

# **JMA/MRI/KU Aerosol Model Activities Overview**

**SEKIYAMA Thomas T.\*, MAKI Takashi\*, OSHIMA Naga\*,  
YUMIMOTO Keiya<sup>\$</sup>**

*\*Meteorological Research Institute, Japan Meteorological Agency*

*\$ Research Institute for Applied Mechanics, Kyushu University*

ICAP 2026 Meeting, Bonn, 10 June 2026

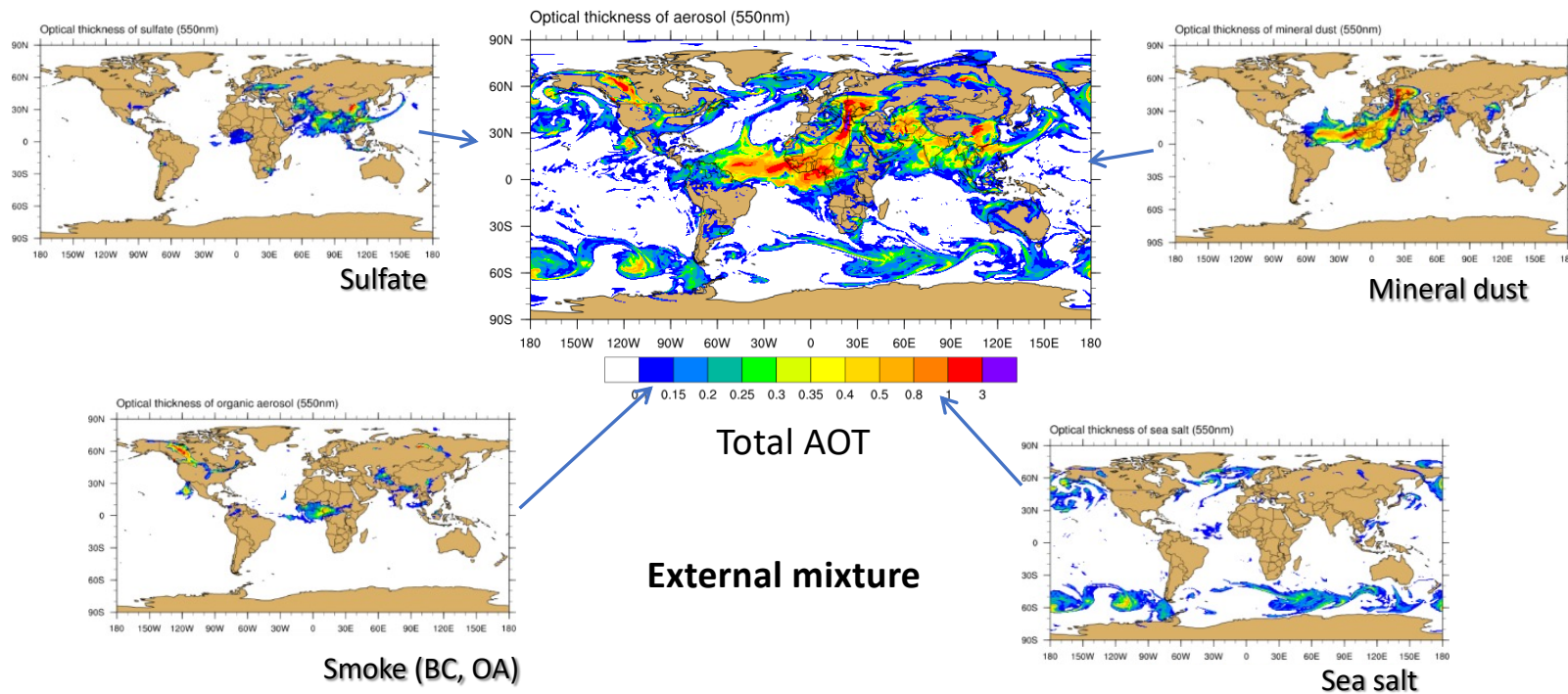
# Outline

- **Overview of the JMA/MRI/KU global aerosol model and data assimilation**
- **Validation studies**
  - **For Stratospheric Aerosol**
  - **With EarthCARE data**
- **Model Update**
  - **Satellite snow data for Dust emission scheme**
  - **Major update of MRI-ESM (ESM2 → ESM3 for CMIP7)**
- **Data assimilation Update**
  - **Himawai 8/9 and GCOM-C DA has started.**
- **Summary**

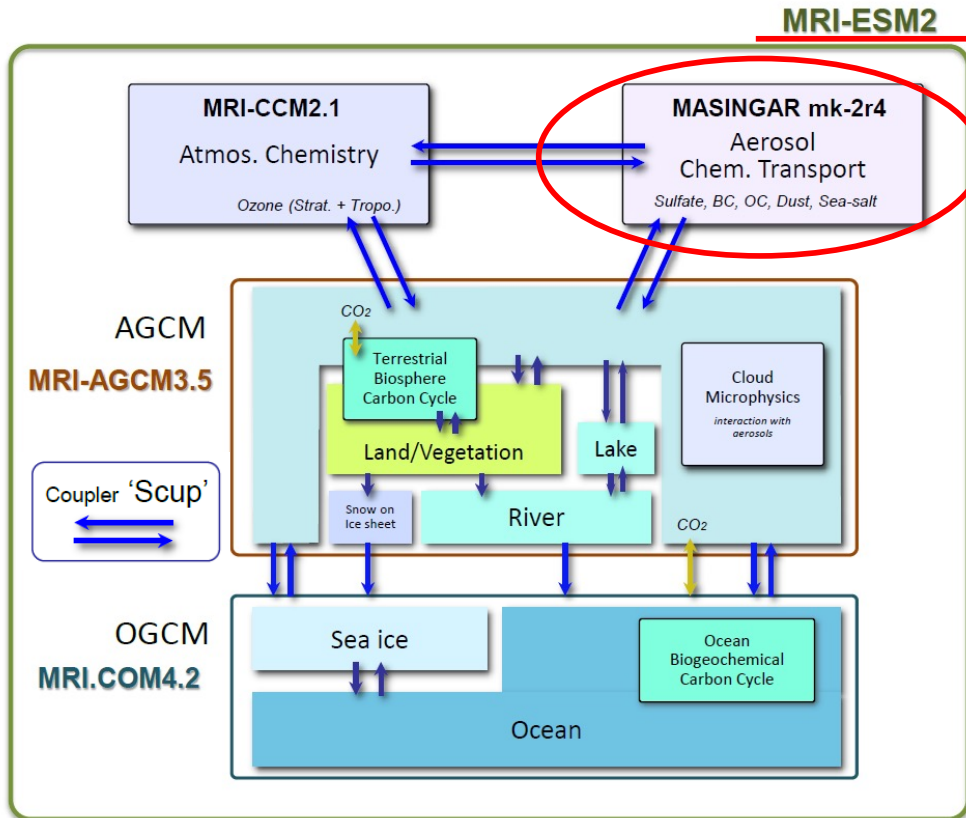
# JMA/MRI Aerosol Transport Model

## (Model of Aerosol Species in the Global Atmosphere: MASINGAR)

- Sulfate, black carbon, organics, sea salt, and mineral dust are included
  - The emission flux of sea-salt, mineral dust, and dimethylsulfide are predicted based on the surface properties calculated by the atmospheric model.
  - Particle size distributions of sea salt and dust are expressed with sectional approach (10-bins from 0.2 to 20  $\mu\text{m}$ )



# MRI-ESM2.0 and MASINGAR aerosol model



[Yukimoto et al., JMSJ, 2019] [Kawai et al., GMD, 2019] [Oshima et al., PEPS, 2020]

- MRI-ESM2.0 is MRI's CMIP6 Earth System Model, including AGCM, OGCM, chemistry, aerosol, and coupler components.
- MASINGAR explicitly represents aerosol transport and aerosol–radiation/cloud interactions.
- Improved aerosol and cloud processes contributed to better global radiation budgets.
- MRI-ESM2.0 contributed to IPCC AR6 and AMAP assessments.

## Limitation for seasonal dust prediction

- JMA's seasonal ensemble prediction system uses aerosol climatology.
- Aerosols and dust are therefore not predicted interactively.

## Recent development

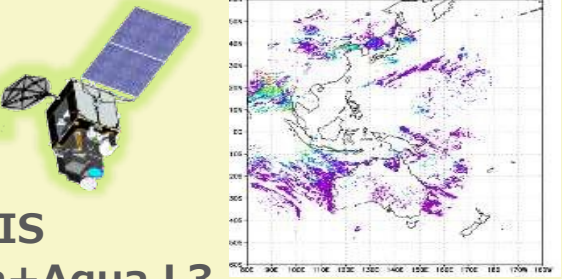
- We developed MRI-ESM3.2 by replacing the AGCM with JMA's operational NWP model.
- This system is being explored for future seasonal prediction applications.

# MASINGAR Implements Aerosol Data Assimilation

Japanese geostationary weather satellite

Thanks to LAADS DAAC NASA

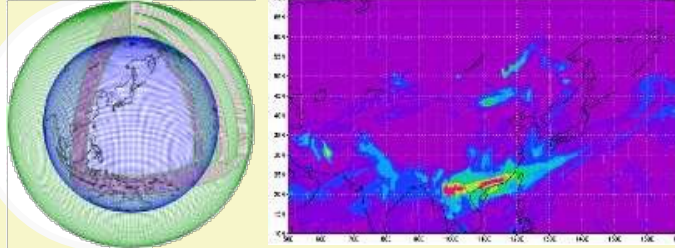
### Himawari 8/9 AOD



**MODIS Terra+Qua L3 AOD**

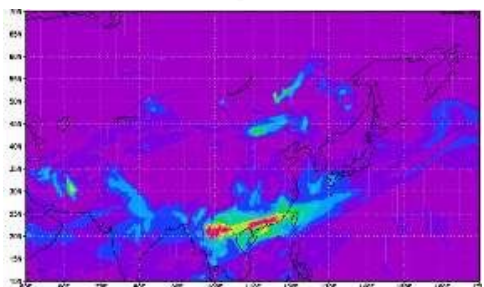
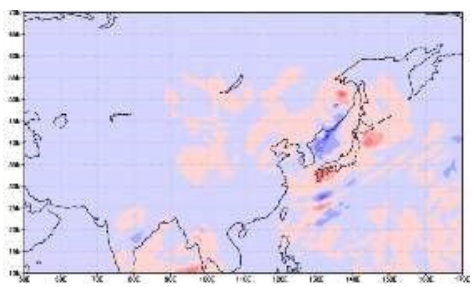
**Observation**

### MASINGAR mk-2



**model**

**Data Assimilation**

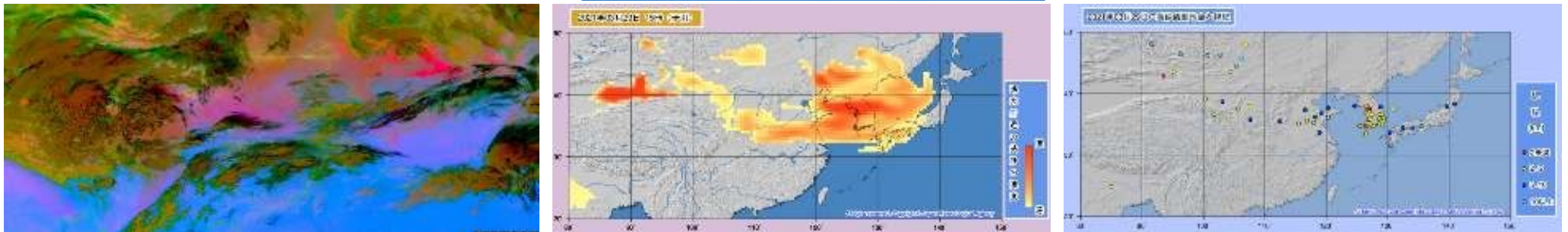


Target: AOD  
Method: 2D-Var  
Frequency:  
Himawari AOD – 4 per day  
00, 03, 06, 09 UTC  
MODIS AOD – 2 per day  
12, 18 UTC

NRT MASINGAR horizontal resolutions:  
TL479 (0.375 degree)

# JMA operational aeolian dust Information

JMA has been providing Aeolian dust information based on numerical forecasts and observations since January 2004 (<http://www.jma.go.jp/en/kosa>).



