

DEVELOPMENT OF EARTH
SYSTEM MODELS TO
ASSESS THE
PREDICTABILITY OF
NONLINEAR
RESPONSES/SWITCHES:
OVERVIEW BY
ROGER A. PIELKE SR.

The following slides are from

***How to Evaluate Vulnerability in Changing Environmental Conditions?* Roger A. Pielke Sr. and Lelys Bravo de Guenni, Eds. Part E of Kabat, P., Claussen, M., Dirmeyer, P.A., Gash, J.H.C., Bravo de Guenni, L., Meybeck, M., Pielke Sr., R.A., Vörösmarty, C.J., Hutjes, R.W.A., Lütkeemeier, S. (Eds.): 2003, 'Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System', Springer, Berlin, Heidelberg, New York, approx. 550 pp., April 2003.**

and

Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. *Climatic Change*, submitted.

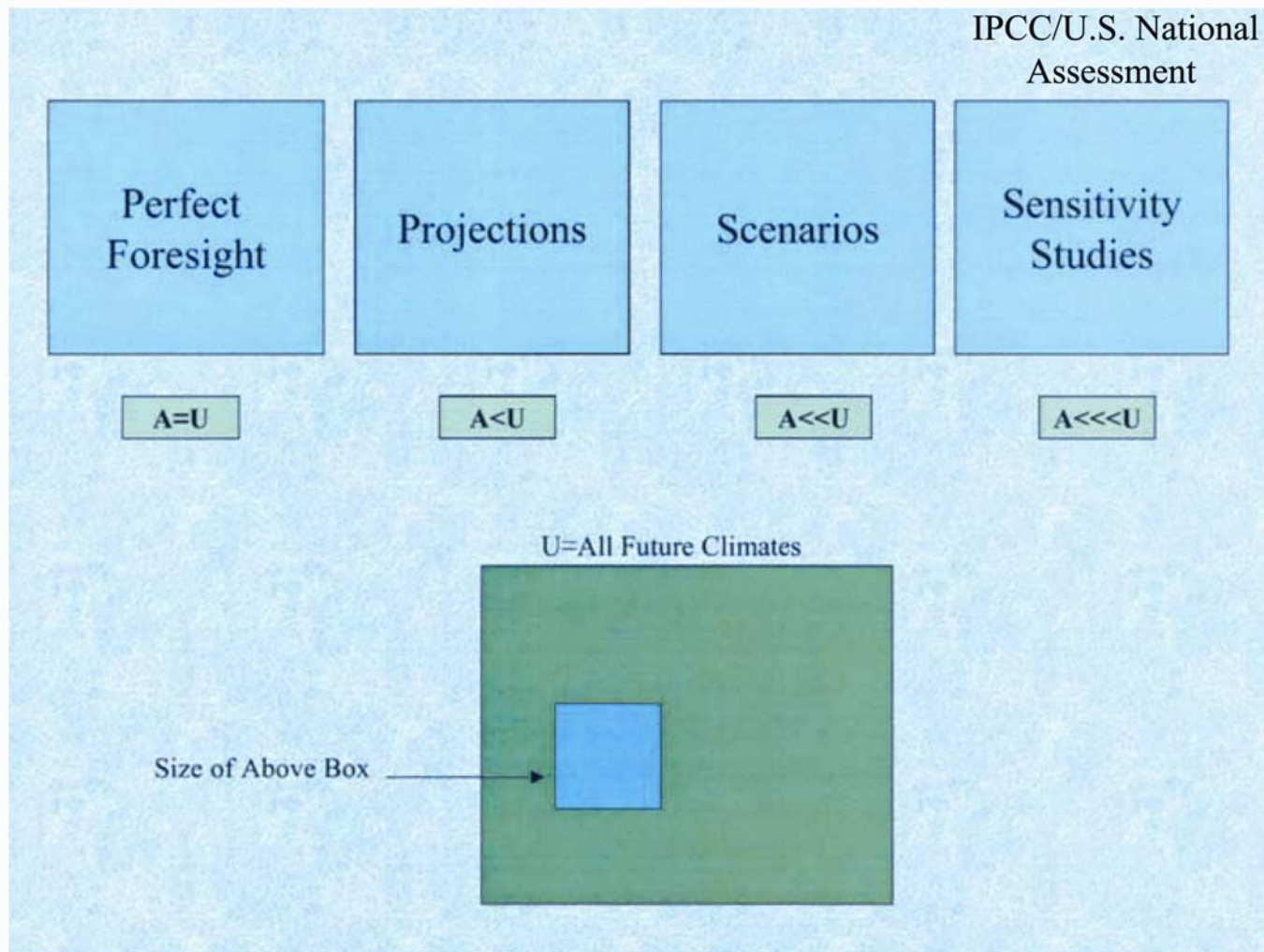
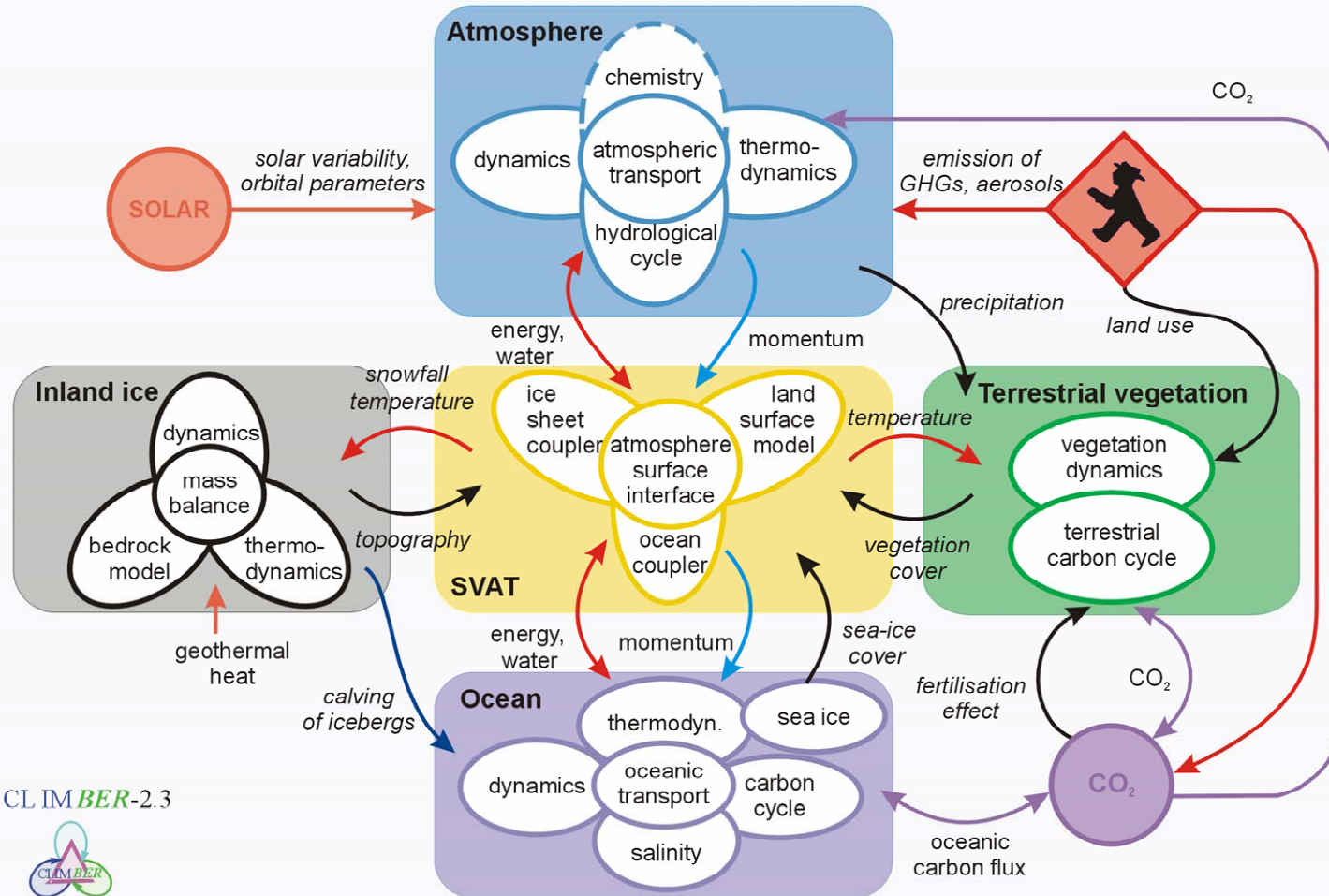
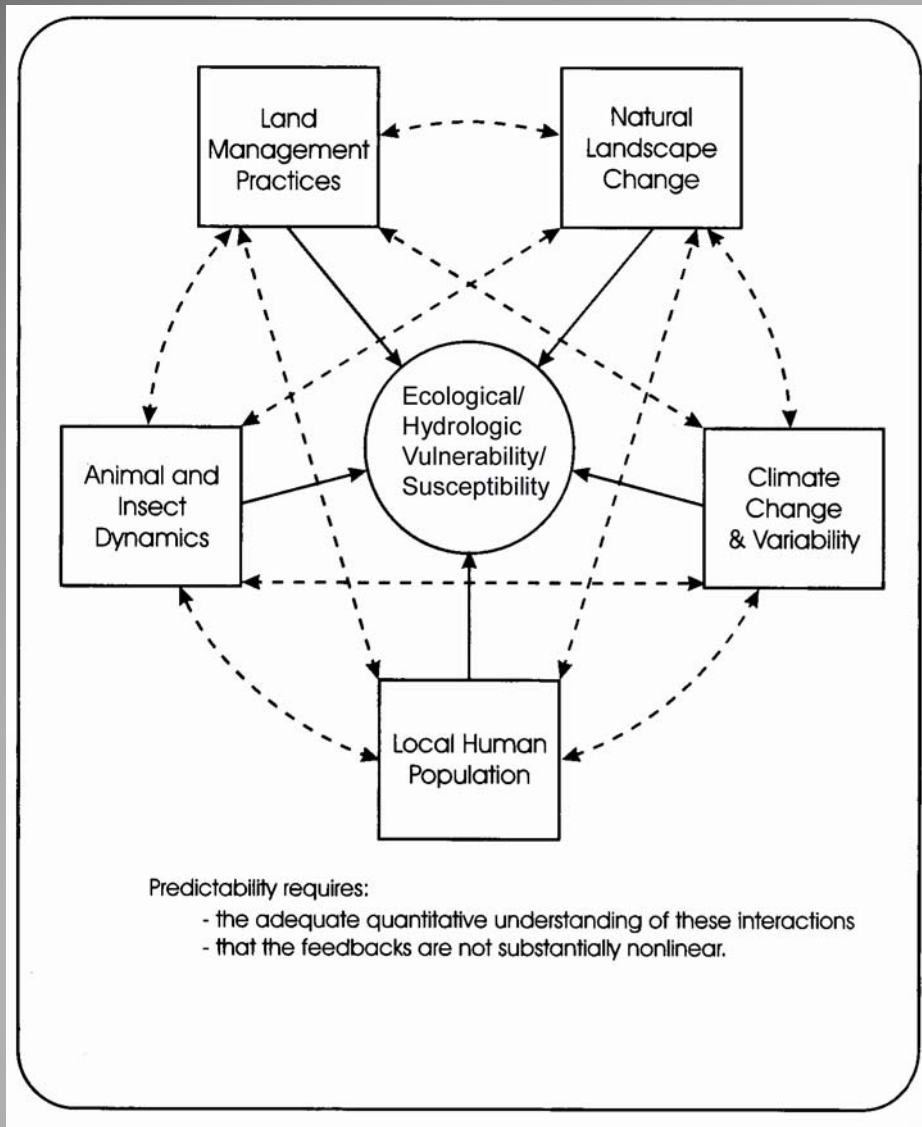


