Representing Agriculture Management in the WRF regional climate model

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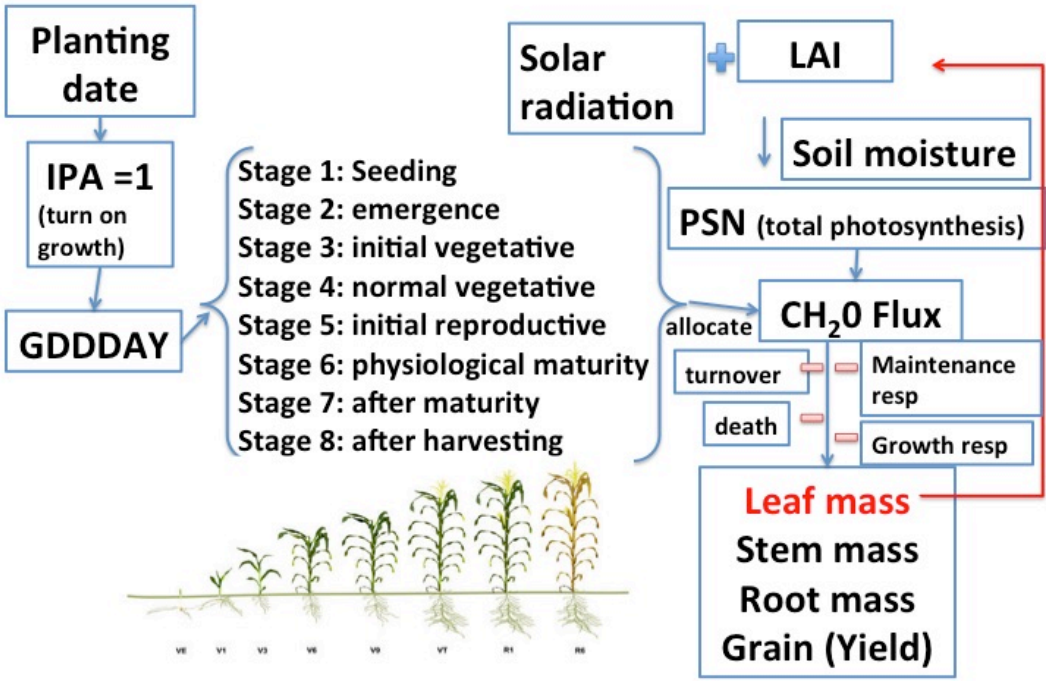
Challenges in modeling agriculture in ESMs

- Crop growth models are not static
- Complex agriculture manag
  practice
  - Rotation and double crops
  - Fertilization
  - Irrigation
  - Tile drainage
- From field scale to regional scales
- How to address those challenges? (using WRF-Crop as an example)

WRF-Crop model development

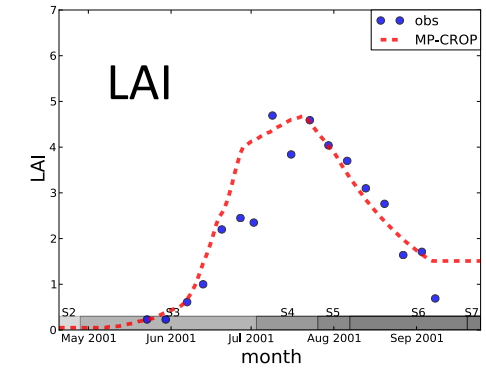
- Noah-MP-Crop (corn and soybean growth) models released in WRF 3.8 (2016)
- Implemented auxiliary crop data sets in WRF 3.9 (2017)

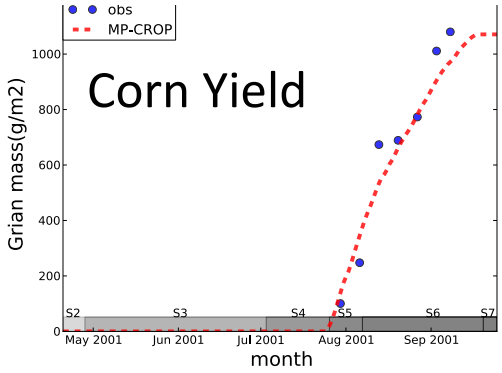
Noah-MP-Crop model



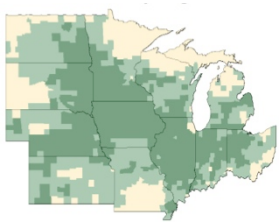
Liu et al., 2016, *JGR-Atmosphere*

Evaluation against field data, the model captured well the seasonal and annual variability of crop phenology and yield



