Effects of agriculture on surface energy partitioning and climate over the continental U.S. using WRF-CLM

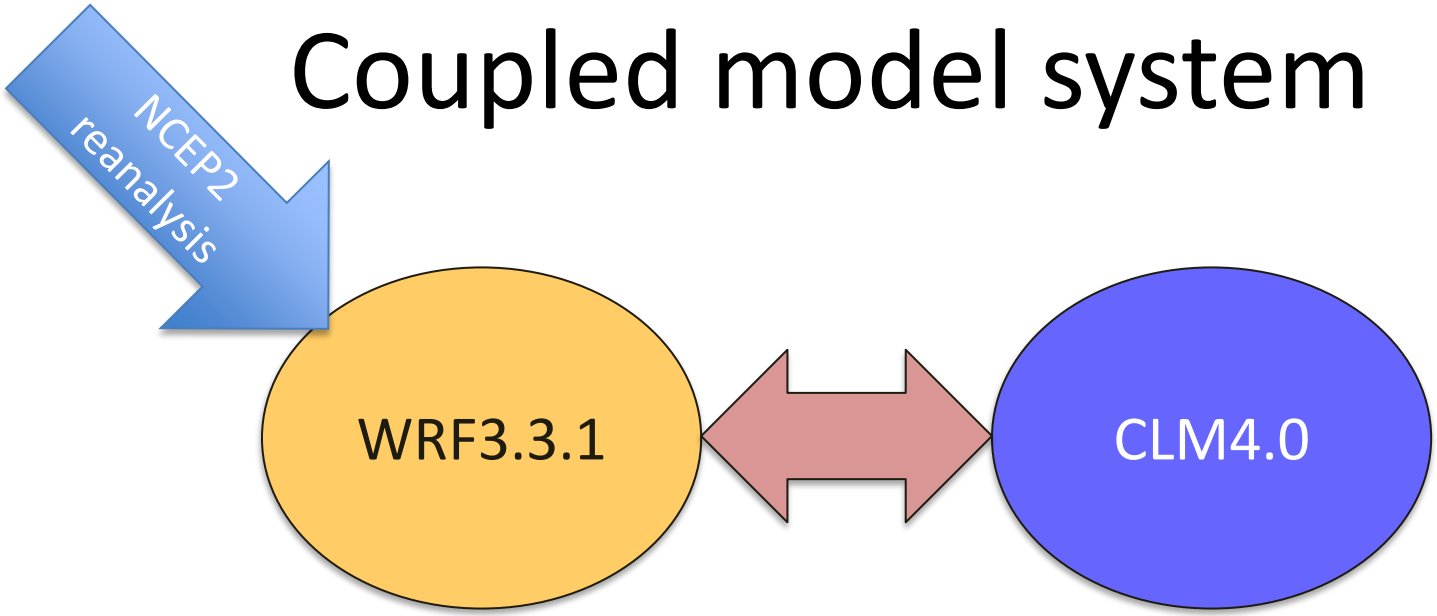
Yaqiong Lu[1], Jiming Jin[2], & Lara M. Kueppers[1,3]
[1]UC Merced, [2]Utah State University, [3]LBNL

With elements of CLM4CNCrop code from Sam Levis, NCAR

Why a regional climate-crop model?

- Agriculture a large footprint in U.S. (and elsewhere) but spatially heterogeneous
- Crops sensitive to climate variability
- Crop systems have large potential biogeophysical climate influence
  - Leaf area index (m2 leaves/m2 ground)
  - Irrigation
- (Ignoring biogeochemical feedbacks at regional scale…for now)

