Condensed Notes from
Water Availability Grand Challenge for North America Workshop
USRA, Columbia, Maryland, 3-5 May 2016

The goal of the workshop was to explore creating a Regional Hydroclimate Project (RHP) that tackles water availability from different vantage points: high resolution climate modeling, evaluation of climate projections, mountain hydrology, observations, ecosystem science, socioeconomic and political impacts, and the intersection of water, energy, and people.

Workshop objectives:

- Determining program elements and structure
- Establishing science focus areas and identifying leaders for each
- Confirming a planning committee
- Developing an independent plan or path forward for each focus area
- Identifying the next steps

Expected workshop outcomes:

- Listing of what the opportunities and challenges are in creating this RHP.
- Develop a plan of action that is cross-agency and endorsed by USGRP.
- Develop key science questions contained in a white paper.

Notes from the meeting have been grouped into the following categories:

- Funding suggestions and examples
- Human Dimension—How human activities impact the water cycle
- Synergies with other programs
- Science questions/potential study areas/issues to address
- Next Steps—developing a project plan
- Action Items

FUNDING SUGGESTIONS AND EXAMPLES

- Need to identify adequate resources and personnel with potential or existing sources of funding.

- The RHP should be leveraged on existing activities as finding big umbrella funding is unlikely in the near future. For example, the international Network for Alpine Research Catchment Hydrology (INARCH) has a for all practical purposes no budget and is dependent upon collaboration and seed money from other organizations such as Environment Canada and WCRP to organize meetings and obtain travel and ECS support.. Also, The Canadian Co-operative Research Network (CCRN) started with small amounts of funding, which it built up over time. The focus on extreme events was important in bringing teams together as the work was tied to the economic prosperity of the country (which was initially ”anti-climate change”). The flood of 2013 also helped in obtaining funding.

- Investigate funding opportunities within the NOAA Climate Project Office FY16 Research Competitions [e.g., Modeling, Analysis, Prediction and Projections (MAPP)]—advances in

understanding and prediction of variability and changes in Earth system; and National Water Center; RTAP (for R2O) NGGPS.

- The California Department of Water Resources has a lot of money that is going to university researchers.

- Could tie RHP results into the national water prediction system

HUMAN DIMENSION – HOW HUMAN ACTIVITIES IMPACT THE WATER CYCLE

- Natural system vs. human influence—Scientists must determine if what the satellite "sees" is natural or human induced.

- GRACE and human impacts on the water cycle—GRACE can monitor the water level of the deepest aquifer and provide total mass change in a column, but has coarse resolution. GRACE measurements show groundwater depletion, but cannot be used to estimate water usage. GRACE data can only be validated where there are observations. Variations in storage need to be addressed in terms of geology (aquitards, etc). There is no way to know how much water storage remains from GRACE measurements or the quality of the water. Also, the recharge points of the water storage are unknown.

- Crop varieties and forestry changes (e.g., pine beetles and loss of conifers) and how they contribute stream flow need to be investigated.

- NOAA has a HD program based on regional problems.

- Time scale—daily to seasonal?

- Show water stress related to population intake.

- Determine the roles of land surface processes and human water use effects on water availability?

- GLASS/GHP workshop is being held next October in Paris on HD issues

SYNERGIES WITH OTHER PROGRAMS

- WCRP Grand Challenge on Water for Food Baskets of the World (food security; water cycle main driver of food production).

- USDA theme "water for agriculture" could be linked to the RHP.

- INARCH has the goal to better understand alpine processes (e.g., how predictable is catchment energy and the water cycle). Issues in downscaling climate models, as well as regional climate model outputs. Satellite sensing issues with alpine terrain; transition from snow to rain is poorly done (using a temperature threshold); clouds, circulation and

climate sensitivity are very uncertain over mountain topography. Melting ice and global consequences—sea level rise.

- NCAR convection permitting modeling/CONUS Weather Research and Forecast (WRF) runs were completed in April 2016 and the data is available.

- Hyper-resolution land surface modeling—Adequately addressing critical water cycle science questions and applications requires systems that are implemented globally at much high resolutions, on the order of 1 km (hyper-resolution). Several groups are doing this on a volunteer basis. HyperHydro group (www.hyperhydro.org) is an open group with no funding that is taking activities that are already underway and grouping them. Three working groups: 1) setting up testbed; 2) computational challenges; 3) parameters

- There are a lot of NASA missions and projects that are ramping up—the RHP activities could be created around some of these

- NOAA is working to include weather-to-climate time scales to make prediction seamless—Using ensemble covariance matrix to propagate forecast uncertainty across climate model components.

- Seductive paradigm of the cloud of points—Full 112-member BCSD CMIP 3 ensemble projection: Lees Ferry gauge for upper Colorado. What causes extreme precipitation in the West?

