

A Northern View on a Living Planet

Earth Observation in Norway



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Living Close to the Arctic

The Norwegian use of space is born out of nature's challenges. A harsh climate, vulnerable nature and areas rich in resources must be managed in the High North.

Our land and sea areas equal half the size of the EU. Being less than 5 million people, we have to explore the most efficient ways of managing our resources.

In the 1970s, Norwegian scientists set out to utilize satellite navigation, satellite communication and, later on, Earth observation to meet the needs of society. Today, Norway is in the lead in areas like sea ice monitoring, oil spill and ship detection and bedrock subsidence monitoring.

Living close to the Arctic can be a challenge, but when it comes to communicating with polar orbiting satellites, it is a key to success. It is no surprise then that the ground station at Svalbard is the worldwide leading provider of satellite ground services.

In space, all nations become small. International cooperation is crucial, especially in the field of Earth observation. Norwegian membership in the European Space Agency, combined with bilateral collaboration, paved the way for the development of space applications in widespread use today.

The vision of the Norwegian Space Centre is that by 2015 Norway shall be the country in the world to benefit most from space activities. We are not there yet, but we are definitely on our way.

Marianne Moen

Deputy Director General
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From Sputnik to Envisat

By Terje Wahl, Director for Space and Earth Sciences at the Norwegian Space Centre

I was born in the same year as Sputnik-1 started the Space Age. And though my childhood years were clearly influenced by the success and drama of Gagarin, Gemini and the Moon landings, Earth observation is the part of space activity which has been closest to my heart for the last 25 year.


Perhaps it started with the picture of the fragile little Planet Earth taken by the Apollo astronauts. Or perhaps it is because most Norwegians are born very interested in meteorology. Anyhow, it is only proper that ESA's biggest remote sensing symposium so far takes place in Bergen, the birthplace of modern meteorology, in the summer of 2010.

ESA's first radar satellite ERS-1 played a special role in Norway's space history. In fact, the ERS-1 project was one of the main reasons why Norway joined ESA in 1987. And the usually



fragmented Norwegian R&D community rallied together to make a really good entrance into the new European arena that had been opened up for us. By coincidence, Norway will also get her first national satellite (AISSat-1) in low Earth orbit in 2010. It means that, in the future, Norway will be in a position to choose whether to conduct certain future space activities in a national context, or through international

collaboration. However, I feel confident that Norway will remain an enthusiastic partner in ESA's Earth observation programme for many years to come. After all, the laws of Newton do not allow for stationary satellite orbits over the Norwegian Sea. So even the laws of physics tell us that some challenges are best solved in a multi-national context. Earth observation clearly is such a topic. ■



The overall picture of global weather patterns is best viewed from space. © NASA

The Weathermen who Paved the Way

Everyone talks about the weather and the best place to see what's on its way is in space. The need for more accurate weather forecasts spearheaded the use of satellite data.

By Berit Ellingsen

Accurate and timely weather forecasts are important for a lot of human activities, from agriculture and fishing, to construction, transportation and communication.

The overall picture of global weather patterns is best viewed from space. The earliest satellites were quickly put in use for meteorology to improve weather forecasting.

The first satellite dedicated to meteorology was launched into space on the 1st of April 1960. From its polar orbit, Television Infrared Observation Satellite, or TIROS-1, sent home pictures of the clouds covering the Earth and the large-scale weather patterns.

Being able to see the cloud cover on a global scale greatly improved the accuracy of both short and long-term weather forecasts.

EXCHANGE OF INFORMATION

With the United States already established as a presence in space, American meteorologists launched several other meteorological satellites and used data from these for weather forecasts early on. European meteorologists also had access to the American polar weather satellites, and benefited greatly from this over the course of many years.

When the European Organization for the Exploitation of Meteorological Satellites, EUMETSAT, was being formed in the mid 1980s, Norway was well aware of the advantages of satellite data and became a member of the organization from its beginning.

Today, Europe has operational weather satellites both in geostationary orbit and in polar orbit, and contributes significantly in the international meteorological context. European weather forecasts still utilize data from American satellites and vice versa.

WIND DATA IMPROVE FORECASTING

Subsequently, methods for obtaining information in addition to clouds and cloud cover from satellites, such as sea

level wind speed, were developed. This turned out to be particularly useful for meteorological modelling.

In the mid-1980s it was suggested that radar instruments able to measure wind speed should be included in the payload of the first European radar satellite, ERS-1. ERS-1 was launched with instruments for measuring sea level wind speed in 1991.

In the early 1990s, researchers at the Norwegian Meteorological Institute demonstrated that such wind speed data increased the accuracy of the numerical weather forecast models significantly.

Later, when Europe was planning its polar weather satellite programme METOP, it was clear that this operational satellite required wind speed sensors for improved weather forecasts.

FRONTRUNNERS IN THE USE OF RADAR SATELLITE DATA

“The research into wind speed satellite data improving weather models was done at the Norwegian Meteorological Institute, particularly by Lars Anders Breivik’s group,” says Terje Wahl, Director for Space and Earth Sciences at the Norwegian Space Centre.

According to Wahl, Norwegian meteorologists were at the forefront of international research when they published their scientific results. As a consequence of their work, wind speed sensors were included on Europe’s series of METOP-satellites.

In the late 1980s, Wahl himself worked with the use of satellite data for ship tracking at the Norwegian Defence Research Institute at Kjeller.

“At the time there were a handful of Norwegian research groups pioneering the use of radar satellite data for various means, not only meteorological forecasting and ship tracking, but also for polar ice research, oceanography and oil spill surveillance,” remembers Wahl.

When Norway joined the European Space Agency in 1987 and took part in



Cloud cover over Scandinavia. © NASA

the planning of ERS-1, these research groups spearheaded the utilization of satellite data in Norway.

A CHOICE FOR THE FUTURE

“The groups met fairly frequently and it was clear to all of us that radar satellites were definitely the choice for the future,” says Wahl. The satellite sensors were able to peer through the cloud cover and perform measurements independently of weather, season and time of day.

For Norway, with its long coast line, variable weather and long winter nights, satellites with both passive and active microwave sensors or radar sensors were regarded as ideal. Today, Norway is one of the biggest users of satellite data per capita among ESA’s member states.

Currently, modern weather satellites are able to measure not only clouds and wind speeds but also air temperature, water vapour, ice cover and even the chemical composition of the atmosphere.



Search and rescue services are dependent on satellites to be effective far out at sea.
© Kystvakten

Saving Lives at Sea

Satellites have had an enormous impact on search and rescue operations in northern waters. With the emergence of Galileo and AIS-satellites it will only get better.

By Christer Aasen

Quick reaction time is vital in search and rescue operations in the Nordic region. Extreme weather conditions and temperatures make it a matter of minutes before a person floating in the sea becomes hypothermic.

Satellites have the unique ability to monitor large coastal and sea areas in short time intervals, and Norway’s membership in the international satellite based search and rescue system (COSPAS/SARSAT), has had an enormous impact on the efficiency of the country’s search and rescue services.

“In 2009, 70 people were rescued in Norwegian waters and territories as a direct consequence of using their distress emergency beacons, but this

varies from year to year. From 1989 to 2009, 845 people were rescued by the help of satellites in the Norwegian Search and Rescue Region,” says Tore Wangsfjord, chief of operations at the Joint Rescue Coordination Centre in Northern Norway.

EXTENDED USE

Much of Norway’s value creation is done at sea, such as transport, fishing, tourism and off shore oil and gas installations. Extended use of Arctic sea waters will increase the risk of accidents and require more efficient ways to monitor Norwegian territorial waters and illegal fishing. The strengthening of search and rescue capacity and

establishing a service for ship detection from satellites has been a prioritized Government strategy.

COSPAS/SARSAT was established in 1979. Search and rescue transponders today are placed on four geostationary satellites and on five polar weather satellites. These are tracking and positioning activated distress emergency beacons and they send the information to ground stations and rescue coordination centres.

This system is especially practical for the Norwegian search and rescue services. Satellites in polar orbits have good coverage in the desolate High North where aircraft and other ships are few and far between.

SATELLITE NAVIGATION SYSTEMS

Norway has been part of the COSPAS/SARSAT system since 1984 and search and rescue was one of the first areas in which satellites were used.

It is believed that the numbers of search and rescue transponders will increase in the future, first and foremost through satellite navigation systems.

“This will have a big impact. Transponders will be attached to the GPS/DASS, the European SAR/Galileo and the Russian GLONASS systems,” says Wangsfjord.

Transponders on so many satellites will lead to near real-time reception and localization of distress signals, independently of where you are on the planet. More satellites will make tracing more secure and more accurate since the radio signals will not be blocked by terrain.

FASTER AND BETTER

Moreover, the SAR/Galileo system will make it possible to send information back to those in trouble, and will tell them that the distress signal has been received by the search and rescue services.

“Tests have shown that this development might make today’s system superfluous. It will be faster and have better positioning,” says Wangsfjord.

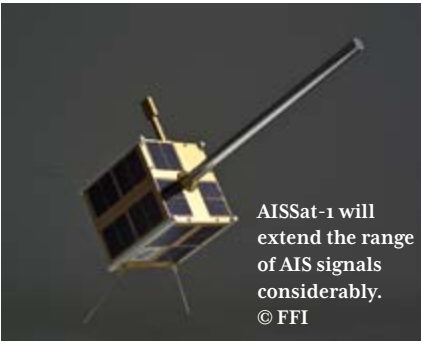
Speed is everything, he explains. “Especially at our latitudes. Time is the most important factor for a successful rescue.”

With today’s system the rescue services receive early detection signals, but not always early positioning. Transponders on navigation satellites will help the rescue services to also get an early positioning.

AUTOMATIC IDENTIFICATION

Another system which has had a major impact on the effectiveness on search and rescue services in the North, is the AIS-system. The Automatic Detection System was set up as an anti collision system for ships over 300 gross tonnes, but has since developed into a ship identification system port authorities use to monitor ship traffic along the coast.

“This is an incredibly helpful tool for us. After an accident at sea, nearby ships are often the first to come to help. With the AIS system we can see which ships are close and direct them towards the site,” says Wangsfjord.



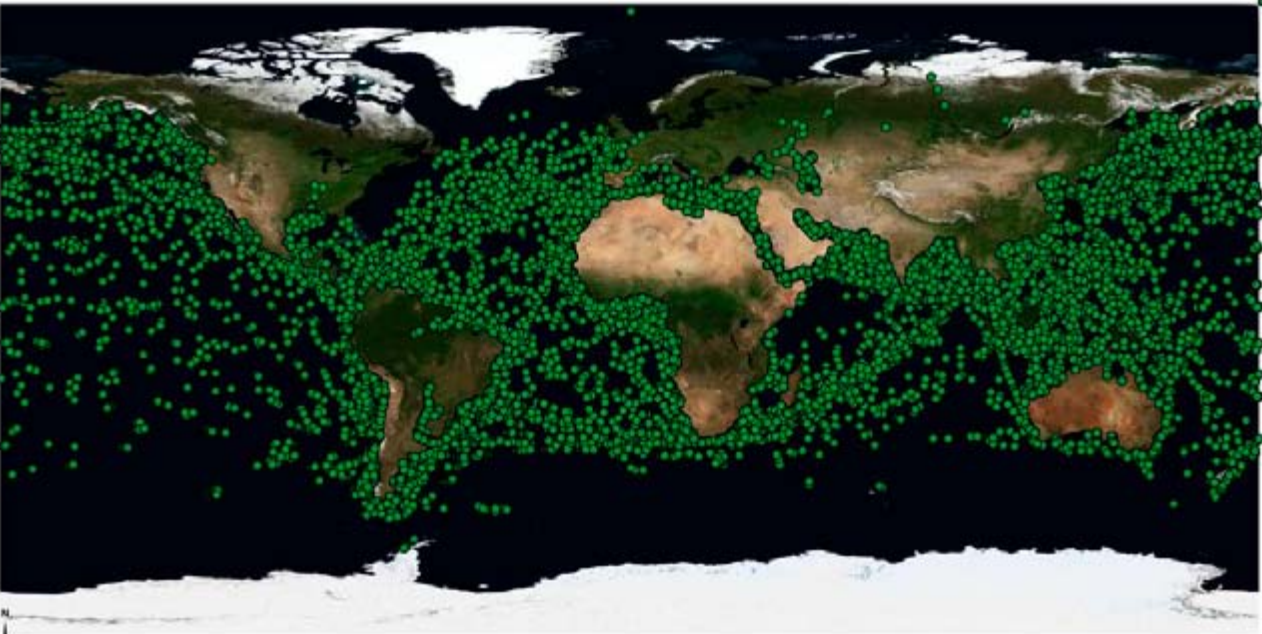
AISat-1 will extend the range of AIS signals considerably.
© FFI

INCREASED RANGE

Today’s land based AIS-system can only monitor ship traffic up to 40 nautical miles from shore. Therefore Norway decided to launch the country’s first test AIS-satellite (AISat-1) in order to increase the range considerably.

In the High North AISat-1 will make a huge difference. Further south there are quite a few AIS stations at sea as well, for instance on the oil platforms in the North Sea. In the High North there are almost none, according to Wangsfjord.

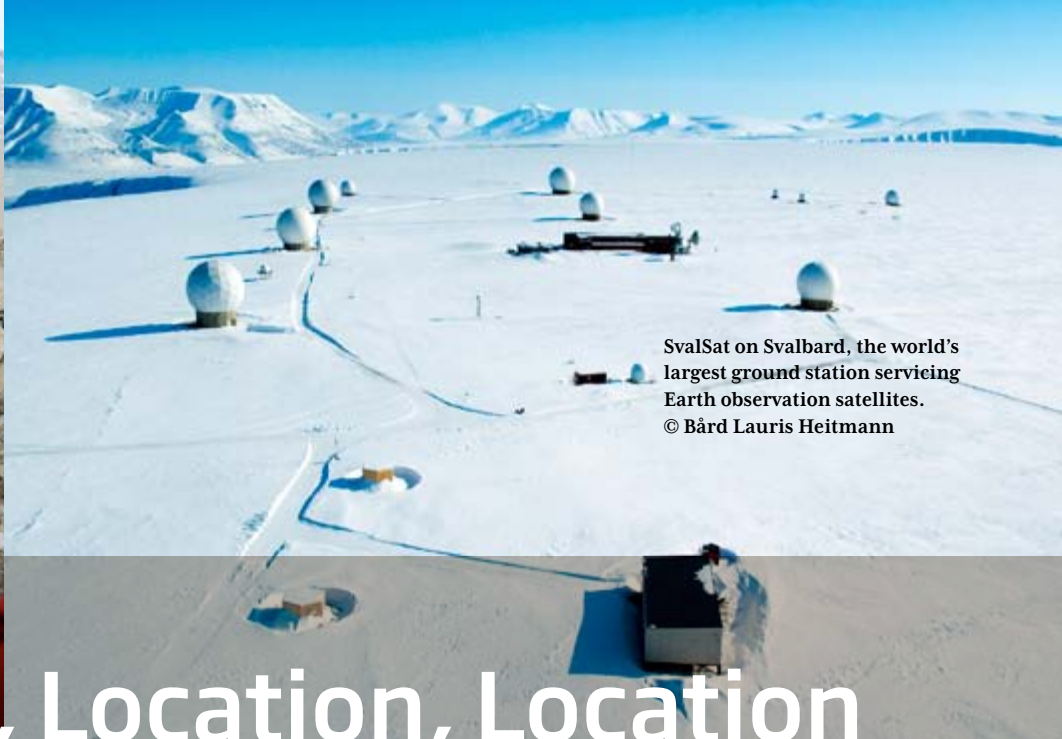
“The problem with today’s AIS system is range, particularly in the High North. That’s where the need is greatest, and a satellite will be a big help.”



