pmod wrc

Annual Report
Jahresbericht 2011

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 2007 wird auch das Europäische UV Kalibrierzentrum durch das Weltstrahlungszentrum betrieben. Das Weltstrahlungszentrum besteht heute aus vier Sektionen:

- Solare Radiometrie
- Infrarot Radiometrie
- Atmosphärische Trübungsmessungen (WORCC)
- Europäisches UV Kalibrierzentrum

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.

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Werner Schmutz

Dienstleistungsbetrieb Weltstrahlungszentrum

Der Trend zu mehr Kalibrierungen hat sich auch 2011 fortgesetzt und wiederum ist ein neuer Rekord von Aufträgen bearbeitet worden. Dies ist auf eine zunehmende Beachtung der WMO-Anleitung zurückzuführen, die für meteorologische Strahlungsmessungen eine Rückführbarkeit auf das SI System fordert. Dies bedeutet schlussendlich eine Rückführbarkeit auf die Referenz am Weltstrahlungszentrum. Dazu kommt, dass immer mehr Firmen auf eine ISO Zertifizierung ihrer Strahlungsmessungen Wert legen, was ebenfalls die Rückführbarkeit auf die Davoser Weltstrahlungsreferenz verlangt. Diese Entwicklung ist einerseits sehr erfreulich, da dadurch die Notwendigkeit eines Strahlungszentrums klar demonstriert wird, aber anderseits fordert die gesteigerte Nachfrage auch immer mehr Ressourcen. Die Anforderungen an die Infrastruktur sind durch die Renovation des Institutsgebäudes für die kommenden Jahre abgedeckt. Der Mehrbedarf an Arbeitskraft wird bei gleichbleibender Tendenz allerdings bald Massnahmen erfordern um weiterhin die Qualität des Dienstleistungsbetriebs zu garantieren.

Bei den Verhandlungen über die Finanzierung des Weltstrahlungszentrums für die Periode 2012 bis 2015 hatten sich schon im Vorjahr alle Parteien auf eine Weiterführung des Zentrums geeinigt, aber es galt noch eine weitere Anforderung zu berücksichtigen: In einem offiziellen Schreiben hatte die Meteorologische Weltorganisation die Schweiz angefragt, ob das bisherige am Observatorium betriebene Europäische Kalibrierzentrum für Ultraviolette Strahlung auf ein Weltzentrum erweitert werden könnte um den weltweiten Kalibrierbedarf von meteorlogischen UV Instrumenten abzudecken. Offensichtlich beansprucht eine Erweiterung der Aufgaben mehr finanzielle Mittel, die im derzeitigen Betrieb des Weltstrahlungszentrums nicht vorhanden sind. Glücklicherweise war der Kanton Graubünden bereit seinen Beitrag ans Weltstrahlungszentrum zu erhöhen um die erweiterte Aufgabe zu ermöglichen. Allerdings wurde die Finanzierung nur um den minimal benötigten Betrag erhöht, was die oben angesprochene zunehmend knapper werdende Personalressourcen nicht entspannt. Trotzdem ist der Ausbau sehr vorteilhaft, da nun das PMOD/WRC vier Weltkalibrierzentren betreiben kann, die alle wesentlichsten Aspekte der meteorologischen Strahlungsmessungen abdecken und dem Observatorium Davos einen international sehr kompetenten und prominenten Auftritt ermöglicht.

Bedingung für die Anerkennung einer sogenannten Kalibrier- und Messfertigkeit eines Labors durch das Internationale Komitee für Masse und Gewichte ist, dass die entsprechende Dienstleistung durch ein Qualitätsmanagementsystem überwacht wird. Zusätzlich zur Solaren-Sektion wurde das QMS am PMOD/WRC letztes Jahr auch auf die Ultraviolett-Sektion ausgedehnt. Dies erlaubte einen Antrag beim Internationalen Komitee zur Anerkennung der UV Messgrössen zu stellen. Langfristig sollen am PMOD/WRC sämtliche Dienstleistungen durch das QMS überwacht werden und alle Messgrössen beim Internationalen Büro für Masse und Gewichte in Paris registriert werden.

Figure 1. Markus Suter bedient Pyrheliometer Instrumente des PMOD/WRC während den National Pyrheliometer Comparisions 2011 in Golden, Colorado, USA.

Entwicklung und Bau von Experimenten

Das kryogene Radiometer CSAR (Cryogenic Solar Absolute Radiometer), eine Zusammenarbeit mit den Metrologie-Instituten National Physics Laboratory in England und dem METAS in Bern, soll in Zukunft die Weltstandardgruppe durch eine genauere, auf das SI System rückführbare, absolute Messung der solaren Bestrahlungsstärke ersetzen. Der Erfolg der Messung hängt von einer entsprechend genauen Bestimmung der Transparenz des Fensters vor dem kryogenen Radiometer ab, das im Vakuumtank eingesetzt wird. Das dafür speziell entwickelte Instrument MITRA überwacht während der Messung laufend diese Transparenzeigenschaften. Im Labor hat MITRA die geforderte 0.01 % Unsicherheit demonstrieren können. Vor der Sonne bringt jedoch ein noch nicht identifizierter Einfluss zusätzliches Messrauschen, das die Genauigkeit deutlich beeinträchtigt. CSAR misst aber dennoch genauer als die Weltstrahlungsreferenz und zeigt auf, dass diese um 0.3 % zu hoch liegt.

Die Doktorarbeit von André Fehlmann am PMOD/WRC hat mit Hilfe von Instrumenten-Charakterisierungen und Instrumenten-Vergleichen am Kalibrierlabor in Boulder Colorado USA die Strahlungsreferenz in Davos mit dem SI System verglichen. Frühere SI-Vergleiche konnten nur die Leistungsmessungen der Radiometer untersuchen. Mit den neuen Experimenten konnte direkt die Bestrahlungsgrösse vergleichen werden. Das Resultat bestätigt den mit CSAR gefundene Abweichung der Strahlungsreferenz, die durch die Weltstandardgruppe in Davos realisiert wird. Die Messungen in Boulder ergeben eine Abweichung von 0.34 %. Die Genauigkeit der Weltstrahlungsreferenz ist mit 0.3 % angegeben. Damit hat der neue Vergleich die Richtigkeit der Strahlungsreferenz innerhalb ihrer Unsicherheit bestätigt. Erstmals konnte aber so mit den verbesserten Messmöglichkeiten eine systematische Abweichung der Referenz zum SI-System bestimmt werden.

Zur Charakterisierung von Strahlungsmessinstrumenten werden im Labor Laser eingesetzt. Diese Lichtquellen sind monochromatisch und deren handelsübliche Leistungen sind ungenügend um das Lichtstrahlenprofil auf solche Durchmesser aufweiten zu können, dass man Bestrahlung von Testgeräten vor Sonne simulieren könnte. Untersuchungen mit Laserlicht sind daher nicht identisch mit den Bedingungen durch die Sonne. Daher wird am Observatorium zurzeit eine Apparatur aufgebaut, die es erlauben wird, mit Heliostaten Sonnenlicht mit einem weitem Strahldurchmesser ins Labor zu spiegeln. Die grossen Spiegel und die stabilen Montierungen sind sehr kostspielig und die Finanzierung nur dank Drittmittel möglich. Wir konnten erfolgreich eine R'Equip Förderung des Schweizerischen Nationalfonds einwerben und mit einem gleich grossen Beitrag einer Stiftung kombinieren. Beide Spiegel sind bestellt und nach Abschluss des Institutsumbaus kann diese neue Forschungseinrichtung realisiert werden.

Weltraumprojekte

Letztes Jahr berichteten wir, dass unser Weltraumprojekt PREMOS auf dem französischen Satelliten PICARD eine solare Bestrahlungsstärke von 1361 W/m² bestimmte, im Gegensatz zu anderen Experimenten wie VIRGO auf SOHO, das rund 4 W/m² höher misst. PREMOS enthält das erste im Vakuum auf SI rückführbare Radiometer und daher ist dieser Wert die zurzeit genaueste Bestimmung der Solarkonstanten. Es ist jedoch so, dass auch VIRGO durch einen Vergleich zur Weltstrahlungsreferenz auf SI rückführbar ist. Die Lösung des Widerspruchs kommt durch den oben beschriebenen neuesten Vergleich der Weltstrahlungsreferenz mit dem SI System, der zeigt, dass die Weltstandardgruppe die Strahlungsreferenz um 0.3 % zu hoch realisiert. Es ist sehr befriedigend, dass nun verschiedene Messungen konsistent den gleichen Wert für die Solarkonstante ergeben.

PREMOS läuft reibungslos und überwacht stetig die solare Bestrahlung ausserhalb der Erdatmosphäre. Leider war es bisher nicht möglich eine nächste Mission zu finden, die nach PREMOS/PICARD die Überwachung der Sonnenstrahlung weiterführen könnte. Dafür geeignete Missionen werden durch die internationale Gemeinschaft der Sonnenforscher zwar diskutiert, aber bisher wurde noch keine der Ideen zur Ausführung ausgewählt. Trotzdem hat Sonnenforschung am Observatorium Davos eine strahlende Zukunft, da das Institut an zwei Experimenten des Forschungssatelliten Solar Orbiter mit baut. Der Start dieses ausserordentlichen Sonnenforschungsprojekts der Europäischen Raumfahrtsagentur ist für das Jahr 2017 geplant.

Klimaforschung

Das wichtigste Projekt der Klimagruppe ist das Projekt FUPSOL (Future and Past Solar Influence on the Terrestrial Climate). Diese Zusammenarbeit mit vier weiteren Schweizer Instituten im Rahmen des SINERGIA Programms des Schweizerischen Nationalfonds ist nun bald in der Hälfte der Drei-Jahres Laufzeit. Erste vorläufige Resultate ergeben, dass eine geringere solare Einstrahlung im 17ten Jahrhundert eine um 0.2 bis 0.4 °C niedrige Temperatur der Nordhemisphäre gegenüber dem 18ten Jahrhundert erklären könnte. Im Weiteren dürften sich die extrem geringen Temperaturen im „Jahr ohne Sommer" 1816 durch eine Kombination der geringeren Sonneneinstrahlung und dem Ausbruch des Vulkans Tambora im Jahr 1815 erklären lassen.

Die vielen weiteren Projekte der Klimagruppe sind mehrheitlich entweder direkt oder indirekt mit dem FUPSOL Projekt verknüpft. So wird das Chemie-Klima Computerprogramm SOCOL gezielt für FUPSOL Anwendungen weiter entwickelt. Ein weiteres Resultat ist eine erste Abschätzung wie sich eine extrem tiefe Sonneneinstrahlung in der Mitte des 21ten Jahrhunderts auswirken würde. Wenn die Sonne uns sehr günstig gesinnt wäre, d.h. sie hätte in Zukunft eine sehr geringe Aktivität, dann könnte dieser natürliche Einfluss die Klimaerwärmung um bis zu 1 °C abschwächen. Dies ist höchst wahrscheinlich die optimistischste Abschätzung und immer noch ungenügend um den menschlichen Einfluss auf unser Klima vollständig kompensieren zu können.

Der Beitrag des PMOD/WRC zum FP7 Projekt SOTERIA war die Berechnung der chemischen Zusammensetzung der Mittleren Atmosphäre in Fast-Echtzeit. Die Webseite war nun bald ein Jahr in operationellem Betrieb und hat gezeigt, dass eine in der Regel automatische Verarbeitung von Daten und Modellrechnungen für ein „Now-cast" mit vertretbarem Aufwand machbar ist.

Untersuchungen zur atmosphärischen Trübung stehen im direkten Bezug zur Dienstleistung als Weltstrahlungs-zentrum. Der Versuch einen Trend in der Trübung der letzten 15 Jahre zu identifizieren, ergab kein signifikantes Resultat. Untersucht man aber die letzten 100 Jahre, dann scheint es eine Periode mit globaler Trübung und anschliessender Erholung zu geben.

Personelles

Sechs Mitarbeiter kamen im Jahr 2011 neu an das PMOD/WRC und vier verliessen das Institut. Das PMOD/WRC beschäftigte per 31.12.2011 35 Mitarbeiterinnen und Mitarbeiter.

Am 1. Januar 2011 hat Manfred Gyo seine Stelle als neuer Leiter der Technik-Abteilung übernommen. Manfred ist ein gut ausgebildeter Elektronik-Ingenieur mit vielen Jahren Erfahrung als IT-Fachmann und im Projektmanagement. Wir sind froh, ihn in unserem Team zu haben und die technischen Herausforderungen mit ihm zu meistern.

Die technische Abteilung wurde am 1. August mit Fabian Dürig verstärkt, der durch seine Ausbildung als Maschineningenieur viel wertvolles Wissen mitbringt.

Zur gleichen Zeit hat Eliane Tobler ihre Ausbildung als KV-Lernende in der Administration begonnen.

Weitere zwei Wochen später, am 15. August 2011 konnten wir mit Luca Egli einen weiteren Wissenschafter anstellen. Luca ist im Rahmen unseres EMRP-Projektes „Traceability for surface spectral solar ultraviolet radiation" tätig.

Ab September verstärkte Rinat Tagirov das Team der Doktoranden und Gaël Cessateur wurde als Postdoc in unsere Solar Physics Group aufgenommen.

Auch im Jahr 2011 haben uns einige Mitarbeiter verlassen: Andreas Schätti, Mechaniker, hat seine temporäre Anstellung beendet und beginnt ein Studium und Nadia Casanova hat ihre KV-Ausbildung erfolgreich abgeschlossen.

Zudem haben zwei Doktoranden ihre Doktorarbeit abgeschlossen und ihre Doktorprüfung erfolgreich bestanden. Micha Schöll und André Fehlmann. Herzliche Gratulation.

Stephanie Ebert hat berufsbegleitend eine Weiterbildung als Desktop-Publisher besucht und konnte im Oktober 2011 die Ausbildung mit einem sehr guten Abschluss beenden. Sonja Degli Esposti bildete sich an der HTW Chur zum Master of Advanced Studies FHO in Business Administration aus. Ich gratuliere beiden herzlich zu diesem Erfolg!

Wie in den vergangenen Jahren haben uns auch im Jahr 2011 zahlreiche Zivildienstleistende unterstützt.

Infrastruktur

Der Umbau des Alten Schulhauses erreichte ab Frühjahr die Hauptphase und das gesamte Institut musste in Provisorien umziehen, wobei sich die Aufteilung des Institutes in zwei Standorte empfindlich auswirkte. Anfangs Jahr zügelte die Belegschaft der Technikabteilung mit all ihren Gerätschaften und Einrichtungen in ein Container-Provisorium auf der Südseite des Parkplatzes. Nach Ostern verliess der Rest der Belegschaft das Observatorium und das ganze Gebäude wurde geleert. Nur ein Optiklabor und die Schwarzkörper Kalibriereinrichtung im Keller wurden während des Umbaus in Betrieb gehalten. Um die fast zwei Drittel des Betriebs unterzubringen mietete das Bundesamt für Bauten und Logistik Büros im Holland Hauses, dem ehemaligen Klinikgebäude der Niederländischen Asthmaklinik in Davos.

Dank

Die Distanz von 1.5 km zwischen den beiden Standorten Holland House und Container beim Alten Schulhaus beeinträchtigte die direkte Interaktion zwischen den Teams spürbar. Insbesondere war das Arbeiten in den neun Containern schwierig und das Raumklima schwankte von tolerierbar bis zu grenzwertig. Arbeitsplätze und Labors waren im Container-Provisorium sehr beengt und machten ein effizientes Arbeiten schwierig. Ich danke allen Mitarbeitern, dass sie das Beste trotz widriger Umstände gaben, und so ermöglichten dass Dienstleistung und Forschung ohne Qualitätseinbussen weiter geführt werden konnten.

Der Umbau des Alten Schulhauses ist sehr kostspielig und wir sind dem Bund zu grossem Dank verpflichtet, dass er diese Investition in die Zukunft des Weltstrahlungszentrums macht. Im Verlauf der Verhandlungen zwischen den Parteien für die Erneuerung der Finanzierung in 2012-2015 erfolgte die Anerkennung durch den Kanton Graubünden für diese grosszügige Unterstützung eines Bündner Betriebs: Der Kanton ist bereit, ab Beginn der neuen Finanzierungsperiode seinen Beitrag zum Betrieb des Weltstrahlungszentrums zu erhöhen und so den Betrieb einer neuen Sektion zu ermöglichen. Ich danke dem Bund, dem Kanton und der Gemeinde Davos für ihre positive Haltung gegenüber dem Observatorium Davos und die Neuunterzeichnung der Vereinbarung zur Finanzierung.

Den Mitglieder des Ausschusses des Stiftungsrates und den Mitgliedern der Aufsichtskommission des Weltstrahlungszentrums verdanke ich herzlich ihre stete Unterstützung und Begleitung der Anliegen des PMOD/WRC. Ohne ihre Unterstützung im Hintergrund und manch direkte Hilfe bei den Verhandlungen wären die nach aussen sichtbaren Leistungen des Observatoriums nicht möglich.

Introduction

Werner Schmutz

Similar to previous years, the demand for calibration services offered by all WRC sections has again increased. This reflects the growing worldwide awareness that traceability of measurements to the SI system is currently an essential requirement. On the one hand this is a welcome development for the future of the PMOD/WRC because it clearly demonstrates that the center is needed. On the other hand, this requires us to have sufficient space on the instrument platforms and more manpower to handle the requests. The first condition is fulfilled by the new infrastructure we will have at our disposal after our move back to the renovated institute building. The demand on manpower is more difficult to handle as the increased funding of the World Radiation Center is being used to cover a new section and not to expand existing services.

Negotiations continued for renewal of the contract to fund the World Radiation Center from 2012 to 2015. A general agreement between all parties has already been reached but there an additional constraint had to be considered: In an official request to Switzerland the World Meteorological Organization enquired whether the present operational services of the European Ultraviolet Calibration Center could be extended to cover worldwide calibrations. Evidently, an enlargement of an operational service requires larger funding. We can report that the canton of Grisons stepped in to cover the necessary funds to make a World Ultraviolet Calibration Center possible. However, the funding covers only the minimal amount needed to operate the new section and does not help to offset the shortage in manpower noted above. Nevertheless, it is a great advantage that starting in 2012 with increased funding, the World Radiation Center in Davos now operates four sections It allows the PMOD/WRC to be a center of competence comprising all aspects of operational meteorological radiation monitoring.

A necessary condition for recognition of a calibration capability by the International Committee for Weights and Measures is that a calibration service is monitored by a quality management system. PMOD/WRC's system was extended last year to also cover services offered by the ultraviolet calibration section in addition to the solar radiometry section. The new measurement quantities have been submitted to the International Committee for Weights and Measures for approval. Efforts are ongoing to extend the quality management system to all sections of the WRC and to have all operational services offered by the World Radiation Center registered at the International Bureau of Weights and Measures.

The space experiment PREMOS on the satellite PICARD is functioning as planned and continuously monitors the solar irradiance with rare interruptions, which are mostly due to satellite operational reasons or dependent on the satellite's low Earth orbit that undergoes a season of Earth-shadow occultation. Unfortunately, it has not yet been possible to identify a future mission with which solar irradiance monitoring can be continued after PREMOS/PICARD. Potential missions are at present under discussion, however, none have so far been selected for implementation. Nevertheless, solar research at PMOD/WRC has a bright future because the institute is contributing hardware to the Extreme-Ultraviolet Imager (EUI) and Spectral Imaging of the Coronal Environment (SPICE) experiments of the Solar Orbiter mission which has been selected as ESA's next solar mission to be launched in 2017.

Characterization of instruments in the laboratory is based on lasers. These light sources are monochromatic and the power of our lasers is insufficient to allow an enlargement of the light beam diameters to simulate irradiance on a solar intensity level. Thus, laser illumination of an instrument is different to illumination by Sunlight. Therefore, the PMOD/WRC is installing a new research facility to project sunlight into our laboratory by means of large heliostat mirrors. The new equipment is expensive and therefore funding had to be obtained from external sources. Our application to the R'Equip funding body of the Swiss National Science Foundation was successful and has been equally matched by a contribution from a foundation. The mirrors have been ordered and the heliostat will be installed in the Fall, when renovation of the institute's building has been completed.

The Cryogenic Solar Absolute Radiometer (CSAR) collaborative project, run together with the National Physics Laboratory (England) and METAS (Bern) metrology institutes aims, to replace the World Standard Group by a more precise SI traceable realization of absolute measurements of solar irradiance. The success of measuring with unprecedented accuracy depends on determining the transmission of the vacuum-tank window. A dedicated instrument, MITRA, which was developed at PMOD/WRC, monitors this transmission. Laboratory characterization has demonstrated that in principle, MITRA is capable of measuring the transmission with an envisaged high accuracy of 0.01 %. Unfortunately, the measurements are affected by noise of yet unknown origin when the instrument is illuminated by the Sun. CSAR measurements are already successful by being more accurate than the World Radiometric Reference, but we have not yet reached the envisaged goal of a ten-fold reduction in the uncertainty.

The main phase of the institute's renovation had a large and noticeable impact on work-day life. At the beginning of last year the technical department staff moved, along with their equipment, to a provisional building on the south side of the parking lot. Working in the nine containers is without comfort and indoor temperatures ranged at times from border-line to tolerable, while the cramped workshop and laboratory space make conditions rather difficult for the technicians. After Easter the rest of the staff moved out, leaving the site completely empty. Only an optical laboratory and a room with the blackbody calibration facility in the basement were kept functional during the entire construction period. The Federal Office for Construction and Logistics rented offices on the first floor of the Holland House for the scientific and administrative department, which is the former clinic building of the Netherland's Asthma Center in Davos. The 1.5 km distance between both sites has obviously hampered day-to-day interaction between both teams, but as all were aware of the problem, operational services and research activities have been carried out without compromising the end-results.

Operational Services

Calibration Services and Quality Management System

Manfred Gyo, Wolfgang Finsterle, Julian Gröbner, and Christoph Wehrli

Quality Management System

Since 2006 the PMOD/WRC maintains an approved Quality Management System (QMS) based on the general requirements for the competence of testing and calibration laboratories (EN ISO/IEC 17025).

In addition to the WRC Solar Radiometry Section the European UV Calibration section was added in 2011. Both sections are now covered by the QMS and calibrate customer instruments in accordance with the EN/ISO standard.

PMOD/WRC is a designated institute of the Swiss National Metrology Institute, METAS, which is a signatory of the CIPM-MRA (Comité international des poids et mesures - Mutual Recognition Arrangement).

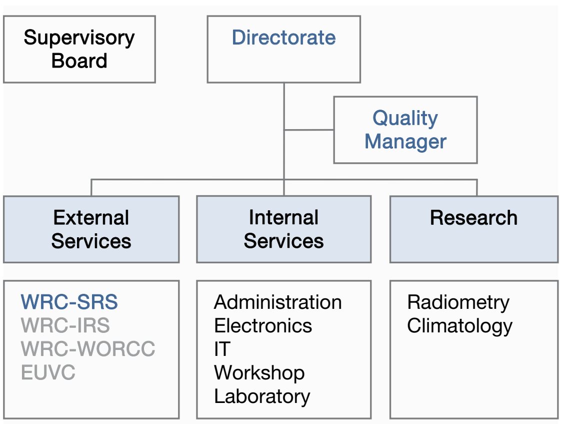

Figure 1. Organizational chart of the PMOD/WRC Quality Management System. The WRC Solar Radiometry Section and the EUVC section perform calibrations according to the EN ISO/IEC standard 17025.

Two calibration and measurement capabilities (CMC) are listed in the database of the „Bureau International des poids et mesures“ (BIPM): Responsivity, direct and global solar irradiation. One new CMC “Responsivity, global solar irradiance weighted (UV (280-400 nm), UVB (280-315 nm), UVA (315-400 nm), Erythema CIE)” was submitted to the inter-RMO review from the EUVC Section of the PMOD/WRC.

A considerable challenge in 2011 was the upholding of calibration services during renovation of the institute. The laboratories had to be moved to temporary buildings, after which a large effort ensured that the necessary environmental criteria for calibration were available. We were glad to handle this challenge and to calibrate 222 instruments in total.

Solar Radiometry Section (WRC-SRS)

A total of 144 calibrations were performed. The WRC section ‘Solar Radiometry’ calibrated 114 pyranometers, 7 pyrheliometers and 23 actinometers during 96 days of measurement.

Infrared Radiometry Section (WRC-IRS)

Due to construction work, all instruments located on the PMOD/WRC roof platform were removed early in the year and re-installed on the roof of the temporary container-village in front of the Observatory. Validation tests were performed on the data acquisition system after relocation to ascertain its operational integrity. The relocation did not affect the outdoor calibration process due to the close proximity between the WISG and the test pyrgeometers on the new measurement platform. The characteristics of the pyrgeometers in the laboratory were not affected.

The Infrared Radiometry section calibrated 22 pyrgeometers relative to the World Infrared Standard Group (WISG).

Two IRIS radiometers were calibrated and compared to the two IRIS radiometers operated at PMOD/WRC. The agreement between all four radiometers, to within ±1 Wm-2, was well within their stated uncertainties.

Atmospheric Turbidity Section (WRC-WORCC)

The World Optical depth Research and Calibration Center calibrated 20 Filter Radiometers against the WORCC Triad standard of which 19 were PFRs and one was an SP02 model. Six of these PFR belong to the GAW-PFR network.

European Ultraviolet Calibration Center (EUVC)

The Ultraviolet Calibration Center of the PMOD/WRC calibrated 19 spectroradiometers at their respective field sites using the traveling reference spectroradiometer, QASUME.

Twelve UV Broadband radiometers were calibrated at PMOD/WRC. Five Array Spectroradiometers with direct, global and radiance optics were calibrated relative to the spectral QASUME irradiance reference in the laboratory. The calibration range extended from the UV to the NIR wavelength region.

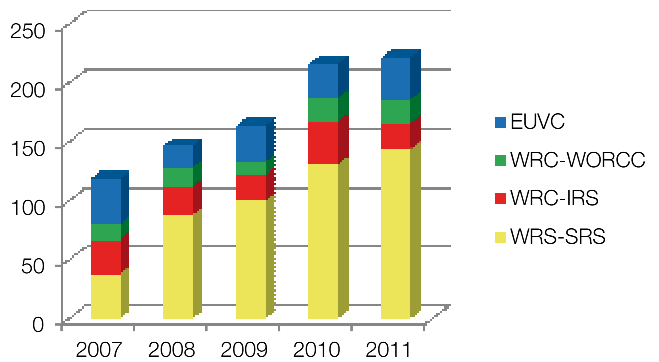

Figure 2. Statistics of instrument calibrations at PMOD/WRC 2007–2011.

