Ice cap meltdown

by Clive Simpson

University of Colorado National Snow and Ice Data Center (SIDC) staff Dr Ted Scambos and Terry Haran conduct calibration/validation studies on Antarctic sea ice near Casey Station, as part of the Australian Antarctic Division research programme. The measurements include gathering in situ data on sea ice temperature and reflectance for comparison with satellite-derived values from several NSIDC data sets. The research vessel Aurora Australis is pictured in the background. NSIDC

Cryosat to place technology into orbit to measure global warming

When the ice monitoring satellite Cryosat launches in the spring of 2005 it will become the first Earth Explorer satellite to take off as part of ESA's Living Planet programme. These European-funded missions are specifically designed to provide speedy answers about different aspects of the Earth's environment – and a fast answer is exactly what we need to the question of what is happening to our polar ice caps.

Cryosat's mission is to monitor precise changes in the thickness of polar ice sheets and floating sea ice over a period of three years, observations that should determine whether or not the Earth's ice masses are actually thinning due to a changing climate.

By accurately measuring the thickness of the ice over three years Cryosat should be able to prove conclusively whether there is a trend towards diminishing polar ice cover and improve our understanding of the relationship between ice and climate change.

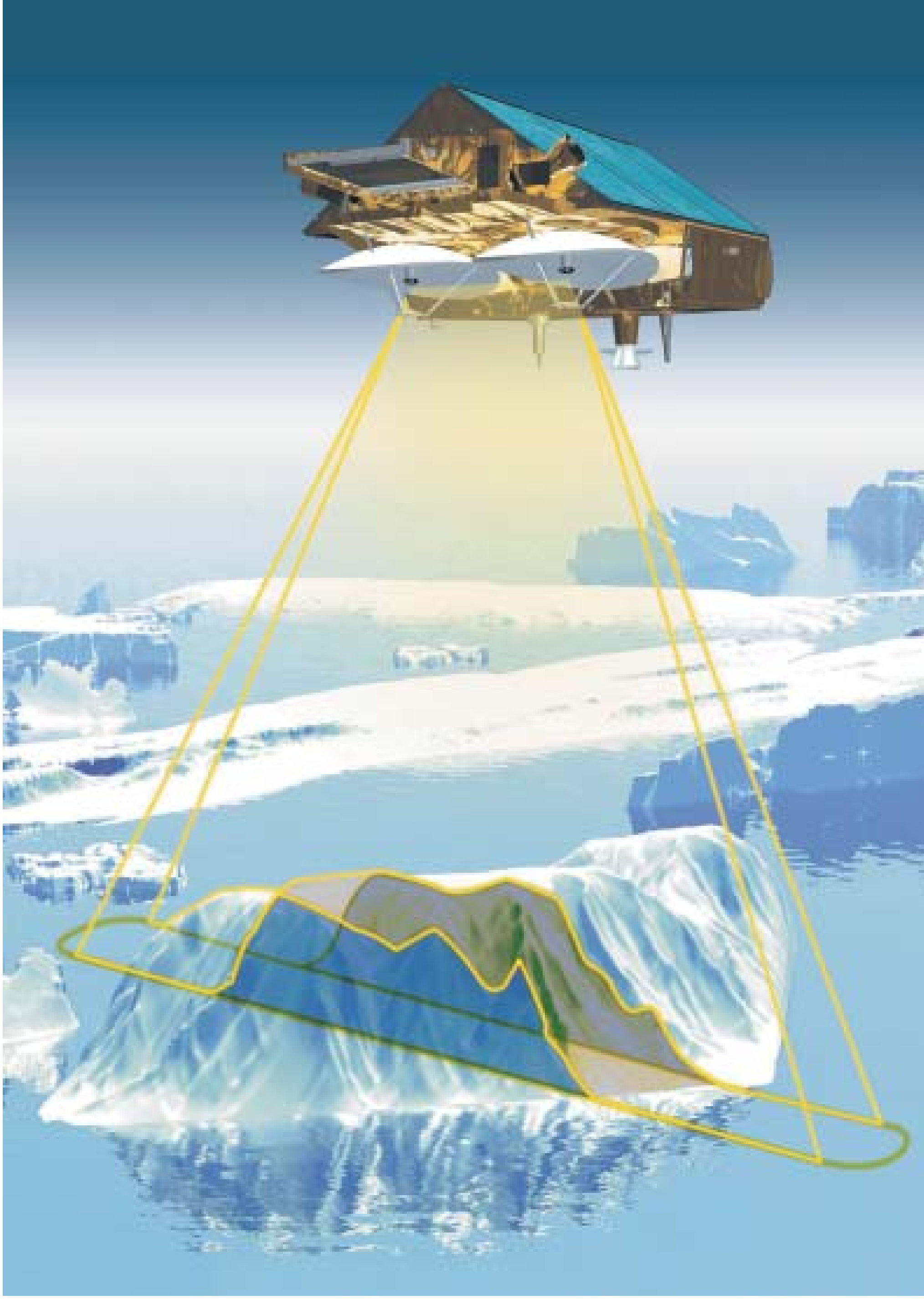
Climate data indicates that the 20th century was the warmest in the last thousand years and the evidence of climate warming can no longer be ignored – the Intergovernmental Panel on Climate Change reported that the average global surface temperature rose by 0.6 degrees in the last century. At the same time – since 1750 – the concentration of greenhouse gases in the atmosphere, such as carbon dioxide and methane, has grown by 30 and 150 percent respectively, largely as a result of human activities.

