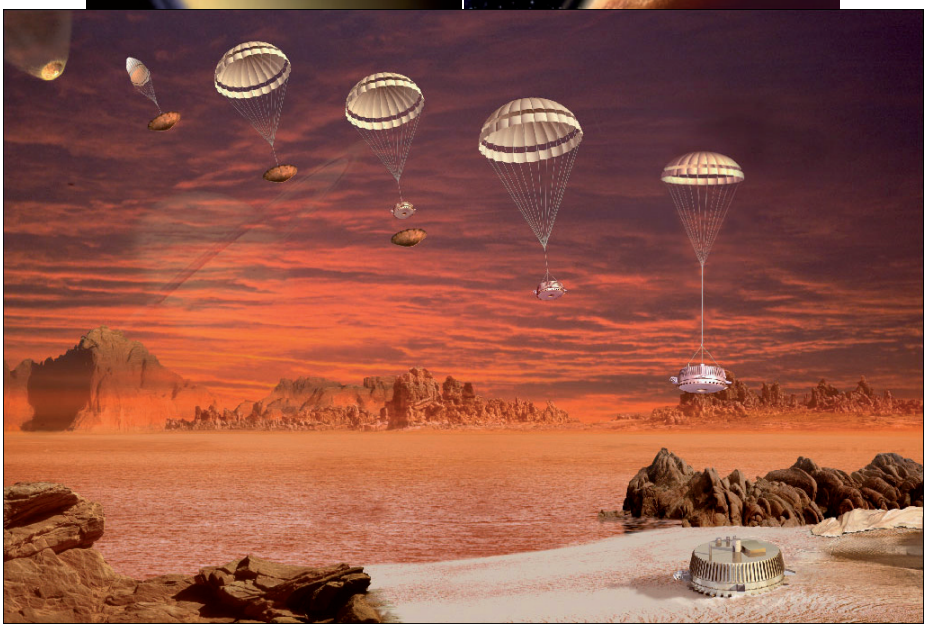
Space Research in Finland

Report to COSPAR 2006



COSPAR
FINNISH NATIONAL COMMITTEE

Tekes

ACADEMY OF FINLAND

Space Research in Finland

Report to COSPAR 2006

Editors

Hannu Koskinen
Sini Merikallio
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Helsinki 2006

Front Cover:

One of the greatest successes of the space research has been the successful landing to the surface of Saturn's moon Titan. The Huygens lander of ESA was sent to its long voyage in October 1997 together with the Cassini spacecraft of NASA. They reached the orbit around Saturn in the summer of 2004. Huygens was separated from Cassini on December 25, 2004, and descended through Titan's atmosphere on January 14, 2005. Finnish scientists and engineers participated in the development of several instruments on both Cassini and Huygens and are now actively analysing the observations.

Pictures: ESA

Back Cover:

The Dutch-Finnish Ozone Monitoring Instrument (OMI) was launched in July 2004 onboard NASA's EOS-Aura satellite. Finnish scientists and engineers participated in the design and manufacturing of OMI. The satellite receiving station in Sodankylä is used for data reception during the overpasses of the Aura satellite. OMI data are processed immediately after the overpass and the resulting ozone and UV images are published in internet within 15 minutes after the overpass.

Pictures: TNO-TPD and NASA

Tekes – Your contact for Finnish Technology

Tekes, the Finnish Funding Agency for Technology and Innovation, is the main funding organisation for applied and industrial R&D in Finland. Funding is granted from the state budget.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities aim to diversify production structures, increase production and exports and create a foundation for employment and social well-being. In 2006, Tekes will finance applied and industrial R&D in Finland to the extent of 460 million euros. The Tekes network in Finland and overseas offers excellent channels for cooperation with Finnish companies, universities and research institutes.

Technology programmes – part of the innovation chain

Tekes' technology programmes are an essential part of the Finnish innovation system. These programmes have proved to be an effective form of cooperation and networking for companies, universities and research institutes for developing innovative products, processes and services. Technology programmes boost development in specific sectors of technology or industry, and the results of the research work are passed on to business systematically. The programmes also serve as excellent frameworks for international R&D cooperation.

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Foreword

This is the bi-annual report of Finnish Space Research to the Committee on Space Research (COSPAR) prepared jointly with Tekes (Finnish Funding Agency for Technology and Innovation). The report describes the overall structure of Finnish space activities, the presently applied strategy, and main funding sources. The major space programmes are briefly listed. The main body of the report describes the progress during 2004–2005 in pure and applied space sciences within the domain of COSPAR activities.

The highlights of Finnish space research during the years 2004 and 2005 were three successful satellite launches with Finnish interests and the remarkable descent of the Huygens probe through the atmosphere of Titan. Several spacecraft continued to produce unprecedented observations from the outer space as well as the Earth and its vicinity, in the analysis of which the Finnish COSPAR community participated being more productive than ever before. In 2004 the COSPAR National Committee celebrated the 40 years of the Finnish membership in COSPAR and in 2005 Finland had been 10 years a full member of ESA. In 2004 Finland also joined the European Southern Observatory (ESO).

Finnish scientific and Earth observation instruments were launched to space in 2004 with Rosetta of ESA and EOS-Aura of NASA and in 2005 with Venus Express of ESA. The launch failure of ESA's Cryosat was, of course, a great disappointment to the Finnish environmental research community.

Due to the strong increase of peer-reviewed international publications involving Finnish space scientists, the publication list is no more included in the printed version of the report. It can be found in the pdf-format together with this report on the web-site of the Finnish National Committee of COSPAR:
http://www.cospar.fi/reports

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List of COSPAR-related publications is available in the web site
http://www.cospar.fi/reports

1 Overview of Finnish Space Activity

1.1 40 years of Finnish COSPAR Membership

Finnish space research utilising space elements began with the first man-made satellites, whose orbital motions were used in studies of the Earth's gravitational field. The International Geophysical Year 1957–1958, which led to the establishment of the Committee on Space Research (COSPAR), also brought several ground-based space research instruments to Finland, in particular all-sky cameras whose modern successors are even today used in studies of the aurora borealis and the physics behind this magnificent phenomenon.

Finland joined COSPAR on June 2, 1964. Exactly 40 years later the Finnish National Committee of COSPAR organised a symposium to celebrate this at the historical House of the Estates in Helsinki. About 80 invited guests attended the symposium, including several veterans of Finnish COSPAR activities such as Academician Pekka Jauho and Professors Martti Tiuri and Juhani Oksman.

The Finnish COSPAR community was extremely pleased to have Prof. Roger-Maurice Bonnet, the President of COSPAR, as the main speaker at the celebration. He had titled his presentation as "COSPAR and Finland: Rising Space Science to the highest levels". Prof. Bonnet had several interesting recollections of the growth of the Finnish space activities from a very modest level in mid-1960s throughout the long period he served as the Director of the ESA Science Programme. During his time at ESA Finland became an associate member of ESA in 1987 and a full member in

Figure 1.1. Roger-Maurice Bonnet, the President of COSPAR (left), Hannu Koskinen, the Chairman of the Finnish National Committee and Petteri Taalas, Director General of the Finnish Meteorological Institute discussing during the 40-year celebration of Finnish membership in COSPAR at the House of the Estates in Helsinki.

1995. It was quite important that Finland joined fully the ESA Science Programme already during the associate membership, as it made possible for Finland to immediately join the Cluster and SOHO missions with significant scientific impact. Today Finnish scientists and industry participate in practically all present and future ESA science missions. Prof. Bonnet pointed out the importance of the fact that Finland lies below the auroral zone, which makes the Solar-Terrestrial physics particularly suitable for Finnish space research. Furthermore, the large land area surrounded by very sensitive seas make the environmental remote sensing another key element in the Finnish space strategy. In fact, more than 60% of Finnish ESA contributions go to the Science and Earth Observation Programmes.

The second speaker in the occasion was Prof. Martti Tiuri, who was one of the first Finnish space scientists in the modern meaning of the word. He became a member of the Finnish National Committee of COSPAR already in 1964 and acted as its chairman for 20 years during the period 1969–1989. From the very beginning the National Committee was leading the efforts to bring the Finnish space research to the international context and level. Finally, in mid-1980s the modern space research started its rapid growth in Finland and one of the landmark events was the XXVII COSPAR Scientific Assembly in Espoo, Finland, where Prof. Tiuri acted as the chairman of the Organizing Committee.

During the first 20 years of COSPAR membership the Finnish space research used mainly ground-based tools in astronomy and ionospheric and magnetospheric physics with occasional collaboration with foreign groups utilising space-borne instruments. The first space instrument project with significant Finnish participation started in May 1985. It was the Swedish-Soviet-Finnish plasma analyser ASPERA for the Soviet Phobos mission. In 1989 ASPERA provided very successful observations of the solar wind plasma interaction with the Martian atmosphere. The project initiated a close co-operation with Sweden, and the fourth ASPERA instrument started its operations in the orbit around Venus in April 2006.

The expansion of Finnish space activities during the 1980s was extremely rapid, in particular in space science. At the same time as Finland became an Associate Member of the European Space Agency (ESA) the Prime Ministers of Finland and Soviet Union signed an agreement of space co-operation, which was later endorsed by the Russian Government. In addition to the Phobos mission the co-operation included the Interball magnetospheric satellites launched in the 1990s, further research of Mars and three astronomy missions. Unfortunately, the ambitious Soviet astronomy missions have not been completed. However, the involvement in the Spectrum-X-Gamma instrumentation paved the way for the presently very active participation in high-energy astrophysics missions, where the Finnish X-ray detector technology has had a central role.

Finnish research groups got an excellent start in the ESA Science Programme with the First Cornerstone missions SOHO and Cluster. Presently Finnish scientific institutes and high-tech companies play various roles (Principal Investigator, Co-Investigator, hardware supplier, system level contractor, etc.) in almost all ESA science missions. The second key line for Finland has been active participation in the Earth Observation Programme of ESA, where the Envisat mission and, in particular, its GOMOS instrument have had a large role. Today these activities cover a wide range of topics with scientific, societal, and technological interests.

Finally, in 1995 Finland became a full member of ESA. While space research itself was well established already during the associate membership, the new status was essential to enable Finnish companies to become involved in technology programmes within the ESA TRP, GSP, and GSTP schemes. At the same time national initiatives and co-operation with other countries and organisations have widened and strengthened.

1.2 Summary of the Finnish Space Policy

Space activities in Finland are administrated in decentralised way mainly involving Tekes (Finnish Funding Agency for Technology and Innovation), the Academy of Finland and the Ministry of Trade and Industry (MTI).

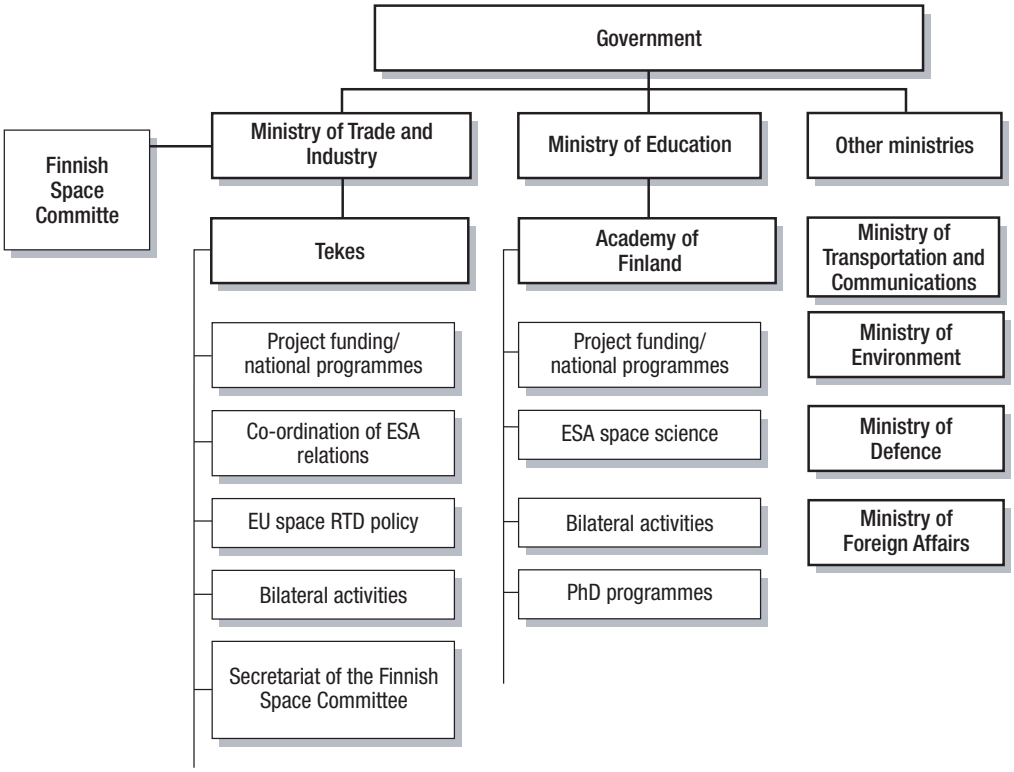

Figure 1.2. Organisation for administration of space activities in Finland.

The Finnish Space Committee (established in 1983) acts as the overall coordinating body for the Finnish space activities. It makes propositions and proposals and gives statements on matters related to space research, education and industrial development, exploitation of knowledge derived from space activities, and national and international cooperation.

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The Committee is nominated on MTI's proposal by the Government for a period of three years. It is chaired by MTI and has members from relevant ministries and main actors. The Committee meets on average six times per year. From 1 April 2004 to 31 March 2007 Finnish Space Committee members are:

Chairman	
Timo Kekkonen	Ministry of Trade and Industry
Vice Chairman	
Mirja Arajärvi	Ministry of Education
Members	
Jaakko Halttunen	Ministry of Foreign Affairs
Juha Ritala	Patria
Susan Linko	Academy of Finland
Petteri Taalas	Finnish Meteorological Institute
Kari Tilli	Tekes
Permanent Advisors	
Markku Ihantola	Finnish Defence Forces
Pekka Jakkula	Elektrobit
Antti Joensuu	Ministry of Trade and Industry
Tuomas Häme	Technical Research Centre of Finland (VTT)
Hannu Koskinen	University of Helsinki
Jarkko Koskinen	Finnish Meteorological Institute
Risto Kuittinen	Finnish Geodetic Institute
Mikael Nyberg	Ministry of Transport and Communications
Esa Panula-Ontto	Tekes
Risto Pellinen	Finnish Meteorological Institute
Yrjö Sucksdorff	Finnish Environment Institute (SYKE)
Juha Vuorimies	Ministry of Environment
Secretaries	
Pauli Stigell	Tekes
Pentti Pulkkinen	Academy of Finland

1.3 International co-operation

ESA is Finland's main international collaborative partner in space activities. Finland has formal co-operation agreements with the following space organisations (the Finnish body which has the responsibility of this collaboration is indicated):

COSPAR	Finnish National Committee of COSPAR
ESA	Tekes (Finnish Funding Agency for Technology and Innovation)
ESO	Academy of Finland
EISCAT	Academy of Finland
EUMETSAT	Finnish Meteorological Institute
EUTELSAT	Telia-Sonera Corporation
INTELSAT	Telia-Sonera Corporation
INMARSAT	Telia-Sonera Corporation
EARSeL	Helsinki University of Technology
SARSAT/ COSPAT	Frontier Guard of Finland

2 Finnish National Strategy for Space Research and Development

2.1 Vision and goals of Finnish space activities

In Finland the guiding principles in the space sector are science and technology policy and the desire to satisfy the needs of the society using the means enabled by space technology. The benefits derived from investment in the space sector are seen in the form of accumulation of human capital, improvement in the international competitiveness of companies, more effective public services and improvements in the quality of life.

The goals are:

- collection of data and scientific research of Earth environment and objects and phenomena in outer space,
- improvement technological competitiveness of industry and service sector thus supporting economical growth through more efficient service provision for society and increase of business activity,
- production of information for the needs of environmental monitoring, protection and sustainable development.

2.2 Strategy for Finnish space activities

The national space strategy for years 2005–2007 is outlined in The Space Activities in Finland, National Strategy and Development Objectives that was published (in Finnish) in June 2005. Strategic areas of the public sector investment are space science, satellite Earth observation, satellite telecommunications, satellite navigation and the industrial production of equipment for space vehicles.

The strategy for the development of space science is:

- The high standard of Finnish space science will be maintained by participation in international projects in key research themes.
- Utilisation of new satellite Earth observation methods will be increased in public sector data use and in geographic information systems. Collaboration agreement in this field was signed between Tekes and Canadian Space Agency in May 2003 and the collaboration has evolved within the Tekes' AVALI-programme.
- International research cooperation concentrates on ESA and EU research projects and on bilateral research projects with e.g. Canada, Sweden, Russia, and the United States.

2.3 Funding sources

The public funding responsibilities concerning space activities are divided between the Ministry of Trade and Industry, Tekes and the Academy of Finland, and several universities and research institutes.

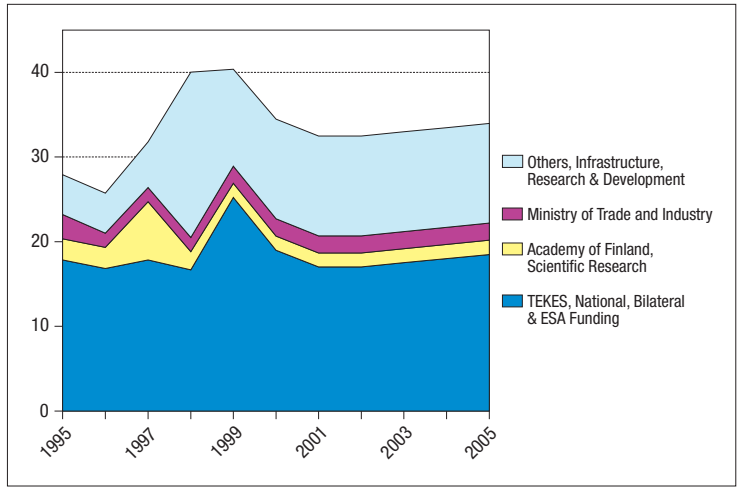

Figure 2.1. Funding of Finnish space activities 1995–2005 (million euros).

Tekes

Tekes, the Finnish Funding Agency for Technology and Innovation (established in 1983), is the main financing organisation for applied and industrial R&D in Finland. Its funds are awarded from state budget. Tekes offers channels for cooperation with Finnish companies, universities and research institutes.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities diversify production structures, increase production and exports, and improve the foundation for employment and social well-being.

Tekes coordinates and offers financial support for participation in international technology initiatives, including EU research programmes, EUREKA, research activities of OECD's energy organisation IEA (International Energy Agency), European Cooperation in Scientific and Technical research (COST), European Space Agency (ESA) and Nordic cooperation.

Technology programmes aim at gaining new technology expertise and product development options in the important business areas of the future. Programmes are an effective form of cooperation for companies and the research sector. In 2005 Tekes had 25 national technology programmes.

In 2005 Tekes total financing for national and international R&D-projects was 429 million euros. From this 18,5 million euros was provided for space activities (ESA, national and bilateral).

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Academy of Finland

The Academy of Finland is an expert organisation for research funding within the administrative sector of the Ministry of Education. The Academy has a board and four research councils, as well as an Administrative Office. The research councils are the Research Council for Biosciences and Environment, the Research Council for Culture and Society, the Research Council for Natural Sciences and Engineering, and the Research Council for Health.

The Academy's function is to improve the quality and prestige of Finnish basic research through selective, long-term funding (typically 3–4 years) based on competition, systematic evaluation, and relevant science policy. The Academy's development initiatives focus on developing professional researcher careers and promoting creative research environments. The various forms of support for research, such as research posts, research projects, and research grants, provide opportunities for versatile funding of research in different disciplines.

The research funding of the Academy of Finland to space research and astronomy has also been quite stable, at the level of about 3 million euros annually, excluding membership fees to international organizations (NOT, EISCAT, most recently ESO), which make about 2,3 million euros annually.

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2.4 The Finnish National Committee on Space Research

The Committee on Space Research (COSPAR) was established by the International Council of Scientific Unions (ICSU) in October 1958 to continue the co-operative programmes of rocket and satellite research, successfully undertaken during the International Geophysical Year of 1957–1958. The ICSU resolution creating COSPAR stated that the primary purpose of COSPAR was to "provide the world scientific community with the means whereby it may exploit the possibilities of satellites and space probes of all kinds for scientific purposes, and exchange the resulting data on a co-operative basis."

Consequently, COSPAR is an interdisciplinary scientific organisation concerned with the progress on an international scale of all kinds of scientific research carried out with space vehicles, rockets, and balloons. COSPAR's objectives are carried out by the international community of scientists working through ICSU and its adhering National Academies and International Scientific Unions. Operating under the rules of ICSU, COSPAR ignores political considerations and considers all questions solely from the scientific viewpoint.

The Finnish National Committee of COSPAR has participated in the international and national co-operation of scientific space research since 1964 by submitting proposals, issuing statements, arranging meetings, and keeping contact with the international COSPAR and its subcommittees. The National Committee celebrated the 40 years of Finnish COSPAR membership on June 2, 2004, with the President of COSPAR, Prof. Roger Bonnet, as the main speaker.

The National Committee is an expert body nominated by the Delegation of the Finnish Academies of Science and Letters. The members of the National Committee represent the active community of space researchers in Finland. The members during 2004–2005 were

Chairman

Hannu Koskinen, University of Helsinki

Members

Martti Hallikainen, Helsinki University of Technology
Juha Hyyppä, Finnish Geodetic Institute
Erkki Tomppo, Finnish Forest Research Institute
Kari Lumme, University of Helsinki
Kalevi Mattila, University of Helsinki
Tuomo Nygrén, University of Oulu
Risto Pellinen, Finnish Meteorological Institute
Pekka Tanskanen, University of Oulu
Martti Tiuri, Parliament of Finland
Seppo Urpo, Metsähovi Radio Observatory
Esko Valtaoja, University of Turku
Martin Vermeer, Helsinki University of Technology

Secretary

Matias Takala, Helsinki University of Technology

On November 16, 2005, the long-time chairman and secretary of the National Committee Prof. emer. Seppo Urpo passed away.

At the beginning of 2006 several changes in the National Committee took place, when Juha Hyyppä, Kari Lumme, Kalevi Mattila, and the secretary left the committee. In January the Committee selected the following new members:

Juhani Huovelin, University of Helsinki
Petri Pellikka, University of Helsinki
Juri Poutanen, University of Oulu
Markku Poutanen, Finnish Geodetic Institute
Merja Tornikoski, Metsähovi Radio Observatory

The new secretary is *Sini Merikallio* from the Finnish Meteorological Institute.

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3 Space programmes supported by Finland

3.1 ESA programmes supported by Finland

Finland participates in ESA's space science, earth observation, telecommunications, navigation and technology R&D programmes.

Space science

Table3.1 summarises the ESA space science missions in which Finland has participated either in providing nationally funded scientific instruments or in construction of satellite platform equipment.

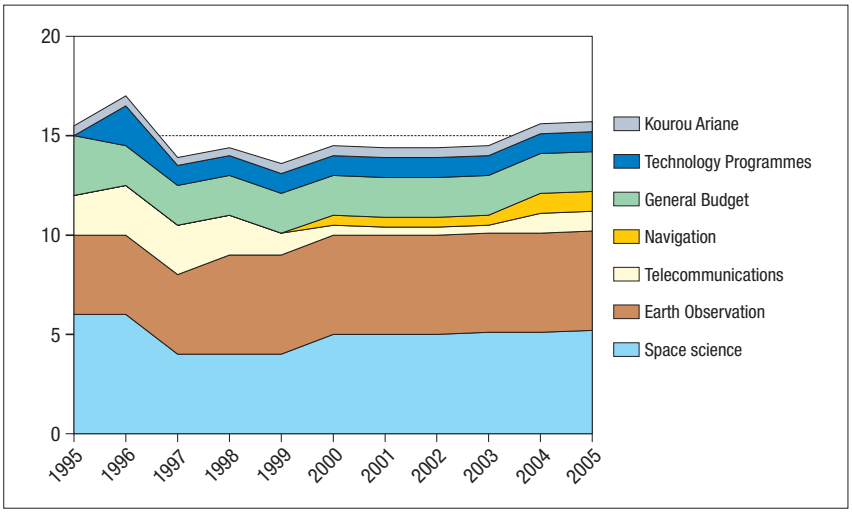
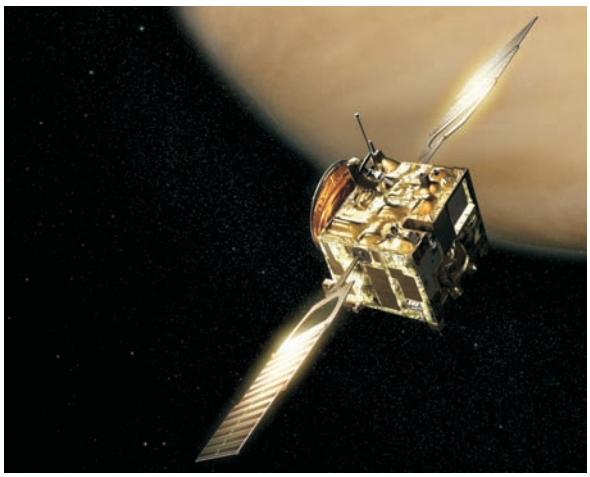


Figure 3.1. Payments to ESA Programmes 1995–2005 by Tekes and Ministry of Trade and Industry (MTI); in million euros.

Table 3.1. Finnish space science instrumentation and industrial participation in ESA space science missions

Programme	Finnish participation	Schedule
SOHO	SWAN and ERNE instruments	Launched 1995
Cluster / Cluster-2	EFW instruments; satellite power system electronics units	Launch failure 1996, launched 2000
Huygens	HASI instrument; ESA funded lander radar altimeter	Launched 1997, measurements 2005
XMM-Newton	Telescope structure and satellite electronics	Launched 1999
Integral	JEM-X instrument	Launched 2002
SMART-1	XSM and SPEDE instruments	Launched 2002
Mars Express	ASPERA-3 instrument, participation in Beagle-2-lander; satellite power electronics	Launched 2003
Rosetta	COSIMA, PP, MIP instruments and lander CDMS; satellite structure and power electronics	Launched 2004
Venus Express	ASPERA-4 instrument participation; power distribution units for spacecraft	Launched 2005
Herschel/Planck	LFI instrument onboard Planck; mirror for Herschel, onboard software for both	Launch 2008



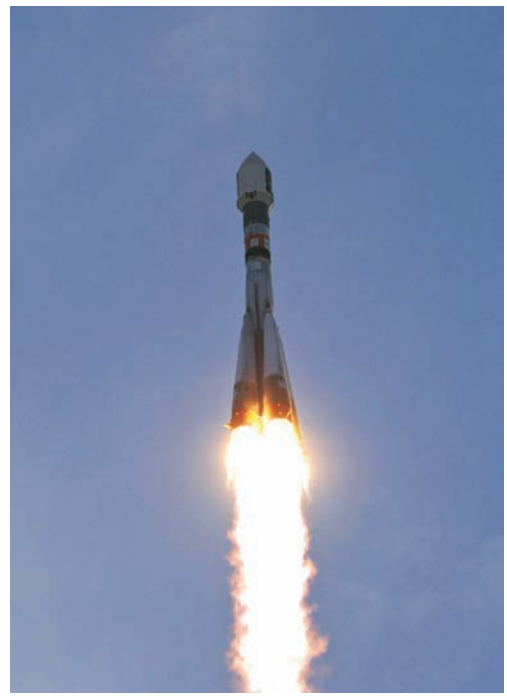


Figure 3.2. Venus Express of ESA was launched with the Soyuz launcher on November 9, 2005. It carries the already fourth version of the ASPERA plasma and energetic neutral atom family, in which Finnish Scientists have been participating since the 1980s. Venus Express was successfully inserted to its orbit around Venus in April 2006.

