Working Group on Environmental Modeling: activities in 2014

The IESP Working Group on Environmental Modeling held a founding get-together in the first week of December 2013 (December 2-6). In that week the Working Group had daily interactions (the international members of the working group were all present) and held a day-long Mini-symposium (on Dec. 4th). The goals of the Working Group were defined and agreed upon and a program for 2014 was decided on consisting of a full-scale workshop in September. In this report the constitution of the working group is presented and an account is given of the workshop.

Members of the Working Group
Arndt Bode (TUM), Carmen de Jong (Savoy Univ.), Patrick Dewilde (TUM-IAS), Kristina Schwarzer (TUM), Claudia Klüppelberg (TUM), Michael Ghil (UCLA), Slav Hermanowicz (UCB), Wolfram Mauser (LMU), Miriam Mehl (Uni Stuttgart), Annette Menzel (TUM-IAS), Peter Wilderer (TUM), Chairman: W. Mauser (LMU)

Focus of the Working Group
“Modeling” consists of the derivation of formal laws that apply to a reasonably well circumscribed domain of interest, with the purpose of allowing formal or numerical representation of the theory and the creation of predictive power. It is often an essential component in a design methodology, allowing designers or policy makers to make justified policy choices.

An important issue in almost any modeling endeavor is the reduction to a model that is as simple as can possibly be without a major loss of accuracy (an issue often called “Occam’s razor”). In the case of very complex systems, like the Earth system, such justified reduction is essential, if only to allow computability. Model reduction is only possible within a well-circumscribed context. A global climate model, for instance, can be constructed with far fewer parameters than a model that accurately predicts local climate evolution, while still being accurate on a global scale. Modeling the full environment and its interaction with human societies is by far more complex an issue, as it has to combine interacting domains and agents of different nature. Results are often intended to serve decision-making processes and may require high resolution at the regional scale.

There are many types of “Environmental Sub-Systems” on Earth. Overall, these are best characterized by their main characteristics: atmosphere, marine and terrestrial water, soil, cryosphere, ecosystems and biodiversity, the techno-urban sphere. Many actions that are highly relevant to society have environmental impacts, whose effects have to be estimated properly, such as greenhouse gas emissions, changed land use, clear cutting of forests, drainage of wetlands, over-exploitation of vitally important resources, the introduction of new species as well as species extinction.

Of special importance are relations and interactions between diverse systems and how they can be made instrumental in each. When modeling environmental systems we often exclude their interactions with social systems e.g. through physical interactions like harvesting but also through regulations, product demand, etc. In this context the main unresolved issues are how
best to characterize formally (within the context of models) resilience, recovery, redundancy and robustness of socio-environmental systems. This requires attention to interactions and their adequate modeling which eventually means to explore how models can talk to each other?

Therefore, a primary focus of the working group will be the underlying communality of modeling principles and methods and not any specific choice of system, of course with a keen interest of how they apply to specific cases.

An illustrative, but non-exhaustive list of environmental topics of interest to the group includes global and regional climate dynamics, hydrology and land-surface processes, and managed and unmanaged ecosystems. On the methodological side, such a list includes several areas of mathematics, statistics and computing, as well as a strong interest for the interfaces among the above-mentioned environmental topics, and for the crucial multi-scale aspect they all possess.

The Workshop on Environmental Modeling, 8. – 12. September 2014, Garching

Aim of the Workshop

The central aim of the workshop is cross-fertilization of expertise in the pretty large area of environmental modeling, by providing the opportunity to top experts, their collaborators and their students to exchange views on how to best approach modeling problems, develop mathematical, statistical, numerical and computing methods for them, profit from experience in other modeling domains and avoid pitfalls.

For maximal profit to the participants, the workshop is divided in two parts. The first two days are intended to be didactical, aiming at bringing non-expert in key fields up to date, while the last three days aim at being exploratory, proposing new approaches, with time for discussions on critical questions.

