Emilio Chuvieco
Editor

Earth Observation of Global Change

The Role Of Satellite Remote Sensing in Monitoring Global Environment

Springer
Chapter 1
International Efforts on Global Change Research

Beatriz Alonso and Fernando Valladares

1.1 Global Change: An Overview

The Earth’s environment is a dynamic system including many interacting components (physical, chemical, biological and human) that are constantly changing. The interactions and feedbacks among these components are complex and register high variability in time and space. Changes have always been present within the functioning of our planet. But during the last decades, human activities have produced an important impact in the Earth system (land surface, oceans, coasts, atmosphere, biological diversity, water cycle, and biogeochemical cycles) causing changes well beyond natural variability (Vitousek 1992, Foley et al. 2005, Levitus et al. 2000). And the magnitude of these changes is increasing throughout the years due to the growth of the population and the extension in scale of activities such as industry or agriculture. Over the past 50 years, the ecosystems have been modified by humans more rapidly and extensively than in any other comparable time period. Since 1950, more land has been converted to cropland than between 1700 and 1850, so approximately a quarter of the Earth’s terrestrial surface is currently occupied by cultivated systems; in the last decades it is estimated that about 20% of the world’s coral reefs were lost and 20% were degraded; since 1960 the amount of water stored behind dams is four times bigger (Millennium Ecosystem Assessment 2005). And these are just some examples. These changes have contributed to an economic development in some regions of our planet, but it has been achieved with a parallel degradation of many ecosystem services, an increase of the risks of nonlinear changes (e.g.: disease emergence, species losses) and the intensification of poverty in some other regions. (Millennium Ecosystem Assessment 2005).

Although global change is now a big issue of international concern, scientists have been interested in it for over a hundred of years. As early as 1827, Fourier was the first who compared the atmosphere functioning to a greenhouse. Some years later, Tyndall discovered the main so-called “greenhouse gases” (GHGs) and proposed a relationship between their concentration and past changes in the climate (O’Neill et al. 2001). And finally in 1896, Arrhenius predicted the potential of CO₂ to alter the climate, as it has been proved today (Arrhenius 1896, Hansen et al. 2005, Harries et al. 2001).
In spite of the growing concern over the last climate change evidences, global change is not restricted to climate, nor can it be understood in terms of a simple cause-effect process. Actually, the most important direct drivers of change are five: habitat change, overexploitation, invasive species, pollution, and climate change (Millennium Ecosystem Assessment 2005). And each of them has a different effect and trend in each specific ecosystem (Fig. 1.1).

The concept of global change brings together a big spectrum of changes suffered by the Earth’s ecosystems. But they have basically three characteristics in common. First, they have an anthropogenic origin. Second, they have an exponential increase rate (Fig. 1.2). And finally they occur in a global scale (Fig. 1.3).

The assessment of the consequences of each separate driver of change in the ecosystems becomes difficult due to the fact that they interact with each other and are affected by feedbacks from the ecosystem impacts (Vitousek 1992). For example, land use change is the most important cause of species loss, but the loss of diversity itself can produce effects on land use (Ehrlich and Wilson 1991). Time scale is also an additional complex factor that must be taken into account to

Fig. 1.1 Main direct drivers of global change in main ecosystem types. The grey scale represents the importance of the impacts on biodiversity over the last century in each ecosystem type (dark being large impact) and arrows indicate the temporal trend of these impacts. Source: Millennium Ecosystem Assessment 2005
evaluate and understand global change (Vitousek 1992). An increase or decrease in a parameter can be considered as a punctual discontinuity or as a trend according to the length of the event. Equally, the drivers of change can produce direct and immediate ecosystem responses but also direct and indirect effects on the long term.

