GC#1: Changes in water availability

Sonia Seneviratne, Graeme Stephens (GEWEX)

- Activities
- Opportunities
- Strategies

Four GEWEX Science Questions underpinning the 2 GEWEX-related GCs

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Grand Challenges		
Changes in Water Availability	1	**Observations and Predictions of Precipitation** How can we better understand and predict precipitation variability and changes?
	2	**Global Water Resource Systems** How do changes in the land surface and hydrology influence past and future changes in water availability and security?
Climate Extremes	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?
	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?

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Activities: Changes in Water Availability

1. White paper was prepared by outgoing chair and delivered to JSC review end of 2013 (in response to action item 22)

2. Two workshops conducted

(i) A workshop on GEWEX Science Question (GSQ) 1 (precipitation): Developing a Water Strategy for the World Climate Research Programme (held 27-28 June 2013, CIRA, Fort Collins, Colorado): http://www.gewex.org/GSQ1_Workshop_Report.pdf

(ii) A Workshop GSQ 2 (water resources) was held in Saskatoon (held 5-7 June 2013, Saskatoon, Canada) : http://www.gewex.org/GSQ2_Workshop_Report.pdf

3. The Pan GEWEX Rio Meeting - Two looming integrative challenges identified

(i) Hydrology of high terrain - a Working Group on High Elevation Precipitation (co-chaired by James Renwick and John Pomeroy, GHP) was established. It would need a connection to CliC and information on it for CLiC is a TBD (action item 48)

(ii) Closing the surface energy balance - we have closure @ 10-20 Wm^{-2} which is too coarse for most climate applications – emerging GDAP/WDAC activity (action item 37)

4. The GEWEX conference to engage community and Pan GEWEX meeting to strategize on steps forward with new initiatives tailored specifically to the GC

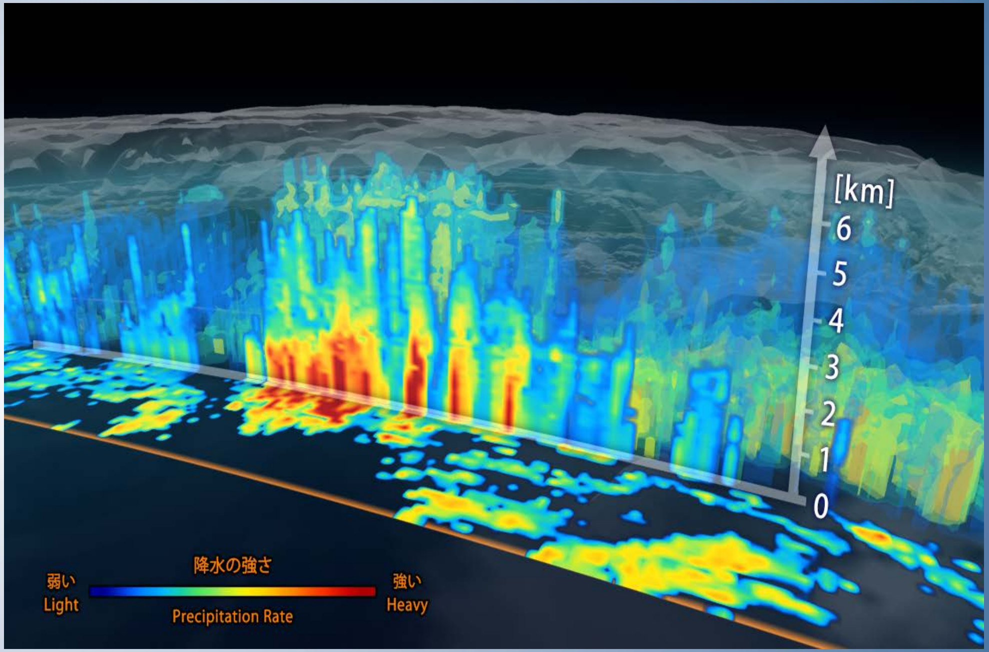
Water Availability Grand Challenge

1) **Opportunitie: exploit existing, improved and new data sets, both satellite and in situ to close the water and energy budgets** :

- Assessments of uncertainties (e.g GDAP data assessments)
- Exploit new opportunities from eg GPM, SMAP, OCO,SMOS …;
- Deeper mining of existing satellite and in situ data, e..g. GRACE, CloudSat, Aquarius, etc
- Better integration of available data e.g. starts with assessments; WDAC surface flux initiative; ESA CCI, NASA NEWS, GHP regional Hydroclimate Projects both for developing more closed budgets and for validating global observations.
- Prepare for and shape future opportunities (EarthCARE, etc) ;

GPM status

1. Core Observatory launched on February 27 (UTC), Japan.
2. Core Observatory completed check-out on May 29.
3. 3. GMI Level 1 data released.
4. 4. DPR Level 1 data are being readied for release.
5. 5. GMI and DPR Level 2 data are scheduled for release in early September.



Early image of the GPM DPR

Advances in global snowfall

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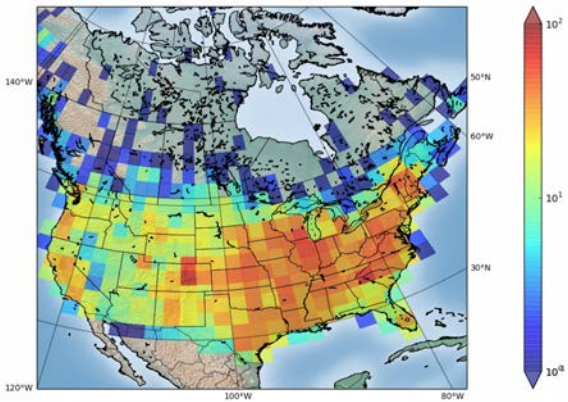
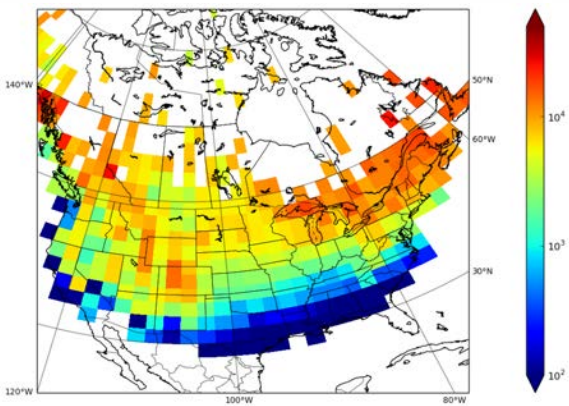
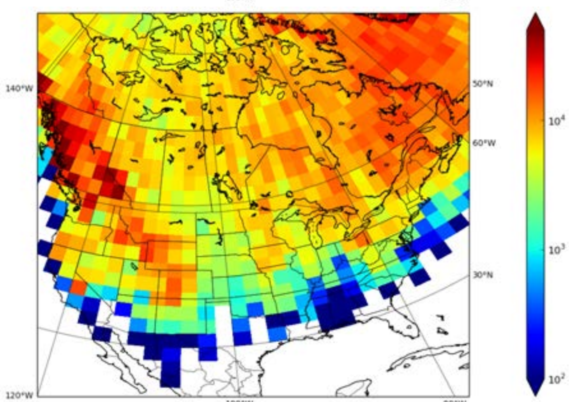


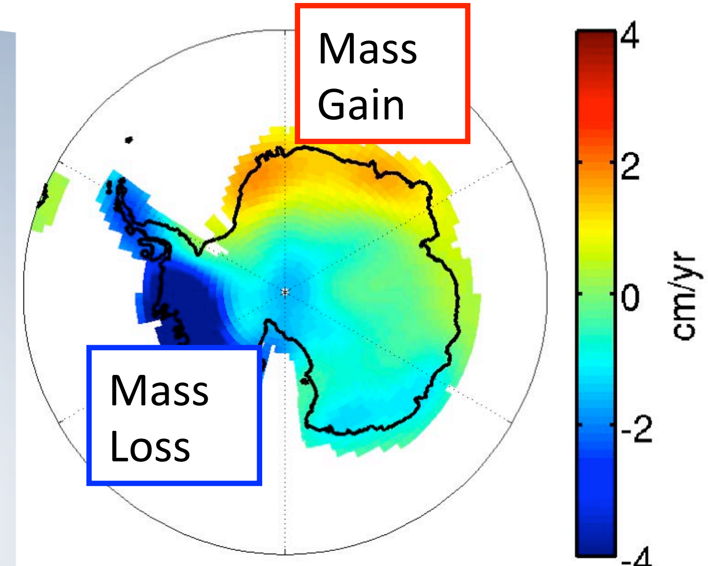
GHCN – 120 stations plus GCOS, coop observers,..



