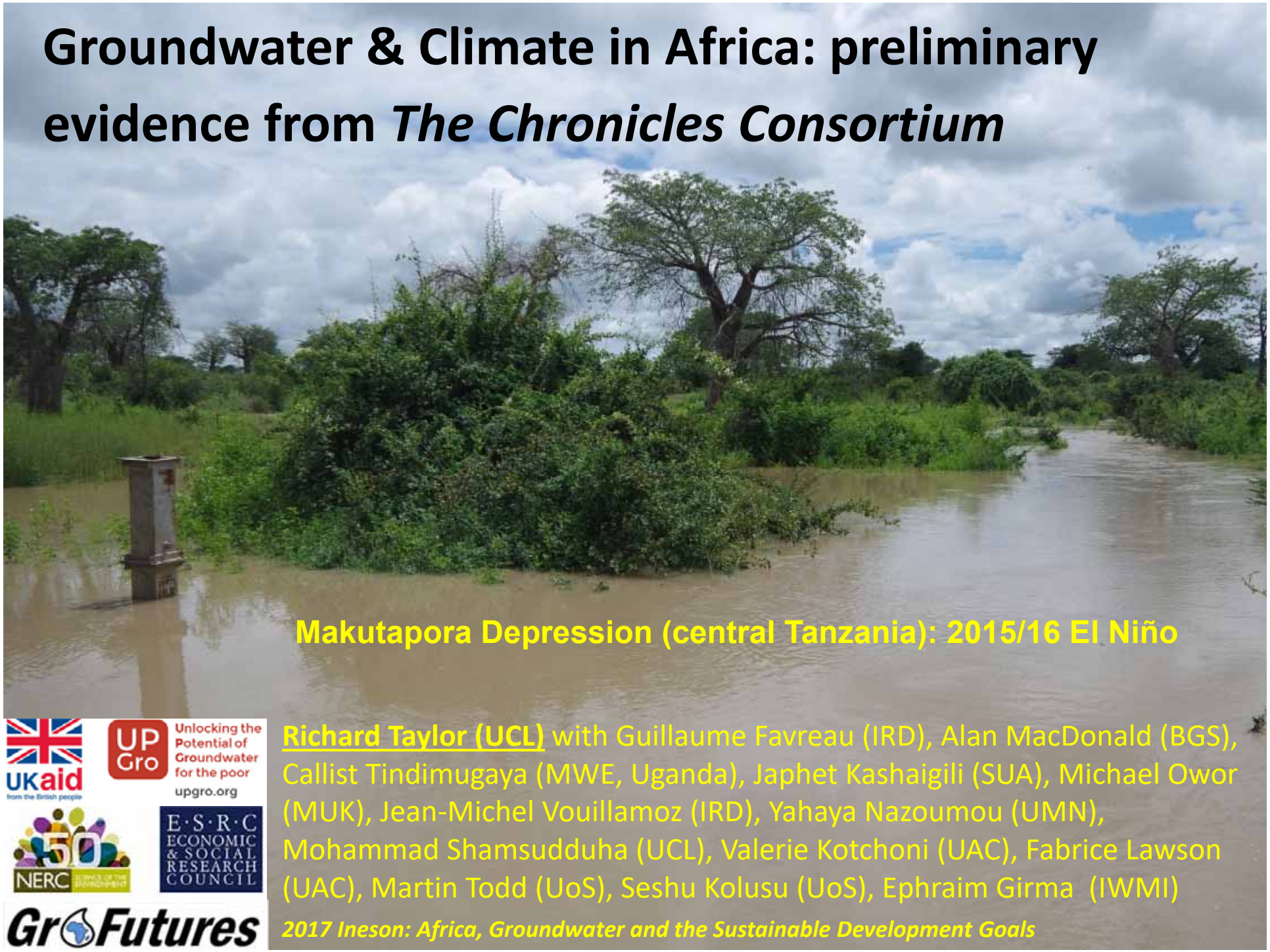
Groundwater & Climate in Africa: preliminary evidence from *The Chronicles Consortium*



Makutapora Depression (central Tanzania): 2015/16 El Niño

UKaid from the British people

UPGro Unlocking the Potential of Groundwater for the poor upgro.org

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E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

GroFutures

Richard Taylor (UCL) with Guillaume Favreau (IRD), Alan MacDonald (BGS), Callist Tindimugaya (MWE, Uganda), Japhet Kashaigili (SUA), Michael Owor (MUK), Jean-Michel Vouillamoz (IRD), Yahaya Nazoumou (UMN), Mohammad Shamsudduha (UCL), Valerie Kotchoni (UAC), Fabrice Lawson (UAC), Martin Todd (UoS), Seshu Kolusu (UoS), Ephraim Girma (IWMI)

2017 Ineson: Africa, Groundwater and the Sustainable Development Goals

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)
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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)
Xu, Yongxin (UWC, South Africa)
and growing… join us?

