PMOD/WRC Semester and MSc projects 2024/2025

Introduction

The Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC) was formed in 1907 and is based in Davos. PMOD/WRC has six key areas that will be further developed in the coming years. These are:

- World Radiation Center: serve as an international calibration center for meteorological radiation instruments and develop radiation instruments for use on the ground and in space.
- Space projects: develop instruments for imaging and radiation measurements of the Sun.
- Technology: underpin the design and development of the instruments for ground and space.
- Climate science: research the Earth's ozone layer and climate evolution
- Solar Science: research the causes of solar activity.
- Teaching: carry out teaching at different levels at ETH-Zürich.

There are MSc projects available that are described below. Please contact the lead supervisor if you require more information. The topics available are wide-ranging, covering solar physics, climate modelling and instrumentation for both ground and space measurements.

Statistical analysis of hot X-ray onsets in solar flares (MSc)

Solar flares, which are the sudden release of magnetic energy occurring in the solar corona, the outermost layer of the solar atmosphere, are the most powerful magnetic events in the entire solar system. They generate radiation across the entire electromagnetic spectrum, from radio waves to γ-rays, and are closely linked to particle acceleration through what is known as the magnetic reconnection. These accelerated particles cause local changes to the solar atmosphere (e.g., heating the solar plasma to extreme temperatures, > 10 MK), as well as propagate to interplanetary space, eventually reaching the Earth and posing risks to humans. This highlights the need to predict their occurrence to mitigate their impact.

The aim of this project is to address the first step of this issue: anticipating their occurrence for a few minutes using near-real-time X-ray (from GOES/XRS) and UV/EUV (from SDO/AIA) observations. This can serve as an alert for observational programs focused on solar flares. This will be done by exploiting the recently discovered "hot onsets" on a statistical basis (a few online articles here: [1] and [2]).

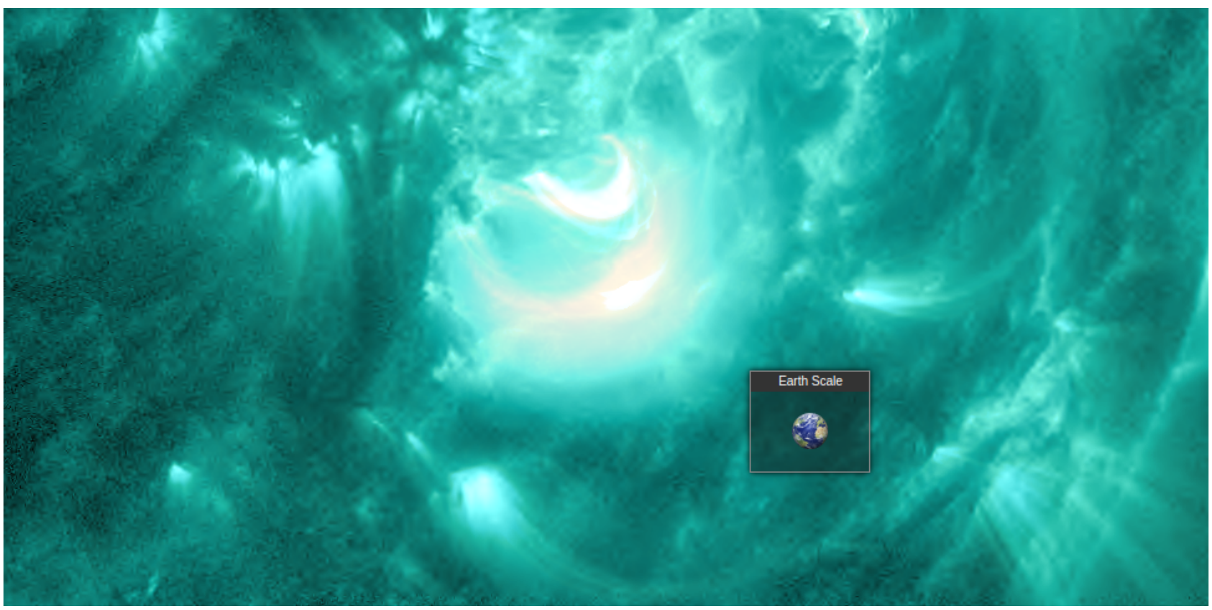


Figure: A solar flare occurred on July 14th, 2024, as observed by SDO/AIA. For comparison, the Earth is shown on scale. Image taken from https://helioviewer.ias.u-psud.fr

Supervisors: Louise Harra, Andrea Battaglia, Hugh Hiudson

Skills or knowledge required for the project: Strong interest in space physics data analysis and first experience with programming languages (preferably python).

