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The **G**lobal **E**nergy and **W**ater cycle **Ex**changes (**GEWEX**) project is a core project of WCRP and is dedicated to understanding Earth's water cycle and energy fluxes at the surface and in the atmosphere. We are a network of scientists gathering information on and researching the global water and energy cycles, which will help to predict changes in the world's climate.

The World Climate Research Programme (WCRP) is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the International Science Council (ISC). See www.wmo.int, www.ioc-unesco.org and council.science.

Disclaimer

Executive Summary

This report documents the proceedings of the 30th Session of the Global Energy and Water cycle Exchanges (GEWEX) Scientific Steering Group (SSG), the annual meeting of the scientists who guide the formation of GEWEX's scientific program as well as the Chairs and Co-Chairs of the GEWEX Panels. The attendees reviewed the progress of GEWEX and its four Panels for the year 2017 and discussed the program's relevance today. Some Panels are undergoing change and growth, such as the Global Atmospheric System Studies (GASS) Panel, while others remain on a path of steady progress, such as the Global Land/Atmosphere System Study (GLASS) Panel. The activities of the International GEWEX Project Office (IGPO) for the year consisted mostly of planning for the 2018 GEWEX Open Science Conference. The meeting ended with a discussion of possible action items for the coming year.

Contents

1 Introduction and Overview

This report summarizes the main developments in GEWEX during the year 2017 and includes the major items and recommendations from the 30th Session of the GEWEX Scientific Steering Group (SSG-30), which was hosted by USRA in Washington, DC, USA, from 29 January to 1 February 2018. Also present at the SSG-30 meeting were representatives of the National Aeronautics and Space Administration (NASA), the Japan Aerospace Exploration Agency (JAXA), the Department of Energy (DOE) and the National Oceanic and Atmospheric Administration (NOAA). This session of the SSG addressed both responses to advice resulting from the latest World Climate Research Programme (WCRP) Joint Scientific Committee (JSC) meeting and developments in WCRP and other global programs. Two of the questions requiring reflection are why GEWEX needs to continue on after 30 years as a core project of WCRP and how it should evolve as WCRP goes through a time of transition. Also worth considering is whether the GEWEX Science Questions are still valid, or if they need to be adjusted. The same applies to the GEWEX-relevant WCRP Grand Challenges.

1.1 GEWEX and GEWEX Panels: Overview of Results, Goals and Plans

This section gives an overview of major results, goals and plans of GEWEX and the GEWEX Panels. The major activities for the GEWEX Panels are described in more detail in Section 2.0.

For GEWEX, 2017 was characterized by activities preparing for the 8th GEWEX Open Science Conference (OSC) to be held in Canmore, Canada in 2018; the ECR Workshop held prior to the Conference; and the GEWEX Panel side meetings during the OSC.

The GEWEX Data and Assessment Panel (**GDAP**) is proposing a name change to GEWEX Data and *Analysis* Panel and expanding its core mission. GDAP is planning a new activity with the Climate and Ocean – Variability, Predictability, and Change (CLIVAR) project concerning Earth's energy imbalance, changing how it conducts assessments by focusing more on application-centric approaches and resurrecting the aerosol and precipitation assessments. GDAP also intends to lead a new integrated assessment to determine how well the energy and water budgets can be closed by using a summary of all GEWEX data sets for intercomparison analyses. In 2018, GDAP leadership will select a new Baseline Surface Radiation Network (BSRN) project manager and address how to continue the International Satellite Cloud Climatology Project (ISCCP) and its Next Generation key climate data records. A fall 2018 meeting in Toulouse, France will be used to facilitate collaboration within the community on the Earth's energy imbalance.

The Global Land/Atmosphere System Study (**GLASS**) Panel's role is to identify and to improve modeling of land-surface processes and land-atmosphere interactions through land-atmosphere coupling, model data fusion and benchmarking. GLASS works with partners to represent the Earth system through a better understanding of the role of land in models. Current projects in the benchmarking category are the Protocol for the Analysis of Land Surface models (PALS), the PALS Land Surface Model Benchmarking Evaluation Project (PLUMBER), International Land Model Benchmarking (ILAMB), the Global Soil Wetness Project 3 (GSWP3), and the GEWEX Soil and Water Initiative (SoilWat), a new study that addresses deficits in descriptions of soils. Projects in the land-atmosphere coupling category are Local Land-Atmosphere Coupling (LoCo); the Land Surface, and Snow, Soil moisture

Model Intercomparison Project (LS3MIP); the Land Use Model Intercomparison Project (LUMIP); and the GEWEX Atmospheric Boundary Layer Study (GABLS)/Diurnal Land/Atmosphere Coupling Experiment (DICE), focusing on single-column models. The projects PALS/PLUMBER, GWSP3, LS3MIP, DICE, LUMIP (working together with the integrated Land Ecosystem-Atmosphere Processes Study, iLEAPS) and LoCo are Cross-Cutting Projects. LoCo is very active, involving many young scientists. The Project for the Intercomparison of Land Data Assimilation Schemes (PILDAS), a new initiative on weather, vegetation moisture on a seasonal time scale and deep-water storage, may be folded into PLUMBER as a sub-project instead of standing as an independent entity. ILAMB and PALS are being brought together within PLUMBER. GASS, one of the GEWEX Panels, might feed Subseasonal to Seasonal Prediction Project (S2S) data into GLASS ventures.

The Global Atmospheric System Studies (**GASS**) Panel is responsible for all atmospheric processes through understanding physical processes and the coupling of those processes to atmospheric dynamics. With the appointment and start of the new co-chairs, Xubin Zeng and Daniel Klocke, GASS has been revitalized and experiencing a growth phase. Daniel Klocke's involvement has resulted in a stronger link with WWRP and new ex-officio members have strengthened the connection to WGNE. Boundaries between WGNE, GLASS and GASS are fluid, which leaves room for cooperation. The co-chairs aim to adopt a more integrated view on the focus points of GASS by looking at interactions between process and physics dynamics coupling, the diurnal precipitation cycle, impact of snowpack and soil temperature on S2S, and by establishing a joint modeling activity for the Caribbean. Some of the still-active projects from the former panel may be incorporated into the new GASS Panel. The Pan-GASS meeting in March 2018 will be helpful in identifying new leaders and organizing new projects. New observational efforts, physics dynamics coupling and next generation modeling/gaining model insights are three of the more important sessions of the conference. Relevant questions to be answered are: 1) which metrics will be used to judge future success and 2) what projects will be added? An important emphasis will be working on topics that agencies are interested in, and finding good leaders to do research who can get the job done. GASS and GLASS will be partnering together for S2S, starting with the diurnal cycle, and would welcome additional support from NASA, DOE and NOAA. GASS will be giving a presentation at the Department of Energy Atmospheric Radiation Measurement (DOE-ARM) meeting.

The GEWEX Hydroclimatology Panel (**GHP**) is less process-oriented than the other GEWEX Panels and focuses on hydrology on a regional scale. Within GHP, the Regional Hydroclimate Projects (RHPs) cover large geographic areas and boast a variety of research activities. The Hydrological cycle in the Mediterranean Experiment (HyMeX) and the Changing Cold Regions Network (CCRN) are mature and approaching their conclusion. CCRN will likely be replaced but may continue another four to five years. The three initiating RHPs are 1) OzEWEX, which is based in Australia and involves many networking activities and incorporates previously established projects; 2) Baltic Earth, which studies the Baltic Sea region and has applied to become a full RHP; and 3) HyVic, which focuses on the Victorian Basin and will likely apply again for RHP status under a different name after receiving potential new funding. Prospective RHPs are: 1) PannEx, which involves research in the Pannonian Basin and is applying for initiating RHP status, having written a white book and science and implementation plans; and 2) ANDEX, which covers the whole Andean mountain range and has planned a second workshop for October 2018 in Chile. Other concepts discussed included a potential program of research studying the western region of North America from 2014; the Third Pole Environment (TPE) group that would like to work with GHP/GEWEX without an RHP status, possibly as a cross-cutting action; and lastly the East Asian monsoon project, which researchers in Japan may revive. Another important component of GHP is the Cross-Cut Projects (CCs), most of

which are in their final stages: INTENSE, which deals with subdaily precipitation and has to determine how to continue its database; INARCH, which studies mountain snow and ice hydrology and atmospheric interactions, and will likely continue on; and the Cold/Shoulder Season Precipitation Near 0ºC project, which is also reflecting on how to move forward and which might work well in GDAP's precipitation assessment. Other potential Cross-Cut Projects include Mounterrain, whose co-chairs have stepped down; Water Management in Models; Evapotranspiration Determination; and Third Pole Environment Water Security. The third and final part of GHP is the Data Centers, which are reportedly running smoothly.

1.2 GEWEX Links to WCRP

WCRP is undergoing a review commissioned by its sponsors (ICSU, IOC and WMO), conducted by a panel of worldwide experts chaired by Julia Slingo. Results of the in-depth study of all of WCRP projects, working groups, etc. are detailed in a 50-page report currently in its final stage of completion. The panel lists seven recommendations, including WCRP's need to be more integrated and connected with the weather community (WWRP). Also addressed is a recommendation for a new strategy plan that focuses on the long-term (10 year timespan) goals and the short-term (5 year timespan) organization of the program and its research. In February 2018, stakeholders will meet with sponsors in Paris to develop this strategy plan in preparation for the JSC meeting in April 2018.

1.3 GEWEX Interactions (Especially with WCRP Sponsors and Partners)

The National Aeronautics and Space Administration (NASA) conducts satellite missions relevant to GEWEX science and will continue to do so in the future. The study of the Earth from space is increasingly important, and NASA is joined by many space agencies and research institutes across the globe in gathering data relevant to the energy and water cycles. GEWEX brings much of that science together and is waiting with keen interest on the announcements from NASA's MEaSURES program, which uses consistent records to understand the Earth system, as it will link to those activities.

NOAA provides essential environmental information, and one of its top priorities is becoming a world leader on Earth system observations and prediction. The Climate Program Office (CPO) is a unique investment in end-to-end monitoring within the US government. It integrates information, engages the community through mission-driven research priorities, and collaborates with national and international communities. From a CPO perspective, GEWEX was always assumed to be involved with fast processes in the climate system, but this is changing. GEWEX needs to play a more interactive role with CPO.

The Subseasonal to Seasonal (S2S) prediction project supports the priorities of the Weather Research and Forecasting Innovation Act of 2017. GEWEX has to come up with a position on transition from weather to climate, as S2S might come at a cost to fundamental science. Demand for seamless weather to climate information is exponential but should not shortchange long-term research for short-term scale in pursuit of providing services.

Currently the Department of Energy (DOE) is updating its strategic planning. One of the major themes is the integrated water cycle. DOE runs many workshops and invites the community to participate and to give input. Workshop reports are available at https://science.energy.gov/ber/community-resources/ber-workshop-reports/.

Looking at the launch schedule of the Japanese Aerospace Exploration Agency (JAXA), the second through fifth satellite programs are related to GEWEX. Global Precipitation Measurement (GPM) data from JAXA is important to GEWEX. There are many good reasons and opportunities to reestablish a good working relationship with JAXA.
In 1989, the US Global Change Research Program (USGCRP) was established to help the United States and the world understand, assess, predict and respond to both the human-induced and natural processes of global change. Thirteen federal agencies are participating in this program, and those with relevant ties to water are mostly collaborating with GEWEX already. The group's work is highly relevant to the WCRP Grand Challenges. The US global water strategy was recently released, but USGCRP is not directly involved in it. Talks of a US RHP are ongoing with different agencies, and the moment is ripe for GEWEX to formulate an action plan related to working with USGCRP to move the US RHP along.

1.4 GEWEX Outreach and Capacity-Building Activities

GEWEX is leading the WCRP Grand Challenge on Changes in Water Availability, which relates to the United Nations Educational, Scientific and Cultural Organization (UNESCO) International Hydrological Programme (IHP) goal to understand uncertainty and translate it back to water security. Future GEWEX activities within this Grand Challenge are planned with IHP.

GEWEX is also exploring potential collaboration with the WMO Hydrology Climate Land Water Department and Regional Panels and the Climate and Cryosphere (CliC) Project. A connection to CliC has been proposed through the GABLS Stable Planetary Boundary Layer Project (GABLS4) over the arctic region. In addition, the Earth System Model-Snow Model Intercomparison Project (ESM-SnowMIP) is a collaborative effort between CliC and GLASS. The Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP), a CliC and GEWEX project, is addressing core research questions of WCRP and is relevant to a large number of WCRP activities.

GDAP shares responsibility with the Global Climate Observing System (GCOS) for the Baseline Surface Radiation Network (BSRN), which is essential to setting standards and providing high quality radiation measurements for the evaluation of satellite data sets and climate models.

GEWEX benefits greatly from its strong interactions with other WMO and WCRP initiatives. The Global Data Centers for precipitation, river runoff, and lakes/reservoirs [Global Runoff Data Centre (GRDC), the Global Precipitation Climatology Centre (GPCC) and the International Data Centre on Lakes and Reservoirs (HYDROLARE), respectively] are affiliated activities under GEWEX and are connected through a number of outside bodies to obtain meaningful data for application to research of interest to the broader climate research community.

Under GDAP, the Surface Radiation Budget Project (SRB) is participating in the WCRP Data Advisory Council (WDAC) Surface Fluxes Task. In addition, GDAP has presented a paper to WDAC on "Data Set Quality Assessments: Needs, Benefits, Best Practices and Governance," which provides guidance for a more homogeneous approach towards assessments of data set quality. The GDAP Co-Chairs continue to be active in the WDAC Observations for Model Intercomparisons Project (Obs4MIPs) Task Team and support the open data call.

GEWEX is working to identify links to new regional groups in Latin America that may require further support to broaden current activities into international studies that fit within the WCRP structure. The 2015 GEWEX SSG meeting was held in Medellin, Colombia and the SSG has a

member from Colombia. A regional initiating RHP meeting for ANDEX was held in late 2017, and a follow-up meeting is planned for October of 2018.

Cross collaboration opportunities between GEWEX and the integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) are being identified within the different GEWEX Panels. Under GHP, the Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction (MAHASRI) which ended in 2016 had collaborative activities with the Japanese iLEAPS and International Geosphere Biosphere Programme (IGBP) communities, as well as the Asian Stratosphere-troposphere Processes And their Role in Climate (SPARC) Project community. Similar collaborations will be envisioned for the follow-on project which is planned for 2019. A new GHP-GLASS-iLEAPS project for the Saskatchewan River Basin or another Regional Hydroclimate Project is being investigated.

HyMeX and the Australian Water and Energy Exchanges research initiative (OzEWEX) are collaborating with the Global Earth Observation for Integrated Water Resource Assessment (Earth2Observe) Project and the Hydrological Ensemble Prediction Experiment (HEPEX) in hydrological forecasting. As Earth2Observe reaches completion in 2017, new avenues need to be pursued.

GEWEX and CLIVAR joint activities include the new JSC task group on extreme weather and climate, and the WCRP Monsoon Panel. In addition, the Earth's energy imbalance issue may become a strong collaborative project with a meeting held in conjunction with the annual GDAP meeting in October of 2017.

Continued collaboration with the Group on Earth Observations (GEO) is provided through the Director of IGPO, who has been active in the Integrated Global Water Cycle Observations (IGWCO) Project. In addition, the Director of IGPO serves on the Board of the FP7 Earth2Observe Project and the Board of the Helmholz Alliance as a user group representative.

There are many cross-collaboration activities between the GEWEX Panels and other programs. GEWEX and iLEAPS collaboration is underway through the GLASS Global Soil Wetness Project, Phase 3 (GSWP-3) Project. In addition, the Land-Use and Climate, IDentification of robust impacts (LUCID) activity is an iLEAPS-GLASS supported project. GLASS is also recruiting member(s) from iLEAPS to be actively involved in both the planning and analysis of its new carbon activity.

To encourage the involvement of young scientists in GEWEX/WCRP activities, IGPO has invited the Young Hydrologic Society (YHS) and the Young Earth System Scientists (YESS) communities to contribute one-half page in each issue of the GEWEX newsletter to advertise their activities. As part of the organization of the GEWEX Conference in 2018, the inclusion of research from both early career scientists and those from lesser-developed countries is important. Funding will be a critical aspect in making in particular the latter aspect a success.

2 GEWEX Panel Status Reports

2.1 GEWEX Data and Assessment Panel (GDAP)

Reporting Period: January 2017 – December 2017
URL: http://www.gewex.org/panels/gewex-data-and-assessments-panel/
Chair(s) and term dates: Tristan L' Ecuyer (2016 - present) and Remy Roca (2016 - present)

2.1.1 Major Panel Accomplishments

- The first year of the new GEWEX Integrated Dataset has been generated and released to support energy and water cycle studies and model evaluation on both regional and global scales.
- The water vapor assessment has been completed and the corresponding report published.
- New versions of several GEWEX-sponsored datasets have been delivered.

2.1.2 Panel Activities

- Sponsored production and analysis of several key energy and water cycle datasets from ground stations and satellites. Examples include:
  - Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Edition-4.0 data product release
  - ISCCP
  - SeaFlux 2.0 climate data record (CDR) being produced by NOAA with improved diurnal temperature, better calibration and random and systematic errors
  - GPCC v8.0 release
  - Global Precipitation Climatology Project (GPCP) v2.3 transitioned to NOAA as part of the Climate Data Records program. Prototype GPCP 3.0 is under evaluation, and will include rain/snow discrimination and error bars
  - The Surface Radiation Budget version 4.0 project (SRB 4.0) has been developed and is under evaluation, as several changes were implemented
- Continued oversight of BSRN with several new benchmarking studies underway directed toward defining an SI traceable reference for longwave irradiance and documenting instrument performance in polar regions
- An initial precipitation assessment documenting differences in climatologies and seasonal cycles of zonal means separated into land and oceanic regions
- A cloud assessment update is underway that will incorporate recent updates to many cloud datasets and six new datasets from spaceborne active sensors that did not participate in the original assessment. The cloud assessment will close once this update is complete
- The LandFlux project continues to refine land-surface evapotranspiration (ET) flux estimates, though momentum has been lost and this activity needs to be redefined as part of a broader integrated land energy and water cycle assessment
- Initiated new paradigm for integrated flux assessments and for redefining core GDAP activities to better support other GEWEX Panels and activities.

2.1.3 New Projects in Place

- Joint GEWEX-CLIVAR activity centering on understanding Earth's energy imbalance (EEI) (expansion of the original CLIVAR "consistency between planetary energy balance and ocean heat storage," or CONCEPT-HEAT, activity).

2.1.4 New Projects and Planned Activities

1. A broader regime-specific precipitation assessment is being developed in coordination with the International Precipitation Working Group (IPWG) and Precipitation Measurement Mission (PMM) communities to address the needs of WCRP user groups. An initial scoping workshop was held in October 2017 after the PMM meeting. A follow-on is planned during the IPWG 2018 meeting in Seoul in November.
2. While assessment of individual parameters will continue, some focus is shifting toward integrated assessments of global data projects that apply energy and water cycle closure constraints as an integrated measure of systematic errors in datasets.
3. A new radiative flux assessment focusing on vertically-resolved fluxes and heating rates from conventional approaches and new active sensors has been proposed.
4. GDAP will continue to actively engage ARM in future assessments and may consider basing a land surface closure assessment around the Southern Great Plains (SGP) site.
5. A formal soil moisture assessment is underway.
6. A formal assessment of land surface temperature is under consideration.
7. Following the new paradigm of integrated assessments using closure constraints, soil moisture, land surface temperature, ground heat flux, and land ET fluxes may be considered as part of an integrated land ET assessment. Such an activity would explore the degree of consistency between LandFlux, soil moisture, land surface temperature (LST), and SRB to identify structural errors in the component fluxes.
8. GDAP may create a pathway toward a next-generation ISCCP product that incorporates improved sensor capabilities in support of the WMO Coordination Group for Meteorological Satellites (CGMS) cloud working group.
9. GDAP could also advocate for data quality standards to be implemented by the International Soil Moisture Network (ISMN) ground-reference data.

2.1.5 Science Highlights

Consensus GDAP assessment activities are evolving along more integrated themes that seek tests of water cycle and energy balance closure and aim to establish consistency between datasets.

2.1.6 Science Issues

1. LandFlux activity has lost momentum and will not likely progress in isolation. It needs to be redefined as part of an integrated view of the land heat budget.
2. The aerosol assessment has concluded, but the draft report has been in limbo for 2+ years and needs to be completed.

2.1.7 Contributions to Developing GEWEX Science

GDAP is providing a new paradigm of water cycle and energy balance closure and aims to establish consistency between datasets.

2.1.8 Contributions to the GEWEX Science Questions

- *Observations and Predictions of Precipitation*
  GDAP provides support and evaluation of ground-based and satellite-based global precipitation products.
- *Global Water Resource Systems*
  N/A
- *Changes in Extremes*
  N/A
- *Water and Energy Cycles*
  GDAP provides support and evaluation of several radiative and evaporative flux datasets. It also conducts tests of water cycle and energy balance closure.

2.1.9 Other Key Science Questions

- Integrated assessment of land energy and water cycle closure in observations and reanalysis
- Tracking energy and water flows on regional scales

2.1.10 Contributions to WCRP Grand Challenges

- *Regional Sea-Level Rise*
  The EEI initiative seeks to connect Earth's top of atmosphere (TOA) energy imbalance to changes in ocean heat content, terrestrial water content, and sea level rise.
- *Improved Understanding of the Interactions of Clouds, Aerosols, Precipitation, and Radiation and Their Contributions to Climate Sensitivity*
  GDAP oversees BSRN, ISCCP, CERES EBAF, and SRB.
- *Past and Future Changes in Water Availability (with Connections to Water Security and the Hydrological Cycle)*
  GDAP oversees and supports the production of global precipitation and evaporative flux datasets: GPCC, GPCP, LandFlux, and SeaFlux.

2.1.11 Cooperation with WCRP Projects and Other International Programs

GDAP will also directly contribute to complementary CONCEPT-HEAT studies directed toward quantifying global and regional EEI and establishing consistency between top of atmosphere fluxes and ocean heat.
Due to various logistical reasons, GDAP is having some difficulty in connecting to the WCRP Task Team for Intercomparison of Reanalyses (TIRA).

2.1.12 Workshops/Meetings Held

- Annual GDAP Meeting, 9–12 October 2017 (Boulder, CO, USA)
- GDAP-CLIVAR one day workshop on Earth's Energy Imbalance, 9 October 2017

2.1.13 Workshops / Meetings Planned

- BSRN Meeting, 16–20 July 2018 (Boulder, CO, USA)
- Annual GDAP Annual Meeting (Lisbon, Portugal, 26–30 November 2018)
- Precipitation Assessment Meeting (Seoul, November 2018) Not in calendar
- Workshop on Earth's Energy Imbalance (Toulouse, France, 13–16 November 2018)
- ISCCP Next-Gen Scoping Workshop (TBD)

- GEWEX Integrated Dataset User Workshop (Spain, March 2019)

2.1.14 Other Meetings Attended on Behalf of GEWEX

- 2nd GEWEX Aerosol and Precipitation (GAP) Workshop in Oxford, UK
- Upper Tropospheric Clouds and Convection (UTCC) PROES Meeting
- WDAC-6

2.1.15 Issues for the SSG

Appointment of new BSRN chief

2.1.16 Key Publications

GEWEX Water Vapor Assessment

2.1.17 GDAP Members

Remy Roca (chair)
Tristan L'Ecuyer (vice-chair)
Isabel Trigo (new)
Seiji Kato (new)
Wouter Dorigo
Andrew Heidinger
Paul Stackhouse
Christian Kummerow
Hirohiko Masunaga
Tianjun Zhou
Claudia Stubenrauch

2.2 GEWEX Hydroclimatology Panel (GHP)

Reporting Period: January 2017–December 2017
URL: https://www.gewex.org/panels/gewex-hydroclimatology-panel/
Chair(s) and term dates: Jason Evans (2012–2019) and Joan Cuxart Rodamilans (2017–2020)

2.2.1 Major Panel Accomplishments

- Active RHPs (CCRN, HyMex, Baltic Earth) are very productive. CCRN is in its final stages and will likely be followed by a larger Canadian effort through the Global Water Futures (GWF) initiative. Baltic Earth demonstrates considerable maturity as a new RHP, building on efforts of previous Baltex-related RHPs.
- A new RHP focused on the Pannonian Basin, PannEx, is in its prospective phase and has applied to the status of Initiating RHP after significant progress. A new effort in South America, AndEx, has been proposed and is under development.
- The CC activities are very productive and there was an expression of interest at the annual GHP meeting to create a new one on the water cycle in the Third Pole region.

