Jahresbericht 2000

Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

Annual Report 2000

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Schweizerisches Forschungsinstitut für Hochgebirgsklima und Medizin

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Zusammenfassung Jahresbericht 2000

Vorwort

Das wichtigste Ereignis für das PMOD/WRC waren die 9ten internationalen Pyrheliometer Vergleiche (IPC). Aus der Sicht des PMOD/WRC waren die Vergleiche ein Grossanlass und damit die Vergleiche erfolgreich durchgeführt werden konnten, bedurfte es des konzentrierten Einsatzes der ganzen Belegschaft, sowohl in der Vorbereitung als auch während den Vergleichen. Es war grossartig zu erleben, wie sich alle Mitarbeiter voll für die reibungslose Durchführung der IPC einsetzten und ich möchte mich hiermit bei meinen Mitarbeitern herzlich für Ihren ausserordentlichen Beitrag bedanken. Nur das Wetter war ausserhalb unserer Kontrolle und dies hat sich auch prompt nicht an die Statistik gehalten: Normalerweise sollte im Davoser Herbst die Sonne an jedem zweiten Tag zu mehr als 50% scheinen und auf Grund der Wetterstatistik haben wir erwartet, dass wir während der Dauer der dreiwöchigen Vergleiche an mindestens vier Tagen unter wolkenlosen Himmel die Vergleichsmessungen durchführen könnten. Leider hatten wir nur gerade an eineinhalb Tagen die für die Kalibrierung von Pyrheliometern nötigen klaren Bedingungen. Das andauernde Warten auf gutes Wetter hatte dann bei den Teilnehmern auch einen etwas zwiespältigen Eindruck hinterlassen, vor allem weil die schlimmste Schlechtwetterperiode in der dritten Woche war. Am Ende der IPC hat ein Teilnehmer diese Situation folgendermassen formuliert: „Wir haben die Instrumente installiert, wir haben die Instrumente getestet und wir waren bereit – aber dann haben die Vergleiche gar nicht stattgefunden.“ Selbstverständlich waren die Beobachtungen, die der Teilnehmer als „Tests“ bezeichnete, ernsthafte Messungen und die Auswertung ergab, dass genügend Daten gesammelt werden konnten, um den Zweck der IPC zu erfüllen, d.h. den Instrumenten einen neuen Kalibrationsfaktor zuzuweisen. Aber um die IPC mit guten Gefühlen zu beenden, hätte es doch noch eines weiteren schönen Tages bedurft. Vor diesem Hintergrund ist es den Teilnehmern hoch anzurechnen, dass uns niemand Vorwürfe machte. Im Gegenteil, alle haben mit ihren Vorträgen, die zum Teil kurzfristig über Nacht zusammengestellt wurden, zu einem spannenden Symposium während den unverhältnismässig vielen Schlechtwettertagen beigetragen. Schlussendlich sind etwa dreimal so viele Vorträge gehalten worden, wie vor den Vergleichen geplant waren.

Zweifellos war für uns „Neuen“ am PMOD/WRC die Gelegenheit, die Menschen hinter den bekannten Namen der internationalen Radiometer-Gemeinschaft kennenzulernen, ein sehr wichtiger Aspekt der Vergleiche. Es sind ja die Teilnehmer, die die Existenz des PMOD/WRC rechtfertigen. Das Weltstrahlungszentrum wäre bedeutungslos, wenn nicht weltweit Pyrheliometer kalibriert werden müssten, d.h. es braucht die „Kunden“, die den Strahlungsstandart an alle Orte der Welt mitnehmen möchten. So gesehen sind die 9ten Internationalen Pyrheliometer Vergleiche vor allem dank dem Interesse unserer Besucher ein Erfolg geworden.

Internationale Pyrheliometer Vergleiche

Als Weltstrahlungszentrum ist das PMOD/WRC für die weltweite Homogenität der meteorologischen Strahlungsmessungen verantwortlich. Um die Kalibrierung der Referenzinstrumente der Regionalzentren zu gewährleisten, sind alle fünf Jahre von der World Meteorological Organization (WMO) Internationale Pyrheliometer Vergleiche (IPC) vorgeschrieben. Im Berichtsjahr wurden die 9ten Vergleiche durchgeführt. Wie schon bei vorangegangen IPCs wurden nebst den 21 Regionalzentren, auch alle Nationalzentren zu den Vergleichen eingeladen, da eine Zusammenlegung der regionalen mit den internationalen Vergleichen der WMO Kosten spart. Dieses Mal nahmen 18 Regionalzentren teil und insgesamt waren es 65 Teilnehmer aus 39 Ländern die nach Davos kamen. Während der dreiwöchigen Dauer der Vergleiche konnte an sechs Tagen gemessen werden; allerdings genügten die Wetterbedingungen nur an einem Tag den für die Kalibrierung von Pyrheliometern gesetzten Richtlinien. Trotzdem reichte die Messzeit aus, um für jedes der teilnehmenden Instrumente einen neuen Kalibrationsfaktor zu berechnen.

Filter Radiometer Vergleiche

Gleichzeitig mit den IPC wurden am PMOD/WRC die ersten Filter Radiometer Vergleiche durchgeführt. Das Hauptziel dieser Vergleiche war die Evaluation der Unsicherheit in der Bestimmung der Trübung der Atmosphäre, der sogenannten Aerosol optischen Dicke (AOD), mittels Filterradiometer. Die Prozedur zur Herleitung des AOD Wertes ist recht kompliziert und verschiedene Institutionen verwenden verschiedene Algorithmen. Bislang war unbekannt, inwieweit die verschiedenen Vorgehensweisen zu übereinstimmenden AOD Bestimmung führen. Die Davoser Vergleiche haben nun ergeben, dass mehrheitlich übereinstimmende optische Dicken bestimmt werden und vor allem wichtig, dass die Abweichung zwischen den Instrumenten kleiner ist als die geforderte Genauigkeit der WMO Richtlinien.

An den Davoser Vergleichen nahm kein CIMEL Radiometer des amerikanischen AERONET Programms teil. Diese Instrumente werden auch zur AOD Bestimmung eingesetzt. Da aber seit mehr als einem Jahr ein Davoser PFR Instrument auf Mauna Loa, Hawaii betrieben wird, wo auch CIMEL Instrumente im Einsatz stehen, konnten die AOD Bestimmungen des PMOD/WRC Instruments mit den lokalen Resultaten des AERONET Programms verglichen werden. Es stellte sich heraus, dass auch in diesem Fall die Übereinstimmung hervorragend ist.

Dienstleistungen

Nebst den Pyrheliometern die an den IPC-IX teilnahmen wurden am PMOD/WRC während 74 sonnigen Tagen 54 Radiometer von schweizerischen und ausländischen Institutionen kalibriert, wodurch das Observatorium rund CHF 30‘000.- einnehmen konnte.

Messnetze

Das GAW Versuchsmessnetz besteht zur Zeit aus drei Stationen von denen die Davoser Filterradiometer Trübungswerte liefern: Mauna Loa (Hawaii, USA), Mace Head (Irland) und Hohenpeissenberg (Deutschland). Nur das Instrument in Deutschland hat während dem ganzen Jahr gemessen, die anderen beiden erlitten Messunterbrüche von je ein paar Wochen. Auf Hawaii hatte das Filterradiometer eine Störung und in Irland war die Sonnennachführung defekt. Ansonsten haben sich die Geräte im Dauerbetrieb bestens bewährt.

Die elf Stationen des PMOD/WRC Messnetzes, die die infrarote Strahlung des Himmels messen, wurden ohne grössere Probleme routinemässig betrieben. Auf Grund dieser Messdaten wird unser neuer Doktorand Bruno Dürr seine Dissertation schreiben.

Als Fortsetzung eines EU Projektes, das Ende April 2000 zu Ende ging, wertete der ETH Doktorand Daniel Schmucki weiterhin die Daten der Messkampagne aus, die im Vorjahr in Garmisch-Partenkirchen gesammelt wurden. Zudem bearbeitete er auch die Beobachtungen unserer UV-Strahlungs-Messstation auf dem Weissfluhjoch.

Entwicklung und Bau von Instrumenten

Im Laufe des Berichtsjahres ist eine erste Serie von 10 Stück PMO6-cc Radiometer aufgelegt worden und Ende Dezember 2000 konnte mit dem Austesten der Elektronik angefangen werden. Die Fertigstellung des Betriebsprogrammes, die elektrische Eichung, die Charakterisierung der Radiometerköpfe und die optische Eichung vor Sonne, können voraussichtlich im Laufe des Frühjahres 2001 abgeschlossen werden. Dann stehen die Radiometer zum Verkauf bereit. Als weitere Verkaufsoption kann zu einem älteren CIR-PMO-6 Typ Sensor auch nur die neue Elektronik angeboten werden. Seit Herausgabe des Informationsprospektes im Herbst 2000, haben sich drei Interessenten nach einem möglichen Liefertermin erkundigt. Zur Zeit sind jedoch noch keine Bestellungen eingegangen.

Die Entwicklungsarbeiten der Elektronik eines 4-Kanal UV-Himmels-Präzisions-Filterradiometers wurden im Berichtsjahr weitergeführt. Das hochempfindliche Instrument zur Messung der Himmels UV-Strahlung hat Probleme mit Störsignalen, die bisher noch keine Testmessung zuliessen.

Die Teilnahme des „Absolute Sky-scanning Radiometer“ an den IR Mess-instrumenten-Vergleiche IPARSC-I in 1999 war ein weiterer Schritt in Richtung der Etablierung eines absoluten Standards für IR-Strahlung. Die Auswertung der Messdaten ergab nämlich, dass die Messresultate des Instruments mit den theoretisch erwarteten Werte übereinstimmen.

Weltraumexperimente VIRGO, SOVIM und PICARD

Die Bestimmung des zeitlichen Verhaltens der absoluten Kalibrierung von Radiometern im Weltraum ist ein sehr schwieriges Problem. Das Verhalten der vier Pyrheliometer, die auf VIRGO installiert sind, wurde aufwendig analysiert und man hofft, dass man nun von einer endgültigen Kalibration der Instrumente nicht mehr allzuweit entfernt ist. Die neu modifizierten Messungen der Totalsonnenstrahlung wurden dann mit der erwarteten Strahlung verglichen und man fand eine befriedigend gute Übereinstimmung.

Seit 1996 arbeiten wir am Weltraumexperiment SOVIM, das für die internationale Raumstation (ISS) vorgesehen ist. Die mechanischen Bauteile mussten zur weiteren Gewichtseinsparung überarbeitet werden. Die Stabilitätsanalyse durch Contraves ist abgeschlossen und die geplante Konstruktion ist für den vorgesehenen Einsatz genügend stabil. Contraves baut nun das sogenannte Qualifikations Modell der Deckel, das dann weitere Tests bestehen muss. Die Programmentwicklung für die Steuerung des Bordcomputers durch die Firma BRUSAG nähert sich dem Abschluss. Die Abnahme wird vermutlich Ende März stattfinden. Der geplante Installierungszeitpunkt von SOVIM auf der ISS verschiebt sich immer weiter zu späteren Daten und zur Zeit wird von einer Inbetriebnahme im Jahre 2005 gesprochen.

Das PMOD/WRC hat der französischen Weltraumorganisation CNES zugesagt zu Ihrem Experiment PICARD ein 4-Kanal Filterradiometer beizutragen; allerdings vorbehältlich der noch nicht gesicherten Finanzierung. Trotzdem haben wir die Entwürfe der mechanischen Bauteile und die Entwicklung der Elektronik zu unserem Instrument PREMOS weiter vorangetrieben und schon fast abgeschlossen.

Oberflächenstrahlungshaushalt in den Alpen und Untersuchungen der UV-Strahlung

Die ersten vier Jahre IR-Strahlungsmessungen mit den 11 Stationen des ASRB Messnetzes wurden von Dr. Ch. Marty in seiner Dissertation ausgewertet. Ein wesentliches Ergebnis seiner Arbeit war eine Methode um anhand von IR Messwerten Perioden von klarem Himmel sowohl Tags als auch Nachts zu erkennen.

Auf die Vergleiche von IR Radiometern 1999 in Oklahoma wurde schon im Zusammenhang mit der Entwicklung des „Absolute Sky-scaning Radiometers" verwiesen. Generell hat die Auswertung der Messresultate dieser Vergleiche ergeben, dass mit modernen, gut kalibrierten Pyrgeometern die IR Strahlung des Himmels auf etwa 2 Wm^{-2} genau ermittelt werden kann. Damit wird es möglich, die wegen der globalen Erwärmung erwartete Änderung der IR Strahlung innerhalb der nächsten 10 Jahren experimentell nachzuweisen.

Die Auswertungen von Albedo Messungen im UV-Bereich mit der PMOD/WRC Messstation auf dem Weissfluhjoch ergab, dass die erythemal wirksame Strahlung durch Schneereflexion bis zu 65% verstärkt werden kann.

Sonnen- und Astrophysik

Bei der Helioseismologie-Forschung am PMOD-WRC stand im Berichtsjahr die Suche nach den g Moden im Vordergrund. Wir haben buchstäblich bis zum letzten Arbeittag von Dr. W. Finsterle Ende November gehofft, dass er aufgrund der nun 4 Jahre langen Sonnenbeobachtungen durch VIRGO die sogenannten g Moden nachweisen könnte, aber leider haben auch die besten Kandidaten die Signifikanzschwelle immer noch nicht ganz erreicht. Die Messdaten von VIRGO werden nun von einem neuen Doktoranden, Herr Richard Wachter, bearbeitet.

Der „Luminosity Oscillation Imager" (LOI) ist ein VIRGO Instrument, das die Variationen der Sonnenintensität mit räumlicher Auflösung erfasst. Eine frühere Analyse dieser Daten liess vermuten, dass die Sonnenoszillationen verschiedene Signalstärken als Funktion der solaren Breite auf der Sonnenscheibe aufweisen. Die neuesten, allerdings noch nicht abgeschlossenen Untersuchungen, können dieses Resultat nicht bestätigen.

Der PMOD/WRC Gastwissenschaftler Dr. G. Gräfener hat an einer Spektralanalyse des heissen Sterns ζ Puppis mit einem modernen Sternatmosphären Programm gearbeitet. Die Untersuchung ist noch nicht beendet, unter anderem da der Hydrodynamikteil zur Berechnung des Sternwindes auf unerwartete, zur Zeit noch nicht geklärte Schwierigkeiten gestossen ist.

Aus den Zusammenarbeiten mit dem Astronomischen Institut der ETH und dem MPA Lindau resultierten verschiedene Publikationen auf den Gebieten der Sonnen- und der Astrophysik mit PMOD/WRC Mitarbeitern als Mitautoren. Darunter ist ein Projekt das mit Instrumenten des Satelliten SoHO die obere Atmosphäre der Sonne untersucht und eines, das die Grundparameter von sogenannten Symbiotischen Sternen zu bestimmen versucht. Diese Projekte sind noch nicht abgeschlossen und werden weitergeführt.

Noch in der Durchführungsphase sind Zusammenarbeiten mit dem Institut für Astronomie in Honolulu und dem University College London. Für das erste Projekt sind Ende Januar 2000 spektroskopische Beobachtungen von sogenannten Wolf'-Rayet Galaxien mit dem 10m Teleskop Keck I auf Hawaii und Ende Februar mit dem 3.5m NTT Teleskop der ESO auf La Silla ausgeführt worden. Für das zweite sind Anfangs September Daten mit einem der 8m Teleskope der ESO auf Paranal gewonnen worden, mit dem Ziel, die Parameter von heissen leuchtkräftigen Sternen in Galaxien der lokalen Gruppe zu bestimmen. Bei diesen beiden Projekten werden die Auswertung und Interpretation der Daten noch einige Zeit beanspruchen.

Infrastruktur

Wir haben begonnen, die Räume des PMOD/WRC zu renovieren, wobei die Erneuerung über die nächsten paar Jahre verteilt erfolgen soll. Letztes Jahr wurden neue Teppiche im Sekretariat und in den angrenzenden Büros und Korridor verlegt und diese Räume sind auch neu gestrichen worden. Der Unterschied zum alten Zustand ist frappant und wir freuen uns jetzt schon auf das Resultat der nächsten Etappe.

Lehrverpflichtungen

An der ETH Zürich wurden folgende Vorlesungen gehalten: W. Schmutz im Wintersemester 1999/2000 die Vorlesung „Galaxien“, im Sommersemester 2000 „Sternatmosphären”, beide zusammen mit zusammen mit Prof. S.K. Solanki, Direktor am Max-Planck Institut für Aeronomie, und im Wintersemester 2000/2001 die Vorlesung „Astronomie“ gemeinsam mit H. Nussbaumer, Professor an der ETH Zürich. C. Fröhlich im Wintersemester 2000/2001 die Vorlesungen „Strahlung und Klima“ und gemeinsam mit Prof. M.C.E. Huber, ESA Science Directorate Paris, „Wissenschaft im Weltraum: Erkundung des Sonnensystems, Physik und Astronomie“. R. Philipona las in den Wintersemestern 1999/2000 und 2000/2001 die Vorlesung „Strahlungsmessung in der Klimaforschung“.

Personal

Urs Schütz, Physiklaborant, hat nach mehr als 7jähriger Tätigkeit am PMOD/WRC eine neue berufliche Herausforderung in St. Gallen angenommen. Herr Schütz trug wesentlich zum Observatoriumsbetrieb bei und ich danke ihm für den geleisteten Einsatz. Christoph Marty hat am 27. März 2000 seine Doktorprüfung erfolgreich bestanden – herzliche Gratulation! Er war nach der Fertigstellung seiner Dissertation noch drei Monate vom PMOD/WRC angestellt, um die Hauptergebnisse seiner Forschung zu publizieren. Zur Zeit arbeitet er als post doc an der Universität Fairbanks, Alaska. Ende November hat Wolfgang Finsterle sein post doc Jahr am PMOD/WRC abgeschlossen. Ich wünsche beiden ehemaligen Doktoranden und Herrn Schütz alles Gute für Ihre Zukunft.

