

Urban air quality predictions with 1km horizontal resolutions using WRF-CMAQ model and Himawari data

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Acknowledgements to Suuri-Keikaku Co., Ltd.

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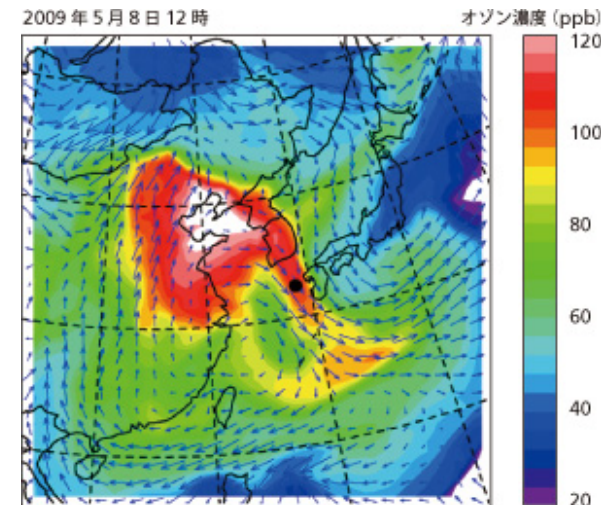


Background

- Health damage due to the air pollution:
A report by WHO (2014) describes that PM2.5, tropospheric ozone, NOx etc. cause the health damage such as lung trouble and cerebrovascular disease, which killed ~3.7 million people in the world in 2012.
(actually more serious than the traffic accident)
- Situation of Japan (especially Kyushu):
Seriously affected by the 'cross-border pollution' from the continent (50% of PM2.5 and tropospheric ozone come from outside Japan), so we need to cover the wide range (at least the whole Asia) in the pollution prediction system.



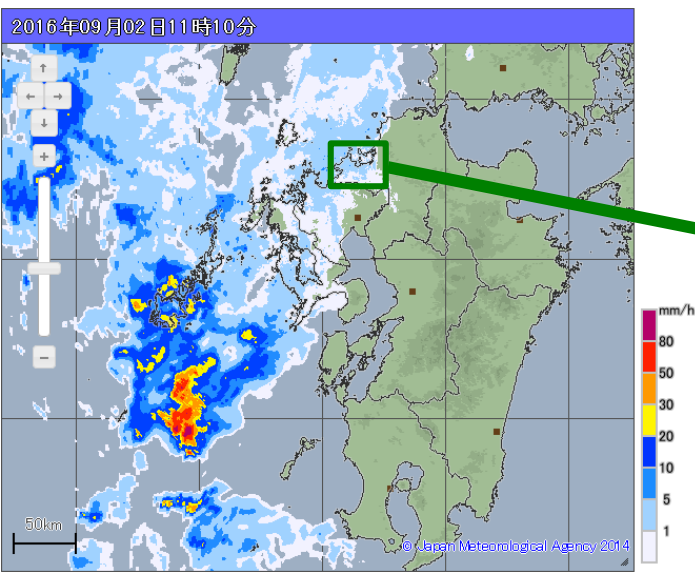
‘Cross-border pollution’
of tropospheric ozone
[Kanaya, 2013]



Our target: towards the urban prediction

- We need to make it possible to predict with very high horizontal resolution, which can divide into municipalities or even streets.
- Also the system needs to cover the whole Asia to well reflect the effects of the 'cross-border pollution'.

Like the 'High-resolution precipitation now cast' [JMA, Japan]



It would be the world's first attempt, as the air pollution predictions up to now (research level) are for only wide ranges (e.g. Asia, Europe, North America).

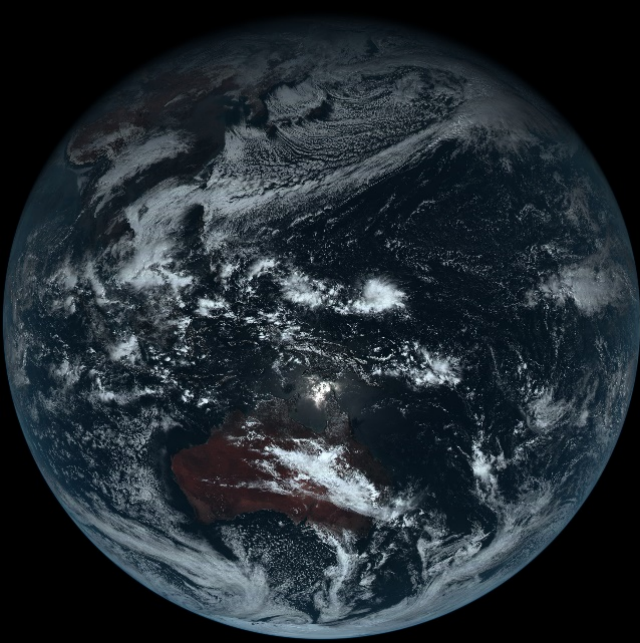
Fukuoka
(the biggest city in Kyushu)