Global change is one of the greatest challenges that humanity faces today. The increasing human transformation of the environment is not sustainable and new strategies for its management are urgently required. Policy makers need a good understanding of the global system to be able to take good decisions. And to get this knowledge it is essential to implement a new research approach based on two key concepts. First of all, multidisciplinarity; it is indispensable a greater integration across disciplines and a closer contact among specialists from different fields in order to understand the complex behaviour of our planet’s environment. Second, long-term perspective; observations in the long term are essential to interpret the experimental results, to analyse the behaviour of models and to propose hypotheses about the effects and trends of global change. Following these principles, numerous efforts have been invested throughout the last decades and ecologists have had to change their traditional focus on organisms, to study the Earth as an integrated ecosystem (Schlesinger 2006).
Fig. 1.3 Examples of the large spatial scale of human activity impacts. A) Impact due to water flow regulation and river channel fragmentation of the main river systems (Source: CBD 2006). B) Forest fragmentation with anthropogenic origin (Source: CBD 2006). C) Global population density (Source: WRI 2000 based on CESISN 2000). D) Terrestrial surface covered by cultivated systems in 2000 (Source: Millennium Ecosystem Assessment 2005).
1.2 The Time Dimension of Global Change and the Notion of “Long term”

Our perception of a given phenomenon is directly related to the scale in space of the ecosystem that we are taking into account. This perception is also different if a variable is analysed just at one specific moment or if the same variable is monitored throughout a period of time. Ecologists agree that carrying out long-term experiments is the only way to detect trends and to make predictions for the future. But what is exactly considered as “long term”? There is not only one answer to this question. Actually, the notion of “long term” will depend on the behaviour of the process we are interested to study. This concept may be easier to understand if we think of one of the global change drivers as for example climate. It is well known that the structure and the functioning of the ecosystems are largely determined by the regularities of our planet’s climate (Parmesan et al. 2000). But this climate regularity suffers frequent nonlinear changes that gives more complexity to the system and introduces uncertainty in ecological research. For this reason, the assessment of how ecosystems respond to climate change depend strongly on the time scale (Greenland et al. 2003): effects will be different according to the type of climatic event and, at the same time, each type of climatic event will produce effects on the ecosystems that will last a different time in the future.

From this point of view it is possible to classify them in the following four time scales:

- Short-term climatic events (e.g.: unusual repeated frequency of floods, hurricanes, drought conditions) that may produce important short and long-term ecosystem responses (Foster et al. 1998) determined also by the timing of the event (Gage 2003).
- The Quasi-Quintennial Timescale, a term used to recognize climatic events that reoccur every 2–7 years as for example the El Niño-Southern Oscillation (ENSO), phenomenon with a worldwide influence (Greenland 2003).
- The Interdecadal Timescale that includes patterns in the global circulation system occurring with recurring cycles (from 10 to 50 years). They are characterized by a variety of indexes as the Pacific Decadal Oscillation (PDO) or the North Atlantic Oscillation (NAO). They usually have a large spatial scale impact (McHugh and Gooding 2003).
- The Century to Millennial Timescale that includes long-term changes that have occurred over centuries (e.g. Little Ice Age) to thousands of years (e.g. Last Glacial Maximum) and that have shaped current ecosystems (Elias 2003).

It is uncommon that an ecosystem suffers the effects of climate variability at one determinate time scale. On the contrary, ecosystems are usually reacting to climate variability happening at several time scales (Greenland et al. 2003). Moreover, the overlapping of climate events at different time scales may reinforce their separate effects because of the possibility of interactions between them (Goodin et al. 2003).
Currently available information suggests that the only way to understand the patterns and behaviour of our planet's climate is trying to extend the scale on time and space of our observations and experiments (Greenland et al. 2003). And the same principle can be applied to the rest of global change drivers and to responses of the ecosystems to global processes as the increase of CO₂, nitrogen or ozone (Schlesinger 2006).

1.3 International Research in Global Change

It has been well proved that human activities are responsible for big impacts in the Earth's environment during the last decades (Rojstaczer et al. 2001, Postel et al. 1996) and all the predictions point out that the ecosystems will continue suffering serious changes during at least several more decades in the near future (Millennium Ecosystem Assessment 2005, IPCC 2001). Global change has thus become an issue of international concern and there is an increasing social interest in finding strategies to deal with it.

