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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

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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 on 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 CO_2 to alter the climate, as it has been proved today (Arrhenius 1896, Hansen et al. 2005, Harries et al. 2001).

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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

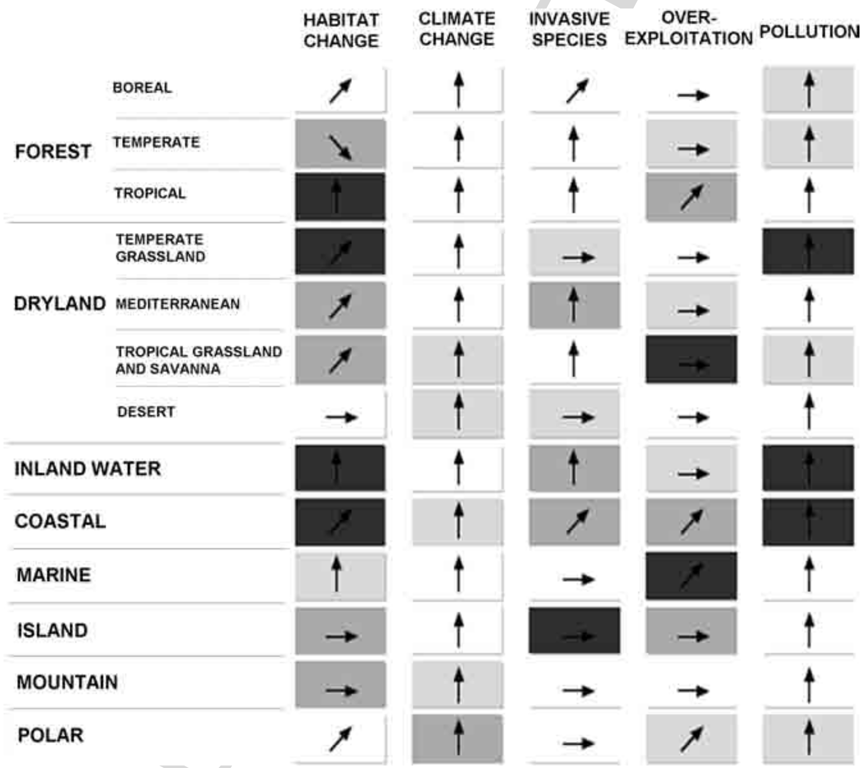

Fig. 1.1 Main direct drivers of global change in main ecosystem types. The grey scale represents the importance of the impacts on biodiversity over the last century in each ecosystem type (dark being large impact) and arrows indicate the temporal trend of these impacts. Source: Millennium Ecosystem Assessment 2005

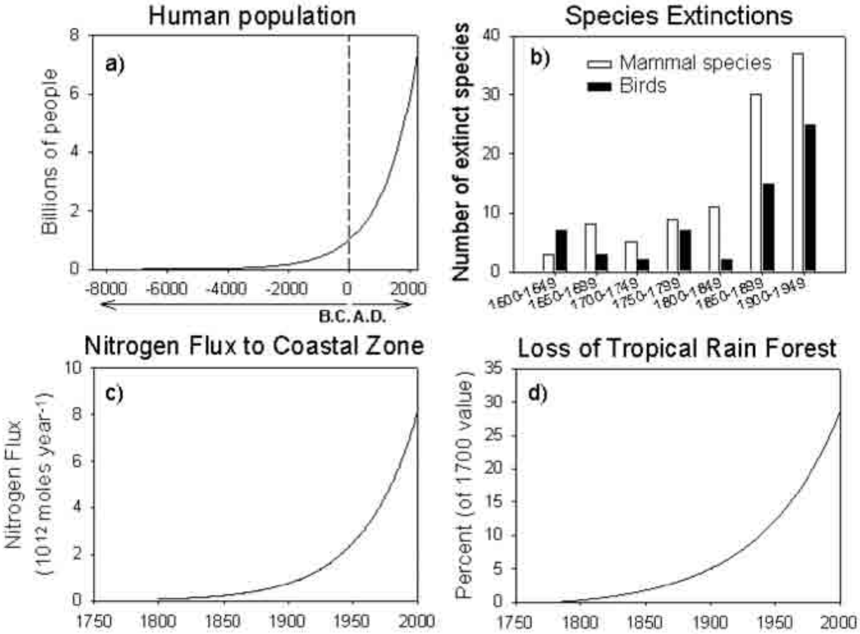

Fig. 1.2 Examples of global changes with exponential increase rates: a) Human population (International Database, U.S. Bureau of Census) b) Species extinctions (Reid and Miller 1989) c) Nitrogen flux to coastal zones (Mackenzie et al. 2002) d) Loss of tropical rain forest (Richards 1991)

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).

