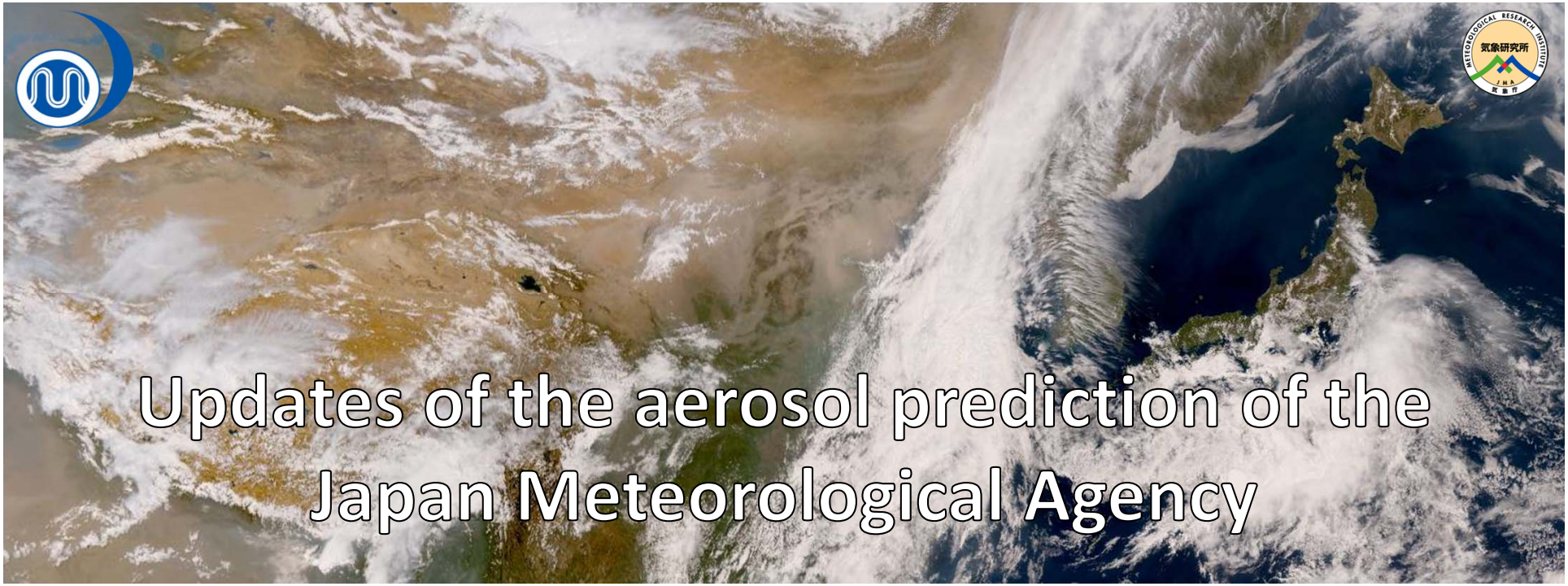

Updates of the aerosol prediction of the Japan Meteorological Agency

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$ Kyushu University, Research Institute for Applied Mechanics

9th ICAP working group meeting, Lille, France, **June 2017**

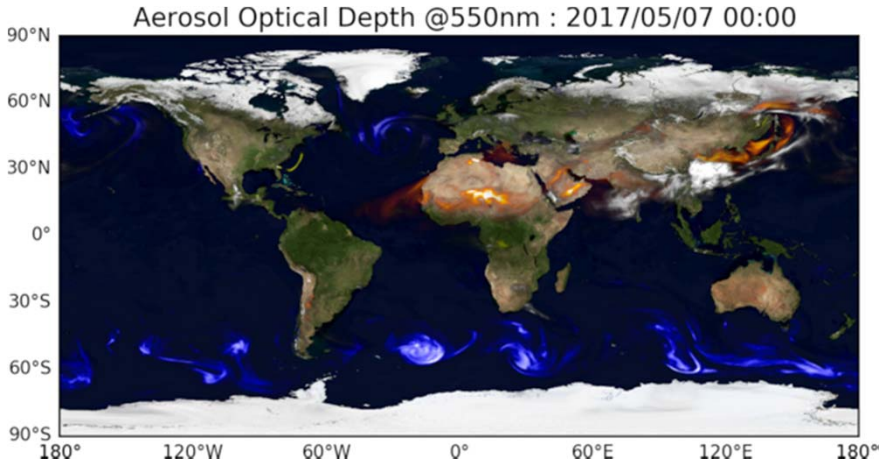
Outline

- Updates of JMA/MRI global aerosol prediction
- Updates of the geostationary satellite Himawari-8
- Data assimilation
  - A case study of data assimilation experiment of a recent dust episode
- Topics: Direct aerosol radiative effect in JMA global NWP model

JMA Aeolian dust Information

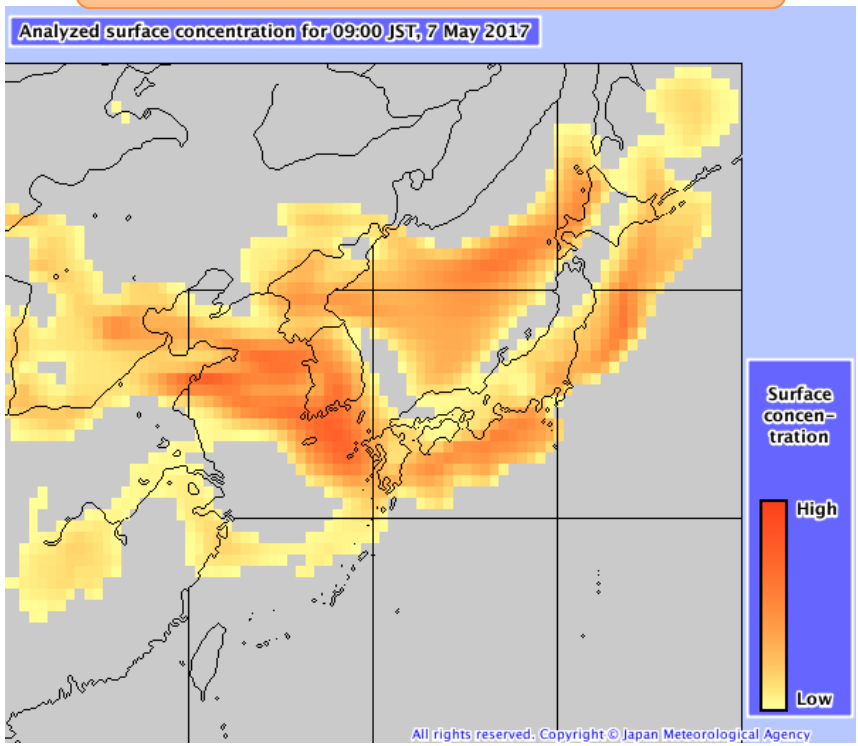
JMA has been providing Aeolian dust information based on numerical forecasts and observations since January 2004.

Global aerosol model MASINGAR



Research & Development in MRI/JMA

JMA Aeolian dust prediction



http://www.jma.go.jp/en/kosa

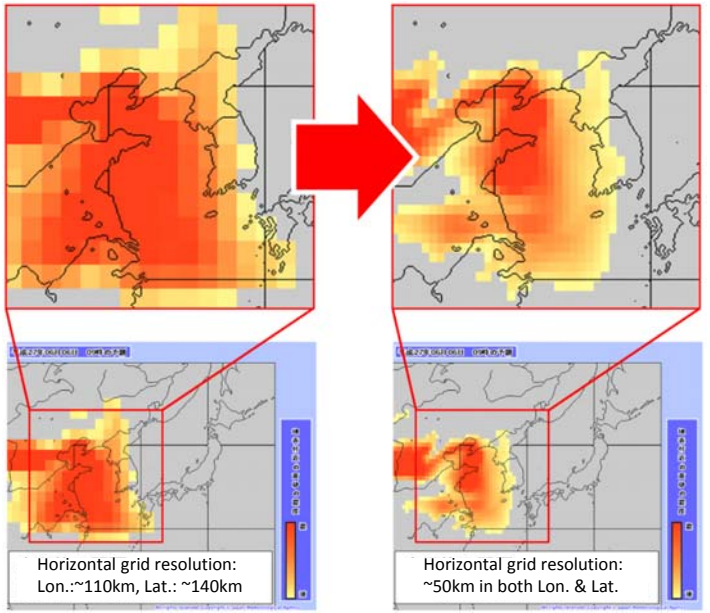
Climate Projection model (e.g., CMIP6, CCMI)