Figure 6. Schematic of different classes of prediction. The size of the box labeled ‘U’ represents the range of future climate, while the box labeled ‘A’ indicates the relative subset of possible future climate that are estimated using the different classes of prediction, (adapted from Pielke Sr., 2001).



Structure of CLIMBER-2, an Earth System Model of Intermediate Complexity (EMIC; Claussen et al. 2002). The model consists of four modules which describe the dynamics of the climate components atmosphere, ocean, terrestrial vegetation, and inland ice. These components interact via fluxes of energy, momentum (e.g., wind stress structure is allowed to change in the case of changes in vegetation cover or the emergence and melting of inland ice masses, for example. The interaction on the ocean), water (e.g., precipitation, snow, and evaporation), and carbon. Also, the land-surface between climate components is described in a so-called Soil Vegetation Atmosphere Transfer Scheme (SVAT). CLIMBER-2 is driven by insolation (which can vary owing to changes in the Earth orbit or in the solar energy flux), by the geothermal heat flux (which is very small, but important in the long run for inland ice dynamics), and by changes imposed on the climate system by human activities (such as land use or emission of greenhouse gases (GHG) and aerosols). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. Climatic Change, submitted. R-260 at <http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml>



RISK

Risk is a quantitative measure of a defined hazard which combines the probability of frequency of occurrence of the damaging event (i.e., the hazard) and the magnitude of the consequences (i.e., expected losses) of the occurrence.

BANDS OF RISK

- A *lower band of risk*, which is acceptable to the affected people and where, for example, the benefits of doing nothing or little outweigh the disadvantages of carrying an unacceptable cost burden.
- A *middle band of risk*, where decisions have to be made which trade off the costs of reducing the risk *versus* the benefits of the risk reduction, and
- An *upper band of risk*, where doing nothing is completely unacceptable, irrespective of cost.

HAZARD

A hazard is a naturally occurring, or human-induced, physical process or event or situation, that in particular circumstances has the potential to create damage or loss. It has a magnitude, an intensity, a duration, has a probability of occurrence and takes place within a specified location.

THRESHOLD

The critical limits (bounds) that the environment can normally tolerate before a negative impact is produced on a system or activity.

INTENSITY

Intensity refers to the severity, or damage-causing potential of a natural process. The hazard intensity is determined by the peak deviation beyond the threshold.

DURATION

The other variable determining the damage-causing potential of an event. Implies exposure to an event, and the longer the exposure, the greater the damage-causing potential. Hazard duration is determined by the length of time the threshold is exceeded.

ADAPTION

The long-term arrangement of human activity to take account of natural events (e.g., becoming more dependent on groundwater than on more erratic surface water resource in more arid zones).

MITIGATION

The intentional response to cope with a hazard (e.g., only constructing buildings beyond a demarcated 1:50 year flood line).

VULNERABILITY

The characteristic of a person or group or component of a natural system in terms of its capacity to resist and/or recover from and/or anticipate and/or cope with the impacts of an adverse event.

ASSAULT EVENTS

Heavy rainfall, flood peak, and pollution levels above a certain concentration, in which case the vulnerability threshold is determined by the system absorption and redirection capacities.

DEPRIVATION EVENTS

Drought, soil erosion or leaching of fertilizers out of the soil, in which case the thresholds of vulnerability are determined by the retention and replacement capacities of the system (e.g., the buffer of deeper soil depth to storing moisture for a plant during a drought, or the rate of weathering to replace soil lost by erosion).

EXTERNAL DIMENSION

The threat of an event, that may increasingly predispose people to risk (e.g., climate change and its impacts on water resources).

INTERNAL DIMENSION

The internal capacity to withstand or respond to an event, such as the defenselessness to cope with a hazard or the lack of means to cope with the aftermath of damaging loss.

Figure E.4 The magnitude of environmental hazard expressed as a function of the variability of a physical element within the limits of tolerance (after: Smith 1996).

