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GEWEX is a Core Project of the World Climate Research Programme on Global Energy and Water Exchanges

GLAFO: The GEWEX Land-Atmosphere Feedback Observatory

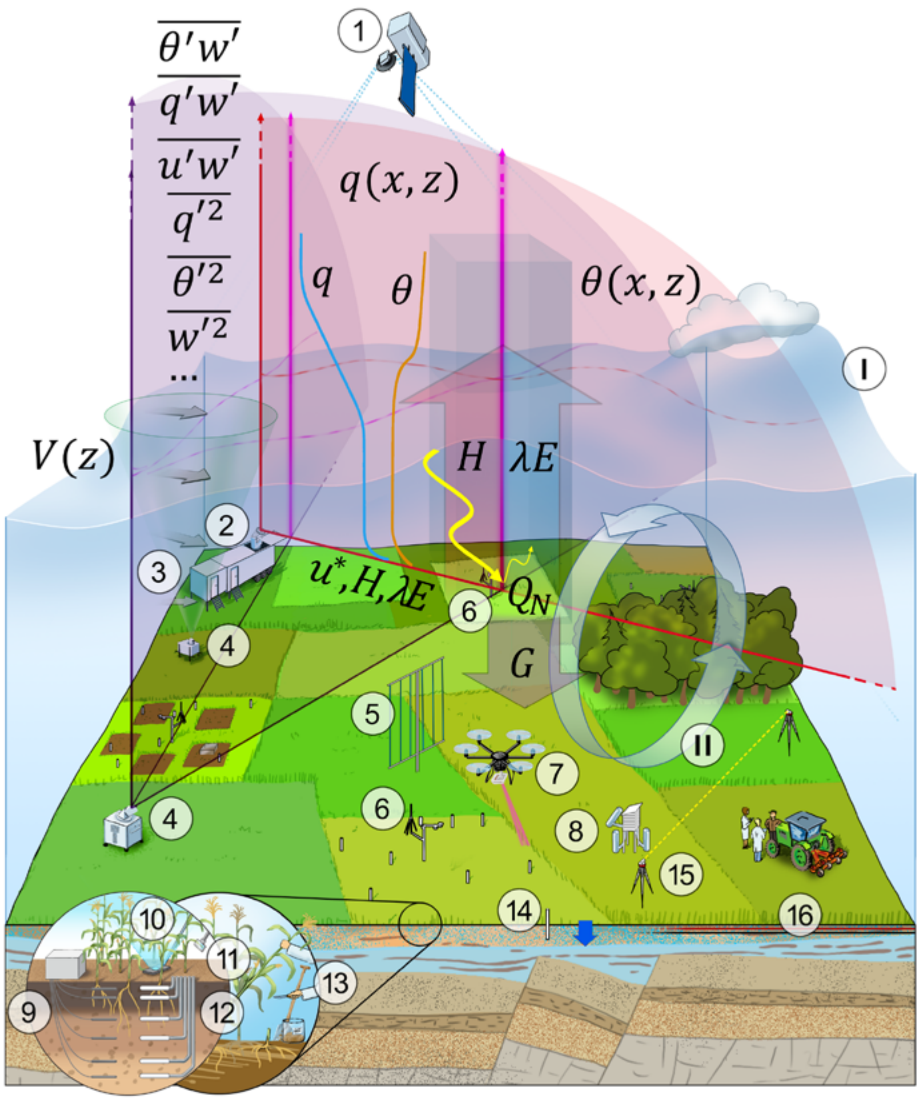

Figure 5. The proposed combination of instruments and their synergistic interaction at the GLAFO sites. I: PBL top, II: sub-mesoscale vortex. (1) Satellite remote sensing; (2) vertically staring Doppler, water vapor, temperature and CO_2 lidar systems; atmospheric emitted radiance interferometer (AERI), microwave radiometer (MWR), cloud radar; (3) scanning Doppler, water vapor, temperature and CO_2 lidar systems; (4) scanning Doppler lidar systems; (5) fiber-based distributed sensors; (6) energy balance and eddy covariance stations; (7) unmanned aerial vehicle (UAV); (8) water vapor and CO_2 isotope sensors; (9) soil moisture and temperature probes; (10) leaf area index (LAI) measurements; (11) gas exchange system for photosynthesis and transpiration rate measurements: (12) tensiometers; (13) in situ canopy measurements, such as biomass and canopy height; (14) soil moisture and temperature network; (15) scintillometer and (16) fiber-based soil moisture and temperature measurements.

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Commentary: Using Multiple Perspectives to Study Complex Processes

Jan Polcher
Co-Chair, GEWEX Scientific Steering Group

GEWEX has had quite some success with coordinated studies where a wide variety of the observations are pulled together to better understand physical processes within the water and energy cycles. The GEWEX Data and Analysis Panel (GDAP) has called these initiatives Process Evaluation Studies (PROES). One particularly nice example is the one on upper troposphere cloud and convection (UTCC), which has generated some interesting insights into high clouds and their impact on climate. The GEWEX Hydroclimatology Panel (GHP) also organizes cross-cut activities that allow the exploration of processes around precipitation and hydrology in more detail.

I would like to propose that we extend this concept of looking from all possible angles at some processes in order to enhance collaborations within GEWEX and try to make in-roads into hard-to-solve problems. There are many processes within the Earth's water cycle that are tackled in different manners within the GEWEX community. The way we address a particular process is not only given by the physical theory on which it is based, but also by the methodology used, the data available or the balance of this process with others. The evolution of our science has caused us to often lose touch with other ways of representing that process. Such an effort would also advance the strategic goal of the World Climate Research Programme (WCRP) to further our fundamental understanding of the climate system.

If we can bring all views of one process that exist within GEWEX together, we will either be able to decide that the various approaches are equivalent or that some methods are not quite adequate and that today some of the hypotheses we have inherited can be relaxed. This can lead to cross-fertilization between the various approaches and thus a general, or even significant, improvement in the way we represent the chosen process.

One process that would be an excellent candidate and would benefit from a cross-GEWEX focus is evaporation or evapotranspiration. We know that evaporation closes the energy and water cycles and is driven by atmospheric turbulence, but each community has put a different emphasis on these three aspects. Within the remote sensing community, evaporation is mostly viewed from an energy balance perspective where the surface temperature is the main indicator. In the hydroclimatic community, evaporation is either dominated by one of two views: i) from the atmospheric turbulence driving diffusion processes or ii) as a residual from the water continuity equation applied to a hydrological unit. In the modeling community, on the other hand, all three approaches need to be combined. Throughout history, the understanding of evaporation has also evolved and each of the pioneering works has put a different emphasis on these three aspects of the flux[1]. A process-oriented study on evaporation would allow us to take stock of the various assumptions made and evaluate how together we can progressively lift them so that all use the most advanced approach to evaporation. That exchange might also trigger some new ideas and original attempts to better estimate the role of evaporation in the global water cycle. GHP has already made a first step in this direction with a cross-cut on evaporation, and we should consider whether that should be extended to the other GEWEX panels.

In the Earth system and the energy and water cycle in particular, there are other processes which would benefit from such an approach. For instance, confronting the various visions on mountain precipitation would be very helpful to encourage progress on this question. The idea was briefly discussed at the most recent GEWEX Scientific Steering Group meeting in Pasadena. The general feeling was that such a process focus would enhance the exchanges between the four GEWEX panels. To achieve this focus, a limited number of processes should be treated concurrently and a strategy needs to be identified to stage such studies over time. This should include the possibility of revisiting some processes after a few years or when new knowledge emerges. The idea of having GEWEX-wide process evaluation studies would hopefully create stronger panel interactions and some overarching activities. It will be a topic of discussion at the next Pan-GEWEX meeting during the week of the 16th of November 2020 in Versailles and will hopefully lead to some concrete proposals.

[1]McMahon, T.A., B.L. Finlayson and M.C. Peel, 2016. Historical developments of models for estimating evaporation using standard meteorological data. *WIREs Water*, 3: 788-818. doi:10.1002/wat2.1172.

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Bert Holtslag, Leader in Atmospheric Boundary Layer Research, Retires

Mike Ek
The National Center for Atmospheric Research (NCAR), Boulder, CO, USA

Prof. dr. Albert A.M. (Bert) Holtslag has retired after more than 40 years in meteorology. This includes 20 years as professor in Meteorology and Air Quality (MAQ) and Chair of the MAQ Section at Wageningen University and Research Center in Wageningen, The Netherlands. During his career, Bert had a profound influence on the Earth system science community in research and leadership of national and international projects that advance knowledge of the atmospheric boundary layer, encouraging further understanding of the complexity of land-atmosphere interactions, and application of these insights to weather, climate, wind energy, urbanization and other areas, with many well-cited publications in internationally-reviewed literature. This included training several M.Sc. and Ph.D. students (including myself) on a variety of subjects, providing a path for them to become productive and inquisitive scientists, in order to make foundational contributions to weather and climate modeling and associated understanding of Earth system processes. As such, we benefited greatly from Bert's role in GEWEX.

