Strategy 2024-2027

Executive Summary

The Physikalisch-Meteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC) has six key areas that will be further developed in the next four years. The core World Radiation Center tasks are supported through core funding from the Bund, Kanton and Gemeinde. The space projects and additional science research are funded through different third-party sources. These are all supported by administration and IT. The six key areas 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. This is Switzerland's contribution to the World Weather Watch Programme of the World Meterological Organisation (WMO).

- *Space projects*: design, develop and operate 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, solar variability impacts, and climate evolution.

- *Solar Physics*: research the causes of solar activity and impact on the Earth.

- *Teaching*: carry out teaching at different levels at ETH-Zürich as well as public outreach activities.

1 Introduction

Since its establishment in 1907, the Physikalisch-Meteorologisches Observatorium Davos (PMOD) has been studying the influence of solar radiation on the Earth's climate. Since 1970 PMOD has been operating the World Radiation Center (WRC) as Switzerland's contribution to the World Weather Watch Programme of the World Meterological Organisation (WMO). PMOD/WRC's core mission is to serve as an international calibration center for meteorological radiation instruments. We develop radiation instruments for use on the ground and in space. We research the influence of solar radiation and activity on the Earth's climate and its impact on the Earth's atmosphere.

The next 4 years sees new instrument development both on the ground and in space. The collaborations with the physics department (and other departments) at ETH-Zürich continues to develop in teaching, research, and technology. The following sections summarise our strategy for the next 4 years in each of our key areas.

2 World Radiation Center (WRC) Strategy

Radiation measurements are a fundamental, integral part of meteorological observations and climate monitoring. The WRC plays a crucial role in maintaining quality standards in global climate monitoring programmes. The World Radiation Center is operated by PMOD/WRC on behalf of the World Meteorological Organisation (WMO) and consists of four sections:

- Solar Radiometry Section (WRC-SRS).
- Infrared Radiometry Section (WRC-IRS).
- World Calibration Center for UV (WRC-WCC-UV).
- World Optical Depth Research and Calibration Center (WRC-WORCC).

The terms of reference of the WRC are to:

- Develop, operate, and maintain reference radiation instrumentation for solar and infrared (terrestrial) radiation as well as atmospheric turbidity measurements.
- Initiate and support initiatives (e.g., global networks and research infrastructure consortia) for the homogenisation of world-wide radiation & aerosol optical depth measurements.
- Implement and maintain a Quality Management System according to ISO 17025.
- Perform research on the impact of solar and infrared radiation on Earth's climate.
- Provide capacity building to operators of radiation instrumentation.

Over the next 4 years, the objective will be to consolidate, strengthen and expand the role of the WRC as world reference center for solar and terrestrial radiation measurements. The designation of PMOD/WRC by METAS has been extended to cover solar spectral irradiance and the ECV surface radiation budget. We will extend the quality management system to all WRC sections, and where appropriate, submit corresponding Calibration and Measurement Capabilities (CMC) through the International Committee for Weights and Measures Mutual Recognition Agreement (CIPM MRA). To demonstrate traceability of the corresponding measurements to the SI, collaborations with national metrology institutes through joint initiatives such as EURAMET's European Partnership on Metrology (EPM) projects are implemented.

The dissemination of the radiation scales to the international community to provide traceable measurements to the SI through WRC references is performed by the following activities:

- International campaigns at PMOD/WRC with the participation of meteorological agencies, universities, and research institutions.
- Participation to regional calibration campaigns (for example organised within the WMO framework).
- Deployment of reference instruments at national and global monitoring networks including research infrastructure consortia (e.g., ACTRIS)
- Participation to measurement campaigns.
- Providing fiducial reference measurements (e.g., traceable measurements) for the ground-truthing of satellite-based Earth-Observation (EO)-products.

Sections 2.1 to 2.10 will summarise the goals for each section of the World Radiation Center and their associated tasks. In addition, sections 2.11 and 2.12 describe the atmospheric ozone monitoring activity, which is an operational task performed on behalf of MeteoSwiss. Sections 2.13 to 2.15 describes capacity building, instrument sales and facilities. Section 2.16 and 2.17 finish with third part funded solar energy applications.

2.1 Solar Radiometry Section (SRS)

The SRS will continue to provide traceability for solar radiometers according to ISO 17025 as well as through the International Pyrheliometer Comparisons IPC-XIV (2025). We will continue to improve our irradiance standards by implementing new technologies and maintain the stability of the World Radiometric Reference (WRR) by regular interlaboratory comparisons.

In space we will focus on the implementation of data-driven methods (machine learning) to process, validate, and correct the measurements from our solar radiometers. All space-

related work is funded by 3rd parties, but synergies with the WRC activities are exploited when and where possible.

Our tasks for the next four years include:

- The SRS calibration laboratory holds two Calibration and Measurement Capabilities (CMCs) for direct and global solar irradiance, respectively, and calibrates over a hundred pyranometers and pyrheliometers each year. Both CMCs refer to the WRR as the reference system for calibrations. The WRR is a conventional reference scale which was first introduced by WMO in 1977 to harmonize solar irradiance measurements worldwide. It is governed by WMO (WMO- No. 8) and realized by a group of pyrheliometers (WSG). Although the WRR is expressed in W/m^2, the scale has a discrepancy of 0.3% with respect to SI units, with the WRR reading higher (Fehlmann et al. 2012). We plan to re-define the WRR, aligning it with SI units, and propose a change of reference to the WMO CONGRESS 2027 session. The “WSG 2.0” concept will introduce full metrological traceability for current and future WSG radiometers, which will continue to serve as working standards for daily operations. Since 2006 transfer standard group of modern-type radiometers has been formed and maintained through regular (yearly) interlaboratory comparisons. The radiometers from the transfer standard group will be able to step in for the current WSG radiometer in case of failure.
- Cryogenic radiometers (Martin et al. 1985) have served within the SI as the reference technology for radiometric measurements since the 1980s. Starting in 2008 the PMOD/WRC together with NPL and METAS have developed and built a cryogenic radiometer for outdoor use which can measure solar power levels. This Cryogenic Solar Absolute Radiometer (CSAR) works in tandem with the Monitor for Integrated Transmission (MITRA), which determines the effective attenuation of the solar spectrum by the front window of CSAR at the time of the measurements (Winkler 2012, Walter et al. 2017). The CSAR & MITRA will be proposed to the WMO congress in 2027 for providing SI traceability for solar irradiance measurements.
- Machine-learning was successfully used to correct the degradation of the solar radiometers on board the SOHO/VIRGO space mission (Finsterle et al. NatSR 11, 2021). We will extend the methods to be used also for lower-level data processing from other space missions.
- Produce irradiance data products from our space instruments for climate and Earth Radiation Budget (ERB) research and provide them to the research community.

