Global Water Cycle Observations

Global Energy and Water Exchanges

GEWEX Organization, Science Questions & Imperatives
WCRP Grand Challenges

Version: 3.0.0 (Oct 18 , 2015)

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BASED UPON CONTRIBUTIONS FROM: GRAEME STEPHENS, SONIA SENEVIRATNE, KEVIN TRENBERTH, MICHAEL EK, MATT RODELL, HOWARD WEATHER AND MANY OTHERS

Outline

- **GEWEX and WCRP, Context, History and Overview**
- **GEWEX Organization**
- **GEWEX Science**
  - GEWEX Science Activities per Panel
  - GEWEX Science Questions
  - GEWEX Imperatives
- **Water Availability Grand Challenge**

World Climate Research Programme

Sponsored by the World Meteorological Organization, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

- **The WCRP Mission:** to facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.

WCRP
World Climate Research Programme

GEWEX

GEWEX

A brief history

- Born out of the realization that the Earth observational systems at that time (the early 1980's) needed to be improved on if more progress was to be made on the meteorology and global climate research.
- Two feasibility workshops were held in 1987 and 1988 and in the first part of 1990 a science plan was finalized
- In December of 1990 the Global Energy and Water cycle Experiment (GEWEX) was approved by WMO and ICSU as a core project of the World Climate Research Programme (WCRP)

What We Do

The Global Energy and Water EXchanges (GEWEX) project of the World Climate Research Programme (WCRP) facilitates, enables, coordinates international climate and related research activities with an emphasis on land – atmosphere processes and interactions.

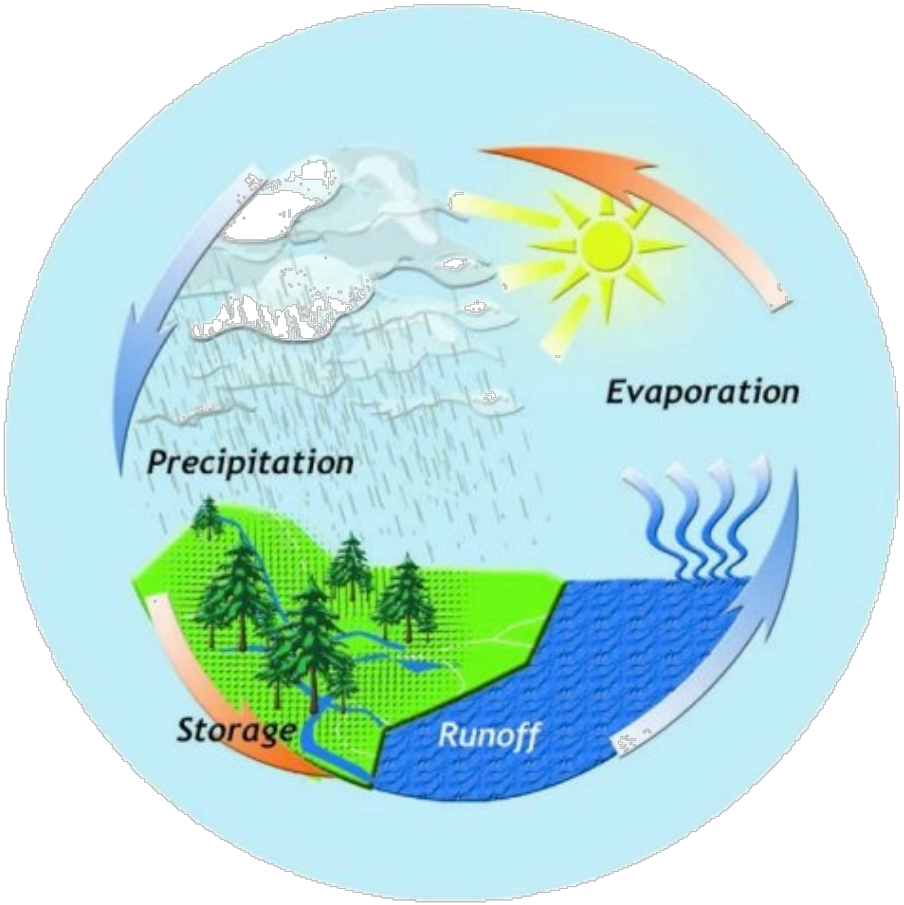
From sub-surface processes related to hydrology to atmospheric processes including interactions between the troposhere and the stratosphere from regional to global scales

The Subject

The Earth – From Global to Local Studies

The Processes

The Earth's Water and Energy Cycle



Why It Matters:

Water

- **Water is both a human and societal need**
  - Is water a tradable or public good (i.e. are we customers vs. citizens)?
- **Fresh Water is a limited recyclable resource**
- **Water 'regulates' the Earth System much like blood in the human body**
- **Global Change and Climate Change are driving the changing pressures on the system**
- **Distribution of Fresh Water is the MAIN Challenge**
- **Understanding the system can help define the current and future strategies for adaptation and planning**

Why It Matters

Energy

- Solar Radiative Energy is “unlimited” and it drives the Earth’s System – and it is where ‘all’ other energy forms are derived from
- Fossil fuels are limited and have applications beyond just as an energy source
- Changes in the way solar energy is transformed (latent vs sensible heat) directly impact the water cycle (think cities vs rural areas, increased CO_2 etc.)

GEWEX Focus

Water and Energy - People

- Water is a local ‘challenge’ driven by global processes
- GEWEX focuses on improved understanding of the relevant geophysical processes of water and energy and the human interaction therein to better model and predict changes
- Water and Energy Security are intrinsically related to Food Security – The Water-Energy-Food Nexus -> PEOPLE

GEWEX

History continued

- Phase I: 1990 -2002
- Phase II: 2002 – 2013
- Phase III: 2013 - 2022

Phase I: 1990 - 2002

Science Objectives

- Determine the hydrological cycle and energy fluxes by means of global measurements of atmospheric and surface properties.
- Model the global hydrological cycle and its impact on the atmosphere, oceans and land surfaces.
- Develop the ability to predict the variations of global and regional hydrological processes and water resources, and their response to environmental change.
- Advance the development of observing techniques, data management, and assimilation systems for operational application to long-range weather forecasts, hydrology, and climate predictions.

