Scale and Scaling in the Climate System

Shaun Lovejoy, M. Crucifix and A. de Vernal

Montreal, Canada, 5-7 October 2015

Forty years ago, at the dawn of the revolution in paleoclimate data, it was believed that atmospheric variability essentially consisted of an uninteresting, spectrally flat (white noise) “background”, interspersed with periodic and quasi-periodic processes such as the diurnal and annual cycles, the Southern Oscillation and Milankovitch cycles (Fig. 1, bottom). Since then, instrumental and paleo data have shown this picture is wrong by a large factor (Fig. 1, top): the background displays nontrivial “variability across scales” that can be roughly divided into five power law (“scaling”) regimes. This state of affairs, underscoring the need for a fresh look at climate variability and theory, motivated this workshop.

The first objective was to get nonlinear geoscientists and paleoclimate scientists to think about effective ways to characterize climate fluctuations, understand their causes, and focus on these aspects when analyzing paleoclimate data; the second was to develop a common research agenda.

The workshop successfully brought communities together with expertise in recent climate (11 participants), paleoclimate (21), climate modeling (9), and nonlinear, statistical and stochastic mathematics (22). Participants, including 14 students, came from Canada, USA, Europe, Asia, and Latin America.

The ice core and marine paleoclimate experts in particular provided an authoritative account of what paleoclimate data can offer (E. Wolff, A. De Vernal), including various pitfalls (M. Kucera). The more applied-mathematics-inclined speakers discussed the origin of long-memory processes (C. Franzke), their detection (K. Rypdal), and some difficulties (T. Nielsen). A wide range of timescales was covered from the instrumental periods permitting the study of spatio-temporal variability (H. Frederiksen). We now have enough accurate data to address questions that were previously impossible, such as the gain between forcing and response at timescales of hundreds of thousand years (P. Huybers).

The overall result was the creation of a PAGES working group “Climate Variability Across Scales” (CVAS, see Program News article on page 32). The workshop was co-organized and funded by McGill University and Université de Québec à Montréal. It received additional funding from PAGES and CLISAP (University of Hamburg).

AFFILIATIONS
1 Department of Physics, McGill University, Montreal, Canada
2 Georges Lemaitre Centre for Earth and Climate Research, Université catholique de Louvain, Belgium
3 GEOTOP, Université de Québec à Montréal, Canada

CONTACT
Michel Crucifix: michel.crucifix@uclouvain.be

REFERENCES

Figure 1: The temperature spectrum (E(ω)) giving the variance per interval of frequency (ω). The bottom (grey) is M. Mitchell’s “educated guess” showing the still dominant view of a fairly flat (white noise) “background” interspersed with spikes corresponding to important (quasi-periodic) processes (Mitchell 1976). Top curves are based on instrumental and paleo-data and their range differs from Mitchell’s guess by a factor of roughly 10¹⁵. In actual fact, the “background” accounts for nearly all the variance, so that the roles of foreground and background must be inverted: Mitchell must be “stood on his head”. To a first approximation, the spectrum can be divided into five power law regimes (linear on this log-log plot, blue reference lines). At the far right, there are two nearly parallel instrumental curves corresponding to the spectra of temperatures averaged over the globe (bottom) and over 5°X5° (top). Also shown (green) are the spikes corresponding to diurnal and annual cycles. Adapted from Lovejoy (2015), which has the full details of the data sources.