

Long-Range-Transported Mineral Dust from Africa and Middle East to East Asia Observed with the Asian Dust and Aerosol Lidar Observation Network (AD-Net)

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AD-Net, the Asian dust and aerosol lidar observation network

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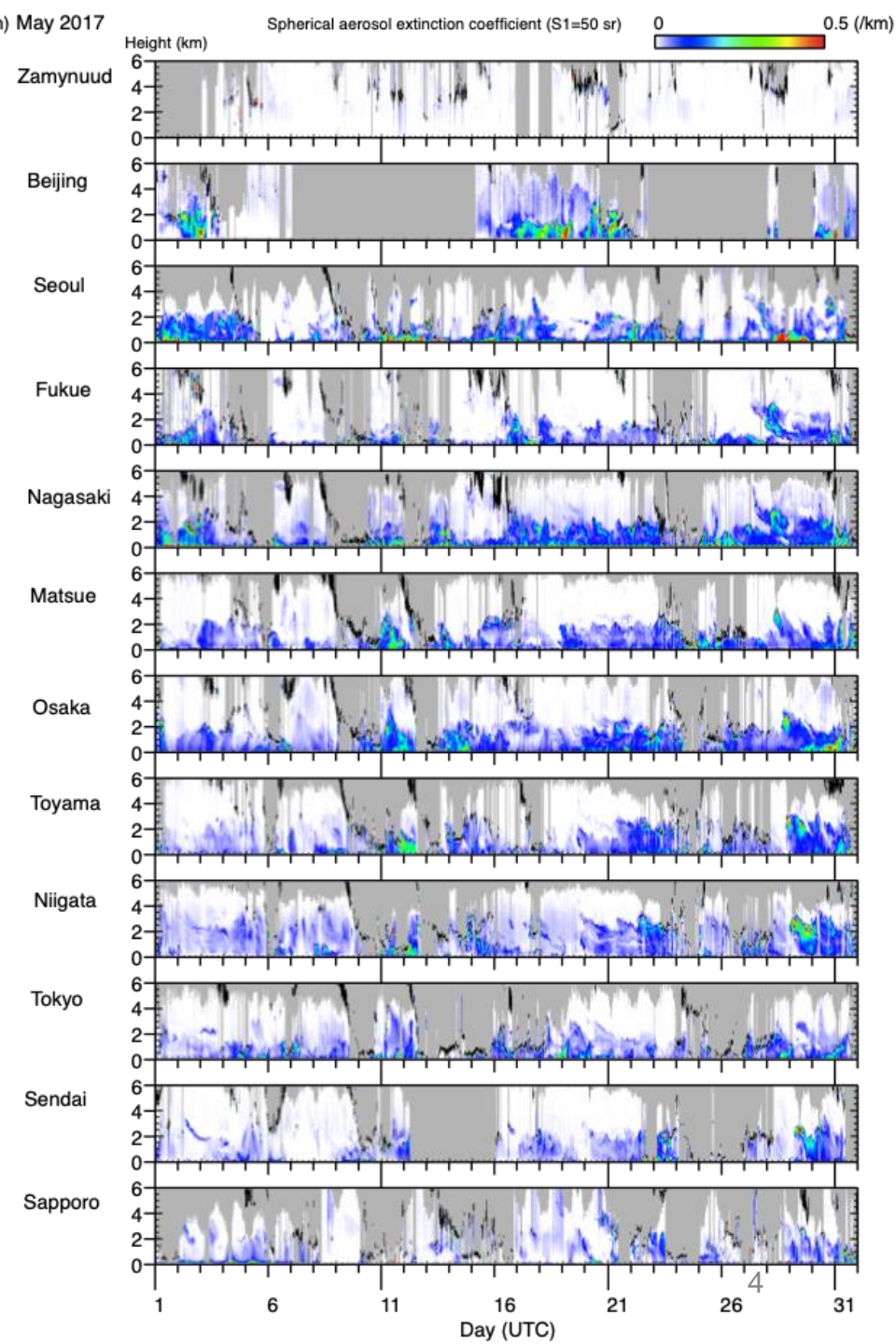
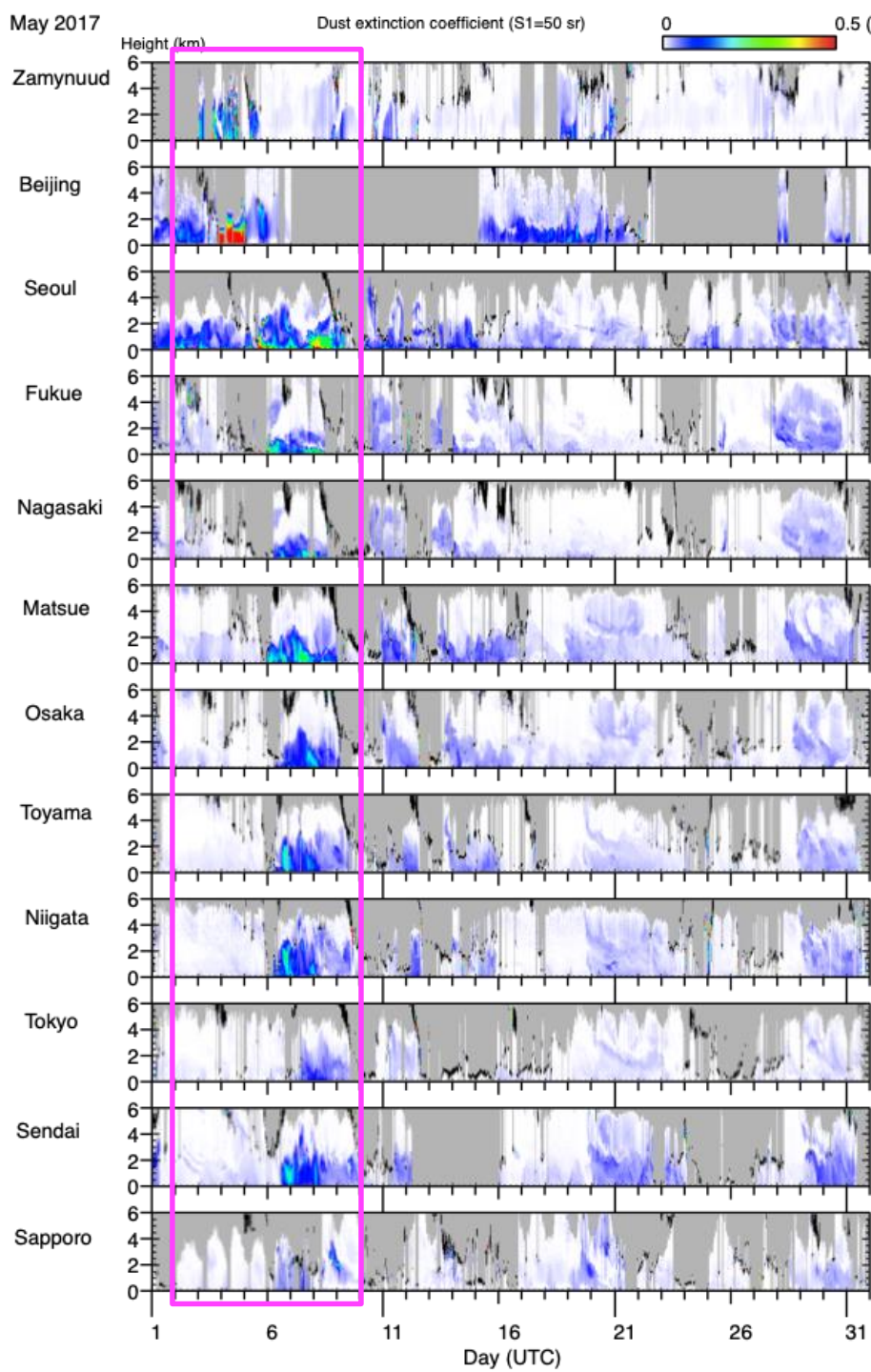
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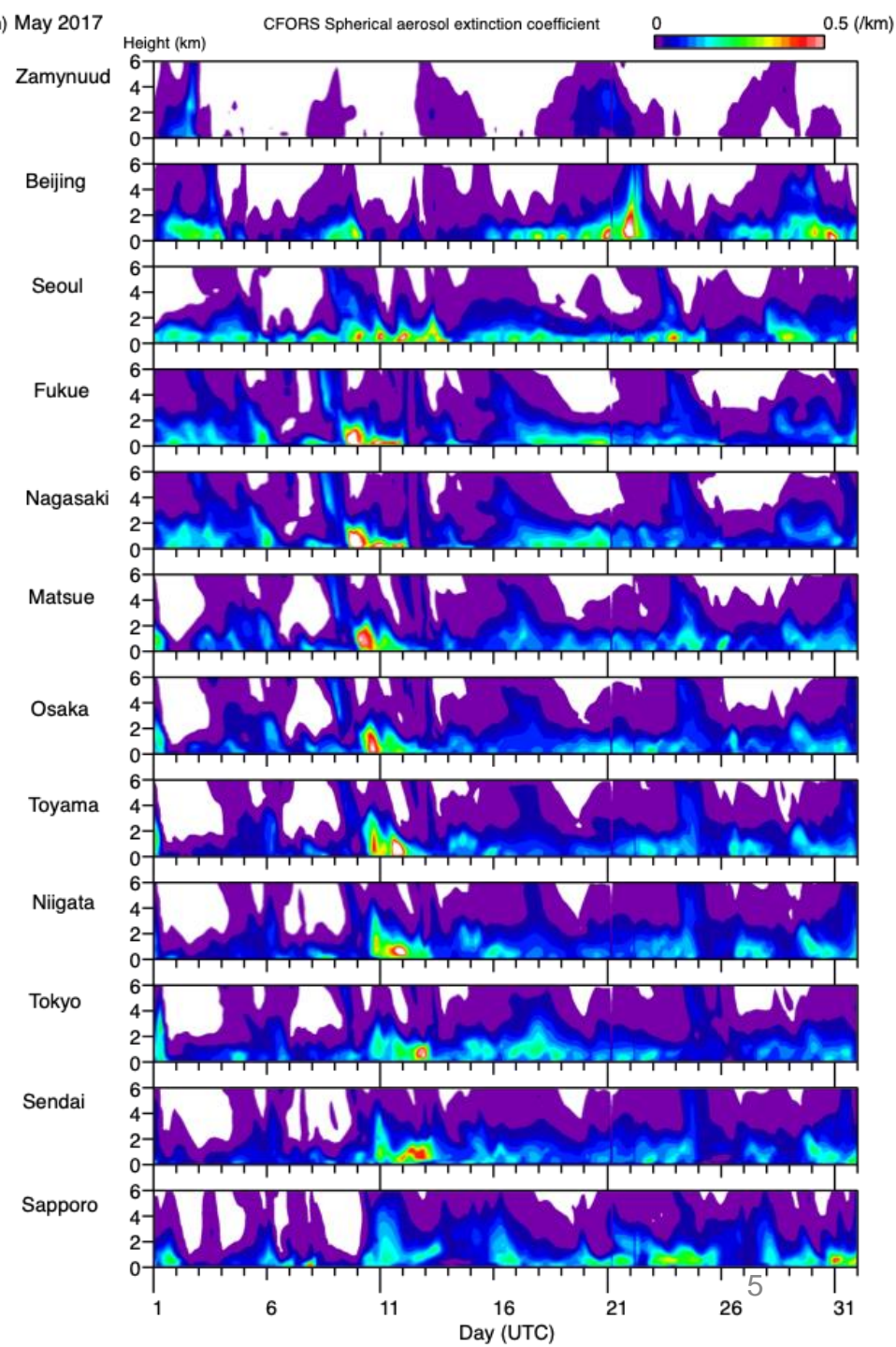
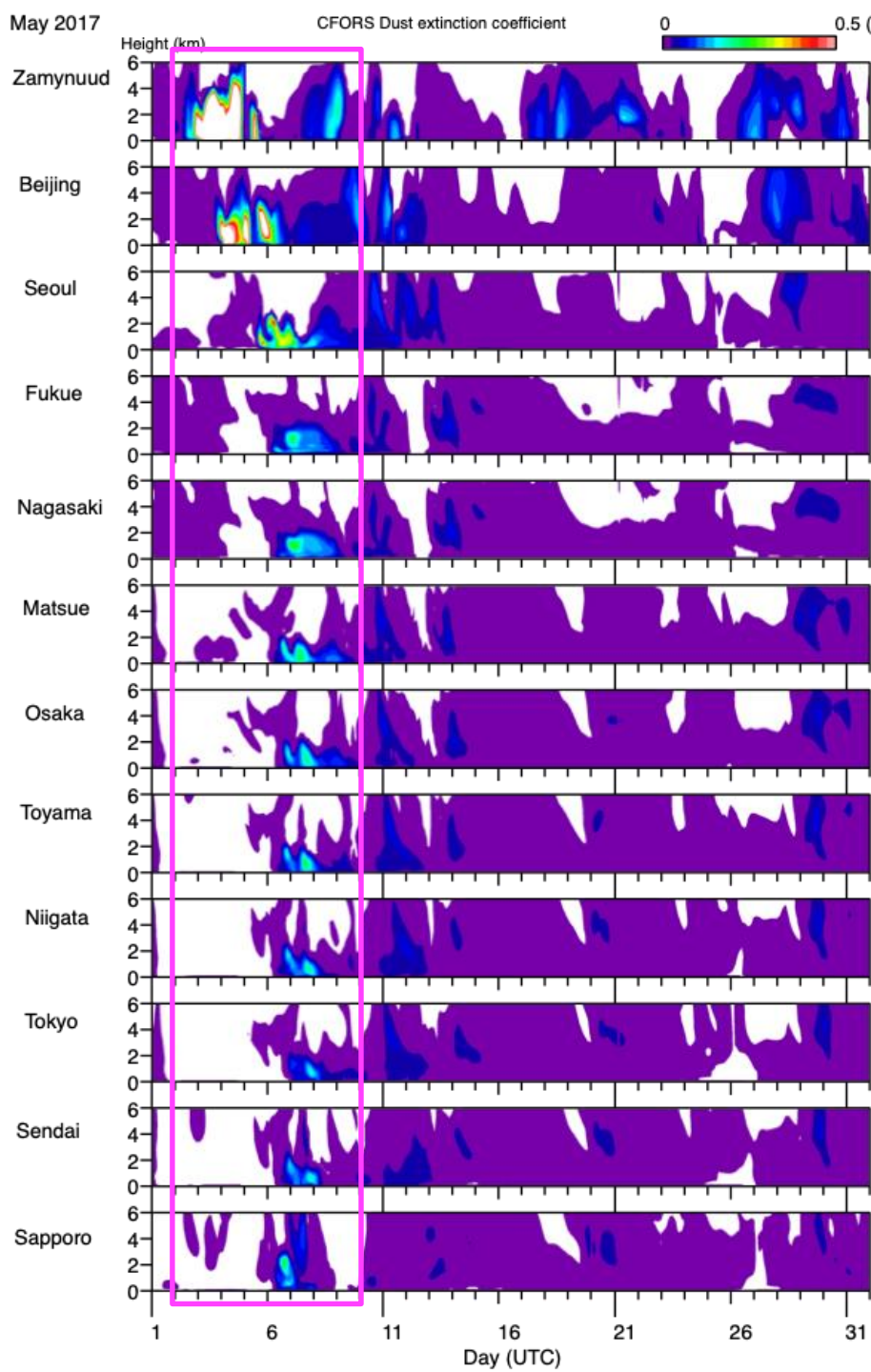
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Continuous observations with multi-parameter lidars





Taklamakan
Gobi
Loess Plateau

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2018 Google
Image Landsat / Copernicus
US Dept of State Geographer

Google Earth

Imagery Date: 12/14/2015 lat 34.384987° lon 104.687174° elev 3304 m eye alt 5509.15 km

Long-range transport of dust from Africa and Middle East to East Asia

Background

- **Tanaka, T. Y.**, Y. Kurosaki, M. Chiba, T. Matsumura, T. Nagai A. Yamajaki, A. Uchiyama, N. Tsunematsu, and K. Kai, 2005: Possible transcontinental dust transport from North Africa and the Middle East to East Asia, *Atmos. Environ.*, 39, 3901–3909. (...Analysis of a dust event in 2003.)
- Tazaki, K., R., Wakimoto, Y. Minami, M. Yamamoto, K. Miyata, K. Sato, I. Saji, S. K. Chaerun, G. Zhou, and T. Morishita, 2004: Transport of carbon-bearing dusts from Iraq to Japan during Iraq's War, *Atmos. Environ.*, 38, 2091–2109. (...Polluted carbon particle from oil field burning.)
- Park, C.-B. **N. Sugimoto**, I. Matsui, A. Shimizu, B. Tatarov, A. Kamei, C.-H. Lee, I. Uno, T. Takemura, **D. L. Westphal**, Long-Range Transport of Saharan Dust to East Asia Observed with Lidars SOLA 1, 121 (2005). (...Lidar observations and analysis of a Sahara dust event in 2005.)

Motivation of this work:

- Central Asian DUst Conference (CADUC) 8-12 April 2019, Dushanbe, Tajikistan (organized by TROPOS)
- CADEX (Central Asian Dust EXperiment) (2015-2016) and recently started continuous observation in Dushanbe by TROPOS.
- It would be interesting if we could observe the same air mass along the transport path to study the change in optical characteristics of dust.
- Recent studies of bioaerosols (microbes attached to dust particles) suggest such long-range transport might be important even if the density of the transported dust is low.

Method

We used the archived NAAPS results to find possible long-range-transported dust cases to East Asia.

We then searched corresponding plumes in AD-Net data.

When we found the corresponding dust plume, we performed backward trajectory analysis using NOAA HYSPLIT.

We confirmed dust transport using the CALIPSO browse data when available.

We studied the dust source areas for the observed plumes using MASINGAR-mk2 calculated separately for different dust source areas.

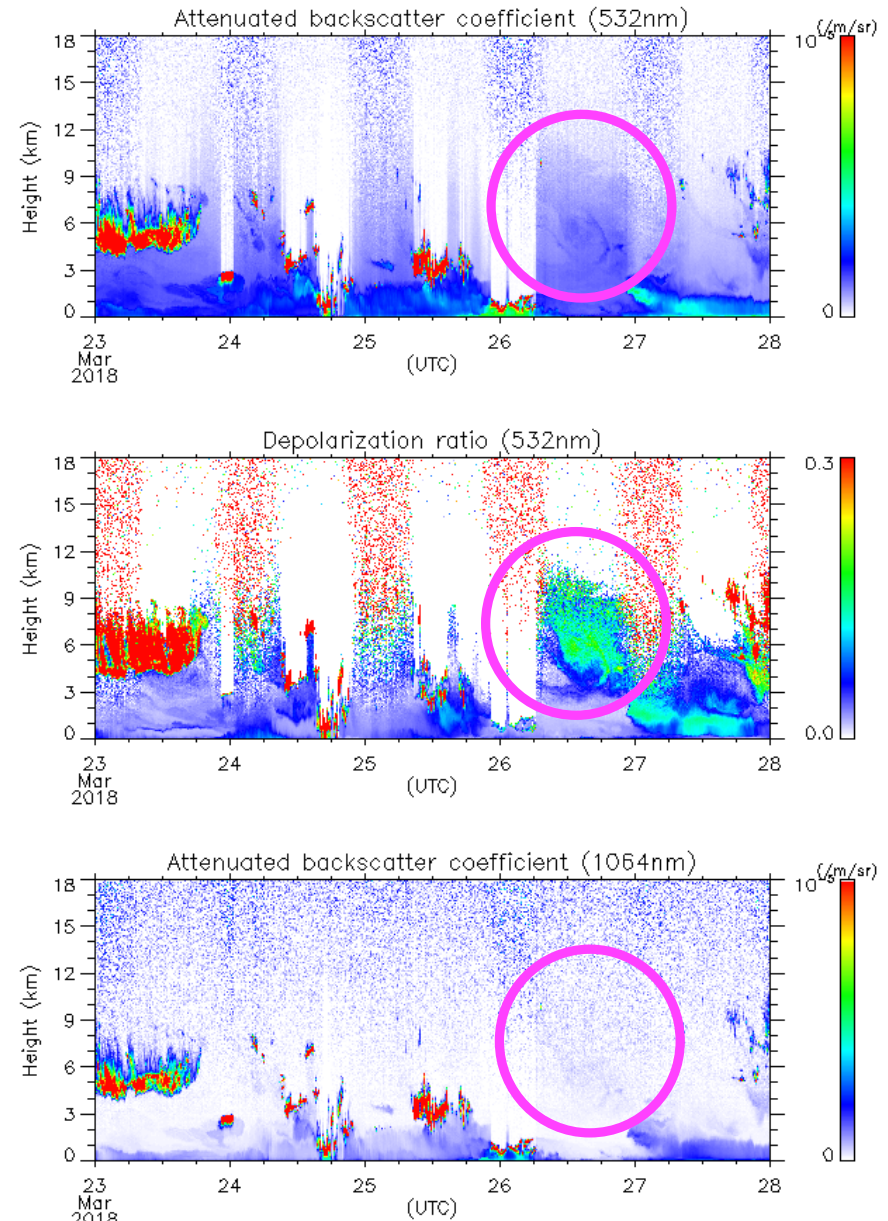
March 2018

Sahara dust, stained snow in Sochi into orange, reached Sapporo 4 days later.

