Volcanic ash plume monitoring using GNSS radio occultation techniques

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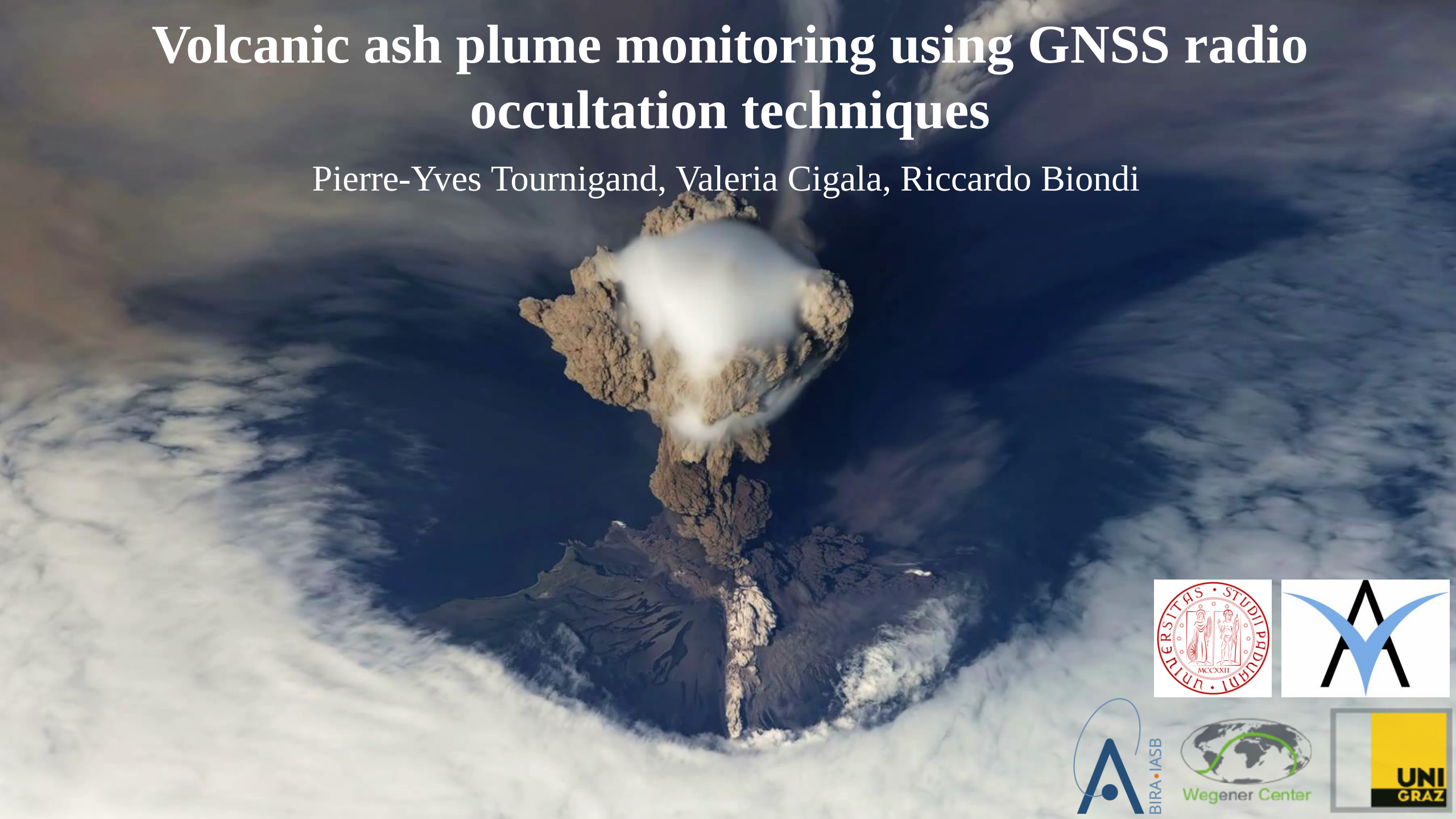


Introduction

Some of the main hazards related to volcanic eruptions originate from volcanic plumes:

Volcanic plumes: mixture of volcanic particles, gases, and entrained air.

- Pyroclastic flows
  - Can rise as high as 40 km

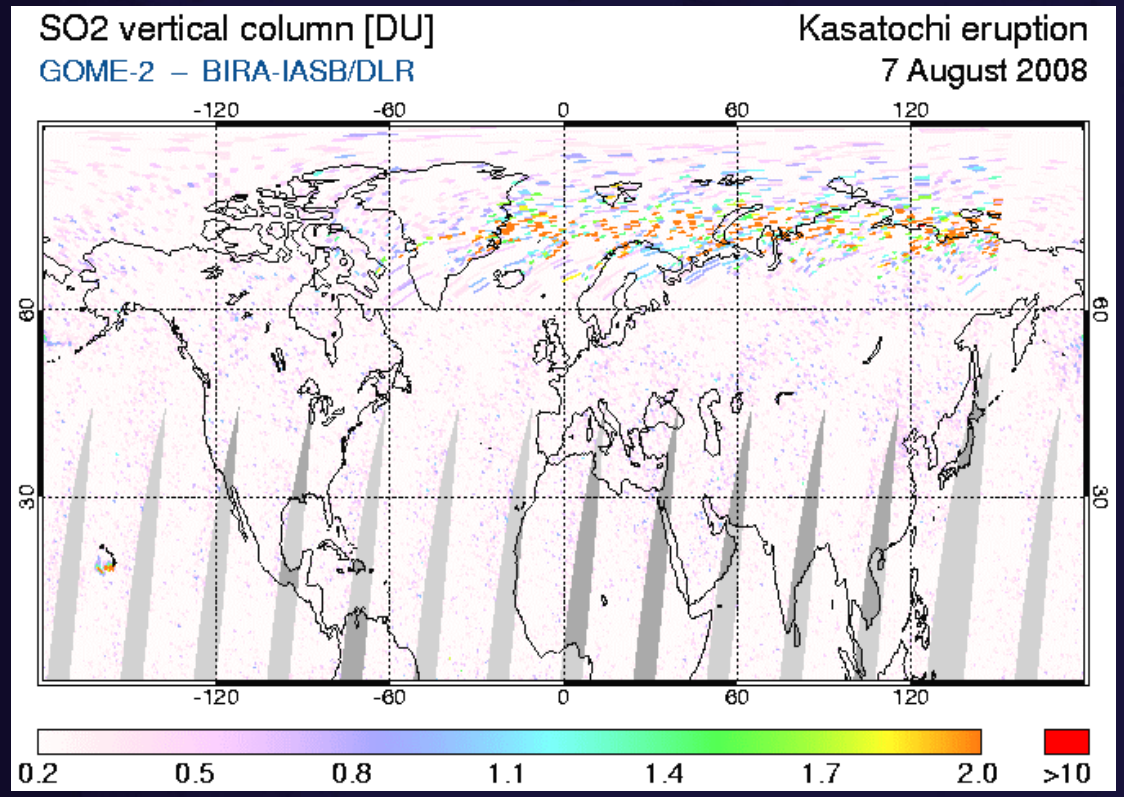
- Ash fallouts
  - Can be dispersed on a global scale