Central Fukuoka



Advanced Himawari Imager (AHI) onboard Himawari 8



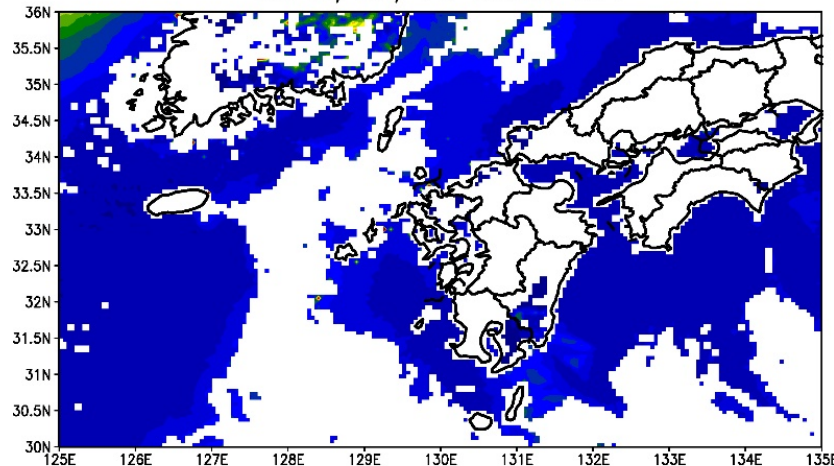
- Observational range: 60°N - 60°S , 80°E - 160°W
- Horizontal resolution: 0.05° ($\sim 5\text{km}$)
- Time resolution: 10 minutes
- Observational parameter:
aerosol optical depth,
angstrom parameter

Advanced Himawari Imager (AHI) onboard Himawari 8

Opacity

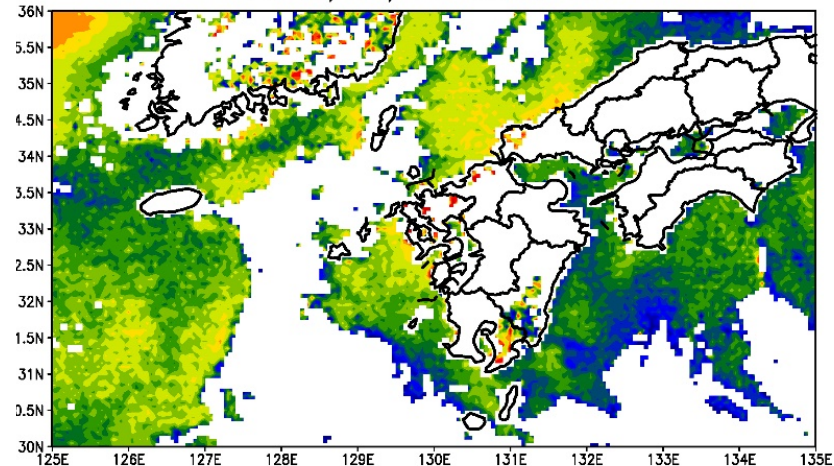
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(Clear)



