Friday Forum Presentation

Present

From Open World Project

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Open World Project

Friday Forum

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Talk Plan

- Other Projects of Interest
- Motivation and Vision
- Core Elements
- Case Study Projects
- Climate Behaviors
- Fisheries Model
- Next Steps

Other Projects of Interest

- Carbon Transition Working Group (http://www.existencia.org/carbon/)
- Peruvian Spatial Fisheries (http://sdresearch.wikischolars.columbia.edu/jar2234+Peruvian+Fisheries)
- Ocean Health Metric (http://sdresearch.wikischolars.columbia.edu/Ocean+Health)
- Empirical Benefits from Marine Protected Areas (http://sdresearch.wikischolars.columbia.edu/jar2234+Marine+Protected+Areas)
- Web-Weaver Data Extractor (http://existencia.org/weaver/)
- CantoVario (http://cantovario.com)
- Slider Extension (http://openworld.existencia.org/index.php?title=Friday_Forum_Presentation)

Introduction

Many of the human behaviors that drive climate change and environmental degradation are deeply embedded in our society, economy, and government, and are mutually reinforcing. Better modeling of human-natural systems can help in many ways:

- Analyzing feedback loops can help identify **leverage points**, where small policy changes can have pervasive impacts.
- Allowing models at diverse scales and contexts to interact can help scientists **integrate knowledge**.
- Interactive models can facilitate **communication** with policymakers and make complex problems intelligible.

The Open Model is a modeling framework aimed at these issues.

Applicability

- Systemically intractable due over-determined, reinforcing drives, and spatially heterogeneous.
- Environmental and public health issues: environmental degradation, agricultural practices in poor countries, obesity, substance abuse, groundwater use, fishery management, passenger transport
- Rebound effects and cross-border shifts (e.g., carbon leakage)

Something for everyone!

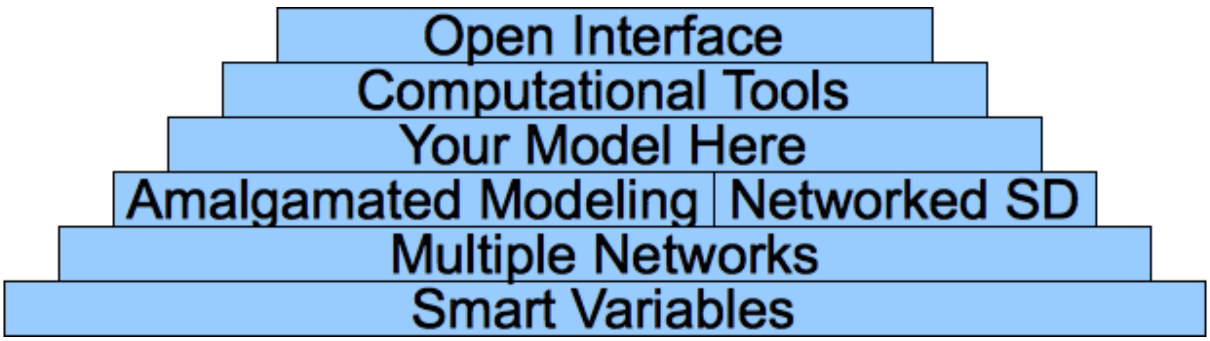
Why bigger models?

- **Accuracy?** Debatable
- **Precision?** Marginally better
- **As a platform?** If it's popular

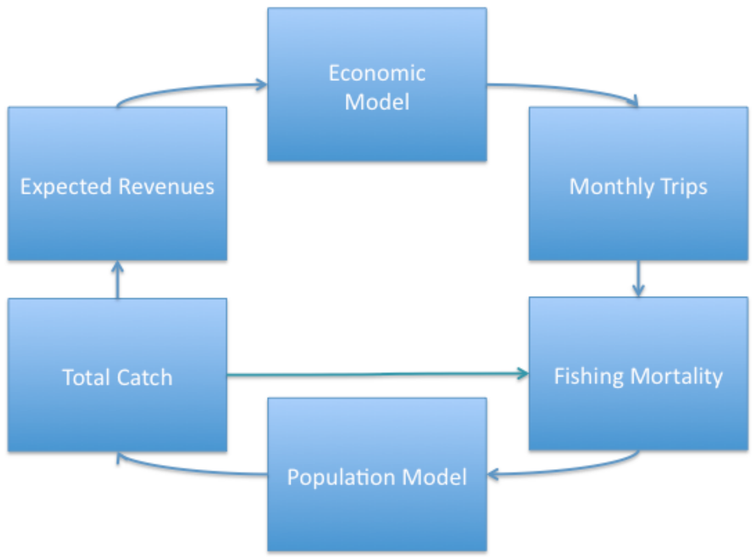
- *Interaction of the components*
- *Finer tipping points*

Core Elements

- Amalgamated Modeling
- Multiple Network Maps
- Networked System Dynamics
- Computational Tools
- Open Interface
- Smart Variables



What is Coupling?



Bioeconomic model from Smith and Wilen, 2003

What is Coupling?

Problems:

- Runaway feedback (resonance)
- Non-realistic calibrated parameters
- Making elements commensurable

Amalgamated Modeling

Amalgamated modeling allows models to interact, specialize, and "overlap".