2.2 Implementation Plan: Solar Radiometry Section (SRS)

- Organize and conduct the 14th WMO International Pyrheliometer Comparison (IPC-XIV) in 2025.
- Fully characterize CSAR & MITRA and work with WMO ET-RR to propose CSAR & MITRA as the new primary reference to the WMO session 2027. This work is

funded by Karbacher Fonds and exploits synergies with the TRUTHS space project.
- Disseminate the new standard in pyrheliometer comparisons and inform the participants, in particular RRCs and NRCs, about the recommendations by WMO ET-RR to transition to the new reference.
- Calibrate the WSG radiometers against the new primary reference (CSAR & MITRA) and continue using them as working standards in the calibration laboratory (WSG 2.0 concept).
- Evaluate opportunities for establishing a 2nd, independent realization of the new primary reference.
- Work with master students of ETH AI Center to develop machine-learning applications for processing TSI data from space experiments.
- Maintain and update regularly the operational TSI and TOR (CLARA) time series on the PMOD/WRC ftp server.

2.3 Infrared Radiometry Section (IRS)

The IRS will continue to provide SI-traceable calibrations of terrestrial radiation instrumentation (pyrgeometers) according to ISO 17025 as well as through International Pyrgeometer Comparisons.

The terrestrial radiation scale is currently defined by the World Infrared Standard Group of Pyrgeometers (WISG). Together with the expert team on radiation references of the WMO, the traceability of terrestrial radiation measurements to the SI will be redefined using at least two candidate radiometers, of which one, the Infrared Integrating Sphere (IRIS), has been developed at PMOD/WRC, while the second, the Absolute Cavity Pyrgeometer (ACP), was developed by NREL, USA. This activity will be supported through the submission of a CMC on terrestrial irradiance, which has become possible because of the extension of the designation of PMOD/WRC as designated institute in the field of “Essential Climate Variable: Surface Radiation Budget”, by METAS in 2023.

2.4 Implementation Plan: Infrared Radiometry Section (IRS)

- Organisation of the 4th International Pyrgeometer Comparison (IPgC-IV) in 2025.
- Submit a Calibration and Measurement Capability (CMC) for terrestrial irradiance to the BIPM to demonstrate traceability of terrestrial irradiance to the SI (initial submission planned in 2024).

- Work with the ET-RR (Expert Team on Radiation References of the WMO) to establish a new terrestrial irradiance reference based on the IRIS.
- Disseminate the new standard in pyrgeometer comparisons and inform the participants, in particular RRCs and NRCs, about the recommendations by WMO ET-RR to transition to the new reference.

2.5 World Calibration Center for UV (WRC-WCC-UV)

The WCC-UV will continue providing SI-traceable calibrations of solar UV irradiance measurements for solar UV filter radiometers and solar UV spectroradiometers. The calibration activities are underpinned by six Calibration and Measurement Capabilities (CMCs) which demonstrate the SI-traceability of these activities.

The quality assurance of solar UV monitoring stations will be continued by using the transportable reference spectroradiometer QASUME to provide on-site calibrations of solar UV monitoring spectroradiometers at a European and global scale.

The International UV calibration campaigns are held every 5 years at PMOD/WRC to provide traceability of the world-wide solar UV measurements to the SI.

2.6 Implementation Plan: World Calibration Center for the UV (WRC-WCC-UV)

- Organisation of the 4th Ultraviolet Calibration Campaign (UVC-IV) in 2027.
- Offer on-site calibration and quality assurance to solar UV monitoring sites through the deployment of the transportable reference spectroradiometer QASUME. Campaigns have already been planned for the years 2024, 2025, and 2026.
- Regular calibration activity for filter UV radiometer calibrations at PMOD/WRC.
- Participation to three projects within the European Metrology Program (EPM) NEWSTAND, Scale-Up, MeliDos (2023-2026).

2.7 World Optical Depth Research and Calibration Center (WORCC)

The WORCC will continue providing traceable calibrations of spectral aerosol optical depth (AOD) with respect to the Global Atmosphere Watch Precision Filter Radiometer

(GAW-PFR) reference for AOD as defined by the WMO. In addition, WORCC has become a member of the European Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS), Centre for Aerosol Remote Sensing (CARS). Within CARS, WORCC will provide SI-traceability to the European AOD monitoring network within ACTRIS.

WORCC is implementing the quality system ISO 17025 for its calibration activities, and discussions have been initiated with the international metrology community within the Consultative Committee for Photometry and Radiometry (CCPR) of the BIPM to establish a new metrology branch for Essential Climate Variables to submit CMCs to demonstrate formal traceability for these parameters.

2.8 Implementation Plan: World Optical Depth Research and Calibration Center (WORCC)

- Organisation of the sixth Filter Radiometer Comparison (FRC-VI) at PMOD/WRC (2025).
- Providing traceability to the Centre for Aerosol Remote Sensing (CARS) of ACTRIS via the deployment of travelling reference filter radiometers (PFRs) to European reference sites to provide continuous traceability measurements to WORCC. The activity is supported by the ACTRIS Swiss project until 2025 and after 2025 is going to be funded by both national initiatives and directly from ACTRIS through the official inclusion of PMODWRC in the ACTRIS/CARS partner institutes.
- Renew and expand the current MoUs with the Skynet Network and with important calibration and measurement facilities (e.g. AEMET, NILU).
- Initiate an EURAMET traceability project with the German NMI PTB to achieve traceability of aerosol remote sensing properties to the SI (activity is an outcome of the EMPIR 19ENV04 Metrology for Aerosol Optical Properties MAPP project)
- Develop a Lunar PFR Triad for providing traceability of lunar irradiance and AOD based on lunar irradiance measurements.
- Continue evaluating array spectroradiometers for the retrieval of spectral AOD as a complement and potential replacement for filter radiometers.
- Continue contributing towards capacity building towards aerosol theory and sun photometer use in training schools (e.g. WMO – GAWTEC) and dedicated workshops.

