Jahresbericht 1999

Physikalisch-Meteorologisches Observatorium Davos

World Radiation Center

Annual Report 1999

A department of the Foundation

Swiss Research Institute for High Altitude Climate and Medicine Davos

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SFI

Schweizerisches Forschungsinstitut für Hochgebirgsklima und Medizin

DAVOS

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Zusammenfassung Jahresbericht 1999

Vorwort

Als ich im Juli 1999 die Leitung des Observatoriums übernahm, waren alle Stellen mit erfahrenen Leuten besetzt und die täglichen Arbeiten wurden erledigt, ohne dass ein Eingreifen meinerseits nötig war. Mit anderen Worten, mein Vorgänger hat mir ein wohlorganisiertes, gut funktionierendes Institut hinterlassen. Diese Situation erlaubte mir, mich in Ruhe nach und nach in die verschiedenen Tätigkeitsbereiche des PMOD/WRC einzuarbeiten.

Die erste Abweichung vom Normalbetrieb war das Ausscheiden des Zuständigen für die Radiometrie im August. Dr. Martin Anklin hat in Basel eine neue Aufgabe übernommen. Erfreulicherweise fand die Ausschreibung seiner Stelle ein grosses Echo und wir konnten aus knapp 30 Stellensuchenden auswählen. Wir haben die sieben Bewerber mit den besten Qualifikationen nach Davos zu einem Vortrag und persönlichen Gespräch eingeladen. Dabei haben sich drei Kandidaten als praktisch gleichwertig und bestens geeignet herausgestellt. Wir entschieden uns für Frau Dr. Isabelle Rüedi, die ihre Arbeit nach dem Jahreswechsel angetreten hat.

Neu für das PMOD/WRC ist, dass wir auch als Unternehmen tätig sind. Wir bauen radiometrische Messinstrumente, die wir in den nächsten Jahren zu verkaufen hoffen. Dies bedingte 1999 erhebliche Investitionen um das notwendige Material einkaufen zu können. Diese Investitionen haben wir aus den Rückstellungen des PMOD/WRC finanziert und sie erscheinen in der Jahresrechung unter der Rubrik „Lagerbestand".

Durch meine frühere Forschungstätigkeit an der ETH wurde Astrophysik auch am PMOD/WRC zu einem neuen Tätigkeitsgebiet. Ich bin Hauptgesuchsteller von Projekten mit internationaler Beteiligung, die eine mehrjährige Laufzeit haben. Diese Projekte beinhalten unter anderem Beobachtungen mit den besten Teleskopen der Welt, dem Keck auf Hawaii und dem VLT in Chile. Die Durchführung und Auswertung dieser Projekte wird noch ein paar Jahre in Anspruch nehmen. Ich habe jedoch nicht die Absicht, die astrophysikalische Forschung am PMOD/WRC auf längere Sicht zu etablieren. Mein Hauptziel ist es, die führende Stellung des PMOD/WRC im Bau von Radiometern im allgemeinen und im speziellen, im Bau von Pyrheliometern für Weltraumexperimente zu bewahren und mit entsprechender Forschung auf dem Gebiet der Sonnenphysik und dem Einfluss der Sonne auf unser Klima zu ergänzen. So haben wir uns u.a. im vergangenen Jahr an den Vorschlägen für neue Sonnenmissionen der ESA beteiligt, mit dem Ziel, dass bei der Auswahl eines dieser Vorschläge auch Pyrheliometer in der Definition des zukünftigen Weltraumexperimentes enthalten sein werden. Da solche Instrumente die Spezialität unseres Institutes sind, erhoffen wir uns dadurch Aufträge für den Bau dieser Instrumente zu erhalten. Eine weitere Initiative ist, dass wir an der ETH Zürich zusammen mit dem Institut für Astronomie und dem Geographischen Institut ein sogenanntes „Polyprojekt" eingereicht haben, das den Einfluss der Variationen der Sonneneinstrahlung untersuchen wird.

Im Folgenden sind wie bisher üblich die einzelnen Tätigkeitsgebiete des PMOD/WRC näher beschrieben. Neben den Dienstleistungs- und Forschungsaktivitäten verdient es jedoch auch unser nicht-wissenschaftlicher Betriebsausflug erwähnt zu werden.

Betriebsausflug

Eine totale Sonnenfinsternis in Europa ist für ein Institut das sich mit der Sonne beschäftigt von besonderer Bedeutung, auch wenn am PMOD/WRC kein direktes Forschungsinteresse an Finsternissen vorhanden ist. Deshalb hat das Observatorium anlässlich der Sonnenfinsternis vom 11. August 1999, bei der die Totalitätszone durch Süddeutschland verlief, einen Betriebsausflug organisiert, an dem fast die ganze PMOD/WRC Belegschaft teilnahm. Wir und interessierte Gäste des SIAF und SLF fuhren frühmorgens mit einem Bus von Davos nach Bad Neuweiher in die Nähe von Baden Baden. Dort hatte eine Bekannte von Sonja Degli Esposti für uns einen romantisch gelegenen Beobachtungsplatz inmitten von Rebbergen mit freier Sicht über die Rheinebene ausgemacht. Wie allgemein bekannt ist, war das Wetter in Westeuropa sehr schlecht und so haben auch wir vor der Finsternis mit Bangen in Regenschauern ausgeharrt und gehofft, dass uns eine rechtzeitige Aufhellung retten würde. Ein Loch in der sonst fast geschlossenen Wolkendecke bewegte sich während der partiellen Phase auf die Sonne zu und in der Tat hatten wir das grosse Glück, dass sich zum Zeitpunkt der totalen Finsternis die restlichen Wolkenschichten in Richtung Sonne auflösten und wir die Sonnenfinsternis im wahrsten Sinne des Wortes ungetrübt erleben konnten. Die Totalitätsphase dauerte nur zwei Minuten und dafür mussten wir sechs Stunden Hinfahrt und sechs Stunden Rückfahrt in einem Bus erdulden. Aber eine totale Sonnenfinsternis ist so vollständig ausserhalb unserer täglichen Erfahrung, dass man vom Erlebnis schlichtweg überwältigt wird. Am Ende waren sich alle Beteiligten einig, dass sich das frühe Aufstehen und die Reisestrapazen mehr als gelohnt hatten.

Dienstleistungen WRC und WORCC

Eichungen von radiometrischen Messinstrumenten gehören zu den Grundaufgaben des WRC. Im Berichtsjahr wurden am PMOD/WRC während 150 Tagen 66 Radiometer von 18 verschiedenen schweizerischen und ausländischen Institutionen geeicht, wodurch knapp CHF 32‘000.- eingenommen wurden. Zusätzlich wurden an unserem Institut UV-Messgeräte geeicht, darunter befanden sich 4 UV-PFR, 4 UV-A sowie 5 UV-B Geräte.

Für das WORCC Projekt wurden zur Überwachung der Stabilität der Empfindlichkeit die Standardinstrumente PFR-N01 und N26 (Präzisionsfilterradiometer) halbjährlich im Labor mit Trap-Detektoren getestet. Gleichzeitig sind 9 PFR Instrumente während insgesamt 12 Monaten auf dem Jungfraujoch installiert worden, um mit der sogenannten Langley Methode geeicht zu werden. Sechs Präzisionsfilterradiometer wurden vor dem Einsatz an GAW Stationen und als Vergleichsstandart im Labor geeicht.

Entwicklung und Bau von Instrumenten

Unter einem Lizenzvertrag stellte die Firma CIR während 20 Jahren PMO-6 Radiometer zum Verkauf her. Der Vertrag ist durch die CIR im August 1998 aufgelöst worden. Das PMOD/WRC hat sich daraufhin entschlossen unter eigener Regie PMO-6 Radiometer herzustellen und zu verkaufen. Dafür entwickelten wir eine moderne analoge Regelelektronik, während für die Kommunikation sowie für die Ablaufsteuerung ein Computersystem eingesetzt wurde. Ende Jahr wurde ein erstes Gerät ausgeliefert. Der Bau einer Serie von zehn Einheiten beginnt anfangs 2000.

Im Berichtsjahr haben wir mit der Entwicklung eines neuen 4-Kanal Himmels-UV-Präzisionsfilterradiometer (UV-PFR) begonnen. Das hochempfindliche Instrument soll für Messungen der Himmels-UV-Strahlung im Bereich von 305 bis 332 nm eingesetzt werden. Das Ziel dieser neuen Entwicklung ist es, ein Gerät zur Erfassung der schwachen diffusen UV-Strahlung zur Verfügung zu haben. Erste Aussenmessungen mit dem Instrument sind für Winter/Frühjahr 2000 vorgesehen.

Das PMOD/WRC organisierte zusammen mit dem US Atmospheric Radiation Measurement (ARM) Science team vom NREL in Golden, dem NOAA in Boulder und der University at Albany die ersten internationalen Vergleiche von Pyrgeometern (International Pyrgeometer and Absolute Sky-scanning Radiometer Comparison, PASRC-I). Die Vergleichsmessungen von 15 Standard-Pyrgeometer aus aller Welt wurden im Southern Great Plane ARM Cloud and Radiation Testbed in Oklahoma durchgeführt. Eine erste Auswertung der Messungen zeigt, dass gut kalibrierte Instrumente absolut innerhalb von 2% bis 3% übereinstimmen.

Weltraumexperimente SOVIM und PICARD

Seit 1996 arbeiten wir am Weltraumexperiment SOVIM, das für die internationale Raumstation (ISS) vorgesehen ist. Die mechanischen Bauteile sind nun unter Einhaltung der Gewichts- und Dimensionslimiten festgelegt worden. Allerdings wurde im November von der ESA ein Produktionsstop ausgesprochen, da die Firma, welche die Ausrichtungsplattform baut, Probleme hat, was bedeutet, dass die Spezifikationen wieder geändert werden könnten. Hingegen kann die Entwicklung der Elektronik und der notwendigen Computerprogramme ungehindert weitergehen. Die Elektronik ist nun soweit fertiggestellt, dass als nächstes der Prototyp des Weltraumradiometers zusammengebaut werden kann.

Im weiteren sind wir mit der französischen Weltraumorganisation CNES bezüglich eines Beitrags des PMOD/WRC zum Experiment PICARD im Gespräch. Unsere Aufgabe wäre es, ein Filterradiometer zu bauen. Da die Finanzierung des Projekts noch nicht gesichert ist, bleibt eine Beteiligung des PMOD/WRC an PICARD grundsätzlich noch offen.

Sonnenstrahlung: Resultate von VIRGO

Bis Ende 1999 sind seit Beginn der Messungen durch VIRGO 1443 Tage vergangen, wovon jedoch Daten für total 177 Tage fehlen. Es sind jedoch trotz dem längeren Ausfall des Satelliten SOHO (siehe Jahresbericht 1998) genügend Daten vorhanden, um die Radiometer auf mögliche Veränderungen während des Unterbruchs untersuchen zu können. Es wurde festgestellt, dass sich das Verhältnis der durch die beiden Referenzinstrumente, DIARAD-R und PMO6V-B, gemessenen Sonnenintensität verschoben hat. Es wurde ermittelt, dass die Messungen des DIARAD um etwa 120 ppm angehoben und diejenigen des PMO6V um etwa 135 ppm erniedrigt werden müssen.

Wie schon im letzten Bericht erwähnt, wurde Ende 1998 ein SIMBA Ballonexperiment durchgeführt. Die Auswertung der Beobachtung zeigt, dass die mit SIMBA98 beobachteten Werte der Sonnenintensität im Vergleich zu früheren SIMBA Resultaten um rund 0.1% tiefer liegen. Diese Veränderung muss noch weiter untersucht werden.

Die Suche nach g-Moden wurde abgeschlossen und das negative Resultat ist in einer eingereichten Publikation beschrieben. Obschon keine g-Moden gefunden und identifiziert werden konnten, wurden obere Grenzen ihrer Amplituden festgehalten.

Diese liegen deutlich unter den theoretisch erwarteten Amplituden von selbstangeregten Oszillationen, d.h. dieser Mechanismus kann nun ausgeschlossen werden. Die nun abgeschlossene Dissertation von Wolfgang Finsterle beinhaltete die Suche nach den g-Moden. Anstelle der g-Moden hat er, entgegen den Erwartungen, p-Moden der Ordnungen 3 bis 5 gefunden, die bisher durch kein anderes Experiment nachgewiesen werden konnten.

Neben diesen direkt auf VIRGO bezogenen Arbeiten wurde auch allgemein an der Interpretation der Variabilität der Sonnenstrahlung weitergearbeitet. Bei dieser Arbeit wurde klar, dass die Zuverlässigkeit der Zeitreihe darauf beruht, dass während den letzten 20 Jahren immer mehrere Experimente gleichzeitig im Weltraum waren. Da dies in Zukunft nur bedingt der Fall sein wird, hat zur Folge, dass künftig Messungen im Weltraum von Radiometern mit wesentlich höherer Genauigkeit durchgeführt werden sollten, die dann als zuverlässige Stützpunkte verwendet werden können. Dafür plädiert ein kürzlich erschienener Artikel von C. Fröhlich in „Nature“.

Oberflächenstrahlungshaushalt in den Alpen und UV-Untersuchungen

Die 11 ASRB Stationen sind nun seit 4 oder mehr Jahren in Betrieb. Eine Auswertung der Messungen bis Ende 1999 zeigte eine Höhenabhängigkeit des Strahlungshaushaltes und es wurde begonnen, den höhenabhängigen Einfluss der Wolken zu analysieren. Eine Zeitreihe von 4 Jahren ist noch zu kurz um endgültige Schlüsse zu ziehen, aber anhand der vorhandenen Daten zeichnet sich ab, dass der (negative) mittlere jährliche Einfluss der Wolken auf die kurzwellige Strahlung mit der Höhe schwach abnimmt und der (positive) mittlere jährliche Einfluss auf die langwellige Strahlung mit der Höhe leicht zunimmt. Der Nettoeffekt des Wolkeneinflusses ist wegen der gegensätzlichen Vorzeichen der kurz- und langwelligen Einflüsse relativ klein, mit der Tendenz, dass tiefer gelegene Orte durch Wolken praktisch nicht beeinflusst werden und höher gelegene Standorte erwärmt werden.

Die Analyse der seit 1994 in Davos und seit 1997 auf dem Weissfluhjoch von UV-Biometern gesammelten Daten zeigt, dass mit modernen UV-Instrumenten intern konsistente Messungen erzielt werden und damit wissenschaftliche Fragestellungen angegangen werden können. Die Alpen gehören zu den europäischen Regionen mit sehr hohem UV Strahlungsanteil als Folge der Elevation, geringen Aerosolteilchengehalt in der Luft und wegen dem grossen Anteil von schneebedeckten Oberflächen. Die Streueigenschaften des Geländes (Albedo) spielen eine wichtige Rolle für die Strahlungseigenschaften im Gebirge. Mit unseren Untersuchungen bestimmten wir die sogenannte effektive Albedo.

GAW Versuchsnetz zur Überwachung der optischen Dicke

Die optische Dicke ist ein Mass für den der Aerosolteilchengehalt der Atmosphäre. Der Versuchsbetrieb des WORCC Messnetzes konnte an den 3 GAW-Observatorien Zugspitze/Hohenpeissenberg, Mauna Loa auf Hawaii und Mace Head in Irland ab Sommer 1999 aufgenommen werden. Weitere Stationen wurden von der Arbeitsgruppe für Aerosolforschung vorgeschlagen, ihre Beteiligung am Projekt wird durch die WMO abgeklärt. Erste Daten der bestehenden Stationen liegen vor und werden ausgewertet; kleinere technische Probleme konnten dank Datenqualitätskontrolle entdeckt und in Zusammenarbeit mit den Stationsverantwortlichen gelöst werden. Die Sonnennachführung in Mace Head wurde nach schweren Regenfällen beschädigt und musste an den Hersteller geschickt werden; im 3. Trimester konnten in Irland keine Messungen mehr gemacht werden.