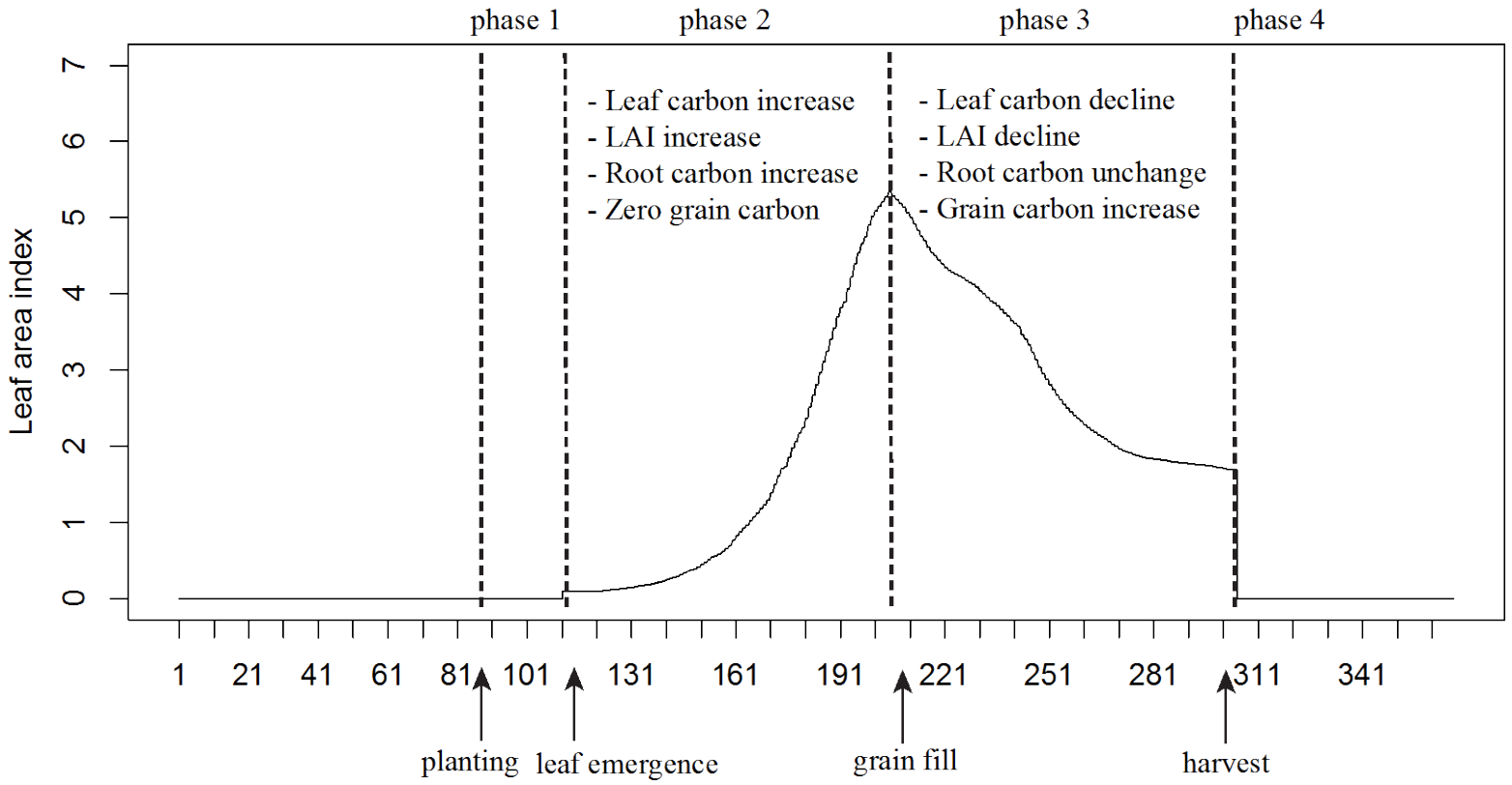
Coupled model system



Resolution	•50km horizontal, 25 vertical layers
Domain	•109 south north and 129 west east grid cells over U.S.
Run times	•5 years: 2002-2006, discarding the first 2 years •10 years: 2002-2011, discarding the first 2 years
WRF schemes	•MYNN boundary layer scheme •CAM longwave/shortwave radiation scheme •New Grell cumulus scheme •Thompson microphysics scheme

(earlier versions: Subin et al. 2011; Lu & Kueppers 2012)

Dynamic crop leaf area phenology



Similar to CLMCNCrop (Levis et al. 2012), *except*

Planting GDD accumulated over fewer years (5 not 20)

Harvest is 1.5 * GDD for maturity so crop dries before harvest (Nielsen 2011)

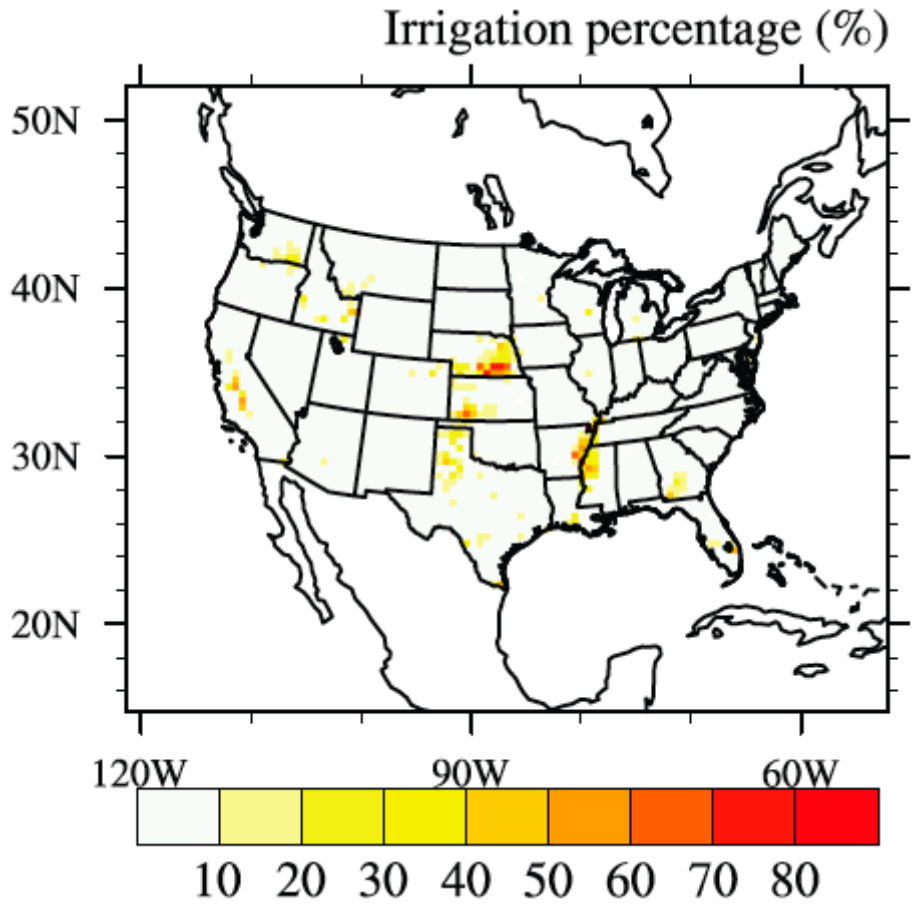
Modified C allocation to better capture water stress effects

Dynamic crop irrigation

- Irrigation applied after leaf emergence
- …and when root water stress increases OR when leaf temp > 35°C
- Water applied as rain 0.0002 mm/s (in range of 4-20 gal/min/acre of current systems)

