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

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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”

Model average irrigation amount

(Siebert, Doll et al. 2005)  (Simulated by WRF-CLM for 2004-2006)
Model vs observed 2005 irrigation

Model (143,000 Mgal/day)

- 40.4% Other
- 16.5% Texas
- 20.4% Nebraska
- 7% California
- 1.9% Colorado
- 1.3% Montana
- 0.4% Oregon
- 0.3% Utah
- 0.4% Wyoming

USGS (128,000 Mgal/day)

- 19% California
- 13% Idaho
- 10% Colorado
- 7% Montana
- 7% Arkansas
- 6% Texas
- 4% Oregon
- 4% Arizona
- 3% Wyoming
- 3% Utah
- 2% Idaho
- 1.9% Colorado
- 1.3% Montana
- 0.4% Oregon
- 0.3% Utah
- 0.4% Wyoming

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

Irrigated – not irrigated difference
Irrigation effects on heat waves
Irrigated – not irrigated differences

Bottom line: irrigation reduced frequency, duration and intensity of heat waves, but 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