Instrument Sales

Manfred Gyo and Julian Gröbner

In 2011, we finished the production of a series of absolute Radiometers (PMO6-cc) and Precision Filter Radiometers (PFR) in order to meet current and future orders. In addition, we have one new instrument within the portfolio: An Infrared Integrating Sphere Radiometer (IRIS) which was developed in 2010. As a result we were able to successfully sell a number of instruments. Five PFR (3 Korea 2 Germany), four PMO6-cc (1 Mexico, 1 Mongolia, 1 South Africa, 1 Columbia) and two IRIS (1 Germany, 1 Australia) were sold. A new series of PFR and PMO6-cc were manufactured. The stock of PFR dropped again so that we plan to produce a new series in 2012.

The development of a precision spectro-radiometer is ongoing but a prototype has been finished. It is planned to have the first instruments available in 2013.

Customer demand shows that high precision instruments built by PMOD/WRC are firmly established within the radiometer marketplace.

Figure 1. IRIS on the measurement platform at PMOD/WRC.

Infrared Integrating Sphere Radiometer (IRIS)

A new reference radiometer for downwelling atmospheric longwave irradiance has been constructed. The new infrared integrating sphere (IRIS) radiometer is designed to acquire measurements with a time constant of less than 1 s.

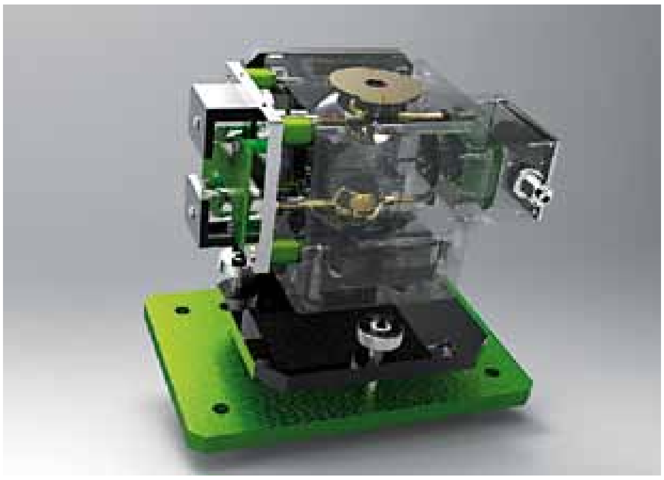

Figure 2. Transparent view of IRIS Sphere.

It consists of a 60 mm diameter gold-plated integrating sphere with three apertures of 8 mm diameter; the aperture facing upwards measures the irradiance from the upper hemisphere, while the aperture at the bottom receives radiation from a small reference blackbody cavity. Two gold-platted shutters rotating at 27 Hz alternatively open and close the upper and lower aperture. A windowless pyroelectric detector from with an organic black coating is placed behind the third aperture and measures the differential signal from the radiation penetrating through these apertures. The IRIS radiometer is able to measure longwave irradiance with an expanded uncertainty of ±2.4 Wm^{-2}.

Four IRIS radiometers have been constructed so far, of which two have been sold and are now being operated as transfer standard pyrgeometers with traceability to the reference cavity BB2007 of the Infrared Radiometry Section of PMOD/WRC.

Reference: Gröbner J.: 2012, A transfer standard radiometer for atmospheric longwave irradiance measurements, Metrologia 49, S105-S111, doi: 10.1088/-1394/49/2/S105.

Solar Radiometry Section (SRS/WRC)

Wolfgang Finsterle

The Solar Radiometry Section of the WRC (WRC-SRS) is responsible for maintaining and disseminating the World Radiometric Reference (WRR). The WRR is the primary reference for shortwave solar irradiance measurements world-wide. In 2011 the SRS/WRC participated with three transfer standards in the National Pyrheliometer Comparison (NPC 2011), organized by the National Renewable Energy Laboratory (NREL) in Golden, Colorado, USA. The main purpose of the NPC was to maintain the WRR-traceability of the US solar irradiance standards and networks. Such inter-laboratory comparisons of standards serve a key role in maintaining the WRR according to the ISO 17025 quality management system.

Due to the ongoing renovation and construction work at PMOD the World Standard Group (WSG) was relocated to the rooftop on the temporary laboratory and office containers in front of the PMOD building. The large solar tracking platform remained in its original place but was sealed to minimize dust contamination. At the temporary site a smaller solar tracker was used to operate the WSG and to calibrate pyrheliometers. The tracking accuracy and data cables were validated before the start of the calibration season. Thanks to the careful testing of the temporary installations and the great efforts by all SRS/WRC staff the 2011 calibration season passed without major problems.

Customer demand in our calibration services kept increasing throughout 2011, although at a slightly slower rate than in recent years. The new-built calibration platform provided the required space to eliminate the backlog which had built up in previous years whenever a large shipping of pyranometers had arrived.

From September 19th through 24th the National Pyrheliometer Comparison (NPC 2011) were held at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, U.S.A. The SRS/WRC participated in the NPC 2011 with a transfer standard consisting of three cavity pyrheliometers. Other notable participants include the national radiation centers of the United States as well as several manufacturers of commercial pyrheliometers. Unlike in previous years, Environment Canada could not participate in the NPC 2011 due to budget cuts by the Canadian government. Such inter-laboratory comparisons are mandated by the ISO 17025 quality management system for calibration and testing laboratories.

The SRS/WRC is conducting two research and development projects aiming at the improvement of the calibration and measurement capabilities in this section:

- The Cryogenic Solar Absolute Radiometer (CSAR) is intended to replace the WSG in the future.
- The heliostat light source will greatly improve the capabilities to characterize pyrheliometers, such as the PMO6 and its successor, which also is currently being developopped.

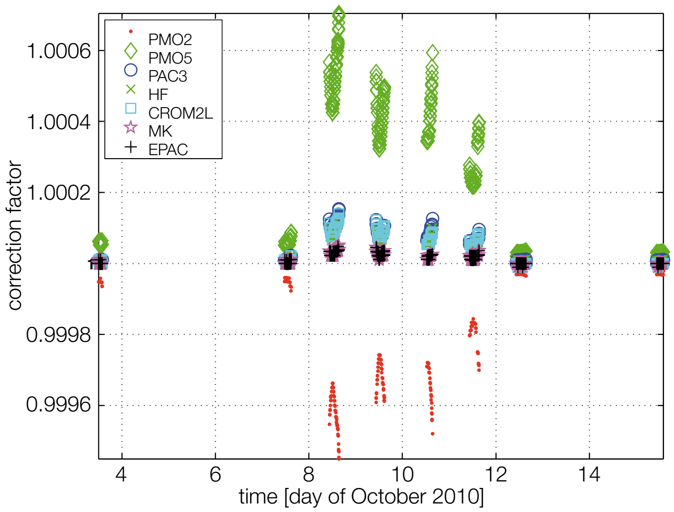

Figure 1. The correction factors for the WSG due to the Saharan Dust Event (SDE, starting October 8). Most of the six WSG instruments (PMO2, PMO5, PAC3, HF18748, CROM2L, and MK67814) were designed before the CIMO recommendations for the viewing geometry became a standard. The instruments "see" different portions of sky around the sun, resulting in relatively large correction factors.

Both projects are described in detail in separate sections of this report. Within the CSAR project the successful defense of his PhD thesis by André Fehlmann at University of Zurich deserves the mention. Noteworthy results form Dr. Fehlmanns thesis include the CSAR-to-WRR ratio of ~0.997 (with the WRR reading higher). This ratio offers a plausible explanation for the disagreement of the solar irradiance values as measured by the space experiments VIRGO and TIM, respectively. While the PMO6/VIRGO radiometers are traceable to the WRR, the TIM radiometer on the American SORCE satellite, which reads ~0.3 % lower than PMO6/VIRGO, can be linked to the cryogenic reference at NIST. This finding was subsequently confirmed by the PMO6/PREMOS space radiometers which are traceable to both WRR and NIST.

Furthermore the thesis presents an algorithm to correct ground-based TSI measurements for sky irradiance under varying conditions and depending on viewing geometry. The algorithm was successfully applied to compensate the effects of a Saharan Dust Event (SDE) which had occurred in the course of the 11th International Pyrheliometer Comparison in 2010 (IPC-XI). During the SDE the excess in relatively large dust particles (>1μm) significantly altered the atmospheric scattering, affecting the ratios between different pyrheliometers by up to 0.1 %, depending on their viewing geometry (Figure 1). Based on this finding the SRS/WRC has decided to evaluate the need to routinely measure the atmospheric scattering properties as part of all calibrations of pyrheliometers.

Infrared Radiometry Section (WRC-IRS)

Julian Gröbner and Stefan Wacker

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

Performance of the WISG

The WISG operated continuously during the whole of 2011, showing an excellent relative stability between individual instruments of ±1 Wm^{-2}. Nevertheless, the WISG radiometer CG4 010535 required an internal recalibration due the observed drift of about 0.14 $Wm^{-2}yr^{-1}$ over the last years. The first step in the recalibration process was to determine the pyrgeometer coefficients k1 and k2 using the reference blackbody BB2007. Subsequently, the sensitivity of CG4 010535 was determined from the remaining three WISG radiometers using the new coefficients where night-time data from the whole of 2011 was used. The resulting change in the average WISG irradiance is -0.18 Wm^{-2}, while the overall variability between the WISG radiometers decreased from 0.85 Wm^{-2}, when using the original calibration, to 0.62 Wm^{-2}, when using the newly recalibrated CG4 010535. The updated WISG reference has been implemented since 1st January 2012.

The Infrared Integrating Sphere Radiometer IRIS

In 2011, three new IRIS radiometers were built, of which IRIS#5 was sold to the Deutsche Wetterdienst, Lindenberg, Germany and IRIS#3 to the Bureau of Meteorology, Melbourne, Australia. Prior to delivery, each IRIS radiometer was calibrated in the PMOD/WRC BB2007 reference blackbody followed by an outdoor intercomparison with IRIS radiometers #2 and #4 which belong to PMOD. Several clear sky nights in April 2011 were used to assess the level of agreement between the IRIS radiometers. As can be seen in Figure 1, the downwelling longwave irradiance measurements from the four IRIS radiometers agreed to better than ±2 Wm^{-2}, which is largely within the estimated uncertainties of the IRIS radiometers [1]. The average difference with respect to the mean is 0.6 Wm^{-2}, -0.6 Wm^{-2}, –1.1 Wm^{-2}, and 0.7 Wm^{-2} for IRIS #2, #3, #4, and#5 respectively while the standard deviations (95 %) are below ±1 Wm^{-2}.

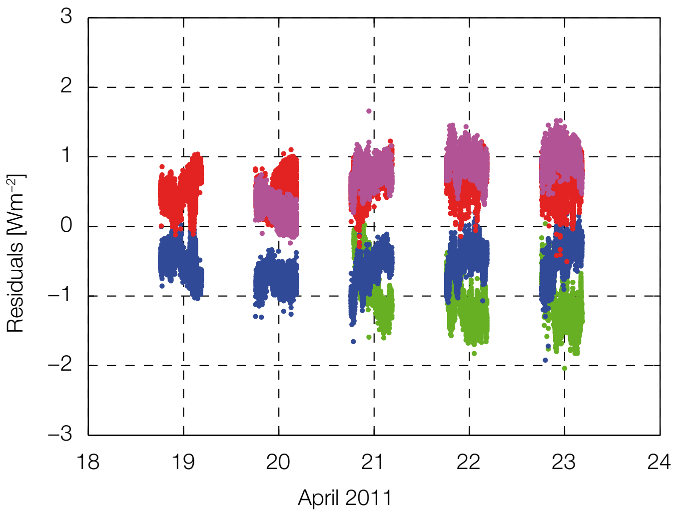

Figure 1. Longwave irradiance residuals relative to their average during an outdoor measurement period between 18 and 24 April 2011. The residuals of the IRIS #2 #3,#4, and #5 radiometers are shown as red, blue, green and violet dots respectively.

The IRIS Radiometers have been deployed on the measurement platforms since October 2009 during clear sky nights. In total, 106 measurement nights between 1 January 2010 and 31 December 2011 were analysed. Preliminary results from this inter-comparison show a seasonal dependence between the WISG and the IRIS radiometers, with higher irradiances in winter, while in the remaining seasons WISG usually measures less than the IRIS radiometers. Table 1 provides a brief summary of this inter-comparison:

WISG Pyrgeometer	Average difference and standard deviation between WISG and IRIS in Wm^{-2}
PIR 31463F3	-3.0±2.3
PIR 31464F3	-2.5±1.8
CG4 FT004	-3.3±2.2
CG4 010535	-1.7±2.2

Table 1. Longwave irradiance comparison between IRIS radiometers and WISG pyrgeometers between 1st January 2010 and 31 December 2011.

A comprehensive report describing the WISG and IRIS measurements is in preparation.

Reference: Gröbner J.: 2012, A transfer standard radiometer for atmospheric longwave irradiance measurements, Metrologia 49, S105-S111, doi: 10.1088/-1394/49/2/S105.

Atmospheric Turbidity Section (WRC-WORCC)

Christoph Wehrli and Stephan Nyeki

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

As in previous years, the GAW-PFR network has further expanded with new sites in Germany (Zingst and Zugspitze). In addition, the Korean Meteorological Agency installed two new PFR systems at Gosan and Ulleung-do islands that will join the network in 2012. A description of all GAW-PFR stations can be found at www.pmodwrc.ch/worcc. Graphs of annual and time-series aerosol optical depth are available, and are updated each month to allow the early detection of any trends.

In 2011, nine instruments of the extended GAW-PFR network were calibrated against the reference Triad at Davos, and four instruments were calibrated by the Langley method at their respective sites. All instruments proved to be stable within expected limits of uncertainty. The data logger system at Mace Head (Ireland) was replaced with a new system. The AERONET CIMEL radiometer at Davos was again re-calibrated by PHOTONS and Level 2 data updated to May 2010.

A last station audit and AOD inter-comparison campaign was conducted at the Puy de Dome “Super-Site” (France) under the EU EUSAAR programme. This concludes our involvement in EUSAAR, which will be documented in a forthcoming paper concerning all 10 sites in Europe.

In view of the excellent stability that the WORCC TRIAD demonstrated during the FRC-III in 2010, the TRIAD configuration was not modified. Its internal consistency was verified through pairwise cross-calibrations as described in our 2008 annual report. All members of the TRIAD are within 1 % of their peers, and their mean bias (MBD) has changed by less than 0.5 %.

	368	412	500	862
A <> B	0.9922	0.9943	0.9940	1.0062
A <> C	0.9952	1.0037	0.9975	1.0041
B <> C	1.0033	1.0097	1.0035	0.9979
MBD	-0.0031	0.0026	-0.0017	0.0028
U95	0.0046	0.0085	0.0015	0.0026

Table 1. Internal consistency of the PFR TRIAD expressed as results of cross-calibrations related to calibration in use. Column headers indicate wavelength in nm.

Figure 1. Temporary installation of the travelling standard PFR during an EUSAAR station audit at Puy de Dome (France).

Annual quality assured data from 10 stations of the GAW-PFR network (total of 31 station years) were updated to 2010 and submitted to WDCA. Daily AOD results from 24 stations are submitted in (quasi) Near-Real-Time. These data are available through http://ebas.nilu.no.

A third GAW-PFR Newsletter was distributed in May, and is available at http://www.pmodwrc.ch/worcc/GAW-PFR_Newsletter_Nr3.pdf.

European Ultraviolet Calibration Center (EUVC)

Julian Gröbner, Luca Egli, and Gregor Hülsen

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

Two major activities determined the work performed within the EUVC in 2011: Firstly, the implementation of the Quality System (QS) for the calibration of solar UV broadband radiometers following ISO 17025 was completed early in the year. The calibrations performed during the remainder of the year were used to improve and fill all missing documentation which surfaced during the routine calibration work. The final internal audit in December 2011 demonstrated the good overall implementation of the QS in the EUVC and was therefore officially included in the QS of the Institute.

Secondly, the kick-off meeting of the EMRP project ENV03 "Traceability of spectral solar ultraviolet radiation" with 11 partners from national metrology institutes, industry and university was held at Davos on 12 and 13 September 2011 with PMOD/WRC acting as coordinator of the project. The aim of the project is to significantly improve the quality of spectral solar UV irradiance measurements and to develop techniques and devices in order to use cost-effective array spectroradiometers in UV monitoring networks. Additional information and ongoing activities can be found at the project web-site: http://projects.pmodwrc.ch/env03/.

A visiting scientist from the Measurements Standards Laboratory (MSL) of New Zealand, Neil Swift, visited PMOD/WRC in order to participate in the yearly UV broadband filter radiometer calibration campaign scheduled in July and August. Neil Swift took responsibility for performing the laboratory calibrations and thereby also acted as an ideal candidate for testing our newly written QS procedures. Furthermore, a UV broadband filter radiometer previously characterized and calibrated at MSL was included in the calibration at PMOD/WRC and served as a transfer standard for a laboratory inter-comparison between the EUVC and MSL.

The QASUME transportable reference spectroradiometer was used for quality assurance site visits at the National Meteorological Agency of Spain, Madrid, in July and at the Agenzia Regionale per la Protezione del Ambiente (ARPA), Aosta, in August. In addition, the 6th calibration campaign in the frame of the RBCC-E was organised at El Arenosillo in southern Spain with the participation of QASUME as the UV reference for all 17 participating Brewer Spectrophotometers. Results of all the QASUME site audits can be found at the EUVC web-site, http://www.pmodwrc.ch/euvc/euvc.php?topic=qasume_audit.

As part of the restructuring work at the Institute, a second optical laboratory dedicated to EUVC activities was constructed in one of the PMOD cellars which used to house the oil tank. The laboratory equipment was moved to the new location in September and began operation after only a minimal "downtime".

Figure 1. Participants of the 6th RBCC-E ozone and UV campaign held in El Arenosillo, Instituto Nacional de Técnica Aeroespacial, Spain from 6 to 13 July 2011 with several Brewer spectrophotometers in the foreground.

Instrument Development

Spectroradiometer for Spectral Optical Depth

Julian Gröbner

The radiative forcing of atmospheric aerosols represents one of the largest uncertainties in the Earth radiative budget. Global networks of surface based sunphotometers such as the GAW-PFR network operated by PMOD/WRC measure the aerosol optical depth at several distinct wavelength channels between the ultraviolet and the infrared.

A new generation of solar spectrophotometers, the Precision Solar Spectroradiometer (PSR), is being developed at PMOD/WRC to eventually replace current filter based sunphotometers. It is based on a temperature stabilized grating spectroradiometer with a 1024 pixel Hamamatsu diode-array detector, operated in a hermetically sealed nitrogen-flushed enclosure. The spectroradiometer is designed to measure the solar spectrum in the 320 to 1040 nm wavelength range with a spectral resolution of about 2 nm full width at half maximum. The optical bench with the optical elements was optimized to reduce the temperature dependence of the solar measurements to less than 1 %K^{-1} over the whole wavelength range. The design benefits from the experience gained from successive generations of the successful Precision Filter Radiometer (PFR), including: an in-built solar pointing sensor, an ambient pressure sensor and temperature sensors to provide routine quality control information which will allow autonomous operation at remote sites with state-of-the-art data exchange via USB or Ethernet interfaces.

The Prototype PSR was exposed to solar radiation for the first time in November 2011. Measurements relative to the PFR triad were used to test its initial performance and stability issues. Based on these initial tests, instrument improvements were implemented and further measurements demonstrated the good performance of the instrument. Figure 2 shows measurements of the direct solar irradiance from the PSR and one reference PFR obtained on January 12, 2012. The figure shows 350 measurements obtained every minute between 8:30 and 15:00 GMT at the coincident wavelengths of the PFR, e.g. 368 nm, 412 nm, 500 nm, and 862 nm. As the PSR provides uncalibrated values proportional to the solar irradiance, the measurements of the PSR were normalised to the PFR signal of the respective channel at local noon to highlight the excellent agreement between both instruments. Indeed, standard deviation values on this day were 1.2 %, 0.6 %, 0.6 % and 0.8 % at 368 nm, 412 nm, 500 nm, and 862 nm respectively.

Figure 1. The prototype PSR being mounted on the solar Tracker on the measurement platform of PMOD/WRC.

Despite the very low diurnal variability between the PSR and the PFR on a single day, the stability of the PSR on successive days exhibited a larger variability of up to 5 %, which could be traced to unstable components in the optical design of the instrument. In addition, open issues such as an active temperature stabilisation and additional outdoor measurements are also required before the next generation instrument can be designed. The aim is to design and build a first-series instrument by spring 2013 in view of its commercialisation.

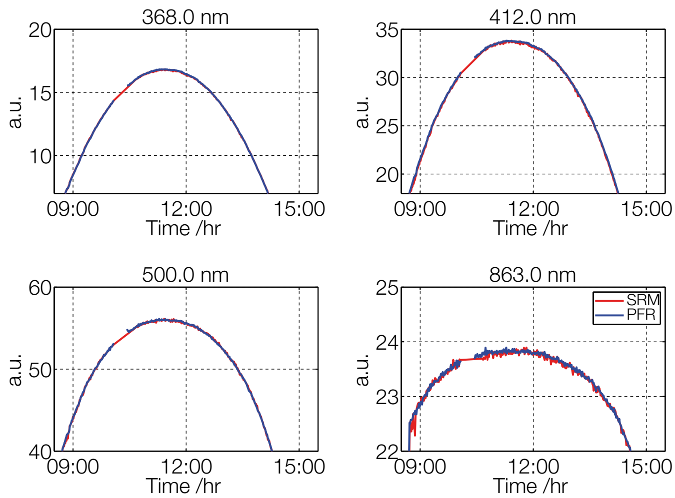

Figure 2. Direct Solar irradiance measurements at 368 nm, 412 nm, 500 nm, and 862 nm between the PSR and a reference PFR at PMOD/WRC on 12 January 2012. The measurements of the PSR were normalised to the PFR signal at local noon.

Heliostat

Markus Suter

As part of the renovation of the institute, the old heliostat system has been removed from the roof. The old system allowed sunlight to enter the clean room where it was mainly used to test instrument functionality. A new heliostat is planned that will have an improved light beam optical quality allowing the beam to be used for scientific laboratory experiments, while keeping the functionality of supplying the clean room with a light beam.

Scientific Motivation

Recent progress in the field of radiometry has illustrated the need for high quality light sources for the laboratory characterisation of absolute radiometers. At the Laboratory of Atmospheric and Space Physics (LASP), University of Colorado, a light source with a scanning laser beam has been built for this purpose (Kopp et al. 2007). While this light source is a very useful tool for the radiometry community, which has run several times alongside PMODs instruments, the exact solar beam geometry could be further optimized. For instance, stray light issues depend strongly on the geometry of the light beam and have been identified by Fehlmann (2011) as a strong source of uncertainty in the characterisation of PMO6 radiometers. The new heliostat will allow stray light effects in radiometers to be further investigated. Another advantage over LASPs facility will be that the heliostat beam is broad-band and not only one wavelength. Parameters such as the absorptivity of cavities can therefore be directly measured with broad-band radiation.

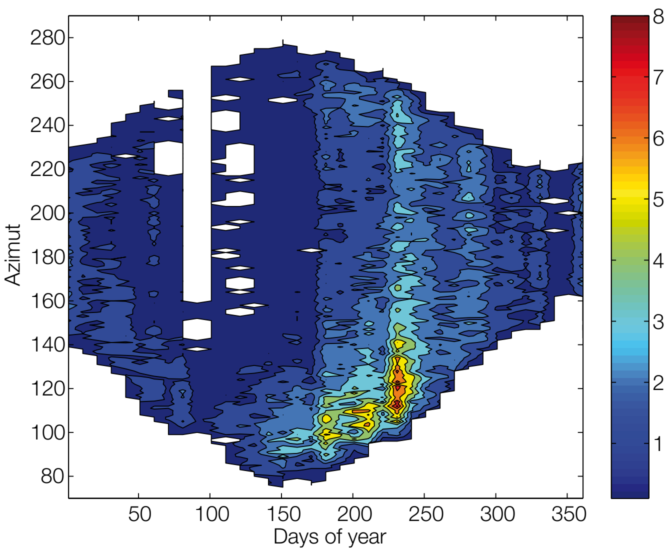

Figure 1. 2D-Histogram of valid pyrheliometer calibration data points. The data is binned by day-of-year and azimut. The scale represents the absolute number of data points per azimut and day oft the period 1990 to 2011.

The new heliostat facility will be very useful for the characterisation of the new DARA and CSAR radiometers.

Site Evaluation

The heliostat was previously located on the roof of the institute but this is no longer an option, as the new clean room as well as the laboratory are situated in the basement of the building. A site evaluation has therefore carried out to select the optimum heliostat location.

Figure 2. Illustration of the new heliostat system.

The newly selected location is directly in front of the laboratory window where the light beam will enter the building. The advantage of this arrangement is that the mirrors are close to the position of the experiments in the laboratory. This gives a relatively wide field-of-view as seen from the experiment position. The field-of-view is determined by the size of the mirrors divided by the distance from the experiment to the mirrors. The disadvantage of this setup is, that the primary (tracking-) mirror is in front of the south-east face of the building and therefore has a limited field-of-view, e.g. in the afternoon the mirror is shaded by the building.

To study the amount of possible operational time that is lost due to shading while having the mirror at the selected position, the dataset from the last 20 years of pyrheliometer calibrations was evaluated. The evaluation showed that only 15 % of possible operational time due to weather conditions would be lost. Figure 1 shows the valid calibration dataset of the last 20 years binned by day-of-year and azimuth. Angles with an azimuth greater than 214 degrees cannot be seen by the heliostat.

The short distance between location of the experiment and the primary mirror, combined with a loss of only 15 % of the operational time favoured the selected location over other possible locations.

Design Consideration

The Heliostat consists of two mirrors. The primary mirror is the tracking mirror that is movable in two axes (Figure 2). The mount is designed to avoid singularities in the mirror coordinates and to have almost continuous movement in both axes. In addition, this configuration allows the mirror to be guided with a simple active tracking system. A secondary mirror, in a fixed position, reflects the light from the primary into the laboratory.

The heliostat is designed so that the field-of-view, when looking out of the laboratory is slightly larger than the view angle of a laboratory mounted PMO6 radiometer. No additional baffles are necessary to prevent stray light from entering the cavity for such a configuration. To determine the field-of-view from the laboratory, a ray tracing model was used (Figure 3).

