MSc/BSc Thesis Topics
July 2023

Atmospheric Chemistry Group

8 potential topics,
at ETH, PSI, Empa, PMOD

For details, please contact us!

Topic 1: Global modeling

Energetic particle precipitation impacts on the atmosphere

Key problem:

- Energetic particle precipitation from various sources provides energy input into the upper atmosphere, producing NO_x and HO_x, which destroy ozone. The NO_x is transported to the stratosphere in polar winter, where it can have an even larger effect.
- Ozone destruction leads to changes in the radiative heating and hence to dynamical changes in the stratosphere, with the potential downward propagation to the troposphere
- The exact details of this mechanism are still uncertain, because particle precipitation events are sporadic and often hidden by atmospheric internal noise, and therefore difficult to derive from observations.

Key question:

Does particle precipitation influence the surface climate and how?

Key tasks:

Analyze long-term idealized time slice simulations with the Earth System Model SOCOLv4 to investigate the impacts of particle precipitation on atmospheric chemistry and dynamics and potential surface effects.

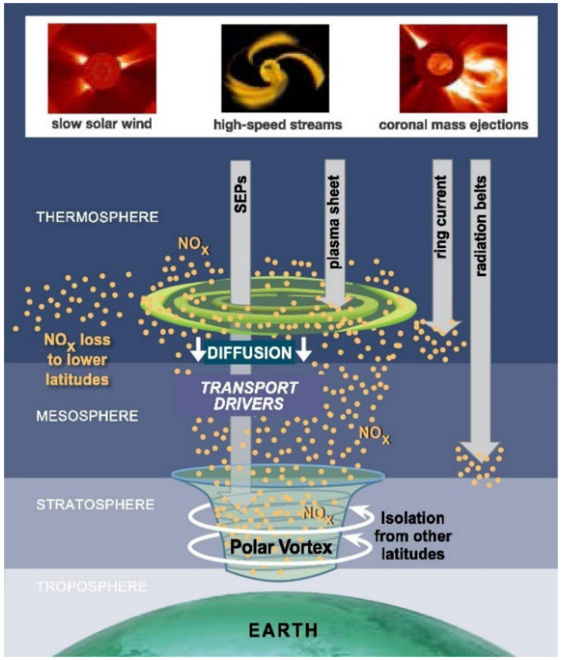

Fig. 1: Schematic representation of the processes involved in the energetic particle impact on nitrogen oxides (NO_x)

Tutor (at PMOD Davos):

Timofei Sukhodolov timofei.sukhodolov@pmodwrc.ch

Topic 2: Global modelling and climate proxy data analysis

Effects of volcanoes on the 17th century atmosphere and climate

Key problem:

- 17th century is characterized by some of the coldest temperatures of the Little Ice Age, as known from climate proxy data
- From ice core measurements, it is also known that there were series of strong volcanic events that were able to reach the stratosphere
- There are still debates whether volcanic activity was the dominant forcing for the observed cold climate, given that volcanic sulfur stays in the atmosphere only for 1-3 years

