GEWEX Activities and Observations in the Hindu Kush Himalayan Region

A brief exploration

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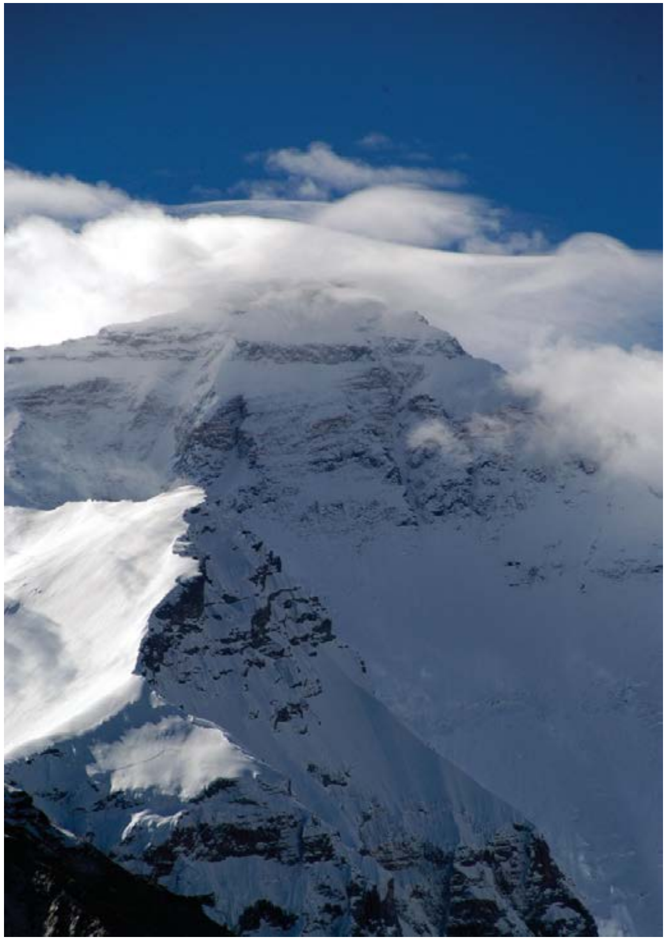
BASED UPON CONTRIBUTIONS FROM: JOHN POMEROY, GRAEME STEPHENS, SONIA SENEVIRATNE, KEVIN TRENBERTH, YAOMING MA, MICHAEL EK, MATT RODELL, ERIC WOOD, JOERG SCHULZ, CHRIS KUMMEROW, ROBERT A. SCHIFFER
AND MANY MORE…

Outline

- Capacity Development
- Very brief GEWEX and WCRP, Context, History and Overview
- GEWEX Science
  - GEWEX Science Activities per Panel
  - GEWEX Science Questions
  - (GEWEX Imperatives)
- Showcase The Challenge: Water Availability & Observations of the Global Water Cycle
- 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

World Climate Research Programme

- **Enablers: Capacity to Act**
- **Across 'scales'**
- **Soft and Hard Capacities**

Individual

This is the only level that is common to all the different definitions of levels.

Competencies, skills, knowledge and the abilities to use them, attitudes, values and culture can all be considered elements of an individual's overall capacity.

Organisational

Some agencies, e.g. UNDP, call this the institutional level

Some include linkages, networks, partnerships and sectors at this level

Sectoral

Many agencies have a fourth level, sometimes called sectoral, sometimes called something else, e.g. the Swiss Agency for Development and Cooperation (SDC) have a fourth level called 'Networks'

Institutional

This is the level of laws, policies and systems

This level exists sub-nationally, nationally, regionally and globally

This is often called the enabling environment

Global

Currently agencies concerned with climate change consider it essential to work at global level because of the complex interconnection of many environmental factors at the global level

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, iwrm, 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

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)

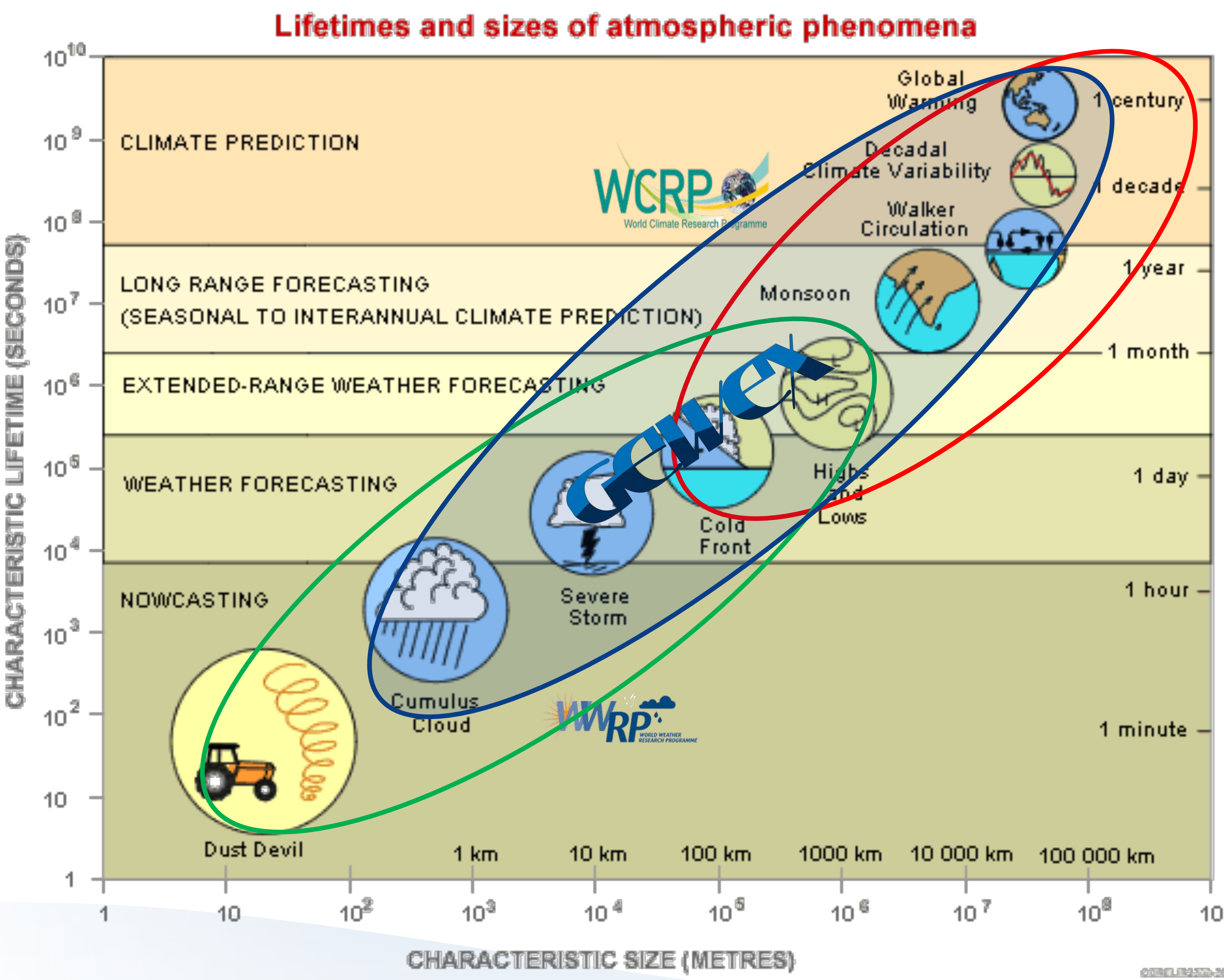
Cryosphere-Climate

Ocean-Atmosphere

Land-Atmosphere

Troposphere - Stratosphere

Regional Climate Downscaling


Lifetimes and sizes of atmospheric phenomena
CHARACTERISTIC LIFETIME (SECONDS)
CHARACTERISTIC SIZE (METRES)
CLIMATE PREDICTION
LONG RANGE FORECASTING
(SEASONAL TO INTERANNUAL CLIMATE PREDICTION)
EXTENDED-RANGE WEATHER FORECASTING
WEATHER FORECASTING
NOWCASTING
Global Warming
Decadal Climate Variability
Walker Circulation
Monsoon
Highs and Lows
Cold Front
Severe Storm
Cumulus Cloud
Dust Devil
1 century
1 decade
1 year
1 month
1 day
1 hour
1 minute
1 km
10 km
100 km
1000 km
10 000 km
100 000 km
WCRP
World Climate Research Programme
WWRP
WORLD WEATHER RESEARCH PROGRAMME