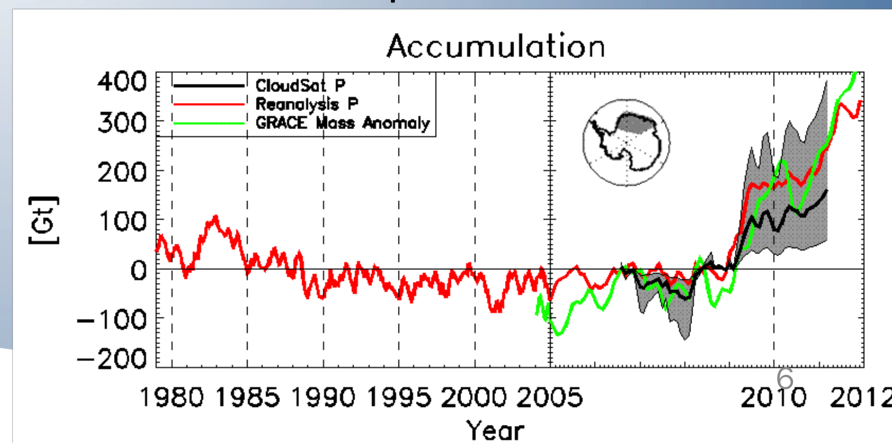
GHCN, 6.6m



GHCN, 7.2m



GRACE and CLoudSat offering clues about ice mass balance and polar snowfall



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2) Opportunties: better joint exploitation of data & models – confront models in new ways

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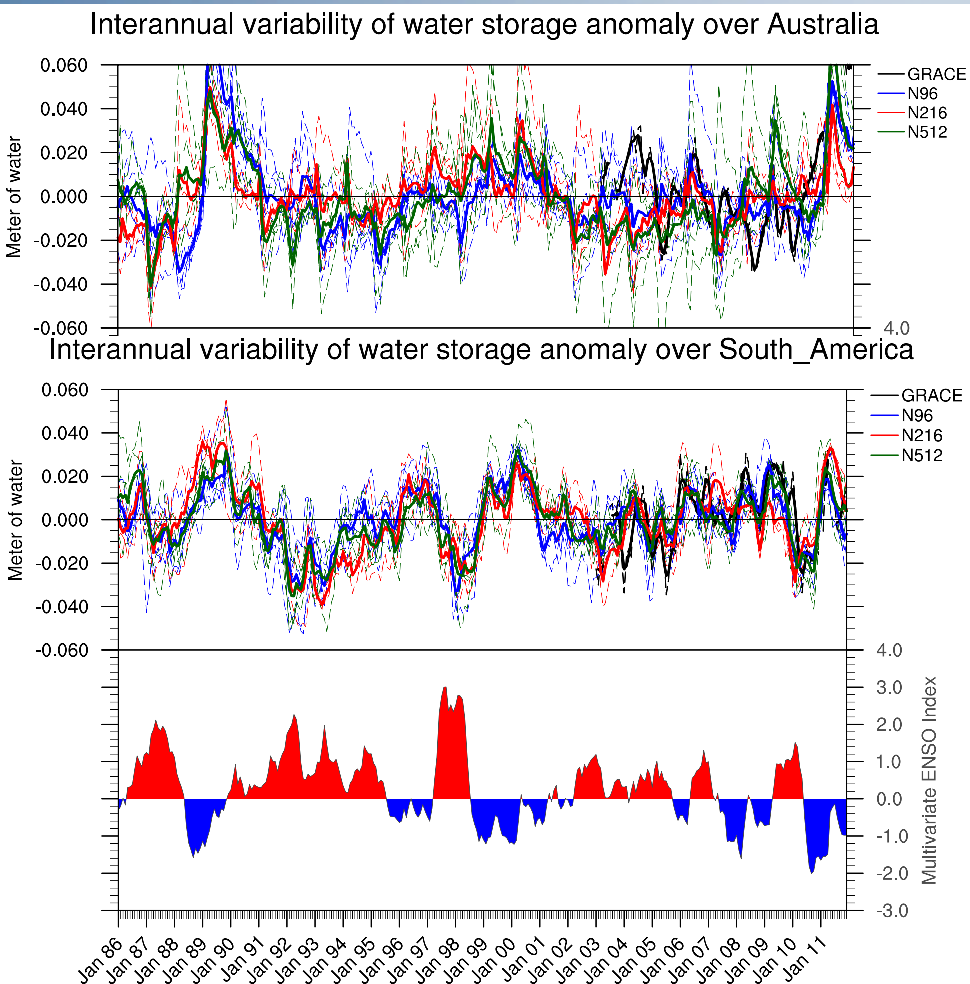
- Making data more accessible (e.g. Obs4Mip).
- Using data in more effective tests of models (e.g. new GEWEX PROES initiative to develop new diagonsotid=s on preciptation, land/atmosphere interactions) focusing at the process level
- Improve process representations in models (i.e their parameterizations)
- Advance sub-system models (e.g. land surface hydrological modeling, land surface models, LES turbulence), etc
- Foster model evolution to higher resolutions (Hi-Res modeling initiative, Grey-Zone project test of scale gaps, etc)

Example: Using GRACE to assess GCMS

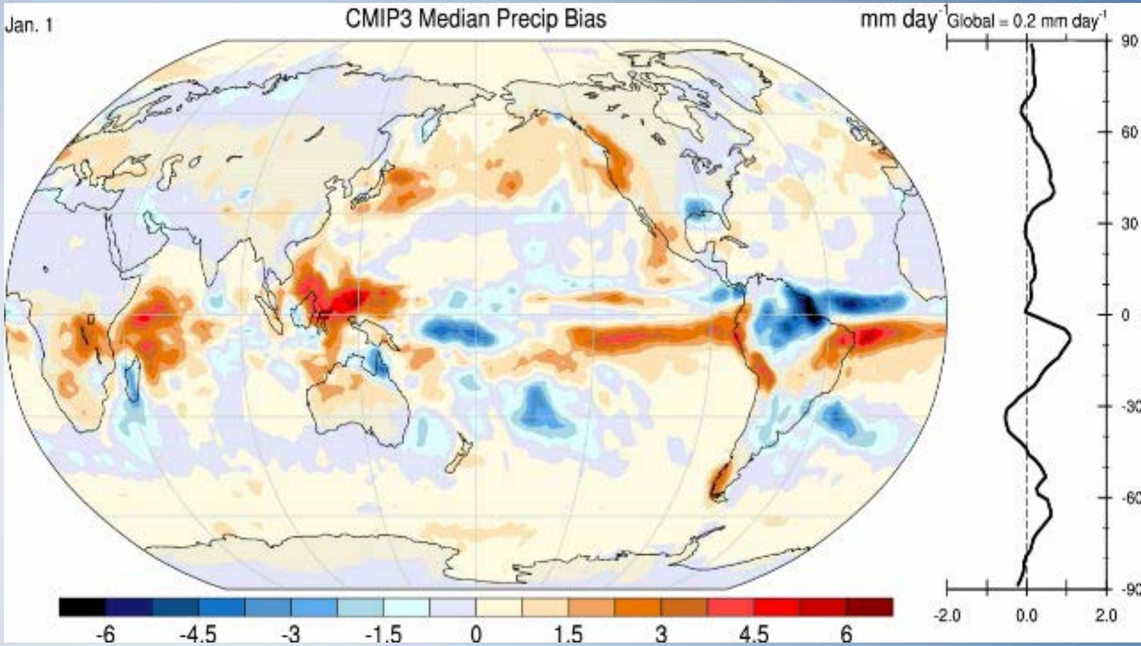


Does this offer hints at the predictability of the hydrological cycle associated with strongly forced events (e.g. ENSO)?