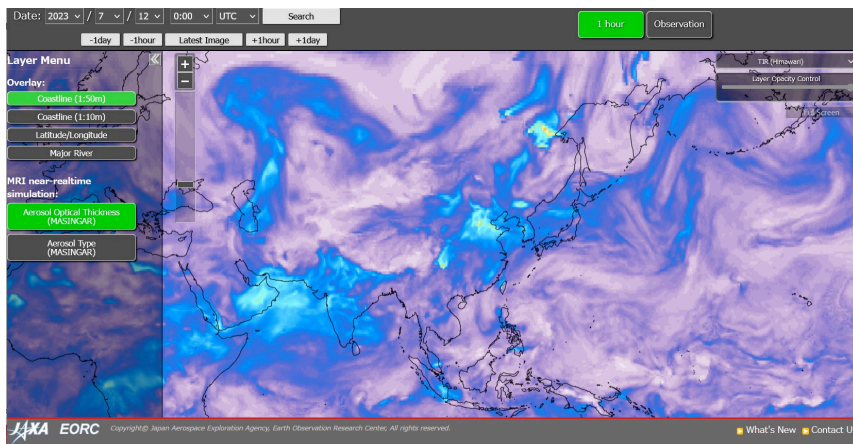
JMA operates a global aerosol model (TL479L40) for the prediction of aeolian dust. The forecast charts up to 4 days ahead with the interval of 6 hours are updated once per day.

JMA also provides aeolian dust prediction results (GRIB2 format) for private weather services via the Japan Meteorological Business Support Center (JMBSC).

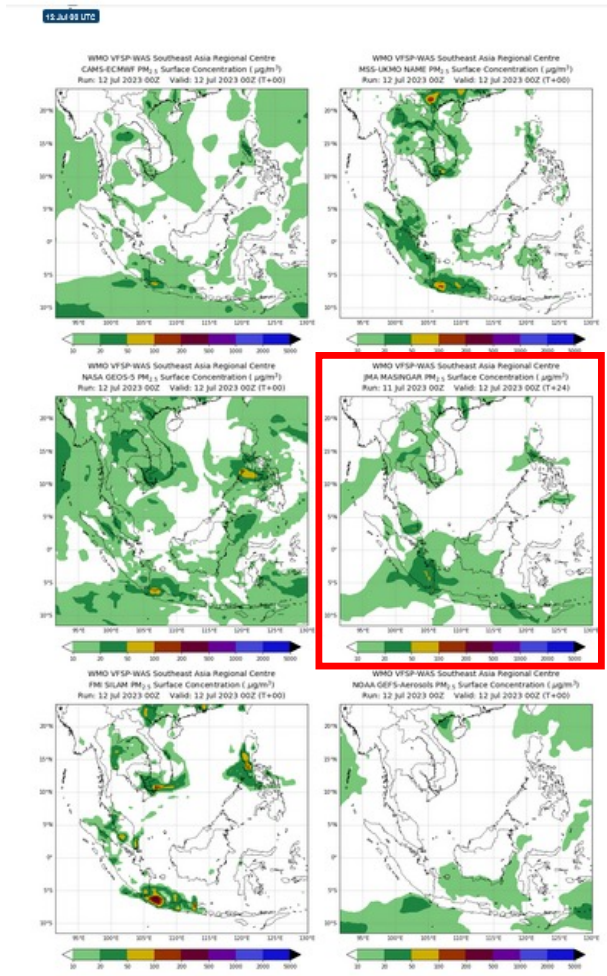
# Near Real Time MASINGAR for ICAP, JAXA, and VFSP-WAS

Near-real-time MASINGAR products are generated for aerosol analysis and prediction.

- Daily aerosol analysis and 5-day forecasts are provided to ICAP.
- The same products are also provided to EORC/JAXA for the JAXA P-Tree project.
- MASINGAR outputs are being prepared for the WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS).
- Model calculations for VFSP-WAS are already underway, while the operational data transfer procedure is still being finalized.

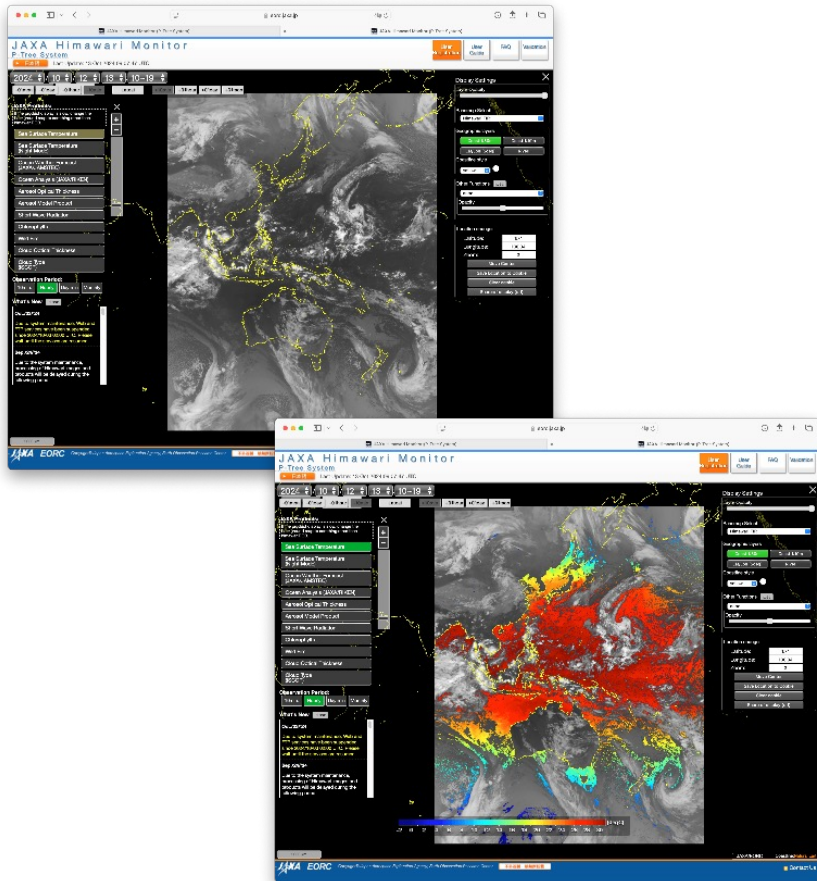


JAXA P-Tree project  
website ([https://www.eorc.jaxa.jp/ptree/aerosol\\_model/index.html](https://www.eorc.jaxa.jp/ptree/aerosol_model/index.html))

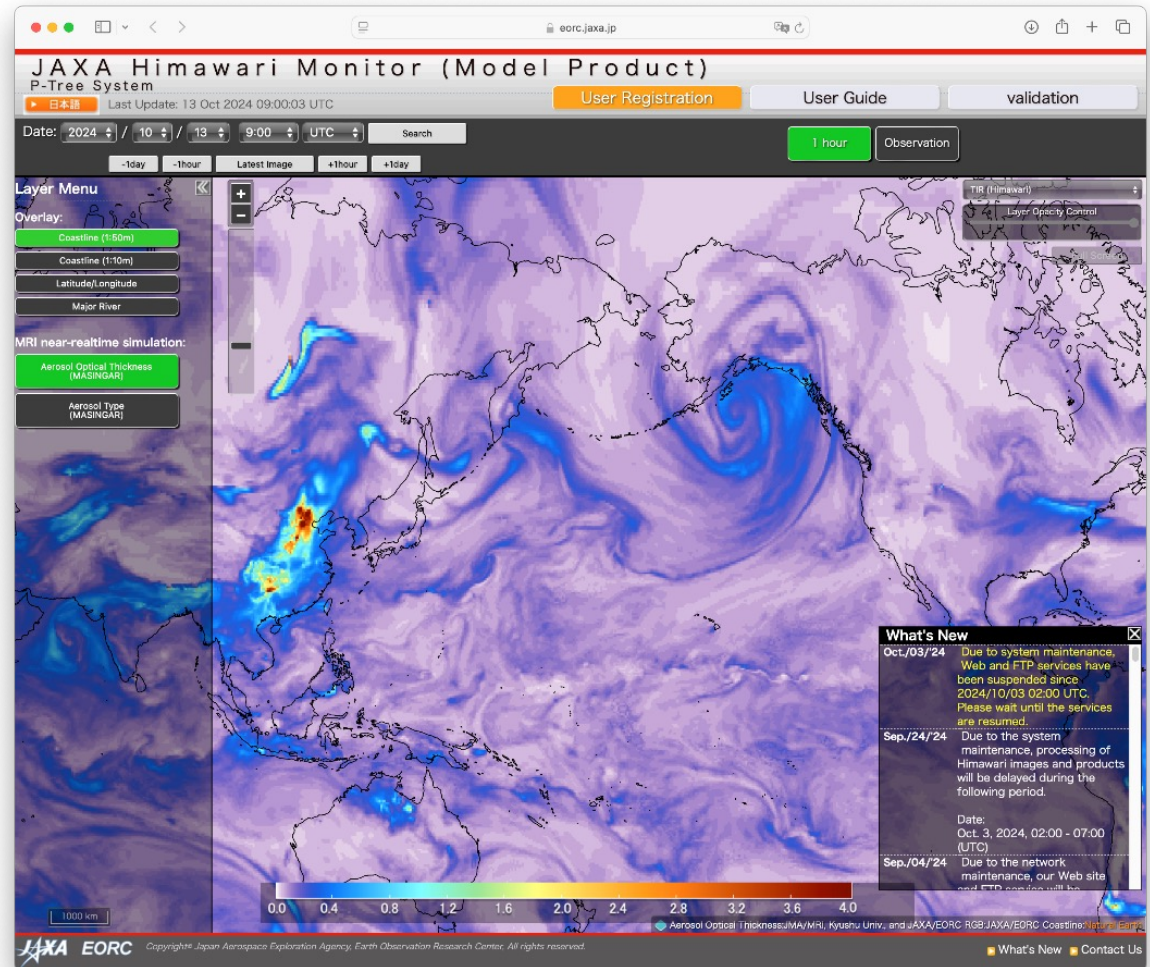


VFSP-WAS  
Website (<https://www.mss-int.sg/vfsp-was/forecasts/smoke-forecasts>)

