CPER

Regional Ecological Response to Continental and Global-Scale Intraseasonal and Interannual Climate Variability

A Proposal for the LTER Coordinating Committee Proposal
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Abstract

The objective of the proposed study is to evaluate the effect of continental and global-scale climatic variability on intraseasonal and interannual ecological variability across the United States. The study will emphasize ecological variation at the regional level, focusing on ecoregions with LTER sites. Satellite-derived vegetation index data (a surrogate measure of ecosystem function) and coarse-resolution climatic (upper air and surface) data will be used to examine the regional-scale temporal variability of ecosystems and climate, respectively. The study will use regression and canonical correlation analyses to assess the proportion and nature of temporal and spatial variation in vegetation index that is explained by climate on regional and continental scales. A comparative analysis of vegetation index for El Niño-Southern Oscillation (ENSO) years versus non-ENSO years will assess the impact of one source of global-scale climate variability on ecosystems in the United States. Results from this study will provide a broad perspective that will serve as a framework for future studies seeking to understand the external causes of intraseasonal and interannual variability at LTER sites.

I. Introduction

On a local scale, variability in climate is recognized as causing considerable within-season and between-year variation in the functioning and condition of ecosystems, affecting, for example, primary production and nutrient dynamics. For long-term ecological research studies, such ecosystem variability can be documented and evaluated in terms of local climatic variation. However, climate variability has a strong extra-local element that extends from the regional to continental to global scales (Yarnal 1985).

This has two implications for LTER-type research. First, ecological response to climate variability is likely to be regional in scope. This is in agreement with Major's (1951) concept of regional climate as a principal factor affecting vegetation. Second, a certain portion of between-year and within-season variation in external factors driving ecosystems is attributable to processes far removed from a given site. For these reasons, an assessment of the contribution of continental and global climate variability to regional-scale ecosystem variability is crucial to understanding the external forces that affect ecosystems.

II. Research Plan

This study will investigate relationships between regional ecosystem variability and regional, continental, and global-scale climate variability. This section describes the measures of ecosystem and climatic variability to be used and the analytical methods to be employed.

Regional-Scale Measures of Ecosystem Function. Until recently, regional-scale ecological data has been difficult to obtain. With the development of satellite-based remote sensing systems, we now have available global coverage of reflected radiation in spectral bands useful in ecology (Greegor 1986, Waring et al. 1986). As a good example, normalized-difference vegetation index (NDVI) is sensitive to the presence of green vegetation because it is based on a strong difference in chlorophyll reflectance between the visible and near-infrared. NDVI is derived from Advanced Very High Resolution Radiometer (AVHRR) channels on the NOAA polar-orbiting satellites.

NDVI has been related to several ecological parameters, including production, photosynthetically-active biomass, and intercepted photosynthetically-active radiation (Sellers 1986). In addition, the integral of NDVI over the growing season has been related to annual production (Goward et al. 1985). While a single, precise ecological interpretation of NDVI is not clear, this index does show the strong spatial and temporal variation of vegetation phenology over North America (Goward et al. 1985) and elsewhere. Consequently, the proposed study will use NDVI as a relative measure of ecosystem function in order to study ecological variability at the regional scale.

A global weekly-composite NDVI data set is available through NOAA for the period April 1982 to the present. The data has a spatial resolution of 15-20 km and is on a grid based on the much coarser resolution (300-350 km) National Meteorological Center (NMC) octagonal grid. The weekly-composite NDVI data will be composited to months to further remove cloud effects and then will be spatially averaged for each NMC grid cell to represent a regional average. There are approximately 250 NMC grid cells with land area for North America. The standard deviation of NDVI within each NMC grid cell will also be calculated to indicate subregional spatial variability. For each year in the record, the integral of NDVI over the growing season will be determined.

Measures of Regional Climate. To study regional and continental variation in climate, a measure of regional climate that is independent of local effects is necessary. One option is to use surface climate (e.g., temperature and precipitation) data that has been objectively analyzed to a coarse grid (e.g. the NMC grid) over the continent and so that local station effects are smoothed out. In addition, atmospheric circulation parameters derived from upper air data are not influenced by local effects and can be used to express regional climatic conditions that affect vegetation in the short and long term (Kittel & Carroll 1986, 1987).

