GEWEX QUARTERLY

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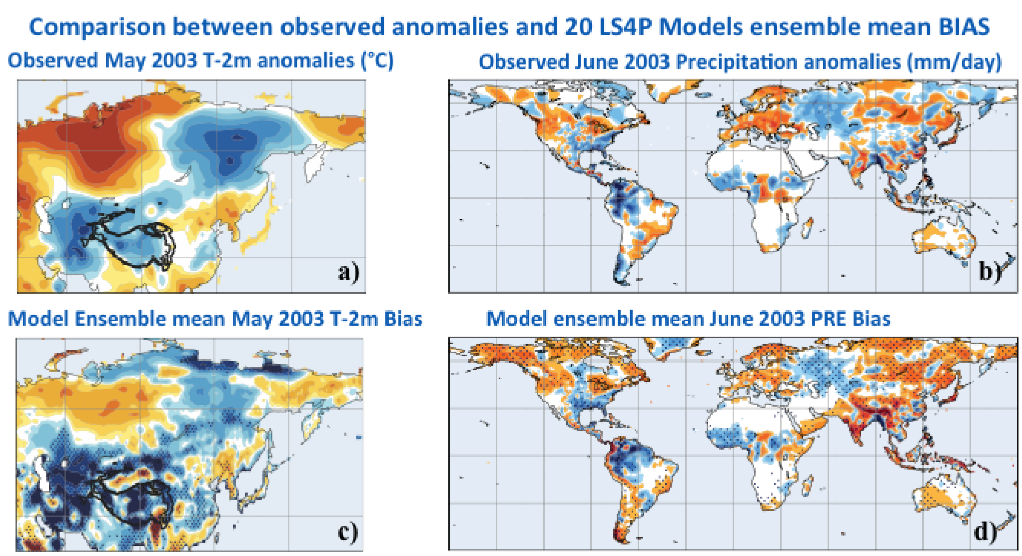
GEWEX is a Core Project of the World Climate Research Programme on Global Energy and Water Exchanges

LS4P and TPEMIP:

Third Pole Land Surface and Subsurface Temperatures May Have Substantial Remote Predictive Capability for Subseasonal to Seasonal Precipitation



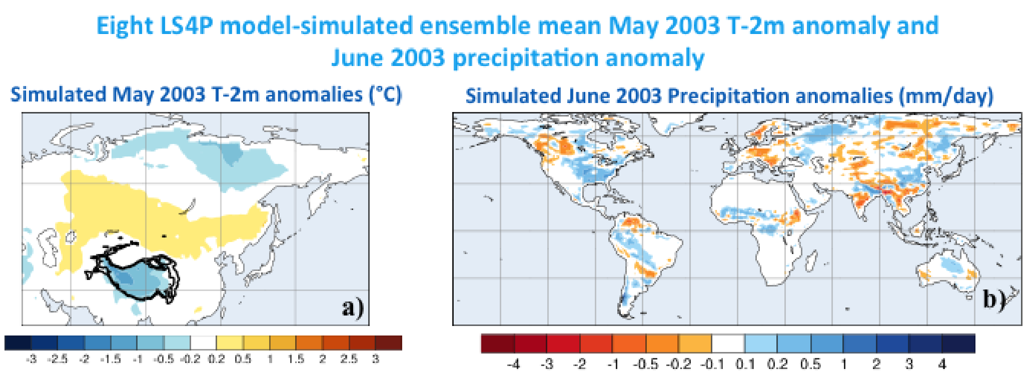


Figure 1 (top). Figure 1. Comparison between observed anomalies and LS4P 20-Model Ensemble mean bias. 1(a) and 1(b) Observed May 2003 T-2m and June 2003 precipitation anomalies, respectively; 1(c) and 1(d) LASP model ensemble mean May 2003 T-2m bias and June 2003 precipitation bias when models have cold bias over the TP. Every model has a large T-2m bias over the Tibetan Plateau area. For models with positive T-2m bias, the T-2m and precipitation biases are multiplied by -1 to be included in the composite. Note: color scales are shown in Figure 2.

Figure 2(a) and 2(b) (bottom). Eight LS4P model ensemble mean for the May 2003 T-2m anomaly and June 2003 precipitation anomalies, respectively, after imposing an LST/SUBT anomaly at the first model integration step.

Inside This Edition

Commentary: Updates to the GEWEX Science Plan

Graeme Stephens
Co-Chair, GEWEX Scientific Steering Group

The very first GEWEX newsletter released in spring 1991 provided contributions by both Dr. Moustafa Chahine, the Chair of the GEWEX Scientific Steering Group (SSG), and Professor Pierre Morel, Director of WCRP. While Dr. Chahine outlined the objectives of GEWEX that shaped the program for many years to come, Professor Morel offered the insight that "A little thought about the problem of climate and climatic variations leads to an understanding that the main difficulty lies with getting the coupling right between the different components of the climate system, the global atmosphere, the world oceans, land and sea ice and the land surface hydrology including snow and vegetation." Although both WCRP and GEWEX have evolved from that time, many aspects of Morel's vision remain true today. As WCRP undergoes a reorganization and develops its strategic plan for the coming years, its focus remains true to Morel's insight that the emphasis will be toward developing a more quantitative understanding of climate processes, which are necessary for "getting the coupling right between the different components of the climate system."

Water and its energy content are the main physical quantities that couple the different components of the climate system. GEWEX grew out of the realization springing from the Global Atmosphere Research Programme (GARP) that there was little understanding of the global energy and water budgets, and that this was not about to change with the major programs of the time like the World Ocean Circulation Experiment (WOCE) and the Tropical Ocean and Global Atmosphere Project (TOGA). It also developed from the emergence of global observations that served as a foundational element of the program, such as the impending observations promised by the National Aeronautics and Space Administration (NASA)'s Earth Observing System (EOS) and satellite observations already being developed for the International Satellite Cloud Climatology Project (ISCCP) and other efforts. Today, GEWEX provides stewardship of major global climate data sets that relate to understanding Earth's water and energy budgets, and is influential in the development of the next generation of critical observations.

In late January 2020, the SSG will meet in Pasadena, California to complete the definition of GEWEX science plan. The science plan is framed around three overarching objectives:

1. Prediction: the extent to which Earth's water cycle can be predicted
2. Process: quantify the inter-relationships between the energy and water cycles
3. Anthropgenic Influences: measure the anthropogenic influences on Earth's water cycle

Key to progress are the initiatives being developed around both modeling and observations. One of the new projects, and one that may well be a flagship effort of WCRP, is the development of the next-generation version of the ISCCP, a coordinated effort across major operational satellite organizations to create global, high-resolution in space and time data products (order 2km global, 10 minute) on clouds and related information that will have many applications. This is an ambitious plan and it has received great interest. The first planning meeting was held 28-30 October 2019 at the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in Darmstadt, Germany. A strategic plan for the ISCCP-next generation is being drafted out of the deliberations of that meeting. A summary of that plan will be provided in a forthcoming GEWEX newsletter. Initiatives such as the new iteration of ISCCP will dovetail well with the refreshed objectives of the GEWEX science plan and provide a foundation for studying the prediction, processes and anthropogenic influences on the water cycle.

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Retirement of Dr. Robert (Bob) A. Schiffer

Peter van Oevelen
Director, International GEWEX Project Office

On November 30, 2019, after 57 years of service at the National Aeronautics and Space Administration (NASA) [at the Jet Propulsion Laboratory (JPL); NASA Headquarters; the Goddard Space Flight Center; University of Maryland, Baltimore County (UMBC); and the Universities Space Research Association (USRA)], Bob Schiffer is retiring. Bob has been one of the critical pillars of GEWEX since its inception, and has been an excellent advisor, fabulous sound board and a wonderful colleague to work with during my 15 years in the GEWEX orbit. Bob's professional experience, which is detailed below, is characterized by great depth and breadth. He should be very proud of all his accomplishments! I am grateful for all the years I have had the pleasure of working with him, sitting through many a meeting, putting out organizational fires, fixing programmatic issues and enjoying pleasant lunches and wonderful dinners. Bob, I thank you on behalf of the entire GEWEX community, which is truly indebted to you. We wish you much enjoyment during your retirement. I know I will miss you, and I hope I can still call on you from time to time for sage advice and to reminisce about the good old times!

Dr. Robert A. Schiffer served as Principal Scientist at USRA in Columbia, MD. He retired from NASA in 2002 after 39 total years of service, including 11 years as a research scientist and engineer at JPL and 28 years at NASA Headquarters in Washington, D.C., where he was Chief of the Atmospheric Sciences Branch and then Deputy Director of the Research Division in the Office of Earth Science. At JPL, he conducted research on space and atmospheric environmental effects on launch vehicles and planetary spacecraft. At NASA Headquarters, Dr. Schiffer was responsible for organizing and managing basic and applied space technology research on global weather and climate analysis and prediction, and served as lead program scientist for a variety of space missions, including the Nimbus and Earth Radiation Budget satellites. In 1981, he was detailed (part-time) to the World Meteorological Organization (WMO) Secretariat in Geneva, Switzerland, where he served as Director of the Radiation Projects Office for the World Climate Research Programme (WCRP) for 15 years. His achievements there include key cornerstone efforts of future GEWEX projects, such as the International Satellite Cloud Climatology Project (ISCCP), the Surface Radiation Budget (SRB) project and the GEWEX Radiative Flux Assessment. For more than 10 years, Dr. Schiffer chaired the U.S. Global Change Research Program (USGCRP) Interagency Committee on Global Observations and Monitoring, and co-chaired the Interagency Committee on the Global Water Cycle. He also acted as principal NASA liaison to the Board on Atmospheric Science and Climate (BASC) at the National Academy of Sciences, and to the Director of the National Weather Service at the National Oceanic and Atmospheric Administration (NOAA). In addition, he served as the Executive Director of the U.S. Secretariat for International Global Observing Systems Programs, sponsored by the White House Office of Science and Technology Policy's Committee on the Environment and Natural Resources (CENR), and co-chaired the U.S./U.S.S.R. Bilateral Working Group on Climate Research. During this period he worked as the Executive Secretary of the NASA Earth Science and Applications Advisory Committee. In 1999, he represented NASA at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) Scientific Forum on Climate Variability and Global Change (UNISPACE Ill) in Vienna. In 2000, he led a NASA delegation to Morocco to open discussions on potential cooperative projects with the Morocco Remote Sensing Center in Rabat. After retiring from NASA, he served as Chief Scientist at the Goddard Earth Science and Technology Center at UMBC, and as NASA principal investigator and Director of the International Project Office for the WCRP Global Energy and Water Cycle Exchanges Project (GEWEX). Dr. Schiffer earned M.Sci. and Ph.D. degrees in Atmospheric Physics from the University of California at Los Angeles (UCLA), and B.Aero.E and M.Aero.E degrees (Aeronautical Engineering) from the Polytechnic Institute of Brooklyn. His doctoral dissertation research at UCLA was on the "Depolarization of Multiply Scattered Atmospheric Radiation due to Molecular Anisotropy". He was licensed as a Professional Engineer in New Jersey (Civil Engineering) and in California (Mechanical Engineering). For his service to NASA, he was awarded the Distinguished Service Medal, NASA's highest award; two Medals for Outstanding Leadership, for his contributions to interagency and international climate research and global environmental observations; and two TERRA awards for contributions to NASA's Mission to Planet Earth science program. He was elected a Fellow of the American Meteorological Society and continues to support NASA and the WCRP on global climate change scientific planning and space-based hydro-meteorological research. Overall, Dr. Schiffer has led key components of NASA, interagency and international scientific research for over 57 years. His impressive career speaks to the caliber of his work, and the GEWEX community is grateful for his contributions.

