Introduction to dynamic irrigation models in Noah-MP

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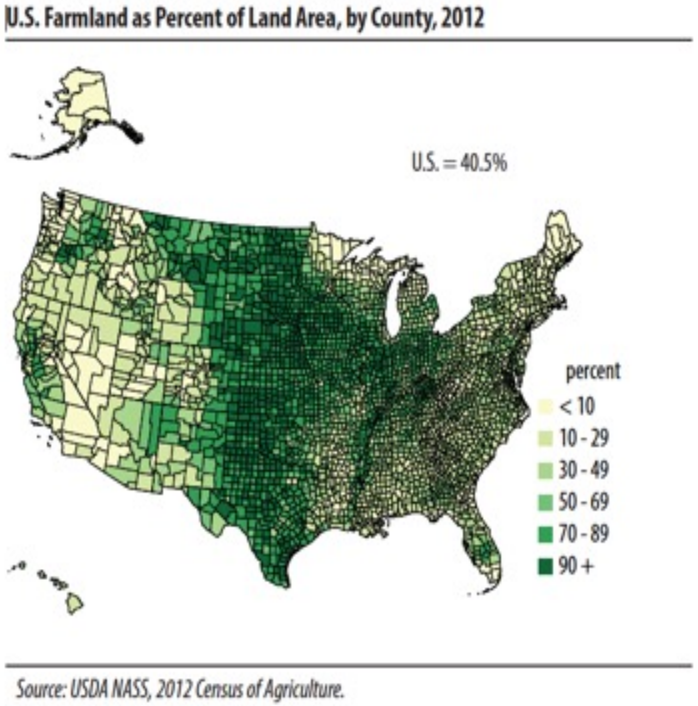
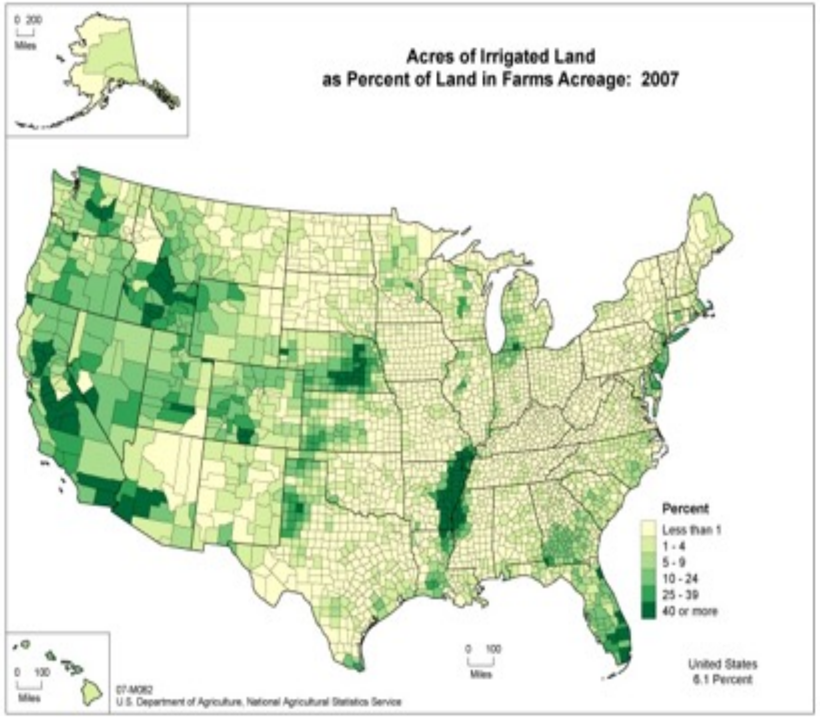
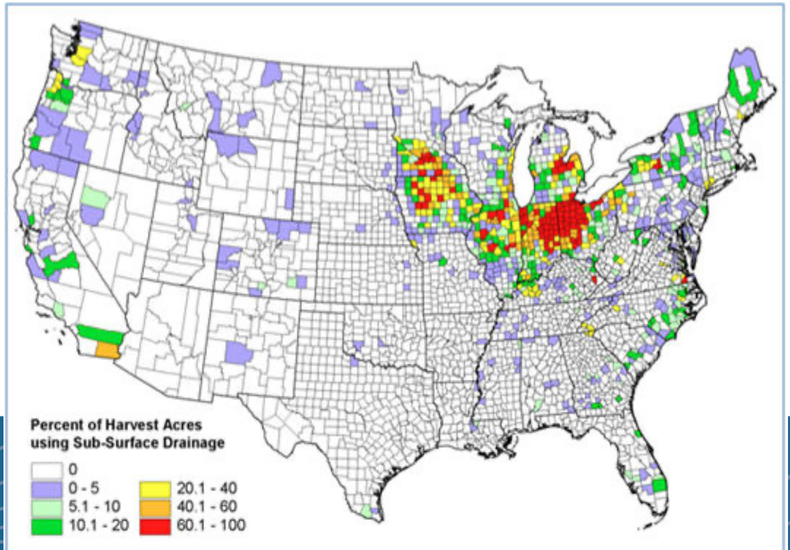
5 November 2021, GLASS/GHP Irrigation Initiative meeting

Agriculture Lands and Management in the U.S.

- 90% of some regions in Great Plains are agricultural lands.
- Irrigation in most Ag regions ~40% of total freshwater withdrawals.
- Extensive use of subsurface tile drainage in Upper Mississippi River Basin (UMRB).
- These ag processes modify surface and energy budgets and influence weather and climate

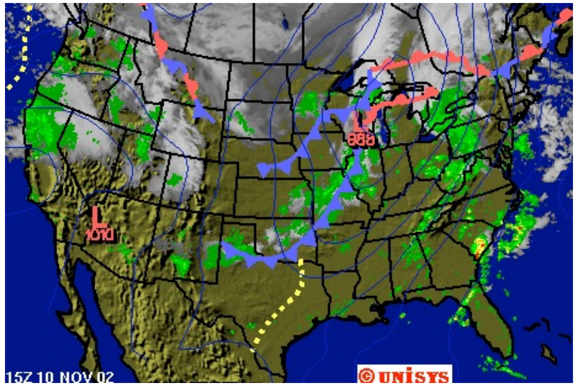




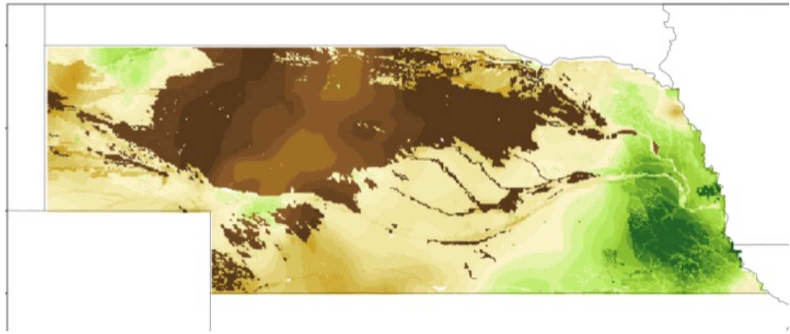


Agriculture Modeling Related Projects (NCAR/RAL/HAP)

