Annual Report Jahresbericht 2014

Physikalisch-Meteorologisches Observatorium Davos und Weltstrahlungszentrum

Mission

Das PMOD/WRC

- dient als internationales Kalibrierzentrum für meteorologische Strahlungsmessinstrumente
- entwickelt Strahlungsmessinstrumente für den Einsatz am Boden und im Weltraum
- erforscht den Einfluss der Sonnenstrahlung auf das Erdklima.

Auftragerteilung

Das Physikalisch-Meteorologische Observatorium Davos (PMOD) beschäftigt sich seit seiner Gründung im Jahr 1907 mit Fragen des Einflusses der Sonnenstrahlung auf das Erdklima. Das Observatorium schloss sich 1926 dem Schweizerischen Forschungsinstitut für Hochgebirgsklima und Medizin Davos an und ist seither eine Abteilung dieser Stiftung. Auf Ersuchen der Weltmeteorologischen Organisation (WMO) beschloss der Bundesrat im Jahr 1970 die Finanzierung eines Kalibrierzentrums für Strahlungsmessung als Beitrag der Schweiz zum Weltwetterwacht-Programm der WMO. Nach diesem Beschluss wurde das PMOD beauftragt, das Weltstrahlungszentrum (World Radiation Center, WRC) zu errichten und zu betreiben.

Kerntätigkeiten

Das Weltstrahlungszentrum unterhält das Primärnormal für solare Bestrahlungsstärke bestehend aus einer Gruppe von hochpräzisen Absolut-Radiometern. Auf weitere Anfragen der WMO wurden 2004 das Kalibrierzentrum für Messinstrumente der atmosphärischen Langwellenstrahlung eingerichtet und 2008 das Kalibrierzentrum für spektrale Strahlungsmessungen zur Bestimmung der atmosphärischen Trübung. Seit 2013 wird auch das Europäische UV Kalibrierzentrum durch das Weltstrahlungszentrum betrieben. Das Weltstrahlungszentrum besteht heute aus vier Sektionen:

- Solare Radiometrie (WRC-SRS)
- Infrarot Radiometrie (WRC-IRS)
- Atmosphärische Trübungsmessungen (WRC-WORCC)
- UV Kalibrierzentrum (WRC-WCC-UV)

Die Kalibriertätigkeit ist in ein international anerkanntes Qualitätssystem eingebettet (ISO 17025) um eine zuverlässige und nachvollziehbare Einhaltung des Qualitätsstandards zu gewährleisten.

Das PMOD/WRC entwickelt und baut Radiometer, die zu den weltweit genauesten ihrer Art gehören und sowohl am Boden als auch im Weltraum eingesetzt werden. Diese Instrumente werden auch zum Kauf angeboten und kommen seit langem bei Meteorologischen Diensten weltweit zum Einsatz. Ein globales Netzwerk von Stationen zur Überwachung der atmosphärischen Trübung ist mit vom Institut entwickelten Präzisionsfilterradiometern ausgerüstet.

Im Weltraum und mittels Bodenmessungen gewonnene Daten werden in Forschungsprojekten zum Klimawandel und der Sonnenphysik analysiert. Diese Forschungstätigkeit ist in nationale, insbesondere mit der ETH Zürich, und internationale Zusammenarbeit eingebunden.

Das PMOD/WRC ist eine Abteilung der Stiftung
Schweizerisches Forschungsinstitut für
Hochgebirksklima und Medizin in Davos.

Physikalisch-Meteorologisches Observatorium Davos
und World Radiation Center (PMOD/WRC)
Dorfstrasse 33
7260 Davos Dorf
Schweiz

pmod wrc

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Werner Schmutz

Wissenschaft

Die im Mai 2014 am Observatorium Davos durchgeführte Tagung "Constraining Solar Forcing by Detection and Attribution for the Holocene" war ein geschätzter Höhepunkt im Wissenschafts-Jahr des Observatoriums. Die wissenschaftlichen Organisatoren waren die Institute des Schweizerischen Forschungskonsortiums Future and Past Solar Influence on the Climate (FUPSOL) mit dem internationalen Partner Past Global Changes (PAGES). PAGES koordiniert und fördert Untersuchungen vergangener Klimata und passt daher mit diesen Zielsetzungen hervorragend zum nationalen Sinergia Projekt FUPSOL, das durch den Schweizerischen Nationalfonds gefördert wird.

Es war eine relative kleine, aber wissenschaftlich hochkarätige Gruppe von achtundzwanzig Personen aus aller Welt. Die Teilnehmer wurden gezielt aufgrund ihres Expertenwissens zur Tagung eingeladen. Die Qualität der Vorträge war hervorragend und die danach geführten Diskussionen führten zu neuen Ideen und Ansätzen, die in den kommenden Jahren die Forschung bezüglich des Einflusses der Sonne auf vergangene Klimata beeinflussen wird. Die Sitzungen fanden im neuen Seminarraum statt, der sich für diesen Workshop bewährte und eine angenehme Tagungsatmosphäre bot, die durch die unaufdringliche aber aufmerksame Betreuung durch die Institutsmitarbeiter sehr unterstützt wurde. Die Tagung wurde durch unsere Besucher sehr geschätzt und eine häufige Frage war, wann das nächste PAGES-FUPSOL Meeting stattfinden wird. Ich danke den PMOD/WRC-Mitarbeitern herzlich für die tadellose Arbeit im Hintergrund und den extra Aufwand während der Tagung.

Dienstleistungsbetrieb Weltstrahlungszentrum

Vor vier Jahren erschien uns die damals über mehrere Jahre jedes Jahr angestiegene Zahl der Kalibrieraufträge ans Weltstrahlungszentrum als bedrohende Entwicklung. Was im Grunde eine positive Tendenz ist, da es durch die Nachfrage die Bedeutung des Weltstrahlungszentrums beweist, wurde besorgniserregend, weil eine weiterhin steigende Nachfrage nicht mehr lange mit der gegebenen Infrastruktur im Alten Schulhaus hätte bewältigt werden können.

Seit 2010 beobachten wir nun eine Stabilisierung der Kalibrieranfragen. Diese Plafonierung ist uns daher willkommen, da sie bedeutet, dass unsere Kalibrier-Infrastruktur ausreicht, um den Dienstleistungsauftrag ans Weltstrahlungszentrum zu erfüllen. Eine genauere Analyse zeigt, dass die neu im 2013 durch die Meteorologische Weltorganisation zusätzlich dem PMOD/WRC übertragene Aufgabe als Welt-Kalibrierzentrum für atmosphärische Ultraviolett-Strahlung eine steigende Anzahl Aufträge erhält. Der Mehraufwand in der UV-Kalibrier-Sektion wird aber durch eine sinkende Nachfrage in der Sektion für solare Radiometrie kompensiert. Wir sehen offenbar einen Wechsel im Kalibrierbedarf: weg von integrierter Strahlung hin zu speziellen Wellenlängenbereichen.

Obwohl sich die Kalibrier-Auftragslage stabilisiert hat, zeigten sich trotzdem Probleme in der Grundfinanzierung des Weltstrahlungszentrums. Es stellte sich heraus, dass die Expansion von einer auf vier Sektionen in den letzten etwas mehr als zehn Jahren ungenügend finanziert war. Die jeweiligen Erhöhungen der Finanzierung bei der Übernahme einer zusätzlichen Kalibriersektion haben sich immer primär an den neu anfallenden direkten Kosten orientiert und der Mehrbedarf an Infrastruktur, Investitionen und Administration wurde vernachlässigt.

Das Defizit in der Grundfinanzierung ist in den letzten Jahren strukturell geworden und eine Korrektur ist nun dringend notwendig geworden. Die Leitung der Stiftung SFI und die Aufsichtskommission suchte das Gespräch mit den Finanzierungspartnern des Weltstrahlungszentrums, Bund, Kanton Graubünden und Gemeinde Davos, um die Lage zu erläutern und wieder eine stabile Finanzierungsbasis zu erreichen. Die Behörden zeigten einerseits Verständnis für die weltweite Bedeutung der Dienstleistung, die das PMOD/WRC für die Meteorologische Weltorganisation erbringt, um den Klimawandel zu erfassen und zu verstehen, und schätzte anderseits die Aktivitäten des PMOD/WRC als Arbeitgeber und Einkommensbeitrag für die Region.

Man einigte sich, die Grundfinanzierung auf die kommende Finanzperiode 2016 – 2019 um knapp 8% zu erhöhen. Damit verbessert sich die Finanzlage des Institutes deutlich, sodass das Weltstrahlungszentrum seine Dienstleistungsaufgaben auftragsgemäss erfüllen kann. Die wiedergewonnene Basis erlaubt auch weiterhin, zusätzliche Drittmittel einzuwerben und Hardware für Weltraumprojekte zu entwickeln und bauen. Ich bin den Behörden für die Anpassung der Grundfinanzierung sehr dankbar und werte es als Ausdruck eines starken Vertrauens in die gute Arbeit des Instituts.

Entwicklung und Bau von Experimenten

Der kommerzielle Verkauf von Instrumenten war im vergangenen Jahr deutlich geringer als in früheren Jahren. Wir verkauften nur ein Präzisionsfilterradiometer, was für diesen, in der Vergangenheit gut nachgefragten Instrumententypus, ungewöhnlich ist. Vermutlich reflektiert das derzeitige niedrige Interesse die Überlegung interessierter Kunden, zu warten, bis das neu entwickelte Präzisions-Spektroradiometer kommerziell angeboten wird. Der Testeinsatz der bisher gebauten Prototypen zeigt, dass das neue Instrument unsere Hoffnung auf ein versatil einsetzbares Strahlungsmessgerät zu verschiedenen Forschungszwecken voll erfüllt. Wir haben jedoch auch realisiert, dass kleinere Designdetails noch optimiert werden müssen, bis wir ein Qualitätsinstrument anbieten können. Die kommerzielle Weiterentwicklung musste jedoch zurückgestellt werden, da die Technik-Abteilung mit dem Bau von vier Weltraumexperimenten ausgelastet war und auch im laufenden Jahr noch ist. Die Situation bessert sich nicht so schnell, da die ESA Sonnenmission Solar Orbiter, mit dem ursprünglich geplanten Start im Juli 2017, auf Oktober 2018 verschoben wurde. Das bedeutet, dass die Bauzeit unserer Hardware-Beiträge zu den zwei Experimenten EUI und SPICE bis Ende 2015 dauern werden, anstatt der eingeplanten Ablieferung per Ende des vergangen Jahres. Die Arbeit für die Solar Orbiter Instrumente kollidiert nun terminlich mit unserem Beitrag zum norwegischen Satellit NORSAT-1, für den wir das Instrument CLARA (Compact Lightweight Absolute Radiometer) entwickeln. CLARA muss bis Herbst 2015 fertig sein, damit der Start des Satelliten Anfangs 2016 erfolgen kann.

Zusätzlich zu diesen Arbeiten für Weltraumexperimente hat die ESA im letzten Jahr die PROBA-3 Mission wieder aktiviert, für die ein Absolut-Radiometer von uns vorgesehen ist. Für diese Mission hatte unser ehemaliger Doktorand, Markus Suter, in seiner Dissertation das Prototypen-Instrument DARA (Digital Absolut Radiometer) ausgiebig charakterisiert und optimiert. Die Technik-Abteilung ist nun gefordert, auch dieses Instrument zu realisieren.

Personelles

Per Ende Jahr wechselte Dr. Christoph Wehrli nach 36 Jahren in den Ruhestand. Zu seinem Abschied besuchte das gesamte Personal am 8. Dezember 2014 die Sternwarte Mirasteilas in Falera. Der Beobachtungsabend war zwar nicht von Wetterglück begleitet, aber trotzdem war der Ausflug ein gelungener und würdiger Anlass für einen Mitarbeiter der solange erfolgreich für das Observatorium tätig war. Er war unser Experte für Filterradiometer und in den letzten sieben Jahren hat er die WRC-Sektion WORCC kompetent und erfolgreich geführt. Wir sprechen ihm unseren herzlichen Dank und die besten Glückwünsche für die Zukunft aus.

Die Administration des PMOD/WRC war mit der schwierigen Situation konfrontiert, dass zwei vollzeitlich angestellte Mitarbeiter gleichzeitig mehrere Monate fehlten. Einer glücklichen Fügung zufolge hatte unsere ehemalige Lehrperson, Eliane Tobler, im Sommer ihre Ausbildung abgeschlossen und sie nahm die Herausforderung an, die volle Arbeitslast zu übernehmen. Es ist sicherlich äusserst selten, dass eine junge Person gerade nach der Ausbildung die Administration einer Firma mit vierzig Mitarbeitern übernimmt, aber sie bewies, dass mit Elan und Mut die Arbeit bewältigt werden kann. Ich bin Frau Tobler sehr dankbar für ihren Einsatz zugunsten des Observatoriums und ich habe grosse Hochachtung vor ihrem ausserordentlichen Einsatz.

Dank

Es braucht den Einsatz und guten Willen von sehr vielen Personen, wenn die Grundfinanzierung des Weltstrahlungszentrums erneuert wird. Besonderen Einsatz war vom Präsidenten der Stiftung SFI und dem ständigem Delegierten der Schweiz an der Meteorologischen Weltorganisation gefordert. Dies sind Dr. Walter Ammann und Peter Binder, die mit ihrem Wirken eine Erneuerung der Finanzierung ermöglichten. Im Hintergrund waren viele weitere Personen aktiv, so unter anderem die Präsidentin der Aufsichtskommission des WRC, Dr. Gabriela Seiz und Peter Morscher, Leiter der Finanzen und Logistik an der MeteoSchweiz.

Die Verhandlungspartner auf Seiten Bund, Kanton Graubünden und Gemeinde Davos, die die Erneuerung der Finanzierung beschlossen haben, waren mit ihrem Vertrauen ins Institut das bestimmende Element. Ihnen allen gilt mein herzliches Dankeschön im Namen des Instituts. Für uns ist die Finanzierung des Weltstrahlungszentrums die Basis für eine gute Leistung. Die Arbeit wird schlussendlich von den Mitarbeitern des PMOD/WRC geleistet, und ihnen danke ich sehr herzlich für ihren grundlegenden Beitrag zum guten Wirken des Observatoriums Davos.

Ein letztes Projekt in der Renovation des Institutsgebäudes ermöglichte den Ausbau der Werkstatt. Einmal mehr bedanke ich mich für die Umbaufinanzierung beim Bundesamt für Bauten und Logistik und beim Projektleiter Herrn Valentin Feubli.

Bild 1. Mitarbeiter des Physikalisch-Meteorologisches Observatorium Davos, PMOD/WRC.

Erste Reihe von links nach rechts: Ricco Soder, Gregor Hülsen, Werner Schmutz (Director), Pierre-Luc Lévesque, Seraina Egartner, Andri Morandi, Irene Keller.

Zweite Reihe von links nach rechts: Silvio Koller, Nuno Guerreiro, Luca Egli, Christine Aebi, Marco Senft, Cassandra Bolduc, Barbara Bücheler

Dritte Reihe von links nach rechts: Benjamin Walter, Natalia Kouremeti, Julian Gröbner, Thomas Carlund, Manfred Gyo, Wilnelia Adams, Valeria Büchel, Margit Haberreiter

Vierte Reihe von links nach rechts: Christian Thomann, Nathan Mingard, Christoph Waupotitsch

Top Row, Left to Right: William Ball, Sven Schütz, Wolfgang Finsterle, Marcel Spescha, Timofei Sukhodolov, Patrik Langer, Stelios Kazadzis

Introduction

Werner Schmutz

The highlight of 2014 regarding science activities at the PMOD/WRC was the 2nd PAGES (Past Global Changes) workshop on "Constraining Solar Forcing through Detection and Attribution for the Holocene". The workshop on Sun-Earth interactions took place in May 2014 and was organised by the Swiss research consortium that conducts the National Science Foundation Sinergia project, "Future and Past Solar Influence on the climate". The workshop partner, the PAGES project, is an international effort to coordinate and promote global change research of the past. A small group of 28 experts were invited to attend the Davos workshop. The quality of the talks was outstanding and the discussions led to new research ideas, which will influence the future of research in the field of Sun-Earth interactions. The renovated seminar facilities supported a fruitful environment for discussions, which was organised by the PMOD/WRC staff in a modest but professional manner. This was much appreciated by our international guests who expressed their wish for a follow-up meeting in the near future.

Since 2010, we have observed a stabilisation of the overall demand for calibration services offered by the World Radiation Center (WRC) sections. This development is very positive because it implies that the infrastructure of the calibration centers is sufficient to cope with the Operational Services given the current funding and the recently renovated facilities. About four years ago, we were concerned that problems in handling an ever increasing demand would occur. A closer analysis of each Operational Service shows that the WRC expansion from a European Calibration Center to a World Calibration Center for UV (WCC-UV), mandated by the World Meteorological Organisation in 2013, has led to a larger workload for that section. However, this has been compensated by a decrease in the workload of the Solar Radiometry Section (SRS). We have thus observed a shift of attention from the calibration of integrated radiation instruments to those with selected wavelength ranges.

Although the demand for instrument calibrations has stabilised, the PMOD/WRC is nevertheless facing financial problems. In hindsight, the expansion to the current four sections of the WRC was insufficiently funded, and only covered the directly increased workload, but not the overhead in infrastructure, investments, and administration. The deficit has become structural such that it will be necessary to undertake certain measures. The overall situation was therefore discussed with funding partners who are in charge of the WRC financing. In recognition that the WRC Operational Services are an essential Swiss contribution to the World Meteorological Organisation (WMO) and its mandate to assess and understand climate change, and that PMOD/WRC activities are a welcome source of income for the region, the funding partners have agreed to increase their contributions for the coming 2016 – 2019 financial period. This improves the state of core-funding for our Operational Services. Not only can the PMOD/WRC continue to fulfill its mandate but it enables further third-party funding to be acquired as well as allowing a continuation of our successful engagement in research projects and the development of space hardware. I am very thankful to our funding partners for this positive outcome, and sign of trust in our motivation and know-how.

Commercial instruments sold by the PMOD/WRC have been in less demand over the last few years. Only one Precision Filter Radiometer (PFR) was sold which, in view of the fact that this instrument type had sold well in the past, probably reflects the decision of potential customers to wait for the newly developed Precision Spectroradiometer (PSR) to become available. Operational tests have shown that the performance of the PSR makes it the versatile research instrument we had envisaged. However, the tests have also revealed that a small number of issues still need to be addressed to make it a top quality instrument of which we can be proud. At present, the development of commercial instruments has been given lower priority as the technical section has had a challenging time in fulfilling a multitude of tasks in 2014, due to a number of reasons. Besides supporting the development of ground-based instruments (e.g. the above-mentioned PSR), the technical section is currently involved in the development of four space experiments. Unfortunately this situation remains precarious as both the EUI and SPICE space experiments onboard the Solar Orbiter, for which we originally expected to have our hardware ready by the end of 2014, are delayed as the whole Solar Orbiter project has been rescheduled for launch in October 2018 instead of July 2017. Thus, the in-house contributions to Solar Orbiter will continue beyond the end of 2015, which will challenge us alongside the ongoing space collaboration with Norway. The latter concerns the construction of the Compact Lightweight Absolute Radiometer (CLARA) experiment that will be delivered by the end of 2015 for a launch deadline at the beginning of 2016. In addition to the above-mentioned three space experiments, the PROBA-3 mission was re-initiated by ESA and will carry an absolute radiometer. The Digital Absolute Radiometer (DARA) experiment was optimised following extensive characterisation of a prototype instrument as part of Mark Suter's PhD Thesis.

The administrative department was faced with the situation where two fully employed senior members of staff were absent for some time in 2014. However, it was fortunate that our former administration apprentice, Eliane Tobler, who finished her training in the summer of 2014, was able to take over the full work load. She demonstrated that she had fully mastered her chosen profession. It is exceptional that such a young person can enter her profession as the Head of Administration in an institute of about 40 staff. She is an example of the potential of young people who with courage and commitment can achieve a great deal. I am very grateful to Eliane for her dedication and greatly appreciate her outstanding efforts.

Operational Services

Quality Management System and Calibration Services

Manfred Gyo, Silvio Koller, Wolfgang Finsterle, Julian Gröbner

Quality Management System

The Quality Manager (QM) position was taken over by Silvio Koller at the beginning of 2014. During the reporting year, five employees attended external ISO 17025 (basic/auditor) training courses to broaden their internal QM expertise.

Activities

Last year's Calibration and Measurement Capabilities (CMC) report of the WRC-WCC-UV section was accepted by the Bureau International des Poids et Mesures (BIPM). Four additional CMCs for broadband detectors with the quantity "responsivity - solar irradiance" are now listed in the BIPM key comparison database.

The WRC-IRS and WRC-WORCC sections continued the adaptation and preparation of their standard procedures and corresponding documentation in accordance with the EN ISO/IEC standard 17025:2005 requirements.

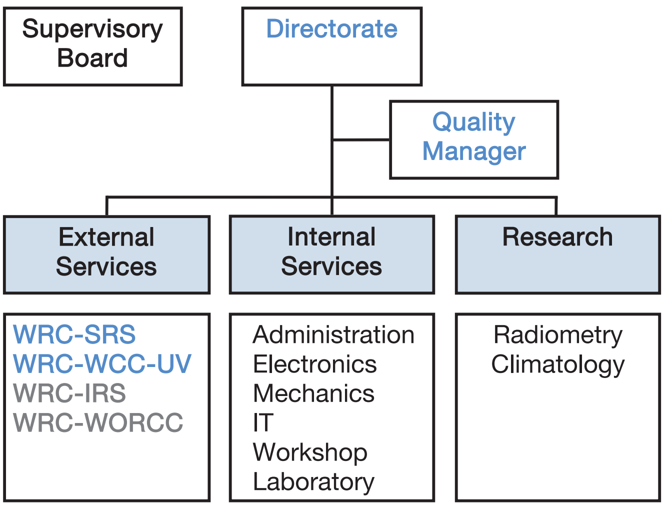

Figure 1. Organigram of the PMOD/WRC Quality Management System. The WRC Solar Radiometry Section (SRS) and the WCC-UV sections (in blue) perform calibrations according to the EN ISO/IEC standard 17025.

Calibration Services

As a general investment in our Calibration Services, a new module of our administration software was purchased to provide streamlined consistency from an initial calibration offer right up to the final accounting paperwork.

Solar Radiometry Section (WRC-SRS)

In 2014, the WRC-SRS Section calibrated 19 pyrheliometers and 77 pyranometers. PMOD/WRC attended a national pyrheliometer comparison at NREL in Golden (CO, USA).

Infrared Radiometry Section (WRC-IRS)

The WRC-IRS Section performed 36 pyrgeometer calibrations in 2014. This section will be audited to ISO 17025:2005 at the beginning of 2015.

Atmospheric Turbidity Section (WRC-WORCC)

The WRC-WORCC section calibrated 19 PFRs against the WORCC Triad standard. In addition, two PSRs were calibrated against a reference standard, traceable to the National German Institute of Metrology (Physikalisch-Technische Bundesanstalt, PTB). The end of 2014 saw the retirement of Dr. Christoph Wehrli, the head of the WRC-WORCC section.

World Calibration Center for UV (WRC WCC-UV)

Twenty-six broadband radiometers were calibrated at PMOD/WRC, resulting in 36 calibration certificates. The WRC-WCC-UV calibrated five spectroradiometers at their respective field sites using the QASUME traveling reference spectroradiometer. In March 2014, the WCC-UV reference was compared to the primary reference at the PTB (Braunschweig, Germany) in the framework of the "Solar UV" EMRP project. Fourty-one certificates are based on the new CMCs and an additional 11 customer calibrations not covered by the CMCs were conducted. The calibration of some instruments results in more than one certificate with these new CMCs. Statistics for 2014 in Figure 2 therefore illustrate the number of certificates instead of calibrated instruments.

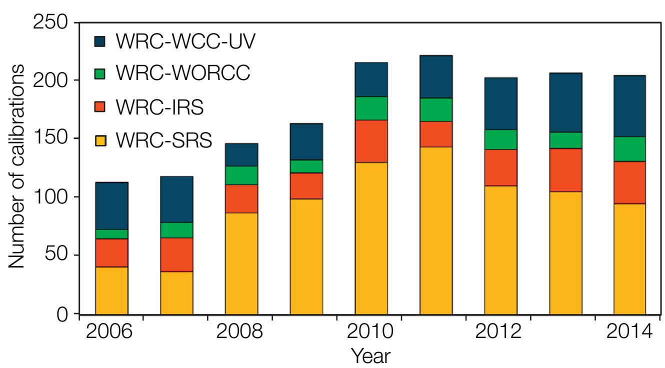

Figure 2. Statistics of instrument calibrations at PMOD/WRC for the 2006–2014 period.

Solar Radiometry Section (WRC-SRS)

Wolfgang Finsterle

The Solar Radiometry Section (SRS) of the WRC maintains and operates the World Standard Group of Pyrheliometers (WSG) which represents the World Radiometric Reference (WRR) for ground-based total solar irradiance measurements.

The WRC-SRS provided routine calibrations of 96 radiometers in 2014 with respect to the WRR. Of these 96 radiometers 77 were pyranometers, 16 were pyrheliometers with thermopile sensor and three were absolute cavity radiometers.

The WSG was operated on 53 days in 2014, mostly for the calibration of customer radiometers, but also for prototype testing. The frequent wet weather conditions during the summer required flexibility from the WRC-SRS staff in order to acquire enough measurements under clear skies to calibrate all customer radiometers in a timely manner.

Figure 1. Nathan Mingard setting up the PMOD/WRC's transfer standard group to conduct solar irradiance measurements during the National Pyrheliometer Comparison at NREL in Golden, USA.

A transfer standard consisting of three active cavity radiometers took part in the annual National Pyrheliometer Comparisons (NPC-2014) from 22 September to 3 October at NREL in Golden, USA (Figure 1). The NPC-2014 results have confirmed the stability of the WSG.

After the calibration season had finished in September the solar tracking platform was prepared to accept the Cryogenic Solar Absolute Radiometer (CSAR) and the Monitor for Integrated Transmittance (MITRA). CSAR (Figure 2) will soon be sent back to the PMOD/WRC from the National Physical Laboratory (NPL, Teddington, UK), and will be permanently installed on the SRS tracker. Together with MITRA, CSAR is expected to replace the WSG and to take on the role of representing the WRR in the future.

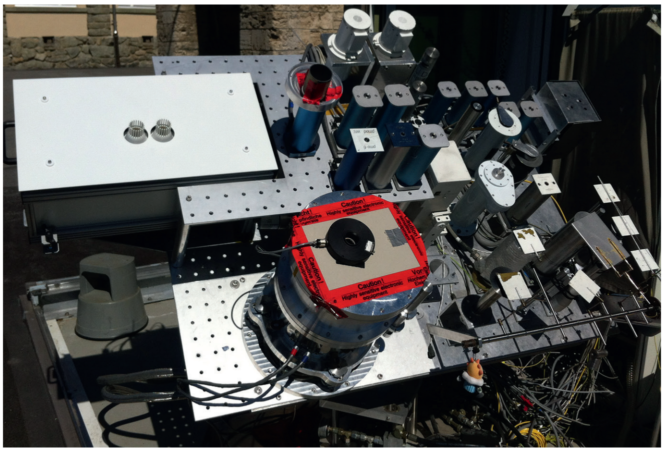

Figure 2. The CSAR instrument (lower centre) mounted on the WSG tracker during tests. MITRA is mounted inside the white temperature controlled box to the left above CSAR. (This picture was taken in early 2015, after CSAR was delivered to PMOD/WRC).

Instrument development activities throughout 2014 have resulted in a significant improvement of the accuracy of MITRA, the design and construction of the CLARA space radiometer (Figure 3) for the NORSAT-1 mission, and the development of the absolute radiometer for Terahertz (THz) radiation. These instruments required novel approaches to improve thermal stability (MITRA), mechanical stability (CLARA), and spectral absorptivity (THz radiometer).

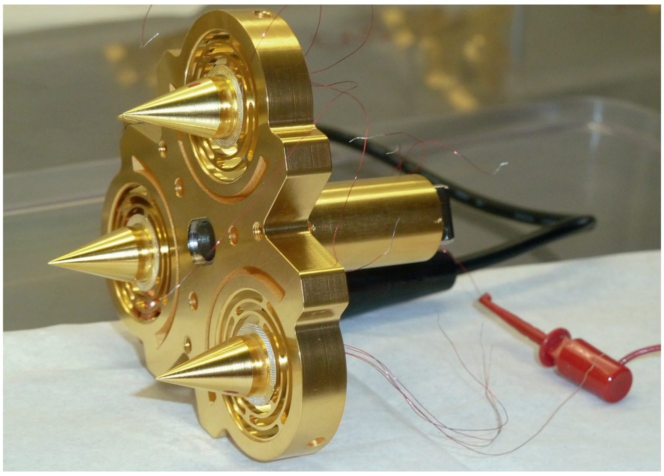

Figure 3: The cavity-heatsink assembly for the CLARA space radiometer during electrical tests at PMOD/WRC.

Infrared Radiometry Section (WRC-IRS)

Julian Gröbner and Stephan Nyeki

The Infrared Radiometry Section of the WRC maintains and operates the World Infrared Standard Group of Pyrgeometers (WISG; see Figure 1) which represents the world-wide reference for atmospheric longwave irradiance measurements.