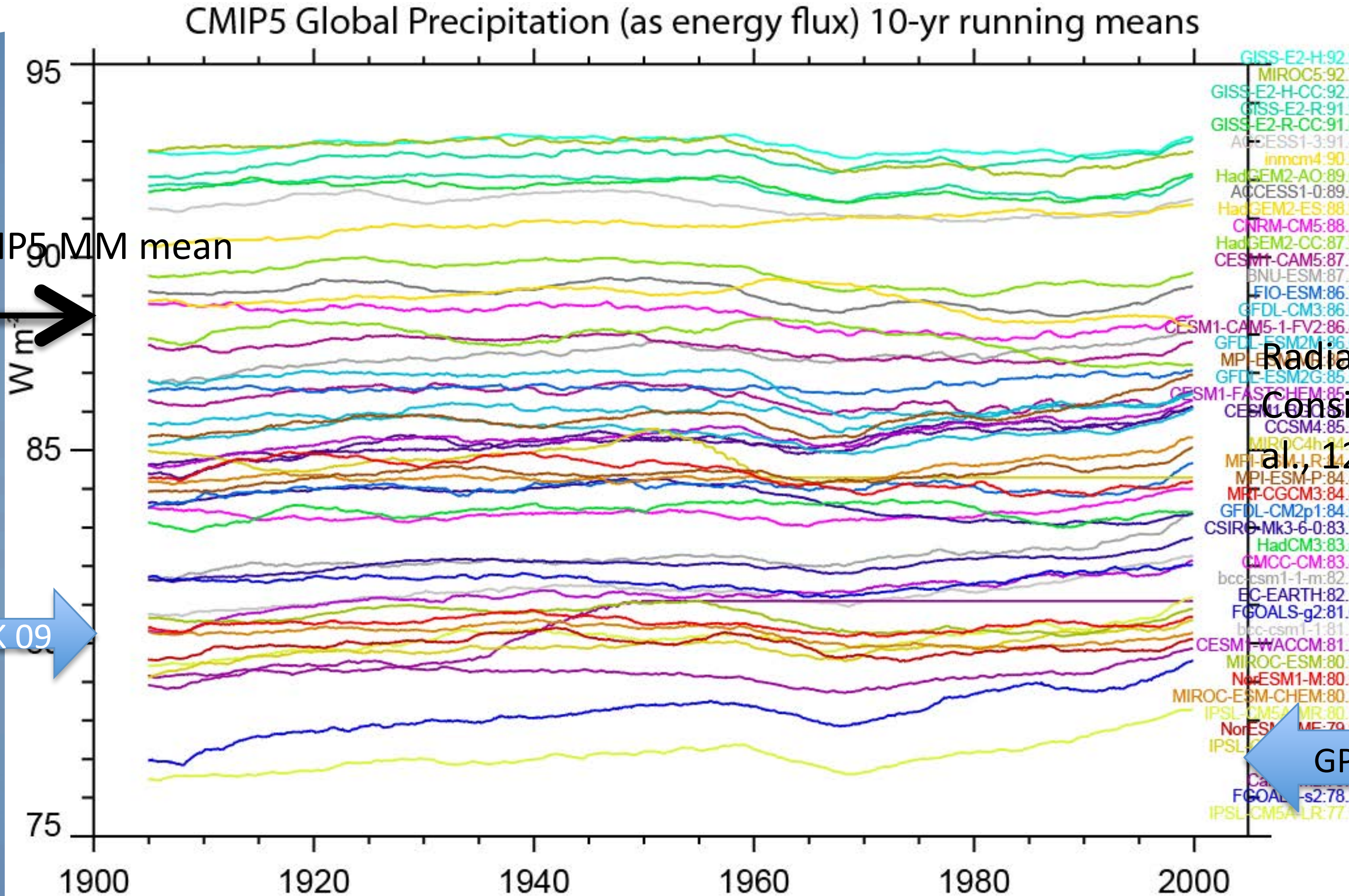
Demory et al., 2014 (in prep)

Precipitation in models: Issues and challenges

- Amount: distribution: double ITCZ
- Frequency: too often
- Intensity: too low
- Runoff: not correct
- Recycling: too large
- Diurnal cycle: poor
- Lifetime: too short (moisture)



