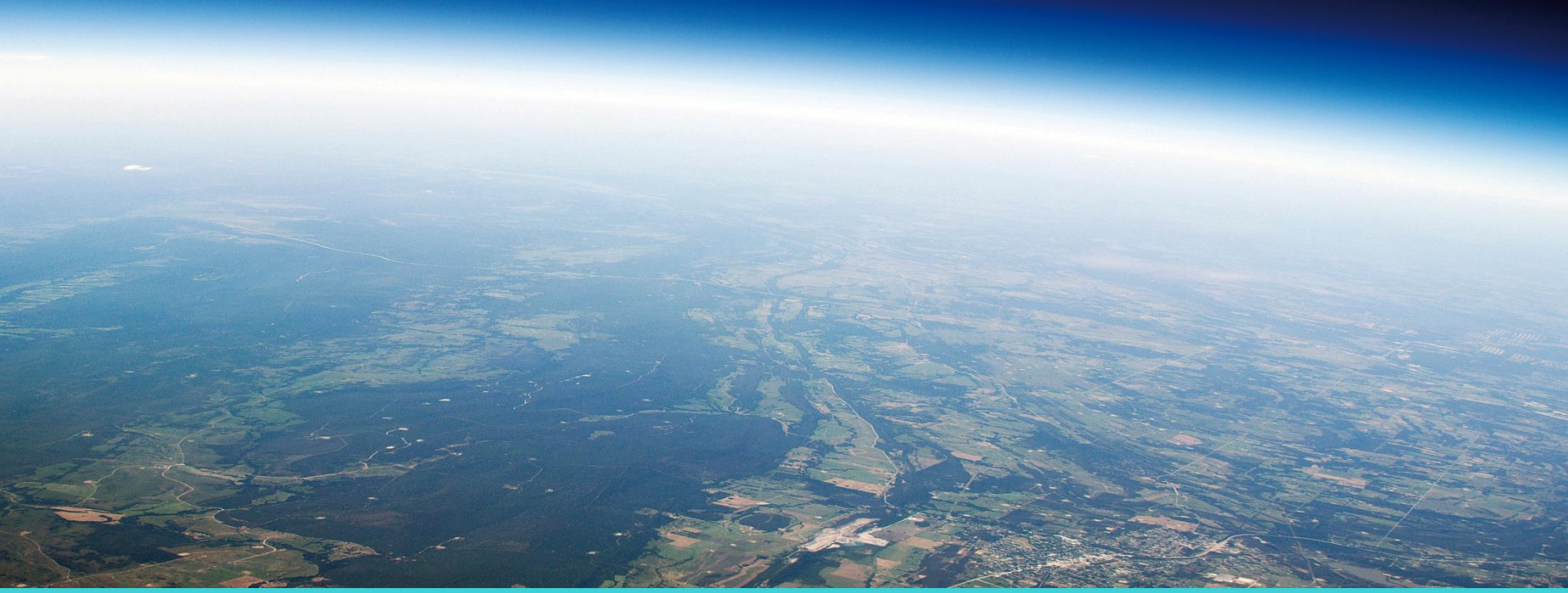


ATMOSPHERIC RESPONSES TO IRRIGATION

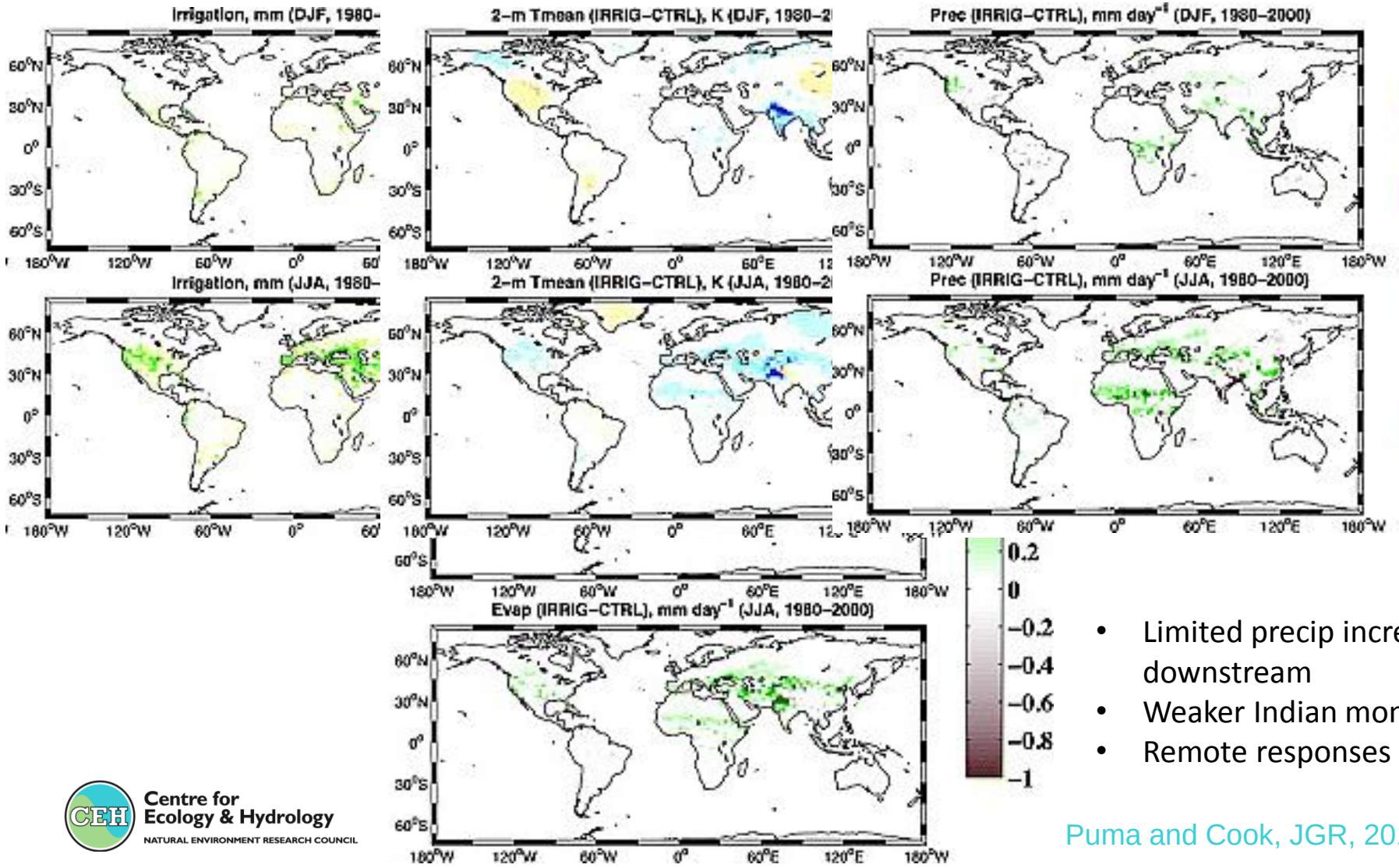
CHRIS TAYLOR

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Effects of irrigation on global climate during the 20th century

GCM study imposed evolving irrigation over 20th century



- Limited precip increases downstream
- Weaker Indian monsoon
- Remote responses

Puma and Cook, JGR, 2010

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Atmospheric responses to irrigation

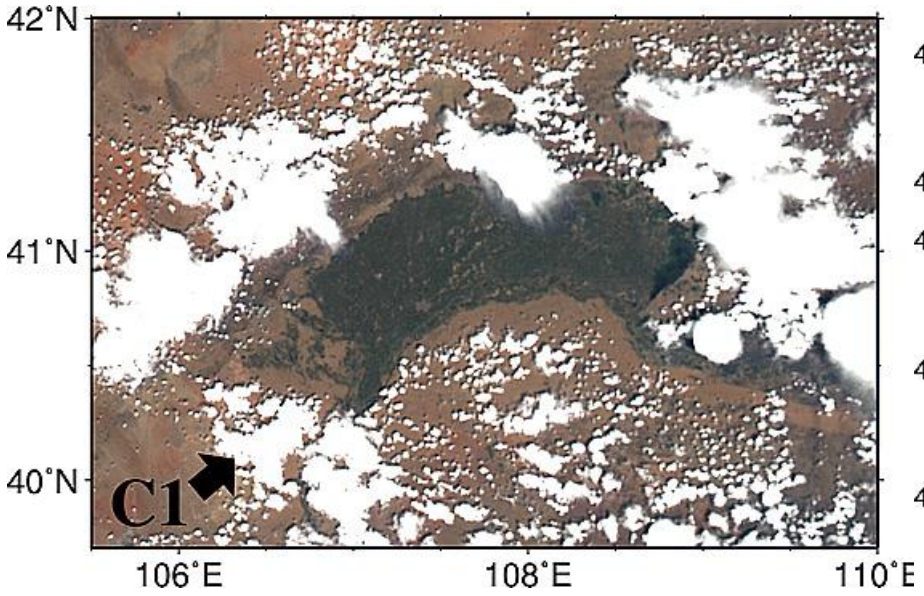
- What processes determine how atmosphere responds to irrigation?