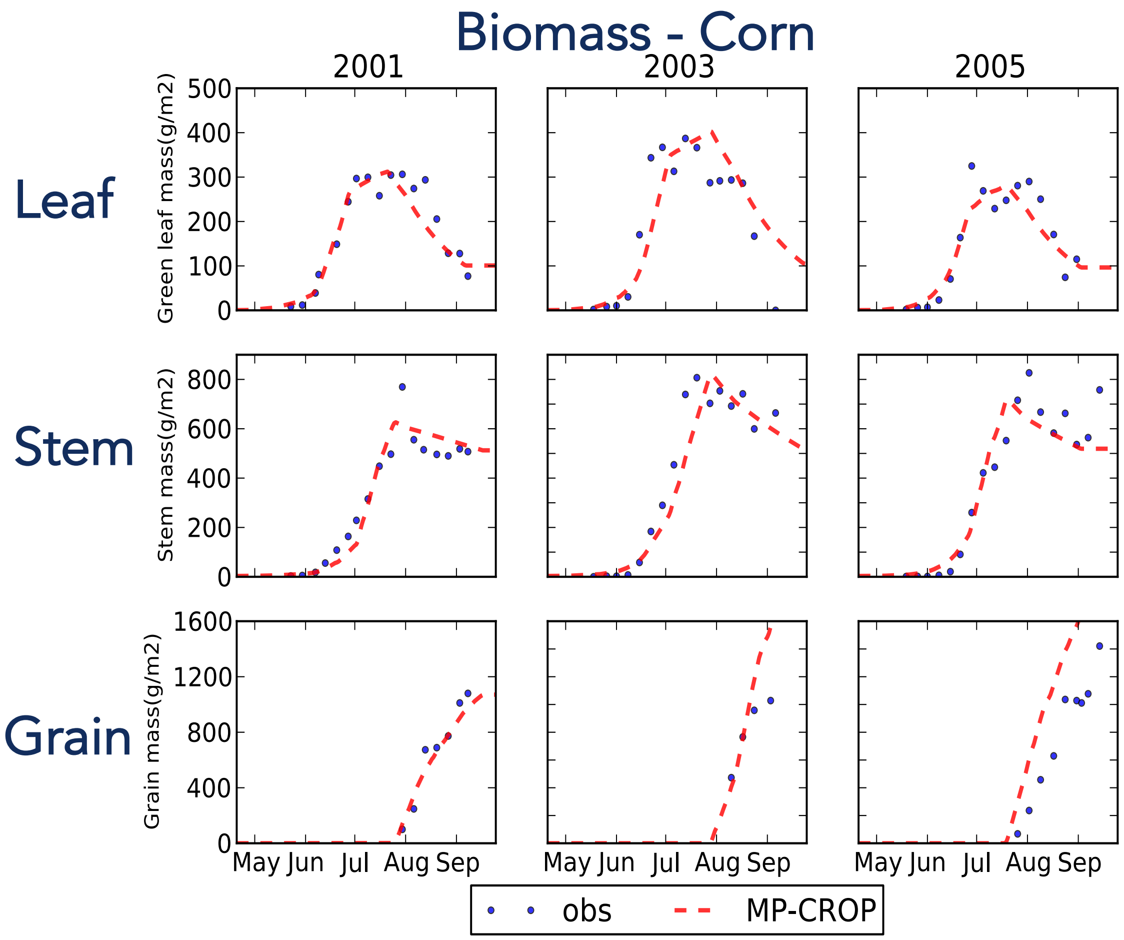
- NSF/USDA EaSM (collaboration with ASU): couple urban and agriculture models to the Weather Research and Forecasting (WRF) model coupled to Noah-MP.
- NSF INFEWS (collaboration with GMU): develop field-scale irrigation forecast to save 10% irrigation water in Nebraska.
- NOAA JTTI (collaboration with ISU): improve representation of crop/irrigation/tile-drainage processes in the operational National Water Model using the Noah-MP.
- NCAR Water System: crop-atmosphere interactions in WRF 4-km regional climate simulations over CONUS.



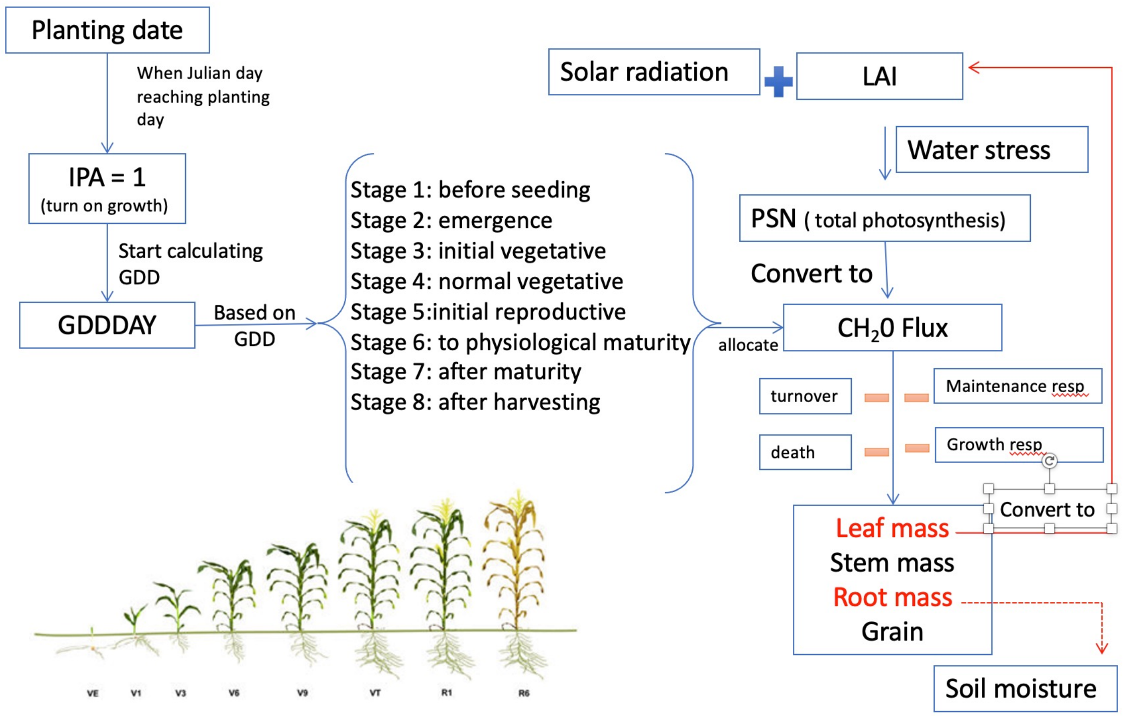
Soil Moisture [volumetric]

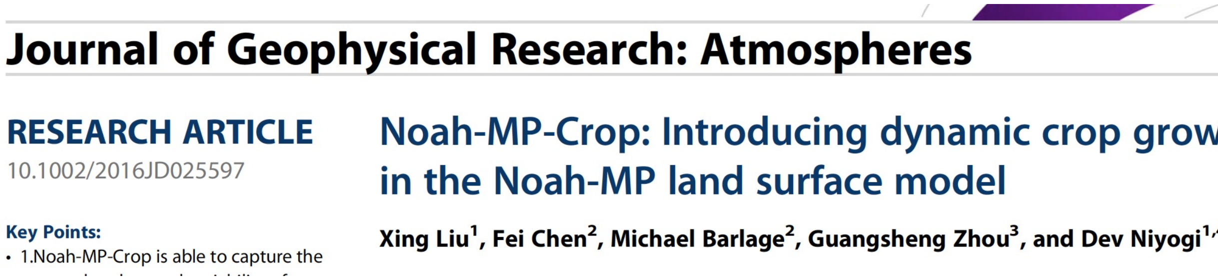


- **Understand the crop-water-atmosphere nexus from continental scales to field scales**
- **Develop modeling tools to predict crop yield and irrigation demand for Ag decision systems**



Noah-MP-Crop Model Framework





Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1002/2016JD025597

Noah-MP-Crop: Introducing dynamic crop grow in the Noah-MP land surface model

Xing Liu[1], Fei Chen[2], Michael Barlage[2], Guangsheng Zhou[3], and Dev Niyogi[1,

