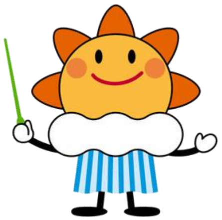
Improvements of the dust prediction system in Japan Meteorological Agency

Akinori Ogi, Taichu Y. Tanaka, Nozomu Ohkawara
Takashi Maki, Tsuyoshi T. Sekiyama, Keiya Yumimoto

Japan Meteorological Agency
Meteorological Research Institute



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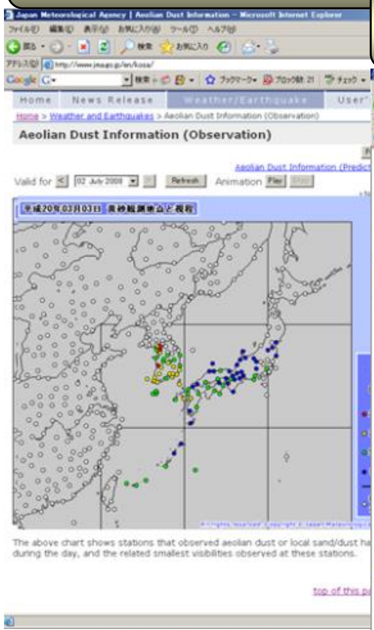
Outline

- Aeolian dust (*Kosa*) information to the public from JMA
- New operational global aerosol forecast model for dust predictions by JMA
- Verification of operational aerosol prediction, mainly focused on aeolian dust (*Kosa*) prediction
- Current development status and future planning
- Summary

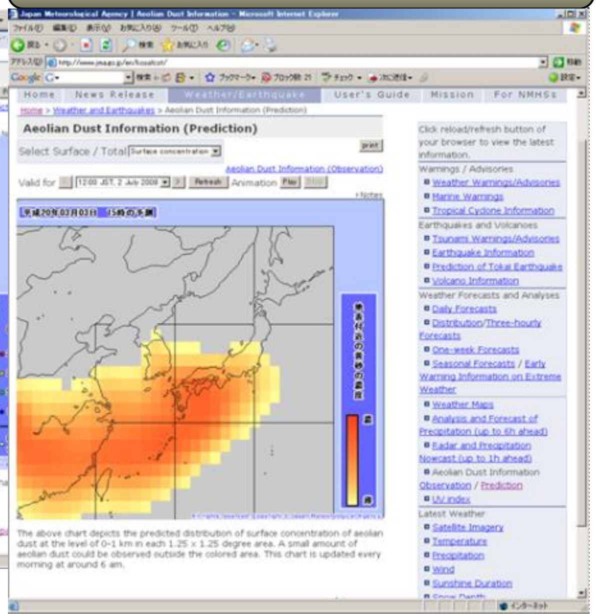
Information on aeolian dust to the public

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

Aeolian dust observation

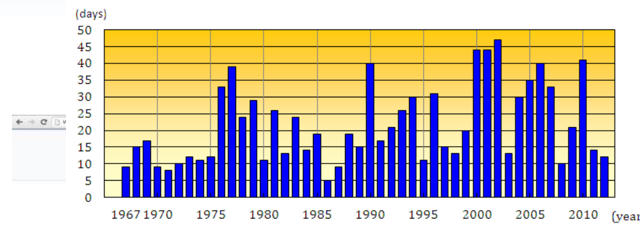


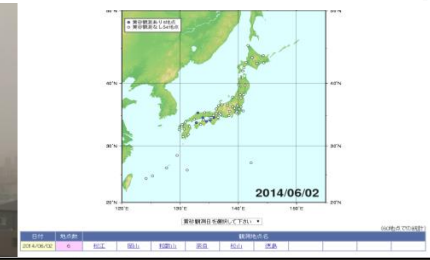
Aeolian dust prediction



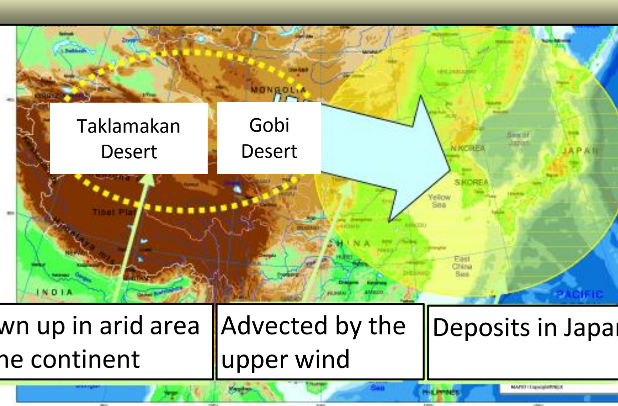
Aeolian dust advisory information
(when required, Japanese only)

Statistics of aeolian dust





Basic knowledge about aeolian dust



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

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Outline of the new operational global aerosol forecast model（MASINGAR mk-2）

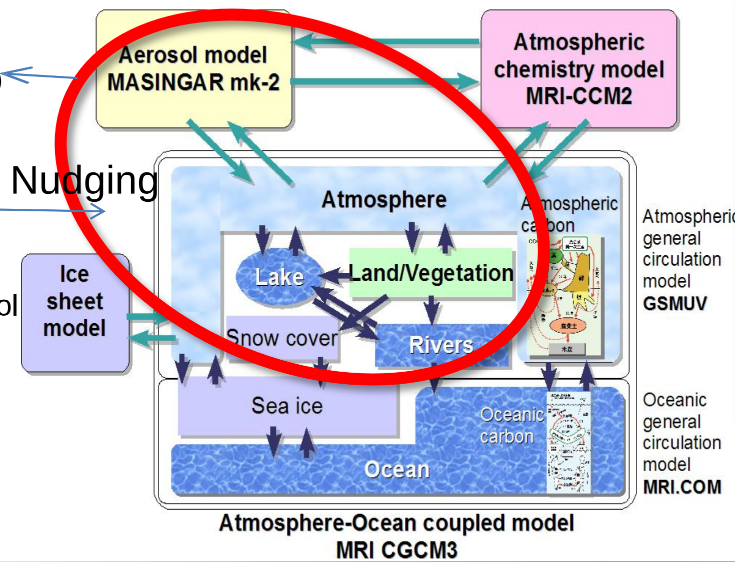
Resolution	TL159L40 Horizontal -110km, Vertical 40 layers (Surface – 0.4hPa)
Types of aerosols	10 bins of dust (0.2 - 20μm), 10 bins of sea salt (0.2 – 20μm), Sulfate, Organic carbon, Black carbon
Dust emission process	Depend on particle size, vegetation, surface condition (soil moisture, snow depth etc..) and surface wind speed
Dust deposition Process	Gravity (dry deposition), removal due to clouds and rain (wet deposition)
Dynamical model	MRI-AGCM3 (GSMUV)
Calculation interval	Once a day (12UTC initial)
Forecast period	5 days (120 hours)

The **MRI-ESM** aims to improve the prediction of global warming. We apply this system to the daily aerosol prediction in JMA.

Output of calculation result(every 3 hours)

Global Analysis and forecast data in JMA (GSM)

* No data assimilation of aerosol



In our daily operational prediction system, we're combining the atmospheric general circulation model (GSMUV) with the global aerosol forecast model (MASINGAR mk-2). We updated the model from November 2014.

Dust emission flux
Function of the surface friction velocity

Updates of the operational global aerosol forecast model

	Old operational global dust forecast model	New operational global aerosol forecast model
Global aerosol model	MASINGAR (Tanaka et al., 2003)	MASINGAR mk-2 (Tanaka et al., manuscript in preparation)
Dust emission	Function of the wind speed (u_{10}) $F = C\, u_{10}^2(u_{10} - u_t)$	Function of the surface friction velocity (Shao et al., 1996; Tanaka and Chiba, 2005)
Included aerosol species	**Mineral dust**	**Mineral dust, sulfate, BC, OA, sea salt**
Resolution	T106L20 (**1.125°**)	**TL159L40(1.125°) (in 2014) →** **TL479L40 (0.375°) (in 2017)**
Atmospheric model	**MRI/JMA 98 AGCM** (Shibata et al., 1998)	**MRI-AGCM3 (Yukimoto et al., 2012)**
Advection	3-dimensional semi-Lagrangian	←
Convective transport	Arakawa-Schubert	Yoshimura (Yoshimura et al.,2014)
Land surface model	3-layer Simple Biosphere	**HAL** (Hosaka et al., manuscript in preparation)
Coupling of aerosol model with AGCM	Subroutine call in each time step	Connected using **SCUP library** (Yoshimura and Yukimoto, 2008)

Verification of dust prediction
- Statistical verification -

We calculate the statistics for dust predictions using SYNOP reports from meteorological observatories in Japan.