- Climate Impact
  - Main gases: H_2O, CO_2, SO_2

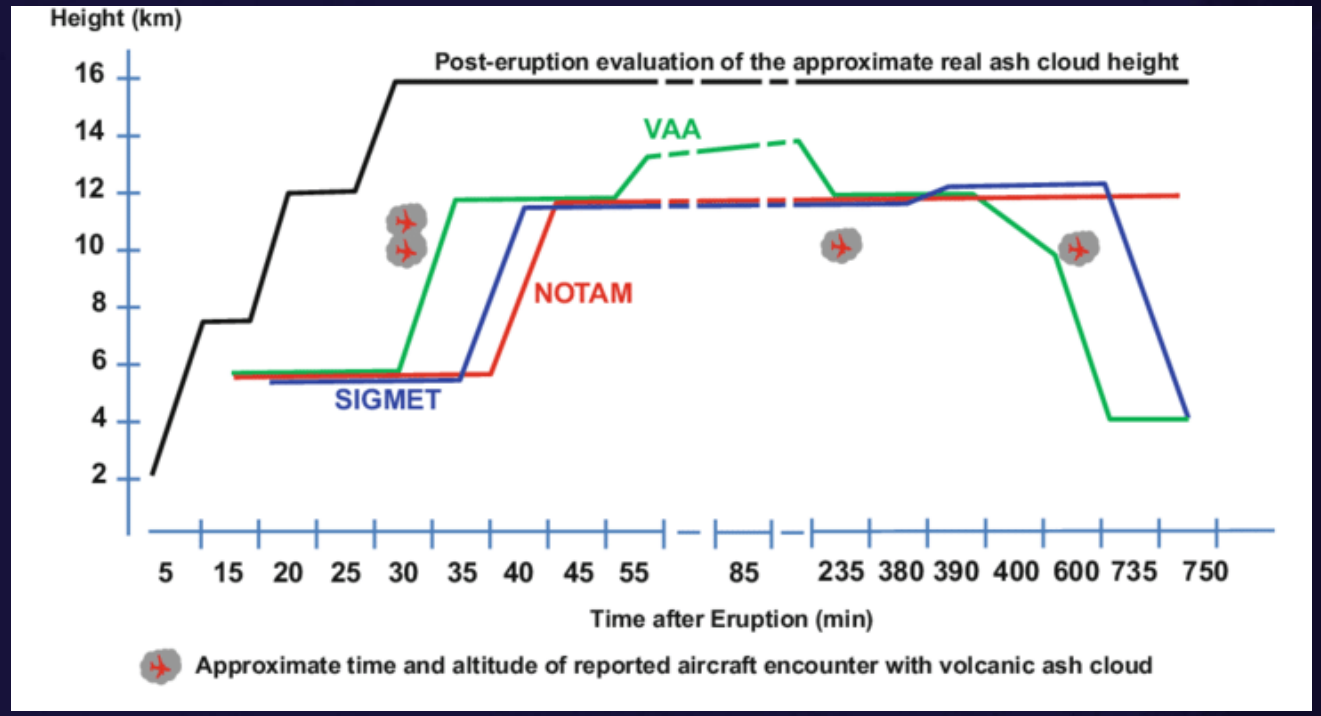
Crucial need for accurate monitoring techniques.

What do we need to know ?

Dispersion area



Altitude



Current techniques:
Hyperspectral UV and IR sensors (AIRS, GOME, MODIS,...)
Photogrammetry
Lidar (CALIOP)

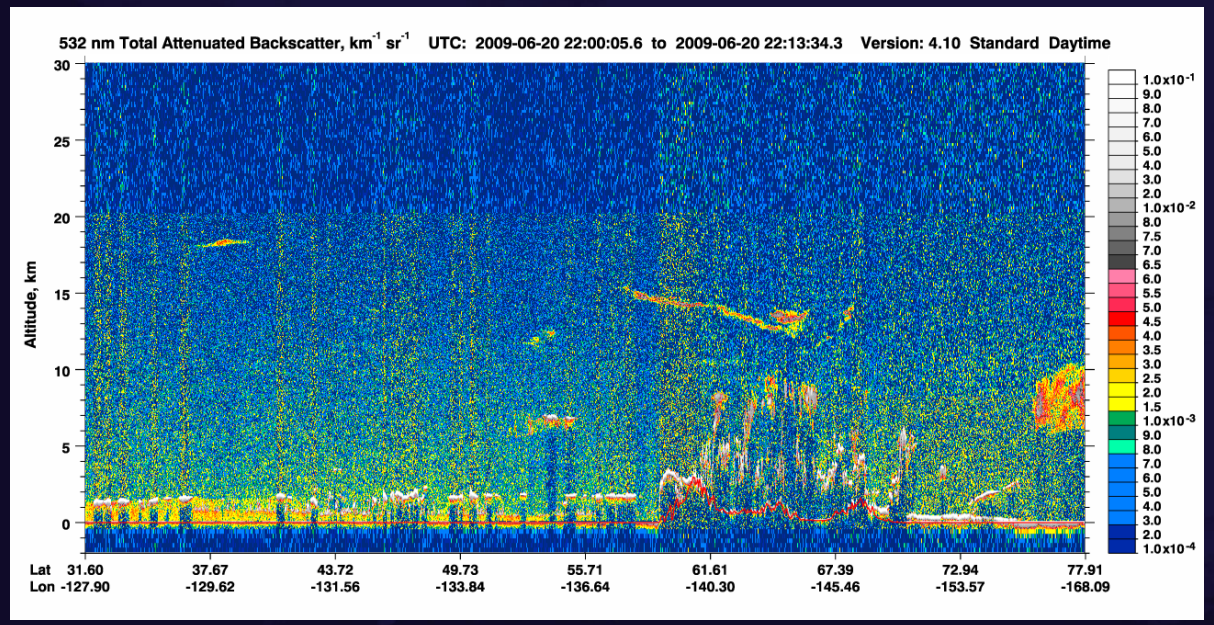
Why GNSS RO ?

