# Aerosol Layer Height Determination:
## An embedded “cloud top” approach

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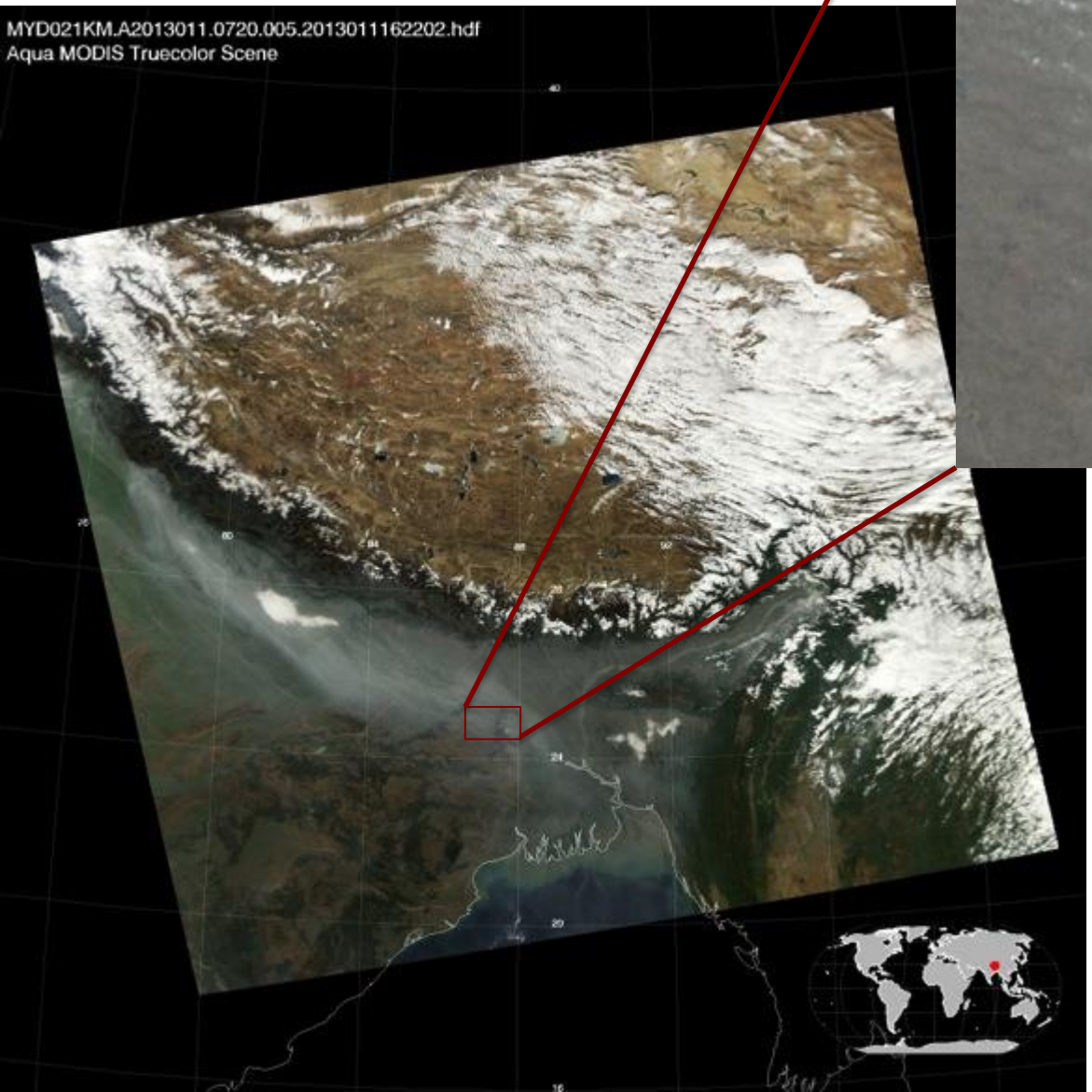
# Importance of Aerosol Layer (Geometric) Thickness

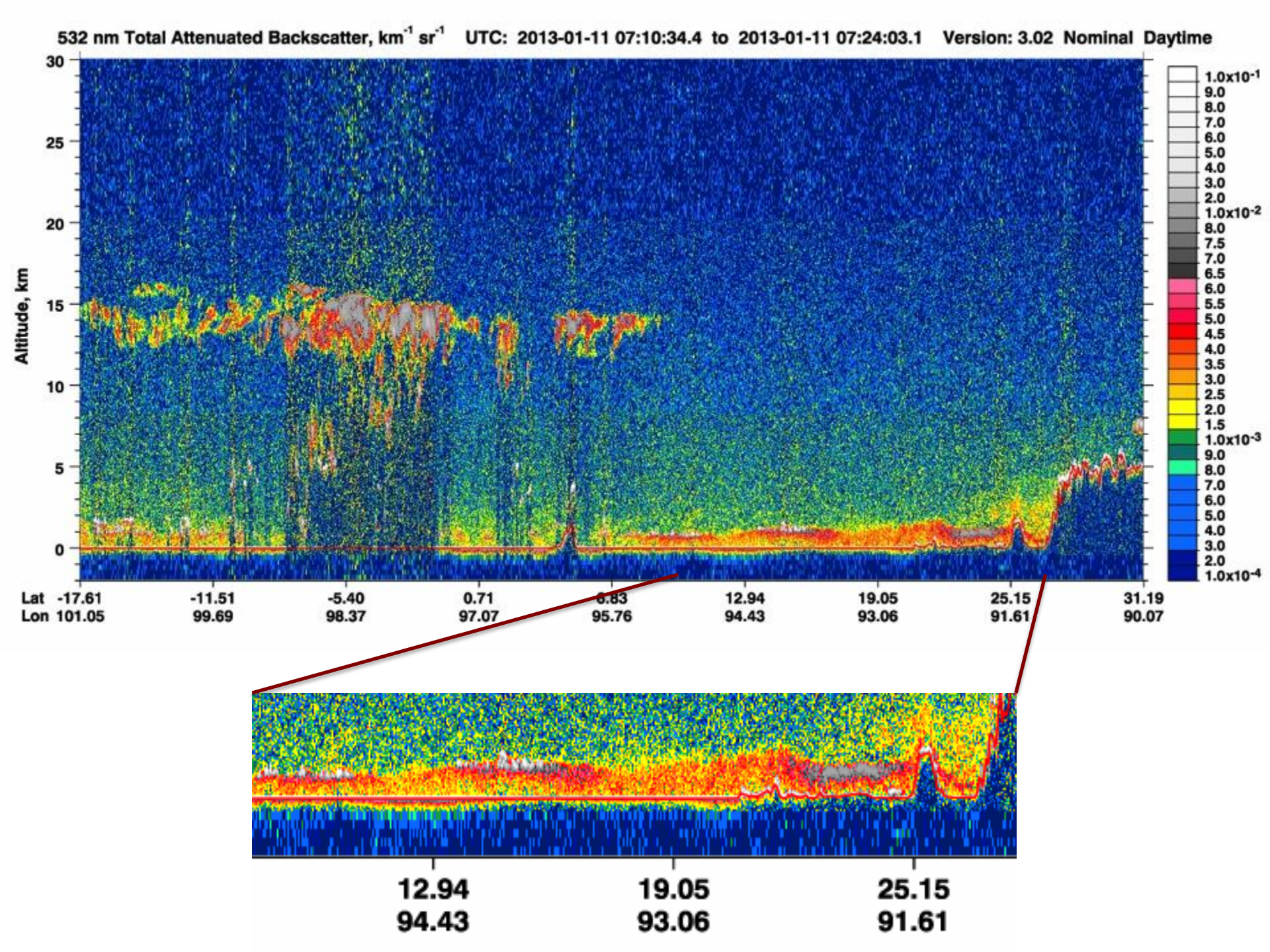
- Long-range transport of aerosols and pollution
- Radiative forcing of aerosol scattering and absorption effects
- Public health and aviation safety concerns
- Interpretation of Aerosol Index (AI)

