certainly archives of operational forecasts) are tricky to archive more frequently than every hour. Focus should be placed on the most interesting ORCESTRA case studies listed above, but storing the entire 24 hour period starting at 00 UTC. Output from ICON-MPI at 1.25 km for this region can be visualized here.

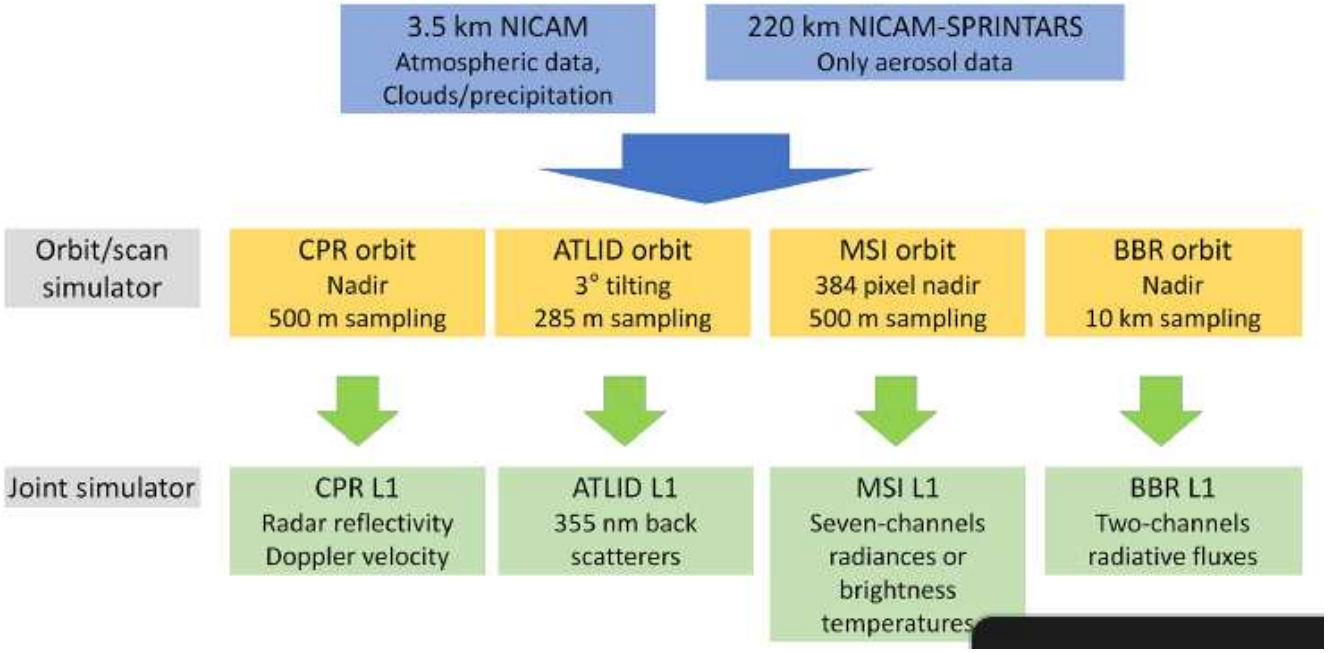
3. The full global dataset could be shared, which would provide a dataset similar to previous global storm-resolving model intercomparisons such as DYAMOND. Such a dataset is particularly requested by JAXA and would benefit the satellite community, who could use it for future applications of satellite projects.

JAXA will offer a data server to archive the output data.

Data analysis

- Compare model with observations for either physical values or sensor signal values
- For the forward model, the use of satellite simulators is expected.
- Satellite simulators used by the individual ECOMIP participants are:
  - The Joint Simulator for Satellite Sensors: Roh et al. (2023,AMT)
  - PAMTRA: Passive and active microwave radiative transfer tool
  - ECSIM: used to simulate EarthCARE observations for the pre-launch special issue of AMT
  - RTTOV: used for simulating microwave, infrared and most recently solar radiances for data assimilation, used by European NWP centres. A radar simulator is under development.
  - COSP: used to simulate radar, lidar and radiometer data targeted at low-resolution climate models used in IPCC.
  - JEDI/CRTM: used to simulate radiances for data assimilation.
  - ZMVar: used by ECMWF for assimilating radar and lidar backscatter profiles.
  - The Spaceborne Radar Simulator (SR-SIM)

Evaluation by using satellite simulator:
Joint Simulator for Satellite Sensors (J-Sim)



Roh et al. (2023, AMT) Introduction to EarthCARE synthetic data using a global storm-resolving simulation

https://www.eorc.jaxa.jp/EARTHCARE/about2/jsim.htm

An example of Joint-Simulator from outputs of NICAM

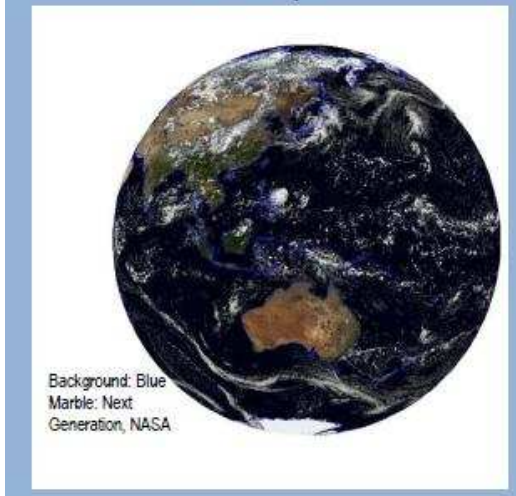
NICAM: Nonhydrostatic Icosahedral Atmospheric Model

Tropical Cyclone Fengshen simulation (Nasuno et al. 2012)

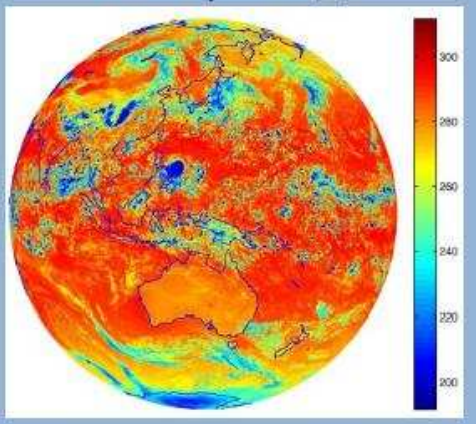
2008/06/17~25 δx=3.5 km

presented by Prof. Masaki Satoh (Univ. Tokyo)

