Network Implications for Global Change Monitoring

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Abstract

The complexity of the Earth system and our limited knowledge concerning the key indicators necessitate a more or less complete monitoring of the Earth system as well as adequate systems for delivery of information into decision-making. Global change impacts are mainly expected on decadal to inter-decadal time scales. Monitoring global change as a contribution to the developing environmental monitoring and assessment programmes therefore requires a crucial long-term component in the design of all aspects of networks. To assure the necessary long-term stability and consistency, a strong operational component is required. Due to a lack of a long-term mandate, services based on voluntary contributions may not be adequate to ensure this operational component. The often technique-oriented observing networks need to be developed along a global strategy and linked into issue-oriented information delivery systems.

1 Introduction

Over the last decade, a very rapid development of the space-geodetic observation techniques has led to unprecedented possibilities to measure positions and opened up for new geo-scientific applications (see, e.g., Plag *et al.*, 1998). Moreover, several space-geodetic methods including Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI) and the Global Positioning System (GPS) have reached a status where the transition from research to operational states appears to be feasible. These techniques have the potential to provide for a reliable long-term monitoring of key parameters describing the Earth's system, such as surface displacements and deformations, Earth orientation, integrated precipitable water vapour content of the atmosphere (IPWC), and electron density in the ionosphere. Moreover, they are the tools for the maintenance of a globally uniform reference system required for all position-dependent information.

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Space-geodetic methods thus potentially can provide a valuable contribution to global or regional monitoring of global change. In fact, the IGS in its home page claims a ”Monitoring of Global Change by Satellite Tracking”. However, while such a claim is easily being formulated, it might not be so easy to actually provide a valuable contribution to Earth system monitoring for scientific and (even more so) societal applications. Due to the complexity of the Earth system, where all system processes are closely intertwined, a relevant contribution of IGS to the monitoring of global change can only be realised if this part of IGS's activities is integrated into a global context.

Environmental security is an issue of increasing importance for a society depending on ever expanding infrastructure and experiencing a concentration of a growing fraction of the population in megacities. Integrated with other techniques, the space-geodetic techniques could contribute to environmental monitoring, for example, with the important application of ”early warning”. Here, too, the value of this contribution will crucially depend on the ability of the space-geodetic community to link itself into a broader context.

Any service based upon an observing system may be viewed from three different aspects, which can be visualised as a triangle (Fig. 1). Each corner is of equal importance for the performance and success of the service. The triangle should be centred around the needs of the users of the service, which may be scientists or the society at large. The design of the *virtual network* including the objectives of the service needs to be such that the products correspond to scientific or societal need. Ideally, the design process should be user-driven, that is, the identification of the user's requirements should be the first step in developing the virtual network. The *physical realisation* of the network including the single stations, the communication tools, the data processing and the analysis has to meet the specifications resulting from the virtual network and, particularly, the objectives of the system. Quality-control of the performance of the physical network and the products as well as the long-term consistency of the operation need to be integral parts of the design of the virtual network. Finally, the *institutional network* has to ensure the political and financial support of the system. The institutional network has to identify the different actors and stakeholders all along the chain of information flow. This may range from research scientist over scientific organisation, governmental institutions and services, all the way to private enterprises. In particular, this includes the owners of the (physical) infrastructure as well as the ”owners” of and contributors to the services provided by or linked to the virtual network. Most of all, the institutional network has to obtain the necessary long-term mandate from the users. In case of environmental monitoring, where both the users and the owners might be governmental bodies, a mandate from the relevant political level may be required to backup for long-term activities.

Below, some basic implications will be discussed, which follow for the virtual and institutional networks from IGS's quest for monitoring of global change. Prior to that, the general background in global Earth monitoring is very briefly described in the next section with main focus on the societal needs.

