Recent progress of the operational dust prediction system in the Japan Meteorological Agency

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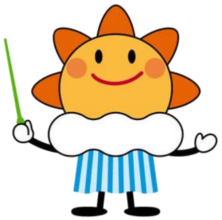


12 July 2016
8th International Cooperative for Aerosol Prediction (ICAP)
@ NOAA Center for Weather and Climate Prediction

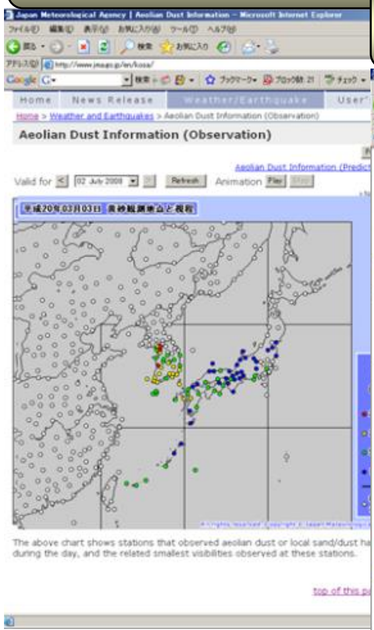
Outline

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

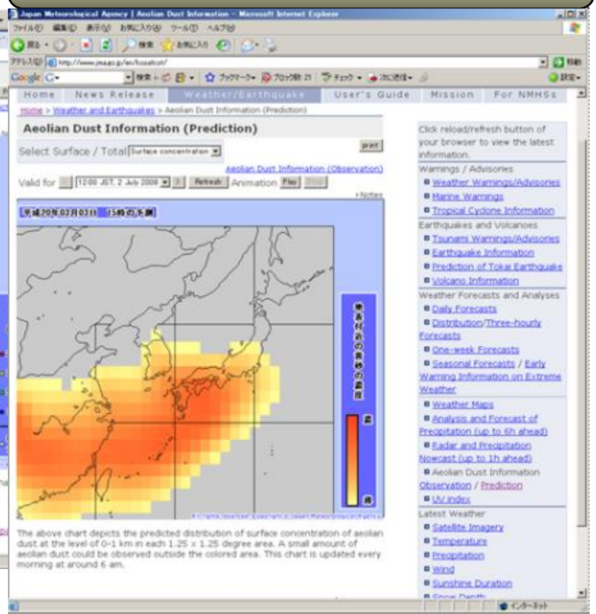
Information on aeolian dust to the public

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

Aeolian dust observation

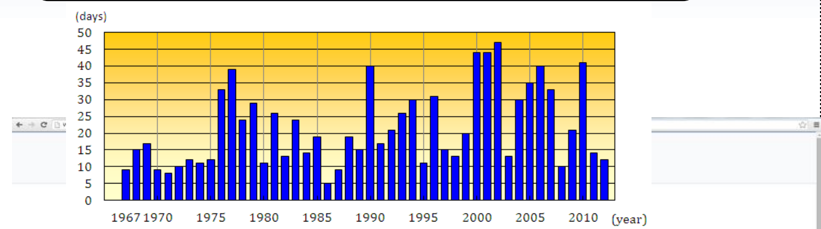


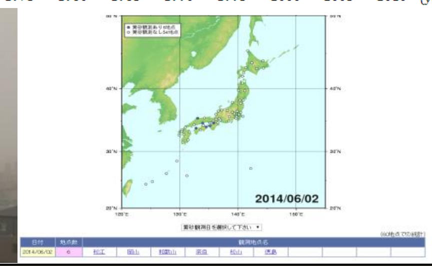
Aeolian dust prediction



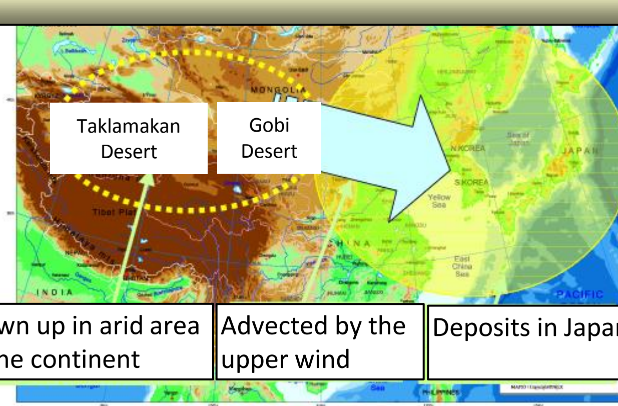
Aeolian dust advisory information
(when required, Japanese only)

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).

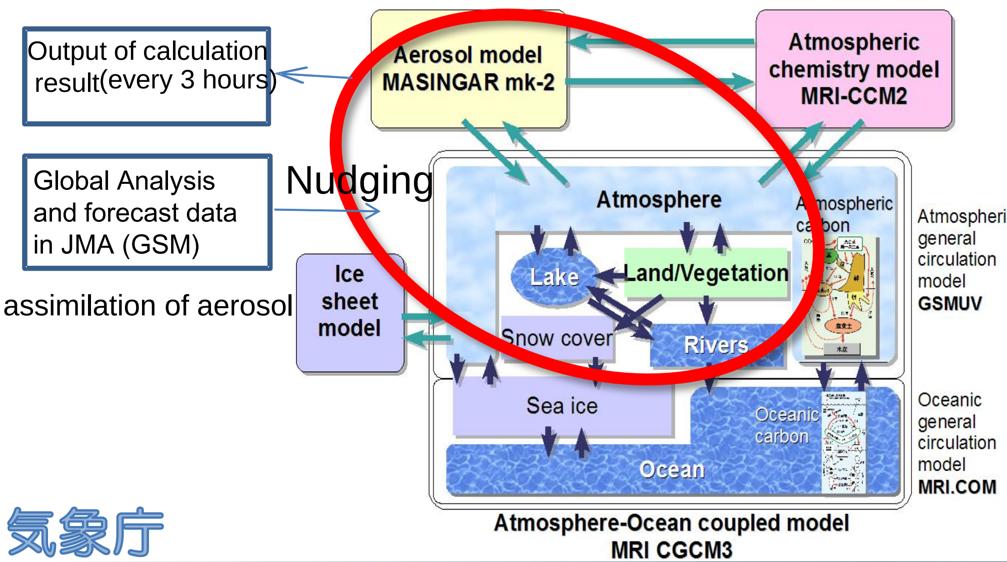
Japan M

JMA

Outline of the current 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.