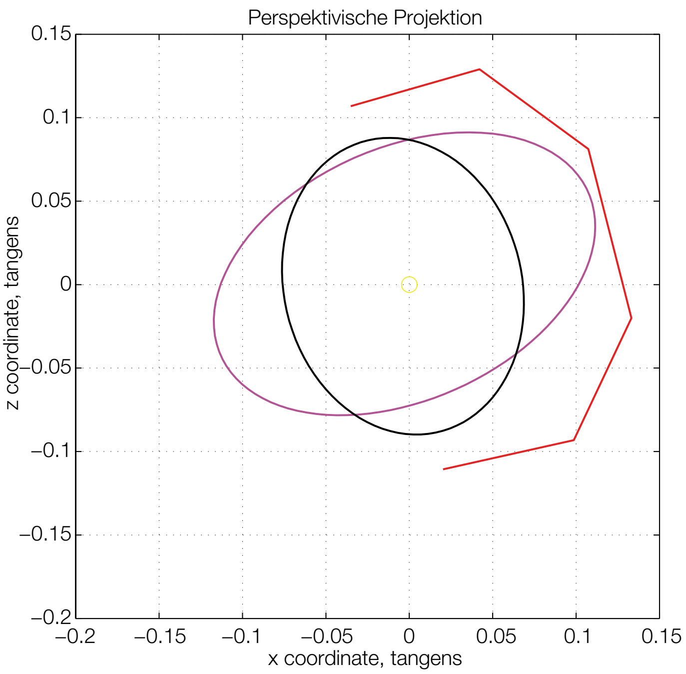

Figure 3. Field-of-view as seen from the laboratory. The black ellipse is the primary mirror and the pink ellipse is the secondary mirror. The yellow circle in the middle of the graph represents the sun with a diameter of half a degree.

Construction

The diameter of the heliostat mirrors are 650 mm, and the thickness is 100 mm. The mirrors are made of Zerodur, a ceramic glass, with no thermal expansion. The weight of a mirror is about 80 kg. The front surface mirrors will be coated with aluminium and a protective layer.

The flatness requirements are very high in order to guarantee a high quality beam profile. It is necessary to support the mirrors in a way that no unintended bending of the mirrors due to self-gravity occurs. While the secondary mirror will be polished to compensate for self-gravity deformation, the primary mirror will be supported in a way to avoid self-gravity deformation.

Construction work has already begun. The site has been concreted and cable conduits have been prepared. The design of the mechanical assembly is currently under way, and the mirrors have been ordered.

References: Fehlmann A., Metrology of Solar Radiometry, PhD-Thesis, Universität Zürich, 2011.

Kopp G., Heuermann K., Harber D., Drake G.: 2007, The TSI Radiometer Facility: absolute calibrations for total solar irradiance instruments. In: Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, volume 667.

MITRA and CSAR

André Fehlmann

Changing atmospheric conditions modify the integral transmittance of the entrance window to the Cryogenic Solar Absolute Radiometer (CSAR). The changes are larger than the intended uncertainty, making the monitoring of the transmittance mandatory. MITRA (The Monitor to measure the Integral TRAnsmittance of windows) is capable of solving this task with an uncertainty of 0.01 %. Yet, the fluctuations of the solar measurements are too large to correct CSAR measurements.

Measurements of the spectral transmittance of Quartz and Sapphire windows combined with synthetic solar spectra show that the integral transmittance of these windows changes with the solar elevation, the season and with variations in atmospheric composition. These changes are larger than the intended uncertainty of 0.01 % of CSAR measurements.

The MITRA instrument uses a passive operation principle where two detectors observe the sun in parallel. First, the detector signal ratio is determined with no window in place, which serves as the reference value. Second, the sunlight to one detector is obstructed by the window under investigation, to obtain a measurement detector ratio. The integral transmittance of the window is then calculated by dividing the measurement ratio by the reference value.

The novel thermal design of the instrument guarantees that both detectors respond equally to changes in the ambient temperature or the solar irradiance. To measure the signals we use fine copper wires wrapped around the detectors as resistance thermometers. The small measurement current of 100 µA is chosen so that self-heating effects become negligible. We purchased two new nano-voltmeters to simultaneously measure the detector signals.

Dark measurements in an environmental chamber have proven the stability of the thermal design and have allowed the integral transmittance to be determined. Although the ambient temperature varied by more than 20 Kelvin, the calculated integral transmittance remained stable within a combined uncertainty of 0.01 %. However, when a window, equivalent to that of CSAR was placed into the beam path of one detector, the measured ratio started to fluctuate.

To resolve this issue we optimized the resistance measurements by reducing the number of thermal contacts in the circuit, and replaced a damaged aperture which might have caused stray light.

The windows are currently at the National Physical Laboratory (NPL) in Teddington for further spectral characterization. These measurements are needed to guarantee the equivalence of the windows used in CSAR as well as in MITRA. As soon as they return to Davos we will be able to check whether or not our modifications were successful. If this is not the case then convection processes will be investigated which may affect the detectors differently when one is covered by a window.

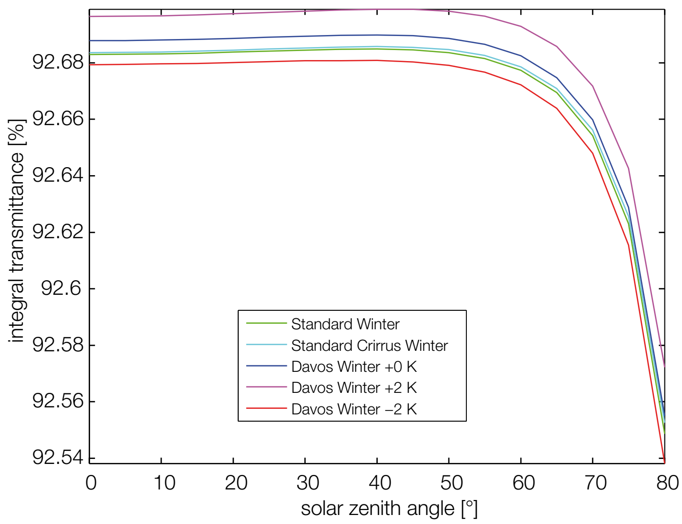

Figure 1. The calculated integral transmittance of a Quartz window for different atmospheric conditions in Winter. We use a climatological mean standard atmosphere with and without invisible cirrus clouds as well as balloon soundings over Davos where the temperature profile was altered by plus/minus 2 Kelvin.

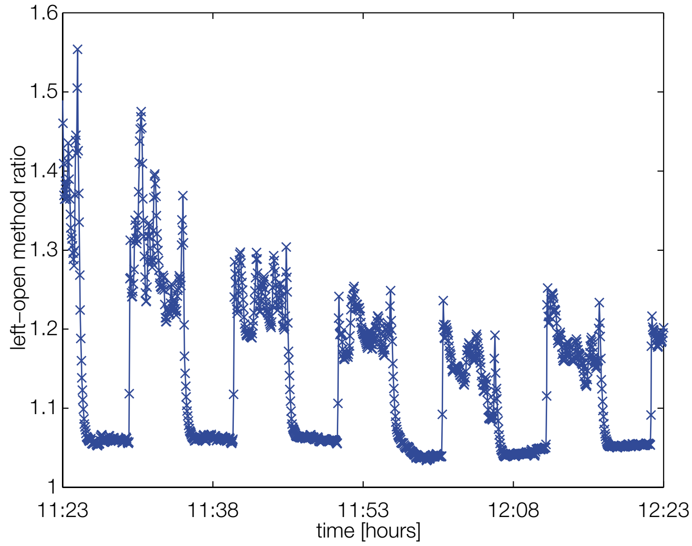

Figure 2. The measured ratio starts to fluctuate whenever a window is introduced into the beam path of one detector but remains stable otherwise.

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

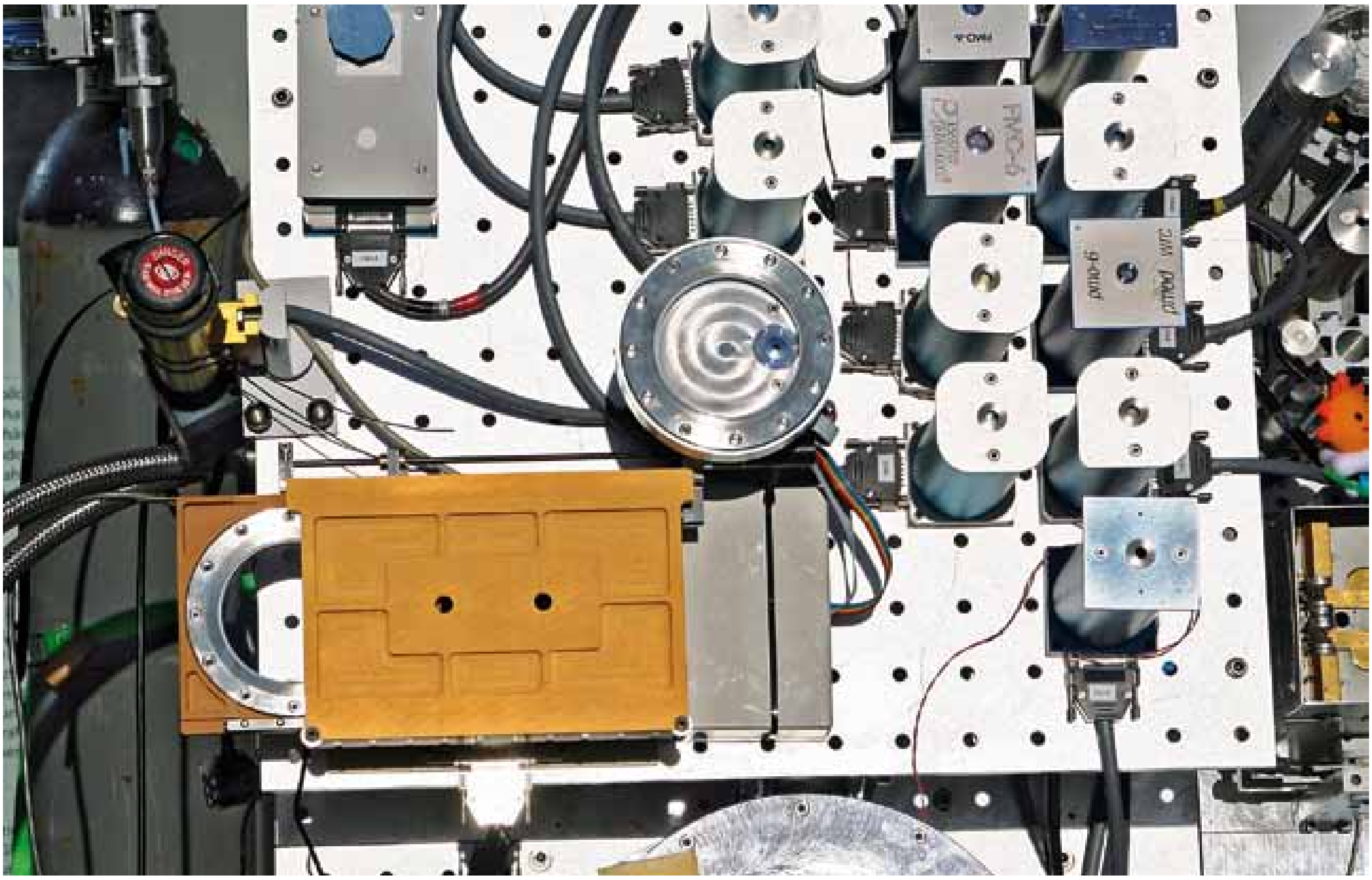

Figure 3. The Nickel-coated (brown) MITRA instrument is operated alongside CSAR on the tracking platform in Davos. A translation stage is used to move the window to the desired position.

Space Experiments

Manfred Gyo, Dany Pfiffner, Fabian Dürig, Wolfgang Finsterle, Markus Suter, and Ricco Soder

PREMOS

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

PREMOS is still operating reliably. Figure 1 illustrates the PREMOS on-board temperature evolution. Compared to last years graph it can be seen that the temperature increases slightly which is due to the optical degradation of the front sun-shield and the radiator.

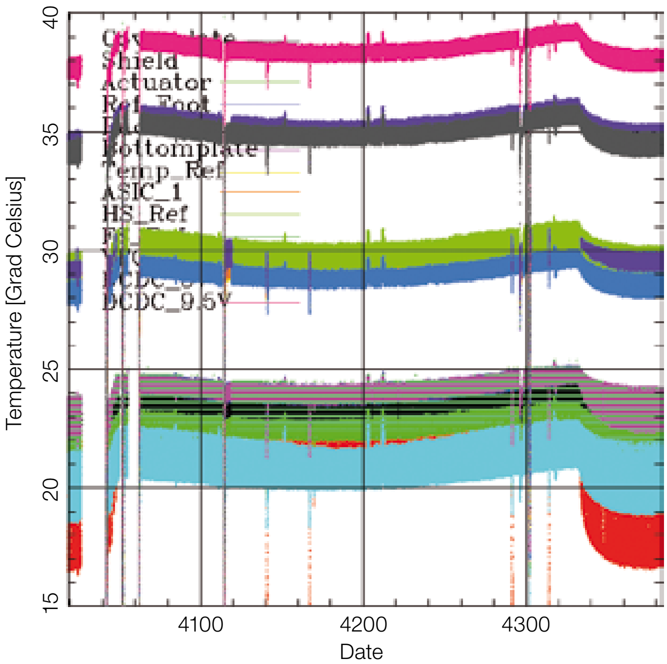

Figure 1. PREMOS Package Temperatures.

Despite a few minor events, described below, PREMOS is still reliably and accurately measuring the total and spectral solar irradiance.

Due to an incorrect filter in the current monitoring system, PREMOS was switched off in January 2011. The current demand of PREMOS is monitored in real-time by the PICARD main computer. If the current consumption is below a certain threshold for too long, PREMOS will be switched off automatically by the space craft computer. This occurred on the 2nd and 7th February 2011 just after leaving the regular earth eclipses, and is the same time of year when the sun-earth distance is at its shortest. As a result, the current demand of the internal heaters dropped to almost zero and triggered the automatic switch-off procedure. PREMOS was switched on again a few days later.

The first data gap in mid-January 2011 is due to a PICARD problem and is not related to PREMOS.

During the days thereafter, PREMOS measured successful through the following eclipses of the sun by the moon:

- 4 January
- 1 June
- 1 July
- 25 November

The figure below shows the solar eclipse on 1 June 2011 as measured by PREMOS with one of the UV-Channels hosted by Filter Radiometer B.

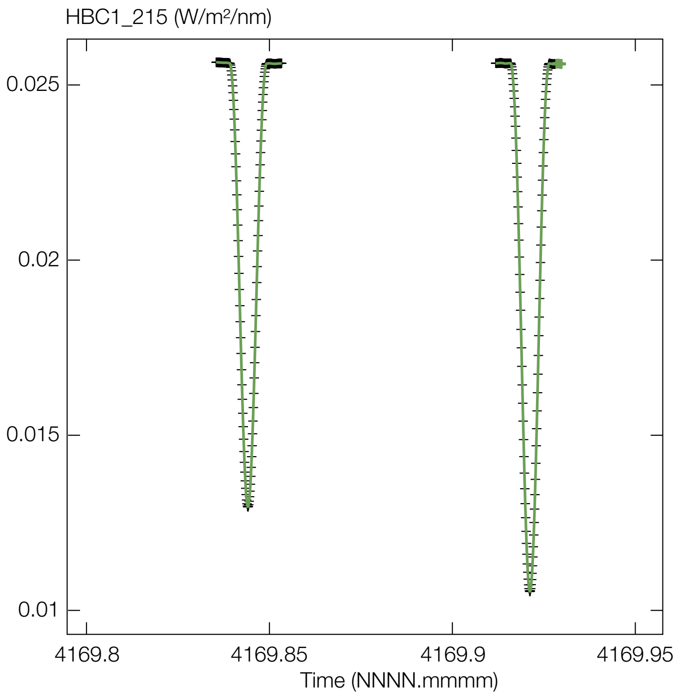

Figure 2. Solar eclipse by the moon from 1 June 2011 as measured by PREMOS.

Due to a few data evaluation improvements, a software update of the evaluation software, hosted by the PICARD data center, was required during 2011.

DARA/SuMo

The Digital Absolute Radiometer (DARA) is the prototype of PMOD's future solar absolute radiometer for ground and space. The DARA prototype currently undergoes extensive testing, characterization and calibration experiments. Subsequent to the NPC 2011 the DARA prototype was calibrated against the TSI Radiometer Facility (TRF) at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, U.S.A.

The Solar Radiometry Section took advantage of the proximity of the LASP/TRF to the site of the NPC 2011 at NREL for a combined-purpose trip to both institutions. After taking the WSG transfer standard to the NPC 2011 (see page 9) the DARA prototype was taken to LASP/TRF for extensive testing and calibration experiments.

The versatile beam geometry of the TRF offered the possibility to produce absorptance maps of the DARA cavities (Figure 1). These maps show enhanced reflections off the central part of the conical cavities where the black paint forms a concave meniscus. Rays of light which fall on the meniscus may be subject to only single-incident absorption an thus can produce higher reflective losses. This could explain the reduced over-all sensitivity of the DARA cavities compared to the TRF (Figure 2).

The tests in the vacuum chamber also revealed thermal problems on the DARA electronics boards. Some electronics components run too hot, thus contributing to higher uncertainties. Proper heat-sinking and/or the use of thermally stable voltage references will help to mitigate these effects.

Figure 3. The DARA package inside the vacuum tank at during the TRF comparison campaign.

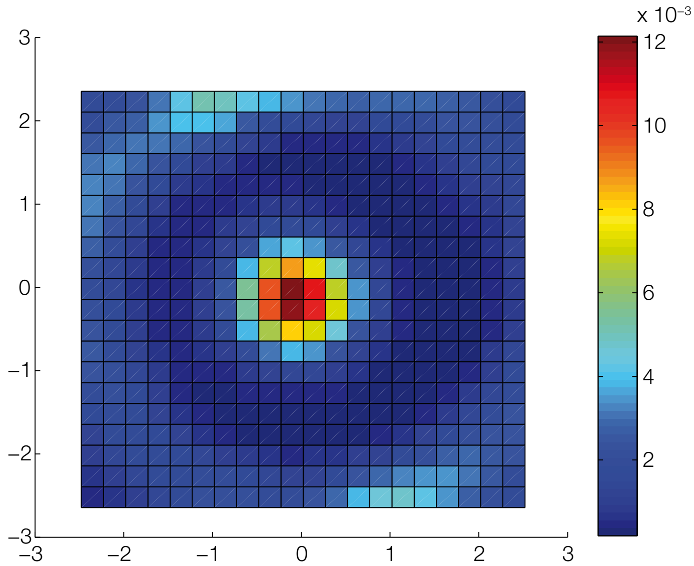

Figure 4. Absorptance map of the DARA cavity C. Yellow/red areas have a lower absorptivity than blue/green areas.

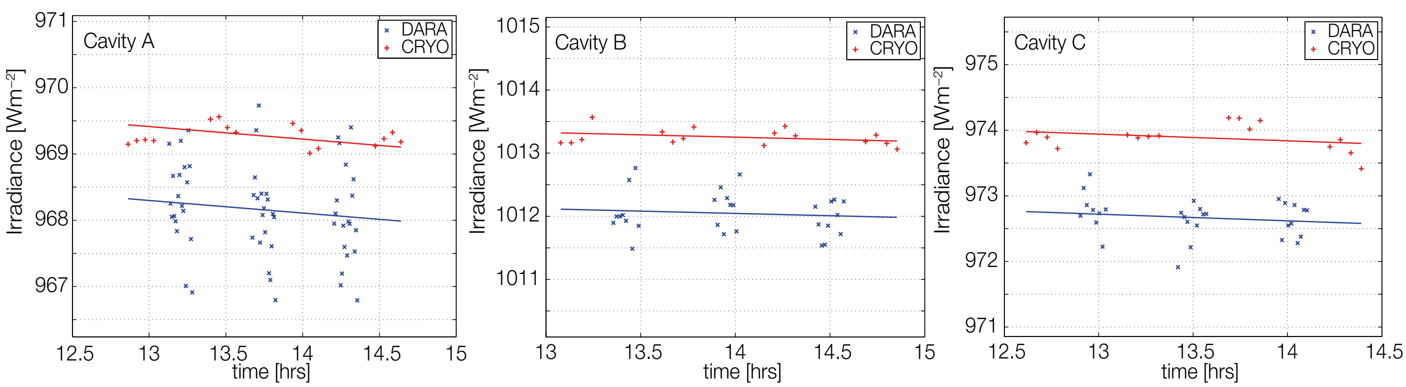

Figure 5. Calibration of the three DARA cavities at LASP, using a 7.3 mm spiral pattern of the beam. All three DARA cavities read some 0.11 % lower than the cryogenic radiometer. The likely cause are reflections off the tip of the conical DARA cavities. More work needs to be done to carefully characterize (and potentially improve) the absorptance of the DARA cavities.

EUI

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

Extrem Ultraviolet Imager (EUI) is a payload on the ESA/NASA M-class mission Solar Orbiter. The hardware, electronics and software will be developed and manufactured by the EUI Consortium consisting of Centre Spatiale de Liège – Belgium (CSL), Royal Observatory of Belgium (ROB), Institut d'Astrophysique Spatiale – France (IAS), Institut d'Optique –France (IO), UCL Mullard Space Science Laboratory – UK (MSSL), Max Planck Institute for Solar System Research – Germany (MPS) and Physikalisch-Meteorologisches Institut Davos und World Radiation Center (PMOD/WRC). The instrument consortium lead is held by the Centre Spatiale de Liège (CSL) in Belgium.

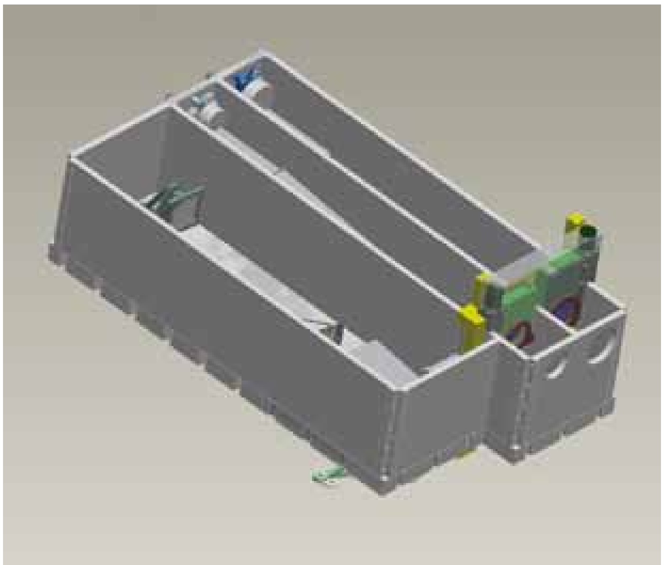

Figure 6. CAD Model of EUI Structure.

The EUI is a suite of imaging telescopes composed of one Full Sun Imager (FSI) alternatively operating at the two 174 Å and 304 Å passbands and two High Resolution Imagers (HRI), one observing the hydrogen Lyman-α line (1216 Å) and the other the extreme ultra-violet (EUV) band 174 Å. PMOD/WRC together with Swiss industry is responsible for the optical bench structure of the instrument. This structure will be designed with an aluminium honeycomb bound by a sandwich of carbon fibre sheets.

The preliminary design was devised during 2011, and was optimized to meet the requirements through a synergy of simulation and construction.

SPICE

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

Solar Orbiter is one of the M-class missions of the ESA's Cosmic Vision program to be launched in early 2017.

PMOD/WRC will provide two mechanisms and the low voltage power supply (LVPS) for SPICE.

Low Voltage Power Supply

The design of the LVPS began in 2011. The schematics and a few simulations of the electrical circuits have been completed. We are still waiting for the mechanical design specifications from our SPICE partners before we can proceed with the print layout and assembly of the prototype.

Slit Change Mechanism

One of the two mechanisms is the so-called slit change mechanism. The SPICE instrument consists of a single element off-axis parabolic telescope and a toroidal variable line-spaced (TVLS) grating spectrograph with two intensified active pixel sensor (IAPS) detectors. The off-axis parabola mirror forms an image of the Sun onto the entrance slit assembly containing four interchangeable slits of different widths. The slit selects a portion of the solar image and passes it to a concave TVLS grating which re-images the spectrally dispersed radiation onto two array detectors. The slits are fabricated on a single crystal Silicon wafer using precision lithography techniques developed for electronic chips.

PMOD will tender the development and manufacture of this slit change mechanism to Swiss industry. The start of phase B has been re-scheduled to early 2012 but some minor activities, e.g. specification documents, have already been completed in 2011.

Contamination Door

The other mechanism is the so-called contamination control door. The development of this mechanism will also be tendered to Swiss industry but PMOD will manufacture the mechanical components. The official start of phase B has been re-scheduled to early 2012. Specification documents have already been written.

Scientific Research Activities

Overview

Werner Schmutz

Projects at PMOD/WRC are all related to solar radiation. We address questions in relation to 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. The research activities can be grouped into three themes:

- Climate modeling;
- Terrestrial radiation balance;
- Solar physics.

Research is financed through third party funding. Last year, we were supported by the Swiss National Science Foundation (7 projects), MeteoSwiss (1 project), and the seventh European Framework Program FP7 (1 project). Hardware development of space experiments is paid by the ESA PRODEX program (3 projects). These funding sources have supported 6 PhD Theses, of which two were completed last year, and 5 postdoctoral positions. The institute's PRODEX projects paid for the equivalent of three technical department positions.

The absolute radiometers of the PREMOS experiment on board the PICARD satellite measure a solar constant of 1361 W/m². This is in disagreement with previous experiments, e.g. such as VIRGO on SOHO, which give an approximately 4 W/m² higher value. PREMOS is the only SI traceable absolute radiometer in space and therefore its measurement is presently the best available value of the solar irradiance. However, VIRGO on SOHO is also traceable to the SI system via a calibration relative to the World Radiometric Reference. There is an additional air-to-vacuum correction needed, which however, cannot be the reason for the large discrepancy. The fact that a comparison of the World Radiometric Reference to the SI system yields an offset of 0.34 % to the WRR scale has been an important result obtained during André Fehlmann's PhD Thesis. In view of this bias the measurements from VIRGO, if an adjustment is made, would agree with those from PREMOS to within the limits of uncertainty.

Progress in increasing the accuracy of ground-based absolute measurements of solar irradiance with the Cryogenic Solar Absolute Radiometer (CSAR) have also allowed the absolute scale of the World Radiometric Reference to be assessed. This project is a collaboration with two metrology institutions, the National Physics Laboratory, England and METAS, Bern. First results from CSAR are 0.3 % lower than the WRR and thus also point towards a bias of the WRR calibration. The quoted uncertainty of the WRR is 0.3 % and it is therefore no surprise that a bias of the reference is becoming apparent in the light of increasingly accurate measurements. It is very satisfactory that different methods now yield a consistent set of cross-calibrations.

The most important project for the PMOD/WRC climate group is the FUPSOL collaboration (Future and Past Solar Influence on the Terrestrial Climate). A preliminary result is that lower solar irradiance might explain a 0.2–0.4 °C lower northern hemisphere temperature in the 17th century compared to the second half of the 18th century. In addition, the extremely low temperatures during "the year without summer" in 1816 may be a combination of the global influence of the Tambora volcanic eruption in 1815 combined with lower solar irradiance which already occurred before the eruption.