Der Eichtransfer zwischen PFR Instrumenten im Netz wurde in Januar 2000 erstmals getestet indem ein frisch geeichtes Referenzinstrument zusammen mit dem operationellen Instrument auf Mauna Loa während 3 Wochen betrieben wurde.

In Davos wurde der parallele Betrieb mit zwei Generationen Sonnenphotometern weitergeführt. Die seit 1995 laufende Zeitreihe wird zum Aufbau einer Trübungsklimatologie Davos verwendet und, wie im Bericht 1997 erwähnt, mit entsprechenden Daten um 1920 verglichen werden. Im Hinblick auf den geplanten internationalen Vergleich von Sonnenphotometern während den IPC-IX wurde mit der Entwicklung zusätzlicher Software begonnen, welche anhand der bestehenden, parallelen Datenreihen getestet wird. Längerfristig wird die Messreihe mit den neuen PFR weitergeführt werden.

Astrophysik

An der Europäischen Südsternwarte (ESO) haben wir photometrische Messungen von massiven heissen Sternen in Galaxien unserer lokalen Gruppe durchgeführt. Die Auswertung und Interpretation dieser Daten erfolgt hauptsächlich durch unsere Partner am University College London.

Am PMOD/WRC haben wir Modellrechnungen für Sternatmosphären durchgeführt. Wir bauten ein bestehendes Computerprogramm bezüglich der Behandlung des Einflusses von Linien der Eisengruppenelementen aus. Das Ziel dieser Rechnungen wird es sein, die Dynamik von expandierenden Atmosphären theoretisch zu verstehen.

Infrastruktur

Im Oktober 1999 hat die Besitzerin unseres Institutes, die Landschaft Davos, neue moderne Isolationsfenster einbauen lassen. Die Verbesserung des Raumklimas im Haus ist merklich und ich danke den Behörden im Namen der Belegschaft des Observatoriums für diese nützliche Investition.

Lehrverpflichtungen

An der ETH Zürich hat C. Fröhlich im Wintersemester 98/99 die Vorlesung „Strahlung und Klima“ und zusammen mit Prof. Dr. M.C.E. Huber die Vorlesung „Wissenschaft im Weltraum: Erkundung des Sonnensystems“ gehalten. Im WS 98/99 hat R. Philipona während der zweiten Hälfte des Semesters die Vorlesung „Mikro-Meteorologie“ von Prof. A. Ohmura gelesen.

Personal

Per Ende Juli hat Dr. Martin Anklin das PMOD/WRC verlassen. Seine Stelle wurde mit Frau Dr. Isabelle Rüedi neu besetzt, die anfangs Januar 2000 ihre Arbeit aufgenommen hat.

Wolfgang Finsterle hat im November seine Doktorprüfung erfolgreich bestanden – ich gratuliere!

Seit dem 26. April 1999 ist das PMOD/WRC als Einsatzbetrieb des Zivildienstes anerkannt. Wir dürfen maximal zwei Personen als Hilfskräfte für Elekronik-, Physik- und allgemeine Hilfsarbeiten einsetzen. Mit unserem ersten "Zivi", Herrn Urs Gähwiler, haben wir nur gute Erfahrungen gemacht und damit steht dem Einsatz von weiteren Zivildienstleistenden nichts entgegen.

Dank

Die Belegschaft des PMO/WRC hat mich sehr freundlich und offen aufgenommen. Ich habe mich sofort bei meiner neuen Arbeit wohlgefühlt und möchte meinen Mitarbeitern für die positive Aufnahme herzlich danken. Die Aufsichtskommission und der Stiftungsrats-Ausschuss haben mich in vielfältiger Weise beraten und ich danke den Mitgliedern der Kommission und des Ausschusses für ihre Unterstützung. Insbesondere möchte ich mich für den zusätzlichen Arbeitsaufwand bedanken, der in einer Sondersitzung erbracht wurde. Dank gebührt auch dem Stiftungsrat, den Behörden und dem Nationalfonds für die stete und wohlwollende Unterstützung des PMOD/WRC.

Davos, im März 2000 PD Dr. Werner Schmutz

Annual Report 1999

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1 Introduction (W. Schmutz)

In July 1999 when I started my new job as director of the PMOD/WRC, the observatory was a well functioning institution with all positions filled by experienced staff. This situation allowed me to be introduced step by step to the different activities of the observatory.

The first deviation from daily routine was the replacement of Dr. Martin Anklin who was leaving end of July and who was in charge of the radiometry on ground and in space. The publication of the job opening prompted a compelling response of more than 30 applications. We invited the 7 most promising candidates to Davos for an interview and a presentation of their ongoing research projects. Three of them turned out to be excellently qualified and we finally selected Dr. Isabelle Rüedi who has started in January.

A new activity for the PMOD/WRC is that we now offer radiometers for sale which we are building in house. In the past year we started to assemble new series of precision filter radiometers and PMO-6 type radiometers. The material for these instruments required a substantial investment that we financed from the reserves. We hope to sell the first few instruments in this year.

Astrophysics is now also an activity at PMOD/WRC, as a consequence of my research at my former position at the ETH. I am principle investigator and co-investigator of international collaborations with upcoming observing time at the best telescopes of the world, the Very Large Telescope (VLT) in northern Chile and the Keck on Hawaii. It is in the nature of such projects that they have a duration of several years and therefore, astrophysics will remain a topic at PMOD/WRC during the next few years. However, it is not my intention to establish astrophysics at PMOD/WRC on the long run. My aim is to preserve the leading role of the observatory in designing and manufacturing radiometers and in particular, in building pyrheliometers for space experiments. This hardware activity should be complemented by research in solar physics and in the influence of the sun on our climate. In line with this main goal we have participated in the definition of future space missions of the ESA. The motivation was to make sure that radiometric instruments will be part of future solar physics experiments. A second initiative was the proposal of a so called “Polyprojekt” to the ETH Zürich together with institutes for Astronomy and for Climate Research. We aim at investigating the influence of the variability of the solar radiation on the terrestrial climate.

As in previous annual reports the activities at PMOD/WRC are presented below. There is however a special section devoted to our non-scientific excursion of the observatory staff which deserves to be reported because of its unique circumstance.

2 Solar Eclipse Excursion (W. Schmutz)

A total solar eclipse is an extremely rare event for a given location on earth. Therefore, it was a unique opportunity to experience such an event when last year the path of totality was crossing southern Germany. On August 11, 1999 the PMOD/WRC rented a bus and almost the whole PMOD/WRC staff and guests from the SLF and the SIAF embarked early in the morning on an excursion to Bad Neuweiher, which is close to Baden Baden. A friend of Mrs. S. Degli Esposti knew of a romantically situated viewpoint in the midst of a vineyard where we had an unobstructed view of the sky and overlooking the Rhein valley. As commonly known, the whether conditions in western Europe were almost completely overcast. This was also true from our point of view and we were waiting for the time of total eclipse in occasional showers, hoping that a brightening would save us the day. There was a spot in the sky where the cloud cover looked less dense moving towards the solar position. Indeed shortly before totality the remaining layers dissolved and we were blessed with an unobstructed view of a beautiful corona and stars in a dark sky. The duration of the totality was less than two minutes and for this experience we had to travel six hours to get to our observing location and six hours to get back. But without doubt, it was worth this effort.

3 Services, Calibrations, and Instrument Development

3.1 Operational Calibrations (I. Rüedi, R. Philipona, R. Venturi, Ch. Wehrli)

The PMOD/WRC is responsible for the world-wide homogeneity of the meteorological radiation measurements. For this we maintain the World Standard Group (WSG) which comprises 7 radiometers of different type and make. The WSG represents the World Radiometric Reference (WRR), which is the reference adopted by the WMO as the basis for all meteorological radiation measurements. In 1999 a total of 66 instruments originating from 18 Swiss and foreign institutes were calibrated at PMOD/WRC. During 150 sunny days 2 absolute radiometers, 5 pyrheliometers, and 16 pyranometers were calibrated with the sun as a source and the WSG as reference. In addition, 4 UV-PFR, 4 UV-A, and 5 UV-B instruments were calibrated through a comparison with the in-house Swiss UV standard. Twenty-one pyrgeometers were calibrated with our characterization apparatus for longwave instruments as well as with reference instruments. Most of these pyrgeometers were also modified with 3 thermistors to better characterize the dome temperature correction. These pyrgeometers belong partly to the Baseline Surface Radiation Network (BSRN), a project of the World Climate Research Program (WCRP). Two CSEM type sun photometers were calibrated against standard lamps and with Langley extrapolations and 10 precision filter radiometers (PFR) were calibrated in the laboratory and/or with the sun as source.

3.2 Precision Filter Radiometers (C. Wehrli)

3.2.1 Absolute calibrations

The reference PFR-N01 instrument was calibrated three times at 6 months intervals with the trap detector and by the lamp based method in order to determine its radiometric stability and to maintain the calibration values found by the SIMBA98 balloon flight.

Variations in the trap calibrations values were found to be less than ±0.7% of the mean and just one channel exhibited a decrease in sensitivity between calibrations. In the most recent calibration of September 1999, improved measurement software was used to make up to 12 scans of each channel. Both previous calibrations were made with just a single scan. These scans were then averaged to improve the signal-to-noise ratio in the band pass wings. The resulting small standard deviation of <0.2% is the indication of a good optical and mechanical stability of the calibration facility. The multiple scan procedure lasted about 60 hours and provoked a lamp failure due to overheating. The daily reproducibility of trap calibrations was tested during calibrations of instrument N26 on the 6., 10. and 14. December 1999. On each day, the instrument was mounted anew and the setup aligned to a laser beam; 3 scans per channel were averaged and the integral responses compared. The differences between the largest and smallest values was only 0.2% of the mean for the 862nm and 0.9% for the 368nm channel. As a result of these trap calibrations, it was concluded that drifts in the sensitivity of N01 must be less than ±0.8% per year and shift in the median wavelength must be less than ±0.1nm

On the other hand, four lamp calibrations of PFR-N01 between March 1998 and October 1999 indicate an increasing sensitivity of all 4 channels of the order of 1 - 1.5% per year, which exceeds the upper drift limit estimated from the trap calibrations. The absolute difference between lamp and trap based calibrations of 2.5% reported in 1998 has therefore increased to 5% which suggests a systematic, progressive error in one of the methods.

In order to judge whether the lamp or the trap calibrations are erroneous, both can be used to estimate expected extraterrestrial signals from a calibrated solar spectrum like the WRC85 atlas or the Kurucz spectrum used in MODTRAN 3.7. These estimates can then be compared to the signals measured during SIMBA98. Figure 1 shows quite clearly, that the lamp calibration systematically overestimates the balloon values by 5%, while the trap calibration agrees within 2% of the balloon results.

As the measured drifts and offsets for both lamps agree within 0.6% and the current measurements and stray light levels during calibration were checked, this finding remains unexplained for the moment. A recalibration of the lamps and further investigations of other possible causes are needed.

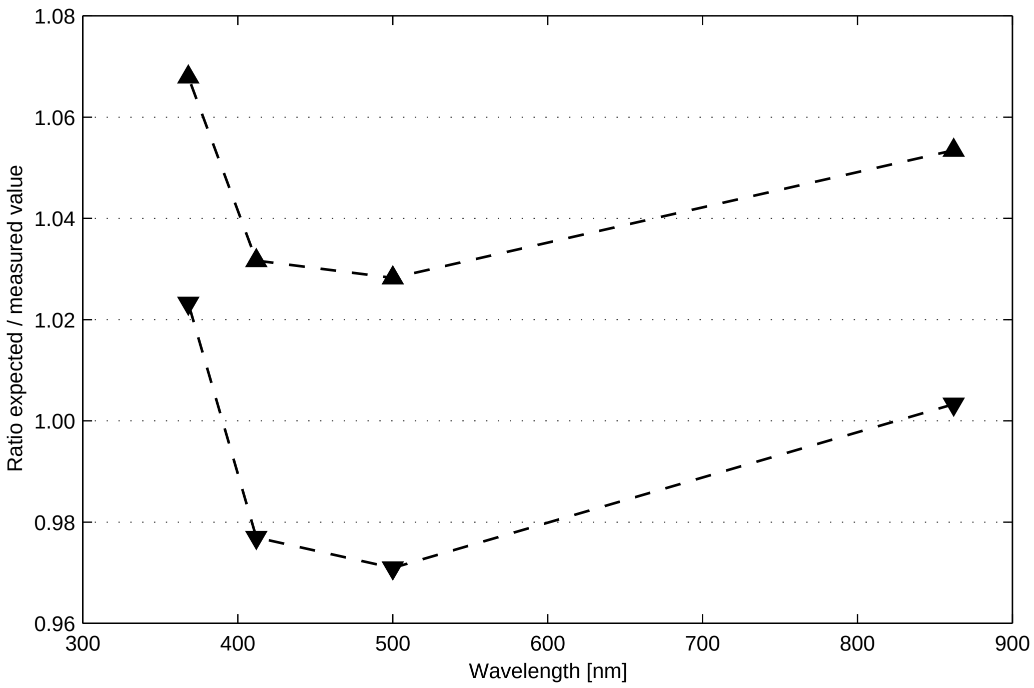

Figure 1: Ratio of extraterrestrial calibration values expected from absolute calibrations by lamp (upper curve) or trap detector (lower curve) in combination with the WRC85 solar spectrum to values measured by Precision Filter Radiometer PFR-N01 during stratospheric balloon flight SIMBA98.

3.2.2 Manufacturing of SeriesII or spectral leak in infrared channel

With the completion of the construction of 30 standard wavelength PFR instruments built for the GAW trial network and the Swiss radiation program CHARM, manufacturing of a second series of instruments was started. Additional filter sets with the same wavelength specifications as before were ordered and a sample was characterized after delivery in spring 1999.

When the first instruments were completed, they were calibrated with the trap facility and their out-of-band rejection checked. Rather unexpectedly, the infrared channel showed a broad spectral leak at the 10^{-3} level for wavelengths below 750nm that was not present in either ours or in the manufacturer's acceptance test. An additional RG blocking glass was optically bonded to the interference filter, but failed to cure the problem. Eventually, it was realized that these infrared filters must contain a component that glows in the infrared when irradiated with visible light, perhaps due to a phosphorous or fluorescing material. By simply reversing the filter in the light path, the spectral leak was reduced tenfold (see Figure 2), and became similar to what was found in the first series of PFRs. A more thorough suppression of this filter fluorescence would involve a major change of the instrument by physically separating the filters from the detectors, which is impossible for different reasons. Eventually, filters of various construction could be selected in cooperation with the manufacturer.