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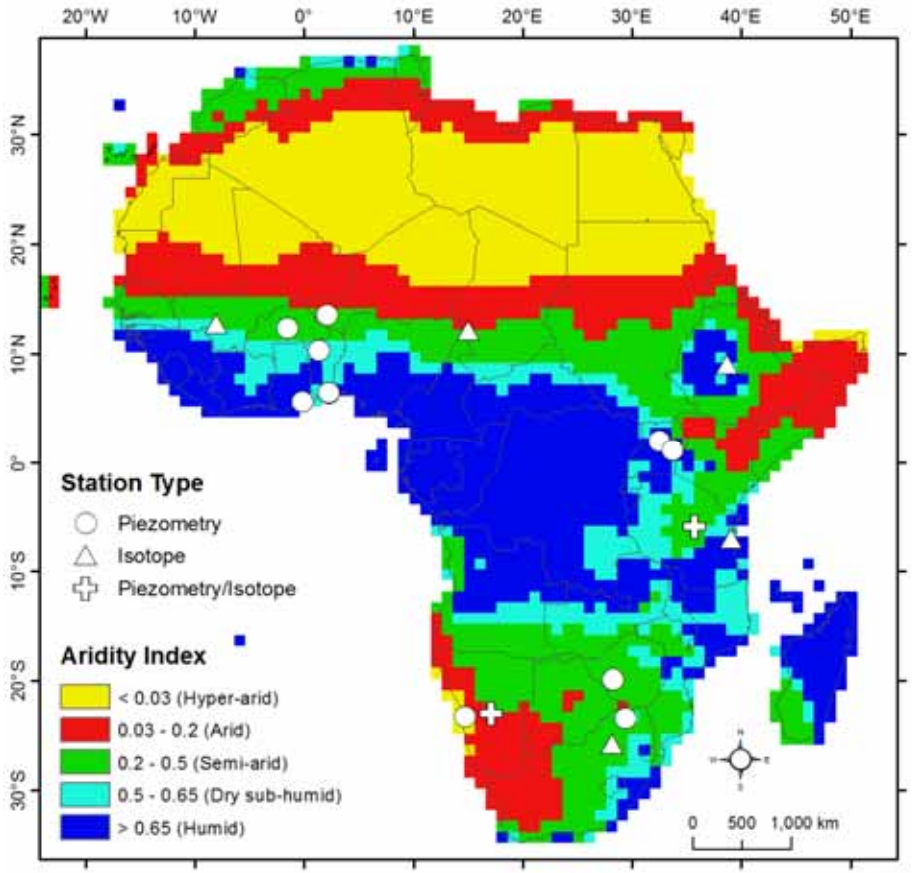
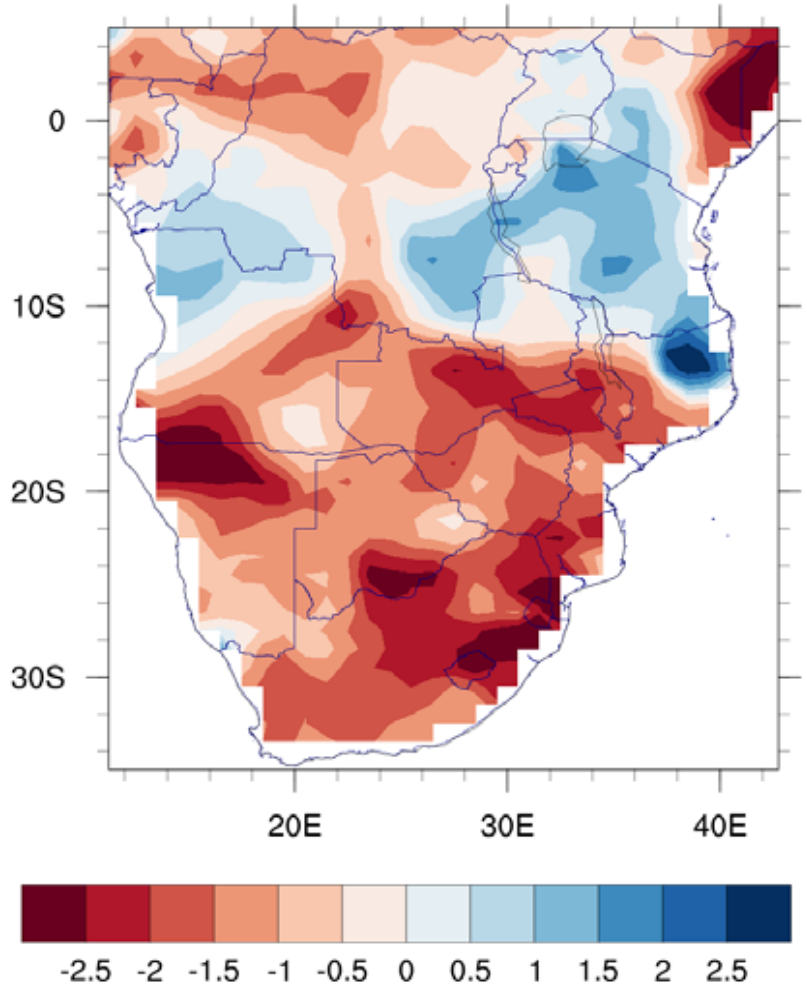


Sokoine University of Agriculture (Tanzania): 9-12 February, 2017

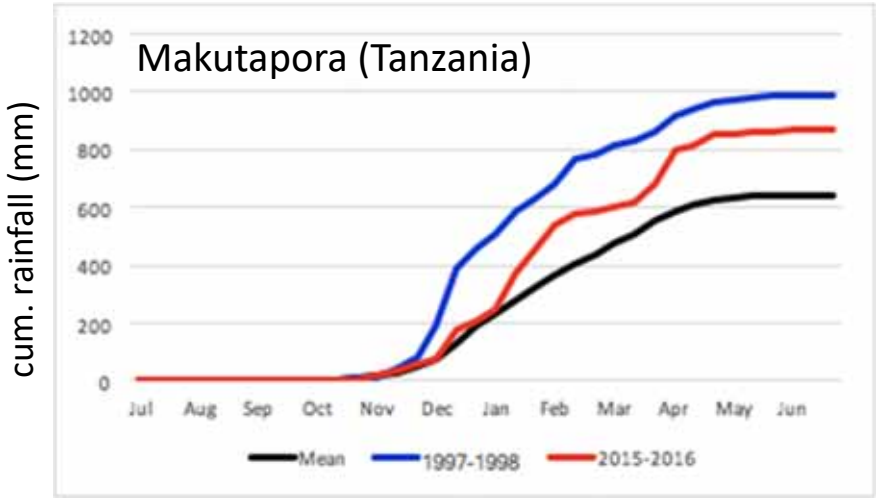
2015-16 El Niño: 2nd strongest in ~150 years

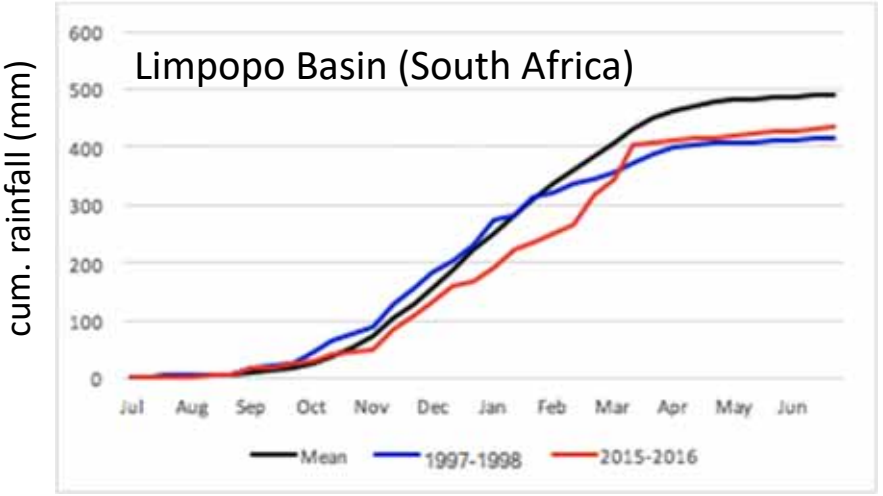
- extreme aridity in the Limpopo Basin (South Africa) and anomalous wetness in the Makutapora Basin of central Tanzania: **ENSO dipole**



