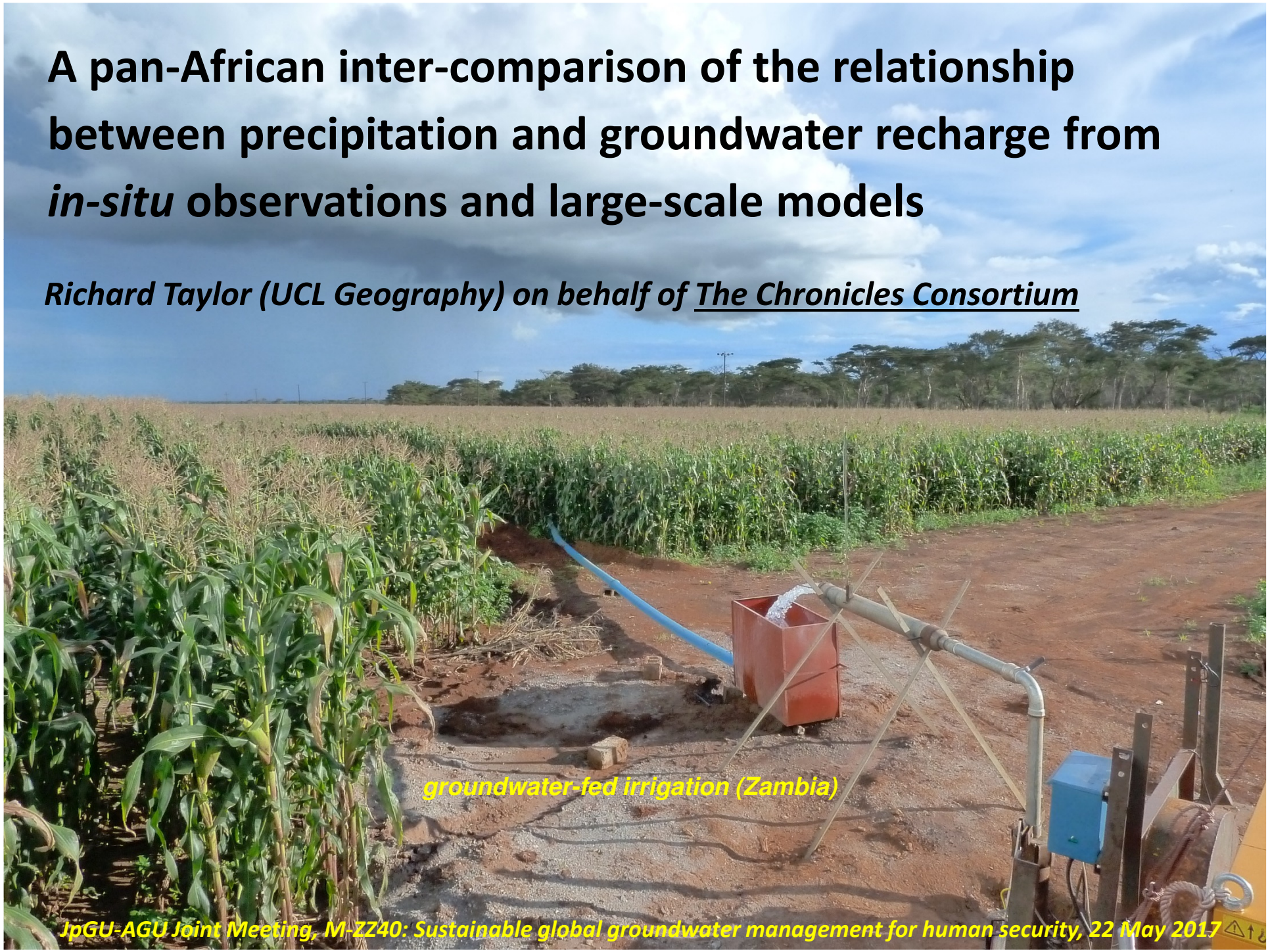
A pan-African inter-comparison of the relationship between precipitation and groundwater recharge from *in-situ* observations and large-scale models

Richard Taylor (UCL Geography) on behalf of The Chronicles Consortium

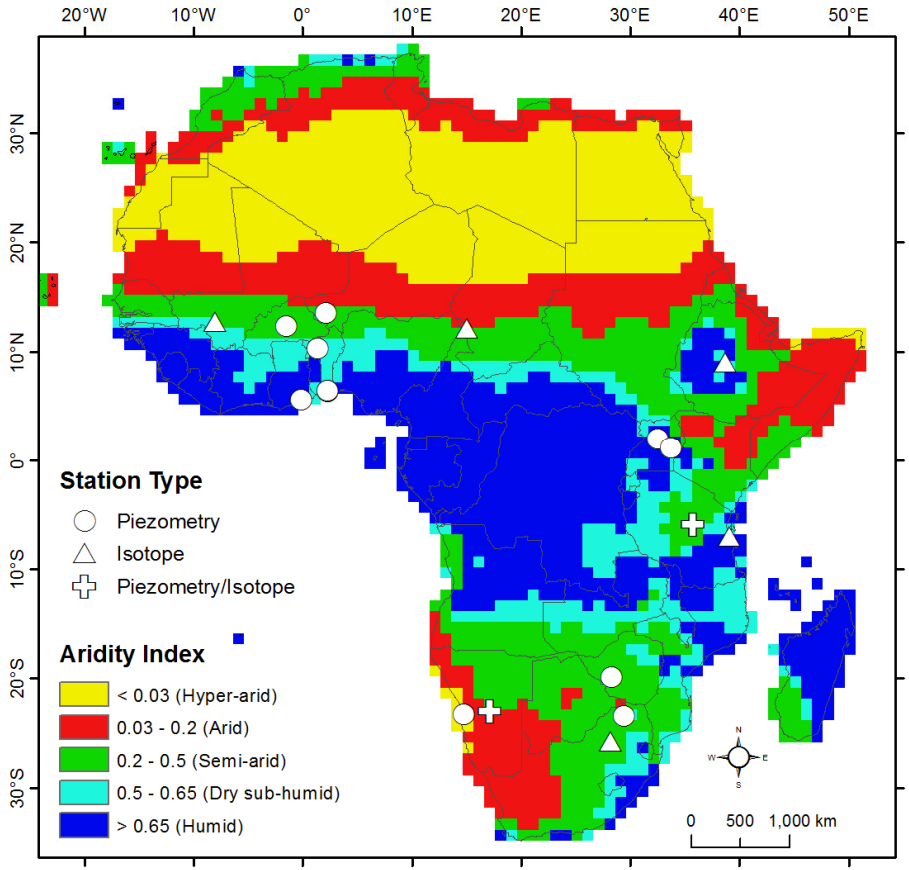


JpGU-AGU Joint Meeting, M-ZZ40: Sustainable global groundwater management for human security, 22 May 2017