2.2.2 Panel Activities

The GEWEX Hydroclimatology Panel (GHP) is organized around several Regional Hydroclimate Projects (RHPs), a number of crosscutting science topics, and global data centers. The aim of GHP is especially focused on improving knowledge on global climate change and its impacts at regional scales, and propagating that knowledge from one region to another, eventually synthesizing the results at the global scale.

The objectives of GHP are to contribute effectively to the leading role that GEWEX plays in the hydrological sciences and related modeling activities. The GEWEX Science Questions (GSQ) and the related WCRP Grand Challenges are key to the strategy for implementation of the Panel activities. The GHP Co-Chairs have fostered discussions on a number of important issues that range from monsoons to extremes and how to help coordinate the number of national/regional initiatives in those areas. These include collaborations with groups that have common interests in land-surface processes, such as the Global Drought Information System (GDIS), GDAP, GLASS, CLIVAR, CliC, and the Working Group on Regional Climate (WGRC).

In keeping with the need to be responsive to the challenges and scientific inquiries of WCRP and GEWEX, GHP has organized itself to address the GEWEX Science Questions (GSQs) from a regional and integrated perspective. The driving premise for this approach is that only at the regional scale can the water cycle be addressed from its physical to human and socioeconomic aspects.

The RHPs (Figure 1) are an essential tool in this endeavor, as they bring together various disciplines on the water issues of greatest importance to the advancement of the GSQs. The Cross-Cut projects allow GHP to propagate knowledge from one region to another and synthesize results at the global scale. They also allow the progress and testing of applications developed with the new understanding that they deliver both science advances and applicable outcomes for stakeholders and services.

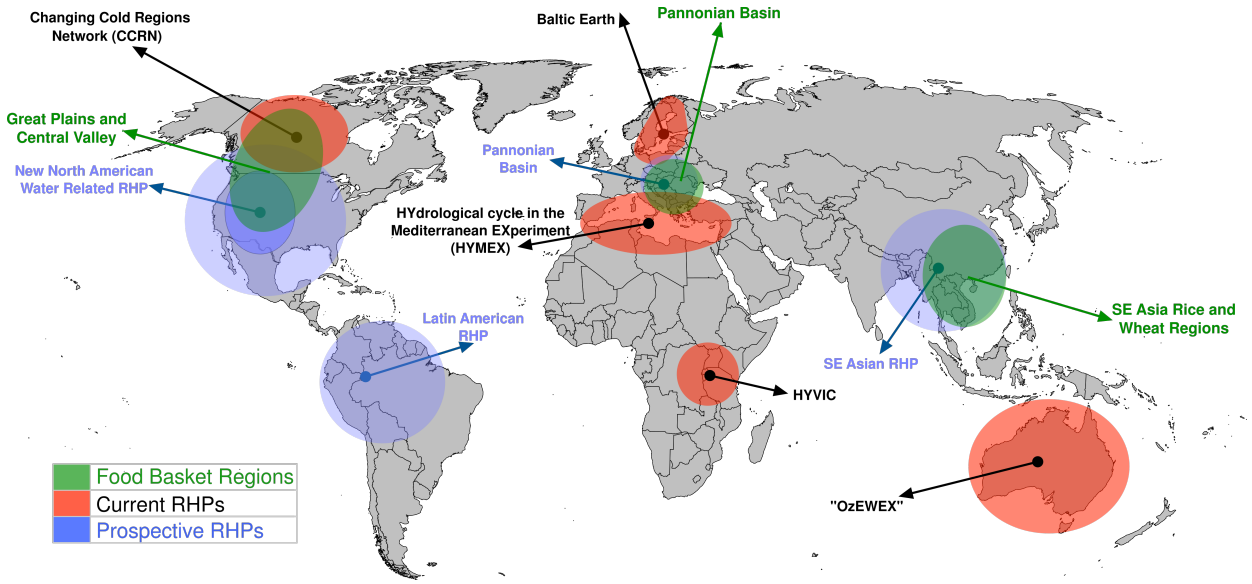


Figure 1: GHP Regional Hydroclimate Projects (RHPs) and Water for the Food Baskets of the World focus regions

GHP Regional Hydroclimate Projects List

Currently active

- CCRN (chair: Howard Wheater)
- HyMex (chair: Philippe Drobinski)
- BalticEarth (chair: Markus Meier)

Initiating

- OzEWEX (co-chairs: Albert Van Dijk and Seth Westra)
- HyVic (chair: Fred Semazzi)

Proposed

- PannEx (co-chairs: Mónika Lakatos and Ivan Güttler)
- AndEx (co-chairs: German Poveda and René Garreaud)

GHP Cross-Cut Projects List

Currently active

- INTENSE (Sub-daily precipitation) (chair: Hayley Fowler)
- Cold/Shoulder Season Precipitation Near 0°C (co-chairs: Ronald Stewart and Pavel Groisman)
- INARCH (Mountain Hydrology) (chair: John Pomeroy)

Proposed

- Including Water Management in Large Scale Models (co-chairs: Richard Harding and Jan Polcher)

2.2.3 New Projects in Place

No new projects in place.

2.2.4 New Projects and Planned Activities

New Projects

The Pannonian Basin RHP (PannEx) held its third workshop in Cluj-Napoca, Romania in March 2017 in order to get feedback from local scientists on the draft white paper and garner further participation from the regions scientists. The White Book has been completed, comprising five Flagship Questions dealing with Agronomy, Air Quality, Sustainable Development, Water management and Education. Also, a Science and Implementation plan has been put together. These two documents were presented at the GHP annual meeting in Kathmandu (October 2017), where the chair of PannEx, M. Lakatos, applied for the status of Initiating RHP. The Panel agreed to do so in view of the good progress of the action and proposes to the SSG that this status is accorded to PannEx. The action has now defined "Task Teams" so that the participants can tackle specific issues and proceed to apply for funding in open calls. A PannEx special session is planned at the European Meteorological Society (EMS) annual meeting to be held in Budapest, Hungary, 3-7 September 2018. A fourth workshop is planned as a side meeting to the EMS meeting.

The Andean RHP (AndEx) held its inception meeting in Medellin in early December 2017, hosted by Prof. Germán Poveda and attended by a few scientists of the different Andean countries and two representatives of GEWEX. An agreement was reached to explore the setting of an RHP covering the Andes range and its surrounding areas with the provisional title "ANDEX: A hydroclimate research program for the Andes." The first-term co-chairs are G. Poveda (Universidad Nacional de Colombia, Medellín, Colombia) and René Garreaud (Universidad de Chile, Santiago, Chile). An open workshop will be held in Santiago de Chile at the end of October 2018, in conjunction with the annual GHP meeting, to define the objectives of the program following a draft White Book that will contain these main issues: 1) the hydroclimate of the Andes (paleoclimate, patterns, and drivers); 2) climate and environmental change (trends, regional modeling, deforestation and land use changes, erosion); 3) high impact events (severe weather, flooding, droughts, landslides, extremes, disaster management, urban pollution); and 4) cryosphere of the Andes (glaciers, seasonal snow cover, paramos, impact on water management, interaction with volcano eruptions). Identification of available and supplementary observations and data are needed and a number of applications were listed (agriculture, energy production, access to fresh water, etc.).

Planned Activities *(extracted from the annual reports)*

Regional Hydroclimate Projects

CCRN

CCRN will be coming to an official end in March 2018. As we enter the final six months of the program, we are focused on incorporating scenarios of change into our regional Modélisation Environmentale Communautaire (MEC) – Surface and Hydrology (MESH) modeling of the Mackenzie and Saskatchewan River systems and examining projected future Earth system change and responses for the 21st century. We will be looking carefully at the results and feeding some of this back to our fine scale models to explore process interactions and feedbacks in more detail and gain further insights into system change. We had a workshop on 2–3 November 2017 to examine the results, plan final model runs and analyses, and develop output products such as model datasets and papers for publication. Our final network symposium, The CCRN Finale, is planned for 4–7 March 2018, where the network will gather for the last time to review our accomplishments, to plan products and publications as a legacy of CCRN, to connect with key stakeholders and partner organizations, and to look to the future in follow-on initiatives (see below). Currently we have our two special issues (*Earth System*

Science Data, ESSD, and *Hydrology and Earth System Sciences*, HESS) open for several months beyond the end date of CCRN and will continue to populate these. We will also be developing a film documentary to showcase the observed Earth system changes, CCRN's science advancements (including projections of future change) and their societal relevance, and the legacy of this important research initiative.

As CCRN is ending, we note a relatively new program that is ramping up, and in many respects following and expanding on some of the activities and scientific issues being addressed in CCRN. The Global Water Futures project (GWF) is a $143 million, seven year (2016–2023), University of Saskatchewan-led research initiative that has an overall mission to improve disaster warning, predict water futures, and inform adaptation to change and risk management. GWF is the largest investment of its kind in university-led water research and aims to provide global leadership in water science for cold regions and to address the strategic needs of the Canadian economy in adapting to change and managing the risks of uncertain water futures and extreme events. Its geographic focus will include not only the Mackenzie and Saskatchewan River Basins, but also a number of other major watersheds across all of Canada, while its science focus will expand to include water quality, social science, health, and water governance.

We envision our link to the GEWEX Hydroclimatology Panel continuing through this major new initiative under the leadership and direction of Distinguished Professor John Pomeroy, who was co-Principal Investigator (co-PI) for CCRN. The CCRN secretariat staff has been expanded to manage this large and complex program and will benefit from including many of the same support and management staff, thus retaining continuity and experience. Most of the CCRN core team and collaborators are also actively involved in GWF and its activities.

HyMeX

Preparation of the Second Mediterranean Coordinated Regional Downscaling Experiment (Med-CORDEX2)

The 10th HyMeX workshop (Barcelona, Spain, 4–7 July 2017) was an opportunity to discuss the implementation of the Med-CORDEX flagship pilot studies (FPS), which can be seen as the follow-up of the first Med-CORDEX exercise (Ruti et al., 2016). There are three Med-CORDEX FPS. One FPS is dedicated to convection and is shared between Med-CORDEX and the European Coordinated Regional Downscaling Experiment (Euro-CORDEX). It aims at investigating convective-scale events, their processes, and their changes in a few key regions of Europe and the Mediterranean using convection-permitting Regional Climate Models (RCMs). The second Med-CORDEX FPS focuses on air-sea interactions, with special emphasis on the role of small-scale ocean processes and waves. The third Med-CORDEX FPS is dedicated to the role of the natural and anthropogenic aerosols in the Mediterranean region.

Future Field Campaigns

Three campaigns are also planned in the frame of HyMeX, to complement the previously conducted fields experiments in the frame of 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 field experiments in preparation are (Fig. 3):

- Exploiting new Atmospheric Electricity Data for Research and the Environment (EXAEDRE) to be conducted in September 2018 on atmospheric electricity in complement to what has been performed during SOP1 (Defer et al., 2015)
- Pelagic Ecosystem Response to dense water formation in the Levant Experiment (PERLE) oceanic experiment to be conducted in October 2018, February 2019 and June-July 2020 in complement to what has been performed during SOP2 (Estournel et al., 2016) but in the Levantine region in the Eastern Mediterranean
- Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE) experiment to be conducted between April 2020 and March 2021, focusing on land surface interactions over the Iberian semi-arid environment

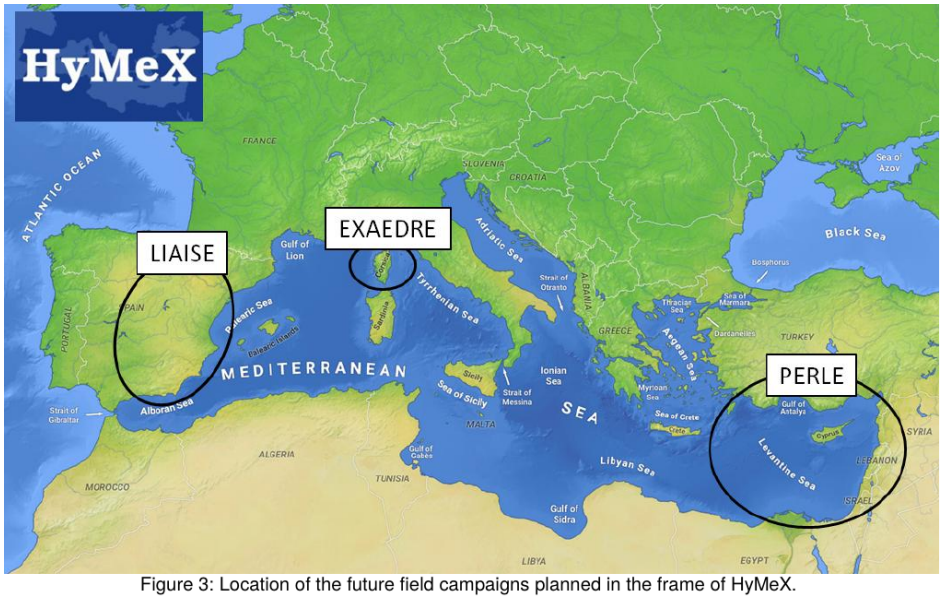


Figure 3: Location of the future field campaigns planned in the frame of HyMeX.

Baltic Earth/Integrated carbon and Trace Gas monitoring for the Baltic Sea (INTEGRAL)

Several of the European nations are investing in the Integrated Carbon Observation System (ICOS). The overall aim of ICOS is to provide European-wide carbon dioxide and other greenhouse gas (GG) concentration and flux data. Integration for the Baltic Sea region, however, has not been pursued. Consequently, the added value of ICOS and related infrastructure for the Baltic Sea ecosystem assessment has not been exploited at all. INTEGRAL will:

- Integrate the different data streams of ICOS and related infrastructure in the pan-Baltic area.
- Provide best charts of seasonal carbon dioxide and GG flux over the Baltic Sea, including advanced remote sensing approaches.
- Integrate the carbon system into a high-resolution 3D model, which will allow for a better description of the biogeochemical coupling of eutrophication and deoxygenation.
- Demonstrate the added value for a better biogeochemical ecosystem status description of the Baltic Sea.
- Advise the implementation of ICOS in the southeastern countries of the Baltic, and actively promote components strengthening the value for Baltic Sea ecosystem status assessment.
- Develop, in close interaction with stakeholders, the strategy for a better, cost efficient monitoring approach for the Baltic Sea by integration of ICOS and related data.

OzEWEX

16 applicants were selected to attend the 2017 Australian Climate and Water Summer Institute during a six week period from 11–23 December 2017 and 7 January – 2 February 2018. The 2017/18 event focused on the following five themes:

- Forecasts – using weather, climate, and water forecasts to benefit economy, society, or the environment
- Droughts – quantifying and predicting the economic and environmental impacts of drought
- Floods – improving flood risk assessment and warning, increasing flood resilience, and supporting emergency response
- Water Sharing – quantifying available water resources, increasing the benefits of water use for people and environment
- Data integration – integrating observation networks, remote sensing, and modeling through data discovery, data fusion, and assimilation.

HyVic

HyVic has been designed to focus on the Lake Victoria basin, involving the five countries of Burundi, Rwanda, Kenya, Tanzania, and Uganda, all belonging to the East African Community (EAC) regional economic union. The funds for the Feasibility Study that led to the establishment of HyVic were also provided by the EAC. However, now it is clear that the most viable strategy for HyVic is to serve a larger group of regional alliance nations, the Intergovernmental Authority on Development (IGAD), comprising the nations of Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, and Uganda. HyVic has been invited through Fredrick Semazzi to be funded for providing scientific oversight for the IGAD Climate Prediction and Applications Centre (ICPAC). This means that HyVic has to take on larger regional responsibility that includes Djibouti, Eritrea, Ethiopia, Somalia, South Sudan, and Sudan, which are not included in its present mandate. The composition of the HyVic panel must also reflect the expanded geographical region. Thus, HyVic will be reconfigured (and renamed) to reflect this expanded mandate. This will involve development of a new science plan and reapplication to GHP for RHP status.

Cross-Cut Projects

INTENSE (Sub-Daily Precipitation)

Continued data acquisition and initiatives to update and expand the existing database are occurring. Thought has been given to where to host data collection and calculation of new indices for sub-daily precipitation. Talks are developing with the European Climate Assessment and Dataset (ECA&D), among others. The data will be held at an approved data center (probably Deutscher Wetterdienst, DWD) where freely distributable and sub-daily seasonal/monthly indices will be developed for all stations. Other station metrics will also be calculated such as diurnal cycle or precipitation-temperature scaling relation. The indices will be made available to the public through a dedicated website, which will also indicate data availability and give links to data providers and licensing arrangements etc. Publications are planned on analyzing the indices.

A further publication is planned on the quality control of sub-daily precipitation assessing the further development of tests of spatial consistency with neighboring gauges and their application to produce a gridded 1 km hourly precipitation product for the United Kingdom (UK). This is being developed for a generic software package which can be applied internationally (including assessment of existing methods from Met Services). These will be quality controlled

using methods developed on UK data [and adapted to local circumstances using the Datasets for Indices of Climate Extremes (CLIMDEX) daily indices]. Planned analysis includes global scale analysis of trends in sub-daily extreme precipitation.

Collaborative work is ongoing with Andreas Prein at the National Centers for Atmospheric Research (NCAR) on climate model projections and observations over the US, aiming at understanding the role of thermodynamics and dynamics in driving sub-daily precipitation extremes. Extreme value analysis methods will be applied to the quality-controlled UK hourly precipitation dataset and used to produce Intensity-Duration-Frequency (IDF) curves to support design and planning decisions. This methodology will then be applied further to the sub-hourly UK data and global datasets as they become available. This will include first analyses of data observations from around the world and first global results and first analyses of large-scale drivers of sub-daily extreme precipitation across multiple geographical regions.

Further development has occurred in the working group on very high-resolution models and common analyses of model outputs – progress was made at the INTENSE September 2017 meeting. A CORDEX Flagship Pilot study has been approved on convection-permitting model comparison over a common domain. The study domain is the European Alps and the Mediterranean. The project will propose a set of common model diagnostics to align with observed indices being calculated.

Efforts have been initiated to explore how sub-hourly in situ and satellite observations can help each other. Remote sensing should be useful because of its spatial coverage and in situ can be a great source to assess satellite performance at each point. The diurnal cycle of remotely sensed precipitation estimates will be assessed using stations where and when available. The scaling differences (point versus grid) are another important topic that needs further exploration.

INARCH (Mountain Hydrology)

INARCH achievements include:

- Participating in snow model comparisons at sites where inputs can measured/defined through links with GLASS (Richard Essery)
- Reducing measurement uncertainty by implementing WMO SPICE recommendations for solid precipitation measurements at all sites and making contact with Global Cryosphere. Watching for how to further improve measurement quality
- Developing a downscaling toolbox by examining various techniques for statistical, dynamical, and medium complexity downscaling.
- Continuing climate sensitivity comparative analysis of various alpine basins using “standard virtual basin” modeling to compare the response of snowcover, snowpack, glaciers, and hydrology to variations in temperature and precipitation in various climate regimes
- The Earth System Science Data (ESSD) Special Issue will continue to receive submissions until 6 April 2018, while other journals will be approached for a special INARCH issue on mountain snow and ice hydrology that includes references to downscaling, processes, and diagnosis of climate change impacts.
- Updating the INARCH website, which will include a downscaling toolbox with a link to methods, as well as metadata for catchments and links to DOI data. A technical document is being planned with UNESCO on “Best Practices in Instrumenting Mountain Research Catchments,” as is a policy-relevant publication with UNESCO on “Risks to World Water Security from Changing Mountain Snow and Ice Hydrology.”

Near 0°C Precipitation

- We have submitted proposals to US and Russian funding agencies to support our further activity on the Cross-Cut Project, keeping in mind that we shall need to (a) go into more details of near-0°C precipitation events and associated perils (changes in timing, intensity, and spatial pattern, handling the inhomogeneity in the data); (b) modify and complete our analyses for those countries, where synoptic information about freezing events is not readily available (first of all, for East Asia countries); and (c) assess the impact of perils associated with the near 0°C precipitation and project their changes in the next decades.
- A concerted effort continues to be made to quality control Canadian operational near 0°C regions and to utilize this information to characterize these regions. This includes the many types of precipitation as well as the associated state variables. It is intended that, once complete, this dataset will form the basis of a journal article and also be made available to everyone via a web portal.

2.2.5 Science Highlights

- Fine scale model advancements have included improvement in process representation within the Cold Regions Hydrological Model (CRHM), and enhanced computational efficiency and landscape representation within the next generation Canadian Hydrological Model (CHM), both developed at the University of Saskatchewan's Centre for Hydrology. CRHM has been set up and applied at selected Water, Ecosystem, Cryosphere and Climate (WECC) observatories for long-term historical runs and diagnosis of hydrological change (Cordeiro et al., 2017; Mahmood et al., 2016; Krogh et al., 2017; Rasouli et al., 2014) and further papers are in development.
- CCRN has made major advancements in regional climate, land surface, and hydrological model development and applications. This work has involved close collaboration and a strong partnership with Environment and Climate Change Canada (ECCC) to help them incorporate improvements into their research and operational models. Our main focus is the ECCC Canadian LAnd Surface Scheme (CLASS), Modélisation Environmentale Communautaire (MEC) – Surface and Hydrology (MESH), and Canadian Terrestrial Ecosystem Model (CTEM) models. The main effort has concentrated on developing and improving large-scale MESH models of the Mackenzie and Saskatchewan River systems, and within this, improving the representation of various processes such as permafrost, wetlands, hydrodynamics and large lakes, and snow processes, and also exploring ways of better handling spatial discretization (especially in mountainous terrain) and in particular, the effects of water management. CCRN is strongly linked to a GEWEX Cross-Cut Project on including water management in large-scale models. Various other activities have supported this work, which has progressed well to the point where we have working models in place for both major basins and we are in the midst of running future climate simulations and incorporating scenarios of landscape and ecological change. These activities were reviewed and discussed in detail at a recent modeling workshop.
- CCRN has focused on in-depth analyses of recent extreme events in western Canada. This includes the 2013 Calgary flood, summer flooding in the prairies, severe dry conditions in 2015 (Szeto et al., 2016) and 2017, extreme wildfires [Northwest Territories (2014), Saskatchewan (2015), Fort McMurray (2016), British Columbia and southern Alberta (2017)], and more. It also included analyses from a variety of perspectives (climate, ecology, hydrology, modeling, etc.) and scales (continental to regional and local).
- An international team conducted an assessment of the extent to which very fine resolution convection-permitting climate models are needed for reliable future climate projections by and has evaluated currently-available model runs and published a paper in the Bulletin of

the American Meteorological Society (BAMS) in early 2017 (DOI: 10.1175/BAMS-D-15-0004.1).

