Validation/assimilation of chemical transport models using AD-Net lidar data

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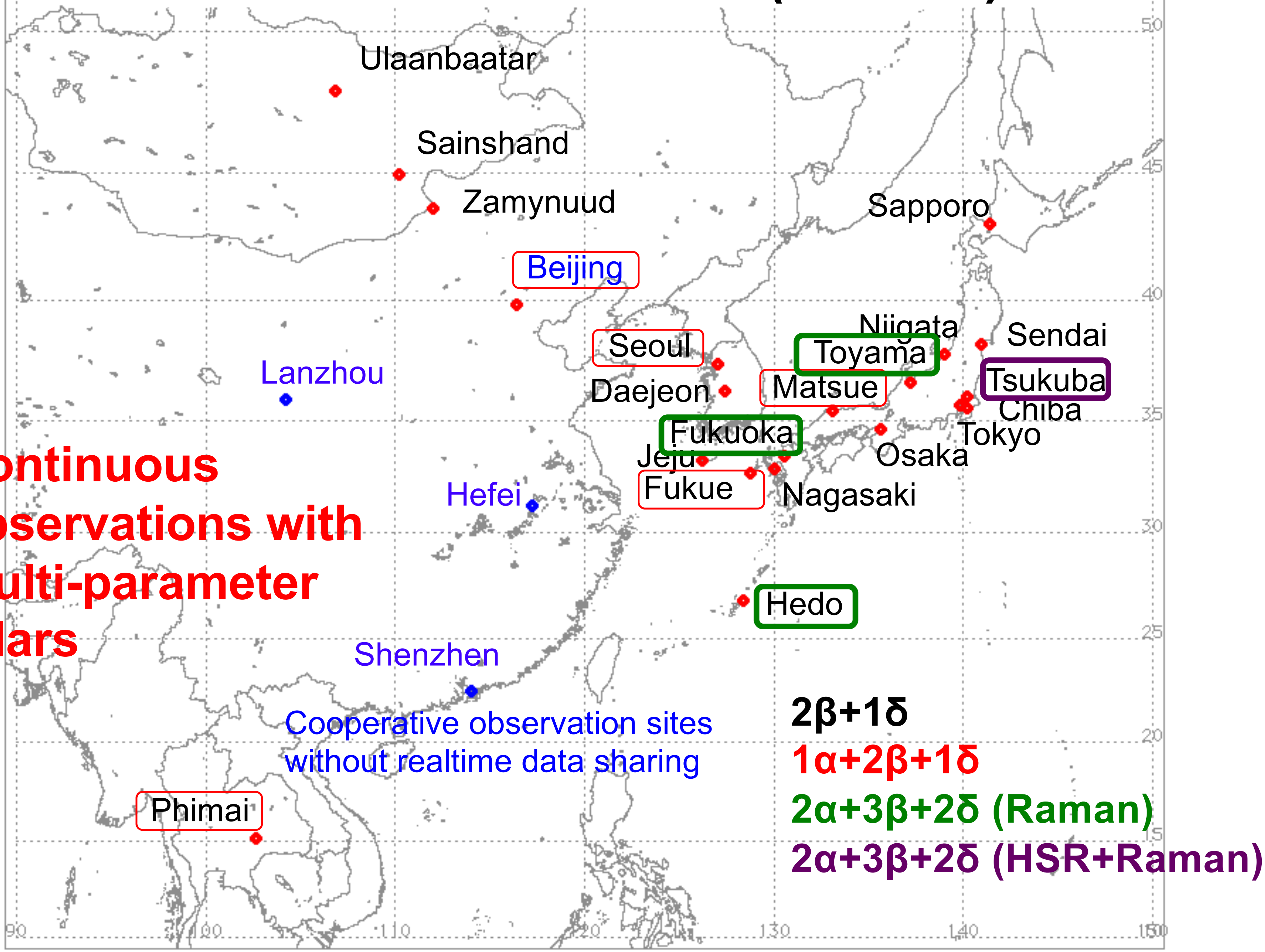
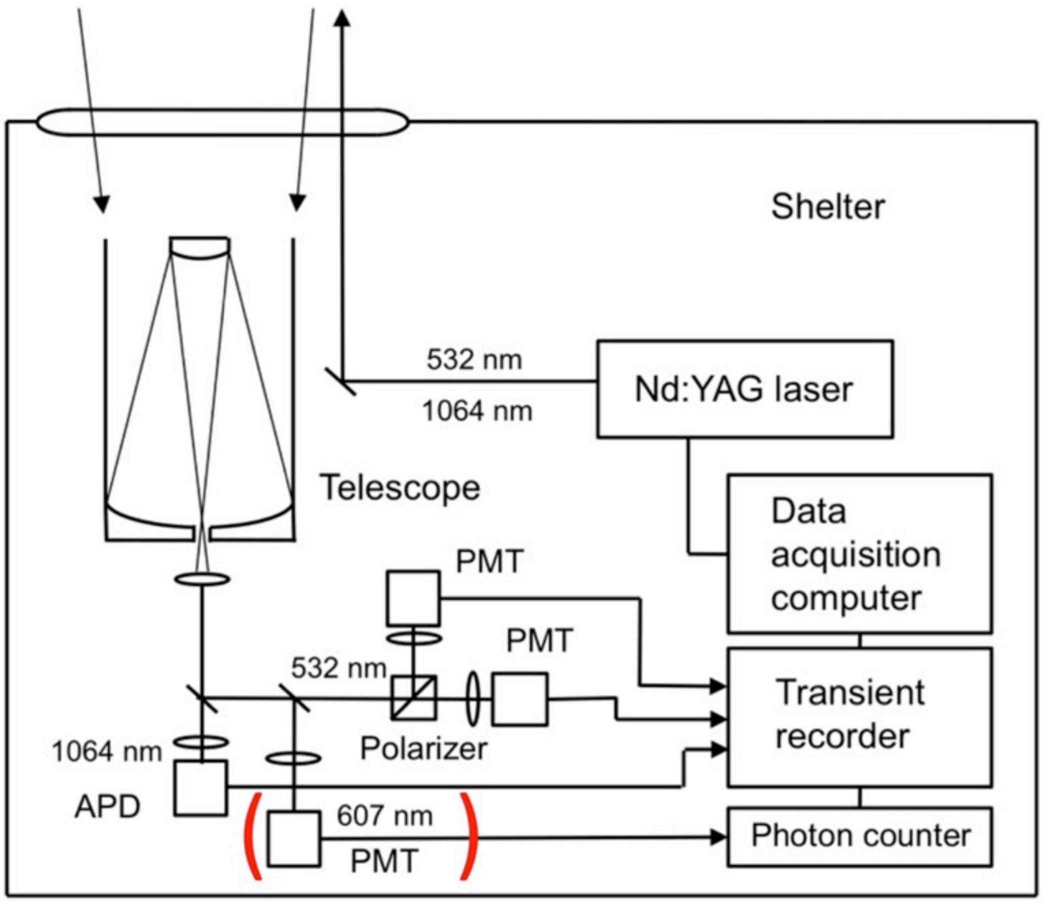
Asian Dust and Aerosol Lidar Observation Network (AD-Net)



Continuous observations with multi-parameter lidars

Lidars in AD-Net



2β+1δ (+1α) lidar

α: extinction,
β: backscattering,
δ: depolarization

www-lidar.nies.go.jp/AD-Net/

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

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Objective and approach

Lidar stations

Data quality control and data processing

Quicklooks

Data products

Publications

Data products

Figures (PNG & PostScript):Monthly THIs of attenuated backscatter coefficient (532nm, 1064nm), volume depolarization ratio (532nm), dust extinctio coefficient (532nm) with cloud/rain flags, spherical particle extinction coefficient (532nm) with cloud/rain flags.

NetCDF files:Similar contents with figures, but independent files are daily basis.

Please contact Nobuo Sugimoto (nsugimot(at)nies.go.jp) or Atsushi Shimizu (shimizua(at)nies.go.jp for the use of the data.

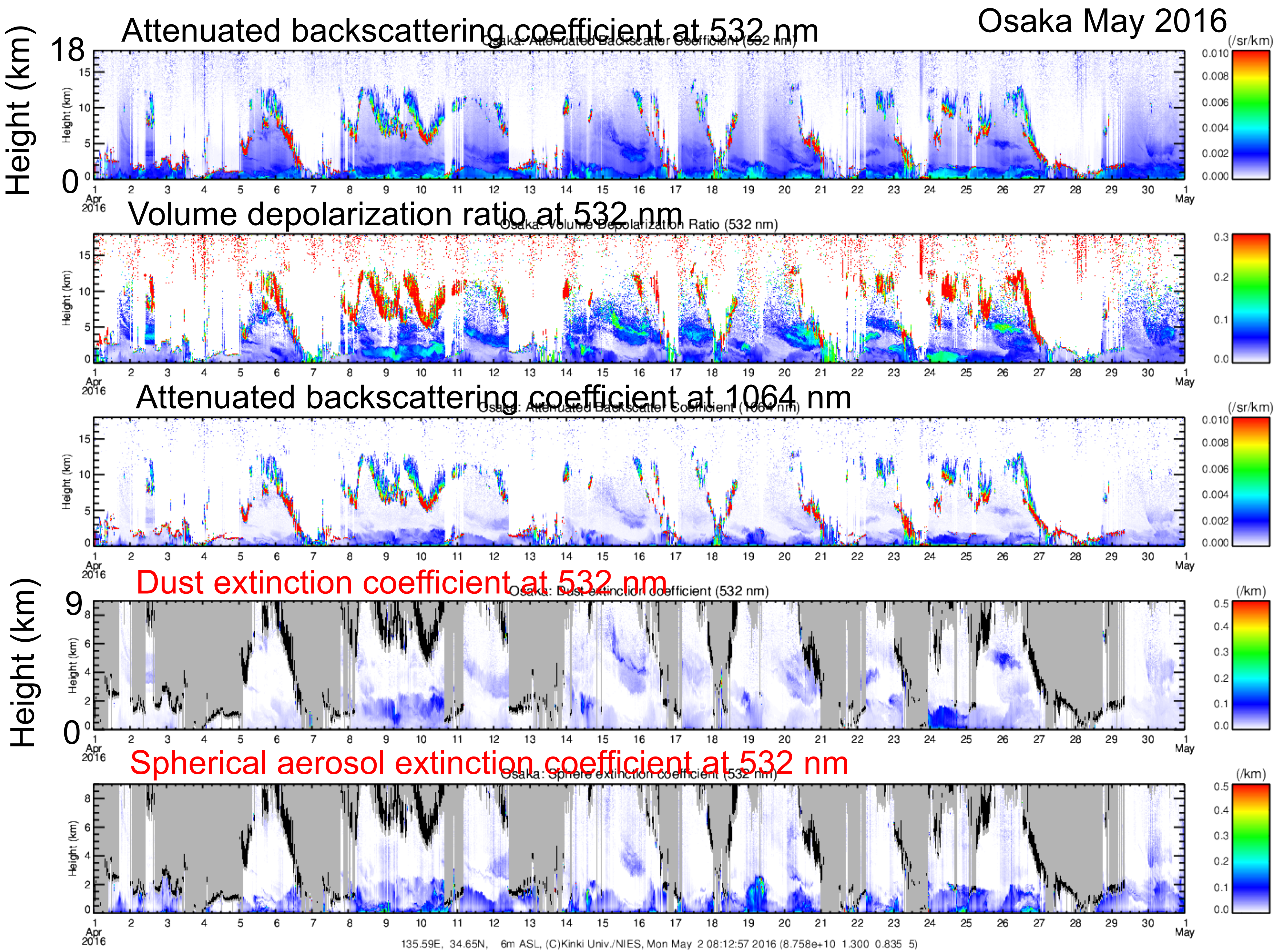
File name and contents of the NetCDF files

PPPYYMMDD.ncdf
PPP:3 letter code
(TKB,TYM,MTS,NGS,NGT,TKY,SPR,SND,CHB,OSK,FKE,HED,SEO,JEJ,DJN,BJN,ZMY,SNS,ULN,PHM)
YYMMDD:date in UTC

Dimensions:
TIME: UTC Start time (sec from 00Z) # every 15 min, 96 prof./day
HEIGHTA: altitude from ground (m) for attenuated backscatter and volume depol. #up to 18km
HEIGHTE: altitude from ground (m) for extinction data #up to 9 km

