

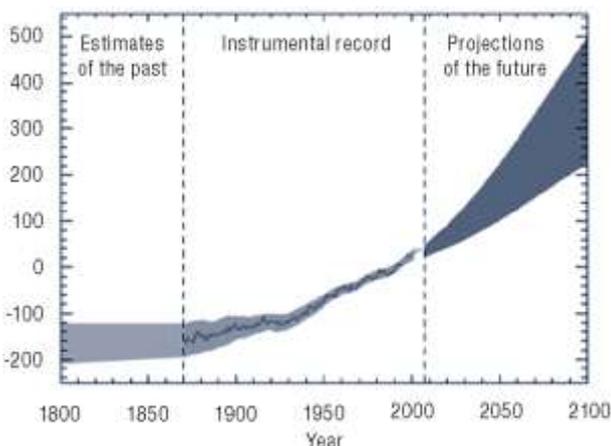
SPACE TECHNOLOGIES AND CLIMATE CHANGE

Climate change is emerging as one of the greatest long-term challenges facing society. The OECD publication “Space Technologies and Climate Change” published in 2008 examines the contributions that space technologies can provide in tackling some of the major problems posed by climate change. Focussing on case studies in water management, marine resources and maritime transport, it sets out the rationale for developing satellite systems that measure and monitor climate change, help mitigate its consequences, and reduce the uncertainties that surround projections. The report underlines the need to consider satellites not just as technology demonstrators, but as components of a critical communication and information-based infrastructure for modern societies.

Climate change is a major challenge

Climate change is emerging as one of the greatest long-term challenges facing society. It is a modification in long-term weather patterns mainly caused by greenhouse gases, which make the earth warmer by trapping energy in the atmosphere. Global emissions of greenhouse gases could grow by a further 37% by 2030. A warmer earth leads to modifications in rainfall patterns and fresh water availability, rises in sea level, and many different effects on plants, wildlife and human activities. However, a high degree of uncertainty still attaches to the various predictions and the science underlying them – as demonstrated by the long-standing worldwide scientific and political debate on these matters. This underscores the importance of better data, better analysis and better science – both to further our knowledge of climate change and its effects on the natural environment and human activity, and to comprehend better the effects human activity is in turn having on natural resources and climate change itself. It is with regard to this knowledge-enhancing function that space has a vital and often unique role to play..

Observed and projected global average sea level rise, 1800-2100



Source: Solomon, S. et al. (eds.) (2007), *Climate Change 2007: The Physical Science Basis*, Cambridge University Press

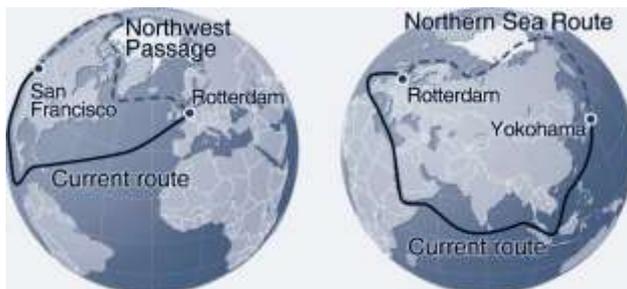
Climate change’s interplay with human activities and natural resources

There is a strong interplay between climate change, human activities and the state of natural resources. To demonstrate this, three complementing “case studies” have been conducted on fresh water management, marine resources and maritime transport.

- Fresh water resources are getting scarcer in many parts of the world because of radical changes in regional water cycles (less precipitation), water mismanagement, and increasing polluted ecosystems. Competition for water is also increasing among agriculture, industry and domestic consumption, especially in countries with high increases in demography. The number of people living in areas affected by severe water stress is expected to increase by another 1 billion to over 3.9 billion.
- Marine environment at risk: 75% to 95% of animal, vegetal and mineral resources exist in a ribbon no larger than 350 kilometres from the coasts, and at depths of less than 200 metres. This natural richness is endangered globally by human activities, pollution and climate change-induced effects (sea temperature changes, shifts in ocean currents, acidification of waters). If current overfishing trends continue, the world will face a scarcity of biological marine resources, with the additional challenge that climate change-induced impacts may be amplified. The top ten fish species that make up 30% of total fish consumed are already either fully exploited or overexploited. Paradoxically, a significant by-product of climate change is the rapid melting of polar ice caps, which had introduced the possibility of exploiting rich oil and gas deposits in previously inaccessible seabed (e.g. Arctic).
- Maritime activity continues growing and increasingly impacts the health of the oceans via different forms of pollution. The number of ships has almost doubled and their capacity almost tripled between

1970 and 2004. Looking ahead, maritime routes could become even busier. Seaborne trade is expected to continue growing annually by 3.3% until 2020. In parallel, climate change impacts, such as melting ice sheets and likely increases in extreme weather events (e.g. hurricanes) are affecting ever more shipping routes and maritime traffic.