analysis: Seshu Kolusu

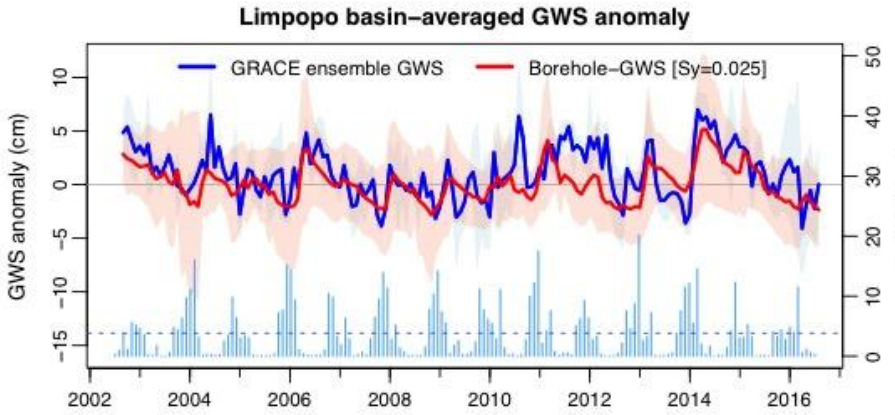
SPEI: 1901-2016

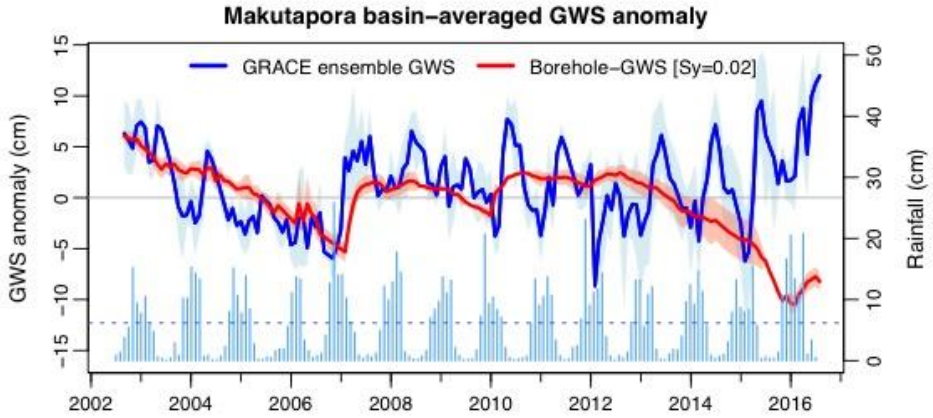


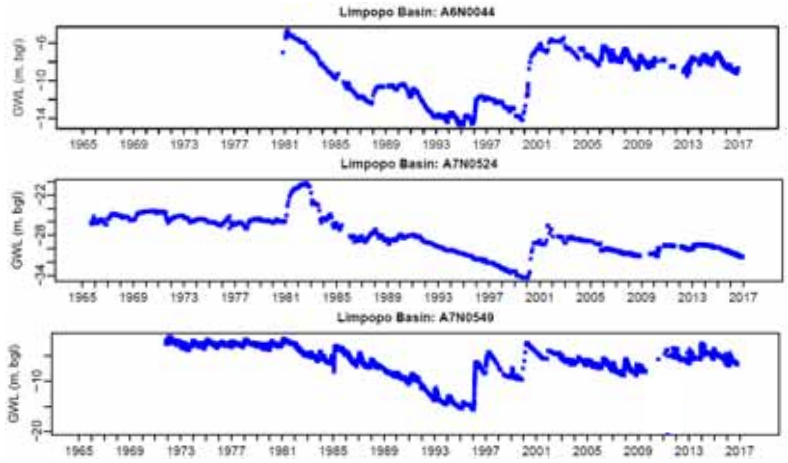


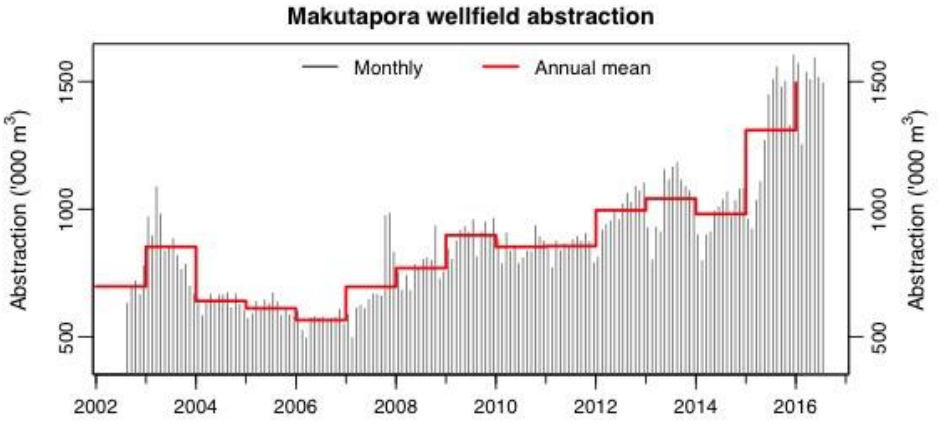
2015/16 El Niño and groundwater storage

- extreme aridity and groundwater-level decline in Limpopo Basin, reflected in GRACE solutions and piezometry
- anomalous wetness and groundwater-level recovery in Makutapora Wellfield despite step-change in intensive pumping