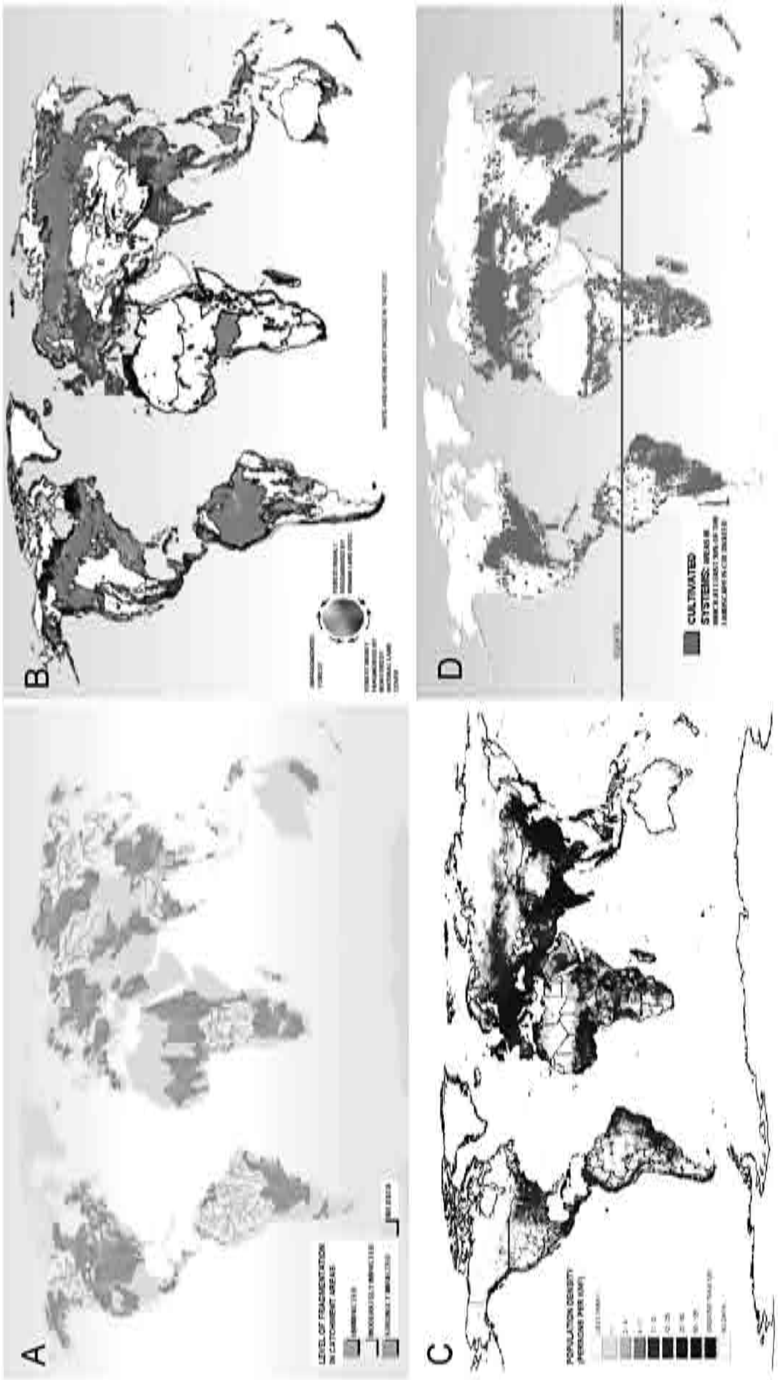

Fig. 1.3 Examples of the large spatial scale of human activity impacts. A) Impact due to water flow regulation and river channel fragmentation of the main river systems (Source: CBD 2006). B) Forest fragmentation with anthropogenic origin (Source: CBD 2006). C) Global population density (Source: WRI 2000 based on CESIN 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). AQ1
– 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 gobal processes as the increase of CO_2, 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