Besides experts in environmental modeling, also experts in relevant areas of general expertise will participate, to enhance utility and motivation for all concerned.

Workshop Schedule:

**Monday, Sept. 8**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tr>
<td>Morning</td>
<td>Registration</td>
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<tr>
<td>12:30</td>
<td>Welcome Coffee</td>
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<tr>
<td>14:00-17:30</td>
<td><strong>Spin-up I</strong>&lt;br&gt;Dynamical Systems and Tipping Points in the Climate System&lt;br&gt;<em>Prof. Michael Ghil</em></td>
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<td>15:00</td>
<td>Coffee Break</td>
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<td>17:30</td>
<td><strong>Bistability and Noise Induced Transitions</strong>&lt;br&gt;<em>Prof. Raman I. Sujith</em></td>
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<td><strong>On Reconciling Models</strong>&lt;br&gt;<em>Prof. Patrick Dewilde</em></td>
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<td><strong>Discussions</strong></td>
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Tuesday, Sept. 9
09:00-12:30  Spin-up II  
Chaos and Non-linear System Dynamics  
Prof. Slav Hermanowicz  
10:00  Coffee Break  
Design Considerations for Crossdisciplinary Spatial Models  
Prof. Wolfram Mauser  
Extracting Information from a Measurement  
Vineeth Nair  
Discussions  
12:30  Lunch  
14:00-17:00  Excursion Leibniz Supercomputing Centre, TUM Campus Garching  
incl. visit of Supermuc and the Virtual Reality & Visualizing Centre  
Prof. Arndt Bode / Rainer Oesmann

Wednesday, Sept. 10
09:00-12:30  Dynamic System Modeling  
Welcome and Introducing the Workshop  
Prof. Wolfram Mauser  
Self-Sustaining Oscillations as a Loss of Multifractality  
Prof. Raman I. Sujith  
11:00  Coffee Break  
Combining Different Worlds – A Scalable Multi-Coupling Approach  
Prof. Miriam Mehl  
Discussions  
12:30  Lunch  
14:00-17:30  Characterizing Environments  
Hyperresolution Data and Tools to Assess Land Surface Water Flows at the Global Domain  
Prof. Bernhard Lehner  
15:00  Coffee Break  
From Model-World to Reality: Interpreting the IPCC Probability Assignments  
Dr. Erica L. Thompson  
Statistical Methods for Detecting and Attributing Climate Changes  
Prof. Philippe Naveau  
Discussions  
18:30  Reception and Conference Dinner

Thursday, Sept. 11
09:00-12:30  Statistical Model Principles  
Statistical Analysis of Climate Extremes using Extreme Value Theory  
Prof. Philippe Naveau  
10:00  Coffee Break  
Intermittent Bursts and Precursors to Self-Sustained Oscillations  
Vineeth Nair  
Intermittency as a Cause of Weak Ergodicity Breaking  
Prof. Holger Kantz  
Discussions
12:30 Lunch
14:00-17:30 Cross Disciplinary Environmental Modeling
Modeling Environment Beyond Physics
Prof. Wolfram Mauser
15:00 Coffee Break
Large-Scale Modelling of Personal Networks in the Diffusion of Socio-Technical Innovations
Prof. Andreas Ernst
Restoration of Ecosystem of the Colorado River: Evidence from System Dynamics Theory
Prof. Slav Hermanowicz
Discussions

Friday, Sept. 12
09:00-12:30 Large Scale Modeling Environments
Boolean Delay Equations: A Simple Way of Looking at Complex Systems
Prof. Michael Ghil
10:00 Coffee Break
Large Scale Earthquake Simulation on Supercomputing Platforms
Prof. Michael Bader
Final Discussion and Further Activities of the Workshop