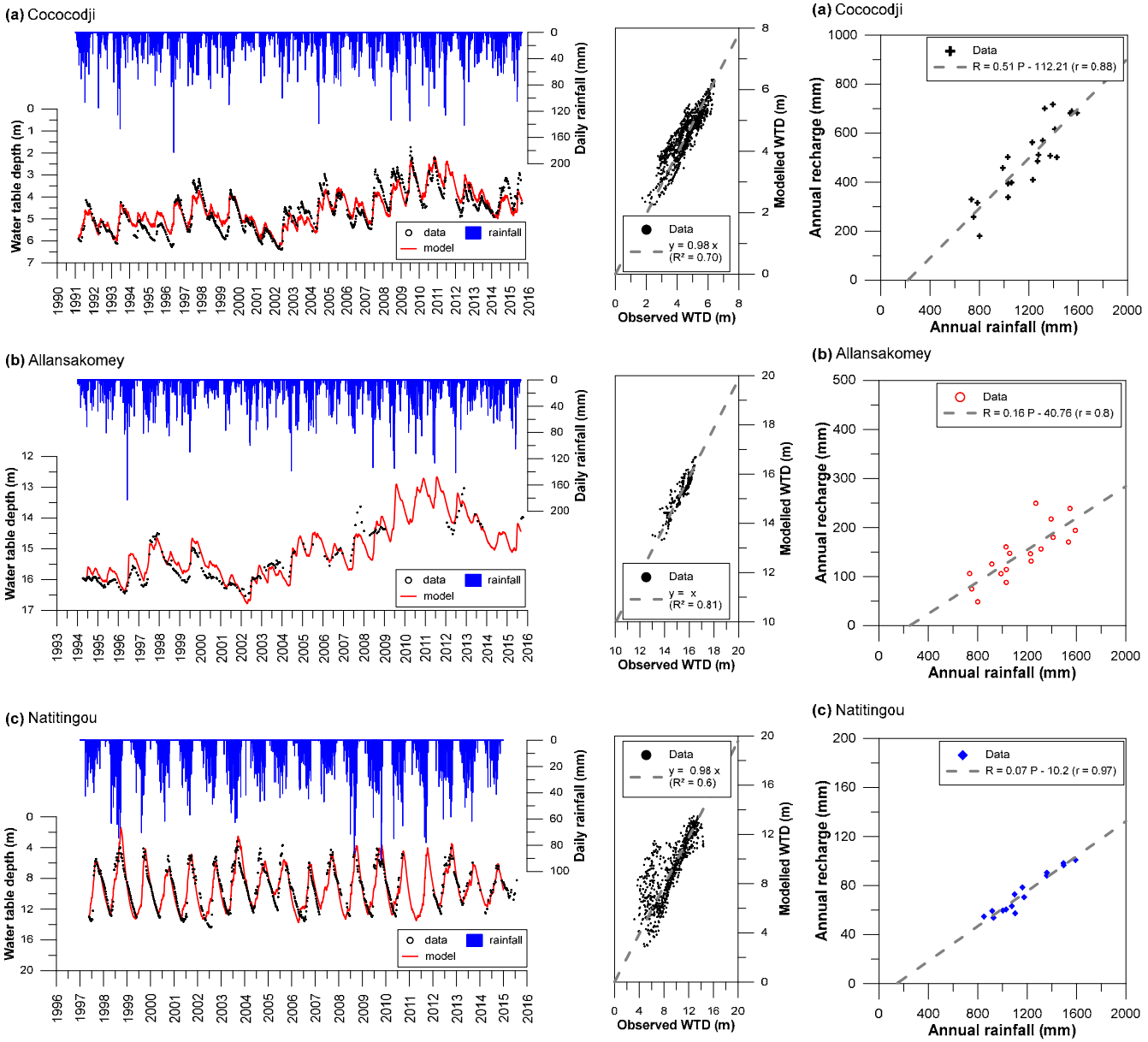




analysis: Mohammad Shamsudduha

groundwater-level monitoring well, Abomey-Calavi (Benin)

observations in seasonally humid Benin

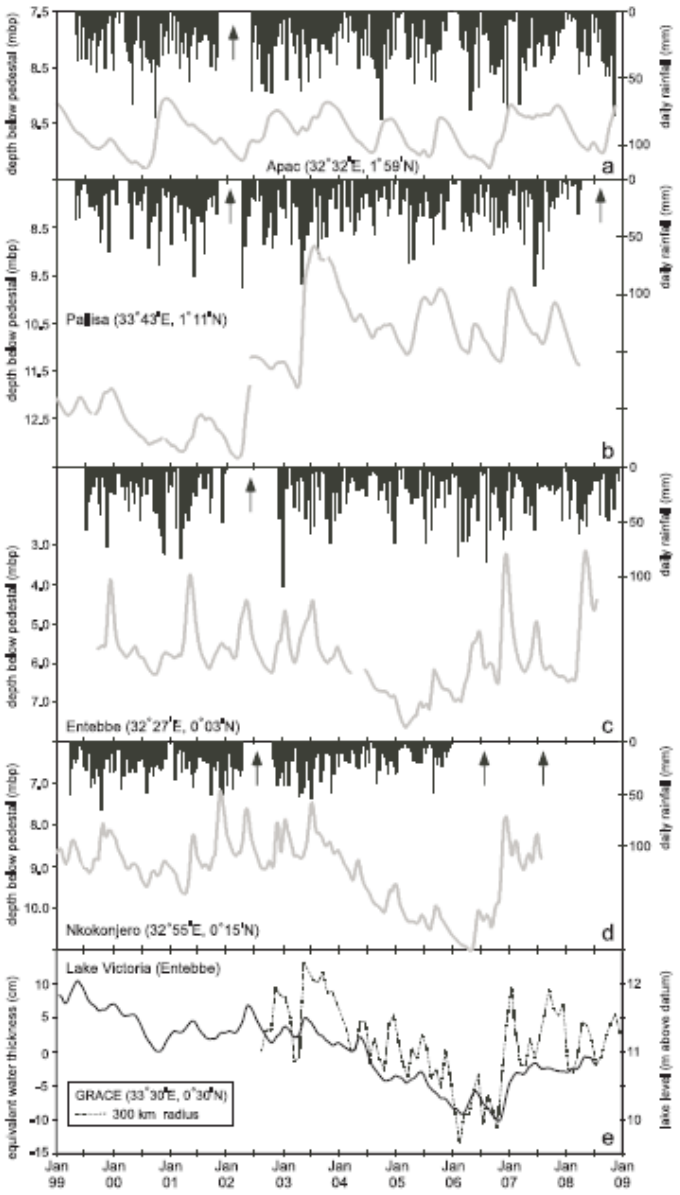


Kotchoni *et al.* (in review) *Hydrogeol. J.*

- hydrographs well simulated using scalar recharge model of rainfall exceeding a threshold: 5 to 15 mm·day^{-1}
- apparent rainfall threshold of ~200 mm·year^{-1} for recharge to occur


paired rain gauge & monitoring well, Soroti (Uganda)

observations in seasonally humid Uganda



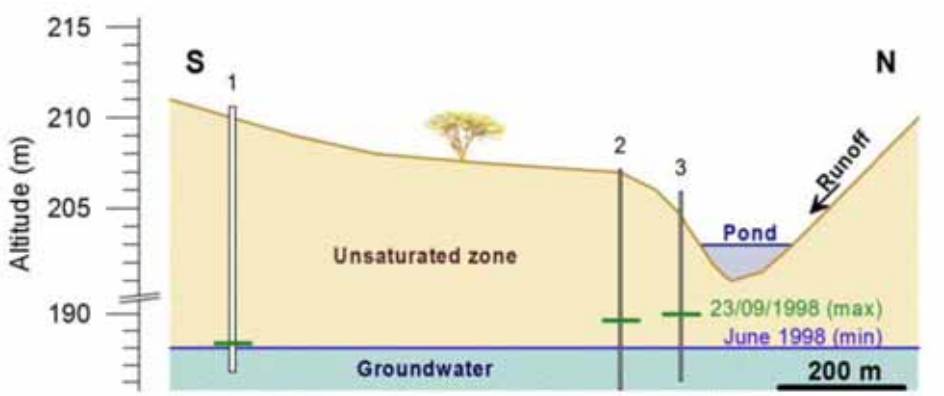
Owor *et al.* (2009) *Environ. Res. Lett.* 4, 035009.

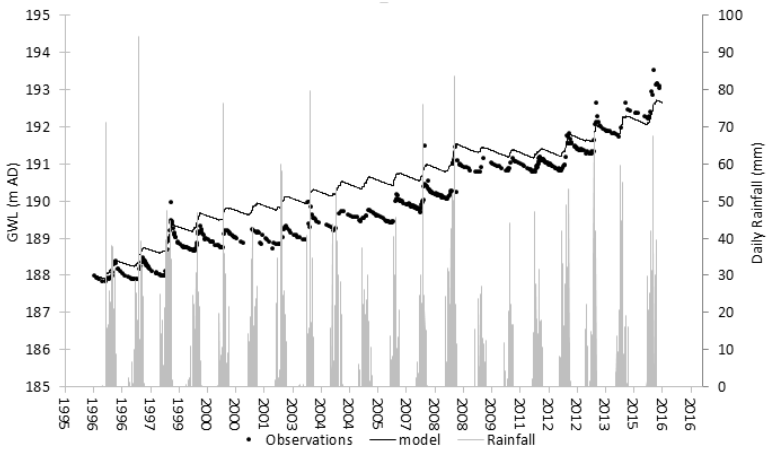
- scalar recharge models of rainfall exceeding 10 m·day^{-1} and cross-correlations of rainfall and groundwater levels indicate lag times of 5 to 13 days