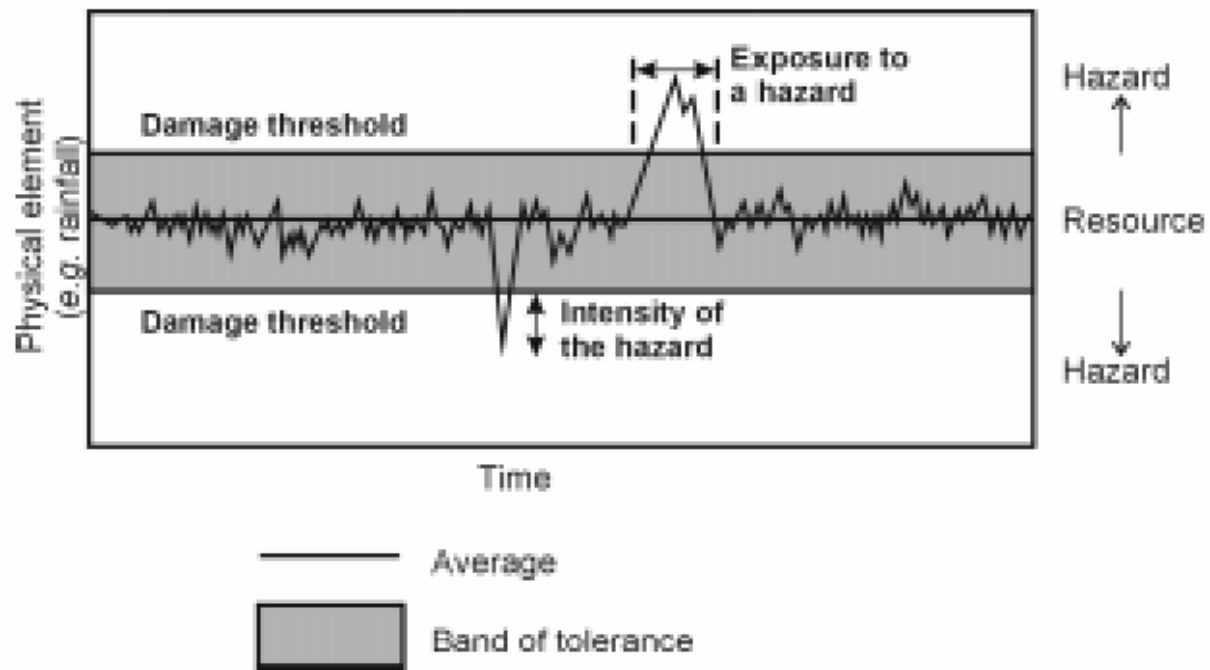
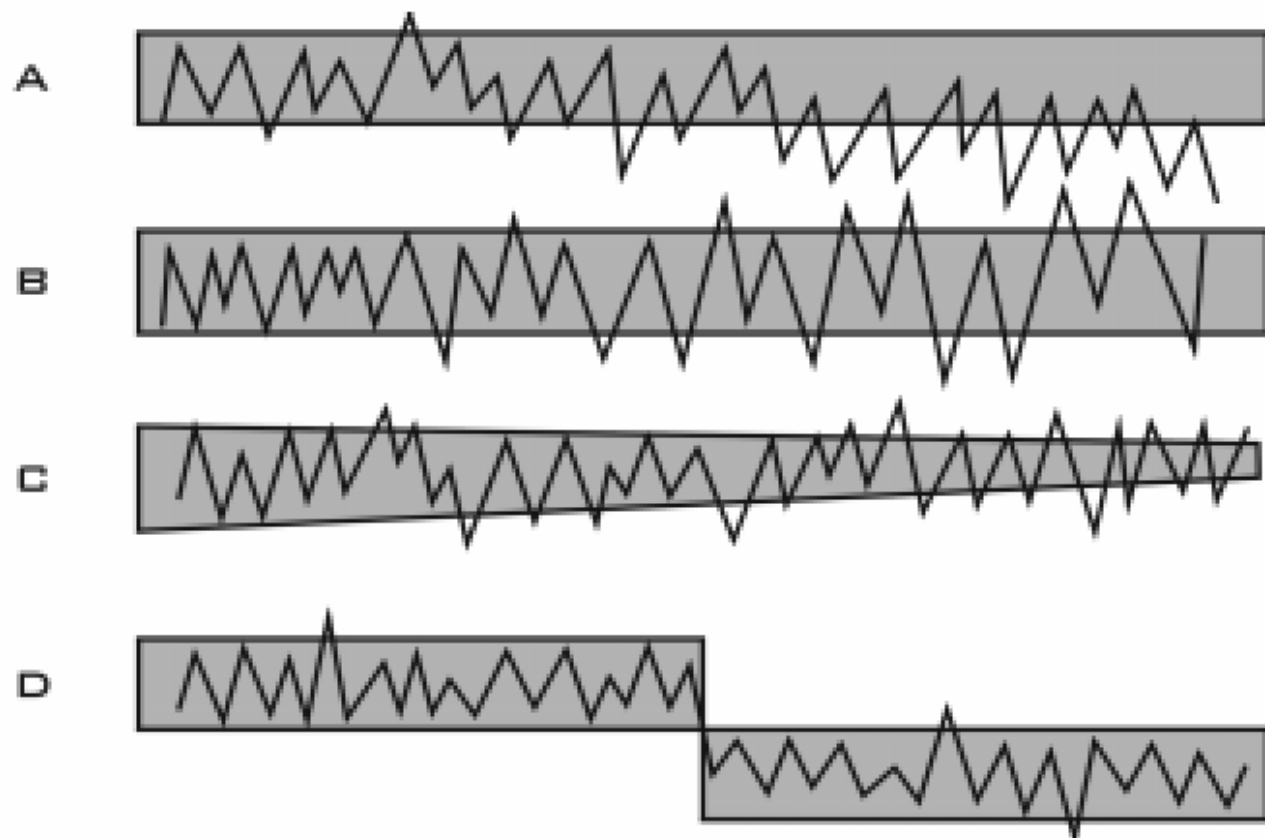
