



Influence of ambient conditions on NOVAC BrO measurements

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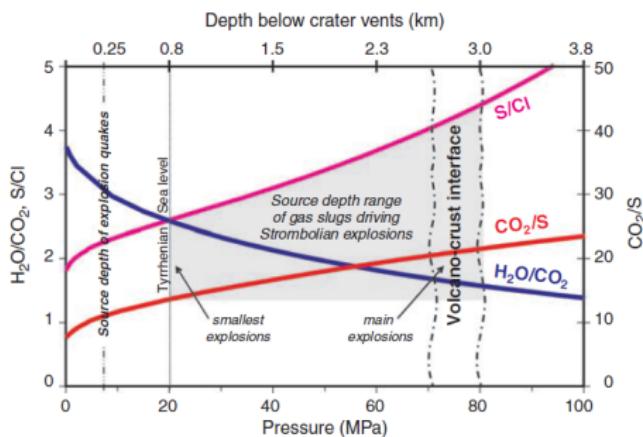
¹Heidelberg University — Institute of Environmental Physics

²MPIC Mainz A yellow square icon containing a white speech bubble with a tail, positioned next to the institution name.

February 21, 2018

Motivation for BrO measurements

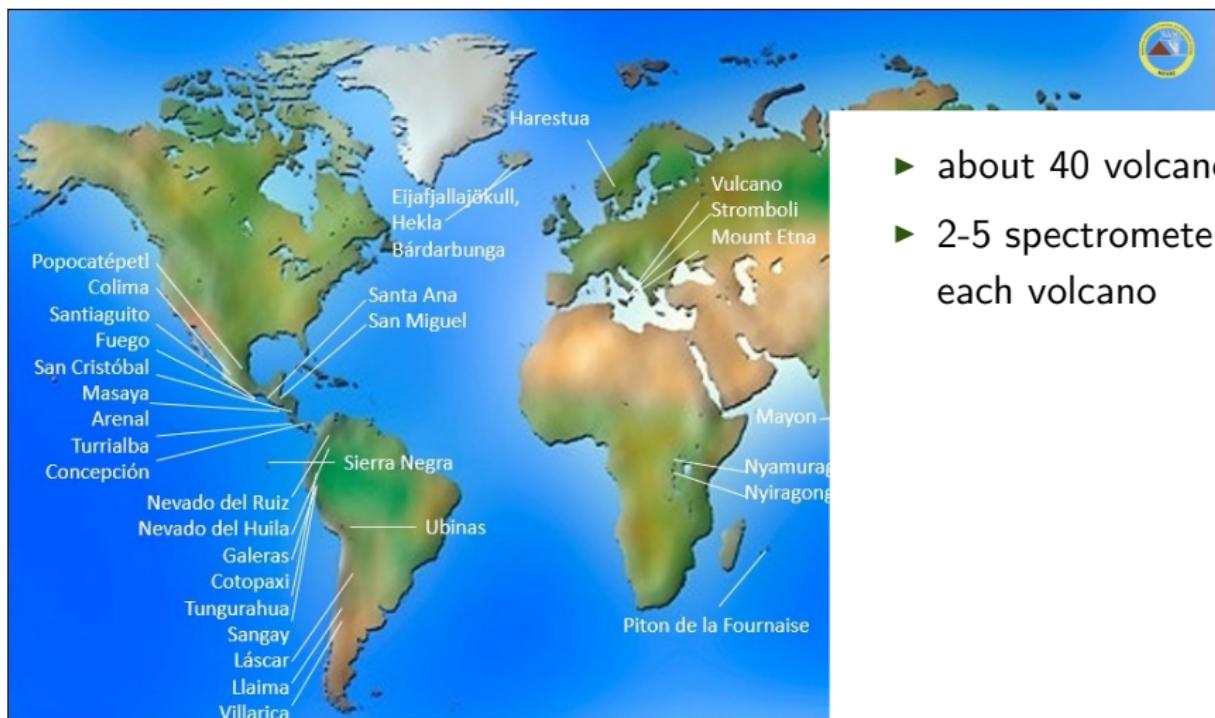
- ▶ The ratio of BrO and SO₂ changes with degassing source depth
- ▶ The ratio of BrO and SO₂ is a proxy for the volcanic activity
- ▶ Change in BrO/SO₂ prior to eruption observed at Etna and Nevado del Ruiz



Network for observation of volcanic and atmospheric change



Network for observation of volcanic and atmospheric change



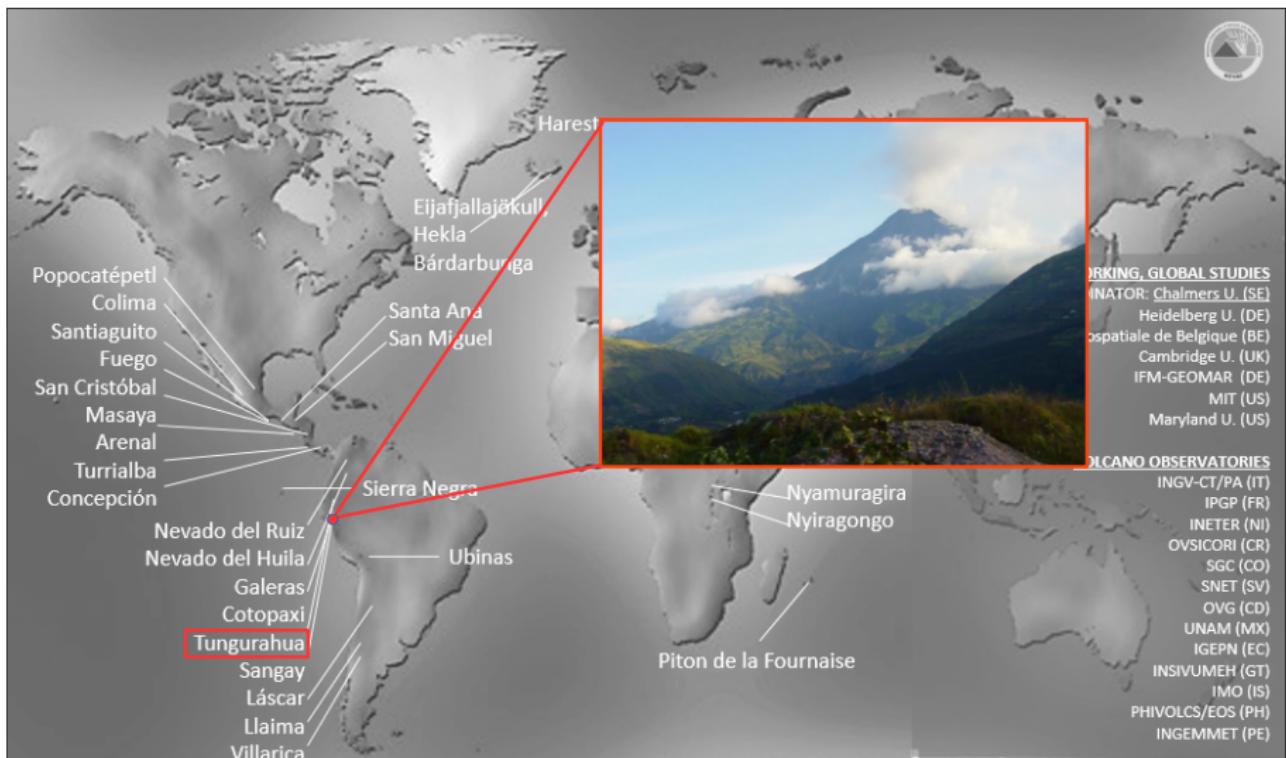
- ▶ about 40 volcanoes
- ▶ 2-5 spectrometers at each volcano