Workplace: ETH Zürich or PMOD/WRC Davos

Contamination trap for a Space Mission (MSc)

Background & Key questions:

Optical space instruments, measuring in the EUV range, are very sensitive to contamination. Once in vacuum, the materials of the instrument and the satellite outgas. The outgassing products condense on optical surfaces and the deposited contaminants are burnt-in by solar radiation.
The key question is how to prevent an optical space instrument from going blind?

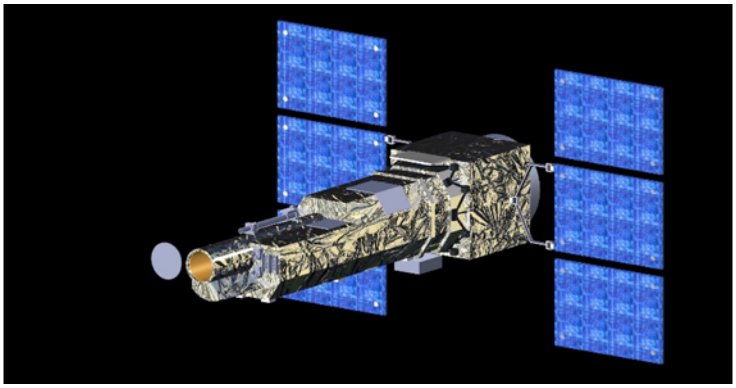


Figure 1 Solar-C (©NAOJ/JAXA)

The project:

The "Physikalisch-Meteorologisches Obersvatorium Davos" (PMOD) develops Solar Radiometers for Space application since decades. These instruments are designed, engineered, and manufactured at PMOD. Due to the vacuum environment in Space, molecular contamination by outgassing products is a common and important topic for most optical instruments.SoSp IM is a Solar Spectral Irradiance Monitor onboard the Japanese Solar-C space mission and measuring in the EUV range. A new type of contamination trap shall now be used to prevent the optical instrument from going blind due to contaminants coming from material outgassing. To prove the new method, an analysis of the materials used in the instrument and their outgassing products is required. A first master thesis was carried out in 2024. Based on the existing results, further analysis and testing in representative environmental conditions is required. The objective of this second MSc thesis on this topic is to develop the concept into a flight-ready system for the SoSpIM instrument.

Workplace: Davos

Skills or knowledge required for the project:

- Basic understanding of materials technology
- Lab experience
- Experience with technical test setups
- Accurate and self-initiative working

Supervisor: Valeria Büchel, valeria.buechel@pmodwrc.ch (PMOD/WRC)

Miniaturization study for space instrument (MSc)

Background & Key questions:
The Physikalisch-Meteorologisches Obersvatorium Davos (PMOD) has been developing optical instruments for space applications for decades. These instruments are designed, developed, and manufactured at PMOD. These instruments must meet a wide range of requirements to fulfil the scientific objectives, to withstand harsh environmental conditions and to operate reliably once in orbit. These boundary conditions make it difficult to make the instrument smaller and lighter. However, size and mass are important to open up more possibilities for future missions.
The key question is how to miniaturize the PMOD space instruments?

Figure 2 SoSpIM (©PMOD)

The project:
The miniaturization study includes the evaluation and assessment of mass and size reduction options. Each reduction option shall be evaluated in terms of impact on science, performance, structural integrity, availability, risk, schedule, cost, compliance with space standards and feasibility.
Clear and feasible miniaturization proposals shall be presented as an outcome of this study.

Workplace: Davos

Skills or knowledge required for the project:

- Engineering background (systems engineering, mechanical engineering and/or electronics engineering)
- Interdisciplinary thinking
- Creativity
- Interest in space-related standards and requirements
- Self-initiative working

Supervisor: Valeria Büchel, valeria.buechel@pmodwrc.ch (PMOD/WRC)

New concept for optimized thermal decoupling of space instruments (MSc)

Background & Key questions:
The Physikalisch-Meteorologisches Obersvatorium Davos (PMOD) has been developing optical instruments for space applications for decades. These instruments are designed, developed, and manufactured at PMOD. These instruments must meet a wide range of requirements to fulfil the scientific objectives, to withstand harsh environmental conditions and to operate reliably once in orbit. For sensitive optical instruments, the sensors often need to be thermally decoupled from the electronics and from the spacecraft. Thermal decoupling has been an issue for all past and current space instruments from PMOD. We are looking for new ideas and concepts for a more efficient thermal decoupling while still maintaining structural integrity.