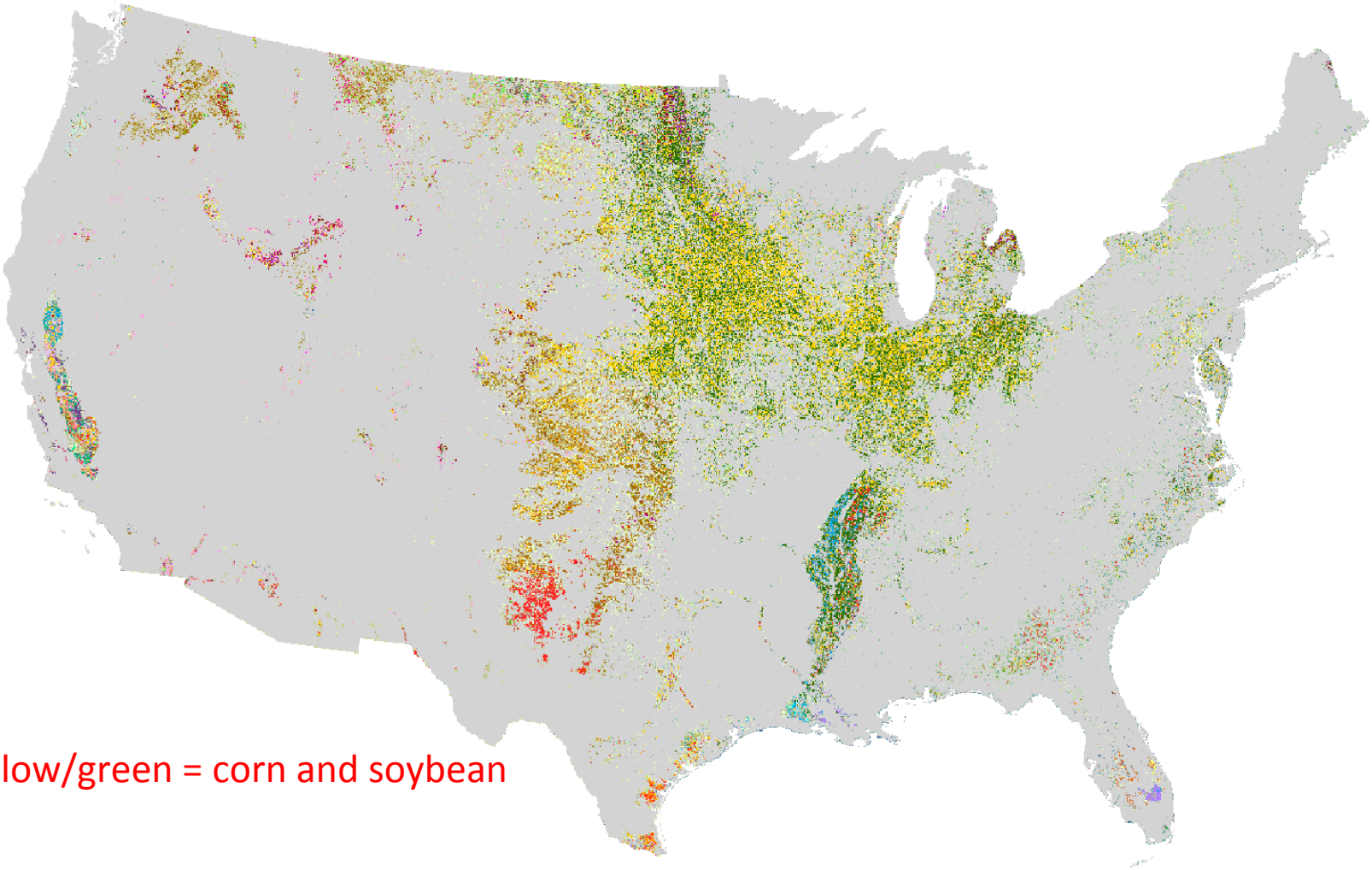


U.S. Corn Belt



Data Requirement for integrated regional crop-climate modeling in WRF

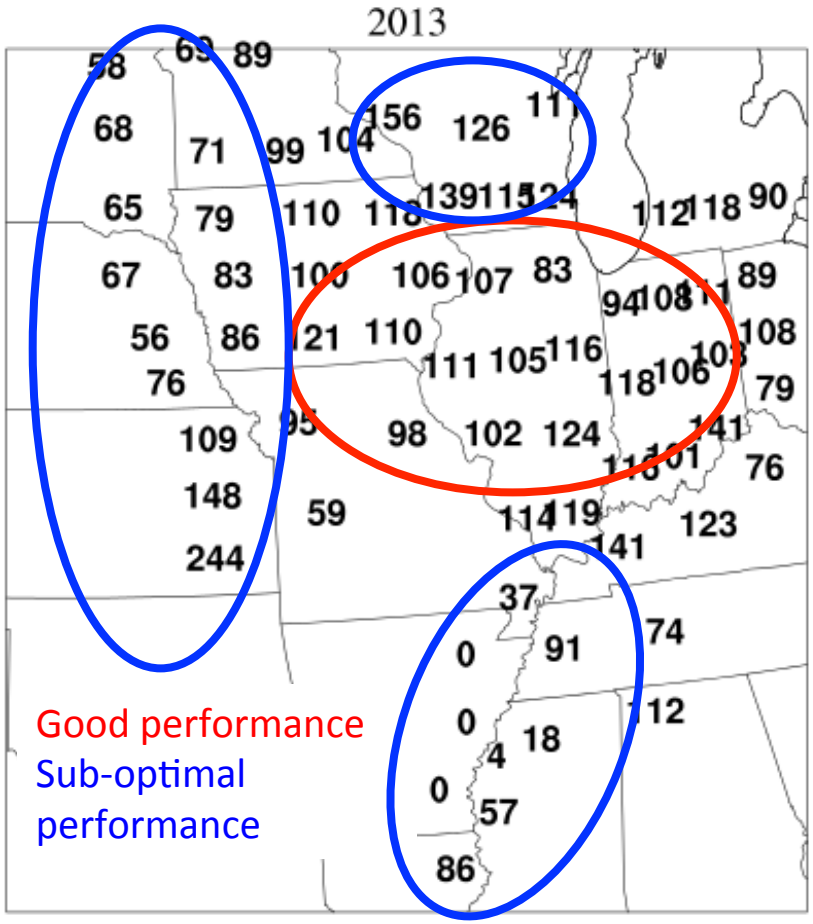
30-meter LandSat-based USDA/GMU CropScape crop type product



