Conceptualizing a framework for inter-scale connections in coupled human-earth systems models.

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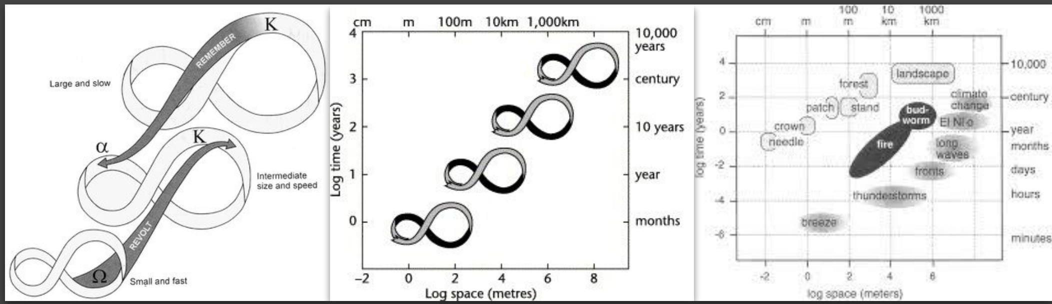
Concepts of scale that are potentially useful for computational modeling...



- **Fast and slow systems; Timeframe scales with spatial size**
  - Gunderson and Holling, 2002: “Panarchy”
  - Gunderson, Allen, &, Holling, 2010. “Foundations of ecological resilience.”

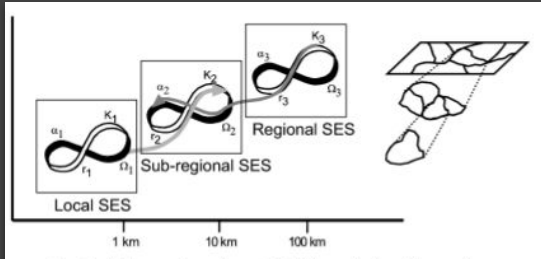
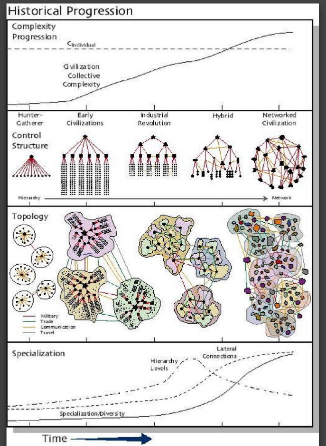


Fig. 3. A hierarchy of nested SES and adaptive cycles.

- **Regional SES that “nest” in time and space.**
  - Bourgeron, Humphries, & Riboli-Sasco, 2009. “Regional analysis of social-ecological systems.”

- **Network complexity and scale; temporal and spatial scale a factor of the minimum number of actors needed.**
  - Bar-Yam, 2004. “Complexity Rising: From Human Beings to Human Civilization, a Complexity Profile”
  - Bar-Yam, 2004. “Multiscale variety in complex systems.”



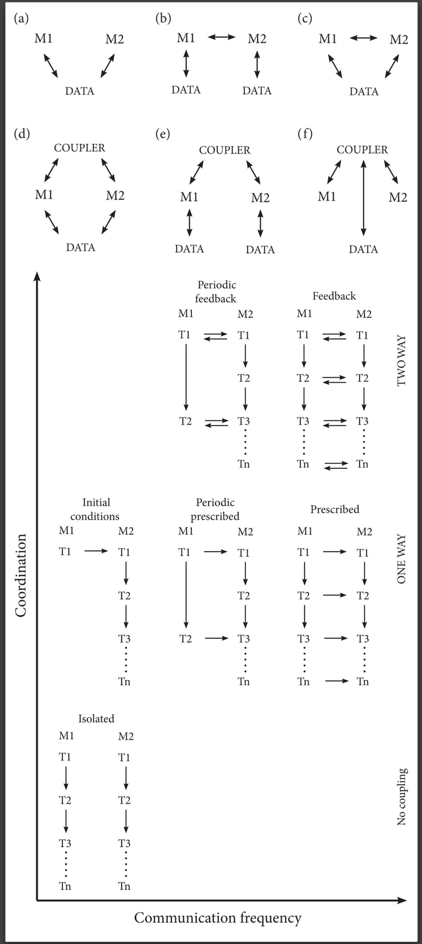
Choices about scale that we make as modelers...