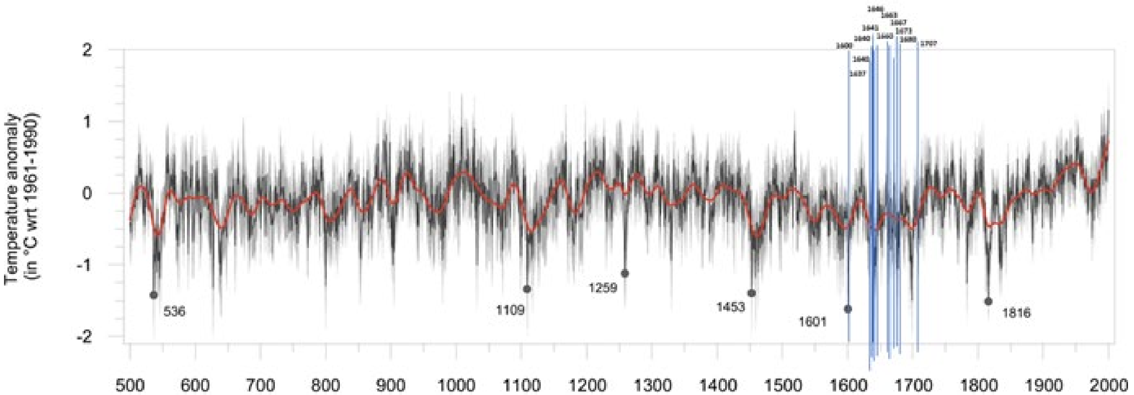

Fig. 1: Tree-ring reconstructions of northern hemispheric extra-tropical land (40–90°N) summer temperature anomalies (with respect to the period 1961–1990) since 500 CE and large volcanic events around 17th century

Key questions:

Can volcanic activity alone explain the temperature reconstructions over the 17th century? Are there additive and/or delayed effects of volcanic cluster eruptions? What were the effects on the stratosphere?

Key tasks:

Analyze 17th century simulation results of the Earth System Model SOCOLv4 and characterize the effects of volcanoes on the atmosphere and climate

Tutor (at PMOD Davos):

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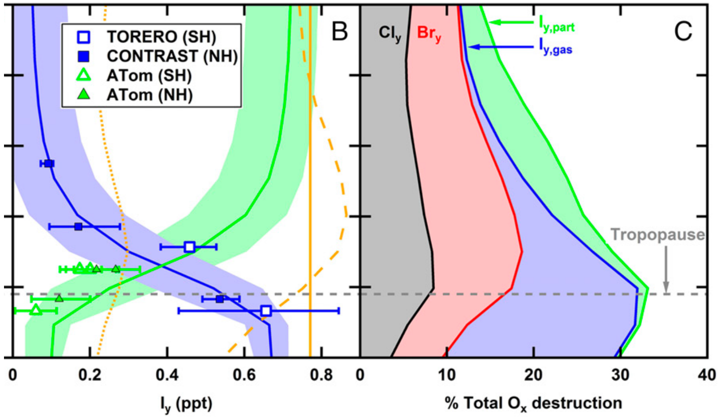
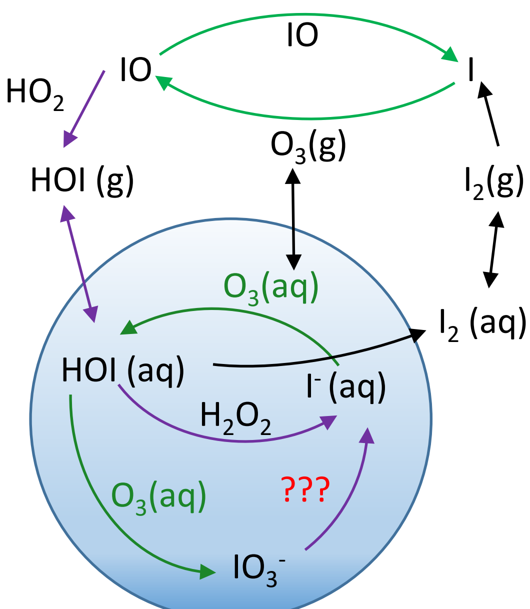
Topic 3: Laboratory work and data analysis

Is iodide a sink for O_3 in the stratosphere ?



Koenig et al., PNAS 2020



Key question

Iodine contributes to catalytic ozone (O_3) loss. Recent measurements indicate higher than expected iodine levels in the stratosphere. A substantial fraction of this iodine is in the particle phase in the form of reduced iodide (I^-) due to poorly understood recycling processes from the more oxidized forms of iodine. Iodide, which is known to be very reactive towards ozone at room temperature, may thus represent an additional sink for O_3. How is iodide formed in the stratosphere?