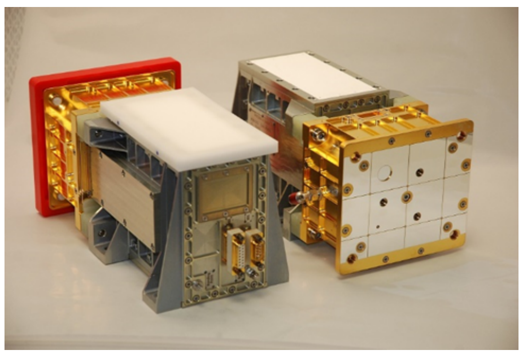


Figure 3 DARA (©PMOD)

The project:
This thesis shall take a closer look at the thermal decoupling of space instruments developed at PMOD. Based on thermal requirements from previous and current space projects at PMOD, a new concept or new concepts for the thermal decoupling shall be developed. Material selection and design shall meet requirements for space projects (e.g. load cases, outgassing, etc.).
Clear and feasible proposals shall be presented as an outcome of this study.

Workplace: Davos

Skills or knowledge required for the project:

- Engineering background (mechanical and thermal engineering, materials technology)
- Interdisciplinary thinking
- Creativity
- Interest in space-related standards and requirements
- Self-initiative working

Supervisor: Valeria Büchel, valeria.buechel@pmodwrc.ch (PMOD/WRC)

Thermal vacuum test setup for large temperature range tests of space hardware (MSc)

Background & Key questions:
The Physikalisch-Meteorologisches Obersvatorium Davos (PMOD) has been developing optical instruments for space applications for decades.
PMOD has extensive infrastructure for the testing of space hardware. The test facilities are used for our own space instruments and are offered as an external service to space industry and other institutes. We would like to extend the temperature range of our thermal vacuum test capabilities, which requires a completely new cooling/heating method.
The objective of this thesis is to develop, build and verify a ready-to-use test setup for future space experiments.

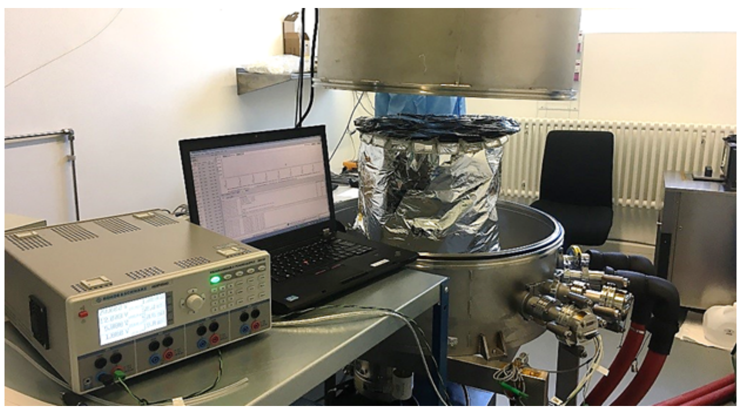


Figure 4 Thermal vacuum chamber (©PMOD)

The project:
A new test setup for thermal vacuum tests of space hardware shall be developed, built, and verified. The equipment shall be ready-to-use for future PMOD space projects, as well as for external services. A technical description of the setup, a data sheet and a user manual are part of this thesis.

Workplace: Davos

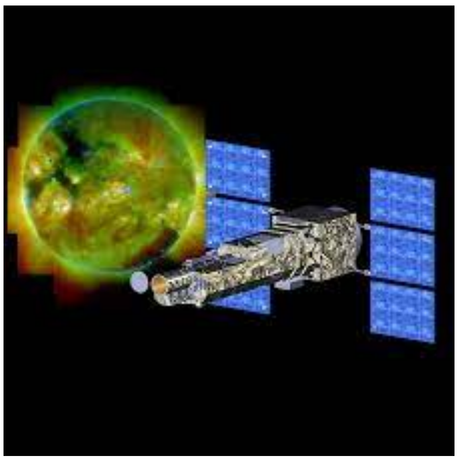
Skills or knowledge required for the project:

- Engineering background
- Interdisciplinary thinking
- Practical experience with lab work and test equipment
- Creativity
- Interest in space-related standards and requirements
- Self-initiative working

Supervisor: Valeria Büchel, valeria.buechel@pmodwrc.ch (PMOD/WRC)

Photodiode Front-Front End Electronics for a Space Instrument

Background
At PMOD, high precision instruments for measuring solar radiation are being developed and refined. This includes instruments for measuring extremely low intensities, such as the radiation reflected by the moon or Extreme-UV radiation in Space.