Both coarse resolution surface and upper air variables will be used in this study to examine regional and continental climate variability. Atmospheric circulation parameters to be studied include 1000-500 mbar thickness, which reflects surface temperature, and 500 mbar positive absolute vorticity advection. 500 mbar positive absolute vorticity advection, in conjunction with 1000-500 mbar thickness, reflects surface moisture conditions. Monthly statistics of these two circulation parameters are calculated from twice daily height data for 1000 mbar and 500 mbar pressure levels. The height data and monthly mean surface climate data are available from the National Center for Atmospheric Research (NCAR) on the NMC grid for the period of the NDVI data for the Northern Hemisphere.

Regional and Continental-Scale Analyses of NDVI and Climate. Three analyses of the temporal and spatial variation of NDVI with respect to climate are proposed. The first analysis will look at six or more ecoregions (such as Blue Grama-Buffalo Grass Steppe, W. Hemlock-W. Red Cedar-Stika Spruce Forest) in the United States with LTER sites. For each of one or two NMC grid cells in each region, an individual multiple regression of monthly composite NDVI on monthly mean climate variables will be done. (Grid cells with a large proportion of cropland will either be discarded or a portion of the cell will be hand-selected for the analysis, based on land-use maps.) The regression analyses will assess the importance of climate variability on the temporal variability of NDVI for each ecoregion considered. Using these results, between and within region differences will also be evaluated.

To understand how the impact of temporal climatic variability on NDVI varies across North America, a second analysis will use all NMC grid cells simultaneously. This will use canonical correlation analysis to consider both the temporal and spatial variation of monthly composite NDVI with respect to monthly mean climate variables. A final analysis will be a multiple regression of the mean yearly integral of NDVI on mean regional climate variables for North America, where NMC grid points are observation points. This will show what proportion of the continental-scale spatial variation of the mean integral of NDVI is explained by the mean climate.

The three analyses will evaluate for different space and time domains the degree to which variation in NDVI is explained by climate. The analyses will also produce corresponding quantitative empirical relationships between NDVI and climate.

Global-Scale Climatic Variability. A major global-scale climatic phenomenon that affects climate in the United States is the El Niño-Southern Oscillation (ENSO). ENSO events are quasi-periodic (3-7+ yrs) changes in atmospheric circulation, sea surface temperatures, and precipitation in the tropical and equatorial Pacific Basin with far-reaching effects around the globe (teleconnections). For example, Strub et al. (1985) found an ENSO effect for an lake ecosystem in the western United States. The proposed study will compare the spatial and temporal patterns of NDVI for recent ENSO years (1982-83 and a smaller event in 1986-87) versus non-ENSO years in order to explore the importance of global-scale climate variability on distant ecosystems. Unfortunately, the analysis is limited by the short (five-year) period of the NDVI data set. On the other hand, interpretation of the analysis maybe straight forward because interannual variability of NDVI is strong (Kittel, unpublished data) and recent ENSO events' teleconnections for the climate of United States are reasonably well known.

III. Summary and Significance

The proposed study will use three analyses to evaluate the effect of intraseasonal and interannual climate variation on regional ecological variability (as indicated by NDVI). A fourth will investigate relationships between the means. While the focus is on regional ecological response, the spatial domain of these analyses will cover a range of scales from regional to continental to global.

The results from the regional and continental analyses will be largely descriptive. Nonetheless, the results are likely to indicate upper air circulation patterns associated with observed regional ecological perturbations. Such patterns may point to distant climatic conditions (e.g. Pacific sea surface temperature distribution) that eventually resulted in the ecological perturbation. This too is the goal of the analysis of ENSO and non-ENSO years. In the future, observations of this kind may be important in a validation phase of a linked general atmospheric circulation model (GCM) and ecosystem regional model, where ecosystem (or agroecosystem) response is modeled for introduced large-scale climatic perturbations.