Surface balance conundrum



CMIP5 MM mean

Radiation balance Considerations & S... al., 12

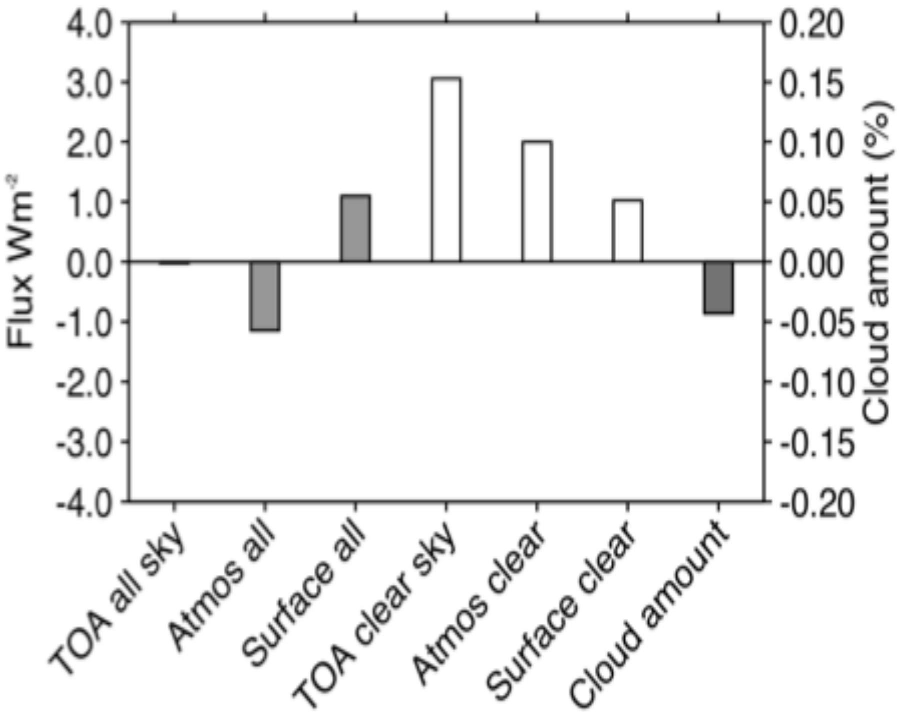
TFK 09

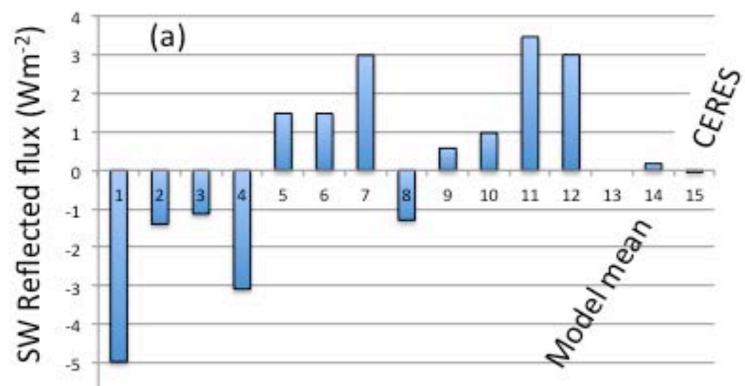
GPCP inferred

10-yr running means

Link between energy and water still remains critical for GC

NH-SH flux differences



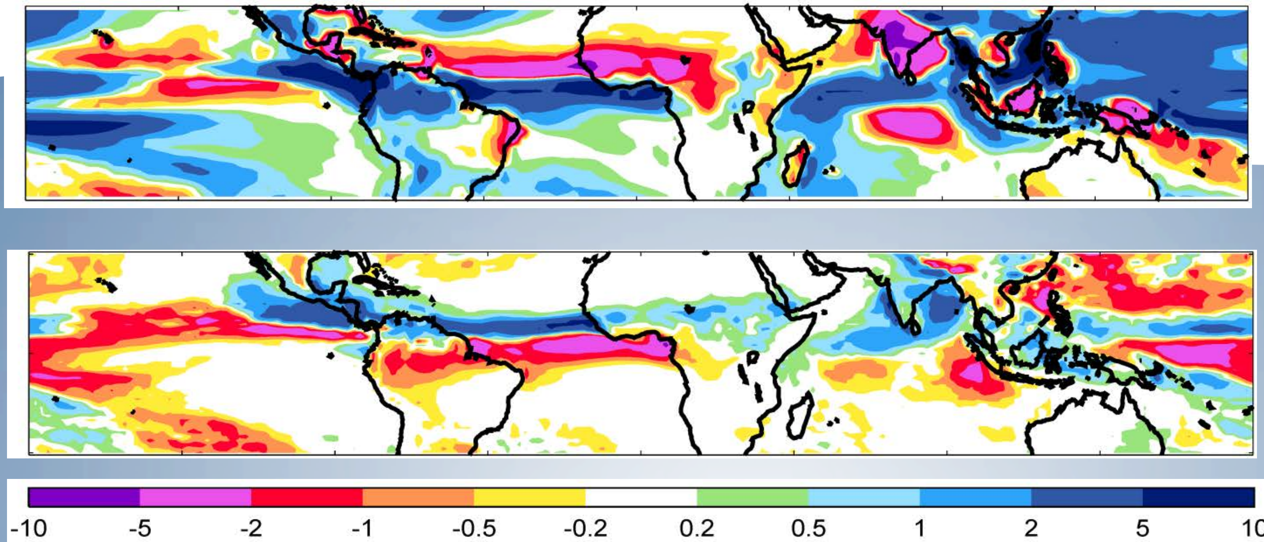


Models lack the observed symmetry – Changes to the symmetry changes the requirement for heat transported across the equator with consequent shifts in ITCZ and patterns of precipitation

Although the hemispheres are structurally different, the reflected flux is identical (~0.1Wm^{-2}) – VonderHaar and Suomi, 1969; Voigt et al., 2012; Stephens et al 2014

Precip bias HadGEM2-ES minus GPCP

Precip change when hemispheric abedos are equilibrated



mm/day

Wet season Precip

Also Haywood et al., 2013 Frierson & Huang, 2012 Voigt et al., 2013;2014

Bias ratio

Key areas affected by monsoonal precipitation

Geographic Region	DJF	MAM	JJA	SON
North Africa	0.64	0.47	0.54	0.17
South Asia	1.05	2.59	0.67	0.70
Amazonia	0.86	0.90	0.73	0.72
South East Asia	1.17	0.35	0.80	0.96

Haywood,Jones et al., personal communication

3) Opportunities: Developing improvement of model representation of water cycle processes – HiRES modeling initiative:

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

Graeme Stephens[1], Jon Petch[2], Cyril Morcrette[2], Malcolm Roberts[2], Stephen Klein[3], Pier L. Vidale[4], Marie-Estelle Demory[4], and Roy Rasmussen[5]

[1]Jet Propulsion Laboratory, Pasadena, CA, USA, [2]Met Office, Exeter, UK; [3]Lawrence Livermore National Laboratory, Livermore, CA, USA; [4]National Centre for Atmospheric Science, University of Reading, UK; [5]National Center for Atmospheric Research, Boulder, CO, USA

the projections used, especially for extreme rainfall is unclear, because predicting changes in the distribution, frequency and intensity of rainfall remains a fundamental weakness in all climate models (Stephens et al., 2010). One hypothesis that is now widely accepted is that the main obstacle to more credible projections of extreme rainfall is insufficient model resolution. Therefore, critical features such as topography and processes such as convection within rain-bearing systems cannot be adequately resolved. One of the goals of the HiRes Project is to develop a systematic approach to test this hypothesis by bringing together models of varying resolutions and observations developed under GEWEX, and new observational resources to define performance metrics to quantify improvements.

Wide interest across the international community and across agencies

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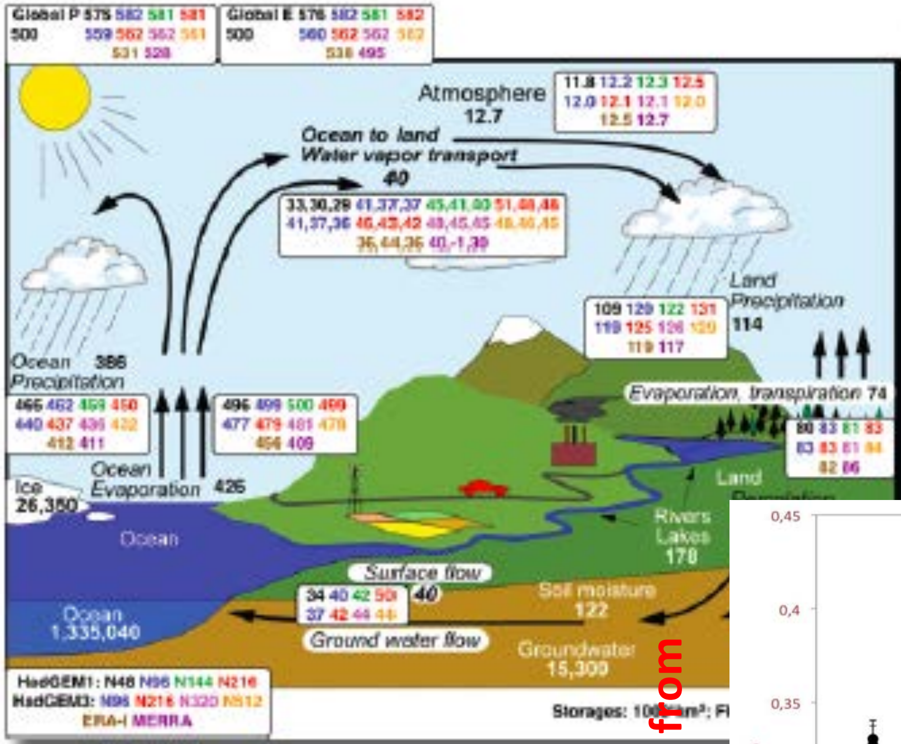
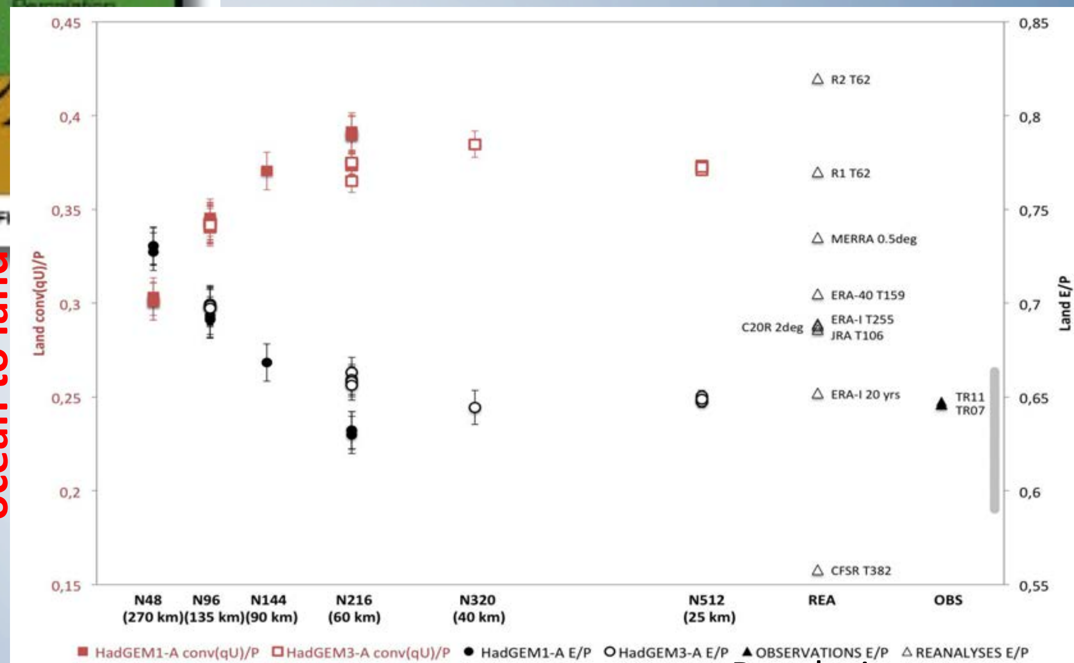