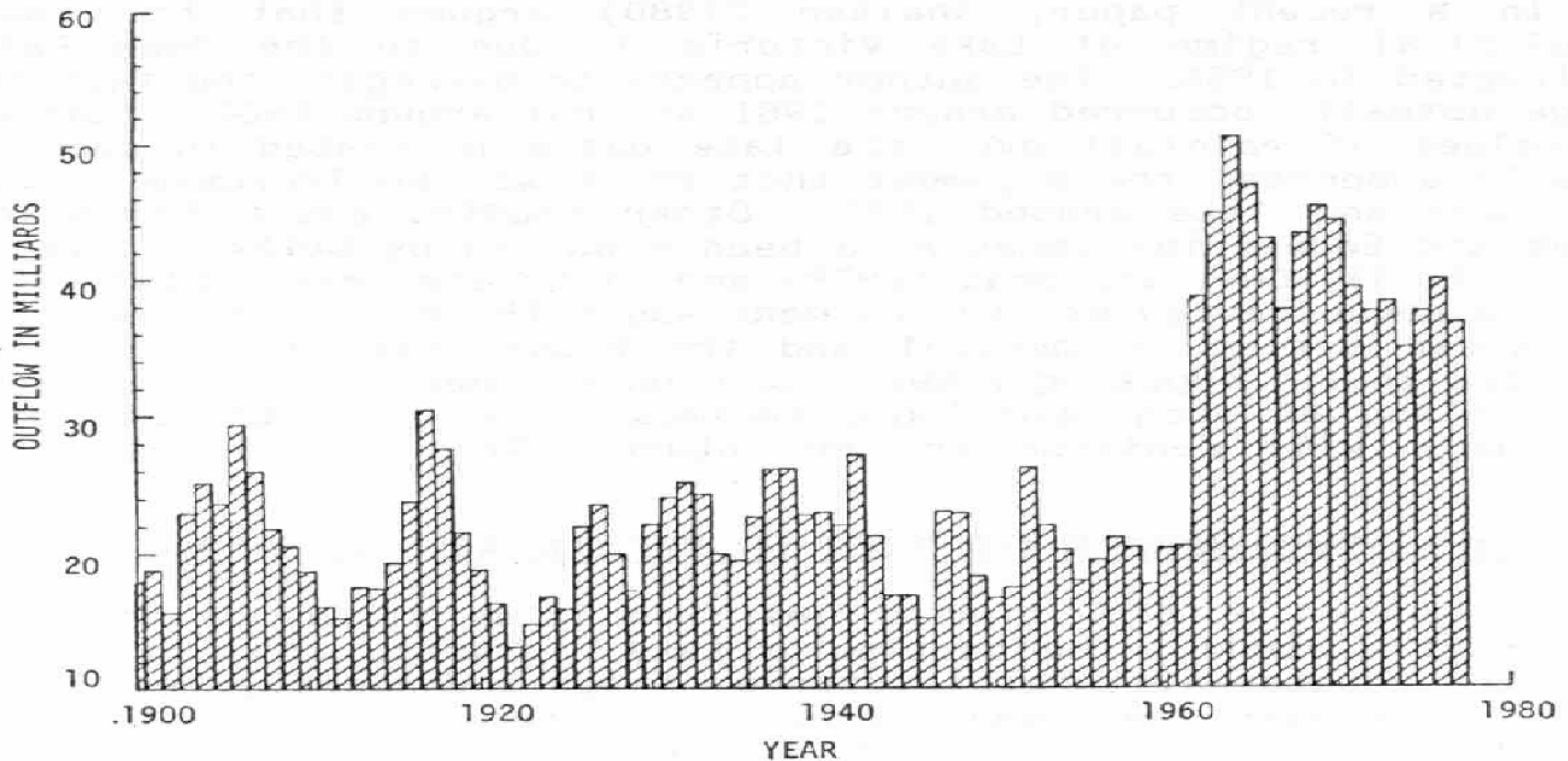
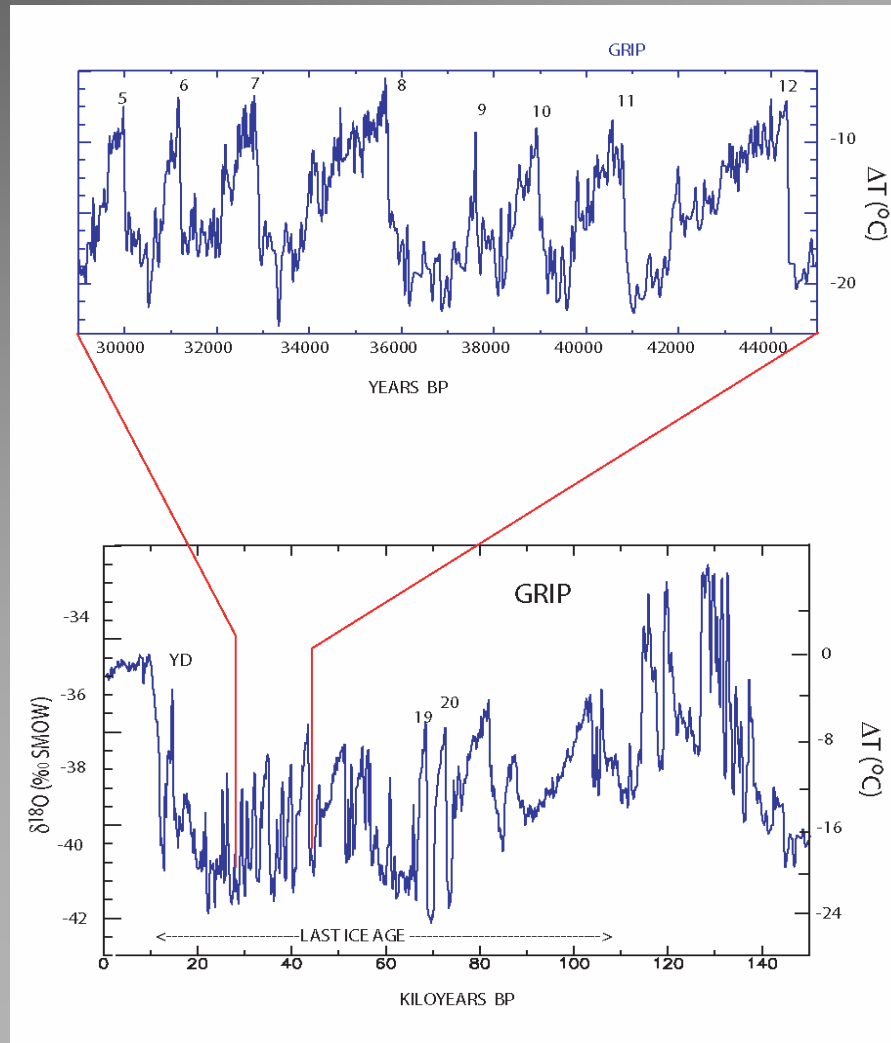


