ATMOSPHERIC RESPONSES TO IRRIGATION

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Effects of irrigation on global climate during the 20th century

GCM study imposed evolving irrigation over 20\textsuperscript{th} century

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

Puma and Cook, JGR, 2010
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

Regional simulation with and without irrigation

Shallow cloud suppression over irrigated zone

Model reproduces cloud field in response to irrigation

Kawase et al, GRL, 2008
Mechanism for impact on shallow cloud

Mesoscale simulations... easy to model, hard to observe

Kawase et al, GRL, 2008
Observational evidence of mesoscale circulations

Taylor et al. GRL 2007

- Observed PBL temperature from ECMWF forecast model
- Low LSTA → wet surface (Meteosat, LandSAF)
- Proxy for soil moisture along aircraft track
- Horizontal air temperature gradient
- LST anomalies [K] from satellite
- Wind vectors from aircraft [m/s]
- 3L temperature from ECMWF recast model
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

Taylor et al, Nat Geo, 2011
Global analysis of local soil moisture impact on rain

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


Soil moisture - AMSR-E and ASCAT
Rainfall – TRMM3B42, CMORPH, PERSIANN
Impact on propagating convective systems? Lake Chad

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

Taylor et al in prep, Lauwaet et al QJ 2012
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: WLI Delft Hydraulics & DNH.


Taylor, GRL, 2010
2. Impact on rainfall via regional circulations: Gezira, Sudan

Simulated mechanism for non-local response

Cool high circulation around irrigation zone

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

Fluctuations in soil moisture in W Africa

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

Impact of Indian irrigation on simulated winds, delayed monsoon

Taylor, J Clim 2008
Guimberteau et al Clim Dyn, 2012
Large-scale irrigation Indo-Gangetic plain
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

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.

Trajectory analysis linking tropical rainfall and vegetation (LAI)
“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

![Map](image-url)
Another example (from yesterday)...

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