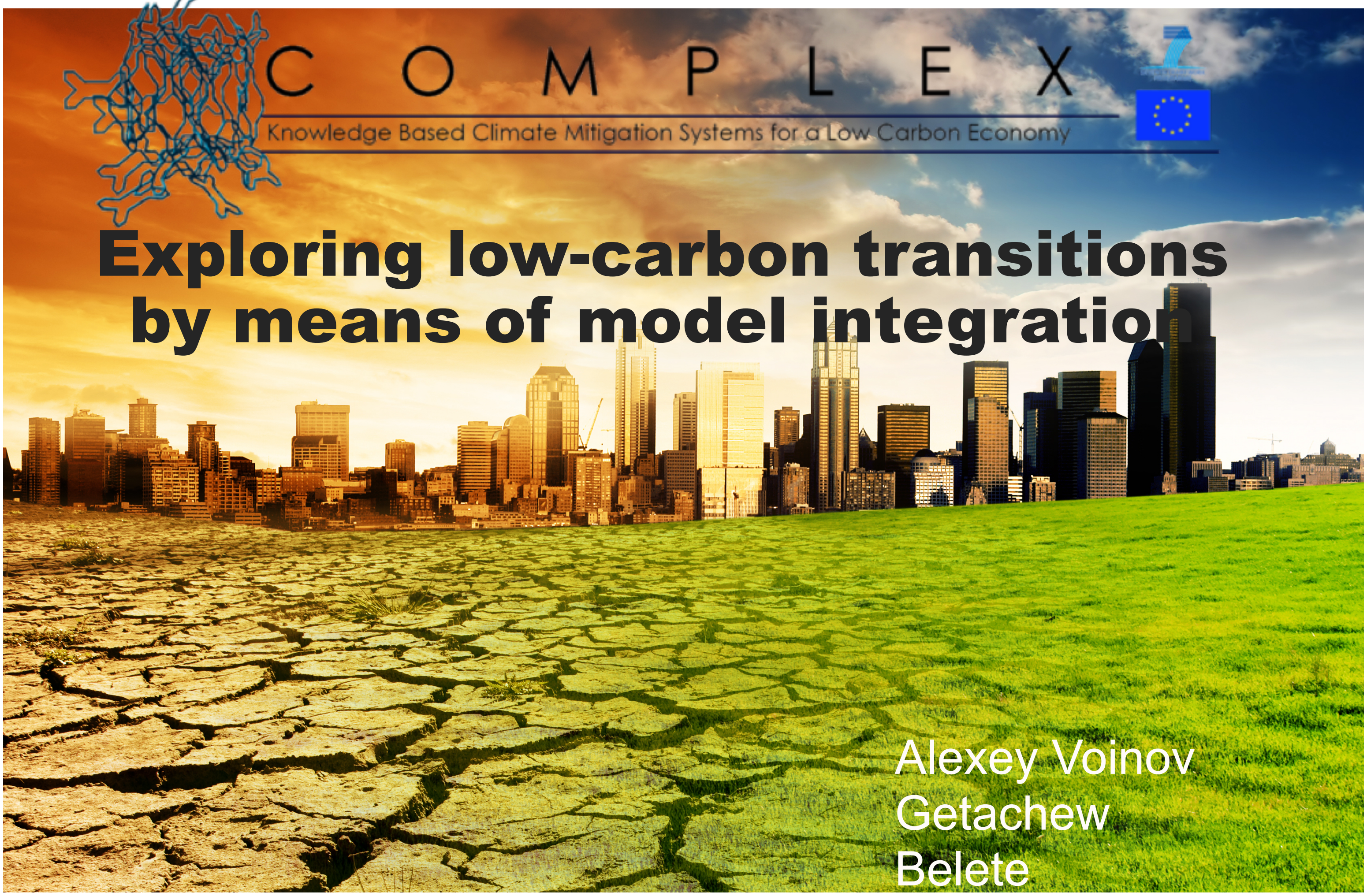


COMPLEX

Knowledge Based Climate Mitigation Systems for a Low Carbon Economy

Exploring low-carbon transitions by means of model integration

Alexey Voinov
Getachew Belete
Tatiana Filatova

The Triple Whammy of Today

- Climate change
- Peak oil
- Globalization

Globally

Climate change

Increased variability:
- floods
- droughts
- hurricanes
- heat waves, etc.

eed for adaptation
d mitigation

Need more energy

oil
er resources)