Phase II: 2002 - 2013

Science Objectives

- **In addition to the Phase I Science Objectives GEWEX in Phase II addresses the following principal scientific questions:**
  - **Are the Earth's energy budget and water cycle changing?**
  - **How do processes contribute to feedback and causes of natural variability?**
  - **Can we predict these changes on up to seasonal to interannual scales?**
  - **What are the impacts of these changes on water resources?**

Phase III: 2013 ~ 2022

Science Objectives & Imperatives

- **Building upon the results and experience from Phase I and II the GEWEX community for Phase III has developed through an open and interactive process:**
  - A new Vision and Mission Statement
  - An Imperatives document describing the framework of necessary activities
  - The GEWEX Science Questions to be address in the next 5 to 10 years and which contribute directly to the WCRP Grand Challenges

GEWEX Vision

Water and energy are fundamental for life on Earth. Fresh water is a major pressure point for society owing to increasing demand and vagaries of climate.

Extremes of droughts, heat waves and wild fires as well as floods, heavy rains and intense storms increasingly threaten to cause havoc as the climate changes. Other challenges exist on how clouds and aerosols affect energy and climate. Better observations and analysis of these phenomena, and improving our ability to model and predict them, will contribute to increasing information needed by society and decision makers for future planning.

GEWEX Mission

To measure and predict global and regional energy and water variations, trends, and extremes (such as heat waves, floods and droughts), through improved observations and modeling of land, atmosphere and their interactions; thereby providing the scientific underpinnings of climate services.

World Climate Research Programme

Sponsored by the World Meteorological Organization, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

- **The WCRP Mission: to facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.**
- The two overarching objectives of the WCRP are:
- 1) ***to determine the predictability of climate***; and
  2) ***to determine the effect of human activities on climate***
- Progress in understanding climate system variability and change makes it possible to address its predictability and to use this predictive knowledge in developing adaptation and mitigation strategies. Such strategies assist the global communities in responding to the impacts of climate variability and change on major social and economic sectors including food security, energy and transport, environment, health and water resources.

WCRP World Climate Research Programme

GEWEX

Six WCRP Grand Challenges 2014

To inspire the community to become involved. They are specific and focused while identifying barriers and ways to advance the science, and they should capture the imaginations of funding agencies, science program managers, and the public.

1	Action-oriented regional climate information
2	Regional sea level
3	Cryosphere in a changing climate
4	Cloud and climate sensitivity
5	Changes in water resources
6	Prediction and attribution of extreme events

Six WCRP Grand Challenges 2015

To inspire the community to become involved. They are specific and focused while identifying barriers and ways to advance the science, and they should capture the imaginations of funding agencies, science program managers, and the public.

1	Decadal Prediction
2	Regional sea level
3	Cryosphere in a changing climate
4	Cloud and climate sensitivity
5	Changes in water resources
6	Prediction and attribution of extreme events

World Climate Research Programme

Joint Scientific Committee

Joint Planning Staff

Modeling Advisory Council

Data Advisory Council

Working Groups on: Coupled Modeling (WGCM), Numerical Experiment (WGNE), Regional Climate (WGRC), Seasonal to Interannual Prediction (WGSIP)

Cryosphere-Climate	Ocean-Atmosphere	Land-Atmosphere	Troposphere - Stratosphere	Regional Climate Downscaling
CliC	CLIVAR	GEWEX	SPARC	WCRP CORDEX

GEWEX

WCRP Organization 2015

WCRP World Climate Research Programme

Joint Scientific Committee | **Joint Planning Staff**

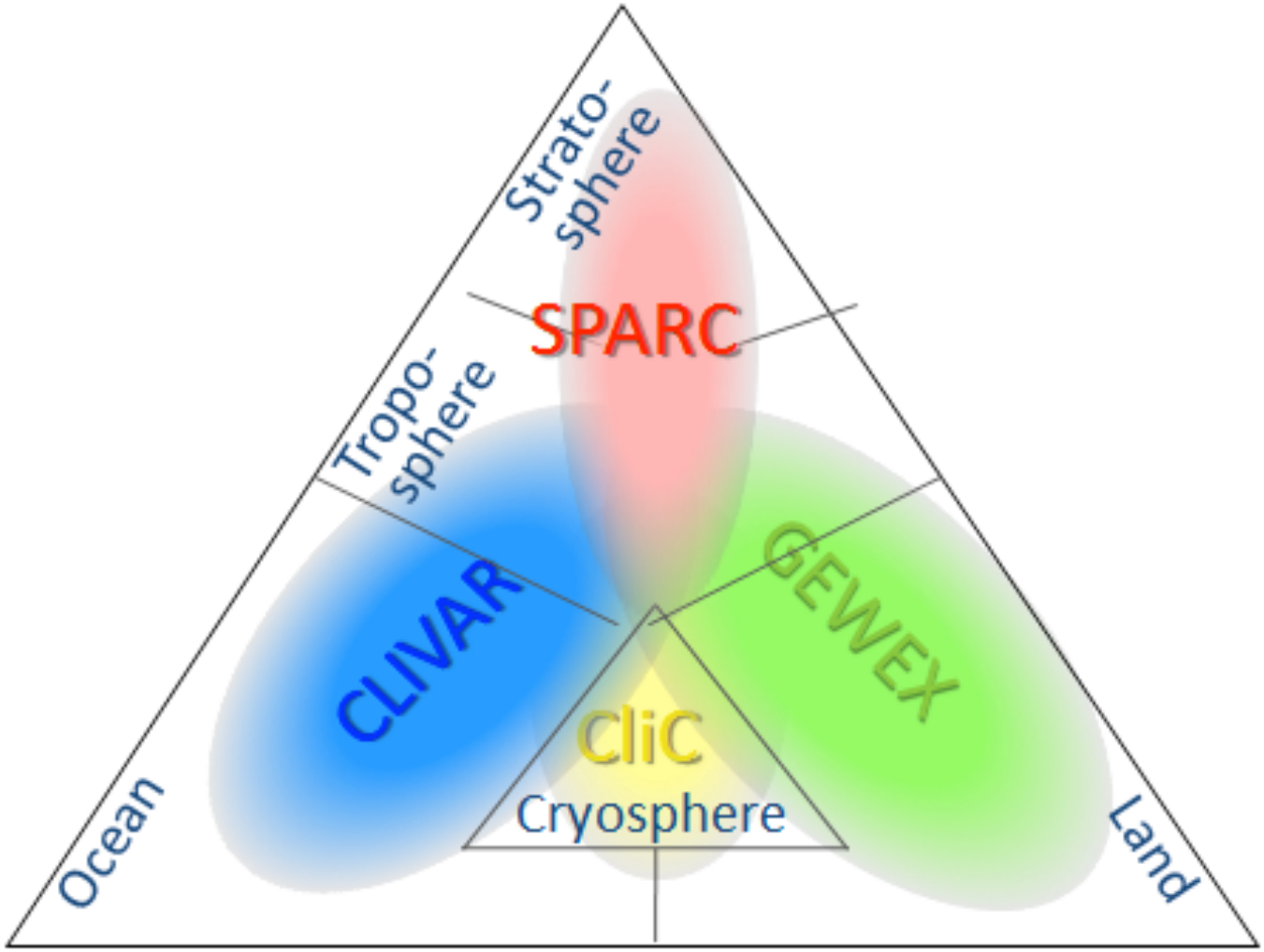
Modeling Advisory Council | **Data Advisory Council**