Participants

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<tr>
<th>Title</th>
<th>First Name</th>
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<td>Prof.</td>
<td>Almut</td>
<td>Arneth</td>
<td>Karlsruhe Institute of Technology</td>
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<td>Dr.</td>
<td>Klaus</td>
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<td>Prof.</td>
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<td>University of Kassel</td>
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<td>Frank</td>
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<td>Michael</td>
<td>Ghil</td>
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<td>Gschlößl</td>
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<td>Max Planck Institute for the Physics of Complex Systems</td>
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<td>Axel Kasparek</td>
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<td>Ulrich Kaul</td>
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<td>Laboratoire des Sciences du Climat et l'Environnement (LSCE) CNRS</td>
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<td>Prof. Dianne Newell</td>
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Feed-back

A questionnaire was handed out to all participants at the last session and a discussion was held on what would be new useful and interesting activities of the working group. The questionnaire was returned by 15 participants, here are the comments and reactions:

Question 1: Would you appreciate the IESP Working Group to organize further activities in 2015 and would you participate in them.

Answers: all 'yes'

Question 2: What kind of activities would carry your preference (e.g., a workshop, a one day symposium, tutorials, etc...)

Answers: workshops (11), tutorials (5), one day symposium (3); further suggestions: a summer school (1); workshop Environmental Modeling II – Socio-environmental Systems; a workshop with a similar structure to this one—perhaps with even more time devoted to the spin-ups; both modes worked well this week, with enough time for discussions.

Question 3: What would be an adequate time frame for such activities?

Answers: like it was done, it was perfect; up to 2 days, max. 3 days; 2-3 days; 2 weeks because it would allow for people to start working together; one-to-two days; September or December; 2-3 days; 2-3 days; 3-4 days, I like the suggestion of including the Rachel Carson Centre and the Deutsches Museum; for me personally, 2-3 days are best to work out for such a workshop. But with the 5 days and the option to participate only a few days it is a very good concept too; 3 days; one week; 6, 9 or 12 months from now; probably one week is needed to cover many viewpoints, but many scientists are hard to capture for that time.

Question 4: Are there topics you have missed in the presentations so far? Which?

Answers: ways of bringing theory and practice together, knowledge transfer on a larger scale; the point of view of a politician; researchers working on instrumental and historical data, or proxies data; researchers working on machine learning and on environmental data; introductory words/slides on environmental models, a rap up and state of the art on environmental models; bridges between theory and application; socio-ecological response to climate change, modeling adaptation; non-equilibrium thermodynamics in environmental systems as possible underlying governing principle (Zehe/Kleidon), Maximum entropy production/Maximum entropy dissipation; contributions from social scientists; increasing policy relevance of environmental modeled topics, environmental politics on climate; indications for wrong policies, paleoclimate modeling and understanding, identification of drivers; flood risk management, decision making strategies; talks on environmental tipping points; needs more “system identification”.

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<tr>
<th>Dr.</th>
<th>Erica L. Thompson</th>
<th>London School of Economics and Political Science</th>
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<td>Prof.</td>
<td>Bruce Ulrich</td>
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<td>Peter Wilderer</td>
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Question 5: do you have suggestions for themes for further activities?

Answers: set up “Themes”; creating concrete projects on an operational basis, invite theorists + operationalists/practicians; support for meetings and start-up funding for proposals resulting from new connections within IESP; looking closer at interaction mechanisms between humans and natural systems; modeling socio-ecological systems response to climate change (alt.: modeling adaptation); how can experiment advance understanding of complex systems (e.g., in biology, ecology etc...) Are there limits? vulnerability and exposure vs. complexity in a system; hydrological modeling and hydraulic modeling using specific software and case studies. Climate change and flood risk management; prediction of tipping points; examples beyond equilibrium, characteristic of trajectories, dynamics of electrical power grid supplies.

Question 6: we appreciate any further comments that may guide our initiatives further.