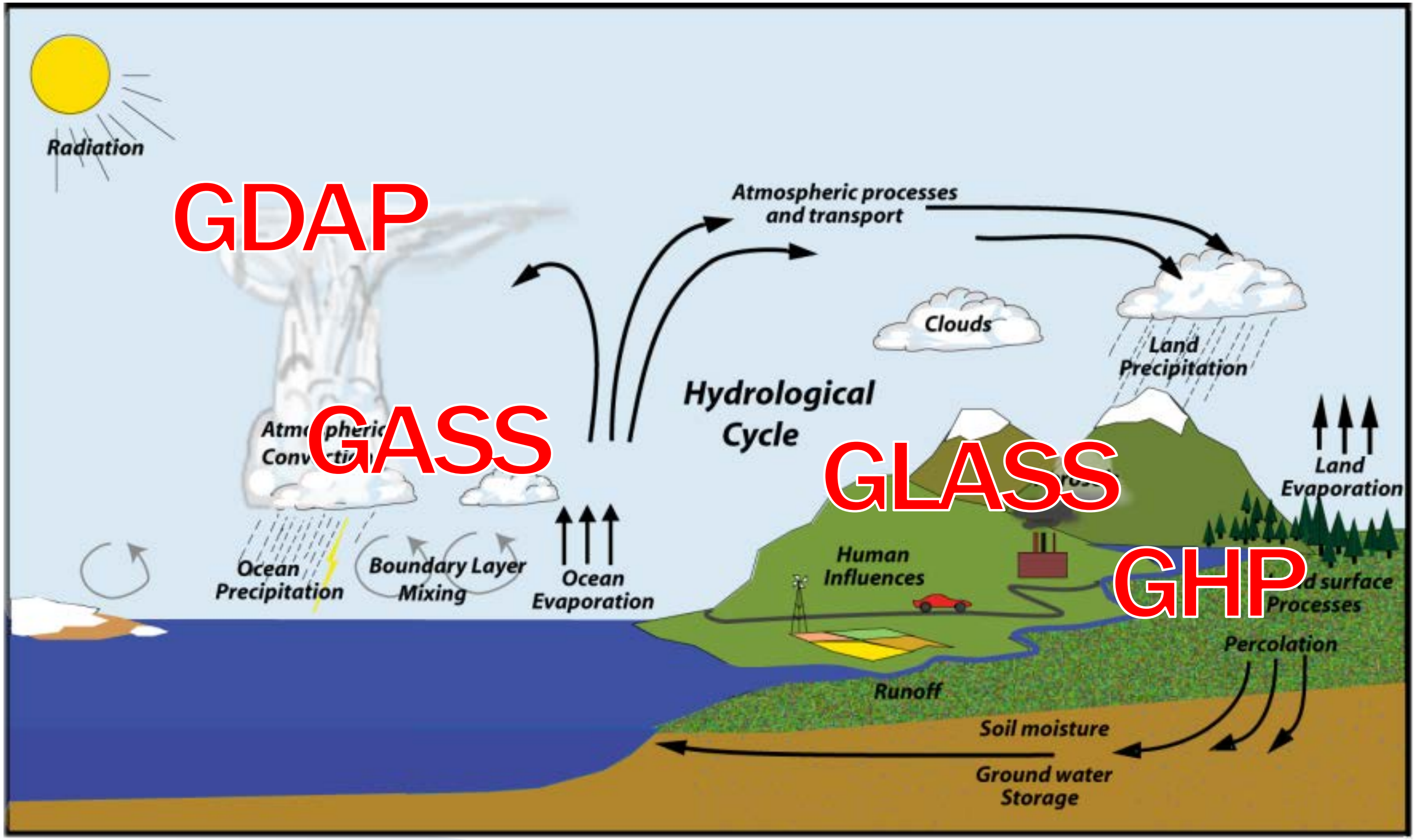
Six WCRP Grand Challenges

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.

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

GEWEX Science

GEWEX: Major Components



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

GEWEX

GEWEX Imperatives

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

Showcase The Challenges

The GEWEX Science Questions shown through two major scientific 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.

GEWEX

Note to the challenges

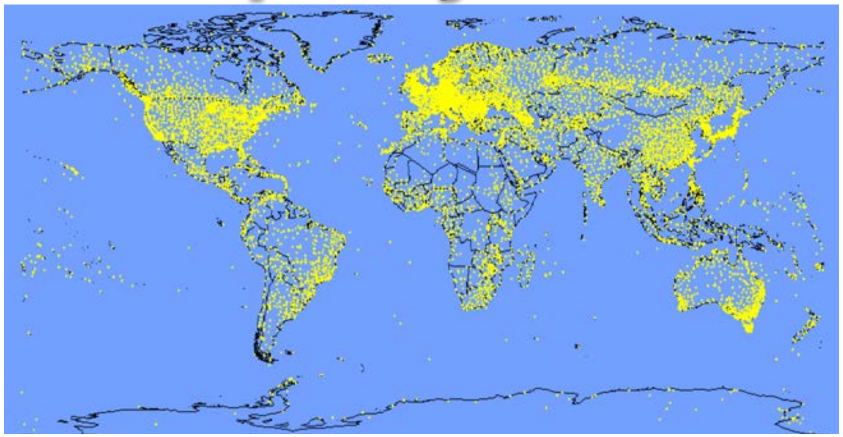
- Those two questions are not independent
- Water availability is a (re)distribution issue (global available water is constant) -> hydrological cycle
- Is the hydrological cycle changing – intensifying?
- Focus on fresh water
- From the global to the local view

Availability of Fresh Water

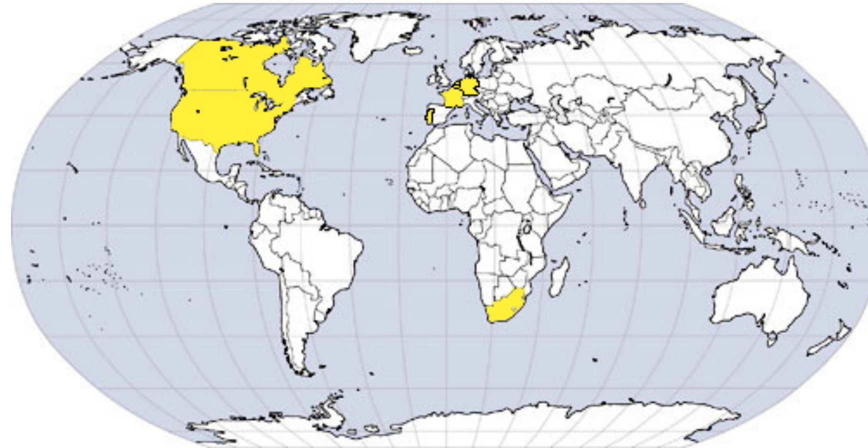
Will it change and how?

The Global View

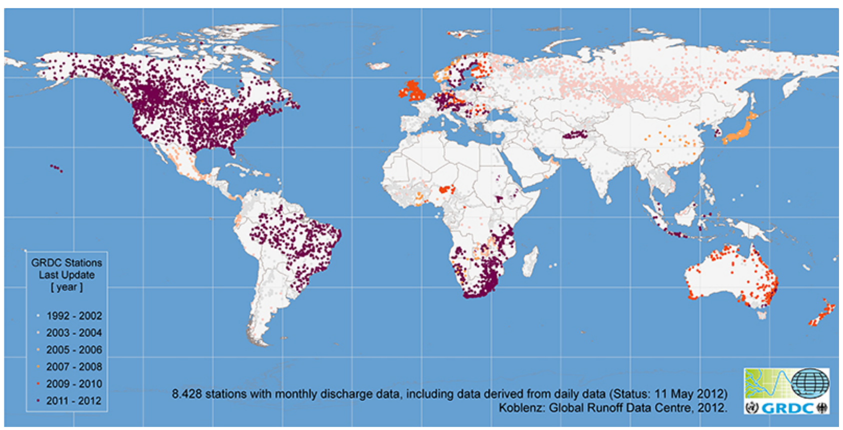
Inadequacy of Surface Observations



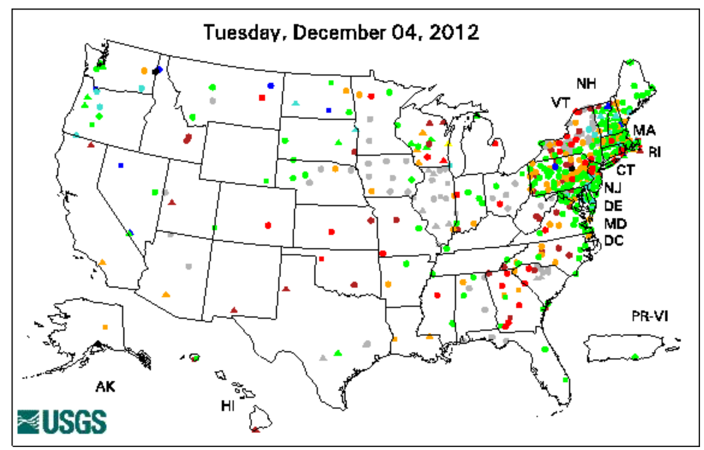
Global Telecommunication System meteorological stations. Air temperature, precipitation, solar radiation, wind speed, and humidity only.



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



River flow observations from the Global Runoff Data Centre. Lighter circles indicate greater latency in the data record.