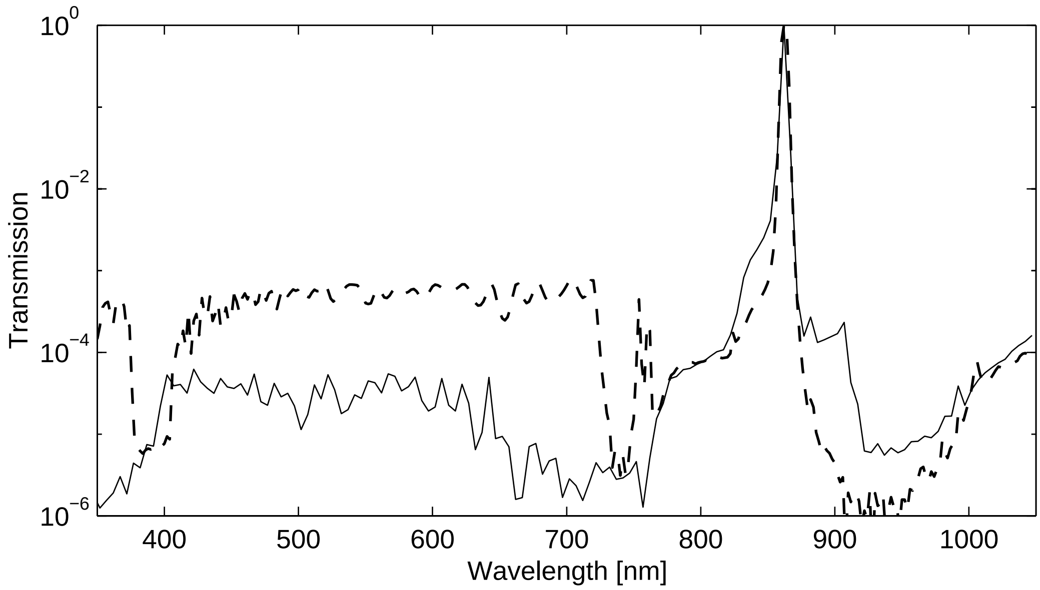

Figure 2: Infrared channel filter transmission of a Precision Filter Radiometer instrument. The dotted line shows filter in original, the solid line in reversed position. An air mass 2 solar spectrum outsides bandpass from 822 to 882nm contributes less than 0.4% to the measured signal.

3.2.3 GAW trial network

The three Global Observatories that agreed to participate in the GAW trial network, were provided with calibrated PFR instruments in 1999. The Meteorological Observatory Hohenpeissenberg (47.8°N, 11.9°E , 985m) is a research station of the Deutscher Wetterdienst and forms, together with Zugspitze (47.4°N, 11.0°E, 2964m), the GAW Observatory representing central Europe. Measurements with PFR-N06 begun on 1st of July 1999. The first results revealed a gross misalignment of the instrument in azimuth and a 1 hour offset in recorded time. Both problems were fixed by station personnel; since July, 31st PFR and ancillary meteorological data have been transmitted on a monthly basis to Davos. A first analysis of clear-sky days shows that the instrument is working well, but Langley extrapolations tend to exceed the calibration values obtained on Jungfraujoch. Further evaluation and perhaps more data for clear days are required in order to produce a quality controlled time series of aerosol optical depths.

Figure 3: Precision Filter Radiometer PFR-N06 mounted on the roof platform at Hohenpeissenberg pointing at the Sun under less than favorable weather conditions.

The GAW observatory at Mace Head (53.3°N, 9.9°W, 20m), situated on the Atlantic coast of Ireland, is operated by the Department of Experimental Physics of the National University of Ireland, Galway. It is recognized as a clean background baseline station for western Europe. PFR-N07 began operations there on 1st of July 1999. Partly cloudy conditions and possibly also gusty winds posed problems for the self-adjusting solar tracker (the same model is used at Hohenpeissenberg and several are operated at Davos). Good pointing was not achieved until July, 26th however, it was lost again on the same day. After heavy rainfall in mid August caused a power failure at Mace Head station, the system remained without power for considerable length of time. When additional problems were discovered, the tracker had to be sent back to the manufacturer for repair. Measurements obtained on a single morning, during its 43 days of operation, could be used to verify the data from Mace Head via Langley extrapolation. The good agreement with initial calibration is not significant, however, as there is only one sample. Experience with these two stations clearly demonstrates, that the independent pointing sensor built into the PFR instruments is a valuable tool for quality control.

The third instrument N27 was installed during a test phase at Boulder, Colorado (40.0°N, 105.3°W, 1729m) from August, 20th until October, 24th. It was then transferred to Mauna Loa Observatory (19.5°N, 155.6°W, 3397m) on Hawaii and since 3rd November it has been operated by the Climate Monitoring and Diagnostic Lab of the National Oceanic and Atmospheric Administration (CMDL/NOAA). Clear-sky conditions in Boulder during September and October permitted 25 Langley extrapolations that confirmed the initial calibration at Jungfraujoch in spring 1999 to better than 1% for 3 channels and to 1.3% for the 862nm channel. The same time period was also evaluated by CMDL using their own algorithms and good agreement to within 0.1% was found, again with exception of the 862nm channel for which CMDL measured a 0.5% lower value. Initial results from Mauna Loa have again confirmed the calibration values and show a remarkably low scatter demonstrating that Mauna Loa is indeed a prime calibration site for filter radiometers. A regression analysis of all pooled calibrations from Jungfraujoch, Boulder and Mauna Loa indicates an annual increase in the calibration of between 0.2% and 2%, which is similar in amount, but opposite in sign, to what was found for previous types of instruments. Further investigation, including a longer calibration history and data from additional instruments is needed to find a representative drift rate for the PFR instruments.

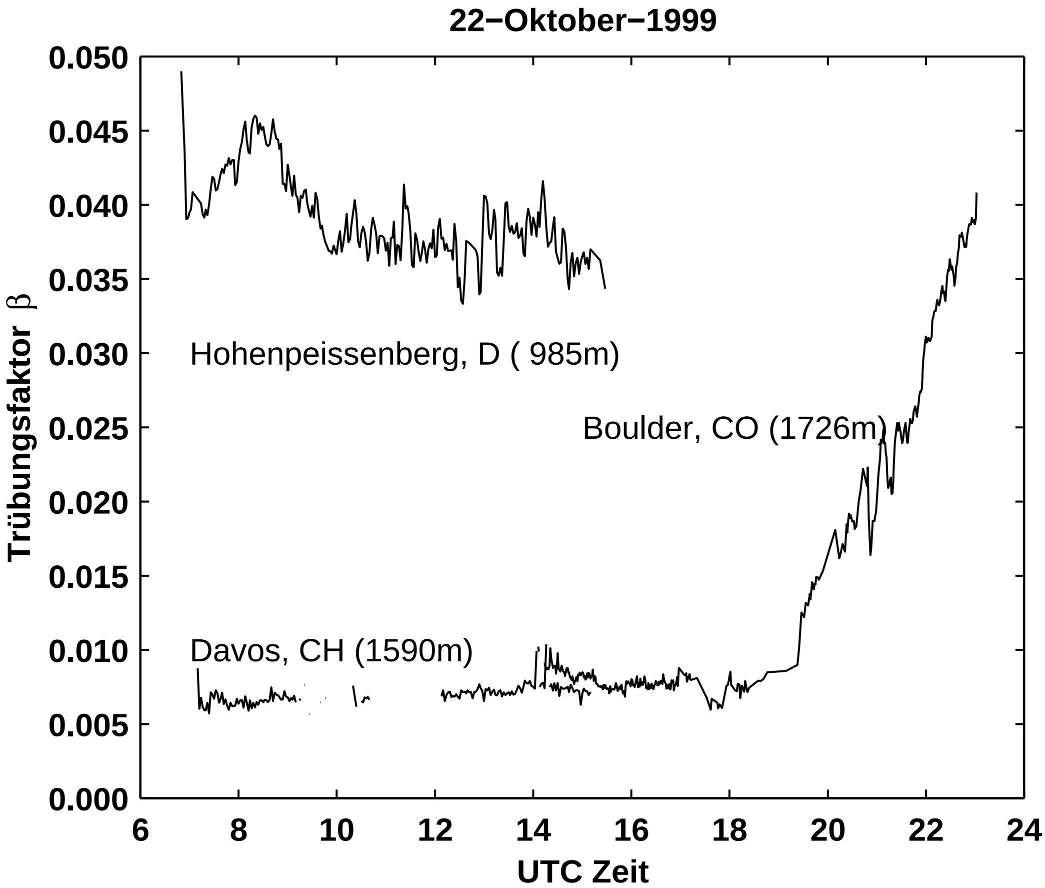

Figure 4: Atmospheric turbidity measured with Precision Filter Radiometers at 3 stations for October 22, 1999. The steadily rising turbidity in the afternoon at Boulder is possibly due to winds turning from west to east and moving aerosol laden air masses from the plains around Denver over the observing site.

In January 2000, a first comparison between our traveling standard instrument N26 and instrument N27 at Mauna Loa was successfully carried out. Simultaneous measurements were made over 21 days that will permit a determination of the drift rates based on the absolute calibration of both instruments. In addition, the traveling standard was calibrated with the Langley method at Mauna Loa. This additional calibration will be transferred to other standard instruments maintained at Davos.

Figure 4 shows the resulting turbidity values on a selected day when clear conditions were present at 3 stations. Note that solar noon occurs at 11 UTC hours in Hohenpeissenberg and Davos, but at 19 UT hours in Boulder.

3.3 UV measurement campaign in Garmisch-Partenkirchen (R. Philipona, D. Schmucki)

As part of the EU project CUVRA (Characteristics of the UV Radiation field in the Alps) a UV measurement campaign was held in March 1999 in the Bavarian Alps. For three weeks the six CUVRA partners measured UV radiation in the vicinity of the Institute für Umweltforschung (IFU) at Garmisch-Partenkirchen. Seven spectroradiometers and two sets of PMOD/WRC precision filter radiometers (PFRs) were deployed at six different sites located within a circle of radius 25 km around IFU (730 m a.s.l.) at altitudes ranging from 600 m a.s.l. at Oberpfaffenhofen up to the Zugspitze at 2964 m a.s.l.. The goal of the campaign was to investigate the UV radiation field in an alpine area and determine its variation with altitude, Aerosol optical depth (AOD), solar zenith angle, tropospheric ozone changes and the effective albedo differences between the measurement sites.

The main task of PMOD/WRC involved testing UV-PFRs and comparing filter radiometric measurements with measurements of spectroradiometers at IFU and at Zugspitze. PFR measurements were also used to accurately determine AOD at the two sites. The two sets of PFRs were mounted on solar trackers and measured direct solar irradiance in eight spectral channels simultaneously. Intercomparisons were made as follows: For the PFRs the PMOD lamp calibration of 18 May 1999 was used; the calibration of this lamp is within 1–2 % of the calibration made with the IFU lamp during the campaign. For a particular wavelength measured with the spectroradiometer, the one minute PFR reading closest to this measurement was chosen. This procedure resulted in a maximum time difference of 30 seconds between the PFR and spectroradiometer measurements. Spectroradiometer recorded spectra with a resolution of 0.5 nm over the wavelength range of 290 nm to 400 nm. These spectra were convoluted with the PFR filter functions at the respective wavelength, a process which yielded UV irradiances measured by the spectroradiometer at the central wavelengths of the PFR and weighted by the PFR filter functions. These values were then compared with measured PFR values.

Spectra of three Bentham DM-300 double monochromators, which measure direct as well as global UV spectra, were compared to PFR measurements. The first intercomparison took place in the first week of the campaign, where spectra of the Innsbruck group Bentham DM-300, measured on 10 March, were compared to PFR measurements. Later in the campaign the two Bentham DM-300 of the IFU group were compared at IFU and at Zugspitze with measurements of 18 and 24 March 1999.

Figure 5 shows the results of the comparison of the spectroradiometer at IFU with PFR measurements on 24 March. In this figure, measurements in five PFR channels between 305 nm and 368 nm have been compared with spectroradiometric measurements at four different air masses (AM). Up to AM 2, all PFR measurements are within 2% of the spectroradiometric values. The measurements in the 305 nm PFR channel begins to deviate from the value obtained from the spectroradiometer at an AM of 2.8, while at AM 5 the signal in this channel is so low that a valid comparison is no longer possible. The four other channels however, still compare within 5% even at AM larger than 2. Similar results were found between the spectroradiometer of the Innsbruck group and PFR measurements: deviations for the longer wavelength channels were within 5% while the values measured in channel 305 nm showed a 10% deviation. However, at Zugspitze the intercomparison revealed differences of about 10% for all the channels, with the spectroradiometer measuring higher UV irradiances. At a special UV radiation campaign at Jungfraujoch the same Bentham DM-300 from the Innsbruck group was again compared to PFR measurements. This time spectroradiometer measurements were made over the wavelength range from 290 nm to 600 nm with a resolution of 0.25 nm. The resulting measurements were compared with those obtained from PFR filter channels between 305 nm and 500 nm. Measurements from 28 June and 17 July 1999 were intercompared and all seven channels agreed within 5% for AM between 1.1 and 2.8.

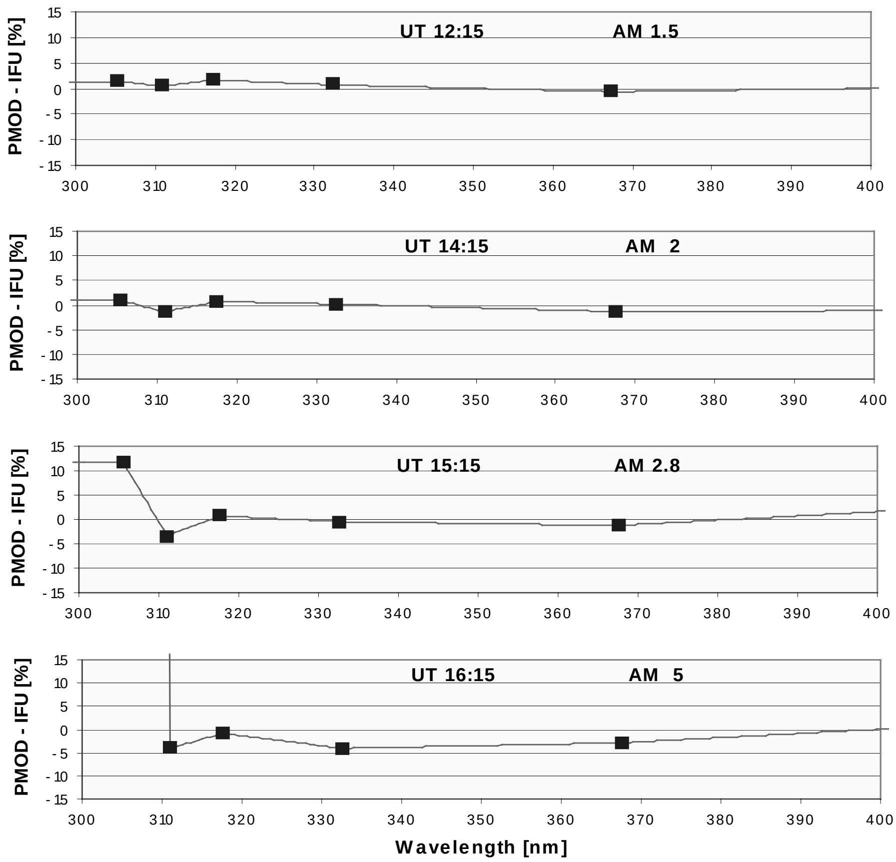

Figure 5: Intercomparison of spectroradiometric and Precision Filter Radiometer (PFR) measurements at 5 PFR wavelengths and 4 different air masses at Garmsich-Partenkrichen on 24 March 1999.

Radiation transfer models were then used to produce synthetic spectra based on PFR measurements. In the lower part of Figure 6 the IFU spectroradiometric spectra are compared with spectra from the model. The difference between the spectra as well as the difference between the IFU synthetic filter values and the PFR measurements are shown in the upper part of the graph. Above 310 nm the two spectra compare reasonable well on average, except for some minor differences which are due to differences in spectral resolution.