- Different scales, different processes:

1. Impact on moist convection in vicinity of irrigation
2. Impact on rainfall via regional circulations
3. Downstream impact via moisture budget

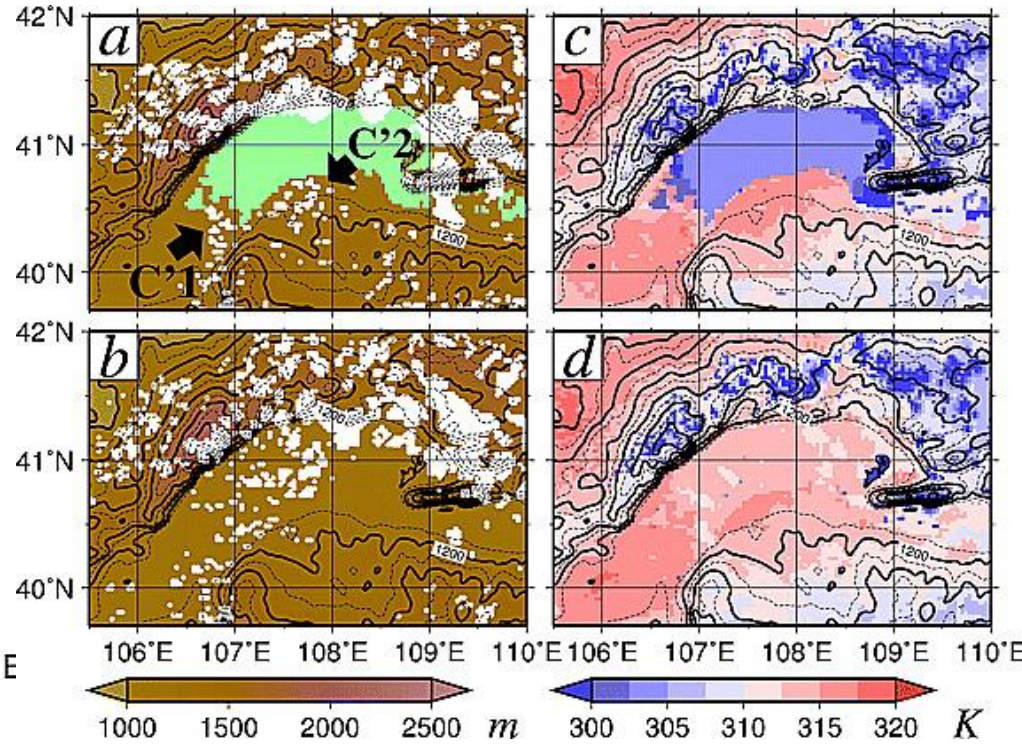
1. Moist convection in vicinity of irrigation

MODIS Aqua view of Hetao Irrigation District 4/8/05



Shallow cloud suppression over irrigated zone

Regional simulation with and without irrigation



Model reproduces cloud field in response to irrigation

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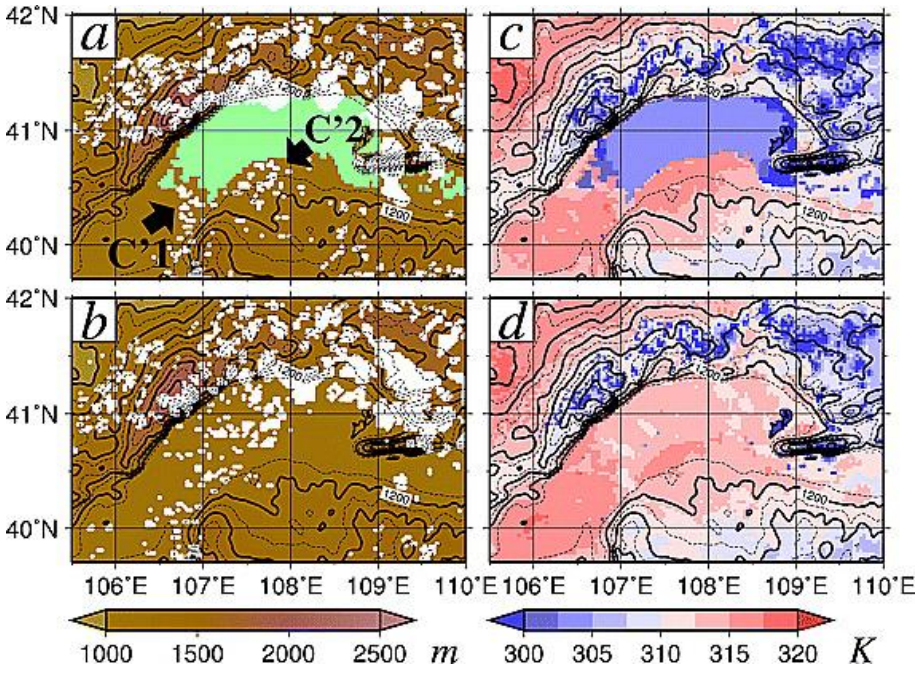
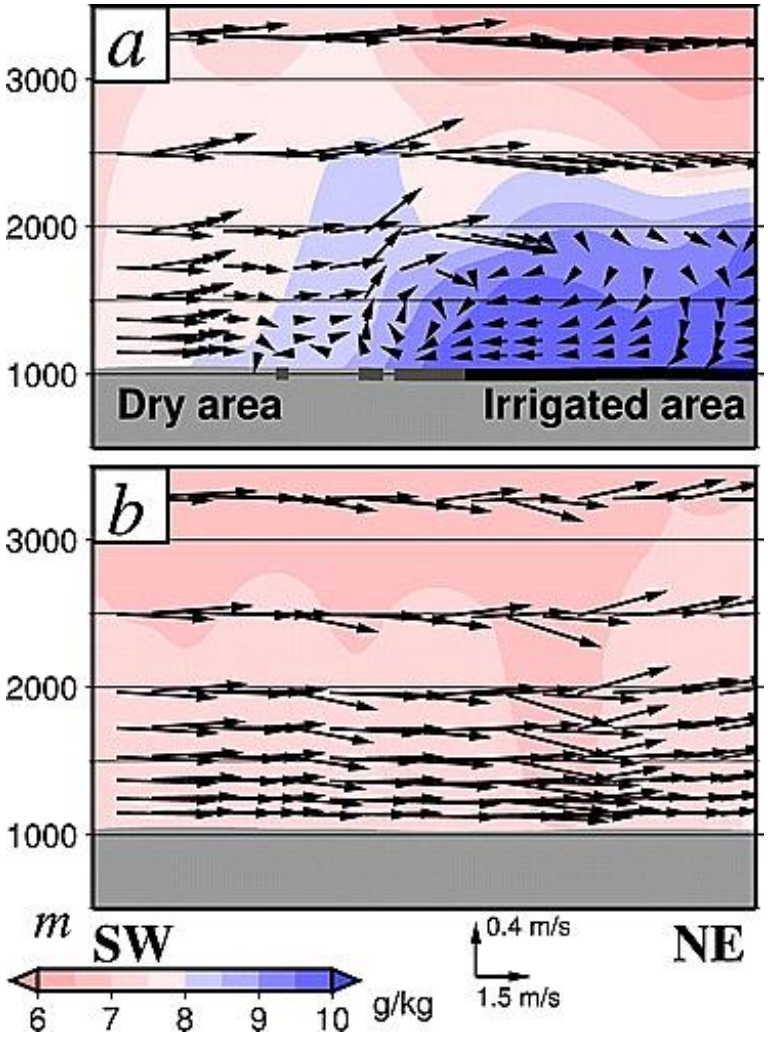
Kawase et al, GRL, 2008

Mechanism for impact on shallow cloud



Mesoscale simulations… easy to model, hard to observe



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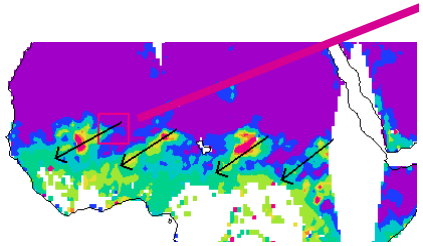
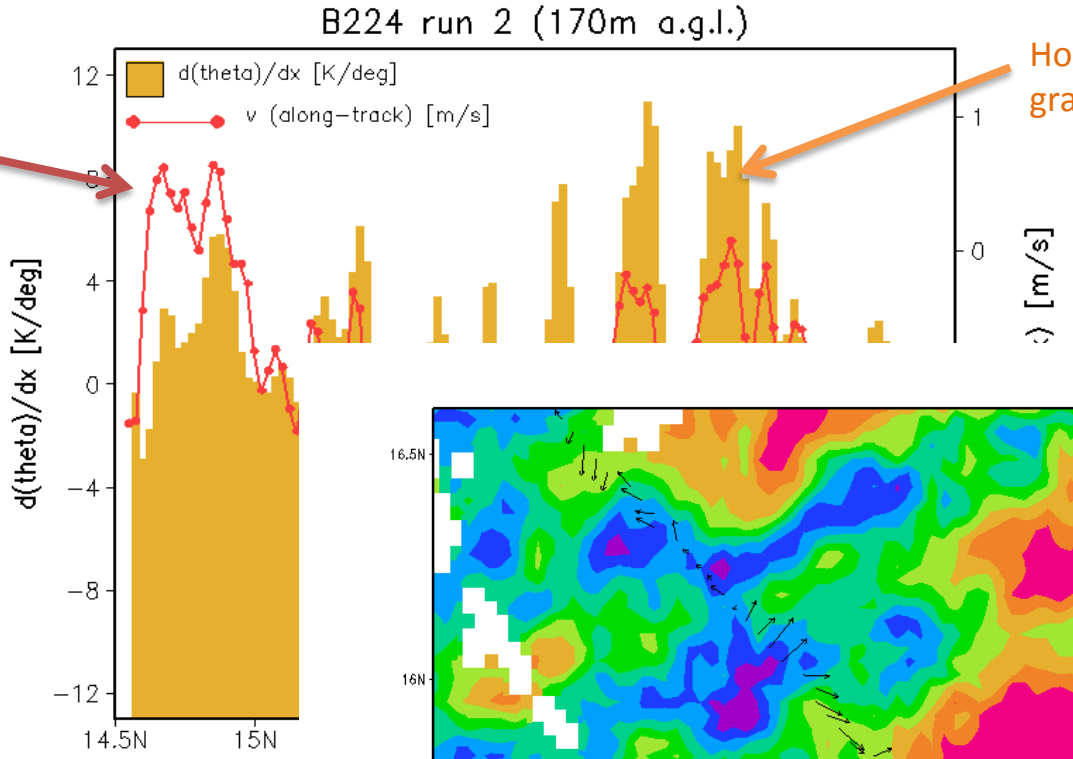
Kawase et al, GRL, 2008