Working Groups on: Couple Modeling (WGCM), Region Climate (WGRC), Seasonal to Interannual Prediction (WGSIP), Numerical Experimentation (WGNE), Data (WGD)

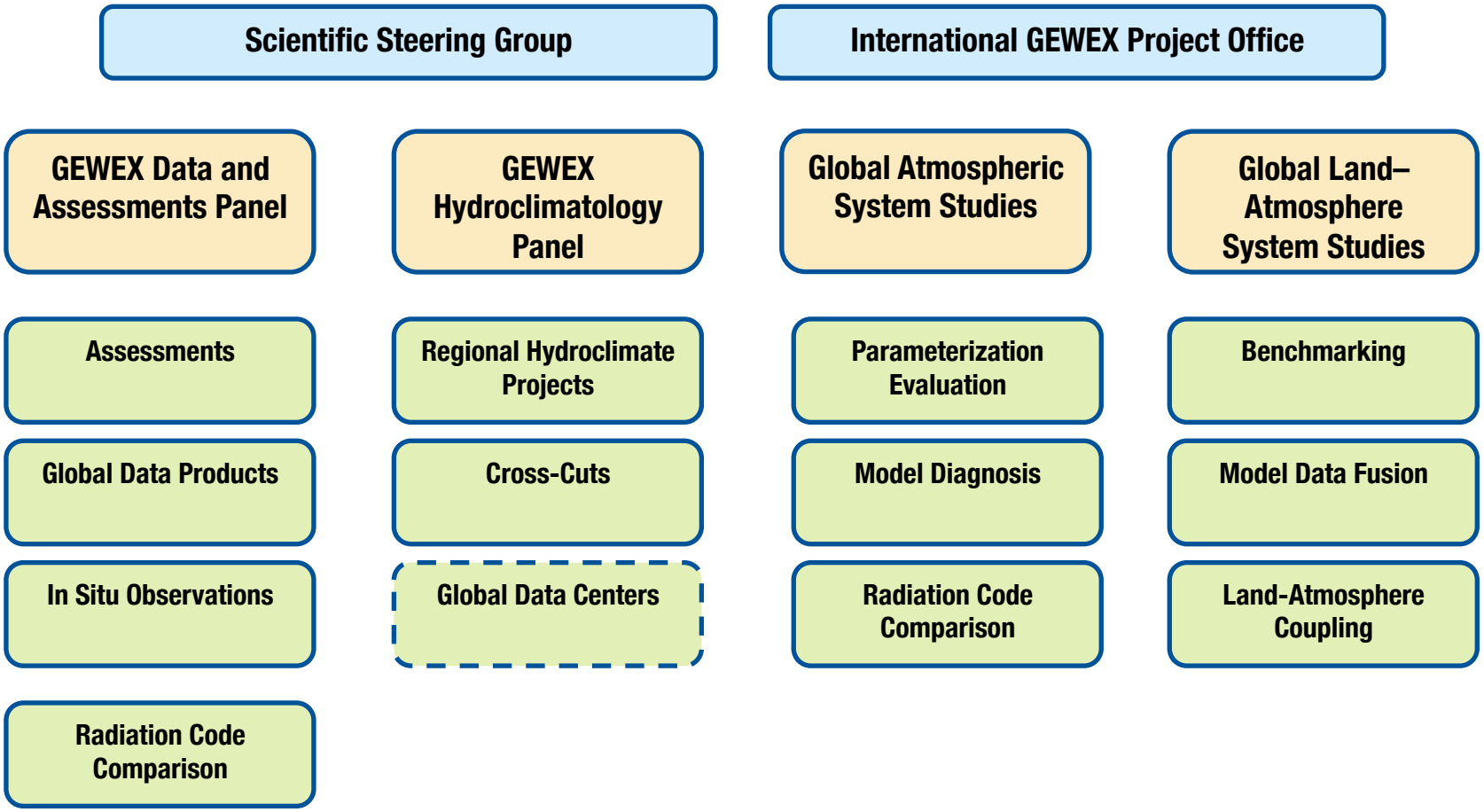
CliC	CLIVAR		GEWEX	SPARC	
Cryosphere-Climate Interactions	Ocean-Atmosphere Interactions	Decadal Prediction	Land-Atmosphere Interactions	Troposphere-Stratosphere Interactions	G
		Regional Sea-Level Rise			G
		Cryosphere in a Changing Climate			G
		Changes in Water Availability			G
		Aerosols, Precipitation & Cloud Systems			Gass
		Climate Extremes			G