Key tasks

- Review of iodine chemistry in the troposphere and the stratosphere
- Laboratory work and data analysis
- Perform kinetic experiments related to recycling reactions of iodate to iodide, e.g., with hydrogen peroxide (H_2O_2)
- Assess implications of results for stratospheric chemistry

Tutor (at PSI)

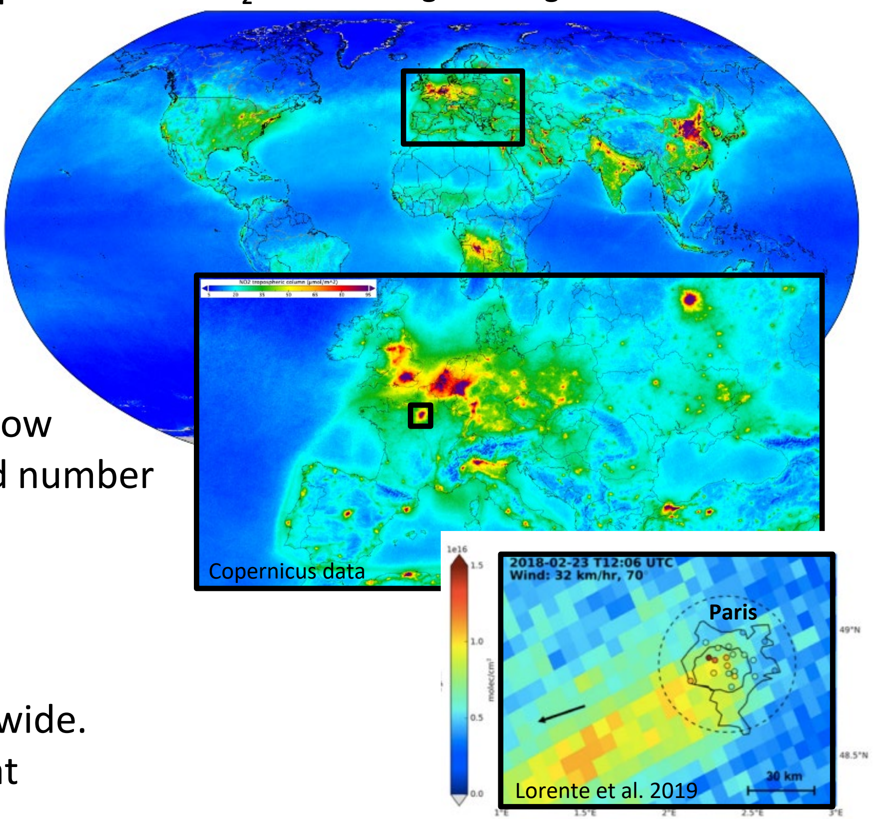
Markus Ammann
Tel. +41 56 310 4049
markus.ammann@psi.ch

Quantifying CO_2 and NO_2 emissions of cities and power plants from satellite observations

Topic

Cities are hot-spots of NO_x emissions. These emissions can be quantified from imaging satellites like TROPOMI using mass-balance methods. The same methods could be applied in the future to measurements from the planned Copernicus CO_2 imaging satellites.

TROPOMI NO_2 satellite images from global to local scale



Key questions

How well can we quantify NO_x emissions from satellite images? What is the day-to-day variability of emissions? How well can annual emissions be estimated based on a limited number of overpasses during a year?

Key tasks

(1) Test and improve emission estimation algorithms.
(2) Quantify emissions of cities (and power plants) worldwide.
(3) Analyze temporal variability of emissions and how that impacts annual emission estimates.

Methods

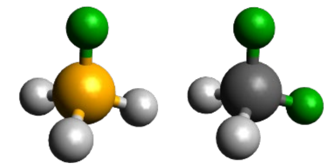
Satellite remote sensing, top-down emission quantification, mass-balance methods

Tutors (at Empa)