Earth Observation

The table below summarises the ESA earth observation programmes and missions in which Finland has participated either in the construction of satellite platform units or remote sensing instruments.

Table 3.2. Finnish participation in ESA remote sensing programmes and their satellites.

Programme	Finnish participation	Schedule
EOPP	Earth Observation technology programme	1986–
EOEP	Earth Observation Envelope Programme	1998–
Earth Watch – GMES	Global Monitoring of Environment and Security – collaborative programme by ESA and EU	2001–
Earth Watch – Infoterra/TerraSAR	Synthetic Aperture Radar mission development programme	2001–
ENVISAT-1 satellite	Software and hardware for GOMOS observation instrument.	Launched 2002
Meteosat Second Generation MSG-1 satellite	Software for the satellite platform, hardware for the SEVIRI observation instrument.	Launched 2002
Cryosat-mission	Radar altimetry mission; secondary structures	Launch failure 2005
GOCE mission	Gravity Field and Steady-State Ocean Circulation Mission; Onboard software	Launch 2006
METOP-1 (Phase C/D) mission	METOP satellite series, GOME-2 instrument electronics and satellite bus S/W development	Launch 2006
ADM-Aeolus-mission	Atmospheric Dynamics Mission; instrument electronics	Launch 2007
SMOS mission	Soil Moisture and Ocean Salinity; radiometer modules	Launch 2007

Telecommunications and navigation

The following table summarises the ESA telecommunication and navigation programmes in which Finland participates.

Table 3.3. Finnish participation in ESA telecommunication programmes.

Programme	Finnish participation	Schedule
ARTES Element 1	Basic specifications of the systems	1993–
ARTES Element 5	Telecommunication systems and equipment programme	1994–
ARTES Element 8	Large platform development for satellite telecommunications	2002–
ARTES Element 9	Galileo satellite navigation system development	1998–

Technology programmes

Finland participates in the development of technologies for ESA's future missions in the mandatory Basic Technology Research Programme (TRP), General Studies Programme (GSP) and in optional General Support Technology Programme (GSTP).

3.2 Bilateral co-operation and programmes

In the mid-1980s Finland entered space activities through bilateral space programmes in space science missions. Bilateral programmes, now including also Earth observation missions, have still an important role in the Finnish space strategy. A list of the operative bilateral programmes is given in table 3.4.

Table 3.4. The main Finnish operative bilateral space programmes.

Programme	Main Partners	Finnish participation	Schedule
Phobos	USSR, SE, D	Electronics for ASPERA instrument and test system for LIMA-D instrument	Launched 1988, mission ended
Freja	SE	Plasma and wave instruments	Launched 1992, mission ended
Interball	USSR/RUS, SE	Electronics for ASPERA instrument	Launched in 1995 and 1996, mission ended
Polar	USA	Mechanisms for EFI instrument	Launched 1996
Mars-96	RUS	Central electronics units, sensors and software for two landers	Launch failure in 1996
Cassini	USA	Hardware for IBS, CAPS and LEMS instruments	Launched 1997
Space Shuttle	USA	AMS instrument	Launch 1998
Stardust	USA	CIDA instrument	Launched 1999
Mars Polar Lander	USA	Pressure instrument	Launched 1999, landing failure
Odin	SE, F, CAN	119 GHz receiver and antenna measurements	Launch 2000
EOS-Aura	USA	OMI instrument	Launch 2004
Phoenix	USA, CAN	Pressure instrument	Launch 2007
Mars Science Laboratory	USA	Pressure and humidity instruments	Launch 2009
Roemer	Denmark	Central processing unit for the satellite	Cancelled
SRG	RUS	Silicon x-ray array (SiXA) for the SODART instrument	Launch TBD
Radioastron	RUS	22 GHz VLBI receiver	Launch TBD

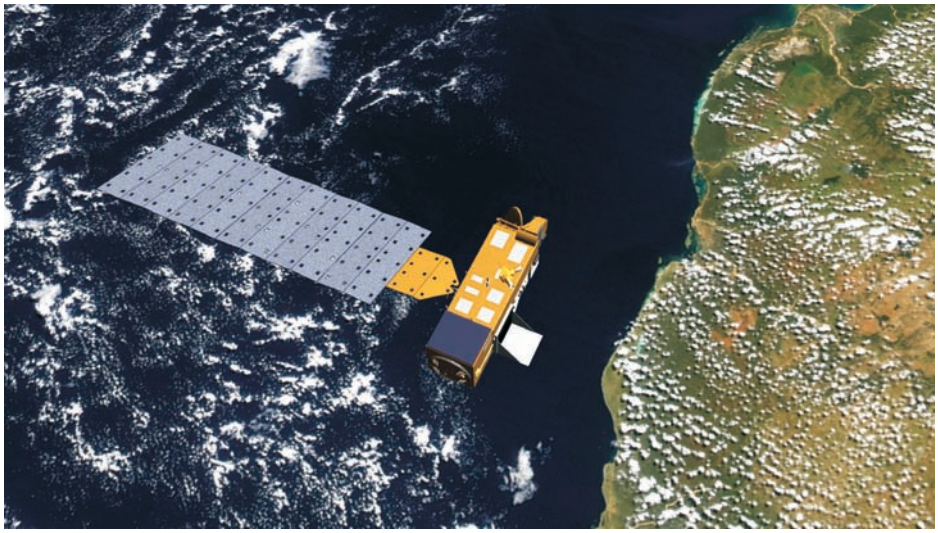


Figure 3.3. NASA's Earth Observation satellite EOS-Aura was launched on July 15, 2004. It carries a Dutch-Finnish Ozone monitor OMI.

3.3 Finnish national space programmes

ANTARES

ANTARES, a national space research programme for years 2001–2004 started in 5 April 2001 and formally ended 31 March 2004. It consisted of space science, remote sensing and space instrumentation projects. It was funded jointly between Academy of Finland and Tekes. The total cost of the projects was 17 M€. The international evaluation of the programme was very positive.

AVALI

"Business opportunities from Space Technology" AVALI technology programme was focused on the creation of new business for industry through space activities derived technology that is transferable to terrestrial applications. AVALI, which ran from 1 March 2002 to 31 December 2005, enabled the use of satellite telecommunications, navigation and remote sensing technologies for terrestrial applications. The development of equipment for commercial satellite markets is a key area for the programme. The goal of AVALI is the creation of new and viable business with the aid of space technology and its applications. AVALI's budget was 23 M€ of which 11,6 M€ was funded by Tekes.

The more detailed objectives of AVALI programme were:

- Utilisation of space technology for terrestrial products and applications,
- Applications based upon spaceborne data and satellites,
- Satellite hardware and software,
- Ground segment hardware and software.

4 Space Science

4.1 Ionospheric and magnetospheric research

Finnish Meteorological Institute, Space Research Unit

A significant improvement in the research conditions at the Finnish Meteorological Institute took place in September 2005 when the whole institute moved to a new building called Dynamicum at the Kumpula Campus in the immediate vicinity of the facilities of the Faculty of Science of the University of Helsinki. At the same FMI bought the, for the time being, fastest supercomputer in Finland that, in addition to operational weather services can be used in space research. In October 2005, the agreement to establish the Kumpula Space Centre was signed by FMI and the Department of Physical Sciences of the University.

Figure 4.1. Preparation of a set of pressure and humidity sensors of Vaisala Oyj for space qualification tests in the new space technology laboratory of the FMI.

The ionospheric and magnetospheric research continues to be one of scientifically most productive fields in the research programme of the FMI. Jointly with the space physics group at the University of Helsinki (UH), FMI scientists study the whole solar-terrestrial chain from the Sun down to the ionosphere. The Sun and the solar wind are studied mainly by the UH group whereas the FMI investigates the processes from the solar wind to the auroral ionosphere. The research programme focuses on ionospheric and magnetospheric dynamics, magnetosphere-ionosphere coupling, space plasma simulations, and space weather applications. The research strategy emphasizes the importance of mastering the full chain of research elements from instrument design, development and construction to data taking, analysis and interpretation. Special emphasis is paid to development of novel modelling and simulation tools as well as theoretical models for maximal utilization of the available data. All research is conducted in wide international collaboration mostly with scientists from Europe, the United States, Russia, and Japan. The EU and ESA joint space strategy is opening new possibilities for space research within the GMES programme, and FMI scientists have played an active role in promoting space weather in the GMES and in the 7th Framework Programme of the EU. FMI is represented in the International Living With a Star (ILWS) initiative, which seeks to establish inter-agency space physics missions that have relevance to space weather science.

The key source of magnetospheric observations during the reporting period has been ESA's fleet of four Cluster spacecraft. The FMI scientists are active in the analysis of Cluster observations together with measurements from the MIRACLE ground-based instrument network that is managed by FMI. The network consists of 29 magnetometers (IMAGE) and 6 all-sky cameras in the Fennoscandian sector. The bistatic coherent backscatter radar, STARE, that has also been an element in MIRACLE, came to the end of its life in May 2005. While the MIRACLE instruments are not solely operated by FMI, FMI has accepted responsibility of gathering and distributing all the data in a common data format, which are then distributed to the wide scientific community. Due to

its open data policy the magnetometer and all-sky data have become widely used throughout the international solar-terrestrial physics community. In particular the IMAGE data covering the wide latitude interval from Estonia to Spitzbergen has become most popular because the auroral zone moves from its northernmost to southernmost stations when the activity changes from extreme quiescence to strong storm conditions. The MIRACLE network is complemented by the international radar network SuperDARN radar system, one leg of which is located in Hankasalmi in the Central Finland. The research involves also active use of the EISCAT radar system located in Nordic countries and Svalbard.

To complement the high-altitude, high-latitude Cluster measurements, China and ESA launched two probes, called Double Star, one to a geosynchronous transfer orbit in December 2003 and another a polar orbit in July 2004. FMI is involved in the scientific analysis of the data, and continues to provide high-quality ground-based measurements for this mission also. Furthermore, FMI has invested considerable effort in developing analysis tools and modelling methods that allow interpretation of the combined set of measurements in terms of ionospheric electrodynamics. A part of the Cluster-Ground-Based analysis has been conducted within the International Space Science Institute (ISSI), where an FMI-led working group produced an extensive review article on the scientific results obtained through combinations of satellite and ground-based observations so far.

Other spacecraft that played important role in the research activities during this period were ACE (for solar wind input to the magnetospheric system), SOHO (for observations of Coronal Mass Ejections, CMEs, that cause the strongest perturbations in the near-Earth space), Polar (for studies of both high-latitude and equatorial region magnetosphere) and Astrid-2 (for small-scale struc-

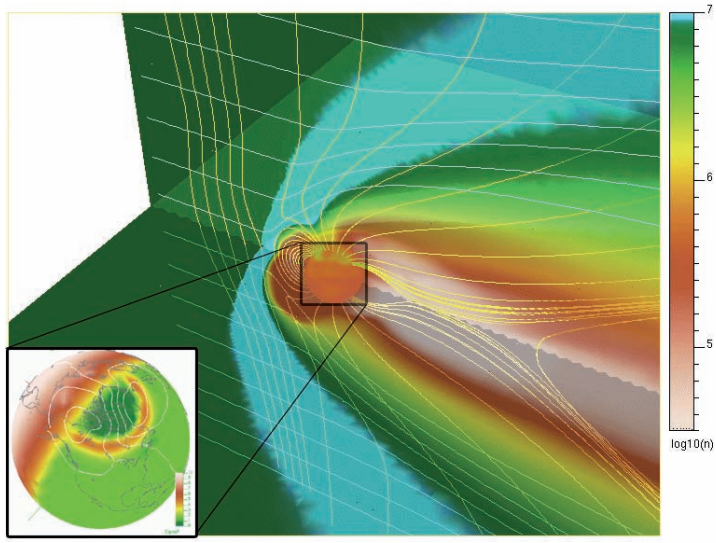


Figure 4.2. MHD simulation of magnetosphere-ionosphere coupling. The colour code indicates the plasma density, the yellow lines are magnetic field lines and blue lines the solar wind streamlines. The magnetic field is an obstacle for the solar wind flow, and thus the density inside the magnetosphere is lower than in the solar wind. The blue region describes the shocked solar wind in front of the magnetosphere. The inner picture shows the ionosphere where the solar UV radiation produces plasma in the dayside, whereas particles precipitating from the magnetosphere form the auroral oval.

tures above the auroral ionosphere) and several geostationary spacecraft that were used as monitors of the phenomena in the inner magnetosphere. Several results on ring current dynamics using satellite and modelling techniques were published during 2004–2005.

FMI has developed a number of computer simulation tools for space plasma physics. In the studies of solar wind interaction with the terrestrial magnetosphere and ionosphere the major tool is the magnetohydrodynamic (MHD) simulation code GUMICS-4, which retains its position as the only comprehensive three-dimensional global simulation model of its kind in Europe. During 2004–2005 the simulations were used in several studies of energy transport and dissipation in the solar wind-magnetosphere-ionosphere system and of reconnection in the magnetotail and on the day side magnetopause. The model was driven by observed as well as synthetic solar wind input. Real input allows the comparison with, e.g., ionospheric observations, whereas idealised simulations are useful to separate the different driver elements, such as changing interplanetary magnetic field or solar wind pressure. In 2005 a project to develop a new space plasma simulation environment at FMI was started, in which several different simulation tools can be incorporated under the same user interface as separate modules.

A leading strategy of the FMI simulation and modelling activities is, whenever possible, to complement the simulation results with actual observations. One particular problem with the energy budget studies is the correct evaluation of the energy sinks in the ionosphere. The group has considered this issue not only by applying the widely used empirical proxies but also by careful study of spacecraft observations of electromagnetic energy flux toward and away the polar ionosphere utilizing data from the Swedish Astrid-2 microsatellite.

Also the Remote Sensing Unit of the FMI contributes to the understanding of the processes in the ionosphere and upper polar atmosphere during strong solar events. These studies utilize ground-based radars, the GOMOS instrument onboard the Envisat satellite and modelling with the Sodankylä Ion Chemistry model.

Scientists from FMI are active in the emerging European Space Weather studies. During 2004–2005 main activities were related to the ESA space weather pilot projects, of which two, AurorasNow! and GICNow! were under the respon-

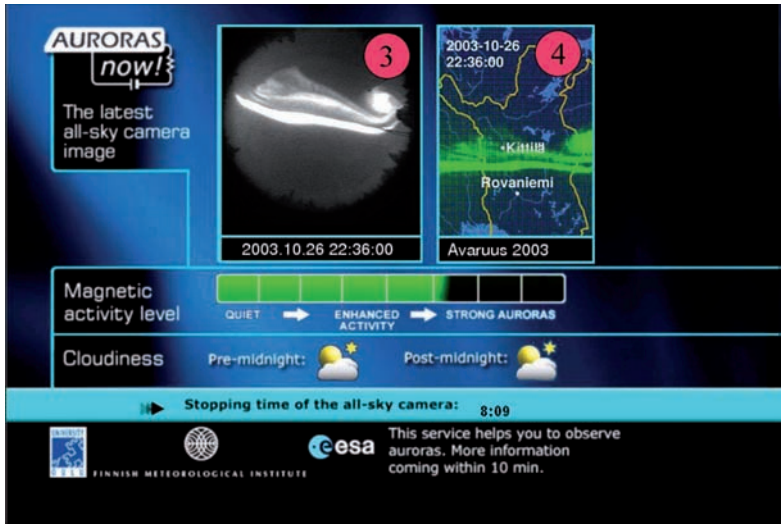


Figure 4.3. The display of the space weather service designed for tourist hotels in the auroral zone.

sibility of FMI. The former was directed to tourist hotels in Finnish Lapland whereas the latter to companies responsible for electric and gas energy distribution networks. GIC studies were also conducted in co-operation with companies and scientists from Sweden, USA, and Canada. In these studies particularly the experience gained from the southern IMAGE magnetometers has turned out to be useful. In 2005 a new project on ionospheric errors in satellite navigation systems was started in co-operation with Finnish high-tech industry.

FMI organised in March 21–27, 2004 the seventh International Conference on Substorms (ICS-7) at Levi in Finnish Lapland. The meeting was attended by about 100 scientists from all over the world.

The scientists and graduate students working at the FMI participate actively in the programme of the Finnish Graduate School in Astronomy and Space Physics. The UH and FMI groups organized jointly the summer course of the Graduate School in June 2005.

University of Helsinki
Department of Physical Sciences
(Space Physics)

Magnetospheric research at the Department of Physical Sciences of the University of Helsinki (UH/PHYS) is conducted in close co-operation with the above reported activities at FMI. Graduate students employed by the University participate in studies on solar wind-magnetosphere interactions, physics of space storms and theory of MHD simulations.

In physics of space storms the UH/PHYS group focused on the solar and solar wind drivers of space weather, in particular on the geoefficiency of coronal mass ejections (CME) that are the main drivers of magnetospheric storms. This work was conducted in collaboration with scientists at Max Planck Institute for Aeronomy in Lindau, Germany, who are involved in the LASCO coronagraph onboard the SOHO spacecraft of ESA and NASA. Quite intriguing results on the different features of storms driven by the shocked region in front of the CME ejecta as compared with the storms driven by magnetic clouds of the ejecta were found, the former being more efficient in driving high-latitude auroral zone activity whereas the latter clearly favoured the growth of the ring current.

UH/PHYS led the space weather consortium SWAP, with participation from FMI, and Universities of Oulu and Turku, in the Antares programme (2001–2004). The leading idea behind the SWAP project was to investigate the entire space weather chain from the Sun to the surface of the Earth. The project was very successful as was the whole Antares programme.

In the joint space physics education scheme with FMI, the University of Helsinki provides the basic education in various topics of space physics both in undergraduate and post-graduate levels. The Master and Ph.D. theses are supervised jointly by the UH/PHYS and the FMI staffs. All UH/PHYS space physics graduate students, irrespective of their funding source, are enrolled in the nationwide Graduate School in Astronomy and Space Physics.

University of Oulu
Department of Physical Sciences and
Sodankylä Geophysical Observatory

The Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory (SGO) of the University of Oulu have a broad research programme in ionospheric and magnetospheric physics, including observations from both ground-based and satellite instruments. This programme is conducted in extensive national and international collaboration with several foreign institutes. Note that the research activities related to the effects of cosmic rays on the atmosphere are described in the Solar System Research section (Section 4.2).

University of Oulu has a co-investigator status in the EFW and RAPID instruments of the Cluster mission, which consists of four identical satellites flying in controlled formation. Because of its great success, the Cluster programme has been extended until 2009. The RAPID instrument has been used to study the dynamics of energetic particles inside the Earth's magnetosphere and at its

boundary layers. A statistical study verified that there is indeed a great flux of energetic particles in the exterior cusp region. However, the flux in the adjacent magnetospheric region was systematically greater by a factor of 3–10. Moreover, correlation with interplanetary and magnetospheric conditions showed that the energetic particles in the cusp come from the adjacent magnetospheric regions either via direct diffusion or via the controlling effect of reconnection. This is in contradiction with the earlier ideas of local or bow-shock related acceleration of cusp energetic particles.

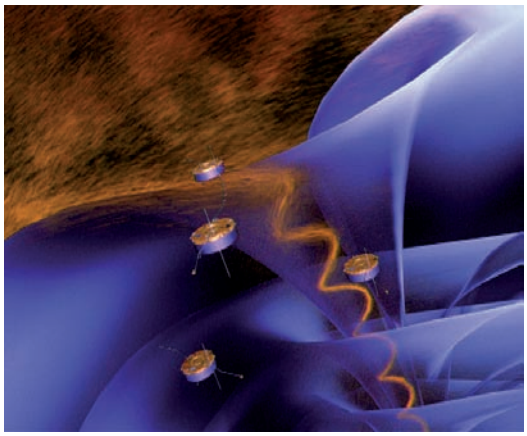


Figure 4.4. An artist's impression of the Cluster satellites making observations in the polar cusp. (Picture: ESA)

The dynamics of energetic particles during the great magnetic storm in March 2001 was studied using the Cluster and the low-altitude NOAA/POES satellites. The different behaviour of energetic electrons and energetic ions was clearly demonstrated. While the most intense fluxes of electrons were related to intense substorms in the storm recovery phase, the largest fluxes of ions were found during the storm main phase. The results suggest the ions are energized in the upper ionosphere and enter directly into the ring current. Moreover, at the end of the storm main phase, an intense burst of energetic electrons was observed at very low latitudes in the nightside. Its subsequent evolution was followed for 20 hours and showing that the electrons, during their eastward drift, were trapped within the South-Atlantic Anomaly region, and could not drift past it. This marks a new, interesting phenomenon related to the energetic particles and a new trapping mechanism whose details are yet unknown but may be related to radial electric fields recently found inside the SAA.

The Oulu group has reanalyzed the magnetic Dst index that is used to monitor the strength of the ring current (flux of equatorial energetic particles) and the development of magnetic storms. Using the magnetic observations at the four original Dst stations the Dst index was extended by 25 years to start from the year 1932. The Dst index was corrected with respect to its extraneous seasonal variation (so called non-storm component), by taking into account the seasonally varying level of the quiet daily curve. While the development of index during individual storms remains roughly the same, the absolute levels can change by as much as 44 nT. This leads to significant changes in many types of studies using the Dst index.

University of Oulu is engaged in continuous support and development of ground-based instrumentation. The magnetic field of the Earth is measured both in Sodankylä and the Oulujärvi site using FGE and TPM magnetometers. A network of search-coil magnetometers for pulsation research is operated with most of its instruments in Scandinavia, one on Crete and one in Ethiopia. Optical auroral instruments have been improved and new instruments are built. Real speed TV cameras and multichannel scanning photometers have been operated during winter period 2003–4 in the Northern Finland, Kilpisjärvi, Kaaresuvanto and Sodankylä. During the winter 2004–5 the instruments were checked and calibrated, but again during the winter 2005–6 all instruments in Finland were making measurements during the whole winter period. The Antarctic photometer in Zhongshan has been working during the Antarctic dark periods. In Ethiopia, a new magneto-optical observatory EFO (Ethio-Finn Observatory) was established on a mountain about 10 km north of Addis Ababa. A new two-channel scanning photometer was built and brought there. It observes atomic oxygen airglow emissions close to the magnetic equator. Magnetic pulsations are also recorded at this site.

The instrumentation working on radio frequencies consists of VLF receivers, an ionosonde and a riometer chain. An imaging riometer (IRIS) installed in Kilpisjärvi by Lancaster University is operated in collaboration with SGO. Construction of a meteor radar, an MST radar and a new ionosonde has been continued. Using the ionosonde observations the peak altitude of the ionospheric F-layer above Sodankylä has been found to move slowly downwards during 1957–2005. These measurements are based on two different ionosondes and the change took place in 1978. At the end of the period in November 2005 SGO took in use a new ionosonde called SGO Alpha Wolf. It is a chirp sounder and has produced exceptionally high quality data since the first soundings.

VLF-measurements revealed some new phenomena. One of them is an auroral activity related hiss cloud that is a very weak noise like event lasting for several hours. A beautiful phenomenon is magnetospheric line radiation (MLR). It has been found earlier but it has been never measured as accurately as in SGO-measurements. MLR is a weak phenomenon and the special feature is that it shows numerous of narrow lines in frequency range from some hundred hertz to 3–4 kHz. The event can last hours. The events systematically show curious features like a frequency range where it has left hand polarization. It is explained as a feature caused by earth-ionosphere waveguide and indicates that these waves often come from long distances. The most interesting feature is that in high resolution measurements the individual lines in MLR can show systematic amplitude and frequency modulation which looks exactly like pearl pulsations (pc1) in ULF-frequencies. This is the first time this phenomenon has been reported.

A satellite tomographic chain of four receivers, extending from Kokkola (Finland) to Tromsø (Norway) has been installed and it has been operational on continuous basis from the beginning of 2003. Tomographic inversion of the data has been carried out and the resulting electron density plots from the vertical plane above the chain are available on web pages for quick-look purposes (http://sgodata.sgo.fi/pub_tomo/ tomo.html).

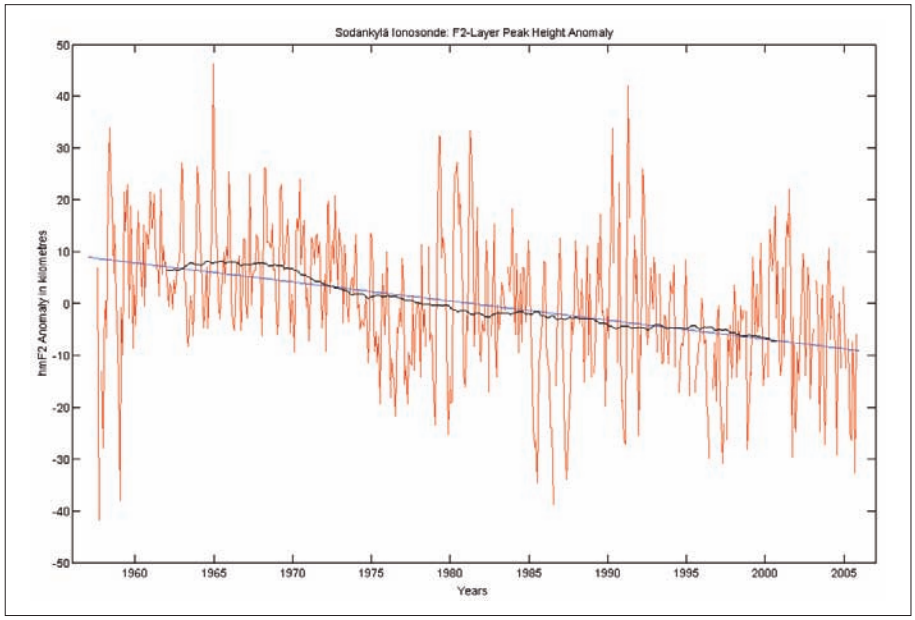


Figure 4.5. Long-term trend of the height of the ionospheric F2 layer at Sodankylä, 1957 to 2005. Red: height anomaly in km, blue: regression line showing a trend of -380 m per year (+/- 33 m/yr), black: running mean over 11 years.

National EISCAT and optical campaigns were organized in February 2004 and October 2005. In both campaigns all EISCAT radars were measuring the ionospheric parameters and all possible optical instruments were measuring the night sky emissions. During the 2004 campaign an isolated and bright auroral arc passed the radar beam, which is under a further study. Studies based on data from a heating experiment during an EISCAT campaign in 2002 revealed that the HF heating system with high power radio transmitter caused relative intensive artificial auroral patches in the vicinity of the radio beam. The heating induced emissions were observed optically with two imaging cameras and two photometers with three different wavelengths. The earlier discovered N_2^+ 427.8 nm emission turned out to consist of at least two different emission bands. The measured altitudes of the patches were around 220 km.