# JAXA's P-Tree Project



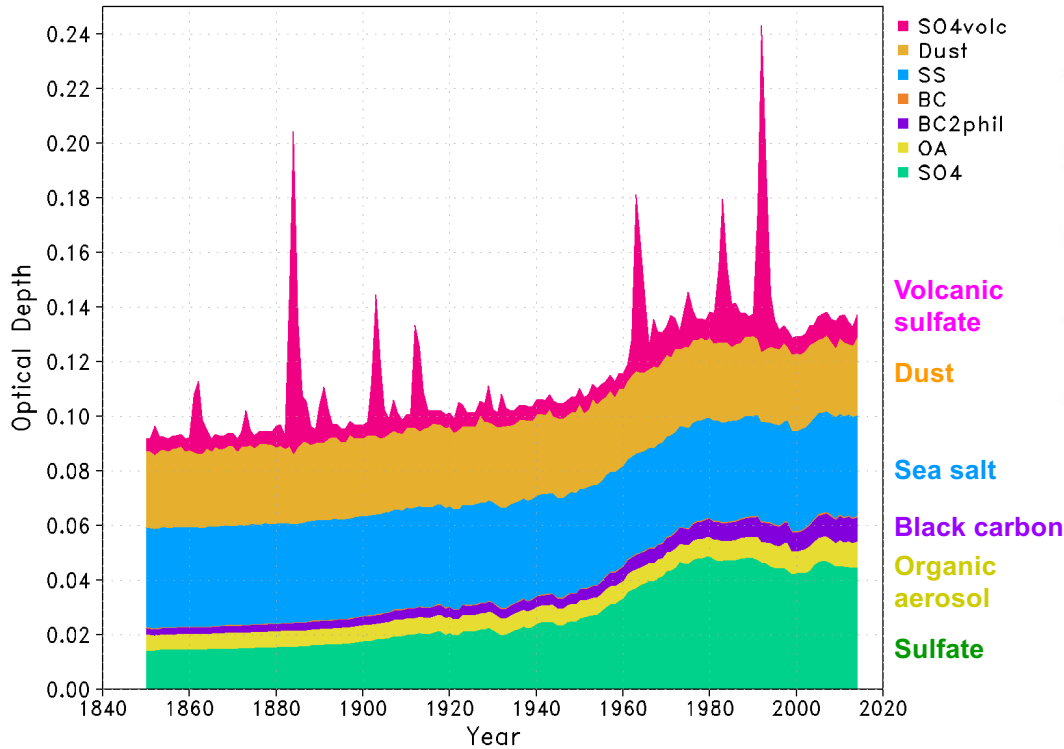
JAXA P-Tree observation website  
<https://www.eorc.jaxa.jp/ptree/index.html>



JAXA P-Tree model website  
[https://www.eorc.jaxa.jp/ptree/aerosol\\_model/index.html](https://www.eorc.jaxa.jp/ptree/aerosol_model/index.html)

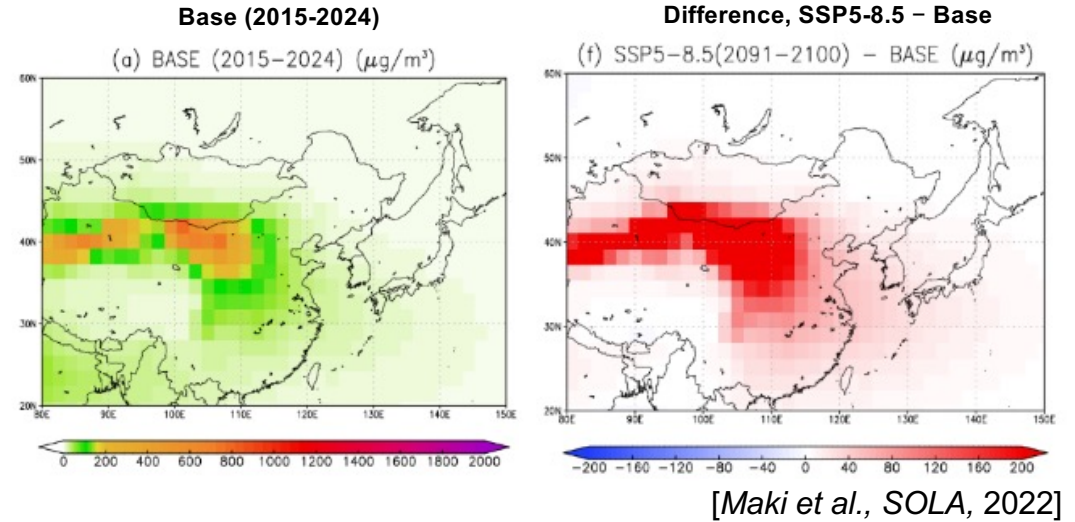
# Climate Change Predictions by MRI-ESM2.0

Globally averaged Annual-mean Aerosol Optical Depth  
run-Dr060\_historical\_101-110



Aerosol optical depth (AOD) and contributions of each aerosol species (global averages, CMIP6 historical simulations by MRI-ESM2.0).

## Future dust emission changes in East Asia by MRI-ESM2.0



Surface dust concentrations (March) in **base period (2015-2024)** and **SSP5-8.5 future (2091-2100)** scenario in East Asia. Dust emissions would increase in early spring from 2015 to 2100 in warmer scenarios (SSP5-8.5), likely due to changes in seasonal transition.

\* SSP5-8.5: a very high-emissions scenario, corresponding to approximately  $4.4^\circ\text{C}$  global warming by the end of the 21st century.

# JRAero and JRAero V2

The Japanese Reanalysis for Aerosol (JRAero)



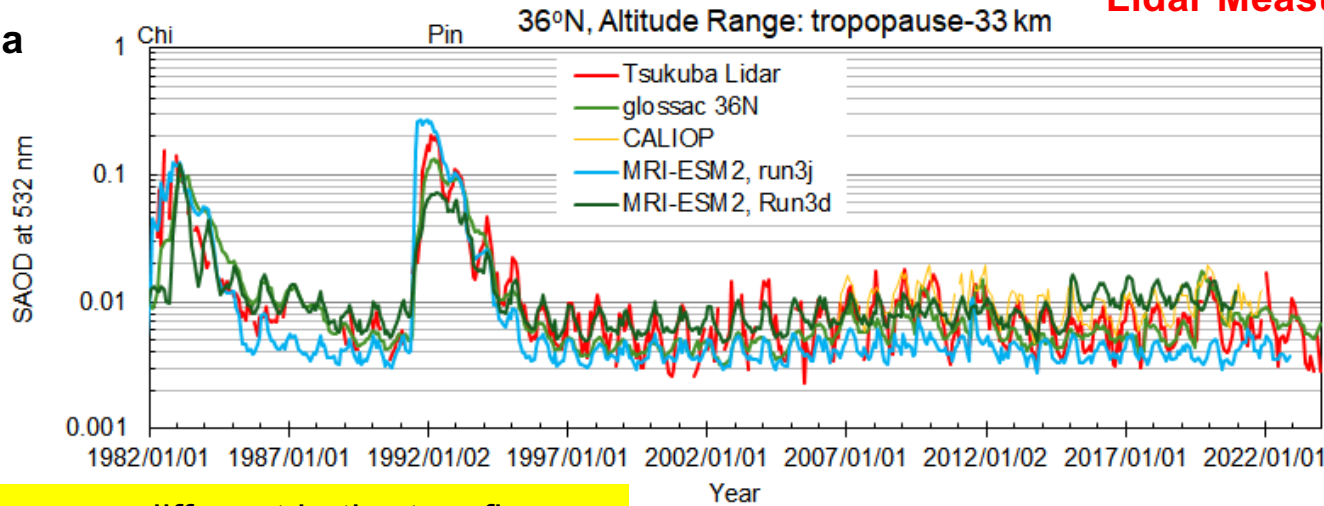
The JRAero version 1 constructed by the MRI/JMA and the RIAM of Kyushu University for 2011–2019.

Probably, the 4th aerosol reanalysis (ECMWF, NASA, NRL, JMA).

We have a plan to update the analysis (version 2) in the future.

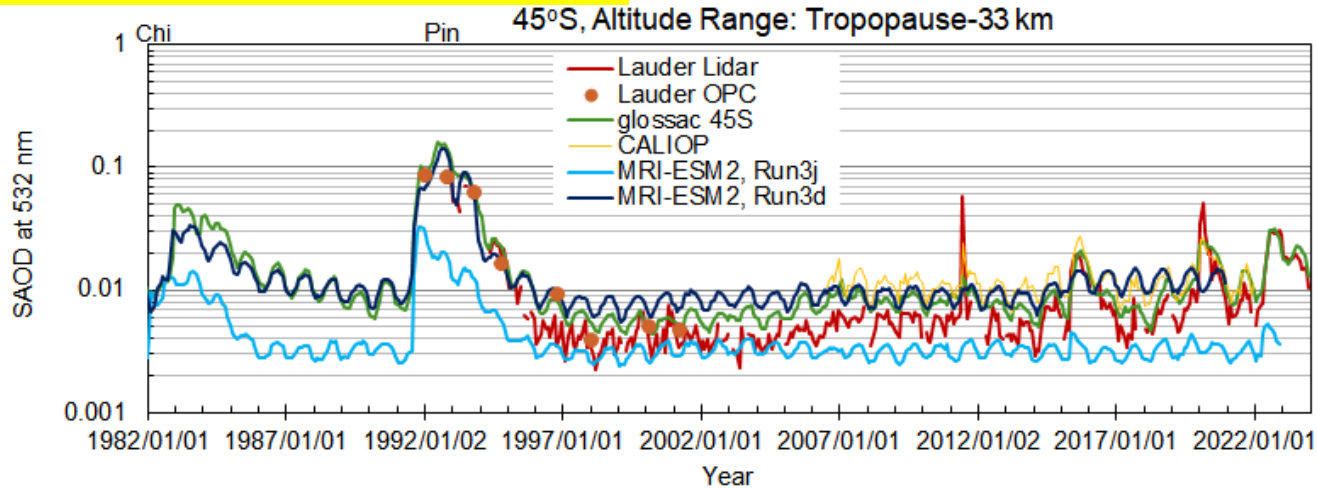
# Validation 1: Stratospheric Aerosol with Lidars

**Tsukuba  
(36N)**



Color lines are different in the two figures

**Lauder  
(45S)**



## Lidar Measurements

MRI-ESM2 Run3d  
with CMIP6 stratospheric aerosol  
dataset, nudged toward JRA-55

MRI-ESM2 Run3j  
with SO2 volcanic emission data  
(same as CMIP7 volcanic  
emission data), nudged toward  
JRA-55

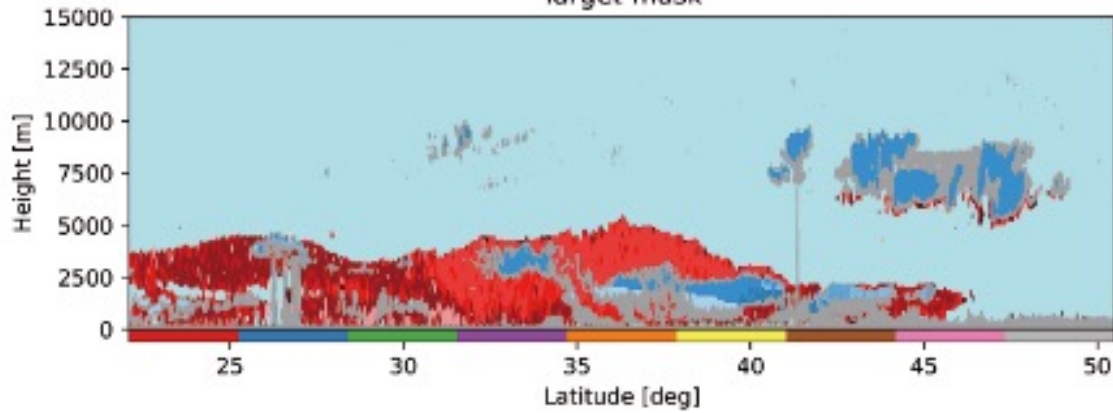
Simulation with SO2 volcanic  
emissions underestimates the  
stratospheric AOD in the southern  
hemisphere. It also underestimates  
the background values.

