A volcanic sulfur dioxide emission inventory from AIRS/Aqua satellite observations

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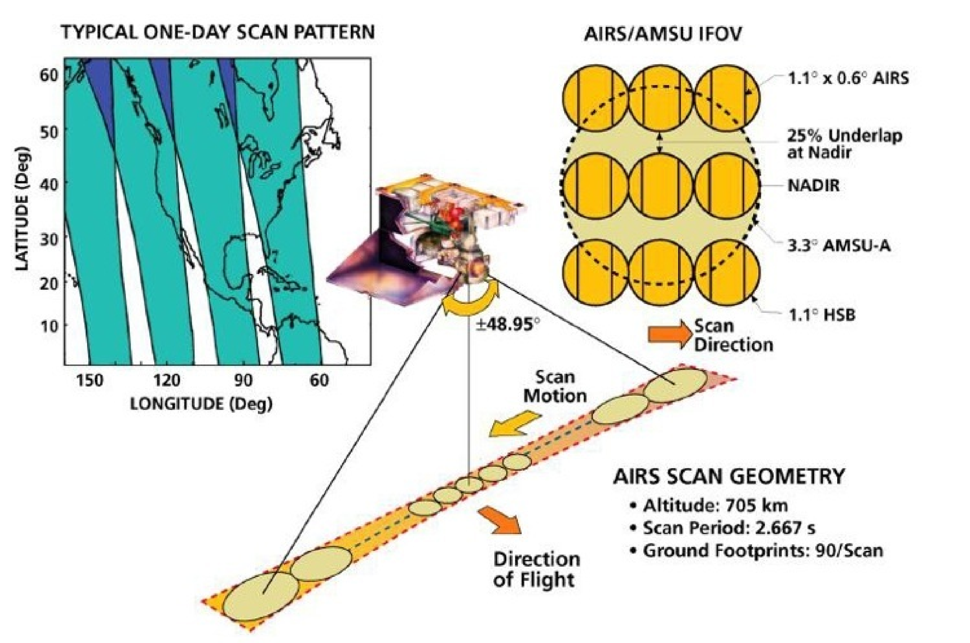
Key points

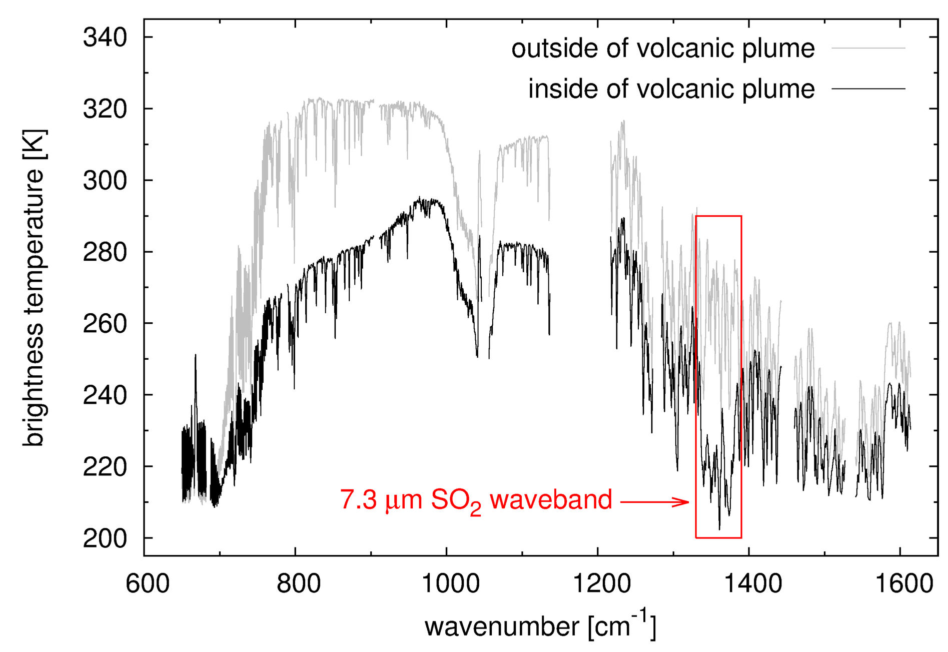
- Monitoring and quantifying volcanic sulfur dioxide (SO_2) emissions is fundamentally important, considering that these emissions are a major source of the stratospheric sulfate aerosol load.
- Stratospheric sulfate aerosols reflect solar radiation and absorb infrared radiation, causing cooling of the troposphere and heating of the stratosphere. Determining the composition and quantifying the contributions of volcanic eruptions to the upper troposphere and lower stratosphere (UTLS) aerosol budget is a key factor for accurate modeling of its climate impacts.
- In the JARA-HPC/VSR project "Inverse Modeling of the Atmospheric Composition" (IMoAC), we used the Lagrangian particle dispersion model MPTRAC and global satellite observations from NASA's AIRS/Aqua instrument to estimate time- and altitude-resolved SO_2 emission rates for most major and selected minor volcanic eruptions during the years 2002 to 2018.
- Here, we further developed the inversion approach of Hoffmann et al. (2016) and optimized the parameter selection to achieve more accurate simulations of different transport patterns of volcanic eruptions. As the inverse modeling approach required many sensitivity studies in an iterative procedure, it was computationally expensive and required significant computing time resources on the JURECA booster (∼5 million core-h).
- Initial evaluation efforts show that the inverse modeling and simulation system provides rather realistic emission estimates and transport simulations of volcanic SO_2.