- Paper published in GRL on the spatial scales of rain cells in connection to the super Clausius-Clapeyron (CC) scaling of rainfall intensities. An analysis of rain radar data using a cloud tracking algorithm has been performed. The results show that only large convective cells produce super CC scaling. Also, a marked increase in convective cell size is found for high humidity (dew point temperatures), which is needed to sustain the super CC scaling (Lochbihler et al.; DOI: 10.1002/2017GL074857).
- We found significant changes in the frequency of freezing rain precipitation occurrence over the extratropical regions of the Northern Hemisphere. In the Arctic and sub-Arctic, step-wise increases in their occurrence in the last decade have been found and in the south, decreases have been observed (Groisman et al., 2016, Environ. Res. Lett.).

2.2.6 Science Issues, Contributions to Developing GEWEX Science, and Contributions to GEWEX Science Questions

Observations and Predictions of Precipitation

Regional Hydroclimate Projects

CCRN

- There has been much individual research progress on atmospheric circulation patterns, instabilities for generating convection, large-scale forcing for drought, precipitation phase changes, winter precipitation extremes, surface hydrologic changes, and runoff, with a number of journal submissions and draft manuscripts based on these studies [Bonsal et al. (2017), Brimelow et al. (2017), Kochtubajda et al. (2017), Zhang et al. (2017)].
- Measurements, correction, and evaluation of precipitation datasets [Pan et al. (2016), Scaff et al. (2015), Smith et al. (2017)].
- Assessments of various precipitation products and remotely sensed observations, including GPM, and characterization and regionalization of precipitation and drought characteristics over western Canada, with several papers in draft [Asong et al. (2015, 2016, 2017), Khaliq et al. (2015), Masud et al. (2015), Wong et al. (2017)]
- A major CCRN effort was centered on a comprehensive focal examination of the extreme weather and flooding in southern Alberta in June 2013, focusing on meteorological, hydrological, and water management aspects of the flood. This has led to a collection of papers being published in a special issue of Hydrological Processes. See http://ccrnetwork.ca//science/2013-Alberta-flood for further details, information products, and links to all published papers.
- Focal examination of extreme events (floods, fires, droughts) affecting the CCRN region from 2009–2017 was conducted with several papers published and others forthcoming. Publications include those listed above and: Blouin et al. (2016), Brimelow et al. (2014, 2015), Masud et al. (2016), Szeto et al. (2015).

HyMeX

In 2015-2016, a number of inter-model studies systematically analyzed the ability of regional climate models to reproduce precipitation using HyMeX data (including satellite) and cloud resolving models (e.g., NWP) operated in the frame of HyMeX (Khodayar et al., 2016, Rysman et al., 2017) and their sensitivity to ocean/atmosphere feedback on the continent (Panthou et al., 2017, Cavicchia et al., 2017) and the sea (Lebeaupin Brossier et al., 2015). A similar approach has been taken in the context of particular phenomena, in particular Mediterranean cyclogenesis (Flaounas et al., 2015a, b).

Baltic Earth

- A coupling of atmosphere and ocean can improve the dry biases for different regional climate models but not always; but particularly for summer heavy precipitation over central Europe. Ho-Hagemann, H.T.M., M. Gröger, B. Rockel, M. Zahn, B. Geyer, H.E.M. Meier, 2017. Effects of air-sea coupling over the North Sea and the Baltic Sea on simulated summer precipitation over Central Europe. Clim. Dyn., 48:1-26, March 2017.
- Liisi Jakobson, Erko Jakobson, Piia Post, and Jaak Jaagus, 2017. Atmospheric teleconnections between the Arctic and the Baltic Sea regions. Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2017-37, 2017 (under review).
- Liga Bethere, Juris Sennikovs, and Uldis Bethers, 2017. Climate indices for Baltic States from principal component analysis. Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2017-34.
- Julia Jeworrek, Lichuan Wu, Christian Dieterich, and Anna Rutgersson, 2017. Characteristics of convective snow bands along the Swedish east coast. Earth Syst. Dynam., 8, 163-175, https://doi.org/10.5194/esd-8-163-2017.

INTENSE

- Global sub-daily precipitation data has been collated (see section on Cross-Cut Projects for a summary of progress).
- Development of procedures for the quality control of sub-daily precipitation data has been undertaken for the UK. Future work will examine how the methods developed can be applied more widely in the context of global data.
- Existing work is examining how large-scale predictors and local-scale thermodynamics drive intense precipitation. This knowledge will be applied to assess which information from coarse-scale models can be used as predictors of intense precipitation.

Precipitation Near 0°C

- Datasets are being carefully produced that document precipitation near 0°C.

Initial assessments of projections are being made and limitations in model physics have been identified and steps have been and continue to be taken to rectify these.

Global Water Resource Systems

Regional Hydroclimate Projects

CCRN

- Completion of inventories and assessments of Earth system change at many WECC observatories and across the CCRN domain: Baltzer et al. (2013), Bash and Marshall (2014), Bonsal et al. (2017), Connon et al. (2014), DeBeer et al. (2015, 2016), Demuth et al. (2014), Dumanski et al. (2015), Ehsansadeh et al. (2014), Harder et al. (2015), Hayashi and Farrow (2014), Ireson et al. (2015), Maillet et al. (2017), Mamet et al. (2017), Marshall (2014b), Patankar et al. (2015), Paznekas et al. (2015), Quinton and Baltzer (2013b), Shi et al. (2015), Shook and Pomeroy (2015), Spence et al. (2015), Yang et al. (2014b)
- Analysis of large-scale hydrological model performance for the Saskatchewan and Mackenzie basins. Identification of key challenges: input uncertainty, permafrost, cold region lakes and wetlands, mountain hydrology, prairie hydrology, anthropogenic water management. Work initiated to address these with a number of draft papers underway and some recent publications. Much of this work (at various stages of development) had been reviewed and synthesized at a recent workshop. Hassanzadeh et al. (2014, 2015),

Mekonnen et al. (2014), Nazemi and Wheater (2014a, 2014b, 2015a, 2015b), Haghnegahdar and Razavi (2017)

- Progress with assimilation of remotely sensed data to constrain large-scale hydrological models, and examination of scaling effects in the models (Yassin et al., 2017)
- Extension of previous work on vulnerability analysis of water resource systems in the SaskRB, which now includes risk-based hydro-economic analysis for Saskatchewan. Hassanzadeh et al. (2015)

HyMeX

The EartH2Observe project, which contributes to HyMeX, has produced a new atmospheric forcing data set (E2OFD) from satellite Earth Observations (EO) to drive land surface models (LSM). It is at 0.25° resolution, over the European Centre for Medium-range Weather Forecasts (ECMWF) Re-Analysis (ERA)-Interim (ERA-I) reanalysis period and includes the new and original rainfall estimates from Multi-Source Weighted-Ensemble Precipitation (MSWEP) data (Beck et al., 2017). The product is global but its quality over the Mediterranean region has been analysed within HyMex. For the Iberian Peninsula, a higher resolution (5 km) forcing data set was also developed by the Observatori de l'Ebre and serves as a reference (Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige for the Iberian Peninsula, SAFRAN-IP). The Organizing Carbon and Hydrology In Dynamic Ecosystems (ORCHIDEE) simulations forced with EartH2Observe and a Weather Research and Forecasting (WRF)-based downscaling of the ERA-I reanalysis were used to analyze the uncertainty propagation due to the forcing. This demonstrated that the high resolution of E2OFD provides details that are also produced by the dynamical downscaling, thus confirming that E2OFD brings added value. Comparing the discharge of some of the large rivers contributing to the Mediterranean Sea shows that the difference between both forcing (E2OFD and WRF) is smaller than systematic errors of the land surface model caused by missing processes: human control of the water cycle. The analysis of the major droughts that have occurred over the Iberian Peninsula in the last 30 years demonstrated that the ability of LSMs to reproduce them does not depend on the resolution of the forcing. This comparison with SAFRAN-IP confirmed the quality of the E2OFD forcing data set (see GSQ4). This drought analysis also demonstrated the difficulty in choosing metrics to define these climatic and hydrological extremes. This is a topic that will require more detailed analysis within the HyMex community and is the focus of a specific Science Team. ORCHIDEE has been used to assimilate river discharge in order to determine where the largest errors occur in the simulated continental water balance. It has demonstrated that over the Mediterranean region, the largest errors are found over irrigated areas because these human controls on the water cycle are not yet simulated.

There are several difficulties in using satellite observations for studying the Mediterranean region. For instance, due to coastal contamination, EOs have many issues over this region. Elevation over mountains is another factor impacting the quality of EOs. Furthermore, there exist a multiplicity of datasets for a same variable (e.g., precipitation) and it is difficult for a user to know which one he should be using. Finally, the datasets are not coherent to each other and therefore, the Mediterranean water cycle budget is not closed when using the EOs. The ESA Water Cycle Multi-Mission Observation Strategy for the Mediterranean (WACMOS-MED) project, which complements the EartH2Observe project and which focuses on the Mediterranean region, has the goal to provide the scientific community with an integrated satellite dataset monitoring, in a coherent way, the water cycle over the continents, ocean, and in the atmosphere. Several datasets have been gathered for each one of these water cycle components: precipitation, evaporation, runoff, ground water storage, atmospheric humidity, etc.

We first analyzed the budget closure of the EO datasets and built a best consensus EO dataset by combining them (Fig. 4). This first combined dataset has then been used to characterize the seasonality and the long-term trends over large Mediterranean basins (Pellet et al., 2017). Comparison with ERA-Interim analysis from the ECMWF shows that the purely satellite dataset has very similar features to ERA-I, but no model is used in our EO dataset. Second, an original merging procedure has been developed to integrate all the satellite datasets in a more hydrologically-coherent way by constraining the water cycle budget closure (Pellet et al., 2018). Validation has been performed using in situ data. This integrated dataset will be made available to the scientific community, in particular the HyMeX community. It is being tested and validated in several contexts, for better modeling of the runoff, or for a better forecast of river discharges from satellite observations.

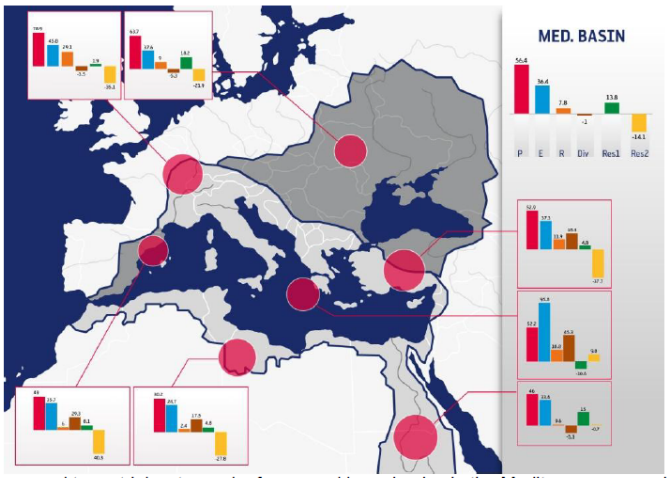


Figure 4: Mean annual terrestrial water cycle, for several large basins in the Mediterranean, as observed by our combined satellite observations dataset..

Changes in Extremes

Regional Hydroclimate Projects

CCRN

- Regional-scale synthesis of Earth system change through analysis of federal and provincial hydro-climatic datasets, remotely sensed data products, climate model reanalysis, and radar, rawinsonde, and lightning detection observations, as well as an integrated literature review of past change over the CCRN domain. This work has been presented and discussed in a 2016 workshop.
- Individual research progress on atmospheric circulation patterns, instabilities for generating convection, large-scale forcing for drought, precipitation phase changes, winter precipitation extremes, surface hydrologic changes, and runoff, with a number of journal submissions and draft manuscripts based on these studies
- A major CCRN effort was centered on a comprehensive focal examination of the extreme weather and flooding in southern Alberta in June 2013, focusing on meteorological, hydrological, and water management aspects of the flood. This has led to a collection papers being published in a special issue of Hydrological Processes. (See http://ccrnetwork.ca//science/2013-Alberta-flood for further details, information products, and links to all published papers.)
- Focal examination of extreme events (floods, fires, droughts) affecting the CCRN region from 2009–2016, with several papers published and others forthcoming. Initial work towards an interdisciplinary examination of the 2014 forest fires in the Northwest

Territories, involving contributions from university and government organizations. Relevant publications include those listed above and: Brimelow et al. (2014, 2015), Masud et al. (2016), and Szeto et al. (2015).

- CCRN will continue to focus on conducting detailed analyses of recent extreme events (floods, droughts, wildfires) in our geographic domain, including the recent short but severe drought in 2015, the sequence of devastating wildfires in parts of the region from 2014 to 2017, local prairie flooding in several of the past years, hazardous winter precipitation, and severe summer weather and hail that has affected several cities in the past year, and examination of the chain-of-events leading up to these events.

HyMeX

Scaling Extreme Precipitation with Temperature

The capacity of the atmosphere to store water vapor increases with temperature according to the Clausius-Clapeyron law (C-C, 7%/°C). Several studies have hypothesized that the evolution of extreme rainfall intensity in future climate will be mainly controlled by this amount and will therefore increase by about 7%/°C. Since then, various studies have focused on the relationship between extreme rains and temperature and show that this relationship does not necessarily follow the law of C-C and depends on many factors. Within HyMeX, and in the frame of the GEWEX cross-cutting activity on sub-daily precipitation, research has focused on the relationship between temperature and extreme rainfall for the Mediterranean region in order to (a) verify whether this relation follows the C-C scaling (both in observations and simulations); (b) to better understand the mechanisms driving the formation of extreme precipitation; and (c) to analyze how these processes will be modified in the future. Drobinski et al. (2016) show that the daily intensity of extreme precipitation increases with the daily temperature of the surface at low temperatures and decreases at high temperatures.

This "hook shape" can be attributed to several factors: (1) reduction of the duration of rainfall events at high temperatures, (2) different synoptic situations leading to extreme precipitation, and (3) decreasing precipitation efficiency and vertical moisture transport.

Drobinski et al. (2017) have also shown using the HyMeX/Med-CORDEX simulations that in a future climate, the range of temperatures over which the daily intensity of extreme precipitation increases with daily temperature rises and that the rate at which the intensity of precipitation decreases at high temperatures decreases. Nevertheless, a large part of the temperature-extreme precipitation relationship in the future can be found by correcting the relation to the climate present by Clausius-Clapeyron law. This correction can only be applied if the relative humidity remains constant between the present and the future. This discovery is quite counter-intuitive because this region warms up and dries up at one of the highest rates on the globe. Drobinski et al. (2017) advocates that the Mediterranean Sea is an immense source of moisture, which makes it possible to counterbalance the effect of continental aridification. Figure 5 summarizes these findings.

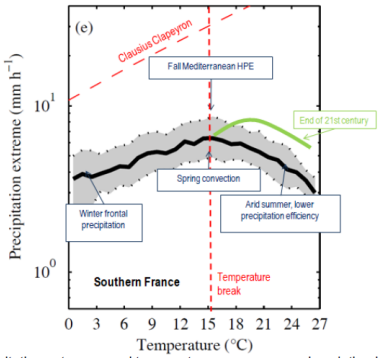


Figure 5: Scaling of precipitation extremes and temperature: processes and evolution in cliùate change. Source: Drobinski et al. (2016, 2017).

Heat Waves, Droughts and Climate Change

The effect on heat waves of vegetation fertilization in a context of climate change has been studied in the frame of HyMeX. Stomata bind water, carbon, and energy cycles. To enable photosynthesis, stomata open to assimilate carbon dioxide, and simultaneously release water vapor. In turn, the surface cools down as energy is converted to latent heat, the most effective form of temperature regulation in the absence of water stress. When the atmospheric concentration of CO_2 increases, with the assimilation of CO_2 given, the evapotranspiration of the vegetation is reduced. This greater water efficiency results in an increase in feedback on the water balance, carbon, and energy at the surface. Lemordant et al. (2016) show that the fertilization of vegetation by an increased concentration of atmospheric CO_2 can mitigate the heat waves at mid-latitudes by mobilizing the preserved water thanks to greater water efficiency before the onset of the heat wave. However, the aridity of the soil at the end of the summer in the Mediterranean is generally exacerbated because a greater vegetation cover "overcompensates" for the greater water efficiency (Fig. 6). These results highlight the potential role of vegetation fertilization by atmospheric CO_2 as a mitigator of extreme hydrological events and as an enhancer of summer droughts. These results can have important implications for the future of agriculture, water resource management, and ecosystem health.

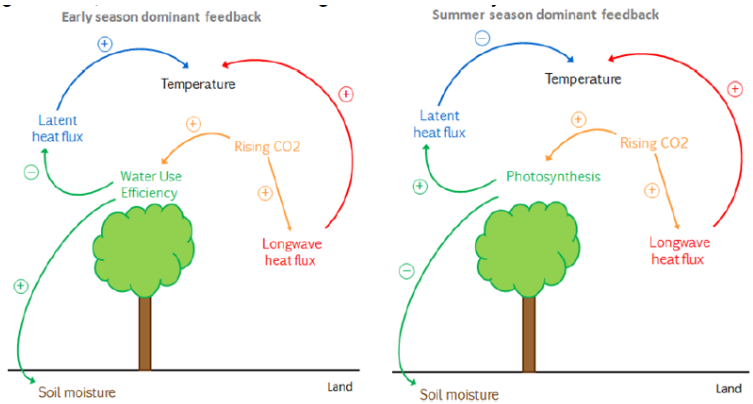


Figure 6: Feedback loops during spring and summer. Source: Lemordant et al. (2016).

Baltic Earth

- Egidijus Rimkus, Edvinas Stonevicius, Justinas Kilpys, Viktorija Maciulyte, and Donatas Valiukas, 2017. Drought identification in the eastern Baltic region using NDVI. Earth Syst. Dynam., 8, 627-637, 2017
- Ari Venäläinen, Mikko Laapas, Pentti Pirinen, Matti Horttanainen, Reijo Hyvönen, Ilari Lehtonen, Päivi Junila, Meiting Hou, and Heli M. Peltola, 2017. Estimation of the high-spatial-resolution variability in extreme wind speeds for forestry applications. Earth Syst. Dynam., 8, 529-545, 2017
- Anton Y. Dvornikov, Stanislav D. Martyanov, Vladimir A. Ryabchenko, Tatjana R. Eremina, Alexey V. Isaev, and Dmitry V. Sein, 2017. Assessment of extreme hydrological conditions in the Bothnian Bay, Baltic Sea, and the impact of the nuclear power plant “Hanhikivi-1” on the local thermal regime. *Earth Syst. Dynam.*, 8, 265-282, 2017

INTENSE

Initial work has been undertaken on observed changes in sub-daily US precipitation extremes. It is planned that this analysis will be performed on additional global datasets where data quality and length allow.

Precipitation Near 0°C

- Precipitation Near 0°C leads to many impacts and so the whole effort is contributing to the study of changing extremes.
- We found significant changes in the frequency of freezing rain precipitation occurrence over the extratropical regions of the Northern Hemisphere. In the Arctic and sub-Arctic, step-wise increases in their occurrence in the last decade have been found and in the south decreases have been observed (Groisman et al., 2016, Environ. Res. Lett.).

Water and Energy Cycles

Regional Hydroclimate Projects

CCRN

- Use of soil moisture monitoring networks for improving observation of soil freeze-thaw processes and evaluation of soil moisture scaling properties at resolutions applicable to the NASA Soil Moisture–Active Passive (SMAP) mission, upscaling of energy and water balance components from point- to field-scales, and evaluation of wetlands and soil moisture using RADARSAT-2 in prairie and taiga–tundra ecoregions. Adams et al. (2015), Burns et al. (2016), Champagne et al. (2016), Djamai et al. (2015), Manns et al. (2015), Rowlandson and Berg (2015), Rowlandson et al. (2015), Roy et al. (2016, 2017), and Williamson et al. (2017)
- An important development for the network is that Li, working with NCAR, has produced 4km WRF climate simulations for the entire CCRN domain (14 years historical simulations, plus pseudo warming simulations of future climate). This provides comparative data for Theme B, C, and D modeling and large-scale climate analysis. Similarly, collaboration with ECCC provides access to the Canadian Regional Climate Model 4 (CRCM4), which provides us with continuous future forcing data to the end of the 21st century. Driving datasets and the progress of WRF runs were presented and discussed the most recent CCRN modeling workshop.

HyMeX

Ocean/Atmosphere Interactions on Precipitation and Water Balance in Regional Climate Models

The possible role of ocean circulation in the "connection" of a strong mistral in the north-western Mediterranean with an intense rainfall event in southern France in November 1999 was analyzed (Lebeaupin-Brossier et al., 2015). These two events are both controlled by intense air-sea fluxes and are separated by a week. From an atmospheric point of view, these two events can be considered totally uncorrelated and independent. Using HyMeX/Med-CORDEX simulations, it has been shown that cyclonic ocean circulation is a key element, which can trap important sea temperature anomalies over several days. In the investigated situation, the mistral induces a rapid cooling of the sea surface temperature in the Gulf of Lion and a strong evaporation due to the strong wind. This cold anomaly is trapped in the cyclonic vortex in the Gulf of Lion and lasts for more than a week. This directly affects the following intense precipitation episode with less energy supplied to the location of the cold anomaly and more evaporation near the coast, thus modulating the location and quantities of precipitation on land. This case-study work has been generalized to all the extreme precipitation simulated over 20 years (duration of HyMeX/Med-CORDEX simulations) and to cases documented within HyMeX in a multi-model approach along the Spanish, French, Italian, and Croatian coastlines (Berthou et al., 2015, 2016, 2017).

Fine-scale Precipitation Processes

A special issue of the *Quarterly Journal of the Royal Meteorological Society* (Ducrocq et al, 2016) presents a wide range of studies exploiting the exceptional dataset of observations and

model outputs collected during SOP1. This special issue consists of a series of 31 papers, including several papers on process understanding for several Intensive Observation Periods (IOPs). These IOP studies showed that a major ingredient for heavy precipitation is the conditionally unstable, low-level marine flow impinging the mountainous coastal regions bordering the western Mediterranean Sea, associated with lifting that lead to the triggering of deep convection at the same place during several hours.

The lifting mechanisms mostly result from the interactions of the low-level circulation with the orography and with sometimes the convective systems themselves (Davolio et al., 2016; Scheffknecht et al., 2016; Barthlott et al., 2016; Barthlott and Davolio, 2016; Duffourg et al., 2016; Röhner et al., 2016). They include orographic lifting, pre-existing convergence lines (dynamically or orographically induced), cold pool (possibly, but not necessarily, resulting from evaporative cooling) and contributions of topographical flows (e.g., gap winds and barrier jets). Often, they interplay and combine and can also occur over the Sea. The origin of the moisture over the Mediterranean Sea is quite diverse (Duffourg and Ducrocq, 2013) and originates from (1) evaporation from the Mediterranean Sea, (2) transport from the North Atlantic Ocean and (3) transport from North Africa. Chazette et al. (2016) highlighted a tropical origin of high water vapor content associated, whereas Röhner et al. (2016) identified the eastern North Atlantic and the Mediterranean Sea as moisture uptake regions.

Drought Characterization, Propagation and Related Processes
Drought affects different aspects of the continental water cycle, from precipitation (meteorological drought), to soil moisture (agricultural drought), streamflow, lake volume and piezometric levels (hydrological drought). The spatial and temporal scales of drought, together with its propagation through the system, must be well understood.