Alternative energy

The Triple Whammy of Today

- Climate change
- Peak oil
- Globalization

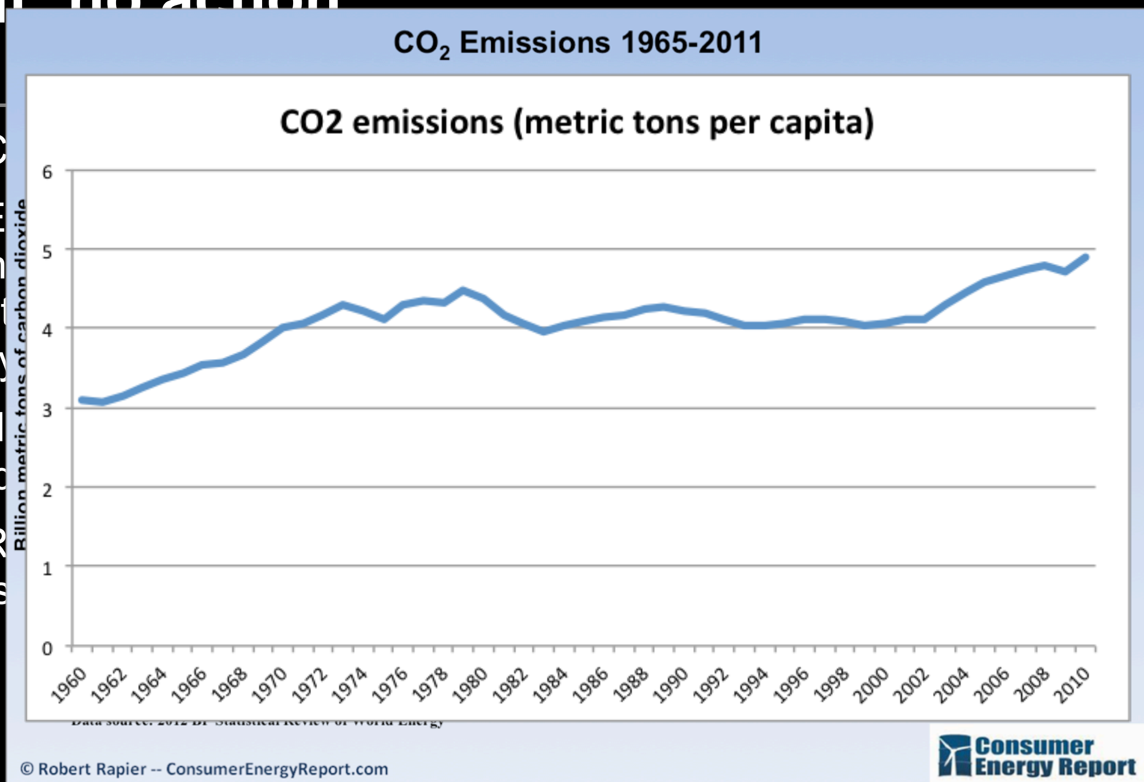
Need action

- Mitigation: stop emitting CO_2.
- Adaptation: get ready, prepare for new climatic conditions.
- We know what has to be done.

Danish police have arrested some 200 climate demonstrators
http://www.rnw.nl/english/article/danish-police-arrest-200-climate-protest

Result: no action

- 2009 - C
- 2010 - E
recession
30.6 gigat
previous y
- 2011 - **N**
2016, and
- 2012 - R
politicians



[1] IEA report: http://www.iea.org/index_info.asp?id=1959
[2] http://www.guardian.co.uk/environment/2011/may/29/carbon-emissions-nuclearpower
[3] World Bank - http://data.worldbank.org/indicator/EN.ATM.CO2E.PC/countries?display=graph

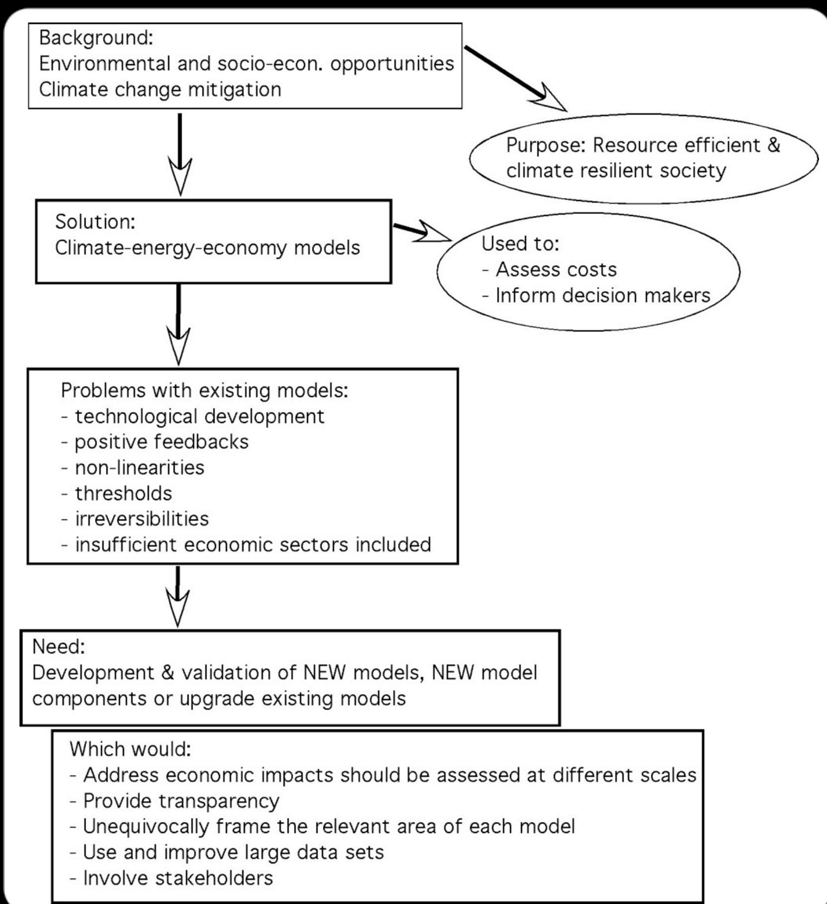
Problems with conventional economic models

- Developed for conditions of abundant natural resources
- Demand side economics
- Economic growth = main goal
- GDP = main indicator
- Systems at equilibrium, only marginal changes assumed
- No account for non-linear processes that result in regime shifts, bifurcations, and structural change

Problems with conventional economic models (cont.)