AIS technology is also placed on the Columbus module on the International Space Station. This is an illustration of the first position reports from the Norwegian AIS receiver (NORAIS), showing locations of ships all over the world in early June 2010. © FFI



Prime Minister Jens Stoltenberg and KSAT's Managing Director Rolf Skatteboe at the opening of the Troll station in the Antarctic. © KSAT



SvalSat on Svalbard, the world's largest ground station servicing Earth observation satellites. © Bård Lauris Heitmann

Location, Location, Location

Kongsberg Satellite Services is the world's leading ground station for Earth observation satellites in polar orbit. Its location in the polar region has been one of the keys to the success.

By Berit Ellingsen

The possibility to downlink recorded data from satellites in polar orbit much more frequently, combined with a solid communication infrastructure for getting the products to the customers, makes KSAT a natural choice for anyone needing to download data from polar satellites.

Kongsberg Satellite Services (KSAT) began as Tromsø Satellittstasjon (TSS) in the 1960s. It was built to receive data from American meteorological satellites in polar orbits.

When Norway joined the European Space Organization ESA in 1987, Norway had already realized the usefulness of radar data from satellites in polar orbit for various applications, including ship detection, ice and oil spill monitoring and oceanography.

Capabilities and equipment for handling data from ERS-1 and for distribution to Norwegian customers was developed and installed at TSS. New radar missions such as Radarsat and Envisat have been added to the list of satellites utilized in near-real time services to users.

Frequent contact with a satellite is an advantage particularly in the commissioning phase after launch when the satellite is being activated in space. Also, during special events, such as an emergency or malfunction, frequent contact is needed.

With its location in northern Norway, TSS had the considerable advantage of being able to see more satellite passes than stations further south. Thus, TSS began selling station services to customers in order to generate a stable income.

ON SVALBARD AND IN THE ANTARCTIC

In 1997, KSAT's ground station on Svalbard, Svalbard Satellite Station (SvalSat) was opened. This station can see all orbital passes of a polar satellite and communicate frequently with it.

Two of SvalSat's first major clients were NASA and the National Oceanic and Atmospheric Administration (NOAA). In close collaboration with them, fibre-optic communication cables were laid between Svalbard and the mainland to secure excellent capacity

for piping payload data to customers fast.

"Since then, KSAT has expanded its activities on Svalbard and in Tromsø repeatedly and developed many services based on the various data acquired," says Per Erik Skrøvseth, Head of International Programmes, Earth Observation at the Norwegian Space Centre.

In 2007, the company opened TrollSat, a satellite station at the Norwegian research facility Troll in Queen Maud Land in the Antarctic. This station gives the opportunity for even more frequent communication with polar satellites.

Today, SvalSat is the world's largest satellite station servicing Earth observation satellites. Other types of satellites, such as navigation and telecommunication satellites, are also served at the company's ground stations for customers all over the world.

"Today, one of the biggest challenges for KSAT is developing better and more services, as well as finding new areas of application, for example monitoring of biomass," Skrøvseth concludes.



In combination with AIS, radar satellites can detect oil spills and ships independently of cloud and light conditions. © Raw data CSA, MDA, 2007

A Different Search for Oil

If you spill it, they will find it. Oil spill detection from satellites has become one of KSAT's most important services.

By Christer Aasen

Approximately one third of Kongsberg Satellite Services' (KSAT) turnover stems from the company's Earth observation services, and one third of this is generated by KSAT's oil spill services. This is a service that the company itself created an international market for on the pillars of Norwegian research and a national need.

When we think of oil spills most of us imagine ships in trouble, coastal areas covered in crude oil with tragic consequences for the local wildlife. However, 90% of all oil spills at sea are relatively small and often dumped into the sea on purpose by ship crews in order to clean the ship tanks.

These types of oil spills are also harmful, but they are hard to detect by conventional means.

FAST DELIVERY

Today KSAT is providing a service using satellite radar images, more precisely Synthetic Aperture Radar (SAR) technology. The company has developed an oil detection service chain capable of providing information to European end users within 30 minutes after a satellite overpass.

This information is used by coastal authorities in combination with other surveillance methods, for example

dedicated aircraft equipped with radar and IR/U scanner.

KSAT was also the first service provider to use the Automatic Identification System (AIS) in combination with oil detection from satellite. AIS is a ship information system used by most European coastal states to monitor the whereabouts of ships over 300 gross tonnes.

Combining these two methods it is possible for KSAT to identify a possible source of the oil spill discovered on the satellite picture.

The information systems are able to detect oil spills and ships independently of clouds and light conditions.



Satellites can detect small and large oil spills at sea.
© iStockphoto.com/davelogan

Radar images from satellites, combined with the AIS system, give a maritime overview picture.
© Raw data ESA, 2009. Processed and analysed by KSAT

Watching the Seas

Norway has vast ocean areas to govern and monitoring them is a difficult task, but satellites make a difference.

By Christer Aasen

As early as the late 1970s experts were curious as to whether satellites could find oil spills at sea. In 1986, Norwegian researchers handed in a coordinated suggestion to ESA to show how observations from the ERS-1 and ERS-2 satellites could give more information on Arctic ice, ship detection, oil spills and other needs within maritime surveillance.

GROUND STATION

Norway decided to build a satellite ground station in Tromsø in Northern Norway to process data quickly. Tromsø Satellite Station (TSS) got the responsibility to develop a national oil service, with a further aim of delivering results internationally.

TSS was later turned into KSAT, a commercial business owned by Kongsberg Defence & Aerospace and the Norwegian state. Since 1996 the national oil satellite service has been operated by KSAT.

“It all started as a national initiative through the Norwegian Space Centre and the research community. From there it evolved towards operational status and then we delivered the service to other European coastal states,” says Line Steinbakk who is leading the development of KSAT’s oil spill services.

“KSAT was the first to make such a service operational and the first to create a commercial market,” she says.

EXTENDED MARKET

In the beginning Norwegian authorities were the only users, but with help from ESA, KSAT extended their market to the Netherlands, Great Britain, Sweden, Germany, Belgium, Finland and Denmark.

To succeed in creating a commercial market and sell the services internationally, KSAT chose to work closely with both the research environment and their customers such as pollution control authorities.

“There is no doubt that this has been the reason for our success. We let the customers become involved in both the development of the market and in our product projects, thus services were well adapted to the needs of the customers,” says Steinbakk.

EUROPEAN CONTRACT

In 2007 KSAT was awarded a contract by the European Maritime Safety Agency (EMSA) to provide a satellite based system for oil spill monitoring in all European seawaters.

As the head of a consortium with two other members (e-GEOS and EDISOFT), KSAT has been systematically monitoring European seas.

From 2011 EMSA will take over the management and issue contracts to service partners for the next generation of services. However, with its unique experience, KSAT is well positioned to compete.

Approximately two million square kilometres of ocean are within Norwegian jurisdiction. No wonder that maritime surveillance aided by satellite radar technology was one of the most important issues for Norway when the country joined the European Space Agency (ESA) in 1987.

“When ESA started work on its first radar satellite, Norway realized that such a satellite could support our needs concerning ocean monitoring”, says Guro Dahle Strøm, Head of National Programmes, Earth Observation, at the Norwegian Space Centre.

INCREASED EFFICIENCY

Satellites are increasing the efficiency of maritime traffic control and the surveillance of illegal fishing in Norwegian waters. Radar images from satellites, combined with the AIS system, give a maritime overview which provides information that can be used by the coast guard. Ships and aircraft can then

be dispatched to sectors with fishing activities.

The areas to be monitored are large and the satellite radars can provide images independently of weather and light conditions.

These national needs were among the main drivers behind Norway becoming an associated member of ESA in 1983 and then taking part in the development of the ERS-1 satellite.

ERS-1 was a research satellite, and gave relatively good coverage of the High North.

“Norway was the first country to make a plan and a strategy to use ERS-1 operationally,” says Dahle Strøm.

Stable access to data is crucial for operational applications. Therefore, Norway built its own ground segment for the satellite. The country developed near real-time data products and signed agreements that gave access to several satellites.

What Norway did with the ERS-1 data became an important demonstrator

and driving force for today’s utilization of ERS-2, ENVISAT and Radarsat data.

Norway started early to demonstrate how the ERS-1 could be used for many purposes, such as ship detection and oil spill detection.

THE DEMONSTRATOR

“ERS-1 became the demonstrator and the ticket to full membership in ESA and the start of the Norwegian space industry,” says Per Erik Skrovseth, Head of International Programmes, Earth Observation, at the Norwegian Space Centre.

What made the Norwegian strategy work was close cooperation between the people who were doing research and development and those using the data operationally.

“Both parties were, and are, benefiting from this,” says Skrovseth. “Using the data operationally will always require improvements that need more scientists and development and will also give researchers access to more data.”

Cold Facts about Sea Ice

Sea ice is one of the most significant climate factors in the Polar regions and it affects many different human activities. Norwegian scientists realized early on the usefulness of satellites in keeping an eye on sea ice.

By Berit Ellingsen

The melting and transport of sea ice in the Arctic is one of the biggest factors for the climate in the region, as well as on a global scale. It is also one of the most important indicators of the global climate, both the long-term natural variations and those that are caused by human activity.

Moreover, important maritime activities such as fishing, shipping and offshore development are also greatly affected by the sea ice conditions.

Norwegian scientists quickly understood the usefulness of satellites in the research and monitoring of sea ice. Ola M. Johannessen, founding director and chairman of the board of the Nansen Environmental and Remote Sensing Center in Bergen, is the Norwegian pioneer in the field.

When he worked with ice monitoring using the American meteorological satellites Nimbus 5 and 7 in the early 1970s, it was clear that satellites were the wave of the future for sea ice research and tracking.

At the time, Johannessen collaborated with several Norwegian scientists and research institutions, including the then director for the predecessor to the Norwegian Space Centre, Bjørn Landmark, providing an official report to the Norwegian Government about the usefulness of satellites in remote sensing.

EXTENSIVE FIELD CAMPAIGNS

In 1981, Johannessen led the NORSEX field experiment, which used both sea ice data from satellites, remote sensing aircraft, ships and ice breakers. It was

an extensive field study with a large group of international researchers taking part.

The experiment and subsequent research report published in the journal Science, as well as a following research conference in Bergen, garnered international attention for the research in remote sensing and monitoring of sea ice that was being done in Norway.

Johannessen and his group followed up with a series of large international field experiments in the Arctic to study the interaction between ice, sea, wind and current. The MIZEX (Marginal Zone Experiments) campaigns were supported by the European Space Agency (ESA) and the Norwegian Space Centre.



Ola M. Johannessen feels at home in the Arctic. © NERSC

“These field experiments included more than seven research vessels, four helicopters, twelve aircraft and 250 scientists of various disciplines,” says Johannessen. They are the largest experiments conducted in the marginal ice zone.

THE VANISHING POLAR ICE

When the European radar satellite ERS-1 was launched in 1991, the monitoring of Arctic ice was one of the new satellite’s areas of application.

Data from the altimeter onboard ERS-1 was used to show that from 1993 to 2003 the ice sheet of the inland regions of Greenland increased in thickness by three centimetres per year. As the ice in the coastal regions of Greenland has a higher yearly melting rate, the Greenland ice cap is decreasing overall.

In the Arctic the ice extent has been reduced by 4-5% per decade while the area covered by the thicker multi year ice has shrunk by about 10% per decade since 1979.

According to Johannessen, if the carbon dioxide in the atmosphere continues to increase at the same rate as it does today, the concentration of greenhouse gases may be doubled by around 2040.

A BLUE ARCTIC OCEAN?

“At that point we may see an ice-free blue Arctic Ocean and open north eastern sea route in the summer,” says Johannessen. However, the wild card in the global climate is what will happen to the melting Greenland ice.

Johannessen muses on the future for the polar sea ice. If more polar ice vanishes, what impact will it have on shipping and other human activities in the area? How will these changes affect the local environment, the fisheries, the polar ecosystems and the entire global climate?

“These are some of the most important questions about the climate in the future,” Johannessen says.

He has high hopes for ESA’s new ice satellite, CryoSat-2. CryoSat-2 will



The future of the global climate and the local environment might be dependent on the future of the polar sea ice. © NERSC



© NERSC

monitor and measure ice thickness. By measuring how much of the sea ice is above the ocean surface, scientists can estimate the total thickness of the ice mass.

“CryoSat-2 will increase the knowledge of the polar ice thickness dramatically and greatly improve the methods of measuring exactly how much ice is vanishing each year,” concludes Johannessen.

INCREASED NEED FOR ICE MONITORING

In the exploration of the Norwegian Arctic and Antarctic areas, the Norwegian Polar Institute, the Norwegian Meteorological Institute and the Nansen Center play important roles.

“During recent years the Norwegian Meteorological Institute has increased its use of satellite data of sea ice and ice conditions around Svalbard,” says Terje Wahl, Director for Space and Earth Sciences at the Norwegian Space Centre.

This is caused by increased activity in shipping, fishing and tourism in the area. Moreover, modern radar satellites

Cryosat-2 will provide more knowledge about sea ice thickness. © ESA



Lasers at Alomar in Tromsø are validating atmospheric data from Envisat. © Alomar



Quality Control in the Remote Wilderness

The validation of satellite data makes sure that the map corresponds to the landscape it illustrates and not the other way around. This quality control often takes place in some of the most remote and spectacular corners of the world.

By Berit Ellingsen

are able to see many details in polar ice, increasing the usefulness of radar satellites as opposed to traditional meteorological satellites in ice monitoring.

THE IMPORTANT ICE FLUX

Today, Norway makes extensive use of radar satellite data from ESA's Envisat satellite, as well as Canada's Radarsat-2.