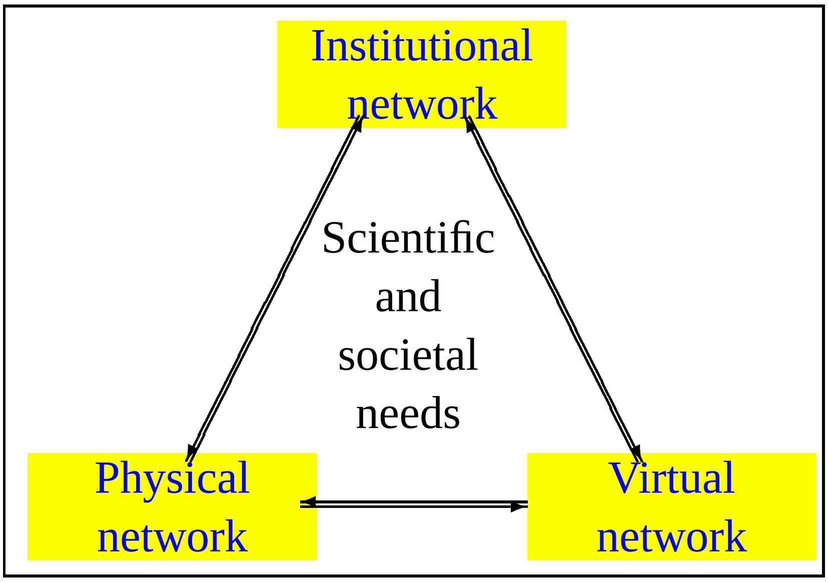

Figure 1: The Network Triangle.
An operational monitoring system should respond to well defined scientific and/or societal needs. The design of the virtual network should be user-driven. The physical network needs to comply to the specifications resulting from the virtual network. Within the institutional network, the owners of the physical and virtual network have to be linked with the users to provide for the necessary resources and the long-term mandate for the maintenance of the system. From Plag (1999).

2 Developments in global monitoring

The need for a comprehensive monitoring and assessment of the global environment was formally acknowledged at the UN Conference on the Human Environment in Stockholm in 1972 with the adoption of an Action Plan. One of the three main components of this plan was the global environmental assessment programme (Earthwatch), which made a number of recommendations concerning evaluation and review, research, monitoring, and information exchange. In preparation of the UN Conference on Environment and Development (UNCED) in Rio in 1992, the United Nation Environmental Programme (UNEP) Governing Council recommended in 1991 that "*Earthwatch should identify global and regional environmental monitoring and assessment needs, co-ordinate and harmonise global, regional and national monitoring and assessment programmes to the extent required, prepare comprehensive assessment statements, inventories and analytical statements, give advanced warning of emerging environmental threats, advise on causal relationships of observed environmental changes, and suggest policy responses and management options where necessary*". At the UNCED, the Agenda 21 was accepted as a plan to progress towards a sustainable development. In Chapter 40, the Agenda emphasised the rapidly increasing need in decision-making for environmental information, and the UN system-wide Earthwatch received a new impetus as one major instrument to implement the Agenda 21. Moreover, the role of Earthwatch was further strengthened in the reviewing of the Agenda 21 through the

UN General Assembly Special Session in June 1997 (for a detailed documentation, see the documents available at the Earthwatch home page http://www.unep.ch/earthw.html. If not mentioned otherwise, all documents related to the following discussion are also available on this web site.).

Under the framework of Earthwatch, a strong international development has taken place over recent years towards a strategy for and implementation of a global observing system including the necessary tools to provide relevant information to the users. Of relevance for the discussion here are the development of an Integrated Global Observation Strategy (IGOS) and the implementation of the three Global Observing Systems (G3OS), namely the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). It is not possible to give here an overview of the current strategies guiding the development in global observing and monitoring. However, it is worthwhile to highlight a few points.

In its newly available draft of ”Earthwatch strategic framework for environmental observing, assessment and reporting”, the main objectives of Earthwatch are described as

- ”*to keep policy-makers informed of the global environmental situation, particularly where it threatens human health and well-being and environmental sustainability*”;
- ”*to provide adequate scientific information on the global environment assembled, integrated and organized so that the current status and trends can be summarized for each global report*”;
- ”*to provide the basis for integrated assessments of the global environment*”.

While data collection is considered to be organised best by environmental components or location or by technologies or methods, it is supposed that delivery of information products will most often need to focus on specific issues. The draft identifies as one major gap in the flow and transformation of data into information in many case not the observation techniques but our ability and a lack of infrastructure to make use of the data. The economic strategy is considered to be as important as the information structure. No reason is seen why the essential environmental information necessary for environmental security is not publicly funded in the same way as many tasks relevant for the physical security of the society are.

In the draft document of IGOS it is stated that ”*IGOS focuses specifically on the observing dimension of the process of providing environmental information for decision-making*”, however, pointing out that data collection is not an end in itself. Among others, IGOS covers all forms of data collection concerning the physical, chemical and biological environments of the planet. IGOS attempts to unite ”*the major satellite and ground based systems for global environmental observations for the atmosphere, the ocean and the land in a framework that delivers maximum benefit and effectiveness in their final use*”. Building on existing national and international mechanisms, IGOS attempts to add values to these.

Among the five major components of considerable strategic importance to IGOS mentioned in the draft, the following three are mentioned here:

- Transition from research to operational: most environmental observations have been and still are collected by scientists as part of scientific programmes serving specific research questions. Funding, planning, and individual careers are not adequate to build up environmental databases relevant for global environmental issues involving time scales of decades to centuries.