Peter and Bob at Bob's retirement lunch, hosted by USRA

In Memoriam: Chuck Long

The BSRN Community

The Baseline Surface Radiation Network (BSRN) and the greater radiation measurement community wish to express our collective grief in the wake of Chuck Long's death on 21 November 2019. Chuck was a noted participant with BSRN and ultimately succeeded Ellsworth Dutton as manager of the network in 2014, maintaining that role until retirement in 2018. He was a cherished colleague, guide, mentor, and good friend to all. Some of us have known Chuck since the nineties, during the early years of the BSRN; others met him later, but we were all immediately taken with his innovative and practical approach to science, and especially the kindness in his interactions with others.

Chuck was a hands-on scientist, always striving to improve radiation measurements by organizing and participating in many field and laboratory experiments during his career. He had a knack for approaching problems from alternative directions, which resulted in insightful and pragmatic solutions that were often revolutionary within the measurement community. It was evident his solutions were based on a deep insight into radiative theory and backed by a substantial amount of research and data management experience. Chuck was also an instrument developer. Requiring an objective way to determine cloud fraction for his research but not finding a reasonably priced option readily available, he set out to build his own solution. That solution, the Total Sky Imager, is now a fully commercialized instrument used by researchers around the world.

Always full of life, with a great sense of humor, and open to discussing science with colleagues of any level, interacting with Chuck was always a pleasure. It was a wise person who paid attention during those conversations as those who did undoubtedly benefited from his sage advice. He tirelessly encouraged and supported younger colleagues, was a true mentor for many BSRN participants, and a genuine pillar of BSRN and the entire radiation measurement community.

Chuck left us an impressive and unique scientific and technical heritage, which we honor by striving to carry on our common passion: increasing humanity's knowledge of Earth's radiation balance. RIP, Chuck. We miss you.

Chuck's Obituary: *https://kochfuneralhome.com/tribute/details/2024/Charles-Long/obituary.html#tribute-start*

LATICE—Land-Atmosphere Interactions in Cold Environments

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The focus of LATICE, a strategic research initiative of the Faculty of Mathematics and Natural Sciences at the University of Oslo, is on cold-region land-surface exchange processes within the Earth system for better prediction of future climate and land-surface states. LATICE is an interdisciplinary initiative to analyze the role of atmospheric, biospheric, cryospheric and hydrospheric interactions in a changing climate. The goal of the project is to improve the understanding of Earth processes and model representation of key features of northern environments, including snow, permafrost, seasonal frost, wetlands and high-latitude vegetation that are not suitably represented in state-of-the-art Earth system models. This will be achieved by linking a wide range of observations and laboratory experiments for model development (Figure 1). Observations comprise targeted field studies, data from regular station networks and remotely sensed data with a focus on the interactions and feedbacks between the land and the atmosphere, including the boreal, alpine and Arctic zones. This work will advance the land module in the Norwegian Earth System Model (NorESM) Community Land Model (currently CLM5.0, which has notable updates on soil, plant hydrology, snow density, carbon and nitrogen cycling and coupling; Lawrence et al., 2018), as well as assisting in evaluating the Functionally Assembled Terrestrial Ecosystem Simulated model (FATES; Fisher et al., 2018), a dynamic vegetation module now under development.

A key achievement of the LATICE project has been the establishment of the Finse Eco-Hydrological Observatory (Finse-EcHO) that integrates field and modeling efforts across observational systems. Finse-EcHO is a low-alpine site located in the central mountainous region of southern Norway at approximately 1200 m.a.s.l. (see Figure 1, lower panel). It is well recognized nationally as a key field site and is also becoming so internationally. This is partly due to the unique location of the LATICE Eddy-Covariance (EC) station (one of only three EC stations in Norway). The infrastructure, combined with a wide range of distributed in situ observations of hydrometeorological variables, including snow cover and depth, as well vegetation characteristics, make it a site of interest to a large community. Data are transmitted real time by a wireless sensor network to a database hosted at the University of Oslo. LATICE recently obtained funding for a climate container that will provide a unique facility to perform dedicated snow-vegetation-soil experiments and will supplement ongoing ecosystem experiments in a climate-controlled phytotron.

The LATICE project responds to the need for more research on high-latitude vegetation, in particular in light of projected strong Arctic and sub-Arctic warming and related biogeographical shifts. Vegetation interacts with climate through albedo, roughness, evapotranspiration, carbon dioxide sequestration and by influencing snow accumulation and ablation. Overall, high-latitude vegetation lead to positive climate feedbacks and is an important element in improving parameterization in land-surface models. This includes the lack of representative plant function types typical for cold regions, such as lichen and mosses that cover large areas in the north. A preliminary comparison of snow depth with vegetation maps, created using the "Nature in Norway" system (*https://www.nhm.uio.no/english/research/projects/nin/*), shows an immense potential for pioneering studies on interactions between climate and vegetation.

Recent work includes integration of fine-scale snow distribution in a coupled land-surface model (Aas et al., 2017), improved representation of snow in a distributed hydrological model (Matt et al., 2018), a high resolution climatology of rain-on-snow events for mainland Norway (Pall et al., 2019), improved representation of snow and permafrost processes (Westermann et al., 2016) and representation of thaw processes in ice-rich permafrost landscapes with laterally coupled tiles in a land-surface model (Aas et al., 2019). We are currently simulating and measuring the effect of snow patches on the structure of the turbulent boundary layer, which we hypothesize influences snow melt significantly. Ecologists in LATICE have mapped the vegetation distribution based on drone aerial surveys at two (1 x 1 km) sites at Finse; one at the eddy covariance (EC)-flux tower and one at a dedicated snow monitoring site for integrated research on atmosphere/snow/vegetation processes. Furthermore, in collaboration with the University of Copenhagen, we are conducting EC measurements of Biogenic Volatile Organic Compounds emitted by the alpine vegetation at Finse. The LATICE group also conducts EC measurements at a permafrost peatland site (Martin et al., 2019) in northern Norway and leads the eddy covariance flux monitoring of a wetland restoration experiment by the Norwegian Environment Agency.

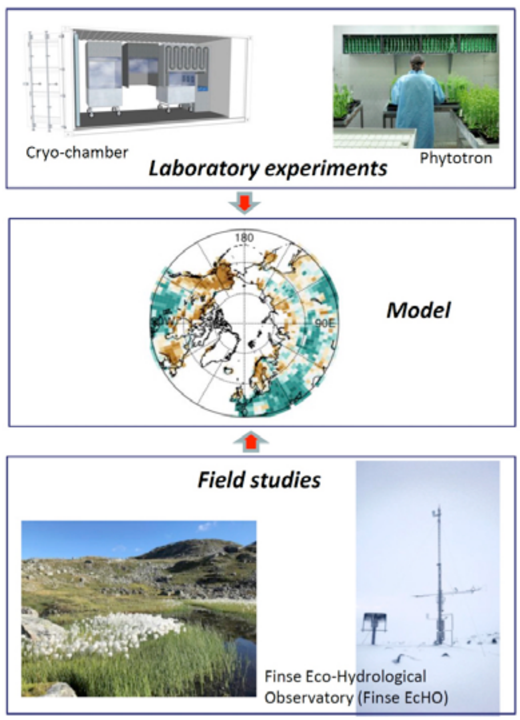

***Figure 1**. The three pillars (laboratory experiments, land-surface modeling and field observations) of LATICE.*

Ongoing studies are planned to evaluate and detect model deficiencies, find the cause of model biases and improve model parameterization (see Figure 1). These include:

- Representation of vegetation-cloud feedbacks (i.e., strong bias in CMIP5 models in depicting correlations between satellite-based observations of cloud cover and Gross Primary Productivity),
- Biases in simulated vegetation distributions by the CLM4.5 dynamic vegetation module for sites in Norway, and
- The failure of CLM4.5 to reproduce seasonal snow cover at high Arctic tundra sites (rather a continuous snow cover is simulated) leading to biased carbon and energy fluxes with potentially large-scale implications.

The LATICE project is seeking to expand its international collaboration with CLM scientists at the U.S. National Center for Atmospheric Research (NCAR) and the World Climate Research Program (e.g., Earth System Model-Snow Model Intercomparison Project; Krinner et al., 2018). A joint high latitude model intercomparison project with the GEWEX Global Land/Atmosphere System Study (GLASS) Panel using LATICE observations for model development and evaluation studies is in the initial planning stages. For local and regional scale studies, LATICE is interested in providing the GEWEX Hydroclimatology Panel with their experiences related to water and energy exchanges For more information about LATICE, please visit *http://www.mn.uio.no/latice*.

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Understanding Aerosol-Cloud Interactions is Key for Reliable Future Heatwave Projections

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The past few years have witnessed numerous heatwaves around the world that have been reported as "record-breaking," "abnormal," "rare" and "catastrophic" by the media. These extreme events have resulted in catastrophic damage to both human society and ecosystems. As the climate warms, it is projected to intensify the frequency and duration of severe heatwaves. Although large gaps still exist in our understanding of the underpinning mechanisms, many studies have identified anthropogenic impacts on heatwave changes (Perkins, 2015). While the increase in well-mixed greenhouse gases (GHG) from human activities is one of the major drivers of heatwaves, the important role of anthropogenic aerosols has also been documented at both global and regional scales.

Aerosols can influence climate by absorbing and scattering shortwave radiation (aerosol-radiation interactions) and by modifying cloud microphysics and precipitation processes (aerosol-cloud interactions). Yet, aerosol forcing remains the dominant uncertainty in current estimates of radiative forcing of climate since the industrial period. Quantifying the influence of anthropogenic aerosols on climate is particularly challenging due to compounding uncertainties associated with the large spatial and temporal variability of aerosols, their short lifetimes, their diverse physical and chemical properties and complex interactions that take place with radiation and microphysical processes (Fan et al., 2016). Worldwide anthropogenic aerosol emissions are projected to decline in the coming decades through measures aimed at improving air quality, thus unmasking a considerable fraction of the GHG-induced warming and substantially modulating the projected near-future climate response. In light of their important role, it is crucial to quantify the potential impact of aerosol declines on changes in future heatwaves.