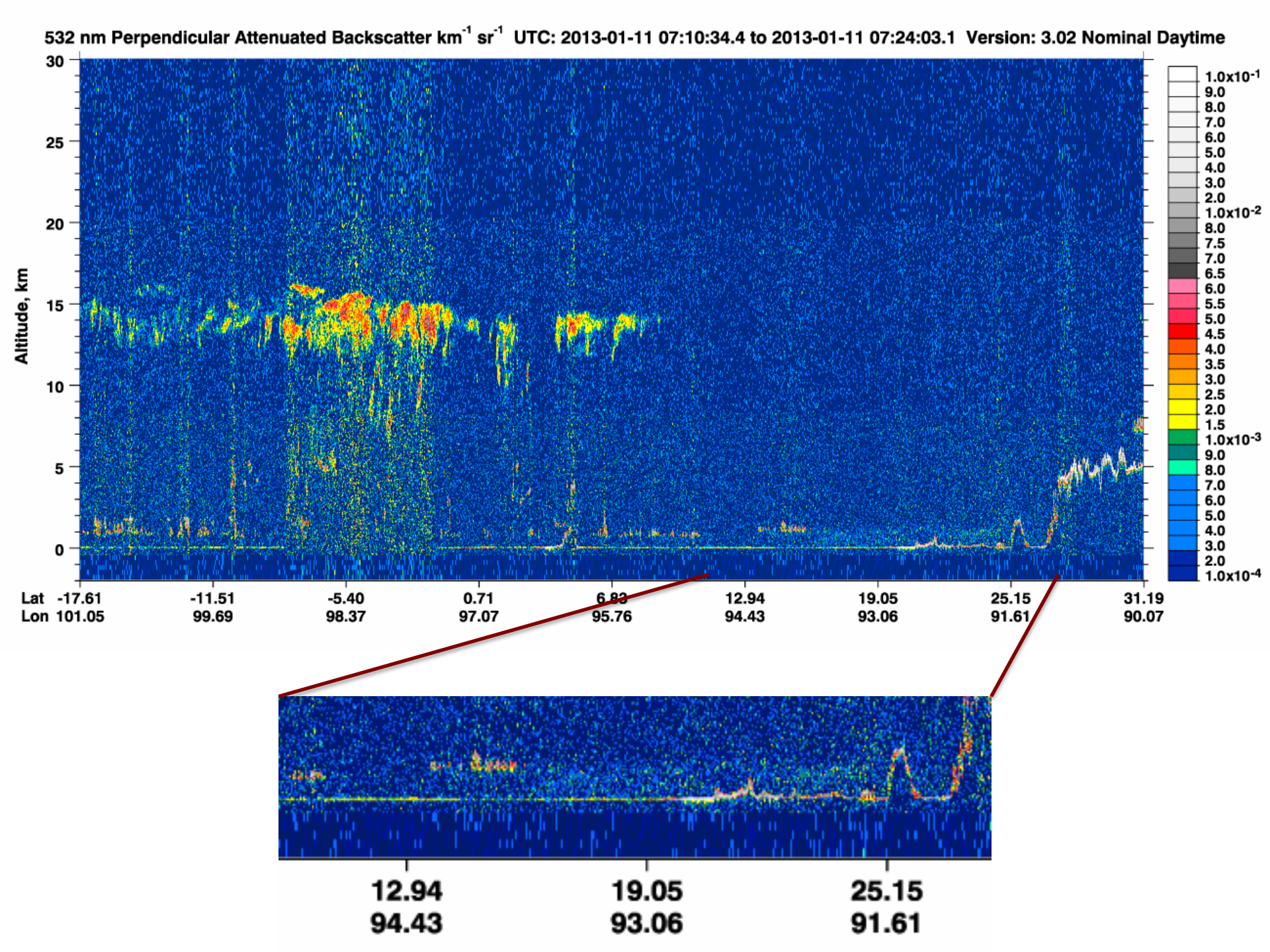
# Motivation and Scope

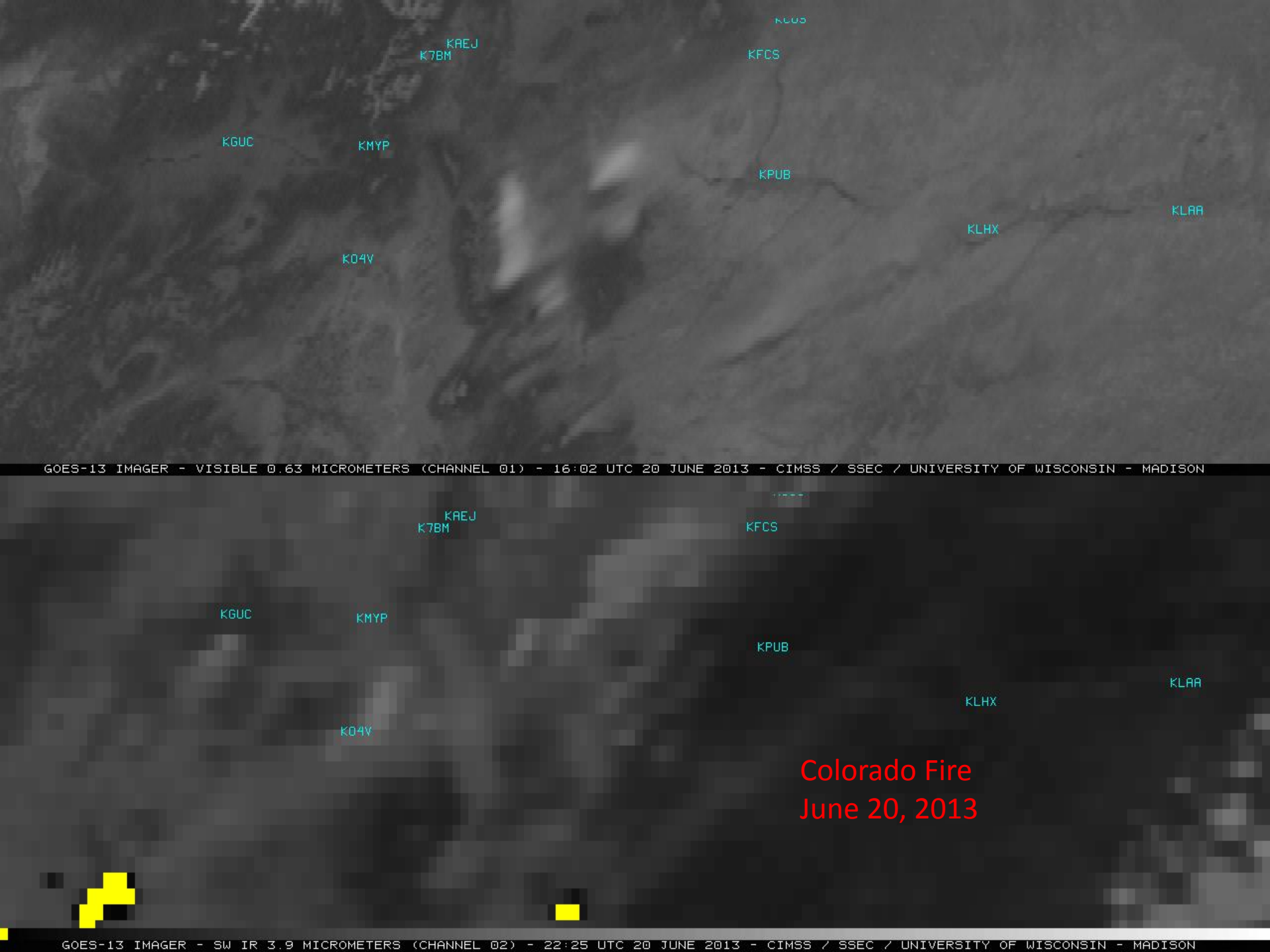
- PBL aerosol and cloud properties
- Aerosol height detection in remote regions
- Passive imaging techniques from space

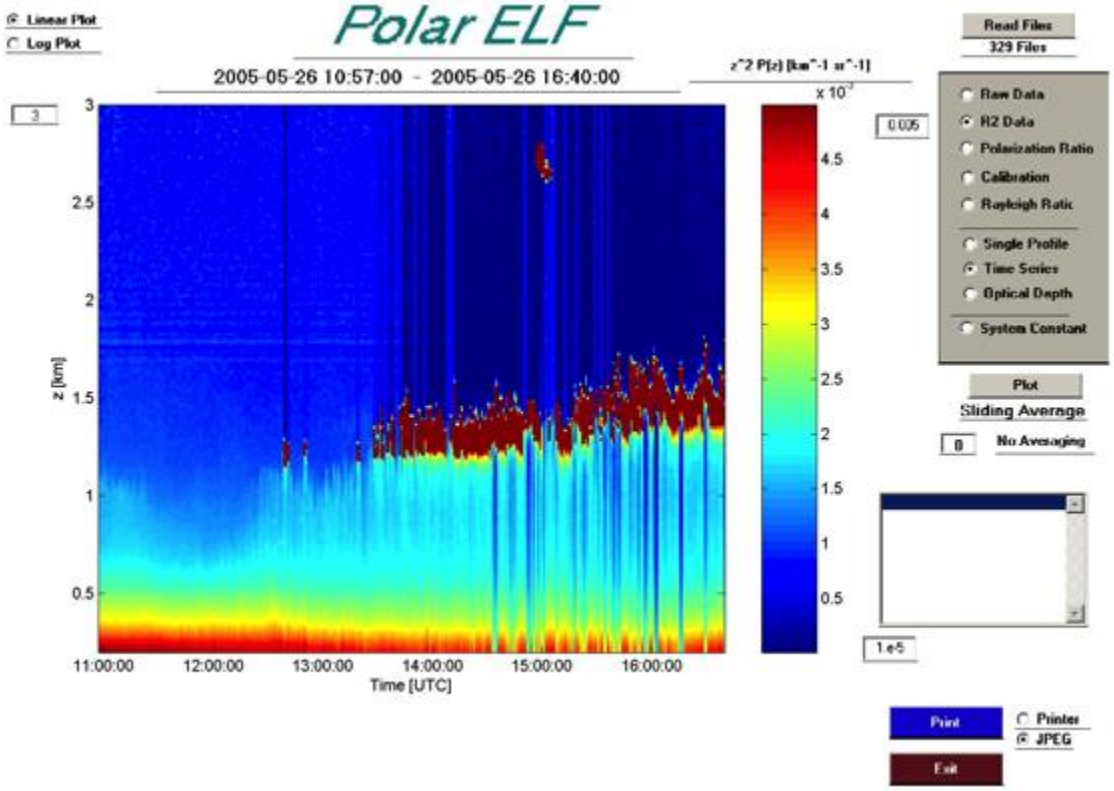
# MODIS Jan.11 2013





532 nm Total Attenuated Backscatter, km-1 sr-1 UTC: 2013-01-11 07:10:34.4 to 2013-01-11 07:24:03.1 Version: 3.02 Nominal Daytime
Altitude, km
30
25
20
15
10
5
0
1.0x10-1
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-2
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0x10-3
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-4
Lat -17.61 -11.51 -5.40 0.71 6.83 12.94 19.05 25.15 31.19
Lon 101.05 99.69 98.37 97.07 95.76 94.43 93.06 91.61 90.07
12.94
94.43
19.05
93.06
25.15
91.61


532 nm Perpendicular Attenuated Backscatter km-1 sr-1 UTC: 2013-01-11 07:10:34.4 to 2013-01-11 07:24:03.1 Version: 3.02 Nominal Daytime
Altitude, km
30
25
20
15
10
5
0
1.0x10-1
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-2
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0x10-3
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-4
Lat -17.61 -11.51 -5.40 0.71 6.83 12.94 19.05 25.15 31.19
Lon 101.05 99.69 98.37 97.07 95.76 94.43 93.06 91.61 90.07
12.94 19.05 25.15
94.43 93.06 91.61

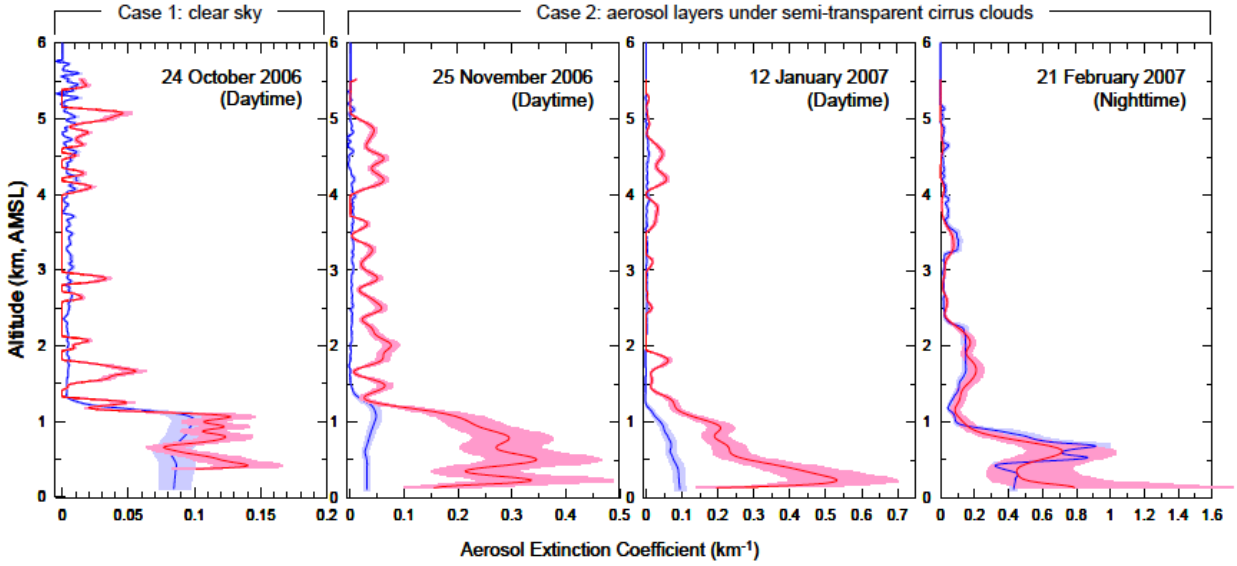

KAEJ
K7BM
KFCS
KGUC
KMYP
KPUB
KLAA
KLHX
KO4V
GOES-13 IMAGER - VISIBLE 0.63 MICROMETERS (CHANNEL 01) - 16:02 UTC 20 JUNE 2013 - CIMSS / SSEC / UNIVERSITY OF WISCONSIN - MADISON
KAEJ
K7BM
KFCS
KGUC
KMYP
KPUB
KLAA
KLHX
KO4V
Colorado Fire
June 20, 2013
GOES-13 IMAGER - SW IR 3.9 MICROMETERS (CHANNEL 02) - 22:25 UTC 20 JUNE 2013 - CIMSS / SSEC / UNIVERSITY OF WISCONSIN - MADISON




Courtesy of Ray Rogers

University of Maryland, Baltimore County (UMBC)

Boundary layer haze rises in the morning and is later topped with clouds.

