Session 2.01: Groundwater in semiarid regions – a long-term view on changes in aquifer balances. Hydrogeology in developing countries

A pan-African inter-comparison of the relationship between precipitation and groundwater recharge from *in situ* observations and large-scale models

Mohammad Shamsudduha (Shams)
UCL Institute for Risk & Disaster Reduction
Department of Geography
University College London (UK)
Email: m.shamsudduha@ucl.ac.uk

Monday, 26th September 2016

Session 2.01| Room: Louisville | Le Corum, Montpellier | France

A pan-African inter-comparison of the relationship between precipitation and groundwater recharge from *in-situ* observations and large-scale models

Shamsudduha, Mohammad *(University College London, UK)*
Taylor, Richard *(University College London, UK)*
Owor, Michael *(Makerere University, Uganda)*
Todd, Martin *(University of Sussex, United Kingdom)*
Wada, Yoshihide *(IIASA, Austria)*
Lo, Min-hui *(National Taiwan University, Taiwan)*
Müller Schmied, *Hannes (Goethe-University Frankfurt, Germany)*
Döll, Petra *(Goethe-University Frankfurt , Germany)*
Rodell, Matthew *(NASA, USA)*
Jasechko, Scott *(University of Calgary, Canada)*
Favreau, Guillaume *(IRD, France)*
Macdonald, Alan *(British Geological Survey, UK)*
Scanlon, Bridget *(University of Texas at Austin, USA)*

Study Group is expanding…

Dependence on groundwater resources

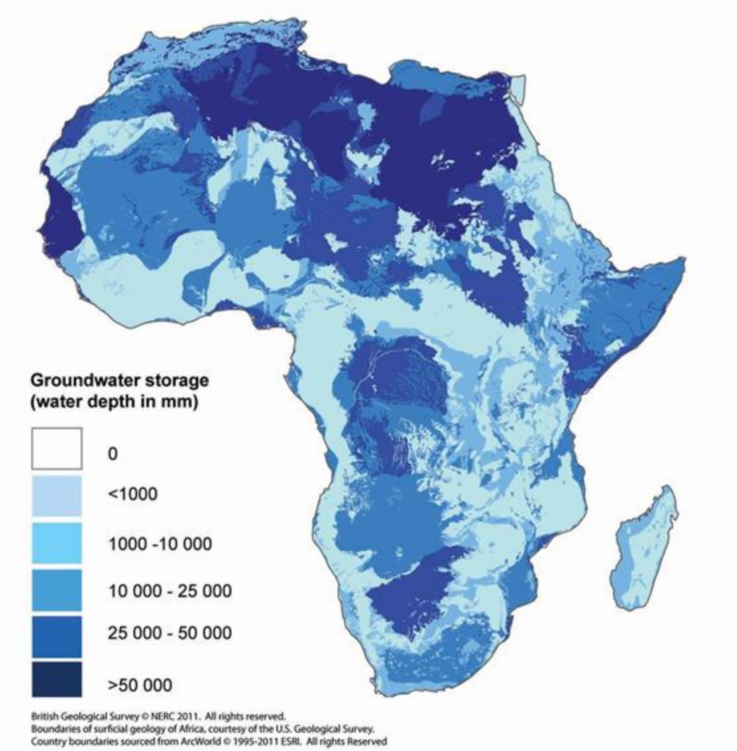
Groundwater is a vital resource upon which dependence is growing globally to sustain and amplify the production of food through irrigation and the provision of safe drinking water

UN SUSTAINABLE DEVELOPMENT GOAL 6: Ensure availability and sustainable management of water and sanitation for all

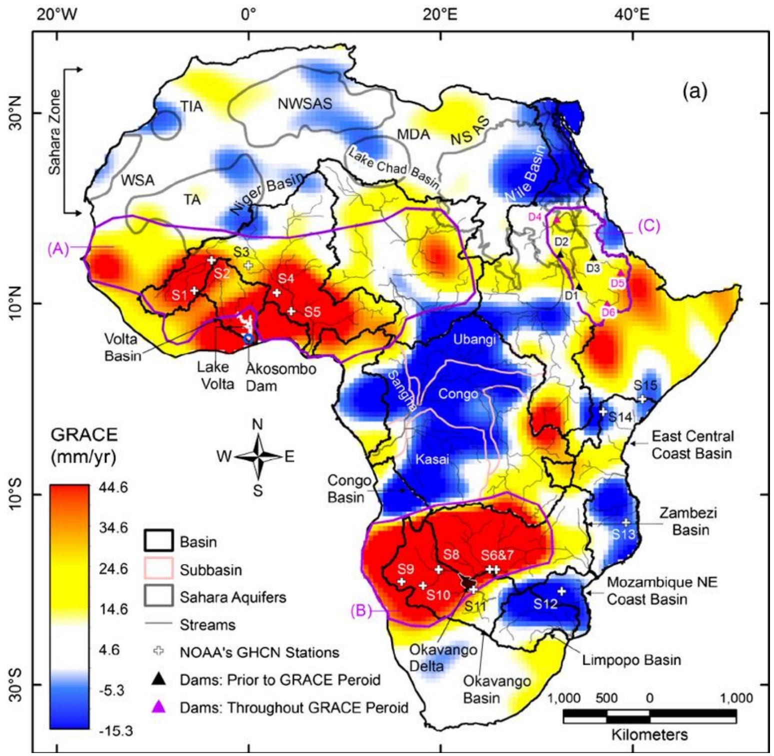
Africa – is the home to the world's most variable freshwater resources, the highest rates of population growth, the lowest rates of per capita food production, and lowest proportions of national populations with access to safe water

assessing groundwater resources

- **reliance on Global Hydrological Models (GHMs) and Land-Surface Models (LSMs) alone or in combination with satellite data (GRACE) to assess impacts of global change – this dependence expected to intensify as large-scale model resolutions increase**



GW storage *MacDonald et al. (2012)*



GRACE TWS trends *Ahmed et al. (2014)*

Land Surface Models (LSMs) / Global Hydrological Models (GHMs)

- **current focus: groundwater recharge (subsurface runoff) estimates from 7 global-scale models including 2 GHMs (WaterGAP, PCR-GLOBWB) and 5 LSMs (CESM-CLM4.5 & NASA's GLDAS LSMs: CLM , NOAH, VIC, MOSAIC)**

Model	Grid	Precipitation	Output
CLM	1°	CMAP	SSR
NOAH	1°	CMAP	SSR
VIC	1°	CMAP	SSR
MOSAIC	1°	CMAP	SSR
CLM4.5	0.5°	CRU-NCEP (v.5)	GWR (diffuse)
PCR-GLOBWB	0.5°	WFDEI	GWR (diffuse)
WaterGAP	0.5°	CRU TS 3.23	GWR (diffuse)
WaterGAP	0.5°	CRU TS 3.23	GWR (combined)