The classical science system has been characterised by the specialisation of researchers. Scientists have usually focused their efforts, knowledge and experience in very specific and concrete topics studied by very small groups of people around the world but with few links to other disciplines. The situation now is different. Researchers have realized the need for a science based on integration and cooperation in order to face the changes that our planet is experimenting. It is time to bring together contributions from natural scientists (ecologists, climatologists, oceanographers, etc.) as well as from social scientists (economists, anthropologists, sociologists) working at every spatial scale (Wessman 1992). This global approach has been possible with the help of new tools that allow the development of a better science, as for example the measurements of net carbon exchange of wide areas by the use of Eddy covariance methods (Schlesinger 2006, Ciais et al. 2005). In addition, the combination of tools such as geographic information systems, remote sensing technologies and simulation modelling has permitted to extrapolate information from individual organisms or processes observed at a given site to a regional or global scale (Roughgarden et al. 1991).

To advance in this new global perspective and communication level, the research community needs to be encouraged beyond the national boundaries on the basis of sharing data and infrastructure. And this is actually one of the main goals of several programmes and organizations involved in global change research (Table 1.1). Most of these programmes and organizations are often collaborating in joint projects and activities. But the exact objectives of all these initiatives and their interrelationships are sometimes unclear and difficult to understand particularly in a first approach or when a complete view of international efforts on global change is looked after. In order to clarify this “soup of acronyms” corresponding to all these programmes and organizations, the main activities in global change research will be reviewed in the next lines, grouped according to their activities.
### Table 1.1 Programmes and organizations involved in global change research

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<th>PROGRAMMES/ORGANIZATIONS</th>
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<td>Biosphere Reserve Integrated Monitoring</td>
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<td>Global Land Project</td>
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(continued)
1.4 Global Observing Systems

To understand the impact of human activities on the ecosystems it has long been recognized the need to obtain detailed data at a global scale (Sanderson et al. 2002). During the 1990s, the use of satellite technology applied to Earth observation made this goal more and more feasible. For this purpose, NASA and other agencies launched the Earth Observing System (EOS) satellites that are currently monitoring many of the characteristics of our planet like temperature or land cover (Schlesinger 2006). The analysis of this extensive data set allows for modelling and predictions that provide valuable information for decision making.

1.4.1 The Integrated Global Observing Strategy (IGOS)

The Integrated Global Observing Strategy (IGOS) aims to provide a framework to harmonize the activities of the systems for global observation of the Earth. It is an over-arching strategy for guiding the execution of observations related to climate, oceans and land surface, making an effort to integrate the existing international global observing programmes. Within IGOS, there are partners involved in link
research, long-term monitoring and operational programmes. The goal is to build a
structure that permits to identify observation gaps. Some of the IGOS partners are:

– The Global Climate Observing System (GCOS). It was established to ensure the
achievement of climate observations and to facilitate their access to all potential
users. GCOS does not make observations directly itself but it encourages and
gives support to national and international organizations in this purpose.

– The Global Ocean Observing System (GOOS). It is a global system for contin-
uous observation of the ocean. As GCOS, GOOS does not make observations
but it is a framework for international cooperation and a forum for interaction
between research and user communities.

– The Global Terrestrial Observation System (GTOS). It is a framework that pro-
motes observations and analysis of terrestrial ecosystems and facilitates interac-
tions between research programmes, monitoring networks and policy makers in
order to manage global change affecting terrestrial ecosystems.

– The Committee on Earth Observation Satellites (CEOS). It is an international
mechanism for the coordination of the international Earth Observation satellite
programs. The main CEOS goal is to ensure the remote coverage of the main
issues related to Earth observation and global change and to prevent overlapping
between satellite missions.

1.4.2 The Global Earth Observation System of Systems (GEOSS)

The Global Earth Observation System of Systems (GEOSS) is a large national and
international cooperative initiative that envisages coordinating the existing Earth
Observation Systems. GEOSS will identify gaps and will support data sharing im-
proving the delivery of information to users. The intergovernmental Group on Earth
Observations (GEO) was established in February 2005 to carry out a 10-Year Im-
plementation Plan of GEOSS. GEO includes 66 member countries, the European
Commission, and 43 participating organizations.