Figure E.5 A schematic illustration in which risk changes due to variations in the physical system and the socio-economic system. In all the cases risk increases over time (with modifications after Smith 1996).



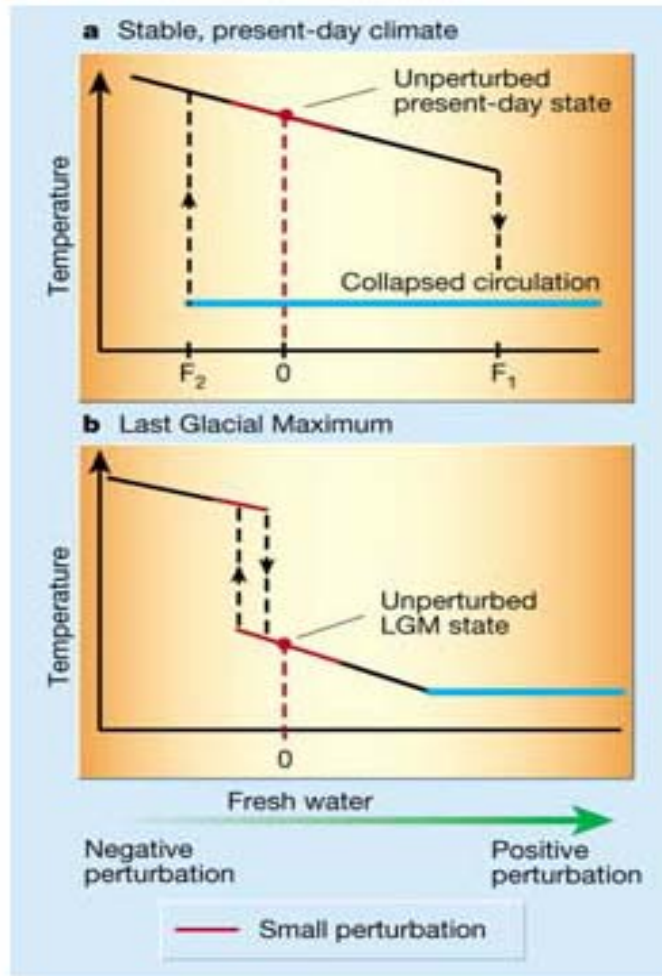


Time series of annual outflows of Lake Victoria, Africa for the period 1900-1977 showing an abrupt shift around 1961 and a slow decaying downward trend (after Salas et al. 1981). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. *Climatic Change*, submitted.
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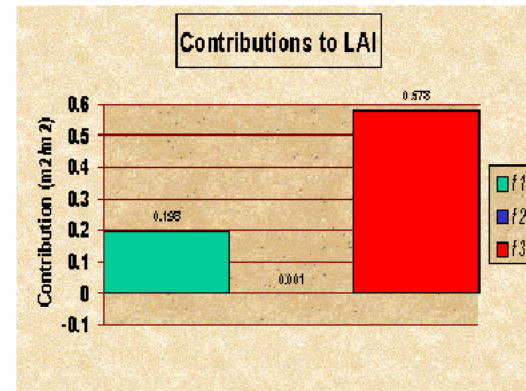
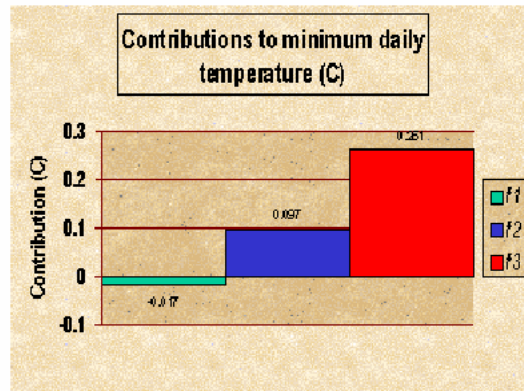
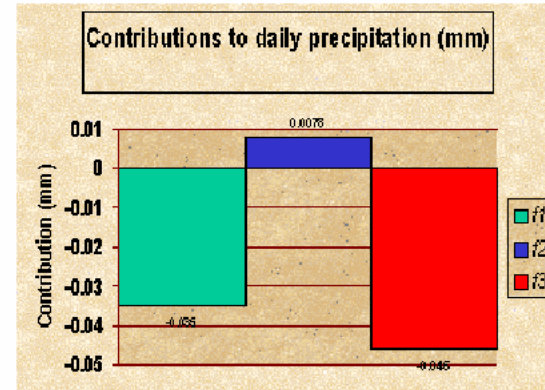
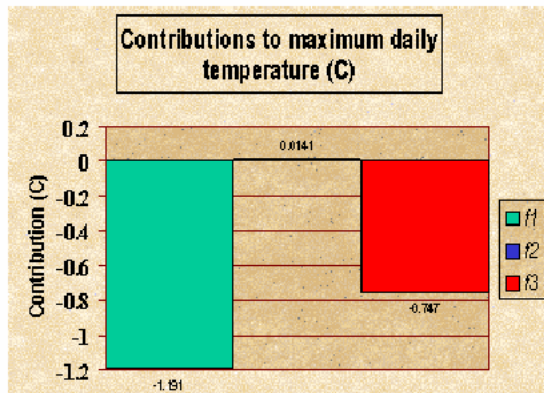


Perhaps the most puzzling feature of recent paleoclimate records, highly relevant to understanding future global climate change, is the fast-warming/slow-cooling sequence found in the stable isotope fluctuations ($\delta^{18}O$) time series of Greenland's ice cores known as the Dansgaard-Oeschger (D/O) oscillations (Jouzel et al. 1994; Alley et al. 1999). The D/O typically show very sudden, 6-10°C warming episodes lasting a few centuries or perhaps even a few decades, followed by millennia of relatively slow cooling. Remarkably, reconstructed sea surface temperatures (SST) in the tropical Atlantic mimic the D/O record in the 30 ka to 60 ka interval, and similar recordings are found in the subtropical Pacific and tropical Indian oceans. The longest period of the signal in the inset is a submultiple of the precession forcing and evidence of precession forcing exists elsewhere in the record (Rial 2003). The ordinals near selected peaks correspond to numbered interstitials and YD is the Younger Dryas event (Dansgaard et al., 1993). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. Climatic Change, submitted.

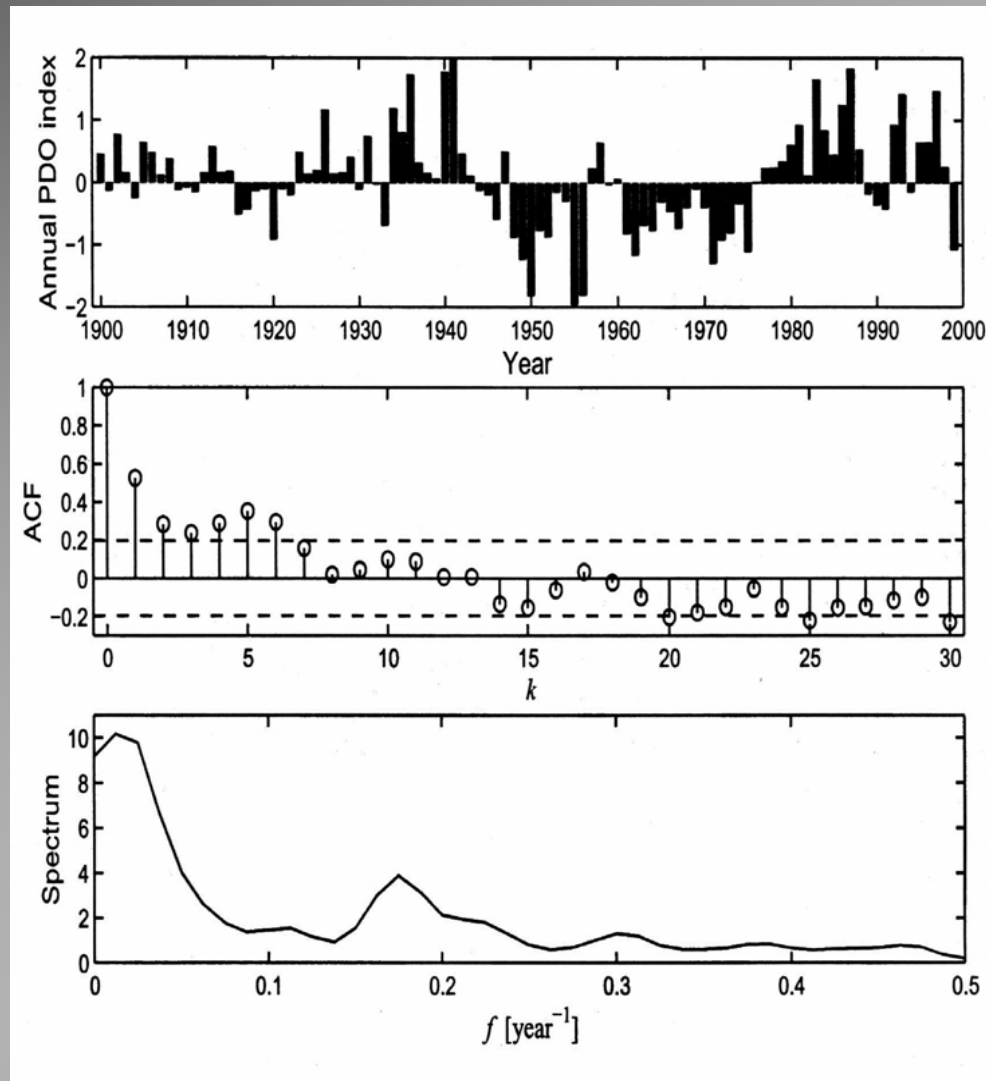
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Climate (temperature) stability as a function of freshwater input at high latitudes in the North Atlantic (after Paillard 2001). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. Climatic Change, submitted. R-260 at <http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml>