3.4 International Pyrgeometer Comparison IPASRC-I (R. Philipona)

The first International Pyrgeometer and Absolute Sky-scanning Radiometer Comparison (IPASRC-I) is an initiative of the Basline Surface Radiation Network (BSRN) community. PMOD/WRC has taken the lead in organizing and conducting this experiment, which involves intercomparing pyrgeometers and absolute instruments measuring downward longwave radiation in the field as well as comparing their results with state-of-the-art transfer model calculations. Following the BSRN pyrgeometer round robin calibration experiment, the aim of IPASRC-I was to evaluate present accuracy levels of pyrgeometer measurements in the field, relative to each other as well as to absolute measurements of downward longwave radiation.

With the assistance of members of the US Atmospheric Radiation Measurement (ARM) Science team from NREL in Golden, CO, NOAA in Boulder, CO, and the University at Albany, NY, the intercomparison was held at the Southern Great Plane (SGP) ARM Cloud and Radiation Testbed (CART) site in Oklahoma. Measuring downward longwave radiation on the roof of the SGP radiation trailer under ideal

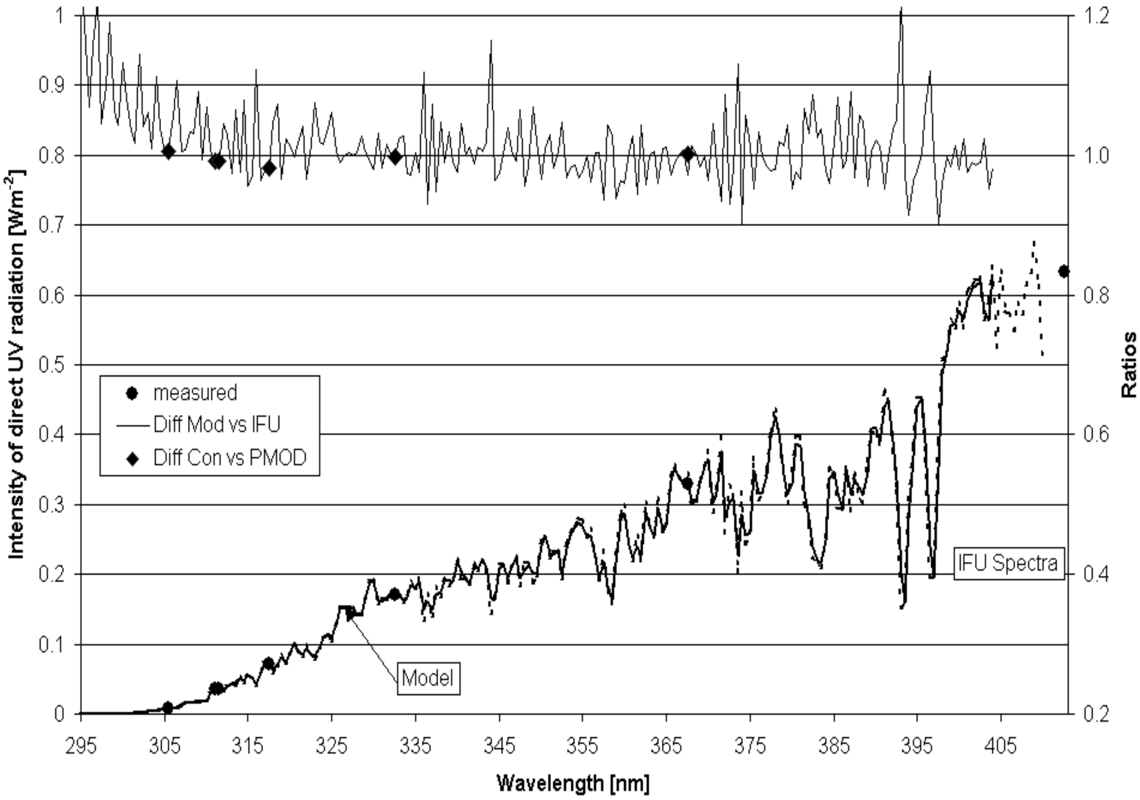

Figure 6: Comparison between UV spectra measured with a spectroradiometer by the Frauenhofer Institute (IFU) in Garmisch and UV spectra derived from UV-PFR data and model calculations for 24 March 1999 (12.15 UTC).

ventilated and shaded conditions, a total of 15 standard pyrgeometers from all over the world were present at the intercomparison. Of the 15 instruments one was a new type CG4 pyrgeometer from Kipp & Zonen and 14 instruments were Eppley PIR pyrgeometers, six of which were modified according to PMOD/WRC standards. Continuous measurements were taken with the 15 pyrgeometers from 21 to 30 September 1999, with measurements taken every seconds and mean values recorded every minute.

The PMOD/WRC Planck Calibrated Sky Radiometer (PCSR), a sky-scanning instrument, took part as an absolute standard for clear sky nighttime measurements. The instrument uses a very sensitive pyroelectric detector and is calibrated during the scans using a black body source as an absolute reference. To prevent any spectral disturbance the sky-scanner has no window and pure longwave radiation measurements must be made at night. During six more or less clear sky nights the PCSR was used to make sky scans which lasted for 24 minutes and from which absolute values of downward longwave radiation could be calculated. Absolute values derived from the PCSR measurements were compared with the mean values of pyrgeometer readings over the 24 minutes. Two chopped pyrgeometer prototypes of the Deutsche Luft und Raumfahrt (DLR) took also part in the intercomparison. The two instruments were developed for aircraft measurements and use a pyroelectric detector and a reference black body for relative calibration.

Preliminary analysis of IPASRC-I measurements indicates that with the user's calibration factors the 15 pyrgeometers show differences of up to 8 Wm^{-2} during night time measurements and up to 12 Wm^{-2} during day time measurements. The nighttime

Figure 7: Pyrgeometers set up on solar trackers and PMOD/WRC absolute sky-scanning Planck Calibrated Sky Radiometer (PCSR) on the radiation trailer of the SGP-CART site at Oklahoma in September 1999.

PCSR results are about 2Wm^{-2} below the mean of all the pyrgeometer measurements. All pyrgeometers were then recalibrated and adjusted to the level found for one particular PCSR nighttime scan sky-scanner reading. With the new comparative calibration, nighttime measurements from all pyrgeometers during the 10 days of the campaign were found to be within 3 Wm^{-2} and daytime differences were below 6 Wm^{-2}. These results demonstrate the stability and reliability of well-calibrated pyrgeometers. During the 10 days of the campaign the pyrgeometers measured downward longwave radiation levels between 260 and 420 Wm^{-2}. Analysis of these measurements is continuing and additional results will be reported in the near future.

3.5 Instrument Development

3.5.1 Commercial Radiometer PMO-6 (H. Roth, U. Schütz, J.U. Wyss)

For the last 20 years, the CIR company of Switzerland, under a contract with the PMOD, has manufactured PMO-6 radiometers for commercial use. After this long period of collaboration with the PMOD/WRC, CIR decided to concentrate its efforts on other business activities and to cease production of radiometers. Since it is in the interest of PMOD to have PMO-6 radiometers commercially available we began to develop a new generation of improved radiometer electronics for the well-known and successful PMO-6 cavity sensor.

The heart of the electronics package consists of an internal PC which provides a communication link between the radiometer and the outside world. It controls the radiometer operations as well as the timing of radiometric measurements. An RS232 interface or the keyboard on the front-panel is used to select the different operation modes and to command the electronics. A two channel Voltage-to-Frequency-Converter (VFC) system converts both the heater current and voltage simultaneously during an integration time of one second with a precision of 20ppm. A 16 Bit A/D converter is used to read the different housekeeping signals. Operations status, readings, and calculated results are displayed on the front-panel LCD. The electronic control-loop used to adjust the cavity heater is equipped with new noiseless pre-amplifiers, a new highly improved integrated Phase-Sensitive-Detector (PSD) system and a low-drift and low-noise PI amplifier.

The first instrument was delivered to Germany at the end of 1999; the manufacturing of a series of 10 additional units will start in early 2000. We believe this new computer controlled radiometer represents a major step forward in the development of highly accurate radiometers

3.5.2 UV-Sky PFR Instrument (H. Roth, R. Philipona)

Over the past two years, the PMOD/WRC has developed two prototype instruments for monitoring UV radiation from the sky. We have used these instruments to make measurements at various locations. The instruments function well and have proven to be very stable in terms of optical path and electronic amplifiers. Unfortunately, the small dynamic range of the instruments limits their scientific use for this type of UV measurement. Therefore, the PMOD/WRC has begun development of a new generation of UV-Sky-PFR instruments. The improvements in the new instruments over the first two analog prototypes are numerous: The four signal channels are chopped at the optical area. The electrical signals are amplified with high gains and converted into pulses proportional to the incoming irradiance by Voltage-to-Frequency-Converters. A sophisticated time-framed signal converting system sums the positive and negative pulses from the open and closed chopper phases. The results of this sum correspond to the incoming optical flux. The digital part of the electrical design is implemented in a Logical Cell-Array (LCA), a modern tool for electronic development and manufacturing. An internal microprocessor communicates with the external host computer and is able to accept commands and handle the data stream from the instrument. We expect the first measurements using this new UV-Sky-PFR will be made some time during the winter/spring of 2000.

3.5.3 Future Space Experiment SOVIM (D. Pfiffner, H. Roth, C. Fröhlich, J.U. Wyss)

Since 1996, we have been working on the construction of the space experiment SOVIM, which is a re-use of the design of SOVA/EURECA. The current status of the instrument is summarized here. We have finished the mechanical design of the new package that contains all three old SOVA packages. We have succeeded in reducing the size and weight to the required values. In November 1999, however, we received an order from ESA to stop fabrication as a result of a problem with the Course Pointing Device (CPD).

Being built by Alenia in Torino, the CPD is overweight and a radical redesign is necessary to correct the problem. The new design is not yet finalized. The manufacturing phase C/D will start only after the evaluation of a suitable contractor (possibly ALENIA).

Progress has been made on the construction of the electronic package, and a prototype of the data acquisition system has been built. This data acquisition system is contained on one printed circuit board and incorporates all 14 analog-to-digital converter channels and the interface to communicate with the computer. The entire computer interface, which interprets the various commands controlling the instruments and the data acquisition, is integrated in one FPGA (Field Programmable Gate Array). The heater drivers are packaged on the same board. A separate board has been designed for the power drivers for the five cover stepper motors. The electronics for the different instrument prototypes has been manufactured and tested. We expect to combine the electronic and mechanical assemblies shortly.

On 10-Nov-1999 BRUSAG, together with a subcontractor, has started with the development for the on-board and EGSE software. This is expected to be finished in 1st September 2000.

4 Scientific Research Activities

4.1 Results from the VIRGO Experiment

VIRGO (Variability of Irradiance and Gravity Oscillations) is an experiment on the ESA/NASA mission SoHO. It is built and operated under the leadership of Claus Fröhlich as PI in cooperation with the IRMB, the SSD and the IAC, who provide hardware and a total of 19 Co-Investigators from 11 different institutes. A detailed description of the instrument can be found in Fröhlich et al. (1995) and first results from VIRGO have been published in 'The First Results from SoHO' (SoHO Science Community 1997). Many publications have resulted from this project; in the following we report on results obtained during 1999.

4.1.1 Total Solar Irradiance (M. Anklin, W. Finsterle, C. Fröhlich)

The TSI record obtained with VIRGO on SoHO is probably the best available to date, primarily because of the very stable thermal environment of SoHO around the Lagrange Point L1 and the truly uninterrupted observations. VIRGO has two types of radiometers, PMO6V and DIARAD, which enables a consistent determination of possible changes (e.g. degradation) during the mission. Such monitoring of possible sensitivity changes has always been an important aspect of the VIRGO project (Fröhlich et al. 1995). Indeed their different characteristics of the two instrument types are reflected in quite different behaviour as shown in Figure 8. This figure shows the level-1 data of the operational and back-up DIARAD-L and -R and PMO6V-A and -B, transformed to SI units, corrected for known instrumental effects (e.g. temperature dependence) and reduced to 1 AU distance. The PMO6V exhibits a much larger degradation than the DIARAD, which is astonishing as during the SOVA/EURECA mission they showed a very similar behaviour. Moreover, the PMO6V radiometers increase their sensitivity at the very beginning of the exposure to radiation before they start to decrease with +3 ppm per exposure day. This effect is still unexplained, but obviously inherent to PMO6V as both show a 1/e time constant of about 7 days of exposure to the solar radiation. DIARAD-L is changing very little and therefore, it is used as an intermediate reference for monitoring the behaviour of the two back-ups, DIARAD-R and PMO6V-B, as shown in Figure 9.

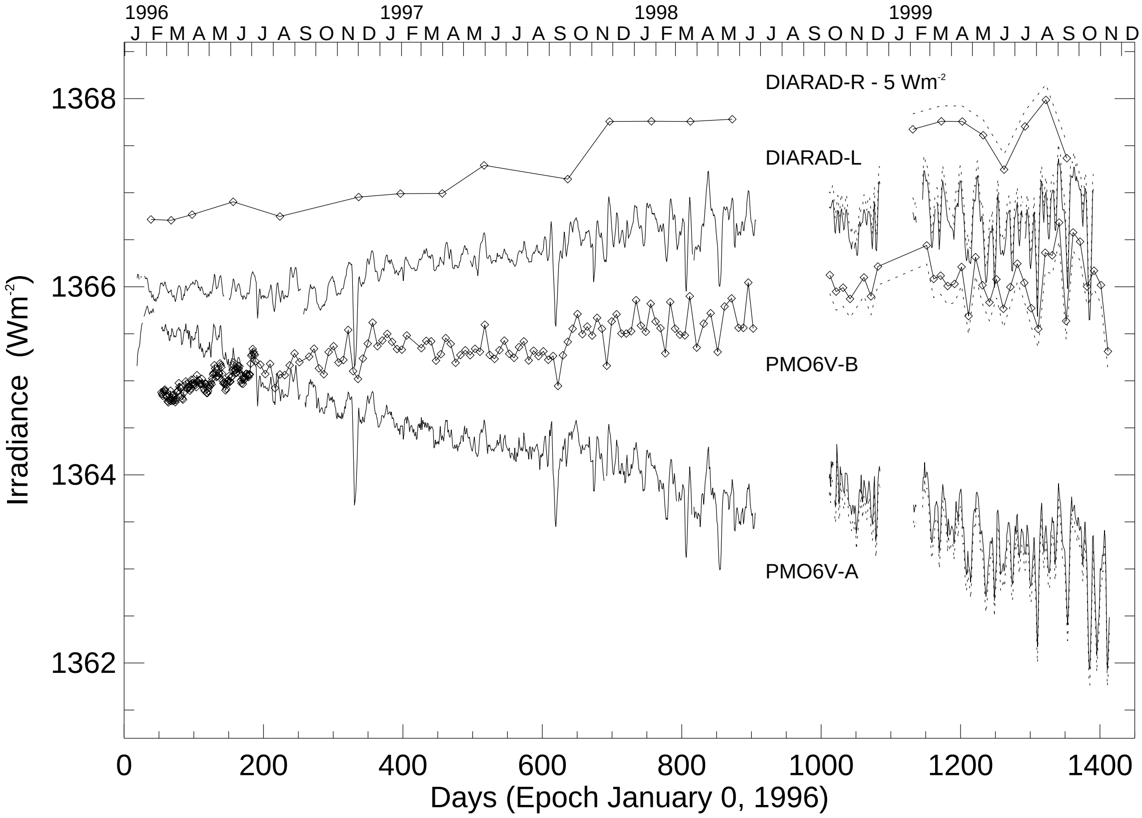

Figure 8: Level-1 radiometer data of DIARAD-R, DIARAD-L, PMO6V-B and PMO6V-A (from top to bottom). The dotted lines after the SoHO interruption (June to September 1998) show the shifts needed to maintain internal consistency over the gap.