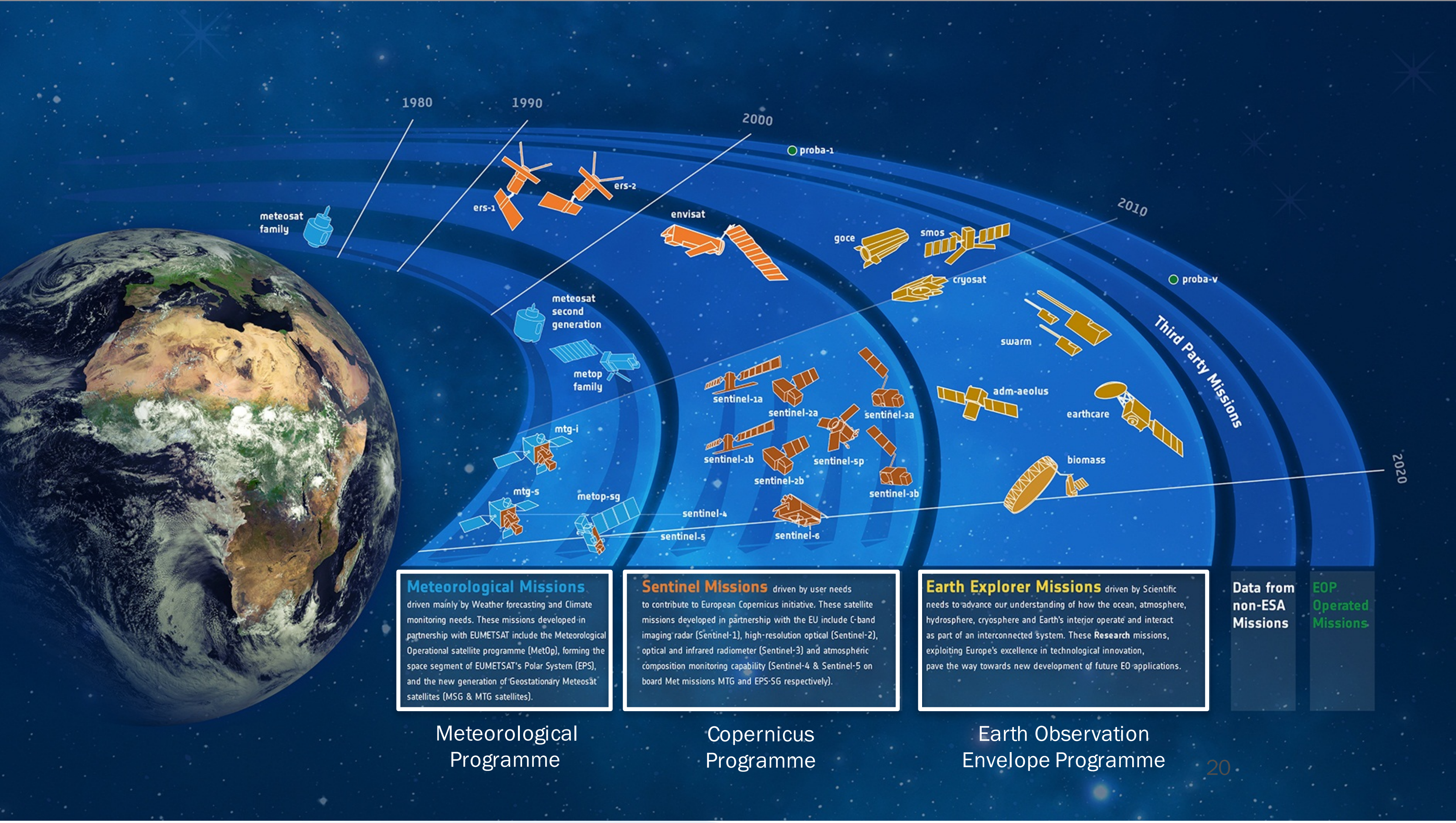


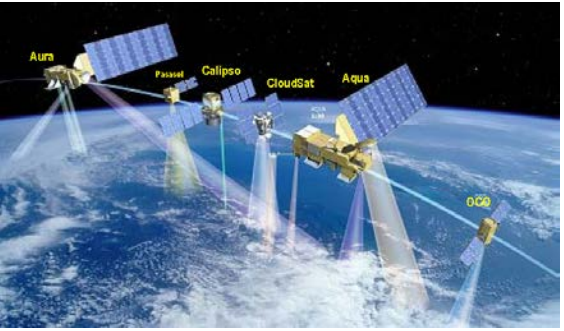
USGS Groundwater Climate Response Network.

Issues include coverage gaps, delays, measurement continuity and consistency, data format and QC, political restrictions


NASA Earth Science Missions
Current & Planned
Formulation
Implementation
Primary Ops
Extended Ops
NI-SAR
PACE
SWOT
TEMPO
GRACE-FO (2)
ICESat-2
CYGNSS
SAGE III (on ISS)
SMAP
OCO-2
TRMM
QuikSCAT
SORCE
EO-1
Landsat-7
(USGS)
ACRIMSAT
Aquarius
Terra
Suomi NPP
(NOAA)
Aqua
CloudSat
Landsat-8
(USGS)
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)

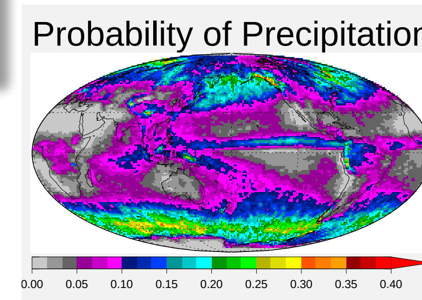
ESA Earth Observation Programmes



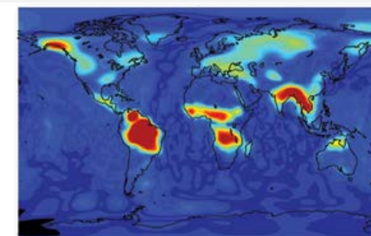


Surface Water balance

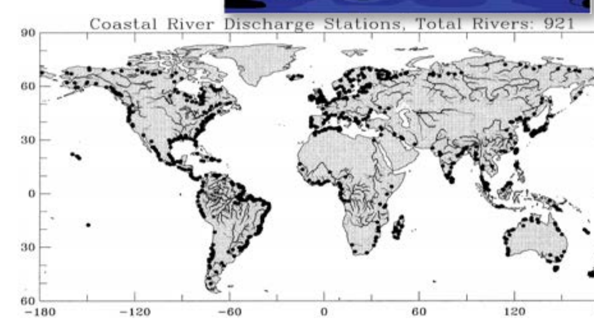
$$\Delta S = P - Q - ET$$



- **Precipitation (P)**
  - In situ: Rain gauges, Snotel
  - RS (**TRMM, CloudSat, AMSR-E, IR**,… .)
- **Change in storage (ΔS)**
  - In situ: Groundwater recharge/flow, soil moisture, standing water, wells
  - RS (**GRACE**, SWOT, AMSR-E→SMOS→SMAP)



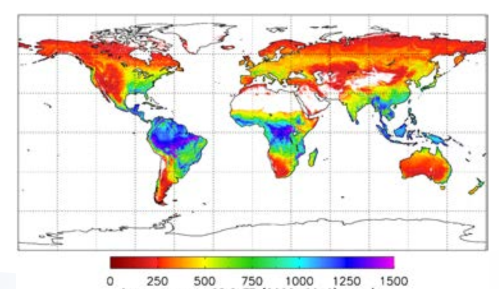
- **Runoff (Q)**
  - In situ: Stream gauges, Global Runoff Data Center,
  - RS (SWOT)



- **Evaporation/Evapotranspitation (ET)**
  - In Situ: Fluxnet
  - RS Quickscat, AMSR-E, MODIS, **ACOS/OCO,…**

  (RS of ET also requires surface net radiation)

- **Global accuracy/consistency/ability?**



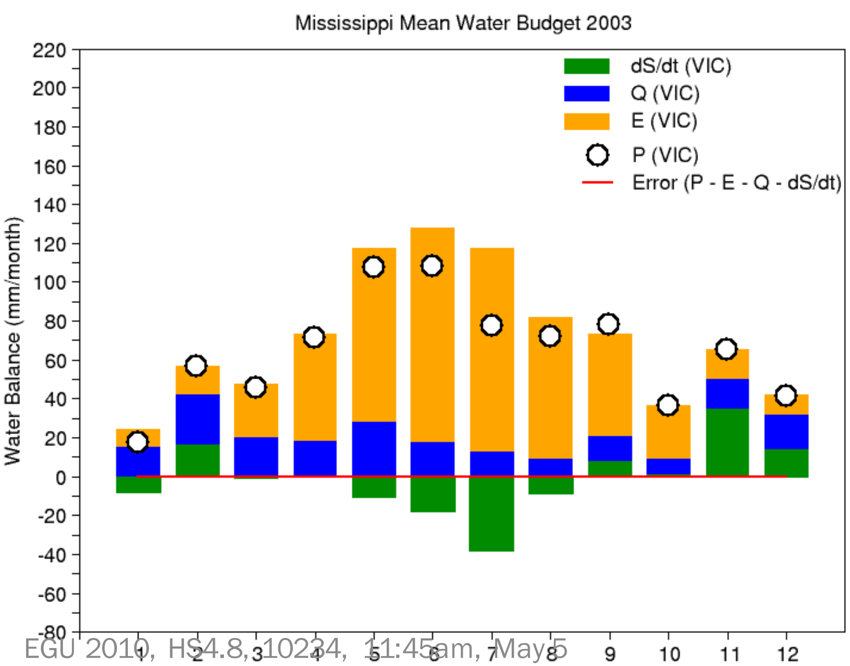
GEWEX

A challenge for Hydrology:

Creating Climate Data Records for the terrestrial water budget using in-situ, remote sensing observations and LSM?