Demory et al., 2013

Transport of water from ocean to land



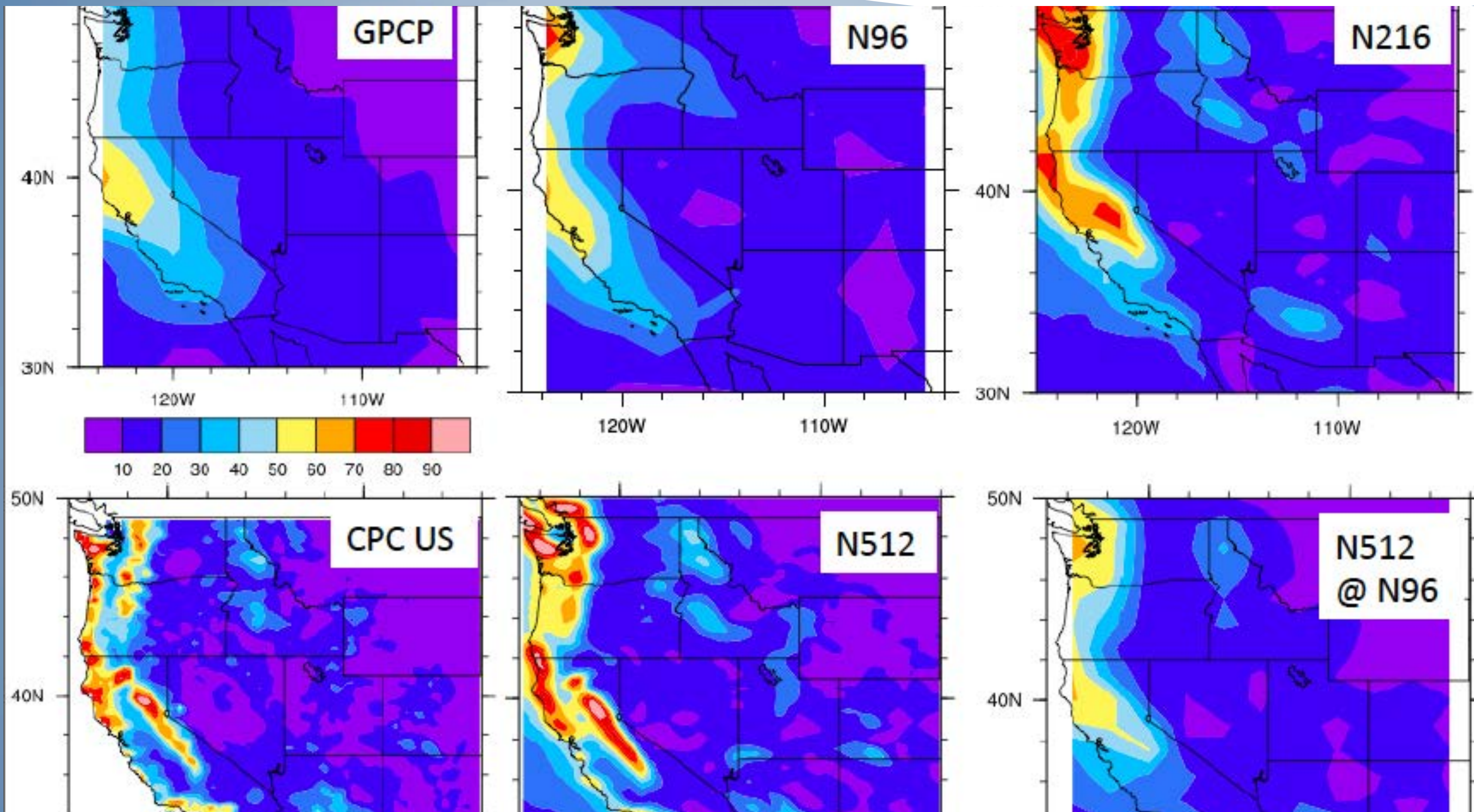
Local recycling of precipitation

Resolution

High local recycling
Low transport

Lower local recycling
Higher transport

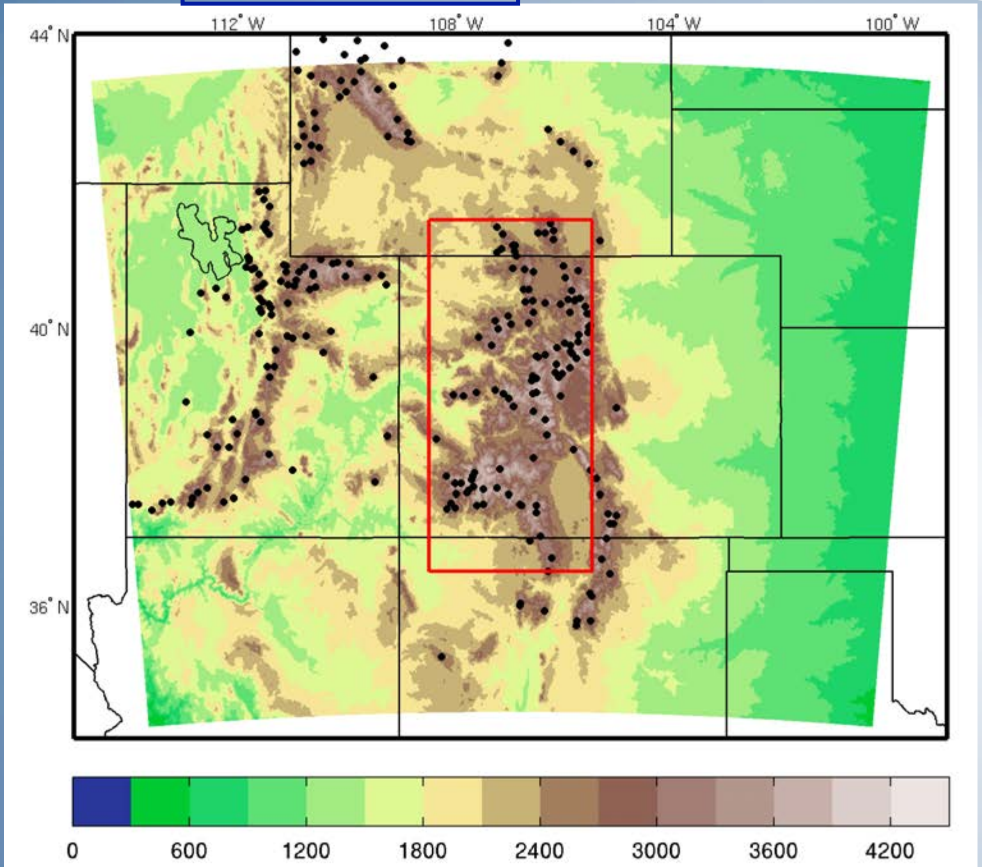
DJF 99th percentile of precipitation



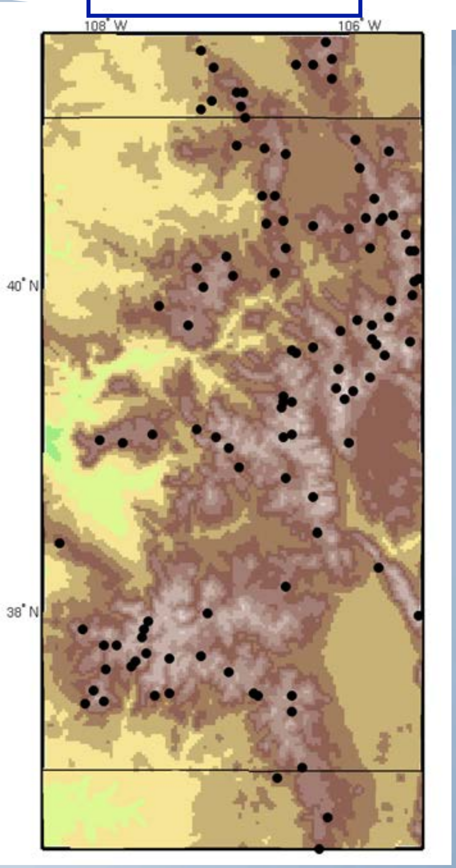
Demory et al., 2014 in prep

High Resolution Simulations of the High Terrain precipitation - the Colorado Headwaters snowfall, snowpack and runoff