A method has been developed for detecting and classifying meteorological droughts over the whole Mediterranean basin (extreme dry spells) in terms of spatial coverage, duration, and occurrence (Raymond et al., 2016), which were then associated with "typical" atmospheric circulation patterns (Raymond et al., in revision). This method also allows the evaluation of the capacity of the regional climate simulations HyMeX/Med-CORDEX to reproduce drought characteristics (Raymond et al., in revision) with a view towards studying their evolution in the context of climate change. Indices are often used to characterize different aspects of drought, built on precipitation (SPI), soil moisture (SSMI), streamflow (SSI), and water table depth. Other indices, such as the Standardized Precipitation Evapotranspiration Index (SPEI), may combine several drought related variables. These indices allow analysis of the temporal scales of drought and its spatial patterns. The objective of the work conducted in the frame of HyMeX and funded by EartH2Observe project is to investigate how sensitive land-surface model (LSM) simulations are to the forcing dataset and model structure, with a focus on drought. A global and a local dataset at different resolutions are used to run LSM simulations. The global dataset is the EartH2Observe dataset (0.25°), which is based on ERA-Interim. The local dataset is the SAFRAN meteorological analysis system (in two versions at 5 km and 30 km). The LSMs used are Surface Externalisée (SURFEX) (using the multi-layer diffusion and 3-layer force-restore versions) and LEAFHYDRO. Standardized indices of the relevant variables are produced for all the simulations performed. Their analysis shows how differently drought propagates through the system in the different forcing-model combinations and how similar the spatial and temporal scales of drought are. The results of this study will be useful to understand the applicability of global datasets for local studies on drought and to better understand the related uncertainties.

Baltic Earth

- Liisi Jakobson, Erko Jakobson, Piia Post, and Jaak Jaagus, 2017. Atmospheric teleconnections between the Arctic and the Baltic Sea regions. Earth Syst. Dynam. Discuss., 2017 (under review).
- Liga Bethere, Juris Sennikovs, and Uldis Bethers, 2017 Climate indices for Baltic States from principal component analysis. Earth Syst. Dynam. Discuss., 2017.
- Ho-Hagemann, H.T.M., M. Gröger, B. Rockel , M. Zahn, B. Geyer, H.E.M. Meier, 2017. Effects of air-sea coupling over the North Sea and the Baltic Sea on simulated summer precipitation over Central Europe. Clim. Dyn., 48:1-26, March 2017.

2.2.7 Other Key Science Questions

None

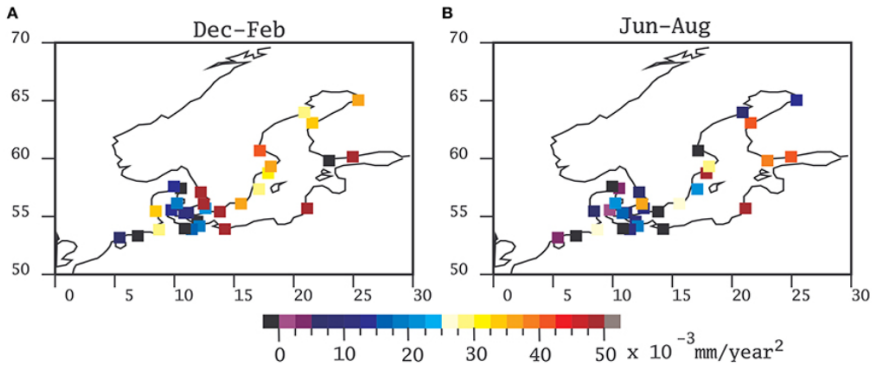
2.2.8 Contribution to the WCRP Grand Challenges

WCRP Grand Challenge on Regional Sea-Level Rise

Baltic Earth

Hünicke, B., and E. Zorita, 2016. Statistical Analysis of the Accerleration of Baltic Mean Sea Level Rise, 1900-2012. *Front. Mar. Sci.*, 22, July 2016.

- Globally, sea level is expected to accelerate.
- An acceleration for the Baltic Sea has been tested statistically since 1900.
- Acceleration was found to be mostly positive but very low and statistically not significant.
- Absolute values due to acceleration would only add some cm to the expected rise of up to 1m at 2100.



Acceleration of the annual mean sea-level in the Baltic Sea tide-gauges estimated in the period 1900–2012 in wintertime (A) and summertime (B) by the method gtols (see paper)

- Meier, H.E.M., A. Hoglund, K. Eilola, E. Almroth-Rosell, 2017. Impact of accelerated future global mean sea level rise on hypoxia in the Baltic Sea. Clim. Dyn. 49(1-2):163-172, July 2017.
- Bierstedt, Svenja E., Birgit Hunicke, Eduardo Zorita, and Juliane Ludwig, 2017. A wind proxy based on migrating dunes at the Baltic coast: statistical analysis of the link between wind conditions and sand movement. Earth Syst. Dynam., 8, 639-652, 2017.
- Česnulevičius, Algimantas, Regina Morkūnaitė, Artūras Bautrėnas, Linas Bevainis, and Donatas Ovodas, 2017. Intensity of geodynamic processes in the Lithuanian part of the Curonian Spit. Earth Syst. Dynam., 8, 419-428, 2017.
- Schade, Nils H., 2017. Evaluating the atmospheric drivers leading to the December 2014 flood in Schleswig-Holstein, Germany. *Earth Syst. Dynam.*, 8, 405-418, 2017.

WCRP Grand Challenge on Cryosphere Response to Climate Change (Including Ice Sheets, Water Resources, Permafrost and Carbon)

CCRN

- Projection results are used to address regional scale effects on land and water resources, using the large-scale models developed in Theme C. This includes the change in river flows for the Saskatchewan, Peace-Athabasca, and Mackenzie River Basins, and effects of climate change for specific ecosystems.
- We will determine whether future changes cross "tipping points" in Earth system behavior, leading to further extremes and dramatic system changes, such as deglaciation, permafrost disappearance and terrestrial ecosystem transition. Local scale assessments have begun in Theme B with several publications (Pomeroy et al., 2015b; Rasouli et al., 2014, 2015; Krogh et al., 2017), and planned CRHM historical and future diagnostic modeling.
- Outputs from this analysis will thus be used to identify global climatological controls on broad regional water resource response, and hence to enable specific design, operational, or policy development problems under climate change to be addressed in Theme E. To address this issue, specific analyses will be carried out utilizing future conditions along with threshold guidance on conditions needed to trigger a fundamental shift.
- Glaciological studies, including mass and energy balance, glacier hydrology, and development of ice dynamic routines for local to regional-scale models, are being conducted, crossing many of our thematic areas. See the CCRN website for information on the glaciological research at several of our WECC observatories. Bash and Marshall, 2014; DeBeer et al., 2016; Demuth et al., 2014; Ebrahimi and Marshall, 2015; Marshall, 2014a, 2014b; Samimi and Marshall, 2017.

WCRP Grand Challenge on Improved Understanding of the Interactions of Clouds, Aerosols, Precipitation, and Radiation and their Contributions to Climate Sensitivity

CCRN

- Specific scientific contributions involve the assessment of large and synoptic scale atmospheric circulation patterns as they relate to observed temporal and spatial trends and variability (including extremes) in hydroclimate over the study region.
- In addition, studies are undertaken to understand the mechanisms which link the regional water and energy response to large-scale forcings. This includes the role of the orographic barrier in amplifying the region's climate sensitivity to upstream large-scale forcings. Statistical techniques and diagnostic studies will be carried out to examine the coupled mode of variability between low-frequency forcings such as sea surface temperature anomalies, large-scale circulation patterns, and warm-season synoptic activities. Armstrong et al., 2015; Asong et al., 2015; Brimelow et al., 2014; 2015; Khaliq et al., 2015; Kochtubajda et al., 2016, 2017; Liu et al., 2016; Masud et al., 2015; Szeto et al., 2015.
- Changes in the large-scale atmospheric circulation are assessed from the fifth Coupled Model Intercomparison Project (CMIP5) and other projections. Their subsequent effects on the continental synoptic activities and associated heat and moisture transports which affect critically regional temperature and precipitation responses will be assessed from the downscaled projections.

Baltic Earth

- Lehmann, A., K. Höflich, P. Post, K. Myrberg, 2017. Pathways of deep cyclones associated with large volume changes (LVCs) and major Baltic inflows (MBIs). J. Mar. Syst., 167:11-18, March 2017

- Liisi Jakobson, Erko Jakobson, Piia Post, and Jaak Jaagus, 2017. Atmospheric teleconnections between the Arctic and the Baltic Sea regions. Earth Syst. Dynam. Discuss., 2017 (under review).
- Liga Bethere, Juris Sennikovs, and Uldis Bethers, 2017 Climate indices for Baltic States from principal component analysis. Earth Syst. Dynam. Discuss., 2017.
- Jaak Jaagus, Mait Sepp, Toomas Tamm, Arvo Jarvet, and Kiira Moisja, 2017. Trends and regime shifts in climatic conditions and river runoff in Estonia during 1951–2015. Earth Syst. Dynam., 2017.
- Julia Jeworrek, Lichuan Wu, Christian Dieterich, and Anna Rutgersson, 2017. Characteristics of convective snow bands along the Swedish east coast. Earth Syst. Dynam., 8, 2017.
- Ho-Hagemann, H.T.M., M. Groger, B. Rockel, M. Zahn, B. Geyer, H.E.M. Meier, 2017. Effects of air-sea coupling over the North Sea and the Baltic Sea on simulated summer precipitation over Central Europe. Clim. Dyn., 48:1-26, March 2017.
- Camenisch, C, K. Keller, M. Salvisberg, B. Amann, M. Bauch, S. Blumer, R. Bradzil, S. Bronnimann, U. Buntgen, B.M.S. Campbell, L. Fernandez-Donado, D. Fleitmann, R. Glaser, F. Golzalez-Rouco, M. Grosjean, R. Hoffamnn, H. Huhtamaa, F. Joos, A. Kiss, O. Kotyza, F. Lehner, J. Luterbacher, N. Maughan, R. Neukom, T. Novy, K. Pribyl, C. Raible, D. Riemann, M. Schuh, P. Slavin, J.P. Werner, O. Wetter, 2016. The 1430s: A cold period of extraordinary internal climate variability during the early Sporer Minimum with social and economic impacts in north-western and central Europe. Clim. Past, 12:2107–2126.
- Barkhordarian, A., H. von Storch, E. Zorita, and J. Gomez-Navarro, 2016. An attempt to deconstruct recent climate change in the Baltic Sea Basin. J. Geophys. Res.-Atmos., November 2016.

WCRP Grand Challenge on Past and Future Changes in Water Availability (with Connections to Water Security and the Hydrological Cycle)

CCRN

- Use of soil moisture monitoring networks for various objectives (see above under GSQ4). Progress has also been made on the quantification of effects of uncertainty in driving variables, and new methods to accommodate this, and in the assimilation of other satellite products in the large-scale hydrological models, in particular the Gravity Recovery and Climate Experiment (GRACE) (in collaboration with Natural Resources Canada).
- Various atmospheric research activities contribute to this Grand Challenge, described above under GSQ1 and GSQ2.
- Various improvements to CLASS and issues under development, including lakes, wetlands, snow/mountain hydrology, frozen soils and infiltration, prairie hydrology, water management, coupled land-surface–groundwater, glacier dynamics, and linkage between hydrology, climate, and vegetation
- Setup and evaluation of MESH over both the Mackenzie and Saskatchewan River basins, with several key focal issues identified for ongoing work, including input uncertainty, soil depth and permafrost initialization/representation, wetlands, and water management. Model development is at the stage where it these are ready for future simulations.
- Research on future conditions over the domain has given some indication of future states and interactions, although with a great deal of uncertainty. In general, results predict continued increase in temperature–more in the cold season and at higher elevations. They also expect an overall increase in precipitation, but with considerable spatial and temporal variability. Northern regions are projected to see more increases in precipitation than southern regions of the study area, which has potentially huge implications for water resources. In parallel, there is a projected increase in the frequency, intensity, and duration

of future droughts including more hot droughts. Overall, future water cycle related variability remains a huge knowledge gap.

- Given the determination and understanding of changing conditions over the region, it is critical to assess how future conditions will evolve, in particular factors affecting water resources and ecosystems. Validated models from Theme C are a critical basis for addressing this issue, including our degree of uncertainty. Projections of future conditions over the region are being developed by CCRN (4 km WRF pseudo-warming) and others will be obtained (CRCM4 projections, with improved CLASS algorithms and explicit representation of feedbacks). Asong et al., 2015, 2016, 2017;, Khaliq et al., 2015; Masud et al., 2015; Yassin et al., 2017.
- Changes in the large-scale atmospheric circulation are assessed from CMIP5 and other projections. Their subsequent effects on the continental synoptic activities and associated heat and moisture transports, which affect critically regional temperature and precipitation responses, will be assessed from the downscaled projections. The initial focus will be on projections of temperature, precipitation, and their variation. Key focal points will be on regional and local scale temperature changes and variations of prolonged summer hot periods, and extension of above freezing conditions. In terms of precipitation, the focus will be on the development of drought, heavy precipitation, extreme precipitation rates, as well as the changing phase of precipitation. Asong et al., 2015; Bonsal et al., 2017; Khaliq et al., 2015; Masud et al., 2015; Stewart et al., 2015.

WCRP Grand Challenge on Science Underpinning the Prediction and Attribution of Extreme Events

CCRN

- Specific scientific contributions involve the assessment of large and synoptic scale atmospheric circulation patterns as they relate to observed temporal and spatial trends and variability (including extremes) in hydroclimate over the study region. Another focus is on precipitation. Studies include the occurrence of precipitation extremes from droughts to heavy precipitation including variability and simultaneous occurrence. The regional and larger scale factors leading to such events will be determined. The factors leading to the changing occurrence of winter precipitation will be examined. Changes in the occurrence of extreme precipitation rates will be determined over some areas and linked with the large and regional scales forcing factors. Asong et al., 2015, 2016, 2017; Bonsal et al., 2017; Brimelow et al., 2014, 2015, 2017; Dumanski et al., 2015; Khaliq et al., 2015; Kochtubajda et al., 2016, 2017; Liu et al., 2016; Masud et al., 2015; Pomeroy et al., 2016a, 2016b; Scaff et al., 2015; Schubert et al., 2016; Shook et al., 2015; Stewart et al., 2015; Szeto et al., 2015.
- Key focal points are on regional and local scale temperature changes and variations of prolonged summer hot periods, and extension of above freezing conditions. A focal examination of changes around the zero-degree Celsius isotherm is ongoing. In terms of precipitation, the focus is on the development of drought, heavy precipitation, extreme precipitation rates, as well as the changing phase of precipitation.
- We are in the process of determining whether future changes cross “tipping points” in Earth system behavior, leading to further extremes and dramatic system changes, such as deglaciation, permafrost disappearance, and terrestrial ecosystem transition. Local scale assessments have begun in Theme B with several publications (Pomeroy et al., 2015b; Rasouli et al., 2014, 2015; Krogh et al., 2017), and planned CRHM historical and future diagnostic modeling.

Baltic Earth

- Egidijus Rimkus, Edvinas Stonevicius, Justinas Kilpys, Viktorija Maciulyte, and Donatas Valiukas, 2017. Drought identification in the eastern Baltic region using NDVI. Earth Syst. Dynam., 8, 627-637, 2017.
- Ari Venalainen, Mikko Laapas, Pentti Pirinen, Matti Horttanainen, Reijo Hyvonen, Ilari Lehtonen, Paivi Junila, Meiting Hou, and Heli M. Peltola, 2017. Estimation of the high-spatial-resolution variability in extreme wind speeds for forestry applications. Earth Syst. Dynam., 8, 529-545, 2017.
- Anton Y. Dvornikov, Stanislav D. Martyanov, Vladimir A. Ryabchenko, Tatjana R. Eremina, Alexey V. Isaev, and Dmitry V. Sein, 2017. Assessment of extreme hydrological conditions in the Bothnian Bay, Baltic Sea, and the impact of the nuclear power plant "Hanhikivi-1" on the local thermal regime. Earth Syst. Dynam., 8, 265-282, 2017.

INTENSE

The INTENSE project is focused on 1) meeting the data requirements and 2) examining trends/variability and processes associated with the core Grand Challenge events of "heavy precipitation" and "drought."

- Data collection activities will contribute information (overarching theme: document) that could underpin detection and attribution studies and model evaluation by collating and quality controlling sub-daily precipitation data (providing data that is extensive in time and space). INTENSE is also examining how sub-daily precipitation extremes may be defined through the use of relevant indices that have to date only been established on daily timescales.
- Analysis of local scale thermodynamics and large-scale predictors will improve understanding and characterization of physical mechanisms leading to the occurrence of floods and droughts (overarching theme: understand), and the relationships between these events.
- By linking observations with the latest generation of climate models (and in particular the emerging high-resolution regional climate models), INTENSE will assess the deficiencies of models in the simulation of key processes and events. It will contribute valuable information as to the types of events that current models can provide credible and robust simulations for, and where high-resolution models offer added value on the projected change signal compared with coarse resolution models (overarching theme: simulate).

WCRP Grand Challenge on Near-Term Climate Prediction

CCRN

Our work on all future assessments of change is based on various climate model projections and forecasts, such as CMIP5, the North American Regional Climate Change Assessment Program (NARCCAP), and CORDEX. We are directly contributing to the development of climate forecasts through our WECC observatories. They provide excellent validation datasets for model downscaling, bias correction, and other activities aimed at improving RCM performance and developing related products.

Baltic Earth

Liga Bethere, Juris Sennikovs, and Uldis Bethers, 2017. Climate indices for Baltic States from principal component analysis. *Earth Syst. Dynam.*, 2017.

WCRP Grand Challenge on Carbon feedbacks in the Climate System

CCRN

- Activities at some of our WECC observatories, in particular the Boreal Ecosystem Research and Monitoring Sites (BERMS), focus on the spatial and temporal variability in the boreal forest's water and carbon balance, and their sensitivity to climate variability and change. Long-term, high-quality, and intensive observations of water, carbon, and energy fluxes at several towers in different forest stands provide exemplary opportunities to observe and understand the carbon balance and feedbacks with the climate system. Work has examined the net annual ecosystem carbon exchange from CO2 flux measurements and partitioned it between gross ecosystem photosynthesis and ecosystem respiration.
- We have conducted preliminary analyses of the CTEM model, focusing on our BERMS sites, and will utilize the model to simulate different ecosystems, particularly around the boreal–prairie transition zone.

Baltic Earth

- Ahlgren, J., A. Grimvall, A. Omstedt, C. Rolff, J. Wikner, 2017. Temerature, DOC level and basin interactions explain the declining oxygen concentrations in the Bothnian Sea. J. Mar. Syst., 170:22-30, January 2017.
- Sveden J., J. Walve, U. Larsson, R. Elmgren, 2016: The bloom of nitrogen-fixing cyanobacteria in the northern Baltic Proper stimulates summer production. J. Mar. Syst., 163:102-112, November 2016.
- Almroth-Rosell, E., M. Edman, K. Eilola, H.E.M. Meier, J. Sahlberg, 2016. Modeling nutrient retention in the coastal zone of an eutrophic sea. Biogeosciences, 13:5753-5769, October 2016.

2.2.9 Cooperation with WCRP Projects and Other International Programs

CCRN

- The International Network for Alpine Research Catchment Hydrology (INARCH) is a GEWEX Cross-Cut Project that is an international spin-off from CCRN, led by distinguished Professor John Pomeroy. CCRN and INARCH are closely linked and share many common research priorities and objectives. A workshop will be held February 8-9, 2018, in Zugspitze, Germany, that members of CCRN will attend.
- The Cold/Shoulder Season Precipitation Near 0°C project is a GHP Cross-Cut Project that addresses multiple aspects of precipitation phase transitions and is led by CCRN investigators. There are many areas of overlap between these projects; in particular, CCRN is conducting a detailed assessment of changes in the 0°C isotherm, with objectives that are directly linked to this project.
- Another GHP Cross-Cut Project is focused on including water management in large-scale models, and is led by several CCRN investigators, including the Principal Investigator. Considerable progress on this issue has been achieved through CCRN studies. Both initiatives have goals to include newly developed reservoir schemes into models, such as MESH.

HyMex

- CLIVAR: HyMeX aims at understanding the variability and trend of the regional climate in interaction with the Mediterranean Sea, and thus contributes to the specific MedCLIVAR program, chaired by Piero Lionello, member of the HyMeX ISSC.
- CORDEX: The regional climate modeling group of HyMeX is at the origin of the selection of the Mediterranean region as an official domain of the CORDEX program. The coordinator of the Med-CORDEX project is Paolo Ruti, who chairs the HyMeX regional climate modeling group with Samuel Somot.
- HyMeX is also endorsed by WWRP and its subprogram THORPEX. Véronique Ducrocq, co-Principal Investigator of the HyMeX programme, is the HyMeX representative at the WWRP scientific committee.

Precipitation Near 0°C

Much of this activity in Canada has been carried out in connection with the Canadian RHP CCRN (Changing Cold Regions Network) and with Environment and Climate Change Canada. The near 0°C region has many hydrologic, ecological, and societal impacts. In the US, France, and the Russian Federation, this activity is carried out in close cooperation with the International Belmont Forum Project "The ARCTIC-ERA (ARCTIC climate change and its impact on Environment, infrastructures and Resource Availability)." Although this activity is relevant to CliC and CLIVAR as well, no linkage has been established.

2.2.10 Workshops/Meetings Held

CCRN

- Fall 2017 modeling workshop, Coast Hotel, Canmore, AB, November 2-3, 2017
- Wolf Creek Research Basin 25th Anniversary Science Summit, Gold Rush Inn, Whitehorse, YT, September 28-29, 2017
- Modeling workshop, National Hydrology Research Centre, Saskatoon, SK, June 2017
- Scenarios of change workshop, National Hydrology Research Centre, Saskatoon, SK, March 20-21, 2017
- 10th HyMeX workshop, Barcelona, Spain (~160 participants); 3-7 July 2017
- EGU General Assembly 2017, Vienna, Austria, 23-28 April 2017. Baltic Earth Session on "Climate change and its impacts in the Baltic and North Sea regions: Observations and model projections" is based on the work of the recently published regional BACC II (Baltic Sea region) and NOSCCA (North Sea region) climate change reports
- Baltic from Space: Joint ESA-Baltic Earth Workshop on remote sensing applications in the Baltic Sea region, Helsinki, Finland, 29-31 March 2017
- Baltic Earth Workshop on "Coupled atmosphere-ocean modeling for the Baltic Sea and North Sea," Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Germany, 7-8 February 2017
- International Baltic Earth Summer School on Climate change in the Baltic Sea region, Askö Laboratory, Trosa, Sweden, 28 August – 4 September 2017
- INTENSE ran a session at EGU 2017 titled "Development of climate datasets: homogenization, trends, variability and extremes, including sub-daily timescales." This was co-convened with Xiaolan Wang, Enric Aguilar, Rob Roebeling and Petr Stepanek. Hayley Fowler also gave an invited talk on INTENSE at EGU 2017.

