# Understanding Climate Variability: A Pre-requisite for Predictions and Climate Change Detection



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It is interesting to note that the person who has worked over the last five years to strengthen and – if needed – to initiate the joint action of the four major Global Change Research Programmes was asked to speak at the conference on "The Disciplinary Way". Maybe because without a high profile in disciplinary research all interdisciplinary and trans-disciplinary research loses its basis and becomes wishful thinking. The content of this contribution is partly a review of the achievements of the World Climate Research Programme (WCRP), the oldest and really globally co-ordinated environmental research programme that attracts the full scientific community. Based on a fore-runner, called Global Atmospheric Research Programme (GARP), and the infrastructure of National Meteorological and Hydrological Services (NMHSs) of about 185 members of the World Meteorological Organisation (WMO) and jointly sponsored since 1980 by WMO and the International Council of Scientific Unions (ICSU, now renamed to International Council for Science), WCRP made major steps forward to reach its major goal: To understand and to predict – as far as possible – climate variability and climate change including human influences.

## Causes of Climate Variability

The components of the climate system, namely air, water, life and solid earth, strongly interact at drastically different reaction time scales from hours (planetary boundary layer) to billions of years (complete rearrangement and formation of continents). Thus, there must be climate variability on all time scales; but in addition there are external influences like the changed luminosity of the sun, varying earth orbital parameters, impacts by comets, meteors and planetoids causing additional variations, which for most cases cannot be distinguished from internally caused variability as long as the history of the influencing factors is not well known. As illustrated in figure 1, the result is an impressive variability which even for the yearly mean hemispheric or global temperature reaches several tenths of a degree Celsius from one year to the next, often 0.4 °C in a decade or 0.8 °C for (taking 5 year averages) in the 20$^{th}$ century. If one plots precipitation of the rainy season, *the* fundamental parameter for the survival of populations in

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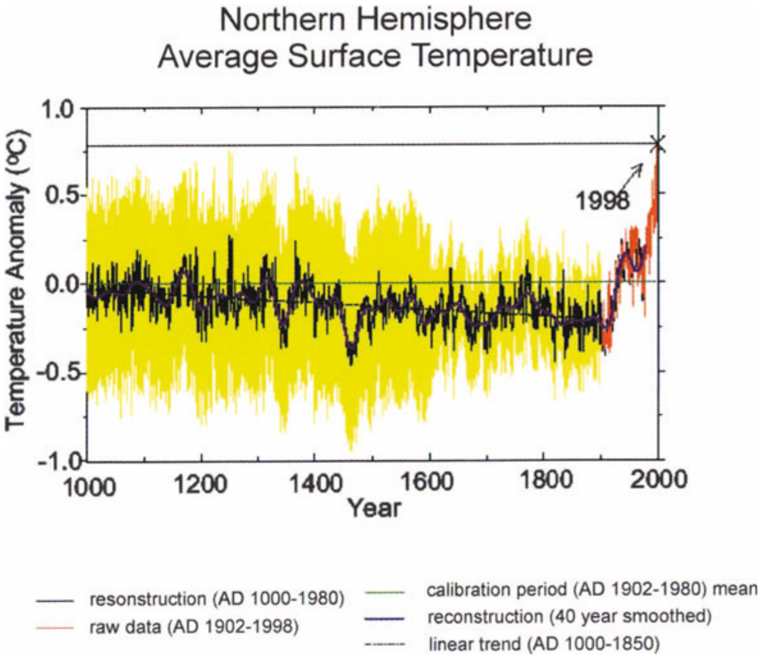


**Fig. 1.** Yearly mean 2 m air temperature of the Northern Hemisphere as derived from direct measurements and layered proxies [Source: Mann et al. (1999).]

many countries, year-to-year variability may reach more than 50 percent in the subhumid or semiarid tropics, indicating the enormous potential for development which would lie in the ability to give physically based probability estimates of the next rainy season, both for avoiding devastating impacts of severe droughts and for getting bumper crops in a good rainy season by adjusting governmental and agricultural management.