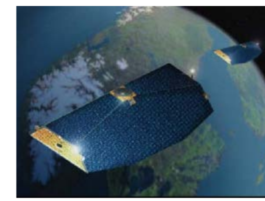
$$\frac{dS}{dt} = P - ET - Q$$

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

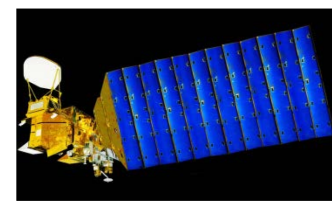


Potential Remote Sensing Datasets

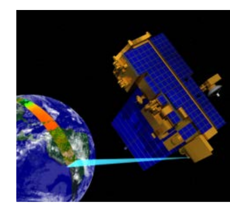
dS/dt from GRACE



ET from
SRB/ISCCP → LandFlux



P from TRMM/CMORPH
PERSIANN → GPM



Q from
TOPEX/POSEIDON/JASON
→ SWOT

Potential global water cycle data sources

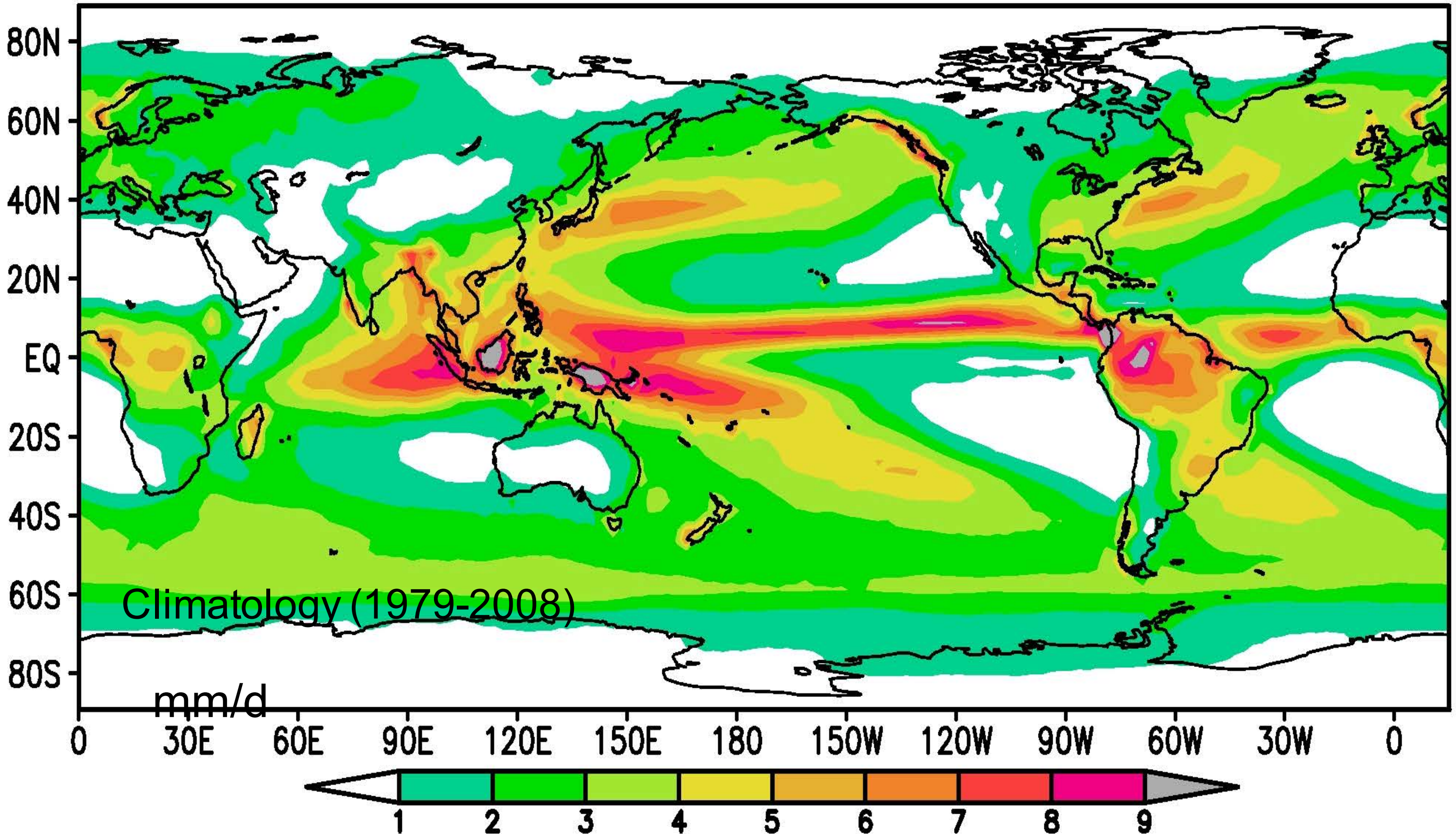
Variable/Source		Type	Period	Resolution	Reference
p	CPC	In-situ	1950-	1º	Chen et al., 2002
	CRU	In-situ	1901-	0.5º	Mitchell & Jones, 2005
	WM	In-situ	1900-	0.5º	Willmott & Matsuura, 2010
	GPCC	In-situ	1900-	0.5º	Schneider et al., 2008
	GPCP/TMPA	RS/in-situ	1998-	0.25º-1º	Huffman et al
e	ET (LandFlux)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

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

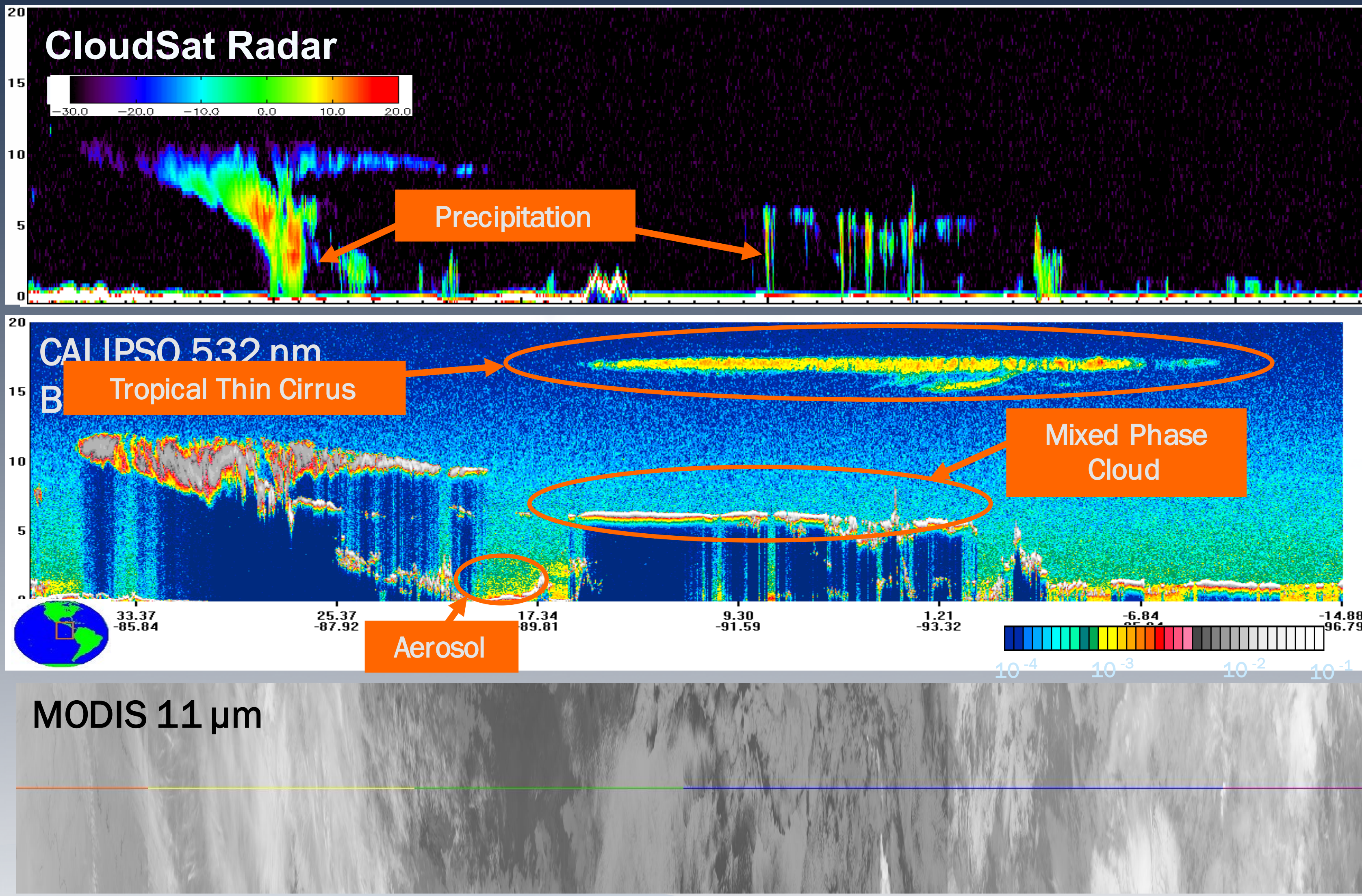
Global Precipitation Climatology Project (GPCP)

