

OVERLOOKED ISSUES IN THE U.S. NATIONAL CLIMATE AND IPCC ASSESSMENTS

An Editorial Essay

Abstract. This essay discusses several issues that have been overlooked in the U.S. National and IPCC assessments. These include the effect on the climate system of anthropogenic land-use change, and the biological influence of enhanced concentrations of atmospheric carbon dioxide. Evidence is presented to demonstrate the important role of these human disturbances to the earth's climate. Several hypotheses are proposed to test which are based on our research results. These include whether human-caused landscape change has an effect at all time scales on local, regional, and global climate that is at least as important as currently expected to be caused by the radiative effect of the anthropogenic doubling of the effective greenhouse gas concentrations. In addition, since landscape (and other atmosphere-surface) interactions involve complex, nonlinear feedbacks, accurate prediction of climate variables beyond seasonal time scales may not be possible. As an alternate paradigm, a vulnerability assessment approach is proposed in which the entire spectrum of environmental stresses are evaluated in order to determine the greatest threats to specific resources.

The mandates of the Intergovernmental Panel on Climate Change (IPCC) is to review 'any change in climate over time, whether due to natural variability or as a result of human activity' (www.ipcc.ch). This essay, however, argues that at least two important forcings have been excluded in the IPCC study and U.S National assessment (<http://www.nacc.usgcrp.gov>). These are the effect on global climate of anthropogenic land cover change and the biological effect of anthropogenically increased concentrations of carbon dioxide. The consideration of these two forcings makes the 1995 IPCC conclusion that '...the balance of evidence suggests a discernible human influence on global climate...' even more obvious, although the relative attribution to specific forcings (such as the radiative effect of increased CO₂) is even more difficult. As Rodhe et al. (2000) have noted, to quantify climatic forcings from the temperature record in models, it is necessary that 'all important forcings, their variations, and their uncertainties have been accurately included, except for the one that is to be quantified'.

If these two forcings are indeed important, it raises the possibility that general circulation models (GCMs) that are integrated without these forcings and are consistent with the observational record are realistic for the wrong physical reasons.

There is considerable recent research work that demonstrates the importance of the two forcings. Recent reviews, with numerous peer reviewed citations, include Cotton and Pielke (1995), Claussen (2001), Pitman et al. (1999), Pielke et al. (1998), Pielke (2001), Avissar (1995) and Eugster et al. (2000). These review papers summarize a wide range of research that documents the role of short



(biophysical), medium (biogeochemical), and long-term (biogeographic) effects of landscape processes on weather and climate. Biophysical effects include, for example, the influence of transpiration on the ratio of sensible and latent turbulent fluxes in the surface heat budget. Biogeochemical effects include the growth of plants, which alter the amount of transpiring leaf surface and the surface albedo, as well as the storage of carbon. Biogeographic influences involve the alteration of vegetation species composition over time.

Figure 1 provides an example of the important role of land surface on deep cumulus convection for an individual day. Figure 1a is the model result for a specific date of cumulonimbus development over the central Great Plains of the United States using the 'current' landscape as of 1989. Figure 1b uses landscape that represents a 'natural' state. Pielke et al. (1997) discuss this experiment, and Shaw et al. (1997), Grasso (1996), and Ziegler et al. (1997) provide real world observational validation of the results for the current landscape. This body of work clearly shows that in the model, the alteration of the landscape (with a reduction in transpiration in the natural landscape) resulted in a reduction in cumulonimbus cloud activity.

Pielke et al. (1999a) reported that the observed reduction in July–August rainfall of about 10% in south Florida this century is of the same order as simulated by a model when the observed land-use change over this time period is used to represent the earth's surface. Chase et al. (1996, 2000) showed, using the CCM2 and CCM3 GCMs at NCAR, that land-use change, particularly in the tropical rainforests, can teleconnect to the middle and higher latitudes, resulting in major alterations to global climate. Figure 2, reproduced from Chase et al. (2000), illustrates the simulated 10-year averaged January near-surface temperature changes which resulted from a conversion of the natural landscape to the current landscape. In this experiment, only about 8% of the earth's land surface was actually changed, such that this is a conservative experiment. Actual landscape change has been estimated to be as high as 45% by Vitousek et al. (1997). Figure 3 from Klein (2001), illustrates the large change of landscape by human activity, much of which has occurred since 1900.