Observational evidence of mesoscale circulations

Along-path wind

Land surface temperature anomaly (Meteosat, LandSAF) along aircraft track
Proxy for soil moisture

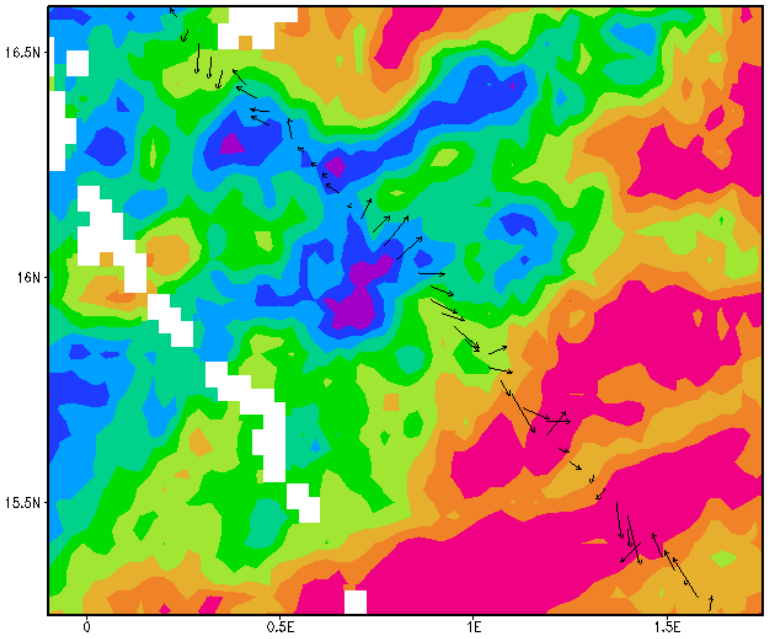




Horizontal air temperature gradient

3L temperature
om ECMWF
recast model

PBL
e



LST anomalies [K] from satellite

Wind vectors from aircraft [m/s]

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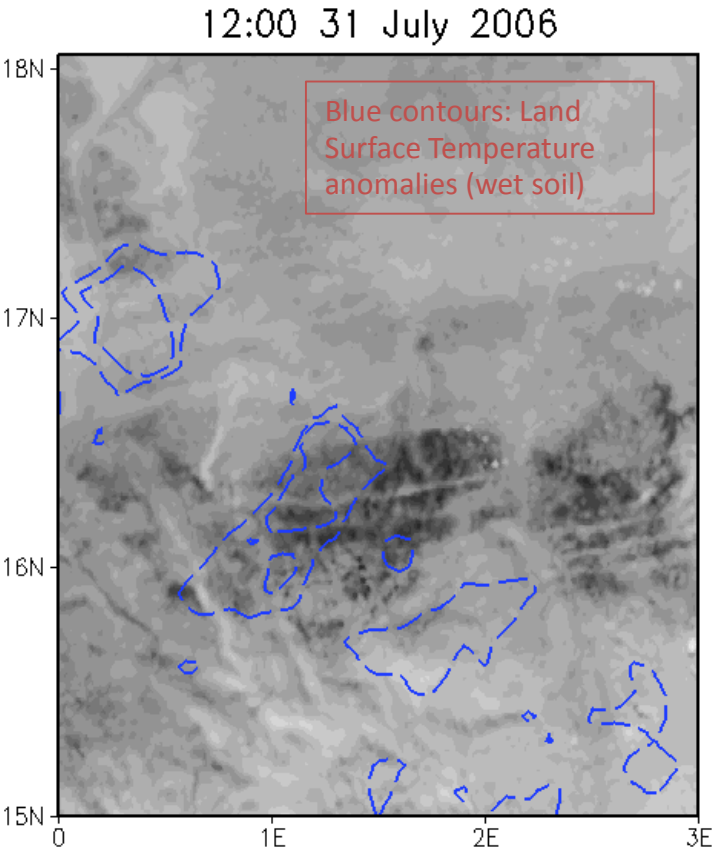
Taylor et al GRL 2007

Impact of heterogeneity on initiation of deep convection

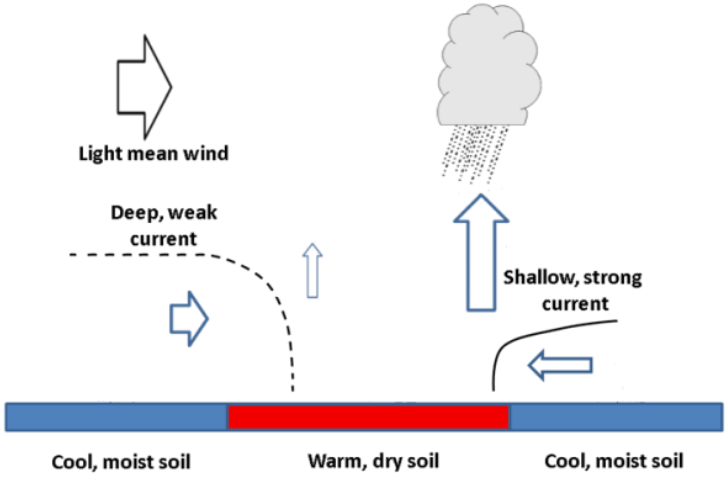


Visible Imagery from Meteosat

Example convective initiation along edge of wet-dry edge

Analysis ~3000 initiations of mesoscale convective systems in western Sahel

Clear preference for initiation on dry side of wet-dry boundaries, consistent with mesoscale models



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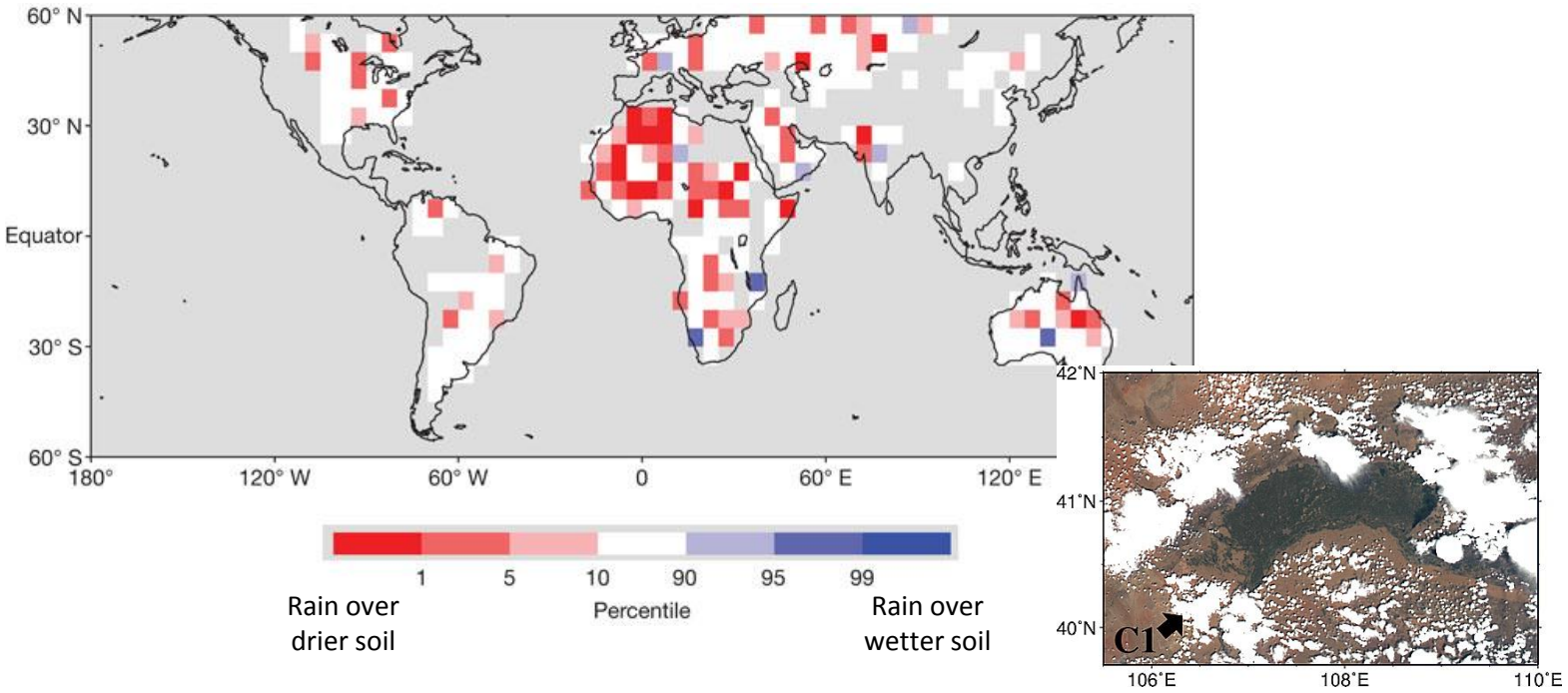
Taylor et al, Nat Geo, 2011

Global analysis of local soil moisture impact on rain

Statistical measure of observed preference for rain over locally dry (red) or wet soil (blue)



Afternoon rain more likely over locally drier land, especially in semi-arid regions

Physical mechanisms favouring rain over wetter surfaces clearly not dominant

GCMs produce opposite effect (more rain over wetter soil)