2.9 GAW-PFR aerosol monitoring network (GAW-PFR)

PMOD/WRC has been responsible for the operation of the GAW-PFR network for aerosol optical depth measurements since the late 1990's. For that purpose, it has developed the Precision Filter Radiometer (PFR) of which more than 80 units have been built. Currently,

more than 40 PFR instruments are operated worldwide, of which 18 by MeteoSwiss. To ensure the long-term operation of the GAW-PFR network and sites maintained by associated institutes, new PFRs have been constructed to replace instruments which are approaching their end-of-life status. Additional improvements consist of enhancing the aerosol related products retrieved from GAW-PFR, to implement spectral AOD measurements using Precision Spectroradiometers (PSRs) at PMOD/WRC and review the GAW-PFR network in view of relocating sites related with currently missing aerosol types (e.g., biomass burning and dust aerosols). The network visibility will be expanded through peer reviewed publications, conference presentations and an interactive website with online provision of the PFR data.

2.10 Implementation Plan: Global Atmosphere Watch Precision Filter Radiometer (GAW-PFR) aerosol monitoring network

- GAW-PFR is supervised by the WMO Scientific Advisory Group for Aerosols and data continue being submitted to the WMO World Data Center for Aerosols.
- We plan to expand or relocate stations of the GAW-PFR network based on the results from the GCOS-CH funded projects (2019-2020 and 2021-2023). Enhanced products (e.g. effective radius and volume) will be derived by implementing the GRASP inversion model in operational basis based on the QA4EO project funded by ESA (2023-2024).
- In parallel, we plan to enhance the GAW-PFR networking activities including national (Germany, Sweden, Finland, MeteoSwiss) networks through the COST action on aerosol spectroradiometry (Harmonia) led by PMOD/WRC (2022-2026).
- Exploit the GAW-PFR datasets in the ESA funded project QA4EO (2021-2024) towards improving surface-based retrievals through algorithm improvements and in the EU-funded project CERTAINTY (2024-2028) on aerosol – cloud interactions.
- Provide capacity building through participation to EU Teaming funded project Excelsior (2022-2026).

2.11 Atmospheric ozone

The atmospheric ozone monitoring activity is an operational task performed on behalf of MeteoSwiss. Three Dobson and three Brewer spectroradiometers are operated at PMOD/WRC, Davos to monitor the atmospheric ozone layer after their transfer from Arosa was successfully achieved in 2021. This is the longest time series of Ozone Dobson measurements worldwide. Our main tasks are to operate and maintain the

instrumentation, perform quality assurance and quality control of the data, and support MeteoSwiss in the analysis and interpretation of the data. The objective is to maintain and reinforce this facility as the reference center for atmospheric ozone monitoring, support climate assessments, and develop, test, and validate new instruments to monitor the atmospheric ozone layer. The aim is to valorise this unique dataset through third party funded projects and through national and international scientific collaborations.

2.12 Implementation Plan: Atmospheric ozone

- Aim to get support through MeteoSwiss and BBL for a new building to host the Dobson spectrophotometers to improve the temperature stability, optimize the energy consumption and reduce the footprint in the “measurement garden” to allow for intercomparison campaigns with Brewer & Dobson participants.
- Prepare an event (symposium) to celebrate the 100-year anniversary of the Arosa/Davos ozone time series, 2026. This will be organised together with MeteoSwiss.
- A Dobson calibration campaign (RDCCE) will be organised in August 2024.
- The Regional Brewer Calibration Campaign is organised every 2 years with the support of the Central Calibration Laboratory for Brewer at AEMET, Spain. The event is open to additional participants. The next event will be held together with the RDCCE in August 2024.
- Scientific valorisation of the Arosa/Davos datasets is planned through SNF funded projects. The project “Quantifying past, present and future Stratospheric and Tropospheric Ozone over the Alps and Europe (STOA).” has been submitted to the SNF in October 2023, and if accepted will provide a scientific assessment of the ozone changes over Europe with the collaboration of MeteoSwiss and BOKU, Austria.

2.13 Capacity development

Current WRC training activities will be expanded to provide capacity development and educate local site operators and scientists to the best practice of solar and terrestrial radiation measurements and calibrations. Due to the increased recognition by the WMO and the international community of the importance of providing traceable measurements for climate assessments, there is a need for specific training and capacity development in this area which PMOD/WRC can offer with particular emphasis on the transition to new standards due to its involvement in the metrological (PMOD/WRC is signatory of the CIPM Mutual Recognition Agreement) and meteorological communities. Such activities include leading European networking actions, participating in WMO related schools (e.g., Global Atmosphere Watch Training and Education Centre, GAWTEC) and participating in other networking and capacity building activities based on global networks or European

research infrastructures. In addition, PMODWRC is aiming to transfer the existing knowledge on solar and aerosol measurements to institutes worldwide through teaming or twinning EU funded opportunities.

2.14 Instrument development and sales

The continuous development and improvement of reference instruments to fulfil the core objectives of the WRC is also an opportunity for providing these instruments to the international community and thereby consolidating the reputation of the PMOD/WRC as highest quality radiation instrument manufacturer.

2.15 Radiometric laboratory facilities

The radiometric facilities of the WRC will be maintained and expanded to satisfy the demands of the various WRC sections and the space activities of the PMOD/WRC. Furthermore, these unique facilities will be made available to external customers at an appropriate cost.

2.16 Solar energy research and applications

This activity is supported through third party funding from national and international funding agencies (e.g. the European Commission science and research programme).

PMOD/WRC has been leading the development of the Solar energy nowcasting and forecasting System (SENSE/nextSENSE). We plan to use such a model in order to contribute towards the GEOS/EuroGEO related goals including GEO vision for energy. In addition, we will initiate research activities towards improving nowcasting and forecasting of solar energy related algorithms and techniques.

