Analysing Stratospheric Volcanic Ash Deposition Using CALIOP Measurements

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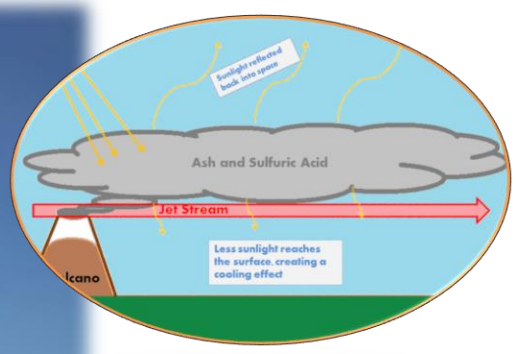
Outlines

1. Why should we care about volcanic ash?
2. What do we want to know about volcanic ash?
3. Measuring ash from space.
4. What we have learned so far.

Why should we care about volcanic ash?

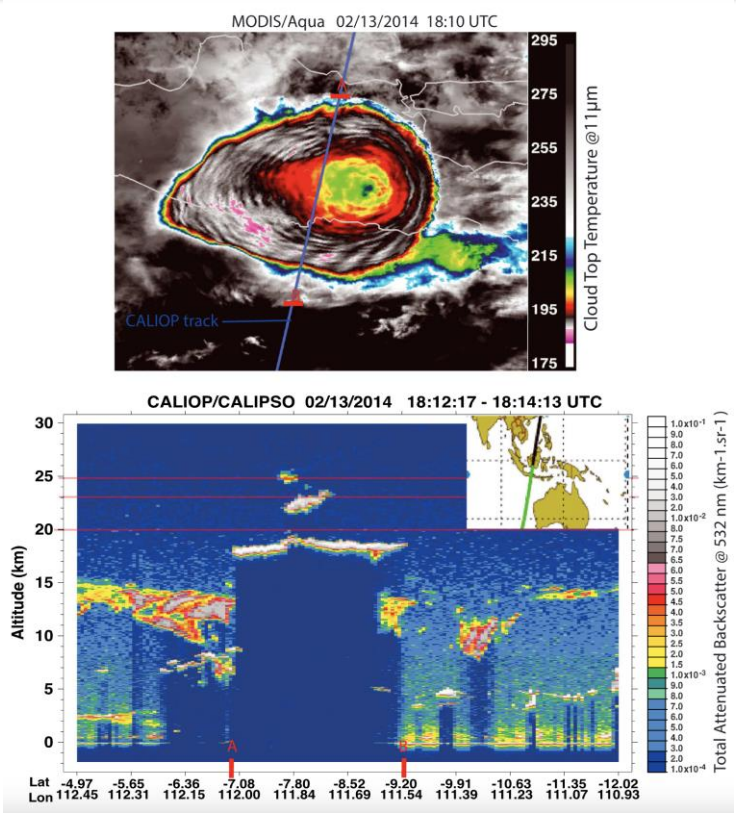
Hazard to aviation



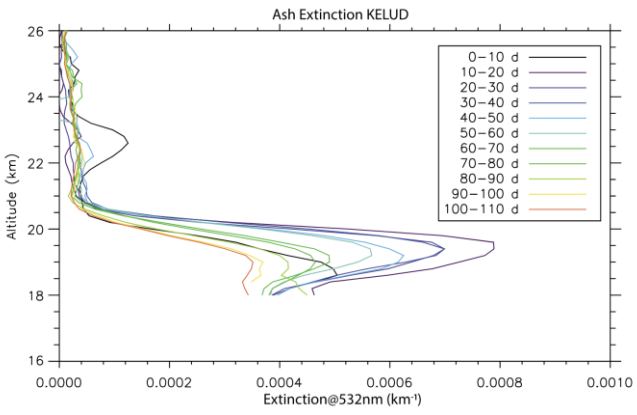
Climate

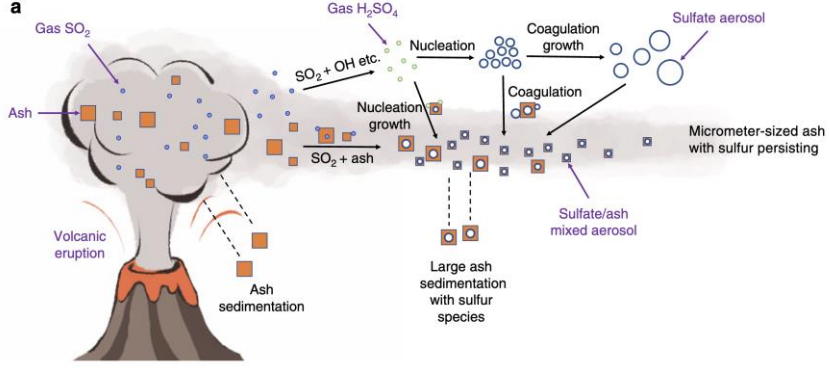
Human health

Volcanic ash in the stratosphere



Vernier, J.-P., et al., 2016. DOI: 10.1002/2016JD025344





Zhu et al., 2020. DOI: 10.1038/s41467-020-18352-5

- Atmospheric lidar provide an effective method to distinguish ash and sulfuric acid.
- 3 months after the eruption, 20–25% of total Kelud Aerosol Optical Depth (AOD) between 18 and 23 km comes from the presence of ash