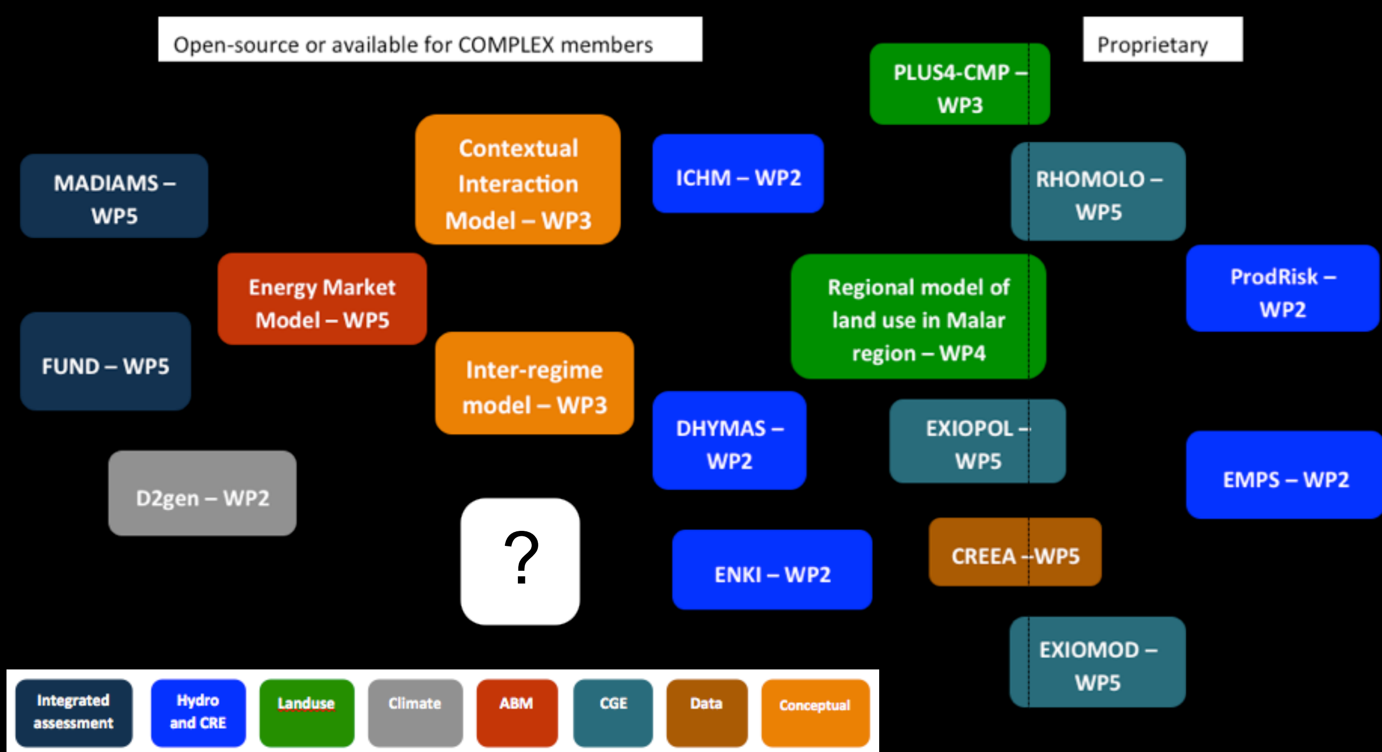
- Assuming spatially uniform systems (local, or regional, or global) with little attention to multi-scale hierarchical processes spanning various scales of space and complexity
- Simple assumptions about human behavior (rationality and homogeneity in preferences)
- No account for adaptation and social learning.

FP7: COMPLEX



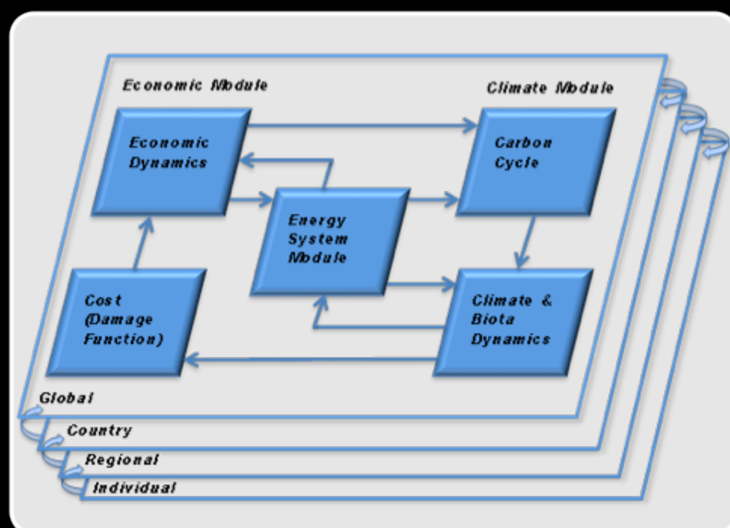
- Knowledge Based Climate Mitigation Systems for a Low Carbon Economy
- http://www.complex.ac.uk/