Climate as an integration of atmospheric, ocean, cryosphere, and land-surface processes is inherently unpredictable beyond some period if the linkages between parts of the earth system are sufficiently nonlinear (Pielke, 1998). There is no demonstrable skill beyond seasonal time scales, for example, and even in that time period only statistical models have shown skill (Landsea and Knaff, 2000). Eastman et al. (2001) and Lu et al. (2001) provide examples of such nonlinearities. Lu (1999), for example, demonstrates using a coupled atmosphere-land surface modeling system (RAMS-CENTURY), the role of seasonal vegetation growth on the evolution of seasonal weather in the central Great Plains of the United States. Soil moisture plays a critical role at the beginning of the growing season on the evolution of the seasonal weather in this region (Pielke et al., 1999b).

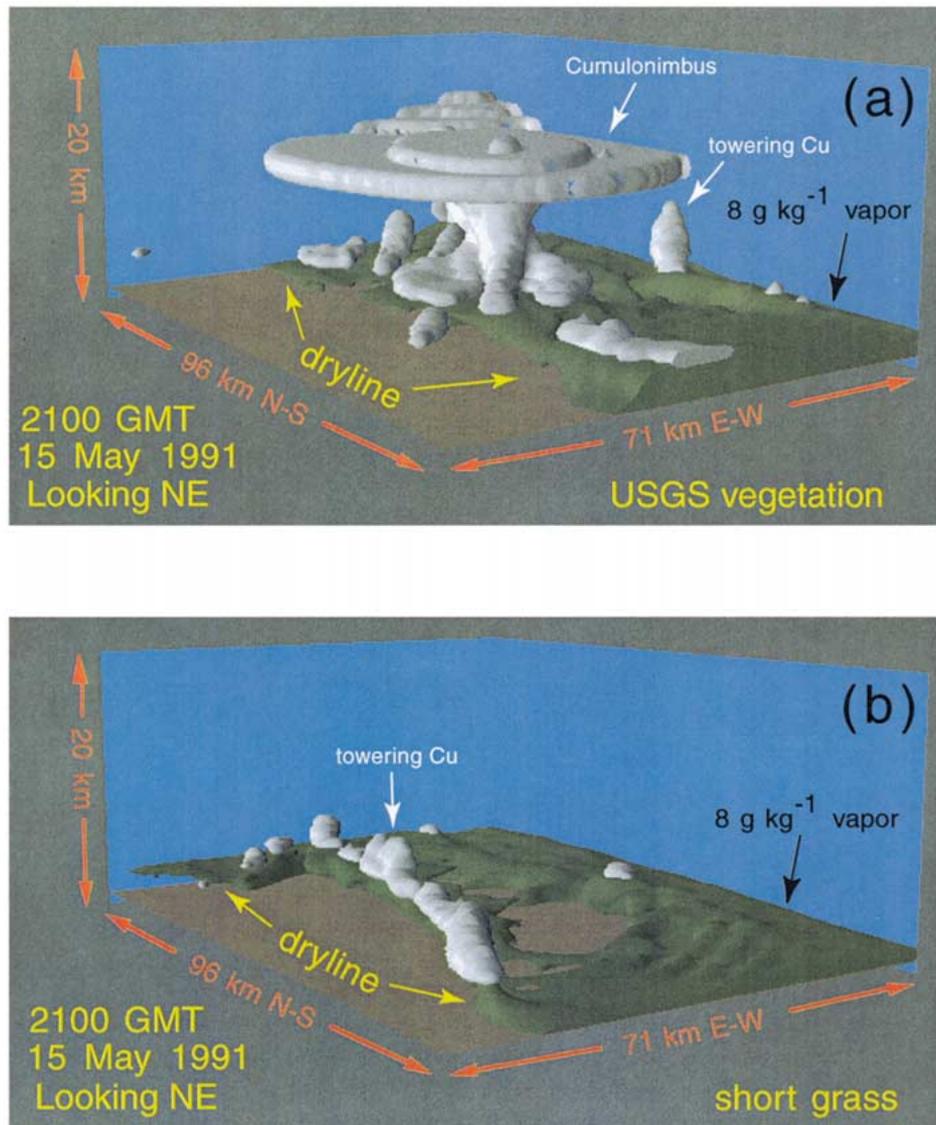


Figure 1. Model output cloud and water vapor mixing ratio fields on the third nested grid (grid 4) at 21 GMT on 15 May 1991. The clouds are depicted by white surfaces with $q_c = 0.01 \text{ g/kg}$, with the sun illuminating the clouds from the west. The vapor mixing ratio in the planetary boundary layer is depicted by the light green surface with $q_v = 8 \text{ g/kg}$. Areas formed by the intersection of clouds or the vapor field with lateral boundaries are flat surfaces, and visible ground implies $q_v < 8 \text{ g/kg}$. The vertical axis is height, and the backplanes are the north and east sides of the grid domain (from Pielke et al., 1997).