The EISCAT UHF/system was used in an ESA-funded study to test the possibility to measure rou-

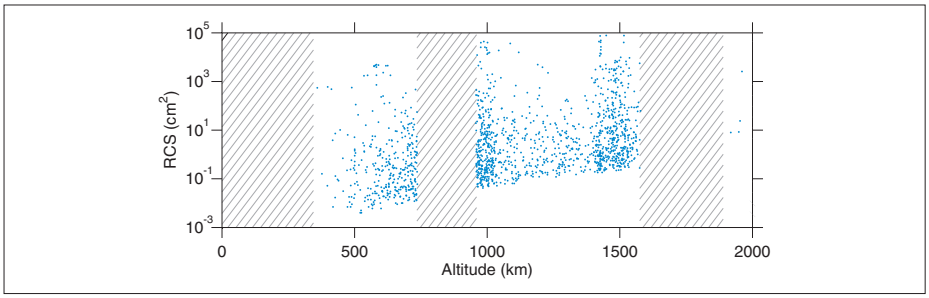


Figure 4.6. Effective cross-sections of 1470 space debris targets measured using EISCAT UHF radar on 7.–29.9.2005

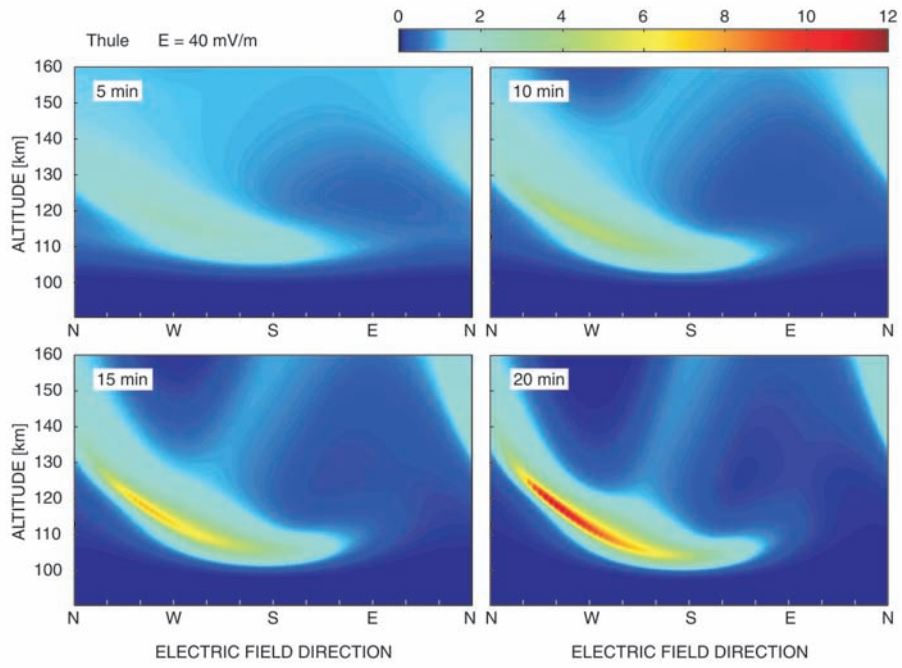


Figure 4.7. Simulation of vertical compression of metal ions due to ionospheric electric field pointing at various directions in Thule. The four panels show ion density profiles for each field direction after compression of 5, 10, 15 and 20 min.

tinely the space debris surrounding the earth down to about 2 cm size by capturing necessary information while EISCAT is running a standard experiment for ionospheric research.

The relationship between polar cap sporadic-E and the interplanetary magnetic field was investigated using ionosonde data from Thule (Greenland) and Longyearbyen (Svalbard). It was found that the occurrence of the layers is closely related to the direction of the interplanetary magnetic field and the relation is different close to the polar cap boundary from that within the central polar cap. The occurrence of the layers was compared with the polar cap electric field calculated from IMF observations using the statistical APL model. The layer occurrence was found to be in a good agreement with the predictions of the electric field model. This seems to be in a conflict with the opinion that the electric field mechanism cannot be effective when the inclination angle is close to 90°. Simulations of vertical plasma compression due to the ionospheric electric field showed that the electric field mechanism is indeed effective even at Thule, where the dip angle is about 86°.

Sodankylä ion chemistry model (SIC) has been extensively used in close collaboration with scientists from the FMI together with EISCAT and satellited data ins studies of the mesosphere and the impact of solar proton storms there.

Sprite is a phenomenon, which belongs to those mechanisms, which form coupling between the Earth and near space. SGO participated in the Eurosprite 2005 campaign as partner of the CAL network.

University of Oulu is in charge of the Finnish Graduate School in Astronomy and Space Physics, which is a network including all astronomy and space physics units in Finland and sponsored by the Academy of Finland. A total of 12 graduate students receive their financing through the Graduate School, four of them at University of Oulu (two in astronomy and two in space physics).

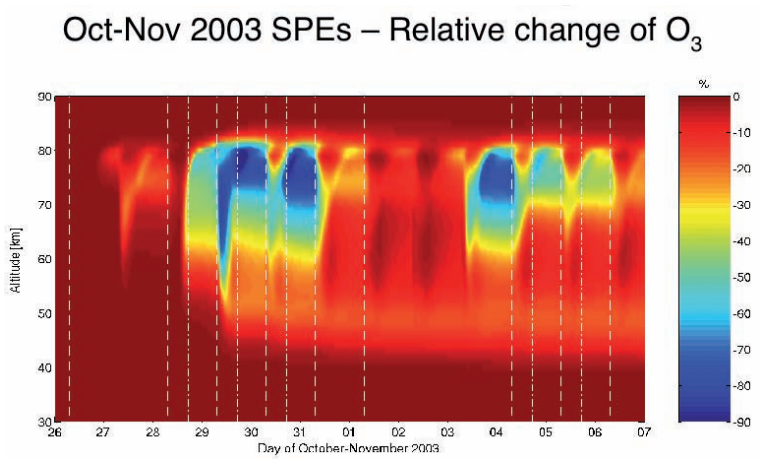


Figure 4.8. Model calculation of ozone reduction in the mesosphere during the solar particle events of Oct-Nov 2003. (Courtesy of FMI)

4.2 Solar system research

Finnish Meteorological Institute
Space Research Unit

The solar system research at FMI includes studies of solar system plasmas, planetary atmospheres and comets. These apparently separate topics are related in several ways. For example, the studies of plasma interactions between the solar wind and the atmospheres of Mars and Venus have direct relevance to the long term evolution of the atmospheres of the planets. Mars represents a case where the planet has lost most of its atmosphere whereas Venus is an example of extreme runaway greenhouse phenomenon. Furthermore, the cometary environments containing both ionized plasma and neutral dust pose interesting problems as well to space plasma physics as to cosmochemistry.

The solar system plasma physics focuses on the space environments of terrestrial planets Mars, Venus, Mercury, and recently Titan, while the planetary atmosphere studies are presently focussed on Mars and Titan. The FMI group is active in instrument design and development, data taking, analysis and interpretation. In 2004 and 2005 FMI's electronics contributions to the ASPERA-4 plasma and neutral atom instrument onboard the ESA Venus Express spacecraft were completed and the spacecraft was successfully launched in November 2005. At the same time similar instrument ASPERA-3 was continuing its measurements around Mars onboard Mars Express and the plasma instrument SPEDE was approaching the Moon onboard ESA's SMART-1 spacecraft that utilises novel ion propulsion technique. New pressure and humidity instruments were prepared for the Phoenix and Mars Science Laboratory missions to Mars in 2007 and 2009.

The absolute high-light of the year 2005 was the descent of ESA's Huygens probe through the atmosphere of Titan. The whole descent was a great success and also the FMI provided pressure instrument PPI worked perfectly measuring the vertical pressure profile of Titan.

Huygens was a part of the joint NASA-ESA Cassini/Huygens mission. While the Huygens observations were limited to the descent, the Cassini spacecraft is expected to pass Titan at least 40 times. The FMI scientists participate also in the studies of the interaction between Titan's atmosphere and Saturn's magnetosphere using the

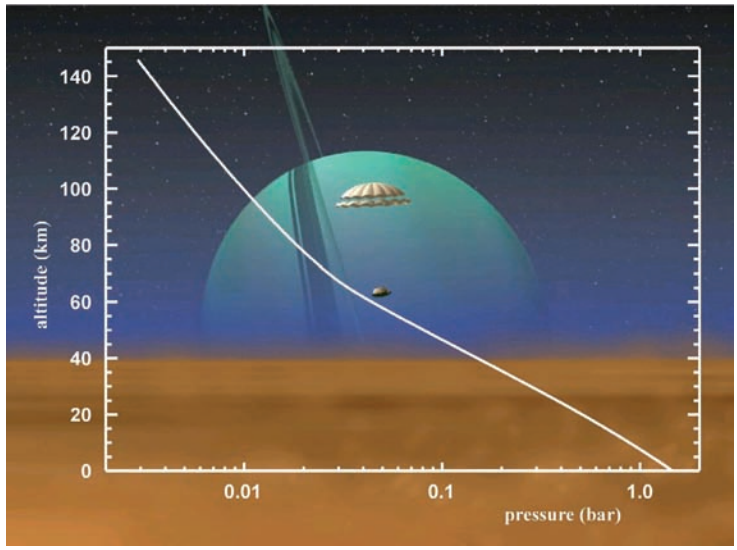


Figure 4.9. Huygens descent through the atmosphere of Titan. The white line is the pressure measured by the PPI instrument.

so-called quasi-neutral hybrid simulation code that has been developed for studies of the solar wind interaction with Mars, Venus, Mercury and Titan. The input data to the simulations are obtained from the magnetic field and plasma instruments onboard the Cassini spacecraft.

FMI's first PI instrument on an ESA mission is the SPEDE (Spacecraft Potential, Electrons, and Dust Experiment) instrument onboard the SMART-1 spacecraft. SMART-1 is ESA's technology mission to the Moon whose primary objective was to test newly developed ion propulsion motors. After a long cruise phase the spacecraft reached the Moon orbit in 2005. When the ion engine was used, SPEDE monitored the out flowing gases and the effects on the spacecraft and its environment. When the ion propulsion is turned off, SPEDE functions as a traditional space plasma instrument providing information on the plasma density and electric field fluctuations.

The longest-term space project at FMI is the participation in the ESA Rosetta mission to comet Churyumov-Gerasimenko. It started already in 1994, when FMI joined the team proposing the Rosetta lander, which before the launch was named Philae. The launch took place in February 2004 and in March 2005 the spacecraft made an Earth swing-by when the instruments were successfully checked. FMI has contributed to several instruments on both Rosetta and Philae and carries the PI responsibility of Philae's permittivity probe that will be used in studies of the water content of the comet in 2014. A taste for cometary data was obtained in late 2003, when NASA's Stardust probed the coma of comet Wild-2. FMI has participated in the CIDA dust analyzer, which recorded details of several dust particles in the comet's environment. The in situ samples of cometary matter were successfully returned to earth in January 2006 and the joint analysis of in situ observations and the returned cometary matter is in progress.

ESA's Mars Express reached Mars during the Christmas holidays in 2003. The ASPERA-3 ion mass spectrometer and neutral particle detector have provided wealth of new exiting observations of the ion escape from the planet, the effects of the southern hemisphere magnetic anomalies, plasma neutral atom interactions and particle acceleration mechanisms. The group's exploration of planetary exospheres continues with a similar instrument ASPERA-4 on board Venus Express that was launched in November 2005 and reached the orbit

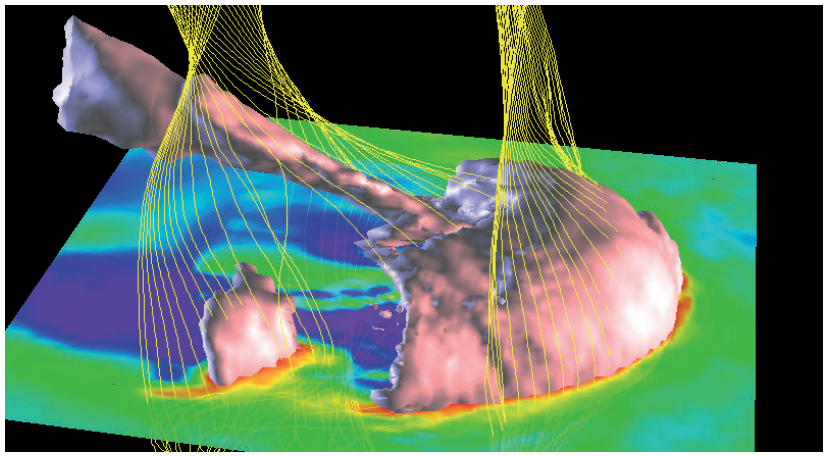


Figure 4.10. Simulation of Titan's motion in the Kronean magnetosphere. The three dimensional surface covers the areas of highest magnetic field density, showing the magnetic barrier against the plasma flow and also the northern mixed wing extending down the tail. Two sets of magnetic field lines illustrate the magnetic draping around Titan.

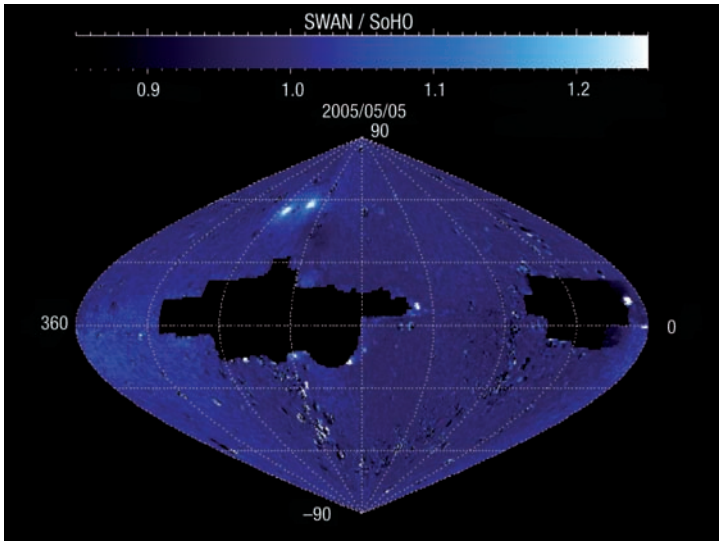


Figure 4.11. SWAN is still going strong. This picture illustrates the break-up of comet 73P/Schwassmann-Wachmann 3. The two birghtest pieces in the top of the picture move fast away from each other. At the moment of taking this picture their distance from the Earth was about 15 million km.

around the planet in April 2006. The first in-orbit tests of the instrument have been successful.

The MetNet prototyping project aims at development of miniaturized landers to carry atmospheric instrument networks to the Martian surface. The project is conducted in close collaboration with the Russian Space Research Institute and Babakin Space Center in Moscow, and was funded in 2004 and 2005 through the Russian debt conversion programme. In this phase the prototype was developed to be ready for a test launch and landing through the Earth's atmosphere in the autumn of 2006.

The Martian meteorology is studied together with a team at the University of Helsinki. A three-dimensional Mars Local Area Model (MLAM) has been developed and installed in the computing infrastructure of FMI. MLAM is based on the local area weather forecast model HIRLAM used operationally in several European countries. The model results have been compared to NASA's Viking Lander observations and the model was used in the selection of the potential landing sites of NASA's next Mars mission Phoenix to be launched in 2007. Actually the whole Viking Lander data set was copied in 2005 to FMI from the University of Washington.

FMI provides a pressure device to the Phoenix mission through a Canadian-Finnish co-operation. The flight units for pressure observations with the Finnish Vaisala sensors were finalized in 2005 and delivered to Canada in 2006. At the same time the development of pressure and humidity sensors for the Mars Science Laboratory of NASA to be launched in 2009 was initiated.

ESA's next planetary mission will be BepiColombo to Mercury jointly with the Japanese space agency JAXA. In 2004 the Finnish consortium to participate in the UK-Finnish X-ray instrument complex MIXS/SIXS was formed and the project started in 2005. The consortium includes scientists from the University of Helsinki and FMI as well as three, potentially four, Finnish industrial companies. On BepiColombo FMI scientists participate also in the SERENA instrument, measuring the energetic neutral atoms, and the MEFISTO instrument, measuring the electric fields in the Hermean magnetosphere.

In December 2005 the SOHO spacecraft had been 10 years in space. The SWAN instrument of FMI and the French Service d'Aeronomie was the first FMI contribution to the ESA Science Programme. It continues observing the Lyman alpha radiation from interstellar hydrogen atoms penetrating to the solar wind, and from the comets. During 2004–2005 in particular the cometary studies have been very productive when conducted in association with the other cometary research activities of the group. SWAN also provides a novel method of identifying solar eruptions on the far side of the Sun, which can be used as a warning of increased solar activity of about 10 days ahead.

Helsinki University of Technology Metsähovi Radio Observatory

The 14-metre Metsähovi radio telescope has been used for studying the solar millimetre-wavelength activity. During 2004–2005 the main emphasis was on using the 37 GHz frequency band and on observing Solar maps during the summer months. Solar radio flares observed during earlier observing epochs (during higher activity) were studied in detail in order to model interacting coronal magnetic loops.

Additionally, a small (1.8-metre) telescope was used for continuous monitoring of the whole solar disk at 11.7 GHz. In addition to recording a continuous data stream of the total flux for further studies, these data were used to trigger observations with the 14-metre telescope as well as to alert collaborators about enhanced solar activity.

University of Helsinki Department of Physical Sciences

As reported in the section on Magnetospheric and ionospheric research the studies of solar activity and in particular the physics of CMEs belong to the key research topics of the space physics group of the Department of Physical Sciences of the University of Helsinki.

Studies of solar particle acceleration and their effects near the Earth have been conducted in close co-operation with the Universities in Turku and Bochum, as well as within a project of the International Space Science Institute (ISSI, Bern) and the EU/ESF COST action 724 "Developing the scientific basis for monitoring, modelling and predicting the space weather". In the latter project the group has had a leading role of the working group studying the radiation environment of the Earth.

Coronal shocks driven by coronal mass ejections (CMEs) are regarded as the most likely source of the largest solar energetic particle events. Efficient particle acceleration in outer corona requires special conditions of the ambient turbulence to prevail, indicating that the turbulence is probably generated by the accelerated particles themselves. This is not possible in particle events of small-to-intermediate intensities. The recent studies by the space physics group have, thus, focused on particle acceleration in shocks operating in the low corona, where the ambient turbulence generated by the Sun may be strong enough to account for efficient particle acceleration at shocks. In addition to the early phases of CME-driven shocks, such shocks include refracting shock waves generated by the initial lateral expansion of the erupting CME mass motions and/or solar flare explosions. The shocks are the strongest in regions where the coronal Alfvén speed is small, i.e., in regions of low

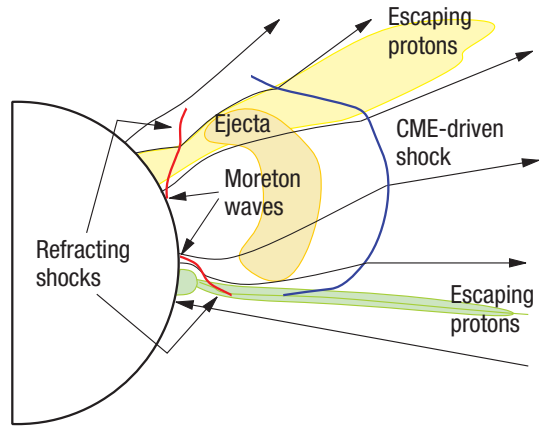


Figure 4.12. A sketch of plausible sites of solar energetic particle acceleration. The blue line illustrates the coronal shocks driven by coronal mass ejection, the red line illustrate refracting shock waves generated by the coronal streamers (yellow regions) and current sheets (green regions).

magnetic fields and high mass density. In 2005 the research was extended to utilize MHD simulations of the CME initiation process. The work is based on the MHD simulation tools developed at FMI adapted to the solar environment.

The UH/PHYS space physics group is also involved in the studies of the solar wind interaction with Mars and Venus reported above in the section describing these activities at FMI. The group participates also actively in the Finnish consortium developing the solar X-ray and energetic particle instrument for BepiColombo.

The scientists from the Division of Atmospheric Sciences of the UH/PHYS have active collaboration on the studies of Martian meteorology with the FMI planetary atmosphere group. This activity was positively intensified under the envelope of the UH/PHYS-led MSW project of the Antares programme (2001–2004). This has led to the three-dimensional Mars Local Area Model (MLAM) based on the local area weather forecast model HIRLAM used routinely in several European countries. Furthermore, the expertise in aerosol physics at UH/PHYS has been applied to the studies of aerosols in the Martian atmosphere. Particles of variable sizes from aerosols to dust are a great concern for both robotic as well as potential future manned missions to the planet.

The Division of Geophysics of the UH/PHYS is active in studies of meteorite impacts. In 2005 the group focused on two main issues: Preparing and realizing European meteorite research tour and detailed physical characterization of selected meteorites in order to conclude their history and origin conditions.

The aim of the European meteorite research tour was to perform measurements of bulk physical parameters (density, magnetic susceptibility, magnetic remanence, porosity) of meteorites in situ in the museum collections using harmless, non-destructive methods. The necessary instrumentation and methodology was prepared and tested in laboratory facilities of Division of Geophysics in 2004 and first half of 2005. Finally the mobile laboratory facility was prepared for the research trip. The research tour itself was conducted in cooperation with Institute of Geophysics, Academy of Sciences of the Czech Republic during October 2005. During the tour the 6 member team measured around 200 individual meteorite samples. The results of the project will be used to enhance existing database of physical properties of meteorites. The petrophysical parameters obtained on meteorites can be applied in rapid and harmless classification of meteorites, solar system history studies, data interpretation of planetary and asteroid space missions, in future sample return research and in asteroid mitigation efforts.

Figure 4.13. Tomas Kohout and Tiiu Elbra performing measurements at Vilnius University during the 2005 European meteorite research tour.

The detailed laboratory studies of meteorite physical properties focused on three meteorites. The Neuschwanstein EL-6 chondritic meteorite was

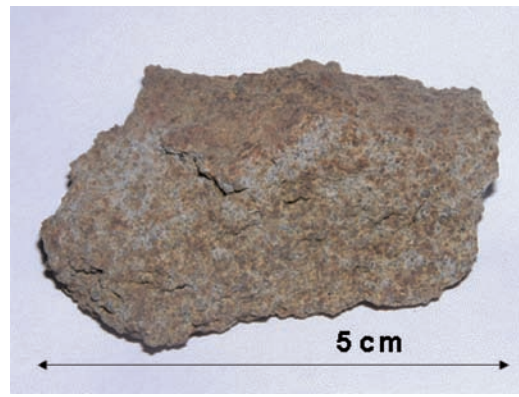


Figure 4.14. The Avnhandava H4 chondrite fragment was subject of extensive studies.

subject of magnetic paleofield studies in order to determine the conditions in the solar system history and to evaluate the sensitivity of the magnetic record to artificial magnetic contamination during meteorite handling. The results indicate that the meteorite was exposed to strong magnetic fields in its history and the significant artificial magnetic contamination can not be ruled out due to soft magnetic nature of the EL meteorites.

On the other side the chondrules extracted from Bjurbole L4 (in cooperation with Laboratory for Extraterrestrial Physics, NASA/GSFC) and Avanhandava H4 chondrites represent promising material with relatively hard magnetic nature and no evidence for artificial magnetic contamination. Both meteorites are outstanding in their porosities (15–25%) among other meteorites of the same class. The friable nature of these meteorites allows separation of individual chondrules. The magnetic conglomerate test applied on chondrules showed random orientation of magnetization direction of individual chondrules. The magnetic paleofield estimation reveals presence of significant paleofields (~20 microtesla) during the meteorite formation period.

University of Helsinki Observatory

Planetary-system research at the University of Helsinki Observatory (UHO) entails theoretical, observational, and experimental studies on key topics of solar-system exploration. In fundamental planetary physics, UHO theoretical research is focussed on light scattering by single small particles, on multiple scattering by complex media of small particles, and the celestial mechanics of the few-body problem. Experiments have been carried out to measure backscattering characteristics of particulate media (scatterometer at the Observatory) and observations have been made using both space-borne and ground-based telescopes.

In scattering of light by single small particles, UHO has studied the particle shape effects, continued studies of polarized light scattering by particles large compared to the wavelength, and carried out discrete-dipole simulations for wavelength-scale scatterers in order to understand their backscattering characteristics. The physical-optics approximation has been compared to the finite-difference time-domain method in the case of tetrahedral particles: the former promises to become a popular method for particles larger than the wavelength of light. UHO has continued studies of light scattering by irregular aerosol particles, with special emphasis of Gaussian-random-sphere modelling for their shapes.

UHO has reached an important milestone in studies of coherent backscattering of light by complex random media: it has published a unique numerical method for the computation of coherent backscattering by spherical scatterers. The novel method has been successfully applied to the interpretation of polarimetric observations of trans-neptunian objects, with several additional applications to follow. Multiple-scattering effects have been further studied for scatterers close to an interface, as well as for clusters of spherical constituent particles. Surface roughness effects have been studied through both numerical simulations and experimental measurements. Polarimetric observations of comets and asteroids have been analyzed statistically, with good prospects for novel future classifications schemes.

In the field of asteroid orbital inversion using statistical methods, UHO has succeeded in develop-

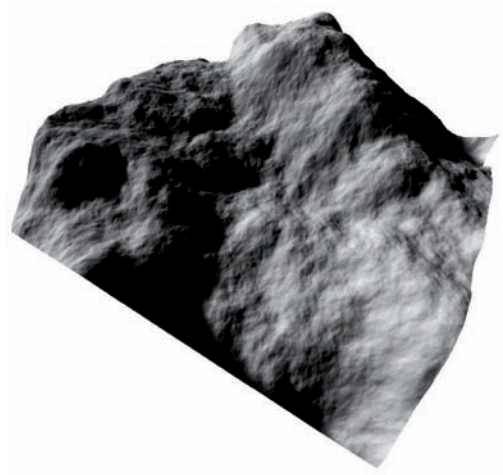


Figure 4.15. Fractional-Brownian-motion (fBm) modelling for the height statistics of planetary surfaces (H. Parviainen, M.Sc. Thesis, University of Helsinki).

ing orbital inverse methods, in essence, for all types of observational data sets. UHO has taken the first critical steps in assessing the asteroid identification problem at discovery: given a large number of astrometric observations, how many different asteroids do they correspond to and what is the partitioning of the observations? Systematic simulations for the asteroid identification problem have allowed making some unique conclusions about the complexity of the problem. The new identification method has been successfully applied to observational data obtained at the VLT. UHO has taken part in the collision probability analysis for the near-Earth object 2004 AS_1. UHO has further developed a general inverse method for the computation of exoplanet orbits using radial-velocity data on the parent star.

Inversion of asteroid photometric observations has yielded numerous near-Earth-asteroid spin and shape models. For high-precision astrometry, an offset can be detected between the asteroid photocenter and barycenter. First studies have been made to utilize the offset in the inversion for spins and shapes.

As to the observations, UHO has two important contributions to the ESA SMART-1 mission: It has a PI for the XSM X-ray instrument. XSM (X-ray Solar Monitor) is the calibration instrument for the D-CIXS imaging spectrometer, and also does independent science by providing long time series of high resolution coronal X-ray spectra of the Sun. The instrument has been designed and built in Finland. UHO is actively participating in the interpretation of the AMIE camera observations of the Moon. It is in charge of high-resolution modelling of the lunar surface using photoclinometric and photogrammetric methods and theoretical interpretation of multi-angular observations of the surface close to the backscattering geometry. SMART-1 was launched in 2003 and the mission will be ending with an impact of the spacecraft on the lunar surface in 2006.

UHO has developed techniques for automated statistical determination of asteroid orbits. For the ESA astrometric mission Gaia (launch in 2012), UHO is managing the work package entitled dynamical modelling of the solar system, entailing

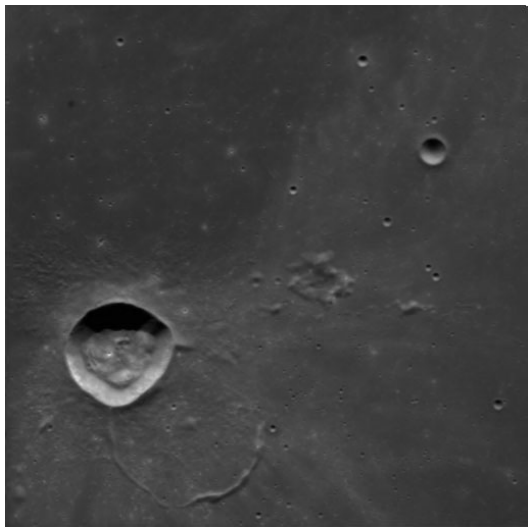


Figure 4.16. This image was taken by the SMART-1/AMIE -camera on January 15, 2006. The target area is at (66.8 W, 32.6 N) in Oceanus Procellarum (Ocean of Storms) and the crater in the image is Lichtenberg. The diameter of the crater is approximately 20 km.

the full solution of the orbital inverse problems for asteroids, comets, natural satellites, and planets as allowed by the high-precision astrometry and photometry. For the Gaia mission, UHO has carried out thorough simulations for asteroid orbital uncertainties, as well as for obtaining asteroid spins and shapes from sparse photometry. UHO has also carried out extensive simulations for the discovery statistics of space-borne near-Earth-object observatories.