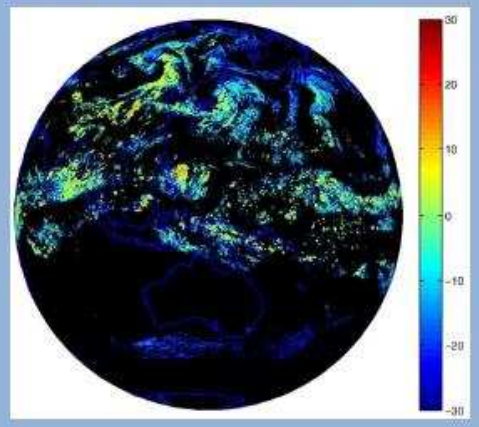
VIS 0.62 μm 2008/06/21 00Z



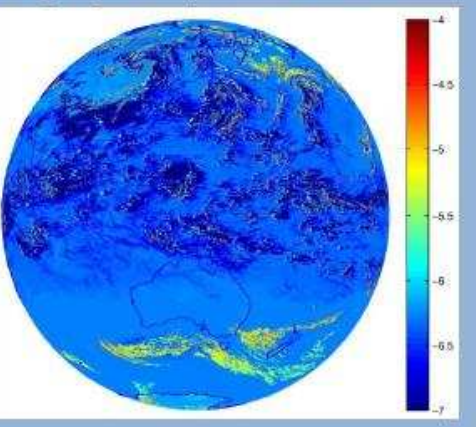
IR 10.8 μm TB [K]



94 GHz CPR [dBZ] at h=10 km



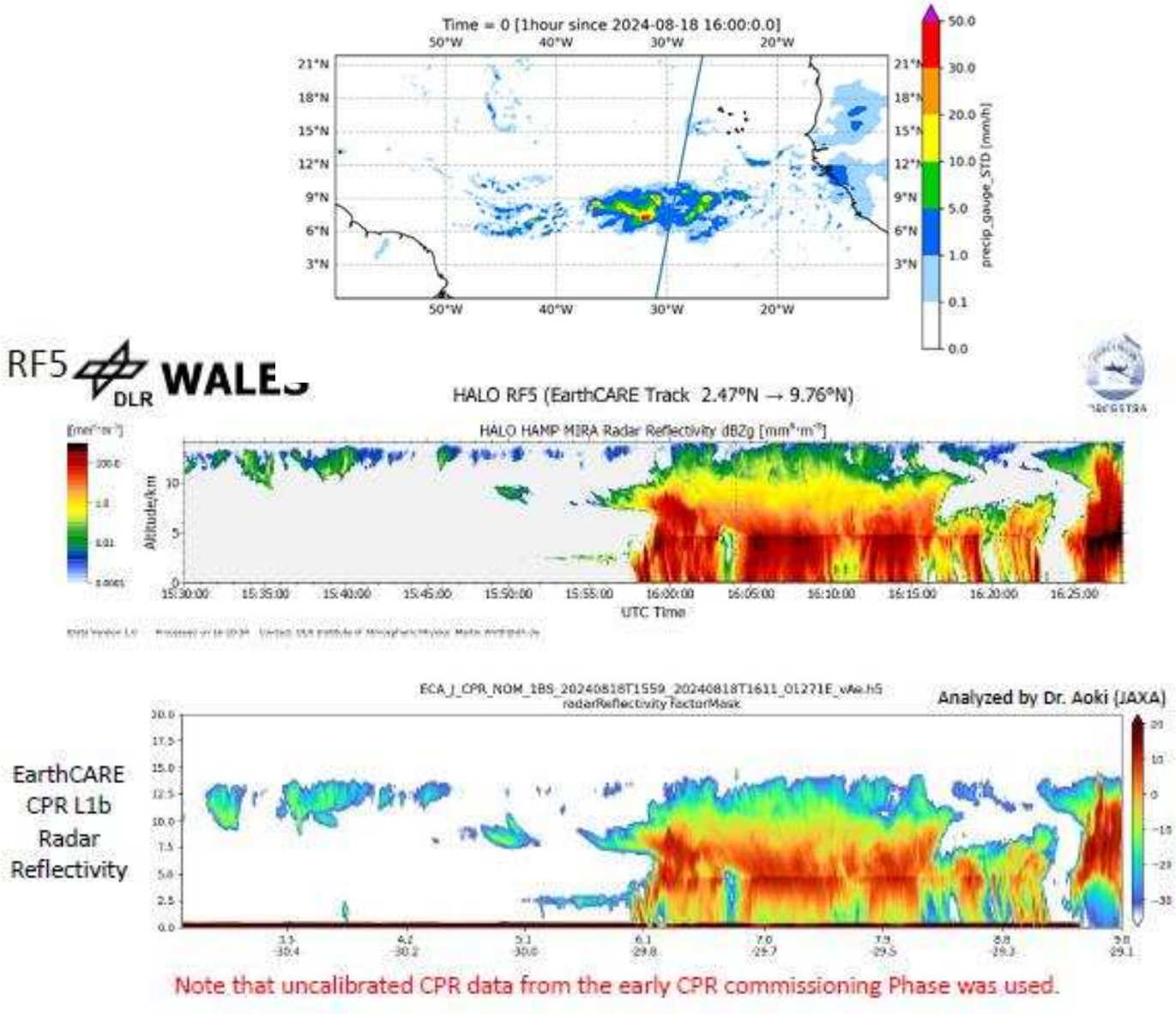
532 nm backscattering coef. Log10[1/m/str] at h=10 km



Potential participants

Participant	Institute	Modelling interests
Masaki Satoh, Woosub Roh	University of Tokyo	Global storm-resolving modelling: NICAM
Robin Hogan, Mark Fielding	ECMWF	Global weather and air-quality forecasting: IFS
Bjorn Stevens	MPI Hamburg	Global storm-resolving modelling: ICON
Philip Stier	University of Oxford	Global aerosol modelling: ICON-HAM-lite
Martina Klose	Karlsruhe Institute of Technology	Global and regional aerosol modelling: ICON-ART & ICON-HAM-lite
Kentaroh Suzuki	University of Tokyo	Global aerosol modelling: NICAM-SPRINTARS
Arlindo da Silva	NASA	Global Earth system modelling: NASA GEOS
Andrew Gettelman	PNNL	Global storm-resolving modelling: DOE-SCREAM
Chris Terai	LLNL	Global storm-resolving modelling: DOE-SCREAM
Lorenzo Tomassini	Met Office	Global and regional storm-resolving modelling: Unified Mode
Jason Cole	ECCC	Global climate modelling: CanAM
Tristan L'Ecuyer	University of Wisconsin - Madison	
Linda Schlemmer, Axel Seifert,Günther Zängl	DWD	Global and regional forecasting: DWD-ICON
Trude Storelvmo	University of Oslo	Aerosol modelling: WRF
Pavlos Kollias	Stony Brook University	Spaceborne radar simulator: SR-SIM
Alessandro Battaglia	Politechnic University of Turin	Spaceborne radar simulator: SR-SIM