"If global warming continues and shipping and other human activities in the Arctic increase, the satellite observation of sea ice and sea ice transport will be absolutely vital for safety issues," says Wahl.

Wahl identifies the sea ice transport in the yearly flux of ice in the Fram Strait between Svalbard and Greenland as one of the most important future climate issues in this field.

The ice on the move in the Fram Strait melts when it reaches warmer waters further south. Most of the ice vanishing from the Arctic follows this

route south. The ice flux through the strait varies from year to year. This ice transport is highly significant for the Arctic ice cap.

CRYOSAT-2 – THE ICE SATELLITE

With more knowledge about sea ice thickness, such as that provided by CryoSat-2, scientists will be able to track sea ice and calculate how many tonnes of ice is being transported out of the Arctic.

"This is in itself a significant climate parameter," says Wahl. In addition, the new data about ice thickness from CryoSat-2 will increase both the knowledge and the usefulness of data from workhorses such as the current weather satellites and ESA's future Sentinels.

Another challenge in using satellite data is the continuation of satellites and sensors over time. Here Wahl sees CryoSat-2 as taking over the work started by the American satellite IceSat. In 2015,



when CryoSat-2 may be nearing the end of its life span, the relay baton will be handed over to the new American ice satellite, IceSat-2, which is being planned at NASA.

Scientists at several Norwegian research institutions are involved with CryoSat-2, including the Nansen Center, the Norwegian Polar Institute, the University Centre in Svalbard and the University of Oslo.

Data from the satellite's sensors need to be validated both during the development phases and after launch. This testing ensures that the data products are of sufficient quality and accuracy. The process is also essential for handling and utilizing the data.

Depending on the needs of the satellite handlers and data users, different validation campaigns are performed.

Before launch, simulation campaigns are done in order to prepare for validation and the potential use of the data.

The most important validation

campaigns are the geophysical validation campaigns, carried out in the months following launch, in the so-called commissioning phase. In these campaigns, geophysical data products are checked against independent on-site measurements of relevant geophysical variables.

LARGE AREAS

Data for validation can be collected on site on land, at sea by ship or buoys, or from the air by balloon, aircraft, helicopter or unmanned flying vehicles. Because satellites cover large areas,

validation campaigns often take place in remote and inaccessible corners of the world.

Moreover, validation has to be done simultaneously with independent methods, or at the same place and time as the satellite performs its measurements. Because of this, validation requires a high degree of precision, time, resources, personnel and coordination.

For some satellite sensors, validation campaigns need to be performed throughout the satellite's entire life span.

Validation by plane and on site at the Austfonna glacier on Svalbard.
© Jon Ove Hagen



Norwegian scientists and authorities realized early on the importance of radar satellite data for Norwegian users.

SPECIAL COASTLINE

For a nation such as Norway, with a long and cloudy coastline, high maritime activity and extensive polar areas, satellite data of sea and land ice, ocean colour and temperature, ship detection and surveillance, and oil spills, were identified as particularly important.

As a consequence, Norway has performed large and highly coordinated validation campaigns covering all these areas.

For example, Norway performed preoperational validation to support service development during the production of ESA's large Earth observation satellite, Envisat.

By doing this, Norwegian scientists and engineers built solid experience and knowledge of radar satellite applications and for carrying out quality assurance.

These capabilities will be invaluable

when preparing for the operational Sentinel satellites that are planned for launch from 2012 and onwards.

THE EARTH EXPLORERS

Today, ESA's new Earth Explorer satellites are important to Norway. The Earth Explorers will collect parameters that have never been measured from space before. A thorough validation of these data is therefore extremely important.

ESA is currently performing validation campaigns with Norwegian support for both the gravity field satellite GOCE and the ocean salinity and soil moisture satellite SMOS, launched in 2009.

CRYOSAT-2

Among the Earth Explorers, ESA's new ice satellite, CryoSat-2, is identified as the most significant for Norway. CryoSat-2 will measure the thickness and volume of sea ice and the ice cap in polar areas. This will be an important contribution to our knowledge of the polar climate systems.

Norwegian scientists have

performed pre-launch validation campaigns for CryoSat-2's instruments since the early planning stages of this Earth Explorer. Validation has been done by aircraft, by ship and on site at the Austfonna ice cap on Svalbard, one of the world's most remote and hostile environments.

The Norwegian Polar Institute, the Nansen Center and the University of Oslo, supported by the Norwegian Space Centre, participated in these campaigns.

"As a result, Norwegian scientists are now very well prepared to receive and validate the real data from CryoSat-2 in the initial commissioning phase," says Guro Dahle Strøm, Head of National Programmes, Earth Observation, at the Norwegian Space Centre.

PREPARING FOR THE SENTINELS

Norway will also support the future validation of Europe's new series of operational satellites, the Sentinel satellites. As for all satellites, quality control in the form of validation is essential for utilizing the Sentinels.

CryoClim will keep an eye on global sea ice, global snow cover and glaciers in mainland Norway and on Svalbard.
© iStockohoto.com/Coldimages



Eye in the Sky for Climate

An effective monitoring of all the different factors that make up the cryosphere will require a high degree of coordination and cooperation. This is what the CryoClim initiative aims to do.

By Berit Ellingsen

The cryosphere is one of the most important components in the global climate system. It includes all the frozen water on the planet; the polar ice caps, sea ice, glaciers, snow and permafrost.

The CryoClim project is developing new services for climate monitoring of the cryosphere, in particular services for keeping an eye on global sea ice, global snow cover and glaciers in mainland Norway and on Svalbard. Later on, the

intention is to include the Greenland ice cap and the glaciers in the Alps as well.

The initiative represents a significant contribution to the important task of monitoring the development of the climate on our planet.

The project was started in 2008 by the Norwegian Computing Center (NR), the Norwegian Meteorological Institute (met.no), the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian

Polar Institute (NPI). It is a European Space Agency (ESA) PRODEX project supported by the Norwegian Space Centre (NSC).

FREE WEB-BASED SERVICE

The project's aim is to develop a web-based service of new and accurate climate products. The proposed system will be integrated into the global system of systems, GEOSS, that is being developed.



Fractional snow cover in Europe 21. March 2008. Image from the CryoClim portal

CryoClim will be network based and utilize the same standards and communication languages that are planned for GEOSS.

This service will be free of charge and accessible on the internet. The web service will follow state-of-the-art principles for spatial data, and the production chains and databases will be hosted by mandated organizations.

Moreover, the CryoClim databases will be integrated over the internet in a seamless and scalable network that will be open for inclusion of other databases or sub-services in the future.

When the data are ready, the operational service will be found at www.cryoclim.net.

FOUR PHASES

The project has been organized into four phases.

Phase 1 was carried out in 2008. This initial part of the project identified user needs, developed a first design of the system and a demonstrator of the system and climate products. This phase also promoted the initiative, established contact with key users and organizations, and developed a work plan for the main project.

The objectives for the ongoing phase 2 include system development and



Barentsburg on Svalbard. © Norwegian Computing Center

verification, creating production chains for global sea ice products, global snow products, glacier products for mainland Norway and Svalbard, and project management, coordination, promotion and outreach.

These activities will continue in phase 3. Phase 4 will extend the time series for all products, find permanent funding for the services developed and complete the project in 2012.

LONGEST DATA SERIES IN THE WORLD

CryoClim is nearing the end of the second phase and the first data will soon be available, says Dag Anders

Moldestad, Senior Adviser for Earth Observation at the Norwegian Space Centre. The first data will be on sea ice and are planned to be available on the web portal in the summer/autumn of 2010. More sea ice data, snow and glacier products will follow in 2011.

The sea ice products are based upon EUMETSAT Ocean and Sea Ice Application Facility (OSI SAF) reanalysis of passive microwave data dating back to 1978.

GLACIERS ON MAINLAND NORWAY AND ON SVALBARD

The project has already analyzed the glacier area outline of more than 3,000

glaciers in mainland Norway once in the period between 1999 and 2006. The outline of 477 glacier lakes is also included in the study. Phase 3 will focus on creating a mid-1980s inventory of glacier area outline and glacier lake outline for mainland Norway.

For glaciers on Svalbard, the data and time series are most mature when it comes to glacier surface type. A potential product related to mass balance is currently under validation.

Black Carbon

Black carbon might be an important contributor to warming in the Arctic.

By Berit Ellingsen

Black carbon consists of tiny particles of carbon less than 100 nanometre in size. They originate from forest fires and untreated emissions from burning wood, oil and gas. They are transported as aerosols high in the atmosphere, particularly from China and other regions of Asia with untreated coal emissions, and precipitate in the Polar regions.

Does black carbon accumulate on the

glaciers? How much does black carbon increase melting rates of polar ice? Does black carbon make seasonal snow melting happen more quickly? Is it possible to quantify the amount of black carbon in polar snow and ice from satellite data? These are some of the questions the project Black Carbon is addressing.

VISIBLE FROM SPACE

Large-scale monitoring of black carbon in snow and ice will improve climate models and increase our understanding of the climate processes in the Arctic and Antarctica.

The first phase of the project started in April 2009 and was completed in March 2010. In the spring and summer of 2009, field and

satellite measurements were performed at Svalbard.

A high concentration of black carbon from local sources is clearly visible in the satellite signal, both on snow and ice. Data from Envisat's MERIS and Terra's MODIS instruments give consistent results with data from ground-based methods.

A possible extension of the project will focus on developing methods for detecting particles at low concentrations and using data from ERS-1 and other satellites to produce long-term datasets of black carbon.

CAN BE REDUCED USING TODAY'S TECHNOLOGY

"It will be a lot simpler and cheaper to reduce

black carbon than to reduce the amount of greenhouse gases in the atmosphere," says Project Leader Rune Solberg at the Norwegian Computing Center.

Technology for cleaning carbon emissions that exists today can reduce the amount of black carbon aerosols significantly.

When this is implemented in coal power plants with untreated emissions, this will not only reduce the amount of black carbon transported to Polar regions, but also greatly reduce the emissions to the local environment.

Black Carbon is a project in ESA's PRODEX programme. The project is supported by the Norwegian Space Centre and carried out by the Norwegian Computing Center (NR) and the University Centre in Svalbard (UNIS).



Meteorological Station at Svalbard. © Norwegian Computing Center

Tracks in the Forest

To combat deforestation, Norway plays an important part in a global programme to monitor forest carbon stocks and emissions.

By Christer Aasen

According to the Intergovernmental Panel on Climate Change (IPCC), up to 20% of global greenhouse gas emissions can be traced to deforestation.

Efforts to minimize deforestation and increase reforestation can reduce greenhouse gas emissions. Many countries around the world want to reverse deforestation, but are lacking adequate monitoring, reporting and verification systems. Such systems are dependent on reliable satellite data and appropriate tools for analysis.

The Group of Earth Observations (GEO) established the Forest Carbon Tracking task in 2008 with this need in mind. Its aim was to provide operational support to countries wishing to establish a national system for forest monitoring and carbon reporting.

The programme is being carried out by a partnership of GEO member governments, key UN bodies, space agencies, the science community and the private sector.

Norway invests NOK 3 billion a year

to fight deforestation around the world. Therefore, it is important that the country plays a part in the Forest Carbon Tracking task as well. Norway's long experience with using and interpreting data from radar satellites is another reason to get involved.

Currently Norway, through the Norwegian Space Centre, is engaged in the programme in two ways. The Space Centre is both part of the programme management and involved in several bilateral cooperation projects which will constitute the future global system.

It is important to build a proper and just structure for such a global monitoring system, not in the least because countries are financially compensated for the amount of forest they manage to preserve and reforest.

One of the bilateral cooperation projects Norway is involved in is with Brazil, a country with vast, but rapidly diminishing tropical forests due to illegal deforestation. Brazil has a well functioning monitoring system in place

for the Amazon region, but the country uses primarily data from optical satellites. Optical satellites can only get good data in daytime and in clear weather.

Brazil wishes to optimize its monitoring system by using radar satellites when necessary. Because of Norway's experience with radar satellites and SAR data, Norway will be a partner in further developing Brazil's system.

Another aim is to make the system more automated. Through the help of algorithms developed at the Norwegian Computing Center, Brazil can extend its present system for the Amazon region to all of Brazil.

Norway is also involved in building a monitoring system in Tanzania, a country which so far lacks an efficient way of using satellite data for carbon tracking. However, Tanzania has a very good system for gathering ground data. Therefore, the country will be a valuable partner for testing models for satellite-based forest monitoring.

Large parts of this mountainside at Lyngen in Northern Norway is at risk of falling into the fjord. © Tom Rune Lauknes/NORUT

Mountains on the Move

High above some of the Norwegian fjords, the mountains are moving. Here, georisks are a present danger, in the form of rock- and landslides.

By Berit Ellingsen

Several mountainsides, particularly in the fjords near Geiranger in Møre and Romsdal in north western Norway, are being kept under constant surveillance. Here, parts of the mountains are breaking up, threatening to crash into the fjord below.

Not only are rock- and landslides dangerous in themselves, but they may also block roads and rail lines, thus making it difficult for emergency aid to

get through and for people to be evacuated. Moreover, the tsunami wave created when a piece of mountain topples into a narrow fjord, might devastate villages and towns far away from the slide itself.

Satellite data and radar interferometry in particular can be of invaluable assistance in the job of identifying and mapping areas with georisks.

Radar data were used to map a part

of the mountain at Nordnes in Lyngen in Troms. Here, the mountainside is slowly breaking loose, with a crack that expands about four centimetres per year.

The most unstable area is under constant surveillance by manual measurements, on site sensors and GPS data. However, after mapping with radar interferometry, two additional sites with possible hazardous rockslide areas

A mountainside close to Tafjord in North West Norway can fall into the fjord and create a devastating tsunami. © Åge Kjelås, Åknes/Tafjord Beredskap IKS



© NILU

Fred Prata and a prototype of the ash detecting camera in front of Mount Vesuvius. © NILU



Softening the Impact of Volcanic Ash

In April 2010 volcanic ash from Iceland grounded air traffic all over Europe. Satellites can help monitor clouds of volcanic ash and reduce the impact on aviation and transport.

By Berit Ellingsen

were found in Lyngen. Measurements on site later confirmed these findings.

LIBRARY OF RADAR SCENES

For radar interferometry, a library of scenes taken at the same angles and modes over a long period of time is needed. When this information is in place, it is possible to identify changes in height of only a few millimetres.

The data used for such radar interferometry in Norway were taken by the Canadian Radarsat-1 and 2. Data from the European Space Agency's satellites Envisat and ERS-1 and 2, as well as from the German radar satellite TerraSAR-X, are also suitable for mapping georisks.