"Climate change is projected to reduce renewable… groundwater resources significantly in most dry subtropical regions (robust evidence, high agreement)."
IPCC WGII (2014) Chapter 3, page 232
"The uncertainties in projected groundwater recharge that originate in the hydrological models have not yet been explored." IPCC WGII (2014) Chapter 3, page 244
artesian borehole, Singida (central Tanzania)

IAH/UNESCO-IHP: *The Chronicles Consortium*

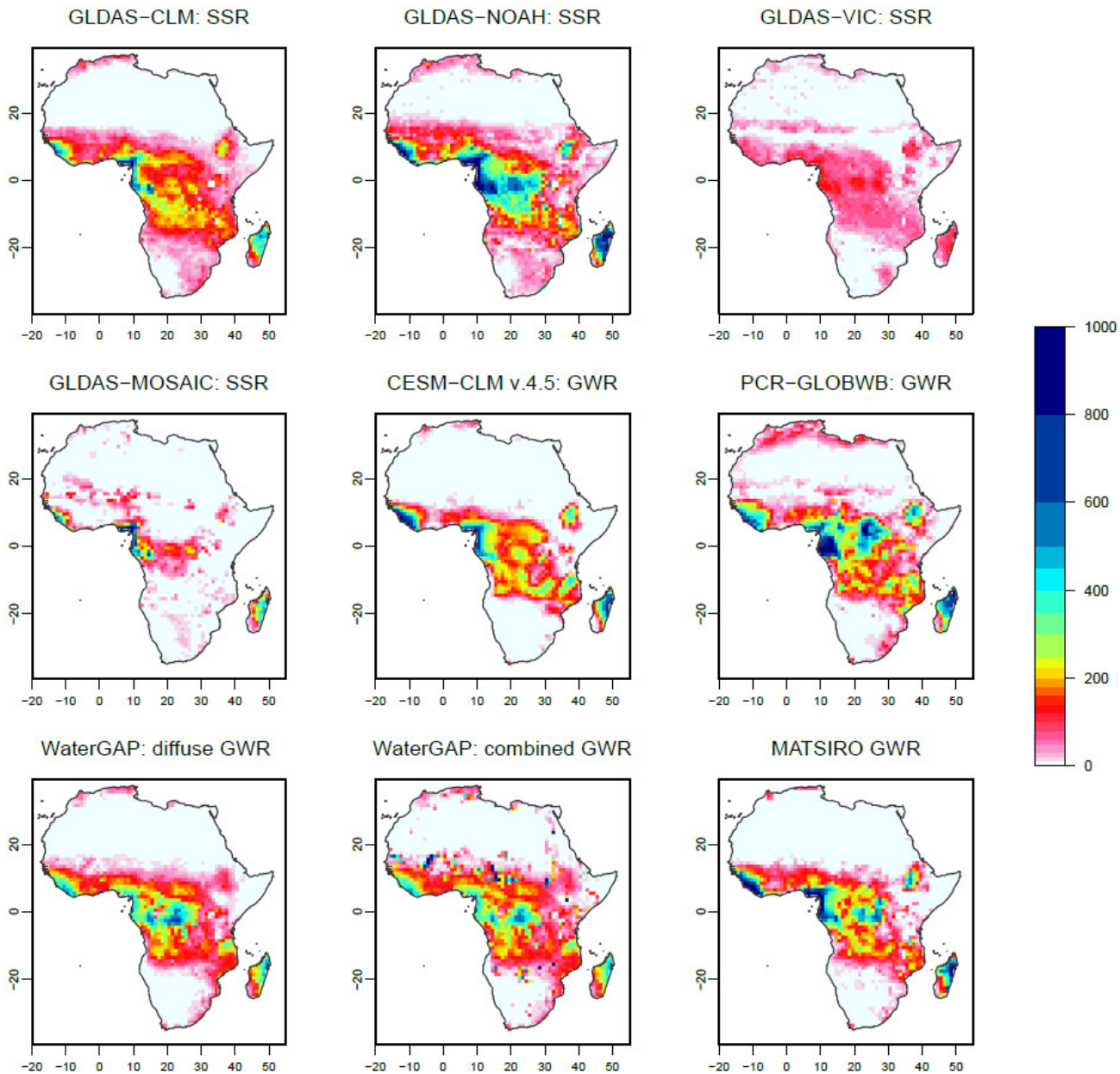
Abiye, Tamiru (University of Witswatersand, South Africa)
Ayenew, Tenalem (Addis Ababa University, Ethiopia)
Boukari, Moussa (Université d'Abomey Calavi, Benin)
Cuthbert, Mark (Cardiff University , UK)
Döll, Petra (Goethe-University Frankfurt, Germany)
Favreau, Guillaume (IRD, France)
Goni, Ibrahim (University of Maiduguri, Nigeria)
Jasechko, Scott (University of Calgary, Canada)
Kashaigili, Japhet (Sokoine University of Agriculture, Tanzania)
Kim, Hyungjun (University of Tokyo, Japan)
Kotchoni, Valerie (Université d'Abomey Calavi, Benin)
Koussoubé, Youssouf (Université d'Ouagadougou, Burkina Faso)
Lawson, Fabrice (Université d'Abomey Calavi, Benin)
Lo, Min-Hui (National Taiwan University, Taiwan)
MacDonald, Alan (BGS, UK)
Müller Schmied, Hannes (Goethe-University Frankfurt, Germany)
Nazoumou, Yahaya (Université Abdou Moumouni, Niger)
Nyenje, Philip (Makerere University, Uganda)
Oki, Taikan (University of Tokyo, Japan)
Owor, Michael (Makerere University, Uganda)
Rodell, Matthew (NASA, USA)
Scanlon, Bridget (University of Texas, USA)
Shamsudduha, Mohammad (UCL, UK)
Sibanda, Tenant (World Vision, Zimbabwe)
Sorensen, James (BGS, UK)
Taylor, Richard (UCL, UK)
Tindimugaya, Callist (MWE, Uganda)
Todd, Martin (University of Sussex, UK)
Villholth, Karen (IWMI, South Africa)
Vouillamoz, Jean-Michel (IRD, France)
Wada, Yoshihide (IIASA, Austria)
and growing… join us?