Bert began studying physics at the University of Applied Sciences in Enschede, earning a B.Sc. in 1976. He started as a Research Associate in the Physical Meteorology Department at the Royal Netherlands Meteorological Institute (KNMI) in De Bilt in 1977, and was later a Scientist with the KNMI Dynamic Meteorology Department. During this time, he took a number of advanced courses in meteorology, turbulence theory and computational fluid dynamics, which culminated in a Ph.D. in Meteorology from Wageningen University in 1987. Later he became a Senior Scientist in the KNMI Climate Research Department, as well as a part-time Professor of Meteorology at the Institute for Marine and Atmospheric Research at Utrecht University. In 1999, he moved to Wageningen University to lead MAQ.

While at Wageningen, he continued his strong influence on the research community, e.g. he initiated the GEWEX Atmospheric Boundary Layer Study (GABLS) in 2000 and was the first co-chair. The overall goal of GABLS has been to improve representing the atmospheric boundary layer in weather and climate models, where he gave direction to scientists at various institutions worldwide on model intercomparisons and assessments. The outgrowth of one of the phases of GABLS was the GEWEX Diurnal Land-Atmosphere Coupling Experiment (DICE), which highlighted the importance of complex land-atmosphere interactions and feedbacks between the land surface and the atmospheric boundary layer. The GABLS and DICE projects continue today.

Bert helped organize a number of scientific meetings and summer schools on boundary layers, land-atmosphere interaction and related topics. At MAQ Wageningen, he hosted a successful American Meteorological Society (AMS) Symposium on Boundary Layers and Turbulence in Wageningen in 2002, the first in The Netherlands. Later, Bert was the local host and co-organizer of the widely-attended GEWEX *7th International Scientific Conference on the Global Water and Energy Cycle, Trending Now: Water* in 2014 in The Hague.

Bert also served the community many other ways. He was a reviewer for international research proposals and programs, including Intergovernmental Panel on Climate Change assessments and numerous professional journals, and was on the editorial boards of several prestigious journals, such as *Boundary-Layer Meteorology.* He participated in a number of committees, review and advisory boards and panels for Dutch agencies and institutes abroad. He was also a member of the Boundary Layers and Turbulence Committee of AMS. In 2015, he was elected Fellow of the AMS, and in 2016 received the Research Award of the Dutch Professional Society for the Promotion of Meteorology.

During his career, Bert collaborated with many researchers. On sabbatical at Oregon State University (OSU) in 1989, he worked on land-boundary layer (PBL) modeling, helping to improve the OSU land and OSU PBL models, which ultimately evolved into the Noah land model and the "Yonsei University" PBL model. These treatments of land and PBL were used in National Centers for Environmental Prediction (NCEP) regional and global models, and in the Fifth-Generation Penn State/National Center for Atmospheric Research (NCAR) Mesoscale Model (MM5) then the Weather Research and Forecasting (WRF) community model, and in the NCAR climate model, with researchers continuing to use and further develop these models. He has strong ties as a visiting scientist with NCAR, having worked in several NCAR labs, most recently in the summer of 2019. He had similar sabbaticals to work on PBL and related topics at Stockholm University, North Carolina State University, the University of Innsbruck and elsewhere.

Bert's farewell symposium at Wageningen University was on 10 October 2019, with presentations on boundary-layer-related topics from his colleagues over the years. These were followed by his farewell address, cleverly titled "Atmospheric Dreams and Perspectives," where he reflected on his career and highlighted forty years of progress and challenges in meteorology. From a Wageningen University and Research's *Resource* magazine article, "Silent Revolution in Meteorology", Bert said, "We now understand the atmosphere much better, so that weather forecasts have improved dramatically in recent decades." He calls it a silent revolution because almost no one outside meteorology has noticed, although the impact is huge. Bert is now Emeritus Professor of MAQ at Wageningen University, and will continue research in the field.

Developing Future Visions on the Water Cycle in a 1.5 Degree Warmer World

Marisol Osman[1,3], Gaby Langendijk[2,3], Yuhan Rao[3,4], Lance DiAngelis[5,6] and Caroline Aubry-Wake[7,8]
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On December 7, 2019, the Young Earth System Scientists (YESS) (*http://www.yess-community.org/*), the Young Hydrologic Society (YHS) (*https://younghs.com/*) and the Association of Polar Early Career Scientists (APECS) (*https://www.apecs.is/*) held a Joint Early Career Researcher (ECR) Workshop entitled "Water Cycle in a 1.5°C Warmer World: Interdisciplinary Approaches" prior to the 2019 American Geophysical Union (AGU) Fall Meeting. The 4-hour workshop brought together 46 early career researchers from different countries and career backgrounds for an interdisciplinary discussion on 1) a joint perspective on the water cycle and governance under climate change, from fundamental processes to societal impacts; 2) how the science of the upcoming generation of researchers can be integrated in the new World Climate Research Programme (WCRP) Strategic Plan and future directions; and 3) how the various ECR networks can work in a more integrative manner, benefit from each other and improve their communication channels.

During the workshop, the participants listened to WCRP Joint Scientific Committee co-chair Dr. Detlef Stammer's overview of the WCRP Strategic Plan and future directions. After that, Dr. Irina Sandu from the European Centre for Medium-Range Weather Forecasts (ECMWF) discussed processes involving the water cycle and feedbacks. She also addressed the challenges to understanding and predicting the water cycle and its associated impacts under climate change. Finally, Dr. Ellen Bruno from the University of California, Berkeley provided an economic perspective on how climate change affects the agricultural sector in California. After the expert presentations, participants were split into three working groups to further discuss and elaborate on ECR perspectives around the main topics.

This workshop was jointly organized by YESS, YHS and APECS under the auspices of the WCRP Climate Science Week and was kindly supported by WCRP, AGU and WCRP sponsors. We would like to thank all the sponsors for their support.

H3S Promotes Learning and Networking among Students and Early Career Scientists during AGU 2019

Leila Saberi
AGU H3S Chair

The American Geophysical Union (AGU) Hydrology Section Student Subcommittee (H3S) was busy hosting several events during the 2019 AGU Fall Meeting in San Francisco, California. On Sunday, the day before the Fall Meeting, H3S helped to organize the interdisciplinary track of the Student and Early Career Scientist (SECS) Conference. This provided an opportunity for students and other early career scientists within the AGU community to make social and professional connections before the meeting. The SECS Conference featured both technical and professional development sessions, such as data management techniques; machine learning applications in geosciences; science technology for geoscience in the past, present and future; drafting journal-ready manuscripts; how to be an effective mentor and mentee and many more.

Throughout the Fall Meeting, H3S focused on facilitating opportunities for SECSs to speak on a variety of topics, as well as to continue their professional development in a welcoming environment. We held several town hall events geared towards brainstorming ideas to develop interdisciplinary research and receiving feedback from students and early career scientists on how AGU could help them succeed further in their careers. H3S also held an amazing team trivia event that brought famous faces and students and early career scientists from three different neighborhoods (Hydrology, Global Environmental Change and GeoHealth) together in a fun event to inspire cross disciplinary networking among SECs. Don't miss next year's team trivia contest!

After a great 2019 and beyond the AGU Fall Meeting, we're excited for 2020! We're planning on continuing our successful events held throughout the year, such as our monthly cyber-panels and cyber-seminars in collaboration with the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), where scientists talk about the keys to their successes, the obstacles they faced and how they overcame them, emerging hydrological problems from their point of view and much more. We're excited to hear your ideas for how H3S can add to the hydrology community and strengthen the international ECS network via Twitter (*@AGU_H3S*) or email (*saber017@umn.edu*).

The team trivia event brought together students and early career scientists from AGU Hydrology, GeoHealth, and Global Environmental Change neighborhoods to expand their network in a fun environment.