Measuring ash from space lidar

Feature	CALIOP	AEOLUS	ATLID
Mission	Part of the CALIPSO mission	ESA's atmospheric dynamics mission	Part of the EarthCARE mission
Launch Date	April 2006	August 2018	May 2024
Primary Objective	Study aerosol and cloud layers	Measure global wind profiles	Provide data on clouds and aerosols, and their interaction
Technology	Polarization lidar	Doppler wind lidar	High spectral resolution lidar
Altitude Coverage	Troposphere and lower stratosphere	Troposphere and lower stratosphere	Troposphere and lower stratosphere
Data Applications	Climate research, air quality monitoring	Weather forecasting, climate research	Climate research, weather prediction
Orbit	Sun-synchronous	Sun-synchronous	Sun-synchronous
Wavelength	532 nm, 1064 nm	355 nm	355 nm
Spatial Resolution	30 m vertical, 5 km horizontal	500 m vertical, 87 km horizontal	100 m vertical

CALIOP aerosol classification

V3 and earlier

- clean marine
- dust
- polluted continental
- clean continental
- polluted dust
- and smoke

V4.1/4.2

Troposphere:

- clean marine
- dust
- polluted continental/smoke
- clean continental
- polluted dust
- elevated smoke
- dusty marine

Stratosphere:

- PSC
- volcanic ash
- sulfate/other
- elevated smoke

V4.5

Troposphere:

- clean marine
- dust
- polluted continental/smoke
- clean continental
- polluted dust
- elevated smoke
- dusty marine

Stratosphere:

- PSC
- volcanic ash
- sulfate/other
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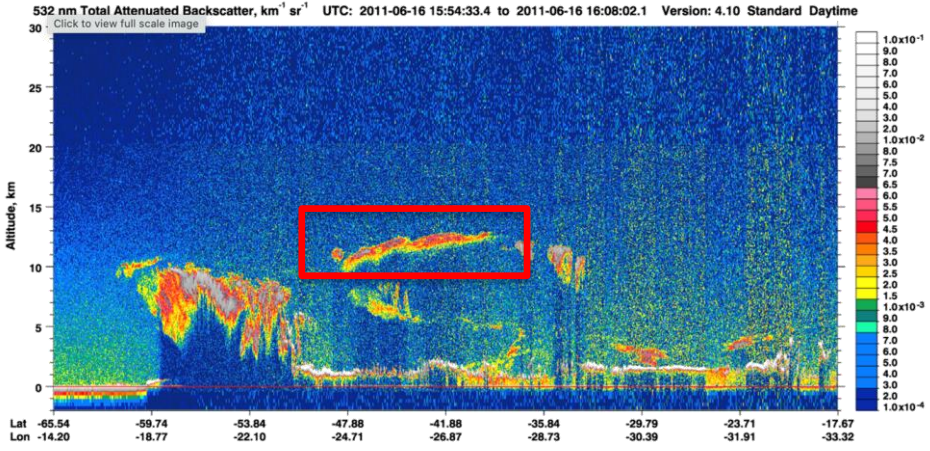
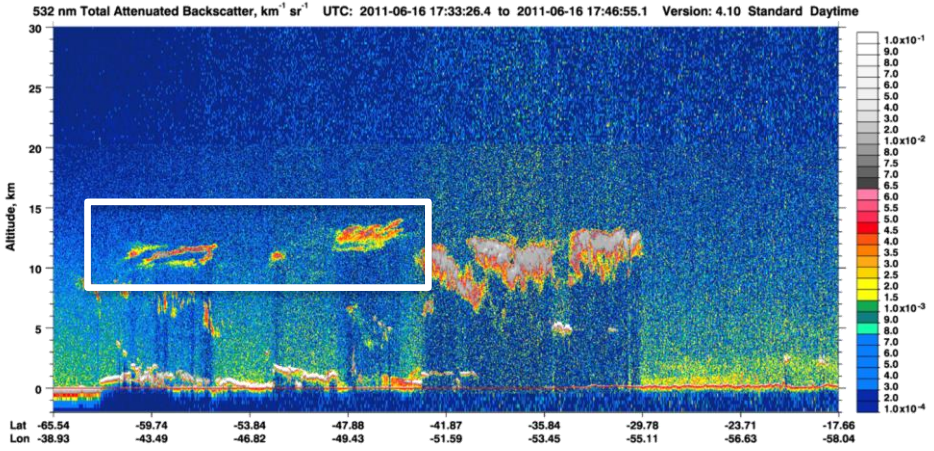
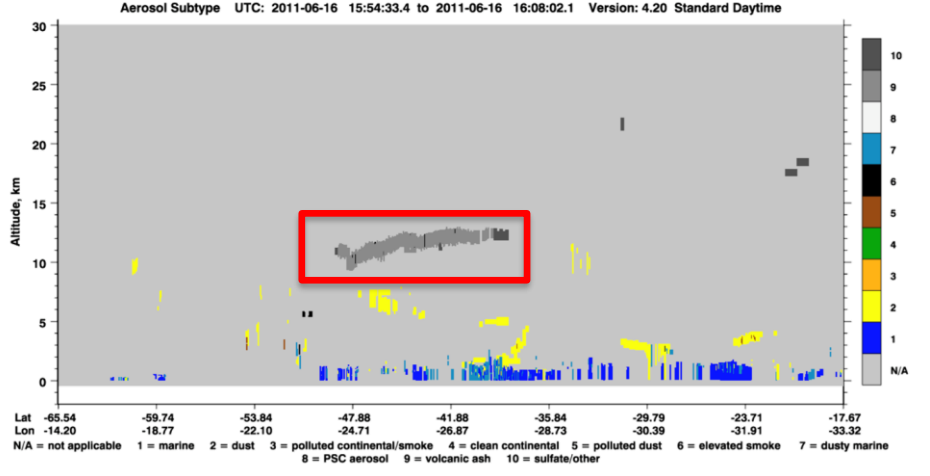
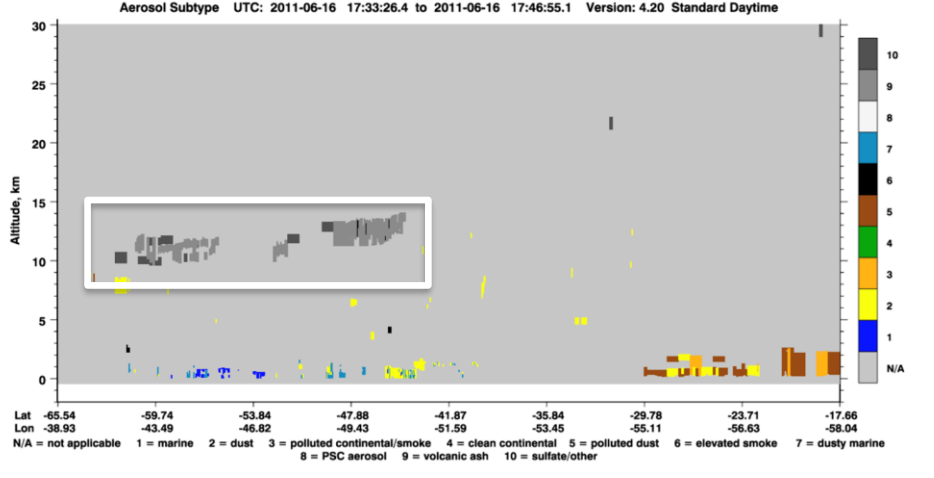
CALIOP aerosol classification