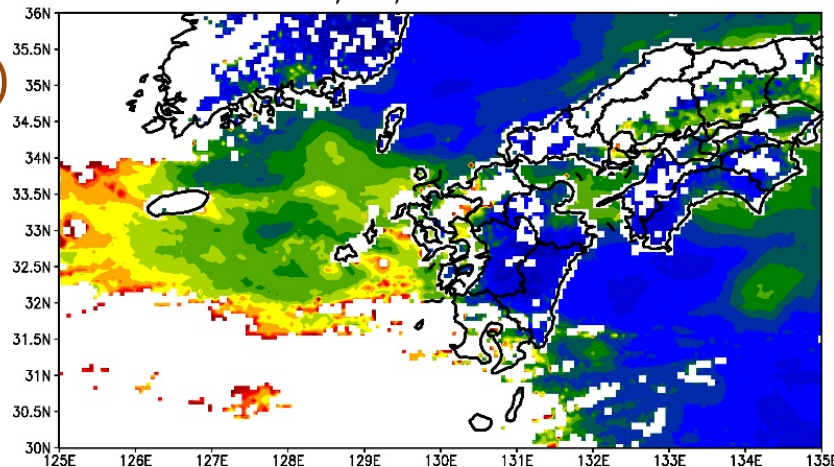
Angstrom parameter

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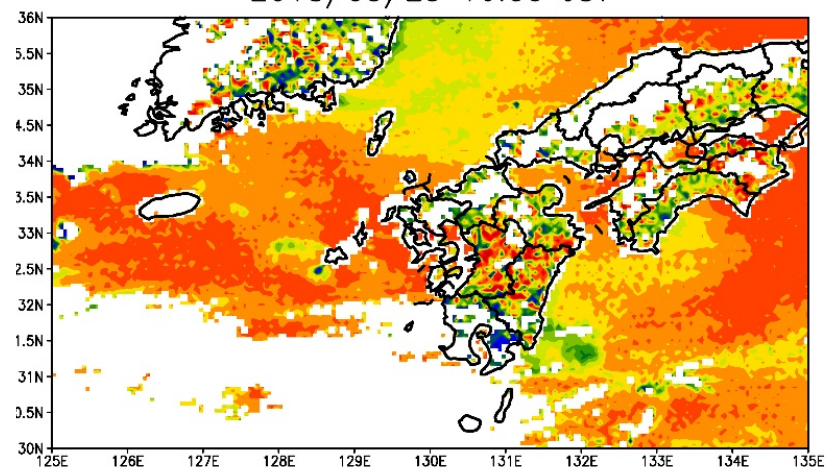


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(Polluted)