The Norwegian georisk project has developed software for using radar interferometry to map areas with possible rockslides. The project has also mapped subsidence near hydropower reservoirs and the Oslo Opera House.

AT THE FOREFRONT OF THE FIELD

"The methods and software developed in Norway are at the forefront of the research field today," says Dag Anders

Moldestad, Senior Adviser for Earth Observation at the Norwegian Space Centre.

Further mapping of geohazard areas in northern Norway, Sunnmøre, Stryn in Sogn og Fjordane and Otta in Oppland, is in progress. The project also aims for a nationwide mapping of all georisk sites in Norway. Given sufficient funding, this will take from three to five years to complete.

The techniques used for mapping changes in height in georisk areas will also be important in monitoring large constructions such as dams, bridges and buildings.

The project is a collaboration between the Norwegian Geological Survey (NGU), the Norwegian Geotechnical Institute (NGI), the Northern Research Institute (NORUT) and the Norwegian Space Centre.

MONITORING PERMAFROST

Data from radar satellites also have the potential of being used for mapping changes in the extent of permafrost areas. Permafrost is defined as ground

that has been frozen for two years or more. Permafrost is an important climate factor in the Arctic and near polar regions.

Exactly how the permafrost is responding to the global temperature and environmental changes is unknown.

A Norwegian pioneer project is using radar interferometry data to develop methods for mapping permafrost in Troms and on Svalbard. So far, the technique has been tested on Svalbard. The project has performed temperature measurements on site and compared the results with satellite data.

"With high-resolution data from satellites such as TerraSAR-X and Radarsat-2, we are able to measure subsidence of the ground that varies with the season," says Moldestad.

Subsidence in areas of permafrost may indicate melting processes in the ground. On Svalbard a multi-year time series of subsidence based on radar interferometry is under development for the permafrost areas in question.

The Norwegian Institute for Air Research, NILU, is leading an ESA project called Support to Aviation for Volcanic Ash Avoidance (SAVAA). This project aims to establish a global alert service for Volcanic Ash Advisory Centres in support of aviation control during volcanic eruptions.

A global alert service for volcanic ash must be able to provide quantitative satellite information and some means of validation, as well as timeliness.

DANGER TO AIRCRAFT

The greatest danger to jet aircraft occurs within three hours of a volcanic eruption. Often the most critical time is at night, when visual identification of airborne volcanic hazards is reduced.

Once volcanic debris has been correctly identified, either through satellite detection of ash or sulphur dioxide, sophisticated atmospheric dispersion models can be run to predict the path of the volcanic clouds.

THE CRUCIAL INJECTION HEIGHT

Perhaps the most critical piece of

information is the injection height of the volcanic debris. Currently, there are no objective means for determining this and usually multiple dispersion simulations must be run and manually matched to current or prior satellite images of the area.

This is a subjective process that takes time and can lead to errors or very conservative assessments of which regions of airspace are safe for flying.

Therefore, SAVAA is setting up a demonstration system able to utilize satellite information and meteorological wind data to compute the injection height profile of volcanic emissions, using trajectory and inverse modelling.

The project is also developing sulphur dioxide alerts for Volcanic Ash Advisory Centres based on satellite data measured in the infrared part of the spectrum.

VOLCANIC ASH ALERT FOR AIRCRAFT

Another NILU project is developing a camera that will enable aircraft to detect ash from volcanic eruptions up to 100 kilometres away.

The camera can detect both sulphur

dioxide concentrations and volcanic ash particles at cruise altitudes and will be integrated with the aircraft's radar system.

"With the help of the new camera aircraft will be alerted when they are approaching a cloud coming from a volcanic eruption, enabling them to avoid the cloud and continue the flight instead of being grounded like today," says Fred Prata, senior scientist at NILU and inventor of the new system. A prototype of the camera has been made and patented.

A special infrared, ground-based camera has also been developed and tested. This technology is intended for use at or near airports as an on site alert system for volcanic ash. This camera will be tested and validated at the Eyafjallajökull on Iceland.

The new technology can also be modified and developed to track other kinds of emissions, for example pollution from shipping or other sources.

Spring Surprise

Maps made from a combination of ground and satellite data show that spring comes much earlier to Norway than before.

By Christer Aasen

Using satellite data dating back to 1982, scientists at Northern Research Institute Tromsø (NORUT) found that the Norwegian spring has been arriving earlier than normal the last 10 years.

Western, eastern, southern and mid-Norway, show clear indications of an earlier spring. In some of these areas spring arrives more than 10 days earlier than normal, in others it arrives four to ten days earlier. In northern and southern mountainous parts of the country, the situation is stable or appears even with a weak delay trend.

These conclusions are based on studies of images from weather satellites and are correlated with ground data. The scientists used a dataset based on the American NOAA satellites for the period of 1982 to 2006. These images have an eight kilometre per pixel resolution. From the period of 2000-2007

they also used a dataset from the MODIS instrument on the Terra satellite which has a pixel resolution of 250 metres.

MORE DETAILS

“After we started to use MODIS we got far more and better details from the images. This allowed us to also monitor the growing season in more detail,” says Stein Rune Karlsen, Senior Researcher at NORUT.

The satellite data have been correlated with field data of the onset of leafing of birch trees from 40 stations across the Nordic countries. Birch is the most common deciduous tree species in the Nordic countries and is well suited as a phenological indicator.

The Arctic and boreal zones are also well suited to monitor the growing season. Human influence on vegetation is

low compared to most other parts of the world. This means it is possible to separate changes directly due to climatic change from man made changes such as agriculture or forestry.

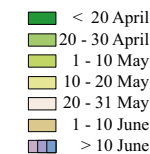
“We have a lot of natural vegetation in Norway and very distinct transitions between the seasons,” says Karlsen.

THREE WEEKS LATER

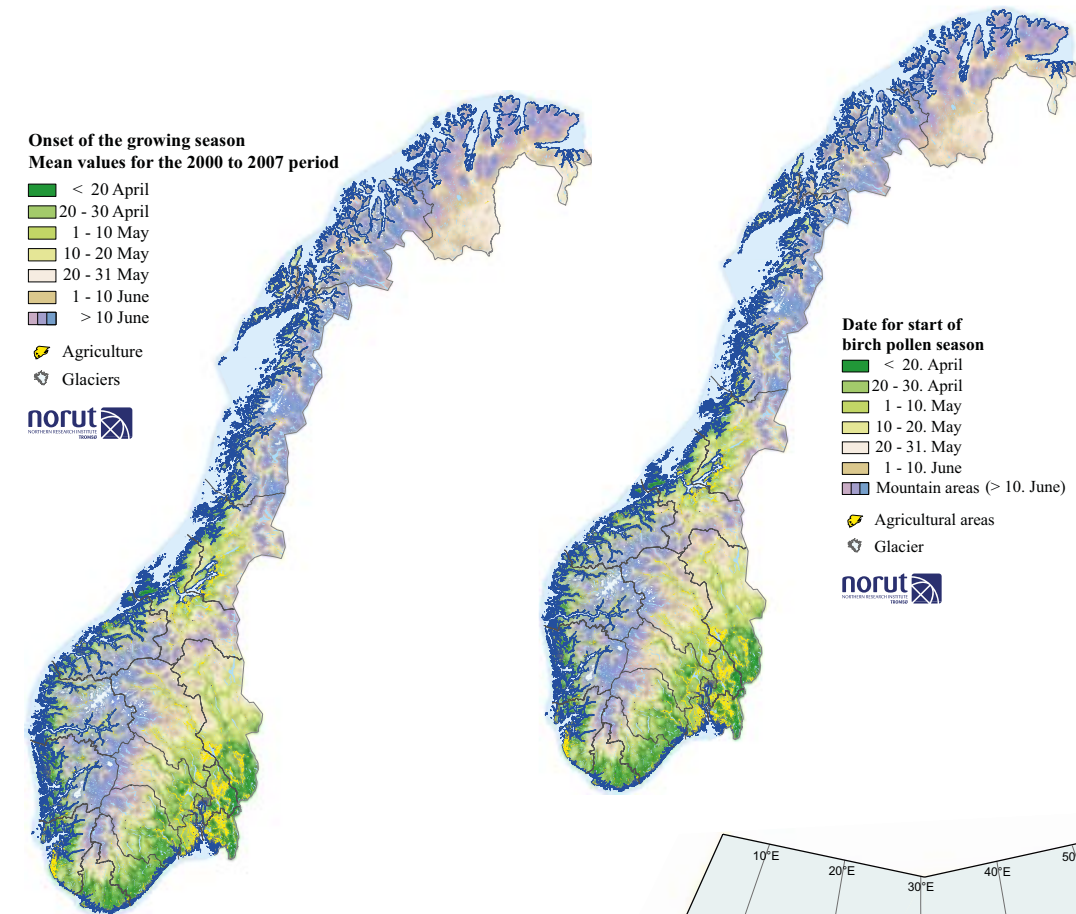
Although the latest map of the growing season is from 2007, Karlsen and his colleagues at NORUT have followed developments from the last three to four years as well. Even though early growing seasons have been less obvious during these years, they have still arrived earlier than the average time for the last 25 to 30 years.

Similar development can be observed in parts of northwest Europe, and if the trend continues, we can

Onset of the growing season
Mean values for the 2000 to 2007 period



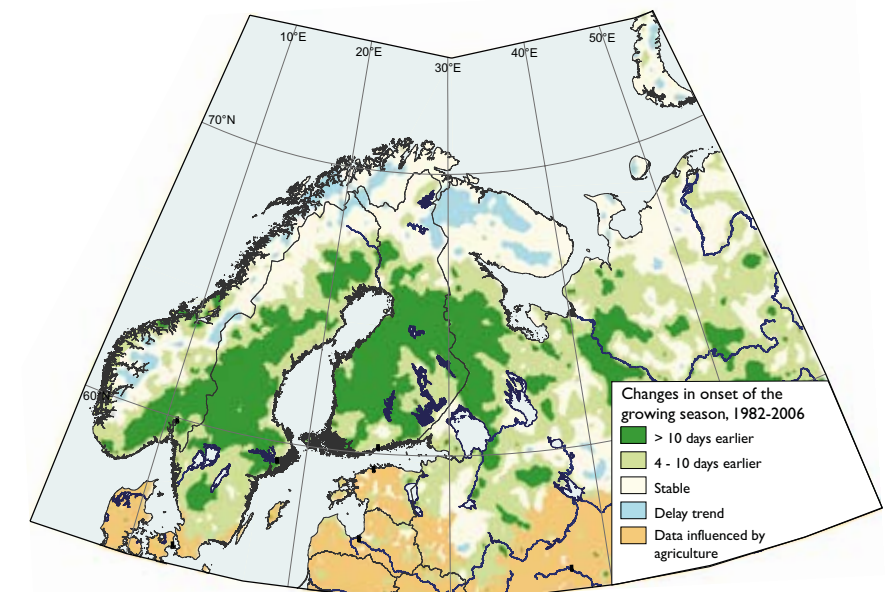
Agriculture
Glaciers



Date for start of
birch pollen season



Agricultural areas
Glacier



expect the spring to come approximately three weeks earlier at the end of the century, according to Karlsen.

Studies in phenology, which is the study of cyclic events of nature, are important for many reasons. Changes in the timing of growing seasons are sensitive bio-indicators of climate change. These changes affect primary industries such as agriculture, animal husbandry and forestry, as well as the population dynamics of wild mammals and birds.

MULTIPLE USE

The resulting growing season maps can be used in other studies, such as research into climate change and ecology. Scientists have found correlations in migration patterns of geese and the timing of the onset of the growing season, and any shifts in the phenological

cycle will affect the finely tuned migration and grazing cycle of the Saami people's reindeer herds.

“These changes are both positive and negative. The reindeer can start grazing on green plants earlier, but bothersome mosquitoes come earlier too,” says Karlsen.

Longer growing seasons for the most

part mean a bigger biomass in Norway. Farmers will have increased production and the forest line will increase. However, further north, in the Arctic zone, there will be problems with the thawing of permafrost and in more southern countries there will be problems with drought and decreased production.

The Numedalslågen river in Vestfold. Image from the QuickBird satellite. © Norwegian Computing Centre/Norwegian Space Centre Riksantikvaren

Archaeology from Space

Archaeological structures and remnants are often hidden in soil or vegetation and are difficult to see at the ground. Their shapes and forms may be easier to recognize from space. A Norwegian project has used satellite images to search for archaeological remnants.

By Berit Ellingsen

Archaeological remnants are often discovered during the construction of structures such as roads and buildings. Excavation can last for months and increase construction costs considerably.

Knowing which areas may contain archaeological remnants is quite advantageous in urban development and planning.

A Norwegian project has utilized satellite data to search for and map sites of archaeological interest. Their methods have received international attention.

SHAPE RECOGNITION

The project was initiated by the Norwegian Directorate for Cultural Heritage which needed a method to search for remnants that would complement other archaeological methods. This led to collaboration with the Norwegian Space Centre and the Norwegian Computing Centre in a forerunner project.

People in the directorate and the scientists decided to focus on sites where construction was already underway and the area was known to contain items of archaeological interest. They developed software that was able to detect

archaeological remnants on satellite images of cultivated land.

Archaeologically interesting objects and structures such as foundations for buildings or burial sites have characteristic shapes and it is these forms that the software recognizes.

The software can scan a large area in a short amount of time for sites containing shapes that may be of archaeological interest.

DISCOVERED NEW SITES

The new software and methods were tested in Vestfold in Eastern Norway in a project by Vestfold County and the Museum of Cultural History in Oslo. It is now being used by several counties.

One of the areas checked was a site where the E18 road was being expanded. The new technique detected several possible archaeological structures and objects.

Along the river Numedalslågen the project found a burial site with four graves, each surrounded by a ring of charred material. These burial rings had been discovered earlier but this was the first time such structures were detected by satellite.

The project also discovered new sites containing archaeological objects.

The new methods of discovering archaeological sites garnered the project international attention. The United Nations Educational, Scientific and Cultural Organization, UNESCO, is interested in learning about the technique and its application from Norway.

A HIGHLY SUCCESSFUL PROJECT

All partners involved regard the project as highly successful and useful.

"In the future, satellite data may make localization and conservation of archaeological sites and cultural heritage easier and more efficient," says Anke Loska at the Norwegian Directorate for Cultural Heritage.

Guro Dahle Strøm, Head of National Programmes, Earth Observation, at the Norwegian Space Centre is also very pleased with the results.

"The Directorate for Cultural Heritage had a specific need, and applications for satellites were able to meet these needs. Now, the project will be further developed and refined by the users, which is one of the best outcomes for a project we can wish for," says Strøm.

Towards a Laser Age

The future that was laid out in science fiction film classics such as Flash Gordon or Star Wars always contained the use of lasers in space, either as weapons or for broadband communication. But now, in 2010, where are the lasers? Actually, we are entering the laser age right now, also within Earth observation.