Gerrit Kuhlmann gerrit.kuhlmann@empa.ch
Dominik Brunner dominik.brunner@empa.ch

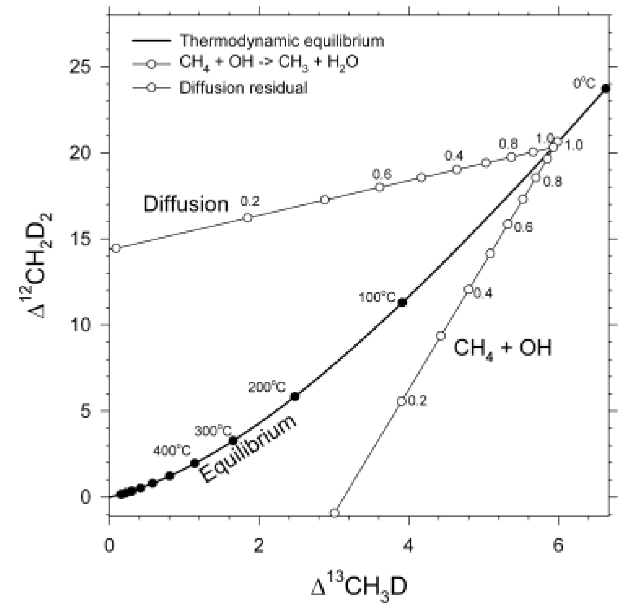
Topic 5: Analytics of novel isotope tracers

Reference scale for novel CH_4 isotope tracers



Key Problem

The global atmospheric methane budget is highly uncertain. Temperature-dependent variation of multiple isotopic substitutions in CH_4 can provide new insights into methane formation and sink processes. Using state-of-the-art laser-based analyzer, we want to experimentally realize a reference scale, which directly links **$^{13}CH_3D$** and **CH_2D_2** abundances with apparent temperature of methanogenesis.

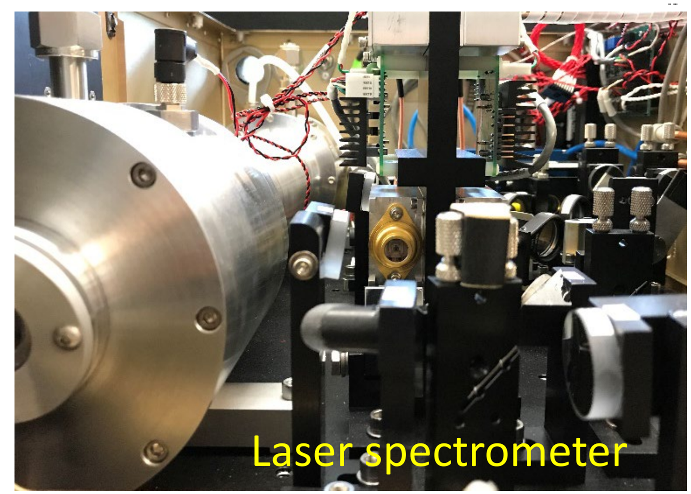


Key Question

Does the experimentally established reference scale adequately reflect temperatures of methane formation in atmospheric samples?

Key Tasks

Acquire and evaluate laser absorption spectra, data analysis, validation of laser measurements, isotopic re-equilibration under controlled conditions, methane extraction from air samples.