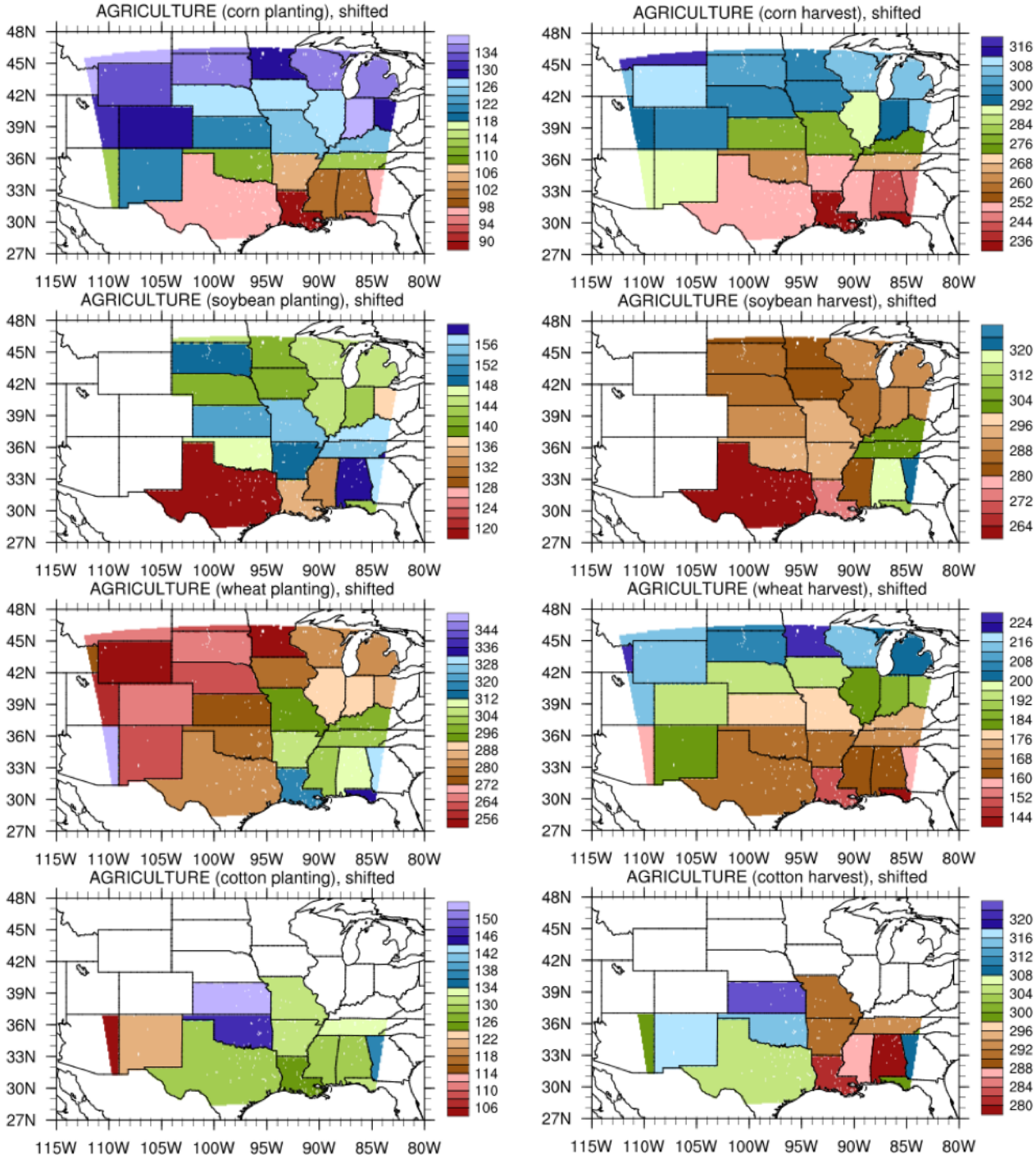
Yellow/green = corn and soybean

Difficulties in regionalizing crop modeling

- For a normal year (2013), WRF-Crop predicted crop yield is good in Corn Belt (Iowa, Illinois, Indiana) near where the model was calibrated (right)
- Challenge: improve model performance beyond calibration region for its global applications using spatially varying parameters



Corn yield ratio (modeled /observed) in % for 73 USDA zones (e.g., <100 implied under prediction)

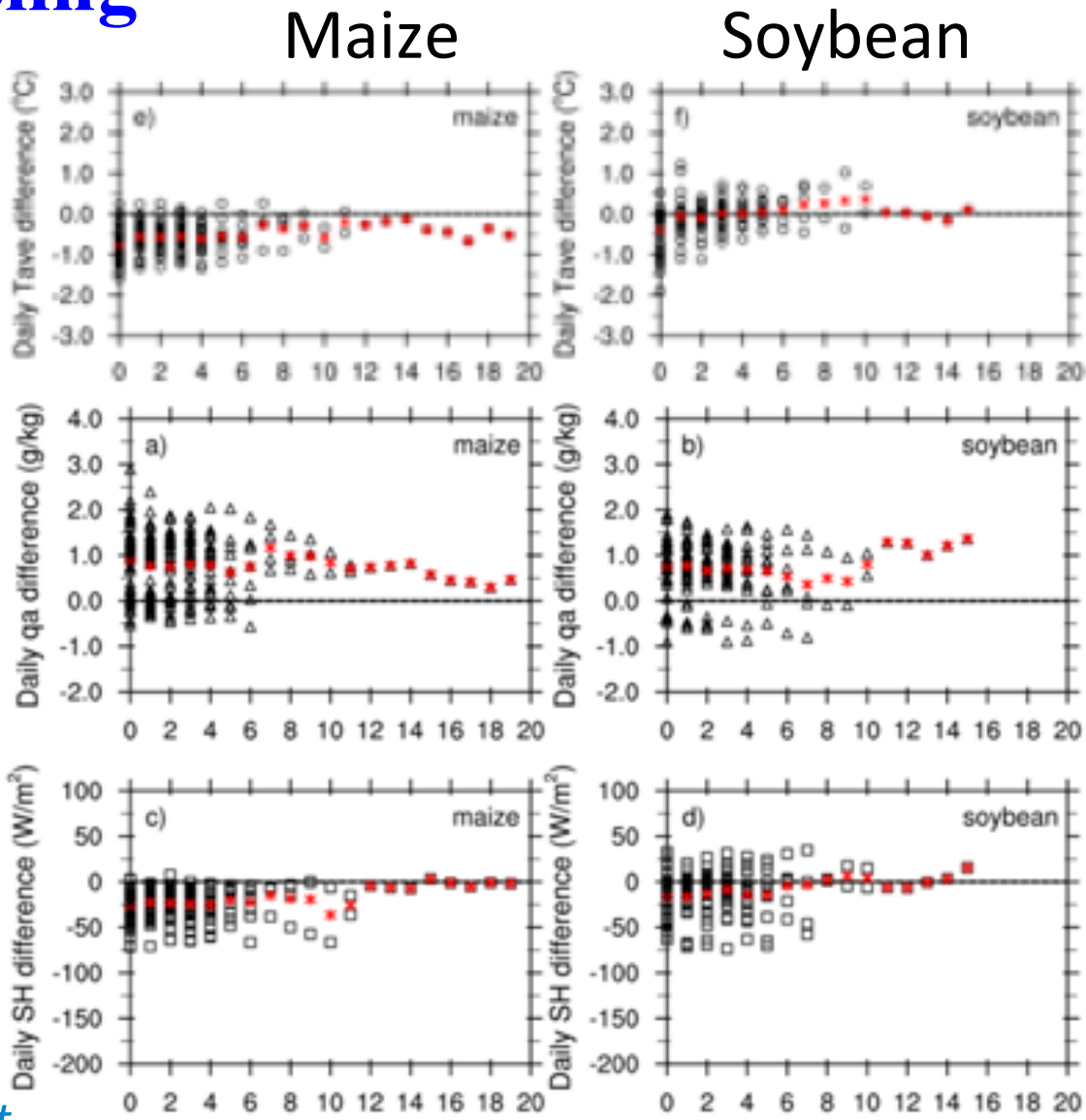


USDA/NASS
State-level data

Data constraints provide key to regionalization of agriculture modeling

Crop irrigation modeling

- Irrigation increase (reduce) humidity (temperature), and altered surface heat fluxes and runoff
- Discrepancies in modeling effects of irrigation on temperature and precipitation
- Need to improve irrigation parameterization in ESMs