UHO is participating in the BepiColombo mission to Mercury (launch in 2013): the Solar Intensity X-ray and particle Spectrometer SIXS (Finnish PI, UK Co-PI) will be providing the calibration observations for the Mercury Imaging X-ray Spectrometer MIXS (UK PI, Finnish Co-PI), which will carry out a global elemental and surface-structural mapping of Mercury.

At the Nordic Optical Telescope, UHO has coordinated a major Nordic observing program on near-Earth objects (NEON). The first results, including a detailed spin and shape model for the near-Earth-asteroid Apollo, have been submitted for publication. At the ESO VLT, UHO has partici-

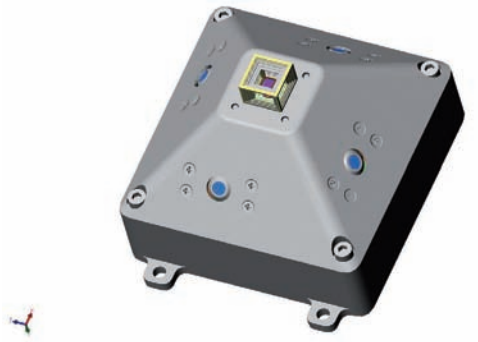


Figure 4.17. Drawing of he SIXS (Solar Intensity X-ray and particle Spectrometer) for ESA's BepiColombo mission to Mercury (Courtesy of Oxford Instruments Analytical Ltd.)

pated in polarimetric observations of transneptunian objects, providing the first ever coherent-backscattering modelling of the first ever polarimetric observations for these distant objects.

The light-scattering studies have also direct applications in industrial processes. UHO has modelled some industrial products like paper coatings for ideal light scattering. One of the purposes is to improve the quality of paper.

University of Oulu
Department of Physical Sciences
Division of Astronomy

The research of the Planetology Group of University of Oulu is based on the recent planetary data sets that are provided by the notable space missions of ESA and NASA. The group has studied the Moon, Mars, Venus and Mercury as well as terrestrial and planetary impact craters and space materials found from the Earth. A series of intense geology studies of the planet Venus using the Magellan radar data set has been performed and also preparations have been made for the future Venus studies, which will take place after the orbit insertion of Venus Express in April 2006.

The most productive research target for the Planetology Group is Mars through the participation in the ESA Mars Express mission. At first, the group was preparing targets and the imaging tasks for the Mars Express High Resolution Stereo Colour camera as participation in the early HRSC Co-I Team activities. The highly successful and still-active Mars Express mission has then produced a huge Martian data flow from the beginning of the imaging phase in January 2004. Additional research materials were – and still are – produced by other MEX instruments and by the NASA Mars orbiters and rovers. The continuing MEX-HRSC work of the Planetology Group has already materialized in several important publications that represent water-, climate- and environment-related aspects in Martian geologic history.

The group also participates in the future Mars mission planning and in international activities of the ExoMars – Aurora programme and the BepiColombo mission. In addition of performing advanced research approaches in planetary geology and in the development of the Martian surface environment, the group has studied terrestrial and planetary impact craters by making field work, sampling and sample research on impactites as well as on space-originated spherules found from terrestrial glaciers. The group participated in the first discovery of space spherules from Novaya Zemlya and in the size determination of the Kara crater which may have contributed to the K/T boundary event. The group has had international co-work with ESA and NASA as well as with several planetary research groups such as Comparative Planetology Laboratory in Vernadsky Institute (Moscow), International Research School in Planetary Sciences of Universita d'Annunzionin (Pescara, Italy), the MEX-HRSC Goup of Freie Universität (Berlin), Institut für Astronomie at Universität Wien (Austria) and Department of Geological Sciences of Brown University (RI, USA), for example.

The Dynamics Group of the University of Oulu has concentrated on the combined dynamical and photometric analysis of Saturn's rings. In particular, the group's model for the selfgravity-induced 100 meter fine-structure (gravity wakes) provided a quantitative explanation for the A ring azimuthal brightness asymmetry, measured by the Voyager probe in both reflected and transmitted light. The amplitude of these structures depends on the local velocity dispersion and surface density, and thus provides strong constraints for ring particles' elastic properties, internal density, and size distribu-

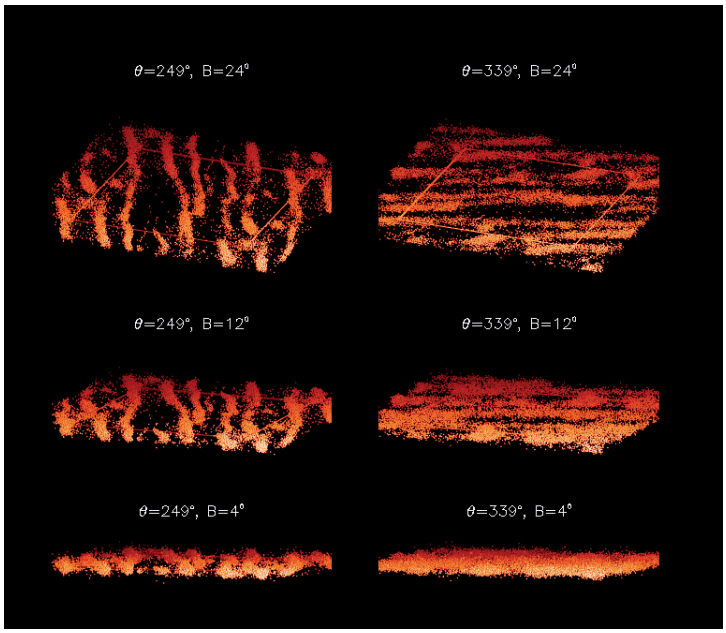


Figure 4.18. A snapshot from a dynamical simulation of Saturn's A ring, displaying a 300 meter by 300 meter local region. The gravity wakes seen in the snapshot trail on the average by about 20 degree with respect to local orbital motion – individual wakes are continuously destroyed and re-created in the competition between the particle's mutual impacts and selfgravity, and the tidal field of the planet. Model predictions are in accordance with the azimuthal asymmetry measured in Voyager flights, and the optical depth profiles obtained in Cassini occultation measurements.

tion. These models also predicted significant optical depth variations depending on the observing longitude with respect to wakes, which prediction was confirmed in 2005 by various Cassini occultation experiments (e.g. UVIS, RSS, VIMS). In addition, the group has participated in modelling of Arecibo observations of Saturn ring's radar echo, and to the analysis of Hubble Space Telescope observations of the B ring spokes. On dynamical side, the group has simulated the formation of gravitational aggregates in the A ring, and studied the density signatures produced by embedded large ring particles. Predicted signatures of 50-100 meter boulders have recently been observed by the Cassini imaging team.

Furthermore, the group has studied the rotational evolution of ring particles, and started modelling their thermal balance, important for interpreting the Cassini CIRS observations.

University of Oulu
Department of Physical Sciences and Sodankylä Geophysical Observatory

The Space Physics Group of the Department of Physical Sciences and the Sodankylä Geophysical Observatory of the University of Oulu are active in heliospheric and solar research. Research is mainly directed to the so-called space climate which includes the analysis of long-term solar magnetic activity, its temporal behaviour at different time scales and spatial structures, as well as its effects on the global structure and evolution of the heliosphere, the long-term properties of the solar wind and interplanetary magnetic field, geomagnetic activity, and cosmic rays. Research includes long-term satellite measurements of solar wind and interplanetary magnetic field, and ground-based and underground cosmic ray measurements. Moreover, the group participates in the Cassini mission to planet Saturn, and preliminary

work is being carried out in the instrument design for the BepiColombo mission.

University of Oulu carries two ground based experiments to measure cosmic rays. Oulu neutron monitor has continuously measured the cosmic ray intensity since 1964. Its data, available via an on-line database (http://cosmicrays.oulu.fi), are routinely used both for scientific and educational purposes and for a radiation hazard warning system and the calculation of radiation doses onboard trans-Atlantic jets. A multi-level (0 m, 90 m and 210 m underground in the rocky soil) muon experiment in Pyhäsalmi mine, in co-operation within the CUPP (Centre for Underground Physics in Pyhäsalmi) project, has been measuring the energy distribution of high-energy (above TeV) cosmic rays since 2003.

Galactic cosmic rays are subject to heliospheric modulation, which results in changes in the intensity and spectrum of cosmic rays detected on Earth. Thus variations of cosmic ray intensity can be used to study the large-scale changes in solar/heliospheric conditions. In order to study the modulation theoretically, a basic numerical model of cosmic ray transport in the heliosphere was developed. This model has been successfully applied to study long-term changes in the solar/heliospheric parameters. Using the model in a combination with a solar magnetic flux model, the cosmic ray intensity for the last 400 years was constructed. Inverting the model, the first physics-based reconstruction of sunspot activity since 850 AD was obtained, which shows that the present high activity period is unique for the last millennium. Moreover, monthly averages of the heliospheric modulation parameter were reconstructed from the measured cosmic ray fluxes over more than 50 years.

The solar influence on Earth's climate variations was studied for the last 1800 years by comparing the recently reconstructed series of sunspot numbers and the cosmic ray flux with various reconstructions of terrestrial Northern Hemisphere mean surface temperature. The study revealed significant correlations up to 99 %, of which the major part is due to the similarity of the long-term trends. In another study, a significant correlation was found between the global distribution of the observed low cloud amount and the calculated tropospheric ionization induced by cosmic rays. The relative inter-annual variability in low cloud amount was found to increase polewards and exhibit a highly significant one-to-one relation with inter-annual variations in the ionization over a wide latitude range. This supports the hypothesis that the cosmic ray induced ionization modulates cloud properties.

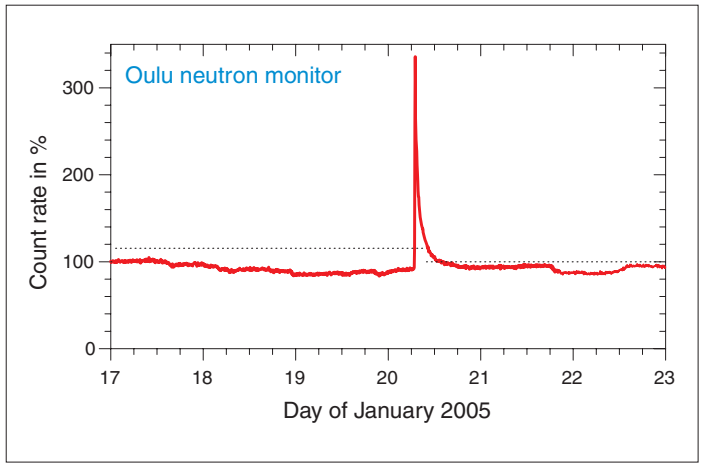


Figure 4.19. Cosmic rays have become important in discussions concerning e.g. the cloud formation in the atmosphere of the Earth. The second strongest proton event, that has been measured, occurred in January 2005.

The long-term properties of solar wind, interplanetary magnetic field and geomagnetic activity were studied. The heliospheric current sheet (the ballerina skirt) was shown not to be planar but systematically shifted southwards during solar minimum times. It was also shown that there is a systematic longitudinal asymmetry in the dominant HMF sector and this leads to a "flip-flop" type behaviour whose period is about 3.2 years. This agrees very well with the similar flip-flop period found in sunspots. These results indicate that the solar dynamo includes three modes: A0, S0 and a non-axisymmetric mode. This result will have a great impact on solar modelling.

An extensive analysis of long-term geomagnetic activity was conducted using data from 7 observatories at different latitudes over the globe. It was found that the centennial development of geomagnetic activity was qualitatively very similar in each location. Also, contrary to earlier speculations, all observatories depicted an increase during the last 100 years but the trends differed considerably from each other.

The first results based the CAPS instrument onboard the Cassini mission to Saturn were published. The Kronean magnetosphere was studied and found to be composed primarily of a complex mixture of water-derived atomic and molecular ions. Four distinct regions characterized by differences in both bulk plasma properties and ion composition were identified. Over the A and B rings, an ionosphere was found in which O_2^+ and O^+ are dominant, which suggests the possible existence of a layer of O_2 gas similar to the atmospheres of Europa and Ganymede.

University of Turku
Space Research Laboratory

The research at the Space Research Laboratory in the University of Turku is focused on phenomena related to solar energetic particles (SEPs). The experimental basis of the research is provided by the observations of the Energetic and Relativistic Nuclei and Electrons (ERNE) experiment onboard the SOHO spacecraft that continues for its tenth year to observe solar phenomena on a wide range of electromagnetic and corpuscular radiation. The observations of the energetic particles are complemented by other SOHO instruments and instrumentation in other ground-based and space-borne observatories.

The group has national and international connections also outside the SOHO context. Part of the theoretical work was conducted in collaboration with researchers from the University of Helsinki, Tuorla Observatory, and Ruhr-Universität Bochum. Within this framework, studies connecting the solar wind and energetic particle energization mechanisms related to plasma turbulence were continued. The group also participates in a European scientific framework COST Action 724: "Developing the Scientific Basis for Monitoring, Modelling and Predicting Space Weather".

The group organized, in collaboration with the American Geophysical Union (AGU), an international conference "Chapman Conference on Solar Energetic Plasmas and Particles" in Turku in August 2004. The results of this successful conference are being published in AGU monograph series title "Solar Eruptions and Energetic Particles" (Vol. 165), and in a Journal of Geophysical Research special section "Solar Coronal Mass Ejections and Energetic Particles" (JGR Vol. 110, Issue A12).

The scientific highlights of the SRL group contain results from both experimental and theoretical work performed in the laboratory. On the observational side, the exceptionally accurate angular resolution of the ERNE high-energy particle detector HED has been utilised in observations of unusual solar and interplanetary events. In May 2–3, 1998 a SEP event was observed when the SOHO spacecraft was inside a magnetic flux rope of an interplanetary coronal mass ejection (ICME). The observed strongly anisotropic fluxes indicated that the plasma turbulence conditions inside the ICME resulted in exceptionally low level of scattering of the energetic particles compared to the open field solar wind, and thus suggested that the turbulence levels inside such a structure are lower than in the solar wind. This interplanetary "highway" for the energetic particles is considered by ESA and NASA as one of the ten most important findings of the SOHO mission.

The anisotropy observations were in a key role also in the study of August 11, 2000 storm particle event. The shock approaching the spacecraft ac-

celerated particles to high energies while travelling in the interplanetary space. This was evidenced by the simultaneous rise of the intensities in a wide energy range of the particle spectrum.

Also the observed behaviour of the particle event anisotropy, which was observed to have a loss-cone structure, supported the scenario of locally accelerated particles. As the shock approached the spacecraft, the intensity of the particles propagating at large angles to the magnetic field was enhanced, and at the shock passage the directionality was of pancake shape, perpendicular to the magnetic field.

The initial proton and helium release during SEP events was studied statistically by using for the first time a cumulative sum analysis method developed specifically for low-statistic Poisson processes. The helium event onset was found to be significantly delayed in majority of the analysed events, with the event configurations suggesting that the magnetic connection between the flare site and the observing spacecraft plays a significant role in the formation of the delay.

Stemming from the theoretical suggestions of a turbulent layer in the vicinity of the Sun, production of energetic particles by CME-driven shock wave in such a layer was studied by means of test-particle simulations. It was discovered that particle acceleration in such layer can be very effective. In addition, the accelerated particles escape from the turbulent layer into the interplanetary space well after the passage of the shock, thus appearing delayed with respect to the CME transit.

In addition to the SOHO/ERNE project, the group also participates in the antimatter magneto-spectrometer project AMS, which is designed to study the fundamental cosmological questions by probing the antimatter abundance in the universe. As a

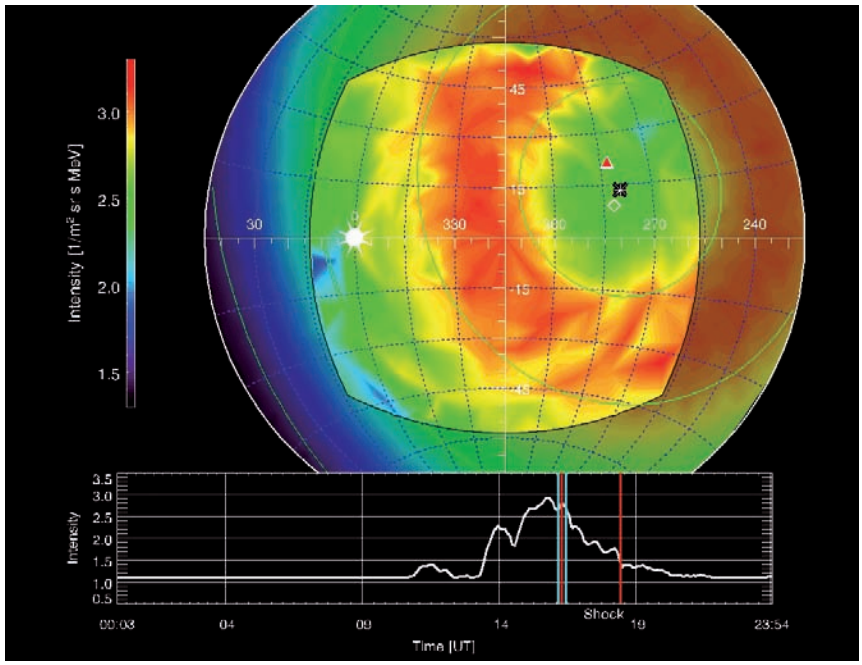


Figure 4.20. Pancake-shaped anisotropy observed by ERNE on August 11, 2000, as an interplanetary shock wave approaches the spacecraft. The direction of the Sun is depicted by the sun symbol on the x-axis. The symmetry axis of the distribution is shown by a cross, and the magnetic field direction as observed by MAG instrument onboard ACE spacecraft and by MFI instrument onboard Wind, are shown by a triangle and a diamond, respectively.

particle detector, it can also be used for other astrophysical research topics. During 2004–2005, the work on AMS detector was centered on building the various subsystems of the detector. The Finnish industry contributed to this work on the precision-cutting of the silicon detectors and in participating the support structure and liquid helium vessel manufacturing. The integration phase will start in 2006, and the launch date is in early 2008.

The SRL participates in the national Finnish Graduate School in Astronomy and Space Physics, a training network of the Finnish astronomy and space physics research groups, funded by the Finnish Academy.

University of Turku
Tuorla Observatory

Studies of numerical methods in celestial mechanics, the few-body problem, and satellite dynamics have been continued in collaboration with several foreign colleagues. Recently an improved analytical theory of the quasi-satellite phenomenon was completed and the orbit of the asteroid 2004 GU 9 was revealed to be one of a long term (1000 years) quasi-satellite of the Earth. New simple ways to compute the influence of the galactic tidal field on the cometary orbits in the Oort cloud was invented and tested. Also new efficient methods to compute the dynamics of relativistic few-body systems, such as black-hole binaries interacting with the surrounding stellar system, was developed and tested. Those methods are useful also with any near Hamiltonian system with some external dissipative forces, such as the air drag in satellite orbits.

Solar studies have included analysis on the nature of high latitude radio enhanced temperature regions and the origin of solar oscillations. The use of radio data has enabled to extend the study of torsional oscillations to chromospheric and low coronal levels, in addition to optical results obtained from the photospheric level. Analysis of CME-related phenomena has been continued in collaboration with several research teams abroad. A mini coronal mass ejection (CME) was discovered and found to have originated from a small solar bright point that could be identified in the interplanetary space from its magnetic helicity. Shock signatures at radio wavelengths have been found in relation with slow halo CMEs, and the analysis suggests that the shocks were created by associated flares rather than the propagating CMEs. Solar particle events have also been investigated together with the SOHO ERNE PI-team at the Space Research Laboratory, and first results show that CME interaction might play a role in accelerating energetic particles. A Swiss multi-frequency solar polarimeter system (TUBE) was moved from University of Bern to Tuorla Observatory in 2005. The automatic full-day solar flux density observations at five frequencies between 8 and 50 GHz will create a unique high-frequency solar burst database in Europe.

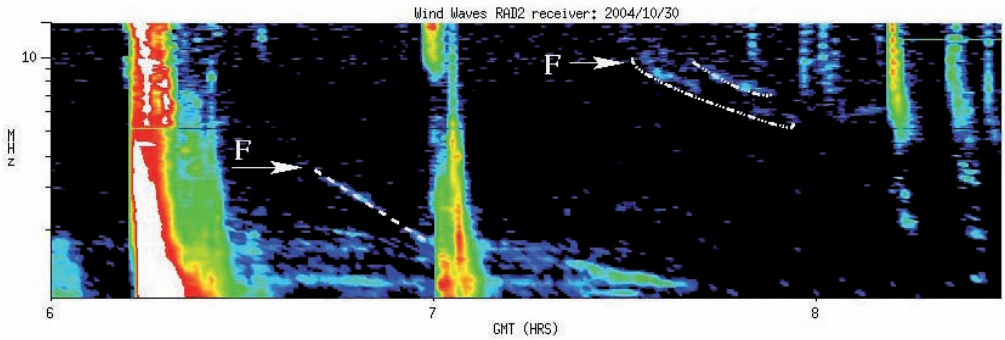


Figure 4.21. Propagating shock waves detected far out in the solar corona. Observations of the WAVES instrument onboard the Wind spacecraft of solar radio type II bursts in the 1–14 MHz frequency range, associated with a halo type coronal mass ejection. Plasma emission at the fundamental (F) is indicated in the spectral plot. Drifts in the emission frequency come from changes in the plasma density, i.e., the burst driver is moving out from the Sun.

4.3 Astronomy and Cosmology

University of Helsinki
Observatory (UHO)

The activities in the area of high-energy astrophysics are divided in two branches, fundamental science, and development of new instruments and technology.

The first part consists of scientific return from the instrument projects, currently INTEGRAL, SMART-1, complemented by public and Guest Observer data from other satellites, currently XMM-Newton, HST, RXTE, Chandra, and data from ground-based facilities like ESO and NOT. The second part is a continuation to the ongoing hardware projects including research also in detector physics. The science topics addressed include accretion discs and super-orbital periods of Low Mass X-ray Binaries, multi-frequency behaviour of micro-quasars, coronae and flaring in active stars and the Sun. In particular, the very broad spectral coverage (INTEGRAL and the AGN-collaboration) and the possibility for a very long monitoring (SMART-1, solar corona), coupled to sophisticated modelling, are the key ingredients of the research.

Development of new instruments is a natural continuation to the ongoing projects, providing valuable access to the guaranteed time also in the future. The aim is to utilise the advances in instrument performance carried out with bigger telescopes, larger field-of-view, and improved performance of new systems in the future plans of ESA (BepiColombo, XEUS, Lobster). Also, reuse of developed technology will be possible for e.g. the solar x-ray monitor XSM for SMART-1, a second version of which will fly with the ISRO's Chandrayaan-1 to a Moon orbit within a few year's timeframe. The systems under development in collaboration with the Finnish industry, VTT, FMI, HIP, and Departments of Physical Sciences and Chemistry of the University of Helsinki are

- Cryogenic X-ray microcalorimeter array based on superconducting Transition Edge Sensors (TES for XEUS)
- GaAs based single element and array-type X-ray spectrometers, and space particle sensors for ESA's cornerstone mission BepiColombo
- Metal surface processing for optical elements with ALD method for BepiColombo X-ray telescope and other potential space missions
- Position sensitive gas-filled soft X-ray counter for astronomical use, based on a new sensor foil, Gas Electron Multiplier (GEM)
- Powerful space instrument onboard data processors for future missions, which are being developed with Finnish industry, targeting for application on BepiColombo, and later for e.g. the XEUS mission.

The scientific use of INTEGRAL has already resulted in a number of scientific papers published in 2003–5. SMART-1/XSM has made observations of the Sun since March 2004. Several refereed papers on the instruments have already been published, and several papers on solar coronal science with very high quality data from XSM/SMART-1 are in preparation. At present, the scientific utilization of INTEGRAL and SMART-1 continues.

Observation programs with other satellites (RXTE, XMM-Newton, Chandra) and ground-based telescopes (e.g. NOT, ESO, ATCA) were continued. The activities have also evolved, and grown to a higher level of collaboration with new plans for instruments and satellites, which combine the expertise and experience of the group and its collaborators. In the year 2004, also bigger contributions in international space science programs have been initiated, i.e. participation at PI level in the next ESA cornerstone mission BepiColombo. The group is also involved at the PI level in the India-ESA collaborative Moon mission plan Chandrayaan-1 with an XSM similar to that of SMART-1, and have recently (2005) initialized a collaborative plan Spectrum-X-Gamma/eROSITA/Lobster of ESA and Russia, with GEM-based detectors for Lobster and possibly also for the Russian X-ray telescopes.

The main aims of the scientific research with the facilities are to study X-ray binaries with novel approaches. One aim of this research program is to study the prevalence, structure and evolution of

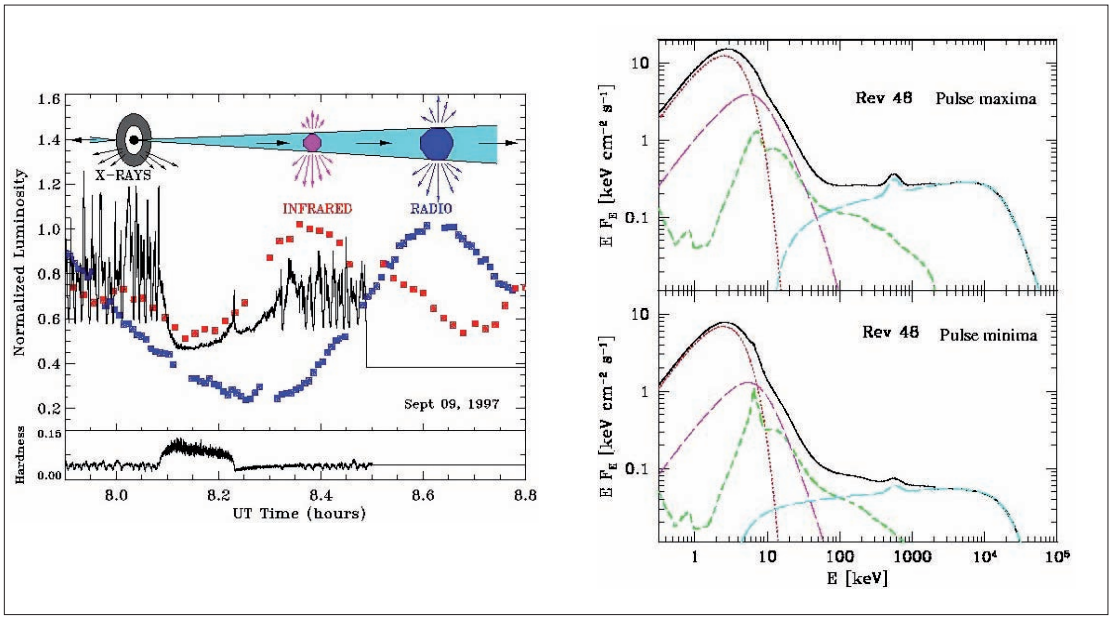


Figure 4.22. *Left:* Radio, infrared and soft X-ray lightcurves of GRS 1915+105 showing the short timescales (of the order minutes) on which phenomena – such as the ejection of the inner disk in bipolar outflows (or jets) occur. *Right:* The high energy spectra of GRS 1915+105 decomposed into separate components. The dotted and long-dashed curves show the unscattered blackbody, and Compton reflection from thermal (red) and non-thermal (cyan) electrons. The short-dashed (green) curve shows the component from Compton reflection. Note the weak e+e- annihilation line at 511 keV predicted by the model, which we shall search for in all the INTEGRAL data.

very short period binary systems. These systems consist of a degenerate primary star and a mass-losing secondary component that in the ultra-short period systems is either a white dwarf or a helium star. These systems are also the main source of gravitational radiation to be measured for the first time by some future mission like ESA's and NASA's joint project LISA. Another important aspect of this research is to disentangle and thus decipher the high-energy spectra of accreting low mass X-ray binaries and also high mass X-ray binaries (e.g. "micro-quasars"). This is done through a truly physical model and observations from e.g. INTEGRAL, and major ground-based radio telescopes.