- **Granularity of model components**
  - How many “agents?” How many (sub)components?
  - How much variability/behavior assigned to one “agent?” Should/can we downscale/upscale?
  - At what level(s) do we want to approximate behavior within and of a system?
- **Approximation of system behavior**
  - True ABM/Genetic algorithms
  - Cellular automatas
  - Non-linear mathematical/regression models
  - Simple (linear) regression/models
  - Boolean decision trees
- **Capacity for emergence**
  - Scalar structures emerge through interactions within the model
  - Scalar structure imposed by model architecture
  - Hybrid: some imposed structure, some emergent structure

From “ad hoc” to intentional..

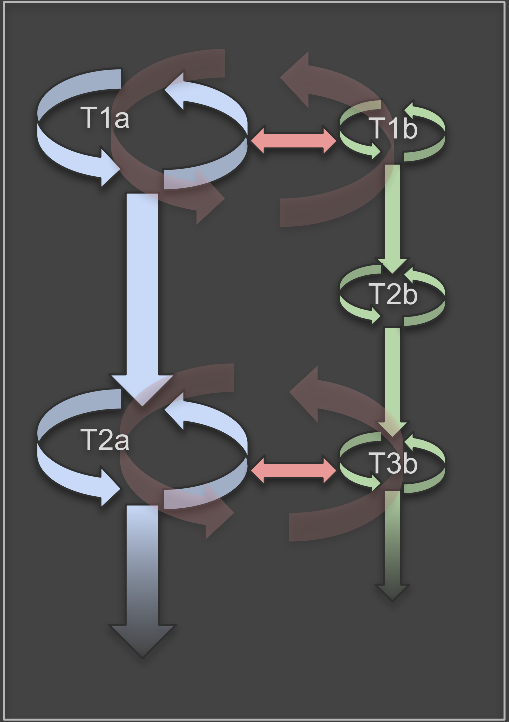
Often, our choices about model architectures are made on an “ad-hoc” basis; we make the choices the seem “reasonable” at the time based on our modeling goals, what we think is important about the system being modeled, and pragmatic concerns (model speed, data needs, coding time).

Creating a “typology” of ways to model scalar interaction would let us explicitly tie back to theory, and would allow us to be more mindful of the ramifications of our choices when it comes to model architecture.

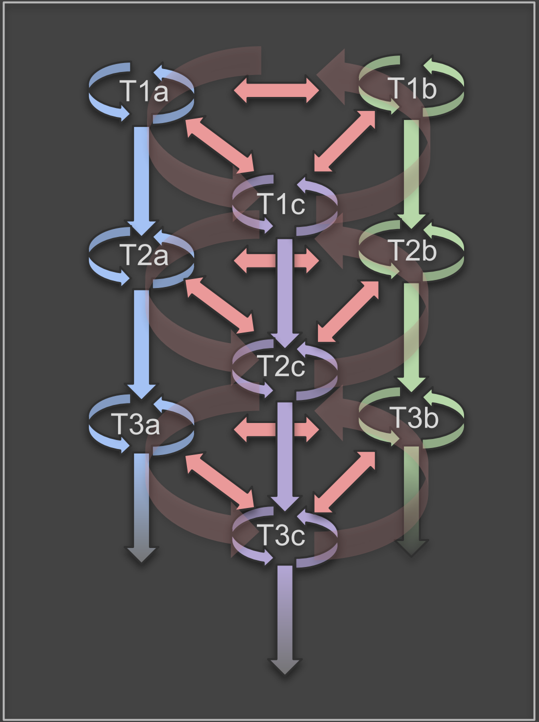


Robinson et al., 2018. “Modelling feedbacks between human and natural processes in the land system.”