The project is a follow-up project in which several electronic circuits were investigated for their suitability for highly sensitive amplification of photocurrents in the range of a few pico amperes. The current phase is dedicated to refining and thoroughly characterizing these circuits. To this end, the circuits must be dimensioned, and the PCBs designed, and measured under various environmental conditions, such as vacuum, high and low temperatures.

Key questions: To what extent can the circuits be optimized in terms of signal-to-noise ratio, temperature dependency, long-term stability and cut-off frequencies? Miniaturization is also an issue.

Skills or knowledge required for the project: Strong interest and expertise in analog electronics, signal measurements. Basic knowledge in schematic design and PCB layout, statistics.

Supervisors: Dany Pfiffner d.pfiffner@pmodwrc.ch (PMOD/WRC), Leandro Meier (PMOD/WRC)

Investigation of Flaring Active Regions on the Sun with Solar Orbiter EUI and SPICE

Background:

The ESA Solar Orbiter space mission reaches solar distances below 0.3 au (30% of the distance between Sun and Earth) it allows for unprecedented images of the solar atmosphere made by the Extreme Ultraviolet Imager (EUI) combined with spectral information from the SPectral Imaging of the Coronal Environment (SPICE) instrument. PMOD/WRC is part of the consortium that built and operates these two instruments.

The project:

In our group we use EUI and SPICE measurements to investigate the active regions on the Sun where eruptive events and solar flares happen. In this master thesis the student will focus on the analysis of the elemental composition in active regions and investigate the temporal evolution of their composition prior, during, and after solar flares. The results will be compared to in-situ measurements of solar energetic particles that escaped from the Sun during the flare and reached the Solar Orbiter spacecraft.

Key question:

What are the (main) mechanisms for energetic particle acceleration in solar flares?

The detailed understanding of the underlying processes will contribute to a better understanding of solar activity and more precise predictions of space weather in the future.

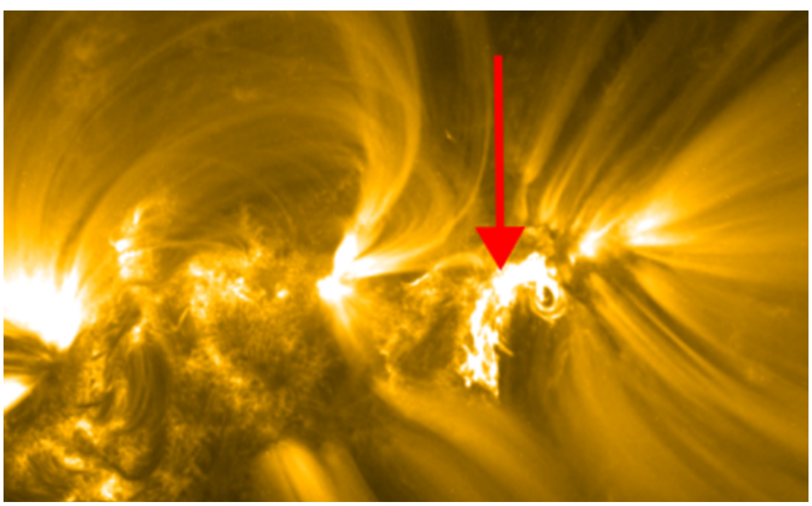


Image of a solar flare within an active region observed on 05/03/2022.

Skills or knowledge required for the project: Strong interest in space physics data analysis and first experience with programming languages (preferably python).