COMPLEX model space

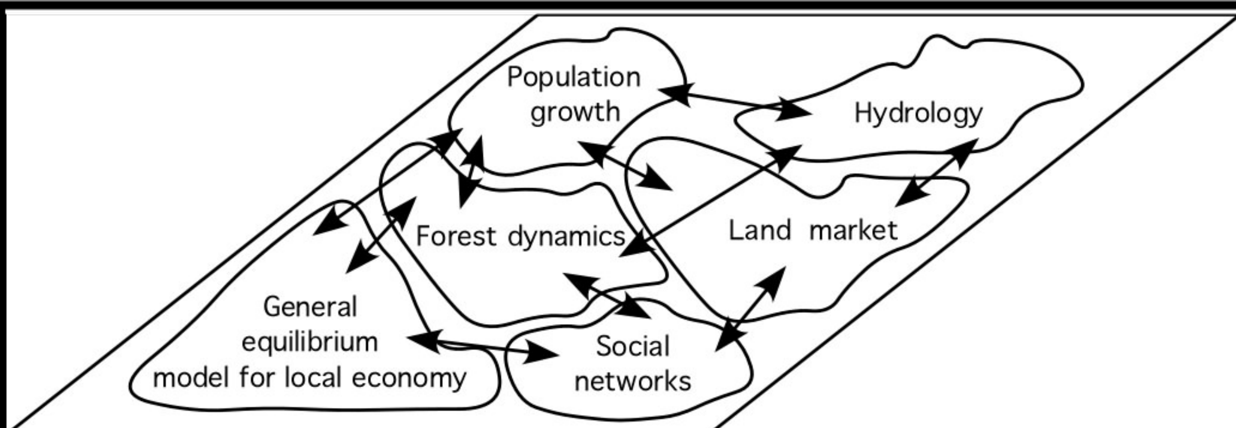


WP6: Integration of models

- Goal: build and analyze the hierarchy of models, which are developed and applied within this project and beyond
- Operate in a generalized ‘socio-environmental model space’ (empirical models, conceptual models, complex computer simulations, and data sets)
- Integrate qualitative models of stakeholder knowledge, opinion and scenarios
- Explore the different models along the complexity continuum to understand how information from more aggregated qualitative models can be transmitted to more elaborated and detailed quantitative simulations, and vice versa.



Integrated modeling



- "Integrated modeling is a systems analysis-based approach to environmental assessment. It includes a set of interdependent science based components (models, data, and assessment methods) that together form the basis for constructing an appropriate modeling system" *

* EPA (2008). White Paper on Integrated Modeling for Integrated Environmental Decision Making: http://www.epa.gov/crem/library/IM4IEDM_White_Paper_Final_(EPA100R08010).pdf

Problems (software angle)

- Written in different languages (conversion is time-consuming and error-prone)
- Code is not well-documented or easy to understand and reuse
- Models have different geometry, dimensionality (1D, 2D or 3D)
- Models may use different types of grids (rectangles, triangles, polygons)
- Each model has its own time loop or "clock"
- Mismatched numerical schemes (explicit vs. implicit).

Peckham, S. 2010. CSDMS Handbook of Concepts and Protocols: A Guide for Code Contributors. http://csdms.colorado.edu/wiki/Help:Tools_CSDMS_Handbook

Problems (modeling angle)

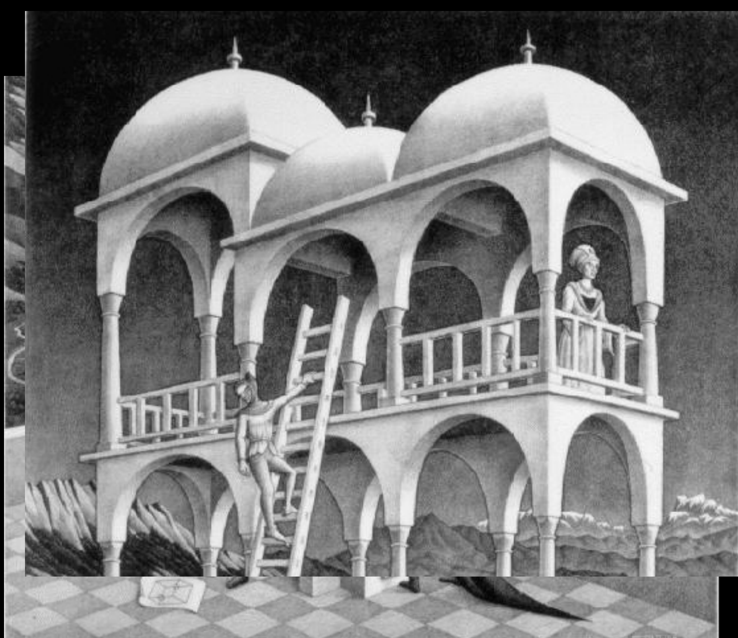
- Are models software?
- Components built by different teams, at different time, at different places, for different goals and purposes.
- Teams use different assumptions, languages and paradigms. Are they compatible?
- How do we calibrate integrated models?
- Complexity curse. Propagation of error and uncertainties.
- How do we communicate models and results?
- Modeling: art or science?