Every model is incomplete; applies to a constrained context.

Let's embrace partial models!

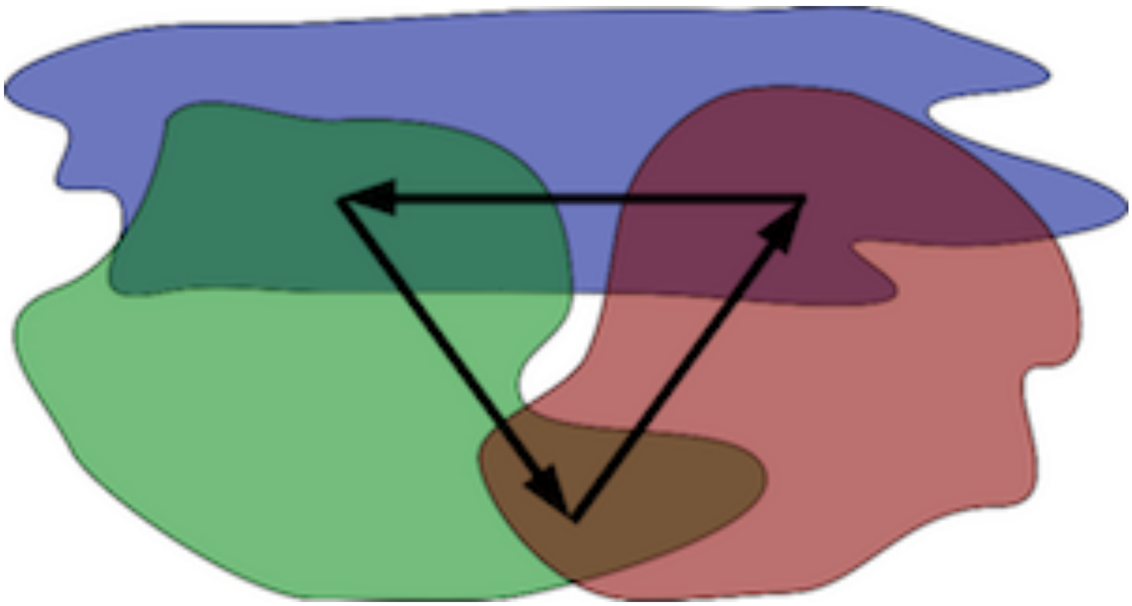
Want a "plugin architecture", where models can easily be allowed to interact

Coupling causes feedback, and models are defined at different scales.

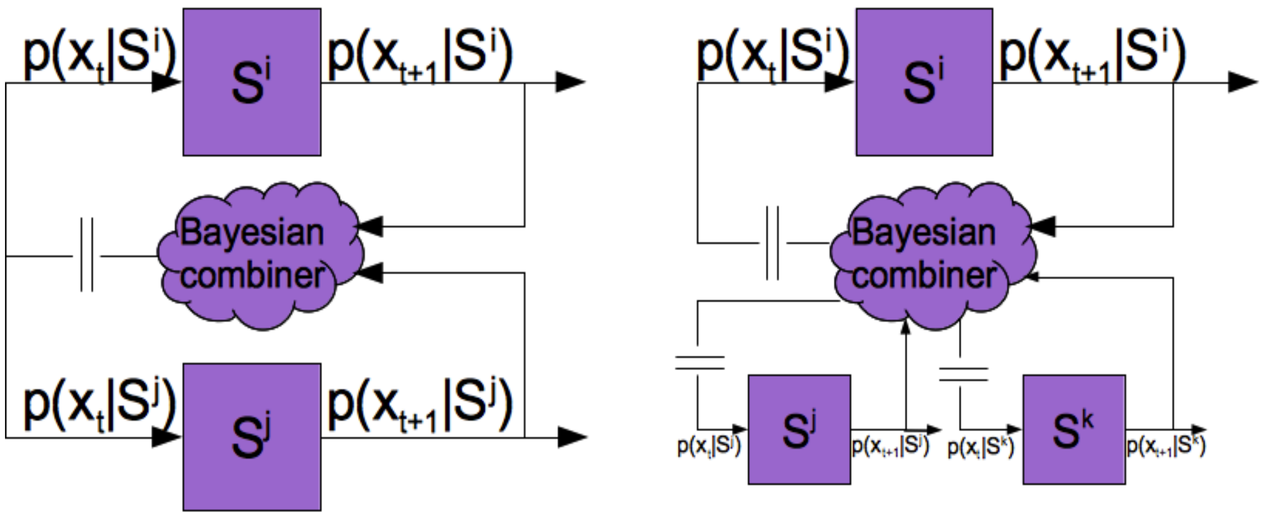
Need a new way to couple models!

Allow overlapping-- models inform different variables, at different scales.