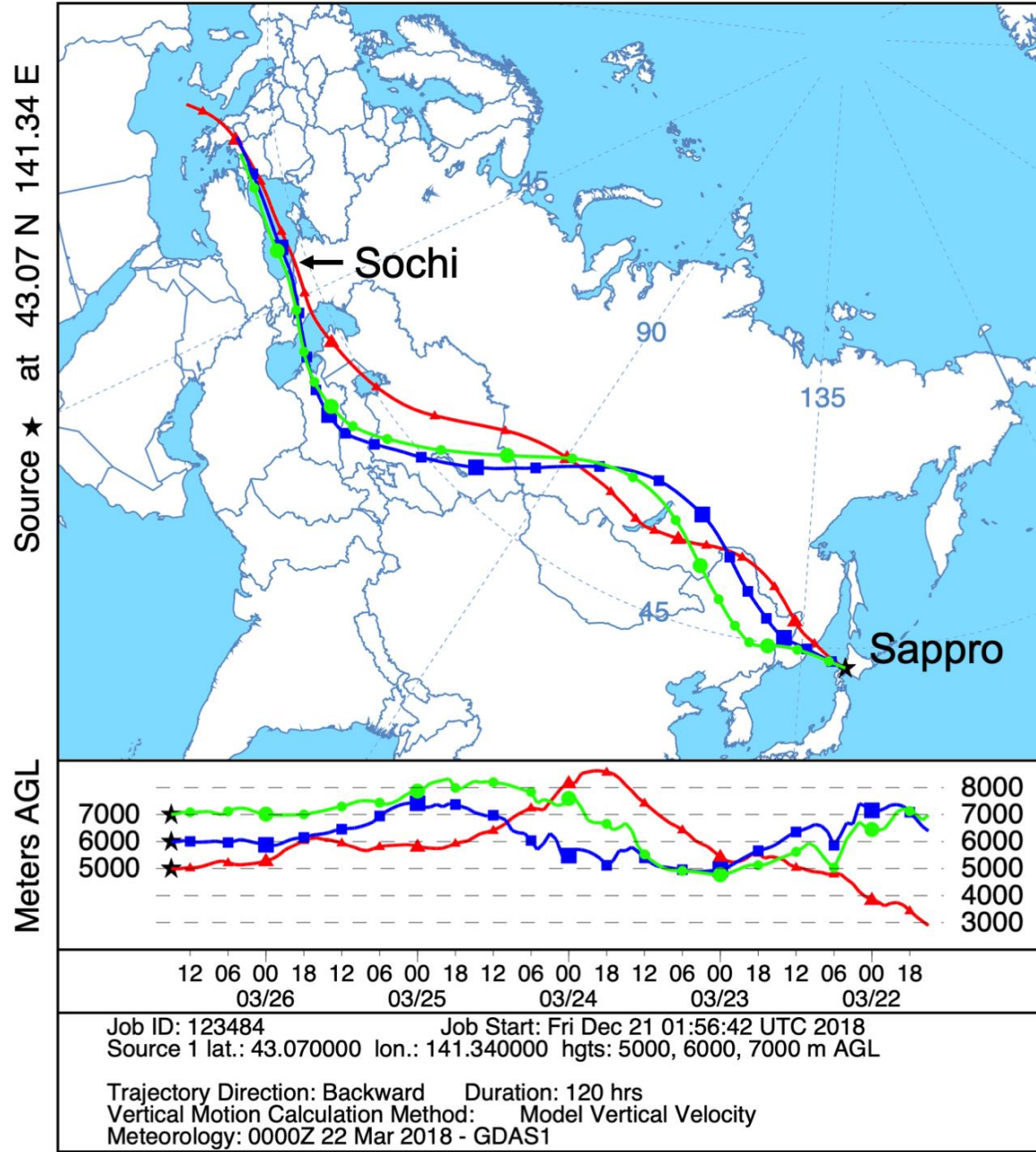


A skiing ground in Sochi, March 23, 2018.
(from National Geographic www page)

Lidar Observation in Sapporo

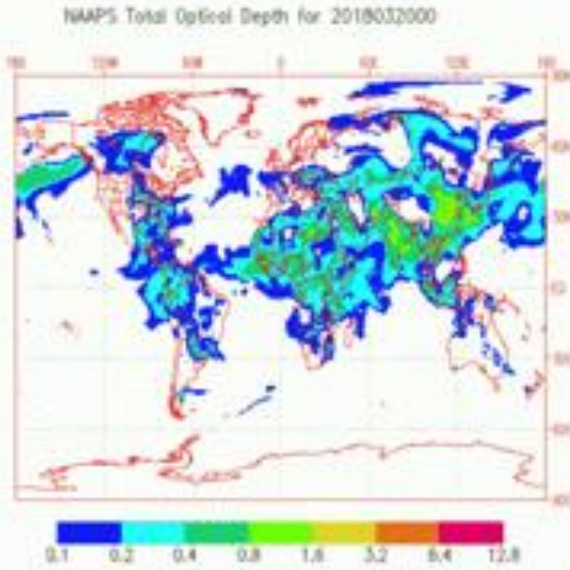


NOAA HYSPLIT MODEL
 Backward trajectories ending at 1500 UTC 26 Mar 18
 GDAS Meteorological Data

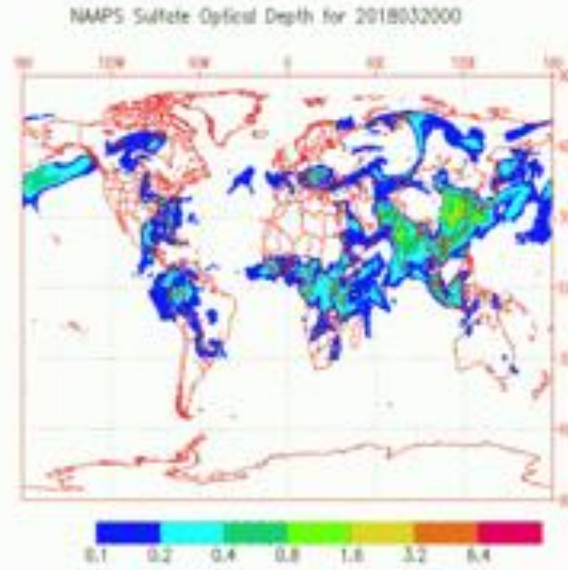


NRL NAAPS

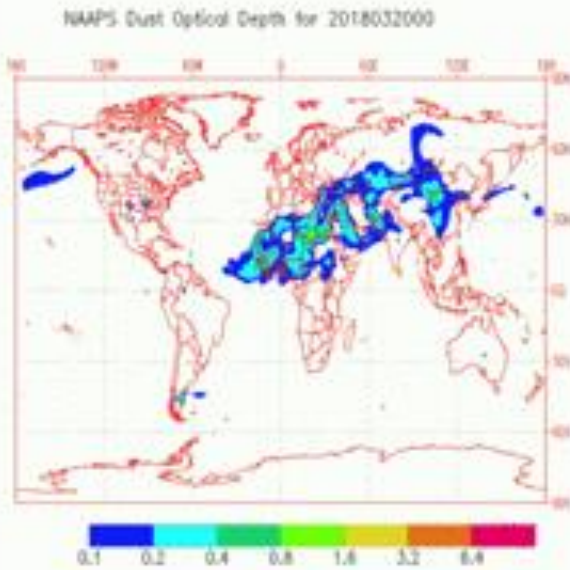
Total AOD



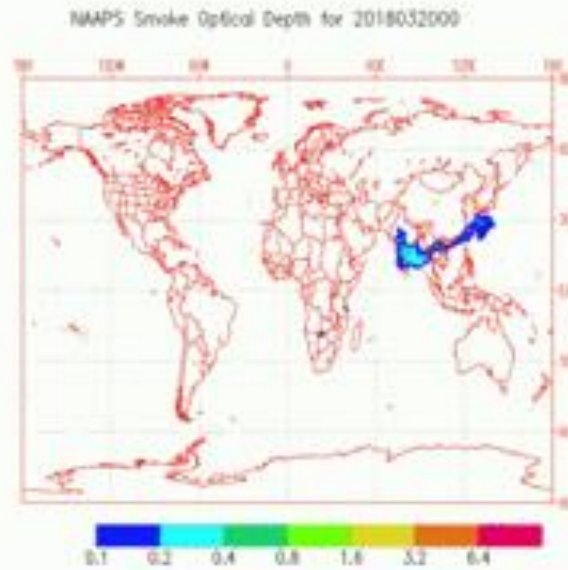
Sulfate AOD



Dust AOD

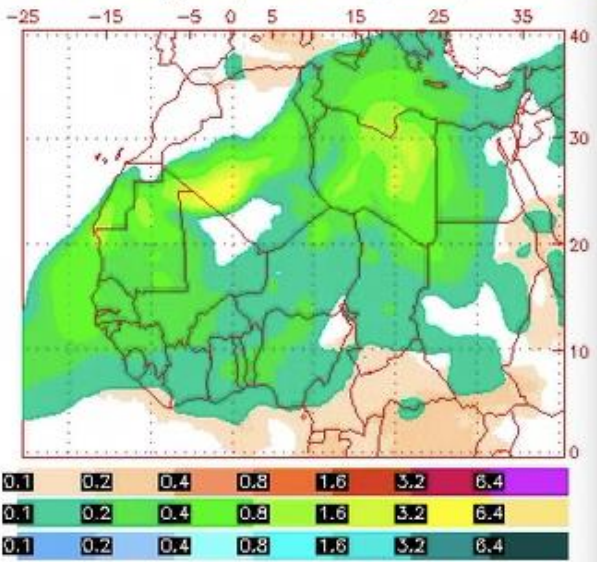


Smoke AOD

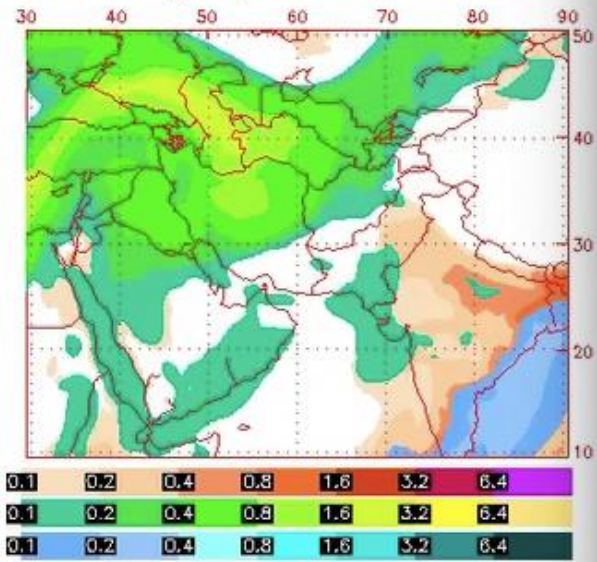


NRL NAAPS

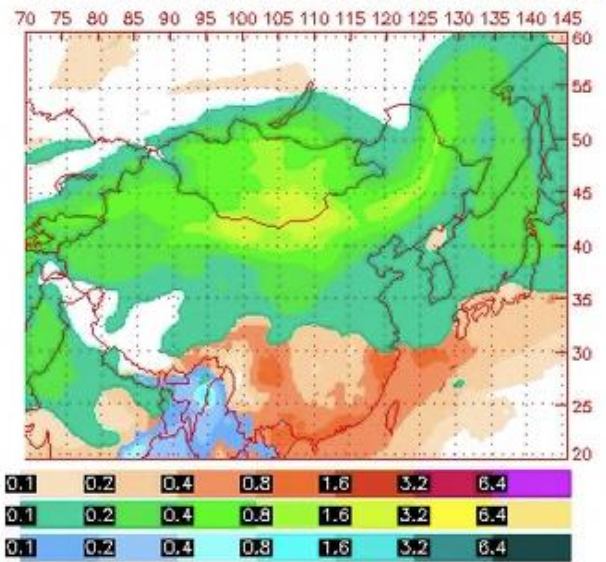
NAAPS Total Optical Depth for 12:00Z 21 Mar 2018
Sulfate: Orange/Red, Dust: Green/Yellow, Smoke: Blue



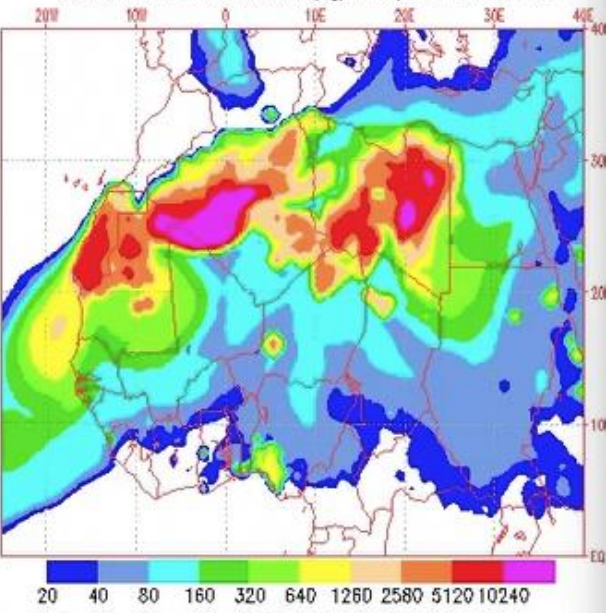
NAAPS Total Optical Depth for 18:00Z 23 Mar 2018
Sulfate: Orange/Red, Dust: Green/Yellow, Smoke: Blue



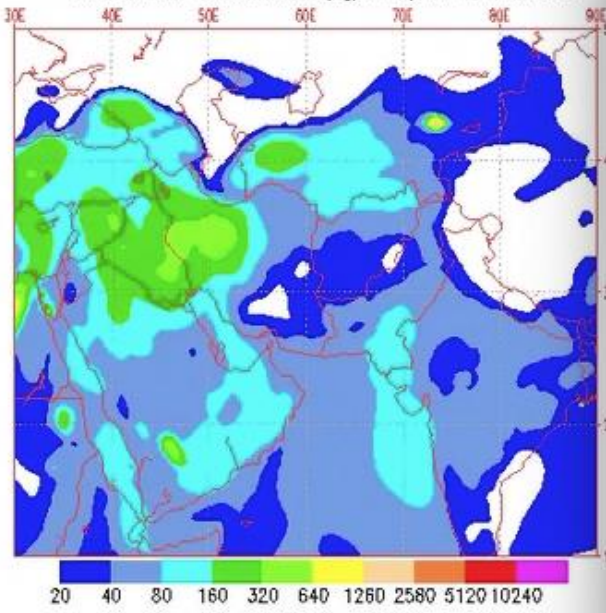
NAAPS Total Optical Depth for 12:00Z 26 Mar 2018
Sulfate: Orange/Red, Dust: Green/Yellow, Smoke: Blue



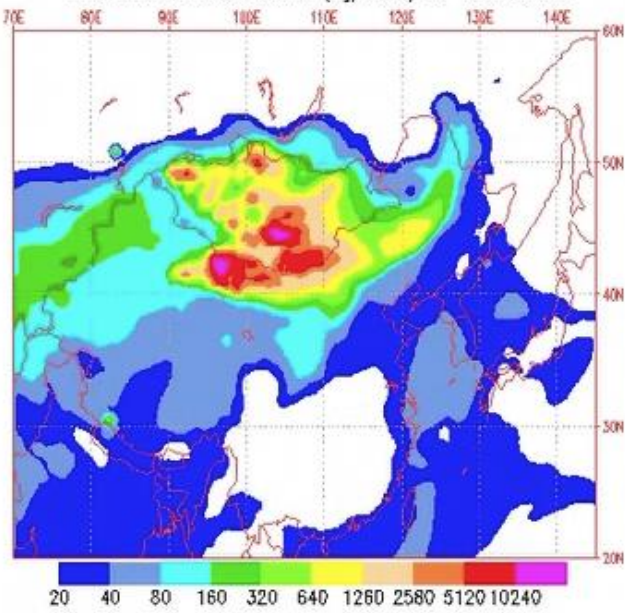
Dust Surface Concentration ($\mu\text{g}/\text{m}^3$) for 2018032112



Dust Surface Concentration ($\mu\text{g}/\text{m}^3$) for 2018032318



Dust Surface Concentration ($\mu\text{g}/\text{m}^3$) for 2018032612



'Made Thu Mar 22 04:56:13 UTC 2018 NRL/Monterey Aerosol Model

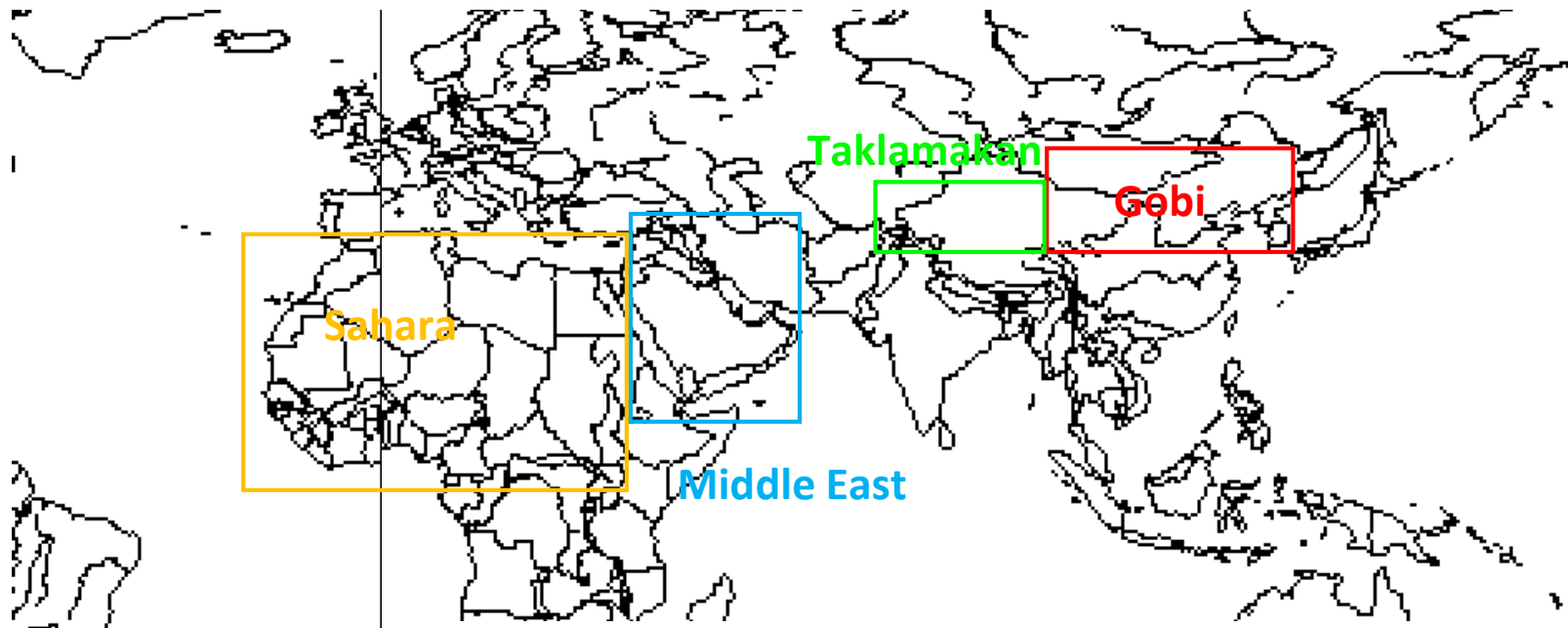
'Made Sat Mar 24 10:55:57 UTC 2018 NRL/Monterey Aerosol Model

'Made Tue Mar 27 04:56:34 UTC 2018 NRL/Monterey Aerosol Model

MRI MASINGAR-mk2 global aerosol transport model

Resolution TL479 ~ 40 km, for 2018
(Resolution TL159 ~ 110 km, for 2015)

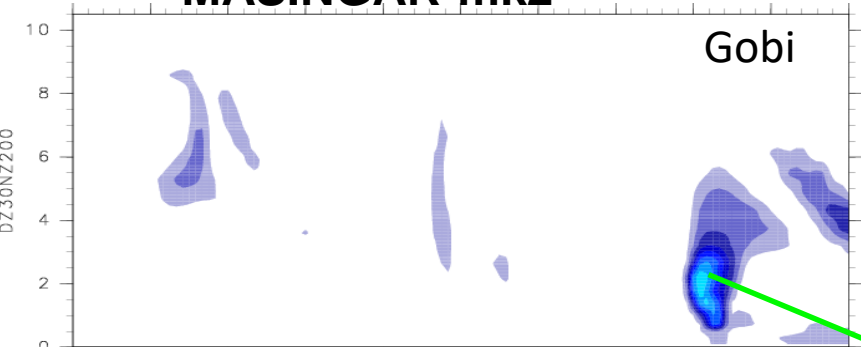
Dust from the four source areas (**Sahara**, **Middle East**, **Taklamakan**, and **Gobi**) were calculated separately.



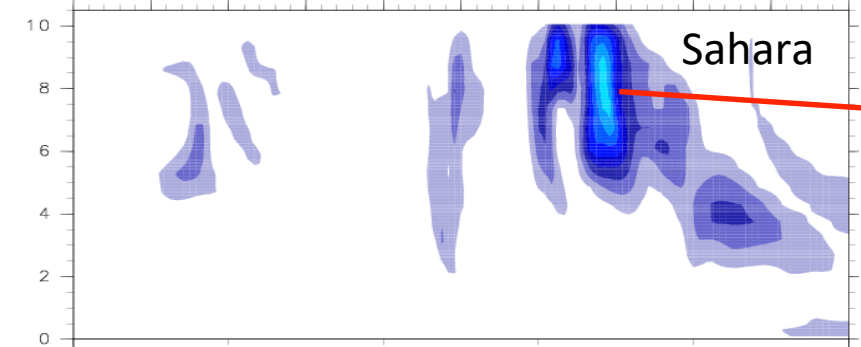
Dust in Sapporo, March 2018

MASINGAR-mk2

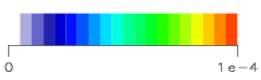
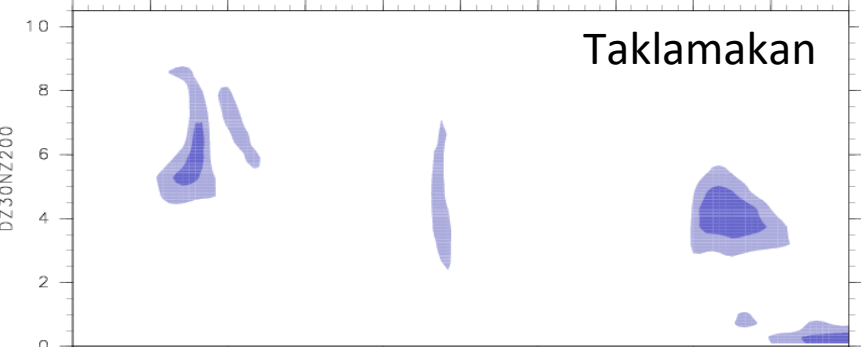
Gobi