2.2.11 Workshops/Meetings Planned

- The CCRN Finale network symposium is planned for March 4-7, 2018. The network will gather for the last time to review its accomplishments, to plan products and publications as a legacy of CCRN, to connect with key stakeholders and partner organizations, and to look to the future in follow-on initiatives.
- 11th HyMeX workshop, 29 May – 2 June 2018, Lecce, Italy
- MedCORDEX-Baltic Earth Workshop in March 2018
- 2nd Baltic Earth Conference in Helsingor, June 2018
- A Baltic Earth Workshop on "Multiple drivers of Earth system changes in the Baltic Sea region," fall/winter 2018
- "Precipitation near 0°C" has a near 0°C session at the 2018 GEWEX Open Science Conference, as well as at the forthcoming AGU Annual Meeting in New Orleans (December 2017) and at the Annual JpGU Conference (Makuhari, Chiba, Japan, in May 2018)

2.2.12 Other Meetings Attended on Behalf of GEWEX

- The Third Pole Science Summit (TPSS): TPE-CSTP-HKT (Third Pole Environment-China Society of Tibetan Plateau-the organizing committee of the 2017 Himalayan-Karakorum-Tibet workshop) Joint Conference was held in Kunming, China from 10 to 12 July, 2017. GEWEX chair P. van Oevelen and GHP co-chair J. Cuxart were present.
- GHP annual meeting held together with TPE: the joint workshop was held in Kathmandu, Nepal from 17 to 19 October 2017. In total, the workshop involved 48 scientists, 14 from GHP, 14 from TPE, and 20 from Nepal.
- Kick-off meeting of ANDEX in Medellín, Colombia, 2–5 December 2017. GEWEX chair P. van Oevelen and GHP co-chair J. Cuxart were present.

2.2.13 Issues for the SSG

- PannEx: GHP proposes that it becomes an Initiating RHP after the completion of the White Book and of the Science and Implementation plan.
- HyVic: Efforts in East Africa remain fragmented and fluid. International funding has backed several projects and closer collaboration with WWRP is being sought. A larger regional perspective (beyond Lake Victoria) is being pushed through IGAD (Intergovernmental Authority on Development) and ICPAC (IGAD Climate Prediction and Applications Centre). A successful way forward remains elusive. Advice/suggestions are welcome.
- OzEWEX: Have not been successful in attracting funding to support RHP research activities. As a result, they have failed to meet some RHP criteria and will likely have their RHP status removed at the next GHP meeting. They have been able to find funding for networking type activities (annual workshop, water and climate summer institute) – these activities are well attended and vibrant, and it would be good to maintain a GEWEX/GHP connection. One proposal, for SSG feedback, is to establish a new type of activity within GHP–a GHP network–that would need to meet the RHP criteria relevant for networking/capacity building only.
- Efforts for an RHP type activity in the USA has stalled. Any suggestions are welcome.
- Panel membership/leadership:
  - Need a new panel member from the USA. Suggestions are welcome.
  - GHP will need a new co-chair in just over a year (preferably from outside Europe). Suggestions are welcome.

2.2.14 List of Key Publications

Relevant publications have been listed throughout § 2.2.

2.2.15 List of Members and Their Term Dates

Prof. Jason Evans, Co-Chair, 2013-2020
Dr. Joan Cuxart Rodamilans, Co-Chair, 2017-2020*
Dr. Nicole van Lipzig, 2014-2019
Dr. Silvina Solman, 2014-2019
Prof. Christel Prudhomme, 2015-2020
Dr Ben Zaitchik, 2015-2017
Dr Craig Ferguson, 2015-2020 (GLASS rep)
Prof. Sylvester Danour, 2016-2018*
Prof. Xin Li, 2016-2018*

2.3 Global Land/Atmosphere System Study (GLASS)

Reporting Period: January 2017–December 2017
URL: www.gewex.org/panels/global-landatmosphere-system-study-panel/
Chair(s) and term dates: Michael Ek (2015-2018) and Gab Abramowitz (2017-2020)

GLASS Overview

GLASS focuses on land surface model development and evaluation, concentrating on improving the representation of land states, fluxes, and interaction with the overlying atmosphere. Ultimately, it aims to understand the predictability of land surface variables and their role in the predictability of weather and climate. While GLASS has recently been organized into three "themes" (Land-Model Benchmarking, Land-Atmosphere Coupling and Model Data Fusion), panel activity is of course community-driven by volunteer based; activity this year has primarily focused on the first of these two themes.

2.3.1 Major Panel Accomplishments

- Local Land-Atmosphere Coupling (LoCo): After being established over a decade ago, the LoCo working group (WG) is going strong, focusing on the goal of accurately understanding and modeling coupled land-atmosphere processes. A BAMS review article led by the LoCo WG was accepted for the December 2017 issue. The article covers the first decade of LoCo with an eye towards future work and is already getting attention via early online release (email from R. Pielke).
- Additional research and analyses spinning off from the PLUMBER experiment (published by GLASS co-authors in 2015) has multiplied, and several external parties have inquired about driving and taking part in a second phase of the experiment. The first paper is past 60 citations in 2 years. Details will follow on planning and a timeline for the follow-up.

2.3.2 Panel Activities

GLASS Panel projects are listed below, divided into the three panel themes identified in the overview above. Most entries have a percentage next to their title, intended to indicate the degree that GLASS has been involved in the project (so that 100% implies entirely a GLASS initiative, and 0% implies the project would have precisely the same form if GLASS did not exist). Most projects are also broken into two sections: 1) "*What is it?"* explains the motivation and structure of the project and may include material duplicated from previous GLASS SSG reports; 2) "*Update"* covers news about this project over the last year.

Projects broadly under the theme of ***Land model benchmarking and evaluation***:

PALS (Lead: Gab Abramowitz; 50%)
What is it? The Protocol for analysis of Land Surface models (PALS) is a web application designed for automated evaluation and benchmarking of LSMs. PALS hosts experiments, which each include: the data sets required to force or constrain a model for a particular experiment; model outputs uploaded by users (who run their models locally), including ancillary files; and automated analyses of model outputs, compared with evaluation data products, other models, and empirical benchmarks. The first-generation PALS site had around 250 users from over 60 institutions and was used both for Model Intercomparison Projects (MIPs) (e.g., PLUMBER, SavannaMIP) and model development. The system is currently offline with the second-generation system in testing and development.

The PALS system had very strong initial uptake, with users at: the UK Met Office (UKMO), NASA, NOAA, NCAR, ECMWF, Oak Ridge National Laboratory (ORNL), Commonwealth Scientific and Industrial Research Organisation (CSIRO), BureauMet, United States Geological Survey (USGS), Center for Ocean-Land-Atmosphere Studies (COLA), Yale, Imperial, University of Exeter, University of Reading, Boston University, University of Colorado, University of Washington, Columbia University, University of Arizona, University of Maryland, Stony Brook, University of Oklahoma, Australian National University, Monash University, University of New South Wales (UNSW), and more than 40 others from over 20 countries.

Development on the second-generation system, however, has been slow, largely due to limited resources and a lack of external collaborators. The second-generation PALS system (*modelevaluation.org*) is not specific to LSMs, and is much more flexible, partly to attract new funding possibilities from other institutions engaged in natural system modeling. Key features of the second-generation system include analysis not being specific to any particular computing language or analysis package. It is structured to allow the original PALS analysis suite, as well as integrate other existing packages, such as ILAMB (Python) or NASA Land Information System Verification Toolkit (LVT) (Fortran), with use of a relatively simple wrapper.

The new system also allows flexible user-defined benchmarks. When submitting a model output to an experiment, users can nominate any other model outputs already submitted as benchmarks, so that the analysis engine can utilize this information when generating plots.

A workflow system dedicated to benchmarking and evaluation allows increasingly strict enforcement of provenance and ancillary data collection. This ultimately aids reproducibility, the ability to tie a model's performance history to changes in structure, and the potential to data mine simulation meta-data as part of automated analyses. With all source code public on GitHub, and coding structures built for team development, the future aim for PALS is simply get the second-generation system functioning and adopted by the community as a community owned project.

Update: After a visit to ORNL in December 2016, where ILAMB developers Nate Collier and Forrest Hoffman are based, Gab Abramowitz, Nate Collier and others have been working to integrate ILAMB into PALS as an analysis engine. While this is not yet fully functional, some successful test cases are completed, and it should be fully realized throughout 2018. UNSW Sydney infrastructure funding has been secured for a ⅔ appointment to develop PALS for 2018, which will ensure development continues throughout 2018. A paper that collated and further developed the FLUXNET data processing routines from the first incarnation of PALS was also published this year (Ukkola et al., 2017). Additionally, the NOAA-funded Global Model Testbed (GMTB) will include a component of its work under PALS.

PLUMBER (Leads: Martin Best, Gab Abramowitz; 100%)
What is it? The PALS Land sUrface Model Benchmarking Evaluation pRoject (PLUMBER) is a LSM MIP that uses the PALS system, designed to highlight the importance of benchmarking over traditional evaluation. That is, defining performance expectations *a priori*. Defining benchmarks before model simulations are performed, if done well, can help answer the question of whether a group model is performing well or not, as opposed to simply identifying which models perform better or worse than others. To achieve this, PLUMBER used two first-generation LSMs and three empirically based models (testing out-of-sample) as a way to set performance expectations. Results for sensible and latent heat flux were compared at 20 flux tower sites across 9 International Geosphere Biosphere Programme (IGBP) vegetation types, using 8 different performance metrics. While LSMs performed markedly better than first

generation LSMs, they performed poorly against empirical models, especially for sensible heat flux. Fifteen different LSM variants participated, including those from the UKMO, ECMWF, Centre National de Recherches Météorologique (CNRM), Laboratoire des Sciences du Climat et de L'environnement (LSCE), NOAA, NASA, COLA and CSIRO. Two papers were published by PLUMBER participants in the *Journal of Hydrometeorology* (2015, 2016, each with more than 20 co-authors), led by Martin Best (UKMO) and Ned Haughton (UNSW). The first currently has 37 citations on Google Scholar – it is clearly having an impact on the broader community. Other bodies of work using PLUMBER data are continuing (e.g., Ukkola et al., 2016, ERL; Clark et al., in preparation).

The key result from the original PLUMBER paper was that despite clearly performing better than older LSMs, current generation LSMs as a whole were not utilizing the information available in their input data about latent and sensible heat fluxes. That is, simple empirical models, tested out of sample (i.e., training site data was not used to test the empirical models), clearly outperformed LSMs for common metrics (such as correlation, normalized mean error, standard deviation and mean).

The second paper by PLUMBER participants (published mid 2016, led by Ned Haughton, UNSW) investigated whether this result was because of methodological flaws in the original PLUMBER experiment, and was essentially a collection of negative results. It investigated whether lack of energy conservation in flux tower data, time scale of analysis, diurnal biases, poor LSM initialization, metric value aggregation, or site choices might have been responsible for the original result. It concluded that the most plausible explanation for the result was a shared weakness amongst LSMs, noting that the mean of all participating LSMs did not show a radical improvement in performance (suggesting that LSM error correlation is high). Recent work by Ukkola et al. (2016, ERL) used the PLUMBER data to show that in dry-down periods LSMs tended to systematically under-estimate evapotranspiration and commonly over-estimated evapotranspiration early in the growing season.

Update: Ned Haughton recently (late 2017) led an accepted paper that built a broader hierarchy of empirical models, extending those used in PLUMBER. Another three tiers of more capable empirical models are again tested out-of-sample, as per original PLUMBER work. This provides a lower bound estimate of how much information about latent/sensible heat fluxes is available in meteorological forcing data (i.e., the predictability of sensible, latent heat flux). This has furthered the goals of PLUMBER in highlighting the importance of this definition of benchmarking, so that LSM performance can then be assessed by utilization of information. We are aware of several other papers in review that also extend the PLUMBER work.

There is also no question that momentum exists for a second PLUMBER experiment, and that it will again be led by GLASS. The original PLUMBER paper attracted significant interest (over 60 citations so far) and several parties have informally proposed additional experiments they are keen to lead as part of a second phase. These range from statistically-based information theory-based analyses through to process evaluation studies. Running these through the revamped PALS application would ensure all analyses and data are publicly available where participants agree. More detail on this is below in §2.3.3., *New Projects and Activities Being Planned.*

SoilWat (Leads: Aaron Boone and Dani Or; 40%)
What is it? Following discussions between GEWEX and the soil and critical zone communities regarding how to improve interactions and integration of soil and subsurface processes in present climate models and other activities of GEWEX, the GEWEX-SoilWat first planning workshop in 2016 attracted 25-30 participants. The key issues discussed revolved around how soil processes (infiltration, evaporation, soil properties, etc.) are represented in land-surface models; issues related to the role of plants in climate models; how to bridge scales between traditional soil models and representation relevant to climate modeling; effective incorporation of groundwater models; and how to best move forward with integration of the communities.

Three subprojects came of this process that are now all active:

1. A survey of how basic soil processes are represented in climate models with emphasis on revisiting the pedotransfer functions used to convert soil information to parameters for modeling, led by Harry Vereecken and Anne Verhoef
2. Soil Parameter MIP, or SP-MIP, aims to assess the utility of more resolved soil maps and conduct a sensitivity analysis to evaluate several climate models using old and new soil maps and parameters. Led by Lukas Gudmundsson and Matthias Cuntz
3. A survey of the groundwater database and investigation of strategies for incorporating groundwater in climate models, led by Stefan Kollet and Anne van Loon.

Update: The “Pedotransfer Functions in Earth System Sciences: Challenges and Perspectives” workshop was held at the Fall AGU meeting (December 2017) to discuss the status of the above-mentioned three subprojects, where the scope of application of PedoTransfer Functions (PTFs) has been expanded from estimating soil hydraulic properties to other soil characteristics such as thermal properties, solute transport and root water uptake, soil carbon pools and nitrogen mineralization. Six major actions were decided upon as outcomes from the workshop: (1) Role of the structure of soil; (2) Infiltration processes, thermal processes, from point to grid-scale and upscaling; (3) “Ksat” in models, but what values of saturation do exist; questions for measures and values, (4) Biotic, biogeochemical processes PTFs, etc.; (5) Thermal data information, thermal conductivity; (6) Soil freezing, how to enter soil freezing in an LSM. It is anticipated that this effort will be included in some aspects of GLASS land model benchmarking efforts.

GSWP3 (Lead: Hyungjun Kim; 50%)
What is it? The Global Soil Wetness Project Phase 3 is a global offline LSM MIP. Meteorological forcing at 0.5 degree has been developed specifically for this MIP and is additionally being used for LS3MIP and SoilWat (both described in this report). The “fast-track” phase of initial simulations using a preliminary version of the forcing data is complete, with submissions from seven institutes [NCAR, Swiss Federal Institute of Technology in Zürich (ETH), University of Tokyo, Meteo-France, ECMWF, Royal Netherlands Meteorological Institute (KNMI), and the Japanese Meteorological Association (JMA)]. Analysis with the ILAMB package is complete, and manuscript preparation from the first-round analysis and validation is under way. The goal was to test the forcing within a subset of the land surface models in order to identify any issues, which in turn could result in changes or updates to the input forcings). This is a critical step, as the model simulations should have the best possible forcing data as inputs. Significant effort has been expended on refining the forcing data (frozen at the end of 2016), and global simulations in some instances (with CLM) have been shown to better use the GSWP3 forcing as opposed to Atmospheric Forcing Data for the Community Land Model (CRU-NCEP) or Water and Global Change (WATCH)-Forcing-Data-ERA-Interim (WFDEI) forcing.

GSWP3 is also tied in with LS3MIP (Land Surface, Snow, Soil moisture Model Intercomparison Project) under its offline component, LMIP (which is endorsed as part of CMIP6). While GSWP3 simulations are run on a 0.5 degree forcing grid, LS3MIP model output is intended to match coupled simulations as closely as possible and so will run on each coupled model's grid. To keep the consistency with CMIP6, a long-term retrospective GSWP3 experiment (EXP1) starts in 1850, with prescribed land-use/land-cover changes derived from the Land Use Harmonization (LUH) data set.

Update: The standard forcing data of EXP1 is generated combining spectral nudging dynamic downscaling and bias correction techniques. 20th Century Reanalysis is spatio-temporally disaggregated to 3-hourly T248 resolution using a global spectral model. Multiple in-situ measured surface variables (i.e., precipitation, short-/long-wave downward radiation and air temperature) are used to reduce intrinsic biases of the downscaled reanalysis fields. This bespoke forcing data was frozen and formally released in early July 2017.

After the LS3MIP kick-off telecon in September 2017, several technical issues on GSWP3 forcing V1 were raised, including negative amount of snowfall and missing value over coastline due to land-sea mask mismatch. To address those, GSWP3 V1.1 is under development with a release slated for early 2018. The update will also include an extended period up to 2014 (Hyungjun Kim); Princeton forcing V2 is available online which runs from 1948 until 2016, and V3 will become available later in 2017, which will have assimilated station data (Justine Sheffield). Therefore, recommended versions will possibly change as time proceeds. See also the LS3MIP update, which is described in detail in the land-atmosphere coupling section.

LS3MIP (Leads: Bart van den Hurk, Sonia Seneviratne, Hyungjun Kim et al.; 40%)
Note that LS3MIP, which is described in detail in the land-atmosphere coupling section, also has a strong benchmarking focus.

International Land Model Benchmarking (ILAMB) project (Lead: Dave Lawrence; 10%)
What is it? Building upon past model evaluation studies, the goals of the International Land Model Benchmarking (ILAMB) project are to:

- Develop internationally accepted land model evaluation experiments by drawing upon international expertise and collaboration
- Promote the use of these benchmark experiments by the international community for model intercomparison
- Strengthen linkages among experimental, remote sensing, and climate modeling communities in the design of new model tests and new measurement programs
- Support the design and development of open source benchmarking tools

ILAMB is mainly lead/funded through the US DOE Regional Climate Modeling Program. Project leadership team includes Forrest Hoffman (ORNL), Jim Randerson (University of California, Irvine), Bill Riley (Lawrence Berkeley National Laboratory), David Lawrence (NCAR), and Gretchen Keppel-Aleks (University of Michigan). It is integrated with all the land MIPs in CMIP6 (LUMIP, LS3MIP, C4MIP) and will serve as one of the land analysis packages for CMIP6 and related MIPs. ILAMB is being utilized by the international land modeling research community and hosted a workshop in May 2016 at DOE with approximately 50 participants from around the world. The workshop report, which was released in spring 2017, provides a roadmap for land model benchmarking/assessment activities going forward.

Update: ILAMB continues to be augmented with new metrics introduced by our international collaborators and will be utilized in CMIP6 assessments, including assessments of LS3MIP land-only simulations. Collaboration with PALS is underway and early results look promising.

LUMIP (Lead: Dave Lawrence; 10%)
What is it? The Land Use Model Intercomparison Project (LUMIP) aims to further advance understanding of the impacts of land-use and land-cover change (LULCC) on climate, specifically addressing the questions: 1) What are the effects of LULCC on climate and biogeochemical cycling (past-future)? and 2) What are the impacts of land management on surface fluxes of carbon, water, and energy, and are there regional land-management strategies with promise to help mitigate against climate change?

In addressing these questions, LUMIP will also address a range of more detailed science questions to get at process-level attribution, uncertainty, data requirements, and other related issues in more depth and sophistication than possible in a multi-model context to date.

There will be particular focus on the separation and quantification of the effects on climate from LULCC relative to all forcings, separation of biogeochemical from bio-geophysical effects of land-use, the unique impacts of land-cover change versus land management change, modulation of land-use impact on climate by land-atmosphere coupling strength, and the extent that impacts of enhanced CO_2 concentrations on plant photosynthesis are modulated by past and future land use.

LUMIP involves three major sets of science activities: 1) development of an updated and expanded historical and future land-use dataset, 2) an experimental protocol for specific LUMIP experiments for CMIP6, and 3) definition of metrics and diagnostic protocols that quantify model performance, and related sensitivities, with respect to LULCC. Here, we describe the LUMIP activity (2), i.e., the LUMIP simulations that will formally be part of CMIP6. These experiments are explicitly designed to be complementary to simulations requested in the CMIP6 Diagnostic, Evaluation and Characterization of Klima (DECK) experiment and historical simulations and other CMIP6 MIPs including ScenarioMIP, C4MIP, LS3MIP, and the Detection and Attribution Model Intercomparison Project (DAMIP). LUMIP includes a two-phase experimental design. Phase one features idealized coupled and land-only model simulations designed to advance process-level understanding of LULCC impacts on climate, as well as to quantify model sensitivity to potential land-cover and land-use change. Phase two experiments focus on quantification of the historic impact of land use and the potential for future land management decisions to aid in mitigation of climate change. This paper documents these simulations in detail, explains their rationale, outlines plans for analysis, and describes a new sub grid land-use tile data request for selected variables (reporting model output data separately for primary and secondary land, crops, pasture, and urban land-use types). It is essential that modeling groups participating in LUMIP adhere to the experimental design as closely as possible and clearly report how the model experiments were executed.

Update: LUMIP kicked off in 2017 so there are no science highlights at this point. It has been presented at many meetings, including AGU, CESM Workshop, ILAMB, and the Coordinated Research in Earth Systems and Climate: Experiments, Knowledge, Dissemination and Outreach (CRESCENDO) meetings. Land Use Harmonization 2 (LUH2) datasets have been made available, with Historic 850-2014 5+ SSP-RCP 2015-2100 datasets released. CMIP6 and LUMIP model experiments will be conducted in 2018, and LUMIP hosts quarterly webinars. One or more meetings are being planned for 2018.

ALMIP2 (Lead: Aaron Boone)
What is it? AMMA (African Monsoon Multidisciplinary Analysis) Land Surface Intercomparison Project Phase 2 (ALMIP2) focused on the local to mesoscale, where the main goal was to improve understanding and modeling of key surface, vegetation, and hydrological processes over West Africa, e.g., the subtle hydrology and vegetation processes in the region (large rooting depths, near-surface aquifers, soil crusting, lateral transfer processes, strong runoff variability). This project is spinning down with a number of papers submitted in 2016. As follow on, in addition to GHP links to AMMA, it was suggested that sensitivity to surface forcing could be further investigated by expanding LoCo or DICE for the AMMA region.

Update: The ALMIP2 project is spinning down, with a few publications in the works that will be part of a special collection in *Journal of Hydrometeorology*. A future DICE-like [Single Column Model (SCM) land-atmosphere interaction] study may be of interest for this region, with details to be determined.

Projects broadly under the theme of ***land-atmosphere coupling***:

LoCo (Lead: Joe Santanello and LoCo working group; 80%)
What is it? The motivation for Local Land-Atmosphere Coupling (LoCo) has been clear for some time, in that the results of offline projects such as the Project for the Intercomparison on Land-surface Parameterization Schemes (PILPS) and the Global Soil Wetness Project (GSWP) are limited by the lack of atmospheric feedback. Although the results of Global Land-Atmosphere Coupling Experiment (GLACE) provide an assessment of global circulation model (GCM) coupling coherence, they cannot isolate and evaluate the processes implied in the coupling that lead to model development. In terms of accurately representing the relationship between soil moisture (SM) and precipitation (P) and coupling strength in models, and to have the proper understanding and related improvement, it is necessary to carefully examine and quantify the full series of interactions and feedbacks (i.e., links in the chain) at the process-level, including the planetary boundary layer (PBL) feedback. To this end, the LoCo Working Group (WG) was established nearly a decade ago to focus on development of quantitative process-based metrics/diagnostics of land-atmosphere (L-A) coupling that could be applied equally to observations and models across scales.

The LoCo WG is comprised of around 15 GLASS panel and non-panel members. It is not meant to be exclusive and has a high proportion of young scientists who have been motivated by L-A interactions studies. Outside GLASS, LoCo has the closest links with GEWEX GASS/GABLS (Global Atmosphere System Studies/GEWEX Atmospheric Boundary Layer Study) and the Diurnal Coupling Experiment (DICE), due to the inherent importance of the planetary boundary layer (PBL) and model development in each. LoCo attempted a CMIP6 request (via GSWP and Land Surface, Snow and Soil Moisture Model Intercomparison Project, LS3MIP) for an increased set of L-A variables to be included in the standard output of participants. This failed due to timing (too late) and time constraints of those involved in GSWP3 and CMIP6.