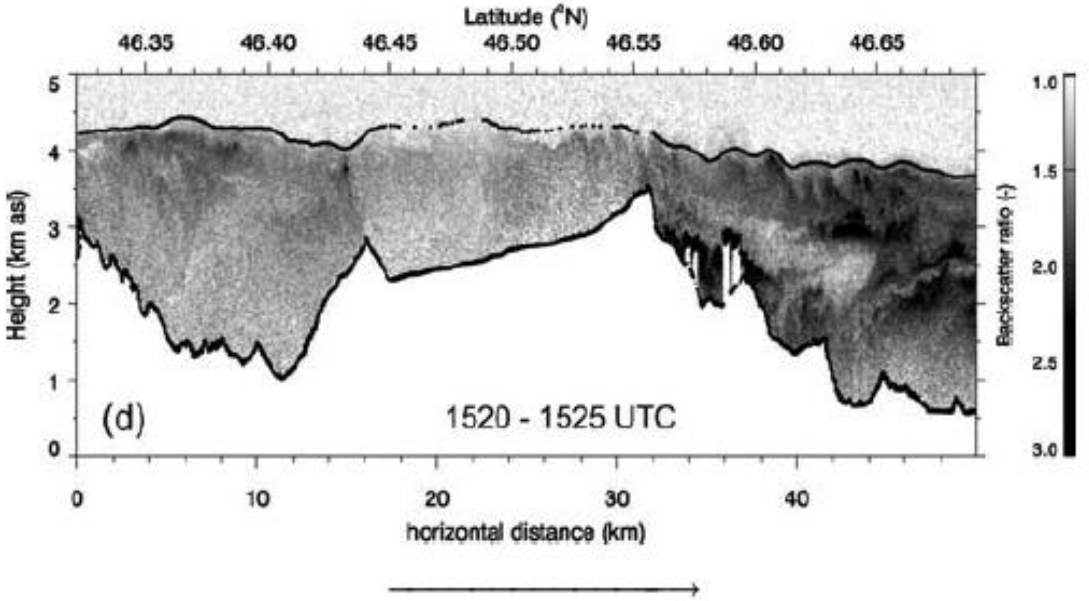



Kim et al. (2008)