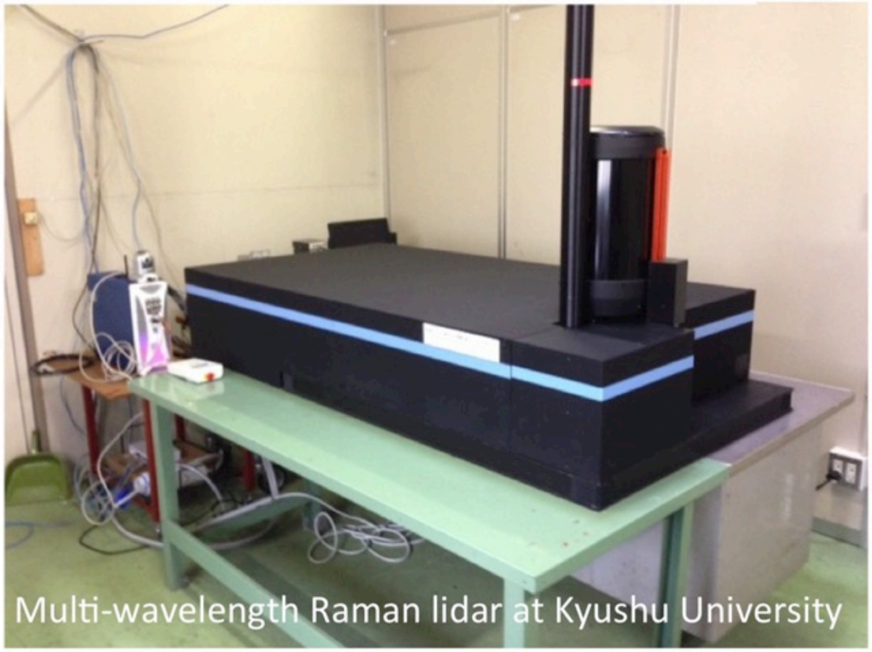
Variables:
ABSC532(T*HA): 532 nm attenuated backscatter coefficient (/m/sr)
ABSC1064(T*HA): 1064 nm (/m/sr)
DEP532(T*HA): 532 nm volume depolarization ratio #S/P
EXT532(T*HE): 532 nm aerosol extinction coefficient (/m)

Standard near realtime AD-Net data products (updated every hour)

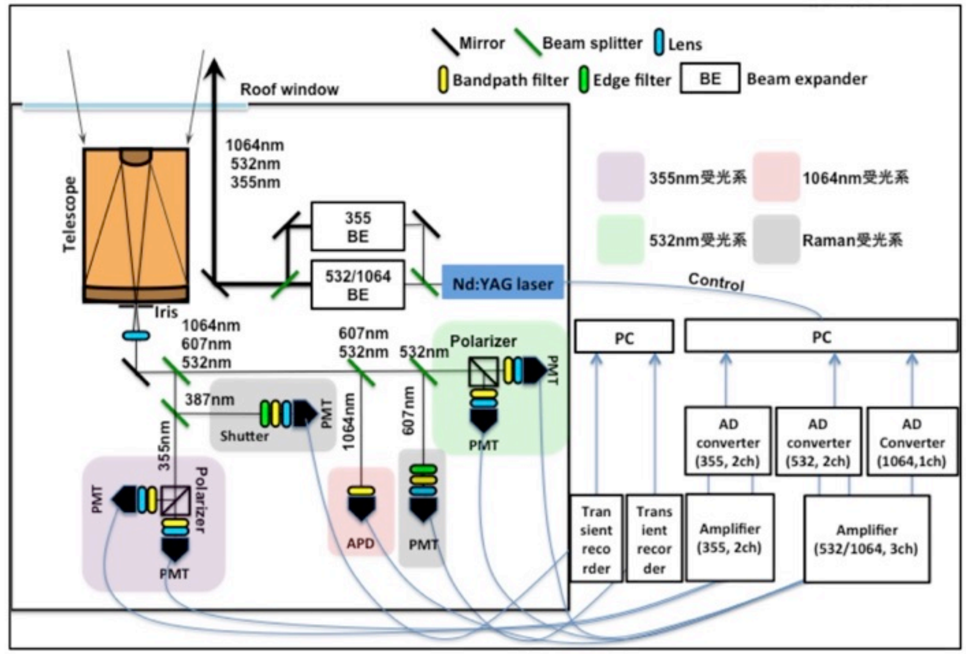


Provided in NetCDF format（http://www-lidar.nies.go.jp/AD-Net/）

Multi-Wavelength Raman Lidar System



Multi-wavelength Raman lidar at Kyushu University

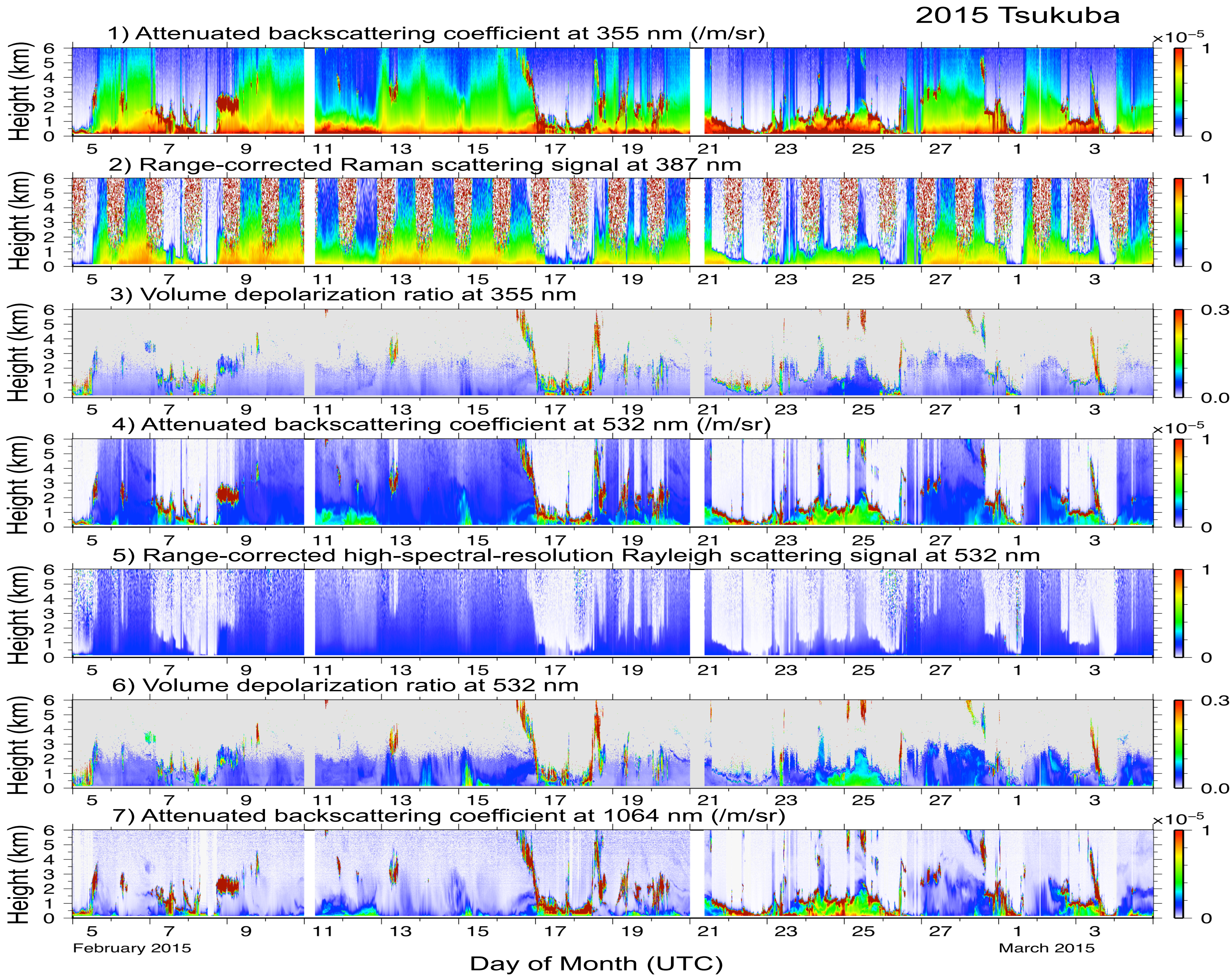


Transmitter	Specification
Laser type	Nd:YAG, Q-switched, linearly polarized
Wavelength	1064, 532, 355nm
Pulse energy	165 (1064nm), 105 (532nm), 60 mJ (355nm)
Repetition	10Hz
Divergence	< 0.1mrad (using a 5x expander)
Pulse duration	4-5ns

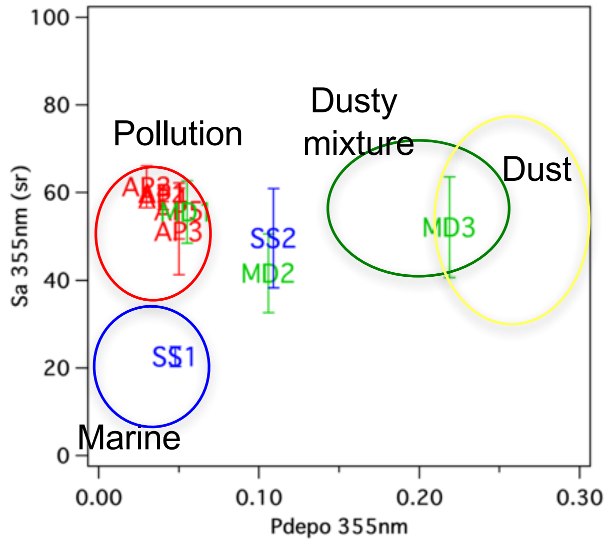
Receiver	Specification
Telescope	Schmidt-Cassegrain, Diameter=20cm, Focal length =2m
FOV	1mrad
Detectors	PMTs for 355, 532nm for elastic channel [Licel] PMTs for 387, 607nm for Raman channel [Licel] APD for 1064nm [Licel]
filter	1nm (FWHM) for each channel

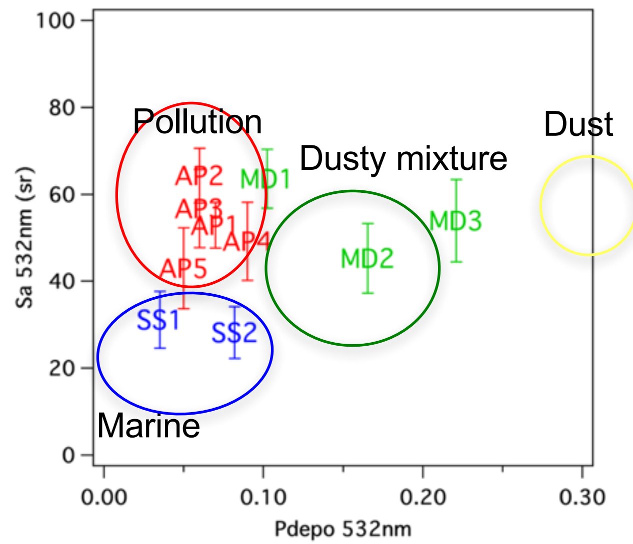
Data acquisition	Specification
Elastic channels	Analog measurement, A/D converter for 355, 532, 1064nm (25MHz, 16bit)
Raman channels	Photon counting & Analog measurement, Transient recorder for 387, 607nm (20MHz, 16bit for analog, 250MHz for photon counting)

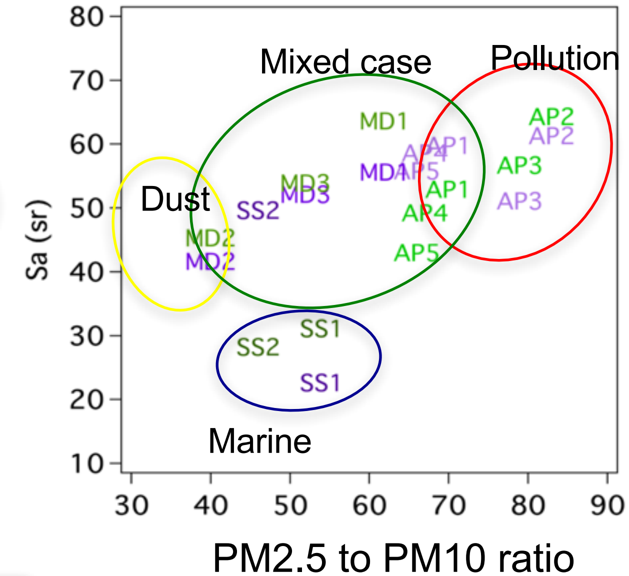
Continuous multi-wavelength HSR-Raman lidar measurements