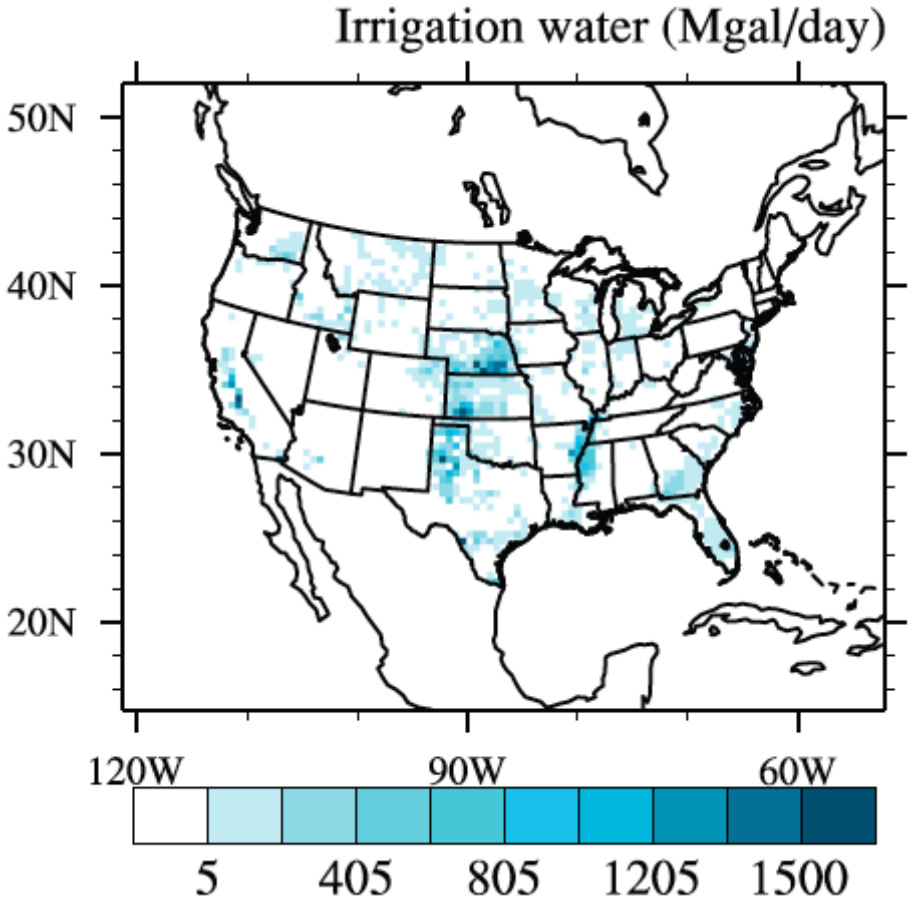
Irrigation distribution

Observed pixel % “equipped for irrigation”



(Siebert, Doll et al. 2005)

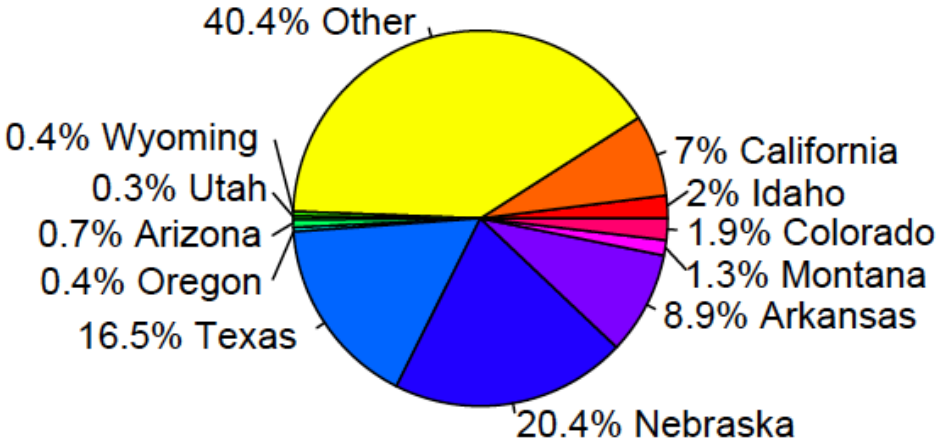
Model average irrigation amount



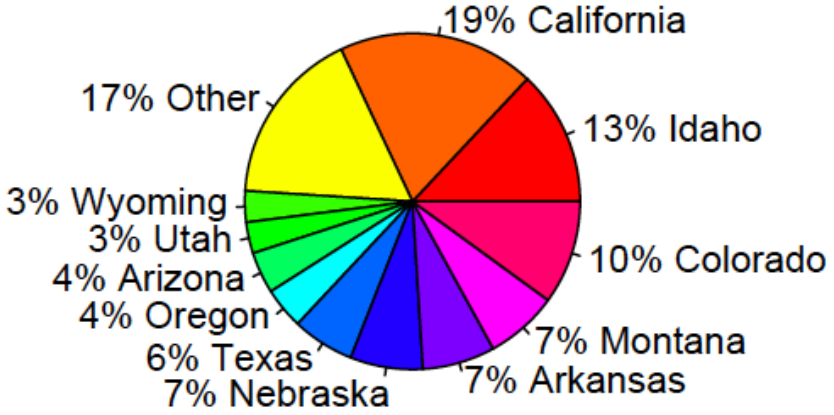
(Simulated by WRF-CLM for 2004-2006)

Model vs observed 2005 irrigation

Model (143,000 Mgal/day)



USGS (128,000 Mgal/day)