Update: With the LoCo effort reaching the 10-year mark last year, the WG felt it timely to pursue an overview paper to the general community (as there had been no such paper to date). BAMS was chosen as the suitable forum, where the motivation and foundation for LoCo, the WG, LoCo metrics and resources, and LoCo's future could all be summarized together and provide a foundation going forward. More importantly, it will serve as an introduction to those in the atmospheric and other communities who have not been familiarized with LoCo (or GEWEX-

GLASS), or who have been confused by the many groups, acronyms, and terminology. This BAMS paper was accepted in December 2017. There are also many studies and publications from the WG in recent years focused on various metrics, models, and applications. See the GEWEX-LoCo website for an updated list of WG members and publications, a synthesis by Paul Dirmeyer, and LoCo coupling metrics toolkit from Ahmed Tawfik.

Observations of L-A processes and the need for assessment/improvement continue to be a recent point of emphasis of the LoCo WG, including the importance of co-located PBL, soil moisture, and surface flux measurements. As a result, field campaigns have been a point of emphasis, such as the enhanced sonde at the DOE Southern Great Plains site (SGP) in summer 2015, improved soil moisture and co-located L-A measurements from DOE-ARM, NY State Mesonet and the recently conducted Land-Atmosphere Feedback Experiment (LAFE: Volker Wulfmeyer, NASA, NOAA) at the SGP site in summer 2017 and The North American Monsoon GPS Hydrometeorological Network, held 20 June-30 September 2017 over the Southwestern US, focused on L-A interactions during the North American Monsoon (B. Lintner). In addition, Joe Santanello has received a second year of funding for his NASA Science Task Group focused on PBL retrieval from space. The National Science Foundation has also funded the Great Plains Irrigation Experiment (GRAINEX, PI: Rezaul Mahmood; Co-I: Joe Santanello), which will be held in summer 2018 over southeast Nebraska, focused on observing L-A interactions over irrigated vs. non-irrigated areas.

Multiple NASA Research Opportunities in Earth and Space Science (ROSES) projects (Science Utilization of SMAP, SUSMAP) are currently underway, many of which utilize new SMAP products in studies of L-A interactions and NWP. There was a WG meeting in July 2017 [International Surface Working Group (ISWG) and SMAP Wx Focus Area] in California, where the connection of soil moisture to NWP was discussed at length as well as the role of data assimilation. It is likely that there will be a close connection between any new GLASS-supported “land DA” initiative and the LoCo WG as a result of this interaction.

The future of LoCo and a three-pronged approach was developed, which continues this year:

1. Continue to follow and broaden the science of LoCo and WG participation. Suggestions: snow, geology, carbon, LULCC, momentum, radiation, fluorescence, monsoon – each are evolving naturally via independent research. This also includes a push for new/improved L-A observations: PBL, soil moisture, and surface fluxes
2. Synthesize what we have now in terms of metrics and message. Leverage off existing MIPs: LoCo-Plumber, LoCo-DICE, and LoCo-CMIP
3. Engage and entrain the operational/model development community. CMIP6 variable request (unsuccessful), and new coupled testbed idea

LS3MIP (leads: Bart van den Hurk, Sonia Seneviratne, Hyungjun Kim et al.; 40%)
What is it? The Land surface, soil moisture and snow model intercomparison project (LS3MIP), part of the CMIP6 experiment suite, aims to assess land surface, snow and soil moisture feedbacks on climate variability and climate change, including:

- Land-atmosphere coupling and its impacts (for climate trends, water resources, predictability);
- Linking patterns and trends of ECVs to land model properties and biases;
- Mapping (uncertainty of) water resources over the 20th century (and beyond);
- Explore model-dependent land-atmospheric coupling;
- Investigate the ability of climate models to capture observed rates of spring snow cover;
- Understand the linkage between snow-albedo feedback and 21st century warming.

LS3MIP therefore focuses primarily on the physical system, with carbon cycle and vegetation dynamics covered in more depth by CMIP complements C4MIP and LUMIP respectively. It is divided into two phases: LMIP (offline) and LFMIP (online, with Feedbacks), and aims both to compare CMIP6 historical and DECK simulations with observations, as well as examine changes to energy and water cycles through the historical period through to projected futures. These also include coordinated SnowMIP model intercomparisons.

The LFMIP experiments include land-atmosphere as well as land-atmosphere-ocean coupled simulations, with different combinations of prescribed land conditions, sea surface temperatures, and smoothed boundary conditions used to assess the roles of land-climate and land-climate-ocean feedbacks on ECVs and seasonal predictability. A detailed description of the protocol was published last year in *Geoscientific Model Development* by van den Hurk et al. (2016).

The LS3MIP timetable is essentially determined by the CMIP6 timetable. Participants include: the Australian Community Climate and Earth System Simulator (ACCESS), Beijing Climate Center second generation Climate System Model (BCC-CSM2-MR), the Canadian Earth System Model (CanESM), CESM, the Centro Euro-Mediterraneo sui Cambiamenti Climatici Climate Model (CMCC-MC), the CNRM Climate Model (CNRM-CM), the European Community Earth-System Model (EC-Earth), the Flexible Global Ocean-Atmosphere-Land System (FGOALS) model, the Geophysical Fluid Dynamics Laboratory (GFDL), the Goddard Institute for Space Studies (GISS), the sixth generation Institut Pierre-Simon Laplace Climate Model (IPSL-CM6), the sixth generation Model for Interdisciplinary Research on Climate (MIROC6-CGCM), the Max Planck Institute-Earth System Model (MPI-ESM), the Meteorological Research Institute-Earth System Model (MRI-ESM1.x), the Norwegian Earth System Model (NorESM), and the UK Earth System Model (UKESM).

Update: The Kick-off teleconference of LS3MIP was held in September 2017 with 25 participants representing 15 groups. General concept and overall status (Bart van den Hurk), status of forcing (Hyungjun Kim), and analysis plans (Sonia Seneviratne and Gerhard Krinner) were presented by the coordination team, and reflections from individual groups were shared. For the “first results” delivery, a meeting will be scheduled in September or October 2018. To archive and maintain related information, a wiki page has been set up as LS3MIP information repository. Currently, the historical LMIP (i.e., land-history) has been tested by six modeling groups [Community Climate System Model (CCSM), MeteoFrance, Institute Pierre Simon Laplace (IPSL), Max Planck Institute, version three of the Hadley Centre Coupled Model (HadCM), and the Model for Interdisciplinary Research on Climate (MIROC)], and IPSL and EC-Earth have done experimentation with various flavors of soil nudging. Requests on “housekeeping” of Data Request and experimental set-up were raised. Duplicated requested variables and several errors in the naming convention will be resolved and variables related to frozen ground will be reprioritized. It has been agreed to perform an LMIP simulation and submit output in 0.5-degree grids instead model native grids. As a mutual piece between LS3MIP and LUMIP, a template for generation future LMIP (i.e., land-future) forcing data was proposed by Dave Lawrence, but further careful consideration is still needed.

GABLS/GLASS/DICE Experiments
(Leads: Adrian Lock and GASS panel members, Martin Best, and some LoCo WG participation)
What is it? Understanding the processes in and modeling the atmospheric boundary layer (ABL), with a focus on the role of land processes and land-atmosphere interaction in the evolving surface fluxes, land states, and atmospheric profiles. The original Dirunal Cycle Coupling Experiment (DICE-1) was motivated by an earlier Global Atmospheric Boundary Layer Study (GABLS) project that identified the importance of land processes and land-atmosphere interaction. The DICE-1 paper is still under preparation (M. Best and A. Lock). The subsequent GABLS4 (or "DICE-over-ice") project had similar goals as DICE-1, except this time with focus on ice/snow-surface-atmosphere interaction in the extremely stable environment of Antarctica, and is being led by Eric Bazile, Fleur Couvreux, and Patrick Le Moigne (Météo-France).

Update: New DICE efforts are being proposed to study other geographical regions leveraging the large amount of data from many land-atmosphere field programs over the year. Mike Ek is currently promoting the initial development of ideas for this effort.

Projects broadly under the theme of ***Model-data fusion***:

While there are currently no community-led projects under this sub-theme within GLASS, after we removed Project for the Intercomparison of Land Data Assimilation Systems (PILDAS) for lack of activity, we note there is still enthusiasm to pursue a scaled-down version of PILDAS – See § 2.3.4. New Projects and Planned Activities for more information.

2.3.3 New Projects in Place

SoilWat (Leads: Aaron Boone, Dani Or, SoilWat team; 40%)
In the last year all three SoilWat projects have started in earnest. See §2.3.2. for more details.

PALS-ILAMB Coupling (Leads: Gab Abramowitz and ILAMB team; 80%)
For the last couple of months of 2017, work began coupling ILAMB into the PALS environment and initial results are encouraging. Both the PALS and ILAMB codes have been evolving to accommodate this effort. Whether or not the combined product will be ready in time to be useful for GSWP3 and LS3MIP is not clear. It will at least be useful for similar efforts of this nature, as well as internal model development programs across many institutions.

2.3.4 New Projects and Planned Activities

PLUMBER2 (Leads: Gab Abramowitz, Martyn Clark, Sujay Kumar; 100%)
As noted above, there is plenty of momentum for a second phase of PLUMBER. So much so that the biggest obstacle is likely to be understanding how we might accommodate all of the additional analyses, variables, and process investigations that have been directly requested, offered to be led by others, or partially already investigated in PLUMBER spin off work. Containing and managing such a large suite of investigations will likely be made easier, and indeed be more easily expanded in future, if we run this through the PALS system (but this will have its own learning curve and investment time of course). Examples of extensions to the existing PLUMBER framework likely to be included are:

- Significant increase in the number and variety of tower sites included with recent release of gap-filled, energy-balance corrected FLUXNET dataset, and quality control flux tower data processing package specifically for LSMs (Ukkola et al, 2017),
- Application of information theory-based metrics for benchmarking (recent work by Grey Nearing, Martyn Clark), and

- Latent factor analysis exploring the similarity of LSMs (Sujay Kumar),
- Application of an improved hierarchy of empirical benchmark models for benchmarking (Gab Abramowitz, as outlined in Haughton et al, 2017, below).

*Timeline***:** A PLUMBER2 planning meeting is scheduled immediately after the GLASS panel meeting in Canmore, May 2018. The timeline will likely be dictated by the availability of PALS-ILAMB coupling.

PILDAS (Lead: Sujay Kumar; 100%)
As noted above, a revival of a more conservative, and more achievable, PILDAS is being discussed. Sujay Kumar is still the likely protagonist, and seems to have the enthusiasm, however identifying at least one other key participant is necessary. A revised PILDAS is still in the inception of ideas stage. We need to have a focused discussion on how the experiment should be structured to be relevant to the community and to make a useful contribution. From the earlier PILDAS effort, we learned that there are very few (2-3) groups that actually have the infrastructure to carry out offline DA integrations. One result that should come out of PILDAS is for us to quantify if the community needs to spend efforts on DA algorithms versus retrievals versus models themselves, so such efforts could be closely related to efforts such as PLUMBER. A simpler PILDAS experiment would be to align it with benchmarking projects. For example, how does a retrieval-based benchmark compare to ground-based benchmark? In other words, is there any utility to assimilating these retrievals (which is less about DA, but the relevant question is whether the community effort needs to be on improving retrievals or DA algorithms)? Another idea is to stand up a statistical benchmark (based on observations) to see if DA systems can beat that. It can then be less about conforming to all the experiment details, which was another problem with the original PILDAS design. Clearly, we need a land DA effort under GLASS, and this was endorsed after feedback from the WGNE panel and others at the Pan-WCRP meeting in Exeter in October 2017.

Timeline: Something that we'll no doubt discuss at this year's Panel meeting in Canmore, with no timeline apparent yet.

LIAISE (Leads: Martin Best, Aaron Boone, et al.; 20%)
Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment (LIAISE). Semi-arid environments are sensitive regions for land-atmosphere coupling with stressed vegetation at times, and often a high degree of heterogeneity. There is a need to better evaluate the simulation of the surface energy budget in order to improve models and properly represent the seasonal dry-down period in these regions. Data sets to be used for comparisons with models will include a comprehensive collection of surface/near-surface measurements over the diurnal cycle for a full annual cycle, augmented by an atmospheric profile and aircraft measurements. The ground site is not yet definitively chosen, but the current likely timing for the measurement program is May 2019 to May 2020, with linkage between GLASS, GHP (e.g., HyMEX), and other projects. An associated French effort, HILIAISE (Human imprint on Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment), is being proposed with the overall objective of HILIAISE to better understand and model the human imprint on the semi-arid energy and water cycles over a region which has significant anthropization.

Timeline: While inclusion of anthropogenic water management in LSMs was the subject of a GHP-GLASS workshop in October 2016, there has been no significant coordinated activity in

this area as far as we are aware. As with all volunteer-led community-based projects, an enthusiastic protagonist with dedicated time is required, and no one appears to have emerged to fill that role at this time.

2.3.5 Science Highlights

See § 2.3.2. Panel activities

2.3.6 Science Issues

See § 2.3.2. Panel activities

2.3.7 Contributions to Developing GEWEX Science

GLASS contributes *most directly* to the following GEWEX Imperatives:

Process: Develop approaches to improve process-level understanding of energy and water cycles in support of improved land and atmosphere models.

- Identify feedbacks and interactions among different processes and build confidence in their replication in models (LoCo).
- Develop metrics to aid benchmarking activities for both un-coupled and coupled modeling activities (PALS/PLUMBER, ILAMB, LS3MIP, GSWP3, DICE).
- With the current and expected increasing complexity of land models in terms of various hydrologic and vegetation treatments, model optimization (i.e., parameter estimation approaches) will continue to be relevant to GLASS efforts (through Model Data Fusion).
- Investigate alternative representations of sub-grid processes in land surface schemes (SoilWat).
- Develop improved understanding of climate variability and change on land surface properties, including soils, vegetation and hydrological processes, and an associated modeling capability (GSWP3, LUMIP, LS3MIP, SoilWat).
- Investigate the scope for development of next generation land surface models with improved representation of subsurface hydrology, including groundwater processes; identify suitable areas for their evaluation.
- Improved representation of cold season land surface, carbon and hydrological processes (potential CCRN project).

Modeling: Improve global and regional simulations and predictions of precipitation, clouds, and land hydrology, and thus the entire climate system, through accelerated development of models of the land and atmosphere.

- Coordinate the construction of a global land reanalysis system, building on ongoing and preparatory activities in Landflux, GSWP3, GLDAS and operational weather centers.
- Develop a framework and infrastructure for evaluation of land-atmosphere feedbacks. This should include the development of more quantitative estimates of uncertainty in the land condition and how this uncertainty propagates through to the atmosphere (e.g., PBL, convection, water and energy, carbon). This objective will be advanced in conjunction with the Processes Imperative in developing diagnostics.
- Organize coordinated intercomparison experiments for a range of model components in state-of-the-art land models, especially with regard to: treatment of soils, groundwater hydrology; surface water treatment (snow, river routing, lakes, irrigation, and dynamic wetlands); vegetation phonology and links between carbon and water; treatment of soils (GEWEX Soils Initiative); and Land Data Assimilation systems (follow-up to the PILDAS initiative).

- Evaluation of these land model components will also have to be considered in their interactive (coupled) context with the PBL, while taking into account and developing more quantitative measures of uncertainty in the land parameters and states will enable more robust evaluation of data assimilation systems.

Additionally, GLASS contributes to: *Technology Transfer* (develop new observations, models, diagnostic tools and methods, data management, and other research products for multiple uses and transition to operational applications in partnership with climate and hydrometeorological service providers) and *Capacity Building* (promote and foster capacity building through training of scientists and outreach to the user community).

2.3.8 Contributions to the GEWEX Science Questions

Observations and Predictions of Precipitation
How can we better understand and predict precipitation variability and changes?

The GLASS activities below address the linkages of precipitation (and its accuracy) to land surface processes and LSM predictability. Related current GLASS activities:

- LS3MIP to begin within CMIP6 framework
- LoCo – Regional/local process-level quantification of land-PBL interactions and impact of land surface on precipitation (POC: Joe Santanello)
- ALMIP2 – Specific precipitation event studies and heterogeneity issues in soil moisture-precipitation feedbacks (POC: Aaron Boone, project ending)
- GSWP3 – Precipitation as a key forcing for 20th Century simulations – this effort should quantify the error bounds on the "land reanalysis" generated due to precipitation uncertainty (POC: Hyungjun Kim)
- Land Model Benchmarking – How precipitation uncertainty impacts offline and coupled model evaluation – spread of LSM physics vs. spread due to precipitation errors (POC: Martin Best, Gab Abramowitz)

Future activities:

- Incorporation of new satellite products (GPM, SMOS, SMAP) into these efforts more explicitly
- PILDAS (re-initiated in some manner) – Land DA of soil moisture; multi-variate coupled DA (precipitation and soil moisture) in a future phase (POC: Sujay Kumar)

Global Water Resource Systems
How do changes in land surface and hydrology influence past and future changes in water availability and security?

Water use, resources, and sustainability issues are at the heart of this challenge. How can GEWEX be positioned to meet this challenge given the current structure and makeup, currently focused on modeling groups and model intercomparisons with loose ties only (at best) with water resource and planning communities? Current activities are trying to answer various aspects of the science issues here (e.g., soil moisture and drought in a changing climate), but are not yet at the stage of integrating the entire terrestrial water budget. GRACE is the only current tool we have in this regard [perhaps the Surface Water and Ocean Topography (SWOT) satellite in the future] but is very limited in space and time scales such that regional and diurnal studies and models cannot be improved or assessed using this dataset. Carbon, ecosystem, cryosphere, groundwater, and distributed hydrology models are not traditionally

GEWEX activities – but fully integrated Earth system and land models are the future, so we need to be forward-thinking. It seems this challenge is really the overarching challenge of all land hydrology for climate studies.

- As a result, this challenge also intersects directly with other entities [iLEAPS, ILAMB, CliC, Distributed Model Intercomparison (DMIP), LULCC/LUMIP]. This challenge might boil down to coordinating model development from previously disparate disciplines and applications, and based on CMIP5 results in terms of the limitations and sensitivities to the land hydrology (e.g. previously reported LUCID results).
- Related concluded GLASS activities:
  - LUCID1 and 2 (POC: Andy Pitman)
  - ALMIP1 and 2 (POC: Aaron Boone)
  - PILDAS/SMAP (DA of surface and root zone soil moisture will be critical to link with GRACE, SWOT)

Changes in Extremes

How does a warming world affect climate extremes, especially droughts, floods, and heat waves, and how do land area processes, in particular, contribute?

This continues to be a "hot topic," e.g., how will the frequency and location of extremes change due to x amount of warming in the future? The NASA Energy and Water Cycle Study (NEWS) chose "Extremes" as one of its core integration projects and could be looked at as a model both of what and what not do, and what can be learned by a limited subset of the community (material available online). Model evaluation and benchmarking becomes critical here as well. Most models are tested offline and only for average conditions, and once into extreme realms of forcing or states, tend to behave much differently.

Recent LSM calibration/parameter estimation studies suggest that a vastly different set of parameters (lookup tables) is required for extremes vs. average conditions.

As observational data improves (e.g., Challenge #1), this is no guarantee the models will behave better as a result. DA and calibration studies should be a focus here. Calibration is a weak component of GLASS currently and should be expanded under Model Data Fusion. You can learn a lot about model behavior and limitations that way, especially in concert with DA.

Related current GLASS efforts:

- LoCo – Quantification during extremes to get at model behavior and how LSMs impact the persistence of droughts/floods/feedbacks. Seasonal drought prediction needs much improvement with the emphasis on the land impact (http://www.climatecentral.org/news/lack-of-warning-on-2012-us-drought-reflects-flaws-in-forecasting-14823/)
- ALMIP2 – Inherently encompasses dry extremes/feedbacks over AMMA with monsoon precipitation
- LS3MIP – Examining impact of soil moisture on extremes in CMIP5 (IPCC report just out on the subject)
- Benchmarking – Should look at model performance stratified by regime (e.g. PLUMBER)

Future activities:

- CORDEX-GLASS collaboration possibly needs to a) exist and b) accelerate to answer these questions in the context of climate model predictions
- PILDAS (as re-initiated) – DA w/calibration for improved soil moisture representation during extreme conditions.

Water and Energy Cycles and Processes
How can understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

This seems to be the most traditional GEWEX-type challenge in that it promotes a lot of activities in the current panels and relies on the strengths of the current makeup. What this challenge also shows is how much more work needs to be done in quantifying and improving water and energy cycle prediction in models of all scales and types. Results and improvements as a result are felt throughout the remaining three challenges, WCRP, and other communities as well. In order to close the land surface energy balance, we need to address all the issues and model evaluation and development listed in this challenge. Also, it will require SMOS/SMAP, GPM, GRACE, etc. to get right. Related to current GLASS efforts:

- GSWP3 – Land reanalysis and sensitivity of surface fluxes to forcing uncertainties including radiation
- LoCo – Determining processes; how land and PBL fluxes are quantified and how they interact with each other
- PILDAS (as re-initiated) – Constraining LSMs with observations for improved land surface energy balance.
- Benchmarking – Assess land surface energy balance in models vs. empirical models and evaluating the "goodness" of a model prediction
- GLASS-GDAP – Improve connection between SRB, Landflux, and GLASS modeling and prediction and consistency between data products and models
- Anthropogenic Influences on the Global Water Cycle initiative: Better characterize and predict the impact of the human imprint on the water cycle

2.3.9 Other Key Science Questions

- Identify causes for PLUMBER results–that is, the source of shared LSM bias. PLUMBER will likely help address this to some degree, but it is definitely a long-term goal.

2.3.10 Contributions to the WCRP Grand Challenges

- Provision of skillful future climate information on regional scales (includes decadal and polar predictability)
- Regional sea-level rise
- Cryosphere response to climate change (including ice sheets, water resources, permafrost, and carbon)
- Improved understanding of the interactions of clouds, aerosols, precipitation, and radiation and their contributions to climate sensitivity
- Past and future changes in water availability (with connections to water security and hydrological cycle)
- Science underpinning the prediction and attribution of extreme events. Identify the role of land processes and land-atmosphere interaction with other components of the Earth system (e.g., atmosphere), in the prediction of extreme events, as well as the evolving high-latitude climate. Partnering with other GEWEX panels, i.e., GHP (regional hydrometeorology/climate projects and associated data sets), GDAP (remote sensing data sets), and GASS (atmosphere-related efforts), is necessary to be successful, and with WWRP, WCRP, Future Earth/iLEAPS and others.

2.3.11 Cooperation with WCRP Projects and Other International Programs

Subseasonal-to-Seasonal (S2S) Project (Paul Dirmeyer is GEWEX/GLASS Liaison)

- S2S hindcast and real-time forecast data set documentation from 11 operational centers was originally lacking information on land surface model characteristics and initialization. GLASS drafted a questionnaire on the recommendation of Frederic Vitart that was circulated to modeling centers. The information has been incorporated into the models' documentation on the S2S Project website.
- Many S2S models still do not report soil moisture, a "required" variable. Once confronted, centers promise to include it with updated versions of their models and S2S data sets. Only about half of the S2S models are thus useful for assessing soil moisture/atmosphere interactions.
- The S2S Prediction project is entering the final year of its 5-year lifetime. A proposal for a second 5-year phase has been drafted with an addition to ensure better representation of GEWEX goals, particularly those regarding surface-atmosphere interactions. This should make S2S model forecasts/hindcasts/data sets more useful and relevant to the GEWEX community.