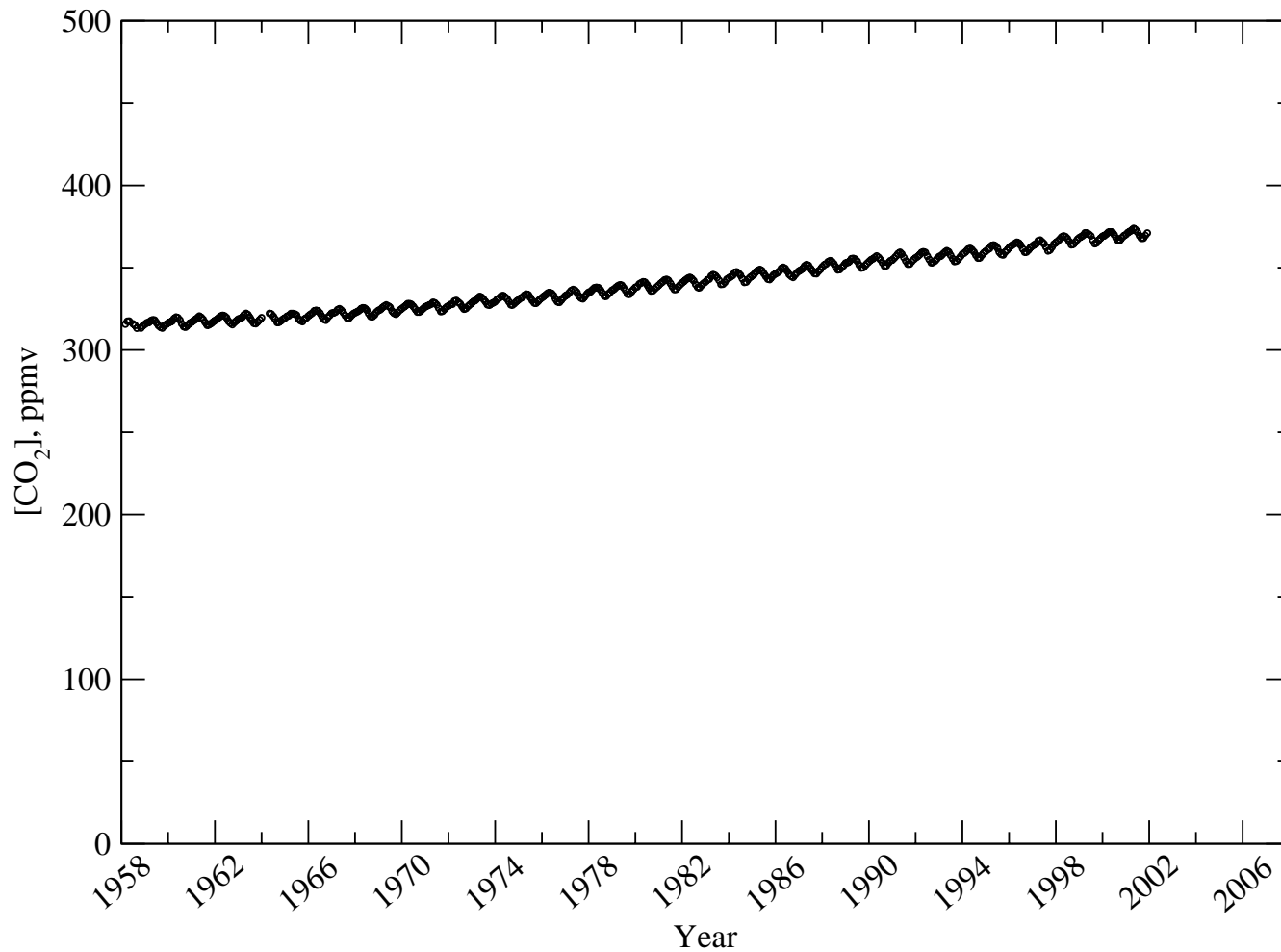
RAMS/GEMTM nonlinear coupled model results – the seasonal domain-averaged (central Great Plains) for 210 days during the growing season, contributions to maximum daily temperature, minimum daily temperature, precipitation, and leaf area index (LAI) due to: f1 = natural vegetation, f2 = 2 x CO₂ radiation, and f3 = 2 x CO₂ biology (adapted from Eastman et al. 2001). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. Climatic Change, submitted. R-260 at <http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml>



Autocorrelation function and spectrum obtained for the time series of annual PDO indices for the period 1900-1999. The time series depicts abrupt shifts and evidence of low frequency (after Salas and Pielke 2002). From Rial, J., Pielke Sr., R.A., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2003: Nonlinearities, feedbacks and critical thresholds within the earth's climate system. *Climatic Change*, submitted. R-260 at <http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml>

MLO CO₂ record

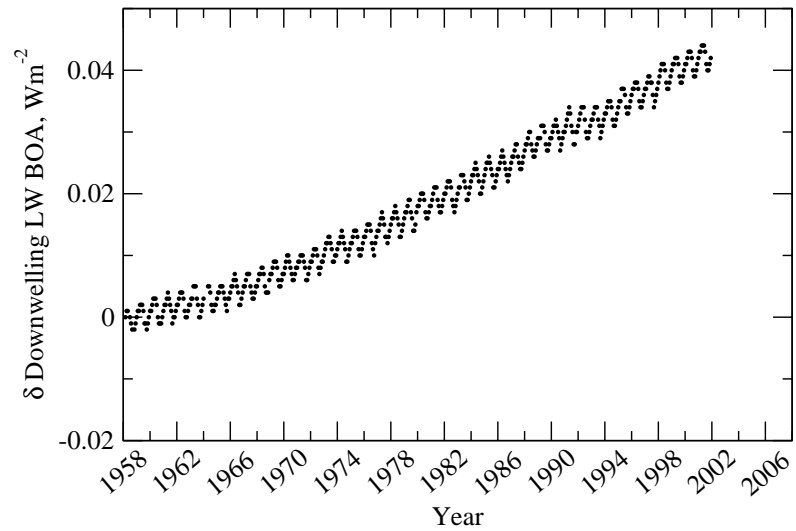
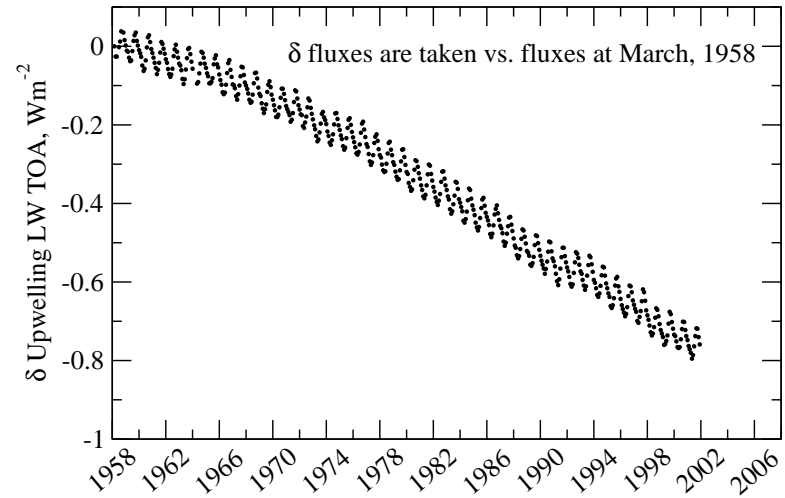
Monthly mean [CO₂]



Courtesy of Norm Wood, Atmospheric Science, CSU, Fort Collins, CO.