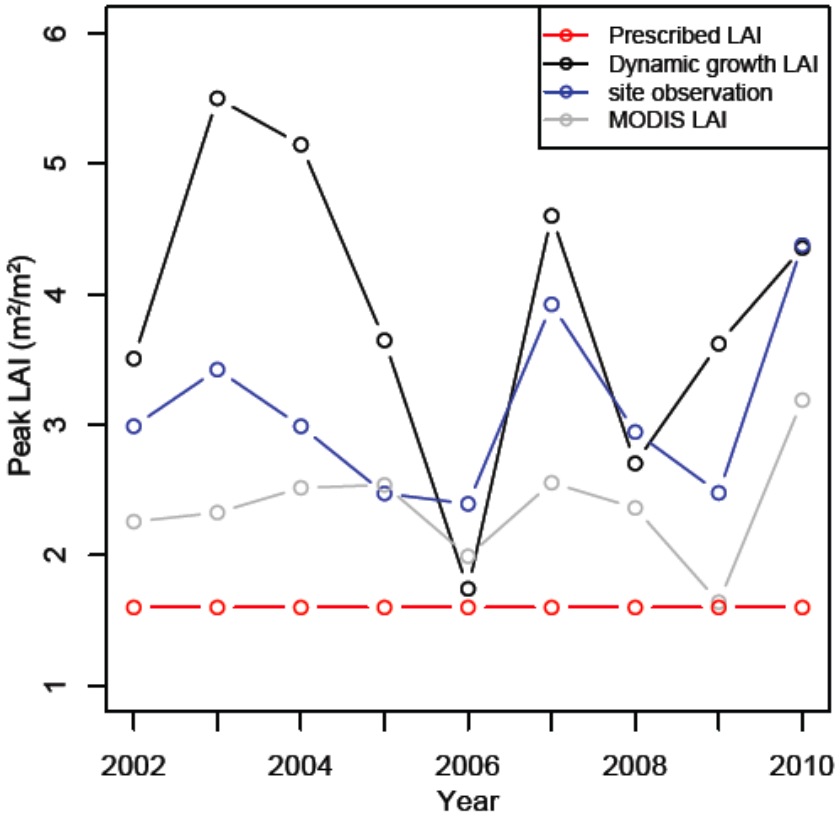
2004-2006 values 113,000-149,000 Mgal/d

2000 withdrawals est 137,000 Mgal/d

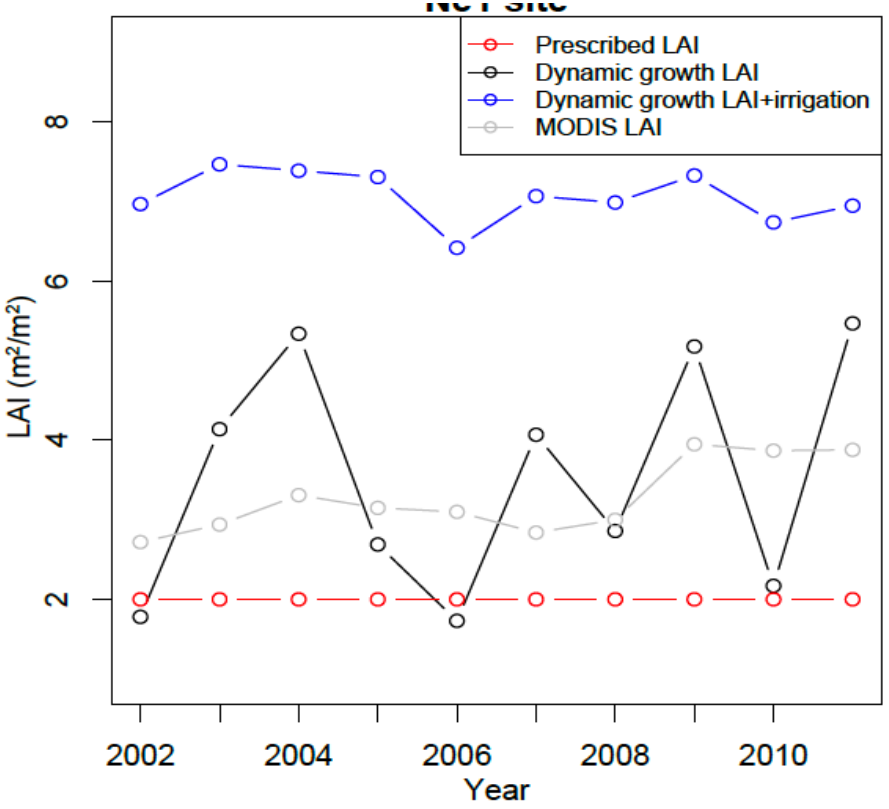
(http://ga.water.usgs.gov/edu/wuir.html)

Model vs observations for peak LAI

ARM (not irrigated, Oklahoma)



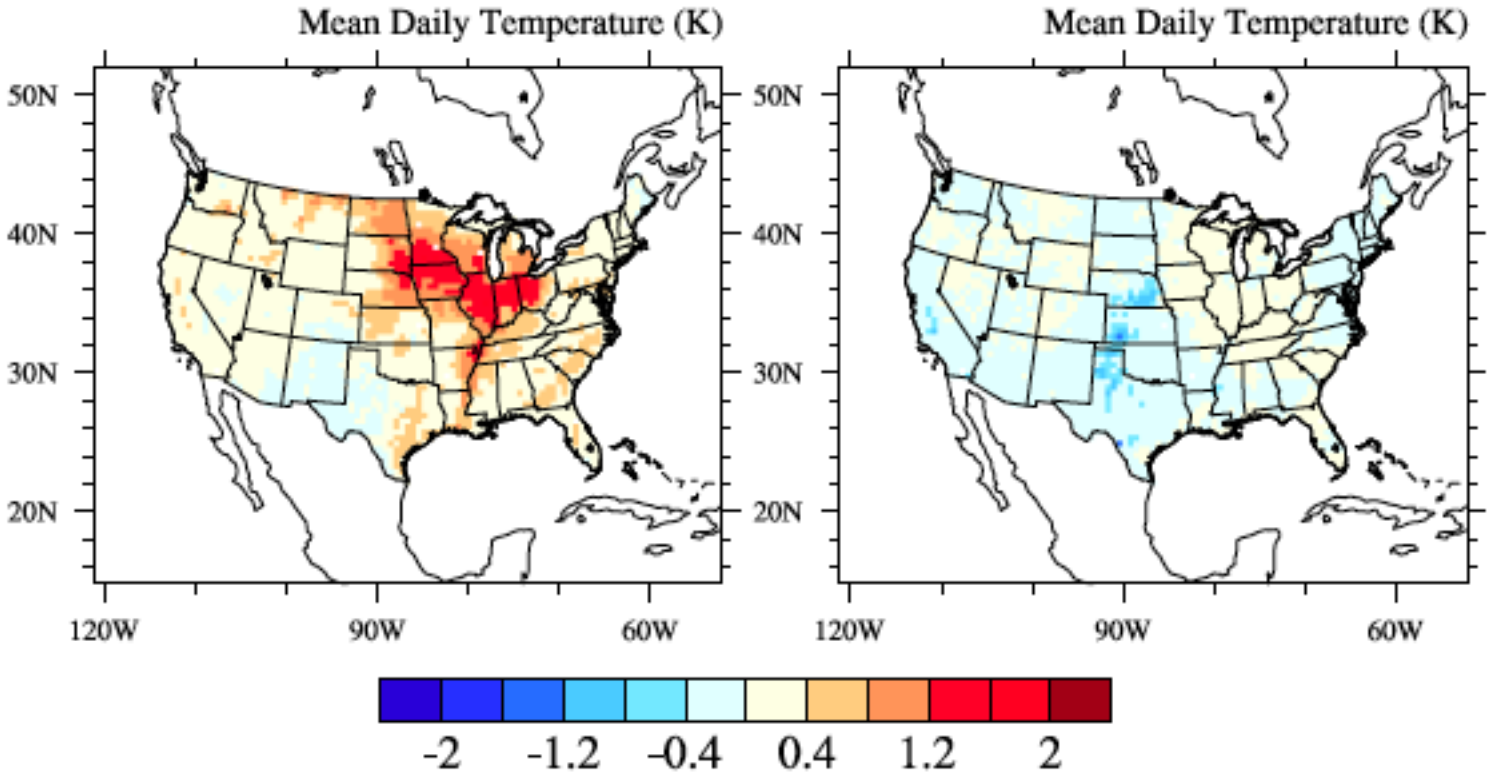
Ne1 (irrigated, Nebraska)