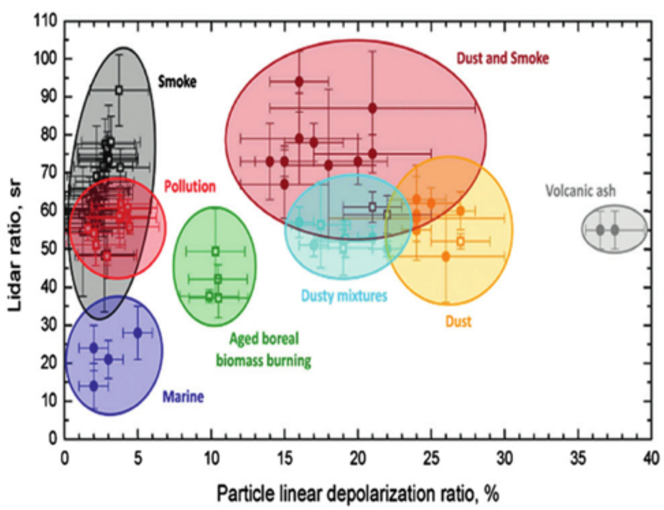


Lidar ratio vs Depolarization ratio (Aerosol types)

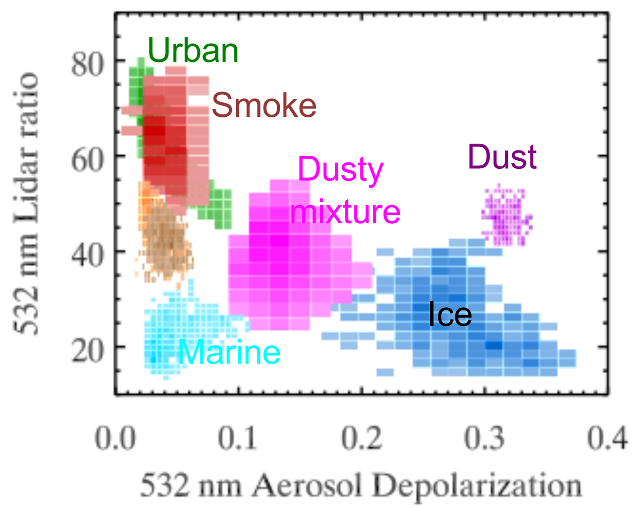








Illingworth et al. 2015



Burton et al. 2012

Optical parameters of aerosols averaged in the boundary layer are plotted. **(Fukuoka, January to April 2015)**

Simultaneous in-situ chemical analysis was performed

→ Nishizawa et al., JQSRT 2016

→ Hara et al., JQSRT 2016.

→ Determining reasonable aerosol optical models

→ → Assimilation of multi-parameter lidar data

Ceilometer AD-Net lidar comparison

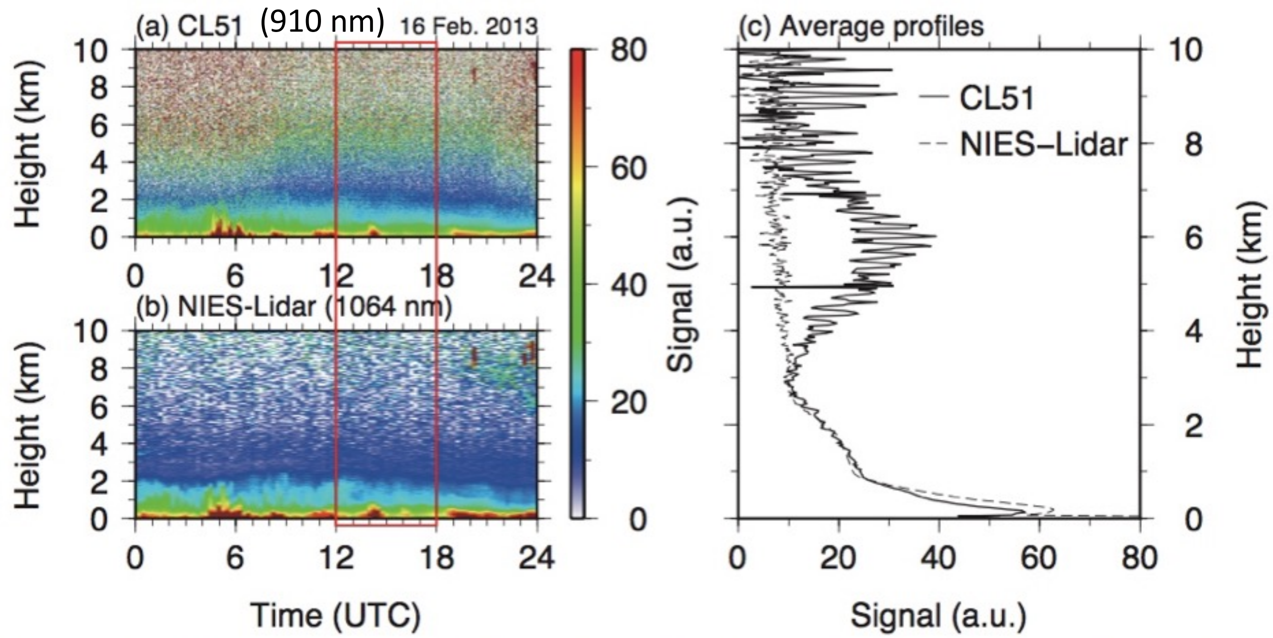
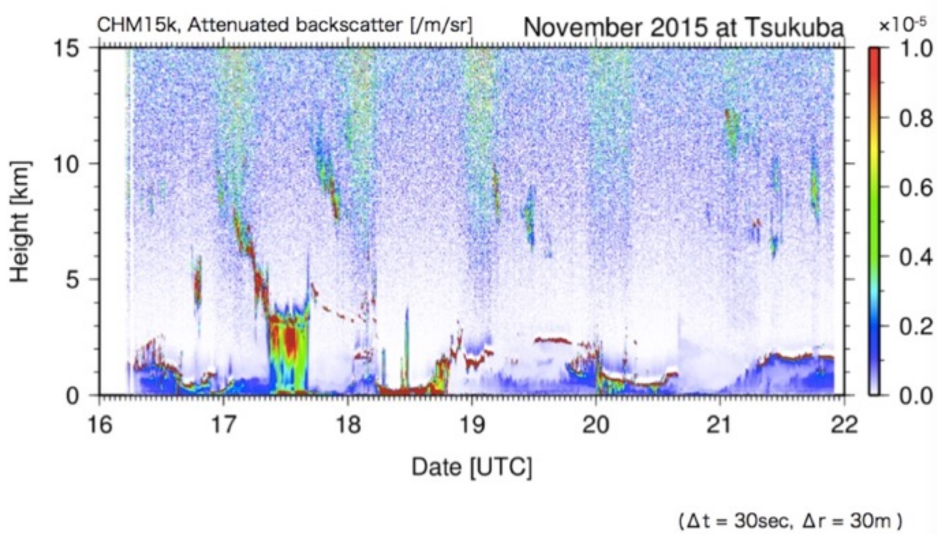
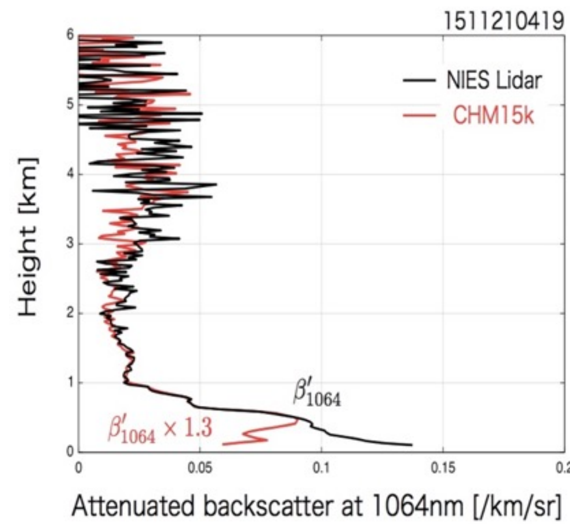


Figure 4. Time-height signal intensity of (a) CL51 and (b) NIES-Lidar at 1064 nm wavelength on 16 February 2013 at Tsukuba, Japan. The red rectangle denotes the signal average period and (c) is the average signal profiles.

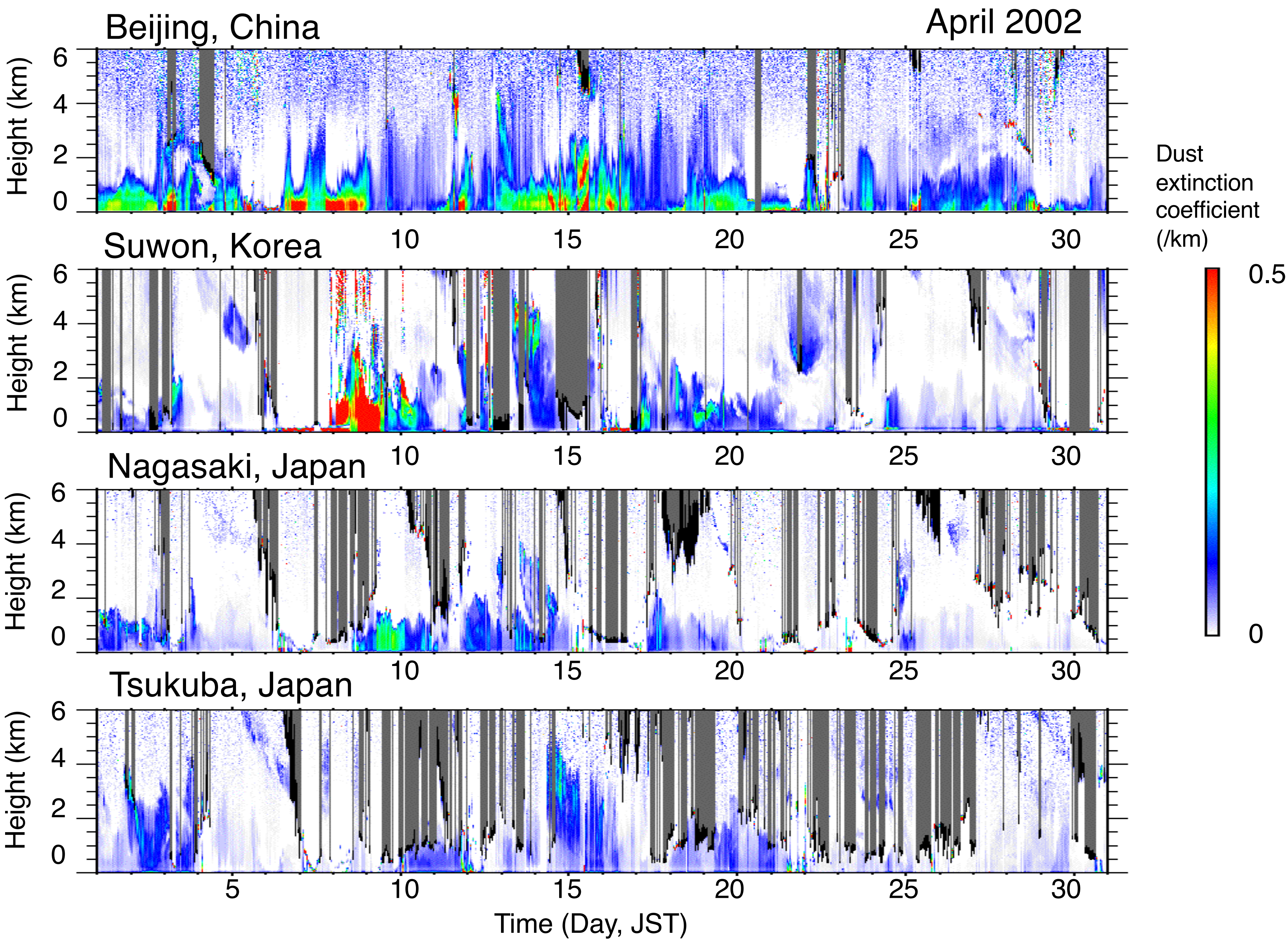
CHM 15k (1064 nm)