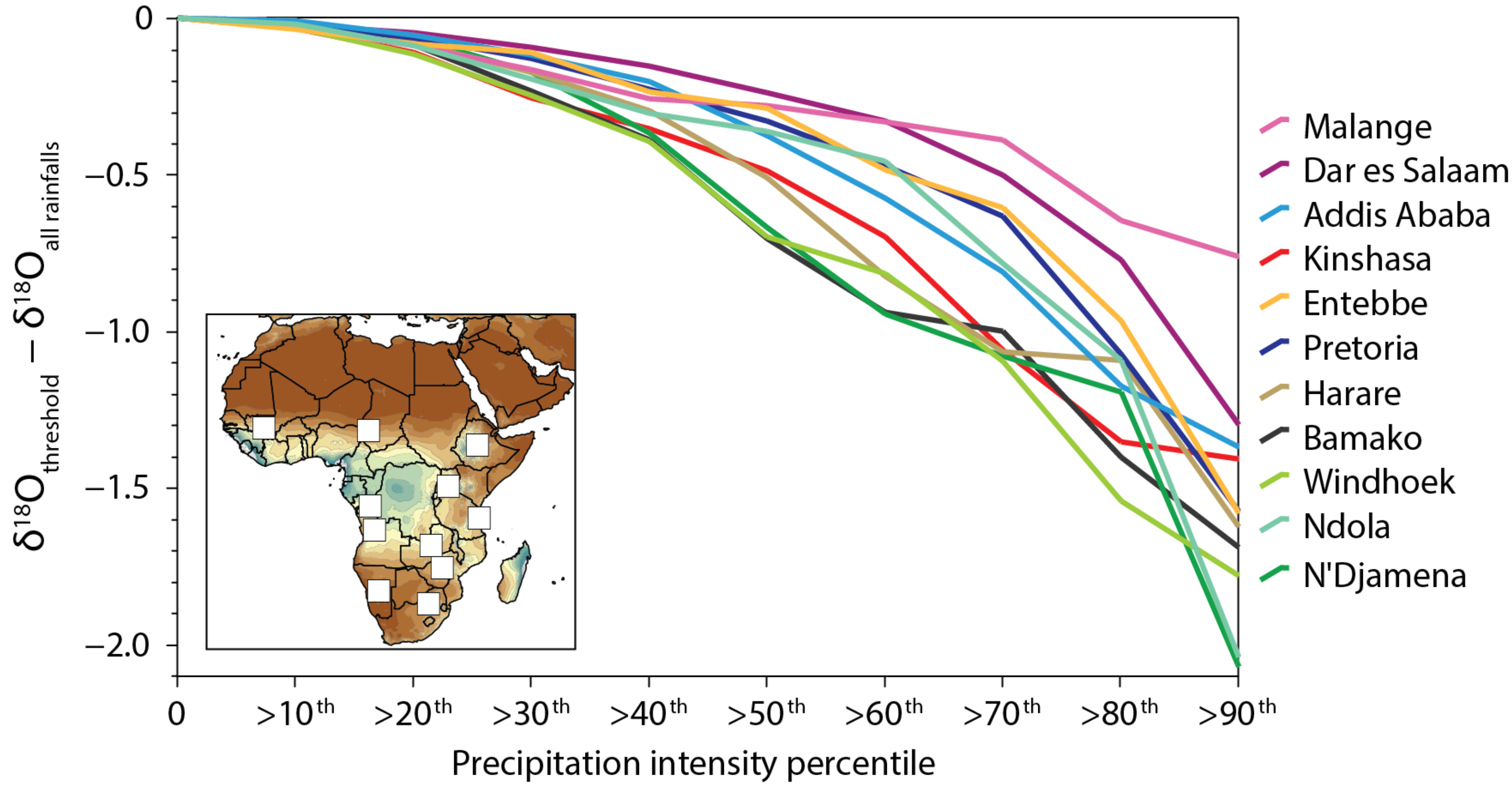
Observations: multi-decadal GWL records

- collation of multi-decadal, *in situ* (piezometric) records of groundwater levels across Africa under *The Chronicles Consortium*

Location	No.	Geology	Climate	Duration
Benin	8	Quaternary sands Continentale Terminale	humid	1991-present
Burkina Faso	2	weathered crystalline rock Continentale Terminale	semi-arid	1978-present
Chad	15	Quaternary sediments	arid	1968-1989
Ghana	1	Quaternary sediments	humid	1976-present
Morocco	25	Plio-Quaternary sediments	arid	1970-present
Niger	50	Quaternary sediments	semi-arid	1987-present
South Africa	21	weathered crystalline rock limestone	semi-arid	1970-present
Tanzania	1	weathered crystalline rock	semi-arid	1954-present
Tunisia	70	Quaternary sediments	semi-arid	1969-present
Uganda	5	weathered crystalline rock	humid	1998-present

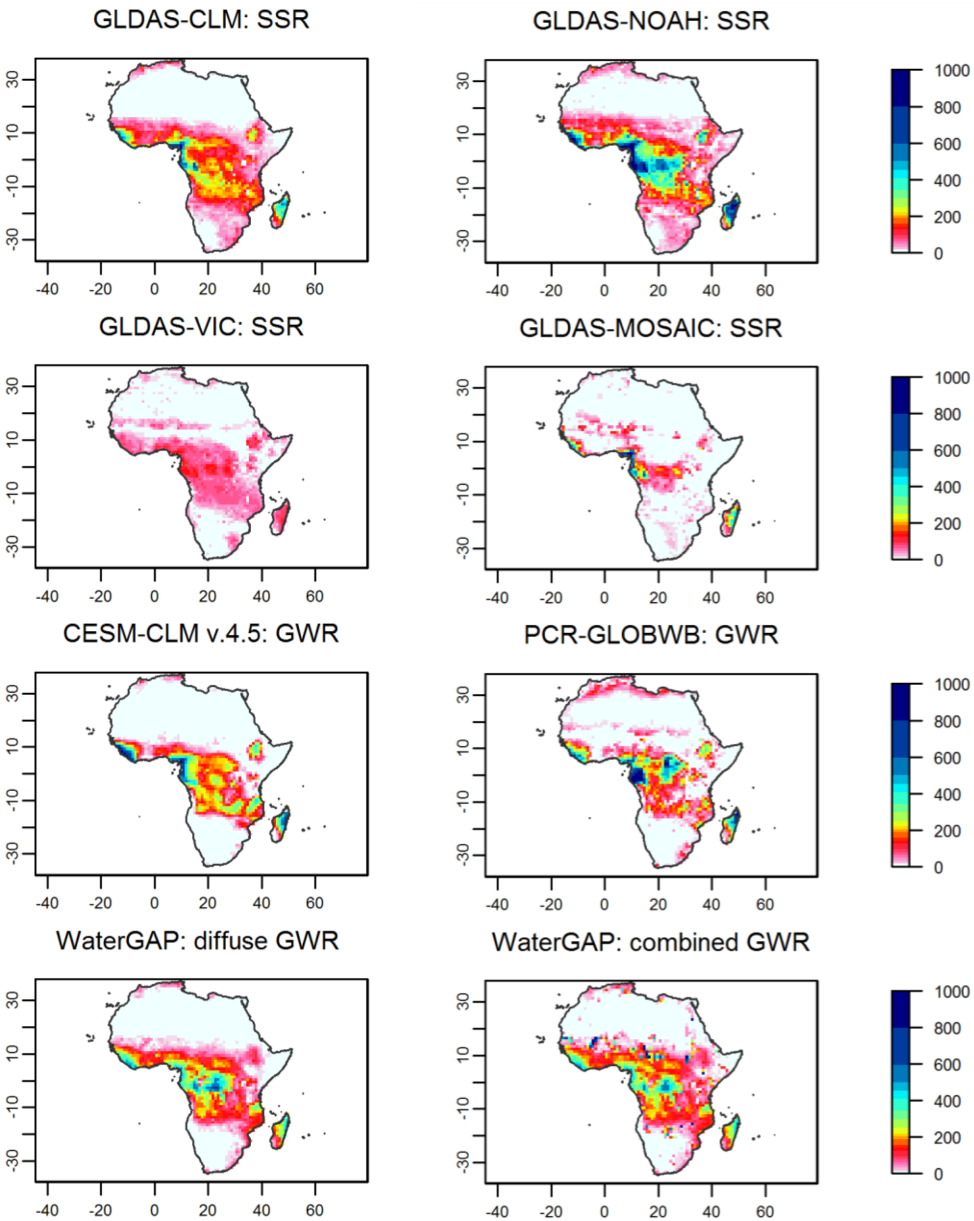
IAEA stable-isotope data in Africa

- **use of rainfall-groundwater stable-isotope (^{18}O:^{16}O) "pairings" as the "amount effect" observed across Africa enables intensity of rainfall recharging groundwater to be traced**