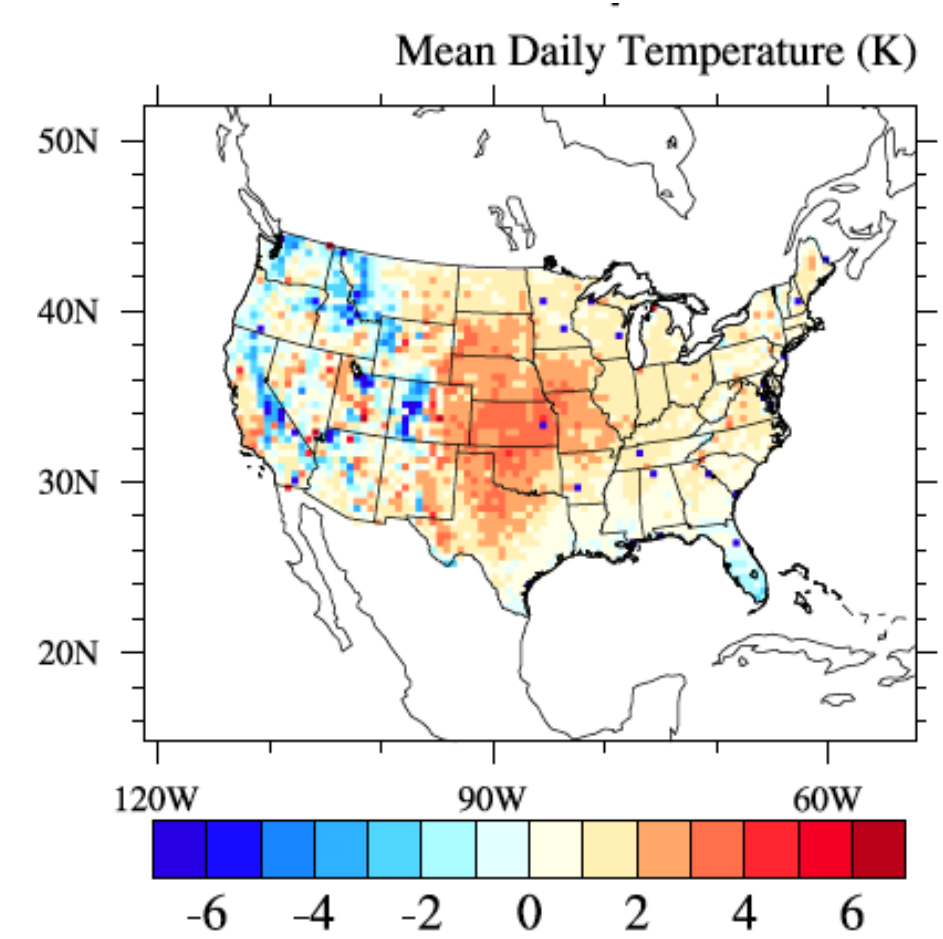
Dynamic crop and irrigation cool

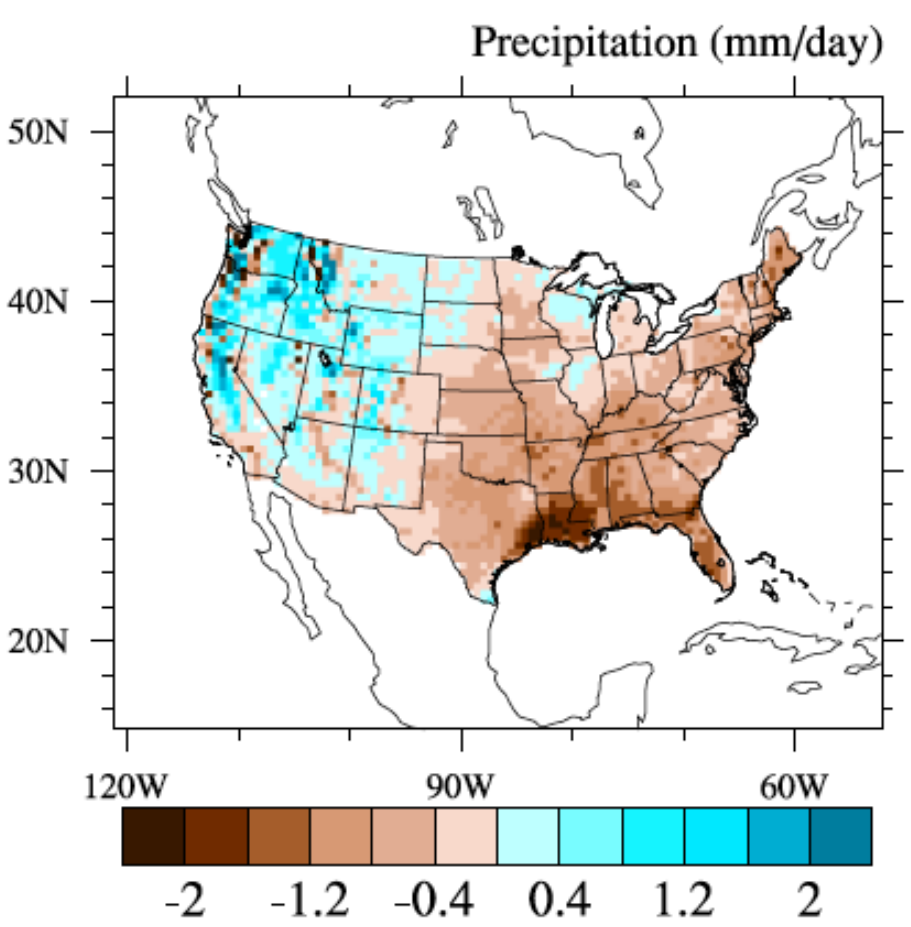
Prescribed – dynamic LAI

Dynamic irrigation – dynamic no irrigation

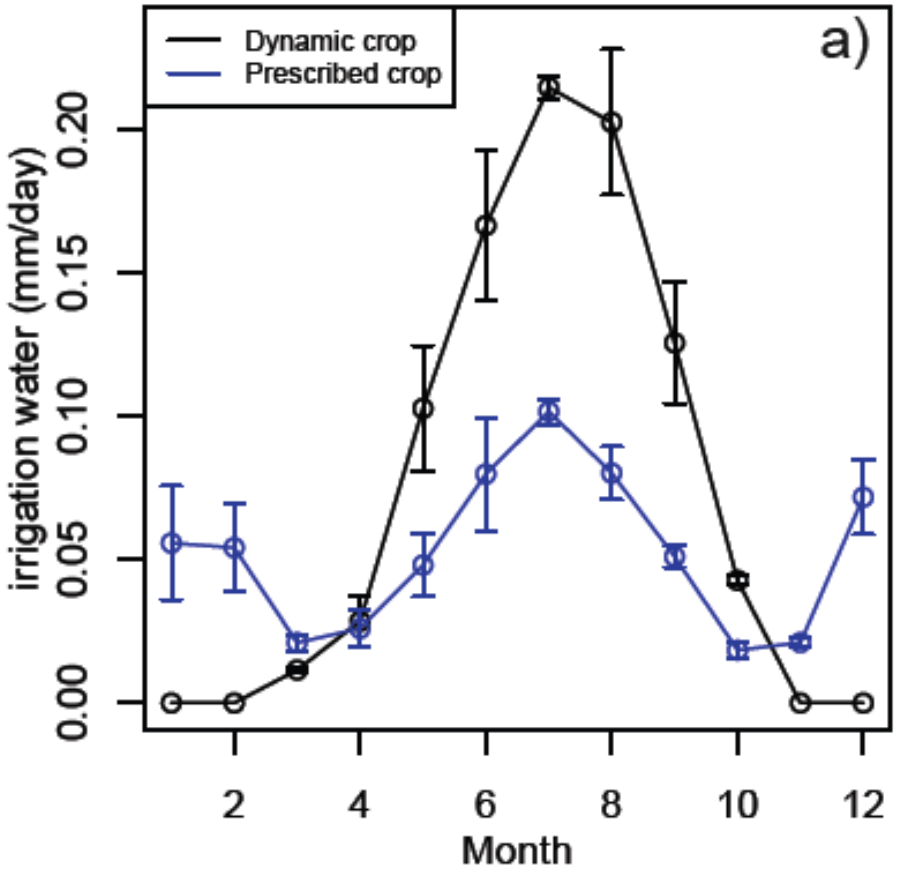