Modified from  
[Sakai et al., JGR, 2025]

# Validation 2: Aerosol species with EarthCARE

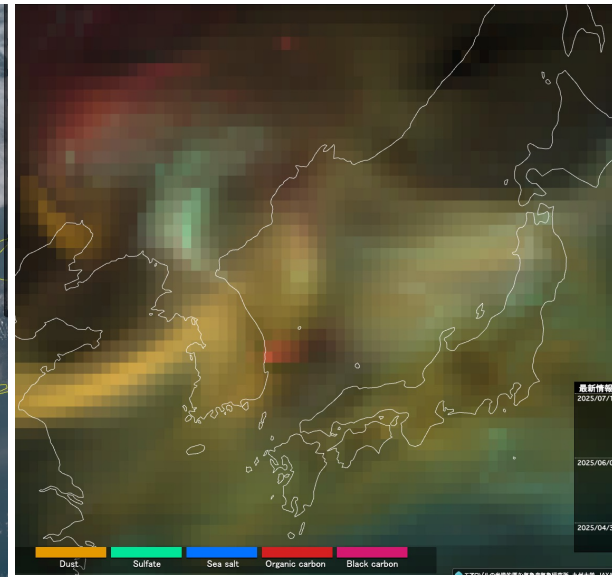
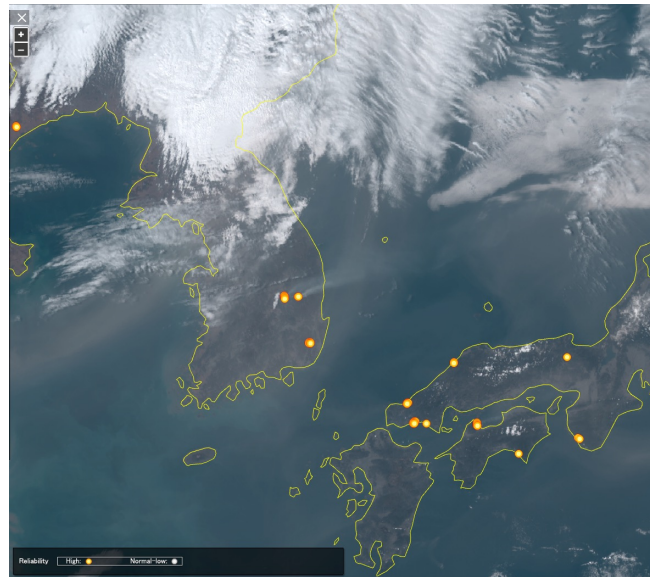
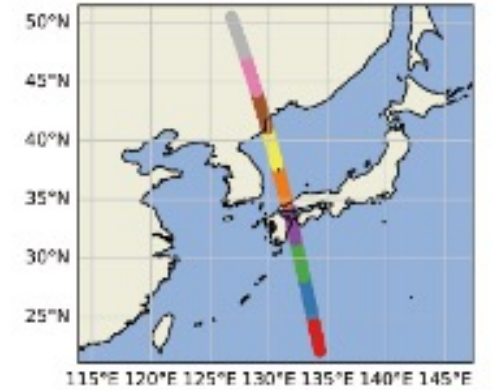
20250324T16

Target mask



- Unknown aerosols
- Pristine
- Pollution
- Dusty mixture
- Dust
- Smoke
- Marine
- Unknown clouds
- 3D ice cloud
- 2D ice plate cloud
- Supercooled water cloud
- Warm water cloud
- Clear air
- Invalid (no data, noisy)

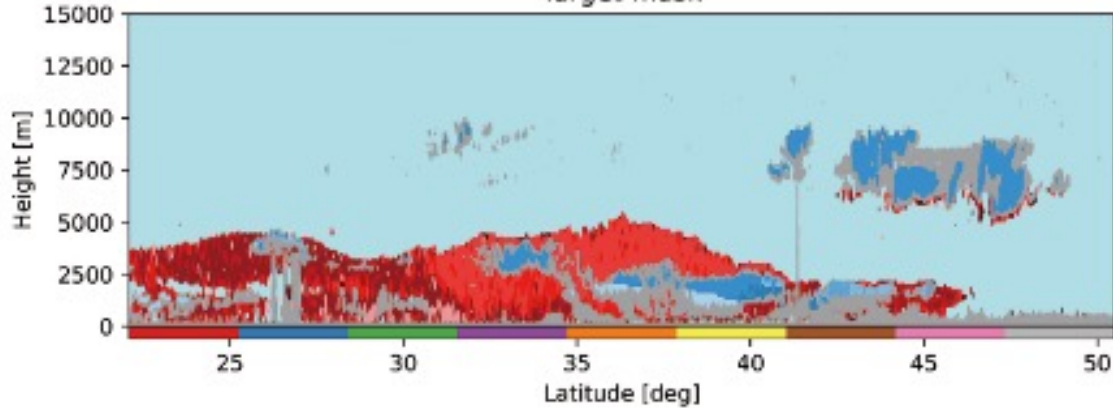
EarthCARE orbit



# Validation 2: Aerosol species with EarthCARE

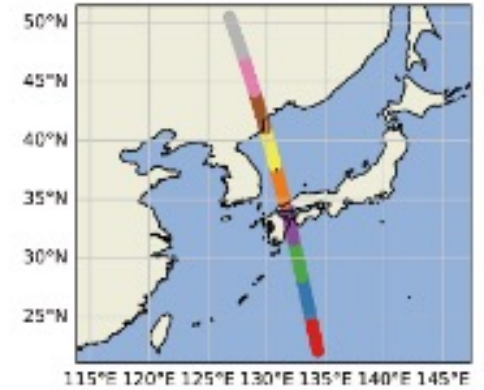
20250324T16

Target mask

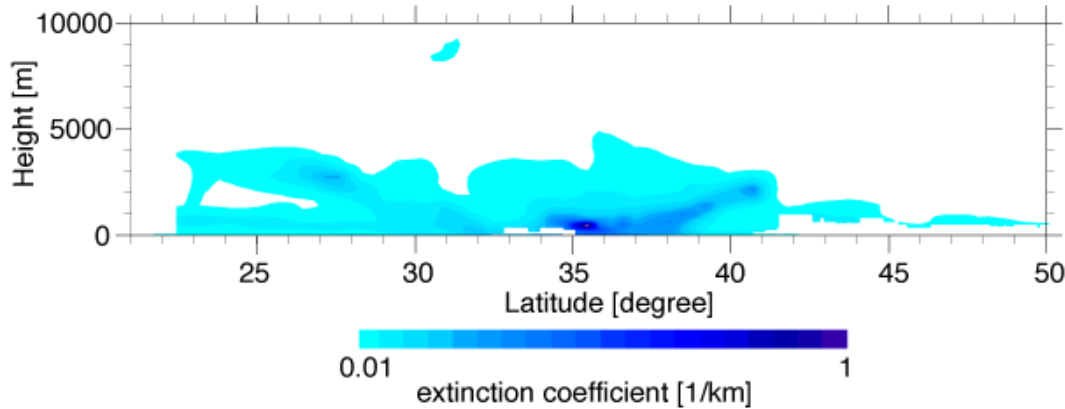


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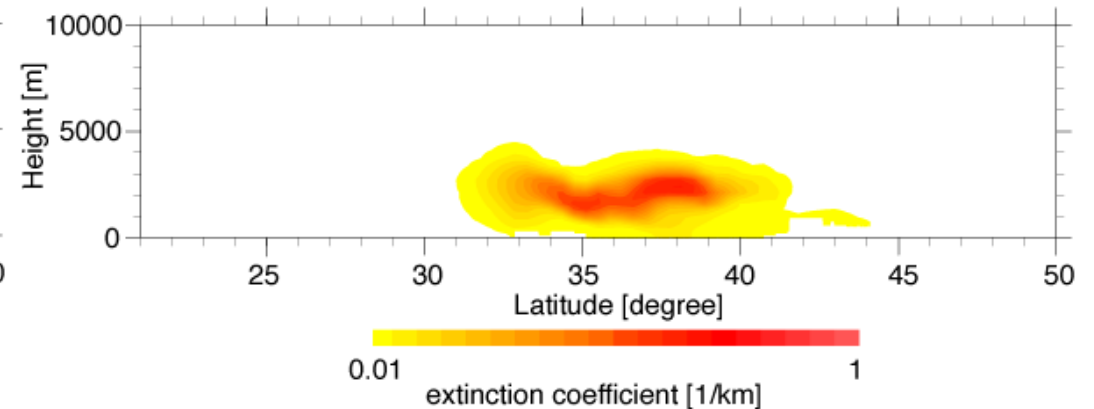
EarthCARE orbit