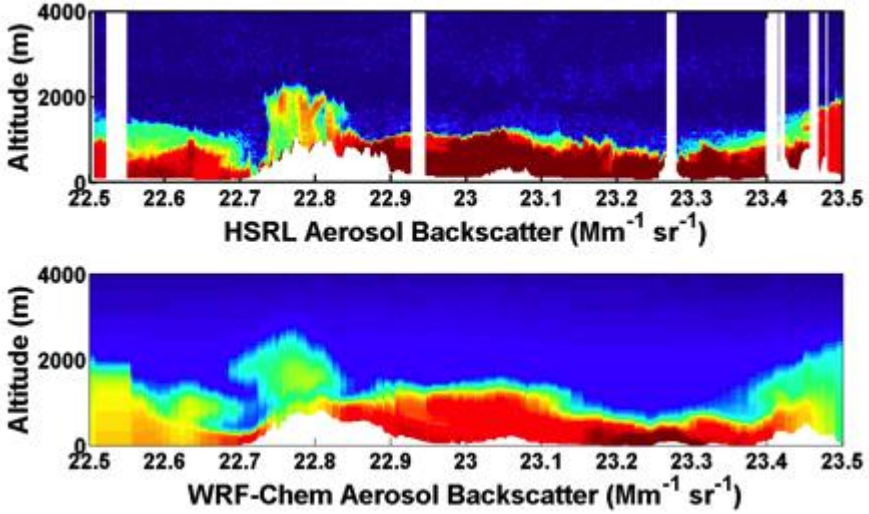
Statistics of CALIOP and SNU lidar

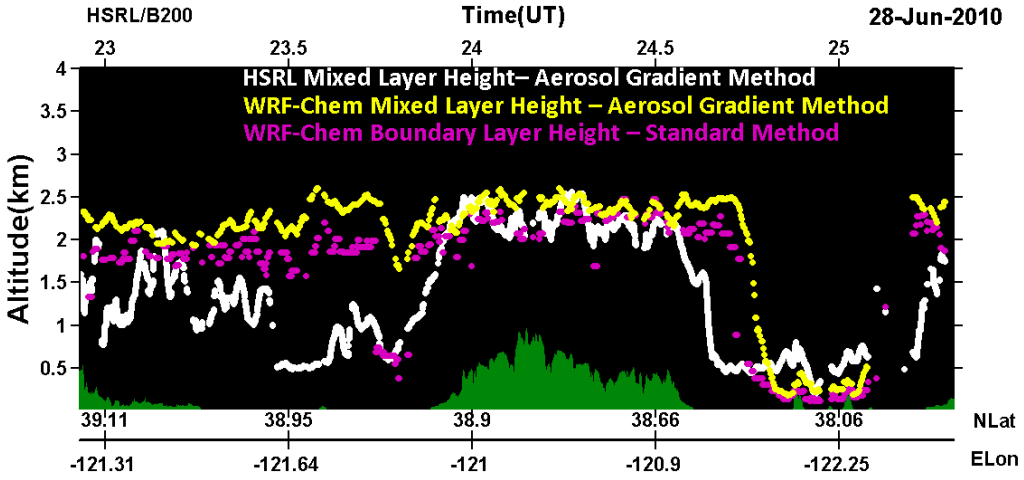
# Effects of Topography

De Wekker et al. [2004]
Lidar measurements over Swiss Alps



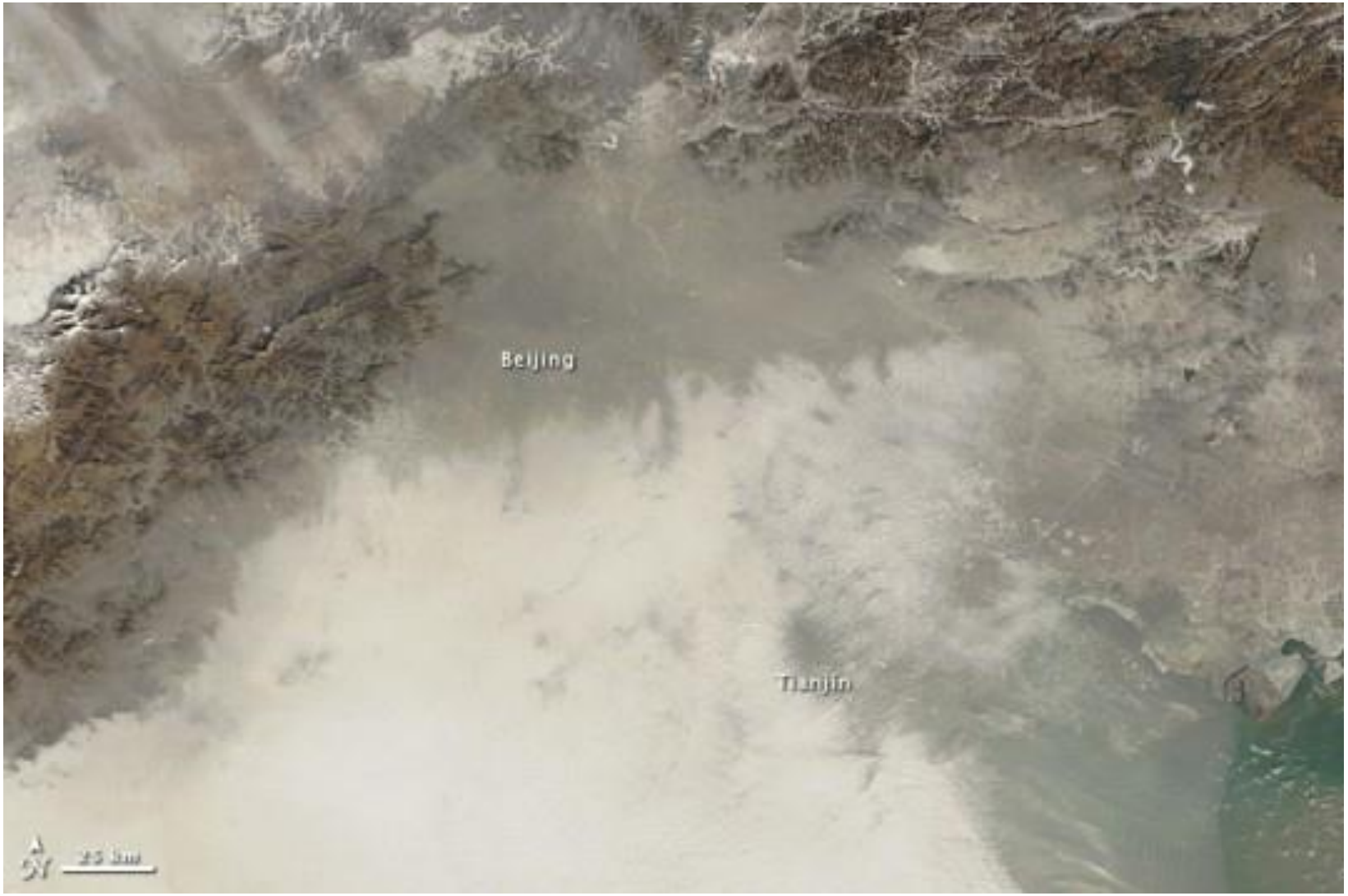

Hostetler et al. [2012]
HSRL Lidar measurements in Califfornia



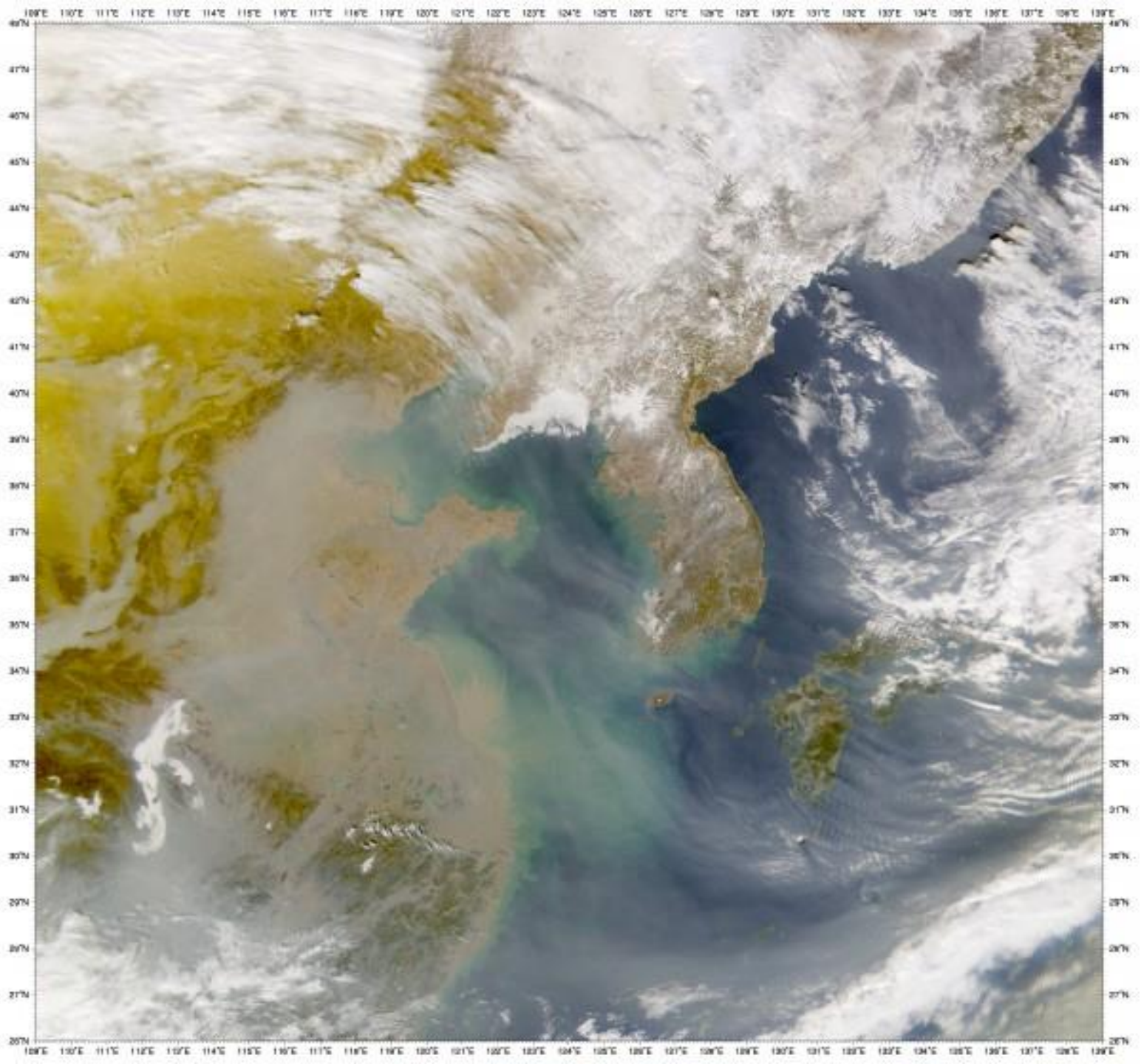



# Effects of Topography (contd.)

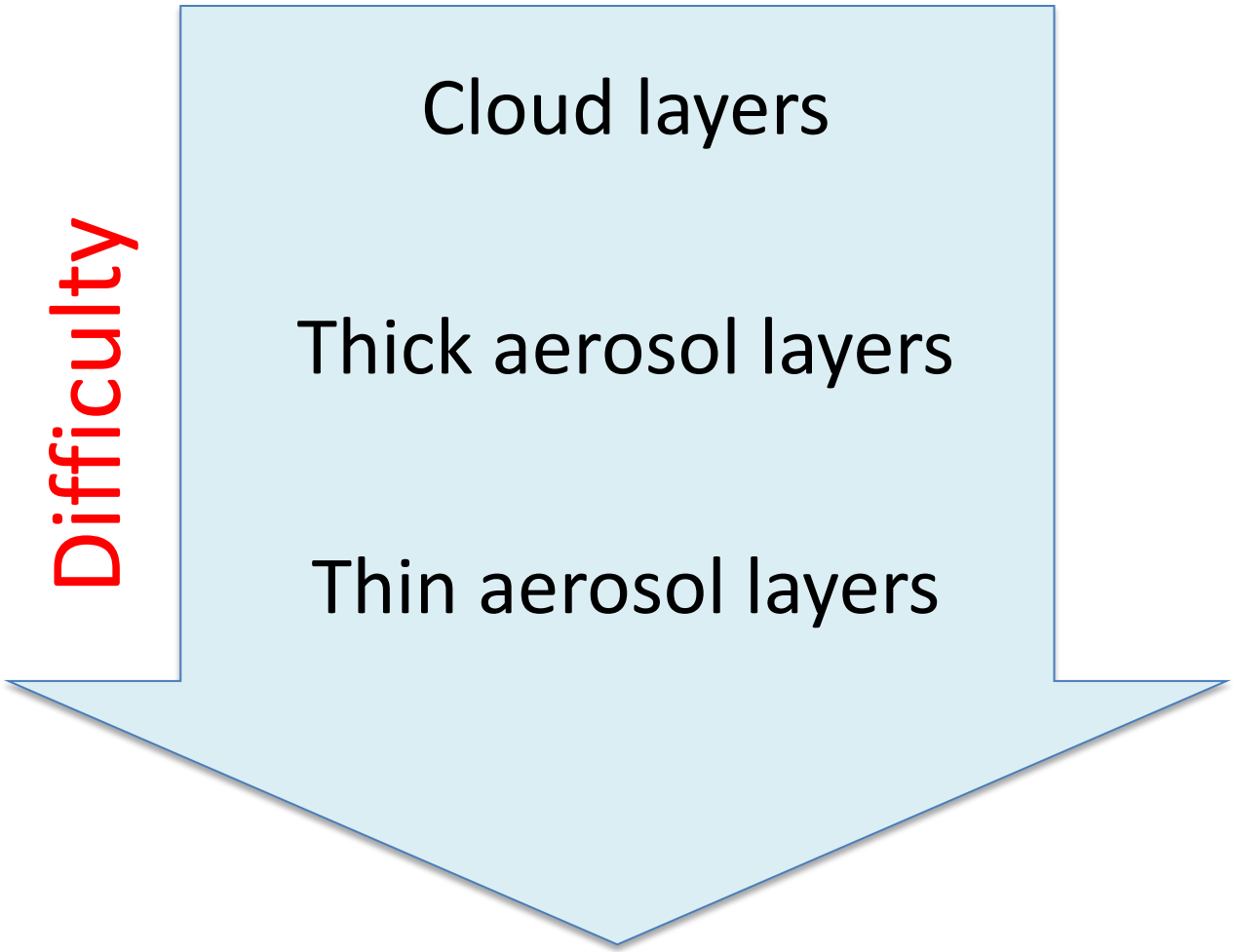
January 14, 2013




Courtesy of NASA Earth Observatory



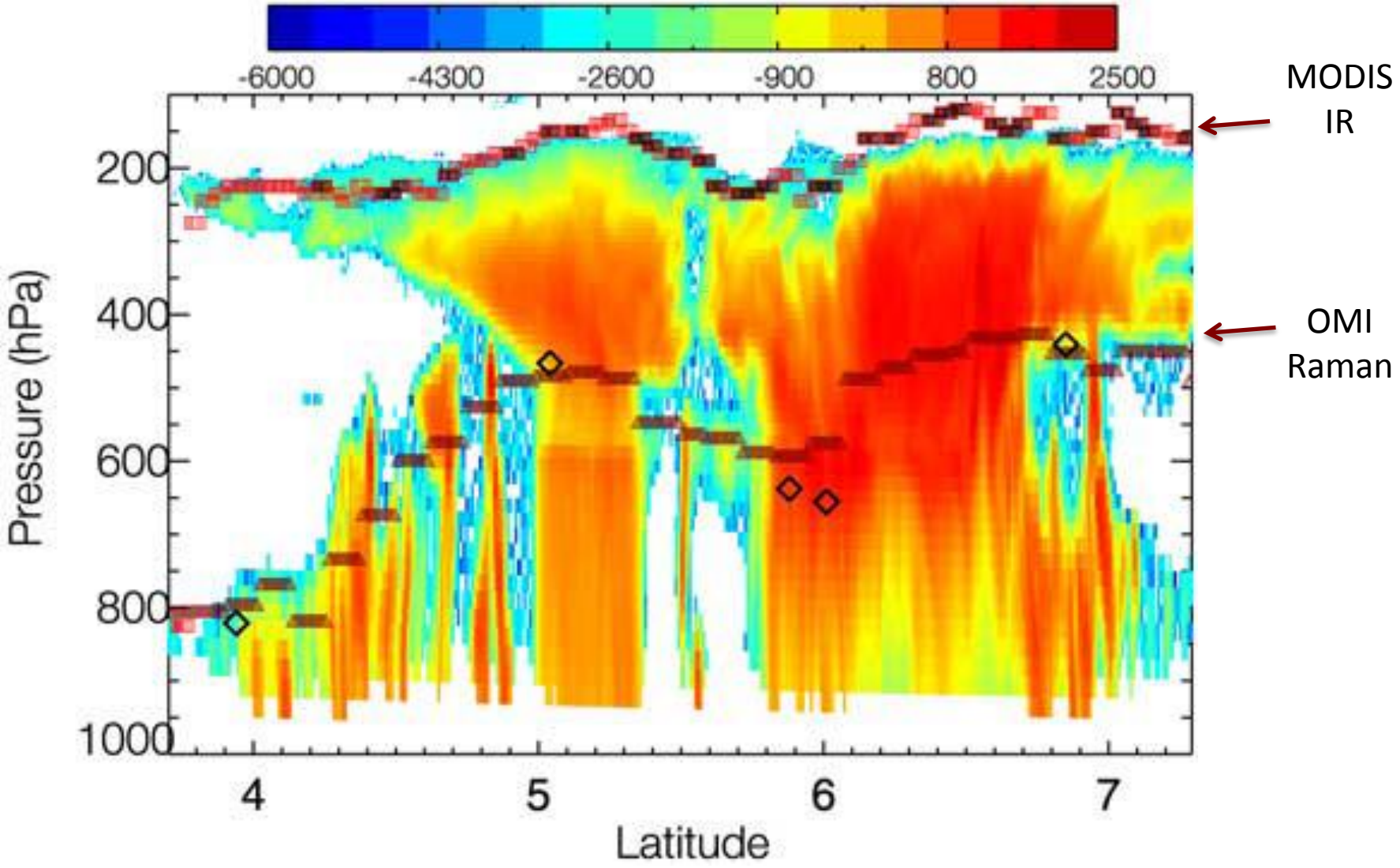
# Determination of Layer Thickness with Passive Techniques