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Nils Janitzek nils.janitzek@pmodwrc.ch (PMOD/WRC, ETH), Prof. Louise Harra louise.harra@pmodwrc.ch (PMOD/WRC, ETH)

Interstellar Ices with the JWST

[6-week Semester Project: latest start date 15 July 2024]

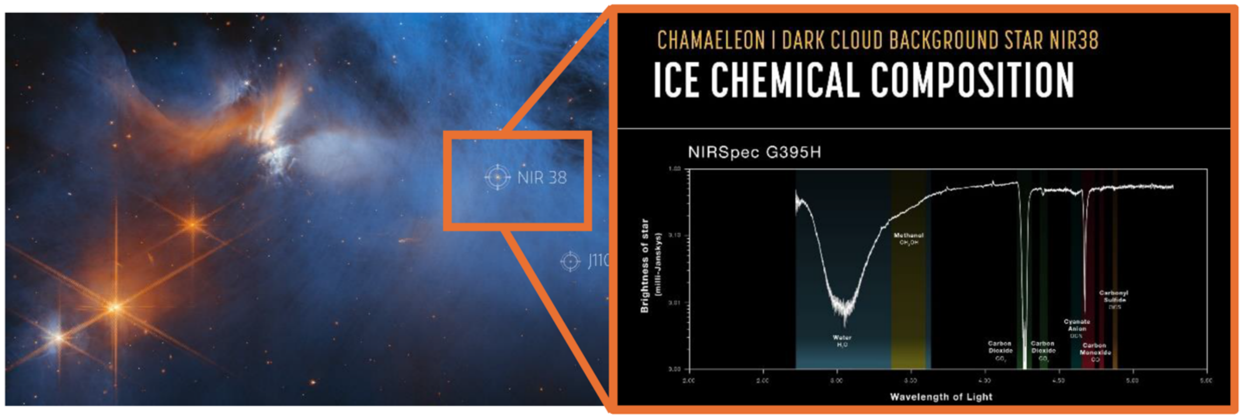


Image Credit: NASA, ESA, CSA, and M. Zamani (ESA/Webb), J. Olmsted (STScI), M. K. McClure (Leiden Observatory), F. Sun (Steward Observatory), K. Pontoppidan (STScI), N. Crouzet (Leiden University), Z. Smith (Open University), & the Ice Age ERS Team.

Backgrounds

Interstellar ice in infant star-forming regions is a key initial ingredient for star and planet formation, which may vary from one cloud to another. With the sensitivity and spatial coverage of JWST, it is now possible to perform unprecedented studies of ice column densities in the densest parts of star-forming regions (e.g., McClure et al. 2023).

McClure et al. 2023: https://www.nature.com/articles/s41550-022-01875-w

The Project

In this project, you will process freshly delivered (April 2024) JWST observations of star-forming regions. You will begin by analyzing images made with the NIRCAM instrument and will learn the key steps in going from raw data to calibrated and cleaned images. Your goal will then be to process these images and obtain constraints on the targets that are seen in the various filters. Depending on progress and interest, there is the possibility of investigating spectra obtained with the NIRSpec instrument, which show absorption bands corresponding to interstellar ices. Your task will be to identify some of these observed ice bands.

JWST Cycle 2 Program: https://www.stsci.edu/jwst/science-execution/program-information?id=3222

Key Question

What is the chemical composition of interstellar ice in infant star-forming regions?

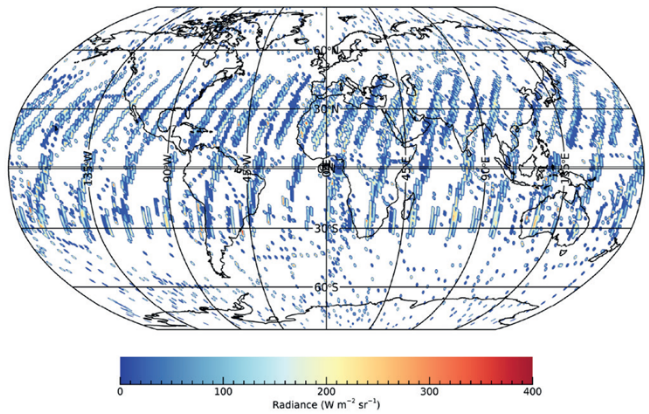
Skills/Knowledge Required for the Project

An interest in physics and chemistry of regions that form stars. Basic Python experience.

Supervisor: Dr. Maria Drozdovskaya (PMOD/WRC), maria.drozdovskaya@pmodwrc.ch

Workplace: PMOD/WRC (partially remote is possible upon agreement)

Analysis of Earth Outgoing Longwave Radiation measured with CLARA (MSc)



Terrestrial outgoing longwave radiation measurements along CLARA's footprint (Haberreiter et al.).