- apparent infiltration velocities of 0.5 to 1 m·day^{-1} in Benin and Uganda are inconsistent with a Darcy-Richards representation of unsaturated zone flow, implying bypass flow

'*dominance of soil macropore flow*' (Beven and Germann, 2013)

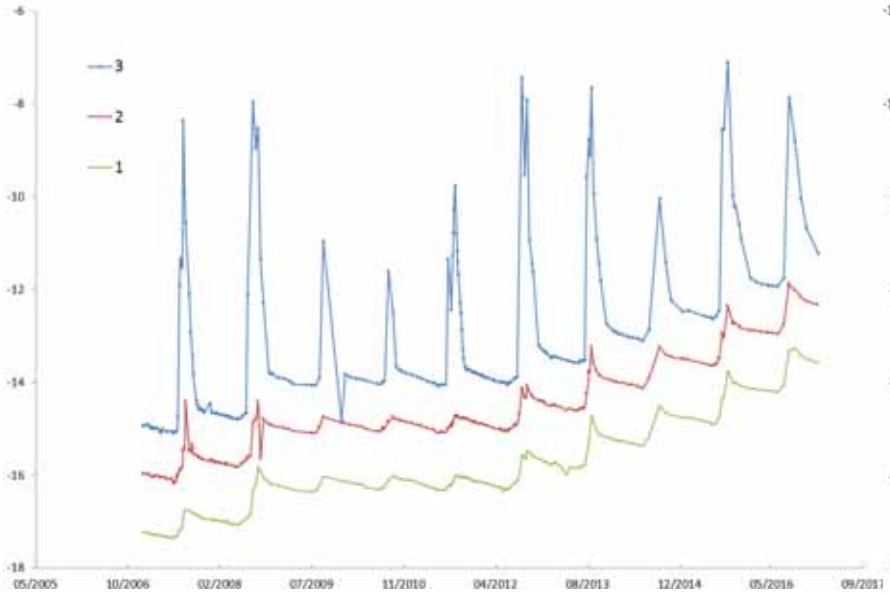
piezo-transect observations in semi-arid Niger

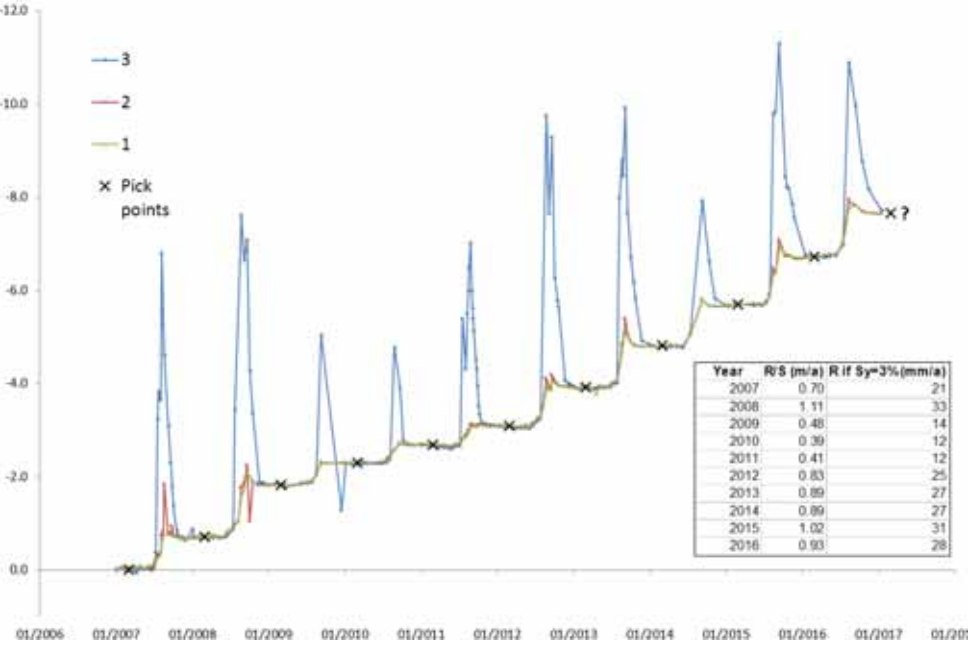




Favreau *et al.* (2009) *Water Resour. Res.* 45, W00A16.

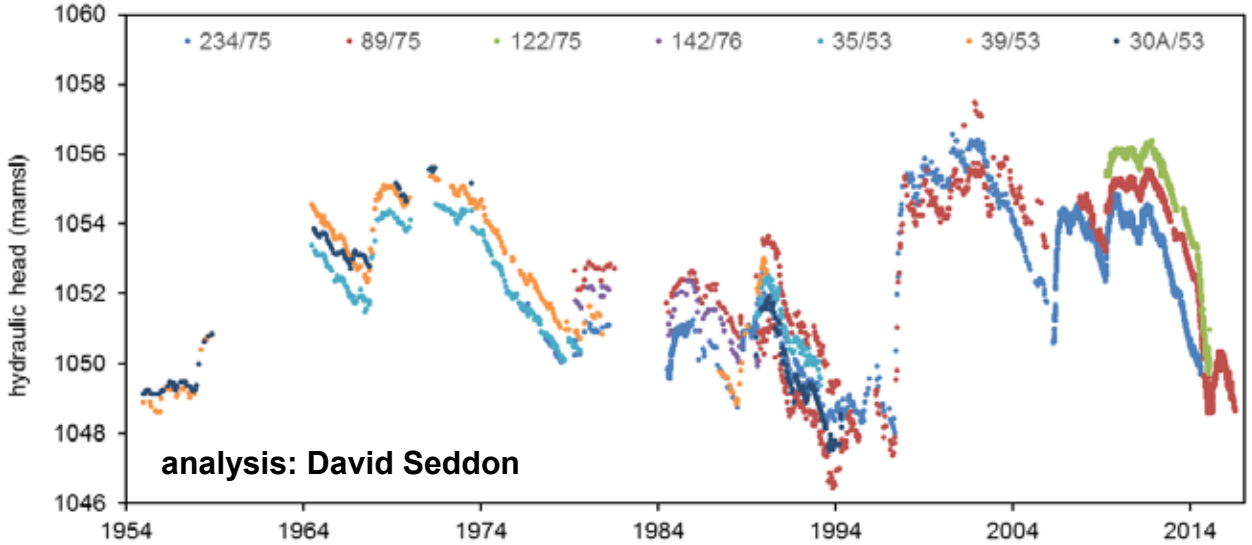
- direct, diffuse recharge model proves inadequate; focused recharge from surface ponds is evident from groundwater-level observations