Jasechko and Taylor (2015)

mapping simulated SSR & GWR

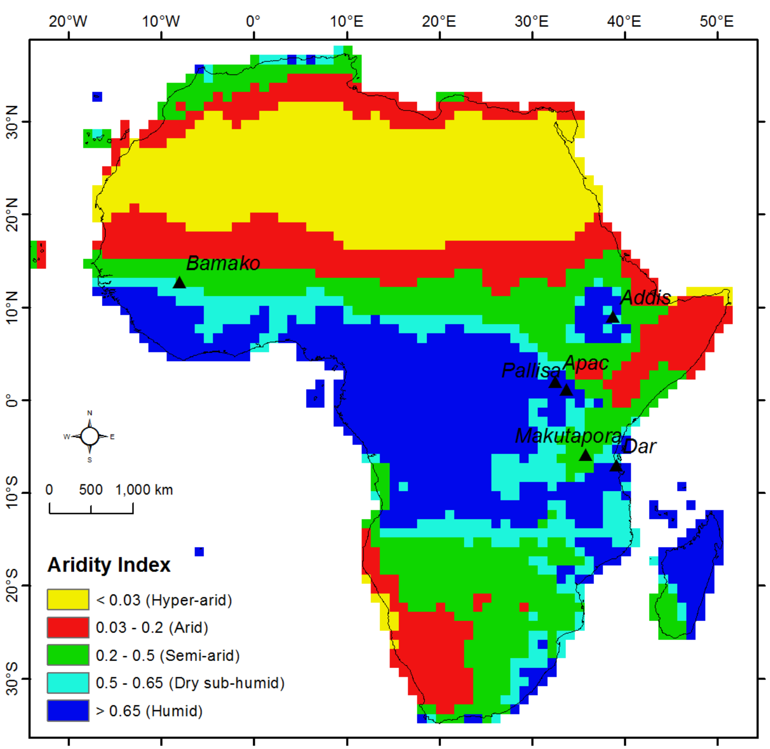


- substantial variations in the magnitude and distribution of mean annual SSR & groundwater recharge (GWR)

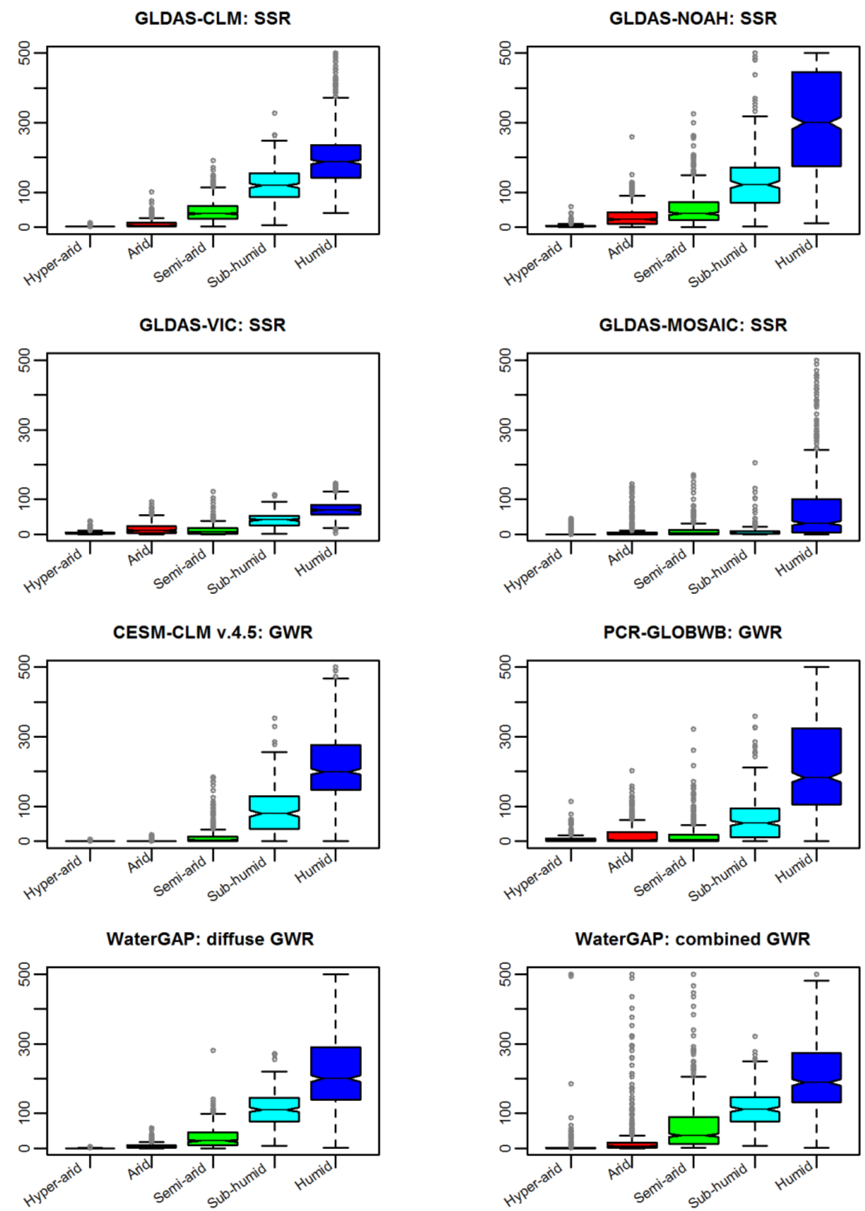
- spatial extent and magnitude of recharge in semi-arid regions increase substantially between WaterGAP (<u>diffuse only</u>) versus WaterGAP (<u>combined diffuse and focused recharge</u>)

simulated SSR & GWR grouped by climate

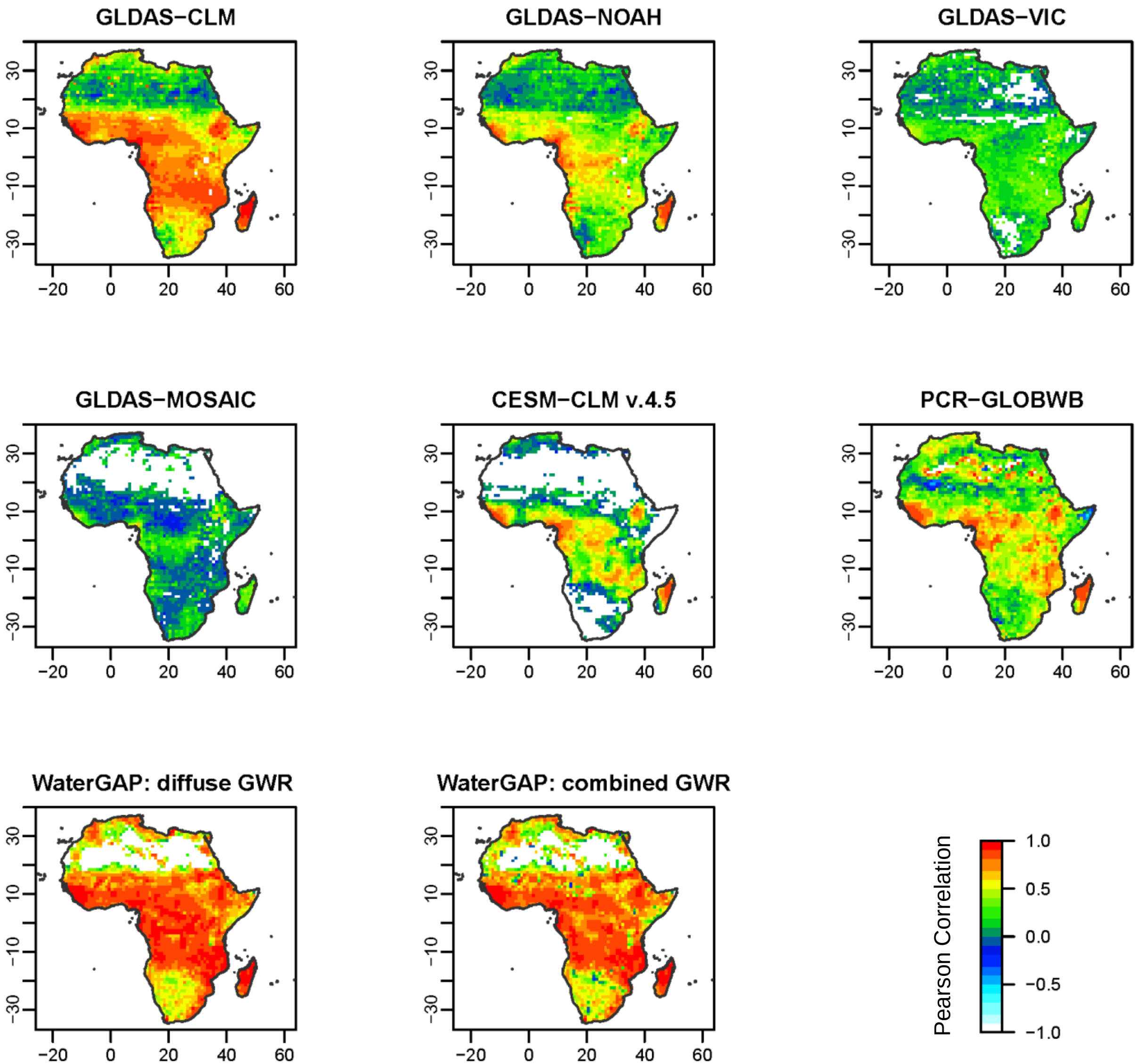
- simulated recharge in semi-arid regions increases with the inclusion of focused recharge in WaterGAP



