Irrigation consistently enhances rainfall around the Gezira Scheme in East Africa

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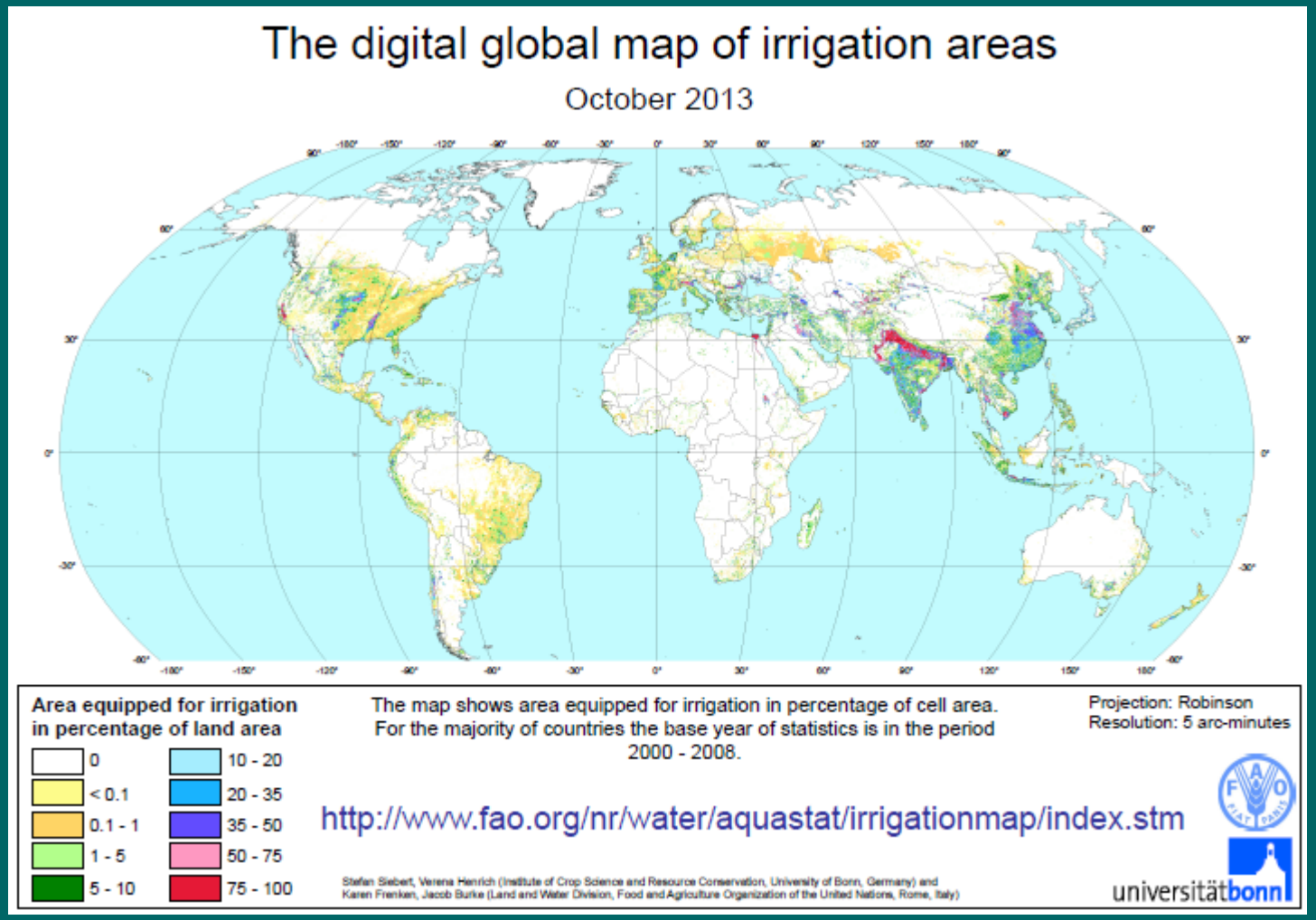
Background

- Rapid changes in land use and land cover (LULC) over the course of the 20th century

- Global area equipped for irrigation (Siebert et al., 2015)
  - 1900 = 63 million ha
  - 1950 = 111 million ha
  - 2005 = 306 million ha

- Irrig water withdrawal
  - 2217-3185 $km^3\ yr^{-1}$ (Siebert et al., 2015)