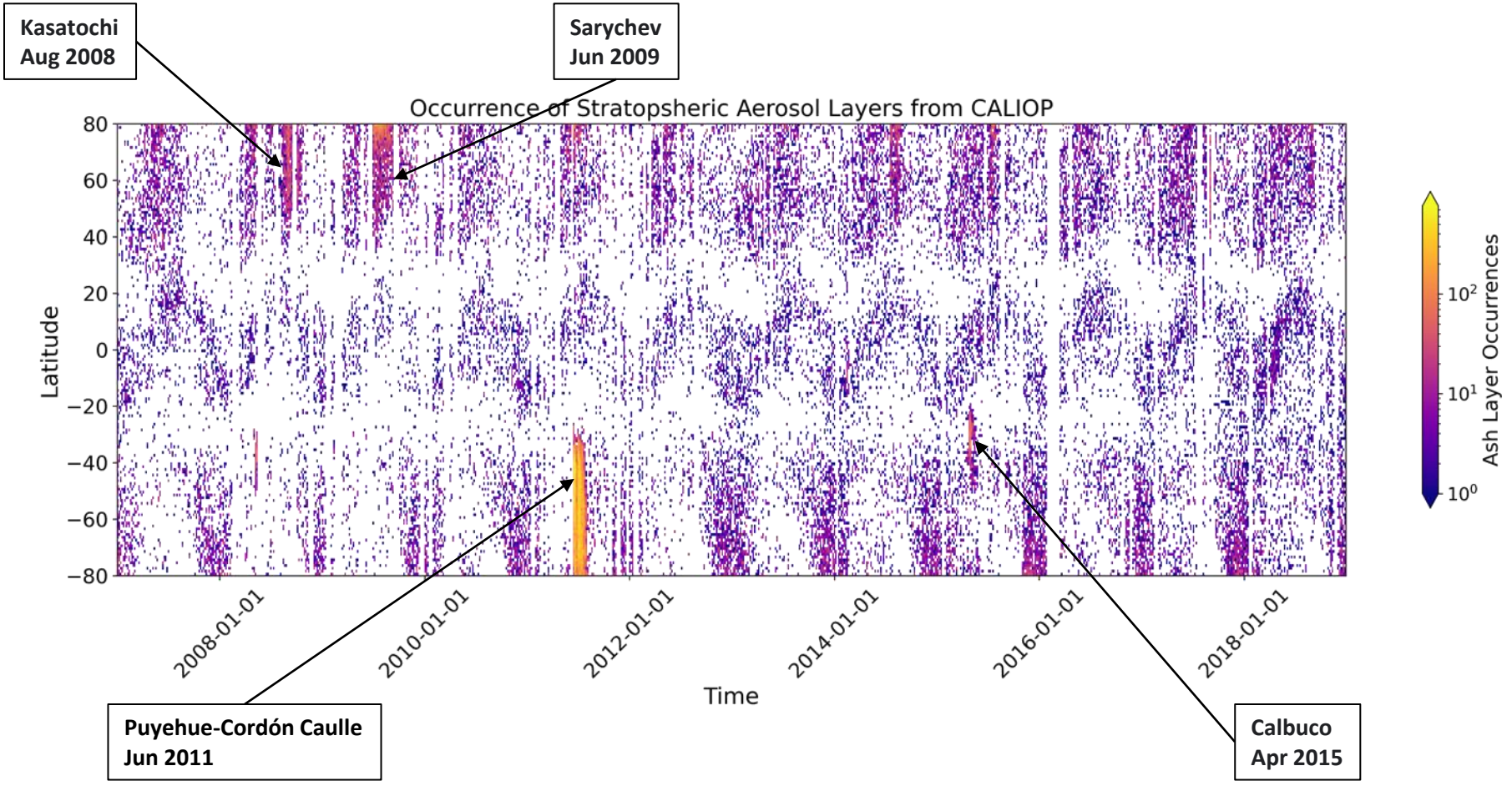




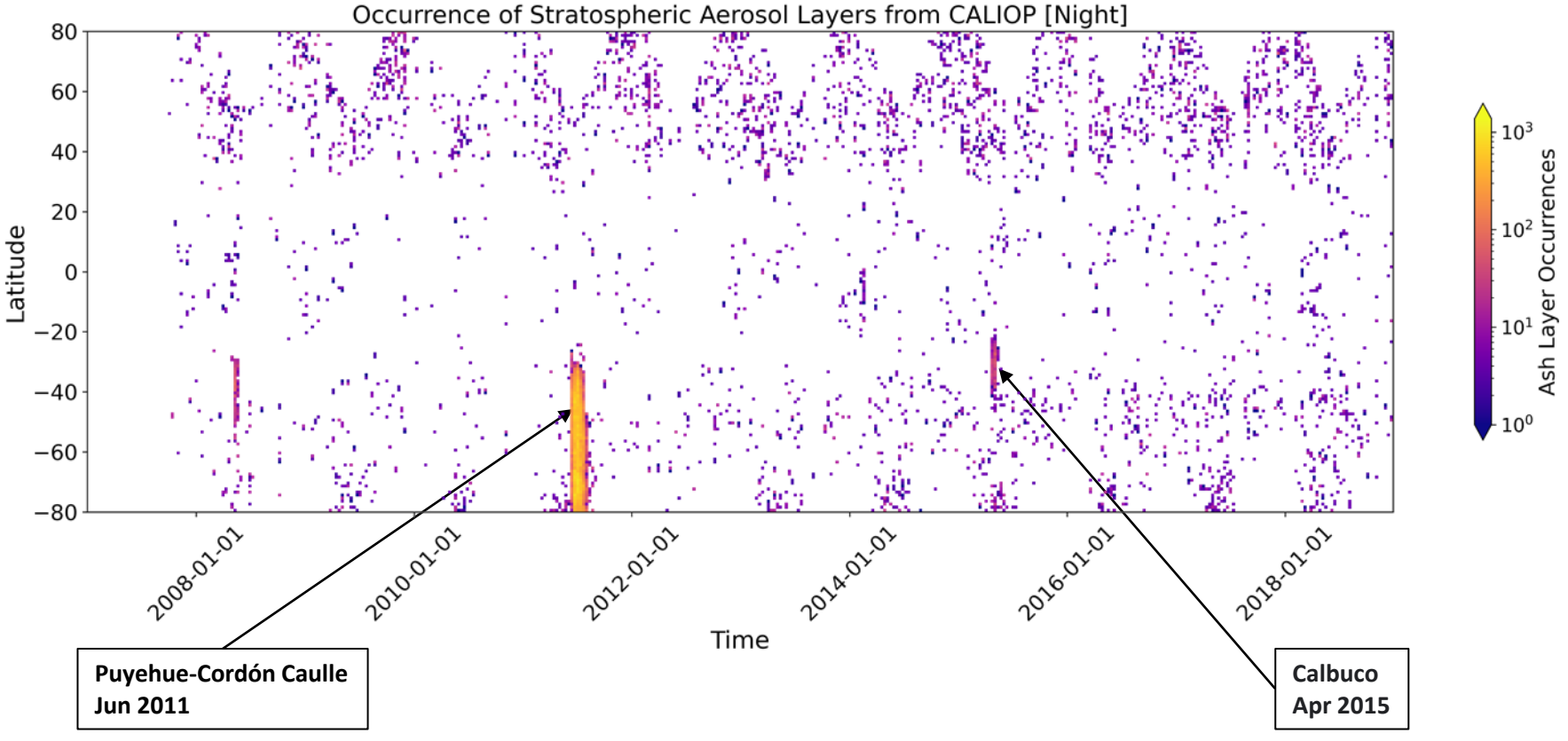




CALIOP ash layer (2006 - 2018): all day