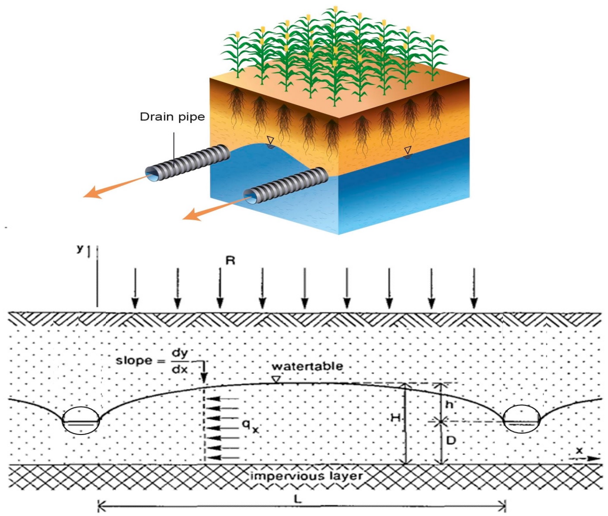
Key Points:
- 1.Noah-MP-Crop is able to capture the

Field scale evaluations using AmeriFlux data from 1) Bondville, IL (2001, 2003, 2005), corn, rainfed; and 2) Mead, NE (2002, 2004, 2006), soybean, rainfed.

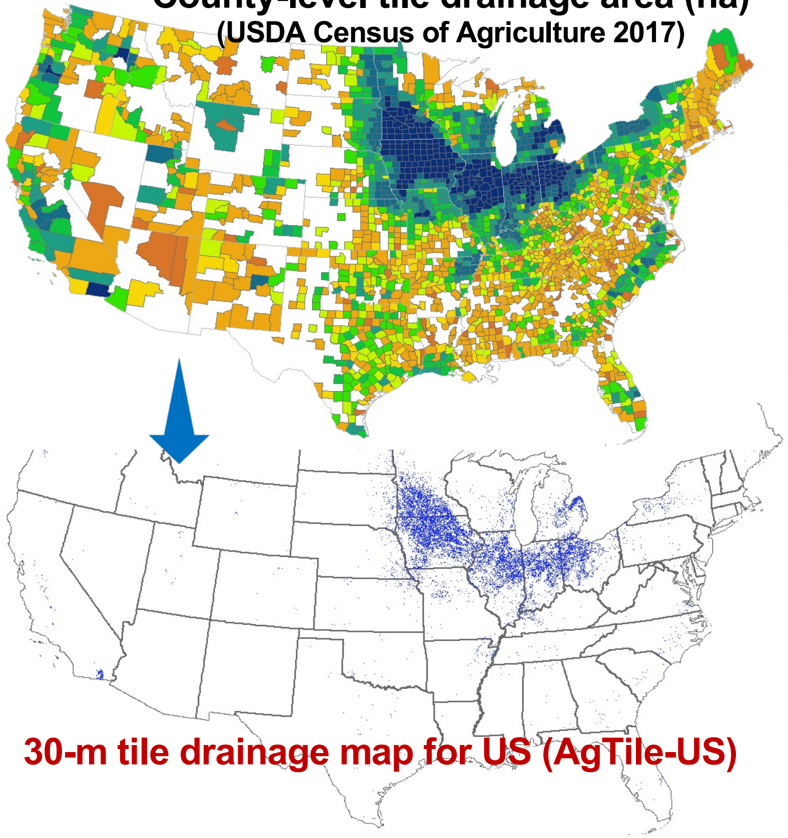
MAE: Mean Absolute Error (Unit: g/m2)

Develop a tile drainage parameterization and high-resolution mapping of tile drained croplands for National Water Model

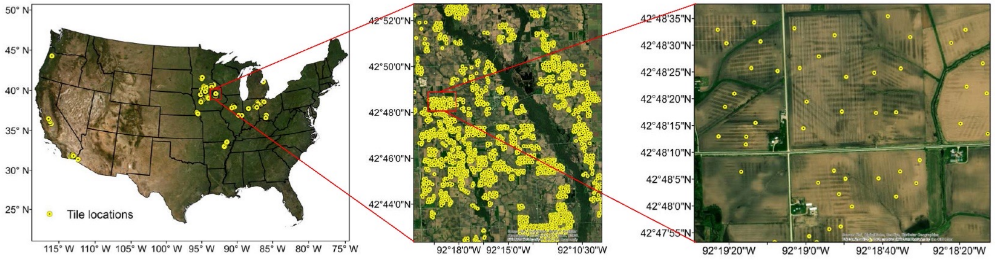
Implemented the Hooghoudt equation-based tile-drainage parameterization.



County-level tile drainage area (ha)
(USDA Census of Agriculture 2017)



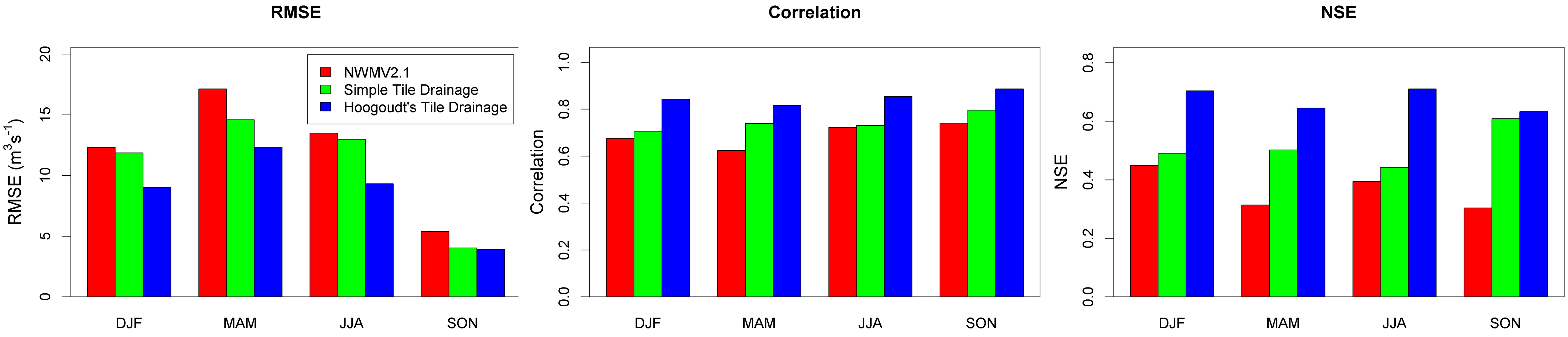
30-m tile drainage map for US (AgTile-US)



30-m AgTile-US data: Valayamkunnath et al. 2020: Scientific Report.

Impact of tile-drainage modeling on surface water cycle: Valayamkunnath et al. 2021: WRR, in review