Amalgamated Modeling

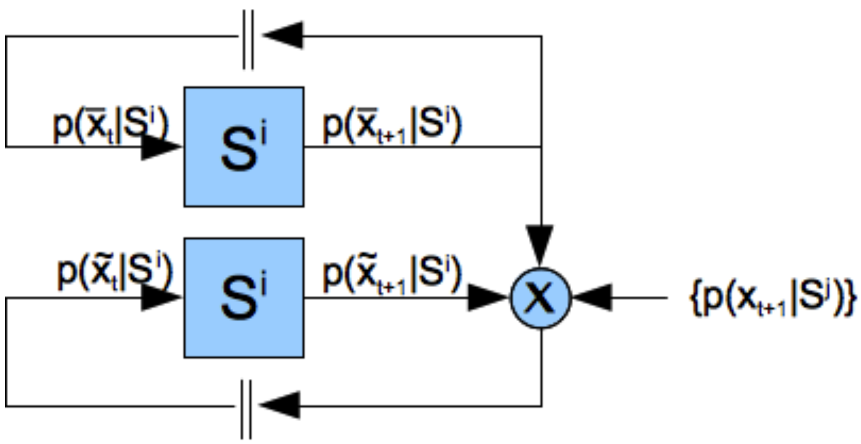


Bayesian Coupling



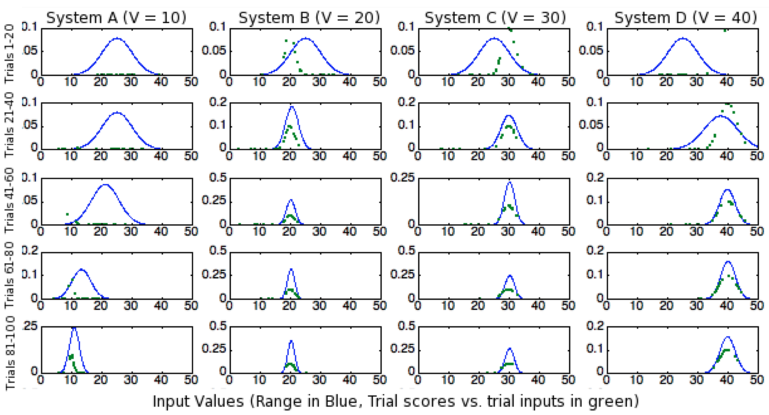
Bayesian Coupling

For a variable θ described by multiple models, each model provides both a PDF across values at a given time *t* when run in isolation, $p(\theta, \bar{S}^i)$, and a distribution that includes feedback effects, $p(\theta, \tilde{S}^i)$. The final distribution is $p(\theta|\cdot) \propto p(\theta) \prod_i p(\theta|\bar{S}^i)^\lambda p(\theta, \tilde{S}^i)^{1-\lambda}$



Amalgamation Challenges

- How do I test it?
- Efficient probability function calculations
- Smooth or spectrally-informed transitions?
- What does downsampling contribute?
- How to ensure that different scales add up?
- How do we understand a multi-scale model?



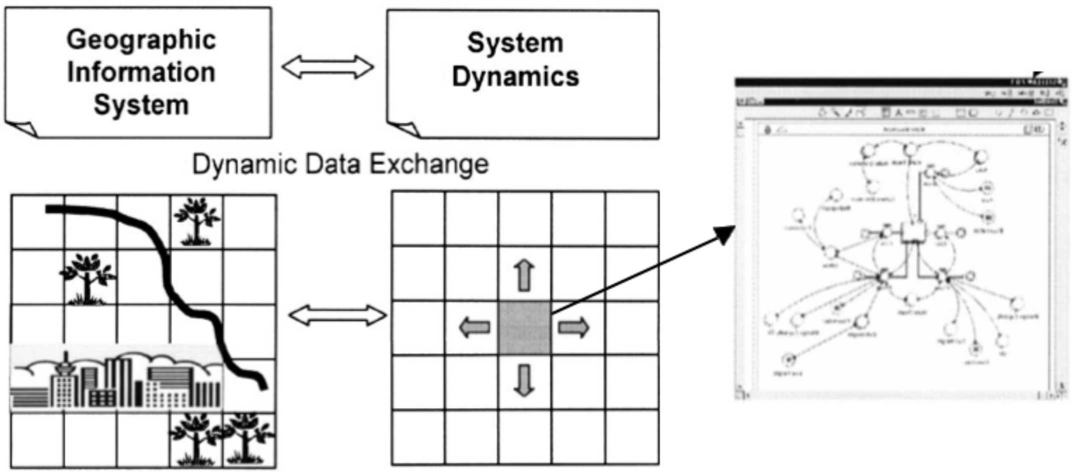
A New System Dynamics

Coupling natural and human systems makes things complex:

feedback, non-linearity, resilience, and spacial heterogeneity

Combine the temporal sophistication of system dynamics,

with spatial heterogeneity



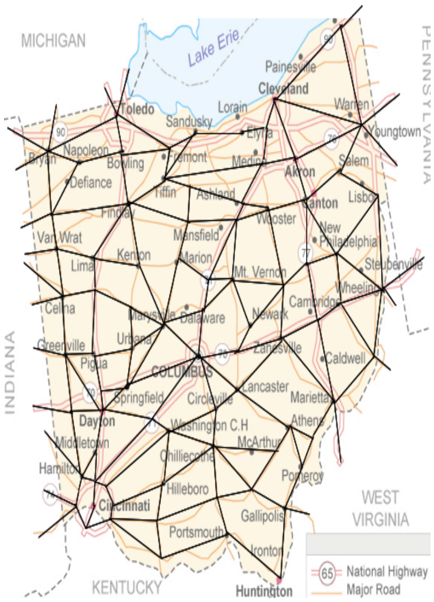
(Ahmad et al 2004; flood management, water resources modeling, invasive species spread)