The many projects of the climate group are mostly directly or indirectly related to the FUPSOL project, in the sense that e.g. modules for the SOCOL chemistry-climate code are being developed, or chemical processes are under investigation. One important side result of FUPSOL is an estimate of the potential influence of a hypothetical extreme decrease in the solar irradiance by the mid 21st century. If the Sun were indeed to behave so "favorably", there would then be a natural forcing to provide a weakening of global warming by up to 1 °C. This is most probably the upper limit of a potential contribution to natural cooling, and even in the most optimistic scenario it would not be sufficient to completely offset anthropogenic warming.

The institute's contribution to the FP7 SOTERIA project, which ended in 2011, was a "nowcasting" model of the chemical composition of the middle atmosphere. The website has now been running in a fully operational mode for more than half a year, and testifies that "nowcasting" is feasible. Research that is more related to the operational services at the World Radiation Center investigates the time-series of Aerosol Optical Depth operational measurements for trends in their long-term evolution. While accurate measurements during the last 15 years do not yield a significant trend there seem to be periods of global dimming and brightening when the last 100 years are investigated.

Parts of the solar group research projects are related to FUPSOL by investigation of past variations in solar irradiance, which in turn is important as a natural forcing in climate-change scenarios. Other solar projects use filter radiometer observations from our LYRA/PROBA2 and PREMOS/PICARD space experiments. In particular, the investigations of Sun eclipses by the moon allow accurate measurement of the center-to-limb variation of the solar radiance. A comparison of the center-to-limb predictions by our COSI solar atmosphere model allows the reliability of the solar irradiance as modeled with COSI to be assessed. A new activity is devoted to modeling solar irradiance variations in the extreme ultraviolet (EUV) spectrum, which determines the physical condition of the Earth's upper atmosphere. The solar EUV flux emerges from the solar corona and chromosphere, which is a focus of the future EUI and SPICE experiments on the Solar Orbiter mission, for which the institute is providing hardware. In the future, solar corona and chromosphere research will become more important for the PMOD/WRC as this will provide a spring-board for future research possibilities when unique new observations become available after the launch of Solar Orbiter in 2017.

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

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

FUPSOL is a Swiss collaboration project lead by PMOD/WRC involving partners from the Institute for Atmosphere and Climate Sciences of the ETH Zürich (IAC ETH), the Swiss Federal Institute of Aquatic Science and Technology, Dübendorf (EAWAG), the Physics Institute (KUP) and Institute of Geography (GIUB) of the University of Bern and the Oeschger Centre for Climate Change Research. The project started in 2010 and aims to quantify solar forcing and its influence on the Earth's atmosphere and climate.

The main efforts during the first phase of the project were aimed at the development of the natural and anthropogenic forcing scenario covering the period 1600–2000, preparation of the atmosphere-ocean-chemistry-climate model, and execution of the planned experiments. In particular, the first "low noise" solar activity record, covering the past 9400 years by combining two available ^{10}Be ice core records with the global ^{14}C tree ring record, has been produced by the EAWAG team. They also derived a time-series (1600–2000) of energetic electron precipitation (EEP) and solar proton events (SPE) by making use of their relationship with the geomagnetic indices, the interplanetary magnetic field and nitrate concentration in ice cores. The time-series of total and spectral irradiance for the period 1600–2000 have been reconstructed by PMOD/WRC (Shapiro et al., 2011). The teams of IACETH and GIUB have prepared the 400-year long time-series of stratospheric volcanic aerosol properties. The new atmosphere-ocean-chemistry-climate model has been developed in collaboration between the teams of IACETH, KUP and PMOD/WRC on the basis of the Earth System model COSMOS and chemistry-climate model SOCOL v 3.0. The model has been extended to include the effects of energetic particles and to better represent the heating rate response to variability in spectral solar irradiance.

After the 100-year long spin-up, the atmosphere-ocean-chemistry-climate model was applied to perform the control run with all forcings kept constant for the year 1600 and two 350-year long 2-member ensemble runs driven by two different specifications of the solar spectral irradiance. The analysis of the temperature time-series obtained from the control run revealed that there is a drift in the model behaviour, which is most probably caused by an inconsistency of the initialization fields and the used radiative forcing. For a first analysis we have subtracted this drift from the model simulations. Figure 1 illustrates the evolution of the simulated annual mean surface temperature anomalies averaged over the Northern hemisphere after the elimination of this drift overlaid to the estimated temperature range obtained from different temperature reconstructions (Jansen et al., 2007).

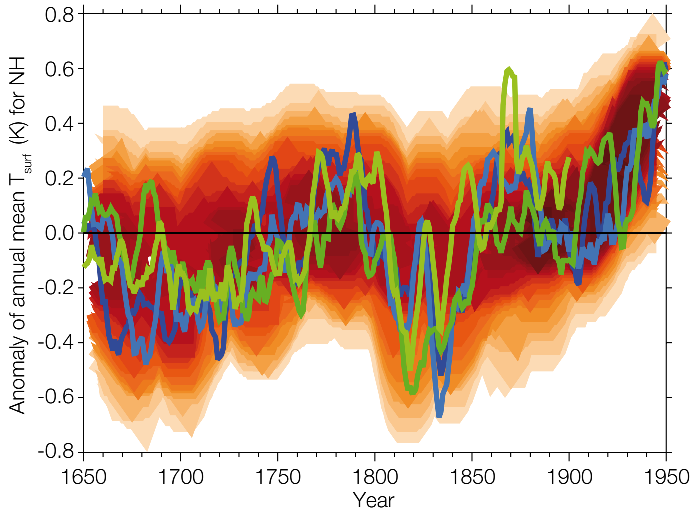

Figure 1. Annual mean surface temperature anomalies (K) averaged over the Northern hemisphere for medium (blue lines) and weak (green lines) solar forcing (see Shapiro et al., 2011 for definition). The shaded area represents the same quantity obtained from different temperature reconstructions (Jansen et al., 2007). The colour shading reflects the uncertainty of the reconstruction.

The model simulations reproduce successfully the colder climates during the Maunder and Dalton Minima as well as the warming during the first half of the 20th century. During the next phase of the project we intend to re-run the simulations starting with more appropriate initialization fields and to perform a sensitivity study to define which mechanism (volcanic eruptions, solar irradiance or energetic particle precipitation) is responsible for the cooling after 1800. The third phase will be devoted to the simulation of climate change in the future in a scenario where solar activity declines substantially.

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Shapiro A.I., Schmutz W., Rozanov E., Schoell M., Haberreiter M., Shapiro A.V., Nyeki S.: 2011, A new approach to the long-term reconstruction of the solar irradiance leads to large historical solar forcing, Astronomy & Astrophysics, 529, A67.

Modeling of the Climate and Ozone Response to a Strong Decrease of Solar Activity

Eugene Rozanov, Tatiana Egorova, Alexander Shapiro, and Werner Schmutz

We estimate the consequences of a potential strong decrease in solar activity using model simulations of the future. A comparison of the results shows that the introduced strong decrease in solar activity leads to a delay of the ozone recovery and partially compensates greenhouse warming.

We have simulated the present and future climate, and atmospheric state using CCM SOCOL v2.0 in time-slice mode. For this study, we conducted three 20-year long runs of CCM SOCOL v2.0 in time-slice mode. The reference run (REF) was driven by boundary conditions for the source gases, aerosol loading, solar irradiance, sea surface temperatures and sea ice concentration, described by Morgenstern et al. (2010), representing the 1995–2005 average climatology. The same procedure was applied to the solar modulation potential (proxy for galactic cosmic rays), ionization rates by solar protons and Ap index (proxy for low energy electrons precipitation). For the second run (ANT) we applied the boundary condition from Morgenstern et al. (2010) averaged over the period 2045–2055 but keeping the solar activity related forcing from the REF simulation. This run represents climate changes due to anthropogenic forcing only. For the third run (APS) we applied anthropogenic forcing identical to the ANT run, but the solar forcing was prescribed for the case of the expected strong decrease in solar activity similar to the Dalton minimum (Shapiro et al., 2011). The comparison of the climatology over the last 10-years allows the potential contribution of solar forcing to future climate change and statistical significance of the results to be estimated.

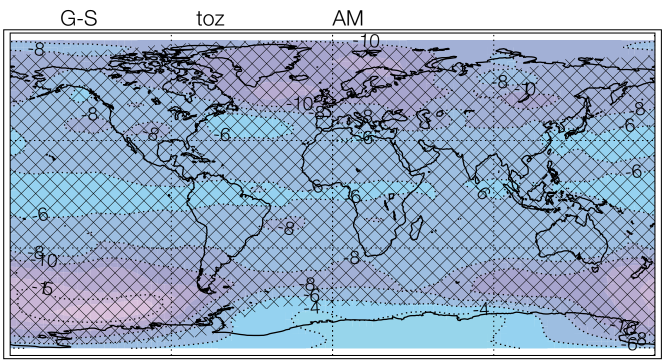

Figure 1. Annual mean difference (DU) of the future total column ozone between APS (anthropogenic and solar forcing) and ANT (anthropogenic forcing) runs. Hatching represent the areas where the statistical significance exceeds the 90 % confidence level.

The difference between the APS and ANT results which represents the contribution of the decline in solar activity are shown in Figure 1 and 2 for the zonal mean total ozone and 2-meter temperature over land masses, respectively.

The results show that the introduced strong decrease in solar activity can lead to a small delay in the ozone recovery and approximately compensate half of the greenhouse warming acting in the direction opposite to anthropogenic effects. On the other hand, the anthropogenically induced cooling in the stratosphere (not shown) is enhanced by a decrease in solar irradiance.

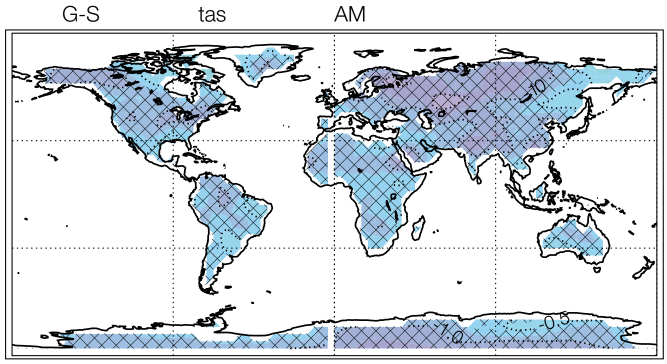

Figure 2. Annual mean difference (K) of the future 2-meter temperature between APS (anthropogenic and solar forcing) and ANT (anthropogenic forcing) runs. Hatching represent the areas where the statistical significance exceeds the 90 % confidence level.

The model results also show that all considered solar forcings are important in different atmospheric layers and geographical regions. However, the variability in solar irradiance can be considered as the most important aspect on a global scale.

These results probably represent the upper limit of the possible solar influence. A deeper understanding and the construction of a better constrained set of future solar forcings as well as the application of the models with an interactive dynamical ocean are necessary to address the problem of predicting the future climate and state of the ozone layer with more confidence. The development of more reliable solar forcing data sets requires the maintenance and extension of all relevant satellite and ground-based observations as well as further theoretical investigations. The results presented here were obtained in the framework of the SNSF funded FUPSOL project.

References:

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Effects of Regional Scale Nuclear Conflicts on Surface UV Radiation

Eugene Rozanov, Julian Gröbner, Leo Maag in collaboration with Thomas Peter, Christopher Hoyle, and Andrea Stenke (IAC ETHZ)

We investigate the effects of a hypothetical, regionally limited nuclear war on the climate, ozone layer and surface UV radiation using the chemistry-climate model (CCM) SOCOL. The predicted major impact on the ozone layer with a resulting massive increase in surface UV radiation fully confirms previous estimates made with other models.

We simulated the climate and atmospheric state changes caused by a regional nuclear conflict using CCM SOCOL v3.0 coupled to a mixed layer ocean. The model experiment is driven by soot aerosol injection caused by a hypothetical nuclear war between India and Pakistan described by Toon et al. (2007), Robock et al. (2007) and Mills et al. (2008). According to this scenario the climate and ozone changes are caused by 5 Tg of tiny (perhaps not the most appropriate word to use) soot particles, which are generated in the firestorms expected in the aftermath of such a conflict.

The massively increased stratospheric temperatures, caused by the soot, lead to the acceleration of chemical reaction cycles, in turn, leading to ozone loss, as described by Mills et al. (2008). In addition, the enhanced temperatures at the tropical tropopause allow more water to enter the stratosphere, which leads to additional ozone loss. The annual mean total column ozone in our experiments with and without soot aerosol is shown in Figure 1. The ozone loss at low latitudes is around 10–20 %, and the initial recovery begins in the tropics after around 5 years. At higher latitudes, ozone loss of 30–40 % is found, with the loss in polar regions being even higher (up to 70 %).

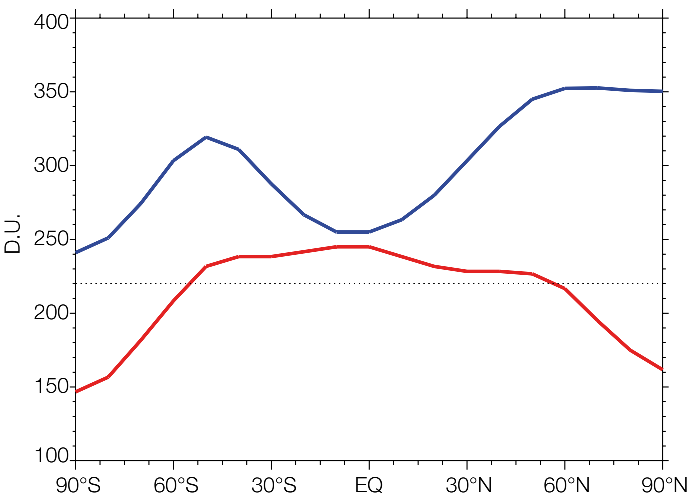

Figure 1. Total column ozone (D.U.) averaged over the two-year period directly following a nuclear war for experiments with (red line) and without (blue line) soot aerosol.

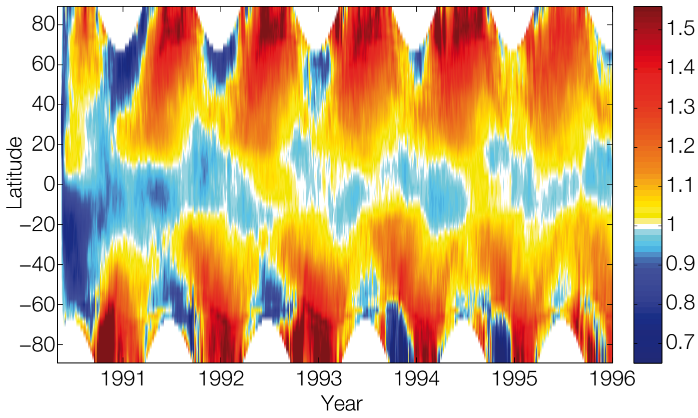

Figure 2. The zonally averaged ratio of the Erythemally weighted UV radiation in the experiment to the control run, for the first six years of the model run. Data are missing during the polar night.

The simulated ozone depletion is in a good agreement with the results obtained by Mills et al. (2008) for a similar soot aerosol loading.

Globally, in the two-year period following a nuclear war with an emission of 5 Tg soot, ozone concentrations are very low, approaching levels around 220 Dobson Units (DU), and are typical of ozone hole conditions. As may be expected, there is far less ozone loss in the 1 Tg simulation. Peak values of 20–30 % ozone loss are only seen in the polar areas for approximately the first two years of the run, whereas at low latitudes, the ozone values are not greatly affected. The ozone loss leads to an increase in the amount of solar UV radiation reaching the Earth's surface. Figure 2 illustrates the erythemally weighted ("sunburning") UV radiation change (the ratio between the experiment and control runs), for the first 6 years of the simulation. Even at latitudes of around 20°N, the summer UV exceeds the normal values by ~20 % after 1–2 years of simulation. Only a slight recovery is visible towards the end of the 6-year time-series, in keeping with the ozone changes shown in Figure 1. At mid latitudes in summer, the UV flux is approximately 30 % greater than in the control run.

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Signature of the 27-Day Solar Cycle in Mesospheric OH and H_2O

Anna Shapiro, Eugene Rozanov, Alexander Shapiro, Tatiana Egorova, and Werner Schmutz in collaboration with Thomas Peter (IAC ETH, Zurich) and S. Wang (JPL, California Institute of Technology, USA)

We analyzed the tropical mean response of the mesospheric OH and H_2O data as observed by the Aura Microwave Limb Sounder (MLS) to 27-day solar variability. We demonstrated that in the mesosphere the daily time series of OH concentrations correlate well with solar irradiance.

The solar energy emitted by the Sun penetrates down through the Earth's atmosphere and triggers many atmospheric processes, for example the water vapor photolysis ($H2O + h\nu \rightarrow H + OH$ for $\Lambda < 200$ nm), which is the main OH production mechanism in the mesosphere. The OH lifetime decreases with altitude reaching a value less than a few seconds at these altitudes. Therefore mesospheric OH is an ideal object for the study of atmospheric solar signatures.

The strongest response to the solar variability can be expected during the solar maximum. However, if we considered only the period of high solar activity then the response could be contaminated by the internal variability of the atmosphere, if it has periods close to 27 days. The correlation between hydroxyl and the solar irradiance would then be artificially high even in the absence of any physical connection. This means that the good correlation of OH with the solar irradiance could not be considered as unambiguous evidence of the connection between the solar irradiance and OH. One way to prove the connection is to analyze OH variability for the different phases of the 11-year solar activity cycle. If the 27-day cycle in OH and H_2O data is caused by solar irradiance one can expect that it will be significantly weaker for periods of lower solar activity.

We performed the analysis for two time periods corresponding to the different phases of the 11-year solar cycle: from December 2004 to December 2005 ('high activity') and from August 2008 to August 2009 ('low activity'). The cross-correlation functions for the daytime OH data calculated for the solar "high activity" period versus the solar irradiance are shown in Fig. 1 (left panel). As the OH lifetime at 75–85 km is very small in comparison to the 27-day solar rotational cycle, the response reaches its maximum at about zero time-lag. The right panel of Fig. 1 shows the cross-correlation functions for OH obtained for the solar "low activity" period versus the solar irradiance. One can see that the correlations are substantially weaker for the solar "low activity" period than for the solar "high activity" period that allows us to conclude that they are physically connected with the solar irradiance variability.

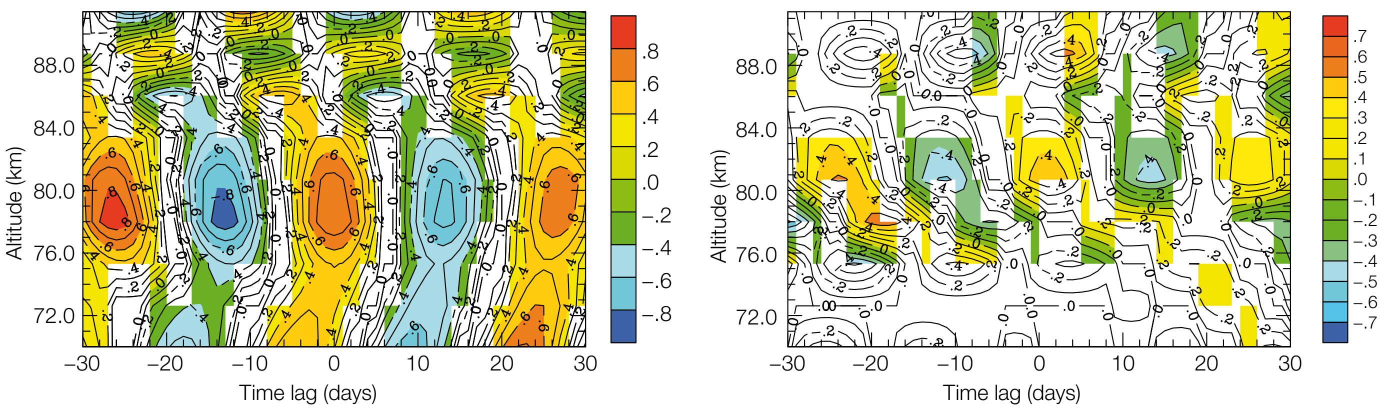

Figure 1. Cross-correlation functions between tropical (27°S–27°N) mesospheric OH and SOLSTICE/SORCE Ly-α irradiance as a function of altitude and response time-lag. Daytime OH for the solar "high activity" (left panel) and "low activity" (right panel) periods. Colored areas: significance ≥ 0.99.

Development of the Sulfate Aerosol Module for CCM SOCOL

Eugene Rozanov in collaboration with J. Sheng and T. Peter, IAC ETH, Zurich

The SNF-supported IASSA project aims to more reliably assess the behavior of sulfate aerosol after possible geo-engineering by injection of sulfur containing gases into the statosphere. During the first phase of the project we developed a new aerosol module to calculate microphysical and optical properties of sulfate aerosol.

The IASSA project aims to investigate future climate and ozone evolution assuming different geo-engineering scenarios with a reasonable level of certainty using a coupled aerosol-chemistry-climate model taking into account the main components of the climate system (atmosphere, clouds, land surface, ocean, sea ice, chemical species, and sulfate aerosol) and their interactions.

We have performed simulations of the Pinatubo eruption as an analog to geo-engineering using different distributions of the primary products and various total amounts of sulfur injected into the stratosphere with the off-line AER 2-D sulfate aerosol model (Weisenstein et al., 2006). This aerosol microphysical model calculates spectrally resolved aerosol size distributions (40 aerosol size bins) taking into account the microphysics of sulfate aerosols including nucleation, condensation, evaporation, coagulation and sedimentation. The eruption is simulated assuming 9 Mt sulfur injected between 20 and 28 km. Figure 1 illustrates extinction at a wavelength of 1020 nm from 1991 to 1995.

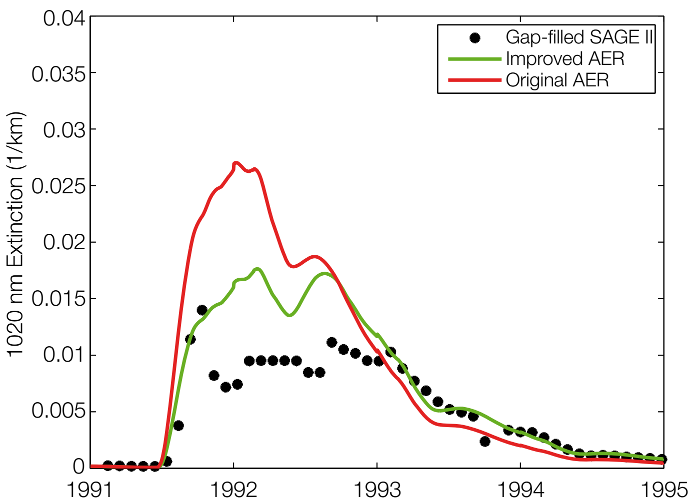

Figure 1. The aerosol extinction coefficient at a wavelength of 1020 nm (at the equator and 20 km altitude) from 1991 to 1995.

The original AER model overestimates the extinction with respect to the satellite measurements after the Pinatubo eruption. To improve the model we developed a new coagulation scheme, which fits the extinction at 1020 nm at 20 km much better, largely correcting the previous deficiencies.

In parallel, we implemented the sulfur cycle, photolysis and aerosol microphysics of the improved AER 2-D aerosol model into our chemistry-climate model (CCM) SOCOL v3.0. The sulfur-containing gases include carbon disulfide (CS_2), dimethyl sulfide DMS, hydrogen sulfide (H_2S), methyl sulfonic acid (MSA), carbonyl sulfide (OCS), sulfur dioxide (SO_2), sulfur trioxide (SO_3) and sulfuric acid (H_2SO_4).

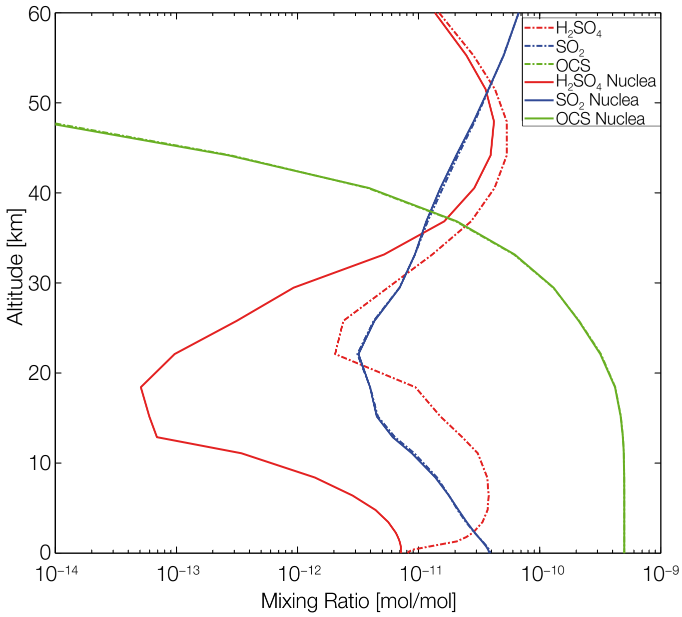

Figure 2. Vertical profiles of H_2SO_4, OCS and SO_2 mixing ratio at the equator. Dashed/solid lines show the results calculated without/with nucleation.

Figure 2 illustrates vertical profiles of primary sulfur compounds H_2SO_4, OCS and SO_2 with and without aerosol nucleation calculated during the test model runs. As expected, the sulfuric acid vapor mixing ratio with nucleation is significantly less abundant than without nucleation due to the formation of the sulfate aerosol layer. The mixing ratio of the other sulfur-containing species is not strongly affected by nucleation. These results compare well with the result shown in Turco et al. (1979). We are now working on emission data of sulfur-containing gases and the method to retrieve aerosol optical properties from the embedded microphysics.

References: Turco R.P., Hamill P., Toon O.B., Whitten R.C., Kiang C.S.: 1979, A One-Dimensional Model Describing Aerosol Formation and Evolution in the Stratosphere: I. Physical Processes and Mathematical Analogs. J. Atmos. Sci., 36, 699–717.

Weisenstein D.K., et al.: 2006, Ch. 6: Modeling of stratospheric aerosols, in SPARC Assessment of Stratospheric Aerosol Properties, Th. Peter and L. Thomason, eds., SPARC Report No. 4.

Chlorine Activation in the Post-Volcanic Stratosphere

Eugene Rozanov in collaboration with K. Dällenbach and T. Peter, IAC ETH, Zürich

We have estimated the contribution of several heterogeneous reactions to the chlorine activation and ozone depletion by volcanic sulfate aerosol for different ambient temperatures using an updated chemical box model.