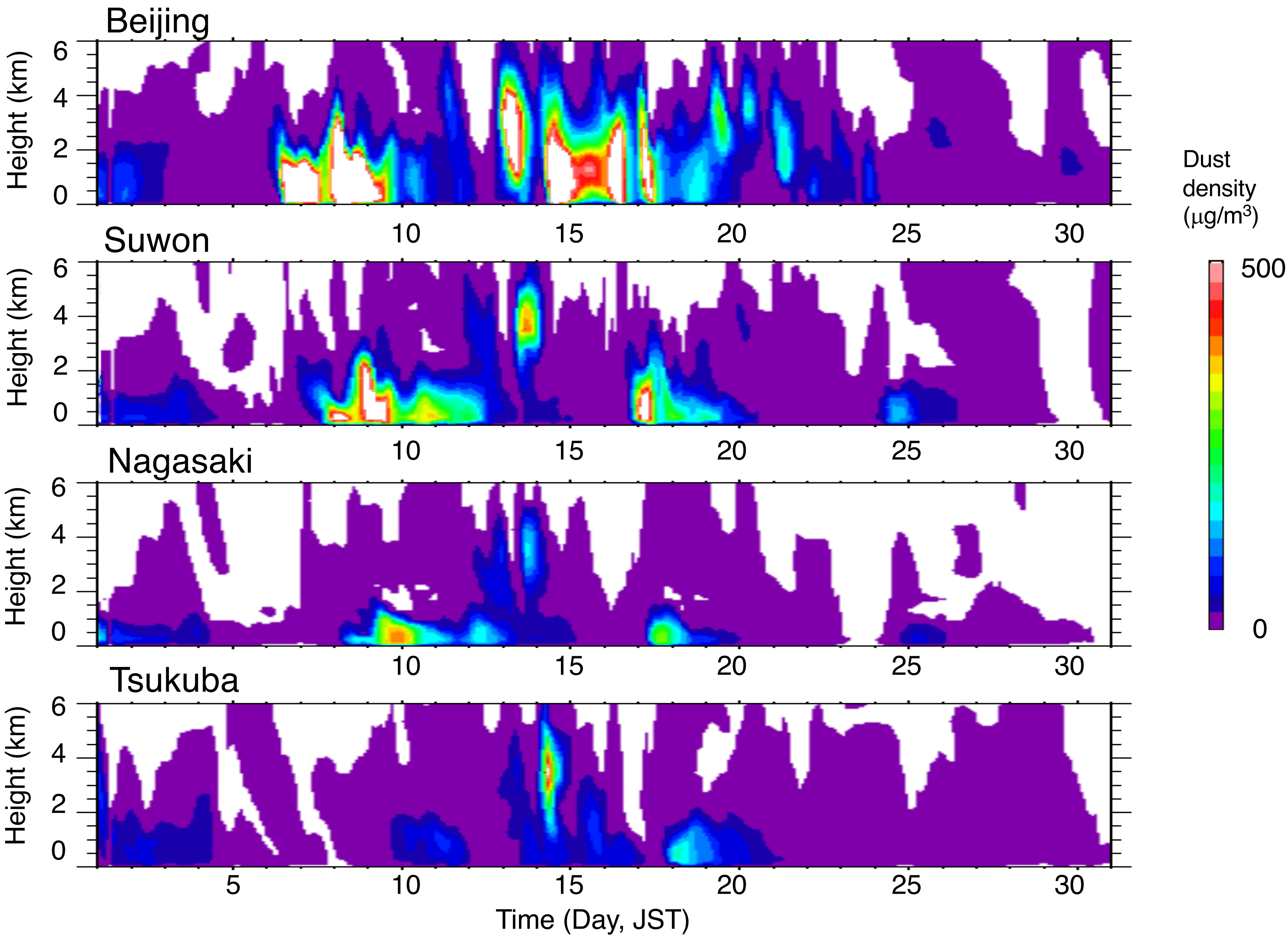


AD-Net Summary

- Continuous observations are performed at 20 locations in East Asia including 3 multi-wavelength Raman lidars and 1 HSRL
- Backscattering lidar data are processed in near realtime and published in NetCDF format (http://www-lidar.nies.go.jp/AD-Net/)
- AD-Net data are used in various studies on Asian dust and regional air pollution, including validation/assimilation of chemical transport models, epidemiology of dust and pollution particles
- A study of assimilation of the multi-parameter lidar data with a chemical transport model is ongoing. Simultaneous in-situ aerosol chemical composition measurements are being performed in Fukuoka (Kyushu U.).
- A study on the use of ceilometers for aerosol measurements in remote areas is ongoing.

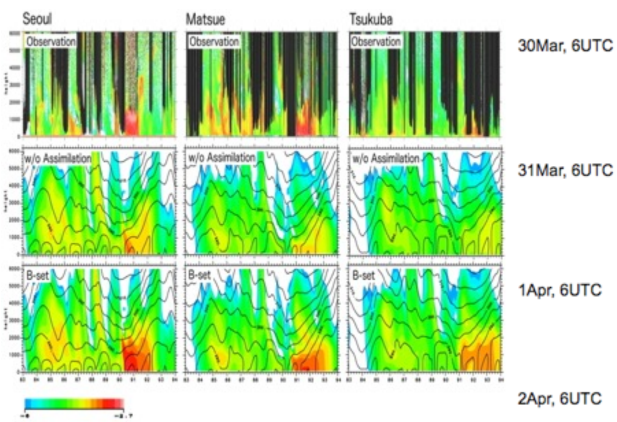


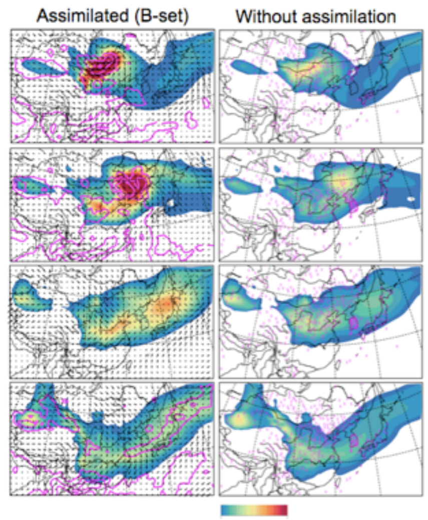
Lidar Dust Extinction Coefficient (S1=50 sr) (April 2002)

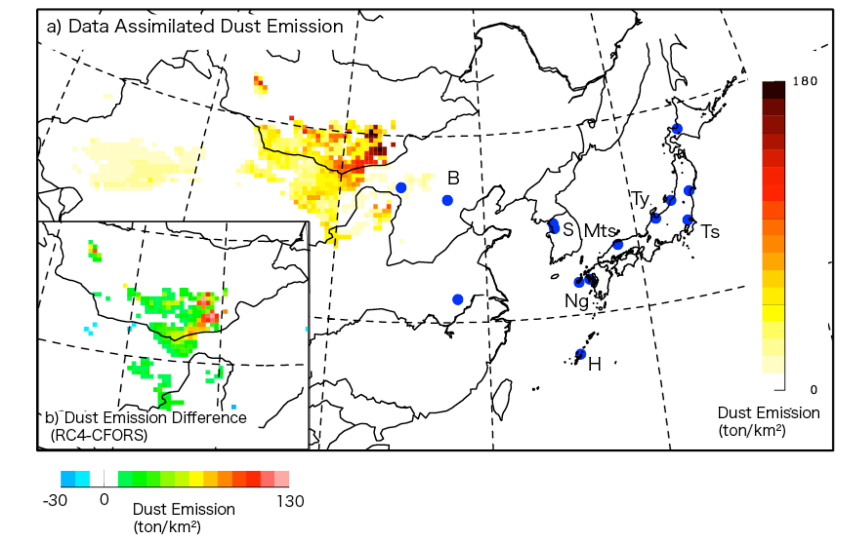


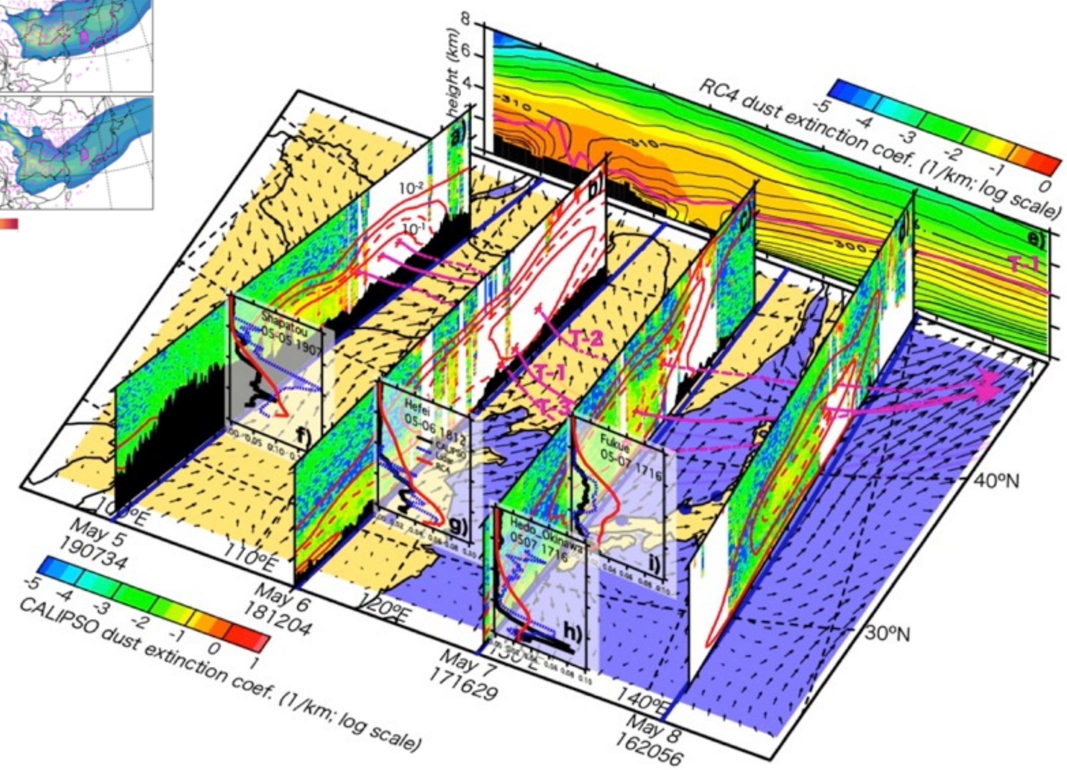
CFORS post analysis (April 2002)