AIRS observations of volcanic emissions

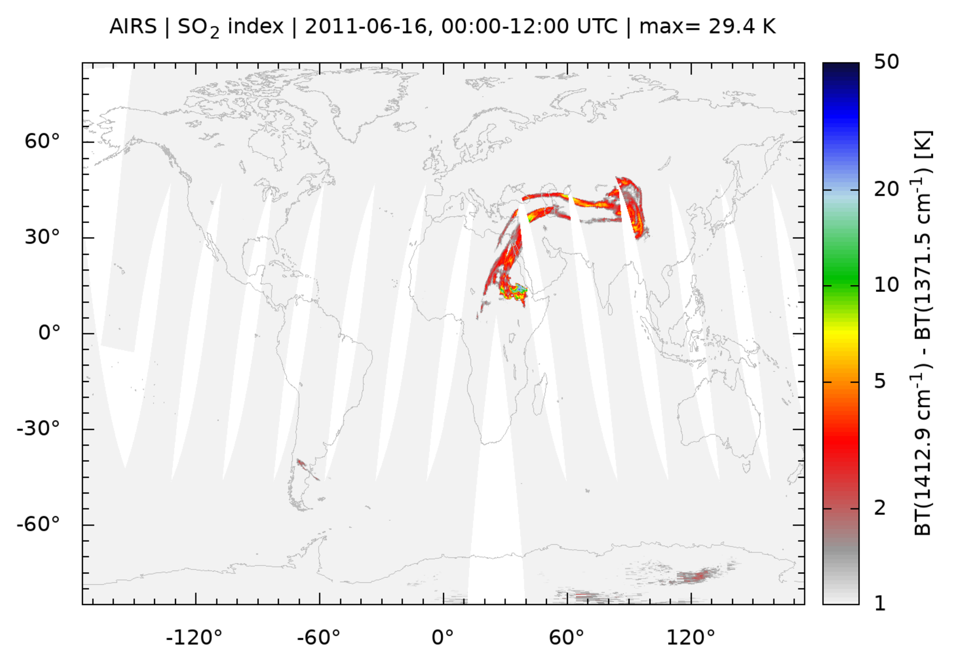
- The Atmospheric Infrared Sounder (AIRS) aboard NASA's Aqua satellite is a hyperspectral infrared sounder with across-track scanning capabilities:



- Volcanic SO_2 can be detected from AIRS radiance measurements covering the 7.3 μm waveband:

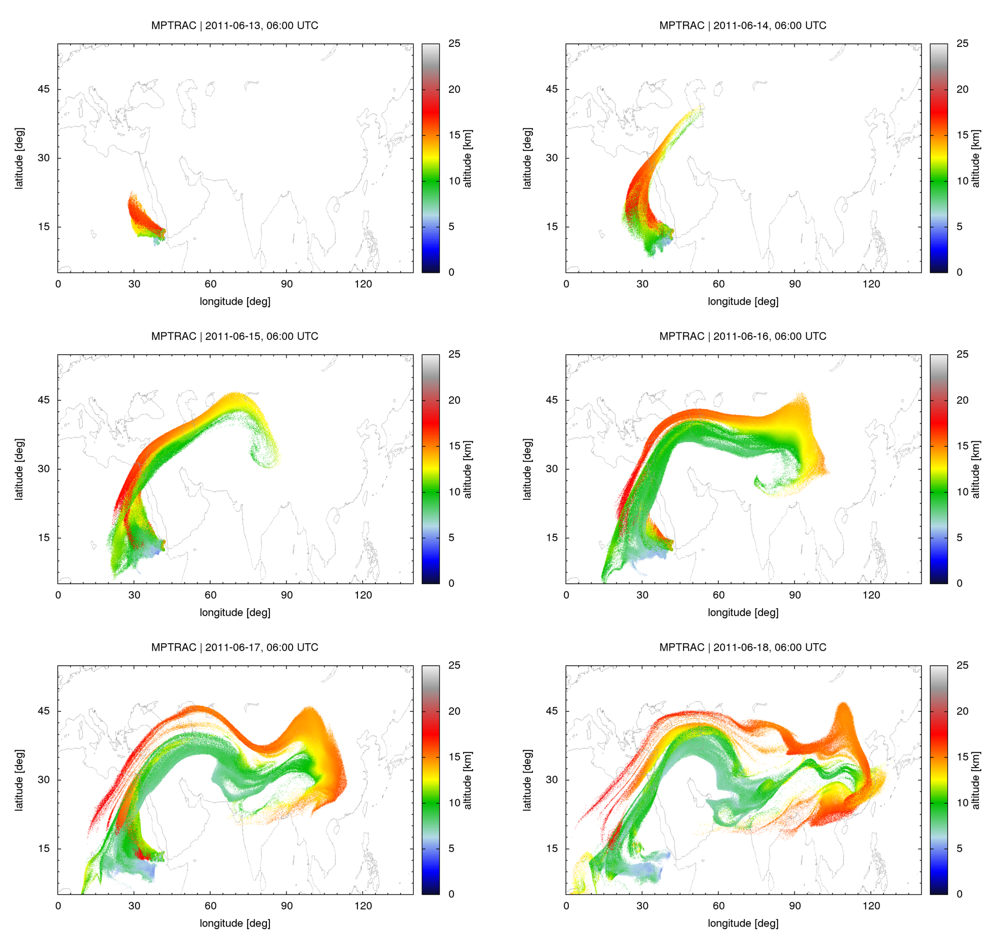


- AIRS observations allow us to track volcanic SO_2 plumes in the upper troposphere and lower stratosphere region for several days to weeks:

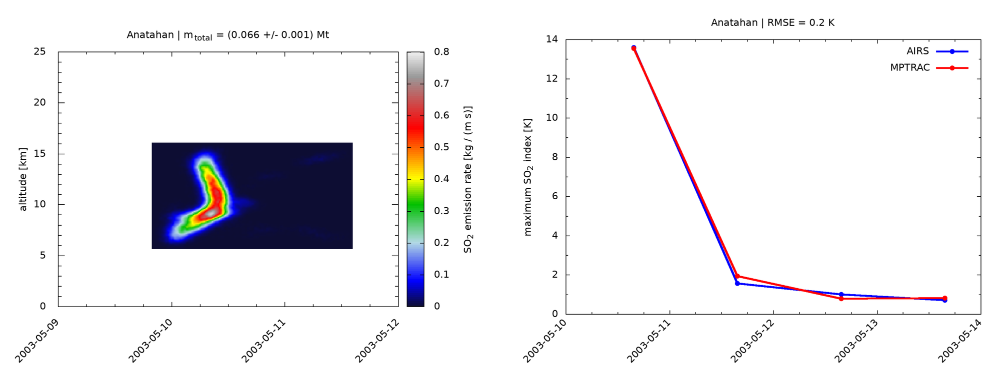


Inverse transport modeling approach

- The inverse modeling system used in this work was build based on existing methods (Hoffmann et al., 2014, 2016; Wu et al., 2017, 2018).
- The system uses the Lagrangian particle dispersion model MPTRAC developed at JSC to calculate backward trajectories from the AIRS detections to estimate the relative distribution of the SO_2 emissions.