It is difficult, however, to predict what effect this will have on the polar ice cover and, since ice plays such a major role in climate regulation and the level of the seas, it is information that could have far reaching consequences for us all.

Using models available at the moment, it is only partially possible to predict how these developments affect the climate. The predictions vary between global warming of between 1.4 to 5.8 degrees Centigrade in the next hundred years. As a consequence, experts expect some polar ice and glaciers to thaw, which could result in the water level of the oceans rising by up to a metre.

Despite being thousands of kilometres away from the most inhabited areas, the presence of ice at the poles plays a central role in the global climate. It has a profound effect on the climate in Europe, Asia and the

An early Envisat's ATSR-2 image of the Larsen Ice Shelf, part of the Antarctic Peninsula. The dividing line between the ice shelf and the sea ice is clearly visible running from the bottom right up through the centre of the image. The oval-shaped piece of ice at the northern extremity of the ice shelf is a large iceberg formed from the disintegration of part of the shelf. ESA



Graphic illustration of how Cryosat's twin antennae will collect data that allows accurate measurements and 3D imagery of sea ice and glaciers to be produced. EADS Astrium

Americas. Three aspects are most important: snow and ice reflect sunlight extremely well, sea-ice cover insulates the water underneath, and large amounts of thawing ice affect the large-scale ocean currents.

Polar ice reflects a large proportion of the sunlight and the absorbed and reflected light balance each other out. But as polar ice melts, less sunlight is reflected and so the polar region warms up. Consequently, more ice begins to melt and the reflective capabilities are further reduced, resulting in a self-accelerating, or runaway, cycle.

During darkness, open water radiates a large quantity of heat – about 90 Watts per square metre. A snow-covered sea-ice slab floating on the ocean surface has a negative effect on this and to a certain extent acts as a thermal blanket, playing a significant part in regulating the heat balance of the Earth. This effect is reduced as soon as the ice thins or decreases in area.

Ocean currents also have a special influence on the climate. They act as heat pumps, as they distribute the energy stored in the oceans around the entire globe. Probably the most well-known example of this is the Gulf Stream, which transports warm water from the tropics diagonally over the Atlantic to Northern Europe and provides Britain with a mild climate and ice-free ports.

If the ice sheets and the outer sea ice cover melt, the relatively larger quantities of fresh water could disrupt or even change these ocean currents – with unforeseeable effects on the climate.