Sahara

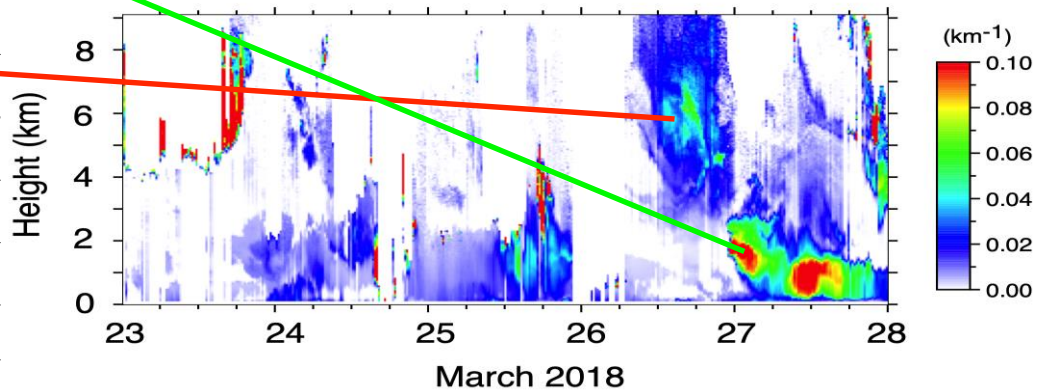


Taklamakan



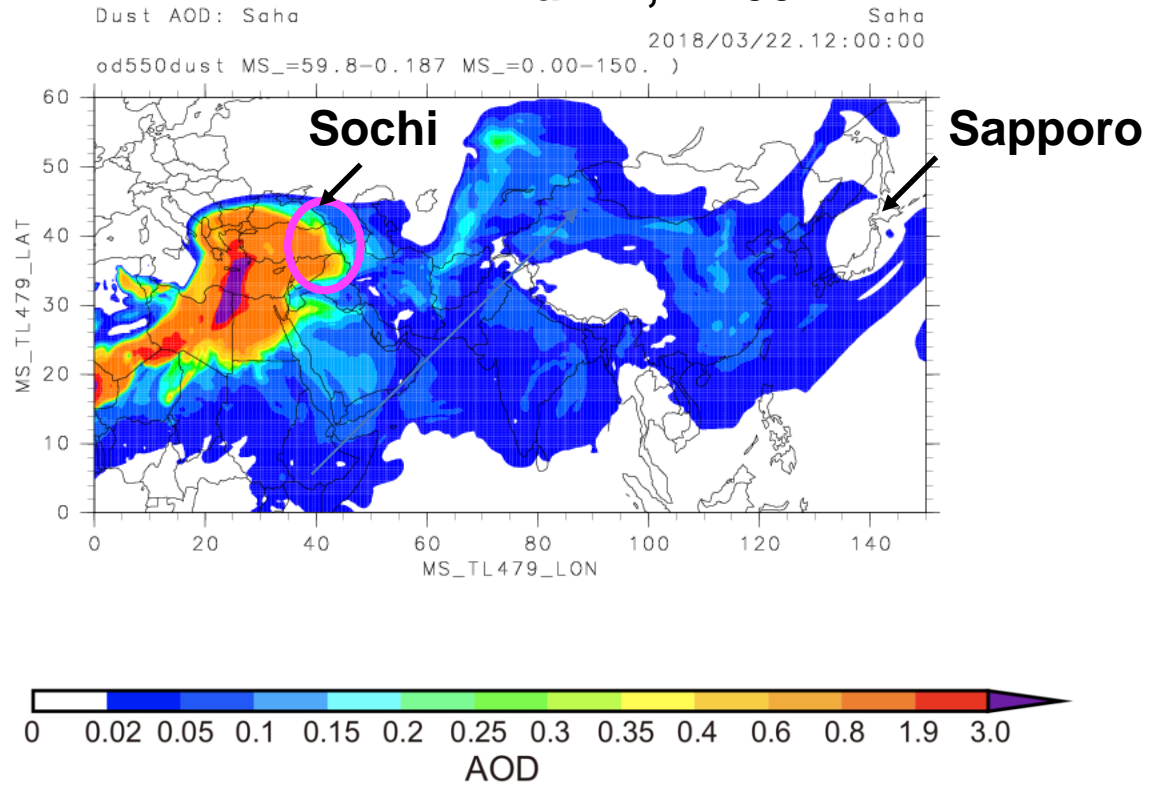
AD-Net Lidar

Dust extinction coefficient Sapporo



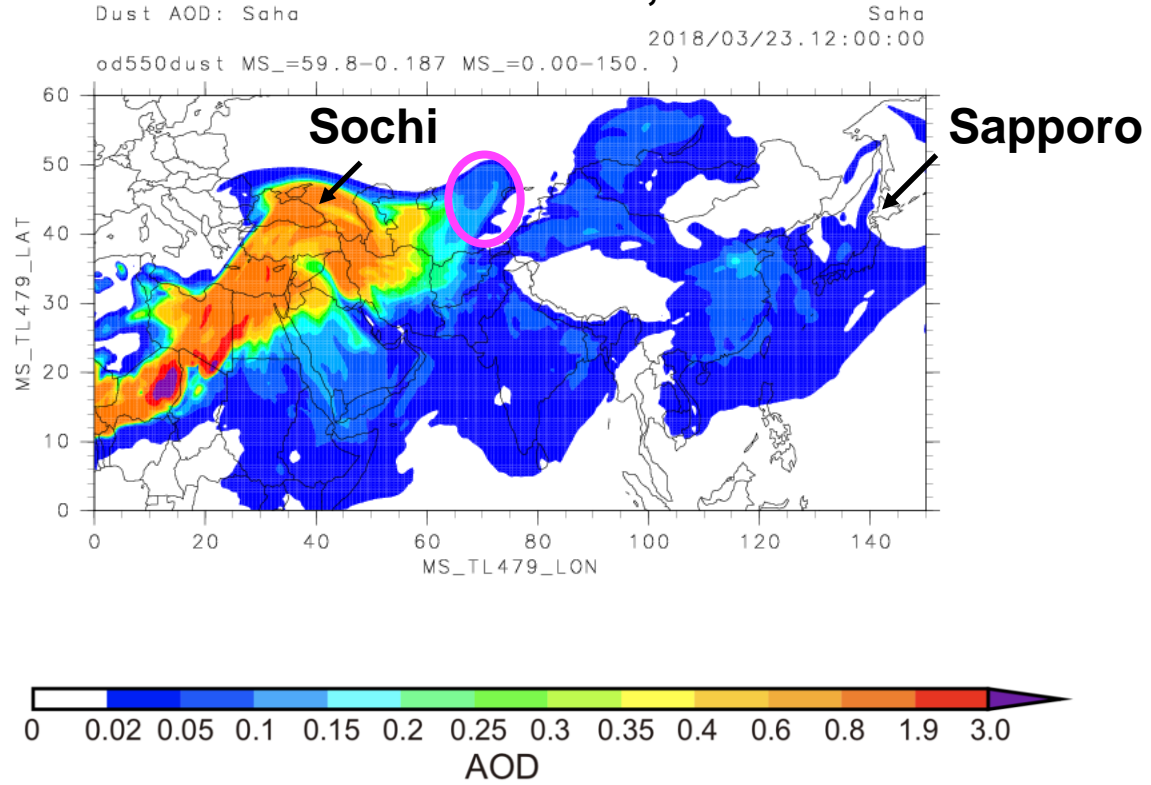
MASINGAR-mk2

Mar 22, 12:00



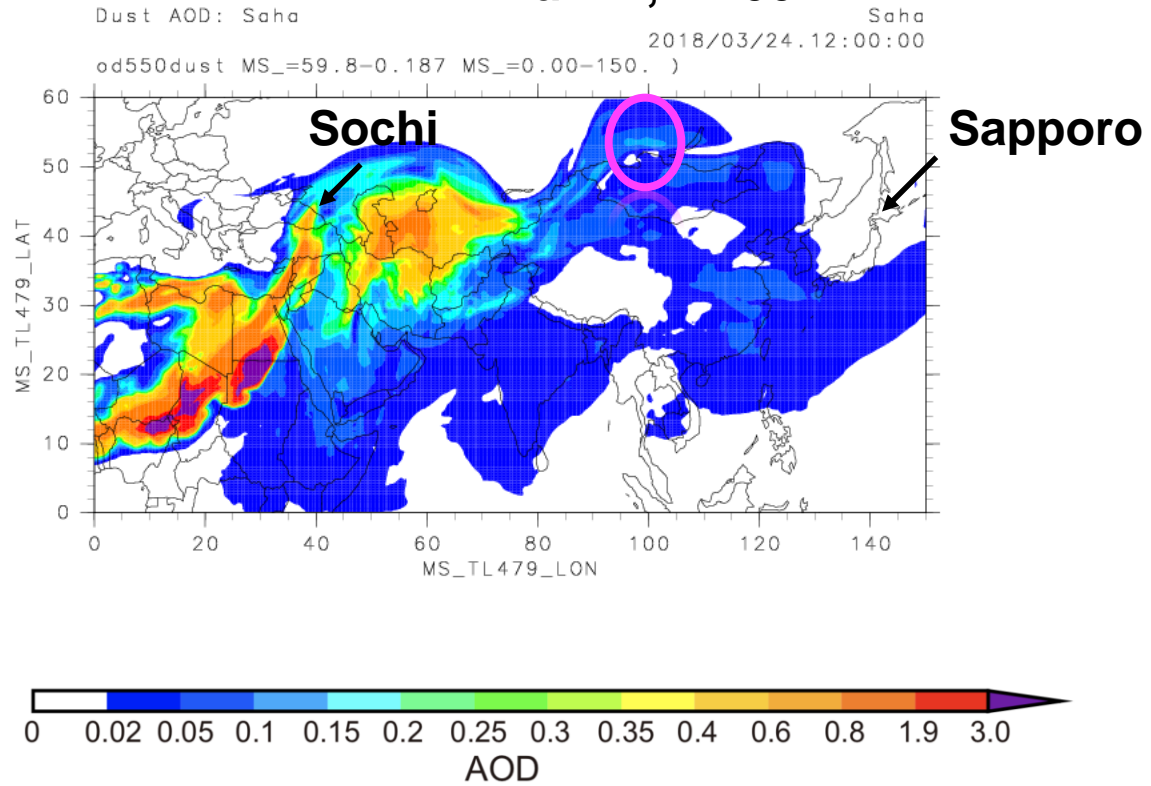
MASINGAR-mk2

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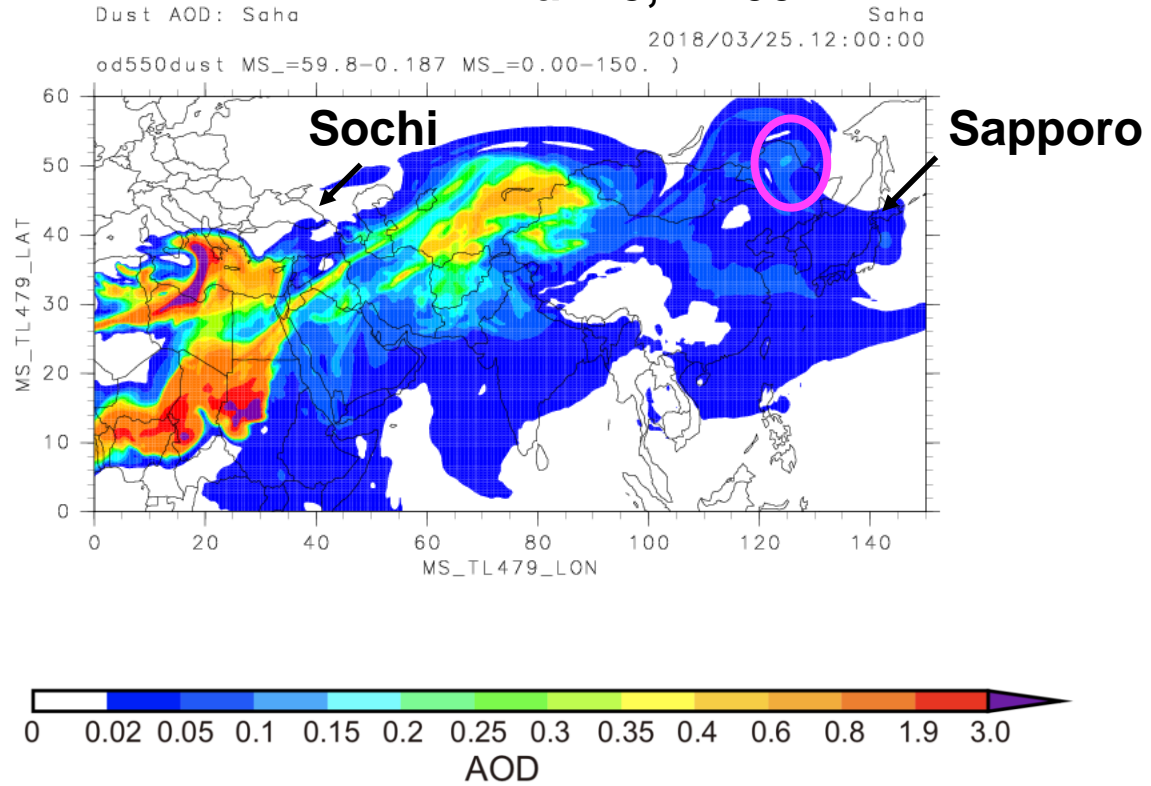
MASINGAR-mk2

Mar 24, 12:00



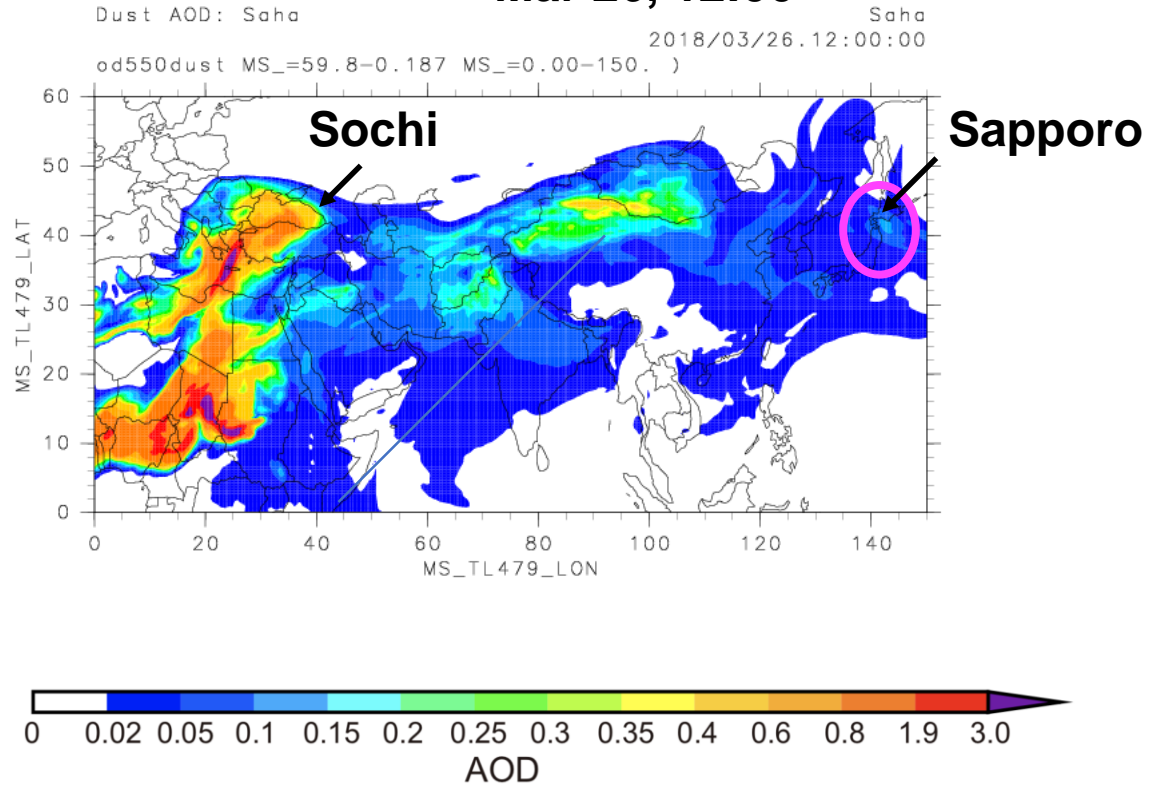
MASINGAR-mk2

Mar 25, 12:00



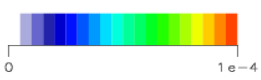
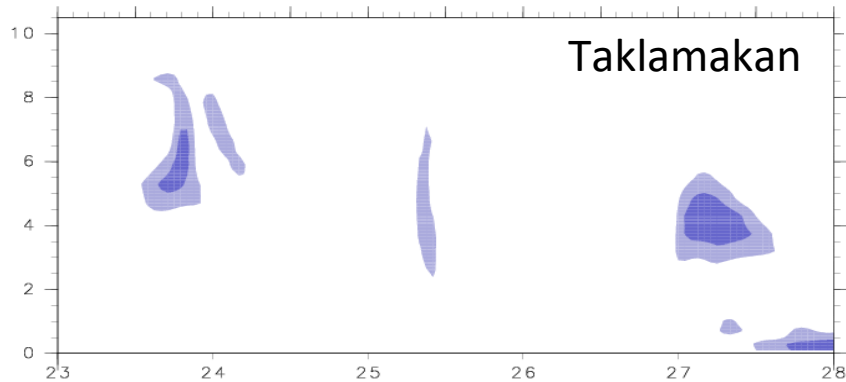
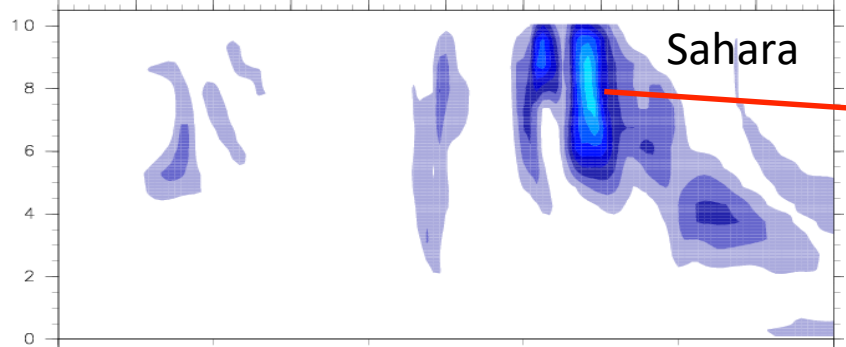
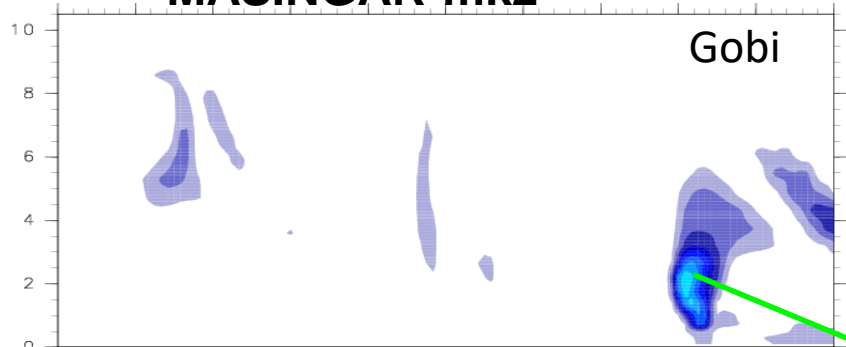
MASINGAR-mk2

Mar 26, 12:00



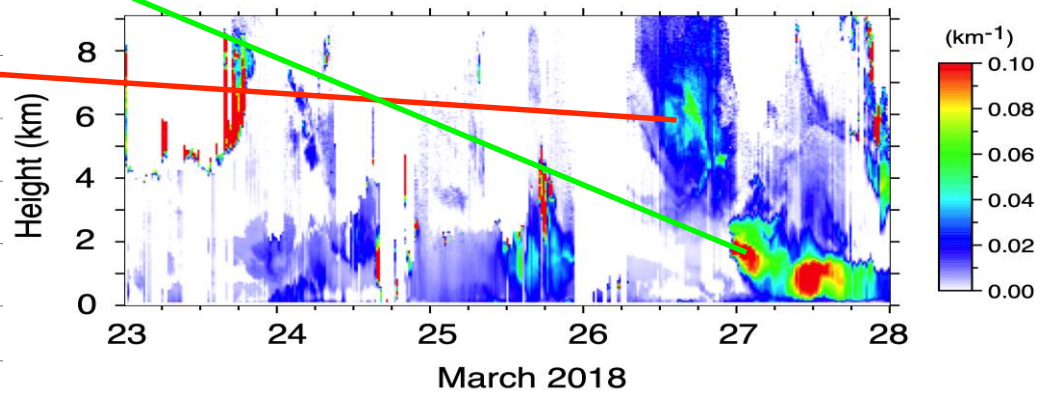
Dust in Sapporo, March 2018

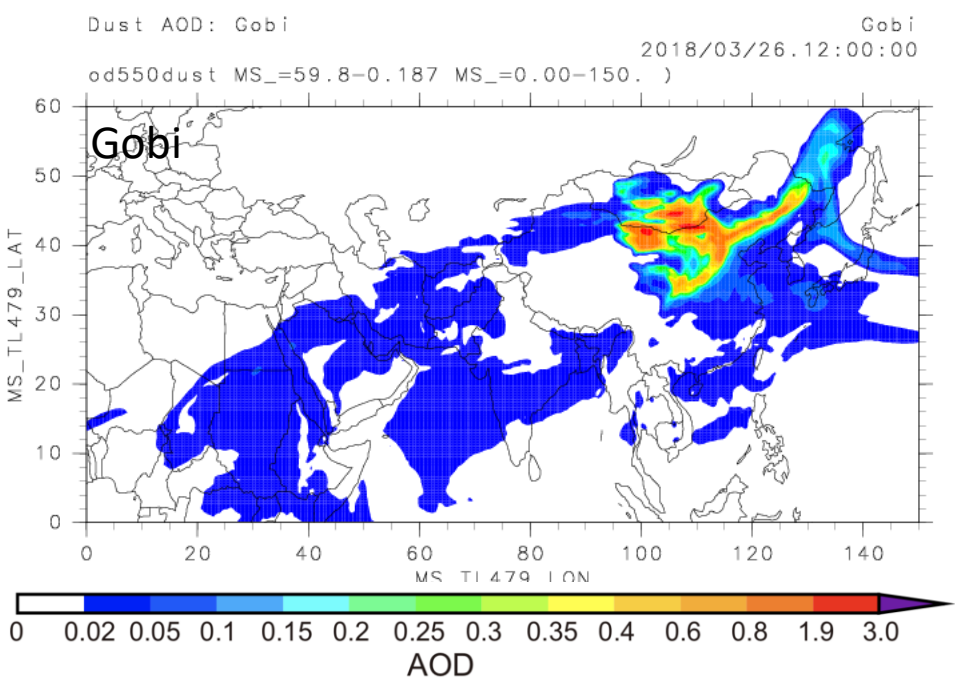
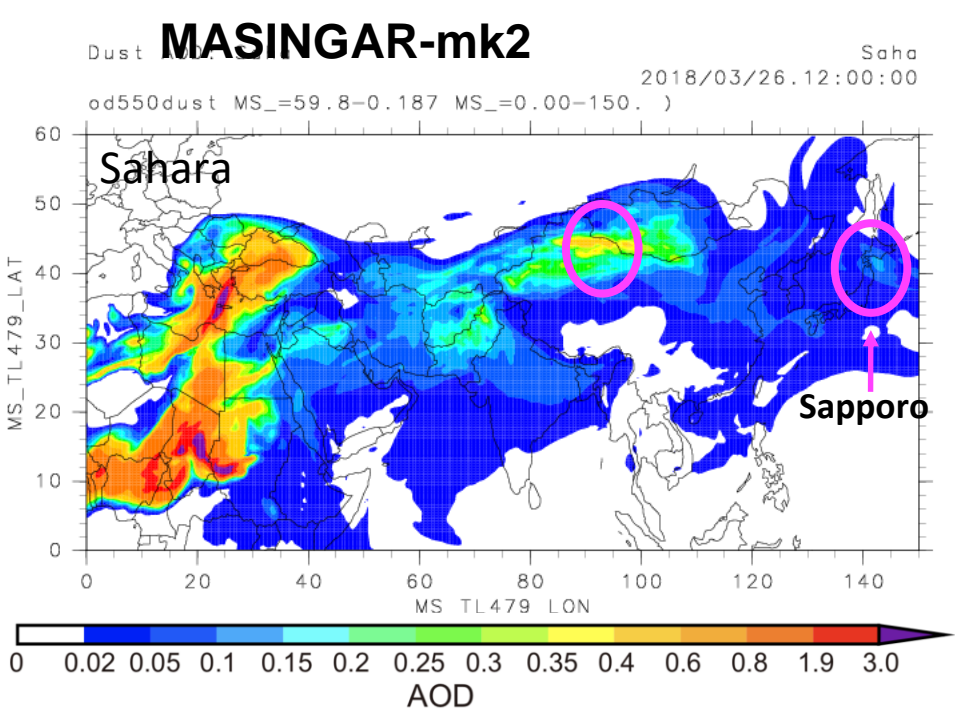
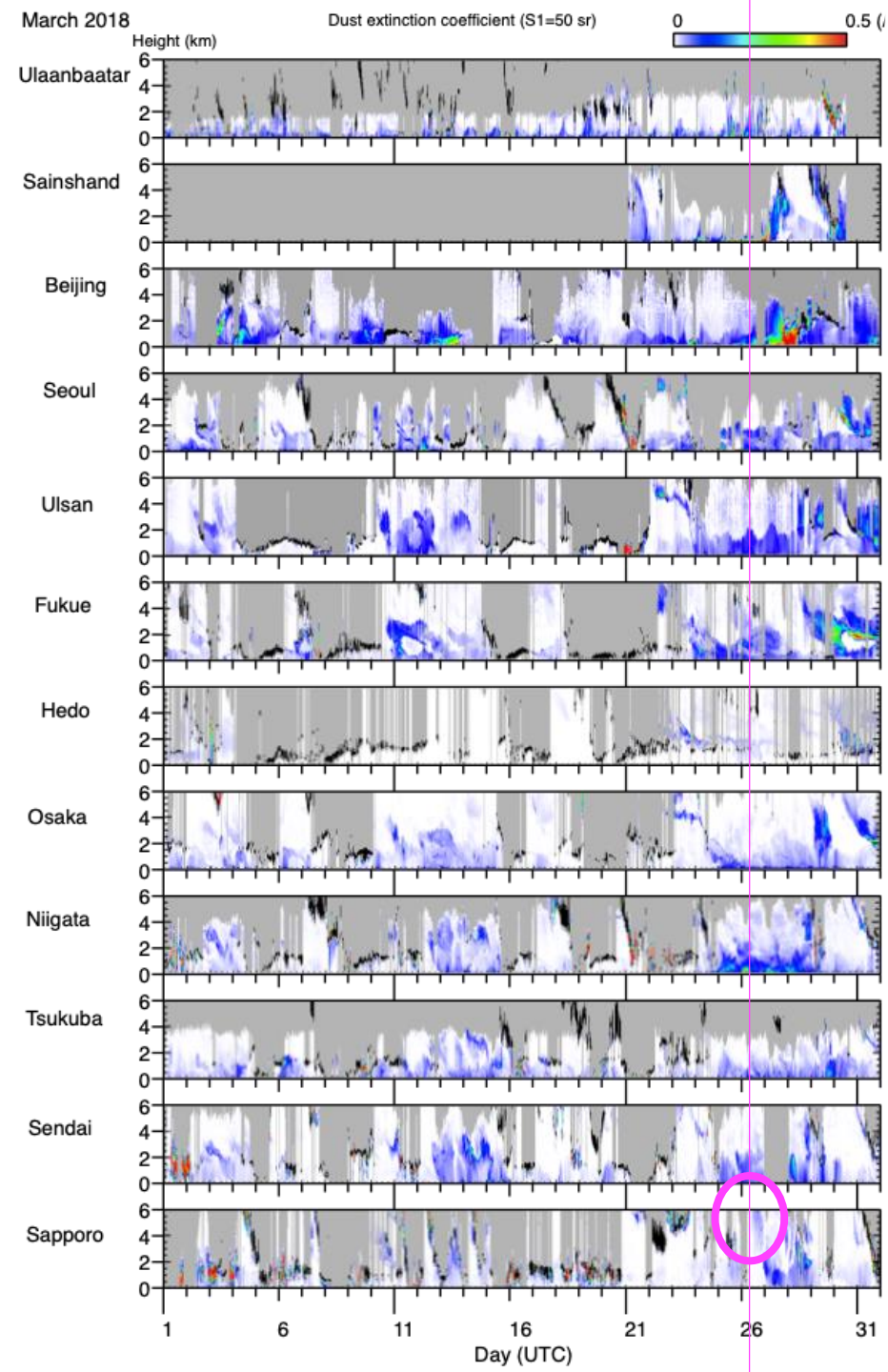
MASINGAR-mk2