The products of powerful volcanic eruptions can reach the stratosphere and form persistent sulfate aerosol layer. The enhancement of aerosol loading can lead to chlorine activation (conversion of chlorine containing gases from passive to active form, e.g. from HCl to ClOx=Cl+ClO+2*CL_2O_2) and subsequent ozone depletion. At present, it is not fully understood which heterogeneous chemical reactions play a major role under volcanically perturbed conditions. Thus the goal of this project is to deepen our understanding of chlorine activation by aerosol particles and to improve the chemical part of the chemical-climate model (CCM) SOCOL by implementing state-of-the-art schemes of reactive up-take coefficients for heterogeneous chemical reactions.

To pursue this goal we transformed the CCM SOCOL chemical module to a box model and implemented a new treatment of $ClONO_2$ + HCl, $ClONO_2$ + H_2O and HOCl + HCl reactions suggested by Shi et al., (2001) with a slightly modified representation of HCl uptake by the droplets. The latter accelerates $ClONO_2$ + HCl and HOCl + HCl reactions but slows down the $ClONO_2$ + H_2O reaction below 195 K compared to Shi et al. (2001). Thus, below 195 K the reactive uptake coefficients are closer to the Hanson et al. (1996) and Hanson and Ravishankara (1994) recommendations used in CCM SOCOL. The new scheme predicts chlorine activation that already becomes significant at somewhat higher temperatures than the original scheme, which will be of particular relevance to volcanic eruptions. Even under background aerosol conditions the new heterogeneous scheme gives enhanced chlorine activation. Under strong volcanic conditions there is, as expected, even more active chlorine at temperatures above 199 K. The difference in the simulated heterogeneous chlorine chemistry only becomes relevant at high temperatures (T > 200 K) under volcanic conditions. Therefore, the effect of the new framework might be small under background aerosol conditions but considerable under volcanic aerosol conditions.

The importance of different heterogeneous reaction chains for the intensity of chlorine activation (ClOx production) depends on the ambient temperature. Figure 1 illustrates the decrease of ClOx caused by the absence of different heterogeneous reactions calculated for the high aerosol loading case. As can be seen from Figure 1 at low temperatures (T < 203 K), direct chlorine activation by $ClONO_2$ + H_2O, $ClONO_2$ + H_2O and HOCl + HCl dominates the chlorine partitioning. At higher temperatures N_2O_5 and $BrONO_2$ hydrolysis is more important than direct chlorine activation.

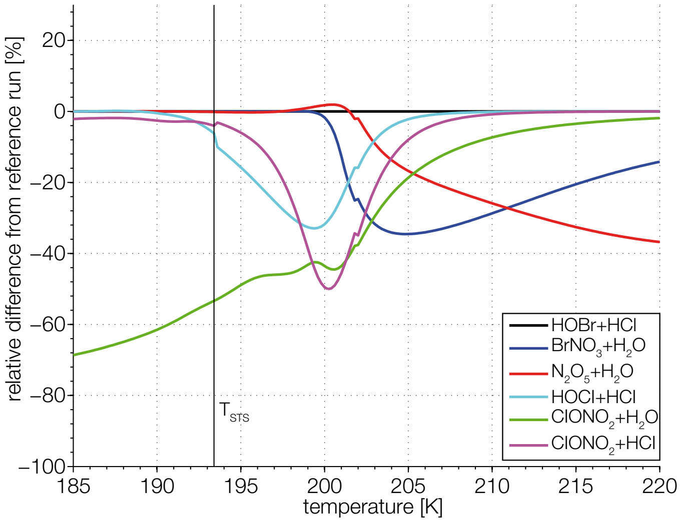

Figure 1. Temperature dependence of ClOx relative difference from a reference run of the model with all reactions included if a specific heterogeneous reaction is blocked. The black vertical line depicts the temperature below which HNO_3 is taken up into liquid aerosols.

The hydrolysis of these species leads to a denitrification of the atmosphere, i. e. there are less active nitrogen oxides available. Thus less active chlorine can combine with NO_2 to form $ClONO_2$ which leads to more intensive chlorine activation in the atmosphere. If the temperatures are low enough, direct chlorine activation becomes important in the mid-latitudes. However, the temperature distribution for January shows that temperatures below 200K only occur very rarely. Therefore, N_2O_5 and $BrONO_2$ hydrolysis seems to limit the ClOx budget in the mid-latitudes. Nevertheless, under strong volcanic conditions, direct chlorine activation can have a larger impact on chlorine partitioning, especially in the cold tropopause region.

References:

Hanson D., Ravishankara A., Lovejoy E.: 1996, Reaction of $BrONO_2$ with H_2O on submicron sulfuric acid aerosol and the implication for the lower stratosphere. Journal of Geophysical Research, 101:9063–9069.

Hanson D., Ravishankara A.: 1994, Reactive uptake of $ClONO_2$ onto sulfuric acid due to reaction with HCl and H_2O. Journal of Physical Chemistry, 98:5728–5735.

Shi Q., Jayne J., Wosnop D.: 2001, Kinetic model for reaction of $ClONO_2$ with H_2O and HCl and HOCl with HCl in sulfuric acid solutions. Journal of Geophysical Research, 106:24259–24274.

Nowcasting of the State of the Middle Atmosphere

Tatiana Egorova, Eugene Rozanov, Marco Senft, and Werner Schmutz in collaboration with Nicky Hochmuth, Institut für 4D-Technologien Fachhochschule Nordwestschweiz – Hochschule für Technik

For the project SOTERIA (Solar-TERrestrial Investigations and Archives) we have developed a space weather service that includes nowcasting of the middle atmosphere parameters including electron concentration and a data archive that could be used for educational and scientific purposes.

In the framework of the SOTERIA project we have developed the climate-chemistry-ionosphere model (CICM) SOCOL[i] (Egorova et al., 2011). SOCOL[i] is running in nowcasting mode using real-time online SSI data provided by LPC2E (Lab. de Physique et Chimie de l'Environnement et de l'Espace) (http://lpc2e.cnrs-orleans.fr/~soteria/). The nowcasting of middle atmosphere parameters is fully operational. We provide online data and visualization of the middle atmosphere state every 2 hours for the following parameters: O_3, NO, NO_2, OH, H_2O volume mixing ratio, electron and total positive ion density, temperature, air density and geopotential height. The model output consists of atmospheric parameters in 3-dimensions for the current time-step and the immediate future (up to 1 day). A progressive archive of past calculations is also publicly available online at http://projects.pmodwrc.ch/lyra/nowcast_data and can be used for educational purposes. The forecast and archived data are stored in NetCDF format.

As an illustration of the online nowcasting of the middle atmosphere we show below the effects of the solar flare event on October 22–26, 2011 on electrons. A coronal mass ejection (CME) hit Earth on Oct. 24th at approximately 1800 UT, leading to an increase in solar irradiance.

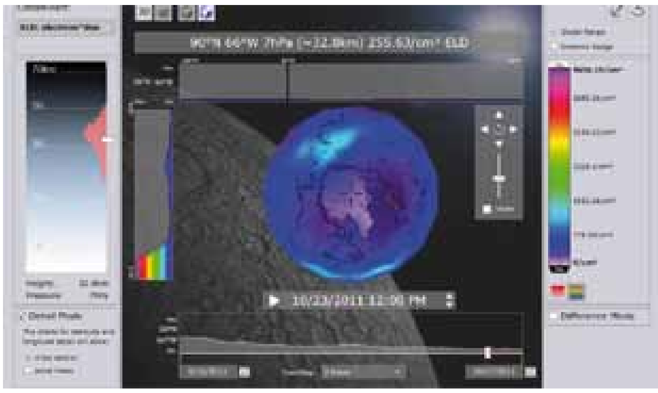

Figure 1. Electron density at ~ 33 km on 23/10/2011 (before the flare).

As can be seen in Figures 1 and 2 the electron density increased significantly after the flare, which the model was able to predict.

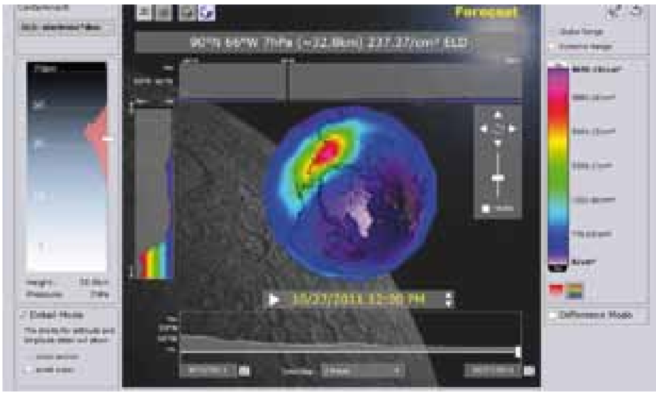

Figure 2. Electron density at ~ 33 km on 27/10/2011 (after the flare).

The operational skills of the model were also checked against a low ozone event over South America in October 2011 when the ozone hole reached land and populated areas in Argentina, Chile and the Falkland Islands. It should be noted that the Viewer shows the mixing ratio and not the total ozone. Therefore it is important to analyse ozone behaviour in the 15–25 km layer as it mainly determines the total column ozone.

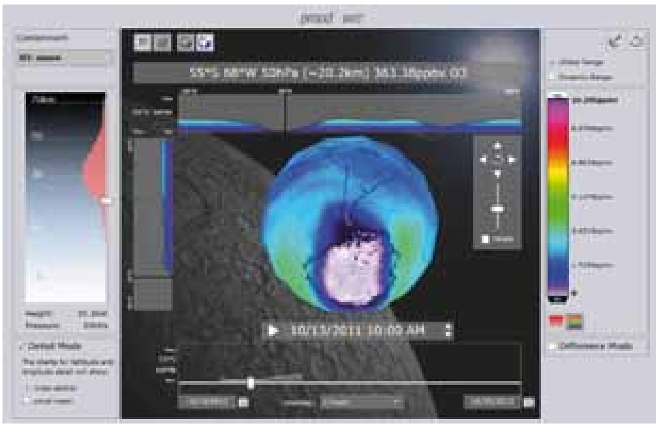

Figure 3. Ozone mixing ratio at 20 km in October 2011.

Figure 3 shows that the model reproduces the observed the northward elongation of the ozone hole and its extension to populated areas in South America in October 2011.

References: Egorova T., Rozanov E., Ozolin Y., Shapiro A., Calisto M., Peter T., Schmutz W.: 2011, The atmospheric effects of October 2003 solar proton event simulated with the chemistry-climate model SOCOL using complete and parameterized ion chemistry, J. Atmos. Sol.-Terr. Phys., 10 73(2–3), 356–365, doi:10.1016/j.jastp.2010.01.009.

The BBLAST Campaign

Stefan Wacker and Julian Gröbner

The PMOD/WRC infra-red section participated in the Boundary-Layer Late Afternoon and Sunset Turbulence (BBLAST) campaign which took place in Southern France in summer 2011. Main objectives of the WRC-IRS were to perform in-situ measurements on the evolution of the atmospheric boundary layer and to provide the community with high quality surface radiation budget measurements in order to guarantee homogenous radiation measurements among the participating research groups.

The BBLAST project aims at investigating the temporal evolution of the atmospheric boundary layer – the layer closest to the Earth's surface where the exchange of energy, impulse and mass between atmosphere and surface take place. The growth of the convective planetary boundary layer (CBL) over land during the day due to solar heating of the Earth's surface has been extensively observed and successfully modeled. However, the early morning transition – when the CBL emerges from the stable nocturnal boundary layer – and the late afternoon transition (LAT) – when the CBL decays to a stable stratified boundary layer again – are still difficult to observe and model. Initiated in 2008, the project has gathered about 30 research scientists from the European Union and the United States to work on this issue. The overall objective of BLLAST is to make more and better observations of the LAT. Therefore, a comprehensive field experiment was scheduled in France, near the Pyrénées Mountains. During three weeks in June and July 2011, continuous measurements in the lower atmosphere were performed. The campaign combined in-situ surface and airborne measurements along with remote sensing facilities.

Figure 1. Instrumental setup of PMOD/WRC with two pyranometers, three pyrgeometers and Rotronic temperature and humidity sensor.

PMOD/WRC deployed an instrumental setup during the field campaign to measure each component of the radiation budget. The tripod featured two well-calibrated pyranometers and pyrgeometers to measure the up- and down-welling short-wave and long-wave irradiance (Figure 1). Furthermore, the setup was equipped with a modified pyrgeometer sensitive in the 8–14 μm wavelength range which is used in conjunction with a traditional pyrgeometer to determine the effective atmospheric boundary layer temperature [Gröbner et al., 2009].

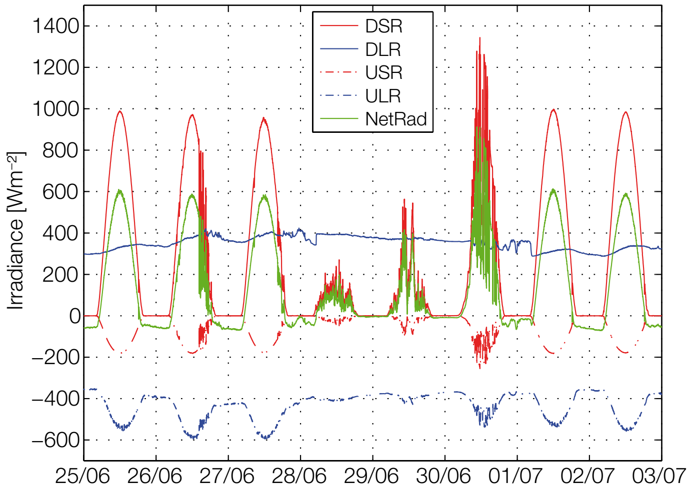

Figure 2. Net radiation derived from the observed down-welling and up-welling short-wave and long-wave irradiances.

The set-up was placed close to the instruments of other participating groups to provide simultaneous measurements with the aim of providing a quality assessment of the radiation measurements. We successfully measured the radiation budget during the whole campaign without any failures despite limited man-power (unattended instruments during most of the time). Furthermore, we precisely observed the LAT using long-wave measurements. The data were reprocessed and submitted to the project's official database (e.g. Figure 2). Our measurements will be used to validate the radiation measurements from the participants, in order to study the surface energy balance by combining the radiation data with sensible, latent and surface flux data and as input parameters for the various models used in the project.

References: Gröbner J., Wacker S., Vuilleumier L., Kämpfer N.: 2009, Effective atmospheric boundary layer temperature from longwave radiation measurements, J. Geophys. Res., 114(D19116), doi:10.1029/2009JD012274.

http://bllast.sedoo.fr/

Ground-Based Aerosol Optical Depth Trends at Three High-Altitude Sites

Stephan Nyeki, Christos Halios, Christoph Wehrli, and Julian Gröbner

Ground-based aerosol optical depth (AOD) climatologies at three high-altitude sites in Switzerland (Jungfraujoch and Davos) and Southern Germany (Hohenpeissenberg) are updated and re-calibrated for the period 1995 – 2010 [Nyeki et al., 2012].

Long-term measurements of ground-based aerosol optical depth (AOD) serve as an important validation of satellite-based and modeling studies of AOD. An area of recent interest in Europe has been to what extent aerosols play a role in the solar dimming/brightening debate. Studies [eg Wild et al., 2009] suggest that the contribution from anthropogenic aerosol emissions to the overall AOD reached a peak value in 1988–1990 and was partly responsible for dimming and consequent brightening over Europe. Sunphotometer measurements have been continuously conducted at three high-altitude sites in Switzerland and southern Germany since the 1990s. These are: 1) Jungfraujoch (JFJ; 3580 m; 46.55°N, 7.98°E), 2) Davos (DAV; 1590 m asl; 46.82°N, 9.85°E), and 3) Hohenpeissenberg (HPB; 995 m; 47.80°N, 11.02°E). All three sites belong to the GAW-PFR (Global Atmosphere Watch – Precision Filter Radiometer; www.pmodwrc.ch/worcc) program of the WMO.

The monthly AOD time-series at all three sites is shown in Figure 1. The full 1991 – 2010 AOD data-set for DAV is shown in Figure 1b to illustrate the Pinatubo eruption where a peak value ~ 0.23 was observed in April 1992.

Application of statistical tests, namely the seasonal Kendall test and Sen's slope estimator, gave the following AOD trends at JFJ, DAV and HPB for 1995–2010, respectively: +0.007 decade^{-1} (statistical significance p = 0.03), +0.002 (p = 0.4), and –0.011 (p = 0.1). Although only the JFJ trend is statistically significant at the 95 % confidence level, the high p-values at DAV and HPB nevertheless indicate trends which currently have an uncertain direction. Similar trends were also found at other PFR wavelengths. Our results contrast weak negative trends at JFJ, DAV and HPB of –0.002, –0.006 and –0.015 decade^{-1} for 1995–2005 in Ruckstuhl et al. [2008] which were not statistically significant at the 95 % confidence level. While our study has extended the available data set from 10 to 15 years, it can be seen that the AOD trend directions are still sensitive to the time-intervals under consideration. The weak trends suggest that no significant decreases in AOD have occurred since at least 1995.

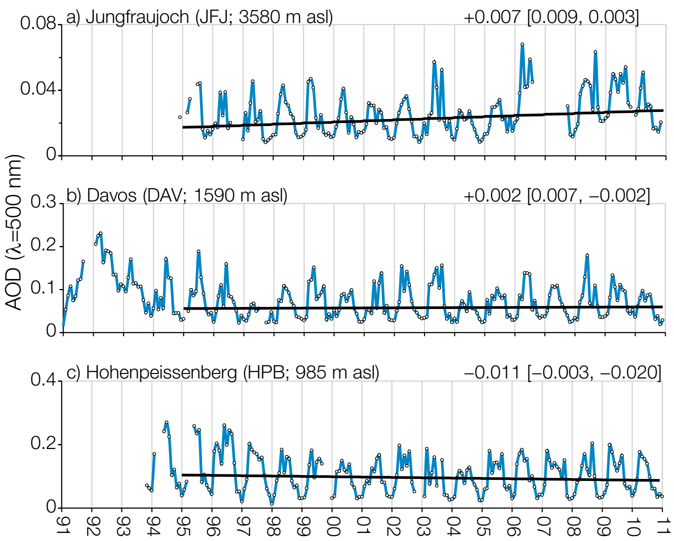

Figure 1. Time-series of monthly AOD average values at: a) JFJ, b) DAV, and c) HPB. Linear trends only relate to data from 1995 onwards. Trends in AOD units are shown per decade. Square brackets denote the 95 % confidence interval.

This may have an impact on the conclusions from a number of studies which have modeled significant decreases in AOD over Europe since the 1990s [Wild et al., 2009; and papers therein]. While observational evidence of a decrease in AOD exists, our study suggests that it may have been spatially and temporally less homogeneous over Europe than previously thought.

References:

Nyeki S., Halios C., Baum W., Eleftheriadis K.,, Flentje H., Gröbner J., Vuilleumier L., Wehrli C.: 2012, Ground-based aerosol optical depth trends at three high-altitude sites in Switzerland and southern Germany from 1995–2010, submitted to J. Geophys. Res.

Ruckstuhl C., Philipona R., Behrens K., Collaud Coen M., Dürr B., Heimo A., Mätzler C., Nyeki S., Ohmura A., Vuilleumier L., Weller M., Wehrli C., Zelenka A.: 2008, Aerosol and cloud effects on solar brightening and the recent rapid warming, Geophys. Res. Lett., 35, L12708, doi:10.1029/2008GL034228.

Wild M., Trüssel B., Ohmura A., Long C.N., König-Langlo G., Dutton E.G., Tsvetkov A.: 2009, Global dimming and brightening: An update beyond 2000, J. Geophys. Res., 114, D00D13, doi:10.1029/2008JD011382.

Apparent Aerosol Transmission from 1909 to 2010 at Davos, Switzerland

Daniel Lachat and Christoph Wehrli

Pyrheliometric measurements have been conducted at the PMOD/WRC from 1909 to the present which represents the longest stationary surface solar radiation record worldwide. The irradiance measurements were carefully screened and homogenized with respect to the World Radometric Reference (WRR). Apparent atmospheric transmission was calculated following the ratio'ing technique used by Hoyt and Fröhlich (1) and shown in our annual report 2010.

There have been efforts to analyse the Dimming and Brightening trends by separating out the contributions of water vapour absorption and aerosol extinction (2). This implies the factorization of transmission into Rayleigh scattering and water vapor absorption, and interpreting the residual as aerosol extinction. Therefore, atmospheric integrated water vapour (IWV) has been estimated from specific humidity and 2m-temperature measurements through correlation with modern time co-located GPS measurements.

Atmospheric transmission due to water vapour absorption and Rayleigh scattering has been calculated by the SMARTS2 radiative transfer model. Apparent aerosol transmission was then obtained as the fraction of the total apparent atmospheric transmission after division by apparent transmission of Rayleigh scattering, water vapour and ozone absorption.

The apparent water vapor transmission series shown in Figure 1 is subject to only small variations, except for the period 1978–1984 which exhibits significantly higher transmission. The causes for this period of a seemingly drier atmosphere are yet to be investigated.

The series of apparent aerosol transmission shown in Figure 2 is overlaid with 72 moving trend-lines spanning 31-years. The periods of Early Brightening, Dimming and Brightening can be clearly detected from the inflexion points of these trend-lines.

The effect of the volcanic eruptions of Katmai/Novarupta in 1911/12, El Chichón in 1982 and Mt. Pinatubo in 1991 show up as very low aerosol transmission with a delay of about 1 year.

In a final step of this study, the series of apparent aerosol transmission will be analyzed in terms of weather conditions. Local and large-scale weather classification schemes will be combined to generate a dispersion classification. This will account for both transport of aerosols and for vertical atmospheric mixing. Single events in the aerosol series will then be analyzed on a daily basis.

References: Hoyt D., Fröhlich C.: 1983, Atmospheric Transmission at Davos 1909–1979, Climate Change 5, 61–71.

Haywood J., Bellouin N., et al.: 2011, The roles of aerosol, water vapor and cloud in future global dimming/brightening, Journ. Geophys. Res. 116, D20203.

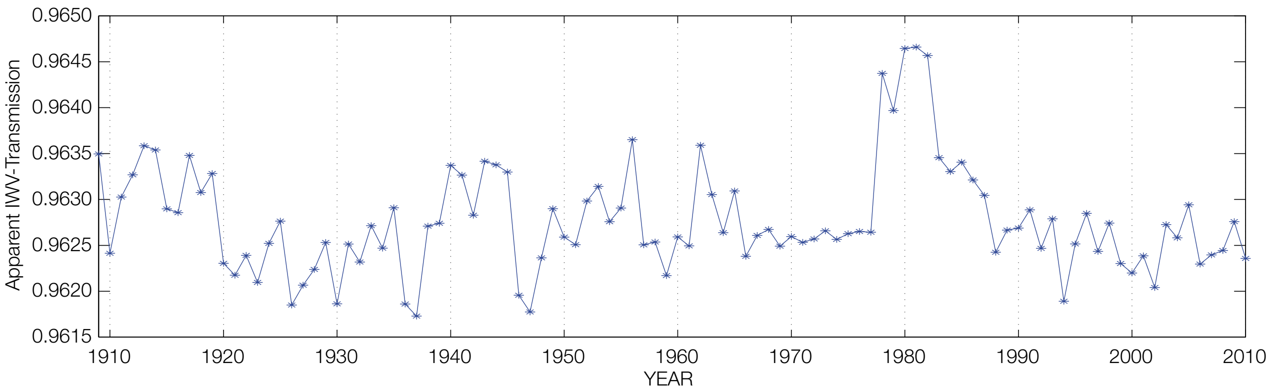

Figure 1. Annual mean of apparent Integrated Water Vapor-Transmission (blue crosses).

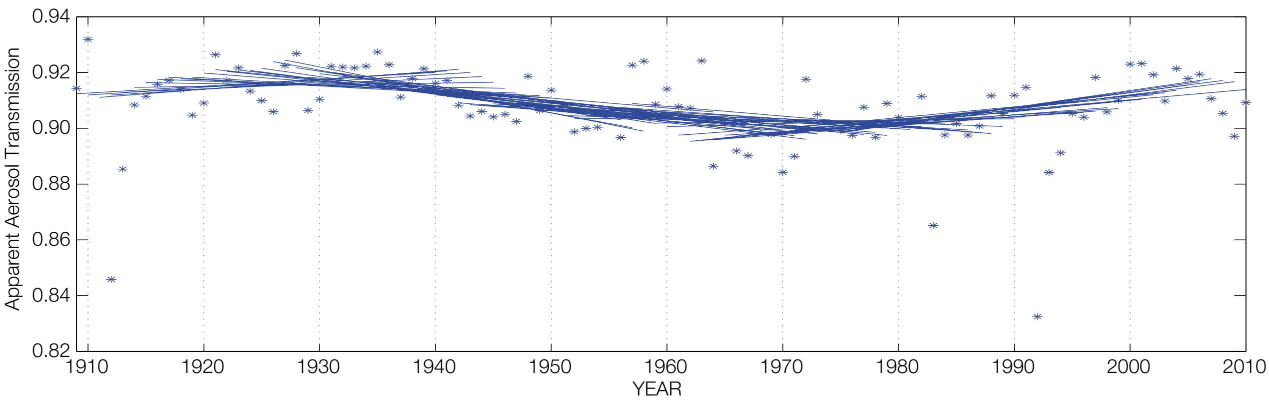

Figure 2. Annual mean of apparent aerosol transmission (blue stars), overlaid with a 31-year floating trend (blue lines).

The Fourth World Radiometric Reference to SI Radiometric Scale Comparison

André Fehlmann

PREMOS absolute radiometers flying on the French satellite PICARD were carefully characterized and calibrated against the World Radiometric Reference (WRR) in Davos and the SI traceable Total solar irradiance Radiometer facility (TRF) at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder. The calibration results were used to compare both scales. We found that internal stray light in our radiometers has been underestimated in the past and that the WRR scale is 0.34 % higher than the SI scale.

PREMOS absolute radiometers were carefully characterized before launch in June 2010, which gave us valuable new insights into effects which influence measurements of our PMO6 type radiometers. We are now able to correct measurements for heating of the precision aperture and drift of the heat-sink temperature. Prior to the integration on the satellite, we compared both dedicated flight instruments and the spare radiometer against the SI radiant power scale at the National Physical Laboratory in Teddington. The set-up of this comparison was equivalent to that used in the first three WRR to SI comparisons. However, our radiometers were operated in vacuum this time, allowing us to avoid an air-to-vacuum correction which has a large uncertainty.

After vibration tests, we detected anomalies in the operation of the PREMOS-A dedicated flight instrument and decided to replace it. However, before the exchange we had the opportunity to visit the SI traceable Total solar irradiance Radiometer Facility (TRF).

Figure 1. The PREMOS/PICARD absolute radiometer mounted on a motorized translation stage inside the TRF vacuum chamber at the Laboratory for Atmospheric and Space Physics in Boulder CO.