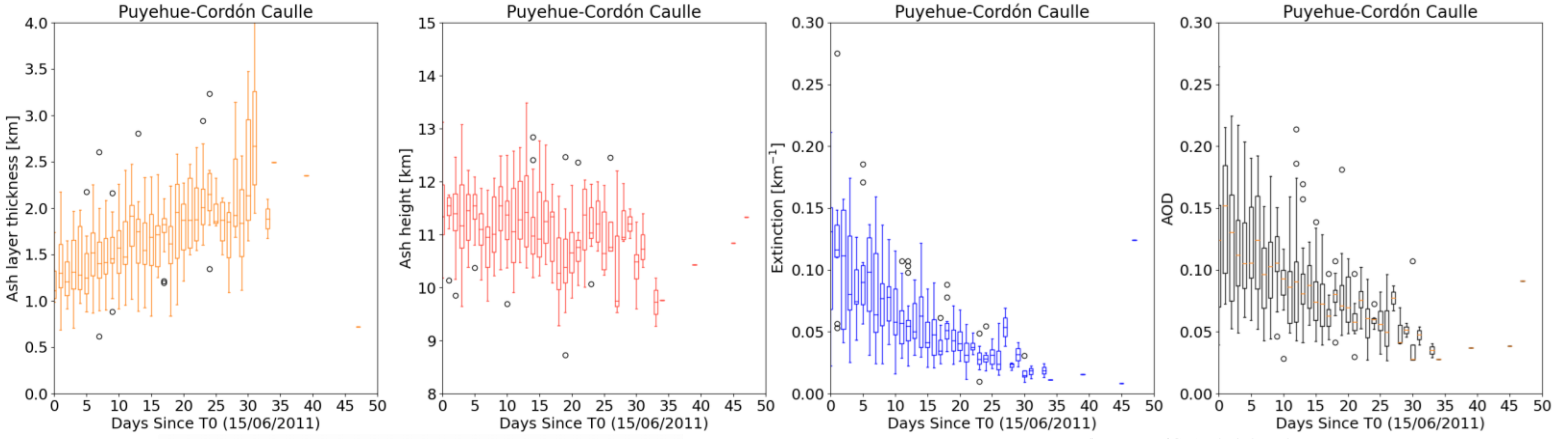


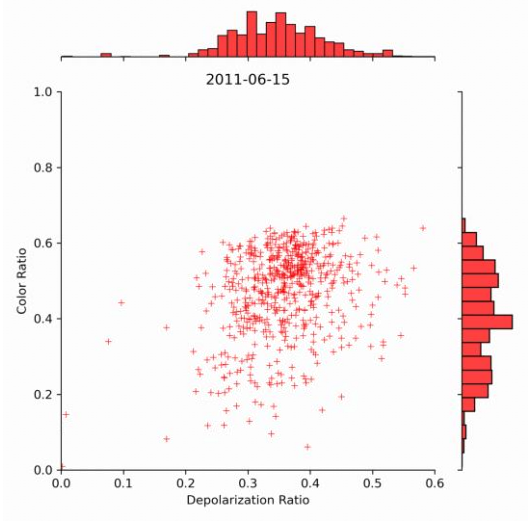
CALIOP ash layer (2006 - 2018): night only