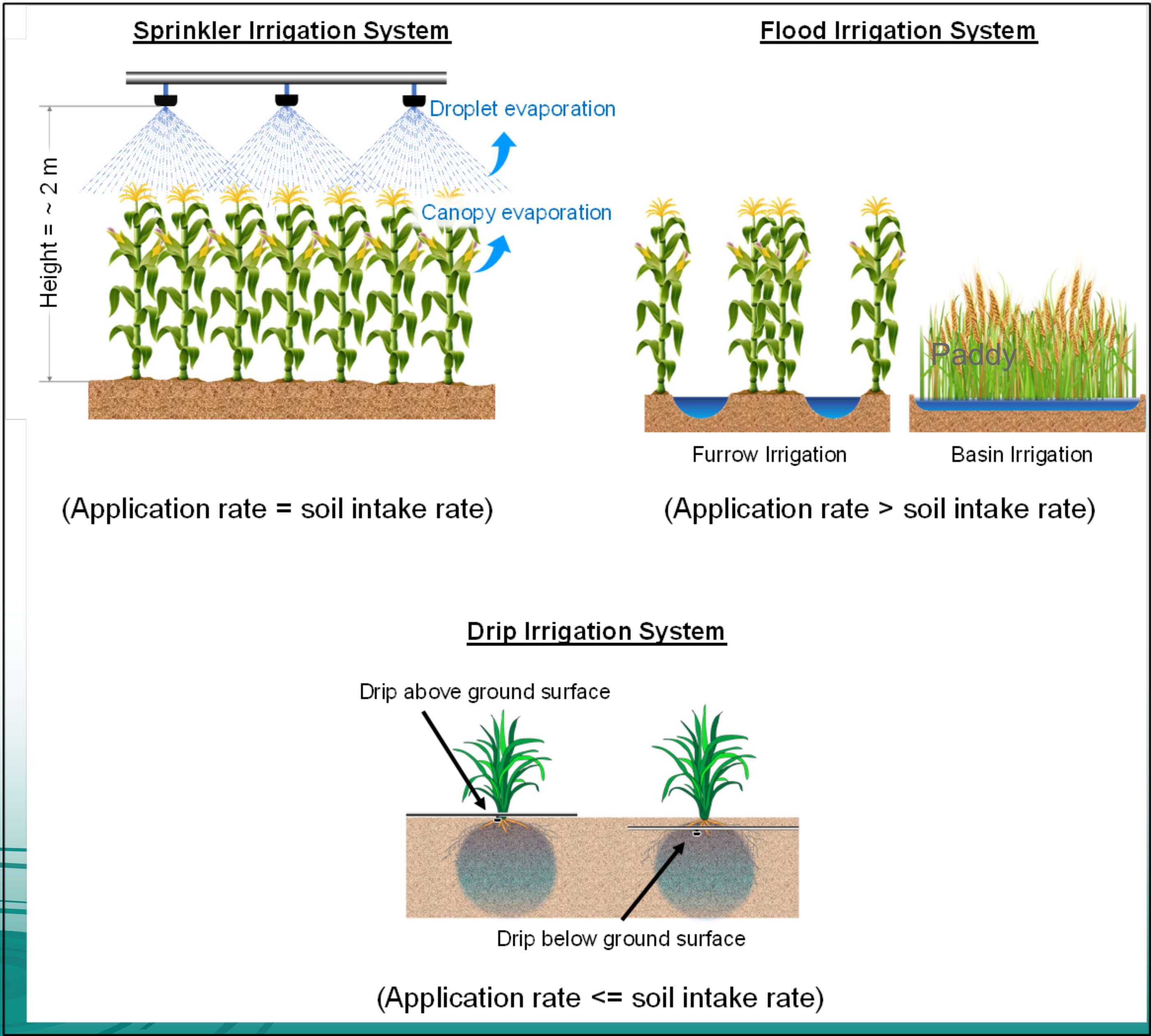
The new tile-drainage improved National Water Model streamflow prediction (Valayamkunnath et al. 2021)



NWMV2.1 Simple Tile Drainage Hoogoudt's Tile Drainage

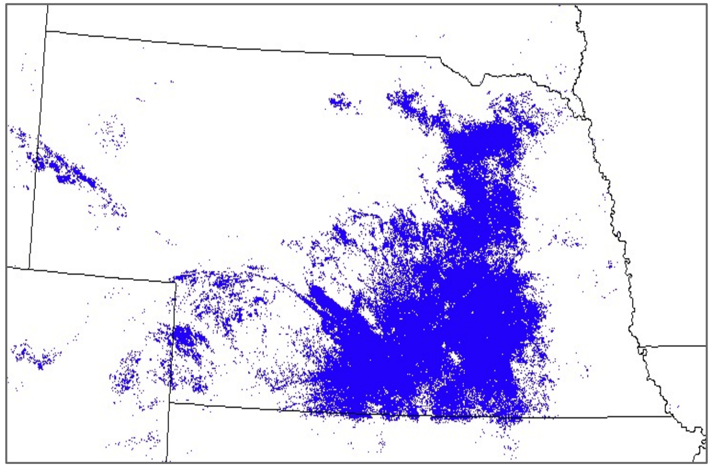
Development of Dynamic Irrigation Schemes for Noah-MP

- Implemented a new dynamic irrigation scheme in Noah-MP and the National Water Model
  - Consider three methods of irrigation
  - Consider sprinkler evaporation
  - Use irrigation area data and Leaf Area Index to constrain models
  - Trigger function = Management allowable deficit (MAD)



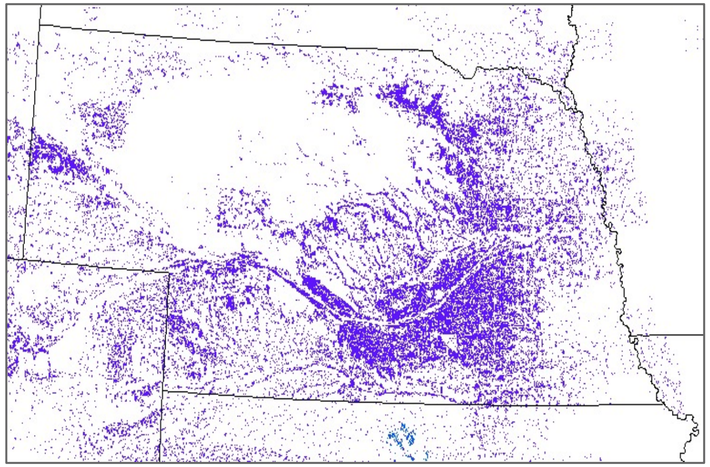
Data used to constrain irrigation models

500-m MODIS Global (Salmon et al., 2015)



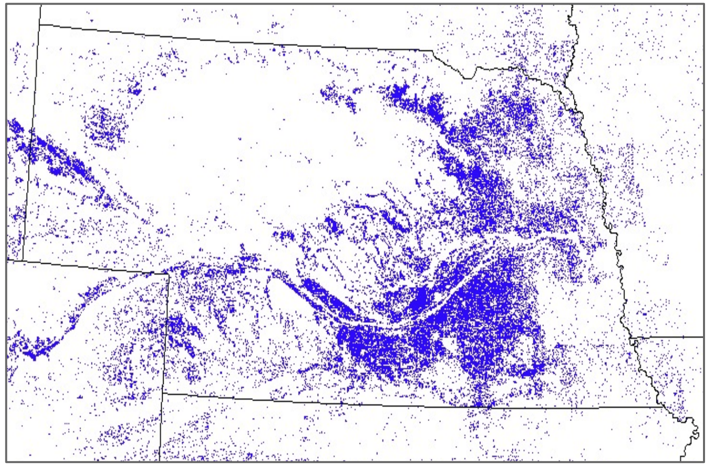
- Overestimated irrigated area compared to MIrAD-US

250-m MIrAD-US (USGS)



USGS irrigation census based data

Global 30-second Global: Meier et al., (2018)