Before we can determine their behaviour we have to correct PMO6V-B for its increase in sensitivity at the beginning of its exposure and a possible long term degradation. The correction for the latter is determined by comparing it to DIARAD-R, whose sensitivity is assumed to be constant over time (change from diamonds to squares in Figure 8). This comparison results in a linear trend in sensitivity of PMO6V-B between mission days 450 and 1000 of -3.6 parts in 10^{-7}per day. The trend of PMO6V-B in sensitivity is interpreted as an irradiation-independent change due to exposure to the space environment and it is assumed to persist through the end of 1999. As PMO6V observes the sun more often than DIARAD-R (once a week compared to once a month) the corrected values of the former are used as a reference (full line in Figure 9 which corresponds to the correction of DIARAD-L) for the adjustment of PMO6V-A shown in Figure 10. It is interesting to note that the deviation of the degradation of PMO6V-A from an exponential behaviour is related to the slow temperature changes of the experiment due to the varying distance from the Sun as is the correction of DIARAD-L. Another interesting effect was observed after an accidental switch-off of the VIRGO experiment for a couple of days in September 1996 (Figure 8): after switch-on DIARAD-L gradually recovered from a change in sensitivity to its previous level in 6-8 weeks (as determined through a comparison to PMO6V which showed no obvious change). Moreover, the ratio to DIARAD-R does not show any significant change during that recovery period, indicating that both instruments react in a very similar way to exposure-independent effects.

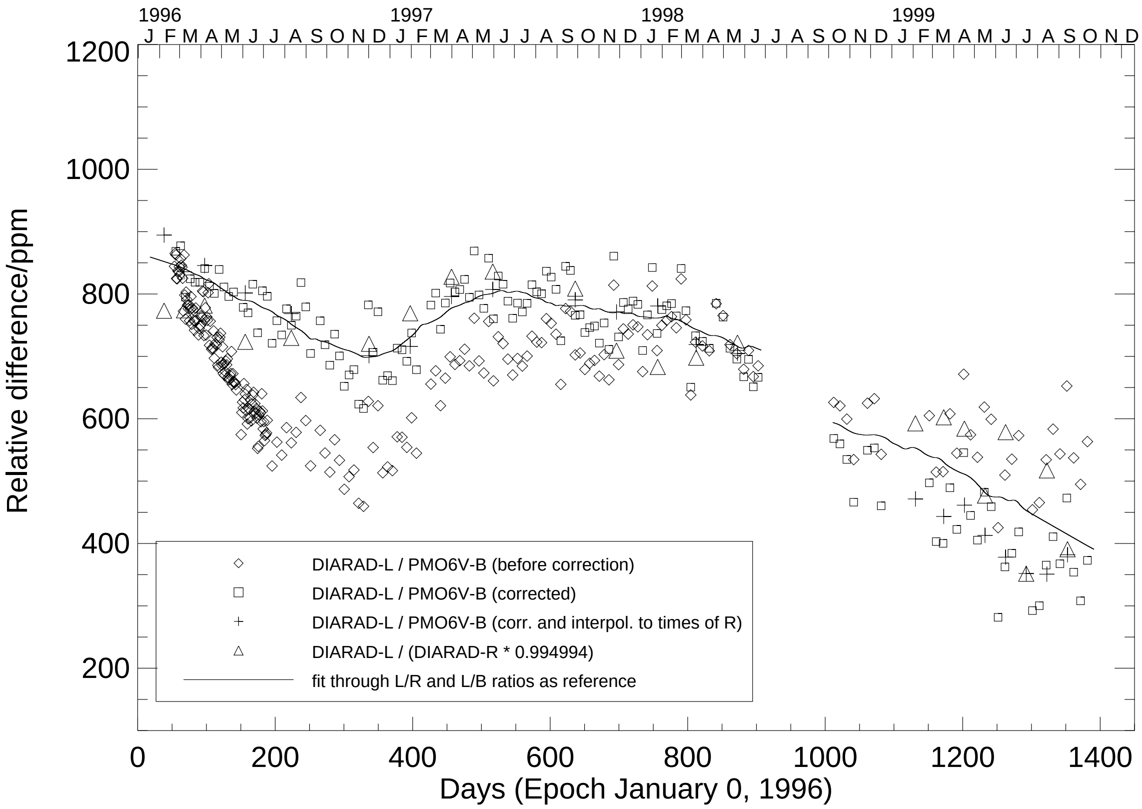

Figure 9: Ratios of DIARAD-L to DIARAD-R and to PMO6V-B for the determination of the degradation of DIARAD-L and PMO6V-B. The solid line corresponds to the degradation of DIARAD-L.

The interruption of the SoHO mission, often called SoHO “vacations”, from 28 June until the end of September 1998 has shown how sensitive thermal radiometers can be to interruptions. The difference between DIARAD-R and PMO6V-B changed by 338 ppm. At first it was not clear how this change should be distributed among the radiometers. As a first trial we applied a correction of +120 ppm to DIARAD-R and -218 ppm to PMO6V-B (which sums to the observed difference of 338 ppm). In order to make the changes for the DIARADs about equal - as after the gap in September 1996 - the adjustment of PMO6V-B had to be changed to -145 ppm yielding for DIARAD-L +116 ppm and for PMO6V-A -125 ppm. The estimated uncertainty of all these corrections is about ±40 ppm. The constraint of the equal changes of DIARAD-R and -L results in an inconsistency which is seen as a difference between the corrected DIARAD-R and PMO6V-B. Thus, the average between both is used as reference for the period after the SoHO gap. Comparison with ACRIM II during the 2.5 years before the SoHO gap shows a slope in the ratio of ACRIM II to VIRGO of -0.09±0.02 ppm/d which may be interpreted as an irradiation-independent (internally undetectable) change of DIARAD-R which we have been assuming to be constant. After correcting for this trend the changes over the SoHO gap expressed as ratios to ACRIM II and ERBS result in -2 ppm (weighted mean of +27±62 ppm and -284±194 ppm, respectively) which makes the VIRGO data simultaneously internally consistent and in agreement with the other available space experiments. With the corrected DIARAD-L and PMO6V values the VIRGO irradiance is calculated according to the prescriptions given in Fröhlich et al. (1997). These data are available as daily and hourly values from http://www.pmodwrc.ch/virgo/virgo.html. An important issue in the context of the solar variability is the reliability of the early increase observed by VIRGO (during the second half of 1996) for which the model (Fröhlich and Lean 1998b) would suggest no trend at all. The determined degradation and the corresponding correction during 1996 is about 120±40 ppm, which is only about a third of the observed increase of about 300 ppm. Even if we assume no correction a significant increase remains; thus, we believe that the increase is real.

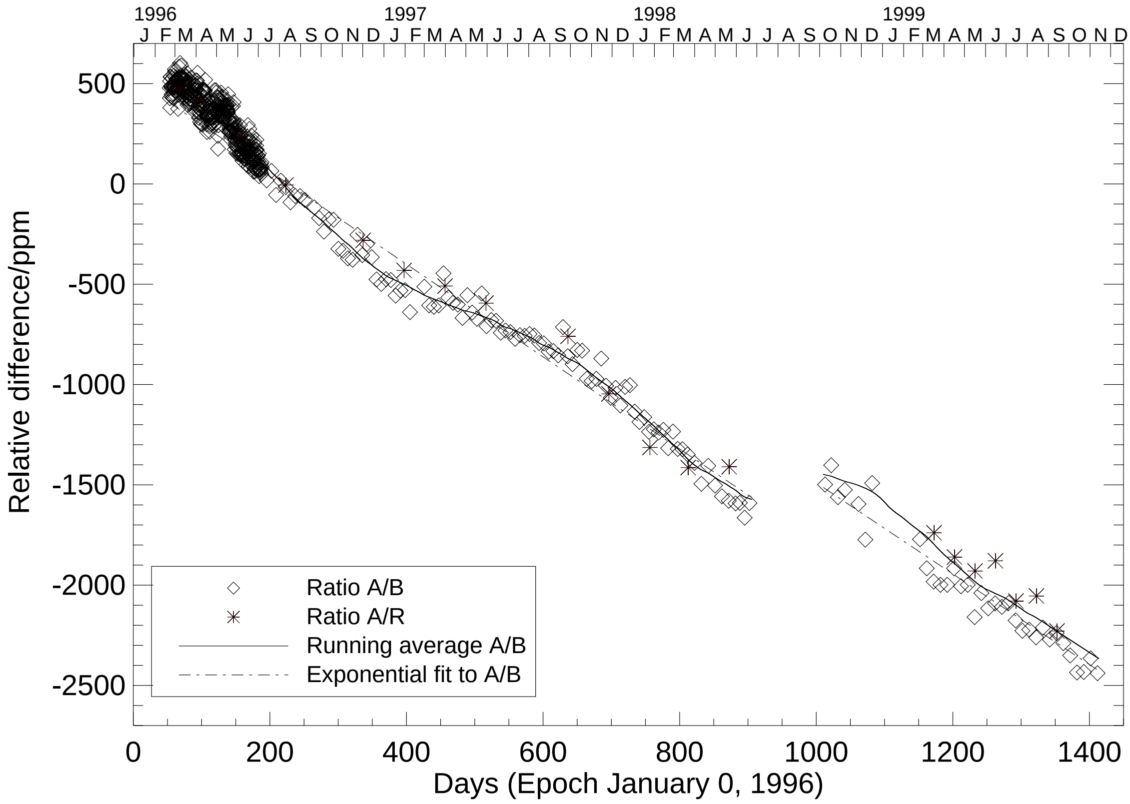

Figure 10: Degradation of PMO6V-A. Note the difference between a simple exponential decline and the observed behaviour which shows a degradation rate changing slowly with the annual course of the temperature due to the changing spacecraft-Sun distance.

4.1.2 Low Frequency Oscillations (W. Finsterle, C. Fröhlich)

A concerted effort to search for g modes was initiated by Thierry Appourchaux in 1998 with members of the VIRGO, MDI and BiSON teams, and several leading theoreticians in the field. This group comprises the *Phoebus* collaboration. Wolfgang Finsterle and Claus Fröhlich from PMOD/WRC were involved in this collaboration and the work of the former was part of his PhD thesis (Finsterle, 1999) which was completed in November 1999. While we have failed to detect g modes, we have nevertheless placed the lowest limits to date on their amplitudes. In the following we briefly describe the results of this endeavour which is now in press (Appourchaux et al., 2000). The amplitude spectra from the three SPM channels (similar to Figure 11, but for lower frequencies) yield an upper detection limit for the red SPM of about 0.5 ppm at 200 μHz, and 0.3 ppm at 1000 μHz. The levels for the other colors scale approximately with the temperature perturbation induced on the blackbody spectrum, with a slightly lower signal-to-noise ratio in the blue channel. The noise in the LOI amplitude spectrum is about 10% higher than the green SPM above 200 μHz, and 30% higher below. The additional noise comes from several sources. The most important are probably small variations in the image size over the detector and the effect of structures rotating into and out of the non-sensitive inter-pixel areas of the detector. Similar investigations of the inherent noise have been made for the velocity instruments and the other methods as e.g., using the multi-variant spectral analysis which allows to suppress the solar noise in the radiometer data by comparing it with the SPM data. The upper detection limits for the velocities measured by each of the instruments used in the *Phoebus* project are: for MDI, 15 ms^{-1} at 200 μHz, and 6 mms^{-1} at 1000 μHz; for BiSON, 12 mms^{-1} at 200 μHz, and 4 mms^{-1} at 1000 μHz; and for GONG, 20 mms^{-1} at 200 μHz, and 5 mms^{-1} at 1000 μHz. The BiSON instrument performs almost as well as MDI above 400 μHz.

The transformation of a theoretical g-mode δr/R perturbation to an observable Doppler shift or intensity variation is a non-trivial problem. The determination of the theoretical conversion factor between velocity and intensity perturbations is fraught with difficulties. The simplistic approach based on p-mode amplitude ratios gives a value of about 4 cms^{-1} ppm^{-1} for low-degree modes, while more-detailed calculations give values for l=1 of 50 to 80 cms^{-1} ppm^{-1}. These theoretical upper limits are an order of magnitude lower than the observational limits set by the work of the *Phoebus* group. It is interesting to note that such lack of detection was predicted aback in 1985 at an ESA conference for the planning of SoHO. Given our current prejudices regarding the expected characteristics of core-penetrating g modes, it therefore seems unlikely that a firm, unambiguous detection will be made in the near future by one instrument or network alone. For example, an improvement in the signal-to-noise ratio (in amplitude) in data obtained by a single instrument by a factor 10 - assuming a stable noise power spectral density, and a coherent mode signature over the duration of the observations - requires a factor 100 increase in observing time. A coordinated, coherent approach which involves the utilization of contemporaneous data from the various active observational programs (e.g., *Phoebus*) would seem to offer the best prospect of future progress.

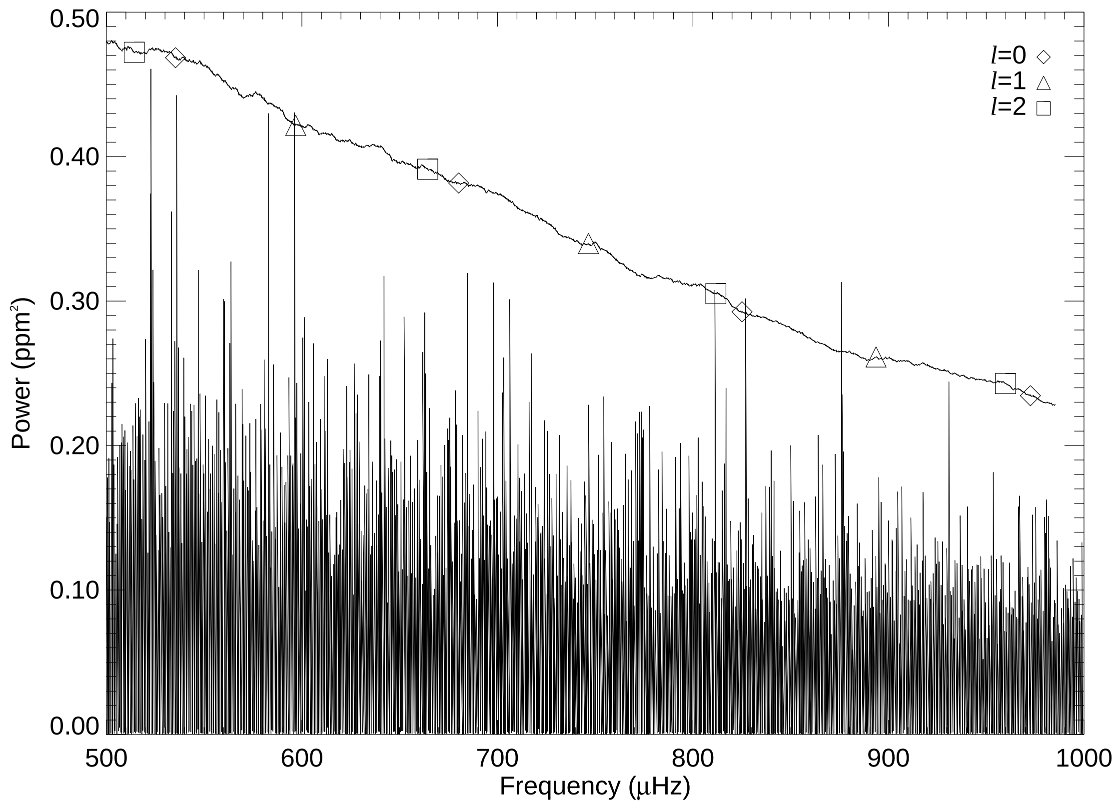

Figure 11: Power spectrum of the SPM green from 500-1000 μHz (555 μHz corresponds to a period of 30 minutes). Four peaks cross the 10% threshold used to discriminate real signals from noise and three of them are close to predicted p-mode frequencies of l=0, 1 and 2 as indicated by the symbols. The highest peak is an artefact due to an interference between the sampling and spacecraft operations.