1.5 International Collaborative Programmes: The Earth System
Science Partnership (ESSP)

The Earth System Science Partnership (ESSP) is a joint initiative that brings to-
gether researchers from different disciplines, and from across the globe, to carry
out an integrated study of the Earth System, the changes that are occurring in it and
their implications for global sustainability. The ESSP is formed by four international
global environmental change research programmes (Fig. 1.4):

• DIVERSITAS – an integrated programme of biodiversity science
• IHDP – International Human Dimensions Programme on Global Environmental
  Change
The main activities of the ESSP are joint projects focused on global environmental changes regarding four topics that are decisive for human well-being: energy and carbon cycle (GCP, Global Carbon Project), food security (GECAFS, Global Environmental Change and Food Systems), water resources (GWSP, Global Water System Project) and human health (GEC&HH, Global Environmental Change and Human Health). The ESSP is also carrying out several integrated regional studies in support of sustainable development at the local level such as the Monsoon Asia Integrated Study (MAIRS). ESSP partners collaborate closely with the Inter-American Institute for Global Change Research (IAI) and the Asia-Pacific Network for Global Change Research (APN).

1.5.1 Diversitas

The mission of DIVERSITAS is to encourage an integrative study of biodiversity, connecting biological, ecological and social disciplines in order to enhance a scientific knowledge for the conservation and sustainable use of biodiversity. To achieve this goal, DIVERSITAS is developing the following core projects (Fig. 1.5):
bioDISCOVERY to assess current biodiversity and predict changes in the future, ecoSERVICES to assess human responses to changes in ecosystems services due to changes in biodiversity and bioSUSTAINABILITY, to guide policy that support sustainable use of biodiversity.

DIVERSITAS has also created four cross-cutting networks to investigate in particular topics: mountain biodiversity (GMBA, Global Mountain Biodiversity Assessment), freshwater biodiversity (freshwaterBIODIVERSITY), agriculture & biodiversity (agroBIODIVERSITY) and invasive species (GISP, Global Invasive Species Programme). In addition, DIVERSITAS participates actively in related activities, establishing strong relationships with: the United Nations Convention on Biological Diversity (CBD), the System for Analysis, Research and Training (START), the European Network for Research Global Change (ENRICH), the Tropical Biology Association (TBA), the United National Environment Programme (UNEP) and the Watson Institute for International Studies.

1.5.2 The International Human Dimensions Programme on Global Environmental Change (IHDP)

The mission of the International Human Dimensions Programme on Global Environmental Change (IHDP) is to encourage and to coordinate research on the human dimensions of global environmental change. IHDP is currently developing six core projects (Fig. 1.6):
Fig. 1.6 Representation of the International Human Dimensions Programme structure. For acronyms see Table 1.1

- **GECHS**, Global Environmental Change and Human Security – Evaluating the relationship between both concepts.
- **IDGEC**, Institutional Dimensions of Global Environmental Change – Assessing the role of social institutions in producing and solving environmental problems.
- **IT**, Industrial Transformation – Exploring new ways to cover human needs using resources in a sustainable manner.
- **LOICZ**, Land-Ocean Interactions in the Coastal Zone – Studying human use of coastal systems.
- **Urbanization and Global Environmental Change** – Evaluating the interactions between global environmental change and urban processes.
- **GLP**, Global Land Project – Studying the effects of human activities on land in terrestrial and aquatic systems.

In addition, IHDP is collaborating in other scientific activities and networks: the Population Environment Research Network (**PERN**), aiming to encourage online exchange among social and natural scientists worldwide, the Mountain Research Initiative (**MRI**), investigating global change in mountain regions, and the Young Human Dimensions Researchers (**YHDR**), seeking to make easier the work of young researchers in the area of human dimensions of global change. The results of IHDP research contribute to international synthesis processes as the
Millennium Ecosystem Assessment (MEA) and the Intergovernmental Panel on Climate Change (IPCC).

