

Science Highlights

Somewhat more than a decade ago it was recognised that the Earth behaves as a system in which the oceans, atmosphere and land, and the living and non-living parts therein, were all connected. While accepted by many, this working hypothesis seldom formed the basis for global change research. Little understanding existed of how the Earth worked as a system, how the parts were connected, or even about the importance of the various component parts of the system. Feedback mechanisms were not always clearly understood, nor were the dynamics controlling the system.

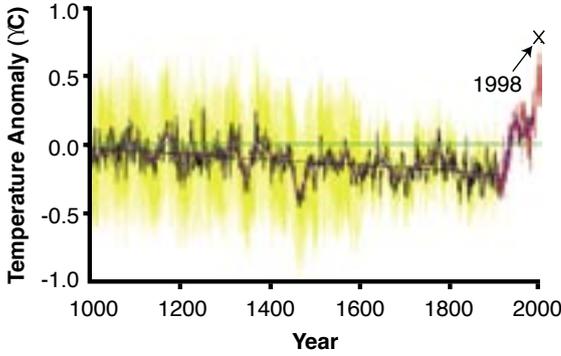
Over the intervening years much has been learned. Global change research has confirmed many of the hypotheses and much of the sketchy understanding of that time, adding a wealth of quantitative detail and process-level understanding at all scales. It is now clear that global change is one of the paramount environmental issues facing humankind at the beginning of the new millennium.

The task of synthesising a decade or more of global change research has been daunting, but the rewards have been great. Detailed results and individual references can be found in the IGBP synthesis volume 'Global Change and the Earth System: A Planet Under Pressure', published by Springer Verlag in the IGBP book series. In this executive summary only generalised highlights are presented, the so-called big-picture findings:

- **The Earth is a system that life itself helps to control.** Biological processes interact strongly with physical and chemical processes to create the planetary environment, but biology plays a much stronger role than previously thought in keeping Earth's environment within habitable limits.
- **Global change is more than climate change. It is real, it is happening now and in many ways it is accelerating.** Human activities are significantly influencing the functioning of the Earth System in many areas; anthropogenic changes are clearly identifiable beyond natural variability and are equal to some of the great forces of nature in their extent and impact.
- **The human enterprise drives multiple, interacting effects that cascade through the Earth System in complex ways.** Global change cannot be understood in terms of a simple cause-effect paradigm. Cascading effects of human activities interact with each other and with local- and regional-scale changes in multidimensional ways.
- **The Earth's dynamics are characterised by critical thresholds and abrupt changes. Human activities could inadvertently trigger changes with catastrophic consequences for the Earth System.** Indeed, it appears that such a change was narrowly avoided in the case of depletion of the stratospheric ozone layer. The Earth System has operated in different quasi-stable states, with abrupt changes occurring between them over the last half million years. Human activities clearly have the potential to switch the Earth System to alternative modes of operation that may prove much less amenable to human life.
- **The Earth is currently operating in a no-analogue state.** In terms of key environmental parameters, the Earth System has recently moved well outside the range of the natural variability exhibited over at least the last half million years. The nature of changes now occurring simultaneously in the Earth System, their magnitudes and rates of change are unprecedented in human history and perhaps in the history of the Earth.

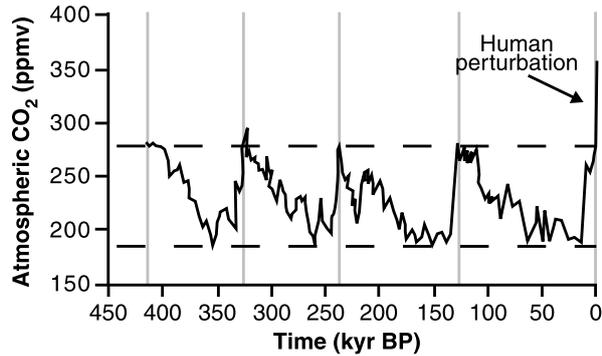
The Earth System is currently operating in a no-analogue state. Human activities are significantly altering the environment at the global scale:

Climate: Mean temperature



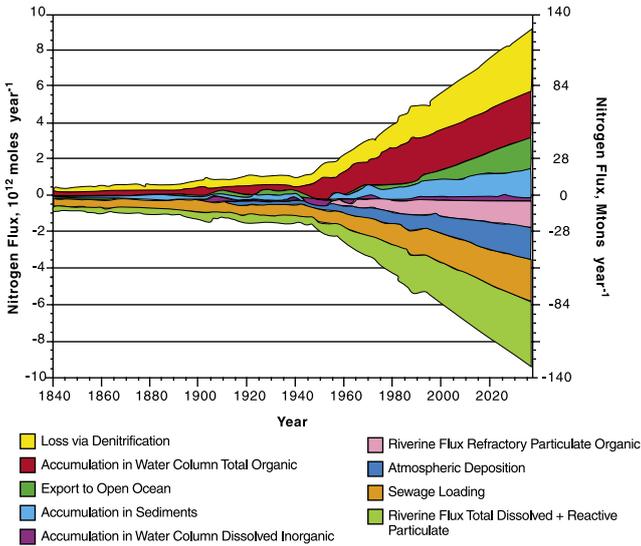
Source: Mann et al (1999) *Geophys Res Lett* 26, 759-762

Atmosphere: CO₂ concentration



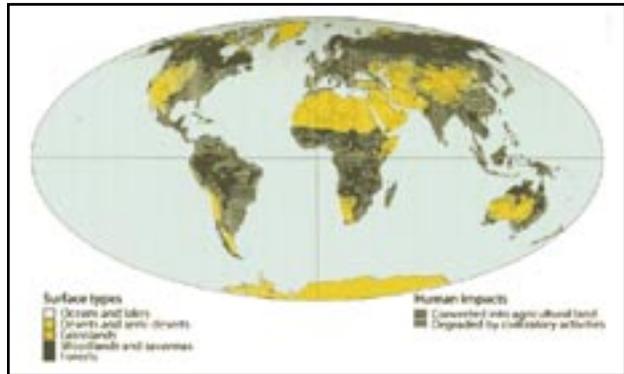
Sources: Petit et al (1999) *Nature* 399, 429-436; Keeling and Whorf (2000), In: *Trends: A Compendium of Data on Global Change*. Carbon Dioxide Information Analysis Centre.

Coastal Zone: Nitrogen flux



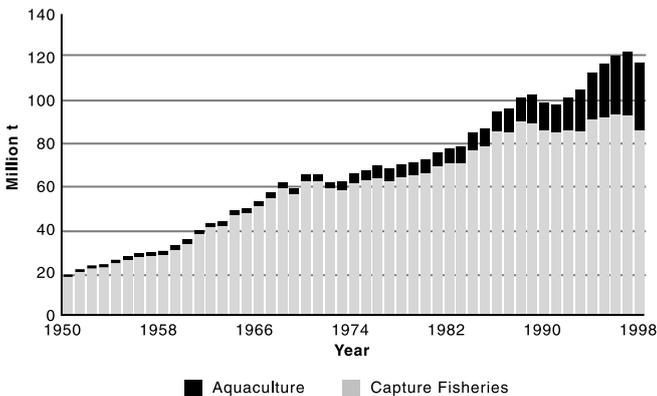
Source: Mackenzie et al. (2002) *Chem Geol*, 190, 13-32

Land: Land cover



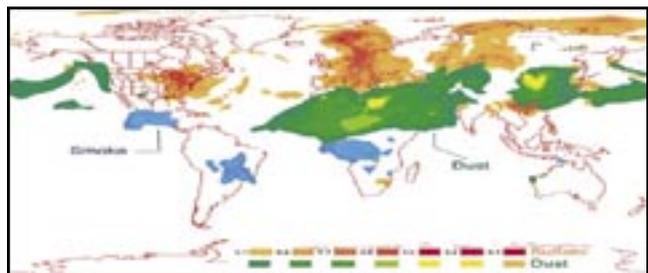
Source: Schellhuber (1998), In: *Earth System Analysis*, Springer-Verlag, pp 3-195

Ocean: Fisheries



Source: FAO (2000) *The State of World Fisheries and Aquaculture*. Food and Agricultural Organisation of the United Nations.

Atmosphere: Aerosols



Source: (<http://www.nrlmry.navy.mil/aerosol/> and Heintzenberg et al. (2003), In: Basseur et al. "The changing atmosphere", Springer- Verlag, pp. 125-156