We conclude that the firm upper limit to the g-mode amplitude at 200 μHz, is below 10 mms^{-1} in velocity, or 0.5 parts-per-million in intensity. This velocity corresponds very approximately to a peak-to-peak vertical displacement of $\delta r/R=2.3\times10^{-8}$ at the solar surface. These levels, much lower than previous values, confirm the theoretical prediction that no g modes could be detected by SOHO.

Interestingly, the analysis of the power spectra of the SPM in the range of the low order p modes shows several peaks reaching above the 10% limit (Figure 11, from Finsterle, 1999) which may be identified as low order p modes. Further analysis is needed to pin down the significance of these observations.

4.1.3 Total Solar Irradiance since 1978 (C. Fröhlich)

In recent years a major effort has been put into the construction of a reliable composite of the total solar irradiance (TSI) not only to allow detailed studies of the mechanisms underlying solar variability, but also to provide a reliable dataset for climate studies and investigations into the solar-terrestrial relationship. A detailed description of the procedures to construct the composite has been presented in earlier reports and can be found in Fröhlich and Lean (1998a,b). A major improvement has been achieved from a detailed re-analysis of the glitches of HF during autumn 1989 and spring 1990 and from the most recent corrections to the VIRGO data as described above.

The HF radiometer on NIMBUS-7 has no back-up instrument and therefore there is no direct method of determining the irradiation-dependent degradation (Hoyt et al. 1992). The cavity of HF has the same characteristics as that in PMO6-type radiometers, which means that both the geometry and the paint in the cavity are the same. As seen in Figure 12 the early data are rather high with a steep increase at the very beginning which immediately suggests that the behaviour could be similar to that of PMO6V on VIRGO/SoHO (Anklin et al., 1998). Thus, we apply corrections for the HF radiometer degradation prior to 1982 by considering the behaviour of PMO6V and by utilizing data from the ACRIM I to fit an exponential function describing the degradation (although we know from VIRGO that an exponential function is only an approximation). Moreover, we adjust HF data prior to the end of 1980 downwards, which corresponds to a slip in the NIMBUS-7 orientation relative to the sun as described in detail in Fröhlich and Lean (1998a).

Adjustments of -0.31 and -0.37 Wm^{-2} were proposed to correct for glitches occurring near 1 October, 1989 and 8 May, 1990. The correction values were detected through a comparison with ERBE data (Lee III et al. 1995) and also with models based on ground based observations by Chapman et al. (1996). The total amount of these two changes is crucial for the determination of the long-term variations in the TSI because they correct data that were taken during the gap between the two ACRIM experiments and thus yield the adjustment of ACRIM II to the scale of ACRIM I via comparison with HF and ERBE. Therefore, these corrections have been revised in detail and the results are presented in Figure 13. Both comparisons show that there was a change in the NIMBUS7 data, although it is not so clear that it happened in two steps. An independent measurements of the total change due to glitches can be derived from comparing the ratio HF/ERBE before and after the glitches happened. The periods used for the comparison cover roughly 15 months before and after and overlap fully with ACRIM I and partly with ACRIM II, which began operating only 500 days after the second glitch. The two data need to be reduced by 69 ppm each to equalize the ratio before and after. This adjustment turns out to change the data on average (over the second 15 months) by 425 ppm which is slightly smaller than the imposed correction of 542 ppm; this rather important difference reflects the noisiness of the HF/ERBE comparison in general and may be an indication of the uncertainty in these comparisons. The presently determined correction is about 40 ppm smaller than what was used in earlier evaluations and 138 ppm smaller than what was originally proposed by Lee III et al. (1995) and Chapman et al. (1996).

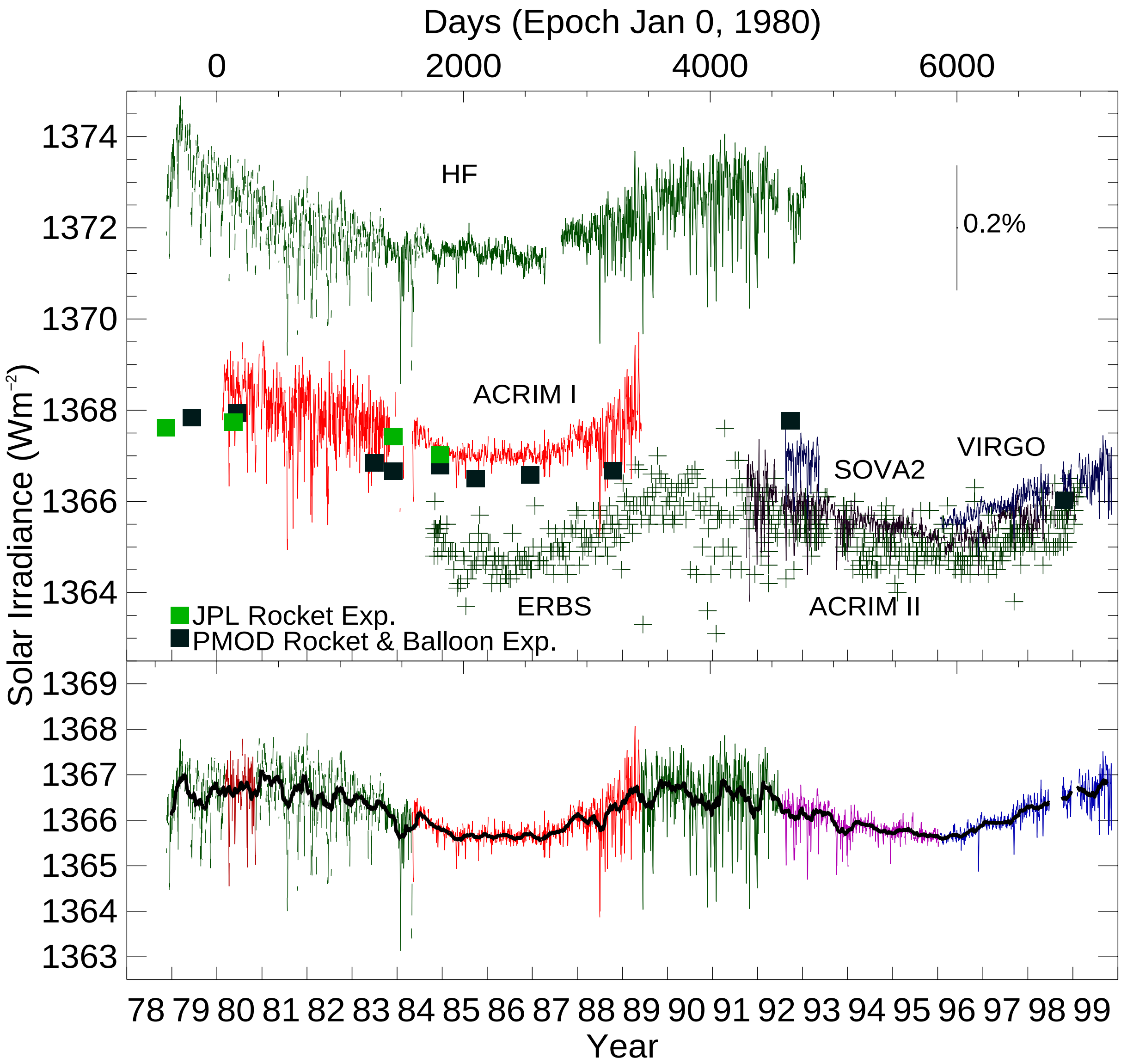

Figure 12: *Top panel:* Daily average values of the Sun's total irradiance, TSI, from November 1978 to the present, as measured by radiometers on different spacecraft (HF on Nimbus7, ACRIM I on SMM, ERBE on ERBS, ACRIM II on UARS, SOVA2 on EURECA and VIRGO on SoHO) are compared. Also plotted are the results from rocket and balloon experiments which were used in 1986 by Willson et al. (1986) to show that the decrease was indeed due to the sun. The data are plotted as published (i.e., degradation corrections have been made only for the two ACRIM, the SOVA2 and the VIRGO radiometers the data are not corrected for degradation).
Bottom Panel: Composite TSI on the same scale as the original data. Aside from the solar cycle variation of about 0.1% no trend in the TSI during the last 20 years can be observed.

The updated composite TSI, shown in Figure 12, was then adjusted to the Space Absolute Radiometer Reference (SARR, Crommelynck et al., 1995); this does not lower the absolute uncertainty, but is convenient for comparison with other data. The data of the most recent composite TSI are available from http://www.pmodwrc.ch/solar_const/solar_const.html.

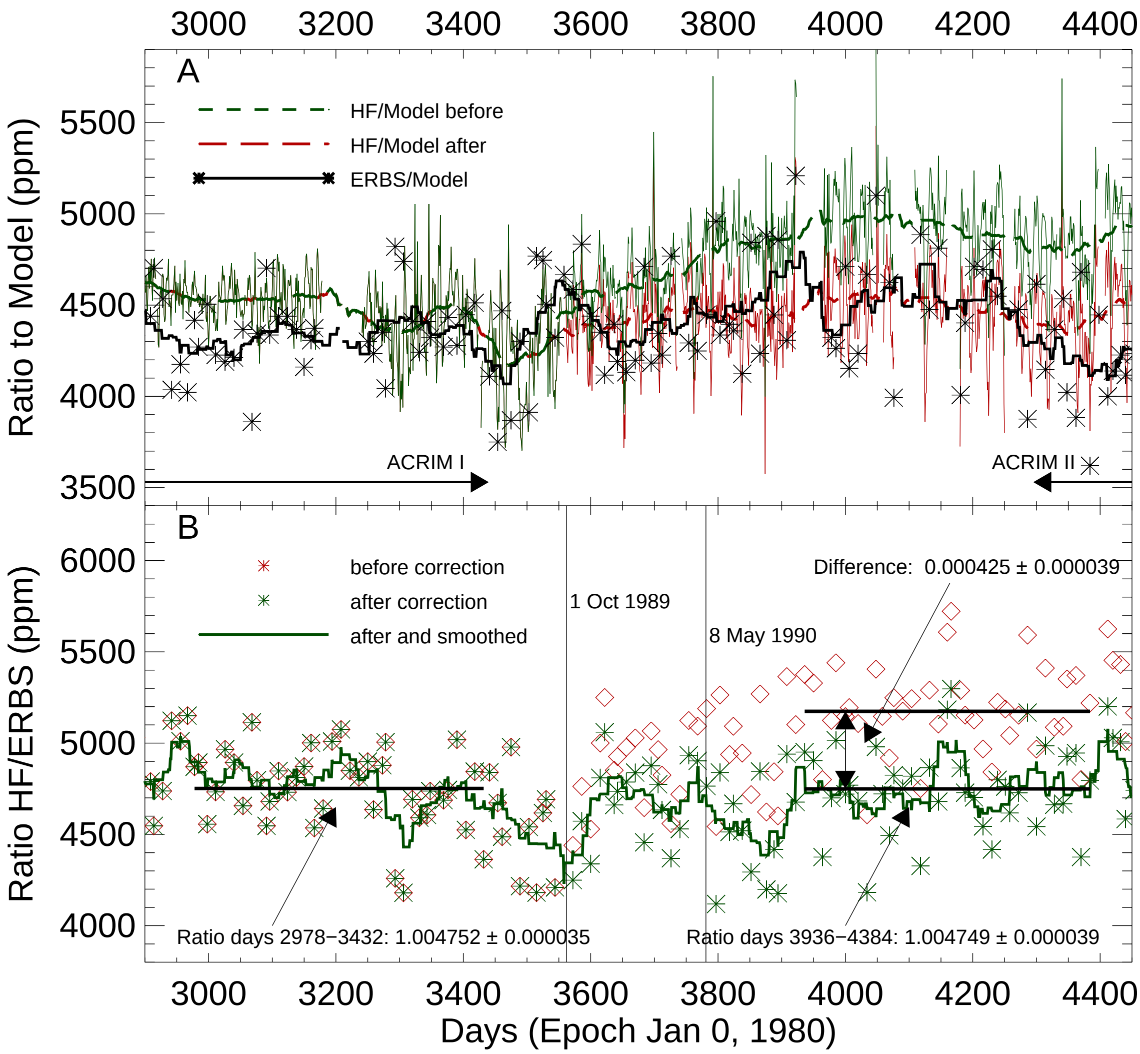

Figure 13: Daily average values of the Sun's total irradiance as measured by HF and ERBS are compared with the model from Fröhlich and Lean (1998b) (A) and with each another (B). Also indicated is the range of the ACRIM I and ACRIM II measurements and the dates when the changes in the HF data occurred.

4.2 Surface Radiation Budget in the Alps (R. Philipona, Ch. Marty)

All of the ASRB-stations have been operational now for four or more years. This resulting dataset allows one to calculate yearly mean values of the surface radiation budget (SRB) for all ASRB-stations. The absolute value of this flux is important for the determination of the energy and evaporation budget and hence the energy flux into the atmosphere. General circulation models (GCMs) and satellite date are essential for understanding the different contributions to the surface radiation budget, but they will be of limited use until their outputs can be validated against accurately measured surface radiation data. The SRB varies with elevation, a fact which has consequences for the dynamics of the atmosphere in mountainous regions. The alpine region is therefore an ideal test bed for the investigation of the SRB to discover evidence for a change of the greenhouse effect. Figure 14 demonstrates that the yearly mean values are positive for all altitudes and vary between 50 W/m^2 at the lower stations and 5 W/m^2 at the highest stations.

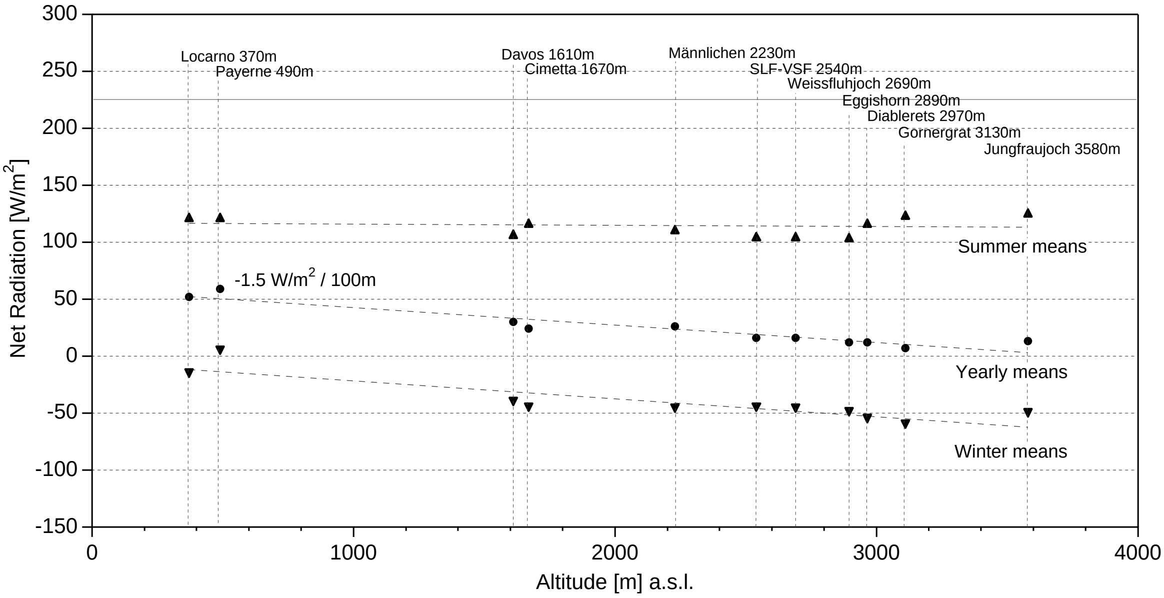

Figure 14: Altitude Gradient of yearly and seasonal mean values of net radiation at all ASRB-stations. Stations above 2800m a.s.l show higher summer values due to less convective clouds.