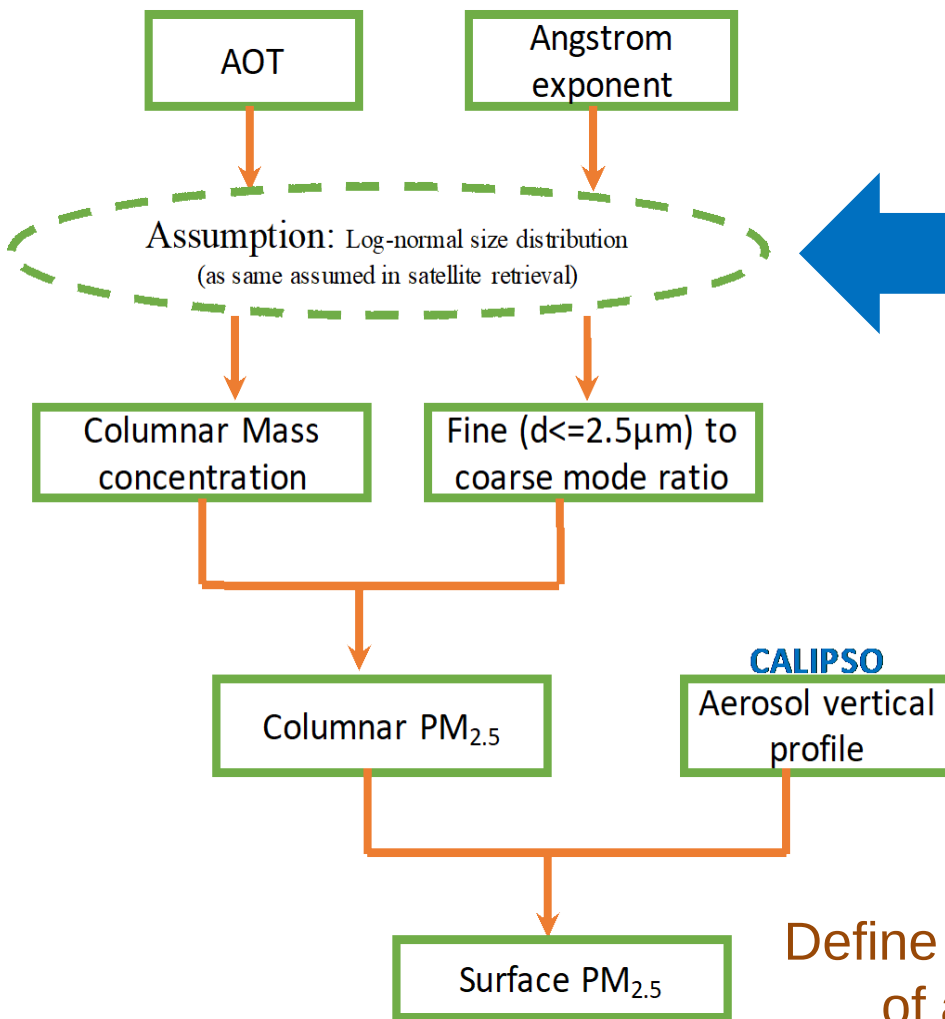


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Himawari 8 data -> surface PM2.5 abundance

Algorithm assuming a bimodal size distribution
[Higurashi and Nakajima, 1999]



Particle size distribution

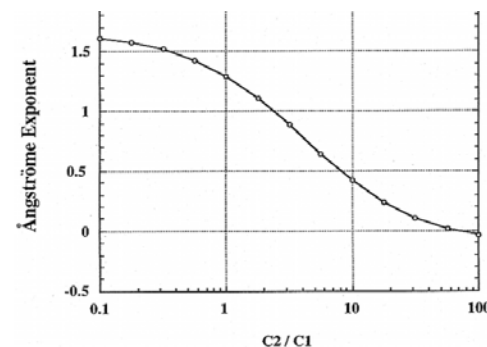
$$\frac{dV}{d \ln r} = \sum_{n=1}^2 C_n \exp \left[-\frac{1}{2} \left(\frac{\ln r - \ln r_{nm}}{\ln s_n} \right)^2 \right], \quad (10)$$

$$r_{m1} = 0.17 \mu\text{m}, r_{m2} = 3.44 \mu\text{m}, s_1 = 1.96, \text{ and } s_2 = 2.37$$

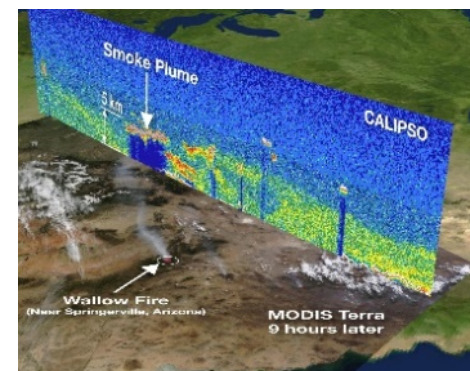
Refractive index

$$1.5 - 0.005i$$

Relationship between C2/C1 and Angstrom exponent

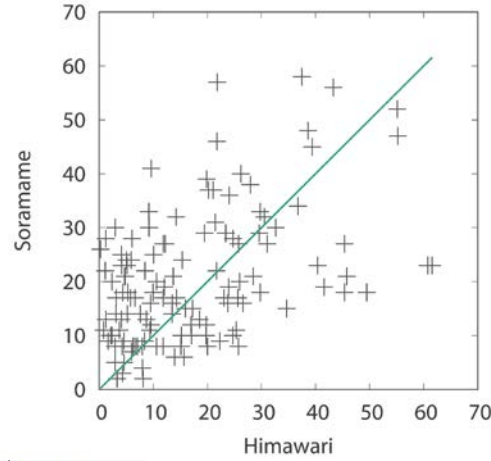


Define the vertical profiles
of aerosols for 1° bins
from CALIPSO
observations by NASA