Network for observation of volcanic and atmospheric change

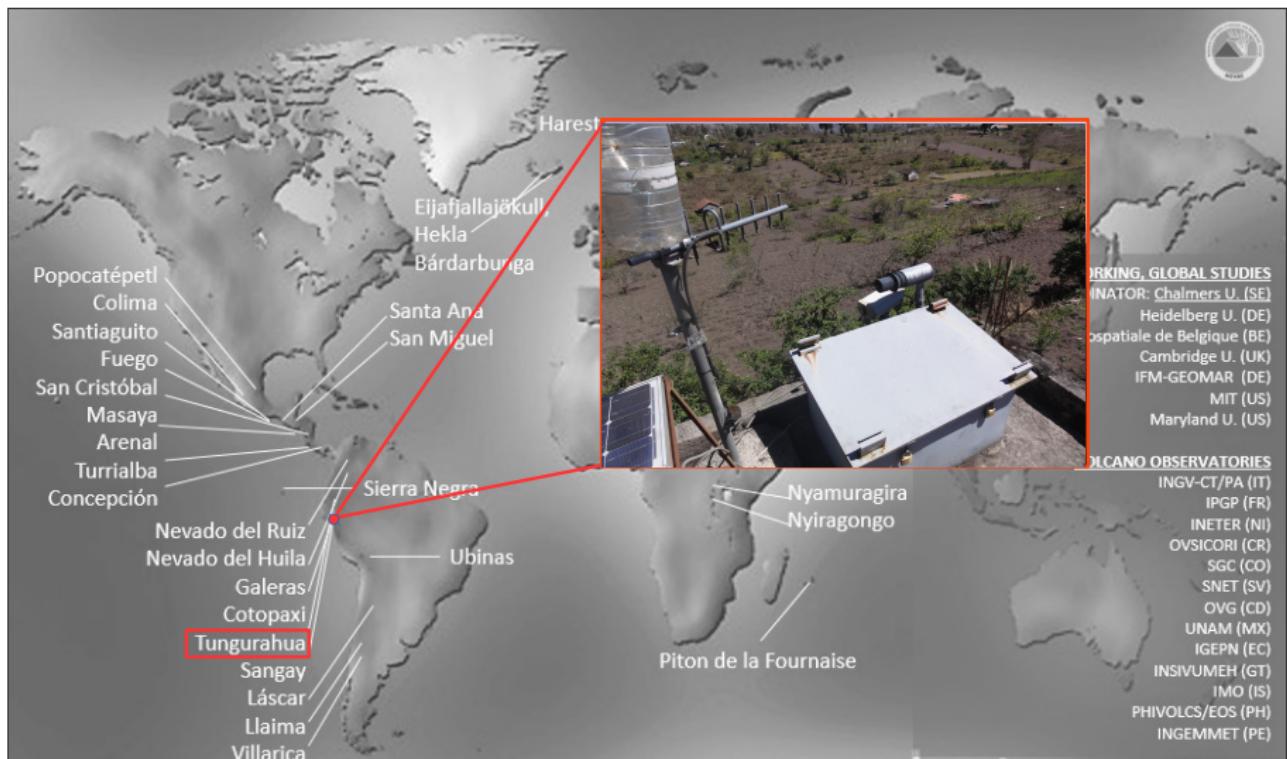


- ▶ Primary use of data SO₂ flux monitoring
- ▶ Lü et al (2014) also retrieved BrO
- ▶ BrO close to detection limit
- ▶ Here we investigate techniques to improve the BrO evaluation from NOVAC data

Measurements at Tungurahua



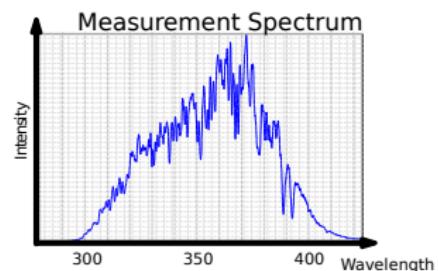
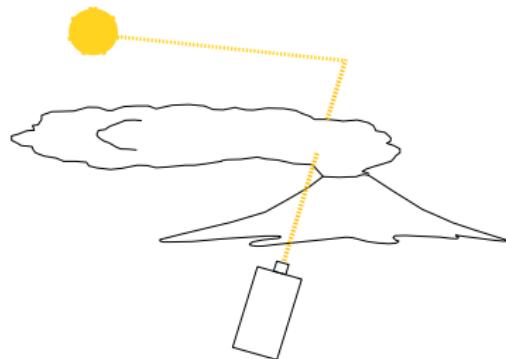
One of the NOVAC stations at Tungurahua



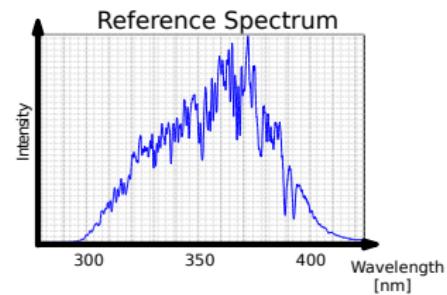
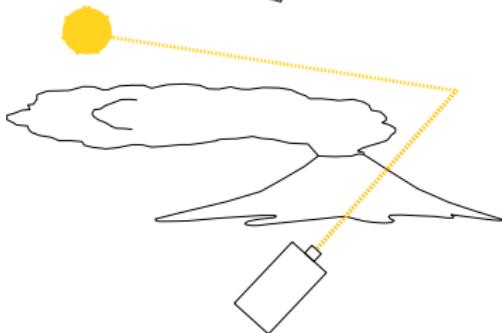
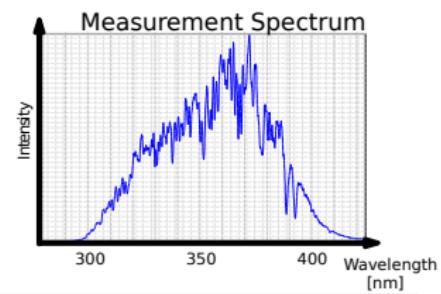
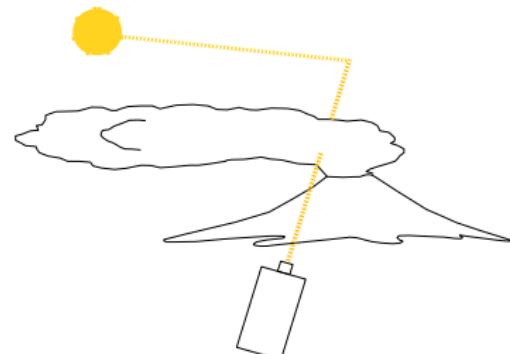
Differential optical absorption spectroscopy (DOAS)



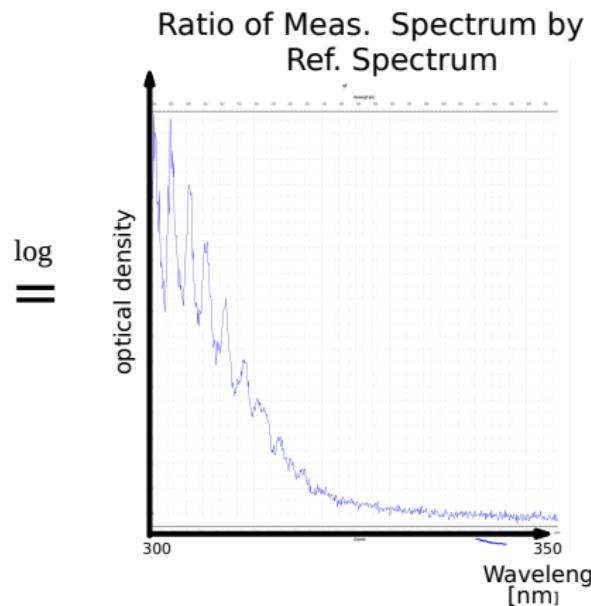
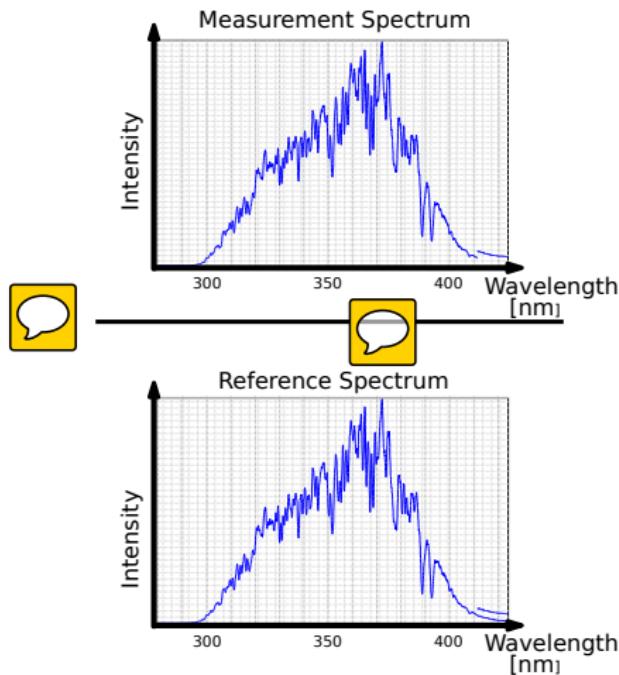
Differential optical absorption spectroscopy (DOAS)