Asian dust study using 4D-Var data assimilation





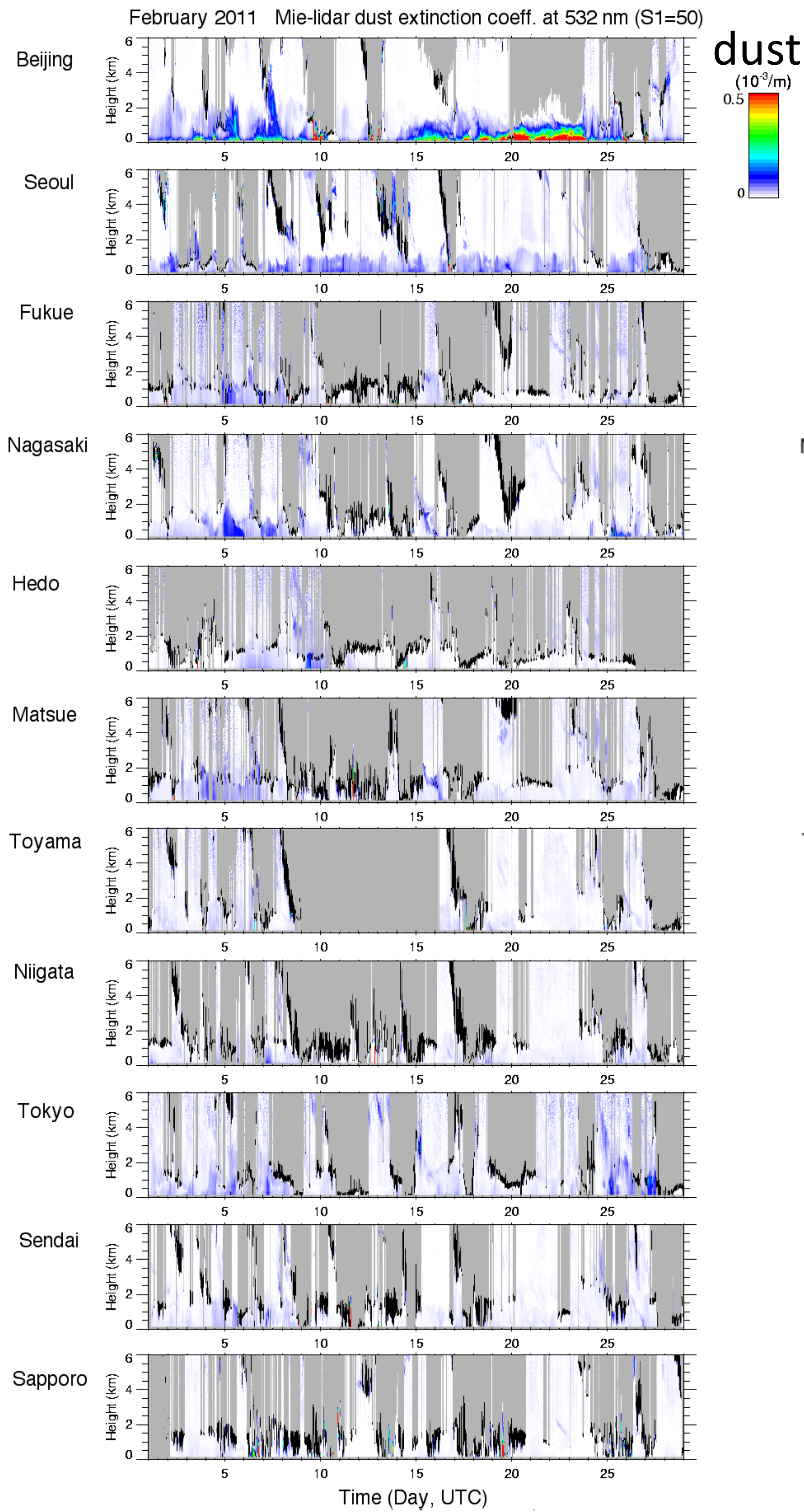




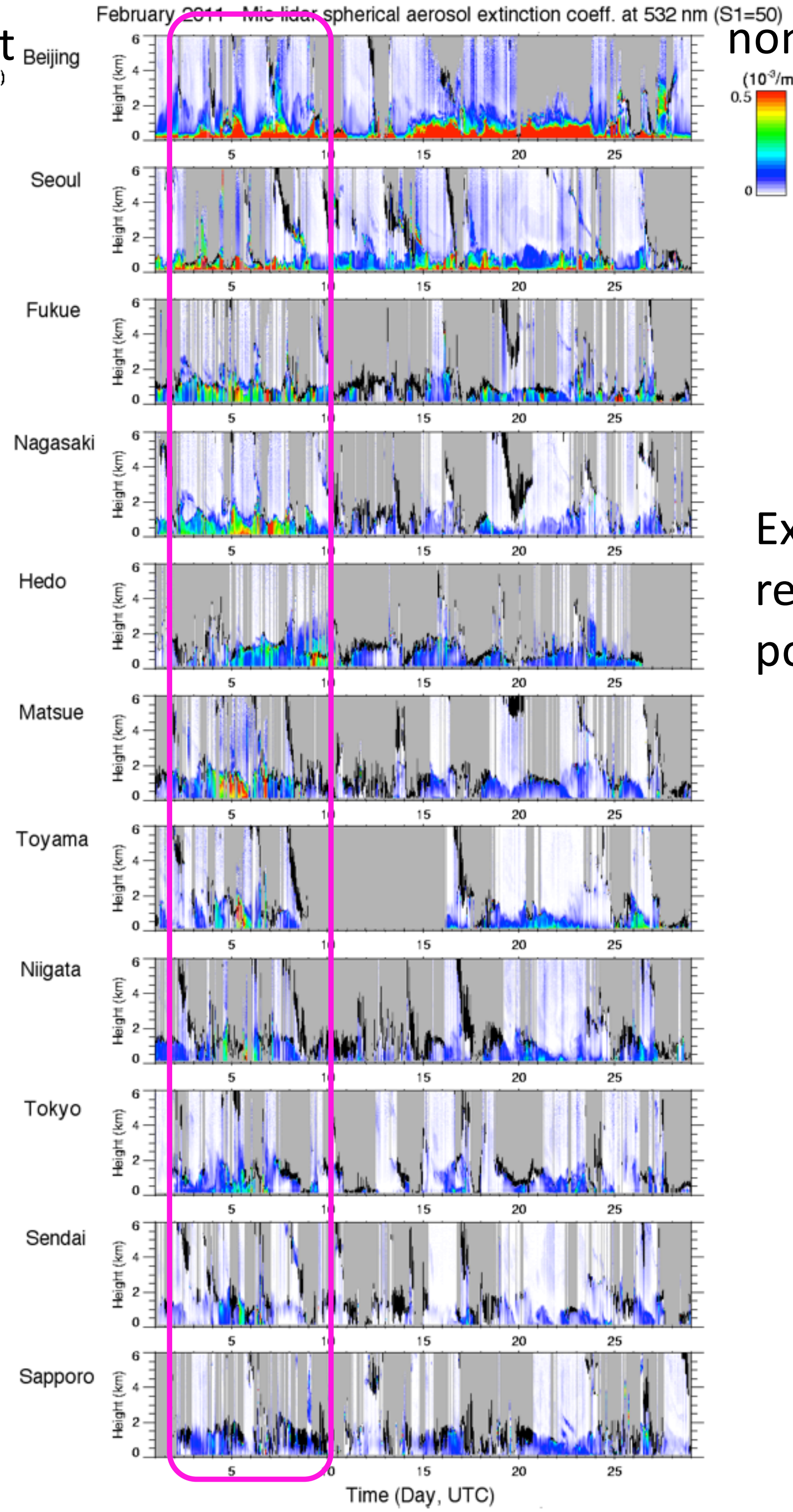
4DVAR data assimilation of Asian dust using the NIES lidar network data (Yumimoto et al. 2007, 2008)

Comparison of the assimilated dust transport model with CALIPSO data (Uno et al. 2008)

Please see the publication list at
http://www-lidar.nies.go.jp/~cml/English/PublicationsE.html



dust



non-dust

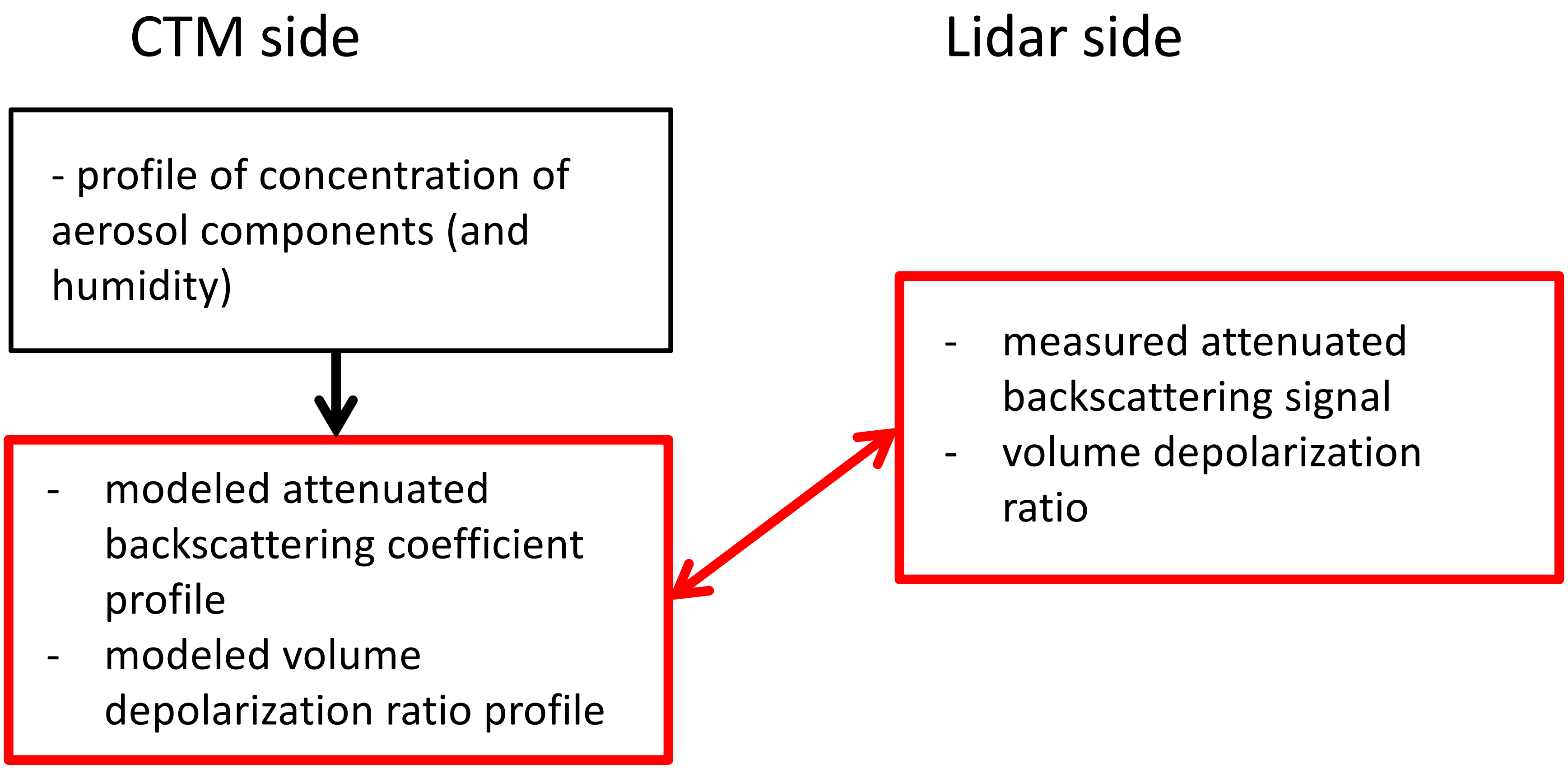
Feb 2011

Example regional air pollution event

Correct methods for using backscattering lidar data in validation/assimilation of chemical transport models

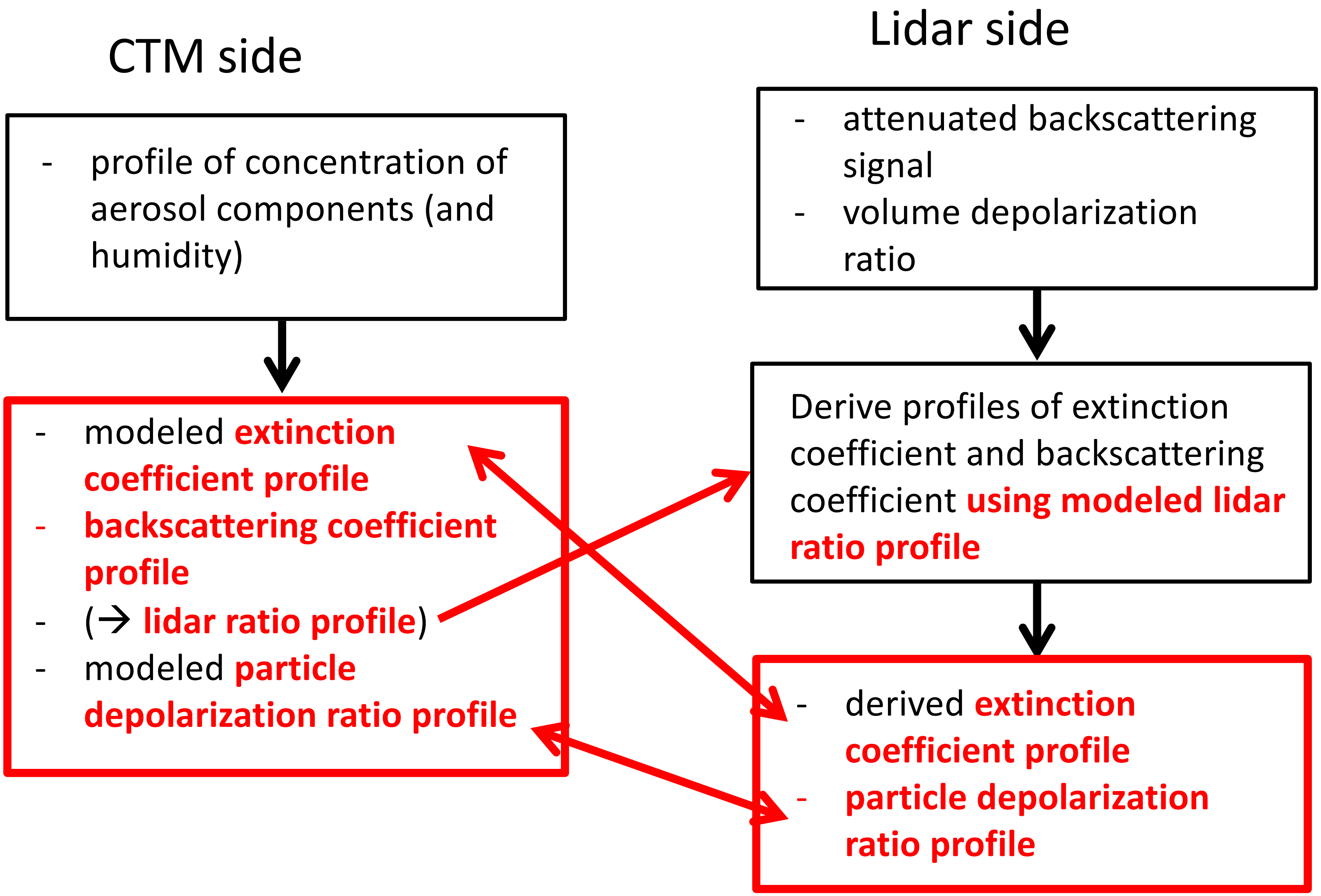
“Correct” means that all assumptions are in the modeling side.