The aim of the research of the solar corona is to disentangle the properties of the hot coronal plasma by analysing the X-ray spectra obtained with our own instruments flying on-board space missions, like XSM/SMART-1. Research by UHO aims at clarifying the physical mechanism of the flares by

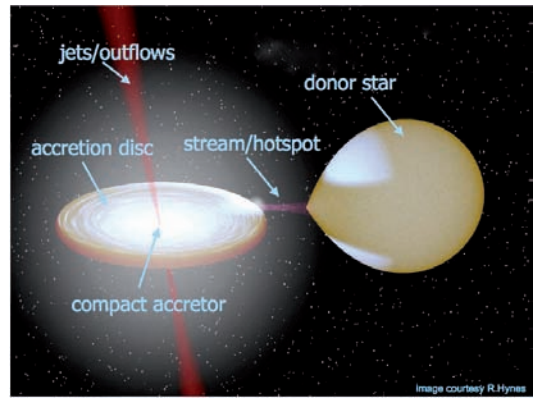


Figure 4.23. A schematic view of a disk accreting interacting compact binary highlighting the different components of a typical low-mass X-ray binary system. The corona is the hot tenuous gas around the disk (Courtesy of R. Hynes).

examining the X-ray spectrum and its variation during the eruptions, and by comparison between different flares. Also time behaviour over longer

time span is studied with the aim of studying the changes of the properties of solar corona during the Sunspot cycle. The methods include developing improved theoretical models based on extensive new very high quality spectroscopic X-ray data from e.g. SMART-1/XSM. In addition, data from the RHESSI and GOES satellites are used as complementary sources of information. After the end of SMART-1 operations in 2006, similar data is expected from a Finnish solar monitor on the Chandrayaan-1 mission, and later with the Finnish solar monitor SIXS on ESA's BepiColombo.

The main observational tools for the studies of clusters of galaxies at UHO are high resolution X-ray imaging and spatially resolved spectroscopy of the hot intra-cluster gas. Data obtained with XMM-Newton and Chandra X-ray satellites is currently used for this analysis. UHO researchers have developed a double-filtering method, which reduces the background uncertainties significantly compared to the commonly used method.

UHO researchers have also been involved in the analysis of archival data from the ISO satellite and preparation for the utilisation of the Planck Surveyor mission of the ESA, which are used for studies of interstellar medium and star formation.

The properties of dust and young stars in molecular clouds have been studied by extensive infrared (3-200 micrometers) mapping performed by the ISO (Infrared Space Observatory) satellite. In the high latitude cloud L1642 these observations have revealed a dense, cold region, which has given birth to two pre main-sequence binary stars. In a small, globule-type dark cloud, we have detected and physically characterized a deeply embedded young stellar object. In an isolated translucent cloud, L1780, our ISO observations exhibit contrasting emission spectrum contributions from the unidentified infrared bands (UIBs), very small grains and large classical grains. The results suggest physical differences in the ISM mixtures between positions within the cloud, possibly arising from grain coagulation processes.

The emphasis of the UHO Planck research is on Galactic interstellar clouds and the physics of the

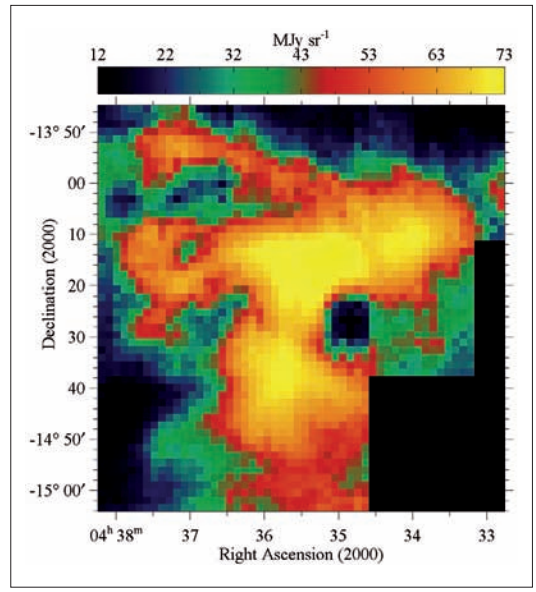


Figure 4.24. High latitude molecular cloud L1642, as mapped with the ISO at 200 micro -meter wavelength. The emission is blackbody emission from cold (14–20 K) dust within the cloud. (Courtesy of UHO)

interstellar dust. Planck will be particularly sensitive to cold dust that could not be detected in earlier infrared surveys that operated at shorter wavelengths. Planck data will also help to unravel the mystery of the so-called anomalous microwave emission, which may be linked with the presence of very small dust particles. Good understanding of dust emission is essential also for CMB related studies.

UHO participates in the construction of template maps for the components of the Galactic diffuse emission. New tools are being developed for analysis of future Planck observations. Further preparatory work is organized through Planck technical working groups, two of which are coordinated by researchers from the Observatory. In 2005 work was started on the simulation of polarized dust emission. This is based on the combination of magnetohydrodynamic simulations for the structure of interstellar clouds (density and magnetic fields) and radiative transfer calculations. The results are used for predictions of the polarized dust signal observed by Planck.

The ESO (the European Southern Observatory) connected activities have also increased strongly after the beginning of Finland's membership in July 2004. A number of observing proposals have been submitted to ESO, and UHO has been the most successful individual science user of ESO in Finland during this decade. A member of the HESA group coordinates and manages the University of Helsinki share of the Finnish in-kind project for partial payment of the entrance fee to ESO, together with the CSC- Scientific Computing Ltd. The project, called ESO-Sampo, conducts development of science data analysis environment for ESO during the period 2005–2007 at UHO. Active preparatory work has also been done together with Finnish industry for future instrument and technology development for ESO.

University of Helsinki
Department of Physical Sciences

The participation of the Department of Physical Sciences of the University of Helsinki (UH/PHYS) in international Astronomy and Cosmology projects is based on specific fields of expertise ranging from the theoretical studies of Big Bang to instrument development for high-energy astrophysics.

During the years 2004-2005 the most important project has been related to ESA's Planck spacecraft to be launched in 2008. One of the most demanding tasks in the studies of cosmic microwave background (CMB) is the conversion of the huge amount of measurement data from the spacecraft to a meaningful physical form. The Planck group at UH/PHYS participates in the development of methods for making full-sky maps of the microwave background and to determine the cosmological parameters from them. The group has written a map-making code that was incorporated in the Planck Data Processing Center data analysis pipeline. The group also participated in the testing of the 70 GHz detectors for Planck that were produced by Electrobit Microwave in Finland. Present activities of the group include comparison of different map-making codes in order to gain understanding of the expected error margins in the maps and investigating the effects of sub-pixel structure and detector shape of the maps.

In particular during the Antares-programme (2001–2004) both the X-ray Laboratory and the Detector Laboratory were active in development of various high-energy instruments for space experiments in close collaboration with the UHO group as discussed above. The X-ray instrument of SMART-1 XSM has made observations of the solar X-rays and its further development will be implemented in the BepiColombo SIXS instrument. The Gas Electron Multiplier (GEM) based detector development also mentioned in the UHO section, is a good example of synergy between elementary particle physics and astrophysics instrument development, as a large number detectors based on the same technology are being delivered to the TOTEM instrument of the Large Hadron Collider of CERN.

University of Oulu
Department of Physical Sciences
Division of Astronomy

The main activities of the high energy astrophysics group are concentrated on the studies of compact astrophysical objects such as black holes and neutron stars in X-ray binaries. Accretion-powered millisecond pulsars were studied actively. The group analyzed the X-ray data from NASA's Rossi X-ray Timing Explorer (RXTE) satellite and from ESA's International Gamma-Ray Astrophysical Laboratory (INTEGRAL) and XMM-Newton satellite on there of the pulsars. An important discovery was made on the further spin-up of the fastest known accreting pulsar IGR J00291+5934 that rotates 599 times per second. This confirms the theory of the origin of radio millisecond pulsars from the neutron stars accreting gas from a companion in low-mass X-ray binaries. The group has also done theoretical studies on the pulse profiles of millisecond pulsars and its polarization properties.

The group also analyzes the X-ray and gamma-ray data on the black hole sources in our Galaxy such as Cygnus X-1 and the microquasar GRS 1915+105. An unprecedented extensive study of more than 40 simultaneous RXTE and Compton Gamma-Ray Observatory observations of Cyg X-1 revealed a strong correlation between various spectral parameters, which provides interesting

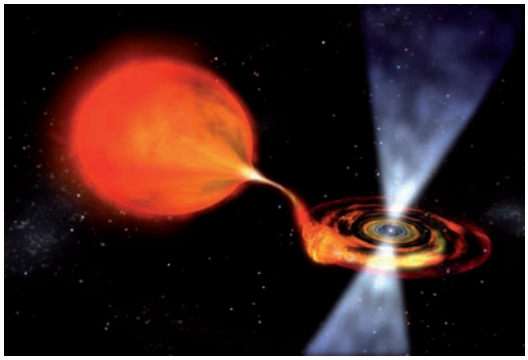


Figure 4.25. Accretion from a low-mass star onto a millisecond pulsar. (Courtesy of NASA)

constraints on the theoretical models of this source.

With the discoveries of optical counterparts of long gamma-ray bursts, their origin is now firmly associated with the death of massive stars. The short bursts probably originate in collisions of compact objects. However, the nature of gamma-ray burst spectra is still unclear. The group has proposed a novel theoretical model, based on synchrotron self-Compton emission of nearly mono-energetic electrons, which describes well the observed spectral properties as well as the temporal evolution.

Ultra-high-energy cosmic rays (with energies above 10^{19} eV) were claimed to correlate with the BL Lacertae objects, a class of active galactic nuclei. The Oulu group has proposed a new statistical method that does not suffer from a posteriori manipulations of tested samples. Its application to the data, revealed no significant correlation between the two types of sources.

Traditional activities of the Division of Astronomy are related to the studies of stellar activity and surface imaging. Studies of magnetically active stars using surface imaging techniques with both spectroscopic and photometric observations have been continued. The group has studied activity phenomena observed in the spot distribution on young single solar-type stars LQ Hya, AB Dor and EK Dra. These include cyclic variations of the mean activity level, differential rotation, persistent active longitudes separated by 180° and flip-flop cycles. The results confirm the presence of cyclic activity in very young dwarfs and allow for studying evolution of the stellar magnetic activity during the main-sequence stage.

The stellar activities are supplemented by the studies of the Sun and the sunspots. The group has recently found that the distribution of sunspots is non-axisymmetric and spot group formation implies the existence of two persistent (on century scale) active longitudes separated by 180°. These regions migrate with differential rotation and periodically alternate their activity levels showing a flip-flop cycle. The pattern and behaviour of active longitudes on the Sun is similar to that on cool, rapidly rotating stars with outer convective envelopes. This suggests that the magnetic dynamo, including non-axisymmetric magnetic fields and flip-flop cycles, is also similar in these stars. This allows to understand better the phenomenon of stellar magnetic activity and to study it in detail on the Sun.

The radially and latitudinally varying rotation profile of the outer convective envelope of the Sun is thought to arise due to the interaction of small-scale turbulence and overall rotation of the star leading to latitudinally varying heat and momentum fluxes. The group has studied these fluxes by means of three-dimensional convection calculations in local rectangular boxes placed at different latitudes on a stellar sphere under the influence of rotation.

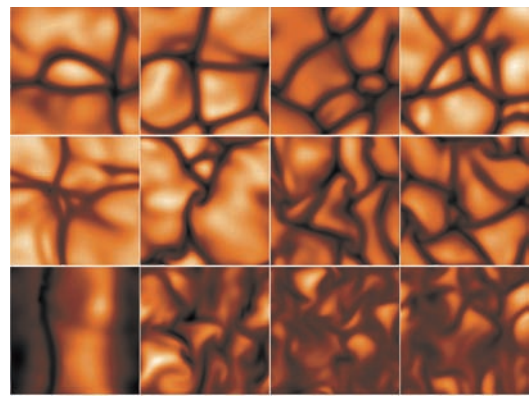


Figure 4.26. The effects of rotation on the surface convective temperature pattern.

Novel techniques for studying cosmic magnetic fields based on molecular spectropolarimetry have been developed. Many diatomic molecules present in the atmospheres of the Sun and cool stars exhibit the Paschen-Back effect at field strengths typical of sunspots and active cool stars. A complete theoretical description of the molecular Paschen-Back effect has been presented, which together with the observations of the spectral line polarization profiles, holds promise to form the basis of new diagnostics of solar and stellar magnetic fields. Among the first results are the explanation of puzzling molecular polarization features observed in sunspots, direct observation of magneto-convection in the coldest parts of sunspot umbra revealed with the help of the molecular bands, and detection of the polarized radiation from spatially unresolved starspots.

Another research field is the studies of masers, which are relatives of lasers in physical laboratories. The difference is that masers are produced naturally in the astrophysical environments and have huge powers. Some late-type stars show strong water maser emission lines at 22 GHz. The research was concentrated on modelling of the dusty molecular disks around spectacular class of stars, so called silicate carbon stars, and its best studied representative V778 Cyg. The proposed approach is based on the extreme sensitivity of the maser emission on the density of molecular hydrogen and geometry of the masing material. Thus, modelling the water maser activity allows us to determine the physical parameters in the emitting region.

The extragalactic research of the Dynamics Group has concentrated on barred galaxies, and the use of bars and bar-related resonance structures as a probe of galaxy evolution in the Hubble sequence. For example, based on the near-IR data from the 2MASS (2-Micron All Sky Survey) and OSUBGS (Ohio State University Bright Galaxy Survey), the group has derived the gravitational potentials for nearly 200 spiral disk galaxies. This yielded a quantitative measure of the bar strength, in terms of the non-axisymmetric perturbation it induces; as an application the correlation between the bar strength and the galaxy nuclear activity was analyzed. The derived potentials were also utilized in simulation measurements of bar pattern speeds, leading to the so far largest sample of systematic pattern speed estimates (38 galaxies). In order to extend these studies to S0's (=disk galaxies, but lacking clear spiral structure), a new optical and near-IR survey of S0 galaxies, similar in size to OSUBGS, using NOT and ESO telescopes, was started. During the years 2004-2005 observations were carried out for 80 galaxies. In particular, a novel 2D structural decomposition method (with bulge, disk, bar + possible additional components) was developed, leading to significantly revised estimate of the bulge/total ratio for S0's, in contrast to previous estimates based on crude 1D decompositions ignoring bars. The group also participates to a 3D-spectrograph instrument project planned for ESO NTT.

University of Turku
Tuorla Observatory

Tuorla Observatory does not at present participate in any space instrumentation project. However, Observatory's scientists are PI's or Co-I's in a number of satellite observing programs related to our various research projects. During the last few years almost every available scientific satellite has been utilized. The group also participates in the scientific operations planning of future missions. These include the ESA Planck mission, and the Japanese VSOP-2 mission, a recently accepted follow-up to the first ever space VLBI mission HALCA.

A new research direction for Tuorla and for Finland is astrobiology. A Finnish Astrobiology Network, which participates in the European Astrobiology Network association in promoting astrobiological research, has been formed and an astrobiology curriculum has been set up at Turku University.

In astrobiological research, investigations of cyanobacterial growth in low pressure and high CO_2 have been carried out in collaboration with the Laboratory of Plant Physiology and Molecular Biology. Growth rates at pressures as low as 30mbar and 100% CO_2 levels have proven to be remarkably high. This set up approaches in pressure and in gas composition the conditions ex-

pected in Martian greenhouses where cyanobacteria could be used both for food and oxygen production. In the ESA coordinated ROME (Response of Organisms to Martian Environment) Network investigations on the ecological feasibility of space missions to Mars have been carried out in terms of life support systems and risk of contamination.

The dynamical stability of extrasolar planets has been studied. The group has searched for stable orbits of earth-like planets in systems where a giant planet is already known to orbit a star. These studies will aid the forthcoming space missions (e.g., Kepler, TPF, Darwin) in their selection of targets in searching for earth-like planets.

Cataclysmic variables are interacting binaries in which gas from a late-type dwarf is flowing towards to a white dwarf. The ROSAT and the XMM satellites have played a major role in detecting new cataclysmic variables In the subclass called intermediate polars the magnetic field is strong enough (few megagauss) to disrupt and truncate the disk at some inner radius. Accretion then continues via accretion curtains on to the surface of the white dwarf, where the gas forms a high temperature shock emitting mainly X-rays. An important signature is circularly polarized cyclotron radiation, observable in the optical regime. In systems called polars the magnetic field strength can be a hundred times stronger. In such cases the accretion disk cannot form at all, and the gas flows towards the white dwarf shock regions along the magnetic field lines.

Large telescopes are needed for circular polarimetric observations in order to achieve high signal-to-noise ratio with a time resolution of a few minutes. The circular polarization originates close the shock region near the surface of the fast spinning star; in some extreme systems such as AE Aqr and DQ Hers the spin periods are as short as a few minutes. The group has been granted three nights with the ESO VLT telescope for the programmes “Soft X-ray Intermediate Polar polarization survey’’ and “Polarization survey for magnetic field strengths in Intermediate Polars’’, with more observing time from the smaller ESO telescopes for programmes “Linear polarization in magnetic Cataclysmic Variables’’ and “Survey of Cataclysmic Variables in Old Open Clusters’’. Earlier ESO program data is being prepared for publication. Preliminary analysis indicates that the expected polarized emission signatures are seen in all observed sources.

The Hipparcos satellite continues to provide fertile grounds for research as a result of the high accuracy distances that it provided more than a decade ago to a large number of nearby stars. During 2004–2005, Hipparcos data have been used to infer indirectly the photometric colours of the Sun from nearby stars very similar to the Sun; to measure the luminosity of the Milky Way disk and its mass-to-light ratio, a quantity of wide utility in stellar and galactic astronomy; to make first steps towards determining the surface temperature scale for low mass stars; and finally, to make a determination of the amount of helium in such low mass stars. The work on galactic kinematics and dynamics will also be extended to the GAIA satellite mission.

Since the regions responsible for the primary energy production of an AGN, within a fraction of a parsec from the supermassive black hole, cannot be resolved, multifrequency studies are the key to further understanding. With new X- and gamma-ray satellites (INTEGRAL, Chandra, XMM-Newton) and TeV telescopes, the focus is now on the highest energies. In addition to satellite data, large international ground telescope networks are required for full frequency coverage. The group has participated in a large number of such collaborations, in particular through the EU TMR network ENIGMA and through our INTEGRAL AGN collaboration.

Since 2002, Tuorla Observatory has been a full member of the MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) collaboration operating the world’s most sensitive TeV telescope on La Palma, Canary Islands. MAGIC started regular observations during fall 2004. Currently its energy threshold is around 100 GeV. So far it has detected 7 blazars, 2 supernova remnants, the Crab pulsar, the Galactic Center, the microquasar LS I+61 303, and obtained upper limits to one GRB. The collaboration is currently

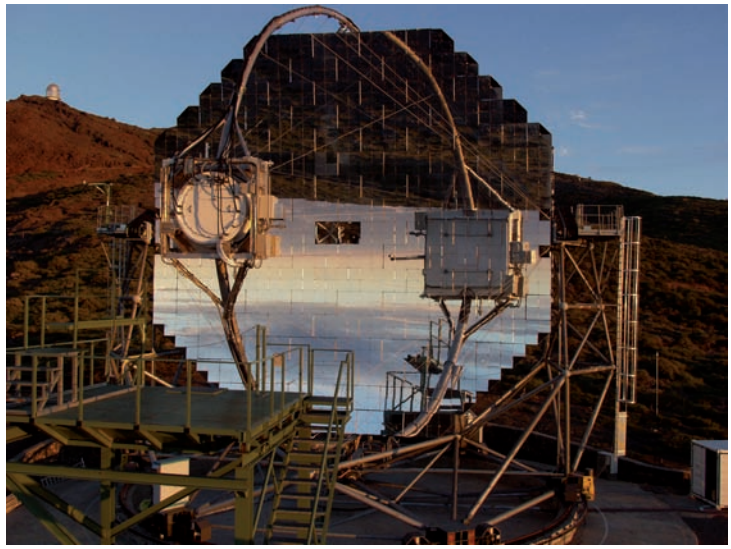


Figure 4.27. The MAGIC TeV Cherenkov telescope on La Palma, Canary Island.

building a second similar telescope, expected to be operational during 2007. The upgraded MAGIC II will be able to observe the 10 GeV – 100 GeV energy range, the very last frequency regime as yet unobserved. The tenfold increase in sensitivity will revolutionize AGN studies, in particular when combined with the future AGILE and GLAST gamma-ray satellites, optical monitoring, mm-to-submillimeter radio observations (APEX, ALMA) and high resolution ground/space VLBI imaging.

High frequency and high resolution VLBI provide information on the structure of the synchrotron and inverse Compton emitting regions close to the black hole. Scientists from Tuorla are at the forefront of high-resolution/frequency VLBI, having participated in all the proposed space VLBI projects including the successful Japanese HALCA, as well as in the planning of VSOP-2. The group has used extensively the VLBA interferometric network, mainly in connection with INTEGRAL satellite projects and is the first to use the full multifrequency and polarimetric capability of the VLBA, having also done the first ever fully calibrated 3 mm polarization observations. The group has developed new analytical and numerical methods for modelling the particle acceleration and radiation processes in the relativistic jets, in particular the inverse Compton processes responsible for the high-frequency radiation. Much of the research has been done within the Planck satellite LFI Consortium in collaboration with the Metsähovi Observatory, as preparatory work for the Planck proprietary science programs.

A special project relates to the predicted next periodic outburst of the only known supermassive binary black hole in the active galaxy OJ 287. The group monitors the H_α of OJ 287 using the VLT FORS2 instrument. The aim is to detect changes in this line due to the gravitational effect of the secondary black hole as it passes close to the primary, predicted to occur during 2006–07. Possible effects are a shift of the line center and changes in the line profile due to the gravitational effect of the secondary. This project will continue until 2008 when the close encounter between the primary and secondary is expected to be over. During this period OJ 287 will also be monitored using a large network of other ground telescopes and satellites.

Understanding the cosmic co-evolution of galaxies and black holes is a key problem for both cosmology and AGN studies. The group has used the

ESO VLT 8m telescopes with the ISAAC and NACO near-infrared imagers to study the cosmological evolution of the host galaxies of high redshift ($1 < z < 3$) quasars, covering a large range of the quasar luminosity function. This work includes the detection of the host galaxy of a $z = 2.9$ quasar, arguably the highest redshift quasar host detected so far. The luminosity evolution of the host galaxies of quasars is consistent with that of massive inactive elliptical galaxies undergoing passive evolution. The nuclear and host luminosities are correlated, and assuming that the host luminosity is proportional to the black hole mass, the quasars emit at very different levels with respect to their Eddington luminosity. Nuclear activity can occur in all luminous ellipticals without producing a significant change in their global properties and evolution. Quasar hosts appear to be already well formed at $z = 2$, and the last major merger event in these (and perhaps all) galaxies must have occurred at very high redshift, in contrast to the predictions of hierarchical models for galaxy formation.

Studies of BL Lac host galaxies have been extended to higher redshifts using a sample of 24 objects at $z = 0.3–1.3$. Images of the sources were obtained using the NOT, ESO-NTT and ESO-VLT telescopes. Analyzing their evolution with redshift, the effective radii of the distant host galaxies were found to be essentially the same as in local samples, and no active luminosity evolution was apparent, implying that the host galaxies were already fully formed at $z = 1.3$. The conclusion is similar to that found for quasars: the host galaxies of BL Lacs formed at a relatively distant epoch ($z\sim2$), and have not evolved much thereafter.

The operational and planned IR-optimized space telescopes (Spitzer, Herschel, James Webb telescope) as well as the rapidly developing optical/near-IR interferometry are crucial for the future research on distant host galaxies at Tuorla Observatory.

In local cosmology the scientists of Tuorla Observatory have continued the study of te distance scale and the Hubble law in collaboration with French, Russian and US astronomers. The bias previously suggested to exist in the extragalactic Cepheid distance indicator has been studied, mainly using HST Key Project observations. Its presence has been confirmed with various checks, e.g. using the full period-luminosity-colour relation whose coefficients have been inferred with a new method. When one takes into account the bias, the Hubble constant derived by the HSTKP drops from 72 to about 60 km/s/Mpc, with major implications for the present cosmological standard model.

The study of dark energy considering its influence on the local Hubble expansion and velocity dispersion has also been continued. A new way to detect the signature of dark energy in the very local Hubble flow just outside the Local Group has been introduced. Preliminary analysis of “Tip of

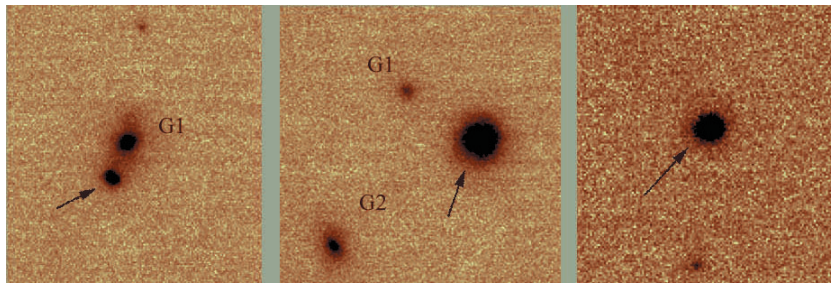


Figure 4.28. Three quasars, marked by arrows, imaged with the European Southern Observatory’s Very Large Telescope using adaptive optics. In the right panel, the host galaxy is seen as slight nebulosity around the central quasar. In the left panel, a much more nearby spiral galaxy in the same field of view as the quasar is marked G1; in the central panel, the two nearby galaxies G1 and G2 are probably neighbours to the quasar itself.

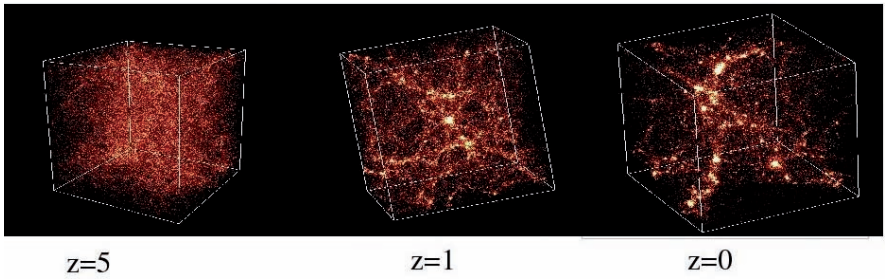


Figure 4.29. Growth of large-scale structure in a 40 Mpc simulation box from redshift 5 to the present epoch.

Red Giant Branch" distances (from HST) to local dwarf galaxies appears to restrict the local dark energy density close to the global one inferred from observations of very distant supernovae.

Numerical simulations are essential and almost only available theoretical tools to study complex nonlinear gravitational dynamics of the galaxy Universe. The latest observational data have been compared with advanced cosmological numerical simulations. This is currently an important topic, with current (WMAP) and forthcoming CMB satellite experiments (Planck) increasing dramatically our knowledge of the basic cosmological parameters. At the same time, deep redshift surveys like the Sloan Digital Survey and the 2dF Galaxy Redshift Survey provide a new level of information on the structure and the evolution of the galaxy universe. Immediate objectives are investigating the effects of evolution for galaxy systems and galaxy substructures. Important applications are gravitational lensing studies. Part of this work is done within the Planck LFI Consortium.