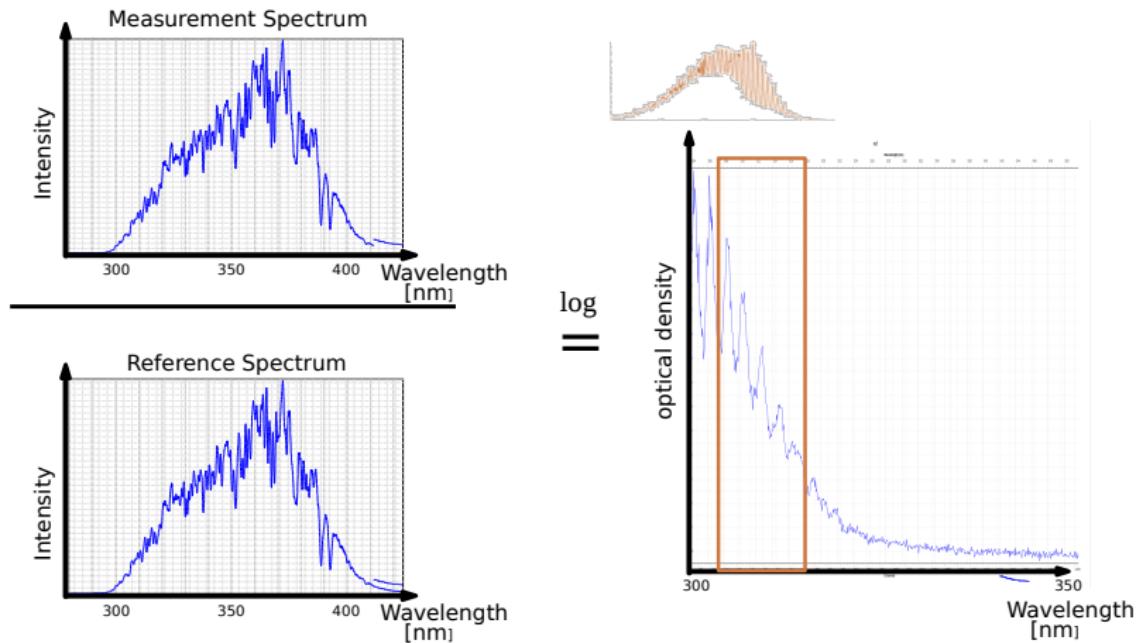
Differential optical absorption spectroscopy (DOAS)



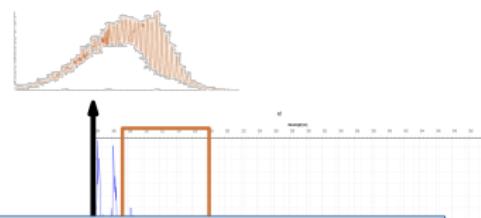
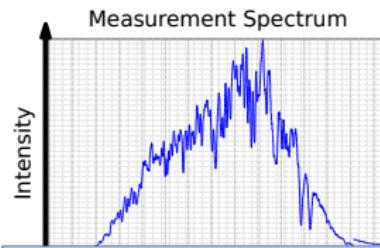
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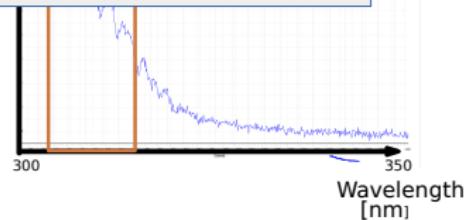
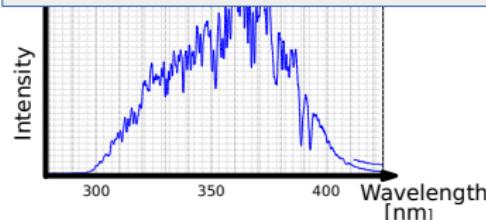
Differential optical absorption spectroscopy (DOAS)



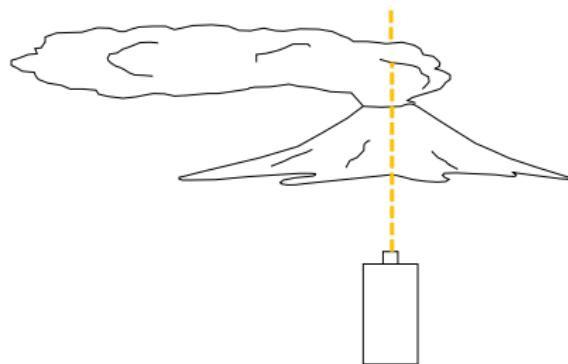
Differential optical absorption spectroscopy (DOAS)



- For Scattered-sunlight DOAS evaluations always a reference spectrum is required
- Choice of Ref. Spectrum can be critical

