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7.5 A GRIDDED HISTORICAL (1895-1993) BIOCLIMATE DATASET FOR THE CONTERMINOUS UNITED STATES

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1. INTRODUCTION

1.1 *Objectives*

Modeling ecological responses to historical climate change and variability over the last 100 years is crucial for validation of ecological models and for understanding potential responses of ecosystems to future climate change. However, such simulations require input of temporally complete climate data at a spatial resolution that adequately captures key climate gradients. Even for the conterminous United States, station density prior to 1940 is insufficient to interpolate station data across the domain with confidence, especially in mountainous regions.

For the second phase of the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP), we developed a 99-yr 0.5° latitude/longitude gridded dataset of monthly precipitation and monthly mean minimum and maximum temperature for the conterminous U.S. Our objective was to create a climate dataset that is (1) temporally complete, with realistic representation of climate variability at year-to-year and decadal scales, and (2) spatially realistic, reflecting topographic and aspect controls over climate.

1.2 *VEMAP*

VEMAP is a multi-institutional, international effort addressing the response of ecosystem biogeography and biogeochemistry to environmental variability in climate and other drivers in both space and time domains. The first phase of VEMAP compared the controls and equilibrium responses of three biogeochemistry models (TEM, CENTURY, and BIOME-BGC) and three biogeography models (BIOME2, DOLY, and MAPSS) to changing climate and elevated atmospheric carbon dioxide concentrations (VEMAP Members 1995, Schimel et al. 1997).

Construction of a common input database assured that differences in the model intercomparison arose only from differences among model algorithms and their implementation rather than from differences in inputs. The VEMAP1 database consists of long-term climate (both monthly and daily versions), climate change scenarios, soil properties, and potential natural vegetation and is available on the web (URL = http://www.cgd.ucar.edu:80/vemap/) and CDROM (Kittel et al. 1995, 1996, Rosenbloom and Kittel 1996).

1.3 *The VEMAP2 Climate Dataset*

The second phase of VEMAP will evaluate the time-dependent responses of ecological models (biogeochemical and coupled biogeographical-biogeochemical models) to an array of historical and projected transient forcings, including climate, atmospheric CO_2, and nitrogen deposition. This paper describes the development of the historical monthly precipitation and minimum/maximum temperature dataset for VEMAP2 for the conterminous U.S.

When completed, the full climate dataset will also include additional required variables (humidity and solar radiation), a daily version, coverages for Alaska and Hawaii, and transient climate change scenarios from coupled atmosphere-ocean general circulation models.

2. METHODS

2.1 *Domain and Approach*

The dataset was developed for the conterminous United States and is on a 0.5° latitude x 0.5° longitude grid.

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Our approach was, stepwise, to:

(1) Combine extant historical station datasets to create a unified set with the highest station density and most complete records as was readily achievable.

(2) Model spatial relationships among stations with long-term records and neighboring shorter-term stations to in-fill and extend back in time the shorter-term station records.

(3) Spatially interpolate these temporally-complete station records to the 0.5° grid using the PRISM model (Daly et al. 1994) that statistically accounts for physical relationships between climate and topography.

2.2 *Station Datasets*

We obtained monthly mean minimum and maximum temperature records for 5476 stations and monthly precipitation records for 8514 stations from the NCDC Historical Climate Network database (HCN; NCDC 1995), other primary and cooperative network datasets (NCDC 1993, 1994a, b), and NRCS Snotel (snowpack telemetry) dataset (Phil Pasteris, personal communication). Inclusion of the Snotel sites significantly improved station density in the mountainous western U.S. (Fig. 1). Stations with records prior to the 1950's were largely from the HCN set.

PRECIPITATION STATIONS

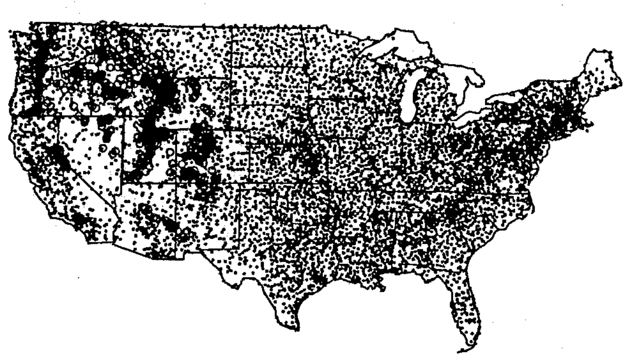

Figure 1. Density of precipitation (dots) and Snotel stations (open circles in the West) used to develop the historical dataset.