Integronsters

http://www.abcgallery.com/M/magritte/magritte57.html
Collective Invention. 1934. Oil on canvas. 73.5 x 97.5 cm.
Kunstsammlung Nordrhein-Westfalen, Düsseldorf, Germany.

A. Voinov, H.Shugart. 'Integronsters', integral and integrated modeling. (Environmental Modeling and Software: 39)

Integronsters: geometry



M.C. Escher
Belvedere 1958 Lithograph
http://www.mcescher.net/target4.html

The complexity curse

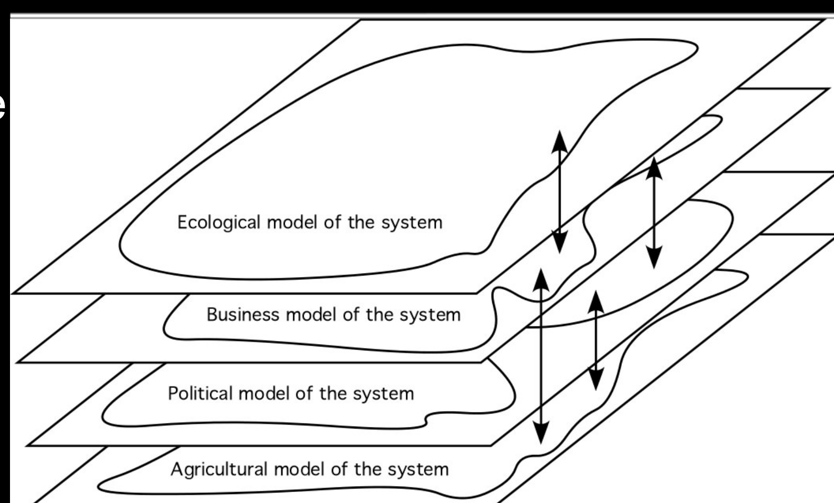
- With integration, models are becoming even more complex
- "A complex model may be more realistic yet at the same time more uncertain"*
- Complex models are hard to test
- Complex models are hard to communicate
- Complex models are hard to trust
- Complex models are hard to calibrate
- In environmental modeling calibration is a must.

* Oreskes, N., 2003. "The role of quantitative models in science," in Models in Ecosystem Science, Ed: C. D. Canham, J. J. Cole, and W. K. Lauenroth (Princeton: Princeton University Press), pp. 13-31.

Voinov, A., and C. Cerco. 2010. Model integration and the role of data. Environmental Modelling & Software 25, no. 8: 965-969.