The Infrared Radiometry Section (IRS) of the WRC provided routine calibrations of 36 pyrgeometers with respect to the WISG. As in previous years, most pyrgeometers came from two manufacturers, namely 21 CG(R)4 from Kipp & Zonen and 11 PIR from Eppley Laboratory Inc.

A necessary step towards the inclusion of the WRC-IRS in the ISO 17025 Quality System was made by documenting the entire calibration process. This included a comprehensive uncertainty budget and demonstration of the metrological traceability of atmospheric longwave irradiance measurements by comparison to the absolute cavity radiometer developed by NREL (Gröbner et al., 2014). The objective is to perform the required audit of the WRC-IRS Quality System in the first half of 2015, allowing pyrgeometer calibrations to be conducted according to the ISO 17025 norm. The goal is to submit a Calibration and Measurement Capability (CMC) on the measurement of atmospheric longwave irradiance to the BIPM key comparison database with the view of including the WRC-IRS into the metrological community.

The project Comprehensive Radiation Flux Assessment (CRUX), funded by the Swiss contribution to GAW, was initiated in January 2014 with Christine Aebi as a PhD student. The main objective of this project is to determine cloud radiative properties according to cloud type and atmospheric composition. A key activity within this project is the development of a thermal infrared cloud camera (IRCCAM) to determine the cloud fraction during the night as a complement to visible sky imagers during the day which were developed in the previous CLASS project. As an additional benefit, it is planned to retrieve cloud base height from the measurement of the effective cloud temperature by IRCCAM. A description of IRCCAM and first measurements can be found later in this annual report.

A joint activity with the company Hukseflux (Delft, Holland) was initiated in July 2014 with the deployment of a direct far infrared radiometer to measure the longwave radiation coming directly from the sun. It essentially consists of a pyrheliometer fitted with a solar blind coated silicon window. Preliminary results were presented in September 2014 at the BSRN workshop in Bologna (http://www.isac.cnr.it/~radiclim/bsrn2014/userfiles/downloads/BSRN_meeting_talks_long.pdf).

Figure 1. The WISG (far right) and other customer pyrgeometers on the PMOD/WRC roof-top with Lake Davos in the background.

In order to address the implications of possible changes to the shortwave (WSG) and longwave radiation (WISG) references, a Task Team on Radiation References was established by the CIMO. The terms of reference of the Task Team are to:

1. Review and report to the CIMO management group about recent developments in reference instruments for solar and terrestrial radiation with regard to observed differences to references currently in use.

2. Assess the potential impact and consequences of a change in solar/terrestrial reference scales for stakeholders.

3. Make a recommendation on requirements and timeliness of a modification of the current references, and if required, develop an implementation plan for the change (including a proposal on how to deal with old data and the timeliness of its introduction).

4. Provide regular progress reports to the CIMO management grroup and recommendations for adoption by CIMO 17 (2018).

References: Gröbner J., Reda I., Wacker S., Nyeki S., Behrens K., and Gorman J.: 2014, A new absolute reference for atmospheric longwave irradiance measurements with traceability to SI units, J. Geophys. Res. Atmos., 119, doi:10.1002/2014JD021630.

Atmospheric Turbidity Section (WRC-WORCC)

Julian Gröbner, Natalia Kouremeti, and Christoph Wehrli

The Atmospheric Turbidity Section of the WRC maintains a standard group of three Precision Filter Radiometers (PFR) that serve as a reference for Aerosol Optical Depth (AOD) measurements within the WMO. WORCC also operates the global GAW-PFR AOD network.

The PFR reference triad has been operating near continuously since early 2005. Occasional interruptions occur when recalibrations are conducted by the Langley-plot technique at Mauna Loa, Hawaii or Izana, Canary Islands. As can be seen in Figure 1, the scatter of AOD measurements at 500 nm with the Triad sun-photometers is less than 0.0002+/-0.0011(1s), which is well within the WMO criterion of 0.005+0.01/m, where m is the airmass.

As mentioned in last year's report, a lunar PFR was installed at Ny Ålesund in February 2014 during the end of the polar night to measure AOD using the Moon as a source. The aim of the project was to establish lunar photometry in order to characterise an arctic aerosol climatology during all seasons and to develop Ny Ålesund as a satellite validation site. After instrument development at PMOD/WRC during the summer months, the instrument was returned to Ny Ålesund for the 2014/2015 polar winter where measurements have been ongoing since October 2014. The activity is conducted within the framework of a project funded by the Svalbard Science Foundation in collaboration with partners from NILU (Norway), ISAC/CNR (Italy), AWI (Germany), NOAA/CIRES (US), and IGF/PAS (Poland). The PMOD/WRC has supplied a modified PFR suitable for lunar measurements.

The project "A Travel Standard for Aerosol Optical Depth" in the UV (UVAOD) was funded by the Swiss COST Office within the COST project ES1207, EUBREWNET, for a two-year period starting in January 2015. The objective is to use UV-PFR sun-photometers as travel standards at the home sites of Brewer spectrophotometers measuring AOD in the 306–320 nm wavelength range.

Following the development of the solar Precision Spectroradiometer (PSR) described in the 2013 annual report, a small series of five instruments was constructed in 2014. PSR-003 was initially deployed between March and June 2014 at the Izana Atmospheric Observatory on the Island of Tenerife, Canary Islands to obtain a spectral AOD calibration in the 300–1000 nm range. It was subsequently deployed at Finokalia, Crete as part of the ACTRIS AOD validation campaign during July 2014. Two PSRs were sold to the Lindenberg Observatory (Germany) where they were deployed in June 2014 for continuous measurements of direct solar irradiance. It was subsequently deployed at Finokalia, Crete and Athens, Greece as part of the European Space Agency funded CHARADMExp campaign, with support from the Transnational Access activity of the ACTRIS network. The main aim of the campaign was to derive optical, microphysical and chemical properties of marine component and its mixture with dust.

Annual quality assured data from five GAW-PFR stations were updated to 2013 and submitted to WDCA. Daily AOD results from 24 stations are submitted in (quasi) near-real-time and are available through ebas.nilu.no within 24 hours.

This report cannot be concluded without mentioning that the "founding father" of WORCC, Christoph Wehrli, retired at the end of the year. Christoph designed the PFR and was instrumental in establishing the GAW-PFR network and its recognition as a primary reference network for AOD. It goes without saying that Christoph's experience will be sadly missed by everyone at PMOD/WRC, and PFR operators all over the world. Fortunately, PMOD/WRC has found a very capable successor to Christoph in Stelios Kazadzis, senior scientist from the National Observatory of Athens, who will start his position as operative head of WORCC on 1 April 2015. We wish him all the best in his new position.

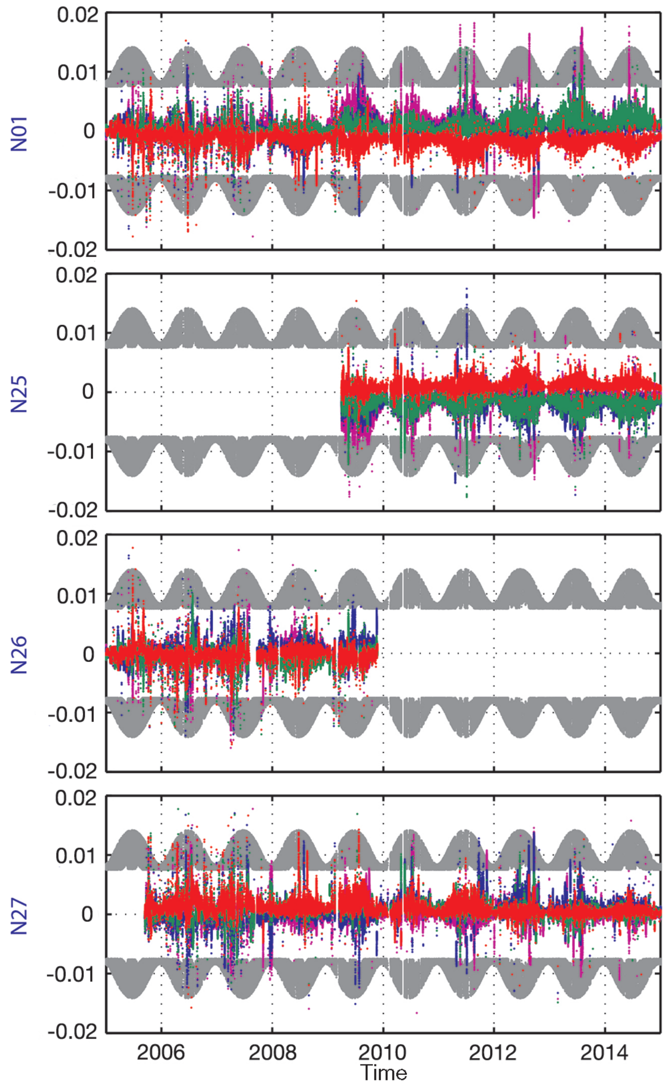

Figure 1. AOD residuals at PFR wavelengths (368, 412, 500 and 867 nm) between the Triad sun-photometers N01, N27 and N25/N26. The measurement gaps are due to recalibrations. The WMO criterion of 0.005+0.01/m (m = airmass) is shown in grey. Coloured dots refer to: magenta = 368 nm, blue = 412 nm, green = 500 nm and red = 862 nm.

World Calibration Centre for UV (WRC-WCC-UV)

Julian Gröbner, Gregor Hülsen, and Luca Egli

The Global Atmosphere Watch (GAW) Ultraviolet (UV) calibration center aims to improve data quality in the Global GAW UV network and to harmonise the results from different stations and monitoring programs in order to ensure representative and consistent UV radiation data on a global scale.

At the end of 2014, four new Calibration and Measurement Capabilities (CMCs) were approved in the framework of the CIPM MRA for the calibration of broadband UV filter radiometers, strengthening the position of PMOD/WRC in the metrological community. The CMCs are now listed in the BIPM key comparison database, at http://kcdb.bipm.org/appendixC/.

The activities of the World Calibration Center for UV (WCC-UV) concentrated on the completion of the SolarUV EMRP Project, which ended on 31 July 2014. In March, a follow-up calibration campaign at the Physikalisch-Technische Bundesanstalt (PTB) was used to improve the traceability of the QASUME spectral irradiance scale by nearly a factor of 2, reducing the uncertainty of solar UV measurements with QASUME to 3%. This represents a major step forward in the measurement of global spectral solar UV irradiance with ground-based spectroradiometers.

In July, the international comparison of UV array spectroradiometers was held at PMOD/WRC, consisting of laboratory characterisations of the participating spectroradiometers using devices developed within the project, followed by outdoor measurements of solar UV spectra in conjunction with the QASUME reference spectroradiometer. A description of the campaign and preliminary results can be found later in this annual report. The 8th workshop for ultraviolet measurements (UVNET) was held in conjunction with the campaign on 15 and 16 July, and had about 30 participants.

The follow-up project, EMRP ENV59-ATMOZ "Traceability for atmospheric total column ozone", held its kick-off meeting on 23 and 24 October 2014 during the first snowstorm of the year. The main objective of the project is to provide a comprehensive uncertainty budget for total column ozone measurements for the standard ozone monitoring instruments Brewer/Dobson, as well as newly developed array spectroradiometers using DOAS-like techniques.

The Bentham DM150 of the WCC-UV Spectral Response measurement set-up was replaced by an Acton SpectraPro-2500 double monochromator. In addition, the light source power of this set-up was increased from 250 W to 1000 W and the coupling in the monochromator was optimised using a parabolic off-axis mirror. The new set-up now has a higher spectral illumination power, an extended spectral range and the ability to conduct irradiance source calibrations from 250 nm to 1200 nm. A description of the Acton SP2500 can be found later in this annual report.

Figure 1. Participants of the 8th UVNET Workshop on 15 and 16 July 2014 at PMOD/WRC.

The QASUME transportable reference spectroradiometer was used during three quality assurance site visits: For the fifth time, after 2002, 2003, 2007, and 2010, QASUME visited the solar UV monitoring sites at Jokioinen and Sodankylä in Finland to perform a comparison of solar UV irradiance measurements with local spectroradiometers. The Norwegian Radiation Protection Agency (NRPA) in Oslo used this opportunity to join the comparison at Jokioinen with its own spectroradiometer. Finally, QASUME visited the PTB Berlin for a comparison of solar UV spectra with the Fourier-Transform Spectroradiometer developed within the SolarUV EMRP project.

Results of all the QASUME site audits can be found at the WCC-UV web-site: http://www.pmodwrc.ch/wcc_uv/wcc_uv.php?topic=qasume_audit

In the framework of scientific studies to detect snow-covered areas using solar UV measurements and effective UV albedo retrievals, PMOD/WRC sent a "Solar Light" UV broadband radiometer to the Center for Snow and Avalanche Studies (CSAS) in Colourado USA. The instrument was continuously operated between 26 February and 31 June 2014 during spring snowmelt in the Senator Becks basin. This dataset will complement similar studies with a UV broadband radiometer in the Dischma valley in Davos during spring 2014, which investigated the ability to measure snow-cover.

Instrument Development

The New Spectral Response and Irradiance Standard Calibration Set-up of the WCC-UV Section

Gregor Hülsen and Julian Gröbner

The Spectral Response Function Set-up (SRF) of the WCC-UV Section was replaced by an Acton SP2500 double monochromator. The new set-up features a higher output intensity of SRF measurements, and enables spectral irradiance calibrations using the same instrument.

The SRF set-up of the WCC-UV section at PMOD/WRC was revised in 2014. The core part of this set-up (a Bentham DM150 with a focal length of 150 mm) was replaced with an Acton SP2500 double monochromator (Princeton Instruments) used in recombining mode (Figure 1). The focal length of this instrument is ~500 mm. It features a triple grating turret currently equipped with two sets of holographic gratings with 2400 and 1200 grooves/mm for the UV and VIS light spectrum, respectively. The triangular slit function can be changed from 0.1 nm to 4 nm full width at half maximum using the motorised slits.

The instrument's multiple entrance and exit slits are currently configured for the following measurement modes:

1. The SRF set-up uses the first entrance slit, which is illuminated with a 1 kW Xenon lamp source, coupled by an off-axis mirror (Figure 1, right). The output beam from the first exit of the second monochromator stage is directed to the test radiometer, and a diode monitors the output beam stability using a 95/5 beam splitter (Figure 1, left). A second calibrated diode can record the relative transmission of the system at the reference plane of the test instruments. The spectral range of the SRF set-up is limited by the emission lines of the Xenon source. Currently these measurements are performed for the 250 - 450 nm range. However, in principle the output light spectra spans the 200 – 1200 nm wavelength range.

2. A fibre-coupled input optic is fixed to the second entrance slit for calibration of irradiance standard lamps (Figure 1, front). A photomultiplier records the radiation at the second exit of the second monochromator stage.

3. An InGaAs detector is mounted on the second exit of the first monochromator stage for the VIS-NIR wavelength range.

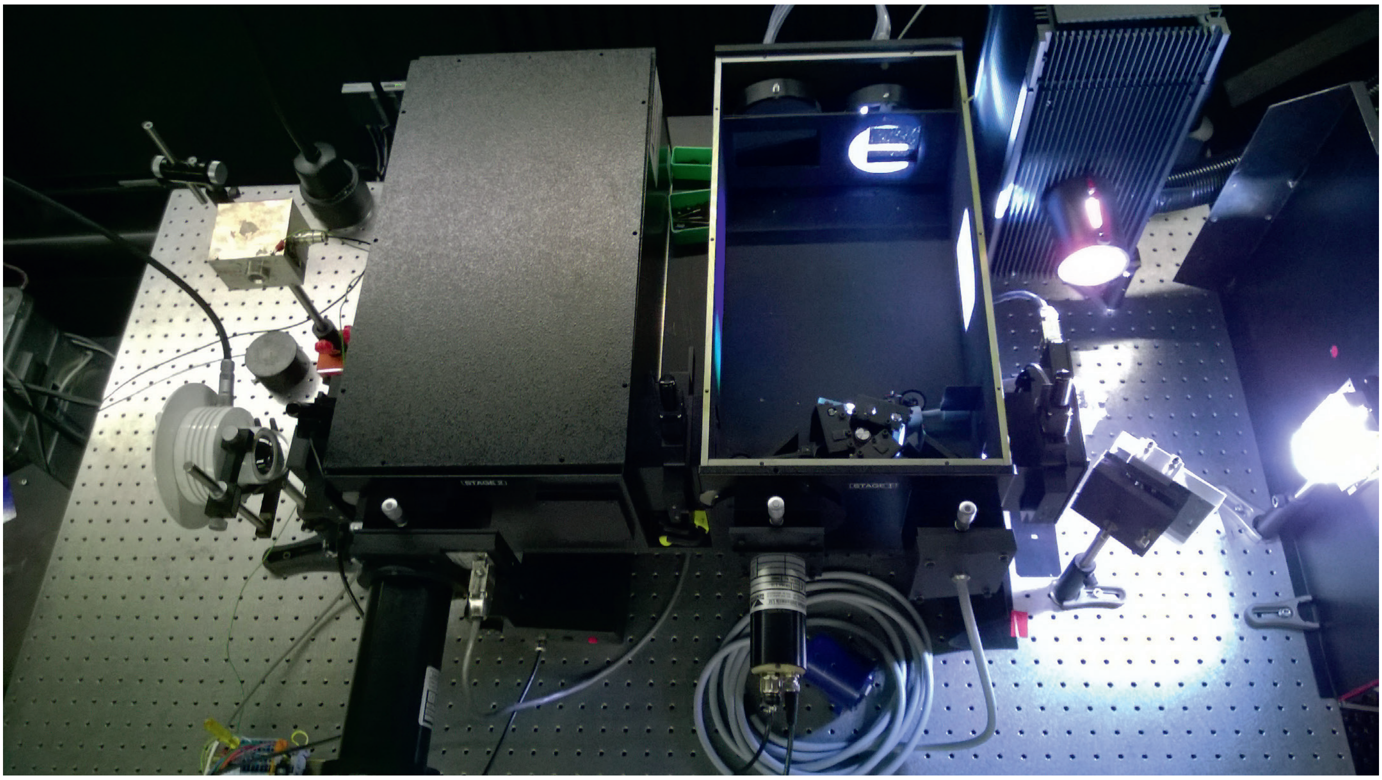

Figure 1. The Acton SP2500 set-up for SRF and irradiance standard calibrations. Left: test UV radiometer and reference diodes, middle: the double monochromator, right: Xenon light source, front: fibre-coupled input optic and two detectors for irradiance calibrations.

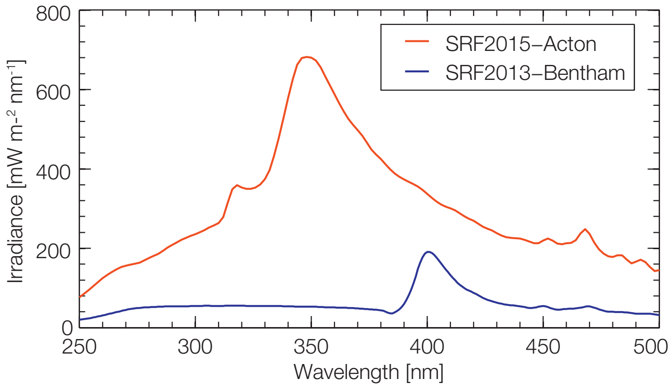

Figure 2. Output irradiance of the old and new spectral response set-up.

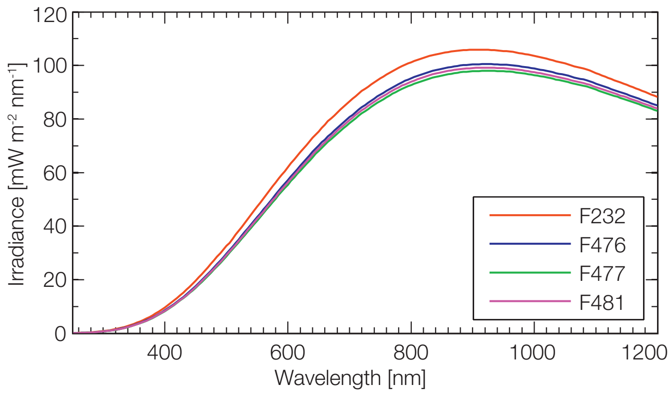

Figure 4. Irradiance of 1000 W FEL-type transfer standards measured using the Acton SP2500 irradiance calibration set-up.

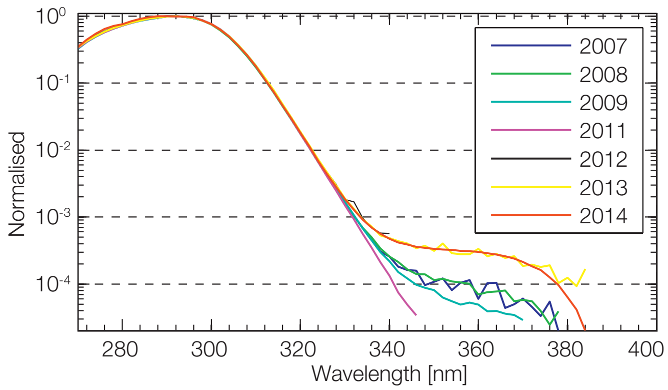

Figure 3. History of the spectral response function from UV Radiometer SL1492, measured with the Bentham DM150 (2007 – 2013) and the new Acton SP2500 (2014).

First tests of the SRF set-up show that the output intensity has significantly increased in the UVB and even more in the UVA wavelength range (Figure 2). The maximum output signal from a Solar Light UV Radiometer has increased by a factor of 8. The low intensity UVA response from these instruments can now be measured with a higher S/N ratio. The history of the SRF measurements of SL1492 is shown as an example in Figure 3.

The irradiance calibration for primary standard sources has been transferred to four 1000 W FEL-type working standard lamps in the 250 – 1200 nm wavelength range using combined measurements from measurement mode 2 – 3 (Figure 4). The offset with respect to the calibration using the standard irradiance calibration set-up (QASUME transfer instrument) is below ±0.5 %. The measurement uncertainty is smaller than 1 % in the 300 – 600 nm range, and increases for smaller wavelengths. The low noise level of the InGaAs diode reduces the uncertainty to less than 0.5 % for VIS-NIR measurements.

Outlook

The SRF mode will be tested in the future using variable slit sizes. The responsivity measurement for UV radiometers can be composed of several overlapping scans using a wide slit function in the low sensitivity range, a medium slit in the sensitive range and a small slit in the intermediate range where the SRF shows a rapid sensitivity change.

In addition, the output beam wavelength range from the SRF set-up can be used for filter transmission measurements in the 200 – 1200 nm range.

The irradiance calibration set-up can be optimised using an input with a higher throughput than the Teflon diffuser optic currently in use. Tests show that the system can measure the irradiance emitted from a 1000 W irradiance standard down to 200 nm with a sufficient signal-to-noise ratio when the intensity is increased by a factor of five.

Window Transmittance Measurements for a Cryogenic Solar Absolute Radiometer

Benjamin Walter

The "Monitor to Measure the Integral Transmittance of Windows" (MITRA) is used to determine the window transmittance for the newly developed Cryogenic Solar Absolute Radiometer (CSAR). Recent technical improvements include a wind-sheltered and electrically-cooled box around MITRA to reduce wind and temperature variations from negatively influencing outdoor measurements. Effects of small residual temperature variations can be corrected for by making use of the instrument temperature gradient. The uncertainty of outdoor measurements was thus reduced from 0.09 % to ~0.015 %, almost fulfilling the MITRA requirement. CSAR and MITRA will be extensively tested in Davos before participating in the 12th International Pyrheliometer Comparison (IPC-XII) in September 2015.

Operating a terrestrial solar absolute radiometer at cryogenic temperatures in a vacuum requires an entrance window with a wavelength dependent reflectivity and absorptivity for the incident radiation. Therefore, the spectrally integrated window transmittance t_{int} needs to be measured to correct the CSAR power reading for these losses (Winkler, 2012). Because the solar spectral irradiance and thus t_{int} change with air mass and atmospheric conditions, MITRA (Figure 1) allows the correction factor t_{int} to be determined in parallel with CSAR measurements. As CSAR aims to reduce the uncertainty of terrestrially measured direct solar irradiance from 0.3 % to 0.01 %, MITRA should measure t_{int} with an uncertainty of 0.01 % or less.

Recent technical improvements to MITRA have focused on the transfer of the laboratory measurement uncertainties to outdoor measurement conditions. Major technical improvements include an electrically cooled box, which surrounds the instrument, and serves as a wind-shelter. In addition, this reduces the influence of temperature variations on the t_{int} measurements. Six air-cooled peltier elements are used to produce a cold, stably stratified air-pool inside the box, keeping MITRA at an almost constant temperature throughout a measurement day. The box, therefore, provides laboratory-type conditions for MITRA on the sun-tracking platform, reducing the previous average outdoor measurement uncertainty from 0.09% (Walter et al., 2014) to about 0.015% (k = 1, Figure 2).

The sine-like behaviour of the t_{int} values (Figure 2) can be explained by small temperture gradients (ca. ± 0.2 K hour $^{-1}$) in the instrument. As these variations are negatively correlated to the temperature gradient of the instrument, the temperature gradient can be used to empirically correct the t_{int} values as a first approach. The mean t_{int} value of 0.9269 agrees extremely well with the average value of t_{int} = 0.9269, as predicted by simulations (Fehlmann, 2011).

A comparison of CSAR with the International System of Units (SI) recently performed at the National Physics Laboratory (NPL) showed good agreement between CSAR and the NPL primary standard absolute radiometer to within the measurement uncertainty of 0.028% (k = 2). The ability of CSAR and MITRA to more accurately realise solar irradiance measurements compared to the World Radiation Reference (WRR) and to provide improved SI traceability will be investigated before these instruments participate in the 12th International Pyrheliometer Comparison (IPC-XII) in September 2015.

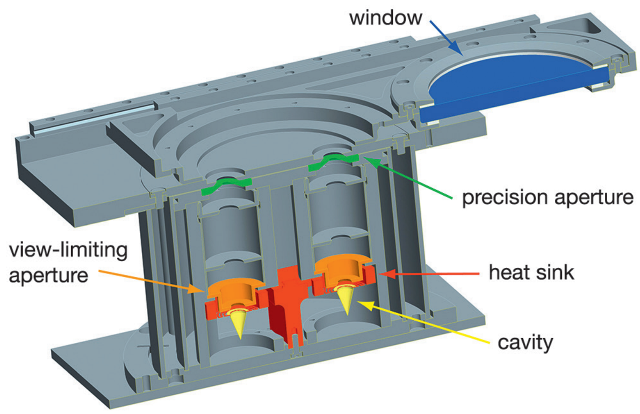

Figure 1. Cross-section through MITRA, illustrating two radiation absorbing cavities being heated about 1°C relative to a common heat sink. The cavity on the right is periodically covered by a window from the same production batch as used by CSAR. Reflection and absorption losses of the window result in a slightly lower temperature of the cavity. Comparing the temperature rise of the obstructed with the unobstructed case defines the spectrally integrated transmittance t_{int}.

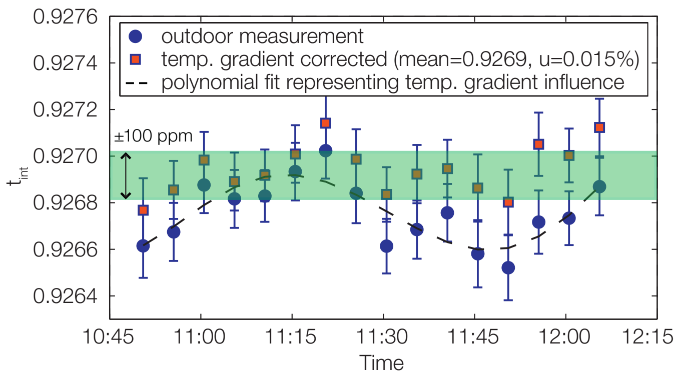

Figure 2. Outdoor t_{int} measurement on the sun-tracking platform showing the influence of temperature gradients which can be corrected.

References:

Fehlmann A.: 2011, Metrology of Solar Irradiance, PhD Thesis, University of Zürich

Walter B., et al., 2014: Spectrally integrated window transmittance measurements for a cryogenic solar absolute radiometer. Metrologia 51: 344 – 349

Winkler R.: 2012, Cryogenic Solar Absolute Radiometer - a potential replacement for the World Radiometric Reference, PhD Thesis, University College London.

Space Experiments

Manfred Gyo, Werner Schmutz, Valeria Büchel, Etienne de Coulon, Fabian Dürig, Wolfgang Finsterle, Patrik Langer, Pierre Luc Lévesque, Margit Haberreiter, Silvio Koller, Nathan Mingard, Dany Pfiffner, Pascal Schlatter, Marcel Specha, Diego Wasser

PREMOS

The PREMOS experiment, a payload aboard the French micro satellite PICARD.

The PICARD mission ended in spring 2014 and with it the shutdown of PREMOS which has had a successful measurement programme. Thanks to all people who supported the mission and the instrument which delivered a high quality solar irradiance data-set.

EUI

The Extreme UV Imager (EUI) experiment, a payload aboard the ESA/NASA Solar Orbiter Mission.