By Terje Wahl

Back in 1991, ESA launched the first European remote sensing satellite with active microwave sensors (scatterometer, altimeter and imaging radar). The ability of microwaves to penetrate clouds and provide observations at night time is a tremendous advantage. However, when it comes to measurement accuracy, there are inherent limitations to what microwave sensors can achieve, due to the long wavelength (which is measured in centimetres).

ENORMOUS POTENTIAL

Active use of light (laser-radar = lidar), with its wavelength about a million times shorter than microwaves, has an enormous potential in satellite remote sensing, both for precise distance measurements and for the detection of certain chemical species.

Space is an almost perfect place for the use of laser, as the vacuum of outer space is free of clouds and atmospheric aberrations. In principle, laser communication between satellites can offer almost infinite bandwidth, and the remote sensing possibilities in cloud-free areas on Earth are vast. Plus, lasers can be used to study the atmosphere itself.

Still, almost 100 years after Einstein laid out the physical principles for the laser, and 50 years after the first working laser was demonstrated in a laboratory, laser based Earth observation is still in its infancy, and remains a tough technological challenge. However, in early 2010, NASA's IceSat-1, which carried a laser altimeter for sea ice and glacier studies, came to the end of its mission. The small Calipso (a Franco-American satellite for the observation of clouds and aerosols) is the sole laser satellite up there today. But a new future is dawning. NASA has recently decided to build IceSat-2, and ESA already has two very advanced laser satellites under construction.

OPERATIONAL METEOROLOGY

- ADM-Aeolus will use a lidar for measurements of wind speed. This is a technique with enormous potential for operational meteorology. Such satellites may one day greatly improve the modelling of the atmosphere, and reduce our dependence on weather balloons launched from remote locations on the globe.
- The EarthCARE satellite (developed

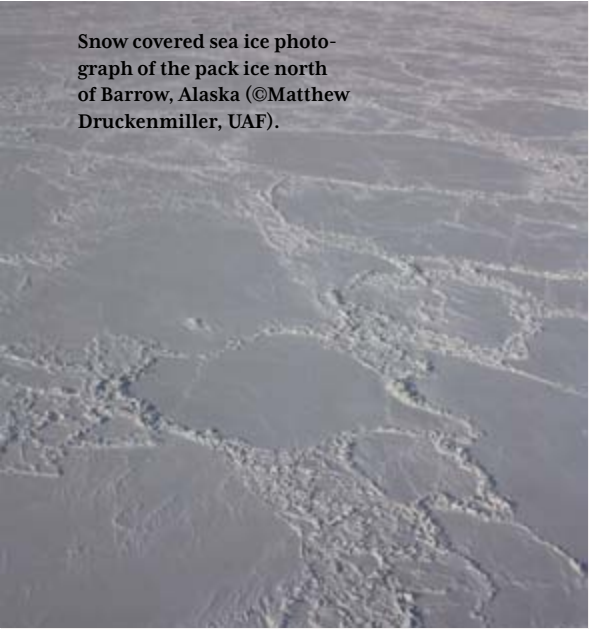
together with JAXA) will look into the details of the clouds and aerosol distribution. Hopefully this will answer the main remaining global warming questions after the 5th Assessment Group of IPCC has completed its work.

Norway is looking forward to this future featuring lasers, and is preparing for it. Norwegian scientists will most likely contribute actively to the validation of ADM-Aeolus and EarthCARE once these satellites are in orbit. And the strong meteorological and air research community in Norway will most likely be among the frontrunners to include such new measurements in their daily monitoring and forecasting tasks.

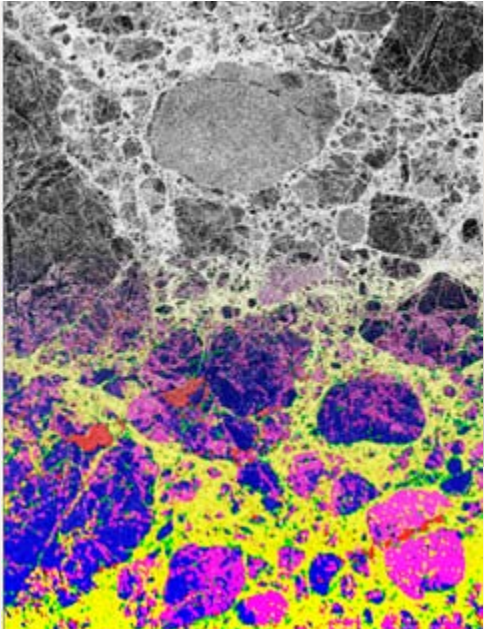
LASER COMMUNICATION

And what about laser communication in space? In fact, laser terminals for data relay via geostationary relay satellites are now being installed on the Sentinel satellites ESA will start launching in 2012 for operational environmental monitoring in the GMES programme. Yes, we are clearly moving toward a laser based future in space.

BARESS: Barents Remote Sensing School



Snow covered sea ice photograph of the pack ice north of Barrow, Alaska (©Matthew Druckenmiller, UAF).



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Right panel: SAR intensity image (top, ALOS PALSAR Fine Beam Quad-pol mode) with its speckled/grainy appearance and a 5 class coloured image segmentation derived from it (bottom).

BArents REmote Sensing School (BARESS) is a research school in Earth observation and remote sensing recently established at the University of Tromsø. The objective is to increase knowledge and build up technological competence and monitoring capability to meet challenges related to climate change and sustainable resource management in the Northern region.

BARESS is affiliated with the Department of Physics and Technology, which is one of six departments within the Faculty of Science and Technology. It is a result of the close collaboration between industry, applied research institutes, education and governmental authorities in the Tromsø Centre for Remote Technology in Tromsø.

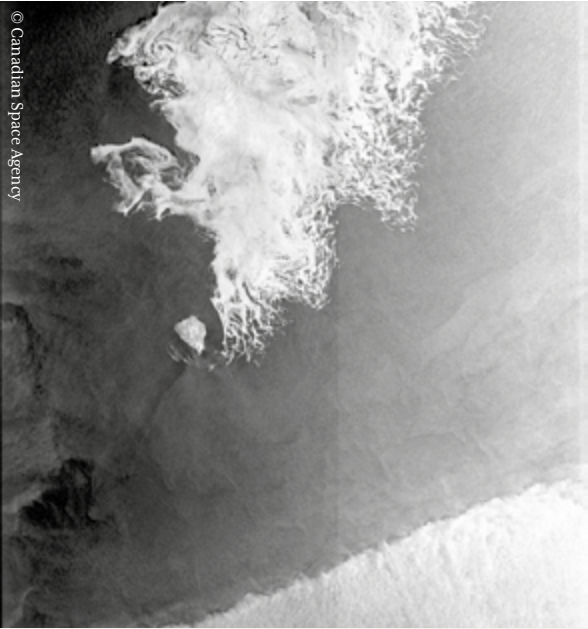
The research school will organize and coordinate education at PhD level in science and technological disciplines of relevance to Earth observation, and constitute a stimulating research environment for students and staff. The research will address the whole spectrum of topics, from theoretical issues in sensor physics, physical and statistical modelling, and advanced signal processing, to current technical issues related to retrieval algorithms,

data fusion and system integration. Applications are within monitoring of the Earth surface, oceans, and atmosphere.

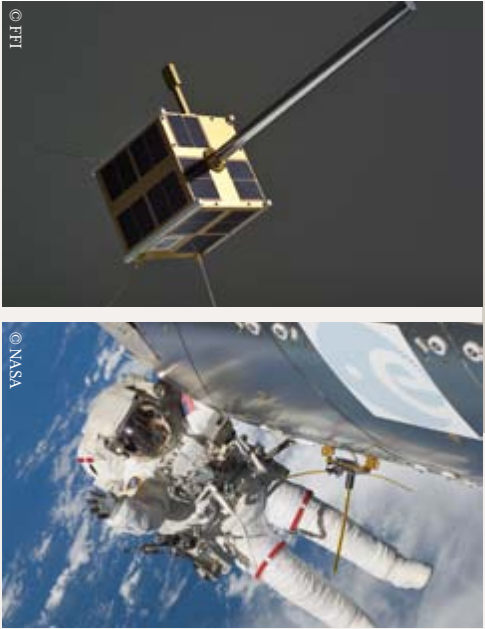
BARESS intends to frequently organize workshops and seminars where national and international leading experts will be invited to lecture. Here students will get the possibility to discuss their research projects with experts in the field. The seminars and workshops will be publicly announced and open to qualified participants.

The research school wants to become an arena for national and international collaboration in the field of Earth observation and remote sensing, and invites institutions with similar PhD programmes to collaborate, for example with student exchange. ■

The Norwegian Defence Research Establishment – FFI



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Satellite radar images and nano satellites are important for developing space based maritime surveillance capabilities. The ISS Columbus AIS is an advanced test lab in space for technology development. The AIS antenna was mounted during an EVA in December 2009.

The Norwegian Defence Research Establishment (FFI) is the primary institution responsible for defence-related research in Norway. The Establishment is also the chief advisor on defence-related science and technology to the Ministry of Defence and the Norwegian Armed Forces' military organization.

FFI has had eyes and ears for space since the dawn of the space age. In the early 1960's, FFI helped set up Andøya Rocket Range, and performed leading research into understanding the physics of the Ionosphere and the Earth's near space – topics that remain of interest as our society becomes more and more dependent on space technology for everything from driving a car, communicating around the globe, to monitoring the natural environment and human activities.

FFI employs almost 700 people working in a wide range of disciplines, from materials sciences to virtual reality, from the sea bed to outer space. International collaboration is a key component of FFI's research activities, carried out both within NATO research

groups as well as in the EU 7th Framework programme and in projects for the European Space Agency.

In the early 1990's, FFI helped set up and evaluate pilot demonstrations for use of European and Canadian radar satellites for maritime surveillance and monitoring. While the main objective was to develop a national capability in near real-time, use of Synthetic Aperture Radar (SAR) data, spin-offs include industrialization of key ground station technology that now is a main stay of Norwegian space industry's exports around the world.

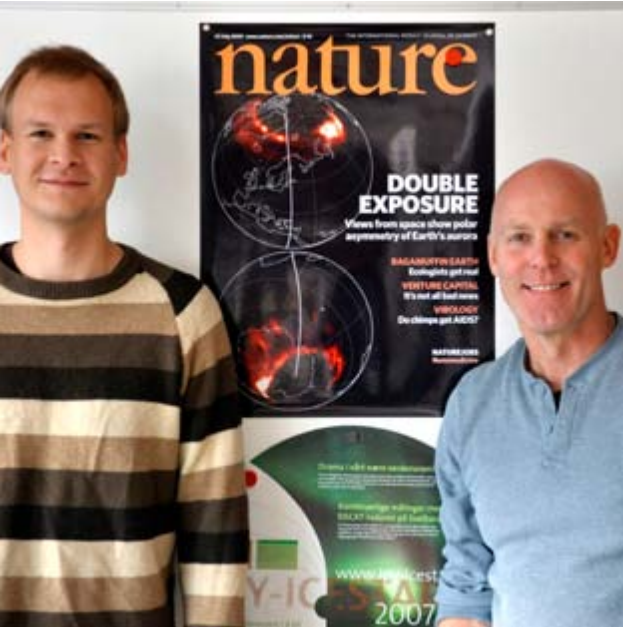
Today, FFI is engaged in many aspects of space technology and applications, with expertise on Global Navigation Satellite Systems (GNSS), space-based geodesy, satellite communications and Earth observation. The FFI satellite applications group is involved in projects developing new operational capabilities where mainly Earth observation satellites play a key role. Methods for using both radar and optical satellite imagery are being developed for mapping and infrastructure monitoring.

More recently, micro-space technology has enabled FFI, with funding from the Norwegian Space Centre, to develop

Norway's first national observation satellite, AISat-1. This nano-satellite is designed to monitor vessel traffic in the Norwegian High North. Ships above 300 tons are required to broadcast their identity, position and other navigation data as messages in the Automatic Identification System – AIS. AISat-1 is designed to receive AIS messages in low Earth orbit. Used together with SAR imagery, this provides a powerful tool for fisheries and border monitoring as well as enhancing maritime safety and security.


Paradoxically, the micro-space development led to the ESA project to deploy AIS receivers on the Columbus module of the International Space Station, i.e. the world's largest platform in space. The COLAIS project is just one step in developing a European capability for global vessel traffic monitoring, using AIS in addition to satellite imagery. Together with Norwegian maritime and space industry, FFI is involved in several ESA system studies aimed at developing an operational AIS satellite constellation. Over the next several years, we thereby expect to help meet Norwegian and EU requirements for monitoring in support of national and international maritime policies. ■

Space Physics in Bergen



Phd student Karl Magnus Laundal (left) og Professor Nikolai Østgaard (right)

Senior engineer Arne Solberg (left) and PhD student Yngve Skogseide (right) developing ASIM for the Space Station.



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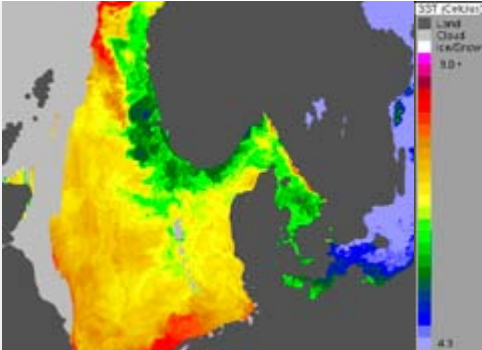
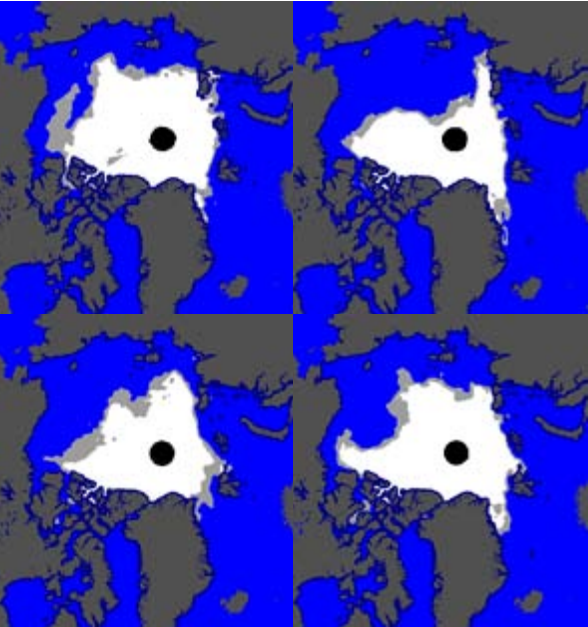
The space physics group at the University of Bergen has more than 40 year experience in building instruments for balloon, rockets and spacecraft. The last 10 years we have contributed to the X-ray camera PIXIE on NASA-Polar, the gamma-detector on ESA-INTEGRAL, particle detector on ESA-Cluster and the infra-red imager SIR-2 on the Indian Chandrayaan-I. Currently we are building a large X- and gamma-ray detector, MXGS, for ESA-ASIM which will fly on the International Space Station.

