PMOD/WRC Semester and MSc projects 2025/2026

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.

High-Resolution Radiative Transfer Modeling for Solar Energy Applications: Validation with Surface Measurements

Background:

Radiative transfer models play a crucial role in accurately predicting solar energy distribution, absorption, and scattering in various atmospheric and engineering applications. While 1D models offer computational efficiency and simplicity, they often fail to capture complex three-dimensional effects such as anisotropic scattering and heterogeneous media, which are critical in real-world solar radiation-based energy systems. In contrast, 3D models provide higher accuracy by accounting for spatial variations, leading to more precise simulations. However, their increased computational cost can be a limitation. Striking a balance between accuracy and efficiency is essential, making the choice between 1D and 3D models dependent on the specific requirements of a given solar energy application.

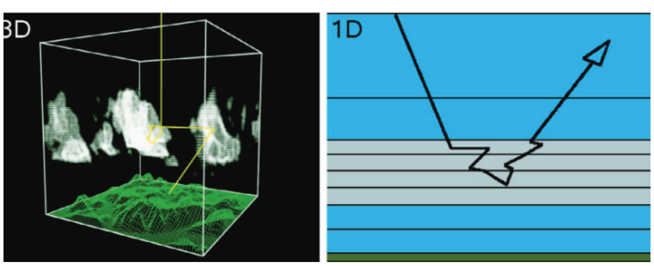
The project:

3D atmospheric scenes of cloud and aerosol properties will be provided in high temporal resolution, enabling its utilisation for solar energy applications. The solar radiation at the ground will be calculated using the MYSTIC/libRadtran RT software, and the calculations will be validated with surface radiation measurements provided by the BSRN network in Europe. Dedicated science studies will be performed, for different atmospheric cases.

Key question:

How does the choice between 1D and 3D radiative transfer models impact the accuracy and efficiency of solar energy predictions, and under what conditions is a 3D model necessary to capture critical radiative processes that 1D models fail to represent?

This question addresses the trade-off between computational feasibility and physical realism, exploring when 3D effects (e.g., anisotropic scattering, cloud heterogeneity, surface variations) significantly influence solar energy distribution.



Definition of three-dimensional (3D) and one-dimensional (1D) radiative transfer. (B. Mayer., 2009)

DOI: 10.1140/epjconf/e2009-00912-1

Skills or knowledge required for the project: Strong interest in solar radiation aerosol and cloud remote sensing, data analysis and experience with programming languages (Matlab, python). MSc project with possible start in September 2025

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Stelios Kazadzis stelios.kazadzis@pmodwrc.ch (PMOD/WRC, ETH), Kyriaki Papachristopoulou (PMODWRC)

The Influence of Dust aerosols and dust mineralogy on Solar Radiation

Background:

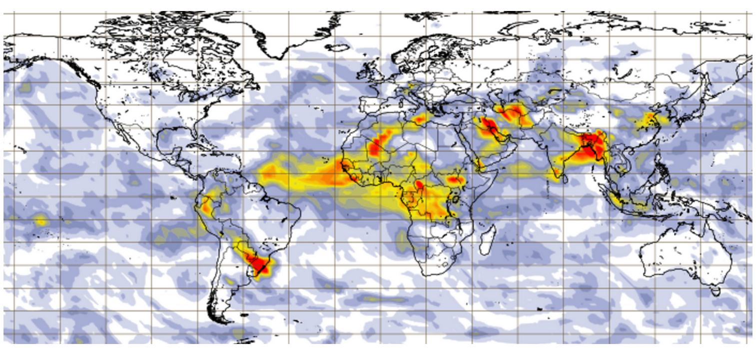
Atmospheric dust plays a critical role in Earth's energy balance by interacting with incoming solar radiation. The mineral composition of dust particles determines their optical properties, influencing whether they absorb or scatter sunlight. Minerals such as iron oxides (e.g., hematite and goethite) tend to absorb radiation, while silicate minerals (e.g., quartz and feldspar) scatter light. These interactions have significant implications for solar radiation, atmospheric heating, cloud formation, and regional climate patterns, especially in arid and semi-arid regions where dust emissions are prevalent.