## Understanding Interannual Variability

The major El Niño event 1982/83 stimulated co-ordinated research within the Tropical Ocean/Global Atmosphere (TOGA) project of WCRP, which started officially in 1985. The major goal was to understand the irregular oscillation in sea surface temperature in the tropical oceans but especially in the Eastern Pacific, which causes weather extremes and related natural disasters on nearly global scales; and to predict it if possible. The breakthrough to seasonal predictions for ENSO affected areas achieved by scientists from several nations working within TOGA can be seen as a major landmark for environmental sciences, since for the first time the probability for given climate anomalies on time scales far beyond the present 6 to 8 days for deterministic weather forecasting can be predicted by

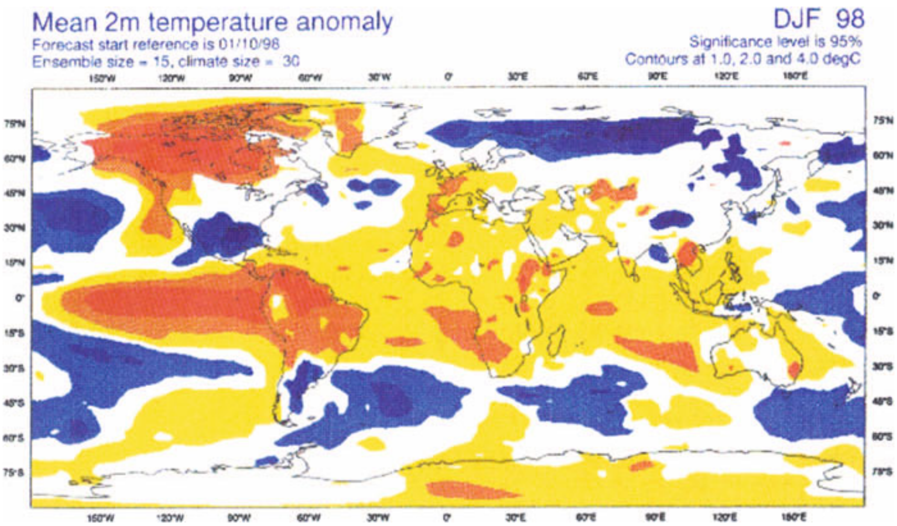


**Fig. 2.** The first global 3 months precipitation anomaly forecast issued by the European Centre for Medium-range Weather Forecast (ECMWF) for December, January and February 1997/98 during the recent major El Niño, based on observations gathered end of October 1998. Only areas were a 95 percent chance of a significant deviation from the mean was forecast are coloured.

supplying the proper starting field in atmosphere and upper ocean to coupled ocean/atmosphere models. These models simulate properly the intrinsic phenomena of the coupled tropical ocean/atmosphere system in the Pacific. To put it simply: Scientists have learned to transport and develop temperature anomalies in their models with the proper speed and partly the proper growth or decay rates, if an embryo of El Niño has been detected by the new subsurface observation system across the tropical Pacific. Since forecasts over several months and even over a few seasons are now available for many regions as probability estimates for a certain deviation from the mean from global 3-D coupled ocean/atmosphere models, mankind has entered a totally new era (see fig. 2). Much more sophisticated planning in many fields is now possible. Examples are: Adapted and often higher electricity production in major water reservoirs, changed agricultural practices even including changed crops, more adequate transport volumes for fossil fuels, higher disaster preparedness, changed behaviour on the stock market, improved holiday planning. If properly exploited, it might lead to faster development of areas suffering from strong natural climate variability. Seasonal forecasts can become an invaluable form of development aid.

## Modelling Climate Variability as a Pre-requisite for Climate Change Detection

The strong climate variability on time-scales of years to decades makes climate change detection difficult. Four inputs are needed for detection: firstly a global coupled ocean/atmosphere/land-model, that simulates variability on time-scales up to decades reasonably well, secondly the history of external influence, thirdly a time series of observed global climate at least for some decades, and fourthly a pattern recognition method that is able to detect the emerging fingerprint. It was only in the mid-nineties that all these ingredients were available for the first thorough detection attempts (e.g. Hegerl et al. 1997). Although numerous time series analyses, for example for global mean near surface air temperature, had earlier pointed to a human influence on this record it could still have been a strong excursion driven by internal climate system component interactions. Only after fingerprinting methods had been applied to the geographical, seasonal and altitudinal changes of temperature during the recent decades did the Working Group I of the Intergovernmental Panel on Climate Change (IPCC) dealing with the Science of Climate Change formulate the now famous sentence: *The balance of evidence suggests a discernible human influence on global climate (IPCC 1996).* The main weaknesses still remaining were the inadequate history of radiative influence, for example for tropospheric sulphate aerosols, and model variability somewhat below the observed level for all models that jointly allowed for increased greenhouse effect and sulphate aerosols. The Second Assessment Report of IPCC thus had added a new pillar concerning anthropogenic climate change in addition to the earlier three: Observed concentration increase of long-lived greenhouse gases, model simulations of global warming for business as usual emission scenarios and past climate evidence for warming during periods with high greenhouse gas concentrations (for methane and carbon dioxide).