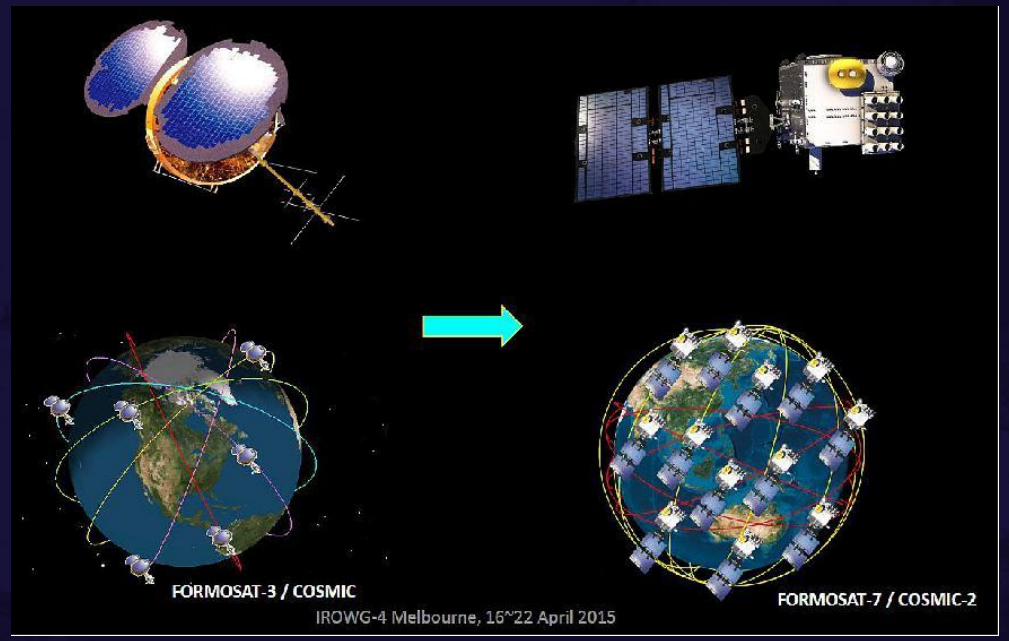
CALIOP Lidar:

- 60 m vertical resolution
- Narrow spatial resolution
- Low temporal resolution

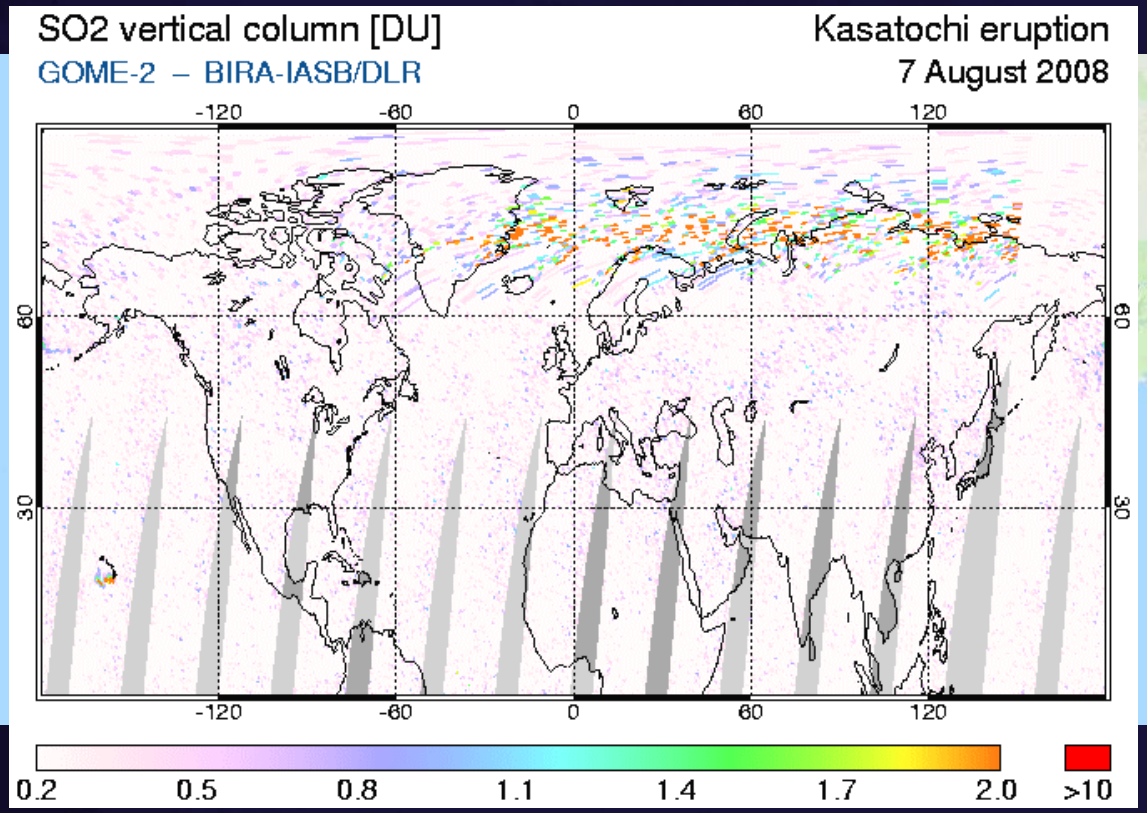
GNSS RO:

- 200 m vertical resolution
- Wide spatial resolution
- High temporal resolution





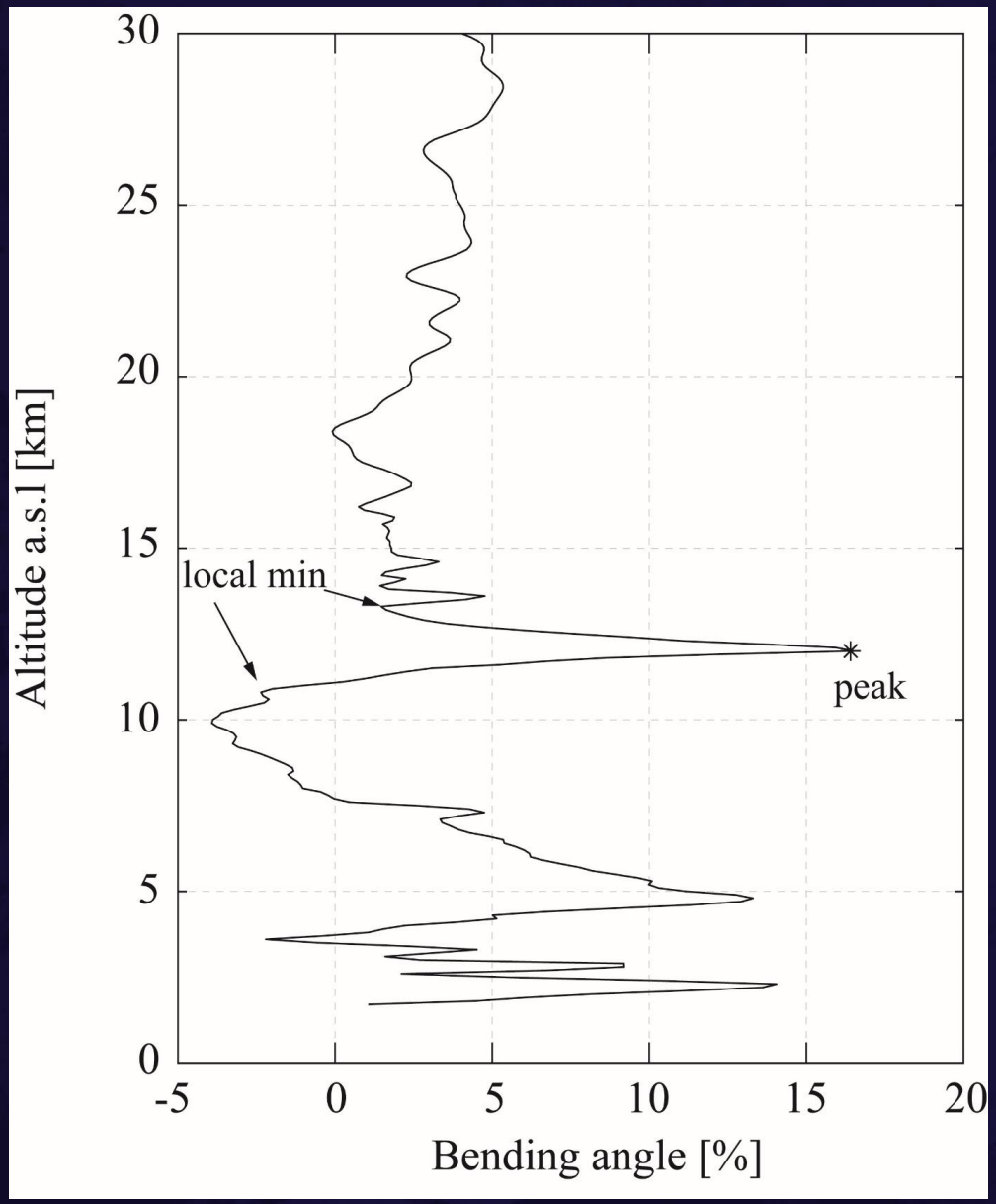
Kasatochi eruption 2008 – Case study



- Aleutian arc
- 314 m above sea level
- 7 of August 2008
- 3 large explosions withing 6h

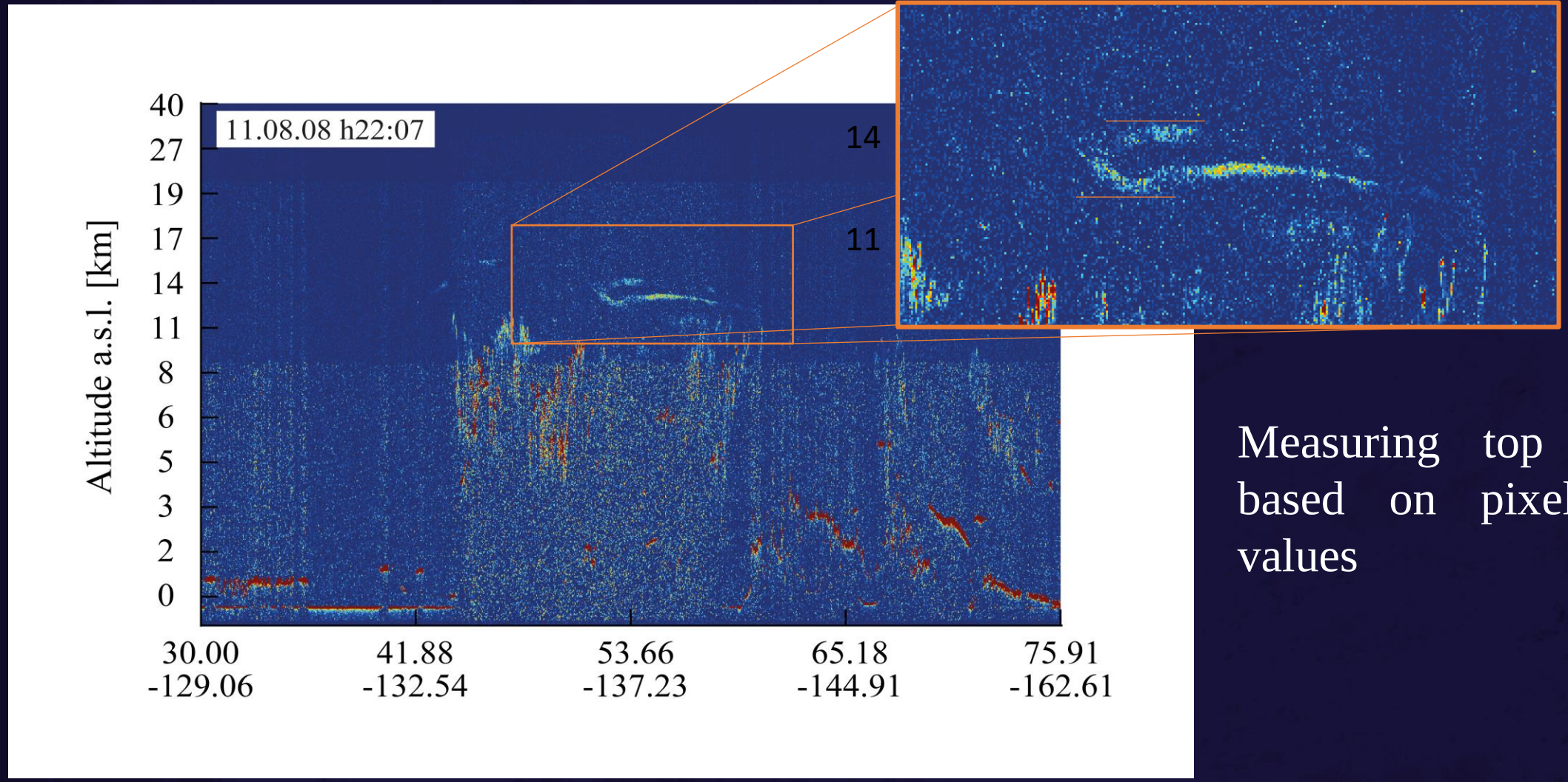
- Plume colomn up to 14 km
- 0.3 to 2.7 Tg of SO_2
- 0.3 to 0.5 Tg of ash
- Detected for 4 months