Full Domain

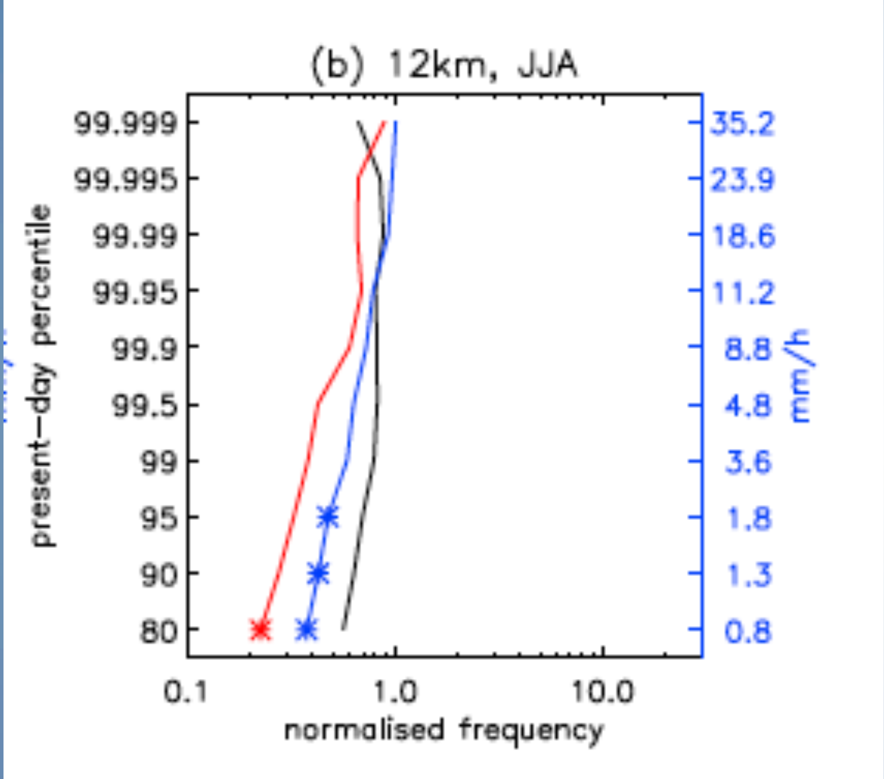


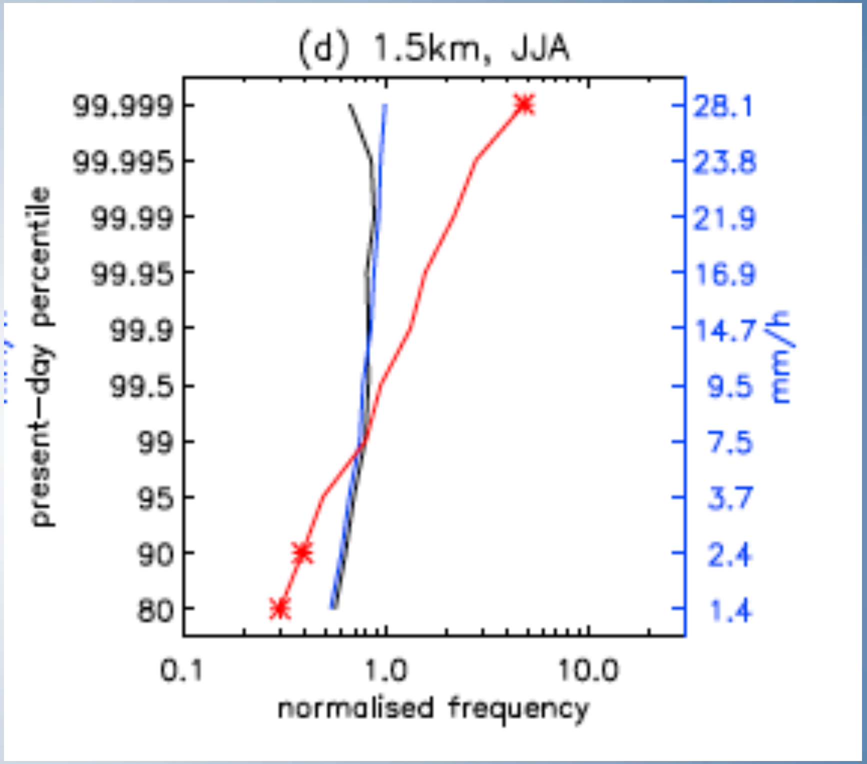
Headwaters domain



● SNOTEL sites

NCAR WRF

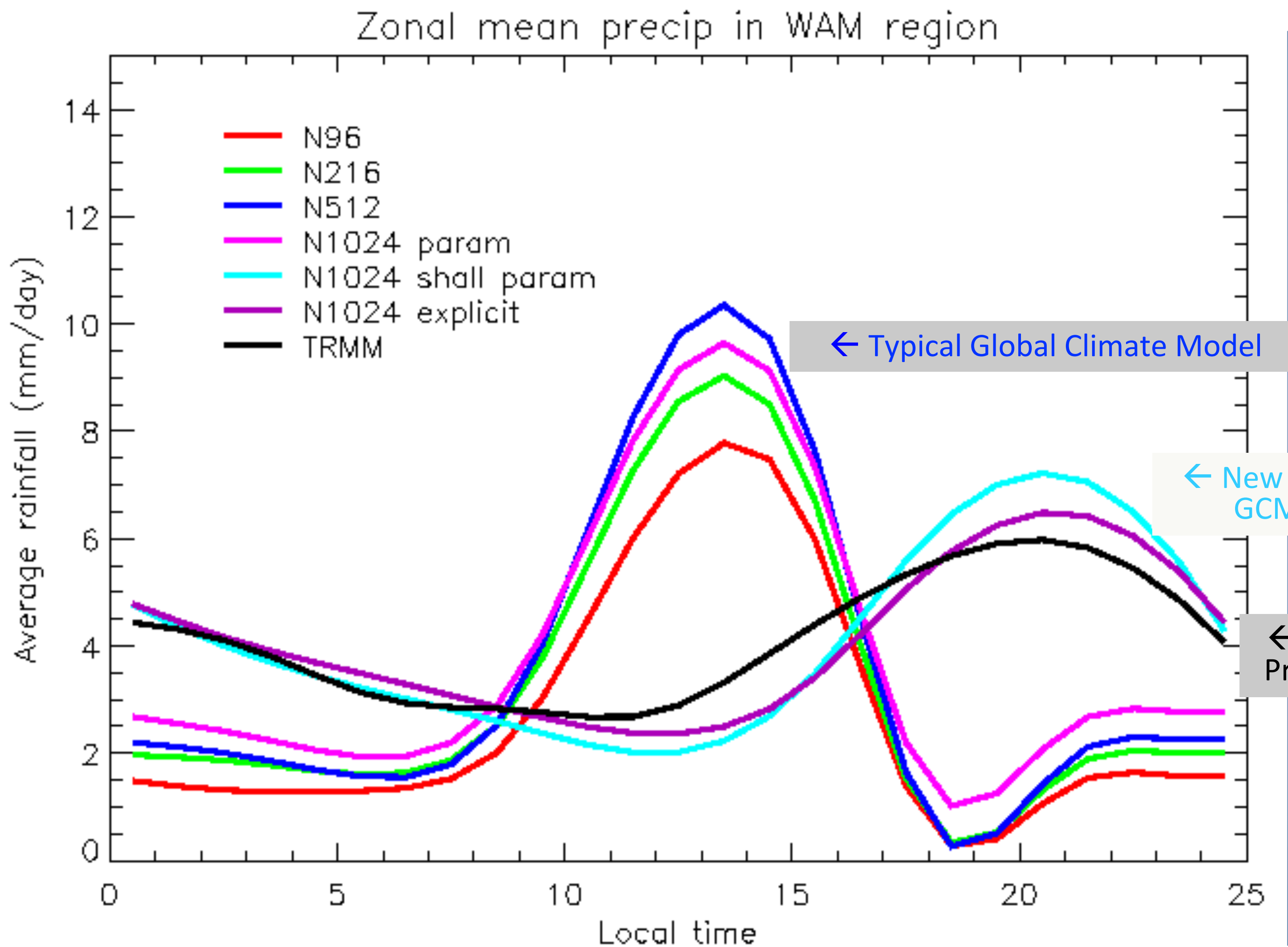




Kendon et al., Nature Geoscie, 2014

West African Monsoon region – mean diurnal cycle of precipitation

no convergence to right answer with convective parameterisation



M. Roberts et al., MO, in prep

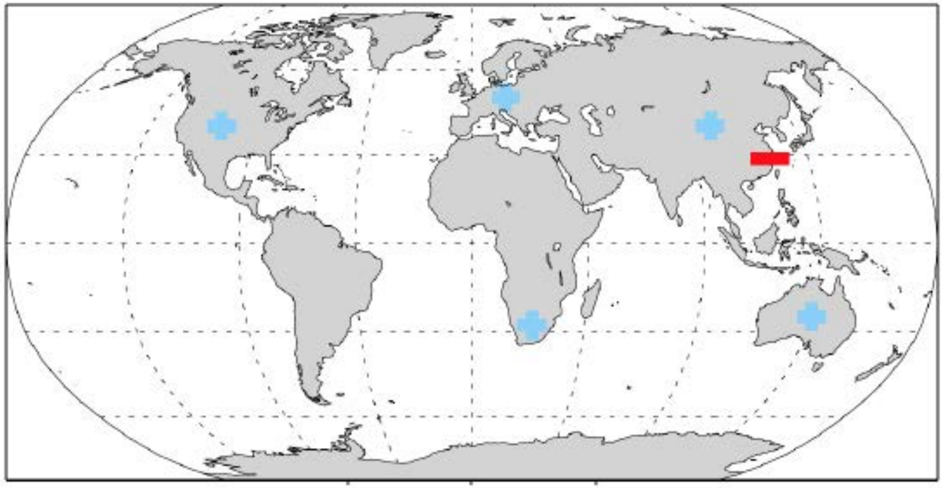
4) Opportunities: improving the information content of existing observations: – GHP and higher resolution data products built up from in situ observations products related to water availability and quality for decision makers and for initializing climate predictions from seasons to years ahead

Improved observations

Sub-daily precipitation Cross-cut project

GEWEX/GHP

- GHP: Review of sub-daily precipitation covering observations and modelling with focus on extremes (subm. to Rev. of Geophysics)
- While only limited regions of the globe have been studied, most show an increase in sub-daily extreme rainfall over the last few decades (but with regional and seasonal variations)



Regional trends in observed sub-daily extreme rainfall based on published studies

(Westra et al., submitted)

Summary:

The GC is being addressed trough the GEWEX 4 Science Questions (GSQs)

- **Observations and Predictions of Precipitation**
- **Global Water Resource Systems**
- **Changes in Extremes**
- **Water and energy cycles and processes**

Summary: Strategy

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1) **Data Assessment and data mining:** Address how well precipitation is measured by various observing systems, and what basic measurement deficiencies

2)**Obervational/model evaluations**: Identify how models can become better and how much confidence can be placed on global and regional climate predictions of precipitation

3) **Analysis:** Quantify how changes in climate affect the characteristics of precipitation (distribution, amount, intensity, frequency, duration, type)

4) **Exploit new capabilities in model and obs:** Provide an assessment of how changes in the land surface and hydrology influence both past and future changes in water availability and security and how new observations and new advances to models might assist in water

5) **Examine Climate change effects on water and ecosystems** - Provide an assessment on how changes in climate affect terrestrial ecosystems, hydrological processes, water resources and water quality,

Backups

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Specific questions addressed at the GSQ1 Workshop

1A. How well can precipitation probability distributions and accumulations be described by various observing systems, what variables define the uncertainty estimates at various space and time scales, and how can they be improved in the future?

1B. How can observations of water and energy parameters be used to better understand relationships among these variables and how they influence precipitation at various scales?

