Karlsruhe Institute of Technology

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Closure of the Large Scale Water Cycle: Performance and Limitations of Models and Observations

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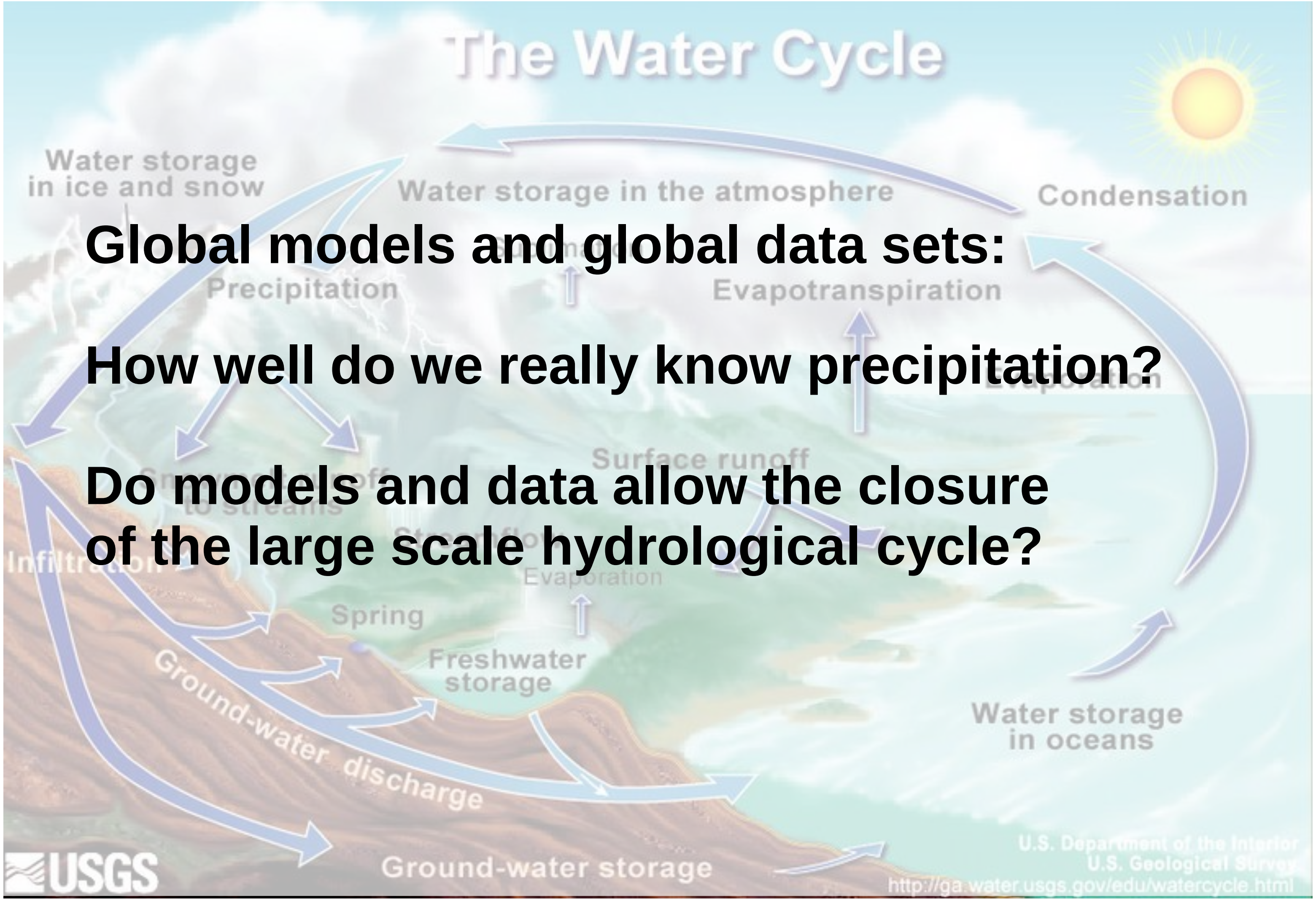
Research Questions



Global models and global data sets:

How well do we really know precipitation?

Do models and data allow the closure of the large scale hydrological cycle?

State of the Art Reanalyses & Observation Data Sets

Reanalysis	Institution	Available time-period	Horizontal Resolution	Vertical levels	Top level	Temporal resolution
ERA-Interim	ECMWF	1979 - present	T255 (≈ 78 km)	60	0.1 hPa	6 h, 1 d, 1 m
MERRA	NASA	1979 - present	$1/2° \times 2/3°$	72	0.01 hPa	6 h, 1 d, 1 m
CFSR	NCEP Climate Forecast System CFSR Reanalysis [1979 - 2010]	1979 - present	T382 (≈ 38 km)	64	0.26 hPa	1 h, 6 h, 1 m

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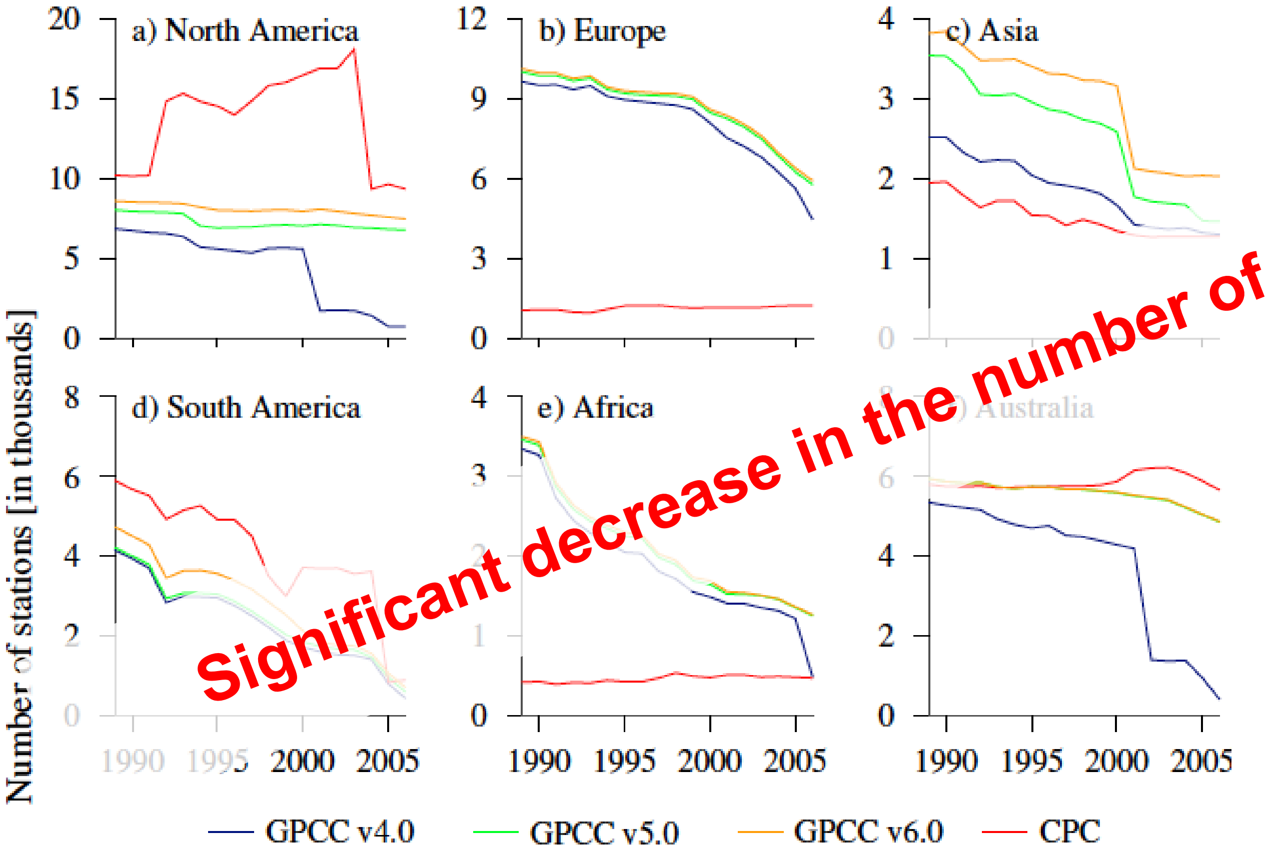
	Variables	Hor. resolution	Period	Output times	Version number
GPCC	P	$0.5° \times 0.5°$	1901 - 2009	monthly	4.0
GPCP	P	$2.5° \times 2.5°$	1979 - 2009	monthly	2.1
CRU	$P, T2$	$0.5° \times 0.5°$	1901 - 2009	monthly	3.0
CPC	P	$0.5° \times 0.5°$	1979 - present	daily	1.0
DEL	$P, T2$	$0.5° \times 0.5°$	1900 - 2008	monthly	2.01