CGIAR Aridity Index



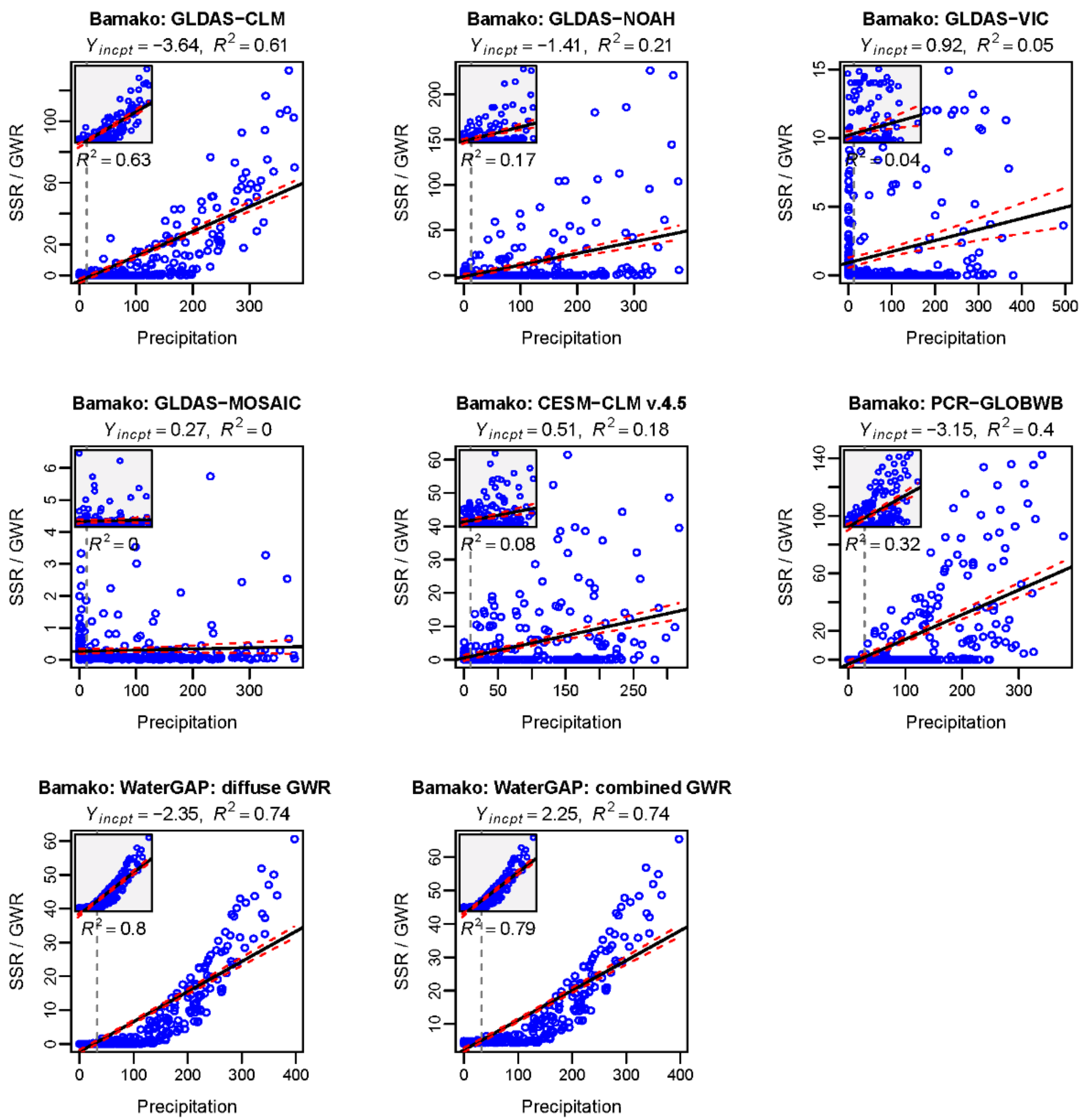
correlation of simulated GWR/SSR and precip



- precipitation and simulated GWR / SSR are strongly correlated in GLDAS-CLM and WaterGAP
- weaker correlations in GLDAS VIC and MOSAIC explained by very low, estimated SSR

semi-arid location: Bamako (Mali)

Bamako (Mali)



Preliminary outcomes:

1. spatial extent and magnitude of simulated GWR & SSR in semi-arid regions are substantially underestimated by large-scale models that ignore focused recharge processes

2. simulated GWR & SSR and precipitation are well correlated in semi-arid areas of some models (GLDAS-CLM, WaterGAP) but very weakly correlated in others

3. non-linearity evident in the relationship between simulated GWR & SSR and precipitation in semi-arid areas (GLDAS-CLM, WaterGAP) – consistent with limited piezometric and isotopic observations

Thanks for listening…

IAH Congress 2016

Montpellier, France

M. Shamsudduha (Shams) | Email: m.shamsudduha@ucl.ac.uk

GroFutures Project Manager (http://grofutures.org/)