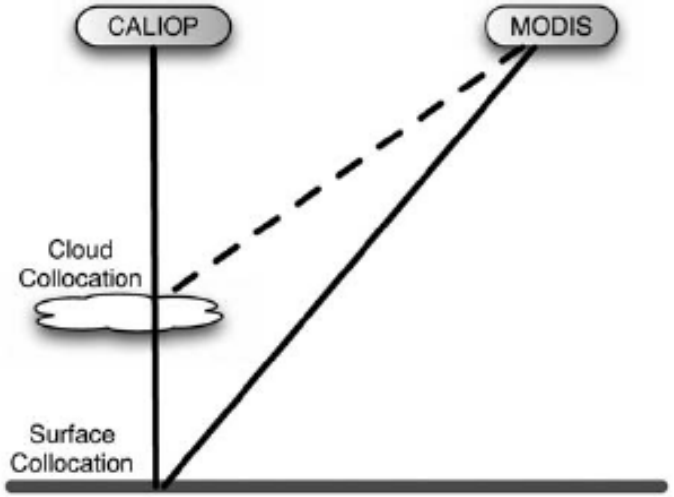
# Approaches

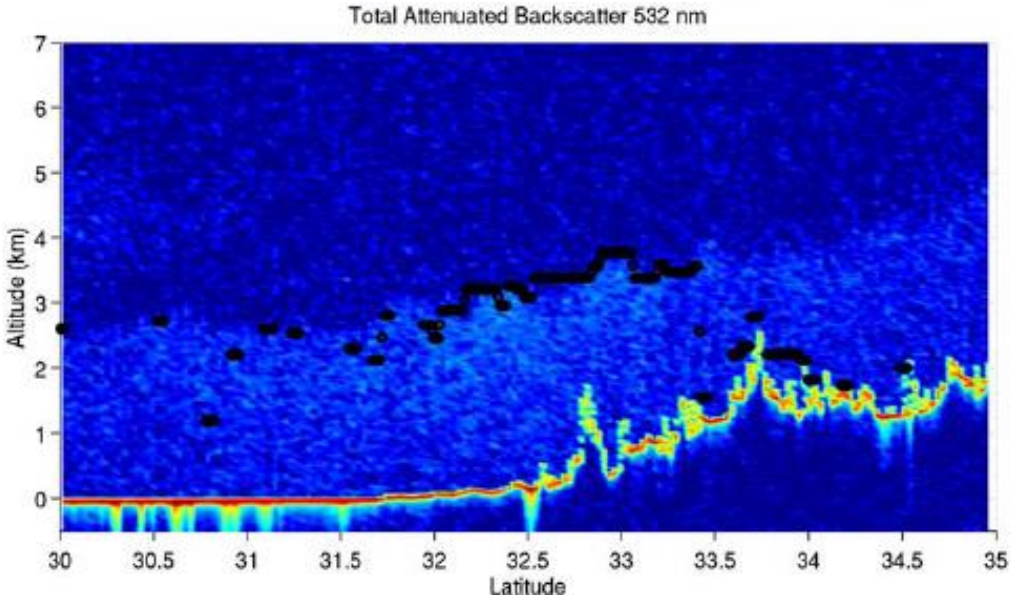
- Thermal IR (e.g., MODIS, VIIRS, GOES-R)
  - Knowledge of temperature lapse rate
  - High pixel resolution
  - Accurate radiometric calibration
  - Good contrast or optical thickness
- Stereoscopic Imaging (e.g., MISR, AATSR)
  - No need for temperature lapse rate
  - High pixel resolution and more than 2 views
  - Accurate pointing knowledge
  - Moderate requirements for radiometric calibration and scene contrast
- Hyperspectral Imaging (e.g., O2 A-band, O2-O2)
  - No need for temperature lapse rate
  - Accurate radiometric calibration (band-to-band)
  - Good optical thickness
  - “Radiation-equivalent” height

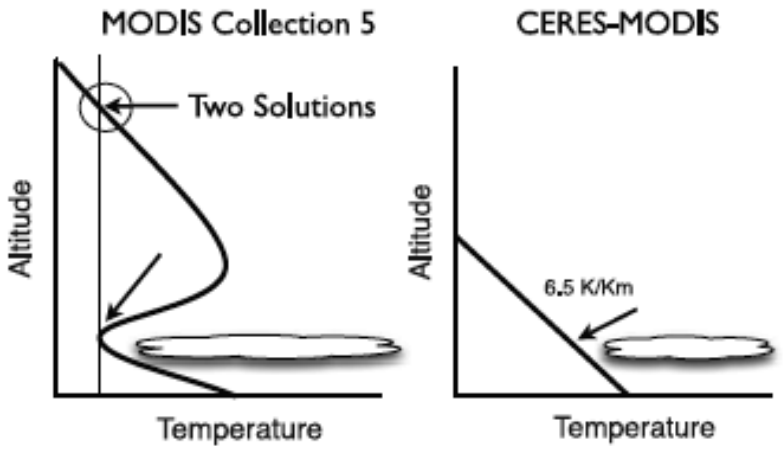
Vasilkov et al. (2008)