* 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

Verification of dust prediction
- Statistical verification -

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

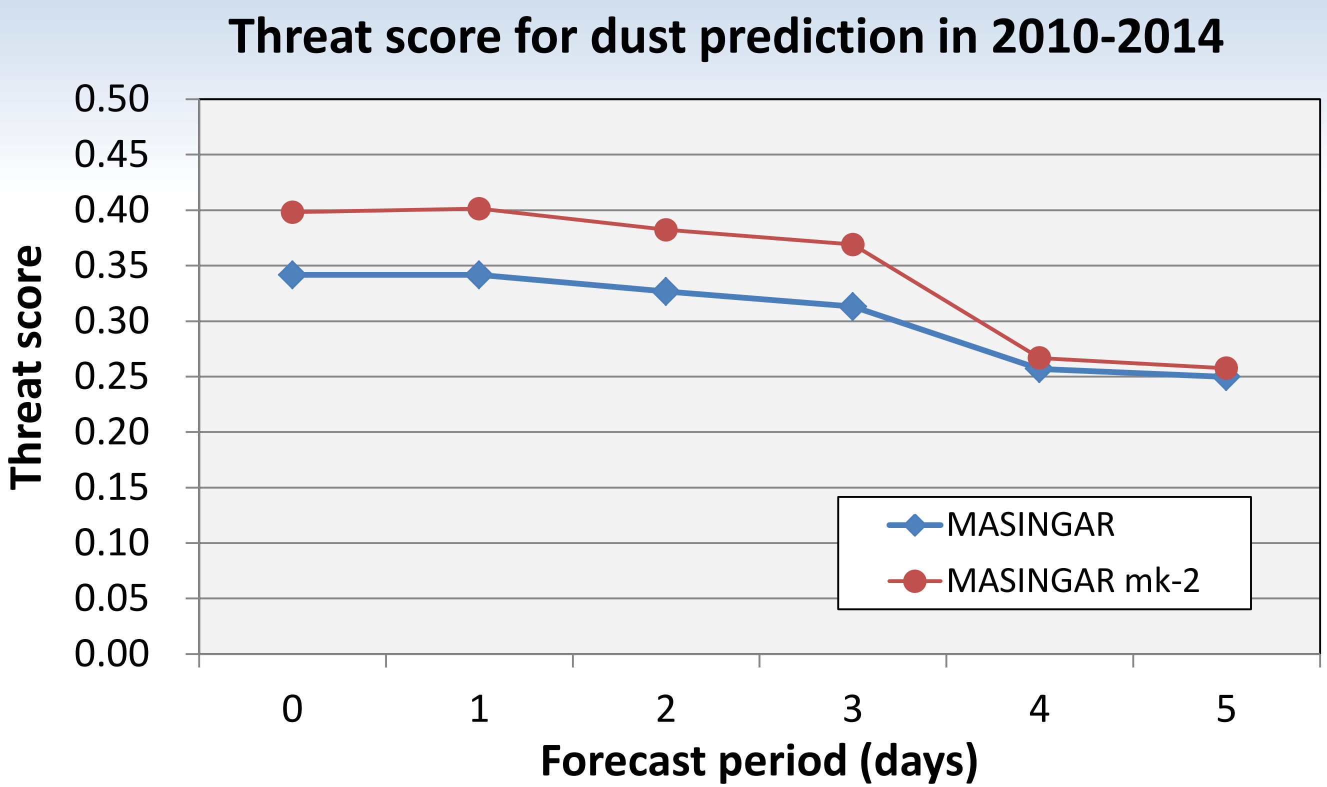
（Verification period：March–May 2010–2014, 00UTC–09UTC）

Dust forecast model surface～1km conc.	
Dust forecast (F)	≧90μg/m^3
No dust forecast (X)	＜90μg/m^3

- 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..)

- Statistical verification -



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

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

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

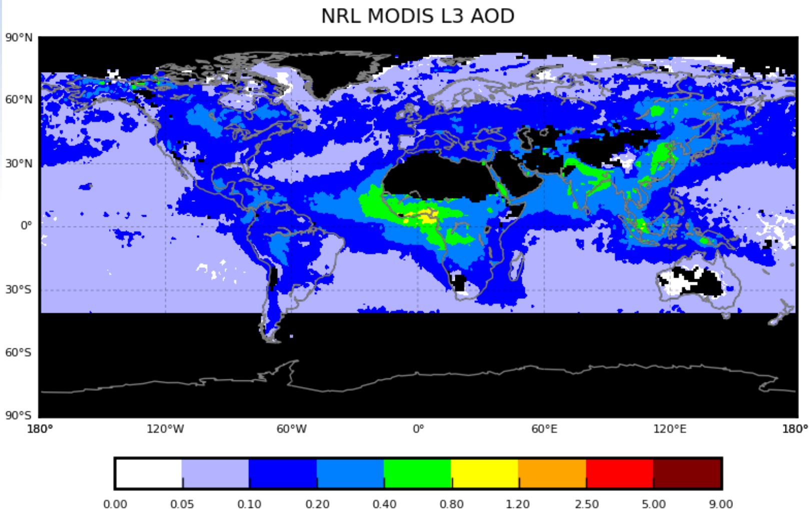
$$\text{Percent Correct} = \frac{FO + XX}{FO + XO + FX + XX}$$

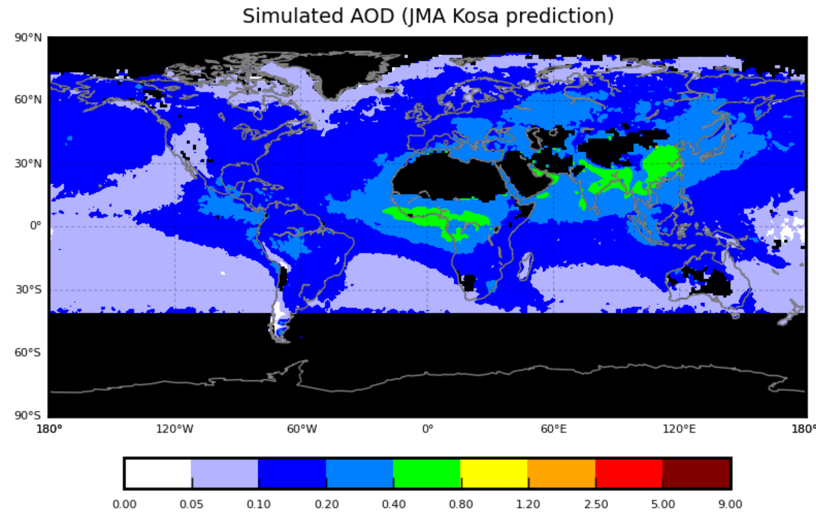
Hit Rate	MASINGAR	MASINGAR mk-2
0 day	0.885	0.725
1 day	0.879	0.727
2 day	0.831	0.697
3 day	0.795	0.669
4 day	0.648	0.493
5 day	0.610	0.484

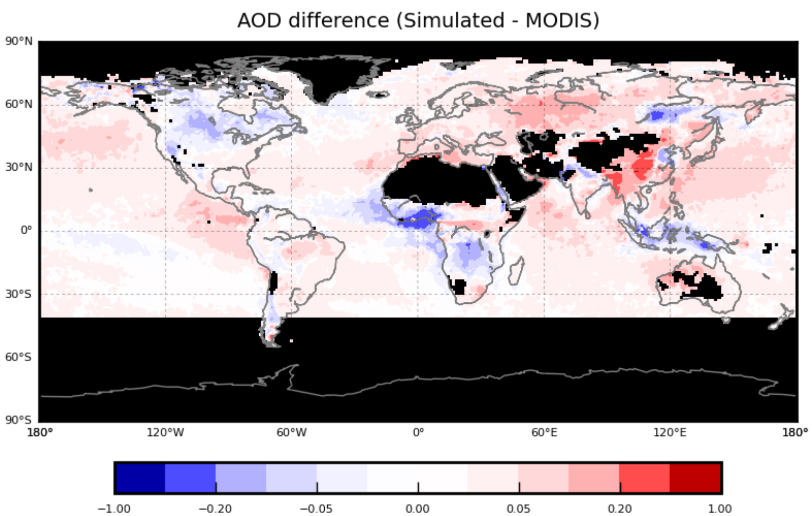
False Alarm Ratio	MASINGAR	MASINGAR mk-2
0 day	0.643	0.531
1 day	0.642	0.528
2 day	0.650	0.542
3 day	0.659	0.548
4 day	0.701	0.633
5 day	0.703	0.645