The critical design review was conducted and finished in 2014. At the same time, the qualification process of the manufacturing process and material continues. Unfortunately, late changes in the instrument design and interface changes between EUI and the spacecraft have led to a re-design of the optical bench. Hence, manufacture of the flight model has been delayed to 2015.

In addition, a new purge distribution system needs to be designed and qualified. The instrument now only has one interface to the spacecraft and the distribution of the nitrogen purge to the three cavities has to be conducted at instrument level. Two consortium meetings were held to coordinate the work, one in spring in Göttingen (Figure 1) , Germany, and one in autumn in Brussels, Belgium.

Figure 1. EUI team members during the consortium meeting in spring 2014.

SPICE

The SPICE experiment, a payload aboard the ESA/NASA Solar Orbiter Mission.

Low Voltage Power System (LVPS)

The LVPS is designed and manufactured by PMOD/WRC (Figure 2). After delivery of the LVPS engineering model (EM) to SWRI and integration into the SEB, the qualification process was successfully started and subsequently finished. A few changes were required due to the outcome of intensive testing at SWRI. In addition, some subsequent requirements by ESA were required to test and integrate into the flight design.

The MRR, for both flight units, was held in June. After the successful MRR the flight PCBs were ordered and then inspected at RAL.

All the flight components and parts were ordered step-by-step during the whole year. Several parts had not arrived at the PMOD by December.

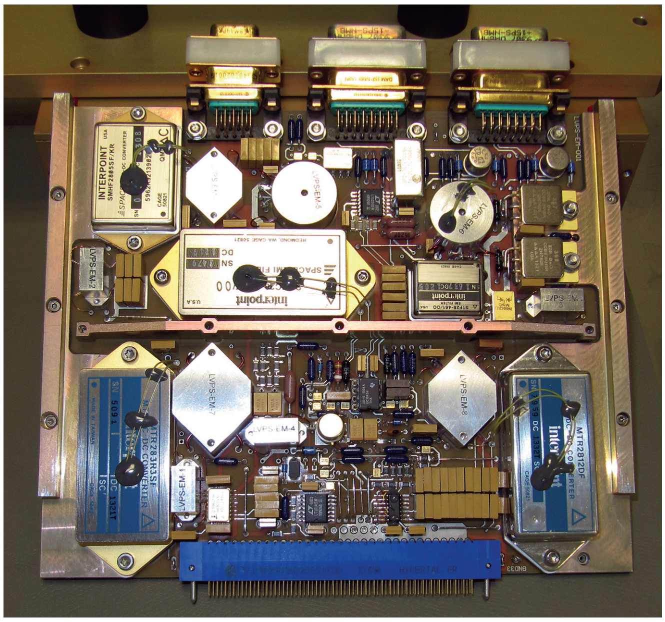

Figure 2. Low voltage power supply of the engineering model.

Slit Change Mechanism (SCM)

The SCM is designed to put one of four slits into position during measurements. ALMATECH, our industry partner for the SCM, has performed a series of tests on different breadboards.

The manufacture of the deliverable models progressed during 2014. A magnetic shield to protect the spacecraft from the rather high dipole of the SCM motor was designed and manufactured.

In addition, a metrology system was developed which will allow the position of the four slits to be accurately measured in vacuum. Final testing of the breadboards (Figure 3), final design modifications and dry lubrication of the moving components were ongoing throughout 2014.

Completion of manufacturing, assembly and testing are the upcoming tasks for 2015. The mechanism is going to be baked-out at PMOD/WRC before delivery in autumn 2015.

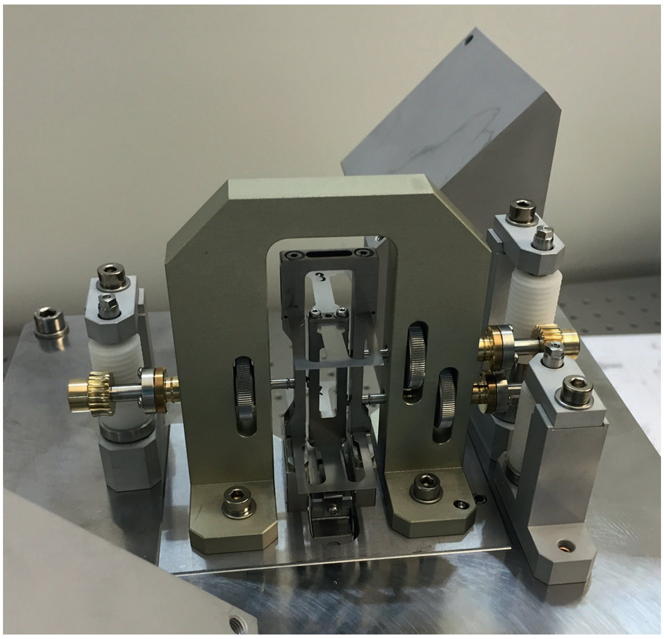

Figure 3. Snubber alignment jig.

SPICE Door Mechanism (SDM)

The SDM is designed to prevent instrument contamination while on the ground and in space. It also allows the instrument to be purged through a labyrinth seal during AIT and launch. The contract for phase D was signed at the beginning of 2014 with APCO Technologies, our industry partner for the SDM. The breadboard successfully passed vibration and EMC testing. After the test campaign, the breadboard was used for the run-in activities of the dry lubricated linear bearings.

The qualification model (QM), flight model (FM) and flight spare (FS) were manufactured in parallel, and have all made significant progress. The different coatings were qualified and the coating of the flight parts has started. Upcoming activities include: assembly, further qualification testing and acceptance testing. The delivery of the flight model is planned for summer 2015. Figure 4 illustrates the SDM mounted on the SPICE structural model during vibration testing.)

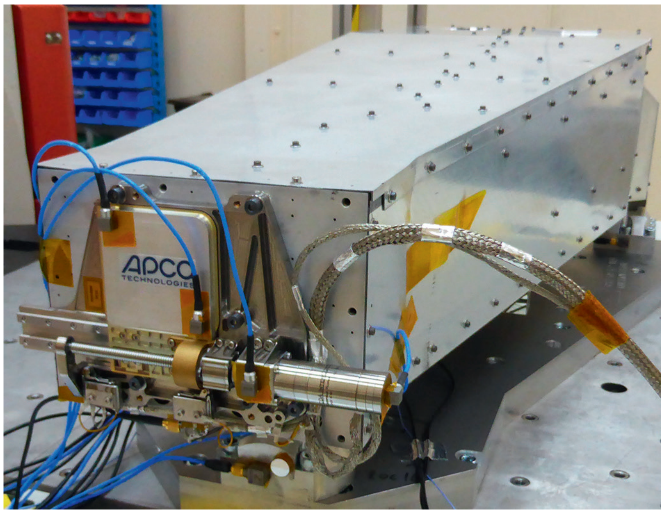

Figure 4. SDM mounted on the SPICE structural model during vibration testing.

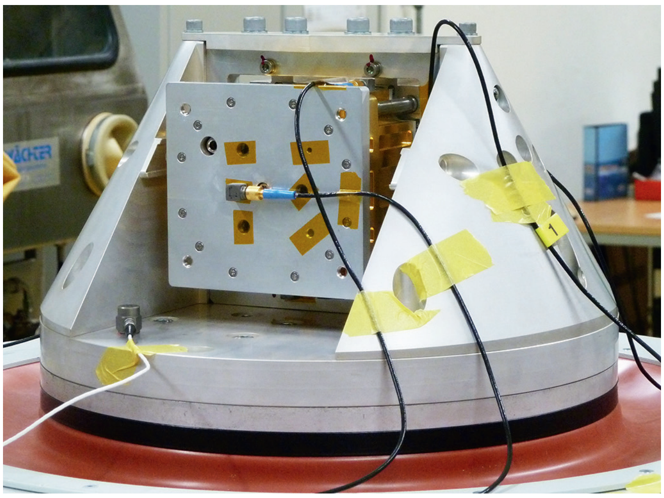

Figure 5. CLARA EM mounted on a dedicated adapter and shaker for vibration testing. Various accelerometers are positioned on the instrument.

CLARA

The Compact Lightweight Absolute Radiometer (CLARA) on the Norwegian NORSAT-1 nano-satellite.

The NORSAT-1 satellite carries a next-generation Automatic Identification System (AIS) receiver system, a Langmuir probe (plasma detector) developed by the University of Oslo, and the CLARA space experiment. The AIS is a GPS-based tracking system for large ships, which Norway has already integrated on previous satellites. PMOD/WRC finalised the design of the CLARA EM in 2014, and manufactured the complete model (Figure 5) as a fully representative radiometer in collaboration with external service partners. The EM design provides the basis for a larger Swiss industry contract, containing mechanical and thermal analysis of the payload instrument, design improvement, manufacture of structural and thermal parts for the flight units and testing activities.

A second contract was issued to provide the onboard software, running of the instruments microcontroller, and the electronic ground support equipment (EGSE) software, which is applied for ground-based activities. Both contracts are under the responsibility of the ESA PRODEX office. Functional tests on the H/W and S/W side were successfully performed. Since the entire cavity and heat-sink design is rather fragile, and is being implemented in a space experiment for the first time, vibration tests were conducted with the EM (Figure 5).

The EM electronics and all spacecraft interfaces were tested during a so-called flat-sat test (Figure 6) at the University of Toronto, Canada. In this test configuration, all electronic PCBs are laid out on a table and connected. This allows good access and thus verification of signals, their timing and their quality. First solar measurements with the CLARA EM are foreseen in early 2015. As the launch of NORSAT-1 is planned for spring 2016, PMOD/WRC has been asked to deliver the flight units in summer 2015 for integration purposes.

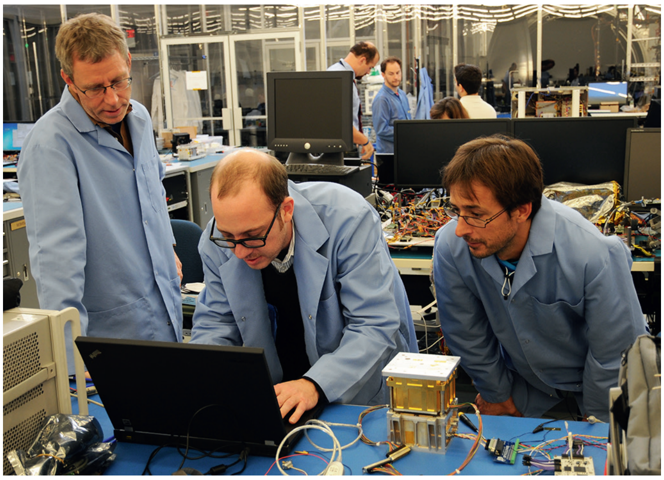

Figure 6. Flat-sat test with the CLARA EM and NORSAT-1 components. (University of Toronto, Canada).

DARA

The Digital Absolute Radiometer (DARA) on the ESA PROBA-3 formation flying mission.

DARA was already presented in 2010 during phase B of the PROBA-3 mission. After an interruption by the mission organisers, the project was “re-launched” during the 4th quarter of 2014. DARA was the predecessor project of CLARA but can now profit from developments achieved with the latter.

A design proposal was finalised (Figure 7) and sent to ESA. DARA will be located on the PROBA-3 occulter spacecraft. The highly elliptical orbit of PROBA-3 will allow long periods of uninterrupted solar observations. As a drawback, a high total dose of ionising radiation will have to be considered in the design.

Industry contracts will begin in spring 2015, and statements of work and technical requirements have therefore been defined for the different tasks. Similar to the CLARA project, Swiss industry will conduct various activities. Further information on PROBA-3 is available at: http://www.esa.int/Our_Activities/Space_Engineering_Technology/Proba_Missions/About_Proba-3.

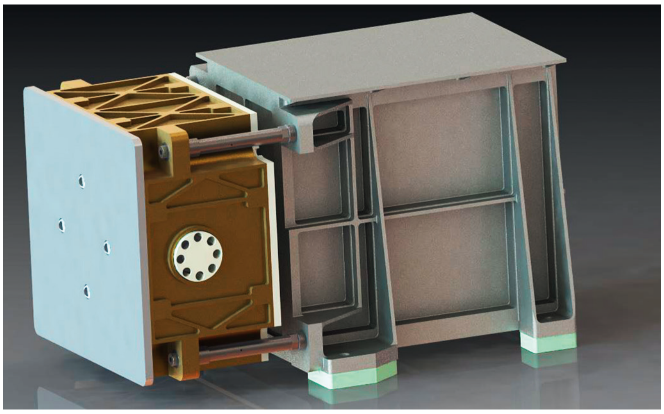

Figure 7. DARA CAD design.

Scientific Research Activities

Overview

Werner Schmutz

Projects at PMOD/WRC are related to solar radiation in which we address questions regarding the radiation energy budget in the terrestrial atmosphere as well as problems in solar physics to understand the mechanisms concerning the variability of solar irradiance. Hardware projects at our institute are part of investigations into Sun-Earth interactions by providing measurements of solar irradiance.

The choice of projects to be conducted at the institute is governed by the synergy between the know-how obtained from the Operational Services of the World Radiation Center and other research activities. Basically, the same instruments are built for space-based experiments as are utilised for ground-based measurements.

The research activities can be grouped into three themes:

- Climate modelling
- Terrestrial radiation balance
- Solar physics

Research activities are financed through third party funding. Last year, five projects were supported by the Swiss National Science Foundation, two projects by the Swiss COST support, one project by MeteoSwiss, two projects by the 7th European Framework Programme FP7, and three projects by the European Metrology Research Programs.

These funding sources support four PhD Theses and seven post-doctoral positions. ESA's PRODEX programme funds the hardware development of space experiments. The institute's three PRODEX projects funded the equivalent of eight technical department positions.

The main project in climate research at PMOD/WRC is "Future and Past Solar Influence on the Terrestrial Climate" (FUPSOL), which is a collaborative multi-institute research programme with partners from EAWAG, IAC ETHZ, University of Bern, and the Oeschger Centre for Climate Change Research.

FUPSOL aims to quantify the solar forcing and its influence on the Earth's atmosphere and climate in the past and future. The project is funded by a 3-year "Sinergia" grant from the Swiss National Science Foundation, and started a year ago. FUPSOL–II is a follow-up from FUPSOL–I, a three-year project that was very successful and resulted in many publications in reviewed journals. Four FUPSOL – I publications were published in 2014.

The number of citations in 2014 again surpassed a total of 1000. Although slightly less than in 2013, the number of citations confirmed an upward trend beginning in about 2006. This reflects an increasing interest by the international scientific community in scientific and space activities at PMOD/WRC.

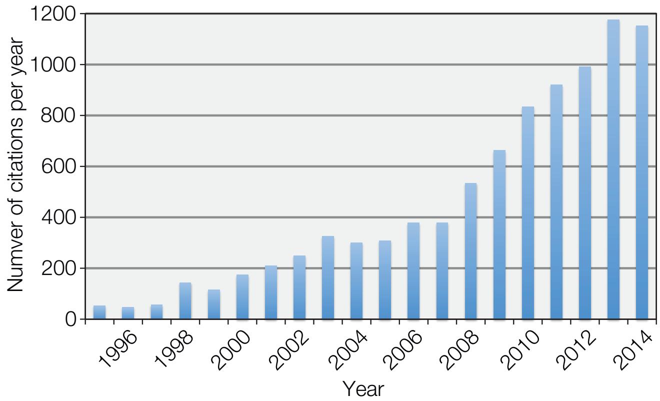

Figure 1. Number of annual citations of publications which include an author with a PMOD/WRC affiliation. A total of 9731 citations of 472 publications were included in Thomson Reuter's Web of Science up to April 2015. Publications can be searched using the following criteria in the address = (World Rad C*) OR (PMOD* NOT PMOD Technol*) OR (Phys* Met* Obs*).*

Future and Past Solar Influence on the Terrestrial Climate (FUPSOL – II)

Werner Schmutz (PI), Eugene Rozanov (project manager) in collaboration with teams from EAWAG, IAC ETHZ, KUP and GIUB of University of Bern and Oeschger Centre for Climate Change Research

FUPSOL is a Swiss collaboration project which aims to quantify the solar forcing and its influence on the Earth's atmosphere and climate in the past and future. The analysis of previous experiments shows that the colder climate during the Dalton minimum is partly explained by a decrease in solar irradiance. We also confirmed that the climate sensitivity of our atmosphere-ocean-chemistry-climate model agrees well with other models. We extended the simulated period from 2100 to 2200 and showed that even a long-term decrease in solar activity cannot compensate greenhouse warming, however, its influence prevents the recovery of the ozone layer. We have also improved applied model and analysis tools in preparation for new climate and ozone layer simulations.

During 2014 we prepared the forcing dataset extending from the year 2100 to 2200 and simulated the climate system behavior from 2000 to 2200 using the atmosphere-ocean-chemistry-climate model (AOCCM) SOCOL-MPIOM (Muthers et al., 2014). We have analysed the stability of the climate and total column ozone response to the potential decline in solar activity. Figures 1 and 2 illustrate the evolution of the global and annual mean surface air temperature and total column during 200 years of simulation for the cases with a constant, strong and weak decrease in solar activity. It is clear that even the extremely low solar activity can compensate only about 0.6 out of 2.1 K of the greenhouse warming in 2200. This value is higher than in 2100 (0.35 K, Anet et al., 2013) but still not high enough to compete with the relatively weak (4.5 W m^{-2}) increase in anthropogenic forcing.

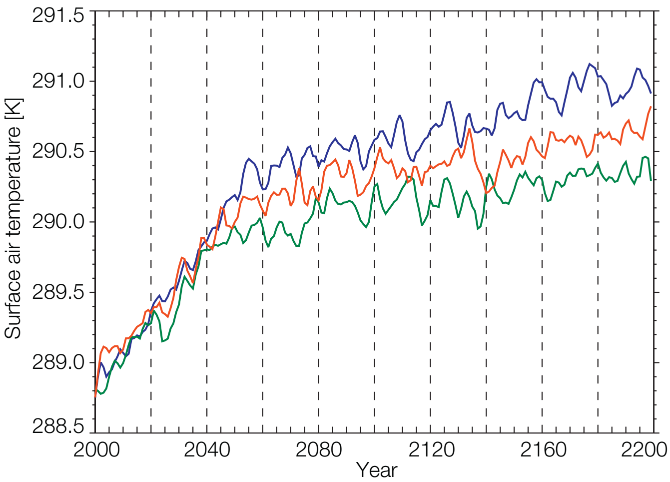

Figure 1. Evolution of the global and annual mean surface air temperature (K) for the cases when the solar irradiance forcing is constant (blue line), strongly (green line) or weakly (red line) decreased.

Figure 2 shows a more pronounced and stable influence of the solar activity on the total column ozone. The strong drop in the solar activity leads to a strong depletion of the total ozone concentration, overcoming its recovery due to the Montreal protocol limitations. Other activities were aimed at the intended improvement of our model tools.

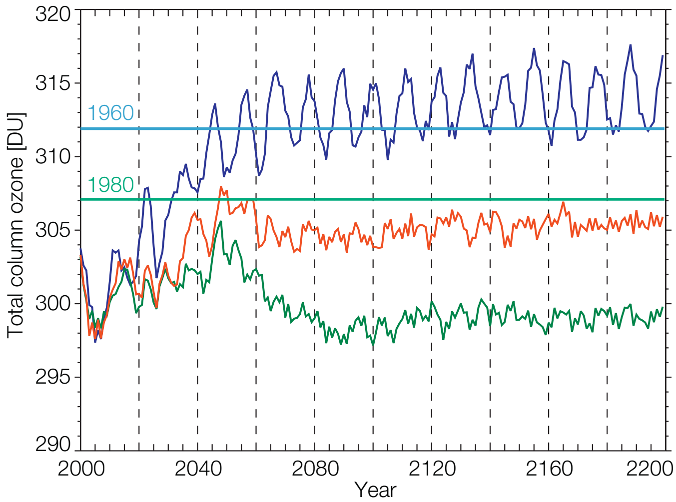

Figure 2. Evolution of the global and annual mean total column ozone (DU) concentration for the cases when the solar irradiance forcing is constant (blue line), strongly (green line) or weakly (red line) decreased. The two lines show total column ozone in 1960 and 1980.

We have introduced a penumbra model and activity belts to the model to calculate the solar irradiance and improve the representation of variability in the 11-year solar cycle. We have added the ionisation rates of middle-range energy electrons to the AOCCM SOCOL-MPIOM model, and analysed their influence on ozone and temperature. We have updated the parameterisation of gravity waves, which will allow the efficiency of the downward propagation of stratospheric perturbations to be increased. We have also updated the parameterisation of the response of the heating rate and photolysis rates to solar irradiance variability.

We have continued the analysis of previous experiments and demonstrated that the colder climate during the Dalton minimum is caused by both volcanic eruptions and a decrease in solar activity (Anet et al., 2014). We have also confirmed that the climate sensitivity of AOCCM SOCOL-MPIOM, which was developed in the first phase of the FUPSOL project, agrees well with other CMIP5 models and the estimates from IPCC 2014. To analyse the response of weather patterns to the solar activity we have developed a method to generate the time-series of new weather types, and produced a time-series covering the period 1763–1998. A preliminary analysis of these data showed that low solar activity is characterised by an increase in easterly flow over Europe.

References:

Anet J. G., et al.: 2013, Impact of a potential 21st century "grand solar minimum" on surface temperatures and stratospheric ozone, Geophys. Res. Lett., 40, 420–442.

Anet J., et al.: 2014, Impact of solar vs. volcanic activity variations on tropospheric temperatures and precipitation during the Dalton Minimum, Clim. Past, 10, 921–938.

Muthers S., et al: 2014, The coupled atmosphere-chemistry-ocean model SOCOL-MPIOM, Geosci. Model Dev., 7, 2157–2179.

The Solar Cycle in CCM SOCOL Hindcast Simulations

Eugene Rozanov in collaboration with Ales Kuchar, Laura Revell, and Andrea Stenke, IAC ETHZ

This study focuses on the response of temperature, ozone and circulation characteristics in the stratosphere/lower mesosphere caused by the 11-year solar variability. We show that the warming in the lower tropical stratosphere usually attributed to the solar influence is actually caused by volcanic eruptions.

To detect variability and changes due to external climate factors, such as the 11-year solar cycle, we have applied an attribution analysis based on multiple linear analysis. The regression model consists of a linear trend, quasi-biennial oscillation, El Niño Southern Oscillation index and stratospheric aerosol optical depth. The solar cycle is represented by the 10.7 cm radio flux. The analyses were determined using hindcast CCMI simulations REF–C1 and REF–C2 (Eyring et al., 2013) with the chemistry-climate model (CCM) SOCOL v3. Figure 1 shows the annually averaged response of the zonal mean temperature to the solar irradiance variability for the period 1979–2009. The double-peaked structure in the stratosphere is visible in the REF–C1 simulations and is in agreement with observations. However, in the REF–C2 simulation, where volcanic eruptions were not included and different sea surface temperatures (SST) were prescribed, the lower stratospheric solar response disappeared.

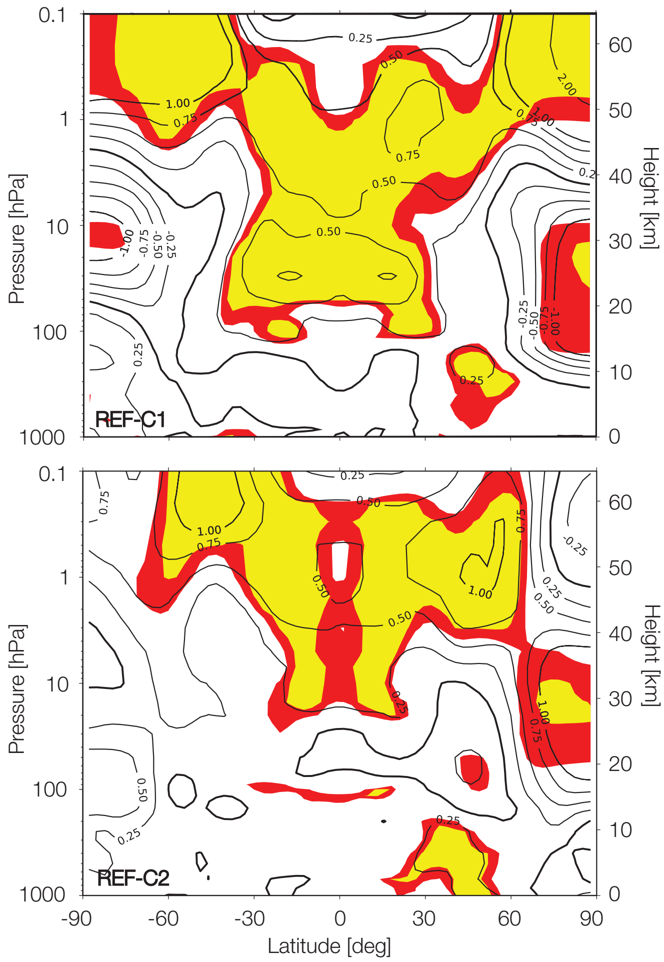

Figure 1. The annually averaged temperature response to solar irradiance variability extracted from REF–C1 and REF–C2 simulations for 1979–2009. The response is expressed as units per S_{max} - S_{min}. Red and yellow areas indicate t-test p-values of < 0.05 and 0.01, respectively.

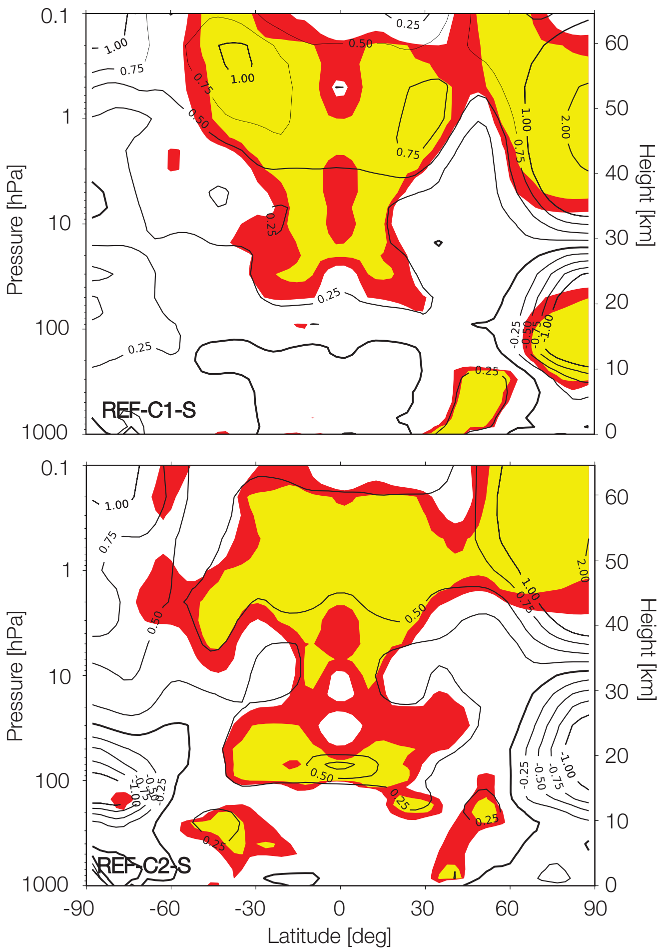

Figure 2. The annually averaged response of the solar signal in the SOCOL v3.0 (REF-C1-S and REF-C2-S) temperature for 1979–2009. The response is expressed as units per S_{max} - S_{min}. Red and yellow areas indicate t-test p-values of < 0.05 and 0.01, respectively

Based on this, two sensitivity simulations were performed examining the possible influence of the SST and volcanic eruptions on the atmospheric response in the lower tropical stratosphere. One simulation was repeated as REF–C1 without any volcanic eruptions (marked as REF–C1–S). The other one was repeated as REF–C1 but using SST from REF–C2 (marked as REF–C2–S). The results for temperature are presented in Figure 2. The results of sensitivity simulations suggest the dominating role of volcanic eruptions on the detected solar signal during the period 1979–2009 in the lower tropical stratosphere since two major volcanic eruptions (El Chichón in 1982 and Mt. Pinatubo in 1991) are aligned to solar maximum periods (Chiodo et al., 2014).

References:

Chiodo G., et al.: 2014, On the detection of the solar signal in the tropical stratosphere, Atmos. Chem. Phys., 14, 5251–5269.

Eyring V., et al.: 2013, Overview of IGAC/SPAR C CCMI Community Simulations in Support of Upcoming Ozone and Climate Assessments, SPARC newsletter, 40, 48–66.

Indirect Effects of Precipitating Energetic Particles After Sudden Stratospheric Warming in January 2009

Eugene Rozanov and William Ball in collaboration with the HEPPA-II team.

We have participated in the HEPPA-II model-observation intercomparison project aimed at the study of indirect energetic particle precipitation effects during the dynamically perturbed winter of 2008/9. To address this problem we have developed a nudged version of our CCM SOCOL v3.0 and simulated the evolution of the atmosphere from October 2008 to May 2009.