  S2S includes 6 subprojects with different research foci – all are open to additional membership by interested parties:
  - Extreme weather (Frederic Vitart)
  - Monsoons (Andrew Marshall, Harry Hendon)
  - MJO (Steven Woolnough and Duane Waliser)
  - Africa (Richard Graham, Andrew Robertson)
  - Teleconnections (Hai Lin, Cristiana Stan)
  - Verification (Caio Augusto dos Santos Coelho, Yuhei Takaya)

- New US effort supported by NOAA/CPO called "SubX" is also a sub-seasonal forecast/hindcast experiment and differs from S2S in the following ways:
  - Evolved from seasonal prediction predecessor: NMME (North American Multi-Model Ensemble) – focus remains on multi–model ensemble techniques
  - Only North American models involved, includes research models (National Center for Environmental Prediction (NCEP) Coupled Forecast System model version 2 (CFSv2), NCEP Global Ensemble Forecast System (GEFS), NASA Global Modeling and Assimilation Office (GMAO), NCAR-Community Climate System Model version 4 (CCSM4), ECCC, USNavy)
  - All models synchronize IC dates, output data grid, land/sea mask, period of hindcasts
  - No time embargo on real-time forecasts
  - Also, more GEWEX-relevant output variables than S2S – another resource for GLASS studies

  Hindcasts from all models are scheduled to be completed by the end of 2017, with operational-style real-time forecasts beginning January 2018.

- NOAA/CPO/Modeling, Analysis, Predictions and Projections (MAPP) project also support a research effort on S2S predictability and prediction. The task force (made of funded PIs) leadership includes Paul Dirmeyer.

Joint GEWEX/CLIVAR Monsoon Panel (MP; Françoise Guichard co-chair)

Regional working groups have been constituted – these are the primary bodies through which research and outreach occur, and include Working Groups from Asia-Australia, Africa, and the Americas. MP membership updates put before the GEWEX SSG include Françoise Guichard, replacing Paul Dirmeyer this year as co-chair from GEWEX, and Francina Dominguez as the second member from the Americas working group. The CMIP6 Global Monsoons Modeling Inter-comparison Project (GMMIP) is comprised of a scientific steering committee and terms of

reference and is, soliciting input from regional monsoon WGs for performing analyses as well as global analyses from the MP. There is interest in promoting a workshop on the role of the land surface and land-atmosphere feedbacks in monsoons, possibly as an International Centre for Theoretical Physics (ICTP) workshop or targeted training activity, and/or as a theme/topic for the next GEWEX Open Science Conference. International CLIVAR Monsoon Project Office (ICMPO)-Pune functionality issues are an ongoing problem; qualified project office personnel and leadership are still lacking.

WCRP Modeling Advisory Council (WMAC; Michael Ek, GEWEX representative)

The Mission of WMAC is to coordinate high-level aspects of modeling across WCRP, ensuring cooperation with main WCRP partners such as the World Weather Research Programme (WWRP), and acting as a single entry point for all WCRP modeling activities. Mike Ek is now representing GEWEX and GLASS interests on land modeling and related efforts.

Working Group on Numerical Experimentation (WGNE; Michael Ek GEWEX/GLASS representative)

The Working Group on Numerical Experimentation (WGNE), jointly established by the WCRP Joint Scientific Committee (JSC) and the WMO Commission for Atmospheric Sciences (CAS), which is responsible for WWRP and the Global Atmosphere Watch (GAW), has the responsibility of fostering the development of atmospheric circulation models for use in weather, climate, water, and environmental prediction on all time scales and diagnosing and resolving shortcomings. Mike Ek has been representing GEWEX and GLASS interests on land modeling and related efforts, where WGNE spans both weather and climate time scales.

HyMeX (Hydrological Cycle in the Mediterranean Experiment, Pere Quintana-Segui/Philippe Drobinski)

The aim of the HyMeX Water Resources and Drought Science team is to improve the knowledge on Mediterranean Drought and Water Resources, understand the relevant processes and feedbacks, including the human component, improve current models and improve our capacity to predict drought at different time scales. Of particular note, remote sensing is crucial for the HyMEX science team where new methods are being developed to estimate surface soil moisture (SSC) using Sentinel-1 and MODIS NDVI data. Additionally, dam level data has been obtained using altimetry data from Sentinel-3. The capacity of land models to reproduce drought and its propagation has been studied in Spain within the FP7 EartH2Observe project showing large differences between the tested models both in terms of drought status and drought propagation. Uncertainty must be reduced in LSMs if they are to be used to study drought, with soil moisture and underground water processes being highly uncertain. HyMEX links with GEWEX GLASS and GHP, and other groups. Several national projects also support HyMEX activities, and proposals are being written that would support the future LIAISE campaign.

iLEAPS collaborations (Eleanor Blyth)

While GEWEX/GLASS focuses on observations and modeling of the land-atmosphere exchanges of heat and water, iLEAPS has as its focus biogeochemical cycles and the interaction of land with atmospheric chemistry and the role of humans. The potential for joint GLASS-iLEAPS activities includes land model benchmarking, observations for process-level understanding, freezing and arctic processes, and extremes. With regards to freezing and arctic processes, a group or key individual is required to move a project on this forward,

perhaps in association with participants in the Year of Polar Prediction (YOPP) under the leadership of the WWRP Polar Prediction Project (PPP).

2.3.12 Workshops/Meetings Held

- GLASS panel meeting, May 2017, Tokyo
- HESS-S4 workshop, May 2017, Tokyo

2.3.13 Workshops/Meetings Planned.

- PLUMBER2 planning meeting in Canmore, AB, Canada in May 2018
- GLASS panel meeting in Canmore, AB, Canada in May 2018
- GEWEX Open Science Conference in Canmore, AB, Canada in May 2018
- PLUMBER2 implementation meeting likely concurrent with GLASS panel meeting 2019
- GLASS panel meeting around May 2019 (location TBA)

2.3.14 Other Meetings That Were Attended on Behalf of GEWEX

- Mike Ek attended the Pan-WCRP modeling working groups meeting in October 2017, in Exeter, UK, which included WGNE and WMAC (Mike is members of both as the GEWEX representative) and reported on GEWEX/GLASS activities of interest to these groups.
- Mike Ek attended the GEWEX SSG-30 meeting in Washington, DC, in Jan./Feb. 2018.
- Gab Abramowitz will attend the Pan-GASS meeting in February 2018 (Lorne, Australia).

2.3.15 Issues for the SSG

None at this time.

2.3.16 List of Key Publications

Dirmeyer, P.A., J. Wu, H.E. Norton, et al., 2016. Confronting weather and climate models with observational data from soil moisture networks over the United States. *J. Hydrometeo*r., 17, 1049-1067, doi: 10.1175/JHM-D-15-0196.1.

Dirmeyer, P.A., L. Chen, J. Wu, et al., 2017. Verification of land-atmosphere coupling in forecast models, re-analyses and land surface models using flux site observations. *J. Hydrometeor*. (in revision).

Getirana, A., A. Boone, C. Peugeot, and the ALMIP-2 Working Group, 2017. Streamflows over a West African basin from the ALMIP-2 model ensemble. *J. Hydrometeor*., 18, 1831-1845. doi:10.1175/JHM-D-16-0233.1

Grippa, M., L. Kergoat, A. Boone, et al., and the ALMIP2 Working Group, 2017. Modelling surface runoff and water fluxes over contrasted soils in pastoral Sahel: evaluation of the ALMIP2 land surface models over the Gourma region in Mali. *J. Hydrometeo*r., 18, 1847-1866. doi:10.1175/JHM-D-16-0170.1

Haughton, N., Abramowitz, G., and Pitman, A. J., 2017. On the Predictability of Land Surface Fluxes from Meteorological Variables. *Geosci. Model Dev.*, https://doi.org/10.5194/gmd-2017-153, accepted Dec 2017.

Hoffman, F.M., C.D. Koven, G. Keppel-Aleks, et al., 2017. International Land Model Benchmarking (ILAMB) 2016 Workshop Report, DOE/SC-0186, U.S. Department of Energy, Office of Science, Germantown, Maryland, USA, doi:10.2172/1330803.

Santanello, J., P. Dirmeyer, C. Ferguson, et al., 2017. Land-Atmosphere Interactions: The LoCo Perspective. *Bull. Amer. Meteor. Soc.* doi:10.1175/BAMS-D-17-0001.1, in press.

Ukkola, A.M., N. Haughton, M.G. de Kauwe, et al., 2017. FluxnetLSM R package (v1.0): a community tool for processing FLUXNET data for use in land surface modelling. *Geosci. Model Dev.*, 10, 3379-3390, https://doi.org/10.5194/gmd-10-3379-2017, 2017.

2.3.17 List of Members and their Term Dates

GLASS membership continues to require management. The three new members shown below with green highlighted rows were invited in 2017 just prior to GLASS beginning to institute a more rigorous policy of making membership about either (a) active project involvement and leadership, or (b) mentoring of active projects by senior members. In reality this policy is likely to be implemented simply via a smaller annual GLASS panel invitation list. Four inactive members formally left the panel after discussions with co-chairs (bottom of the table below). Glass panel will also need to choose a new co-chair in 2018, as Mike Ek's term will end in 2018.

Name	Affiliation	Membership	Term	Active Projects	External Reps
Gab Abramowitz	UNSW Sydney	Co-chair	2017-2020	ILAMB, PALS, PLUMBER	
Michael Ek	NCEP	Co-chair	2015-2018	DICE, PALS, PLUMBER	WGNE, WMAC
Eleanor Blyth	CEH	iLeaps rep.			iLeaps
Aaron Boone	CNRM-Météo France	Sr. member		ALMIP2, SoilWat	SoilWat
Nathan Brunsell	U. Kansas	Member			
Martyn Clark	NCAR	Member	2017 -	PLUMBER2	
Paul Dirmeyer	COLA / George Mason Univ.	Sr. member			S2S, Monsoon panel
John Edwards	UK Met Office	Member			GASS
Craig Ferguson	SUNY	Member/ GHP rep			GHP
Pierre Gentine	Columbia U	Member			
Chiel van Heerwaarden	Wageningen U	YSM*			
Hyungjun Kim	U Tokyo	Member		GSWP3, LS3MIP (LMIP)	
Sujay Kumar	NASA	Member		PILDAS	
David Lawrence	NCAR	Member		ILAMB, LUMIP	
Aude Lemonsu	CNRM-Météo France	Member	2017 -		
Lifeng Luo	Michigan State Univ.	Member	2015 -		
Pere Quintana Seguí	Ebro Observatory	HyMex rep			HyMex
Joshua Roundy	Univ. Kansas	YSM		LoCo	
Joseph Santanello	NASA	Sr member		LoCo	
Ahmed Tawfik	NCAR	YSM*		LoCo	
Tomo Yamada	Hokkaido Univ.	YSM*			
Kun Yang	ITP/CAS	Member	2017		

* YSC: Young Scientist Career

Emeritus (i.e., copy on emails, but participation not necessarily expected)

Name	Affiliation	Membership	Term	Active projects	External reps
Gianpaolo Balsamo	ECMWF	Emeritus			
Martin Best	UK Met Office	Emeritus		LIAISE, DICE	LIAISE
Taikan Oki	U Tokyo	Emeritus			
Christa Peters-Lidard	NASA	Emeritus			
Andrew Pitman	UNSW Sydney	Emeritus			
Sonia Seneviratne	ETH	Emeritus			
Bart van den Hurk	KNMI	Emeritus			
Matt Rodell	NASA	Emeritus		GLDAS, terrestrial water	

LoCo Working Group

Name	Affiliation	Membership	Term	Active Projects	External Reps
Benjamin Lintner	Rutgers Univ.	LoCo WG			
Patricia Lawston	NASA	LoCo WG			
Benoit Guillod	ETH	LoCo WG			
Obbe Tuinenburg	Univ. Utrecht	LoCo WG			

Potential New Members

Name	Affiliation	Membership	Term	Active Projects	External Reps
Martin de Kauwe	Macquarie Univ.				
Mike Barlage	NCAR/RAL				
When Zhou	City University of Hong Kong				

Past Members

Name	Affiliation	Membership	Term	Active Projects	External Reps
Patricia de Rosnay	ECMWF	Member		PILDAS	
Wade Crow	USDA	Member		PILDAS	
Rolf Reichle	NASA	Member		PILDAS	
Fei Chen	NCAR	Member		LSM bench-marking	

2.4 Global Atmospheric System Studies (GASS)

Reporting Period: July 2017–December 2017
URL: https://www.gewex.org/panels/global-atmospheric-system-studies-panel/
Chair(s) and term dates: Xubin Zeng (July 2017–June 2020) and Daniel Klocke (July 2017–June 2020)

2.4.1 Major Panel Accomplishments

Two new co-chairs were appointed in July 2017. In cooperation with past panel members, co-chairs and the broader community have developed a vision and strategy document for a proactive and actionable future GASS panel, which has been published in the August 2017 edition of *GEWEX News*.

To transform the vision and strategy into concrete projects, the upcoming Pan-GASS conference from 26th February to 2nd March 2018 in Lorne, Australia is of great importance. Abstract submission has been closed. With the effort of the organizing committee chaired by Ben Shipway (UK Met Office), more abstracts were submitted than we expected. And the organizing committee decided to decline some of the abstracts that are not closely relevant to the Conference. This Conference will also serve as the "official" re-launch of GASS and its future projects, with breakout groups organized around potential future GASS projects.

2.4.2 Panel Activities

We have communicated with past panel members about their future involvement in GASS activities. The key point is that we ask all future panel members to be actively involved in GASS projects (as a leader, contributor, and/or user).

Our primary Panel activity has been to organize a highly successful Pan-GASS Conference. So far, sessions have been finalized, with oral and poster presentation notifications emailed to participants. We have talked with various people and organizations about potentially leading future GASS projects. We will ask various participants to prepare 1–2 page white papers on potential GASS projects before the Conference. Then breakout meetings will be held on these white papers during the Conference to generate the momentum. Shortly after the Conference, we will have the list of GASS panel members and GASS projects for GEWEX SSG approval.

2.4.3 New Projects in Place

As mentioned above, we expect to have a list of GASS projects available after the Pan-GASS Conference.

2.4.4 New Projects and Planed Activities

See § 2.4.2.

2.4.5 Science Highlights

For the new GASS panel, not yet.

2.4.6 Science Issues

Discussed in the *GEWEX News* article in the August 2017 issue (See § 2.4.1.).

2.4.7 Contributions to the Developing GEWEX science

Both co-chairs are involved in the relevant GEWEX discussions. Links to the modeling panels within WCRP (GEWEX/GLASS and WGNE) will continue and potentially be strengthened through common projects. GASS will also be closely linked to WWRP through the involvement of one co-chair. GASS is also exploring the link to the aerosol, precipitation, and cloud activities in Aerosols, Clouds, Precipitation and Climate (ACPC) and GAP, as one ACPC representative will give a talk on ACPC at the Pan-GASS Conference, and one GASS co-chair will attend the coming ACPC Conference in April 2018.

2.4.8 Contributions to the GEWEX Science Questions

- Observations and Predictions of Precipitation
- Global Water Resource Systems
- Changes in Extremes
- Water and Energy Cycles

GASS is relevant to three of the four questions above (precipitation, extremes, and water and energy cycles).

2.4.9 Other Key Science Questions

In our *GEWEX News* article, we mentioned several such questions, such as:

- Coupling dynamics with physics (e.g., surface-boundary layer-convection coupling)
- Mechanisms for the diurnal cycle of precipitation over different regions
- Role of land processes in sub-seasonal to seasonal (S2S) prediction

2.4.10 Contribution to the WCRP Grand Challenges

GASS relates to two WCRP Grand Challenges: “Clouds, Circulation, and Climate Sensitivity” and “Weather and Climate Extremes.”

2.4.11 Cooperation with Other WCRP Projects and Other International Programs

Close links to WGNE in terms of model development are maintained. Direct connections of GASS to WWRP are established by contributing to the action areas of WWRP and by reporting to WWRP-SSC. Cooperation with ACPC and CFMIP will be maintained through common projects. Potentially links might be established with CLIVAR (surface fluxes).

2.4.12 Workshops/Meetings Held

None

2.4.13 Workshops /Meetings Planned

- The Second Pan-GASS Conference will be held in Australia from 26 February–2 March 2018. No travel support is available from GEWEX.
- After all Panel members are selected, we will decide if we will need to have a Panel meeting in late 2018 or early 2019.

2.4.14 Other Meetings Attended on Behalf of GEWEX

- Pan WCRP modeling meeting, including the WGNE-32 session, 9–13 October 2017, UK MetOffice, Exeter, UK
- WWRP-SSC, 25-26 October 2017, Geneva, Switzerland

2.4.15 Issues for the SSG

None at present.

2.4.16 List of Key Publications

None. (See § 2.4.1.)

2.4.17 List of Members and their Term Dates

To be determined.

Annex 1: List of Participants

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Annex 2: SSG Agenda

Monday, 29 January 2018: Introduction and International and US Programs

8:30	8:50	Registration	
9:00	9:05	Opening and Welcome	Sonia Seneviratne, Graeme Stephens, Peter van Oevelen
9:05	9:20	Logistics/Conference Update	Peter van Oevelen
9:20	10:00	WCRP Report (10min Discussion)	Boram Lee, Guy Brasseur
10:00	10:30	SSG Chairs Report	Graeme Stephens, Sonia Seneviratne
10:30	11:00	Break	
11:00	11:15	GDAP Short Overview	Remy Roca, Tristan L'Ecuyer
11:15	11:30	GLASS Short Overview	Michael Ek, Gab Abramowitz
11:30	11:45	GASS Short Overview	Daniel Klocke, Xubin Zeng
11;45	12:00	GHP Short Overview	Jason Evans, Joan Cuxart
12:00	12:30	NASA	Jack Kaye, Hal Maring
12:30	14:00	Lunch	
14:00	14:30	NOAA	Wayne Higgins, Jin Huang
14:30	15:00	DOE	Sally McFarlane, Renu Joseph
15:00	15:30	JAXA	Riko Oki
15:30	16:00	Break	
16:00	16:30	ESA	Michael Rast
16:30	17:00	USGCRP	Jennifer Arrigo
17:00	17:30	Discussion Programs	All
17:30	18:00	Intro to GEWEX "Updated Science Questions"	Graeme Stephens, Sonia Seneviratne
18:00		Adjourn	
18:00	19:30	Reception	

Tuesday, 30 January 2018 – *The GEWEX Science Panels*

8:30	10:00	GHP Panel Science/Action Items	Joan Cuxart, Jason Evans
10:00	10:30	Discussion	
10:30	11:00	Break	
11:00	12:30	GLASS Panel – Science/Action Items	Michael Ek, Gab Abramowitz
12:30	14:00	Lunch	
14:00	15:30	GASS Panel – Science/Action Items	Daniel Klocke, Xubin Zeng
15:30	16:00	Break	
16:00	17:30	GDAP Panel – Science/Action Items	Remy Roca, Tristan L'Ecuyer
17:30	18:00	Discussion	Graeme Stephens
18:00		Adjourn	

Wednesday, 31 January 2018

8:30	9:00	Rapporteur Report GHP	Michael Bosilovich, German Poveda, Lisa Alexander
9:00	9:30	Rapporteur Report GDAP	Remko Uijlenhoet, B.J. Sohn
9:30	10:00	Rapporteur Report GLASS	Paul Dirmeyer, Branka Ivančan-Picek
10:00	10:30	Rapporteur Report GASS	Qinyun Duan, Gianpaolo Balsamo
10:30	11:00	Break	
11:00	11:15	SPARC	Judith Perlwitz
11:15	11:30	WWRP	Sarah Jones
11:30	12:30	CLIC/CLIVAR/CORDEX/US CLIVAR	Remote/Mike Patterson
12:30	14:00	Lunch	
14:00	14:30	New Member Presentations	B.J. Sohn
14:30	15:00	New Member Presentations	Qinyun Duan
15:00	15:30	JSC Action Items	Graeme Stephens, Sonia Seneviratne, Peter van Oevelen
15:30	16:00	Break	
16:00	17:30	GEWEX Science Questions Update	

Thursday, 1 February 2018

8:30	8:45	Monsoon Panel	Remote
8:45	9:00	Update on TPE and GHP-TPE Workshop	Peter van Oevelen
9:00	9:30	Extremes Grand Challenge	Sonia Seneviratne
9:30	10:00	Water Grand Challenge	Jan Polcher, Peter van Oevelen
10:00	10:30	Earth Energy Imbalance/Concept Heat	Tristan L'Ecuyer
10:30	11:00	Break	
11:00	11:30	Update on Korean Space Program	B.J. Sohn
11:30	12:30	Other Activities	Graeme Stephens, Sonia Seneviratne
12:30	14:00	Lunch	
14:00	14:30		
14:30	15:30	Draft Actions and Recommendations of this SSG-30	Peter van Oevelen
15:30	16:00	Break	
16:00	16:30	Next Meeting, AOB	Peter van Oevelen, Sonia Seneviratne, Graeme Stephen
16:30	17:00	Adjourn	

Annex 3: Rapporteurs Reports on GEWEX Panels

1. GEWEX Data and Assessments Panel (GDAP)

Rapporteurs: Remko Uijlenhoet and B.J. Sohn

1.1. Overview

GDAP seems to be accelerating with respect to previous years, largely thanks to excellent panel leadership. Comprehensive written and oral report. New paradigm ("*consistency is a way of life*") underlining integrated surface water and energy assessments (measurements of all states and fluxes are combined in a coherent manner). Note that meaning of acronym GDAP has changed, although it's not clear if is accepted by the SSG already.

1.2. Objectives

Core mission:

- Production and analysis of datasets
- Dataset assessments
- Ground-based networks
- Interface between GEWEX activities and datasets
- Represent GEWEX (data) at meetings (WCRP, WMO, GCOS)

Clear in principle, but could be slightly better articulated given the (proposed?) change of the meaning of the acronym GDAP from GEWEX Data and Assessment Panel to GEWEX Data and Analysis Panel.

1.3. Status

Current status of panel accurately and comprehensively represented in written document and oral presentation.

Soil moisture
The International Soil Moisture Network (ISMN) seems to be a Vienna initiative only or is it really integrated in GEWEX? It's unclear if the Cosmic Ray Soil Moisture Observing System (COSMOS) data (Cosmic Ray Sensors) is integrated in the ISMN database. In GDAP, the soil moisture people are mainly remote sensors, rather than modelers (link to GLASS) or in-situ experts (Soils Initiative). This might be a time to attract new members that address this issue. GEWEX might consider making soil moisture a cross-cutting theme (Action: Peter).

Runoff
GRDC does a great job, but not really integrated into GEWEX/GDAP (perhaps GHP can cover this and communicate with GDAP?).

Precipitation
- GPCC climatology and daily products (10,000–30,000 stations) – fine.
- Precipitation assessment under GDAP: joint IPWG-GEWEX effort (10 chapters, with leaders identified; chapter on extremes still needs to be included; cold season/frozen precipitation seems to be lacking still from the list; products for end-users: agriculture, water management, etc.) – great.
- Weather radar data are included in the assessment (C. Kidd in GDAP; also relevant to extremes grand challenge – L. Alexander).
- Recommendation: link up with INTENSE project by Hayley Fowler et al. (new member?)

Aerosols
Aerosol assessment report never released! (Action: Graeme Stephens)

Clouds
A new initiative is the International Cloud Working Group (ICWG), equivalent to IPWG; next generation ISCCP.

Water vapor
Water vapor product has been rapidly produced by GDAP. A BAMS paper will follow shortly.

Integrated assessment
Ground-based data as "anchor points": Inclusion of European sites in addition to ARM sites (Cabauw, Lindenberg, Sodankylä, Palaiseau, Chilbolton, etc.).