1.5.3 The International Geosphere-Biosphere Programme (IGBP)

The mission of the International Geosphere-Biosphere Programme (IGBP) is to study the interactions between physical, biological and chemical processes of the Earth System and the changes that they are suffering due to human impacts. This research is developed by a set of core projects focused on the main compartments of the Earth system (land, ocean, and atmosphere), the points of contacts between them and the integration of Earth system information by means of palaeo-environmental studies and modelling. These projects are (Fig. 1.7):

- **AIMES**, Analysis, Integration and Modelling of the Earth System – Analysing the human impacts in the global biogeochemical cycles.
- **GLOBEC**, Global Ocean Ecosystem Dynamics – Studying the effects of global change on marine populations.

![Fig. 1.7](image_url) Representation of the International Geosphere-Biosphere Programme structure (Adapted from the IGBP web site). For acronyms see Table 1.1
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- **GLP**, Global Land Project – Co-sponsored with IHDP (see Sect. 5.2).
- **ILEAPS**, Integrated Land Ecosystem-Atmosphere Processes Study – Assessing the transport and the transformation of energy and matter through the land-atmosphere interface by the action of physical, chemical and biological processes.
- **LOICZ**, Land-Ocean Interactions in Coastal Zone – Co-sponsor with IHDP (see Sect. 1.5.2).
- **PAGES**, Past Global Changes – Studying the Earth’s environment in the past in order to make predictions for the future.
- **SOLAS**, Surface Ocean-Lower Atmosphere Study – Analysing the main biogeochemical-physical interactions between the atmosphere and the ocean and the effects of global change on this system.

IGBP is also linked to the global observations community (participating in IGOS, GEO and CEOS), collaborates with other international organizations (the Scientific Committee for Oceanic Research (SCOR), the Commission on Atmospheric Chemistry and Global Pollution (CACGP) and the Intergovernmental Oceanographic Commission (IOC)) and contributes to global assessments as the Millennium Ecosystem Assessment (MEA) and the Intergovernmental Panel on Climate Change (IPCC).

### 1.5.4 The World Climate Research Programme (WCRP)

The mission of the World Climate Research Programme (WCRP) is to study climate variability and climate change. To achieve this mission, WCRP is developing the following core projects (Fig. 1.8):

- **CLIVAR**, Climate Variability and Predictability – Observing, simulating and predicting the Earth’s climate system.
- **SPARC**, Stratospheric Processes And their Role in Climate – Assessing the interaction between chemical, radioactive and dynamical processes in the stratosphere.
- **CLIC**, Climate and Cryosphere – Evaluating the effects of climatic variability and change on the cryosphere.
- **SOLAS**, Surface Ocean-Lower Atmosphere Study – Co-sponsor with IGBP (see Sect. 1.5.3).
WCRP is also participating in GEO, works closely with GCOS and GOOS and contributes to the efforts of the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC) and the Millennium Ecosystem Assessment (MEA).

![Diagram of the World Climate Research Programme structure]

**Fig. 1.8** Representation of the World Climate Research Programme structure. For acronyms see Table 1.1

### 1.6 Monitoring Networks and Databases

#### 1.6.1 The International Cooperative Programmes (ICP)

In the framework of the Convention on Long-range Transboundary Air Pollution the Working Group on Effects was established in order to develop international cooperation in the research on air pollutant effects. Its six International Cooperative Programmes (ICPs), based on long-term monitoring, identify the most endangered areas: ICP Forests, ICP Waters, ICP Materials, ICP Vegetation, ICP Integrated Monitoring and ICP Modelling and Mapping. There are currently 51 countries involved in the Convention as Parties.

#### 1.6.2 Long-Term Ecological Research Networks: ILTER and Others

The International Long Term Ecological Research (ILTER) is a “network of networks” engaged in long-term, site-based ecological and socioeconomic research
aiming to obtain a good knowledge of ecosystem functioning. ILTER was created in 1993 following the successful previous example of the Long Term Ecological Research Network (US-LTER) in United States. The US-LTER programme was established in 1980 with a small set of sites, number that has increased to 26 over the years covering an extended variety of ecosystems.