 Answers: get more groups at LMU involved in particular in Meteorology (Prof. G.C. Craig, dr. Tijana Janjic, dr. Bernhard Mayer (DLR) and Prof. Roland Potthast (chief of R&D at DWD); annotate questions with names (who has a solution?), group questions (e.g., modeling, computational methods and tools, fundamental application-driven questions); try to involve more young researchers in order to spur a new generation; make it clear whether the activity is meant for students or for senior researchers only; thank you for the arrangements this year: the room was very comfortable, the snacks and dinner excellent and the size of the group was ideal; disseminate results to the public?; the next meeting should aim to establish one or two groups, where scientists would collaborate on projects. For e.g., I’d like to collaborate with people working on prediction of tipping points.

Research questions collected during the discussions following the presentations

As one of the goals of the workshop was to explore unresolved issues and define new research questions, each presentation and discussion was followed by an inventory of issues raised. Here is a list of the research questions collected:

1. Find bifurcations and proximity of tipping points with simpler models (background: an equal amount of time is spent on resolution as on finding the bifurcation).
2. What is the quality of the chaotic characteristics gleaned from the data: are they enough to base decisions on them?
3. More demonstrations to show that environmental systems can be described by simple non-linear dynamical systems.
4. How to cover the gap from theory to applications?
5. What has to be improved in environmental models? (1) Understanding humans; (2) robustness; (3) consistency.
6. How do environmental systems relate to tipping points and their analysis?
7. What are good model validity ranges? +60% to -40%?
8. Replace concentrations by emissions.
9. The dimensionality analysis in environmental systems.
10. Diagnostic procedures.
11. Multi-scale earth system modeling.
12. Replace pixels by vectors.
13. How to generate synthetic data consistent with (few) real data observations.
14. How to put valid scientific language to policy makers so that they can appreciate the impact of uncertainty and the level of validity.
15. Scenario generation rather than prediction as a model goal.
16. Replace expensive, distribution or correlation based methods by easy to gauge extreme event estimates.
17. Go back to the past (use proxies!) and generate much more data (try to predict the past more accurately.)
18. What are the links between extreme event statistical methods and the modeling of climate? Linking up modeling and statistics.
19. Model selection and validation for climate modeling.
20. What is the link between non-stationarity and weak ergodicity?
21. Identify and integrate strategies (Traits vs. species, plant development, modeling plants as productive units, best economic models.)
22. Identify and integrate actors in combined human-environment models (economic drive, culture)
23. What are models good for? Is big data analysis enough?
24. Validation of simple models for human behavior.
25. How to couple models for human behavior as intelligent agents with other infrastructural models?
26. How to derive and monitor policies on dynamic system data analysis?
27. How to marry dynamic system models with stochastic models?
28. Can we learn from environmental systems using dynamic model identification?

Conclusions and plans for the future

The final discussion in the workshop was on future. The wrap up of this discussion lead to the following recommendations:

- team up with an existing series of research conferences (suggestions: Gordon Research Conferences, Activities of the Rachel Carson Centre)
- support collaborations, create interfaces
- let the next workshop be more productive (hands-on) than reproductive
- select a few concrete questions to be worked on by the participants (suggestions: how to model floods?, how to react when there is a catastrophe?, how to link with authorities?)
- select one or two themes and a theme coordinator
- define a clear goal for the next meeting: what it should accomplish
- concentrate on attracting people who are active, involve younger people (Ph.D.’s) via poster presentations.

As safe conclusions the following may be proposed:

- the workshop has been of very high quality and has been very much appreciated by the participants, both for its content and its format;
- as main results of the workshops intensive discussions between specialists of various disciplines and an inventory of new development and research issues may be counted. In particular, the aim of cross-fertilization between central disciplines has been achieved;
- an inventory of possibilities for the future has been made, it will be up to the Board to decide on which new activities would be best. All participants without exception have expressed their interest in continuing the cooperation.

Further information

can be found on the IESP website, including power-point accounts of most presentations.