Sokoine University of Agriculture (Tanzania): 9-12 February, 2017

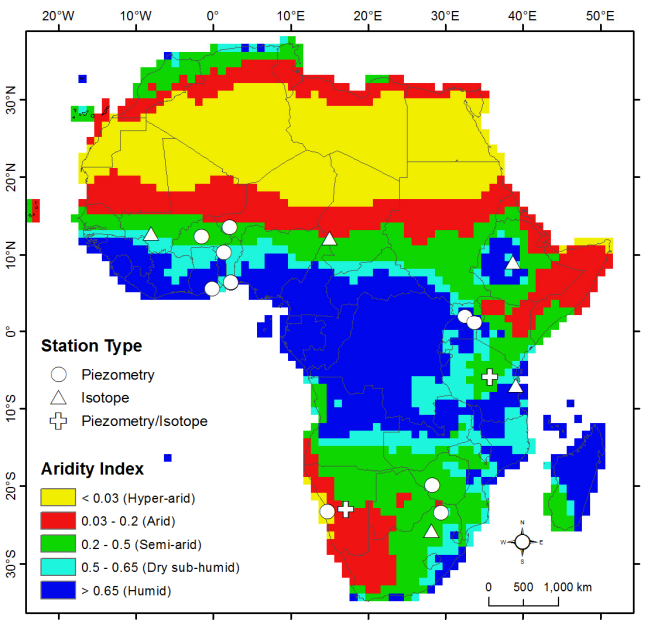
Inter-comparison of 4 GLDAS LSMs & 5 GHMs

- **uncertainty** in the magnitude and distribution of modelled recharge is **substantial** - *mean annual recharge subsurface runoff (SSR) & groundwater recharge (GWR) from 1980-2014*