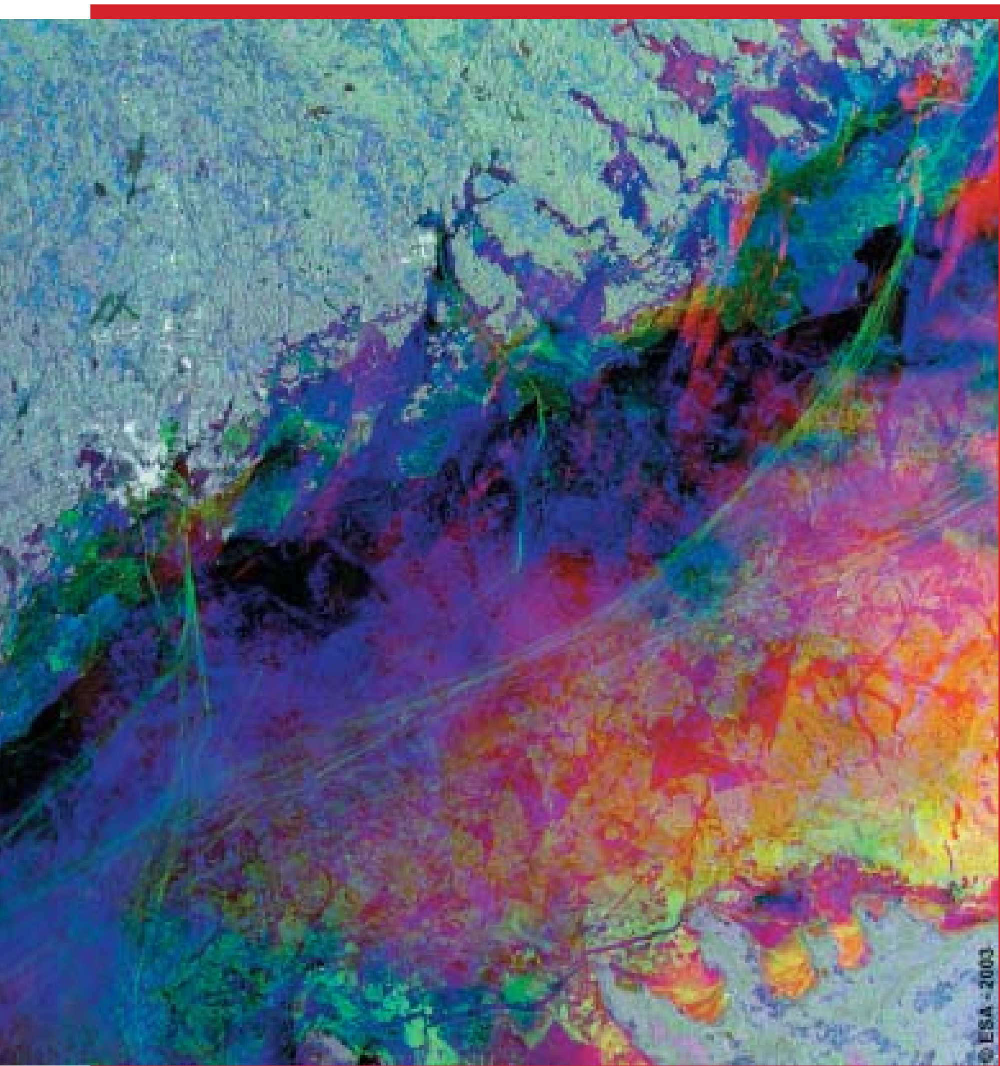
Much of the uncertainty in the climate models of today is due to the lack of precise measurement of the polar ice and its development. Experts estimate that the sea ice has receded by 10 to 15 percent since 1950, and the thickness of the Arctic ice is reported to have reduced by 40 percent in the last few decades.

These statements, however, are extremely uncertain due to the lack of widespread information on sea ice thickness.

The 70 million euros ice research satellite CryoSat will measure changes in the thickness of ice sheets and polar ocean sea ice cover with unprecedented accuracy, providing climate researchers with data previously unavailable from these uninhabited regions.

It has been developed and built for ESA by EADS Astrium at its Friedrichshafen, Germany-based satellite centre and will be launched from the Plesetsk Cosmodrome in Russia by a Rockot launcher provided through Eurockot, an associate company of EADS.

CryoSat will circle the Earth in a polar orbit at an altitude of 720 km. Its radar altimeter will measure the thickness and circumference of the polar ice sheets and sea ice cover.



An Advanced Synthetic Aperture Radar (ASAR) multi-temporal colour composite image from Envisat in July 2003 showing an area of 100 km swath width centred over the ice-covered Gulf of Finland that separates the countries of Finland (north) and Estonia (south). Ice is visible on the bay as yellow patches on the Estonian side of the bay and blue green patches on the Finnish side. Other landmarks visible are the city of Helsinki. (bright white area, centre left) and Vantaa airport north of the city. *ESA*

Earlier radar satellites, such as the ERS-1 and 2 or the giant Envisat spacecraft, were only equipped with a single antenna with which they could gather information about uniform ice surfaces over a large area.

CryoSat, on the other hand, has twin antennas. This double radar will be able to scan the surface very precisely and produce imagery in a similar to the way in which humans, with two eyes, see in 3D.

This system, known as radar interferometry, boasts an average accuracy of one to three centimetres and so can also collect data on inhomogeneous ice structures with very steep walls in polar seas, glaciers or ice sheets. To achieve this extraordinary precision, the orbit altitude of the satellite must be constantly known and, to determine this to within a few centimetres, ground stations emit signals, which are received and processed by an on-board instrument called DORIS. This altitude information is then conveyed via the normal data stream to the ground station.

CryoSat's outer surface also incorporates a laser retro-reflector which, similar to cats eyes on the road, reflects a ray of light. A laser beam transmitted from a ground station and reflected by CryoSat would enable the height of the satellite to be determined.

