Workshop on

Multi-Model Integration

supported by FP7-funded project COMPLEX

http://owsgip.itc.utwente.nl/projects/complex/

IIASA, Schlossplatz 1, A-2361, Laxenburg, Austria

13-14 June 2016

WODAK ROOM

Background

Composite social-environmental systems are at the focus of systems analysis nowadays. Due to their high complexity, a plethora of models has been put forward to represent the dynamics of these systems. In particular, a few models attempting to represent the same phenomenon may differ because of initial and boundary conditions, parametric and structural uncertainty and, therefore, produce different results.

Climate science is the field, which pioneered recognition of the need and challenge of model inter-comparison and integration. CMIP – Coupled Model Inter-comparison Project under the World Climate Research Programme (WCRP) – was one of the first attempts to standardize and consolidate the study of coupled atmosphere-ocean general circulation models across different groups in the systematic fashion. Later projects, such as CORDEX-MIP, Water-MIP, ISI-MIP, Ag-MIP etc., extend the model inter-comparison to other dimensions relevant to integrated assessment. For example, the ISI-MIP project focuses on providing cross-sectoral global impact assessments,

Water-MIP focuses on inter-comparisons of land-surface-hydrology models and global hydrology models, and so on.

Generally, it is believed that using knowledge from several available models representing the same phenomenon should improve our confidence in the overall results, which they produce; this bringing together knowledge from model ensembles is referred to as "integration of models". IPCC adopted the practice of using multiple models for deriving future projections of climate[1].

Several methods have been proposed to "integrate" (or "average") alternative models, among which computing a multi-model mean with equal weights is the simplest. Many researchers argue for using weights representing our experience and/or expectations regarding model skill, which relates to a more general issue of model validation. The raise of computational power and accumulation of historical data of appropriate quality have triggered the use of past-experience-based Bayesian techniques. One of the more recent advances is the idea of deriving weights based on the pseudo out-of-sample predictive ability of models. Despite considerable progress in particular applications, development of well-justified tools for integration of the results of alternative models into a consolidated picture remains a strong challenge in systems analysis of complex social-environmental systems.

Goals

The workshop is intended to bring together experts **in the methodology and applications of "integration" of alternative models in different fields** for complex social-environmental systems. The workshop will specifically focus on

1) State-of-the-art in different communities in what concerns using multiple models, as well as constructing and working with multi-model ensembles; examples of existing multi-model ensembles and open questions; comparison of advantages and shortcomings of current practices;
2) Statistical methods and techniques that have been used to "integrate" alternative models, examples of their applications in different fields; comparison of their power and limitations;
3) Concepts of model validation, specifically focusing on multi-model ensembles;
4) Challenges and good practices related to communicating uncertainty and its sources to end-users and decision makers due to multiplicity of models and their stochastic nature.

[1] See Chapter 9, 5th Assessment Report and the report from the IPCC Expert Meeting on Assessing and Combining Multi Model Climate Projections National Center for Atmospheric Research
Boulder, Colorado, USA, 25-27 January 2010, https://www.ipcc-wg1.unibe.ch/guidancepaper/IPCC_EM_MME_GoodPracticeGuidancePaper.pdf