Odd nitrogen (NO_x = NO + NO_2) can be produced in the mesosphere/lower thermosphere by precipitating energetic electrons and transported lower into the atmosphere during polar winter. This causes ozone loss via catalytic cycles with further implications for the tropospheric surface climate. This process has different features in the northern and southern hemisphere. During the dynamically stable Austral winters, NO_x production depends mostly on the geomagnetic activity level, while in the northern hemisphere less stable dynamics may modulate downward transport. This leads to a dependence of the total effect on the state of the polar vortex. One good case which illustrates these peculiarities is the major stratospheric warming in January 2009, which caused a very efficient descent and elevated NO_x level in the upper stratosphere despite quiescent geomagnetic conditions.

HEPPA-II is a subproject of the SPARC SOLARIS-HEPPA activity (http://solarisheppa.geomar.de/heppa2) aimed at evaluating the model performance in simulating the observed downward transport of NO_x during the dynamically active 2008/2009 winter. The observed temperature, NO_x and CO during October 2008–May 2009 were compared to simulations of eight state-of-the-art atmospheric models nudged to re-analysis data.

We have participated in the HEPPA-II project using a specially designed nudged version of our CCM SOCOL v3.0 (Stenke et al., 2013) and simulated the evolution of the atmosphere from October 2008 to May 2009. Because our model top is at 80 km, we cannot simulate NO_x production in the thermosphere and, therefore, the NO_x mixing ratio in the uppermost model layer was prescribed using MIPAS data.

Figure 1 illustrates the simulated evolution of the polar temperature. Due to the applied nudging, the observed temperature evolution can be reproduced well. Sudden warming in the upper stratosphere at around 20 January 2009 is clearly visible. The formation of the elevated stratopause in February, and the recovery of the cold temperature inside the vortex, are also clearly visible in the model output. Figure 2 demonstrates the simulated time evolution of the NO_x mixing ratio (ppbv) averaged over the northern polar cap, overlaid with observations from MIPAS.

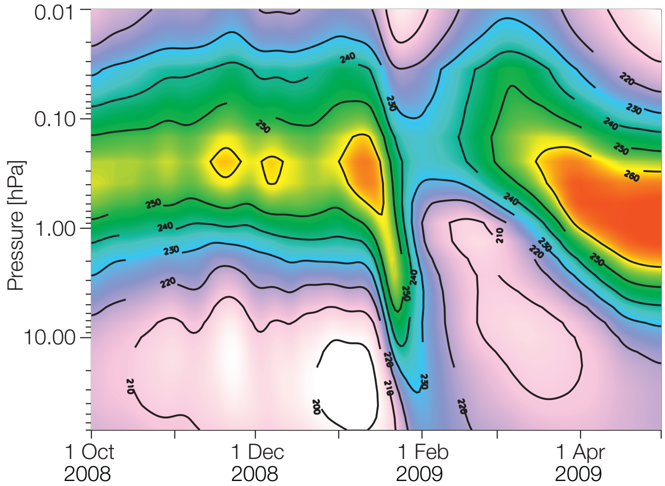

Figure 1. The simulated time evolution of the air temperature (K) over the northern pole during the winter of 2008/2009.

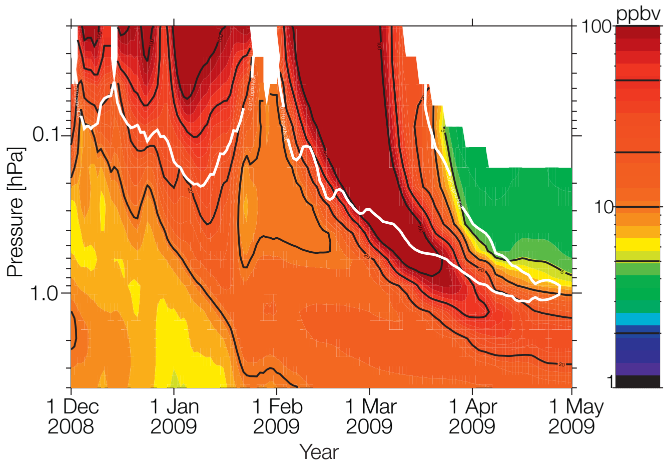

Figure 2. The simulated time evolution of the NO_x mixing ratio (ppbv) averaged over the northern polar cap during the winter 2008/2009. The white line shows 10 ppbv NO_x observed by the MIPAS instrument.

The model captures the first spike of enhanced downward transport reasonably well. However, during the main event the simulated downward NO_x propagation is too strong and intensive compared to MIPAS data. The careful and extensive analysis of all observed and simulated data is ongoing.

References: Stenke A., et al.: 2013, The SOCOL version 3.0 chemistry-climate model: description, evaluation, and implications from an advanced transport algorithm, Geosci. Model Dev., 6, 1407–1427.

Response of Atmospheric Chemical Components During the SEP and Extreme GLE Events of January 2005

Eugene Rozanov in collaboration with Irina Mironova, SPbU, S. Petersburg, Russia (collaboration inside COST ES1005)

During the short-term scientific mission (STSM) in the framework of COST ES1005 "TOSCA" action we studied the impact of galactic and solar energetic particles on the physical and chemical properties of the Earth's atmosphere. We installed the chemistry-climate model (CCM) SOCOL v2.0 on the computers provided by the Institute of Physics, St. Petersburg State University (SPbU), and used it to conduct an ensemble simulation of the January 2005 event.

Previous analysis of the stratospheric response to the January 2005 Solar Energetic Particles/ Ground Level Enhancement (SEP/GLE) event showed that cooling and additional aerosol formation could happen during stable mid-winter conditions (Mironova et al., 2012). However, the reasons for the cooling and its connection to polar stratospheric clouds (PSC) remains unclear. One way to resolve the problem is to apply a chemistry-climate model and to compare the simulated response against observations. The SOCOL chemistry-climate model (CCM) was chosen because of its ability to treat additional sources of NO_x and HO_x produced by energetic particles (Rozanov et al., 2012). SEP effects on the chemistry of the upper atmosphere using the data retrieved from the MLS instrument onboard the EOS AURA satellite were presented by Damiani et al., (2008). They showed that SEP could lead to short and medium-term ozone depletion caused by an increase of HO_x/NO_x and intensification of relevant catalytic cycles.

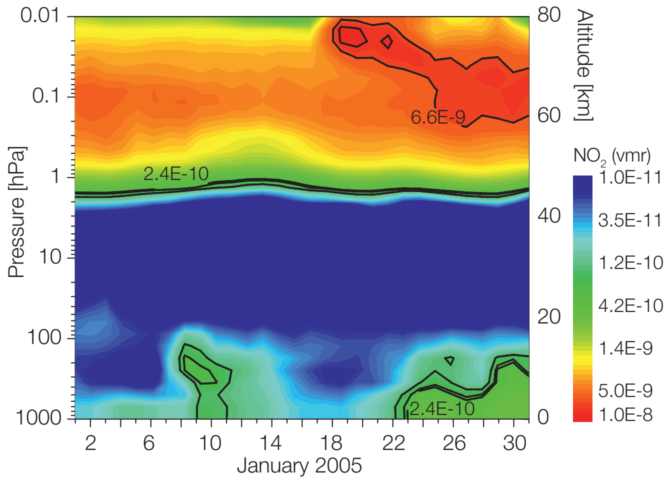

Figure 1. Mean NO_2 mixing ratios (mol/mol) over the polar cap in January 2005 simulated with the SPbU version of CCM SOCOL.

During the STSM, we installed CCM SOCOL on the local computers at SPbU and applied it to simulate the state of the stratosphere in January 2005 taking into account ionisation rates by GCR and two SEP events on 17 and 20 January. The ionisation rates for the period from July 2004 to March 2005 were provided by I. Usoskin (University of Oulo, Finland).

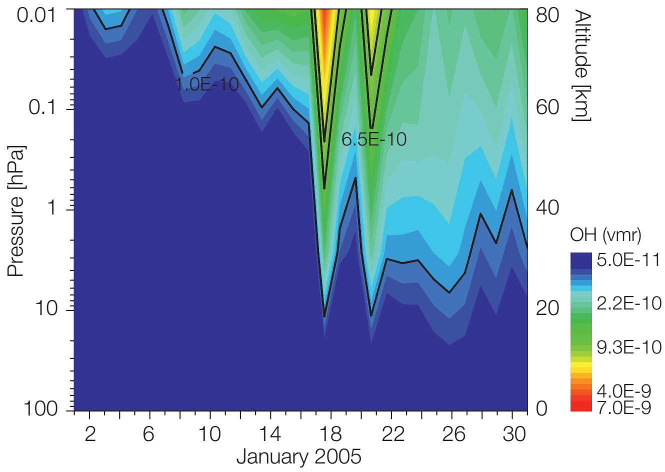

Figure 2. Mean OH mixing ratio (mol/mol) over the polar cap in January 2005 simulated with the SPbU version of CCM SOCOL.

The simulated anomalies of the mean NO_2 mixing ratios over the polar cap in January 2005 are presented in Figure 1. An increase of NO_2 in the mesosphere and downward propagation of these anomalies are clearly visible. The obtained results resemble the observations, however, further analysis is required to establish their statistical significance.

Figure 2 illustrates more than an increase of the mesospheric OH concentration. This increase seems to persist from the 17 January to the end of the month and has two maxima during the sub-events on 17 and 20 January 2005. These SEP events were completely different. The first has proton fluxes at lower energies hitting the high Earth's atmosphere while the second had more pronounced effects on the low Earth's polar atmosphere. Despite this, two SEP events resulted in the strong production of OH in the polar mesosphere.

The installation and test runs of CCM SOCOL on the computers at the Institute of Physics, St. Petersburg State University, open the possibility of a new collaboration aimed at a more detailed analysis of the obtained results and will allow new interesting issues to be investigated.

References:

Damiani A., et al.: 2008, Solar particle effects on minor components of the Polar atmosphere, Ann. Geophys., 26, 361–370.

Mironova I., et al.: 2012, Possible effect of extreme solar energetic particle event of 20 January 2005 on polar stratospheric aerosols: Direct observational evidence, Atmos. Chem. Physics, 12, pp. 769–778.

Rozanov E., Calisto M., Egorova T., Peter T., Schmutz W.: 2012, Influence of the precipitating energetic particles on atmospheric chemistry and climate, Surv. Geophys, 33, 3, 483–501, doi: 10.1007/s10712-012-9192-0.

Study of the Middle Atmosphere Response to Short-Term Solar Irradiance Variability

Timofei Sukhodolov, Eugene Rozanov in collaboration with IAC ETHZ

The chemistry climate model SOCOL v3.0 is used to characterise the solar rotational cycle induced signal in the middle atmosphere. The analysis of the simulations and observations showed the presence of several atmospheric harmonics which can potentially contribute to the distortion of the solar signal in the mesosphere-stratosphere region.

One important climate influencing process is the downward propagation of solar UV induced perturbations in the tropical stratosphere, which is known as the top-down mechanism of solar influence on climate (e.g., Gray et al., 2010). However, not all aspects of this mechanism have been clearly identified and chemistry–climate models (CCMs) differ in their representations. One of the main problems of the solar 11-year signal derived from observational data during the satellite era is the influence of volcanic eruptions and a number of atmospheric modes of similar variability. Another problem is the small number of solar cycles covered by satellite observations (currently only three). To overcome these difficulties and to study the details of solar signal propagation we decided to focus on the solar rotational cycle caused by the longitudinally inhomogeneous distribution of solar magnetic field features. The magnitude of irradiance variations during the 27-day cycle is similar to that during the 11-year cycle. Together, with the availability of many observed rotational cycles, this makes the statistical analysis more robust.

For the study we used SOCOL v3.0 CCM (Stenke et al., 2013), which was recently upgraded to fulfil the requirements of the CCM validation project. We carried out two modelling experiments for the period 2004–2005: One reference experiment with realistic solar forcing and another with a suppressed rotational cycle. For each of the experiments we ran the ensemble of eight members. As a proxy we used the irradiance at 205 nm filtered by 35-and 7-day filters. The wavelet analysis of the proxy shown in Figure 1 allowed the 480-day period of the more pronounced variability to be identified, which we further used for cross-correlation and Fourier analysis of the modelled hydroxyl, ozone and temperature fields.

The obtained correlation fields are similar to previous observational and modelling studies while the temperature response remained unclear. Compared to the signal obtained from the ERA-Interim re-analysis data, modelling results show no response in the tropical region (Figure 2). Moreover, the run with the supressed rotational cycle demonstrated a higher correlation in these regions than the reference run. Fourier analysis of the modelled fields revealed the presence of several modes with a periodicity close to 27-days, whose superposition can lead to the distortion of the solar signal. This also follows from the fact that the modelled results significantly vary between the ensemble members depending on the dynamical state of the system. Similar harmonics are also visible in the re-analysis temperature (Figure 3). The origin of these features is uncertain and requires further investigation.

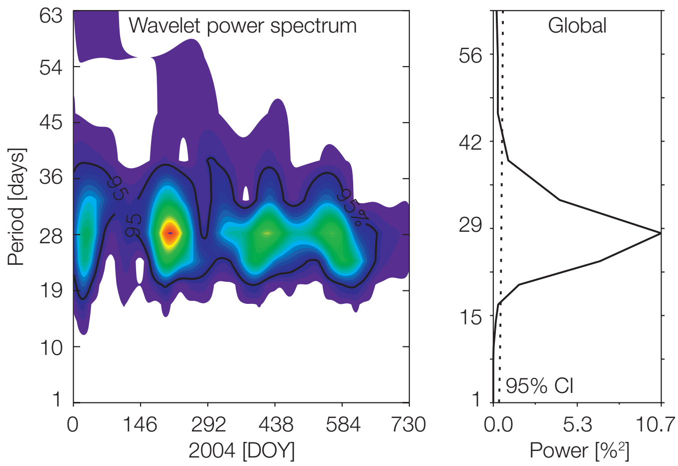

Figure 1. Wavelet analysis of the 205 nm irradiance proxy. The 95% confidence interval (CI) is shown in the right panel.

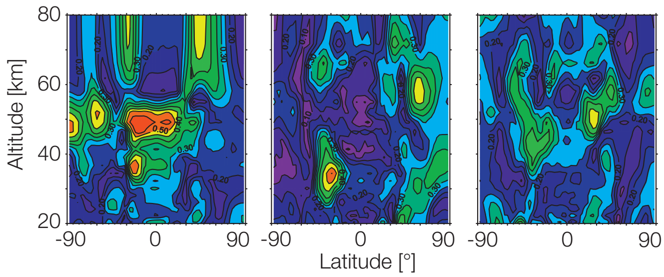

Figure 2. Maximum absolute correlation from ±30-day phase lag cross-correlation function of the temperature versus the solar irradiance at 205 nm. Left: ERA-Interim re-analysis, middle: run with suppressed rotational cycle, right: reference run.

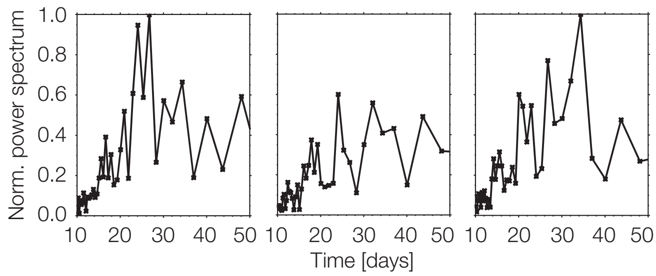

Figure 3. Normalised power spectrum of the 20°S–20°N temperature at 1 hPa. Left: ERA-Interim re-analysis, middle: run with suppressed rotational cycle, right: reference run.

References:

Gray L. J., et al.: 2010, Solar influences on climate, Rev. Geophys., 48, RG4001, doi:10.1029/2009RG000282.

Stenke A., et al.: 2013. The SOCOL version 3.0 chemistry-climate model: Description, evaluation, and implications from an advanced transport algorithm, Geosci. Model Dev., 6, 1407–1427.

Study of Factors Influencing Ozone Layer Evolution (SILA)

William Ball, Eugene Rozanov, Timofei Sukhodolov, and Anna Shapiro in collaboration with IAC ETHZ

The ongoing SILA project aims to understand unforced ozone variability and its interplay in response to SSI variability. The project has several main objectives, which are to:

(i) Understand specific stratospheric events: a large ozone increase and temperature decrease in August 2004; an ozone decrease due to anomalously low Arctic temperatures, and ozone trends due to Sudden Stratospheric Warmings (SSWs).

(ii) Determine whether there is a link between spontaneous ozone variability and effects caused by SSI variability.

(iii) Identify which SSI dataset gives the best agreement between modelled and measured stratospheric ozone responses to the 11-year solar cycle (see Ermolli et al., 2013).

(iv) Reproduce the January 2009 SSW event so that Switzerland can participate in the international model-measurement intercomparison activity HEPPA - II (see contribution in this report).

(v) Join the international Chemistry-Climate Model Initiative (CCMI) to study troposphere-stratosphere coupling with different Chemistry Climate Models (CCMs).

To achieve these goals, we use the SOlar Climate Ozone Links (SOCOL) model which is a state-of-the-art atmospheric CCM. The SOCOL model has been developed at PMOD/WRC and IAC/ETHZ as a fully coupled ocean-atmosphere model with a detailed stratospheric chemistry scheme. It has been shown to give an excellent simulation of stratospheric chemistry (e.g. Stenke et al., 2013). Successful modifications to SOCOL include nudging, which was also a major task of this project, and have allowed us to join the HEPPA - II and CCMI projects.

One of the major tasks of this project is to identify the SSI which gives the best agreement with observations. We have performed runs using SORCE, NRLSSI and SATIRE - S SSI datasets (Figure 1) as well as perpetual solar maximum and minimum conditions for all datasets between 2001 and 2011. Due to the nudging of the dynamics, any difference in the temperature and ozone response between the simulations is due to the input SSI datasets. This allows us to then quantify the photolytic and heating impacts of SSI on stratospheric chemistry and temperature. Initial results are shown in Figure 2, where the difference between a constant Sun and a Sun changing from solar maximum to minimum is given for each SSI dataset. The results from the perpetual maximum show that they are robust and not an artifact of the year and month of solar maximum. The next step is to compare these results with observations.

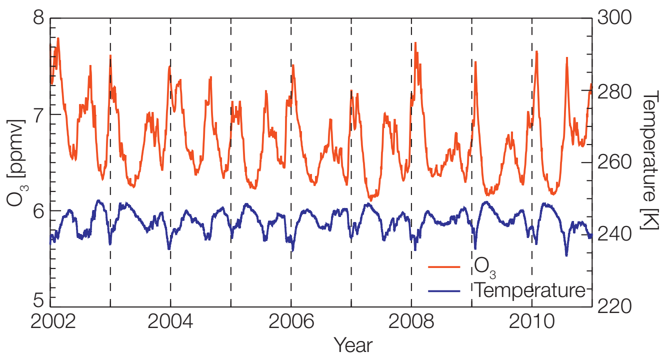

Figure 2. Nudged SOCOL CCM output at 4 hPa for tropical ozone concentration (red, left axis) and temperature (blue, right axis) between 2002 and 2010 using NRLSSI solar data.

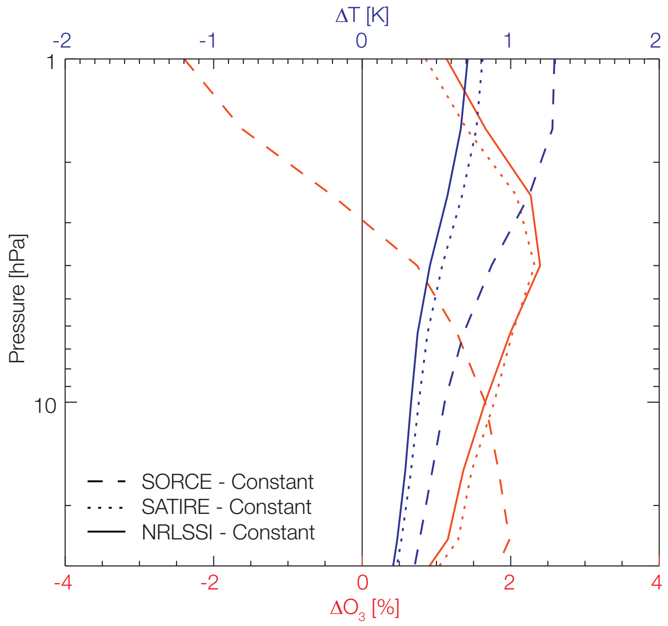

Figure 1. The change in temperature (blue, top axis) and ozone (red, lower axis) between solar maximum (2002) and minimum (2008) using SATIRE - S input spectra (dotted line), SORCE (dashed line) and NRLSSI (solid line) relative to a constant Sun (using 3-month averages).

The nudged version of SOCOL also allows us to gain a better understanding of spontaneous events in the stratosphere such as the August 2004 event, where observations detected a ~10% increase in ozone at 35 – 45 km, relative to 2008, with a simultaneous ~4 K decrease in temperature. We are analyzing the runs, discussed above (e.g. NRLSSI in Figure 1) using SORCE, NRLSSI and SATIRE - S SSI datasets to investigate if SSI had any influence on this event. Our initial findings suggest this event may rather be the result of internal variability; the analysis is ongoing. The same computer simulations also contain the information needed to investigate the other specific stratospheric events we aim to understand.

References:

Ermolli I., et al.: 2013, Recent variability of the solar spectral irradiance and its impact on climate modelling, Atmos. Chem. Phys., 13, 3945 – 3977, doi:10.5194/acp-13-3945-2013.

Stenke A., et al.: 2013, The SOCOL version 3.0 chemistry-climate model: Description, evaluation, and implications from an advanced transport algorithm, Geosci. Model Dev., 6, 1407 – 1427.

Solar Variability and Climate Change During the First Half of the 20th Century (SOVAC)

Tatiana Egorova, Eugene Rozanov, and Werner Schmutz in collaboration with the FUPSOL - II project team

In the SOVAC project, we study the causes of observed climate warming during the first half of the 20th century using the climate evolution from 1860 to 1960 simulated with the atmosphere-ocean-chemistry-climate model (AOCCM) SOCOL – MPIOM. A comparison of the results with observations shows that only strong solar forcing can explain the observed warming trend. However, the analysis of other model results does not fully support this conclusion.

During the second year of the SOVAC project, we performed four reference and five sensitivity model runs driven by different combinations of forcing. We have also collected all available observation-based data sets such as CRUTEM, NCDC, JMA, GISS, NERSC and NOAA CIRES. In the framework of the SolMIP (Solar Model Intercomparison Project) activity we have acquired the results of models which participated in the IPCC CMIP-5 (Coupled Model Inter-comparison Project phase 5) exercise and analysed the climate and ozone response to decadal scale solar variability (Mitchell et al., 2015; Hood et al., 2015). We have also prepared statistical software for the extensive comparison of simulated and observed climate change in the 20th century. In collaboration with the FUPSOL team, we published a paper describing AOCCM SOCOL - MPIOM v3.0, and analysed the causes of the simulated warming trend in the 20th century (Muthers et al., 2014). At present, most of the planned model runs have been completed. However, the analysis of the model performance showed that the efficiency of the top-down mechanism of the influence of solar activity on the climate is very low in AOCCM SOCOL - MPIOM v3.0 (Anet et al., 2014).

The comparison of AOCCM SOCOL - MPIOM simulations with CMIP-5 models and observation results will be described in the paper (Egorova et al., 2015). Historical simulations of models participating in CMIP-5 are forced by time-evolving anthropogenic and natural changes. We used CMIP-5 models for our analysis which have: 1) their highest layer at 80 km or above, 2) include interactive ozone, and 3) prescribe solar forcing (SF) according to the recommendation of the SOLARIS-HEPPA working group (Wang et al., 2005). There are some different features in the chosen CMIP-5 models that we should keep in mind when analysing the results, including: 1) the number of ensembles members is different, 2) the different description of the QBO: - spontaneous, nudged or absent, and 3) the different number of bands that represent the short-wave component of the solar irradiance in the model's radiation scheme.

The chosen models are: CESM1-WACCM (1), GFDL - CM3 (5), GISS-E2-H (5), GISS-E2-R (5), MIROC-ESM-CHEM (1) and MRI-ESM1 (1), where the brackets represent the number of ensemble members. We have two ensemble members with strong and weak solar forcing for SOCOL.

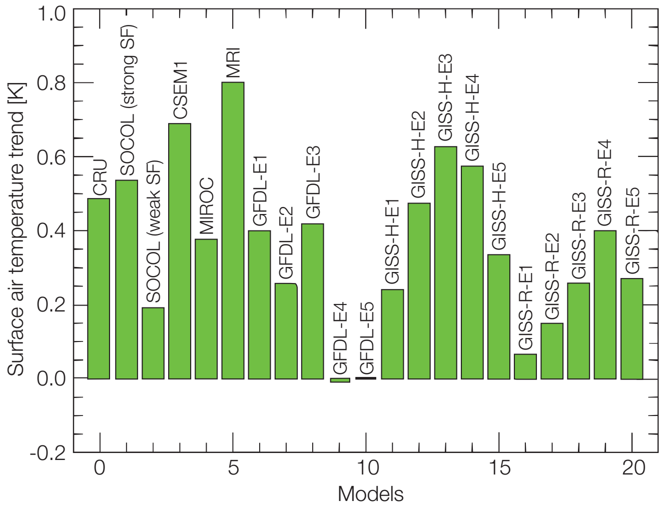

Figure 1. Surface air temperature trend (K) during 1910 – 1950 obtained with observations (CRU data set) and simulated with the AOCCM SOCOL-MPIOM and several other CMIP-5 models.

Figure 1 illustrates the trend in surface air temperature (K) during 1910 – 1950 obtained from the CRUTEM data set, and simulated with AOCCM SOCOL - MPIOM and other chosen models participating in the CMIP-5 activity. It is seen that some of the simulations from SOCOL (strong SF) and GISS-H-E2 reproduce the observed surface air trend quite well while the most of the other models over- or underestimate the trend. Despite use of the same external forcing data-set, models show a large spread in the temperature trend at the surface. In order to understand the reason for this difference between the models, it is necessary to continue the analysis using advanced statistical methods.

References:

Anet J., et al: 2014, Impact of solar vs. volcanic activity variations on tropospheric temperatures and precipitation during the Dalton Minimum, Clim. Past, 10, 921 – 938, doi: 10.5194/cp-10-921-2014.

Egorova T., et al.: 2015, SOVAC: Solar variability and climate change during the first half of the 20th century, in preparation.

Hood L. et al.: 2015, Solar signals in CMIP-5 simulations: The ozone response, QJRMS, doi: 10.1002/qj.2553.

Mitchell D., et al.: 2015, Solar signals in CMIP-5 simulations: The stratospheric pathway, QJRMS, doi: 10.1002/qj.2530.

Muthers S., et al.: 2014, The coupled atmosphere-chemistry-ocean model SOCOL - MPIOM, Geosci. Model Dev., 7, 2157 – 2179.

Wang et al.: 2005, Modeling of the sun's magnetic field and irradiance since 1713. Astrophysical Journal 625(1), 522 – 538.

Characterisation Studies of the Precision Solar Spectroradiometer (PSR)

Julian Gröbner and Natalia Kouremeti, in collaboration with Saulius Nevas, PTB, and Peter Blattner, METAS

Several units of the Precision Solar Spectroradiometer (PSR) were manufactured and optically characterised. The characterisation consisted of linearity and temperature dependence tests as well as the measurement of the line-spread functions over the full wavelength range from 300 nm to 1000 nm using the tunable laser set-ups at PTB and METAS.

A small series of five PSR instruments were manufactured in spring 2014, and fully characterised for linearity and temperature dependence. One PSR, PSR-003, was taken to PTB in order to characterise its line-spread function over the full wavelength range from 300 nm to 1000 nm using the PLACOS facility (Nevas et al., 2009). These measurements were then used to determine the stray light matrix to correct for the in-range stray light.

The linearity of the data acquisition system was tested for integration times between 10 ms and 8000 ms. As can be seen in Figure 1, the departure from linearity was significantly less than ±0.5%. Similarly, the linearity of the detector was determined by varying the intensity of a laser line and comparing the signal of the PSR with a calibrated reference diode over an intensity variation from 1000 counts to 245000 counts. No departure from linearity was seen within the observed variability of ±1%.

The sensitivity of the PSR to temperature was investigated by changing the temperature of the whole instrument, while leaving the detector stabilised at 20°C, effectively allowing changes due to distortions of the optical bench to be determined. The change in sensitivity was less than 0.1% K^{-1} for all PSRs. Similarly, the wavelength shifts due to temperature changes were not larger than 0.01 nm K^{-1}. These measurements confirmed the near temperature independence of the PSR optical bench design.

The line-spread functions were initially determined at PMOD/WRC for selected wavelengths using lasers at 325 nm, 375 nm and 633 nm, and were detailed in a previous annual report. Here, we present measurements performed at the PTB PLACOS facility, with follow-up measurements performed at METAS for the infrared wavelength range. An overview of the measurements is shown in Figure 2, showing the line-spread functions between 300 nm and 1000 nm and over 6 orders of magnitude. From this data, a stray light matrix can be calculated to correct for in-range stray light following the methodology of Zong et al. (2006). From the same dataset, the wavelength dispersion and resolution of the PSR were determined. As can be seen in Figure 3, the change in Full Width at Half Maximum (FWHM) varies from 1.4 nm to 6 nm over the wavelength range of the instrument.