Herr Richard Wachter, diplomierter Physiker der Universität Augsburg und nun Doktorand an der ETH Zürich, ist Nachfolger von Dr. Finsterle auf der vom SNF finanzierten Doktorandenstelle für Forschung auf dem Gebiet der Helioseismologie. Er hat am 1. August 2000 seine Arbeit am PMOD/WRC begonnen. Neu steht Dr. R. Philipona eine Doktorandenstelle durch ein SNF Projekt für Forschung im Zusammenhang mit dem ASRB Messnetz zur Verfügung. Diese Stelle wurde mit dem Dipl. Natw. ETH Bruno Dürr besetzt, ebenfalls Doktorand an der ETH Zürich.

Dr. Götz Gräfener, wissenschaftlicher Mitarbeiter der ETH Zürich, und Gastwissenschaftler am PMOD/WRC hat das Observatorium per Ende April verlassen. Er ist zur Zeit wissenschaftlicher Mitarbeiter am Institut für Physik und Astrophysik der Universität Potsdam.

Unsere Erfahrungen mit Zivildiensteinsätzen am PMOD/WRC bleiben durchwegs positiv. Bis Ende 2000 waren vier weitere Dienstleistende im Einsatz: Pascal Güntensperger, Urs Zimmerli, Pascal Häring und Christian Thomann.

Dank

Die Belegschaft des PMO/WRC hat durch Ihren Einsatz für das Observatoriums den ersten Dank verdient. Für die vielen, nicht selbstverständlichen Zusatzleistungen möchte ich allen ein herzliches „Danke schön“ aussprechen. Die Ernst Göhner Stiftung hat das PMOD/WRC mit einem grosszügigen Beitrag beschenkt. Ich bin für diese Unterstützung sehr dankbar, denn die üblichen Einnahmen erlauben wohl einen normalen Betrieb, sowie auch Investitionen in kleinerem Rahmen, aber es fehlen die Mittel für ausserordentliche Anschaffungen. Dem Förderverein verdankt das Observatoriumsgebäude eine Beschriftung auf der Südwestfassade. Auch im vergangenen Jahr hat die Aufsichtskommission das PMOD/WRC nicht nur im wörtlichen Sinn überwacht, sondern auch beraten und ich danke den Mitgliedern der Kommission für ihre Unterstützung. Bedanken möchte ich mich auch beim Stiftungsrat und insbesondere beim Stiftungsrats-Ausschuss, der sich in zahlreichen Sitzungen um das Wohlergehen des PMOD/WRCs kümmerte, sowie bei den kommunalen und kantonalen Behörden und dem Nationalfonds für die stete und wohlwollende Unterstützung des PMOD/WRC.

Davos, im März 2001 Dr. Werner Schmutz, Privatdozent ETH Zürich

Annual Report 2000

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1 Introduction

Werner Schmutz

The 9th International Pyrheliometer Comparisons (IPC) represented the most important event of the year for the PMOD/WRC. For an organization of the size of PMOD/WRC, hosting the IPC is quite a demanding task, requiring the dedicated effort of the entire staff during both the preparatory phases as well as the comparisons themselves. I wish to express my deepest appreciation to the PMOD/WRC staff whose unstinting dedication and eager willingness to take on responsibilities for various tasks enabled the entire event to go so smoothly and successfully.

Despite all of our preparations, however, the weather remains beyond our control and, not surprisingly, conditions were nothing like we had expected from the weather statistics. During a normal autumn one should expect sunny, clear skies for more than 50% of the day every other day. Based on these statistics, we had anticipated about four cloudless days suitable for the calibration of the instruments during the three weeks of the IPC. Unfortunately, Nature was rather uncooperative: conditions were suitable for the comparisons for only one and a half days. The last week in particular was dreadful and this dampened the spirits of the participants considerably. As one remarked, "We installed our instruments, we tested the instruments, and we were ready but then the comparison never started." Examination of the measurements obtained during suitable observing time revealed that the data are, in fact, sufficient for a reliable calibration of the participating pyrheliometers. However, without a doubt, one more clear day would have been beneficial for both the comparisons as well as the mood of the participants. Nevertheless, we greatly appreciated the generally positive attitude of the participants.

On the other hand, as a result of the inclement conditions, the symposium, which was held during the bad weather time, was substantially extended thanks to the numerous contributions from the IPC participants; some of these talks were put together on very short notice, even overnight. By the close of the Comparisons nearly three times as many talks were given as had been originally planned.

An important consequence of the Comparisons, in addition to the obvious scientific and technical aspects, was that we newcomers to PMOD/WRC had an opportunity to meet the individuals associated with the names in the radiometric community, to attach faces to names, in other words. After all, the participants are at the heart of the global radiometric measurements and provide the raison d'etre for the PMOD/WRC. If no one needed to transfer the World Radiometric Reference then the World Radiation Center would be without significance. In the end, therefore, it was the enthusiasm and interest of our visitors from all over the world that contributed greatly to the success of the 9^{th} International Pyrheliometer Comparisons.

2 Comparisons

2.1 International Pyrheliometer Comparisons (IPC-IX)

Isabelle Rüedi

The Ninth International Pyrheliometer Comparisons (IPC-IX) took place in Davos from 25 September to 13 October 2000. They were held together with the Regional Pyrheliometer Comparisons of all regions. 65 participants from 39 countries took part in the comparisons with a total of 88 instruments. The main aim of these comparisons is the world-wide dissemination of the World Radiometric Reference (WRR).

Since the last comparisons, several instruments of the World Standard Group (WSG) exhibited various problems. CROM3R was very unstable during the whole period

Figure 1 Photographs taken during the 9th International Pyrheliometer Comparisons.

Figure 1 continued.

due to malfunctioning of the instrument's electronic. PMO5 presented a slight drift which was also due to an electronic problem: the drift of the heater current's amplifier, as was found just after the IPC. PAC3 measured too little and was unstable over a long time period which happened to be due to the presence of an insect in its cavity. Since the insect was removed and the cavity cleaned, the instrument has gone back to its past performances (before 1992). Finally, a new electronic was built for TMI67814 but unfortunately, it did not work properly during a year as was found last summer. Taking these problems into account, only PMO2, CROM2L, HF18748 and TMI67814 can be used for the determination of the WRR at the time of the IPC.

The weather conditions were unfortunately very bad throughout the IPC. Although measurements were carried out on 6 days only data from two days may be used for the final evaluation of the participants' absolute cavity radiometers. The Angström radiometers being even more sensitive to non-perfect weather conditions, only 1 day may safely be used for their evaluation. Ideally, at least 3 days of good weather should be used for the calibration of such instruments. Therefore, in order to ensure an absolutely reliable transfer of the WRR into the future, it was decided that additional measurements, carried out just after the IPC should be used for the determination of the factors of the WSG instruments.

A new factor was determined for each participating instrument. In spite of the bad weather condition prevailing during the IPC, most of the instruments didn't show large changes. The mean and standard deviation of the factors obtained for the instruments which also took part to IPC-VIII are very close to the WRR and similar to those obtained at past IPCs, which is an additional confirmation of the stability of the WRR.

Figure 2 shows the WRR-factors of the WSG instruments obtained at the IPCs from 1980 to 2000. The very small changes of the factors in time (except for the problems cited above) proves the stability of the WSG instruments. However, all the radiometers belonging to the WSG are at least 20 years old. Instruments of that age are of course subject to failures and it was decided that potential replacement instruments should be found. Such instruments should be operated together with the WSG in order to gain some history.

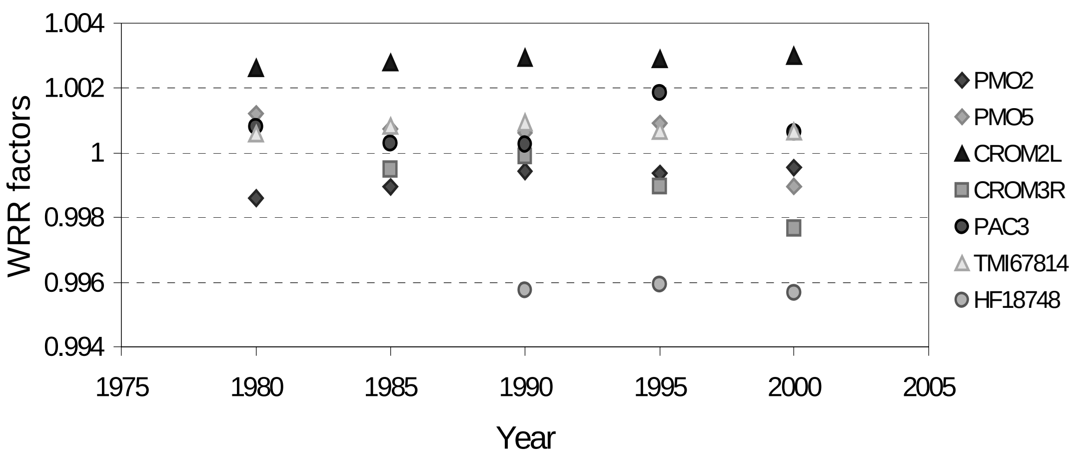

Figure 2. WRR factors obtained for the WSG instruments from IPC-V to IPC-IX.

The training of radiation expert is also an important part of the IPC. The bad weather days gave us ample time to carry out the *Course on Meteorological Radiometry* and an extensive *Symposium* which were very much appreciated by the participants. Altogether it amounted to roughly 40 lectures.

2.2 Filter Radiometer Comparison, FRC-I

Christoph Wehrli

On the occasion of IPC-IX the first WORCC comparison of filter radiometers for the determination of aerosol optical depth was also held at Davos. International specialists from 11 institutions and 7 countries participated with a total of 16 instruments. Most filter radiometers were sun-tracked devices, two were rotating shadow band instruments and all of them were operated automatically. None of the CIMEL type participated, for a separate comparison with a PFR instrument see chapter 4.9.

A goal of this comparison was to estimate the uncertainty in determination of aerosol optical depth AOD, which is a measure of the turbidity of the atmosphere, from simultaneous measurements with different, independently calibrated filter radiometers. Nine instruments were recently Langley calibrated at various altitudes ranging from sea-level in Sweden to Jungfraujoch at 3600m. The WORCC standard instrument PFR N01 was calibrated by a stratospheric balloon flight in 1998 and its sensitivity monitored since then by absolute calibrations and comparisons to Langley calibrated standards. The remaining instruments came without independent calibrations and were provided with calibration values based on PFR-N01 during the comparisons.

The comparison was performed at 5 common WMO wavelengths of 368, 412, 500, 778 and 862nm and 2 optional wavelengths at 610 and 675nm. Measurements of direct beam irradiance with a sampling rate of 1 minute were collected in daily ASCII files; equivalent values for the rotating shadow band instruments were prepared from cosine corrected total and diffuse hemispheric measurements by the participants. Ancillary station pressure was interpolated from 10 minute data collected by the weather station of Météo Suisse located at PMOD and daily values of total ozone were obtained from the Dobson station at Arosa, about 15 km south-west of Davos.

Atmospheric transmission values were calculated using the 'given' calibrations and evaluated for AOD according to the standard scheme used with PFR instruments

Figure 3. Some instruments participating in filter radiometer comparison (left plate: 2 rotating shadow band radiometers; right plate: 7 tracking radiometers) under examples of prevailing sky conditions.

Albeit weather conditions were far from favourable (see Figure 3) 340 samples could be collected in two 'clear-sky' periods on 27. September and 9. October 2000. Figure 4 shows and Table 1 summarizes some initial results using the independently calibrated instruments only. On 9. October, when the sky was clearer than on 27. September, results from ten filter radiometers are within a single standard deviation range of about 0.01 and, if the two last radiometers are omitted, within 0.005 optical depth. The largest differences in AOD, evaluated according to a common scheme, between 8 instruments are about 0.015. These results are well within the goal of 0.02 set by the WMO (1993).

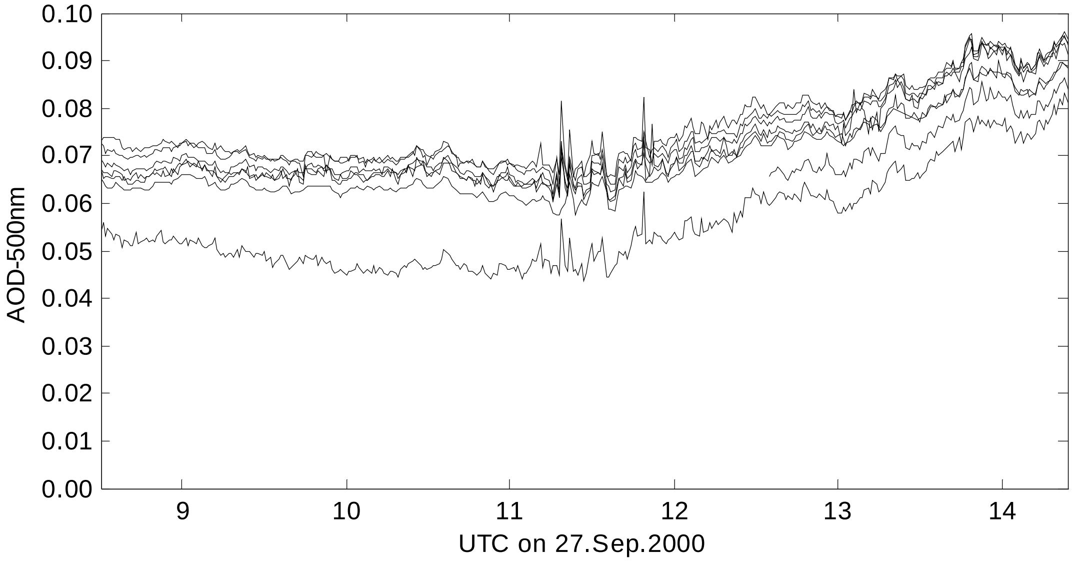

Figure 4 Aerosol optical depth at 500nm showing the close agreement of 8 previously calibrated filter radiometers. Before noon at 11:20 UT the atmosphere was quite clear and stable, in the afternoon, the sky became more hazy and showed signs of thin cirrus clouds. The mean AOD of all instruments averaged over the period shown is 0.071 with a standard deviation of 0.007. Excluding the lowest and the partial lines reduces the standard deviation to 0.003.

A possible explanation for the higher AOD retrieved from SP1-03 is, that it measures less circumsolar radiation in its narrow 1° field of view than the other radiometers which have fields of view around the WMO recommended 2.5° or use the shadow-band approach. More comparison data and/or model calculations would be required to check such differences due to field of view effects. The MS110JMA radiometer was evaluated using a calibration obtained shortly after FRC-I by the participating institution. As these new calibration values differ by up to 20% from the initial values determined a year

Table 1 Averages of aerosol optical depth at 7 wavelengths measured on 9. October by 10 filter radiometers. Original calibration values given by participants were used for evaluation. The 8 instruments listed first are grouped much tighter than the whole ensemble.

Wavelength	*368*	*412*	*500*	*778*	*862*	*610*	*675*
PFR-N01	0.049	0.042	0.031	—	0.013	—	—
PFR-N26	0.048	0.042	0.032	—	0.013	—	—
PFR-N20	0.056	0.051	0.031	—	0.011	—	—
CS1010	—	0.039	0.031	0.012	—	0.021	—
CSEM2016	0.046	—	0.029	0.014	—	—	—
CSEM2000	0.053	0.051	0.028	0.013	0.012	0.013	0.016
MFRSR378	—	0.052	0.033	—	0.019	0.023	0.021
MFRSR914	—	0.049	0.042	—	0.023	0.032	0.028
SP1-03	0.073	0.062	0.045	0.026	0.022	0.038	—
MS110JMA	0.033	—	0.016	0.003	0.003	—	0.004
Average	0.051	0.048	0.032	0.014	0.014	0.025	0.017
Std.dev. 1-10	0.012	0.007	0.008	0.008	0.007	0.010	0.010
Range	0.040	0.023	0.029	0.023	0.012	0.025	0.025
Std.dev. 1-8	0.004	0.005	0.004	0.001	0.005	0.008	0.006
Range	0.010	0.013	0.014	0.002	0.012	0.019	0.012

before, it is problematic to interpolate reliable values for the FRC-I period. Further evaluation of measurements, including cross-calibration of additional instruments are still under way.

Reference

World Meteorological Organization, Report of the WMO workshop on the measurment of atmospheric optical depth and turbidity. Silver Spring, 6 - 10 December 1993, Environmental pollution monitoring and research programme report series Nr. 101, Geneva.

Participating Institutions:
Atm.Sci.Res.Center SUNY, Albany, USA
Bureau of Meteorology, Melbourne, Australia
Deutscher Wetterdienst, Potsdam, Germany
EKO instruments, Tokyo, Japan
Japan Meteorological Agency, Tokyo, Japan
Meteorological Office, East Hampstead, United Kingdom
Meteo Suisse, Payerne, Switzerland
NASA Langley Research Center, Hampton, USA
PMOD/WRC, Davos, Switzerland
Meteorological and Hydrological Institute, Noorköping, Sweden
University of Colima, Mexico

Participating instrument types:

4 WORCC PFR	*4 channels*
3 Carter-Scott SP02	*4 channels*
3 CSEM SPM2000	*3 channels*
2 EKO MS110	*5 channels*
2 Schulz SP01	*7 channels used*
2 MFRSR7	*5 channels*
1 ASR1	*7 channels*

3 Services, Calibrations, and Instrument Development

3.1 Operational Calibrations

Isabelle Rüedi, Rolf Philipona, Mario Roveretto, Remo Venturi, Christoph Wehrli

The PMOD/WRC is responsible for the world-wide homogeneity of the meteorological radiation measurements. For this purpose, we maintain the World Standard Group (WSG) which comprises 7 radiometers of different type and make. The WSG materializes the World Radiometric Reference (WRR), which is the reference adopted by the WMO as the basis for all meteorological radiation measurements. The world-wide dissemination of the WRR is secured by the International Pyrheliometer Comparisons, which are carried out on a five year basis. From September 25 to October 13 2000, the Ninth International Pyrheliometer Comparisons took place in Davos (c.f. Sect. 2.1).