The ASRB-network also allows a study of cloud feedback at different altitudes, a process which is responsible for major uncertainties in our current understanding of the greenhouse problem. Clouds are a key variable in balancing the Earth's radiant energy by regulating the planetary albedo. An increase in planetary albedo cools the Earth-atmosphere system. On the other hand, clouds absorb longwave radiation emitted at relatively high temperatures by the Earth's surface and emit it back to the Earth. This trapping of longwave radiation by clouds tends to warm the Earth' s surface. Therefore, clouds have two competing effects on the Earth's radiation balance: A negative feedback by decreasing shortwave transmission to the earth surface and a positive feedback by increasing longwave re-emission in the atmosphere.

These effects can be quantified by defining the cloud radiative forcing. Surface measurements like the ASRB-network allow a determination of the cloud radiative forcing at the surface, hereafter called cloud radiative forcing (*CF*) for convenience. The *CF* is calculated in terms of the difference between the clear-sky (clr) and the all-sky (all) net radiation results and can be expressed as the sum of the shortwave (CF_{SW}) and longwave (CF_{LW}) cloud radiative forcing:

$$CF = CF_{SW} + CF_{LW} = (SWnet_{all} - SWnet_{clr}) + (LWnet_{all} - LWnet_{clr}).$$

Through the study and measurement of CF, we hope to answer several questions: Do clouds, on average, increase or decrease the net radiation? What are the regional and seasonal differences in the net radiation? What is the amount of short- and longwave cloud radiative forcing? Some of this questions can be answered by analyzing the ASRB-data (cf. Fig 15).

Clouds generally have a larger albedo than the earth surface. Hence, shortwave cloud forcing (CF_{SW}) is always negative and results in cooling by reflecting incoming solar radiation back to space. The yearly mean shortwave cloud forcing decreases slowly with altitude due to less solar absorption in the alps due to more snow. The absolute values vary from about -50 W/m^2 to -20 W/m^2 causing a gradient of 0.51 W/m^2/100m.

Longwave cloud forcing (CF_{LW}) is always positive because the trapping of the longwave radiation by clouds warms the Earth-atmosphere system. Yearly mean values exhibit a slight increase with altitude as a result of the altitude gradient of the longwave net radiation. The absolute values vary from about 35 W/m^2 at the lowest stations to 60 W/m^2 at the highest stations, yielding a gradient of 0.55 W/m^2/100 m.

The absolute values of the net cloud forcing (*CF*) are small compared to those for short- and longwave cloud forcing. The yearly mean values for net cloud forcing show an altitude dependence (1 W/m^2/100 m) ranging from -7 W/m^2 at Payerne to 32 W/m^2 at Jungfraujoch. This result reveals that short- and longwave cloud forcing nearly cancel each other at the lower stations, whereas at higher locations CF_{LW} dominates. This indicates that clouds mitigate the decrease in temperature with altitude by cooling lower stations and warming mountain stations. This is also demonstrated by the reduction of the altitude gradient of net radiation from clear-sky conditions (-2.6 W/m^2/100 m) to one of the all-sky conditions (-1.5 W/m^2/100 m). It can be concluded that clouds have almost no impact on the yearly mean net radiation at lower stations, but clearly show a warming effect at stations above 2000 m a.s.l..

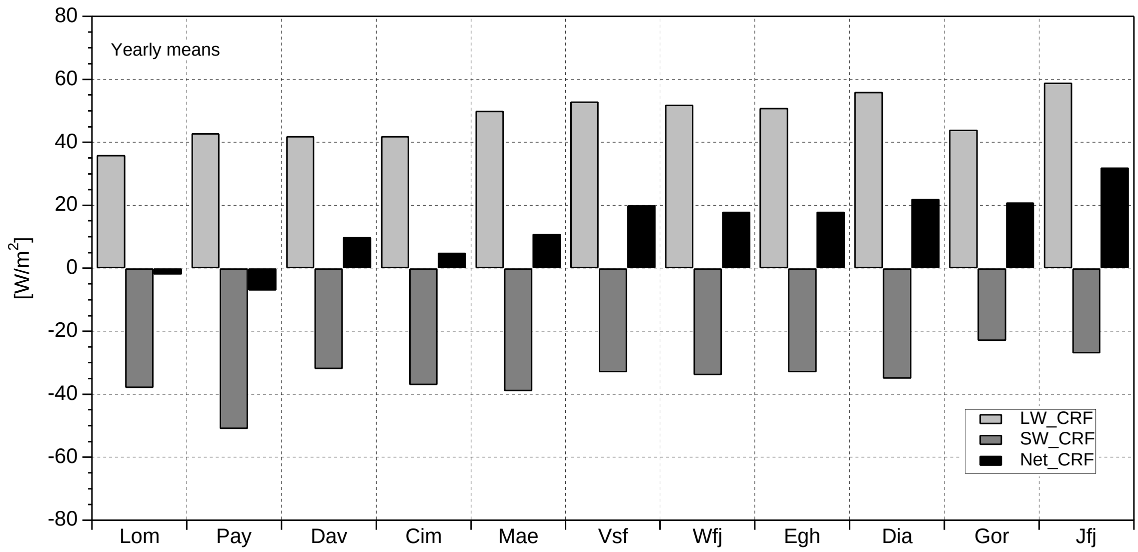

Figure 15: Yearly means of shortwave, longwave and net cloud radiative forcing at all ASRB-stations. Short- and longwave cloud forcing almost cancel each other at the lower stations. Longwave cloud forcing dominates at the higher stations.

4.3 UV radiation and effective albedo (R. Philipona, D. Schmucki)

In Davos and near the Weissfluhjoch, UV-Biometers from Solar Light have been measuring the direct, the diffuse and the global component of the erythemal UV radiation since 1994 and 1997, respectively. Experience has shown that at carefully maintained stations the direct and diffuse components add up to the observed value of the global UV radiation within 3%. This test only verifies relative stability whereas there is an additional uncertainty in the absolute values of about 10%, according to the WMO/STUK intercomparison (*Leszczynski et al., 1998*). The sites are also equipped with global UVA broadband filter instruments and several shortwave instruments. Additionally, at the Weissfluhjoch site continuous albedo measurements are performed in the erythemal UV, UVA and shortwave band. Local albedo values derived from these measurements over the past few years reflect the large difference between summer and winter conditions. In general albedo values are much higher at all wavelength ranges during winter (October - April). These results are well-known (*Blumthaler and Ambach*,

1988) and can be explained by the large annual variability of the fraction of the snow-cover.

Year	Summer [%]			Winter [%]		
	UV_{ee}	UVA	SW	UV_{ee}	UVA	SW
1997	3.31	4.18	13.18	n.a.	n.a.	n.a.
1998	3.04	3.83	10.0	90.76	93.37	84.51
1999	3.15	3.85	10.51	91.66	93.01	86.42

Table 1: Seasonal averages of local albedo values measured near Weissfluhjoch (2540 m a.s.l.). For the calculation of mean values, daily measurements around solar noon (±1 hour) were used. The results are given for erythemal UV (UV_{ee}), UVA and short wavelength radiation (SW).

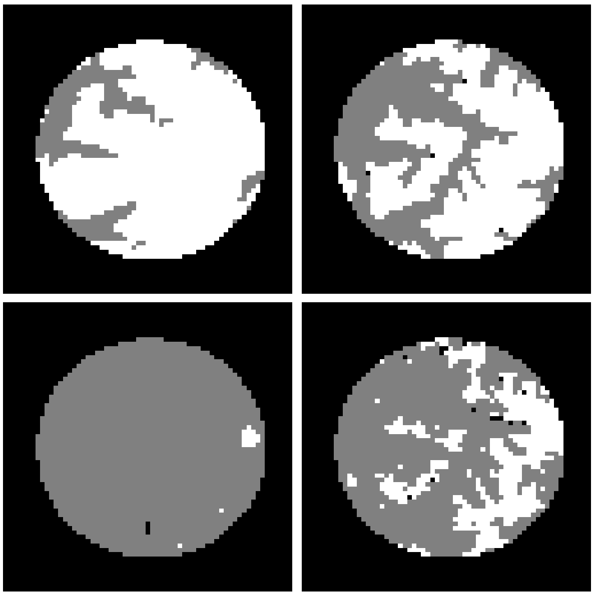

Figure 16: Snow maps of the area surrounding Davos (center of the pictures) from 29 March, 10 May, 26 August and 20 September 1998 (upper left to lower right) with snow-covered (white), snow-free (grey) and cloudy (black) sections. The pictures were derived from data taken by the NOAA-14 satellite (AVHRR) and represent conditions in the early afternoon. The radius of the circle is 25 km and includes mainly mountainous regions.

Typically, albedo values in the visible wavelength range are significantly higher than those in the UV range during summertime (see Table 1). From July to September, when the area around the Weissfluhjoch investigation site is nearly completely snow-free, the albedo of the shortwave radiation amounts to 11%. The albedo at UVA and erythemal UV wavelengths has values between 3%-5% with only small variations from 1997 to 1999. In contrast to summer seasons the highest reflectance for winter months is found for UVA radiation. The average values for the whole winter season amount to 93%. For erythemal UV and shortwave radiation, albedo values are around 91% and 85%, respectively.

As a consequence of the low aerosol levels, high elevation and numerous snow-covered surfaces the Alps are one of the regions in Europe with very high ambient UV radiation levels. Albedo investigations play a key role in the understanding radiative transfer over Alpine terrain. The difficulty to determine the effective albedo is due predominantly to the inhomogeneous surfaces in Alpine regions and a number of additional interrelated parameters. Most of these parameters can be corrected for or normalized using simple methods. After making these corrections the only remaining influence on the ratio between direct and diffuse erythemal UV radiation is related to the surrounding surfaces within a radius of about 25 km. Satellite data from selected days allow one to determine the fraction of snow coverage within this radius (see Fig. 16). With this information and data from local albedo measurements in the UV (see Table 1) it is possible to calculate **effective albedo values** for these selected days. A correlation between effective albedo and the ratio of direct to diffuse UV radiation was found to be linear for constant solar elevations (see Fig. 17). This correlation, together with accurate measurements of direct and diffuse UV radiation, then allows a determination of the effective albedo at any Alpine location for any clear-sky day.

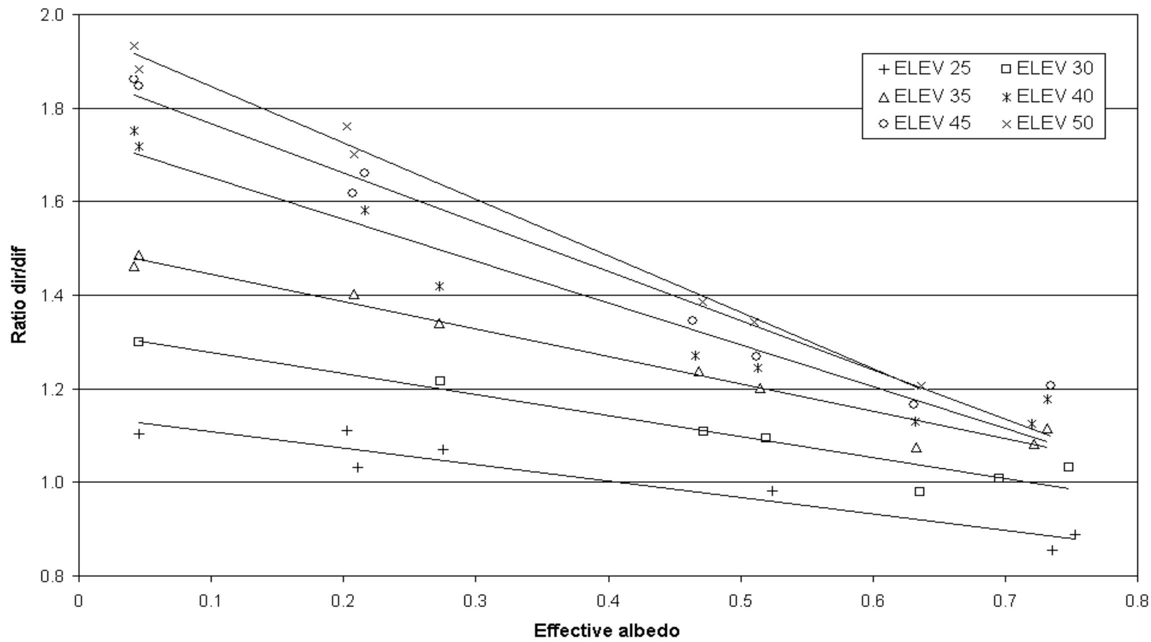

Figure 17: Linear fits to the effective albedo as a function of the ratio of direct to diffuse UV radiation (ozone and aerosol corrected) of ten selected clear-sky days from the year 1998. The calibration curves were calculated for six different solar elevations. Effective albedo values are determined from satellite measurements.

4.4 Astrophysics (W. Schmutz)

Within the last year, two projects of an astrophysical nature have been completed and the results published in the European journal Astronomy and Astrophysics. The first of these, involving a collaboration with researchers at the University College London, the ST-ECF/ESO Garching, the University of Pittsburgh, and the University of Amsterdam, compared the theoretical predictions for the strength of extreme UV radiation from Wolf-Rayet stars with the values derived from the observed properties of surrounding nebulae (Crowther et al. 1999). The other investigation, involving a collaboration with researchers at the ETH Zürich, used spectroscopic UV observations obtained with the HST in 1996, as well as archival UV data obtained with the IUE satellite and ground-based optical spectroscopic observations obtained at ESO over several years, to study the matter surrounding the symbiotic stellar systems RW Hydrae and SY Muscae and determine the velocity structure of the mass outflow from the red giant. A second paper on this topic, carried out by the same ETH team and using the same data set, is nearly finished and will be submitted shortly. In this paper we report evidence for a bow shock produced as a result of the accretion of the mass lost by the red giant onto its white dwarf companion.

Two investigations in collaboration with University College London are continuing. The first, nearing completion at the end of 1999, involved a study of Gamma Velorum, a binary stellar system composed of a Wolf-Rayet star and an O star. Our goal is to determine both the masses and the luminosities of the stellar components. The masses are derived from the orbital motion of the binary components while the luminosities are calculated from the parallax (and hence, distance) measured by the Hipparcos satellite. When this work is completed, the Wolf-Rayet star in Gamma Velorum will be the only one of its kind with the two basic stellar parameters, mass and luminosity, determined observationally. A comparison with the theoretical predictions for the relation between these two parameters would then provide a fundamental test of stellar models. The results will be published shortly in the third installment of a series of papers that analyze this system.

The second joint project with UCL is still in the starting phases. We intend to analyze hot luminous stars in Local Group galaxies. Due to the large distances of these objects observations with the most powerful telescopes in the world are required. So far, we have obtained photometric filter measurements with the NTT of ESO and we will acquire a first set of spectroscopic observations with the VLT of ESO in September 2000. The observational data will then have to be analyzed in detail. The completion of this project is therefore still a few years away.

Together with W. D. Vacca at the University of Hawaii we have been analyzing the near-infrared properties of the massive X-ray binary Cyg X-3. This object is the only known system thought to have survived a common envelope phase in the evolution of a close binary. Near-infrared images of this system were obtained with the HST in 1998 and near-infrared spectra were obtained with UKIRT on Mauna Kea, Hawaii in 1999. The reduction and interpretation of the data is in progress and a paper is expected to be ready for submission later this year.

