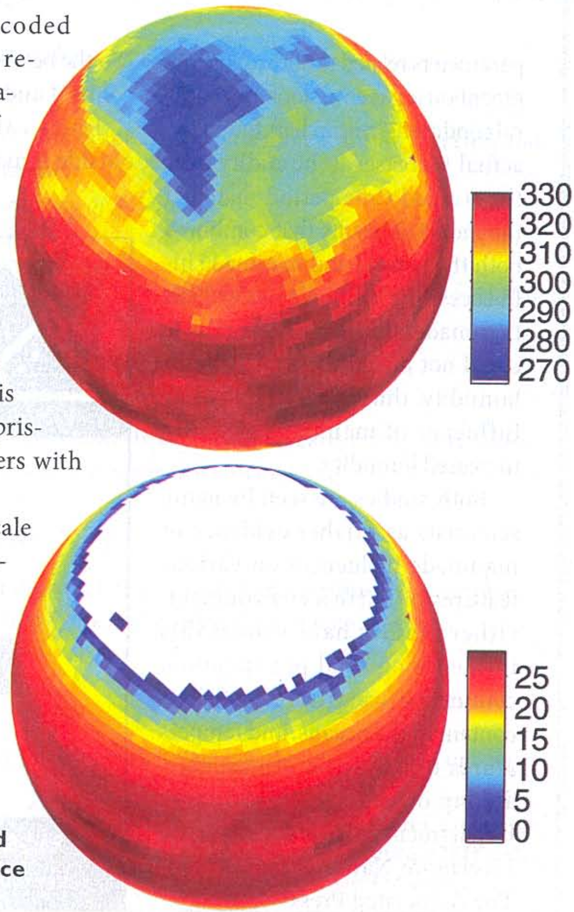
Mean Climate and Variability of an Idealized 'Aqua-Planet'

It is very difficult to identify controlling mechanisms behind climate and climate variability because there is a myriad of drivers acting on a vast range of time scales that, due to nonlinearities and feedbacks, do not superpose. As a result, it is all but impossible to carry out "what if" experiments even with observations. Moreover, climate models have to represent key processes parametrically and are used almost exclusively in "simulation and projection" mode rather than for asking mechanistic questions.

In an attempt to exploit in a different way the information and knowledge encoded in climate models, researchers at the Massachusetts Institute of Technology have recently begun to use them to explore the climate of highly idealized worlds in which, for example, there is no land, or the land distribution is highly idealized comprising meridional barriers with and without gaps.

Millennial time-scale simulations of a coupled atmosphere–ocean–ice system in the absence of land and driven by mod-



Atmospheric temperature at 500 mb (K, top) and sea surface temperature and ice distribution (°C, bottom) in an equilibrium state after 3000 yr of integration of a coupled atmosphere–ocean–ice model on an "aqua-planet." Sea ice extends down to 55° latitude in each hemisphere.

ern-day orbital and CO_2 forcing yield a climate on this so-called "aqua-planet" in which ice caps reach down to 55° latitude and both the atmosphere and ocean comprise eastward- and westward-flowing zonal jets whose structure is set by their respective baroclinic instabilities. Despite the zonality of the ocean, it is remarkably efficient at transporting heat meridionally through Ekman transport and eddy-driven subduction. Indeed the partition of heat transport between atmosphere and ocean is much the same as the present climate, with the ocean dominating in the tropics and the atmosphere in the middle-to-high latitudes.

Variability of the system is dominated by the coupling of annular modes in the atmosphere and ocean. Stochastic variability inherent to the atmospheric jets drives variability in the ocean. Zonal flows in the ocean exhibit decadal variability which, remarkably, feeds back to the atmosphere, coloring the spectrum of annular variability. A simple stochastic model can capture the essence of this process.

We are presently studying, in an aqua-planet framework, the role of geometry in constraining ocean pathways and the ability of the ocean to transport heat poleward; the possibility of the coupled system exhibiting multiple equilibria; snowball earth scenarios; and coupling in biogeochemical cycles. Our goal is to improve our understanding of the interaction between the atmosphere and ocean in setting the climate of our own planet.—John Marshall (Massachusetts Institute of Technology), D. Ferreira, J.-M. Campin, and D. Enderton. *"Mean Climate and Variability of the Atmosphere and Ocean on an Aqua-Planet," in the December* Journal of the Atmospheric Sciences.