During 74 sunny days 4 absolute radiometers, 2 pyrheliometers, and 21 pyranometers were calibrated with the Sun as a source and the WSG as reference. These instruments belong to 12 independent institutions. We also calibrated an albedometer, although unofficially without a certificate.

With a black-body as radiation source we calibrated 22 pyrgeometers. Four of these instruments have been modified and two were repaired. We also used our IR radiation facility to calibrate (unofficially) an IR thermometer.

We have calibrated 6 PFRs in our optical laboratory and outside, with the sun as a radiation source. As usual the reference PFRs, N-01 and N-26, were calibrated twice with the trap detector to monitor their stability.

3.2 GAW trial network

Christoph Wehrli

In the following paragraphs we report some results and problems from the operation of the first 3 stations of the GAW trial network as well as the status of the planned future expansion of the network.

A set of computer codes for the evaluation of PFR measurements were translated (by a civilian service conscript) from Matlab environment to a Java application with graphical user interface. This software is distributed freely together with the PFR instruments and it allows users at GAW stations to verify the proper functioning of the instrument as well as to perform AOD evaluation and Langley calibration. This Java software can be downloaded from

ftp://ftp.pmodwrc.ch/worcc/dusttracker.

Raw data are still transferred to WORCC where they are verified and evaluated for AOD. These data are considered preliminary or levlel1 results, until routine field calibration, by travelling standards or in situ as in the case of Mauna Loa, are available to assert the stability of the instruments. Final AOD values, or level2 results, can be determined only after such quality control measure and may require re-processing of all raw data between calibrations. Until this task is completed, level1 data are available from WORCC upon request.

3.2.1 Mauna Loa, Hawaii

Routine monitoring of housekeeping parameters revealed a slowly developing malfunction of the thermostatic system in the instrument at Mauna Loa which required the unit to be sent back to Davos for replacement of a crumbling Peltier element. This was an excellent opportunity to check the absolute calibration and band pass profiles of a PFR instrument after 11 months of routine operation. While no shift in effective median wavelengths could be detected, changes in absolute response between 0.3% and 1.7% were found. Whether these changes are instrumental or due to poor reproducibility of the trap calibration procedure is ambiguous, the Mauna Loa instrument was one of the first units measured during the test phase of the spectral calibration facility. After repair, the instrument was compared to 2 reference PFRs to check its calibration. A 2% loss of sensitivity, compatible with the absolute calibration, was detected in the UV channel, changes in the other channels were below 1%. The instrument resumend operation after 51 days and showed no more problems.

Figure 5. PFR-N07 at the Atlantic coast of Ireland, pointing towards sunset.

3.2.2 Mace Head, Ireland

After the broken sun tracker was returned, measurements started again in mid March and lasted until 21. August when another power failure caused the tracker to stop. As there is no permanent staff at Mace Head and regular visits of the responsible scientist were reduced in holiday season, the problem went unnoticed for several weeks. Data are now available again since 23. September 2000.

Given weather conditions that are quite different from a site like e.g. Hawaii, Langley calibration is not possible at the Irish coast and the travelling standard method is the only way to maintain the PFR calibrated at this kind of location. A standard PFR was thus sent to Mace Head in December 2000 where this method will be tested under less ideal conditions. If low solar elevation and typically intermittent sunshine prevent a successful comparison, the PFRs will be swapped and the station instrument returned to Davos for calibration.

3.2.3 Hohenpeissenberg, Germany

The instrument has measured without interruption during the whole year 2000. A number of Langley extrapolations indicate about 2% higher calibration values than originally obtained on Jungfraujoch. The station instrument needs to be checked by a traveling standard in order to confirm a possible change in calibration. Aerosol optical depth were calculated using original calibration values. Daily means for 114 selected days in 2000 are illustrated in Figure 6. The wavelength exponent of 1.34±0.5 agrees well with the general value given by Iqbal (1983) for natural atmospheres.

Reference

Iqbal M.: 1983, Introduction to Solar Radiation, Academic Press, Toronto

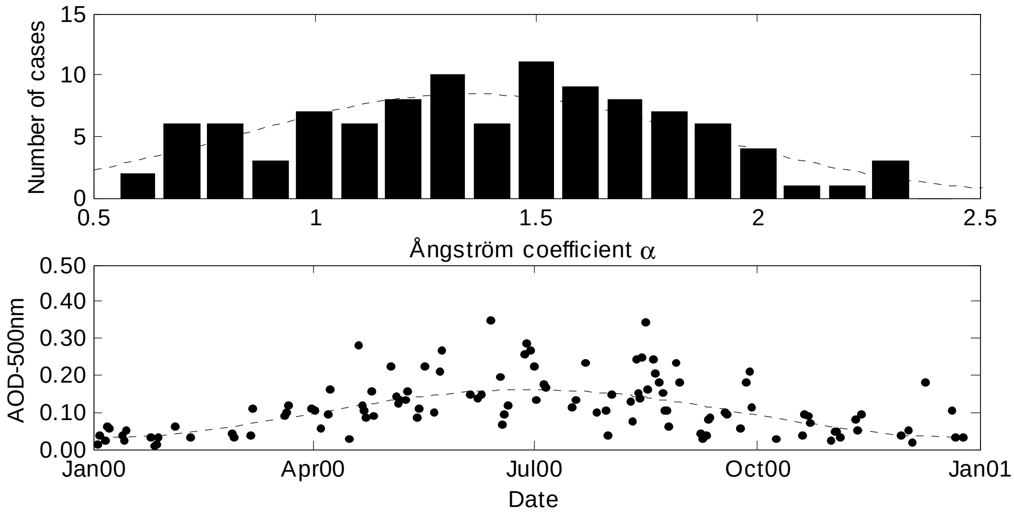

Figure 6: Aerosol optical depth characteristics at Hohenpeissenberg for 2000. The top panel shows a histogram of the wavelength exponent, i.e. Ångström coefficient α, together with a fitted normal distribution. Then mean value of α=1.35±0.52 closely matches the general value given by Iqbal (1983) for the natural atmosphere. The bottom panel shows the annual cycle of AOD at 500nm with clear winter skies and markedly higher turbidity during summer.

3.2.4 PFR calibration at GAW station by traveling standard.

The calibration of PFR instruments operating at GAW stations is maintained by periodic comparison at the site to a traveling standard PFR. A first comparison in January 2000 at Mauna Loa has shown that the local instrument N27 was still within 0.6% of its original calibration obtained in spring 1999 at Jungfraujoch. Because Mauna Loa is itself an excellent site for filter radiometer calibrations, both PFRs participating in the comparison were self-calibrated there at the same time permitting to verify the calibrations performed at Jungfraujoch and to retrieve a 'Mauna Loa' calibration by the traveling instrument N26 to Davos. For PFR N27 at Mauna Loa, the transferred and autonomous calibrations differ at most by 0.7% in the 412nm channel. Based on this first test comparison, we estimate the stability of PFR instruments to be good enough to require only an annual re-calibration for maintaining a 1% uncertainty.

Table 2. Results of PFR comparison at Mauna Loa in January 2000. Extraterrestrial values of the local instrument N27 have changed less than 0.6% in relation to the travelling standard N26. These differences in calibration are smaller than the scatter in the initial values, except in the 862nm channel.

	862 nm	**500 nm**	**412 nm**	**368 nm**
N26 calibration JFJ (4/99)	3.473	3.880	3.807	4.243
stdev. N=25	0.002	0.007	0.008	0.013
Ratio N27 / N26 at MLO	0.9964	0.9827	0.9930	0.9620
stdev. N=10 days	0.0007	0.0006	0.0009	0.0012
N27 re-calibration	3.461	3.813	3.780	4.082
N27 original calibration	3.441	3.802	3.760	4.075
stdev. N=10	0.009	0.021	0.027	0.043
N27 Correction factor	1.0057	1.0028	1.0054	1.0017
N27 calibration MLO (1/00)	3.464	3.814	3.807	4.103
stdev. N=13	0.001	0.001	0.001	0.002
Difference to re-calibration	-0.0034	-0.0012	-0.0267	-0.0212
Difference in %	-0.10%	-0.03%	-0.70%	-0.52%

3.2.5 Deployment of PFRs at new sites

Following a letter sent by WMO secretariat on 1st August to 5 potential sites proposed by the Scientific Advisory Group (SAG) on Aerosols, 3 stations agreed to install and operate a PFR instrument and 1 responded positiv. Direct contacts with Regina, Canada, Ryori, Japan and Izaña, Spain are established and PFRs are being prepared for shipment. The station at Ny Ålesund, Sweden will be contacted in April, after the arctic winter.

3.3 The ASRB network

Rolf Philipona, Christoph Marty, and Bruno Dürr

Eleven stations of the Alpine Surface Radiation Budget (ASRB) network are in use since 1995. Data from four years of continuous measurements of all stations were analyzed by Christoph Marty and summarized in his Ph.D. thesis which he finished in March 2000 (Marty, 2000). A new method to separate clear-sky from cloudy-sky conditions resulted from this work. The Clear-sky Index (CSI) (Marty and Philipona, 2000a) is of major importance for further analysis of ASRB data like the cloud forcing and the greenhouse effect. Parts of Christoph's work were presented at IRS2000 (Marty and Philipona 2000b) and further publications are in preparation. ASRB investigations continue on a new research project „Greenhouse-effect in the Alps: by models and observations“ which was granted by the Swiss National Science Foundation on which Bruno Dürr could be hired as a new Ph.D. student.

3.4 The CUVRA project

Rolf Philipona and Daniel Schmucki

The research project Characterization of the UV Radiation field in the Alps (CUVRA) which was granted for two years from the European Commission was terminated end of April 2000. Several papers with respect to albedo were published in the context of this project. A general paper which summarizes the results of the CUVRA campaign at and around Garmisch-Partenkirchen describes the variability of spectral solar ultraviolet irradiance in an alpine environment (Gröbner et al., 2000). A method to determine the effective albedo using the ratio between direct and diffuse UV measurements was established and tested with UV measurements from the Weissfluhjoch station and with the help of satellite measurements in collaboration with the Geographical Institute of the University of Berne (Schmucki et al., 2001). A further investigation demonstrates the UV increases on normal-to-the-sun oriented receivers versus horizontal receivers with respect to albedo and solar elevation (Philipona et al., 2001a)

3.5 Instrument Development

3.5.1 Commercial Radiometer PMO6-cc

Hansjörg Roth, Isabelle Rüedi, Klaus Kruse, Urs Schütz, and Jules Wyss

After the successful completion of a prototype end of 1999 we started to manufacture a series of 10 PMO6-cc radiometers. The control software and the electronics has been upgraded and a new prototype was built, which installed in September 2000 on the solar tracker of the WSG, to verify the quality and stability of the new product. The comparisons with the WSG yield excellent results, implying that the new instrument type is stable and reliable. Instruments will be ready for delivery to customers in spring 2001.

3.5.2 The Absolute Sky-scanning Radiometer

Rolf Philipona

Previous annual reports reported about research conducted at PMOD/WRC on absolute radiometry for longwave radiation measurements. The purpose is to provide an instrumentation which serves as world standard for longwave radiation. The approach consists of measuring longwave radiance from the sky at various directions during clear-sky night conditions and to use a Gauss integration to calculate hemispherical irradiance on the horizontal surface to which pyrgeometer measurements can be compared to. The Planck Calibrated Sky Radiometer (PCSR) was successfully used in the International Pyrgeometer and Absolute Sky-scanning Radiometer comparison (IPASRC-I) which was held at the Atmospheric Radiation Measurement (ARM) program‘s Southern Great Plains (SGP) site in Oklahoma in fall 1999. Detailed analysis of the IPASRC-I measurements have shown that pyrgeometer measurements, atmospheric emitted radiance interferometer (AERI) measurements and radiative transfer models found results of longwave irradiance for four clear-sky nighttime test cases within 2 Wm^{-2}. These results boost confidence in the correctness of clear-sky atmospheric longwave measurement and calculations and in particular in the absolute value determined with the sky-scanning radiometer. The name of this instruments has now been changed to Absolute Sky-scanning Radiometer (ASR) and a detailed paper on the ASR is accepted for publication in Applied Optics (Philipona, 2001).

3.5.3 UV Precision Filter Radiometers

Rolf Philipona, Hansjörg Roth, and Jules Wyss

For direct solar UV-radiation measurements eight UV-Precision Filter Radiometers (UV-PFR) have been manufactured, tested, and are in use at various locations. UV-PFRs measure spectral radiation at 332, 318, 311and 305 nm within a narrow bandwidth of about 1.25 nm. In the 1999 annual report successful comparisons with spectro-radiometers were reported from Garmisch-Partenkirchen, Zugspitze and Jungfraujoch.

UV-PFRs are continuously deployed on Jungfraujoch since June 1999 and at Davos since January 2000. One UV-PFR was used in collaboration with MetoSwiss and the Institute of Applied Physics of the University of Berne at the ozone station Arosa and was successfully used to determine total ozone amount (Ingold et al., 2001). One instrument is deployed at the research station Summit in the center of Greenland in a collaboration with the Institute for Climate Research of ETHZ. Three UV-PFRs are sold to MeteoSwiss and will be deployed on their RASTA stations.

3.5.4 UV-Sky Precision Filter Radiometer

Hansjörg Roth, Rolf Philipona, and Jules Wyss

The developing of a new generation of UV-Sky-PFR instruments takes more time than anticipated. There are sources of electronic noise originating in digital logic circuits and the motor drive that affect negatively the signal path of the very sensitive amplifiers. So far it was not possible to eliminate the problems.

3.5.5 Future Space Experiment SOVIM

Claus Fröhlich, Dany Pfiffner, Hansjörg Roth, Isabelle Rüedi, Werner Schmutz, and Jules Wyss

The space experiment SOVIM is a re-use of the SOVA experiment flown on EURECA. It incorporates three PMO6 type radiometer, two filterradiometer (SPM at 402, 500 862 nm), a Two-Axis SunSensor (TASS) from PMOD/WRC and a DIARAD type radiometer from IRMB. This instrument is managed by PMOD/WRC and lead by Claus Fröhlich as PI. It will fly together with SOLPSPEC (solar spectral irradiance from 180 to 3000nm) and SOLACES (solar spectral irradiance from 17nm to 220nm) on the International Space Station (ISS) mounted on an Express Palette with solar tracker. Since 1996 we are working on the design and adaptations necessary to be accommodated.

The mechanical design of the package needs still some improvements, mainly to reduce the weight. The design is now transferred to our new new mechanical drawing system (Pro Engineer 3D CAD) which eases changes and more importantly allows detailed checks in a 3D view to avoid conflicts not easily seen in 2D representations. The FE analysis of the package, done by Contraves, is finished and results show that the design conforms with the stability requirements. The design of the mechanical covers is completed and the Contraves is manufacturing the Qualification Model which will be used for all environmental, mechanical and electrical tests. After successful completion of these tests, the manufacturing of the five flight cover units will be initialized.

The definition of the onboard software and also the software for the Instrument Test Equipment is completed and the coding nearly finished. BRUSAG has been contracted for this task and the integration of the software in the on-board computer is scheduled for March 2001. For these tests simulators for the covers and heaters and for the instruments have been built. The data acquisition electronics for our instruments has been re-designed to implement improvements such as submultiplexer for the back up operation of the three PMO6-Radiometer. The computer interface, which interprets the different commands to our instruments and the data acquisition, is completed. To test the communication and all the commands between the UIM and the FPGA, our apprentice has build a "SOVIM UIM Testbox" with a computer interface and an integrated frequency counter for the output of the voltage-to-frequency converters. Prototypes of the SPM and PMO6-Radiometer are on the tracker for tests with the sun as source. The first results look very promising.

The schedule of the Project has again suffered from changes mainly due to delays of ISS, but also due to problems with the delivery of the express palettes and interference problems with an American instrument with large magnetic stray fields. The present solution is to put all 4 European palettes on the COLUMBUS module which is European and thus allows a better control of the technical and programmatic aspects. This solution became possible because of the many delays in the ISS programme which lead finally to COLUMBUS being in space before a possible launch of the Express Palettes which were originally foreseen to fly during the early utilization phase which is soon over and has never been used.

3.5.6 Future Space Experiment PREMOS

Werner Schmutz, Hansjörg Roth, Isabelle Rüedi, Christoph Wehrli, and Jules Wyss

The PMOD/WRC has decided to participate in the future space mission PICARD directed by the French space agency (CNES) and the Centre National de la Recherche Scientifique, Service d'Aeronomie Paris (CNRS). A memorandum of understanding between the PMOD/WRC and CNES has been drafted and should be signed in 2001. Scheduled to be flown on a dedicated microsatellite in 2005, PICARD is a French-built experiment with the goal of measuring the solar diameter with unprecedented accuracy, while simultaneously recording the total solar irradiance and the spectral irradiance at selected wavelengths. The PMOD/WRC will provide the instrument PREMOS (Precision Monitoring of Solar Variability), which is equipped with filter radiometers to measure the solar spectral irradiance in four wavelength bands, including the UV at 230 nm. In order to keep the costs relatively low, the mechanical and electrical design will duplicate as much as possible that of the sun photometers currently under construction for SOVIM. We have nearly finalized the electrical and mechanical design, the latter based on the newly acquired 3D CAD system. Although the CNES will contribute funds to the PREMOS project, their financial support will not be sufficient to cover all of the construction costs. Therefore, additional funding for PREMOS by the Swiss PRODEX is crucial for the realization of the project. Last year, the project was presented to the PRODEX Program Committee, who endorsed it, provided that PICARD obtains approval from the European Space Agency (ESA). The ESA decision is still pending.