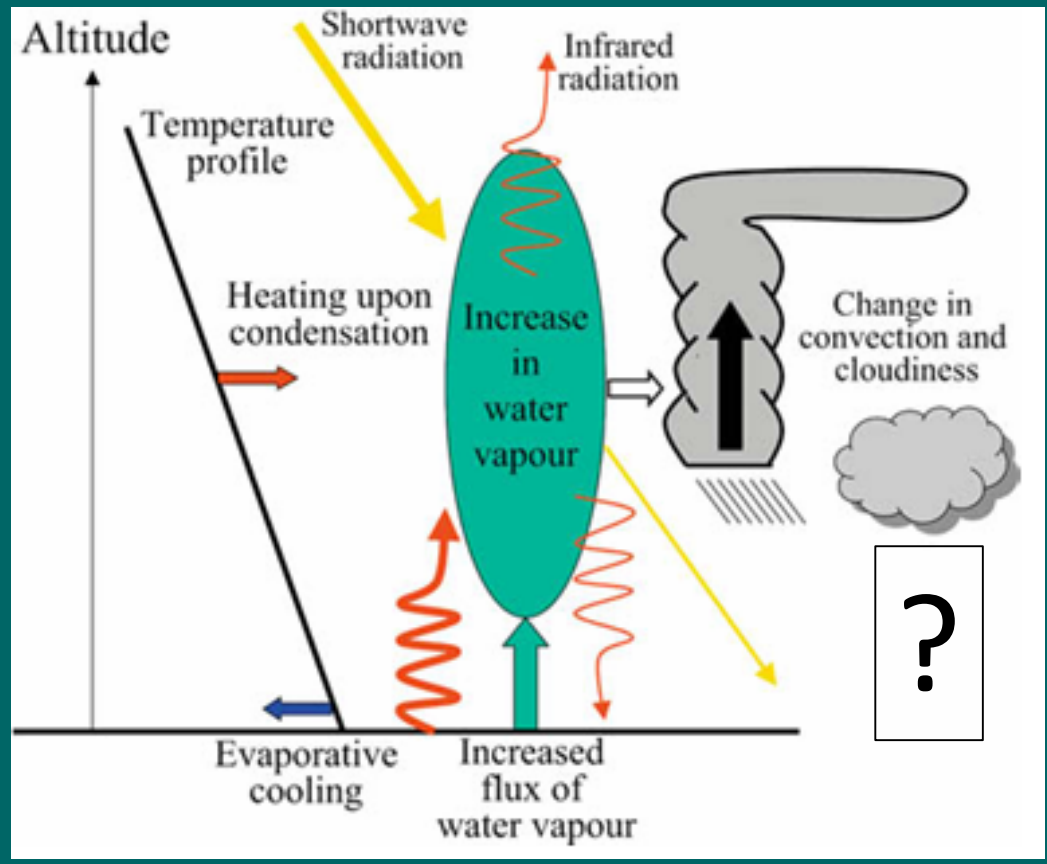


Source: FAO, 2013

Irrigation Studies

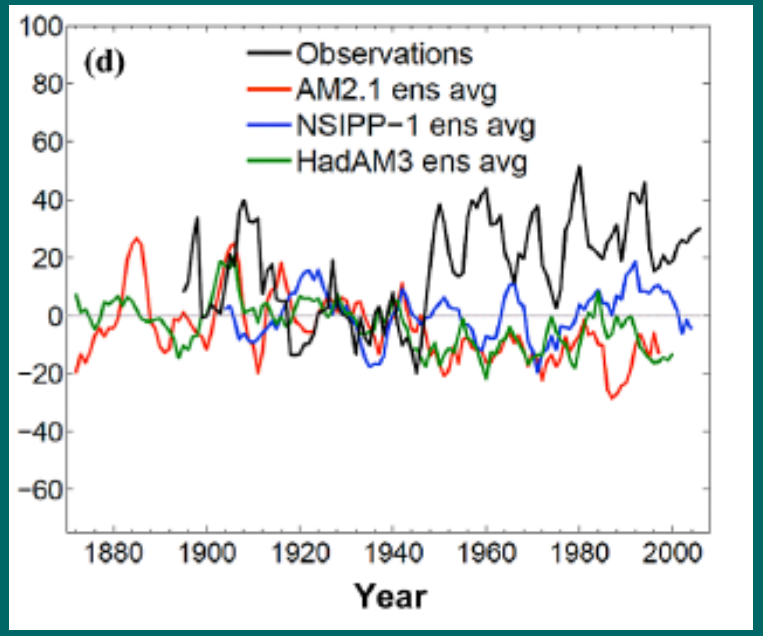
- Previous research has shown that irrigation may affect:
  - Soil moisture
  - Surface energy budget
  - Air temperature
  - Atmospheric moisture
  - Wind patterns
  - Rainfall

- The effects of irrigation on rainfall are most difficult to determine



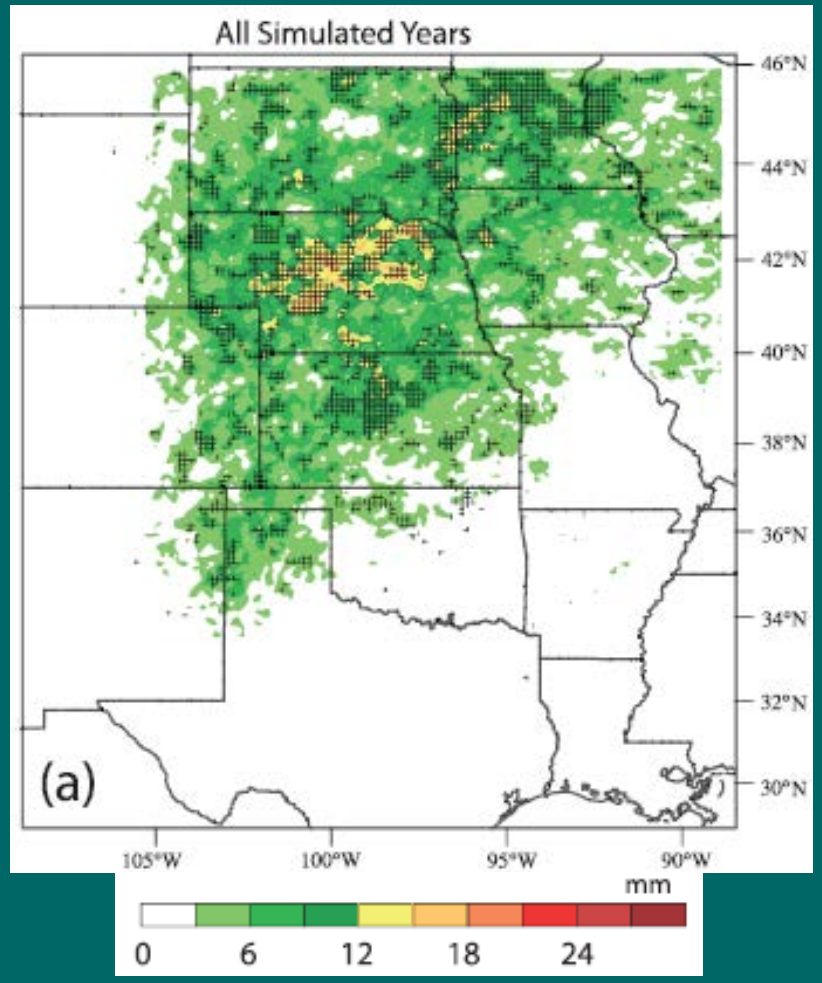
Source: Boucher et al., 2004 [adapted]

DeAngelis et al., 2010



U.S. Midwest July precip anomalies (%)