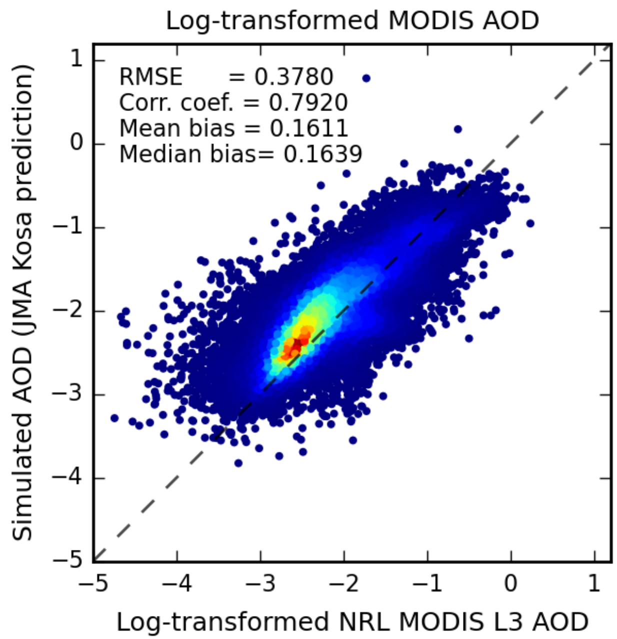
Percent Correct	MASINGAR	MASINGAR mk-2
0 day	0.912	0.943
1 day	0.912	0.944
2 day	0.912	0.942
3 day	0.910	0.941
4 day	0.903	0.930
5 day	0.905	0.928

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



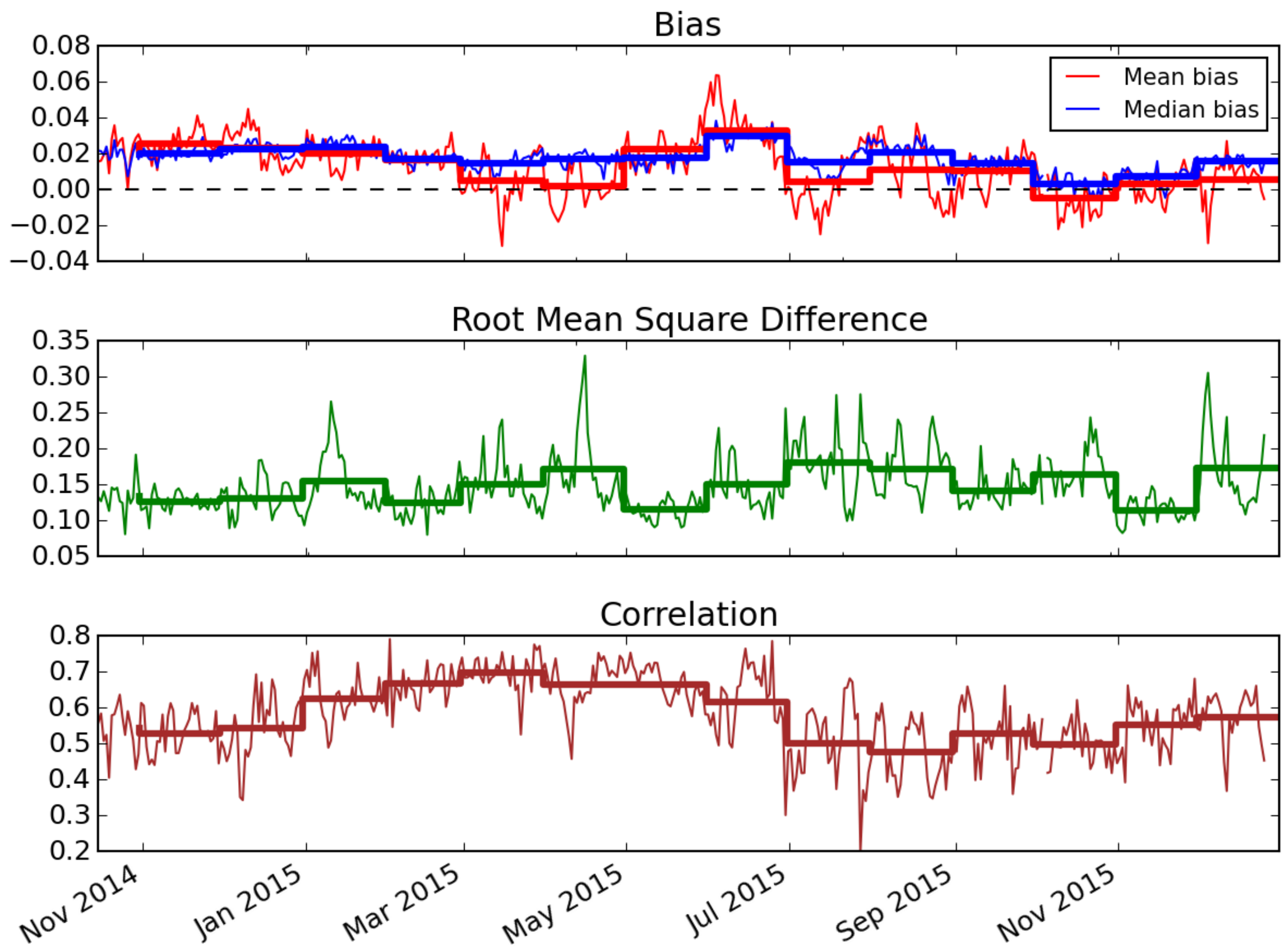






(Average : Oct. 2014 – Oct. 2015)

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



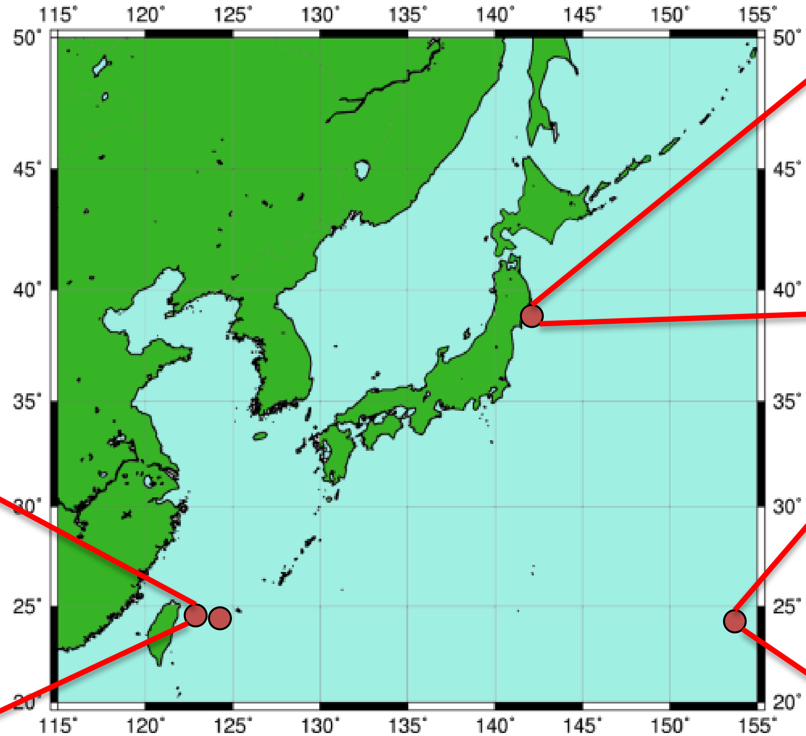
According to the comparison with the MODIS AOD data, we have also seen a small positive bias in simulated AOD relative to MODIS AOD observations.

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 aerosol prediction system.