NICAM Experimental Example Case for 18 August 2024



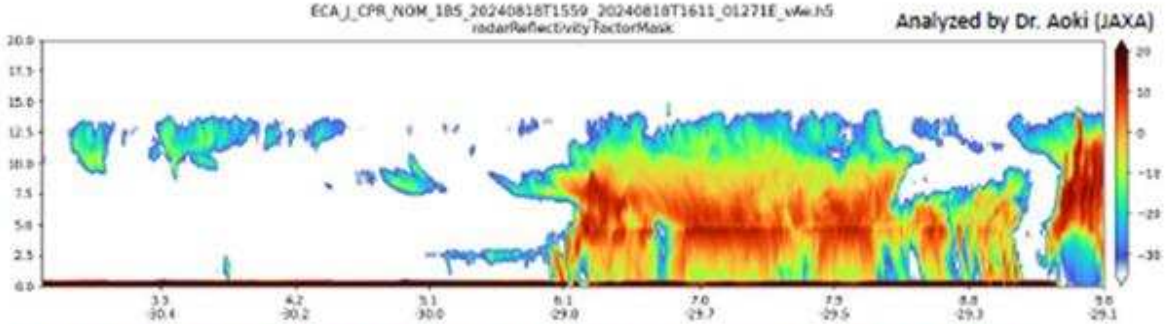
NICAM: Nonhydrostatic Icosahedral Atmospheric Model

- GL11L78 (dx=3.5km)
- Cloud microphysics scheme：NSW6
- Turbulent scheme: Smagorinsky scheme
- Initial condition: ERA5:2024/08/17 00Z
- 2-day simulation: Case for 2024/08/18 16 Z
- Plotted DBZ>-36dBZ

Courtesy of Silke Gross
Shunsuke Aoki

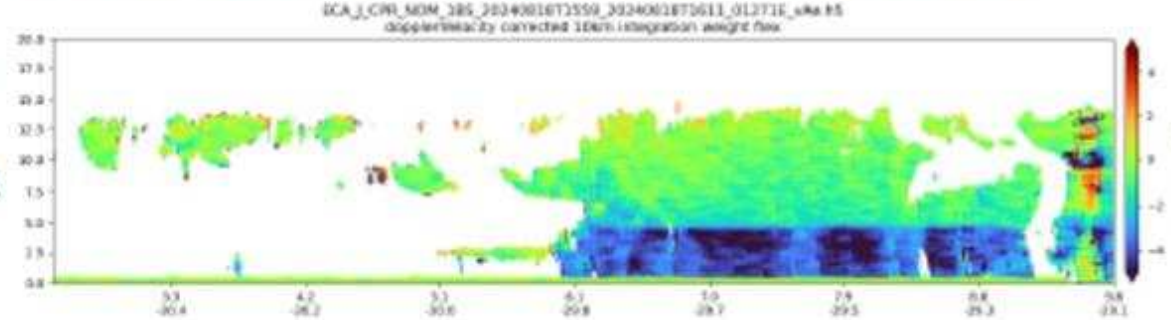
EarthCARE

EarthCARE CPR L1b Radar Reflectivity



Note that uncalibrated CPR data from the early CPR commissioning Phase was used.

Doppler Velocity (bias-corrected, 10km integrated, & unfolded)

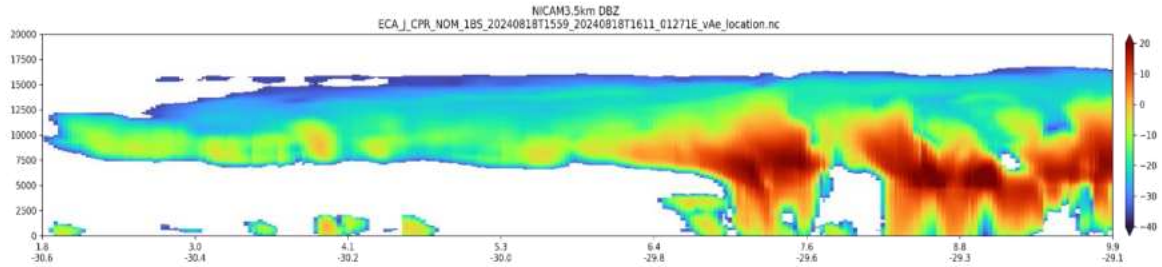


Analyzed by Dr. Aoki (JAXA)

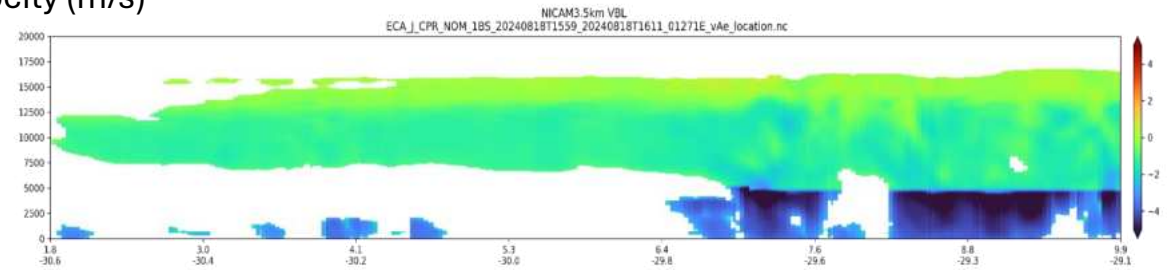
Note that uncalibrated CPR data from the early CPR commissioning Phase was used.