https://www.un-igrac.org/special-project/chronicles-consortium

Collation of multi-decadal GWL records

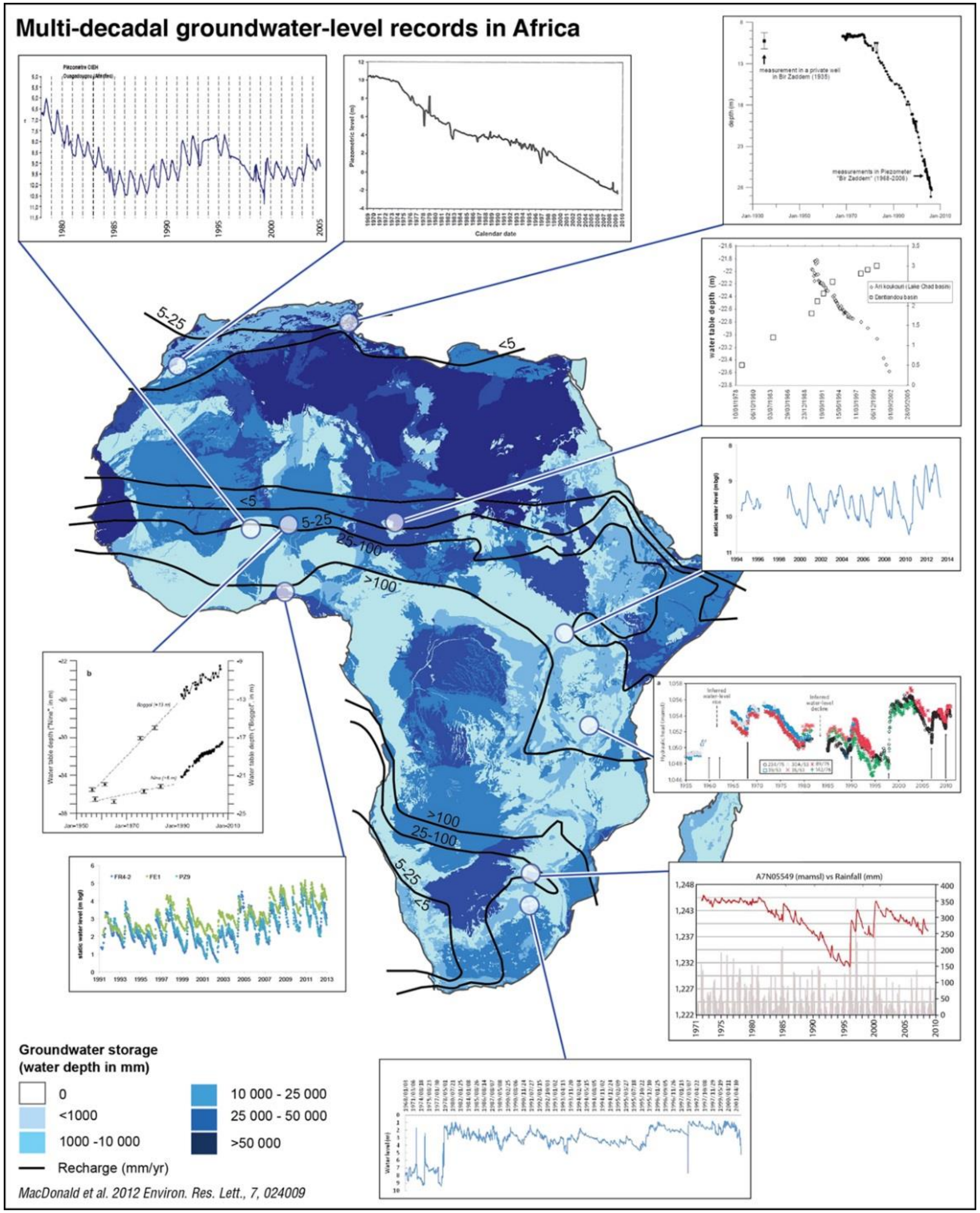
The Chronicles Consortium

Multi-Decadal Groundwater Levels in Africa

- Tamiru Abiye, University of Witwatersrand (South Africa) - Co-Chair
- Guillaume Favreau, IRD (France) - Co-Chair
- Richard Taylor, UCL (UK) - Co-Chair
- William Agyekem, Water Research Institute (Ghana)
- Safouan Ben Ammar, ICSU (Tunisia)
- L'houssaine Bouchaou, Université Ibn Zohr (Morocco)
- Moussa Boukari, Université d'Abomey Calavi (Benin)
- Mark Cuthbert, UCL (UK)
- Youssouf Koussoubé, Université de Ouagadougou (Burkina Faso)
- Japhet Kashaigili, Sokoine University of Agriculture (Tanzania)
- Alan MacDonald, British Geological Survey (UK)
- Yahaya Nazoumou, Université Abdou Moumouni de Niamey (Niger)
- Benjamin Ngounou Ngatcha, Université de Ngaoundéré (Cameroon)
- Michael Owor, Makerere University (Uganda)
- Bridget Scanlon, University of Texas at Austin (USA)
- Mohammad Shamsudduha, UCL (UK)
- James Sorensen, British Geological Survey (UK)
- Martin Todd, University of Sussex (UK)
- Henri Totin, Université de Parakou & Université d'Abomey Calavi (Benin)
- Karen Villholth, International Water Management Institute (South Africa)

