Self-organizing maps in review: recent applications in polar (paleo)climatology

David B. Reusch
517 Deike Building
Penn State University
University Park, PA 16802
dbr@geosc.psu.edu

The global climate system and natural archives of its history are linear only by approximation. Available observational and instrumental records are inadequate for full characterization of natural variability; proxy histories from, e.g., ice cores and tree rings are thus necessary to more fully understand climate change, past and future. Linear tools have proven highly valuable in understanding paleoclimatic records such as these, and others, but are inherently limited to linear relationships. Motivated by these and other reasons, we have assembled a suite of nonlinear, highly adaptive tools based on artificial neural networks and applied these tools to several problems in (paleo)climatology.

Self-organizing maps enable unsupervised classification of large, multivariate data sets, e.g., time series of the atmospheric circulation or sea-ice extent, into a fixed number of distinct generalized states or modes, organized spatially as a two-dimensional grid, that are representative of the input data. When applied to atmospheric data, the analysis yields a nonlinear classification of the continuum of atmospheric conditions. In contrast to principal component analysis, SOMs do not force orthogonality or require subjective rotations to produce interpretable patterns.

Results to date have been encouraging and include: improved reconstructions of past climates from ice-core and automatic weather station measurements; new perspectives on sea-ice variability; and a new look at Holocene variability in ice core chemistry datasets. Further data are needed, but we are optimistic that these neural-net techniques will prove a useful complement to the traditional linear approaches, capturing more of the rich nonlinearity of the earth system.