Directly analogous to impact of irrigation

Note some evidence that presence of irrigation/dams enhances rain in region

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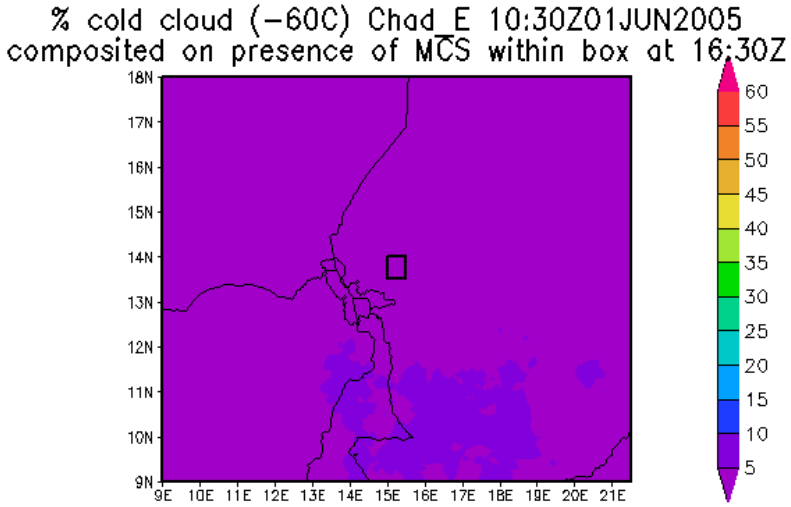
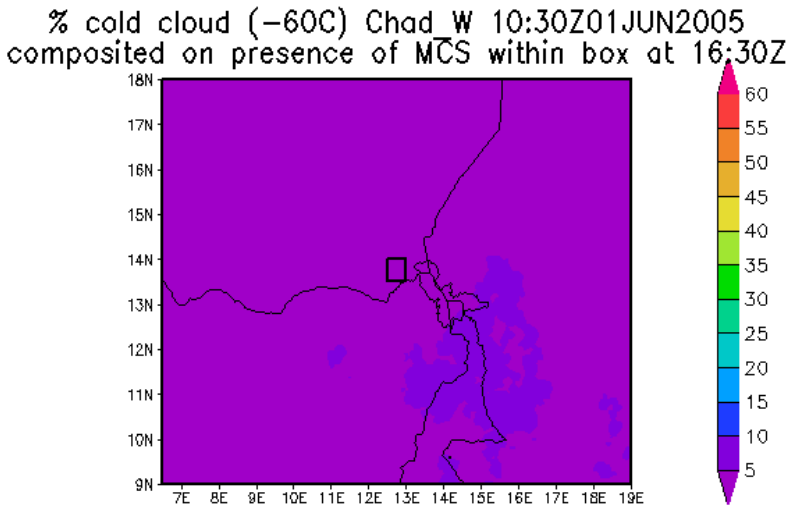
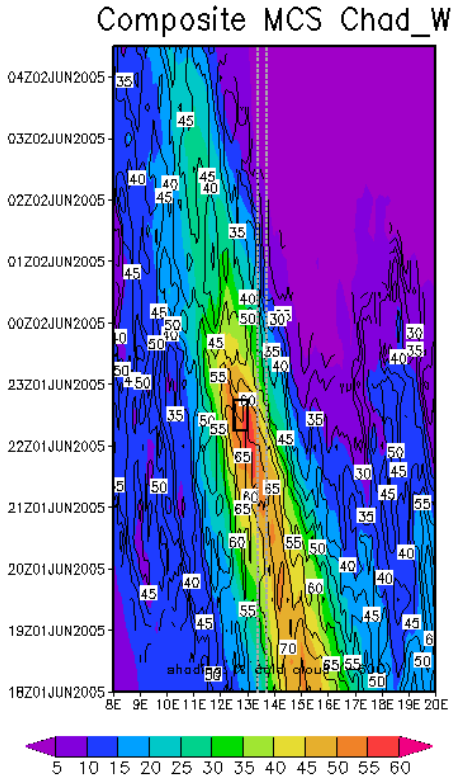
Soil moisture - AMSR-E and ASCAT
Rainfall – TRMM3B42, CMORPH, PERSIANN

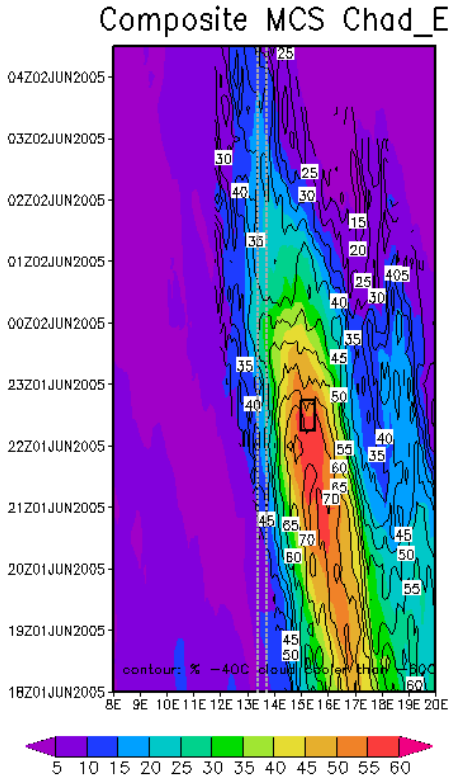
Taylor et al, Nature, 2012

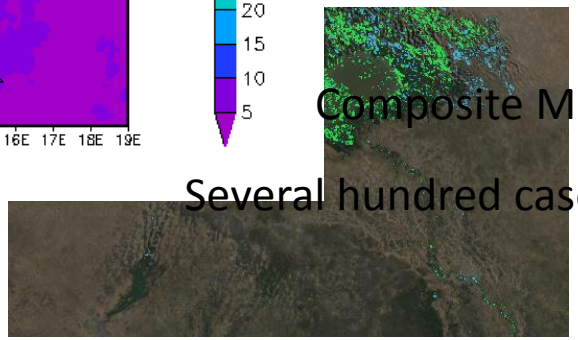
Impact on propagating convective systems? Lake Chad











Composite MCS up/downstream of Lake Chad

Several hundred cases in each composite (JJAS 1982-2005)

Taylor et al in prep, Lauwaet et al QJ 2012

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Feedback via river network Niger Inland Delta (Mali)

Simulated impact of water management on discharge in wetland

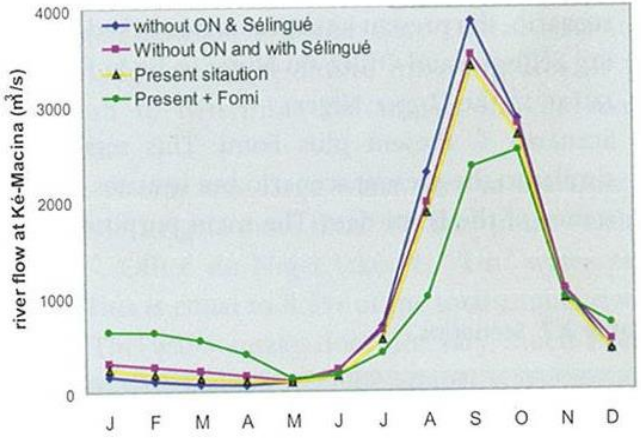
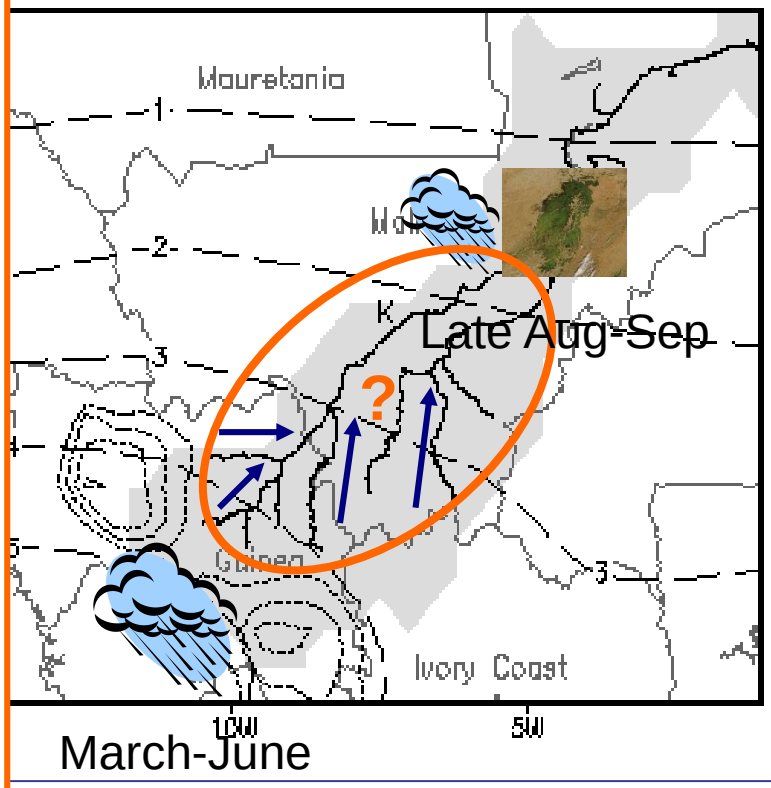