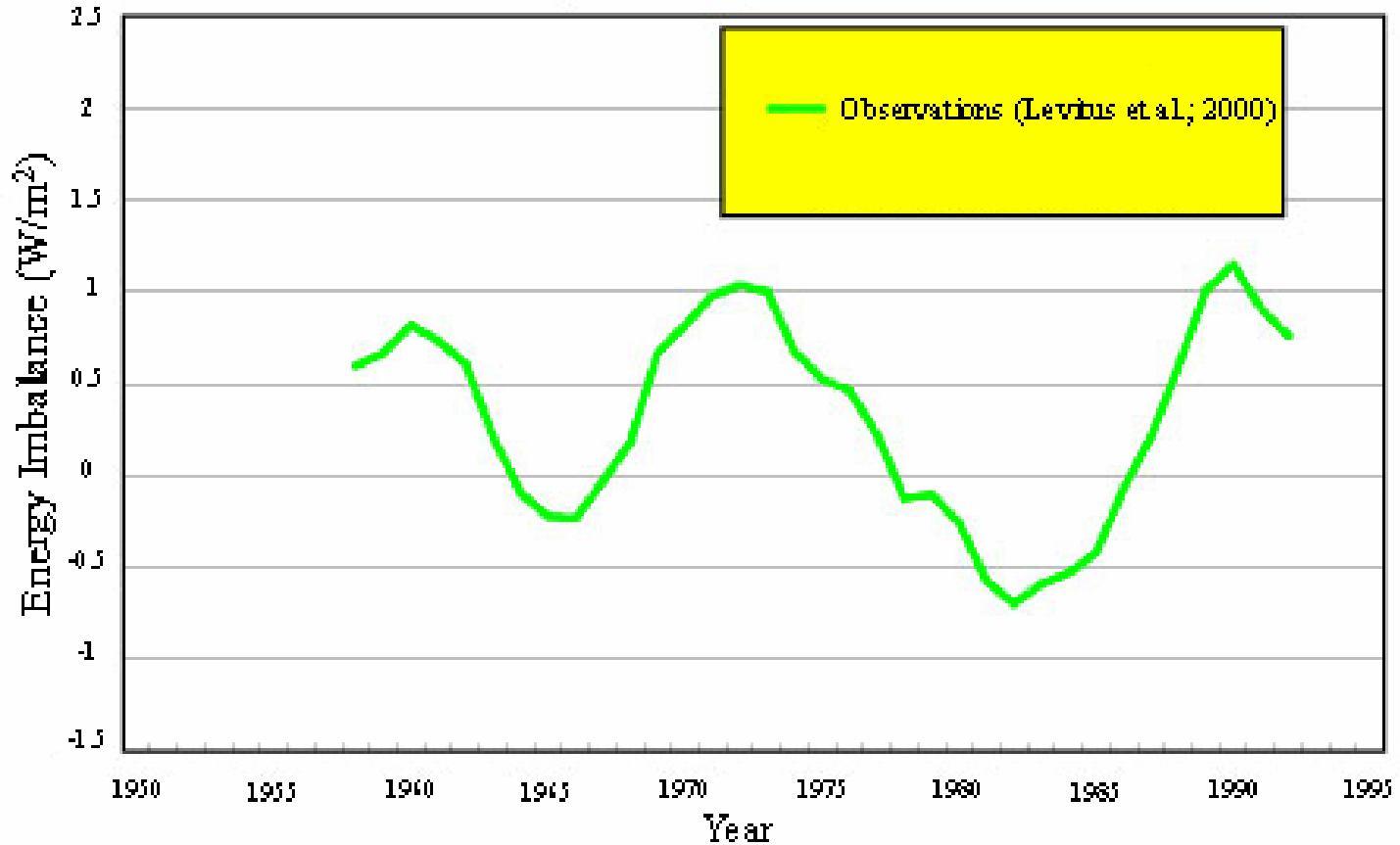
Radiative fluxes for MLO [CO₂] record

McClatchey tropical atmosphere (BOA = sea level), monthly mean [CO₂]



Courtesy of Norm Wood, Atmospheric Science, CSU, Fort Collins, CO.

Annual Planetary Energy Imbalance (Heat Input to Oceans)
[5-year running mean]



Planetary energy imbalance (heat storage in the upper 3 km of the world ocean) observations expressed in units of watts m⁻² (adapted from Levitus et al. 2001). (Figure prepared by Alan Robock, Rutgers University, 2001, personal communication.)

CCCma: GLOBAL TEMPERATURE ANOMALY

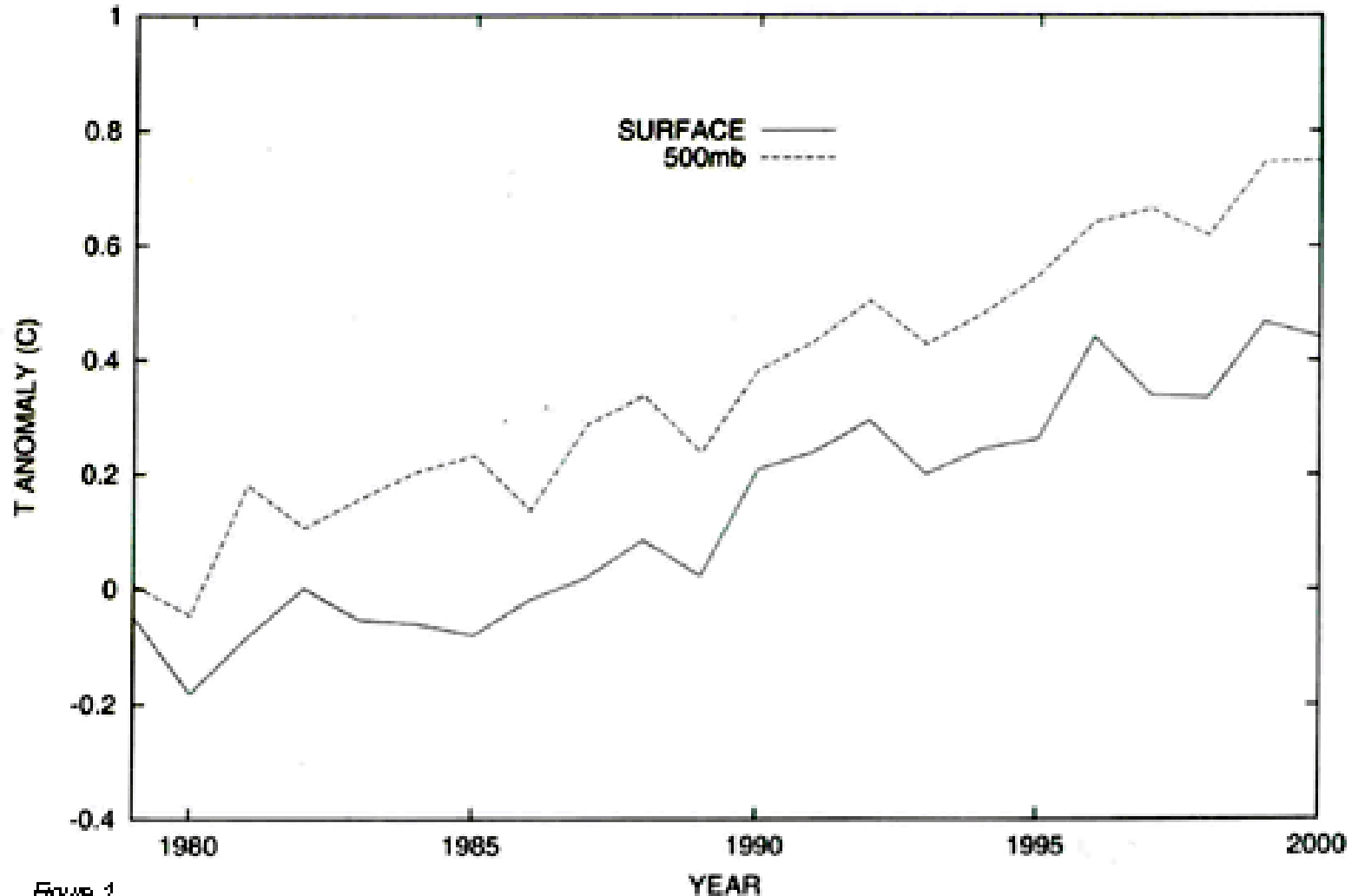
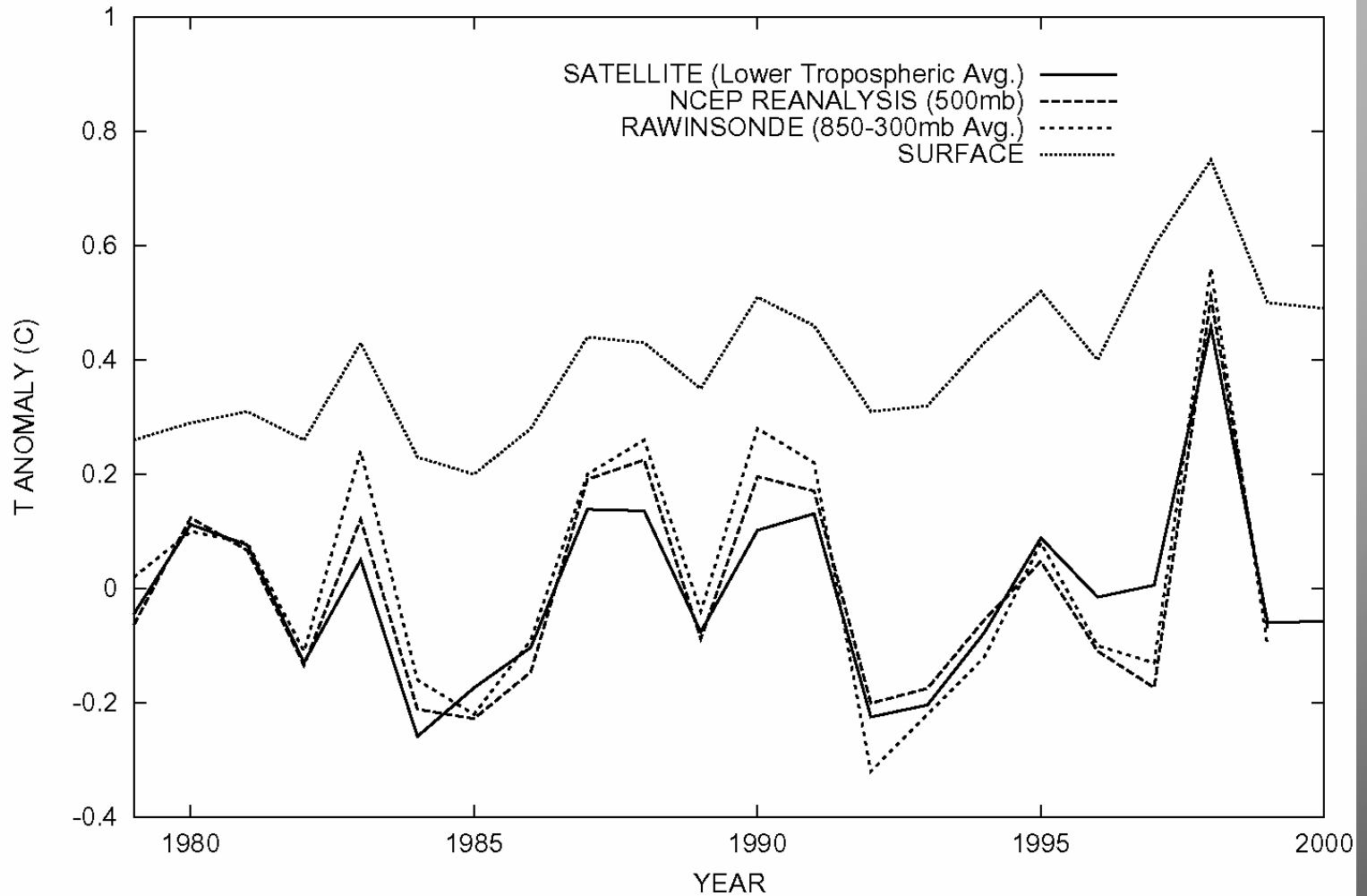