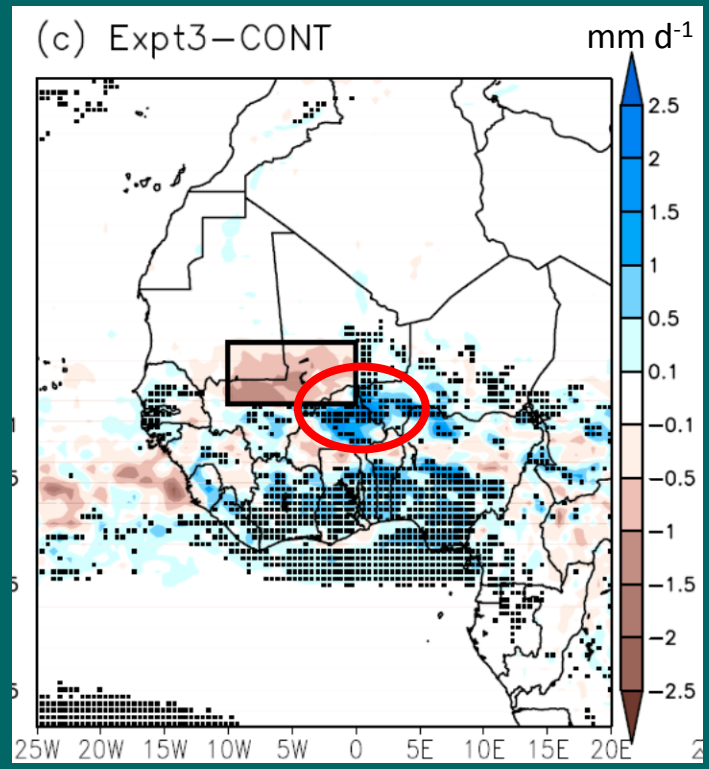
Harding and Snyder, 2012



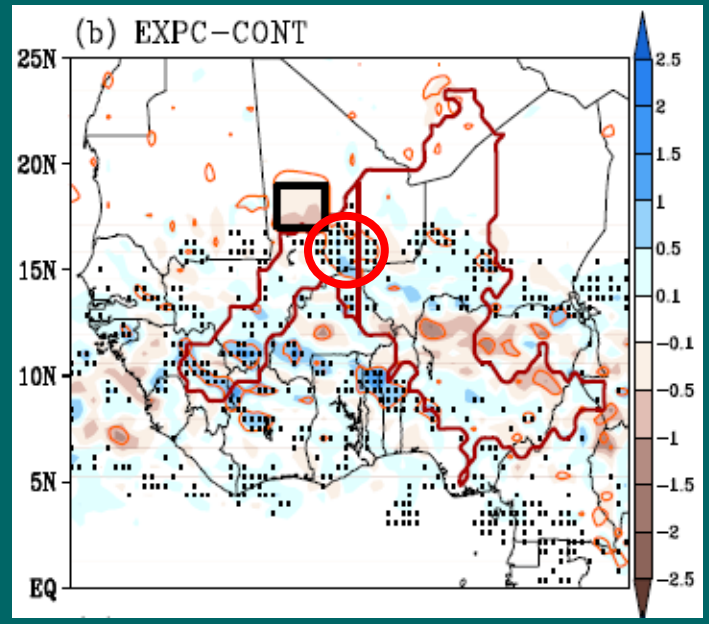
May-Sept mean irrigation-induced precip (mm)

West Africa

- “Hot spot” for soil moisture-rainfall coupling (Koster et al. 2004)
- Simulations with hypothetical irrigated areas
- Opposing effects on rainfall