Method using attenuated backscattering coefficient



The use of **attenuated backscattering coefficient** is **not recommended for ground-based lidars**, because it is generally difficult to simulate near surface aerosols with CTMs, and large error is expected in the modeled attenuated backscattering coefficient profile.

Method for ground-based lidars



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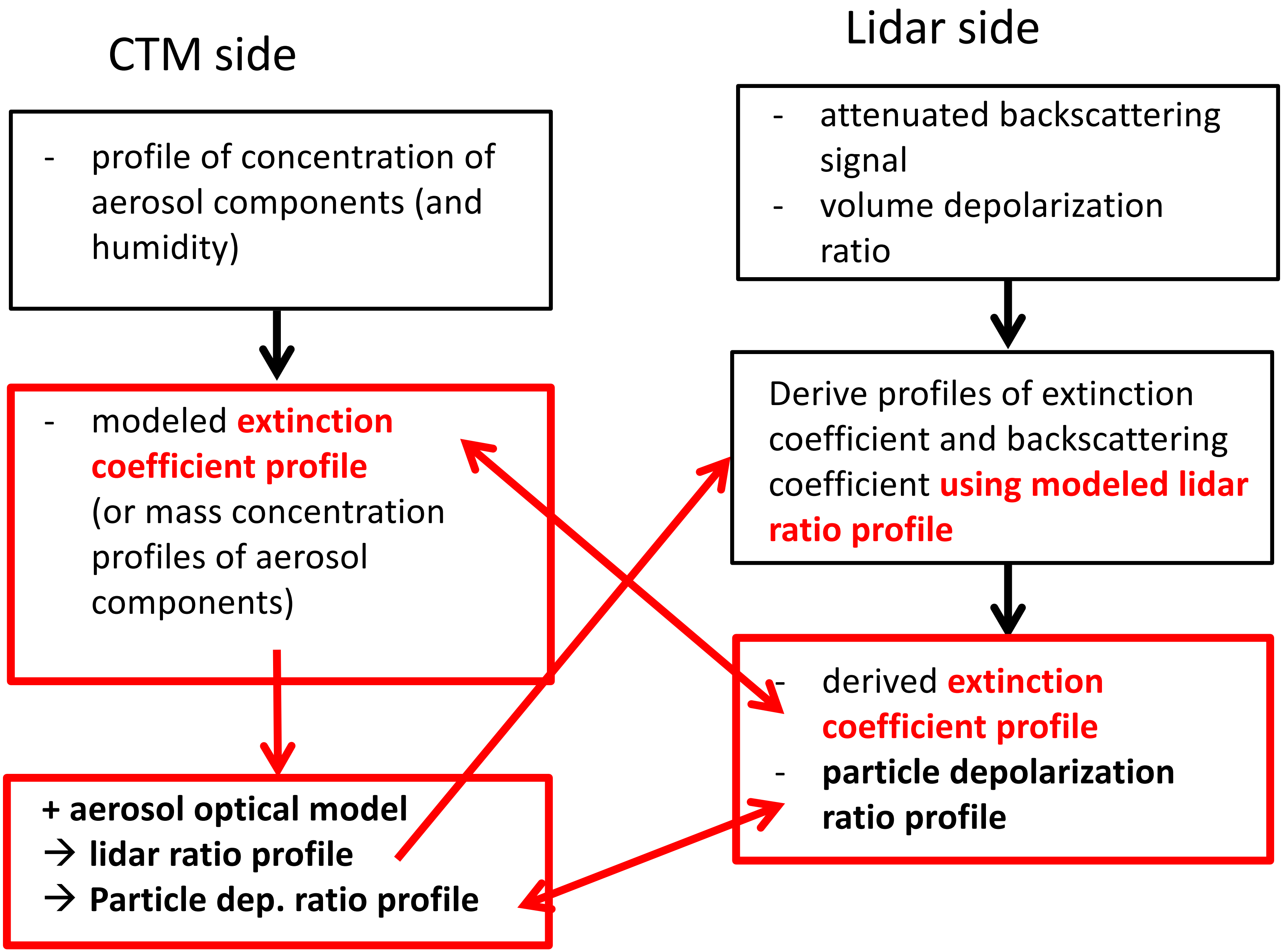
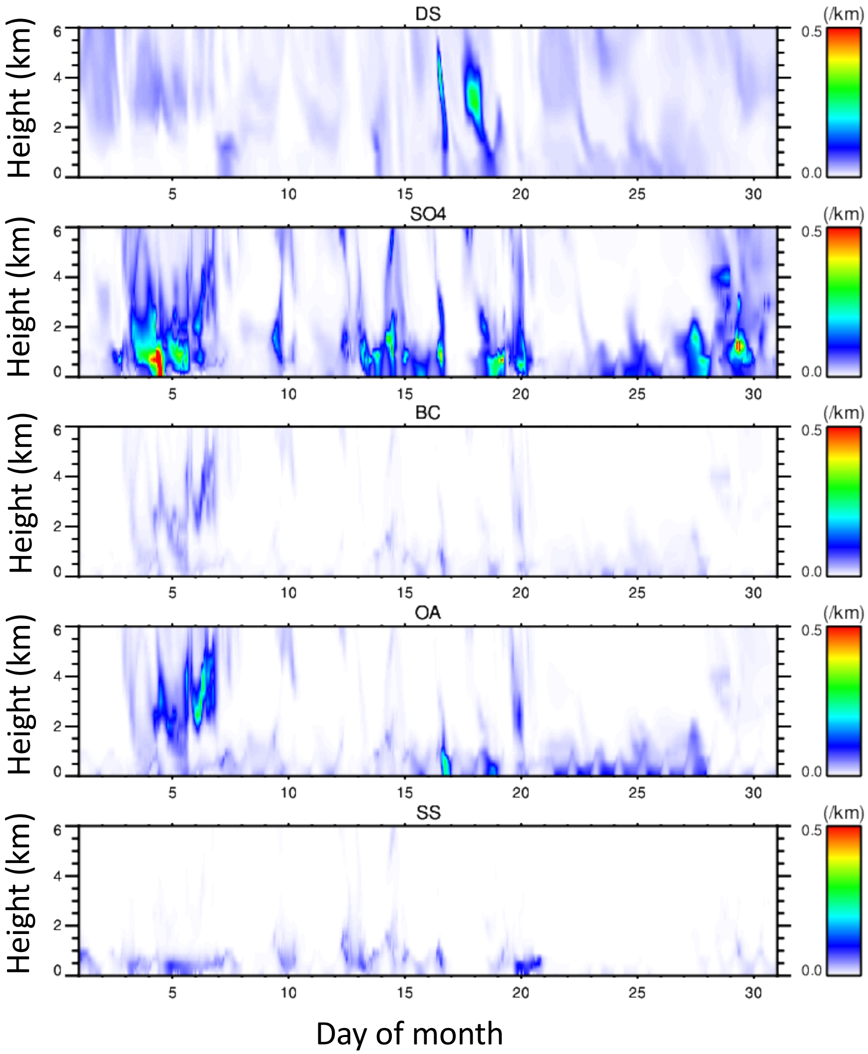
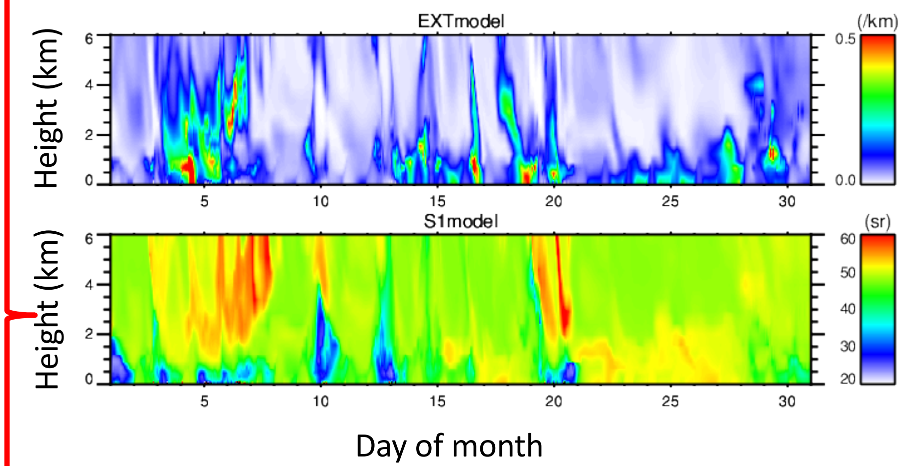


Example with MASINGAR mk-2 (Fukuoka, April 2015)





S1
Dust: 48 sr (Spheroid model, mode radius 2 μm）
SO4: 50 sr (Geoschem, Rh=60% (dry radius 0.08 μm))
BC: 101 sr (OPAC)
OA: 52 sr (OPAC water-soluble model, Rh=60%)
Sea salt: 20 sr (OPAC, Rm=3μm, RH=60%)