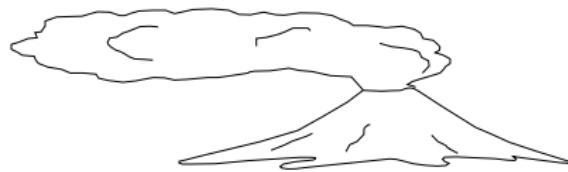


Determination of SO₂ Emission



1. Get Pre Reference Spectrum

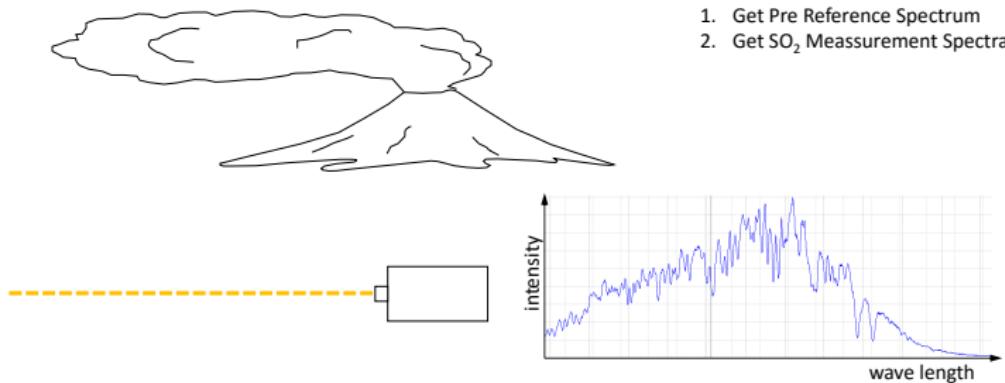
Determination of SO₂ Emission



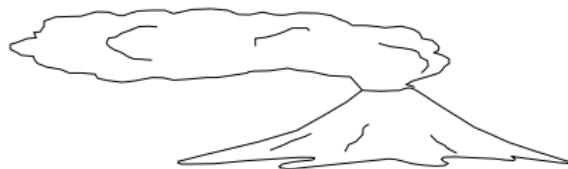
1. Get Pre Reference Spectrum



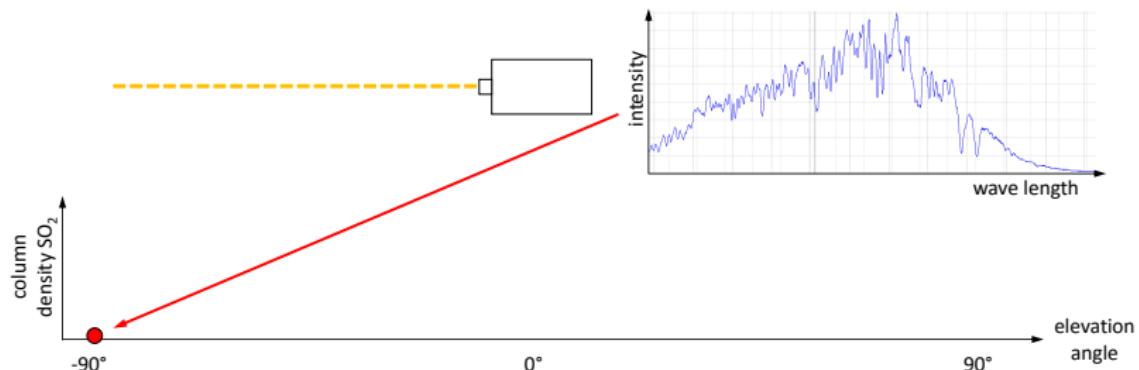
Determination of SO₂ Emission



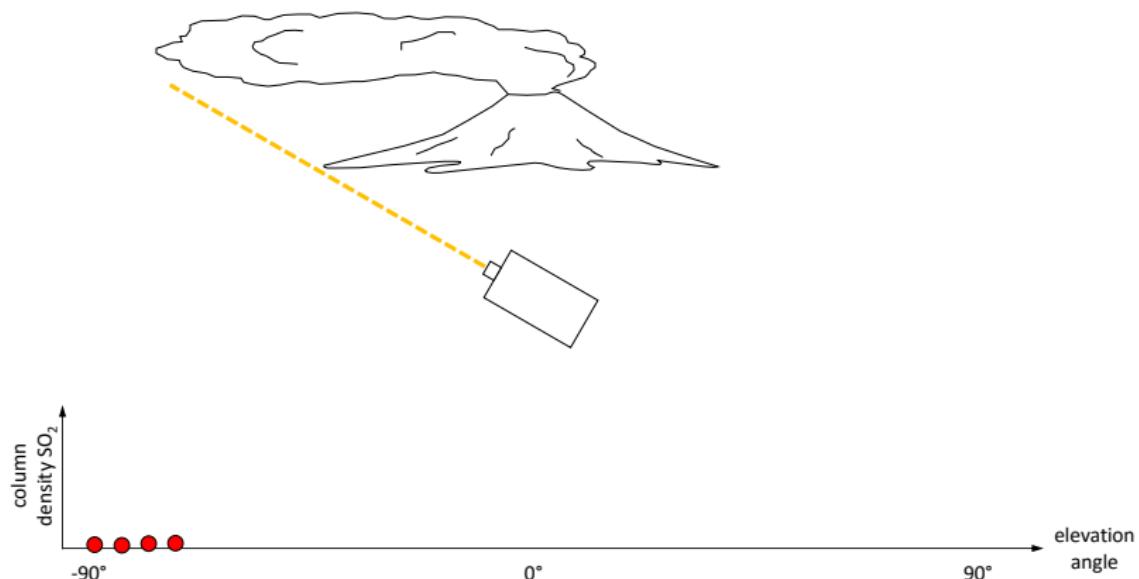
Determination of SO₂ Emission



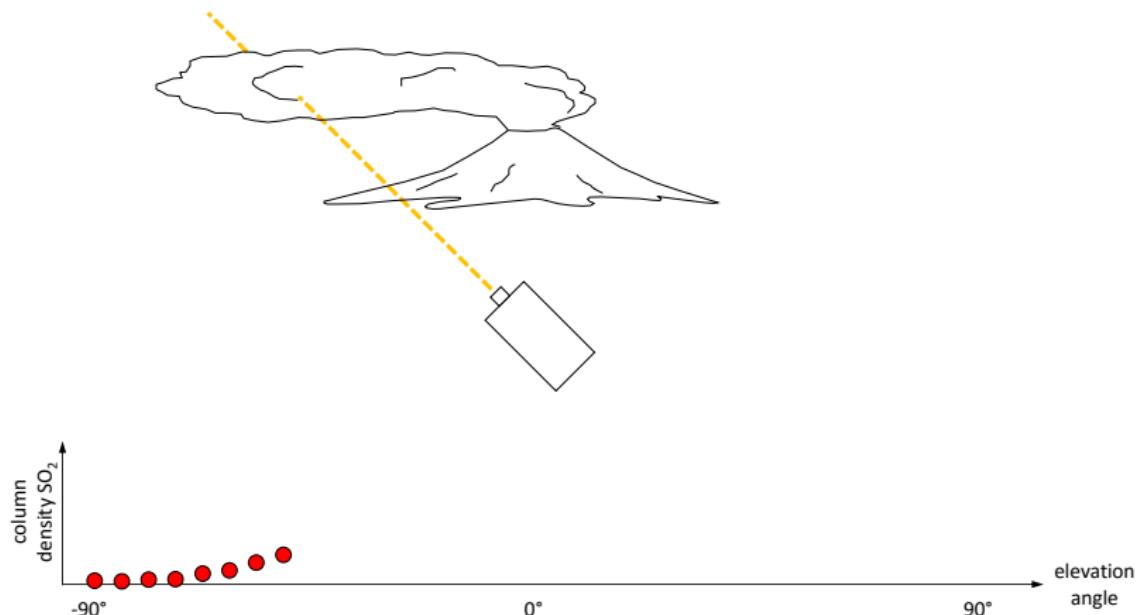
1. Get Pre Reference Spectrum
2. Get SO₂ Measurement Spectra
 - Measure SO₂ difference



