C2SM-NEWSLETTER

Center for Climate Systems Modeling
No. 5, March 2011

Vegetation models gain in stature

Harald Bugmann – C2SM member

Institute of Terrestrial Ecosystems, ETH Zurich

About 25 years ago, the biosphere in climate models was little more than "green slime" characterized by a few parameters, without much internal structure, let alone dynamics. Similarly, models simulating ecosystem dynamics at small (i.e., at the hectare or even square meter) scales either sacrificed process resolution for structural complexity, or vice versa. Where do we stand today? Has the ever increasing computing power led to commensurate advances in our ability to simulate biological dynamics?

The first individual-based model of mixed-species terrestrial ecosystems was developed in 1968/69 as a collaboration between Yale University and the IBM Research Laboratories in New York, clearly indicating that its implementation was at the frontier of computer science. As a consequence, models that were developed in that period for mixed forest stands typically could not afford high process resolution, whereas most "physiological" models of gas exchange were only applicable for simple stands (i.e., single-species, even-aged stands).

Over the years, this situation has changed dramatically. Today, many local-scale vegetation models feature a highly detailed temporal resolution (seconds to minutes) and high structural complexity, e.g., distinguishing all kinds of plant organs among which carbon and nutrients are shifted around.

>> page 2

C2SM Center for Climate Systems Modeling

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

>>

Similarly, at the scale of the biosphere, current Dynamic Global Vegetation Models (DGVMs) typically embody a mechanistic treatment of photosynthesis and respiration, they simulate the coupled fluxes of carbon and water through the soil-plant-atmosphere continuum, and they increasingly consider land management practices. Particularly the latter represents a tremendous advancement compared to the situation a few years ago when the biosphere was treated in global models as if it was untouched by humans.

Pivotal for these developments was certainly the availability of increasing computing power, high-level programming languages and their skillful use. Thus, the facilities and support offered by C2SM is instrumental in promoting not only the further development of atmospheric models, but also land surface models. Yet, I would argue that ultimately it is not computing power that is limiting our ability to accurately represent biospheric dynamics at virtually any scale, no matter how computationally demanding simulations of the biosphere in coupled Earth System Models or the simulation of adaptive ecosystem management practices at the local to regional scale may be (or may become). Why do I think so?

On the one hand, as Reto Knutti has argued in a recent Editorial of this Newsletter, simpler models usually yield more insights than complicated ones – in addition to the fact that complicated models tend to lead to artifacts in their behavior because of multiple feedback loops whose interactions are hard to understand.

One the other hand, after more than 20 years in ecological modeling and a number of sometimes shocking, but always truly revealing experiences in our efforts, I am inclined to think that mainstream ecological research sometimes neglects certain processes altogether, or may be focusing on relatively unimportant processes.

For example, recent studies suggest that enhanced plant growth as induced by CO_2 fertilization is likely to be accompanied by reduced plant longevity (or, in managed systems, shorter rotation periods), such that there may be no net carbon gain at the ecosystem scale and in the long term, contrary to findings from short-term experiments and in stark contrast to the results from virtually all current DGVMs, which do not include any longevity effects of CO_2. Instead, a lot of effort is spent in DGVMs on modeling the plant-scale carbon balance based on a mechanistic treatment of photosynthesis and respiration. Ongoing studies in our group suggest that, rather surprisingly, these processes contribute little to simulated net primary productivity, because other processes in DGVMs are dwarfing the signal coming from these highly "mechanistic" parts of the models. Another example is the fact that in current research little focus is placed on better understanding allocation patterns of trees (i.e., the distribution and investment of carbon by plants to cope with unfavorable environmental conditions, such as drought), although allocation is highly likely to be of primary importance for determining the behavior of vegetation in the face of climate change.

Thus, the computing power is there to do sophisticated modeling and simulation studies; the models have a stature (i.e., structural and process resolution) that renders them truly interesting for detailed analyses and further scrutiny regarding the relative importance of processes currently incorporated in the models; and if we are able to identify those processes that truly determine the biological response at the scale of interest, all we have to do is to implement them correctly. What a fun piece of work in front of us!