Particle depolarization ratio
Dust : 0.35
Others: 0.00

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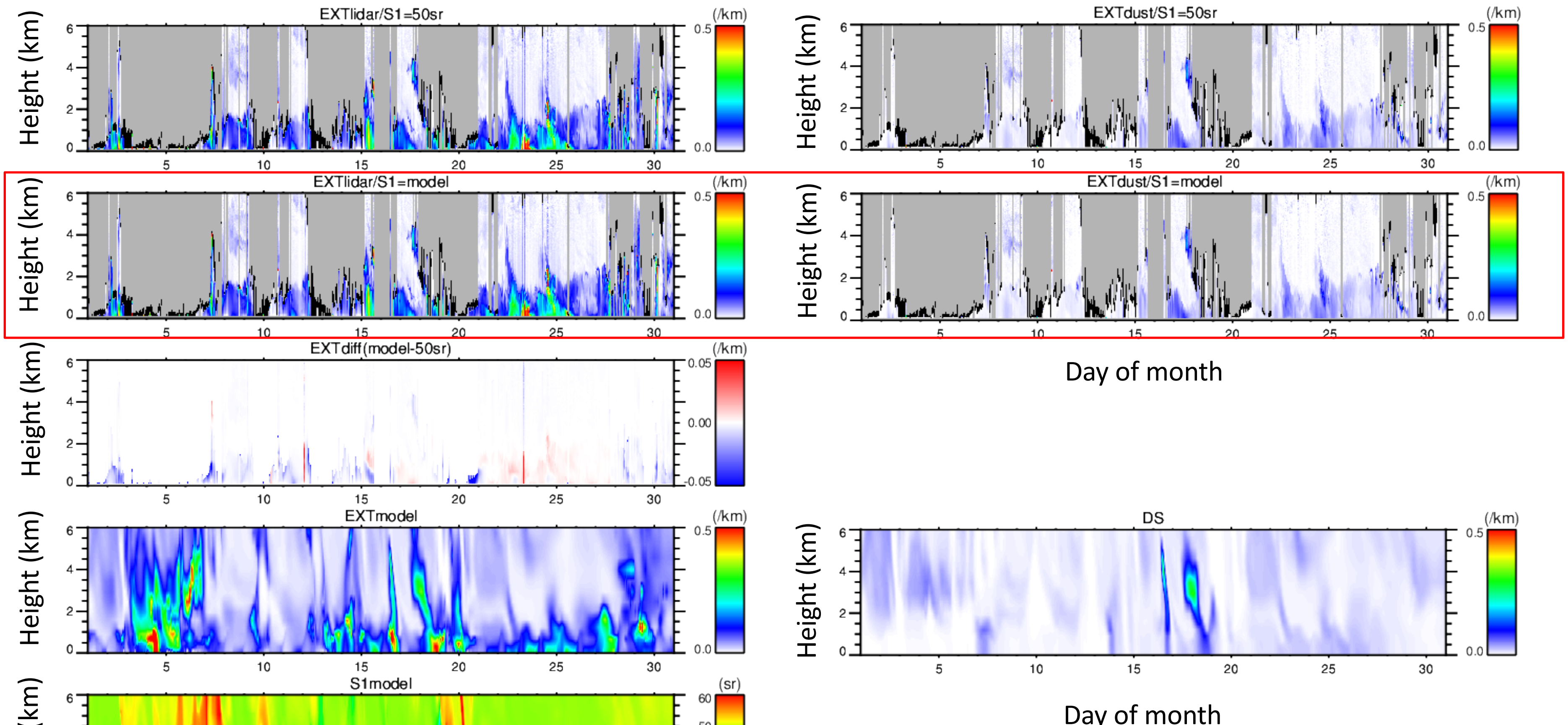
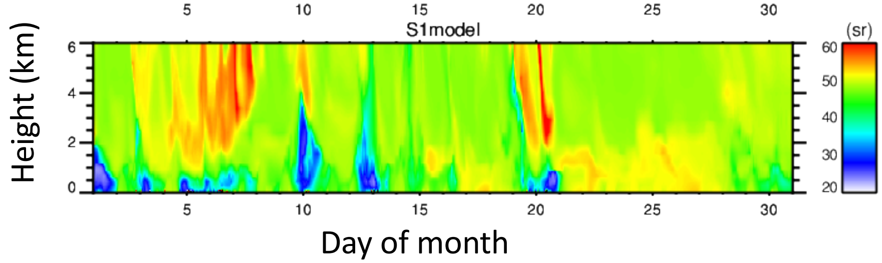
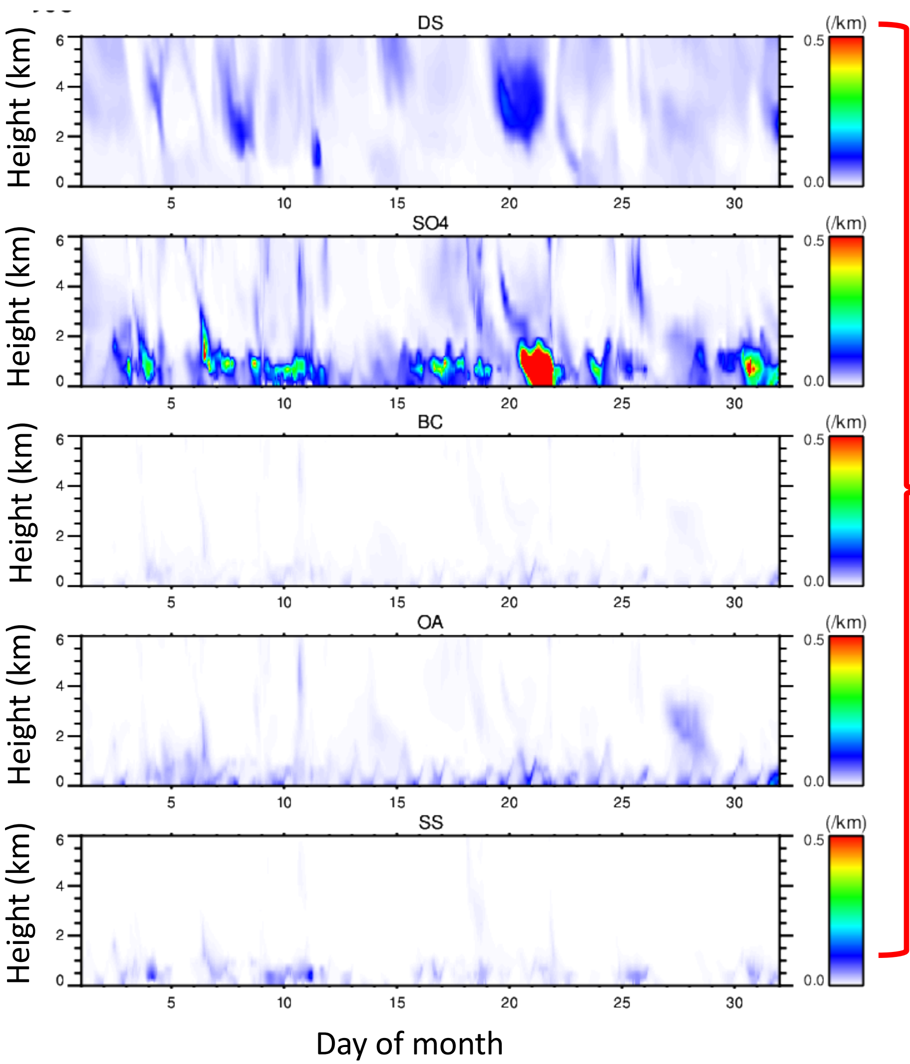
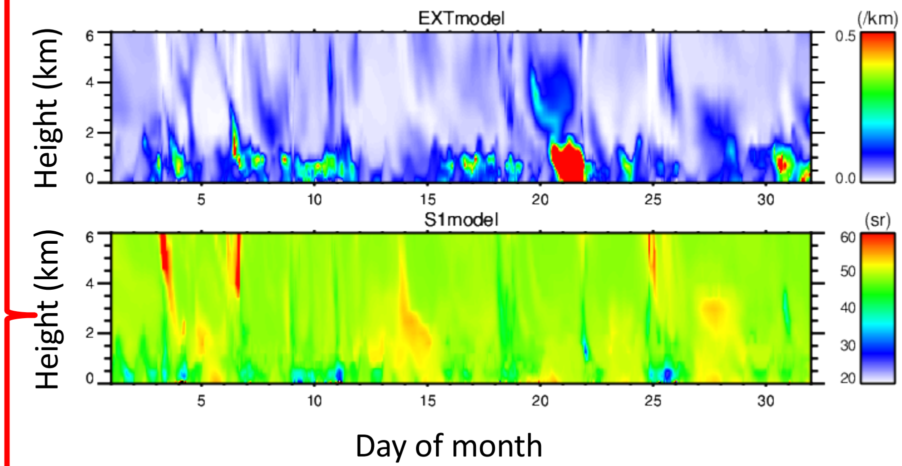




Lidar data analysis: (same as AD-Net but with the modeled lidar ratio profile)
Data quality check → cloud detection → determine the range of analysis → Fernald inversion (with iteration)

Example with MASINGAR mk-2 (Fukuoka, May 2015)





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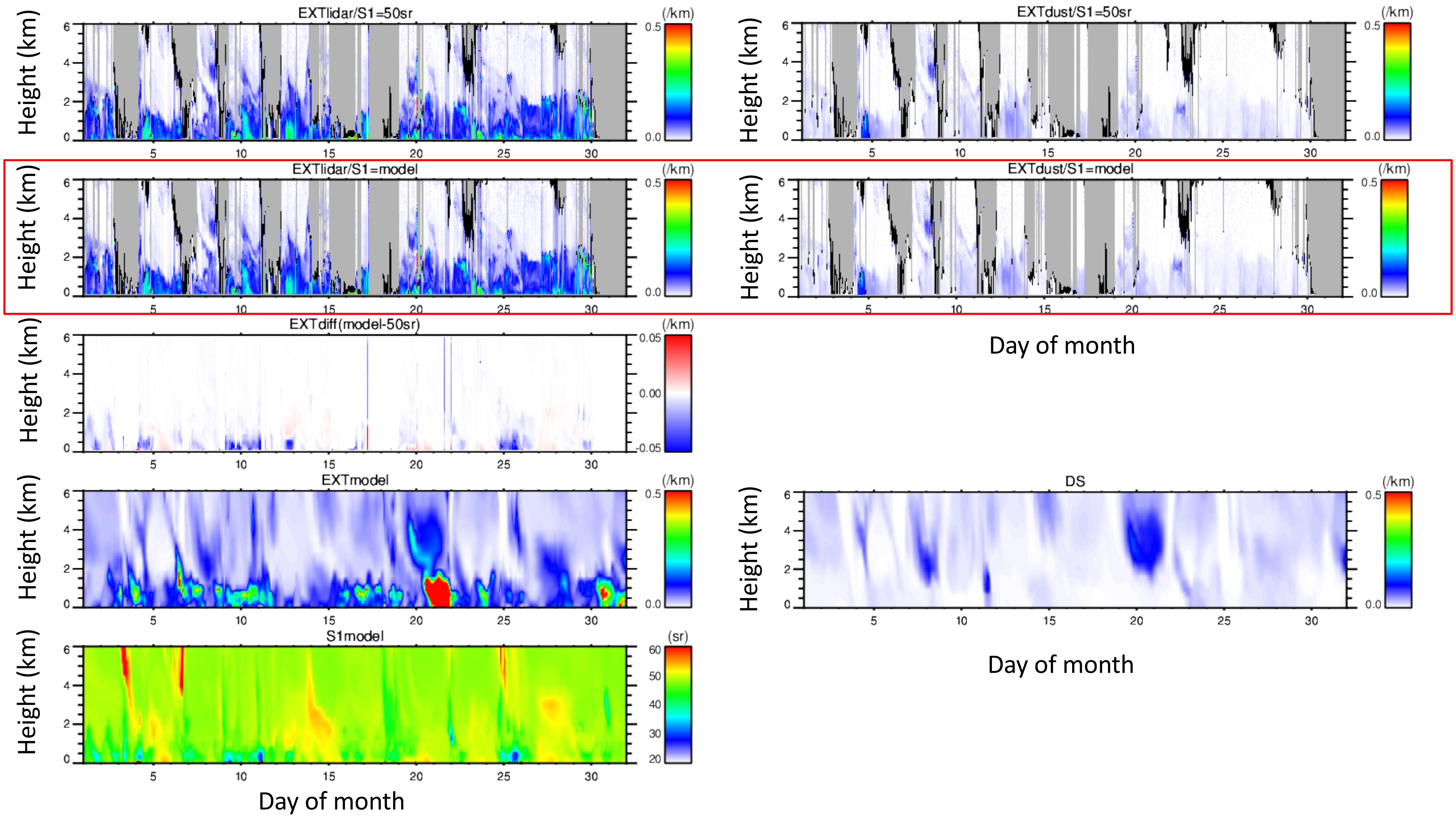
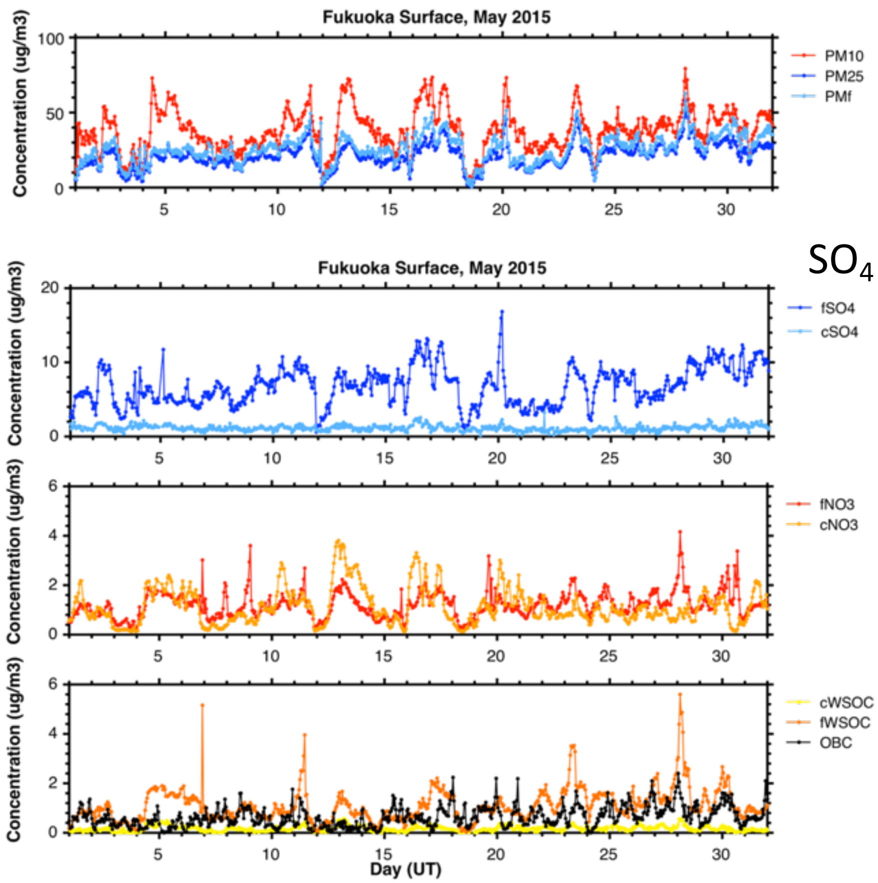
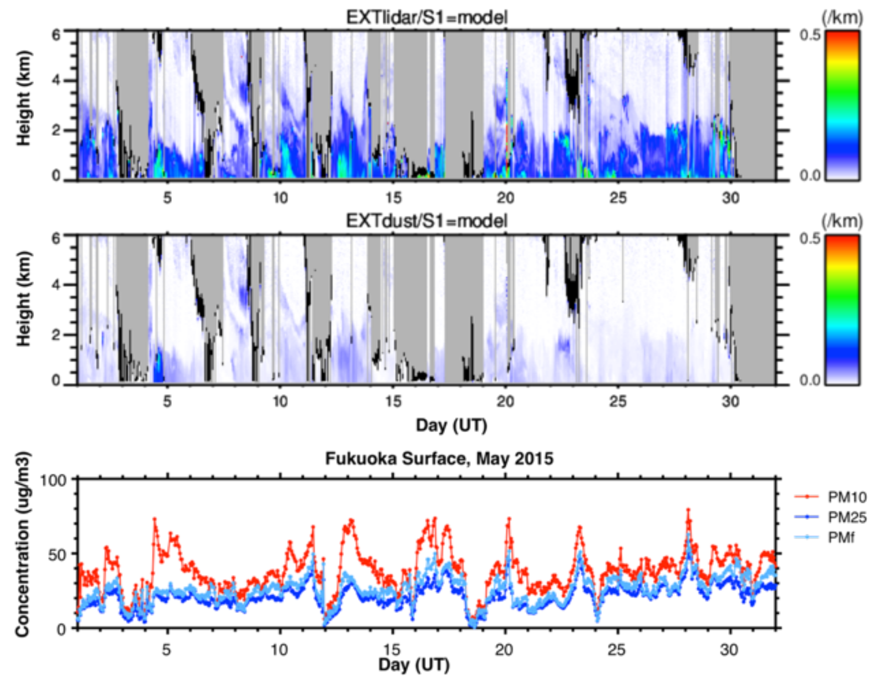


