GEWEX Activities and Observations in the Hindu Kush Himalayan Region

A brief exploration

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BASED UPON CONTRIBUTIONS FROM: JOHN POMEROY, GRAEME STEPHENS, SONIA SENEVIRATNE, KEVIN TRENBERTH, YAOMING MA, MICHAEL EK, MATT RODELL, ERIC WOOD, JOERG SCHULZ, CHRIS KUMMEROW, ROBERT A. SCHIFFER
AND MANY MORE...
Outline

- Capacity Development
- Very brief GEWEX and WCRP, Context, History and Overview
- GEWEX Science
  - GEWEX Science Activities per Panel
  - GEWEX Science Questions
  - (GEWEX Imperatives)
- Regional Hydroclimate Projects in HKH Regional Context – GEWEX INARCH
Capacity Development
A Crucial Element - Research

- **Aiming to empower long-term achievements in climate research**
  - Streamlining activities to clearly defined current/future research priorities
  - Continuous advocacy for **data and knowledge sharing**
  - Investment for **early career scientists**

- **Critical need for partnership**
  - Coordinated support with limited resources; in particular, climate research/applications for **regions**
  - Synergies to promote common research agenda across organizations, domains and communities
  - **Inclusive partnership** to further develop, based on science priorities
Capacity Development
A Crucial Element - Action

- **Enablers: Capacity to Act**
- **Across ‘scales’**
- **Soft and Hard Capacities**
Take Home Points

- Continued need for sustained obs.
- Observations, Data, Information and Knowledge are not the same!
  - Action can be taken without the above!!
- Stewardship of existing obs. Networks
- In the era of adaptation and mitigation in the context of climate change: research is more needed than ever! No obs. No monitoring. No Clue. . .
- Data access and sharing need constant attention and improvement
- Earth Observation an essential but not magical part of the observational system
- Integration of networks beyond WMO, Research... e.g. Agriculture, Industry
- Observations of the human dimension (extraction, iwmr, LULC, etc.) CRITICAL
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
World Climate Research Programme

Working Groups on: Coupled Modeling (WGCM), Numerical Experiment (WGNE), Regional Climate (WGRC), Seasonal to Interannual Prediction (WGSIP)
Lifetimes and sizes of atmospheric phenomena

- **CLIMATE PREDICTION**
  - Global Warming
  - Decadal Climate Variability

- **LONG RANGE FORECASTING**
  - (Seasonal to Interannual Climate Prediction)
  - Monsoon

- **EXTENDED-RANGE WEATHER FORECASTING**
  - Walker Circulation

- **WEATHER FORECASTING**
  - Cold Front
  - Highs and Lows

- **NOWCASTING**
  - Severe Storm
  - Cumulus Cloud
  - Dust Devil

- **CHARACTERISTIC LIFE TIME (SECONDS)**
  - 1 minute
  - 1 hour
  - 1 day
  - 1 month
  - 1 year
  - Decade
  - Century

- **CHARACTERISTIC SIZE (METRES)**
  - 1 km
  - 10 km
  - 100 km
  - 1000 km
  - 10 000 km
  - 100 000 km
Six WCRP Grand Challenges

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.

<table>
<thead>
<tr>
<th></th>
<th>Decadal Prediction</th>
<th>Regional sea level</th>
<th>Cryosphere in a changing climate</th>
<th>Cloud and climate sensitivity</th>
<th>Changes in water resources</th>
<th>Prediction and attribution of extreme events</th>
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GEWEX Science
GEWEX: Major Components
# Four GEWEX Science Questions

For the next 5 to 10 years

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<tr>
<td>1</td>
<td>Observations and Predictions of Precipitation</td>
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<td>2</td>
<td>Global Water Resource Systems</td>
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<td>3</td>
<td>Changes in Extremes</td>
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<td>4</td>
<td>Water and Energy Cycles and Processes</td>
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## GEWEX Imperatives

<table>
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<th>Datasets</th>
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<td>Analysis</td>
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<td>Processes</td>
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<td>Modeling</td>
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<td>Applications</td>
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<td>Technology Transfer</td>
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**GEWEX**
Showcase The Challenges

The grand environmental challenges facing human society involve the changing of Earth’s water cycle.