The optical characterisation of five PSRs has led to the following conclusions: i) The temperature dependence is negligibly small, as expected from the mechanical design, ii) the linearity of the detector is better than 1% over the full dynamic range of the instrument, and iii) the stray light matrix was determined for PSR-003 and is being applied to solar measurements in order to correct for the in-range stray light.

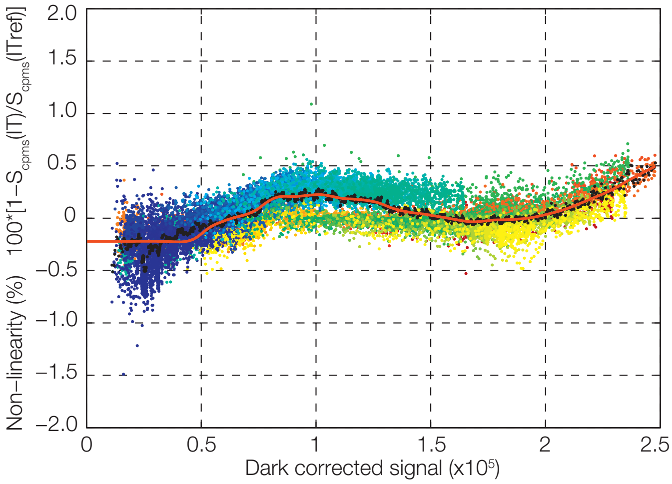

Figure 1. Departure from linearity for PSR-006 for integration times from 10 ms to 8000 ms.

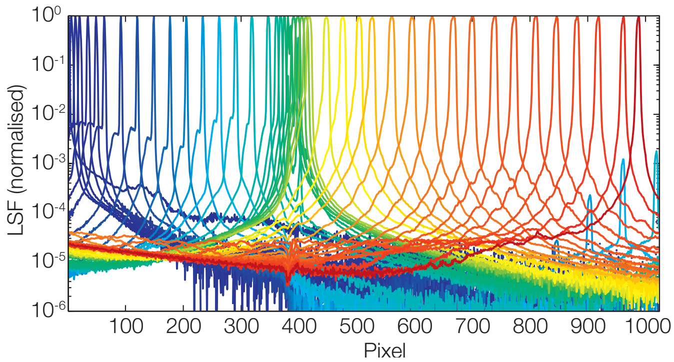

Figure 2. The line-spread functions (LSF) for PSR-003, measured with the tuneable laser set-ups at PTB and METAS.

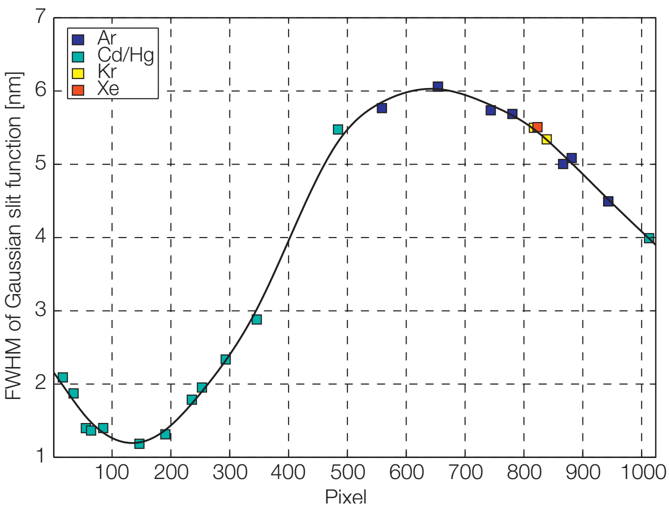

Figure 3. Variability of the PSR-006 slit function over its wavelength range.

References: Nevas S., et al.: 2009, Colourimetry of LEDs with array spectroradiometers, MAPAN—J. Metrol. Soc. India 24, 153–162.

Zong Y., et al.: 2006, Simple spectral stray light correction method for array spectroradiometers, Appl. Opt. 45, 1111–1119.

Advances in Solar Radiometry

Wolfgang Finsterle and Markus Suter

Markus Suter successfully defended his PhD thesis "Advances in Solar Radiometry" on 11 December 2014 at the Physics Institute, University of Zürich. His PhD thesis sets new standards for the characterisation and traceability of ambient temperature solar radiometers.

Markus Suter worked on his PhD project at PMOD/WRC for four years. The goal was to accurately implement the absolute irradiance scales in the newly-built DARA (Digital Absolute Radiometer) prototype radiometer. This goal was exceeded in the sense that both current irradiance scales, namely the SI laboratory scale and the World Radiometric Reference (WRR), were implemented in DARA alongside its own "native" scale. The native scale results from a meticulous determination of all instrumental properties that influence the measurement result and quantifies them in SI units. This process is called the characterisation of the radiometer. The WRR and SI laboratory scales were implemented through end-to-end calibrations of DARA against the WRR and the NIST-traceable TSI Radiometer Facility (TRF) at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, USA.

The reason to implement all three scales in DARA was to compare them, and to confirm the difference in the WRR-to-SI scale observed by Fehlmann et al. (2012). The WRR was found to yield significantly higher irradiance readings than the DARA native and SI laboratory scales by 3100 parts per million (ppm). On the other hand, the DARA native and SI laboratory scales are equivalent to within the uncertainty of the comparison (Figure 1). The excellent agreement of the DARA characterisation with the end-to-end TRF calibration confirms the high accuracy of the DARA characterisation and builds confidence in our technical understanding of solar radiometry.

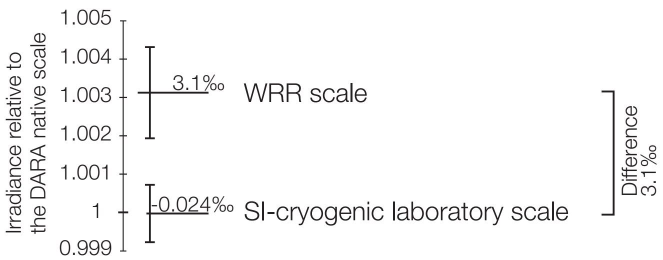

Figure 1. The differences between the WRR and the SI laboratory scales with respect to the DARA native scales are shown. While the SI and DARA native scale are equivalent to within 24 ppm, the WRR scale gives a higher irradiance by about 3100 ppm. This result independently confirms the findings by Fehlmann et al. (2012). The vertical error bars indicate the uncertainty of the scale comparison.

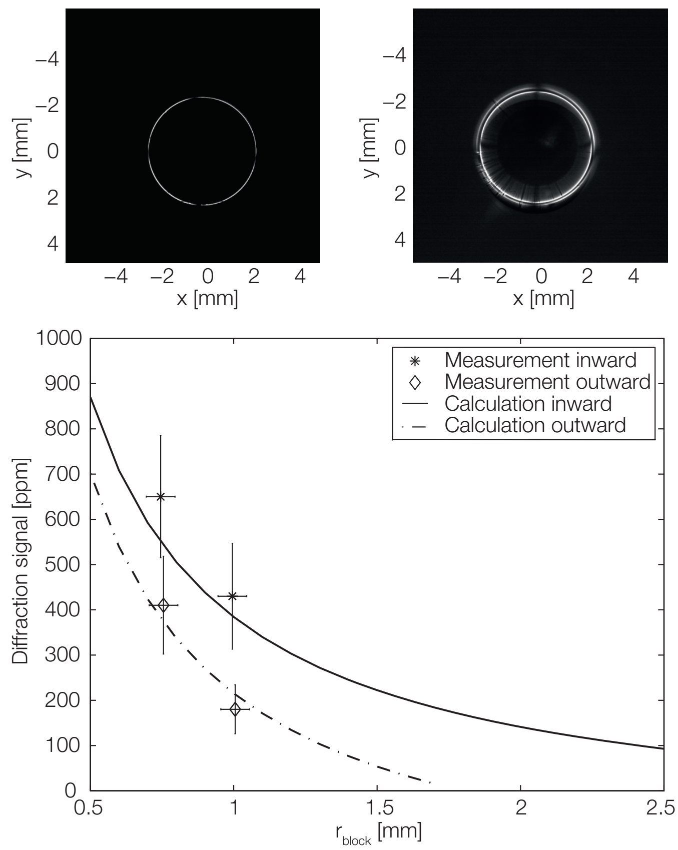

Figure 2. Sunlight is scattered off (upper left panel) and diffracted at (upper right panel) the DARA entrance aperture. The lower panel shows good agreement of the measured intensity in the diffraction pattern with predictions based on numerical simulations. The Heliostat solar light source was used to produce these images and measurements, therefore ensuring that the results are transferable to real solar observations.

The combined uncertainty of the DARA native scale is as low as 180 ppm for extraterrestrial measurements and 200 ppm for measurements in Davos. This makes DARA the most accurately characterised solar absolute radiometer to date. For reference, the combined uncertainties of PMO6 and TIM/SORCE are 560 ppm (ground-based; Brusa and Fröhlich, 1986), and 200 ppm (extraterrestrial; Kopp et al., 2005), respectively. All uncertainties are expressed with a coverage factor k = 1.

References:

Brusa R. W., Fröhlich C.: 1986, Absolute radiometers (PMO6) and their experimental characterisation, Appl. Opt., 25, 4173–4180.

Kopp G., Heuermann K., Lawrence G.: 2005, The total irradiance monitor (TIM): Instrument calibration, Solar Physics, 230, 111–127.

Fehlman A., Kopp G., Schmutz W., Winkler R., Finsterle W., Fox, N.: 2012, Fourth World Radiometric Reference to SI radiometric scale comparison and implications for on-orbit measurements of the total solar irradiance, Metrologia, 49, S34–S38.

The GAW-PFR Aerosol Optical Depth Network: The 2000 – 2014 Time-Series at Summit Station, Greenland

Stephan Nyeki, Christoph Wehrli, J. Gröbner, Natalia Kouremeti in collaboration with Karl Schroff, IACETHZ, Switzerland, Stefan Wacker, ASIAQ, Greenland, and Kerstin Stebel, NILU, Norway

Aerosol optical depth (AOD) measurements at Summit station in Greenland are presented for the 2000–2014 period. The long-term AOD average of 0.058 (λ = 500 nm) is similar to values at other Arctic (Ny Ålesund) and Antarctic (Marambio and Troll) stations. Summit data are reported here for the first time.

Greenland is currently the focus of intense research efforts to quantify the effect of global warming on its ice-sheet mass balance, and on sea-level rise. Related studies aim to quantify the impact of aerosols on snow properties (Dumont et al., 2014) and their impact on the radiation balance. An important parameter in such studies is the Aerosol Optical Depth (AOD). While long-term ground-based AOD measurements using modern stable sun-photometers are rare in the Polar Regions, several sites have time-series longer than 10 years (see Tomasi et al. 2015; and references therein). Among these is Summit station (72.58°N, 38.46°E, 3250 m asl) which has a unique location on the central Greenland ice sheet. The station was built in 1989 as a base-camp for ice-core drilling but has since then grown into an international scientific facility.

AOD measurements began in 2000 at Summit, and continue to the present under a joint collaboration between: 1) NSF (National Science Foundation, USA), 2) NOAA (National Oceanic and Atmospheric Administration, USA), and 3) the GAW-PFR (Global Atmosphere Watch Precision Filter Radiometer) network. The currently available AOD time-series at Summit station spans the period 2000–2014, and is reported here for the first time.

Measurements were conducted with a PFR at four wavelengths (λ = 368, 412, 500 and 862 nm) while GAW-PFR algorithms (e.g. Nyeki et al., 2015) were used for the determination of AOD. The combined uncertainty related to instruments and retrieval algorithms was estimated to result in an AOD uncertainty <0.010 at λ = 500 nm. A graph of the 2000–2014 Summit AOD time-series is shown in Figure 1. The sparseness of the time-series is apparent upon first inspection, especially during the 2006–2008 period when the PFR was not operated due to logistical reasons. Several other years were affected by tracker problems as a result of the harsh polar conditions encountered throughout the year. For instance, average daily temperatures in July/January are -13/-43°C. In addition, it should be noted that AOD measurements

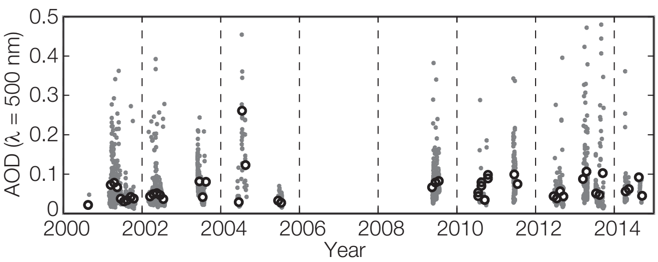

Figure 1. AOD time-series at the GAW-PFR Summit station. Monthly mean (black circles) and 1-hr (grey circles) data are shown.

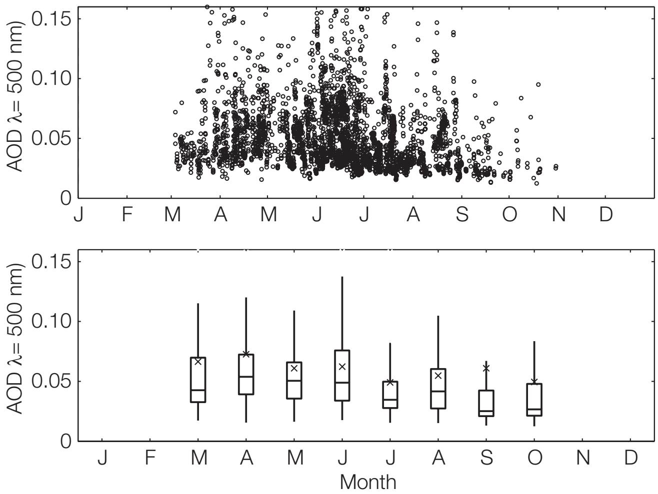

Figure 2. Annual cycle of monthly AOD for the 2000–2014 period at Summit illustrated using hourly (upper plot) and monthly (lower, box-and-whisker plot) data.

from November to February are unavailable due to the Arctic night. Despite these aspects, the 2000–2014 AOD average of 0.058 (λ = 500 nm; standard deviation = 0.037) is similar to values at other remote Arctic (Ny Ålesund, Svalbard) and Antarctic (Marambio and Troll) sites in the GAW-PFR network.

More insight into the characteristics of AOD at Summit is shown in Figure 2. Median AOD values from the March to June period (0.049) appear to be slightly elevated in comparison to the July to October period (0.032). As median rather than average values are more robust to outliers, they allow the underlying cycle to be more clearly revealed. A similar reduction in AOD and in-situ aerosols (Eleftheriadis et al. 2009) during the Arctic summer has also been observed at Ny Ålesund, and has been commonly attributed to the position of the Arctic polar front. During the winter, the front is situated at ~50°N, hence allowing long-range transport from major industrial regions in Europe, Russia and N. America into the Arctic. The circulation pattern is different in summer when the front is situated further to the north (about 70°N), hence preventing polluted air masses from effectively reaching the Arctic.

References:

Dumont M. et al.: 2014, Contribution of light-absorbing impurities in snow to Greenland's darkening since 2009, Nature Geoscience, 7, 509-512, doi:10.1038/ngeo2180.

Eleftheriadis K., Vratolis S., Nyeki S.: 2009, Aerosol black carbon in the European Arctic: Measurements at Zeppelin station, Ny-Ålesund, Svalbard from 1998–2007, Geophys. Res Lett., 36, L02809, doi:10.1029/2008GL035741.

Nyeki S., et al.: 2015, The GAW-PFR aerosol optical depth network: 2008–2013 time-series at Cape Point station, South Africa, J. Geophys. Res., Atmos., 120, doi:10.1002/2014JD022954.

Tomasi C., et al.: 2015, Aerosol remote sensing in polar regions, Earth Science Reviews 140, 108–157, doi:10.1016/j. earscirev.2014.11.001.

Spectral Aerosol Optical Depth From a Precision Solar Spectroradiometer During Three Field Campaigns

Natalia Kouremeti and Julian Gröbner

Spectral aerosol optical depth (AOD) was obtained from a precision solar spectroradiometer (PSR) during three field campaigns. The AOD comparison with the co-located Cimel-AERONET and/or PFR instruments showed a mean agreement of 0.02±0.004 in all common wavelengths verifying the stable operation of the PSR during this period.

PSR-003 was the first instrument of the initial series of PSRs, which was released on February 2014 and was characterised through extensive laboratory measurements at PMOD/WRC. PSR-003 measures in the spectral range 305–1025 nm with a resolution of approximately 1.5 to 5 nm. After characterization of PSR-003, the instrument was deployed at three locations: Izaña (28.3°N, 16.5°W), Finokalia (35.3°N, 25.7°E) and Athens (38°N, 23.8°E; Figure 1) during March to August 2014. The purpose of these field campaigns was: 1) Calibration of AOD measurements by determining the extraterrestrial spectrum (ETS) using the Langley method, 2) participation in the ADAMA campaign (ESA CHARADMExp project), and 3) operation of the instrument under high ambient temperatures to examine its performance.

The instrument was deployed from March to June 2014 at Izaña. During this period, 31 half-days were used to determine the ETS with a standard deviation of 0.8%. The spectral AOD from PSR-003 was derived at coincident wavelengths to the co-located CIMEL and PFR filter sunphotometers at Izaña. Values were within 0.01 for this period, demonstrating the good performance and stability of the PSR. Moreover the comparison of the observed ETS spectrum with a solar spectrum from the literature (see 2012 annual report) gave good agreement (Figure 2). This confirms our calibration procedures and demonstrates that spectral AOD can be derived from a calibrated PSR with an uncertainty better than ±0.025 using only a literature ETS and a laboratory spectral irradiance calibration based on transfer standard lamps.

The ADAMA campaign (funded by ACTRIS) took place from 22 June to 17 July 2014 with the objective of deriving optical, microphysical and chemical properties of the aerosol marine component and its mixture with dust, by employing sophisticated instrumentation installed at the Finokalia ACTRIS site (Crete, Greece). PSR-003 provided spectral direct solar irradiance and AOD measurements. An extensive data set was acquired, covering different types of marine and marine/mixed aerosols, with AOD at 500 nm varying from 0.05 to 0.5. The comparison with the co-located AERONET-CIMEL (NOA) gave mean differences of 0.004, 0.024, 0.019, 0.015, 0.016, 0.016, 0.010 for wavelengths 340, 380, 440, 500, 675, 870 and 1020 nm, respectively, and a correlation coefficient better than 0.97. The final campaign in Athens ran from 17 July to 20 August 2014 during which the internal instrument temperature varied in the 20–39°C range. Comparison of AOD with a collocated AERONET sunphotometer were satisfactory, giving differences of 0.05, 0.03, 0.03, 0.02, 0.01, 0.02, 0.03 at the above-mentioned wavelengths.

Near continuous measurements at these sites for a total of five months allowed spectral AOD during more than 70% of clear sky conditions to be derived. PSR-003 ran stably during this period, with only few operational problems which were accounted for. A follow-up calibration campaign with a slightly improved PSR is scheduled for spring 2015 at Izaña.

Figure 1. PSR-003 and AERONET-CIMEL at NOA, Athens, Greece.

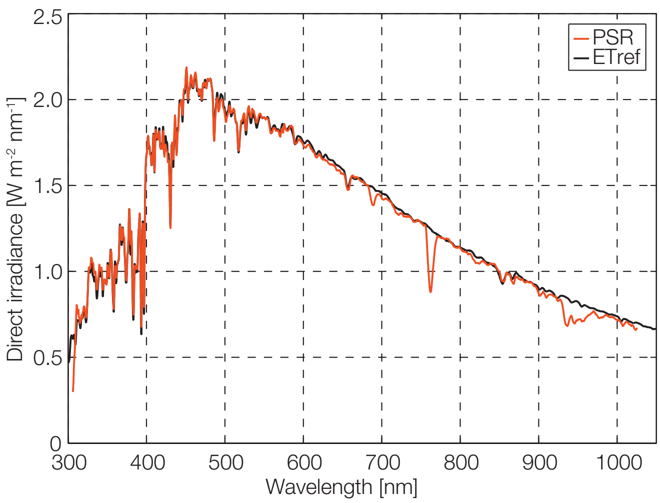

Figure 2. Comparison of ETS from the literature (COKITHQA, black curve) and the PSR (red curve). The absorption bands at 752 nm and around 950 nm are from O_2 and water vapor, respectively.

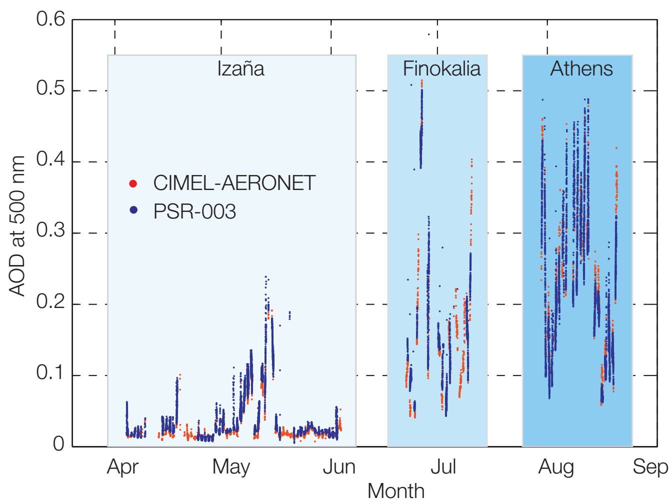

Figure 3. Overview of all three field campaigns during 2014.

Development of a Thermal Infrared Cloud Camera (IRCCAM)

Christine Aebi, Julian Gröbner, Ricco Soder, Pascal Schlatter and Fabian Dürig

Small changes in cloudiness and radiation can have large impacts on the Earth's climate. In order to assess the opposing effects of clouds on the radiation budget and the corresponding changes, frequent and more precise radiation and cloud observations are necessary. Within the framework of the project "A comprehensive radiation flux assessment" (CRUX), a new instrument has been developed: The thermal InfraRed Cloud CAM (IRCCAM).

Data from visible all-sky cameras at Davos, Jungfraujoch and Payerne allows the fractional cloud cover and cloud types to be automatically determined during the day (Wacker et al., 2015). However, in order to complement these methods so that measurements druing the night can be conducted, the thermal InfraRed Cloud CAM (IRCCAM) was developed. The IRCCAM is mainly used to measure the whole upper hemisphere during the night. Using data gained from the IRCCAM, we aim to determine the altitude of clouds and their temperature. Subsequent calculations then allow the fractional cloud cover and different cloud types to be determined.

The IRCCAM (Figure 1) was developed and constructed in 2014. A thermal camera (GOBI 640 GigE 640 x 480 microbolometer from Xenics) views downward onto a polished convex aluminium

Figure 1. The InfraRed Cloud CAM (IRCCAM) on the PMOD/WRC roof in Davos, Switzerland

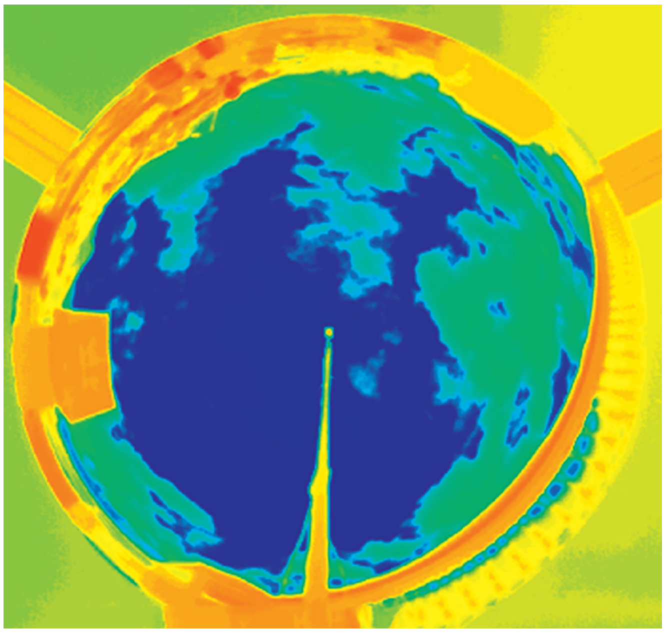

Figure 2. Picture taken by the IRCCAM on the PMOD/WRC roof in Davos at 10:27 UTC on November 3, 2014. Different colours show the structure of the sky (green colours: clouds, blue: clear sky, red: the instrument itself and the roof railing).

mirror. The camera is sensitive in the 8–14 µm wavelength range, has a focal length of 25 mm, and a field-of-view of 18° x 24°. The mirror has a spherical shape (radius sphere: 286 mm and diameter half-sphere: 390 mm) allowing the whole upper hemisphere to be reflected on it. The camera is supported by only one arm, on a framework with a total height of 1855 mm.

The IRCCAM was installed and tested during several days in winter 2014 on the PMOD/WRC roof in Davos. The output of the camera is counts per pixel, and an example is shown in Figure 2 which was taken at 10:27 UTC on November 3, 2014.

A visual analysis of Figure 2 permits clouds (green colours) and the clear sky (blue) to be distinguished. The red colours depict the instrument itself and the roof railing. In a visual comparison, the pictures taken by the IRCCAM and those taken by the visible all-sky camera generally show good agreement in the occurrence of clouds. It was even possible to detect cirrus clouds and condensation trails.

Several modifications and improvements of the IRCCAM are already planned. The aluminium mirror will be gold-plated in order to decrease its emissivity factor. In addition, the camera system will be changed in order to make it weatherproof. Finally, in order to obtain temperature per pixel instead of counts per pixel from the IRCCAM, the thermal camera will be calibrated in the PMOD/WRC blackbody.

References: Wacker S., et al.: 2015, Cloud observations in Switzerland using hemispherical sky cameras, J. Geophys. Res. 120, 695–707, DOI: 10.1002/2014JD022643.

Quality Assessment of Solar UV Irradiance Measured with an Array-Spectroradiometer

Luca Egli, Julian Gröbner, and Gregor Hülsen in collaboration with participants of the solar UV intercomparison at PMOD/WRC

At the end of the European EMRP-ENV03 project "Solar UV", an intercomparison of array-spectroradiometers, belonging to the end-user community, measured global UV irradiance from 7 to 17 July 2014 on the PMOD/WRC measurement platform. The results of the intercomparison revealed that array-spectroradiometers, currently used for solar UV measurements, are generally unable to determine the UV index with uncertainties less than 5% for all atmospheric conditions.

The reliable quantification of ultraviolet (UV) radiation at the Earth's surface requires accurate measurements of spectral global solar UV irradiance, with uncertainties of less than 5%. This requirement is currently achieved with double monochromator scanning spectroradiometers (Gröbner et al., 2005).

Array-spectroradiometers are cost and maintenance effective instruments measuring an entire spectrum within seconds. Due to their single monochromator set-up, however, the measurements are mainly influenced by stray light (Nevas et al., 2014). Within the European EMRP-ENV03 "Solar UV" project, coordinated by PMOD/WRC, new devices, guidelines, and characterisation and correction methods have been developed. The project's aim was to improve solar UV measurements with array-spectroradiometers and to provide instrument-support to the end-user community. By the end of the project, 15 array-spectroradiometers from five different manufacturers and different models maintained by 10 end-users, had been compared to the portable reference scanning spectroradiometer QASUME (Gröbner et al., 2005).

The quality of the array-spectroradiometers was assessed by the determination of the UV index, which is the measured spectrum, weighted with the action spectrum of the erythemal weighting function. Figure 1 shows the ratios between the UV index determined by the array-spectroradiometers and the QASUME reference (blue points) as a function of the solar zenith angle (SZA) during all days of the intercomparison. As can be seen in the figure, the UV indices of array-spectroradiometers are largely overestimated by almost all instruments. Some of the instruments are able to measure the UV index close to 5% uncertainty on average, but only at low SZA around noon. At higher SZA, the instruments exhibit large over-estimates compared to a double monochromator such as QASUME II (Figure 2, grey points). Agreement with QASUME is better than 5% for all SZA during all days of the intercomparison.

Spectral analysis revealed that the UVB part of the spectrum is largely overestimated by all instruments due to the influence of stray light. This effect explains the overestimation of the UV index. Even thorough calibration, characterisation and sophisticated correction methods for stray light reduction were not able to substantially improve the performance of end-user array-spectroradiometers.