NICAM

Radar Reflectivity (dBZ)

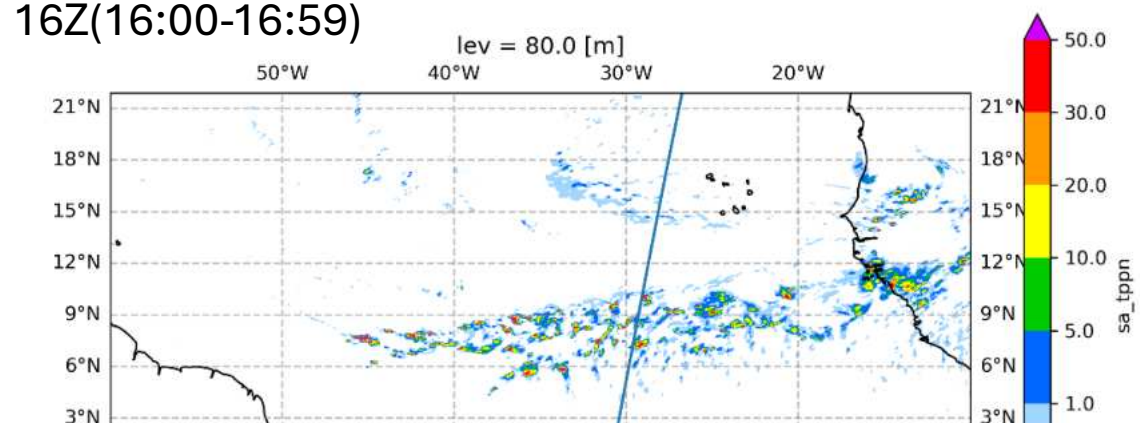


Doppler velocity (m/s)

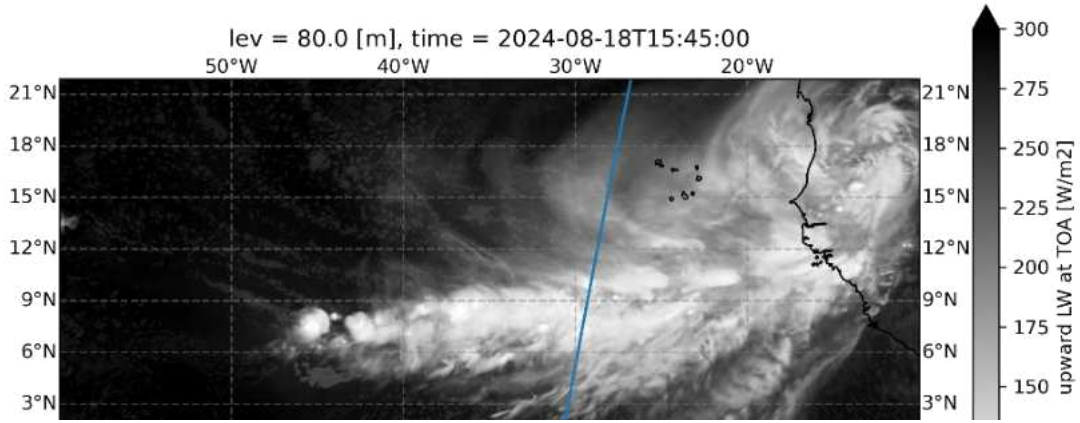


NICAM vs Observation

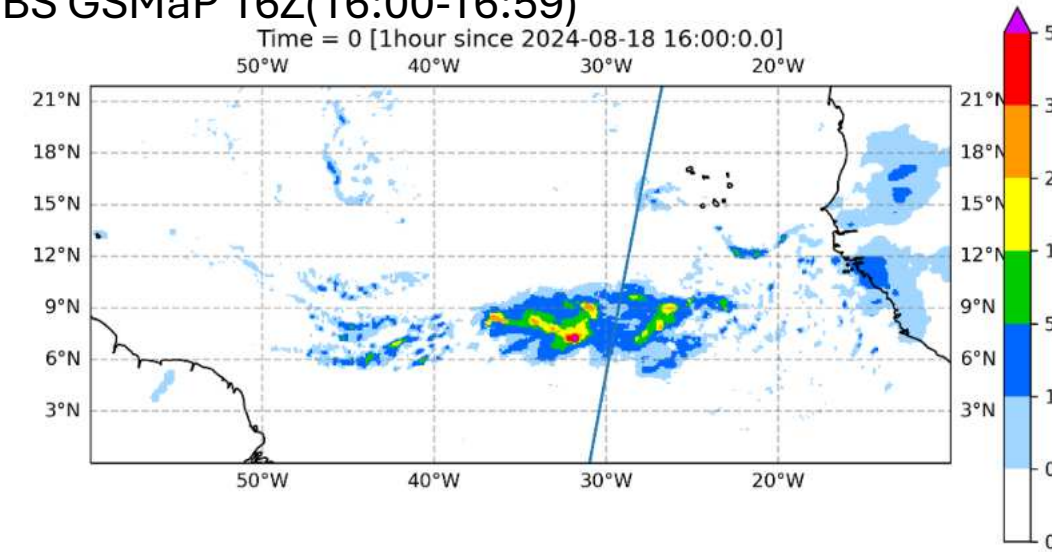
NICAM 1-h accumulated precipitation [mm/hr]
16Z(16:00-16:59)



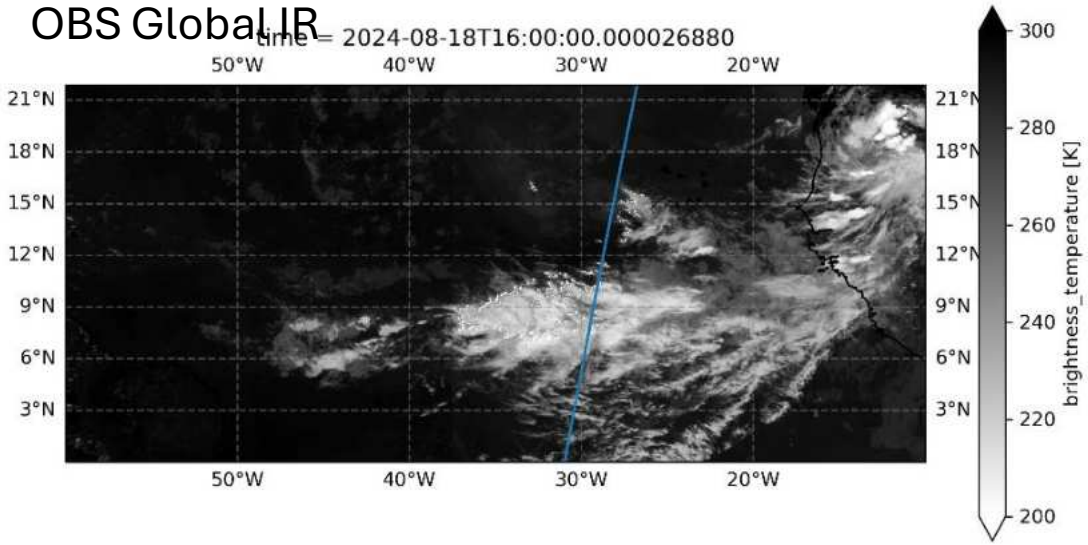
NICAM OLR



OBS GSMaP 16Z(16:00-16:59)