(Verification period：March–May 2010–2014, 00UTC–09UTC)

Dust forecast model surface～1km conc.	
Dust forecast (F)	≧90μg/m³
No dust forecast (X)	＜90μg/m³

- This threshold value is based on the past research results relating to the dust concentration and visibility. (Iwakura and Okada, 1999)

SYNOP reports at meteorological observatories in Japan	
Dust observation (O)	Visibility becomes less than 10km because of aeolian dust. Other phenomena (e.g. rainfall..) have not been seen within an hour.
No dust observation (X)	Aeolian dust that visibility becomes <10km has not been seen. Other phenomena have not also been seen within an hour.
Unknown	Other than those above. (We cannot know whether the aeolian dust has been observed because of the rainfall, etc..)

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- Statistical verification -
How to calculate the statistics of dust prediction

FO : Forecast･Observation
FX : Forecast･No Observation
XO : No Forecast･Observation
XX : No Forecast･No Observation

$$\text{Threat Score} = \frac{FO}{FO + FX + XO}$$

It combines 'Hit Rate' and 'False Alarm Ratio' into one score for low frequency events.

$$\text{Hit Rate} = \frac{FO}{FO + XO}$$

It's the fraction of observed events that are forecasted correctly.

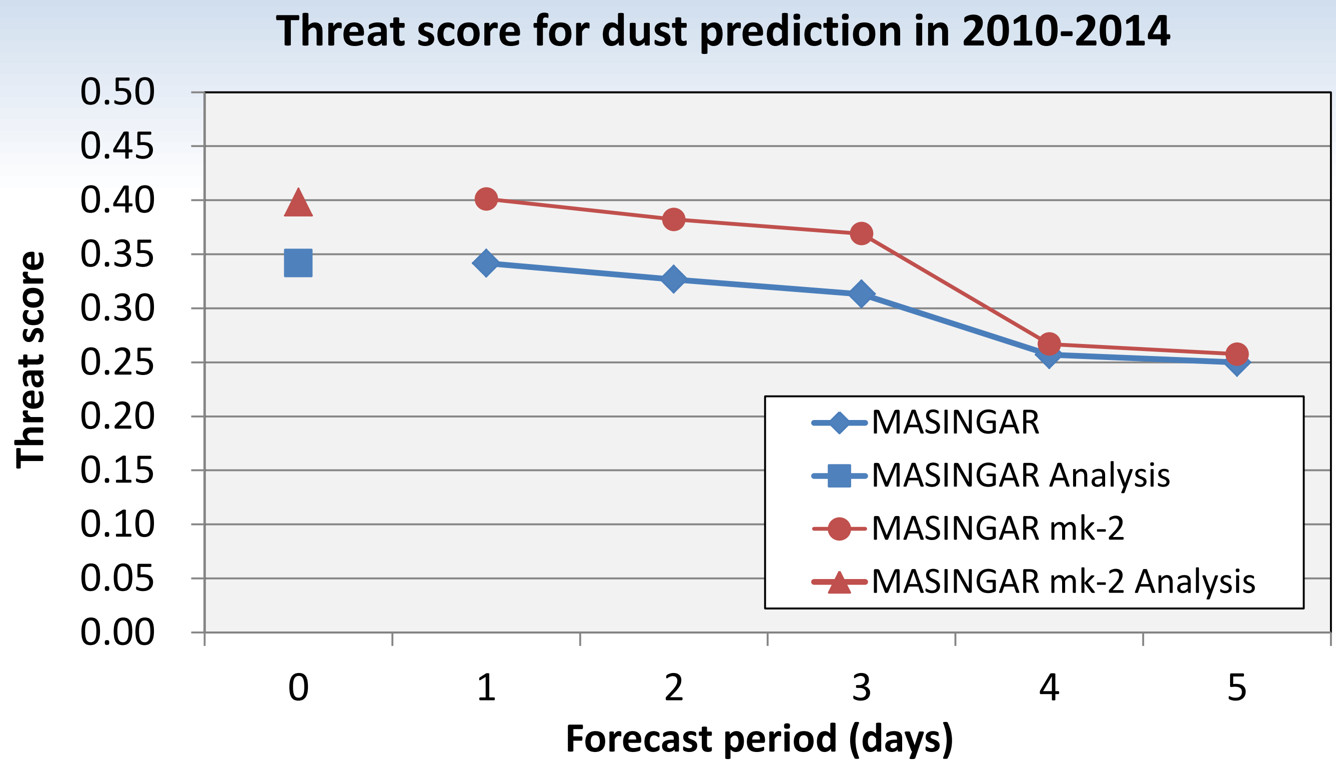
$$\text{False Alarm Ratio} = \frac{FX}{FO + FX}$$

It's the fraction of forecasts that are wrong, i.e., are false alarm.

$$\text{Percent Correct} = \frac{FO + XX}{FO + XO + FX + XX}$$

It's the fraction of forecasts that are correct.

- Statistical verification -



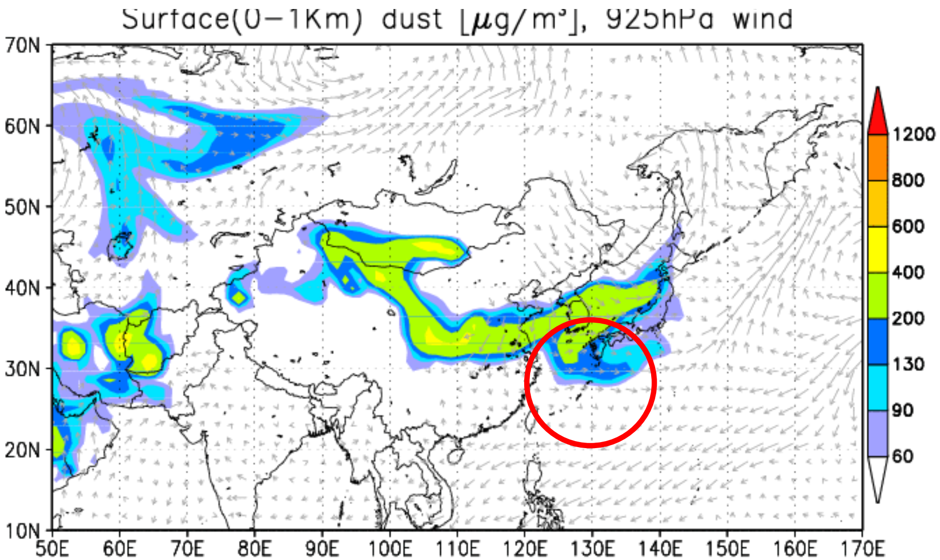
Hit Rate	MASINGAR	MASINGAR mk-2
0 day	0.885	0.725
1 day	0.879	0.727
2 day	0.831	0.697
3 day	0.795	0.669
4 day	0.648	0.493
5 day	0.610	0.484

False Alarm Ratio	MASINGAR	MASINGAR mk-2
0 day	0.643	0.531
1 day	0.642	0.528
2 day	0.650	0.542
3 day	0.659	0.548
4 day	0.701	0.633
5 day	0.703	0.645

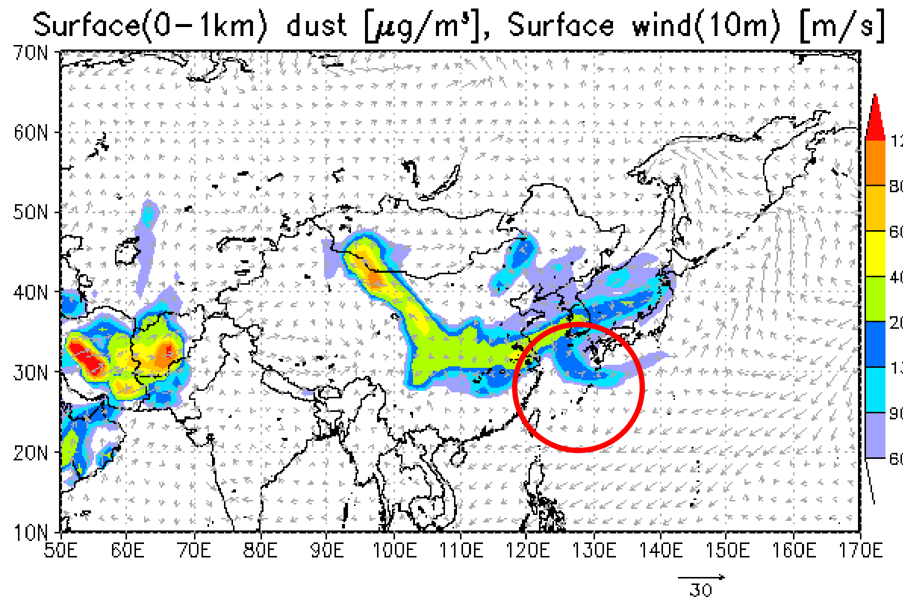
Percent Correct	MASINGAR	MASINGAR mk-2
0 day	0.912	0.943
1 day	0.912	0.944
2 day	0.912	0.942
3 day	0.910	0.941
4 day	0.903	0.930
5 day	0.905	0.928