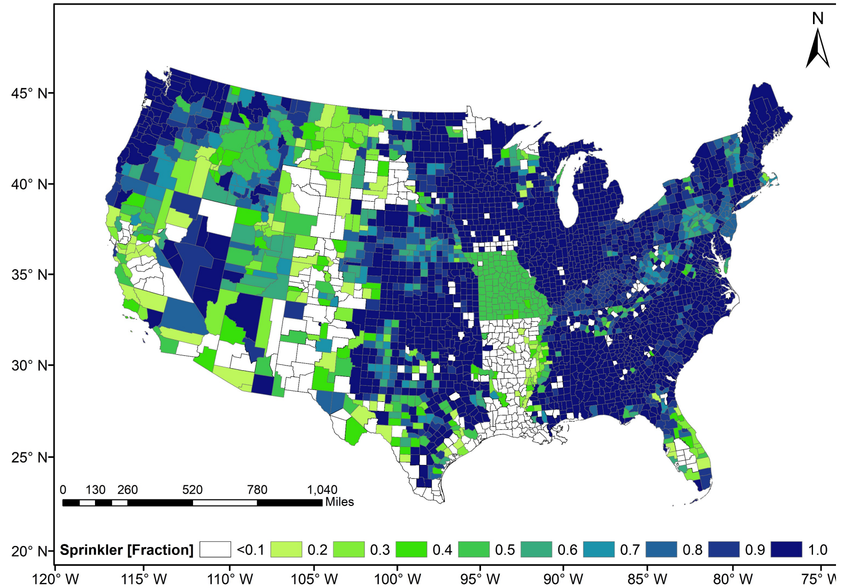


Well-Captured the MIrAD-US irrigated area pattern compared to MODIS Global

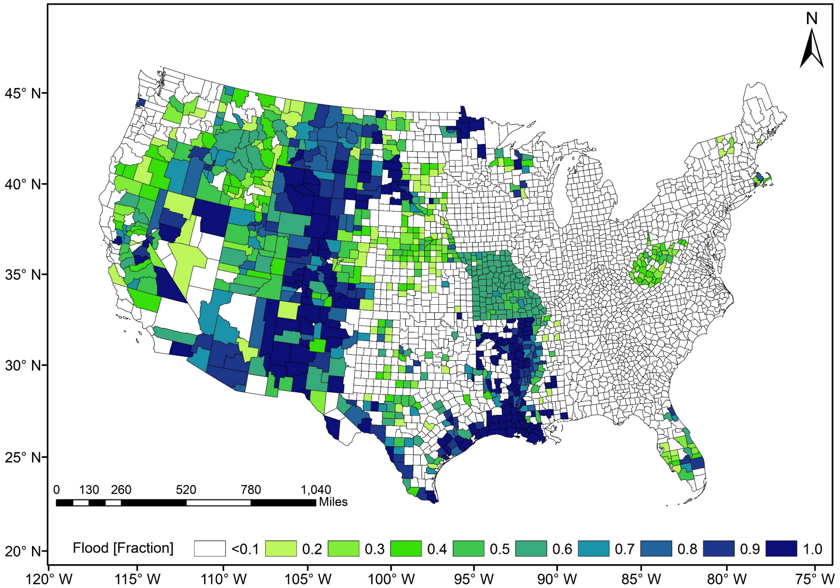
Data used to constrain irrigation models

- 30-meter USDA/GMU crop frequency data
- 250-m MIrAD-US (USGS) for US and Meier's 30-seoncd for globe
- U.S. state-level planting and harvest data, ⅛° climate spatially-varying GDD for crop growth

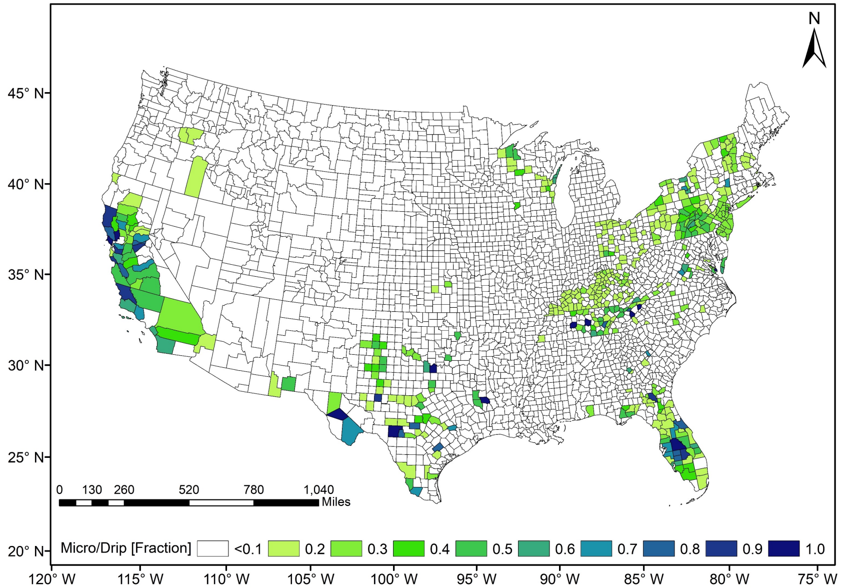
Sprinkler irrigation fraction [-]



Flood irrigation fraction [-]

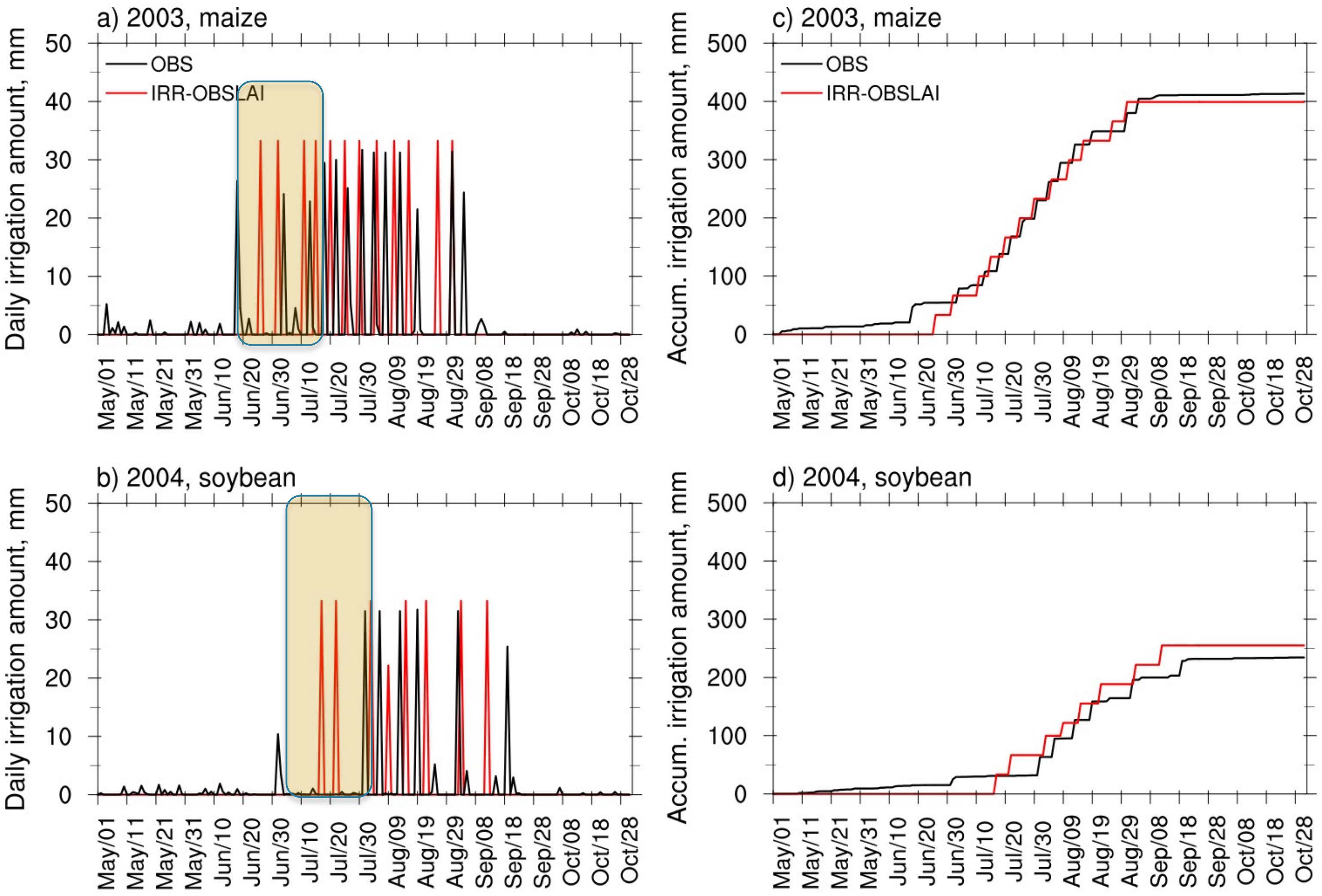


Micro irrigation fraction [-]