WRF3.3-CLM4CropIrr vs PRISM obs

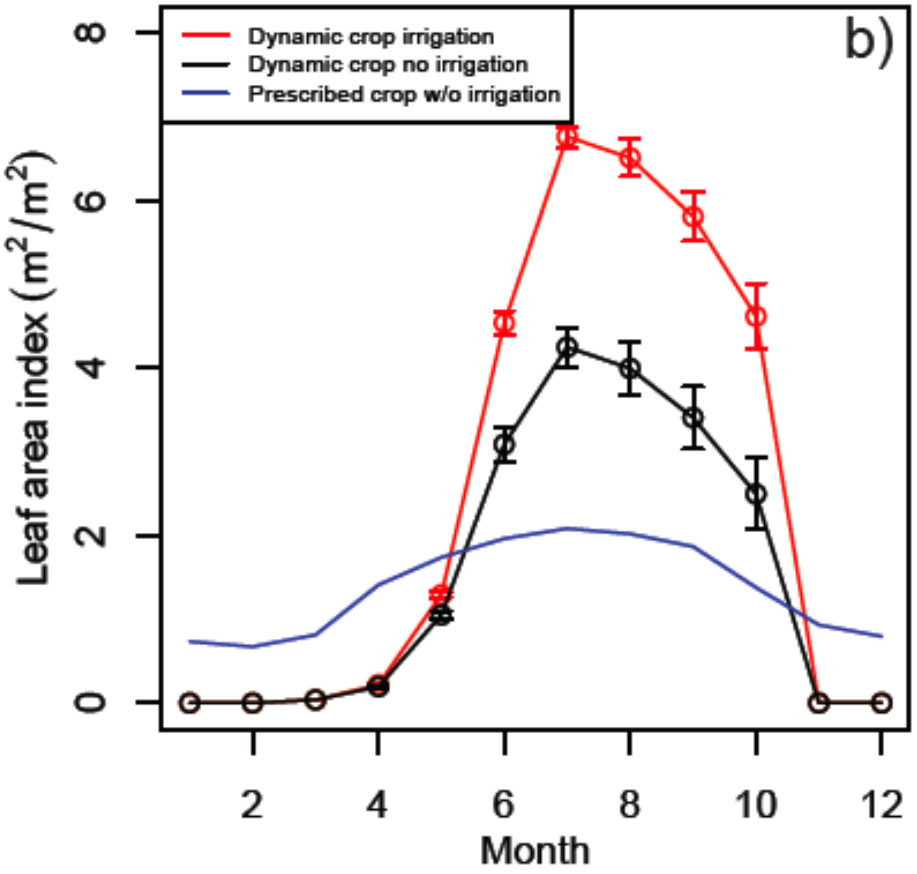




LAI and irrigation water synergies

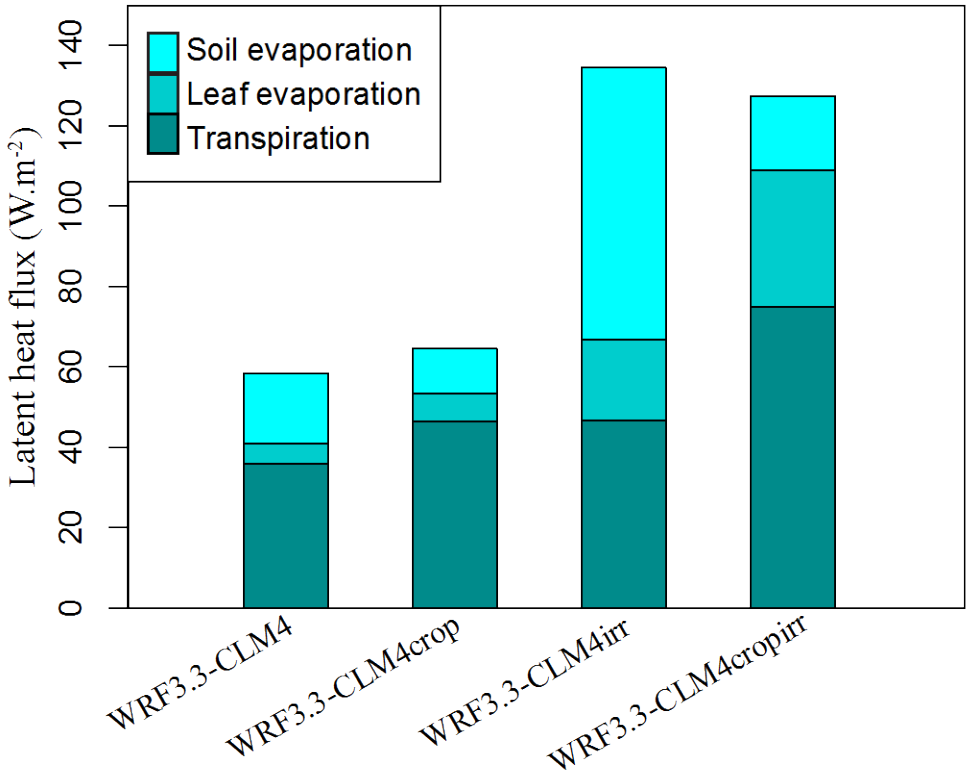


Dynamic LAI model uses more irrigation water