GEWEX

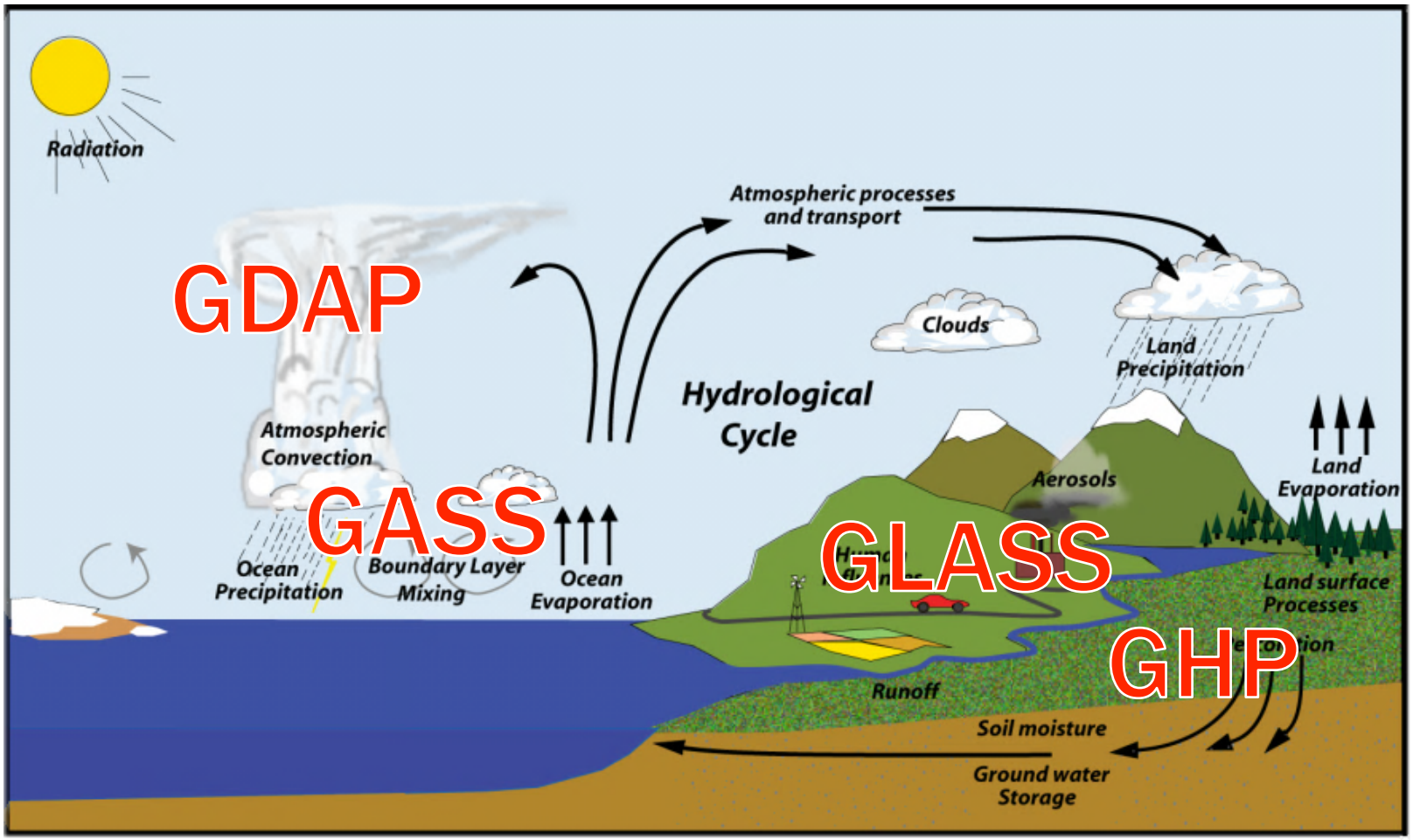
GEWEX within WCRP



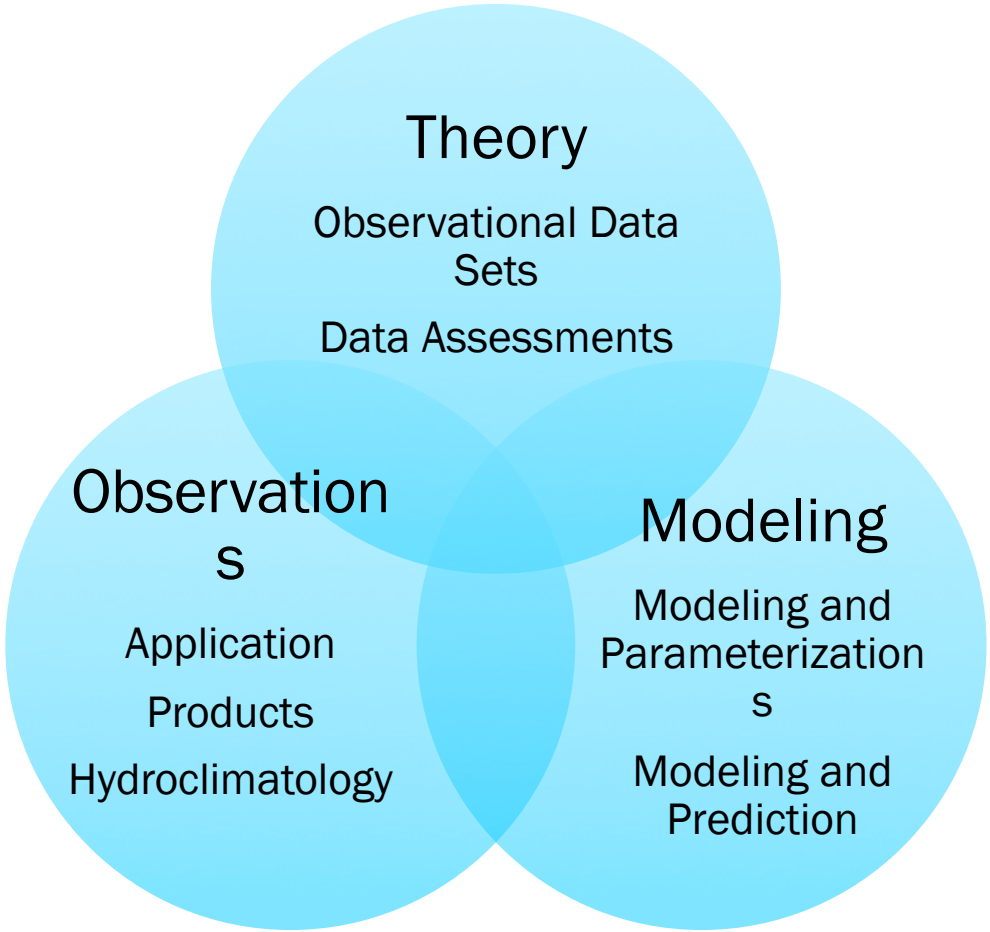
GEWEX Organization



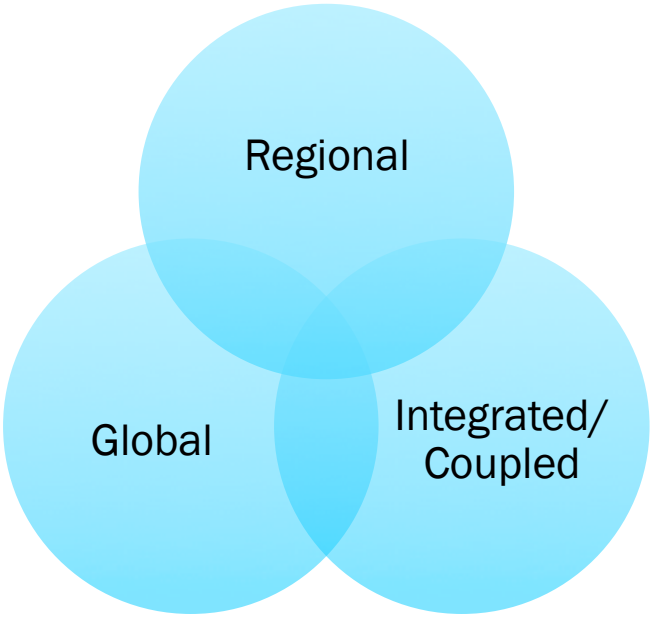
GEWEX: Major Components



The Tools

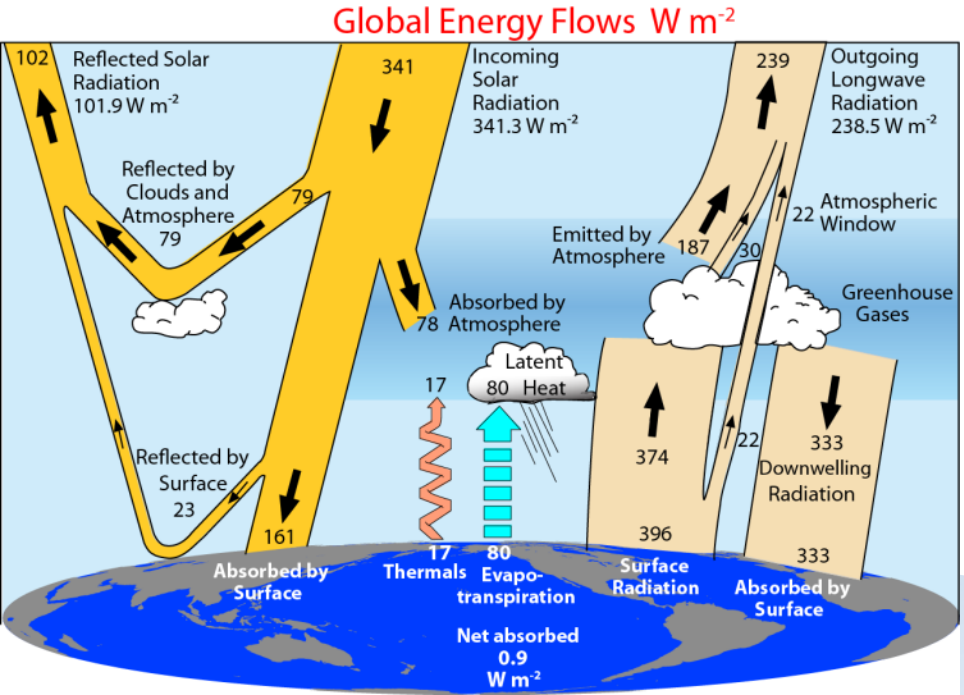


Fields of Use



GEWEX Data and Assessments Panel

- **Radiative processes** and understanding
  - Develop and improve of **radiative transfer** codes, comparisons
- **Global Data sets**
- Global In-situ **observational networks**, development and standardization (radiation, soil moisture)
- Reprocessing of datasets
- **Assessment** and intercomparison studies
- http://www.gewex.org/GDAP.html