A more immediate benefit, however, will be that this study will lay the foundation for similar studies at the site level, where ecological field data can be utilized. This study will provide a regional perspective on the role of continental and global climatic variability in interannual and intraseasonal variability of ecosystems.

References

Goward, S.N., C.J. Tucker, and D.G. Dye. 1985. North American vegetation patterns observed with the NOAA-7 advanced very high resolution radiometer. Vegetatio 64:3-14.

Greegor, Jr., D.H. 1986. Ecology from space. Bioscience 36:429-432.

Kittel, T. 1986. Global relationships between thermally-controlled vegetation boundaries and tropospheric circulation parameters. Program of the IV International Congress of Ecology, p. 203. (Abstr.)

Kittel, T.G.F., and J.J. Carroll, III. 1987. The distribution of North American vegetation in relation to atmospheric dynamics. (In prep.)

Major, J. 1951. A functional, factorial approach to plant ecology. Ecology 32:392-412.

Sellers, P.J. 1986. Canopy reflectance, photosynthesis, and transpiration. Int. J. remote Sensing 7:1335.

Strub, P.T., T. Powell, and C.R. Goldman. 1985. Climatic forcing: Effects of El Niño on a small, temperate lake. Science 227:55-57.

Waring, R.H., J.D. Aber, J.M. Melillo, and B. Moore, III. 1986. Precursors of change in terrestrial ecosystems. Bioscience 36:433-438.

Yarnal, B. 1985. Extratropical teleconnections with El Niño/Southern Oscillation (ENSO) events. Progress in Physical Geography 9:315-52.

Time Line (Assuming 1 Jan 88 start date)

Jan 88	Purchase NDVI, upper air, and surface climate data.
Feb - Sept 88	Create NMC grid-averaged monthly-composited NDVI data set for North America. Create atmospheric circulation parameter monthly mean data sets. Perform regional, continental, and global NDVI-climate analyses.
Oct - Dec 88	Prepare publications.

Budget

Funds are requested for three months salary, purchasing of required data sets, computer time, publication preparation costs, and miscellaneous costs. The data sets needed are the global weekly composite NDVI, twice-daily 1000 and 500 mbar height, and monthly surface temperature and precipitation data for the period 1982 through 1987, or as available. The first three years of NDVI data is already on hand, so only data from 1985-on needs to be purchased. Computer processing is anticipated to be extensive because of the size of the data sets and will be done on the Cooperative Institute for Research in the Atmosphere's VAX 780 and MicroVAX II/GPX, at Colorado State.

BUDGET EXPLANATION

	Budget
A. Personnel	
1. T.G.F. Kittel * (3 mo)	7,077
TOTAL SALARIES AND WAGES (A+B)	7,077
C. Fringe Benefits @ 18.80% of *	1,330
TOTAL SALARIES, WAGES & BENEFITS (A-C)	8,407
E. Travel	
1. Domestic	0
Explanation	
G. Other Direct Costs	
1. Material and Supplies	1,300
2. Publications/Page charges	450
4. Computer Services	5,000
6. Other	
a. Communications	650
c. Data Processing Services	0
d. Publications Services	0
f. Secretarial Services	2,530
h. Postage, freight, misc.	0
TOTAL OTHER	3,180
TOTAL OTHER DIRECT COSTS	9,930
H. TOTAL DIRECT COSTS (A-G)	18,337
I. Indirect Costs @ 39.9% MTDC	
Yr 1 base/$18,337	7,316
J. TOTAL DIRECT & INDIRECT COSTS (H+I)	25,653

OBM Circular A21 requires the distribution basis for recovering indirect costs to be Modified Total Direct Costs. Indirect costs for organized research is assessed at 39.9% on-campus rate against all items in the budget except capital equipment, tuition, CSU computer services, and subcontracts in excess of $25,000.

Service rates shown have been reviewed by CSU Accounting Section, and are subject to internal audit at CSU and to external audit, both State and Federal.