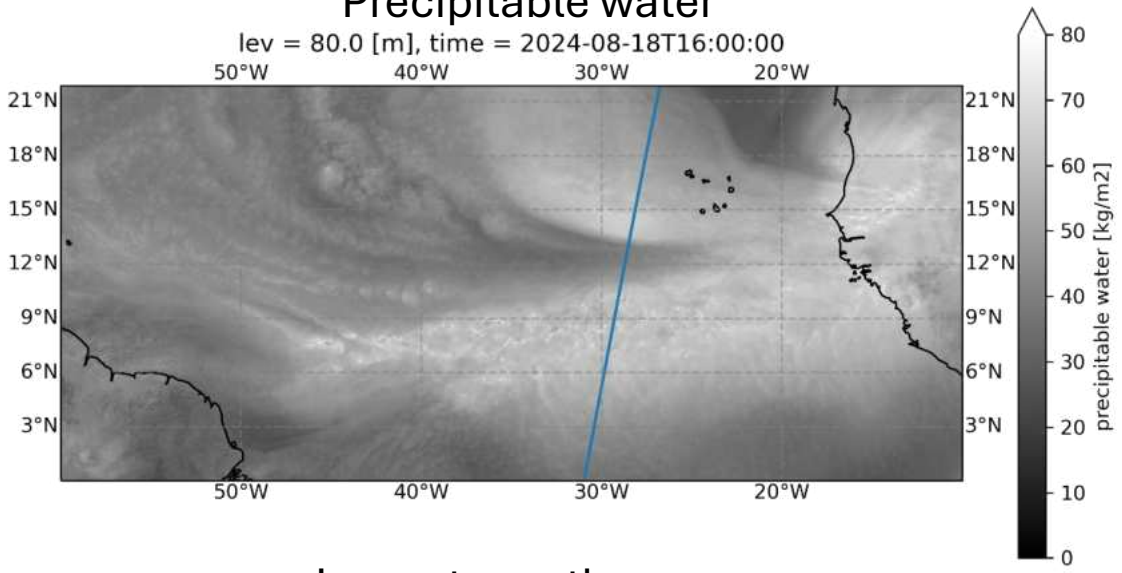


OBS Global IR

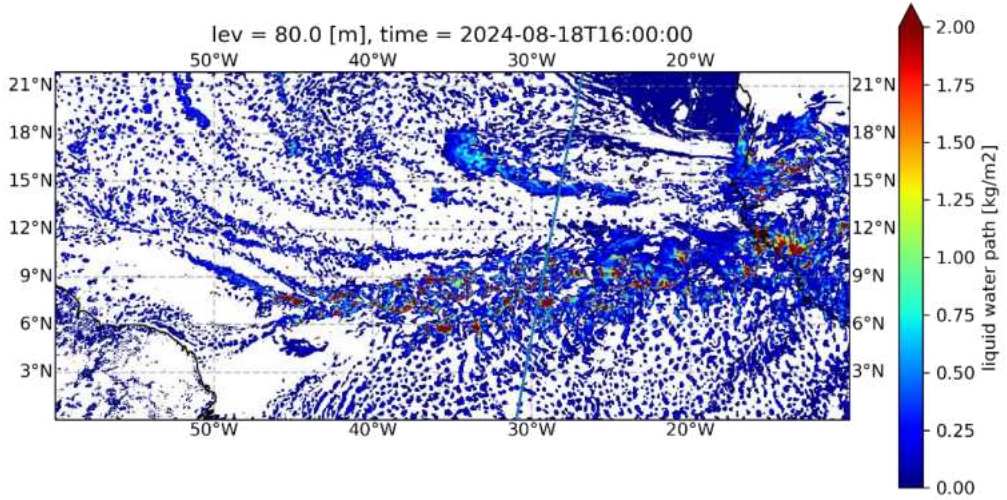


NICAM variables

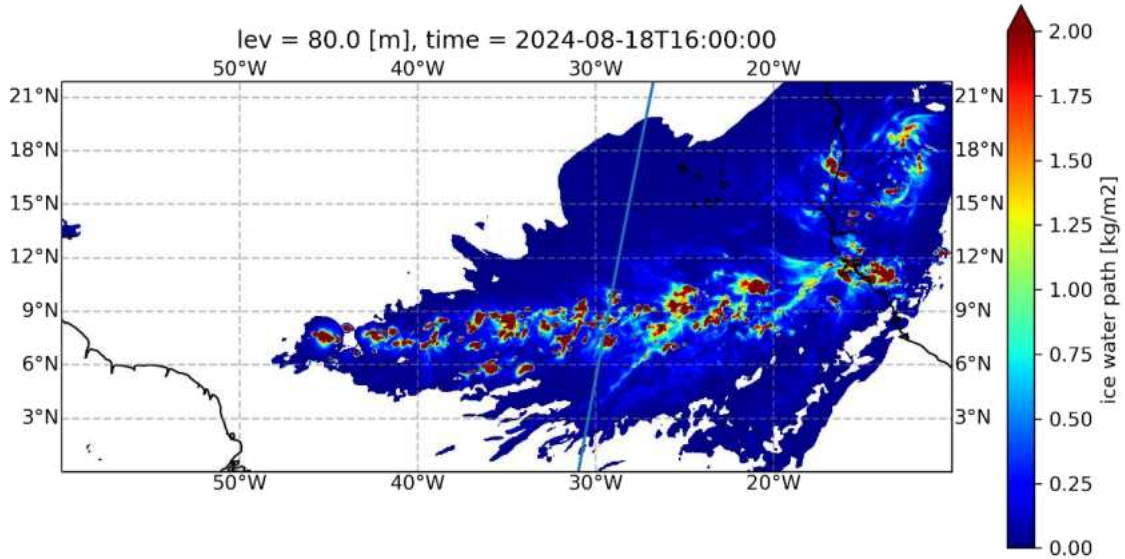
Precipitable water



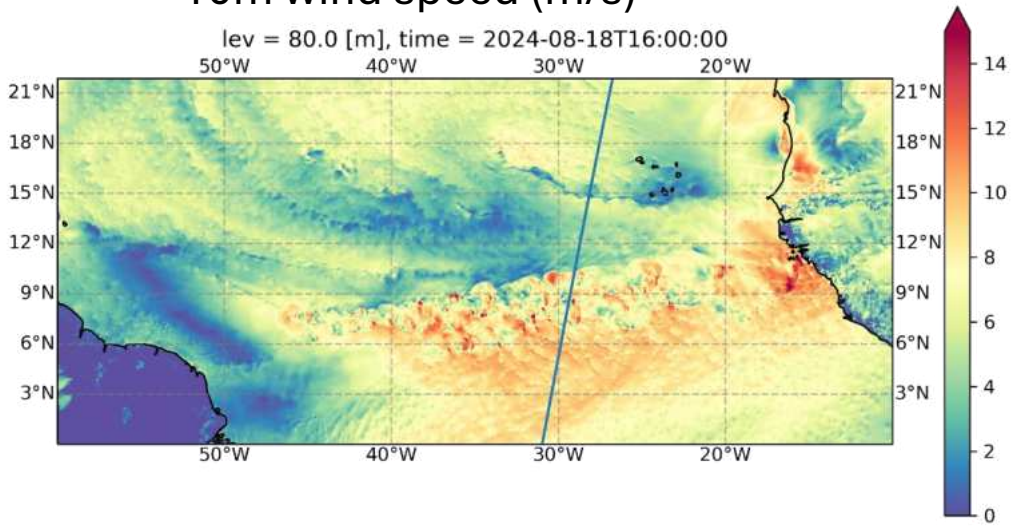
Liquid water path



Ice water path



10m wind speed (m/s)