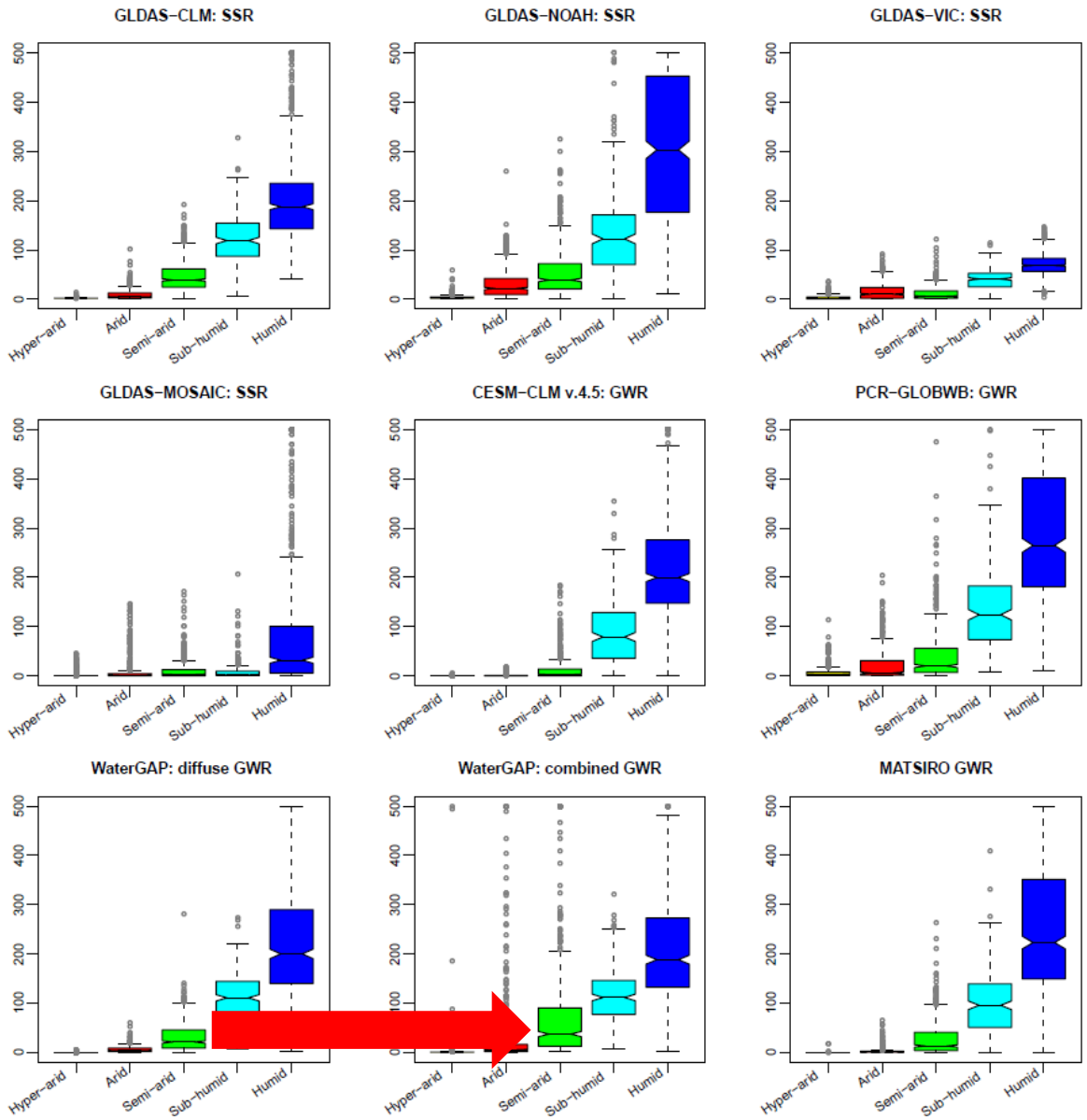


modelled recharge by climate zone

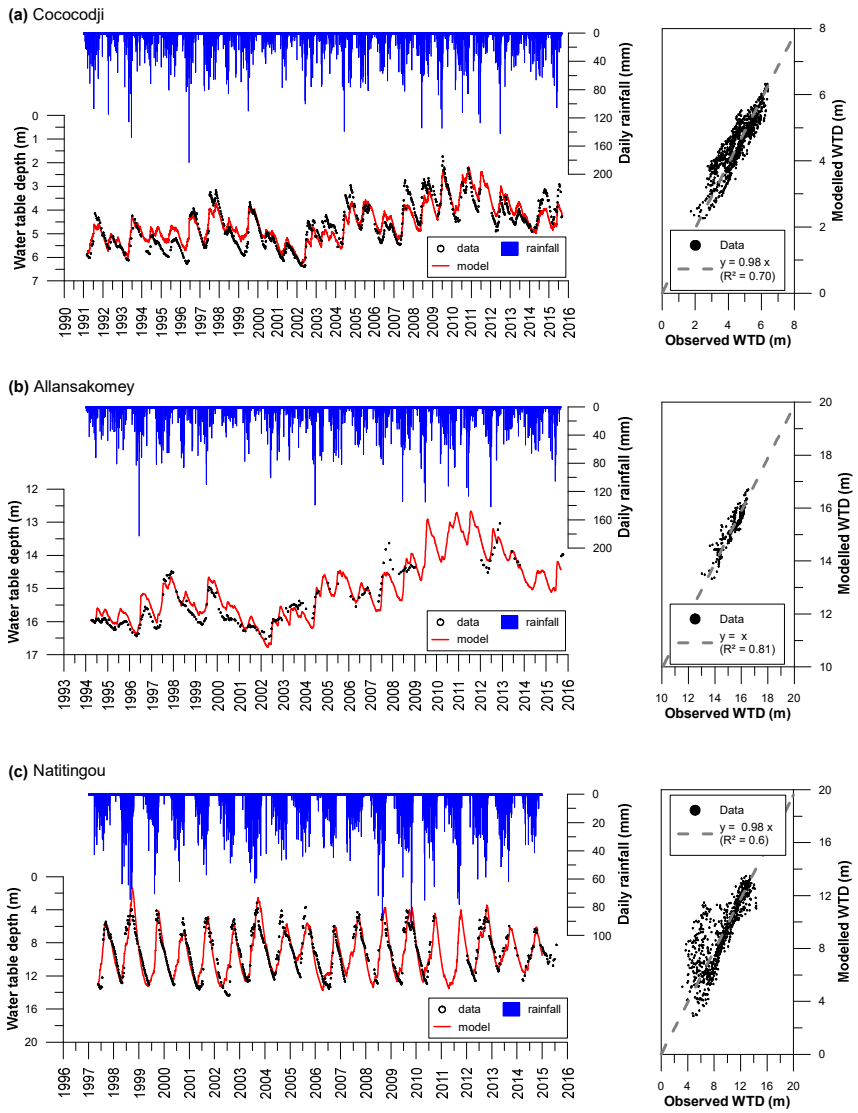
- **uncertainty** in simulated recharge increases in **semi-arid** regions