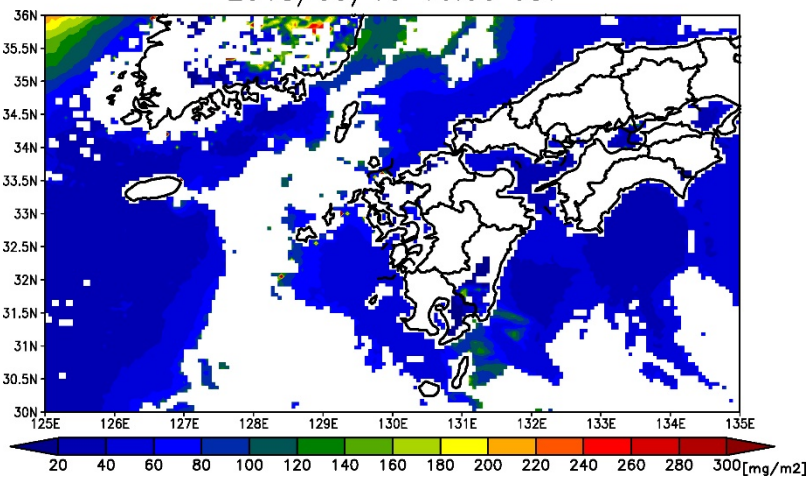
Derived surface PM2.5 abundance

Correlation with ground observations
(by Soramame of MOE, $r=0.4701$)



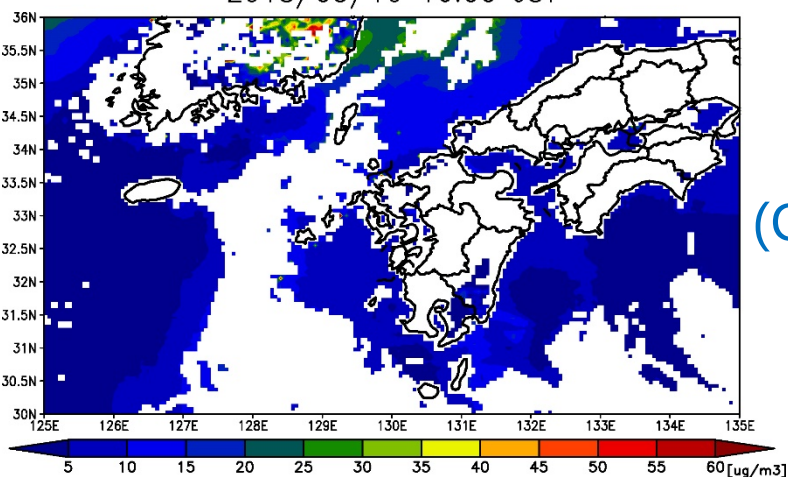
PM2.5 column density

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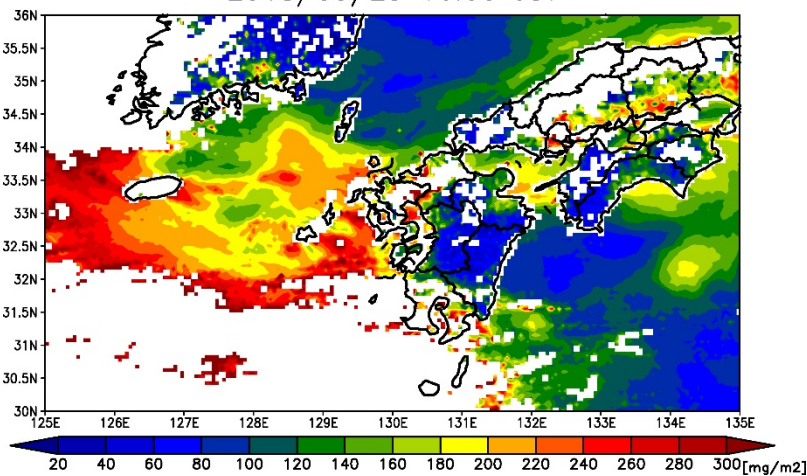
Surface PM2.5 abundance

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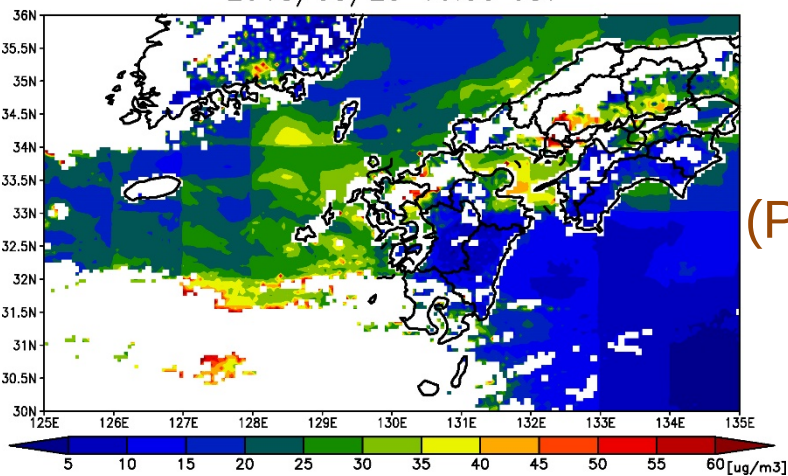