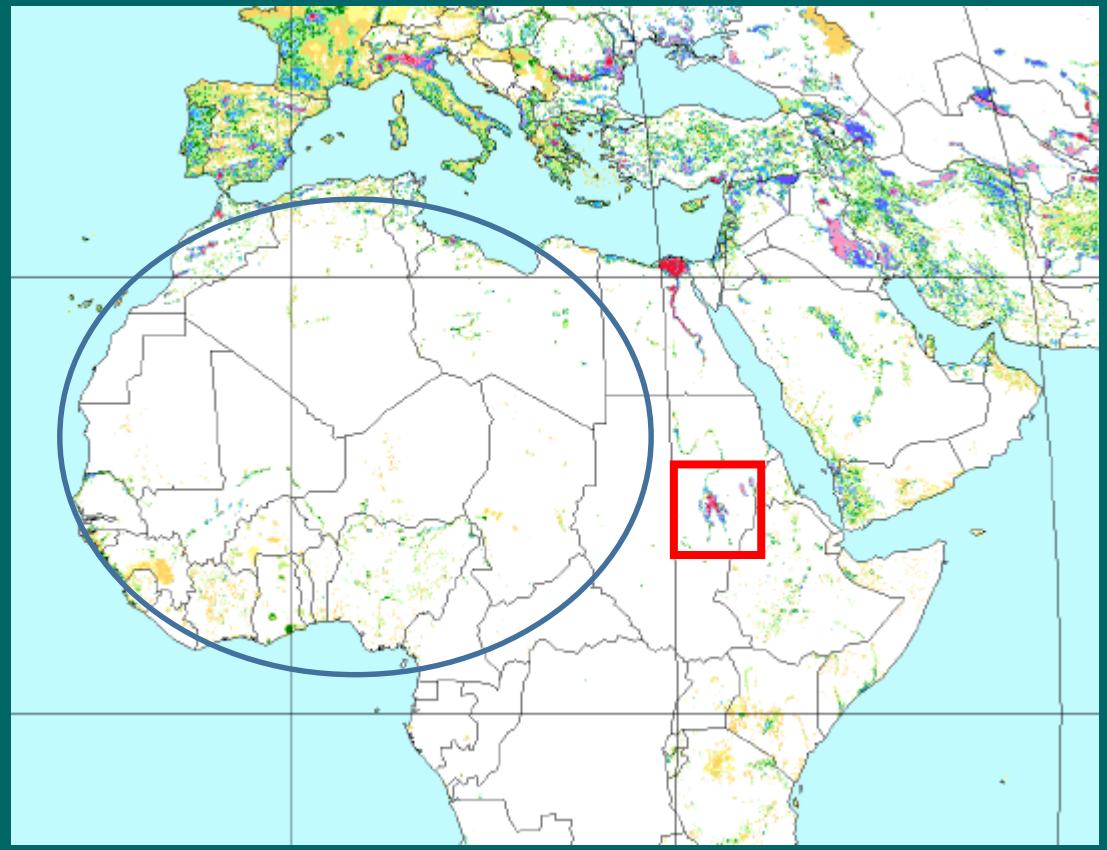
Im et al., 2014



Im and Eltahir, 2014

Motivation for work in East Africa

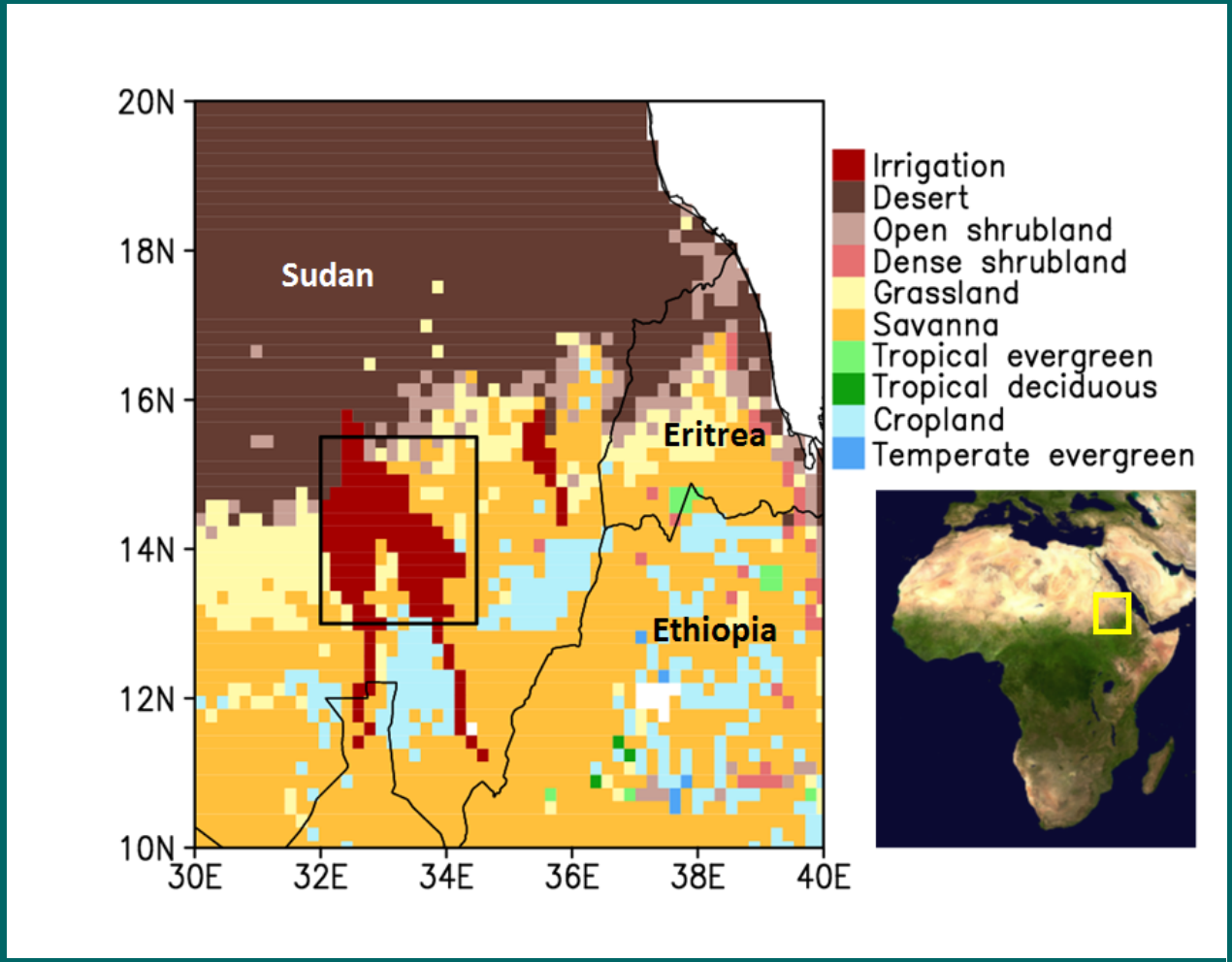
- West Africa studies are only hypothetical
- No large-scale irrigation schemes in West Africa for validation
- We need observations to substantiate theoretical results



Adapted from FAO, 2013

Experimental Design

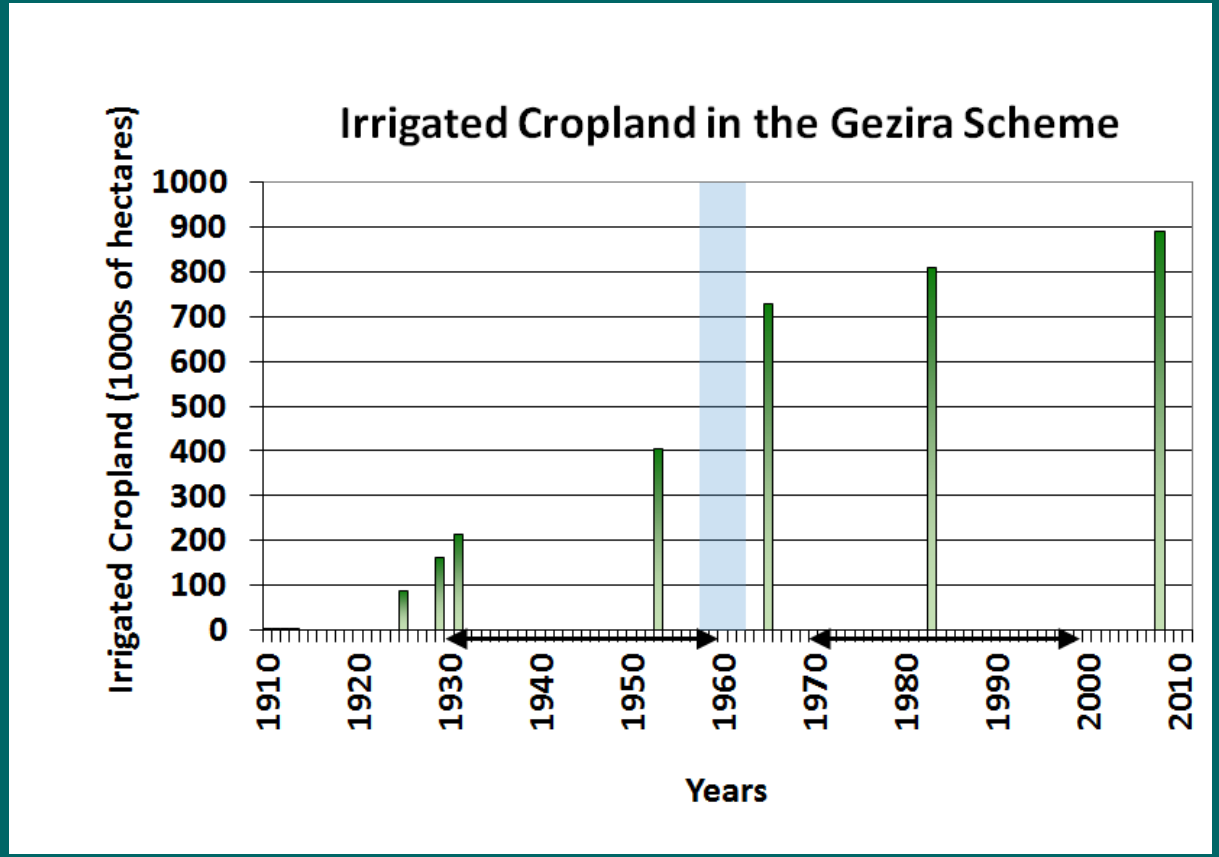
- Simulations using the MIT regional climate model – MRCM
- Three 30-year simulations from 1979 to 2008 (90 total years)
  - 20-km horizontal grid increments
- Irrigated grid cells are wetted to relative field capacity from July to September