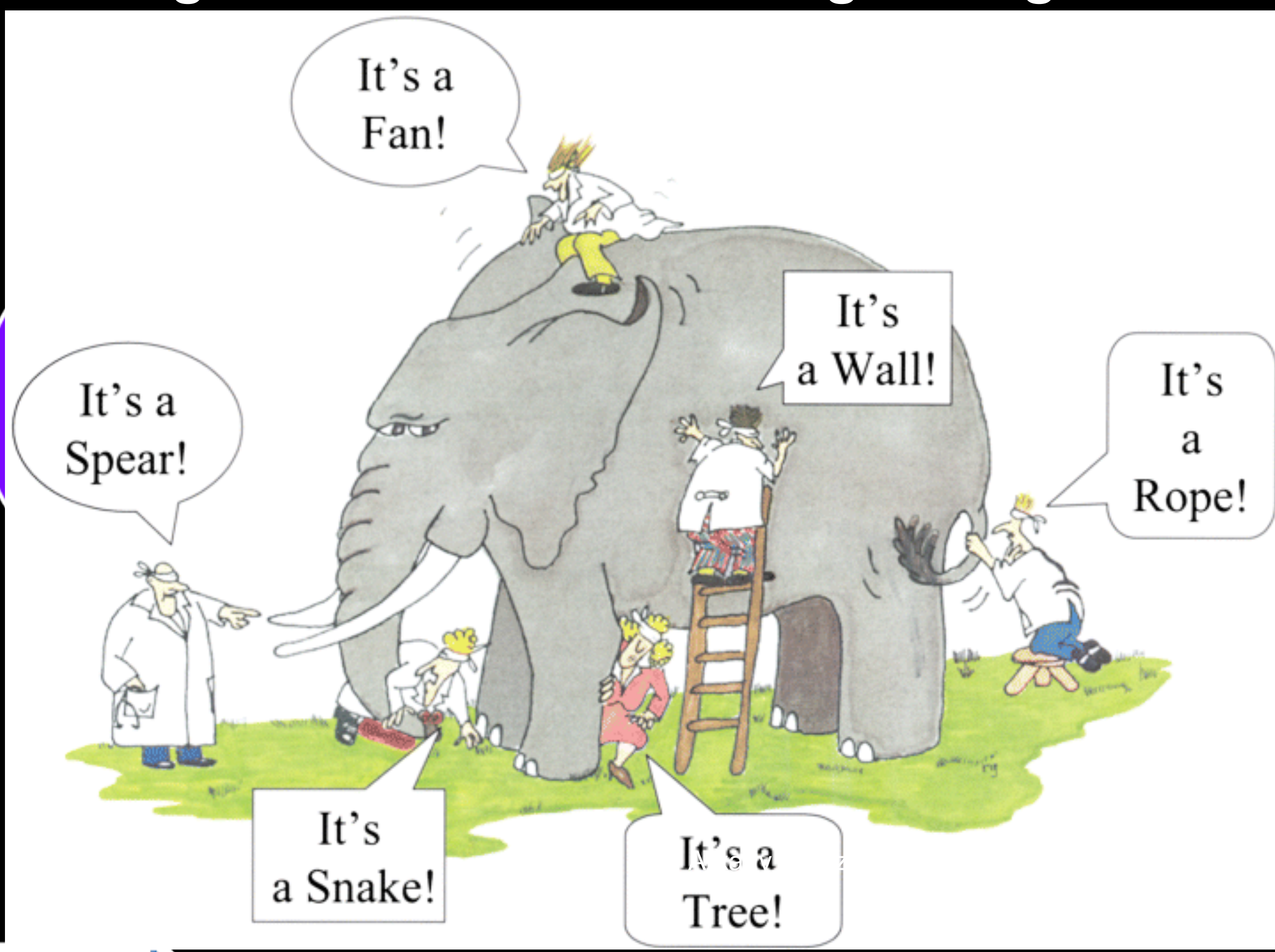
Integral modeling

- Built by the same team
- Uses the same modeling paradigm
- More interested in the overall system dynamics rather than in the detailed analysis of what can happen
- Has a disciplinary bias
- Integration of knowledge



Laniak, G., et al. Integrated Environmental Modeling: A Vision and Roadmap for the Future. (Environmental Modeling and Software: 39)

Integral models - Knowledge integration



First candidates for integration

- FUND - Integrated assessment model (IAM)
- EXIOMOD - Country level Computational General Equilibrium Model (CGE)
- RHOMOLO - NUTS2-region level CGE
- Agent-based model (energy market in NUTS2)
  - Supply-side: diffusion of low carbon energies (LCE) among heterogeneous firms
  - Demand-side: behavioral change at household level
- MADIAMS - System Dynamics (SD) model

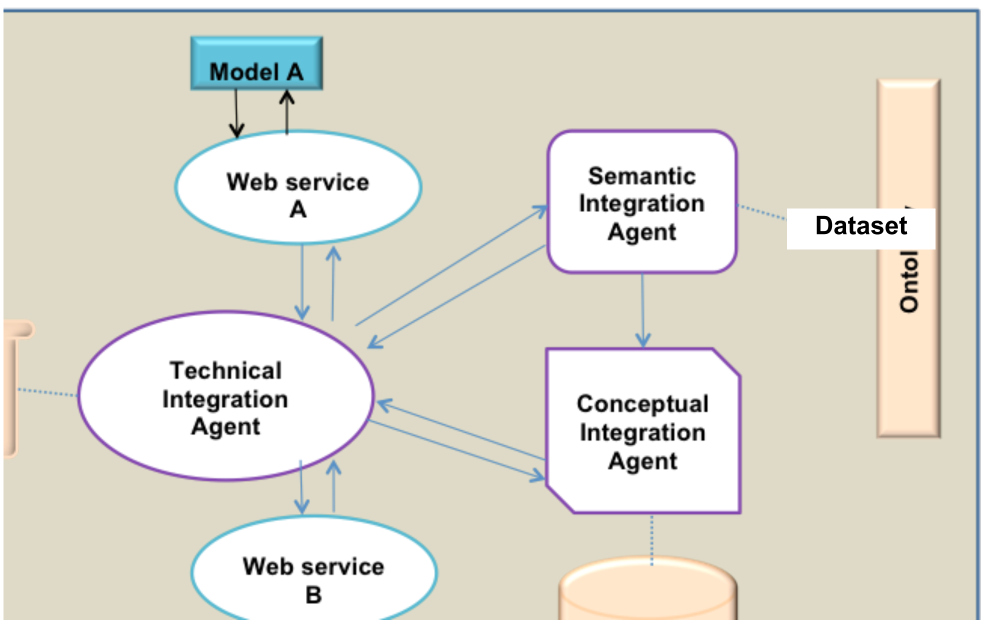
Technological imperative

- Make models more like software and modeling more like science, less like art;
- Focus on standards for data, model input and output, and interfaces. Adopt existing and develop new ones;
- Develop standards for model conceptualization, formalization, and scaling;
- Semantic technologies;
- Ontology engineering;
- Metadata, markup languages;
- Require good documentation, including examples and test cases;
- Ensure transparency, portability, and reusability, and include procedures for version control, bug tracking, regression testing, and release maintenance.