PS: A few years ago, I would have been afraid of writing such an editorial because it may convey the notion that biospheric modeling is still in its infancy, given all the uncertainties outlined above. However, several discussions with colleagues from atmospheric sciences have convinced me that the problems are similar across the various disciplines – only the names of the specific processes are different, of course.

» www.c2sm.ethz.ch

Feedback from the C2SM Scientific Advisory Board

At its first meeting, the C2SM Scientific Advisory Board reviewed positively the Center's activities and achievements and gave encouraging suggestions for it's future development.

The C2SM Scientific Advisory Board (SAB) – composed of Prof. Huw C. Davies (Prof. emeritus ETH Zurich, SAB chairman), Dr. David Bresch (Swiss Re), Dr. Albert Klein Tank (KNMI), Prof. John Mitchell (UK Met Office), Dr. Christoph Ritz (ProClim), and Prof. Bjorn Stevens (MPI for Meteorology) – held its first meeting in November 2010. The SAB has the mandate to advise the Center on strategic matters and in particular to provide feedback regarding the achievements as well as the planned developments. *>> page 3*

>>

The purpose of the first meeting was to get acquainted with the C2SM past, current and future development. On the first day, the C2SM structure, aims, activities and achievements were presented to the SAB. The C2SM SAB and the Steering Committee had also the opportunity to meet with the ETH Vice-President for Research Prof. Roland Siegward and Dr. Sonja Negovetic to discuss about the fundamental needs and underlying rationales for having a competence center such as C2SM anchored at ETH. On the second day, the presentations and discussions between the SAB and the Steering Committee focused on the future development of the Center and in particular on the science proposals which were planned to take place in the frame of the C2SM phase-2 preparation.

As part of its feedback, the SAB reported that "*the Center has during its first phase of development made significant progress on several fronts*", through, for example, the establishment of inter-disciplinary research and cooperative activity between core partners and the development of a solid technological/logistical platform for facilitating modeling activities. In order to help the Center to "*build upon, realize, and exploit its enormous potential*", the SAB has encouraged the Steering Committee to "*develop an ambitious long-term strategy that articulates clearly its vision and distinctiveness*" and highlighted that "*its [C2SM's] continued ability to function at the highest academic level will require sustained funding support*". Finally, the SAB has provided constructive comments on the planned research proposals.

In summary, the meeting with the SAB has proven to be extremely useful. Following recommendations by the SAB, the C2SM Steering Committee has engaged in the development of a long-term vision and is currently seeking inputs from the Center's members about, for example, the areas in which they think the C2SM core activities could be enhanced and/or developed.

It is also worth noting that since the SAB meeting in November, two scientific proposals have been submitted, including a SNF Sinergia "CarboCount CH: Quantifying greenhouse gas fluxes and their sensitivity to climate variations: A case study in Central Europe and Switzerland" (lead by D. Brunner, Empa, submitted 15 January 2011) and a "Collaborative, Highly Interdisciplinary Research Projects" (CHIRP) ETH project "Modeling the water cycle in a changing climate – a multiscale interaction challenge" (lead by N. Gruber, ETH, submitted on 1 March 2011). **(ib)**

» www.c2sm.ethz.ch/people/sab

Data retrieval for the next IPCC assessment report

C2SM coordinates the retrieval of data from the Coupled Model Intercomparison Project Phase 5 (CMIP5) for the use at the Institute for Atmospheric and Climate Science, and possibly within the Swiss climate community. We are also prepared to retrieve further datasets, such as the upcoming CORDEX regional climate simulations.

After first positive experiences with retrieving and updating simulation results from the ENSEMBLES project, C2SM is ready to retrieve further datasets.