Aeolian dust advisory information

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

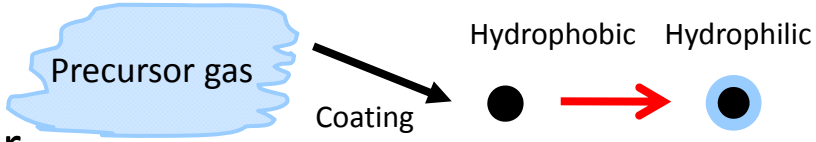
Updates of JMA/MRI aerosol NRT forecast

- JMA's operational aeolian dust forecast upgrade on Feb. 21, 2017.
  - Horizontal resolution: TL159 (~1.125deg.) ➔ TL479 (~0.375 deg.).
  - Model version: MASINGAR mk-2 rev.2 ➔ **mk-2 rev.3**
- Development of the climate model for CMIP6, MRI-ESM2 is (almost) finished.
  - Global aerosol model MASINGAR mk-2 rev.4c is coupled.
- Personnel changed:
  - **Keiya Yumimoto** left MRI to be the associate professor in Kyushu University and now visiting researcher in MRI
  - **Tanaka** moved from 1st lab (CTM) to 2nd lab (urban met.) but still involved in the development of MASINGAR.



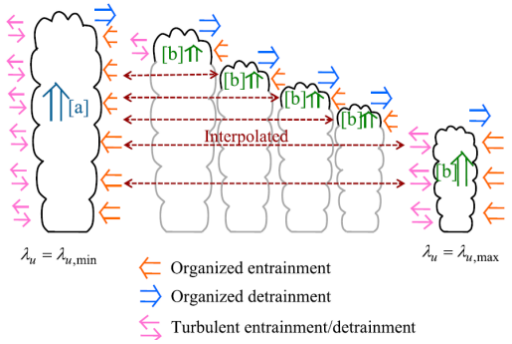
Development version: MASINGAR mk-2 rev.4

- Improved treatments of black carbon (BC)
  - Aging process of BC
    - Current: Constant conversion rate from hydrophobic particles to hydrophilic particles (time constant: 1.2 days)
    - New version: Conversion rate depending on the gas-to-particle mass transfer onto the hydrophobic BC (Oshima and Koike, 2013)



  - Enhancement of light-absorption of water-contained BC by assumption of "core-shell" or Maxwell-Garnet approaches in Mie scattering (Oshima et al., 2009)

- Simultaneous treatment of vertical transport and wet deposition of aerosols in convective cloud.



Schematic figure of the convective transport scheme (Yoshimura et al. 2015)

Updates of the geostationary satellite Himawari-8

31 Aug 2016:

- "Himawari L1 Gridded data (NetCDF4 format)" as well as the "Himawari Standard Data (HSD format)" provided by the Japan Meteorological Agency (JMA).
- JAXA Himawari-8 monitor renewed.

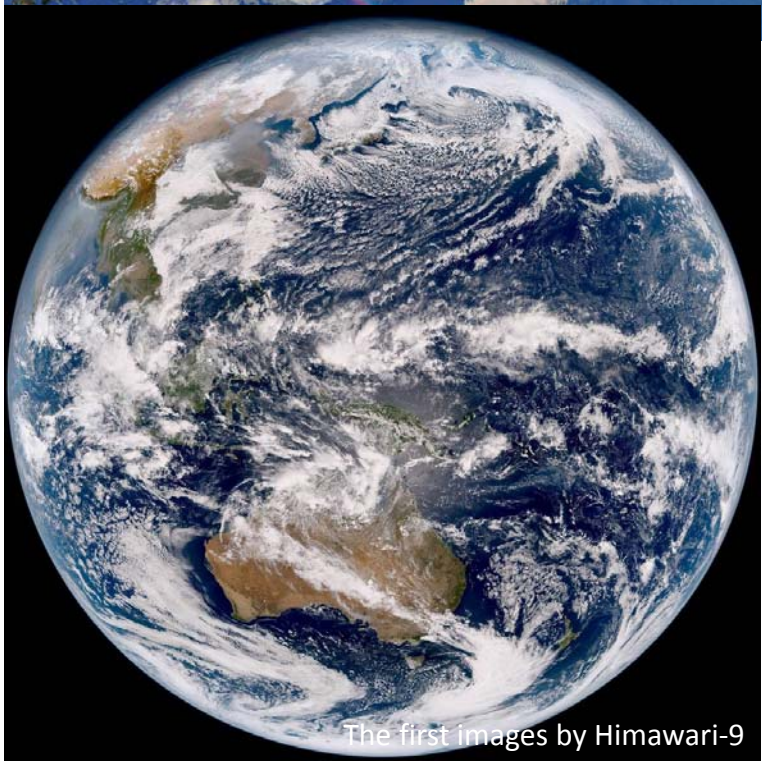
21 Dec 2016:

- Himawari-8 L2 Aerosol Product, L3 Hourly Aerosol Product (Version 1.0) and L2 Fire Product (Version Beta). are released.

Himawari-9 was launched

- JMA's geostationary meteorological satellite Himawari-9, which is the identical twin of Himawari-8, was launched on 2 Nov. 2016.
- The first images from all 16 bands were captured by Himawari-9 on 24 Jan. 2017.
- Himawari-9 started backup operation at 00 UTC on 10 March 2017

More information:
http://www.jma-net.go.jp/msc/en/support/index.html



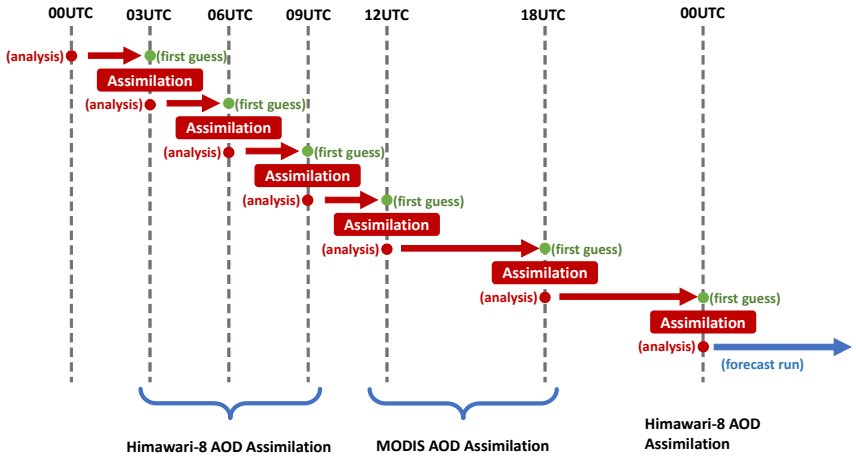
The first images by Himawari-9

Data assimilation

- Updates of data assimilation
- Aerosol reanalysis
- DA Experiment of the JAXA Himawari-8 AOD: A case study of a recent dust episode

Updates of aerosol data assimilation

- Started sending forecast with NRT MODIS AOD data assimilation with 2D-VAR to ICAP-MME (Aug. 2016)
- 2D-VAR background error estimation changed from climatological to pseudo-ensemble (Dec. 2016)
- MODIS Collection 5 MxAODHD ➔ Collection 6, L2 AOD (MxD04_L2) (April 2017)
- DA Experiment with JAXA Himawari-8 aerosol L3 product is under way.
  - Quality control of AOD
  - Testing the frequency of DA (now 3-hourly from 0z to 9z)



Himawari-8/MODIS AOD hybrid assimilation

Aerosol Reanalysis ver. 1 (JRAero)

- Aerosol reanalysis using MASINGAR mk-2 and 2D-VAR
- Period: 2011-2015
- Horizontal resolution: TL159L40 (~1.1deg, 40 layers)
- Observation data for DA: NRL-UND MODIS AOD
- The description paper Yumimoto et al., doi:10.5194/gmd-2017-72 is now in review.
- Data availability:
  now in preparation
  (in netCDF format)

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https://doi.org/10.5194/gmd-2017-72
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Discussion papers

Abstract | Discussion | Metrics

Development and technical paper

22 Mar 2017

JRAero: the Japanese Reanalysis for Aerosol v1.0

Review status
A revision of this discussion paper is under review for the journal Geoscientific Model Development (GMD).