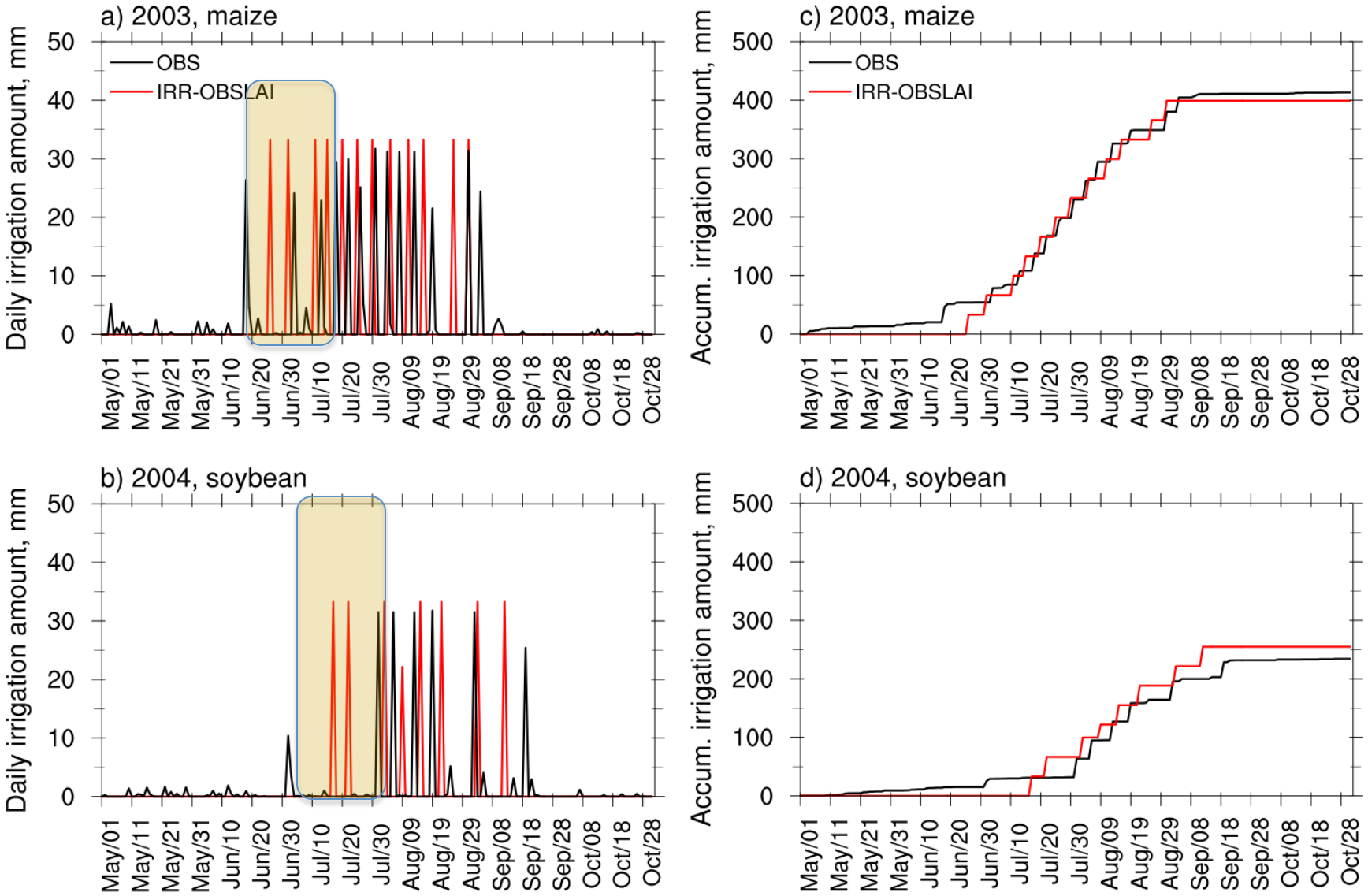
Chen et al., 2018, *Environ. Res. Lett.*,

Using 10-year data over nearby irrigated and non-irrigated sites, Mead, Nebraska.

Irrigation parameterization

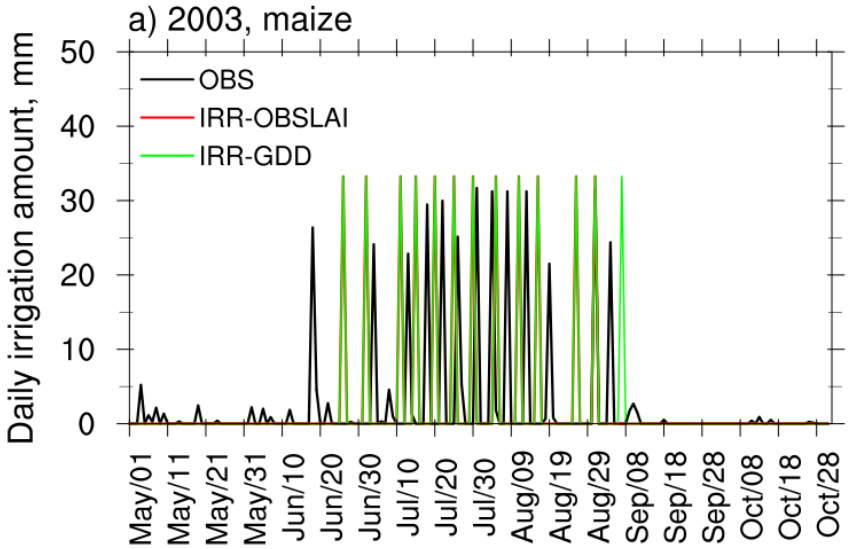
- **Goal:** calculate the timing and amount of irrigated water within irrigated agriculture lands
- **Timing:**
  - Crop growing season: when LAI is above a threshold
  - Soil-moisture deficit trigger: when the root-zone soil moisture availability (MA) is below the trigger criterion: $MA = (SM_{REF} - SM_{WP})/(SM - SM_{WP})$.
  - Irrigation stops if precipitation is above a threshold
- **Amount:** the smaller amount of $(SM_{REF} - SM)$ and maximum irrigation threshold
- **Duration:** total irrigation water computed above is applied as precipitation input at a uniform rate between the beginning and ending of irrigation

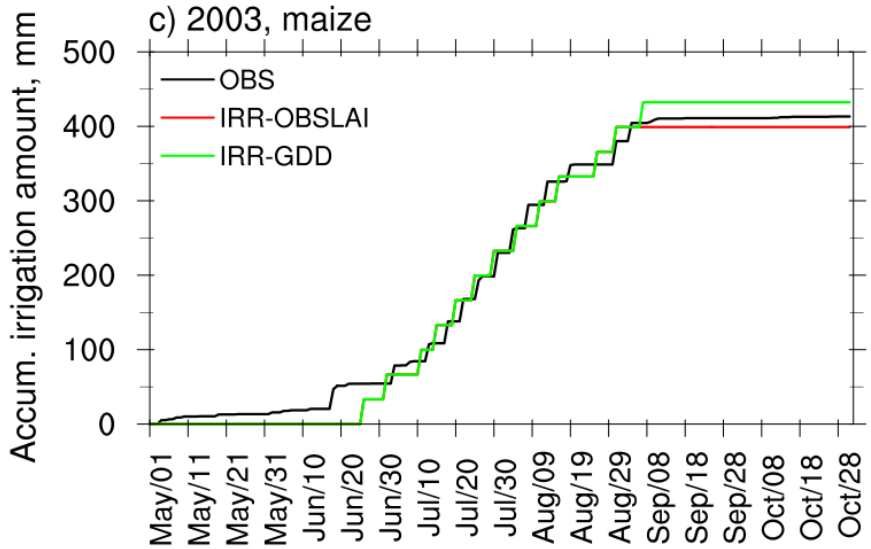
Modeling irrigation at field scales using only MODIS LAI to define growing season