A New Ensemble of High-Resolution Climate Change Simulations from CORDEX CORE

Armelle Reca Remedio[1], Erika Coppola[2], Claas Teichmann[1] and the CORDEX-CORE Team
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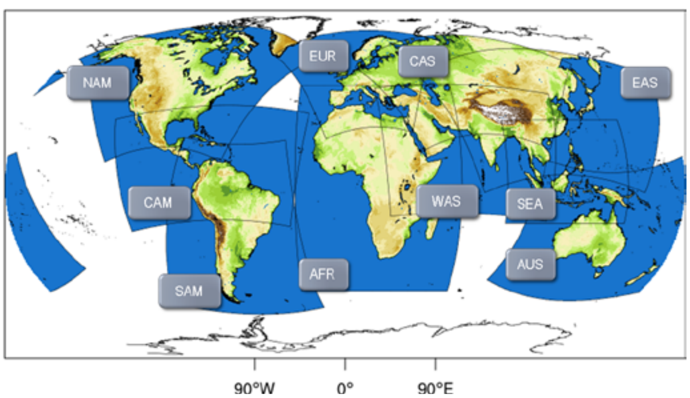
The new ensemble of high-resolution climate change simulations from the Coordinated Output for Regional Evaluations (CORE) is an effort of the World Climate Research Programme (WCRP) Coordinated Regional Downscaling Experiment (CORDEX) community to provide regional climate change information for the world's major inhabited areas. In addition to the existing CORDEX simulations, this new ensemble will be used as one of the solid scientific foundations for further research to improve the understanding of local fine scale phenomena and to provide ensemble-based studies on vulnerability, impact, adaptation and climate services. This is set of general circulation models used were the Norwegian Earth System Model (NorESM) (or the Geophysical Fluid Dynamics Laboratory Earth System Model, GFDL-ESM), Max-Planck-Institut Earth System Model (MPI-ESM) (or the European community Earth-System Model, EC-Earth), and the Hadley Centre Global Environment Model (HadGEM) (or the Model for Interdisciplinary Research On Climate, MIROC5), which were selected to cover the spread of low, medium and high equilibrium climate sensitivity at a global scale. The CORDEX-CORE (25 km) simulations are extending the CORDEX (50 km) regional climate information in at least nine CORDEX domains. The CORDEX-CORE domains and the list of simulations performed are shown in Figure 1.

Three papers from the CORDEX-CORE effort on the evaluation of mean climate, climate hazard indices and the added value index were submitted in December 2019. These papers, which include CORDEX simulations, will serve as a contribution to the upcoming Intergovernmental Panel on Climate Change 6th Assessment Report Atlas. Regional climate simulations from the CORDEX-CORE activity are now available in the Earth System Grid Federation (ESGF, *https://esgf-data.dkrz.de/search/cordex-dkrz*). For other RegCM simulations not available in ESGF, please find further information on data access at *http://users.ictp.it/~jciarlo/*.



Domains	ERA-Interim	NCC-NORESM	GFDL-ESM2M	MPI-ESM-LR	MPI-ESM-MR	HadGEM-ES	MIROC-MIROC5
EUR-11/22	REMO, RegCM	REMO, RegCM		REMO, RegCM		REMO, RegCM	
AFR-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO, RegCM	
CAM-22	REMO, RegCM	REMO	RegCM	REMO	RegCM	REMO, RegCM	
SAM-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO, RegCM	
WAS-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO	RegCM
EAS-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO, RegCM	
SEA-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO, RegCM	
AUS-22	REMO, RegCM	REMO, RegCM		REMO	RegCM	REMO, RegCM	
NAM-22	REMO, RegCM	REMO	RegCM	REMO	RegCM	REMO, RegCM	

Figure 1. (Left) The CORDEX-CORE domains: North America (NAM), Central America (CAM), South America (SAM), Europe (EUR), Africa (AFR), South Asia (WAS), East Asia (EAS), Southeast Asia (SEA) and Australasia (AUS). In addition, REMO simulations are performed over the Central Asia (CAS) domain. (Right) The list of simulations performed by REMO ( ) and RegCM (ICTP) using different boundary conditions.

especially important for those regions for which little, if any, climate information at high resolution was available until now. We envision the CORDEX-CORE simulations facilitating further studies to assess future climate in terms of mean, extremes and hazards; to examine single phenomena such as monsoons or tropical cyclones across multiple domains; and to assess consistency of climate change signals and possible added value in comparison with other global and regional climate ensembles.

The CORDEX-CORE simulations are designed to use a core set of regional climate simulations driven by a reanalysis for the hindcast simulations and by a core set of global climate simulations for the future climate change scenarios using Representative Concentration Pathway 2.6 (RCP2.6) and RCP8.5. Initially, the Regional Model (REMO) and Regional Climate Model (RegCM) from the Climate Service Center Germany (GERICS) and the Abdus Salam International Centre for Theoretical Physics (ICTP), respectively, were used with a resolution of 0.22° (about 25 km). The core

We encourage the use of CORDEX-CORE for any scientific studies and urge collaboration with model data producers in order to give feedback on the model simulations, interact regarding the scientific studies and/or propose co-authorships. Further information can be found here: *http://www.cordex.org/experiment-guidelines/cordex-core*.

CORDEX-CORE Team:

Daniela Jacob, Katharina Buelow, Thomas Remke, Arne Kriegsmann, Kevin Sieck, Lars Buntemeyer, Diana Rechid, Torsten Weber, Filippo Giorgi, Francesca Raffaele, Taleena Rae Sines, Abraham Torres, Graziano Giuliani, Adriano Fantini, James Ciarlo, Sushant Das, Fabio di Sante, Emanuela Pichelli, Russel Glazer, Ivan Girotto, Moetasim Ashfaq, Eun-Soon Im, Melissa Bukovsky, Gao Xuejie

The GEWEX Land-Atmosphere Feedback Observatory (GLAFO)

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Introduction

In the 21st century, due to climate change, a further increase in extreme events is expected. We must understand and predict these events as best as possible for the protection of humankind and the environment as well as for supporting a sustainable development of the Earth system. In particular, it is essential to realize this for the land system, which consists of soil, land cover and the atmosphere and includes the various human impacts on this system. The land system is also referred to as the "Critical Zone" (see Richter et al., 2018).

However, in spite of the recent advancements of Earth system, climate and numerical weather prediction models, climate projections as well as short-range and seasonal weather forecasts suffer from limitations of the model parameterization of land-surface exchange and transport processes, for both convective and stable planetary boundary layers (PBLs). Weaknesses of these schemes have been exemplified in various studies, e.g., within the Land Atmosphere Feedback Experiment (LAFE; Wulfmeyer et al., 2018), where significant errors of the Monin-Obukhov Similarity Theory (MOST) were detected and characterized (Lee and Buban, 2020). There are also issues with the land-atmosphere (L-A) turbulence parameterization in the convective PBL (e.g., Shin and Dudhia, 2016; Dirmeyer et al., 2018).

Improvement of the aforementioned models, including their land-surface models (LSMs), will likely lead to an advanced representation of L-A feedback and thus to an improved prediction of clouds and precipitation because an accurate parameterization of land surface and PBL processes is fundamental to simulate the pre-convective environment and the environment around convective systems.

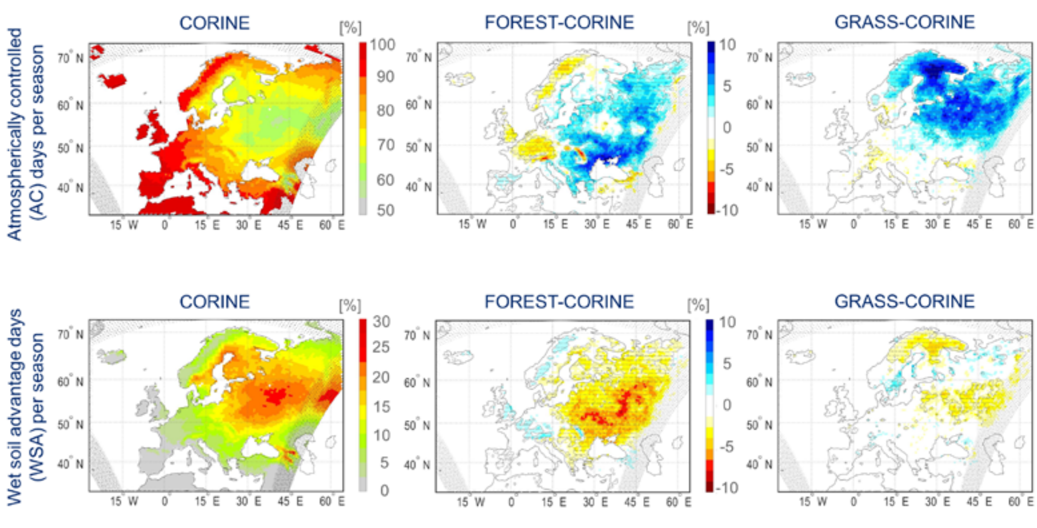

Fig. 1: Sensitivity of L-A feedback to land cover change (Jach et al., 2019) using the Weather Research and Forecasting-Noah Multi Parameterization (WRF Noah-MP) model with a grid increment of 0.44°.