Our work (Zhao et al. 2019) made use of the fully-coupled Community Earth System Model (CESM1) large ensemble simulations (Kay et al., 2015) to investigate future changes in heatwaves under the Representative Concentration Pathway 8.5 scenario (RCP8.5). The impact of aerosol reductions was calculated as the difference between experiments forced by the RCP8.5 forcings and a paired set of simulations where aerosol emissions were fixed at 2005 levels.

Future GHG increases will result in heatwaves that are, when globally averaged over land, significantly more intense (2.4 K), longer (17 days), and more frequent (12 more per year), compared to present-day by 2081–2100. These changes will be further aggravated by aerosol reductions. Namely, an additional increase of 0.6 K (25%), 7 days (41%) and 2 per year (12%) in intensity, duration and frequency, respectively, on top of the GHG-related changes. Changes in heatwave magnitude (an integration of intensity and duration) are driven mainly by mean climate warming and show only a small contribution from changes in future climate variability (internal processes that cause fluctuations around the average without causing the long-term average itself to change). Following the RCP8.5 scenario, we find that on global average, present-day (1986–2005) heatwave magnitude records will be exceeded in about 65% of the years in the second half of the twenty-first century (i.e., 2051–2100). The earliest emergence of record-breaking heatwave events will occur in the tropics as their small temperature variability makes present-day records much easier to be disrupted with a relatively small amount of warming. Record-breaking heatwaves, especially those in the tropics and the Southern Hemisphere, stem primarily from GHG increases. However, a prominent aerosol signal is recognizable in the Northern Hemisphere, in particular over Europe, China and eastern USA.

Future GHG increases and aerosol reductions both result in climate warming and increases in heatwave metrics. However, when normalized by the amount of global mean warming, aerosol reductions, compared to GHG increases, lead to much stronger responses in heatwave magnitudes (Figure 1a). By 2081–2100, while aerosol-driven changes in monthly mean surface air temperature tend to stabilize, heatwave duration continues to rise concurrently with changes in daily maximum temperature (Figure 1b), leading heatwave magnitude to increase exponentially with warming. Changes in cloud liquid water path (Figure 1c) and in top-of-the-atmosphere clear-sky shortwave radiation (Figure 1d) reflect the predominant role of aerosol-cloud interactions in increasing daily maximum temperature and, thereby, heatwave duration/magnitude. More specifically, the response of cloud droplet size and cloud albedo to a given change in aerosol loading is exponentially larger in cleaner air, resulting in coherent variations in daytime surface shortwave radiation and atmospheric stability. Therefore, with a decrease in aerosols, daytime temperatures progressively increase and become more variable, while nighttime temperatures are less influenced by aerosol-cloud interactions. Consequently, unlike mean temperature and daily minimum temperature, the daily maximum temperature continues to increase. Such different changes in daily minimum, mean and maximum temperatures may indicate the fact that aerosols have strong impacts on the temperature diurnal cycle. This will be investigated in our future works.

We note that the various RCP scenarios have similar aerosol but different GHG emission pathways. In particular, the lower GHG increases in other RCP scenarios compared to RCP8.5 may induce smaller changes in heatwave metrics. However, in other RCP scenarios, compared to GHGs, aerosols are likely to play a more important role in future heatwave projections. In addition, policy measures to control climate change, as well as air pollution, could follow many possible future aerosol emission pathways. For example, the responses of heatwaves may differ under other future scenarios such as the shared socio-economic pathways in which the spatial patterns of emission reductions differ compared to the RCP scenarios (Gidden et al., 2018).

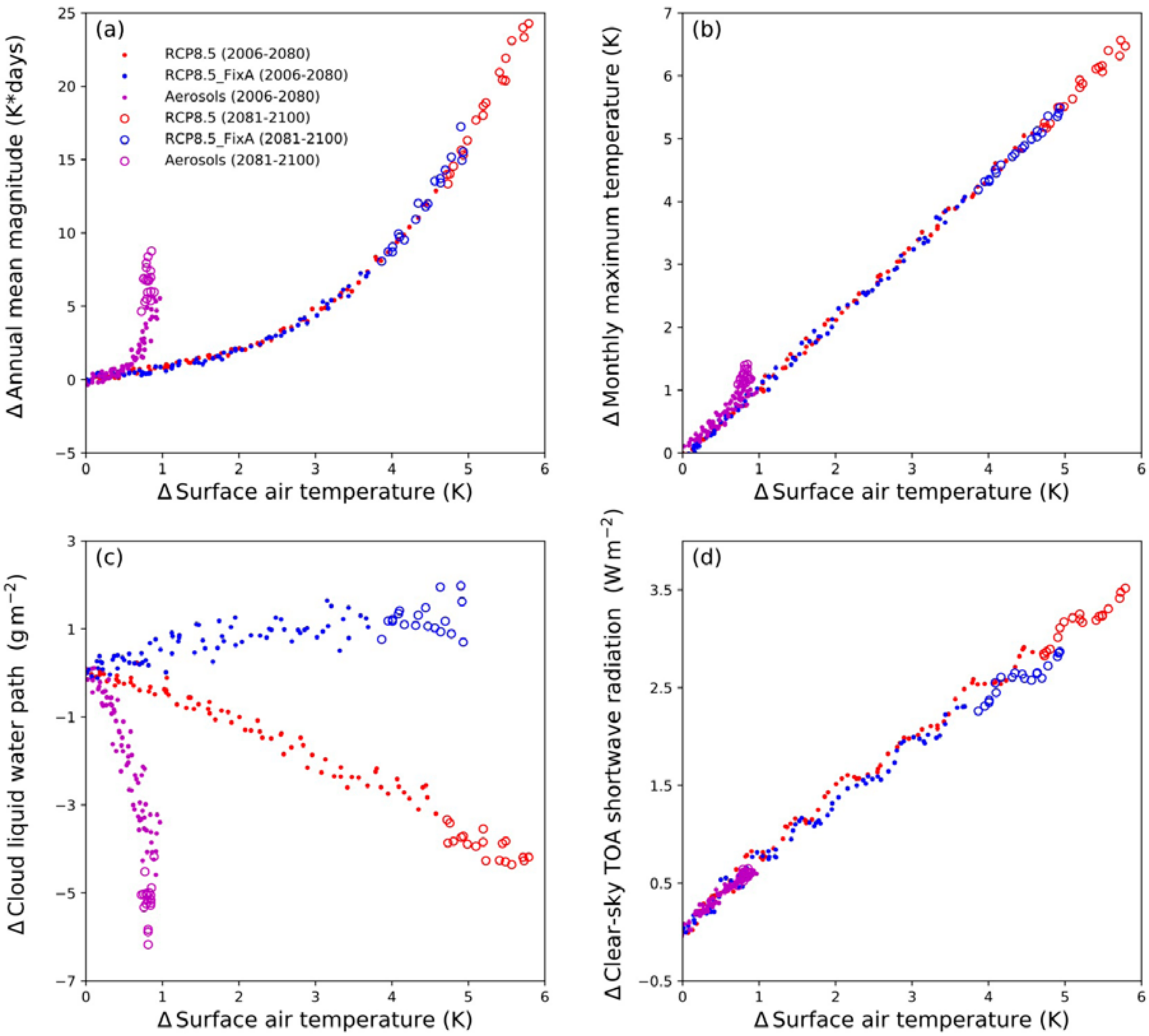

***Figure 1**. Scatterplots of changes (ensemble mean of annual mean) in land area-weighted mean heatwave magnitude (K*days) against global land mean surface temperature change. Also shown are changes in the annual mean of global area-weighted mean (b) monthly maximum temperature (TX, K), (c) cloud liquid water path (g m^{-2}) and (d) total net clear-sky shortwave radiation at top-of-the-atmosphere (W m^{-2}), all plotted against land area-weighted mean surface temperature change (K). All scatterplots are plotted separately for the period 2006–2080 (filled small dots) and 2081–2100 (large circles). The color conventions are: red for RCP8.5 (GHGs + aerosols), blue for RCP8.5_FixA (GHGs only) and magenta for aerosols, isolated by the difference RCP8.5 - RCP8.5_FixA.*

The results described here suggest a critical and progressively larger role of aerosol-cloud interactions in modulating the occurrence and characteristics of future heatwaves worldwide, with consequent crucial implications for human health, societies, infrastructures and ecosystems. In light of the models' large discrepancies in representing the poorly-constrained aerosol-cloud interaction related processes (Fan et al., 2016), these findings further emphasize the compelling need to address this potentially large source of uncertainty in future climate projections. Even further, the non-linear response of the magnitude of the temperature response to changes in aerosol loading and the buffering of the aerosol indirect effects may translate into even larger uncertainties in aerosol-mediated responses in future climate.

In short, given the detrimental impacts of changes in future heatwaves, and to more effectively manage climate risks, we call the attention of the community to prioritize efforts towards reducing uncertainties in aerosol-cloud-radiation interactions. These will help achieve more reliable projections of future climate extremes, as well as effective strategies for climate risk management.

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Meeting/Workshop Reports

Remote Effects of Tibetan Plateau Spring Land Surface Temperature on Global Summer Precipitation and its S2S Prediction: Second Workshop on LS4P and TPEMIP

Nanjing, China
7–9 July, 2019

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After the first workshop on the "Impact of initialized land temperature and snowpack on sub-seasonal to seasonal prediction" (LS4P) and "Third Pole Experiment Multi-Model Intercomparison" (TPEMIP) during the 2018 American Geophysical Union (AGU) Fall Meeting in Washington, D.C., USA (Xue et al., 2019), more observational and modeling studies have supported the concept that the high elevation land surface temperature/subsurface temperature (LST/SUBT) in the Third Pole region (TP) has a substantial remote predictive capability for precipitation at subseasonal to seasonal scales (S2S). Following recommendations from the first LS4P Workshop in Washington, D.C., the second workshop on LS4P and TPEMIP was held at Nanjing University in China from 7–9 July 2019. Its aim was to engage the broader international scientific community in order to review the progress and issues in using Earth system models (ESMs) and regional climate models (RCMs) to a) identify the role of TP LST/SUBT on S2S prediction, b) initiate research on the effect of light absorbing aerosols (LAA) in the snow on the LST anomaly in the TP and on S2S prediction and c) promote and pursue RCM intercomparison TP studies.

Attended by 47 participants from different institutions around the world, the workshop was very productive with five sessions and many inspiring presentations. GEWEX, the Third Pole Experiment (TPE) program, UCLA and Nanjing University sponsored the event. The workshop information and relevant materials can be found on the LS4P project website (*http://ls4p.geog.ucla.edu*). Dr. Tandong Yao, Co-Chair of the TPE program, presented the TPE scientific and societal foci and interdisciplinary research activities in the TP. Dr. Peter Van Oevelen of the International GEWEX Project Office reported on GEWEX's current and planned high mountain activities. Various measurements from TPE and the Third Tibetan Plateau Atmospheric Scientific Experiment (TIPEX-III), as well as satellite remote sensing of components of the water cycle, cryosphere, vegetation, radiation, land surface properties, aerosols and planetary boundary layer in the TP, were presented during the workshop. Dr. Xin Li of the Institute of Tibetan Plateau Research, China, provided an overview of the Big Data Center for the TP, which not only provides various data sets for TP research, but will also host the database that will store the LS4P model products. Dr. Chunxiang Shi of the Chinese National Meteorological Information Center discussed efforts to produce the most up-to-date TP 2-meter temperature data set spanning the past 30+ years with half degree resolution and adequate topographic information. This data set will be used by the LS4P for model evaluation and experimental design.