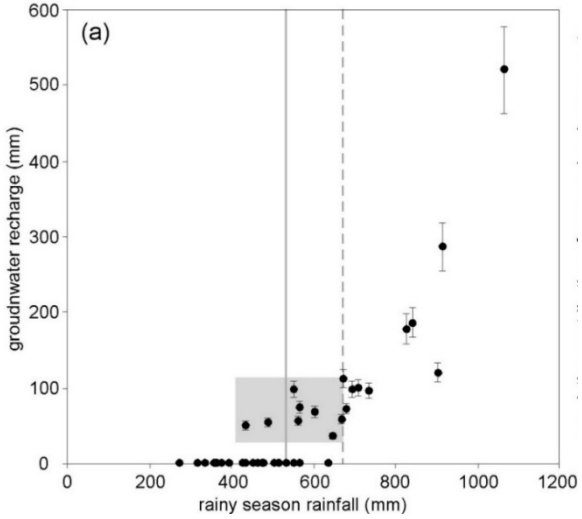


analysis: Mark Cuthbert

nested observations in semi-arid Tanzania



- recharge occurs episodically (El Niño) and results disproportionately from heavy rainfall - focused recharge inferred from site monitoring

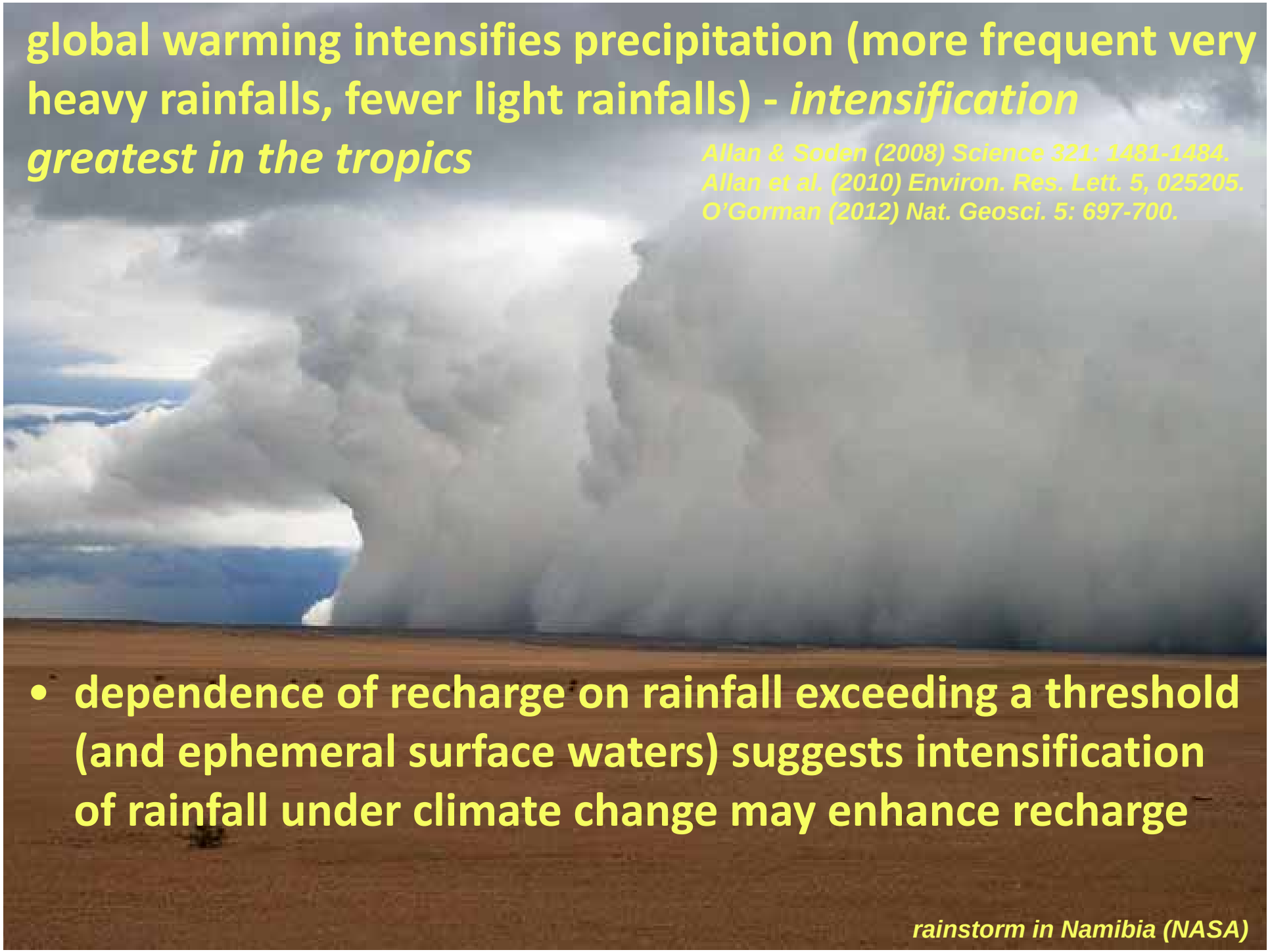


Taylor *et al.* (2013) *Nat. Clim. Change* 3, 374-378.

ephemeral stream flow in central Tanzania during 2015-16 El Niño

Evidence from *The Chronicles Consortium*

- **'chronicles' contextualise climate influences on groundwater recharge and storage: EA/SA El Niño dipole**
- **40 'chronicles' averaged over an area of ~47 000 km^2 (Limpopo Basin) correlate well (r = 0.62) with a mean GRACE satellite footprint (~200 000 km^2)**
- **rapid water-table responses to rainfall observed in humid Benin and Uganda are inconsistent with Darcy-Richards soil-zone flow**
- **focused recharge from ephemeral ponds and river discharge observed in semi-arid Niger and Tanzania**



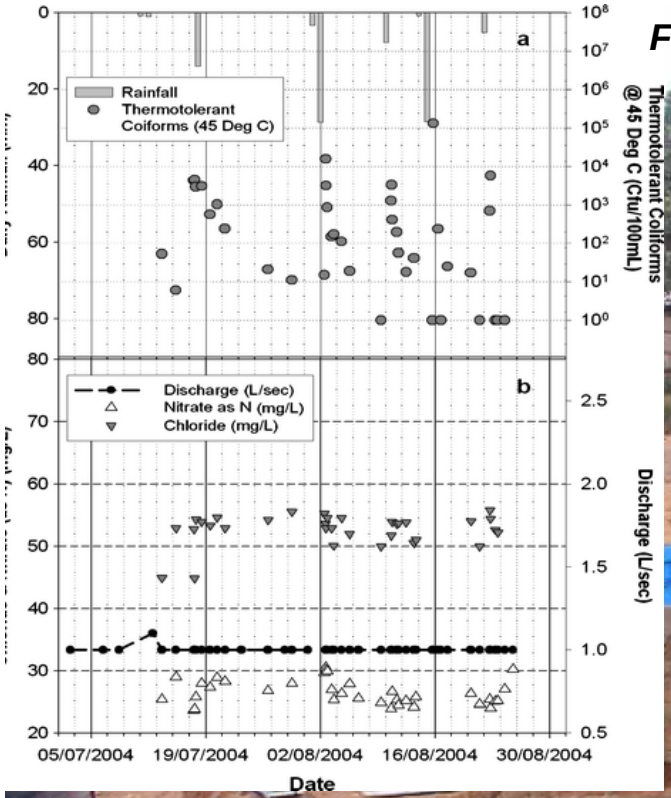
global warming intensifies precipitation (more frequent very heavy rainfalls, fewer light rainfalls) - *intensification greatest in the tropics*

Allan & Soden (2008) Science 321: 1481-1484.
Allan et al. (2010) Environ. Res. Lett. 5, 025205.
O'Gorman (2012) Nat. Geosci. 5: 697-700.