With a warming planet, perhaps the two most pressing questions facing us are:

- Will the availability of fresh water change and how?
- By how much will sea level rise?

and our challenge is to develop an understanding that can provide quantitative answers to them.
Note to the challenges

- Those two questions are not independent
- Water availability is a (re)distribution issue (global available water is constant) -> hydrological cycle
- Is the hydrological cycle changing – intensifying?
- Focus on fresh water
- From the global to the local view
Availability of Fresh Water

Will it change and how?
The Global View
Inadequacy of Surface Observations

Global Telecommunication System meteorological stations. Air temperature, precipitation, solar radiation, wind speed, and humidity only.

Eight countries make groundwater data publicly available through the Global Groundwater Monitoring Network.

Issues include coverage gaps, delays, measurement continuity and consistency, data format and QC, political restrictions.
Surface Water balance

\[ \Delta S = P - Q - ET \]

- **Precipitation (P)**
  - In situ: Rain gauges, Snotel
  - RS (TRMM, CloudSat, AMSR-E, IR, …)

- **Change in storage (\( \Delta S \))**
  - In situ: Groundwater recharge/flow, soil moisture, standing water, wells
  - RS (GRACE, SWOT, AMSR-E \( \rightarrow \) SMOS \( \rightarrow \) SMAP)

- **Runoff (Q)**
  - In situ: Stream gauges, Global Runoff Data Center,
  - RS (SWOT)

- **Evaporation/Evapotranspiration (ET)**
  - In Situ: Fluxnet
  - RS Quickscat, AMSR-E, MODIS, ACOS/OCO,…
  - (RS of ET also requires surface net radiation)

• Global accuracy/consistency/ability?
A challenge for Hydrology:
Creating Climate Data Records for the terrestrial water budget using in-situ, remote sensing observations and LSM?

\[
\frac{dS}{dt} = P - ET - Q
\]

What the budget should look like?
(from off-line modeling, forced closure)

Potential Remote Sensing Datasets

- \( \frac{dS}{dt} \) from GRACE
- \( ET \) from SRB/ISCCP → Land Flux
- \( P \) from TRMM/CMORPH → GPM
- \( Q \) from TOPEX/POSEIDON/JASON → SWOT
## Potential global water cycle data sources

<table>
<thead>
<tr>
<th>Variable/Source</th>
<th>Type</th>
<th>Period</th>
<th>Resolution</th>
<th>Reference</th>
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<tr>
<td><strong>p</strong></td>
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<td>CPC</td>
<td>In-situ</td>
<td>1950-</td>
<td>1º</td>
<td>Chen et al., 2002</td>
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<td>CRU</td>
<td>In-situ</td>
<td>1901-</td>
<td>0.5º</td>
<td>Mitchell &amp; Jones, 2005</td>
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<tr>
<td>WM</td>
<td>In-situ</td>
<td>1900-</td>
<td>0.5º</td>
<td>Willmott &amp; Matsuura, 2010</td>
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<tr>
<td>GPCC</td>
<td>In-situ</td>
<td>1900-</td>
<td>0.5º</td>
<td>Schneider et al., 2008</td>
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<tr>
<td>GPCP/TMPA</td>
<td>In-situ</td>
<td>1998-</td>
<td>0.25º-1º</td>
<td>Huffman et al</td>
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<td>ET (LandFlux)</td>
<td>RS</td>
<td>1984-2006</td>
<td>1º</td>
<td>Vinukollu et al., 2010; Ershadi et al., 2013</td>
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<td>(4 algorithms)</td>
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<td>ERA-Interim</td>
<td>Reanalysis</td>
<td>1989-</td>
<td>T255</td>
<td>Simmons et al., 2006</td>
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<tr>
<td>MPI</td>
<td>In-situ</td>
<td>1989-</td>
<td>T255</td>
<td>Jung et al (2009)</td>
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<td>VIC</td>
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<td>1948-</td>
<td>1/2ºx1/3º</td>
<td>Sheffield &amp; Wood, 2007</td>
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<td>In-situ</td>
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<tr>
<td>GRACE</td>
<td>RS</td>
<td>2002-</td>
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<td>Swenson &amp; Wahr, 2002</td>
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Precipitation