- Statistical verification -
Case study for verification of dust prediction

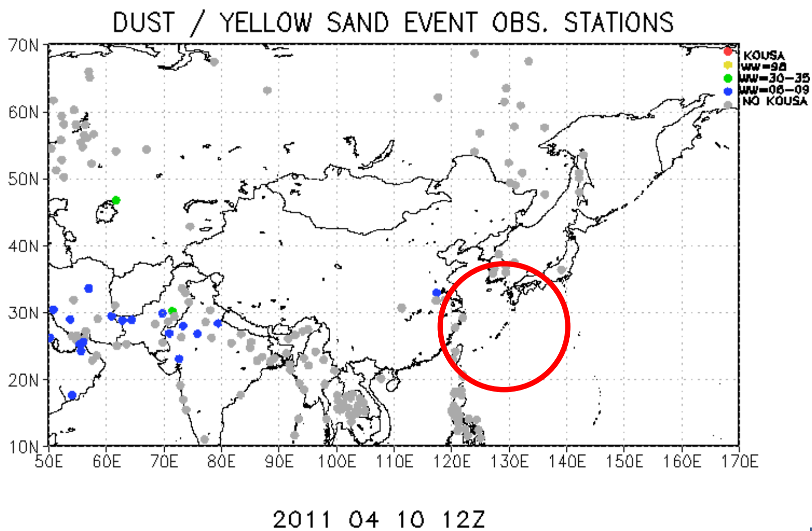
MASINGAR



MASINGAR mk-2



SYNOP



- The dust prediction of the old model is overestimated around Japan area. In the new model, the dust prediction is improved well and the distributions of dust predictions are matched with the SYNOP observation results.

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- Statistical verification -

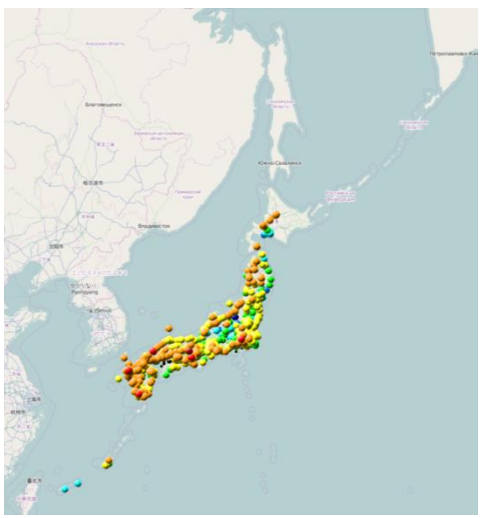
- The threat score for dust prediction is improved mainly for the first half of the forecast period.
- A comparison result of various statistical scores suggests that the threat score, false alarm ratio and percent correct are improved respectively although the hit rate becomes slightly worse.

→ These results suggest that the overestimation of dust prediction is improved.

- Quantitative verification -
Predicted dust concentration against surface SPM observation

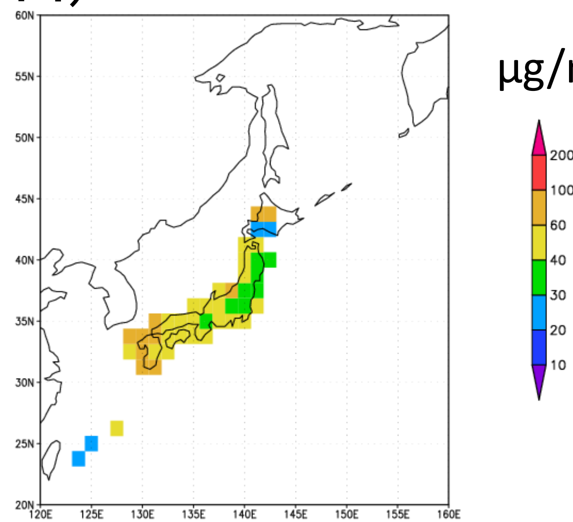
We use the data that the Ministry of Environment has been operating as the Atmospheric Environmental Regional Observation System called “Soramame-kun” to compare observed surface SPM and predicted dust concentration. We convert the SPM data at each stations into grid point data to match the model grid. Then we calculate time series statistics for each grid.

(Verification period : March–May 2010–2014)



Observed SPM raw data

grid



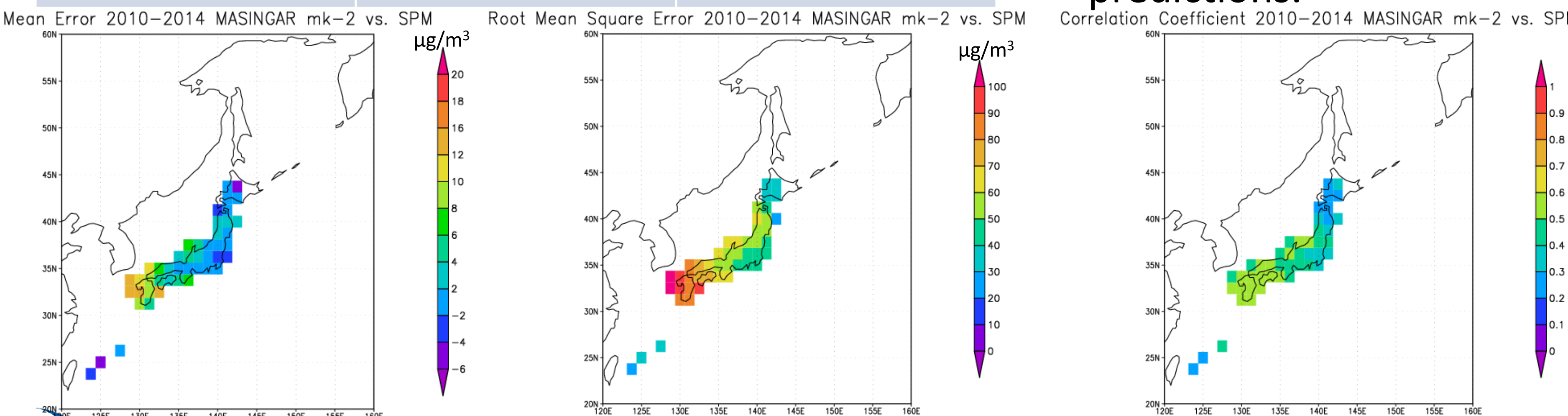
Observed SPM grid data

- Quantitative verification -
Predicted dust concentration against surface SPM observation

All over Japan (Ave. Mar.-May. 2010-2014)

Statistics	MASINGAR	MASINGAR mk-2
Mean Error (ME)	20.96 (μg/m³)	3.33 (μg/m³)
Root Mean Squared Error (RMSE)	82.50 (μg/m³)	59.91 (μg/m³)
Correlation Coefficient (CC)	0.45	0.44

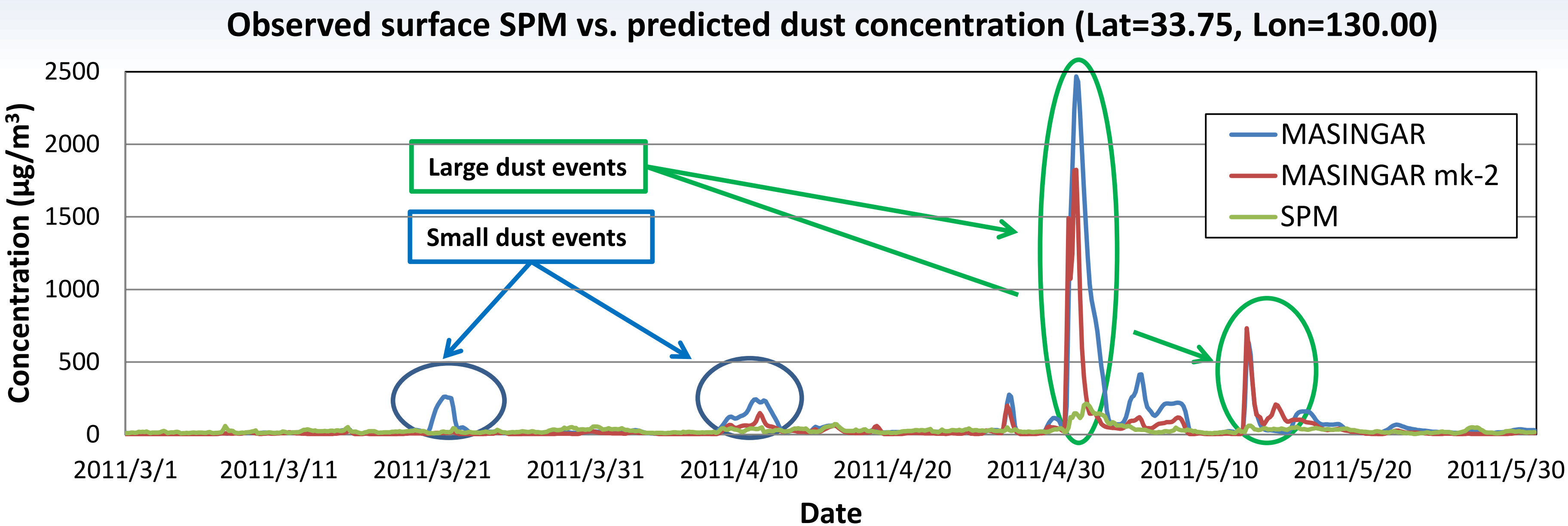
- The ME and RMSE are well improved.
- The RMSE is still high and the tendency is remarkable in western Japan.
- We admit a positive bias (ME>0) for dust predictions.