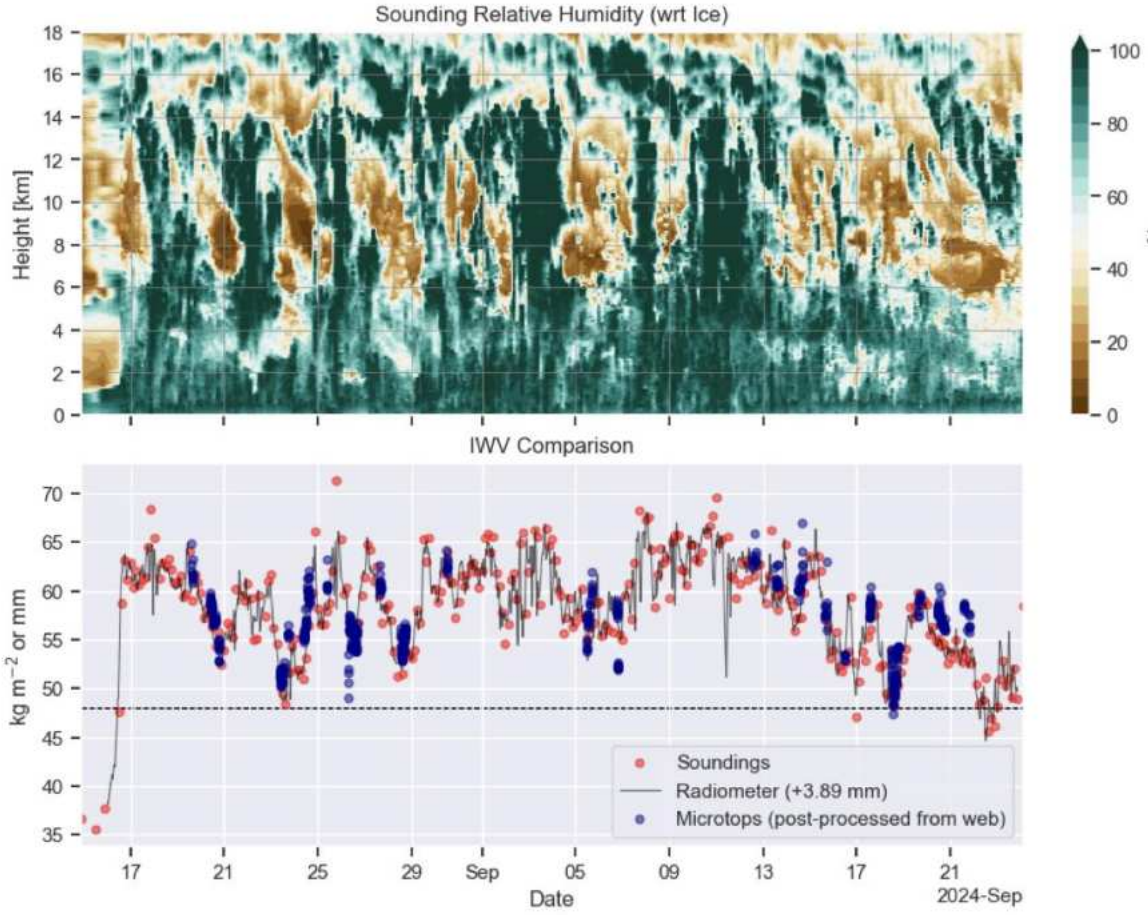


BOW-TIE: **Beobachtung von Ozean und Wolken – Das Trans ITCZ Experiment**

(Translation: ocean and cloud observation - the trans-ITCZ experiment)

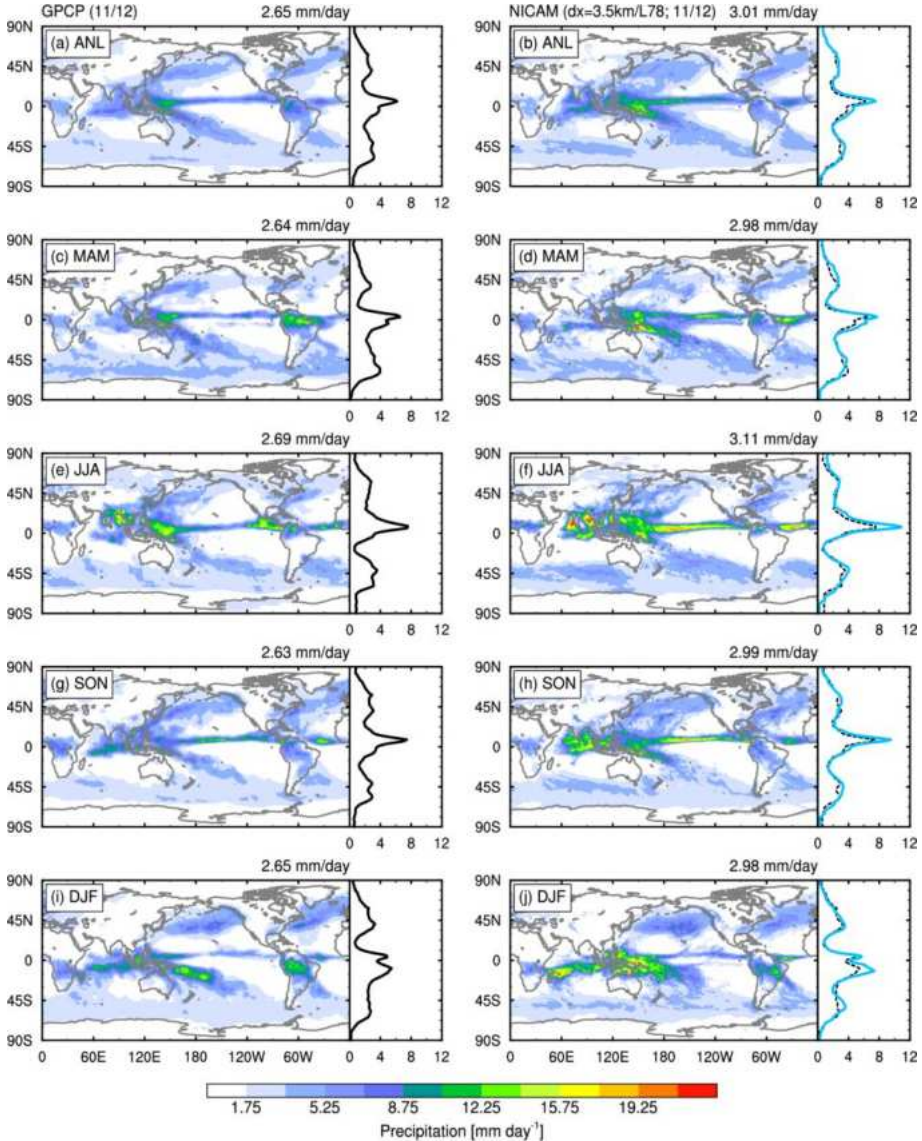
Possible targets of the 60-day free run to compare with the equatorial disturbances