International Groundwater Resources Assessment Centre

www.un-igrac.org

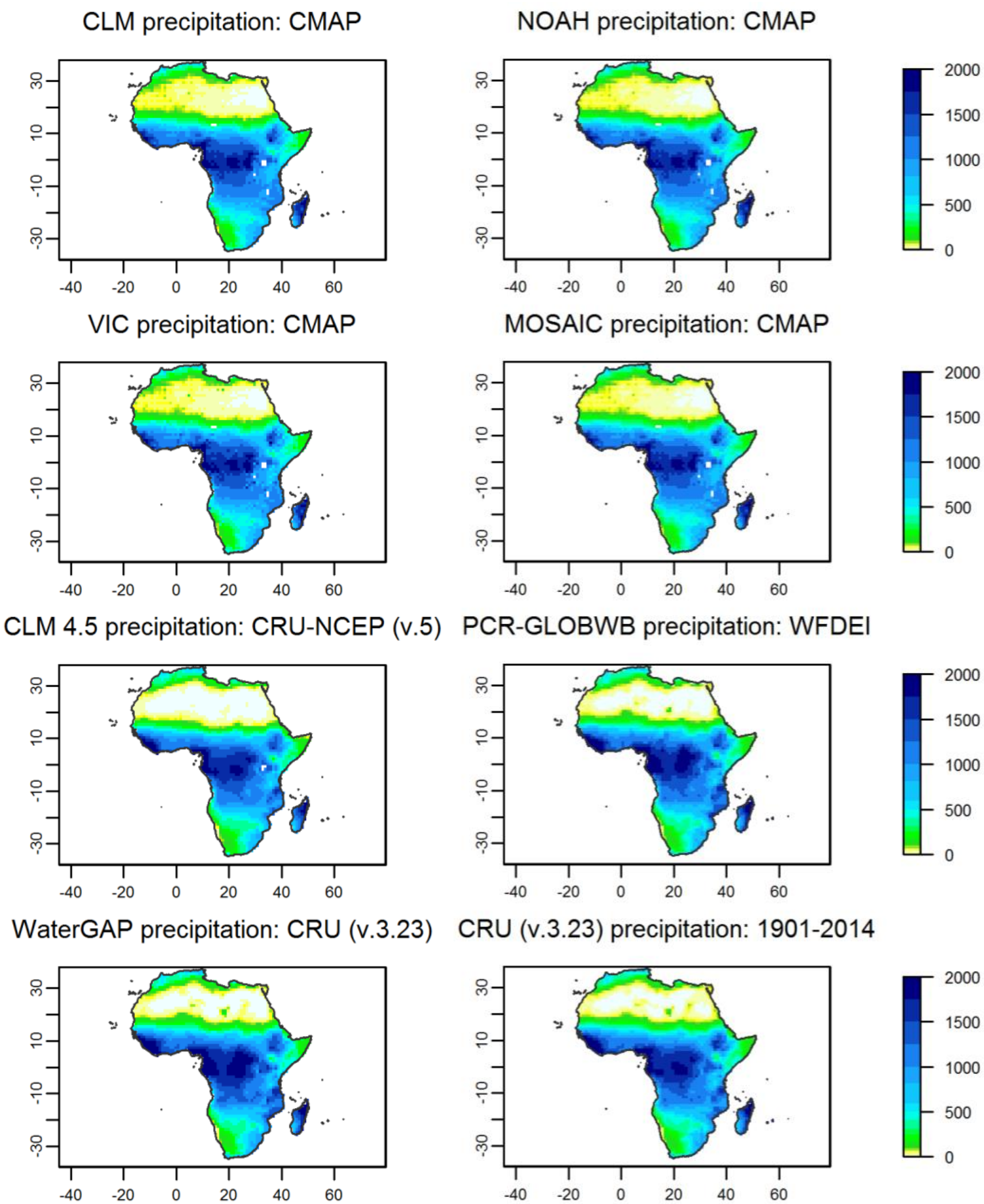


MacDonald et al. 2012 Environ. Res. Lett., 7, 024009

IAEA stable-isotope data in Africa

Location	P samples	P period	Mean annual P	GW samples
Addis Ababa	299 (296)	1961-2009	1100	13
Bamako	147 (140)	1962-1998	920	10
Dar es Salaam	125 (117)	1960-1973	1140	9
Entebbe	197 (192)	1960-2006	1570	56 (IAEA TWIN)
Harare	257 (192)	1960-2003	890	none within 100 km
Kinshasa	60 (59)	1961-1968	1380	none within 100 km
Malange	330 (204)	1961-2009	1140	none within 100 km
Ndola	143 (133)	1968-2009	1210	none within 100 km
N'Djamena	86 (75)	1963-1995	550	320 (IAEA TWIN)
Pretoria	245 (168)	1958-2001	680	none within 100 km
Windhoek	141 (97)	1961-2001	360	1 (IAEA TWIN)

Global-scale model analysis: preliminary results

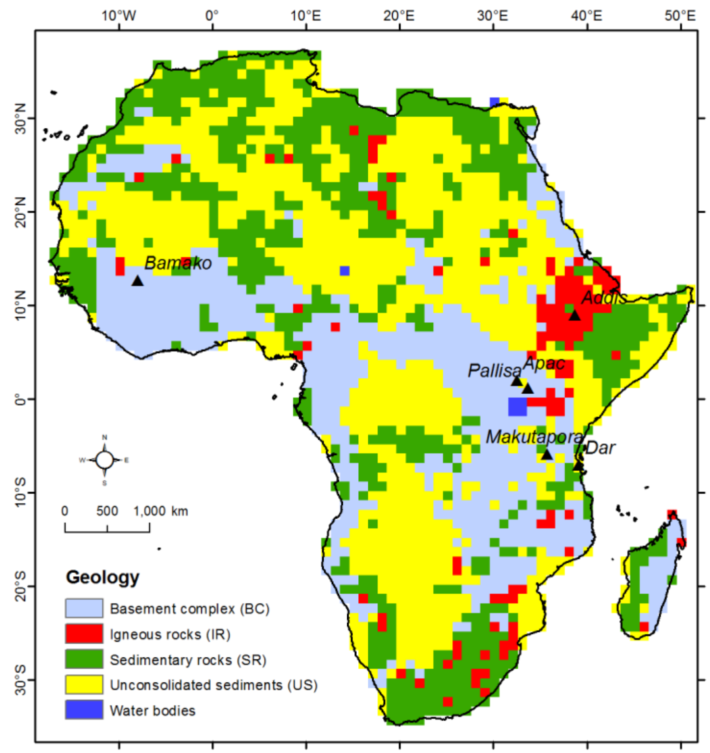


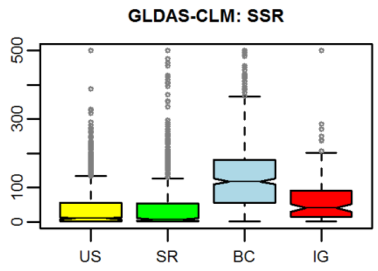
Forcing Precipitation Data

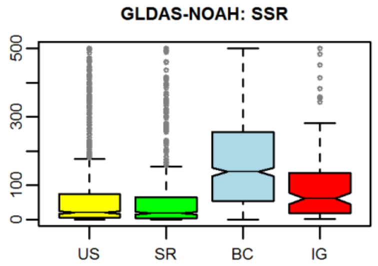
- *GLDAS LSMs (CLM, NOAH, VIC, MOSAIC) employ NOAA CPC's Merged Analysis of Precipitation data; CESM-CLM 4.5 employs CRU-NCEP; PCR-GLOBWB employs WFDEI; WaterGAP employs CRU (TS 3.23) forcing precipitation data*
- *Spatial patterns in gridded precipitation products (1980–2014) are consistent with each other and highly comparable to long-term (1901–2014) records*
- *A maximum cut-off value of 2000 mm is used; Maximum mean annual precipitation: 3000 mm (CMAP), 2700 mm (CRU-NCEP), 5100 mm (WFDEI), 3000 mm CRU (TS 3.23)*

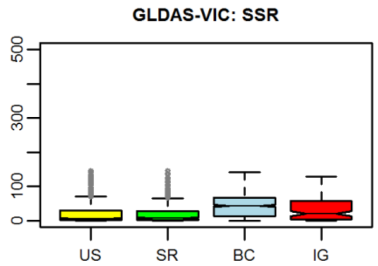
Global-scale model analysis: preliminary results

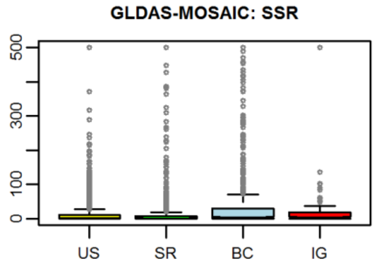
Africa: geological classification (GLiM database)

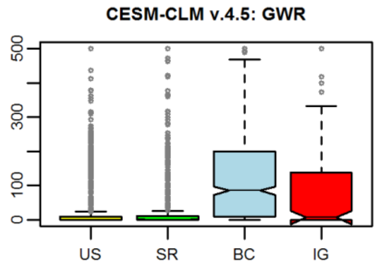


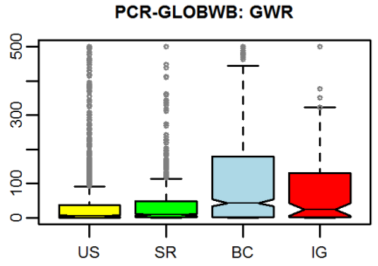


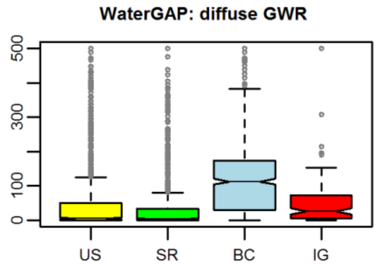


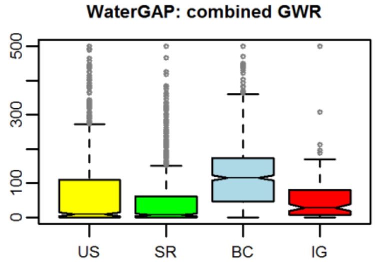






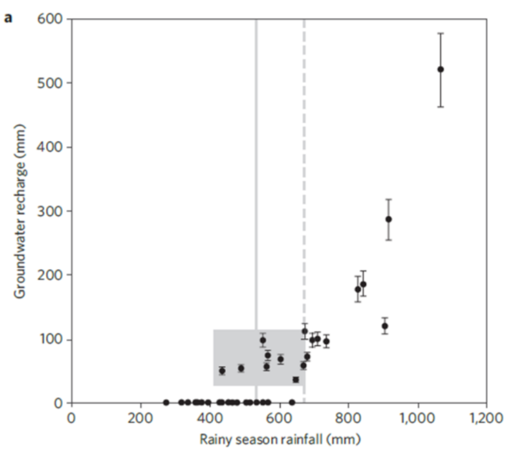




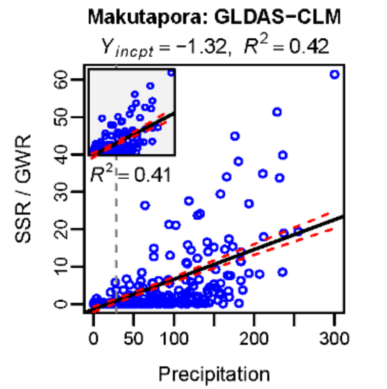


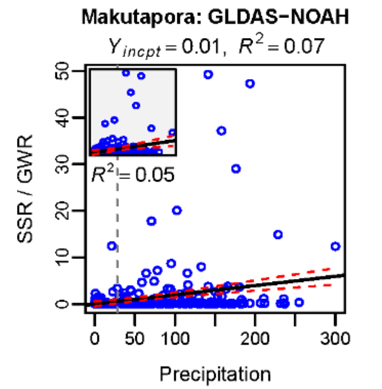
semi-arid location: Makutapora (Tanzania)