2.3 *Statistical Reconstruction of Station Records*

To create complete precipitation and temperature records for the period 1895-1993, we took advantage of local spatial autocorrelation structure to predict monthly values where a record is discontinuous or incomplete (Royle et al. 1997a, b). Predictions of monthly precipitation and temperature anomalies (from long-term means) were made using a local (moving window) kriging prediction method similar to that of Haas (1990, 1995). In this approach, for each site of prediction, only nearby sites were used to estimate the covariance structure of the process and to make predictions. This is practical both computationally, because it greatly reduces the size of the linear system that must be solved for each prediction, and theoretically, because one would not expect processes over such a large region to possess a stationary covariance function.

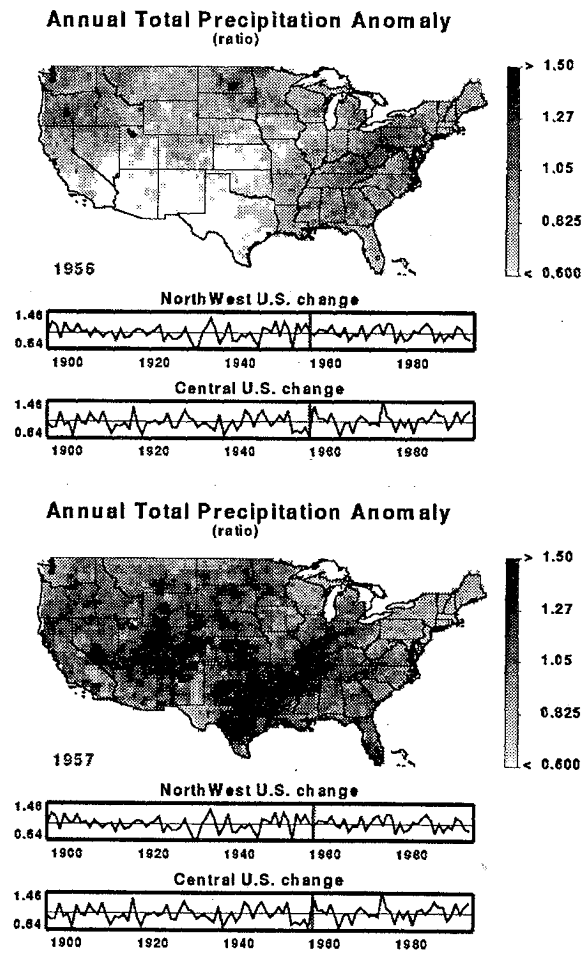

Figure 2. Example output from the VEMAP2 historical precipitation dataset: annual precipitation anomalies for 1956 and 1957. Mapped anomalies are presented as ratios of each grid cell's long-term mean. Plots below each map are time series of anomalies averaged for the Pacific Northwest and Central U.S. (roughly Kansas and Nebraska); anomalies are from the corresponding region's long-term spatial average.

The prediction neighborhood consisted of the 10 nearest neighbors with observations. Larger neighborhoods were considered, but with little increase in precision. Unlike Haas (1995), we did not allow the spatial covariance function to vary in time. That is, stationary covariance models were fit to long-term estimates of the covariances. The temperature dataset consisted of monthly minimum and maximum temperature and these were converted to mean and range summaries for statistical analyses. Standard bivariate prediction (i.e., co-kriging) methodology was used for the temperature data. Cross-validation was used to evaluate the spatio-temporal distribution of prediction errors.

2.4 *Spatial Interpolation — PRISM*

We used PRISM (Parameter-Elevation Regression on Independent Slopes Model; Daly et al. 1994; see other papers in this volume) to spatially interpolate the temporally-complete station records to the 0.5° grid. PRISM accounts for the effects of elevation and aspect on the distribution of precipitation and temperature to grid the station data. Temperature interpolation also incorporates the effects of basin topography on establishment of temperature inversions.