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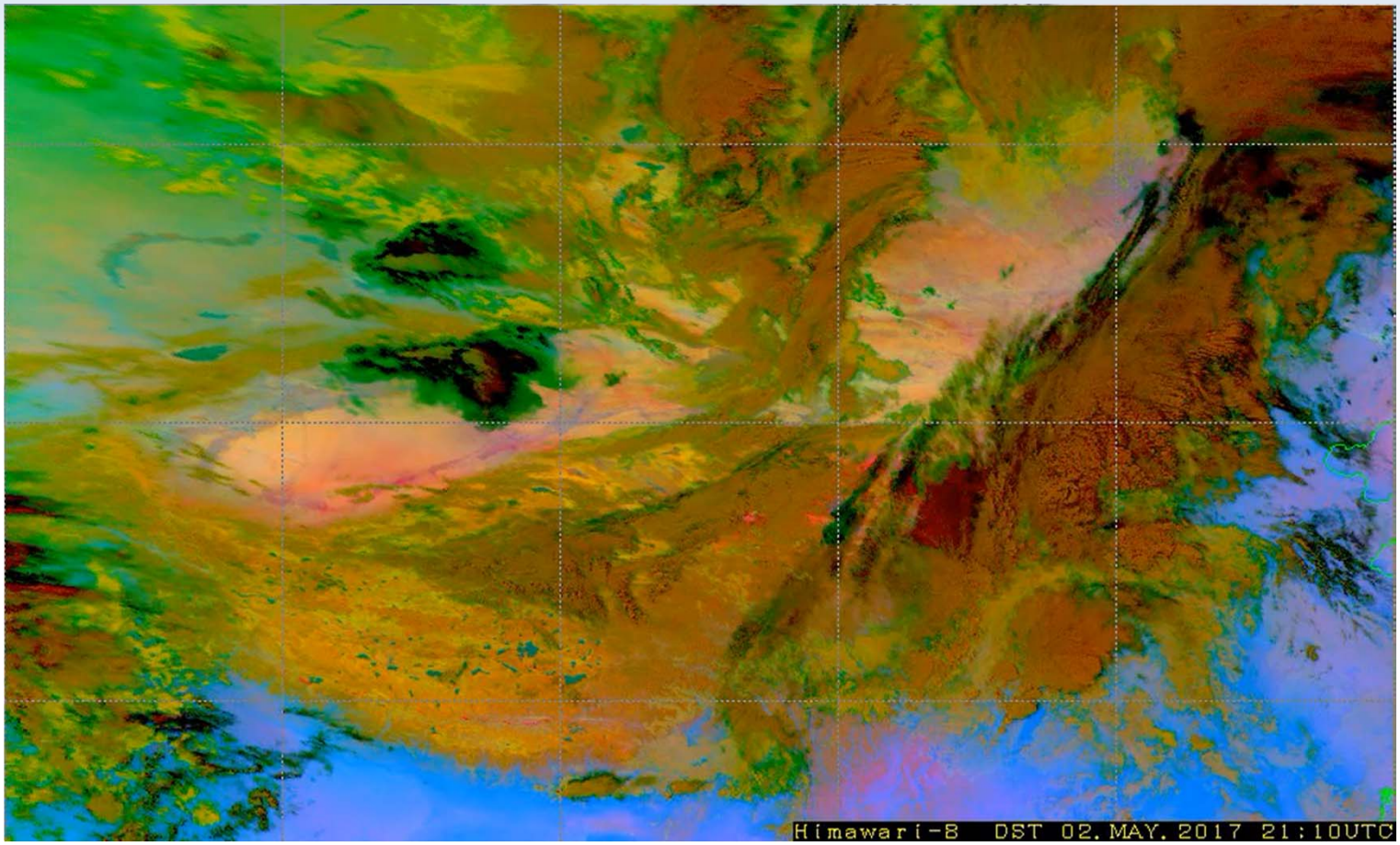
Received: 15 Mar 2017 – Accepted for review: 21 Mar 2017 – Discussion started: 22 Mar 2017

Abstract. A global aerosol reanalysis product named the Japanese Reanalysis for Aerosol (JRAero) was constructed by the Meteorological Research Institute (MRI) of the Japan Meteorological Agency. The reanalysis employs a global aerosol transport model developed by MRI and a 2-dimensional variational data assimilation method. It assimilates maps of aerosol optical depth (AOD) from MODIS onboard Terra and Aqua satellites every 6 hours and has a TL159 horizontal resolution (approximately 1.1° × 1.1°). This paper describes the aerosol transport model, the data assimilation system, the observation data, and the set-up of the reanalysis and examines its quality.

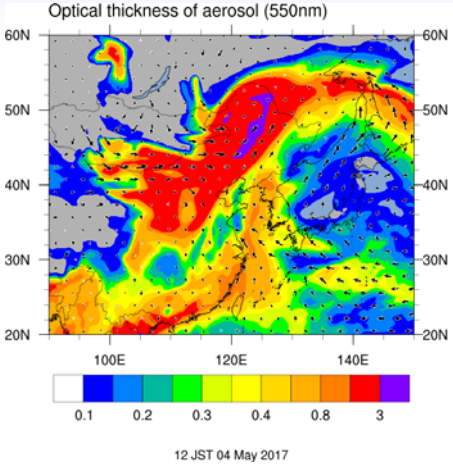
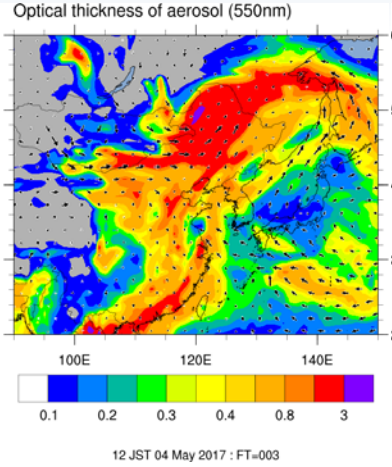
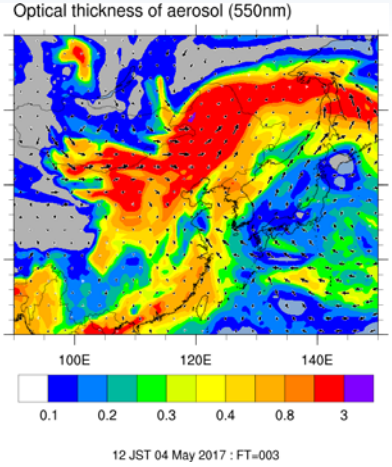
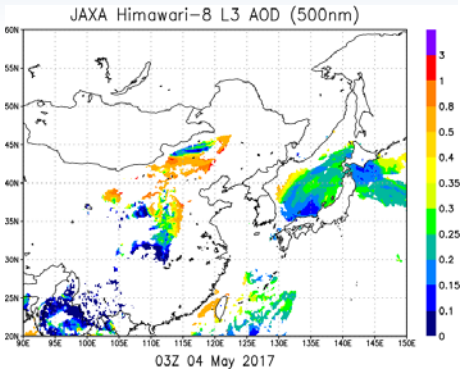
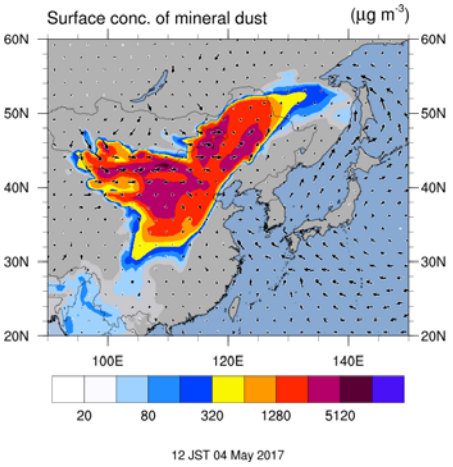
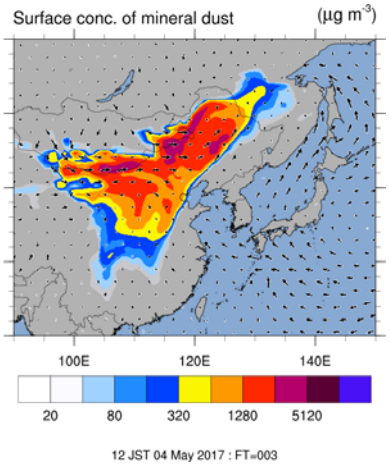
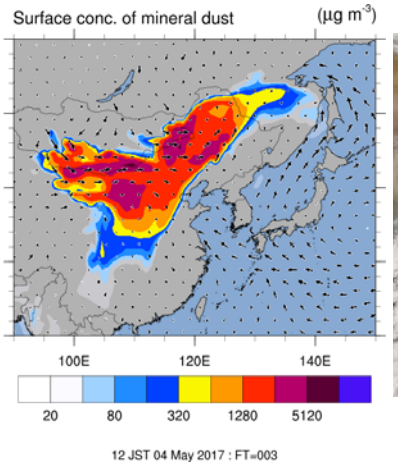
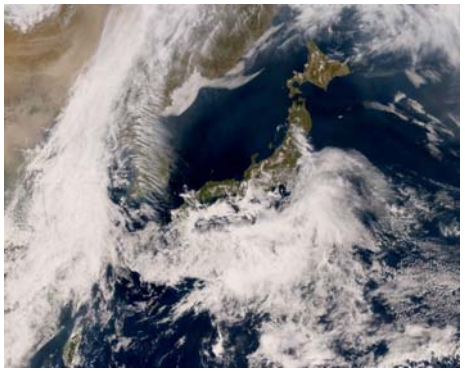
Recent aerosol episode: dust storm over Mongolia and China, 2-8 May 2017