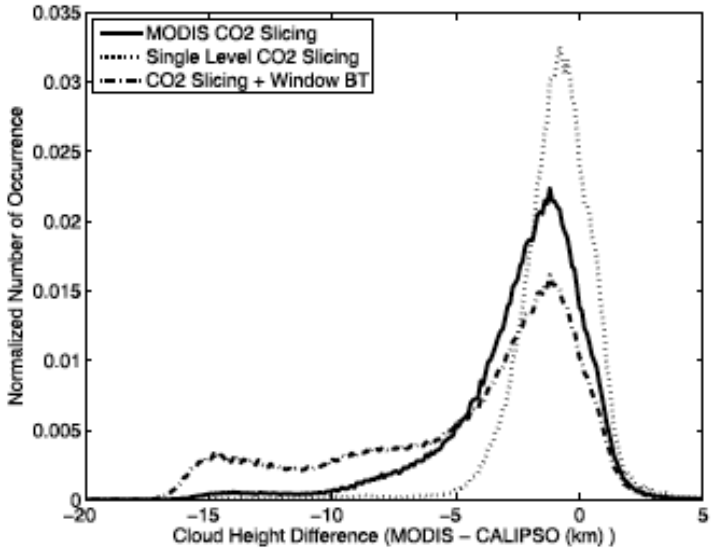


# MODIS (Holz et al., 2008)

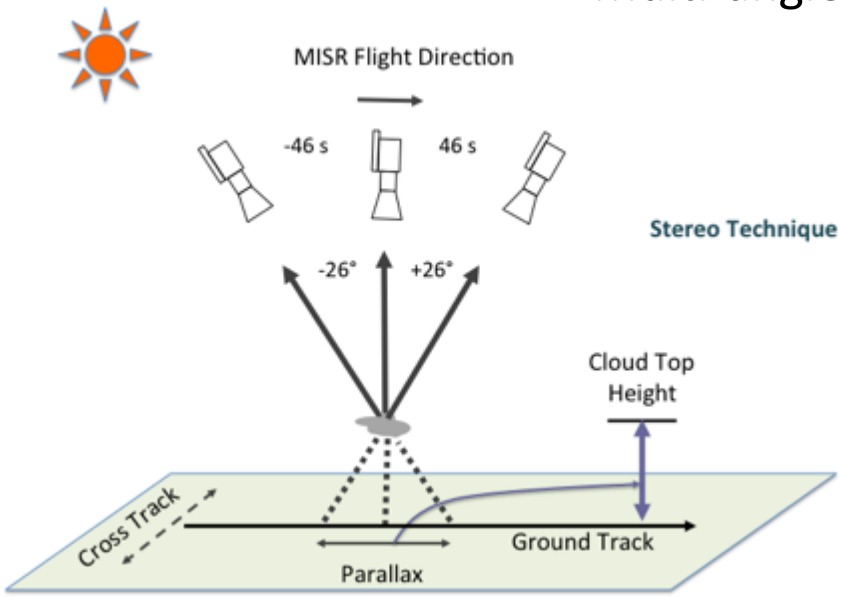


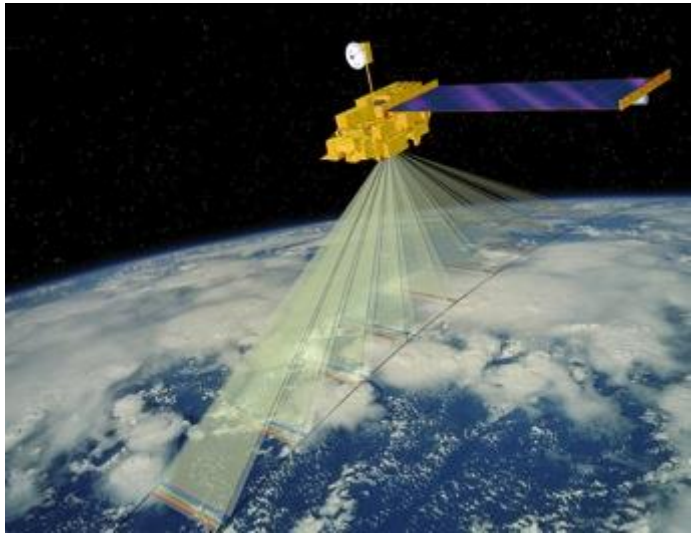



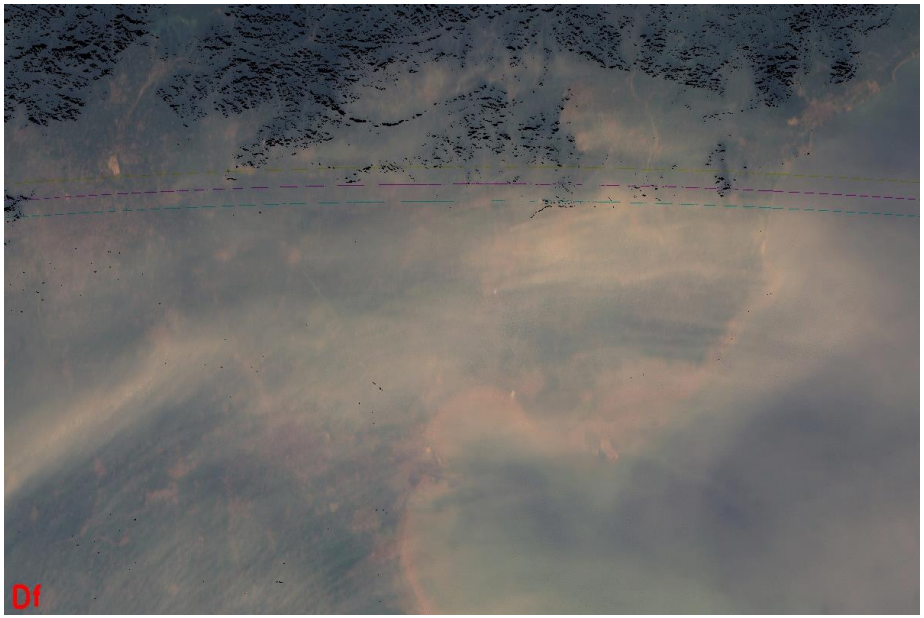



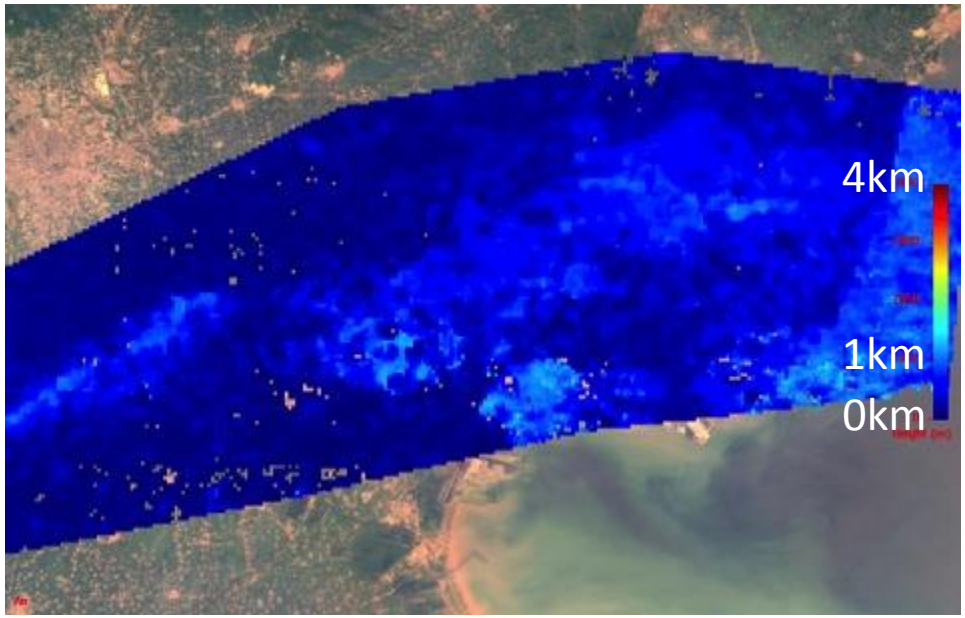



# Multi-angle Imaging SpectroRadiometer (MISR)



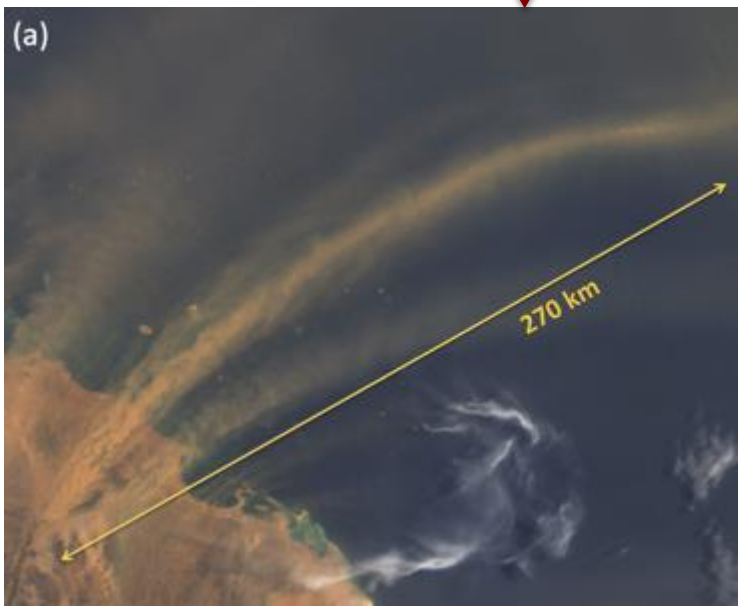



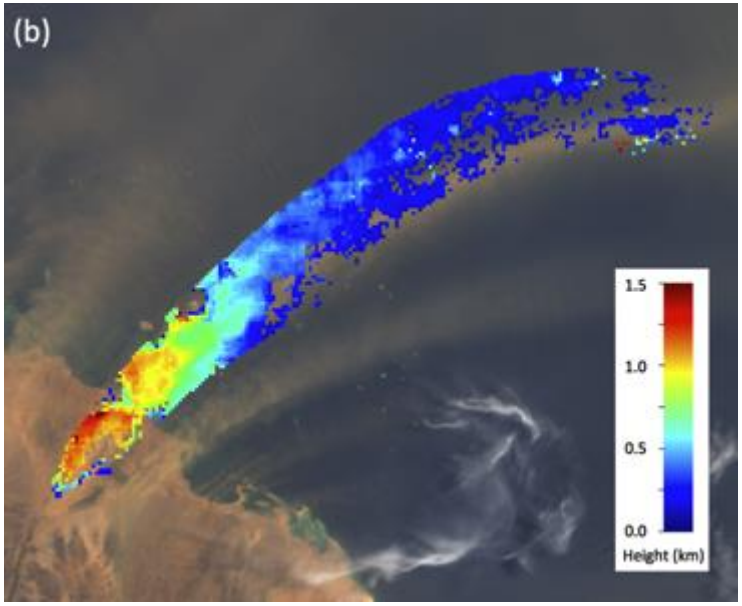


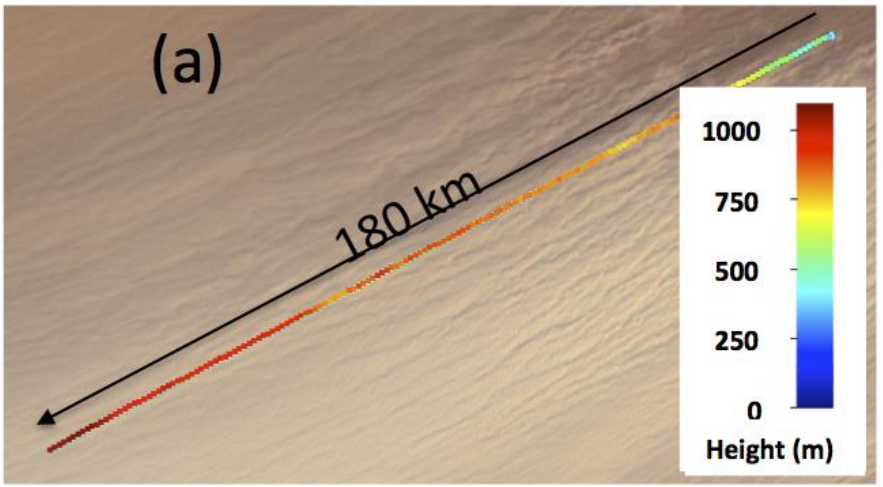


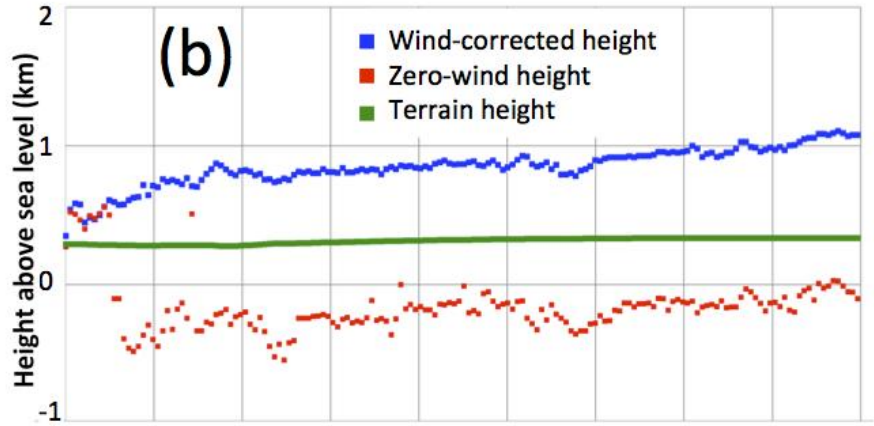
Bodele Depression of Chad →

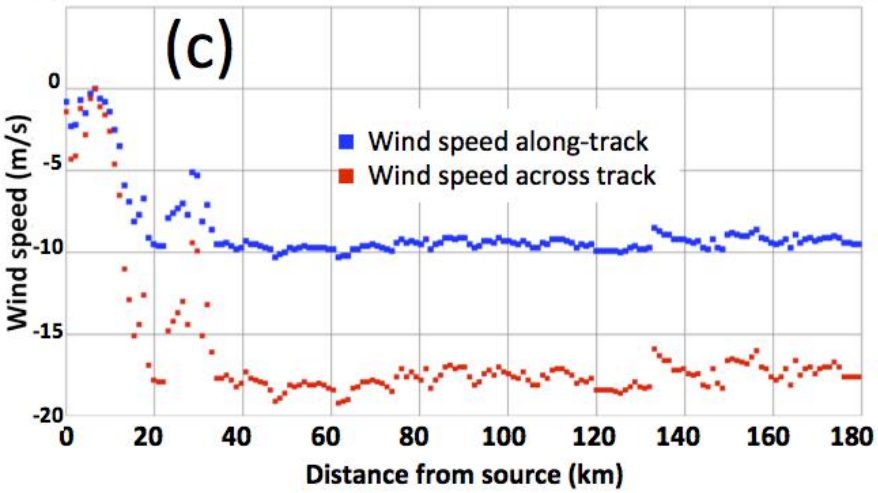
Sudanese Red Sea Coast ↓

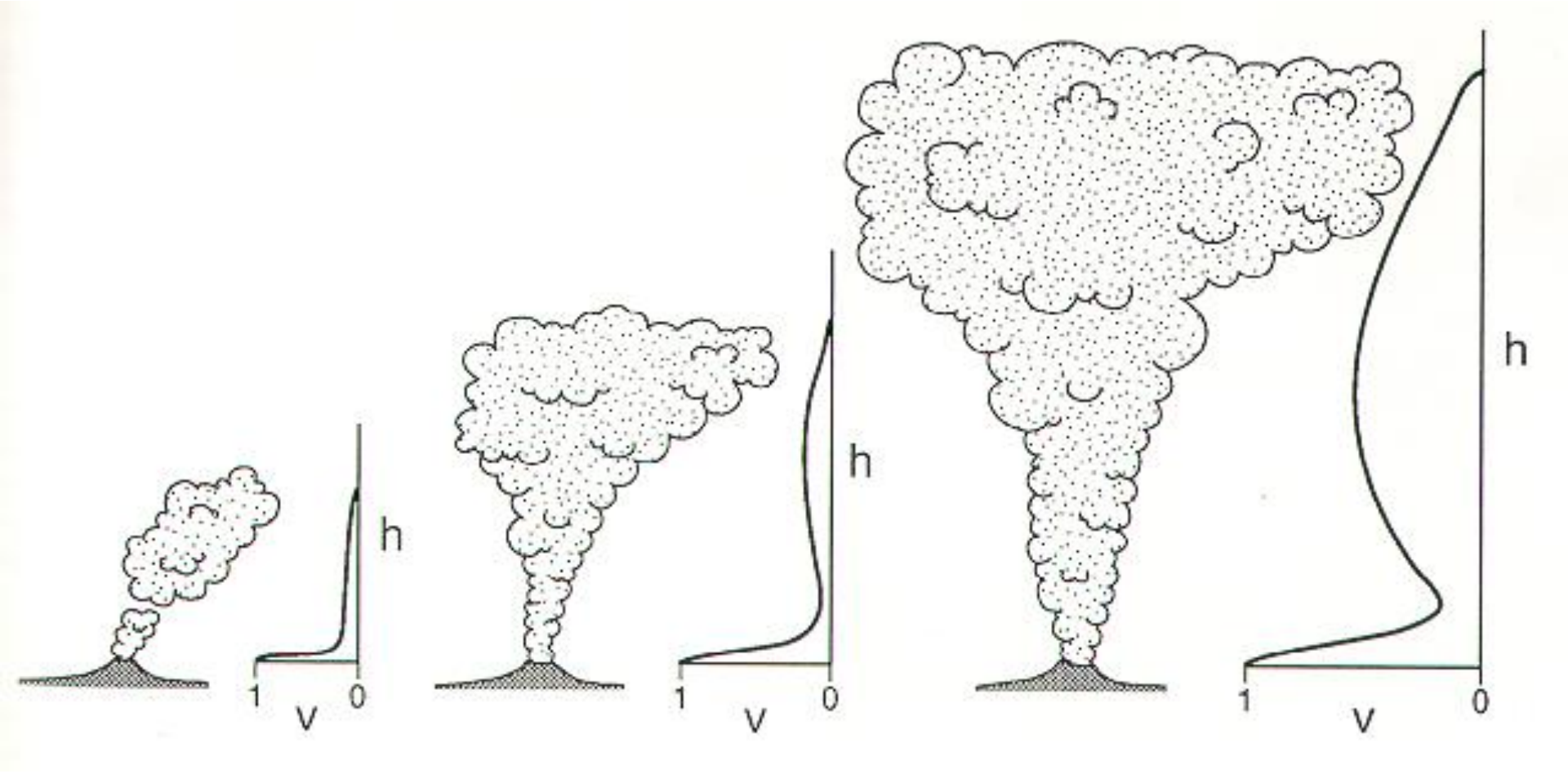