Slowly, the data from the simulations for the upcoming IPCC assessment report (AR5) are becoming available. With an overall volume in the order of Petabytes, this poses a serious challenge both to the data providers as to the users. C2SM is coordinating the data retrieval for its members, motivated by four goals:

- Avoid multiple downloads, saving bandwidth and local disk space.
- Assure efficient updates of new datasets or versions
- Collect and coordinate issues concerning data quality
- Foster research productivity by transferring technical tasks from the research groups to C2SM

So far, the Center is retrieving data for the Institute for Atmospheric and Climate Science at ETH Zurich, focusing on daily and monthly data. However, anyone within the C2SM community is invited to submit a wish list of simulations and variable to download. You can follow the progress of this project on our wiki, where we will also document further details.

In addition to the CMIP5 dataset, C2SM is also prepared to retrieve further datasets that are of interest for several research groups within the community. One prominent examples is the COordinated Regional climate Downscaling Experiment (CORDEX). If you know of other upcoming datasets, please do not hesitate to contact us. **(tc)**

» www.c2sm.ethz.ch/services/
» wiki.c2sm.ethz.ch/Wiki/CMIP5

PhD project “Towards kilometer-scale climate modeling”

Cloud-resolving numerical models are a powerful tool to shed light on the physics and dynamics of atmospheric convection, which primarily acts at the kilometer scale, but influences even the global scale. The computational resources improve steadily and appear not to be the limiting factor to apply such models. But are we ready yet to employ cloud-resolving models for improved climate predictions at regional scales?

Due to computational constraints, current global and regional climate models (GCMs and RCMs) operate at grid spacings of 20-300 km. Many important processes can thus not explicitly be resolved and are parameterized instead, which may have some severe implications in terms of weather forecast and projections of future climate. Specific difficulties are well known for land-surface processes, moist convection, or turbulence and boundary layer processes over complex topography. These difficulties feed back to the whole climate system. In fact, much of the uncertainty about the sensitivity of the climate system with respect to greenhouse gas forcing is known to be associated with the treatment of moist convection and clouds.

The goal of the PhD project of Wolfgang Langhans (group of Christoph Schär) is thus to replace parameterizations of moist convection in RCMs by an explicit representation, and to refine other parameterizations using a higher spatial resolution of at least ~2 km. In close collaboration with MeteoSwiss an updated version of the COSMO-CLM model is used with a focus on moist convection over the Alpine topography.

First simulations conducted at such high resolution revealed several issues. First, significant energy is contained in motions at scales close to the grid-scale, since there is no energy gap between resolved and unresolved motions. Ultimately, small-scale numerical and turbulent diffusion thus gain in relevance at these scales. Numerical diffusion conceptually aims at the removal of grid-scale energy of numerical origin. This grid-scale filter highly influences the growth of convection, particularly if applied to buoyancy and horizontal velocity components (see Figure). The implication is that numerical diffusion has to be used with caution at such resolutions to avoid an unnecessarily strong influence on the development of moist convection.

Second, although such resolutions are fine enough to resolve grid-scale instabilities, convective plumes still remain under-resolved. Thus, even finer mesh-sizes improve the realism of simulated convective plumes and flow properties are expected to converge. Aspects concerning the convergence of real-case simulations at kilometer-scales are currently studied.

Finally, month-long real-case simulations have been conducted and a verification against ground-based and remote sensing data is expected to enhance our understanding of the interaction of thermally-driven circulations and the initiation of moist convection within the Alpine region. The simulated summer period is marked by strong radiative heating so that thermally driven flows develop along mountain slopes and valleys. First results from this validation demonstrate the feasibility of cloud-resolving simulations to capture the mean diurnal cycles of thermally-driven pressure gradients, valley winds, and precipitation. In contrast, a convection-parameterizing model fails in reproducing the observed characteristics.