- Asian dust phenomena are observed in Japan on 6 May 2017 (new record of the latest dust phenomena in a year).

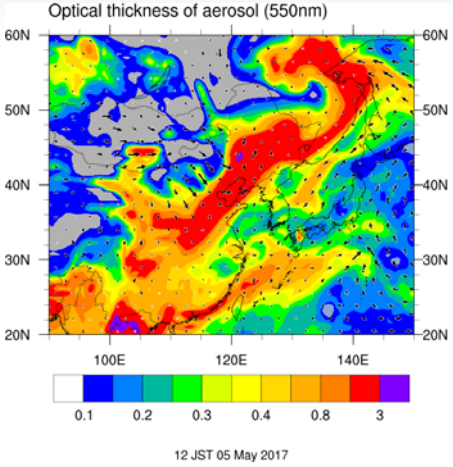
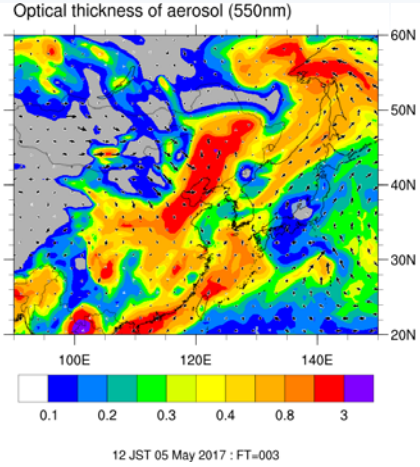
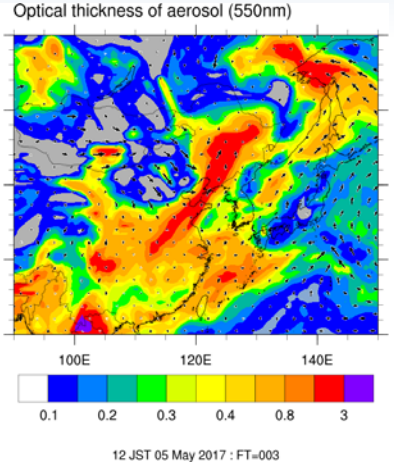
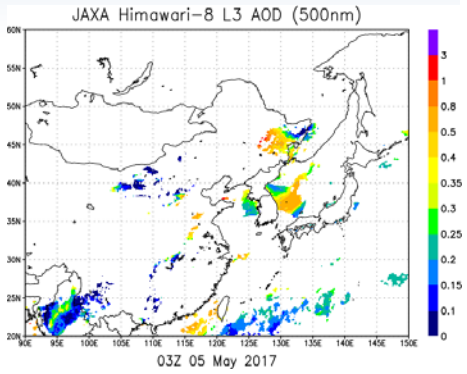
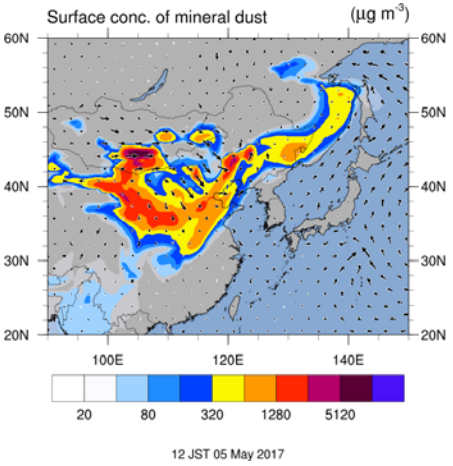
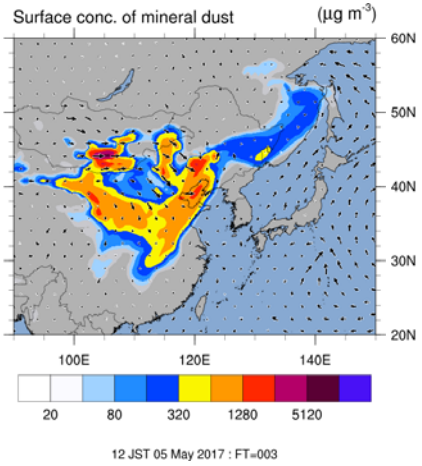
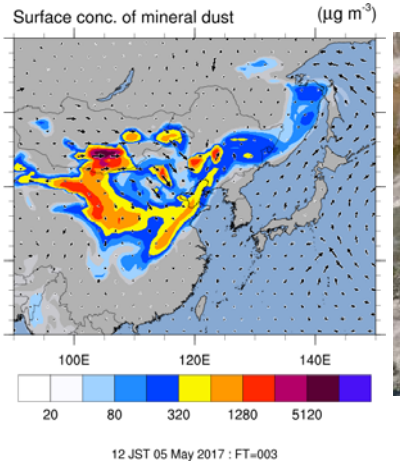
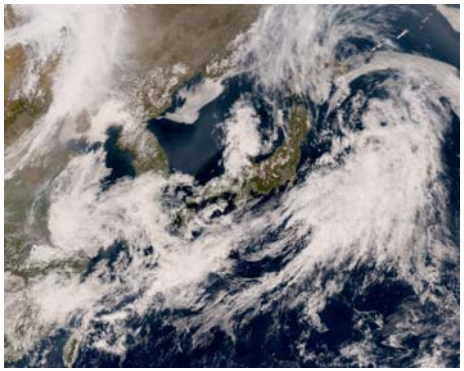
Forecast comparison : 2017/05/04 3z (FT=3)

3Z 4 May 2017

	Without DA	Himawari-8 DA	MODIS DA	JAXA Himawari-8 L3 AOD
Total AOD				
Surface dust				**Himawari-8 True Color Reproduction image** 