Statistics for each grid map (ME, RMSE, CC)

- Quantitative verification -
Case study for predicted dust concentration against surface SPM observation

※Near Fukuoka city (in 2011)



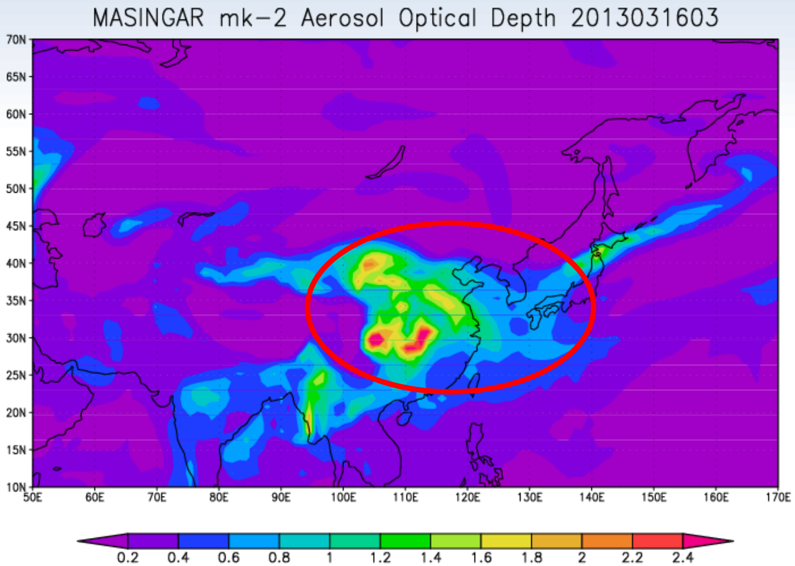
- During small dust events, the new model values show good agreement with observations. On the other hand, the predicted dust concentration is still overestimated during large dust events.

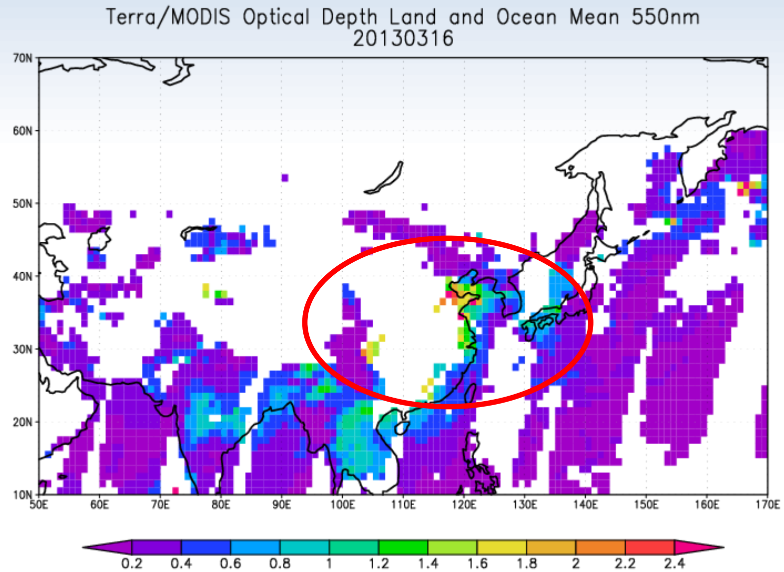
→ As a result, there is a tendency that RMSE is still large. And there is room for improvement in quantitative dust prediction accuracy.

Near Fukuoka city (Ave. Mar.-May. 2010-2014)

Statistics	MASINGAR	MASINGAR mk-2
Mean Error (ME)	29.80 (μg/m³)	10.55 (μg/m³)
Root Mean Squared Error (RMSE)	126.53 (μg/m³)	96.91 (μg/m³)
Correlation Coefficient (CC)	0.60	0.55

- Quantitative verification -
Case study for model AOD forecast against satellite-based observation



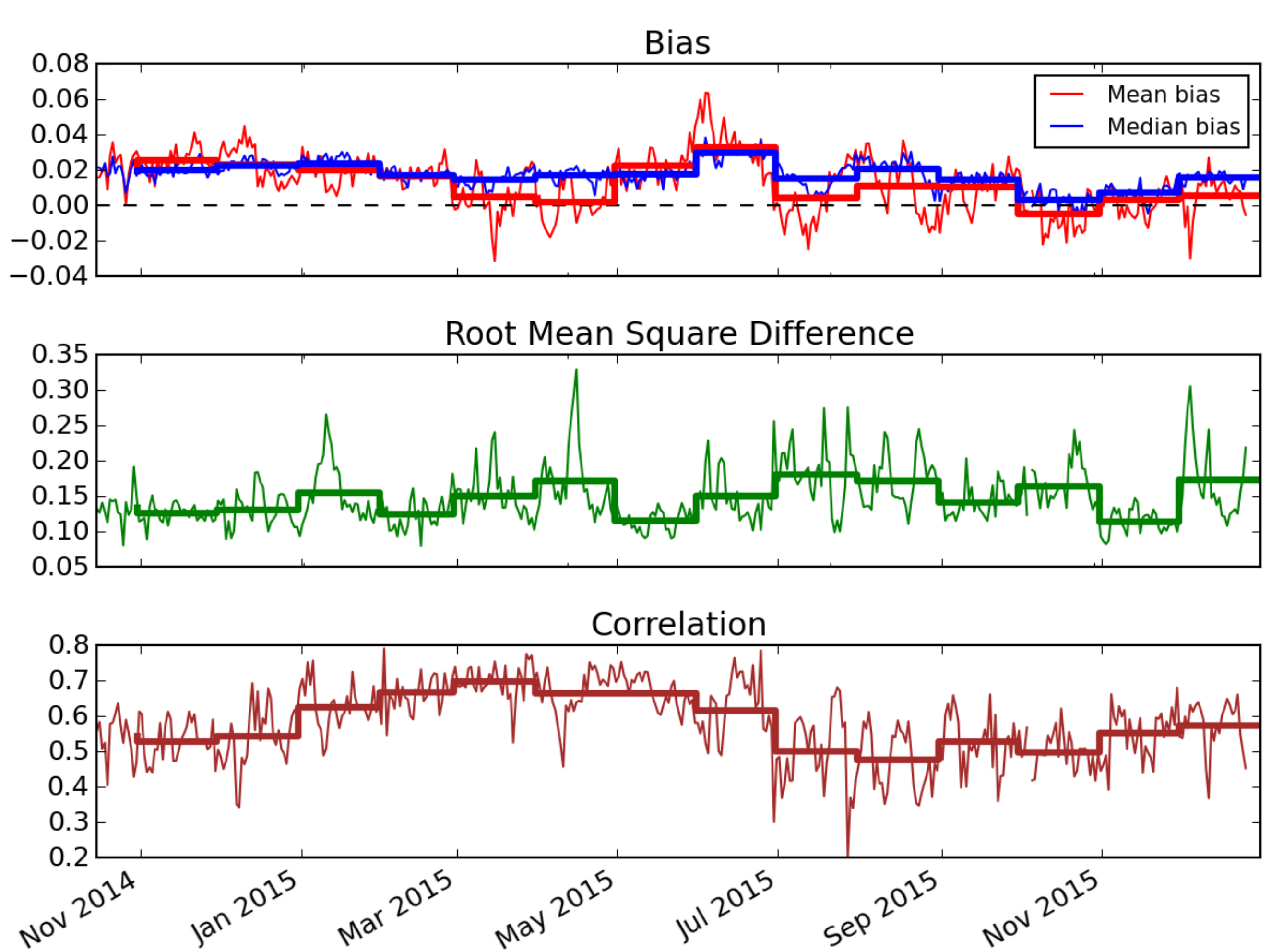


16 Mar. 2013

- The new operational global aerosol forecast model includes 5 major aerosol species (mineral dust, sulfate, black carbon, organic carbon, sea salt) and we have also been calculating 3-hourly AOD.