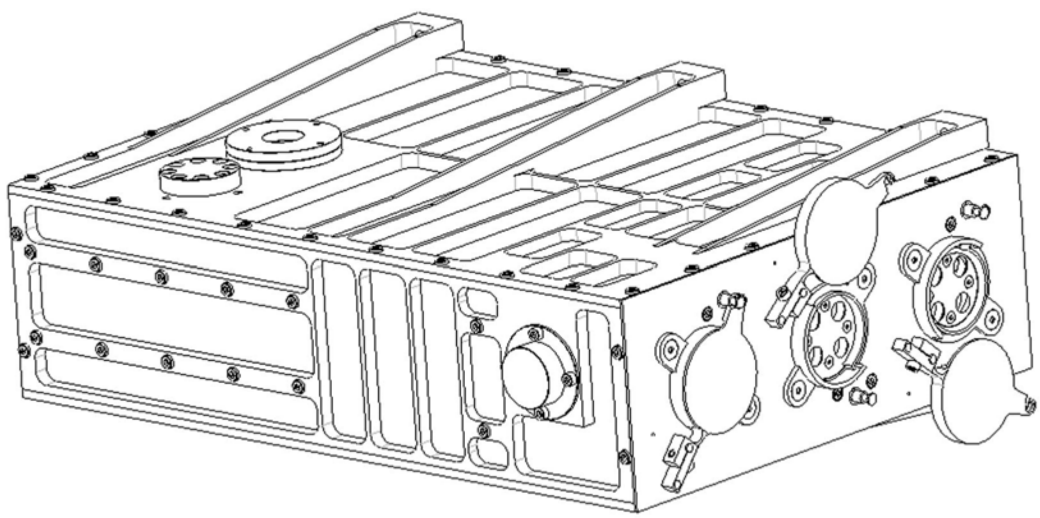

Figure 7. 3D design of PREMOS, the contribution of PMOD/WRC to the French space experiment PICARD.

4 Scientific Research Activities

4.1 VIRGO Radiometry and its Long-Term Behavior

Claus Fröhlich and Wolfgang Finsterle

The early increase of the VIRGO total solar irradiance (TSI) shortly after the minimum in 1996 was until recently an unresolved issue (Fröhlich and Lean, 1998; Fröhlich, 2000), as it was incompatible with the empirical models based on the influence of sunspots (PSI), faculae and the network (Mg-II index). With increasing solar activity the VIRGO TSI achieved levels of the preceding activity maxima well before the activity maximum of cycle 23 was reached. An obvious question, however, is what could be the physical reason for such a behaviour and why have other radiometers of similar type in space not shown such an increase with time. The radiometers are based on thermal flux measurements and are thus very sensitive to changes in the thermal environment, which is extraordinary stable on SoHO and, in contrast on e.g. Earth orbiting satellite quite variable. Under varying conditions the radiometer never reach a thermally steady state and the long-term change translate into noise. First we examine each type of radiometer separately for exposure dependent effects and then compare the resulting time series in order to determine possible long-term changes which are independent of exposure time. The detailed analysis is described in Fröhlich and Finsterle (2001), and here we present a summary of an internally consistent description of the behavior. The analysis is ongoing and here we report on the status of the research as of the end of 2000.

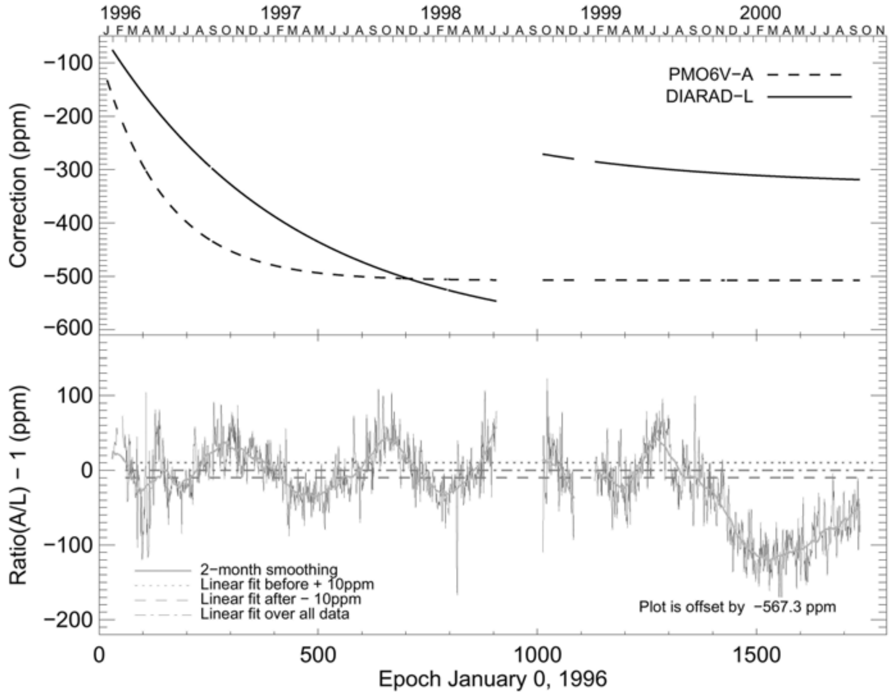

Figure 8. Corrections for the exposure independent behavior of PMO6V-A and DIARAD-L (top panel) and the corrected ratio (lower panel).

The level 1 product of the VIRGO data is obtained after reducing the raw data to physical units and by applying all *a-priori* known instrumental effects such as electrical calibration and corrections for the thermal environment and operational corrections for distance and velocity to the sun. These data show a combination of the variation of the sun's irradiance and instrumental changes. It is also obvious that the two back-up instruments show more closely the irradiance changes whereas the operational ones are more strongly influenced by long-term sensitivity changes. We first determine for each radiometer the exposure dependent changes by comparing the operational one with its backup (for details see Fröhlich and Finsterle, 2001). For both type of radiometers the degradation model assumes a sensitivity increase at the beginning and a dose dependent degradation over the whole mission time. To account for changes related to the paint we assume a hyperbolic behaviour as function of exposure time $a(1+t_{exp}/\tau)^{-b}$. The main reason for this choice is that a hyperbolic function describes a change in optical properties the subsequent change in response to the radiation more physically than an exponential one. The decrease in sensitivity with exposure time, normally termed degradation, is assumed to be a linear function, the slope of which is modulated by the dose of the received radiation weighted with a hyperbolic function in time; the latter simulates the decrease of the sensitivity to irradiation with time. For the dose the MgII index from the SUSIM experiment on UARS isused (for the data see Floyd et al.,1998). In this approximation the period before and after the SoHO vacations are treated differently to reflect possible sensitivity changes during the exposure to the cold environment. In the case of DIARAD-R the total exposure time is about 1.5 days after five years in space and thus it is assumed to have no exposure dependent change. For PMO6V-B, the exposure time was early in the mission quite important, and reached about 10 days when the cadence was changed from once every 8 hours to about once a week (around mission day 210) and 15 days after 5 years. The parameters are varied in such a way that the standard deviation from a linear fit to the ratio of the readings of the back-up to the ones of the operational radiometer is minimized and the slope becomes zero. It is important to note that the dose dependent degradation was essential to achieve the low variation around the horizontal line (55.5 and 35.3 ppm for PMO6V and DIARAD respectively). In the case of the DIARAD-L the corrections are such that the degradation at the beginning is masked by an increase in sensitivity, which was early in the mission interpreted as if DIARAD had no long-term change at all. The early increase is similar to the one of PMO6V, but with a longer time constant. In parallel with this increase in absolute sensitivity an increase of the relative sensitivity to short-term variations by more than 30% is observed for DIARAD (determined by comparison with the short-term variance of PMO6V).

The comparison of the time series of PMO6V-A and DIARAD-L – corrected for the exposure dependent changes – shows a trend which obviously has to be exposure independent. For this increase in sensitivity we propose an exponential function:We minimize the standard deviation from a regression line to the ratio V-A/DIARAD-L by varying the parameters *a* and τ for PMO6V-A; then we minimize τ of DIARAD-L and adjust its *a* coefficient so that the slope becomes zero. This is done iteratively and the procedure converges well to the curves shown in Figure 8, mainly due to the fact that the time constants of the two radiometers are (fortunately) quite different. It is assumed that the effect starts with the switch-on of the instrument and is due to the slightly higher temperature of the cavity relative to the surroundings. After the SoHO vacations a change of 276 ppm of the ratio PMO6V-A/DIARAD-L is observed. Presently this change attributed to a change of DIARAD, because a similar change occurred after the an accidental switch-off of VIRGO for 3 days. The final VIRGO level-2 irradiance is presented in the next Section.

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Floyd L., Reiser P., Crane P., Herring L., Prinz D. and Brueckner, G.: 1998, UV measurements from SUSIM on UARS, *Solar Phys.* 177, 79–86.

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Fröhlich C., and Lean J.: 1998, The sun's total irradiance: Cycles and trends in the past two decades and associated climate change uncertainties, *Geophys. Res. Let.* 25, 4377–4380.

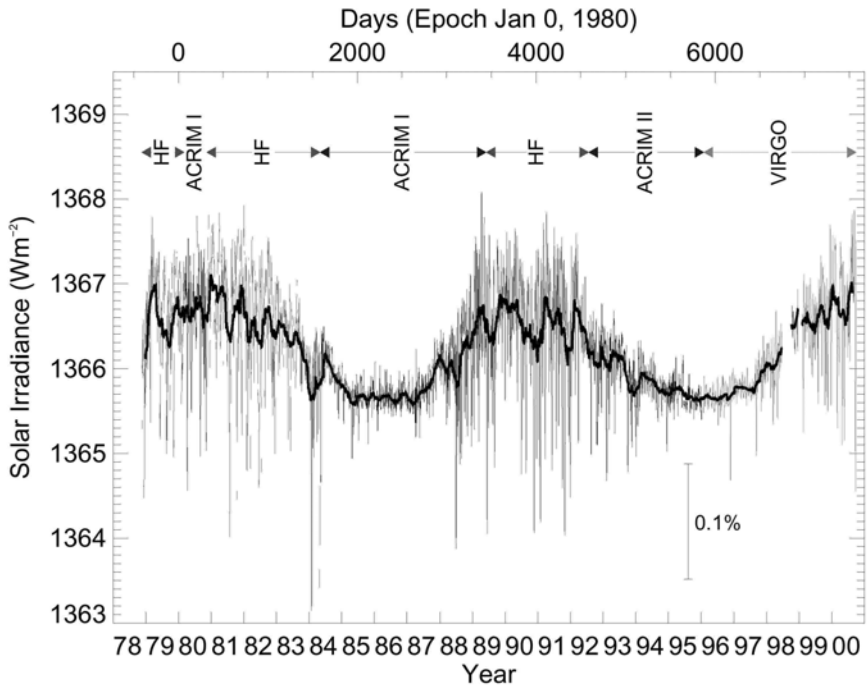

Figure 9. Composite *TSI* updated with the VIRGO Version 3.50 data.

4.2 Longterm Behavior of Total Solar Irradiance since 1978

Claus Fröhlich

From the analysis described in the previous Section a new version of the VIRGO *TSI* can be constructed as a composite of the results from the corrected data of DIARAD-L and PMO6V-A. As described in Fröhlich and Finsterle (2001) the short-term sensitivity change of the DIARAD as observed at the beginning of the mission has to be corrected first. At the beginning of the mission the PMO6V data are less reliable, partly due to the early increase which cannot be determined very accurately as PMO6V-B was only operative after the major increase of PMO6V-A was over, and partly due to the new type of operation which was needed after the failure of the shutters (Fröhlich et al., 1997). Thus, before end of February 1996 the PMO6V data are discarded. During the periods when both radiometers are available the average of PMO6V-A and the short-term corrected DIARAD-L is used. If only one radiometer is available it is multiplied or divided by the interpolated average ratio. The *TSI* from February 1996 until September 2000 (Version 3.50) is available as daily and hourly values from www.pmodwrc.ch in files with an explaining header and three columns listing the VIRGO, PMO6V and DIARAD level-2 values. With the new VIRGO *TSI* we have also updated the composite which is shown in Figure 9 and is also available from the PMOD/WRC Webserver as version 19.

This composite is compared to the model calibrated over the full period of the composite as described in Fröhlich (2000). The result is shown in Figure 10 and the onset into the new cycle 23 has no longer the pronounced difference due to the early increase of the VIRGO radiometry. Thus the revision of the VIRGO radiometry has not only helped to better understand the problems with room-temperature radiometers in space, but also to produce a reliable composite which allows to study the influence of solar activity on *TSI* in more detail and possibly will resolve the important question of how much of the *TSI* changes are related to the direct influence of the manifestations of the magnetic fields on the surface and how much is due to thermal effects, also produced by the activity, but more indirectly.

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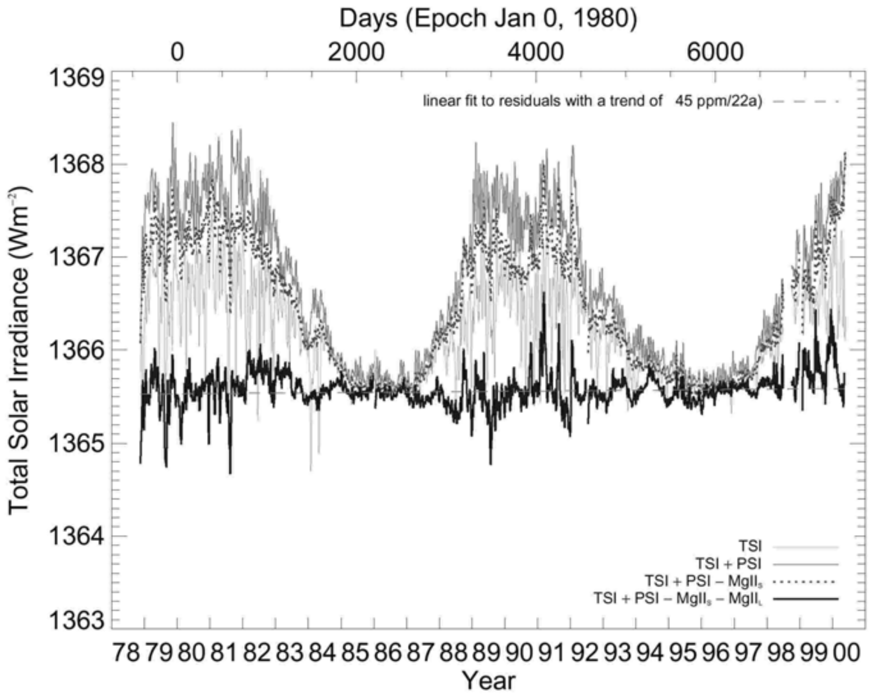

Figure 10. Comparison of the composite with the new VIRGO data with the model composed of PSI and a long and a short-term MgII index.

4.3 Interpretation of TSI Variations

Claus Fröhlich

The first results from VIRGO (Fröhlich et al. 1997) indicated that there was a latitudinal variation in the vigour with which solar p modes are excited by turbulent convection, and suggested that perhaps the excitation is different in latitudes of greater magnetic activity. This latitude dependence can be inferred from the different amplitudes for different tesseral orders which are oriented on great circles inclined by $\arccos(m/l)$ from the equator. As the amplitude of a mode is proportional to the excitation its vigour at different latitudes can be inferred from the m dependence of the amplitudes and thus provides a diagnostic tool to study activity related changes of the turbulent convection near the surface. With this in mind Fröhlich et al. (2001) investigated the m-dependence of the amplitudes of p modes with $l \leq 4$ from VIRGO-LOI data for the period from March 1996 until March 2000. The inferred amplitude functions do not exhibit local maxima at the latitudes of active regions, as the function presented previously by Fröhlich et al. (1997) suggested. We suspect that the earlier relatively short data set was too heavily influenced by realization noise. In addition at the time, the data for $l \leq 4$ were fitted using power spectra and not Fourier spectra, which can influence the amplitude ratios. It is perhaps pertinent to remark that if we include modes of higher degree (fitted using power spectra up to l = 7) in our analysis, the inference becomes similar to that reported previously, and is not strongly dependent on the maximum value of l. However, these higher-degree modes cannot be isolated so well from the others in the signal, and therefore are more heavily contaminated by interference. Besides the fact that the observed distribution is likely a manifestation of instrumental calibration errors one can still recognize a possible change with increasing solar activity. During solar minimum the excitation shows a minimum around ≈55 degree and a small maximum at ≈30 degree. With increasing time and activity the minimum is gradually filled-in and the maximum weakened, leading to a constant excitation from the equator to up to ≈30 degree followed by a gradual increase with latitude towards the pole. This interesting result needs obviously more investigation, but may be in line with the observed decrease of the amplitudes with increasing solar cycle, as noted in the present data-set and stated earlier by e.g. Bogdan et al. (1993). On the other hand it is opposite to the observations of increased brightness in the activity bands migrating from high latitudes at solar minimum towards the equator at activity maximum (e.g. Kuhn and Libbrecht, 1991).

Another way of studying the influence of activity on *TSI* is the comparison of the latter with the changes of the frequencies of p modes. The result of such a comparison using data from VIRGO/LOI and the BISON network is shown in Figure 11 and covers the period from the maximum of solar cycle 22 until mid 2000. It is interesting to note that the correlation of the irradiance with the frequency change is higher (r^2 = 0.92) than with MgII index. This may indicate that indeed an further component – not directly related to the magnetic fields – may influence *TSI* .