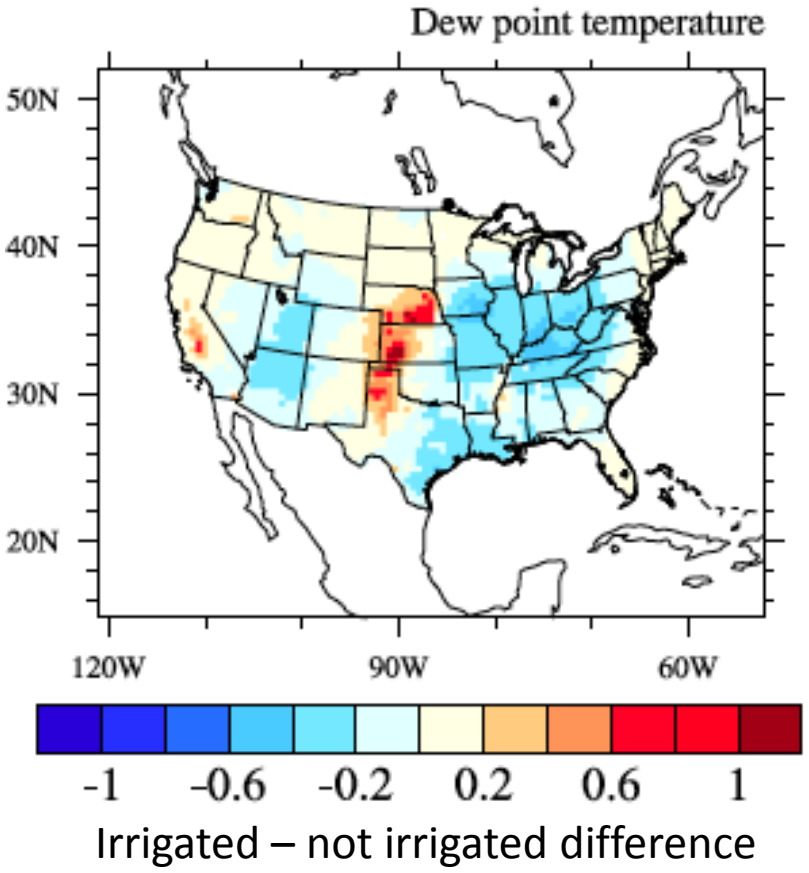
Irrigated crop model has greater LAI

Irrigation without dynamic LAI results in too-high soil evaporation



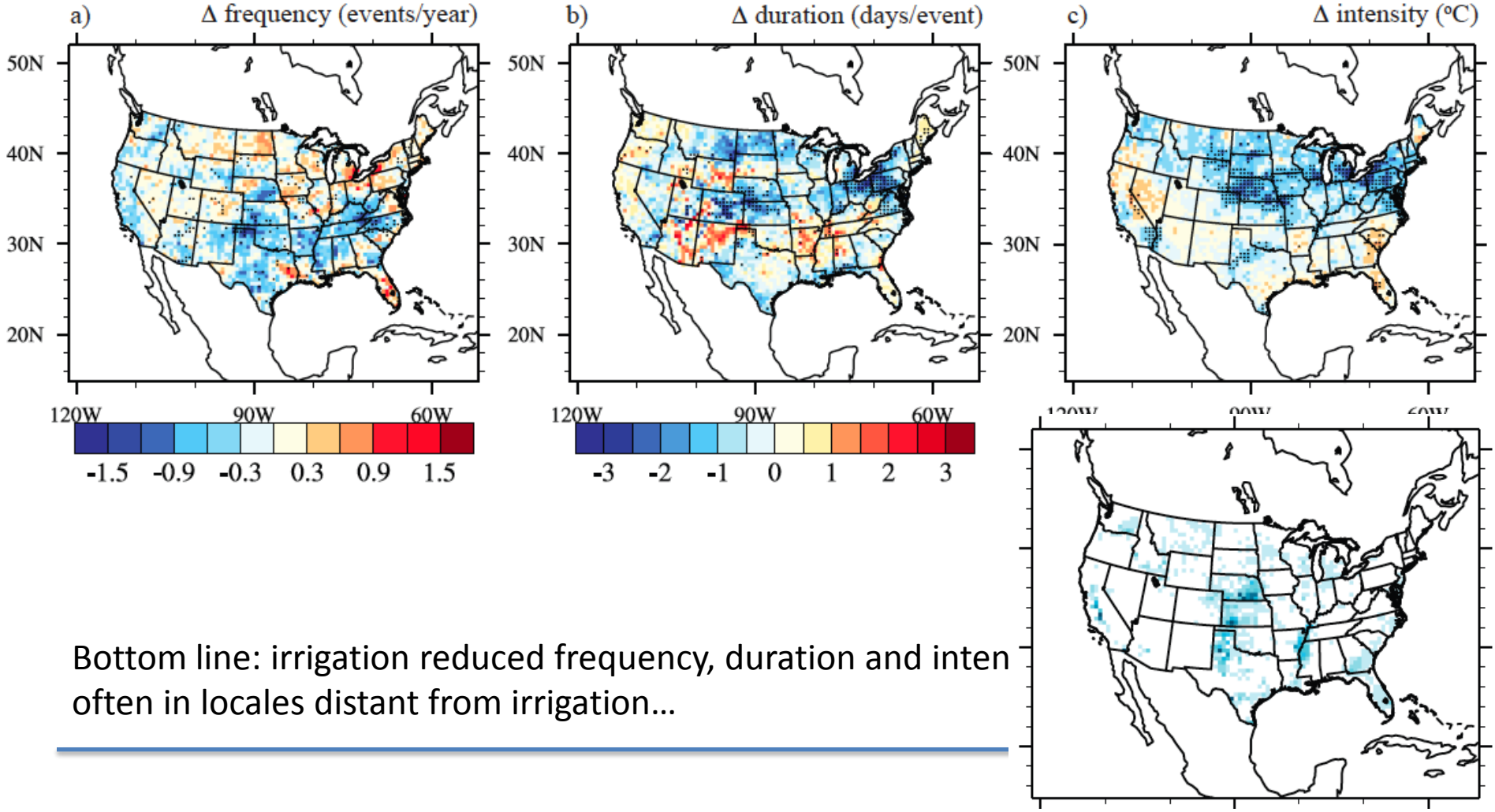
Can irrigation exacerbate heat waves?