Current and future sea routes around the Arctic Basin



Source: United Nations Environment Programme (UNEP) (2007), *Global Outlook for Ice and Snow*, Geneva.

Responding to the climate change challenges calls for a major effort on two fronts:

1. First, closing the gaps in our knowledge. A number of climate-related sciences are progressing rapidly and more information is becoming available, but data to help better understand atmosphere-, land- ocean-related processes and human influences, are still lacking in many instances.
2. Second, reducing uncertainty surrounding future projections. Advances in climatology and modelling techniques are key in this respect and will require continued improvement in the collection, range and quality of climate-related data.

The role of space technologies

A wide variety of satellites and their ground systems are already in place. These range from meteorological satellites to telecommunication, navigation and earth observation satellites. They bring already some key societal contributions:

- **Meteorology:** Significant improvements achieved in weather predictions over the past decade are due in large part to a larger international fleet of improved meteorological satellites, bringing about notably substantial gains in the management of agriculture and energy.
- **Over half the Essential Climate Variables** (atmospheric, oceanic, terrestrial, etc.) identified by the United Nations Framework Convention on Climate Change depend on satellite information, with many of those systems developed as short-term

R&D programmes for scientific research. Climatologists and glaciologists rely more than ever on continuous satellite observations of the Arctic and Antarctic to study, in almost real-time, climate change processes.

- **A number of scientific discoveries concerning climate change** have been made thanks to space-based data. For example, the Topex-Poseidon and Envisat missions have shown through space altimetry that oceans have been rising over the past decade; collected data have also provided unexpected information for monitoring oceanic phenomena, such as variations in ocean circulation on the level of the El Niño 1997-98 event.
- **Keeping track of the world's water supplies:** satellites contribute to the understanding of the global water cycle and to improved fresh water management. Clouds, water vapours, precipitation and sea-levels are all measured from space, in coordination with in-situ systems. Already in many OECD countries, satellite data are used to monitor daily the quality of water bodies, detecting in particular natural and man-made pollutants (e.g. harmful algal blooms, oil spills).
- **Satellites represent often the only recourse** in places in the world where ground systems are not deployable; particularly in the cases of telecommunications and climate monitoring systems (e.g. data from buoys and communications with ships at sea).

The challenges

There have never been so many connections and “eyes in the sky” providing links, signals, and data useful for climate research and monitoring. And more are planned. But some technical and governance improvements are needed, particularly for the earth observation infrastructure.

- There are still gaps in earth observations’ coverage that sometimes limit the adequacy of the sensors available.
- The multitude of formats renders access to the data difficult, let alone its manipulation.
- Data integration into larger information systems can also be complex and time-consuming, especially for real-time applications (e.g. sea traffic monitoring, oil slick detection).
- The outlook for setting up an improved international global observing system (GOS) by 2015 and 2025 is favourable. But this international effort will require sustained investments.

- Transitioning observing systems from research to operation faces serious governance problems in many countries, which have not yet been resolved.

The earth observation sector is experiencing many changes, as new actors are undertaking their own space programmes. The development of strong earth observation programmes in Asia (e.g. India, China), South America and Africa is an encouraging factor, as more institutional actors than ever before are involved in developing systems. The multiplication of commercial initiatives and systems from which climate data can be derived is also a positive sign. But despite a more evenly distributed workload thanks to international co-operation, developing the necessary systems will come at a cost. Based on past investments and the needs identified for renewal of existing systems and the development of new systems, a conservative guess would point to worldwide investment requirements in space-based earth observation of around USD 38-40 billion by 2020, averaging USD 1.5 to a little more than USD 3 billion a year.

Estimated annual investments (maintenance, replacement, expansion) in Earth observation (2006, 2005, 2004)*

Year	Annual investments (in billion USD and as % of total in-orbit assets at end-2006)	
2006	3.2 billion USD	15%
2005	1.1 billion USD	6%
2004	1.6 billion USD	10%

Not taking into account some large previous R&D investments in instruments & necessary support space-based infrastructure

It cannot be assumed investments on this scale will be easy to secure. Investments are subject to difficult, often contentious political, technical and economic decision-making processes. What will be required to ensure that adequate levels of investment in space systems are ultimately realised? The answer, first and foremost, is an improved and extended tool box to help policy makers arrive at investment decisions based on good data and analysis. There are several evaluation methods that can be used for analysing the socio-economic return of large programmes. Four main categories with key methods and findings have been identified.

What can we learn from cost-benefit analysis?

There are strong indications that satellite monitoring, navigation and communications provide qualitative and quantitative advantages, as long as those systems are integrated in wider information systems (Figure 3). The following socio-economic benefits are generally associated with the development of space systems:

Regional economic growth: Whenever many employees from a given sector are working in one area, the region tends to benefit from positive economic spillovers (the same concept applies to the economic effects of large military bases or automotive industry concentration). Although estimates vary depending on methodologies, the European spaceport in French Guyana is credited with generating 20% of this French department's GDP in 2005, with 1 350 people employed in the sector and 5 800 derived jobs in other sectors. In the United States, the NASA John C. Stennis Space Center was responsible for more than 1 600 NASA scientists and engineers with economic impacts totalling USD 691 million in 2005 on Mississippi and Louisiana communities.

