The water GC questions

'How does fresh water vary within the Earth system and how will its 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 canunderstanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

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

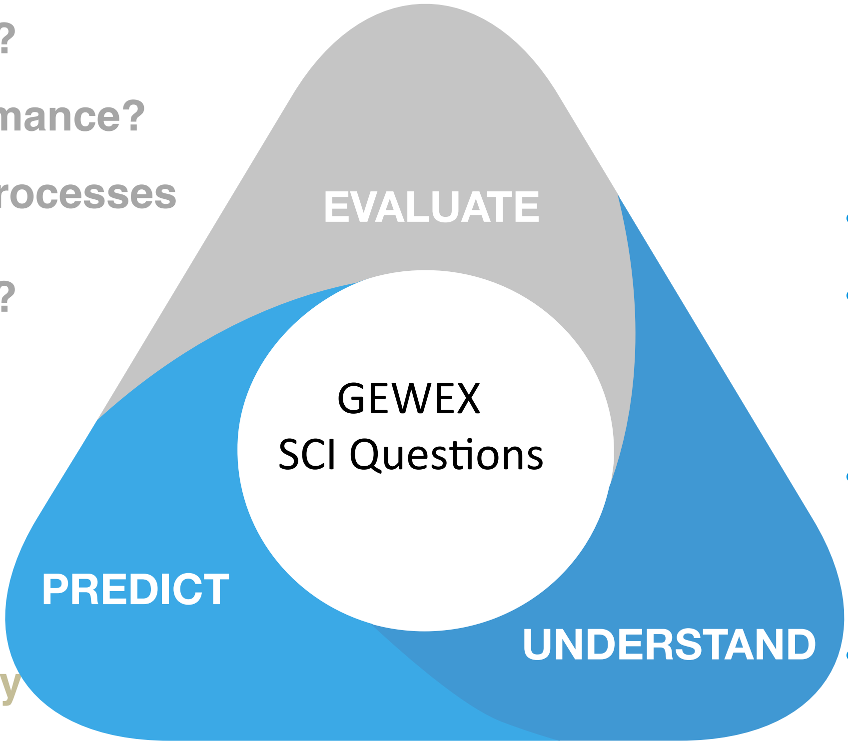
These three questions form the basis/focus of the Water Availability Grand Challenge.

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?
- Aerosol?

- Model improvements by adding key processes
- Modeling human impacts
- Resolution

Implementation activities

Evaluate

- *Precip Assessment study*
- *New initiatives on mountain precip & frozen precip*
- *Development of new data sets (e.g. INTENSE, radar),*
- *Model evaluation though focused MIPS (LS3MIP,LMIP) Planned workshops a& contributions to obs4mip*
- *Model Process evaluations (PROES)*

Understand

- *Monsoons in a changing climate ('joint with CLIVAR')*
- *Energy controls on global & regional water cycles*
- *Hydrological sensitivity*
- *New modeling initiatives under HiRes (e.g. HiREsMiP)*
- *Workshops-hydrological sensitivity?" June 2016; HiRES, NCAR Boulder, Sept 2016; water management , Sept 2016*

Predict

- *Model improvements*
  - *HiRES*
  - *Soil processes; & Subsurface hydrology;*
  - *GDIS;*
  - *Water management influences in large scale models;*
  - *Workshops*

GDAP

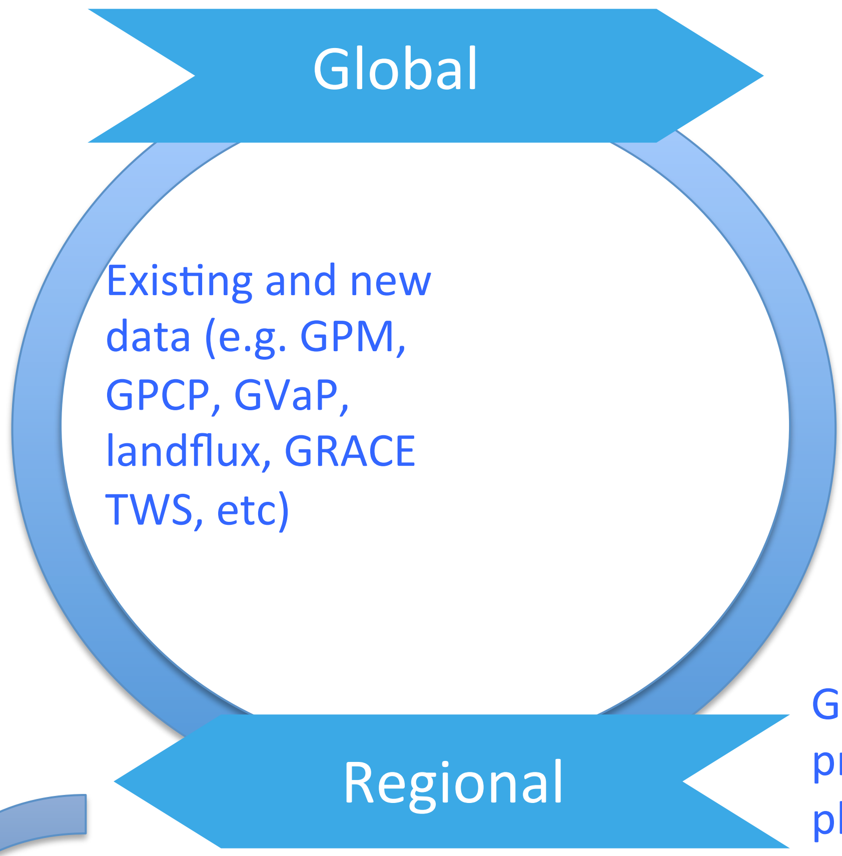
GHP

GASS

GLASS

A perspective

- ESM evaluation, development
- Global-scale observations
- Global-scale process understanding
- Global HiRes
- Global resource systems
- Global energy/ water balance



- Regional HiRes models
- Regional observations
- Regional-scale process understanding
- Regional resource systems

GHP CC, RHPs, Land-atmos process improvement, moist physics process improvement

UNESCO

Decision support, stakeholders, impacts, ….

Q1 How can we better understand and predict precipitation variability and changes?