NEAR SURFACE TEMPERATURE DIFFERENCE

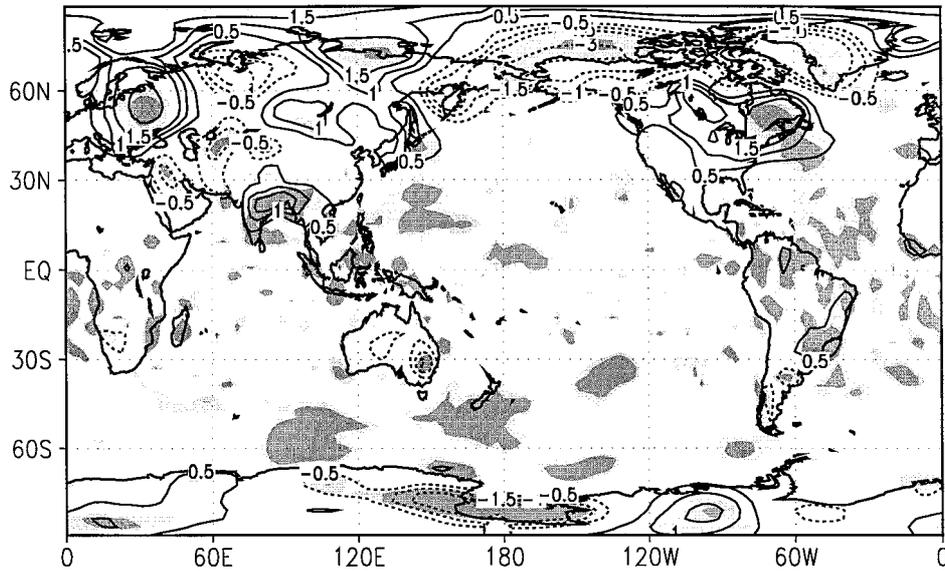


Figure 2. Simulated January reference height temperature difference (current-natural) (C); regions of statistically significant differences are shaded. (from Chase et al., 2000).

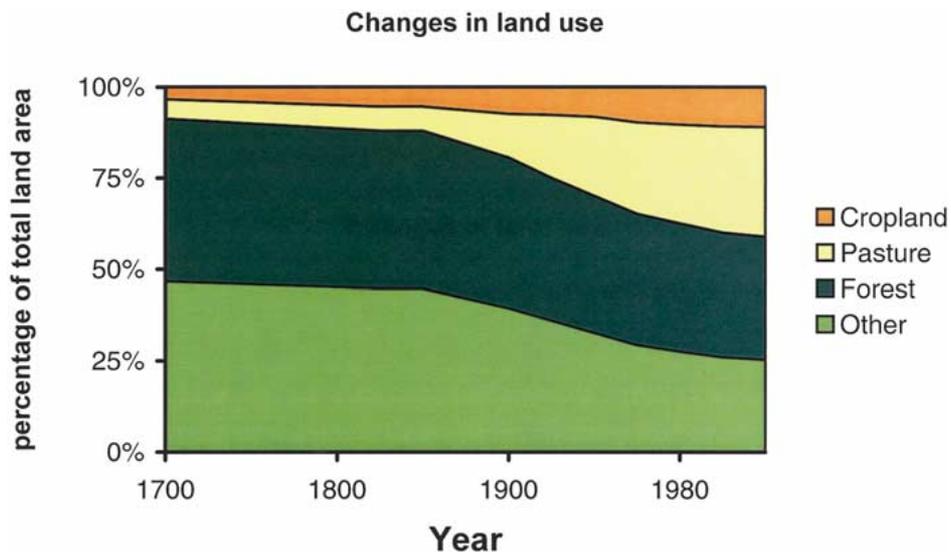


Figure 3. Estimate changes in land cover and population from 1700 to 1995; the 'other' class includes all non-forested and non-agricultural vegetation types, such as grasslands, tundra, and deserts. (from Klein, 2001).