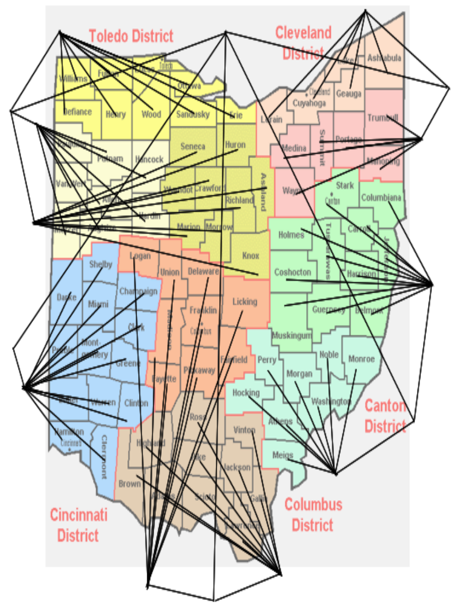
Multiple Networks

Models use multiple networks simultaneously

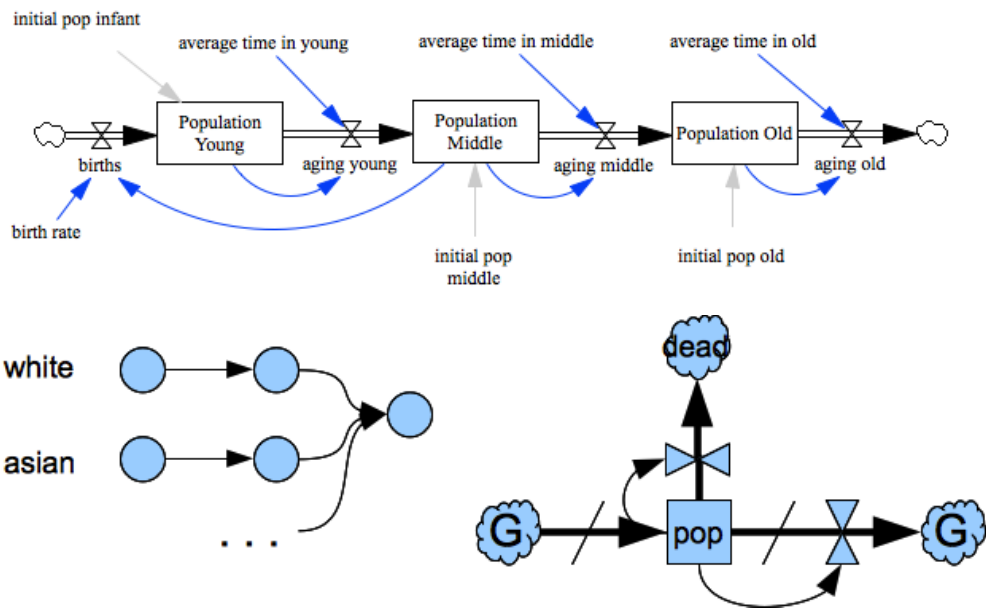
- Different paths on which stocks flow
- Disaggregations into structured classes
- Capturing network properties