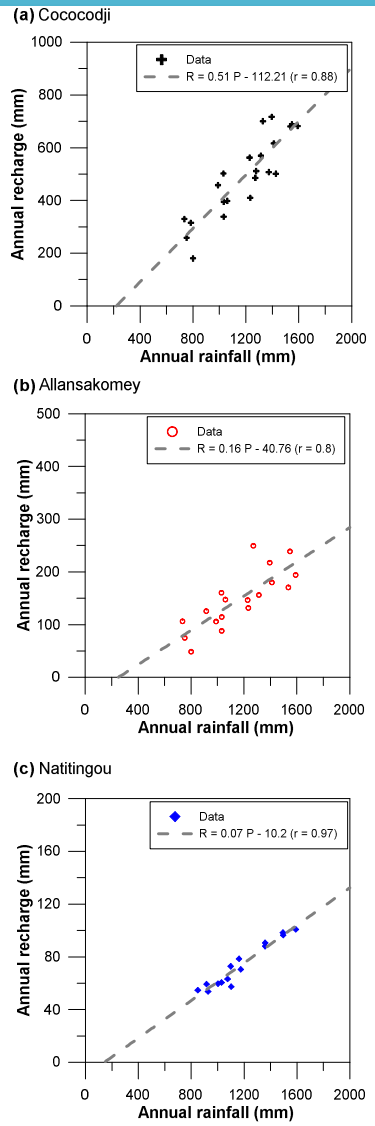


CGIAR Aridity Index



observations in seasonally humid Benin

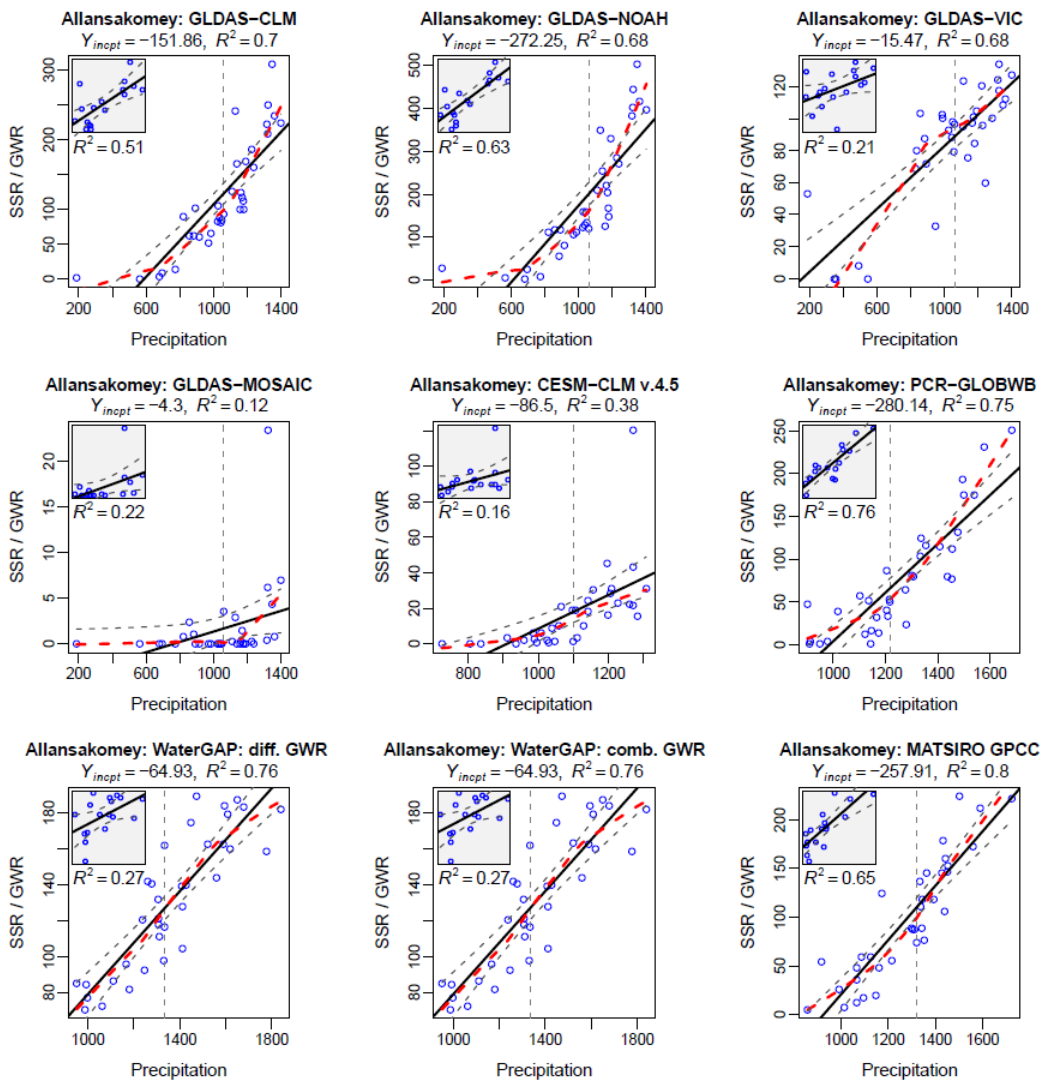


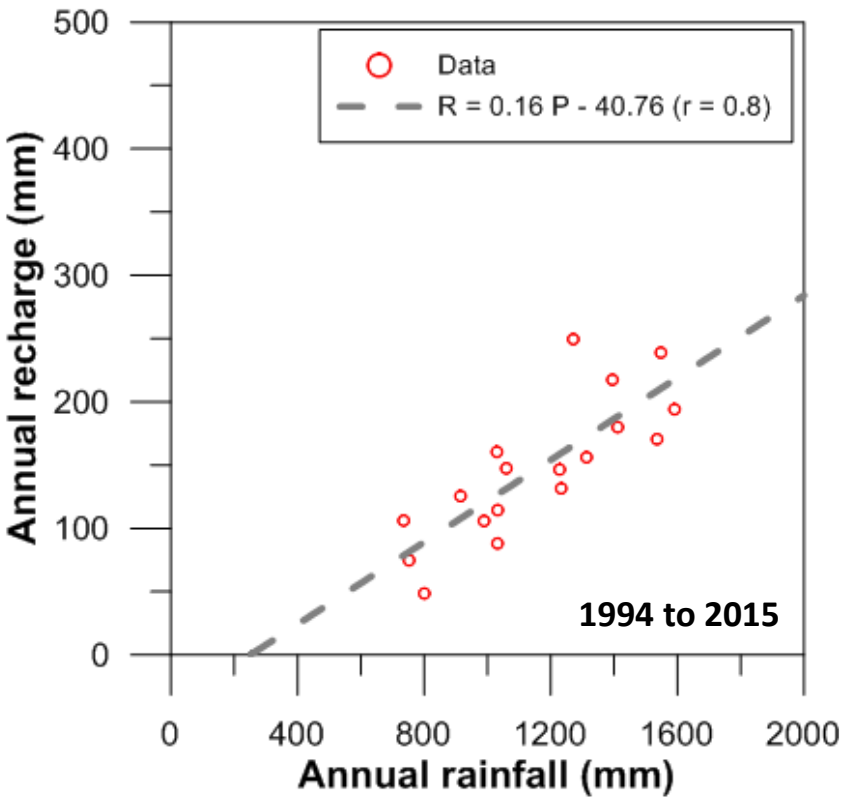


- GW levels well simulated using scalar recharge model of precip exceeding a threshold (5 to 15 mm·day^{-1}) & short lag times
- apparent precip threshold of ~ 200 mm·year^{-1} for recharge to occur

- rapid responses to rainfall inconsistent with a Darcy-Richards representation of unsaturated zone flow, implying bypass flow

observations vs. models in humid Benin

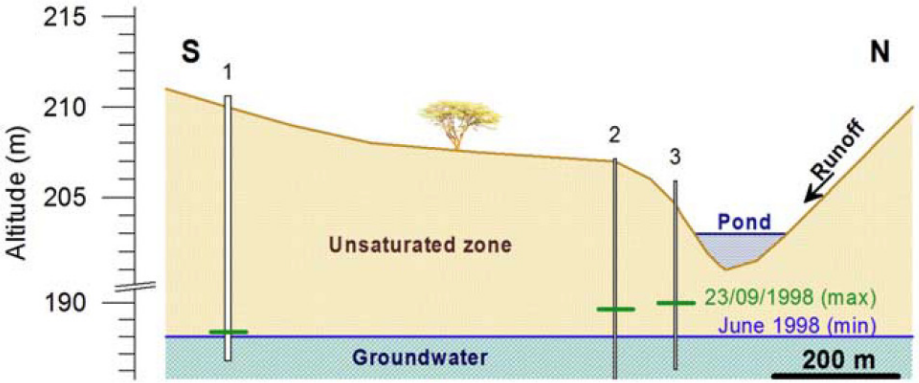


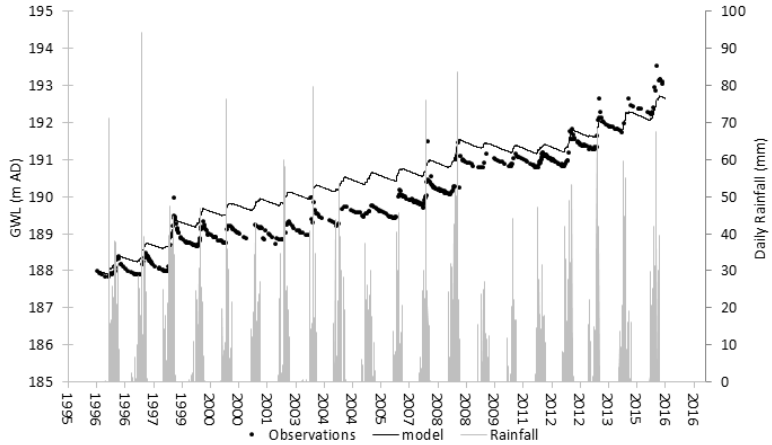


Kotchoni et al. (in review) Hydrogeol. J.