1C. How much confidence do we have in the physics of models used to predict long-term climate changes in precipitation and what metrics can be applied to track progress in the model representations of precipitation physics?

1D. What is the role of data assimilation in bridging the gap between observations and models and how can we advance diagnostic methods that can deal more directly with the physics and parameterization of convection; and what planned and new observing systems could improve knowledge going forward?

GEWEX

There are multiple benefits and the results are important for society

- Improved models => improved predictions
- All time scales, monthly, seasonal, decadal, centennial
- All space scales: regional to global
- Extremes
- Quantified uncertainties
- Information for water managers, decision makers, users
- Drought Information System
- Effects of management decisions
- Better interactions between research and users

GEWEX Science Questions

How can we better understand and predict variations and changes in precipitation?

- use and development of expected improved **datasets** on: precipitation and soil moisture from ongoing and planned satellite missions, as well from in-situ observations;
- evaluation and **analysis** into various products;
- document the mean, variability, patterns, extremes and full probability density functions,
- **confront models** in new ways;
- improve understanding of atmospheric and land surface **processes** and their **modeling** that improve simulations of precipitation;
- employ new techniques of data assimilation and forecasts that improve predictions of the hydrological cycle.

These results should lead to improved climate services.

GEWEX Science Questions:
Global water resources

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

- *Address terrestrial water storage changes*
- ***Close the water budget over land***
- *Exploit new datasets, data assimilation, improved physical understanding and modeling skill across scales,*
- *Catchments to regional to global to the entire hydrological cycle including hydrogeological aspects of ground water recharge.*
- *Use of **realistic land surface** complexity with all anthropogenic effects included instead of a fictitious natural environment.*
- *Includes all aspects of **global change:** water management, land use change and urbanization; water quality and especially water temperature (affected by industrial and power plants use); later nutrients.   cont…*

GEWEX Science Questions:

Global water resources

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

- *The **ecosystem response** to climate variability and responsive vegetation must be included.*
- *Cryospheric changes such as permafrost thawing and changes in mountain glaciers must be included.*
- *Feedbacks, tipping points, and extremes are of particular concern.*