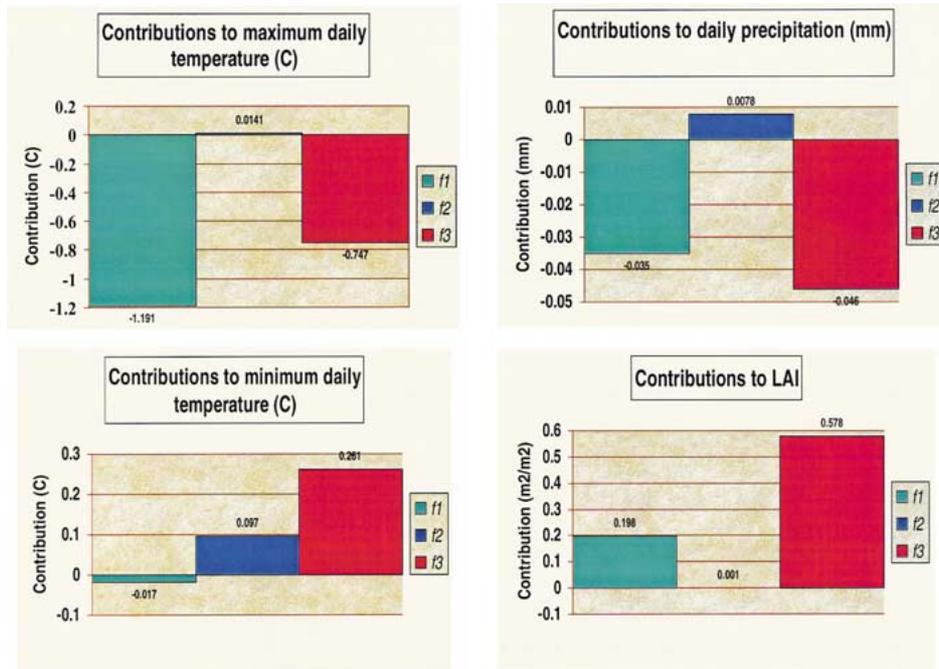


Figure 4. RAMS/GEMTM coupled model results – the seasonal domain-averaged (central Great Plains) for 210 days during the growing season, contributions to maximum daily temperature, minimum daily temperature, precipitation, and leaf area index (LAI) due to: f1 = natural vegetation, f2 = $2 \times \text{CO}_2$ radiation, and f3 = $2 \times \text{CO}_2$ biology (adapted from Eastman et al., 2001).

Figure 4, adapted from Eastman et al. (2001), shows the results using a coupled atmospheric-land surface modeling system (RAMS-GEMTM) over the central Great Plains where the relative importance of land use change, doubled CO_2 in the radiation calculation, and doubled CO_2 in the biophysical/biogeochemical calculation are examined in a 210-day model run during the growing season. This is a sensitivity experiment to explore whether the effects of improved water use efficiency per stoma on the plant (a biophysical effect) and vegetation growth changes (a biogeochemical effect) associated with increased CO_2 are likely to have regional climate consequences.

The model results indicate that the biophysical/biogeochemical effect of a doubling of CO_2 would have an immediate, and much more important effect on seasonal weather, whereas the radiative effect of increased CO_2 is governed by the thermal response time scale of the atmosphere-ocean components of the climate system which have a 15–25 year or longer response time, depending on the rate of radiative forcing change (Harvey, 2000). While the biological effect of enhanced CO_2 , still needs to be investigated for other regions and time scales, its importance on seasonal time scales suggests that it will also be important on even longer time scales. A climate change model which does not investigate the biogeochemical

effect of increased CO₂ on longer-term climate change is therefore incomplete. In Figure 4, a conversion of the current landscape to the natural landscape in this region, and the effect of a doubling of CO₂ in the biophysical/biogeochemical calculation are both shown to produce cooling.

This result indicates that climate change as realized at the regional scale involves more than just the radiative effect of a global change in CO₂, and other greenhouse gas and aerosol concentrations. If enough land areas are similarly affected, a global feedback response should be expected, as shown in the Chase et al. (1996, 2000) land-use change experiment.

There are three main hypotheses from this work that need to be rigorously tested.