Since the foundation of ILTER, long-term ecological research initiatives have spread quickly. This is due to the recognition of the importance of long-term research in order to understand complex environmental issues such as global change. Up to now, thirty-two formal national LTER networks have become ILTER members and many other countries are working on it (Fig. 1.9). This is the case of some European countries like Spain, for instance, that is making efforts to consolidate the Spanish LTER Network, REDOTE. At European level, the network of excellence ALTER-net promotes the integration among all the actors involved in biodiversity research, monitoring and policy in order to develop a European LTER Network.

Focused on Africa, ROSELT Network is providing long-term ecological data in order to improve the knowledge of the processes, causes and effects of desertification in the circum-Saharan area.

1.6.3 Fluxnet

FLUXNET is a “network of regional networks” of micrometeorological tower sites that record the exchanges of water vapour, carbon dioxide and energy between
terrestrial ecosystems and atmosphere using eddy covariance methods. Currently, FLUXNET includes over 400 tower sites operating in continuous. Data related to the vegetation, hydrology, soil and meteorological characteristics at the tower sites is also collected. FLUXNET is supported by ILEAPS (See Sect. 1.5.3)

1.6.4 The Biosphere Reserve Integrated Monitoring (BRIM)

The Biosphere Reserve Integrated Monitoring (BRIM) is an initiative launched in 1991 in order to monitor abiotic, biotic and socio-economic parameters in the world network of Biosphere Reserves providing integrated data. Biosphere Reserves are sites recognized by UNESCO for supporting sustainable development, conservation and research. Currently, 507 sites from 102 countries worldwide are included within the World Network sharing experience and information. BRIM, whose aim is to build on existing initiatives, is collaborating with other international programmes and long-term initiatives, as GTOS and ILTER.

1.6.5 Databases

It is clear that global change is an issue that requires collaboration and cooperation among researchers worldwide beyond national boundaries. Data sharing becomes crucial to facilitate synthesis processes and significant advance in scientific knowledge. Currently, there is an extraordinary development of new tools and protocols in order to make easier data store and management. These tools, in combination with the use of Internet, have permitted a very simple and rapid access to the information and a wide spread of scientific results with a remarkable example in the gene bank, where DNA sequences are shared. A variety of scientific organizations have already made available their databases including useful data for the study of global environmental changes. These are some examples:

- The Global Biodiversity Information Facility (GBIF, www.gbif.org) has created a database comprising global biodiversity information.
- The NOAA National Geophysical Data Center (NGDC, http://www.ngdc.noaa.gov/) provides long-term geophysical data, as well as earth observations from space.
1.7 Conclusions

As shown throughout this text, there is currently a large number of scientific programmes, monitoring networks and international organisations involved in global change research. The existence of so many initiatives is itself a proof of the importance of global change and reveals the general concern over the new situation that the Earth system is facing today. The population growth and the increasing impact of human activities over the last century have produced dramatic changes in the functioning of ecosystems whose consequences in the future are still complex to evaluate. Due to the global dimension of these environmental changes, it is required to develop strategies at a global level, to encourage international collaboration and to promote communication among the society, the scientific community and the policy makers. Following this principle, the Kyoto Protocol constitutes a historical milestone in cooperation and commitment at global level. This is the first international agreement aiming to reduce greenhouse-gas emissions responsible of climate change and even though it seems insufficient to reverse the negative influence of human activities on Earth climate, its international dimension is unprecedented. The Protocol was signed in 1997 but it did not enter into force until the 16th February 2005 without the support of one of the most strategic countries, the United States. Those that have signed the Kyoto Protocol are already adopting appropriate measures to reduce the emissions. But even though all these actions are highly valuable, they are not enough. There is still much research to do to prevent climate change and to mitigate the effects of global change, since many of these effects are still poorly understood. Delaying the making of decisions is a big risk for the sustainability of our planet and the survival of future generations. But such decisions can not be made without a global long term and multidisciplinary vision at which all the initiatives described here are aimed.

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