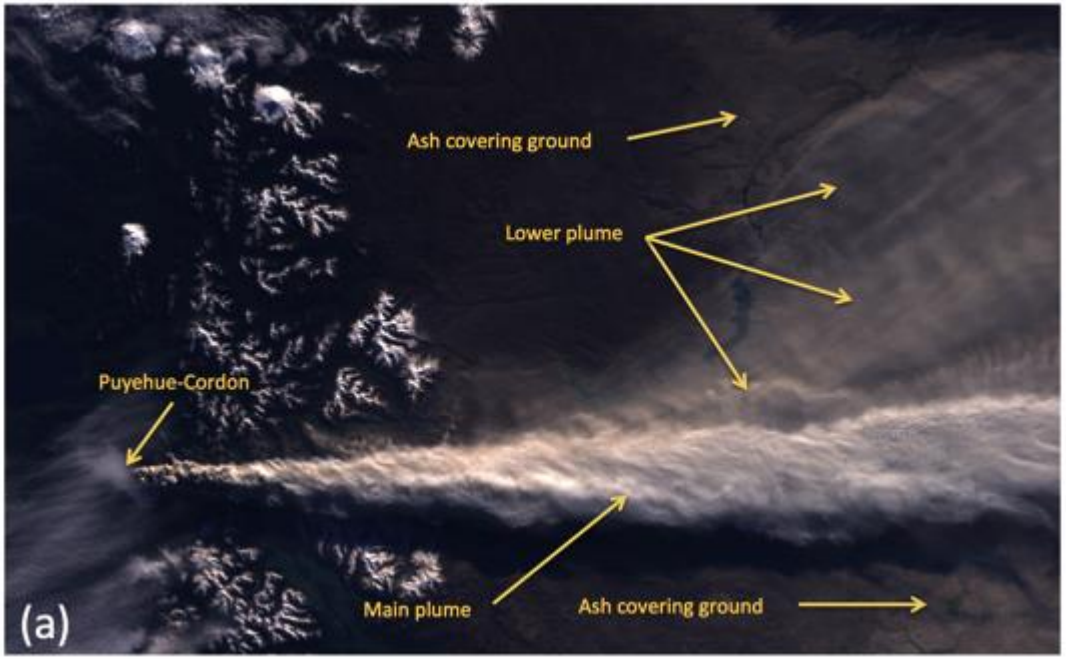



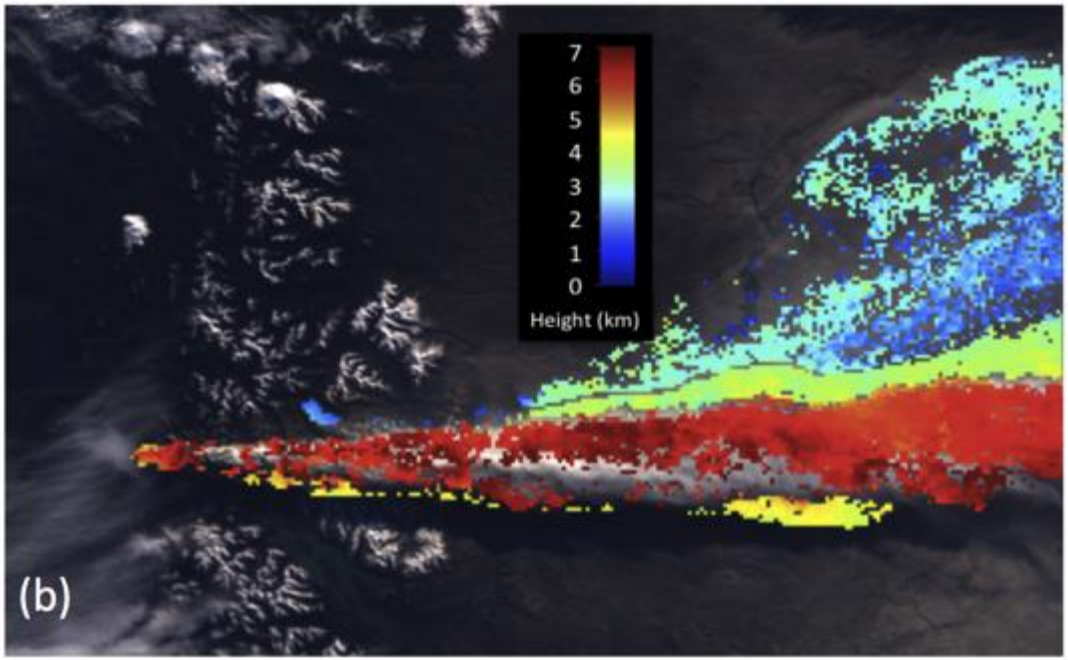



**Three possible modes of behavior of eruption columns - intensity of eruption increases from left to right. Wind is from the left in each case. At side of each diagram are shown normalized velocity (v) profiles versus height (h) for these columns. Left, weak isolated thermals, which are influenced by the wind. Center, a higher intensity buoyant column, influenced by wind only at the top. Right, a high intensity, superbuoyant column with a pronounced umbrella region.**

**From Self and Walker, 1994**

Puyehue-Cordon, Chile
(June 5, 2011)