After the first workshop, the LS4P teams succeeded in accomplishing major tasks assigned during the first phase of activity, and the preliminary analyses were reported. Twenty LS4P ESM groups submitted Task 1 results, which aim to show the relationship between the ESM-produced May 2003 T-2m temperature bias in the TP and the June 2003 precipitation bias. May 2003 was a very cold month in the TP. Figures 1a and 1b (see cover for all figures) show the observed cold T-2m anomaly in the TP in May 2003 and the observed global June 2003 precipitation anomaly patterns, respectively. Every ESM has a large T-2m bias in the TP. Eleven (nine) LS4P models have positive (negative) May 2003 T-2m biases, respectively. For models with positive May T-2m bias, their temperature and precipitation biases are multiplied by -1 to be included in the ensemble mean composite, which is compared with the observed anomalies. Figures 1c and 1d show the simulation biases from the 20-ESM ensemble means for the May 2003 T-2m and June 2003 precipitation, respectively. Both Figure 1a and Figure 1c show that with a cold May TP, the Iranian Plateau to the west of the TP was also cold, and the Eurasian continent shows planetary wave-like warm-cold-warm patterns. The observed 2003 June precipitation anomaly and June precipitation simulation bias as shown in Figures 1b and 1d, respectively, have a remarkable similarity, with the global spatial correlation coefficient being 0.57. In particular, the precipitation bias patterns in the U.S. and southern Canada, northern South America, West Africa, Western and Eastern Europe and the Eurasian Russia continent, South Asia, Indonesia and Australia are generally consistent. East Asia, which was our original focus area (Xue et al., 2018), only constitutes a small portion of all these similar patterns. The agreement between model results and observations from diverse independent sources greatly stimulates our scientific curiosity to extend our assessment of the TP LST/SUBT effect expanding from our original focus on East Asia to the entire globe.

Since every ESM has large positive/negative bias in the TP May T-2m simulation, in order to generate the observed May 2003 T-2m cold anomaly in the TP, each modeling group participating in LS4P Task 3 imposed a LST/SUBT anomaly in the TP at the initial time step aiming to reproduce the observed May 2003 cold anomaly. Due to current models' inability to preserve the surface temperature anomaly, the ESMs still

Participants of the Second LS4P atnd TPEMIP Workshop

have difficulty fully reproducing the observed May 2003 T-2m anomaly. Nevertheless, 10 model groups have submitted their preliminary results for Task 3, which reproduced the observed May 2003 TP T-2m anomaly to various degree of realism. These modeling groups and ESMs include the Bureau of Meteorology Australian Community Climate and Earth-System Simulator version S2 (BOM-ACCESS-S2), the European Centre for Medium-Range Weather Forecasting Integrated Forecasting System (ECMWF-IFS), the Institute of Atmospheric Physics/Chinese Academy of Sciences (IAP/CAS), the Climate Forecast System of the Indian Institute of Tropical Management (CFS_IITM), the Japan Meteorological Agency (JMA)/Meteorological Research Institute (MRI), the Korea Institute of Atmospheric Prediction Systems (KIAPS)/Korea Meteorological Administration (KMA), the State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG)/CAS in China, Météo-France and the Centre National de Recherches Météorologiques-Climate Model 6 (CNRM-CM6), the Lawrence Livermore National Laboratory(LLNL)/U.S. Department of Energy (DOE) Energy Exascale Earth System Model (E3SMv1), and the University of California, Los Angeles (UCLA)-Climate Forecast System (CFS)/Simplified Simple Biosphere (SSiB) model in the U.S. Figure 2a shows that after imposing the LST/SUBT anomaly at the first integration time, the model ensemble mean produces a clear but weaker May 2003 T-2m anomaly in the TP. Please note that the results in Figures 2a and 2b correspond to those reported at the workshop, which were based on results from an 8-model mean. The simulated ensemble mean of the June 2003 precipitation anomaly is shown in Figure 2b. By comparing Figures 1b and 2b, the potential hot spots of Tibetan Plateau effects are identified. The areas having the most possible effects from the TP LST/SUBT are: the eastern part of China, South Asia, the continental U.S. and southern Canada, northern South America, West Africa, Western and Eastern Europe and the Eurasian Russian continent, Indonesia and Australia. In Figure 2b, the signals are weaker over some areas than what is shown in Figure 1b, which seems to be consistent with the weaker May T-2m anomaly in the ensemble mean (Figure 2a). We started the LS4P initiative for East Asia. Within the past year, we have found that it turns out to be a global issue. Since the Task 3 test is still ongoing and the model-produced LST anomaly is still weaker than observed, more tests with improved modeling are required to further confirm TP LST/SUBT effects. However, from the preliminary results from Task 1 and Task 3, as well as from Task 2 and other data analyses based on observations (not shown), for the first time it has been suggested that the spring LST/SUBT in the TP may have a global impact on summer precipitation and its S2S prediction. All these findings provide assurance that our approach is in the right direction.

In addition to the LST/SUBT, another factor under investigation in LS4P is the LAA in the snow, which affects the snow melt and spring LST/SUBT in the TP and the monsoon in South and East Asia. A review of measurements and modeling of light-absorbing particles in snow/ice over the TP and their climatic and hydrological impact was reported by Dr. Yun Qian of the Pacific Northwest National Laboratory. Dr. Shichang Kang of the State Key Laboratory of Cryospheric Science at the Chinese Academy of Sciences discussed the sources and temporal and spatial characteristics of some aerosols in the TP. Dr. William Lau of the University of Maryland and Dr. Xiaohong Liu of the University of Wyoming presented the impact of LAA in terms of the impact of snow effects on the monsoon and possible underlying mechanisms.

In addition to the ESM, the RCM is also an important tool in identifying the LST/SUBT effect (Xue et al., 2018). While RCMs have exhibited skillful downscaling ability in S2S regional prediction in different regions of the world, Dr. Guiling Wang of the University of Connecticut showed that modeling of S2S TP weather/climate and associated prediction of rainfall in downwind regions remain scientifically challenging. Drs. Deliang Chen of the University of Gothenburg, Shiori Sugumoto of the Japan Agency of Marine-Earth Science, and Tomonori Sato of Hokkaido University all demonstrated the urgent need to conduct high-resolution RCM downscaling in TP research. Dr. Kun Yang of Tsinghua University has demonstrated that some features, such as complex terrain effects and west-east precipitation oscillation in lake areas caused by lake-air interaction in the TP, can only be produced by fine-resolution RCMs. However, he also pointed out that using high-resolution models requires high computational cost and sometimes is associated with less numerical stability. In addition to RCM downscaling, some promising results from preliminary testing using the RCM with a larger domain to test LST/SUBT effect in the TP were also reported.

In the breakout discussion session, the ESM, RCM and LAA groups discussed issues and future plans for the next stage of research. For the ESM group, modeling groups will work on the improvement of the LST memory simulation to produce a more stable T-2m anomaly close to the observed one. This problem may be rooted in the deficiency in producing proper soil memory and land/atmosphere interaction. To improve the simulation, some technical suggestions were distributed to the ESM group members. Meanwhile, a test of the sea surface temperature effect will be conducted as Task 4 for comparison with the LST/SUBT effect. For the LAA group, the objectives are better understanding of the relationship among LAA deposition, snowmelt/albedo reduction, TP land-atmosphere coupling and Asian summer Monsoon rainfall variability and predictability. The focus will be on the relationship between snow darkening effect and LST/SUBT anomalies, surface energy and water balance (including runoff) and S2S prediction. The LAA experiments will be coordinated with the main LS4P experiments. The RCM group discussed issues in RCM intercomparison and the experiment to test the LST/SUBT remote effect. The RCM domain size and resolution were reviewed, and the RCM model output list is available on the LS4P website. LS4P will complete the first three tasks around the end of 2019. There are two LS4P sessions at the 2019 AGU Fall Meeting along with a mini-workshop in order to discuss the LS4P main results, a special issue in Climate Dynamics, and a possible LS4P article in a high impact journal.

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The GEWEX Water Vapor Assessment (G-VAP): Summary of the 8th Workshop

Madrid, Spain
13–14 June 2019

Marc Schröder[1], Hélène Brogniez[2], Shu-peng Ho[3] and Participants of the 8th G-VAP Workshop
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The major purpose of G-VAP is to quantify the state-of-the-art in water vapor products being constructed for climate applications, and by this, support the selection process of suitable water vapor products by the GEWEX Data and Analysis Panel (GDAP) for its production of globally-consistent water and energy cycle products. Workshops are carried out on an annual basis to discuss recent findings, to further refine the plan and to implement new activities as well as to draft and consolidate the assessment reports. The 8th G-VAP workshop was hosted by the Agencia Estatal de Meteorologia (AEMET) in Madrid, Spain, and took place on 13 and 14 June 2019. Approximately 20 participants from research institutes [Consiglio Nazionale delle Ricerche (CNR), Laboratoire de Météorologie Dynamique-Institut Pierre Simon Laplace (LMD-IPSL), Karlsruhe Institute of Technology (KIT), Max Planck Institute for Chemistry (MPI-C)], universities (Free U. Berlin, U. of Bremen, U. of Cologne, Colorado State U., U. of Leicester, U. of Miami, U. of Michigan, U. of Paris-Saclay, Vanderbilt U.), from weather services [AEMET, the Danish Meteorological Institute (DMI), Deutscher Wetterdienst (DWD), the National Oceanic and Atmospheric Administration (NOAA)] as well as from space agencies [the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)] attended the workshop. A group photo of workshop participants is shown in figure 1. The presentations of the 8th G-VAP workshop are available at *www.gewex-vap.org*. The main objectives of the 8th workshop were to present updates on water vapor data records and associated retrievals; to present and discuss results from the analysis and the characterization of water vapor products; to discuss the next steps of G-VAP, including potential new activities; to initiate a special issue in a peer-reviewed journal; and to discuss time line changes and the G-VAP data archive.

The workshop started with a welcome address by AEMET and introductory presentations on G-VAP and on the objectives of the meeting. After an overview talk on water vapor in the climate system, the first block of presentations focused on user needs and applications, i.e., from GEWEX and the climate modeling community. Participants discussed gathering feedback from climate modeling groups, including the Climate Modeling User Group of the ESA Climate Change Initiative (CCI) program, on how to intercompare data records in order to provide useful information to them.