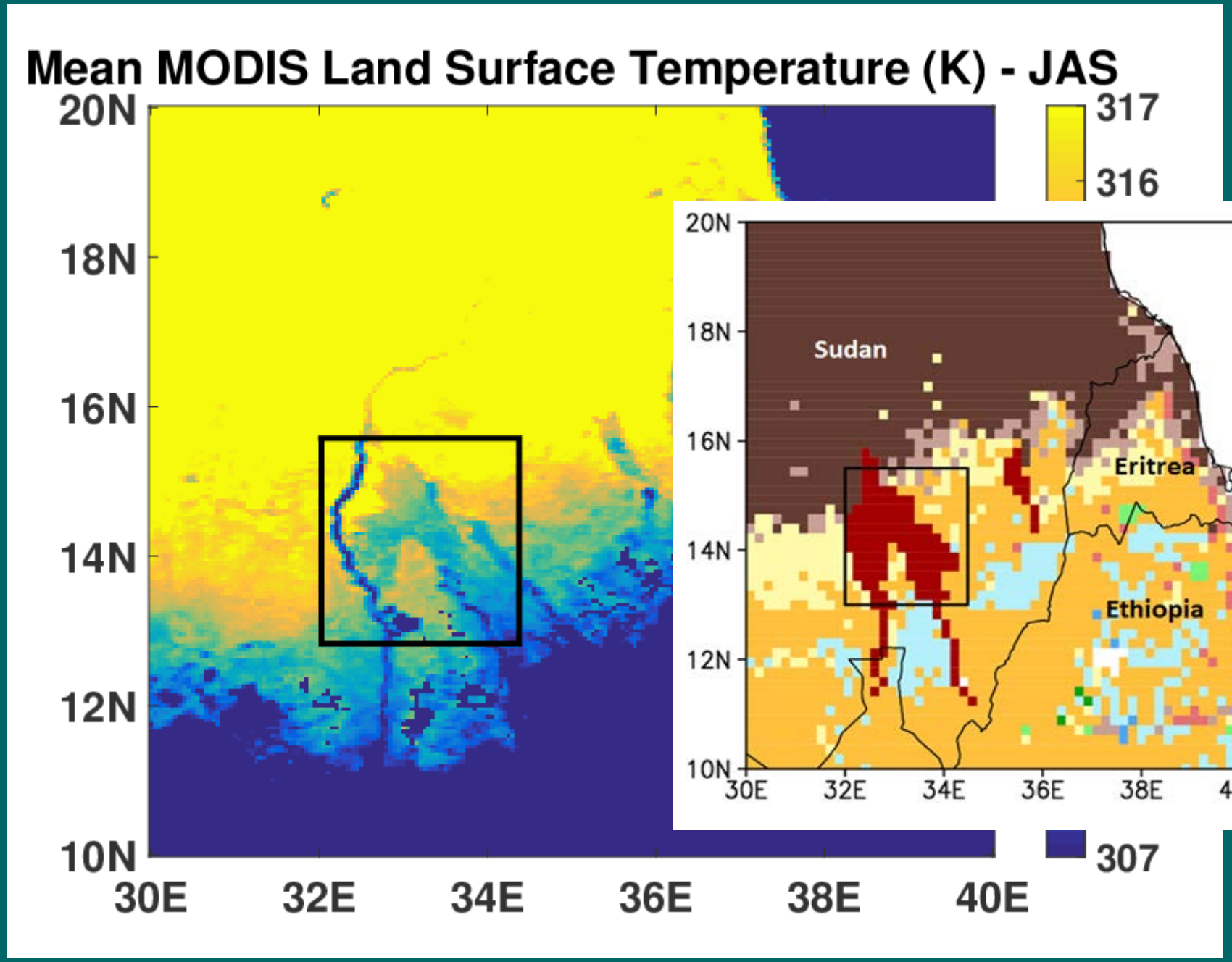
Alter et al., 2015

Observational Analysis

- Manaqil Extension (MEX)
  - Rapid expansion from 1958-1962 (blue vertical bar)
- Obs time periods used
  - Pre-MEX– 1930-59
  - Post-MEX – 1970-99
- Data sources
  - Gridded data (University of Delaware - UDel)
  - Station data (GHCN)



Alter et al., 2015 (data from Ministry of Water Resources and Electricity in Sudan)