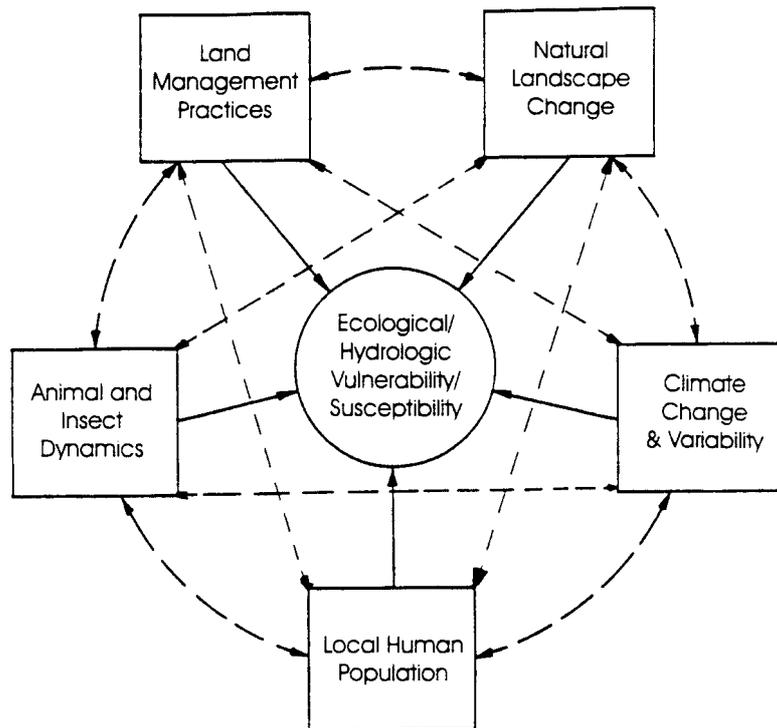
1. Landscape directly and indirectly influences the earth's energy budget through biophysical, biogeochemical, and biogeographic effects.
2. Human-caused land-use change has an effect at all time scales on local, regional, and global climate that is at least as important as currently expected to be caused by the radiative effect of the anthropogenic doubling of the effective greenhouse gas concentrations.
3. Since landscape (and other atmosphere-surface) interactions involve complex nonlinear feedbacks, accurate prediction of the variability of climate variables, such as temperature, precipitation, soil moisture, and vegetation growth, beyond seasonal time scales may be unachievable.

A broader assessment of environmental stresses is therefore appropriate as a guide to policymakers rather than just providing a subset of possible future climate conditions (Pielke Jr., 2001). If climate prediction is not possible beyond some time scale, a focus on vulnerability is the preferred scientific approach to provide policymakers useful information (Pielke Jr., 1998). Figure 5, as reproduced from Pielke et al. (1999c), illustrates an example of this approach. With this approach, the spectrum of environmental stresses is assessed in order to determine which are associated with the greatest threat (in this example to water resources). The needs of the policymaker are better met with this perspective, in that the focus is on decisions and not predictions (Sarewitz et al., 2000). This vulnerability perspective is further illustrated in Pielke and Guenni (1999), Petschel-Held et al. (1999), and Schellnhuber et al. (1997).

Figure 6 presents a topology of climate model results as:

- Sensitivity studies.
- Scenarios.
- Projections.
- Perfect foresight.

In a sensitivity analysis, only a limited subset of the important forcings on climate is perturbed (e.g., the radiative effect of a doubling of CO₂ and other anthropogenic greenhouse gases; anthropogenic aerosols, etc.). This is the approach used



Predictability requires:

- the adequate quantitative understanding of these interactions
- that the feedbacks are not substantially nonlinear.

Figure 5. Use of ecological, hydrologic vulnerability/susceptibility in environmental assessment (from Pielke et al., 1999c).

to produce the IPCC reports. This method could, in principle, generate accurate predictions *if* other climate forcings, such as landuse change and the biological effect of doubled CO₂ were unimportant, and the nonlinear interactions are relatively small and/or occur on longer time periods than the prediction time period. However, these two effects are important on the regional, and apparently, the global scale as discussed earlier in this essay. Moreover, the nonlinear interactions occur on all time scales.

A scenario approach would apply if all of the important direct and feedback effects on climate were included. A scenario is then a realization out of an ensemble of possible simulations. If the realizations cover the ensemble space, then the ensemble of model results could be considered realistic projections of the 'universe' of potential future climates. One useful product of scientific assessments, such as the IPCC, would be to provide guidance on the estimated relative size of the scenario space, in the context of the potential ensemble space.