Data Source: USGS County-level water use 2015

Figures from Prasanth Valayamkunnath



Challenge in modeling irrigation


JAMES Journal of Advances in Modeling Earth Systems

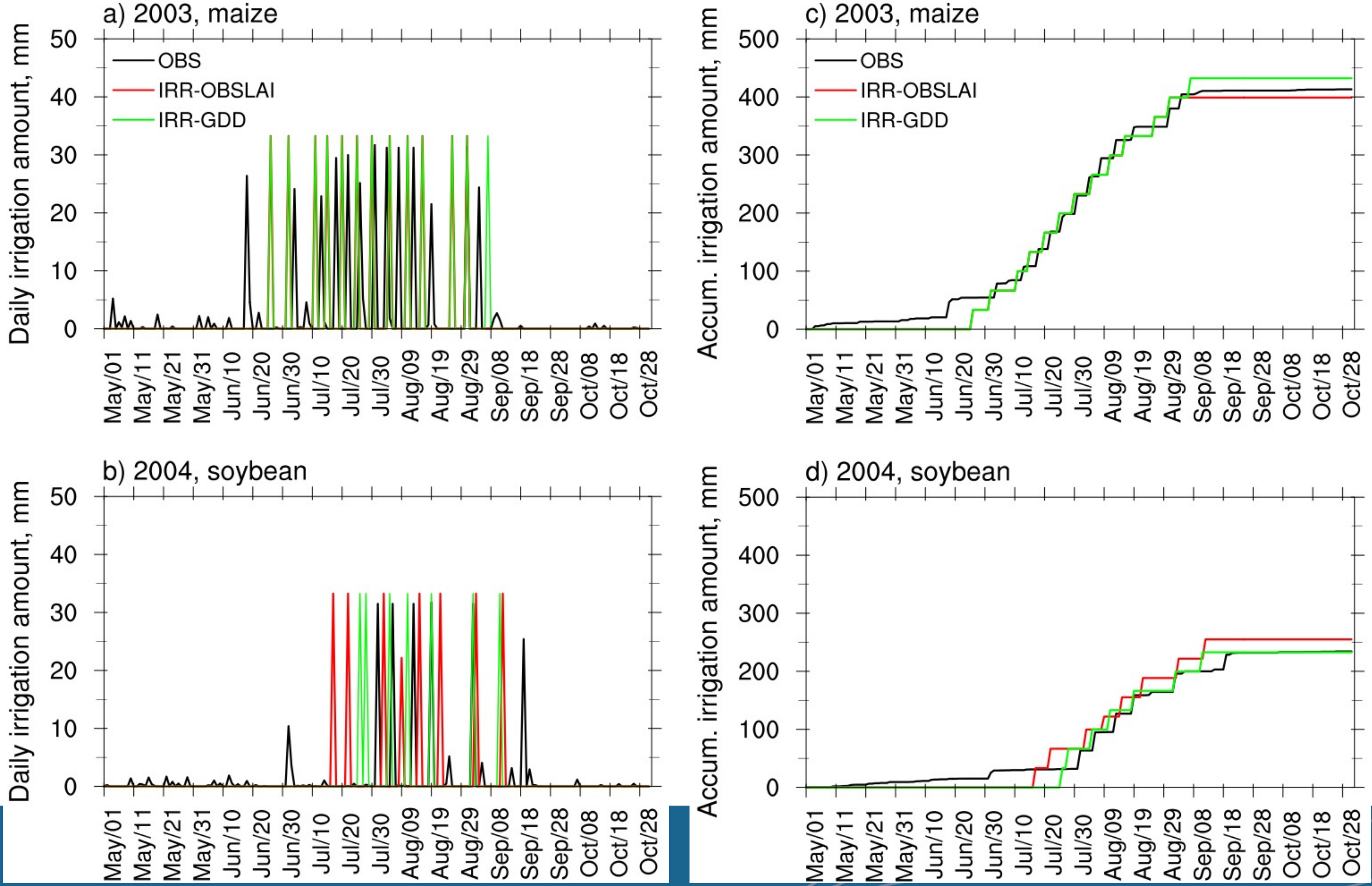
RESEARCH ARTICLE
10.1029/2018MS001595

Key Points:
- A dynamic irrigation scheme was incorporated into Noah-MP, using soil moisture availability and crop

Lessons Learned From Modeling Irrigation From Field to Regional Scales

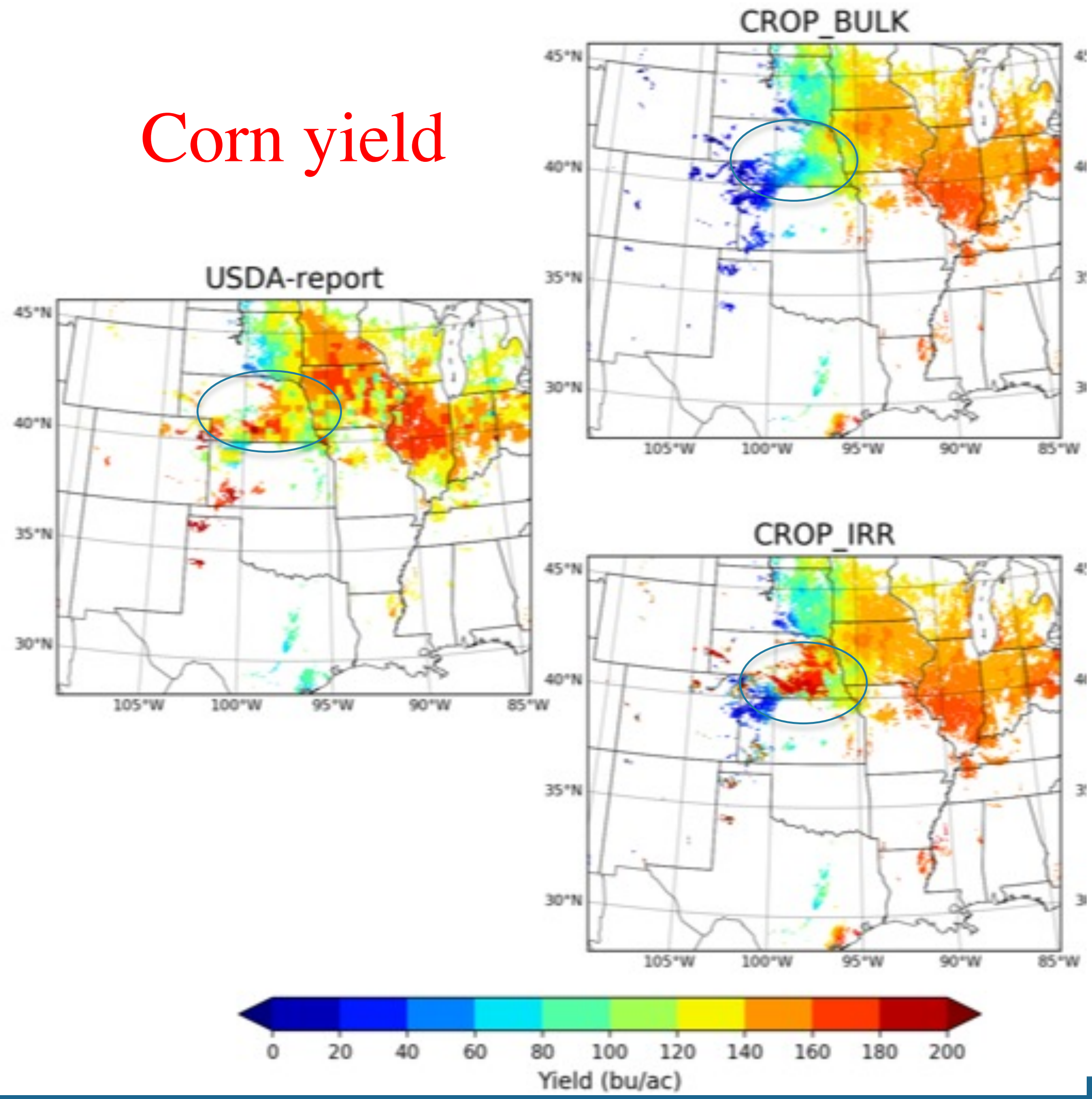
Xiaoyu Xu[1,2], Fei Chen[3], Michael Barlage[3], David Gochis[3], Shiguang Miao[2], and Shuanghe Shen[1]