The sensitivity of lower tropospheric processes to changes in land cover is demonstrated in Fig. 1 using the CTP-HI_{low} metrics (Findell and Eltahir, 2003a, 2003b) developed as part of the GEWEX Global Land/Atmosphere System Study (GLASS) Panel Local L-A Coupling (LoCo; Santanello et al., 2018) project. These results were achieved within the scope of the WCRP Flagship Pilot Study (FPS) Land Use & Climate Across Scales (LUCAS; Jach et al., 2019) and show the modification of L-A feedback by changing the current land use [from the Coordination of Information on the Environment (CORINE) Land Cover product] to forest or grassland. The feedback strength to the atmosphere is presented in terms of atmospherically controlled (AC) days (upper panels of Fig. 1) versus days that have a high probability of positive feedbacks (wet soil advantage, WSA; bottom panels of Fig. 1). In the southeastern part of Europe, changing the current land cover (as given by the CORINE database) to forest would cause less favorable conditions for feedbacks and additionally, a modification from WSA to dry soil advantage. The transition from CORINE to grassland would mainly have an effect over Scandinavia and Russia, leading to an increase of atmospherically controlled days. These model results were computed with a horizontal grid increment of 0.44°. It is important to verify these results with suitable observations, which require sufficient vertical resolution of humidity and temperature profiles for the derivation of the CTP-HI_{low} metrics.

At the recent GLASS Panel meeting (Boulder, 6–8 August 2019), a strategy to improve the parameterization chain in the L-A system was proposed, which is entirely based on observations. Models are only as good as the data that have been used for their development, improvement and verification. Therefore, any biases introduced by the combination of observations with model simulations should be minimized. An analysis of the situation led mainly to four recommendations:

1. Dedicated long-term measurements (>10 years) at observatories: Statistically sound results with respect to the mean and the probability density function of critical variables must be achieved. However, the current set of observations at most of the observatories is not yet of sufficient quality to provide reliable data sets for studying L-A feedback.
2. Synergetic observations of weather-critical processes in the land system: Due to the coupling of L-A processes and the feedback between them, it is necessary to extend the observations to all compartments, from groundwater to the vadose zone, to land cover and to the lower troposphere, including the interfacial layer at the PBL top. Otherwise, the constraints provided by the observations will be inadequate with respect to the investigation of L-A feedback, current parameterizations and the development of advanced ones.
3. Simultaneous profiling of atmospheric mean profiles, their gradients and turbulence: It is not sufficient to measure only coarse profiles or integrated values of key variables in these compartments. It is critical that the measurements reach a vertical resolution so that (possibly also horizontal) gradients of these variables are resolved. In addition, when going from the surface into the interfacial layer in the PBL, the observations must have turbulence-scale temporal and spatial resolutions in order to make the development of flux-gradient relationships possible as well as the study of higher-order moments such as skewness and kurtosis.
4. A standard observatory configuration suitable for a global network deployment strategy in all climate zones: As an increase of extreme events is expected in all regions of the planet, the robustness of new parameterizations must be investigated in all climate zones.

Based on these considerations, we propose the development and operation of the GEWEX Land Atmosphere Feedback Observatories (GLAFOs). This must be an interdisciplinary effort bringing experts together from soil sciences, hydrology, biogeochemistry and plant physiology, as well as meteorology and remote sensing (see also Richter et al., 2018).

New Measurement Capabilities and First Applications for Studying L-A Feedback

One key motivation of the GLAFOs is the fact that many initiatives have emerged focusing on enhanced understanding and observations of the PBL and the L-A system, such as the U.S. Decadal Survey for Earth Observing Missions, the National Aeronautics and Space Administration (NASA) PBL Incubator Team and working groups of the Atmospheric Radiation Measurement (ARM) program. Meanwhile, several new instruments have become available, allowing the vision behind this initiative to be realized. With respect to the soil, new space-borne observations of soil moisture have become available, such as the Soil Moisture Active Passive (SMAP) products. In the future, these will be complemented by advanced products based on Sentinel 1 observations with the potential to reach a horizontal resolution of the order of 10 m (Gao et al., 2017; Lievens et al., 2017). These retrievals can be verified and extended with new ground-based sensors such as cosmic ray detectors (e.g., Montzka et al., 2017).

With respect to land cover, we expect that the new generation of high-spatial resolution, multispectral sensors, such as those installed on the Sentinel 2 satellite, will considerably advance our knowledge of soil properties, vegetation types and vegetation properties. This is fundamental information for the improvement of LSMs. However, these remote sensing observations do not provide direct information on land surface fluxes. Thus, the information obtained from these spaceborne imagers must be combined with the profiles of variables in the surface layer and in the canopy and with model output. Near-surface profiling capabilities are available via fiber-based distributed sensors (e.g., Thomas et al., 2012), whereas isotope measurements can be used for separating soil evaporation and transpiration of the canopy (Dubbert and Werner, 2019). Furthermore, for determining the CO_2 assimilation, its dependence on air temperature, moisture and radiation profiles in the canopy must be known. This is essential for developing advanced photosynthesis models and implementing accurate vegetation dynamics in LSMs.

For atmospheric measurements, it will be decades before spaceborne capabilities able to sense the lower troposphere will be advanced enough to obtain high-resolution measurements required for process-level L-A research. In the meantime, ground-based profiling instruments are a very active area of research and development for such purposes. For example, scanning Doppler lidar systems (DLs) have been available for more than a decade now and have been extensively used for wind and turbulence profiling in the PBL (e.g., Bonin et al., 2017; Muñoz-Esparza, 2018). However, for the understanding of exchange and transport processes, DL measurements must be complemented with high-resolution observations of temperature and water vapor, and ideally also CO_2. Only with this combination of measurements it is possible to derive profiles of sensible and latent heat fluxes, which determine the evolution of moisture and temperature in the PBL. With respect to water vapor measurements, the water vapor differential absorption lidar (WVDIAL) (Muppa et al., 2016) and the Raman lidar (WVRL) (Wulfmeyer et al., 2010; Turner et al., 2014) techniques have demonstrated sufficient resolution for turbulence measurements.

With respect to temperature, a breakthrough has been achieved using the rotational Raman lidar technique (Lange et al., 2019) so that it is now also possible to measure temperature profiles, inversions and turbulent quantities even in the daytime convective boundary layer (CBL; Behrendt et al., 2015). This new capability in temperature profiling is demonstrated in Fig. 2.

During LAFE, for the first time, scanning WVDIAL, temperature Raman lidar and Doppler lidar systems were used to observe high vertical resolution (15–100 m) thermodynamic and wind profiles in the surface layer simultaneously. Due to their range resolution, vertical profiling is performed in dependence of range and extended from the surface to the mixed layer. Surface in situ observations at 2 m and 10 m heights can be combined with lidar scans.

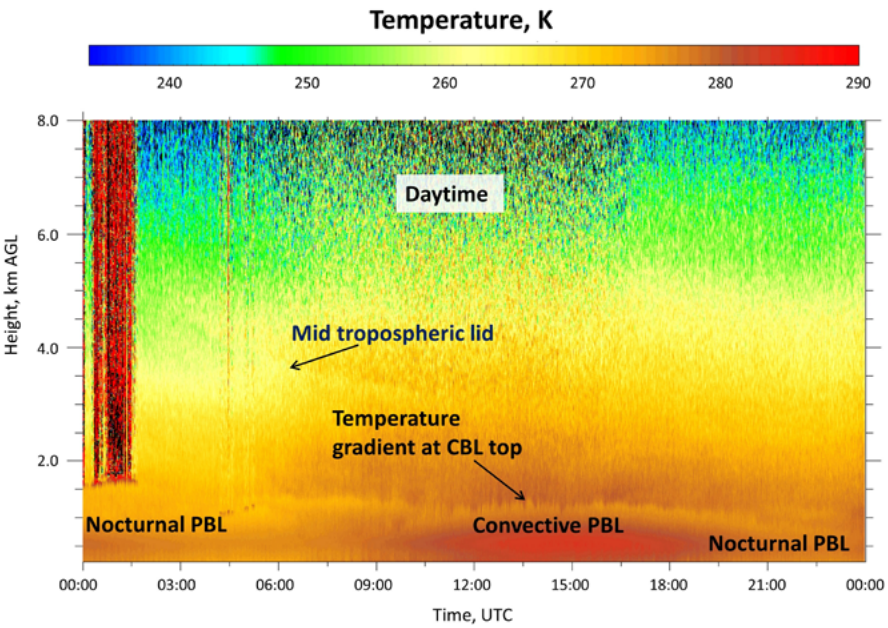

Fig. 2*: Time-height cross-section of the temperature field measured with resolutions of 10 s and 100 m at the new Land-Atmosphere Feedback Observatory (LAFO; see* https://lafo.uni-hohenheim.de/en*) of the University of Hohenheim.*

First results from both in situ and lidar observations showed strong deviations from the expected profiles based on MOST. Moreover, Lee and Buban (2020) demonstrated that a surface layer parameterization with a bulk Richardson number approach is superior to MOST (Fig. 3). Additional measurements are required to confirm these very interesting results, which indicate the potential to replace MOST with a more accurate parameterization of surface layer processes.