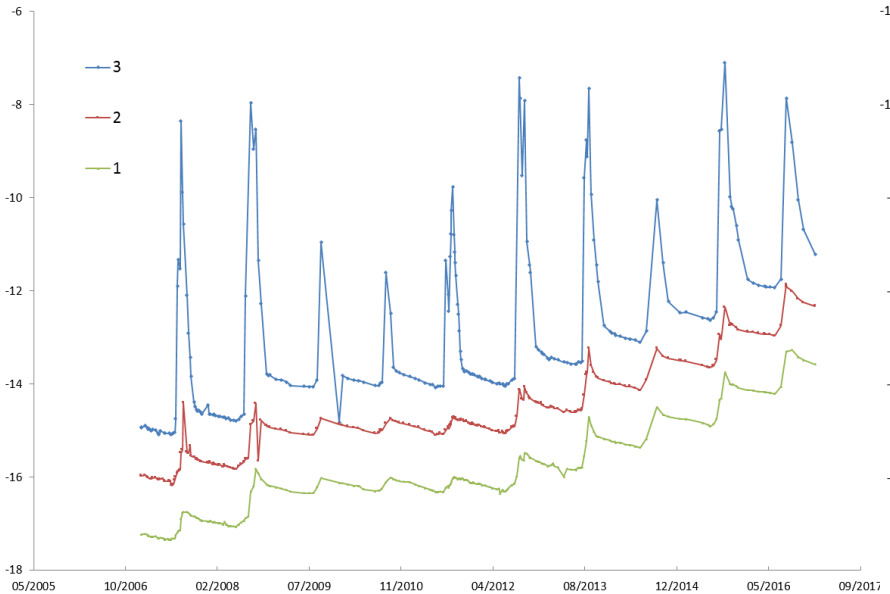
- observed and simulated relationships between precipitation & diffuse recharge in humid areas (e.g. Benin, Uganda) compare favourably

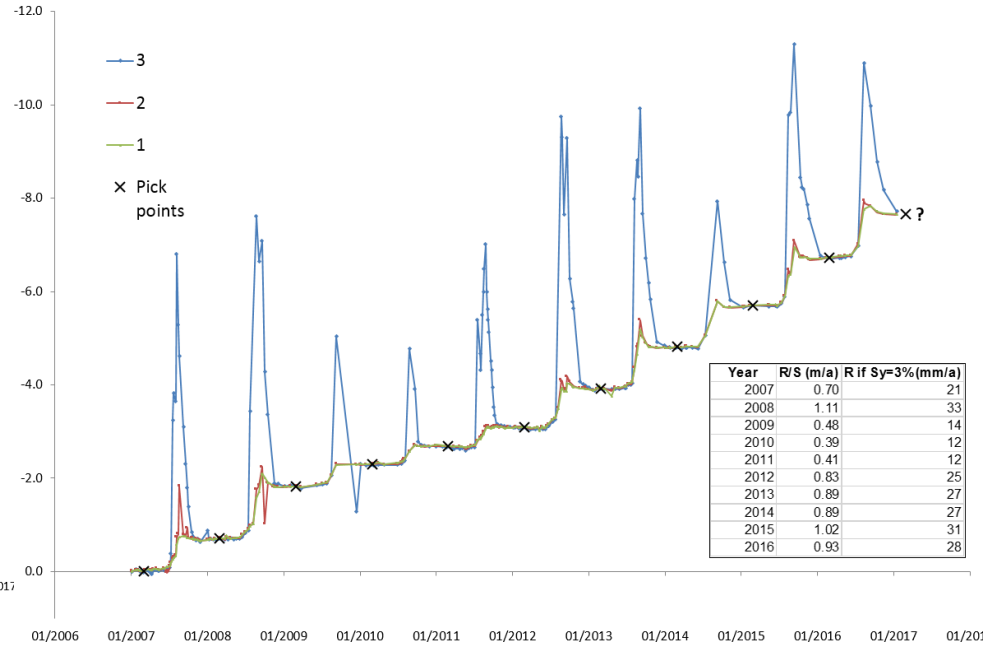
recharge observations in semi-arid Niger





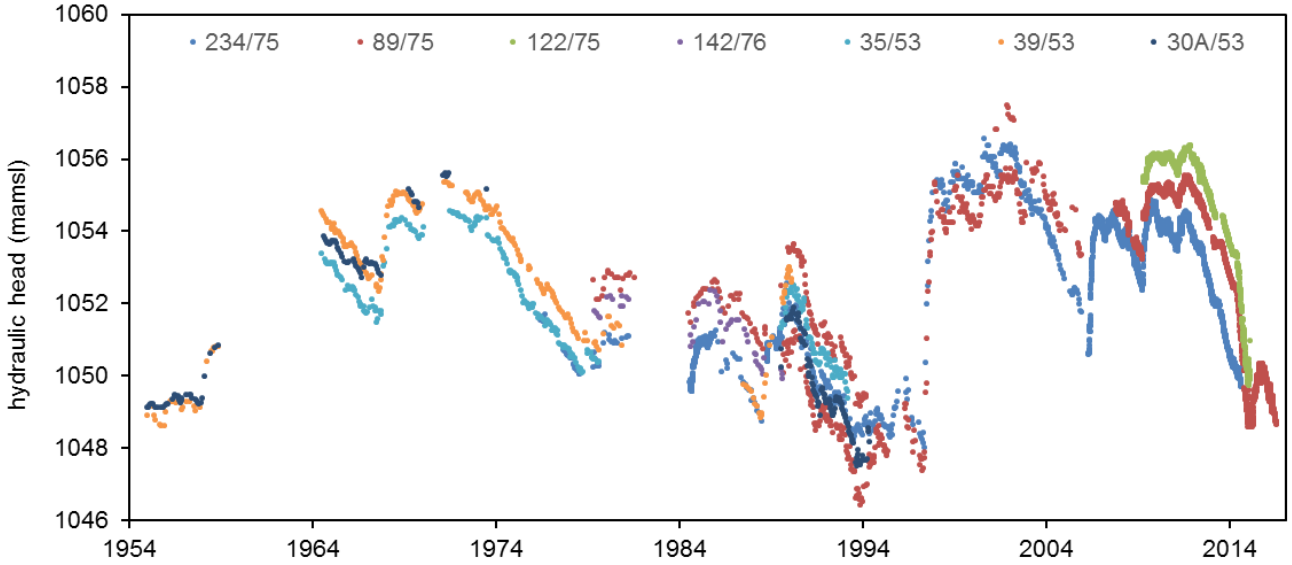
- diffuse recharge model proves inadequate; focused recharge pathway is evident from groundwater-level observations