GPCC: Global Precipitation Climatology Centre
GPCP: Global Precipitation Climatology Project
CRU: Climate Research Unit
CPC: Unified gauge based analysis of Global Daily Precipitation from Climate Prediction Centre
DEL: University of Delaware Air Temperature & Precipitation

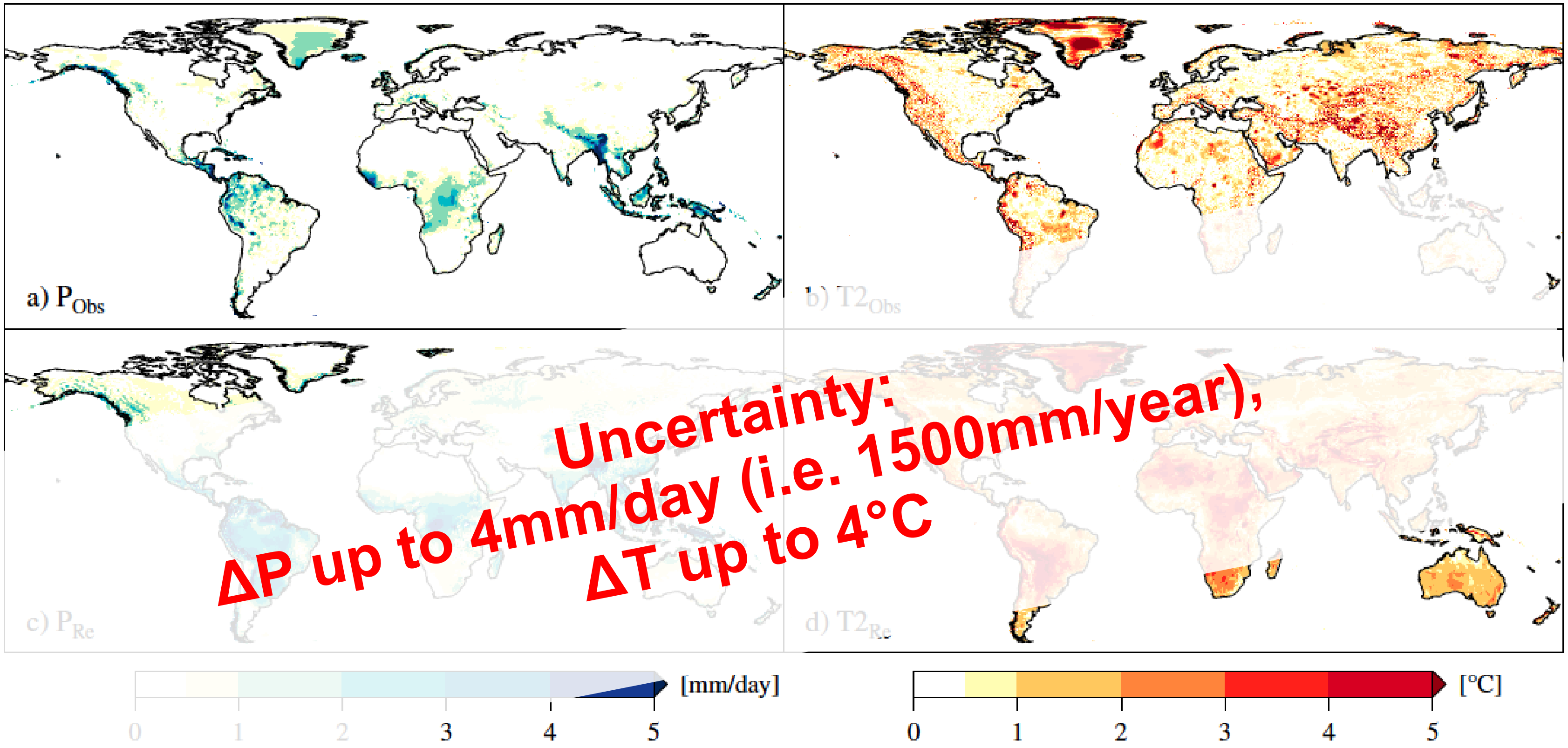
Caution: Significantly Varying Number of Original Data



Continent	Area [10^6 km^2]
North America	19.3
Europe	5.7
Asia	37.4
South America	17.8
Africa	30.0
Australia	7.7

Lorenz and Kunstmann, 2012 (JoHM)

How Well Do We Really Know the Water Cycle?



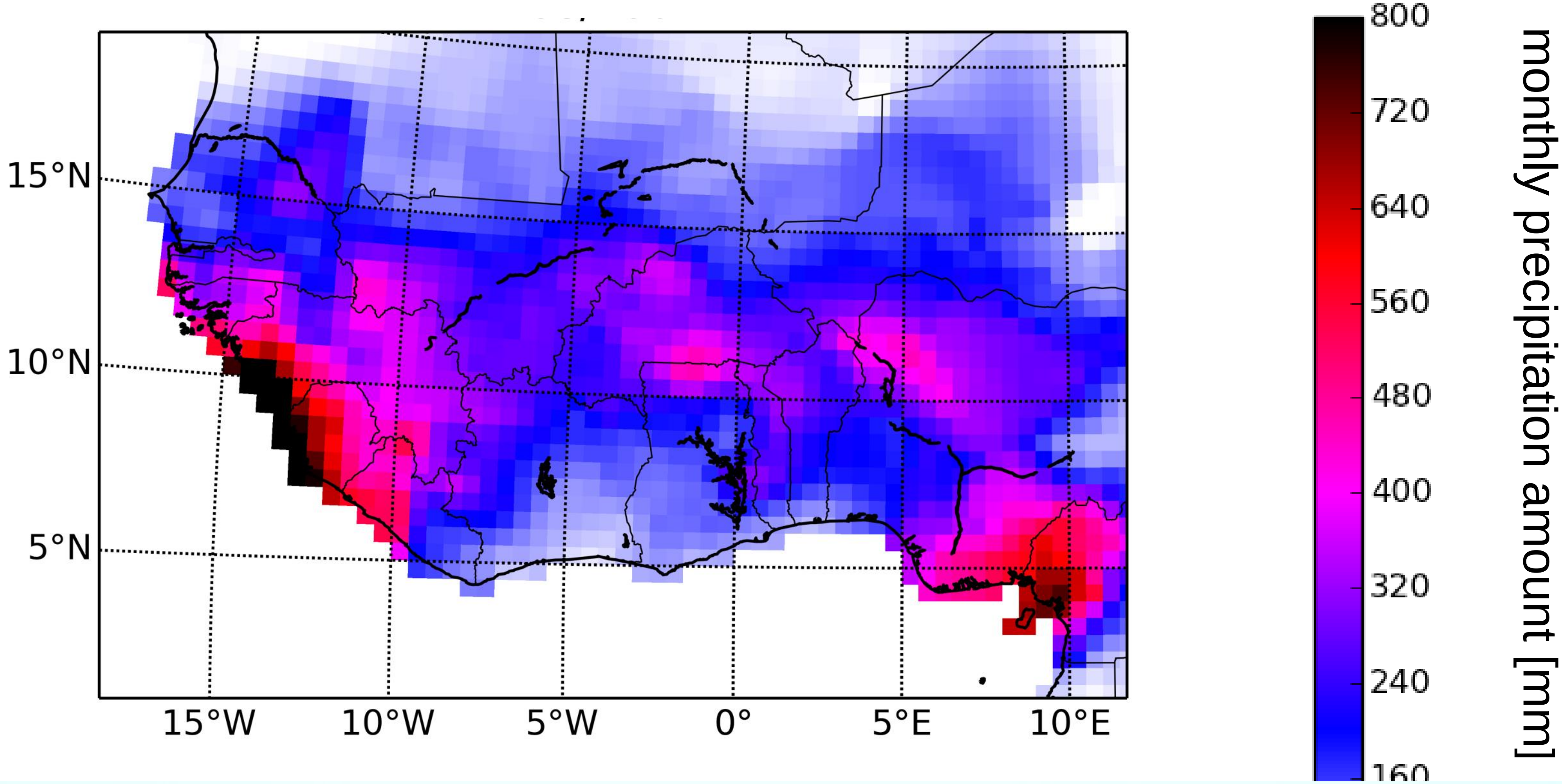
Precipitation observation ensemble: GPCC, GPCP, CPC, CRU, DEL