The homogeneous 11 mm diameter beam of this facility over-fills the radiometer's apertures and thus, for the first time, offers the possibility to calibrate a radiometer in a laboratory for irradiance measurements. This is a further improvement with respect to the NPL comparisons where the light source was a narrow laser beam whose diameter was smaller than the radiometer apertures. The variable beam diameter of the TRF also allowed us to investigate the internal stray light of the PMO6 type radiometers which is caused by the illuminated precision aperture when measuring irradiance. We found that the stray light has been underestimated by about a factor of ten in past characterizations of PMO6 type radiometers. As a consequence, we designed a new radiometer generation which has the smallest aperture at the entrance to the instrument and thus has no internal stray light. This aperture geometry is equivalent to the Total Irradiance Monitor (TIM) radiometer design by LASP. The TIM instrument, flying on the SORCE satellite, measures 4.5 W/m² lower than the WRR traceable PMO6/VIRGO radiometers and other instruments in space and it was speculated that stray light may be the reason for this difference.

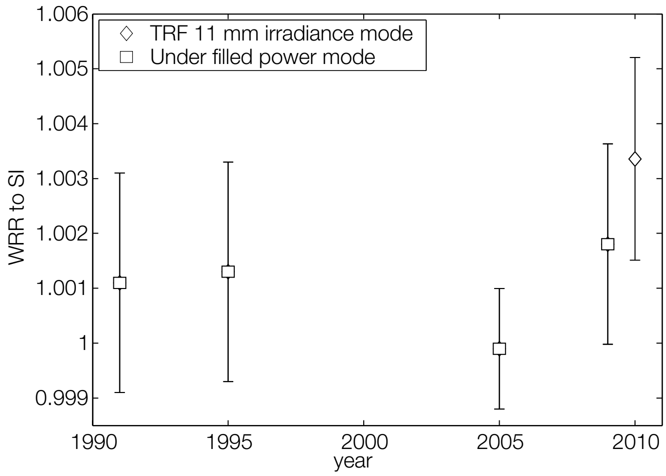

Figure 2. The results of all WRR to SI comparisons. Our 2009 comparison in power mode, e.g. with a narrow laser beam smaller in diameter than the aperture, agrees with the first and the second comparison. The result of the third comparison in 2005 might be too low because of a non-linear response of the reference trap detector. The irradiance comparison in 2010 at the TRF is even higher due to internal stray light in our radiometers.

Finally, the WRR and TRF calibrations were used to compare the WRR with the SI radiometric scale. We found that the WRR is 0.34 % higher than the SI scale. About two thirds of the difference can be attributed to stray light. The remaining difference is consistent with the findings of the first and the second WRR to SI comparisons. A non-linear response at high power levels of the trap detectors used in the comparison may be the reason for the good agreement of both scales in the third comparison. Our result provides a good explanation of the observed differences in space because if we use the WRR calibration for PREMOS, then our results agree with VIRGO. However, if we apply the TRF calibration to PREMOS, then the results are in very good agreement with TIM.

References:

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

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The Cryogenic Solar Absolute Radiometer (CSAR)

André Fehlmann in collaboration with METAS Bern Switzerland and NPL Teddington UK

The Cryogenic Solar Absolute Radiometer which was assembled in 2010 and participated in the 11th International Pyrheliometer Comparison 2010, was returned to the National Physical Laboratory for necessary modifications. In 2011, CSAR was brought back to the PMOD/WRC for further comparisons to the World Radiometric Reference (WRR). The preliminary results show that CSAR measures 0.3 % lower than the WRR.

The Cryogenic Solar Absolute Radiometer (CSAR) is the result of a joint project by PMOD/WRC, the National Physical Laboratory (NPL) and the Swiss Metrology Office (METAS). The instrument was assembled at the NPL in Teddington starting in April 2010 and participated in the 11th International Pyrheliometer Comparison (IPC) in September and October 2010. CSAR results showed that the measurements were drifting and that the changes were correlated to changes of the ambient temperature. After the IPC, CSAR was returned to the NPL for modifications of the detector stages. By improving the thermal heat-sinking of the wires going from ambient temperature to 20 Kelvin, we were able to eliminate disturbing environmental influences on CSAR measurements.

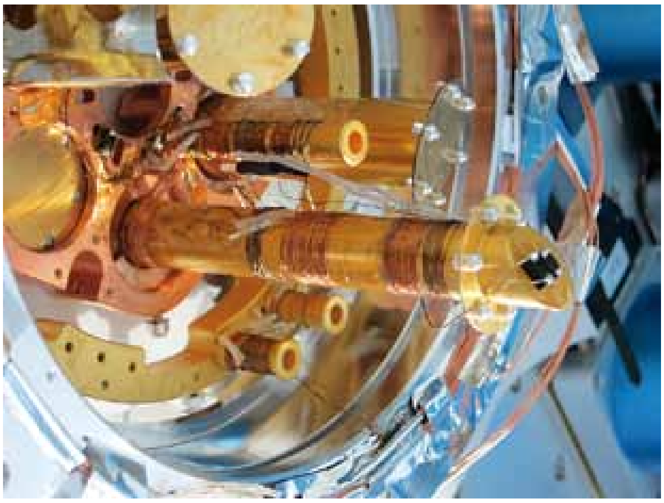

Figure 1. The long cylindrical CSAR detector cavities have different lengths. Electrical resistors (black blocks) are used to substitute optical with electrical power. Thermal disturbances of the measurements can be avoided by wrapping the wires, which lead to the detectors, around an object on every temperature stage.

Laboratory measurements at the NPL have proven the stability of CSAR results after the modifications and therefore we brought the instrument back to Davos for further WRR comparisons.

In February and March 2011, CSAR measured the Total Solar Irradiance (TSI) on the solar tracking platform in Davos. To rule out errors due to the transmittance correction of the entrance window, we used two different window materials – fused Quartz and Sapphire. The preliminary results show that CSAR measures 0.3 % lower than the WRR.

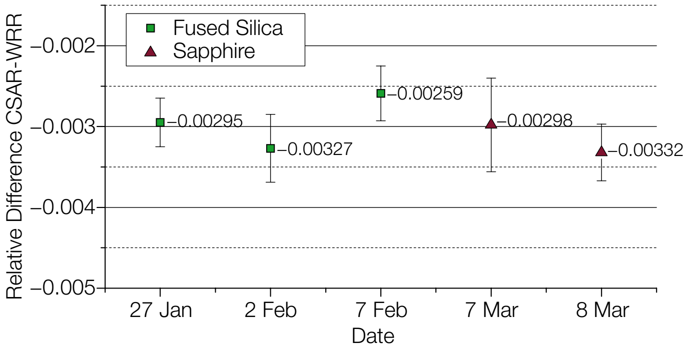

Figure 2. Preliminary CSAR values are 0.3 % lower than those of the WRR. This result is independent of the CSAR entrance window.

Due to the ongoing renovation of the PMOD/WRC, it was not possible to operate CSAR after March 2011.

However, a special control electronics unit dedicated to CSAR operation was developed during the rest of 2011. This will allow us to regularly run the instrument alongside the WRR without the need to manually interfere with the stabilisation of the reference blocks, the power dissipation on the detectors or the shutter operation.

The apparent difference between the CSAR and the WRR measurements has been independently confirmed by the calibration work performed by PREMOS radiometers currently flying on the French PICARD satellite (cf. scientific research activity section). Further characterisation of the CSAR and WRR comparisons will give a clearer picture and allow a fundamental discussion about the future of the reference scale for TSI measurements.

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

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

Figure 3. CSAR on the tracking platform in Davos together with Rainer Winkler (NPL) and André Fehlmann (PMOD/WRC) who jointly designed and built the instrument.

Irradiance Calibration of Diode Array Spectroradiometers

Gregor Hülsen and Julian Gröbner

Four spectroradiometer systems were calibrated at PMOD/WRC. The lowest uncertainty of these devices is about 2 % and 5 % in the VIS and NIR wavelength ranges, respectively. The low sensitivity at both ends of the spectral range limits the accuracy of the systems for the specified wavelength range.

In spring 2011, the spectral responsivity of four diode array spectroradiometers was investigated at the European UV Calibration Center (EUVC) at PMOD/WRC. Two different types were calibrated: Three spectroradiometers from StellarNet Inc. and one system from Avantes Inc. All systems comprised a spectroradiometer measuring in the wavelength range 350–1100 nm (UV-VIS) and another in the NIR (900–1700 nm, StellarNet; 1000–2200 nm, Avantes AvaSpec 256-2.2). The StellarNet spectroradiometers were equipped with an entrance optic for direct solar irradiance measurements, which could be modified to measure global irradiance as well. The Avantes system was equipped with two separate entrance optics for direct and global irradiance measurements.

The global irradiance calibration was performed relative to the 1000 W FEL transfer standard tungsten halogen lamp F300. The distance to the lamp was 700 mm, and the device integration time was adjusted to obtain a full-scale count output in the most sensitive wavelength region. The direct irradiance calibration was performed at a distance larger than 2 m, with ~10 times longer integration time.

One example of the calibration measurement is given in Figure 1. The spectral results of the uncertainty estimate are shown in Figure 2. After the calibration measurements the FEL lamp was used to verify the calculated responsivity (see Figure 3). In regions of their highest sensitivity the calibrations exhibit uncertainties below 3 % (UV-VIS-StellarNet: 450–900 nm), below 5 % (UV-VIS-Avantes: 450–800 nm), below 5 % (NIR-StellarNet: 950–1650) and below 30 % (NIR-Avantes: 1250–1900 nm). The signal-to-dark ratio of the Avantes-NIR was below 1.2 during the calibration at a distance of 400 mm. The three different StellarNet-systems show substantially different measurement uncertainties, where the newest spectroradiometer is the most stable. Two systems have very low sensitivities due to the presence of a pinhole in their entrance optics.

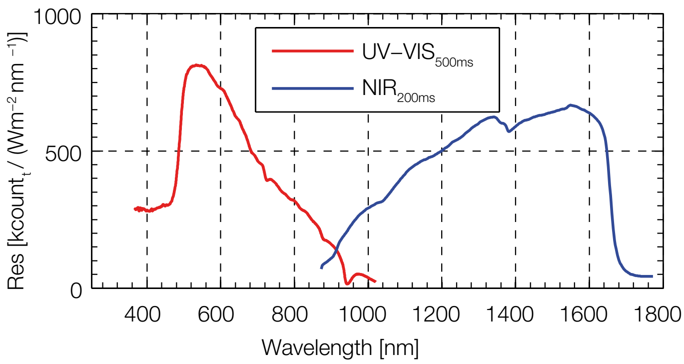

Figure 1. Spectral responsivity of a StellarNet Balck C SR 50 (UV-VIS) instrument, together with the RED Wave NIR InGaAs spectroradiometer with an uncertainty below 10 % (see fig. 2). The integration time was 500 ms and 200 ms, respectively. The data is based on the average of 100 measurements.

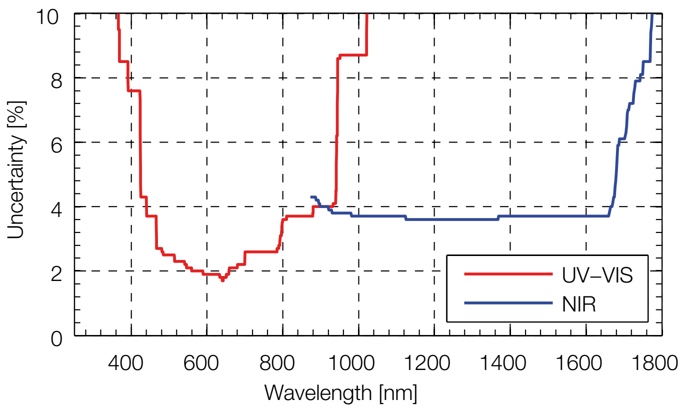

Figure 2. Uncertainty of the global irradiance calibration (system description: see caption fig. 1).

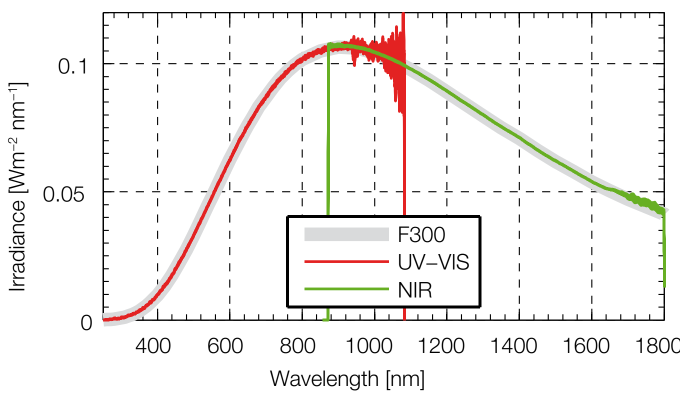

Figure 3. Irradiance of 1000 W FEL transfer standard F300 recorded by the system shown in figure 1. The spectral irradiance of the lamp is shown in gray (system description: see caption figure 1).

The Quasi Biennial-Periodicity Signal in Helioseismic Observations

Rosaria Simoniello and Wolfgang Finsterle

We looked for signatures of quasi-biennial periodicity (QBP) over different phases of solar cycle by means of acoustic modes of oscillation. Low degree p-mode frequencies are shown to be sensitive to changes in magnetic activity induced by the global dynamo.

Evidence of shorter periodicities than the 11-year period in solar activity proxies are very well known in the literature. Particularly prominent are the ones between 1.5 and 4 years and hereafter these are referred to as quasi-biennial periodicity (QBP). In solar activity proxies the QBP appears intermittently and tends to be stronger over periods coinciding with solar maxima, and they are not recognized as typical feature of every cycle. We investigated the solar cycle changes in p-mode frequency shifts by using helioseismic instruments: Birmingham Solar Oscillation Network (BiSON), Global Oscillation at Low Frequency (GOLF) and the Solar PhotoMeters (SPM) of the Variability of solar IRradiance and Gravity Oscillations (VIRGO) on board the SOlar Heliospheric Observatoy (SOHO) satellite, and Global Oscillation Network Group (GONG). Fig.1 shows the solar cycle changes in p-mode frequency shifts for all the helioseismic instruments. We clearly spot likely signatures of QBP in all of them, although there are differences in the data sets. The signal-to-noise ratio in GOLF data appears different in the red and blue wing-configurations, being slightly better during the red-wing period. This might explain why the faint signal of the QBP is less prominent in GOLF data. Furthermore, for VIRGO observations, the continuum intensity data sample a different (i.e.deeper) region where the temperature variations induced by the acoustic oscillations may be quite small.

By looking at the solar cycle changes in p-mode frequency shift as function of the spherical degree l, we detected likely signatures of the two-year cycle at all levels of solar activity; instead, surface activity indices mainly show it over periods coinciding with solar maxima. We also noticed that, away from the solar maximum, the QBP shows up in each low-degree mode over different periods of solar activity phase. This results from the different spatial configuration of the modes over the solar disk. For example, we found seismic signatures over the low-activity phase (September 2006) in the modes l=0, 2 but not in the dipole mode l=1.

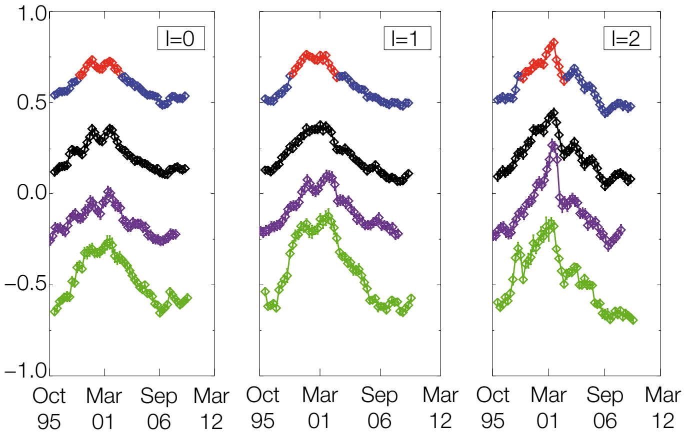

Figure 1. Solar cycle changes in p-mode frequency shifts (muHz) for l=0, 1, 2 from VIRGO (green), BiSON (black), GONG (purple), and GOLF (blue and red to identify the corresponding wing configuration) observations over solar cycle 23 and beginning of solar cycle 24.

In integrated sunlight observations, the observed l=1 frequency is a weighted measurement of the visible components (l=1, |m|=1), while in the case of the l=2 mode, the fitted frequency corresponds to the weighted measurement of the zonal (l=2, m=0) and sectoral (l=2, |m|=2) components. The spatial structure of the oscillation means that the sectoral components |m|=l are more concentrated around equatorial latitudes than the zonal components (m=0), and is particularly true with increasing l. As a consequence, the contribution to the QBP signal over the minimum activity might have its origin at higher latitudes.

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Investigating the Significance of the Quasi-Biennial Periodicity Signal

Rosaria Simoniello and Wolfgang Finsterle

We investigated the significance of the quasi-biennial periodicity (QBP) signatures over solar cycle 23 found in GONG data by applying the wavelet analysis, in order to check whether the signature of the QBP signal over the minimum phase is reliable.

Evidence of QBP has been found in all low degree modes and over different phases of solar cycle 23. To investigate the significance of these signatures, we applied the wavelet analysis developed by Torrence and Compo (1998) to the azimuthal components of the mode l=1.

Figure 1 and Figure 2 show the results for the azimuthal components of the modes l=1. We found signatures of the QBP at 80 % confidence level even over the minimum activity phase in the zonal components of the mode. This feature is peculiar of acoustic waves, as solar activity proxies mainly show it over periods coinciding with solar maxima. The significant periodicity occurs at T=1.7 for l=1,m=0, T=2.1 for l=1 and m=1. It is interesting to note that the zonal modes show a slightly different periodicity from the one detected in the sectoral components. This point will be further investigated in future work. Furthermore the signal strength in the zonal component of the mode is weaker compared to the signal in the sectoral component.

In summary the wavelet analysis confirms that a further periodicity of approximately two-years is indeed present in the data at confidence level of 80 %. Furthermore the findings seem also to point to a likely persistent nature of the QBP signal, since we found evidences that this mid-term periodicity is also present over periods of the low activity phase.

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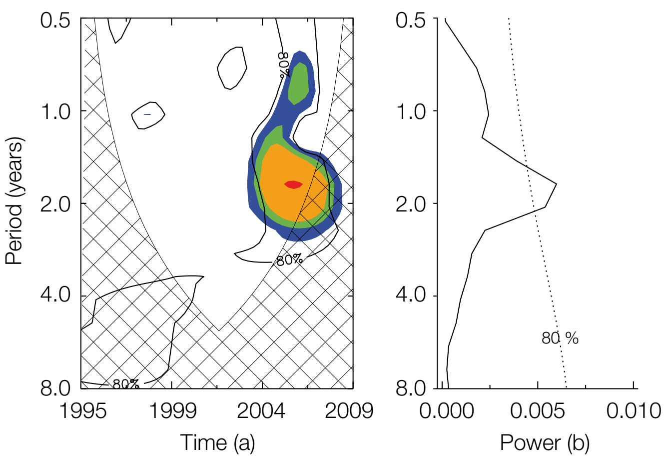

Figure 1. The local wavelet power spectrum for l=1, m=0. White represent areas of little power, red those with the largest power. Solid rings identify areas at power of 0.0025, 0.005, 0.0075 over time, and only those that achieved 80 % confidence level are labeled. (b) Global wavelet power spectrum. The dotted line identifies the 80 % of confidence level.

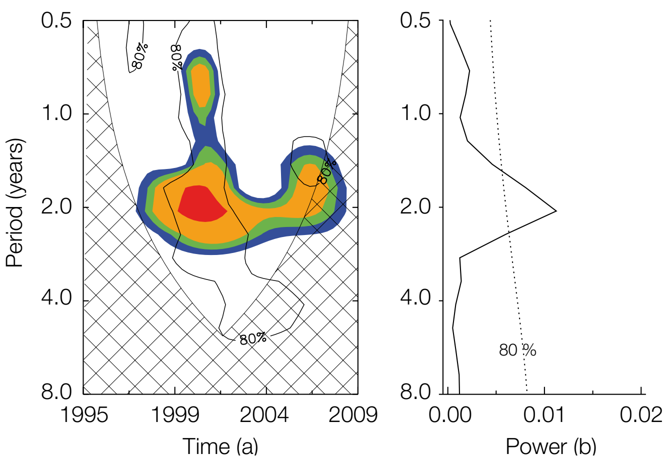

Figure 2. The local wavelet power spectrum for l=1, m=1. White represent areas of little power, red those with the largest power. Solid rings identify areas at power of 0.005, 0.01, 0.015 over time, and only those that achieved 80 % confidence level are labeled. (b) Global wavelet power spectrum. The dotted line identifies the 80 % of confidence level..

The Place of the Sun among Sun-Like Stars

Alexander Shapiro, Werner Schmutz, Eugene Rozanov, and Gaël Cessateur

There is a discrepancy between the irradiance variability of the Sun and Sun-like stars. We propose an explanation for this long-known problem.

Radick et al. (1998) and Lockwood et al. (2007) have shown that the Sun is significantly less variable than stars of the same activity level and is an outlier among its stellar cohort. The solar variability in the Strömgren filters b and y should be about 0.1 % to be consistent with the approximately 20-year monitoring period of 32 Sun-like starts. At the same time, modern measurements and reconstructions give a significantly smaller value of the solar variability (0.01–0.04 %) during the approximately 30-year period of solar space-borne observations. Up to now this anomalous solar behavior remains unexplained.

We believe that one of the possible explanations is connected with the fact that consecutive measurements of solar irradiance are only available since the availability of satellite observations (i.e. since 1978). Meanwhile, the proxy data indicate that the Sun was at a maximum plateau-state in its long-term evolution during this period. Thus the long-term trend in the solar irradiance is expected to be very small. This implies that the current satellite measurements only catch the variability due to the 11-year activity and 27-day rotational solar cycles. At the same time it is known that during the last millennia the level of solar activity has been significantly variable. If a change in solar activity causes a change in the solar irradiance level then the Sun underwent trough the sequence of periods when the long-term variations were relatively strong and could even dominate the 11-year cycle. During these periods the variability of the Sun (e.g. RMS calculated for the 20-year period) was significantly larger than at present. Thus the variability of the Sun could be time-dependent and its present anomalous behavior is just a temporary phase in the long-term evolution.

Figure 1 presents the time dependence of the RMS calculated for the 20-year periods according to Shapiro et al. (2011) reconstruction, which yields a significant historical variability of the solar irradiance. One can see that the solar variability was very small for the last 30 years, but there were periods of remarkably strong variability in the past.

Comparison of the mean variability of the Sun with the variability indicated by Sun-like stars can be used to estimate the value of the long-term trend in the solar variability. This will ultimately allow existing reconstructions of past solar irradiance to be independently tested.

At present, an exact estimate of the long-term trend in the solar irradiance is hampered by uncertainties in stellar variability and the inclination effect. The latter arises from the special position of Earth-based observers as the Sun is observed from its equatorial plane, while the stars are observed from arbitrary directions. The first estimates show that the long-term trend in the solar irradiance consistent with 7 W/m² solar forcing from the present to the Maunder minimum can solve the disagreement between the stellar and solar variabilities.

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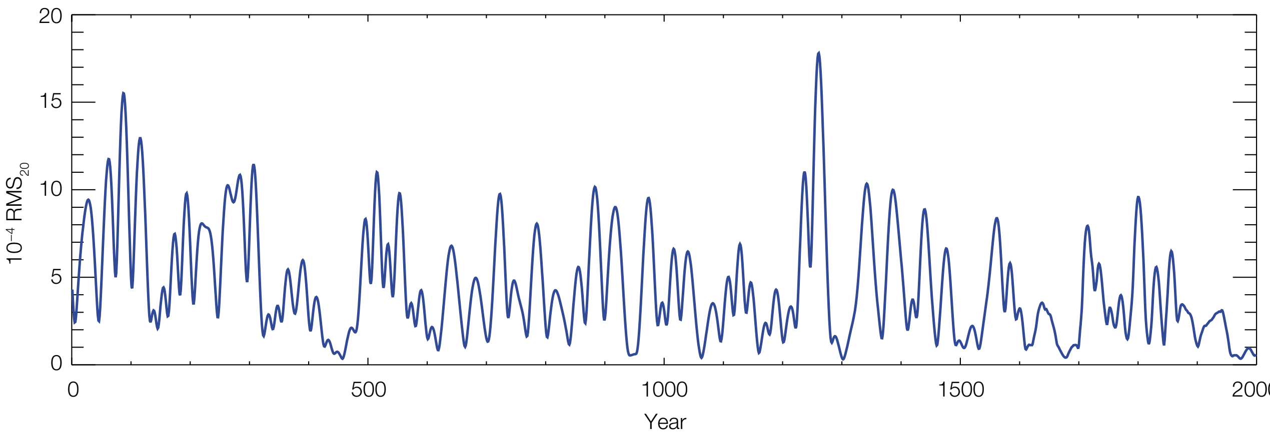

Figure 1. Solar variability vesrus time according to the reconstcruction by Shapiro et al. (2011). RMS values of the mean irradiance in Strömgren filters b and y ((b+y)/2) for 20 year time intervals are plotted (i.e. the value for the year X is the RMS of the set of annual (b+y)/2 values for the [X–9,X+10] time period).

The Solar Spectral Irradiance as a Function of the Mg II Index

Alexander Shapiro, Werner Schmutz in collaboration with LATMOS-CNRS, France; SSAI, USA; Solar-Terrestrial Centre of Excellence, Belgium; Canadian Space Agency, Canada

We present a new method to reconstruct the Solar Spectrum Irradiance (SSI) in the 120–400 nm region based on the Mg II index and ^{10}Be data.

Thuillier et al. (2012) suggested that the Mg II index could be used to reconstruct the solar spectrum (121–400 nm) back to 1978.

It has been observed that over the last three solar cycles, the annual values of the Mg II index have shown a strong correlation with annual values of the modulation potential determined from the neutron-monitor data (see Fig. 1). Assuming that this correlation can be applied to the past, we reconstruct the Mg II index from the modulation potential determined from ^{10}Be data back to the Maunder Minimum. By then applying the Thuillier et al. (2012) approach we obtain the SSI reconstruction. This reconstruction yields a very small value of the forcing between the present and Maunder minimum (see Fig. 2). This is a direct consequence of the extrapolation of the Thuillier et al. (2012) approach, established from observations during the last several solar cycles, to the past 400 years. This is equivalent to the assumption that that the same mechanism is responsible for the 11-year cycle and for the long-term trend. Shapiro et al. (2011) made an opposite assumption and obtained a significantly larger forcing value. At present the observational data do not favour the selection of any particular reconstruction out of those proposed. Therefore, until new evidence becomes available, we are in a situation where different approaches and hypothesis yield different solar forcing values. Our result allows the climate community to evaluate the full range of the present uncertainty in solar forcing.