In vertically staring mode, temperature and water vapor Raman lidar measurements have been combined with Doppler lidar for flux profiling so that the derivation of transport processes can be extended to the interfacial layer (Behrendt et al., 2019). Previously, this combination of instruments was merely used during case studies, but now these measurements are available routinely, e.g., at the ARM Southern Great Plains (SGP) site (Sisterson et al., 2016). An example of the daily cycle of the latent heat flux profile for the LAFE Intensive Operational Period 11 (IOP11) on 23 August 2017 is presented in Fig. 4.

The time-height cross section shows strong entrainment during the morning transition and a very reasonable evolution of the flux profiles during the evolution of the CBL with a latent heat flux of approximately 200–300 Wm^{-2} in the CBL. Currently, the whole month of August 2017 is being processed in order to derive daily statistics of these flux profiles. These results will permit the direct evaluation of flux-gradient similarity relationships (Wulfmeyer et al., 2016), which was recently demonstrated for variance-gradient similarity relationships (Turner et al., 2014; Osman et al., 2019). Also, the availability of flux, mean and gradient profiles will allow a comprehensive determination of L-A feedback metrics (Santanello et al., 2018). These examples illustrate the considerable progress made in recent years, and the potential of new instruments for the observation of L-A feedback. Therefore, it is very timely to start the GLAFO initiative.

Proposed GLAFO Design

We propose to design and develop observatories in different climate regions based on the LAFE setup (Wulfmeyer et al., 2018), but with an extension of the instrumentation. To date, such long-term L-A "supersites" have only existed in a handful of locales such as the SGP (U.S. Department of Energy's ARM program), Germany (Lindenberg), Switzerland (Payerne), The Netherlands (Cabauw) and Chilbolton (UK), and even so rely on traditional measurements of soil, land cover, fluxes and balloon

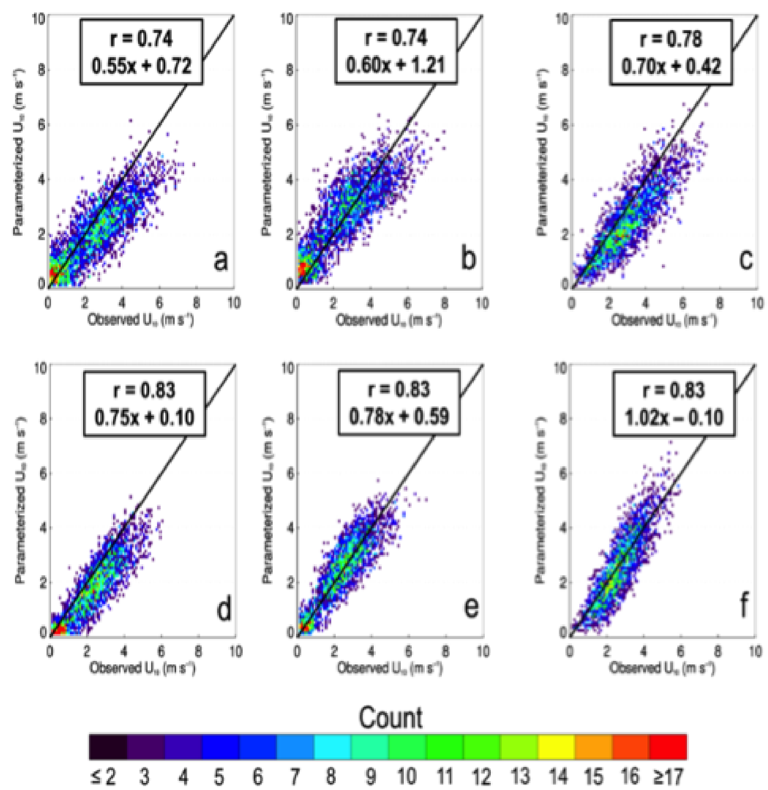

Fig. 3*: Density plot showing the relationship between observed 10 m wind speeds (U_10) and (a) U_10 computed using MOST relationships from Dyer and Hicks (1970), (b), U_10 computed using MOST relationships developed from LAFE and (c) U_10 computed using a bulk Richardson number approach (c) for a site near Belle Mina, Alabama, USA. Same for panels (d), (e) and (f), but for Cullman, Alabama, USA. The black line shows the 1:1 line; the Pearson correlation coefficent (r) and the equation for the line of best fit are shown at the top of each subpanel. Figure modified from Lee and Buban (2020).*

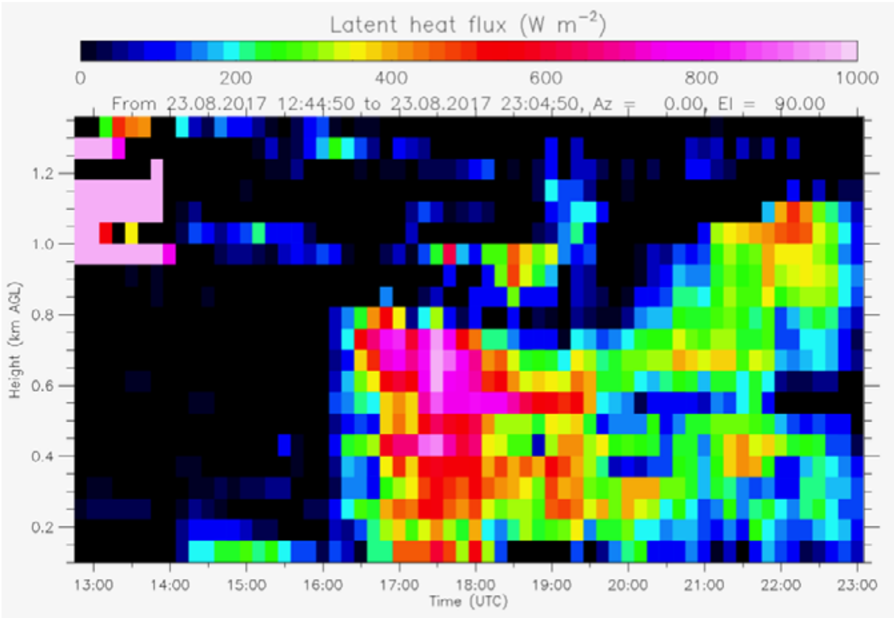

Fig. 4*: First measurement of the daily cycle of the latent heat flux at the ARM SGP site on 23 August 2017 during LAFE. Note that sunrise occurred around 12 UTC.*

soundings. We now have the capability to build L-A observatories that reflect the scientific community's requirements to advance our understanding utilizing recent developments in measurement technologies. These measurements should contain:

- **Soil**: Soil moisture, matric potential and temperature profiles complemented with hydrological components such as ground water level, surface and sub-surface runoff, soil evaporation from micro-lysimeters or equivalent and precipitation measurements. Ideally hydraulic and thermal conductivities are also determined (see, e.g., Tian et al., 2018). Possibly soil heat flux plates, although the profile measurements will allow for their determination using the calorimetric method.

- **Vegetation**: Vegetation type and state, rooting depth and distribution; leaf area index; biomass; canopy height; canopy properties (including "response curves" to determine key canopy exchange parameters such as Vcmax; vulnerability curves, etc.), radiation, moisture and temperature profiles; sap flow and isotope measurements to separate respiration, interception and transpiration from overall evapotranspiration measured with eddy covariance (EC); net ecosystem exchange; estimate of plant water stress.

- **Surface layer**: Energy balance using radiation and EC measurements; isotope measurement of fiber optic-based temperature profiles; towers with measurements at 2 m and 10 m; scanning temperature, water vapor, Doppler and CO_2 lidar.

- **PBL mixed and interfacial layers**: Six beam staring Doppler lidar for the profiling of turbulent kinetic energy (TKE), momentum flux, TKE dissipation rate and horizontal wind profiles; vertically staring Doppler lidar for vertical wind measurements; vertically staring water vapor, temperature and CO_2 lidar; Fourier-transform infrared spectrometers (such as the atmospheric emitted radiance interferometer, AERI; Knuteson et al., 2004) for measurements of temperature and water vapor profiles, cloud properties (e.g., liquid water path and effective radius) (Turner and Blumberg, 2019), and also for radiative heating profiles; microwave radiometer; scanning cloud and precipitation radar.

It is envisaged that the setup of this instrumentation is performed in stages, e.g., setting up the vertically staring instruments first, followed by the scanning systems, etc.

The combination of these instruments and their synergetic operation is depicted in Fig. 5 (see cover). Using coordinated scans, the effects of the horizontal heterogeneity of the soil, the land cover and the atmosphere can be studied, which is important for the development of new model parameterizations in complex terrain, and to check their performance. Continuous operation will permit the investigation of diurnal cycles, the morning and nighttime transitions and the afternoon decay of the PBL.