Monday 13 June 2016

10:30	Bus transfer from **Hotel Jagdhof** to IIASA
11:00-11:15	**Welcome** *Pavel Kabat:* **About IIASA and why such a workshop at IIASA** *Nick Winder:* **About COMPLEX project** *Elena Rovenskaya:* **What do we want to achieve in this meeting**
	Session 1: How do we use multi-model ensembles in different applications? (Part 1) Chair: *Anna Shchiptsova*
	In this session there will be presented and discussed the state-of-the-art in different communities in what concerns using multiple models, including constructing and working with multi-model ensembles; examples of existing multi-model ensembles and open questions; comparison of advantages and shortcomings of current practices.
11:15-11:35	*Wolfgang Cramer:* **Do's and don't's in biospheric model inter-comparisons** During the 1990s, growing computer power created the possibility to run spatially distributed global models of biospheric processes over tens of thousands of grid cells. The richness of the resulting output implied the opportunity and also the need for quantitative model inter-comparisons. Experience from these learning-by-doing exercises demonstrated the critical importance of, i) careful design for the setup of model simulations including the selection of driving data, ii) the development of new and suitable methods for visual and numerical inspection of multi-dimensional outputs, and iii) the identification of useful target conclusions from the inter-comparison. Model averaging, despite being demanded from users, was not found to be of much use. Instead, the identification of outliers generated directly useful results that helped to distinguish between models and/or to improve them. Future multi-model analyses of earth system components could benefit from some of the experiences being made and thereby deliver more robust findings.
11:35-11:55	*Claas Teichmann:* **Using model ensembles for climate services** Due to changing climate conditions in many regions of the world, adaptation measures need to be implemented in order to maintain living conditions. In order to develop optimal adaptation measures, robust climate information is needed. Climate services aim at transforming climate-related data into customized products to support adaptation. Climate services are based, among others, on observational data as well as on global and regional climate projections. Projected climate data is associated with different types of uncertainties. A general procedure is presented about how to assess uncertainties of potential future climate evolutions with climate model experiments, and how to derive robust climate change information. This talk will show some examples of how ensembles of climate model simulations are used in practice.
11:55-12:15	*Sonia Seneviratne:* **Reducing changes in regional extremes: Integrating global CO2 mitigation and regional climate engineering**

12:15-12:35	*Joeri Rogelj:* **Current approaches for multi-model knowledge integration from Integrated Assessment Model (IAM)** Integrated Assessment Models (IAM) combine insights from various fields — such as economics and the geophysical, biological, social, and engineering sciences — for the systematic analysis of possible future development pathways. Scenarios developed by IAM thus describe — under an internally consistent set of assumptions — how the future could potentially unfold, what the impact of specific policies might be, or what costs and benefits they would entail. They are widely being used to inform international climate policy, and more recently their use is extending towards also including other societal objectives, like the UN sustainable development goals. IAMs are diverse in their structure and underlying assumptions and scenarios under nominally similar assumptions can therefore differ to an important degree. Often, results from multiple IAM frameworks are therefore combined in order to identify robust features of the modelled results. Approaches for doing this are still in their infancy. In this presentation, I provide an overview of current dominant approaches and of first attempts to improve the scientific robustness of IAM results integration.
12:35-13:15	**Sandwich lunch**
13:15-13:35	*Valentina Krysanova*: **Hydrological model intercomparison: are we approaching robust climate impact projections?** An overview of regional-scale hydrological model intercomparison for twelve large river basins worldwide performed in the framework of ISI-MIP (Inter-Sectoral Impact Model Intercomparison Project) will be presented. Nine regional-scale hydrological models were included in the study, and some of the outputs were compared with those from nine global-scale hydrological models. Selected results related to model evaluation, projection of impacts, uncertainty assessment and cross-scale comparison of model evaluation and impacts will be shown, and related to the robustness of impact projections.
13:35-13:55	*Simon Gosling:* **Dual-scale hydrological model ensemble projections of the effect of 1,2 and 3°C global warming** In this talk I will present results from simulations of two multi-model ensembles of impact models – one ensemble comprising a set of catchment-scale hydrological models and another comprising a set of global hydrological models. The impact model ensembles provide projections of the impact of climate change on river flows in eight catchments across the globe when the models that comprise each ensemble are forced with global warming scenarios of 1, 2 and 3°C above pre-industrial, as represented by an ensemble of global climate models. I will discuss the similarities between the two impact model ensembles and the challenges posed by using two large impact model ensembles in climate change impact assessment.
13:55-14:15	*Peter Burek, Yoshihide Wada & Yusuke Satoh:* **Asian water futures – a multi scenario, multi model and multi-criteria assessment** A better understanding of the current and future sustainability of water resources availability and use is essential for the implementation of the recently agreed Sustainable Development Goals (SDGs). Long-term/efficient strategies for coping with current and potential future water-related challenges like water scarcity are urgently required. Although Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) were developed for the impact assessment of climate change, very few assessments have yet combined the SSPs with the RCPs to assess future water resources.