Example with MASINGAR mk-2 (Fukuoka, May 2015)

Surface in-situ observation data

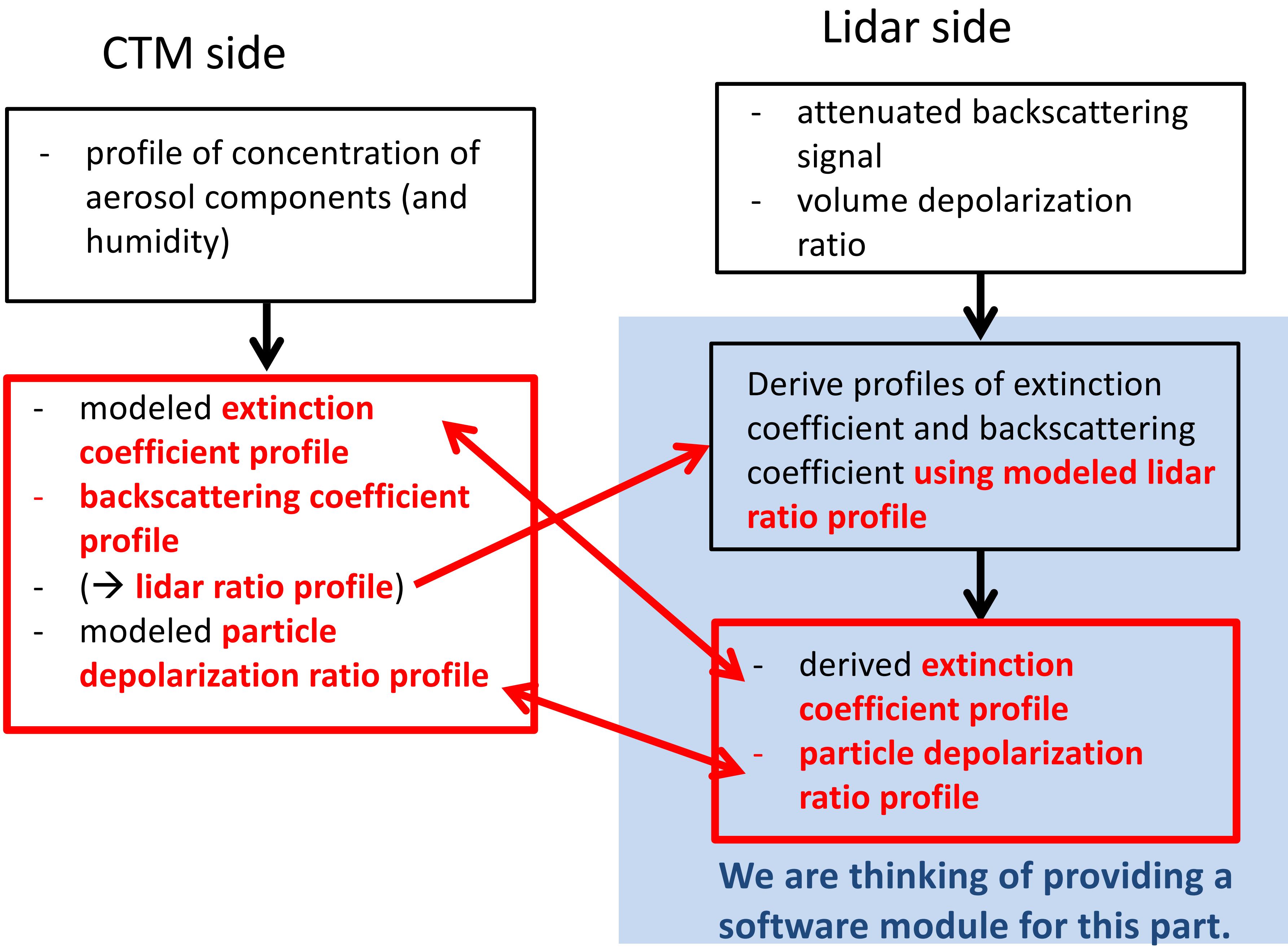


SO$_4$

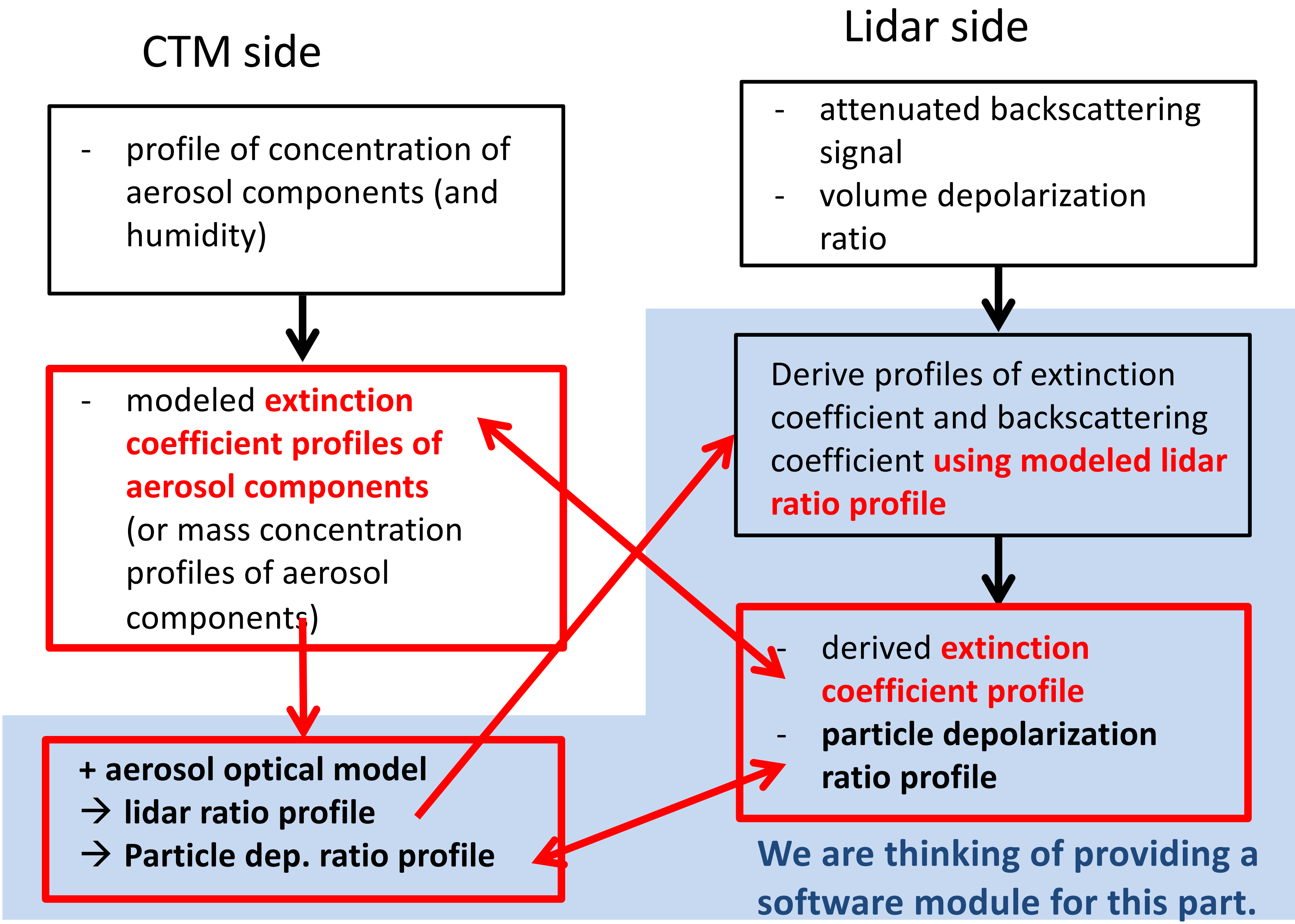


The lidar data was consistent with the surface data

Method for ground-based lidars



Method for ground-based lidars



Method for ground-based Raman (or HSR) lidars

CTM side

- profile of concentration of aerosol components (and humidity)

↓

- modeled **extinction coefficient profile**
- **backscattering coefficient profile**
- (→ **lidar ratio profile**)
- modeled **particle depolarization ratio profile**

Lidar side

- attenuated backscattering signal
- volume depolarization ratio

↓

- derived **extinction coefficient profile**
- derived **lidar ratio profile**
- **particle depolarization ratio profile**

Conclusions

- Methods for using ground-based backscattering lidar data in validation/ assimilation of CTMs were studied.

- **The method using modeled lidar ratio to derive extinction coefficient is recommended.**

- The method was tested using AD-Net data and MASINGAR mk-2.

- We are thinking of providing a software module to use the AD-Net data with this method.

- However, the difference between the extinction coefficient derived with the fixed lidar ratio (S1=50 sr) and the modeled lidar ratio was much smaller than the difference between the model and the observation. Therefore, we think extinction coefficient profiles with the fixed lidar ratio may be used for most purposes. (They are provided in the standard near-realtime AD-Net products at http://www-lidar.nies.go.jp/AD-Net/)

Thank you