- **dependence of recharge on rainfall exceeding a threshold (and ephemeral surface waters) suggests intensification of rainfall under climate change may enhance recharge**

rainstorm in Namibia (NASA)

Flynn et al. (2012) WASP

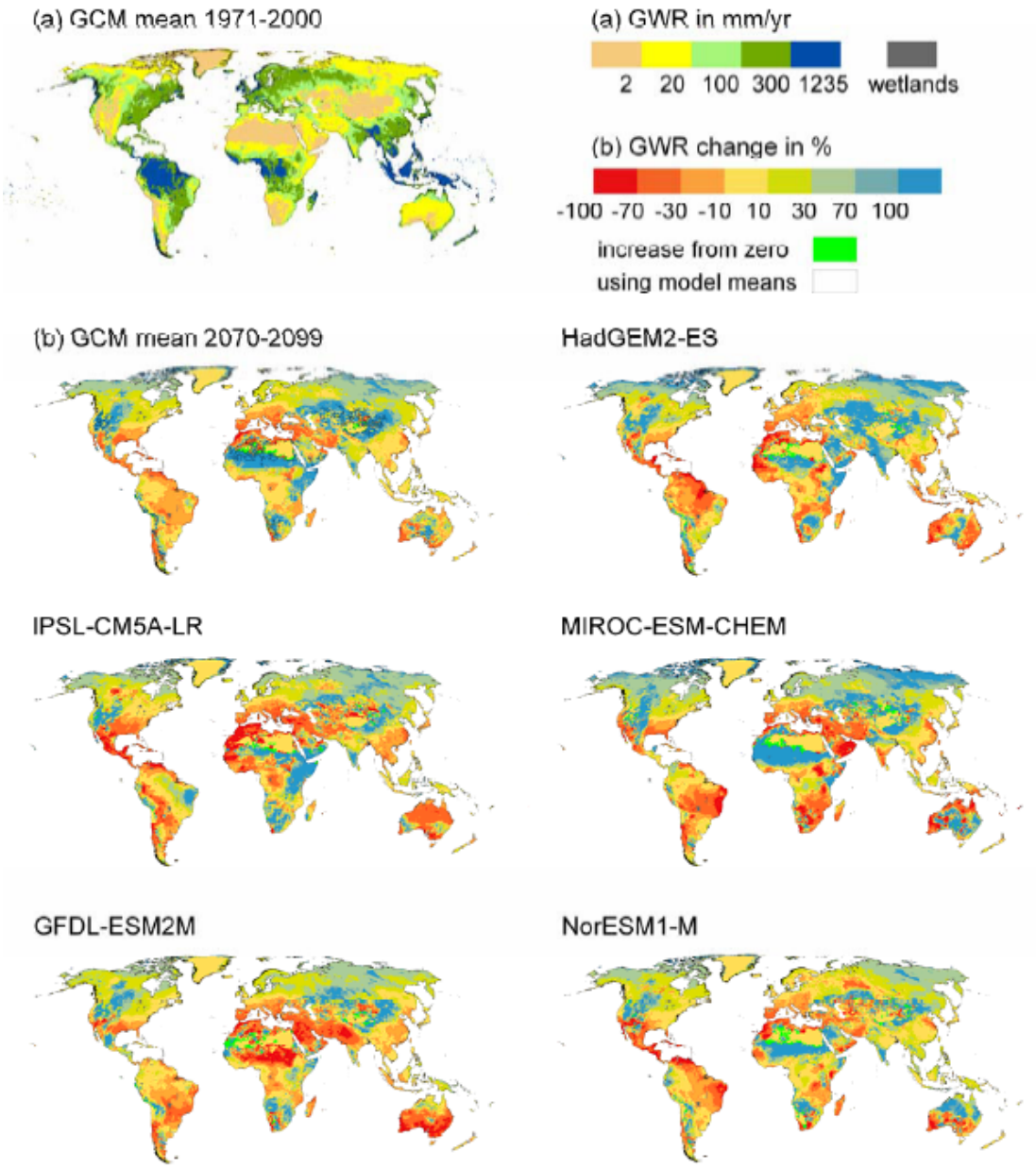


- **macropore flow inferred from hydrographs highlights the vulnerability of shallow groundwater traced by pathogenic bacteria/viruses**

Dr. Robinah Kulabako (UPGro T-Group) monitoring "Bwaise Spring", Kampala

large-scale models (LSMs/ESMs, GHMs)

- recharge pathways (*soil macropores, focused*) very rarely represented in large-scale models
- inter-comparison of recharge estimated from observations and GLDAS LSMs (subsurface runoff) & GHMs (WaterGAP, PCR-GLOBWB, MATSIRO, CLM4.5)



Portmann et al. (2013) Environ. Res. Lett. 8: 024023.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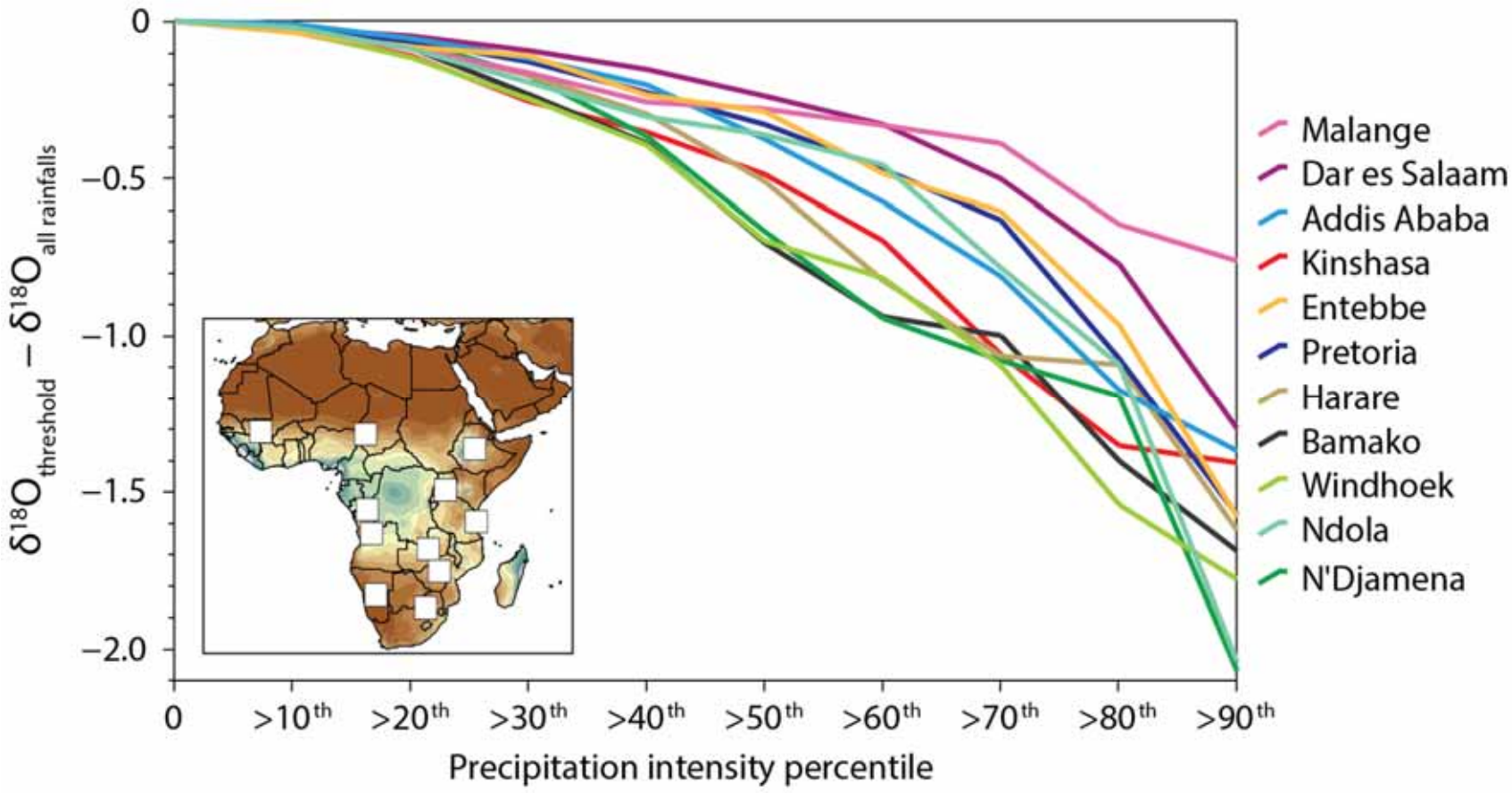
observations of stable-isotope tracers