ASIM is a collaboration between Denmark, Norway, Spain and Italy. At the University of Bergen the Space Physics group works closely together with the Microelectronics group at the Department of Physics and Technology. ASIM will study the 'Terrestrial Gamma Flashes' (TGF), a phenomenon discovered 15 years ago and the most energetic photon phenomenon known to exist on Earth. The highest photon energy in a TGF reported so far, 40 MeV, was observed by the Italian mission Agile. These gamma flashes are therefore the most energetic photon phenomenon known to exist on Earth. Although they are related to electric discharges in lightning it is not known how electrons can be accelerated to such high energies to produce these gamma flashes. These are exotic phenomena where there are still more unknowns than knowns. Researchers from more than 15 countries are involved in the scientific collaboration of ASIM.

Another research area where we have made important scientific contributions is the study of aurora borealis (north) and aurora australis (south). Last summer we had the cover of Nature with results showing that the two auroral oval are not necessarily similar, but can be quite different, most probably due to electric currents that flow along the magnetic field lines that connects the two hemispheres from the southern auroral region out in space and into the auroral region of the opposite hemisphere.

Other research areas are boundary phenomena in the near-Earth space (Cluster) and the effect of energetic particles when they bombard our atmosphere. The group has three faculty members, several active professor emiriti, Phd and Master students and engineers involved in instrument design. ■

Norwegian Meteorological Institute



Ice cover September 15, 2006, 2007, 2008 and 2009, white represents closed ice and grey represents open ice (osisaf.met.no).

SST in the North Sea and Skagerrak 28 March 2007 based on NOAA AVHRR data (osisaf.met.no).



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Modern weather and ocean forecasting is largely dependent on use of satellite data. At the Norwegian Meteorological Institute satellite images have been used in decades by the on-duty meteorologists for weather analysis. The operational sea ice service is using high resolution satellite data to make detailed ice charts. The marine forecast centre is using satellite data to monitor ocean wind and waves. One of the most important applications of satellite data is in numerical weather prediction (NWP). Here satellite data is used in an automatic process called "data assimilation" to give the best possible description of the state of the atmosphere as the starting point for the model forecast run. Satellite data giving information on atmospheric temperature and humidity profiles is crucial, and so is satellite data

describing the state of the Earth surface. In this short presentation we will focus on the use of satellite data to get information on sea surface temperature (SST) and Sea Ice.

Variations in these parameters impact the ocean-atmosphere fluxes of heat, momentum and water, and thereby the development of both local as well as large scale weather systems. For example, the formation of polar lows which are the high latitude counterpart to tropical cyclones, can create dramatic weather at sea and in coastal areas.

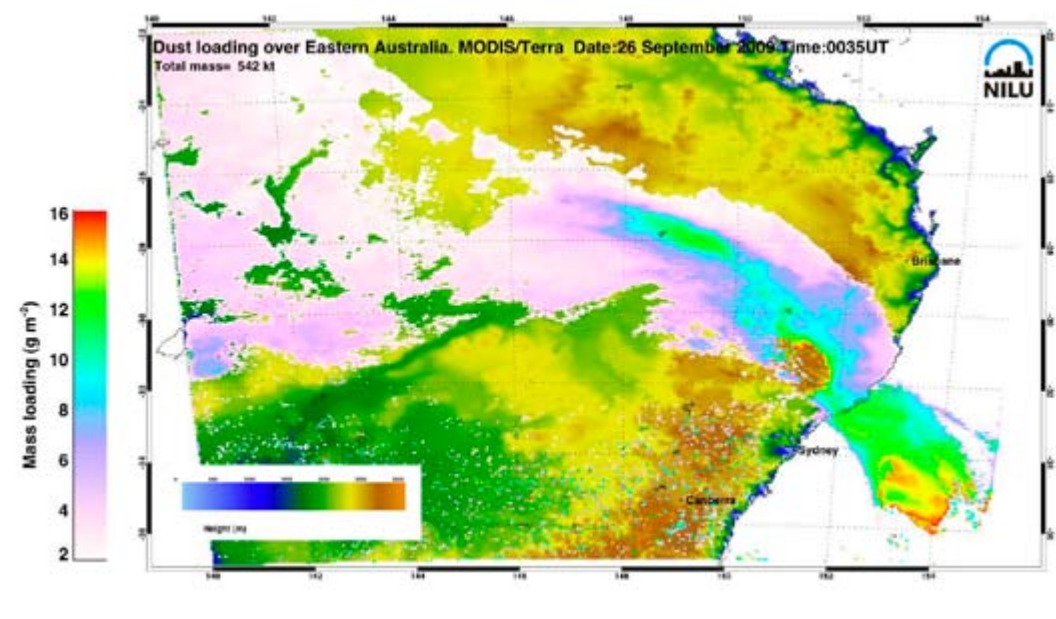
To cover the needs for accurate SST and sea ice data in weather and ocean forecasting the Norwegian Meteorological Institute in partnership with Eumetsat and the meteorological institutes in Denmark and France are running a service organized in the Ocean & Sea Ice Satellite Application Facility, OSI SAF. The data are freely available from <http://osisaf.met.no/>. Here we give two examples. The first figure shows Northern hemisphere

ice cover around minimum ice season September 15, the four last years, 2006-2009, based on SSMI (passive microwave data). Analysis based on passive microwave data from 1979 to present are the backbone of sea ice monitoring over the last three decades in both the Arctic and Antarctic. The decline in Arctic sea ice extent, with the minimum in September 2007, is documented by the time series of these data. Reprocessed global sea ice concentration data for climate studies are available from <http://osisaf.met.no/>.

The second figure shows SST in the North Sea and Skagerrak 28 March 2007 based on NOAA AVHRR data. The coastal current along the Norwegian coast forms vortexes which can be regarded as the "ocean weather". These vortexes are seen as gradients in the SST field in the image.

Both ice and SST data are assimilated in global and regional NWP models as well as in ocean forecast models and thereby contribute to the quality of weather and ocean forecast as can be enjoyed by everybody through open services like <http://www.yr.no/>. ■

Earth observations at NILU



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Figure: Mass loading (g/m^3) and dust particle size retrievals (μm) using MODIS infrared data, a microphysical particle model and radiative transfer calculations.

NILU is an independent, nonprofit research institution established in 1969. Through its research NILU increases the understanding of processes and effects of climate change, of the composition of the atmosphere, of air quality and of hazardous substances. Based on its research, NILU markets integrated services and products within the analytical, monitoring and consulting sectors. NILU is concerned with increasing public awareness about climate change and environmental pollution.

Earth observations have been an important part of NILU's research for many years. Today, the institute is engaged in several scientific projects focusing on the use of satellite imagery for environmental monitoring and reporting, such as:

Support to Aviation for Volcanic Ash Avoidance – SAVAA: NILU coordinates an ESA funded activity to improve monitoring and forecast techniques

used by the aviation industry and their Volcanic Ash Advisory Centres (VAACs).

Using Satellite data for official Air Quality reporting: Through its participation in the ESA GMES projects PROMOTE I and II (Protocol Monitoring), NILU has investigated satellite based aerosol products to see if they are useable for official reporting procedures. As of today the monitoring of Air Quality in Europe¹ is based on ground based in-situ observation from European monitoring stations. The results of NILU's investigations show a gradual improvement in satellite data quality and usability for Air Quality monitoring purposes. Satellite data are particularly useful in remote or harsh environments where ground based monitoring facilities are not possible. The results have been published in the annual reports that are provided to the UN-Economic Commission for Europe from 2005 to 2009.

¹ Performed under both the UN European Monitoring and Evaluation Programme (EMEP) to assess long range transport of pollution and under the EU Air Quality Framework Directive to assess the exceedances of legal thresholds of pollution levels.

Mineral dust monitoring for Air Quality compliance monitoring: Scientists at NILU have developed algorithms for the detection of and quantitative estimation of dust load based on infrared spectroscopy.

Through the recently started EU GMES project PASODOBLE, a Dust Awareness Service is being set up for providing quantitative aerosol information to end users. The service will make use of SEVIRI visible and infrared channels and includes additional infrared retrievals from other satellites and instruments. The service will derive aerosol optical depth (AOD), effective particle radius within the size range of 1-10 μm as well as total mass of airborne particles. Using the NILU FLEXPART model, forecasts of the dust episodes will be provided. Quantitative analyses will be done to provide particle size and concentrations which will directly lead to an indicator of exceedances caused by dust. ■

Norwegian Institute for Water Research



An Envisat/MERIS image from the Norwegian west coast showing a bloom of the coccolithophore *Emiliania Huxleyi*. In situ data are collected by an automated sensor system (Ferrybox) onboard the Hurtigruten ship "Trollfjord" (orange line). Aquaculture sites are shown (red dots). ©ESA/NIVA



The network of ships of opportunity collecting in situ data for satellite validation. Red lines are operated by NIVA, and blue by NIVA's partners. ©NIVA



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The Norwegian Institute for Water Research (NIVA) has since the launch of the Envisat satellite participated in the scientific team of the European Space Agency (ESA) performing calibration and validation of the MERIS sensor onboard Envisat. NIVA has also developed its own operational products and services based on integration of satellite ocean colour and in-situ data. NIVA actively collaborates with several international partners within this field and the activities are supported by ESA, EU and the Norwegian Space Centre.

Ships of opportunity

In-situ observations are vital for validation of the satellite ocean colour products. Installing scientific equipment on commercial ferries and cargo ships, so-called Ferrybox systems, offers a cost-effective method of realising a host of in-situ measurements. In 2010 NIVA operates Ferrybox systems onboard five ships of opportunity that cover large areas of the Norwegian coast and adjacent oceanic waters. The

systems on board continuously measure a range of important environmental parameters. Connected automatic water samplers enable laboratory analyses of an extended set of parameters.

Integrated observation system

Satellite data from the Envisat MERIS sensor and in-situ data collected from ships of opportunity are integrated and presented in an operational near real-time service hosted by NIVA (www.ferrybox.no). Satellite data are updated daily and maps of selected geophysical products from MERIS are visualized together with ship observations immediately after the measurements have been performed.

Water quality and algae blooms

The integrated observation system is open to all users and is tailored for automatic data and information presentation to the environmental authorities, fishery, aquaculture and the public. The system provides short and long term monitoring of the marine water quality, phytoplankton biomass and other environmental indicators. In case of algae blooms the observations are feasible for early warning of potential harmful blooms. In combination with other oceanic and meteorological

observations and models the information can be used for subsequent risk assessment.

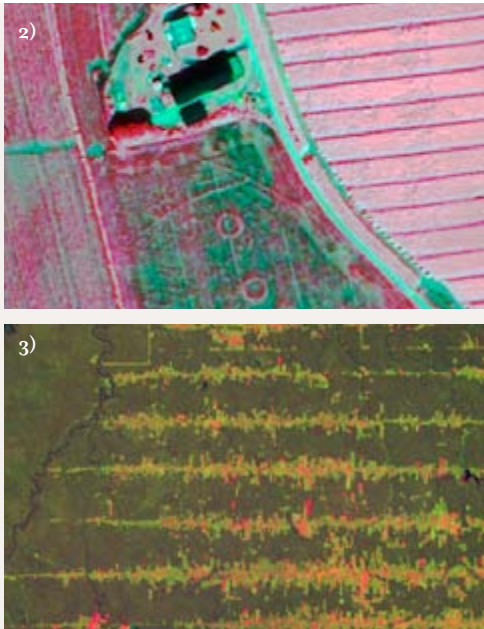
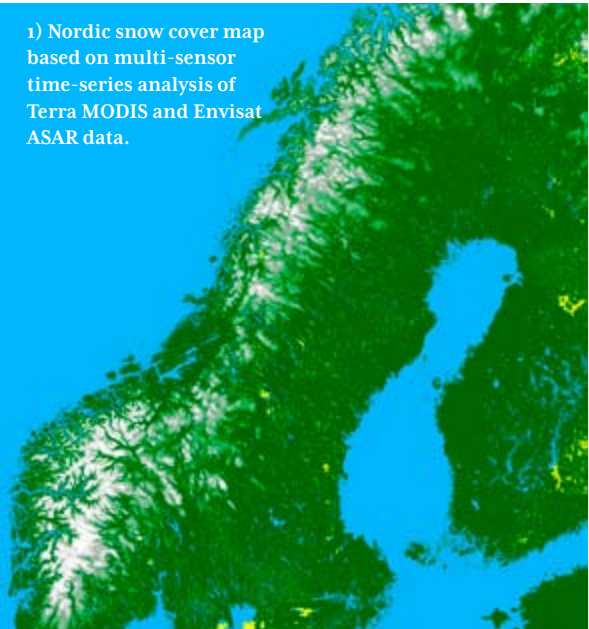
Validation of Satellite Ocean colour products

Since the launch of Envisat, NIVA has participated in the validation of the MERIS products using in-situ data collected from ships of opportunity and from dedicated field campaigns. Reflectance from the ocean surface and concentrations and optical properties of water constituents (e.g. chlorophyll, suspended matter and yellow substance) are quantitatively compared with the corresponding MERIS data products.

Satellite Algorithm development

The demands for high quality satellite data are becoming increasingly important for the monitoring of coastal waters and the Arctic. The ocean colour products in optically complex coastal waters and at high latitudes often require the satellite algorithms to be tuned to the local conditions. At NIVA the knowledge of the local biochemical and optical properties of the Norwegian and adjacent waters is therefore used in combination with hydro-optical modelling to develop new satellite products with enhanced quality. ■

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2) Circular structures are remains of ancient graves from the Viking age detected in Quickbird imagery.
3) Detection of deforestation in Brazil by new methods processing Landsat data.

The Norwegian Computing Center (NR) does research and development on methodologies for analysis of Earth observation data, in particular methodologies for semi-automatic and automatic classification, parameter retrieval and object recognition. Building on national and international collaboration, NR has been able to make significant contributions in several application areas, like monitoring of environment and climate, environmental emergency detection, natural resource mapping and map revision.