A major part of this synergistic sensor configuration was designed and operated during LAFE at the ARM SGP site (Wulfmeyer et al., 2018). A similar instrument suite is planned for the LAFO site (s. *https://lafo.uni-hohenheim.de/en*) of the University of Hohenheim in Stuttgart, Germany. Moreover, existing observatories, such as those of the ARM program and at weather observatories such as Lindenberg, Cabauw, Payerne and Chilbolton, contain a majority of these instruments. It should be relatively straightforward to extend their current instrumentation in order to become one of the GLAFOs.

It is also very important to coordinate the setup of GLAFOs with related scientific activities. For instance, in the U.S., the bedrock to boundary layer (B2B) initiative has been proposed. This project has overlapping goals, but it focuses more on hydrological aspects with respect to L-A feedback. Furthermore, there are several biogeoscience and environmental research networks such as the TERrestrial ENviromental Observatoria (TERENO) in Germany, the ARM sites, the International Long-Term Ecological Research Network programs (ILTERs), the Critical Zone Exploration Network and Critical Zone Observatory programs (CZEN and CZOs), Earth and ecological observatory networks (EONs), the National Ecological Observatory Network (NEON) and FLUXNET (Richter et al., 2018), which all could be coordinated with the GLAFO initiative.

Scientific Goals, Expected Outcomes and Applications

During the GLASS meeting, the following goals and expected impacts were identified:

G1. Determine turbulence profiles and investigate new relationships among gradients, variances and fluxes

→ Process understanding, development of new turbulence and shallow convection parameterizations

G2. Investigate surface fluxes using a combination of in situ sensors and scanning wind, humidity and temperature lidar systems

→ New parameterizations of the surface layer and fluxes based on other scaling variables and considering land heterogeneity and entrainment

G3. Characterize the diurnal cycle, transitions, the mesoscale and seasonal variability of the PBL, L-A feedback as well as the moisture and energy budgets

→ Deeper insight into L-A feedback and PBL water, energy and CO_2 budgets across various time scales

G4. Verification of large eddy simulation model runs and improvement of the parameterization chain turbulence representations in mesoscale models

→ Model verification, test of vegetation, surface fluxes as well as turbulence and shallow convection parameterizations

The following applications and impacts are envisaged:

A1. L-A data assimilation, regional scale reanalyses

→ Significant forecast improvement including extreme events, process understanding, impact analyses

A2. Testbed for providing synergetic data products

→ Refinement and extension of data sets, e.g., for L-A feedback

A3. Calibration of passive remote sensors from ground and satellites, investigation of inter-sensor consistency with inter-site intercomparisons

A4. Incubator for interdisciplinary research, testbed for sensor development/collocation across a range of climates

A5. Training of future users of these data (e.g., in weather services, scientists and students)

Summary

In summary, during the 2019 GLASS Panel Meeting, a new initiative was developed and designed for the establishment of the GEWEX Land-Atmosphere Feedback Observatories (GLAFOs). These sites would address the compelling needs of advanced observations for studying L-A processes in the era of climate change and for the development of advanced model systems to improve the prediction of extreme events in particular. This project is very timely due to the availability of novel instruments that can operate synergistically, having the potential to improve and develop observationally-based parameterizations and to verify model output with unprecedented detail and accuracy. The new LAFO site in Germany may serve as the standard for this initiative but there are already many observatories, such as the ARM SGP site, that can be easily adapted, so it should be possible to develop several GLAFOs in various climate zones within the foreseeable future.

There are several community efforts planned to foster the GLAFOs at upcoming meetings and conferences. These include community meetings, contributions to conferences and the development of a white paper. We invite the GEWEX and Earth system science communities to join and strengthen this effort by their active participation.

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Meeting/Workshop Reports

The 2019 Water Futures Conference

Bengaluru, India
24–27 September 2019

Richard Lawford
NASA GESTAR/Morgan State University

The Water Futures conference, "Toward a Sustainable Water Future," was organized by the Sustainable Water Future Programme (SWFP) and the Divecha Centre of Climate Change and hosted by the Indian Institute of Science (IISc) in Bengaluru, India from September 24 to 27, 2019. The meeting attracted an estimated 700 experts in water and water-related disciplines who came primarily from various parts of India and also from Southeast Asia, Europe, North and South America, Africa and Australia.

The meeting highlighted the advances of the SWFP since it became Future Earth's global research platform for water with its expertise and innovation in water research, policy, security and sustainability. The meeting had a strong focus on water security under current trends of development and climate change, and on vulnerable environments where the impacts of these changes are particularly concerning.

The meeting opened with special sessions featuring political figures and the leaders of the Southeast Asia Future Earth Hub exploring the plans, capabilities and research strategies of Future Earth for Asian water management and environmental issues including air quality, food security and climate change. Presentations demonstrated that the Hub was capable of undertaking the appropriate research to support India's development. For their part, ministers and other high-ranking officials gave their thoughts on the benefits of possible government collaboration with Future Earth.

The first afternoon featured presentations on global issues such as assessing the ability of water systems to cope with environmental changes, and introductory sessions on specific conference themes. The themes were aligned with many of the SWFP working groups, including sustainability, urban water issues, groundwater, socio-cultural and ecological aspects of water management, the Water-Energy-Food (W-E-F) Nexus and the impacts of climate change on the hydrology of mountain regions.

The scientific presentations provided overviews and updates on related programs, including the SWFP COMPASS project and its contributions to national water resource assessments, the World Meteorological Organization (WMO) and the Centre for Ecology and Hydrology (CEH) on water resource monitoring, the United National Environmental Programme (UNEP) and water quality monitoring, and the International Rivers program and ecological flows and the need for coordinated land and water management. The International Rivers presentation illustrated how drought exposed the effects of the misuse of water appropriations by a major water user. These papers were followed by overviews on climate change with speakers outlining its effects on glacier melt, snow distributions, groundwater, lake water quality and agricultural water use. A special session focused on innovations to achieve sustainable groundwater use in India, where urban development and the W-E-F Nexus have large impacts.

Parallel sessions featured SWFP themes of water governance, ethics, water resource assessment, groundwater, urban water, the W-E-F Nexus and capacity development. In addition, topics covered security in the water space, monitoring Sustainable Development Goal 6 (SDG6) implementation and assessing changes in the hydrological cycle. Other sessions addressed water security in India and water infrastructure development challenges throughout the country. A special session on "Leaving no one behind: Digital water" focused on the use of new technologies such as big data, block chain technologies and Artificial Intelligence (AI).

A contingent from the Canadian Water Futures program node led discussions on the cryosphere in mountain regions. Their sessions, which have many links to the GEWEX program, addressed issues such as using Earth observations to measure glacier melt and to estimate water availability from snow melt. These discussions led to an agreement to develop a Future Earth Himalayan initiative proposal for the Southeast Asia Future Earth program.

The W-E-F Nexus and the challenges of implementing and monitoring SDG6 were also featured. The Indian government continues to invest in many areas of water research. GEWEX and SWFP could have a number of opportunities for joint work in India and Southeast Asia. The U.S. and Indian space agencies have collaborated on a joint mission known as the National Aeronautics and Space Administration (NASA)-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (SAR), or NISAR, mission. After its expected launch in 2022, it will provide new SAR data that will be optimized for monitoring hazards and global environmental change.

On the social side, our hosts were very attentive and kind. In addition to the support given at the meeting, site visits were arranged and a tour of Bengaluru was provided, which featured historical and cultural aspects of the city as well as some incidental exposure to monsoon type rains.

The draft statement from the conference involved a clear expression of intent to develop a data and information platform to support water management decision-making. This platform would take advantage of new information sources including satellites, big data and citizen data. The three main action areas for this development would include: 1) creating a digital environment, 2) creating the integrated platform architecture and 3) capacity development. This statement has been finalized and was introduced at the Budapest Water Summit in October 2019. Given the directions of this recommendation, it appears that there may be opportunities for the SWFP Data and Observations committee and other SWFP groups as well as GEWEX to become more active in developing the architecture of data services during the coming months and populating its data services with appropriate data sets and applications software.