Volcanic plume altitude



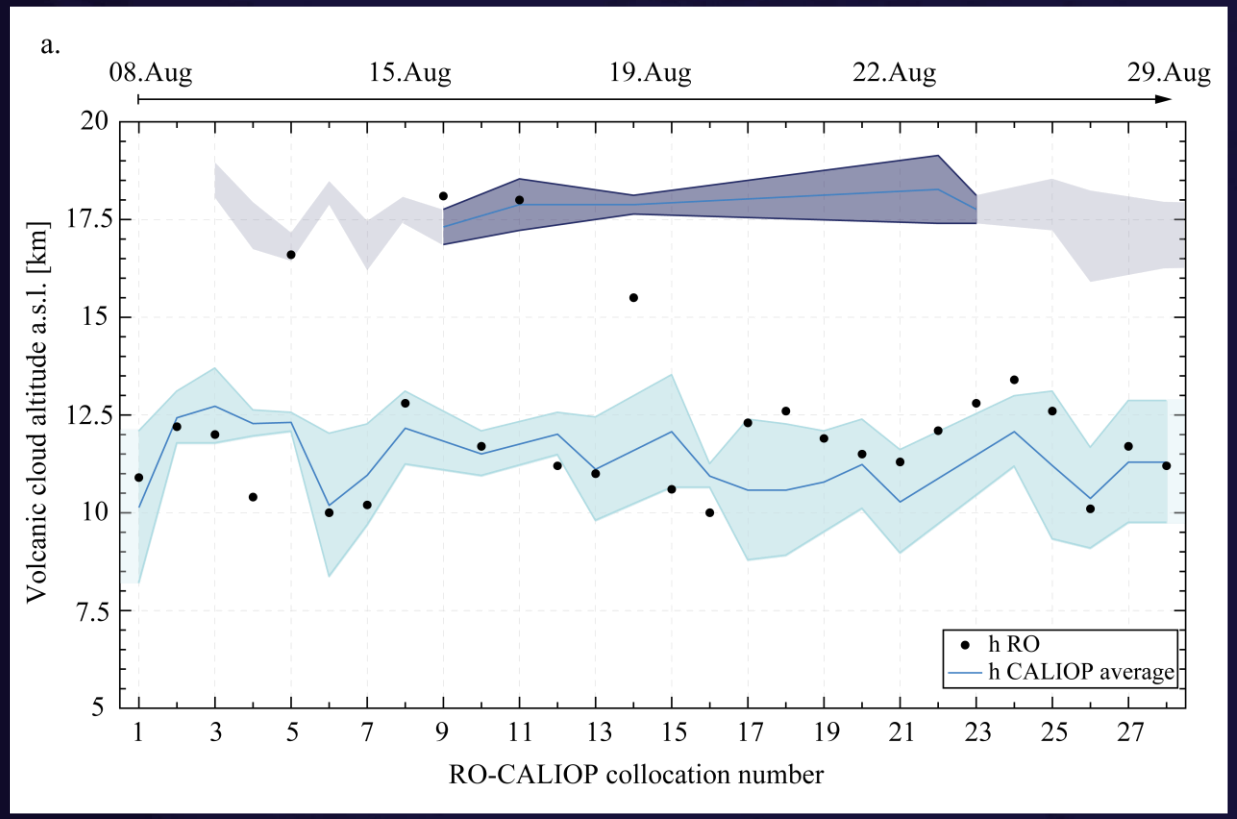
- Climatology on 10° latitude band
- Calculate the bending angle anomaly
- Select peaks with prominence > 5% above 10 km