A series of presentations provided updates on retrievals, data records and related validation results. Also, uncertainty estimates were evaluated and through this, the consistency among observing systems was analyzed as well. Among other items, the need for synchronized satellite/Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) observations was mentioned and the value of a multi-hyperspectral profile product was discussed and emphasized. The general consensus was that model dependency of retrieval schemes should be minimized, if not completely avoided, because forecasters typically want to compare a model-free observation with their own model. Then, G-VAP activities were presented with a focus on process studies, introduced by a presentation on the GEWEX Upper Tropospheric Clouds and Convection Process Evaluation Study (UTCC PROES).

One study observed a dry bias during the day between the Infrared Atmospheric Sounding Instrument (IASI) and GRUAN, while comparisons between Global Positioning System Radio Occultation (GPS RO) and GRUAN exhibit a wet bias during night. It was agreed that the G-VAP team working on the consistency activity will further analyze this contrast. Other uncertainty sources, i.e., not related to GRUAN approaches, may explain these differences, e.g., potential issues in the water vapor continuum absorption. It was the consensus that uncertainty analysis is of relevance to G-VAP (reconfirming an existing G-VAP recommendation) and results from related analyses will be summarized in the next WCRP report. Also, the analysis of free tropospheric humidity (FTH) variability in subsiding regions urgently requires the temporal extension of the existing FTH data record (current temporal coverage until 2009). The last scientific talk introduced the ESA Water_Vapour_cci project and its various links to G-VAP. These links include an analysis of the clear-sky bias in response to a G-VAP recommendation.

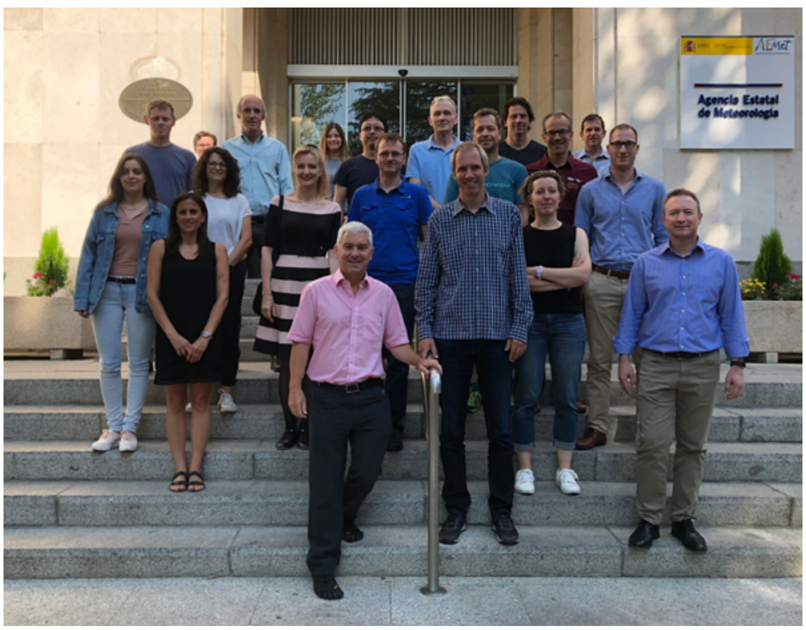

Figure 1. *Group photo of participants of the 8th G-VAP workshop*

Finally, the time line, the update of the G-VAP archive and the initiation of a special issue were discussed. The submission of the next WCRP report will be postponed to fall 2021. The assessment plan v2, available at *http://gewex-vap.org/?page_id=19*, will need to be updated accordingly. Also, new versions and data records will comprise the G-VAP data archive version 2. The archive will be an update of the G-VAP data archive version 1 (Schröder et al., 2018). However, the common period will be changed to the temporal coverages of each individual data record. The archive will be closed in Quarter 1 of 2021. Lastly, participants decided to initiate a collection of peer-reviewed publications on the analysis of atmospheric water vapor in Copernicus journals, e.g., Atmospheric Chemistry and Physics, Atmospheric Measurement Techniques, Earth System Science Data and Geoscientific Model Development.

In addition to proposals outlined in the WCRP report on G-VAP (Schröder et al., 2017), new recommendations were made at the close of the workshop. The analysis of the global water and energy budgets requires, among other things, global humidity profiles at high temporal resolution as consistent input to the various variables of the closures studies. Thus, it is necessary to assess options to merge or combine the various observing systems to provide such data. Deliberations following a presentation on water vapor isotopologues concluded with the call for the sustained provision of tropospheric water vapor isotopologue data. After presentations on uncertainty analysis were given, participants noted that the need to provide uncertainty estimates and their evaluation requires substantial resources. This is not sufficiently covered by current funding schemes, even though substantial progress was made in various projects. Thus, activities around uncertainty estimation and evaluation require increased funding budgets. Related to the quality analysis, concerns about the potential impact of 5G telecommunication links on microwave observations were raised and discussed. It is important to ensure that developments around 5G telecommunication links do not impact microwave observations around 23 GHz via radio-frequency interference.

The next workshop will take place at DMI, Copenhagen, Denmark tentatively in October 2020.

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Report of the 12th HyMeX Workshop

Split, Croatia
20–23 May 2019

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Introduction

The 2019 HYdrological cycle in the Mediterranean EXperiment (HyMeX) Workshop was the twelfth in a series of annual workshops, held this year in Split, Croatia, between 20 and 23 May. The general objectives of the HyMeX workshops are to present and discuss recent scientific progress in the understanding of the Mediterranean water cycle, from multiscale and multidisciplinary approaches, and to foster further collaborations within the HyMeX community. The HyMeX and Mediterranean water cycle science topics encompass heavy precipitation, flash floods and social vulnerability, integrated prediction of heavy precipitation and impacts, Mediterranean cyclones, ocean circulation and processes, drought and water resources, the water cycle and renewable energy. The 12th HyMeX Workshop consisted of plenary and parallel sessions, both oral and poster, as well as meetings on future work within HyMeX and beyond. Sessions and meetings were dedicated to recent and future field campaigns: Exploiting new Atmospheric Electricity Data for Research and the Environment (EXAEDRE), Pelagic Ecosystem Response to dense water formation in the Levant Experiment (PERLE) and Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE). Over 100 scientists from more than 10 countries participated in the event (Fig. 1).

Continuum Scale and Integrated Analysis

About 60 talks and 35 posters presented scientific results on the main HyMeX topics in plenary and parallel sessions. The sessions included heavy precipitation, ocean circulation processes, cyclones and strong winds, flash floods and vulnerability, flash-flood prediction, the water budget, drought and water resources and integrated prediction. Seven parallel working sessions for each HyMeX science team enabled transdisciplinary discussion and promoted exchange on current and future field campaigns.

This year, the regional climate modeling community attended a number of Mediterranean Coordinated Regional Downscaling Experiment (Med-CORDEX) workshops, as the second modeling exercise is underway. This group was therefore underrepresented with respect to previous years.

The workshop program, presentations and more information about HyMex are available at: *http://www.hymex.org*.

Ongoing and Future Field Campaigns

Three current or planned campaigns were designed within the framework of HyMeX to complement finished field experiments from the Enhanced Observation Period (Braud et al., 2014) and Special Observation Periods (SOP1, Ducrocq et al., 2014; Ferretti et al., 2014 and SOP2, Estournel et al., 2016) (see Drobinski et al., 2014 for a full overview). The new field experiments are (Fig. 2):

- EXAEDRE, which took place between September and October 2018 and centered on atmospheric electricity, completing the activities of SOP1 (Defer et al., 2015)
- PERLE, an oceanic experiment that was initiated in October 2018 with the PERLE-1 cruise and continued in March 2019 with the PERLE-2 cruise, complementing

***Figure 1**. Participants of the 12th HyMeX workshop in Split, 20-23 May 2019. Source: P. Drobinski.*

***Figure 2.** Location of the three recent and future field campaigns planned within the HyMeX framework.*

the activities of SOP2 (Estournel et al., 2016) but in the Levantine region in the Eastern Mediterranean

- LIAISE, which will be conducted between April 2020 and March 2021 with a focus on land surface interactions over the Iberian semi-arid environment

The EXAEDRE campaign objectives are to: (1) provide in situ measurements to characterize the electrical and microphysical cloud properties for a better understanding and modeling of microphysical, dynamical and electrical processes in thunderstorms; and (2) validate new airborne and ground-based instrument concepts developed within EXAEDRE. The campaign took place between 13 September and 8 October 2018 with a primary regional target: Corsica (<150 km). About 26 flight hours were completed, with weather forecast guidance provided by the students and teachers of the Météo-France Meteorology School. On the ground, a super site was set up at San Guiliano. Figure 3 shows an example of a cross-section of Radar Aéroporté et Sol de Télédétection des propriétés nuAgeuses (RASTA) cloud radar measurements (wind velocity, reflectivity, etc.) on board the French Falcon 20 during a thunderstorm of the Intensive Observation Period #7. The airborne measurements were made in the vicinity of the ground-based site, and included Doppler cloud radar measurements, in situ measurements, electric field mills, 3D-wind retrieval from the Doppler radar (3 antennas looking up and 3 antennas looking down) and microphysical properties (ice water content, etc.).

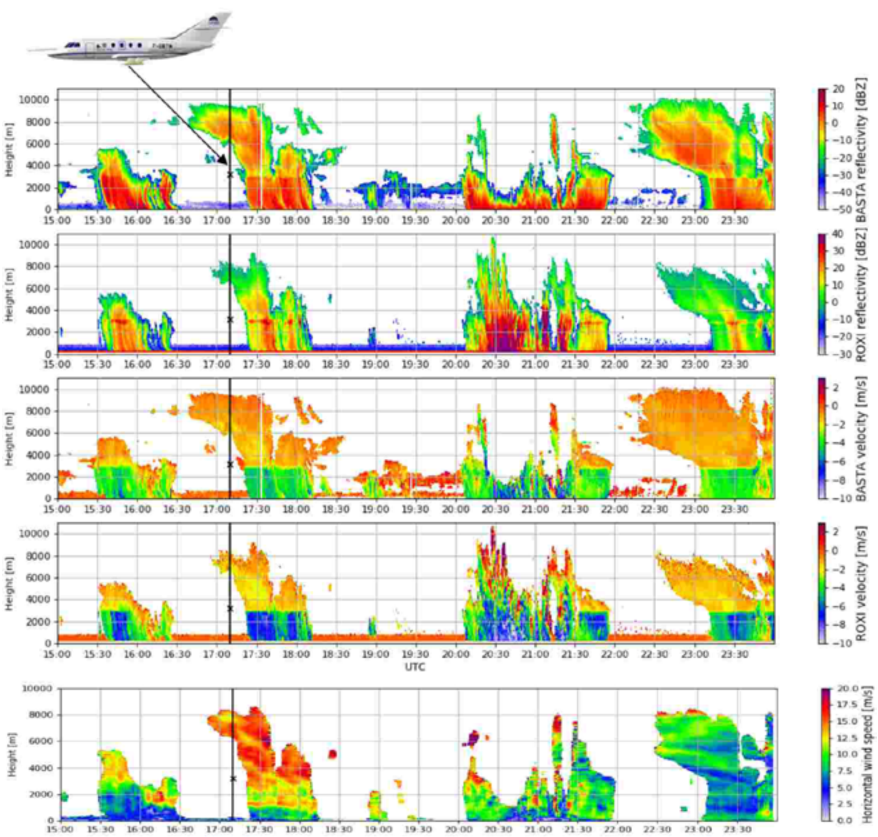

Figure 3. *Cross-section of RASTA cloud radar measurements onboard the French Falcon 20 during the IOP 7 (courtesy of E. Defer).*

In brief, the field campaign was very successful. Different young, mature and old electrical cloud systems were documented. Most airborne data have been quality controlled and are ready for scientific investigation. The data set is available in the HyMeX database. In the case with most electrical activity (IOP2), an electric field up to 50 kV/m was measured in cloud regions with graupels measured at flight level (8-10 km) and with a large variety of lightning flashes at different altitude ranges. Observational- and modeling-based scientific and instrumental studies are ongoing at lightning flash, electrical cell, storm and regional scales based on the EXAEDRE special, enhanced and long observation period (SOP, EOP, LOP) data sets. EXAEDRE is promoted on Youtube at *https://youtu.be/eYT2VsBOwRo*.

