Geophysical Research Abstracts, Vol. 8, 08941, 2006
SRef-ID: 1607-7962/gra/EGU06-A-08941

Strategies for modeling multi-scale systems: Explicit numerical reductionism or emergent interactions?

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Many geophysical systems involve disparate processes interacting across a great range of time and space scales. When attempting to construct numerical models to explore how a system works or to make numerical predictions, there has been a strong tendency toward 'explicit numerical reductionism'—the direct representation of interactions at scales as small as possible. Parameterizing sub-grid-scale processes is often seen as an unfortunate necessity, to be avoided if possible. On the other hand, when devising an exploratory model (Murray 2002, 2003), a top-down strategy is often employed; an effort is made to represent only the *effects* that much smaller-scale processes have on the scale of interest. This approach allows investigation of the interactions between the emergent variables and structures that most directly explain many complex behaviors. As a caricature, we don't investigate water-wave phenomena by simulating molecular collisions. In addition, basing a model on processes at much smaller scales than those of the phenomena of interest leads to the concern that model imperfections may propagate up through the scales; that if the small-scale processes are not treated very accurately, the key interactions that emerge at larger scales may not occur as they do in the natural system. However, this risk can be bypassed by basing a model directly on larger-scale interactions. For this reason, it has been suggested recently that a top-down approach leads to models that are better able to make practically useful numerical predictions.

I will illustrate these points with examples from coastal-processes research.