- Quantitative verification -
Surface AOD observation in JMA

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

Precision Filter Radiometer (PFR)



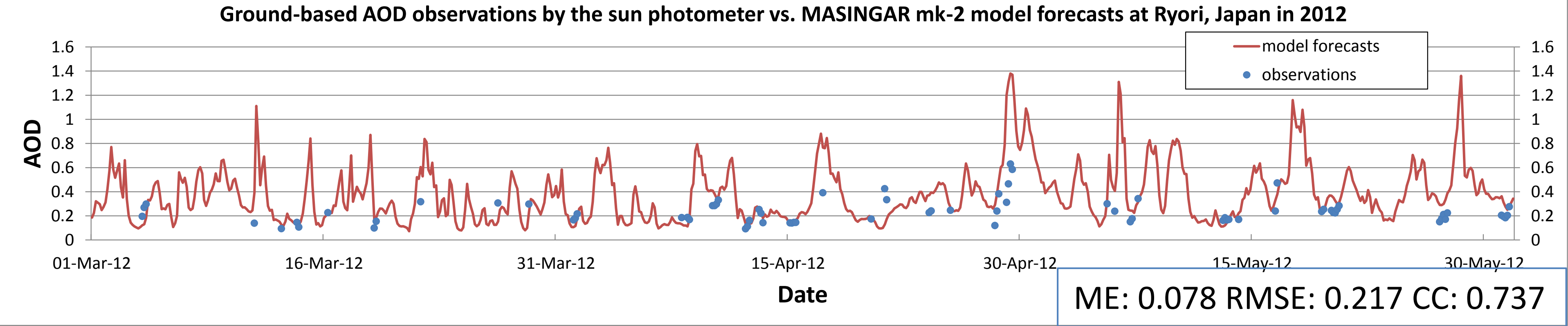
Ryori

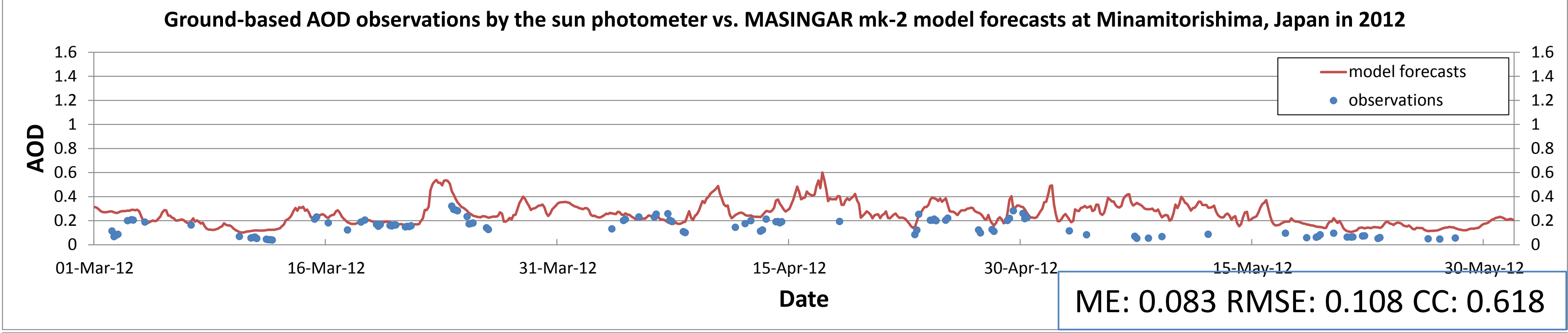
Yonagunijima → Ishigakijima (since Apr. 2016)

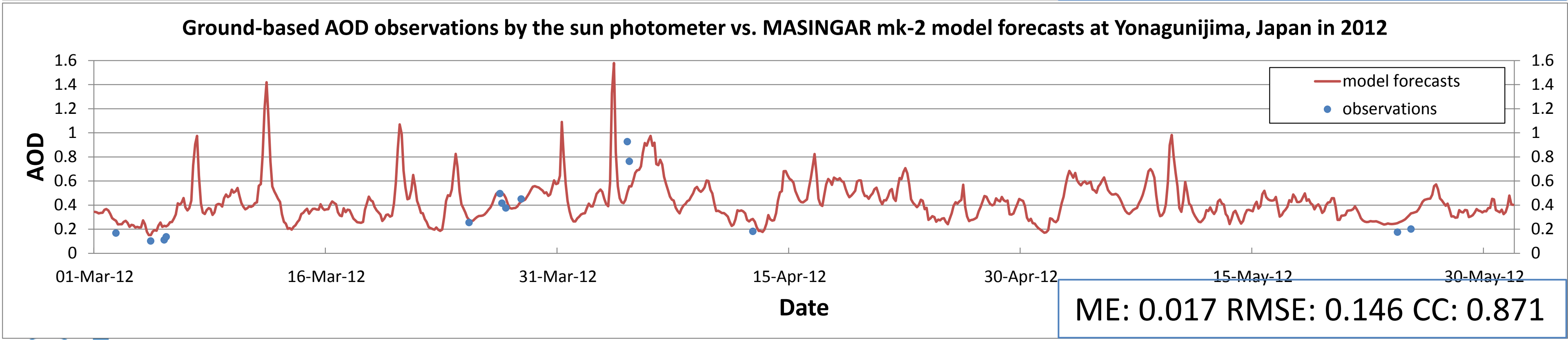
Minamitorishima

Replacement of PFR to Sky Radiometer is now underway.

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

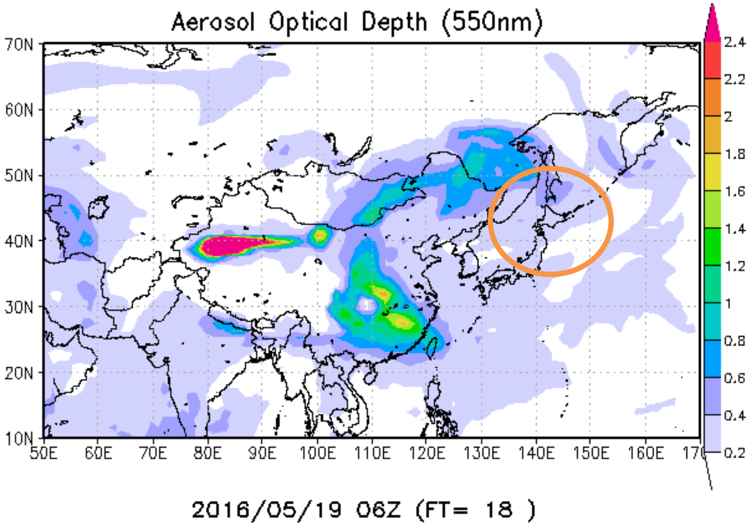




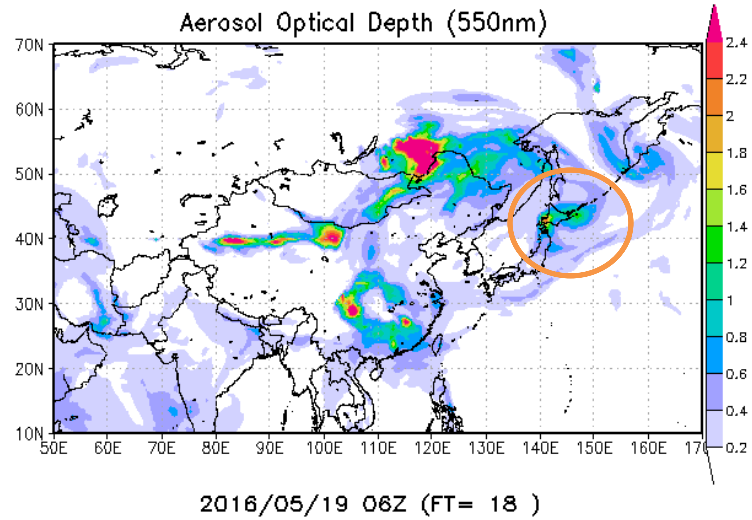


These results show a good correlation between ground-based AOD observations by the sun photometer and model forecasts. And there appears to be a small positive bias in these cases.