	The International Institute for Applied Systems Analysis (IIASA) Water Programme under the Water Futures and Solutions Initiative (WFaS) developed a set of water scenarios consistent with RCPs and SSPs, and applied the latest climate changes scenarios. Here this study focuses on results for Asian countries for the period 2010-2050.
14:15-14:35	*Jacob Schewe:* **Fish and MIPs – making sense of heterogeneous model ensembles** I will present some initial analysis of an ensemble of marine ecosystem and fisheries models within ISIMIP, which may serve as an illustration of a very heterogeneous set of models that makes integration challenging. Depending on time I'll also present some applications using the ISIMIP global hydrological model ensemble.
14:35-14:45	**Coffee break**
	Session 2: Advances in methods to integrate models within ensembles (Part 1) Chair: *Elena Rovenskaya*
14:45-15:05	*Jesus Crespo Cuaresma:* **What to do when you don't know what to do: Bayesian approaches to model uncertainty in the social sciences** Modern Bayesian model averaging methods, which are used to address specification uncertainty in econometrics, are presented and discussed. Bayesian statistics provides a natural setting to integrate out model uncertainty in social science applications, where often several competing theoretical frameworks are available.
15:05-15:25	*Konrad Bogner:* **The optimal combination of different hydro-meteorological forecast systems. Applications to hydro-meteorology** The main objective of a probabilistic flood forecasting system is the reliable and sharp estimation of the predictive uncertainty, which contains all information available about the forecast variable given the history of observed and predicted values. In order to increase the quality of model simulations and forecasts post-processing methods have been developed for the removal of bias and dispersion errors and to derive predictive uncertainties. Therefore various statistical methodologies have been tested and applied to hydrological model simulations/forecasts. The degree of complexity of the analysed technologies varies from simplified autoregressive approaches to methodologies utilizing different modern statistical tools like Wavelet Transformations and Quantile Regression methods. The possible improvements of these error correction methods have been analysed by the use of different verification measures like the Continuous Ranked Probability Score (CRPS). Nowadays a great variety of different Numerical Weather Predictions (NWPs), the driving forces of the stream-flow forecasts, are available with different resolutions and forecast horizons and encompassing deterministic forecasts and Ensemble Prediction Systems (EPSs). In order to calibrate these multi model forecasts, optimal weights for the combination of the forecasts have to be estimated according to their previous forecast quality. Therefore different forecast calibration methods have been tested such as the Non-homogeneous Gaussian Regression (NGR) model and the Bayesian Model Averaging (BMA). First results indicate the importance of the proper combination of forecasts in view of reliability and sharpness of the forecast system.

15:25-15:45	*Anna Shchiptsova:* **Integrating alternative stochastic based on the principle of "mutual compatibility"** In this talk we present an integration method based on a principle of mutual compatibility of prior estimates. The method does not take into account credibility of the sources of the estimates, including their past performance. We demonstrate the method by applying it to integrate two types of estimates of the annual Net Primary Production (NPP) of the forest ecosystems in seven bioclimatic zones in Russia.
15:45-15:55	**Coffee break**
	Session 3: Communication of uncertainty Chair: *Jesus Crespo Cuaresma*
	In this session there will be discussed challenges and good practices related to communicating uncertainty and its sources to end-users and decision makers due to multiplicity of models and their stochastic nature.
15:55-16:55	**Discussion Panel** *Konrad Bogner, Wolfgang Cramer, Katja Frieler, Matthias Jonas, Claas Teichmann, Sonia Seneviratne, Uno Svedin*
16:55-17:45	**General Discussion – sharing impressions from the day** Chair: *Jesus Crespo Cuaresma*
17:45	Bus transfer to the workshop dinner at **Weinbau Christian Baitschev**, Josefigasse 13, Guntramsdorf