Temperature observation ensemble: CRU, DEL

Reanalysis ensemble: ERA-Interim, MERRA, CFSR

Lorenz and Kunstmann, 2012 (JoHM)

Illustration of Problem: GPCC Precipitation August 2007

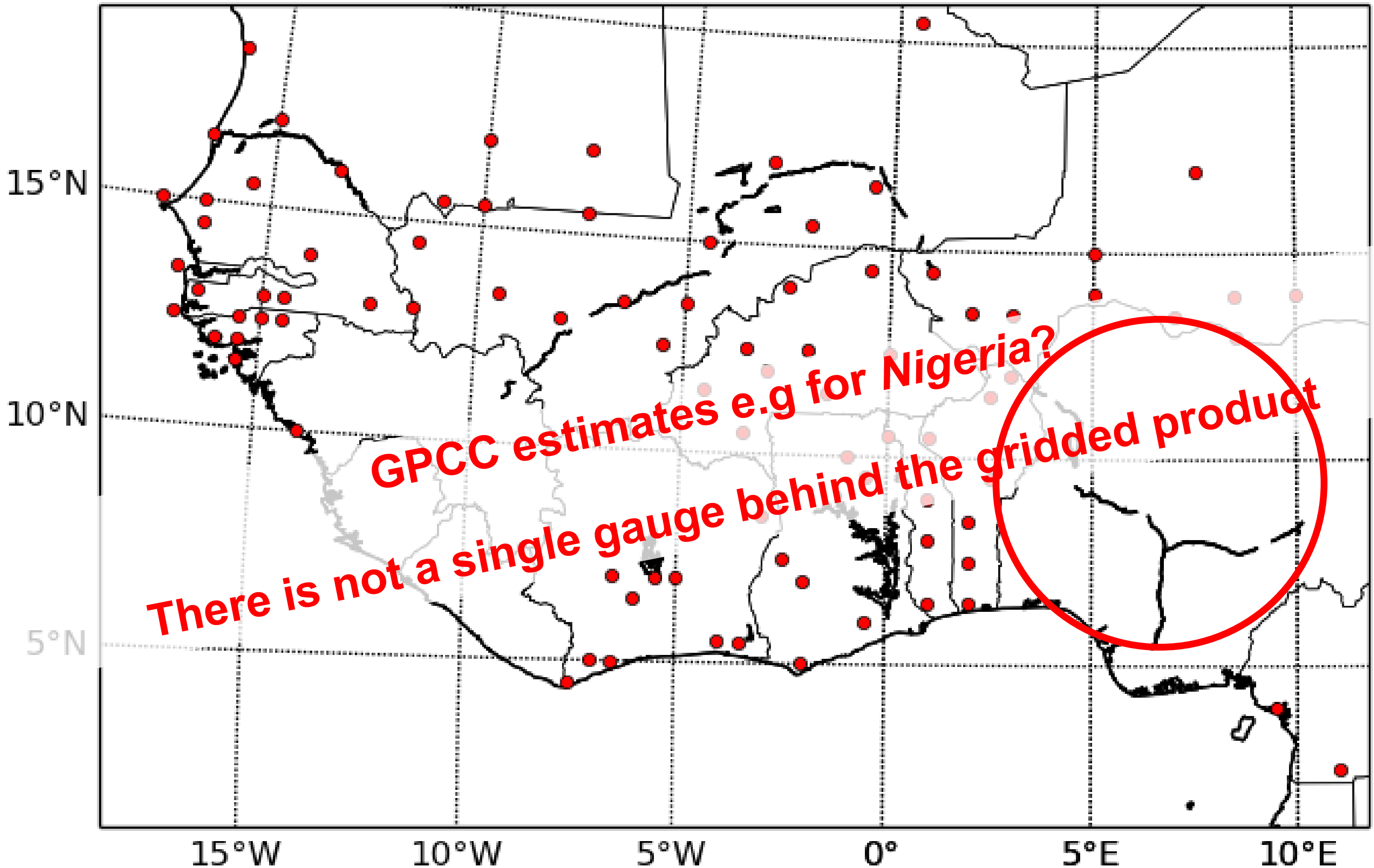


WASCAL

West African Science Service Center on Climate Change and Adapted Land Use

Federal Ministry of Education and Research

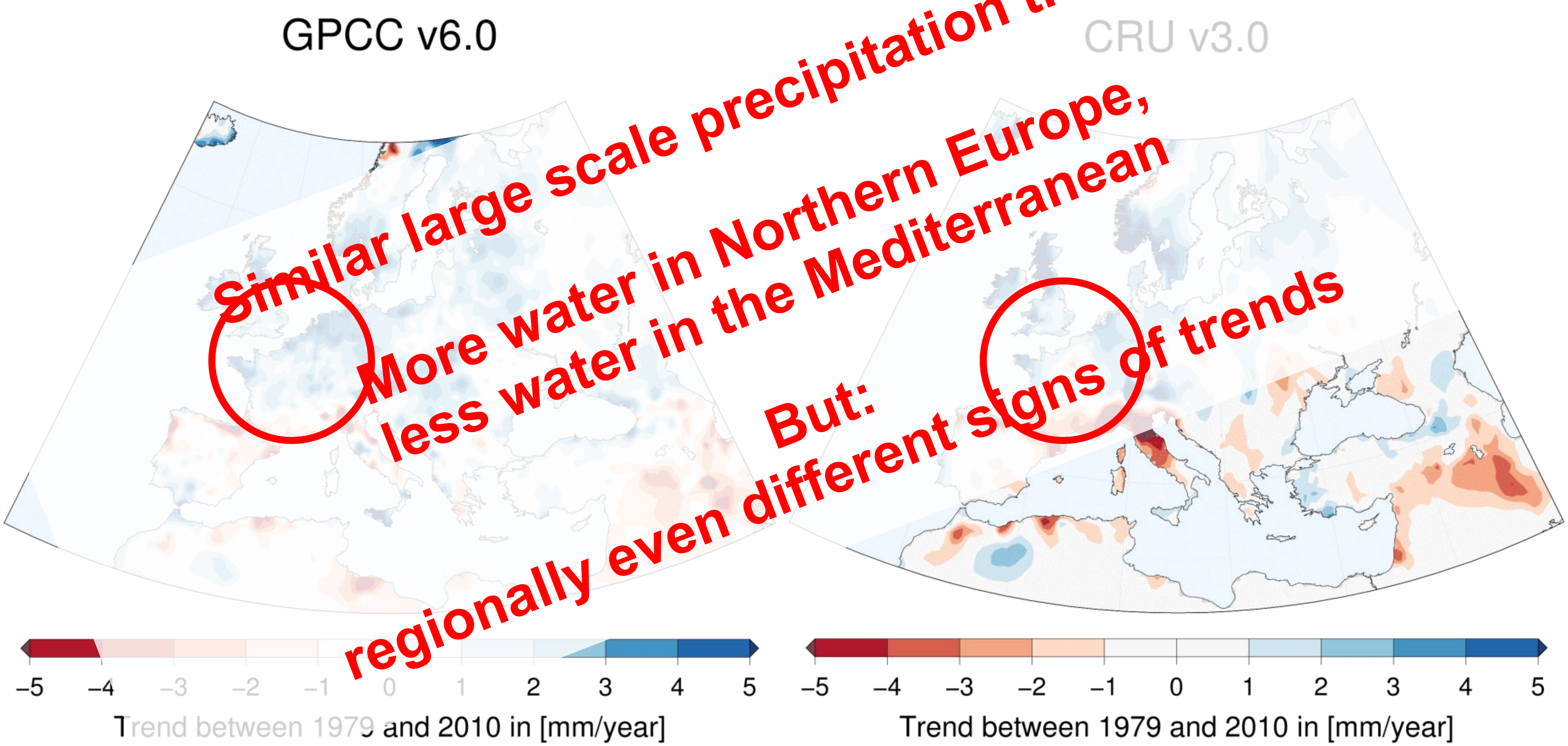
GPCC Precipitation Sites for August 2007