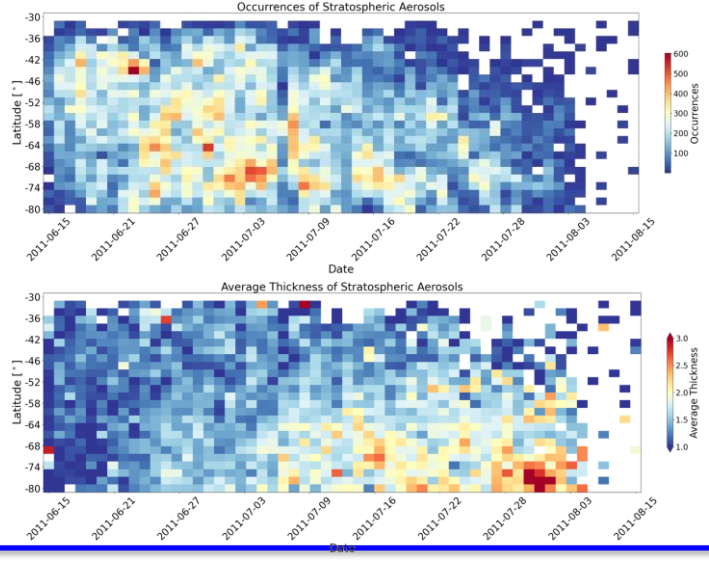


Puyehue-Cordón Caulle 2011 eruption

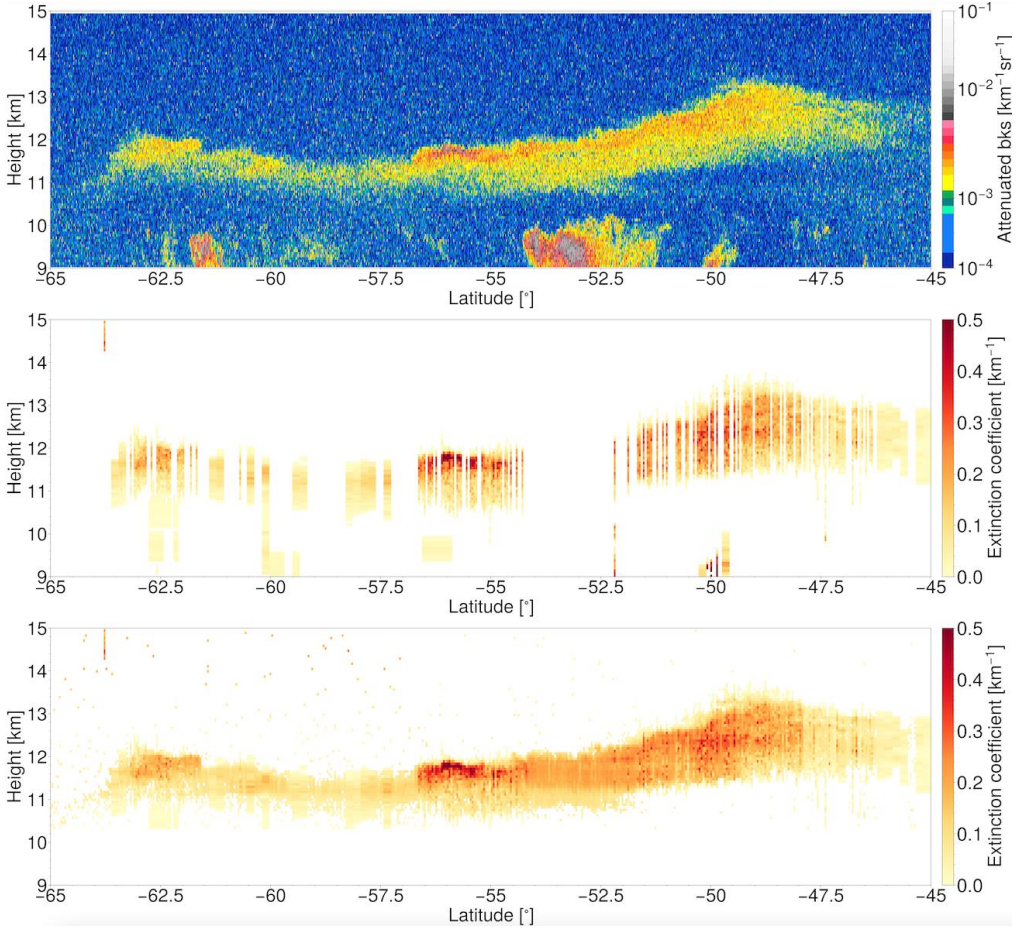
[80° S, 0]