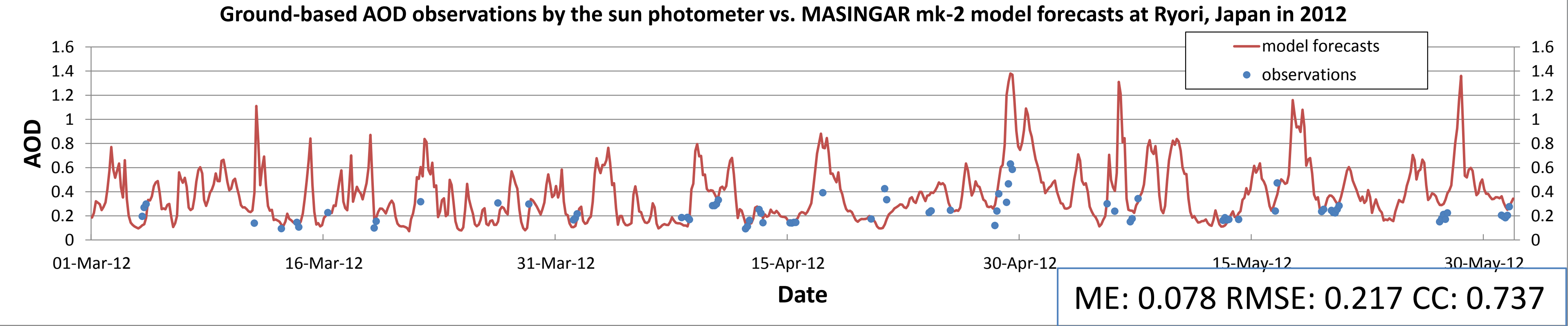
- In this case, it can be seen that high AOD regions spread from eastern China to western Japan due to air pollution and the new model can predict the distribution of AOD well.

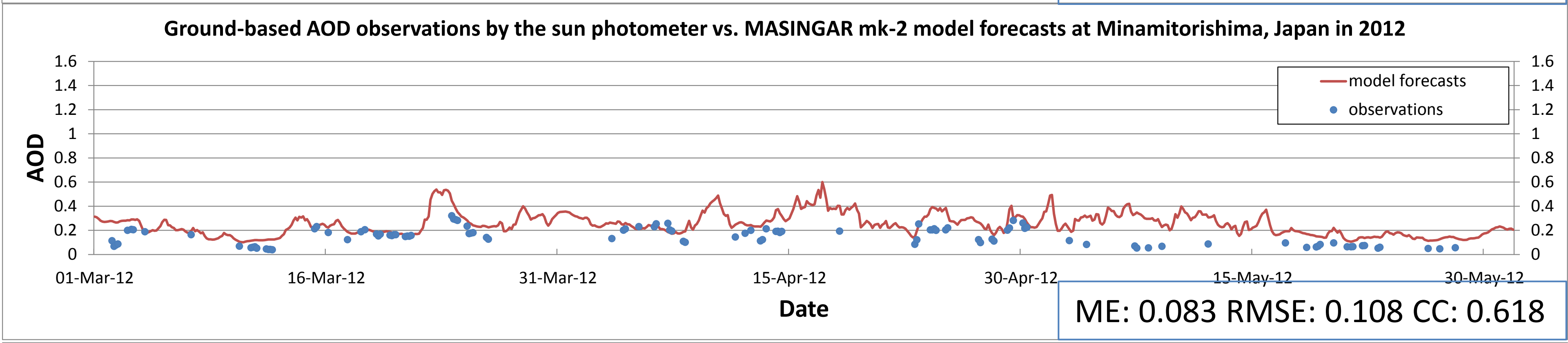
- Quantitative verification - Model AOD forecast against satellite-based observation

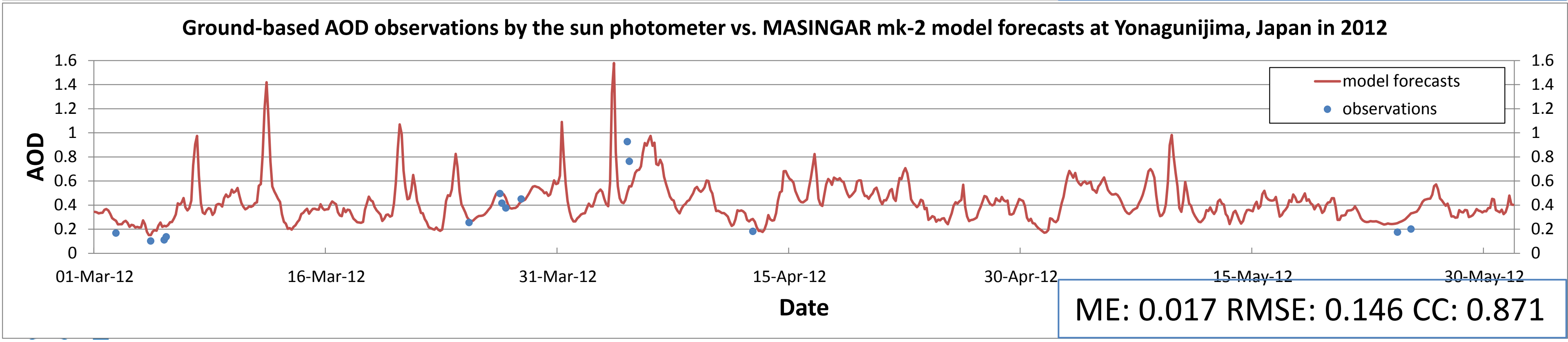


According to the comparison with the MODIS AOD data, we have also seen a small positive bias in simulated AOD relative to MODIS AOD observations.
The correlation coefficient is low in the summer and fall because of the uncertainty for smoke predictions in the operating system. So we are going to use the near real-time smoke data (GFAS daily fire products) to the operational dust prediction system.

- Quantitative verification - Model AOD forecast against ground-based observation

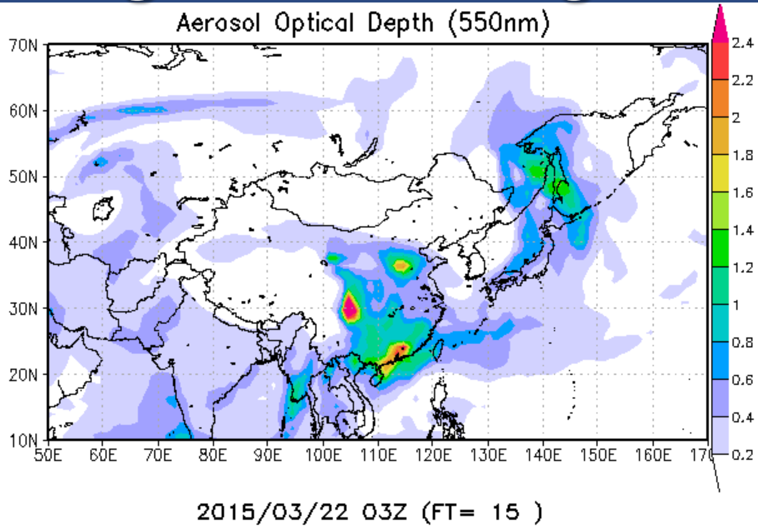




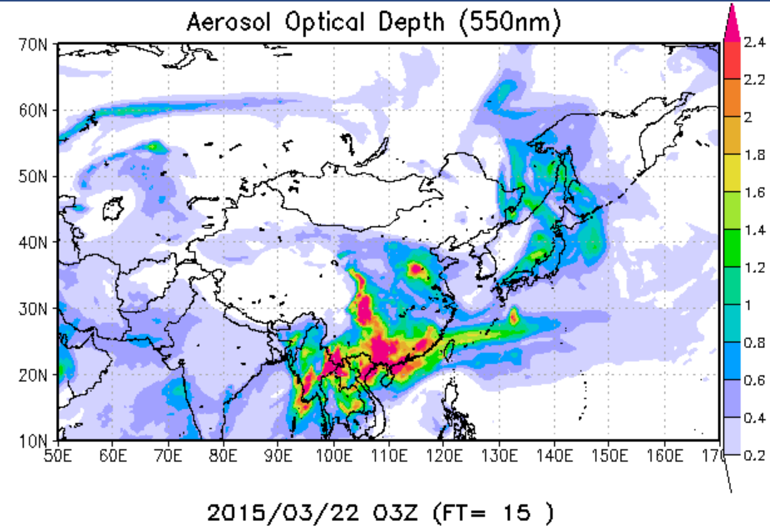


These results show a good correlation between ground-based AOD observations by the sun photometer and model forecasts. And there appears to be a small positive bias in these cases.