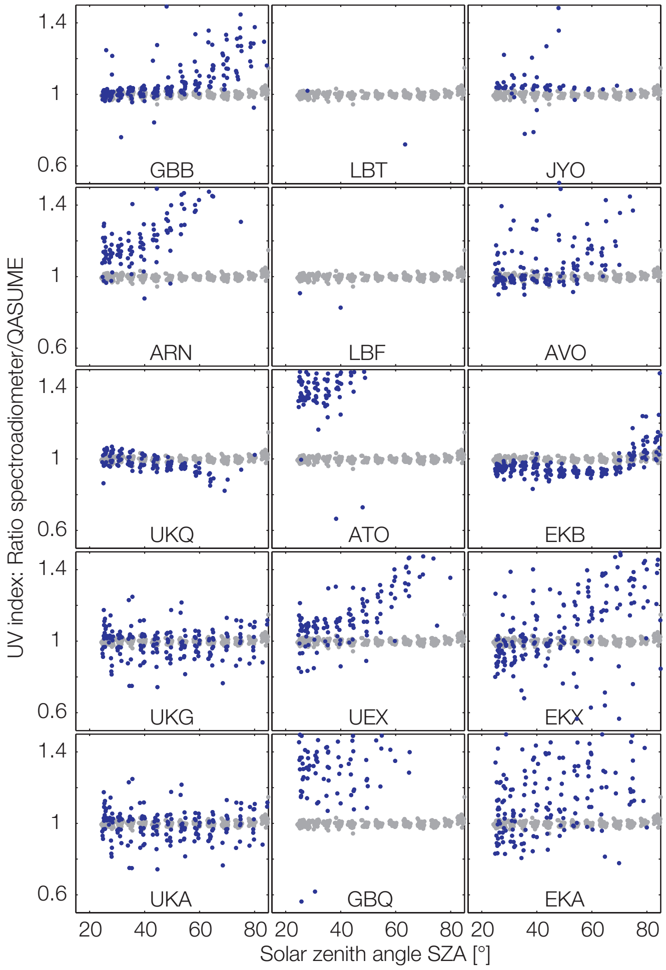

Figure 1. Ratio of the UV index measured by end-user array-spectroradiometers (blue points) and the QASUME portable UV reference spectroradiometer for all solar zenith angles during the intercomparison at PMOD/WRC. For comparison, the ratio between the new portable reference QASUME II and QASUME is shown in grey points, representing the benchmark for the uncertainty which is required for reliable solar UV monitoring. LBT and LBF spectroradiometers overestimate by more than about 50%.

We can conclude that array-spectroradiometers measurements are at present insufficient to determine the UV index for operational monitoring. In future, the World Calibration Center for UV radiation (WCC-UV) at PMOD/WRC may investigate other approaches to obtain reliable information from array-spectroradiometers for solar UV monitoring.

References:

Gröbner J., Schreder S., Kazadzis A. F., Bais M., Blumthaler P., Görts R., Tax T., Koskela G., Seckmeyer A., Webb R., Rembges D.: 2005, Appl. Opt., 44: 5321–5331.

Nevas S., Gröbner J., Egli L., Blumthaler M.: 2014, Appl. Opt., 53, 19, 4313–4319.

Intercomparison Between the Transportable Reference Spectroradiometer QASUME and a New Fourier Transform Spectroradiometer

Gregor Hülsen and Julian Gröbner in collaboration with PTB, Berlin, Germany

A new Fourier Transform Spectroradiometer was built within the framework of the EMRP project ENV03. Its performance during solar UV irradiance measurements was validated using the QASUME transportable reference spectroradiometer.

Within the EMRP project ENV03 "Traceability of spectral solar ultraviolet radiation" a Fourier Transform Spectrometer system (FTS) was constructed at the Physikalisch-Technische Bundesanstalt (PTB), Berlin. The acronym of this system is "PFS" (PTB-FTS). The main advantage of this device is the direct traceability to the wavelength scale.

A Bruker VERTEX 80v Fourier transform spectrometer was equipped with a fibre coupled input optic, a J1002 from CMS Schreder, identical to the QASUME optic. To record low intensity UV radiation, a Hamamatsu photosensor module H10723-210 was used as the detecting device (Meindl et al., 2014).

The prototype PFS was validated in April 2014 during a five-day intercomparison relative to the European reference spectroradiometer QASUME (Hülsen and Meindl, 2014). The measurement protocol consisted of measuring solar irradiance spectra from 290 to 400 nm. QASUME measured one spectrum every 15 minutes, in steps of 0.25 nm with 1.5 seconds between each wavelength increment. The FTS continuously recorded interferograms, where each interferogram was measured in about 0.6 sec. In order to limit the amount of data, 32 interferograms recorded in 19 seconds were averaged. A further averaging of the recorded interferograms was performed during post-processing of the data, depending on the atmospheric conditions. The spectral resolution of the FTS was set to 10 cm-1. A Blackman-Harris-4-Term apodization was applied to the measured interferograms to reduce the signal leakage into side-lobes. The resolution after applying this apodization is about 20 cm. Different spectral filters were applied during the measurements.

The resulting spectra were further processed using the new matSHIC algorithm. Finally, the irradiances at common wavelengths of the PFS spectra and the corresponding QASUME spectrum were extracted to enable a comparison of both datasets.

The ratios between PFS and QASUME have an average offset of 5%. The diurnal variation of the PFS to QASUME ratio is 8% which decreases constantly from the morning to the afternoon and rises again in the evening. The cause can to some degree be linked to the different input optics of both devices (azimuth error, temperature / humidity sensitivity of the teflon sensor, cosine error).

Acknowledgment: The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

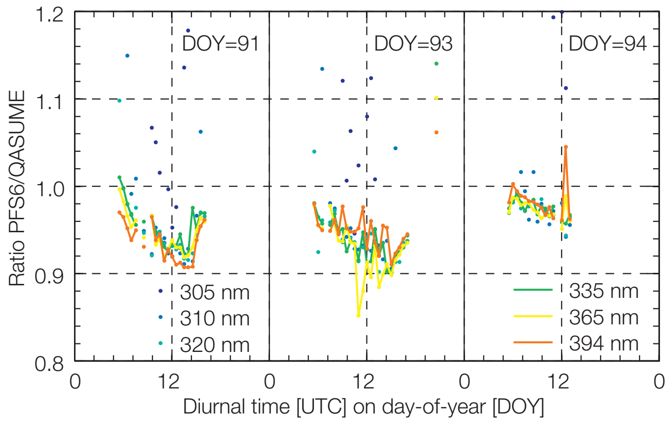

Figure 1. Temporal evolution of the PFS to QASUME ratio. Each point in the graph represents a measurement averaged over a wavelength interval of 5 nm centred on the respective wavelength.

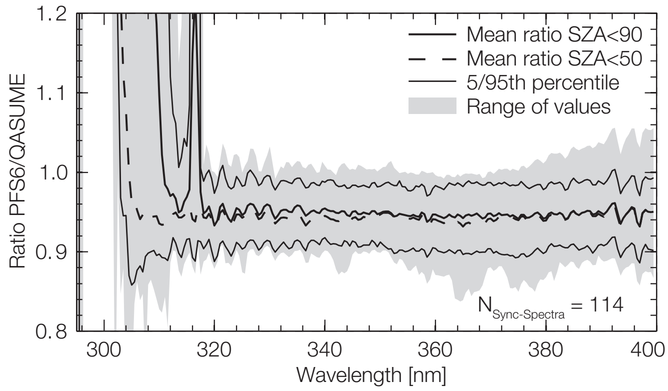

Figure 2. Average ratio of PFS to QASUME spectra using 5781 PFS-spectra fitted to 114 QASUME spectra.

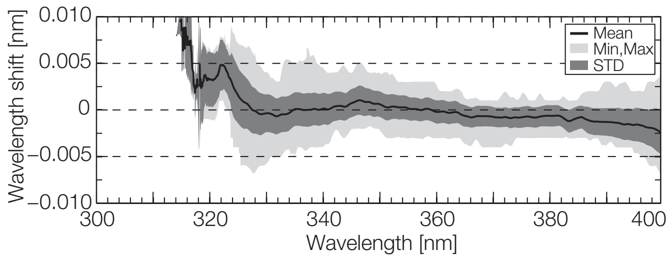

Figure 3. No wavelength shift of PFS (calculated using matSHIC)

References:

Hülsen G. and Meindl P.: 2014, Protocol of the intercomparison of the Fourier transform spectroradiometer PFS of the PTB with the travelling reference spectroradiometer QASUME from PMOD/WRC at PTB Berlin, Germany, on March 31 to April 4, 2014, http://www.pmodwrc.ch/wcc_uv/qasume_audit/reports/2014_04_PTB-Berlin_Germany.pdf

Meindl P., Wähmer M., and Monte C.: 2014, Usability of a Fourier transform spectroradiometer for absolute surface spectral solar UV irradiance measurements. Optic Express, 22, No. 21.

SOLID - First European Comprehensive Solar Irradiance Data Exploitation – Technical and Scientific Management

Margit Haberreiter and Werner Schmutz in collaboration with the SOLID consortium

The SOLID project started in December 2012, thus this report for 2014 mainly covers the second year of the project.

Uncertainty Workshop at Imperial College London: A dedicated workshop was organised in April 2014 at Imperial College, London, England, to discuss details of the uncertainties of the solar spectral irradiance data set to be used within the SOLID project.

The 2nd SOLID Annual Meeting: The 2nd Annual Meeting of the SOLID consortium was held from 28–31 October 2014 at the University of Bremen, Germany. The proceedings can be found on the SOLID webpage: http://projects.pmodwrc.ch/solid/. Each beneficiary of SOLID was represented by at least one scientist from the SOLID consortium.

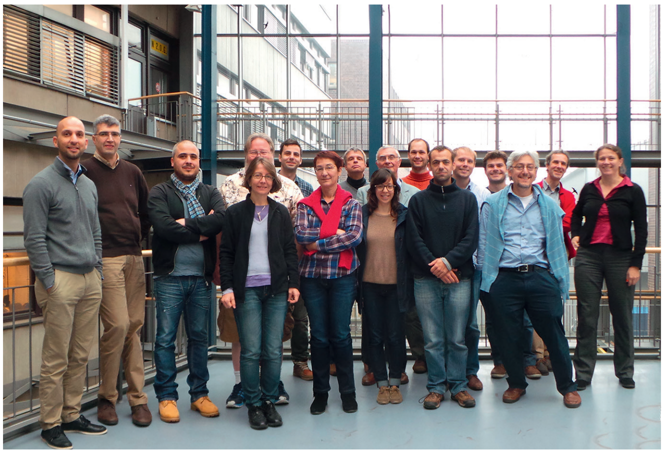

Figure 1. Group photo of the 2nd Annual SOLID Meeting: (from left to right): Omar Ashamari, Rami Qahwaji, Wissam Chehade, Ilaria Ermolli, Marty Snow, Thomas von Clarmann, Klairie Tourpali, Mark Weber, Maria Dasig-Espuig, Gerard Thuillier, Micha Schöll, Matthieu Kretzschmar, Robert Schäfer, Benjamin Mampaey, Giulio Del Zanna, Thierry Dudok de Wit, Margit Haberreiter and Werner Schmutz (not in the picture).

SOLID Webpage and Database: In 2014, the existing SOLID webpage and database were continuously updated and improved. They can be accessed through the following links:

Webpage: http://projects.pmodwrc.ch/solid

Database: http://projects.pmodwrc.ch/solid-visualization/makeover/

TOSCA - SOLID Summer School: The 2nd TOSCA Training School on Solar Variability and Climate Response, organised by Ilaria Ermolli was also supported by the SOLID project. Margit Haberreiter gave a lecture on "Solar and Space Forcing."

TOSCA - SOLID Working Group Meeting: The SOLID consortium also participated in the TOSCA Working Group Meeting "From the Maunder Minimum to the 21st century" held in Corfu, Greece, from 29 September to 2 October 2014.

Annual Newsletter: An annual newsletter is regularly published by the SOLID consortium. The first newsletter was released early 2014, while the second newsletter will be distributed in early 2015.

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first european comprehensive solar irradiance data exploitation

solid

SEVENTH FRAMEWORK PROGRAMME

Newsletter #1

Greetings from SOLID

SOLID RESEARCH! This is our task. It is our pleasure to welcome you to the first European comprehensive Solar Irradiance Data exploitation (SOLID), a collaborative SPACE project funded by the 7th Framework Programme of the European Commission. It comprises of 10 Partners from 7 European Countries. It is coordinated by PMOD/WRC and runs from 1/12/2012 until 30/11/2015.

Solar irradiance and its variations is the most important natural factor in the terrestrial climate and as such, the time dependent spectral solar irradiance is a crucial input to any climate modelling. There have been previous efforts to compile solar irradiance but it is still uncertain by how much the spectral and total solar irradiance changed on yearly, decadal and longer time scales. Observations of irradiance data exist in numerous disperse data sets.

A major objective of SOLID is to analyze and merge the complete set of European irradiance data, complemented by archive data that include data from non-European missions. The SOLID-consortium unifies representatives from all European solar space experiments and European teams specialized in multi-wavelength solar image processing. It also includes the European groups involved in irradiance modelling and reconstruction. They will work together to produce reconstructed spectral and total solar irradiance data as a function of time. The reconstructed time series will be used to bridge gaps in time and wavelength coverage of the observational data. This will allow the SOLID team to reduce the uncertainties in the irradiance time series, an important requirement by the climate community and to provide uniform data sets of modelled and observed solar irradiance data from the beginning of the space era to the present including proper error and uncertainty estimates. Climate research needs these data sets and therefore, the primary benefit is for the climate community, but the stellar community, planetary, lunar, and ionospheric researchers are also interested in having at their disposition incident radiation of the Sun. The organization structure of SOLID (with leading partners) is the following:

- Management (Margit Haberreiter)
- Irradiance and proxy data exploitation (Matthieu Kretzschmar)
- Multi-wavelength solar image processing for novel SSI proxies (Rami Qahwaji)
- Modelling of spectral irradiance based on observed proxies (Thierry Dudok de Wit)
- Modelling of spectral irradiance based on modelled proxies (Yvonne Unruh)
- Scientific Interaction with User Communities (Kleareti Tourpali)
- Scientific and Technical Management (Margit Haberreiter)
- Dissemination (Kleareti Tourpali)

The first year of the SOLID project was very active and this newsletter summarizes the progress so far and reflects emerging ideas. We very welcome comments on the contents of the newsletter.

Contents

COMPOSITION OF SOLID

Steering Board	Advisory Board
Margit Haberreiter (PMOD/WRC)	Katja Matthes, (GEOMAR)
Matthieu Kretzschmar (LPC2E)	Farzad Kamalabadi (Uni. of Illinois)
Mark Weber (UBre)	Matt Deland (SSAI)
Rami Qahwaji (UNIBRAD)	
Thierry Dudok de Wit (LPC2E)	
Yvonne Unruh (Imperial)	
Kleareti Tourpali (AUTh)	

Figure 2. The first annual SOLID newsletter published early in 2014.

Review of Periodic Report: The successful second SOLID review meeting was held on 23 January 2015 in Brussels, where the second Reporting Period covering the period from 1 December 2013 to 30 November 2014 was reviewed and approved.

Upcoming Activities: The 3rd Annual Meeting of the SOLID Consortium is planned for Autumn 2015 and will be organised by the kind support of the Aristotle University of Thessaloniki, Greece.

Acknowledgement: This work has kindly received funding from the EC's 7th Framework Programme (FP7 2012) under grant agreement Nr. 313188 (SOLID).

Irradiance Reconstruction within the SOLID FP7 Project

Margit Haberreiter in collaboration with the Royal Observatory, Belgium

Within the FP7 SOLID project, we aim to provide a consistent data set for the solar spectral irradiance. As part of this activity we provide the EUV reconstruction by using PROBA2/SWAP and SDO/AIA images.

Following the state-of-the-art semi-empirical approach to reconstruct solar spectral irradiance (SSI), Haberreiter et al. (2014) reconstructed the EUV from 1996 to 2010 based on a 6-component model using SOHO/EIT images and spectra calculated with the Solar Modelling Code (SOLMOD; Haberreiter, 2011). In collaboration with the Royal Observatory, Belgium, this work has now been extended to the reconstruction based on PROBA2/SWAP and SDO/AIA images for the 2011–2014 time period.

The solar images were segmented using the SPoCA tool (Verbeeck et al., 2014). For the reconstruction, we used synthetic spectra for each of the solar features identified from the segmentation of solar images (see Figure 1). Along with the filling factors derived from the PROBA2/SWAP images, the variation of solar spectral irradiance was determined. We carried out the EUV reconstruction for the 6–20 nm wavelength range and for the time period from 1 January 2010 to 16 September 2014.

The results are shown in Figure 2, which shows the SOLMOD reconstruction (black) compared with the daily minimum value from PROBA2/LYRA data (green). Also plotted are daily mean LYRA data (red) from Kretzschmar et al. (2012), which are corrected for the specific degradation in this channel. Moreover, SDO/AIA images have also been used to reconstruct the EUV. A comprehensive SSI time-series using SOHO/EIT, PROBA2/SWAP, and SDO/AIA is currently in preparation by Haberreiter et al. (2015).

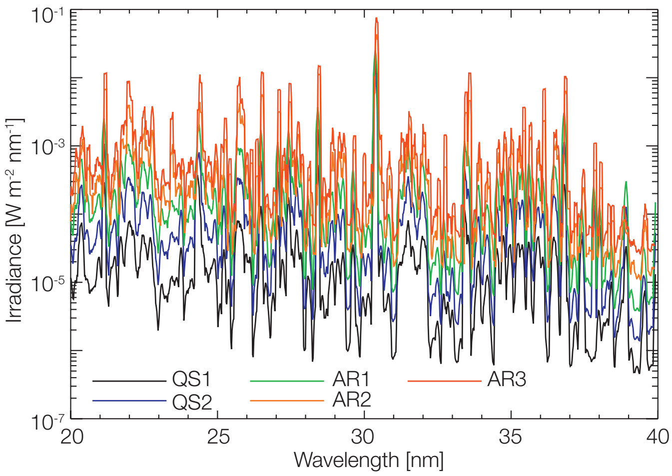

Figure 1. Irradiance spectra as calculated with the SOLMOD code for the five different components: quiet corona (QS1), coronal quiet network (QS2), coronal active network (AR1), active regions (AR2), and bright active regions (AR3); from Haberreiter et al. (2014). Not shown is the spectrum for coronal holes.

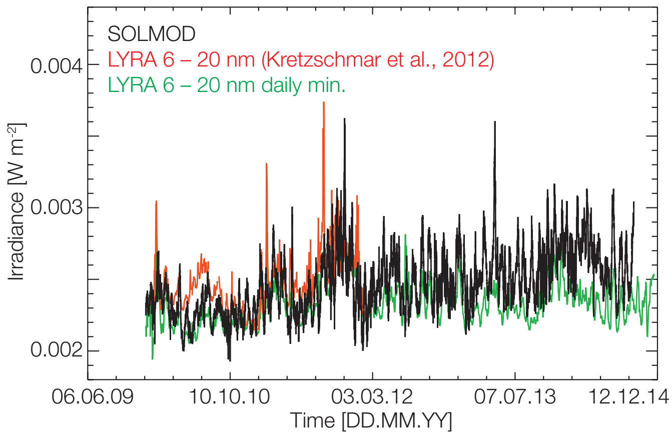

Figure 2. Comparison of the SOLMOD reconstruction based on the 6–20 nm spectral range (black), the LYRA Zr-channel daily minimum (green), and the daily mean value corrected for degradation (red) as provided by Kretzschmar et al. (2012).

Acknowledgement: This work has kindly received funding from the EC's 7th Framework Programme under grant agreement Nr. 313188 (SOLID).

References:

Haberreiter M.: 2011, Solar EUV spectrum calculated for Quiet Sun conditions, Sol. Phys., 274, 1–2, 473–479.

Haberreiter M., Delouille V., Mampaey B., Verbeeck C., Del Zanna G., Wieman S.: 2014, Reconstruction of the solar EUV irradiance from 1996 to 2010 based on SOHO/EIT images J. Space Weath. Space Clim., 4, A30

Haberreiter M., Delouille V., Mampaey B., Verbeeck C., et al.: 2015, in preparation.

Kretzschmar M., Dammasch I.E., Dominique M, Zender J., Cessateur G., D'Huys E.: 2012, Extreme ultraviolet solar irradiance during the rising phase of solar cycle 24 observed by PROBA2/LYRA, J. Space Weath. Space Clim., 2, A14.

Verbeeck C., Delouille V., Mampaey B., De Visscher R.: 2014, The SPoCA-suite: Software for extraction, characterization, and tracking of active regions and coronal holes on EUV images, Astron. Astrophys., 561, A29.

Solar Rotational Variability Modelled with COSIR

Gaël Cessateur, Alexander Shapiro, Werner Schmutz in collaboration with MPI, Göttingen, Germany

We present a new model for solar spectral irradiance variability, COSIR (Code for Solar Irradiance Reconstruction). We investigate how well COSIR agrees with measurements on the solar rotational timescale for different wavelength regions covering the UV to the near IR (up to 1 µm). We use data from PREMOS radiometers onboard the French PICARD mission, from SPM/VIRGO onboard the SOHO satellite, and from SOLSTICE/SORCE and SIM/SORCE spectrometers.

We present a new model of spectral solar irradiance variations, hereafter named COSIR (for COde for Solar Irradiance Reconstruction), based on a combination of the SATIRE-S and COde for Solar Irradiance (COSI, Shapiro et al. 2010). We employ a 5-component model which separately treats contributions from the quiet Sun, sunspot umbrae, sunspot penumbrae, active network, and faculae.

We use COSI to calculate spectra of individual magnetic features. Network, faculae and sunspots were identified in daily HMI data following the method of Yeo et al. (2013). Sunspots were distinguished by the continuum intensity, and network and faculae by the magnetogram signal. The magnetic field threshold B_{thr} between faculae and network is a free parameter of our model. All pixels that lie between the values of B_{noise} and B_{thr} correspond to the network, while pixels above B_{thr} up to 800 G are then considered as facular pixels. To determine B_{thr}, we first compare the COSIR model with TSI measurements as observed by PREMOS which are displayed in Figure 1. Both time-series are in excellent agreement, with $R^2 = 0.943$, achieved with a B_{thr} value of 165 G.

We now consider comparisons of the COSIR model with solar spectral irradiance observations, such as those from SOLSTICE/SORCE (180–310 nm) and from SIM/SORCE (310–1000 nm). The R^2 value between the COSIR reconstruction and observations as a function of wavelength in intervals of 5 nm is given in Figure 2. Modelled data and observations are in good agreement for most wavelengths roughly below 250 nm, and from 500 nm up to 800 nm. The agreement between COSIR and SORCE deteriorates between 250 and 400 and upwards of 800 nm. This is most likely due to measurement uncertainties of SORCE observations.

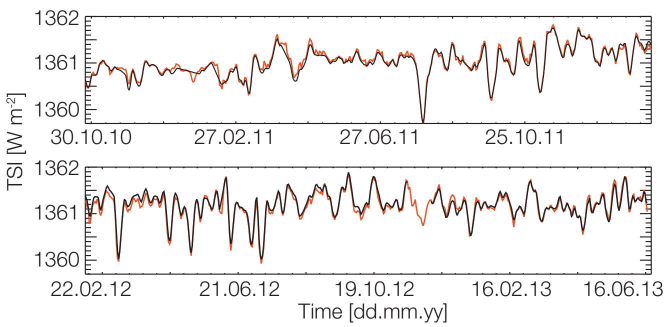

Figure 1. Daily value of the total solar irradiance (TSI) from November 2010 to June 2013 as modelled with the COSIR model (red) and as measured by PREMOS/PICARD (black).

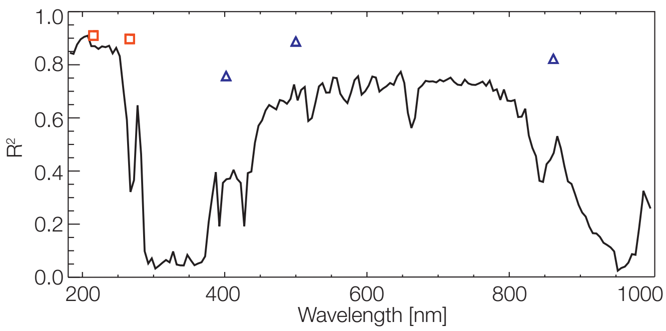

Figure 2. The correlation coefficient R^2 between COSIR modelled data and SORCE observations from March 2011 to May 2013, as a function of wavelength (from 180 nm to 1 µm) in intervals of 5 nm for rotational modulations. Values of R^2 between PREMOS and SPM observations and COSIR are also displayed (red squares and blue triangles respectively).

We can also perform comparisons between the COSIR model with SSI observations from radiometers such as PREMOS/PICARD and SPM/VIRGO. In the UV spectral range, we find excellent agreement between the COSIR model and PREMOS observations at 210 nm and at 266 nm (with R^2 equal to 0.91 and 0.89 respectively). While sunspots do not contribute to the variability at 210 nm, their contribution becomes more important at 266 nm. The agreement with SPM measurements at 400 nm, 500 nm, and 862 nm are rather good with R^2 values of 0.76, 0.87 and 0.82, respectively. Figure 3 displays a direct comparison between COSIR modelled data, and SORCE and SPM observations at 500 nm.

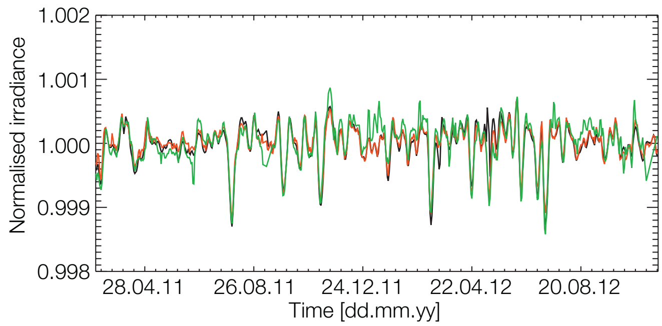

Figure 3. Irradiance from SPM/VIRGO observations (black), from COSIR calculations (red) and SIM/SORCE observations (green) at 500 nm.

References:

Shapiro A. I., Schmutz W., Schoell M., Haberreiter M., Rozanov E.: 2010, NLTE solar irradiance modelling with the COSI code. Astron. Astrophys., 517, A48.

Yeo K. L., Solanki S. K., Krivova N. A.: 2013, Astron. Astrophys., 550, A95.

Understanding the Implication of Small Scale Heating Events in the Solar Upper Atmosphere

Nuno Guerreiro, Margit Haberreiter, and Werner Schmutz in collaboration with the University of Oslo, Norway

The mechanism responsible for coronal heating remains an open question in solar physics since it was first discovered in the 1930s. We used a 3D magnetohydrodynamics (MHD) simulation to better understand the potential role of small-scale events in heating the corona. We developed a method to study the small-scale events at any instant in time and over their lifetime. The outcomes of applying this new methodology to the simulations are reported.

One of the most compelling mechanisms to explain coronal heating is based on the idea that small-scale heating events can account for the energy supply needed to maintain the coronal energetic balance.

The method we developed computes the properties of the heating events at any instant. We found about 10^4 events at any time over an area of 128 Mm^2. The study of the volumes allows us to conclude that the larger structures are a combination of small-scale events. The events have an average lifetime of 1 minute.

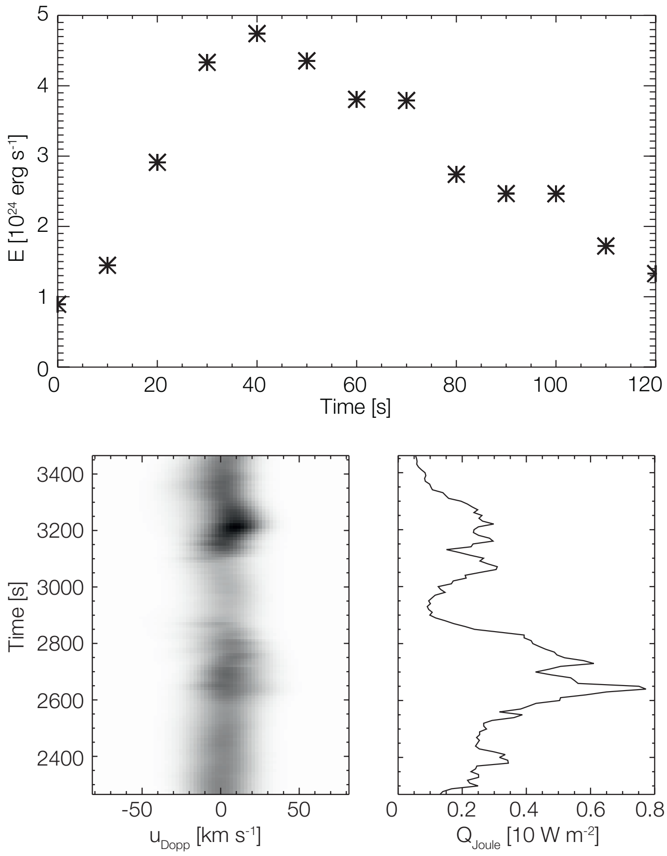

Figure 1. Energy of an event at each instant over its lifetime (top panel). Intensity of the Fe IX emission line (lower left panel) and Joule heating (lower right panel) integrated along the line-of-sight for a specific event and location over t=1300 s (lower right panel). The intensity is indicated by the shading, which varies from low (white) to high (black). The area of the measurements is centred at the maximum of the event at a certain instant, t=2652 s.