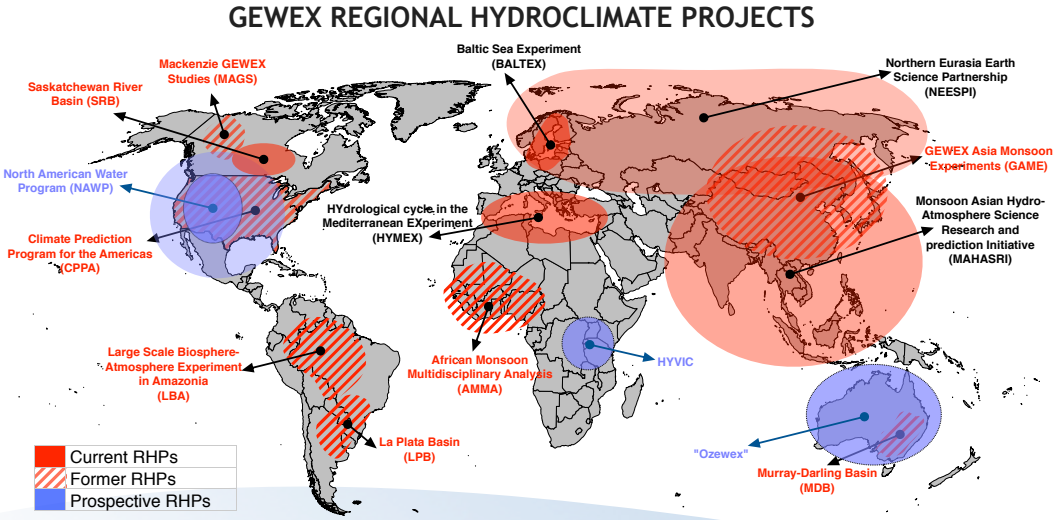


Global datasets

Aerosols
Clouds
Radiation
Water Vapor
Precipitation
Surface fluxes
Soil Moisture
...

GEWEX Hydroclimatogy Panel

- **Regional hydroclimate projects**
- Globally distributed extensive **regional data sets** : water and energy cycle observations (in situ and space borne and modeling data)
- **Global Data Centers**; data management system / GEO Prototype for Water Cycle Observations
- **Regional climate and hydrological modeling and process** Descriptions
- **Hydrological Applications** and Forecasting (Drought monitoring, Hydrological Ensemble Predictions…)
- http://www.gewex.org/projects-ghp.html