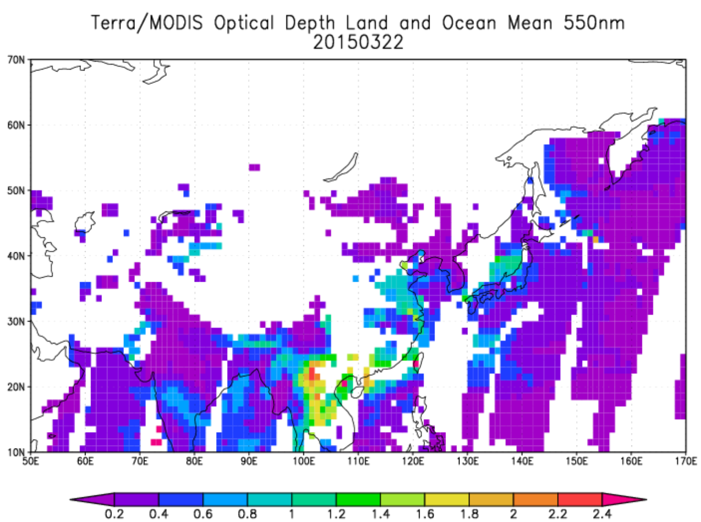
High-resolution global aerosol forecast model

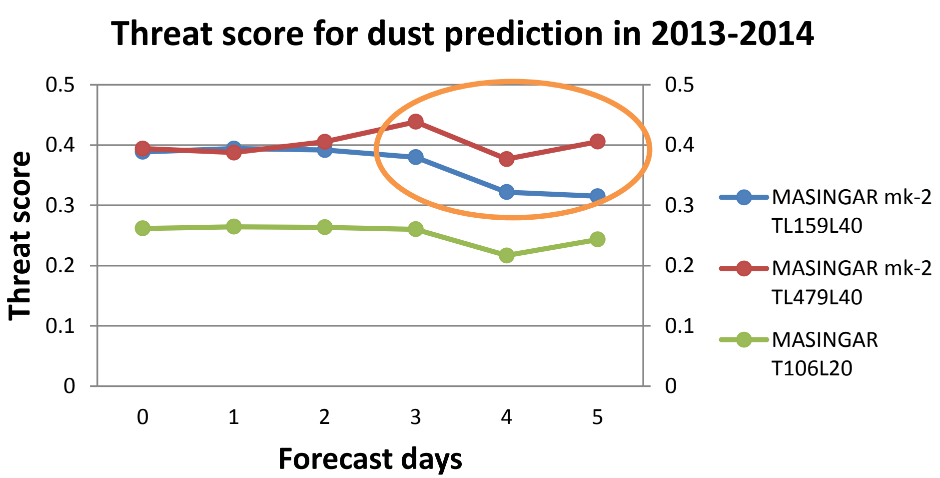


TL159L40 (~110km)



TL479L40 (~40km)

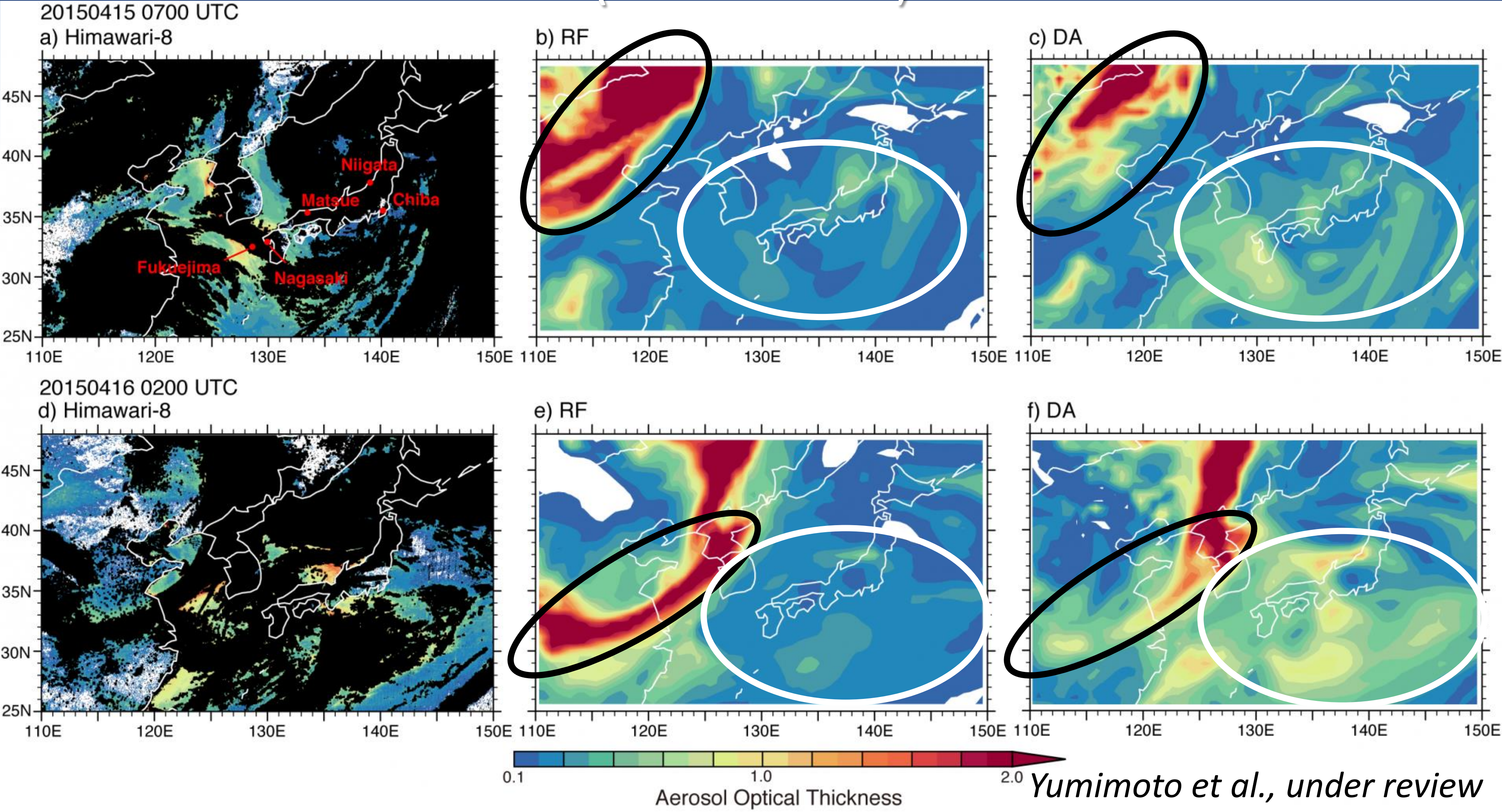




We have been developing a new version of the high-resolution global aerosol forecast model and verifying the test data. A preliminary result of the threat score for dust predictions shows a better performance mainly in the latter half of the forecast period.

We are planning to introduce this version of the model to the operational dust prediction system in the near future.

Aerosol data assimilation using the satellite AOD data (Himawari-8)



Yumimoto et al., under review

Himawari-8, a new geostationary satellite was launched in October 2014 and we have also been developing an aerosol data assimilation system with LETKF using that data.

By assimilating the AOD data, we have confirmed the overestimated dust area is modified and the air pollution over Japan is reproduced well.

We are also planning to introduce this assimilation system to the operational dust prediction system in a few years.

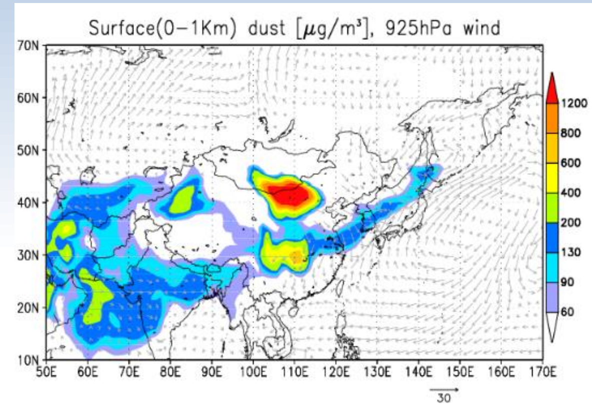
Summary

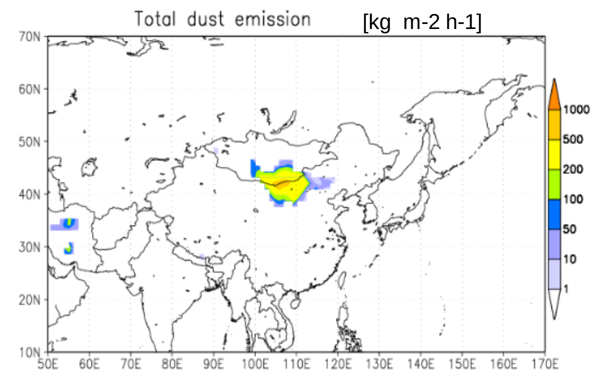
- JMA upgraded the operational global aerosol forecast model (MASINGAR mk-2) for dust predictions in November 2014.
- The statistical verification results show the dust prediction is improved well in the new model and it can predict dust distributions better than the old one.
- The comparison between the AOD observations and the new model forecasts indicates a good performance although we have seen a small positive bias in the current version of the model.
- JMA has been developing a new version of the high-resolution forecast model and an aerosol data assimilation system for the operational dust prediction system.

That is all for my presentation. Thank you very much for your kind attention!