ACRONYM	PROGRAMMES/ORGANIZATIONS	WEB SITE
AIACC	Assessment of impacts and Adaptation to Climate Change in Multiple Regions and Sectors	www.aiccproject.org
AIMES	Analysis, Integration and Modelling of the Earth System	www.aimes.ucar.edu
ALTERNET	A Long-Term Biodiversity, Ecosystem and Awareness Research Network	www.alter-net.info
APN	Asia-Pacific Network of Global Change Research	www.apn-gcr.org
BRIM	Biosphere Reserve Integrated Monitoring	-
CACGP	Commission on Atmospheric Chemistry and Global Pollution	http://croc.gsfc.nasa.gov/cacgp/
CAN	Climate Action Network	www.climnet.org
CEOS	Committee on Earth Observations	www.ceos.org
CLIC	The Climate and Cryosphere Project	http://clic.npolar.no/
CLICK	USGS Center for LIDAR Information Coordination and Knowledge	http://lidar.cr.usgs.gov/index.php
CLIVAR	Climate Variability and Predictability	www.clivar.org
CPWC	Co-operative Programme on Water and Climate	www.waterandclimate.org
DIVERSITAS	An International Programme of Biodiversity Science	www.diversitas-international.org
ENRICH	European Network for Research in Global Change	http://mediasfrance.org/Reseau/Lettre/09/en/Internat/enrich/enrich.html
ESSP	Earth System Science Partnership	www.essp.org
FAO	Food and agriculture Organization	www.fao.org
GAIM	Global Analysis, Interpretation and Modelling	http://gaim.unh.edu/
GBIF	Global Biodiversity Information Facility	www.gbif.org
GCOS	Global Climate Observation System	www.wmo.ch/web/gcos/gcoshome.html
GCP	Global Carbon Project	www.globalcarbonproject.org
GCRIO	US Global Change Research Information Office	www.gcrio.org
GECAFS	Global Environmental Change and Food Systems	www.gecafs.org
GEC&HH	Global Environmental Change and Human Health	-
GECHS	Global Environmental Change and Human Security	www.gechs.org
GEO	Global Earth Observations	www.earthobservations.org
GEOSS	Global Earth Observation System of Systems	http://www.epa.gov/geoss/
GEWEX	Global Energy and Water Cycle Experiment	www.gewex.org
GISP	The Global Invasive Species Programme	www.gisp.org
GOFC-GOLD	Global Observation for Forest & Land Cover Dynamics	www.fao.org/gtos/gofc-gold
GLOBEC	Global Ocean Ecosystem Dynamics	www.globec.org
GLP	Global Land Project	www.globallandproject.org

(continued)

Table 1.1 (continued)