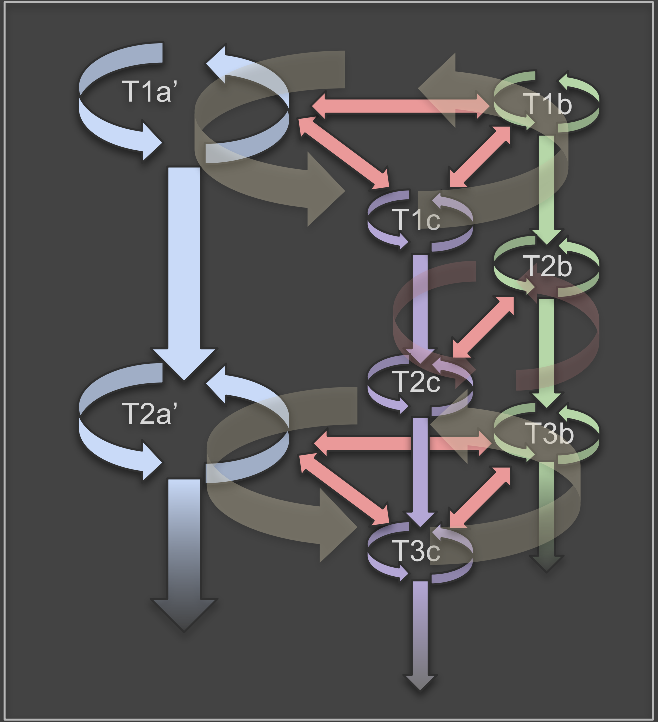
Some initial conceptual diagrams...



Larger-slower system coupled to a smaller faster system. Model architecture is reasonably simple, but macro-scale emergent phenomena may be time-lagged and not fully representative.

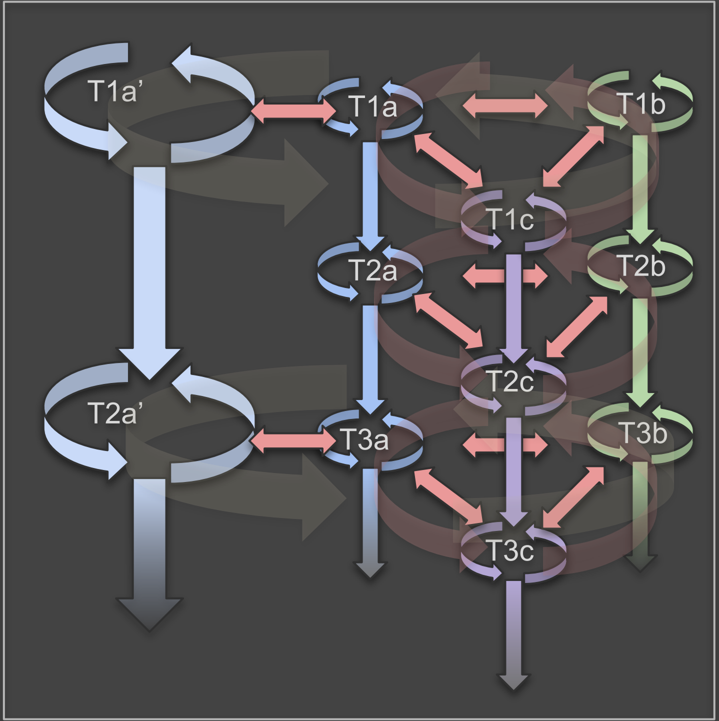


Coupling of multiple systems of similar size and temporality. Representative macro-scale emergent phenomena are likely, but model architectural complexity is increased.



Larger-slower system coupled to other smaller faster systems. A compromise in model architecture complexity with some trade offs: some macro-scale patterns will emerge at the faster time scale, and others may be time lagged at the larger time scale.

Some initial conceptual diagrams...



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Here we see perhaps a “downscaling” of a large, slow model into a smaller, faster sub-model that can interact with other systems of similar size and temporality.

There are many more iterations of this that can be explored, and hopefully we can come up with some sort of meaningful typology or phylogeny that can help us be more mindful of the theoretical and practical implications of scalar design in models.