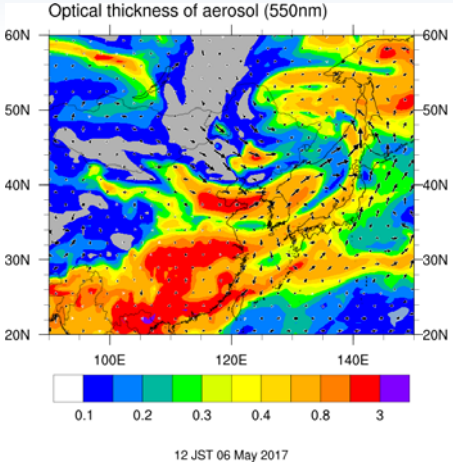
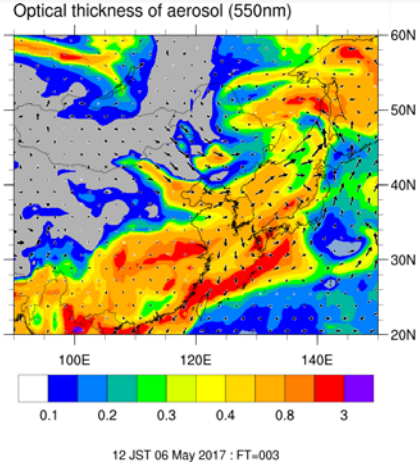
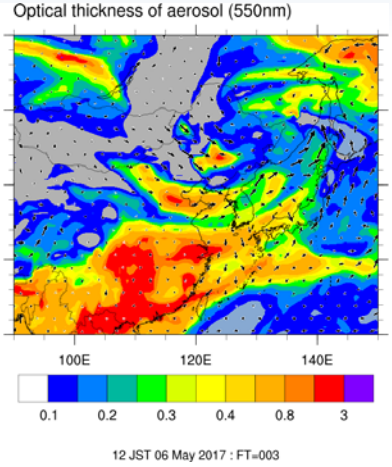
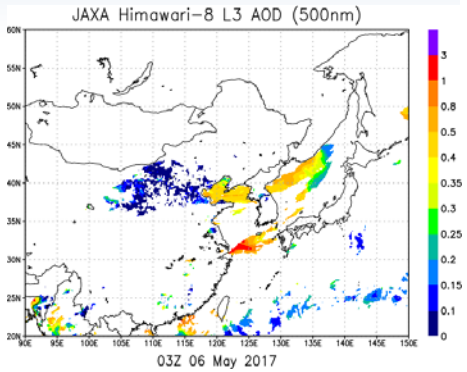
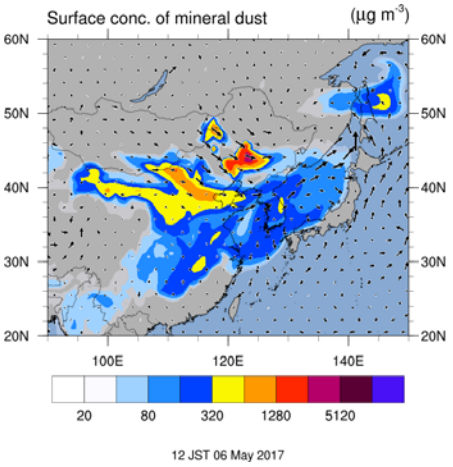
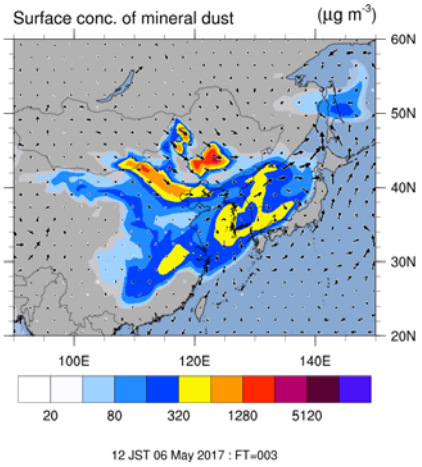
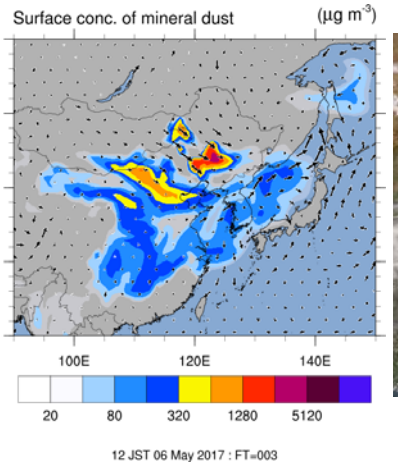
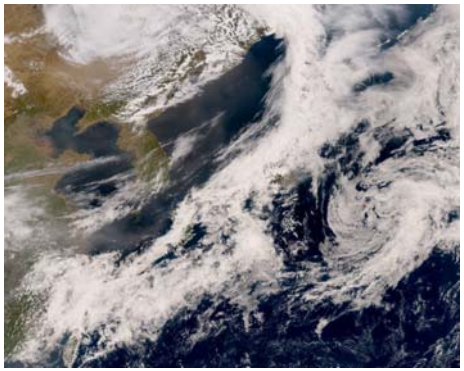
Forecast comparison : 2017/05/05 3z (FT=3)

3Z 5 May 2017

	Without DA	Himawari-8 DA	MODIS DA	JAXA Himawari-8 L3 AOD
Total AOD				
Surface dust				**Himawari-8 True Color Reproduction image** 

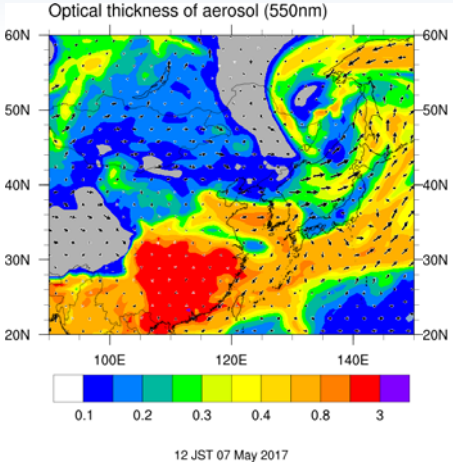
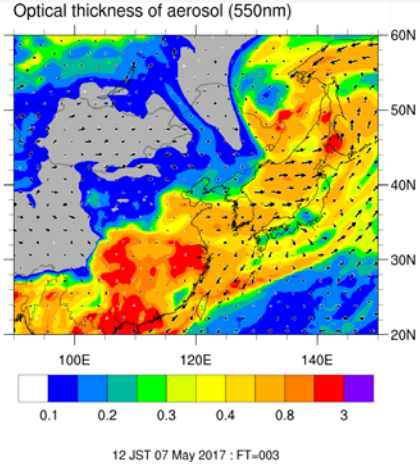
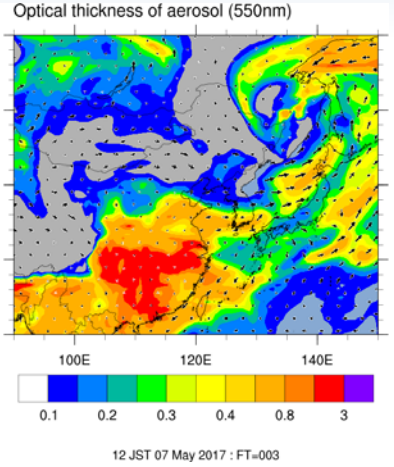
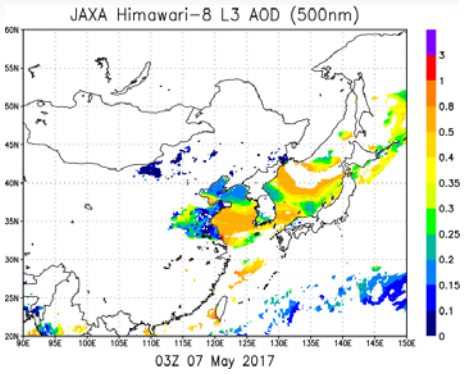
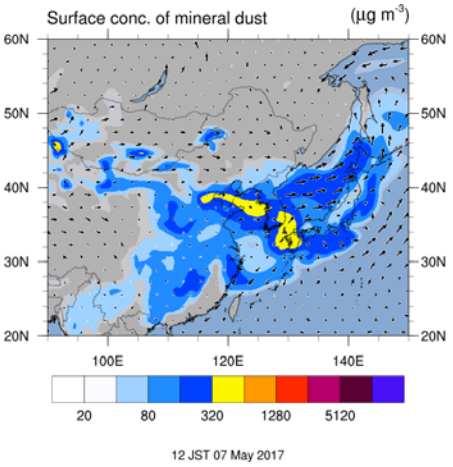
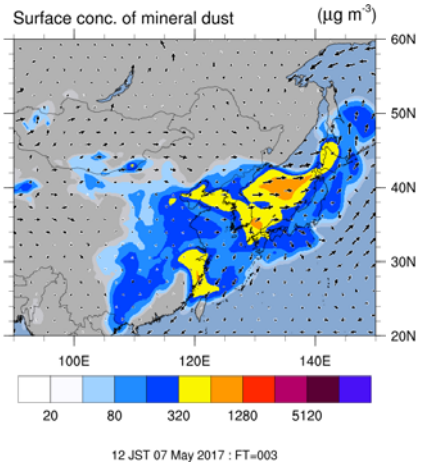
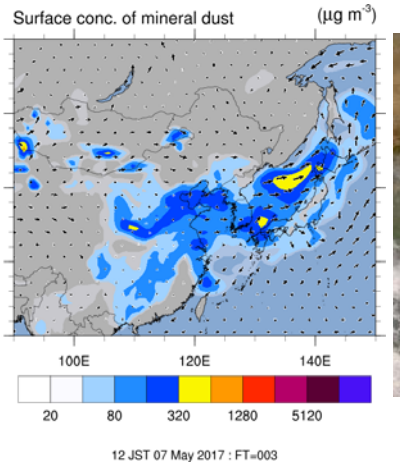
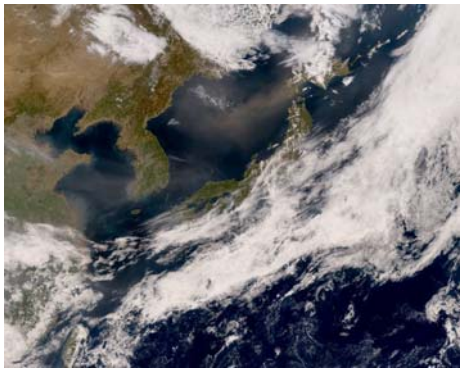
Forecast comparison : 2017/05/06 3z (FT=3)