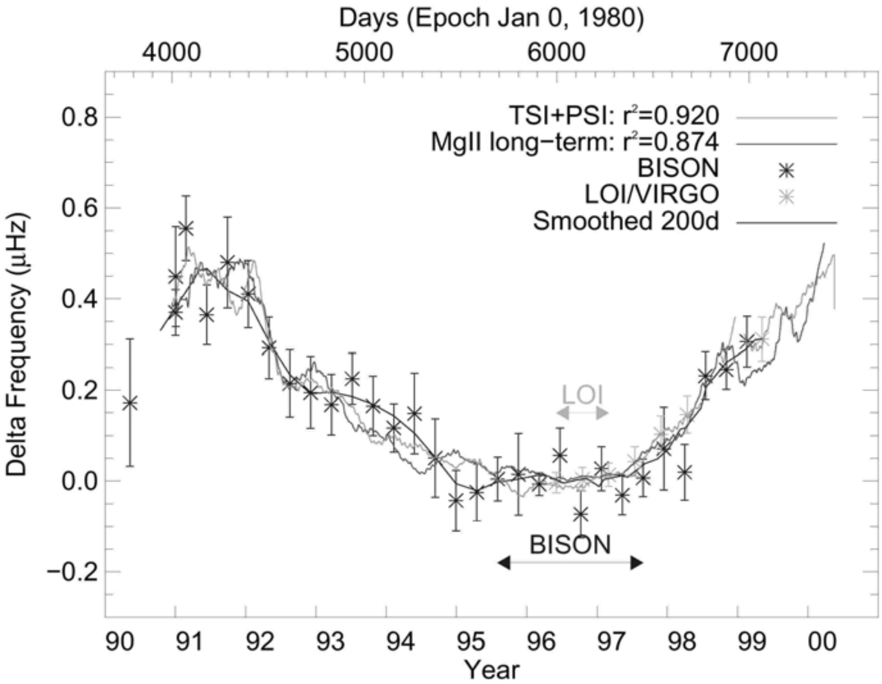

Figure 11. Comparison of p-mode frequency changes with changes of *PSI*-corrected irradiance and the longterm MgII-index. The time identified by the arrows indicate the periods when the BISON and LOI data. have been normalized to zero.

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4.4 Search for g Modes and low-frequency p Modes

Wolfgang Finsterle, Richard Wachter, Claus Fröhlich, and Werner Schmutz

Solar internal gravity waves are expected to oscillate as standing waves (g modes) with frequencies below 450 μHz (i.e., periods longer than 37 minutes) in cavities located in the deep interior of the Sun. At the lower boundary of the solar convective zone they excite pressure waves, which reach the solar surface where they produce detectable brightness variations. Once excited, each g mode is expected to oscillate for years, certainly longer than the time interval of our present observations with the VIRGO experiment on SoHO. This implies that we do not yet resolve the widths in frequency of g modes. So we have to look for single frequency bin, exceeding the solar noise in a significant manner. They same argument applies to low frequency pressure modes (p modes). However, due to the increasing sound speed towards the core p modes do not penetrate so deeply into the Sun and therefore they do not reveal as much information of the solar interior as the g modes.

The investigated time series are from the three channel sunphotometers (SPM) of VIRGO covering 1441 consecutive days starting on 22 February, 1996 with an interruption of some 100 days in summer 1998. Outside this long-term interruption the data fill factor is about 95%. To restore lost power due to short interruptions, the remaining gaps have been filled by using cross-correlation between the red, green and blue channels. This is possible, because the spectra are dominated by solar and not instrumental noise. In our nearly four years long time series, the natural frequency resolution is 8 nHz. The discreteness of the spectra can cause a distribution of power in adjacent bins. In order to concentrate the power of the sharp modes into a single resolution bin, we over-sampled the power spectra. This was achieved by repeatedly cutting the last two readings off our time series, until they are shortened by 2 hours, which corresponds to a shift in the sampling frequency of 8 nHz at 150 μHz. Then the resulting spectra are combined to yield the over-sampled spectra.

We have investigated the variability of the time series in the frequency range 150...850 μHz. In each color channel we selected those peaks which have less than 0.1 probability to appear by chance over a 70 μHz wide frequency band. In the considered frequency range 1 peak per channel is expected to cross this limit by chance. We found five of them in the red, four in the green and two in the blue channel. Some of them appear in multiple channels simultaneously, resulting in a total of seven peaks located at mutually different frequencies. We calculated the significance (i.e., 1 minus the probability to appear by chance over a 70 μHz band) for all of these peaks in each spectrum and selected those peaks with the highest average significance. Three peaks fall out of consideration because their average significance is below 0.90. The remaining three peaks have an average significance of 0.91 up to 0.95. These strong candidates for solar eigenmodes are located at 222.626 μHz, 236.773 μHz and 596.166 μHz, respectively. Two of them agree very well with frequencies predicted by solar model M1 (Provost et al., 2000). According to this model the 222.626 μHz peak belongs to the g mode of radial order *n*=3 and degree *l*=2 (predicted at 222.70 μHz), while the 596.166 μHz peak corresponds to the p mode *n*=3, *l*=1 (596.79 μHz). Both of these modes are expected to be accompanied by other peaks in a distance of roughly 0.8 μHz, which could not be observed. The lack of multiplets, and also the arbitrary selection of only two out of 26 possible modes within our frequency range, can be explained by the fact that modes need to interfere constructive with solar noise in order to reach detection limit.

Unfortunately, the attempt to reveal another signature of a coherent signal, especially differences in the mutual phase at the expected mode frequency has failed. So, it is not clear, whether the peak corresponds to an eigen mode or is just produced by solar noise.

4.5 Investigation of the solar upper atmosphere

Isabelle Rüedi in collaboration with A. Brkovic, A. Pauluhn, K. Stucki (ETH, Zurich) and S.K. Solanki (MPA Lindau)

The UV instruments onboard the SOHO satellite were specially designed to investigate the upper layers of the solar atmosphere where mysterious processes such as the acceleration of the solar wind to the high speeds observed at the Earth and the heating of the million degree corona are supposed to take place. We made use of those instruments to investigate the source region of the solar wind, the quiet Sun intensity distribution of EUV lines and variability, blinkers and finally the intercalibration of the instruments which were used for those investigations.

Coronal holes are the source of the fast solar wind and the primary example of coronal heating in regions with a significant excess of magnetic polarity, but are not yet well understood.

Data were analyzed which originated from 26 far-ultraviolet emission lines observed on both sides of the boundary of polar coronal holes as well as other quiet Sun areas along the limb. The observations were made with the SUMER instrument. Line intensities, shifts and widths in coronal holes were compared with the corresponding values obtained in the quiet Sun. We find that with increasing formation temperature, spectral lines show on average an increasingly stronger blueshift in coronal holes relative to the quiet Sun at equal heliospheric angle, with the coolest lines in our sample (formation temperature ~ 10^4 K) indicating a small relative redshift. With respect to the rest wavelength, however, only lines formed above $5{\cdot}10^5$ K show blueshifts in coronal holes, which is not very different from the quiet Sun. The width of the lines is generally larger inside the coronal hole. Intensity histograms also exhibit distinct differences between coronal hole and quiet-Sun data. For cooler chromospheric lines, such as Ni II, the coronal holes display a greater spread in intensities than the quiet Sun. Transition-region lines, e.g. O IV, do not reveal such differences, while Ne VIII shows characteristics of a coronal line with lower average intensity and lower intensity spread inside holes.

The solar wind emanates in coronal holes, but the mechanism by which it is accelerated to the high speeds observed near the Earth is still not clear.

We studied the relationship between wavelength shifts and intensities of chromospheric, transition-region and coronal UV emission lines in polar coronal holes and in the normal quiet Sun using SUMER data. Within coronal holes almost all the lines showing the network and formed above 30’000 K show a correlation between blueshifts and brightness. This extends and supports the conclusion reached by Hassler et al. (1999) that the fast solar wind emanates from the network. In the normal quiet Sun, however, we find that only lines formed above $2\text{-}3\cdot10^5$ K show such a trend, the cooler lines being more redshifted in the network. This suggests that either there is a fundamental difference in the initial acceleration of the solar wind in coronal holes and the normal quiet Sun, or that the wavelength-shift versus brightness relationship in the quiet Sun stems from other processes or structures (loops) than in coronal holes (open field lines).

The EUV emission of the quiet Sun forms a pattern of bright and dark structures. The bright parts are referred to as the chromospheric or transition region network and surround darker cells with a diameter of approximately 30’000 km. The brightness enhancements in the network result from concentrations of magnetic field, which are produced by convection in the photospheric supergranules.

We modeled the frequency distribution of EUV emission line intensities in the quiet Sun using different distribution functions. The data were obtained in a number of spectral lines observed with two extreme ultraviolet spectrometer (SUMER and CDS). In this way, the influence of spatial and spectral resolution as well as other instrument-specific parameters can be identified. We show that the frequency distribution of the radiance is best modeled by a log-normal distribution (better than by two Gaussians). This suggests that the same heating processes are acting on the network and the intra-network. The parameters of the log-normal fit show a clear temperature dependence.

We studied brightness variations of solar features in the quiet Sun at three different temperatures sampled simultaneously in the chromospheric He I 584.3 Å, the transition region O V 629.7 Å and coronal Mg IX 368.1 Å lines.

In all parts of the quiet Sun, from darkest intranetwork to brightest network, we find significant variability in the He I and O V line, while the variability in the Mg IX line is more marginal. The relative variability is independent of brightness and strongest in the transition region line. Thus the relative variability is the same in the network and the intranetwork. More than half of the points on the solar surface show a relative variability, determined over a period of 4 hours, greater than 15.5% for the O V line, but only 5% of the points exhibit a variability above 25%. Most of the variability appears to take place on time-scales between 5 and 80 minutes for the He I and O V lines.

Clear signs of ``high variability'' events are found. For these events the variability as a function of time seen in the different lines shows a good correlation. The correlation is higher for more variable events. These events coincide with the (time averaged) brightest points on the solar surface, i.e. they occur in the network. The spatial positions of the most variable points are identical in all the lines.

Blinkers are transient brightenings seen in the EUV. These brightenings are candidates for microflare activity. Their properties were determined using the same CDS observations as above. They are present in both bright and dark regions, but their number density is somewhat larger in the brighter areas. The size, duration and intensity ratios were investigated as well as their correlation.

Blinkers in the 3 lines are poorly correlated. This suggests that the transition region reacts independently of the chromosphere and corona to energy deposition, so that these parts of the atmosphere are at least decoupled from each other. This agrees with the expectations of models having separate transition region loops, but contradicts the classical picture of the transition region as being heated by conduction from the corona.

The full potential of the complementary spectrometers SUMER and CDS on SOHO can only be achieved if a good inter-calibration of the two spectrometers exists. We carried out such an investigation between the SUMER A and B detectors and CDS NIS for the time span before as well as after the loss of SOHO which caused several changes for the instruments exposed to temperatures far away from nominal. The relative performances of the instruments was determined and recommendations are given on how to ensure consistency between different data sets.

4.6 The Clear-Sky Index

Christoph Marty and Rolf Philipona

Accurate surface radiation fluxes are required to quantify atmosphere-surface energy exchanges. In climate research, detailed investigations of the influence of diverse atmospheric conditions on radiative fluxes ask for a well-defined distinction between clear-sky and cloudy-sky situations. Effects of clouds, the so called ''cloud forcing'', can only be determined by explicitly separating clear-sky from all-sky radiation measurements. A Clear-Sky Index (CSI) to separate clear-sky from cloudy-sky situations has therefore been introduced, using accurate atmospheric longwave radiation in conjunction with air temperature and humidity measurements at the station. Although in our investigations CSI has only be used to decide between clear- and cloudy-sky, the CSI has no strict limit and may also be divided in different subcategories to define the percentage of cloud coverage. With the dramatic decrease of uncertainty on longwave downward irradiance measurements due to improved instruments and calibration techniques, the implementation of the CSI offers new possibilities in the field of meteorology and radiation climatology. This clear-sky index, which has the important advantage to be applicable 24 hours a day, was tested and first used on measurements of the Alpine Surface Radiation Budget (ASRB) network, and was of prime importance for the determination of the altitude dependence of cloud forcing and greenhouse effect over the Alps.

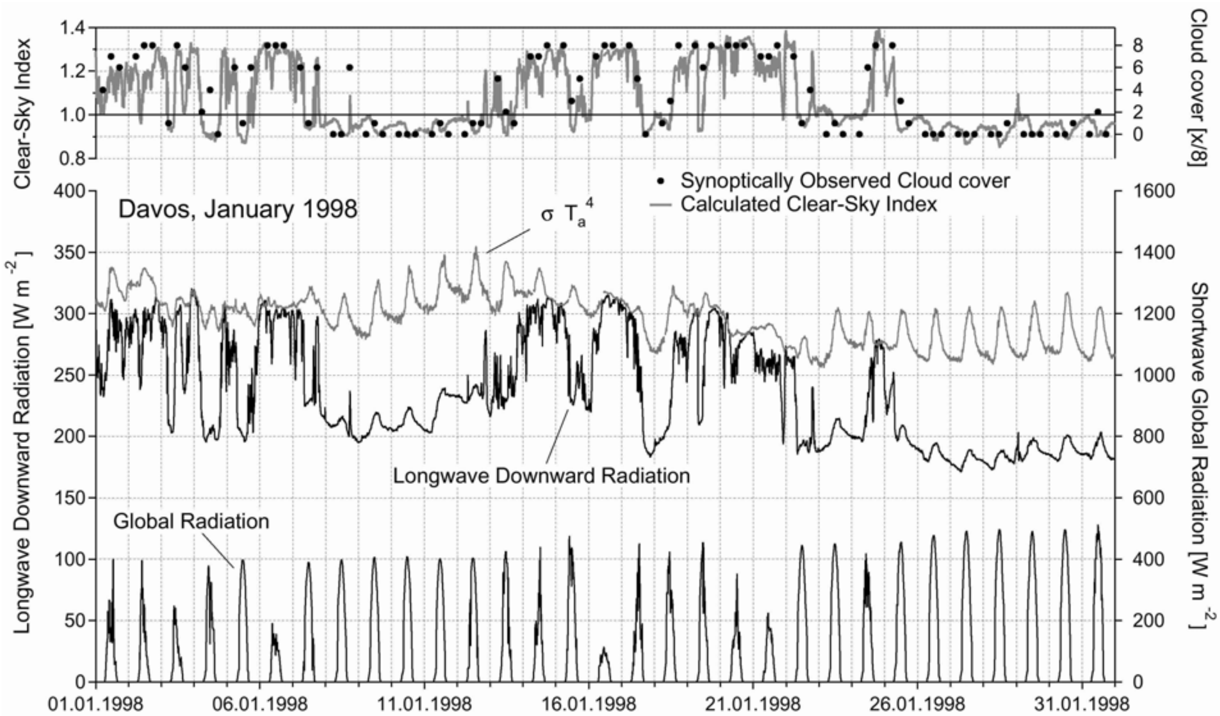

Figure 12. Comparison between the calculated Clear-Sky Index (continuous curve) and the synoptic cloud cover observation (dots) for January 1998 at the ASRB–station Davos. Clear-sky situations are defined for CSI smaller than 1 and correspond fairly good with cloud observations lower than 2/8. Low levels of longwave downward radiation also indicate clear-sky situations as well as high continous curves of shortwave global radiation.

More details about the CSI can be found in a paper by Marty and Philipona (2000).

References

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4.7 Atmospheric Longwave Irradiance Uncertainty

Rolf Philipona

The first International Pyrgeometer and Absolute Sky-scanning Radiometer Comparison (IPASRC-I), which was held in fall 1999 at the Atmospheric Radiation Measurement (ARM) program's Southern Great Plains (SGP) site in Oklahoma, shows astonishingly good agreement between downward longwave radiation measurements and calculations of different instruments and radiative transfer models. The difference, averaged over four nighttime cases, between the Absolute Sky-scanning Radiometer (ASR) and pyrgeometers, AERI, LBLRTM and MODTRAN is less than 2 Wm^{-2} (see Figure 13). This result boosts confidence in the correctness of present day clear-sky nighttime longwave irradiance measurements and calculations indicating that absolute uncertainty levels as low as ± 1.5 Wm^{-2} or 0.5 % are practicable and realistic at least for mid-latitude summer conditions. The ASR was used as a reference standard instrument to field calibrate pyrgeometers which produced remarkable improvements in pyrgeometer precision compared to standard blackbody calibrations. IPASRC-I demonstrates that state-of-the-art pyrgeometers are "Precision Infrared Radiometers" (PIRs) if they are correctly calibrated and deployed. A second IPASRC campaign is planed to investigate longwave radiation under arctic winter conditions at the ARM, CART site in Barrow in early 2001.