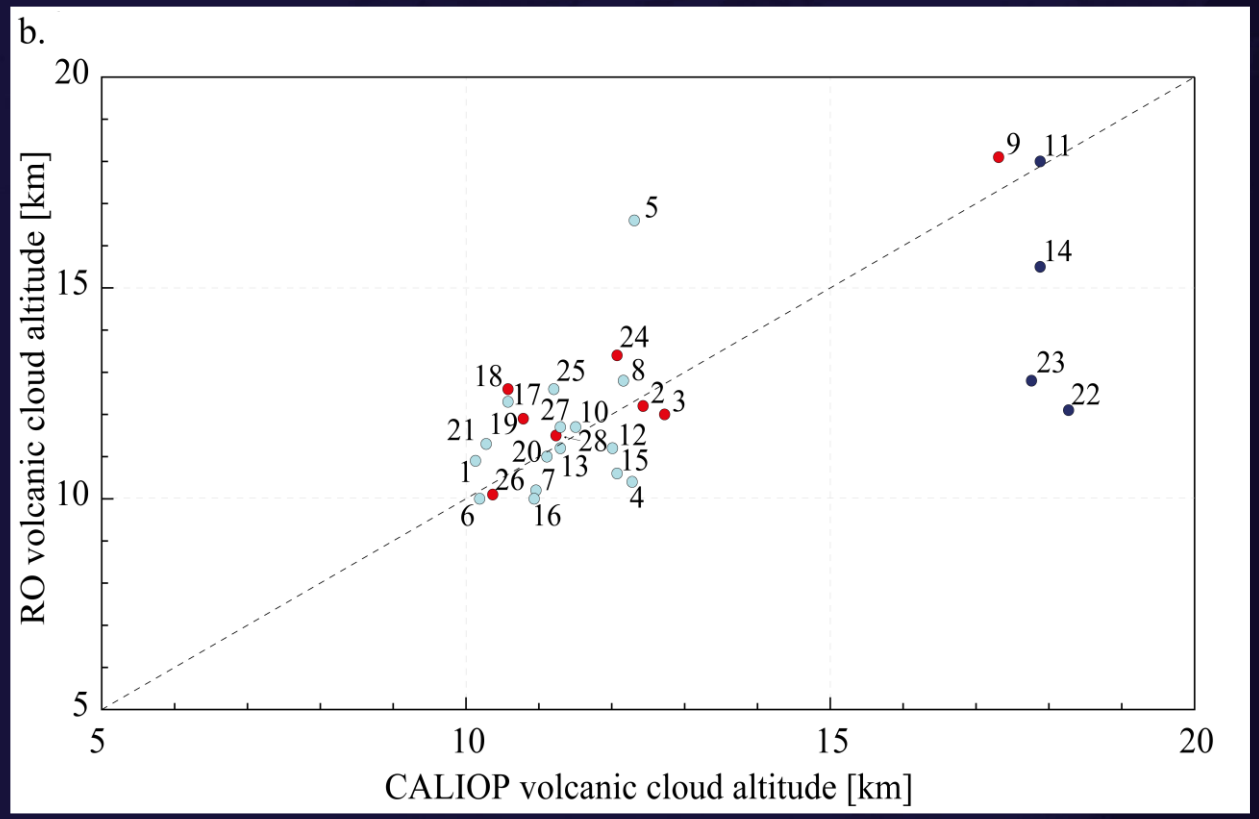
Altitude estimation validation



Measuring top and bottom based on pixel backscatter values

RO vs CALIOP



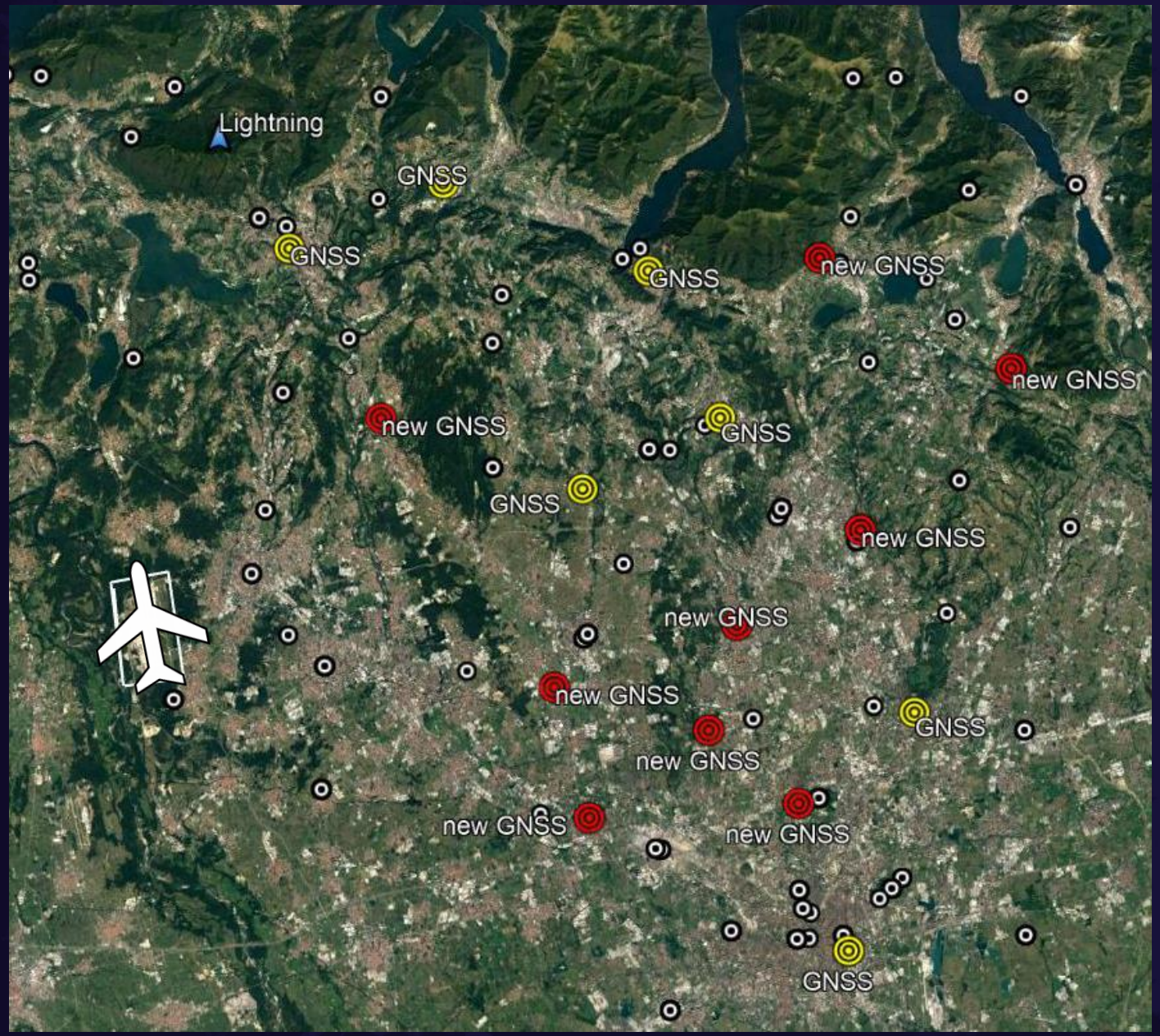


The error between CALIOP and RO volcanic cloud altitude is:

- 2.25 km with all samples
- 1.38 km when removing the outliers (more than 4 km discrepency)
- 1.07 km when using a 4h time range (in red)

Cigala, V., Biondi, R., Prata, A.J., Steiner, A.K., Kirchengast, G., and Brenot, H., (in review). GNSS radio occultation advances the monitoring of volcanic clouds: the case of the 2008 Kasatochi eruption. Remote Sensing.