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



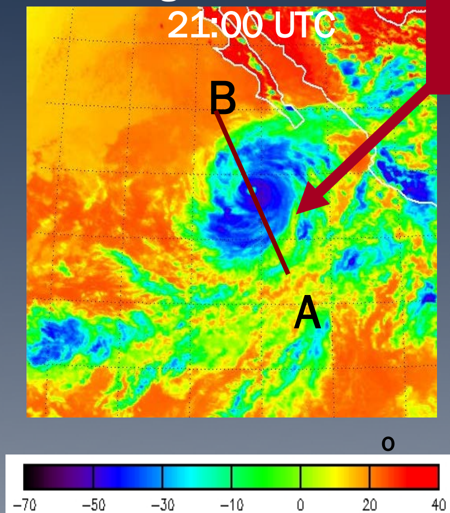
GPCP data used in > 1500 journal articles

Synergy



GEWEX

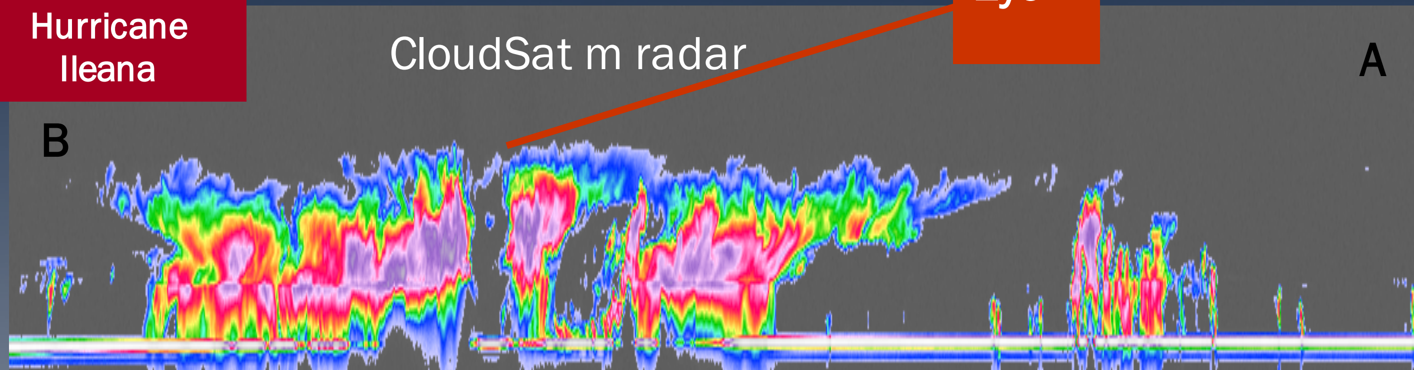
23 Aug 2006 GOES-11
21:00 UTC



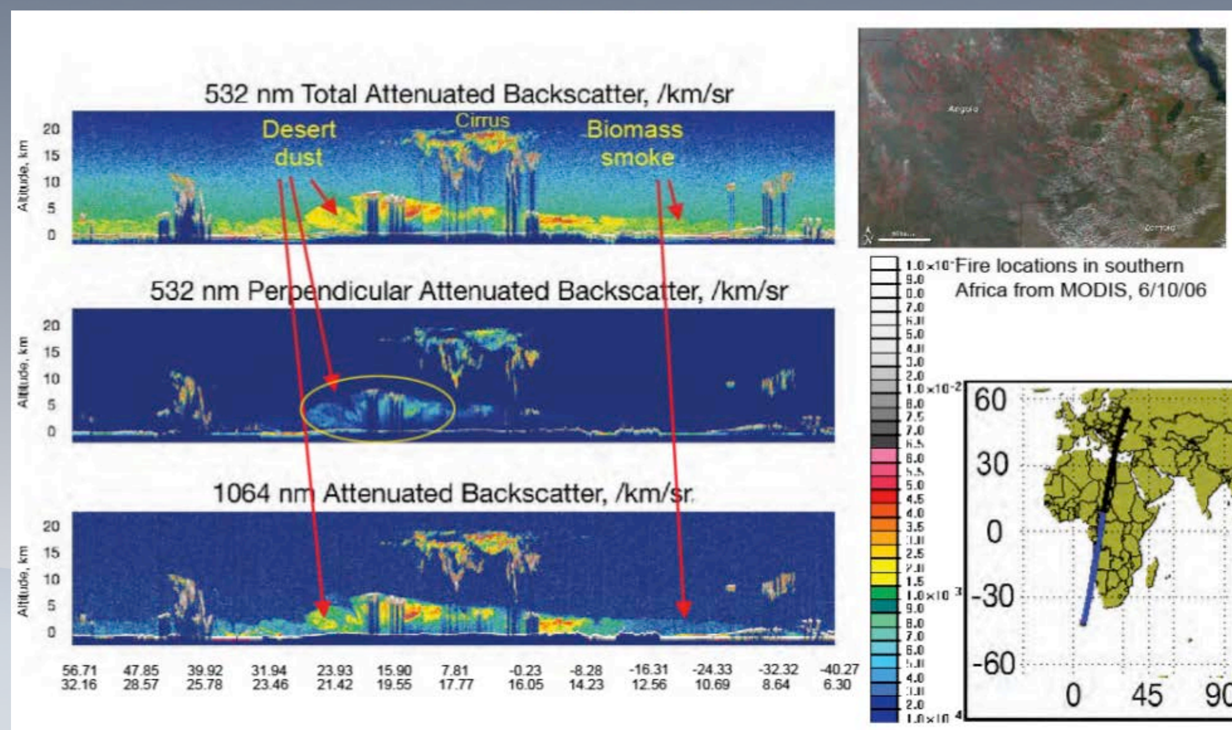
Hurricane Ileana

Brightness Temperature
(C)

Eye



CALIPSO Frist 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…)