Monitoring climate change in the cryosphere
Climate change indicators and climate model scenarios indicate that the global climate will change with increasing speed in the coming years with one of the most significant changes being a global warming. The cryosphere is a very sensitive component of the Earth to global warming. NR's contributions to Earth observation methodology for cryospheric monitoring are mainly

related to snow and monitoring system development. New algorithms have been developed for a new era of multi-sensor monitoring – multi-sensor time-series retrieval of snow cover and snow wetness. The methods have been demonstrated for Terra MODIS and ENVISAT ASAR, MERIS and AATSR data and are applied in projects like CryoClim and GlobSnow.

Detection of marine oil spill pollution
Oil spills are major sources of marine pollution. The amount of oil spill from rinsing tankers and “natural losses” in the Mediterranean alone is estimated to 600,000 tons yearly (three times the Amoco-Cadiz pollution). The problem is correspondingly large along the European Atlantic coast and in the Baltic. Marine oil spill can be detected by means of optical and radar sensors. Since SAR sensors are independent of sunlight and penetrate clouds, these are usually preferred for monitoring purposes. NR represents one of the leading research groups in the world with respect to development of automatic oil spill detection algorithms. The first methodological approach was developed in the beginning of the 1990s and demonstrated on ERS-1 SAR

data over the North Sea. The algorithm has since then been improved and tailored to ENVISAT ASAR and Radarsat 1 and 2 data. The algorithm is now implemented in a software system run by Kongsberg Satellite Services (KSAT).

Monitoring the state of forests and natural vegetation
Forests and mountain vegetation comprise a dominating part of the natural vegetation in Norway. The traditional monitoring paradigm, based on field surveys, is expensive and error prone. Recent advances in air- and space-borne monitoring technology has gradually opened to more efficient and reliable approaches for monitoring the state of the natural vegetation. NR has developed advance classification methods taking into consideration the vegetations states through the season. Furthermore, NR has developed a technique to reduce the effect of clouds when classifying time series of satellite observations. The methodology is now tested out on satellite images of tropical forests and will hopefully contribute to improve monitoring of deforestation. Work is currently carried out in collaboration with Brazil and Tanzania. ■

Northern Research Institute (Norut)



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Left: Landsat ETM based vegetation map of Southern Norway with 25 different classes.

Right: The Norut unmanned aircraft system in flight.

Earth observation is an essential tool for environment monitoring. Northern Research Institute (Norut) is a key player within the field.

Norut is a national research institute located in northern Norway, with a special focus on innovation in the High North. Norut has research activities within technology and social science and carries out research commissions for industry, the public sector, and research councils.
Norut has long experience with data from Synthetic Aperture Radar (SAR), optical and atmospheric instruments. Norut has skills and experience particularly related to: satellite based oceanography, mapping of the cryosphere, vegetation maps, monitoring effects of climate change, rainforest change detection and geohazard surveillance. In recent years there has also been widespread activity in the use of unmanned aircraft systems (UAS). The department has been engaged in a number of projects initiated by the EU, the Norwegian Research Council, the Norwegian Space Centre and the European Space

Agency (ESA). The following presents some of the current projects.

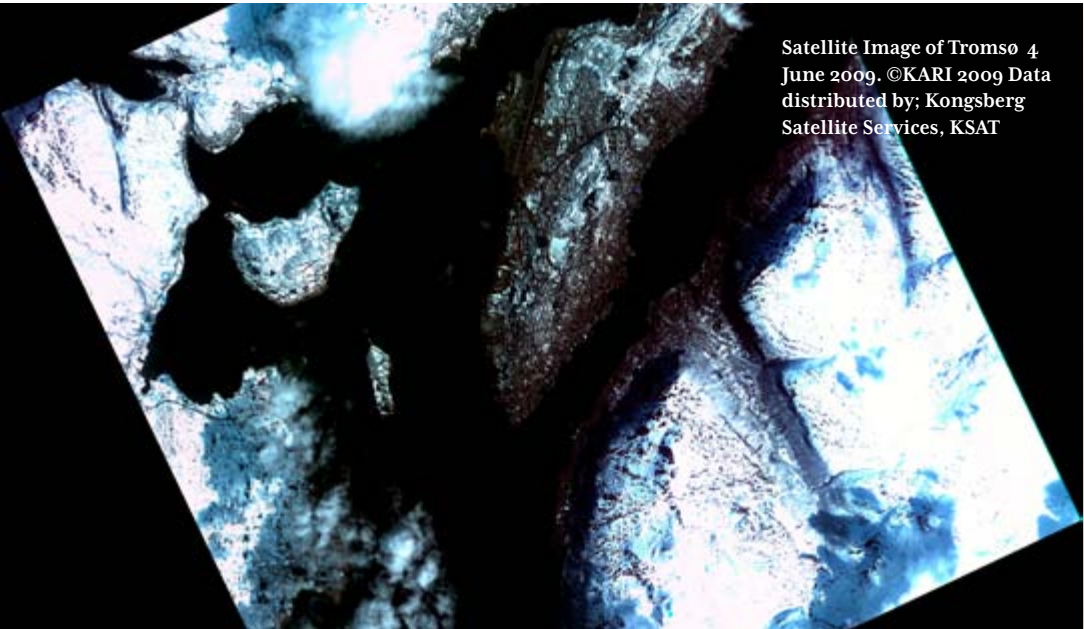
Vegetation mapping: By combining the spectral information in satellite images with different types of ancillary data, highly reliable vegetation maps are produced. Norut is the leading national institute in producing vegetation maps based on remote sensing data. During the past decades Norut has created maps for the entire Norwegian mainland, including Spitsbergen. The area is highly affected by the global climate change and the maps produced will in future studies serve a important reference data in monitoring and modelling the predicted changes.

Snow monitoring: Norut provides methods and software for retrieval of snow parameters from Earth observation. An operational service based on multi-temporal fusion of SAR and optical data have for several years been run through the Polarview service. Currently this service is developed into a pan-European snow monitoring service. Norut also participate in the development of future satellite missions such as CoReH2O aimed at monitoring the cryosphere.

Ocean wave imaging: Norut contributed to a break through within SAR ocean wave imaging with a paper published in 1995, where for the first time it was shown how ocean wave propagation direction can be resolved from satellite SAR data. To day this is the standard way of processing SAR data for wave spectra retrieval, and Norut's methodology is currently running on all ESA processing ground stations. As a result of this innovative research, Norut became an Expert Support Laboratory for ESA's SAR missions.

UAS: Norut started its UAS programme in 2005 to create a platform that could serve as a complement to satellite remote sensing, bridging the gap between point measurements and satellite data. Today the UAS is used in a number of project ranging from mapping of oil spills, volcanic ash concentration, search and rescue to science missions on sea-ice, black-carbon and snow cover. Norut has integrated a wide range of instruments, including radar sounders, meteorological sensors, and hyperspectral imagers. ■

Tromsø Centre for Remote Technology



In January 2008 the remote sensing cluster in Tromsø founded Tromsø Centre for Remote Technology (TCRT) to generate more research, business and activity among its owners.

The remote sensing cluster in Norway
In Tromsø you find the most competent institutes and businesses in satellite-based remote sensing in Norway. Through a long-term capacity building Tromsø has taken a leading domestic position, both in terms of research, technology development, service development and delivery, as well as the establishment and operation of the relevant infrastructure in this area. Today over 200 persons work on a daily basis in this field in Tromsø. To maintain and develop this position TCRT was founded in 2008, to meet the increased needs for corporation between the owners in a strong international competition.

Objectives for Tromsø Centre for Remote Technology

- Strengthen and increase the research and development in the field by public and private sector

- Increase the corporation between relevant universities, institutes and companies
- Contribute to strengthening the national commitment of the center's fields
- Contribute to the strengthening of research and development environments to make them more accessible and better able to provide companies research and development expertise

Owners of TCRT

The Founders and owners of TCRT are Faculty of Science and Technology, University of Tromsø, NORUT as, Kongsberg Spacetec as, The Norwegian Polar Institute and Kongsberg Satellite Services as. These owners represent the whole chain of development of new products and services using remote sensing, from research, technology and service development to the end user.

Projects

TCRT have participated in a range of projects and the most important are:

- BarentsWatch, earlier called "Barentshavet på Skjerm" and "iNord", where Norway is trying to establish a holistic monitoring and surveillance system

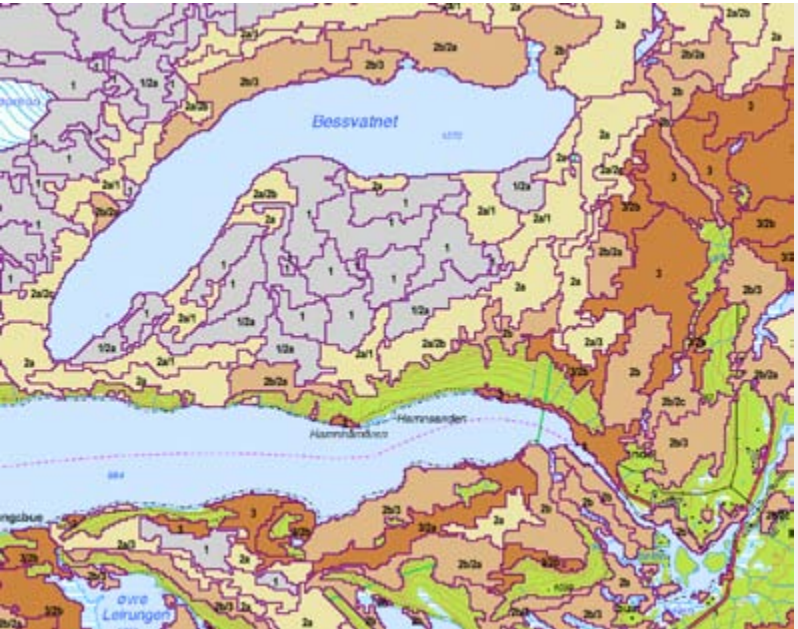
for the Barents Sea.

- Establishment of "Barents Remote Sensing School" (BARESS) at the University of Tromsø, supported financially by the Foreign Department of Norway and the local funds.
- The application "SatCent" to the Norwegian Research Council to establish a centre for research driven innovation.
- Established a regional forum in northern Norway for space related businesses, remote sensing, technology and innovation called "Forum for Remote Technology".

TCRT has also participated in international applications in the European Union research programs and are looking for opportunities with new partners.

Read more about Tromsø Centre for Remote Technology at www.fjernteknologi.no ■

Remote sensing at Campus Ås



Land resource map of a mountain area near Besseggen, Oppland. Land resources above the tree line are mapped from Landsat 5 images. The dataset is complete for all Norwegian mountain areas and is part of the national land resource data base. Base map N50 © Norge digitalt



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Campus Ås is the location of the Norwegian University of Life Sciences and several public institutions and research institutes working with agriculture and forestry.

The university offers, as part of its curriculum, courses in terrestrial remote sensing. Research at the university is wide-ranging but major attention is currently on LiDAR technology.

LiDAR (LIght Detection And Ranging) laser technology is an effective remote sensing technique for mapping the three dimensional structure of forest ecosystems. The technique is applicable on various scales stretching from individual trees over forest stands and properties up to entire forest ecosystems, as well as national and global mapping.

The LiDAR group at the Norwegian University of Life Sciences has its focus on seven research areas: (a) Methodologies for forest management inventories; (b) Sample surveys combining airborne LiDAR, optical

satellite data and field data for regional and national forest resource and biomass inventory; (c) Assessment of changes in alpine tree lines and mountain forest carbon pools caused by climate change and changing land use; (d) Studies of processes linked to the carbon cycle and emissions of other green house gases; (e) Modelling of relationships between vegetation communities and forest canopy structures; (f) Fusion of LiDAR- and multi- and hyperspectral data for classification of tree species and vegetation, and; (g) Derivation of highly detailed information on single-tree level related to wood- and tree properties

The Norwegian Forest and Landscape Institute (NFLI) is the public institution responsible for land resource surveys in Norway. It is also a research institute for forestry and landscape studies. The principal method for land resource surveys are field inventory and interpretation of aerial photographs. Satellite remote sensing is used for surveys of large areas in situations where resources are scant and the demand for accuracy is relaxed.

Productive forest areas in Norway are mapped using kNN methodology. Data from the National Forest Inventory combined with Landsat images and auxiliary data are used to generate elementary forest statistics and thematic maps. The Norwegian mountains (145,000 km²) have been mapped from Landsat, SPOT and IRS images using a two-step segmentation procedure followed by a manual review of the results. Satellite imagery combined with data from existing maps and registers were also used in the production of the Corine Land Cover maps of Norway.

NFLI currently pursue research on remote sensing techniques for biomass estimates for open natural land and improved detection of forest limits and logging activities. The institute also investigates spaceborn synthetic-aperture radar (SAR) for monitoring forest resources and forest disturbances. The National Forest Inventory moreover expects in the future to be using LiDAR for regional inventories. ■

Kongsberg Spacetec AS



KONGSBERG

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Kongsberg Spacetec AS - is the world leading supplier of ground stations for data acquisition from Earth observation and meteorological satellites, including production of value added applications (optical and SAR).

Kongsberg Spacetec has more than 25 years of experience delivering and installing systems on-site.

Kongsberg Spacetec provides:

- Meteorological turn-key systems and value added products
- Environmental and marine surveillance systems and value added applications
- Direct Ingest System
- Station Control System
- Engineering, installation, training, maintenance and support
- Consultancy & studies

Kongsberg Spacetec has close co-operation with many of the larger international space companies, and has been involved in several of the European Earth observation programme, including ESA's ERS and ENVISAT programme, as well as EUMETSAT's MSG and EPS programmes.

Our satellite ground station system is based on Kongsberg Spacetec's **MEOS** (Multi-mission Earth Observation System) and on the RUS - Reference User Station developed for EUMETSAT's Polar System (EPS) Core Ground Segment.

Kongsberg Spacetec's MEOS supports a wide range of satellites: GOES, MTSAT, MSG, NOAA, TERRA and AQUA, METOP, FY-1-2-3, Orbview-2/SeaStar, ERS-1/2, RADARSAT-1/2 and ENVISAT.