How about the derivation of climate trends from these data sets?

Trends from Gridded Observation Data Sets?

Europe



Similar large scale precipitation trends:

More water in Northern Europe, less water in the Mediterranean

But:

regionally even different signs of trends

Example Syria

Umstrittene Studie: Löste Klimawandel den Syrien-Krieg aus?

Von *Axel Bojanowski*

Eine alarmierende Studie hat weltweit für Aufregung gesorgt. Die Autoren behaupten, der Kli... Dürre und Bürgerkrieg in Syrien mitverursacht. Doch die These ist kaum zu halten.

Samstag, 07.03.2015 – 00:01 Uhr

Drucken | Senden | Merken

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Kommentieren | 33 Kommentare

Teilen | Empfehlen 595 | Twittern

Wenig Zeit? Am Textende gibt's eine Zusammenfassung.

Hamburg - Den "ersten Klima-Krieg der Neuzeit", meldet das "Hamburger Abendblatt". "Eine starke Verbindung" zwischen Klimaerwärmung und dem Krieg in Syrien erkennt die "New York Times". Und "Spektrum der Wissenschaft" stellt fest: "Die Erderwärmung trägt eine Mitschuld am Bürgerkrieg in Syrien."

Eine erschreckende Diagnose. Doch sie ist wohl kaum zu halten, viele Experten zweifeln an der Arbeit, die den Berichten zugrunde liegt.

Dabei handelt es sich um eine von Fachkollegen begutachtete Studie im Wissenschaftsmagazin "Proceedings of the National Academy of Sciences" (PNAS). Die Chronologie der Katastrophe beginne demnach mit der Industrialisierung im 18. Jahrhundert: Treibhausgase, die der Mensch seither in großer Menge in die Luft bläst, verändern das Klima, wohl auch in Syrien.

THEMA Klimawandel

Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley[a,1], Shahrzad Mohta..., Mark A. Cane[c], Richa..., and Yochanan Kushnir[c]

[a]University of California, Santa Barbara, CA 93106; [b]School of International and Public Affairs, Columbia University, New York, NY 10027; and [c]Lamont–Doherty Earth Observatory, Columbia University, Palisades, NY 1096...

Edited by Brian John Hoskins, Imperial College London, London, United Kingdom, and approved January 30, 2015 (received for review November 16, 2014)

Before the Syrian uprising that began in 2011, the greater Fertile Crescent experienced the most severe drought in the instrumental record. For Syria, a country marked by poor governance and unsustainable agricultural and environmental policies, the drought had a catalytic effect, contributing to political unrest. We show that the recent decrease in Syrian precipitation is a combination of natural variability and a long-term drying trend, and the unusual severity of the observed drought is here shown to be highly unlikely without this trend. Precipitation changes in Syria are linked to rising mean sea-level pressure in the Eastern Mediterranean, which also shows a long-term trend. There has been also a long-term warming trend in the Eastern Mediterranean, adding to the drawdown of soil moisture. No natural cause is apparent for these trends, whereas the observed drying and warming are consistent with model studies of the response to increases in greenhouse gases. Furthermore, model studies show an increasingly drier and hotter future mean climate for the Eastern Mediterranean. Analyses of observations and model simulations indicate that a drought of the severity and duration of the recent Syrian drought, which is implicated in the current conflict, has become more than twice as likely as a consequence of human interference in the climate system.

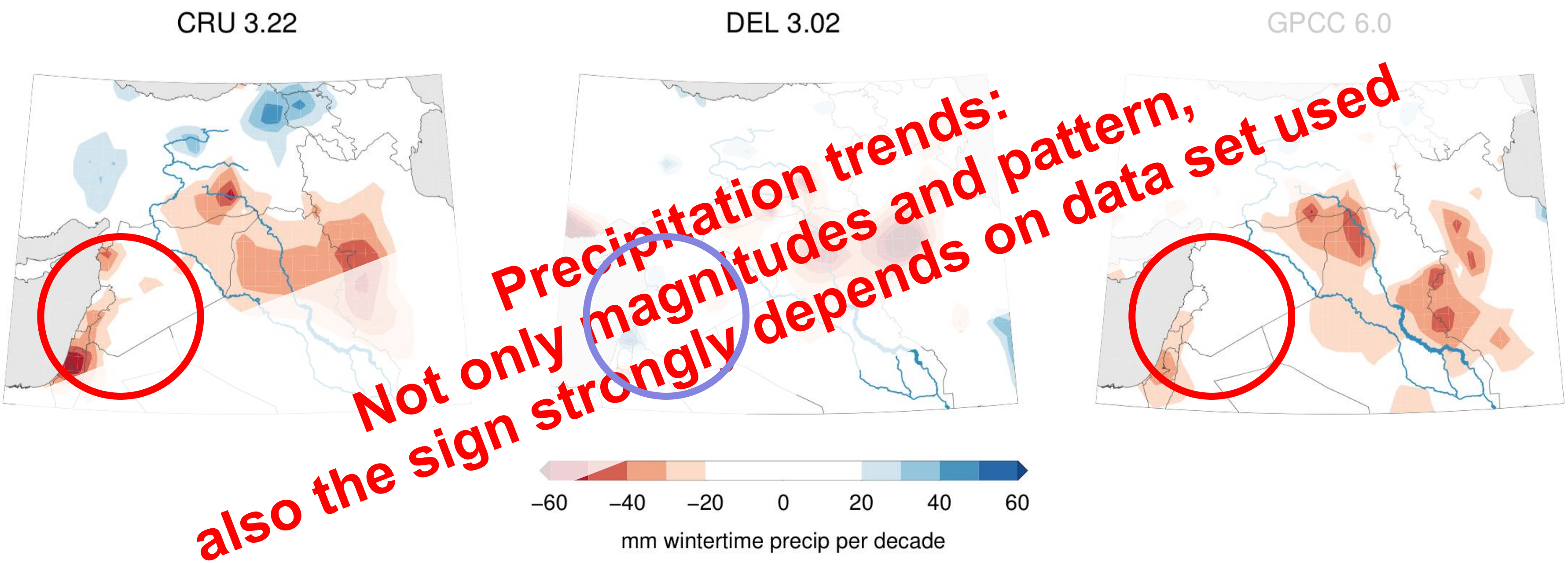
drought | Syria | climate change | unrest | conflict

Syria's water security by exploiting limited land and water resources without regard for sustainability (10).