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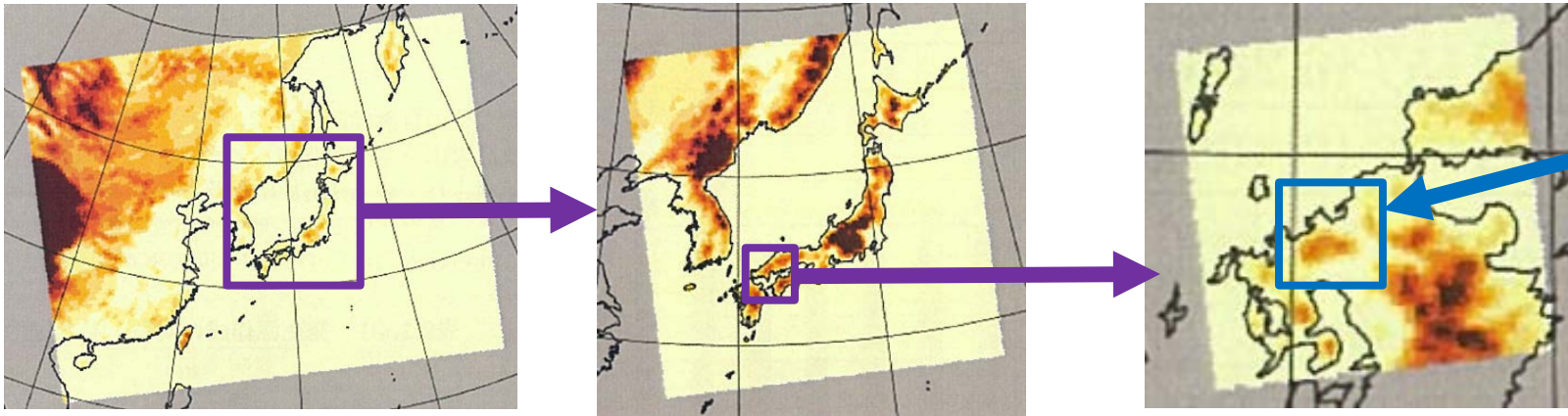
Simulation with 1km horizontal resolution with WRF-CMAQ (no assimilation), for Fukuoka city

Domain 1 (40km res.)

Domain 2 (20km res.)

Domain 3 (5km res.)

Domain 4
(1km res.)