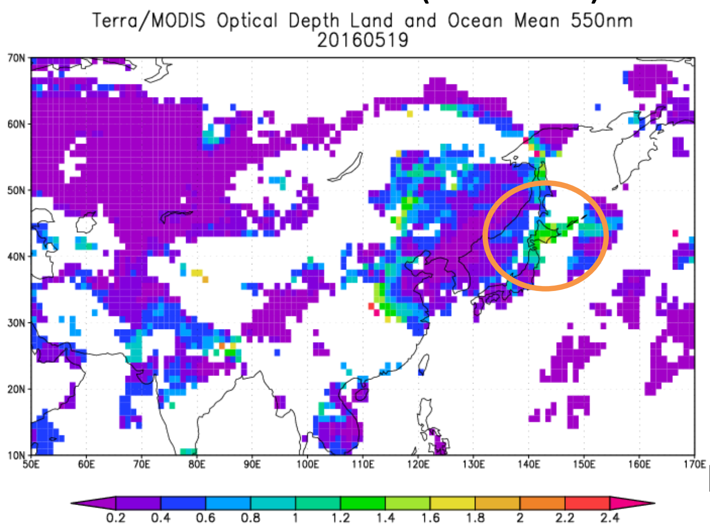
High-resolution global aerosol forecast model

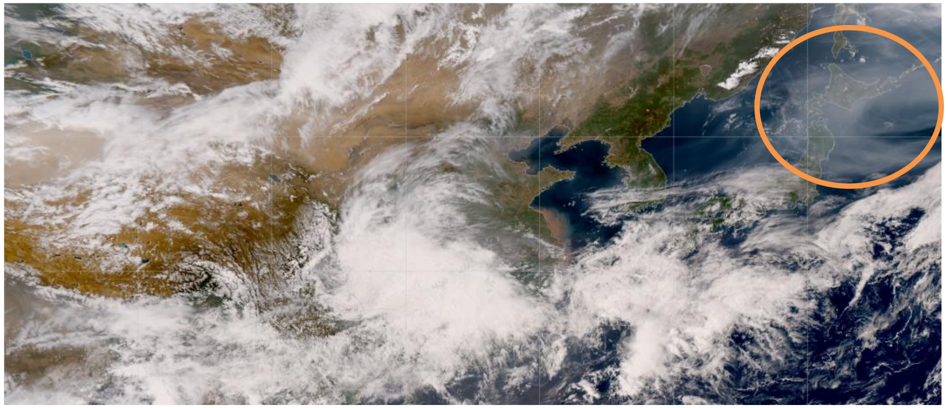


TL159L40 (~110km)



TL479L40 (~40km)





Himawari-8 True Color Reproduction image 2016051906UTC

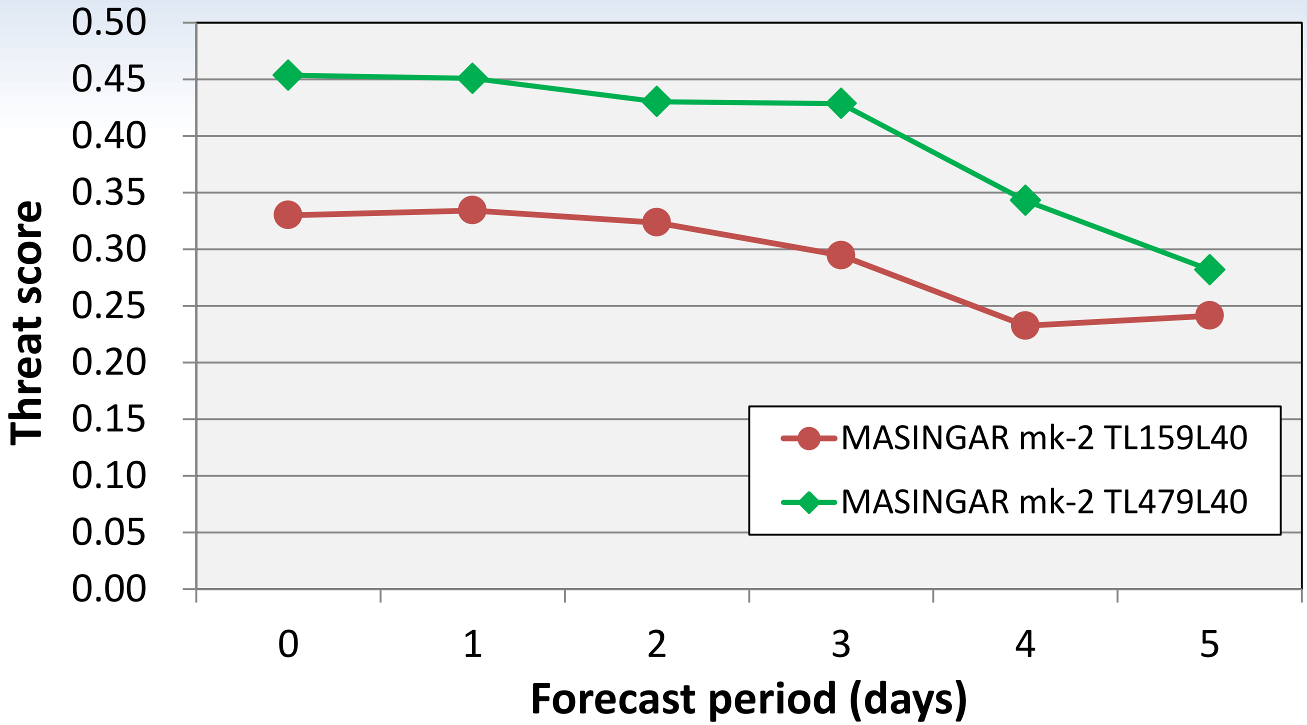
We have been developing a new version of the high-resolution global aerosol forecast model (MASINGAR mk-2 with TL479L40) and verifying the test data.

Using GFAS daily fire products (thanks to ECMWF!), the high-resolution model simulates dense areas of smoke around northern part of Japan and Himawari-8 also represents these areas.

And some bias correction methods are included in this version for reducing overestimation of AOD prediction.

- Statistical verification -

Threat score for dust prediction in 2013-2015



* A preliminary result

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

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

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

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

Hit Rate	MASINGAR mk-2 TL159L40	MASINGAR mk-2 TL479L40	False Alarm Ratio	MASINGAR mk-2 TL159L40	MASINGAR mk-2 TL479L40	Percent Correct	MASINGAR mk-2 TL159L40	MASINGAR mk-2 TL479L40
0 day	0.771	0.795	0 day	0.634	0.486	0 day	0.952	0.970
1 day	0.776	0.795	1 day	0.630	0.490	1 day	0.952	0.970
2 day	0.771	0.795	2 day	0.642	0.516	2 day	0.950	0.967
3 day	0.700	0.695	3 day	0.663	0.472	3 day	0.948	0.971
4 day	0.582	0.563	4 day	0.721	0.533	4 day	0.941	0.966
5 day	0.565	0.479	5 day	0.704	0.594	5 day	0.945	0.962

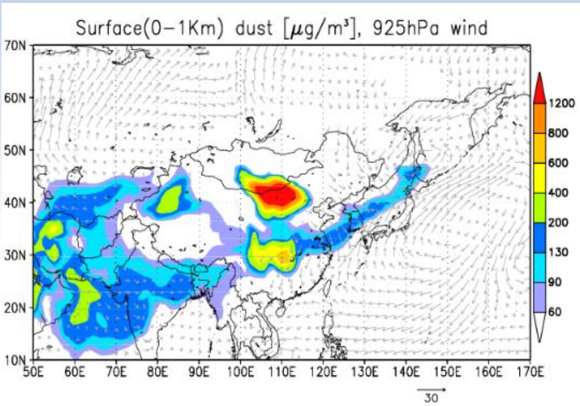
Summary

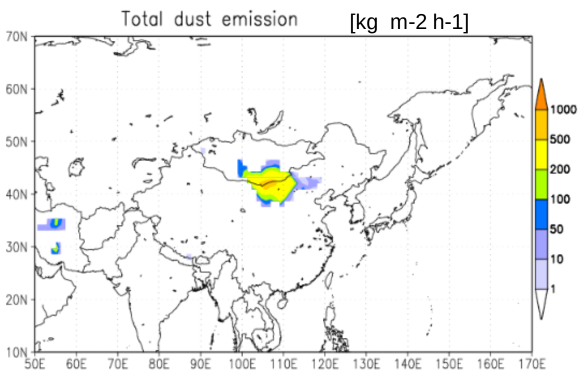
- The current operational global aerosol forecast model (MASINGAR mk-2 with TL159L40) has been used for dust predictions since Nov. 2014.
- The statistical verification results show the dust prediction is improved well in the current model and it can predict dust distributions better than the old one.
- The comparison between the AOD observations and the current 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 (MASINGAR mk-2 with TL479L40) for the operational dust prediction system and we have evaluated its forecast accuracy.
- We are now testing this system for operational use.