Helsinki University of Technology Metsähovi Radio Observatory

The Metsähovi group studies Active Galactic Nuclei (AGNs) using the 14-metre Metsähovi telescope for long term monitoring of AGN variability as well as for one- to few-epoch observations of several large source samples. The data are used in connection with data gathered from other instruments – including many space borne instruments – to study the activity behaviour of AGNs across the electromagnetic spectrum.

Metsähovi is a member of the Planck satellite's LFI consortium. The team actively participates in the core activities of the Planck Extragalactic Point Sources Working Group. The main tasks in 2004–2005 were the development of the Planck Quick Detection System software and the definition of its triggering criteria, the construction of the Planck Pre-launch Catalog of point sources (including observations and analysis), and analysing the scientific data of extragalactic point sources.

As part of our Planck foreground studies observations of a complete sample of BL Lacertae Objects (BLOs) have been made at 37 GHz. The main objective of this project is to get a full understanding of the BLO population all the way from the radio-selected BLOs to the X-ray-selected BLOs, and to put special emphasis on the Intermediate BLOs. In addition to the 37 GHz observations a unique, large data base of multifrequency data for the complete BLO sample has been collected and the spectral energy distribution of these objects has been studied.

In addition to the complete BLO sample other subpopulations of AGNs as part of the Planck foreground project have been studied. These populations include gigahertz-peaked spectrum sources and other inverted-spectrum sources as well as some faint flat-spectrum sources. Objects that were detected by the WMAP satellite but resisted identification in the published WMAP extragalactic source catalogue have been tried to identify. Fields of the unknown WMAP sources have been observed and some of the extragalactic sources in those fields in an active radio state have

been detected, making them good candidates for the WMAP source counterparts.

Metsähovi is part of the EU-funded research training network ENIGMA (European Network of the Investigation of Galactic Nuclei through Multifrequency Analysis). Within the ENIGMA network and also in collaboration with other multifrequency observers (e.g. the WEBT network) many individual AGNs (e.g., 0235+164, MARK421, MARK501, H1426+428) across the electromagnetic spectrum have been studied, including satellite instruments observing in the high-energy region (XMM, RXTE). The well- studied quasar 3C273 was in a very faint multifrequency state in June 2004, being also faintest ever in the millimetre domain. Target-of-Opportunity observations on the very weak jet emission of 3C273 were initiated, together with multifrequency satellite observations (INTEGRAL, XMM- Newton, RXTE) and ground based observations.

Since the early 1990's Metsähovi has been one of the few institutes in the world where Very Long Baseline Interferometry (VLBI) data acquisition systems have been constructed and developed further. This technology accumulation has its roots in the early 1990s when the Academy of Finland financed the initiation of VLBI research at Metsähovi in conjunction with the Radioastron project. Experience originally gained in building an own VLBA Data Acquisition Rack has enabled matching and surpassing the traditional designs of MIT Haystack Observatory. Recently the team has focused on transforming commercially available off-the-shelf technology for VLBI data acquisition applications and on exploiting high- speed Internet protocols for e-VLBI. The latter has already produced several "world records" in data transfer speed over the Internet.

Figure 4.30. Setting up one of the first VLBI Standard Interface (VSI) based acquisition systems for unformatted VLBA sampler at 1 Gbps.

Metsähovi disk VLBI recorders played a key role also when the ESA Huygens probe on-board the Cassini Saturn mission descended into Titan on 14-Jan-2005. Even though not visible for European stations, an exceptionally large number of VLBI observatories in the US and on the Australian continent followed and recorded the faint Huygens S-band signal during the descent to Titan. VLBI observations were correlated and specially post-processed at JIVE to reconstruct the descent trajectory of the Huygens probe. Four of the Australian observatories (including the 64-meter Parkes dish) are equipped with

Metsähovi VLBI disk recorders. The versatility of Metsähovi PC-based recording allowed developing reformatting and narrow-band data extraction software that allowed the Australian stations to join this unique experiment.

5 Applications, Earth Observations and Space Technology

5.1 Space geodesy

Finnish Geodetic Institute (FGI)

Satellite based methods, especially GPS and the European Galileo in the future, have completely changed the Earth research. Global and regional permanent GPS networks form nowadays the frame where local and global changes can be studied. The Global Geodetic Observing System (GGOS) integrating all modern geodetic techniques is the response of the geodetic community to the Earth studies. The Finnish permanent GPS network FinnRef® is a part of this global structure.

The network consists of 13 permanent GPS stations and it is the backbone of the Finnish realisation of the European-wide reference frame EUREF. Four stations in the FinnRef network belong to the EUREF permanent GPS-network (EPN), and one station belongs to the network of the International GNSS Service (IGS). Through these stations FinnRef® creates a connection to the global reference frames and the stations are used for maintaining global reference frames and global geodetic studies. In 2004–2005 the data flow of the FinnRef® network was renewed when most of the stations were connected with ADSL

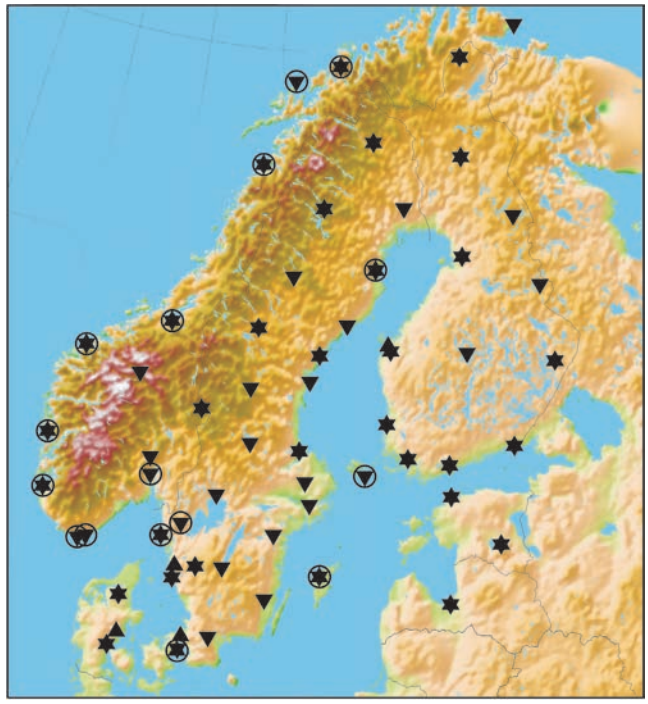


Figure 5.1. Nordic Geodetic Observing System (NGOS) network connect existing space geodetic and traditional networks. Upside-down triangles denote permanent GPS stations, triangles absolute gravity points, and circles are tide gauges planned for the NGOS network.

modems. This allows real-time data access in the future.

The FinnRef® is also used for local studies on crustal movements as well as a reference for local and national GPS measurements. The ten-year time series of FinnRef® make it possible to monitor country-wide deformation. Even annual movements of few millimetres are visible in the time series. These include e.g. crustal uplift due to postglacial rebound.

The study of land uplift was continued by re-computing the uplift values between Metsähovi and other FinnRef stations using data from the permanent GPS network FinnRef. The GPS determinations were used together with observations obtained from the superconducting gravimeter to model the atmospheric loading effect. The work was a part of the joint project with the Finnish Meteorological Institute to model the atmospheric effect on the GPS signal.

The BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea Level and Tectonics) project continued. The research area of the project covers the whole of Fennoscandia. The aim of the project is to develop models to mechanism of the post glacial rebound. Basic observation data is collected from the permanent GPS stations in the area, and the data from the FinnRef stations are transferred daily to the Onsala Space Research Station in Sweden. Researchers from United States, Canada, Great Britain, Sweden and the FGI are taking part in the BIFROST project.

Investigation of local crustal motions contained in a contract with Posiva Oy was continued on the candidate sites for final nuclear waste disposal. The local networks at Olkiluoto, Kivetty and Romuvaara are annually measured with GPS.

A GPS project under the umbrella of Geo-Satakunta was continued with three annual GPS campaigns on 10 pillars in the Pori-Rauma area. The purpose is to study crustal deformations, and get better understanding of geological and geophysical processes in the area. Other partners in the study are the Geological Survey of Finland, Cities of Pori and Rauma, Posiva, and Satakuntaliitto.

Figure 5.2. GPS measurements at Olkiluoto (Photo Joel Ahola)

Initiated by the EUREF subcommission, a EUVN-DA (European Unified Vertical Network - Densification Action) GPS campaign was made in the summer of 2005. The purpose of the campaign is to densify the European GPS/levelling network. A total of 31 points were observed in Finland, and all points were connected to the precise levelling network.

GPS Virtual Reference Station (VRS) method was tested in extensive field measurements in 2003. Results of the tests, covering accuracy and reliability of the method were published in 2004–2005. The VRS concept has been used since 2000 in Finland and a private Finnish company has established a network of 80 stations to provide VRS service.

The Metsähovi research station is an essential part of the activities of the FGI. The measurements taken at the station serve both the FGI's own research and the international scientific community. Metsähovi data are used e.g. in maintaining global

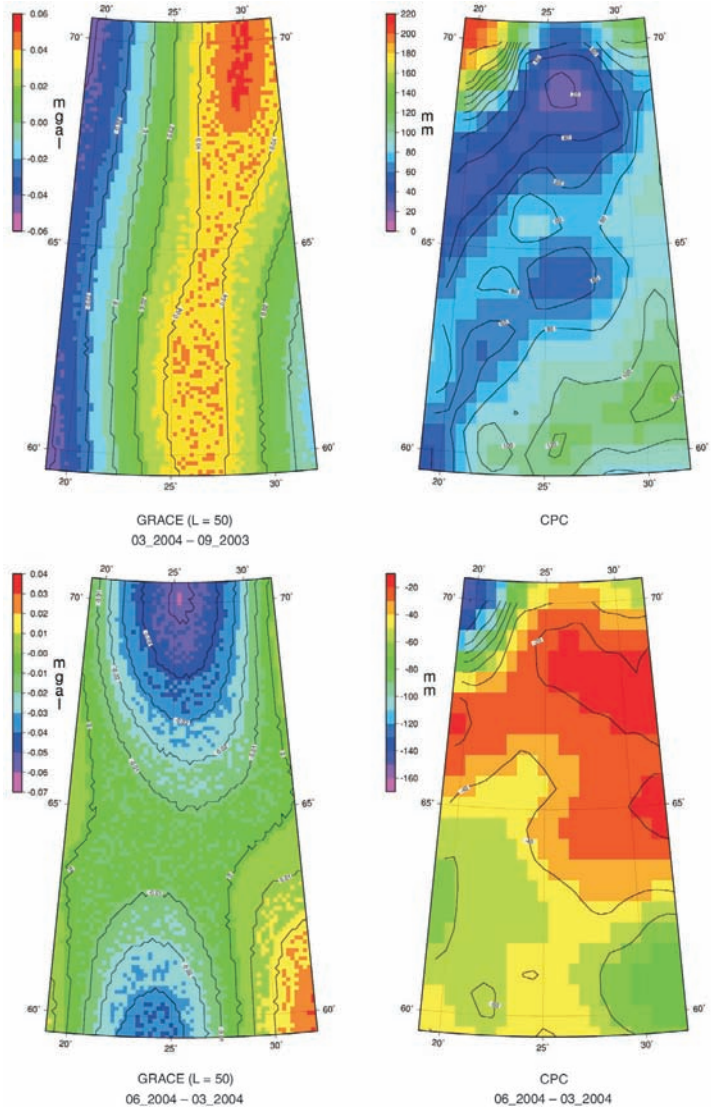


Figure 5.3. Change in gravity anomalies from GRACE (left) and water storage change from The Climate Prediction Center (right) between September 2003 – March 2004 (top) and March 2004 – June 2004 (bottom). During the first interval there is a large rise in total water storage and during the latter interval the water storage is decreased. (Courtesy of NASA)

reference frames, computing satellite orbits and geodynamics studies. The instrumentation covers the satellite laser ranging (SLR), geodetic VLBI, GPS and GLONASS receivers, DORIS beacon, superconducting gravimeter, seismometer and the fundamental absolute gravity point. Renewal of the SLR facility was started in 2005 and therefore no observations in the latter half of the year 2005 were made. Geodetic VLBI observations were continued in co-operation with the Metsähovi Radio Observatory of TKK. Metsähovi participates annually in four to six IVS (International VLBI Service) campaigns. VLBI data are used for determining the Earth Orientation Parameters (EOP), monitoring tectonic motions, and maintaining the global reference frame.

A study on the usage of gravimetric satellites CHAMP, GRACE and GOCE in geoid determination, and space-borne geoid model accuracies in Finland was made. FGI has the co-investigator status of the CHAMP satellite, which opened the possibility to use the CHAMP data products. Co-operation with the University of Stuttgart continued. In recent years especially studies of hydrology and its effect on gravity and loading were continued using the global watershed model of the Climate Prediction Center (CPC). Watershed Simulation and Forecasting System (WSFS) of the Finnish Environment Institute was also available.

A permanent GPS station at the Finnish Antarctic base Aboa was established in the beginning of the year 2003. During the field expeditions the data of the whole year are collected. Using data from repeated absolute gravity measurements, GPS and local kinematic GPS determination of snow/ice changes, allows us later to estimate the direction of the vertical crustal motion and the behaviour of the surrounding glacier. Currently three years of continuous GPS time series exist from Aboa.

In co-operation with the European Space Agency (ESA) a Ranging and Integrity Monitoring Station (RIMS) of the European Geostationary Navigation Overlay Service (EGNOS) was established in Virolahti, Finland. The RIMS will ensure the quality of the EGNOS service in Finland. The station is now in operation.

Helsinki University of Technology (TKK) Department of Surveying

In May 2005 TKK's Surveying Department's Institute of Geodesy was commissioned to re-measure (modernize) the base network of the city of Joensuu. This included the determination of transformation parameters from the local system to kkj (National Map Grid Co-ordinate System) and to the geocentric EUREF-FIN, in both directions. Staff and students participated in the work, which counts as a course.

During 2005, a software package for geodetic GPS vector computation was developed based on the GPS Toolkit from University of Texas at Austin. It, like the Toolkit, is available as free software under the Lesser GPL licence.

5.2 Earth observation and atmospheric sciences

Finnish Environment Institute Geoinformatics and Land Use Division

The Finnish Environment Institute (SYKE) is both a research institute and a centre for environmental expertise serving the whole of Finnish Environmental administration, local authorities, general public and private industry. The Geoinformation and Land Use Division (GEO) looks after the GIS and earth observation data, while also maintaining and developing information systems related to land use in Finland.

The remote sensing group at GEO provides the environmental administration with the earth observation data it requires. GEO operates the daily processing of the EO data (AVHRR, MODIS, MERIS), implements the information systems required, plan and develop the methodologies required in these systems and conduct research on remote sensing technology in order to support environmental monitoring with new EO based data. This includes validation of EO products with in-situ observations in addition to theoretical and experimental research on water optics and general spectral radiance measurements. The research and development work is completed in cooperation with national and international partners.

Presently operational, daily end-products are
- SCA-maps (snow covered area) during snow melting season,
- SST-maps (Sea surface temperature),
- water quality maps (chlorophyll-a and turbidity) during spring and summer
- algae bloom maps during surface floating cyanobacteria bloom period in July-August.

Production of there data is partly completed within GMES service elements.

During 2005 GEO completed the production of land cover information over Finland in European CORINE Land Cover 2000 project. The production was based on automated interpretation of LANDSAT 7 ETM images with aid of field data and data integration with national GIS data sets describing the land use and soils of Finland.

Figure 5.4. CORINE2000 data over Finland.

New oil spill detection system in the Baltic Sea (BORIS) has been taken into pre-operational use. Oil spills are detected using EO data (RADARSAT) and observations are integrated with environmental GIS data and combined with drifting models in near-real-time.

Finnish Geodetic Institute Department of Remote Sensing and Photogrammetry

Finnish Geodetic Institute (FGI), Department of Remote Sensing and Photogrammetry, concentrates on interpretation methods and new applications of digital camera images, laser scanning, BRDF and SAR. The group of about 15 researchers has coordinated four international projects during 2005 (2 EuroSDR, 1 Eureka, 1 bilateral) and the number of remote sensing projects during 2004–2005 exceeds more than 30. In the following three examples of projects carried out are depicted.

Field calibration and testing will be part of the future photogrammetric production line. Calibration will take the geometric, spatial resolution and radiometric properties of the sensors into consideration. FGI's Sjökulla test field with essential additional targets is a prototype for the future photogrammetric field calibration site.

Three leading digital photogrammetric systems (Vexcel UltraCamD, Intrgraph DMC, Leica Geosystems ADS40) were tested at the Sjökulla test field in 2004–2005. Images were also collected in Sjökulla in 2005 with two medium format systems, EnsoMosaic of Stora Enso Ltd. and DSS of Applanix. The UltraCamD and DMC are multi-head systems, which means that the large format image is a virtual image composed of several smaller format images collected with separate cameras; ADS40 works on a pushbroom principle. Testing of the geometric quality revealed that the multi-head sensors contain special geometric errors showing different systematic errors for each composite image. This systematic error can be detected from the residuals of the image observations. Despite these systematic errors, good point determination accuracy could be obtained. For instance, at the largest scales, with a ground sample distance (GSD) of 4–8 cm, the best accuracy was 1 cm in horizontal coordinates and 2–3 cm in height. In the radiometric testing and calibration a grey scale, painted on tarpaulins, was used. Accurate bidirectional reflectance distribution functions (BRDF) were measured in a laboratory using FGI's new automatic field spectrogoniometer, which is equipped with an ADS Field Spec Pro FR spectrometer. The grey scale can be used for the evaluation of the sensor's dynamic area, linearity, noise, stability and uniformity, and for the absolute calibration of the sensor. The linearity and dynamic area of DMC was good excluding the green channel. The green channel saturated on reflectance between 55% and 65%; the linearity was good in the area that was not saturated. Results of the tests have shown that the first generation digital photogrammetric sensors are of high quality, but that there is also room for improvement in the sensors' performance and the post-processing methods.

Due to the fast development of airborne sensors and methods during the last 5–6 years, it was accepted that under the EuroSDR Commission III "Production Systems and Processes", a joint test

Figure 5.5. The Sjökulla test field, test targets for the spatial resolution and radiometry.

was undertaken in order to compare various methods of building extraction. The objective of the EuroSDR Building Extraction comparison was to evaluate the quality, accuracy, feasibility and economical aspects of semi-automatic building extraction based on photogrammetric techniques with the emphasis on commercial and/or operative systems, semi-automatic and automatic building extraction techniques based on high density laser scanner data and semi-automatic and automatic building extraction techniques based on integration of laser scanner data and aerial images. The project consists of three test sites by the FGI and one test site by the Institut Geographique National (IGN) in Amiens. For each test site the partners were provided data of aerial images, camera calibration and image orientation information, ground control point coordinates and jpg images of point locations, laser scanner data and cadastral map vectors of selected buildings. 3D-models were obtained from 11 participants. Results show that laser scanning is superior in deriving building heights, extracting planar roof faces and ridges of the roof, whereas photogrammetry and aerial images are superior in building outline and length determination. In general the plane target accuracy is affected by the degree of automation; low degree of automation produced better accuracy. The target height accuracy seems to be almost independent of the degree of automation

Forests are living ecosystems, influenced by continuous natural and anthropogenic processes. Forest changes can be found either by detecting actual forest change or by executing an inventory twice on the same area. The goal of this study is to detect the changes in forested area using multitemporal laser scanner data. Main interests are forest growth estimation both at individual tree level and at plot level. Laser datasets used were acquired over Kalkkinen test site from three laser surveys conducted in September 1998, June 2000 and

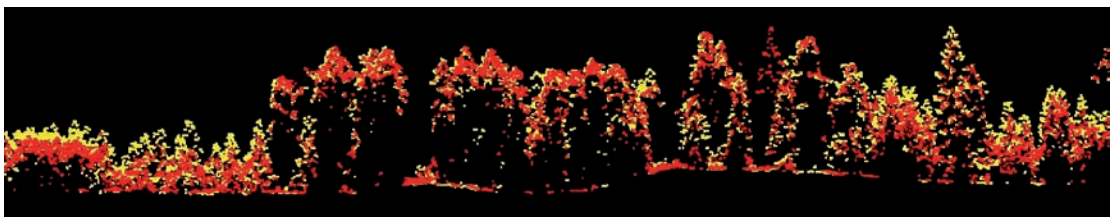


Figure 5.6. 3-m wide canopy profile for a 150-m long cross-section. Yellow: 2003, Red-1998. The growth of trees is easy to observe especially for young trees. The fallen tree (visible in red but not in yellow) is seemingly easy to detect.

May 2003 using the Toposys 83 kHz lidar system. Datasets have a point density of 10 points/m^2. Individual tree height growth was demonstrated using 82 sample trees (pine) and plot level growth, including tree height growth, DBH growth and volume growth, was estimated for 22 sample plots mainly consisting of Norway spruce, Scots pine and birch. In the study, different algorithms and methods are developed for growth estimation. Three different types of variables were extracted from the point clouds representing each tree/plot using different methods; they were the difference between the highest laser hits, the difference between the digital surface models (DSMs) of the tree crown and the differences between the 85th, 90th and 95th percentiles of the height histograms corresponding to the crown. Best correspondence with the field measurements for individual trees was achieved with an R^2 value of 0.68 and a RMSE of 43 cm. The results indicate that it is possible to measure the growth of an individual tree with multi-temporal laser surveys. At plot level analyses, the best result was obtained based on individual tree identification and matching. An improved tree-to-tree matching technique was used for linking the same tree identified from different acquisitions. The method is based on minimizing the distances between treetops in the N-dimensional data space.

Finnish Meteorological Institute Remote Sensing Unit

FMI has a long heritage in Earth observation where its expertise covers the whole chain of EO-mission from design of satellite sensors to EO-based operational services. During last years FMI has strengthened this chain by putting more efforts to ground segment, especially, at FMI's Arctic Research Centre in Sodankylä. FMI has continuous operational reception of satellite missions that currently include EUMETSAT Meteosat-series, NOAA polar orbiters, EOS-AURA OMI and EOS-TERRA MODIS. The data are used both in research and operational services.

The middle atmosphere research is based on combined use of data from satellites sensors, ground-based instruments and sophisticated modelling. Main part of data is obtained from FMI developed satellite instruments: OSIRIS on Odin, GOMOS on Envisat and OMI on EOS-Aura. The most important model is a three-dimensional chemical transport model FinROSE.

The Odin satellite has worked almost flawlessly since the launch in 2001. The Odin mission has already doubled its original lifetime expectation and in March 2006 the funding was secured for Odin to continue one year more. The only problem that has affected the scientific output is the quality of the attitude data. In order to correct this problem the whole Odin data set was reprocessed in 2005. The processing provides global distributions of ozone, nitrogen dioxide, and aerosols. The results will be compared and validated against several ground based instruments as well as satellite instruments including GOMOS.

Since the launch of Envisat in 2002 GOMOS has measured over 300 000 stellar occultations. The quality of the ozone profiles from GOMOS has turned out be excellent in statistical comparisons with ground based instruments. The global ozone distribution from GOMOS measurements in 2003 has also been compared with the well-known Fortuin-Kelder ozone climatology. A generally good agreement was found but differences in the polar stratosphere were also evident. This is connected to an enhanced polar ozone loss but also interesting connection to the Sun was revealed. The large solar proton outbursts lead to the precipitation of energetic protons to the polar atmosphere. The precipitation produces excess amounts of HO_x and NO_x that play a major role in the catalytic destruction of ozone. By GOMOS measurements it has been possible to monitor the increase of NO_x and loss of ozone in the polar night conditions. The detailed mechanism has been studied using the Sodankylä Ion Chemistry (SIC) model. A totally new research window has been opened by the two GOMOS photometers. Fast fluctuations in the stellar light intensity (i.e., scintillations) tell the fine structure in the neutral density field. This structure is caused by turbulence and waves in the stratosphere. By a complicated analysis of photometer data statistical properties of the stratospheric turbulence and waves can be estimated.

The FinROSE chemistry-transport model is based on the NCAR ROSE model. FinROSE is a 3D grid point model using a flux-form semi-Lagrange transport scheme. Simulations are typically run with a horizontal grid resolution of 10°x5° (long-lat) at 32 levels up to 0.1 hPa (ca. 65km) using ECMWF 6 hourly analysis or forecast meteorological data. The model features detailed middle atmospheric chemistry together with a detailed parameterisation for heterogeneous processing on/in liquid binary aerosols and PSCs, including PSC sedimentation and a NAT-rock parameterisation. The chemistry scheme includes 27 long-lived species/families, and 14 species in photochemical equilibrium with about 120 gas-phase reactions, 10 heterogeneous reactions and 37 photodissociation processes. The rate constants used for the chemical kinetics are according to the recommendations given in JPL 2000/2002. Photolysis rates are derived from a look-up table depending on solar zenith angle, ozone column and altitude. The look-up tables have been compiled using PHODIS-radiative transfer model. The chemical rate equations are solved by considering a chemical equilibrium state for short-lived species and a semi-implicit scheme is used for the integration of the long-lived species.

FinROSE is used to analyse chemical and dynamical processes in the atmosphere. The group has also started to assimilate satellite data into the FinROSE model. Presently, GOMOS and OSIRIS ozone profiles and a Kalman filter assimilation scheme are being used.

The Dutch-Finnish Ozone Monitoring Instrument (OMI) was launched in July 2004 onboard NASA's EOS-Aura satellite. So far the performance of both the satellite and the OMI instrument have been outstanding. FMI has developed for OMI the Very-

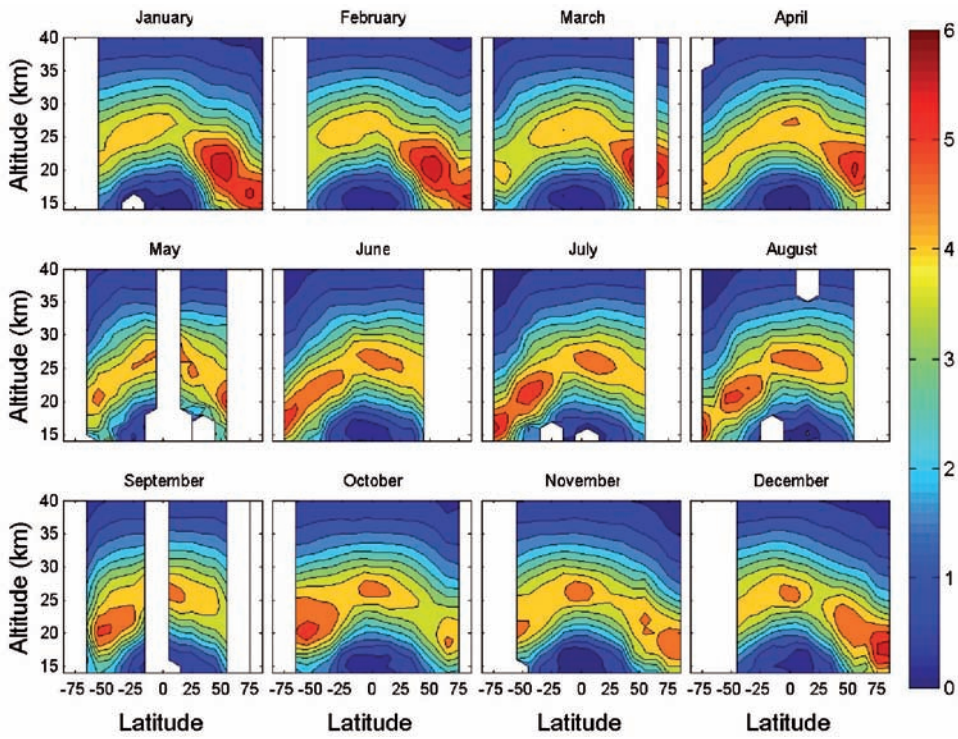


Figure 5.7. Ozone number density (in units of 10^{12} cm^{-3}) from GOMOS. White areas denote missing data. Instrumental problems in May-June 2003, the restriction to dark limb measurements, and the removal of low quality occultations are the sources of missing data areas. The contours are separated by 0.5 units. The figure shows clearly the ozone layer and its height dependence of latitude. The seasonal variations are also evident.