The project:

This project aims to investigate the impact of dust aerosols and dust mineralogy on solar radiation by using remote sensing measurements form the surface and from space. Global datasets of outgoing shortwave radiation and aerosol optical properties will be used together with mineralogy-based maps. Also, surface based measurements of solar radiation in specific locations will be used.

Key Question

How does the mineral composition of atmospheric dust influence the absorption and scattering of incoming solar radiation, and what are the broader implications for climate and energy balance? This question will guide the research in determining which areas depending on aerosol load and which mineral components contribute most to atmospheric warming or cooling and how their distribution affects different climate regions globally.



Global aerosol optical depth with Saharan dust event for 23.02.2022 based on Copernicus Atmospheric Monitoring Service data.

Skills or knowledge required for the project: Strong interest in atmospheric physics, solar radiation and aerosols, data analysis and experience with programming languages (Matlab, python). MSc or semester project with possible start in spring or fall 2025

Workplace: ETH Zürich or PMOD/WRC Davos

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

EarthCare Aerosol Optical Depth Validation using Surface-Based Sun Photometers

Background:

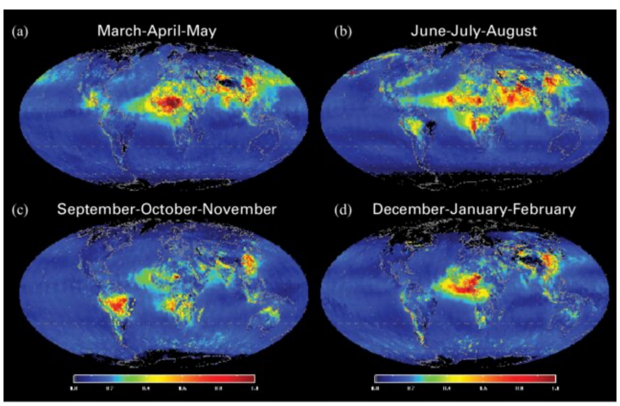
The EarthCare satellite mission, a joint initiative by ESA and JAXA, aims to improve our understanding of clouds, aerosols, and radiation balance in the Earth's atmosphere. One of the key components of this mission is the retrieval of Aerosol Optical Depth (AOD), a measure of aerosol concentration in the atmosphere. Surface-based sun photometers, such as those in the AERONET and GAW-PFR network, provide highly accurate AOD measurements that can be used to validate satellite observations.

The project:

This MSc project will focus on comparing AOD data retrieved from EarthCare with ground-based sun photometer measurements. The student will analyze datasets from various locations, assess uncertainties, and explore factors affecting discrepancies between spaceborne and ground-based observations. This will contribute to improving the accuracy of EarthCare's aerosol products. The student will have the opportunity to work with various datasets, apply statistical analysis techniques, and potentially contribute to the improvement of satellite aerosol retrieval algorithms.

Key Question

How can data from ground-based sun photometers be effectively utilized to validate and enhance the aerosol optical depth measurements obtained from the EarthCare satellite, thereby improving our understanding of aerosol impacts on climate and air quality?



Global aerosol optical depth maps taken from Lau et al.

Skills or knowledge required for the project: Strong interest in atmospheric physics, aerosols, data analysis and experience with programming languages (Matlab, python). MSc or semester project with possible start in spring or fall 2025

Workplace: ETH Zürich or PMOD/WRC Davos

Supervisors: Dr. Stelios Kazadzis stelios.kazadzis@pmodwrc.ch (PMOD/WRC, ETH), Kyriaki Papachristopoulou (PMODWRC)

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?