3Z 6 May 2017

	Without DA	Himawari-8 DA	MODIS DA	JAXA Himawari-8 L3 AOD
Total AOD				
Surface dust				**Himawari-8 True Color Reproduction image** 

Forecast comparison : 2017/05/07 3z (FT=3)

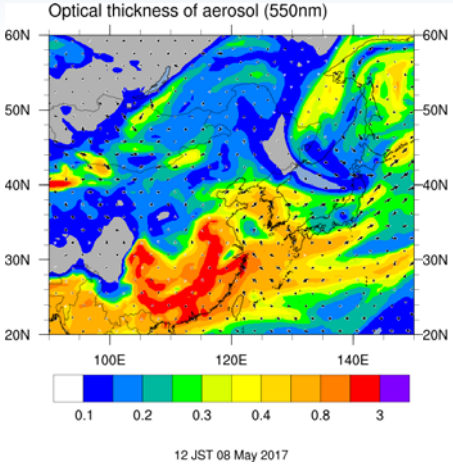
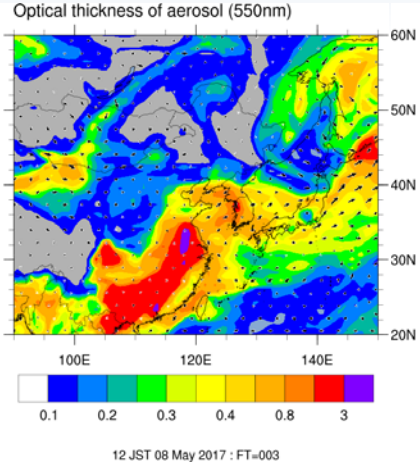
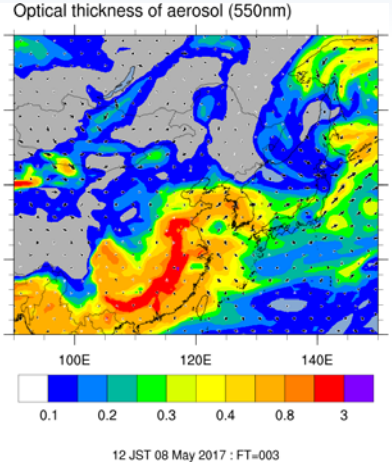
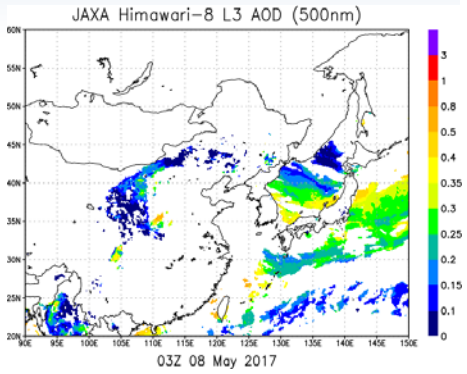
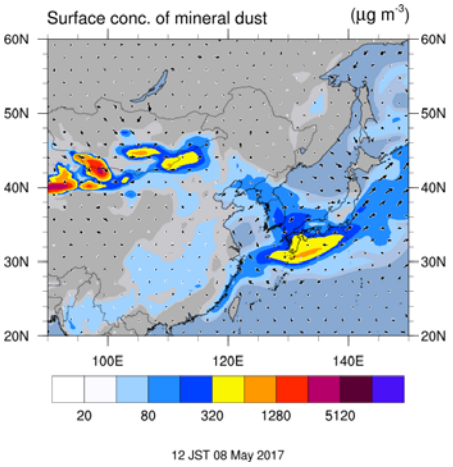
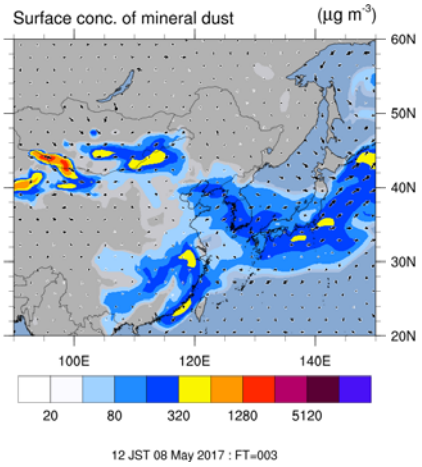
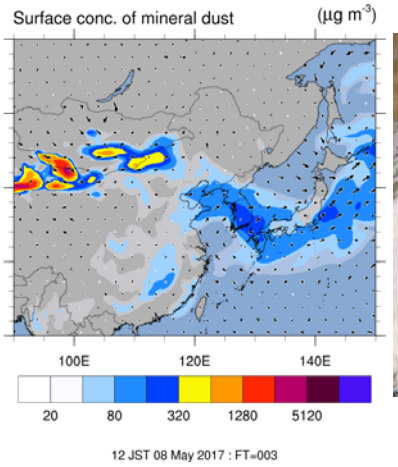
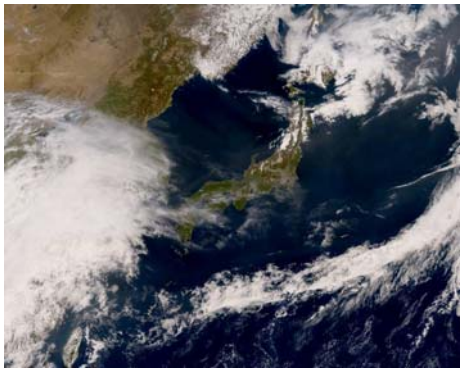
3Z 7 May 2017

	Without DA	Himawari-8 DA	MODIS DA	JAXA Himawari-8 L3 AOD
Total AOD				
Surface dust				

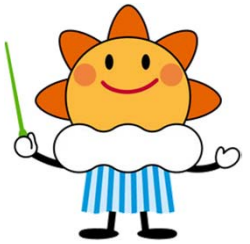
Himawari-8 True Color Reproduction image

Forecast comparison : 2017/05/08 3z (FT=3)

3Z 8 May 2017

	Without DA	Himawari-8 DA	MODIS DA	JAXA Himawari-8 L3 AOD
Total AOD				
Surface dust				**Himawari-8 True Color Reproduction image** 

Direct aerosol radiative effect in JMA's global NWP model (Global Spectral Model, GSM)



Update of aerosol radiation in JMA's global NWP

On May 2017, JMA's global NWP model (GSM) was upgraded to include a new radiation scheme with improved aerosol treatments. (***Yabu et al., submitted to WGNE Bluebook***).

