Introductory Overview

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The El Niño–Southern Oscillation (ENSO) is a coupled ocean–atmosphere phenomena that has a worldwide impact on climate. An aperiodic phenomena that reoccurs every 2 to 7 years, the ENSO is second only to seasonal variability in driving worldwide weather patterns. As Greenland notes in chapter 6, the term "quasi-quintennial" is chosen to recognize that climatic events other than ENSO-related events might occur at this timescale, although it is widely recognized that ENSO contributes the lion's share of the higher frequency variability in paleorecords of the past several thousand years. In this section, we consider variability with cycles of 2 to 7 years and the resulting ecological response. Although we emphasize the ENSO timescale in this section, there is growing evidence that this phenomena is neither spatially nor temporally stable over longer time periods. Indeed, Allan (2000) suggests the ENSO climatic variability must be viewed within the context of climate fluctuations at decadal to interdecadal timescales, which often modulate the higher frequency ENSO variability. As a consequence, results in this and the next section often display overlapping patterns of variability, and their separation is not sharply defined.

An important theme in this section is the worldwide influence of ENSO-related climate variability. Greenland (chapter 6) provides an LTER network overview with an analysis of ENSO-related variability of temperature and precipitation records for many LTER sites from the Arctic to the Antarctic. He discusses the general nature of ENSO and its climatic effects, summarizes previous climate-related work in the LTER network, and provides a cross-site analysis of the correlations between the Southern Oscillation Index (SOI) and temperature and precipitation at LTER sites. His results are consistent with the expected patterns of the geography of ENSO effects on the climate. Greenland's cross-site analysis provides the basis for studying climate variability and ecosystem response within the context of the series of framework questions that form an underlying theme for this volume.

Brazel and Ellis (chapter 7) provide an excellent analysis of climate-related parameters within the context of ENSO indices. Reporting on the Central Arizona and Phoenix (CAP) LTER urban-rural ecosystem, these authors provide a comprehensive analysis linking water-related parameters to climate forcing, as indicated by these indexes. Their studies show a strong connection between ENSO and winter moisture in Arizona, perhaps making it possible to forecast impending conditions. This arid to semiarid ecosystem is strongly dependent on water resources, and Brazel and Ellis provide several excellent examples of ecological response to ENSO-related climate variability. Their examples show that both the natural and human components of the CAP ecosystem are substantially affected at the ENSO timescale. They also discuss how climate responses potentially result in complex cascades within this ecosystem. For example, drought periods lead to dust storms, wildfires, vegetation change, water quantity and quality changes, and the subsequent consequences of these changes.

A study of a Puerto Rican tropical rainforest (Luquillo Experimental Forest LTER, LUQ) provides dramatic contrast to the arid southwestern United States. Schaefer (chapter 8) studies the effects of ENSO and the North Atlantic Oscillation (NAO) on extreme rainfall events and finds the effects of those oscillations to be minor. Schaefer focuses on extreme rainfall events because of the highly nonlinear response of the system to precipitation whereby 75% of the sediment export occurs during only 1% of days with the greatest rainfall. These major sediment exports have important, and generally nonreversible, ecological effects on both the watersheds and downstream ecosystems. This study provides an excellent example of the high sensitivity of an ecosystem to the extreme nonlinearity of the process such that more regular variability may be overwhelmed.

The western Antarctic Peninsula (site of the Palmer LTER, PAL) is now a recognized "hot spot" with respect to a global warming trend (IPCC 2001). Smith and coworkers (chapter 9 and Synthesis) show that there is a significant correlation between air temperature of the western Antarctic Peninsula (WAP) and the SOI. Further, there is a strong anticorrelation between sea ice extent in the area and the SOI. These observations are further evidence for ENSO-related teleconnections to high latitudes. This Antarctic marine ecosystem is dominated by sea ice, and these researchers show that sea ice extent in the WAP has trended down and the sea ice season has shortened. Although ecological responses to this climate variability are evident at all trophic levels, Smith and coworkers show that changes are most clearly seen in a shift in the population size and distribution of penguin species with different affinities to sea ice. Analogous to, but in distinct contrast to, the extreme nonlinearity of sediment processes for a tropical rainforest, this study also emphasizes the importance of nonlinear processes. At the PAL site, the fine balance of temperature with respect to the phase transition between ice and water is such that warming trends may remove large areas of this ice-related habitat with significant consequences for this marine environment.

Welch and coworkers (chapter 10) report on studies of the driest and coldest deserts on the planet (McMurdo Dry Valleys, MCM). These workers show that the key climatic parameters influencing ecosystem structure and function are the ones that affect the state of water. The ecosystem is very sensitive to relatively small climatic variations because the change between ice and liquid water is delicately balanced. Thus, small changes in temperature and/or radiant energy are amplified by large, nonlinear changes in the hydrologic budgets that can cascade through the system. Indeed, this cold dry ecosystem provides outstanding examples of how small climatic shifts cascade with impacts on stream, lake, and soil ecosystems. Further, these small variations can have a significant multiyear impact. The record from Taylor Valley is too short to discern statistically significant long-term trends or ENSO-related variability, although a few paleorecords show dominant periodicities coincident with the SOI.

The five chapters in this section examine dramatically different ecosystems that often represent extremes with respect to temperature and/or precipitation. Interestingly, a common theme for such ecosystems is a high sensitivity whereby relatively small changes are amplified and cascade through the system.

References

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CLIMATE VARIABILITY AND ECOSYSTEM RESPONSE AT LONG-TERM ECOLOGICAL RESEARCH SITES

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LTER

OXFORD
UNIVERSITY PRESS
2003