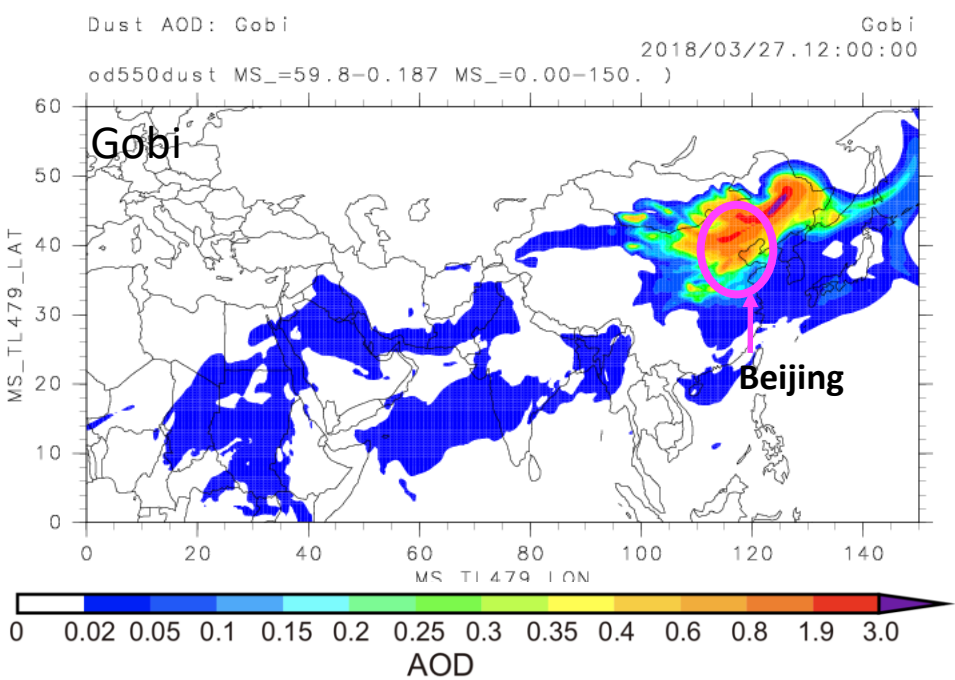
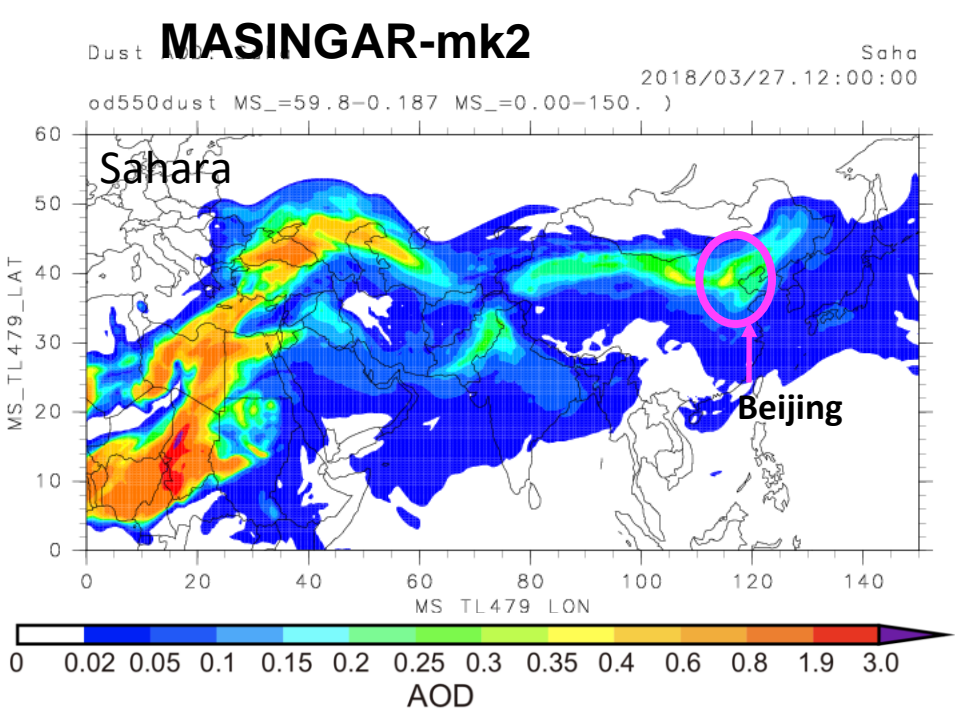
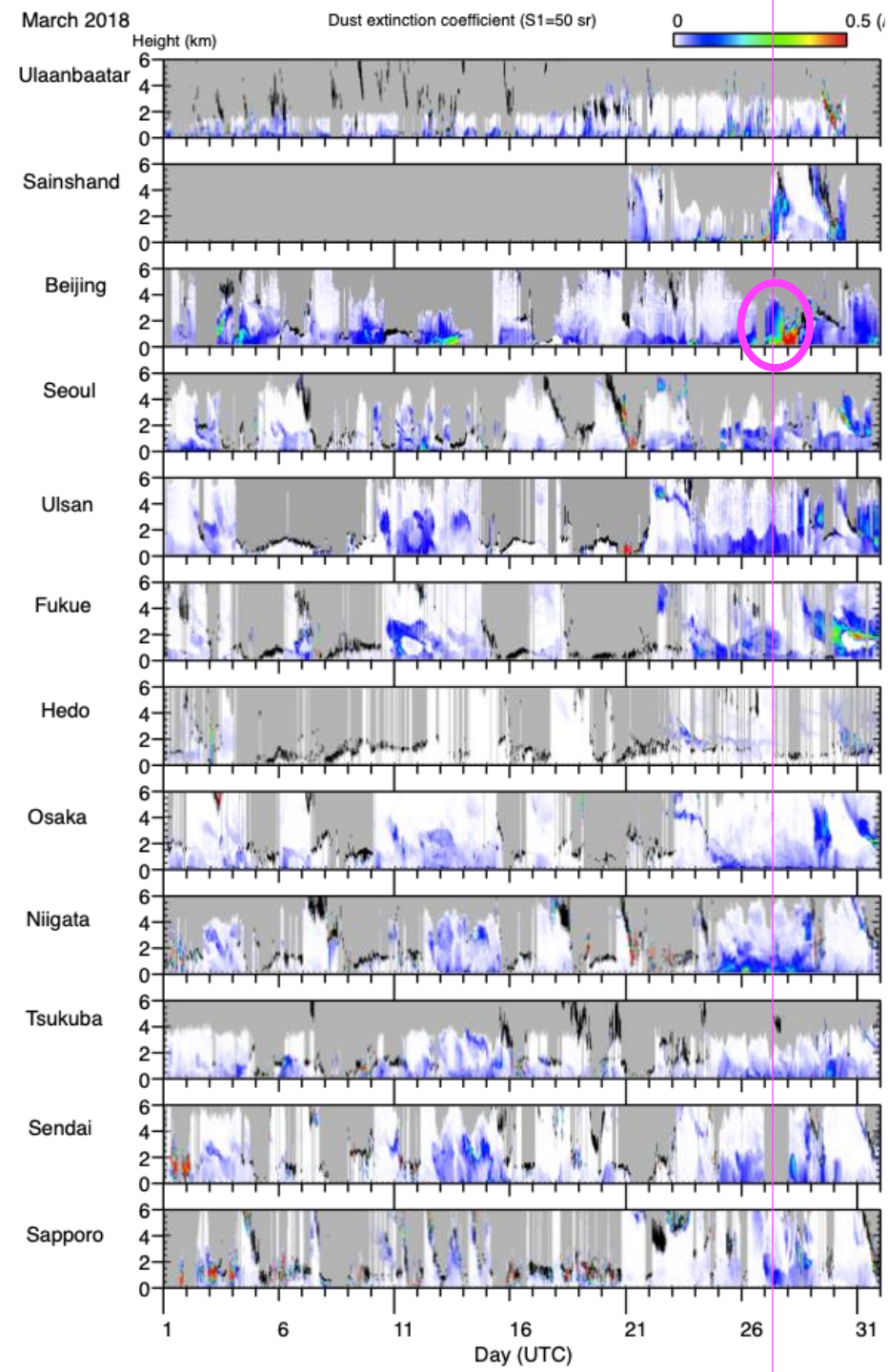


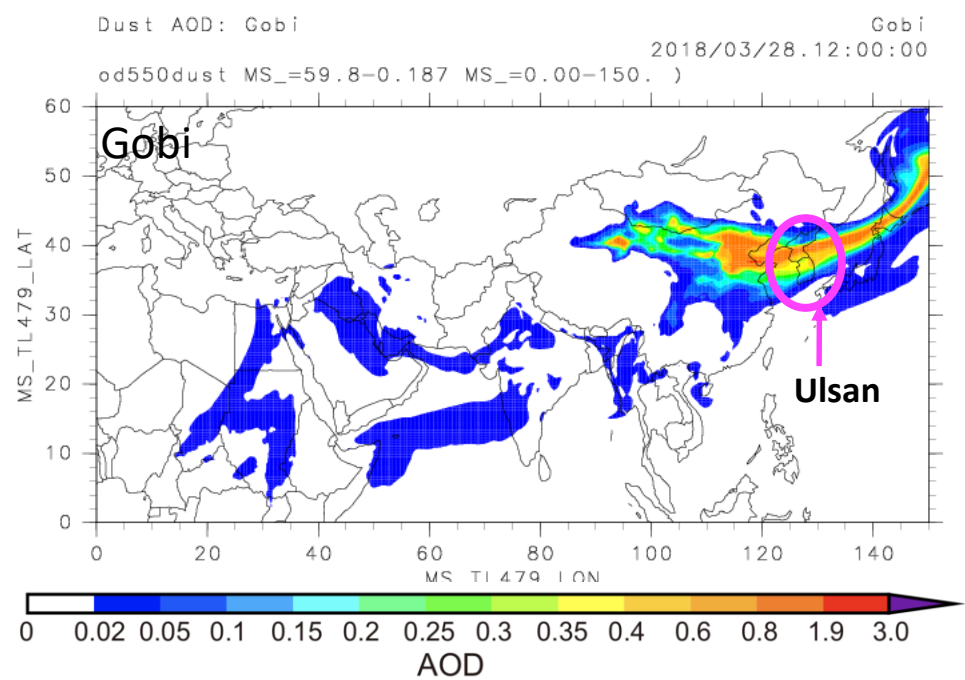
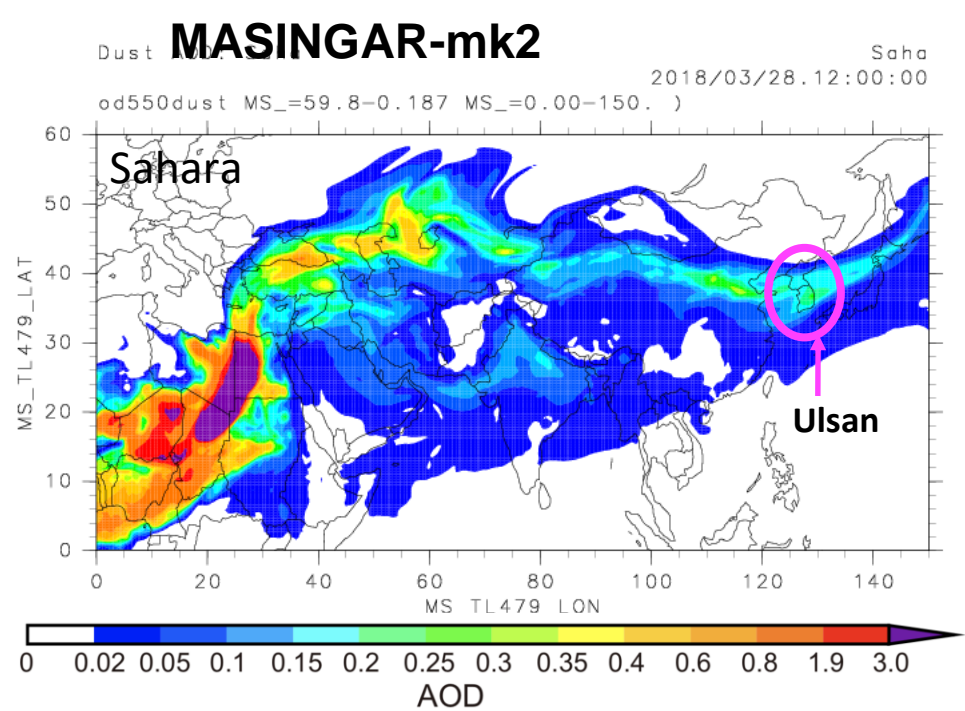
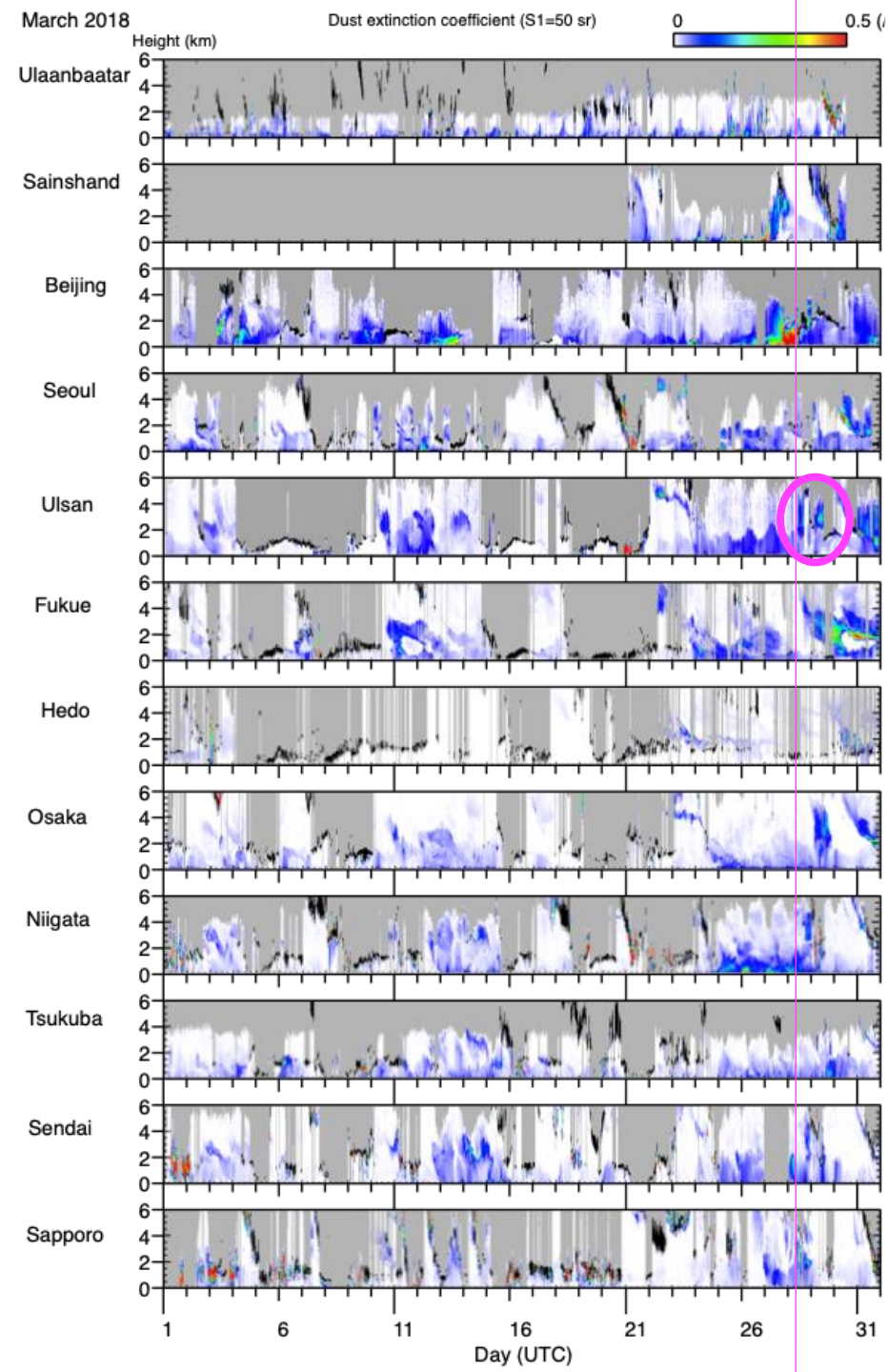
AD-Net Lidar

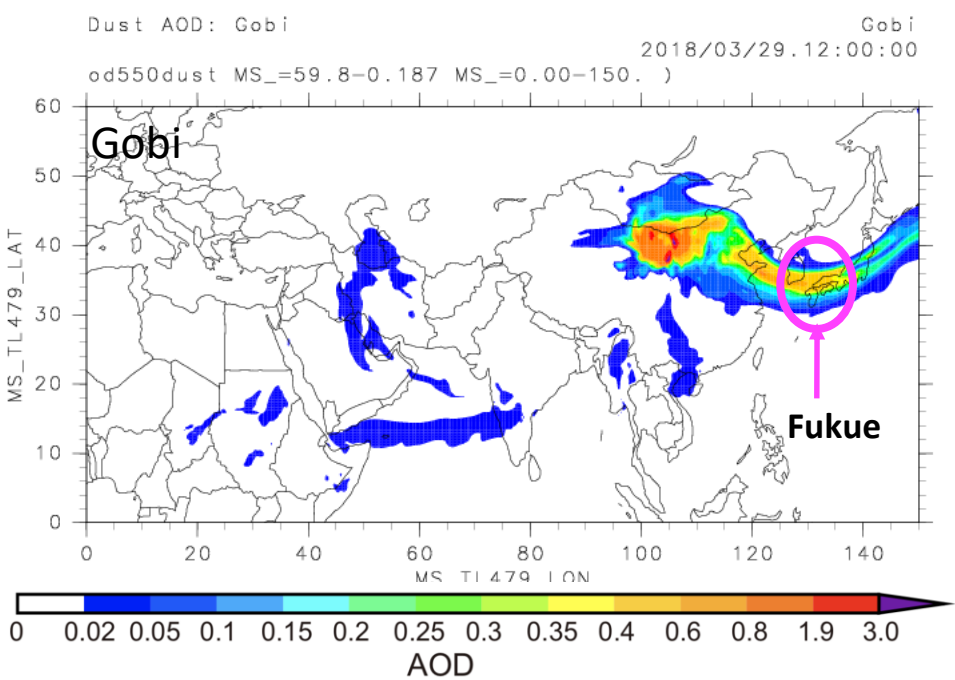
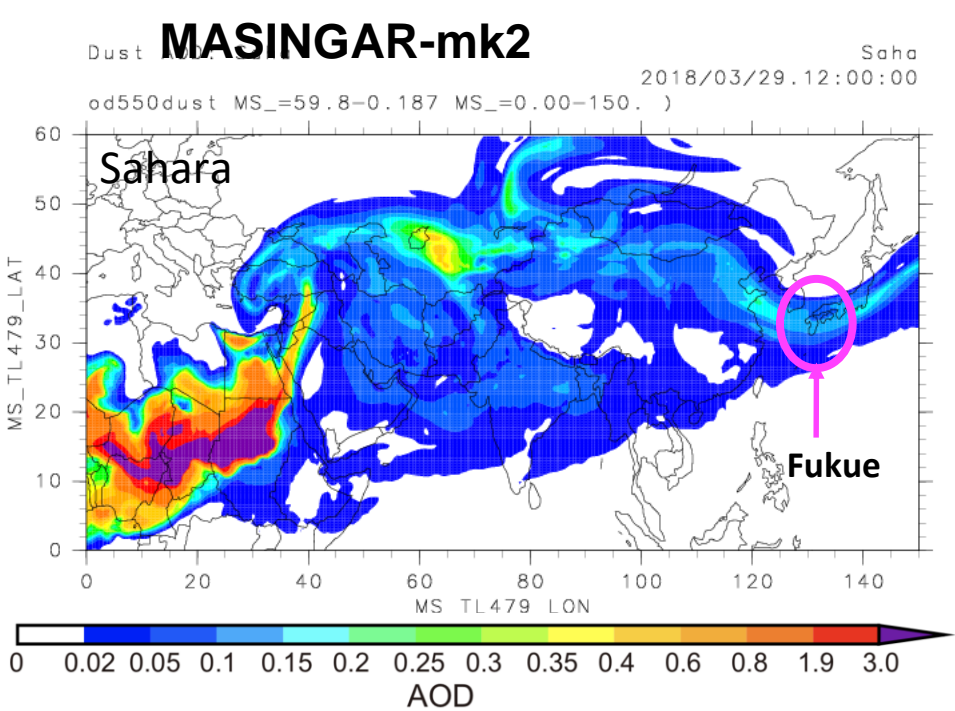
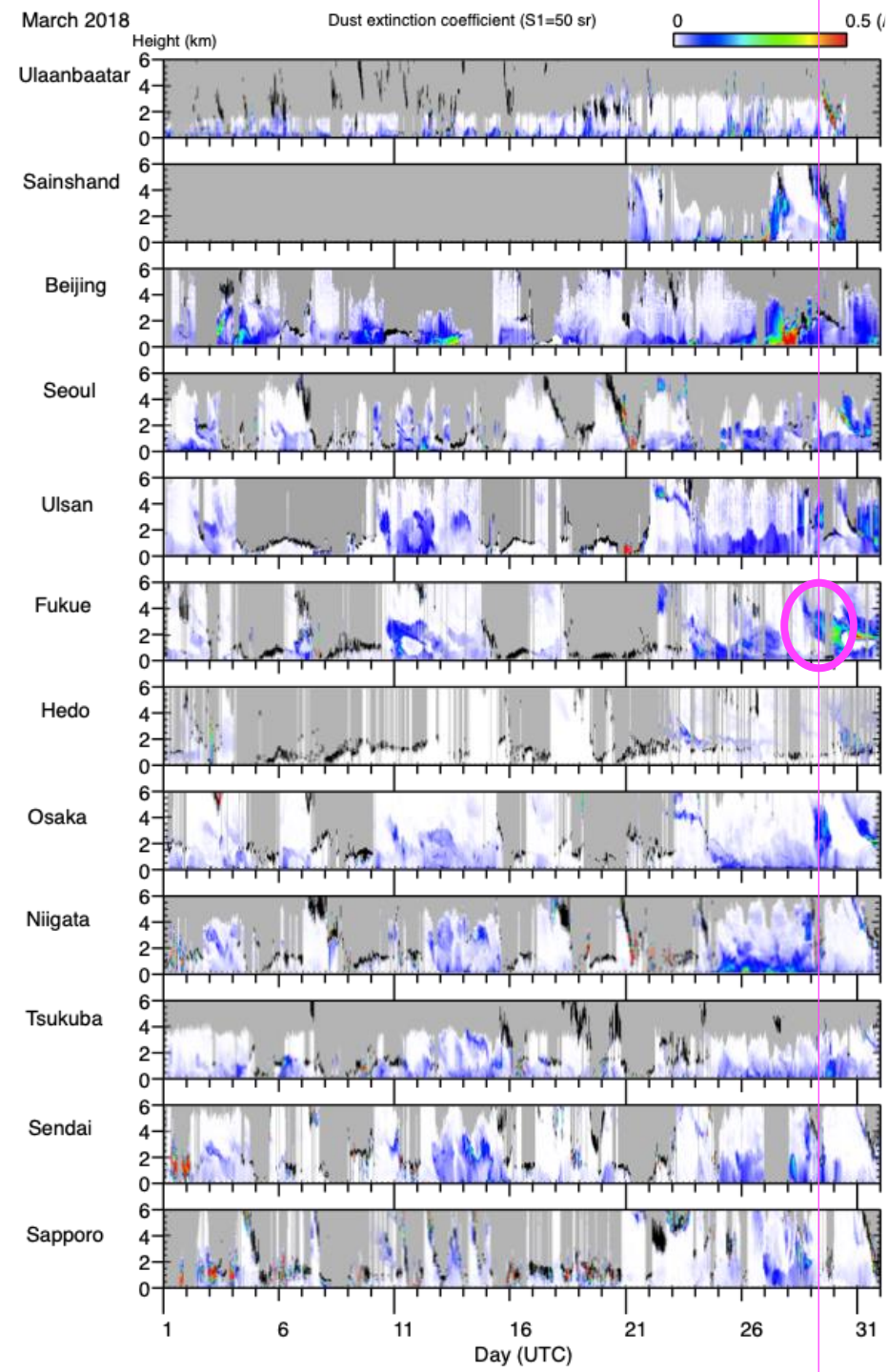
Dust extinction coefficient Sapporo