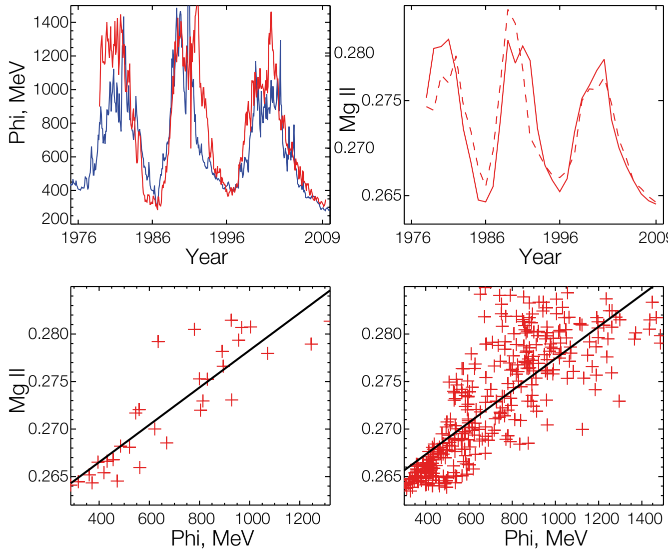

Figure 1. Upper left panel: Monthly values of the Mg II index (red line) and the modulation potential (blue line); upper right panel: annual values of the measured Mg II index (solid red line) and Mg II index reconstructed from the modulation potential (dashed red line); lower left panel: annual values of the Mg II index vs annual values of the modulation potential, the straight line results from a linear fit between these two data sets; lower right panel: the same as lower left panel but produced with monthly data.

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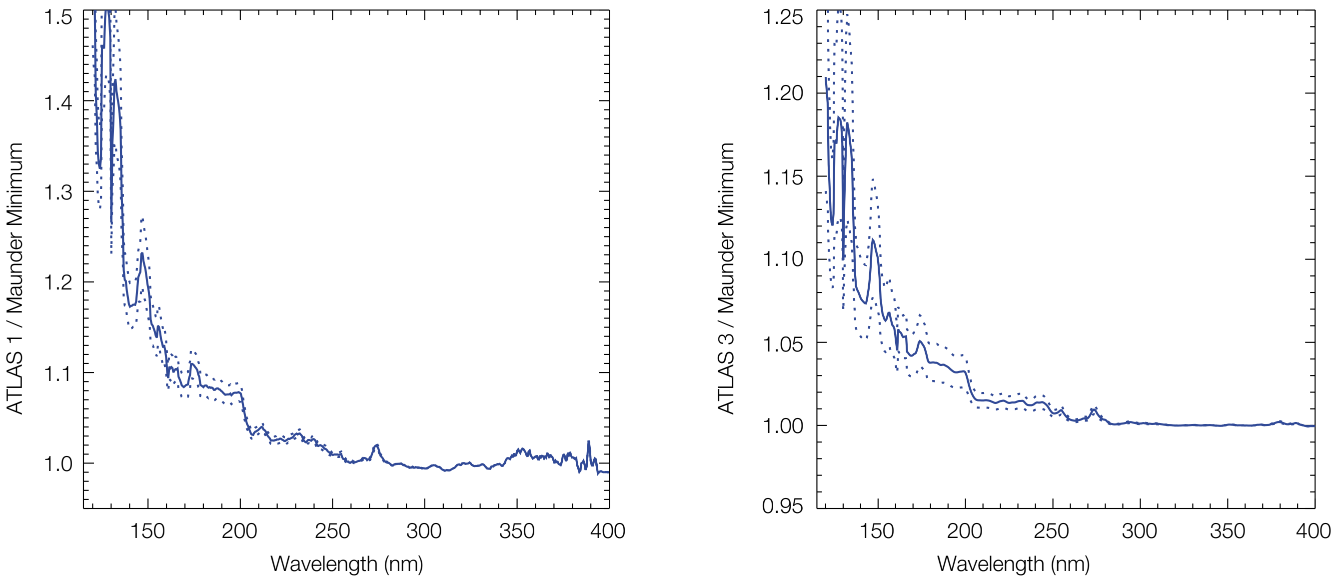

Figure 2. Ratios of the ATLAS 1 (left panel) and ATLAS 3 (right panel) spectra to the reconstructed Maunder Minimum spectrum. The dotted lines on both panels indicate the uncertainty of the approach.

Reconstruction of the EUV Irradiance for Solar Cycle 23

Margit Haberreiter

We present reconstructions of the EUV from 26 to 34 nm from February 1997 to May 2005, covering most of solar cycle 23. The reconstruction is based on synthetic EUV spectra calculated with the spectral synthesis code Solar Modeling in 3D (SolMod3D). These spectra are weighted by the relative area coverage of the coronal features as identified from EIT images. The reconstructed EUV irradiance shows good agreement with observations taken with the CELIAS/SEM instrument onboard SOHO.

The EUV radiation incident on the upper Earth's atmosphere leads to a change in its temperature and density. In order to understand the effects of changing EUV radiation on the Earth's atmosphere a continuous data set covering short-term and long-term variations is essential. However, as space instruments are limited with regard to their temporal and spectral coverage, reliable models are needed to fill the gaps of the observational data sets. Here we discuss reconstructions of the EUV with a focus on the wavelength range from 26 to 34 nm as observed with the SOHO/SEM instrument onboard SOHO.

The spectral synthesis of the EUV is carried out with the SolMod3D code (Haberreiter 2011). It is a state-of-the-art radiative transfer code in full non-local thermodynamic equilibrium (NLTE). SolMod3D allows for the spherical line-of-sight integration which is very important for the correct calculation of the coronal emission. The code has already been successfully employed for the calculation of the quiet Sun EUV spectrum and for solar limb studies (Thuillier et al. 2011).

The calculations of the spectra are based on semi-empirical structures that represent a temporal and spatial mean of the photosphere, chromosphere, transition region and corona. For the photosphere, chromosphere, and transition region the full NLTE radiative transfer is solved, and is based on the latest semi-empirical atmospheric structures by Fontenla et al. (2009). The coronal lines are calculated as optically thin lines. Currently we employ four coronal structures; three represent different features of the quiet Sun, i.e. the quiet corona, coronal network and active coronal network as described in Haberreiter (2011). A fourth structure is used for the bright coronal regions. The coronal holes are currently represented with a contrast of 0.5 with respect to the quiet corona.

First, intensity spectra are calculated for different features on the solar disk as described above. These spectra are then weighted by filling factors derived from the analysis of solar images. For the study presented in here we use the 3-component analysis of images taken with the Extreme UV Imaging Telescope (Delaboudinière et al. 1995) onboard SOHO carried out by Barra et al. (2009). This analysis provides the disk-integrated relative area coverage of coronal holes, the quiet corona, and active coronal regions detected on the solar disk. However, in this analysis the extended active regions located beyond the solar limb are not yet taken into account. Therefore, in order to compensate for the missing radiation, we assume an additional 20 % increase of the irradiance due to the flux coming from the extended corona. The analysis of detailed features of the off-limb will be included in future work.

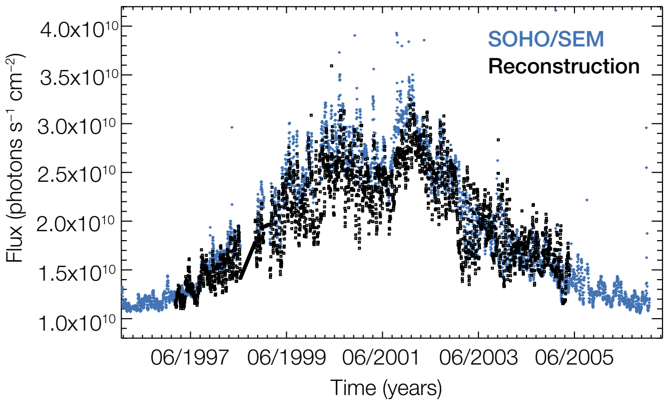

Figure 1. Reconstruction of the EUV photon flux at 1 AU for the wavelength range from 26 to 34 nm (black squares) compared with the SOHO/SEM observations for the same wavelength range (blue diamonds). See also Haberreiter (2012).

Figure 1 shows the reconstruction of the EUV photon flux in the wavelength range from 26 to 34 nm from Feb 14, 1997 to May 1, 2005 (black squares). The reconstructed irradiance shows good agreement with the observations from the CELIAS/SEM instrument onboard the SOHO satellite. The good agreement shows that our approach is suitable for the study of the EUV variability. Nevertheless, further analysis is required, in particular the study of the off-limb contribution to the EUV irradiance and the consideration of additional coronal activity features.

Acknowledgement: MH acknowledges the support of the Swiss Holcim Stiftung Wissen.

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Formation of the Solar Lyman-α Line

Micha Schöll, Werner Schmutz, Margit Haberreiter, and Alexander Shapiro

The solar Lyman-α line is an important line for solar physics as well as for impact on the climate. The temperature structures in the solar chromosphere and lower transition region are the dominant factors that determine the strength and shape of Lyman-α line. We modified existing solar atmosphere structures to better reproduce the observed solar Lyman-α line in high spectral resolution using the Code for Solar Irradiance (COSI).

The spectral irradiance emitted by the solar Lyman-α line varies over timescales from minutes to decades and possibly to millennia. The variations in this line are of special interest to solar physics and climatology due to its impact on the ozone layer and the temperature sensitivity of the upper mesosphere (Rozanov et al., 2002). A new method to reconstruct the long-term solar irradiance back to the Maunder minimum has been developed by Schöll (2011). This model uses the Code for Solar Irradiance (COSI, Haberreiter et al. 2008, Shapiro et al. 2010) and also employs the "active area enhancement" (AAE), a height-dependent model describing the magnetic expansion of active areas such as faculae and sunspots over the photosphere and chromosphere. This approach improves the agreement with the observed solar spectrum in the UV shortwards of 180 nm, including the Lyman-α emission line at 121.5 nm.

The method used by Schöll (2011) and further employed by Shapiro et al. (2011) uses atmosphere structures constructed by Fontenla et al. (1999) (hereafter FAL99). Possible changes to the FAL99 atmosphere structures and COSI are discussed in Schöll (2011) in order to obtain an improved line profile. These changes include: 1) adjusting the temperature and density stratification and additional Doppler broadening of the atmospheric models and 2) the implementation of ambipolar diffusion as described by Fontenla et al. (1990).

Recent SUMER measurements yielded a rich dataset of quiet-Sun Lyman-α profiles (Curdt et al., in prep.). The line intensity varies by two orders of magnitude but the self-similarity of the lines is remarkable, especially in the wings of the line. The synthetic Lyman-α profile modeled with the existing atmosphere structures displays three discrepancies to observations: The steepness of the Gaussian broadening, the strong collisional broadening, and the width of the peaks, which are narrower in the calculation compared to observations. Here we attempt to fit the synthetic Lyman-α profile to observations with minimum change to the FAL99 atmospheric structure.

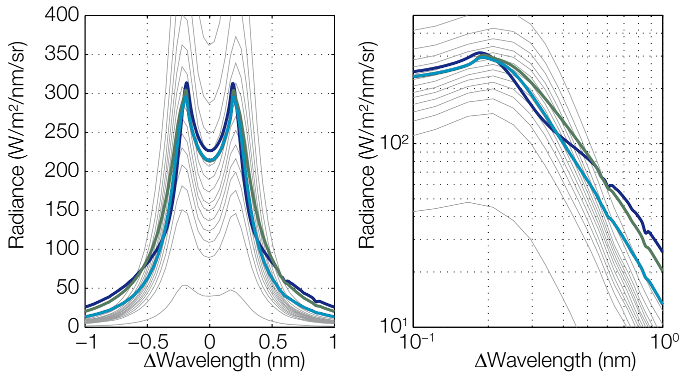

Figure 1. The Lyman-α spectral line calculated with the COSI code compared to SUMER observations. Left: The synthetic line profiles based on the original temperature profile (dark blue), along with the calculation based on a decrease of the temperature gradient in the chromosphere by a factor two (green) and a factor 4 (light blue). Each thin line represents the sorted average of 4000 observed SUMER profiles. Right: The right part of the same profiles as in the left frame plotted in a log-log scale.

The formation height of Lyman-α line in the solar atmosphere is above the temperature minimum and thus, only the layers of the chromosphere and the lower transition region need to be changed. The Lyman-α line profile depends on the temperature gradient and the density. Figure 1 shows the temperature dependence of Lyman-α by decreasing the temperature gradient of the chromosphere by a factor of two and four. The best fit to Lyman-α is obtained by using a flat chromosphere but retaining the structure of the FAL99 transition region. The extension of the chromospheric plateau is similar to results obtained in Fontenla et al. (2009).

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Solar Rotational Variability in the LYRA 199–222 nm Spectral Band

Anna Shapiro, Alexander Shapiro, Werner Schmutz, Christoph Wehrli, and Eugene Rozanov in collaboration with ROB Belgium

We analyzed the variability of the spectral solar irradiance during the period January 7–20, 2010, as measured by the Herzberg channel (199–222 nm) of the Large Yield RAdiometer (LYRA) onboard PROBA2. We present the algorithm that allows the solar variability to be extracted from LYRA data. A comparison of results with SOLSTICE/SORCE measurements and calculations with the Code for the Solar Irradiance (COSI) is also made.

LYRA is a solar radiometer onboard PROBA2, which is a technologically oriented ESA micro-mission, and observes the solar irradiance in two UV and two EUV spectral channels. Our analysis is restricted to the LYRA Herzberg channel as irradiance in the Herzberg continuum (199–222 nm) is especially important for climate modeling. The analysis of the rotational cycle solar variability in this channel is significantly hampered by severe degradation and pointing fluctuations which in combination with the inhomogeneous sensitivity of the diamond detectors has resulted in significant data fluctuations.

We analyse LYRA data for the period January 7–20, 2010. During this period, one sunspot group surrounded by the plage region made a full transit through the near-side of the solar disk. Using a special technique we extracted the solar signal from the data. Our final product is a single irradiance value every four-orbit interval. Depending on the employed filter degradation and off-pointing correction we produced two LYRA time series. The comparison of these time series (version 1 and version 2) with SOLSTICE measurements and calculations with COSI is presented in Figure 1. The SOLSTICE data (available with 1 nm spectral resolution) and the calculated irradiance (available with 5 mÅ spectral resolution) were converted with the combined profile of the Herzberg filter and detector. Although LYRA measurements indicate a significant increase in irradiance on January 13 and 14 that is not shown in SOLSTICE/SORCE measurements and COSI calculations, the solar signal extracted from the LYRA time series is in reasonable agreement with SOLSTICE and COSI data.

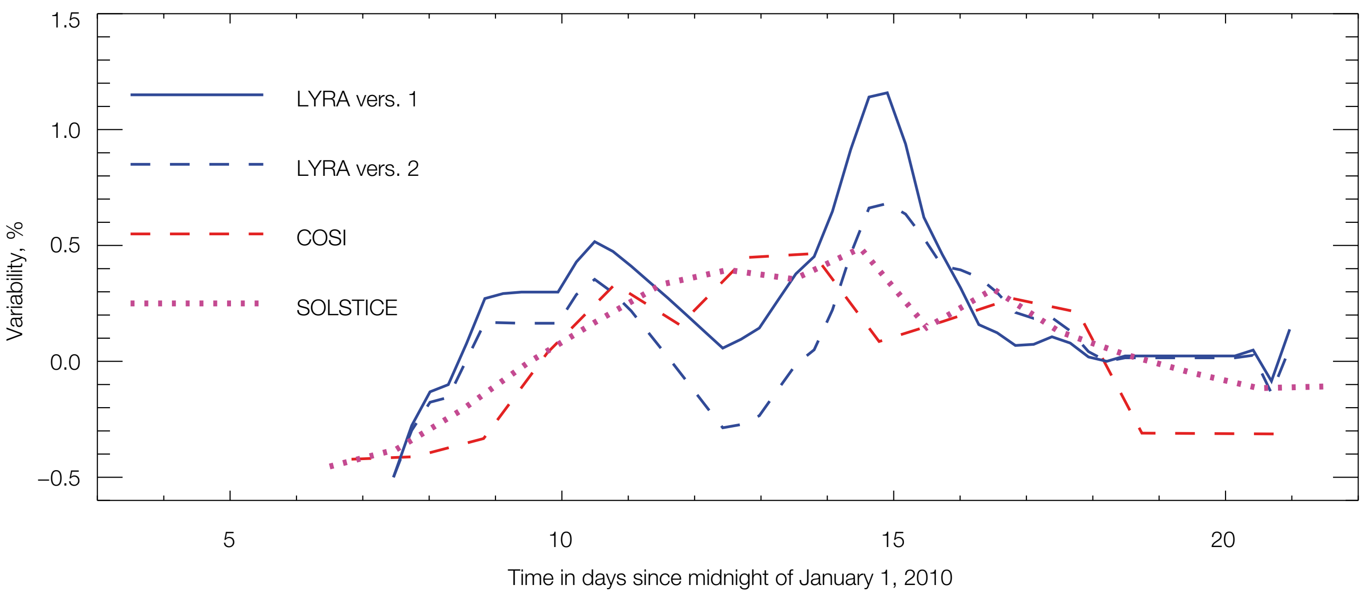

Figure 1. The variability of the solar irradiance in the Herzberg continuum range (199–222 nm) as measured by LYRA and SOLSTICE, and in COSI calculations.

Solar Eclipses Observed by LYRA

Alexander Shapiro, Werner Schmutz, Anna Shapiro in collaboration with ROB Belgium

We analyse the light curves of recent solar eclipses measured by the Herzberg channel (200–220 nm) of the Large Yield RAdiometer (LYRA) onboard PROBA2. The measurements allow us to accurately retrieve the center-to-limb variations (CLV) of the solar brightness. Comparison of the CLV retrieved and calculated with the 1D NLTE radiative transfer COde for Solar Irradiance (COSI) provide us with the possibility to test and constrain the existing 1D models of the solar atmosphere.

The light curves of the two transits from the eclipse on January 15, 2010 are presented in Figure 1. The profiles of the variation in irradiance during the transits depend on the CLV of the solar brightness and thus the measurements allow the CLV to be determined.

We employ the COSI code to model the CLV dependencies and compare them with those deduced from LYRA measurements. In panel (a) of Figure 2 we present the CLV calculated by employing different models of the solar atmosphere. One can see that the calculations with model C, which is usually used to describe the average quiet solar atmosphere, underestimate the CLV and are outside of the estimated error region. One of the possible reasons for this could be the assumption that the missing UV opacities (which have not yet been identified, see Kurucz (2005) and Shapiro et al. (2010)) do not depend on the depth in the solar atmosphere. In panel (b) of Figure 2 we present the calculated CLV assuming that the additional opacity scales with the relative concentration of different chemical species.

Our results suggest that the missing opacity originates in the layer a few hundred kilometers below the temperature minimum and could be due to the unaccounted lines of neutral iron or another element with a similar ionization potential (e.g. silicon or magnesium) or due to the unaccounted molecular lines (e.g. CN). The fact that COSI calculations are in good agreement with the measurements strongly supports its suitability for modeling the solar variability.

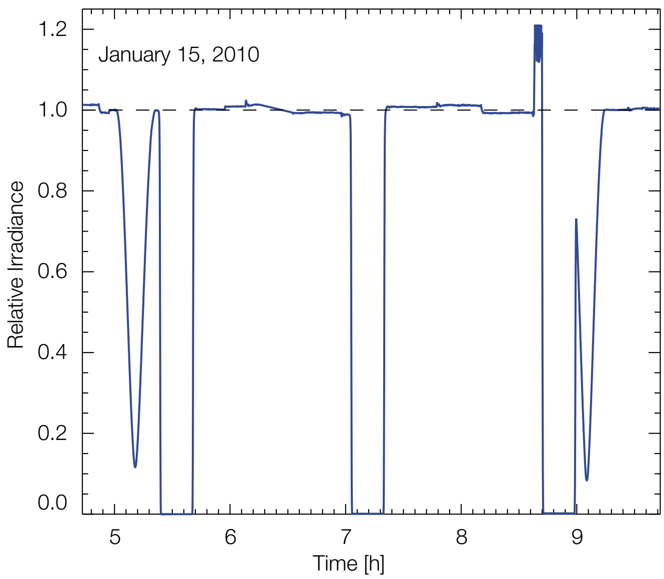

Figure 1. Relative variations of the irradiance as measured by the Herzberg channel of LYRA on January 15, 2010. One can see two partial solar eclipses separated by the three occultations (periods of time when PROBA-2 enters the Earth's shadow). The periodic abrupt changes of the irradiance level are due to the spacecraft maneuvers.

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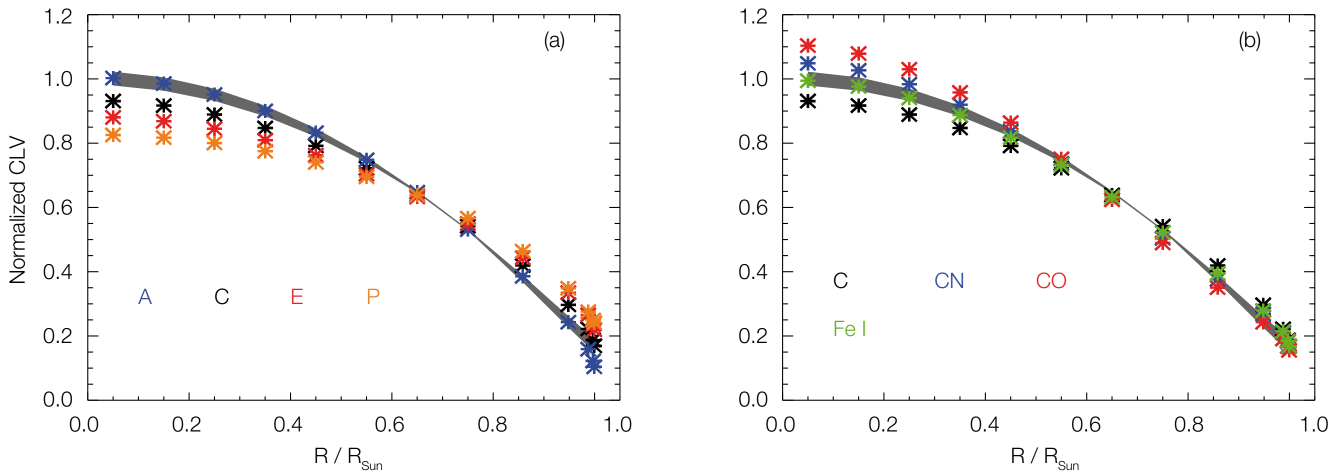

Figure 2. Comparison of the CLV retreived from the analysis of eclipse observations with calculated CLV. Calucaltions presented in panel (a) are performed employing different solar atmosphere models: faint supergranule cell interior (model A), average supergranule cell interior (model C), quiet network (model E) and plage (model P). Calculations in panel (b) are perfromed with model C and by scaling the additional opacity with the relative concentration of CN, CO and Fe I. The "C" points correspond to the height-independent additional opacitiy. The shaded area on both panels indicates the error range of the CLV retrieved from LYRA data.

Analysis of Solar Eclipses Observed by PREMOS/PICARD

Rinat Tagirov, Alexander Shapiro, Werner Schmutz, Gaël Cessateur in collaboration with CNES, Paris, France

The PREMOS instrument onboard the PICARD mission comprises two experiments. One, observing solar irradiance in five spectral channels (two UV, one visible and two near infrared, see Fig. 1) with filter radiometers, and the other measuring the total solar irradiance with absolute radiometers. We analyse light curves of recent solar eclipses measured by PREMOS.

During eclipses different parts of the Sun are consecutively covered by the Moon. Hence light curves of eclipses can be used to accurately retrieve center-to-limb variations of the solar brightness (CLV). The formation height of solar radiation depends on the observing angle and wavelength. Therefore CLV retrieved from measurements in different spectral channels provides important information about a broad range of heights in the solar atmosphere and is valuable for adjusting and refining radiative transfer models.

PREMOS has observed three solar eclipses (June 1, 2011; July 1, 2011; November 25, 2011) up to now. We employ the radiative transfer COde for Solar Irradiance (COSI) to model the CLV (Figure 1) and the light curves of these eclipses. Detailed analysis of the discrepancies between the theoretical and the observed light curves in all PREMOS channels (Figure 2) will allow us to constrain and improve existing semi-empirical 1-D models of the solar atmosphere.

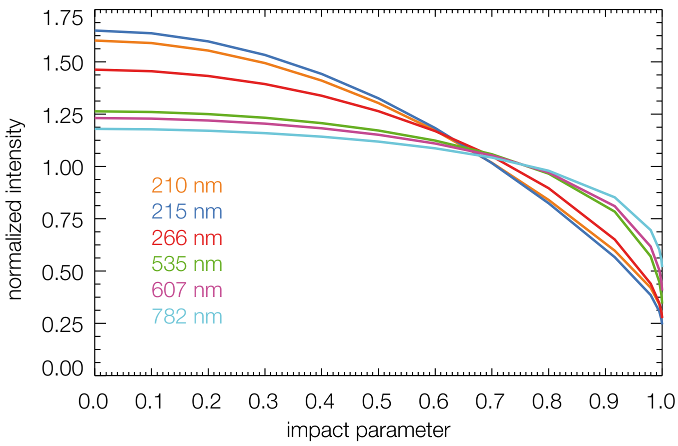

Figure 1. Center-to-limb variations of the solar brightness calculated with COSI and convolved with PREMOS transparency curves.

A similar analysis for the eclipses on January 15, 2010 and July 11, 2010 was recently performed by Shapiro et al. (2012) using the measurements in the Herzberg channel of the LYRA instrument onboard the PROBA-2 mission. We compare the main results and show that the measurements in five PREMOS spectral channels allow us to significantly complement the analysis of the LYRA measurements.

References: Shapiro A., Schmutz W., Dominigue M., Shapiro A.: 2012, Eclipses observed by LYRA – a sensitive tool to test the models for the solar irradiance, Sol. Phys., in press.