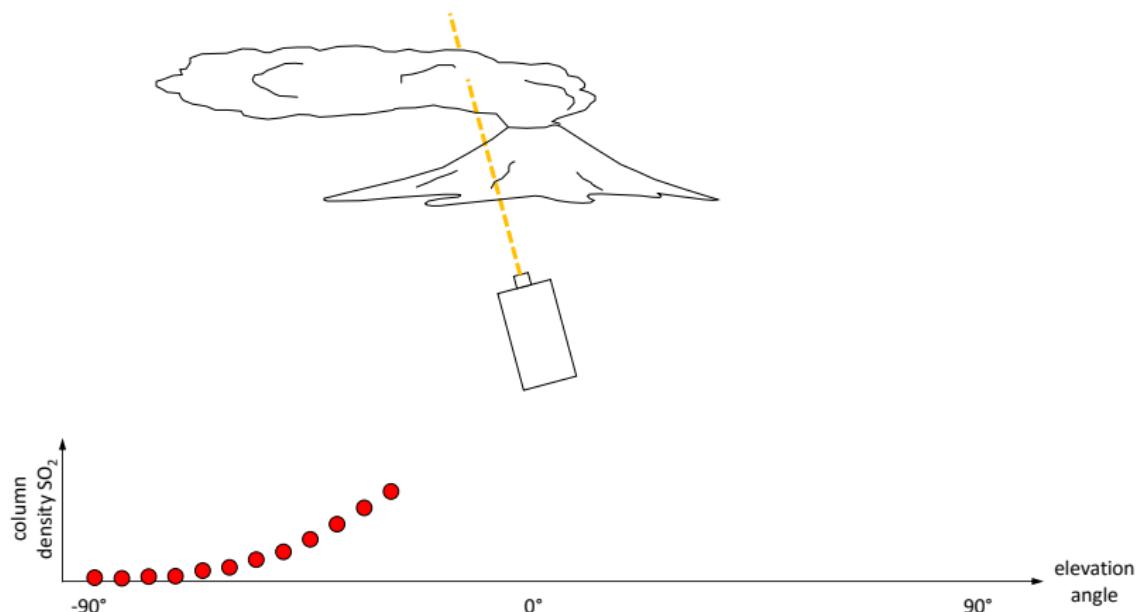
Determination of SO₂ Emission



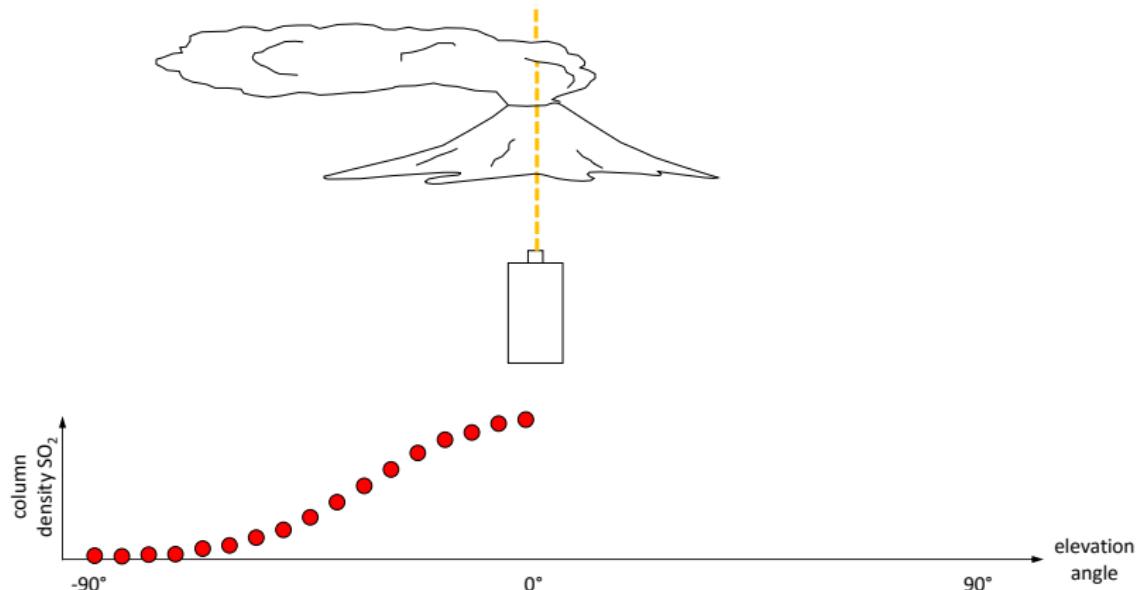
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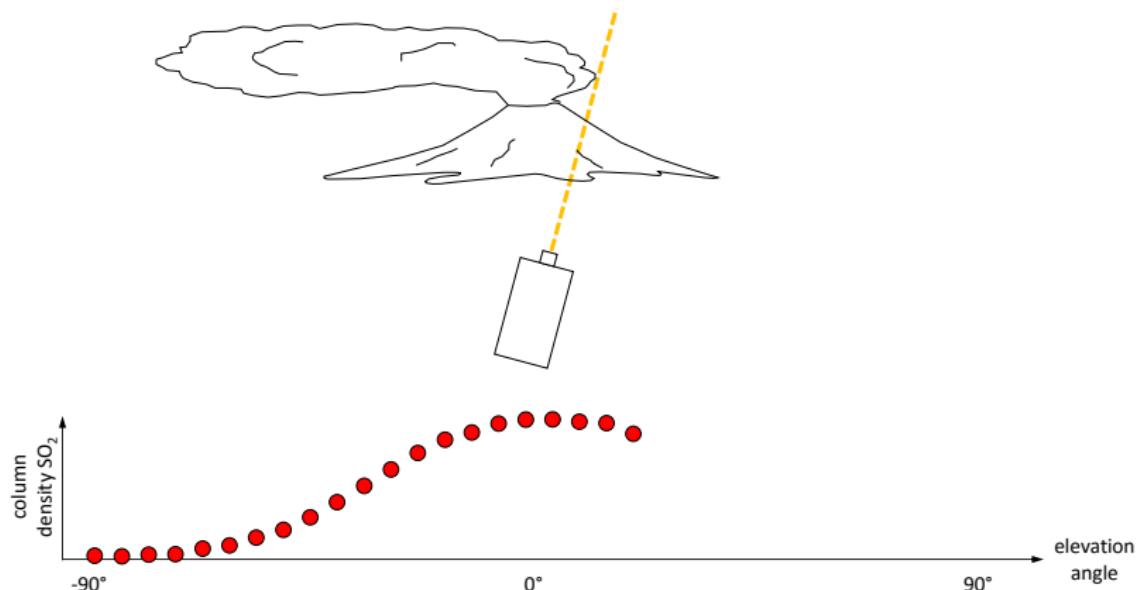
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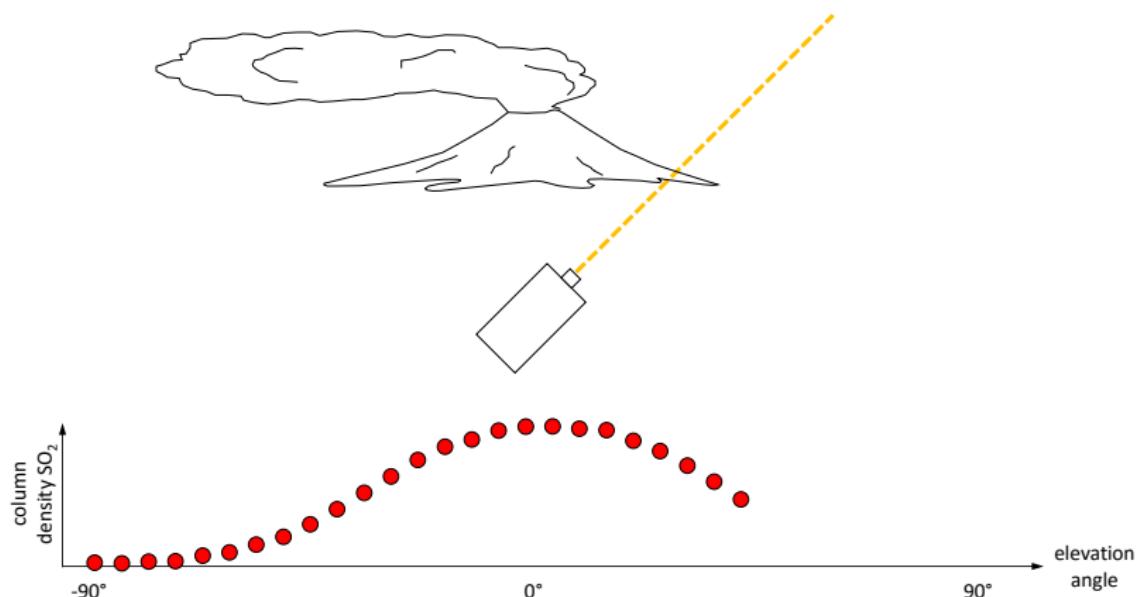
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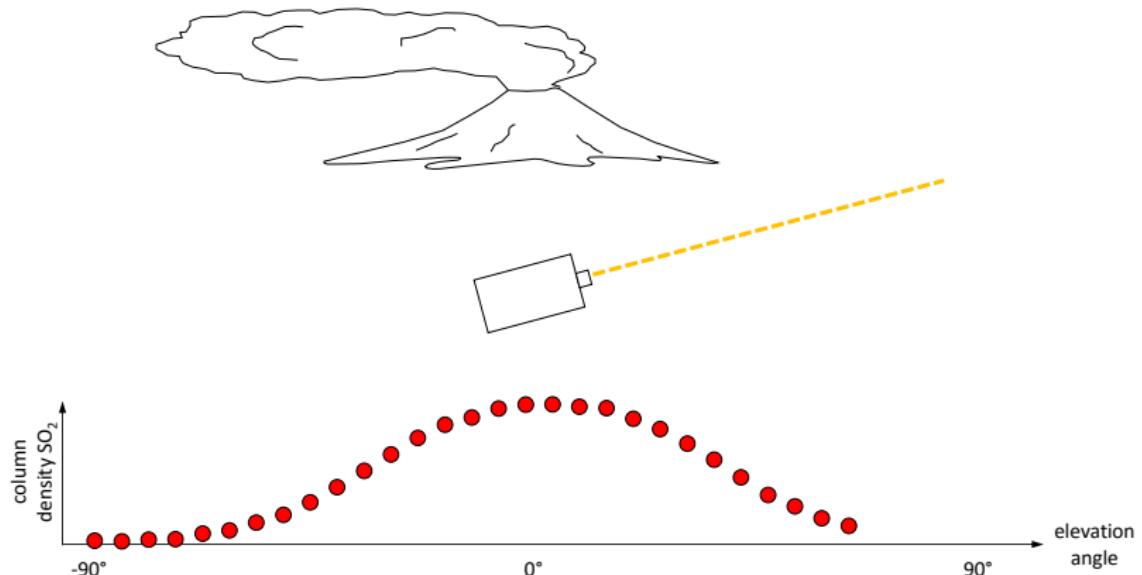
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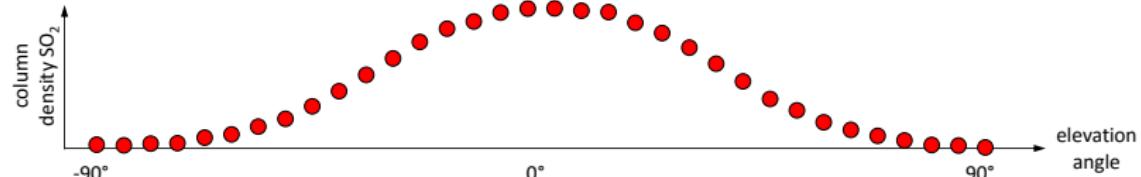
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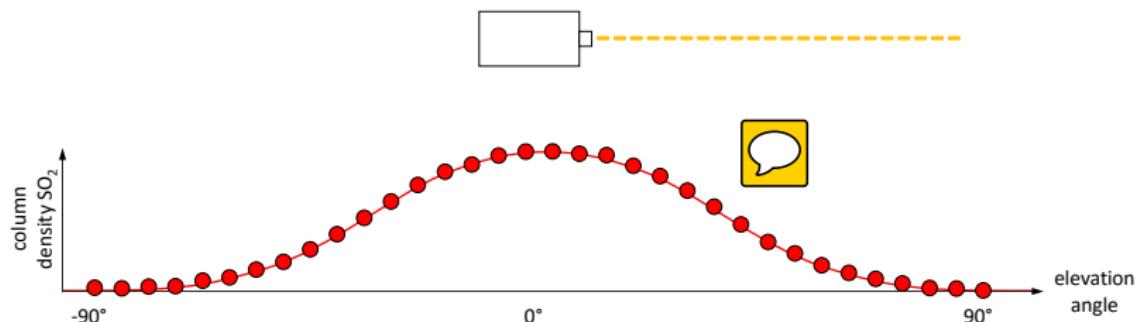
Determination of SO₂ Emission