Multiple Networks in Ohio

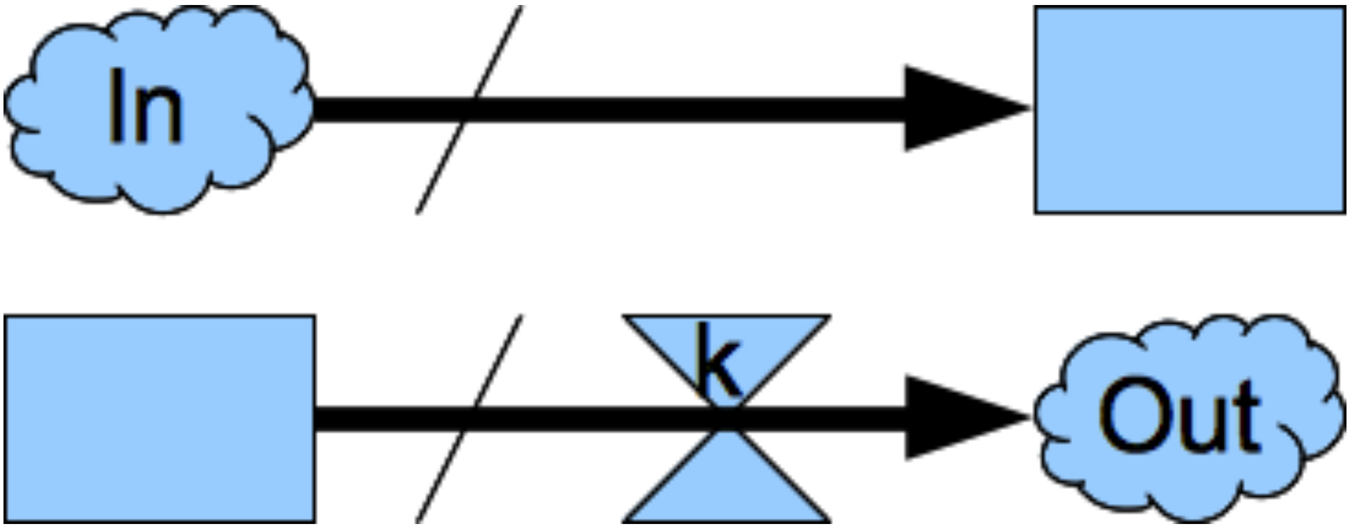




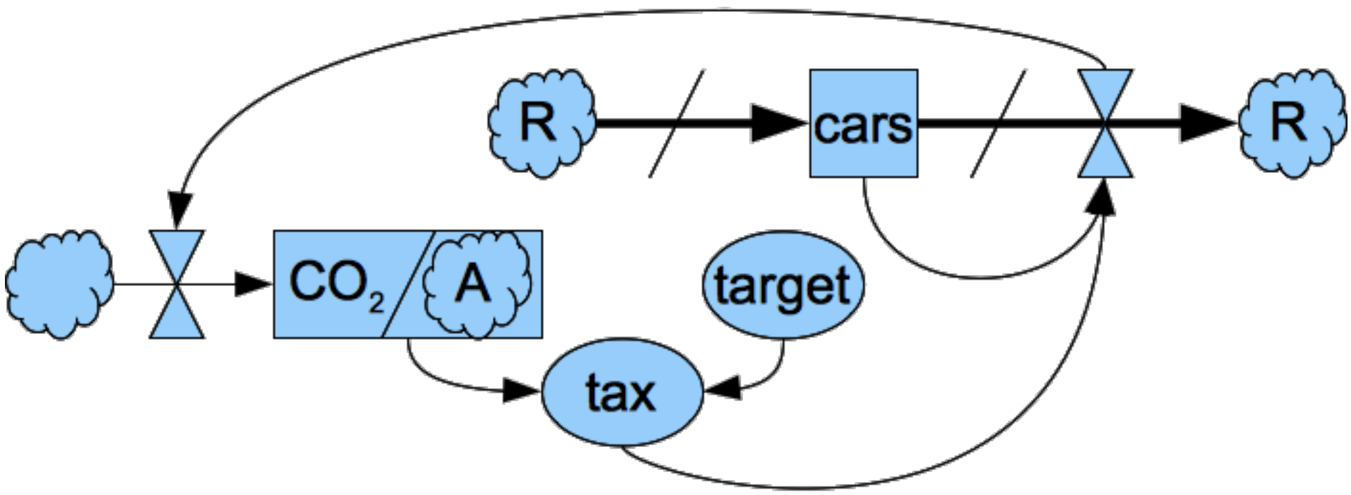
Disaggregating System Models



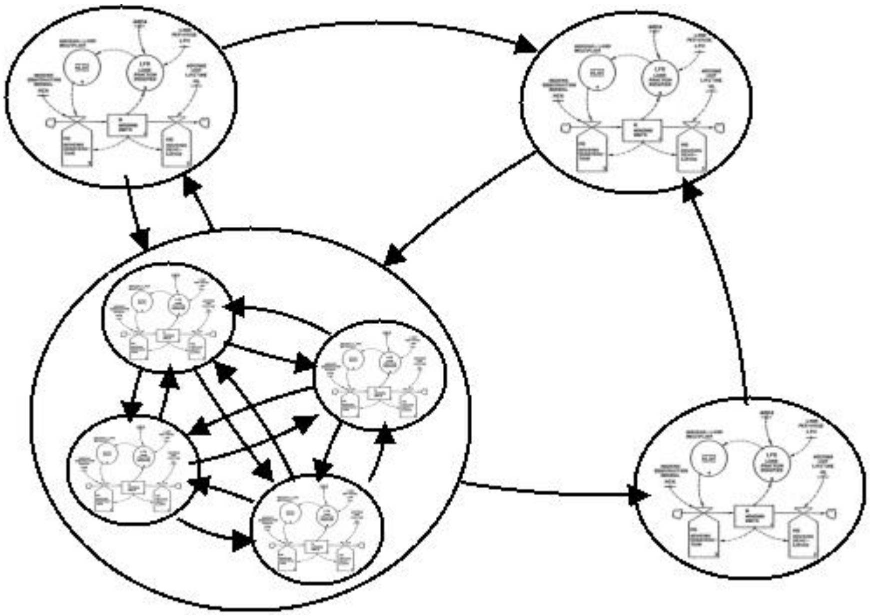
Networked System Dynamics



Networked System Dynamics



Self-Similar Networks



Networking Challenges

- Ensure that the separate blocks match the aggregate
- What is a full language of networked system dynamics?
- Can a model only apply to part of a network?
- How to ensure that missing models "fail gracefully"?