1.4. Vision

Panel chairs seem to have a clear vision on where to go with the panel. Nevertheless, change of panel name from "assessments" to "analysis" needs some additional discussion. Where does "assessment" change into "analysis"? Which part of the "analysis" should be covered by GDAP and which part should be covered by the other panels?

1.5. Future

GDAP continues to play a fundamental role in the GEWEX community and beyond. Again, energetic and strong panel leadership is appreciated. As mentioned before, GDAP might consider attracting new members for its panel, e.g., Gabrielle de Lannoy (DA and soil hydrology expertise); links to GLASS community; representation from Soils Initiative.

1.6. Key results

The first year of the new GEWEX Integrated Dataset has been generated and released to support energy and water cycle studies and model evaluation on both regional and global scales. The water vapor assessment has been completed and corresponding report published. New versions of several GEWEX-sponsored datasets have been delivered. Clear vision on future development of GDAP.

1.7. Issues

Still a lot of "assessments" for a panel that has changed its name from "assessments" to "analysis" panel. Does the transition from "assessments" to "analysis" have implications for the relation between GDAP and the other science panels (GASS, GLASS, and GHP)? There could be the risk of replication, e.g., the GDAP LandFlux (GLEAM, the Global Land Evaporation Amsterdam Model, etc.) product vs. GLASS. On the other hand, "analysis" articulates the fact that GDAP is a science panel, not just an engineering panel. Other points are listed under "§3. Status."

1.8. Recommendation:

Focus not just on one (precipitation, etc.) product. Integrated ("consistent") product could be just one of the products generated by GDAP.

2. GEWEX Hydroclimatology Panel (GHP)

Rapporteurs: Lisa Alexander, Michael Bosilovich and Germán Poveda

2.1. Accomplishments and Activities

GHP reports strong accomplishments and continued activities, advancing toward GEWEX objectives, noting progress in mature RHPS (HyMEX, CCRN) and new efforts (PannEx and ANDEX). CCRN is close to completion with a final project meeting in March. Funding has been received for a large Global Water Futures initiative, which will likely continue CCRN's efforts. PannEX and Baltic Earth are now well developed enough to be endorsed as an initiating and full RHP respectively. INARCH fieldwork and model comparisons are well developed and making progress. The agenda of meetings and workshops is strong and productive. The INARCH Special Issue is developing nicely, and a noteworthy achievement.

2.2. Contributions

GHP has made relevant contributions to the WCRP Grand Challenges in topics such as:

- Provision of skilful future climate information on regional scales
- Regional sea-level rise
- Cryosphere response to climate change
- Interactions of clouds, aerosols, precipitation, and radiation and their role in climate sensitivity
- Past and future changes in water availability
- Documenting extremes and the science behind the process understanding, prediction and attribution of extreme events.

2.3. Future

There seems to be an imbalance of effort toward precipitation, while GLASS handles soil moisture and evapotranspiration. River flow, in particular, floods and connections to P, E, soil moisture and snowmelt, do not appear well connected (though this is not across GHP, as HyMeX does emphasize full budget research and data). Similarly, groundwater appears marginalized, a fundamental component of resource management and long-term drought. The SSG should consider inviting a groundwater expert to be part of it.

A potential topic for GHP to consider is water quality and its connection with water quantity at different time scales. GHP is focused on the "offer" part of water, the "demand" part is not considered extensively. For instance, the proposed scientific meeting in Canmore this year is aiming at Grand Challenges on Extremes and Water for the Food Baskets of the World. The latter one brings about the demand side of the issue. If so, water for all types of consumptions is important (human, agriculture, industry, etc.). A decision from GEWEX needs to be made in this regard.

Development of the US RHP appears to be leaning toward applications. As this effort progresses, points 3a-d may be worth revisiting in the context of new RHPs for the US and the Andes. Can the US RHP be linked to USGCRP's National Climate Assessment structure? The National Climate Assessment (NCA) is huge, would need a tractable subset, perhaps more research oriented (though NCA has ties to applications). Perhaps this is a good question for the new US panel member.

An area to consider as the fledgling cross-cut with GLASS develops is, aside from the fluxes, the local understanding of the meteorology data (for forcing land models) and the geography

(soil and vegetation characteristics, topography) in the RHPs. The offline land modeling in GLASS is very much local and GHP (or the RHPs) have a lot of local knowledge to offer.

From the slide it is not clear what the goal of the ET Determination project/CC is. Is this more structured than it appears, since it is incorporated into the Canmore conference? Is this something that could help bring a GLASS/RHP CC into focus?

GHP proposes a GDAP cross-cut that seems to have little maturity at this point. In the context of the GDAP integration effort, RHPs (which were then called Continental Scale Experiments, or CSEs) played a significant role in regional energy and water cycle comparison to global data sets (e.g., the work of J. Roads in early 2000s). This cross-cut could be more than a validation exercise by building on the previous work. Perhaps the annual meetings could overlap at the same location one year, with a joint session, or a joint breakout at the 2018 GEWEX Open Science Conference in Canmore?

The Cold Shoulder work seems to be a useful and interesting topic. However, how does this fit with the overall GEWEX Science Questions/plan? Is it just extremes? The relationship needs improved articulation.

INTENSE is very promising, but the focus seems to have been primarily on the observational effort so far. It would be good to have more details on specific model experiments, e.g., understanding why models are unable to reproduce the diurnal cycle of precipitation.
While the cross-cutting activities provide some sort of mechanism for synthesizing results across RHPs, it would be good if there was an activity to better consolidate results across RHPs and to better articulate the outcomes for the overall GEWEX goals. One recommendation is to encourage the use of the GDAP Integrated Product with some basic metrics that could be used and intercompared across all RHPs to contribute to a global synthesis, while building on similar studies of past GHP efforts.
There appear to be problems with legacy documentation and databases. This is particularly important for the cross-cut activities and especially INTENSE so that the global data gathered does not get lost when the project ends.

HyVic appears to be stalling and may require a new science plan (or leadership) and RHP proposal.

While there are clear links to the WCRP Grand Challenges on Extremes and Water Availability, a tangible connection/outcome is not particularly clear. INTENSE is clearly contributing to the Extremes Grand Challenge, but the Near 0°C Precipitation and INARCH projects are not currently linking in with that Grand Challenge. It would be good to articulate who (and what) those links are specifically and to ensure two-way communication between the leadership of both the cross-cuts and the Grand Challenges.
The panel members are directed to think on the key science questions that they anticipate wanting to tackle in the next 5-10 years. This will help consolidate the direction for GHP going forward and would help incorporate some of the missing elements that currently exist.

2.4. Summary

There is tremendous work going on in GHP, and many of the regional projects are performing successfully. The leadership has done a tremendous job with the variety and number of efforts within the GHP. Congratulations to Jason and Joan for leading this effort. It is hoped that these suggestions prove useful.

3. Global Land/Atmosphere Study (GLASS)

Rapporteurs: Branka Ivančan-Picek and Paul Dirmeyer

3.1. Overview

GLASS continues to be a largely productive and energetic panel, and an important contributor to GEWEX. However, in the interannual ebb and flow of activity, GLASS seems to be coming into a trough.

3.2. Objectives

GLASS has elements that promote science to improve the best estimates and the model representation of state variables, understanding of land/atmosphere feedbacks, and understanding of the role of the land surface in predictability on a range of time and space scales. The three elements are: land-atmosphere interactions, model-data fusion and model benchmarking.

3.3. Status

GLASS has a number of projects and efforts under its umbrella, most of which have been quite productive. Overall performance has been laudable. However, some elements have been moving slowly or stalled. DICE has tremendous potential to directly address key aspects of the land-atmosphere process research, but progress has been very slow. PILDAS has stalled completely. Some re-invigoration is suggested (see “Issues” below).

3.4. Vision

GLASS strives for better representation of the Earth system by understanding the role of land and identifying and improving modeling of land-surface processes and land-atmosphere interactions to support the GEWEX mission. The “Made in GEWEX/GLASS” percentages for each effort that are listed in the written report are a useful indicator of contributed value, which could be copied by other panels.

3.5. Future

Not a lot new appears to be in the pipeline. SoilWat shows great potential for real improvement in LSMs. PLUMBER2 will be evolutionary, and bringing innovative new tools (e.g., information theory tools) should inform LSM development. Much will clearly occur in the context of CMIP6. Otherwise, GLASS appears to be entering an innovative lull; specific suggestions below under “Issues.”

3.6. Key Results

LoCo and PLUMBER were identified as impactful ongoing efforts that are at a level of maturity to communicate useful conclusions to the scientific community. The LoCo group has published a summary “state of the science” paper in BAMS. Several papers from PLUMBER have provided detailed critical assessment of basic LSM performance relative to objective benchmarks. There was also acknowledgement that the linking of PALS and ILAMB software has been a noteworthy and very useful accomplishment.

3.7. Issues

Several issues were identified that need to be addressed:

- Active outreach to early career scientists in membership and participation is laudable. Other elements of diversity in membership, leadership and participants is lacking. An open solicitation (perhaps via GEWEX News and/or E-News Update) for panel membership could help open doors to the "club." This needs a fair vetting system. Likewise, topical expanse to include/expand links to hydrology and ecology should be pursued.
- Greater coordination with other activities within and beyond GEWEX is encouraged. Specifically:
  - Take advantage of the reconstitution of GASS to coordinate and collaborate on relevant coupled L-A problems ("physics" in models) from square-one.
  - Potential GDAP-GLASS links have been under-exploited and would be mutually beneficial, including data assimilation issues.
  - With GHP, better representation of modeling elements in RHPs should be accomplished through GLASS.
  - IGPO, WCRP and WWRP IPOs can aid GLASS in identifying the best potentially useful partners/partnerships outside GEWEX.
- To invigorate future innovation, a useful exercise would be to come up with a (succinct) ~6-8 year "vision" and a ~3-4 year "implementation" plan to orient thoughts toward future science. This ties to recruitment diversity as well. For instance, the recently released Decadal Survey "incubator" status on PBL measurement from satellites could be one major future element that links with GASS and also crosses over with CLIVAR, WWRP, etc.

4. Global Atmosphere System Study (GASS)

Rapporteurs: Qingyun Duan and Gianpaolo Balsamo

4.1. Overview

The provided overview was very clear and focused. GASS is a crucial panel for GEWEX and there is renewed force and enthusiasm!

4.2. Objectives

The objectives for the GASS panel are now much more clearly defined with a set of priorities and a list of actions, which makes it easy for rapporteurs to evaluate outcomes (e.g., metrics definition). The focus on atmospheric physics and dynamics coupling, with particular attention to water cycle, and breaking into grey-zones give a good framework. Extension to consider some anthropogenic influence (e.g., the Single-column Urban Boundary Layer Intercomparison Model Experiment, SUBLIME) might be needed/beneficial in light of WCRP changes. Recommended to adapt/extend objectives progressively to map onto the Strategy Plan.

4.3. Status

The chairs worked efficiently to set the context for GASS. The 2nd Pan-GASS Understanding and Modeling Atmospheric Processes meeting is priority one, as it will set the tone for the renewal of GASS.
Recommendation:

- Establish links with projects/initiatives to report on progress for next year's GASS report [e.g., PROES, GAP, ACPC, the Climate Impacts Research Consortium (CIRC), CAUSES).
- Use the Pan-GASS event as advertisement for panel membership (e.g., cherish diversity).
- Link with other GEWEX panels, in particular with GLASS (SCM experiments, GABLS/DICE legacy), WGNE (Systematic Model Errors), S2S (coupling-strength, e.g., LoCo & predictability, e.g., GLACE).
- Involvement in the GDAP "Assessment" to "Analysis" transition (e.g., model-data comparison, needs feedback from scientific users of dataset).

4.4. Vision

Process adherence needs resolution and model complexity to go hand-in-hand and to be supported by observations (field-campaigns, sites, profilers, radars, lidars, satellites). Field campaigns are key for innovation and participated engagement.

4.5. Future

Actions need concerted view of the GASS panel, therefore April 2018 meeting needed.

4.6. Key Results

Demonstrated building blocks for the GASS research areas via a set of white papers (to become available via GEWEX once finalized).

4.7. Issues

Strong leadership and renewed energy to this panel is clear uptake action from previous year reported issues. No new issues.

Annex 4: Acronyms and Other Abbreviations

ACPC	Aerosols, Clouds, Precipitation and Climate
AGU	American Geophysical Union
ALMIP2	Land Surface Model Intercomparison Project (CMIP)
AMMA	Multidisciplinary Analysis of the African Monsoon
ARM	Atmospheric Radiation Measurement (US Department of Energy)
ARMBE	ARM Best Estimate
AWI	Alfred Wegener Institute
BAMS	*Bulletin of the American Meteorological Society*
BSRN	Baseline Surface Radiation Network
CAUSES	Clouds Above the United States and Errors at the Surface
CC	Cross-Cut Project
CCI SM	Climate Change Initiative-Soil Moisture (ESA)
CCMP	Cross-Calibrated Multi-Platform
CCRN	Changing Cold Regions Network
CCSM	Community Climate System Model
CDR	Climate Data Record
CEH-GEAR	Centre for Ecology and Hydrology Gridded Estimates of Areal Rainfall
CESM	Community Earth System Model
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System
CFMIP	Cloud Feedback Model Intercomparison Project
CGMS	Coordination Group for Meteorological Satellites
CLASS	Canadian Land Surface Scheme
CliC	Climate and Cryosphere Project (WCRP Core Project
CLIVAR	Climate and Ocean – Variability, Predictability, and Change (WCRP Core Project)
CMAP	CPC Merged Analysis of Precipitation (NOAA)
CMIP	Coupled Model Intercomparison Project (WCRP)
CMORPH	CPC MORPHing technique (NOAA)
CNRM	Centre National de Recherches Météorologique (National Center for Meteorological Research)
COLA	Center for Ocean-Land-Atmosphere Studies
CONVEX	Research Project on Observational Evidence and Process Understanding to Improve Predictions of Extreme Rainfall Change
CORDEX	Coordinated Regional Climate Downscaling Experiment (WCRP)
CPC	Climate Prediction Center (NOAA)
CPO	Climate Program Office
CRCM	Canadian Regional Climate Model
CRHM	Cold Region Hydrological Model
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTEM	Canadian Terrestrial Ecosystem Model
DECK	Diagnostic, Evaluation and Characterization of Klima experiment
DIAL	Differential Absorption Lidar
DICE	Diurnal Land/Atmosphere Coupling Experiment
DOE	Department of Energy
DOIs	Digital Object Identifiers

DWD	Deutscher Wetterdienst (German Weather Service)
EBAF-4	Energy Balanced and Filled (EBAF) Top-of-Atmosphere (TOA) Edition-4.0
ECA&D	European Climate Assessment and Dataset
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-range Weather Forecasts
ECVs	Essential Climate Variables
EEI	Earth's Energy Imbalance
EGU	European Geophysical Union
EO	Earth Observations
ERA-Interim	ECMWF Re-Analysis (ERA)-Interim
ESA	European Space Agency
ESGF	Earth System Grid Federation
ESMs	Earth Science Models
ESSD	*Earth System Science Data*
ET	Evapotranspiration
ETH	Swiss Federal Institute of Technology in Zürich
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EXAEDRE	Exploiting new Atmospheric Electricity Data for Research and the Environment
EXP1	Long-term Retrospective Experiment
FE	Future Earth
FIDUCEO	Fidelity and Uncertainty in Climate data records from Earth Observations
FMI	Finnish Meteorological Institute
FOCI	Frontiers of Climate Information (WCRP)
FPS	Flagship Pilot Study (HyMeX)
GABLS	GEWEX Atmospheric Boundary Layer Study
GAIA-CLIM	Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring
GAP	GEWEX Aerosol and Precipitation project
GC	Grand Challenge (WCRP)
GCOS	Global Climate Observing System
GDAP	GEWEX Data and Assessment Panel
GDIS	Global Drought Information System
GEO	Group of Earth Observation
GERICS	Climate Service Center Germany
GEWEX	Global Energy and Water Cycle Exchanges (WCRP Core Project)
GFCS	Global Framework for Climate Services
GHP	GEWEX Hydroclimatology Panel
GHRSST	Global High Resolution Sea Surface Temperature
GNSS	Global Navigation Satellite Systems
GLACE	The Global Land–Atmosphere Coupling Experiment
GLASS	Global Land/Atmosphere System Study
GPCC	Global Precipitation Climatology Centre
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Mission
GRACE	Gravity Recovery and Climate Experiment
GRL	*Geophysical Research Letters*
GSFC	Goddard Space Flight Center (NASA)
GSMaP	Global Satellite Mapping of Precipitation (JMA)
GSOP	CLIVAR Global Synthesis and Observations Panel

GSQs	GEWEX Science Questions
GSW	GEWEX Soils and Water
GSWP3	Global Soil Wetness Project 3
G-VAP	GEWEX Water Vapor Assessment
HEPEX	Hydrologic Ensemble Prediction Experiment
HESS	Hydrology and Earth System Sciences
HIRS	High Resolution Infra-Red Radiation Sounder
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data
HyMeX	Hydrological Cycle in the Mediterranean Experiment
HyVic	Hydrology of Lake Victoria Basin
IASOA	International Arctic Systems for Observing the Atmosphere
ICDR	GPCP Monthly Interim Climate Data Record
ICSU	International Council for Science
IDF	Intensity-Duration-Frequency
ICPAC	Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre
IGBP	International Geosphere Biosphere Programme
IGAD	Intergovernmental Authority on Development
IGPO	International GEWEX Project Office
IGWCO	Integrated Global Water Cycle Observations
ILAMB	International Land Model Benchmarking
iLEAPS	integrated Land Ecosystem-Atmosphere Processes Study
INARCH	Alpine Research Catchment Hydrology
INTENSE	INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOCCG	International Ocean Color Coordination Group
IOP	Intensive Observation Period
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IPSL	Institute Pierre Simon Laplace
IPWG	International Precipitation Working Group
IQuOD	International Quality Controlled Ocean Database
IR	Raman lidar and infrared
ISCCP	International Satellite Cloud Climatology Project
ISI-MIP	Intersectoral Impact Model Intercomparison Project (CMIP)
ISMN	International Soil Moisture Network
ISSI	International Space Science Institute
IUGG	International Union of Geodesy and Geophysics
JAXA	Japan Aerospace Exploration Agency
JMA	Japanese Meteorological Association
JSC	Joint Scientific Committee (WCRP)
KMI	Belgium Meteorological Institute
KNMI	Royal Netherlands Meteorological Institute
LAC	Land-Atmosphere Coupling
LAFE	Land-Atmosphere Feedback Experiment
LAI	Leaf Area Index

LE	Latent Heat
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
LIAISE	Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment
LIS	Land Information System (NASA)
LoCo	Local Land-Atmosphere Coupling
LoCo WG	Local Land-Atmosphere Coupling Working Group
LSM	Land Surface Model
LST	Land Surface Temperature
LS3MIP	Land Surface, and Snow, Soil moisture Model Intercomparison Project
LUCID	Land-Use and Climate, IDentification of robust impacts
LULCC	Land Use Cover Changes
LUMIP	Land Use Model Intercomparison Project (CMIP)
MAC v1	Max Planck Aerosol Climatology version 1
MAHASRI	Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction
MDF	Model Data Fusion
MEaSURES	Making Earth System Data Records for Use in Research Environments
Med-CORDEX	Mediterranean Coordinated Regional Downscaling Experiment
MERRA	Modern-Era Retrospective Analysis for Research and Applications
MESH	Modélisation Environmentale Communautaire (MEC)–Surface and Hydrology
MIP	Model Intercomparison Project
MOUNTerrain	GEWEX Mountainous Terrain Precipitation Project
NARCCAP	North American Regional Climate Change Assessment Program
NASA	National Aeronautics and Space Administration
NEESPI	Northern Eurasia Earth Science Partnership Initiative
NCA	National Climate Assessment
NCAR	National Centers for Atmospheric Research
NCEI	National Center for Environmental Information
NCEP	National Center for Environmental Prediction
NDVI	Normalized Difference Vegetation Index
nnHIRS	neural network High Resolution Infra-Red Radiation Sounder
NOAA	National Oceanic and Atmospheric Administration (USA)
NWP	Numerical Weather Prediction
OAFlux	Objectively Analyzed Air-sea Fluxes
Obs4MIPS	Observations for Model Intercomparisons
ORA-IP	Ocean Reanalysis Intercomparison project
ORNL	Oak Ridge National Laboratory
ORCHIDEE	Organizing Carbon and Hydrology In Dynamic Ecosystems
OzEWEX	Australian Energy and Water Exchanges
PALS	Protocol for the Analysis of Land Surface models
PannEx	Pannonian Basin Experiment
PBL	Planetary Boundary Layer
PERLE	Pelagic Ecosystem Response to dense water formation in the Levant Experiment
PI	Principal Investigator
PILDAS	Project for the Intercomparison of Land Data Assimilation Schemes
PLUMBER	PALS Land Surface Model Benchmarking Evaluation Project

PMM	Precipitation Measurement Mission
POC	Point Of Contact
Qa	Atmospheric humidity
RAOBS	Paposo Lower Site Radiosondes
RCM	Regional Climate Model
RHPs	Regional Hydroclimate Projects
PROES	Process Evaluation Study
S2S	Subseasonal to Seasonal Prediction Project
SACRA	Global data sets of satellite-derived crop calendars for agricultural simulations
SAFRAN-IP	Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige for the Iberian Peninsula
SCM	Single Column Model
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SCOR	Scientific Committee on Oceanic Research
SGP	Southern Great Plains ARM site (USA)
SMAP	Soil Moisture Active Passive (NASA)
SMOS	Soil Moisture and Ocean Salinity (ESA)
SoilWat	GEWEX Soil and Water Initiative
SOP	Special Observation Period
SPARC	Stratospheric Processes and their Role in Climate (WCRP Core Project)
SRB	Surface Radiation Budget Project
SSC	Scientific Steering Committee
SSCZP	Soil Systems and Critical Zone Processes
SSG	Scientific Steering Group (GEWEX)
SSMIS	Special Sensor Microwave Imager/Sounder
SST	Sea Surface Temperature
SWOT	Surface Water and Ocean Topography satellite
TIRA	Task Team for Intercomparison of Reanalyses (WCRP)
THORPEX	The Observing system Research and Predictability Experiment
TOA	Top Of Atmosphere
TU Wien	Vienna University of Technology
UCAR	University Corporation for Atmospheric Research
UCI	University of California, Irvine
UKMO	UK Met Office
UKWIR	UK Water Industry Research
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNSW	University of New South Wales, Sydney, Australia
URC	International Radiation Commission
USDA	United States Department of Agriculture
USGCRP	US Global Change Research Program
USRA	Universities Space Research Association
UTLS	Upper Troposphere Lower Stratosphere
UTTC	Tropospheric Clouds and Convection (PROES)

WACMOS-ET	Water Cycle Observation Multi-mission Strategy-EvapoTranspiration
WCRP	World Climate Research Programme (WMO, IOC and ICSU)
WDAC	WCRP Data Advisory Council
WECC	Water, Ecosystem, Cryosphere and Climate (CCRN)
WGIR	Working Group on Information for Regions (WCRP, to be approved)
WGNE	Working Group of Numerical Experimentation
WGRC	Working Group on Regional Climate (WCRP)
WMO	World Meteorological Organization
WMO SPICE	World Meteorological Organization's Solid Precipitation Intercomparison Experiment
WRMC	World Radiation Monitoring Center
WRF	Weather Research and Forecasting
WWRP	World Weather Research Programme
YESS	Young Earth System Scientists Community
YHS	Young Hydrologic Society

The
World Climate Research Programme (WCRP)
facilitates analysis and prediction of Earth system change for use in a range of practical applications of direct relevance, benefit and value to society.