The PERLE action, shared between the HyMeX and Marine Ecosystem Response in the Mediterranean Experiment (MerMeX) programs, aims at describing the formation and spreading of Levantine Intermediate Water and determining its role in the distribution of nutrients and in the structuration of the planktonic ecosystems in the eastern Mediterranean. It is a complement to the SOP2 experiments conducted in the northwestern Mediterranean in winter 2013 with similar objectives. The first two cruises started in October 2018 and March 2019 with profiling floats deployed during the PERLE-1 cruise in October 2018 and moorings deployed during the PERLE-1 (October 2018) and PERLE-2 cruises (March 2019). Glider sampling started in October 2018 and will be repeated until June 2020. Figure 4 shows one cross-section of the temperature, salinity and oxygen measurements collected by a glider between 10 December 2018 and 14 February 2019.

Finally, the LIAISE field campaign will explore the surface/atmosphere interactions over the Iberian Peninsula. Specifically, its goal is to achieve better understanding of the dry down of soils after the winter rainfall has ended, as this is a critical season for the Mediterranean climate. Funding is currently being secured (e.g., the recent support of the French National Research Agency, ANR), so the campaign schedule stands. It will be held in 2020 and will end in the summer, following the vegetation phenological cycle (Boone et al., 2019).

HyMeX Activities in 2020

HyMeX was designed as a 10-year program starting in 2010 and ending in 2020, and wrap-up activities are planned for its final year. A joint special issue is being organized, and as decided during the workshop, each science team will contribute one or two scientific review papers in addition to the overview paper on HyMeX's greatest achievements.

The 2020 HyMeX workshop will contain plenaries, a limited number of parallel and poster sessions and sessions with a specific scope, including: 10-year achievements with final syntheses and review, transfer to society, and beyond 2020. The workshop scientific committee, composed of Science Team Leaders, will be set up by October 2019. This committee will also be responsible for the reviews that will be presented at the workshop.

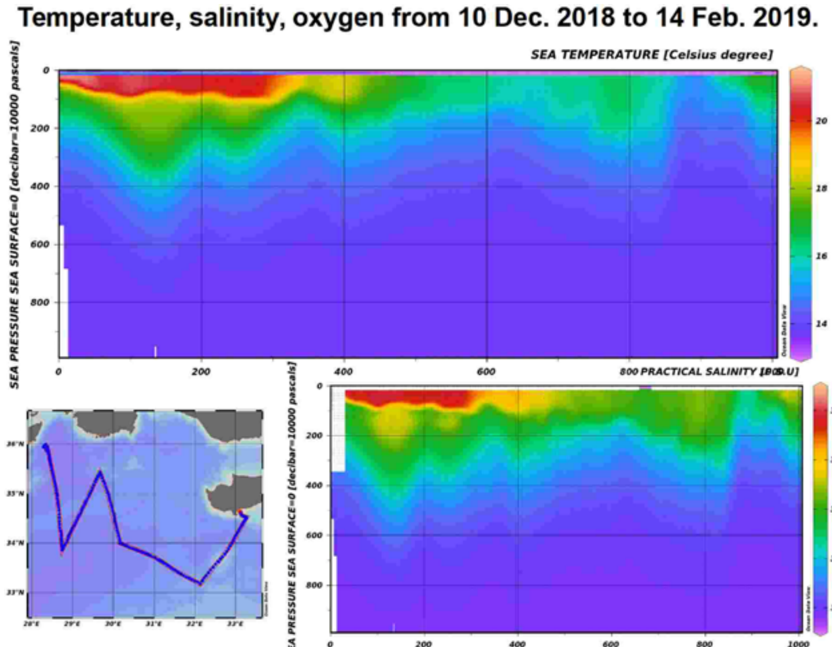

Figure 4. Cross-section of glider measurements of temperature, salinity and oxygen measured during the 2018-2019 survey between 10 December 2018 and 14 February 2019 (PERLE-1 cruise) (courtesy of P. Testor).

HyMeX Beyond 2020

The duration of HyMeX is 10 years, with the program set to conclude in 2020. Some activities will end next year while others will continue. A transition is planned to bridge the current version of HyMeX to a program that will extend beyond 2020.

Some projects with campaigns and their exploitation phase, as well as existing collaborations within Science Teams, will continue past 2020. The community has also expressed its interest in regular workshops as meeting points.

The form of the representation of HyMeX within the World Weather Research Programme (WWRP), the World Climate Research Programme (WCRP) and GEWEX has yet to be discussed. The current iteration of HyMeX will end as a GEWEX Regional Hydroclimate Project (RHP), without excluding the possibility that the governance of the future program will propose a new RHP. Discussions with the WCRP Joint Scientific Committee (JSC) should be organized, with GEWEX as an intermediary, as the JSC has launched four core programs where regional activities are key. As other Mediterranean programs will soon or have already ended [e.g., the Mediterranean Experiment (MEDEX), Mediterranean Climate and Ocean–Variability, Predictability, and Change (Med-CLIVAR), Med-CORDEX, Impact of Climate Change (IMPACTCC), Mediterranean Experts on Climate and environmental Change (MEDECC), Mediterranean Science Commission (CIESM), etc.], discussions should be organized to envisage, if relevant, a more integrated or at least coordinated effort in the region.

A new preliminary coordinating board was put in place at the 12th HyMeX Workshop, which will coexist during the 2019–2020 transition period with the exiting coordinating board, the HyMeX International Scientific Steering Committee. The group gathers experts of various disciplines and is composed of Aaron Boone, Eric Defer, Emmanouil Flaounas, Samiro Khodayar, Cindy Lebeaupin Brossier, Olivier Payrastre, Pere Quintana-Segui, Hélène Roux, Alexandre Stegner and Yves Tramblay. Other volunteers are welcome to join the board. Its tasks will be to set up a process to engage with other communities or program steering groups, provide a synthesis of the tangible (database, website, mailing lists) and intangible assets of HyMeX, define new and updated objectives to be possibly compiled in a new whitebook and to define a platform to meet and present the new scope and configuration options at the 2020 HyMeX workshop.

The HyMeX database is being transferred under the umbrella of the French Data and Services Cluster for the Atmosphere (AERIS), a new service building a general portal for geophysical data. The HyMeX data policy will first be extended and then a review of the data sets will be carried out to check the provider, access level and terms, preparing for an evolution of the data policy and access granted on a data set basis.

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GLASS Panel 2019 Annual Meeting

Boulder, CO, USA
6–8 August 2019

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The 2019 Global Land/Atmosphere System Study (GLASS) Panel Meeting was held over three days in early August at the National Center for Atmospheric Research (NCAR)'s Foothills Lab in Boulder, Colorado. About twenty-five people participated in the event. A recurring theme was the need for coordinated observations to improve understanding of the land-atmosphere system in different climatic regimes and confront and improve Earth system models. The meeting covered a range of topics including project updates, exploration of mutual interests between GLASS and other GEWEX Panels, and presentations from new GLASS members. We heard about numerous observationally-driven initiatives, including the Land-Atmosphere Feedback Experiment (LAFE) field campaign at the Southern Great Plains site in Oklahoma and Kansas, and the associated Land-Atmosphere Feedback Observatory (LAFO) at Hohenheim University; the upcoming Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) experiment in Spain; and the Bedrock to Boundary Layer meeting as a National Oceanic and Atmospheric Administration (NOAA)-centered initiative to address these issues. The Local Land-Atmosphere Coupling (LoCo) project update included mention of a handful of other important field campaigns and/or new monitoring stations [the Great Plains Irrigation Experiment (GRAINEX), Nebraska, USA; the Ruisdael Observatory, The Netherlands; the Finse Eco-Hydrological Laboratory, Norway]. On the final day, we discussed a proposal presented by Volker Wulfmeyer for GLASS Land-Atmosphere Feedback Observatories (GLAFOs), building on the success of LAFE and LAFO. All of these field efforts stem from the recognition that the evolution of clouds and precipitation is dependent on the evolution of the boundary layer (BL), which has long been difficult to adequately observe and monitor. Recent advances in instrumentation are now making better BL observations a reality.

The GLAFO vision includes defining a standard set of measurement devices that would allow for full and continuous characterization of the boundary layer, surface layer, soil profile and vegetation, and installing these suites of devices at various sites in different climatic regimes. We intend to follow-up with this meeting discussion by first determining where existing field sites can be augmented to include the full suite of GLAFO instruments, and then by writing a paper outlining the justification and benefits of a consistent and compatible measurement platform at different field locations. We are hopeful that international and national funding agencies will hear this unified voice from the land-atmosphere scientific community as an opportunity to advance land-atmosphere interaction science rapidly.

In addition to these themes, we heard research presentations from two new Panel members, Nate Chaney and Samiro Khodayar Pardo. We also heard brief reports on various GLASS-relevant activities including efforts at National Aeronautics and Space Administration (NASA)-Goddard to model irrigation (Patricia Lawston), single-column modeling work at NCAR (Grant Firl), precipitation downscaling efforts at the University of Kansas (Joshua Roundy), research from the Geophysical Fluid Dynamics Laboratory (GFDL) on the changing continental hydrologic cycle (Kirsten Findell), efforts at NCAR related to the North American Coordinated Regional Climate Downscaling Experiment (CORDEX) project (Rachel McCrary) and research on water security projections from NCAR (Flavio Lehner).

The GLASS Panel meeting was an excellent forum for sharing advances in observing and modeling the land and land-atmosphere system. We look forward to building on the progress and momentum of the meeting in the months ahead.