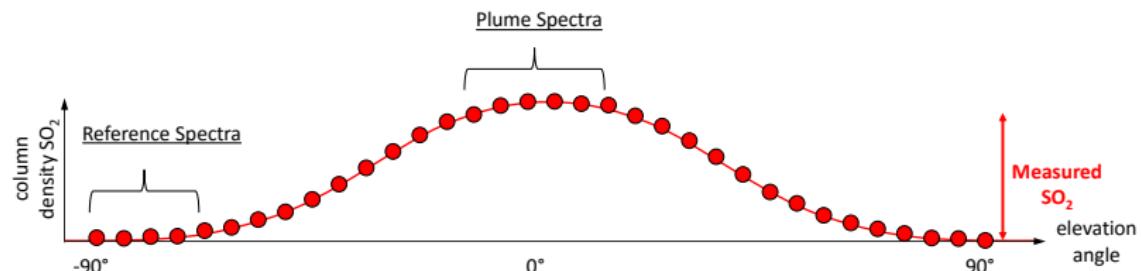
Determination of SO₂ Emission



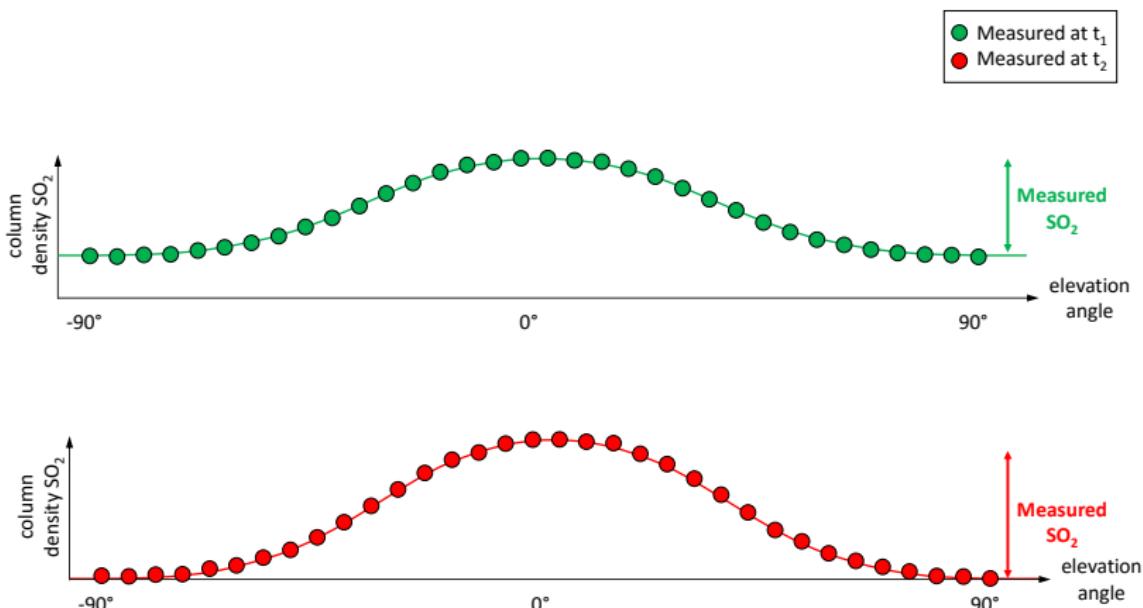
Determination of SO₂ Emission



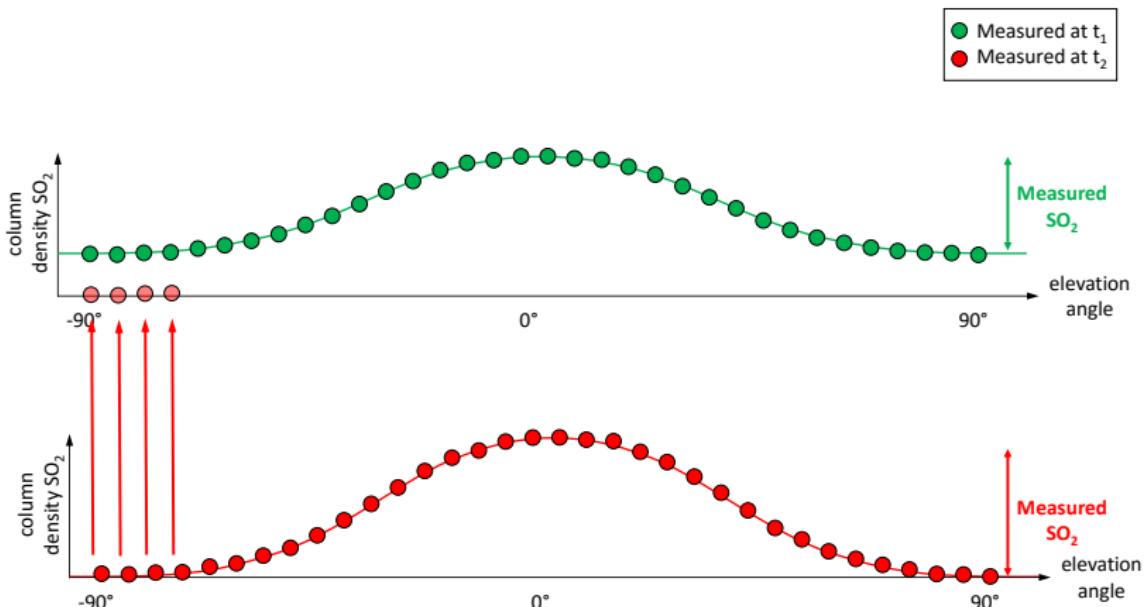
Plume composition measurement -BrO/SO₂



The problem of choosing the right reference



The problem of choosing the right reference



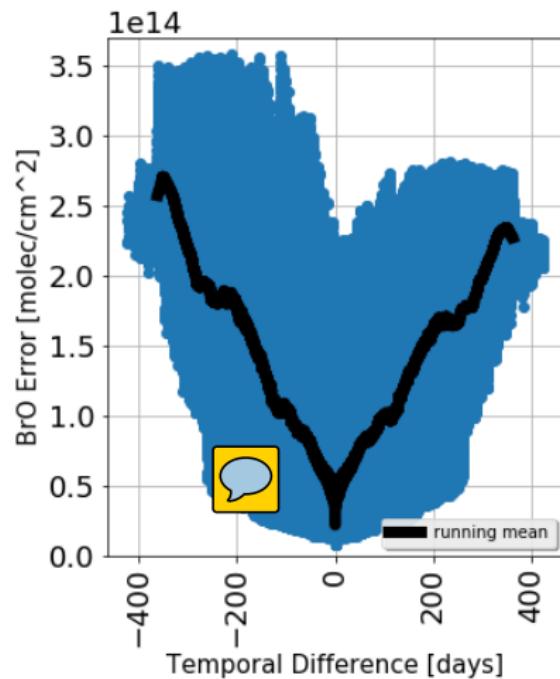
Checking for contamination



- ▶ Possible contaminations can be checked by a theoretical solar atlas spectrum to evaluate the SO₂ amount in the reference.
- ▶ Data are contaminated if the SO₂ amount in the reference is above $2 \cdot 10^{17}$
- ▶ Only accept SO₂ SCDs above the plume limit of $7 \cdot 10^{17} \frac{\text{molec}}{\text{cm}^2}$