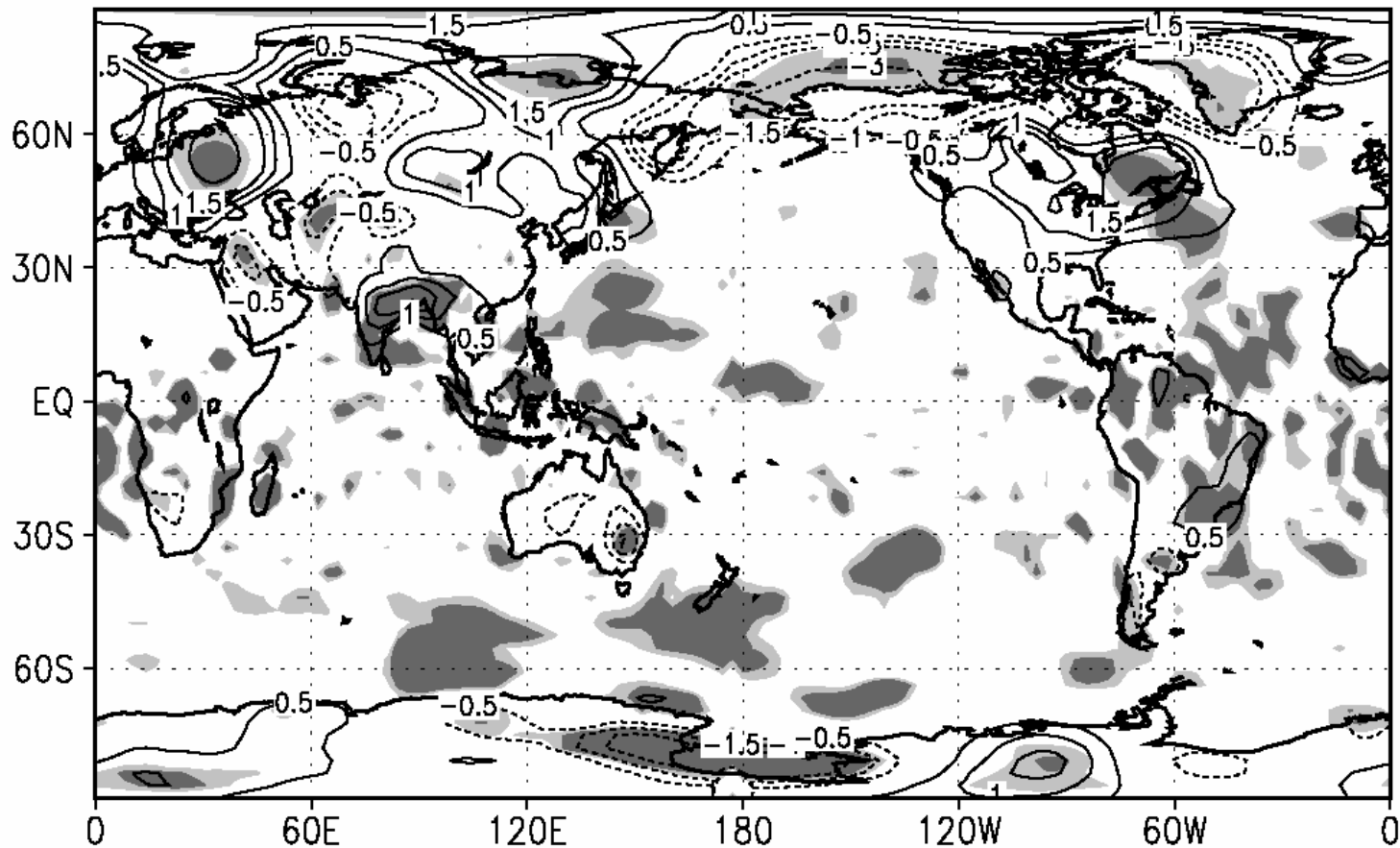
Figure 1

Canadian GCM projection of surface and 500 mb temperature for the period 1979-2000. Plot prepared by Dr. Thomas Chase, CU, Boulder, from data at <http://www.cccma.bc.ec.gc.ca/data/cgcm2/cgcm2.shtml>

OBSERVATIONS: GLOBAL TEMPERATURE ANOMALY



NEAR SURFACE TEMPERATURE DIFFERENCE



Simulated January reference height temperature difference (current-natural) (C); regions of statistically significant differences are shaded (from Chase et al. 2000).

Policy Statement on Climate Variability and Change by the American Association of State Climatologists

1. Past climate is a useful guide to the future - Assessing past climate conditions provides a very effective analysis tool to assess societal and environmental vulnerability to future climate, regardless of the extent the future climate is altered by human activity. Our current and future vulnerability, however, will be different than in the past, even if climate were not to change, because society and the environment change as well. Decision makers need assessments of how climate vulnerability has changed.
2. Climate prediction is complex with many uncertainties. The AASC recognizes climate prediction is an extremely difficult undertaking. For time scales of a decade or more, understanding the empirical accuracy of such predictions - called "verification" - is simply impossible, since we have to wait a decade or longer to assess the accuracy of the forecasts.