Courtesy of D. Nelson

# More ….

# Berlin’s Eve

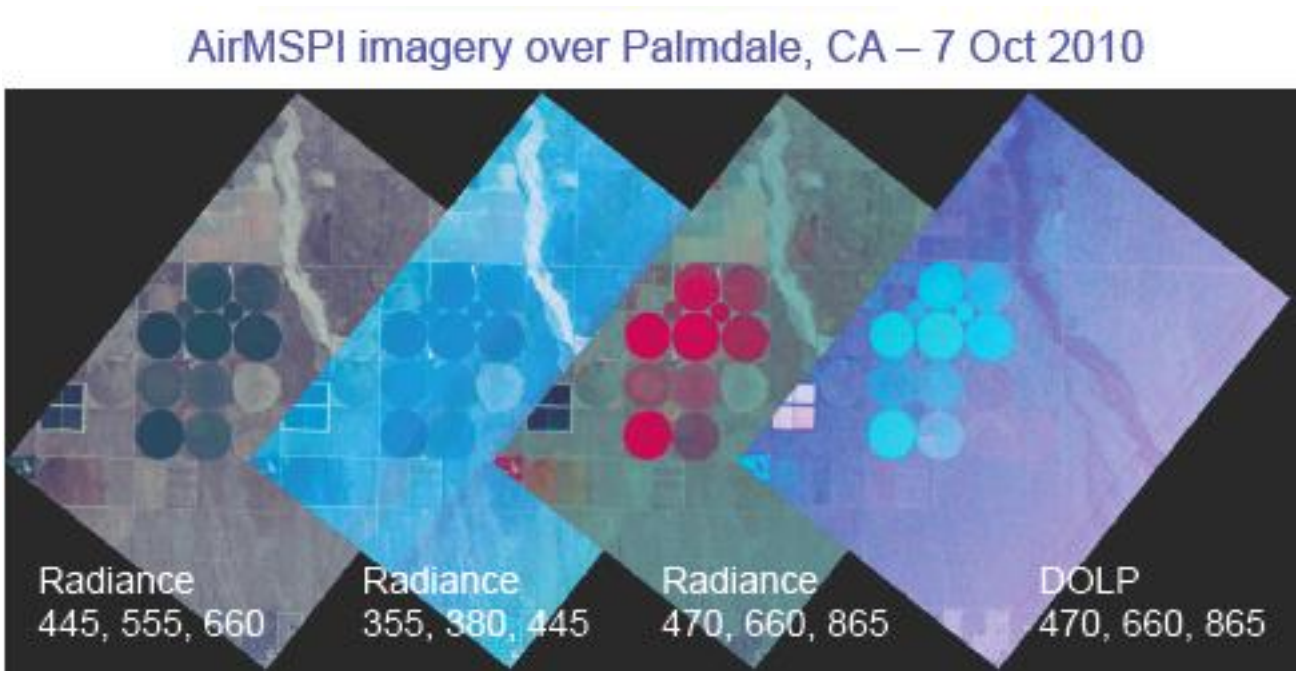
# Los Angeles' Day

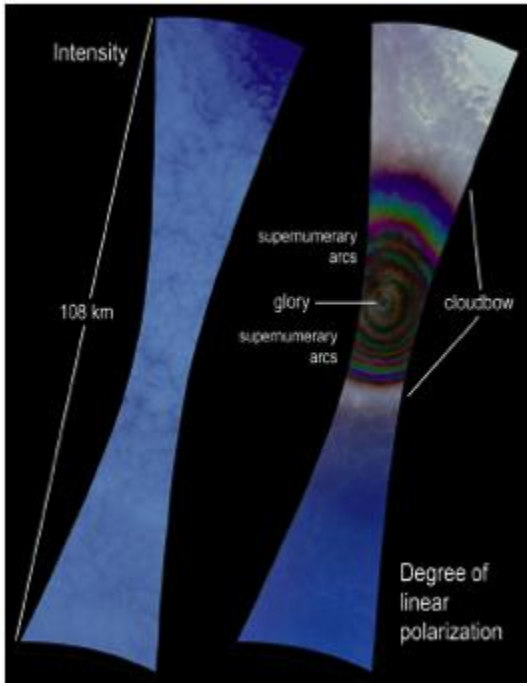
# New Instrument Measurement Concepts

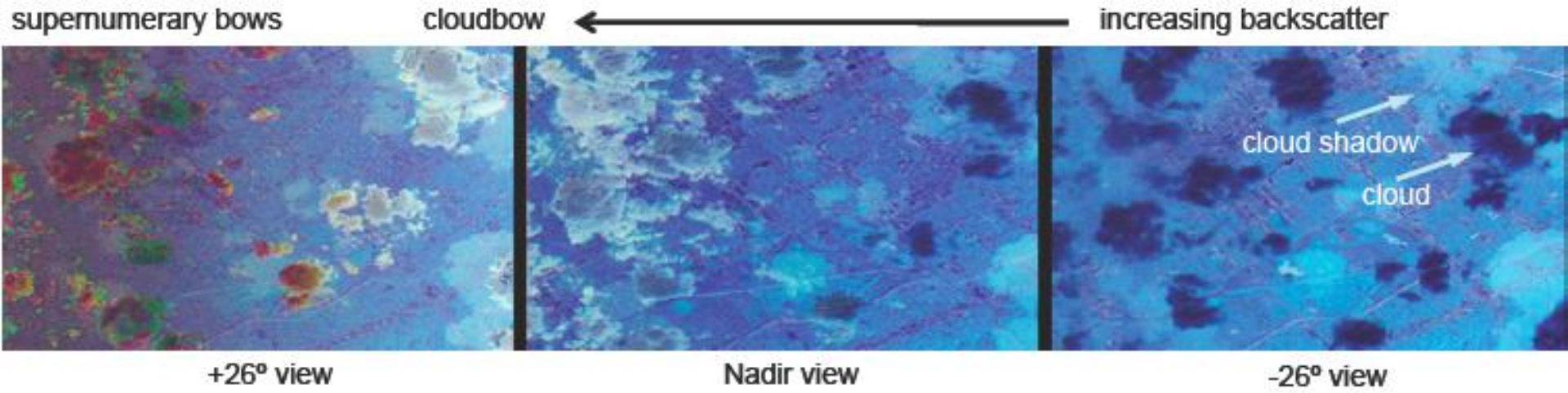
| Concept | Description | Heritage | Future |
|---|---|---|---|
| APS + 3MI | Heritage scanner providing very high accuracy multispectral polarimetry swath center. | ADEOS/POLDER PARASOL/POLDER Glory/APS | MetOp-SG/3MI |
| MSPI | Multiple pushbroom cameras providing high accuracy polarimetric imagery without any moving parts using photoelastic modulators (PEMs) | Terra/MISR for multiangle architecture | NASA ACE |
| PACS | Suite of three wide angle cameras with modified 3-way Phillips beamsplitter to provide high angular density using compact design and no moving parts plus a high resolution cloud imager | POLDER for wideangle lens | NASA ACE |

APS = Aerosol Polarimetry Sensor
3MI = Multi-polarization, Multi-directional, Multi-spectral Instrument
MSPI = Multiangle SpectroPolarimetric Imager
PACS = Passive Aerosol and Cloud Suite
ACE = Aerosol Cloud Ecosystem

# Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) on ER-2

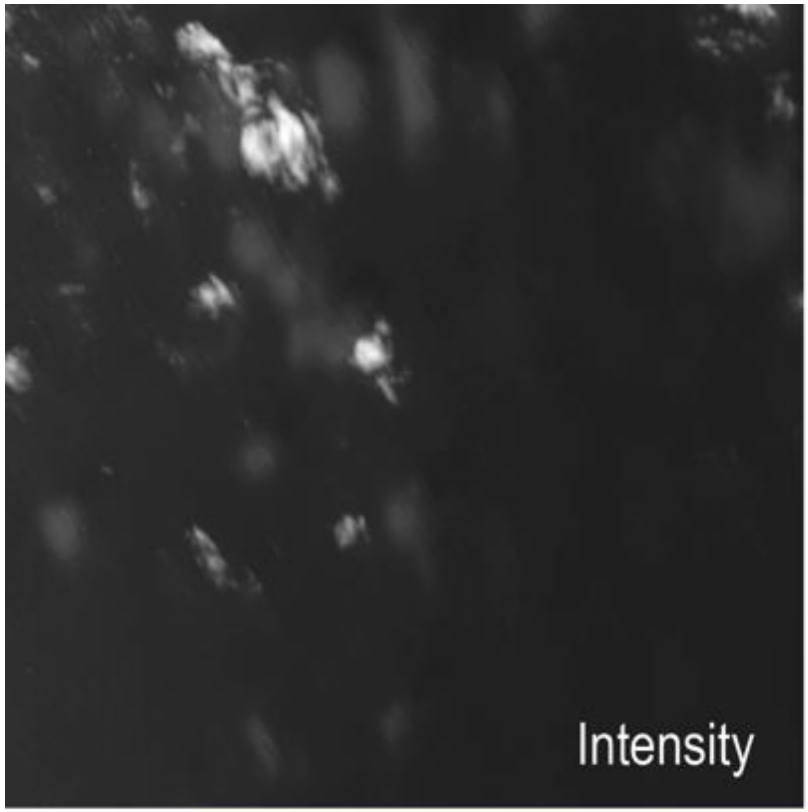


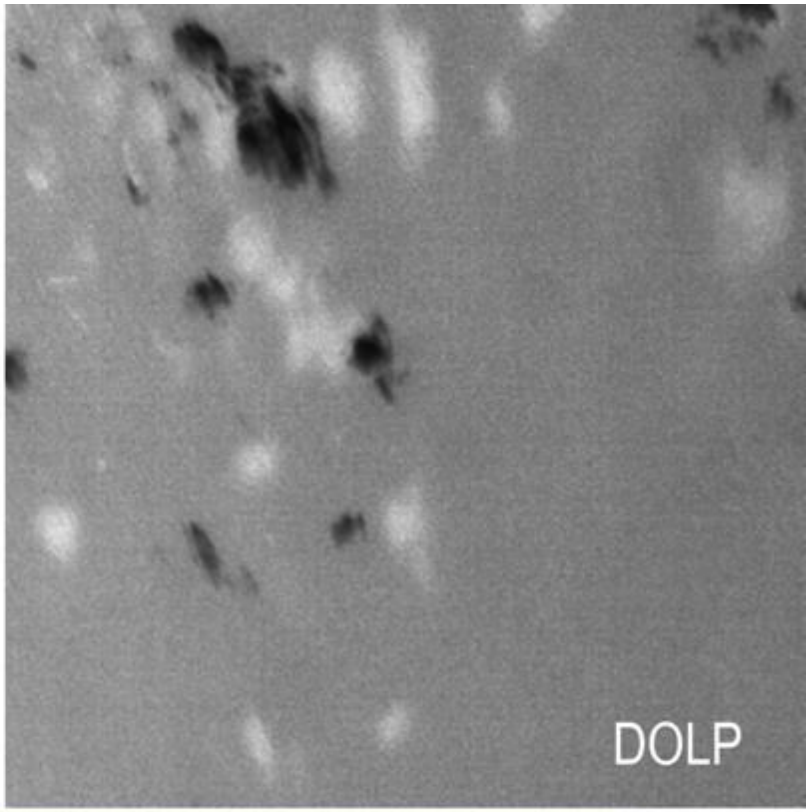



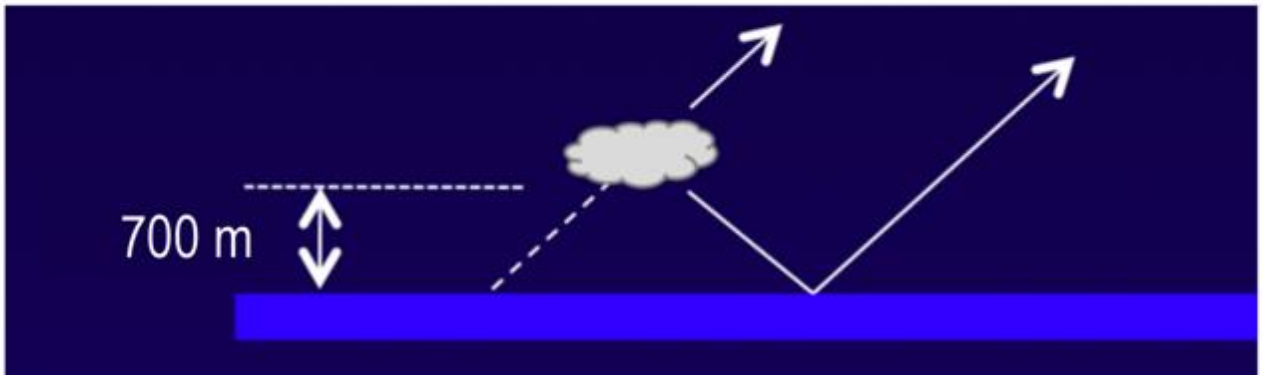




Diner et al. (AGU 2010)

# Airborne Multiangle SpectroPolarimetric Imager (AirMSPI)




Diner et al. (2013)

# Summary

- Passive stereo and thermal IR techniques are capable for providing accurate aerosol layer thickness in moderate and thick AOD/COD cases.
- Future (e.g., ACE and MetOp-SG in ~2020) stereo polarimetric imaging is promising to offer more sensitivities to aerosol physical and microphysical properties.
- Some smart, inexpensive ideas work well from the ground.

# Extra

# Aerosol Layers above PBL

- Aerosol (absorption) above clouds
  - OMI [Torres et al., 2012]
  - POLDER [Waquet et al., 2013]
- Optically-thick volcano, wildfire, dust plumes
  - MISR [Nelson et al., 2008; Martin et al., 2010]