Challenges of the present* – a glimpse into the (near) future

* As exposed at the GEWEX OSC

Extremes and Water on the Edge

2018 GEWEX Science Conference, Canmore, Alberta, Canada | May 6-11, 2018

Topics included:
Nexus of water, energy, and food | Climate extremes | Extreme weather | Atmospheric modeling and observations | Land modeling and observations | Global energy and water cycles, Mountain and high-latitude hydrology

450+ abstracts received
350 registered
ECS workshop - 70 applicants, space for 40
Phase III: Quantitative understanding and prediction of the Global water and energy system

Integrated observing strategies of the Earth system - address gaps (mountain & cold phase hydrology)

Advances in Earth system modeling

Need to study process interactions across time scales

Instead of the traditional paradigm of properties define processes, study how processes define properties. Martyn Clark

Challenge is that humanity is embedded in a deeply interconnected living Earth system, Betts
The 4 GEWEX Science Questions sit under these bigger, overarching science questions:

- **OBS**: New observations and observational syntheses
- **UNDERSTANDING**: Precipitation and radiation, Land processes, land and water use, carbon-water coupling, Water and energy feedbacks in the Earth system, Extremes
- **MOD**: New and improved models
- **PREDICTABILITY**: Model evaluation, observational constraints, Closing water and energy balances across scales, The Human dimension – both impact of changing water cycle on society and the impact of human activity on the water cycle

**Cross-cuts**

- **GDAP**: Precipitation and radiation
- **GHP**: Land processes, land and water use, carbon-water coupling
- **GASS**: Water and energy feedbacks in the Earth system
- **GLASS**: Extremes
**Existing PROES activities under GASS:**

1) **GEWEX Process Evaluation Study on Upper Tropospheric Clouds and Convection (UTCC PROES)** - Stubenrauch

2) **GEWEX Aerosol-Precipitation (GAP)** van den Heever/Stier (& works closely with ACPC)

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In a nutshell – this PROES seeks to examine how well models make rain and the nature of model bias that extends across the scale of models - this example shows how rain is influenced by atmospheric thermodynamics in nature but not in models - PROES works with modeling groups to understand why and how fixes might be developed.
INTENSE – a GHP CC that also connects to the GC and now to GDAP

INTENSE research questions

Thanks to:
- Lizzie Kendon and team, Robert Dunn, Nigel Roberts (UK Met Office)
- Stephen Blenkinsop, Renaud Barbero, Steven Chan, Liz Lewis, Selma Guerreiro, Xiao-Feng Li (Newcastle University)
- INTENSE partners (especially Geert Lenderink, Seth Westra, Christoph Schär, Nicolina Ban, Jason Evans, Lisa Alexander)

Australia: Changes in magnitude

Getting: Spain, Argentina, Ecuador, Columbia, Bahamas, the Philippines, New Zealand, a few stations in Kenya, Tuvalu, the Caribbean, South Africa, Colombia, Fiji, Israel, India, Denmark, Slovenia, Iran, Bangladesh, Russia, Hungary, Czech Republic, China, Uruguay, Vanuatu, Hong Kong, Poland, Vietnam, Mexico

precision=0.1mm

Guerreiro et al., in prep
Phase III: Quantitative understanding and prediction of the Global water and energy system

**Challenge – representing the influence of humanity in the physical Earth system (Betts)**

**Challenge – balance between complexity and reality; as models increase in complexity, how do we know they are approaching reality (Dave Lawrence)**

**Challenge – a more process based understanding of the water/energy ‘system’**

**Challenge – can we evolve our analysis systems to provide the energy and hydrological information on increasingly finer scales.**
One of our challenges: bridging the scale divide

Global km-scale modeling

Global/regional scale ESM

Upscale

Downscale

Local Hadley Circulation (IAA 35 - 40 E; CPN)

Kocke et al., 2017

Frequency/total number

precipitation (mm h⁻¹)
Vision of GEWEX as expressed through this OSC

• Address the scientific problems
  • Water and Extremes
  • Land-atmosphere interactions
  • Energy and water budgets
  • High-resolution modeling
  • Heat waves & extremes: past, present, and future
  • Weather & climate extremes
  • Cold-regions Earth system changes
  • Storms and high-impact weather
  • Irrigation & water cycle over breadbaskets

• Provide guidance to society

HiRes: A Proposal for a Coordinated GEWEX Initiative to Advance Projections of Hydrological Extremes

The GEWEX Cloud System Study (GCSS)

Abstract

The World Climate Research Programme’s Global Energy and Water Cycle Experiment (GEWEX) addresses both the hydrological and meteorological components of the water cycle. One of the challenges faced by the project is the projections used, especially for extreme rainfall, which is a fundamental weakness in all climate models (Stephens et al., 2010). One hypothesis that is adopted so that appropriate parameterizations can be developed for the distinctive types of cloud system occurring in different regions of the globe. The description and understanding of cloud systems must be achieved in GEWEX will also enable the development of improved...
“Adequately addressing critical water cycle science questions and applications requires systems that are implemented globally at much higher resolutions, on the order of 1 km, resolutions referred to as hyperresolution in the context of global land surface models.”