Despite significant improvements compared to convection-parameterizing models, future work is still necessary to address some of the issues of cloud-resolving models, such as the parameterization of turbulent diffusion, the transition between shallow and deep convection, and the gained benefit of even further increased resolutions. **(wl)**

» www.c2sm.ethz.ch/research/phd/kilometer-scale

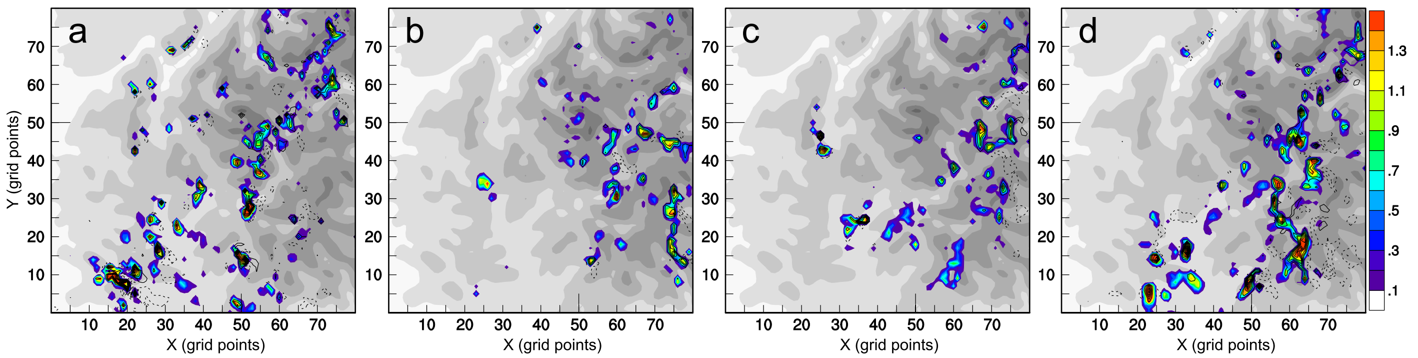

Illustration of the high-resolution nature of simulated atmospheric convection over South-Eastern France in a subdomain covering 180x180 km at 2.2 km resolution. Topography is shown in gray (intervall 600 m). The colors indicate cloud water (g/kg) associated with convective clouds, and the black contours the associated distribution of vertical velocity (interval 1 m/s) at 4 km altitude. The four panels show results at 1600 UTC 17 July 2006 obtained from simulations using different formulations of numerical diffusion. Note the significant differences in the intensity of the convective plumes.

Agenda

Kolloquium – IAC ETH Zurich

until May 2011 (Mondays, 16:15)
ETH Zentrum, Zürich

» www.iac.ethz.ch/events/?type=a

Monday Seminars – Climate & Environmental Physics

until June 2011 (Mondays, 16:15)
University Bern, Sidlerstrasse 5, Bern

» www.climate.unibe.ch/?L1=courses&L2=seminar

12th Swiss Global Change Day

Tuesday, 19 April 2011
Freies Gymnasium, Beaulieustr. 55, Bern

» events.scnat.ch/proclim/index_en.php?id=15220

Climate Economics and Law Conference

Thursday-Friday, 16-17 June 2011
University of Bern, Bern

» www.nccr-climate.unibe.ch/conferences/climate_economics_law/

Updates & Further events

» www.c2sm.ethz.ch/news

Imprint

Center for Climate Systems Modeling (C2SM)
ETH Zurich
Universitätstrasse 16
8092 Zurich
www.c2sm.ethz.ch

Editor

Center for Climate Systems Modeling (C2SM)
Thierry Corti, ETH Zurich
Phone: +41 44 658 87 06
tcorti@env.ethz.ch

Authors

Isabelle Bey (ib)
Thierry Corti (tc)
Wolfgang Langhans (wl)

Credits

Cover: Nasa/courtesy of nasaimages.org
Page 4: Wolfgang Langhans

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie
MeteoSchweiz

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Volkswirtschafts-
departement EVD
Forschungsanstalt
Agroscope Reckenholz-Tänikon ART

EMPA
Materials Science & Technology