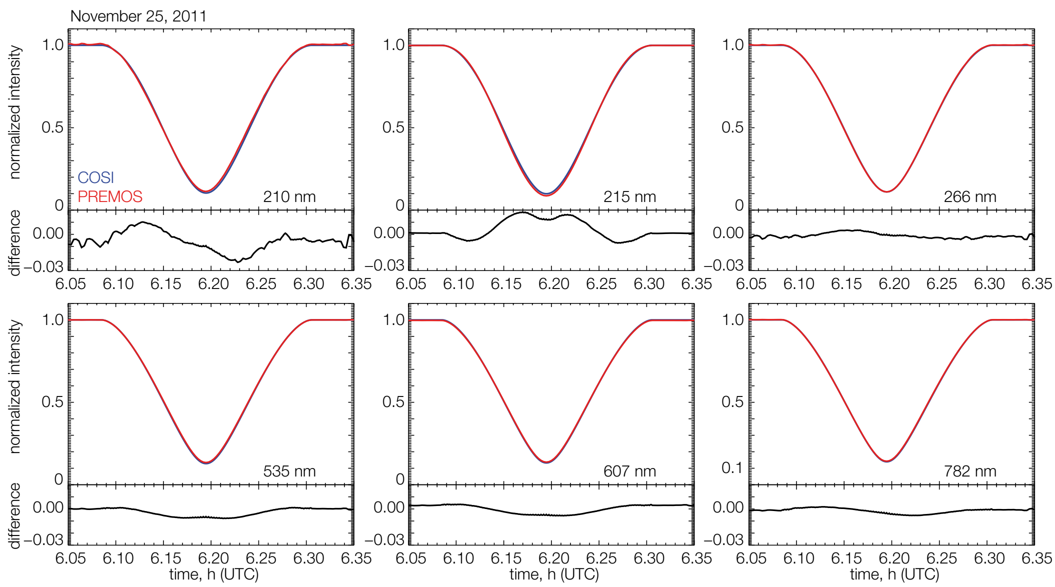

Figure 2. Comparison of the November 25, 2011 eclipse profiles in all spectral channels as calculated by COSI and observed by PREMOS. Upper panels: the modeled light curve vs. the observed one. Lower panels: the difference between the curves displayed on the upper panels (theory minus observations).

First Light of PREMOS/PICARD

Werner Schmutz, André Fehlmann, Wolfgang Finsterle, and the PREMOS team, in collaboration with LASP Boulder USA, NPL Teddington UK, LATMOS France, CNES France, METAS Bern Switzerland, and PTB Berlin Germany

PREMOS on the French satellite PICARD is the first operational space experiment with an absolute radiometer that has been calibrated in vacuum traceable to the SI system. The measurements of PREMOS at first light on July 27, 2010, yield a Solar Constant of 1360.9±0.4 W/m², with the error being the one-sigma uncertainty of the instrument calibration.

PREMOS measurements are resolving an eight-year discrepancy in the actual value of the Total Solar Irradiance. The experiment TIM on SORCE measured a Total Solar Irradiance around 1360.9 W/m² in 2010, whereas other experiments, e.g. VIRGO on SOHO or ACRIM3 on ACRIMSAT, yielded values of the order of 1365.4 W/m². The difference of 4 W/m² between VIRGO and TIM is about a factor five or ten, respectively, larger than the uncertainties claimed by both experiments. In addition to the power calibration reported by Schmutz et al. (2009), the irradiance response of one of the PREMOS absolute radiometers was at the Total solar irradiance Radiometer Facility (TRF) located at the Laboratory for Atmospheric and Space Physics (LASP) in Boulder USA. Figure 1 shows one of four calibration runs of the absolute radiometer, which yielded a combined calibration accuracy of 330 ppm. On first light, the difference of PREMOS/PICARD to TIM/SORCE was 0.4 W/m², with PREMOS reading lower but agreeing well within the common uncertainty. Thus, the demonstrated measurement agreement by two independent experiments has decreased by about a factor ten.

The characterization of PREMOS at TRF allows the past discrepancy to better be understood. Instruments having a view-limiting aperture in front and a smaller precision aperture, which defines the area, behind, such as e.g. the PMO6 and ACRIM type instruments, have a large amount of light within the instrument. This additional light is not fully absorbed by the baffle system and produces scattered light that contributes to the power measured by the cavity. Scattered light was one of the potential systematic errors suspected by Butler et al. (2008) as a possible reason for the discrepancy in measurements of the solar constant. The stray light contribution has been estimated in the past for PMO6 type instruments but was severely underestimated. The characterization of the PREMOS flight instrument yielded a stray light contribution of 1800 ppm, much higher than the expected 250 ppm.

A VIRGO spare instrument of type PMO6-V has also been investigated for stray light at the TRF facility and a stray light contribution of 2960 ppm was found. As the amount of stray light varies from instrument to instrument, the uncertainty of this additional characterization is undetermined. Nevertheless, if we assume

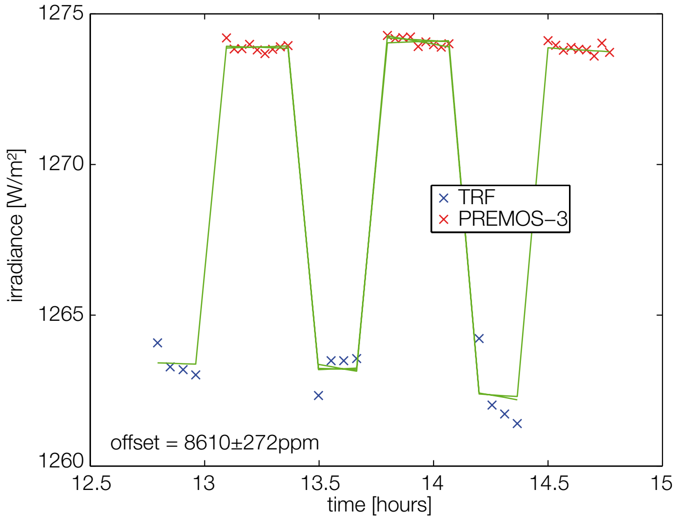

Figure 1. Comparison of the absolute radiometer PREMOS-3, which is the operational PREMOS A instrument, to the cryogenic radiometer at the TRF facility at LASP in Boulder USA. The upper measurements are the values of PREMOS-3, the lower ones of TRF radiometer. The offset between the two instruments drawn in green allows for a quadratic slow drift in irradiance of the illuminating laser. The difference between the measurements yields the calibration. The uncertainty of the calibration is given by the combined uncertainties of the comparison and the uncertainty of the TRF facility, which is traceable to a primary cryogenic radiometer at NIST.

that this correction can be applied to the VIRGO flight instruments the discrepancy of VIRGO to TIM and PREMOS is reduced by 4 W/m². Thus, in essence, the VIRGO difference is most probably due to underestimated stray light in the VIRGO instruments. VIRGO instruments on SOHO have also been calibrated against the World Radiometric Reference (WRR) at Davos. Recent investigations have now revealed that WRR measurements are too high by 3400 ppm relative to the SI system (Fehlmann et al. 2012). This yields a consistent evaluation of the solar constant from three instruments: TIM/SORCE, VIRGO/SOHO (corrected), and from PREMOS/PICARD.

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Other Publications

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Administration

Personnel Department

Sonja Degli Esposti and Werner Schmutz

The year 2011 was affected by the renovation work at our institute. All staff had to leave the building in spring and were housed in two different premises which meant the packing of all belongings and organization of work in a new environment. This implied a lot of additional work as well as having to cope with a new situation. All staff members did a great job!

In 2011, six new employees joined our institute.

On 1st of January 2011, Manfred Gyo started his job at PMOD/WRC as our new head of the technical department. Manfred is a well-trained electronic engineer with years of experience in IT Systems and Project management. We are happy to have him in our team and to tackle all our current and future challenges with him.

Further space projects required the reinforcement of our technical department: Fabian Dürig, a mechanical engineer, joined the technical group on 1st August 2011 and supports the team in many areas. We are glad to have him at PMOD.

At the same time, Eliane Tobler, our new administration apprentice started her education in our department. We all wish Eliane a successful apprenticeship and are looking forward to the upcoming three years.

Two weeks later, on 15th August 2011, Luca Egli, a physicist was hired and took over the position within our EMRP-Project "Traceability for surface spectral solar ultraviolet radiation". Luca did his PhD studies at the Institute for Snow and Avalanche Research (SLF) in Davos where he already gained experience in radiation measurements. Welcome Luca!

In September, Rinat Tagirov, a new PhD Student was hired. He started his work within the Swiss National Science Project “Swiss Solar Radio Flux Monitor: Technology demonstration and physical understanding of the solar irradiance at radio frequencies” on 1st September 2011. With his employment the number of PhD students increased to six.

Gaël Cessateur was hired on 1 December 2011 and is working as a Physicist in our Solar physics Group. Bienvenue Gaël!

As in every year, a few employees left our institute: Matthias Müller discontinued his apprenticeship in order to pursue a different career in Lucerne . Andreas Schätti, mechanic, finished his temporary employment in August and started his studies.

In 2011, the second administration apprentice successfully finished her training. Nadia Casanova spent three years at our institute and became acquainted with the numerous administrative tasks of a research institute. We thank Nadia for her contribution to the administration and for the successful completion of her apprenticeship.

Edgar Schmucki, a PhD student, pursued his education in a different research field and started a new PhD at the Institute for Snow and Avalanche Research in Davos.

In 2011, two PhD students successfully finished their thesis and obtained a Doctorate: André Fehlmann and Micha Schöll – congratulations to both of them. Well done!

Last year Stephanie Ebert started a course in Desktop Publishing and successfully finished it with a degree in October. She is responsible for the layout of all our publications and really does a good job! Sonja Degli Esposti successfully received the Master of Advanced Studies FHO in Business Administration from HTW Chur. Congratulations, Stephanie and Sonja!

Last but not least: Numerous civilian conscripts had their hands full during the last year. Many thanks again to them all.

Scientific Personnel

Prof. Dr. Werner Schmutz	Director, physicist
Dr. Gaël Cessateur	Postdoc solar physics group, physicist (since 01.12.2011)
Dr. Luca Egli	Postdoc EUVC section, physicist
Dr. Tatiana Egorova	Climate group scientist, meteorologist
Dr. Wolfgang Finsterle	Head WRC-section solar radiometry, physicist
Dr. Julian Gröbner	Head WRC-sections IR radiometry, WORCC and EUVC, physicist
Dr. Margit Haberreiter	Scientist, physicist, solar physics
Dr. Gregor Hülsen	EUVC scientist, physicist
Dr. Stephan Nyeki	WORCC scientist, physicist
Dr. Eugene Rozanov	Climate group scientist, physicist
Dr. Alexander Shapiro	Postdoc solar physics group, physicist
Dr. Rosaria Simoniello	Postdoc solar physics group, physicist
Dr. Stefan Wacker	Postdoc, WORCC section, physicist
Dr. Christoph Wehrli	WORCC scientist, physicist
Dr. André Fehlmann	PhD student, UNIZH (until 31.10.2011) Postdoc solar physics group, physicist (since 01.11.2011)
Daniel Lachat	PhD student, UNIBE
Edgar Schmucki	PhD student, UNIBE (until 28.02.2011)
Markus Suter	PhD Student, UNIZH
Dr. Micha Schöll	PhD student, ETHZ (until 30.11.2011) Postdoc (until 31.01.2012)
Anna Shapiro	PhD student, ETHZ
Tagirov Rinat	PhD student, ETHZ (since 01.09.2011)

Technical Personnel

Manfred Gyo	Head technical department, electronic engineer, Quality System manager (since 01.01.2011)
Daniel Bühlmann	Technician
Etienne de Coulon	Software development engineer
Fabian Dürig	Mechanical engineer (since 01.08.2011)
Daniel Pfiffner	Project manager space experiments, deputy head technical department and Quality System, electronic engineer
Andreas Schätti	Mechanic (until 31.07.2011)
Marco Senft	Software developer
Ricco Soder	Research engineer
Marcel Spescha	Technician
Christian Thomann	Technician
Diego Wasser	Electronic technician
Matthias Müller	Electronics apprentice, 2nd year (until 31.03.2011)
Thierry Hartmann	Electronics apprentice, 1st/2nd year

Administration

Sonja Degli Esposti	Head administration/Human Resources
Stephanie Ebert	Administration, book-keeping
Irene Keller	Administration, import/export
Nadia Casanova	Administration apprentice, 3rd year (until 31.07.2011)
Eliane Tobler	Administration apprentice, 1st year (since 01.08.2011)

Caretaker

Stana Petrovic	General caretaker, cleaning

Civilian Service Conscripts

Detlef Conradin	until 14.02.2011
Japhet Schmid	03.01. – 04.03.2011
Samuel Giger	07.03. – 13.05.2011
Leo Maag	28.03. – 12.09.2011
Amos Schaub	16.05. – 22.07.2011
Espen Denstad	05.09. – 30.12.2011
Dominic Peter Burren	05.09. – 23.12.2011

Public Seminars

25/01/2011	Ilya Usoskin, Sodankyla Geophysical Observatory, Univ. of Oulu, Finland, Long-term reconstructions of solar activity in the past by means of cosmogenic isotope method
08/03/2011	Dr. Donald Hassler, Southwest Research Institute, Boulder, USA, The SPICE instrument
14/03/2011	Albert Romann, Pulsed and modulated photoacoustic and transmission spectroscopy on trace gases employing continuously tunable CO2 and diode lasers
24/03/2011	Markus Roth, KIS Freiburg i. Br., Helioseismology in solar cycle 24
01/04/2011	JungMi Lee, South Korea, The GAW Programme Activities in the Korean Met. Administration (KMA)
11/05/2011	Rinat Tagirov, Physical Conditions in Molecular Clouds at High Redshift
17/05/2011	Gaël Cessateur, CNRS Orleans, Solar UV Variability: From Modelisation to Application
11/07/2011	Eric Shirley, NIST, TSI Instruments and Diffraction and Other Effects
22/08/2011	Michael Gnos, Sustainable Energy Technologies LLC Florida, USA, On the Design of a Low Cost Pyrheliometer System
01/09/2011	Chris Hoyle, Climate consequences of a regional nuclear conflict
29/09/2011	Michele Bianda, IRSOL Istituto Ricerche Solari Locarno, A short introduction to Istituto Ricerche Solari Locarno, IRSOL; H.N. Smitha, IRSOL Istituto Ricerche Solari Locarno, Quantum Interference phenomena in the Second Solar Spectrum
30/09/2011	Christos Halios, University of Athens, Application of statistical methods on long-term measurements

Course of Lectures, Participation in Commissions

Werner Schmutz	Course of lecture Astronomie, HS 2011, ETH-ZH Examination expert in astronomy, BSc ETH-ZH, PhD sci. nat. ETH-ZH, and PhD Uni ZH Vice president of the International Radiation Commission (IRS, IAMAS) Comité consultatif de photométrie et radiométrie (CCPR, OICM) Science Programme Committee, ESA Expert group on space weather of the UN Committee on the Peaceful Uses of Outer Space Swiss representative in the Committee on Space Research (COSPAR) Swiss Management Committee delegate to the COST action ES00803 (ECF) Swiss Management Committee delegate to the COST action ES01005 (ECF) President of the national Committee on Space Research, Commission of SCNAT Executive board of the Swiss Society Astronomy Astrophysics (SSAA), SCNAT Member of the Commission for Astronomy, SCNAT GAW-CH working group (MeteoSwiss)
Wolfgang Finsterle	CIMO expert team on Standardization
Julian Gröbner	Course of Lecture Solar Ultraviolet Radiation WS 2011, ETH-ZH GAW-CH Working group (MeteoSwiss) NEWRAD Scientific committee member - chair elect Chairman of Infrared Working group of Baseline Surface Radiation Network (BSRN) International Radiation Commission (IRS, IAMAS) CIMO expert team on New In-Situ Technologies
Margit Haberreiter	Course of lecture Astronomie, HS 2011, ETH-ZH, 2 lectures Scientific Organizing Committee of the IAU Symposium 286 Swiss Management Committee substitute delegate to the COST action ES01005 (ECF); Work package leader IAU Working Group on Comparative Solar Minima
Eugene Rozanov	International Commission on the Middle Atmosphere (ICMA, IAMAS) Swiss Management Committee delegate to the COST action ES01005 (ECF)
Christoph Wehrli	Aerosol Optical Depth course at GAWTEC and at Korea Met. Agency GAW-CH Working group (MeteoSwiss) Scientific Advisory Group Aerosol (WMO/GAW) SAG sub group AOD, chairman (WMO/GAW) Working group Baseline Surface Radiation Network (WMO/WCRP)

Modernization and Renovation of the Institute Building

Werner Schmutz and Stephan Nyeki

Renovation work on the Institute building continued throughout 2011 (see Figure 2). The main phase of the building renovation started after Easter, when all staff, office furniture and laboratory equipment had to be re-located. Technical staff had already re-located to a container block in the Institute car park which allowed them continued easy access to workshop facilities. Scientific staff re-located to Holland House, just opposite the Davos Congress Center. Holland House is a fine example of Belle Époque architecture and used to house the Netherlands Asthma Center. The main phases of the renovation work in 2011 included the following:

- Renovation of the roof including a new concrete floor in the loft which is now a multi-media seminar room for scientific and public meetings.
- A new staircase extends up to roof-level where a large platform will accommodate an extensive suite of instruments for calibration and long-term measurements.
- Renovation of the inner and outer walls was completed towards December 2011, while heating, telephone, security, and fire systems were still being worked on.
- Old features of the Institute, a former schoolhouse at the turn of the 20th Century, such as wood paneling and flooring were renovated to keep the character of the building as intact as possible. An interesting feature came to light during renovation of the dome roof in Figure 1: A note was found in the decorative sphere at the top of the dome. The note listed the names of the roofers, the construction date (9 July 1910), the time taken (7 weeks), and the daily wages (CHF 7.50) for a day's work 9.5 hours. A similar note was therefore placed into this historical archive to be discovered during the building's next renovation!

Figure 1. View of the PMOD dome roof.

At the time of writing, Technical staff were about to move back into the lower floor of the Institute building. Scientific staff will have to wait until October 2012 before they can also move back as one important phase of renovation remains, namely, the installation of the geo-thermal central heating facility. The car park will become a building site again when boreholes are sunk several hundred meters into the bedrock under the Institute to extract geothermal heat.

The entire modernization and renovation program has not been without expense: The Federal Office for Building and Logistics contributed over CHF 4.659 Million in 2011. However, the results will be worth the effort and we look forward to moving back.

Figure 2. Vew of the PMOD shortly before removal of the scaffolding.

Bilanz 2011 inklusive Drittmittel

Aktiven	31.12.2011 CHF
Flüssige Mittel/Wertschriften	2'463'725.85
Forderungen	187'896.30
Kontokorrent Stiftung	4'385.05
Aktive Rechnungsabgrenzungen	230'954.10
	2'886'961.30

Passiven	
Verbindlichkeiten	239'269.30
Passive Rechnungsabgrenzungen	1'366'132.75
Rückstellungen	1'063'076.19
Eigenkapital	218'483.06
	2'886'961.30

Erfolgsrechnung 2011 inklusive Drittmittel

Ertrag	CHF
Beitrag Bund Betrieb WRC	1'287'868.00
Beitrag Kanton Graubünden	213'316.95
Beitrag Gemeinde Davos	558'802.80
Beitrag Gemeinde Davos, Mieterlass	149'486.60
Beitrag Bund (BBL) Vorprojekt Umbau Institutsgebäude	4'659'000.00
Beitrag GAW/CH für EUVC	166'649.00
Indirekte Kosten SOTERIA	35'594.00
Overhead SNF	115'632.42
Instrumentenverkäufe	434'157.65
Kalibrationen	234'430.20
Übriger Ertrag	13'157.50
Finanzertrag	19'243.00
Ausserordentlicher Ertrag	2'551.02
Drittmittel	1'287'418.70
	9'177'307.84

Aufwand	CHF
Personalaufwand	3'247'756.35
Investitionen	390'780.65
Unterhalt	58'048.70
Verbrauchsmaterial	108'721.40
Verbrauch Commercial	147'088.30
Reisen, Kongresse, Kurse	162'392.45
Raumaufwand/Energieaufwand	221'893.20
Verwaltungsaufwand	112'655.28
Finanzaufwand	23'752.96
Übriger Betriebsaufwand	25'876.80
BBL Vorprojekt Umbau Institutsgebäude	4'659'000.00
	9'157'966.09
Ergebnis 2011	19'341.75
	9'177'307.84

Abbreviations

AERONET	Aerosol Robotic Network, GSFC
AOD	Aerosol Optical Depth
ASRB	Alpine Surface Radiation Budget
BIPM	Bureau International des Poids et Mesures, Paris, F
BISON	Birmingham Solar Oscillation Network
BOLD	Blind to Optical Light Detector
BOS	Bolometric Sensor, Belgium instrument on the mission PICARD
BSRN	Baseline Surface Radiation Network of the WCRP
BUSOC	Belgian User Support and Operation Centre of ESA
CCM	Chemistry-Climate Model
CAS	Commission for Atmospheric Sciences, Commission of WMO
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
CMC	Calibration and Measurement Capabilities
CNES	Centre National d'Etudes Spatiales, Paris, F
CNRS	Centre National de la Recherche Scientifique, Service d`Aéronomie Paris
CoI	Co-Investigator of an Experiment/Instrument/Project
COSI	Code for Solar Irradiance – Solar Atmosphere Radiation Transport Code developed at PMOD/WRC
COSPAR	Commission of Space Application and Research of ICSU, Paris, F
CSAR	Cyrogenic Solar Absolute Radiometer
CSL	Centre Spatial de Liège
CTM	Chemical Transport Model
CUCF	Central UV Calibration Facility, NOAA, Boulder, USA
DARA	Digital Absolute Radiometer
DIARAD	Dual Irradiance Absolute Radiometer of IRMB
DLR	Deutsche Luft und Raumfahrt
ESA	European Space Agency
ESF	European Science Foundation
ESTEC	European Space Research and Technology Center, Noordwijk, NL
ETH	Eidgenössische Technische Hochschule (Z: Zürich, L: Lausanne)
EUI	Extrem Ultraviolet Imager, Experiment on Solar Orbiter, to be launched 2017
EURECA	European Retrievable Carrier, flown August 1992 – June 1993 with SOVA Experiment of PMOD/WRC
EUSAAR	FP6 project: European Supersites for Atmospheric Aerosol Research
EUV	Extreme Ultraviolet Radiation
EUVC	European Ultraviolet Calibration Center at PMOD/WRC
FMI	Finnish Meteorological Institute
FP7	European Framework Program of the European Commission
FRC-III	Third Filter Radiometer Comparison
FSI	Full Sun Imager
GAW	Global Atmosphere Watch, an Observational Program of WMO
GAWTEX	GAW Training & Education Center
GCM	General Circulation Model
GHG	Greenhouse Gases
GOLF	Global Oscillations at Low Frequencies, Experiment on SOHO
GSFC	Goddard Space Flight Center, Greenbelt, MD, USA
HRI	High Resolution Imagers
IACETH	Institute for Climate Research of the ETHZ
IAMAS	International Association of Meteorology and Atmospheric Sciences of IUGG
IAPS	Intensified Active Pixel Sensor
IAS	Institut d'Astrophysique Spatiale
IAU	International Astronomical Union of ICSU, Paris, F
ICSU	International Council of Scientific Unions, Paris, F
IO	Institut d'Optique
IPC	International Pyrheliometer Comparisons
IR	Infrared
IRC	International Radiation Commission, Commission of IAMAS
IRIS	Infrared Integrating Sphere Radiometer
IRMB	Institut Royal Météorologique de Belgique, Brussel, B
IRS	International Radiation Symposium of the Radiation Commission of IAMAS
IRSOL	Istituto Ricerche Solari Locarno
ISO/IEC	International Oranisation for Standardization/International Electrotechnical Commission
ISS	International Space Station
IUGG	International Union of Geodesy and Geophysics of ISCU
JRC	Joint Research Center of the European Commission in Ispra, I
KIS	Kiepenheuer-Institut für Sonnenphysik, Freiburg i.Br., D
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

MGO	Main Geophysical Observatory, St. Petersburg, RUS
MITRA	Monitor to Determine the Integrated Transmittance
MPS	Max Planck Institute for Solar System Research
MSSL	UCL Mullard Space Science Laboratory
NASA	National Aeronautics and Space Administration, Washington DC, USA
NEWRAD	New Developments and Applications in Optical Radiometry
NILU	Norwegian Institute for Air Research
NIST	National Institute of Standards and Technology, Gaithersburg, MD, USA
NOAA	National Oceanographic and Atmospheric Administration, Washington DC, USA
NPL	National Physical Laboratory, Teddington, UK
NRI	Near Infrared
NRL	Naval Research Laboratory, Washington DC, USA
NREL	National Renewable Energy Lab, Golden, CO, USA
ODS	Ozone Destroying Substances
PFR	Precision Filter Radiometer
PI	Principle Investigator, Leader of an Experiment/Instrument/Project
PICARD	French Space Experiment to Measure the Solar Diameter, to be launched 2010
PMOD	Physikalisch-Meteorologisches Observatorium Davos
PMO6	PMO6 Type Radiometer
PREMOS	Precision Monitoring of Solar Variability, PMOD/WRC Experiment on PICARD, to be launched 2010
PROBA 2	ESA Technology Demonstration Space Mission, launched 2 December 2009
PRODEX	Program for the Development of Experiments, ESA
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig & Berlin, D
RBCC-E	Regional Brewer Calibration Center for Europe, Izaña Observatory
ROB	Royal Observatory of Belgium
QASUME	Quality Assurance of Spectral Ultraviolet Measurements in Europe
QMS	Quality Management System
RA	Regional Association of WMO
RMO	Regional Metrology Organisation
ROB	Royal Observatory of Belgium
SCNAT	Swiss Academy of Sciences
SCOPES	Scientific Collaboration between Eastern Europe and Switzerland, Grant of the SNSF
SLF	Schnee und Lawinenforschungsinstitut, Davos
SFI	Schweiz. Forschungsinstitut für Hochgebirgsklima und Medizin, Davos
SI	International System of Units
SIAF	Schweiz. Institut für Allergie- und Asthma-Forschung, Davos
SMHI	Swedish Meteorological and Hydrological Institute
SNSF	Swiss National Science Foundation
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
SORCE	Space Mission of NASA
SOTERIA	Solar-Terrestrial Investigations and Archives
SOVA	Solar Variability Experiment on EURECA
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
STEP	Solar Terrestrial Energy Program of SCOSTEP/ICSU
SuMo	Sun Monitor
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor on Board UARS
TSI	Total Solar Irradiance
TVLS	Toroidal Variable-Line-Space
UARS	Upper Atmosphere Research Satellite of NASA
UCL	University College London
UV	Ultraviolet
UVA	UV Radiation in the Range of 315–400 nm
UVB	UV Radiation in the Range of 280–315 nm
VIRGO	Variability of Solar Irradiance and Gravity Oscillations, PMOD/WRC Experiment on SOHO, launched December 1995
WCRP	World Climate Research Program
WDCA	World Data Center for Aerosols, Ispra, I
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
WISG	World Infrared Standard Group of Pyrgeometer, maintained by WRC
WMO	World Meteorological Organization, a United Nations Specialized Agency, Geneva
WRC	World Radiation Center, Davos
WRC-IRS	Infrared Radiometry Section of WRC
WRC-SRS	Solar Radiometry Section of WRC
WRC-WORCC	World Optical Depth Research and Calibration Center, WRC Section
WRDC	World Radiation Data Center, St. Petersburg, RUS
WRR	World Radiometric Reference
WSG	World Standard Group, realizing the WRR, maintained by WRC
WWW	World Weather Watch, an Observational Program of WMO

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