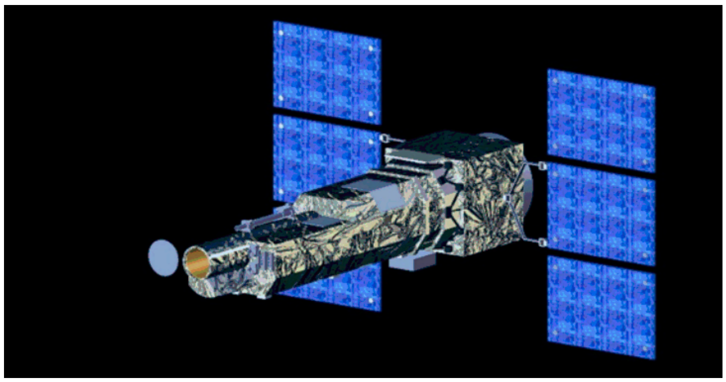


Figure 1 Solar-C (©NAOJ/JAXA)

The project:

PMOD/WRC 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)

Development of digitalised design workflow for structural analysis of space instruments

Background:

The Physikalisch-Meteorologisches Obersvatorium Davos (PMOD) has been developing optical instruments for space applications for decades. These products are designed, developed, and manufactured at the institute. These instruments must meet a wide range of requirements to fulfil the scientific objectives, to withstand harsh mechanical loading conditions during the satellite launch and to operate reliably once in orbit. For that reason, their lightweight structural design of the instrument housing must meet strict static, dynamic and thermal requirements.

The project:

Numerical structural analysis and optimization algorithms can enhance the mechanical performance by iterating certain design variables such as material distribution or wall thickness. In this project, a Python-based tool will be developed to serve as a robust interface between CAD design (SolidWorks) and the finite element discretized mesh (Nastran) of thin-walled structural components of a space instrument. This highly automated interface will enable seamless updates in both directions, ensuring smooth synchronization between CAD design modifications and finite element model changes. This workflow will establish a direct link between construction, prototyping, and analysis models, leveraging well-established Python libraries.

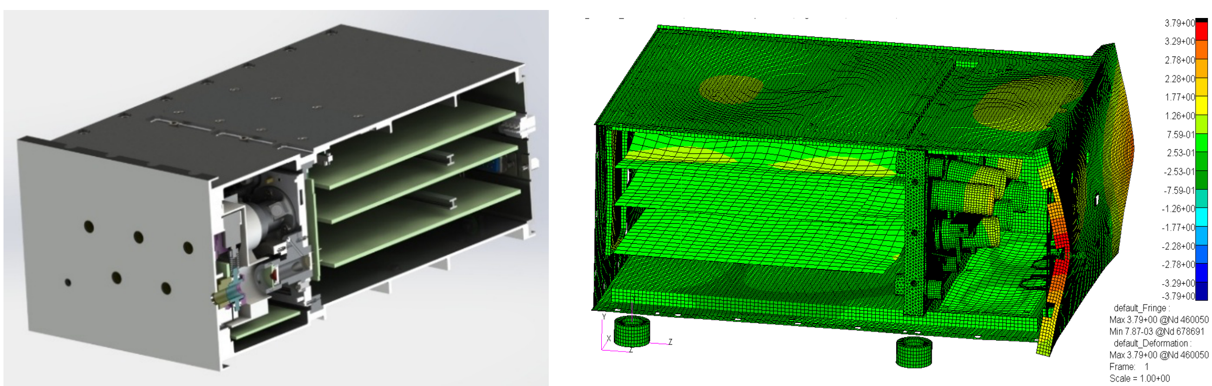


Figure 1: Space instrument design and modal analysis of the structure

Skills or knowledge required for the project:

- Basics of technical mechanics and experience with typical scripting environment (e.g. Python)
- Experience with an FE software (e.g. MSC Nastran) and/or CAD software (e.g. Solidworks) is beneficial but not required