Tuesday 14 June 2016

08:00	Bus transfer from **Hotel Jagdhof** to IIASA
08:30-08:35	**Welcome to Day 2**
	Session 1: How do we use multi-model ensembles in different applications? (Part 2) Chair: *Matthias Jonas*
	In this session there will be presented and discussed the state-of-the-art in different communities in what concerns using multiple models, including constructing and working with multi-model ensembles; examples of existing multi-model ensembles and open questions; comparison of advantages and shortcomings of current practices.
08:35-08:55	*Petr Havlik and Hugo Valin:* **Multi-model integration in global agricultural sector projections Germany**
08:55-09:15	*Hyungjun Kim:* **Global Soil Wetness Project Phase 3: a community effort to develop a framework for global-scale ensemble land surface simulation, validation, and benchmarking framework** Land states, such as soil-moisture, snow and vegetation, play a critical role in energy and water balance at the land surface influencing the partitioning of net radiation and precipitation, and its memory effect is important to (sub-) seasonal predictability. In

	spite of the considerable advancements in models and observations during past decades, our knowledge and numerical implementations are still lacking. In the third phase (GSWP3), a long-term comprehensive and extensive set of quantities for hydro-energy-eco systems will be produced in order to investigate the long-term changes of the components of the energy-water-carbon cycles and their interactions, with appropriate model verifications in ensemble land simulations. It also contributes to modeling community efforts for evaluation and benchmarking of state-of-the-arts modeling systems. By including a wide range of land surface, hydrologic, and ecological models, the impacts of missing/included processes and model uncertainty can be investigated. In this presentation, the details of the project will be introduces which includes the experiment structure, land forcing data generation, and preliminary results of long-term (1901-2010) land surface estimation and known problems. Also, a liaison role of the project between international modeling initiatives such as LS3MIP/CMIP6, LUMIP/CMIP6, ISI-MIP, ILAMB, CLiC/WCRP, and GEWEX/WCRP will be introduced.
09:15-09:35	*Katja Frieler:* **Ensemble medians as „best models"?**
09:35-09:45	**Coffee break**
	Session 2: Advances in methods to integrate models within ensembles (Part 2) Chair: *Anna Shchiptsova*
	In this session there will be presented and discussed statistical methods and techniques that have been used to "integrate" alternative models, examples of their applications in different fields; comparison of their power and limitations, potential for extensions.
09:45-10:05	*David Stainforth:* **Conceptual Barriers to Multi-Model Integration of Climate Projections** Climate is a complex nonlinear system. There is much to be learned from low-dimensional nonlinear systems regarding how we should go about predicting its future behaviour. I will touch on micro- and macro- Initial Condition Uncertainty (ICU) and the need for appropriately designed Initial Condition Ensembles (ICEs) to be able to understand changing climate within a computer model. My main focus, however, will be on sensitivity to errors in model formulation (the Hawkmoth effect) and the consequences of a) lack of independence between models, b) the extrapolatory nature of the climate prediction problem, and c) in-sample analysis for statistical interpretation of ensembles. I will conclude with arguments for viewing multi-model and perturbed-physics ensembles as potentially, at best, providing non-discountable envelopes / domains of possibility.
10:05-10:25	*Simon Gosling:* **Multi-model combination of global hydrology model simulations using evolutionary-based computational learning techniques** In this talk I present a novel application of computational learning techniques to combine runoff simulations from multiple global hydrological models that participated in ISI-MIP2.1A, into a single multi-model combination (MMC) estimate of runoff. The MMC is developed by applying different weights to the individual global hydrological models according to their performance (performance is assessed by comparing simulations to observations). Across several global catchments we find that our MMC performs better than the ensemble mean of multiple global hydrological models and also

	better than any individual model. Our approach appears to be a more informed method for considering results from multiple models than the ensemble mean.
10:25-10:35	**Coffee break**
	Session 3: Model validation Chair: *Elena Rovenskaya*
	In this session there will be discussed the concepts of model validation, specifically focusing on multi-model ensembles.
10:35-11:35	**Discussion Panel** *Sambit Bhattacharya, Wolfgang Cramer, Hyungjun Kim, Valentina Krysanova*, *Pavel Kabat, Jacob Schewe, David Stainforth*
11:35-12:35	**General Discussion – sharing impressions from the day and from the entire event** Chair: *Elena Rovenskaya*
12:35-13:15	**Sandwich lunch**