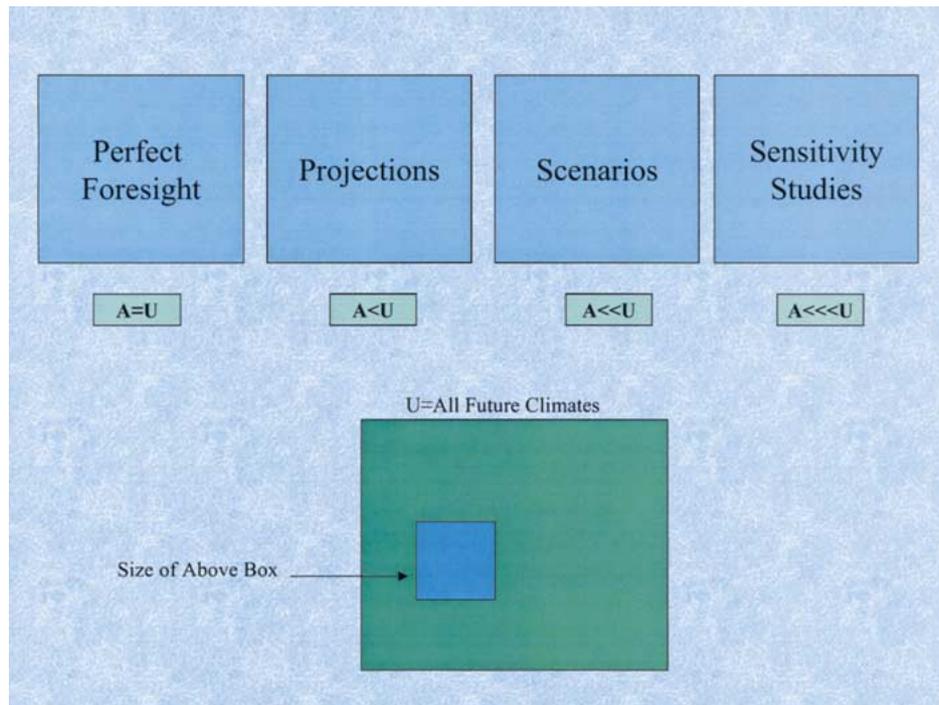


Figure 6. Schematic of different classes of prediction. The size of the box labeled 'U' represents the range of future climate, while the box labeled 'A' indicates the relative subset of possible future climate that are estimated using the different classes of prediction, (adapted from Pielke Sr., 2001).

Projections, of course, are still not perfect foresight. Thus a vulnerability approach would still be warranted to alert policymakers to the consequences of climate surprises. In discussions of climate change by policymakers and researchers alike, sensitivity studies and scenarios are often framed as predictions of the state of the future climate (e.g., Climate Impacts LINK 1997, their Figure 5; Atmosphere, 1999). These sensitivity studies and scenarios are often referred to as 'projections' by this community with the claim they are 'plausible scenarios' and not 'predictions'. However, one of the definitions of 'projection' in Webster's New World Dictionary (1988) is that a 'projection' is 'a prediction or advance estimate based on known data or observations: extrapolation'.

In contrast to weather prediction, where we feel that we understand, reasonably well, all of the important physical effects and feedbacks, the climate system is a much more complex dynamical system (Pielke, 1998). Climate is more than just long-term weather statistics, but involves the interactive influences of the land, atmosphere, oceans and lakes, and continental glaciers over all time scales. The concern of the IPCC and U.S. regional and national assessments should be with respect to all of these interactions over the next 50–100 years, not just the limited set that has been evaluated so far.

Unless it can be shown that land cover change and biogeochemical effects on the regional and global climate systems are insignificant relative to the radiative effect of a doubling of CO₂, the IPCC and U.S. National Assessment reports are, therefore, summaries of sensitivity analyses only. They are not vulnerability assessments since they do not explore the spectrum of environmental threats to a region or globally (e.g., such as the effect of regional landuse change in the future on the regional water resources, even if the large-scale weather patterns did not change).

It is clear, of course, that human activities have had and will continue to have a discernible influence on the climate system. But there remains considerable barriers in the way of accurately predicting the future and in shaping that future in desired ways based on predictive modeling. This conclusion suggests a need to include within the process of climate assessment, information that can assist decision makers to deal with societal vulnerabilities to climate, as well as threats from the remainder of the spectrum of environmental stresses (Sarewitz and Pielke, 2000). This is in addition to seeking to reduce uncertainty about the future. This perspective of investigating the Earth system in its entirety, including 'its full functional and geographical complexity over time...' is presented in Moore (2000) as part of the new International Geosphere-Biosphere Programme (IGBP) structure. Gupta et al. (2000) present a new National Science Foundation initiative (WEB – Water, Energy, Biota) as a vehicle to study the Earth system as an integrated system.

Acknowledgements

Support for this research was provided by NASA Grant No. NAG8-1511, NOAA Contract No. NA-67RJ0152 Amendment 29, NSF Grant No. DEB-9632852, EPA Grant No. R824993-01-0, USGS Grant No. 99CRAG005 SA 9005CS0014 and Tulane University Grant No. TUL-062-98/99. Dallas Staley and Allison Edwards prepared and edited the text. An earlier version of this text appeared in the *Proceedings of the 11th Symposium on Global Change Studies*, 9–14 January 2000, 80th AMS Annual Meeting in Long Beach, California. The constructive comments by Drs. Michael C. MacCracken and L. Danny Harvey are very much appreciated in the preparation of the final version of this essay.