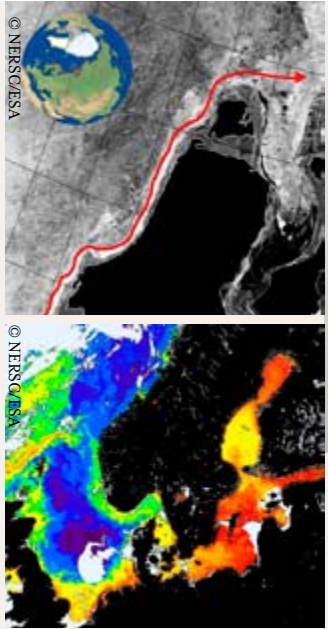
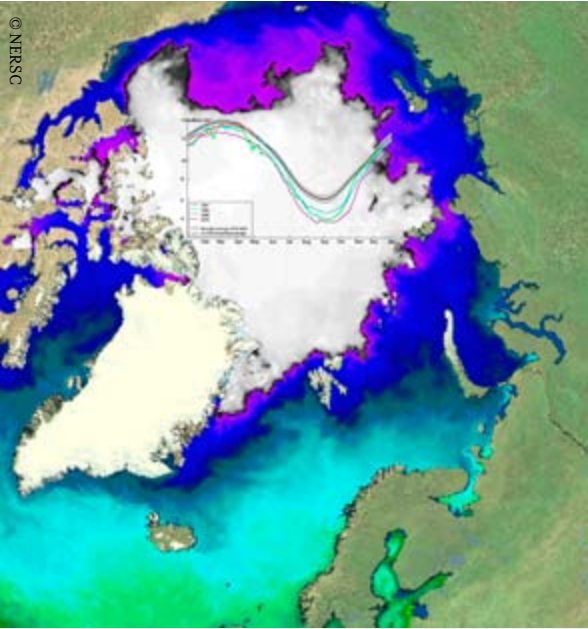
We have delivered systems to customers like:

- METEO France
- UK-met
- Russian Met
- NASA
- Eumetsat
- Several Asian Earth observation institutes

Kongsberg Spacetec can proudly claim to supply well proven and innovative state-of-the-art technology.

Kongsberg Spacetec is a part of the international technology corporation KONGSBERG, with total annual revenues NOK 13,8 billion. KONGSBERG has offices in 25 countries and about 5500 employees. ■

Nansen Environmental and Remote Sensing Center



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TOPAZ modelling and satellite observations of Arctic sea ice cover (left). Supporting navigation through sea ice along the Northern Sea Route (upper right). Monitoring of marine ecosystem and algae blooms using satellite data (lower right).

The Nansen Center has pioneered marine and polar Earth observations research during the last three decades. The research covers sensor signal processing, retrieval algorithms, assimilations of EO products in forecasting models and applications in climate and environmental research.

The Nansen Center is an independent non-profit research foundation affiliated with the University of Bergen.

Its vision is to serve the society through advancing knowledge on the behaviour of the marine environment and climate system in the spirit of Fridtjof Nansen.

The Center generates and implements research projects funded by research councils, EU, space agencies, governmental agencies, industry and private donations.

Main research areas are:

- Climate understanding, variability and change
- Climate process research
- Ocean modelling, data assimilation and forecasting
- Marine and Polar environmental studies

- Socio-economic impact of global change

The satellite Earth observation research covers sensor signal processing, development of retrieval algorithms, assimilation in forecasting models and their applications in climate and environmental studies. Innovative use of SAR and other EO data for studies of ocean currents have been developed. Development of new retrieval algorithms and validation of the mean dynamic topography, sea surface salinity and sea ice thickness are respectively carried out for the new ESA Earth explorer missions GOCE, SMOS and CryoSat-2. In addition, retrieval algorithms for the marine ecosystem and harmful algae blooms monitoring and studies are developed using optical satellite data (hab.nersc.no).

The Center develops and maintains the *TOPAZ* ocean and sea ice forecasting systems (topaz.nersc.no) that utilizes information from several satellite and in-situ measurements through an advanced data assimilation system. This system delivers daily information about met-ocean, sea ice and iceberg conditions, supporting navigation and off-shore operations in the Arctic and other waters.

The Center studies climate variability and processes in the Arctic and their teleconnections with lower latitudes, using models and long-term data from satellites and in situ observations. The Center contributes to the ocean and sea ice components of the *Norwegian Earth System Model* (NorESM) used for climate studies.

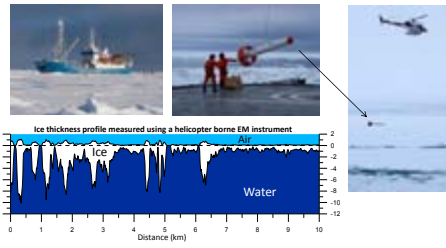
Outreach and communication of research results, data and information products for use by the society is important. The *Arctic Regional Ocean Observing System* (www.arctic-roos.org) is an international monitoring and forecasting cooperation lead by the Nansen Center, where daily, seasonal and long-term information and forecast of the Arctic and sub-Arctic seas are made available. The Center is also responsible for the *Arctic Marine Forecasting Centre* of the EU MyOcean project (www.myocean.eu.org), where the *TOPAZ* system provides 10 days forecasts of ocean and sea ice variables for a wide range of users.

The Center is the leader of the Nansen Group with research institutions located in Russia, India, China and South Africa. ■

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Scientists doing work on a Svalbard glacier. © Elvar Ørn Kjartansson/
Norwegian Polar Institute
Fig text: Radar altimeter (CryoSat-2) pre launch calibration and validation studies in the Fram Strait. Ice thickness and freeboard are measured using a helicopter borne EM bird. © Norsk Polarinstitutt

The Norwegian Polar Institute (NPI) is Norway's main institution for polar environmental research and advisory services, environmental monitoring, mapping and expeditions to the polar regions. The institute reports to Norway's Ministry of the Environment and is a liason and service body for national and international polar research.

The NPI is headquartered at the Polar Environmental Centre in Tromsø. The Svalbard office comprises offices and a logistics unit in Longyearbyen and research facilities in Ny-Ålesund. The institute also runs the research station Troll in Dronning Maud Land in Antarctica and is a partner in the Fram Laboratory in St. Petersburg, Russia.

Norwegian Polar Institute – remote sensing of polar regions
Remote sensing plays an important

role in polar areas providing good temporal and spatial coverage in areas otherwise difficult to access. With the poor light conditions in winter, and the otherwise logistically difficult and harsh environment, there is no other method that can provide such good data coverage. Therefore, for NPI, remote sensing data is a key tool, used extensively to fulfill the institute's role as consultant and supplier of knowledge to Norwegian authorities. Remote sensing data is today at NPI used as a monitoring tool, as well as for research and development. Due to NPI's extensive field activities and appropriate polar platforms giving unique polar knowledge, NPI have been actively involved in pre satellite calibration and validation missions, as well as in enhancing and developing algorithms for sea ice and land ice feature and properties extraction.

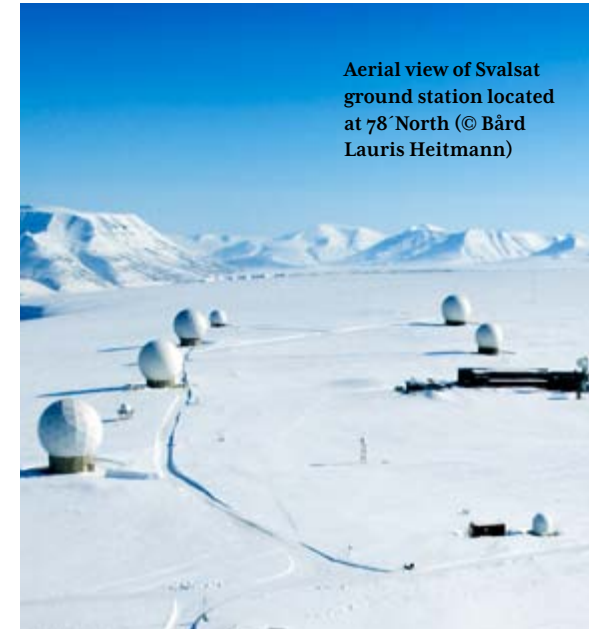
Today, remote sensing data is extensively used to improve our understanding of the cryosphere and its processes, including multi-disciplinary aspects,

for example relating satellite tracked animal habitats with sea ice information extracted from SAR data. Both optical and active remote sensing techniques are routinely used, but with focus on active instruments due to their light and weather independence.

In order to understand how changes in polar regions effect wildlife, we need to improve our understanding of interactions between climate and Arctic and Antarctic species, and their habitats. Gathering data on individual animals in the Arctic and Antarctic is challenging. The satellite based tracking system (Argos) allows us to track mobile platforms worldwide using the Doppler effect.

Since the late 1980s the Norwegian Polar Institute has tracked marine mammals (whales, seals, polar bears, walruses) and more recently birds (ptarmigans, ivorygulls), giving us unprecedented access to behavioral and environmental data (through a large range of sensors) in areas that would otherwise be inaccessible. ■

Kongsberg Satellite Services, KSAT



Aerial view of Svalsat ground station located at 78° North © Bård Lauris Heitmann)



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Ice Routing, up to date satellite information "in-field" - for safer and more cost-effective operations.

Oil spill in satellite image; long black tail with a bright white dot at the end, signature of vessel (©ESA 2006 processed by KSAT)

Unique location, state-of-the-art technology and experienced staff combined with a fully operational service chain enables Kongsberg Satellite Services (KSAT) to alert European coastal states of oil spills in their waters in less than 30 minutes after satellite acquisition.

KSAT has for more than a decade explored the use of advanced space technology focusing on maritime applications derived from Synthetic Aperture Radar (SAR). By working closely with national and international authorities and end-users, the satellite based services offered by KSAT has proved strong and viable, as shown through the best oil spill service available in the world today.

Through a unique ground station network, with installations close to both poles ensuring rapid access to satellite data from anywhere in the world, KSAT is able to provide multi mission near real-time services to customers around the world.

Oil spill and vessel detection

The keyword when it comes to monitoring oil spills is time. Time is crucial

both for catching the polluters but most importantly for timely alerts, damage-control and clean-up operations to be effective. Yesterday's information is of no use when your concern is today., KSAT is today the lead company in the European Maritime Safety Agency's Clean Sea Net Service, (CSN) providing EU Member States with monitoring and rapid reports of illegal discharges and accidental oil spills at sea within 30 minutes from acquisition. For vessel detection services positions, estimated size and heading is provided and combining the satellite data with information from the Automatic Identification System (AIS) or other tracking system allows the responsible user to perform more effective and targeted inquiries towards the non-reporting vessels. For the purpose of environmental protection this can be used as part of identifying the potential source of a spill.

Ground Station Network

From start of operations going back to 1967 in Tromsø, KSAT has become a world leading provider of ground station services. The company currently operates four ground stations; the Tromsø Station at 69°N, Svalbard

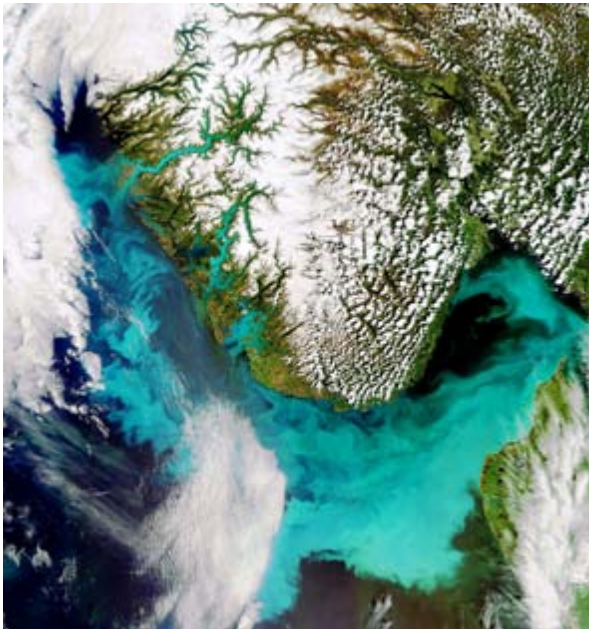
Satellite Station (SvalSat) at 78°N, Grimstad at 58°N and the Antarctic station (TrollSat) at 72°S, forming the unique KSAT "pole-to-pole" concept. SvalSat is the only commercial ground station in the world able to provide all-orbit-support (14 passes per day for most polar orbiting satellites) and has in a few years become one of the largest Polar Ground Stations in the world.

Ice Routing

Operating in icy- waters can be difficult if you do not know what lies over the horizon. Indeed, sometimes it's better to go around heavy ice than to plough on through it, at the expense of high fuel consumption. The only way to have an idea of what lies ahead is to get a synoptic view. Building on KSAT's common goal of delivering near real-time information to end users anywhere in the world, KSAT is developing new automatic algorithms to extract the maximum amount of information about the ice and delivering this directly to the field.

Even if the user is in a tent in the middle of the Arctic Ocean or half-way up a mountain they can still access the images, and they can view them on mobile devices. ■

The Norwegian Space Centre



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Algae bloom off the coast of Norway. Image from ENVISAT.
© ESA

Scandinavia in winter. Image captured by ENVISAT. © ESA

The Norwegian Space Centre (NSC) is the national space agency in Norway, organized as a government agency under the Ministry of Trade and Industry.

Earth Observation has become a vital tool for a wide range of applications and research in Norway. The Norwegian Space Centre has played an instrumental role in the development of new applications.

The NSC represents Norway in various ESA and EU committees that decides which new satellites will be built and how to use the ones already in orbit.

Moreover, NSC plays an important role in guiding Norwegian companies and institutes in their relationship with ESA. It is important for NSC to stimulate the use of satellite data in new ways that benefits society.

Within the last ten years, satellite observations have become an essential part of numerous activities, including weather forecasting, sea monitoring, monitoring of forest fires and deforestation, thematic mapping, and polar studies.

Polar orbiting satellites, 800 – 1000 km above the Earth's surface, are most valuable to Norway. The reason is that their orbits converge at the poles and therefore provide more coverage at our latitudes than they do closer to the equator.

The Norwegian Space Centre's application programme has supported users, research communities and businesses in testing the potential of Earth observation from satellites. Priority is given to the development of applications having public or industrial benefit.

Some examples of projects supported by the NSC:

Oil spill and ship detection service: Kongsberg Satellite Services (KSAT) provides near-real time detection of oil spills in European waters using satellite based Synthetic Aperture Radar. Integration of other types of information such as ship identification from the Automatic Identification System helps to quickly establish a better maritime picture in case of illegal oil discharge.

Algae bloom and water quality along the coast: Algae bloom along the Norwegian coast has been monitored by Norwegian scientists for many years, using the MERIS instrument on

ENVISAT. This information is vital for Norwegian governmental management and fish farmers since algae might harm the fish.

Bedrock subsidence monitoring: Radar satellites and interferometric analysis have been instrumental in detecting new areas with potential for hazardous landslides in Northern Norway.

Cryospheric climate monitoring: ESA and the NSC are funding the initial phase of a new operational service for long term systematic monitoring of the cryosphere. Included in the plans for the CryClim project are services for global snow and sea ice products and glacier products covering mainland Norway and Svalbard.

Satellite monitoring of aerosols and air quality: With support from NSC, the Norwegian Meteorological Institute and the Norwegian Institute for Air Research (NILU) are advancing the use of satellite measurements in data bases and model predictions for aerosols, air pollution and air quality. The Norwegian institutions have important international roles in this field. ■