Background:
The Earth Radiation Budget (ERB) is the difference between the incoming solar and outgoing terrestrial radiation at the top of the Earth atmosphere. Starting in 2020, the PMOD-built CLARA radiometer onboard the NorSat1 microsatellite[1] measures the outgoing longwave radiation (OLR) on the night-side of Earth. The OLR and the reflected outgoing shortwave radiation (OSR) build the total outgoing radiation (TOR). To understand the evolution of climate change it is of key importance to know TOR to a high degree of accuracy. The CLARA instrument is now the first to measure the OLR component as absolute radiometer, i.e., with a higher absolute accuracy compared to previous instruments, such as the CERES[2] instrument.

Key questions:
- What is the temporal and spatial variability of the terrestrial OLR radiation?
- Can the SI-traceable CLARA data be used to benchmark other space data?

The project involves:
- the remapping of the CLARA footprint to the grid of the CERES data
- the analysis of the temporal and spatial variability of the CLARA OLR data
- the comparison of the co-located and simultaneous CLARA OLR with CERES OLR observations

Skills of knowledge required for the project:
Interest in Earth observations from space as well as some basic skills in programming, data processing and data visualization.
Supervisors: Dr. Margit Haberreiter (margit.haberreiter@pmodwrc.ch) and Dr. Wolfgang Finsterle (PMOD/WRC)

[1] https://www.utias-sfl.net/norsat-1/
[2] Clouds and the Earth's Radiant Energy System (CERES), https://ceres.larc.nasa.gov

Volcanic influence on atmospheric transport of 10Be cosmogenic isotope

Background:

Cosmogenic isotope 10Be is an important proxy of past solar activity. Its transport in the atmosphere is complicated by its attachment to sulphate aerosols, which can result in spikes in 10Be ice core records after major volcanic eruptions mimicking solar particle events. The mechanisms behind the influence of volcanic eruptions on transport and deposition of isotopes are not properly identified.

The project:

This project will combine numerical modelling and analysis of ice core records. Simulations will be performed with our in-house aerosol-chemistry-climate model SOCOLv4 for the selection of strong historical volcanic eruptions, as well as for artificial events for sensitivity analysis.

Key question:

How important is gravitational sedimentation of aerosols in the stratosphere under different conditions?

Can we see volcanic signal in 10Be deposition to ice cores?

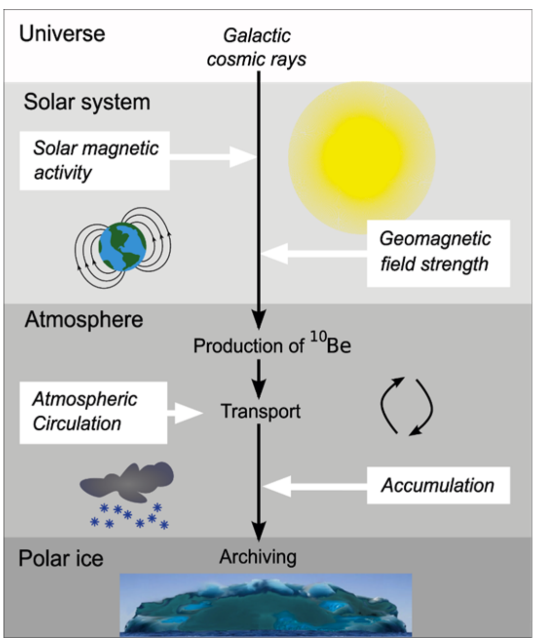


Figure: 10Be life cycle.

Skills or knowledge required for the project: Strong interest in atmospheric physics, data analysis and visualization, some knowledge of Linux environment and Bash scripting.

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Timofei Sukhodolov timofei.sukhodolov@pmodwrc.ch (PMOD/WRC), Prof. Louise Harra louise.harra@pmodwrc.ch (PMOD/WRC, ETH)

Changes in surface heat and precipitation due to solid particle injection into the stratosphere

Background:

Solar radiation modification is a widely discussed topic on how to alter the radiation budget of the Earth and thus counteract the warming due to greenhouse gases. One such idea is to inject sulphur dioxide into the stratosphere. However, this technique produces several unwanted side effects due to the absorbing properties of sulphur. Recently the idea of injecting solid particles gained attention in the scientific community. These particles have similar optical properties as sulphur dioxide but without absorption. However, even with solid particles there are regional differences in different climate variables.

The project:

In this project we would analyse climate simulations which include different kinds of particles. The special focus will be on regional differences such as shifts in precipitation pattern, heat transport, and atmospheric dynamics. This work also helps to disentangle forced vs. unforced climate variability.