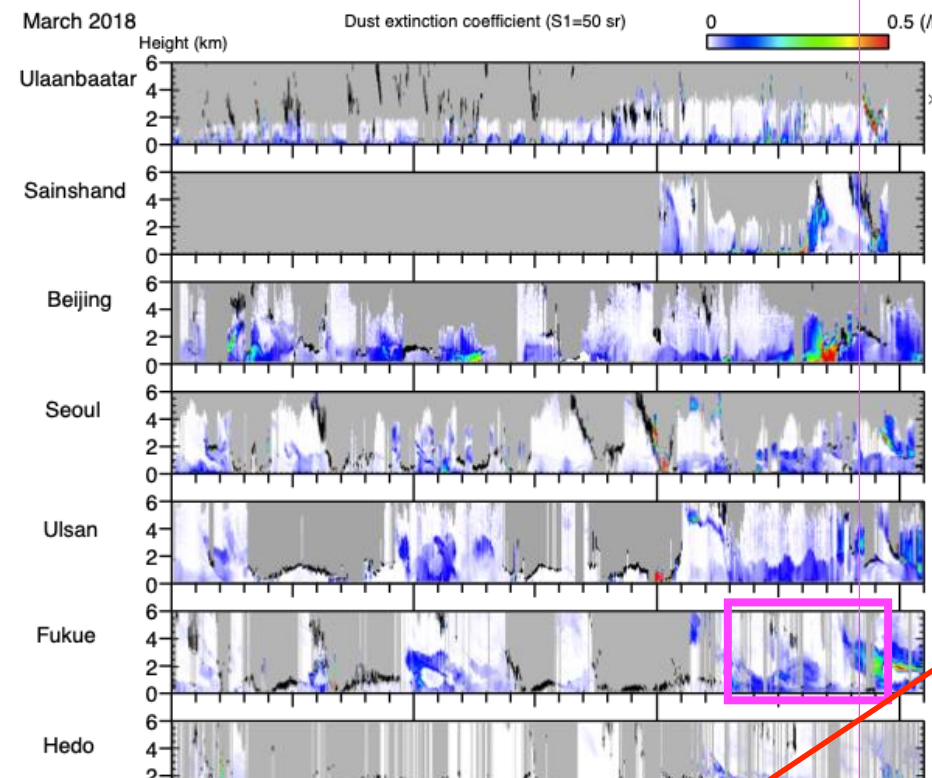






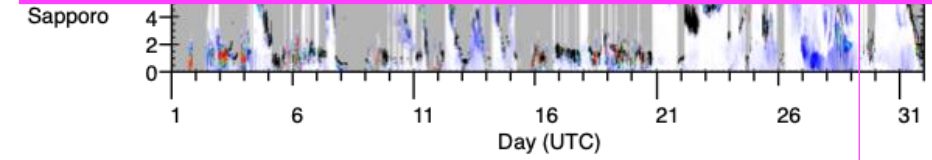
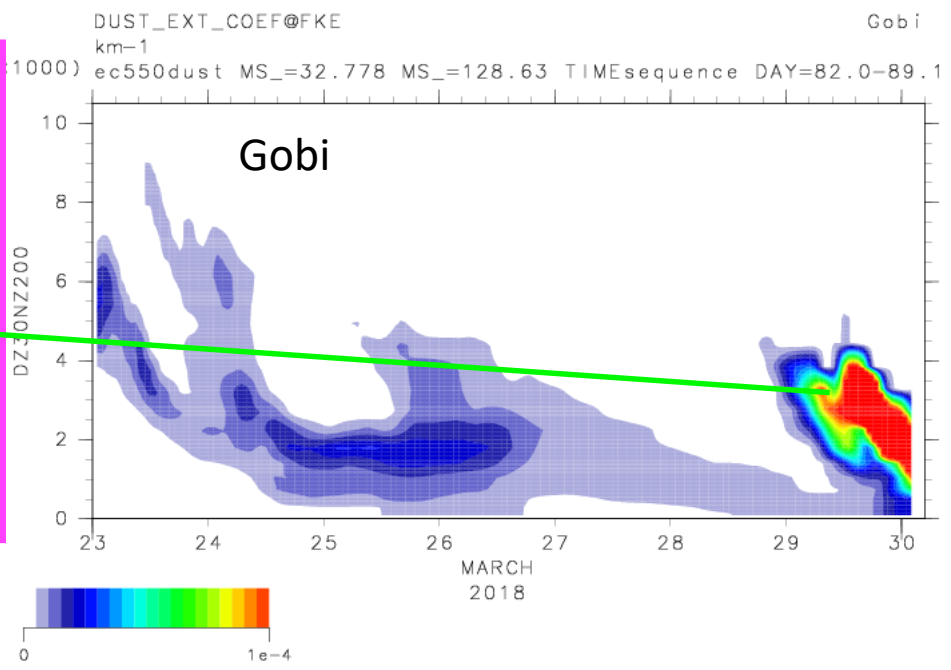
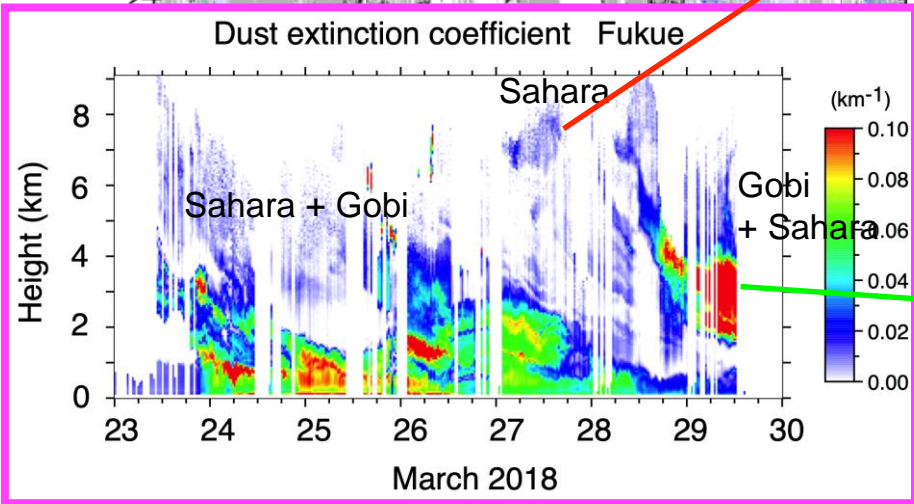
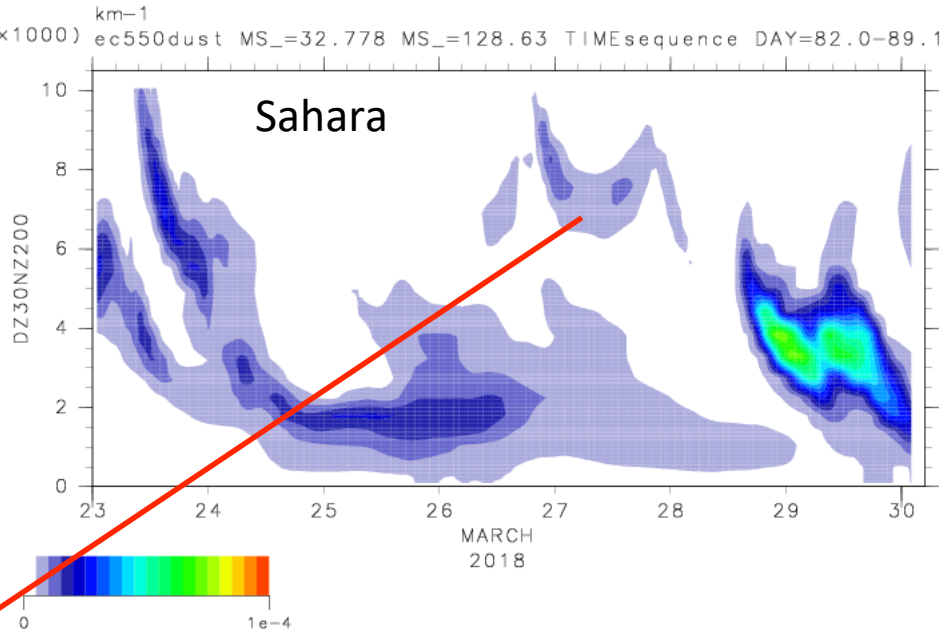




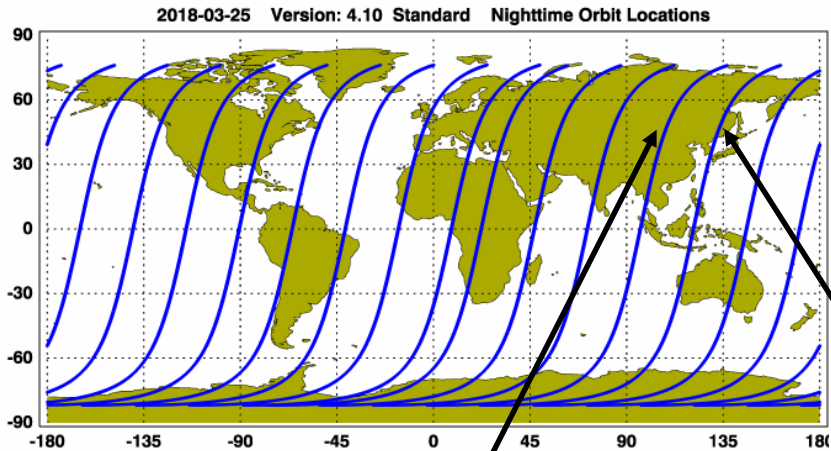


MASINGAR-mk2

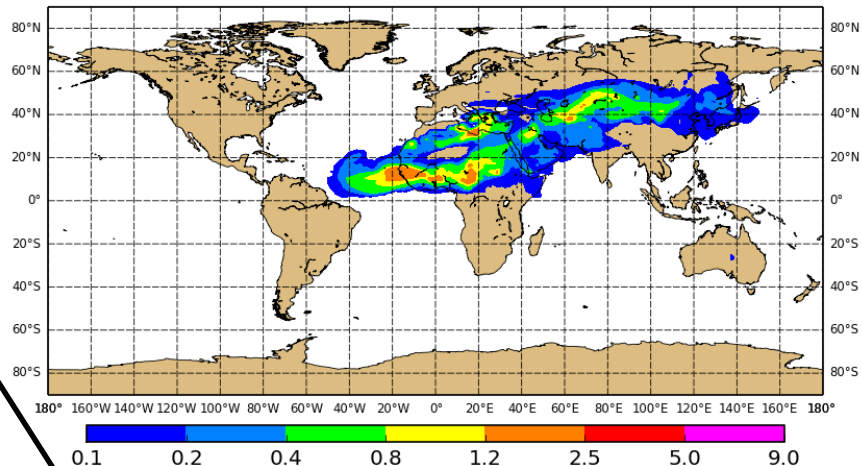
Fukue



CALIPSO 2018-03-25

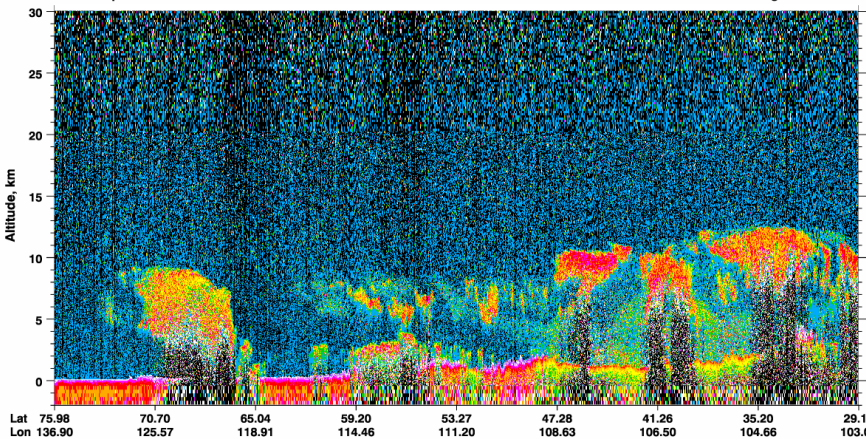


Sunday 25 March 2018 00UTC ICAP Forecast t+018
 Sunday 25 March 2018 18UTC Valid Time
 DUST Aerosol Optical Depth at 550nm (nMEM = 7)

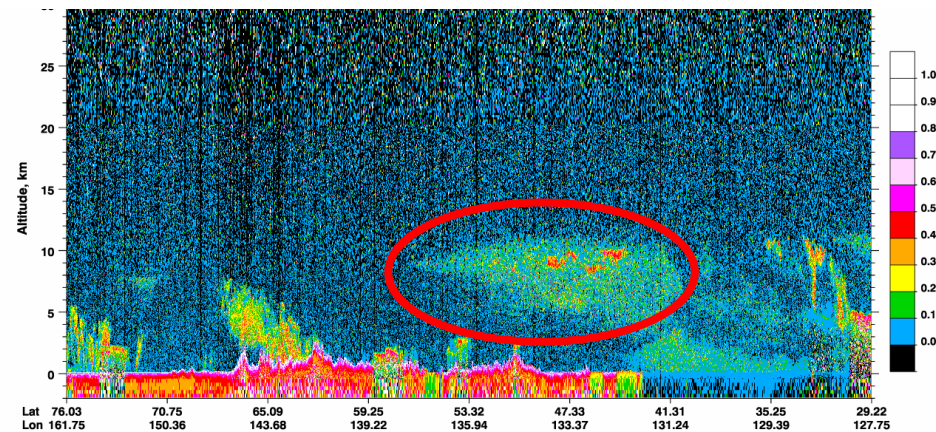


Plots Generated Monday 26 March 2018 11UTC NRL/Monterey Aerosol Modeling

Depolarization Ratio UTC: 2018-03-25 18:57:57.6 to 2018-03-25 19:11:26.3 Version: 3.40 Standard Nighttime



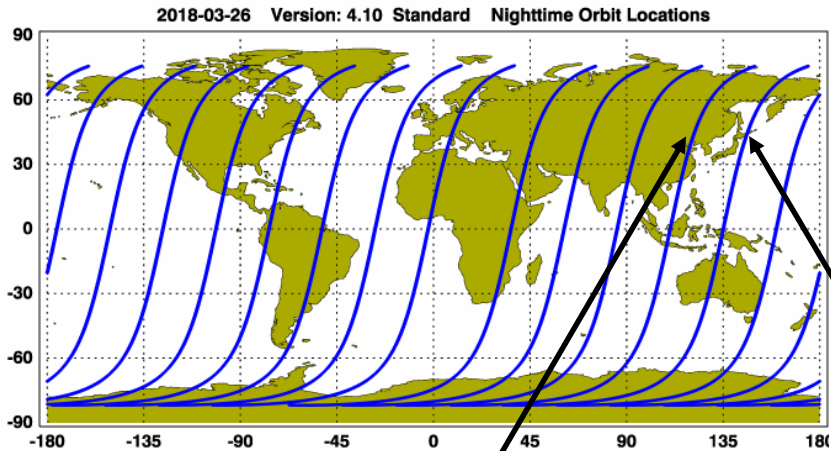
76.0 N



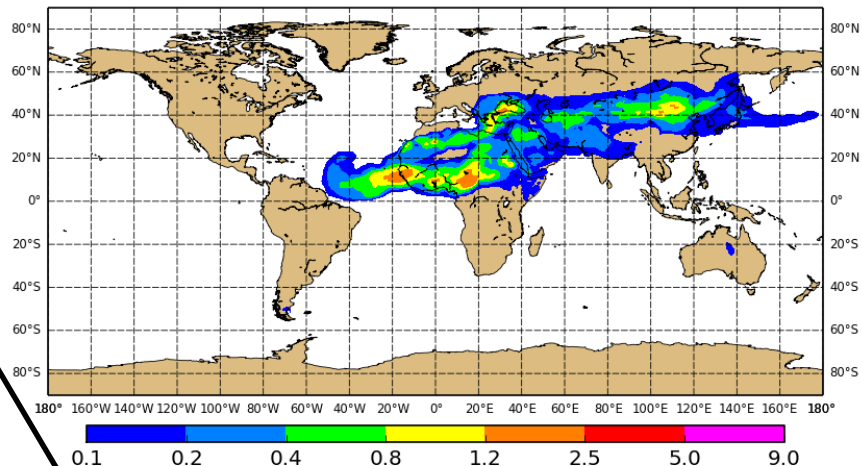
76.0 N

29.2 N

CALIPSO 2018-03-26

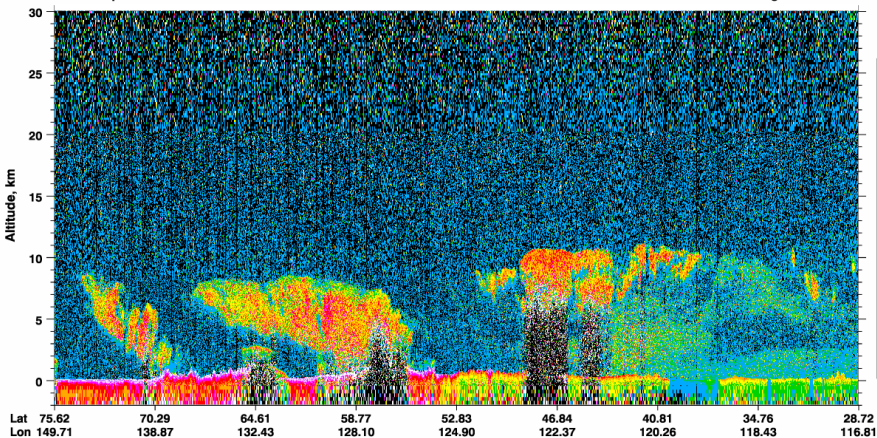


Monday 26 March 2018 00UTC ICAP Forecast t+018
 Monday 26 March 2018 18UTC Valid Time
 DUST Aerosol Optical Depth at 550nm (nMEM = 7)



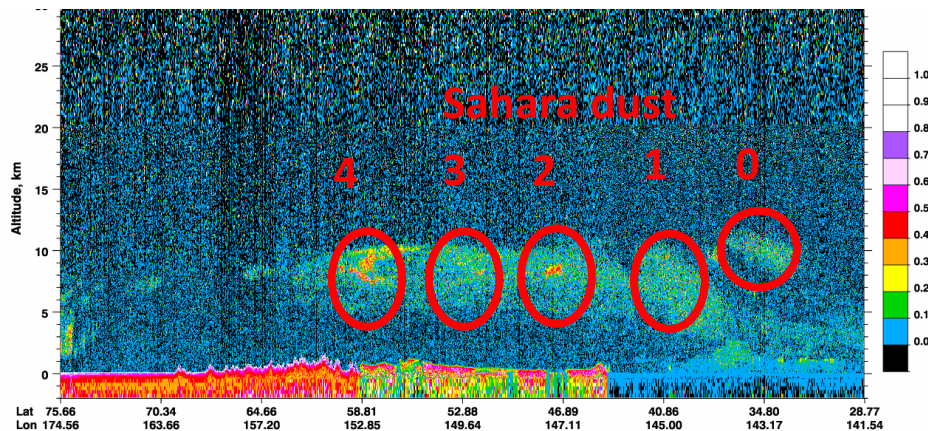
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75.6 N