References

- Atmosphere: 1999: *Newsletter of CSIRO*, Issue 7, for more information contact Kevin Walsh, kevin.walsh@dar.csiro.au.
- Avissar, R.: 1995, 'Recent Advances in the Representation of Land-Atmosphere Interactions in General Circulation Models', *Rev. Geophys. Supplement*, 1005–1010, U.S. National Report to International Union of Geodesy and Geophysics 1991–1994.
- Chase, T. N., Pielke Sr., R. A., Kittel, T. G. F., Nemani, R., and Running, S. W.: 1996, 'The Sensitivity of a General Circulation Model to Global Changes in Leaf Area Index', *J. Geophys. Res.* **101**, 7393–7408.

- Chase, T. N., Pielke, R. A., Kittel, T. G. F., Nemani, R. R., and Running, S. W.: 2000, 'Simulated Impacts of Historical Land Cover Changes on Global Climate in Northern Winter', *Clim. Dyn.* **16**, 93–105.
- Claussen, M., (ed.): 2001, 'Does Landsurface Matter in Climate and Weather? Part A', in Kabat, P. (chief ed.), *Vegetation, Water, Humans, and the Climate – a New Perspective on an Integrative System*, A Synthesis of the IGBP Core Project, Biospheric Aspects of the Hydrologic Cycle, in preparation.
- Climate Impacts LINK: 1997, *Newsletter of the U.K. Department of the Environment, Transport and the Region's Climate Impacts LINK Project*, Climatic Research Unit, University of East Anglia, U.K., Issue No. 15, December.
- Cotton, W. R. and Pielke, R. A.: 1995, *Human Impacts on Weather and Climate*, Cambridge University Press, New York, p. 288.
- Eastman, J. L., Coughenour, M. B., and Pielke Sr., R. A.: 2001, 'The Effects of CO₂ and Landscape Change Using a Coupled Plant and Meteorological Model', *Global Change Biol.*, in press.
- Eugster, W., Rouse, W. R., Pielke, R. A., McFadden, J. P., Baldocchi, D. D., Kittel, T. G. F., Chapin III, F. S., Liston, G. E., Vidale, P. L., Vaganov, E., and Chambers, S.: 2000, 'Land-Atmosphere Energy Exchange in Arctic Tundra and Boreal Forest: Available Data and Feedbacks to Climate', *Global Change Biol.* **6**, 84–115.
- Grasso, L.: 1996, *Numerical Simulation of the May 15 and April 26, 1991 Tornadoic Thunderstorms*, Ph.D. Dissertation, Atmospheric Science Paper 596, Colorado State University, Dept. of Atmospheric Science, Fort Collins, CO 80523, p. 151.
- Gupta, V., Duffy, C., Grossman, R., Krajewski, W., Lall, U., McCaffrey, M., Milne, D., Pielke Sr., R., Reckhow, K., and Swanson, F.: 2000, 'New Interdisciplinary Initiative Combines Water, Earth, and Biota', *EOS* **81**, 484.
- Harvey, L. D. D.: 2000, *Global Warming: The Hard Science*, Prentice Hall, p. 336.
- Klein, G. K.: 2001, 'Estimating Global Land Use Change over the Past 300 Years: The Hyde 2.0 Database', *Global Biogeochem. Cycles*, in press.
- Landsea, C. W. and Knaff, J. A.: 2000, 'How Much Skill Was There in Forecasting the Very Strong 1997-98 El Niño?' *Bull. Amer. Meteorol. Soc.* **81**, 2107–2119.
- Lu, L.: 1999, *Implementation of a Two-Way Interactive Atmospheric and Ecological Model and its Application to the Central United States*, Ph.D. Dissertation, Atmospheric Science Paper No. 687, Colorado State University, Dept. of Atmospheric Science, Fort Collins, CO 80523, R. A. Pielke, P. I., p. 134.
- Lu, L., Pielke, R. A., Liston, G. E., Parton, W. J., Ojima, D., and Hartman, M.: 2001, 'Implementation of a Two-Way Interactive Atmospheric and Ecological Model and its Application to the Central United States', *J. Climate* **14**, 900–919.
- Moore III, B.: 2000, 'Sustaining Earth's Life Support Systems – the Challenge for the Next Decade and Beyond', *IGBP Newsletter* **41**, 1–2.
- Petschel-Held, G., Block, A., Cassel-Gintz, M., Kropp, J., Ludeke, M. K. B., Moldenhauer, O., Reusswig, F., and Schellnhuber, H. J.: 1999, 'Syndromes of Global Change: A Qualitative Modelling Approach to Assist Global Environmental Management', *Environ. Model. Assess.* **4**, 295–314.
- Pielke Jr., R. A.: 1998, 'Rethinking the Role of Adaptation in Climate Policy', *Global Environ. Change* **8**, 159–170.
- Pielke Jr., R. A.: 2001, 'Room for Doubt', *Nature* **410**, 151.
- Pielke Sr., R. A.: 1998, 'Climate Prediction as an Initial Value Problem', *Bull. Amer. Meteorol. Soc.* **79**, 2743–2746.
- Pielke Sr., R. A.: 2001, 'Influence of the Spatial Distribution of Vegetation and Soils on the Prediction of Cumulus Convective Rainfall', *Rev. Geophys.* **39**, 151–177.