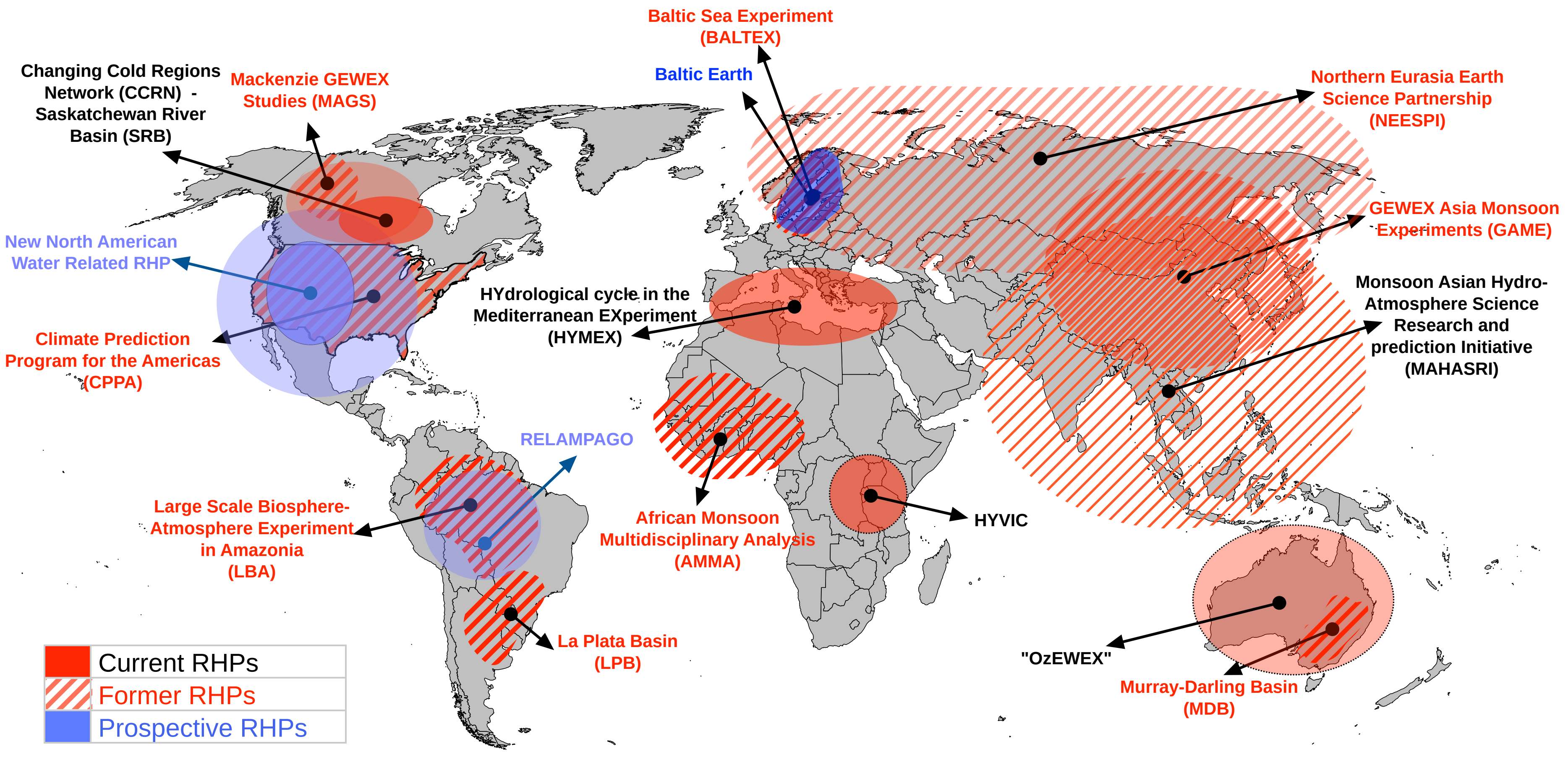
The Local View

Regional HydroClimate Projects - RHP

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



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

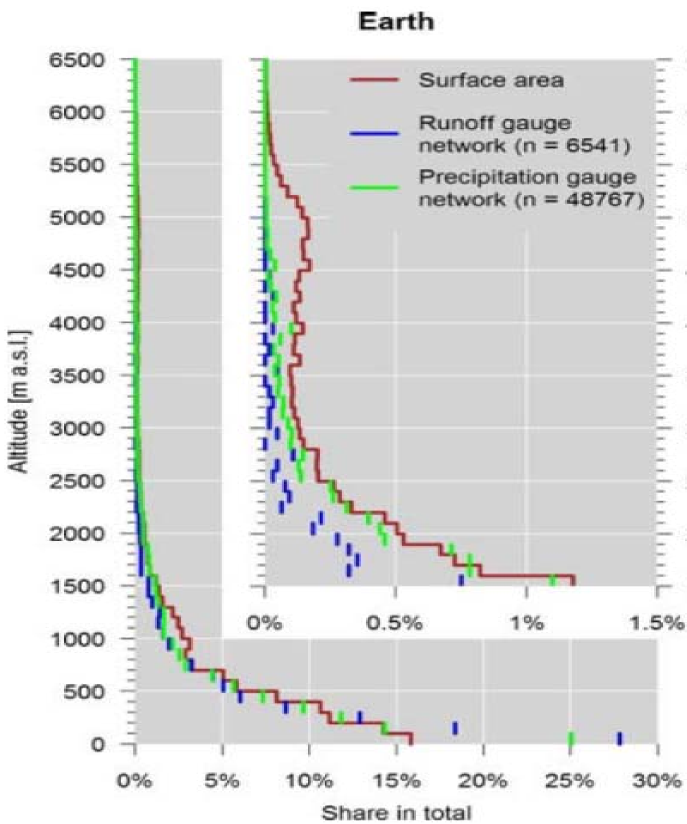
Urgency

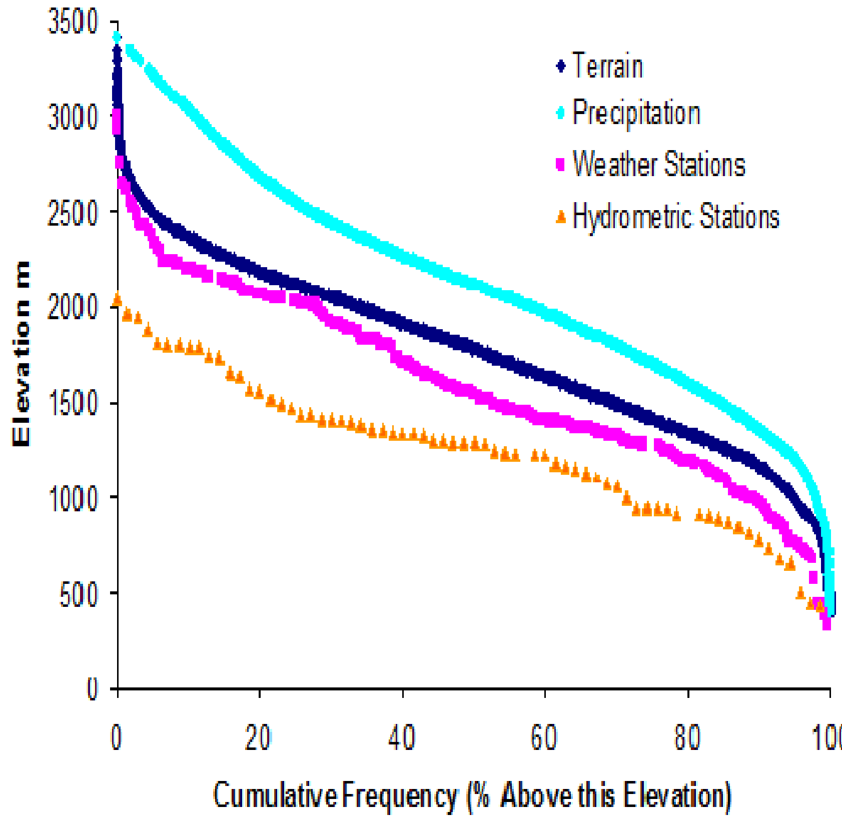
- to IPCC (2014) WG II report – "***In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality***"
- Alpine catchments receive and produce a disproportionately large fraction of global precipitation and 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).
Right Side: (Pomeroy, Sinclair – in preparation).

Objective

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

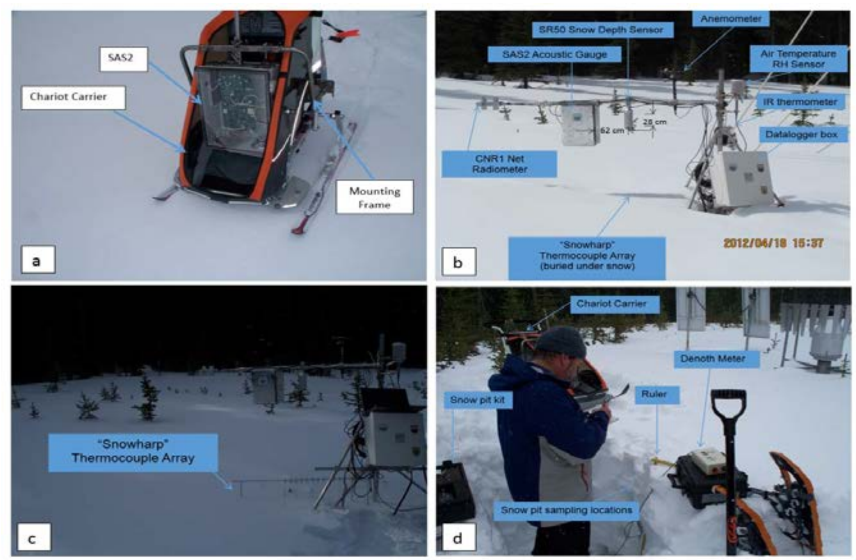
Sub-Objectives

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

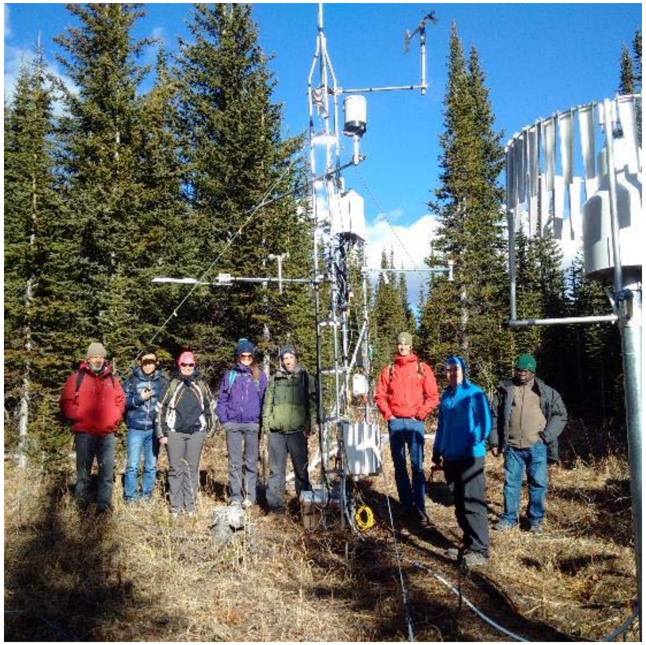
Earth Syst. Sci. Data, 4, 13–21, 2012
www.earth-syst-sci-data.net/4/13/2012/
doi:10.5194/essd-4-13-2012

Open Access Earth System Science Data

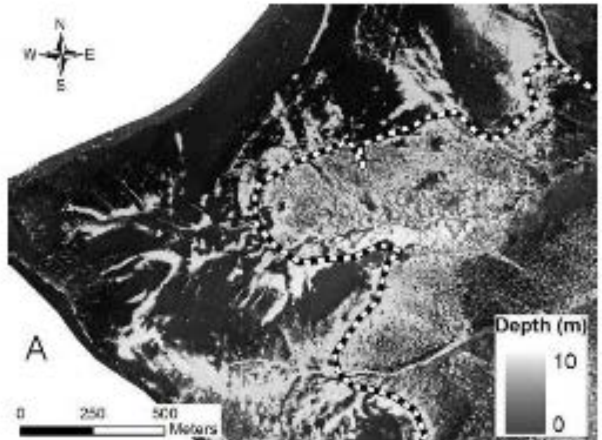
An 18-yr long (1993–2011) snow and meteorological dataset from a mid-altitude mountain site (Col de Porte, France, 1325 m alt.) for driving and evaluating snowpack models