- USDA-ARS—Monitoring of fluxes of snow/snowmelt, ground water recharge, etc.

- Soil Moisture Network – US working to organize a national network

- NWS National water model (WRF-Hydro System) being developed—this is going to happen and could be a part of this RHP. Goal is global to street scales.

- Ameriflux towers

- NEON - National Ecological Observatory Network—a continental-scale observation system for examining ecological change over time involving hundreds of scientists and engineers.

- DIurnal cycle Coupling Experiment (DICE)— GEWEX GLASS/GASS activity for land and boundary layer communities

- The North American RHP could be the flagship effort for the US GEWEX Project Office.

SCIENCE QUESTIONS/POTENTIAL STUDY AREAS/ISSUES TO ADDRESS

- Downscaling—how?
- Ensembles
- Sensitivity studies

- State of water cycle — Could this RHP be used for the production of a 2-year state of the water cycle?

- Need better understanding of water use and impacts on the water cycle

- What region within the US would we recommend for agriculture in the future?

- Look at uncertainty in chain of events of (e.g., soil moisture, irrigation/water management impacts?) Downscale smaller domains to address these types of questions?

- Climate and weather often seen as two different camps but this type of project could serve as a bridge between these.

- Key way we get better at prediction is by focusing on a region.

- Land surface atmosphere modeling related:
    - GLACE—Global Land-Atmosphere Coupled Experiment (completed 10 years ago)—showed hot spots of land surface control on precipitation and temperature (through terrestrial and atmospheric legs) are in transition regions
    - Coupling complexity of local land atmosphere interactions; interdisciplinary approach needed

- What metrics are needed? Approaches needed to be developed in tandem.

- Pieces of land-atmosphere coupled processes are monitored by uncoordinated networks with stations in different locations at different frequencies. Close to perfect is ARM SGP. However, the boundary layer is still poorly measured at SGP.

- Proposal for long-term: Have two transects for observations: east to west (across moisture and elevation) and north to south (across temperature and seasonality)

- Fluxes and atmospheric profiles measurements needed. How high of a vertical resolution is needed? Use temporary continuous profilers?

- Consider use of new technologies (small scale sensible heat sensor that can be flown on a plane)

- What is the value of remotely sensed snow observations for stream flow predictions?

- Southwest US has monsoon precipitation; Coastal areas have atmospheric rivers

- What are sources of uncertainty in our system?

- Benchmarking—can benchmarks show much uncertainty in boundary conditions, parameters, and due to model structure? Number one uncertainty in soil moisture is due to parameters. ET uncertainty is due to forcing. Benchmarking requires observations.

Some key challenges for understanding precipitation in the western US:

- Capturing orographic precipitation remains a challenge for remote sensing of precipitation
- A large fraction of precipitation falls in winter as snow over mountains. Yet, snow retrieval skill is very limited from space (if any)
- In practice we don't determine precipitation phases from space. It is based on establishing relations between temp and precipitation phases observed in stations. Given that temp data is often from reanalysis and at coarse spatial resolution it can be a large source on uncertainty
- High resolution modeling remains as a viable alternative
- Spatial resolution of temperature important in western US.
- Big challenge is transition of snowfall to rainfall in a warming climate-significant issue in water resources

Observed changes in mean and extreme precipitation over the Great Plains

- Half of CO2 increase during industrial revolution has occurred since 1992
- N. Great Plains precipitation increased from summer to fall
- S. Great Plains precipitation increased from Oct to March
- In the Corn Belt the spring and fall are wetter
- Extreme precipitation Big floods in Ames: 1993, 2010; 31 percent increase in heavy precipitation
- S. Dakota has more precipitation now than Ohio
- More precipitation is not always better for agriculture (erosion, nutrient runoff, soil moisture, field operations and crop drying
- No obvious relation to precipitation to patterns of warming. Both global and regional models predict the trend of more frequent heavy precipitation
- Water-related limitations in understanding: Relative role of large-scale climate change and variability versus local influences (e.g., LULCC, land feedback)

- Key objectives and tasks: Detailed assessment of LULCC change in cover type, intensity (urbanization, agriculture management, tiling, etc). Improved detail and realism of land surface processes in models, including comparison to observations.

- Social, economic and environmental benefits: More effective management of water quantity (local and regional infrastructure, agricultural uses), water quality (drinking water, recreation, Gulf hypoxia), and transportation.

- No ET data available back to the 1950s. Earliest is 1970s.

RHP could be the flagship project for the new US GEWEX Project Office.

Noted: Water managers generally distrust models but they do trust Paleo projections.

Strategy
What do see as key objectives and tasks?