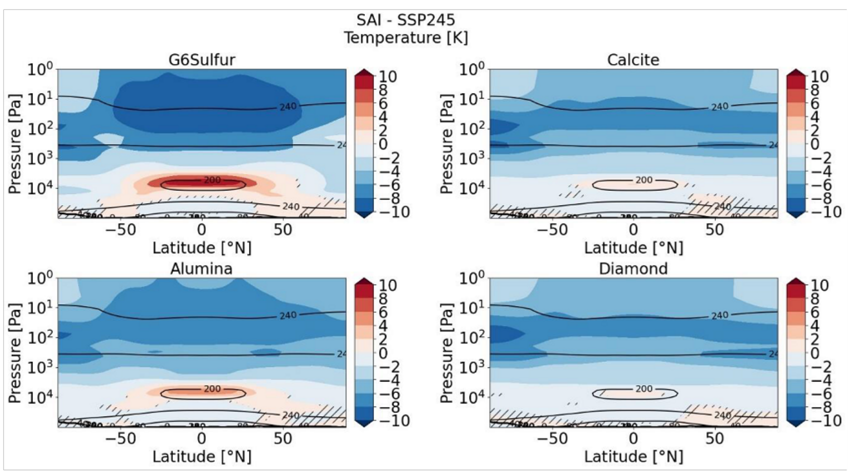


Figure: Annual mean temperature change between stratospheric aerosol injection scenarios and the SSP2-4.5. The contours represent the mean values from SSP2-4.5.

Skills or knowledge required for the project:

Programming skills in a visualisation language such as Python, IDL, NCL or similar

Supervisors: Dr. Jan Sedlacek (jan.sedlacek@pmodwrc.ch) and Dr. Timofei Sukhodolov (timofei.sukhodolov@pmodwrc.ch) . Workplace is at PMOD/WRC in Davos or at ETH Zürich.

Energetic particle precipitation impacts on the atmosphere

Background:

Energetic particle precipitation from various sources provides energy input into the upper atmosphere, producing NOx and HOx radicals, which destroy ozone. The NOx 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.

The project:

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.

Key question:

Does particle precipitation influence the surface climate and how?

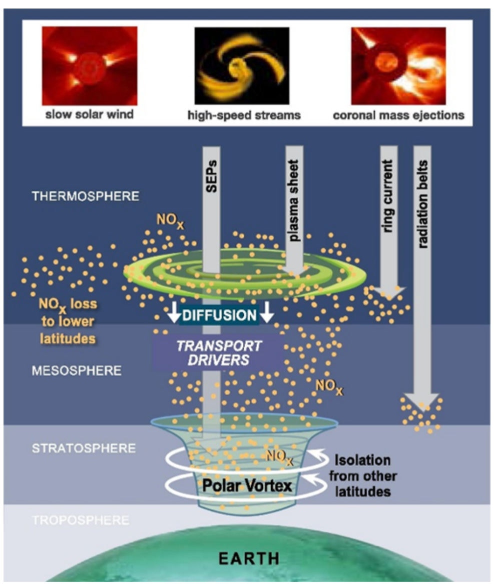


Figure: Schematic representation of the processes involved in the energetic particle impact on nitrogen oxides (NOx)

Skills or knowledge required for the project: Strong interest in atmospheric physics, data analysis and visualization, some knowledge of Linux environment and Bash scripting.

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Timofei Sukhodolov timofei.sukhodolov@pmodwrc.ch (PMOD/WRC), Prof. Louise Harra louise.harra@pmodwrc.ch (PMOD/WRC, ETH)

Effects of volcanoes on the 17th century atmosphere and climate

Background:
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.

The project:

Analyze 17th century simulation results of the Earth System Model SOCOLv4 and characterize the effects of volcanoes on the atmosphere and climate. Compare results to climatic proxies and reanalysis data.

Key question:

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?