Fast-Delivery (VFD) processing scheme that enables fast utilization of ozone and surface UVB data. VFD is based on Direct Broadcast (DB) receiving of OMI data in Sodankylä during the overpass of the Aura satellite. The OMI data are processed immediately after the overpass and the resulting ozone and UV images are published in internet at http://omivfd.fmi.fi within 15 minutes after the overpass. The processing software for cloud and ozone product were developed by KNMI of The Netherlands, while the surface UV algorithm was developed jointly by FMI and NASA/GSFC. In addition to VFD processing FMI is responsible for production of global surface UV data from OMI. The primary objective of the campaign was to establish the performance of the satellite-retrieval and ground-based methods for ozone monitoring at low solar elevation angles.

FMI participates actively in four Eumetsat's Satellite Application Facilities that aim to produce operational services from EO-data. FMI coordinates activities in the Satellite Application Facility on Ozone Monitoring (O3M-SAF) while other partners come from The Netherlands, Germany, Greece, Denmark and France. SAF produces near real-time and offline products and validation services. Near real-time products are GOME-2 total ozone and ozone profiles, HIRS total ozone and UV clear-sky fields. Offline products derived from GOME-2 data are total column amounts of ozone, NO2, BrO, ozone profiles, aerosol index and optical depth and UV fields including cloudiness and albedo. The ozone and UV data will be validated against ground-based observations of total ozone and UV as well as balloon borne, microwave and lidar observations of the vertical distribution of ozone. An important part of the O3M SAF activities has been related to scientific work to develop radiative transfer calculation methods and other algorithms used for satellite ozone and related data retrieval.

The Satellite Application Facility on Climate Monitoring (CM-SAF) products are based on meteorological satellite data for climate monitoring, climate change detection and assessing the climate variability. The Operations Leading Entity is Deutscher Wetterdienst (DWD), which also is responsible for most of the operational processing. Other partners are from Belgium, Finland, The Netherlands, Sweden and Switzerland. The operational product list consists of cloud parameter products, components of the surface radiation budget and humidity composite product. FMI continues the development of the surface albedo product and has already demonstrated the albedo map for the Arctic area including sea ice albedo. The MSG/SEVIRI data based albedo product is already operationally processed and the NOAA/AVHRR based algorithm will be adapted to METOP/AVHRR, when the launch of METOP takes place.

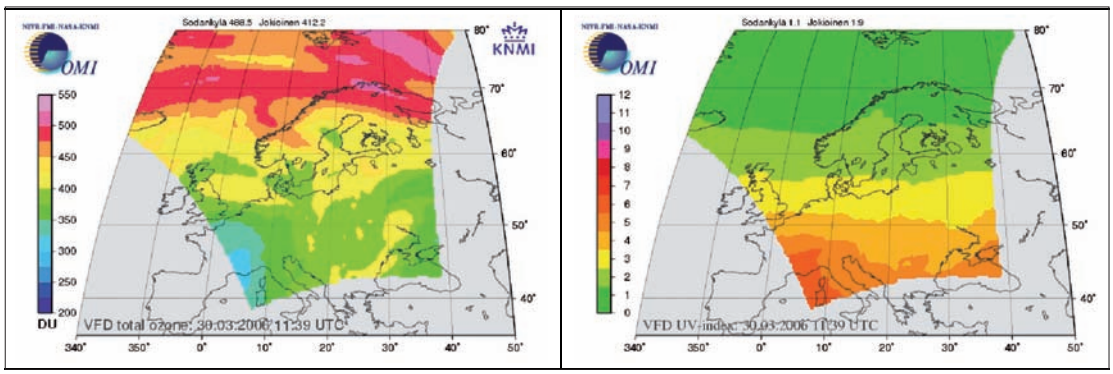


Figure 5.8. The total column ozone and erythemal UV index from OMI on March 30, 2006. The OMI data is received in Sodankylä satellite data centre during the overpass of the Aura satellite. Processing of the overpass data is performed within 15 minutes and the result images are published in internet at http://omivfd.fmi.fi.

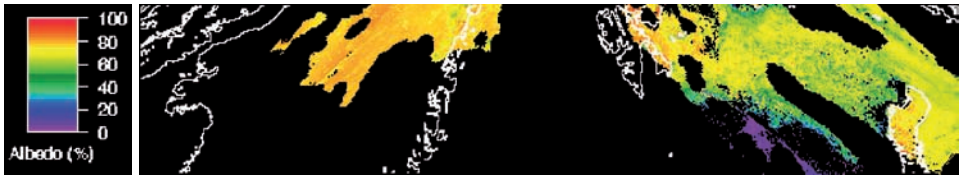


Figure 5.9. The monthly mean broadband surface albedo of the Arctic test area in April 2005. Clouds and water are masked black.

FMI participates also in the Satellite Application Facility on Land Monitoring, where FMI's task is to develop snow detection algorithm for flat areas, and in the newest Satellite Application Facility HydroSAF that develops services for hydrological applications on the field of precipitation, soil moisture and snow. The SAF is coordinated by Italy. FMI together with the Finnish Environment Institute (SYKE) and TKK is responsible for the development of snow monitoring services. Other participants include Germany, Austria, Poland, Romania and Turkey.

Methods for boreal forest leaf area index (LAI) retrieval using satellite images have been developed in co-operation with Department of Forest Ecology of the University of Helsinki and the Suonenjoki Research Station of the Finnish Forest Research Institute. FMI specialized in deriving an algorithm for LAI estimation using ENVISAT ASAR alternating polarization SLC images. The method will be further improved in the future with the high resolution Radarsat-2 data to enable species detection.

FMI is also coordinating the development of the Sodankylä-Pallas satellite CAL-VAL site in northern Finland. The data sets available for the Sodankylä-Pallas region include a large variety of atmospheric sampling, profiling and automatic surface parameter monitoring data from FMI, as well as various data sets from other co-operating institutes, such land cover characteristics from SYKE. The Sodankylä-Pallas satellite calibration and validation site is coordinated by the Arctic Research Centre of FMI and the activities of the site are related e.g. to the Nordkalotten Satellite Evaluation co-operation Network (NorSEN), and to the Global Atmosphere Watch (GAW) network.

Mesoscale analysis is an important step in developing better nowcasting methods for weather forecasting. In that analysis the remote sensing data (operational satellites mainly) is essential because of it's areal extent, short repetition cycle, real time availability and relatively good resolution. The Local Analysis and Prediction System (LAPS) is the main tool bench for this work. FMI is also active in several training courses on remote sensing (EUMETCAL, EUMeTrain, NOMEK). They consist of lectures, computer aided learning and distant learning sessions.

Geological Survey of Finland

The Remote Sensing group of the Geological Survey of Finland has during 2004–2005 worked for three major remote sensing topics:

- Comparison of satellite-borne Hyperion hyperspectral images with airborne Hymap hyperspectral images as tools for mapping environmental impact of mineral mining.
- Development of interpretation methods for mire (peat bog) types using airborne hyperspectral data.
- Development of Web Server for geoscience image/map data.

The aim of the HyMap-Hyperion comparison project was to test whether the classification of hyperspectral EO-1 satellite Hyperion data (from the Lahnaslampi talc mining environment in NE-Finland) can reveal approximately the same environmental features as can be achieved using the HyMap data. The environmental stress caused by mining impact in forest is very low in this test area. After supervised classification the resulting environmental classes from HyMap and Hyperion classifications were compared to each other.

HyMap data can map dust-affected vegetation around the talc mining area. Hyperion data are much noisier, but can, however, show the same largest environmentally analogous classes. Correlation between the HyMap and Hyperion overlapping channels are systematically high. Temporal changes between these airborne and satellite borne recordings do occur and the environmental features are not spectrally equal in HyMap and Hyperion data.

Remote sensing and identification of types of mire sites plays an important role when peat is considered as energy resource, but on the contrary, bogs can also be seen as long term sinks for carbon dioxide. The most common mire site types in the study area were spectrally well separable. Sphagnum dominated signatures were a 'Sphagnum fuscum bog' and a 'low-sedge fen' signature, and Carex dominated were a 'tall-sedge fen' and a 'flark fen' signature.

The map server tool GeoImage was developed for access, delivery and analysis of satellite image data combined with other geoscience image/map data. The server offers geo-referenced wavelet compressed satellite imagery and pixel maps on geology, geophysics, geochemistry and classical or hyperspectral airborne imagery from Finland. The data sets can be zoomed, panned and combined and images can be included in own documents. GeoImage tools will be publicly available by the end of 2006.

University of Helsinki
Department of Geography

Remote sensing research at the Department of Geography of the University of Helsinki started in 2002 and currently falls within Geoinformatics, one of the focus areas of the Department and the Faculty of Science. The emphasis of remote sensing research is on the development of methods for mapping land cover characteristics and its changes using optical satellite and airborne remote sensing data. Basic remote sensing research has been conducted into airborne and satellite data calibration, especially into the removal of bidirectional effects. The current fields of application are land use change detection, developing methods for glacier monitoring and testing new satellite data for forest vegetation and land cover mapping. The study ar-

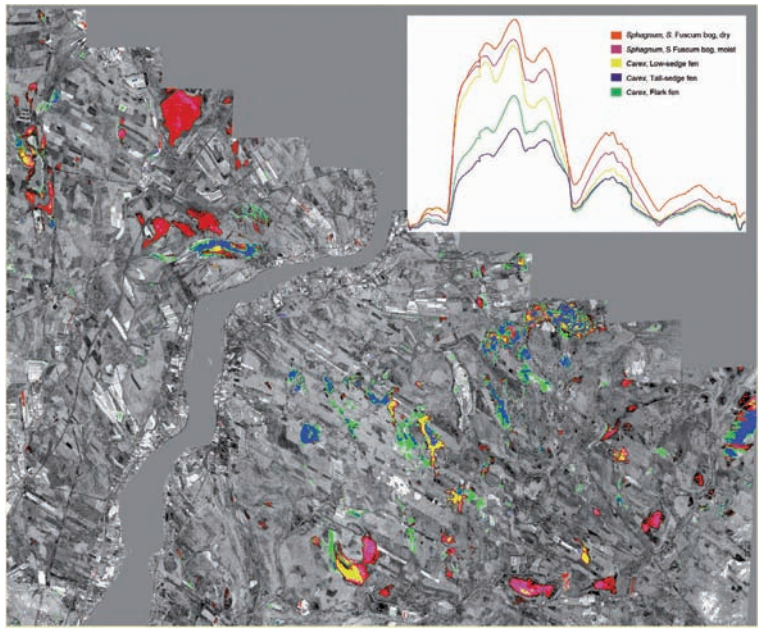


Figure 5.10. Example of mire site classification in Northern Finland near the town of Kemi. Width of the area is 19 km

eas are Northern Finland, the Alps and Kenya. The GeoInformatics Research Group (GIRG) also hosts an airborne false/true colour airborne digital camera system and related flight planning, navigation and processing software for airborne remote sensing data acquisition.

The department was involved in the OMEGA project, which focused on development of glacier monitoring methods and systems using airborne and spaceborne remote sensing data, from airborne laser scanner data through to optical satellite data. The 3-year project was funded by the European Commission and finished in 2004. The GIRG developed methods for semi-automated glacier delineation, glacier zone mapping and glacier change detection in Ötztal, Austria, using Landsat TM and ETM+data. Another research field was the applicability of airborne false colour digital camera data for mapping glacier zones in the same area.

The main current research project is the TAITA project, which is focusing on the development of land use change detection methodologies using remote sensing and GIS, and applying the created databases for conservation and development. In the first 3-year phase remote sensing data from 1955 to 2004 was compiled, processed and analysed, while in the second 4-year phase the database will be applied for studies related to soil erosion modelling, forest fragmentation and connectivity studies, and for the development of participatory rural appraisal methods. Mapping of the landscape through remote sensing techniques has utilised both multi-temporal SPOT XS satellite imagery and detailed 0.5m resolution digital aerial photo mosaics. Extensive field work has been conducted to gather training areas and ground reference test data, and remote sensing research has focused on the methodological development of calibration, classification and change detection techniques to enhance the accuracy of land cover mapping in this complex heterogeneous environment. A comprehensive GIS database covering the socio-economic as well as the environmental aspects of the study area in south-western Kenya is being constructed and the results made available to Kenyan and international partners via an ArcIMS powered web service. The project also

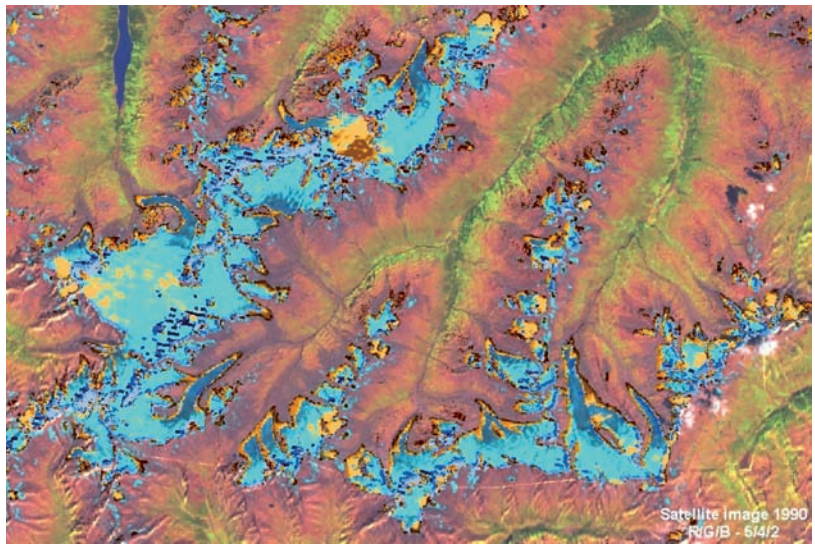


Figure 5.11. Glacier loss in the Öztal region of Austria studied by Landsat TM/ETM+ data between 1985 and 2002. The brownish tones by the glacier edges indicate glacier loss of different epochs.

provides GIS and remote sensing training for the Kenyan counterparts for capacity building.

The northern boreal forests of Finland have been studied using ASTER, MODIS and MISR data. The suitability of visible to shortwave infrared ASTER data at 15 m and 30 m resolution for estimating forest biophysical variables, aboveground tree biomass and the leaf area index (LAI) in the tree line mountain birch forests has been tested in a set of studies in northernmost Finland. The results indicate significant relationships between the biomass, LAI and ASTER data. The best models were applied for biomass and LAI mapping, and to calculate biomass and LAI statistics for the most widespread subalpine mountain birch forest types. The ASTER data has also been used together with stand wise forest inventory data for estimating the biomass of boreal forest stands in mineral soils. Non-linear regression analysis and neural networks were applied to develop models for predicting biomass according to stand wise ASTER reflectance. The ASTER bands appeared to be sensitive to tree biomass, in particular the green band.

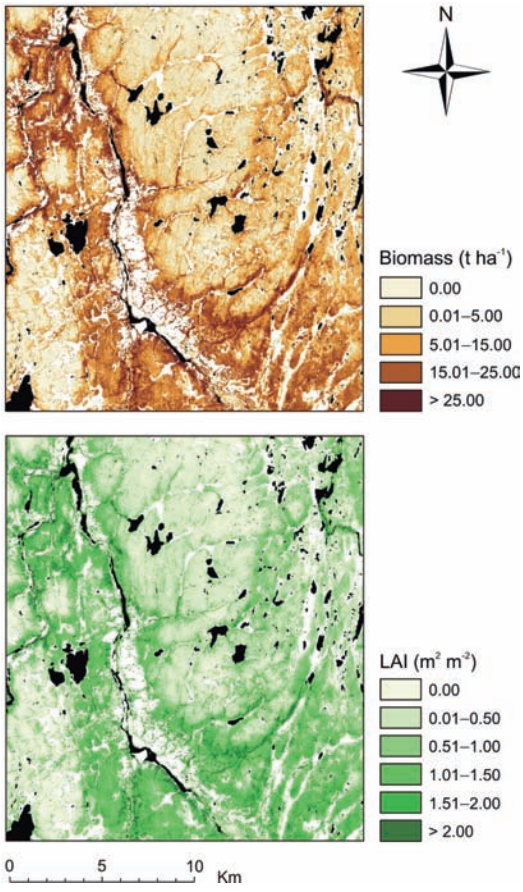


Figure 5.12. Predicted biomass and LAI surfaces in mountain birch forest in northernmost Finland using ASTER satellite data. Black areas are water, while white areas are pine forests and mires.

In addition, the potential of multiangular MISR data at 275 m and 1.1 km resolutions to estimate tree cover and height in northernmost Finland has also been studied. The tree cover and height were estimated using neural networks, which were trained and assessed by high-resolution biotope inventory data. The estimation errors reduced considerably when multispectral nadir data were used together with multiangular data. All the spectral-angular data together produced lower estimation errors than single band nadir, multispectral nadir or single band multiangular data alone. The results suggest that directional information has potential to improve tree cover and height estimates in the tundra-taiga transition zone.

In addition to boreal forest studies, other biogeographical applications have been remote sensing of aquatic vegetation and forest damage. BRDF effects were studied on false-colour aerial photography over aquatic vegetation as well as changes of the vegetation pattern in inland lakes of Finland. Forest damage caused by ice storms was mapped using optical airborne and satellite remote sensing data in temperate Canadian forests in cooperation with Carleton University.

A new research field for the group is hyperspectral remote sensing through an EC-funded SSA project HYRESSA (Hyperspectral remote sensing in Europe). The project studies the user requirements and data providers of hyperspectral remote sensing data within EU member states.

University of Joensuu
Faculty of Forestry

During recent years the research on remote sensing at the University of Joensuu, Faculty of Forestry has mostly concentrated on applications that utilize high resolution remote sensing data of digital photographs and airborne laser scanning (ALS) images.

The doctoral thesis of Perttu Anttila "Assessment of manual and automated methods for updating stand-level forest inventories based on aerial photography" tested the applicability of different inventory and updating methods that are based on aerial photography for the regional forest inventory of private forests in Finland. Four approaches were chosen: 1) stand level visual interpretation of changes and simulation of stand development, 2) automatic, stand level interpretation of aerial photographs utilising nonparametric estimation, 3) automatic, photogrammetric estimation of mean height, and 4) automatic, monoscopic identification of individual trees. Approaches 1 and 2 are inventory or updating methods, while approaches 3 and 4 can be considered as components of such methods. Approach 1 was found to be appropriate for operative use for estates that have not ordered a forest plan, provided that the strict prerequisites for the inventory area are met. The accuracy of approach 2, as such, was not considered to be high enough for forest planning, but this very inexpensive method could turn out to be applicable, if its accuracy could be improved. Approach 3 was based on image matching and would be most useful as a part of other methods, like template matching in multiple images. Although only identification of trees was tested in approach 4, the applicability of whole single tree based inventory method was appraised. Relatively high costs and low accuracy limit the possibilities to use this method, in practice.

The project "The usability of single tree laser scanning in forest planning " concentrated on the examination of basic accuracy of single tree estimates, change detection, development of crown segmentation methods, determination of multilayered forests and regression based laser scanning approach. The project was carried out in co-operation with the Finnish Geodetic Institute.

In the study area of boreal forest reserve including highly heterogeneous stand structures the reliability of laser scanning based individual tree height estimates has been found to be very good (error less than 1 m). Over 80% of the dominant trees were detected. Due to the dense understorey tree layer in most of the sample plots, only about 40% of all trees were detected. Detection of suppressed trees from a height model based on laser scanning is difficult, but it is possible to predict these trees by using theoretical distribution functions. Two

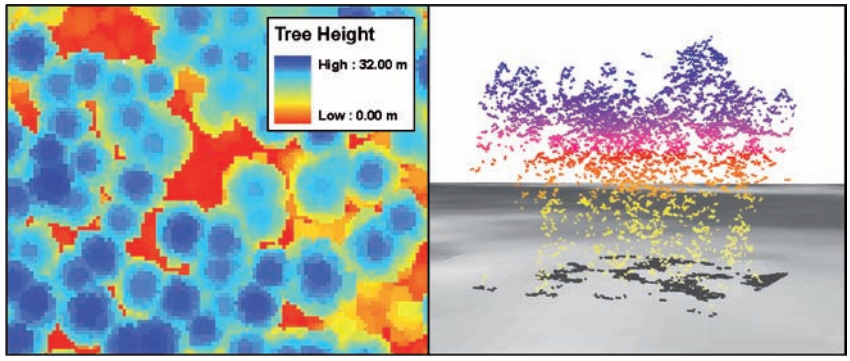


Figure 5.13. Basic principles to utilize the ALS data: The detection of individual trees (left) and canopy height distribution method (right).

different methods were used to predict small trees. The results showed that the Root Mean Square Error (RMSE) for the timber volume was about 25% when using only information obtained from laser scanning. The use of the parameter prediction method to describe small trees improved the accuracy considerably; the RMSE being 16.0%. When a left-truncated theoretic height distribution was used to predict the heights of the missing small trees, the RMSE was 22.5%.

Applicability of small footprint, high sampling density airborne laser scanner data for boreal forest change detection, i.e. forest growth and monitoring of individual fallen and cut tree, was demonstrated for the first time. Two laser acquisitions, one in September 1998 and another in June 2000, were carried out in Kalkkinen using Toposys-1 laser scanner. Novel algorithms were developed for the general change detection, individual cut and fallen tree detection and forest growth measurements at plot and stand level. The obtained results were very accurate and promising.

In the case of individual tree detection, one problem on aerial images or on raster canopy height models is handling of tree crowns of different sizes. On laser scanner data one size attribute, height, is directly available. Three different adaptive methods for individual tree detection on the canopy height model were developed.

Laser scanner data produce accurate information on a tree canopy since the quantiles of the height distribution of laser scanner data are related to the vertical structure of the tree canopy. Since some of the laser pulses will penetrate under the dominant tree layer, it may be possible to analyse also multilayered stands. The results showed that multi-layered stand structures can be recognised and quantified using quantiles of laser scanner height distribution data.

Finally, three laser scanning based volume prediction methods were compared: a direct prediction model for the stand volume, a volume prediction system based on the modelled percentiles of the basal area diameter distribution, and a parameter prediction method used to determinate Weibull based diameter distributions for the volume prediction. The accuracies of the tested prediction methods were almost equal and superior when compared to the other published results of both remote sensing studies and also practical field assessments in Finland.

Some other main research projects are “Monitoring system based on modern remote sensing imagery for natural forests and restored forests of conservational areas 2005–2007” funded by Finland’s environmental administration. Both ALS data and digital aerial photographs are used in this project which co-operation partners are the Finnish Forest Research Institute and the Finnish Geodetic Institute. The study area is Koli National park. In the projects “Laser scanning based estimation of stand characteristics” and “Estimation of stand characteristics of marked stand using laser scanning and harvester data 2005–2006” mainly ALS data were used. The co-operation partner of the first project was the Forest Development Centre TAPIO.

The main aim of the project “The use of airborne laser scanning in the estimation of accurate forest resources 2005–2007” is to develop remote sensing data based forest inventory system. Both digital aerial photographs and ALS data are used. UPM Kymmene, Arbonaut Oyj and the Forest Development Centre TAPIO are also involved. Finally University of Joensuu, Faculty of Forestry is also involved in the project “Measurement techniques for forest change detection using ALS 2005–2207”, led by the Finnish Geodetic Institute.

Finnish Forest Research Institute (METLA) Multi-Source National Forest Inventory of Finland (NFI)

The Finnish Forest Research Institute, Metla, is an impartial state research organization founded in 1917. The National Forest Inventory (NFI) is one example of official duties of Metla. NFI has produced large-area forest resource information for 85 years. Since late 1980s, the NFI has applied the multi-source forest inventory method that combines information from field measurements with satellite images and other numeric data sources (multi-source national forest inventory, MS-NFI). The method produces forest resource information for smaller areas than is possible using sparse field data only, like for municipalities, and also thematic maps about forest resources. MS-NFI products are employed as input information in small area forest management planning by forestry authorities and for timber procurement planning by forest industries. Furthermore, the results have been applied in ecological studies and in other research purposes.

The MS-NFI method is under continuous development. Recently, a method to utilise large area variation of forests as additional information and genetic algorithm based optimization in feature weighting were introduced. Updating of NFI field plot data based on multi-temporal satellite images and growth model has been developed and applied. Model based approaches have been developed for error estimation and for an alternative to k-NN estimation.

The MS-NFI team is firmly established in the field of forest remote sensing. The MS-NFI method has been successfully tested or applied also outside of Finland, and its further development work is going on. Examples are Austria, China, Germany, Ireland, Italy, New Zealand, Norway, Poland, Sweden and USA.

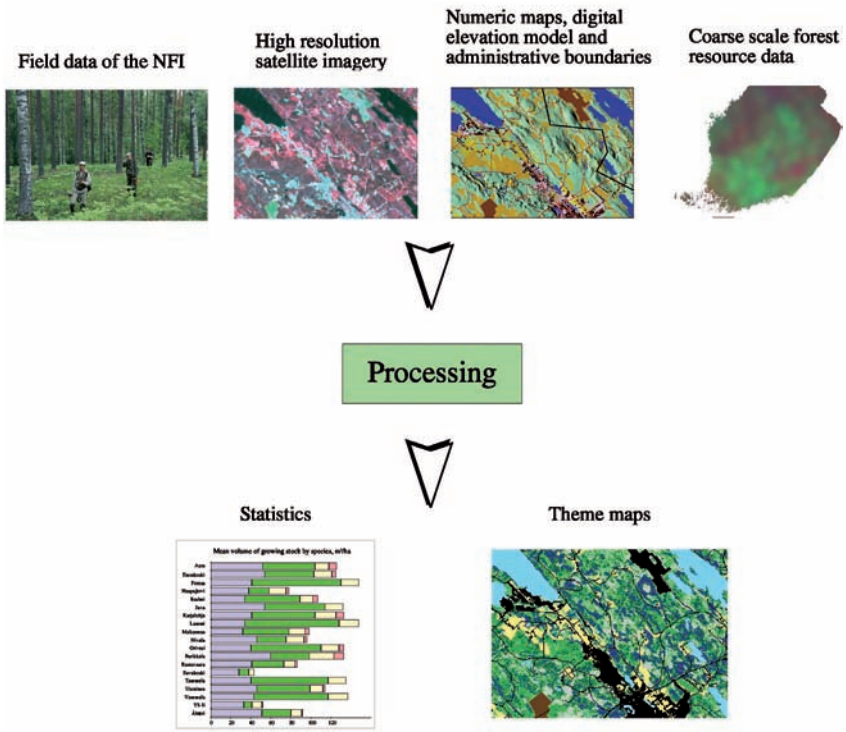


Figure 5.14. The Multi-Source National Forest Inventory employs field data satellite images, digital map data including digital elevation model, large scale variation of forests and administrative boundaries, and produces forest resource information for small areas and thematic maps.