Enhance irrigation scheme by including GDD (growing degree days): Activate irrigation: GDD>280 for corn, GDD >560 for soybean



Joint simulation of crop growth and irrigation for central U.S.

Corn yield



Well simulated corn yield in rainfed region

Simulation without irrigation underpredicted yield in irrigated region (Nebraska)

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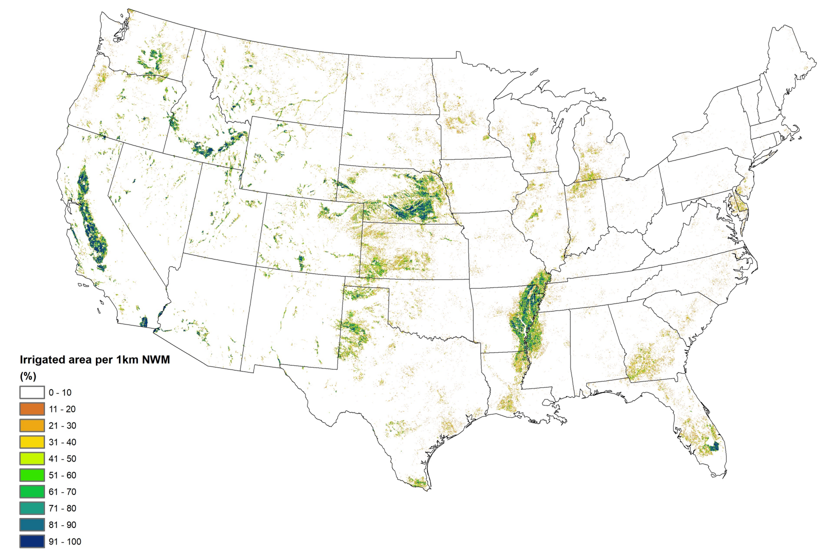
10.1029/2020MS002159

Key Points:
- Joint modeling of crop growth and irrigation improves crop-yield simulation in irrigated regions
- Applying the state-level planting date helps improve the

Joint Modeling of Crop and Irrigation in the central United States Using the Noah-MP Land Surface Model

Zhe Zhang[1,2], Michael Barlage[3], Fei Chen[3], Yanping Li[1,2], Warren Helgason[1,4], Xiaoyu Xu[5], Xing Liu[6], and Zhenhua Li[1,2]

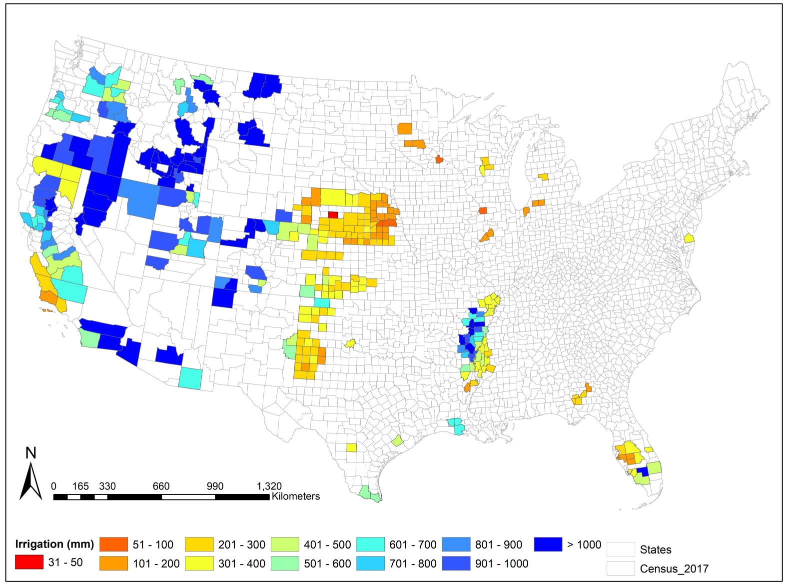
Irrigation fraction (%) on 1km NWM grid



Continental-scale irrigation-model calibration over 747 heavily-irrigated counties and regionalization

Irrigation model parameters

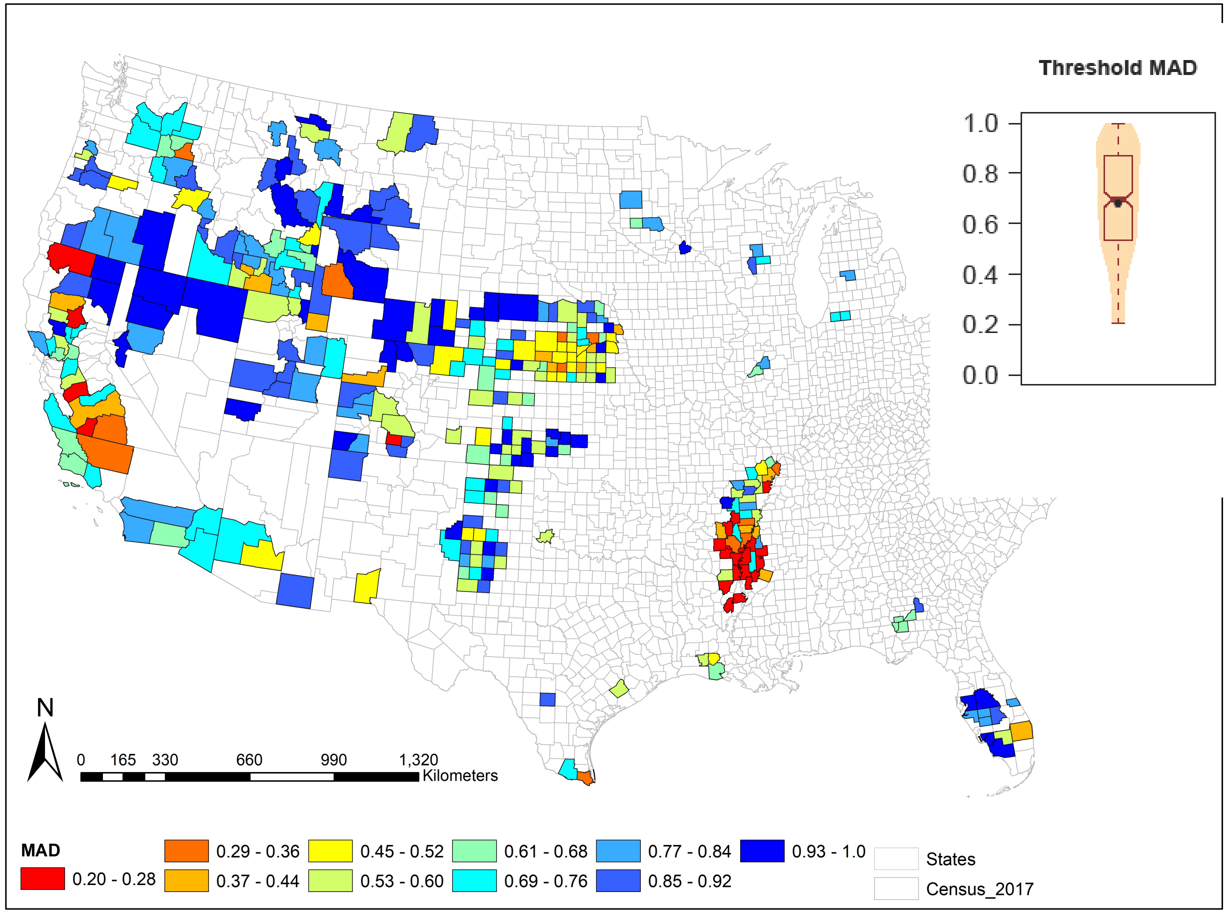
IRR_FRAC	= 0.10	! Irrigation Fraction
IRR_LAI	= 0.05	! Minimum LAI to trigger irrigation
IRR_MAD	= 0.50	! Management Allowable Deficit (0-1)
FILOSS	= 0.10	! fraction of flood irrigation loss (0-1)
SPRIR_RATE	= 6.40	! mm/h, sprinkler irrigation rate
MICIR_RATE	= 1.38	! mm/h, micro irrigation rate
FIRTFAC	= 1.00	! flood application rate factor
IR_RAIN	= 1.00	! maximum precipitation to stop irrigation trigger