CARGO project



Malpensa airport

Meteorological station

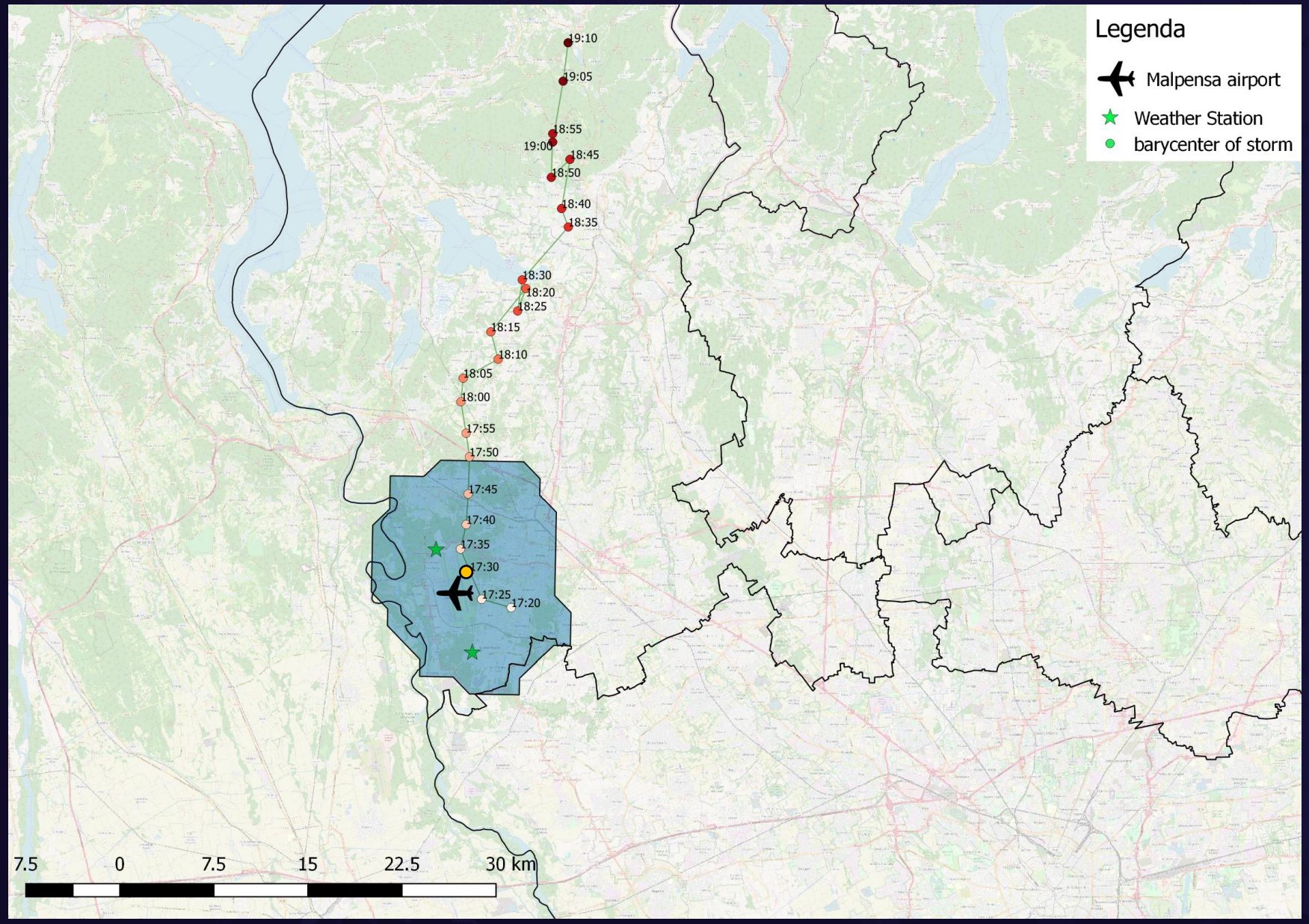
GNSS national network

GNSS low cost

Lightning sensor

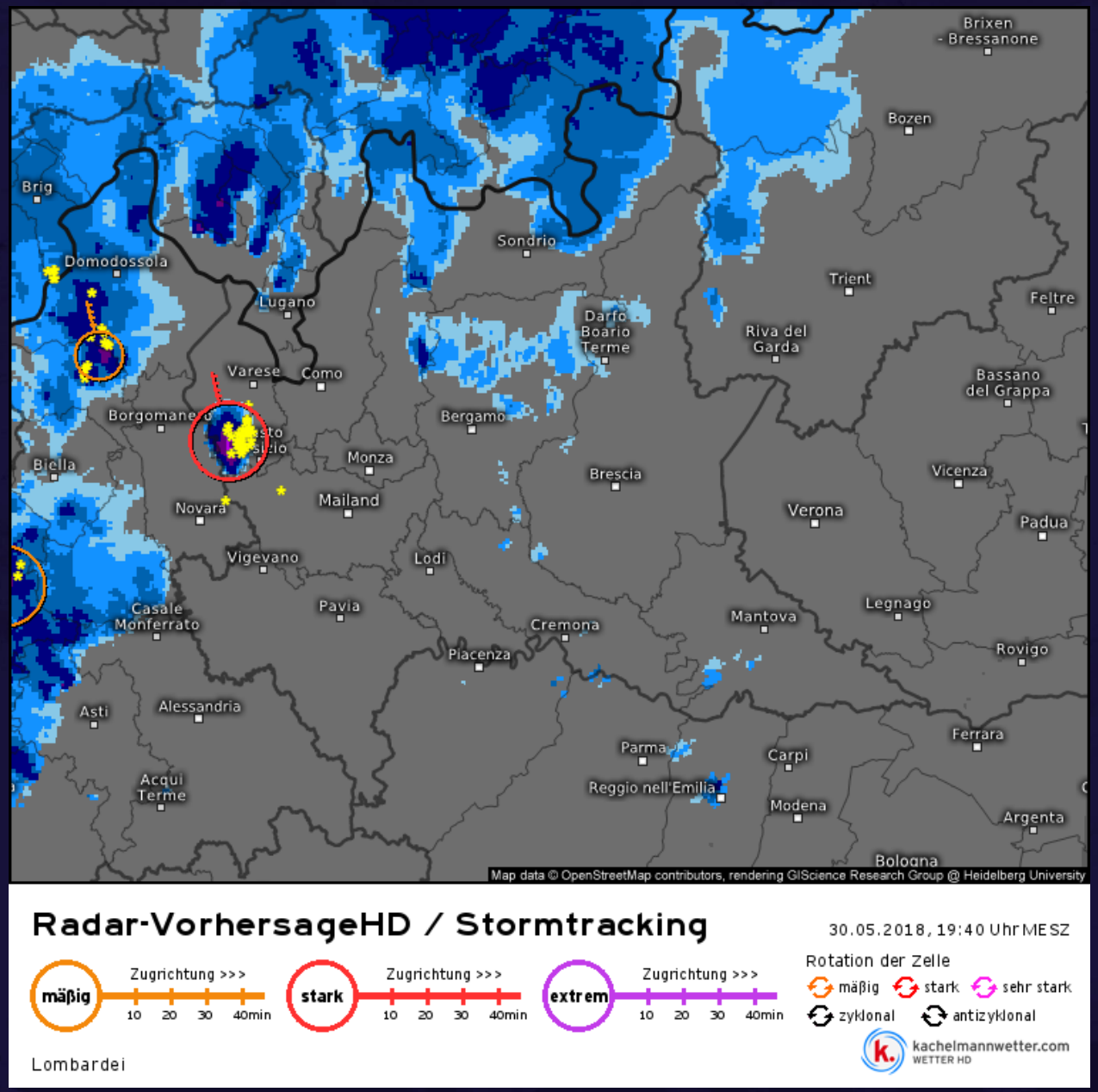
Nowcast the development and intensification of convective cells from GNSS-derived water vapor and measurements of the rate of lightning activity.

CARGO project



The project is based on the comparison between the water vapor and lightning spatio-temporal behavior and the rain phenomena detected by meteorological radars.

CARGO project



Conclusion

RO has potential for large spatial and temporal coverage

RO is a blind technique: validation needed

GNSS RO potential operational tool

RO proved useful to detect convective cloud top

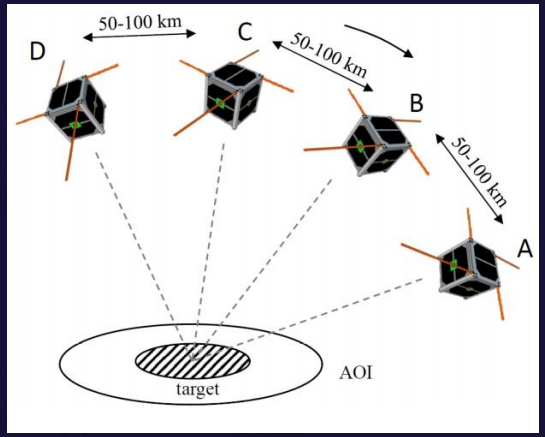
GNSS is crucial for nowcasting of pre-convection environment, especially if combined to ground-based, in order to forecast extreme weather events