Outline of the old operational global aerosol forecast model（MASINGAR）

Resolution	T106L20 Horizontal -110km, Vertical 20 layers (Surface - 34hPa)
Type of aerosol	10 bins of dust (0.2 - 20μm)
Dust emission process	Depend on particle size, vegetation, surface condition (soil moisture, snow depth etc..) and surface wind speed
Dust deposition process	Gravity (dry deposition), removal due to clouds and rain (wet deposition)
Dynamical model	MRI/JMA98 (MJ98)
Calculation interval	Once a day (12UTC initial)
Forecast period	5 days (120 hours)





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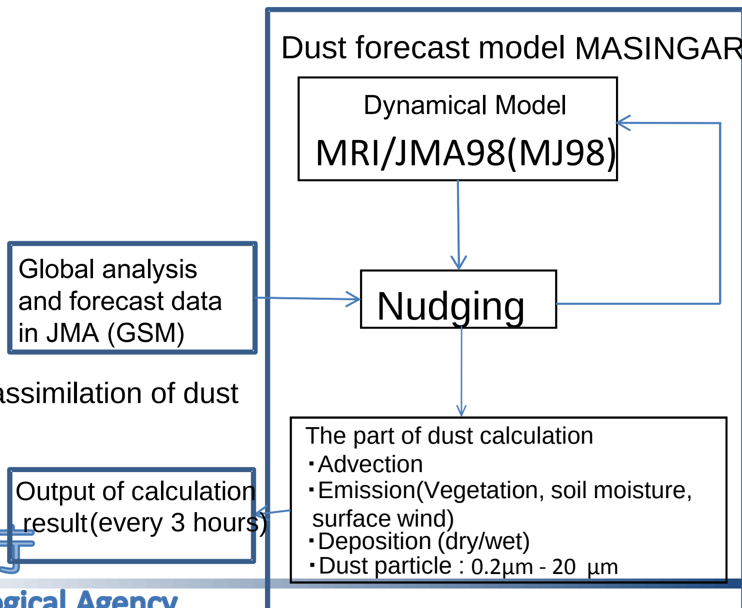


* No data assimilation of dust

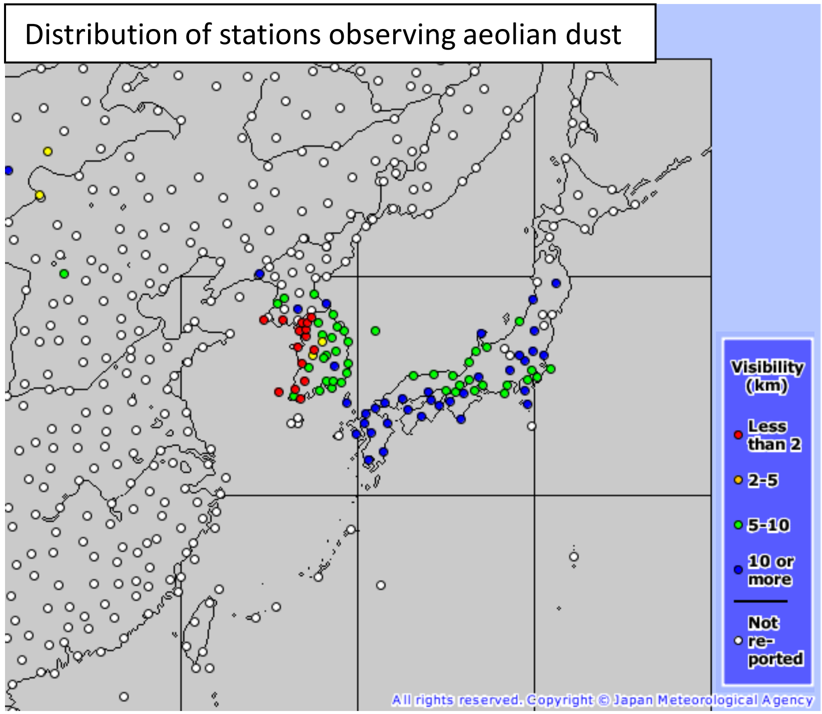
Dust emission flux $\propto (U_{10} - U_t) \cdot U_{10}^2$

U_{10} Surface wind U_t Threshold of wind speed (> 6.5m/s)

The dust emission flux is proportional to the cube of the wind speed.

- Statistical verification -
Visibility and meteorological conditions

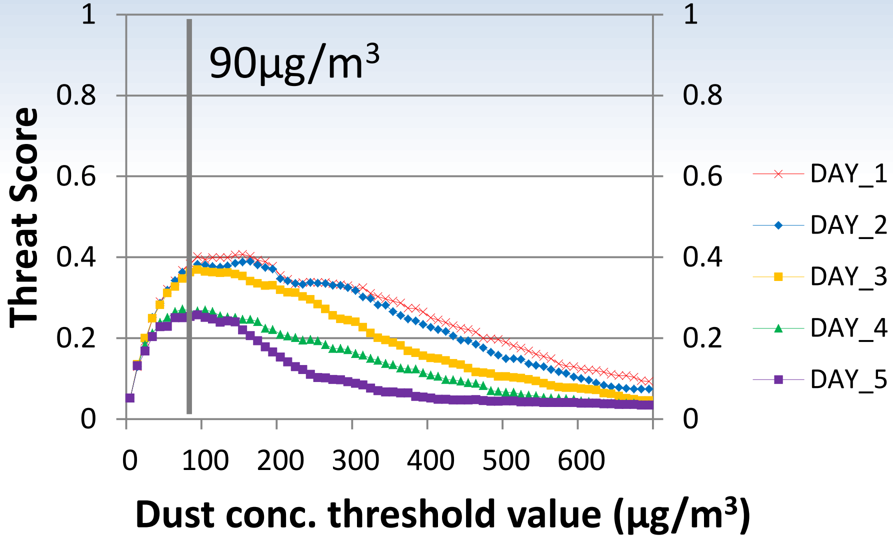
- JMA operates 60 manned observational stations, which observe aeolian dust in terms of the visibility and meteorological conditions.
- The minimum visibility at each station is categorized in different colors on the JMA website.
- When the visibility becomes below 10 km, the station reports aeolian dust in SYNOP messages.

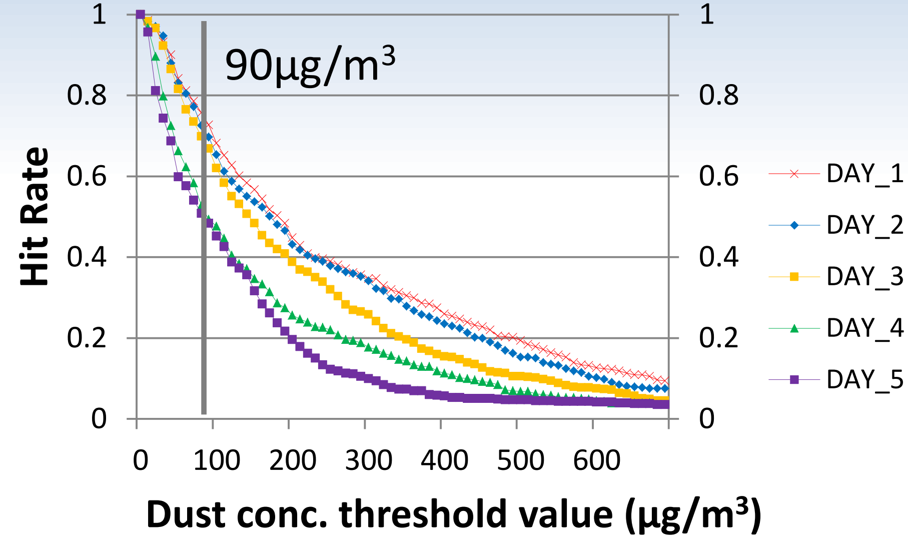


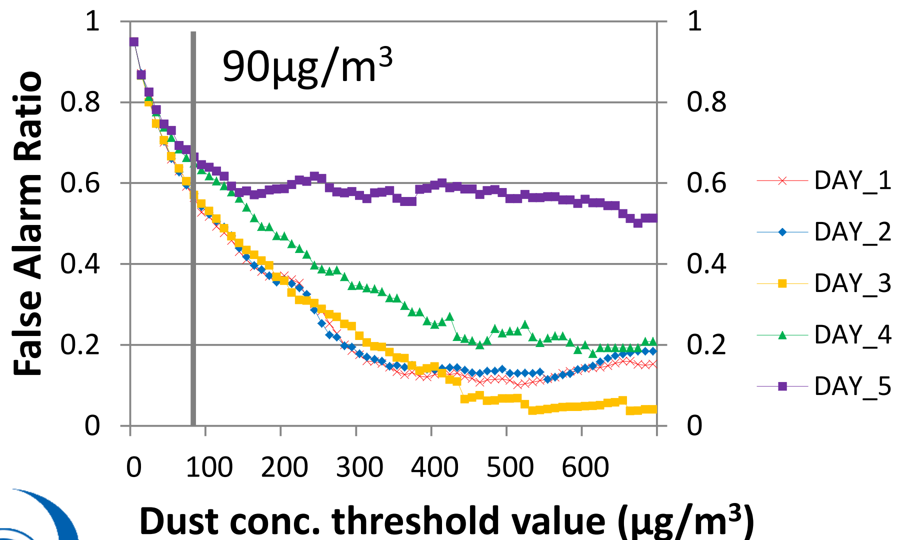
Map of stations observing aeolian dust *Kosa* or local sand/dust haze during the day