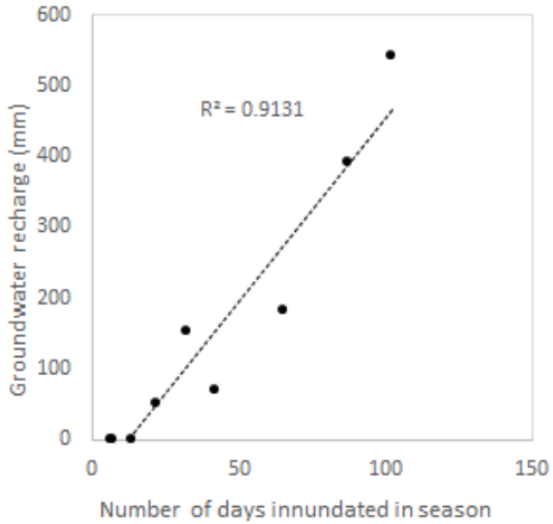


Year	R/S (m/a)	R if Sy=3%(mm/a)
2007	0.70	21
2008	1.11	33
2009	0.48	14
2010	0.39	12
2011	0.41	12
2012	0.83	25
2013	0.89	27
2014	0.89	27
2015	1.02	31
2016	0.93	28

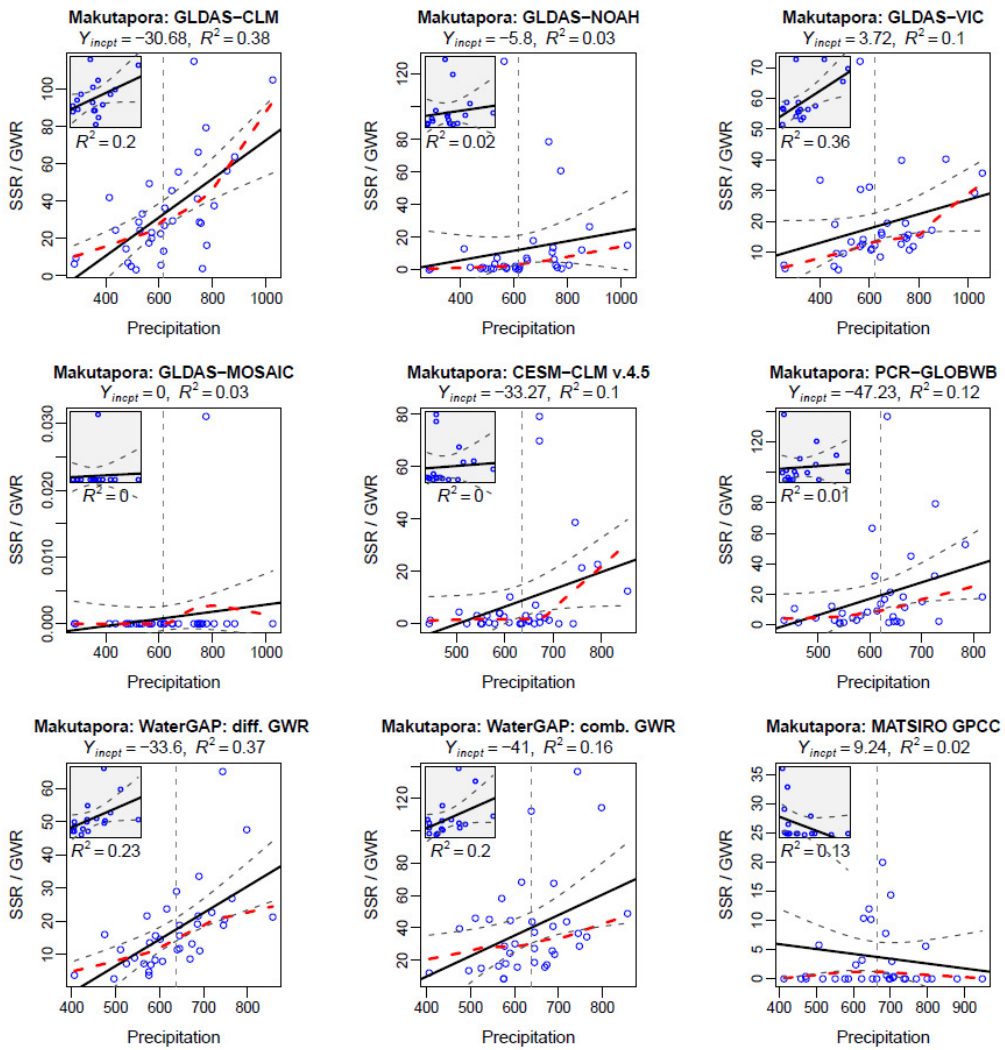
recharge observations in semi-arid Tanzania

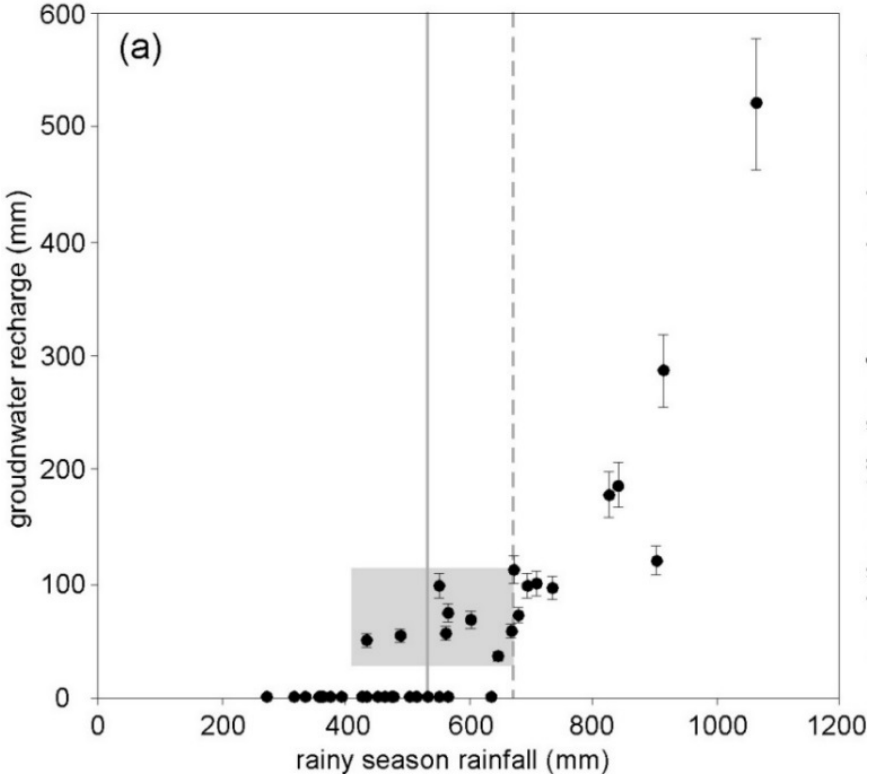


- recharge occurs episodically (El Niño) and strongly correlated to the duration of ephemeral stream discharge (*i.e.* focused recharge)