CryoSat's radar altimeter works day or night and can also penetrate clouds. Therefore, it is particularly suited to the research of the large polar ice sheets, which rise up to 4000 metres above sea level and which are often cloud covered.

The fast, high achieving and cost-effective nature of an Earth Explorer mission such as Cryosat has a knock-on effect for the dedicated on board computer hardware and software. This has been a challenge for the UK's leading specialist in the field, Bristol-based SciSys which was due to deliver a final version of Cryosat's on board application software before the year end.

"The on-board software on a mission such as Cryosat plays a vital role as it is responsible for controlling the precise orbit and attitude of the spacecraft as well as handling all of its communications with the ground segment," said John Auburn, SciSys sales director.

"Post-launch, the only thing on the spacecraft that can be changed is its software, so it absolutely central and critical to the mission," he explained.

"Our contribution is also central to the aim of keeping costs down and delivering high quality results, quickly. We have had a team of SciSys engineers working very closely with the satellite prime contractor in Germany."

Such close cooperation is designed to minimise the impact of changing requirements on the development, and keep time wasted and costs down. As a result, SciSys has been involved through all the stages of this development – from the initial software architecture and definition of the communications protocols, through to integration of the software on-site with the hardware supplier in Italy, and support of system level testing.

According to Auburn, being such an active member of the team this has required a willingness to learn about the overall spacecraft and its specific subsystems, becoming a solutions provider rather than just reporting problems.

"We see this as the way of the future," he

CryoSat data

Mass:	**approx 650 kg**
Instruments:	**Radar altimeter ata receiver Laser retro-reflector**
Height resolution:	**1 to 3 cm**
Horizontal resolution:	**approx. 300 m**
Total finance value:	**approx 140 million euros**
Of which industrial:	**approx 70 million euros**
Mission duration:	**over three years**
Orbit:	**720 km altitude, 92 degrees inclination**
Planned launch date:	**spring 2005**

Artist's impression of Cryosat in Earth orbit. EADS Astrium

John Auburn, of SciSys.

said. "The on-going success of Cryosat and the Earth Explorer programme will depend on contractors' capabilities to develop these kind of improved working methods and efficiencies."

In the future SciSys will re-use processes, methodologies and core software in comparable systems in other domains, and for similar missions being planned by ESA.

The development of on-board application software for new Earth Explorer satellites AEOLUS and SMOS, which are also destined to study environmental conditions around the globe, is one current example.

"Software may not have the visual impact of rockets, launchers and satellites, but it has become the key part of these complex missions and without it these ambitious projects would never get off the ground," said Auburn.

"Now, through software's reusable nature, and a well-established level of expertise and experience in a wide range of space missions, we see a growing move towards projects like Cryosat. These projects are vital to our future, as they bring us fast, reliable information about changes happening on Earth – that could have a huge impact on the way we live."

SciSys managing director, John Haynes, agrees that benefits will accrue to scientists, engineers and the space industry as a whole.

"ESA's Living Planet programme is a new and much more flexible approach to the observation of Earth from space," he said. "Industry and research organisations have quickly realised the enormous value of the information Earth observation missions can deliver and now they are requesting faster and more specific information to help find answers to the immediate environmental uncertainties of the 21st century."

Haynes says that, as a result, the space industry is being pushed to deliver very specific results, quickly and effectively – and he believes that, given the importance of such information to all our futures, this is no bad thing.

"The clear benefits for industry are that this rapid push forward is providing huge opportunities for partnerships as well as promoting a much more open system for mission proposals," he said.

"The whole communication process, including the regulatory and administrative procedures for research missions, is being streamlined, a fact that benefits everyone and can only support the increasing speed of development and the reduction of costs that these missions must deliver."

Technical overview

SciSys's mission critical real-time software has been designed not only to be robust, but also flexible. It provides both Cryosat's data handling capability and its Attitude and Orbit Control. It acts as Bus Controller on the Satellite's Mil-Std-1553 bus, controlling, monitoring and collecting data from the various on-board instruments. Written in Ada to meet the Packet Utilisation Standard, it not only includes telecommand and telemetry handling but also event reports that can autonomously trigger recovery actions, system logging, timeline scheduling, for those periods when commanding is impossible, as well as monitoring and statistical analysis of any information requested. The vast amount of data collected can be transmitted in real time and/or stored on-board for later transmission. The attitude and orbit control software provides the stringent pointing demanded of the Cryosat instruments. It receives control data via the Mil Bus and discrete links and provides commands to the satellite actuation system via the Mil-Bus. With system/sensor redundancy, as well as fault detection and recovery, this software has been designed to meet the high integrity requirements for this crucial element of the Cryosat satellite.