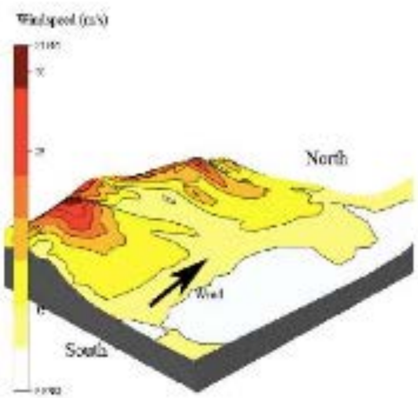
S. Morin[1], Y. Lejeune[1], B. Lesaffre[1], J.-M. Panel[1], D. Poncet[1], P. David[1,†], and M. Sudul[1,†]
[1]Météo-France – CNRS, CNRM-GAME, URA1357, CEN, Grenoble, France
[†]deceased
Correspondence to: S. Morin (samuel.morin@meteo.fr, col.de.porte@meteo.fr)

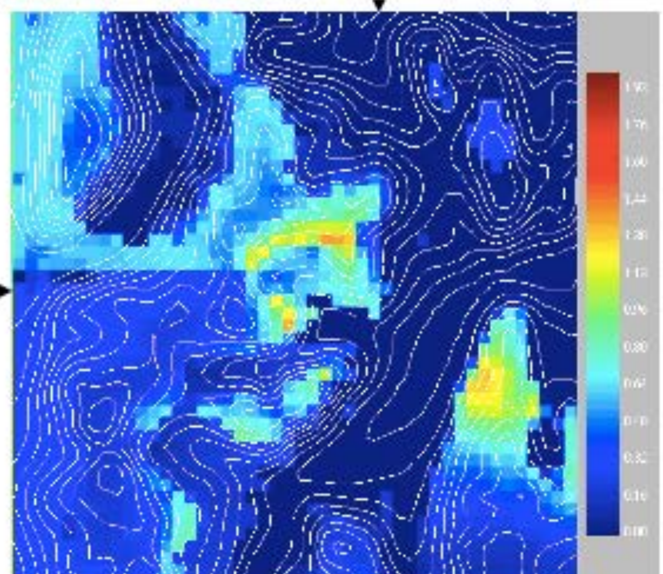
Received: 16 January 2012 – Published in Earth Syst. Sci. Data Discuss.: 6 February 2012
Revised: 31 May 2012 – Accepted: 9 June 2012 – Published: 6 July 2012



Integrated Alpine Observing & Predicting Systems - IAOPS

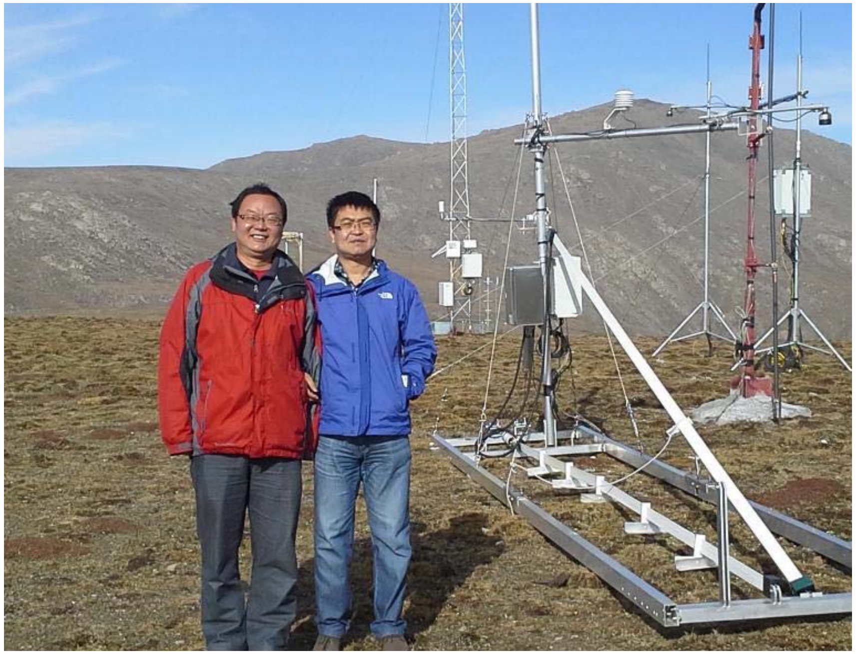






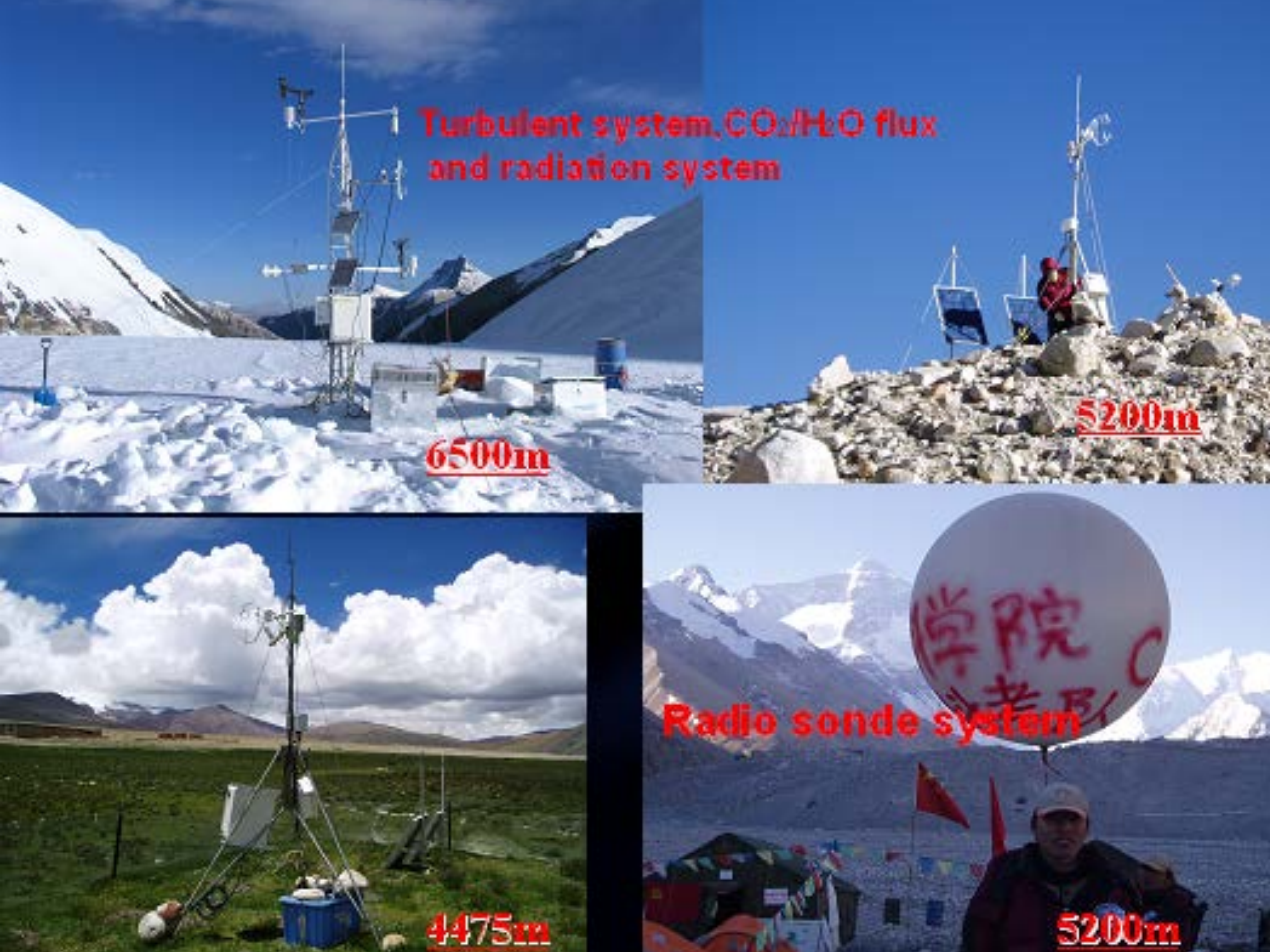
Instrumented alpine catchments with, remote sensing, atmospheric modelling, downscaling, data assimilation in order to better evaluate mountain water and energy exchange.