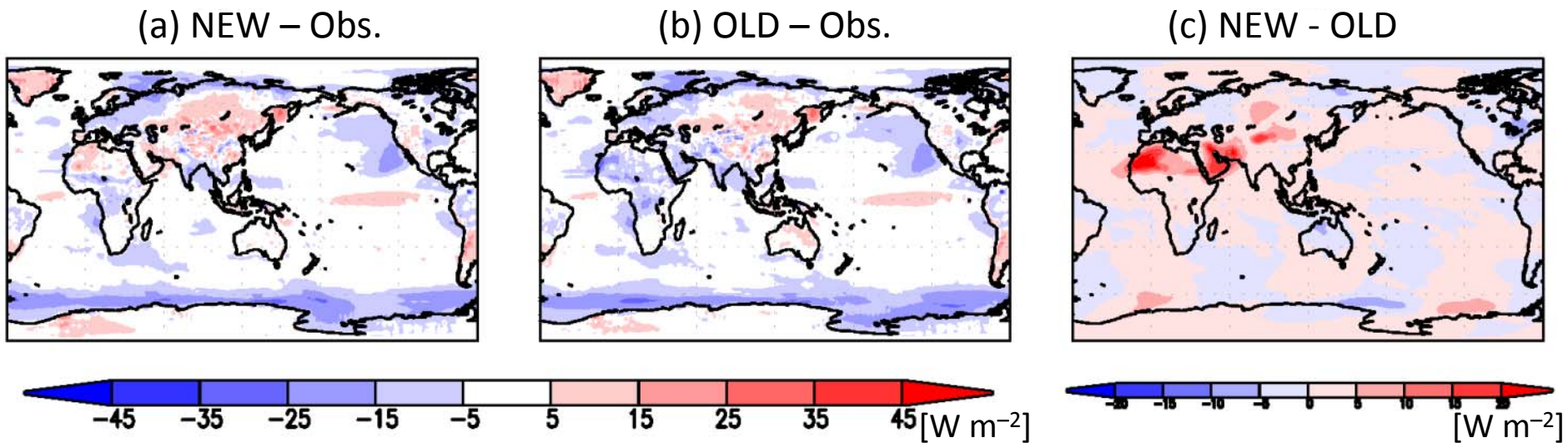
Previous scheme

- Aerosol distribution is derived from **Satellite-based Monthly averaged climatological AOT** (MODIS, MISR, and OMI).
- Simply assumed vertical distribution
- Aerosol types are separated to **continental** and **maritime** only. Optical properties of the aerosol types are based on WMO TD-No.24 (1986).

NEW scheme

- **3-dimensional** aerosol distribution with **five aerosol types**
  - Based on MASINGAR mk-2's monthly averaged aerosol distribution of recent 6-years (2009-2015).
  - Mineral dust and sea-salt are separated into 6 and 2 size bins, respectively.
  - Horizontal distribution is adjusted to satellite-based climatology
- Optical properties: **OPAC** (Hess et al., 1998), Seinfeld & Pandis (2006), etc.
- Hygroscopic growth factor: κ-Kohler theory (Petters & Kreidenweis, 2007)

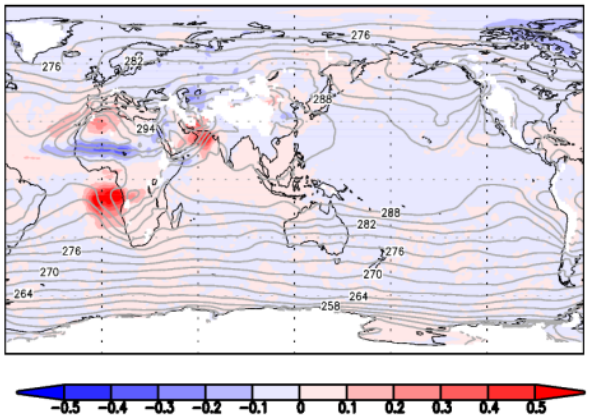
Climatological experiment: radiation difference



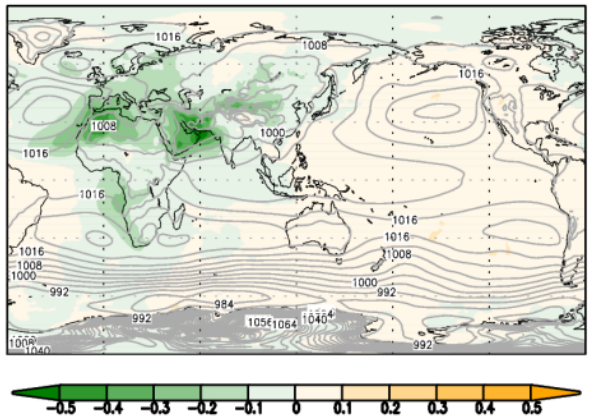
- 10-year cases of 1-month prediction with TL479 resolution model and prescribed surface conditions
- Difference of clear-sky downward longwave (LW) radiation fluxes at the surface in July are shown (Observation: CERES)
- The new scheme improved the downward LW flux around the Sahara desert and Arabian Peninsula, which is caused by warmer tropospheric atmosphere due to enhanced absorption of shortwave (SW) radiation flux by the light-absorbing aerosols (dust and BC).

Climatological experiment: meteorology

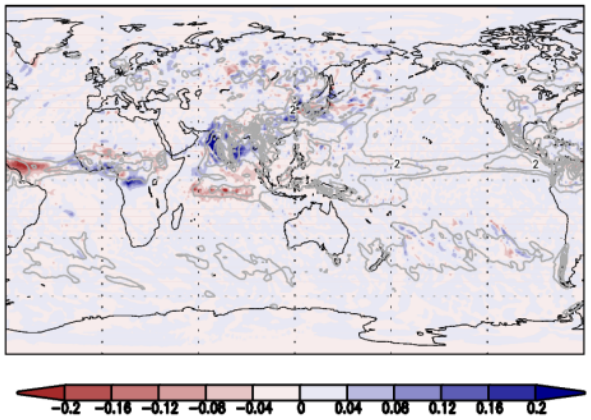
(a) 850 hPa temperature [K]



(b) Sea level pressure [hPa]



(c) Precipitation [mm day^{-1}]



Climatological difference for July. Shading indicates NEW – OLD, and contours show climatological distributions of OLD.

- Enhanced the aerosol feedback mechanism in NEW through:
  - SW absorption over Sahara/Arabian Peninsula

  ➔heating in lower troposphere ➔ inducing unstable air profile

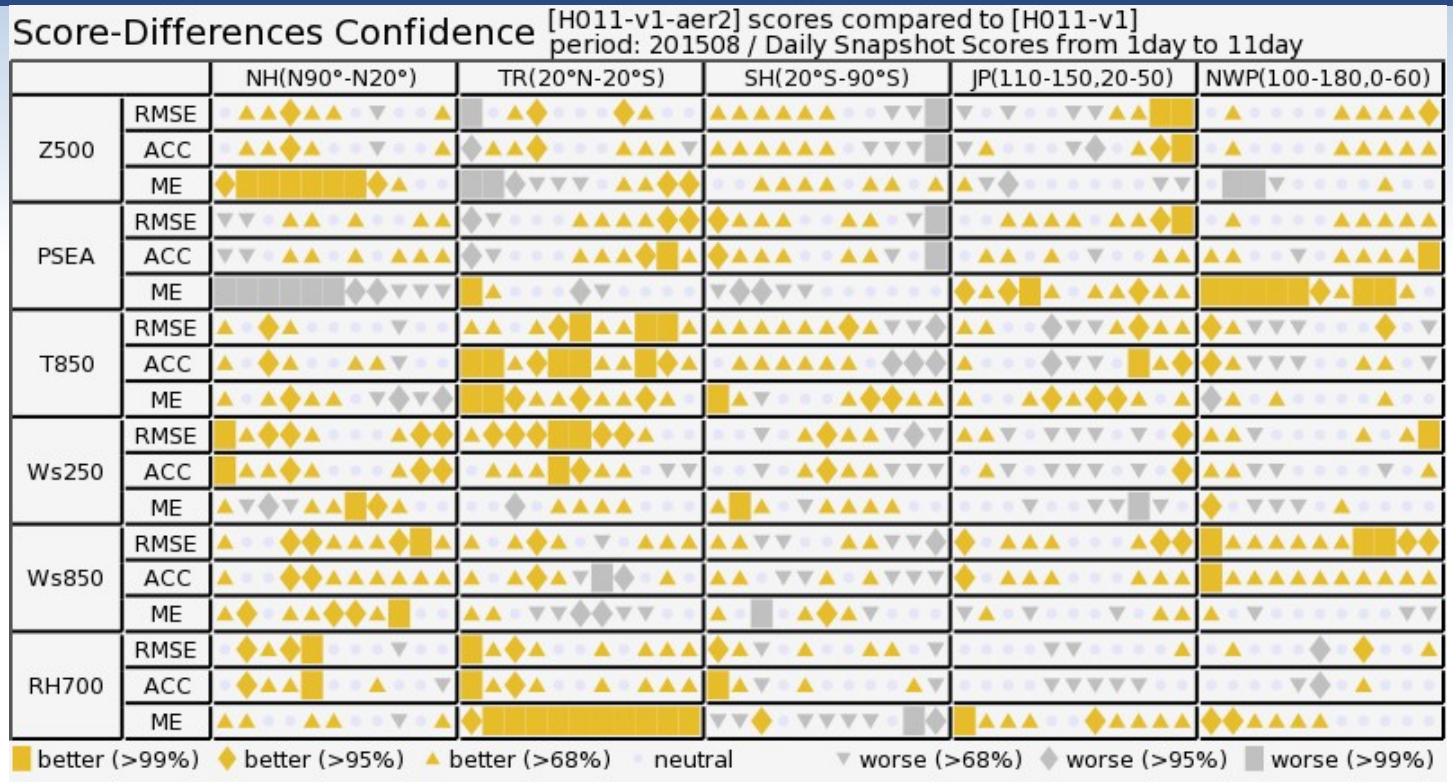
  ➔cyclonic circulation anomaly ➔ atmospheric circulation change in wide area
- Precipitation in tropics:
  - near the African Continent increased
  - near the Southern America Continent decreased
- Enhanced light- absorption due to mineral dust aerosol induces **weaker Walker circulation in the Atlantic**, like as Lau et al.(2009).