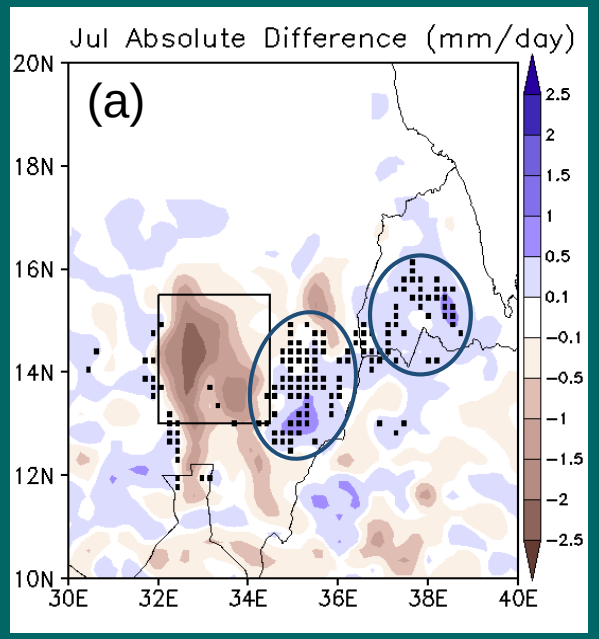


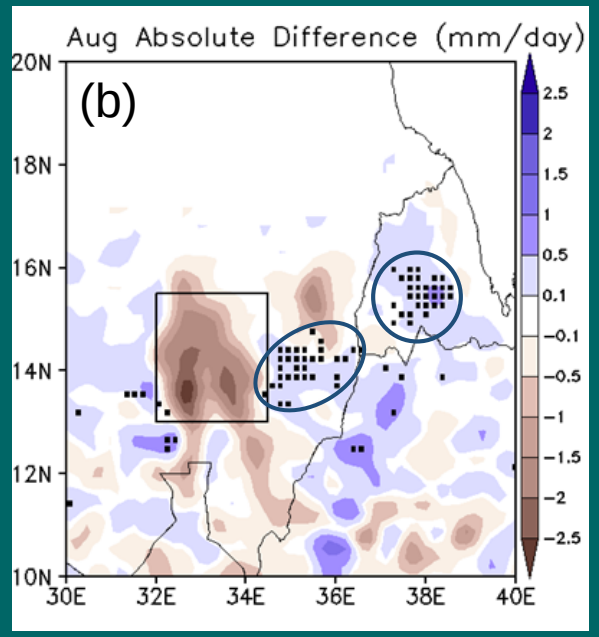
Alter et al., 2015

July

August

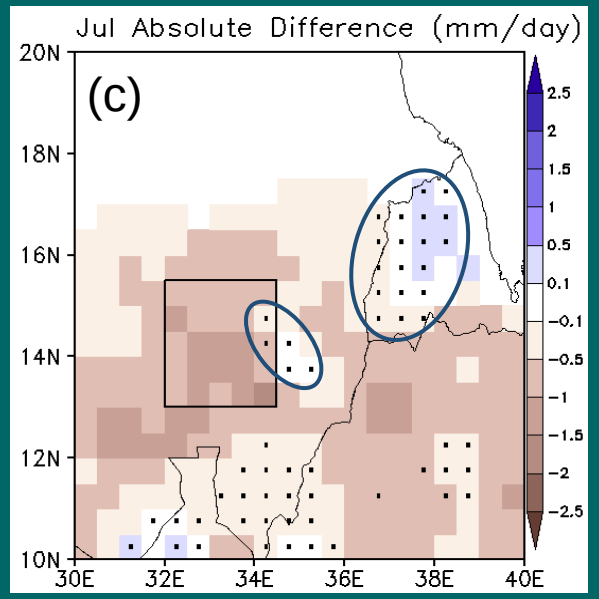
Simulated

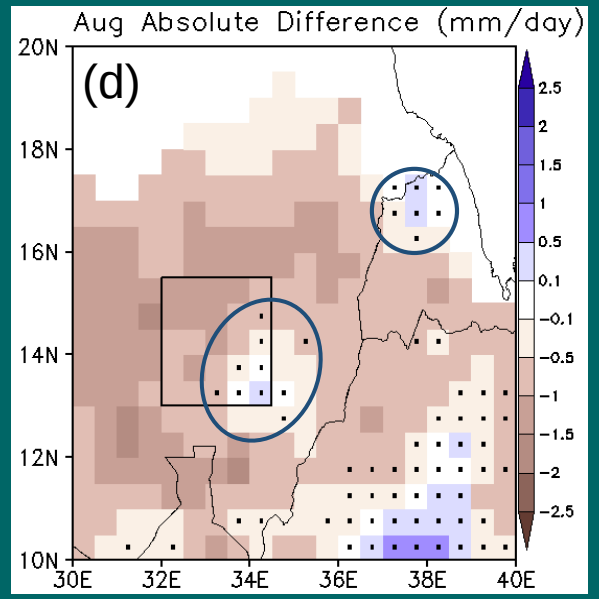




Dots
Where irrig rainfall > control rainfall in at least 70% of model years

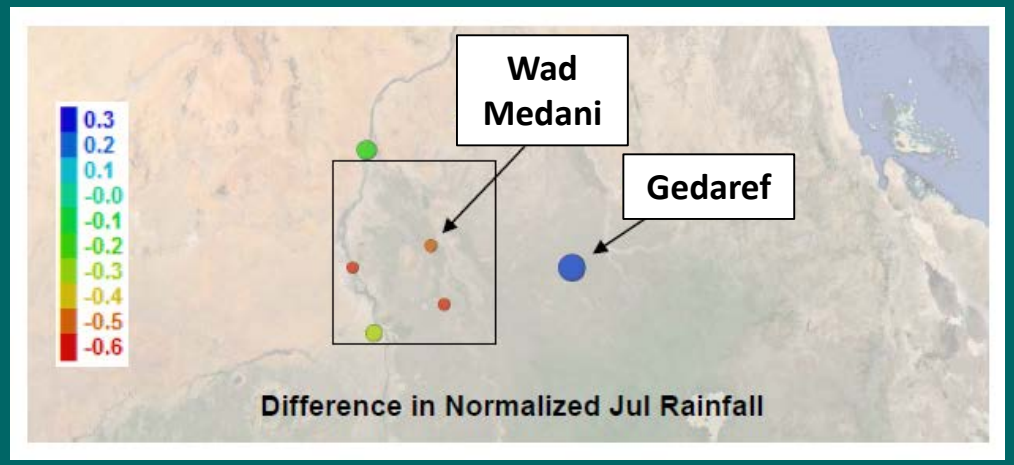
Observed (UDel)