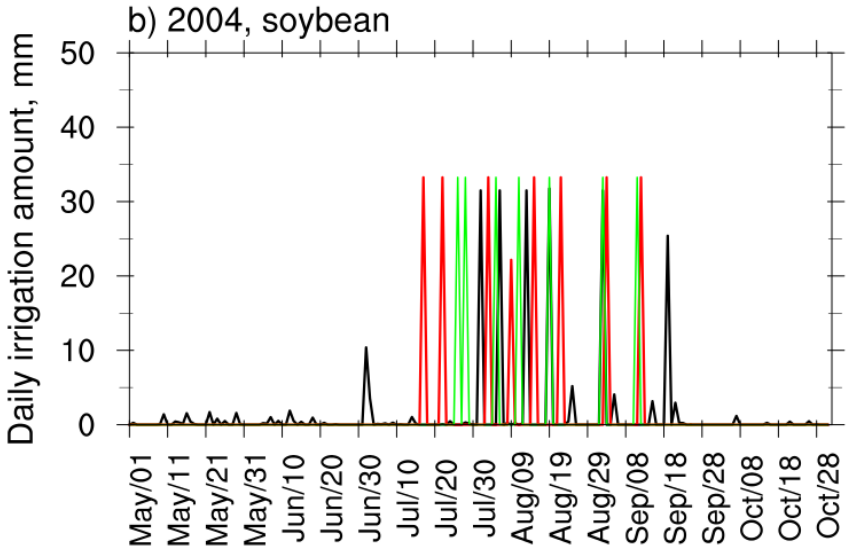


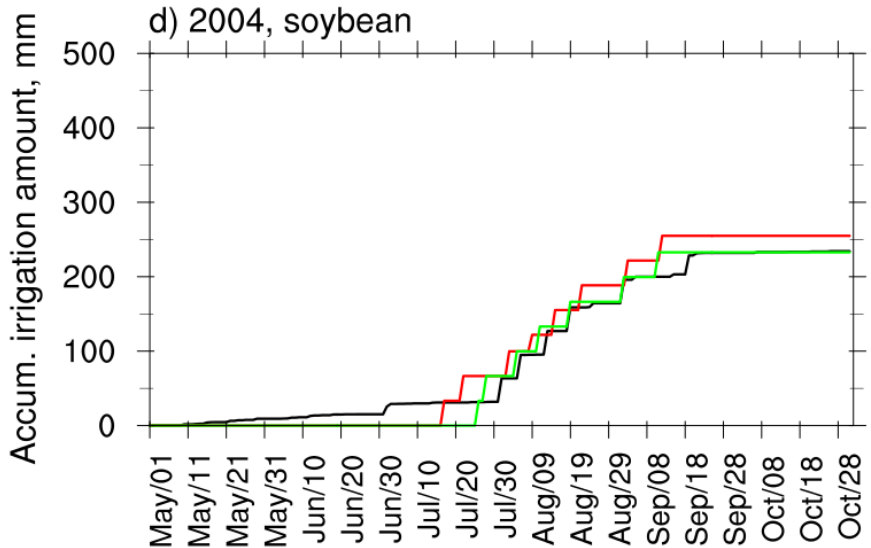
Enhance irrigation scheme by including GDD (growing degree days)