One critical consequence of these unsustainable policies is the decline of groundwater. Nearly all rainfall in the FC occurs during the 6-month winter season, November through April, and this rainfall exhibits large year-to-year variability (Figs. 1A and 2A). In Syria, the rain falls along the country's Mediterranean Sea coast and in the north and northeast, the primary agricultural region. Farmers depend strongly on year-to-year rainfall, as two thirds of the cultivated land in Syria is rain fed, but the remainder relies upon irrigation and groundwater (11). For those farms without access to irrigation canals linked to river tributaries, pumped groundwater supplies over half (60%) of all water used for irrigation purposes, and this groundwater has become increasingly limited as extraction has been greatly overexploited (4). The government attempted to stem the rate of groundwater depletion by enacting a law in 2005 requiring a license to dig wells, but the legislation was not enforced (6). Overuse of groundwater has been blamed for the recent drying of the Khabur River in Syria's northeast (6). The depletion of groundwater during the recent drought is clearly evident from remotely sensed data by the NASA Gravity Recovery and Climate Experiment (GRACE) Tellus project (Fig. 2C) (12).

Serious "socio-economic" facts are explained and correlated with climate change ...

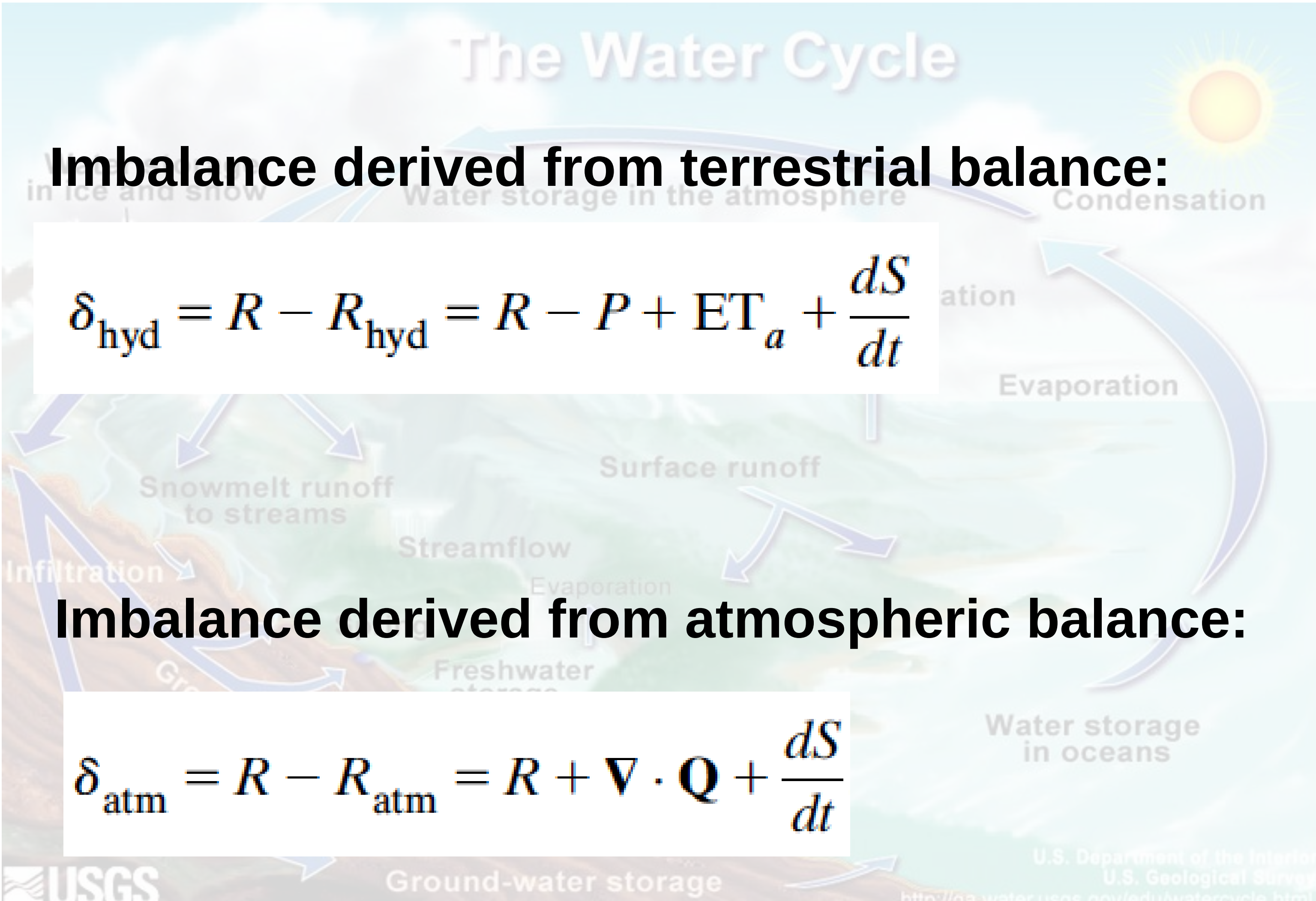
Example Syria



1980-2010

How about the closure of the water balance?

Closure of the Water Cycle in Global Datasets



Imbalance derived from terrestrial balance:

$$\delta_{\mathrm{hyd}} = R - R_{\mathrm{hyd}} = R - P + \mathrm{ET}_a + \frac{dS}{dt}$$

Imbalance derived from atmospheric balance:

$$\delta_{\mathrm{atm}} = R - R_{\mathrm{atm}} = R + \nabla \cdot \mathbf{Q} + \frac{dS}{dt}$$

Closure of the Water Cycle in Global Datasets

Variable	Dataset	Version	Resolution		Time period
			Spatial	Temporal	
P	GPCC	6.0	0.5° × 0.5°	1 month	1901–2010
	GPCP	2.2	2.5° × 2.5°	1 month	1979–present
	CPC	1.0	0.25° × 0.25°	1 month	1979–present
	CRU	3.1	0.5° × 0.5°	1 month	1901–2009
	DEL	2.01	0.5° × 0.5°	1 month	1900–2008
ET_a	ERA-Interim	—	0.75° × 0.75°	1 month, 1 day, 6 h	1979–present
	GLDAS	Noah 3.3	1.0° × 1.0°	1 month, 3 h	1948–present
	GLEAM	v1B	0.25° × 0.25°	1 day	1984–2007
	MOD16	—	0.5° × 0.5°	1 yr, 1 month, 8 days	2000–10
	FLUXNET MTE	—	0.5° × 0.5°	1 month	1982–2011
	MERRA-Land	1.0	⅓° × ⅔°	1 month, 1 day, 1 h	1980–present
$\nabla \cdot \mathbf{Q}$	ERA-Interim	—	0.75° × 0.75°	1 month, 1 day, 6 h	1979–present
	MERRA	—	½° × ⅔°	1 month, 1 day, 6 h, 3 h, 1 h	1979–present
	CFSR	—	0.5° × 0.5°	1 month, 1 day, 6 h	1979–2011
dM/dt	GRACE GFZ	R5	—	1 month	2003–present
	GRACE CSR	R5	—	1 month	2003–present
R_{obs}	GRDC	—	—	—	—
R_{mod}	GLDAS	VIC	1.0° × 1.0°	1 month, 3 h	1979–present
	GLDAS	CLM 2.0	1.0° × 1.0°	1 month, 3 h	1979–present
	GLDAS	Noah 2.7	0.25° × 0.25°	1 month, 3 h	2000–present
	GLDAS	Noah 3.3	1.0° × 1.0°	1 month, 3 h	1948–present
	GLDAS	Mosaic	1.0° × 1.0°	1 month, 3 h	1979–present
	MERRA-Land	1.0	⅓° × ⅔°	1 month, 1 day, 1 h	1980–present