- Archiving - building long-term time series: proper data archiving and the building of long time series is considered to be one of the most neglected aspects of environmental observations.

- Harmonisation, quality assurance, calibration/validation: the percentage of data not useable outside the local context due to lack in one or all these points is considered to be frighteningly large.

The partners in the development of the IGOS currently are the Committee on Earth Observation Satellites (CEOS), the sponsors of the G3OS, the programme offices of the G3OS, the International Group of Funding Agencies for Global Change Research (IGFA), the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WRCP). Additional partners are explicitly welcome.

Scientific support to policy-making has gained increasing importance in both the formulation of conventions and their supervision. Most often, the lack of sufficient data on the global environment is the main bottle-neck. The presently available monitoring systems are, though advancing rapidly, still not adequate to provide the required database. This was very recently emphasised by the "Report on the Adequacy of the Global Climate Observing System" to the Fourth Conference of the Parties (COP) of the UN Framework Convention on Climate Change (UNFCCC) (GCOS-48, 1998).

It should also be mentioned here that in its 1995 assessment, the Intergovernmental Panel on Climate Change (IPCC) emphasised the major uncertainties in our knowledge of the Earth system and its natural variability as well as anthropogenically induced change (Houghton *et al.*, 1996). In particular, at decadal to inter-decadal time scales, our ability to separate natural from man-made variations is hampered by a lack of knowledge of system processes, an insufficient data base and methodological problems (see Plag, 1999, for a more detailed discussion). This supports the request of IGOS for data archiving and the building of homogenous long-term time series.

3 Some requirements for the virtual network

Ideally, the design of a virtual network would be defined in order to provide products responding to clearly identified user requirements. Based on a thorough analysis of the "market", which as a result should identify all potential users (including future ones) of the network and their needs for specific products, a description of the user requirements should clearly specify the required properties of the products. These properties should be given in terms of availability, integrity, continuity, consistency, precision and accuracy. The design of the virtual network has to be such as to provide for these properties. This design process would also result in a set of specifications for the performance of the physical network and the quality of the observations provided by this network as well as the communication tools to be used.

However, over the last two decades the space-geodetic techniques have been in a state of intensive research and a very rapid development both in terms of accuracy, applicability and availability. Consequently, much of the development has been stimulated by ad-hoc responses to emerging needs and new potentials and capabilities. Within IAG, CSTG has provide some co-ordination (see e.g., Beutler *et al.*, 1999), but very little was and possibly could have been done to bring forward a clear or even integrated strategy for building space-geodetic networks and services. The space-geodetic networks developed under IAG were and still are science-driven.

Prompted by the success of the IGS, other science-driven space-geodetic networks are currently in a phase of a reorganisation, which led to the establishment of several mono-technique services. Similar to the IGS, these new services focus on fostering the specific technique, the quality and availability of the data products, and partly the co-location with other techniques.

The design of a virtual network also strongly depends on the associated institutional network. In particular, the design can be modular or uniform, hierarchical and top-down or more democratic and bottom-up. For a network owned by a single institution or an organisation, a hierarchical structure with clear competence for decisions and delegation of work may be appropriate and most efficient. However, for regional or global networks it is hard to imagine a physical implementation which is not bottom-up and to a large extent depending on the voluntary contributions of the actors.

A service based on voluntary contribution is characterised by

- relatively high fluctuation of contributors and support;
- inconsistencies in observations, meta-information, and, eventually, products;
- relatively high probability of errors;
- unequal and time-dependent performance levels of different contributors;
- slow and/or insufficient response of contributors to requests from the network.

The design of the virtual network has to account for these deficiencies. In particular, the necessity of a comprehensive network monitoring and quality control is obvious. Therefore, regional to global monitoring networks should integrated these elements as part of the design of the virtual network.

The Earthwatch strategy requests as a design principle that it should not be allowed that data are cut off from their sources and collected in secondary locations where they can go out of date. To follow this principle puts a high demand on the data archiving facilities incorporated in the design of the virtual network. In particular, since data archiving only makes sense if the archived data are consistent, the virtual network has to assure the consistency of data and products.

4 Comments on the institutional network

Meteorological and some hydrological observations are the very few examples of user-driven observational networks, which have been operational for several decades if not centuries. Only recently, a rapidly growing number of operational global or regional monitoring systems have been established within the Earthwatch framework. These systems serve the increasing demand for environmental information in ”early warning” as well as for the building up of environmental databases of the changing planet.

It is important to note that all these systems are institutionalised in a different way than the voluntary science-driven networks prevailing in geodesy. While the former ones are initiated through intergovernmental processes with a strongly formalised sponsoring, are the latter ones to a large extend based on voluntary contributions and the availability of budgets of single individuals and their institutions. These networks are mostly supported with scientific recognition by IAG and/or IAG commissions.