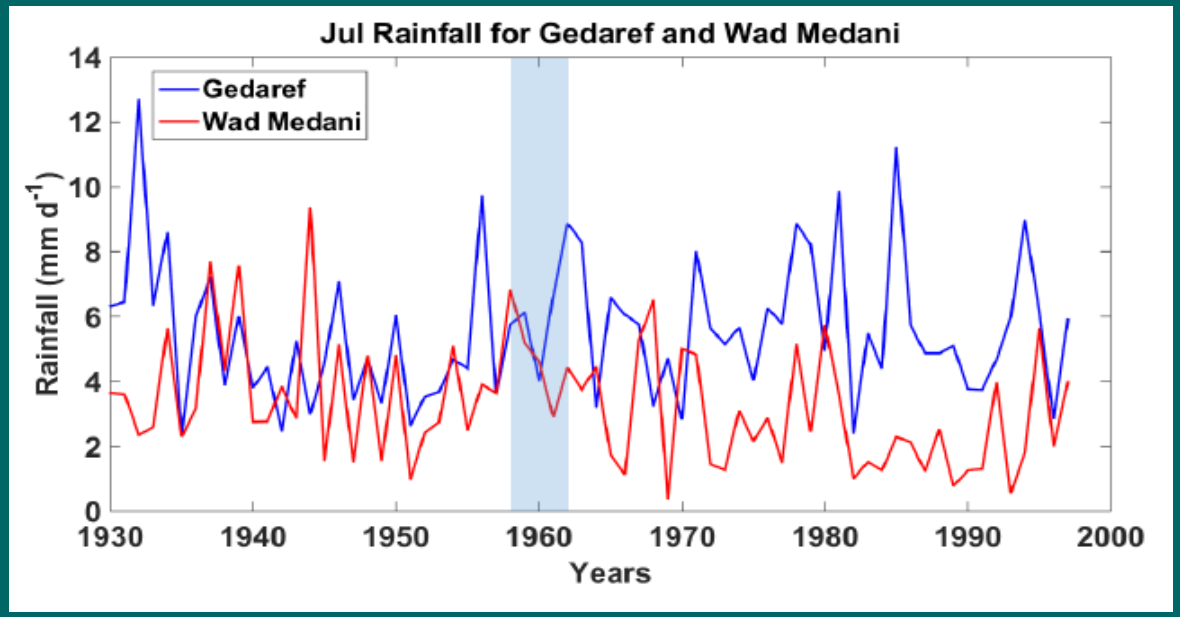


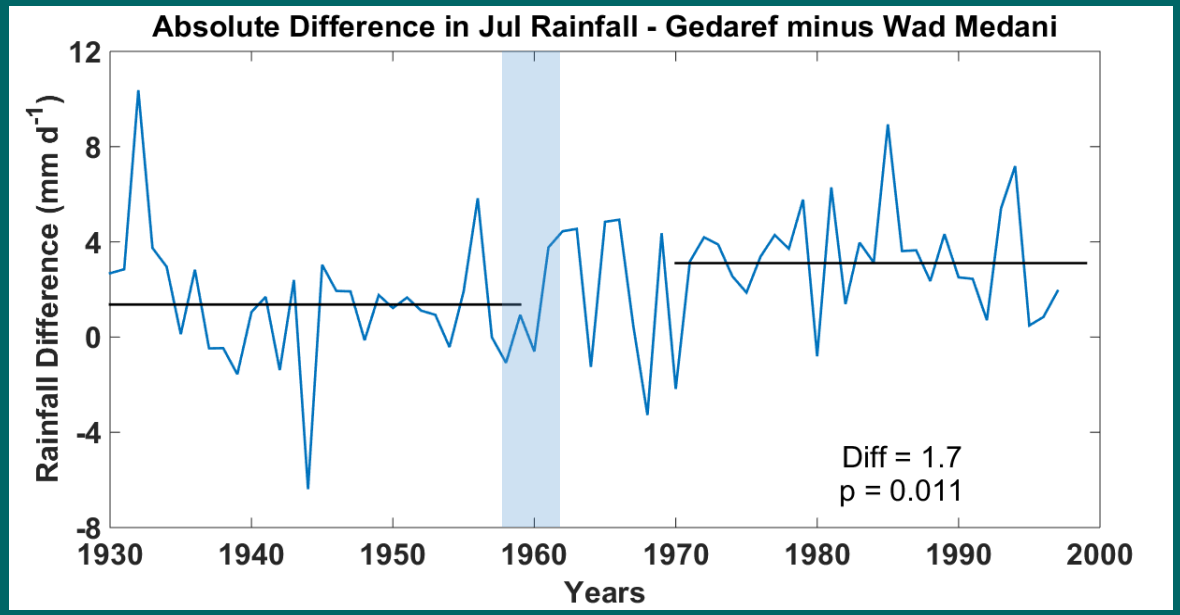
Dots
≥80th percentile of Consistency of Relative Change Index (CRCI)