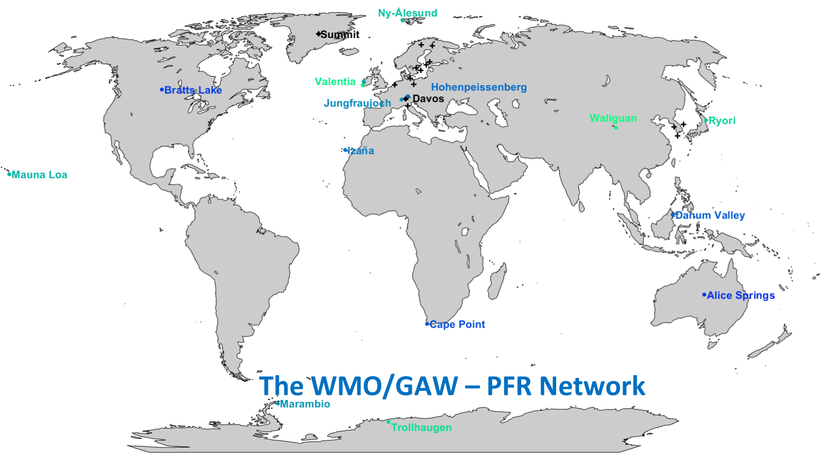


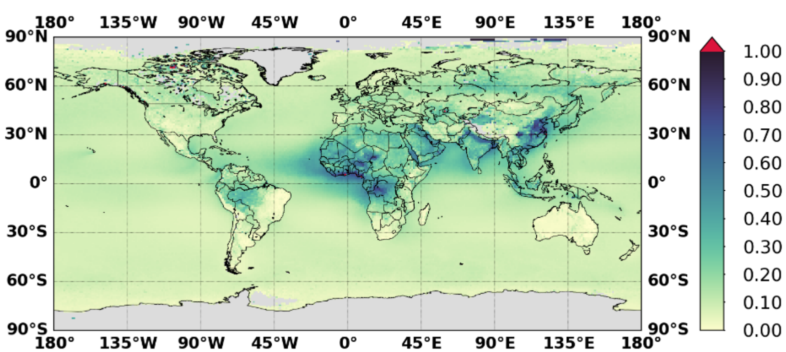
Tutors (at Empa)

Joachim Mohn, Ivan Prokhorov
joachim.mohn@empa.ch, ivan.prokhorov@empa.ch

Topic 6: Aerosol data analysis – long-term, global scale

Aerosol long term trends: Do surface and satellite based measurements agree ?





MODIS satellite 2000-2019 mean aerosol optical depth

Key problems:

- Aerosol optical properties directly and indirectly affect the Earth-Atmosphere radiative balance
- Investigate long term aerosol measurement changes
- Assess uncertainties in aerosol radiative effects
- Sparse but accurate surface-based measurements and dense and less accurate satellite-based are key datasets in such studies
- Do they agree? Are there differences comparable with known aerosol long term changes ?

Key task:

Analyze surface based and satellite measurements at particular locations with 10+ years of aerosol measurements

Workplace:

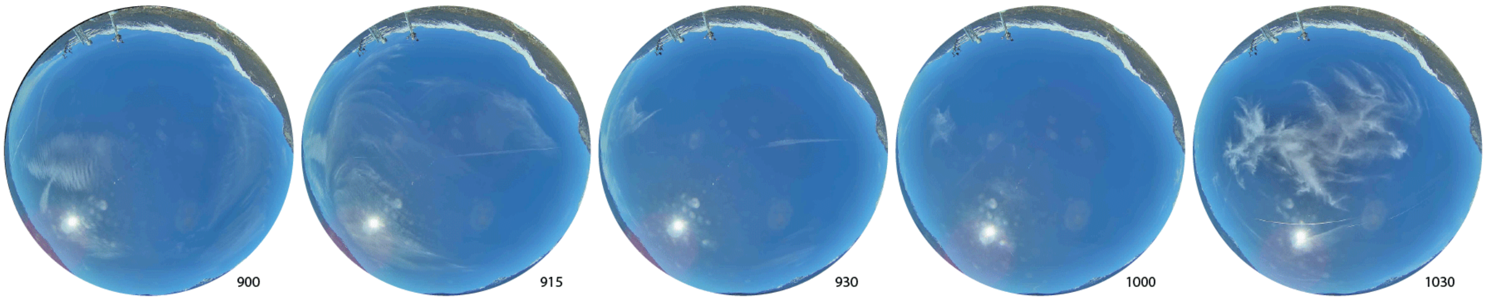
ETH Zurich, possibility to spend 1 month in Davos

Tutors (at PMOD)

Stelios Kazadzis, Tom Peter
Stelios.kazadzis@pmodwrc.ch, thomas.peter@env.ethz.ch