2.17 Implementation for solar energy

- Exploitation of the developed application and methods towards new projects related with Earth observation though EuroGEO initiatives (GEO vision for Energy and GEO Cradle – capacity building-) and ESA related initiatives related with the new initiative Destination Earth (DestinE).
- Participation in the renewable energy action group of EuroGEO.

- Enhance collaboration with Swiss groups dealing with solar radiation and energy applications.

3 Space Projects strategy

Putting instruments into space provides a clean environment, with continuous observations, and no dependence on weather conditions. Continuous solar irradiance measurements are an important international goal as input into climate models, such as those from the SOHO-Virgo mission. Incoming solar radiation and outgoing reflected radiation will be measured with the TRUTHS mission to provide standards in space. Instruments in space can provide us with different views unobtainable from Earth such as the Solar Orbiter Mission getting in close to the Sun and out of the ecliptic plane. We are taking observations of the Earth's radiation balance with the PMOD-built Compact Lightweight Absolute Radiometer (CLARA). The JAXA Solar-C mission will provide important measurements of the solar irradiance that impacts different layers of the Earth's atmosphere. These are all important research areas within the institute that are respected internationally. The space instrumentation provides key opportunities to work with industry within Switzerland.

3.1 Operational Spacecraft

There are five operational spacecraft that we designed and built instrumentation for. SOHO-Virgo is the longest dataset – now at 28 years old. CLARA is an innovative small satellite and continues to operate. The technology demonstrator mission, Proba-2, has our Lyra instrument onboard which is still operational. Solar Orbiter was launched in February 2020, and PMOD/WRC is involved in two instruments (EUV Imagers and the spectrometer, SPICE). Our more recent launch was JTSIM-DARA on 4 July 2021 which is operating successfully. The Proba-3 DARA instruments will soon join the fleet with a launch in 2024. In 2023 we successfully obtained funding for the key operations phases of these missions through ESA Prodex. This provides security in our involvement in the scientific phase of these missions.

We are responsible for different aspects of operations and calibration activity for each mission. Each mission has different demands and different complexities and requires intensive cooperation with the spacecraft operations and coordination with other instruments both on other space missions and ground-based observatories.

3.2 Future Spacecraft Mission Involvement

Space missions are developed over many years, and we are involved in a number of these at different stages. Our involvement is through irradiance instruments and in more recent years through imaging instruments.

There are two space missions that we have received funding for and are in the development phase.

- Traceable Radiometry Underpinning Terrestrial- and Helio- Studies (TRUTHS) – this is an ESA mission in which the industry prime is Airbus Defence and Space, UK. It is building on the CSAR instrument described in Section 2.1. A collaboration within Switzerland has been proposed to ADS and it is planned that we continue development in 2024 on this instrument.
- Solar-C – this is a JAXA-led mission, and we have a solar spectral irradiance monitor (SoSPIM) on the mission. We are going through Preliminary Design Review (PDR) for the instrument in autumn 2023 and phase C/D to build the flight model will start after this. Launch is due in 2028 in Japan.

We are involved in the proposal submission to NASA for involvement in the EUV Imager in the Vigil mission. Vigil is ESA's space weather mission (previously known as Lagrange) in which we were involved in the development of an imager. NASA has now taken responsibility for the delivery of an imager. The NASA selection will be in spring 2024.

We have also been involved in proposals to the Heliophysics decadal in the US which includes future solar polar missions. The outcome of the decadal will be known in 2024. These concepts are for missions launched in the 2030s.

3.3 Implementation plan for Space projects

A key issue is ensuring involvement in the operations of the missions we're involved in. It is key that this funding is maintained to provide a strong science return for the investment in the instruments that we build.

We will continue to work with our international collaborators on the projects currently in design and build phase. Solar-C is due to be launched in 2028, so before this we need a clear science strategy to optimise the science return. This will be developed before the launch of Solar-C and the plan will feed into space weather aspects. PMOD/WRC staff are actively involved in high level planning of the mission's operations and how it will coordinate with other space and ground-based facilities.

Another key issue is managing the workload on the space projects – these have peaks and troughs in workload that are sometimes unpredictable. We have developed collaborations with ETH D-PHYS technical pool that we can build on to support some of these activities. We also need to maintain the balance in workloads between the space projects and the WRC activities in the technical department.

For longer term future projects such as polar missions or radiometers on other planets, we will develop plans and proposals with international partners when opportunities arise.

4 Technology Strategy

The technology department has world recognised skills in electronics and mechanics for instrumentation. The technology department has a broad remit covering instruments and maintenance of the World Radiation Center instruments (which are many) alongside highly specialised space instruments which are funded from third party funds. The major tasks are:

- Maintenance of specific WRC infrastructure (hardware and software)
- Space projects: project management, product assurance, system engineering, subcontractor management
- Space instruments development, manufacturing, and testing
- Support of terrestrial PMOD/WRC research projects and infrastructure
- Research instrument development and manufacturing (e.g prototypes or single instrument developments)
- Small series instrument production and repairs of customer instruments
- Operation and maintenance of PMOD/WRC technical infrastructure (electronics & mechanics labs, workshop, cleanroom, vacuum lab etc,)
- Scientific support for operational space instruments
- Offering and performing of external services (e.g., space projects environmental testing).
- Institute's IT infrastructure
- Apprentices' education
- Safety officer and housekeeping

The technology department manages many different tasks with different deadlines and pressures from space agencies, international partners and internally. In the next four years the following areas will be enhanced and developed:

- **WRC Support:** The technics department is responsible for the proactive support of the WRC in system maintenance and development. This task as well as new developments in cryogenic measurements are important in the next years.
- **Instrument development & manufacturing:** Existing ground-based instruments will be developed and manufactured. New instruments will be designed. Increased collaboration with science, institutes, universities, agencies, and industry are key to achieve new high-end instruments. Miniaturization of space instruments is a goal to provide more opportunities to launch instruments.