Non Dust

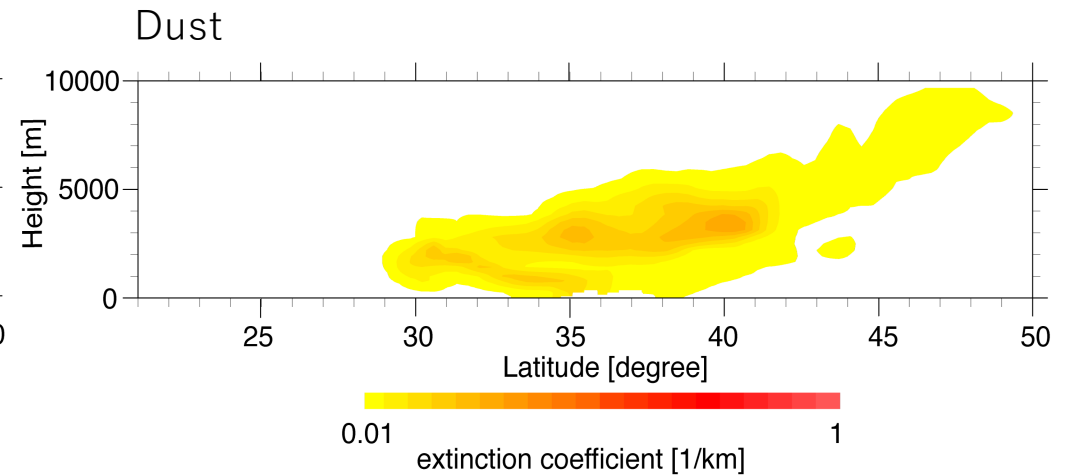
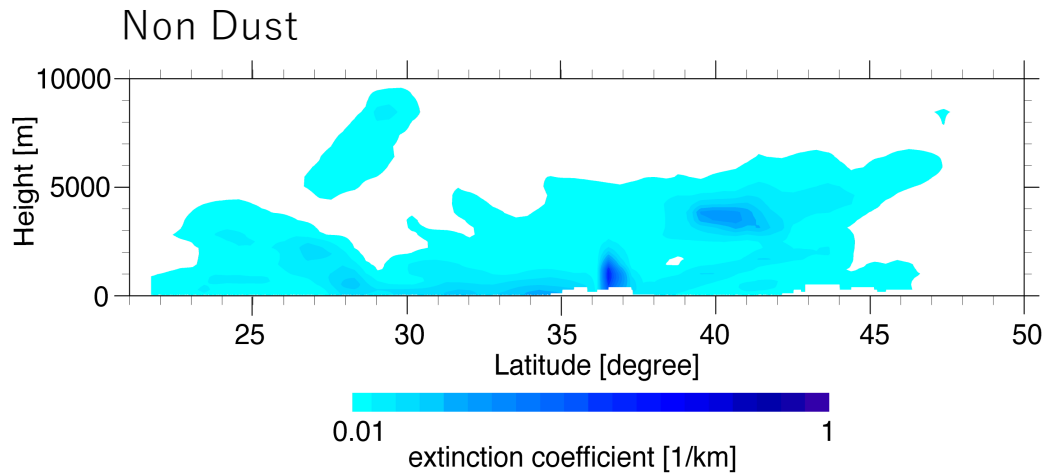
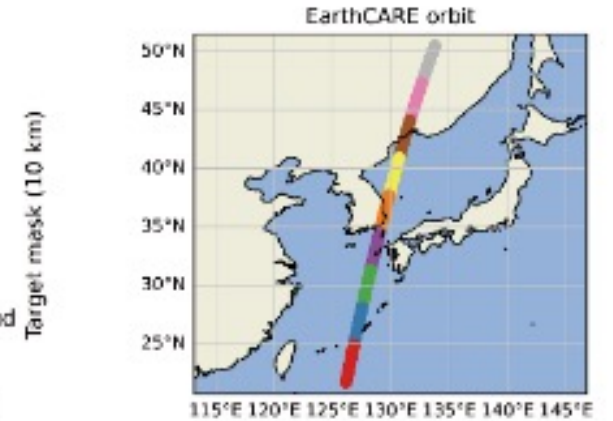
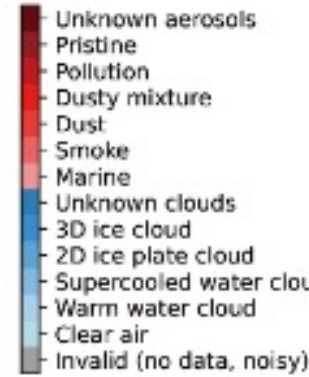
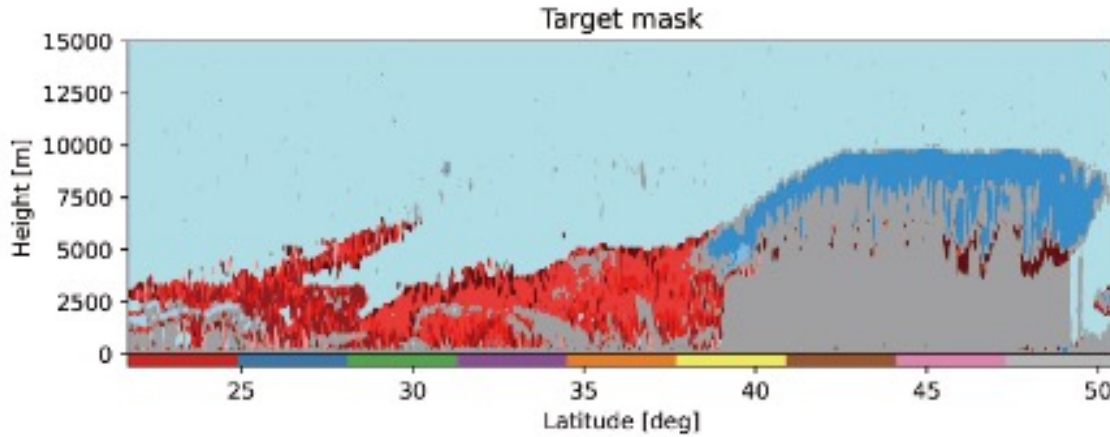


Dust



# Validation 2: Aerosol species with EarthCARE

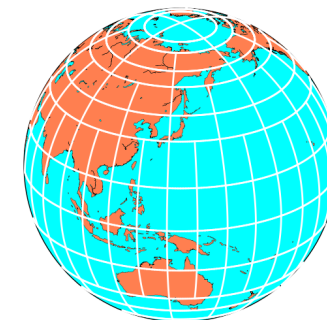
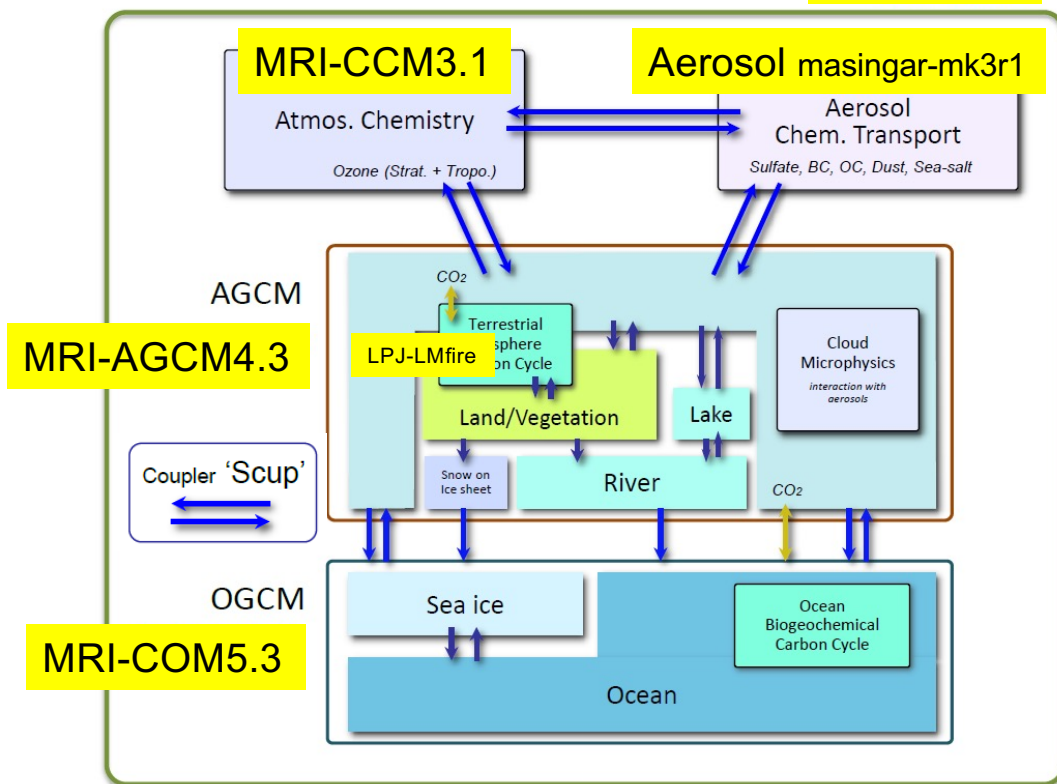
20250325T05



# Development of a new MRI-ESM3 for CMIP7

CMIP7 model

MRI-ESM3



Horizontal:

- AGCM: TL159 (110 km)
- Aerosol: TL95 (180 km)
- CCM: T42 (280 km)

Vertical: L100 (up to 0.01 hPa)

Replacing AGCM with MRI-AGCM4, which is based on the JMA's operational numerical weather prediction model

Improving the component models and coupled them

Higher model calculation speed (AGCM, CCM, Aerosol)

- Reduced gaussian grid
- 2-dimensional decomposition with square-like regions (higher communication speeds)
- OpenMP etc.

⇒ The new MRI-ESM3 is approximately 3-4 times faster than the previous MRI-ESM2.0.

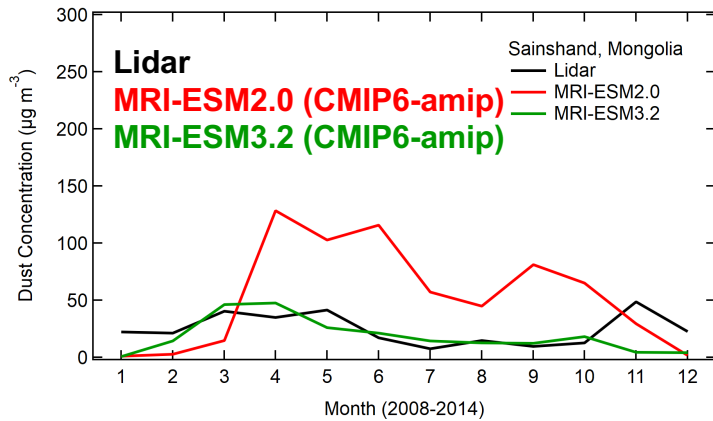
The stable version MRI-ESM3.4 is scheduled to be used for

- CMIP7 (contributing to IPCC AR7)
- JMA Aeolian Dust Information and UV Index Forecast

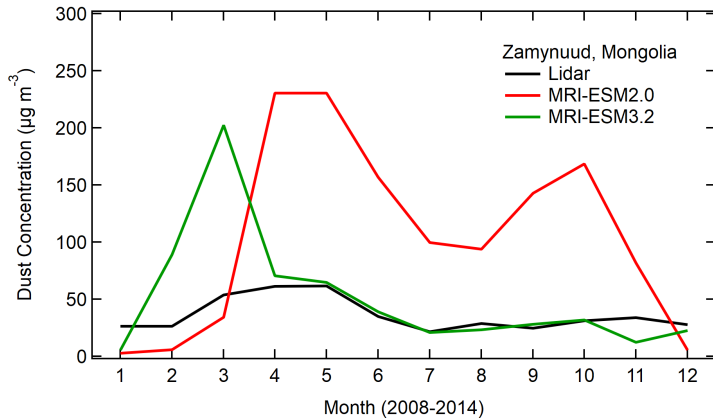
Including a dynamic global vegetation model with interactive wildfire scheme

# Comparisons at Gobi Desert and Greenland (Dust)

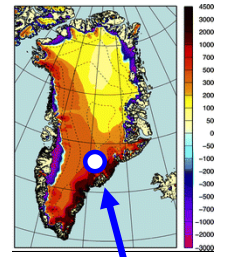
0-1 km Sainshand (2008-2014)