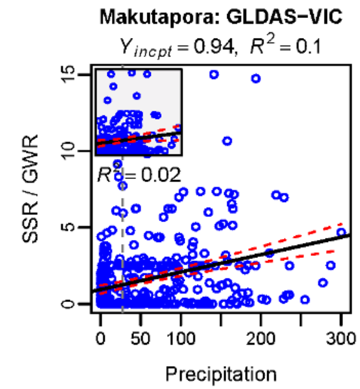
Makutapora (Tanzania)

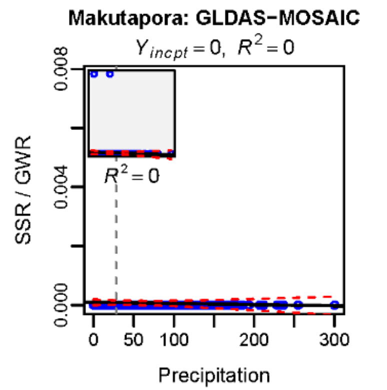


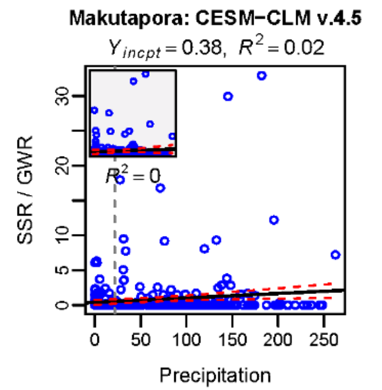
Taylor et al. (2013)