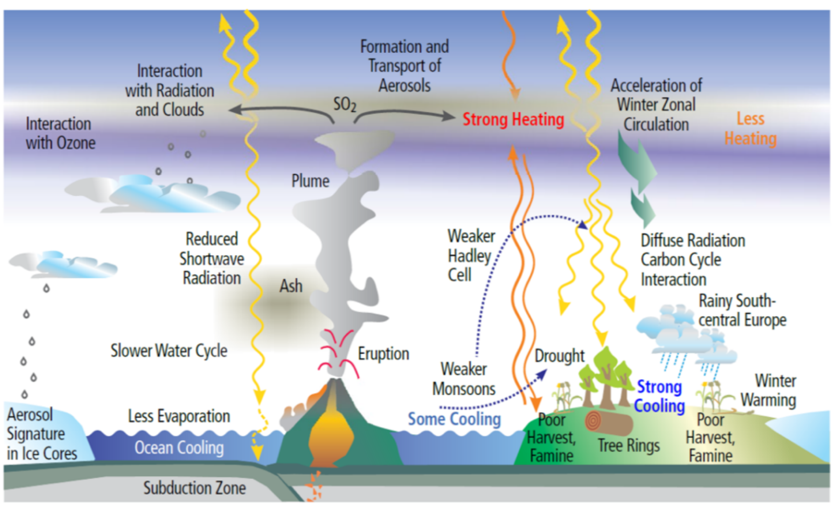


Figure: Schematic representation of volcanic effects on the atmosphere

Skills or knowledge required for the project: Strong interest in atmospheric physics, data analysis and visualization, some knowledge of Linux environment and Bash scripting.

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Timofei Sukhodolov timofei.sukhodolov@pmodwrc.ch (PMOD/WRC), Andrin Joerimann (andrin.joerimann@pmodwrc.ch)
Supervisors: Dr. Stelios Kazadzis stelios.kazadzis@pmodwrc.ch (PMOD/WRC), Prof. Louise Harra louise.harra@pmodwrc.ch (PMOD/WRC, ETH)

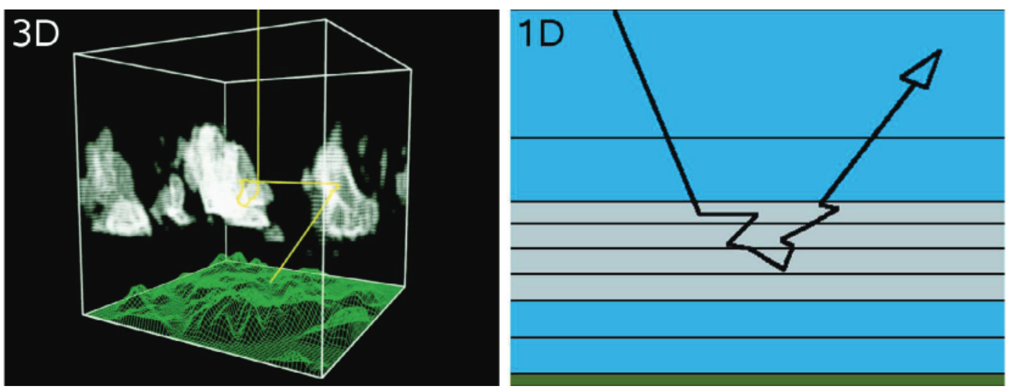
Aerosol–cloud interactions modeling and climate (MSc)

Background:

The impact of anthropogenic aerosols on clouds is a leading source of uncertainty in estimating the effect of human activity on the climate system. Modeling the solar radiation and accurate estimation of the surface reaching fluxes is challenging due to varying geographical parameters such as topographic shadowing and reflection from the inclined surfaces. This is further complicated by the presence of atmospheric components, e.g., aerosols and clouds. Simultaneous aerosol/cloud retrievals using 1D radiative transfer codes cannot account for 3D effects such as shadows, cloud induced enhancements and darkening of cloud edges

The project:

Radiative transfer is usually done under the assumption that the atmosphere is one-dimensional (1D) that it varies only in the vertical direction while horizontal variations are neglected, at least for radiative transfer applications. The reason is that Homogeneous plane-parallel clouds are the only ones for which we know how to solve the radiative transfer in reasonable computer time. On the other hand, 3D radiative transfer cab much more accurately represent the radiation transfer through clouds and aerosol-cloud atmospheric scenes. The project deals with working with realistic aerosol-clouds scenes and different models in order to simulate the radiation at the surface and top of the atmosphere.



3D vs 1D modeling from B. Mayer, 2009

Key question:

What are the main differences between 1D and 3D modeling for realistic cloud and aerosol atmospheric scenes? And how these differences affect our understanding on aerosol-cloud climate effects ?

Skills or knowledge required for the project: Strong interest in atmospheric physics, data analysis and visualization, basic knowledge on Python or matlab or R scripting.

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Stelios Kazadzis stelios.kazadzis@pmodwrc.ch (PMOD/WRC)