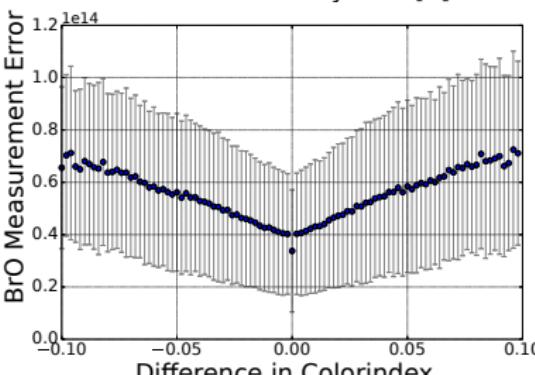
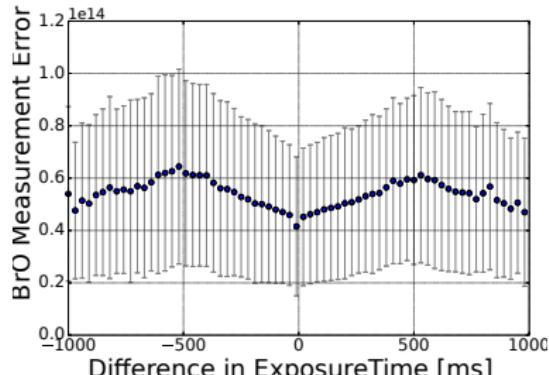
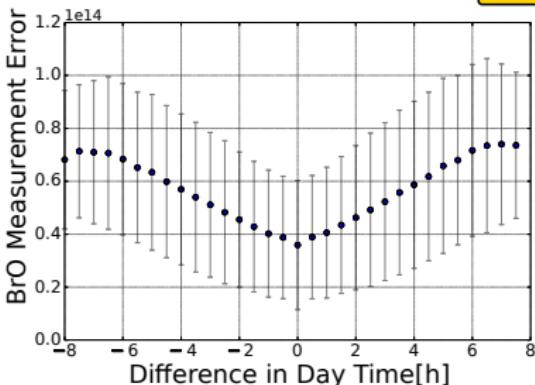
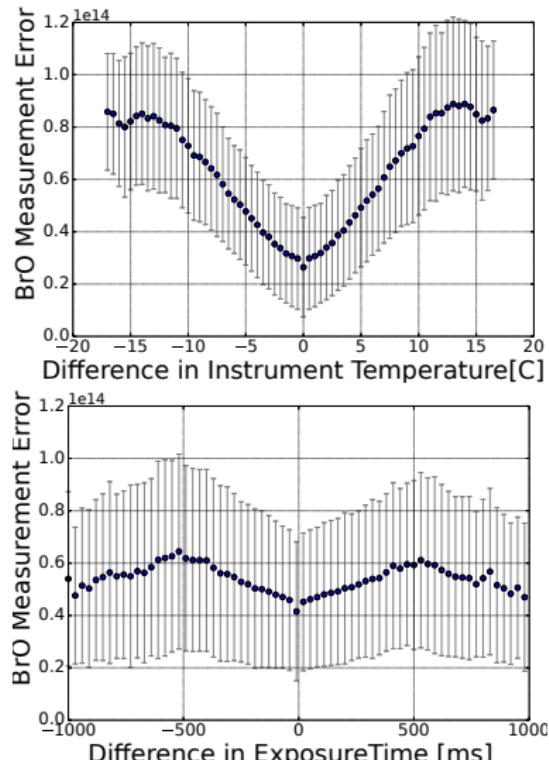


Temporal difference between the reference and the plume



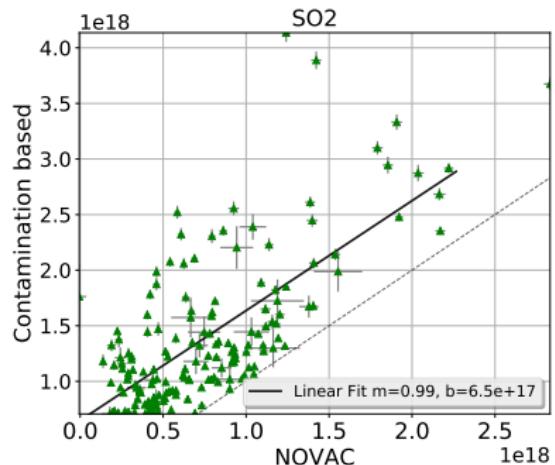
- ▶ Increase of BrO error with temporal difference
- ▶ The sign of the temporal difference irrelevant
- ▶ Restrict temporal difference to two weeks

Influence of ambient conditions on BrO measurement error



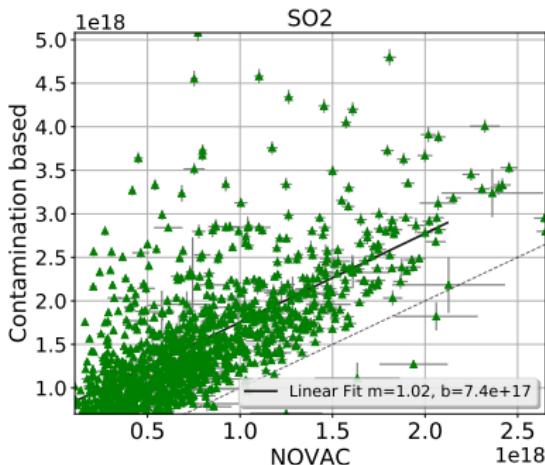


Comparison of the different evaluations - SO₂



(a) Data of Tungurahua

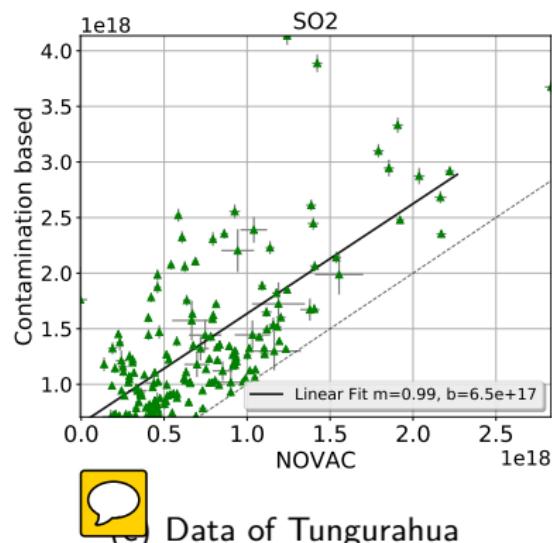
- ▶ Contamination lead to a offset on SO₂ SCDs



(b) Data of Nevado Del Ruiz

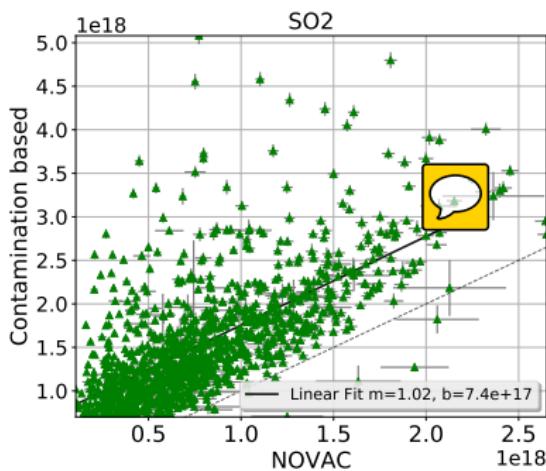
- ▶ Behavior at Tungurahua and Nevado Del Ruiz is equivalent

Comparison of the different evaluations - SO₂



Data of Tungurahua

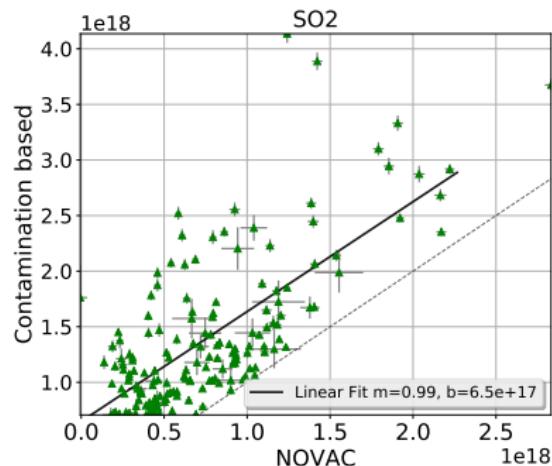
- ▶ Contamination level and offset on SO₂ SCDs



(d) Data of Nevado Del Riz

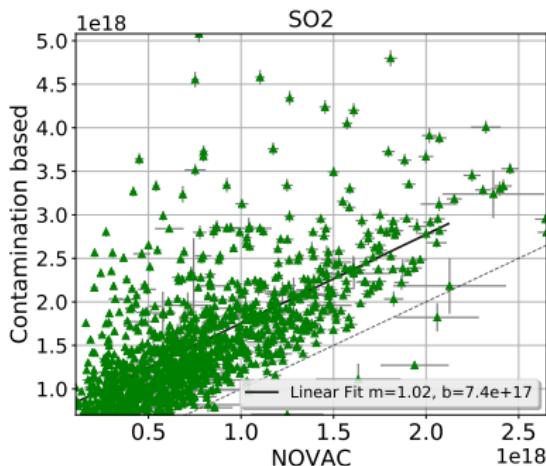
- ▶ Behavior at Tungurahua and Nevado Del Ruiz is equivalent