- **Innovation:** To strengthen PMOD's position as a leading research institute, new technologies and new instruments shall be developed based on needs and requirements from science department, both for ground and space.
- **External Services:** PMOD has an extensive technical infrastructure and expertise in development, manufacturing, and testing activities. This infrastructure and know-how shall be offered more extensively to other institutes and industry as external services.
- **Education:** Apprenticeships in different disciplines shall be offered. The technology department will also offer and supervise Bachelor- and Master theses.
- **IT:** The demands on IT are constantly increasing. This includes future challenges such as cyber security, data handling, user support, and flexible working options,

4.1 Implementation plan for the Technology Department

The retirement of one of the co-heads of the technical department early in the coming strategy period leads to a re-organisation of the team. A new engineering group lead is responsible for the technology department overall staff leadership, the link to the other institute departments and the top-level tasks coordination.

Several measures are planned to achieve the goals set in the Technology strategy.

- **Team and skills.** To maintain and expand the know-how and skills, jobs must be maintained and developed. A competence centre for instrument development for ground and space applications shall be created. The know-how in space projects will be better distributed and to be used for external services. To be ready for the future of the WRR, cryogenic skills shall be built up either internally or through collaboration.
- **Efficiency.** Efficiency is to be increased through improved processes in project management, planning and development, as well as through targeted coaching, further training, and synergies with other institutes.
- **Collaboration.** The collaboration within PMOD, with other institutes in Davos, with ETH, with FHGR and other universities of applied sciences shall be intensified. In this way, synergies can be exploited, and innovative ideas implemented. The use of the ETH IPA and D-PHYS technical pools shall be developed. Closer collaboration with FHGR in the fields of photonics, AI in software engineering and computational and data sciences through BSc theses are planned.
- **Innovation**
  New, innovative technologies and instruments are to be developed in collaboration with the science groups and other partners. The cooperation with ETH should be used to initiate and realise innovative projects.

- **Education**
  Education is in the institute's DNA. Apprenticeships in different disciplines shall be offered. A new apprenticeship in mechanics as well as an optional apprenticeship in IT and/or physics lab technician shall be assessed.
- **External Services:** The existing know-how and infrastructure shall be used to become an established provider for space environmental testing in the Swiss space community. Vacuum tests, bake-out, outgassing tests, and other specific tests can be offered. These external services include planning, test setup, realisation, manufacturing of support equipment, and reporting. The build-up of the capacity for analysing molecular and particulate contamination samples shall be assessed. The external services shall help to ensure the financial means needed to maintain and develop the technical department. Through daily use, the infrastructure is kept technically at a good level and the handling of it is trained.

5 Climate Science Strategy

The climate modelling group studies the evolution of the Earth's atmosphere, ozone layer, and climate in the past and future using numerical models and observations. More specifically, the key expertise of the group lies in the research focused on the middle atmosphere. This region is the most responsive to and thus illustrative for any perturbations in Earth radiation balance and is characterized by large influences of both natural and anthropogenic forcings, strong chemistry-climate feedbacks, and vertical dynamical coupling to the lower and the upper atmosphere. Understanding climate and atmospheric composition responses to different forcings can help to improve projections of future climate and to identify the degree to which human activity can influence it. The range of forcings addressed by the group includes traditional ones like solar irradiance variations, energetic particle participation, volcanic eruptions, anthropogenic emissions of greenhouse gasses and ozone-destroying substances, as well as newly emerging potential future scenarios like solar radiation management using stratospheric aerosol injections, increase in rocket launches frequency, and evolution of the Earth's magnetic field.

The group already has a well-established role in the middle atmospheric, chemistry-climate modelling, and ozone layer scientific communities, and it is the only group in Switzerland that focuses on modelling of the ozone layer, the effects of solar variability on the atmosphere and climate, and chemistry-climate feedbacks. Moreover, the activities of the climate group link the operational duties of the WRC and the PMOD solar physics group with the context of fundamental global processes in the atmosphere and foreseen impacts of natural and anthropogenic factors in the future. The group and its modelling tool were initially created for this purpose, and the plan is to continue serving it. Also, it is important to continue maintaining such core group activities to represent and

underpin the interests of Swiss society in the international assessments and activities on the ozone layer and climate. Besides operational activities related to these topics, the group will search for new actual scientific problems and methods emerging from the quickly developing and changing scientific landscape. Given the limited size of the group, we try to maintain a dialogue and/or scientific integration with other groups with adjacent interests in Switzerland (PSI, IAC ETH, University of Lausanne) and abroad.

The group will continue working on the development and application of the Earth System Model (ESM) SOCOL (SOlar-Climate-Ozone Links), which is our main modelling tool and the only active model in Switzerland that can address questions related to the ozone layer evolution and solar geoengineering in their full complexity. The ESM SOCOL has interactive gas-phase/heterogeneous chemistry and bin-resolved stratospheric sulfate aerosol microphysics, coupled ocean and dynamical vegetation models, allowing to interactively simulate various feedbacks in the Earth system. The last version of the ESM SOCOLv4 was released in 2021 and is currently being actively exploited in various projects by us as well as by our collaborators worldwide. Such collaborators include groups in Finland, Austria, USA, Spain, and Denmark, for whom we run biweekly user meetings and provide user support. We will participate in any new bilateral collaboration calls relevant to our area of interest. Future development of the model will require transitioning to the new coupled climate Earth system model (ICON-ESM), as it provides a better scalability and application range, has large user community, and a potential to exploit graphics processing units (GPUs) in the future. Transitioning to ICON-ESM is an important future step to stay on track with the scientific requirements to the complexity of the modern ESM as well as with the changing availability of high-performance computing resources. Although the model is expected to be well good enough to be competitively used for the ozone, stratospheric aerosol, and solar variability science for the next 5-10 years, we will still search for funding for this important next step already in the allocated period of this strategy plan. Potential funding schemes for this activity would include participation in calls from the Platform for Advanced Scientific Computing (PASC) and Global Climate Observing System (GCOS) programs, which focus on technical developments.