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

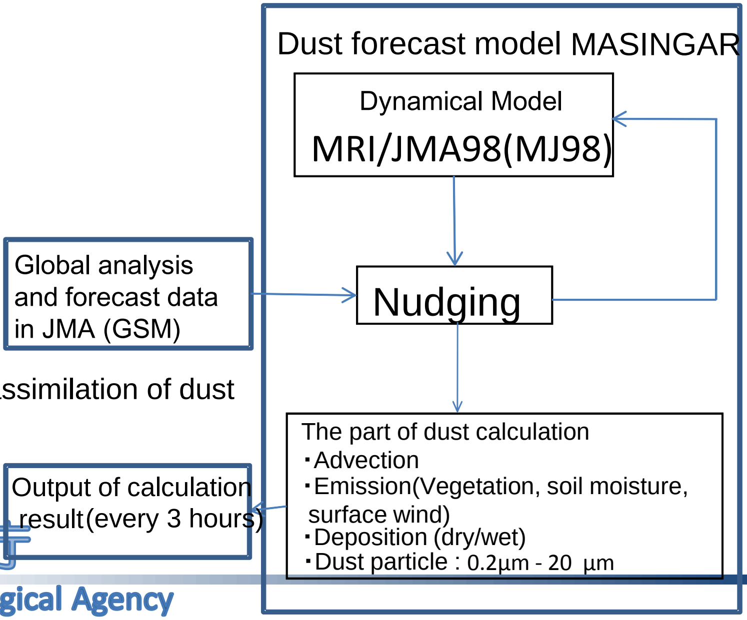
Outline of the old operational global aerosol forecast model（MASINGAR）

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)





30 March, 2012
12UTC ini



* 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)

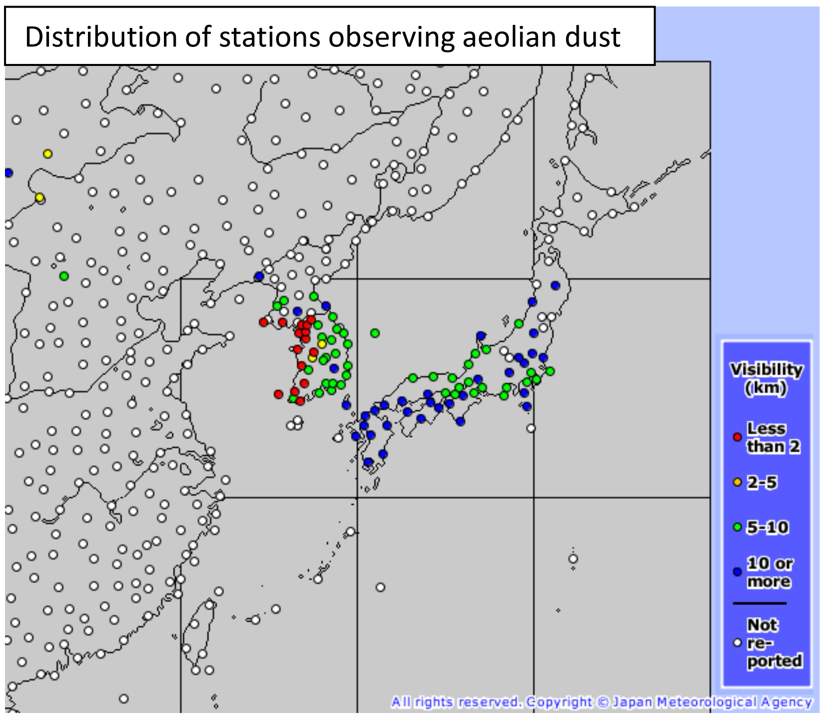
The dust emission flux is proportional to the cube of the wind speed.

Updates of the operational global aerosol forecast model

	Old operational global dust forecast model	Current 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)

- Statistical verification -
Visibility and meteorological conditions

- JMA operates 59 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 -
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.

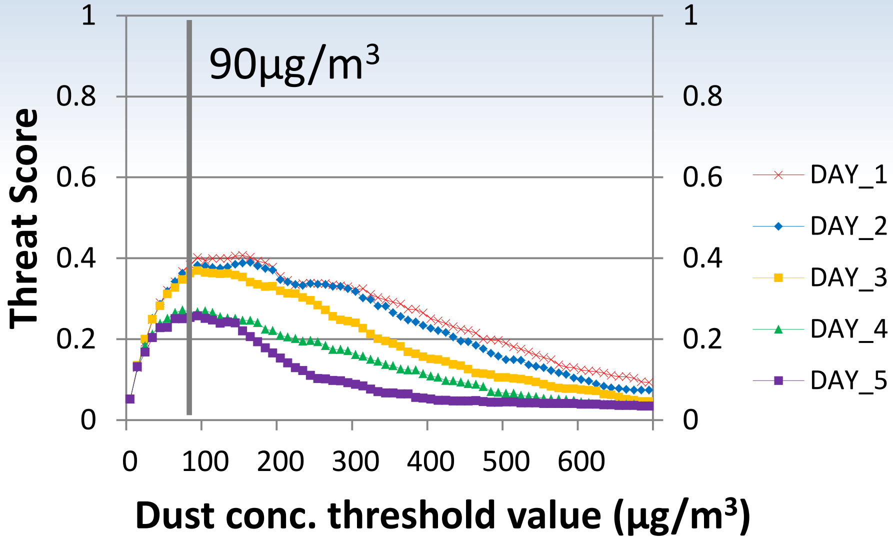
$$\text{False Alarm Ratio} = \frac{FX}{FO + FX}$$

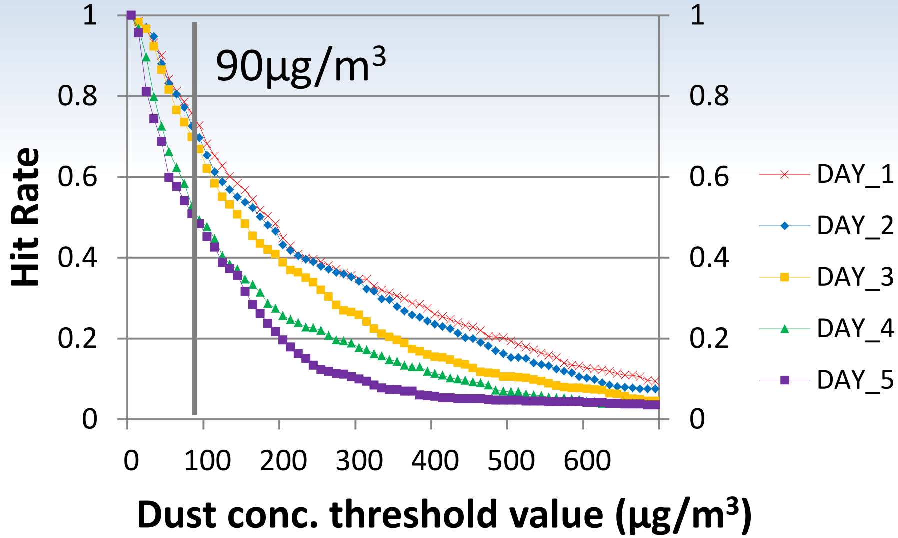
It's the fraction of forecasts that are wrong, i.e., are false alarm.