## Attribution of Climate Change to Causes

After detection attribution is the next goal. As the increased greenhouse gas concentrations will cause cooling of the stratosphere, it seemed straight-forward to attribute the observed cooling there to this changed atmospheric composition.

However, the cooling trend during the recent decades was especially strong in the lower stratosphere for mid and high latitudes in altitudes where models would only point to the crossover from warming below to cooling above. Joint evaluations of ozone and temperature trends supported by model calculations have led to one of the first attributions of a climate change phenomenon to distinct causes: *The cooling in the lower stratosphere is largely due to ozone depletion and to a lesser extent to increased greenhouse gas concentrations*[1].

[1] WMO, UNEP (1999) assess ozone depletion regularly. The most recent assessment is published as Report No. 44 in the Global Ozone Research and Monitoring series of WMO, Geneva

## WCRP, Interdisciplinarity and Transdisciplinarity

Part of the success of WCRP is due to the comparably low level of interdisciplinarity needed for some breakthroughs in the understanding of climate variability. Only two different disciplines of geosciences had to co-operate to get seasonal climate anomaly predictions for areas affected by the El Niño/Southern Oscillation phenomenon: meteorologists and physical oceanographers. The new tools they had to use jointly were: new observations of basic physical parameters at the ocean surface and in the upper ocean, partly from high-tech sensors, plus coupled ocean-atmosphere models of medium complexity. If the contribution of soil moisture to predictability on time-scales of weeks to months is sought another group of disciplines in geosciences have to co-operate, namely meteorology, hydrology and soil sciences.

The proper application of these predictions, however, still needs typical transdisciplinary research involving not only social sciences but also many categories of users. Therefore, I tried to encourage the START (Global Change *Syst*em for *A*nalysis *R*esearch and *T*raining) project Climate Variability Predictions for Agricultural Production (CLIMAG), because it has all the ingredients needed to collate the parents of START (IHDP, IGBP, WCRP), to activate the regional START network to challenge the global projects of IGBP and WCRP, to bring in the farmers and the economists, the latter dealing with the food market over a larger area. A major challenge for WCRP projects caused by CLIMAG is: better regionalisation of further improved seasonal predictions. This means nesting of circulation models, ensemble predictions and dynamical down scaling in order to assess the probability of certain weather extremes, up to now hidden in an originally coarse seasonal prediction. On the other hand crop yield modellers (often just applying the model for a plot) have to upscale their results to a region and have to include the hitherto mostly omitted influence of pests and diseases into their models. The success of this transdisciplinary research in CLIMAG rests on excellent contributions in all disciplines, interdisciplinary co-operation, co-ordination across major groups of disciplines, acceptance by the users and joint funding by several nations, i.e., the stakes are very high. For the funding the major obstacle is the neglect of the correlation between standard of living and research/ development expenditure (see also section The Widening Gaps) in most developing countries.

## The Inadequate Infrastructure of Some Global Change Research Programmes

Mankind has no chance to reach sustainable development in the coming century without global change research programmes, as clearly indicated by the detection of the Antarctic ozone hole and the phasing out chlorofluorocarbons and halones just in time to prevent a major disaster. But also the detection of global anthropogenic climate change (see IPCC 1966) has with high probability stimulated the acceptance of the Kyoto Protocol. This protocol of the United Nations Framework Convention on Climate Changes (UNFCCC) is the first major attempt to start global Earth system management by prescribing emission reductions for the

**Table 1.** Infrastructure for Global Change Research Programmes and an assessment of their adequacy

| Programme | Date of Birth and Sponsors | Secretariat in | Number of Staff | Number of International project offices (IPOs) | Problems |
|---|---|---|---|---|---|
| World Climate Research Programme (WCRP) | 1980 WMO, ICSU, IOC (since 1993) | Geneva at WMO | 8 | 5 | some IPOs too small |
| International Geosphere-Biosphere Programme (IGBP) | 1986 ICSU | Stockholm Swedish Academy of Sciences | ~10 | 9 | some IPOs too small, basic funding endangered |
| DIVERSITAS Programme on Biodiversity Research | 1991 UNESCO, several unions of ICSU | Paris at UNESCO | 1 | none | absolutely inadequate infrastructure |
| International Human Dimensions Programme of Global Environmental Change (IHDP) | 1966 ICSU ISSC | Bonn at University | ~5 | 1 | inadequate infrastructure both for secretariat and IPOs |

major consumers of fossil fuels after 200 years of continuous growth in fossil fuel use by the industrialised countries.