Workplace: ETH Zürich (remote) or PMOD/WRC Davos

Supervisors: Oliver Schwahofer oliver.schwahofer@pmodwrc.ch (PMOD/WRC)

Optimal control of the absorbing blackbody temperature in solar radiometers

Background:

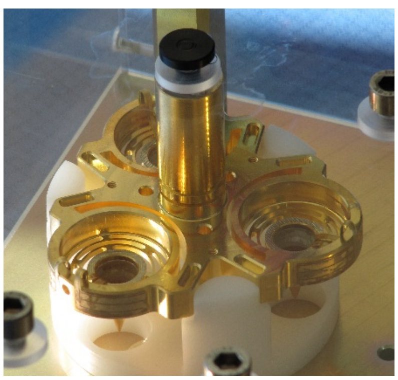
The state-of-the-art technology to measure the Total Solar Irradiance (TSI) accurately is electrical-substitution radiometry. The principle of such radiometers is based on absorbing blackbodies that are electrically heated to maintain a stable temperature. The solar radiation is modulated using a shutter and the difference in electrical power needed for the temperature to remain constant between open and closed shutter periods is equal to the absorbed radiative power. PMOD/WRC has been developing both Earth- and space-based radiometers for decades (e.g. EURECA, PICARD, PROBA-3, and TRUTHS).

The project:

Until now, PMOD/WRC radiometers use a proportional-integral (PI) controller to keep the absorbing blackbody temperature at a constant value. The challenge is to design a controller that on the one hand rejects big perturbations quickly but on the other hand does not excessively amplify the noise in the temperature measurement once steady-state is reached.

Based on these instruments being well modelled systems operating in a controlled environment, *optimal control* has the potential to perform this task better than the currently used PI controllers.

The objective of this MSc thesis is to compare suitable control algorithms for the temperature control, improve system identification, and validate the findings on a laboratory setup .



Absorbing blackbodies of the Digital Absolute RAdiometer (DARA).

Key question:

Can the current temperature controller be significantly improved?

Skills or knowledge required for the project:

- Strong interest in control engineering
- First experience with system modeling software (e.g. OpenModelica, Simulink)
- Ideally first experience with software prototyping and interfacing with laboratory equipment (e.g. python, LabVIEW)

Workplace: PMOD/WRC Davos to conduct experiments

Supervisor: Florian Reinhard florian.reinhard@pmodwrc.ch (PMOD/WRC)

Analysis of the atmospheric life cycle and surface deposition of cosmogenic nuclide 36Cl

Background:

Cosmogenic nuclides, including ^{10}Be, ^{36}Cl, and ^{14}C, are generated in the atmosphere through the interaction of precipitating energetic particles with the atmospheric constituents. These energetic particles mostly originate from the galactic cosmic rays (GCR), but during solar proton events (SPEs) there is an additional production of nuclides from solar protons. For SPEs with energies less than 100 MeV, the production of ^{36}Cl is significantly higher than that of ^{10}Be. The observed ratio of $^{36}Cl/^{10}Be$ is used to reconstruct the energy spectra of SPEs. This project aims to enhance our understanding of the 36Cl behavior in the atmosphere by adding its treatment to a global chemistry-climate model.

The project:

This project concentrates on cosmogenic nuclide ^{36}Cl. We will model natural and anthropogenic (nuclear tests) production, transport, and deposition of ^{36}Cl and its time evolution with the global chemistry-climate model and analyze model output with full and simplified chemistry treatment for the first time. Simulated data will be compared with available observations over the 20th century.

Key Questions:

Are the atmospheric life cycle and deposition patterns of ^{36}Cl significantly different from those of ^{10}Be? How different is it for the different production sources?