International Collaboration through Field & Model Experiments



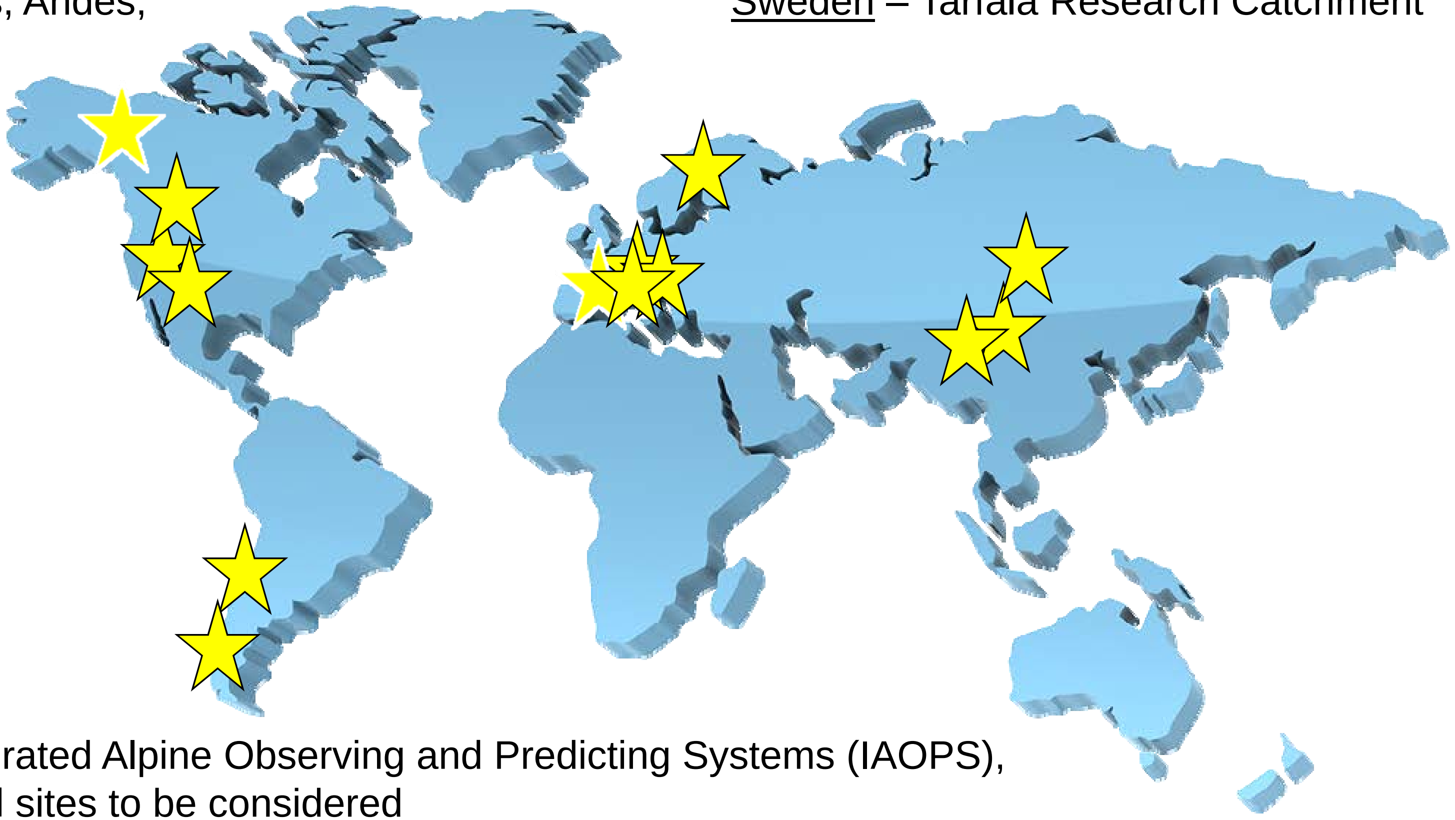
Upper Heihe River Basin, 4150 m China

Zugspitze, 2650 m Germany


Turbulent system,CO_2/H_2O flux
and radiation system
6500m
5200m
4475m
Radio sonde system
5200m

INARCH: International Network for Alpine Research Catchment Hydrology

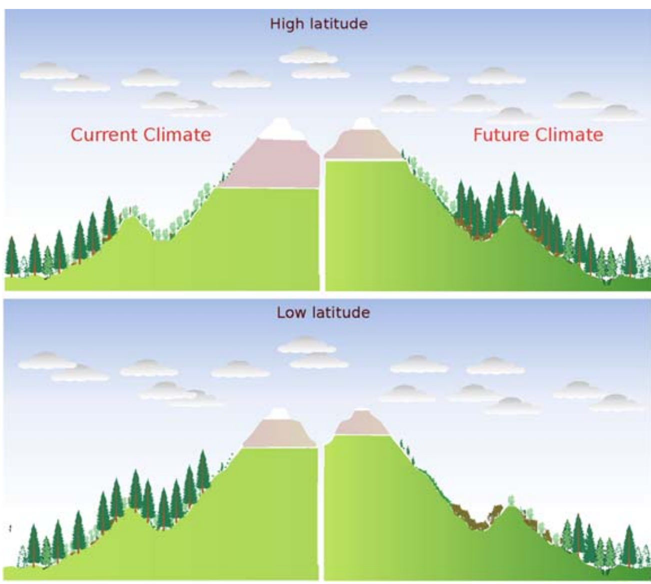
Canada – Canadian Rockies, BC & Yukon;
USA – Reynolds Creek, ID; Senator Beck, CO, Niwot Ridge, CO.
Chile - Upper Maipo & Upper Diguillín River Basins, Andes,
Germany – Schneefernerhaus & Zugspitze;
France – Arve Catchement, Col de Porte & Col du Lac Blanc;
Switzerland – Dischma & Weissfluhjoch;
Austria - OpAL Open Air Laboratory, Rofental
Spain – Izas, Pyrenees;
China – Upper Heihe River, Tibetan Plateau,
Nepal – Langtang Catchment, Himalayas
Sweden – Tarfala Research Catchment

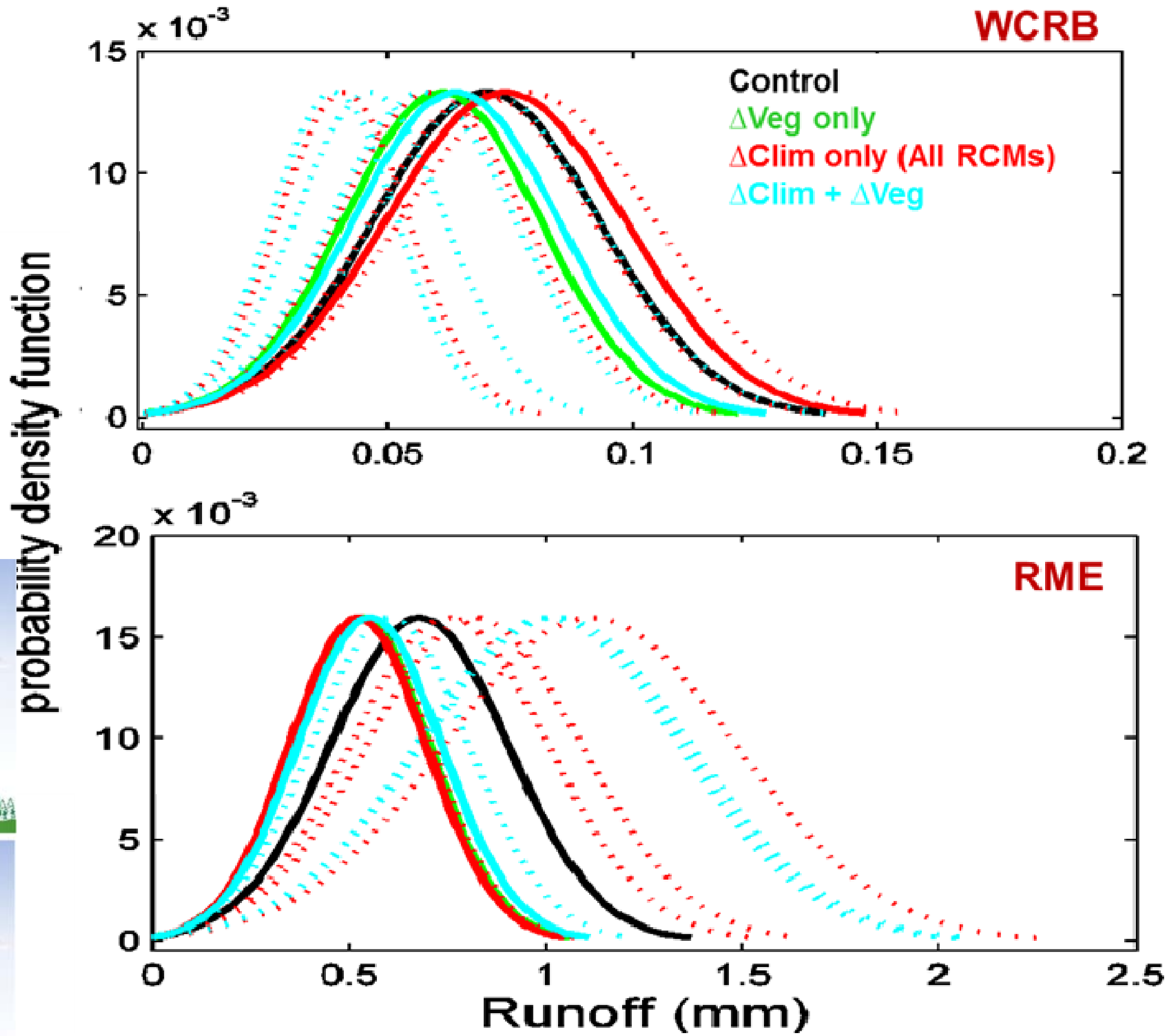


Integrated Alpine Observing and Predicting Systems (IAOPS), initial sites to be considered

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 oN)
Reynolds Mountain East Basin, Idaho, USA (43 oN)





Linkages

- GEWEX GHP Projects
  - Precipitation phase
  - Mountain precipitation
  - Changing Cold Regions Network
- Global Crysophere Watch
- WMO-SPICE
- UNESCO-International Hydrological Programme efforts on climate change impacts on snow, glacier and water resources within the framework of IHP- VIII (2014-2021) ***'Water Security: Responses to Local Regional and Global Challenges'.***
- International Commission for Snow and Ice Hydrology (IUGG)

Other Activities

- Mounterrain (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!
  - 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, iwrm, LULC, etc.) CRITICAL**

GEWEX

MORE INFORMATION ON:

HTTP://WWW.GEWEX.ORG

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