models/observations in semi-arid Tanzania

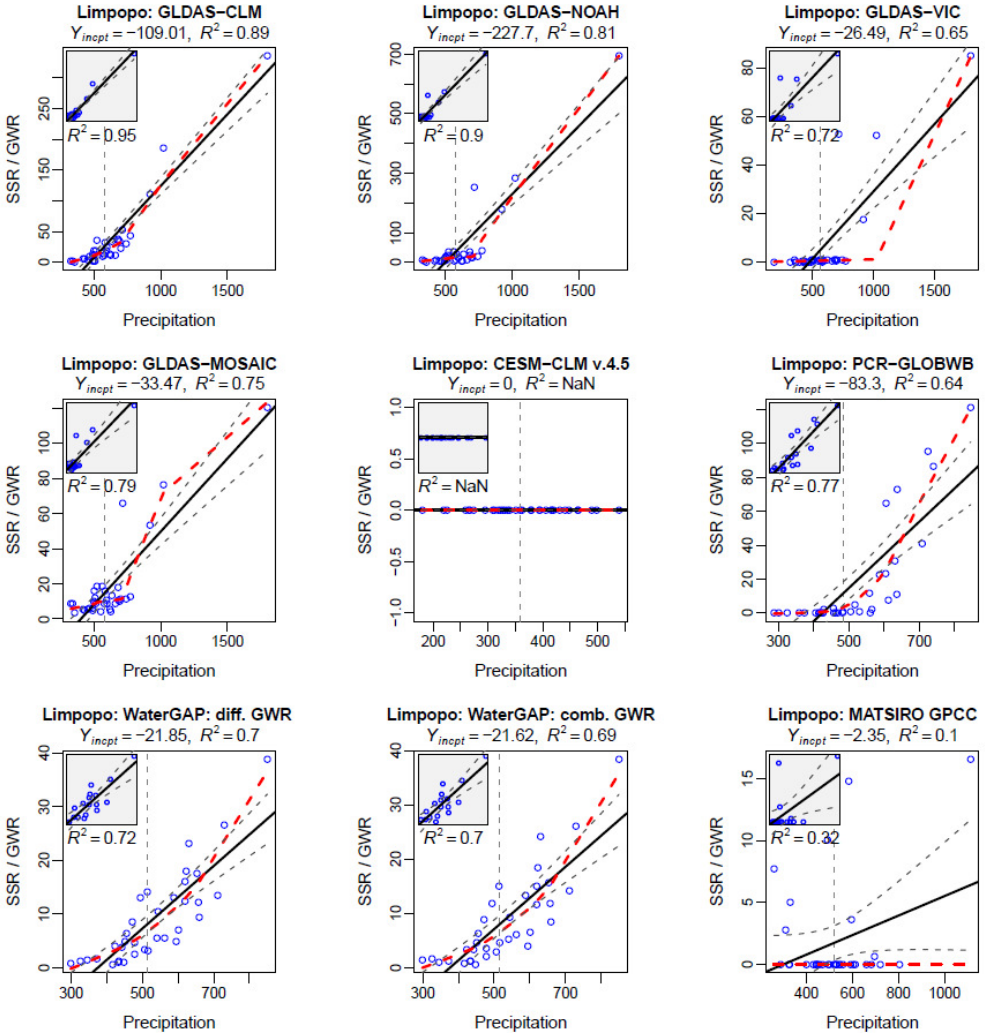


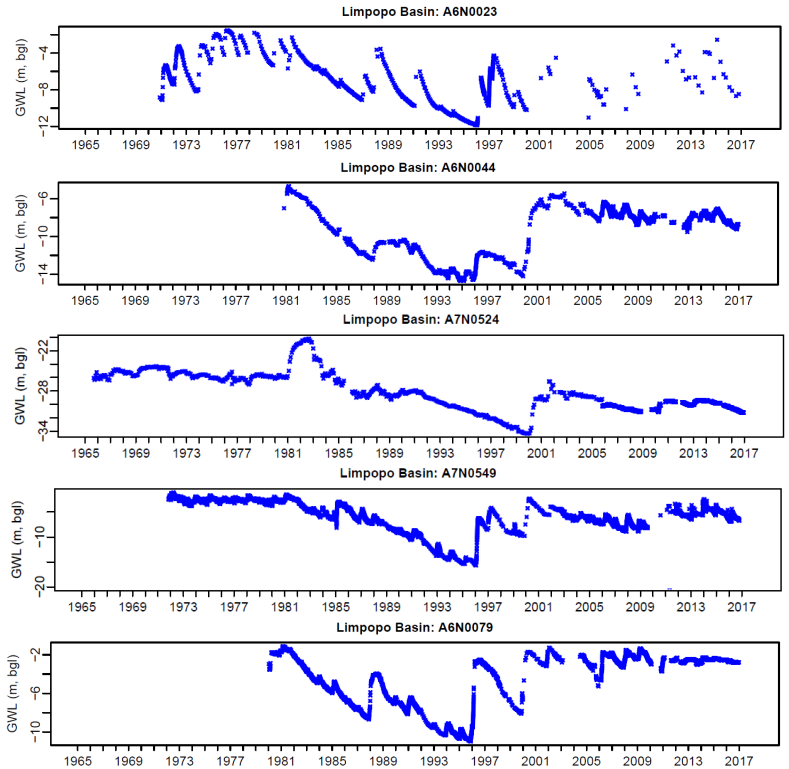


Taylor et al. (2013) Nat. Clim. Change 3, 374-378.

- observed non-linear relationship between precipitation & recharge not well represented in models based on diffuse recharge pathways

models/observations in semi-arid South Africa





Limpopo Basin: a selection of DWAF records

- observations clearly reveal substantial, episodic recharge events but these are not well represented in most large-scale models

Preliminary results from the inter-comparison:

- **substantial uncertainty exists in recharge modelled by 4 GLDAS LSMs (subsurface runoff) & 5 GHMs**

- **modelled and observed relationships between precipitation & diffuse recharge in humid areas are comparable – *rapid water-table responses inconsistent with Darcy-Richards soil-zone flow***

- **models are inconsistent with observed recharge in semi-arid environments - models do not represent focused recharge, *the primary pathway by which recharge is observed to occur***

- **observations across Africa indicate a bias in recharge to heavy rainfall events (daily to seasonal) via pathways (*i.e.* soil macropores, focused) not currently represented in models**

Thanks for listening!

Victoria Falls