- Pielke Sr., R. A., Avissar, R., Raupach, M., Dolman, H., Zeng, X., and Denning, S.: 1998, 'Interactions between the Atmosphere and Terrestrial Ecosystems: Influence on Weather and Climate', *Global Change Biol.* **4**, 461–475.
- Pielke Sr., R. A. and Guenni, L. I.: 1999, 'Vulnerability Assessment of Water Resources to Changing Environmental Conditions', *IGBP Global Change Newsletter* **39**, 21–23.
- Pielke Sr., R. A., Lee, T. J., Copeland, J. H., Eastman, J. L., Ziegler, C. L., and Finley, C. A.: 1997, 'Use of USGS-Provided Data to Improve Weather and Climate Simulations', *Ecol. Appl.* **7**, 3–21.
- Pielke Sr., R. A., Liston, G. E., Eastman, J. L., Lu, L., and Coughenour, M.: 1999b, 'Seasonal Weather Prediction as an Initial Value Problem', *J. Geophys. Res.* **104**, 19463–19479.
- Pielke Sr., R. A., Liston, G. E., Lu, L., and Avissar, R.: 1999c, 'Land-Surface Influences on Atmospheric Dynamics and Precipitation', Chapter 6 in Tenhunen, J. D. and Kabat, P. (eds.), *Integrating Hydrology, Ecosystem Dynamics, and Biogeochemistry in Complex Landscapes*, John Wiley and Sons Ltd., pp. 105–116.
- Pielke Sr., R. A., Walko, R. L., Steyaert, L., Vidale, P. L., Liston, G. E., and Lyons, W. A.: 1999a, 'The Influence of Anthropogenic Landscape Changes on Weather in South Florida', *Mon. Wea. Rev.* **127**, 1663–1673.
- Pitman, A., Pielke Sr., R., Avissar, R., Claussen, M., Gash, J., and Dolman, H.: 1999, 'The Role of the Land Surface in Weather and Climate: Does the Land Surface Matter', *IGBP Global Change Newsletter* **39**, 4–11.
- Rodhe, H., Charlson, R. J., and Anderson, T. L.: 2000, 'Avoiding Circular Logic in Climate Modeling. An Editorial Essay', *Clim. Change* **44**, 409–411.
- Sarewitz, D. and Pielke Jr., R. A.: 2000, 'Breaking the Global-Warming Gridlock', *Atlantic Monthly* **286**, 55–64.
- Sarewitz, D., Pielke Jr., R. A., and Byerly, R. (eds.): 2000, *Prediction: Decision Making and the Further of Nature*, Island Press, Washington, D.C., p. 400.
- Schellnhuber, H.-J., Block, A., Cassel-Gintz, M., Kropp, J., Lammel, G., Lass, W., Lienenkamp, R., Loose, C., Ludeke, M. K. B., Moldenhauer, O., Petschel-Held, G., Plochl, M., and Reusswig, F.: 1997, 'Syndromes of Global Change', *GAIA* **6**, 19–34.
- Shaw, B. L., Pielke Sr., R. A., and Ziegler, C. L.: 1997, 'A Three-Dimensional Numerical Simulation of a Great Plains Dryline', *Mon. Wea. Rev.* **125**, 1489–1506.
- Vitousek, P. M., Mooney, H. A., Lubchenco, J., and Melillo, J. M.: 1997, 'Human Domination of Earth's Ecosystems', *Science* **277**, 494–499.
- Ziegler, C. L., Lee, T. J., and Pielke Sr., R. A.: 1997, 'Convective Initiation at the Dryline: A Modeling Study', *Mon. Wea. Rev.* **125**, 1001–1026.

Department of Atmospheric Science,
 Colorado State University,
 Ft. Collins,
 Colorado 80523,
 U.S.A.
 E-mail: pielke@snow.atmos.colostate.edu

R. A. PIELKE SR.