Gridded station values

Satellite derived

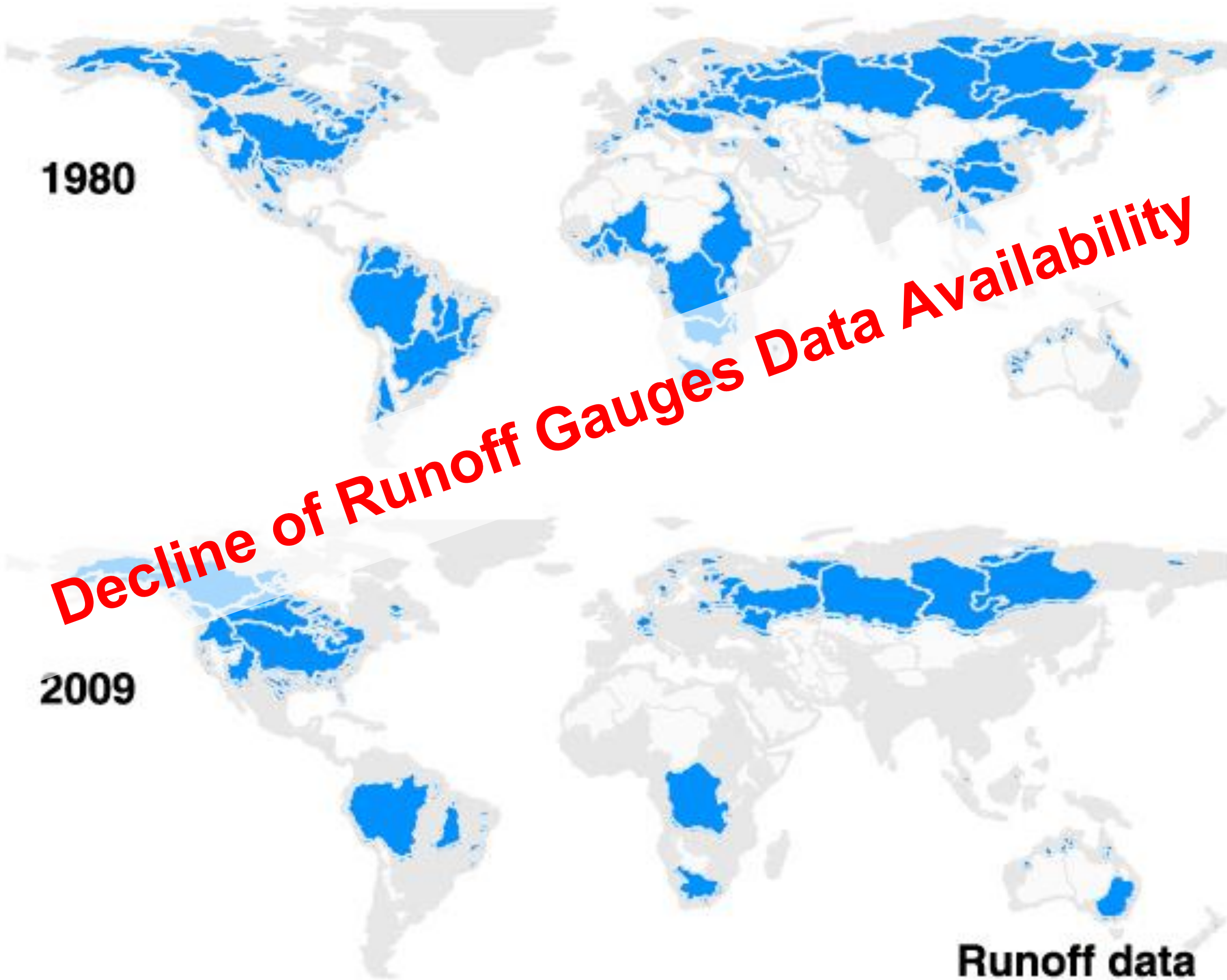
Reanalyses/Global Models

Gauge values

In total 90 combinations possible for water balance closure

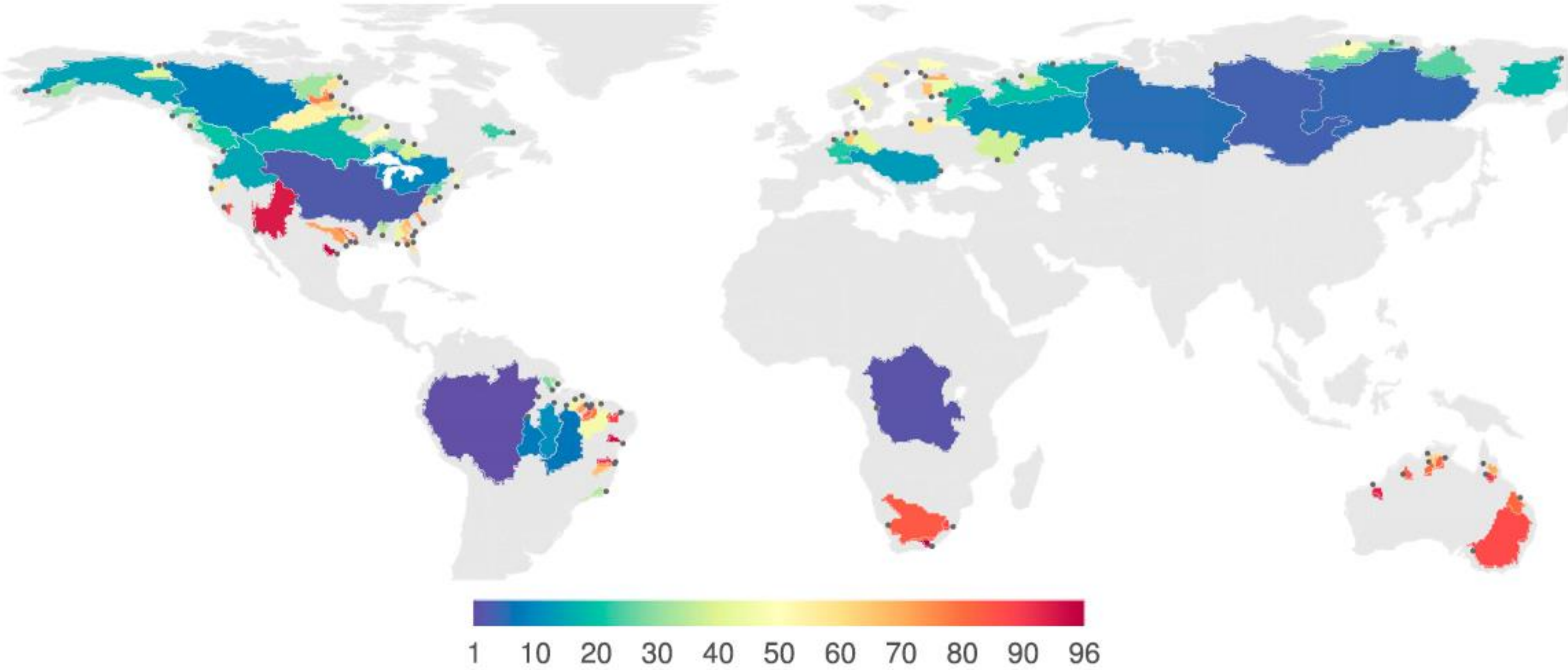
Lorenz et al., 2014 (JoHM)

Closure of the Water Cycle in Global Datasets



Lorenz et al., 2014 (JoHM)