The group will continue to participate in the international scientific collaboration activities: Chemistry-Climate Model Initiative Phase 2 (CCMI-2022), Interactive Stratospheric Aerosol Model Intercomparison Project (ISA-MIP), Hunga Tonga-Hunga Ha'apai eruption model intercomparison projects (Tonga-MIP and HT-MIP), and High Energy Particle Precipitation in the Atmosphere (HEPPA IV), Scientific Committee on Solar Terrestrial Physics (SCOSTEP), as well as the International Commission on the Middle Atmosphere (ICMA).

5.1 Implementation plan for Climate Physics

In terms of implementation, the group activities will be organized around three main key points:

1. Continuation of traditional operational activities, which include providing expert support and modelling data for the groups in PMOD/WRC and other groups in Switzerland in the questions related to the global processes linked to the ozone layer, stratospheric aerosols, solar variability, and their connection to climate and society.
2. Continuous search for actual scientific problems, related to the group's activities, strongly prioritizing collaborative opportunities with other groups. The climate group has already participated in several proposals with the groups within PMOD/WRC (with Julian Groebner and with Louise Harra) as well as is in the process of working on several project proposals with the groups from PSI (Markus Ammann, experimental chemistry), IAC ETH (Beiping Luo, aerosol microphysics) and University of Lausanne (Daniela Domeisen, stratosphere-troposphere coupling).
3. Scientific integration with the collaborative groups in Switzerland and abroad. Stronger connection to other institutes allows the climate group to broaden the potential range of activities, as well as provides additional resources in terms of computational facilities, students, tools, and discussions. For example, through such collaborations the group has access to computational resources in Finland, Austria, and US.

In terms of already confirmed and funded scientific investigations, in the next four years we will focus on the following topics:

- In addition to the known factors influencing the ozone layer and climate, in the future there could be new dangers, such as the quickly growing industry of rocket launches and geoengineering scenarios through stratospheric aerosol injections. Both these new factors can negatively impact the recovery of the ozone layer and substantially affect climate globally and regionally. We will explore potential future scenarios involving these two forcings in sets of numerical experiments by collaborating with international teams (New Zealand and US).
- Strong volcanic eruptions and solar variability in the past will be studied by using our model as well as available proxy-based climate reconstructions and direct ice core measurements. Comparing these experiments with the latest reconstructions and reanalysis of climate variables will allow us to investigate the importance of the natural forcings for the long-term climate evolution. We will exploit our model results to interpret measurements of sulphate and cosmogenic isotopes ^{10}Be and ^{36}Cl in ice cores. This is funded through Karbacher Fonds and SNSF (collaboration with France and Finland).
- Special attention will be paid to the recent Hunga Tonga-Hunga Ha'apai volcanic eruption. It was an underwater eruption with the explosivity being unprecedented in the satellite era. Although releasing only a modest amount of SO_2, this eruption co-emitted huge amounts of water vapor (10% of the whole stratospheric water vapor burden) and the resulting aerosol optical depth was the highest for the last 30 years. The combined aerosol and water vapor has caused substantial impacts

on the dynamics and chemistry of the stratosphere, which we will study with our model. This is funded through SNSF (collaboration with Austria and US).

- Geomagnetic excursions are a major factor that can influence the biosphere and climate, as the closest strong event of such kind (Laschamps event 41-42 ka ago) coincided with major environmental changes and the extinction of living species. The mechanisms of such potential influences are, however, still unclear. We will study the Laschamps event by using our model, as it can interactively treat all involved processes important for the proposed causation links. This is funded through SNSF (collaboration with Finland).

6 Solar Physics Strategy

The solar physics research areas are being driven by the missions that PMOD/WRC have played a part in defining and building such as Solar Orbiter (launched in 2020), and the future Solar-C mission to be launched in 2028. The science goals are focussed on understanding the physical phenomena on the Sun that impact the Earth, through magnetic fields, plasma, and energetic particles. The climate group has been studying the link between solar extreme events and impact on the Earth's atmosphere. The solar aspect of research links to this through understanding the physics behind space weather.

Solar Orbiter is a key mission for Switzerland with three of the ten instruments having PMOD/WRC and FHNW (Fachhochschule Nordwestschweiz) involvement. Louise Harra is co-Principal Investigator of both the EUV Images and the SPICE instrument. Säm Krucker (FHNW) is PI of the STIX instrument. Solar Orbiter observations are being coordinated with other space and ground facilities such as Hinode (Louise Harra was PI of the EIS instrument for 13 years), NASA Interface Region Imaging Spectrograph (IRIS) missions (Louise Harra is co-I), NASA Solar Dynamics Observatory and the new 4m ground-based solar telescope Daniel K. Inouye Solar Telescope (DKIST). Combining these impressive remote sensing datasets with in-situ datasets provides key linkage science to understand the creation of the solar wind and its propagation into the heliosphere. The new datasets that will be available in the coming years guarantee discovery level science. Each orbit of Solar Orbiter provides new science opportunities. The operations are planned until 2029. The questions below will be the focus:

- **Creation of fast solar wind**: *Understanding jet behaviour in coronal holes* The *fast solar wind* is known to come from coronal holes. Coronal holes, although described as 'holes' since they are dark in EUV and X-ray wavelengths, do show activity on small-scales, such as jets, plumes and bright points. An additional and intriguing phenomenon known as stealth jets has been found in the Hinode EIS spectroscopic data – these features are seen clearly in measurements of non-

thermal velocity but not in intensity. These dynamical processes have the possibility of contributing to the fast solar wind. We will develop observing strategies to physically understand these small-scale structures and how they can be linked to the solar wind. In 2025, the Solar Orbiter spacecraft will do another Venus flyby. This will take the mission out of the ecliptic plane to get the first proper view of the solar poles. This will be an intense focus of observational coordination and science.

- **Creation of slow solar wind**: *Understanding the evolution and magnetic sources of active region upflows.* The slow solar wind is highly variable and is known to come from a range of sources, from high out in the streamers to low down in the corona. In this work, we will focus on one potential source, which is based on one of the most significant results from the Hinode mission - that is the discovery of the consistent upflows at the edges of active regions. These are measurements as blue-shifts in the coronal emission lines. We have defined and carried out observing programmes with DKIST and Solar Orbiter. This takes advantage of not only new instrumentation, but also the different viewpoints which provide a stereoscopic and spectroscopic view for the first time.
- **What triggers solar flares**: *Understanding the differences between eruptive and non-eruptive flare triggers.* Solar flares are sudden releases of energy caused by the reconnection of magnetic field lines at regions of strong magnetic activity in the solar atmosphere (known as active regions). These events can accelerate particles to very high energies and emit very strong bursts of radiation across the electromagnetic spectrum. Sometimes they produce eruptions and energetic particles and sometimes they do not. We will explore different aspects of flares. One question is understanding where and how the flare is triggered. To do this we will take advantage of a spectroscopic observations with high spatial resolution coronal measurements.