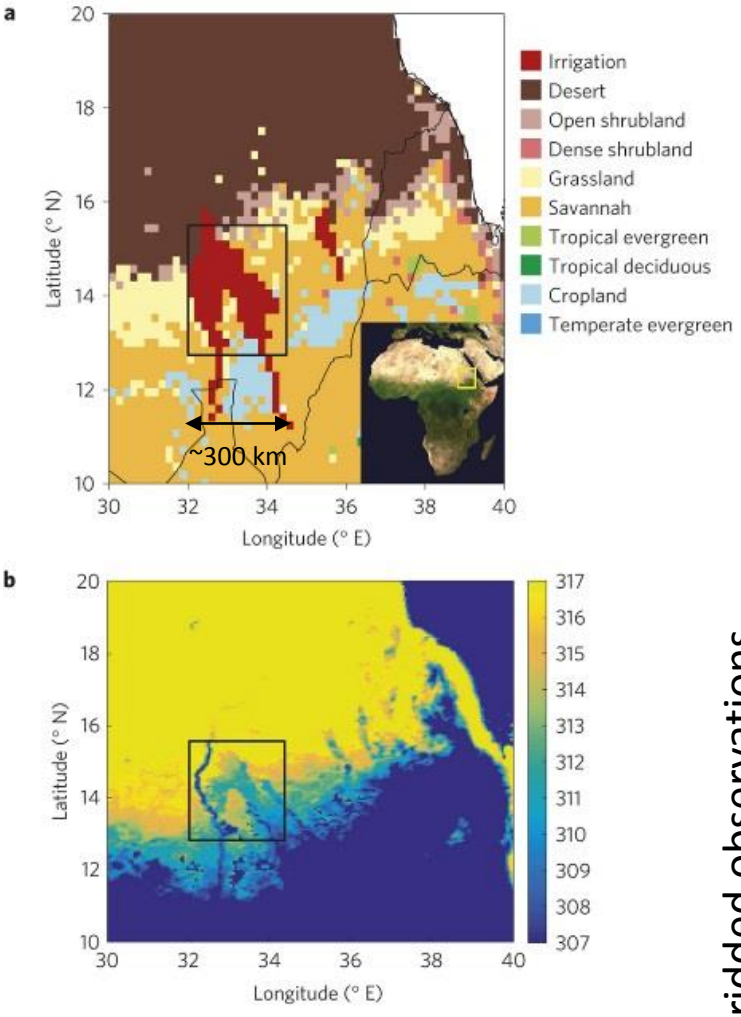
Fig. 2.21. Model run 2: The average monthly flow of the Niger at Ké-Macina, calculated over the period 1980-2001. The four condition are the same as in Fig. 2.19, but in contrast to model run 1, the two reservoirs are used to produce electricity. Source: WLIDelft Hydraulics & DNH.

Zwarts, van Beukering, Kone and Wymenga: The Niger, a lifeline. Effective water management in the Upper Niger Basin, 2005



Taylor, GRL, 2010

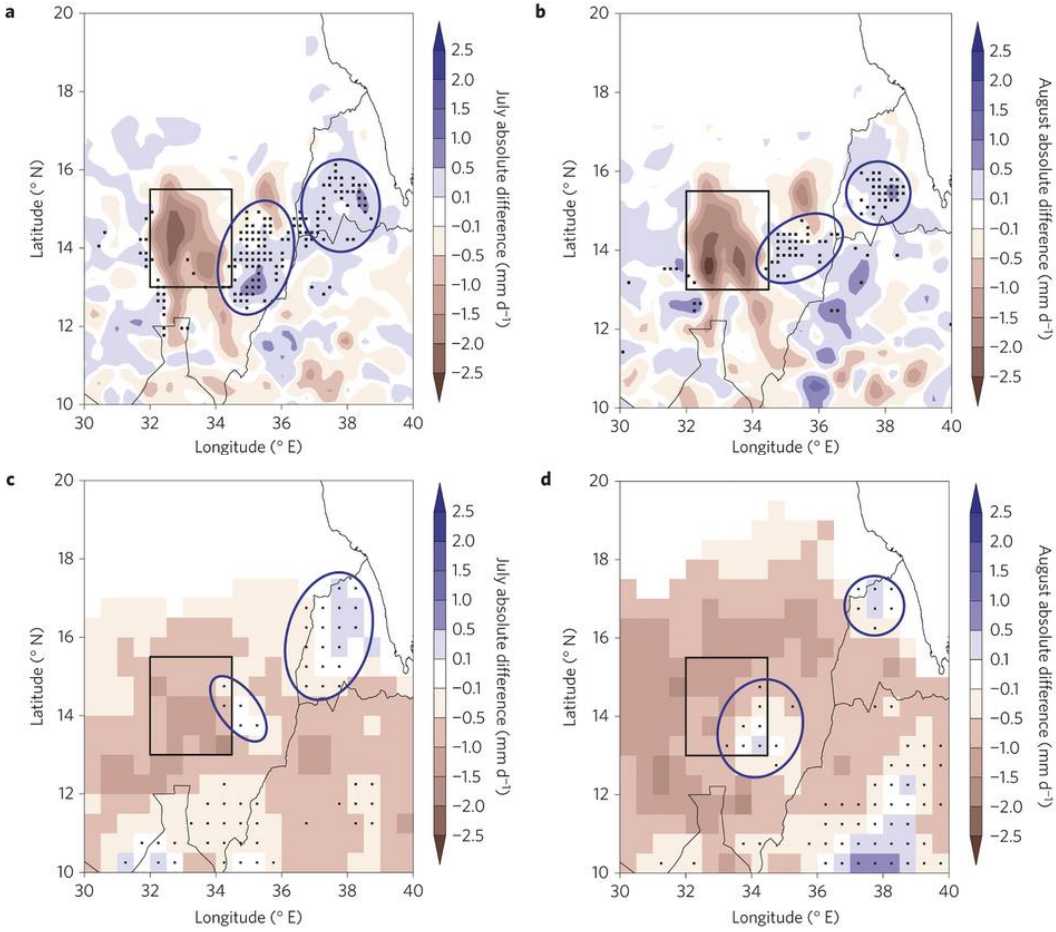
2. Impact on rainfall via regional circulations: Gezira, Sudan



RCM irrigation-control

Gridded observations Post-pre expansion

Rainfall changes (mm/day)



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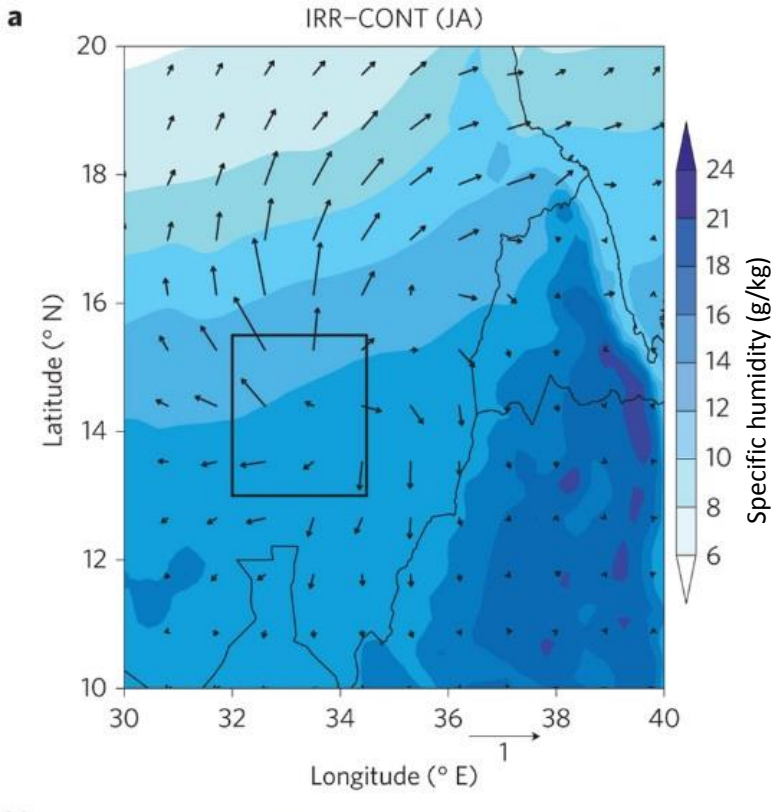
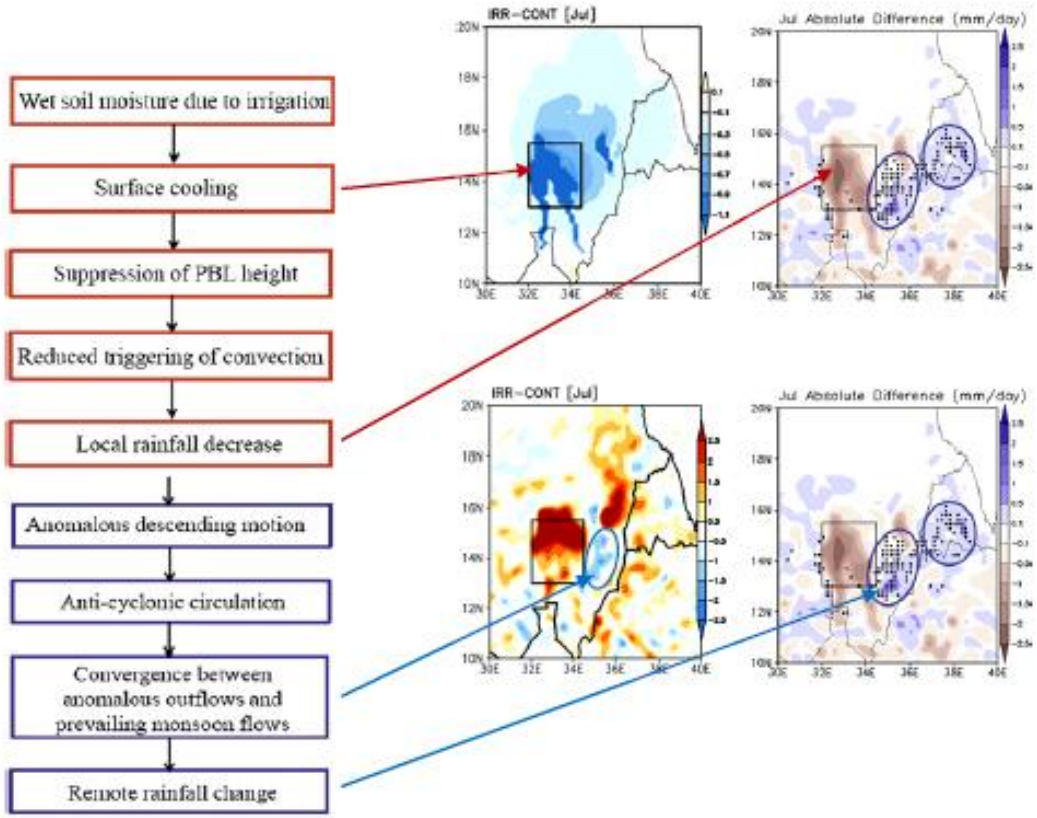
Alter, R. E., E.-S. Im, and E. A. B. Eltahir. *Nature Geo, 2015*