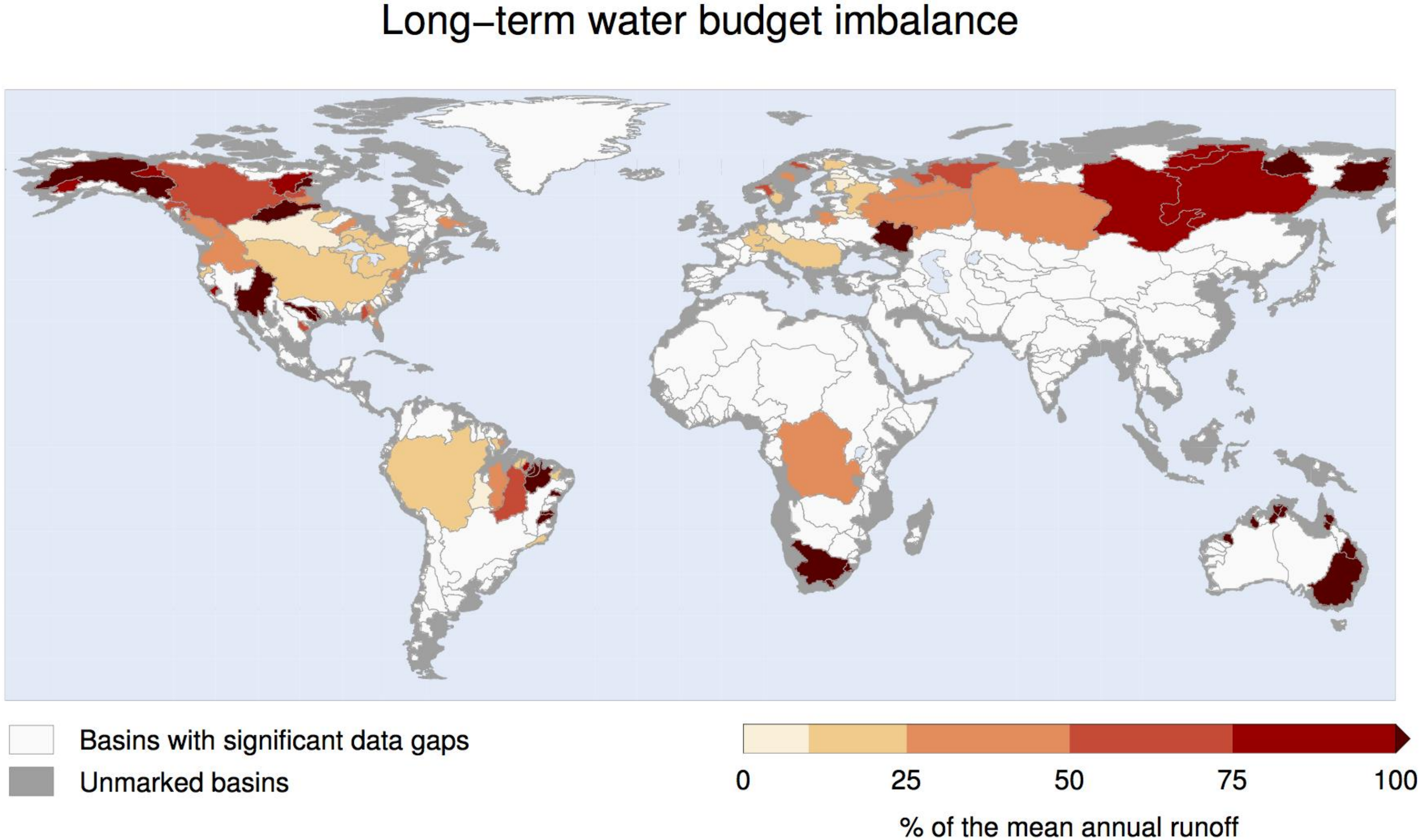
Closure of the Water Cycle in Global Datasets



In total consideration of 96 catchments

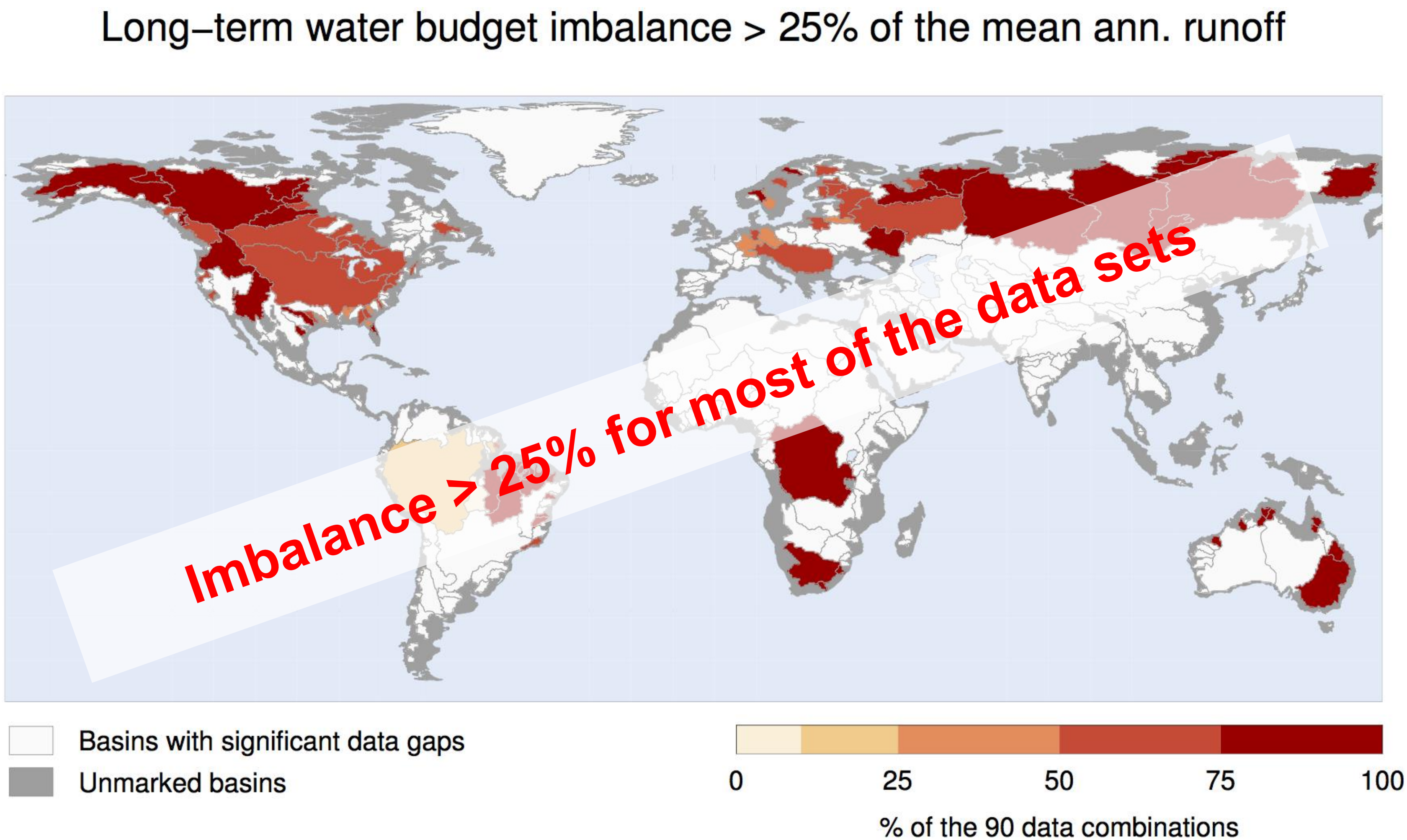
Lorenz et al., 2014 (JoHM)

Analysis of the Closure of Modeled Water Budgets



P: GPCC; ET: MOD16; dS/dt: GRACE GFZ Release 5

Analysis of the Closure of Modeled Water Budgets



Lorenz et al., 2014 (JoHM)

Summary and Conclusions

- Still **major knowledge gaps** in understanding the **water cycle**, not only on large scales, also on smaller regional scales

- **Hydrological analyses and trend derivation** based on gridded observations need careful treatment

- Tremendous **imbalances in water balance closure**

- **Concerted modeling and observation efforts** as prerequisite for future improvement of regional water cycle analysis & -quantification

Thank You for Your Attention

and to Christoph Lorenz, Gerhard Smiatek

and Jan Bliefernicht for selected results

Example Syria: Figeh Spring/Damascus

Hydrological Climate Change Impact Analysis for the Figeh Spring near Damascus, Syria

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(Manuscript received 14 May 2012, in final form 17 October 2012)