- easterly waves
- ITCZ break-up, organization, and climatology



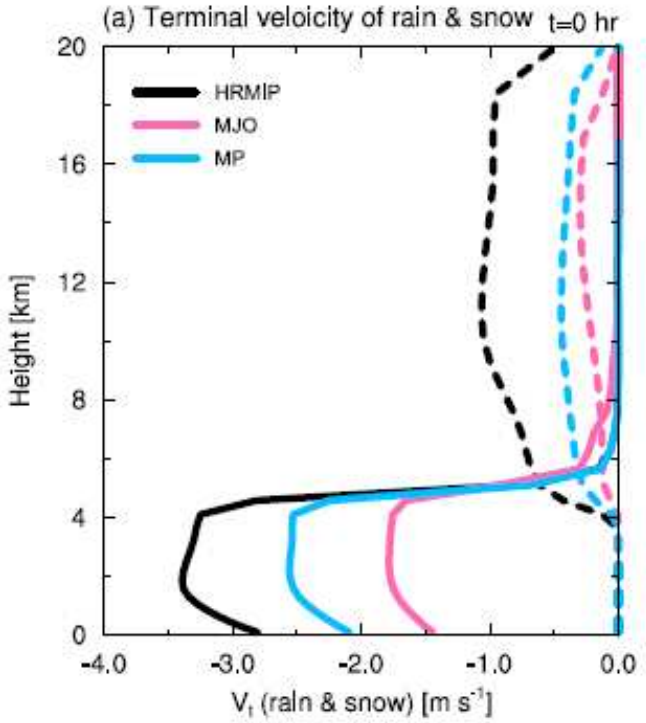
Courtesy of Daniel Klocke (MPI-M) for the time series of all the sounding relative humidity from the BOW-TIE ship observation.

GSRM Intercomparison Experiments:

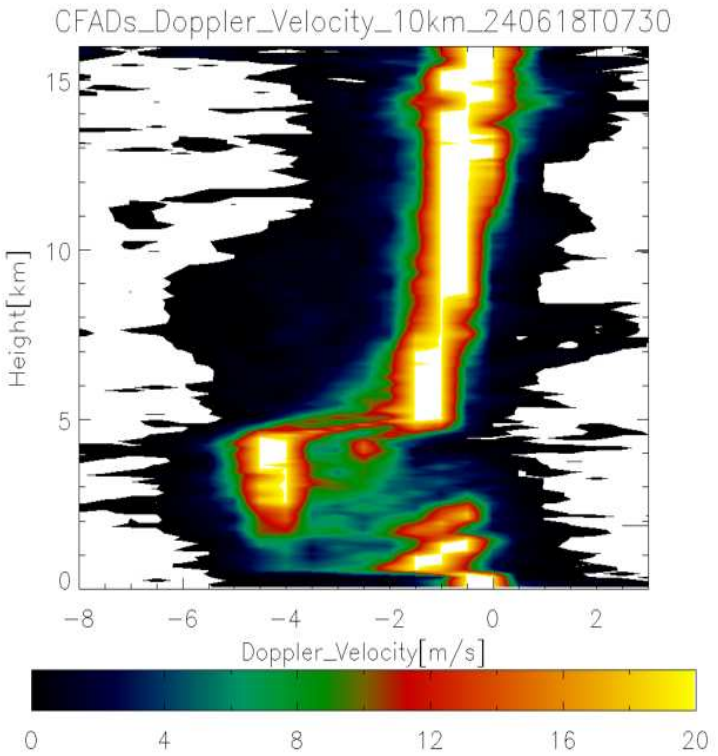


1 year intercomparison experiments (Sendai Protocol)

Takasuka et al. (2024, PEPS) A protocol and analysis of year-long simulations of global storm-resolving models and beyond. Global km-scale Pan-Hackathon: May 11-16, 2025



Takasuka et al. (2024, JAMES)