Comparison of the different evaluations - SO₂



(e) Data of Tungurahua

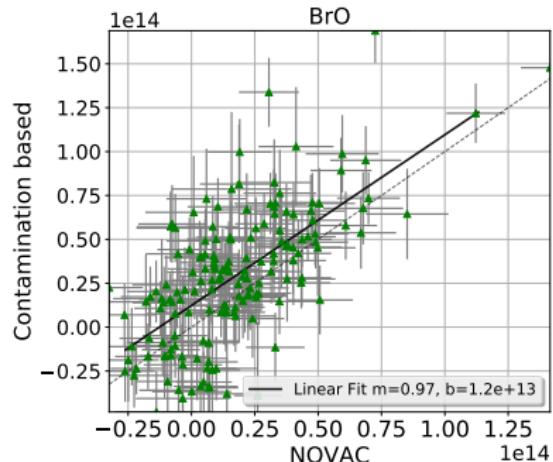
- ▶ Contamination lead to a offset on SO₂ SCDs



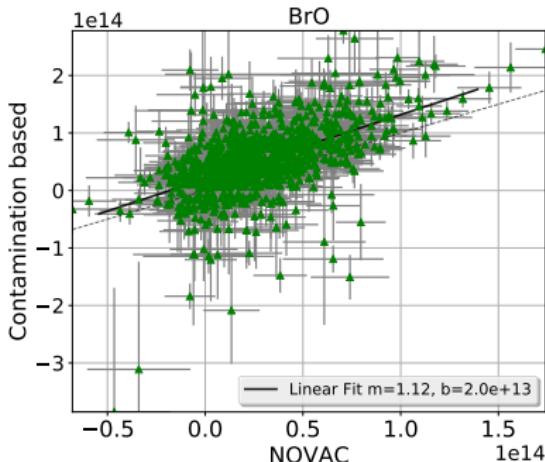
(f) Data of Nevado Del Riz

- ▶ Behavior at Tungurahua and Nevado Del Ruiz is equivalent

Comparison of the different evaluations - BrO



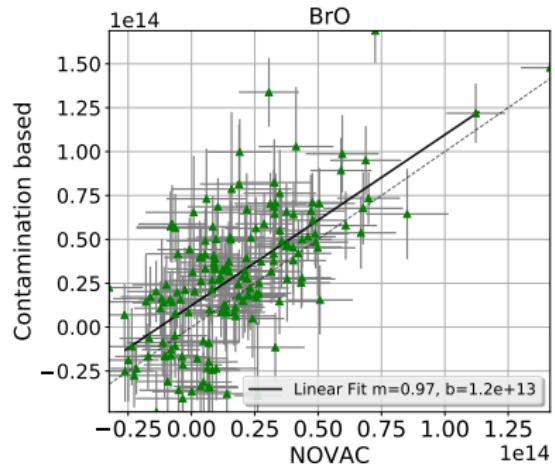
(g) Data of Tungurahua



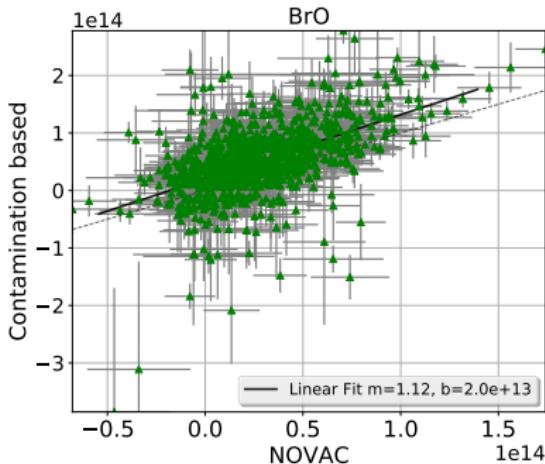
(h) Data of Nevado Del Riz

- ▶ Contamination lead to a offset on BrO SCDs
- ▶ proportional BrO increase lower as for SO₂

Comparison of the different evaluations - BrO



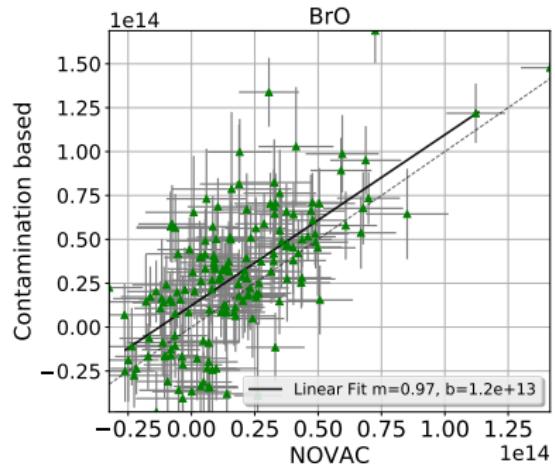
(i) Data of Tungurahua



(j) Data of Nevado Del Riz

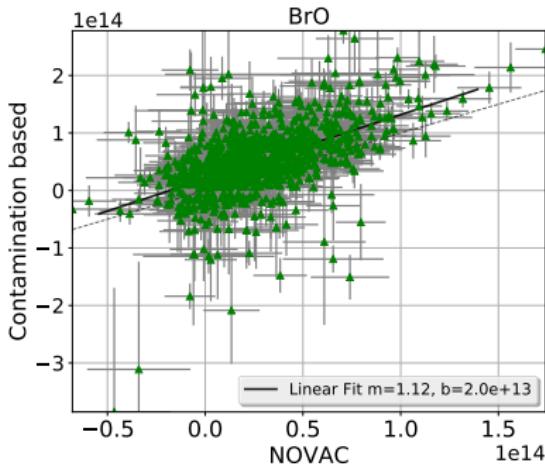
- ▶ Contamination lead to a offset on BrO SCDs
- ▶ proportional BrO increase lower as for SO₂

Comparison of the different evaluations - BrO



(k) Data of Tungurahua

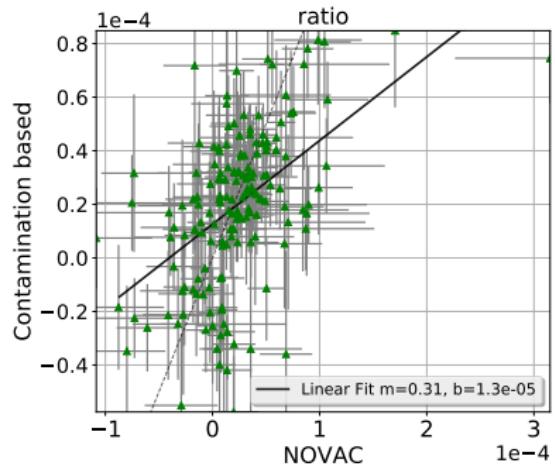
- ▶ Contamination lead to a offset on BrO SCDs



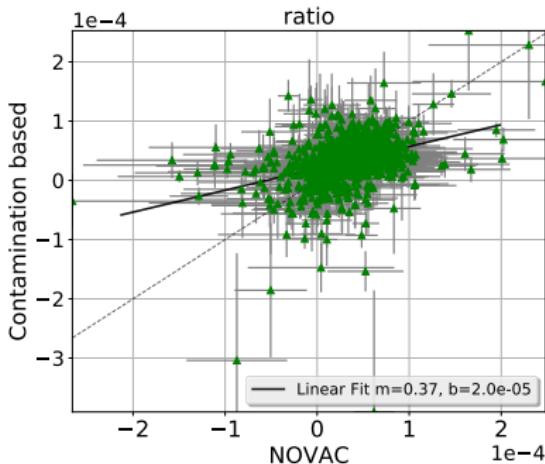
(l) Data of Nevado Del Riz

- ▶ proportional BrO increase lower as for SO₂

Comparison of the different evaluations - BrO/SO₂



(m) Data of Tungurahua



(n) Data of Nevado Del Riz

- ▶ Increase of low BrO/SO₂ ratios
- ▶ Decrease of high BrO/SO₂ ratios

Comparison with NOVAC evaluation

	Tungurahua	Nevado Del Ruiz
Total Amount of Data	6500	14005
Total amount of Data above Plume Limit	6.7%	12.8%
Contaminated Data	6.0%	9.9%

Comparison with NOVAC evaluation

Not contaminated data

	Tungurahua	Nevado Del Ruiz
Within Plume 	5.5%	8.8%

- ▶ percentage refers to the not contaminated data

Comparison with NOVAC evaluation

Contaminated data

		Tungurahua	Nevado Ruiz	Del
Within Plume-limit	NOVAC 	19.2% 41.9%	39.9% 77.9%	
not analysable		2.5%	7.8%	

- ▶ percentage refers to the contaminated data

Summary

- ▶ Contaminated reference spectra lead to significant underestimation of SO₂
- ▶ Optimized Evaluation: Keep environmental conditions of measurement and reference spectra similar
- ▶ More valid Data with optimized reference evaluation

Outlook

1. Measurements at volcanoes to verify the contamination
2. Examine contamination of the plume due to further measurements
3. Is contamination a result of low wind velocities?

Thanks for your attention