Simulated mechanism for non-local response



Cool high circulation around irrigation zone



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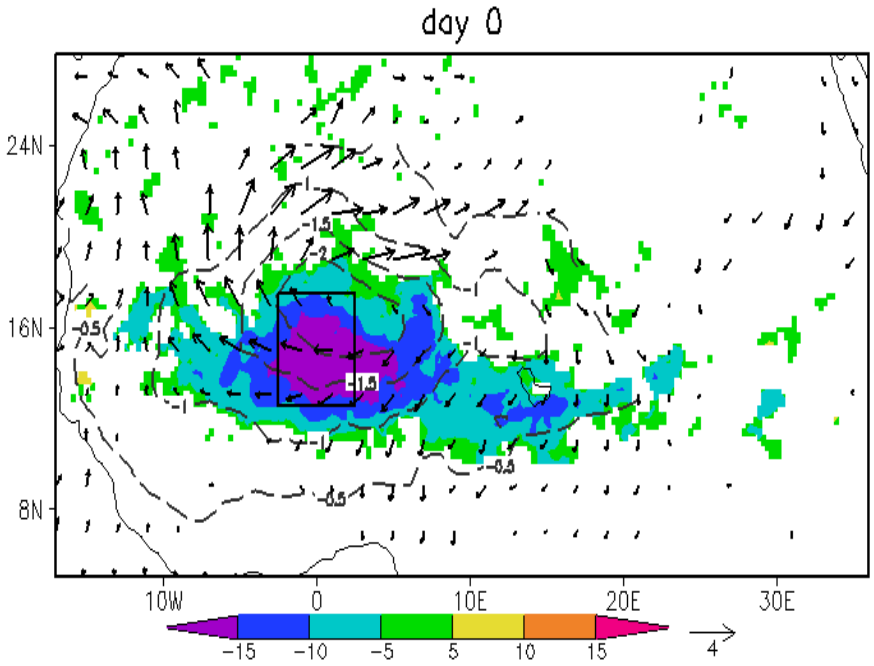
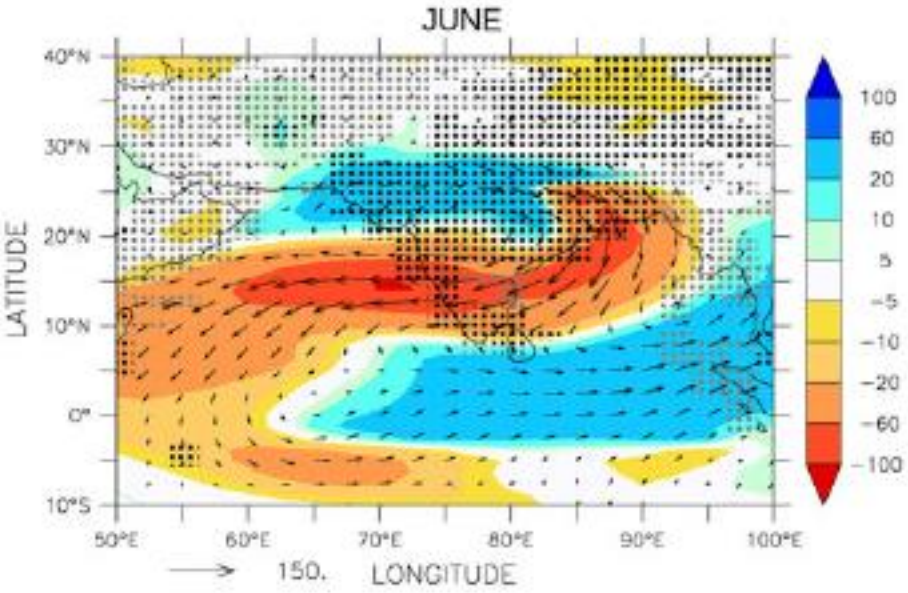
Alter et al, Nature Geo, 2015

Regional circulation response to soil moisture



Composite wet spell H (W m^{-2}) estimated from observed sm, reanalysis winds



Changes in vertically-integrated moisture transport (kg/m/s)
(irrigation – no irrigation simulations)

Fluctuations in soil moisture in W Africa

Impact of Indian irrigation on simulated winds, delayed monsoon

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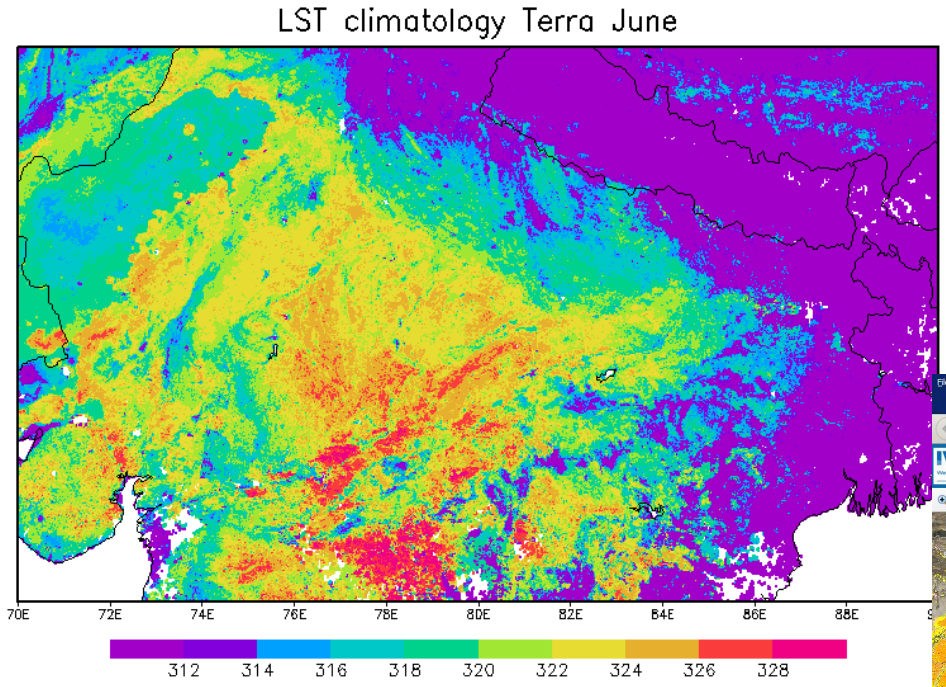
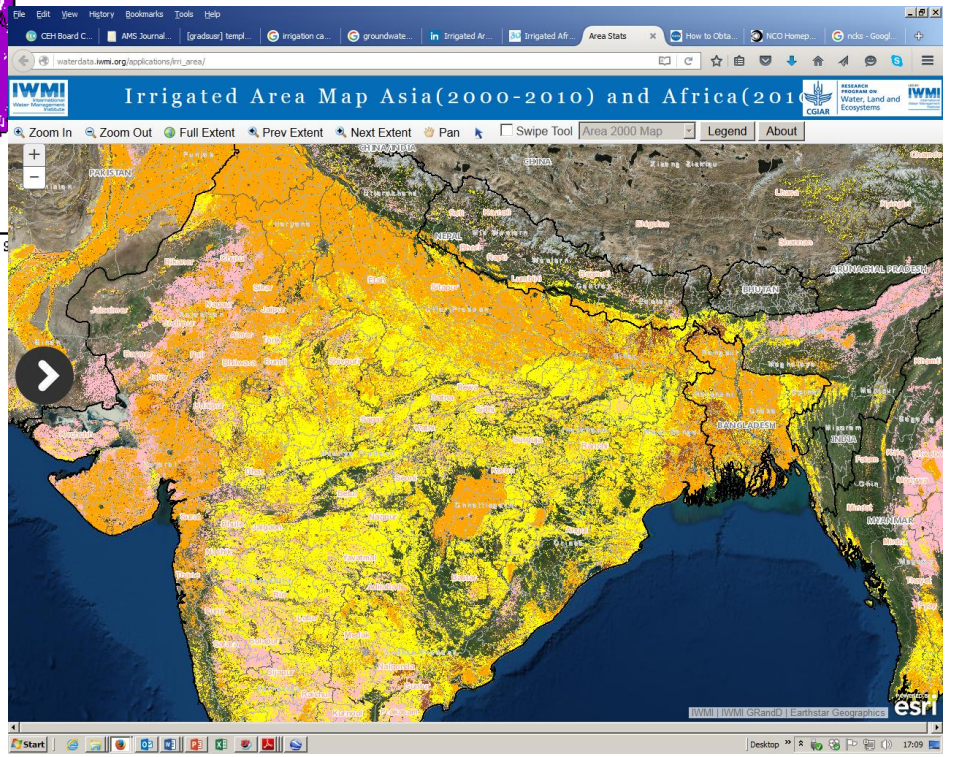
Taylor, J Clim 2008
Guimberteau et al Clim Dyn, 2012