- Irrigation increases dew point temperature too
- Heat index (Schoen 2005) includes both T and Td
- Increased Td can exacerbate heat wave impacts



Irrigation effects on heat waves

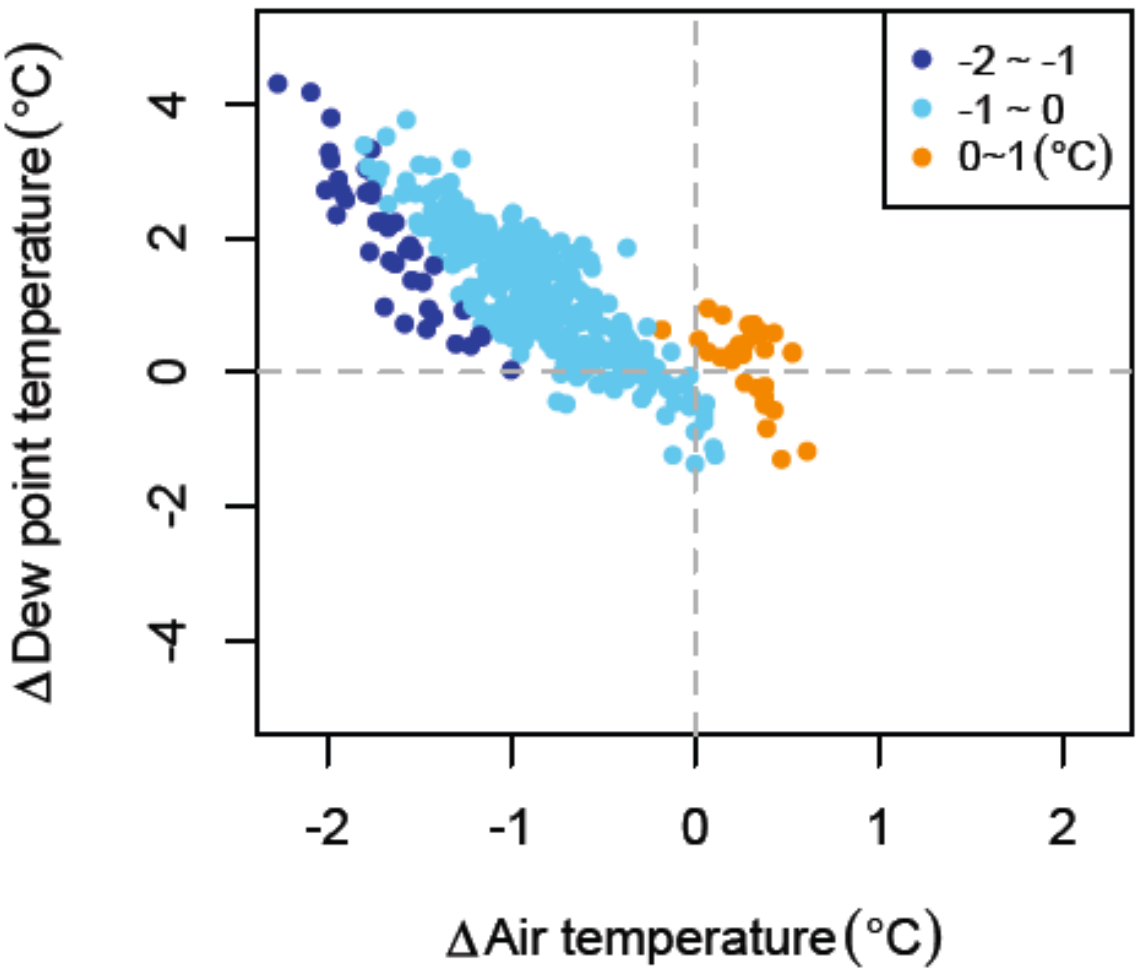
Irrigated – not irrigated differences



Bottom line: irrigation reduced frequency, duration and inten
often in locales distant from irrigation…

Can irrigation increase heat wave intensity? Only where air T increased.

CROPIRR-CROP heat index



Next steps

- Convert generic “crop” to real crops (corn, wheat, soy, sorghum, cotton, other?) and validate yields (irrigated and non) – transition to new CLM4.5CNCrop?
- Longer historical simulations to look at county yield *variability* relative to USDA statistics
- Force CLM4CNCrop (with all crops) with mid-century climate scenarios
- Sensitivity studies of potential farmer adaptations