It is interesting to note that many of these science-driven voluntary networks have demonstrated an extreme ability to survive for a long time and to develop a long-term stability. Nevertheless, the establishment of an environmental monitoring system providing both long-term consistency required for global change monitoring and near real-time applications with considerable consequences in case of failure to meet the specifications, might require a different approach.

5 Are there consequences for IGS?

If it is correct to interpret IGS's claim for ”Monitoring Global Change by Satellite Tracking” as a quest for direct or indirect contributions to the rapidly developing global environmental monitoring and assessment programme, then it can be recommended that the IGS focuses some more attention on a few central issues.

If IGS intends to contribute in one way or another to the monitoring of global change for use in the broad context of environmental assessment, then the adherence to a globally accepted strategy in the design of the service, the maintenance of the databases in agreement with the global strategy, the linking of IGS's databases to other relevant databases, and the supply of high-level products within an integrated environmental information network are issues to focus on. This must not be misunderstood as if IGS would have to develop all this by itself. Rather, to achieve such a contribution, IGS needs to develop and maintain an awareness of the global development in Earth observing and to build up or strengthen the interaction with relevant scientific and societal programmes and services.

It appears to be of major importance to interact with programmes such as the G3OS outside of the traditional IAG and IUGG environment. Following the notion of Earthwatch that delivery of information products will most often focus on specific issues, IGS might once more take a lead and show how space-geodetic techniques with their high potential in data collection can contribute or even be integrated in information delivery systems focusing on specific environmental issues.

Of course, due to the rapid global development (which was only very briefly touched upon here), this may easily develop into a vast task. It is therefore recommended that IGS approaches this aspect of ”Monitoring Global Change” with great care but nevertheless in a clearly articulated way. A first step could be to trace existing and investigate potential new links between IGS and, e.g., the G3OS. Furthermore, the comparison of IGS’s internal strategies to the emerging ones for global observing and information distribution could help to identify discrepancies and to adjust IGS’s future development accordingly to minimise the discrepancies.

Another, most likely more difficult issue is the question of how to handle the deficiencies of a voluntary-based service. It could be worthwhile to work out ways and methods to strengthen or even formalise the commitment of the different actors to the service.

The issues mentioned here are mainly related to the virtual and institutional networks but might eventually have consequences for the physical network, too.

It should be kept in mind that the strong support for global integrated monitoring expressed recently at the Fourth COP of the UNFCCC very likely will result in a re-directing of national funding of observational infrastructure (see the document COP, 1998, for instructive reading). Those who do not want or do not demonstrate that they are valuably contributing to a global integrated monitoring of the Earth system might loss in this process.

References

Beutler, G., Drewes, H., Reigber, C., and Rummel, R. (1999). Space techniques and their contribution within IAG at present and in future. *CSTG Bulletin*. submitted.

COP (1998). Review of the implementation of commitments and other provisions of the convention other matters related to implementation research and systematic observations. Technical report, UNFCCC. Recommendation of the Subsidiary Body for Scientific and Technological Advice, accepted at the Fourth Conference of the Parties of the United Nations Framework Convention on Climate Change, November 2-13, 1998, Buenos Aires, Argentina. Available at http://www.unfccc.de as document FCCC/CP/1998/L.4.

GCOS-48 (1998). Report on the adequacy of the global climate observing systems. Technical report, World Meteorological Organisation. Report to the Fourth Conference of the

Parties of the United Nations Framework Convention on Climate Change, November 2-13, 1998, Buenos Aires, Argentina. Available e.g. at http://www.unfccc.de as document FCCC/CP/1998/MISC.2.

Houghton, J. T., Meira Filho, L. G., Callander, B. A., Harris, N., Kattenberg, A., and Maskell, K., editors (1996). *Climate Change 1995 - The Science of Climate Change*. Cambridge University Press.

Plag, H.-P. (1999). Integration of geodetic techniques into a global earth monitoring system and its implication for earth system sciences. *CSTG Bulletin*. submitted.

Plag, H.-P., Ambrosius, B., Baker, T. F., Beutler, G., Bianco, G., Blewitt, G., Boucher, C., Davis, J. L., Degnan, J. J., Johansson, J. M., Kahle, H.-G., Kumkova, I., Marson, I., Mueller, S., Pavlis, E. C., Pearlman, M. R., Richter, B., Spakman, W., Tatevian, S. K., Tomasi, P., Wilson, P., and Zerbini, S. (1998). Scientific objectives of current and future WEGENER activities. *Tectonophysics*, **294**, 177–223.