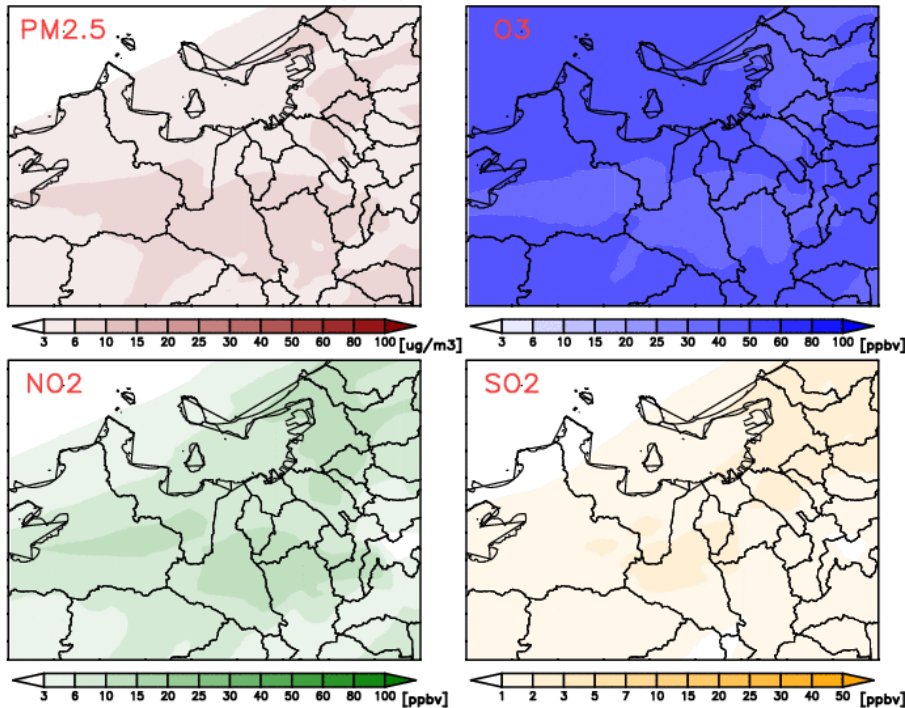


- Anthropogenic emission (SO_2 , NO_x , PM, VOC, CO, NH_3): from MIX Asian emission inventory (based on 2010 data with annual correction for each country to estimate the emissions in 2015)
- Plant emission (VOC): from MEGAN simulation (Plant Functional Type definition from MODIS database)
- Nudging NCEP FNL reanalysis data (T, u, v, q; 1 deg in horizontal, 6 hours in temporal)

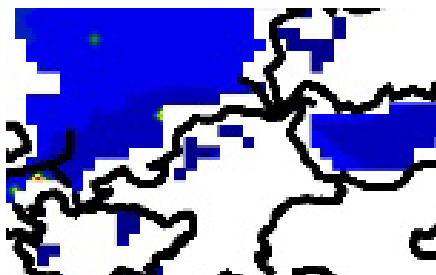
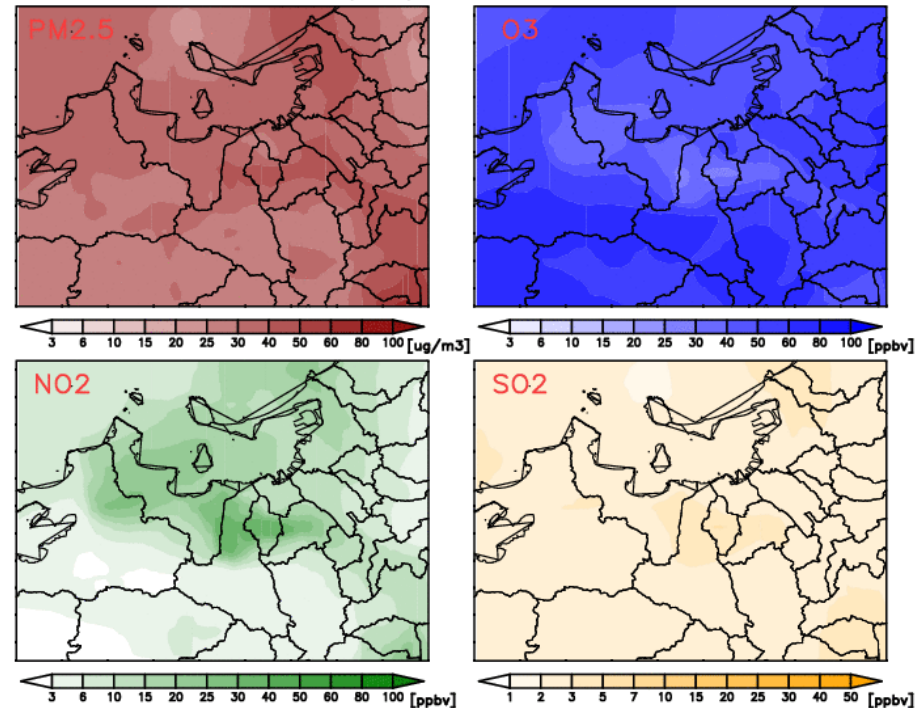
Simulation with 1km horizontal resolution with WRF-CMAQ (no assimilation), for Fukuoka city

(Clear) (Polluted)

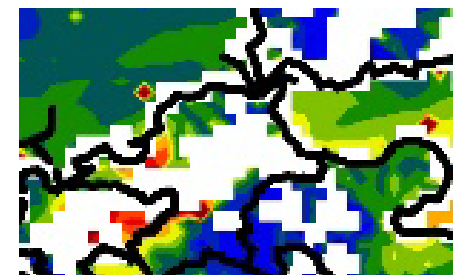
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Surface PM2.5 from Himawari