ACRONYM	PROGRAMMES/ORGANIZATIONS	WEB SITE
GMBA	Global Mountain Biodiversity Assessment	http://gmba.unibas.ch/index/index.htm
GOOS	Global Ocean Observing Systems	www.ioc-goos.org
GTOS	Global Terrestrial Observing Systems	www.fao.org/GTOS
GWSP	Global Water System Project	www.gwsp.org
IAI	Inter-American Institute for Global Change Research	www.iai.int
ICSU	International Council for Science	www.icsu.org
IDGEC	International Dimensions of Global Change Environmental Change	http://www2.bren.ucsb.edu/∼idgec/
IGAC	International Global Atmospheric Chemistry	www.igac.noaa.gov
IGBP	International Geosphere-Biosphere Programme	www.igbp.net
IGFA	International Group of Funding Agencies for Global Change Research	www.igfagcr.org
IGOS	The Integrated Global Observing Strategy	www.igospartners.org
IHDP	International Human Dimensions Programme on Global Environmental Change	www.ihdp.org
ILEAPS	Integrated Land Ecosystem-Atmosphere Processes Study	www.atm.helsinki.fi/ILEAPS
ILTER	The International Long Term Ecological Research Network	www.ilternet.edu
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research	www.imber.info
IOC	Intergovernmental Oceanographic Commission	http://ioc.unesco.org/iocweb/index.php
IPCs	International Cooperative Programmes	www.unece.org/env/wge/icps.htm
IPCC	International Panel on Climate Change	www.ipcc.ch
IRI	International Research Institute for Climate Prediction	www.iri.columbia.edu
IT	Industrial Transformation	www.ihdp-it.org
IUCN	The World Conservation Union	www.iucn.org
JGOFS	Joint Global Ocean Flux Study	http://www1.whoi.edu/
LOICZ	Land Ocean Interactions in Coastal Zones	www.loicz.org
LUCC	Land Use and Cover Change	www.geo.ucl-ac-be/LUCC/
MAIRS	Monsoon Asia Integrated Regional Study	www.mairs-essp.org
MEA	Millennium Ecosystem Assessment	www.maweb.org
MRI	Mountain Research Initiative	http://mri.scnatweb.ch/
NASA	National Aeronautic and Space Administration	www.nasa.gov
NGDC	NOAA National Geophysical Data Center	www.ngdc.noaa.gov
NOAA	National Oceanic & Atmospheric Administration (U.S. Department of commerce)	www.noaa.gov
PAGES	Past Global Changes	www.pages.unibe.ch
PERN	Population Environment Research Network	www.populationenvironmentresearch.org/

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Table 1.1 (continued)

ACRONYM	PROGRAMMES/ORGANIZATIONS	WEB SITE
REDOTE	Spanish Long Term Ecological Research Network	www.redote.org
ROSELT	Long Term Ecological Monitoring Observatories Network	www.roselt-oss.org
SCOPE	Scientific Committee on the problems of the Environment	www.icsu-scope.org
SCOR	Scientific Committee on Oceanic Research	www.jhu.edu/∼scor
SOLAS	Surface Ocean-Lower Atmospheric Study	www.solas-int.org
SPARC	Stratospheric Processes and their role in Climate	www.atmosp.physics.utoronto.ca/SPARC/index.html
START	System for Analysis, Research and Training	www.start.org
TBA	Tropical Biology Association	www.tropical-biology.org
UNEP	United Nations Environment Programme	www.unep.org
UNFCCC	UN Framework Convention for Climate Change	www.unfccc.int
USGS	U.S. Geological Survey	www.usgs.gov
US-LTER	The US Long Term Ecological Research Network	www.lternet.edu
WCRP	World Climate Research Programme	http://wcrp.wmo.int/
WMO	World Meteorological Organization	www.wmo.int
YHDR	Young Human Dimensions Researchers	www.ihdp.uni-bonn.de/html/initiatives/i-yhdr.html

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 continuous 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 promotes observations and analysis of terrestrial ecosystems and facilitates interactions 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 improving the delivery of information to users. The intergovernmental Group on Earth Observations (GEO) was established in February 2005 to carry out a 10-Year Implementation 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 together 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