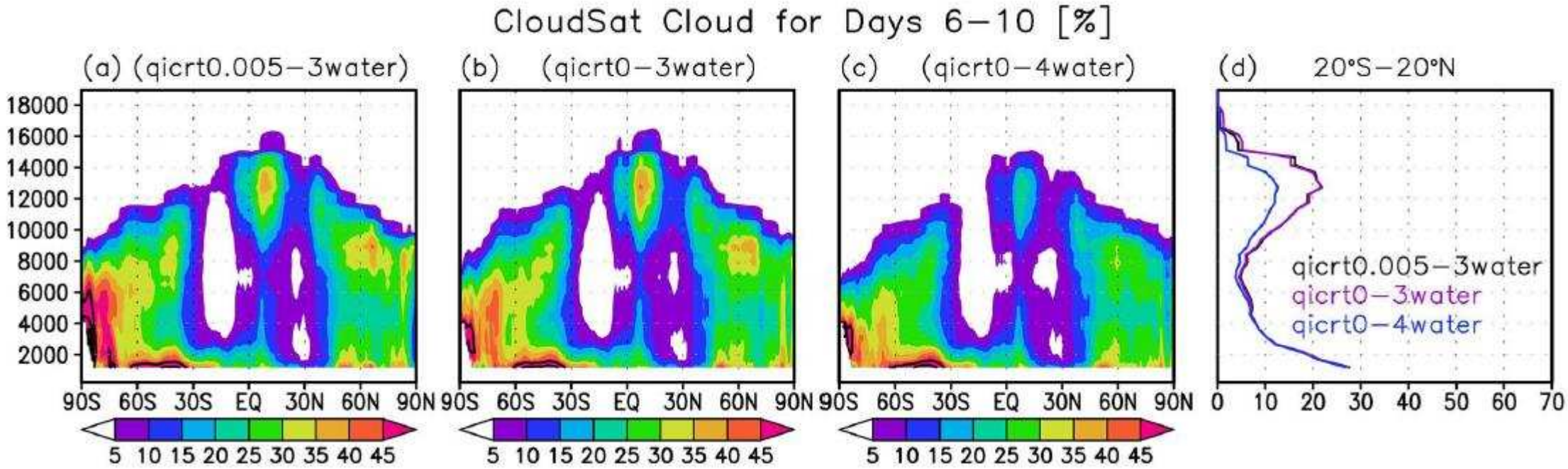
Terminal velocity of cloud ice in models

The terminal velocity of cloud ice is used as a tuning parameter of upper clouds.

Kodama et al. (2012, JGR)

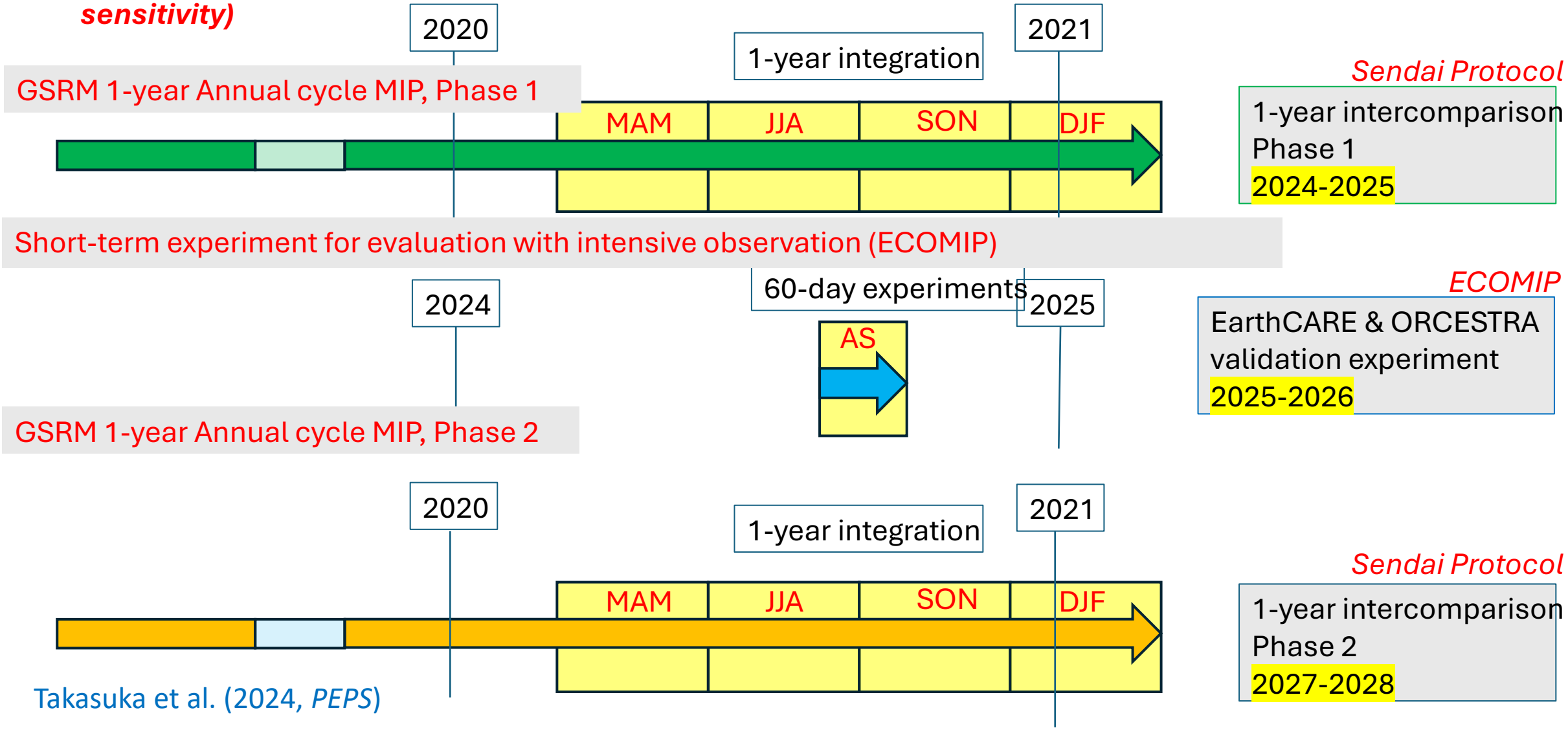
Table 1. Design of the Sensitivity Experiments

Run Name	q_{icrt} (g/kg)	Cloud Ice Fall Process
qicrt0.1–3water	0.1	No
qicrt0.01–3water	0.01	No
qicrt0.005–3water (Control)	0.005	No
qicrt0.001–3water	0.001	No
qicrt0–3water	0	No
qicrt0–4water	0	Yes



Timelines of GSRMIPs

For understanding the impacts of the observations in improving climate simulations (e.g., climate sensitivity)



Takasuka et al. (2024, *PEPS*)

Summary

- Introduction of ECOMIP: EarthCARE, ORCESTRA MIP
- Example of a NICAM 3.5km simulation
- Two types of experiments
  - Case study: two days simulation (with one-day spin-up time): direct comparisons with observation data
  - 60 days simulation (with ten days spin-up time) : statistical analysis (like CFADs, CFEDs), evolutions of tropical disturbances
- Timeline: upcoming meetings
  - Global km-scale Hackathon: 12-17 May, 2025, Tokyo Node etc.
  - CFMIP meeting: 7-10 July 2025, Exeter, UK
  - International Nonhydrostatic Modeling Workshop: 17-19 November 2025, Morioka, Japan
  - ESA-JAXA EarthCARE In-Orbit Science and Validation Workshop : 1-5 December 2025, Tokyo, Japan
  - Summarize ECOMIP within 2026 (TBD)