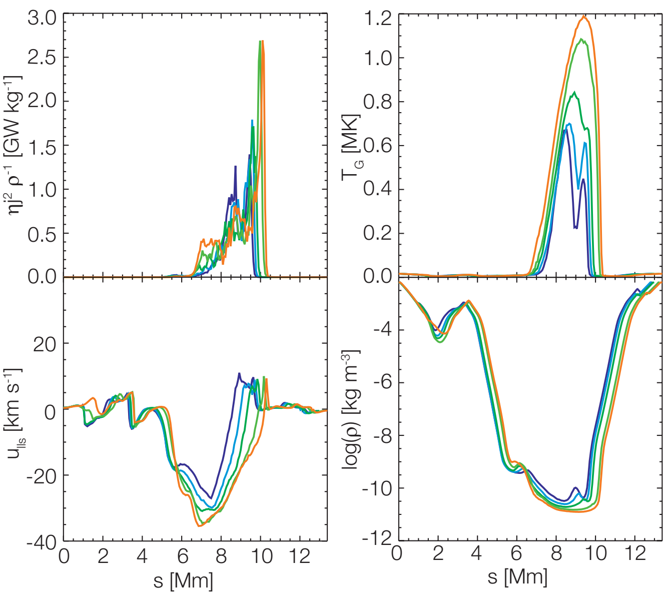

Figure 2. Upper left panel: Joule heating per particle, $\eta j^2 \rho^{-1}$. Lower left panel: velocity along the field lines. Upper right panel: temperatures. Lower right panel: densities along the field line. We follow a loop over 100 s in 20 s intervals - from purple for the moment we start following the line, via turquoise, to yellow at the end of the time-series shown. Velocities along the loop are positive in the direction of increasing loop coordinates.

The upper left panel of Figure 1 displays the total energy dissipated every 10 s over the event's lifetime. This particular event has a lifetime of about 2 minutes. The signature of the events on the spectral lines can be seen when computing the intensities along the line-of-sight over time at the locations where the events occur (Figure 1, lower left panel). The response of the Fe IX (17.1 nm) intensity to the heating event over time (lower left panel) is illustrated. Also shown is the Doppler shift associated with the event, better seen at around t = 2650 s. A recurrence of events in this region is also visible in the Joule heating per particle (lower right panel).

Furthermore, we study the plasma response to the events along the magnetic loops in the vicinity of the core dissipative region of each event. Figure 2 shows the evolution of the temperature, density, joule heating per particle, and velocity along a magnetic loop. The loop went through a maximum dissipation region of a specific event and was followed thereafter. We can see significant variations of the plasma along the field line as a consequence of the heating event.

A New Numerical Scheme for Accelerating Λ-Iterations in COSI

Rinat Tagirov, Alexander Shapiro, and Werner Schmutz

The implementation of the new numerical scheme for accelerated Λ-iterations within the COde for Solar Irradiance (COSI) has been accomplished and allows us to reliably calculate the solar spectrum from radio wavelengths to the UV.

COSI was originally developed to model the expanding atmospheres of hot stars. To this end, the co-moving system of reference (Mihalas, 1978), hereinafter abbreviated as CMF, was used in the code for solving the radiative transfer equation. Along with CMF, the so-called core saturation operator (Hamann, 1986) was employed to accelerate the Λ-iterations, coupling the radiative transfer equation to the statistical balance system (see the previous annual report). Classic Λ-iterations without any acceleration are known to converge extremely slowly in optically thick parts of the spectrum (Mihalas, 1978) and "worse yet, exhibit a pathological behaviour in that the solution stabilises long before the correct solution is reached" (Hubeny, 2003). The above-mentioned operator was chosen as that which adequately describes the radiative transfer in fast expanding atmospheres.

Later, at PMOD/WRC, COSI was applied to simulate the conditions in the solar atmosphere where plasma movements are of the same order of magnitude as the micro-turbulence. It turned out that in this case the accelerated Λ-iterations (ALI) with a core saturation operator are virtually reduced to the classic Λ-iterations. This drawback of the code was the reason for unreliable calculations of level populations in the atmospheric regions where strong UV lines and the radio spectrum are formed ,and eventually lead to incorrect irradiances in the corresponding spectral regions. Therefore, we implemented the local operator for the radiative transfer in spectral lines so that the code could handle the case of a slowly moving atmosphere.

Our numerical tests showed that the local operator works adequately under solar conditions, and that the convergence time is good. Hence the emerging intensity in the radio wavelengths

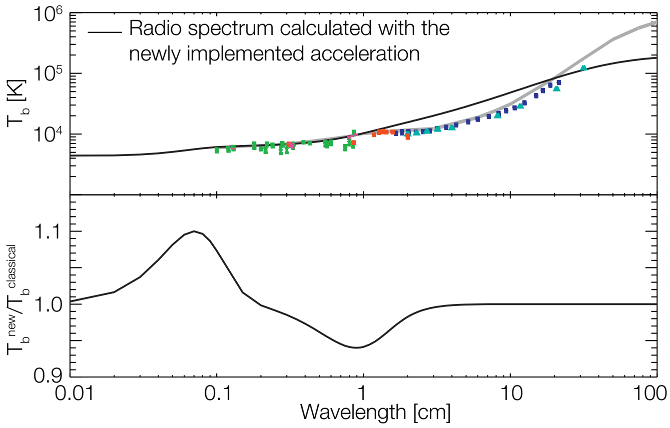

Figure 1. Upper panel: The solar radio spectrum as calculated by COSI with the newly implemented acceleration compared to the available observations. Lower panel: Ratio of the brightness temperature calculated with the new acceleration to that calculated using classic Λ-iterations.

(Figure 1) and in strong UV lines (Figure 2) can now be reliably calculated. Further tests revealed that the new ALI scheme can also be used for an expanding atmosphere, but this leads to a slower convergence. To our knowledge, the local operator has never been used together with the CMF approach and therefore our work presents a valuable contribution to radiative transfer theory especially since the local operator, unlike its COSI predecessor, works autonomously (i.e., does not contain any free parameters that need manual adjustment during the Λ-iteration process) and is quite simple to construct.

References:

Hamann W.: 1986, Line formation in expanding atmospheres: Multi-level calculations using approximate lambda operators, Astron. Astrophys., 160, 347 – 351.

Hubeny I.: 2003, Accelerated lambda iteration: an overview, Stellar Atmosphere Modeling, ASP Conf. Ser., 288, 17 – 30.

Mihalas D.: 1978, Stellar Atmospheres, 2nd ed.

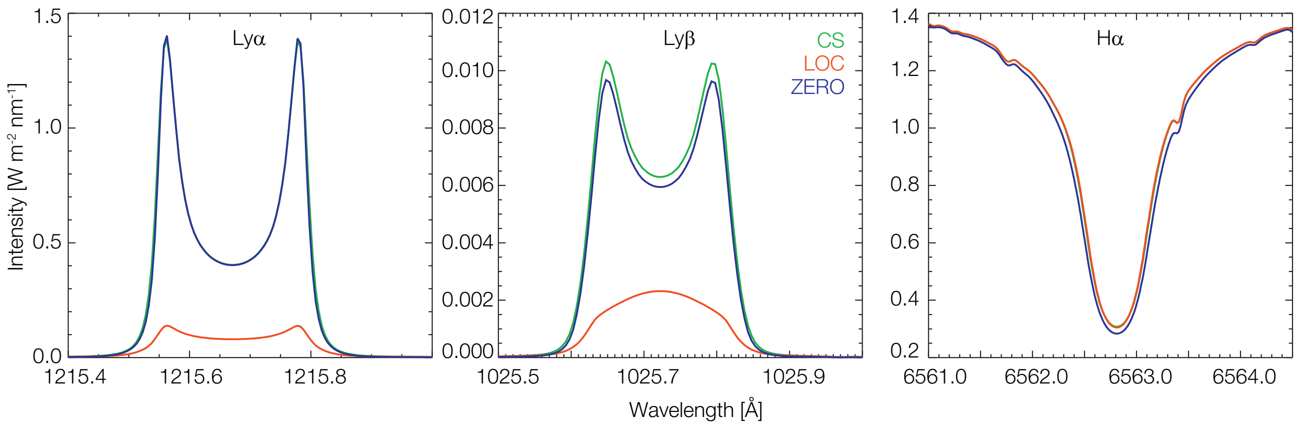

Figure 2. Lyα, Lyβ and Hα lines calculated for the solar case using the new acceleration (LOC), core saturation operator (CS) and classic Λ-iterations (ZERO).

Modelling of Total Solar Irradiance on the Decadal and Multi-Centennial Timescales

Wilnelia Adams, Alexander Shapiro, Rinat Tagirov, Werner Schmutz, and Eugene Rozanov

A number of improvements and updates are introduced into an existing model of solar irradiance. Two timescales that are relevant in modelling of the atmospheric response to changes in the radiative output of the sun are discussed: The 11-year solar cycle (decadal) and irradiance variations over a 400-year period since the Maunder Minimum (multi-centennial). Results show that better constraints on the amplitudes of TSI variations are obtained on both timescales.

Satellite data of TSI has only been available since 1978. Improvements followed in the quantification and modelling of irradiance variations associated with the 11-year solar cycle (Ermolli et al., 2013). Much work is still required to constrain the historical solar radiative forcing of climate over the Holocene. The work presented here is largely based on Shapiro et al. (2011). Improvements in modelling TSI are obtained on two timescales of interest to the climate community: The 11-year solar cycle (decadal) and constraints on the long-term trend in TSI variations since the Maunder Minimum (multi-centennial).

In the approach by Shapiro et al. (2011), the solar spectrum is treated as the sum of time- and wavelength-dependent spectral contributions to irradiance from the quiet sun and three photospheric features: Sunspots, faculae and active network. Each spectrum is weighted according to the area coverage of the solar disk by each feature. New model characteristics introduced are as follows:

Penumbra contribution to the sunspot spectrum: Sunspot penumbrae are introduced into the model and their spectral contribution to the irradiance is considered.

Activity belts: A more realistic distribution of sunspots and faculae are introduced.

Calculated contrasts between sunspots, faculae and quiet sun: Datasets of sunspot and faculae filling factors are used to establish empirical relations with sunspot number. This eliminates free-parameter scaling of contrasts.

Figure 1 shows TSI modelled over the last 3 cycles. Shapiro et al. (2011) obtained a difference of 6 Wm–2 between TSI of the present day and the Maunder Minimum (1645–1715). Other reconstructions result in no more than 1.5 Wm–2. This large value is due to the hypothesis that quiet sun irradiances are linearly correlated with large-scale variations in the solar modulation potential. The contrast between models C and A of Fontenla et al. (1999) appear in the time-dependent interpolation term that constrains historical quiet sun irradiance variations between the level of the present-day quiet sun and the "base model" of the quiet sun. The base model is the lowest level of quiet sun irradiance if large-scale surface magnetic features are absent for more than a solar cycle.

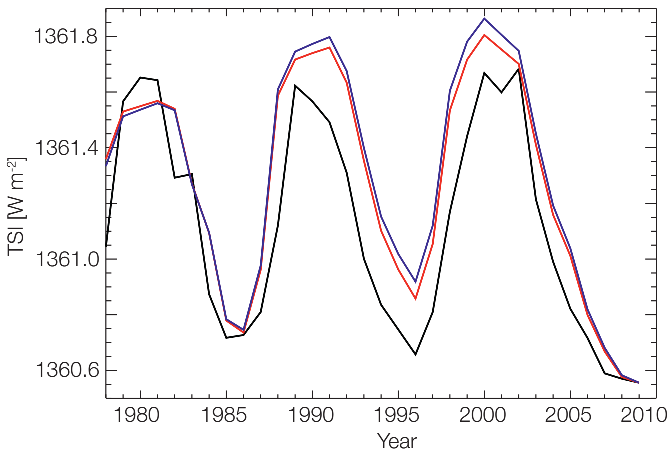

Figure 1. TSI for the period 1978–2010: updated TSI modelling (red), the PMOD composite (black) and TSI modelled by Shapiro et al. (2011) (blue).

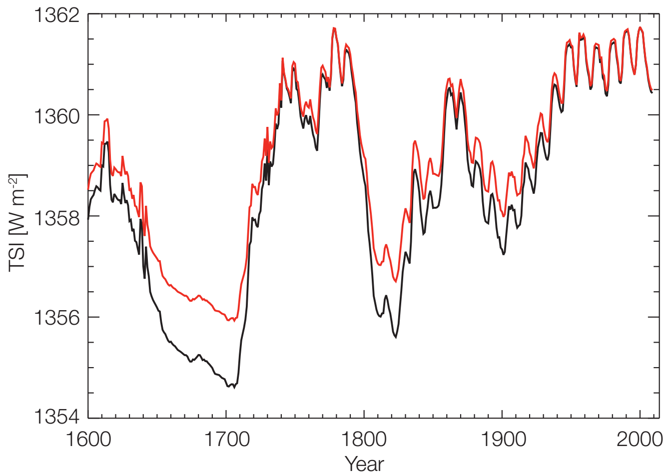

Figure 2. Reconstructions of historical TSI variations, 1600–2014. The new reconstruction (red) is shown with that by Shapiro et al. (2011) (black).

Judge et al. (2012) noted that the Fontenla model A has an upper photospheric temperature that is too low to adequately represent the base model. We adopt their recommendations here and replace the contrast between the current state of the quiet sun (Fontenla model C) and the base model (Fontenla model A) with models C and B by Vernazza et al. (1981), respectively. Figure 2 shows the new TSI reconstruction. The difference in TSI between the present day and the Maunder Minimum is reduced to 4.8 Wm–2.

References: Ermolli I., et al.: 2013, Atmos. Chem. Phys., 13, 3945–3977.

Fontenla J., et al.: 1999, ApJ, 518, 480.

Judge P. G., et al.: 2012, Astron. Astrophys., 544, A88.

Shapiro A. I., et al.: 2011, Astron. Astrophys., 529, A67.

Vernazza J. E., et al.: 1981, ApJS, 45, 635.

Publications

Refereed Publications

Arfeuille F., Weisenstein D., Mack H., Rozanov E., Peter T. Brönnimann S.: 2014, Volcanic forcing for climate modeling: A new microphysics-based dataset covering years 1600–present, Clim. Past., 10, 359–375, doi: 10.5194/cp-10-359-2014.

Anet J., Muthers S., Rozanov E., Raible C., Stenke A., Shapiro A. I., Brönnimann S., Arfeuille F., Brugnara Y., Beer J., Steinhilber F., Schmutz W., Peter T.: 2014, Impact of solar vs. volcanic activity variations on tropospheric temperatures and precipitation during the Dalton Minimum, Clim. Past, 10, 921-938, doi: 10.5194/cp-10-921-2014.

Barreto A., Cuevas, E., Palle, P., Romero, P. M., Guirado, C., Wehrli, C. J., Almansa, F.: 2014, Recovering long-term aerosol optical depth series (1976-2012) from an astronomical potassium-based resonance scattering spectrometer, Atmos. Meas. Tech., 7, 4103-4116, doi: 10.5194/amt-7-4103-2014.

Barthelemy M., Cessateur, G.: 2014, Sensitivity of upper atmospheric emissions calculations to solar/stellar UV flux, J. Space Weather Space Clim., 4, A35.

Barthelemy M., Lamy L., Menager H., Schulik M., Bernard D., Abgrall H., Roueff E., Cessateur G., Prange R., Lilensten, J.: 2014, Dayglow and auroral emissions of Uranus in H-2 FUV bands, Icarus, 239.

Chipperfield M. P., Liang Q., Strahan S. E., Morgenstern O., Dhomse S. S., Abraham N. L., Archibald A. T., Bekki S., Braesicke P., Di Genova G., Fleming E. L., Hardiman S. C., Iachetti D., Jackman C. H., Kinnison D. E., Marchand M., Pitari G., Pyle J. A., Rozanov E., Stenke A., Tummon F.: 2014, Multimodel estimates of atmospheric lifetimes of long-lived ozone-depleting substances: Present and future, J. Geophys. Res. Atmos., 119, doi:10.1002/2013JD021097.

Gromke C., Horender, S., Walter, B., Lehning, M.: 2014, Snow particle characteristics in the saltation layer, J. Glaciol., 60, 221, 431-439, doi: 10.3189/2014JoG13J079.

Feldmann A., Burnitt T., Porrovecchio G., Smid M., Egli L., Gröbner J., Nield K.: 2014, Diode-Array UV solar spectroradiometer implementing a digital micromirror device, Metrologia, 51, 6, doi:10.1088/0026-1394/51/6/S289.

Finsterle W., Koller S., Beck I., Spescha M., Suter M., Walter B., Schmutz W.: 2014, The new radiometer CLARA, Proc. SPIE 9264, doi: 10.1117/12.2069614.

Gröbner J., Reda I., Wacker S., Nyeki S., Behrens K., Gorman J.: 2014, A new absolute reference for atmospheric longwave irradiance measurements with traceability to SI units, J. Geophys. Res. Atmos., 119, doi:10.1002/2014JD021630.

Haberreiter M., Delouille V., Mampaey B., Verbeeck C., Del Zanna G., Wieman S.: 2014, Reconstruction of the solar EUV irradiance form 1996 to 2010 based on SOHO/EIT images, J. Space Weather and Space Climate, 4, A40.

Kazadzis S., Veselovskii I., Amiridis V., Gröbner J., Suvorina A., Nyeki S., Gerasopoulos E., Kouremeti N., Taylor M., Tsekeri A., Wehrli C.: 2014, Aerosol microphysical retrievals from precision filter radiometer direct solar radiation measurements and comparison with AERONET, Atmos. Meas. Tech., 7, 2013–2025.

Kreuter A., Buras R., Mayer B., Webb A., Kift R., Bais A., Kouremeti N., Blumthaler M.: 2014, Solar irradiance in the heterogeneous albedo environment of the Arctic coast: Measurements and a 3-D model study, Atmos. Chem. Phys., 14, 5989-6002, doi: 10.5194/acp-14-5989-2014.

Lothon M., Lohou F., Pino D., Couvreux F., Pardyjak E. R., Reuder J., Vila-Guerau de Arellano J., Durand P., Hartogensis O., Legain, D., Augustin P., Gioli B., Lenschow D. H., Faloona I., Yagüe C., Alexander D. C., Angevine W. M., Bargain E , Barrie J., Bazile E., Bezombes Y., Blay-Carreras E., van de Boer A., Boichard J. L., Bourdon A., Butet A., Campistron B., de Coster O., Cuxart J., Dabas A., Darbieu C., Deboudt K., Delbarre H., Derrien S., Flament P., Fourmentin M., Garai A., Gibert, F., Graf, A., Groebner J., Guichard F., Jimenez M. A., Jonassen M., van den Kroonenberg A., Magliulo V., Martin S., Martinez D., Mastrorillo L., Moene A. F., Molinos F., Moulin E., Pietersen H. P., Piguet B., Pique E., Roman-Cascon C., Rufin-Soler C., Said F., Sastre-Marugan M., Seity Y., Steeneveld G. J., Toscano P., Traulle O., Tzanos D., Wacker S., Wildmann N. Zaldei A.: 2014, The BLLAST field experiment: Boundary-Layer Late Afternoon and Sunset Turbulence, Atmos. Chem. Phys., 14, 10931-10960, doi: 10.5194/acp-14-10931-2014.

Muthers S., Anet J. G., Raible C. C., Brönnimann S., Rozanov E., Arfeuille F., Peter T., Shapiro A. I., Beer J., Steinhilber F., Brugnara Y.,Schmutz W.: 2014, Northern hemispheric winter warming pattern after tropical volcanic eruptions: Sensitivity to the ozone climatology, J. Geophys. Res. Atmos., 119, 1340–1355, doi:10.1002/2013JD020138.

Muthers S., Anet J. G., Stenke A., Raible C. C., Rozanov E., Brönnimann S., Peter T., Arfeuille F. X., Shapiro A. I., Beer J., Steinhilber F., Brugnara Y., Schmutz W.: 2014, The coupled atmosphere–chemistry–ocean model SOCOL-MPIOM, Geosci. Model Dev., 7, 2157–2179, doi:10.5194/gmd-7-2157-2014.

Nevas S., Gröbner J., Egli, L., Blumthaler M.: 2014, Stray light correction of array spectroradiometers for solar UV measurements, App. Opt., 53, 19, 4313-4319.

Refereed Publications

Ring J., Akdis C., Lauener R., Schaeppi G., Traidl-Hoffmann C., Akdis M., Ammann, W., Behrendt H., Bieber T., Biedermann T., Bienenstock J., Blaser K., Braun-Fahrlaender C., Brockow K., Buters J., Crameri R., Darsow U., Denburg J. A., Eyerich K., Frei R., Galli S. J., Gutermuth J., Holt P., Koren H., Leung D., Mueller U., Muraro A., Ollert M., O'Mahony L., Pawankar R., Platts-Mills T., Rhyner C., Rosenwasser L.J., Schmid-Grendelmeier P., Schmidt-Weber C.B., Schmutz W., Simon D., Simon H.U., Sofiev M., van Hage M., van Ree R.: 2014, Global Allergy Forum and Second Davos Declaration 2013 Allergy: Barriers to cure - challenges and actions to be taken, Allergy 69, 978–982, doi: 10.1111/all.12406.

Shapiro A. I., Solanki S. K., Krivova N. A., Schmutz W. K., Ball W. T., Knaack R., Rozanov E. V., Unruh Y. C.: 2014, Variability of Sun-like stars: Reproducing observed photometric trends, Astron. Astrophys. 569, A38, doi: 10.1051/0004-6361/201323086.

Sukhodolov T., Rozanov E., Shapiro A. I., Anet J., Cagnazzo C., Peter T., Schmutz W.: 2014, Evaluation of the ECHAM family radiation codes performance in the representation of the solar signal, Geosci. Model Dev., 7, 2859–2866, doi:10.5194/gmd-7-2859-2014.

Thuillier G., Bolsée D., Schmidtke G., Foujols T., Nikutowski B., Shapiro A. I., Brunner R., Weber M., Erhardt C., Hersé M., Gillotay D., Peetermans W., Decuyper W., Pereira N., Haberreiter M., Mandel H., Schmutz W.: 2014, The solar irradiance spectrum at solar activity minimum between solar cycles 23 and 24, Sol. Phys. 289, 1931–1958, doi: 10.1007/s11207-013-0461-y.

Thuillier G., Melo S. M. L., Lean J., Krivova N. A., Bolduc C., Fomichev V. I., Charbonneau P., Shapiro A. I., Schmutz W., Bolsée D.: 2014, Analysis of different solar spectral irradiance reconstructions and their impact on solar heating rates, Sol. Phys. 289, 1115–1142, doi: 10.1007/s11207-013-0381-x.

Thuillier G., Schmidtke G., Erhardt C., Nikutowski B., Shapiro A. I., Bolduc C., Lean J., Krivova N., Charbonneau P., Cessateur G., Haberreiter M., Melo S., Delouille V., Mampaey B., Yeo K. L., Schmutz W.: 2014, Solar spectral irradiance variability in November/December 2012: Comparison of observations by instruments on the International Space Station and models, Sol. Phys. 289, 4433-4452, doi: 10.1007/s11207-014-0588-5.

Wacker, S., Gröbner, J., Vuilleumier, L.,: 2014, A method to calculate cloud-free long-wave irradiance at the surface based on radiative transfer modeling and temperature lapse rate estimates, Theor. Appl. Clim., 115, 551-561, doi: 10.1007/s00704-013-0901-5.

Wacker S., Gröbner J., Zysset C., Diener L., Kazantzadis A., Tzoumanikas P., Vuilleumier L., Stöckli R., Nyeki S.: 2014, Cloud observations in Switzerland using hemispherical sky cameras, Atmos. Res., 2014.

Walter B., Fehlmann A., Finsterle W., Suter M., Soder R., Schmutz W.: 2014, Spectrally integrated window transmittance measurements for a cryogenic solar absolute radiometer, Metrologia 51, S344–S349, doi: 10.1088/0026-1394/51/6/S344.

Walter B., Horender S., Voegeli C., Lehning M.: 2014, Experimental assessment of Owen's second hypothesis on surface shear stress induced by a fluid during sediment saltation, Geophys. Res. Lett., 41, doi:10.1002/2014GL061069.

Other Publications

Adams W., Shapiro A. I., Schmutz W., Tagirov R.: 2014, "FUPSOL Subproject A, TSI and SSI modelling for years 1800–2200", 2nd Past Global Changes (PAGES) Workshop: Constraining Solar Forcing through Detection and Attribution for the Holocene, 20–23 May 2014, PMOD/WRC, Davos, Switzerland.

Adams W., Shapiro A. I., Schmutz W., Tagirov R.: 2014, A new model of solar irradiance – Reconstructions into the past and forecasts into the future", 4th Conf. "Graubünden forscht – Young Scientists in Contest', 10–11 Sept. 2014, Davos, Switzerland.

Adams W., Shapiro A. I., Schmutz W., Tagirov R.: 2014, A new model of solar irradiance, TOSCA/SOLID Workshop: Long-term Solar Activity and their Impacts, 29 Sept.–2 Oct. 2014, Corfu, Greece.

Adams W., Shapiro A. I., Schmutz W., Tagirov R.: 2014, A new model of solar irradiance, Solar Metrology – Needs and Methods, 7–9 October 2014, Paris, France.

Aebi C.: 2014, A comprehensive radiation flux assessment at different sites in Switzerland, 4th Conf. "Graubünden forscht – Young Scientists in Contest', 10–11 Sept. 2014, Davos, Switzerland.

Ball W. T., Yeo K-L., Krivova N. A., Solanki S. K., Unruh Y. C., Morrill J.: 2014, Evaluation of solar irradiance models for climate studies. EGU 2015 General Assembly Conf. Abstracts 17, 11817.

Ball W. T., Rozanov E., Shapiro A. V.: 2014, Can we use the ozone response in a CCM to say which solar spectral irradiance is most likely correct? EGU 2015 General Assembly Conf. Abstracts 17, 11274.

Cessateur G., Schmutz W., Shapiro A.: 2014, The PREMOS/PICARD radiometer: An overview after 3 years of observations, EGU General Assembly Conf. Abstracts 16, 15741.

Cessateur G., Schmutz W., Shapiro A.: 2014, The PREMOS/PICARD radiometer: An overview after 3 years of observations. In: 40th COSPAR Scientific Assembly, p. 469.

Egli L., Nevas S., Blattner P., El Gawhary O., Kärhä P., Gröbner J.: 2014, Characterization of array spectroradiometers for solar UV measurements, Proceedings of CIE TC Expert Symposium, Vienna, Austria, 12 Sept., 2014, ISBN 978-3-902842-22-0.

Egorova T., Rozanov E., Schmutz W.: 2014, Solar variability and climate change during the first half of the 20th century (SOVAC), 4th Conf. "Graubünden forscht - Young Scientists in Contest", Sept. 10–11, 2014, Davos, Switzerland.

Finsterle W., Fehlmann A., Walter B., Pfiffner D., Schmutz W.: 2014, The Total Solar Irradiance record from PREMOS, EGU General Assembly Conf. Abstracts 16, 16936.

Finsterle W., Koller S., Beck I., Spescha M., Suter M., Walter B., Schmutz W.: 2014, The new TSI radiometer CLARA. In: Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series 9264, eid. 92641S, doi: 10.1117/12.2069614.

Guerreiro N., Haberreiter M., Hansteen V., Curdt W., Schmutz W.: 2014, Signatures of small-scale heating events in EUV spectral lines as modeled from 3D MHD simulations, EGU General Assembly Conf. Abstracts 16, 13047.

Guerreiro N., Haberreiter M., Schmutz W., Hansteen V.: 2014, Identification and characterization of small-scale heating events in the solar atmosphere from 3D MHD simulations. In: 40th COSPAR Scientific Assembly, p. 1095.

Guerreiro N.: 2014, The role of small scal heating events in the coronal heating, 4th Conf. "Graubünden forscht - Young Scientists in Contest", Sept. 10–11, 2014, Davos, Switzerland.

Haberreiter M., Delouille V., Mampaey B., Verbeeck C., Wieman S.: 2014, Reconstruction of the solar EUV irradiance from 1996 to 2012 based on SOHO/EIT images, EGU General Assembly Conf. Abstracts 16, 11329.

Haberreiter M., Delouille V., Del Zanna G., Ermolli I., Kretzschmar M., Mampeay B., Dominique M., Schmutz W.: 2014, Reconstruction of the solar EUV irradiance as observed with PROBA2/LYRA, EGU General Assembly Conf. Abstracts 16, 14449.

Haberreiter M., et al.: 2014, Results from the first year of SOLID - the First Comprehensive European Solar Irradiance Data Exploitation, EGU General Assembly Conf. Abstracts 16, 13475.

Haberreiter, M.: 2014, SOLID - an FP7 Project towards the first European Comprehensive Solar Irradiance Data Exploitation, Abstract of the invited talk, 5th HEPPA/SOLARIS Workshop, Baden-Baden, Germany

Haberreiter, M.: 2014, SOLID – a European Project towards a Comprehensive Solar Irradiance Data Exploitation, Abstract of the invited talk, SORCE Meeting, Florida, USA

Haberreiter, M.: 2014, Assimilation of solar spectral irradiance data within the FP7 SOLID project, Invited Review, European Solar Physics Meeting, Dublin, Ireland

Haberreiter, M., Beer, J., Muscheler, R., Delouille, V., Mampaey, B., Verbeeck, C; Schmutz, W.: 2014, Towards the longterm reconstruction of the Solar EUV irradiance for planetary science applications, Abstract for ESWW-11, Liege, 2014.

Haberreiter M, et al.: 2014, Solar EUV modeling efforts within the FP7 SOLID project, Abstract for ESWW-11, Liege, 2014.

Halain J.-P., ... Schmutz W.: 2014, The extreme UV imager of solar orbiter: From detailed design to flight model, SPIE Conf. Ser. 9144, id. 914408, doi: 10.1117/12.2055207.