Activate irrigation: GDD>280 for corn, GDD >560 for soybean

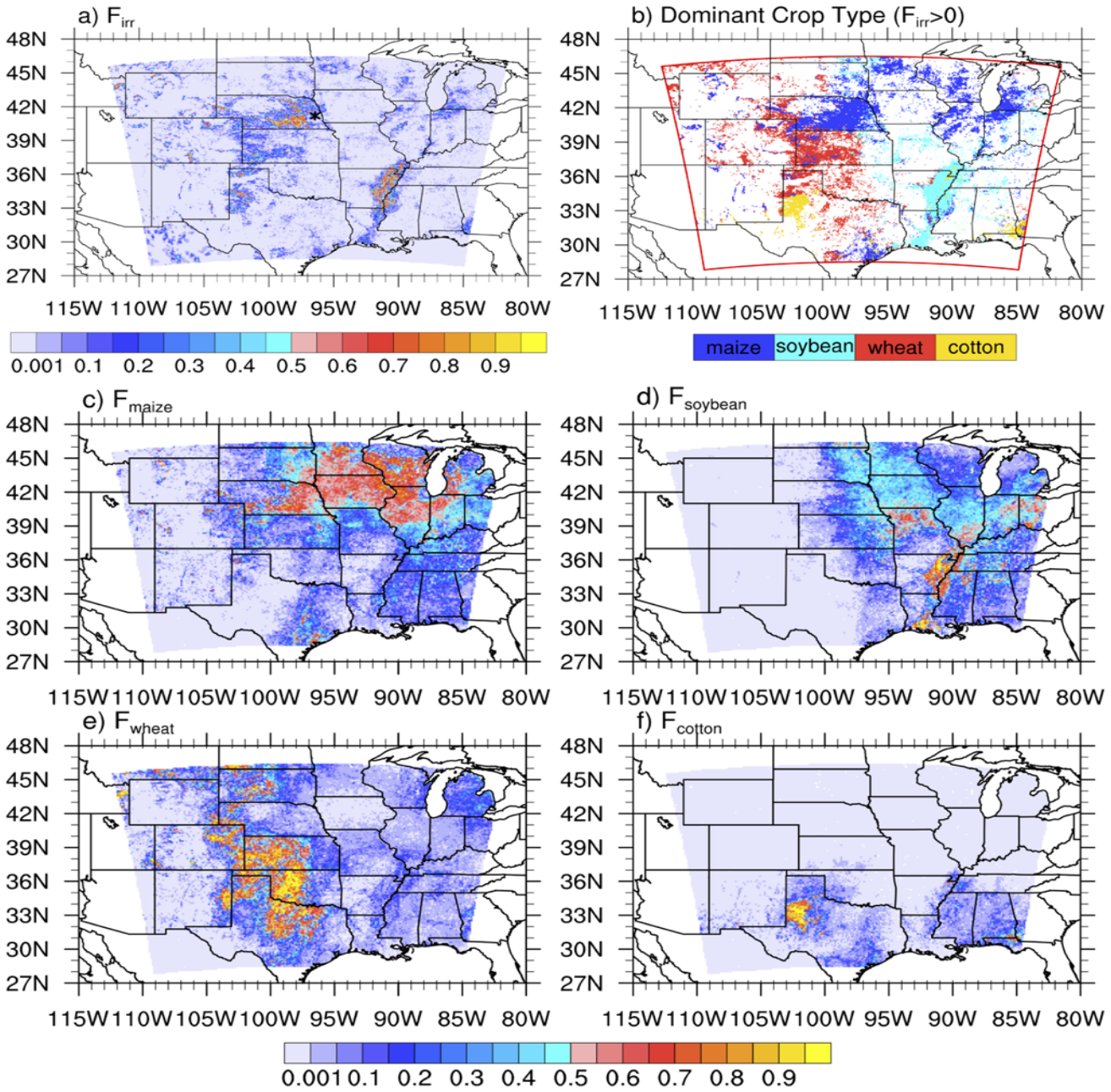






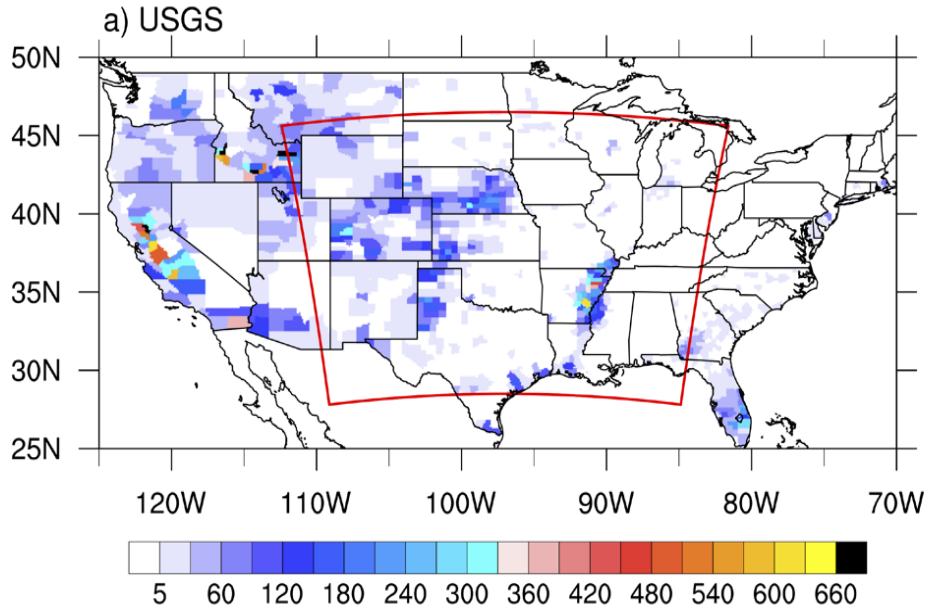


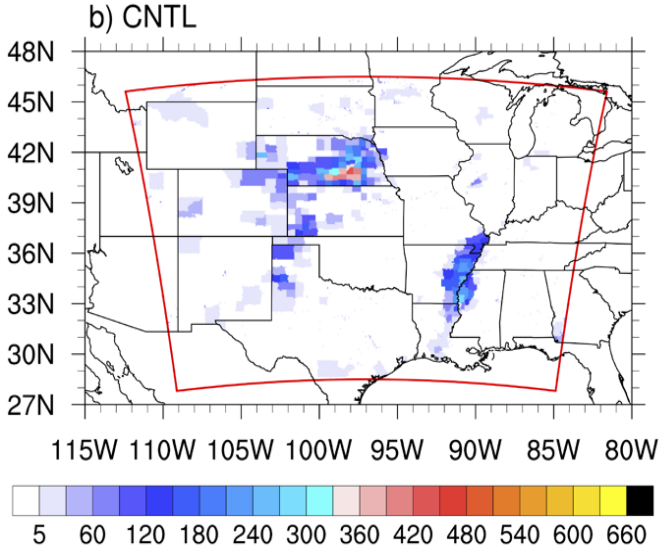
Modeling irrigation at regional scales

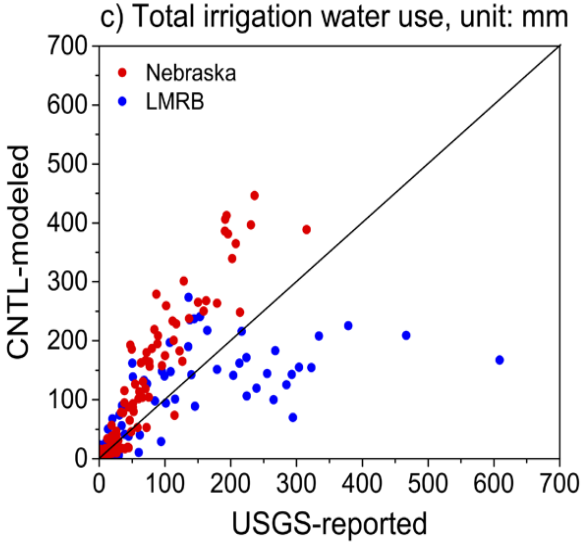


Crop irrigation modeling is constrained by MODIS 500-m irrigation fraction, USDA 30-m dominant crop types and fraction of each crop type, and USDA/NASA planting/harvest dates.