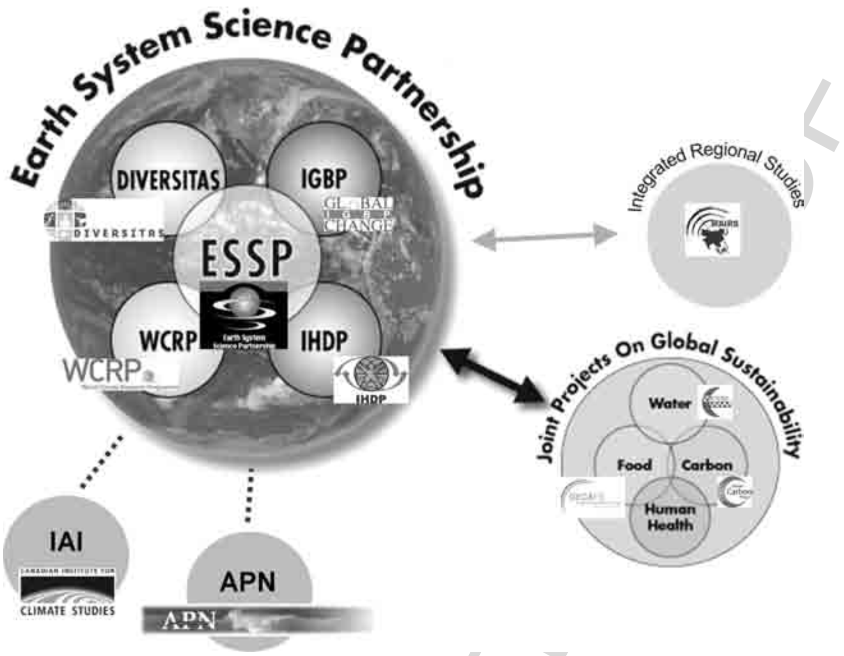

Fig. 1.4 Representation of the Earth System Science Partnership structure (Adapted from the ESSP web site). For acronyms see Table 1.1

- **IGBP** – International Geosphere-Biosphere Programme
- **WCRP** – World Climate Research Programme

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 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):

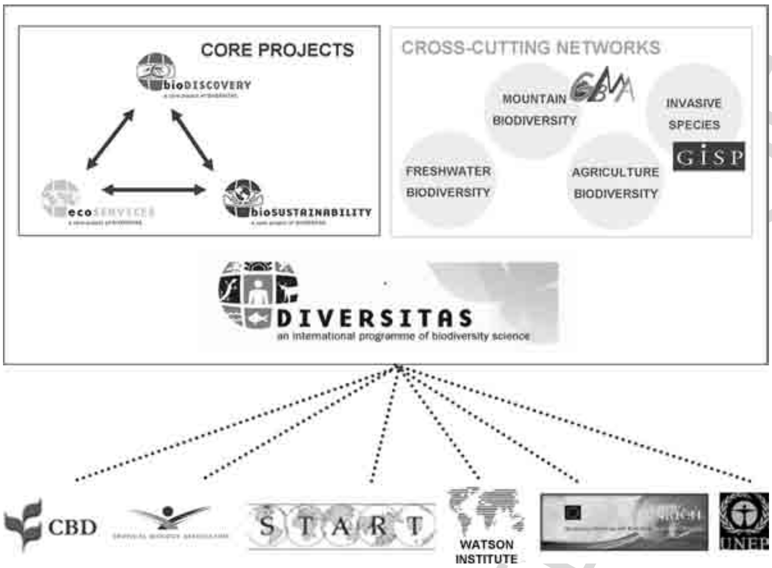

Fig. 1.5 Representation of DIVERSITAS structure. For acronyms see Table 1.1

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):

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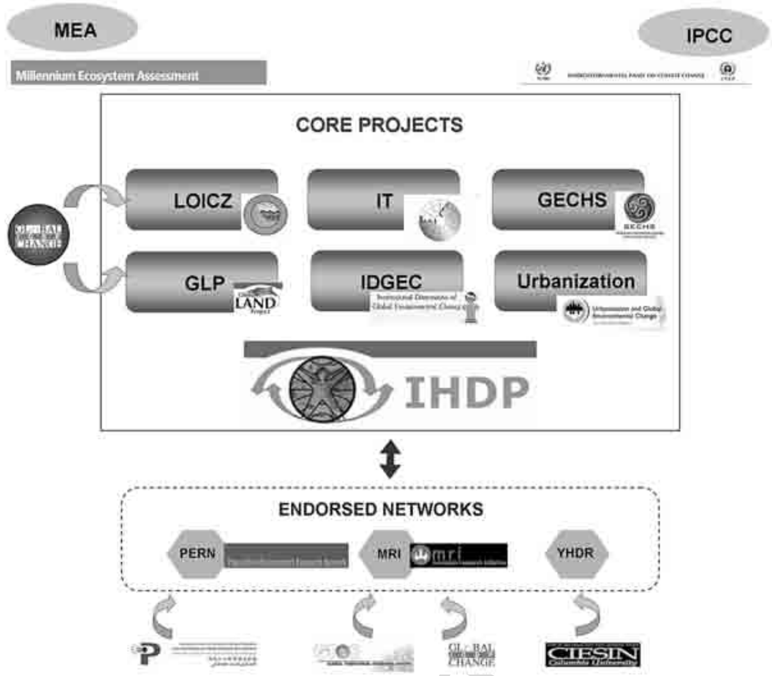

Fig. 1.6 Representation of the International Human Dimensions Programme structure. For acronyms see Table 1.1

- **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 on-line 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.