Meta-model standards

- Meta-model = a model of a model
- Hierarchical universal model documentation standard
- With the goal of facilitating
  - Reuse, replication, reproducibility
  - Comparison, evaluation
  - Integration, interface
  - Communication, publication, archiving
  - Links to stakeholders, mental models, etc.
- Communicating assumptions
- Challenges: acceptance, completeness, flexibility, inclusivity, transparency, ease of use, keywords

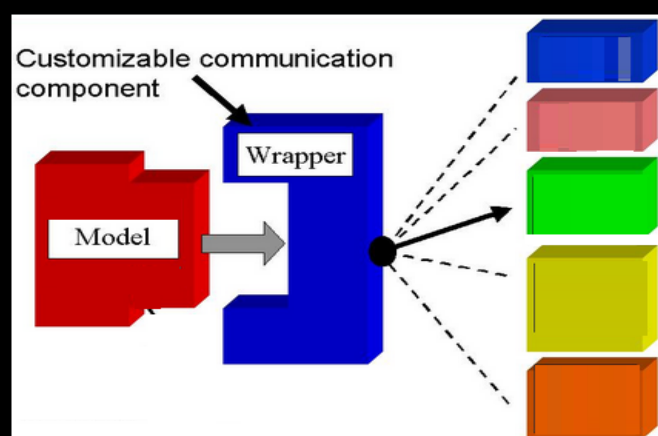
Model integration



Service oriented architecture

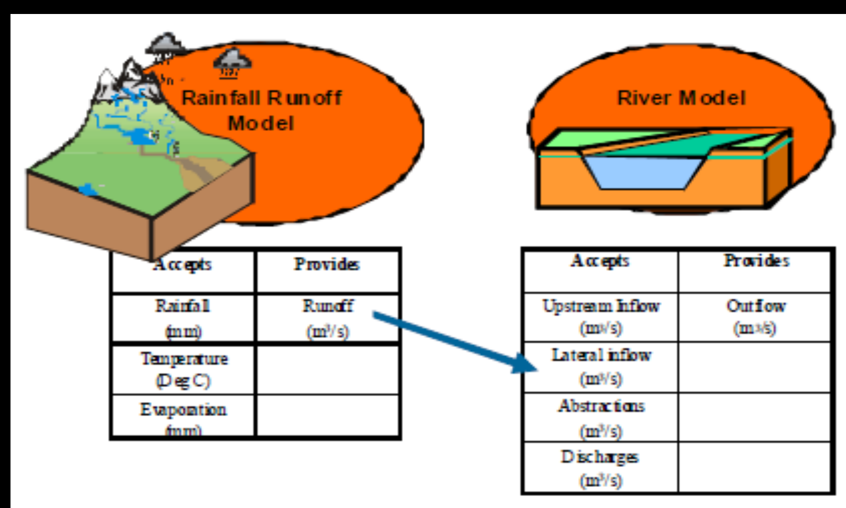
- Probably essential for multi-disciplinary linking
- A model is a composition of two major parts:
  - Interface that defines inputs, outputs and parameters of a model,
  - Core which implements the model processes and equations
- Wrapper is a program or script that sits between a model and the model space
- A CSDMS wrapper?

Developing wrappers as a calling interface to existing code to assure language interoperability and to convert existing models into interoperable components.