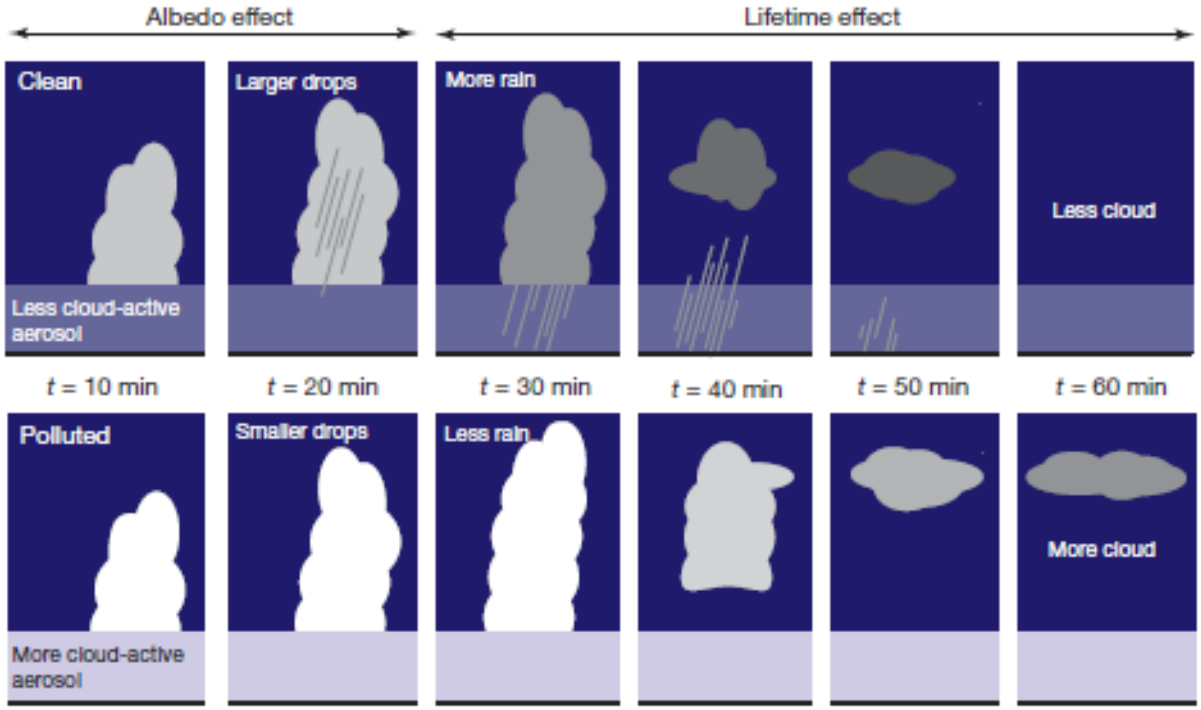


RHPs	Proposed
BALTEX	NAWP
HYMEX	✔HYVIC
LBA	TPE
LPB	BALTIC-EARTH
MAHASRI	✔OZEWEX
MDB	
AMMA	New
NEESPI	✔SasRB - CCRN

GEWEX Modeling: GASS

Global Atmosphere System Study

- **Atmospheric processes,** esp. clouds, convection, microphysics
- Model **Parameterization** evaluation and development
- **Data sets** and **tools**, intercomparisons
- **Atmospheric Boundary Layer**
- Strong cooperation with NWP via WGNE
- http://www.gewex.org/gass_panel.html



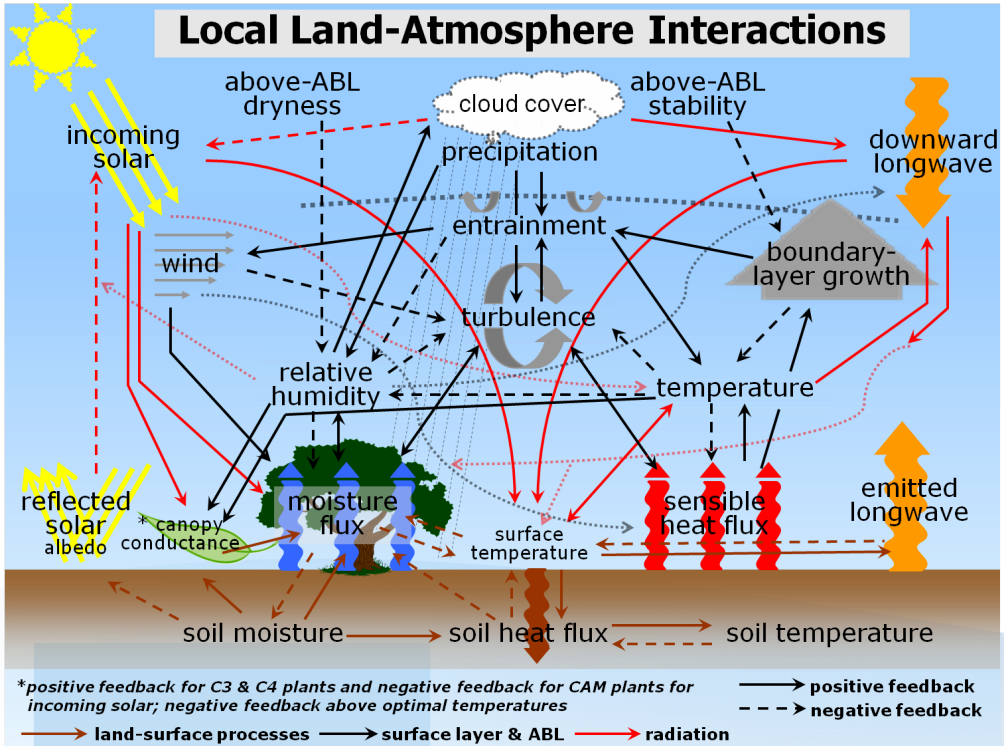
Projects

Boundary Layer clouds
Polar clouds
Convection, clouds
GABLS3
MJO
Single Column Models
Cloud Resolving Models
Greyzone Project
GASS-GHP links

GEWEX Modeling: GLASS

Global Land Atmosphere System Study

- Land surface modeling
- Model **Parameterization** and development from land surface process
- **Data sets** and **tools**, intercomparisons
- **Land-atmosphere coupling**
- **Model Data Fusion**
- Strong cooperation with NWP via WGNE
- http://www.gewex.org/glass_panel.html



Ongoing:

ALMIP2 – Links to GHP

GLACE2-CMIP

LoCo Working Group

LUCID2 – Links to iLEAPS

GSWP3 – Links to carbon community

PILDAS – Links to WGNE

DICE – GLASS/GABLS diurnal cycles

PALS/Benchmarking (PLUMBER) – Links to GHP

LoCo/SGP testbed

GEWEX Science Questions

- Are these questions actionable/action-oriented?
  - I.e. are they tractable, and is there a way forward?
- What new opportunities have arisen that relate to observations (such as new satellites; proposed field projects), models (computers, better resolution, new models like CMIP5), ideas?
- What benefits might accrue? What are the impacts? Why does it matter? Are there links to food, water, health, energy, biodiversity…?

Four GEWEX Science Questions

For the next 5 to 10 years

1	Observations and Predictions of Precipitation
2	Global Water Resource Systems
3	Changes in Extremes
4	Water and Energy Cycles and Processes

Four GEWEX Science Questions

For the next 5 to 10 years

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

Four GEWEX Science Questions

For the next 5 to 10 years

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

Four GEWEX Science Questions

For the next 5 to 10 years

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

Four GEWEX Science Questions

For the next 5 to 10 years

4	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?

1. Observations and Predictions of Precipitation

How can we better understand and predict precipitation variability and changes?

- How well can precipitation be described by various observing systems and what basic measurement deficiencies and model assumptions determine the uncertainty estimates at various space and time scales
- How do changes in climate affect the characteristics (e.g., distribution, amount, intensity, frequency, duration, type) of precipitation, with particular emphasis on extremes of droughts and floods?
- How much confidence do we have in global and regional climate predictions of precipitation?