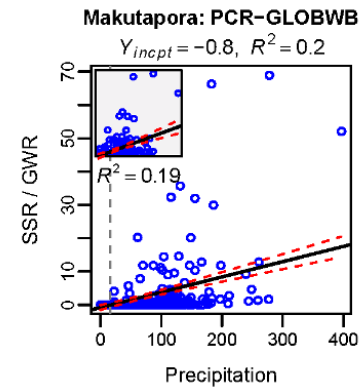


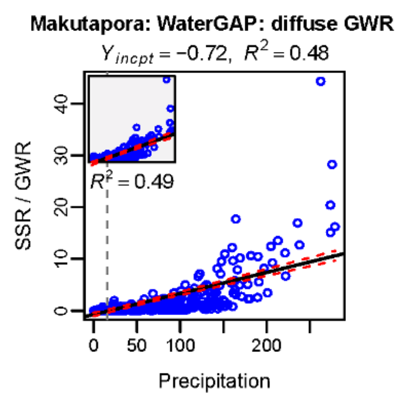


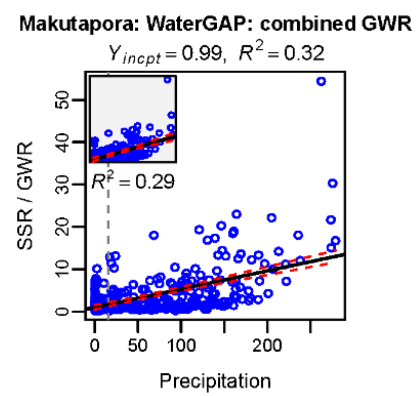






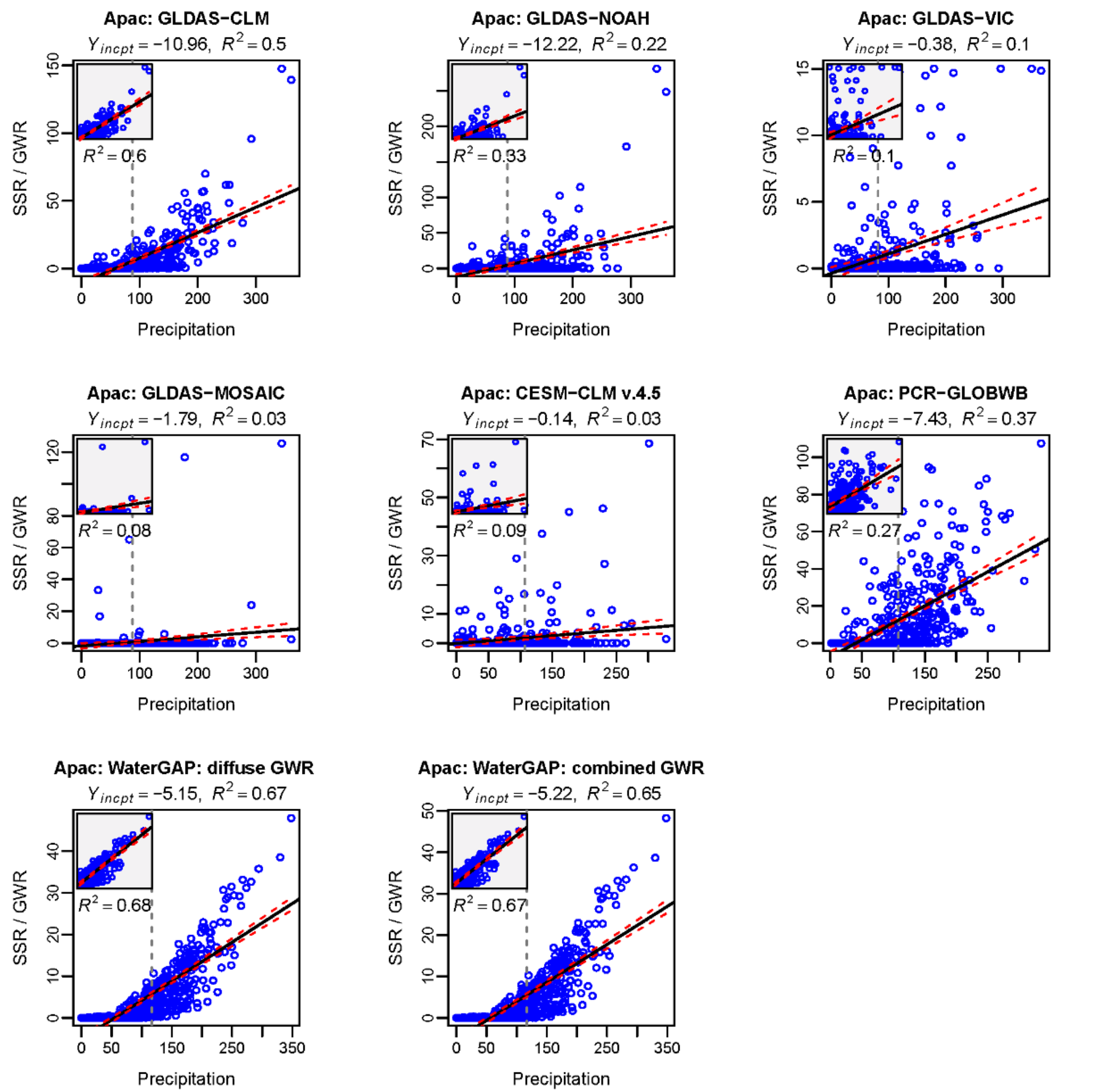






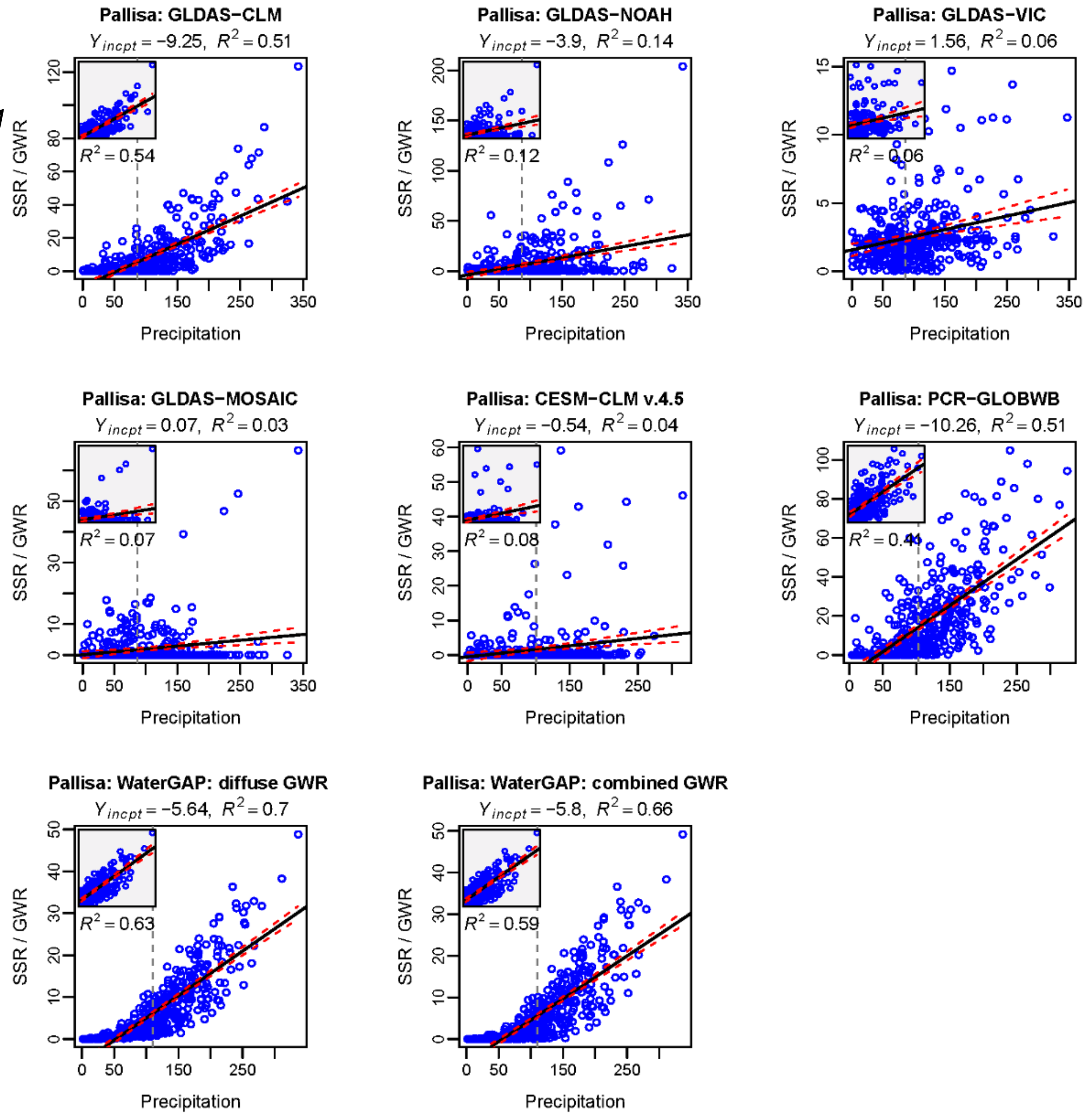
Global-scale model analysis: preliminary results

Apac (Uganda)



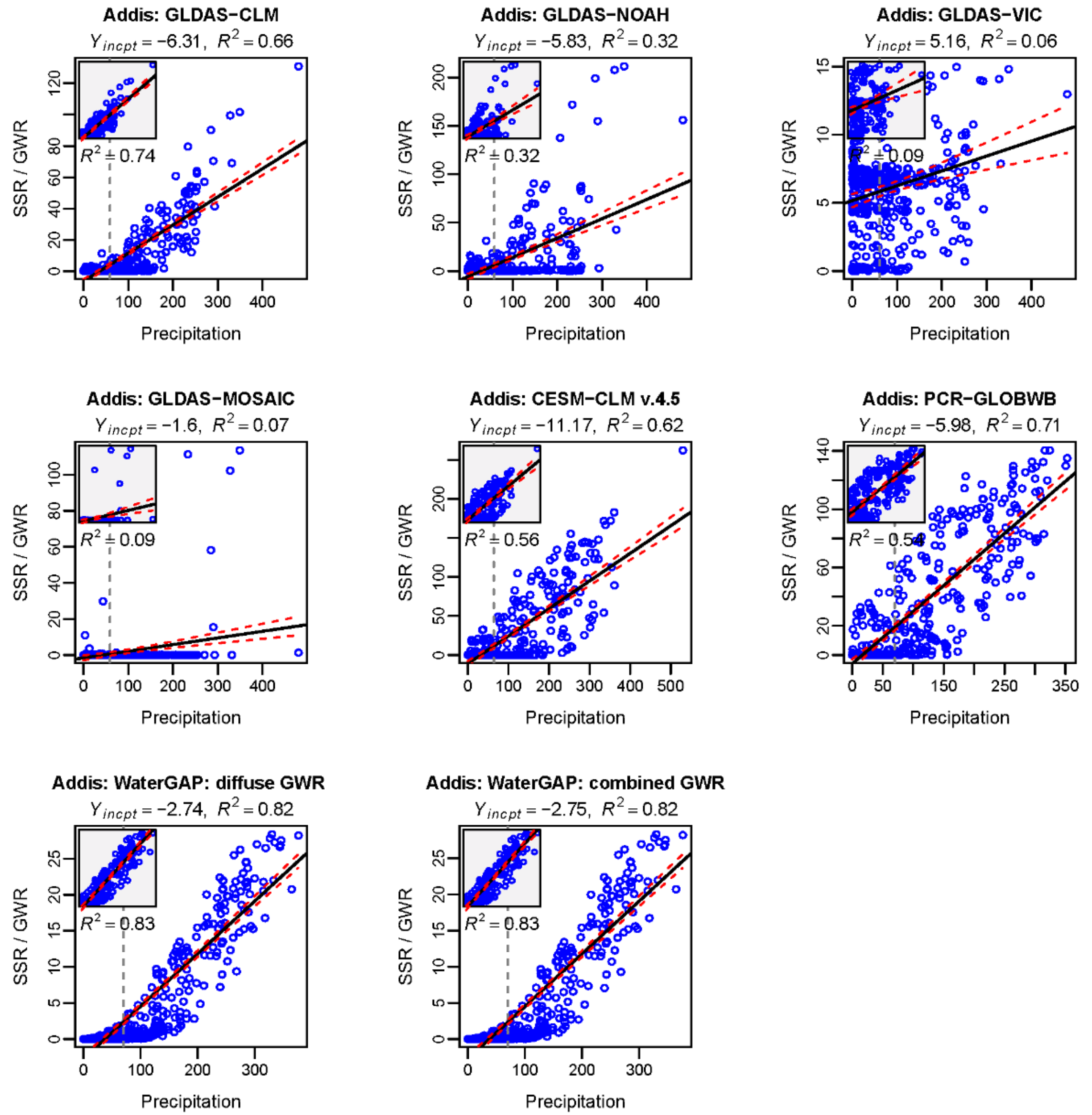
Global-scale model analysis: preliminary results

Pallisa (Uganda)



Global-scale model analysis: preliminary results

Addis Ababa (Ethiopia)



Global-scale model analysis: preliminary results

Dar e Salaam (Tanzania)