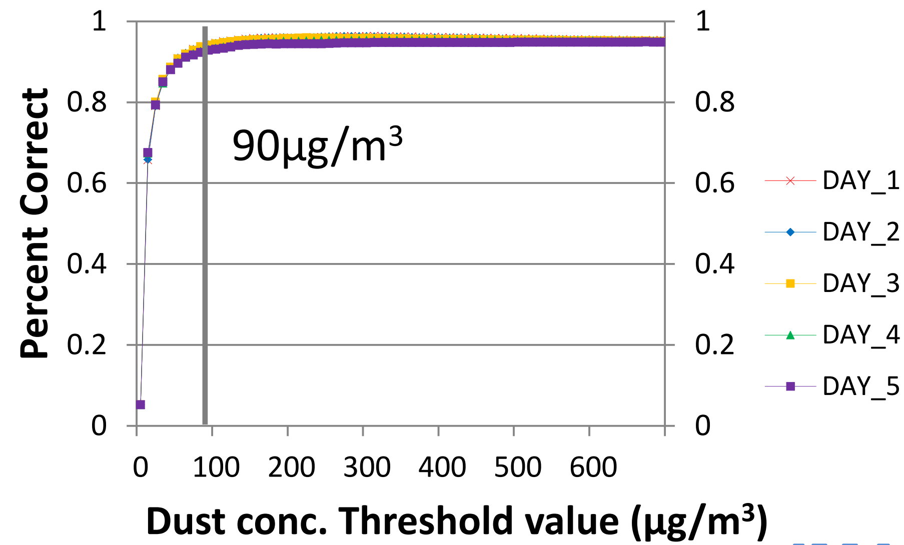
➢ **This observation is used for the validation of dust prediction with Threat Score (TS).**

- Statistical verification -
Other statistics of dust prediction (MASINGAR mk-2)





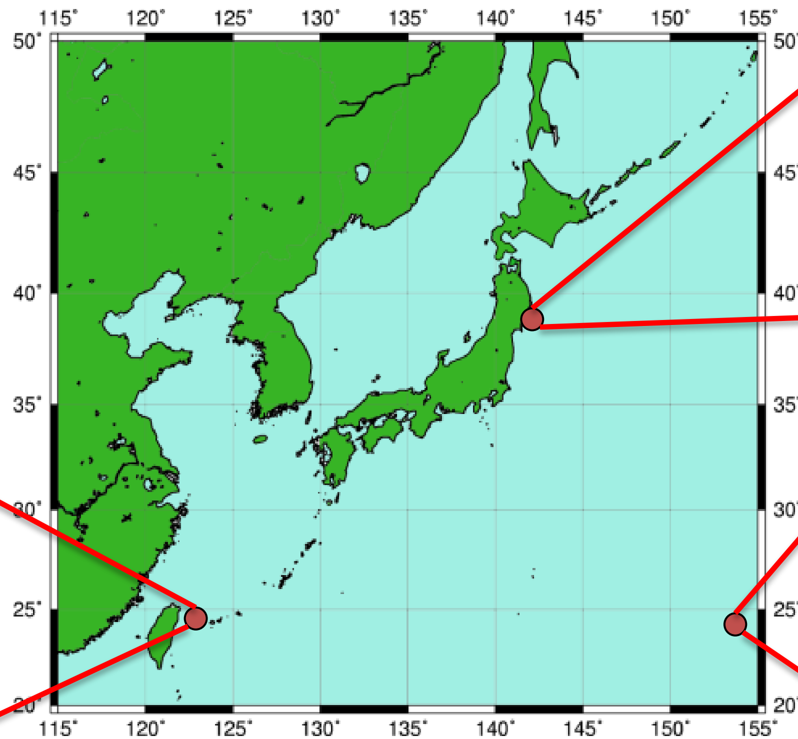




- Quantitative verification -
Surface AOD observation in JMA

JMA has been conducting AOD measurements using sun photometers at 3 WMO/GAW stations as part of its environmental monitoring network.

Precision Filter Radiometer (PFR)



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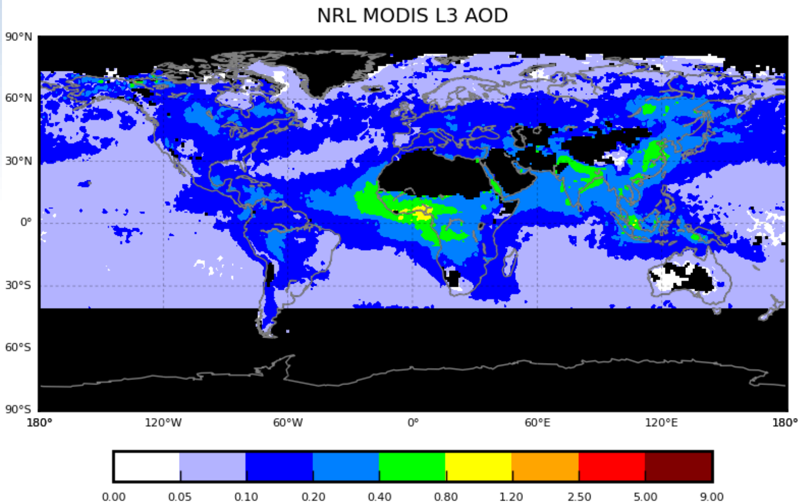
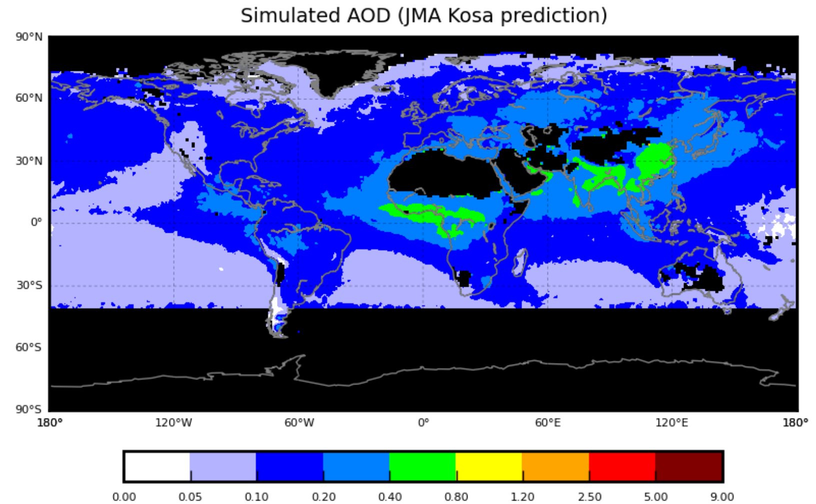
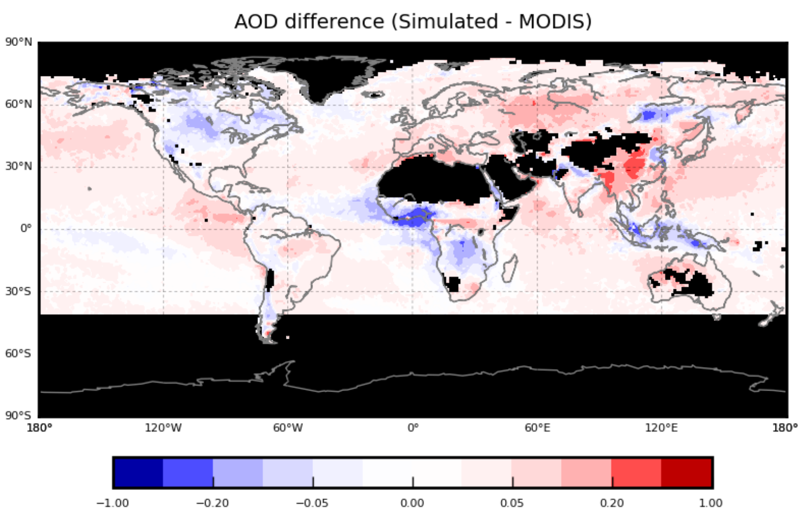
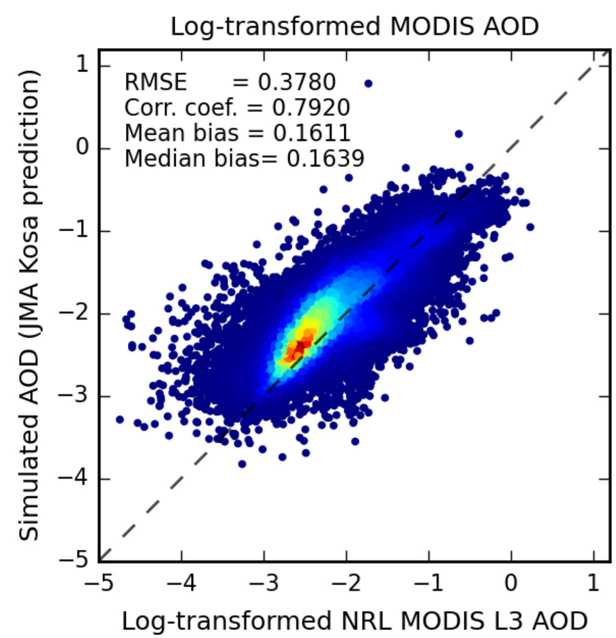
- Quantitative verification -
Model AOD forecast against satellite-based observation









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