- Map hypothesis-driven, process-based routes and checkpoints to address specific questions through observations and model experiments

- Prioritize routes/systems
- Do it
- Recognize the difference between impact and science driven questions and develop alternative routes with common checkpoints
- Do both
- Welcome surprises
- Critical mass participating

High-resolution modeling

- Warm/dry grass of mid-continental US could serve as key grand challenge (for USGRP) and one that would have impact on model development.
    - New tools for downscaling focusing possibly on ensembles, sensitivity, etc.
- Questions about how to do the downscaling--has to be done with coarse research models and drive different land surface models….

California Drought

- 2000-2010 snowpack was very dusty --based upon graduate student study published in *Geophys. Res. Letters* in 2013. CPCRC used this information to fix their forecasts.
- Weekly flights over snow pack-- data is available via website (aso.jpl)
- Radiative forcing modeling – working on retrospective form and projections out to 150 years. Use MODIS time series.
- Alpine modeling – avalanche distribution (1.5 to 3 m data available).

Most relevant RHP research questions

- What characteristics of precipitation affect water availability and how are they changing?

Most relevant RHP research foci:

- High resolution coupled climate modeling
- Evaluation of climate projections and assessment of climate impacts
- Mountain (terrain) hydrology
- Observations for process level understanding and model evaluation and refinement.

Which water related limitations in process understanding, modeling and monitoring in the western US and Canada require a large 5-10 year integrated and interdisciplinary team approach?

Understanding, anticipating changes in precipitation and stream flow seasonalities and frequencies

Address the following:

- Long term, high resolution, coupled modeling
- Water resources risk assessment-threats to life, property
- Water availability, changing legal rights, water quality

Integrated water availability (WA) project

- To what accuracy is the current WA and regional water use known?

- How have/may changes in land use, including snow cover and phenology, feedback on local and remote WA?
- What are the key processes and their sensitivities well modeled?
- Can we verify process sensitivities through existing observations or a new campaign (i.e., summit to plains)?
- Central Valley WA project at intra-seasonal timescales: accounting for direct surface/ground water withdrawal and global warming indirect effects

Look at what we have first. How much water is there (take inventory) and how is it going to change? Have more than one region (e.g. each region is affected by a monsoon). Mountain regions are key.

Integrated system observations– "state of the water cycle"?

ET issues in models that require better observations

Need a tie-in with snow physics

Complex terrain slopes are an important area of study

NLDAS ensemble – areas where we do not agree?

Recommendation was made for including the California Central Valley if the region of study is the Rocky Mountain corridor. Look at surface and subsurface issues related to recharging groundwater in the central valley.

Use North American CORDEX as the backbone of the project?

Data bazaar – need one place to find all the data. Data access problems have hindered progress in past projects.

NEXT STEPS—DEVELOPING A PROJECT PLAN

The RHP approval/assessment criteria is available at gewex.org under RHPs. RHPs are expected to last 5-10 years.

The North American RHP project plan should have a science plan and an exit plan that includes a science and applications synthesis and data archival procedure. Broad scale science questions and areas of interest should be listed.

There are GEWEX science questions that address regional aspects and have broader science to advance. Need metrics to address questions.

Develop an overarching science question.

Define scientific scope, and then define the region that ties into it.

A schematic approach was used in the research plan for CCRN with different themes. E.g., How we can improve our understanding? What are the hotspots? Prediction and up scaling (land surface models)

The progress of the project could be measured in process level understanding and prediction.

The plan should address fundamental scientific issues that now prevent us from doing reliable projections. Also should address uncertainty in water supply at different scales.

What observations do we need to address processes and how does it all fit together?

- Improve national water model.
- Improve ET cross scales.

Work can be broken down into components:

- Take stock component
- Observation component
- Evaluation component
- Modeling component

Address how all this ties into global picture.

What are the hooks needed to get this project going?

Take Inventory

- Modeling
- Observational Networks
- Projects

Develop wish list of model simulations

What can we do sooner than later?

RHPs in other countries usually have several sources of funding. Smallest pot of funds is for overall coordination. More money is available for addressing particular regional issues. Our challenge is to bring current research together and find a way to fund our research.

Suggestion to list process questions in a table and how they can be addressed within ongoing projects and determine what other research, etc. is needed.

ACTION ITEMS

A1. Monthly RHP WebEx teleconferences will be conducted at the end of the month. Roy Rasmussen will set up and run them. IGPO will pool attendees to determine the best date and time for the telecon and send out the announcement.)

A.2 Proposed science questions should be sent to IGPO to collate and distribute (due a week before the teleconference)

A.3 Prepare and distribute an overview PowerPoint presentation summary of all presentations from the meeting (Peter van Oevelen)

A.4. Provide early to mid-career scientist support for addressing observations (Craig Ferguson and Tom Painter)

A.5 Host the next meeting at Mammoth Lakes, CA. Date TBD. (Tom Paine)