- Direct EO Measurements e.g. GPCP, TRMM, GPM
- Understanding clouds and precipitation processes e.g. Cloudsat
- Aerosols and water vapor
- Rain gauge data e.g. GPCC
- Global Climate Models precipitation representation
Global Precipitation Climatology Project (GPCP)

Robert Adler, U. of Maryland-College Park, USA

GPCP data used in > 1500 journal articles
Synergy

CloudSat Radar

- Precipitation

CALIPSO 532 nm

- Tropical Thin Cirrus
- Mixed Phase Cloud
- Aerosol

MODIS 11 µm
Eye

Hurricane Ileana

CloudSat m radar

23 Aug 2006  GOES-11
21:00 UTC

Brightness Temperature (°C)

CALIPSO First light
Challenges - Precipitation

- Models: global models have biases that point to problems in the way precipitation (and cloud) physics is represented. Global models also miss major storm types (e.g. MCSs) that for example deliver large fractions of precipitation to real Earth (too little too often)

- Process perspective: We still do not know the extent to which the water cycle is influenced by aerosol but anecdotal evidence is building

- Observations: we still have a way to go and need to approach the problem in a more integrated way (tie clouds, aerosol and precipitation and then link to soil moisture, etc.) - globally our capabilities to address water cycle processes, while improved, seriously lag behind the science and model development
Change in Storage
Earth Observation

- Snow
  - GRACE, GPM

- Ground water and soil moisture
  - GRACE, ASCAT, AMSR-E, SMOS, SMAP, Tandem-L?

- Lakes and rivers
  - TOPEX/Poseidon, SWOT
Futures Prospect

• Due to the incompleteness of ground-based observations, additional space-based observation of water is critical.

• Future relevant satellite observing systems will include GRACE FO (terrestrial water storage), SWOT (surface water and river stage), Landsat 9 (land use / land cover), Sentinels, EARTHCare . . .

• Gaps in satellite observation of the water cycle:
  ➢ Snowpack / snow water equivalent (feasible)
  ➢ Evapotranspiration (demonstrated; needs a dedicated mission?)
  ➢ River flow/level (to be addressed by SWOT in 2020)
  ➢ Total groundwater storage and high resolution GW change (???)
  ➢ Water quality (infeasible beyond surface water color/turbidity)
  ➢ Water use (infeasible...)

GEWEX
The Local View
Brief History

- Continental Scale Experiments – CSE’s
- First one established in 1991: GCIP
- Shortly after more followed but most did not start as a GEWEX activity!!
- Open access and exchange of data envisioned but only partial successful
- Data management, protocols and QC well established
- Data used as integrator and collaboration stimulator
From CSE’s to RHP’s – Status 2016

1. Climate Prediction Program for the Americas (CPPA)
2. Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)
3. African Monsoon Multidisciplinary Analysis (AMMA)
4. Baltic Sea Experiment (BALTEX)
5. Baltic Earth
6. HYdrological cycle in the Mediterranean Experiment (HYMEX)
7. Mackenzie GEWEX Studies (MAGS)
9. Changing Cold Regions Network (CCRN) - Saskatchewan River Basin (SRB)
10. Northern Eurasia Earth Science Partnership (NEESPI)
11. GEWEX Asia Monsoon Experiments (GAME)
12. Monsoon Asian Hydro-Atmosphere Science Research and prediction Initiative (MAHASRI)
13. NEHVIC
14. RELAMPAGO
15. Baltics Earth
16. Hydrological cycle in the Mediterranean Experiment (HYMEX)
17. "OzEWEX"
18. Murray-Darling Basin (MDB)
Cross Cutting Activities

INARCH:
International Network for Alpine Research Catchment Hydrology

John Pomeroy,
Centre for Hydrology & Global Institute for Water Security,
University of Saskatchewan, Canada

www.usask.ca/hydrology  john.pomeroy@usask.ca
Urgency

- to IPCC (2014) WG II report – “In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality”
- Alpine catchments receive and produce a disproportionately large fraction of global precipitation and runoff.
- Snowfall does not equal accumulation on the ground!
- Snow, ice, and phase change domination of alpine hydrology means that it is especially sensitive to temperature change.
Significance