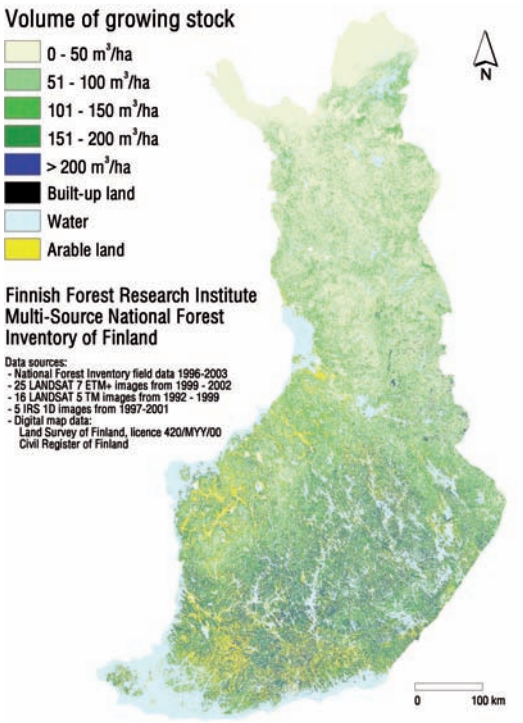


Figure 5.15. Map depicting the volume of growing stock, produced in the Finnish multi-source national forest inventory. Note that the classification is done for the visual image. The unit in the original digital data is 1 m^3/ha.

The current research activities of the MS-NFI team include:

- Maintaining Multi-Source Finnish forest resource information
- Developing of advanced multi-source estimation methods, examples are Bayesian methods, regression methods and improved k-NN methods
- Developing model-based error estimation methods.
- Updating of NFI -information by means of remote sensing data (an operative method has been developed and applied at regional level)
- Utilisation of imaging spectrometry in large area forest inventories
- Utilisation of SAR data in large area forest inventories
- Estimating carbon balance of forests.

5.3 Space Technology

Helsinki University of Technology (TKK) Laboratory of Space Technology (LST)

A significant level in seasonal snow melt monitoring has been reached at TKK/LST. The in-house developed satellite SAR-based Snow Covered Area (SCA) estimation method has been implemented for operational use. The system utilizes commercially available Radarsat Wide Swath data to produce Snow Covered Area (SCA) maps during the snow melt season. The method has been developed in close co-operation with the Finnish Environment Institute (SYKE), and is being taken into operational use during spring 2006 within SYKE's Watershed Simulation and Forecasting System (WSFS). The main advantage of the satellite SAR-based method is the ability to produce information on snow cover independent of weather and illumination conditions. The alternative method, already in use in the operational WSFS, is based on optical remote sensing data; the availability of optical data is dependant on solar illumination and cloud-free weather. The novel snow monitoring system shall utilize both the optical data and the SAR data, thus incorporating the benefits of both data sources to enhance the capabilities of the Watershed Simulation and Forecasting System.

The research on the remote sensing of water quality in Finnish lakes and coastal areas has continued at TKK/LST during 2004-05 with participation in several national and international water quality related projects. The main research partners have been Finnish Environment Institute (SYKE) and Finnish Institute of Marine Research (FIMR). The goal of the research has been not only to create maps of water quality parameters such as turbidity and chlorophyll-a, and to improve the accuracy of the estimation, but also to develop methods for disseminating that information to potential end-users in a timely manner. For example, the turbidity algorithm developed at TKK/LST has been in use at SYKE and the resulting turbidity maps of the Gulf of Finland have been published in Internet usually only one day after the data was acquired by the satellite. In 2004 TKK/LST acquired, in collaboration with SYKE, two portable spectrometers that operate in the vis-

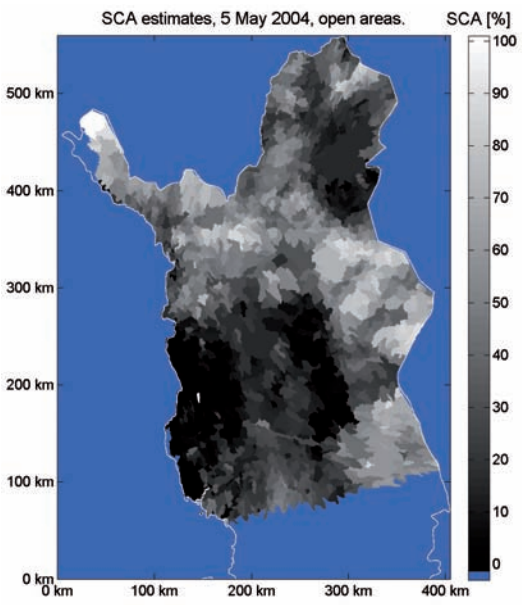


Figure 5.16. An estimate for Snow Covered Area (SCA) (%) for open areas in northern Finland on 5 May 2006, generated from a Radarsat SCW image.

ible and near-infrared region and can be used during *in situ* measurement campaigns. The data they provide will be used for improving bio-optical models, characterizing the effects of the air-water interface on the optical signal, and the development of methods for atmospheric correction.

A semi-automatic flood detection system for spaceborne SAR images has been developed by TKK/LST. The system is based on the Active Contour Model that is a snake algorithm, utilising SAR image statistics in the area delineation process. It has been shown that this method can struggle the noise and the wind induced effects in SAR images unlike e.g. the traditional thresholding method. The system is designed to be nearly automatic, requiring as its only input a configuration file consisting e.g. of the parameters of the SAR scene to process. Both ERS-2 and Radarsat SAR images were used to evaluate the water area delineation performance. An accuracy validation in a metrical scale was conducted with a multisensor data set. The tests that were run suggest that the

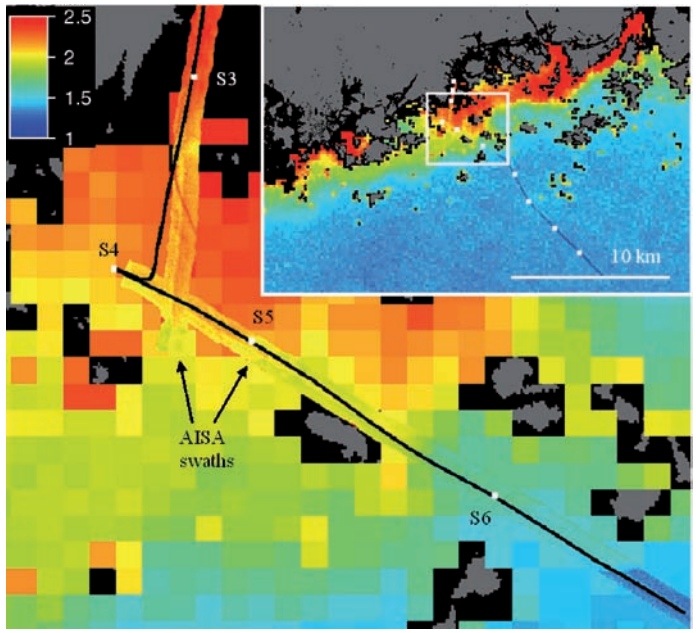


Figure 5.17. The absorption of colored dissolved organic matter (CDOM) at 400 nm near the city of Helsinki on April 27, 2004 estimated with MERIS and AISA.

system can reliably detect and delineate all up to moderate size of water bodies with good accuracy.

TKK/LST operates its airborne 36.5 GHz fully polarimetric radiometer. Recently the radiometer has been used to investigate the retrieval of wind speed and direction using polarimetric radiometry over the Gulf of Finland. The measured parameters have among others dependency on the incidence angle and this effect has been studied with the latest results in order to improve the retrieval accuracy.

Correct classification of remotely sensed imagery is a problem, because the parameters of interest are not directly measured. With indirect measurements variables like brightness, backscatter, colour, polarization, texture and shape, are used to estimate the stem volume, for example. Pixel-wise classification based on polarization responses has been developed by TKK/LST for large-area characterization. Three teaching areas were selected for classification: Forest, farmland and water.

The Calibration System (CAS) instrument for the SMOS interferometric radiometer has been developed by Elektrobit Microwave Ltd; TKK/LST has been the main subcontractor, being responsible for the testing of CAS. The development philosophy of CAS included prototypes and three other models; Structural and Thermal Model (STM), Engineering Model (EM) and Flight Model (FM). The prototypes were applied to verify the design at block diagram level, EM was used to qualify the overall design (including mechanical, electronics, thermal and microwave design) with representative electronics components. Also, EM was applied to consolidate the test program and characterization approach. In the manufacturing of FM, ESA's product assurance requirements were applied in full. After manufacturing, a rigorous test campaign, including both characterization and environmental tests, was carried out.

The engineering model and flight models of the reference radiometer of the ESA near-future SMOS satellite were manufactured by Elektrobit Microwave Ltd. TKK/LST conducted testing and characterization to the units. The units went through an extensive campaign including characterization, vibration, thermal vacuum cycling and EMC tests. During the project TKK/LST has de-

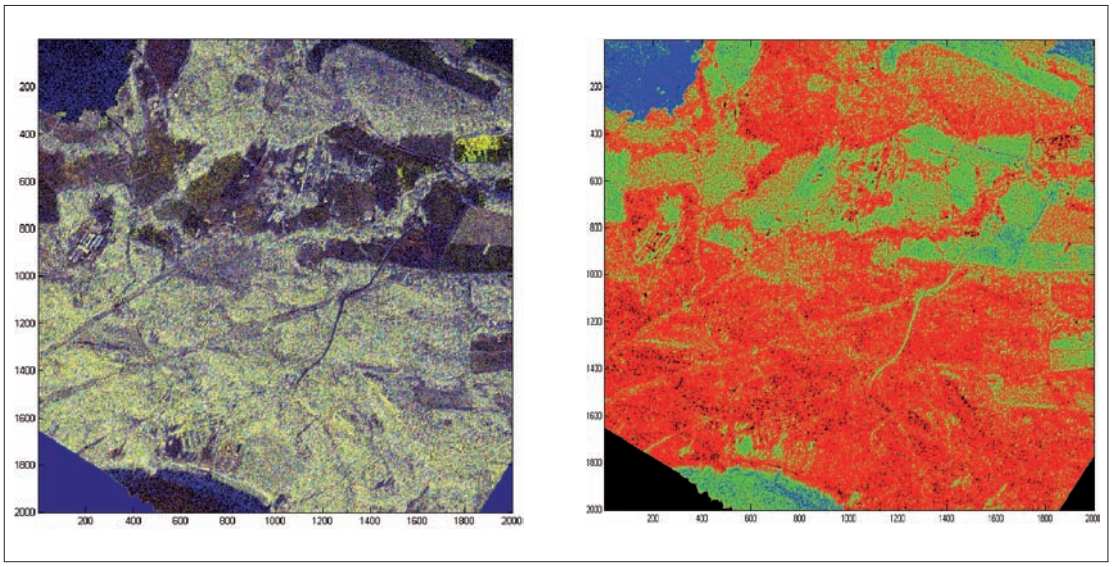


Figure 5.18. *Left:* Optimized L-band SAR image (left): maximum backscatter in red, minimum in green and maximum polarization in blue. *Right:* Classification results. Areas likely to be forested are in red, farmland in green and water in blue.

veloped new radiometer measurement and calibration techniques. The reference radiometer is a decisive factor for the performance of the interferometric radiometer onboard the SMOS satellite.

TKK/LST is developing a novel L-band airborne radiometer using two-dimensional aperture synthesis (HUT-2D) for remote sensing purposes. The instrument is similar to that onboard the European Space Agency's (ESA) SMOS (Soil Moisture and Ocean Salinity) satellite. The HUT-2D instrument is accommodated under the TKK research aircraft fuselage. The instrument consists of total 36 L-band receivers in U-shape geometry. The receiver outputs are digitally sampled and correlated to achieve an image of the target without any mechanical scanning with good geometric resolution. Test flights have been conducted with an instrument subassembly and the results have been promising. The instrument integration and final tests are under way.

Helsinki University of Technology (TKK) Radio Laboratory

The TKK Radio Laboratory has carried out research in satellite application oriented antenna measurement techniques and instrumentation development at millimetre and submillimetre wavelengths. This work has been done together with MilliLab. The main focus has been in developing the hologram based compact antenna test range (CATR). Recently, a new project was started with ESA/ESTEC aiming at the Planck RFQM antenna test at 650 GHz in the end of 2006.

Millimetre Wave Laboratory of Finland (MilliLab)

MillimetreWave Laboratory of Finland (MilliLab) is a joint laboratory between VTT, Technical Research Centre of Finland and TKK, Helsinki University of Technology. MilliLab is also a European Space Agency Centre of Competence called ESA External Laboratory on Millimetre Wave Technology. MilliLab was established in 1995. Its main purpose is to support European space industry to meet the demands of future ESA missions, which will include an increasing number of millimetre wave instruments for astronomical and remote sensing applications.

MilliLab supplies services at millimetre wave frequencies in the field of device modelling, device characterisation, measurements, testing, research, and development. The parent organisations of MilliLab, VTT, and TKK have a substantial amount experience and expertise in the field of microwave and millimetre wave technology.

A low noise receiver for the ESA Planck mission and an antenna test method for future mm-wave space telescopes are the main development projects in MilliLab, related to space applications. In the Planck Low Frequency Instrument (LFI) MilliLab's responsibility together with Elektrobit Microwave Ltd. is to design and construct the 70 GHz receivers. In order to obtain maximum sensitivity, the receiver is divided into a front-end cooled to 20 K and a 300 K back-end. The most vital parts of the receiver are the Low Noise Amplifiers (LNA) to be realised by utilising the InP MMIC technology. The use of integrated circuits is important due to the large number of receivers in the LFI. Altogether 6 identical back- and front-end receiver chains will be made in Finland.

Presently, development of the Protoflight Model (PFM) of the 70 GHz receivers has been finished, and the receivers have been sent to Italy for integration in the LFI. Currently 70 GHz Flight

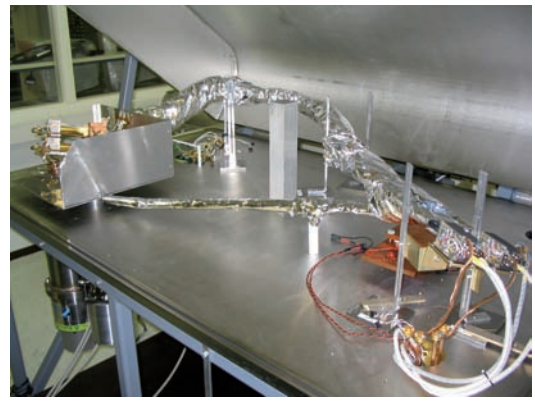


Figure 5.19. A pair of Planck Low Frequency Instrument 70 GHz Radiometer Chain Assemblies under test at the large cryogenic chamber in Elektrobit Microwave.

Spares (FS) manufacturing has started. With the PFMs, extremely low noise temperatures have been obtained. A system noise temperatures between 26 and 36 K have been measured over the required 63-77 GHz band for the six 70 GHz full Radiometer Chain Assemblies (RCAs).

The main scientific goal for the ESA Planck mission is to measure Cosmic Microwave Background (CMB) radiation anisotropy. A consequence of the unprecedented angular resolution and the measurement sensitivity of the background radiation is the possibility to uncover the wealth of cosmological information encoded in the anisotropy pattern.

In addition to the 1.5 m telescope and LFI, the Planck spacecraft will have the High Frequency Instrument (HFI) on board. The LFI comprises receivers for 30, 44, and 70 frequencies. The HFI, for its part, has receives for frequencies of 100, 143, 217, 353, 545 and 857 GHz using bolometers. Planck will be launched to the sun-earth synchronous L2 orbit in 2008 together with the Herschel spacecraft.

VTT Technical Research Centre of Finland

VTT is the biggest contract research organisation in Northern Europe. VTT provides high-end technology solutions and innovation services. With its about 2700 employees, VTT can combine different technologies, create new innovations and a substantial range of world class technologies and applied research services thus improving its clients' competitiveness and competence. In the field of Remote Sensing the annual volume of the research work in the years 2004–2005 has been 15 man-years.

VTT develops advanced image interpretation methods for analysing the information content of digital satellite images. The field of expertise is remote sensing of the natural environment, particularly forestry applications, including the whole value-adding chain from geometric and radiometric processing up to the delivery of versatile mobile and fixed platforms. VTT also does research in the fields of data fusion, sensor webs and GIS. The VTT Remote Sensing team is a forerunner in the utilisation techniques of Earth observation data, helping their customers to improve their competitiveness by timely and research-based information on the environment. VTT is involved in the research network that comprises key actors in Earth observation in Europe, North America and Japan. International cooperation is mostly connected to ESA and EU projects and to the exchange of personnel. VTT carries out projects for international customers in collaboration with domestic companies.

VTT has been participating in the following research projects:

- Environmental monitoring system ENVIMON
- GMES Service Element: GSE Forest Monitoring funded by ESA.
- Prediction of natural disasters, such as landslides using SAR interferometry (co-operative work with a Japanese research institute).
- SAR image mosaic of Europe and Northern Asia
- TESI – TerraSAR Exploitation and Service Infrastructure Consolidation – Forest Inventory Service
- ENBOR-2 – Mapping of Boreal Forests based on ENVISAT satellite imagery
- CORINE Land Cover: Methods and tools for satellite image reflectance calibration and interpretation
- ViewIce – Route planning tool for icebreakers.

The ENVIMON project started in 2004 and will last up to 2006. The mission of ENVIMON is to make the environmental monitoring efficient and accurate with cost-effective manner for the participating organizations. Main objective was to build a system to meet diversified environmental monitoring needs. In the project a common software framework EOFrame has been designed and implemented. The six Earth Observation applications built in the project utilizes the resulting software platform. This opens new possibilities for the development of novel environmental monitoring applications to be made in an effective and time-saving manner.

GSE Forest Monitoring (GSE–FM) is a unique multi-disciplinary enterprise funded by ESA delivering a suite of standardised products and ser-

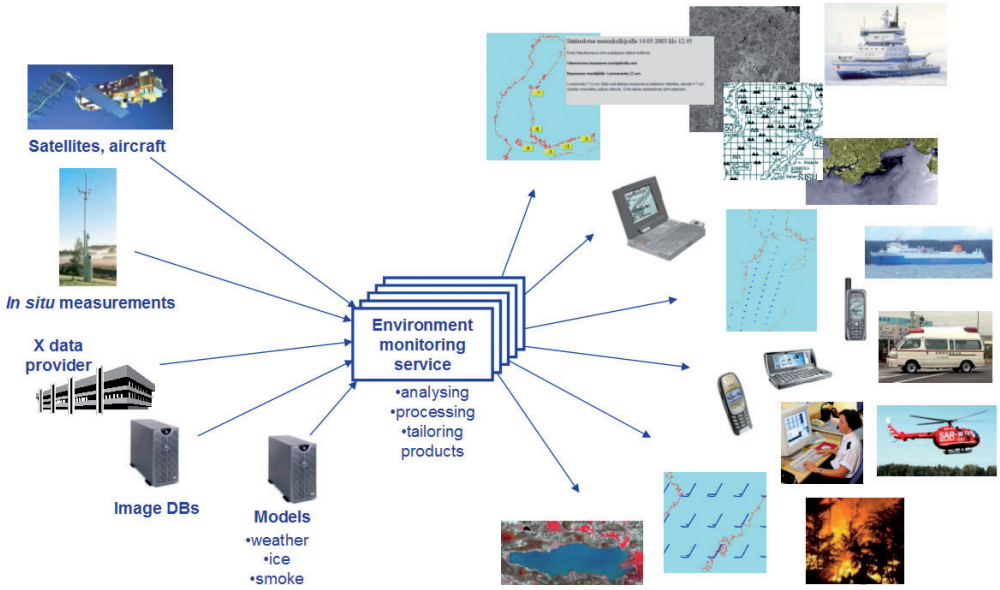


Figure 5.20. The ENVIMON concept employs diverse data sources. It pre-processes, analyses and prepares the data into proper products, and delivers them at the right time, in the right form and via the appropriate channel to different end users that use diverse terminal equipment.

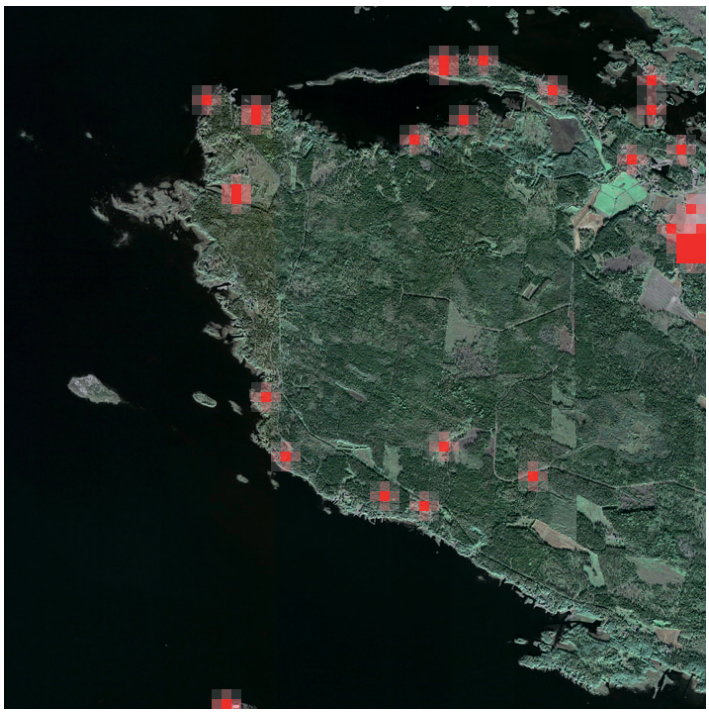


Figure 5.21. Self-Organizing Maps (SOMs) can be successfully applied to content-based image retrieval. The potential of PicSOM, an image database browsing system, applied to remote sensing images to detect targets like houses, roads or man-made structures, as well as changes between two QuickBird images, has been investigated.

vices to support forest monitoring activities. GSE-FM supplies accurate, timely and readily available information on the state of forests to a variety of users and beneficiaries. VTT has participated as a service provider in the GSE-FM consortium led by a German coordinator GAF AG.

In the co-operative work with the Japanese research institute NIED (National Research Institute for Earth Science and Disaster Prevention) the main target is to study the potential methods of repeat-pass interferometry in view of using SAR data in forecasting land slides by detecting minor (of the order of 10 cm) land surface movements that are supposed to be present before landslides occurs. The co-operation initialized in 2002. Recently the research work has been focused on an interferometric quantity called triherence that was adopted for mapping of points where the interferometric phase is stable over at least one triplet consisting of three consecutive SAR scenes. The prototype software for triherence computation was delivered to NIED and it can be tested using SAR data from the new ALOS PALSAR instrument.

In the context of the Global Boreal Forest Mapping project (GBFM), an initiative of the national Space Development Agency of Japan, a continental scale radar mosaic of the Eurasian Taiga was compiled. The mosaic is composed of blanket observations of this ecosystem acquired by the L-band radar instrument on-board the JERS-1 spacecraft. The pixel spacing is 100 metres and the map projection is Albers equal area conical. Results obtained so far indicate that the Eurasian GBFM mosaic constitutes an important source of information about an area of the world that hosts a series of natural and human induced processes of great relevance for global change studies and environmental sustainability.

TESI – TerraSAR Exploitation and Service Infrastructure Consolidation was an ESA Earthwatch project running from 2004 to 2005. It was linked directly to other TerraSAR-related activities. VTT participated in TESI by developing Forest Inventory Service that was one the eight services delivered to reference users within a well-defined and thoroughly documented road test scenario. The Forest Inventory Service provides forest cover

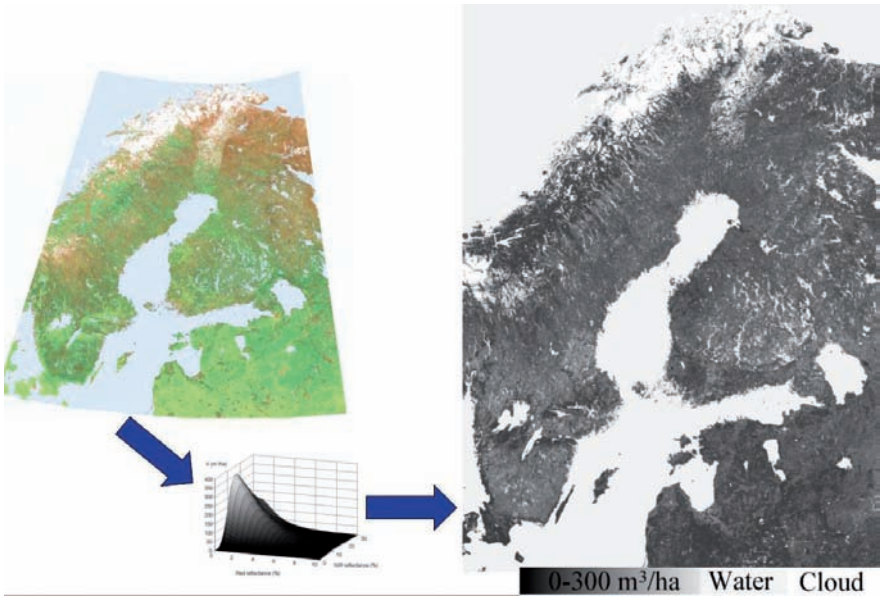


Figure 5.22. Forest stem volume estimate has been computed for Modis mosaic of pixel size 250 m using biomass function method developed by VTT.

maps and maps about forest characteristics using high to medium resolution Earth observation data.

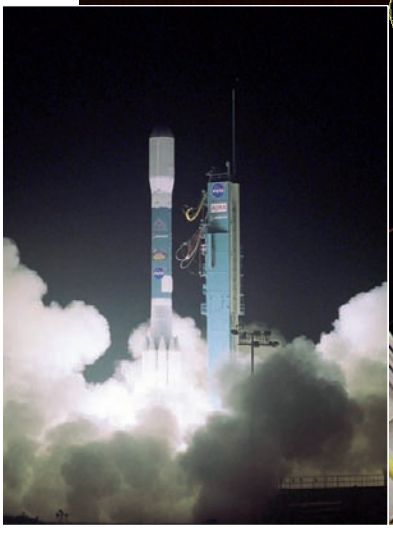
Mapping of Boreal Forests based on Envisat satellite imagery has been investigated in the ENBOR project. Estimation algorithms have been developed for both optical and Synthetic Aperture Radar imagery registered by Envisat.

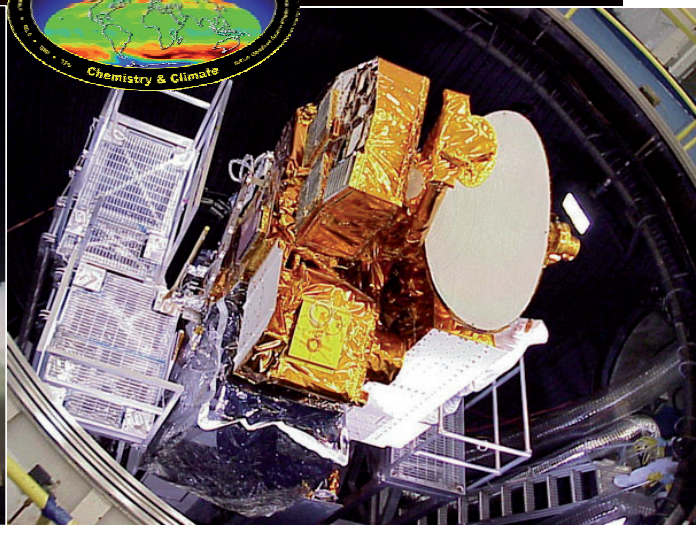
VTT developed and tailored its probability method and the related PROBA software in cooperation with the Finnish Environment Institute for operative use in the CORINE vegetation mapping. The Finnish Environment Institute produced and delivered land cover data of the Finnish area to the European Environmental Agency for the European CORINE (Coordination of information on the environment) Land Cover 2000 data base. Part of the land cover data extracted from existing geographic databases, but many forest and vegetation variables were estimated from Landsat ETM+ satellite imagery.

VTT has developed a ship route planning tool ViewIce that can be used to view ice maps and weather forecast maps, as well as the latest satellite images of ice conditions. ViewIce calculates the optimal ship route based on ice model predictions. ViewIce also offers water level and wave forecasts, so it can also be used to plan routes in summer and in ice-free conditions.

Space Research in Finland

Report to COSPAR 2006





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