2. Global Water Resource Systems

How do changes in land surface and hydrology influence past and future changes in water availability and security?

- **How do changes in land surface and hydrology influence past and future changes in water availability and security**
- **How do changes in climate affect terrestrial ecosystems, hydrological processes, water resources and water quality, especially water temperature?**
- **How can new observations lead to improvements in water management?**

3. Changes in Extremes

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

- What are the short-term, mid-term and strategic requirements for the existing observing systems and data sets, and which observations are needed to accurately quantify trends in the intensity and frequency of extremes on different space/time scales?
- How can models be improved in their simulation and predictions or projections of the magnitude and frequency of extremes?
- How can the phenomena responsible for extremes be better simulated in models?
- How can we promote development of applications for improved tracking and warning systems arising from extremes?

4. 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?

- Can we balance the energy/water budget at the top-of-atmosphere?
- Can we balance the energy/water budget at the surface of the Earth?
- Can we further track the changes over time?
- Can we relate the changes in surface energy/water budget with atmospheric-oceanic processes and long-term variability
- Can we improve confidence in feedbacks associated with cloud-aerosol-precipitation interactions in the climate system?

GEWEX Imperatives

The Imperatives – things that must be done - provide a strategic view of GEWEX activities for 15 years beyond 2013. They form the framework for a more focused set of GEWEX Science Questions (GSQs) whose main focus is on the 5-10 year period from 2013-2022.

GEWEX Imperatives

Datasets	1	Applications	5
Analysis	2	Technology Transfer	6
Processes	3	Capacity Building	7
Modeling	4		

Water Availability Grand Challenge

A concise overview 2015

Version: April 7, 2015)

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General Challenge

Water has posed societal and human challenges throughout history

- **Too much, too little, too bad ⇒ Quantity and Quality**
- **A cross sectoral approach to water security**
  - Access to fresh water
  - Safety from water related disasters
- **Better planning, strategy for adaptation and mitigation**

So really nothing new ?

Well fortunately not exactly!

- As society seem not very willing to learn from others and from our past.
- The next slide shows the lessons learned from the extensive drought in Victoria, Australia in the early 2000's - The WCRP Water Availability Grand Challenge focuses on the science in this realm to better address the "Four Key Principles"

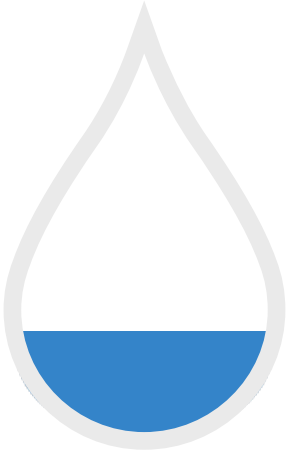
Four Key Principles

John Thwaites, Monash University, Melbourne, VIC, Australia

GEWEX Science Conference 2009, Melbourne, Austrialia

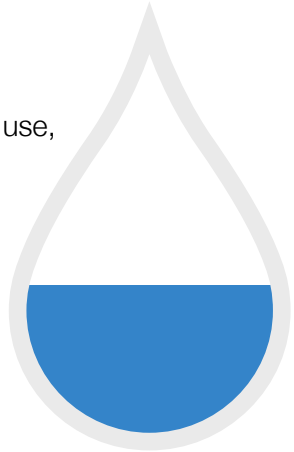
Conservation

Limit use, appropriate pricing, reduce spillage, change in societal attitude . . .



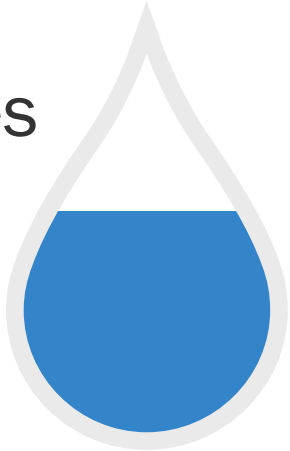
Recycling

Reuse of water, stormwater use, split sewage system . . .



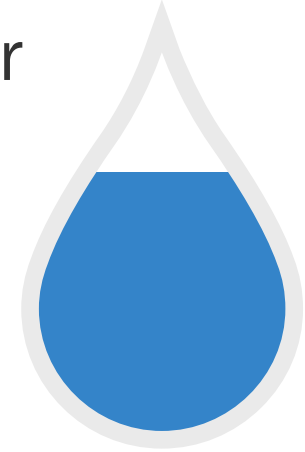
Boosting Supplies

Increase surface and sub surface reservoirs, desalinization plants, …



Looking after Rivers

A healthy ecosystem is more efficient, river systems are part of groundwater recharge . . .



Preview: Short term deliverables

- Global water/energy isnt 'balanced" (WG on E fluxes/water to deliver joint energy/water balance with full error characterization– 3yrs)
- Provide the basis for understanding global hydological sensitivity & regional hydrological change.
- Precipitation assessment study – report documenting major gaps in observations/ capabilities
- One known gap concerns mountain precip. Develop new initiatives to target this gap and provide data in selected regions (e.g. MOUNTerrain, INARCH) : output Q/C mountain precip. data products in selected regions3-5 yrs
- Improve representation of land water fluxes, water management influences in climate models (LS3MIP, LUMIP, HUMAN) – 3 -5 years (CMIP6 cycle)
- Improve modelling the terrestrial water cycle over complex terrain realized through high resolution modelling (HiRES, HiRESMIP) 3-5 yrs
- Develop new data records from non traditional data sources (e.g. GPS), traditional sources data underutilized (e.g. surface radar network data), emerging space assets (GRACE, GPM, SMAP) 3-5 yrs.

Water Availability Grand Challenge

'How will the character of fresh water availability change in the coming decades?'

How can we better understand and predict precipitation variability and changes?

.

How do changes in the land surface and hydrology influence past and future changes in water availability and security?