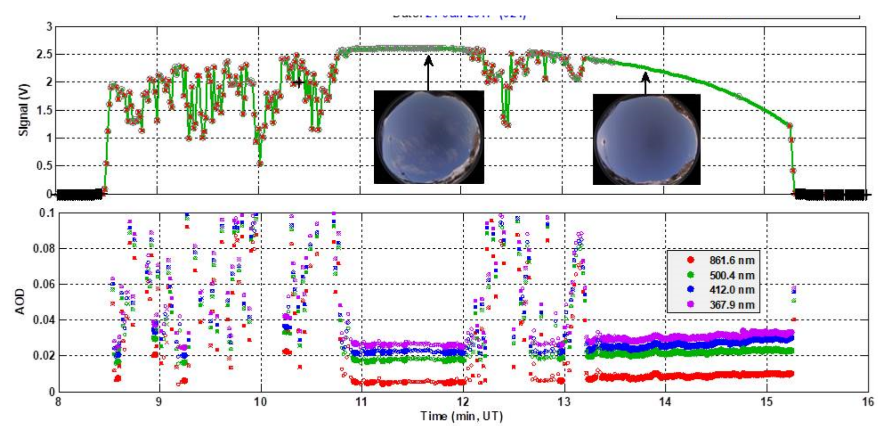
Topic 7: Aerosol, sun-photometric measurements

How easily can we distinguish aerosols and clouds ?



Key problems:

- Aerosol optical properties directly and indirectly affect the Earth-Atmosphere radiative balance
- Instruments measuring total column aerosol load are based on cloudless measurements
- Distinguishing aerosols from clouds, especially in the case of thin invisible/subvisible clouds is not easy !



Key task:

Develop methods in order to separate cloudless from cloudy related direct sun - aerosol measurements.

Methods can be based on physical processes, sky camera and other data and machine learning techniques

Workplace:

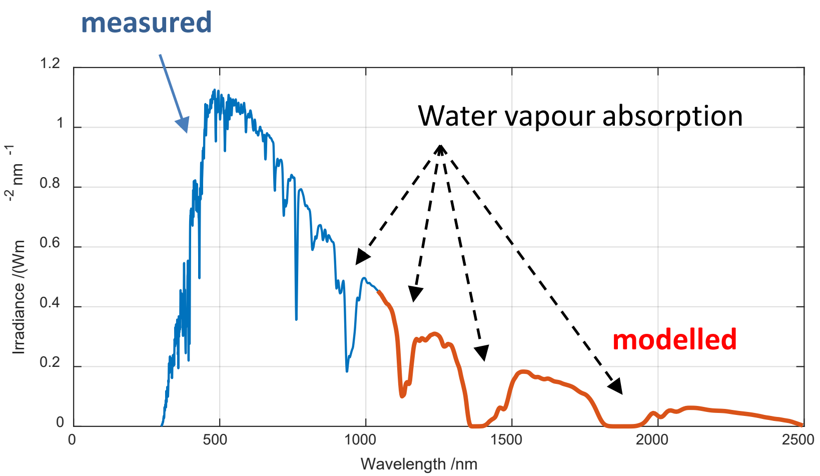
ETH Zurich, possibility to spend 1 month in Davos

Tutors (at PMOD and ETHZ)

Stelios Kazadzis, Tom Peter
Stelios.kazadzis@pmodwrc.ch, thomas.peter@env.ethz.ch

Topic 8: Solar radiation spectrum modelling

How well can the total solar spectrum be retrieved from visible range spectroradiometer measurements?



World standard group (WSG) representing the total solar irradiance reference.

Reference: Gröbner, J., and N. Kouremeti, The Precision solar Spectroradiometer (PSR) for direct solar irradiance measurements, Solar Energy 185, 199-210, 2019.

The precision solar spectrradiometer (PSR).

Key problems:

- Ground-based measurements of the solar spectrum are available only for $\lambda < 1050$ nm.
- Need total solar spectrum for solar energy applications and Earth radiation budget studies.
- The total solar spectrum can be obtained via radiative transfer calculations from the measured part of the spectrum by deriving the atmospheric composition (H_2O, aerosols…).

Key task:

Retrieve atmospheric water vapor from measured solar spectra, use radiative transfer modelling (LibRadtran) to extend the measured solar spectrum and compare to total irradiance measurements by the World Standard Group.

Workplace:

ETH Zurich, visits to PMOD/WRC Davos.

Tutor (at PMOD)

Julian Gröbner
julian.Groebner@pmodwrc.ch