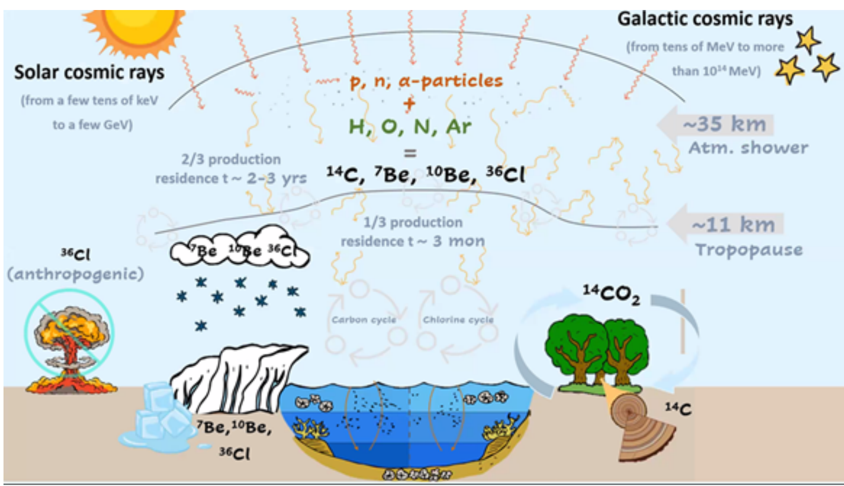


Figure: Schematic illustration of the production and deposition of cosmogenic isotopes.

Skills or knowledge required for the project: Strong interest in atmospheric sciences, data analysis, and some experience with programming languages (Python, Matlab, Bash, etc).

Workplace: ETH D-PHYS, possibly PMOD/WRC Davos

Supervisors: Dr. Tatiana Egorova tania.egorova@pmodwrc.ch (PMOD/WRC), Dr. Timofei Sukhodolov Timofei.Sukhodolov@pmodwrc.ch (PMOD/WRC), Prof. Louise Harra (ETH/PMOD)

Coronal Mass Ejections evolution during long term evolution of an active region

Background:
Active regions are the most dynamic structures in the solar atmosphere. They are one of the sources of the large amounts of material released from the solar atmosphere, known as coronal mass ejections. These are often, but not always, associated with flares, abrupt brightenings observed over their source regions. These coronal mass ejections affect interplanetary space, and can reach Earth then create aurora, as well as influence our technology. They can cause damage to satellites and even lead to deorbiting. It is important to understand how coronal mass ejections are related to their source region.

The project:
The project focuses on coronal mass ejections originating from an active region that were observed over more than three solar rotations. One of the coronal mass ejections related to this active region caused auroras around the globe, including in Switzerland (see image), on 10 May 2024. The active region was continuously tracked by satellites: Solar Orbiter monitoring the far side of Sun, and Solar Dynamics Observatory and Solar and Heliospheric Observatory near Earth. The student will analyse this unique data set to identify coronal mass ejections related to this active region and investigate the evolution of their properties during the active region's lifetime.

Key questions:

(1) How does the frequency of coronal mass ejections change throughout the lifetime of an active region? (2) How do the properties of coronal mass ejections (e.g. propagation speed) change during the lifetime of an active region?

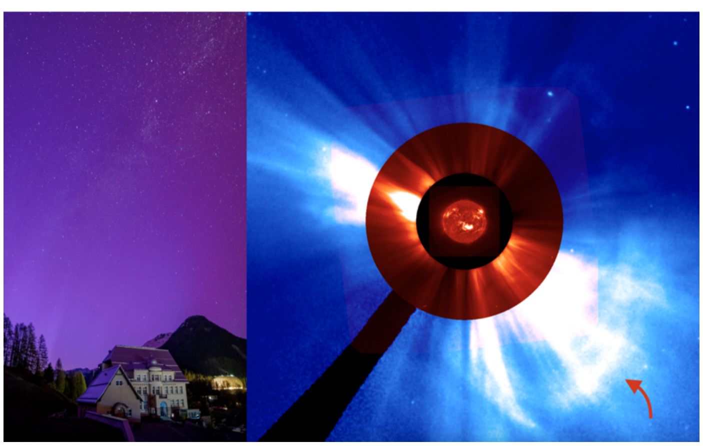


Fig. *The aurora observed above PMOD/WRC in Davos on 10 May 2024 (left) originating from coronal mass ejection (right), observed with SOHO and SDO satellites, highlighted with read arrows.*