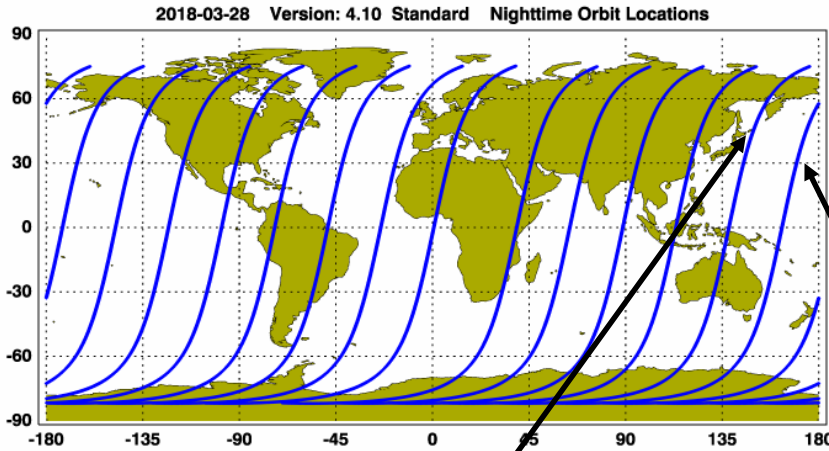
28.7 N



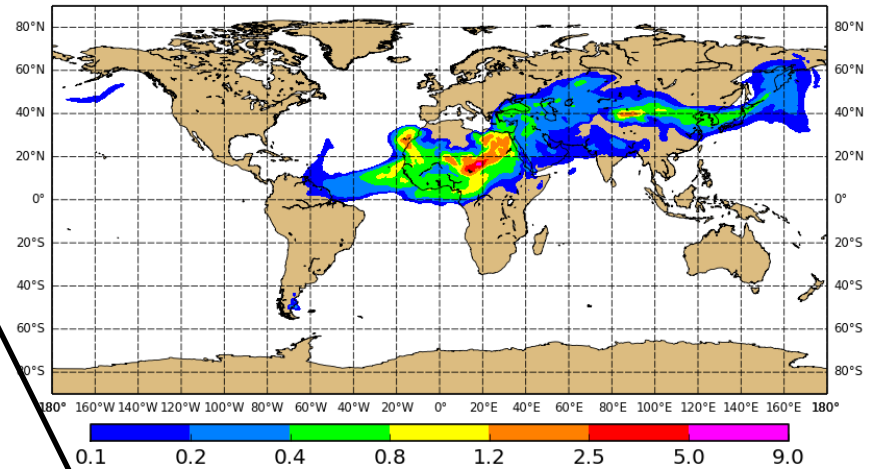
75.7 N

28.8 N

CALIPSO 2018-03-28

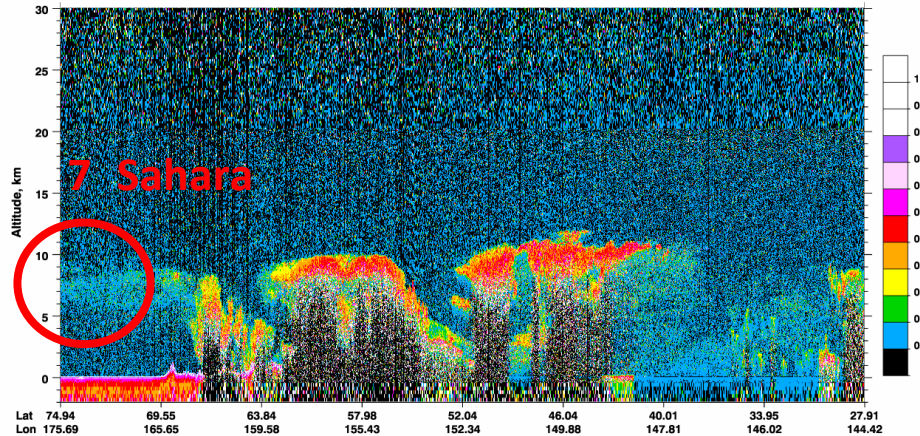


Wednesday 28 March 2018 00UTC ICAP Forecast t+018
 Wednesday 28 March 2018 18UTC Valid Time
 DUST Aerosol Optical Depth at 550nm (nMEM = 7)



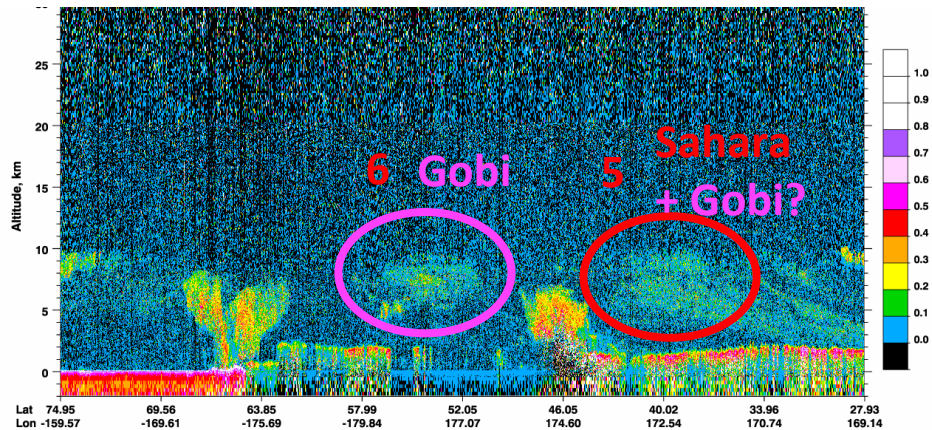
Plots Generated Thursday 29 March 2018 11UTC NRL/Monterey Aerosol Modeling

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74.9 N

27.9 N

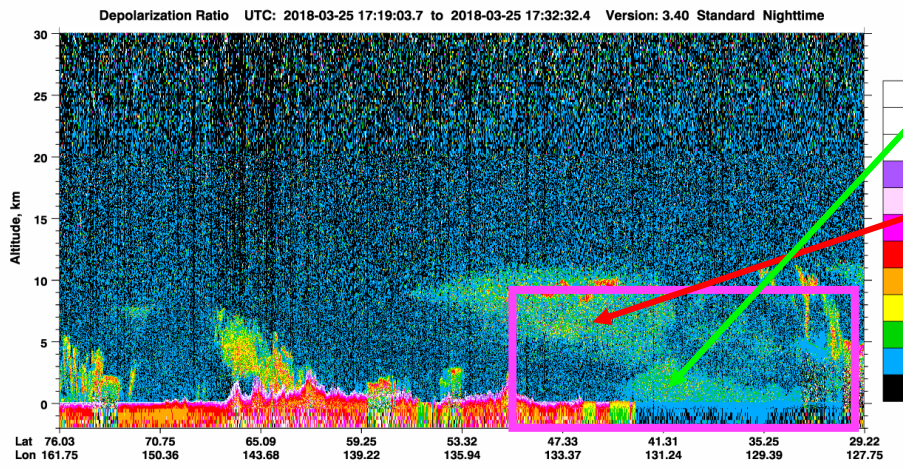
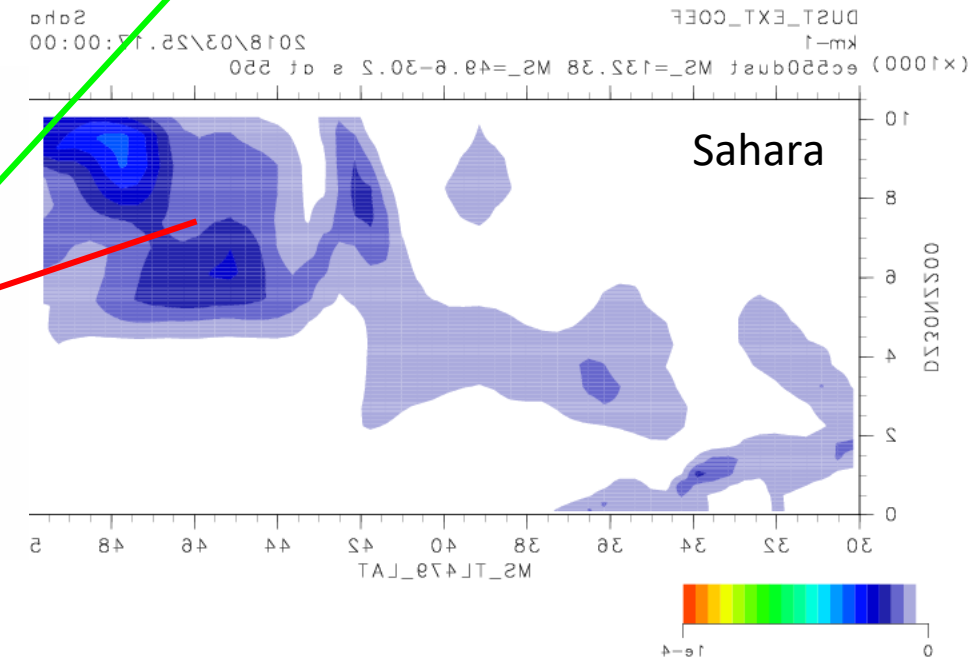
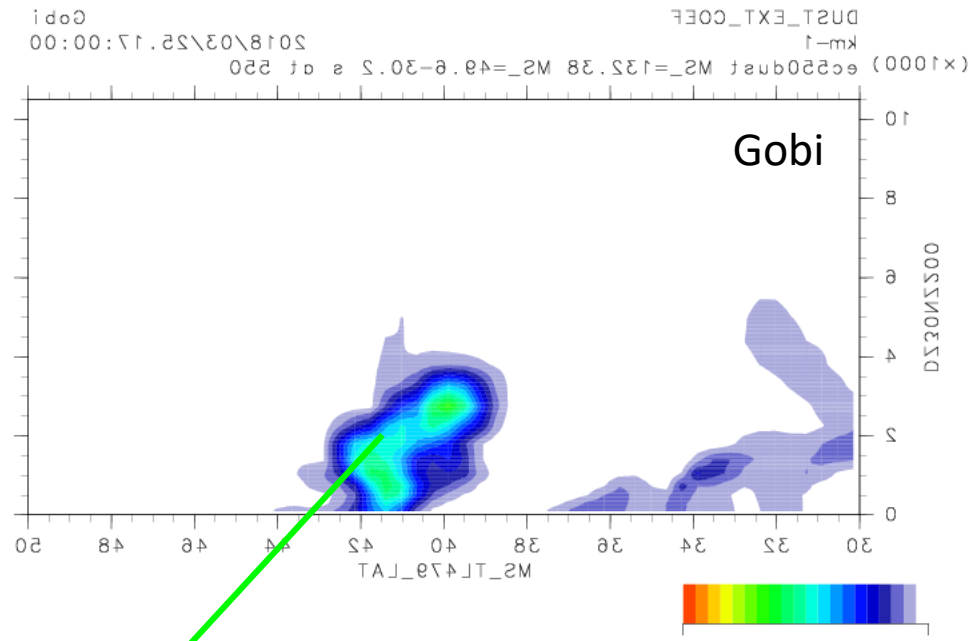
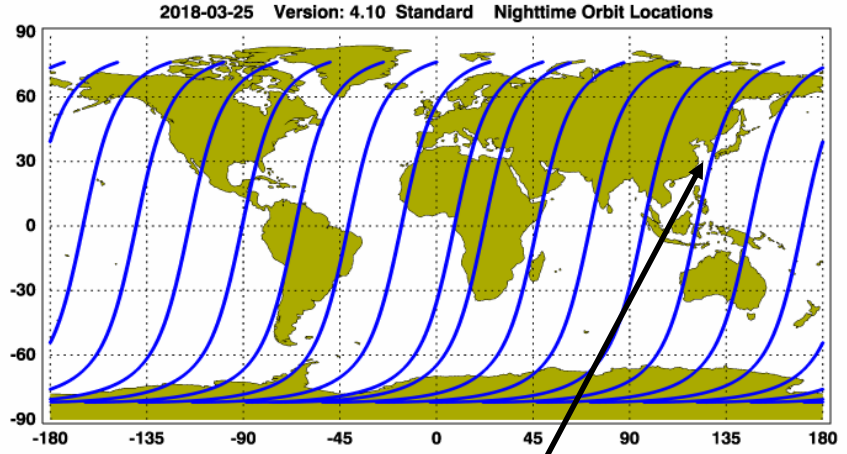


75.0 N

27.9 N

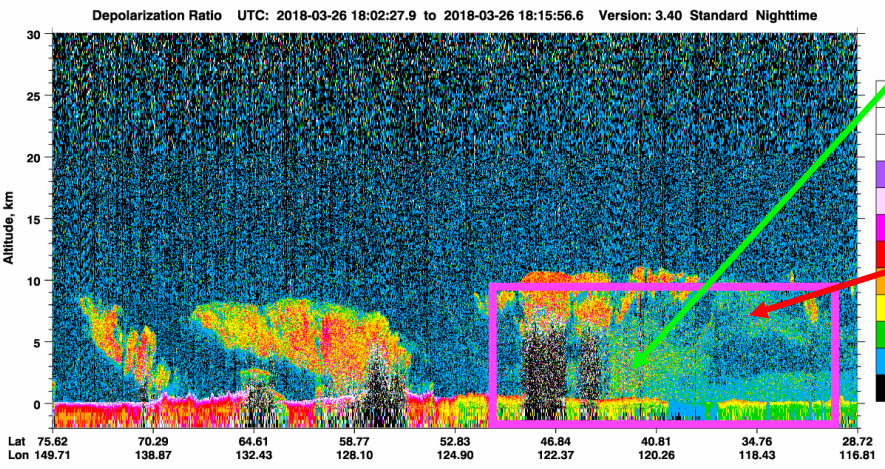
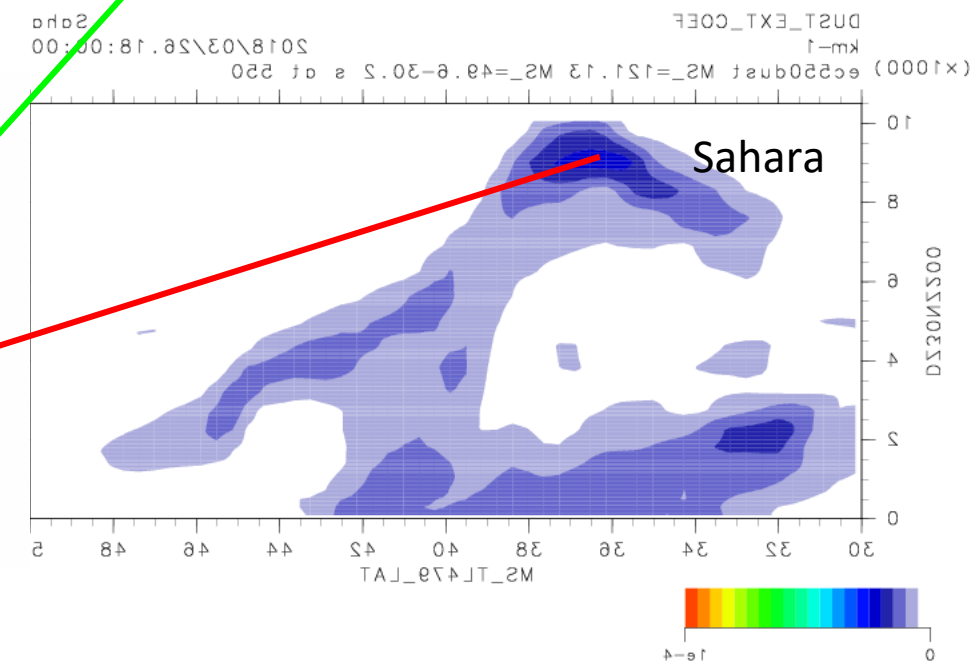
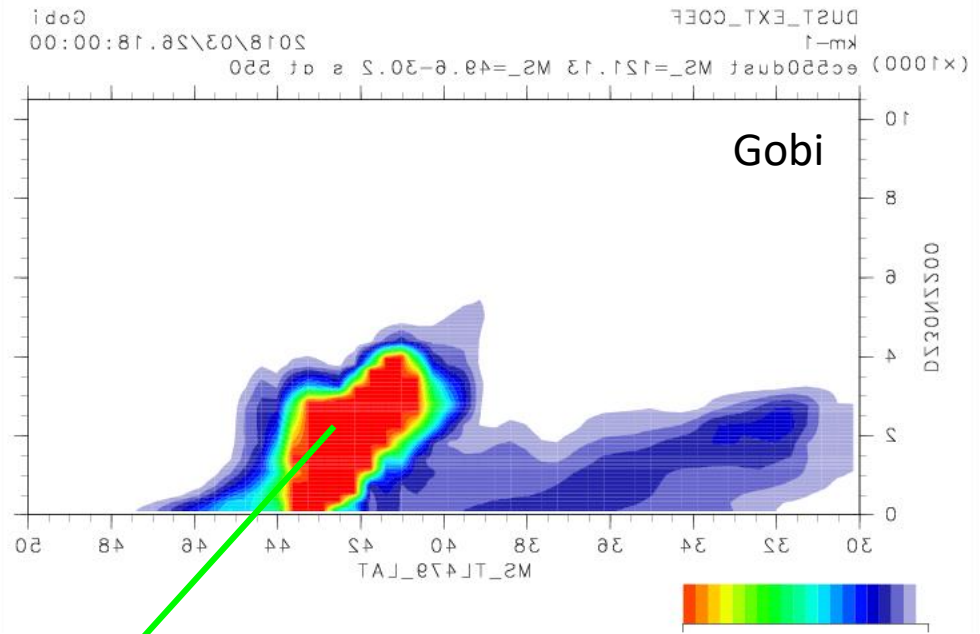
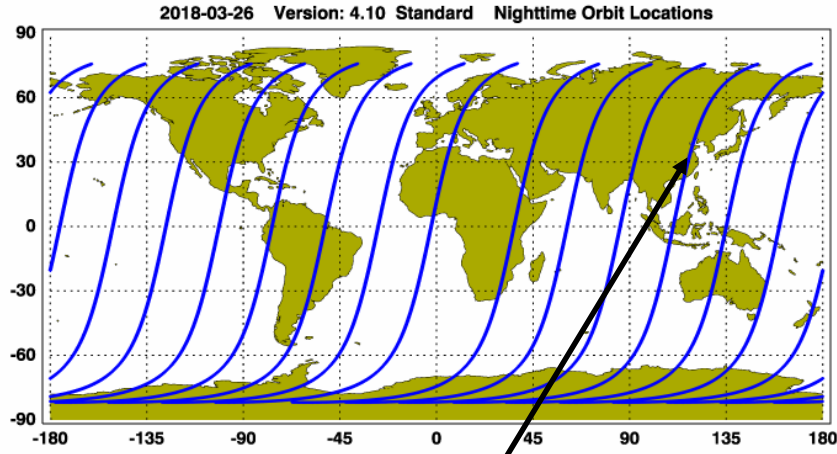
2018-03-25

MASINGAR-mk2



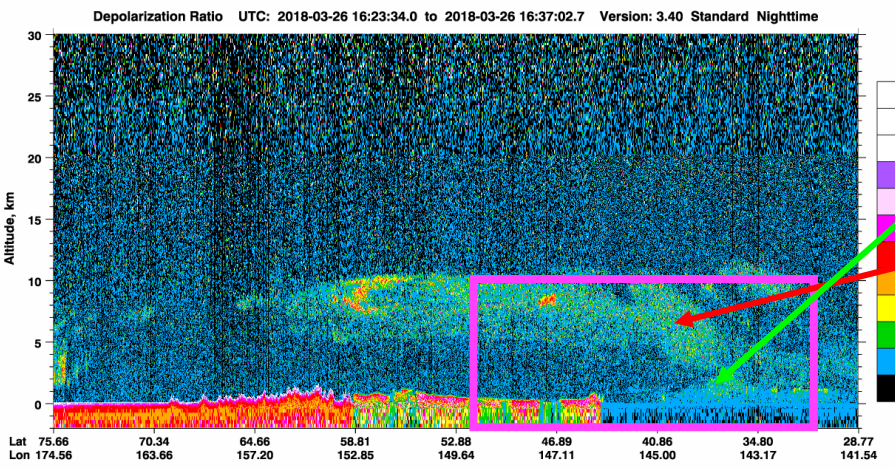
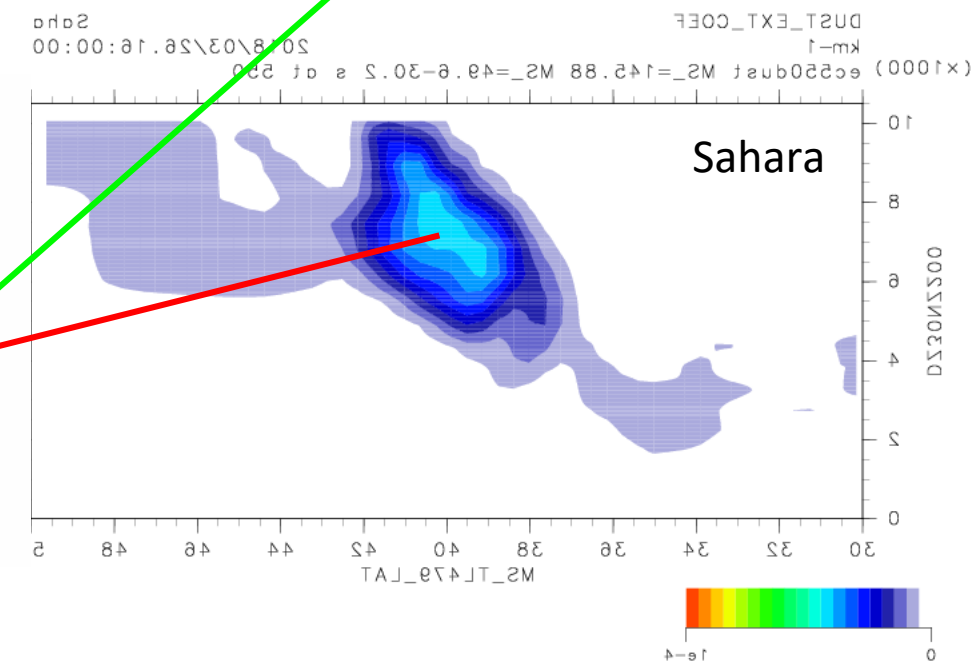
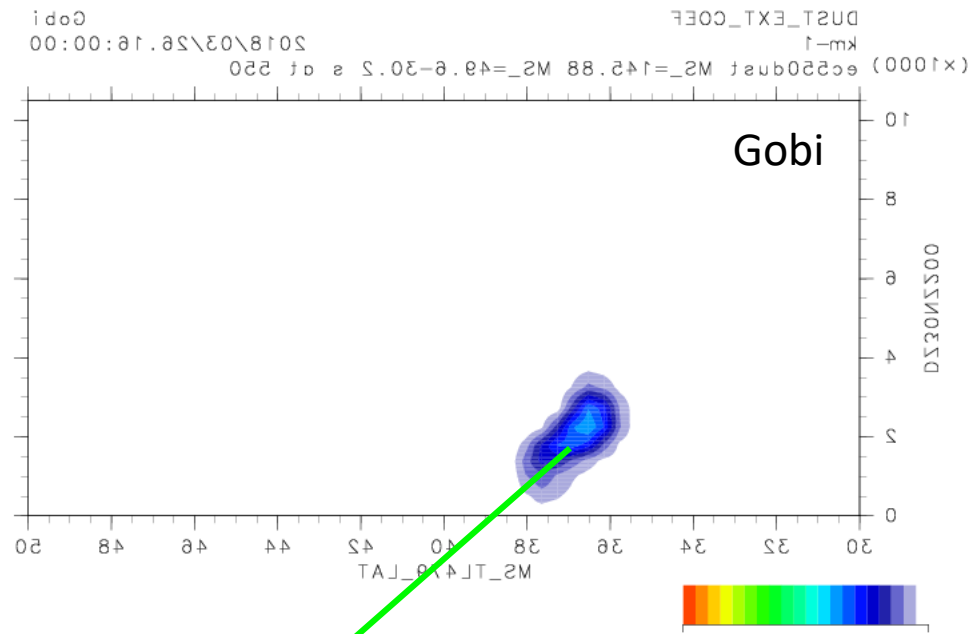
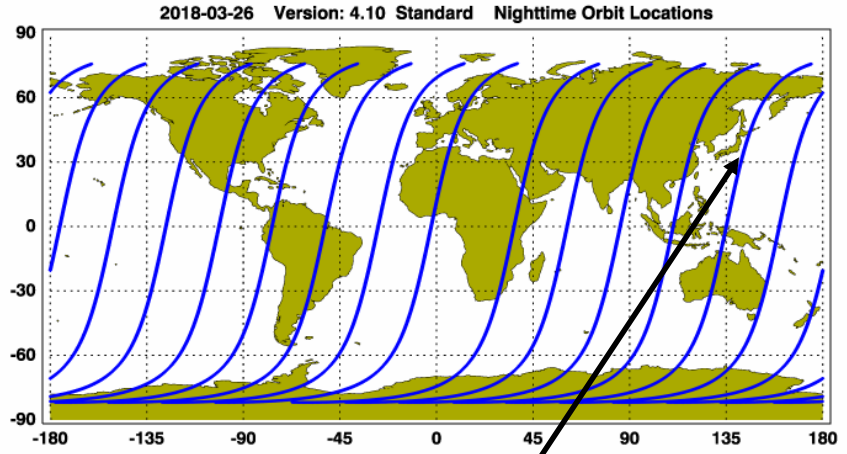
2018-03-26