LoCo Project

The LoCo project and working group update was presented by Joseph Santanello. LoCo consists of 18 international scientists across academia and government, with a LoCo review article recently published in the *Bulletin of the American Meteorological Society* (Santanello et al., 2018) summarizing the last decade of research. LoCo has identified three near-term objectives that it has made significant progress on: 1) promoting the importance and development of improved observations of the land-atmosphere (L-A) system, namely planetary boundary layer (PBL) profiles, as well as improved utilization of soil moisture and surface flux measurements in models; 2) pursuing adoption of LoCo metrics by operational numerical weather prediction (NWP) and climate centers; and 3) expanding the scope and reach of LoCo in terms of processes and scale beyond that of warm season thermodynamics and beyond that of 1-D column assumptions. Progress on those goals is evident in the recent NASA Decadal Survey prioritization of PBL measurements and spaceborne mission concepts, and in the new NOAA/U.S. Department of Energy (DOE) Climate Process Team (including six GLASS panel members) tackling the difficult issue of communicating subgrid-scale heterogeneity between the land and the atmosphere. Numerous proposals are being submitted to other funding agencies to address remaining goals and continue this momentum of LoCo outreach to the scientific, modeling and observational communities.

SoilWat

Anne Verhoef reported on the GEWEX Soil and Water (SoilWat) Initiative GLASS working group, which has as its main objective to improve the representation of water-related soil and subsurface processes in land models (LMs) and climate models, and to identify the most pressing challenges and topics related to this effort. This activity has already produced review papers on pedotransfer functions (PTFs) and on infiltration, as well as related datasets (Van Looy et al., 2017; Vereecken et al., 2019). During the meeting, Anne gave an overview of a selected number of SoilWat activities relating to the assessment and improvement of PTFs used in land models, and the incorporation and assessment of the effects of soil structure on land surface fluxes on the plot and global scale.

LUMIP and ILAMB

David Lawrence presented updates for both the Land Use Model Intercomparison Project (LUMIP) and the International LAnd Model Benchmarking Project (ILAMB). LUMIP simulations are ongoing at the modeling centers, and data is starting to appear at the Coupled Model Intercomparison Project Phase 6 (CMIP6) data distribution site. Analysis plans are in place, and these efforts were discussed at a workshop in September 2019 at the Aspen Global Change Institute. A paper documenting the ILAMB package has been published (Collier et al., 2018). ILAMB is being used by several modeling centers and model intercomparison projects. Analysis of CMIP6 (versus CMIP5) models using ILAMB is underway.

The Panel discussed the possibility of providing input to the Climate Data Guide (*https://climatedataguide.ucar.edu/*) on datasets of high relevance to the GLASS community. The Climate Data Guide is a data portal that combines data discovery, metadata, figures and world-class expertise on the strengths, limitations and applications of climate data. The Panel agreed that providing data pages for key GLASS-related datasets would be valuable, though a lead to push this idea through has not yet been identified.

Group photo of participants of the annual 2019 GLASS Workshop

PLUMBER2 and Modelevaluation.org

Gab Abramowitz presented progress on the Protocol for the Analysis of Land Surface models (PALS, now at *modelevaluation.org*) and the PALS Land Surface Model Benchmarking Evaluation Project Phase 2 (PLUMBER2) land model intercomparison experiment. Gab showed an example of PALS aiding development of the Community Atmosphere–Biosphere Land Exchange (CABLE) land model through benchmarking multiple model configurations, following the original PLUMBER framework. The full functionality of the ILAMB suite is also available through PALS as one of the analysis engines. PALS is hosting PLUMBER2 and Urban-PLUMBER.

A proposed global-scale land surface budget-based experiment was also shown, using the Derived Optimal Linear Combination Evapotranspiration (DOLCE) and Conserving Land-Atmosphere Synthesis Suite (CLASS) products (Hobeichi et al, 2018, 2019), focusing observationally constrained uncertainty estimates for surface energy and water budget terms. It was argued that understanding the circumstances in which land models were outside observational uncertainty ranges was likely more informative than simply quantifying model-observational discrepancy for different products using traditional metrics.

Finally, progress with PLUMBER2 was discussed. Sample Network Common Data Form (NetCDF) driving data has been distributed to participants, and the facility to assess model output formats on PALS is ready. Some of the tower data processing issues were outlined, noting that this had slowed progress somewhat. It is anticipated that all data for the experiment should be released within a month or two, with a total of 200-300 sites anticipated in the final product. Initial analyses were outlined to include an improved empirical model hierarchy (following Haughton et al, 2018), quantile-based (rather than rank-based) metric averaging and a Budyko-style analysis following recent work by Martyn Clark.

Discussion around the synthetic experiment part of PLUMBER2 suggested that the nature of the synthetic forcing datasets still required some iteration with the GLASS community, but there was agreement that this would likely be a valuable addition. Details of relatively flexible data assimilation-based submissions to PLUMBER2 (using whichever sources participants chose) were presented with slides provided by Sujay Kumar.

GSWP3 and LS3MIP

Hyungjun Kim shared progress on the Global Soil Wetness Project Phase 3 (GSWP3) and on the Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP). GSWP3's goal is to produce a century-long comprehensive set of quantities for hydro-energy-eco systems in order to investigate the long-term changes of energy-water-carbon cycle components and their interactions. Hyungjun showed the progress to-date by comparing preliminary output from three participating models of snow cover, evapotranspiration (ET), runoff and terrestrial water storage anomalies with observational equivalents. Additional pilot studies tackle questions of long-term variability and trends of runoff at global and continental scales. The LS3MIP experiment is designed to provide a comprehensive assessment of land surface, snow and soil moisture-climate feedbacks and to diagnose systematic biases in the land modules of current Earth system models using constrained land-module-only experiments. These experiments are being conducted as part of the CMIP6 initiative; significant progress is expected in the coming months as CMIP6 deadlines approach.

Crosscuts and Projects with Other GEWEX Panels

Craig Ferguson provided an overview of the current portfolio of the GEWEX Hydroclimatology Panel (GHP) Regional

Hydroclimate Projects (RHPs), crosscuts, and data centers. Of direct relevance to GLASS's current activities are the HYdrological cycle in the Mediterranean Experiment (HyMeX) RHP's 2020 field campaign, Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE), and the crosscutting initiatives related to evapotranspiration and water management in models. Martin Best provided a presentation about many of the details of the LIAISE experiment. Large-scale irrigation, vegetation heat and water stress response and the land-atmospheric processes that determine land anomaly impacts on regional climate variability at the heart of these GHP activities are also central to multiple GLASS projects [e.g., phase 2 of the Diurnal Land/Atmosphere Coupling Experiment (DICE-2), LoCo, PLUMBER2]. GLASS was well represented at the evapotranspiration crosscut workshop in October 2019. Over the coming months, GLASS will work together with GHP and the GEWEX Data and Analysis Panel (GDAP) to define and team-build for the water management crosscut.

John Edwards shared information on some of the Global Atmospheric System Studies (GASS) Panel efforts that are relevant to the GLASS community. Papers on the large-eddy and single column model intercomparisons in the fourth phase of the GEWEX Atmospheric Boundary Layer Study (GABLS4) are in an advanced stage of drafting and submission is expected in the near future. Following the Pan-GASS workshop in Melbourne last year, a number of new projects on drag, fog modeling and convective processes have been launched. The analysis of results from some of these is beginning.

Paul Dirmeyer provided an update on the beginnings of the second phase of the International Subseasonal to Seasonal (S2S) Prediction effort. The parallel Subseasonal Experiment (SubX) project, centered on North American models, is undergoing review to determine whether and how it will continue. There are currently several other multi-model projects with bearing on the role of various aspects of the land surface on S2S timescales: the "Changing Arctic Cryosphere: Snow and Sea-Ice Impact on Prediction and Climate over Europe and Asia" (SNOWGLACE, on snow initial states), the Global Land-Atmosphere Coupling Experiment–Earth System Model (GLACE-ESM, on vegetation states), the Impact of Initialized Land Temperature and Snowpack on Sub-seasonal to Seasonal Prediction project (LS4P, on initial soil temperature in elevated terrain) and the Land Feedback Model Intercomparison Project with a pseudo-observed boundary condition (LFMIP-Pobs, including all land states, especially soil moisture). All of these efforts produce large global sets of model forecast output on daily or finer time scales that can be mined to examine the impact of the land on subseasonal predictions in a range of frameworks from operational forecasting to predictability in a changing climate. A summer school at NCAR on the S2S topic will occur in July 2020, providing an opportunity to expose and educate 80-100 students and young scientists on the role of the land in subseasonal prediction.

Eleanor Blyth presented an overview of the Integrated Land Ecosystem Atmosphere Processes Study (iLEAPS) program. The five core themes in their science strategy are the urban environment, managed land, forests, arctic and mountain regions, and arid and semi-arid regions. In each of these themes, iLEAPS coordinates science that relates to the ecosystem-atmosphere interactions of water, carbon and other biogeochemicals. Two meetings of interest include the joint iLEAPS-GEWEX workshop for land model developers in September 2020 in Oxford, UK, and the 6th Open Science conference in collaboration with OzFlux in February 2021 in Auckland, New Zealand.

The Land Atmosphere Feedback Experiment (LAFE)

Volker Wulfmeyer gave an overview of the Land Atmosphere Feedback Experiment (LAFE) from the Southern Great Plains in 2017 (*www.arm.gov/research/campaigns/sgp2017lafe*). This experiment included simultaneous measurements of sensible and latent heat flux profiles and the comparison of variance profiles with similarity relationships, where surface layer observations strongly question the applicability of Monin-Obukhov similarity theory. The use of a bulk Richardson number relationship showed much better agreement with observations. Also, the current state of turbulence-permitting modeling and the use of these simulations and the LAFE observations for comparisons with turbulence parameterizations was outlined. The new operational Atmospheric Raman Temperature and Humidity Sounder (ARTHUS), which typically has resolutions of 10 s and 100 m during daytime and nighttime in the lower troposphere, will contribute significantly to process understanding, parameterization development and data assimilation efforts if operated 24/7 at various sites such as the new Land Atmosphere Feedback Observatory (LAFO, *https://lafo.uni-hohenheim.de/en*).

Volker also presented the new integrated Land System Model developed within the German Research Foundation Collaborative Research Unit 1695 at the University of Hohenheim (*https://klimawandel.uni-hohenheim.de*). This model system is capable of simulating crop growth and yield, as well as the feedback to farming activities and management by coupling with a multi-agent system. He showed that the implementation of crop growth had a significant positive impact on the simulation of surface temperatures and two-legged feedback metrics between soil moisture, latent heat flux, and convective available potential energy. The CORDEX Flagship Pilot Study (FPS) Land Use and Climate Across Scales (LUCAS) was also presented (*www.hzg.de/ms/cordex_fps_lucas*). Land use modifications from the current land use to forest or grassland has significant influence on L-A coupling strengths, particularly over south central and eastern Europe.

Presentations from New GLASS Panel Members

Samiro Khodayar Pardo is a senior scientist at the Mediterranean Center of Environmental Studies (CEAM) in Valencia, Spain, and leader of the junior research group "Extreme Weather in a Changing Climate" at the Institute of Meteorology and Climate research, Karlsruhe Institute of Technology (KIT, Germany). Her scientific work focuses on the improved understanding and modeling of extreme weather and climate phenomena, with particular interest on the role of land-atmosphere interactions. For these investigations, she applies process-based evaluations across space/time scales using the synergy of state-of-the-art observations and high-resolution modeling. She is also an International Scientific Steering Committee member for the HyMeX program, where she coordinates the scientific team on heavy precipitation.