Dispersion and altitude estimation

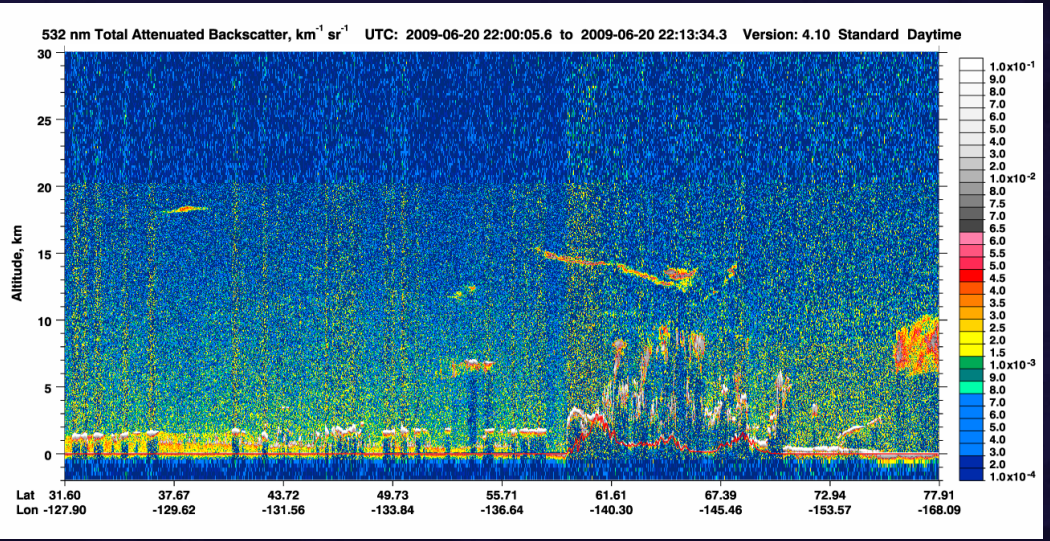
Hyperspectral UV and IR sensors

	Volatile species									
Sensor[a]	H_2O	CO_2	CO	SO_2	H_2S	HCl	BrO	OClO	CH_3Cl	Timespan
TOMS*										1978–2005
SBUV* (P)										1978–present
HIRS*										1978–present
GOME										1995–2003
MODIS*										1999–present
ASTER										1999–present
MOPITT										1999–present
SCIAMACHY (L)										2002–2012
MIPAS (L)										2002–2012
AIRS										2002–present
ACE (L)										2003–present
SEVIRI										2004–present
OMI										2004–present
MLS* (L)										1991–2001; 2004–present
TES (P)										2004–present
GOME–2*										2006–present
IASI*										2006–present
OMPS*										2011–present
VIIRS										2011–present
CrIS										2011–present
AHI										2015–present
GOSAT (P)										2009–present
OCO–2										2014–present

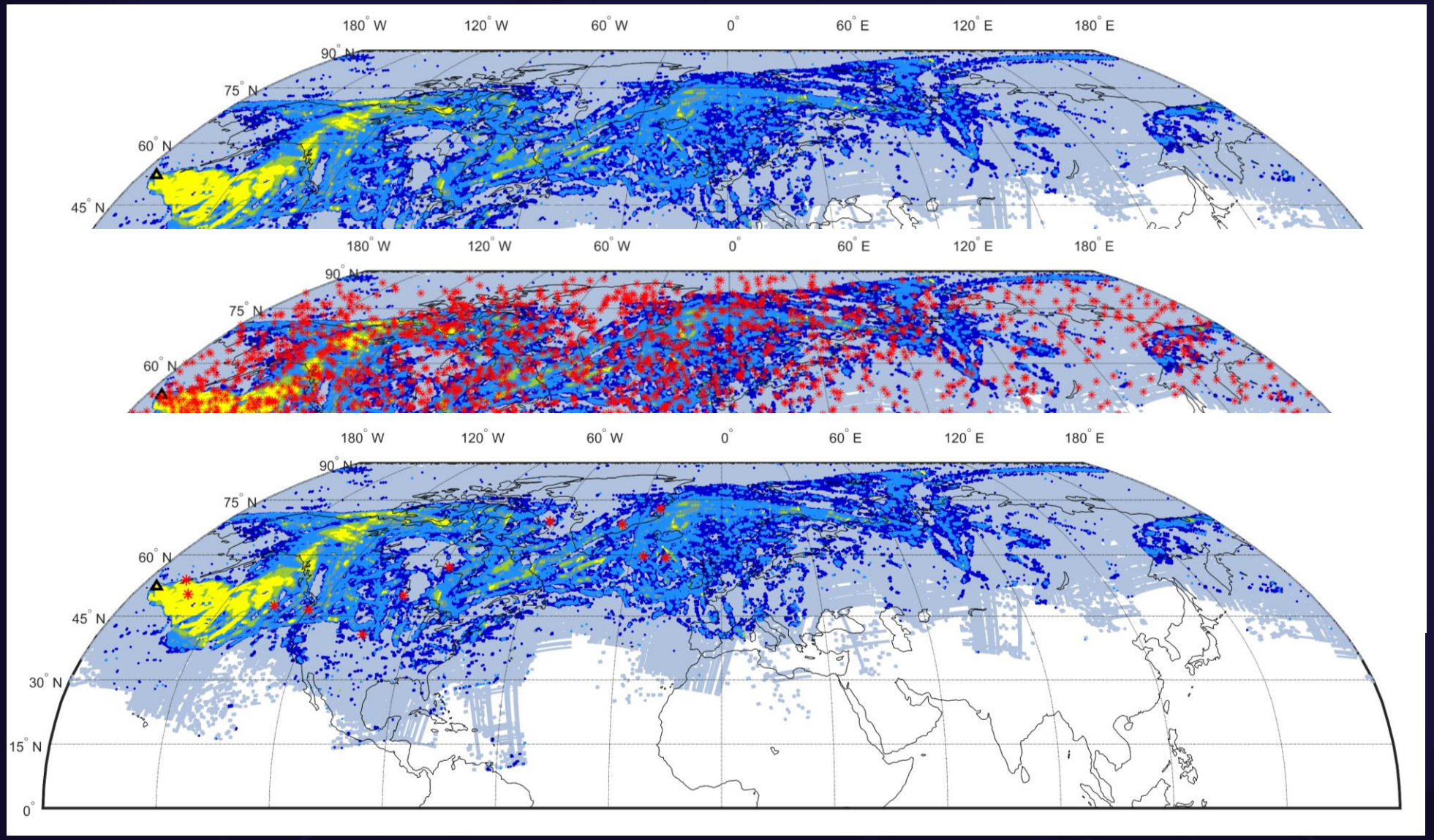
Photogrammetry



Lidar



Collocations



AIRS SO_2

12h and 0.2°

2348 RO profiles

28 collocated CALIOP and RO profiles

RO vs CALIOP error analysis