Kozubek M., Rozanov E., Krizan P., The stratospheric response to external factors based on MERRA data using linear multivariate linear regression analysis, Atmos. Chem. Phys. Discuss., 14, 23891–23911, 2014.

Krucker S., Saint-Hilaire P., Hudson H. S., Haberreiter M., Kleint L., Hurford G. J., Fivian M. D., Battaglia M., Martinez A., Oliveros J. C.: 2014, HMI and Rhessi measurements of the radial location of solar flare footpoints to subarcsecond accuracy, American Geophysical Union, Fall Meeting, Abstract SH31C-05 .

Mbatha N., Nyeki S., Brunke E.-G., Labuschagne C., Observation of biomass burning aerosols at Cape Point using a GAW Precision Filter Radiometer and CALIPSO satellite: 2014 , Annual Meeting of the South African Society for Atmospheric Sciences (SASAS), 1–2 October 2014, Potchefstroom, South Africa.

Muthers S., Anet J. G., Stenke A., Raible C. C., Rozanov E., Brönnimann S., Peter T., Arfeuille F., Shapiro A.I., Beer J., Steinhilber F., Brugnara Y., Schmutz W.: 2014, The coupled atmosphere-chemistry-ocean model SOCOL-MPIOM, Geoscientific Model Development Discussions 7, 3013–3084, doi: 10.5194/gmdd-7-3013-2014.

Nyeki S., Wacker S., Gröbner J., Vuilleumier L.: 2014, Time-series of downward long-wave radiation using modified CGR3 pyrgeometers in Switzerland, 13th Baseline Surface Radiation Network (BSRN) Scientific Review and Workshop, Bologna, Italy, 9-12 Sept. 2014, WCRP Report No. 17/2014, p. 26.

Qahwaji R., Haberreiter M., Ipson S., Ahmed O., Nibouche O.: 2014, Segmentation of SOHO/MDI continuum and magnetogram images with the ASAP tool for SSI reconstruction, EGU General Assembly Conf. Abstracts 16, 13589.

Rozanov E., Energetic particles and the atmosphere: A long-term prospective, Abstract of the invited talk for 40th COSPAR Scientific Assembly, Section D2.2, Moscow, 2014.

Rozanov E., Modeling efforts toward understanding the energetic particle effects in the atmosphere, Abstract of the invited talk for ESWW-11, Liege, 2014.

Rozanov E., Climate-related effects of cosmic rays, Abstract of the invited talk for European Cosmic Ray Symposium, Kiel, 2014.

Rozanov E., Solar and particle effects on the tropospheric climate, Abstract of the invited talk for 5th International HEPPA Workshop, SPARC/SOLARIS-HEPPA, Baden-Baden, 2014.

Rouzé M., Hauchecorne A., Hochedez J.-F., Irbah A., Meftah M., Corbard T., Turck-Chièze S., Boumier P., Dewitte S., Schmutz W.: 2014, The PICARD Scientific Mission: status of the program, 13th International Conference on Space Operations 5-9 May 2014, Pasadena, CA, AIAA 2014-1705, 16 pp, doi: 10.2514/6.2014-1705.

Schmutz W., Finsterle W., Walter B., Suter M., Andersen B., Osmundsen M.: 2014, CLARA – A compact and light-weight absolute radiometer on the NORSAT-1 mission. In: 40th COSPAR Scientific Assembly, p. 2930.

Schmutz W., Haberreiter M., Shapiro A., Cessateur G., Wehrli C., Adams W.: 2014, Assessment of the spectral solar cycle variations in the visual and near IR from VIRGI/SOHO data. In: 40th COSPAR Scientific Assembly, p. 2929.

Schmutz W., Thuillier G., Finsterle W., Walter B., Fehlmann A.: 2014, The TSI record from PREMOS/PICARD. In: 40th COSPAR Scientific Assembly, p. 2931.

Sukhodolov T., Rozanov E., Shapiro A. I., Anet J., Cagnazzo C., Peter T., Schmutz W.: 2014, Evaluation of the ECHAM family radiation codes performance in the representation of the solar signal, Geoscientific Model Development Discussions 7, 1337–1356, doi: 10.5194/gmdd-7-1337-2014.

Sukhodolov T., Schmutz W., Shapiro A., Tourpali K., Peter T., Rozanov E., Bais A., Telford P.: 2014, Middle atmosphere heating rate and photolysis response to the uncertainties in spectral solar irradiance data. In: 40th COSPAR Sci. Ass.embly p. 3225.

Sukhodolov T., Rozanov E., Shapiro A. I., Anet J., Cagnazzo C., Peter T., Schmutz W.: 2014, Evaluation of the ECHAM family radiation codes performance in the representation of the solar signal, Geosci. Model Dev., Disc., 7, 1337–1356, doi: 10.5194/gmdd-7-1337-2014.

Sukhodolov T.: 2014, Sensitivity of the photolysis rate to the uncertainties in spectral solar irradiance variability, 4th Conf. "Graubünden forscht - Young Scientists in Contest", Sept. 10–11, 2014, Davos, Switzerland.

Tagirov R.: 2014, Fast non-LTE transfer numerical schem for solar spectrum modeling, 4th Conference "Graubünden forscht - Young Scientists in Contest", Sept. 10–11, 2014, Davos, Switzerland.

Walter B.: 2014, The monitor to measure the integral transmittance of windows (MITRA), 4th Conference "Graubünden forscht - Young Scientists in Contest", Sept. 10–11, 2014, Davos, Switzerland.

Administration

Personnel Department

Barbara Bücheler

The numerous accomplishments in 2013 encouraged us to approach 2014 with the same energy and enthusiasm. We began the year with the annual meeting of the eHEROES project on 10–12 March. Nearly 40 participants from various international Universities and research centres attended the meeting. The next event was the FUPSOL workshop from 20–23 May where the topic was Solar Forcing in the Holocene by "Detection and Attribution". This was followed by an evening gathering of the Project Team on the 11 June which marked the official end of the PMOD/WRC renovation. The final event of 2014 was the 8th UVNet measurement campaign with workshop presentations on 15–16 July.

Research is a core discipline at the PMOD/WRC, and we are glad to have two new motivated members of staff. Wilnelia Adams and Christine Aebi began their PhDs in Spring, funded by the Swiss National Science Foundation. They were joined in September by William Ball, a post-doc in the climate group. 2014 was also a year in which several staff left the PMOD/WRC. The post-docs Gaël Cessateur, Anna Shapiro und Alexander Shapiro left the Solar Physics Group to pursue their careers abroad, while Markus Suter successfully finished his PhD. We thank them all for their work and efforts. In addition, Christoph Wehrli retired after having been a long-standing scientist at PMOD/WRC for 36 years. We are honoured to have worked with him throughout this time, and thank him for his commitment, enthusiasm and loyalty. We wish him all the best in the future. His successor, Stelios Kazadzis began in 2015, and we also wish him a good start in his new job.

Kathrin Anhorn joined the Administration Section in August as a trainee book-keeper in August, filling the position held earlier by Eliane Tobler who passed her exams in 2014. Eliane then took over the duties of Alison Gustavsson, who left at the end of August. We thank Eliane for her commitment in the last three years, especially as she stayed on six months longer than planned until February 2015, thereby delaying a long-planned trip abroad.

October saw further changes in the Administration Section when Sandra Kissling, the section Head, decided to leave for new challenges at the beginning of 2015, and to pass on the position to her successor, Barbara Bücheler. Throughout this challenging time in 2014, both Elisabeth Jenny and Seraina Egartner helped on a temporary and part-time basis to keep the Administration Section running. We would like to express our thanks to Sandra, Eliane, Alison and Elisabeth for their commitment, and wish them success in the future.

Several members of staff also left the Technical Section in 2014. Due to the financial difficulties experienced in this year, the PMOD/WRC had to release Diego Wasser from employment in November 2014. He was an esteemed and long-standing electronics technician, and we unfortunately regret this unavoidable step. We wish Diego all the best in the future. On the brighter side, Thierry Hartmann successfully finished his electronics training after 4 years. His position has now been taken by Andri Morandi, who is a 3rd year electronics trainee. Etienne de Coulon left for new challenges after having been a software developer for four years. He will return in May 2015 to conduct his civilian service. Interestingly, another former civil service conscript, Patrik Langer, joined the Technical Section early in 2014 and has been working as a mechanical engineer since November.

As in previous years, a number of civil service conscripts worked at the PMOD/WRC. We thank the following for their great help. Fabian Tischhauser, Hans Kessler, Remo Waser, Simon Pfister und Patrik Langer.

The team-work demonstrated by all PMOD/WRC staff in 2014 has taken us several more steps towards fulfilling our commitments in the fields of Solar Radiation and Climate science, as well as Space Experiments. Thank you to all staff at the PMOD/WRC

Scientific Personnel

Prof. Werner Schmutz	Director, physicist
Dr. William Ball	Postdoc in Climate Group (since 01.09.2014)
Dr. Gaël Cessateur	Postdoc in Solar Physics Group, physicist (until 30.11.2014)
Dr. Luca Egli	Scientist in WCC-UV section, physicist
Dr. Tatiana Egorova	Scientist in Climate Group, meteorologist
Dr. Wolfgang Finsterle	Head of WRC-SRS section, physicist
Dr. Julian Gröbner	Head of WRC-Sections IR, WORCC and WCC-UV, physicist
Dr. Nuno Guereirro	Scientist in Solar Physics Group, physicist
Dr. Margit Haberreiter	Head of Solar Physics Group, physicist
Dr. Gregor Hülsen	Scientist in WCC-UV section, physicist
Dr. Natalia Kouremeti	Scientist in WORCC section, physicist
Dr. Stephan Nyeki	Scientist in IR section, physicist
Dr. Eugene Rozanov	Head of Climate Group, physicist
Dr. Alexander Shapiro	Postdoc in Solar Physics Group, physicist (until 31.07.2014)
Dr. Anna Shapiro	Postdoc in Climate Group, physicist (until 30.06.2014)
Dr. Benjamin Walter	Postdoc in Solar Physics Group, physicist (3rd year)
Dr. Christoph Wehrli	Scientist in WORCC section, physicist (until 31.12.2014)
Wilnelia Adams	PhD SNF project (since 01.02.2014)
Christine Aebi	PhD SNF project (since 01.04.2014)
Florian Henschel	Trainee (until 30.04.2014)
Markus Suter	PhD student, UNIZH (until 31.10.2014)
Timofei Sukhodolov	PhD student, ETHZ (1st and 2nd year)
Rinat Tagirov	PhD student, ETHZ (3rd year)

Technical Personnel

Manfred Gyo	Head of Technical Department, electronic engineer, Quality System manager
Valeria Büchel	Mechanical engineer and part time project manager space experiments
Lara Carisch	Engineer (until 31.05.2014)
Etienne de Coulon	Software development engineer (until 28.02.2014)
Fabian Dürig	Mechanical engineer (until 28.02.2014)
Thierry Hartmann	Electronics apprentice (until 31.07.2014)
Silvio Koller	Project and system engineer Space and Science Instruments, Quality System Manager
Patrik Langer	Mechanical engineer (since 15.11.2014)
Andri Morandi	Electronics apprentice, 3rd and 4th year
Daniel Pfiffner	Project manager Space Experiments, deputy head Technical Department and Quality System, electronic engineer
Marco Senft	IT Administrator
Marcel Spescha	Technician
Diego Wasser	Electronic technician

Technical Personnel within the Science Department

Nathan Mingard	Physics laboratory assistant
Ricco Soder	Research engineer
Christian Thomann	Technician

Administration

Sandra Kissling	Head of Administration/Human Resources
Kathrin Anhorn	Administration apprentice (1st year)
Seraina Egartner	Administration, book-keeping (until 28.02.2014)
Stephanie Ebert	Administration, book-keeping (until 30.06.2014)
Alison Gustavsson	Administration, book-keeping (until 31.08.2014)
Elisabeth Jenny	Administration temp. (31.07.2014 – 30.11.2014)
Irene Keller	Administration, import/export
Christian Stiffler	Book-keeping
Eliane Tobler	Administration apprentice (3rd year), book-keeping and Head of Administration

Caretaker

Maria Sofia Ferreira Pinto	General caretaker, cleaning
Sonja Veras Araujo	General caretaker, cleaning (until 31.07.2014)
Eufémia Soares Ferreira	General caretaker, cleaning (until 02.12.2014)

Civilian Service Conscripts

Hans Kessler	02.06.2014 – 29.08.2014
Patrik Langer	06.01.2014 – 28.02.2014
Simon Pfister	01.09.2014 – 31.01.2015
Fabian Tischhauser	06.01.2014 – 28.02.2014
Remo Waser	29.09.2014 – 26.01.2015

Meeting Organisation

eHEROES	2nd Annual Meeting of the FP7 eHEROES consortium, 10 – 12 March 2014
PAGES FUPOSOL II	2nd Workshop Solar Forcing Working Group at Davos Workshop of the PAGES Solar Working Group Constraining Solar Forcing by Detection and Attribution for the Holocene, 20 – 23 May 2014
Mid-Year Assembly	Swiss Space Industries Group Meeting, 4 July 2014
EMRP SOLAR UV	Solar UV Intercomparison, 7 – 16 July 2014
8th UVNET	8th UVNET Workshop on Ultraviolet Radiation Measurements, EMRP ENV03, 5 – 16 July 2014 at Davos
EMRP ATMOZ	ATMOZ Kick-Off Meeting, EMRP ENV59, 23 – 24 October 2014

Public Seminars

06.03.2014 Dr. Gérard Thuillier, LATMOS, France, " Recent results using the SOLSPEC and SOLACES spectrometers onboard the International Space Station”.

04.06.2014 Dr. William Ball, Imperial College, London, "Our current understanding of solar irradiance and its effect on stratospheric ozone".

20.08.2014 Prof. Stuart Jefferies, University of Hawaii, USA, "A picture is worth a thousand words".

19.09.2014 Dr. Thomas Kentischer, Kiepenheuer Institute, Freiburg, Germany, "The visible tunable filter for DKIST".

01.10.2014 Dr. Pavle Arsenovic, ETH, Zürich, Switzerland, "Solar influence on the future climate".

04.11.2014 Dr. Henri Diémoz, ARPA, Italy, "Activities at ARPA Aosta".

Lecture Courses, Participation in Commissions

Werner Schmutz	Lecture course in Astronomy, HS 2014, ETH-ZH Examination expert in Astronomy, BSc ETH-ZH President of the International Radiation Commission (IRS, IAMAS) Member of the Comité Consultatif de Photométrie et Radiométrie (CCPR, OICM) Swiss delegate to the Science Programme Committee, ESA Member of the Space Weather Working Team Steering Board of ESA Swiss representative in the Committee on Space Research (COSPAR) Member of the Federal Commission for Space Affairs (CFAS) Swiss Management Committee delegate to the COST action ES01005 (ECF) President of the National Committee on Space Research, commission of SCNAT Member of the Commission for Astronomy, SCNAT Member of the GAW-CH Working Group (MeteoSwiss)
Wolfgang Finsterle	Member of CIMO ET Intercomparisons Member of CIMO TT Radiation References Member of EURAMET TC-PR Chairman of ISO/TC180 SC1 (Solar Energy, Climate - Measurement and Data)
Julian Gröbner	Lecture course in Solar Ultraviolet Radiation WS 2014, ETH-ZH GAW-CH Working Group (Meteoswiss) Chair of the NEWRAD Scientific committee Chairman of Infrared working Group of Baseline Surface Radiation Network (BSRN) Member IAMAS International Radiation Commission Member of the CIMO Task Group on Radiation – Vice Chairman Swiss delegate to the Management Group of COST ES1207 A EUropean BREWer NETwork - EUBREWNET and Working Group Leader of WG1 "Instrument characterisation and calibration" Member of the EURAMET Task Group on Environment
Margit Haberreiter	Elected President of the EGU Division on Solar-Terrestrial Sciences (starting April 2015) Member of the SPICE Science Steering Committee Co-Investigator of EUI and SPICE onboard Solar Orbiter Swiss Substitute Delegate of the Management Committee of the COST Action ES1005 TOSCA, Leader of WP1.1 Swiss Substitute Member of the Inter-programme Coordination Team on Space Weather (ICTSW), WMO Member of the Inter-Division IAU Working Group "Impact of Magnetic Activity on Solar and Stellar Environment" Member of the Inter-Division A-G WG "Nominal Units for Stellar & Planetary Astronomy" Co-Convenor EGU2014 Sessions ST 1.4: Solar irrad. variability: Meas., Models, Proxies, and Causes, and CL5.12: Solar Influence on the Middle Atmos. and Dynamical Coupling to the Tropos. and Ocean Co-Convenor of the ESWW11 Session Key observables for assessing long-term changes of the Geospace 2nd TOSCA Training School (jointly with SOLID) held at International Center for Theoretical Physics (ICTP), Trieste, Italy, 13-17.10.2014, Title: Solar and Space Forcing, 14.10.2014 Haberreiter, M., Experience of a Coordinator, H2020 - Space Applicant Training, EURESEARCH, Bern, Switzerland, 25.2.2015
Eugene Rozanov	International Commission on the Middle Atmosphere (ICMA, IAMAS) Swiss Management Committee delegate to the COST action ES01005 (ECF)
Christoph Wehrli	GAW-CH Working Group (Meteo Swiss) Scientific Advisory Group Aerosol (WMO/GAW)

Modernisation and Renovation: Mechanical Workshop

Werner Schmutz and Christian Thomann

The renovation of the mechanical workshop was finally finished in 2014, a year later than planned as a result of constraints on the financial budget in 2013.

Despite the tight budget in 2014, it was nevertheless possible to give the workshop a "light" renovation and to construct three extra rooms (see Figures 1 and 2): The ESD room, a room for the spray-bench, and another for the circuit-board milling machine which included a store-room.

Other renovation items included the following: 1) The existing lighting in the workshop was replaced with modern LED lights which use 1/3 less energy, 2) the workshop walls were newly painted, and 3) the double-doors to the car-park were replaced.

Other small jobs in the main building were finally completed in 2014. For instance, all lighting in the corridors had to be replaced due to several electrical problems. LED lights replaced the old filament bulbs which had the positive side-effect of reducing the electrical consumption by 80%. Lastly, new roof-avalanche backstops dachlawine were installed on the PMOD/WRC roof.

Initial operation during 2014 has shown that the above-mentioned laboratories and rooms can now be operated under very stable environmental conditions.

Figure 1. View of the new stairs in the renovated workshop.

Figure 2. View of the renovated workshop with offices and gallery in the background.

Bilanz 2014 (inklusive Drittmittel) mit Vorjahresvergleich

Aktiven	31.12.2014 CHF	31.12.2013 CHF
Flüssige Mittel	1'508'609.56	1'086'503.14
Forderungen	66'278.95	170'680.24
Aktive Rechnungsabgrenzungen	900.00	651'012.56
Total Aktiven	1'575'788.51	1'908'195.94
Passiven		
Verbindlichkeiten	190'046.00	264'049.85
Kontokorrent Stiftung	115'958.35	40'441.25
Passive Rechnungsabgrenzung	282'428.44	445'748.84
Rückstellungen	945'320.19	1'113'394.74
Eigenkapital	42'035.53	44'561.26
Total Passiven	1'575'788.51	1'908'195.94

Erfolgsrechnung 2014 (inklusive Drittmittel) mit Vorjahresvergleich

Ertrag	CHF	CHF
Beitrag Bund Betrieb WRC	1'366'936.00	1'366'896.00
Beitrag Bund (BBL), Umbau PMOD/WRC	300'000.00	656'000.00
Beitrag Kanton Graubünden	452'088.00	452'088.00
Beitrag Gemeinde Davos	589'555.00	589'555.00
Beitrag Gemeinde Davos, Mieterlass	160'000.00	160'000.00
Overhead SNF	111'412.61	114'742.55
Instrumentenverkäufe	126'075.00	110'924.90
Reparaturen und Kalibrationen	184'567.50	183'344.62
Ertrag Dienstleistungen	14'075.00	0.00
Übriger Ertrag	279'374.49	26'816.85
Finanzertrag	685.36	21'512.10
Kursdifferenzen	550.21	0.00
Kongressertrag	0.00	573'870.80
Ausserordentlicher Ertrag	1'775.35	10'149.30
Auflösung Rückstellungen	0.00	100'000.00
Drittmittel	2'055'227.20	2'080'388.22
Total Ertrag	5'642'321.72	6'446'288.34
Aufwand		
Personalaufwand	4'178'914.75	3'914'619.84
Investitionen Observatorium	165'838.35	131'432.26
Investitionen Drittmittel	125'466.74	453'112.25
Unterhalt	41'280.89	55'672.10
Verbrauchsmaterial	246'544.78	118'775.59
Verbrauch Commercial	56'363.12	123'849.16
Reisen, Kurse	198'248.26	187'335.29
Kongressaufwand ohne Personalaufwand	0.00	521'082.08
Raumaufwand/Energieaufwand	206'885.57	214'853.90
Versicherungen, Verwaltungsaufwand	141'712.18	127'156.17
Finanzaufwand	2'057.23	5'883.01
Übriger Betriebsaufwand	54'456.05	34'092.76
BBL, Umbau PMOD/WRC	300'000.00	656'000.00
Ausserordentlicher Aufwand	2'575.08	7'817.03
Nicht gedeckter Aufwand EU-Projekte	80'198.00	67'866.00
Total Aufwand	5'800'541.00	6'619'547.44
Jahresergebnis vor Auflösung Rückstellungen	–158'219.28	–173'259.10
Auflösung Rückstellungen zur Defizitdeckung	155'693.55	0.00
Jahresergebnis	–2'525.73	–173'259.10
	5'642'321.72	6'446'288.34

Abbreviations

ACTRIS	Aerosols, Clouds, and Trace gases Research InfraStructure Network
AERONET	Aerosol Robotic Network, GSFC, USA
AOCCM	Atmosphere-Ocean-Chemistry-Climate Model
AOD	Aerosol Optical Depth
BIPM	Bureau International des Poids et Mesures, Paris, France
BSRN	Baseline Surface Radiation Network of the WCRP
CCM	Chemistry-Climate Model
CCPR	Comité Consultatif de Photométrie et Radiométrie, BIPM
CIE	Commission Internationale de l'Eclairage
CIPM	Comité International des Poids et Mesures
CIMO	Commission for Instruments and Methods of Observation of WMO, Geneva, Switzerland
CLARA	Compact Light-weight Absolute Radiometer
CMC	Calibration and Measurement Capabilities
CNES	Centre National d'Etudes Spatiales, Paris, France
CNRS	Centre National de la Recherche Scientifique, Service d'Aéronomie Paris, France
COCOSIS	Combination of COSI Spectra
COSI	Code for Solar Irradiance, solar atmosphere radiation transport code developed at PMOD/WRC
COSIR	Code for Solar Irradiance Reconstruction
COSPAR	Commission of Space Application and Research of ICSU, Paris, France
COST	European Cooperation in Science and Technology
CSAR	Cyrogenic Solar Absolute Radiometer
CTM	Chemical Transport Model
DARA	Digital Absolute Radiometer
DLR	Deutsche Luft und Raumfahrt, Germany
EIT	Extreme Ultraviolet Imaging Telescope onboard SOHO
EMRP	European Metrology Research Programme
ESA	European Space Agency
ESF	European Science Foundation
ETH	Eidgenössische Technische Hochschule (Z: Zürich, L: Lausanne)
EUI	Extrem Ultraviolet Imager, Experiment on Solar Orbiter, to be launched 2017
EUV	Extreme Ultraviolet
FP7	European Framework Programme of the European Commission
FTS	Fourier Transform Spectrometer
FUPSOL	Future and Past Solar Influence on the Climate
GAW	Global Atmosphere Watch, an Observational Programme of WMO
GAWTEX	GAW Training and Education Centre
GCM	General Circulation Model
GHG	Greenhouse Gases
GSFC	Goddard Space Flight Center, Greenbelt, MD, USA
HRI	High Resolution Imagers
IACETH	Institute for Climate Research of the ETHZ., Switzerland
IAMAS	International Association of Meteorology and Atmospheric Sciences of IUGG
IAU	International Astronomical Union of ICSU, Paris, France
ICSU	International Council of Scientific Unions, Paris, France
IPC	International Pyrheliometer Comparisons
IR	Infrared
IRC	International Radiation Commission, Commission of IAMAS
IRIS	Infrared Integrating Sphere Radiometer
IRS	International Radiation Symposium of the Radiation Commission of IAMAS
IRRCAM	Infrared Cloud Camera
ISO/IEC	International Oranisation for Standardisation/International Electrotechnical Commission
ISS	International Space Station
IUGG	International Union of Geodesy and Geophysics of ISCU
LASP	Laboratory for Atmospheric and Space Physics, Boulder, USA
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales, French research institution
LVPS	Low Voltage Power Supply
LYRA	Lyman-alpha Radiometer, Experiment on PROBA 2, built by PMOD/WRC
METAS	Federal Office of Metrology
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MITRA	Monitor to Determine the Integrated Transmittance
MPS	Max Planck Institute for Solar System Research
MRA	Mutual Recognition Arrangement
MRR	Manufacturing Readiness Review
NASA	National Aeronautics and Space Administration, Washington DC, USA
NEWRAD	New Developments and Applications in Optical Radiometry
NILU	Norwegian Institute for Air Research, Norway
NIST	National Institute of Standards and Technology, Gaithersburg, MD, USA
NOAA	National Oceanographic and Atmospheric Administration, Washington DC, USA
NORSAT-I	Norwegian Satellite-I
NPL	National Physical Laboratory, Teddingtion, UK
NRI	Near Infrared

NRL	Naval Research Laboratory, Washington DC, USA
NREL	National Renewable Energy Lab, Golden, CO, USA
PFR	Precision Filter Radiometer
PI	Principle Investigator, Leader of an Experiment/Instrument/Project
PICARD	French Space Experiment to Measure the Solar Diameter, launched 2010
PMOD	Physikalisch-Meteorologisches Observatorium Davos, Switzerland
PMO6	PMO6 Type Radiometer
PREMOS	Precision Monitoring of Solar Variability, PMOD/WRC Experiment on PICARD
PROBA 2	ESA Technology Demonstration Space Mission, launched 2 December 2009
PRODEX	Programme for the Development of Experiments, ESA
PSR	Precision Spectro Radiometer
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig and Berlin, Germany
QASUME	Quality Assurance of Spectral Ultraviolet Measurements in Europe
QMS	Quality Management System
RA	Regional Association of WMO
SATIRE-S	Spectral and Total Irradiance Reconstructions for the Satellite era
SCNAT	Swiss Academy of Sciences
SLF	Schnee und Lawinenforschungsinstitut, Davos, Switzerland
SFI	Schweiz. Forschungsinstitut für Hochgebirgsklima und Medizin, Davos, Switzerland
SI	International System of Units
SIM	Spectral Irradiance Monitor
SIAF	Schweiz. Institut für Allergie- und Asthma-Forschung, Davos, Switzerland
SNSF	Swiss National Science Foundation, Switzerland
SOCOL	Combined GCM and CTM Computer Model, developed at PMOD/WRC
SOHO	Solar and Heliospheric Observatory, Space Mission of ESA/NASA
SOLAR	Experiment Platform on the ISS
SOLID	Solar Irradiance Data Exploitation
SOLMOD	Solar Modelling code
SORCE	Solar Radiation and Climate Experiment, NASA Space Mission
SOTERIA	Solar–Terrestrial Investigations and Archives
SOVAC	Solar Variability and Climate Change
SOVIM	Solar Variability and Irradiance Monitoring, PMOD/WRC Experiment on the International Space Station Alpha, 2008
SPICE	Spectral Imaging of the Coronal Environment, Experiment on Solar Orbiter, to be launched 2017
SSI	Solar Spectral Irradiance
STM	Structural Model
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor on Board UARS
SZA	Solar Zenith Angle
TIM	Total Irradiance Monitor
TRF	TSI Radiometer Facility
TSI	Total Solar Irradiance
UARS	Upper Atmosphere Research Satellite, NASA
UV	Ultraviolet
UVA	UV Radiation in the 315–400 nm range
UVB	UV Radiation in the 280–315 nm range
VIRGO	Variability of Solar Irradiance and Gravity Oscillations, PMOD/WRC Experiment on SOHO, launched December 1995
WCRP	World Climate Research Program
WDCA	World Data Centre for Aerosols
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
WISG	World Infrared Standard Group of Pyrgeometer, maintained by WRC-IRS
WMO	World Meteorological Organisation, a United Nations Specialised Agency, Geneva, Switzerland
WRC	World Radiation Centre, Davos, Switzerland
WRC-IRS	Infrared Radiometry Section of the WRC
WRC-SRS	Solar Radiometry Section of the WRC
WRC-WORCC	World Optical Depth Research and Calibration Centre of the WRC
WRC-WCC-UV	World Calibration Centre for Ultraviolet of the WRC
WRR	World Radiometric Reference
WSG	World Standard Group, realising the WRR, maintained by WRC

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PMOD/WRC, Davos, Switzerland

Dorfstrasse 33, 7260 Davos Dorf, Switzerland
Phone +41 81 417 51 11, Fax +41 81 417 51 00
www.pmodwrc.ch