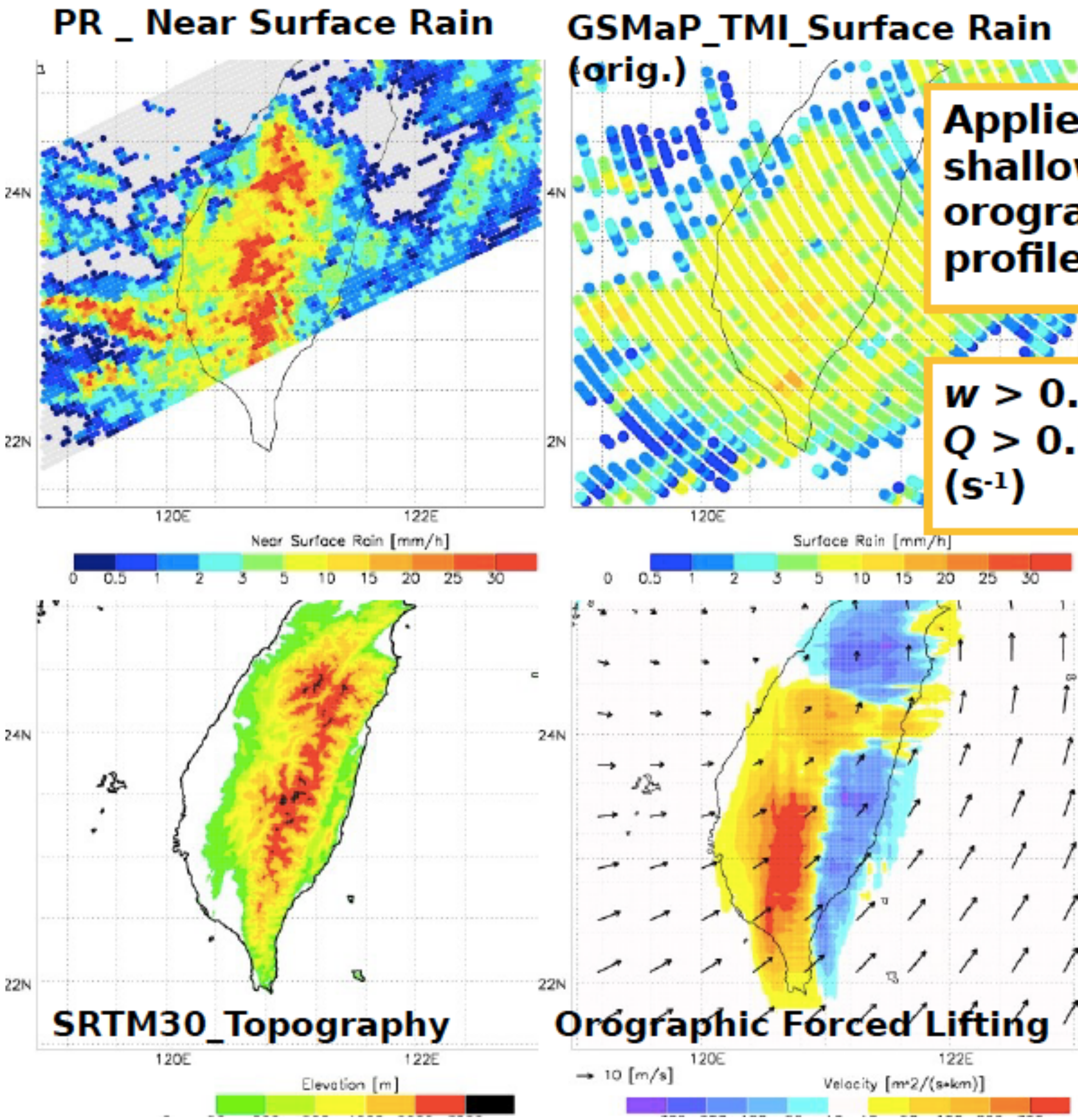
1) Urgency for monitoring mountainous areas

- 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***"

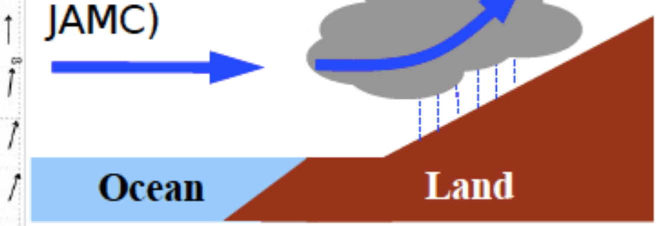
2) Mount terrain - precipitation in mountainous regions

3) Precipitation assessment

Typhoon Morakot (2009) over Taiwan (Taniguchi et al. 2013, JHM)

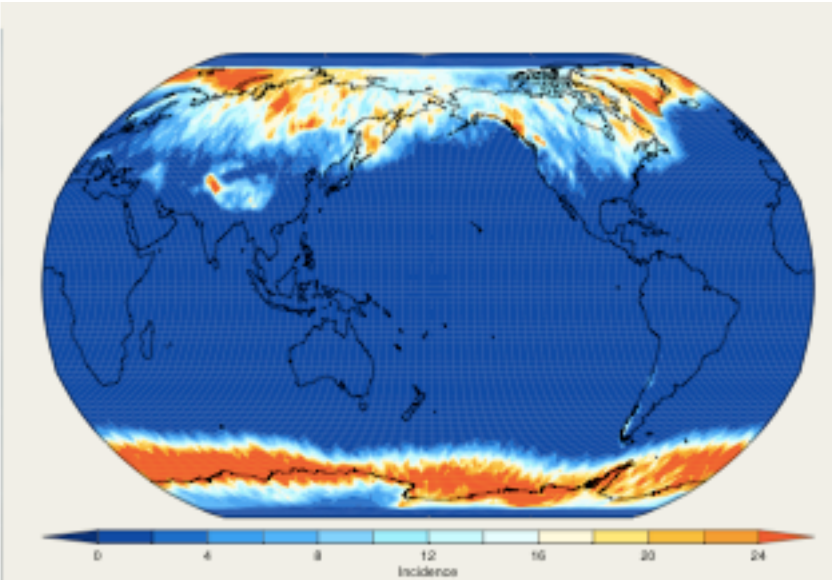


Shige et al. (2013, JAMC)

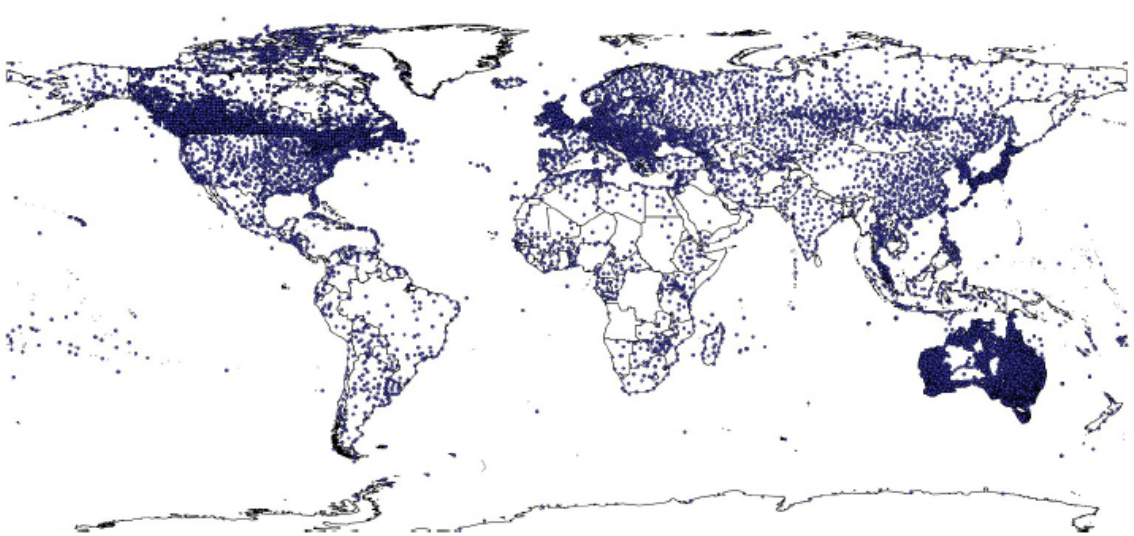


The revised scheme has been incorporated into the GSMaP V6 (Yamamoto and Shige 2015, AR).