3. RESULTS

3.1 *Temperature and Precipitation Datasets*

The local kriging approach filled in missing parts of station records and extended them back to 1895, creating a temporally complete dataset of roughly 8500 precipitation and 5500 minimum and maximum temperature time series (as illustrated in Figs. 2 and 3). Cross-validation of precipitation output showed that, from the most recent to the earliest part of the record, prediction errors roughly doubled as station numbers decreased by an order of magnitude (~8500 to ~700).

Anomaly maps of these data show, in animations (section 3.2) and in selected time slices (Figs. 2 and 3), that patterns of interannual variability were, on the first order, spatially broad and cohesive but were also highly variable year to year. Certain patterns, as discernable in eigenfunction analyses, were commonly repeated throughout the record.

PRISM-generated fields strongly reflected the effects of topography on temperature and precipitation. This was most clearly illustrated in the output maps for regions with significant gradients in temperature and precipitation in spite of low station density (not shown). Regions with the steepest precipitation gradients were the Sierra Nevada and Cascades because they separate coastal and inland regimes. Strongest temperature inversions showed up in medium-size Rocky Mountain basins, such as the Big Horn Valley.

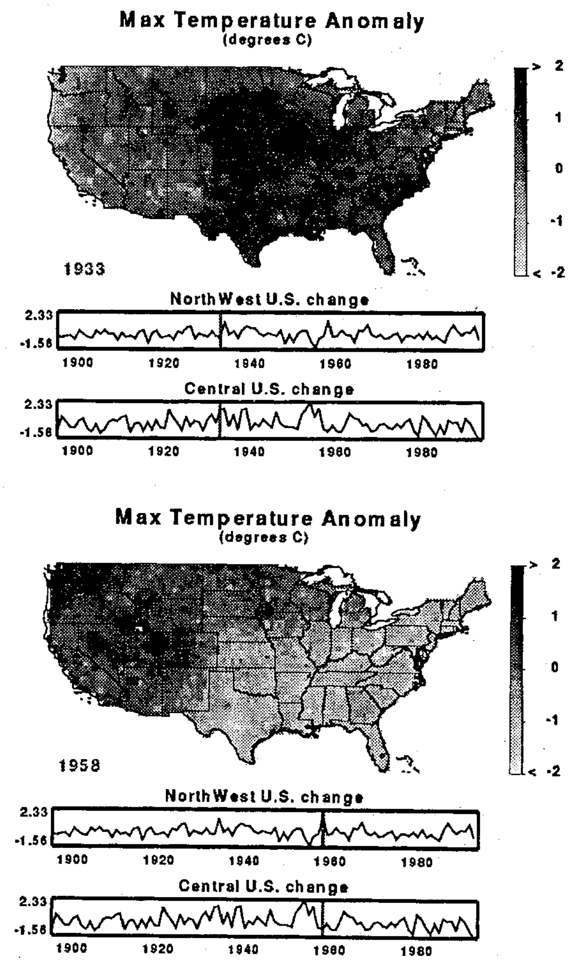

Figure 3. As in Fig. 2, except for annual maximum temperature anomalies for 1933 and 1958. Anomalies are in absolute differences (in °C).

3.2 *Animations*

Animations of annual precipitation and annual mean maximum and minimum temperature are on the VEMAP web site (see section 1.2).

4. CONCLUSION

Through statistical analysis of spatial covariance structure and through use of physically-guided statistical relationships between climate variables and topographic controls, we created a long-term (99 year), gridded dataset of monthly precipitation and monthly mean minimum and maximum temperatures. The dataset is temporally complete, with realistic representation of climate variability at year-to-year and decadal scales, and spatially realistic, reflecting, at least at a resolution of 0.5°, key climate gradients across the domain. These features of climate, temporal and spatial variability, are key determinants of functional and structural dynamics and distribution of ecosystems. Their capture in the data is crucial for reliable and validatable simulations of ecological processes.

5. PUBLIC RELEASE DATE

Following beta testing, we anticipate that the dataset will be publically released mid to late 1998 over the web and via ftp.

6. ACKNOWLEDGEMENTS

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