The Latsis Symposium 2019–High-Resolution Climate Modeling: Perspectives and Challenges

Zürich, Switzerland
21–23 August 2019

Christoph Schär[1], Roy Rasmussen[2], Andreas Prein[2] and Christopher Castro[3]

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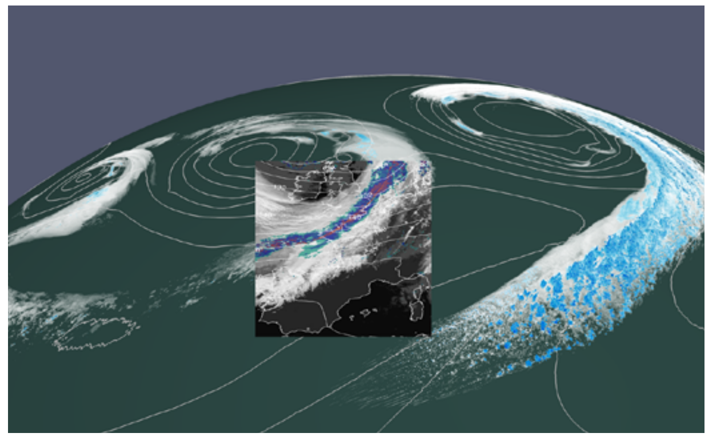

The 2019 Latsis Symposium was hosted together with the 3rd GEWEX Workshop on Convection-Permitting Climate Modeling (CPCM) from August 21–23, 2019 at ETH Zürich in Switzerland. The symposium focused on scientific and technical challenges related to kilometer-scale global and regional climate modeling. It brought together climate modelers and computer scientists with the aim of addressing climate and weather time scales, the water cycle and extreme events, as well as emerging supercomputing platforms and software strategies.

The international symposium hosted 112 participants from 19 countries who delivered 11 invited presentations, 35 oral talks and 41 poster presentations. The topics spanned global to regional kilometer-scale modeling, numerical and computational approaches, atmospheric processes in current and future climates and kilometer-scale models for prediction across scales. The symposium consisted of ten oral sessions, four poster sessions and a panel discussion. PDFs of the presented slides can be accessed from the workshop website at *https://latsis2019.ethz.ch/programme/pdownloads.html*.

Compared to the first two GEWEX CPCM workshops in 2016 and 2018, there was a clear group consensus on the need to develop global kilometer-scale modeling capabilities. The inclusion of the computer science community at this symposium enabled discussion of this objective, especially regarding the capabilities and requirements of next-generation high-performance computing systems. Achieving the goal of global kilometer-scale modeling will demand a major restructuring of current numerical modeling codes and close collaboration between the model development, computer science and hardware development communities. A computational speedup factor of ~100 will be necessary to run coupled global climate simulations with a horizontal grid spacing of 1 km at a rate of one simulation year per day. Strategies for achieving such a speedup were discussed at the workshop and focused around the variety of possible numerical approaches, using emerging hardware architectures with accelerators (e.g., graphics processing units), the use of domain-specific languages (DSLs), the exploitation of reduced precision, the use of new programming models to optimize data handling and workflows and the development of new strategies to cope with the output avalanche from high-resolution models.

Participants at the Latsis Symposium

Besides addressing the technical aspects for bridging the software and performance gaps of kilometer-scale global weather and climate models, major development efforts will be necessary to improve the representation of processes and feedbacks in such models (e.g., energy and mass conservation, the coupling of Earth system components, model physics). Initiatives such as the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND, *https://www.esiwace.eu/services/dyamond*) aim to address the challenges of global kilometer-scale models. DYAMOND consists of nine global atmosphere-only models with a horizontal grid spacing of 5 km or less that simulate a common 40-day period. An important approach towards global kilometer-scale modeling is to improve regional kilometer-scale climate models on continental-scale domains. This approach has the advantage of being able to simulate several decades instead of only weeks, allowing for a more systematic evaluation of model performance and facilitating an easier detection and improvement of model deficiencies, especially with regard to process representation. Simulations of this type were presented by several groups focusing on Europe, North America, Africa and the tropical Atlantic.

Multiple presentations focused on the added value of kilometer-scale compared to coarser-resolution models. Substantial and consistent progress was demonstrated in the representation of convective processes. Particularly large improvements were found in the tropics, where kilometer-scale models resolve persistent model biases by better representing tropical overturning circulation, substantially improve the representation of tropical clouds and wind systems and enhance sub-seasonal predictability in mid-latitudes by improving the simulation of the Madden-Julian Oscillation. These results demonstrate the ability of kilometer-scale models to capture complex, multiscale process interactions that range from the storm to synoptic scales.

Another active research area was the simulation of extreme events and how they change under global warming. Presentations focused on rainfall extremes from single thunderstorms to mesoscale convective systems, orographic precipitation extremes, hail, wind gusts and tropical cyclogenesis. The presentations showed significant skill in the simulation of all these phenomena once model horizontal scales of a few kilometers were reached.

An evening side meeting on "convective-permitting modeling for sub-seasonal to seasonal forecasting" took place in the ETH video center and was attended by 40–50 in-person and remote participants, representing countries throughout the world. While kilometer-resolution models have been used in the context of historical climate simulations and climate-change projections, their application to the sub-seasonal to seasonal (S2S) forecast timescale (weeks to months) is comparatively underexplored. During the forum, there were several overview presentations given by forum facilitators on the topics of convective-permitting modeling, the Coordinated Regional Downscaling Experiment (CORDEX) project and lessons learned from dynamical downscaling of seasonal forecasts in the United States. The presentations were followed by an open discussion, oriented to both scientific and logistical aspects of initiating a possible new CORDEX-like effort to dynamically downscale S2S reforecast products. Subsequent to the Latsis Symposium, facilitators will prepare a summary document that will be shared with the World Meteorological Organization, as well as follow-on presentations at the American Geophysical Union (AGU) and American Meteorological Society conferences within the United States. The facilitators will use the list of registered attendees of the forum as a basis for pursuing any community research efforts proceeding forward.

On the first evening of the event, a public lecture was held on the topic of why we need better climate models. The presentation by Reto Knutti provided an overview of climate change and the role of models in quantifying past and future changes and informing mitigation and adaptation decisions. It gave a broad perspective on the challenges and opportunities of the next generation of weather and climate models and their value to society. The lecture was attended by about 250 people from both the workshop and local community and was followed by a very active and interesting discussion.

The symposium closed with a panel discussion covering major challenges and opportunities in kilometer-scale modeling such as observational needs, future software and hardware demands, data volume and sharing, emerging science topics and the integration of high-resolution model results into larger-scale efforts such as the Climate Model Intercomparison Project (CMIP). The community realized that it is important to integrate institutions that do not have the necessary resources to run large kilometer-scale models into high-resolution modeling efforts. Furthermore, writing a community white paper was suggested as one of the outcomes of the meeting. This paper would outline the need and potential benefits of kilometer-scale climate models.

The 4th GEWEX Convection-Permitting Climate Modeling workshop will be held in Kyoto, Japan from September 2nd to 4th 2020 (*http://www.jmbsc.or.jp/tougou/WS2020/WS2020index.html*). Furthermore, a kilometer-scale climate modeling session (*https://agu.confex.com/agu/fm19/webprogrampreliminary/Session80373.html*) took place at the AGU Fall Meeting (San Francisco, U.S.A.; December 9–13, 2019) and another is planned for the European Geosciences Union (EGU) General Assembly (Vienna, Austria; May 3–8, 2020). Updates about these meetings and other community activities will be posted through the Convection-Permitting Climate Modeling community e-mail list (*ral-cpcm@ucar.edu*; to subscribe, send an e-mail to *prein@ucar.edu*).

2019 GEWEX Hydroclimatology Panel (GHP) Meeting

Sydney, Australia
11–12 October 2019

Joan Cuxart and Francina Dominguez
GHP Co-Chairs

Hosted by Jason Evans, the 2019 GHP Meeting and the Determining Evapotranspiration Workshop were held at the Climate Change Research Center (CCRC) of the University of New South Wales in Sydney, Australia. During the GHP meeting, participants shared and reviewed the status of current and future GHP projects. We also welcomed four new Panel members: Vidya Samadi of the University of South Carolina; Li Jia from the Earth Observation for the Water Cycle (EO-Water) Lab, part of the Institute of Remote Sensing and Digital Earth (RADI) of the Chinese Academy of Sciences; Ali Nazemi of Concordia University; and Andreas Prein of the National Center for Atmospheric Research (NCAR). Two other new members, Ivana Stiperski (University of Innsbruck) and Paola Arias (Universidad de Antioquia), could not be present. After seven years of excellent leadership, Jason Evans stepped down as co-chair of GHP at the end of the meeting. Francina Dominguez was appointed as the new co-chair of GHP. Silvina Solman ended her service as Panel member after her second three-year term.

GHP is comprised of three different types of projects: Regional Hydroclimate Projects (RHPs), an essential tool in understanding and predicting hydroclimates; Cross-Cut Projects (CCs), which encourage proliferation of knowledge from region to region, allowing the synthesis of results at a global scale; and Global Data Centers, which collect and distribute hydrologically-relevant data. The progress of ongoing and initiating GHP projects in each category was reviewed during the meeting.

Current Regional Hydroclimate Projects (RHP) and Cross Cut (CC) Projects

The Hydrological cycle in the Mediterranean eXperiment (HyMeX) RHP, focusing on the Mediterranean Basin, will end in 2020 after a 10-year span. There are still ongoing activities on convective precipitation in Corsica and on deep water formation in the Eastern Mediterranean. The last experimental campaign planned for April to October 2020 is the Land Surface Atmosphere Interactions over the Iberian Semi-Arid Environment (LIAISE) project, which concentrates on the effects of irrigation and terrain heterogeneity. The possibility of HyMeX transitioning to a GHP network was discussed.