Global snowfall



INTENSE
Sub-daily

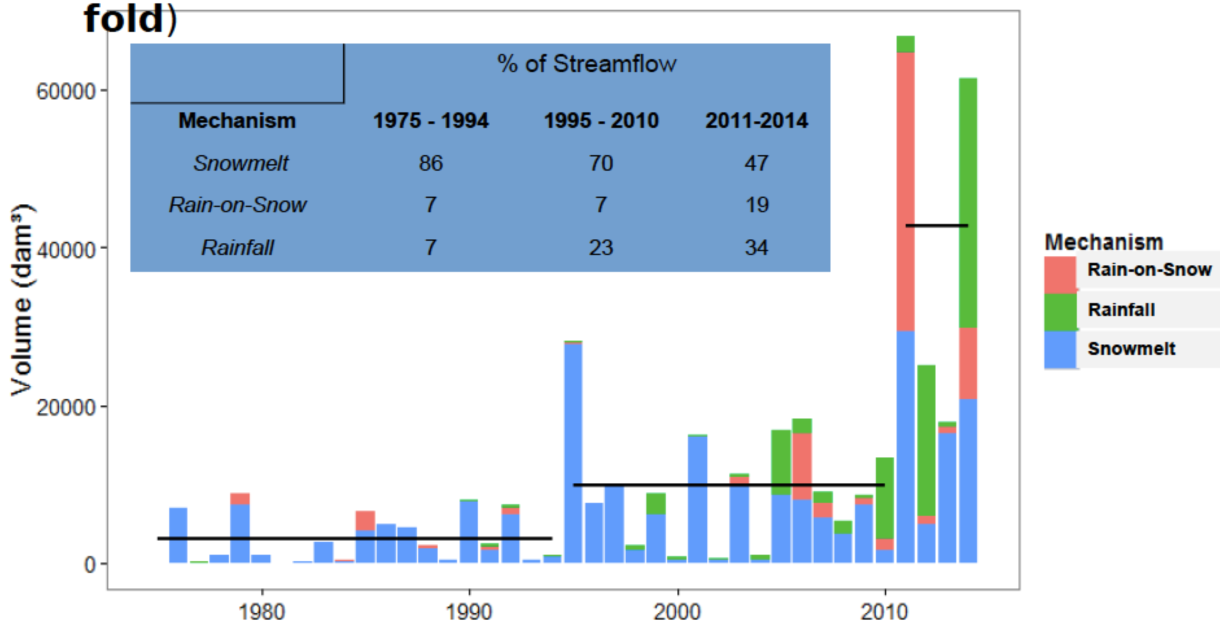


Understanding

- MIPS

Runoff Processes (1975 – 2014)

- Increased runoff contributions from:
  Snowmelt (**5-fold**), rain-on-snow (**34-fold**), rainfall (**150-fold**)

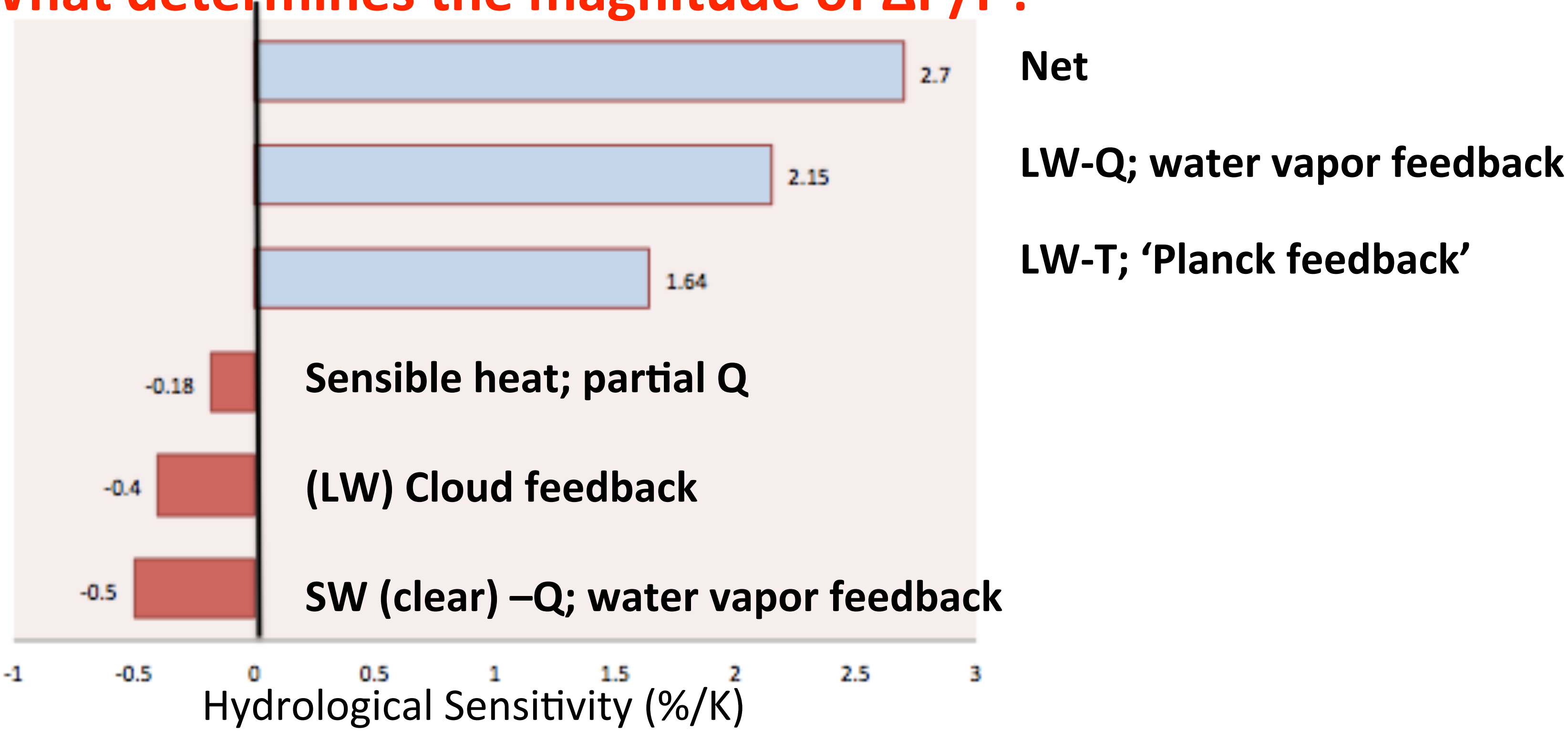


Mechanism	% of Streamflow 1975 - 1994	1995 - 2010	2011-2014
Snowmelt	86	70	47
Rain-on-Snow	7	7	19
Rainfall	7	23	34

Understanding impact of precipitation character and land use change to river runoff

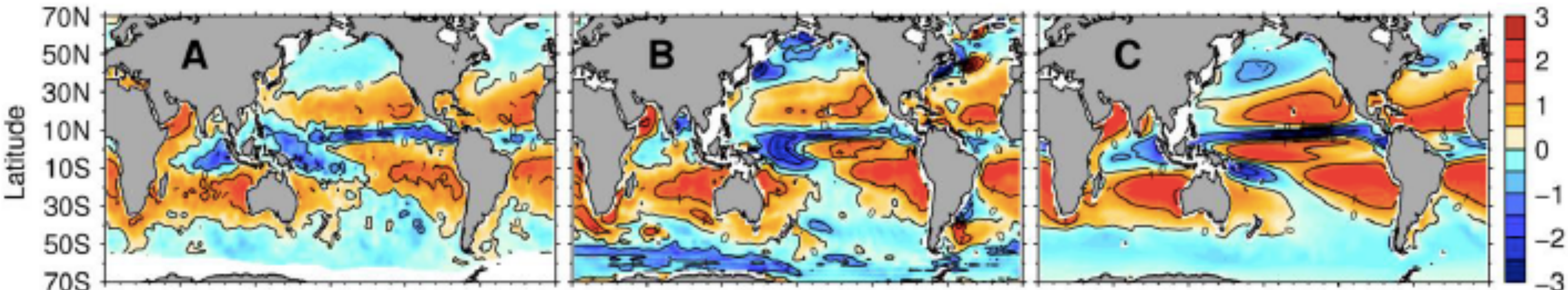
Global sensitivity

- **Why is ΔP/P < ΔW/W? - This is set by the absorption/emission physics, largely water vapor controlled, and non-linear. The 'Planck' response too is small (~1.6%/K)**
- **What determines the magnitude of ΔP/P?**



- **What contributes to the model-spread in ΔP/P? Model spread in representation of absorption/emission physics (e.g. solar water vapor absorption, DeAngelis et al., 2015). Absorbing aerosol (black carbon) is a potential source of large uncertainty (e.g. Pendegrass & Hartmann, 2012)**