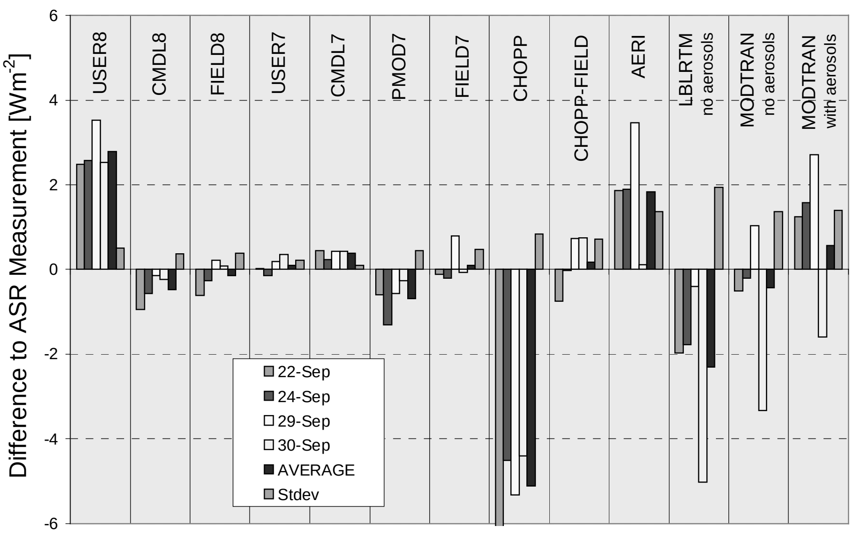

Figure 13. Differences of measurements and model calculations to the Absolute Sky-scanning Radiometer (ASR) for 4 nighttime cases and average and standard deviation over the 4 cases. The USER8 pyrgeometer group has one instrument far to high which makes the average over the group to high. All other pyrgeometer groups show average irradiances which are very close to the ASR measurements. The chopped pyrgeometer showed irradiances about 5 Wm^{-2} low compared to the ASR. With the new field calibration this instrument is also close to the absolute measurements. The Atmospheric Emitted Radiance Interferometer (AERI) measurements is on average about 2 Wm^{-2} higher than the ASR. LBLRTM model calculations are about 2 Wm^{-2} low but if aerosol would be included these irradiances increase by about 1.5 Wm^{-2} which gets them very close to the absolute measurements. MODTRAN calculations without aerosols are below and with aerosols about 1 Wm^{-2} higher.

The demonstrated low uncertainties in atmospheric longwave irradiance are very encouraging and may allow in the future to observe possible greenhouse effect induced climate changes. The IPASRC-I results have been summarized in a paper entitled „Atmospheric Longwave Irradiance Uncertainty: Pyrgeometers compared to an Absolute Sky-scanning Radiometer, AERI and Radiative Transfer Model Calculations“ which was submitted to the *Journal of Geophysical Research* (Philipona et al., 2001)

4.8 Albedo-enhanced Maximum UV Irradiance

Rolf Philipona and Daniel Schmucki

Global solar UV Index is determined with erythemal measurements on flat horizontal receivers measuring irradiance with a hemispherical 2π opening angle. Measurements on tilted rather than horizontal flat receivers, however, show different signal levels and on clear-sky days maximum global irradiance levels are achieved by tilting the flat receiver surface normal to the sun. The direct component is amplified by the inverse cosine of the zenith angle, but over surfaces with high local albedo this accounts for only about half of the signal rise of global irradiance. Diffuse UV radiation however, which stems from important Rayleigh- and multiple-scattering and high reflection on snow covered surfaces has a complicated relation between irradiances measured on horizontal versus normal to sun oriented receiver surfaces. The relation largely depends on the albedo of the surface surrounding the receiver and on the solar elevation angle.

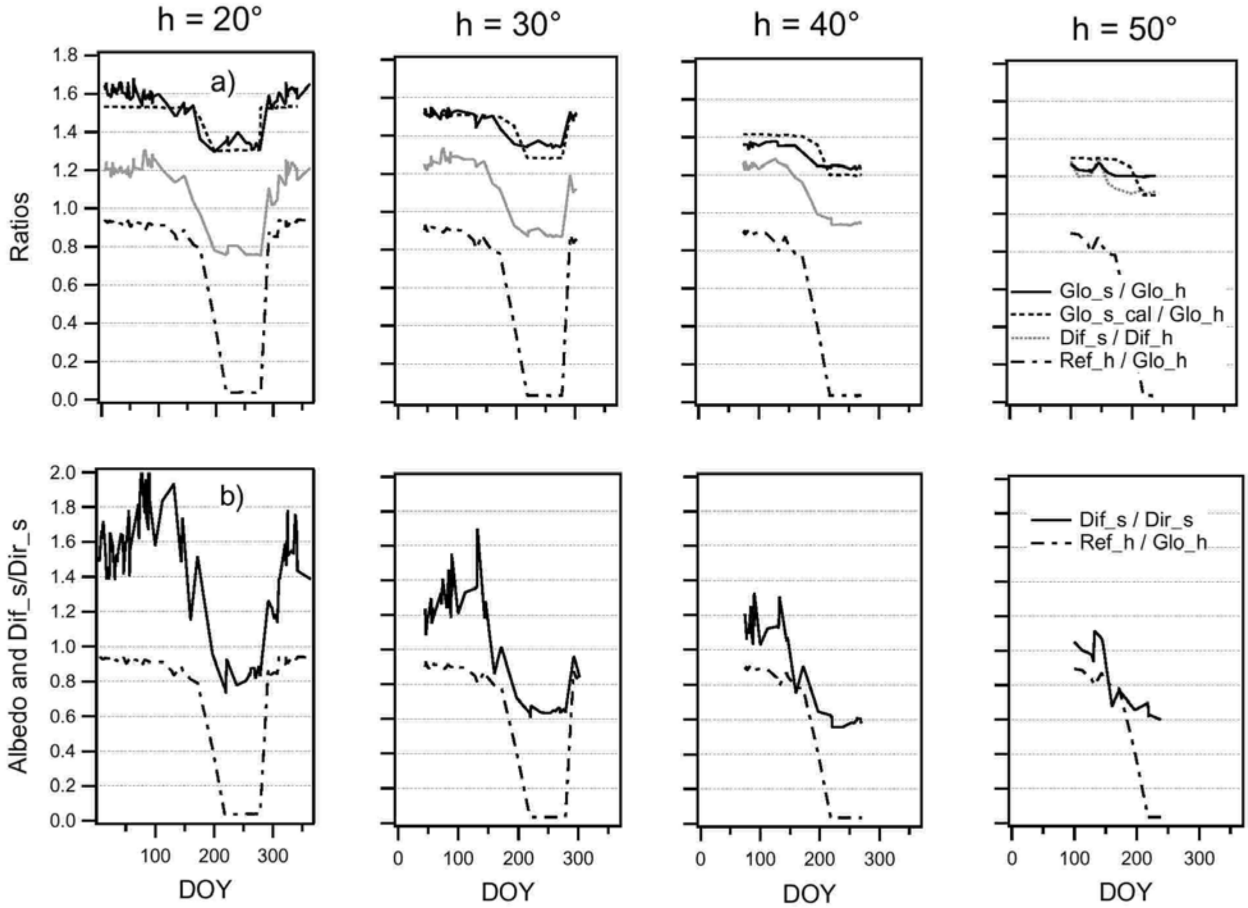

Figure 14. Annual evolution (DOY = Day of Year) of ratios of – a) Global UVery normal oriented (_s) versus horizontal surfaces (_h), measured and calculated (_s_cal), as well as diffuse UVery normal-to-the-sun-oriented versus horizontal surfaces and the albedo (Ref_h/Glo_h) at four solar elevation angles. b) Diffuse versus direct UVery normal-to-the-sun-oriented and the albedo.

This investigation is based on erythemal effective UV irradiance (UVery) measurements made at the UV station Weissfluhjoch which is located in the investigation field of the Swiss Institute for Snow and Avalanche Research (SLF) in the heart of the Parsenn ski area in the Swiss Alps. Two years of measurements of direct, diffuse, global, reflected and global normal-to-the-sun UVery irradiance are used. Global UVery signal rises, on normal-to-the-sun-oriented versus horizontal receivers, of up to 65 % were measured on fresh snow and solar elevation angles below 30°. An empirical expression has been deduced from the measurements, relating global UVery irradiance on normal-to-the-sun versus horizontal receivers as a function of solar elevation *h* (degrees) and local albedo α.

$$\frac{Glo\_s\_cal}{glo\_h} = \frac{\alpha^{0.05}}{(\sin h)^{0.02h}}$$

The solar elevation-dependent annual plots in Figure 14 show the ratios of the calculated global normal-to-the-sun oriented versus the horizontal measured irradiance and they match the measured ratios well. The results demonstrate considerable increases of global solar UVery irradiance levels, received by sun tanning individuals exposing their faces normal to the sun compared to levels indicated by the global solar UV-Index. A detailed paper on this investigation has been published in Philipona et al. (2001).

Reference

Philipona R., Schilling A., Schmucki D.: 2001, Albedo enhanced Maximum UV Irradiance – measured on surfaces oriented normal to the sun, *Photochemistry and Photobiology*, 73, 366–369.

4.9 Aerosol Optical Depth (AOD) Comparison at Mauna Loa

Christoph Wehrli

The determination of AOD from atmospheric extinction measurements by a Langley calibrated spectral radiometer is not unambigous because the calibration method makes assumptions about the temporal and spatial stability of AOD itself and because of choices to be made in modelling of the non-aerosol atmospheric extinction components. A comparison of results obtained by different instruments and evaluation algorithms yields a fair estimate of uncertainties in AOD.

Mauna Loa, where a PFR is operated since November 1999, is also the principal calibration site for the AERONET programme. This world wide network in operation since 1993 uses commercial CIMEL radiometers with 7 channels centered at 1020, 870, 670, 500, 440, 380 and 340nm. Measurements with variable sampling rate are collected via satellite links and evaluated at NASA Goddard Space Flight Center. The co-location of instruments at MLO provides an excellent opportunity to compare results from the new PFR instruments to the well established AERONET system under very clear skies conditions.

Both instruments agree in wavelength only at 500nm; the 3 other channels of PFR deviate from the CIMEL wavelengths by up to 28 nm. Therefor the Aeronet results were fitted by Angström's law and interpolated to match the PFR wavelengths. The CIMEL instrument takes measurements according a specific daily schedule while the PFR employs a sampling cadence of 1 minute. For each Aeronet sample, PFR results were thus interpolated between adjacent 1 minute samples.

Aeronet Level2 data which are fully calibrated and manually inspected for cloud influence are available up to December 1999; data for 2000 have not yet final status.

PFR data were evaluated using the average values from 17 Langley calibration in January 2000. A number of 351 simultaneous samples were compared and are summarized in the table below:

Table 3. Comparison of AOD determinations obtained by CIMEL and PFR instruments.

Wavelength [nm]:	367.6	412.0	501.2	862.4
Mean AOD CIMEL :	0.0217	0.0154	0.0098	0.0045
Mean AOD PFR :	0.0203	0.0163	0.0114	0.0049
AOD Difference :	0.0015	-0.0009	-0.0016	-0.0004
Stdev. AOD PFR :	0.0040	0.0036	0.0030	0.0014

Differences in AOD of less than 0.002 have to be considered excellent, they indicate a calibration uncertainty of less than 0.1% for both instruments.

Acknowledgement

The permission of Dr. Brent Holben, principal investigator of Aeronet and the Mauna Loa site, to use the CIMEL data is gratefully acknowledged.

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AERONET homepage http://aeronet.gsfc.nasa.gov:8080/

4.10 Cloud filtering in PFR measurements

Christoph Wehrli

Determination of aerosol optical depth from measurements of atmospheric extinction and Langley calibration of the instruments involved, rely on clear sky conditions during observations. The data evaluation is severely hampered by the presence of optically thin clouds in the path of observation. Cloud contamination can be avoided in manual measurements by visual judgement of trained operators, but automated observations require cloud-screening by algorithms which should provide reliable results under a wide range of sky conditions.

L. Harrison and J.Michalsky (1994) have proposed such an algorithm based on finite differences and least squares filtering aimed at Langley calibrations over a limited air mass range. Their method is based on the fact that the first derivative of irradiance with respect to air mass $\delta E \approx \Delta E/\Delta m$ is always negativ. Any sample where $\delta E>0$ is affected by a cloud intruding the path of observation before noon or leaving it in the afternoon. Cloud induced irradiance variations 'towards noon', that is rising AM or falling PM levels, cannot be discerned by the sign of δE and are handled by assuming a time symmetric cloud perturbation. In addition they use filters based on statistical analysis of higher order derivatives. This method does not work well for air mass less than 2 because the small Δm strongly enhances any signal fluctuations ΔE. Although this is no big restriction if mean values of aerosol optical depth (AOD) are derived from the slopes of a Langley regression, it excludes a significant part of daily measurement for instantaneous AOD determinations.

Using *a priori* information of exoatmospheric signal and wavelength besides assuming that AOD is varying more slowly than a cloud perturbation, PFR measurements are cloud-flagged when the observed signal rate of change is positiv or smaller than twice the rate of a pure Rayleigh sky. This filtering step is routinely applied on raw measurements, together with other tests that result in a numeric data quality flag associated with each sample.

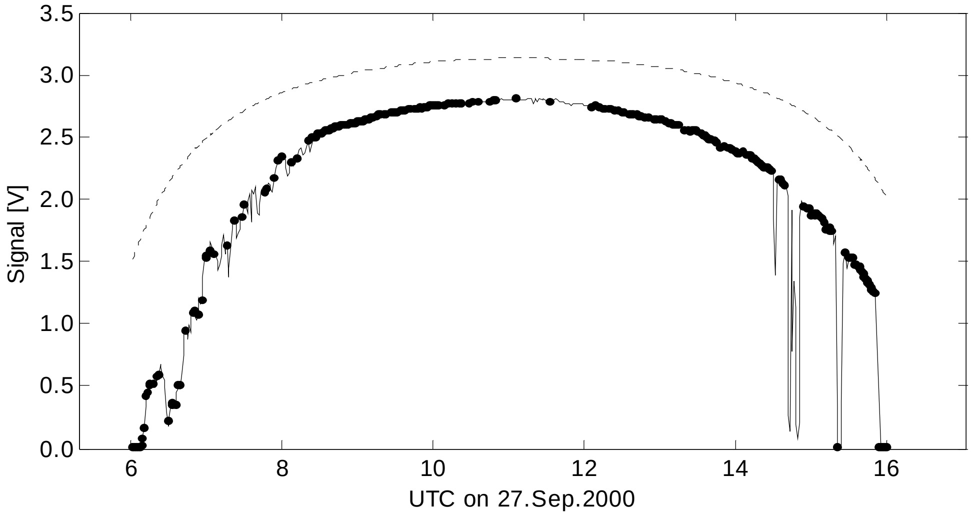

Figure 15. Cloud filtering of PFR signal measured on 27.September 2000 in Davos. The solid line represents all one minute samples, clear sky samples are indicated by dots and the dotted line on top shows the expected signal assuming aerosol and cloud free Rayleigh conditions. Some morning samples are obviously misinterpreted as cloud-free, but are quite easy to eliminate during further evaluation.

Reference

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4.11 Topics in Astrophysics

4.11.1 Accretion in RW Hydrae

Werner Schmutz in collaboration with T. Dumm, D. Folini, H. Nussbaumer, H. Schild, and R. Walder (ETH Zürich)

RW Hya is a detached eclipsing symbiotic double star system. Data obtained with IUE and HST show that outside of the main eclipse there is a phase of attenuation of the continuum by Rayleigh scattering. We interpret this as the result of occultation along the line of sight by material accreting onto the hot companion. We computed a 3D hydrodynamical model of wind accretion onto a white dwarf in order to predict the circumstellar velocity and density distribution. From this model we computed synthetic line profiles as a function of the view angle of the system and compared these predictions with Hα spectra that we obtained at different binary phases. The observations have been collected over the past two years at ESO telescopes on La Silla. We have also been awarded additional HST observing time in the upcoming cycle 9 in order to complete the analysis.

4.11.2 Modeling of stellar atmospheres

Götz Gräfener and Werner Schmutz in collaboration with W.-R. Hamann (University Potsdam)

We concentrated on modeling the radiation-driven winds from hot stars. Theoretical stellar spectra were calculated with a computer code which models expanding stellar atmospheres in non-LTE and incorporates the most important atomic species (H, He, C, N, O, and the iron group elements). Figure 17 shows a comparison between theoretical and observed line profiles in the spectrum of the hot star ζ Puppis.

We extended the atmosphere code by incorporating hydrodynamics; the wind-structure is now computed consistently with respect to the calculated radiation pressure.

As a first test, this code was applied to the hot star ζ Puppis. Unfortunately, the calculated mass loss rate turned out to be about a factor of two below the observed value. This result probably indicates that we are still missing some of the opacities from trace elements like Ne, Si, P, S, Ar, and Ca; these elements have yet to be included in.

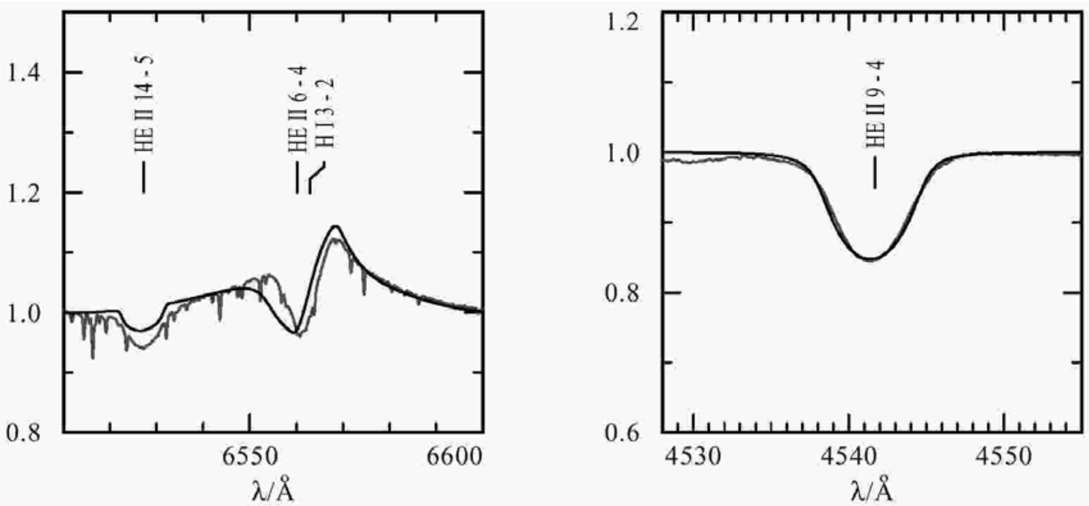

Figure 16. Comparison of synthetic line profiles with observed spectra of the O star ζ Puppis. The spectra are normalized to the intensity level of the continuum radiation. The left line profile is in emission which indicates that it is formed in the stellar wind, the right profile is of photospheric origin.