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

GEWEX Science Questions

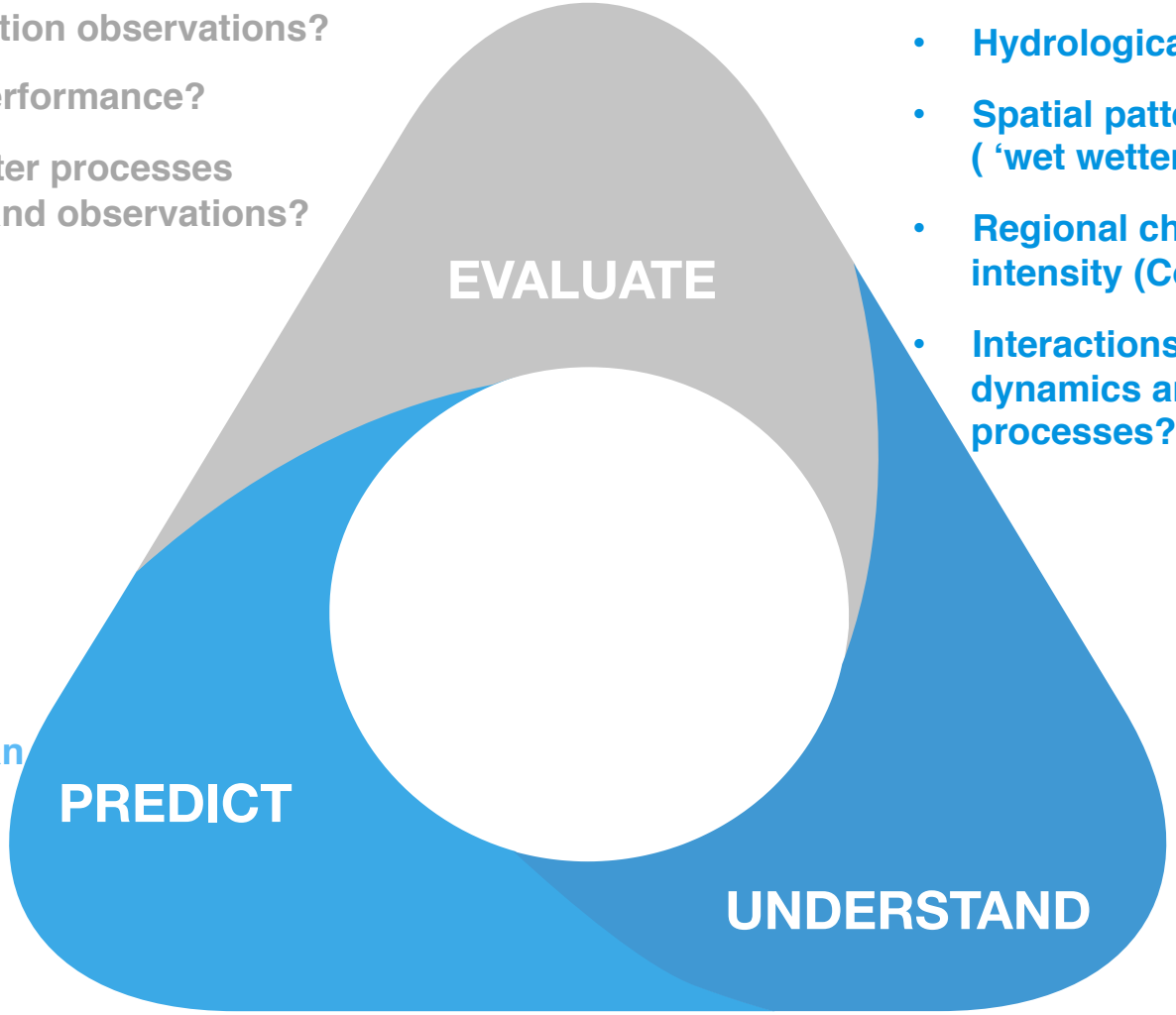
These first two questions form the basis/focus of the Water Availability Grand Challenge.

Extremes Grand Challenge

This questions is directly related to the above two questions but tackled primarily within the Extremes Grand Challenge

Water Availability GC - Themes

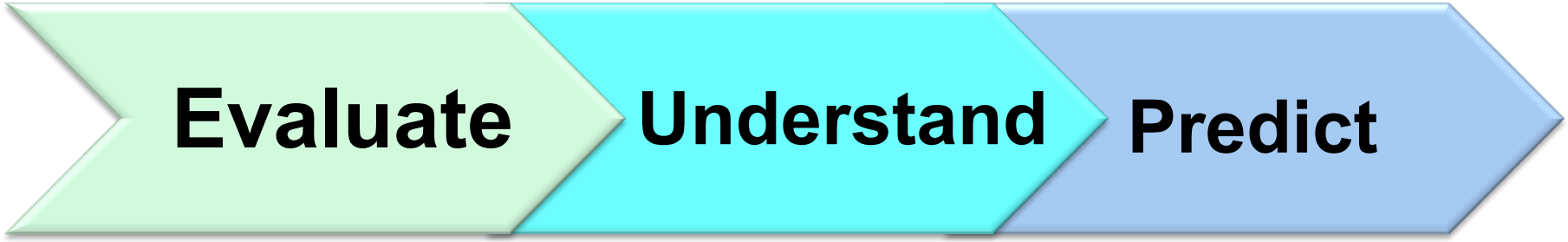
- Precipitation observations?
- Model performance?
- Land-water processes models and observations?



- Hydrological sensitivity?
- Spatial pattern of precip change? ('wet wetter, dry drier'?)
- Regional changes to precipitation intensity (Convection?)
- Interactions between land water dynamics and atmospheric processes?

- Models improvements
- Modeling human impacts

Implementation activities



	Evaluate	Understand	Predict
GDAP	• *Precip Assessment study* • *New initiatives on mountain precip & frozen precip*	• *Monsoons in a changing climate (joint with CLIVAR)* • *Energy controls on global & regional water cycles*	• *HiRES* • *Soil processes w soils community;*
GHP	• *Development of new data sets (e.g. INTENSE),*	• *Hydrological sensitivity*	• *Subsurface hydrology;* • *GDIS;*
GASS	• *Model evaluation though focuses MIPS (LS3MIP,LMIP) Planned workshops a& contributions to obs4mip*	• *New modeling initiatives under HiRes (e.g. HiREsMiP)*	• *Water management influences in large scale models;*
GLASS	• *Model Process evaluations (PROES)*	• *Proposed Workshops: Fall 2015 'What sets the hydrological sensitivity?" CalTech ; Fall/Spring 2015; HiRES, NCAR Boulder*	• *Workshops under planning*

Conclusion

The successful implementation of the WCRP Grand Challenges and associated science questions described here depend significantly upon the GEWEX Imperatives: observations and data sets, their analyses, process studies, model development and exploitation, applications, technology transfer to operational results, and research capacity development and training of the next generation of scientists.

They involve all of the GEWEX Panels and will benefit greatly from strong interactions with other WCRP projects such as CLIVAR, SPARC, and CliC and other sister global environmental change research programs such as the IGBP, the International Human Dimensions Programme (IHDP), and DIVERSITAS.

Acknowledgement

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