Changing Water supply: some suggestion that changes will be larger than models project



Evaporation –minus precipitation

Salinity

Durack et al. 2011
Change in Salinity over 50 years

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

The hydrological 'sensitivity' is subject to the same feedbacks to control the 'climate' sensitivity

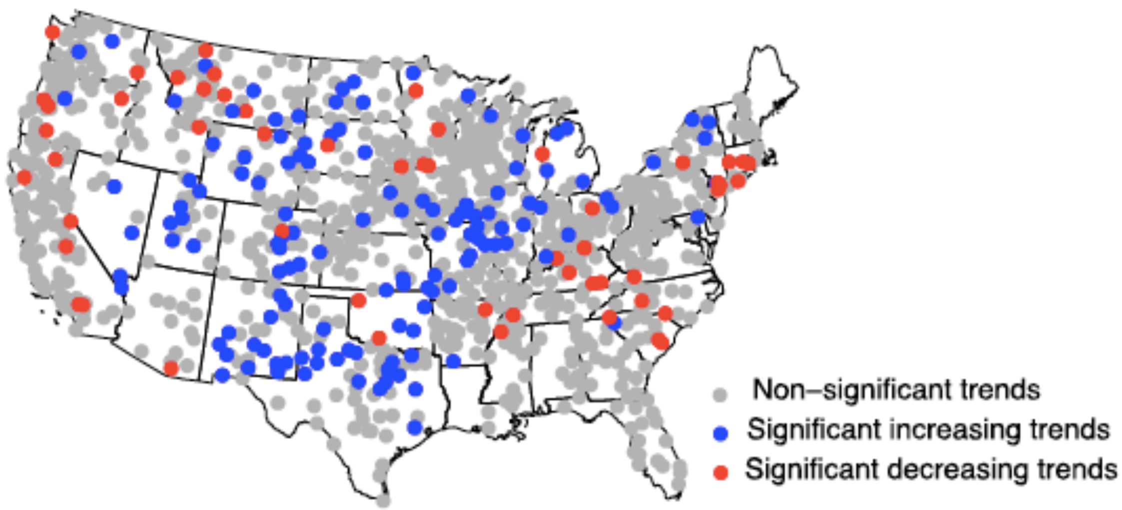
Example from Mauritsen & Stevens, 2015

Underscores links to climate grand challenge

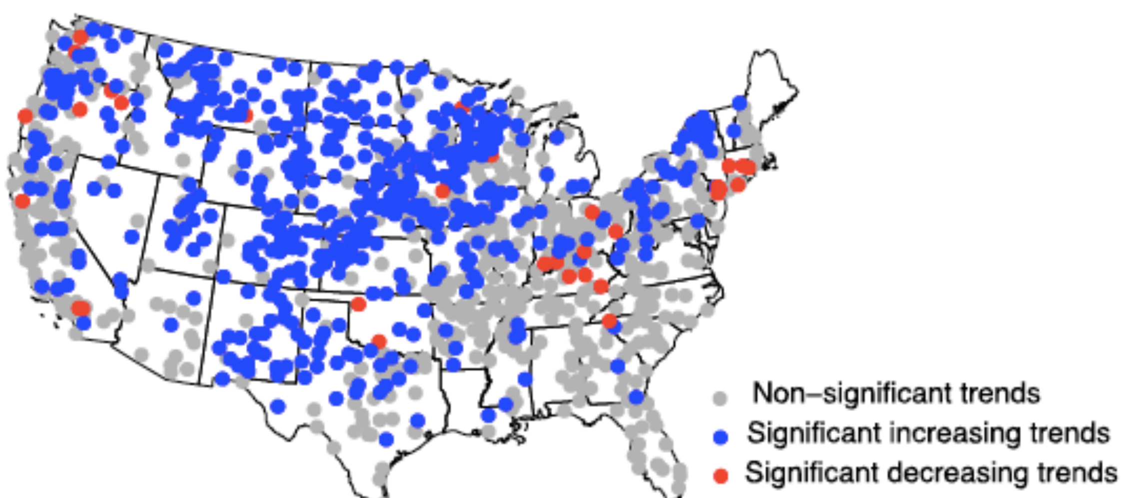
Trends in extreme P

Newcastle University
UK | Malaysia | Singapore

a) Trends in DJF heavy rainfall events (daily scale)



b) Trends in DJF heavy rainfall events (hourly scale)