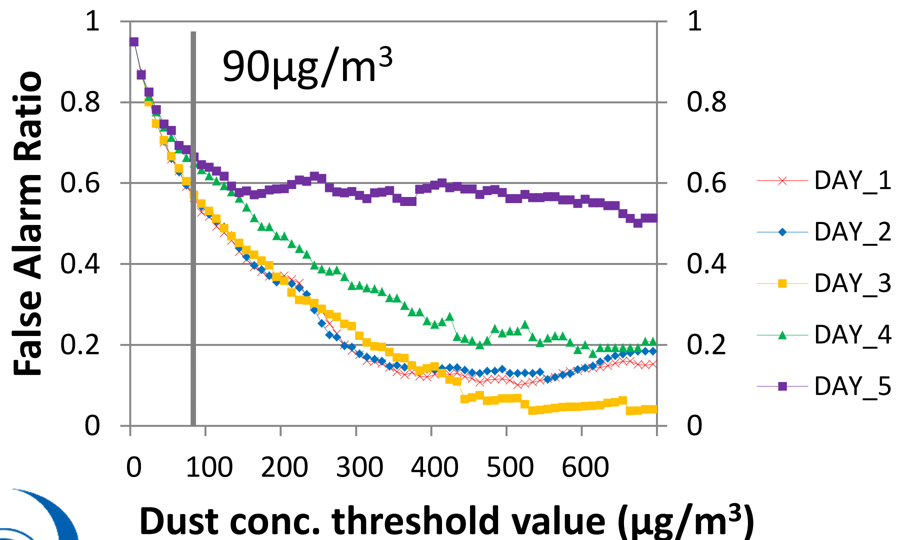
$$\text{Percent Correct} = \frac{FO + XX}{FO + XO + FX + XX}$$

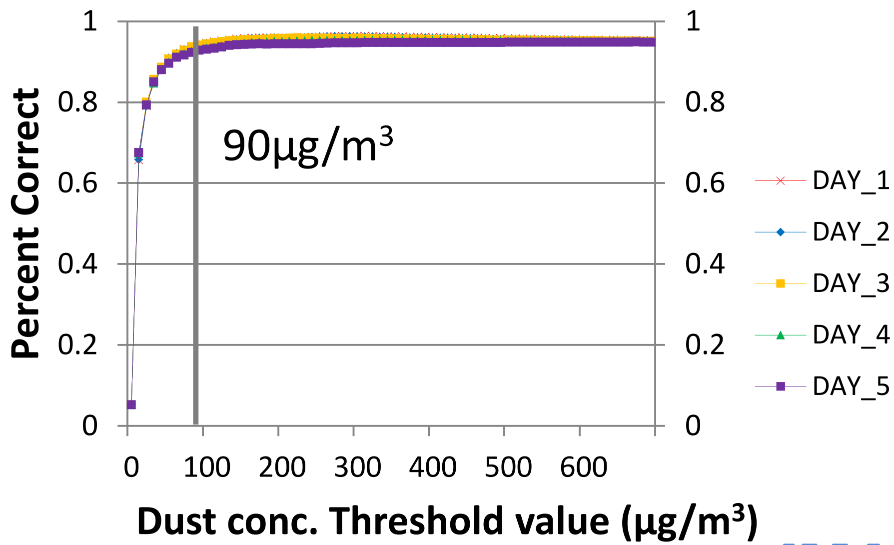
It's the fraction of forecasts that are correct.

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





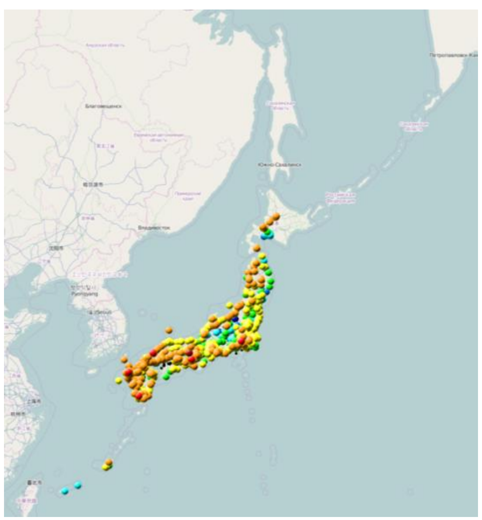




- Quantitative verification -
Predicted dust concentration against surface SPM observation

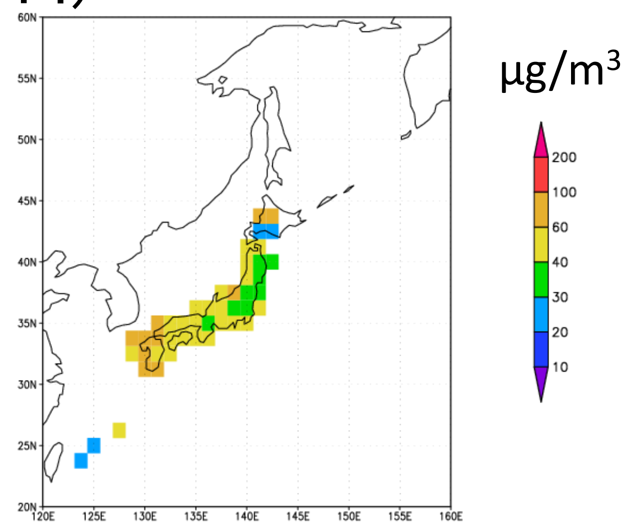
We use the data that the Ministry of Environment has been operating as the Atmospheric Environmental Regional Observation System called "Soramame-kun" to compare observed surface SPM and predicted dust concentration. We convert the SPM data at each stations into grid point data to match the model grid.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

(Verification period : March–May 2010–2014)



Observed SPM raw data

grid



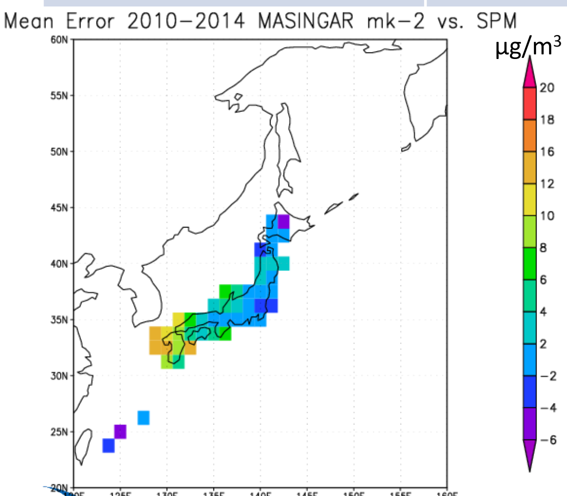
Observed SPM grid data

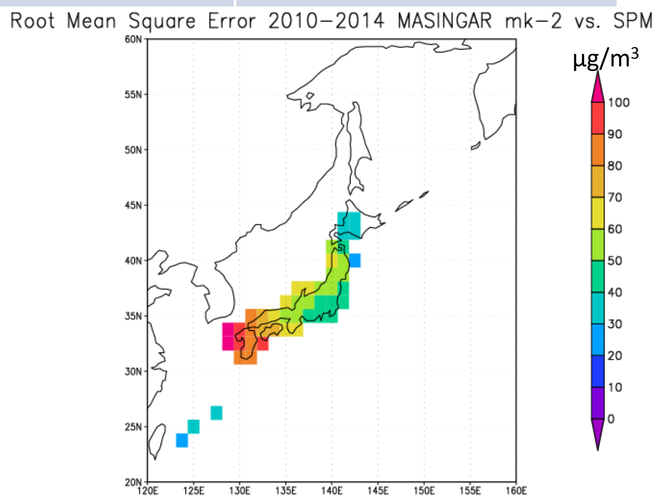
- Quantitative verification -
Predicted dust concentration against surface SPM observation