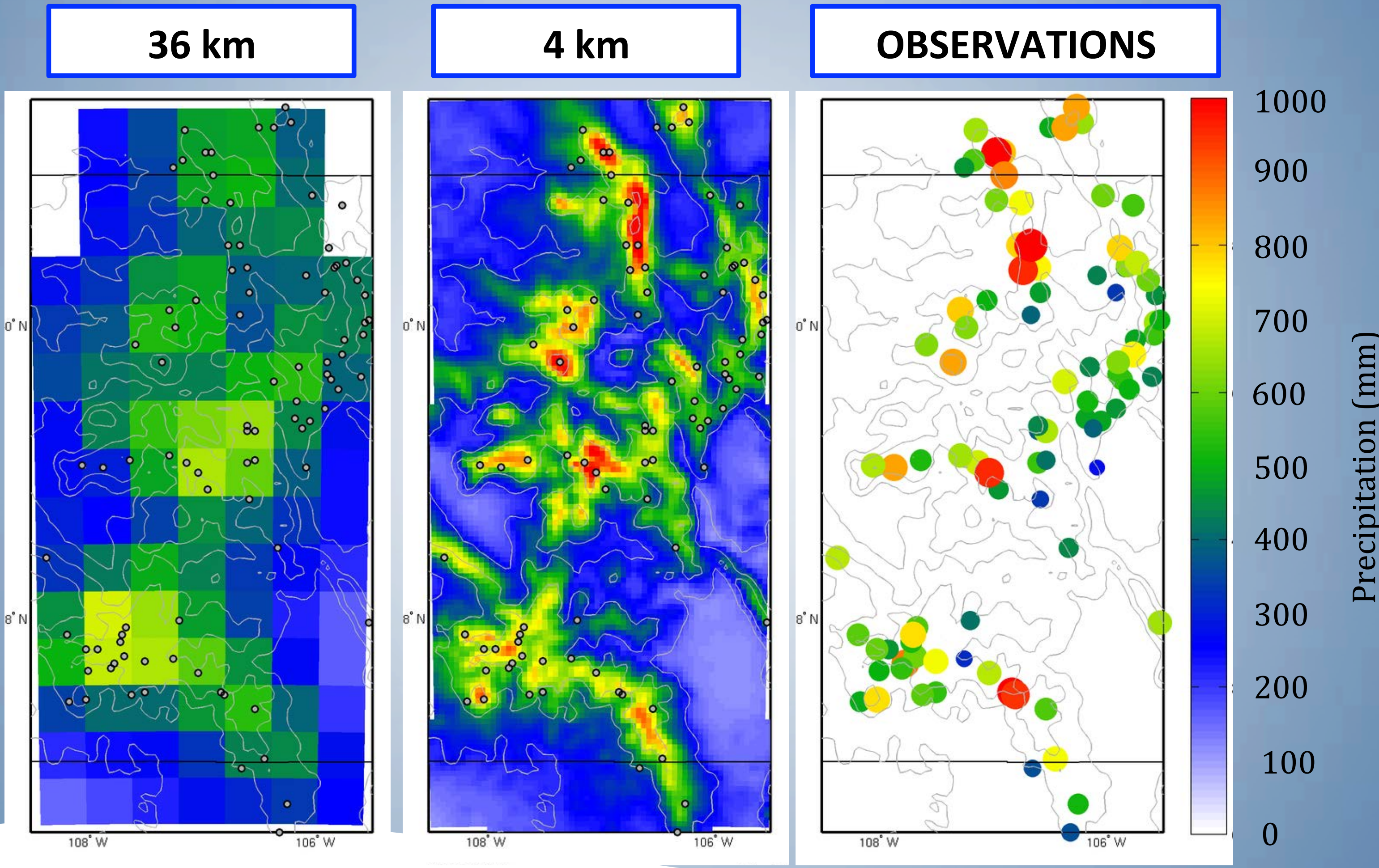
The results should enhance the evaluation of the vulnerability of water systems, especially to extremes, which are vital for considerations of water security and can be used to increase resilience through good management and governance.

GEWEX Science Questions (GSQs)

"Water availability" will be addressed in all 4 GSQs,

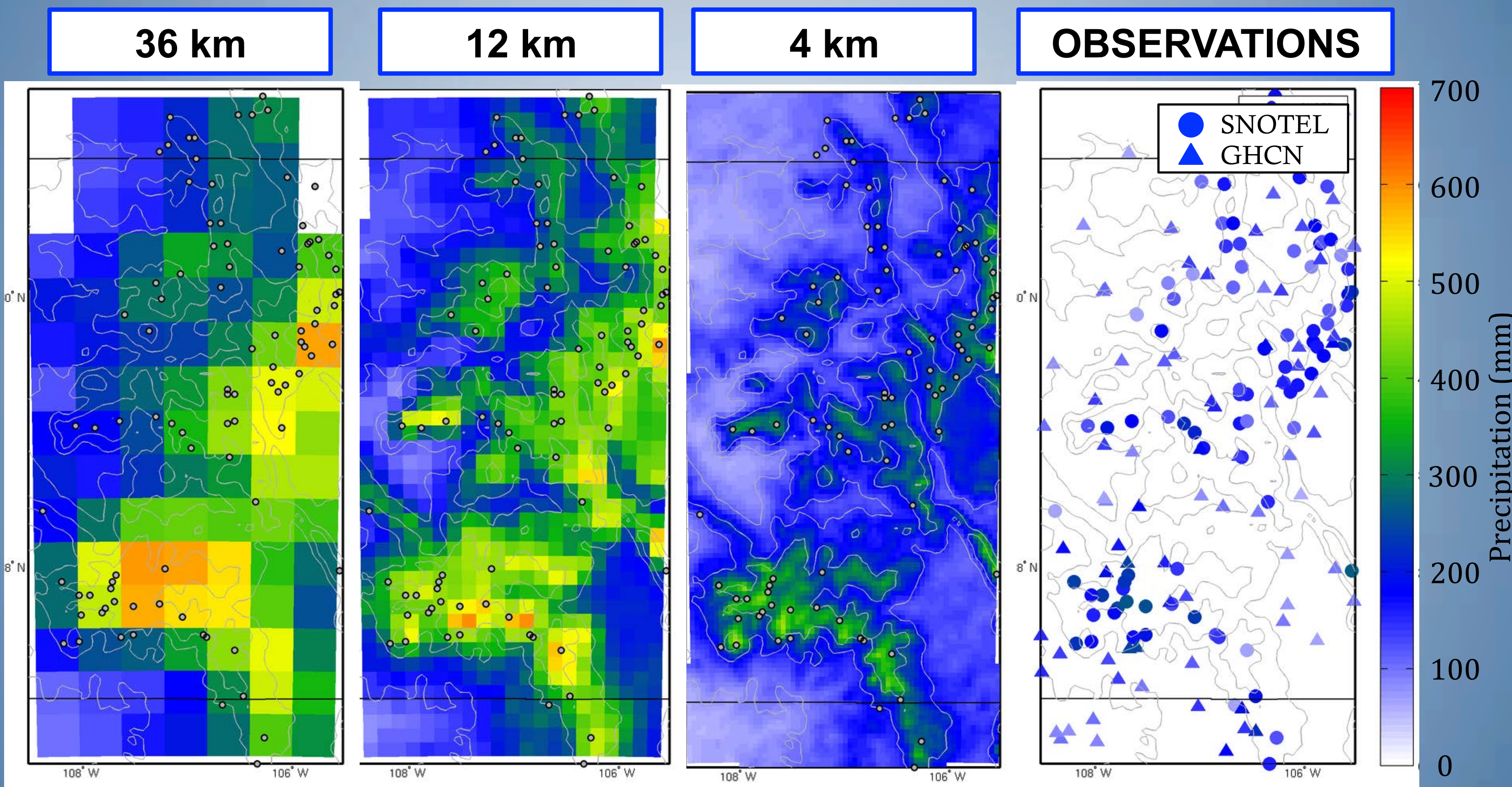
- **Observations and Predictions of Precipitation**
- **Global Water Resource Systems**
- **Changes in Extremes**
- **Water and energy cycles and processes**

7-year average cool-season precipitation: 1 October – 31 May



7-year average warm-season precipitation:

1 June – 30 September



Observations and Predictions of Precipitation- GSQ 1

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- **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 (distribution, amount, intensity, frequency, duration, type) of precipitation – with particular emphasis on extremes of droughts and floods?**
- ***How do models become better and*** **how much confidence do we have in global and regional climate predictions of precipitation?**

Global Water Resource Systems -GSQ 2

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- How do changes in the 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?

GEWEX