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

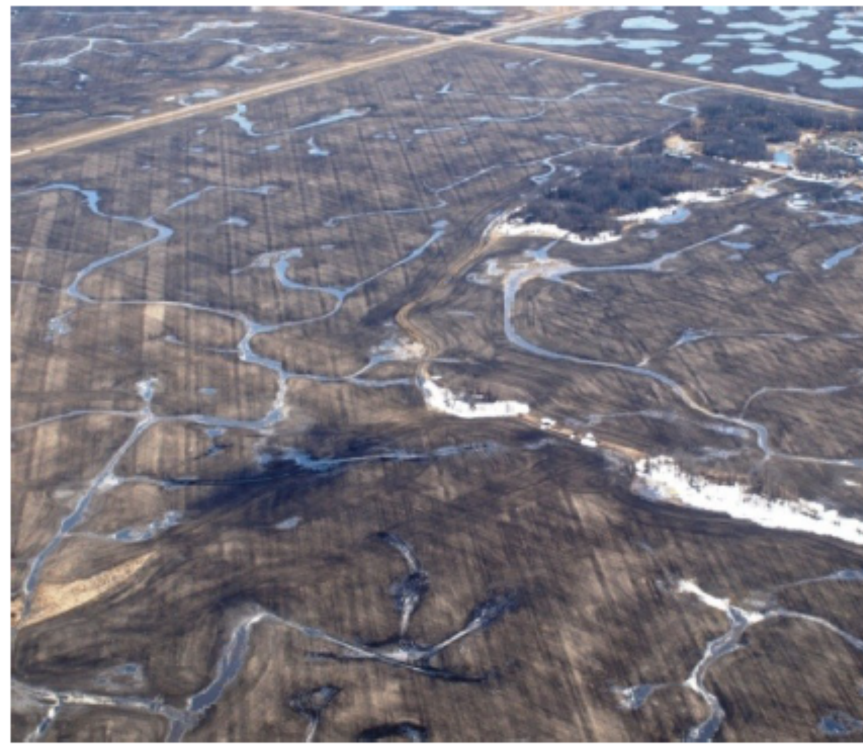
Changing Cold Regions Network

Global Institute for Water Security

Loss of depressional storage capacity, increase in channelization

No Drainage

Artificial Drainage

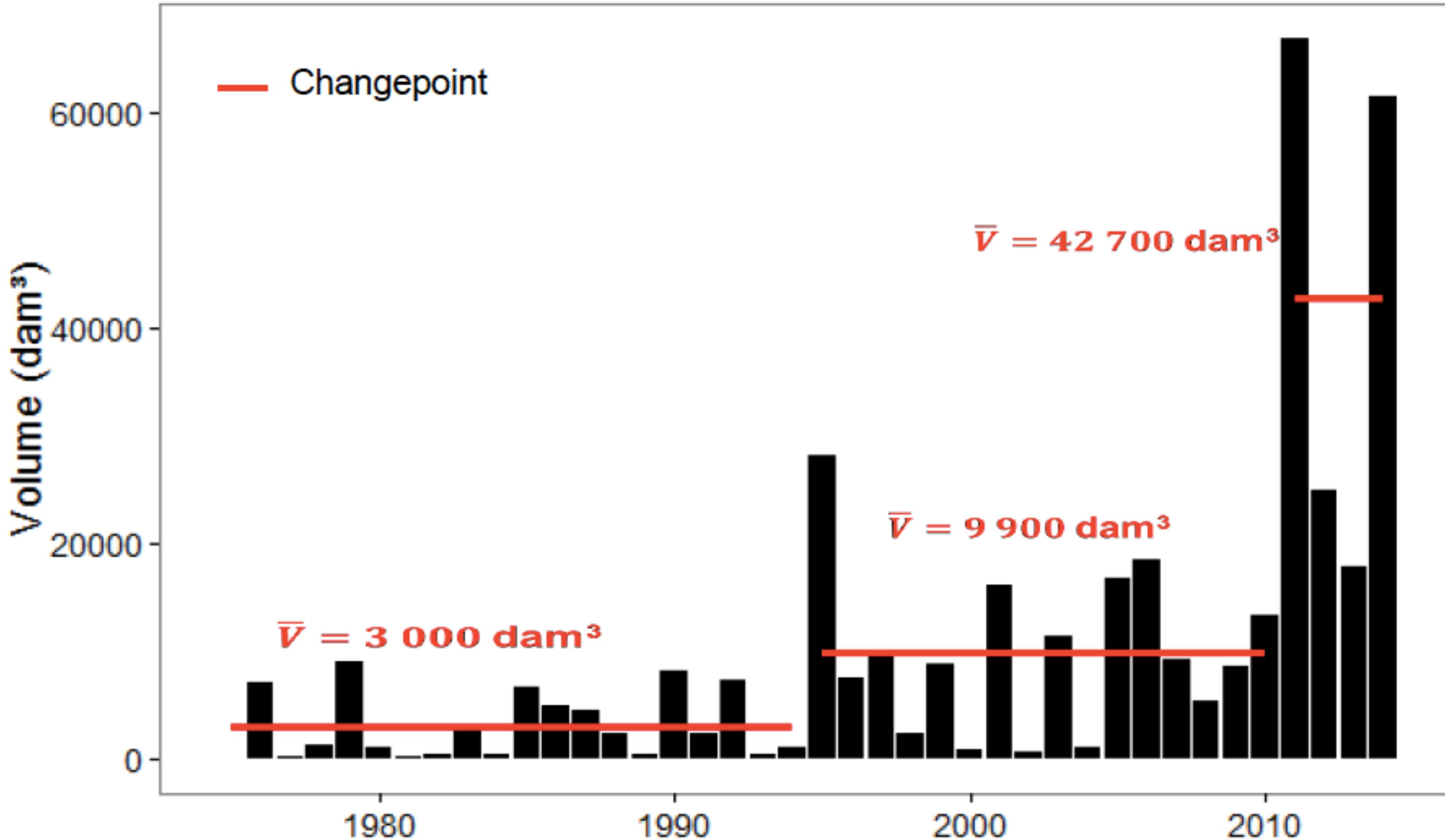


Human modifications of land water balances – A CCRN EXAMPLE

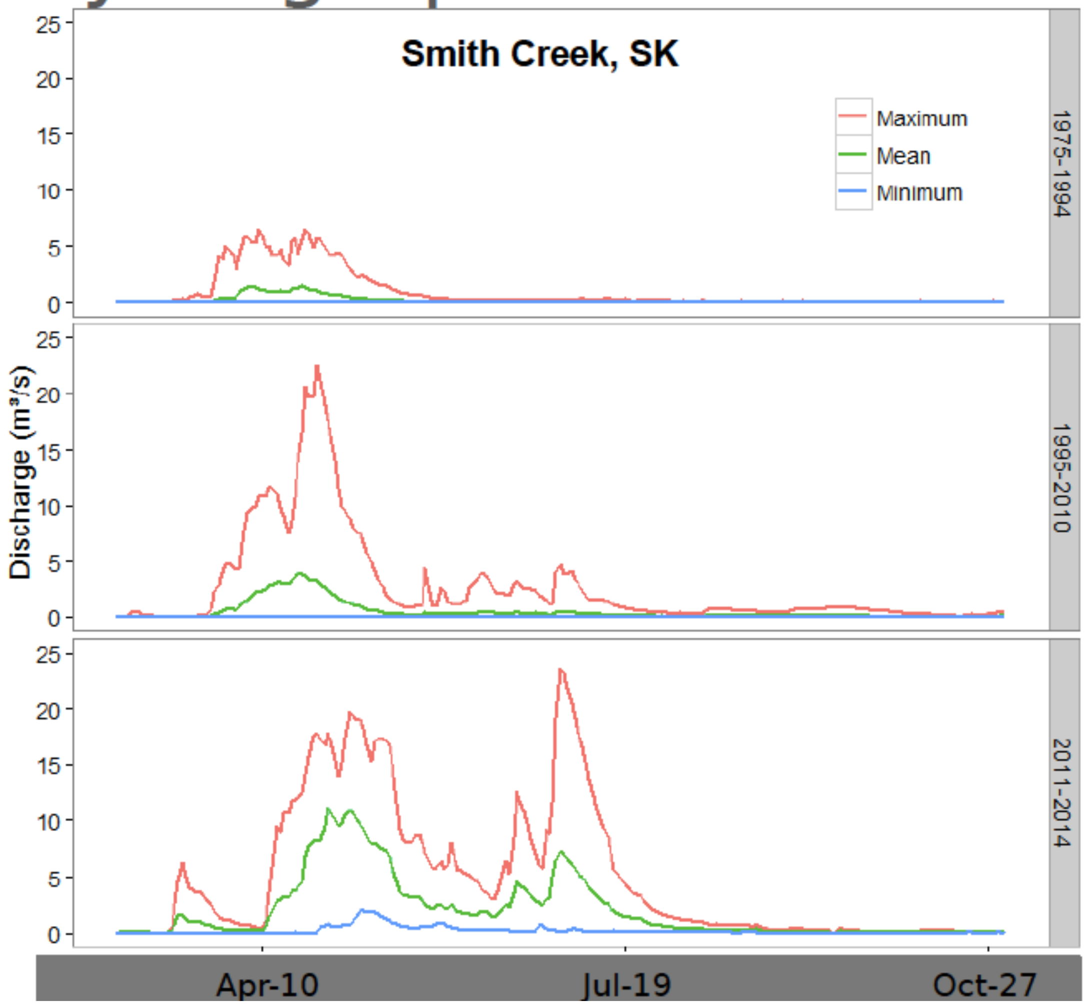
Global Institute for Water Security

Annual Streamflow Volume (1975 – 2014)

- 14-fold increase in streamflow volumes ($p<0.001$)



Hydrographs



<u>1975-1994</u>

Snowmelt driven

<u>1995-2010</u>

Increased spring and summer runoff

<u>2011-2014</u>

Second peak flow in summer months caused solely by rainfall runoff

Importance of underground water processes

HyMeX

MISTRALS

Results on drought processes

➲Better understanding of underground water processes :

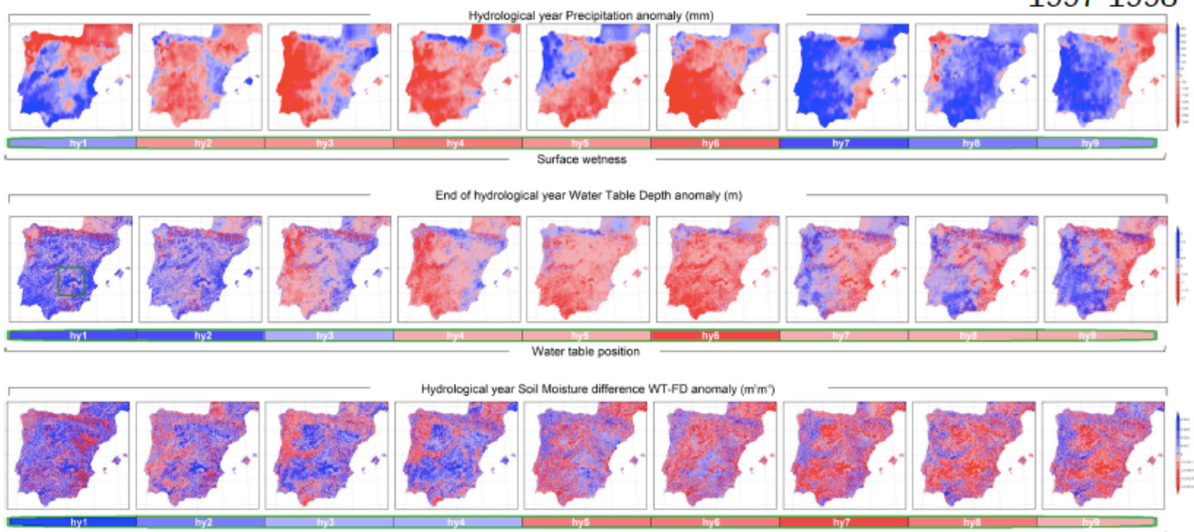
Comparing 2 simulation of LEAFHYDRO :

- WT : Run with water taible
- FD : Free drainage case.