Computational Tools

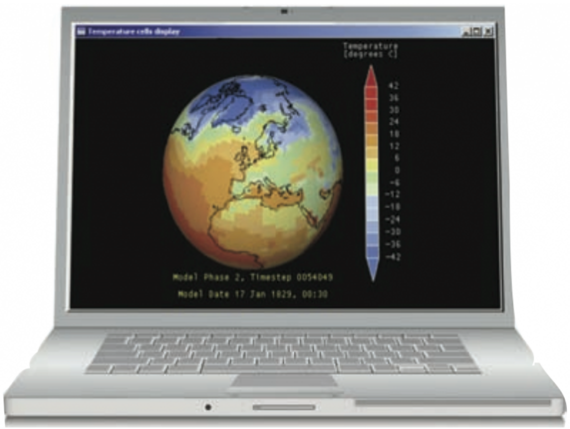
- Evaluate model performance (Barlas 1996)
- Identify driving feedback loops
- Identify tipping and leverage points
- Construct simplified models for communication
- System Regression: construct models from data

Integrating Data

- Calibration
- Validation
- Filling in missing models

We need a smart (context-aware and incomplete-welcoming) data library!

Open Interface



- For researchers: Testing partial models, Ask questions of the whole, Contributing models
- For policy-makers: Interact with the model, Visualize results, Outline scenarios
- For model: A large model, Many eyes

Smart Variables: Dimensions

- 3 vs. 3 [tonnes] vs. 1350487537 [seconds since Jan. 1, 1970]
- Dimensional analysis at the heart of science
- Automatic model checking, unit conversion

Smart Variables: Maps

"Maps" are dimension-aware functions in space-time, often tied to data streams (e.g., IRI tsvs, geotiffs). Maps of different resolutions can be manipulated transparently. Example:

```
GeographicMap<double>& degreeDayMelt =
   (degreeDayFactor + degreeDaySlope * elevation)
   * (snowCover / 100) * (surfaceTemp - ZERO_CELSIUS)
   * (surfaceTemp >= ZERO_CELSIUS);
```

- elevation is a static map at $1 km$ resolution
- surfaceTemp is a daily varying map at $.25^\circ$ resolution, read from the file 1 day at a time
- snowCover is a weekly varying map at $.33^\circ$ resolution, reconstructed for past years

Smart Variables: Relations

Variables can represent relationships or differential equations between other variables.

Example (the heat equations):

```
q = -k * Grad(u);
Diff(u) = (-1 / c_p * rho) * Div(q);
```

The equations themselves are saved within `q` and `Diff(u)`, so the model can be run.

Networked Equations Language

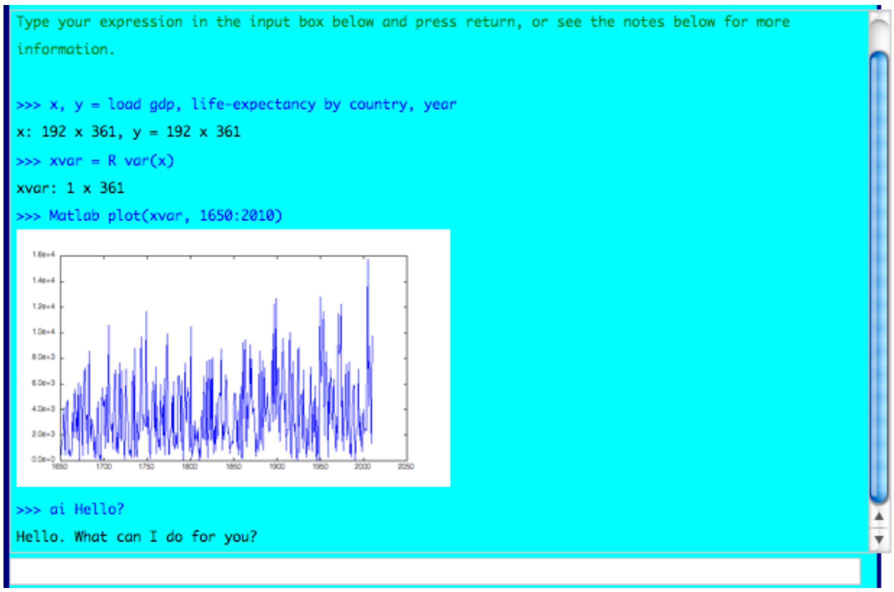
Custom **Modeling Language** combines a units-aware equation-like syntax with networks and GIS.

```
capacity = 1e10 [tons];
rate = 0.0077 [tons/year];
biomass = Stock(1e7 [tons]);
catches = TimeSeries("catches.tsv", [tons/year]);
biomass += rate * biomass *
  (1 - biomass / capacity) - catches;

print(biomass[0:100], "\t");
```

Toolbox

Transparently combine Matlab, R, shell scripting, Mathematica and other code.



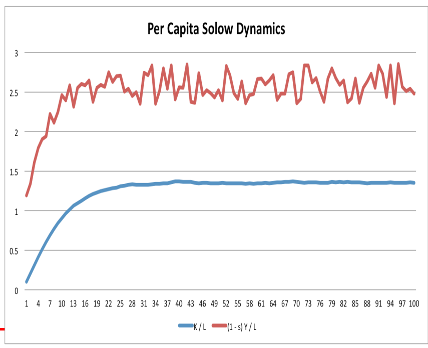
Extensions

- Memetic propagation of models
- Integration with climate models
- Importing Vensim models

Case Study: Networked Economics

Step 1: Reconstruct Solow Growth (with some random shocks):