6.1 Implementation plan for Solar Physics

Science from the Solar Orbiter mission is the focus of the group for the next 4 years. Harra currently has Karbacher Fonds to work on solar wind formation in which a new researcher will join in January 2024. We have also just received SNF funding that begins in 2024 for 4 years to study solar wind formation. We will be looking in addition, for a PhD student to focus on small-scale dynamics related to the fast solar wind.

The scientific links across Switzerland have been developed – these include FHNW, IRSOL, University of Bern, PSI and other departments within ETH which have an interest in the impact of the Sun on the Earth. We are planning for future funding to support collaborations on the topic of space weather which includes seminars and symposia.

Harra is a member of the ISSI team 'Novel Insights Into Bursts, Bombs, And Brightenings In The Solar Atmosphere From Solar Orbiter'. This takes advantage of the new perihelia data from Solar Orbiter. We will also propose ISSI teams in the future to develop interdisplinary fields for topics such as solar-ionospheric physics (impact of solar flares) and coordination between DKIST and Solar Orbiter facilities – both having complex and diverse datasets which allow us to address new science questions such as the magnetic field behaviour in the corona related to upflowing plasma regions.

In the next 4-year period, we will develop the science community that will be key to studying the impact of flares on the Earth's atmosphere using the data from our instrument SoSPIM on Solar-C. This science community will be diverse including solar physics, ionospheric physics, and modelling of the atmosphere.

7 Teaching Strategy

PMOD/WRC has a good history of successful PhD student training, and we aim to continue this. The strong link with ETH-Zürich continues to open new opportunities for teaching. A block course in D-PHYS led by Harra and Quanz on 'The Sun, stars and exoplanets' started in June 2020 and will continue annually. The course on 'Atmospheric Remote sensing' started in 2022 by Gröbner and Kazadzis hosted by the Environment Systems Science Department (D-USYS). In addition, all our PhD students and postdoctoral research assistants provide teaching assistant (TA) support in D-PHYS.

One of the goals is to enhance our interaction with ETH MSc students. We are now regularly having project students from ETH D-PHYS, D-USYS. In addition, we have had group projects in the ETH computer science department. The students are based on the science side of the institute dominantly. We would like to extend this to the technical department more frequently.

In 2022, the ETH Studio Davos was set up to allow internships in Artificial Intelligence, data science and remote sensing. We have had one student to date through the internship scheme and will develop ideas to foster this collaboration and opportunity. In 2024 we will collaborate also on a project with Lab42 in Davos.

7.1 Implementation plan for Teaching

We will continue with teaching at ETH and take opportunities that arise for teaching some lectures in different courses. We provide support for general astrophysics at ETH but also specialization in Solar and Climate Physics to attract new generations of scientists in these fields related to PMOD.

We will develop our projects for students for semester and MSc projects. The projects include collaborations between science group within PMOD and outside. An example is the development of projects based on the impact of solar flares on the Earth's atmosphere bringing together synergies between the Solar and Climate modelling groups. We will collaborate with ETH and FH Graubünden for students interested in technical projects.

We will develop projects for ETH Studio Davos and search for appropriate collaborations with other local research institutes.

8 International cooperation, outreach strategy

We consider it of importance to enhance the profile of the institute regionally, nationally, and internationally:

- Internationally – we intend to continue to hold regular international meetings and invite experts to visit. We will continue with our long-standing international collaborations (which include many research institutes, agencies, and industry across the world) and develop new ones.
- Nationally – we will continue to develop collaborations across universities and industry at a national level for our research and space projects.
- Regionally – we intend to build on the experience we had with Solar Orbiter to engage the national and local media in significant events and results from the institute. Our focus will be on the local population in Davos and the surrounding areas, schoolchildren, and the national media.
- Publications – refereed publications are important to maintain and expand our reputation scientifically. Publications are in our list of key performance indicators, and we consider this as a high priority.

8.1 Implementation plan for National and International cooperation and outreach

Now that the pandemic is over, we are hosting many visitors at PMOD/WRC, in particular the next IPC will be held in 2025 which will attract visitors from over 20 countries.

We will coordinate with the research institutes in ETH, Davos Science City and Academia Raetica for opportunities for educational outreach within the Kanton and beyond.

We have strong international collaborations in all aspects of the institute – these will be maintained and developed. This includes extensive collaborations with Swiss industry – especially on the space projects.

9 Administration and Human Resource strategy

Administration Strategy

The main task of the administration is to ensure the smooth operation of the institute. All employees in the department contribute to this and are responsible for the following tasks in particular:

- Liquidity Management
- Institute accounting, as well as project accounting and billing
- Point of contact for all stakeholders, both internal and external
- Import/export of instruments, including integration with the quality management system
- Market presence

The Administration strategy for the upcoming period focuses on these core tasks with the intention of carrying out these activities more efficiently, with fewer errors, greater transparency, and meeting the needs of stakeholders. Important guidelines for this desired development trend were already set towards the end of the 2020-2023 strategy period.

Hence the key points of the strategy are therefore digitalization, automation, and process optimization, modernization of market presence, efficiency gains in quality management, and analysing potential further development opportunities.

- **Digitalization and Automation / Process Optimization**: We aim to digitize and largely automate our administrative tasks. The more efficient processes should lead to increased transparency and forward planning. Internally, these improvements will lead to a better communication and simplification in the interaction between employees and the administrative department. Externally, these improvements lead to more credibility, reliability, and transparency for our third-party funders as well as our supervisory board.