Major implications of hyper resolution:
1. Runoff generation
2. Biogeochemical cycling
3. Land-atmosphere interactions
4. Snow & freeze/thaw

* All depend on accurate representation of saturated and unsaturated areas (i.e. accurate topography)
Thriving on Our Changing Planet
A Decadal Strategy for Earth Observation from Space

A report of the Decadal Survey for Earth Science and Applications from Space
Released: 5 January 2018
Report available at: http://www.nas.edu/esas2017

#EarthDecadal
Panels

Global Hydrological Cycles and Water Resources
Co-Chairs: Jeff Dozier, UC Santa Barbara and Ana Barros, Duke University
The movement, distribution, and availability of water and how these are changing over time

Weather and Air Quality: Minutes to Subseasonal
Co-Chairs: Steve Ackerman, University of Wisconsin and Nancy Baker, NRL
Atmospheric Dynamics, Thermodynamics, Chemistry, and their interactions at land and ocean interfaces

Marine and Terrestrial Ecosystems and Natural Resource Management
Co-Chairs: Compton (Jim) Tucker, NASA GSFC and Jim Yoder, WHOI
Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and factors that influence health and ecosystem services

Climate Variability and Change: Seasonal to Centennial
Co-Chairs: Carol Anne Clayson, WHOI and Venkatachalam (Ram) Ramaswamy, NOAA GFDL
Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

Earth Surface and Interior: Dynamics and Hazards
Co-Chairs: Dave Sandwell, Scripps and Doug Burbank, UC Santa Barbara
Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate
### TABLE 3.3 Science and Applications Priorities Table

The Science and Applications portion of the full Science and Applications Traceability Matrix (SATM) in Appendix B.

<table>
<thead>
<tr>
<th>Societal or Science Question/Goal</th>
<th>Earth Science/Application Objective</th>
<th>Sci/App Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>QUESTION H-1.</strong> How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as drought and floods?</td>
<td>H-1a. Develop and evaluate an integrated Earth System analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.</td>
<td>Most Important</td>
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<td>H-1b. Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and Orographic scales suitable to capture flash floods and beyond.</td>
<td>Most Important</td>
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<td>H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.</td>
<td>Most Important</td>
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<tr>
<td><strong>QUESTION H-2.</strong> How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?</td>
<td>H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.</td>
<td>Very Important</td>
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<td>H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td>H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.</td>
<td>Most Important</td>
</tr>
<tr>
<td>QUESTION</td>
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<tr>
<td>W-1a. Determine the effects of key boundary layer processes on weather, hydrological, and air quality forecasts at minutes to subseasonal time scales.</td>
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<tr>
<td>W-2a. Improve the observed and modeled representation of natural, low-frequency modes of weather/climate variability (e.g. MJO, ENSO), including upscale interactions between the large-scale circulation and organization of convection and slowly varying boundary processes to extend the lead time of useful prediction skills by 50% for forecast times of 1 week to 2 months.</td>
<td>Most Important</td>
<td></td>
</tr>
<tr>
<td>W-3a. Derive how spatial variability in surface characteristics modifies and/or modifies natural cycles of energy (e.g. water, energy, and momentum) and thereby influence weather and climate?</td>
<td>Very Important</td>
<td></td>
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<tr>
<td>W-4a. Measure the vertical motion within deep convective storms, heavy precipitation, and what clouds occur exactly when and where they do?</td>
<td>Most Important</td>
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<tr>
<td>W-5a. Improve the understanding of the processes that determine air pollution distributions and aid estimation of global air pollution impacts on human health and ecosystems by reducing uncertainty to ~10% of vertically-resolved tropospheric fields (including surface concentrations) of specified pollutants (PM2.5, ozone (O3), and nitrogen dioxide (NO2)).</td>
<td>Most Important</td>
<td></td>
</tr>
</tbody>
</table>
Path from Science & Applications to Observational Priorities

Blue: Science & Applications; Green: Observables

Appendix A
Program of Record
Fundamental to achieving many of the prioritized science and applications objectives

Table 3.5
8
Targeted Observables
to be implemented in support priority science & applications objectives (of 22 final Observable candidates)

Table 3.3
24 of 103
Science & Applications Objectives identified as Most Important

Appendix B - SATM
103 Science & Applications Objectives supporting 35 Science & Applications Questions

Appendix D
280 total
Community RFI Responses describing desired science & applications and related observations

ESAS-Recommended Observing System Priorities 2017-2027

ESAS-Recommended Science/Applications Priorities 2017-2027

Objectives satisfied by existing space-based observations
Anticipated Science/Applications Accomplishments

DESIGNATED Program Element

- Make-up and distribution of aerosols and clouds
- Severe weather, convective storms
- Impacts of changing cloud cover and precipitation

Candidate EXPLORER Program Element

- Sources and sinks of CO2 and methane
- Contributions of glaciers and ice sheets to sea level rise
- Impacts of ocean circulation and exchange with atmosphere on weather and climate
- Changes in ozone and other gases and impacts on health and climate
- Snow amounts and melt rates and implications for water resources
- Impact of changes in land cover and related carbon uptake on resource management
- Transport of pollutants and energy between land, ocean, and atmosphere

Incubator Program Element

- Winds
- PBL(?)

Also EEI

Growth or shrinkage of glaciers and ice sheets

Alterations to surface characteristics and landscapes

Movement of land and ice surfaces

Trends in water stored on land

Evolving characteristics and health of terrestrial vegetation and aquatic ecosystems
Technology innovation was seen as an essential ingredient for advancing Earth Science objectives for the decade.

Small-sat lidar

3U IR spectrometer

Advanced GPS receiver – GNSS-refl
The coming focus of Earth Obs on convection
Imagine an observing system built as a clustered of observations. So now we have profiles of $\Delta Z$, $Z$ and $\Delta M$ versus $Z$. $\Delta Z$ versus updraft velocity. Convective mass flux.
First successful operation in Nadir Pointing & first possible detection of rain over the Sierra Madre Oriental, near Monterrey, Mexico.

Fast growing orographic precipitation developed shortly before RainCube’s pass which skirted its north-eastern edge.