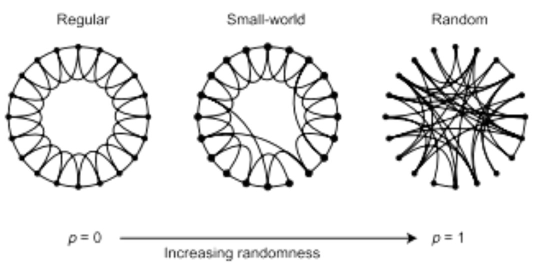
- $\frac{dL}{dt} = \lambda L(t)$
- $Y(t) = K(t)^{\alpha} L(t)^{1-\alpha} \varepsilon(t)$
- $\frac{dK}{dt} = sY(t) - \delta K(t)$



Case Study: Networked Economics

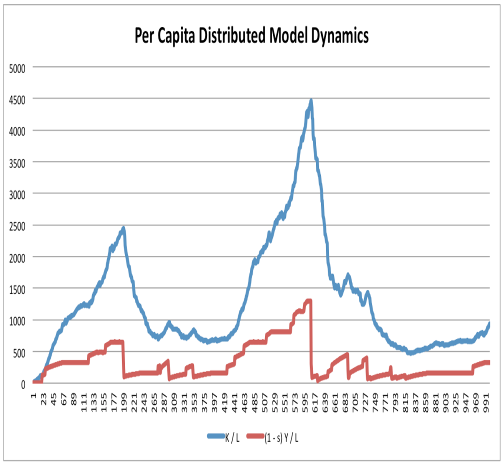
Step 2: Make a "distributed" analog to Solow growth:

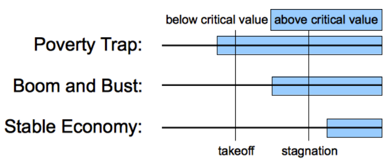
- Multiple firms, with individual capital stocks
- Separate growth and decay: $g[t]h1sY[t]$, $d[t]$ / $h1\delta K[t]$
- If $g[t] \geq d[t]$, growth: $K[t + 1] = K[t] + g[t]$
- If $g[t] < d[t]$, stagnation: $K[t + 1] = K[t]$
  - And probability of collapse, so expected value follows Solow
  - $K[t+1]h1K[t] + g[t] - d[t]/h1(1 - P(c))K[t] \implies P(c) = (d[t] - g[t])/K[t]$
- Firms can make connections to each other, which increase "technology" (specialization) factor



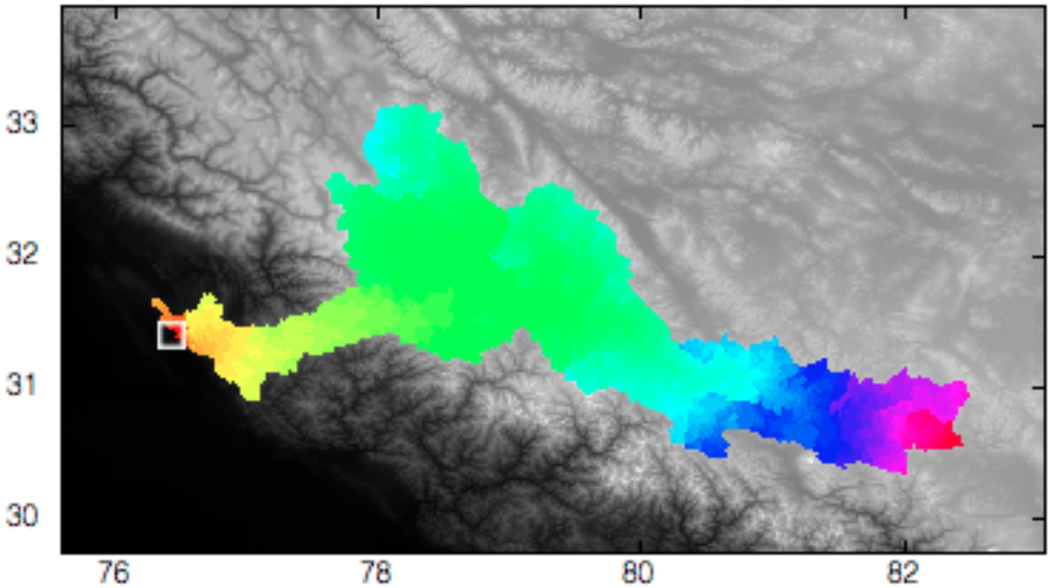
- But when collapse, connections severed, capital goes to 0