- Ongoing change in climate has already resulted in shorter seasonal snowcover duration, earlier spring hydrographs, greater rainfall fraction of total precipitation, glacier volume decline, ground thaw and woody vegetation increase in many alpine catchments.
- Some alpine catchments are contributing to higher frequency of floods and/or droughts.
Alpine Regions are Data Scarce

Left Side: (Viviroli et al. 2011).
Objective

To better understand alpine cold regions hydrological processes, improve their prediction, diagnose their sensitivities to global change and find consistent measurement strategies.
Sub-Objectives

1. How different are the measurement standards and how do these affect scientific findings?
2. How do the predictability, uncertainty and sensitivity of alpine catchment energy and water exchange vary with changing atmospheric dynamics?
3. What improvements to alpine energy and water exchange predictability are possible through improved physics, downscaling, data collection and assimilation in models?
4. Do existing model routines have a global validity?
5. How do transient changes in perennial snowpacks, glaciers, ground frost, soil stability, and vegetation impact alpine water and energy models?
Data Requirements

Surface based data requirements for this project will primarily be met by

• openly-available detailed meteorological and hydrological observational archives from long-term research catchments at high temporal resolution in selected heavily instrumented alpine regions,

• atmospheric model reanalyses,

• downscaled climate model as well as regional climate model outputs.
Activities

1. Facilitate exchange and collaboration
2. Improve algorithm development.
3. Examine hydrological model sensitivity to atmospheric change.
4. Demonstrate improvements to model predictability.
5. Evaluate mountain forcing fields.
6. Evaluate downscaling schemes.
7. Foster research and development.
8. Facilitate education and training.

AGU Fall Meeting 2015 - Session C027: Improved Understanding and Prediction of Mountain Hydrology through Alpine Research Catchments
Integrated Alpine Observing & Predicting Systems - IAOPS

Instrumented alpine catchments with, remote sensing, atmospheric modelling, downscaling, data assimilation in order to better evaluate mountain water and energy exchange.
International Collaboration through Field & Model Experiments

Upper Heihe River Basin, 4150 m China  
Zugspitze, 2650 m Germany
Turbulent system, CO₂/H₂O flux and radiation system

Radio sonde system
INARCH: International Network for Alpine Research Catchment Hydrology

Canada – Canadian Rockies, BC & Yukon; USA – Reynolds Creek, ID; Senator Beck, CO, Niwot Ridge, CO.
Chile - Upper Maipo & Upper Diguillín River Basins, Andes,

Germany – Schneefernerhaus & Zugspitze;
France – Arve Catchement, Col de Porte & Col du Lac Blanc;
Switzerland – Dischma & Weissfluhjoch;
Austria - OpAL Open Air Laboratory, Rofental
Spain – Izas, Pyrenees;
China – Upper Heihe River, Tibetan Plateau,
Nepal – Langtang Catchment, Himalayas
Sweden – Tarfala Research Catchment

Integrated Alpine Observing and Predicting Systems (IAOPS), initial sites to be considered
WCRP Grand Challenges

Changes in water availability with rising temperature, changing precipitation and transient changes to vegetation cover in mountains. Wolf Creek Research Basin, Yukon, Canada (61°N) Reynolds Mountain East Basin, Idaho, USA (43°N)
Linkages

- GEWEX GHP Projects
  - Precipitation phase
  - Mountain precipitation
  - Changing Cold Regions Network

- Global Crysosphere Watch

- WMO-SPICE


- International Commission for Snow and Ice Hydrology (IUGG)
Other Activities

- Mountertain (Lead: J. Renwick)
- MAHASRI Legacy – NEW Asian RHP(s): Taikan Oki, Jun Matsumoto, ??
- Next INARCH Workshop in Paris region 9/2016
- GEWEX Panels – GHP, GDAP, GLASS and GASS
- WCRP Water Availability Grand Challenge
- Human Dimension in Hydrological Modeling across Scales
Take Home Points

- Continued need for sustained obs.

- Observations, Data, Information and Knowledge are not the same!
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CRITICAL
MORE INFORMATION ON:
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