Modeling irrigation at regional scales

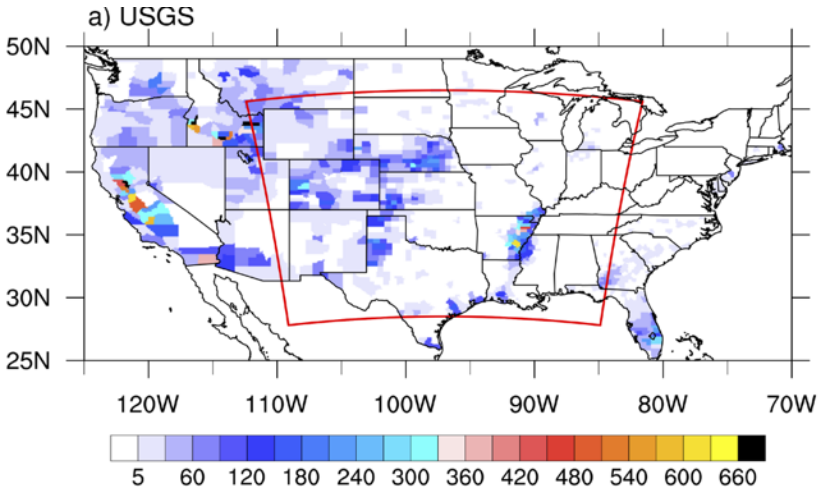


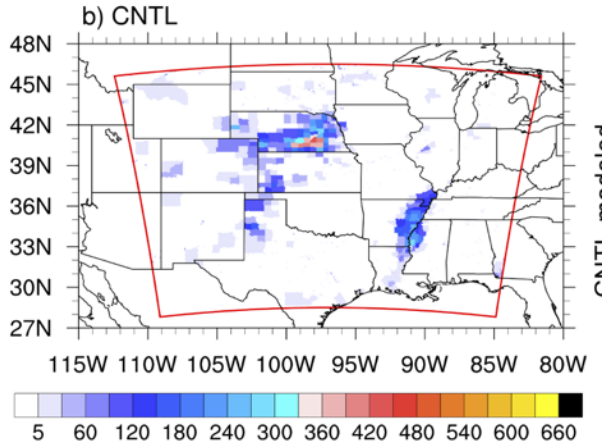


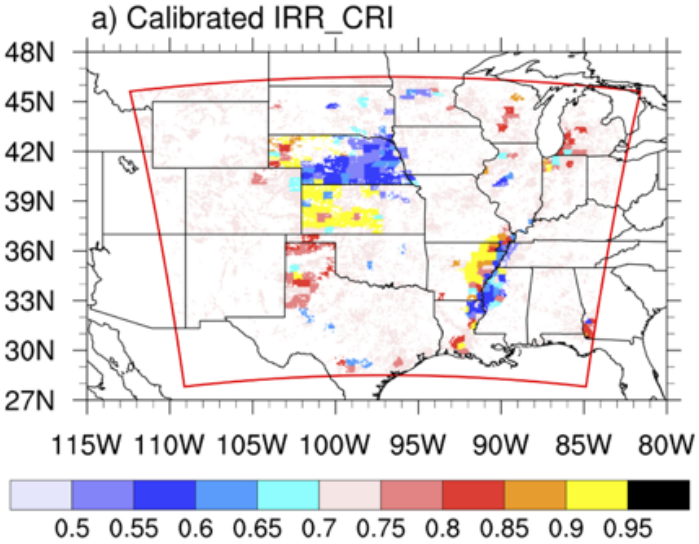


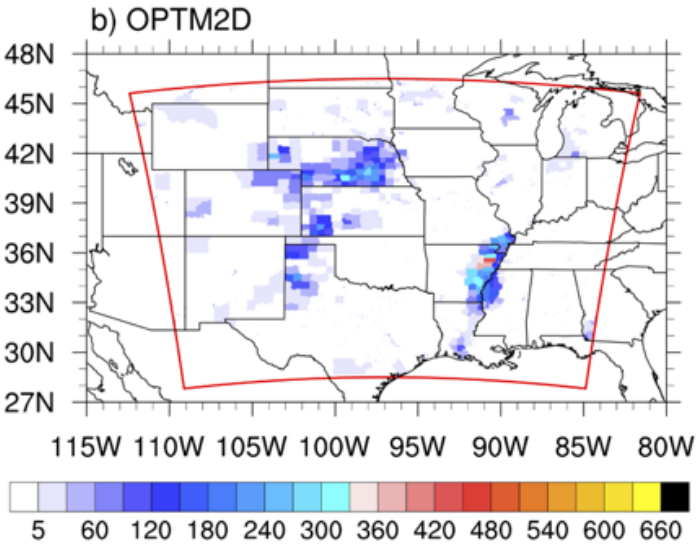
Compared to USGS county-level year 2000 annual irrigation withdrawals, the model using field-scale calibrated parameters overestimates irrigation amount in Nebraska, but underestimates it in Lower Mississippi River Basin.

Modeling irrigation at regional scales
Parameter calibration





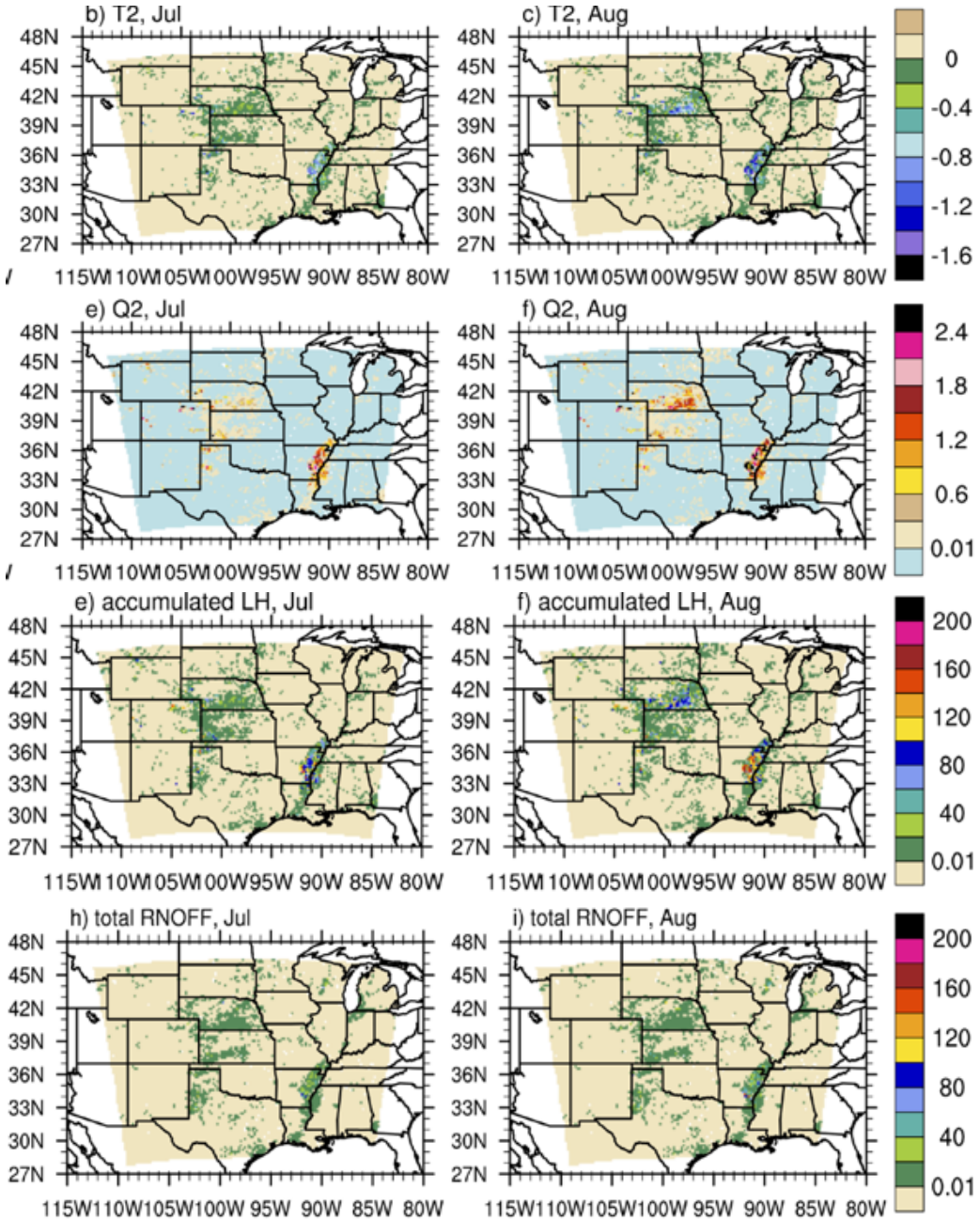




County-level calibrated IRR_CRI (soil moisture trigger criterion) values

Optimized simulation with calibrated IRR_CRI

Modeling hydrometeorological effects of irrigation



Reduce monthly temperature by 0.8~1.2 K in southeastern NE and by up to ~1.4 K in eastern AR