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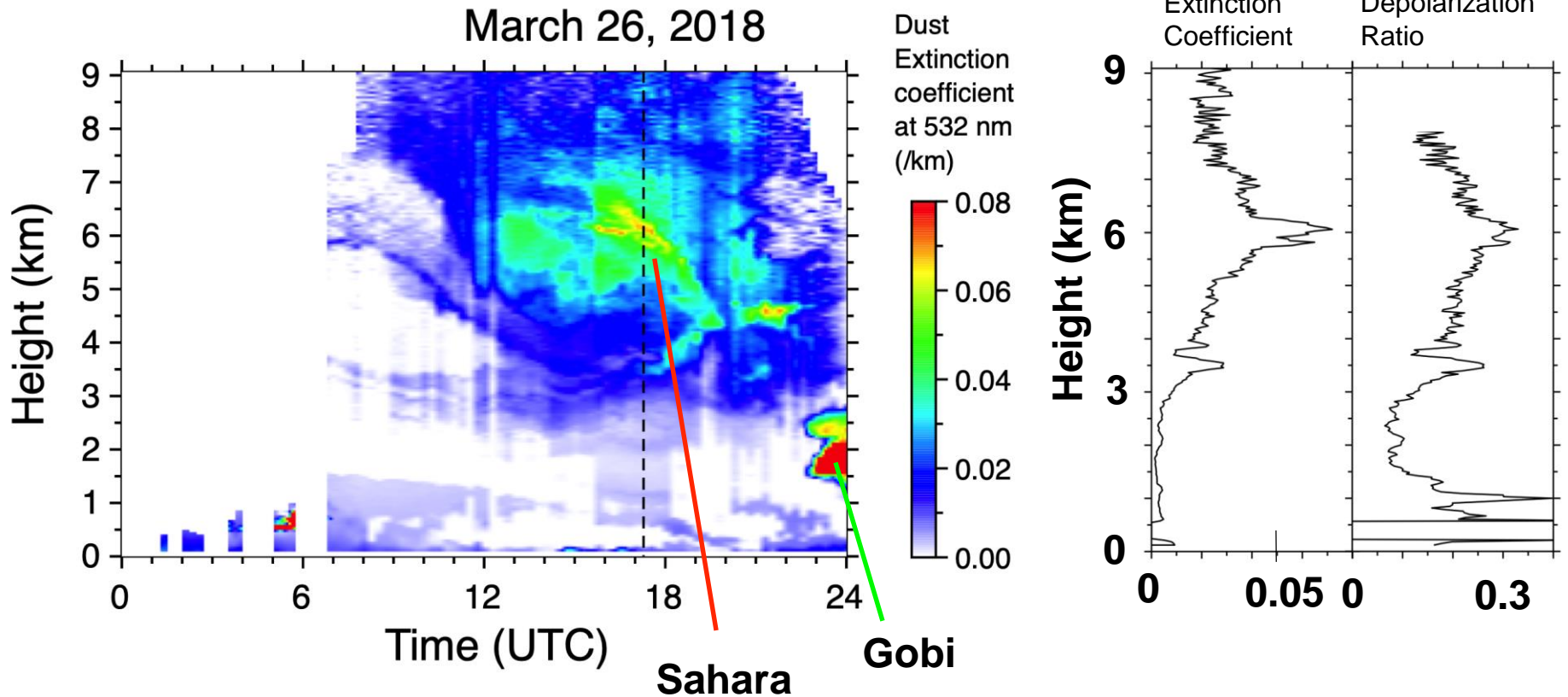


2018-03-26

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Sahara dust observed in Sapporo

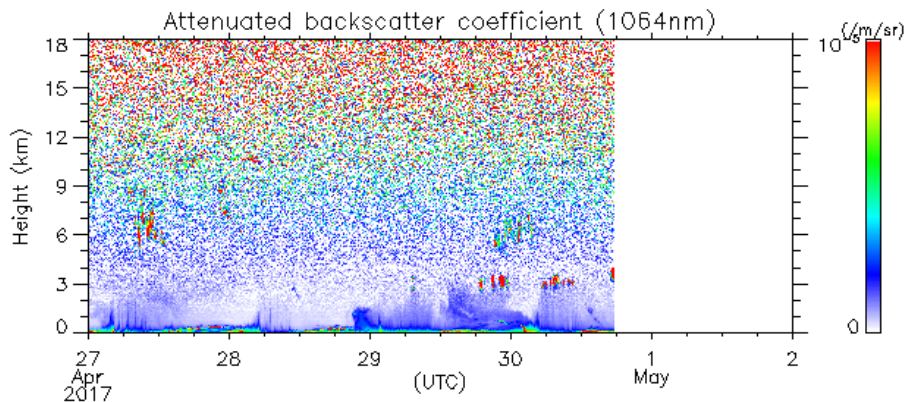
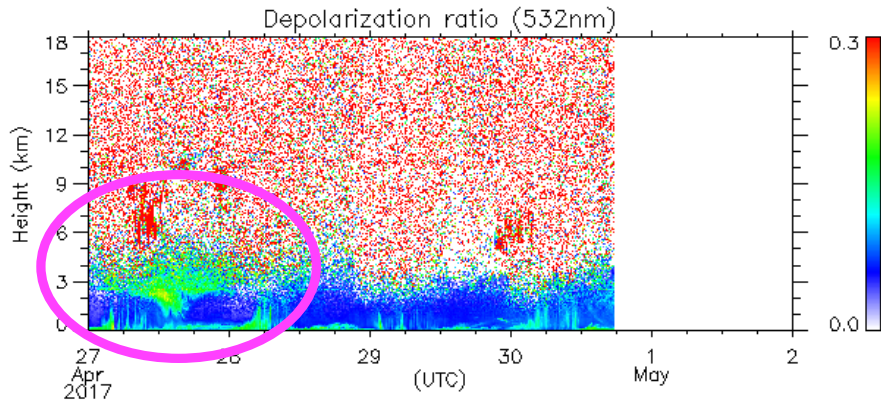
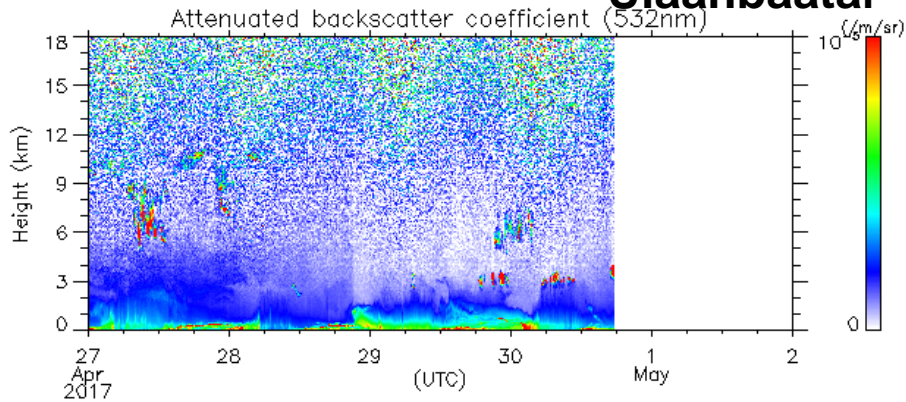


Concentration of the Sahara dust above Sapporo was about $50 \mu\text{g}/\text{m}^3$ at the maximum on 26 March 2018. AOD was about 0.2.

Sahara dust case in April 2017

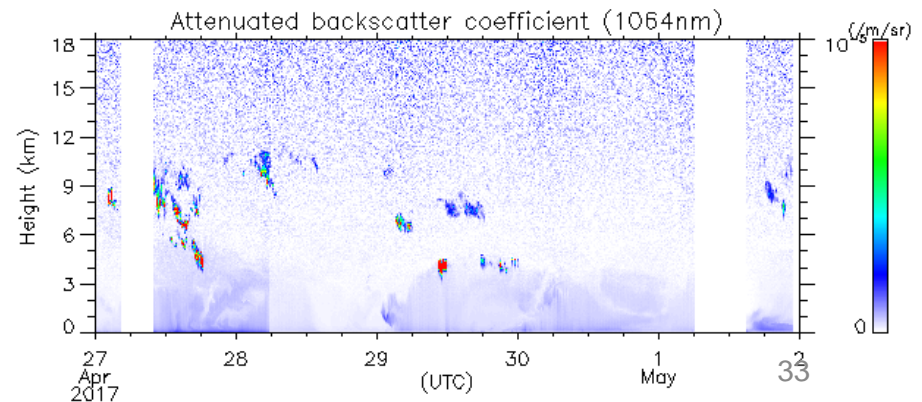
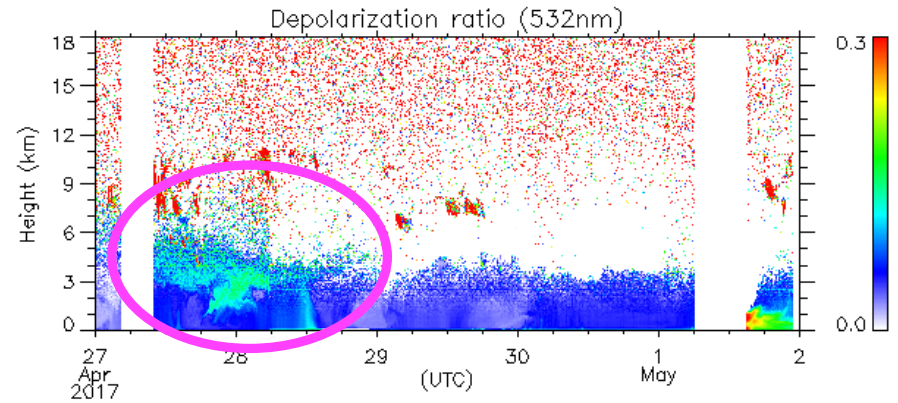
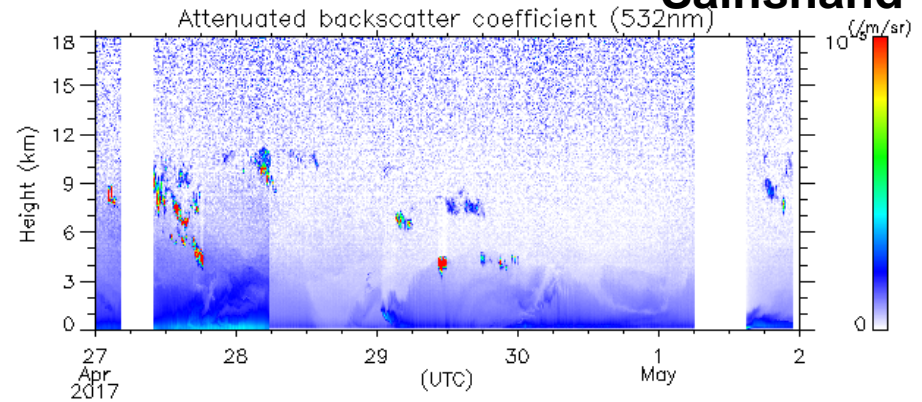
Lidar Observation in Ulaanbaatar

Ulaanbaatar

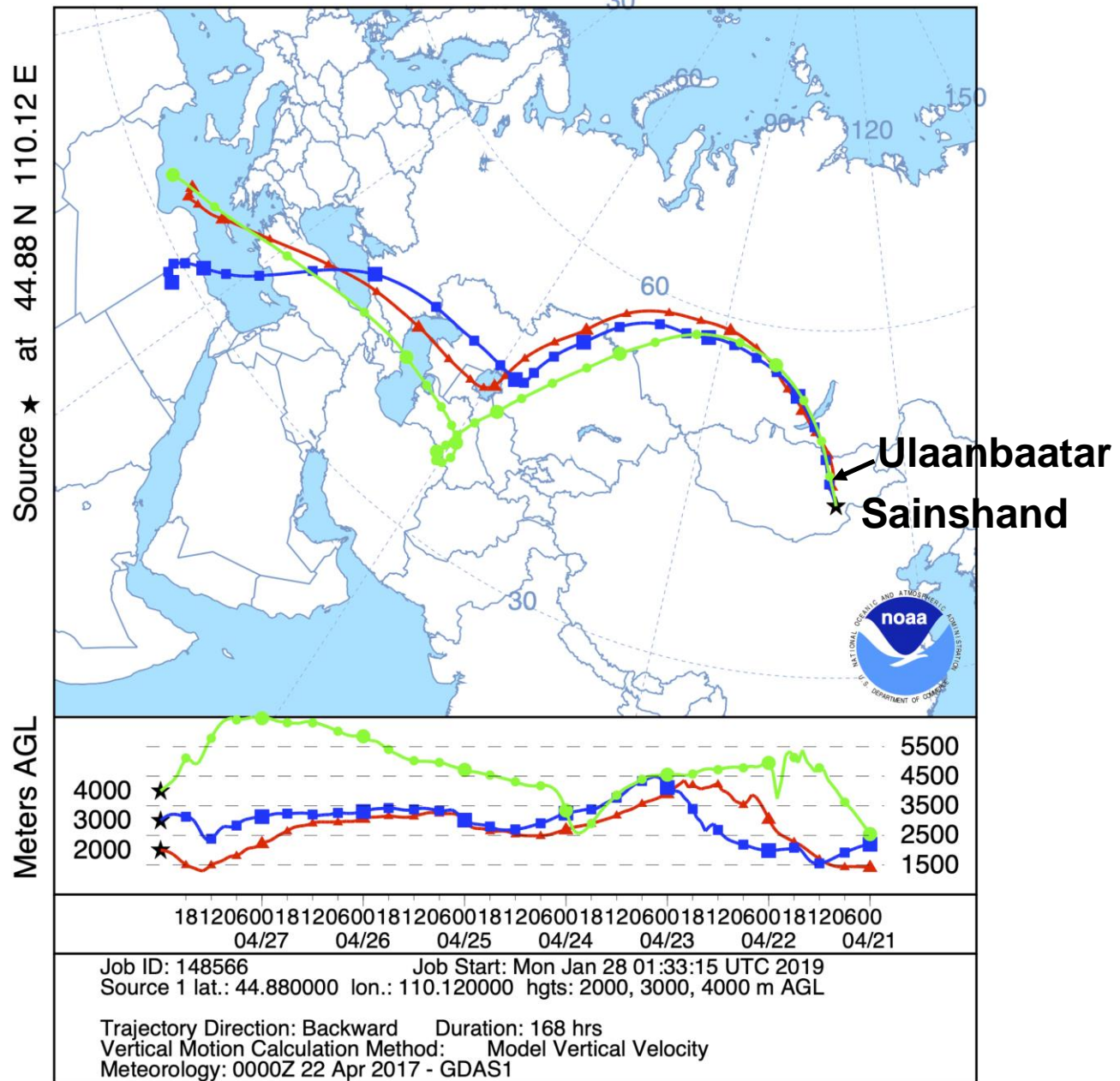


Lidar Observation in Sainshand

Sainshand



NOAA HYSPLIT MODEL
 Backward trajectories ending at 0000 UTC 28 Apr 17
 GDAS Meteorological Data



Middle East dust case in April 2015 observed in Dushanbe

14566

J. Hofer et al.: Lidar observations during CADEX

Atmos. Chem. Phys., 17, 14559–14577, 2017

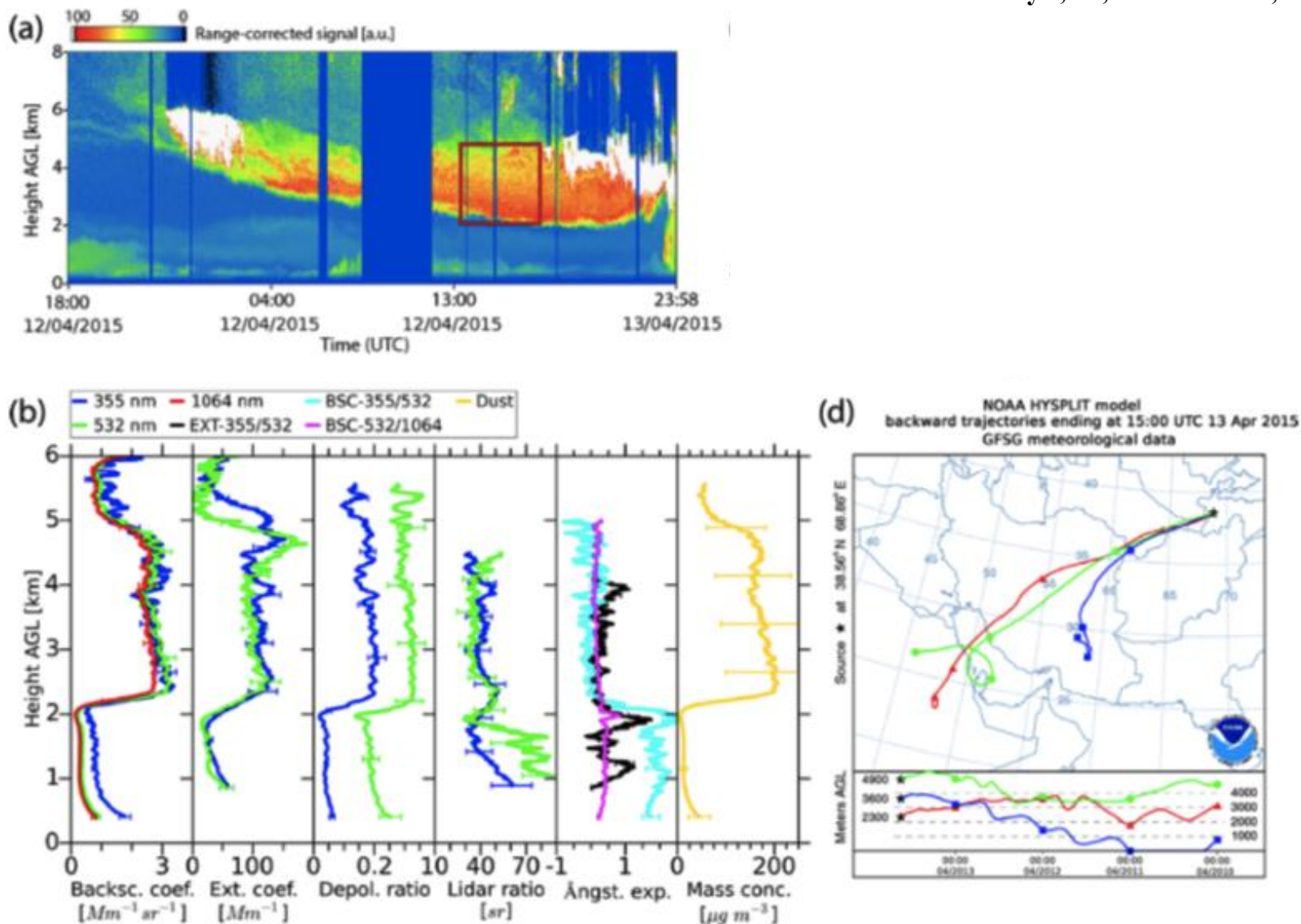
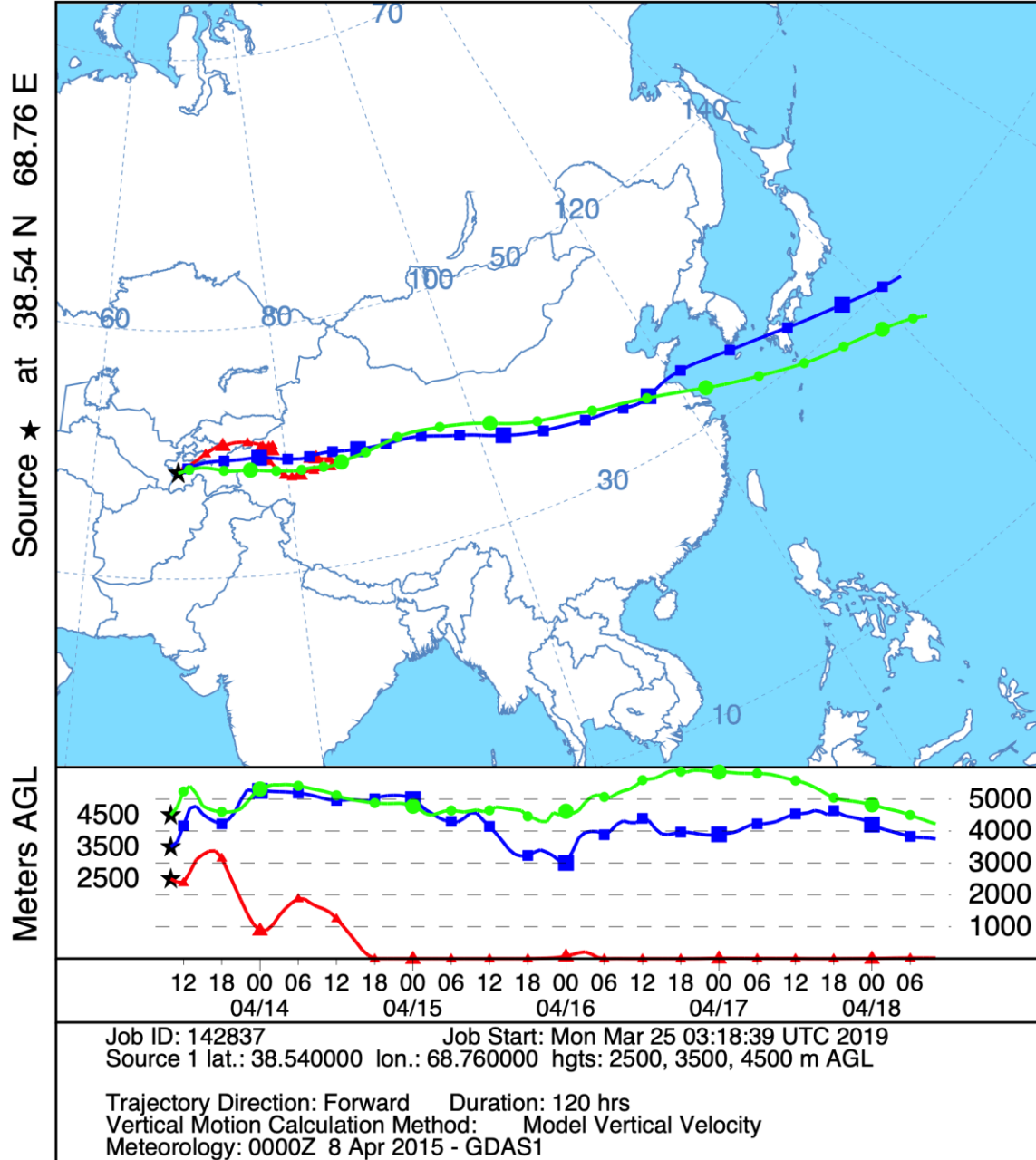