ABSTRACT

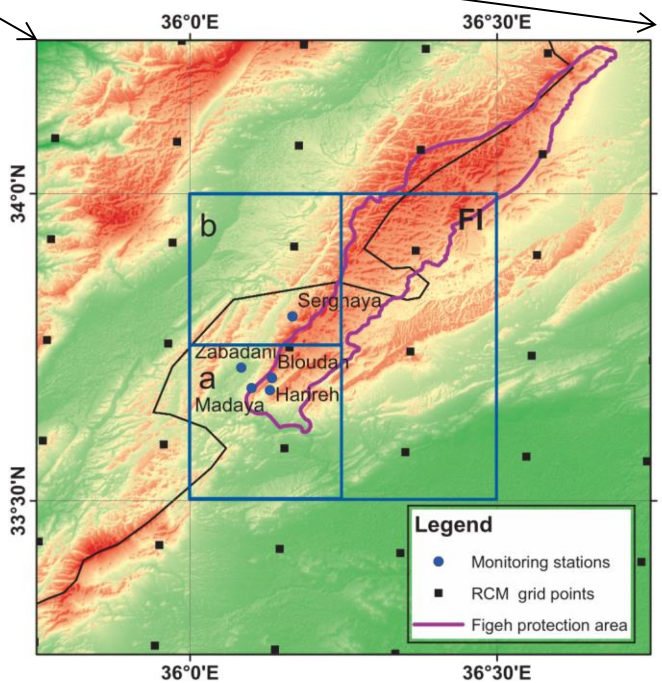
A set of downscaled climate change data from transient experiments with regional climate models has been used to access the future climate change signal in the area of the Figeh spring system in Syria and its potential effects on future water availability. The data ensemble at a spatial resolution of 0.25° has been investigated for the period 1961–90 for present-day climate and the periods 2021–50 and 2070–99 for future climate. The focus is on changes to annual, seasonal, and monthly surface air temperature and precipitation. For the first time, the Figeh spring discharge has been assessed with a hydrological runoff model based on an artificial neural network (ANN) approach. The ANN model was formulated and validated for the years 1987–2007, applying daily meteorological driving data. The investigations show that water supply from the spring might face serious problems under changed climate conditions. An expected, a precipitation decrease of about −11% in winter and −8% in spring, together with increased temperatures of up to +1.6°C and a significant decrease in snow mass, can substantially limit the water recharge potential already in the near future until 2050. In the period 2070–99, the annual precipitation amount is simulated to decrease by −22% and the annual mean temperature to increase by +4°C, relative to the 1961–90 mean. The ensemble mean of the relative change in mean discharge reveals a decrease during the peak flow from March to May, with values up to −20% in 2021–50 and almost −50% in the period 2069–98, both related to the 1961–90 mean.

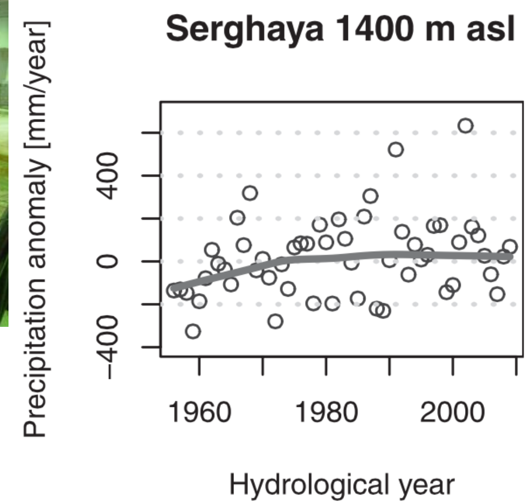
1. Introduction

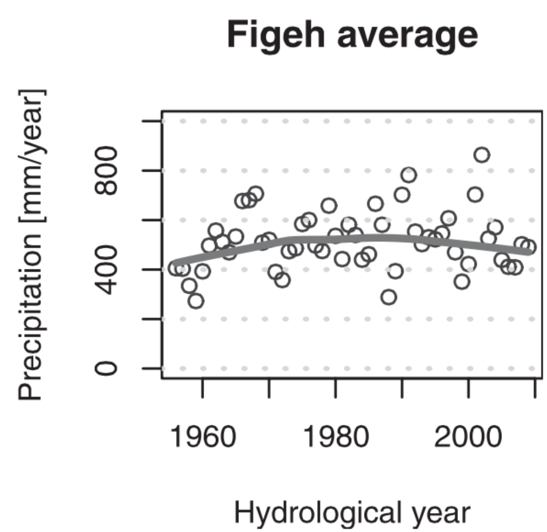
The Figeh spring, located 16 km northwest of Damascus,

a record global 12-month running mean temperature high was reached (Hansen et al. 2010), and the EM re-

Example Syria: Figeh Spring/Damascus







Smiatek et al., 2013 (JoHM)

Analysis of the Closure of Modeled Water Budgets

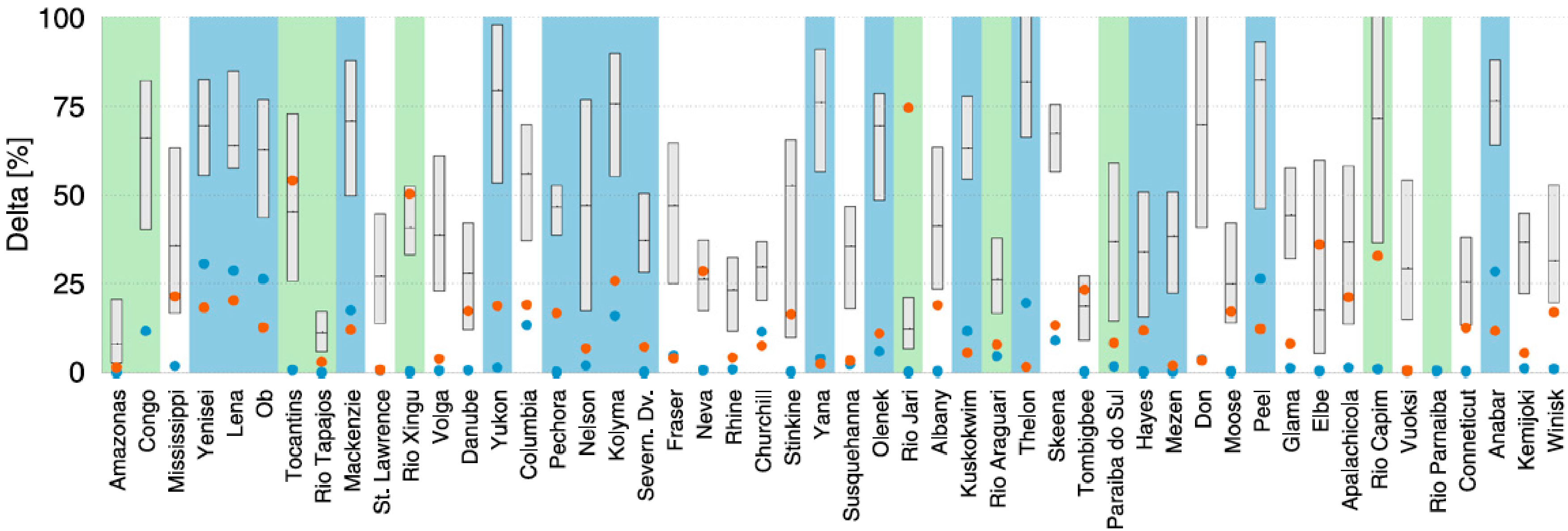


FIG. 9. Box plot showing the relative water cycle imbalance with respect to the observed mean annual runoff. The lower and upper bounds of the gray boxes depict the 25th and 75th percentile of the 90 ensemble members of R_{hyd}; while the line within the boxes shows the median imbalance. The blue (red) dots are the minimum imbalances from R_{hyd} (R_{atm}). The background colors indicate Arctic (blue) and tropical (green) catchments. The Arctic catchments have been chosen according to the entries in the ArcticRIMS database. For the tropical regimes, we have selected the basins within 23.5°S–23.5°N latitude.

Lorenz et al., 2014 (JoHM)