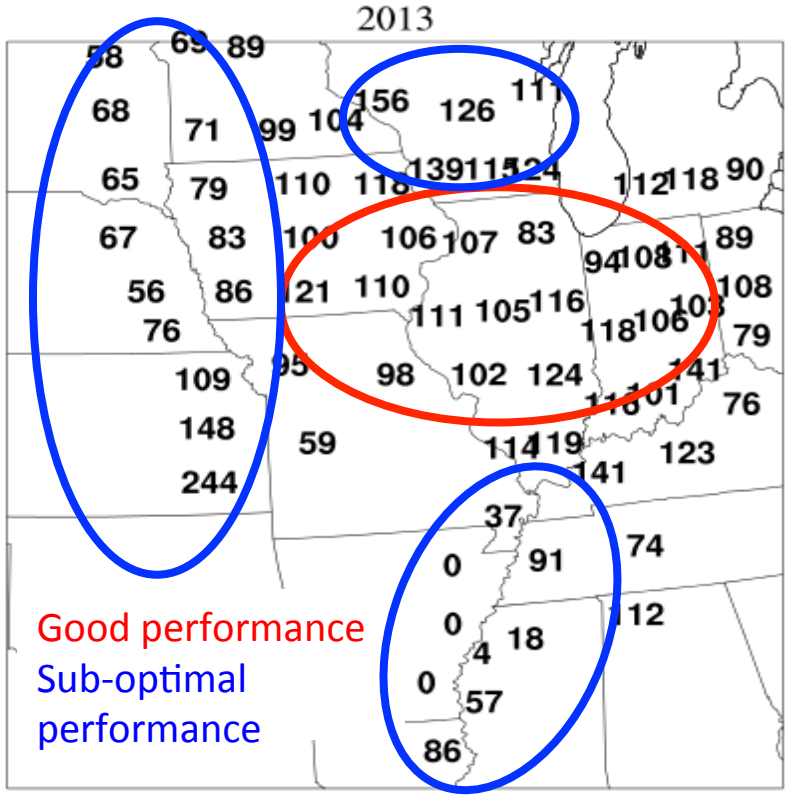
Increase air humidity by ~1.2~1.8 g kg^{-1} (NE) and 2.4 g kg^{-1} (AR)

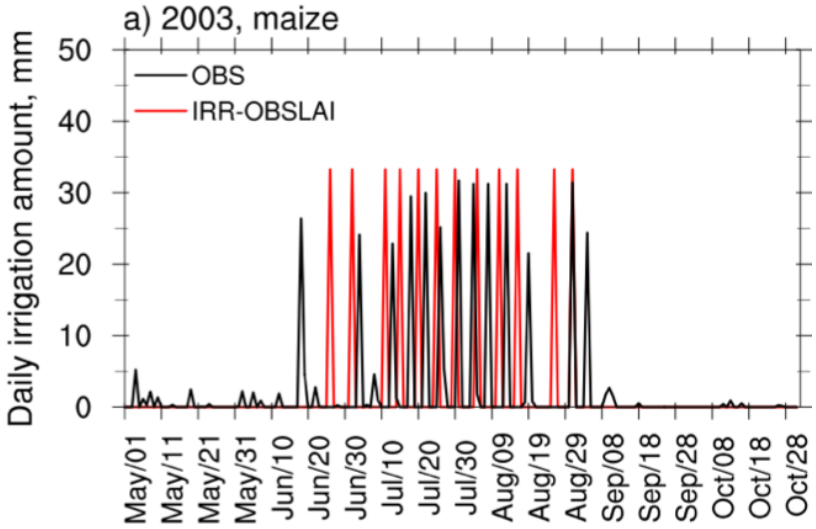
most of irrigation water are used to increase soil moisture and evaporation, rather than runoff.

- increase monthly evaporation by up to 80 mm in NE and ~120 mm in AR
- increase monthly total runoff by ~ 20 mm

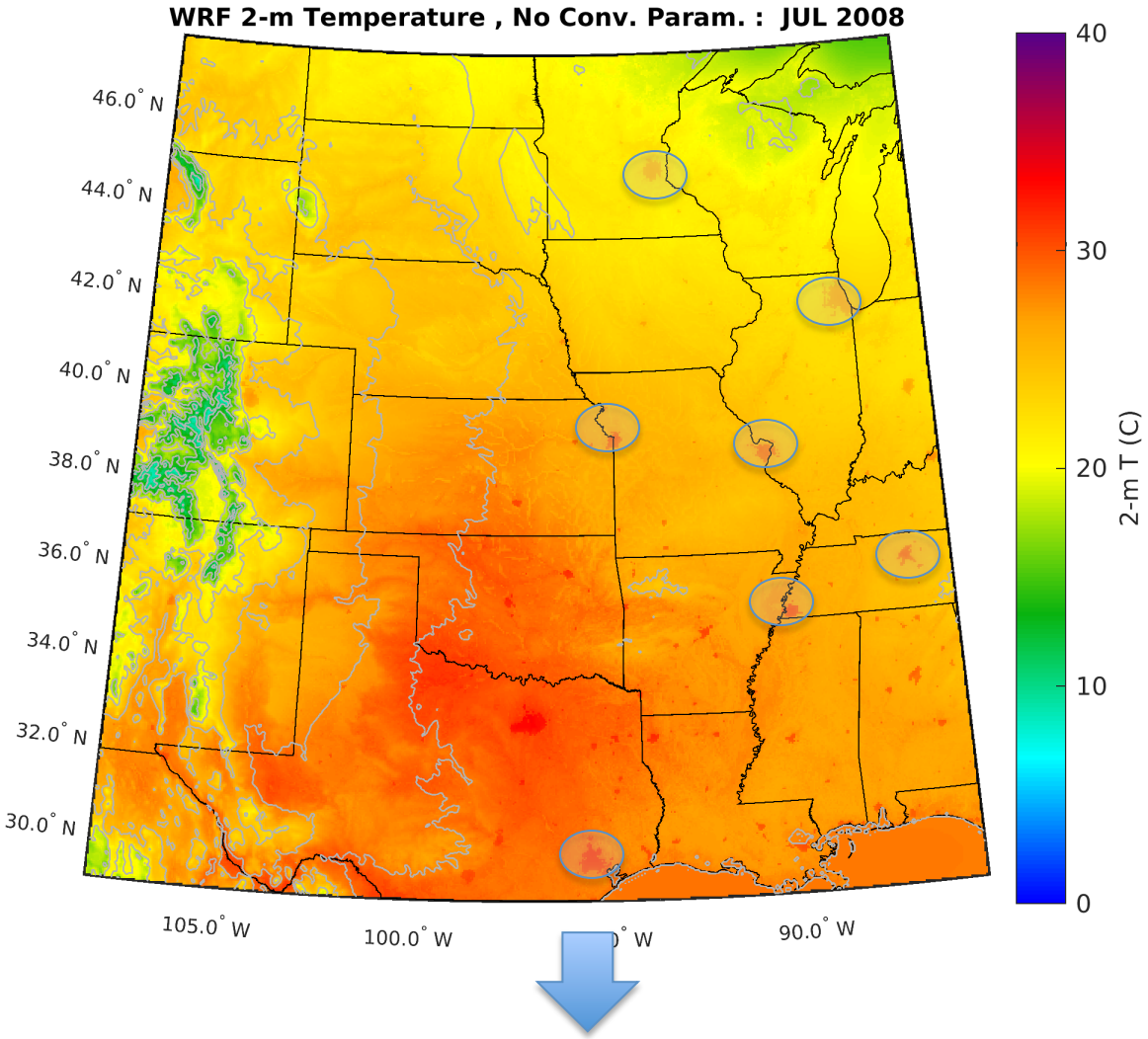
Lessons learned

- Regional calibration of crop and irrigation model parameters helps transition field-scale crop modeling to regional scales
- Integrating agriculture management data is key to constraining agriculture model solutions
- Need to connect irrigation with other water cycle components (underground water, reservoir, etc)





Convection-permitting regional climate modeling



Human-permitting modeling