The same team is also investigating the stellar populations within star-forming knots found in starburst galaxies. In January and February 2000 we used the Keck I telescope in Hawaii and the NTT of ESO in Chile to obtain the first high resolution spectra of such knots. Through this work, we hope to [find a satisfactory explanation, in terms of stellar populations, for the unusual strengths of some emission lines seen in the optical spectra.

G. Gräfener, ETH research assistant and guest scientist at the PMOD/WRC, in collaboration with members of the Universität Potsdam, has calculated stellar atmosphere models for the hot stars Zeta Puppis and WR111. We have compared observed spectra of these stars in the UV and optical wavelength ranges with synthetic spectra computed using the Potsdam group's expanding stellar atmosphere code, which incorporates complex model atoms of H, He, C, N, O, and the elements of the iron group. The computations have been improved with respect to the treatment of line-blanketing effects. The code now computes the opacities in non-LTE without using previously needed approximations. This allows not only the successful reproduction of the heavily blended line spectrum in the UV wavelength range – the so-called iron forest – but also, a realistic calculation of the driving force of the expanding atmosphere. The goal of this work is to calculate a fully self-consistent hydrodynamic stellar atmosphere.

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5 Personnel

5.1 Scientific Personnel

Dr. Claus Fröhlich	Physicist, director until 30.6.1999, solar variability, helioseismology, radiation budget, PI VIRGO, SOVIM; CoI SOVA, GOLF, MDI
PD Dr. Werner Schmutz	Physicist, director since 1.7.1999, solar physics, astrophysics, influence of the sun on the terrestrial climate
Dr. Martin Anklin	Physicist, absolut-radiometry, calibration of short wave instruments, CoI VIRGO (PMO6-Radiometer), SOVIM, SOVA (left 31.7.1999)
Dr. Rolf Philipona	Physicist, surface radiation budget, pyrgeometry, calibration of longwave instruments, UV instrumentation, CUVRA
Christoph Wehrli	Physicist, sunphotometry, calibration of sunphotometers and filter radiometers, CoI VIRGO (sunphotom.), SOVIM, SOVA
Dr. Wolfgang Finsterle	PhD student SNF: helioseismology with VIRGO data
Christoph Marty	PhD student GIETHZ: surface radiation budget
Daniel Schmucki	PhD student CUVRA: UV-radiation investigation

5.2 Technical Personnel

Hansjörg Roth	Electronic Engineer, deputy director, head electronics department, experiment manager VIRGO and SOVIM
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
Remo Venturi	Physics technician, general laboratory, WRC calibrations
Jules U. Wyss	Mechanic, general mechanics, design and manufacturing of mechanical parts for space and other instruments
Christian Heldstab	Electroncis apprentice, 4. year (until 20.8.1999)
Danilo Dorizzi	Electroncis apprentice, 2./3. year
Gianmarco Külbs	Electroncis apprentice, 1. year (since 16.8.1999)
Urs Gähwiler	Civilian Service conscript (from 12.5. until 10.9.1999)

5.3 Administration

Sonja Degli Esposti	General administration, personnel, book keeping

5.4 Caretaker

Klara Maynard	General caretaker, cleaning

5.5 Guest scientists, students

Dr. Götz Gräfener	Postdoctoral Research Scientist, ETH Zürich, Inst. f. Astronomie (since 1.7.1999)
Andreas Müller	Student, ETH Zürich, Abteilung Werkstoffe (8.2. – 19.3.1999)
Bernhard Zobrist	Student, ETH Zürich, Institut für Klimatologie (16.8. – 10.9.1999)

6 Publications

6.1 Refereed articles (accepted before end 1999)

Appourchaux T., Fröhlich C., Andersen B., Berthomieu G., Chaplin W., Elsworth Y., Finsterle W., Gough D., Hoeksema J., Isaak G., Kosovichev A., Provost J., Scherrer P., Sekii T., Toutain T.: 2000, Observational upper limits for low-*l* solar g modes, *ApJ,* in press

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6.2 Other Publications, Conference Proceedings, Abstracts, and Posters

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7 Lectures and Participation in Meetings and Courses

18. – 19.1.	CUVRA-Meeting, Garmisch-Partenkirchen,Germany	Rolf Philipona
9. – 10.2.	SOVIM Techn. Meeting, ESTEC Noordwijk, The Netherlands	Claus Fröhlich
15.2.– 17.2.	ESA SPC, Paris	Claus Fröhlich
3.3.	SOVIM Techn. Meeting, Contraves, Zürich	Claus Fröhlich, Hansjörg Roth, Daniel Pfiffner
8. – 27.3.	CUVRA Messkampagne, Garmisch-Partenkirchen, Germany	Rolf Philipona Daniel Schmucki
12.3.	Besprechung Beteiligung Weltraumausstellung, VSM, Zürich	Claus Fröhlich
21. – 27.3.	29th SSAA Saas Fee Course, Physics of Star Formation in in Galaxies, Les Diablerets	Wolfgang Finsterle
23.3.	GAW-CH Meeting, Zürich	Christoph Wehrli
23. – 24.3.	Wissenschaftl. Beirat, KIS, Freiburg	Claus Fröhlich
25. – 28.3.	Royal Swedish Academy, Solar Terr. Relationship, Stockholm	Claus Fröhlich
29. – 31.3.	“100 Jahre Radiometrie”, Tagung PTB, Berlin	Claus Fröhlich
14. – 15.4.	Alpsat-Planung, Spiez	Claus Fröhlich
18. – 20.4.	EGS Annual Meeting, The Hague,	Claus Fröhlich
19. – 23.4.	EGS Annual Meeting, The Hague,	Rolf Philipona Daniel Schmucki
3. – 7.5.	Gastwissenschafter am KIS, Freiburg	Claus Fröhlich
19. – 20.5.	ESA SPC, Berne	Claus Fröhlich
26. – 28.5.	ISS-SOVIM Meeting, ESTEC, Noordwijk, The Netherlands	Claus Fröhlich

31.5. – 4.6.	ESA Symposium “Balloon and Rockets”, Potsdam, Germany	Martin Anklin
7.–11.6.	Aerosol SAG Meeting, Boulder, Colorado, USA	Claus Fröhlich
15.6.	Vortrag „Die Sonne”, Ulm	Claus Fröhlich
15. – 17.6.	PFR Installation, GAW Station in Mace Head, Ireland	Hansjörg Roth
21. – 22.6.	SOHO SWT Meeting, Orsay	Claus Fröhlich
22. – 23.6.	PICARD Meeting, Verrieres	Claus Fröhlich
24. – 25.6.	Aerosol Forschungsschwerpunkt, Wissenschaftliche Zwischenberichte, München, Germany	Claus Fröhlich
26. – 27.6.	SPM Workshop Madison, Wisconsin, USA	Christoph Wehrli
28.6. – 1.7.	AMS Conference, Atm. Radiation, Madision, Wisconsin, USA	Christoph Wehrli
28.6. – 2.7.	Solar Variability and Climate Workshop, ISSI, Berne	Claus Fröhlich
29.6. – 2.7.	Solar Variability and Climate Workshop, ISSI, Berne	Werner Schmutz
7. – 9.7.	Kolloquiumsvortrag, GKSS Geesthacht, Germany	Claus Fröhlich
19. – 23.7.	IUGG Conference, Birmingham, Great Britain	Claus Fröhlich Christoph Wehrli Martin Anklin
25. – 28.7.	IUGG Conference, Birmingham, Great Britain	Christoph Marty
4. – 5.8.	LBV Workshop, Institut für Astronomie, Zürich	Werner Schmutz
11.8.	Total Eclipse	all
24. – 30.8.	SORCE SWT Meeting, Boulder & Taos, USA	Claus Fröhlich
30.8. – 3.9.	Modellierkurs IRSA, Grenoble, France	Daniel Schmucki
6. – 7.9.	Vortrag an EPS11, London, Great Britain	Claus Fröhlich
8. – 9.9.	Besuch Staatssekretär Kleiber am ESTEC Noordwijk, NL	Claus Fröhlich
15. – 18.9.	WR Begutachtung AFI, Leipzig, Germany	Claus Fröhlich
9.9. – 3.10.	IPASRC-I Messkampagne, Golden und SGP Oklahoma, USA	Rolf Philipona
28. – 30.9.	PICARD-Technical Meeting, Paris, France	Hansjörg Roth
6. – 8.10.	CUVRA-Meeting, Grenoble, France	Rolf Philipona Daniel Schmucki
14.10.	SANW, SGAA-Jahresversammlung, Luzern	Werner Schmutz
21. – 22.10.	International Ozone Symposium, Basel	Daniel Schmucki
25. – 27.10.	NEWRAD-99 Conference, Madrid, Spain	Claus Fröhlich Christoph Wehrli
25. – 26.10.	GAW-CH Meeting, Geneva	Werner Schmutz
28.10.	UV Calibration Workshop, Madrid, Spain	Christoph Wehrli
27.– 29.10.	G-Mode Workshop, ESTEC, Noordwijk, The Netherlands	Claus Fröhlich
30.11.	Colloquium, SMA, Zürich	Rolf Philipona
8. – 11.12.	SOI Workshop:Helioseismology at Low Angular Degree	Claus Fröhlich Wolfgang Finsterle
13. – 18.12.	AGU Fall Meeting, San Francisco, UsA	Claus Fröhlich

8 Course of Lectures, Participation in Commissions

Course of lecture “Radiation and Climate“, WS 98/99, ETHZ	Claus Fröhlich
Course of lecture “Space Science and Applications”, together with Prof. M.C.E. Huber, WS 98/99, ETHZ	Claus Fröhlich
Course of lecture “Microklimatologie”, shared with Prof. A. Ohmura, WS 98/99, ETHZ	Rolf Philipona
Course of lecture “Strahlungsmessung in der Klimaforschung”, WS 99/00, ETHZ	Rolf Philipona
Space Commission of SANW	Claus Fröhlich
Delegate at Space Science Program Committee (SPC) of ESA	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 Martin Anklin Wolfgang Finsterle Hansjörg Roth Christoph Wehrli
GAW-CH Working Group (SMA)	Werner Schmutz Christoph Wehrli
WMO/GAW Aerosol SAG	Claus Fröhlich
Commission of Final Examination of apprentices	Hansjörg Roth
Examination Expert: Final Examination in Astrophysics	Werner Schmutz
Examination Expert: PhD Thesis Marcel Fligge, Wolfgang Finsterle	Claus Fröhlich

9 Public Seminars at PMOD/WRC

2.8.99: Dr. H. Riesen, Australian Defence Force Academy, School of Chemistry, "Laserspektroskopie von Koordinationsverbindungen in Festkörper"

26.8.99: Dr. S. Nyeki, Paul Scherrer Institut, Lab. fuer Radio und Umweltchemie, "The GAW aerosol monitoring programme at the high-alpine station Jungfraujoch (3580 m asl)"

27.8.99: Dr. I. Rüedi, ETH Zürich, Institut für Astronomie, "Ueberblick über Infrarotpolarimetrie und Rb-Atomuhren"

30.8.99: Dr. Ch. Kleefeld, National University of Ireland, Atmospheric Physics Group, "Aspekte der Aerosolphysik in der marinen Atmosphaere polarer und gemaessigter Breiten"

31.8.99: A. Indermühle, University of Bern, Climate and Environmental Physics, "Langzeit Variationen der atmosphärischen CO2 Konzentration"

2.9.99: Dr. P. Blattner, University of Neuchâtel, Institute of Microtechnology, "Recent advancements in the field of micro-optics"

39.99: Dr. U. Schühle, "Molekülspektroskopie im Laborexperiment und auf der Sonne"

14.12.99: Dr. U. Frei, Hochschule Rapperswil, Institut für Solartechnik, "Wärme von der Sonne – Thermische Sonnenenergie-Nutzung"

10 Guided Tours and Visiting Scientists at PMOD/WRC

15.4.	Guided tour for patients of Alexanderhaus-Klinik, Davos
20.5.	Guided tour for Kantonsschule Heerbrugg
16.6.	Guided tour for Schweizerische Alpine Mittelschule Davos
9.7.	Guided tour for Tourismus Fachschule Luzern
15.7.	Guided tour for Allgemeine Berufsschule Zürich
27.7.	Guided tour for Schule Dietikon
30.7.	Guided tour for participants Sommer-Seminar Woche
12.8.	Guided tour for guests Hotel Central Davos
21.8.	Guided tour for Davos Tourismus
26.8.	Guided tour for students, Institute of Meteorology, University of Berne

9. – 13.8.	Prof. Dr. G. Koenigsberger, UNAM Mexico
9. – 13.8.	Dr. Orsola De Marco, University College, London
5. – 6.7.	Eidg. Meteorologische Kommission

11 Abbreviations

AOD	Aerosol Optical Depth
ACRIM	Active Cavity Radiometer for Irradiance Monitoring
ACU	Attitude Control Unit
AGU	American Geophysical 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 Synchrotron
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 Diagnostic Laboratory
CNES	Centre National d'Etudes Spatiales, Paris, F
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 manufactured 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
PHOBOS	Russian Space Mission to the Martian Satellite Phobos
PFR	Precision Filter Radiometer
PI	Principle Investigator, Leader of an Experiment/Instrument/Project
PIR	Precision Infrared Pyrgeometer von Eppley
PMOD	Physikalisch-Meteorologisches Observatorium Davos
PMO6-V	VIRGO PMO6 type radiometer
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 (starting 1996 at PMOD)
WRC	World Radiation Center
WRR	World Radiometric Reference
WSG	World Standard Group

12 Rechnung PMOD/WRC 1999

12.1.1 Allgemeiner Betrieb PMOD/WRC (exkl. Drittmittel)

Ertrag	
Bund, Betrieb WRC	781'000.00
Bund, WORCC	150'000.00
Kanton Graubünden	131'158.80
Landschaft Davos	196'738.20
Landschaft Davos, Mieterlass	133'500.00
Zuweisung Stiftung	190'000.00
Instrumentenverkauf	64'442.90
Bundesamt für Gesundheit	60'000.00
Div. Einnahmen, Eichungen	38'417.05
Aktivzinsen	6'503.35
Total 1999	1'751'760.30
Aufwand	
Gehälter	1'073'028.35
Sozialleistungen	203'094.85
Investitionen	65'178.17
Unterhalt Apparate	13'979.75
Verbrauchsmaterial	97'468.28
Reisen und Kongresse	38'326.03
Bibliothek und Literatur	9'672.50
Raumkosten	180'017.00
Verwaltungskosten	78'618.24
Total 1999	1'759'383.17
Ergebnis	-7'622.87
	1'751'760.30

12.1.2 Bilanz PMOD/WRC (exkl. Drittmittel)

Aktiven	31.12.99	31.12.98
Kassa	797.40	1’755.15
Postcheck	31’402.09	67’676.99
Bankkonten	545’528.20	631’116.50
Debitoren	49’919.45	51’060.78
Kontokorrent IR Radiometrie ETH		598.25
Kontokorrent SNF	38’573.75	50’045.34
Kontokorrent CUVRA	-	23’400.00
Kontokorrent PRODEX	67’713.84	16’510.95
Warenlager	80’000.00	-
Transitorische Aktiven	31’869.00	-
Total Aktiven	845’803.73	842’163.96

Passiven	31.12.99	31.12.98
Kreditoren	10’564.24	74’204.15
Kontokorrent Stiftung	101’737.45	35’997.65
Transitorische Passiven	274’359.15	279’375.00
Rückstellungen	314'087.35	299'908.75
Eigenkapital	145'055.54	152'678.41
Total Passiven	845'803.73	842'163.96