Prolonged droughts reduce the influence of the water table on soil moisture and increase the impact. Míguez-Macho and Martinez de la Torre 2014.

1989-1990

1997-1998



ALMIP AMMA Land Surface Model Intercomparison Project

SOILWAT

Prediction - knowledge transfer to model development

- Including water management in large scale models (R. Harding/J. Polcher)
  - Proposed to be jointly with GLASS
  - The rational is explained in a GEWEX News article
  - Workshop to held from 28 Sept. 2016 to 30 Sep, Gif-sur-Yvette
  - The workshop should produce tangible objectives

What changes with resolution?

HiRes

HiRESMIP

PRIMAVERRA

What changes with resolution?

The global hydrological cycle

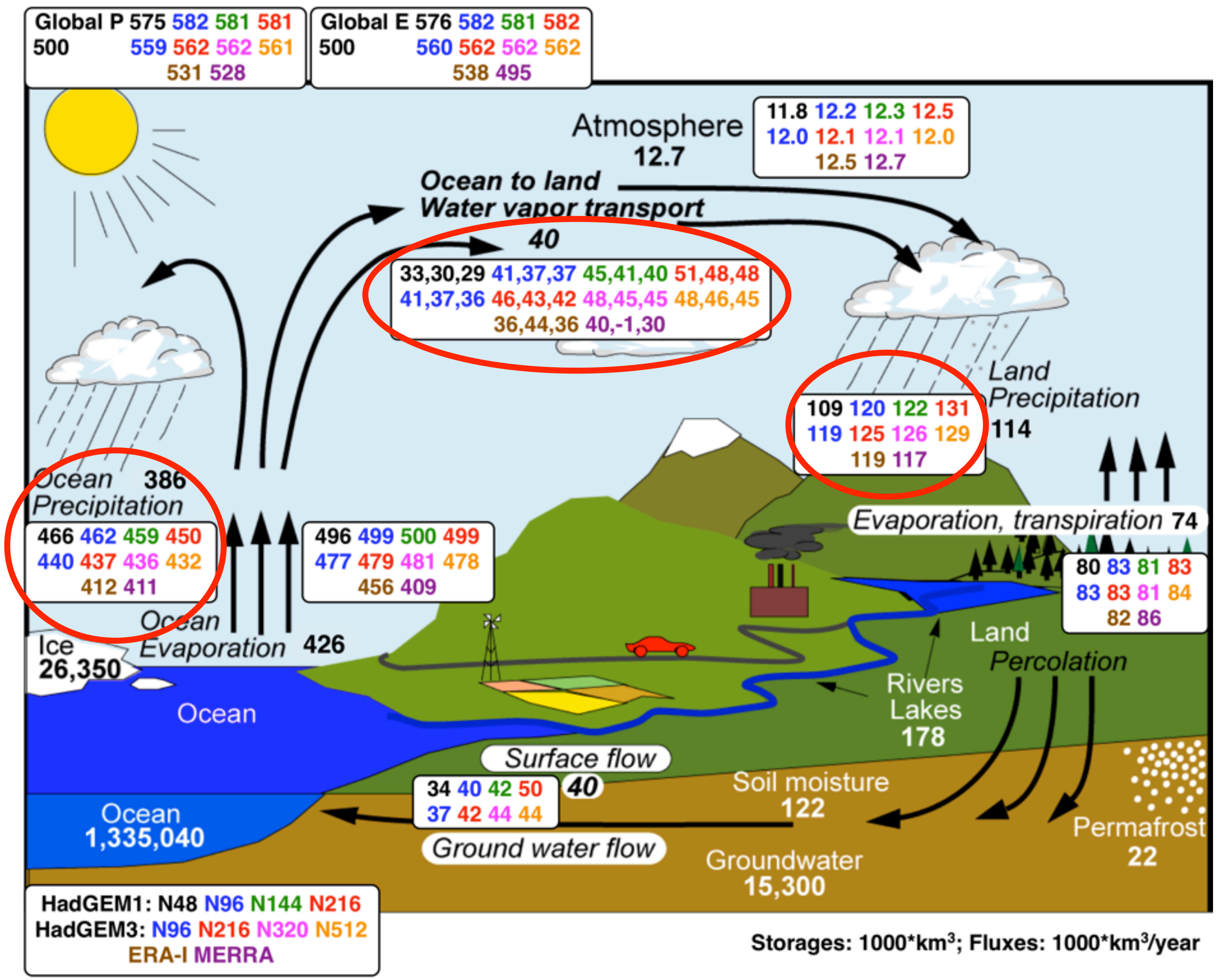


Figure adapted from Trenberth et al, 2007, 2011

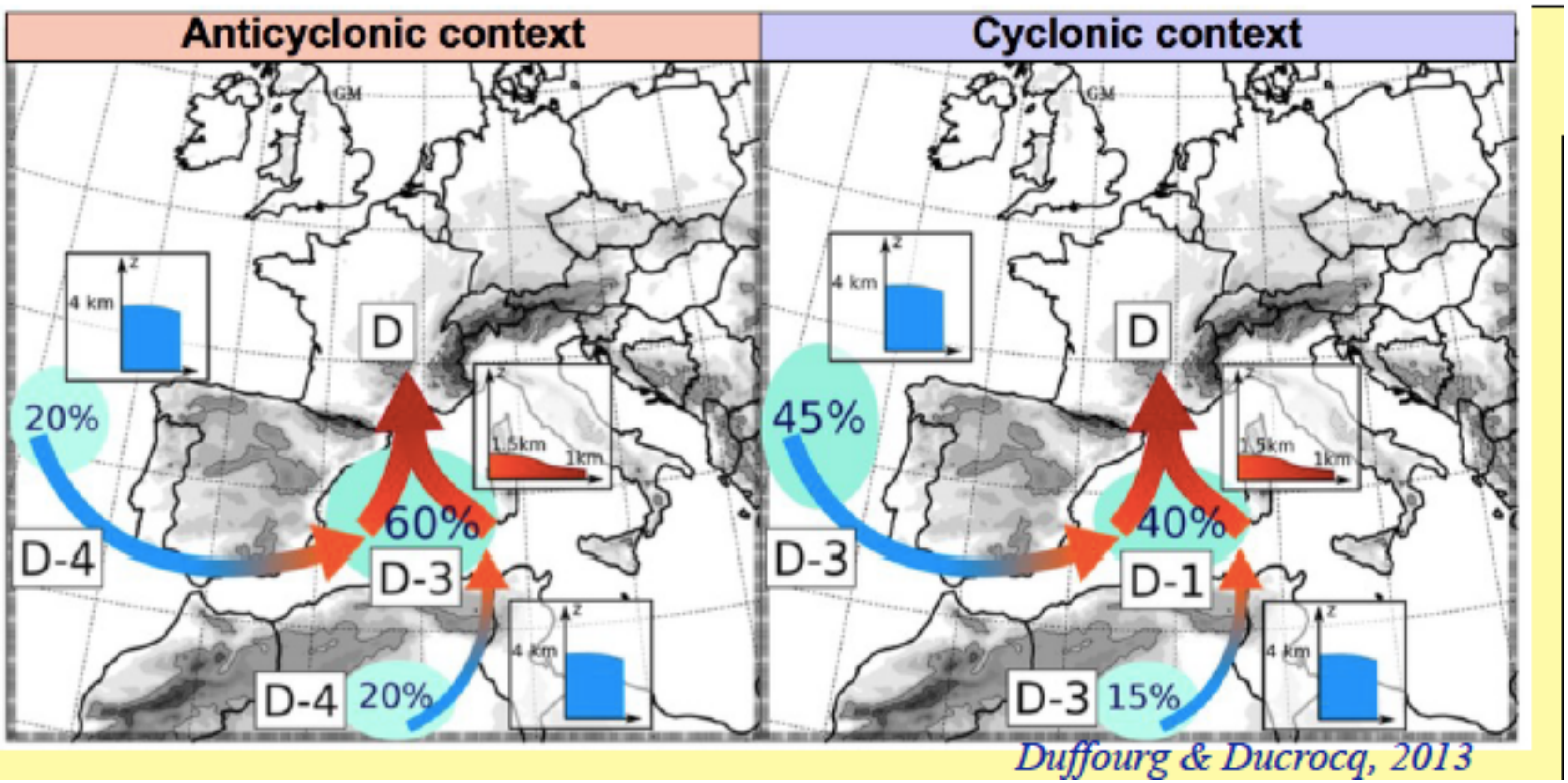
- Classic GCMs too dependent on physical parameterisation because of unresolved atmospheric transports
- Role of resolved sea→land transport larger at high resolution
- Hydrological cycle more intense at high resolution