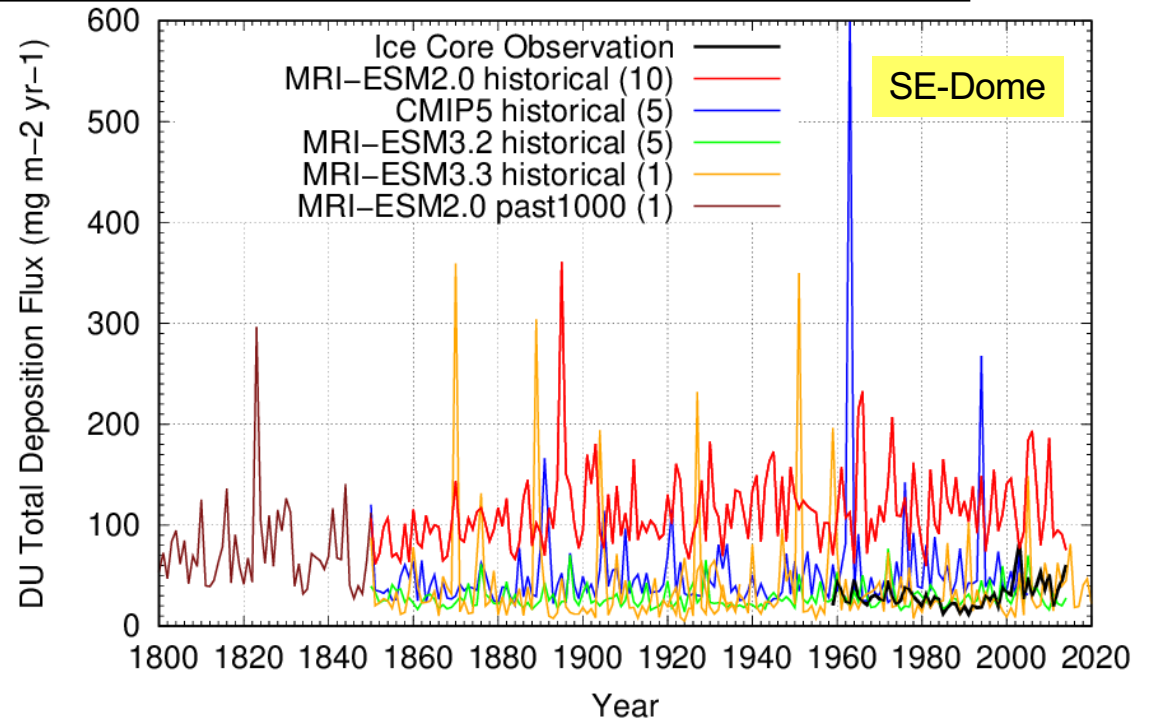
Zamynnuud (2008-2014)



- Ice Core Observation (SE1)
- 850-1849: MRI-ESM2-0, CMIP6 Past1000 (1 member) & SO2volc
- 1850-2005: MRI-CGCM3, CMIP5 historical (5 members)
- 1850-2014: MRI-ESM2-0, CMIP6 historical (10 members)
- 1850-2014: MRI-ESM3-2, CMIP6 historical (5 members)
- 1850-2014: MRI-ESM3-3, CMIP7 historical (1 member, test)



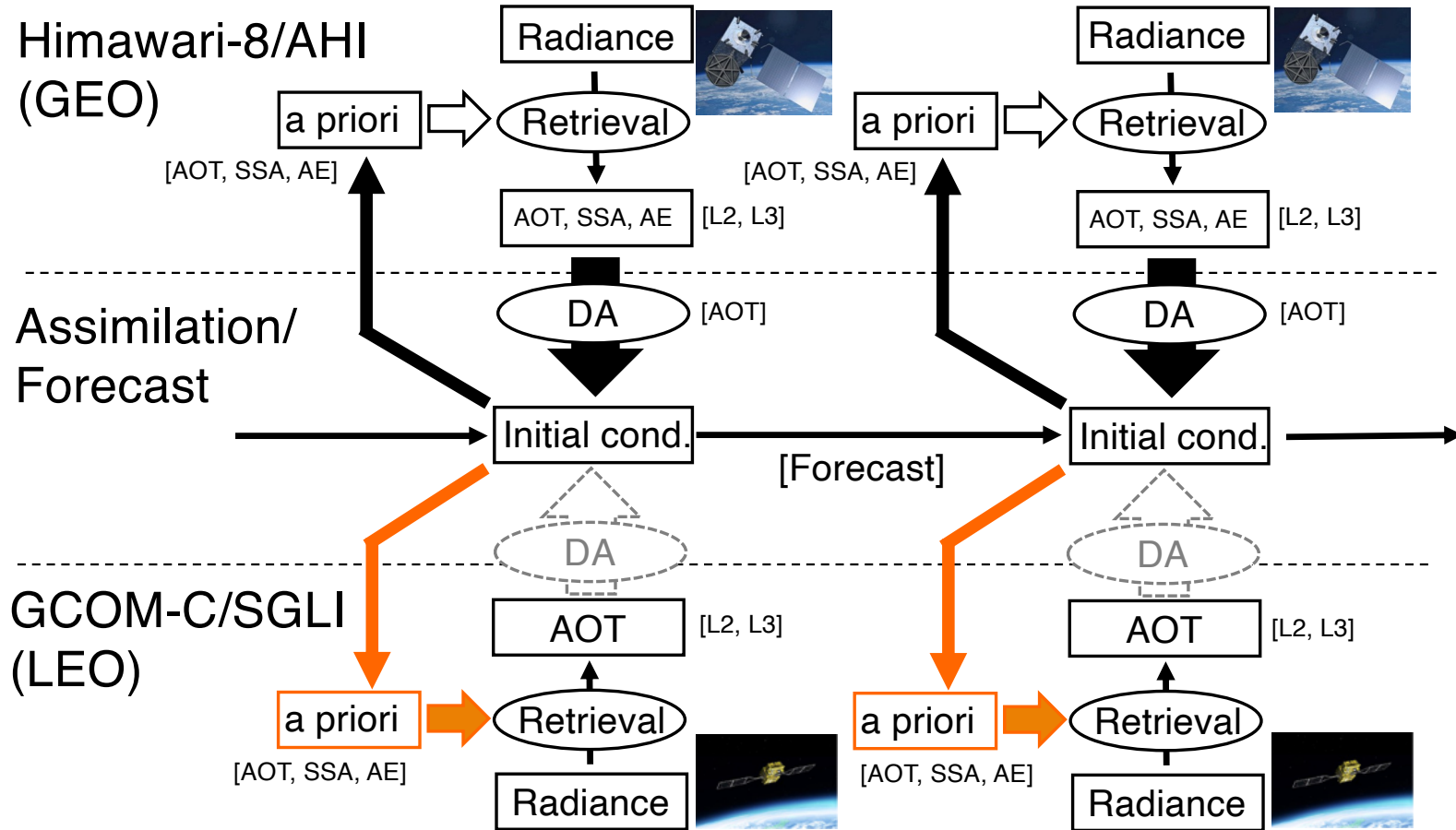
63E) SE-Dome



MRI-ESM2-0 largely overestimated the historical dust deposition in Greenland.  
 MRI-ESM3-2 and MRI-ESM3-3 reproduces the observed dust deposition flux.

MRI-ESM3.2 represents the observed dust concentrations better than MRI-ESM2.0.

# Current Aerosol DA/FC/RT System

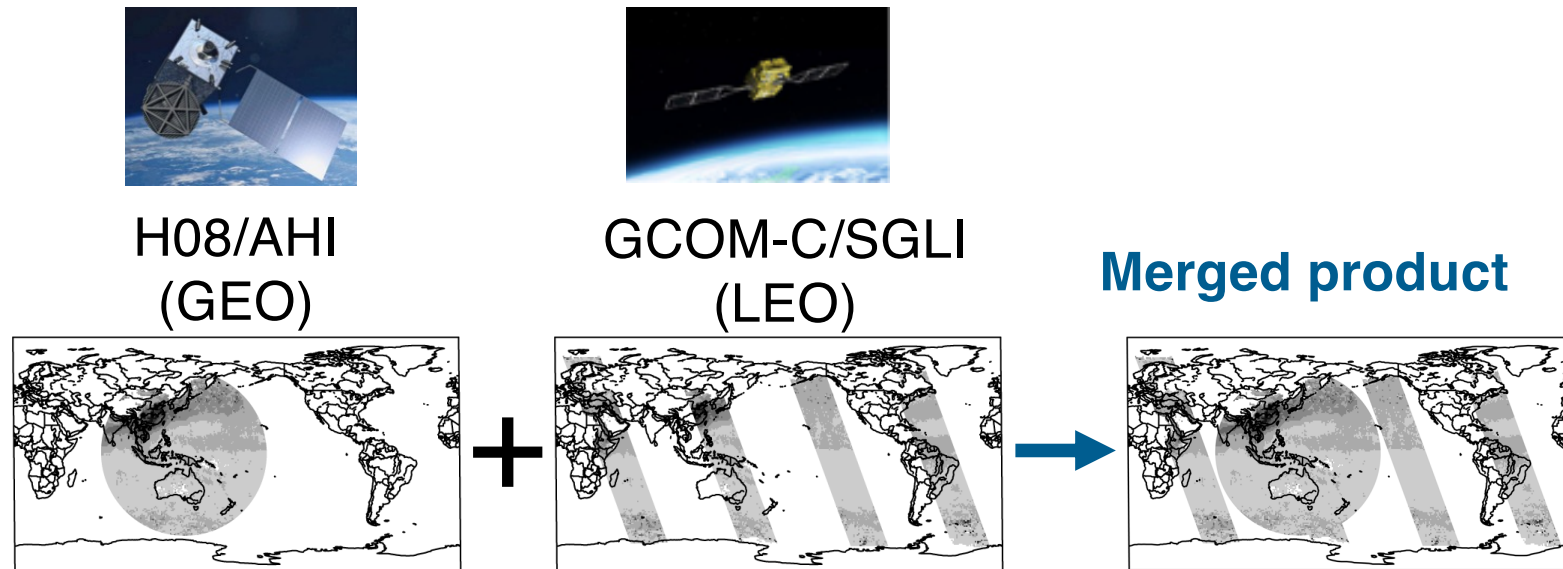


**Now, forecasted AOTs are used to SGLI retrieval as a priori!**

But, SGLI AOTs are NOT used to data assimilation, yet.