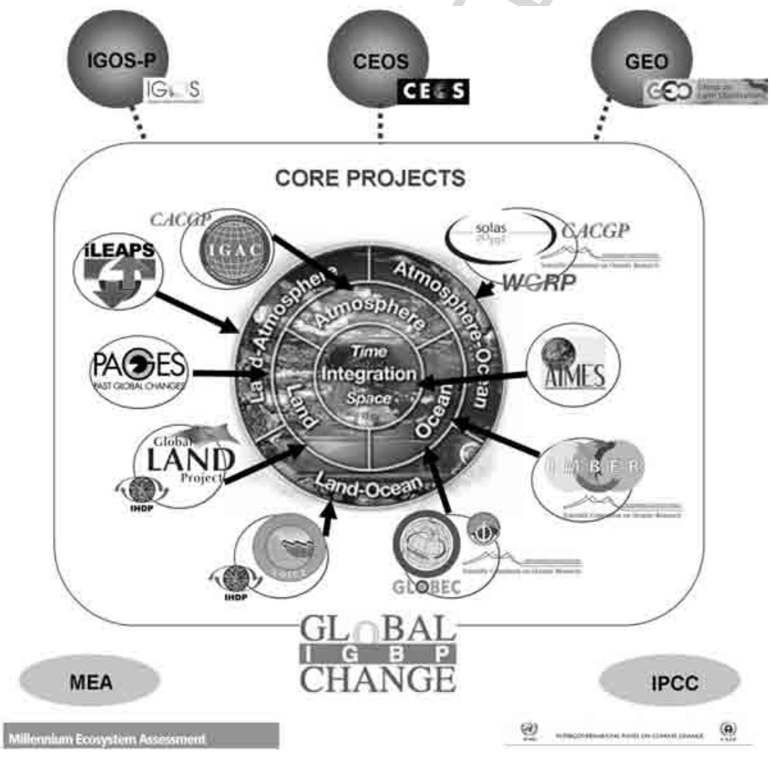

Fig. 1.7 Representation of the International Geosphere-Biosphere Programme structure (Adapted from the IGBP web site). For acronyms see Table 1.1

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- **GLP**, Global Land Project – Co-sponsored with IHDP (see Sect. 5.2).
- **IGAC**, International Global Atmospheric Chemistry – Examining the role of atmospheric chemistry in the Earth System.
- **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.
- **IMBER**, Integrated Marine Biogeochemistry and Ecosystem Research – Studying and predicting ocean responses to global change.
- **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):

- **GEWEX**, Global Energy and Water Cycle Experiment – Observing and modelling the global hydrological cycle.
- **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)**.

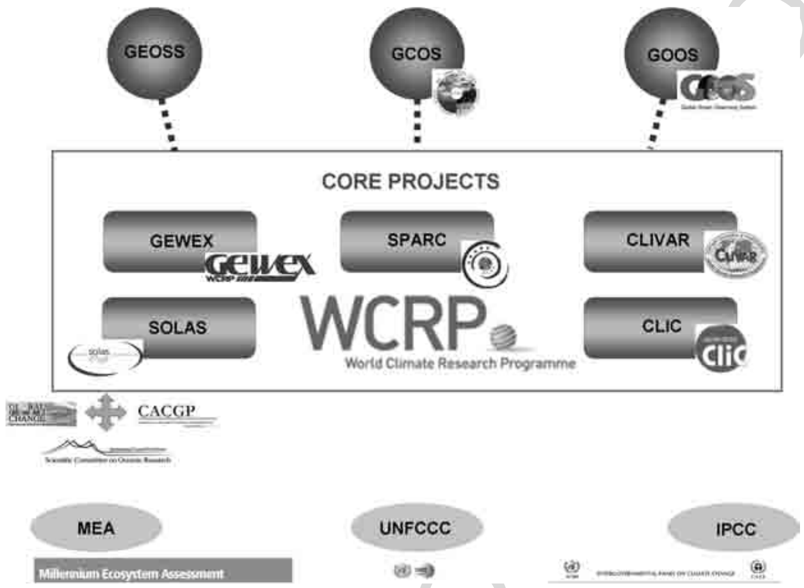

Fig. 1.8 Representation of the World Climate Research Programme structure. For acronyms see Table 1.1