4.11.3 The orbital elements of FG Ser and AR Pav

Werner Schmutz in collaboration with T. Dumm, U. Mürset, H. Nussbaumer, H. Schild (ETH Zürich) and Hans-Martin Schmid (Landessternwarte Heidelberg)

We completed an observing project, begun in 1991, to determine the orbital parameters of long period symbiotic binaries. The last two systems for which we have determined orbital parameters are FG Ser und AR Pav. There are now eight symbiotic systems for which the stellar masses have been measured from orbital motion. We find that the masses of the less massive, hot companion are in the range 0.40 to 0.65 M⊗ and therefore, these stars are white dwarfs. The more massive companions are classified as M giants and have masses between 1 to 4 M⊗.

4.11.4 Extragalactic Wolf-Rayet stars

Werner Schmutz in collabortation with H. Schild (ETH Zürich) and P. Crowther (University College London)

At the ESO-run VLT UT2 8 m telescope on Paranal in Chile we observed spectra of extragalactic Wolf-Rayet stars in order to determine their stellar parameters and mass loss rates. During periods of poor seeing conditions we also obtained images of the Sculptor group galaxy NGC300 with special narrow band filters in an attempt to search for Wolf-Rayet stars. The filter combinations are chosen to maximize the the detection of the strong 469 nm emission line seen in the spectra of Galactic Wolf-Rayet stars. We discovered six Wolf-Rayet stars that had not been known previously. The data reduction and analysis of the images and spectra are in progress.

4.11.5 Analysis of Wolf-Rayet galaxy spectra

Werner Schmutz in collabortation with W.D. Vacca (IfA Honolulu and MPE Garching)

Using the HiRes spectrograph at the Keck I telescope on Mauna Kea, Hawaii, at the end of January 2000 we obtained spectra of so-called Wolf-Rayet galaxies (galaxies whose integrated optical spectra exhibit the broad emission lines from Wolf-Rayet stars). At the end of February we complemented the Keck data with low resolution spectra obtained at the 3.5 m NTT telescope on La Silla. We are investigating the nature of the anomalously strong emission line at 464 nm, which supposedly is due to N III. The data reduction and analysis of the spectra are in progress.

4.11.6 The nature of the mass donor in Cyg X-3

Werner Schmutz in collabortation with W.D. Vacca (IfA Honolulu and MPE Garching)

Cyg X-3 is a highly variable X-ray binary, believed to consist of a hot star which is feeding a black hole. The nature of the high mass stellar donor has not yet been unambiguously identified, although it is most likely a Wolf-Rayet star. In order to derive a mass loss rate from the change of the binary period and to derive the hot component's stellar parameters with a spectroscopic analysis, we have collected a number of moderate resolution (R=2000) spectra, covering the 1-5 micron wavelength range, with the new cross-dispersed IR echelle spectrograph at the NASA Infrared Telescope Facility on Mauna Kea, Hawaii. The observations gathered to date have been reduced and additional observations will be carried out in July 2001.

5 Personnel

5.1 Scientific Personnel

PD Dr. Werner Schmutz	*Physicist, director, solar physics, astrophysics, Sun-Earth connection, PI PREMOS*
Dr. Claus Fröhlich	*Physicist, solar variability, helioseismology, radiation budget, PI VIRGO, PI SOVIM, CoI GOLF, MDI*
Dr. Rolf Philipona	*Physicist, surface radiation budget, pyrgeometry, calibration of longwave instruments, UV instrumentation, CUVRA*
Dr. Isabelle Rüedi	*Physicist, absolute radiometry, solar physics, calibration of shortwave instruments, CoI VIRGO (PMO6 radiometers), SOVIM, PREMOS*
Christoph Wehrli	*Physicist, design and calibration of filter radiometers, CoI VIRGO (sunphotometers), SOVIM, PREMOS*
Dr. Wolfgang Finsterle	*Physicist, helioseismology with VIRGO data (left November 2000)*
Richard Wachter	*PhD student (ETH ZH), helioseismology with VIRGO data (since August 2000)*
Dr. Christoph Marty	*PhD student GIETHZ: surface radiation budget (left May 2000)*
Daniel Schmucki	*PhD student CUVRA: UV-radiation investigation*
Bruno Dürr	*PhD student (ETH ZH): greenhouse effect in the Alps(since May 2000)*

5.2 Technical Personnel

Hansjörg Roth	*Electronic Engineer, deputy director, head electronics department, experiment manager VIRGO, SOVIM, PREMOS*
Daniel Pfiffner	*Electronic Engineer SOVIM, design, contracts, cleanliness & quality assurance*
Klaus Kruse	*Mechanic Engineer, computer specialist, responsible for SUN server and local area network, PC software*
Urs Schütz	*Physics technician, general laboratory, design and manufacturing of radiometers (left July 2000)*
Remo Venturi	*Physics technician, general laboratory, WRC calibrations*
Mario Roveretto	*Technician (since 1. September 2000)*
Jules U. Wyss	*Mechanic, general mechanics, 3D design and manufacturing of mechanical parts for space and other instruments*
Danilo Dorizzi	*Electroncis apprentice, 3rd/4th year*
Gianmarco Külbs	*Electroncis apprentice, 1st/2nd year*
Pascal Güntensperger	*Civilian Service conscript (1.1. – 30.4. and 4.9 – 2.11.)*
Urs Zimmerli	*Civilian Service conscript (3.7. – 13.10.)*
Pascal Haering	*Civilian Service conscript (since 13.11.)*
Christian Thomann	*Civilian Service conscript (since 4.12.)*

5.3 Administration

Sonja Degli Esposti	*General administration, personnel, book keeping*

5.4 Caretaker

Klara Maynard	*General caretaker, cleaning*
Ida Agnello	*part time cleaning*

5.5 Guest scientists, students

Dr. Götz Gräfener	*Postdoctoral Research Scientist, ETH Zürich, Inst. f. Astronomie (1.7.1999 – 29.5.2000)*
Donald Nelson	*NOAA, Boulder, California, USA (16.10. – 21.10.2000)*
Saskia Bourgeois	*Student, ETH Zürich, Institut für Klimaforschung (28.2. – 27.3.2000)*
Sandro Battaglia	*Student, ETH Zürich, Abtlg. Maschinenbau und Verfahrenstechnik (7.2. – 27.3.2000)*
Olivia Martius	*Student, ETH Zürich, Institut für Klimaforschung (14.8. – 8.9.2000)*

6 Publications

6.1 Refereed articles (accepted before end 2000)

Brkovic A., Rüedi I., Solanki S.K., Fludra A., Harrison R.A., Huber M.C.E., Stenflo J.O., Stucki K.: 2000, EUV brightness variations in the quiet Sun, *A&A* 353, 1083–1093.

De Marco O., Schmutz W., Crowther P.A., Hillier D.J., Dessart L., de Koter A., Schweickhardt J.: 2000, The γ Vel binary system: II. WR stellar parameters and the photon loss mechanism, *A&A* 358, 187–200.

Dumm T., Folini D., Nussbaumer H., Schild H., Schmutz W., Walder R.: 2000, A wind acrretion wake in RW Hydrae?, *A&A* 354, 1014–1020.

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Finsterle, W.: 2000, *Helioseismology with VIRGO Data: The Search for Solar G Modes*. *PhD Thesis #13422*, ETH Zürich.

Fröhlich, C.: 2001, Total solar irradiance since 1978, *Adv. Space Res.* in press.

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Fröhlich, C., Finsterle, W.: 2001a, Total Solar Irradiance from VIRGO on SoHO, in A.Willson (ed.), *The Solar Cycle and Terrestrial Climate*, ESA SP-463, ESA Publications Division, Noordwijk, The Netherlands, in press.

Fröhlich, C., Finsterle, W.: 2001b, VIRGO Radiometry and Total Solar Irradiance 1996-2000 Revised, in P.Brekke, B.Fleck and J.B. Gurman (eds.), *Recent Insights into the Physica of the Sun and Heliosphere – Highlights from SoHO and other Space Missions* , ASP Conference Series, Vol. 200, in press.

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Fröhlich, C., Anklin, M.:2000, Uncertainty of Total Solar Irradiance: An Assessment of the Last 20 Years of Space Radiometry, *Metrologia*, 37, 387–391.

Göbner J., Albold A., Blumthaler M., Cabot T., De la Casiniere A., Lenoble J., Martin T., Masserot D., Müller M., Philipona R., Pichler T., Rengarajan G., Schmucki D., Seckmeyer G., Sergent C., Weihs P.: 2000, The Variability of Spectral Solar Ultraviolet Irradiance in an Alpine Environment, *Journal of Geophysical Research*, 105, B22, 26991–27003.

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Spectrometry. In: *Proceedigs of the Quadrennial Ozone Symposium*, Sapporo, Japan,

Ingold T., Mätzler Ch., Wehrli Ch., Heimo A., Kämpfer N., Philipona R.: 2001, Ozone column density determination from direct irradiance measurements in the UV performed by a four channel Precision Filter Radiometer, *Applied Optics*, accepted

Marty Ch. and Philipona R.: 2000, The Clear-Sky Index to separate Clear-Sky from Cloudy-Sky Situations in Climate Research, *Geophysical Research Letters*, 27, 2649 – 2652.

Marty Ch.: 2000 Surface radiation, cloud forcing and greenhouse effect in the alps. Doctoral thesis, Swiss Federal Institute of technology, Zürich, *PhD Thesis* #13609.

Marty Ch., Philipona R.: 2001, Surface Radiation Budget and Cloud Forcing over the Alps, In: Proceedings *IRS'2000: Current Problems in Atmospheric Radiation*, A. Deepak Publishing, Hampton VA, USA.

Mürset U., Dumm T., Isenegger S., Nussbaumer H., Schild H., Schmid H.M., Schmutz W.: 2000, High resolution spectroscopy of symbiotic stars. V. Orbital and stellar parameters for FG Ser (AS296), *A&A* 353, 952–957.

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Renaud A., Staehelin J., Fröhlich C., Philipona R., Heimo A.: 2000, Influence of Snow and Clouds on Erythemal UV Radiation: Analysis of Swiss Measurements and Comparison with Models, *Journal of Geophysical Research*, 105, 4961–4969.

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Schmucki D., Voigt S., Philipona R., Fröhlich C., Lenoble J., Ohmura A., Wehrli Ch.: 2001, Effective Albedo derived from UV Measurements in the Swiss Alps, *Journal of Geophysical Research*, 106, 5369–5383.

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Stucki K., Solanki S.K., Schühle U., Rüedi I., Wilhelm K., Stenflo J.O., Brkovic A., Huber M.C.E.: 2000, Comparison of far ultraviolet emission lines formed in coronal holes and the quiet Sun, *A&A* 363, 1145–1154.

Wehrli Ch., 2000: Calibrations of Filter Radiometers for Determination of Atmospheric Optical Depth, *Metrologia* 37, 419–422.

6.2 Other Publications, Conference Proceedings, Abstracts, and Posters

Brkovic A., Solanki S.K., Rüedi I.: 2001, Comparison of blinkers observed with CDS and with SUMER. In: P. Brekke, B. Fleck and J.B. Gurman (eds.), *Recent Insights into the Physics of the Sun and Heliosphere: Highlights from SOHO and other Space Missions, Astron. Soc. Pacific Conf. Ser.* Vol. 200, in press

Damé L., Cugnet D., Hersé D., Crommelynck D., Dewitte S., Joukoff A., Rüedi I., Schmutz W., Wehrli C., Delmas C., Laclare F., Rozelot J.-P.: 2001, PICARD: Solar Diameter, Irradiance and Climate. In: *SOLSPA*, in press

Pauluhn A., Solanki S.K., Rüedi I., Landi E., Schühle U.: 2001, Statistical features of the Quiet Sun in EUV. In: P. Brekke, B. Fleck and J.B. Gurman (eds.) *Recent Insights into the Physics of the Sun and Heliosphere - Highlights from SOHO and Other Space Missions, Astron. Soc. Pacific Conf. Ser.* Vol. 200, in press

Pauluhn A., Solanki S.K., Schühle U., Wilhelm K., Lang J., Thompson W.T., Rüedi I., Hollandt J., Huber M.C.E.: 2001, Comparison of quiet Sun radiances measured by CDS and SUMER on SOHO. In: *The 3-D Heliosphere at Solar Maximum*, in press.

Rüedi I., Fröhlich C., Schmutz W., Wehrli Ch.: 2000, Report on the International Pyrheliometer Comparisons - The Maintenance and Dissemination of the World Radiometric Reference. *IOM Report No. 74* (WMO/TD-No. 1028), p. 64–67.

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7 Participation in Meetings and Courses

9.1. – 6.2.	*Beobachtungen auf Mouna Kea, Hawaii*	*Werner Schmutz*
20. – 29.2.	*Beobachtungen auf La Silla, Chile*	*Werner Schmutz*
4. – 10.3.	*Solar Influence on Climate, a NASA WS, Tucson, USA*	*Claus Fröhlich*
13. – 20.3.	*ARM Science Team Meeting San Antonio, Texas, USA*	*Rolf Philipona*
21.3.	*GAW-CH, Berne*	*Rolf Philipona* *Werner Schmutz* *Christoph Wehrli*
22. – 23.3.	*Solar Observatory Kanzelhöhe, Treffen, Austria*	*Christoph Wehrli*
23. – 25.3.	*SOHO-SWT Lindau, Germany*	*Claus Fröhlich*
6.4.	*ProClim Tagung, Bern*	*Rolf Philipona*
7. – 8.4.	*UV-Vergleich Briancon, France*	*Rolf Philipona*
26. – 29.4.	*EGS-Meeting, Nice, France*	*Daniel Schmucki*
29.4. – 11.5.	*BSRN-Meeting, Melbourne, Alice Springs, Australia*	*Rolf Philipona*
2. – 8.5.	*SORCE-Meeting, Boulder, USA*	*Claus Fröhlich*
8. – 9.5.	*UV-Seminar, Arosa*	*Daniel Schmucki*
24. – 26.5.	*MAP-Meeting, Slovenia*	*Bruno Dürr*
15. – 19.7.	*SOLICE-Meeting, London, Great Britain*	*Werner Schmutz*
19. – 21.7.	*COSPAR, Warschau, Poland*	*Claus Fröhlich*
22. – 28.7.	*IRS 2000, St. Petersburg, Russia*	*Rolf Philipona*
6. – 10.8.	*IAU 2000, Manchester, Great Britain*	*Claus Fröhlich*
8. – 13.9.	*GAW-SAG Meeting, Galway, Ireland*	*Christoph Wehrli*
25. – 29.9.	*SOLSPA-Euroconference, Teneriffa, Spain*	*Claus Fröhlich*
2. – 6.10.	*SOHO10-GONG, Teneriffa, Spain*	*Claus Fröhlich*
12. – 13.10.	*SANW, Winterthur*	*Rolf Philipona*
13.10.	*SANW, Winterthur*	*Werner Schmutz* *Wolfgang Finsterle* *Bruno Dürr*
13. – 16.9.	*SORCE-Meeting, Snowmass, Colorado, USA*	*Claus Fröhlich*
20. – 29.10.	*TECO 2000, Beijing, China*	*Isabelle Rüedi* *Rolf Philipona*

24.10.	*GAW-CH Meeting, Zürich*	*Werner Schmutz* *Christoph Wehrli*
30.10.	*Course „Interkulturelles Management in der Forschung“, St. Gallen*	*Rolf Philipona*
5. – 7.11.	*3D CAD Course, RAND Technologies*	*Jules Wyss*
7. – 10.11.	*SPECIAL Workshop, Northeim, Germany*	*Werner Schmutz*
17.11.	*BSRN-Meeting, Zürich*	*Rolf Philipona*
28.11 – 2.12.	*3D CAD Course, RAND Technologies*	*Jules Wyss*
12. – 14.12.	*SOHO-SWT, Stanford, California, USA*	*Claus Fröhlich*
15. – 19.12.	*AGU Fall Meeting, San Francisco, California, USA*	*Claus Fröhlich*

8 Course of Lectures, Participation in Commissions

Course of lecture „Galaxien“, WS 1999/2000, ETHZ	*Werner Schmutz*
Course of lecture „Sternatmosphären“, SS 2000, ETHZ	*Werner Schmutz*
Course of lecture „Astronomie“, WS 2000/2001, ETHZ	*Werner Schmutz*
Course of lecture „Strahlung und Klima“, WS 2000/2001, ETHZ	*Claus Fröhlich*
Course of lecture „Wissenschaft im Weltraum“, WS 2000/2001, ETHZ	*Claus Fröhlich*
Course of lecture “Strahlungsmessung in der Klimaforschung”, *WS 1999/2000, and WS 2000/2001, ETHZ*	*Rolf Philipona*
Commission for Astronomy (SANW)	*Werner Schmutz*
Space Commission (SANW)	*Claus Fröhlich*
ESO User Committee	*Werner Schmutz*
Beirat Kiepenheuer Institut, Freiburg, Germany	*Claus Fröhlich*
Working Group for Baseline Surface Radiation Network (WMO/WCRP)	*Claus Fröhlich* *Rolf Philipona*
SOHO Science Working Team	*Claus Fröhlich*
VIRGO Team	*Claus Fröhlich* *Wolfgang Finsterle* *Hansjörg Roth* *Christoph Wehrli* *Isabelle Rüedi*
GAW-CH Working Group (SMA)	*Werner Schmutz* *Christoph Wehrli*
WMO/GAW Aerosol SAG	*Claus Fröhlich* *Christoph Wehrli*
Member Jury for the Habilitation of Th. Appourchaux	*Claus Fröhlich*
Commission of Final Examination of apprentices	*Hansjörg Roth*
Examination Expert: PhD Christoph Marty,	*Rolf Philipona*
Examination Expert: Final Examination in Astrophysics	*Werner Schmutz*