Large-scale irrigation Indo-Gangetic plain





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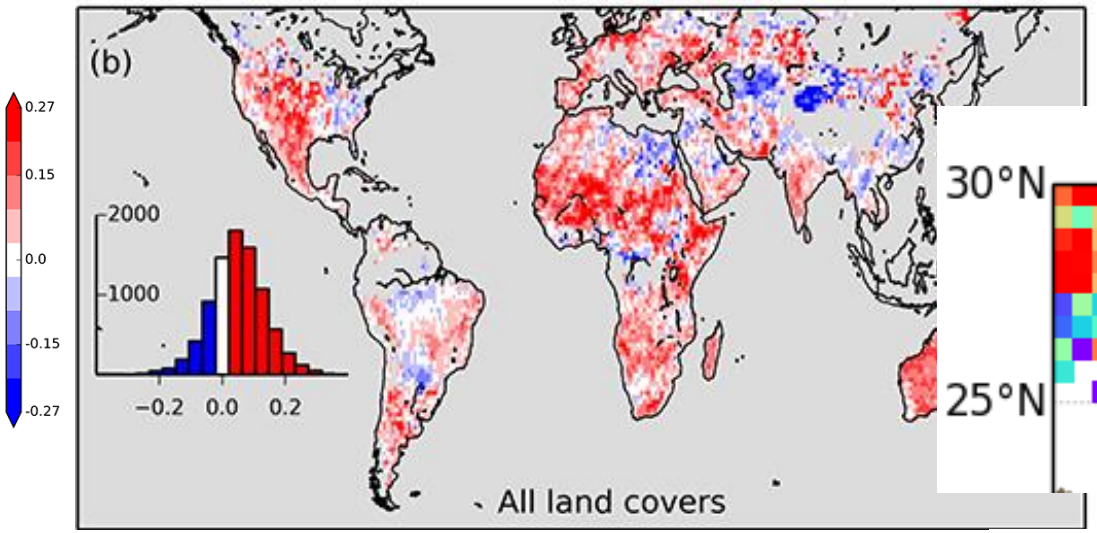
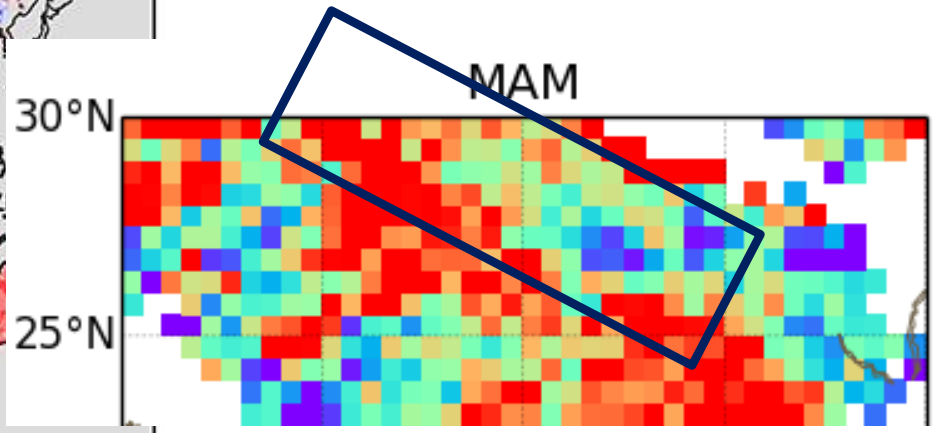
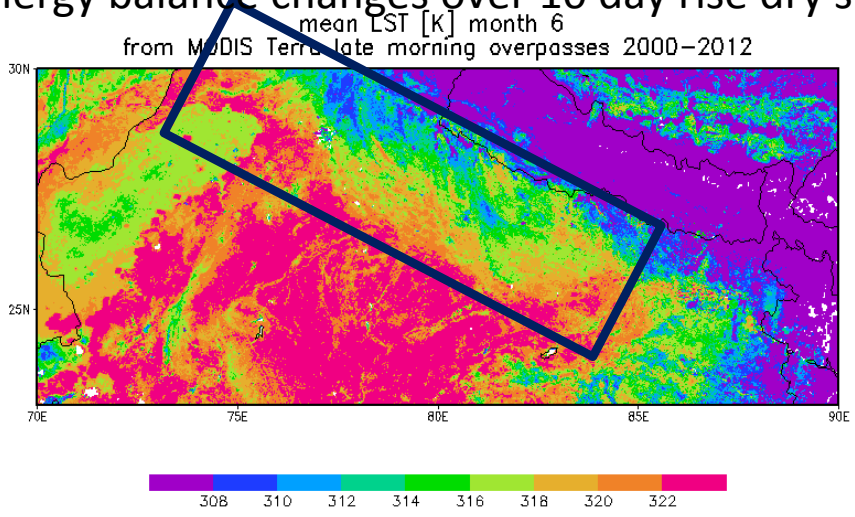
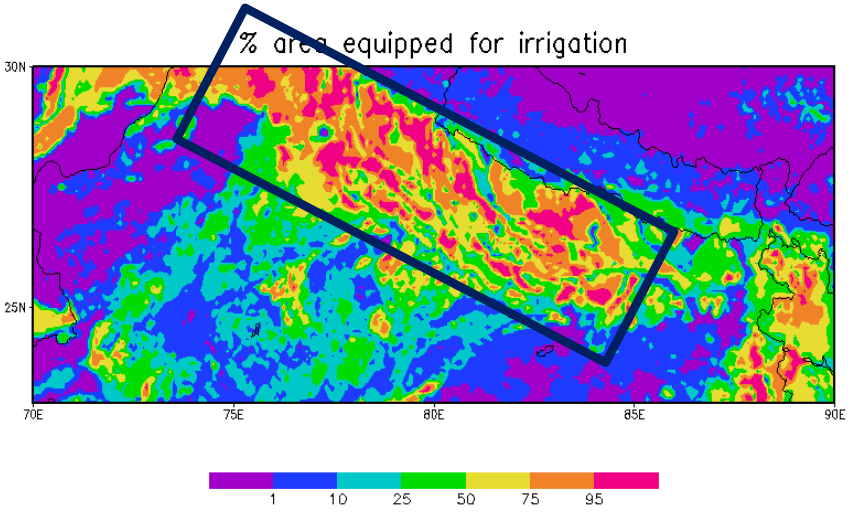
Temporal dynamics of surface energy balance – response to dry spells





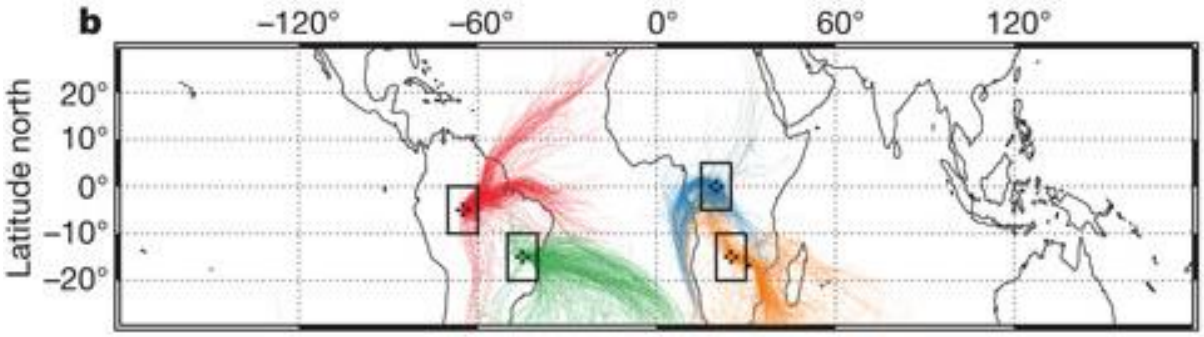
Observed measure (from LST dynamics) of how surface energy balance changes over 10 day rise dry spell





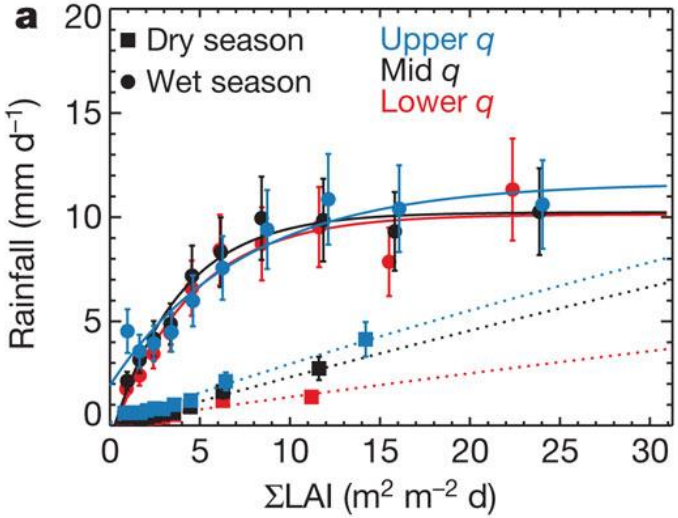
Gallego-Elvira et al, GRL 2016

3. Downstream impact via atmospheric water budget



Trajectory analysis linking tropical rainfall and vegetation (LAI)

Precip rises with airmass exposure to LAI.
Expect similar positive impact from irrigation at large scales (100s km, days)
BUT NOTE: Impacts on regional circulations may also be important