Nate Chaney is an Assistant Professor at Duke University in North Carolina, USA. Nate spoke about the availability of petabytes of data from satellite remote sensing providing us with a unique opportunity to make large improvements in the representation of land surface heterogeneity in Earth system models. The synthesis of these data through clustering at the sub-grid level enables an effective and efficient use of these data for their representation within large-scale models. These advances in the representation of sub-grid heterogeneity can then be used to understand how a more robust representation of sub-grid land surface heterogeneity impacts the coupled land and atmosphere. Building on this work, a recently assembled climate process team (led by Nate) will explore how the coupling of the land and atmosphere at sub-grid scales influences the macroscale response of the coupled land-atmosphere. This project, dubbed the Coupling of Land and Atmospheric Subgrid Parameterizations (CLASP), will provide a more formal coupling between sub-grid parameterizations of heterogeneity between the land and atmosphere in a suite of U.S. climate models.

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Alaska Soil Moisture and Wetland Mapping Validation Workshop

Fairbanks, AK, USA
9–13 September 2019

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The Alaska Soil Moisture and Wetland Mapping and Validation Workshop was hosted at the University of Alaska Fairbanks (UAF) from 9–13 September 2019. The workshop was organized by UAF, the U.S. Geological Survey (USGS) and George Mason University, and was sponsored by the World Meteorological Organization. One objective of this workshop was to improve soil moisture and wetland mapping over high latitudes to support a better understanding of the Soil-Ecosystem-Carbon-Climate (SECC) nexus, or the feedbacks between soils and ecosystem carbon cycling and the climate. The workshop included two days of presentations with discussions and three days of visits to long-term study sites in and around Fairbanks. The presentations and discussions focused on (1) assessing the current understanding and state-of-the-art techniques for detection of soil moisture and wetlands in high latitude ecosystems, and (b) identifying current and future research directions and data gaps. Field site visits included the Alaska Peatland Experiment (APEX) fen and bog ecosystems, the U.S. Army Corp of Engineers Cold Regions Research and Engineering Laboratory (CRREL) Permafrost Tunnel and the upland boreal ecosystems at Nome Creek. In collaboration with the National Aeronautics and Space Administration (NASA)'s Arctic Boreal Vulnerability Experiment (ABoVE), a small crew of participants also collected in situ soil moisture data synchronized with the airborne imagery acquisition campaign conducted by NASA's L -band fully polarimetric Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument. These in situ observations will contribute to the calibration and validation effort of soil moisture remote sensing products in the region.

High latitude areas, defined as above 60°N latitude, are warming faster than other regions. Permafrost landscapes contain 38% of the world's surface waters, but the characterization of surface water dynamics across northern high latitudes remains highly uncertain, as does the influence of permafrost on hydrology, leading to major challenges in mapping and characterizing soil moisture and wetlands in the region. Permafrost is actively thawing in high latitudes in response to climate warming, affecting soil moisture and saturation. Changes in soil moisture affect carbon sequestration potential by impacting water availability for plant growth, and by influencing soil decomposition rates and the relative contribution of aerobic and anaerobic processes driving soil carbon emissions (in the form of carbon dioxide and methane). Soil moisture also affects the risks of wildfires that are common in this region and that alter the landscape in many ways, producing massive carbon emissions to the atmosphere, altering permafrost and vegetation composition and reducing soil carbon storage. Wetlands are hotspots of methane production and have the potential to significantly affect radiative forcing at the regional level. In ice-rich permafrost regions, permafrost degradation can result in ground subsidence and the formation of new wetlands or lakes (i.e., thermokarsts) with drastically different carbon dynamics than permafrost plateau ecosystems. While thermokarsts can result in a local increase in water accumulation and soil moisture, the deepening of the permafrost table and the reshaping of the local hydrological network may result in drying soils in upland and draining areas. Permafrost thaw may also result in lake drainage and loss of lakes to dry meadows. Therefore, the dynamics of soil moisture and wetland distribution and their importance for regional carbon dynamics, water resources, wildlife habitat, infrastructure development and landscape accessibility remain a critical science priority for the high latitude regions. The support and maintenance of a long-term and dense network of field observation sites is critical for a better characterization of the spatio-temporal patterns of soil moisture and permafrost dynamics in high latitude regions.

Under a projected 2°C warming scenario by the end of the century, ecosystem models predict a loss of 33–55% of the permafrost extent in Alaska by 2100, and an associated increase in the release of greenhouse gasses. These estimates only account for the effect of permafrost thaw on the increase in soil carbon stocks available for decomposition. The impact of soil moisture modified by permafrost thaw on soil greenhouse gas release has yet to be determined. Additionally, the direction and magnitude of the changes in lateral transport of carbon associated with permafrost thaw are still unknown.

Wetlands in Alaska are widely used by local native and non-native communities and the recreation and tourism industries. Arctic wetlands are also threatened by oil and gas extraction, mining and climate change. Predicting the consequences from these forces allows more intelligent management and accurate, up-to-date geospatial wetland information is key to this process. This information may also be essential for infrastructure planning and maintenance. Many of the wetland wildlife habitats in Alaska are located in managed public lands. Data on wetland distribution and dynamics can inform land management decisions in this critical environment, including decisions to help species adapt to environmental change. Surface and subsurface processes in high latitude ecosystems have been identified as research priorities by the U.S. Global Change Research Program in the Fourth National Climate Assessment and the Second State of the Carbon Cycle Report. Large national research programs are supporting advances in high latitude wetland ecology, such as the NASA ABoVE program, the Next Generation Ecosystem Experiments Arctic Project that aims to better understand the terrestrial carbon system and the USGS permafrost and hydrology research in the region.

Workshop attendees outside an APEX bog site

Remote sensing methods used to develop soil moisture and wetland map products include NASA's Soil Moisture Active Passive (SMAP) and Landsat 8 satellites, and the European Space Agency (ESA)'s Soil Moisture and Ocean Salinity (SMOS), Sentinel 1 and Sentinel 2 satellites. Optical, microwave, radar and Synthetic Aperture Radar (SAR) are used to help characterize wetland mapping and detect land cover change, vegetation productivity and fine-scale terrain in Alaska. These products are also being used to understand the effects of snow cover on soil moisture, water table depth and fire in high latitude ecosystems. Remote sensing data can cover a broader area than in situ measurements, but it has its own restrictions such as limited temporal resolution, difficulty penetrating clouds, inability to access deep soils and difficulties in detecting land cover, snow, ice, water and other attributes, including rapid changes from disturbances such as wildfires or thermokarsts. Furthermore, because of the high spatial variability of ecological processes in these landscapes, efficient calibration and validation of spatial products from remote sensing data rely on a high density of ground-truth in situ data. Empirical modeling that incorporates machine learning, algorithms and intermediate-scale measurements such as remote sensing via aircraft can help bridge the gap between in situ and remote sensing information, allow for more automatic mapping from optical and radar remote sensing or be used for calibration and validation of large-scale remote sensing data. Furthermore, large international databases, such as the International Soil Moisture Network, centralize in situ observations, and their development and maintenance are of critical importance to improve the calibration and validation of spatial products.

In situ monitoring of high latitude soil moisture and wetlands includes gravimetric analysis, vegetation descriptions, electrical resistivity tomography (ERT), nuclear magnetic resonance (NMR), time-domain electromagnetics (TDEM), gas collection and passive seismology. NMR can determine soil pore size, moisture content and soil texture up to 100m below ground, and ERT can be used along 50-500m transects at depths to 20m. Ambient seismology can be used to take continuous measurements over tens to hundreds of square meters at depths to 20m and can complement other methods of data collection. In situ measurements can capture fine scale spatio-temporal variations and document processes that remote sensing acquisition cannot. However, in situ measurements vary

Attendees walk outside a National Ecological Observatory Network (NEON) data collection station near Denali National Park, AK.

highly over small spatial scales, can be costly and time consuming and may be difficult to collect due to limited access.

Process-based biosphere models are an effective tool in integrating remotely-sensed map products and in situ measurements in high latitude regions. They constitute an important forecasting tool to help improve our understanding of the fate of high latitude ecosystems under a changing climate. Improved accuracy and spatio-temporal resolution for remote sensing products and extensive in situ observations are critical to inform biosphere models and improve their capacity to represent the process interactions at play in high latitude ecosystems. Biosphere models help quantify how environmental shifts resulting from historical and projected changes in climate and disturbance regimes may impact the regional carbon balance and its feedback to climate as well as the capacity of high latitude ecosystems to provide other ecosystem services critical for local and global populations. With the significant improvement of remote-sensing products, it is critical that biosphere models add to the traditional use of in situ observations for model parameterization and validation, developing data assimilation techniques that allow a dynamic, real-time integration of remote-sensing data. This integration will improve the capacity of process-based models to represent the spatial variability of environmental variables needed to better understand and predict changes to high latitude wetlands and understand their global significance. There is a strong need for increased spatial resolution, particularly for small wetlands, increased frequency of data collection and more ground measurements to calibrate and validate remote sensing.

Bringing together scientists who approach and use wetland and soil moisture mapping in different ways helps build an understanding of the state of the science and our future needs. Different methods of study complement one another to enhance our overall understanding of these important systems. Future workshops may be planned to expand on soil moisture mapping outside the boundaries of Alaska and reach out to the international high latitude community.

GEWEX/WCRP Calendar

For the complete Calendar, see http://www.gewex.org/events/

12–16 January 2020—100th American Meteorological Society Meeting—Boston, Massachusetts, USA

22–24 January 2020—2020 GDAP Meeting—Tucson, Arizona, USA

27–31 January 2020—32nd Session of the GEWEX Scientific Steering Group (SSG)—Pasadena, California, USA

27–31 January 2020—2020 Sun-Climate Symposium: What is the Quiet Sun and What are the Subsequent Climate Implications?—Tucson, Arizona, USA

3–14 February 2020—2020 Australian Climate and Water Summer Institute—Canberra, Australia

3–4 February 2020—Discussion Meeting on Intensification of Short-Duration Rainfall Extremes and Implications for Flash Flood Risks—London, UK

10–12 March 2020—Nansen Tutu Centre 10th Anniversary Symposium—Cape Town, South Africa

31 March–1 April 2020—5th Annual Workshop of the International Network for Alpine Research Catchment Hydrology (INARCH)—Zaragoza and Benasque, Spain

31 March–2 April 2020—Workshop on Societally-Relevant Multi-Year Climate Predictions—Boulder, Colorado, USA

1–3 April 2020—Challenges in Meteorology 7: Meteorology Supporting Public Authorities—Zagreb, Croatia

3–8 May 2020—European Geosciences Union (EGU) General Assembly 2020—Vienna, Austria

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