# Assimilation with **MULTIPLE** Imagers

Integrate AOTs from GEO and LEO into one composite → DA



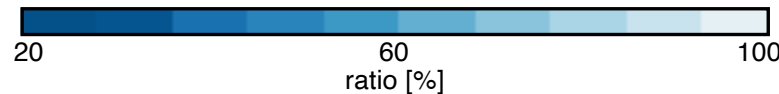
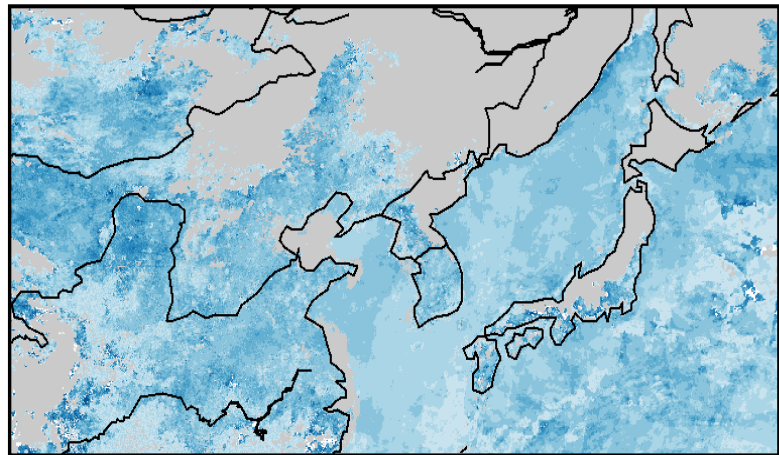
- Increase data coverage (especially on land areas)
- Reduce observation error
- Make QA/QC in the composite process
- The merged product is useful to not only data assimilation but also aerosol research and monitoring

# Assimilation with **MULTIPLE** Imagers

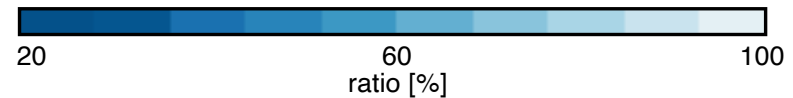
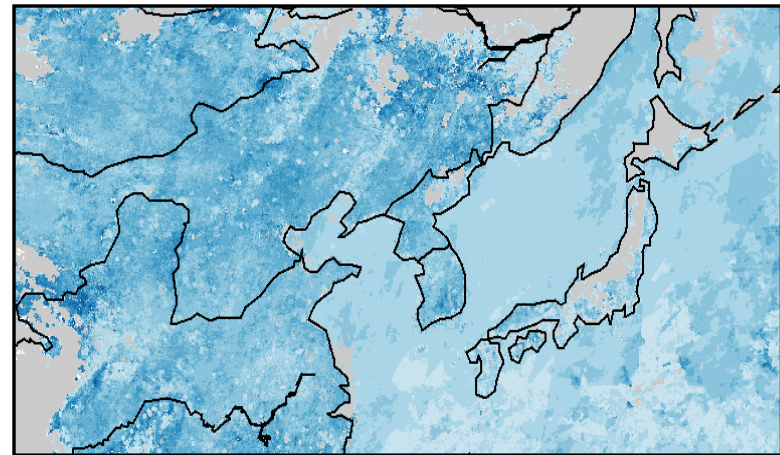
Monthly average of rate of uncertainty of merged AOT to AHI AOT

$$\frac{\varepsilon_{Composite}}{\varepsilon_{AHI}}$$

March 2022



April 2022

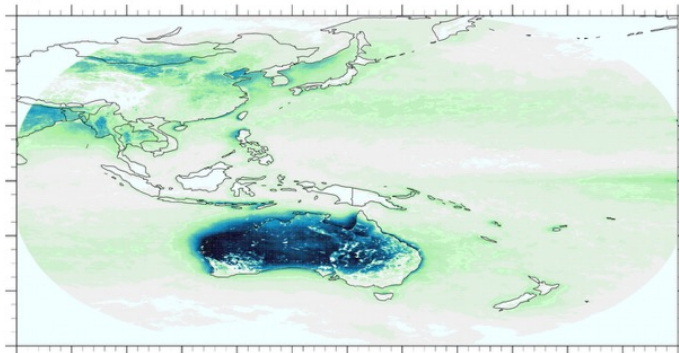


- Merged data reduced uncertainties across the entire area.
- Tends to reduce uncertainties more on land area.

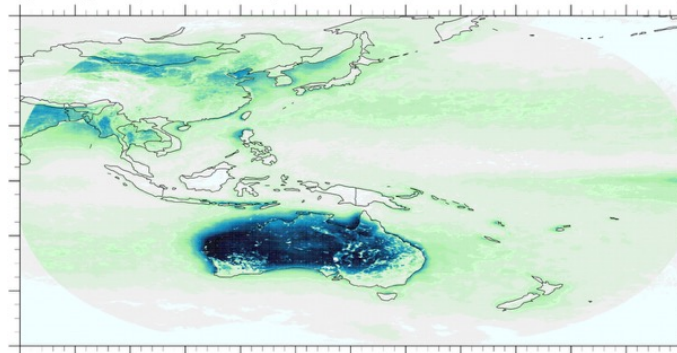
# Assimilation with **MULTIPLE** Imagers

Number of observations used for data assimilation

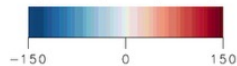
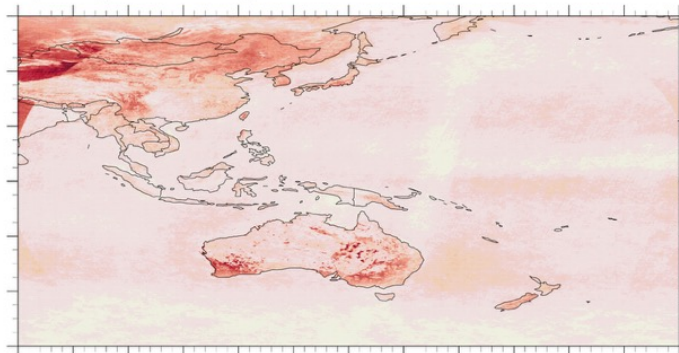
a) AHI only



b) Merged (AHI + SGLI)



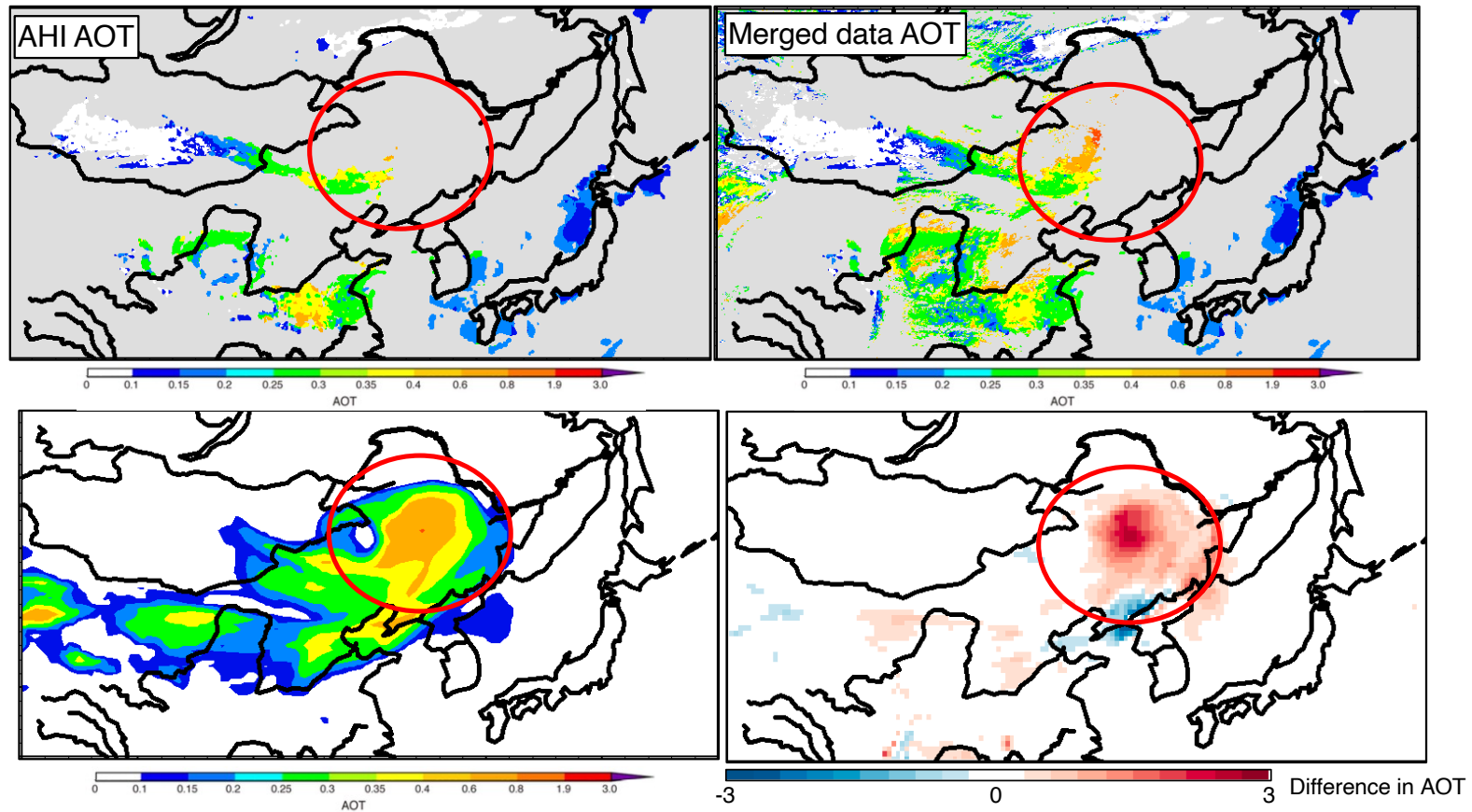
c) Merged - AHI only



- Merged data reduced uncertainties across the entire area.
- Tends to reduce uncertainties more on land area.

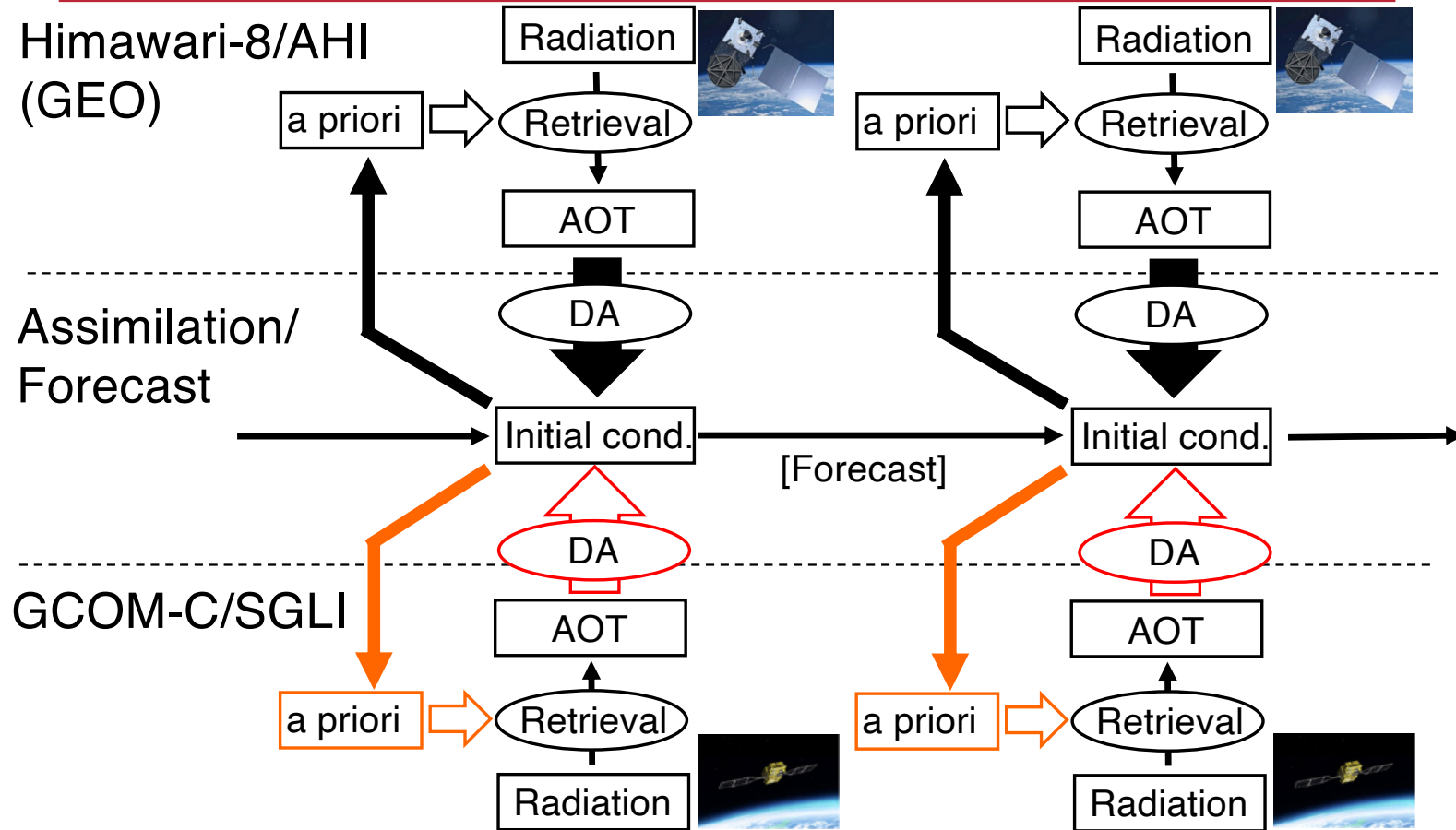
# Assimilation with **MULTIPLE** Imagers