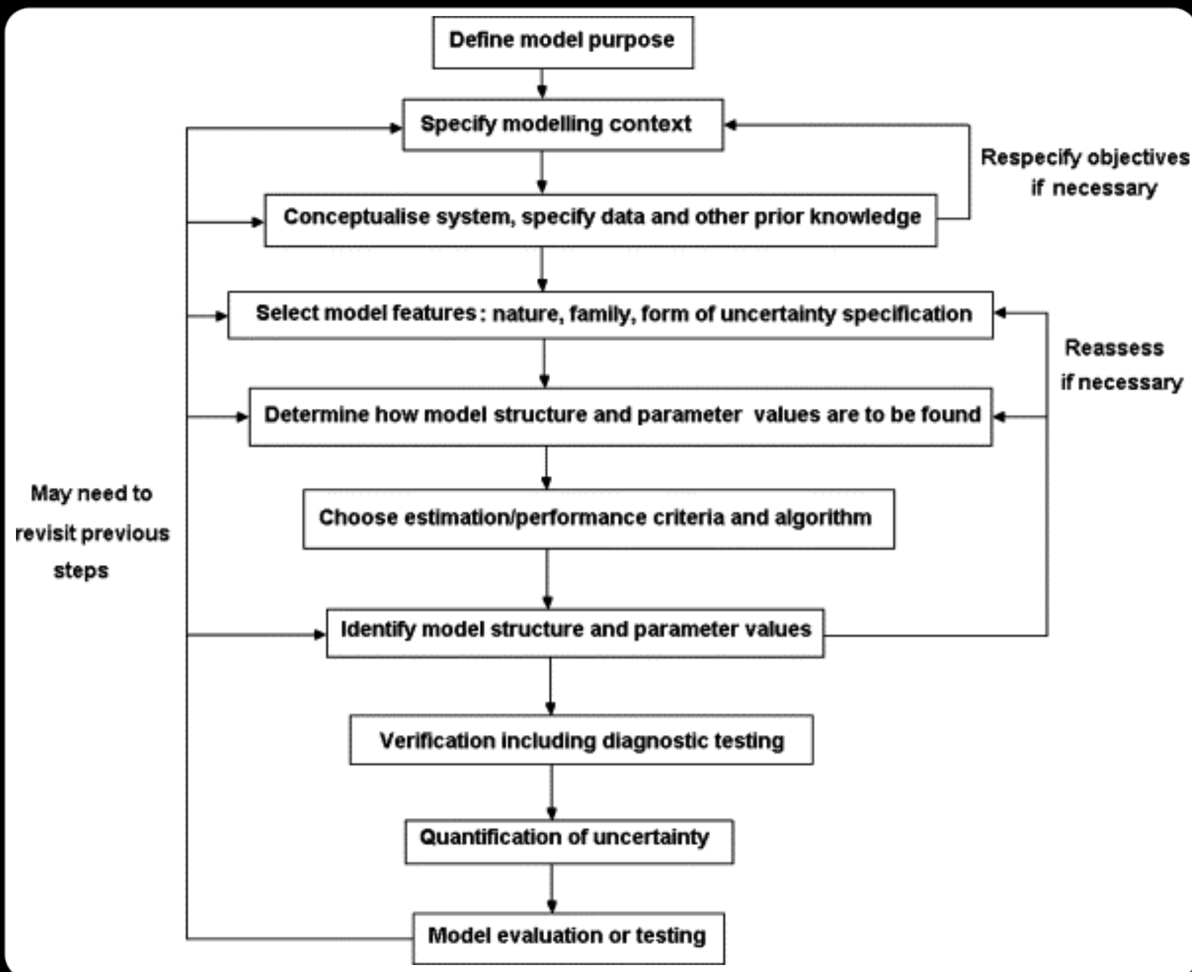
Semantic mediation

- Ontology enables model integrators to communicate independent of implementation type, modeling framework, and programming language.
- Ontology for integrating multidisciplinary models
  - cover all participating concepts in those disciplines ?
  - what is the scope?



Social imperative

- Collaborative, open source research and modeling
- Modeling with stakeholders, integrating stakeholders models
- Toolboxes and model repositories for participatory modeling
- Integrating conceptual models, integrating numbers with ideas
- Visualizations and perceptions - learn from media and commerce
- Put the ‘user’ upfront, understand their needs and behavior



A.J. Jakeman, R.A. Letcher, J.P. Norton, 2006. Ten iterative steps in development and evaluation of environmental models, Environmental Modelling & Software, Volume 21, Issue 5, p. 602-614

Role of applied science (modeling)

Seven commandments for a socio-environmental modelling agenda

- Stop pretending that **applied** science and models are always objective and value neutral – they are not. Acknowledge implicit decisions and assumptions, document and communicate them.
- Make it clear that scientific values are based on facts and knowledge, which makes them transparent.
- Scientific values are not set in stone – they can change when new knowledge becomes available.
- Engage with stakeholders to define problems together, discuss values and implicit decisions within the modelling process.

Seven commandments for a socio-environmental modelling agenda (cont.)

- Engage with policy makers to help them understand the solutions and make sure they act accordingly. Use the modelling process to engage the public in debates about our future.
- Treat modelling as a process, which evolves and adapts to accommodate new knowledge and data, which does not have a final solution because there are no final solutions for open systems.
- Turn around the weapons used in mass media and advertisement. Present and deliver results in ways that can influence personal choices, and bring them in agreement with planetary boundaries.

Voinov et al., 2014. Values in socio-environmental modelling: Persuasion for action or excuse for inaction. *Environmental Modelling & Software*: 53

The process

Voinov et al., 2014. Values in socio-environmental modelling: Persuasion for action or excuse for inaction. *Environmental Modelling & Software*: 53

theguardian

News | Sport | Comment | Culture | Business | Money | Life & style

Comment is free

Scientists have a moral obligation to take action on climate change

Calling on all scientists to refrain from public advocacy and leadership is wrong. We are in a global crisis, and the scientific fraternity has an ethical obligation to act

Dan Cass
theguardian.com, Thursday 15 August 2013 05.50 BST
Jump to comments (…)

'We need some scientists to show social leadership, not just scientific leadership'. Photograph: Getty/Joe Raedle

Conclusions

- Think beyond your domain and discipline
- Beware of integronsters
- Think about calibration. Two-way coupling can be problematic for calibration
- Integral models may be more appropriate than integrated models
- How to scale up and down across structural complexity?
- How to engage and provide for stakeholders?
- Time and space scales

Conclusions (cont.)

- Are we creating too much complexity and is too much complexity causing too much uncertainty?
- The stakeholder (user, customer) is the ultimate judge of the 'goodness' of your model (system)
- Stakeholders have to be 'educated' to appreciate your model (system)
- Integration of knowledge, integrating conceptual, mental models

C O M P L E X