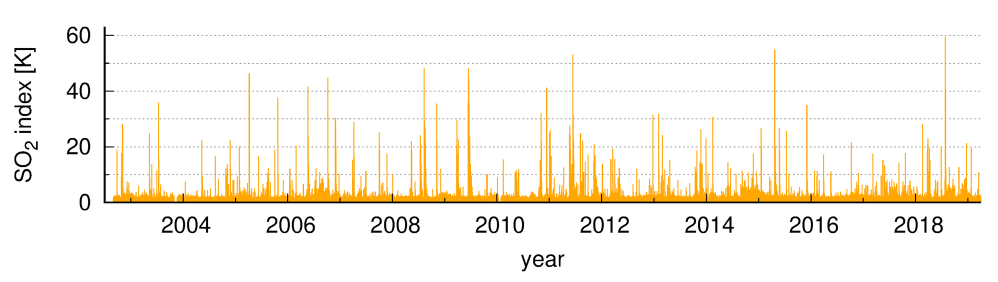


- The system uses the radiative transfer model JURASSIC developed at JSC to constrain the total amount of SO_2 released into the UT/LS by a volcanic eruption.

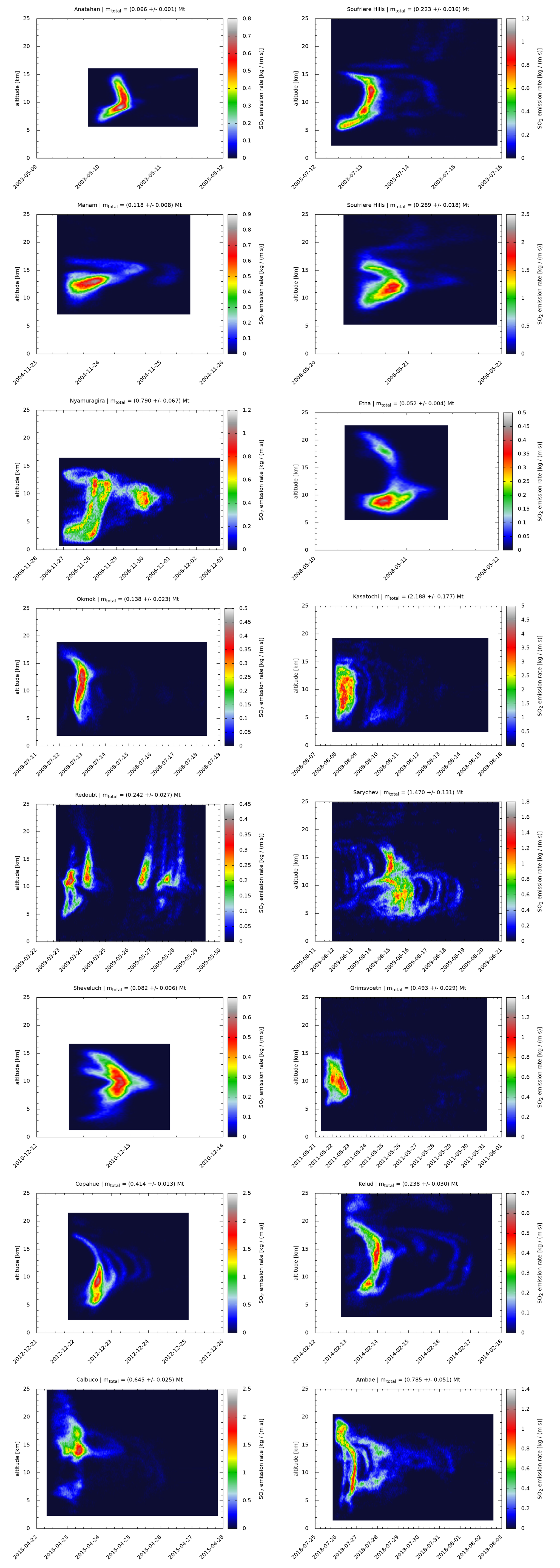


Volcanic SO_2 emission inventory

- We identified the eruption cases to be analyzed by means of inspection of the AIRS satellite observations. We found 8 major events with an SO2 index (SI) exceeding a level of 40 K and 17 minor events with an SI exceeding 30 K, which we included in the final emission inventory.



- Estimates of volcanic SO_2 emission rates from selected eruptions in 2003 – 2018:



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