The Baltic Earth RHP, concentrating on Earth system science for the Baltic Sea region, proceeds with its current main research themes, which include water oxygenation in coastal areas, marine ecosystems and climate variability and projections. The RHP is producing nine Baltic Earth Assessment Reports (BEARs) and has a large number of activities planned for the coming years.

One lesson learned from both HyMeX and Baltic Earth is that the model of small groups obtaining their own funds and coalescing is a durable and flexible paradigm.

The Pannonian Basin Experiment (PannEx) is an Initiating RHP centered in the Pannonian Basin in Europe. The 5th workshop was held in Novi Sad, Serbia in June 2019, and the progress of the different Task Teams has been revised. A call from the European Space Agency (ESA) related to drought in the Pannonian Basin was awarded to the DryPan proposal. The PannEx chair will invite the DryPan team to report on its activities at the 6th PannEx workshop, planned for June 2020. A number of bilateral initiatives are in progress, and some papers are being published.

The International Network for Alpine Catchment Hydrology (INARCH) CC, focusing on understanding hydrological processes in alpine cold regions, has been very active. The 5th INARCH workshop is planned for spring 2020. The project has a relevant role in the new World Meteorological Organization (WMO) initiative called the "High Mountain Summit." There are clear links with the ANDEX RHP, the Third Pole Environment (TPE) effort, the proposed CC named Transport and Exchange Processes in the Atmosphere over Mountains Experiment (TEAMx) and perhaps a Western U.S. RHP, if it comes to fruition. The INARCH CC will end in 2020 and its leaders are currently reflecting on how to proceed with its legacy.

Participants of the 2019 GHP Meeting

The INTElligent use of climate models for adaptation to non-Stationary hydrological Extremes (INTENSE) CC, focusing on subdaily precipitation, has been very active in data acquisition, analysis and publication of manuscripts. The data has also been added to the Global Precipitation Climatology Center (GPCC) global repository. This activity will also end in 2020.

The Near 0°C Precipitation CC is coming to a close with the generation of a data base containing records and related climate analysis from different regions, especially in the Northern Hemisphere. Numerical simulations with special focus on microphysics and analysis of Coupled Model Intercomparison Project (CMIP) projections have also been performed.

Data Centers

Steady and significant progress was reported by the Global Precipitation Climatology Centre (GPCC) related to precipitation data. The center provides precipitation climatology, monthly data from 1891–2018, daily data from 1982–2018 and a monitoring product. The Global Runoff Data Centre (GRDC) focuses on acquisition, harmonization and storage of global historical river discharge data. With increasing data requests and new projects such as Global Freshwater Fluxes, this data center is very active. Finally, the International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) continues gathering information on the water level of lakes and reservoirs worldwide.

Prospective RHPs and CCs

There are currently five activities exploring the possibility of becoming a new GHP action. The first is the ANDEX RHP, which focuses on the Andes Mountains of South America. The organizers are in the process of amalgamating the community and obtaining international support. After the initial meeting at the end of 2017, the workshop in October 2018 and writing workshop in April 2019, the group's plan is to have the first draft of the white book ready by the end of 2019 and then to begin writing the implementation plan. ANDEX will apply for formal RHP status in 2020.

Third Pole Environment-Water Sustainability (TPE-WS) is an RHP initiative intending to explore water sustainability in the expansive high mountain region of South Asia. The team is working on a science plan and different subgroups have been established. Members will have a proposal ready by November or December of 2019.

The Asian Precipitation Experiments (AsiaPEX) RHP, focusing on understanding Asian land precipitation, will apply for RHP status shortly. Many in-person meetings and the Kick-Off Conference in Sapporo, Japan in September 2019 were successful. The group is planning a 2020 field campaign. A proposal will be ready by November or December of 2019.

The TEAMx initiative was recently approved as a GHP Cross-Cut. This CC focuses on multi-scale transport and exchange in the atmosphere over mountains. The team is organized and active, having completed a Memorandum of Understanding, review papers and a workshop. An intensive field campaign focusing on the European Alps is planned for 2023. The geographical scope of the project will broaden in the future through links with other international groups.

The Determining Evapotranspiration (Determining ET) CC is an activity focusing on advancing the understanding and determination of evapotranspiration. Thirty four participants from all around the world came together for a two and a half day workshop held just before the GHP meeting. Several areas of interest have been established and a new meeting is planned a year from now. The group will consider organizing as a GEWEX Cross-Cut, or alternatively a PROcess Evaluation Study (PROES), and this will be further reflected on during the coming months.

Report on the First Determining Evapotranspiration Workshop

Sydney, Australia
8–10 October 2019

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In the context of the Global Energy and Water cycles EXchanges (GEWEX) core project of the World Climate Research Programme (WCRP), there is a special interest in fostering research on the subject of Evapotranspiration (ET). Activities in this topic are arguably not currently well coordinated or addressed within the program. To tackle this issue, in 2018 the GEWEX Hydroclimatology Panel (GHP) suggested holding a workshop that encouraged open reflection on the subject, allowing interested members of the scientific community to propose relevant subjects of investigation. To foster discussion, a reflection paper was published in *GEWEX News* in the first quarter of 2019 (Cuxart et al., 2019) describing the results of a preliminary informal meeting held in May 2018 during the GEWEX Open Science Conference in Canmore, Canada. The importance of ET was also flagged during the Global Land-Atmosphere System Studies (GLASS) Panel meeting (August 2019, Boulder, CO, USA), where "the global estimation of ET" was proposed as a potential GLASS project.

Participants of the Determining Evapotranspiration Workshop

This workshop was hosted by Jason Evans of the Climate Change Research Center (CCRC) at the University of New South Wales (UNSW) in Sydney, Australia, from 8–10 October 2019, and co-organized by Joan Cuxart, Anne Verhoef and Toby Marthews. Thirty-four scientists attended from universities and research centers from around the world. Specialists in meteorology, hydrology, soil physics, plant sciences and environmental systems discussed ET in this multidisciplinary forum. The workshop combined presentations by the attendees with discussion slots. The sessions were devoted to basic processes, process modeling and different ways to determine ET and its components across a range of problems, applications and spatiotemporal scales.

During the discussion, the focus was mostly on the model description of the relevant processes concerning ET, and five groups were formed to address the following themes: i) open-water evaporation, ii) interception, iii) soil evaporation, iv) transpiration and v) landscape ET. Each group reported on its reflections to the others in a final session, in which it was decided that the group should preferably continue its activities along these lines and try to expand the community of scientists interested in this topic.

Because of the expertise represented at the break-out meeting, the open-water evaporation group focused on lakes and discussed the influence of the heterogeneity of the lakes themselves and of their surroundings, as well as the validity of the hypotheses currently made in lake evaporation parameterizations. They also highlighted the need to go from 1-D model approaches to 2-D or 3-D.

The interception group made an inventory of the currently-existing methods of dealing with rain and snow interception, as well as dew, and listed the relevant physiographic parameters that would be needed for a better representation of the problem.

The group tasked with a discussion on soil evaporation identified key processes that require special attention, including the diurnal cycle, the transport and energetics of water across the soil substrate and at the soil-atmosphere interface, as well as the influence of edaphic factors such as soil type.

The discussions on transpiration indicated the need for closer links between the exchange of water (vapor) and CO_2, for which current descriptions of the processes at leaf and plant level may be limited. The related interactions with the atmosphere should be a priority for further research, especially through the use of remote sensing data and in situ measurements.

Finally, the landscape ET group considered (i) how the heterogeneity of the land surface challenges the determination of the value of ET at one point; (ii) which relevant spatial and temporal scales should be taken into account and (iii) which conceptual tools are needed to address these issues. The importance of a carefully-nested combination of (novel) surface and boundary layer measurement equipment was emphasized. The Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) campaign, planned for summer 2020 on the Iberian Peninsula, could provide a benchmark study of landscape-scale ET determination.

As a result of these comprehensive discussions, a second workshop will be organized relatively soon to keep the involved community active and try to expand and attract input from other interested parties. The University of Wageningen in The Netherlands will host this event from 26 to 28 August 2020. Furthermore, the group has not yet made a recommendation on how to organize itself within GEWEX: either as a Cross-Cut action with GHP taking advantage of all the regional activities, or as a Process Evaluation Study (PROES) with a more general perspective.

References

Cuxart, J., A. Verhoef, T.R. Marthews and J. Evans, 2019. Current Challenges in Evapotranspiration Determination. *GEWEX News*, 29:5-6, *https://www.gewex.org/gewex-content/files_mf/1551991026Q1_2019.pdf*.