- **Modernization of Market Presence:** The modernization of our market presence primarily aims to increase our visibility regionally, nationally, and internationally. Our market presence shall be done in a target-oriented way. The modernization of our market presence will largely reduce resource consumption, particularly regarding printing and paper costs.

- **Efficiency Improvement in Quality Management**: The import/export area is fully QM-certified (ISO/IEC 17025). The process flows are interdisciplinary, cross-departmental, and involve a variety of people. Currently, various process steps are carried out manually or in physical form. In the upcoming period, the interface between administration and science shall be made more efficient, with the goal of increasing efficiency and reducing redundant work steps and potential sources of errors.

- **International leadership:** The administration department can contribute its expertise in a beneficial way. A recently acquired example of this is the COST project CA 21119 HARMONIA, in which PMOD/WRC acts as the grant holder. The upcoming period will be used to analyse such opportunities.

Human Resources Strategy

Overall, our HR department's strategy focuses on attracting, developing, and retaining top talent while creating a positive work environment that aligns with the organization's goals and values. We therefore set following subgoals:

- **Employer of choice and working environment:** Our HR strategy aims to build a positive reputation as an employer of choice. Through creating a welcoming company culture where everyone feels safe and secure, we make a step towards this goal. The creation and the fostering of this culture is an ongoing project, which we try to achieve through the implementation of policies, setting up of employee committees, encouraging diversity and inclusion, addressing any issues promptly and constantly raising awareness for each other.
  Through new ways of conducting the annual appraisals, we aim to receive feedback on various issues, such as conduct of supervisor, appreciation, working place equipment as well as further career progression steps. If needed, special trainings will be conducted, or external help will be called in.

- **Talent acquisition and retainment:** When acquiring new members of staff, we want to implement an effective talent acquisition process.
  One of the main goals of our HR department is to retain our top talents. Our social benefits such as flexible working-hours and location, additional children's allowances, ≤ 5 weeks of holiday/ year, additional days of vacation if public holidays fall on weekends, free allocation of vacation throughout the year, possibility of unpaid leave, staff events and equal payment promotes a healthy work environment, which leads to a positive impact on this goal.

- **Employee engagement:** Another aim of the strategy is to enhance employee engagement. By setting up our joint committee on diversity and equality a first step

was taken. In the ongoing period, we try to foster this engagement through regular communication channels, team-events, brain-storming events, and staff surveys.

- **Labour law, process optimization and technologies:** HR stays updated on labour laws and regulations to ensure the organization remains compliant. This includes managing payroll processes accurately, maintaining proper documentation for employees, and addressing any legal issues promptly. The HR department improves their strategy through asking for feedback from managers and employees. Based on these insights, HR makes necessary adjustments to improve its practices. Additionally, technology is used to streamline processes, enhance efficiency, and improve data management including data protection.

- **Diversity and Equality:** A joint committee on diversity and equality was set up in 2023. The current strategy period focuses on ongoing improvements of the work culture, employee satisfaction and equality. The committee organizes training to raise awareness for unconscious biases, mistreatments, bullying and all other forms of unfair behaviour and implements measures to guide and assist whistle-blowers and all affected people.

9.1 Implementation plan for Administration and HR

Already towards the end of the last strategy period, significant steps were taken towards a digital office environment. This trend should be continued. The goals set in the strategy will be achieved through comprehensive analysis of current processes, exploring available solutions in the market, and engaging in discussions with employees and external stakeholders.

10 Acronym list

ACP - Absolute Cavity Pyrgeometer
ACTRIS - Aerosol, Clouds and Trace Gases Research Infrastructure
AOD – aerosol optical depth
CARS - Centre for Aerosol Remote Sensing
CERTAINTY: Cloud-aERosol inTeractions & their impActs In The earth sYstem
CIPM - International Committee for Weights and Measures
CIMO - Commission for Instruments and Methods of Observation
CLARA - compact lightweight absolute radiometer
CMC - Calibration and Measurement Capabilities
CSAR - Cryogenic Solar Absolute Radiometer
DARA - Davos Absolute Radiometer
ECV - Essential Climate Variable
EEI - Earth Energy Imbalance
EIS – EUV Imaging Spectrometer
EMPIR - European Metrology Research Programme for Innovation and Research
EO – Earth Observing
EPM European Partnership in Metrology
ESA – European Space Agency
ESM - Earth SystemModel
ETH - Swiss Federal Institute of Technology Zurich
EUI – EUV Imagers
EURAMET – European Association of national metrology
EuroGEO – Earth Observation in Europe
FRC - Filter Radiometer Comparison
GAW - Global Atmosphere Watch
GEOSS - Global Earth Observation System of Systems
FHNW – Fachhochschule Nordwestchweiz
IEA - International Energy Agency
IRIS - InfraRed Integrating Sphere radiometer
IRS – infrared radiometry section
ISO - International Organization for Standardization
JAXA – Japan Aerospace Exploration Agency
KCDB - Key Comparison Database
MAPP - Metrology for Aerosol Optical Properties
METAS – Swiss Federal Institute of Metrology
MeteoSwiss – Federal Office of Meteorology and Climatology
MITRA - Monitor for Integrated Transmittance
MRA - Mutual Recognition Agreement
NASA - National Aeronautics and Space Administration
NPL – National Physical Laboratory
PFR - Precision Filter Radiometer
PSI – Paul Scherrer Institut
PTB - Physikalisch-Technische Bundesanstalt
SENSE – Solar Energy Nowcasting System

SOCOL - SOlar-Climate-Ozone Links
SOHO – Solar and Heliospheric Observatory
SPICE - Spectral Imaging of the Coronal Environment Instrument
SRS- Solar Radiometry Section
STIX - The Spectrometer / Telescope for Imaging X-rays
TSI – total solar irradiance
TRUTHS - Traceable Radiometry Underpinning Terrestrial- and Helio- Studies
TTSM - Task Team on Radiation References
Virgo – Variability of solar irradiance and gravity oscillations
WCCUV - World Calibration Center for UV
WISG - World Infrared Standard Group of Pyrgeometers
WORCC- World Optical Depth Research and Calibration Center
WRC- World Radiation Center
WRR - World Radiometric Reference
WSG - World Standard Group of pyrheliometers
WMO - World Meteorological Organisation