Impact of the new aerosol scheme on forecast skill

- Analysis-Forecast cycle experiment with operational high-resolution model

- CNTL model : TL959 GSM with old aerosol-radiation scheme
- TEST model : TL959 GSM with new aerosol radiation scheme
- Experiment period:
  - Summer: August 2015
  - Winter: January 2015
- Verification: against JMA global analysis

August skill score



RMSE
Root mean square error
ACC
Anomaly correlation coefficients
ME
Mean Error

👍**Better** (Statistically significant >99%)

RMSE and ACC

- Tropical T850, Tropical W250 (mid.), NH W250, part of RH700

Mean Error

- NH Z500 (until mid.), tropical T850, tropical RH 700, etc.

👎**Worse** (Statistically significant >99%)

RMSE and ACC

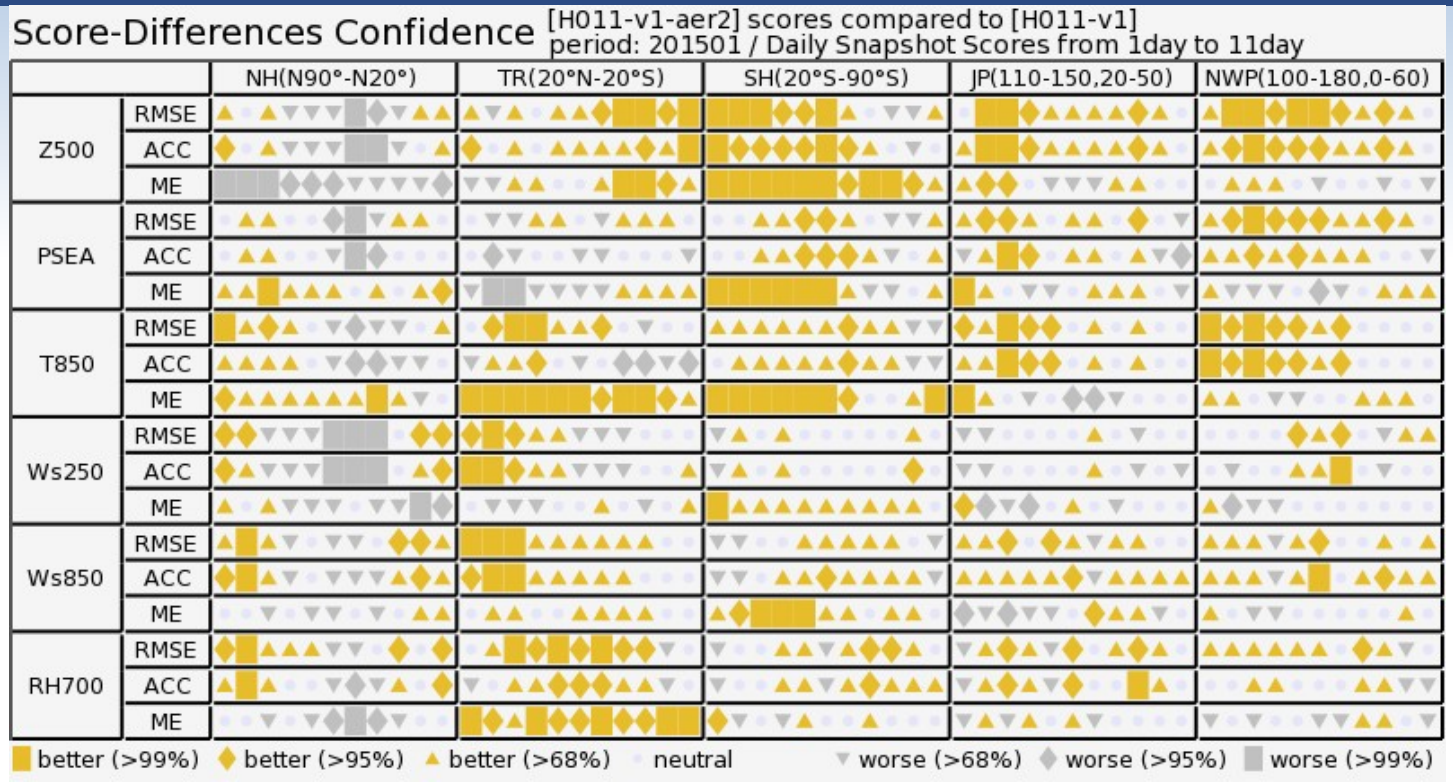
- SH Z500, Sea level pressure (later), Tropical Z500 (early †)

Mean Error

- NH Sea level pressure (~mid ※), Tropical Z500 (early†)

† Better against radiosonde. ※ Better in JP and NWP area.

January skill score



RMSE
Root mean square error
ACC
Anomaly correlation coefficients
ME
Mean Error

👍**Better** (Statistically significant >99%)

RMSE and ACC

- Tropical W850/W250/T850 (early), Z500 (late), RH700 (~mid.), SH Z500 (~mid.)

Mean Error

- Tropical T850, RH700, SH Z500, PSEA/T850/W850 (~mid), SH PSEA (early), T850 (mid)

👎**Worse** (Statistically significant >99%)

RMSE and ACC

- NH Z500/PSEA/W250 (mid. †)

Mean Error

- NH Z500 (early, †), RH700 (mid.), W250 (late), Tropical PSEA (early)

† Better in JP and NWP area.

Summary

- JMA's operational NRT aerosol prediction is updated:
  - Model update: MASINGAR mk-2r2 → mk-2r3, TL479 (~40km) horizontal resolution
- JAXA Himawari-8 aerosol product ver. 1 is released.
- NRT DA system using JAXA Himawari-8 AOD is under development
- Aerosol Reanalysis ver. 1 (JRAero) produced for the period: 2011-2015.
- Aerosol-radiation scheme of JMA's global NWP model (GSM) is updated to incorporate five aerosol species based on 3-dimensional monthly climatological global aerosol distribution.
  - Numerous scores for the tropics and the summer hemisphere are significantly improved.
  - This suggests that enhanced light absorption by aerosols has a positive influence on model performance both in the tropical region and in the middle latitudes via the modulation of global atmospheric circulation.

Future tasks

- Operational implementation of Himawari-8 AOD data assimilation (after upgrade of JMA's supercomputing system in 2018)
- NRT DA using lidar measurement (3D-VAR)
- Integrated approach with chemistry model
  - Adding nitrates; Modal approach for aerosol microphysics
- Nesting of regional chemical transport model (NHM-Chem) for detailed prediction over targeted area (East Asia)
- Incorporation of microphysical aerosol model from NHM-Chem

- NWP impact experiments with daily analyzed aerosol distribution

Ichi (3 weeks old) and Ray (2 years old)

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- ***Atmospheric Environment and Applied Meteorology Research Division, MRI, JMA***
- ***Atmospheric Environment Division, Global Environment and Marine Department , JMA***
- ***Meteorological Satellite Center, JMA***