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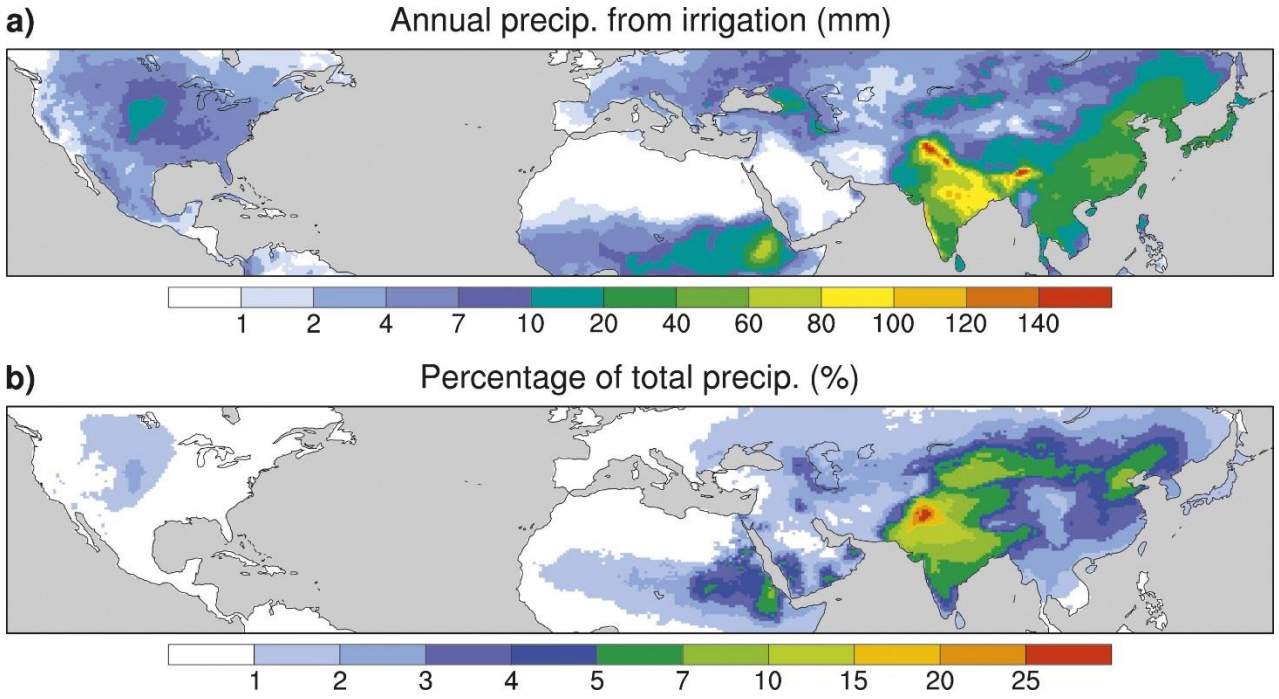
UNIVERSITY OF LEEDS

Spracklen et al Nature, 2012

“Where Does the Irrigation Water Go?”

Back-trajectory approach
Compute fraction of water in column from irrigation in previous 15 days
Precipitation increase is much less than the ET increase over most areas



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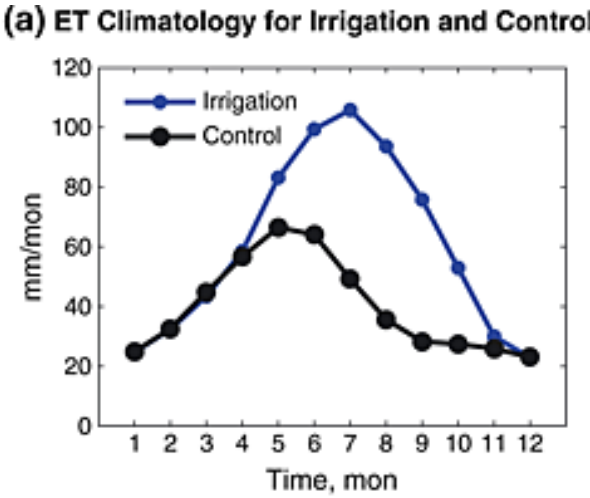
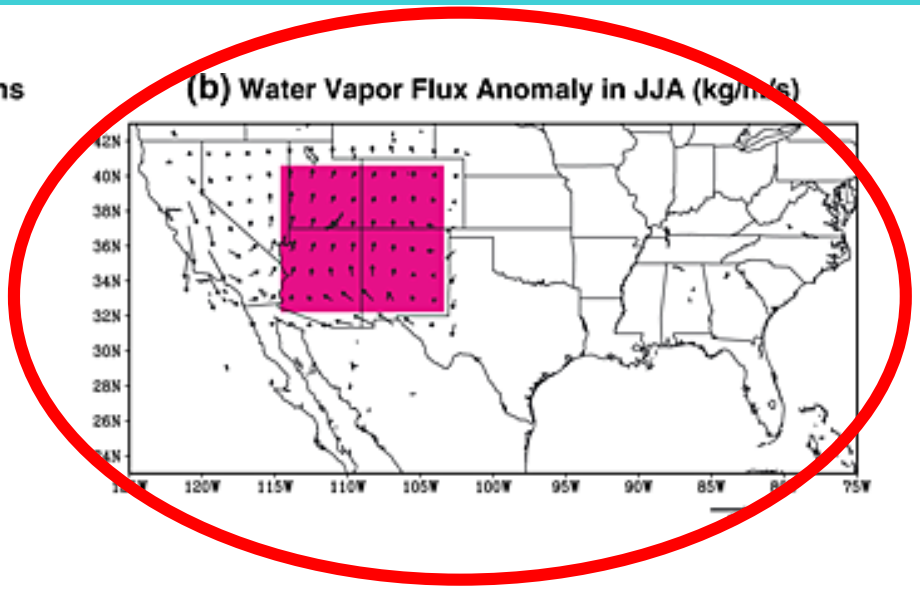
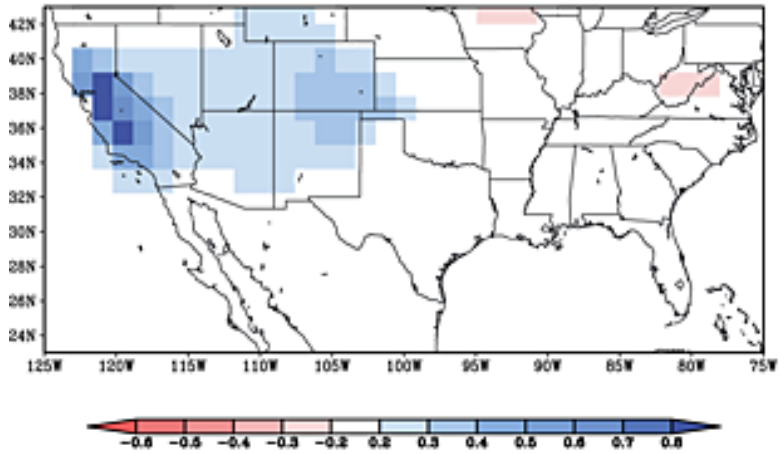
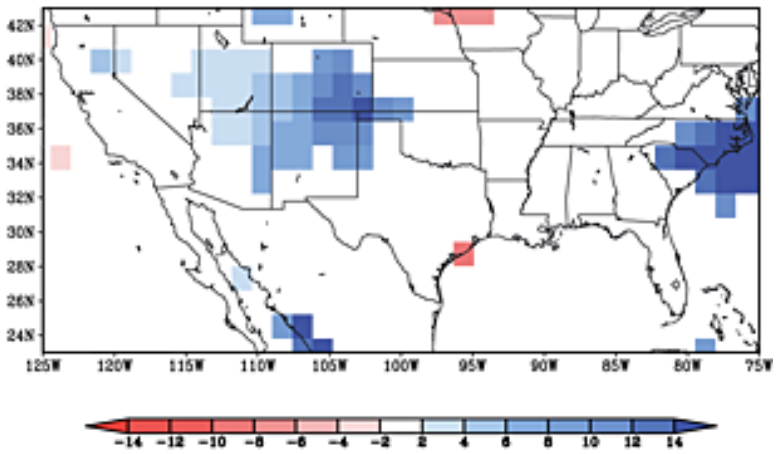
Wei et al J Hydromet 2013

Another example (from yesterday)…









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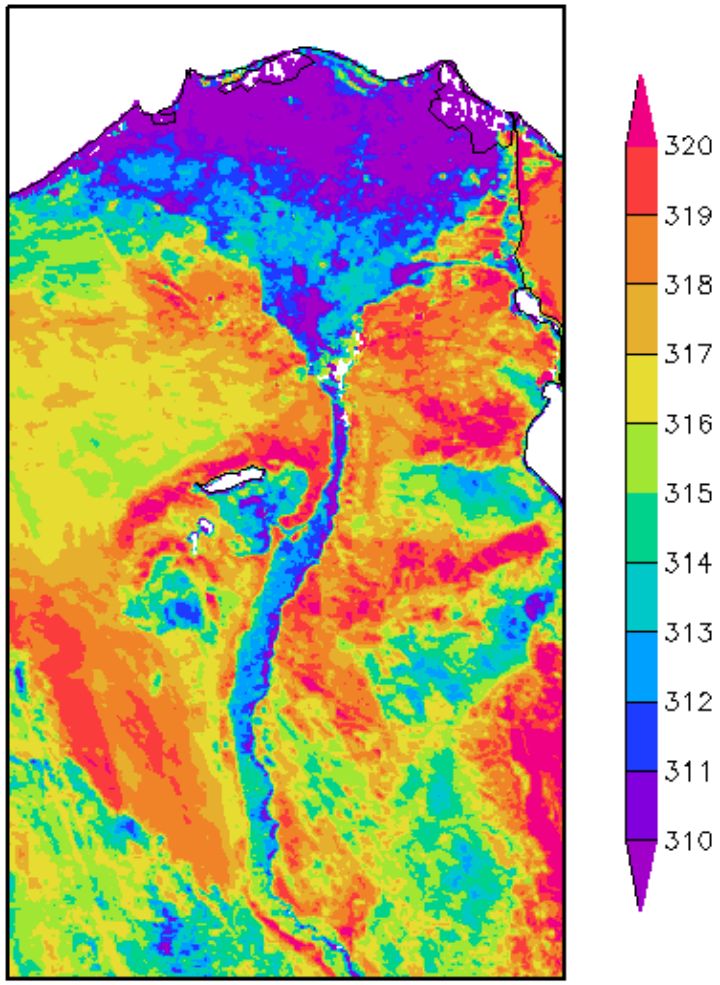
Lo and Famiglietti, GRL 2013

Summary: Impact of irrigation on rain

- Important secondary effect in some regions, esp semi-arid tropics
- Strong sensitivity to spatial scale
- Less than 100km (hours): expect daytime mesoscale circulations to dominate
  - analysis of patchy sm in Sahel: clearest signal 10-40km
- 100s-1000s km (1+ days)
  - effects via regional circulation on moisture transport
  - moisture transport can be important downstream of irrigation hotspots
- GCMs can deceive
  - Convection-permitting simulations can help



June daytime LST climatology lower Nile