Are we prepared to detect further signals of global change that could threaten mankind early enough? If one looks at table 1 the answer is a disappointing "No" for some of the global environmental trends and their potential consequences. While WCRP can rely on an infrastructure which is in large parts just adequate with some problems in the area of international project offices (IPOs) which are not adequately funded (examples: GEWEX and SPARC), IGBP has recently suffered from a decline of funding by ICSU and has similar problems in the area of IPOs as WCRP. The real inadequacy of infrastructure becomes visible for the programmes DIVERSITAS and IHDP. Eight years after its foundation DIVERSITAS is still without any basic infrastructure needed for globally co-ordinated research projects. As this inadequacy is so obvious, the International Group of Funding Agencies (IGFA) supporting Global Change research programmes has decided in October 1999 in Beijing to help DIVERSITAS through a joint action. Hopefully deeds follow words. The youngest of the programmes (IHDP) is in the build-up phase which started when ICSU became sponsor besides the International Social Sciences Council (ISSC) in 1996, that had tried to attract the full scientific community into the HDP since 1992. The infrastructure is still not adequate and the secretariat in Bonn needs more international donors to guarantee continuing German support. Hopefully IPOs will be formed when the implementation plans follow the scientific plans for the present four projects.

## The Widening Gap between the Major Research Nations and the Majority of Countries

When WCRP invited nations to the International CLIVAR Conference in December 1988 we expected that most nations would tell how they would contribute to the *Cli*mate *Var*iability and Predictability study. However, about half of the 65 nations present asked WCRP to help develop means to translate improved climate variability predictions on seasonal to interannual time-scales to ease their use in a special area. In other words: potential donors declared themselves as recipients of anticipated research results.

The background for this behaviour is a widening gap between a few key research nations and the majority of nations not devoting enough resources to research and development. If developing countries will not increase the percentage of the gross national product devoted to research and development they have no chance to grow economically – in a sustained manner – faster than the upper rich part of the OECD countries. There is high correlation between living standard and research/development expenditure of a country. Even inside the European Union this relation holds. It hampers the reduction of differences in living standard if most of the Mediterranean EU members do not increase the research/development expenditure in relating to GNP to levels typical further North.

Why am I pointing to this basic problem? Because all our net-working in global change research, for example through the Global Change *Syst*em for *A*nalysis, *R*esearch and *T*raining (START, jointly supported by IHDP, IGBP and WCRP) will not be successful in the long run if the developing nations will not shift expenditure from, for example, subsidies for fossil fuel to research and development. While the leading research nations give on average a bit less than 3 percent of GNP South America invests only 0.5 and Africa even only 0.2 percent; but also the Russian Federation fell to about 0.5 percent.

## Earth System Analysis

Environmental Research already has acted as an early warning system for mankind. Examples are stratospheric ozone depletion, acidification of soils and freshwater systems, detection of anthropogenic climate change. In all the cases mentioned either the reversal of the trend or first internationally co-ordinated measures to dampen the growth rates have been reached. However, since we do not have a continuous global observing system besides the meteorological one, we do not know how many threats to the global environment and thus our development continue to be undetected. We need an *Earth System Analysis* based on global observations of physical, chemical, biological and socio-economic parameters, which then help to build improved models of the coupled system used for scenarios of possible futures. These scenarios are input for decision making. They have to be open for frequent revision, whenever more solid findings are available through better validation data sets for the models. Only in this manner can we pave the way to a sustainable future. Such an Earth System Analysis needs revised structures in research: Global programmes with sustained infrastructure, stronger co-ordination among the programmes, joint projects, strong interdisciplinarity, an open dialogue with decision makers of all groups in all regions, growing shares of GNP for education, research and development. Such an investment would be a low cost/high benefit undertaking. A shining example is for me the breakthrough to seasonal climate anomaly predictions. An investment of about 300 million US$ over 10 years is returned now to a single nation avoiding larger damage through preparedness for one El Niño event.

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