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

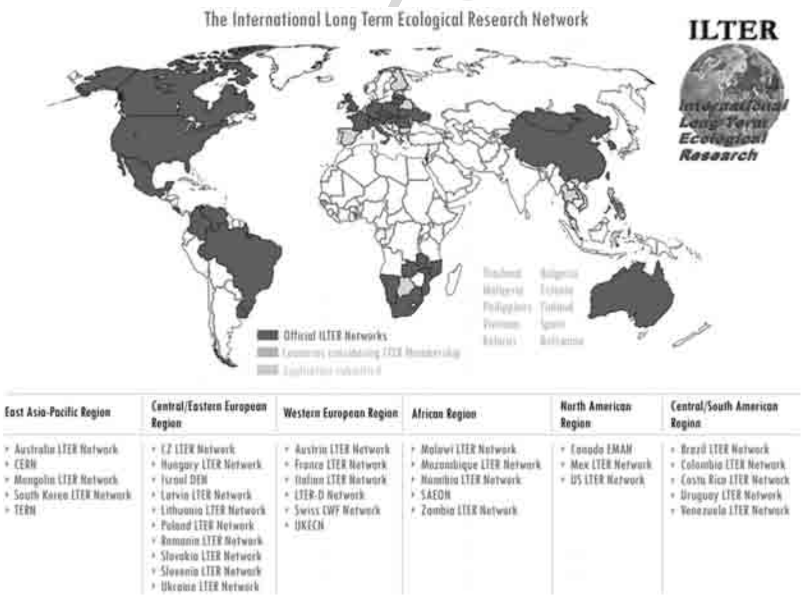

Fig. 1.9 Official members of the International Long Term Ecological Research Network and countries that are considering joining it. Source: ILTER

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 U.S. Long Term Ecological Research Network (**US-LTER**, www.lternet.edu) provides long-term data series related to climate, biodiversity, nutrients, fauna, vegetation, substrate, hydrology and ecophysiology from different ecosystems in the United States.
– 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.
– The USGS Center for LIDAR Information Coordination and Knowledge (**CLICK**, http://lidar.cr.usgs.gov/index.php) facilitates access to data of LIDAR remote sensing.

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.

Acknowledgments This chapter has been possible thanks to the discussions within REDOTE, GLOBIMED and CEICAG Networks funded by the Spanish Ministry of Education and Science. It has benefited by the insightful comments of Gerardo Benito, Regino Zamora, Sergi Sabater and Teresa Sebastiá. We would also like to acknowledge the support and help from our colleagues at the Centro de Ciencias Medioambientales (CSIC), especially from Silvia Matesanz.

References

Arrhenius S (1896) On the influence of carbonic acid in the air upon the temperature of the ground. The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science vol 41 pp 237–276

Ciais P, Reichstein M, Viovy N, Granier A, Ogée J, Allard V, Aubinet M, Buchmann N, Bernhofer C, Carrara A, Chevallier F, De Noblet N, Friend AD, Friendlingstein P, Grünwald T, Heinesch B, Keronen P, Knohl A, Krinner G, Lonstau D, Manca G, Matteucci G, Miglietta F, Ourcival JM, Papale D, Pilegaard K, Rambal S, Seufert G, Soussana JF, Sanz MJ, Schulze EP, Vesala T and Valentini R (2005) Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nature vol 437 pp 529–533

Elias S (2003) Millennial and century climate changes in the Colorado Alpine. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 370–383

Ehrlich PR and Wilson EO (1991) Biodiversity studies: Science and policy. Science vol 253 pp 758–762

Foley JA, DeFries R, Asner GP, Bardford C, Bonana G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibb HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N and Snyder PK (2005) Global consequences of land use. Science vol 306 pp 570–574