## Asian DSS events in May 2023



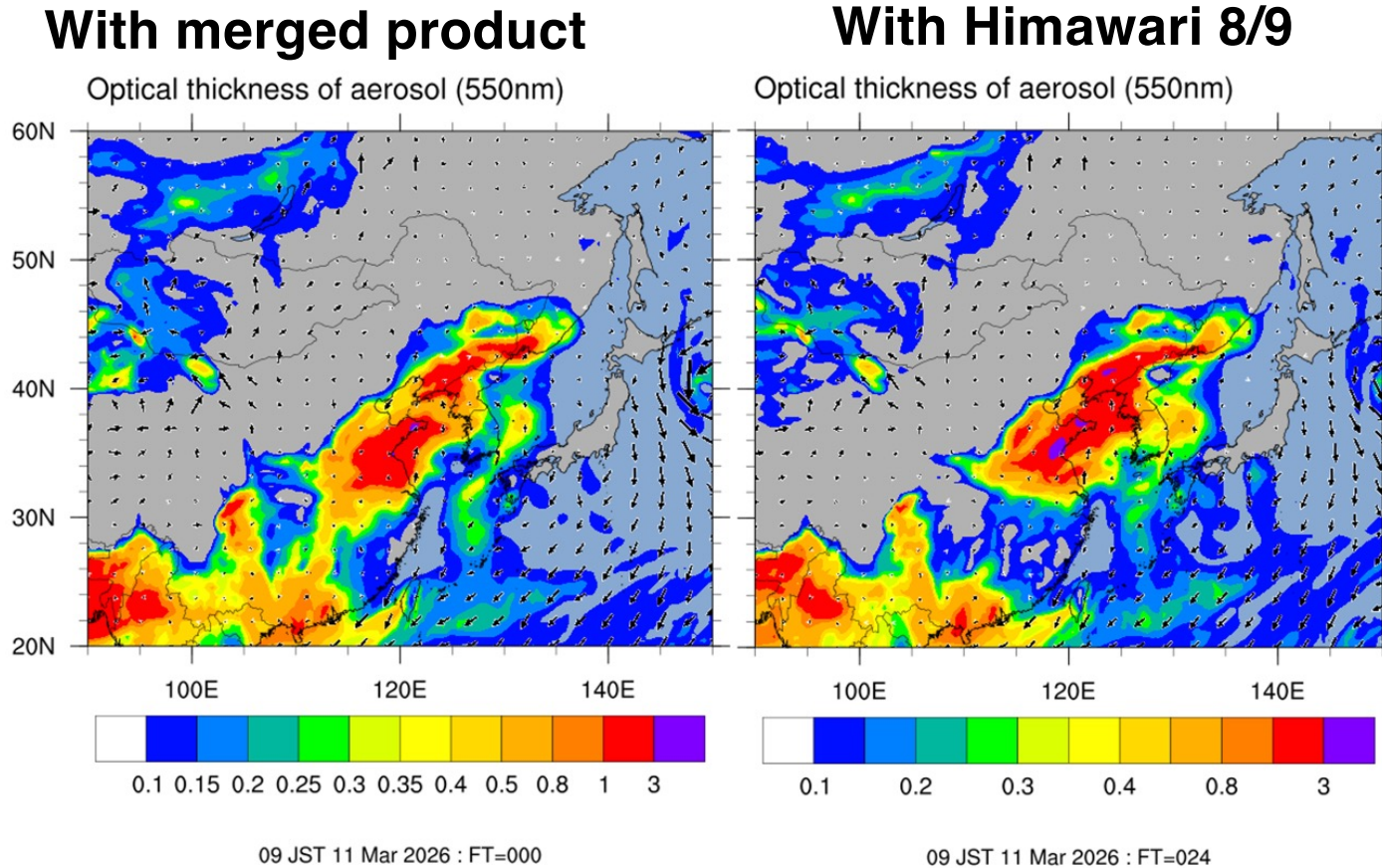
- ↑ Merged data successfully capture the core of the SDS over the land.
- ↓ Through DA, the merged data increased concentration of the SDS.

# Coming Aerosol DA/FC/RT System



- Information from each satellite cross-propagated through DA and forecast. (Information from AHI is used in retrieval process of SGLI)

# Parallel Operation and Validation Are Underway

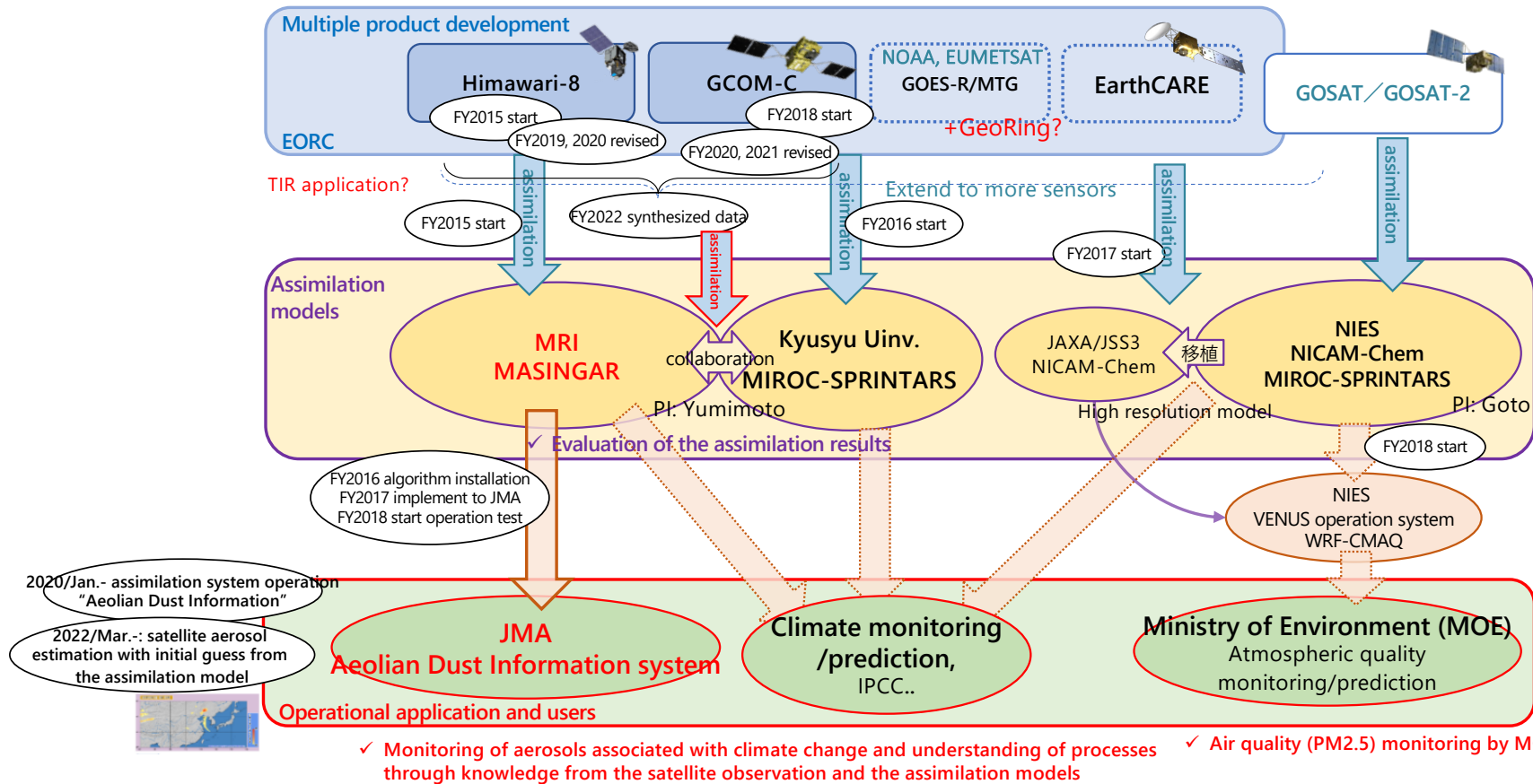


The forecast system based on merged data is currently being run in parallel with the existing system, and its forecast performance is under evaluation.

Once the validation is completed, the products will be distributed to ICAP and through JAXA P-Tree.

# Integration of multiple satellite data through model assimilations

Operational application and contribution to the climate prediction with Japanese key organizations



- MRI: Meteorological Research Institute, Japan
- JMA: Japan Meteorological Agency
- NIES: National Institute for Environmental Studies, Japan
- MOE: Ministry of Environment (MOE)
- MASINGAR: a global tropospheric aerosol chemical transport model developed by MRI
- MIROC-SPRINTARS: Spectral Radiation-Transport Model for Aerosol Species, SPRINTARS with an atmosphere-ocean GCM, MIROC developed by AORI
- NICAM-Chem: a global cloud resolving model, Nonhydrostatic ICosahedral Atmospheric Model with chemical transport model
- WRF-CMAQ: Weather Research and Forecasting Model (WRF) with Community Multiscale Air Quality model
- JSS3: JAXA Supercomputer System Generation 3

✓ Monitoring of aerosols associated with climate change and understanding of processes through knowledge from the satellite observation and the assimilation models

✓ Air quality (PM2.5) monitoring by MOE

# Summary and Outlook

- ✓ **MASINGAR as a core aerosol system**

Analysis, forecast, assimilation, reanalysis, and climate applications.

- ✓ **Operational and international contribution**

JMA Aeolian Dust Information, ICAP, JAXA P-Tree, VFSP-WAS.

- ✓ **Validation and model development**

Lidar, EarthCARE, MRI-ESM3, CMIP7.

- ✓ **Multi-satellite aerosol assimilation**

Himawari-8/9 + GCOM-C merged AOT improves coverage and uncertainty.

- ✓ **Next step**

Parallel validation is underway; products will be delivered to ICAP and JAXA P-Tree.