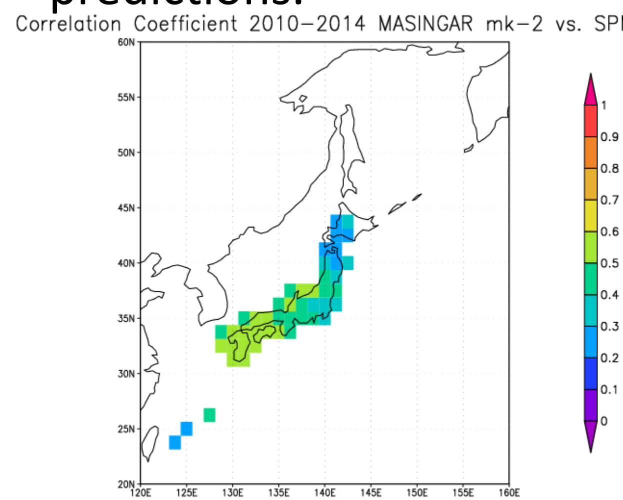
All over Japan (Ave. Mar.-May. 2010-2014)

Statistics	MASINGAR	MASINGAR mk-2
Mean Error (ME)	20.96 (μg/m^3)	3.33 (μg/m^3)
Root Mean Squared Error (RMSE)	82.50 (μg/m^3)	59.91 (μg/m^3)
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.



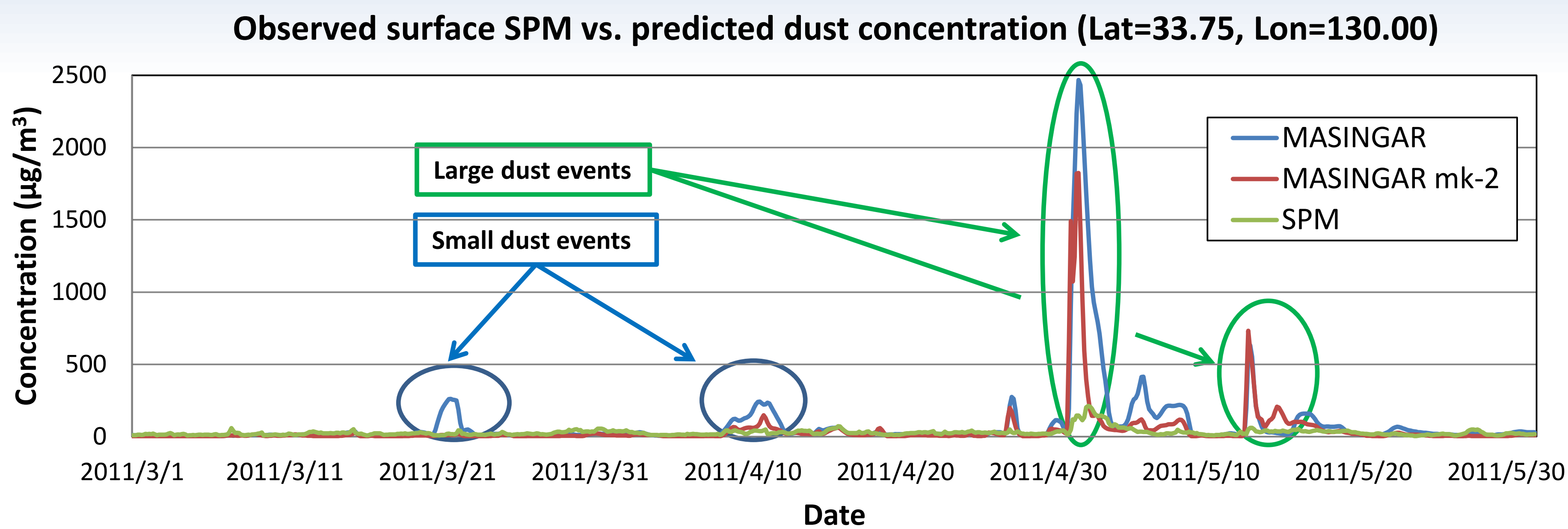




Statistics for each grid map (ME, RMSE, CC)

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

※Near Fukuoka city (in 2011)



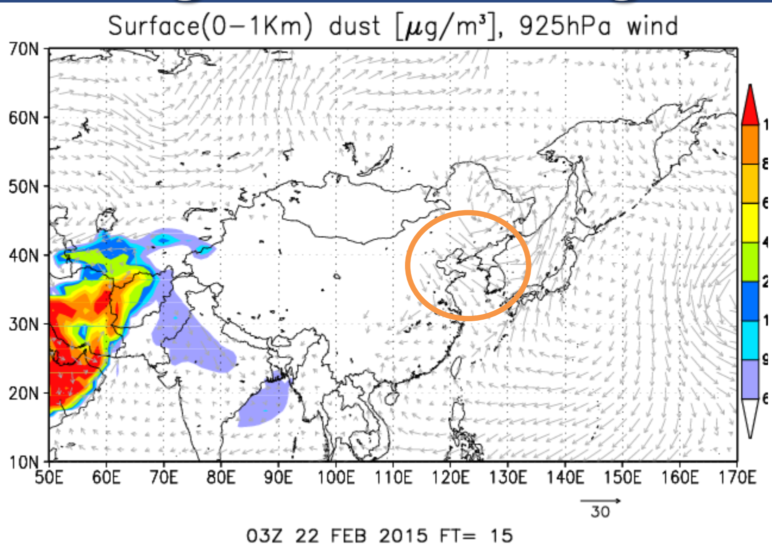
- During small dust events, the current model values show good agreement with observations. On the other hand, the predicted dust concentration is still overestimated during large dust events.

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

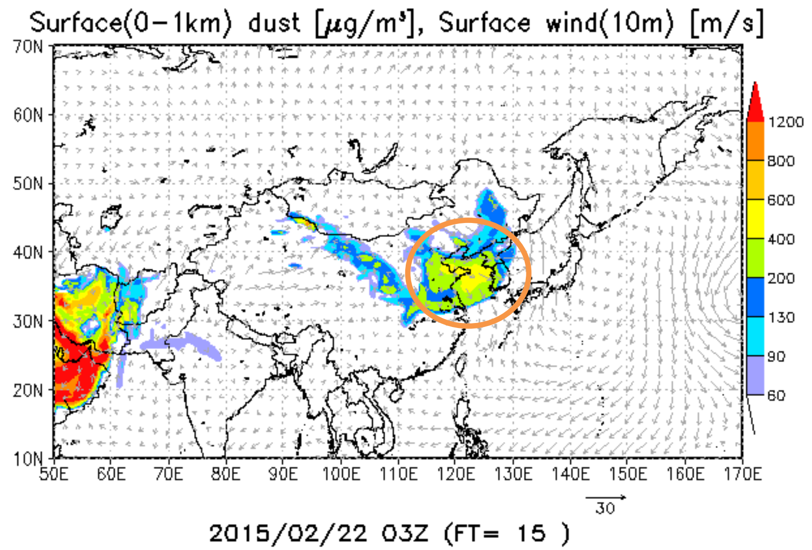
Near Fukuoka city (Ave. Mar.-May. 2010-2014)

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

High-resolution global aerosol forecast model



TL159L40 (~110km)



TL479L40 (~40km)