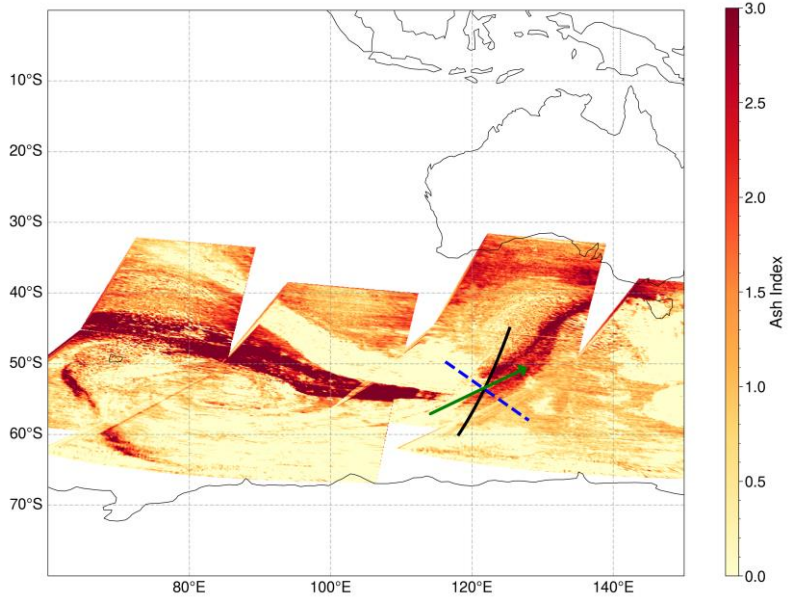




Puyehue-Cordón Caulle 2011 eruption

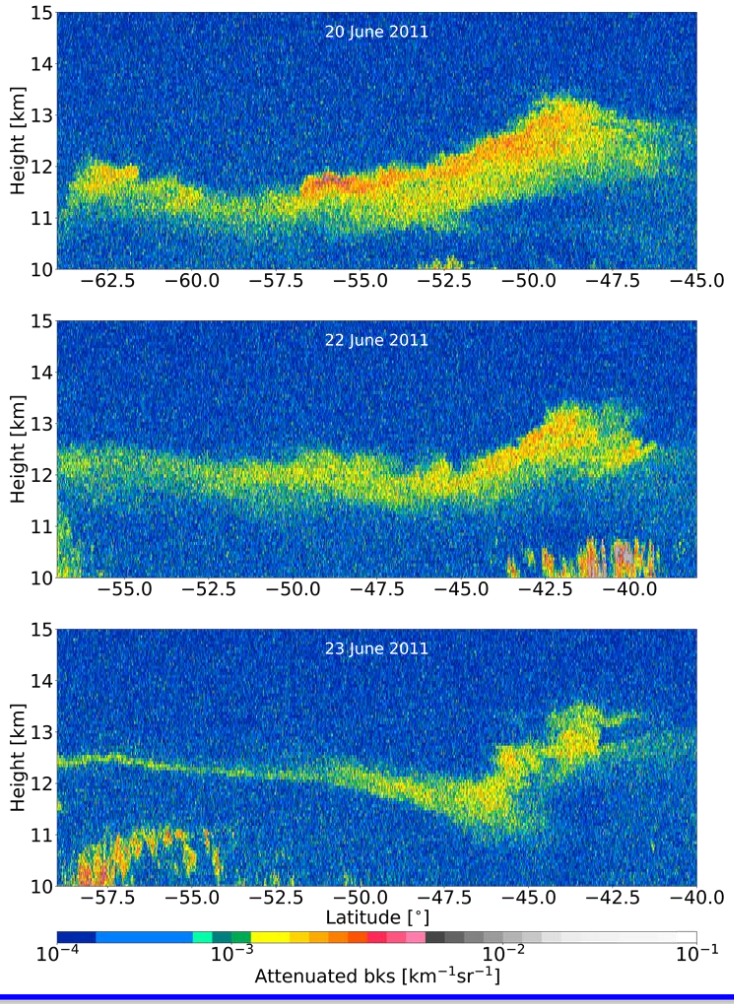


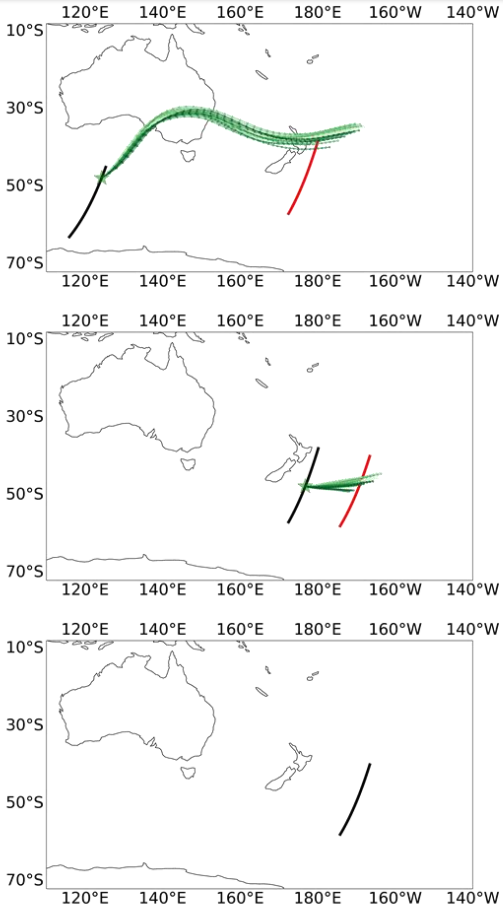
CALIOP Level 1 & 2 data

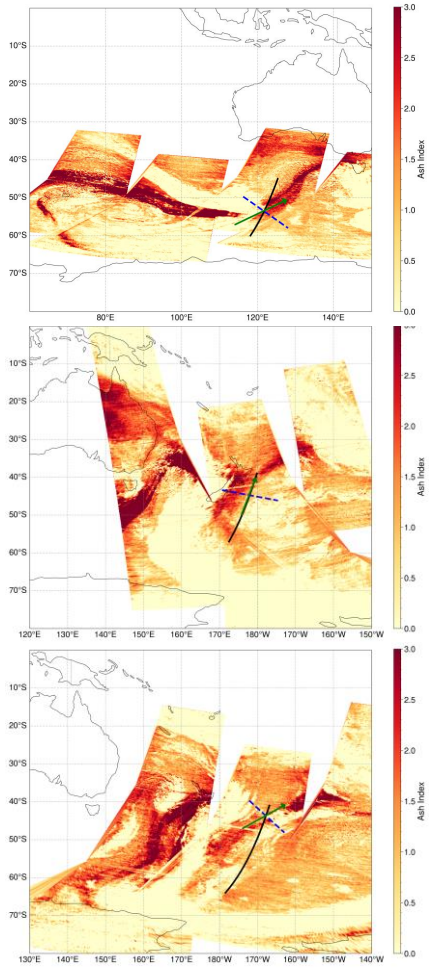


AIRS ash index calculated from Brightness Temperature threshold method

Puyehue-Cordón Caulle 2011 eruption







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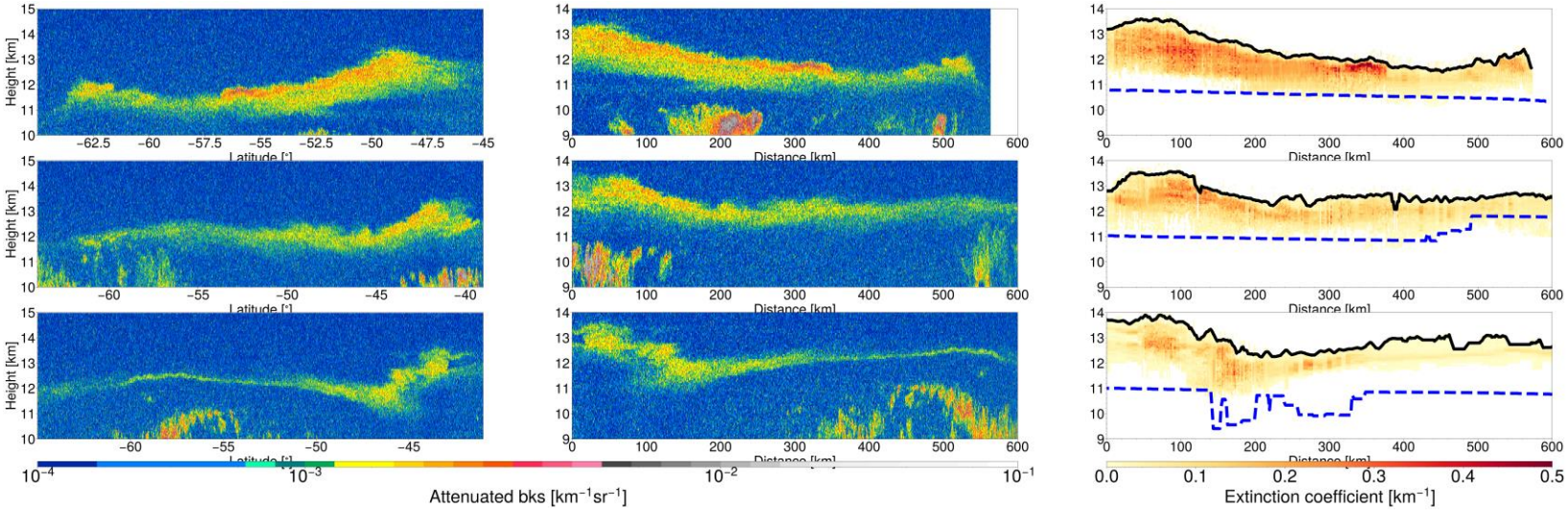

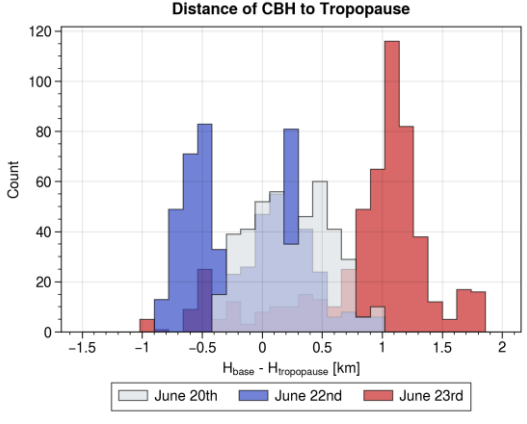

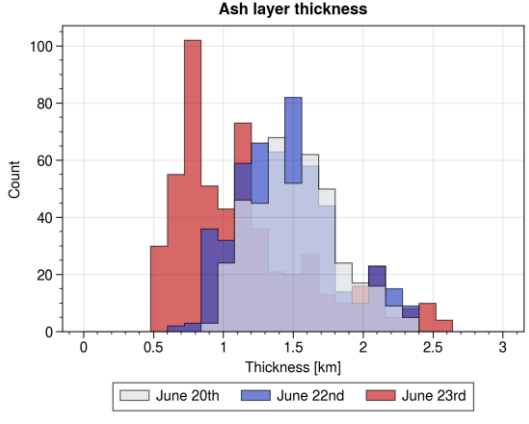

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Conclusions

- Space Lidar, specifically CALIOP, has proven effective in tracking volcanic ash globally.
- With its vertical resolution ranging from 60 m to 180 m in the stratosphere, CALIOP is well-suited for analysing the stratospheric ash layer thickness.
- Our global assessment of the ash layer, using CALIOP data from 2006 to 2021, reveals seasonal patterns in both tropical and polar summers. These patterns are potentially influenced by noise or aerosol misclassification.
- Implementing data cleaning techniques to eliminate isolated ash layers has effectively reduced these seasonal patterns, revealing a clearer connection between volcanic eruptions and ash injection into the stratosphere.
- Case study:
    - Puyehue-Cordón Caulle 2011: Initial ash layer thickness was 1.22 km (SD = 0.27 km) and increased to 1.96 km (SD = 0.19 km) by day 25;
    - Raikoke 2019: Initial ash layer thickness was 1.01km (SD = 0.19) and expanded to 1.44 km (SD = 0.48 km) by day 45;
    - In both cases: Post-eruption, as the ash layer thickness in the stratosphere increased, we observed a consistent decline in ash layer extinction. However, the ash layer AOD remained relatively stable, suggesting that the ash layer undergoes vertical expansion during the deposition process.
- Next steps:
    - Refine our data filtering approach to better represent the general distribution of the ash layer in the stratosphere.