Markets: In the satellite communications sector, the maritime markets are well identified and very dynamic. According to NSR data (2007), the number of satellite terminals on maritime platforms will grow overall from 225 000 in 2005 to over 605 000 in 2012 and provide revenues of over USD 1 billion at the end of 2012.

Cost-efficiency: the possibility of accessing information and communicating anywhere in the world brings substantial cost efficiencies. Radar imagery has for example been extensively used by Canada and Norway to provide observations over large areas in much less time and costs than just with aircraft patrols. In addition, improved ship detection over large geographic zones enabled by integrating satellite imagery with aerial patrols helps deter illegal fishing and oil spills. A surveillance system set up in the Kerguelen Island (South Indian Ocean) by France in 2004 cut the number of illegal fishing incursions in the vicinity by nine-tenths by late 2005, and no illegal incursion was detected in 2007.

Improved productivity: several studies on commercial fishing operations and maritime transport point to improvement particularly due to GPS plotters. Transit time savings for commercial ship routing is also an essential economic benefit, based on improved weather-related information, navigation and real-time communications at sea.

Cost avoidance in terms of lives saved and reduced damages to property remains a significant positive return on investments for disaster prevention and management applications. This is especially true in the case of floods,

with data not easily aggregated but that may well yet be underestimated.

Exploring novel pathways for investments decisions

A number of positive impacts can be detected by standard socio-economic analysis. However, the lack of quantifiable aggregated benefits coupled with the sheer unpredictability of climate change, clearly complicates major investment decisions based on sole cost-benefit analysis. In light of this, it can be argued that policy makers need to explore new pathways to reaching decisions.

The infrastructure approach: It is possible to consider space tools as parts of a larger infrastructure and compare the relative levels of investment with those required for terrestrial infrastructures (roads, power, rail, etc.). The earth observation and meteorological satellite infrastructure plays a key role in climate monitoring and can serve as an illustration. As demonstrated in the report, the overall cost of setting up such a system – including both R&D and operational satellites – is not unduly high, nor are the rates of annual investment to maintain and expand the space infrastructure and its related networks, compared with other large infrastructure.

THE OECD SPACE FORUM

The Organisation for Economic Co-operation and Development (OECD) launched the 'Space Forum' in cooperation with the space community. The Forum aims to assist governments, space-related agencies and the private sector to better identify the statistical contours of the growing space sector worldwide, while investigating the space infrastructure's economic importance and potential impacts for the larger economy. The Forum includes organisations from Canada, France, Germany, Italy, Korea, Norway, Switzerland, the United Kingdom, the United States, as well as the European Space Agency. The Forum builds on the recommendations presented in the OECD publication *Space 2030: Tackling Society's Challenges* (2005), which benefited from consultation with more than a hundred public and private actors in the international space community.

The risk management approach: Another novel angle could be to assess the operational usefulness of data by taking a risk management approach to space-based infrastructure. Interesting parallels can be drawn with the significant role of economic information or weather risk insurance packages. Weather is a major determinant of earnings performance for entire economic sectors (e.g. utilities). The US Department of Transportation estimates that weather-related delays in air transport cost passengers USD 10 billion in lost time and productivity each year in the United States alone. On an even larger scale, systematic climate monitoring may become an essential tool for governments to hedge the risks associated with climate change and unsustainable resources management (in fisheries for example). Not taking any specific step to reduce uncertainties may come at political, societal and economic costs (i.e. costs of inaction).

Towards establishing a sustainable financial and regulatory framework for the space infrastructure

As in the case of other traditional infrastructures, the space infrastructure will increasingly require a sustainable regulatory and financial framework to deliver the right products and services. This can be done by supporting larger public use of existing space applications nationally and internationally. As a possible way ahead for earth observation infrastructure in particular, more attention should be paid to building on major decades-long national and international efforts to develop and sustain operational satellite meteorology.

For climate monitoring to develop fully as a routine activity, with long-term continuity of measurements and the attendant socioeconomic benefits, institutions will increasingly have to share in the effort and provide adequate support to agencies responsible for satellite R&D activities and the operational weather agencies, as they monitor the state of the planet and inherit new climate-related tasks. To build on existing and future capabilities, private sector participation also will require further encouragement through a supportive legal and regulatory environment for commercial activities and the reinforcement of private provision of space goods and services, whenever possible.

For more information

<http://oe.cd/spaceforum>

Anita Gibson, OECD Directorate for Science, Technology and Innovation, E-mail: anita.gibson@oecd.org

Version of brochure: August 2014