9 Public Seminars at PMOD/WRC

25.4. Richard Wachter, University Augsburg, Germany: „Abraham-Lorentz-Theorie für Phasenwirbel“
25.9.–13.10. IPC Symposium
3.11.: Dr. Alfred Gautschy, Sternwarte der Universität Wien:
„Schwingende Sterne, ein Beispiel von Reverse Engineering“
4.12. Jeffrey Linskey, JILA, University of Colorado, Boulder, USA:
"Recent stellar observations with HST, FUSE, and Chandra"

10 Guided Tours at PMOD/WRC

2.2. Guided tour for Sekundarschüler, Davos Platz
11.2. Guided tour for Staatssekretär Ch. Kleiber, Ständerat Ch. Brändli, Nationalrätin B. Gadient, Prof. Dr.Dr. W. Siegenthaler, P. Stiefel, B.A. Maechler, H. Wälti, Prof. K. Blaser
29.2. Guided tour for students ETH Zürich, Abtlg. Strahlungsmessungen und Klimatologie
16.3. Guided tour for J.-P. Ruder, Bundesamt für Bildung und Wissenschaft
25.5. Guided tour for Durchgangszentrum für Asylsuchende, Chur
15.6. Guided tour for Schweizerische Alpine Mittelschule Davos
7.7. Guided tour for Sheraton Hotels Davos

19.8.	Guided tour for Familie Hefti
30.8.	Guided tour for Dr. Baltensperger, Paul Scherrer Institut
31.8.	Guided tour for Bankbehörde und Geschäfsleitung, Graubündner Kantonalbank
1.9.	Guided tour for participants Geschäftsprüfungskommission des Ständerates
8.9.	Guided tour for Verkehrsbetriebe Davos, Ch. Ambühl
11.9.	Guided tour for participants Jahrestagung Verband Schweiz. Messerschmiedmeister und verwandter Berufsgruppen
21.9.	Guided tour for Brigitte Klaute, Deutscher Wetterdienst, D-Geisenheim
26.10.	Guided tour for participants International Group of Funding Agencies for Global Change Research
7.11.	Guided tour for Gesellschaft für Meteorologie und Agrarforschung
8.12.	Guided tour for students Technische Operations-Assistenten, Aarau

11 Participants IPC-IX

Eliphaz Bagarukayo	*Uganda*	*Joseph Michalsky*	*USA*
Alexander Baskis	*Israel*	*Darius Mikalajunas*	*Lithuania*
Klaus Behrens	*Germany*	*Svetlana Morozova*	*Russia*
Barbara Bogdanska	*Poland*	*Agustín Muhlia Velázquez*	*Mexico*
Fernanda Carvalho	*Portugal*	*Zoltan Nagy*	*Hungary*
André Chevalier	*Belgium*	*Donald W. Nelson*	*USA*
Christian Conscience	*Belgium*	*Ifeanyi D. Nnodu*	*Nigeria*
Fred Denn	*USA*	*Peter Novotny*	*Australia*
Steven Dewitte	*Belgieum*	*Jean Oliviéri*	*France*
Meena Dhavraj	*Norway*	*Cristian Oprea*	*Romania*
Taha Nagy El-Hosary	*Egypt*	*Bouziane Ouchene*	*Algerie*
Vivien S. Esquivel	*Philippines*	*Olga Pakhaljuk*	*Ukraine*
Brian Fabbri	*USA*	*Alexandre Pavlov*	*Russia*
Wei Fang	*China*	*Maria Pavlovitch*	*Russia*
Patrick Fishwick	*United Kingdom*	*Thomas Persson*	*Seden*
Javier Fonseca	*Mexico*	*Jiri Pokorny*	*Czech Republic*
Bruce Forgan	*Australia*	*Chintamani Rahalkar*	*India*
Ignacio Galindo	*Mexico*	*Ibrahim Reda*	*USA*
Hailu Kiros Gedamu	*Ethiopia*	*Georgina Rios*	*Mexico*
Federico F. Giménez	*Argentina*	*Tony Sample*	*Italy*
Serge Ginion	*Belgium*	*David Shearn*	*United Kingdom*
Stuart Goldstraw	*United Kingdom*	*Ovidio Simbaqueva*	*Colombia*
John R. Hickey	*USA*	*Tom Stoffel*	*USA*
Kohei Honda	*Japan*	*Nugool Suppjaroen*	*Thailand*
Viera Horecká	*Slovakia*	*Irene Trebejo Varillas*	*Peru*
Thomas Ingold	*Switzerland*	*Kiyotaka Uchida*	*Japan*
Ain Kallis	*Estonia*	*Fernando A. Vigón del Busto*	*Cuba*
Gilberto Lara Azocar	*Chile*	*Gang Wang*	*China*
Kevin Larman	*USA*	*Ernst Wessely*	*Austria*
Jens Lattauschke	*Germany*	*Yun Yang*	*China*
Leif Liedquist	*Sweden*	*Haishun Yao*	*China*
Wenhua Lu	*China*	*Arkawat Ying-Ariyakul*	*Thailand*
Pierre Malcorps	*Belgium*	*Bingxi Yu*	*China*
Bruce McArthur	*Canada*	*Willem J. Zaaiman*	*Italy*

12 Abbreviations

AOD	*Aerosol Optical Depth*
ACRIM	*Active Cavity Radiometer for Irradiance Monitoring*
ACU	*Attitude Control Unit*
AGU	*American Geophyiscal Union*
ARM	*Atmospheric Radiation Measurement*
ASRB	*Alpine Surface Radiation Budget, PMOD/WRC Project*
ATLAS	*Shuttle Mission with solar irradiance measurements*
AU	*Astronomical Unit (1 AU = mean Sun-Earth Distance)*
AVHRR	*Advanced Very High Resolution Radiometer*
BAG	*Bundesamt für Gesundheitswesen*
BBW	*Bundesamt für Bildung und Wissenschaft, Bern*
BESSY	*Berliner Elektronen Speicher Sychrotron*
BiSON	*Birmingham Solar Oscillation Network*
BSRN	*Baseline Surface Radiation Network of the WCRP*
BRUSAG	*Brusa AG*
BUWAL	*Bundesamt für Umwelt, Wald und Landschaft, Bern*
CART	*Cloud and Radiation Testbed*
CD-ROM	*Compact Disc - Read Only Memory*
CHARM	*Swiss (CH) Atmospheric Radiation Monitoring, CH-contribution to GAW*
CELIAS	*>Charge, Element and Isotope Analysis System= Experiment on SOHO*
CIE	*Commision Internationale de l=Eclairage*
CIMO	*Commission for Instruments and Methods of Observation of WMO, Geneva*
CIR	*Compagnie Industrielle Radioélectrique, Gals*
CMDL	*Climate Monitoring and Diagnostik Laboratory*
CNES	*Centre National d'Etudes Spatiales, Paris, F*
CNRS	*Centre National de la Recherche Scientifique, Service d`Aeronomie Paris*
CoI	*Co-Investigator of an Experiment/Instrument/Project*
COSPAR	*Commission of Space Application and Research of ICSU, Paris, F*
CPD	*Course Pointing Device*
CSEM	*Centre Suisse de l'Electro-Mécanique, Neuenburg*
CUVRA	*Characteristics of the UV radiation field in the Alps*
DIARAD	*Dual Irradiance Absolute Radiometer of IRMB*
DLR	*Deutsche Luft und Raumfahrt*
EDT	*Eastern daylight saving Time*
EGS	*European Geophysical Society*
EGSE	*Electrical Ground Support Equipment*
EISLF	*Eidgenössisches Institut für Schnee- und Lawinenforschung, Davos*
ENET	*supplementary meterological network of SMA*
ERBS	*Earth Radiation Budget Satellite*
ERS	*Emergency Sun Reacquisition*
ESA	*European Space Agency, Paris, F*
ESO	*European Southern Observatory*
ESOC	*European Space Operations and Control Centre, Darmstadt, D*
ESTEC	*European Space Research and Technology Centre, Noordwijk, NL*
ETH	*Eidgenössische Technische Hochschule (Z: Zürich, L: Lausanne)*
EURECA	*European Retrievable Carrier, flown August 1992 - Juni 1993 with SOVA Experiment*
EUV	*Extreme Ultraviolet Radiation*
FDE	*Fault Detection Electronics*
FWHM	*Full width half maximum (e.g. filtertransmission)*
GAW	*Global Atmosphere Watch, an observational program of WMO*
GCM	*General Circulation Model*
GIETHZ	*Geographisches Institut ETHZ*
GOLF	*Global Oscillations at Low Frequencies= experiment on SOHO*
GONG	*Global Oscillations Network Group*
GSFC	*Goddard Space Flight Center, Maryland, USA*
HECaR	*High sensitivity Electrically Calibrated Radiometer*
HF	*Hickey-Frieden Radiometer manufactuired by Eppley, Newport, R.I., USA*

HP	*Hewlett Packard*
HST	*Hubble Space Telescope*
IAC	*Instituto de Astrofísica de Canarias, Tenerife, E*
IAD	*Ion assisted deposition of thin dielectric layers*
IAMAS	*International Association of Meteorology and Atmospheric Sciences of IUGG*
IAS	*Institut d'Astrophysique Spatiale, Verrières-le-Buisson, F*
IASB	*Institut d'Aéronomie Spatiale de Belgique, Bruxelles, B*
IAU	*International Astronomical Union of ICSU, Paris, F*
IFU	*Institut für Umweltwissenschaften, Garmisch-Partenkirchen*
ICSU	*International Council of Scientific Unions, Paris, F*
IDL	*Interactive Data-analysis Language*
IKI	*Institute for Space Research, Moscow, Russia*
INTRA	*Intelligent Tracker from BRUSAG*
IPASRC	*International Pyrgeometer and Absolute Sky-scanning Radiometer Comparison*
IPC	*International Pyrheliometer Comparisons*
IPHIR	*Inter Planetary Helioseismology by Irradiance Measurements*
IR	*Infrarot*
IRMB	*Institut Royal Météorologique de Belgique, Brüssel, B*
IRS	*International Radiation Symposium of the Radiation Commission of IAMAS*
ISA	*Initial Sun Acquisition*
ISS	*International Space Station*
ISSA	*International Space Station Alpha (NASA, ESA, Russland, Japan)*
IUGG	*International Union of Geodesy and Geophysics of ISCU*
JPL	*Jet Propulsion Laboratory, Pasadena, California, USA*
KrAO	*Crimean Astrophysical Observatory, Ukraine*
LASCO	*Large Angle and Spectrometric COronograph*
LOI	*Luminosity Oscillation Imager, Instrument in VIRGO*
MDI	*see SOI/MDI*
MODTRAN	*Moderate Resolution Transmission Code (in Fortran)*
NASA	*National Aeronautics and Space Administration, Washington, USA*
NIMBUS7	*NOAA Research Satellite, launched Nov.78*
NIP	*Normal Incidence Pyrheliometer*
NOAA	*National Oceanographic and Atmosperic Administration, Washington, USA*
NPL	*National Physical Laboratory, Teddington, UK*
NRL	*Naval Research Laboratory, Washington, USA*
NREL	*National Renewable Energy Lab*
NTT	*New Technology Telescope*
OCAN	*Observatoire de la Côte d'Azur, Nice, F*
PC	*Personal Computer*
PCSR	*Planck Calibrated Sky Radiometer*
PFR	*Precision Filter Radiometer*
PHOBOS	*Russian Space Mission to the Martyan Satellite Phobos*
PI	*Principle Investigator, Leader of an Experiment/Instrument/Project*
PICARD	*French space experiment to measure the solar diameter (launch 2005)*
PIR	*Precision Infrared Pyrgeometer von Eppley*
PMOD	*Physikalisch-Meteorologisches Observatorium Davos*
PMO6-V	*VIRGO PMO6 type radiometer*
PREMOS	*Precision Monitoring of Solar Variability, PMOD experiment on PICARD*
PRODEX	*Programme for the Development of Experiments der ESA*
PTB	*Physikalisch-Technische Bundesanstalt, Braunschweig & Berlin, D*
RA	*Regional Association der WMO*
RASTA	*Radiometer für die Automatische Station der SMA*
SANW	*Schweizerische Akademie der Naturwissenschaften, Bern*
SARR	*Space Absolute Radiometer Reference*
SLF	*Schnee und Lawinenforschungsinstitut, Davos*
SFI	*Schweiz. Forschungsinstitut für Hochgebirgsklima und Medizin, Davos*
SGP	*Southern Great Plane*
SIAF	*Schweiz. Institut für Allergie- und Asthma-Forschung, Davos*
SIMBA	*Solar Irradiance Monitoring from Balloons*
SMA	*Schweizerische Meteorologische Anstalt, Zürich*

SMI	*Swiss Meteorological Institute*
SMM	*Solar Maximum Mission Satellite of NASA*
SNF	*Schweizer. Nationalfonds zur Förderung der wissenschaftlichen Forschung*
SOHO	*Solar and Heliospheric Observatory, Space Mission of ESA/NASA*
SOI/MDI	*Solar Oscillation Imager/Michelson Doppler Imager, Experiment on SOHO*
SOJA	*Solar Oscillation Experiment for the Russian Mars-96 Mission*
SOL-ACES	*Solar Auto-Calibrating EUV/UV Spectrometer for the International Space Station Alpha by IPM, Freiburg i.Br., Germany*
SOLERS22	*Solar Electromagnetic Radiation Study for Solar Cycle 22, of STEP, ISCU*
SOLSPEC	*Solar Spectrum Instrument for the International Space Station Alpha by Service d=Aeronomie, Verriere-le-Buisson, France*
SOVA	*Solar Variability Experiment on EURECA*
SOVIM	*Solar Variability and Irradiance Monitoring for the International Space Station Alpha by PMOD/WRC Davos, Switzerland*
SPC	*Science Programme Committee, ESA*
SPM	*Sonnenphotometer*
SPP-U	*Schwerpunktsprogramm Umwelt des SNF*
SRB	*Surface Radiation Budget*
SSD	*Space Science Department of ESA at ESTEC, Noordwijk, NL*
STEP	*Solar Terrerstrial Energy Program of SCOSTEP/ICSU*
STUK	*Finish Center for Radiation and Nuclear Safety*
SUMER	*Solar Ultraviolet Measurements of Emitted Radiation*
SW	*Short Wave*
SWT	*Science Working Team*
TSI	*Total Solar Irradiance*
UARS	*Upper Atmosphere Research Satellite of NASA*
UCL	*University College London*
UCLA	*University of California Los Angeles*
UKIRT	*United Kingdom Infrared Telescope*
USA	*United States of America*
UTC	*Universal Time Coordinated*
UV	*Ultraviolet radiation*
VIRGO	*Variability of solar Irradiance and Gravity Oscillations, Experiment on SOHO*
VLT	*Very Large Telescope*
WCRP	*World Climate Research Programme*
WMO	*World Meteorological Organization, Geneva*
WORCC	*World Optical Depth Research and Calibration Center (since 1996 at PMOD)*
WRC	*World Radiation Center*
WRR	*World Radiometric Reference*
WSG	*World Standard Group*

13 Donation (Ernst Göhner Stiftung, Zug)

Donation for extraordinary investments: CHF 100’000.-. In 2000 the PMOD/WRC bought the 3D CAD software *Pro Engineer* and the necessary computer hardware for CHF 30’000.-.

14 Rechnung PMOD/WRC 2000

14.1 Allgemeiner Betrieb PMOD/WRC (exkl. Drittmittel)

Ertrag

Bund, Betrieb WRC	790’000.00
Bund, WORCC	150’000.00
Kanton Graubünden	133'126.15
Landschaft Davos	199'689.25
Landschaft Davos, Mieterlass	133'500.00
Zuweisung Stiftung	190'000.00
Instrumentenverkauf	26'329.10
Bundesamt für Gesundheit	20'000.00
Div. Einnahmen, Eichungen	62'078.90
Aktivzinsen	8'710.25
Total 1999	1'713'433.65

Aufwand

Gehälter	1'047'748.20
Sozialleistungen	211'123.95
Investitionen	63'588.59
Unterhalt Apparate	12'142.60
Verbrauchsmaterial	83'575.84
Reisen und Kongresse	33'693.73
Bibliothek und Literatur	14'939.32
Raumkosten	176'353.90
Verwaltungskosten	80'497.54
Total 2000	1'723'663.67
Ergebnis	-10'230.02
	1'713'433.65

14.2 Bilanz PMOD/WRC (exkl. Drittmittel)

Aktiven	**31.12.2000**	**31.12.1999**
Kassa	1’678.60	797.40
Postcheck	18’825.19	31’402.09
Bankkonten	617’998.28	545’528.20
Debitoren	43’591.55	49’919.45
Verrechnungssteuer	2’567.35	
Kontokorrent Claus Fröhlich	-976.20	
Kontokorrent SNF	37'592.70	38'573.75
Kontokorrent PRODEX	128'417.69	67'713.84
Warenlager	50'000.00	80'000.00
Transitorische Aktiven	3'142.65	31'869.00
Total Aktiven	902'837.81	845'803.73

Passiven	**31.12.2000**	**31.12.1999**
Kreditoren	48'111.84	10'564.24
Kontokorrent Stiftung	116'833.65	101'737.45
Transitorische Passiven	359'790.60	274'359.15
Rückstellungen	264'189.05	314'087.35
Eigenkapital	113'912.67	145'055.54
Total Passiven	902'837.81	845'803.73