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 : Prof. Louise Harra louise.harra@pmodwrc.ch (ETH, PMOD/WRC), Dr. Yingjie Zhu yingjie.zhu@pmodwrc.ch (ETH), Dr. Krzysztof Barczynski (PMOD/WRC) and Dr. Ioannis Kontogiannis ikontogianni@phys.ethz.ch (ETH)

Analysis of solid particle injection strategies for geoengineering

Background:
Stratospheric aerosol injection (SAI) is one of the most widely discussed scenarios for potential future solar radiation modification to counteract climate change. The traditionally considered sulfur-based SAI approach has side effects, such as stratospheric ozone depletion and absorption of terrestrial radiation, which has important implications for large-scale atmospheric circulation and regional climate. Using different injection locations, amounts, and timing these side effects can be somewhat reduced. In recent years, less absorptive materials have been suggested as an alternative to sulfate, such as calcite and diamond dust. However, all research on solid particle injections has been so far just repeating the default injection schemes of SO2, and there were no experiments to identify their optimal injection strategies, while the behavior of solid particles in the atmosphere has significant differences compared to sulphate aerosols.

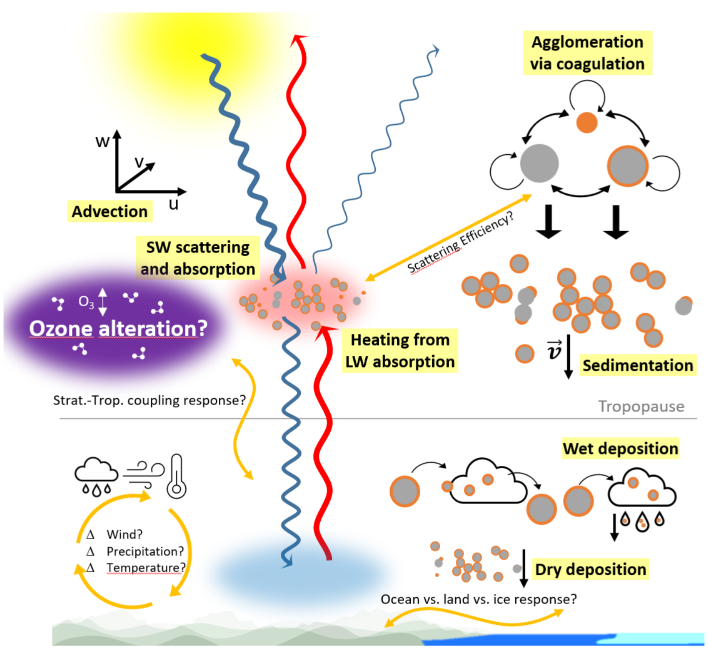


Figure 1: Schematic illustration of the processes involved in the SAI

Key question: What is the optimal SAI strategy for non-absorptive materials?

The project: Analyse different simulations with a global chemistry-aerosol circulation model (SOCOL) where several injection scenarios are applied for various SAI materials. The focus will be on analyzing the changes in physical quantities such as temperature, precipitation, winds, etc.

Skills or knowledge required for the project: Strong interest in atmospheric sciences, data analysis, and some experience with programming languages (Python, Matlab, Bash, etc).

Workplace: ETH D-PHYS, possibly PMOD/WRC Davos

Supervisors: Dr. Jan Sedlacek jan.sedlacek@pmodwrc.ch (PMOD/WRC), Dr. Timofei Sukhodolov Timofei.Sukhodolov@pmodwrc.ch (PMOD/WRC)