Foster DR, Knight DH and Franklin JF (1998) Landscape patterns and legacies resulting from large, infrequent forest disturbances. Ecosystems vol 1 pp 497–510

Gage SH (2003) Climate variability in the North Central region: Characterizing drought severity patterns. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 56–73

Goodin DG, Fay PA, and McHugh MJ (2003) Climate variability in Tallgrass Prairie at multiple timescales: Konza Prairie Biological Station. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 411–423

Greenland D (2003) An LTER Network overview and introduction to El Niño-Southern Oscillation (ENSO) Climatic signal and response. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 102–116

Greenland D, Goodin DG and Smith RC (2003) An introduction to climate variability and ecosystem response. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 3–19

Greenland D, Goodin DG, Smith RC and Swanson FJ (2003) Climate variability and ecosystem response – Synthesis. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 425–449

Hansen J, Nazarenko L, Ruedy R, Sato M, Willis J, Del Genio A, Koch D, Lacis A, Lo K, Menon S, Novakov T, Perlwitz J, Russell G, Schmidt GA and Tausnev N (2005) Earth's energy imbalance: Confirmation and implications. Science vol 308 pp 1431–1435

Harries JE, Brindley HE, Sagoo PJ and Bantges RJ (2001) Increases in greenhouse forcing inferred from the outgoing longwave radiation spectra of the Earth in 1970 and 1997. Nature vol 410 pp 355–357

IPCC, 2001: Climate Change 2001: Synthesis report. A Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T. and the Core Writing Team (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 398 pp

Levitus S, Antonov JI, Boyer TP and Stephens C (2000) Warming of the world ocean. Science vol 287 pp 2225–2229

Mackenzie FT, Ver LM, Lerman A (2002) Century-scale Nitrogen and Phosphorus Controls of the Carbon Cycle. Chemical Geology vol 190 pp 163–178

McHugh MJ and Goodin DG (2003) Interdecadal-Scale variability: An assessment of LTER climate data. In: Greenland D, Goodin DG and Smith RC (eds) Climate variability and ecosystem response at Long-Term Ecological Research sites. Oxford University Press pp 213–225

Millennium Ecosystem Assessment, (2005) Ecosystems and human well-being: Synthesis. Island Press, Washington, DC.

O'Neill BC, Mackellar FL and Lutz W (2001) Population and climate change. Cambridge University Press, USA

Parmesan C, Root TL and Willing MR (2000) Impacts of extreme weather and climate on terrestrial biota. Bulletin of the American Meteorological Society vol 81 pp 433–450

Postel SL, Daily GC and Erlich PR (1996) Human appropriation of renewable freshwater. Science vol 271 pp 785–788

Reid WVC and Miller KR (1989) The scientific basis for the conservation of biodiversity. World Resources Institute, Washington DC

Richards JF (1991) Land transformation. In: Turner BL, Clark WC, Kates RW, Richards JF, Matthews JT, and Meyers WT (Eds). The Earth as transformed by human action: Global and regional changes in Biosphere over the last 300 years. Cambridge University Press, New York, pp 163–178

Rojstaczer S, Sterling SM and Moore NJ (2001) Human appropriation of photosynthesis products. Science vol 294 pp 2549–2552

Roughgarden J, Running SW and Matson PA (1991) What does remote sensing do for ecology? Ecology vol 72 pp 1918–1922

Sanderson EW, Malanding J, Levy MA, Redford KH, Wannebo AV and Woolmer G (2002) The human footprint and the last of the wild. Bioscience vol 52 No 10 pp 891–904

Schlesinger WH (2006) Global change ecology. Trends in ecology and evolution vol 21 pp 348–351

Secretariat of the Convention on Biological Diversity (2006) Global Biodiversity Outlook 2. Montreal, 81 + vii pages

Vitousek PM (1992) Global Environmental Change: An Introduction. Annual Review of Ecology and Systematics vol 23 pp 1–14

Wessman CA (1992) Spatial scales and global change: Bridging the gaps from plots to GCM grids cells. Annual Review of Ecology and Systematics vol 23 pp 175–200