Case Study: Networked Economics

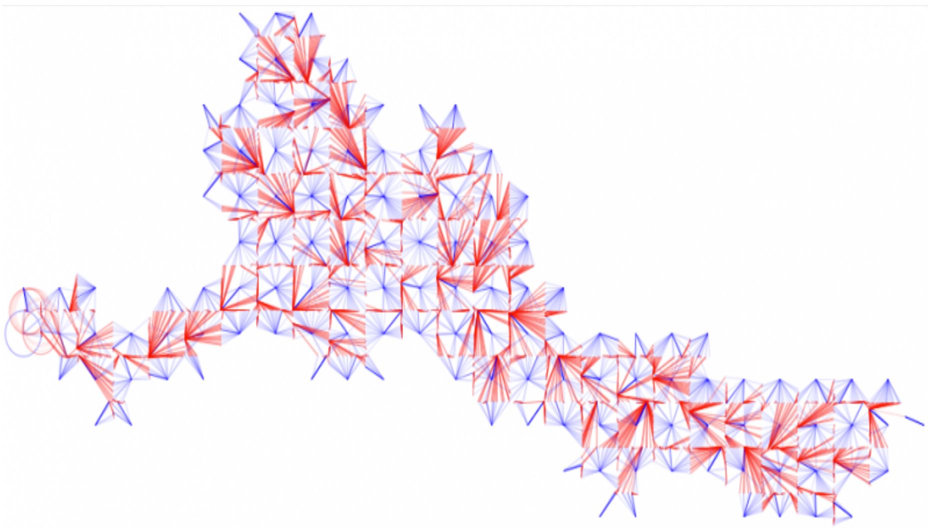




Case Study: Hydrological Modeling



Case Study: Hydrological Modeling



Model for Climate Behaviors

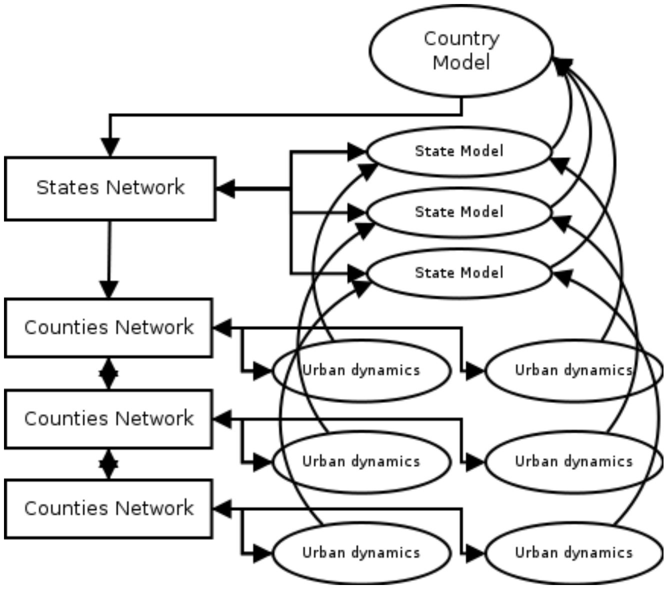
Overdetermined status-quo:

- Politicians won't make unpopular changes
- Businesses won't take action alone
- Consumers have great difficulty without support
- Carbon leakage
- Rebound effects

Model for Climate Behaviors

- Climate behaviors as aggregate activity
- Looking for leverage points
- Not trying to predict future states

Model for Climate Behaviors



(Self-similar Meadows 2004 regionally, Forrester 1971 for urban)

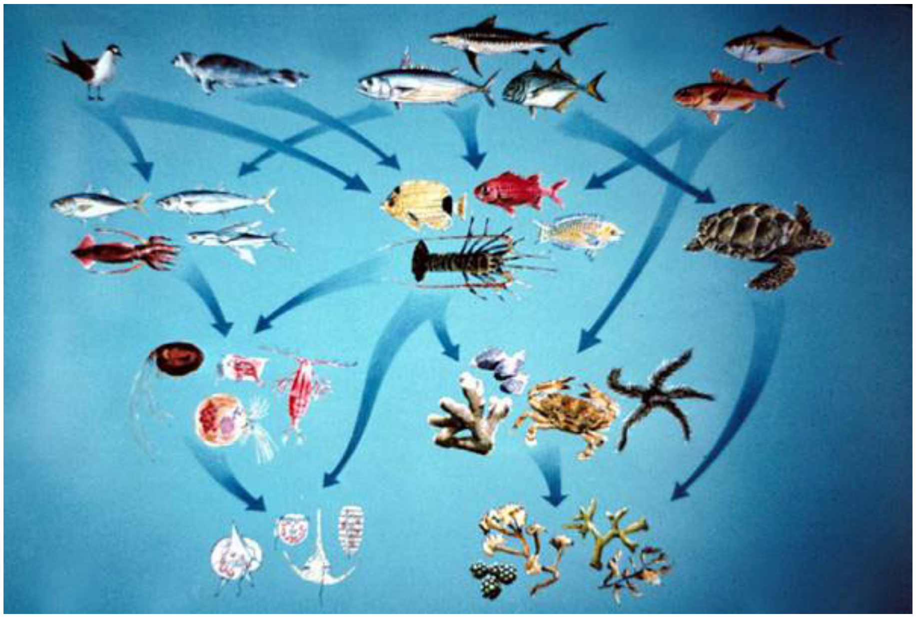
How Many Variables?

- World3/2000: 283
- System Dynamics National Model: 2000+
- Encyclopedia of World Problems and Human Potential: 56,135
    - environmental feedback loops: 2,675

Multimanaged Fisheries Project

- Collapsing fisheries, despite new management
- Perverse economic incentives
- Multiple scales of uncertainty
- Unintended policy consequences

Multimanaged Fisheries Project



Multimanaged Fisheries Project

- $g_t^i = r^i s_t^i \left(1 - \frac{s_t^i}{K_t^i}\right)$
- $K_t^i = \sum_{j \in q(i)} w^{ij} s_t^j$
- Nature: ecosystem and regional models
- Social: Fishing community, policy-makers, NGOs
- Plug-in different "fish" and "policy" modules
- Working with stakeholders

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