Equivalent resolution at 50N:

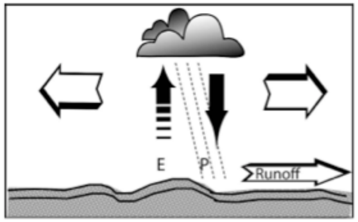
270 km
135 km
90 km
60 km
40 km
25 km

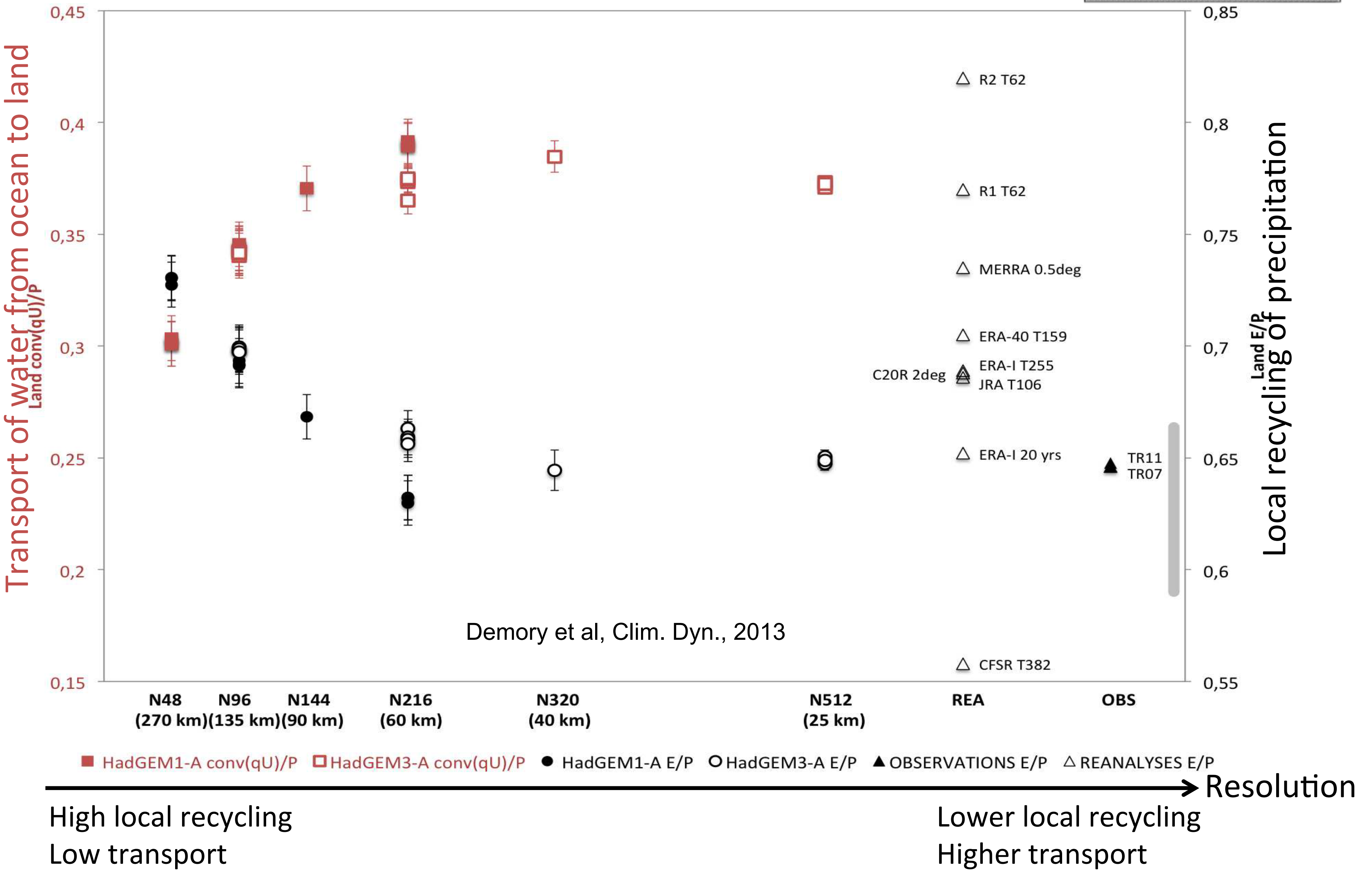
Demory et al., Clim. Dyn., 2013

Moisture source and transport



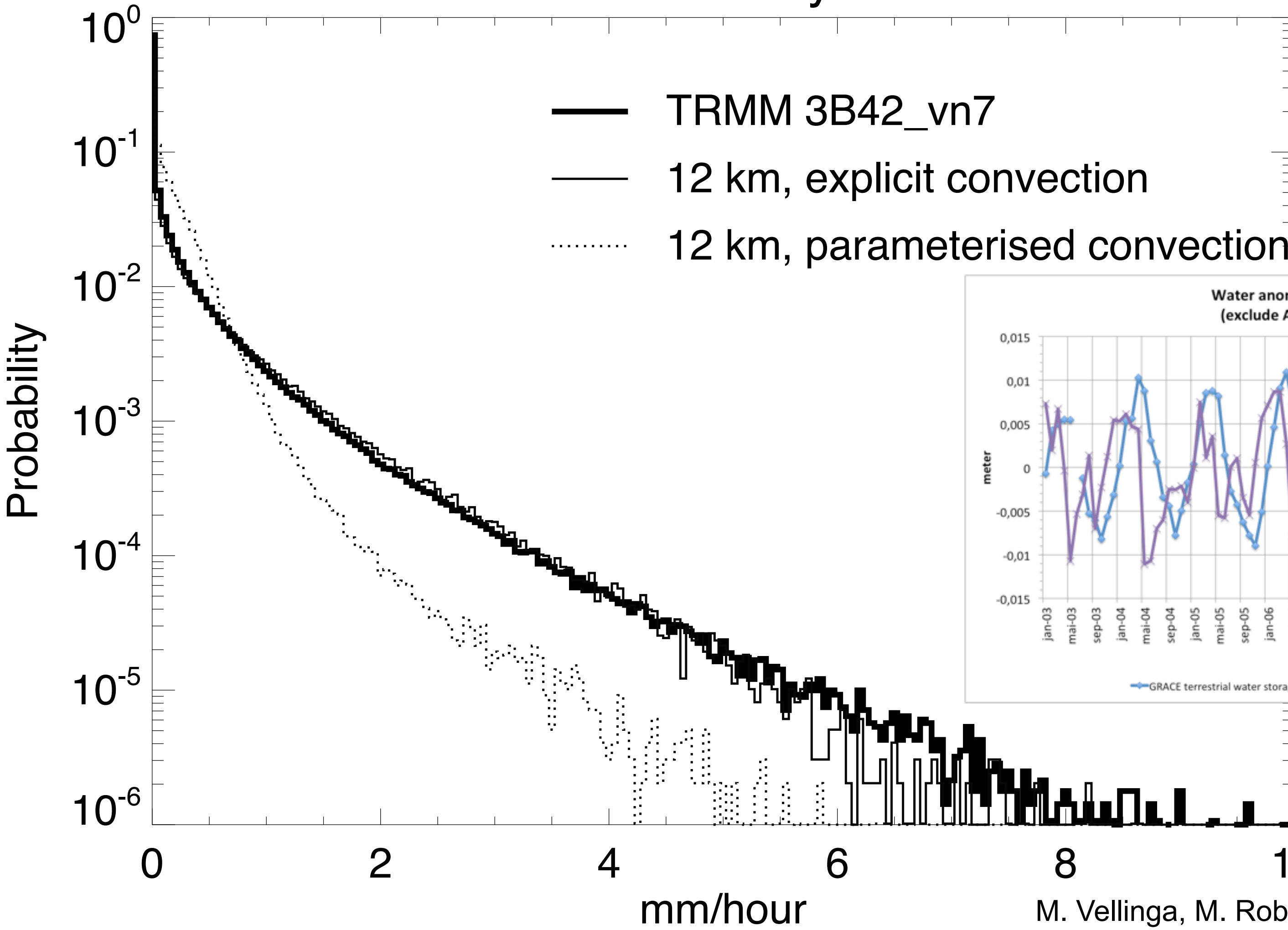
Relative roles of remote transport and local re-cycling in forming precipitation over land



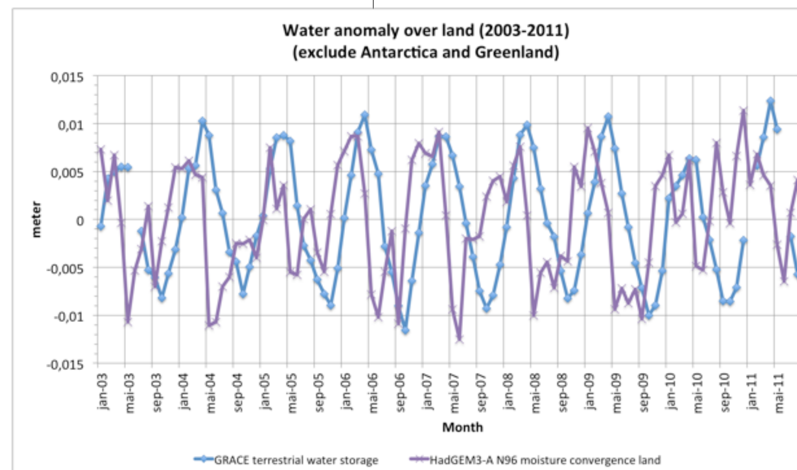


Precipitation spectra, GCM comparison with TRMM

Meridional mean 3-hourly rainfall in Sahel



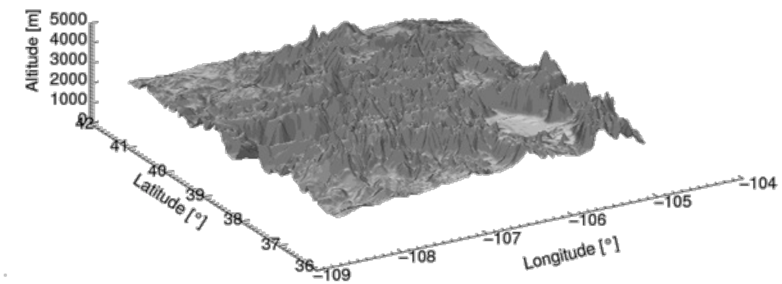