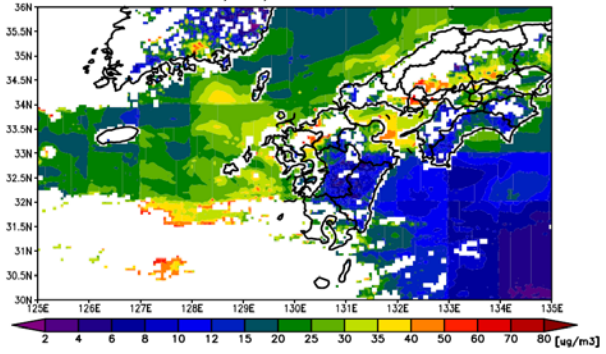


Next step: Assimilation to the model

Surface PM2.5

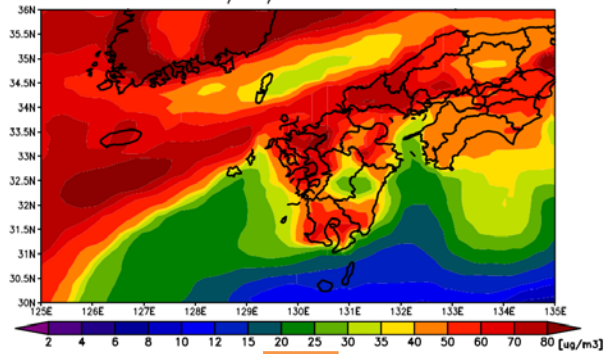
Himawari

2018/03/25 16:00 JST



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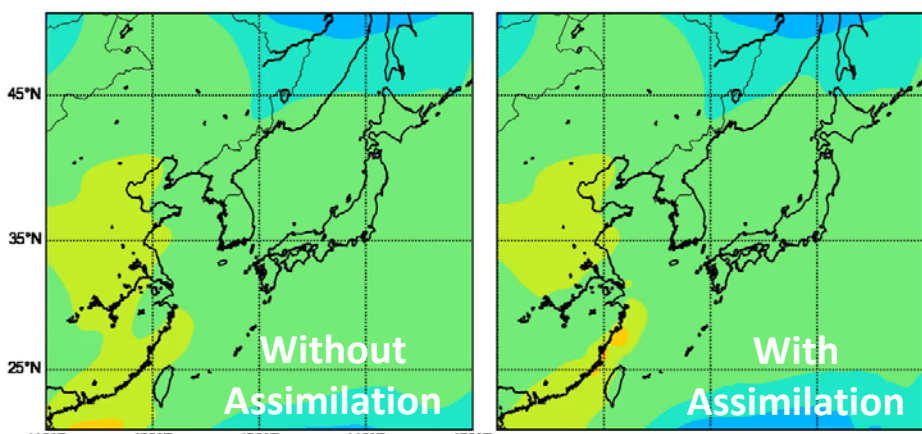
CMAQ



?

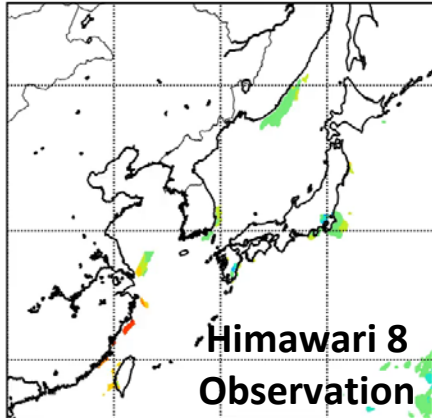
Nudging Himawari 8 AOT data
to NICAM-SPRINTARS
(Kuroda et al., in preparation)

2016-03-01 10:00 JST



Aerosol Opacity

0.02 0.03 0.05 0.07 0.10 0.20 0.30 0.50 0.70 1.00



Summary

- For the construction of health care system due to air pollution, we need a prediction system with very high horizontal resolution at the target region.
- Also the prediction system should cover the wide (global) region, because the effects of 'cross-border' pollution are important.
- Himawari 8 observes the 2D aerosol opacity distributions of the wide range in east Asia with the horizontal resolution of $\sim 5\text{km}$ and time resolution of 10 minutes, which would be good to use the prediction of the cross-border pollution.
- We have an algorithm to derive the surface PM_{2.5} abundance from Himawari 8 data, and the simulation with 1km horizontal resolution at Fukuoka city with WRF-CMAQ is available.
- We plan to assimilate the Himawari data to our WRF-CMAQ, and verify the forecasting of air quality in Fukuoka.