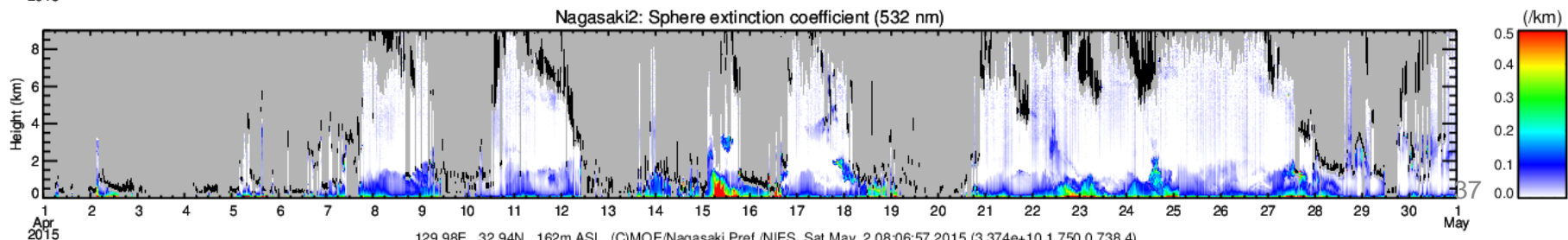
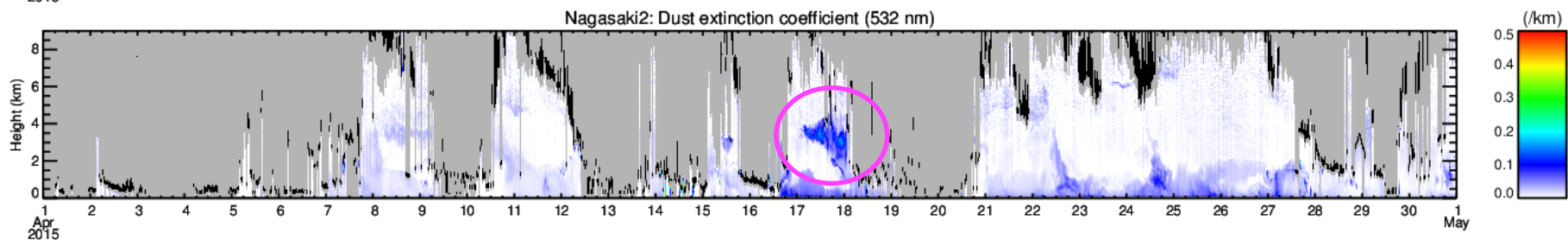
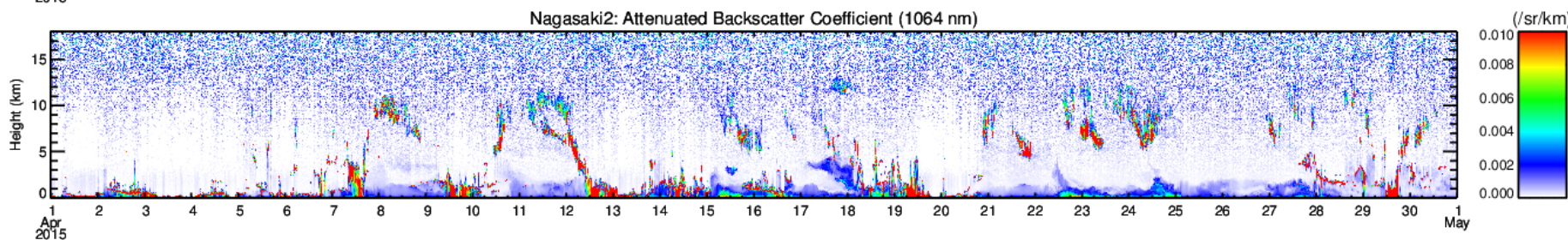
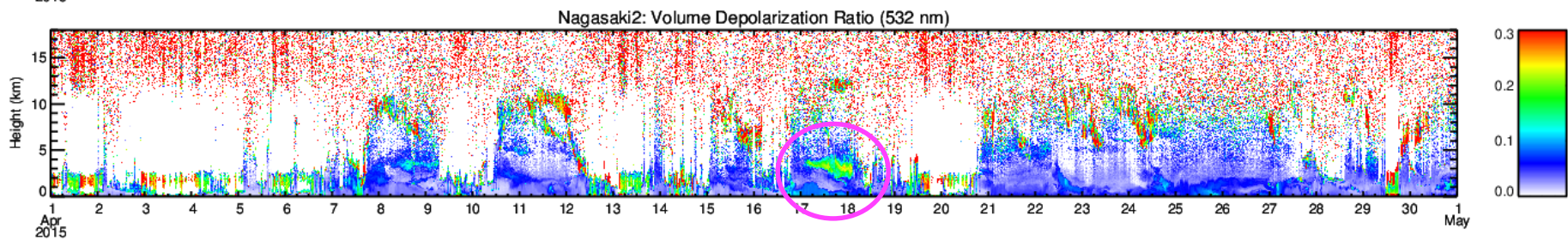
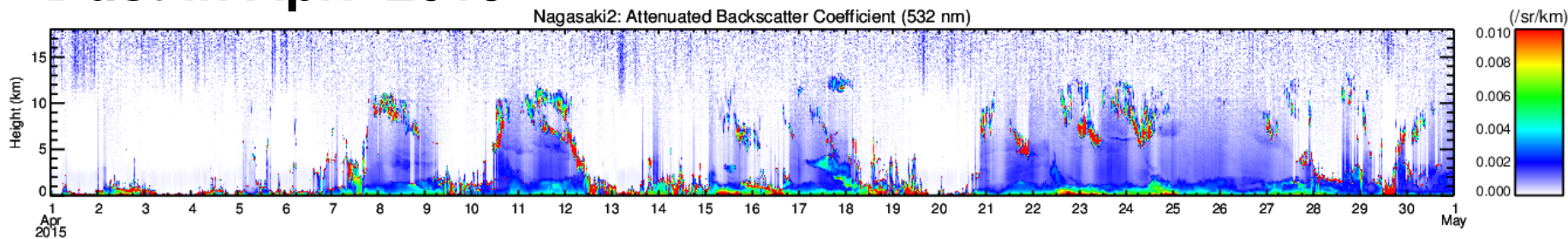
Figure 5. Case 1: a lofted layer of Middle Eastern dust is shown. (a) Same as Fig. 4a, b, c, but on 12 April 2015, 18:00 UTC – 13 April 2015, 23:58 UTC. (b) The averaged lidar profiles were measured on 13 April 2015, 15:10–16:08 UTC. Lidar signals are smoothed before calculation

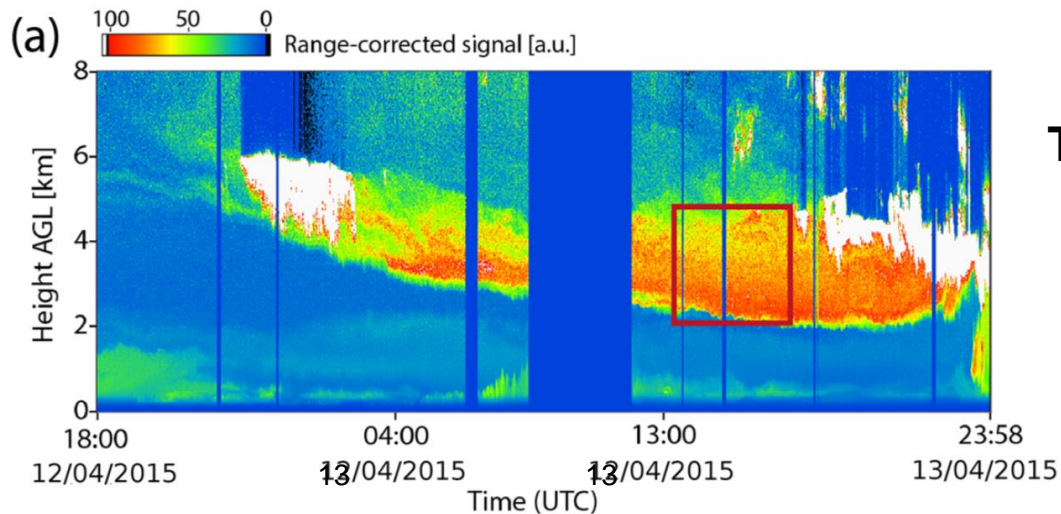
NOAA HYSPLIT MODEL
 Forward trajectories starting at 1000 UTC 13 Apr 15
 GDAS Meteorological Data



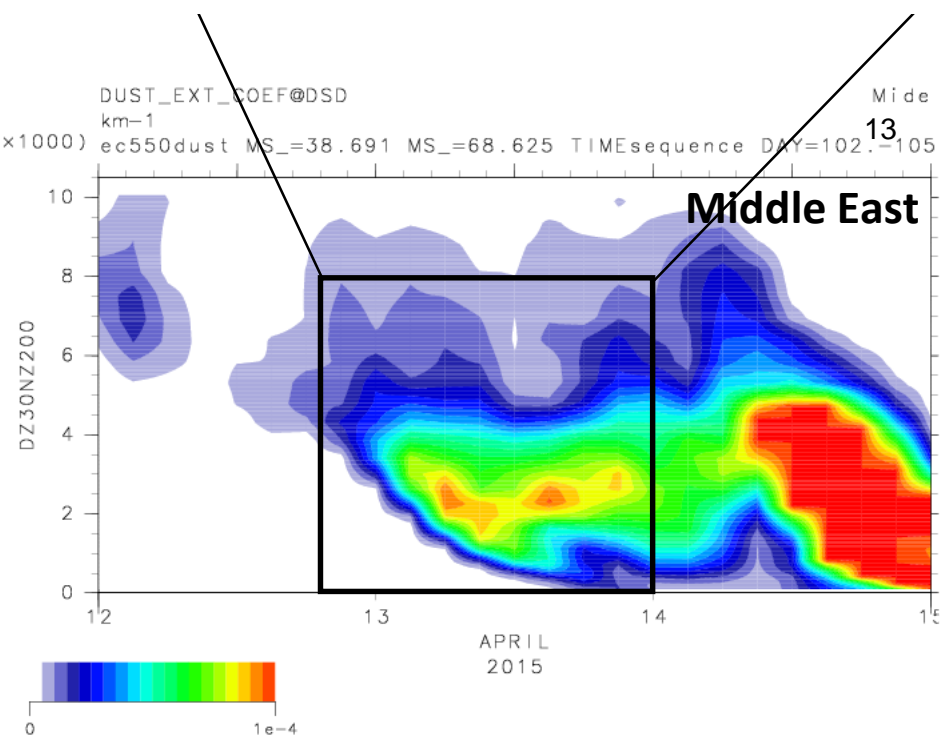
Forward trajectory from Dushanbe, Tajikistan

Dust in April 2015

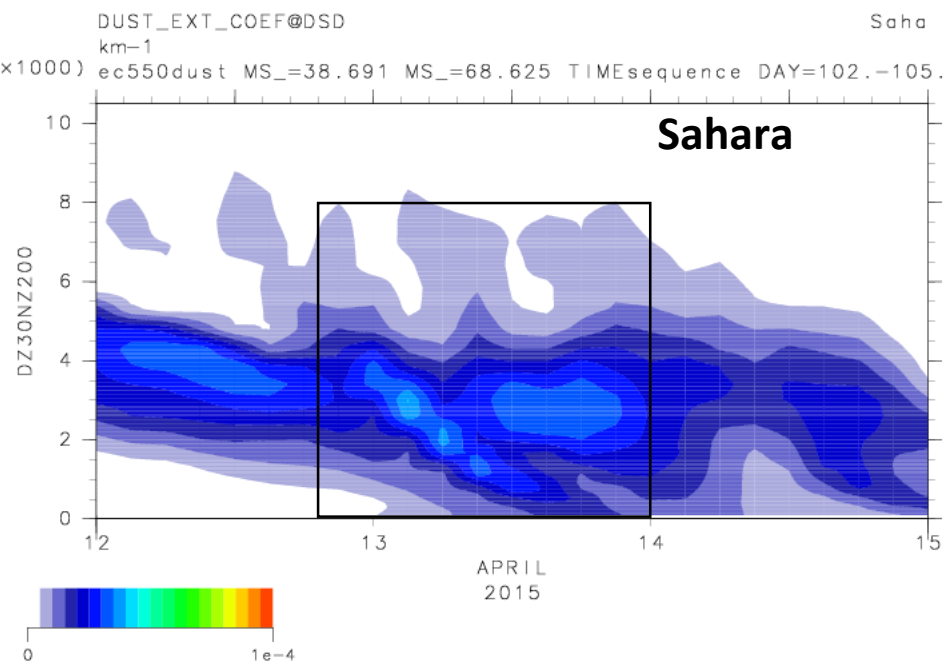




TROPOS Lidar

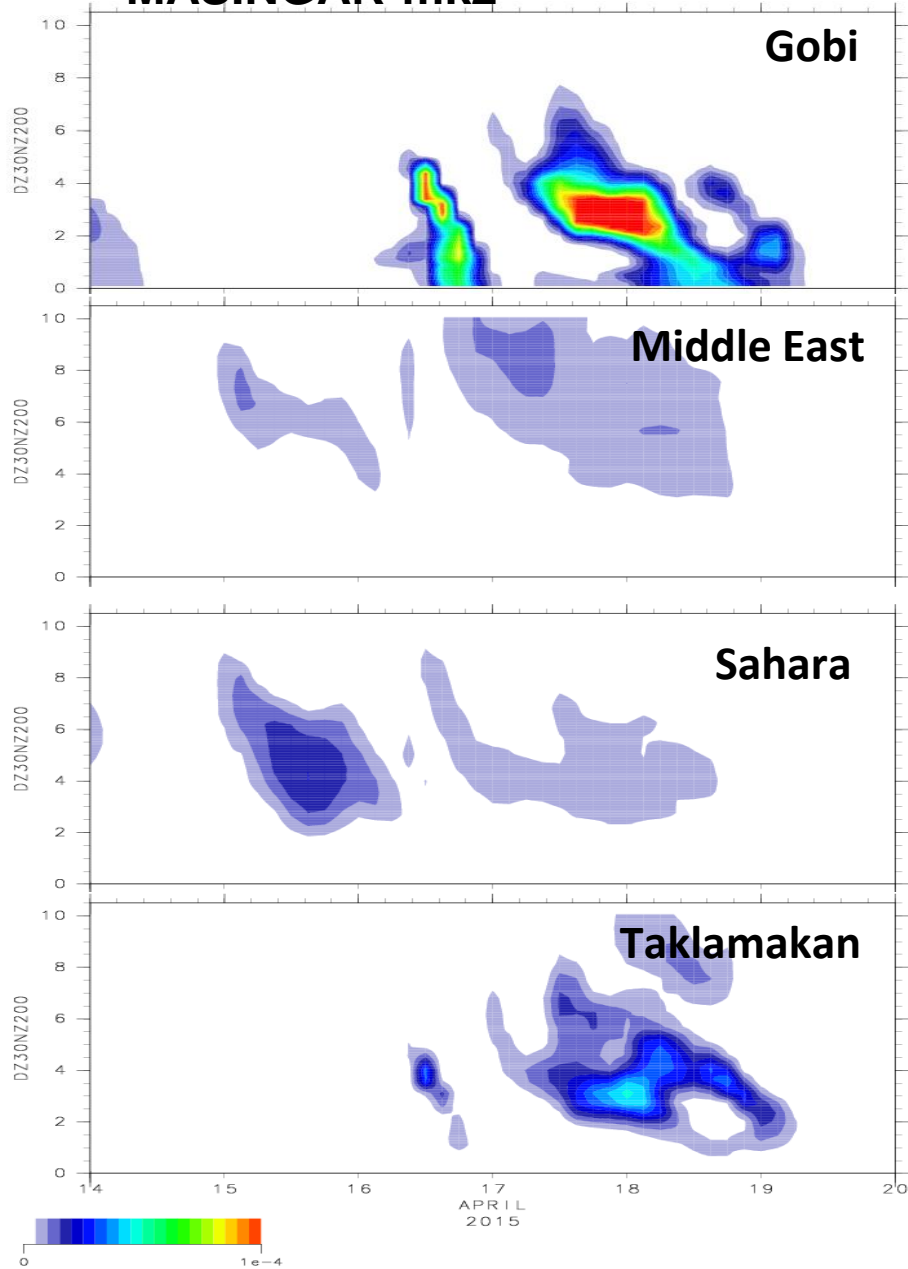


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Dust in April 2015 in Nagasaki

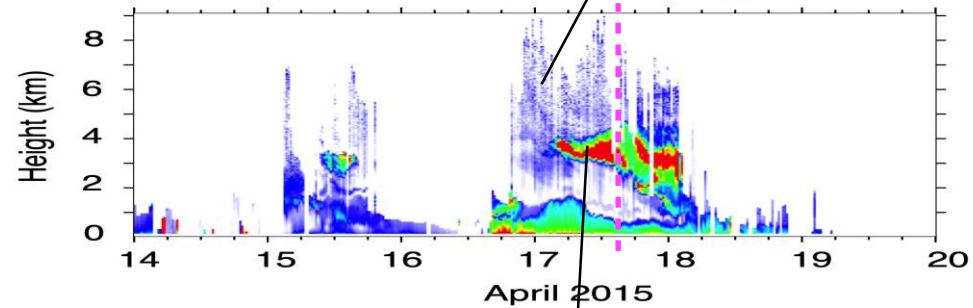
MASINGAR-mk2



Middle East

AD-Net Lidar

Dust extinction coefficient Nagasaki

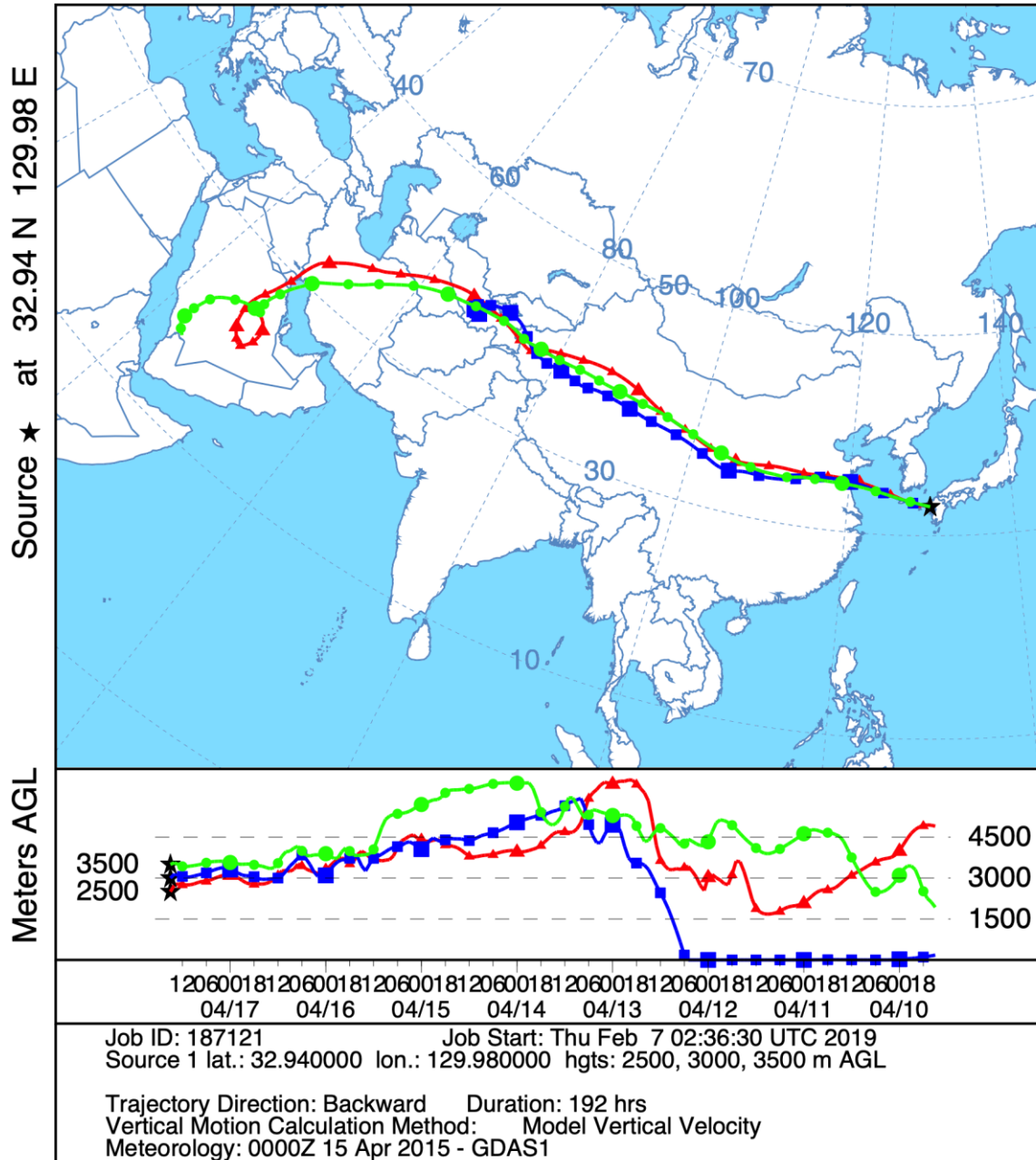


Gobi + Taklamakan

+ Middle East

+ Sahara

NOAA HYSPLIT MODEL
Backward trajectories ending at 1500 UTC 17 Apr 15
GDAS Meteorological Data



Major long-range transported dust events observed with AD-Net

2005.03.07-08 Suwon; Jeju; Tsukuba ← Sahara (Park et al., 2005)

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2015.04.17 Nagasaki ← Dushanbe, Tajikistan ← Middle East

2015.04.27 Sendai ← Sahara

2016.03.29 Sainshand ← Sahara

2017.04.27-28 Sainshand; Ulaanbaatar ← Sahara

(A portion of the transported dust was taken into the boundary layer in Mongolia)

2018.03.26-27 Sapporo; Fukue ← Sochi, Russia ← Sahara

2018.03.30-31 Sapporo ← Sahara

2019.03.15 Sainshand ← Sahara

Summary

- Dust from Africa and Middle East are transported to East Asia every year in the springtime (mostly in March and April).
- In seasons other than spring, no significant long-range-transported dust cases have been observed, so far.
- The transport path arriving in East Asia often passes through Kazakhstan and Russia.
- Dust transported across the high mountain in the west of the Taklamakan desert was also observed.
- Long-range-transported dust is often mixed with the dust from the Taklamakan and the Gobi. Analysis using global dust transport models with source identification tags is useful.

Concluding remarks

- Vertical profile measurements are essential for understanding the mixing of dust from different source regions.
- Further observational studies using multi-parameter lidars, sky radiometers and modeling studies are required. We still do not understand, for example, the changes in size distribution and optical characteristics during transport.
- Mongolia is an important location not only as the source area of Gobi dust but also for studying the characteristics of long-range-transported dust from Africa and Middle East. We are thinking of improving one of the AD-Net lidars in Mongolia to a multi-wavelength Raman lidar or HSRL. Also, it will be useful if we have observation sites in Kazakhstan.

Thank you