Demory in collaboration with Boening, grew out of our joint JPL/GEWEX GRACE workshop

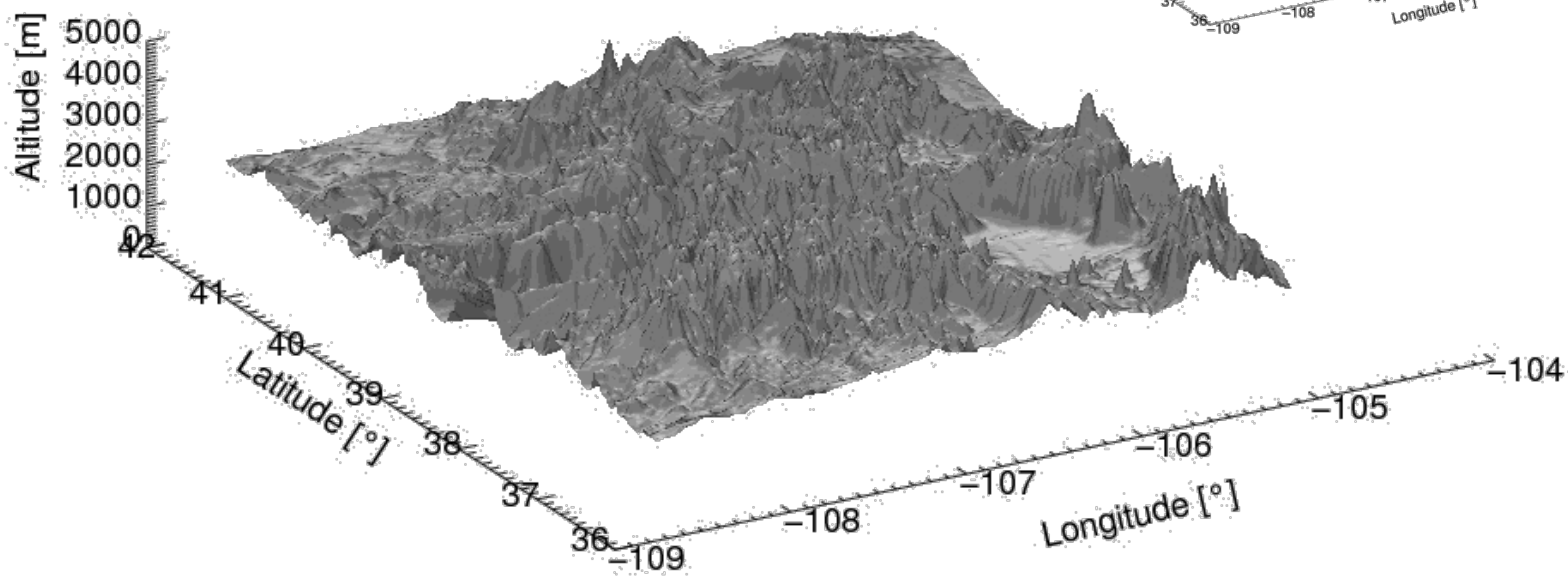


M. Vellinga, M. Roberts et al. 2014,

Value of high-res. regional model

Resolution : 2.4 km





Courtesy Andy Prein

Example of impact of resolution (resolved topography) on snow pack

30% too little precip in the winter and 65% too much in the summer using 36 km model compared to 4 km model (compensating errors)

Evapotranspiration in the 36 km model 38% higher than the 4 km model