Alter et al., 2015



GHCN

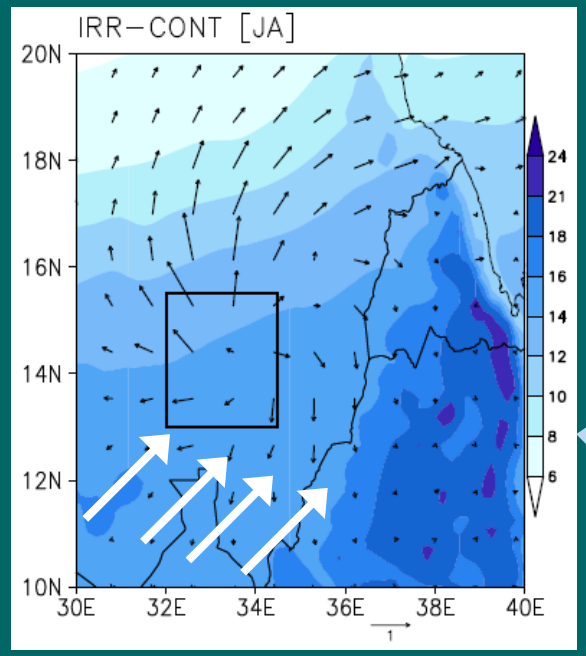


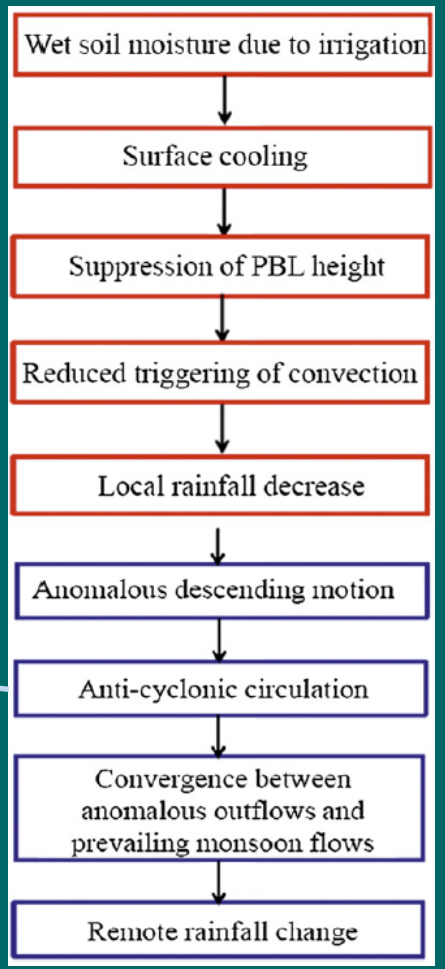


Alter et al., 2015

Potential Mechanism

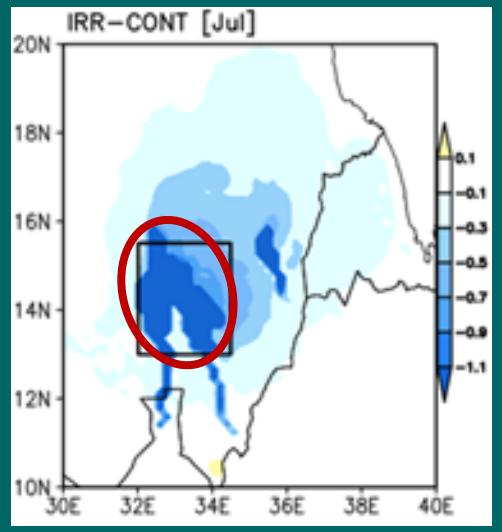
Wind @ 925 hPa (m s^{-1})



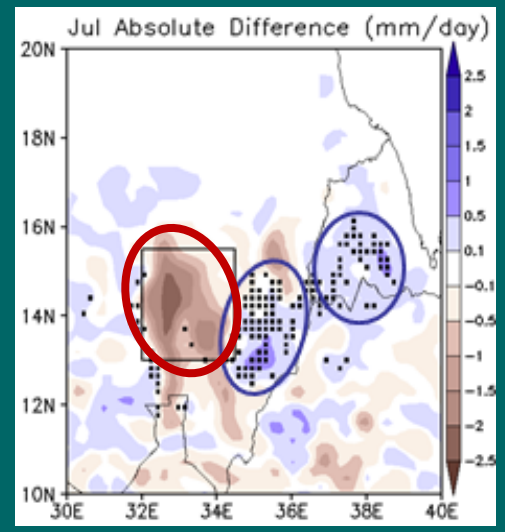


Source: Im et al. 2014

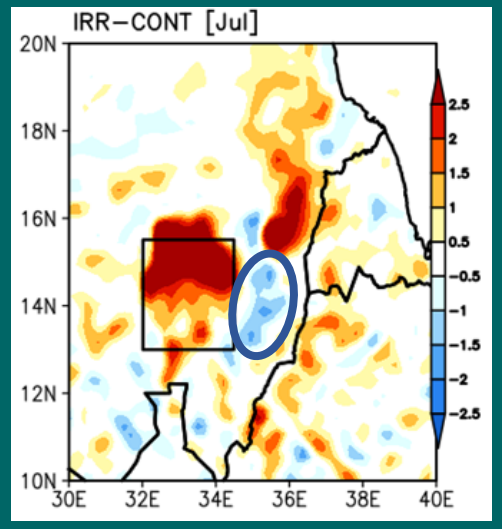
Surface air temperature (K)



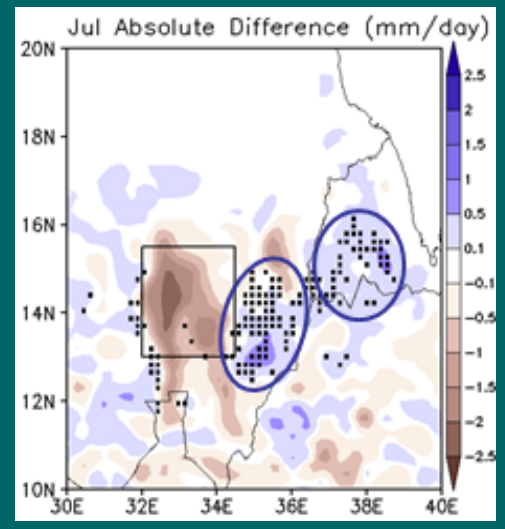
Rainfall



Omega @ 700 hPa (Pa s^{-1})



Rainfall



Alter et al., 2015

Implications and Future Work

- Negatives
  - Possible feedback loop that challenges hydrological sustainability
- Positives
  - Can improve productivity of existing crops (e.g., Gedaref) or create new areas of cropland
  - Optimize locations of irrigated cropland
- Currently applying same experimental framework for irrigation in central United States

Conclusions

- Simulations and observations agree that irrigation in Gezira:
  - Enhances rainfall around irrigated areas
  - Reduces rainfall over irrigated areas
  - Cools temperature over irrigated areas
- Enhancements in rainfall are consistent
- Negative effects over irrigated area, positive effects in surrounding areas
- Strategic placement of irrigated cropland can be beneficial for economies in Africa and the rest of the world

Source: Visible Earth, NASA