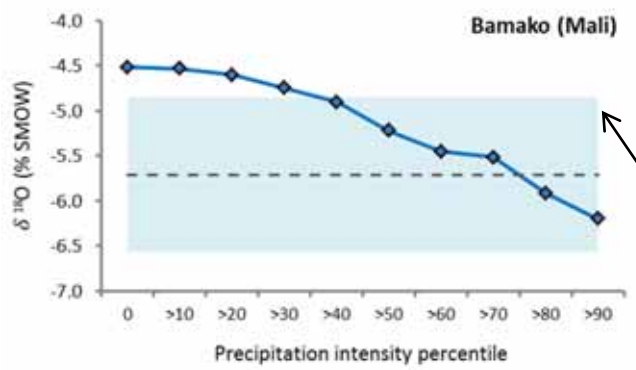
“amount effect” enables the use of rainfall-groundwater stable-isotope (^{18}O:^{16}O) “pairings” to trace the monthly rainfall intensities to groundwater recharge

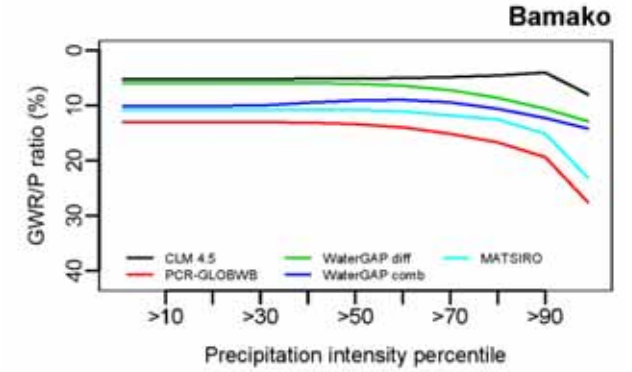


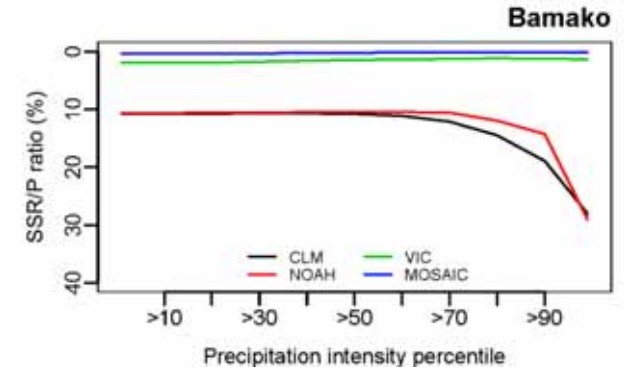
rainfall – groundwater isotope pairings

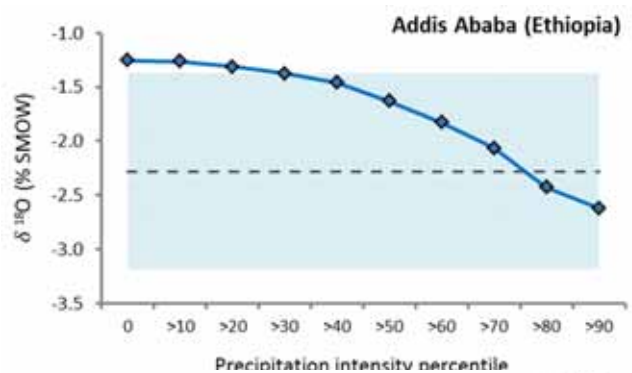
(semi-arid)

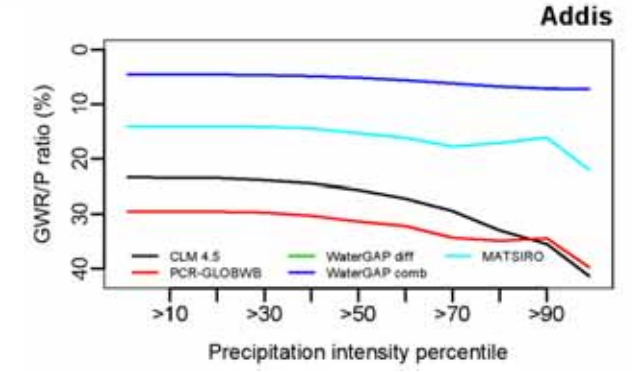
(humid)

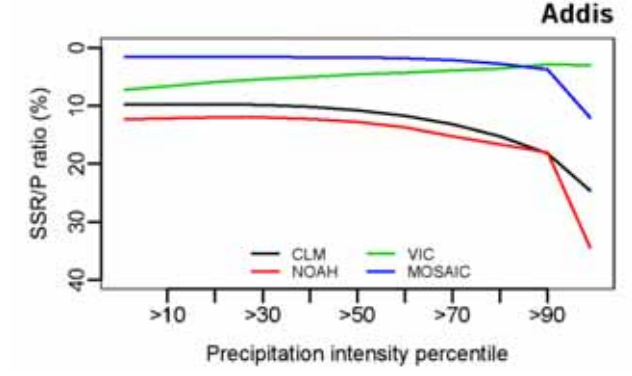












new instrumentation to monitor 2015/16 El Niño

14 Nov 2015

21 Jan 2016