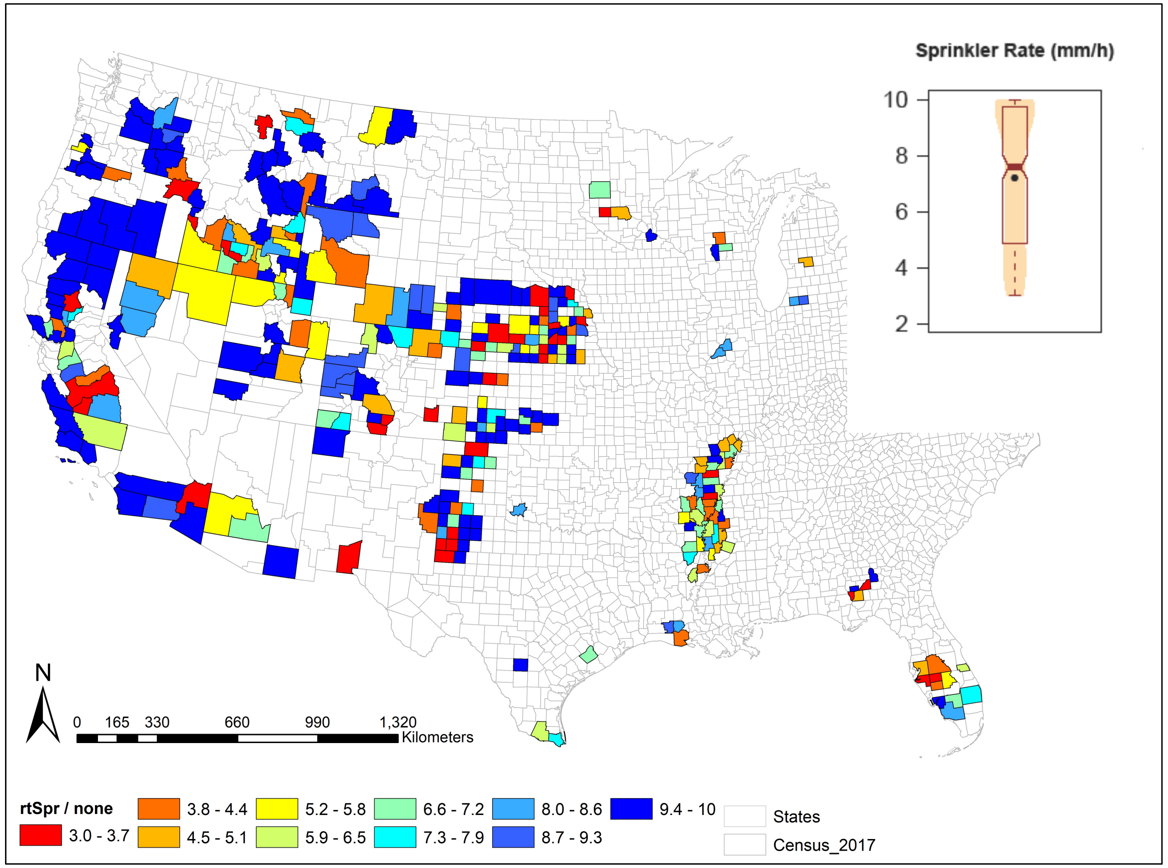
USGS county-level irrig water amount (mm)

Spatial distribution of calibrated parameter distribution

Management Allowable Deficit

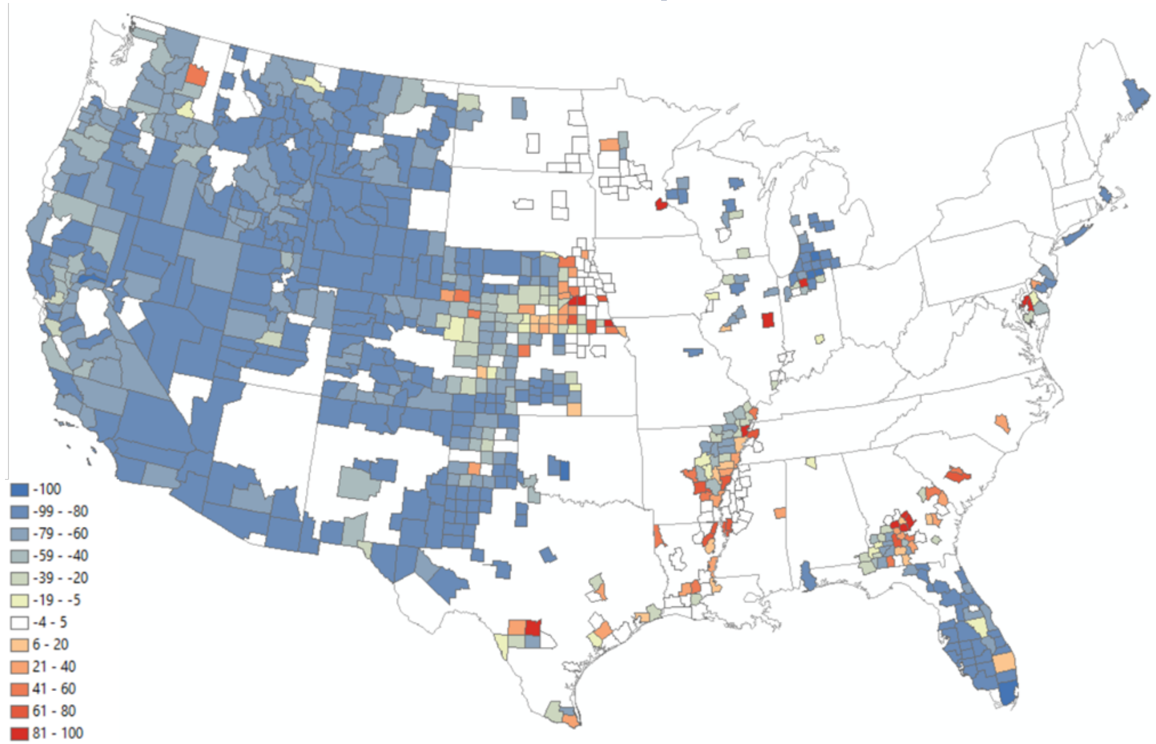


Sprinkler Rate (mm/h)

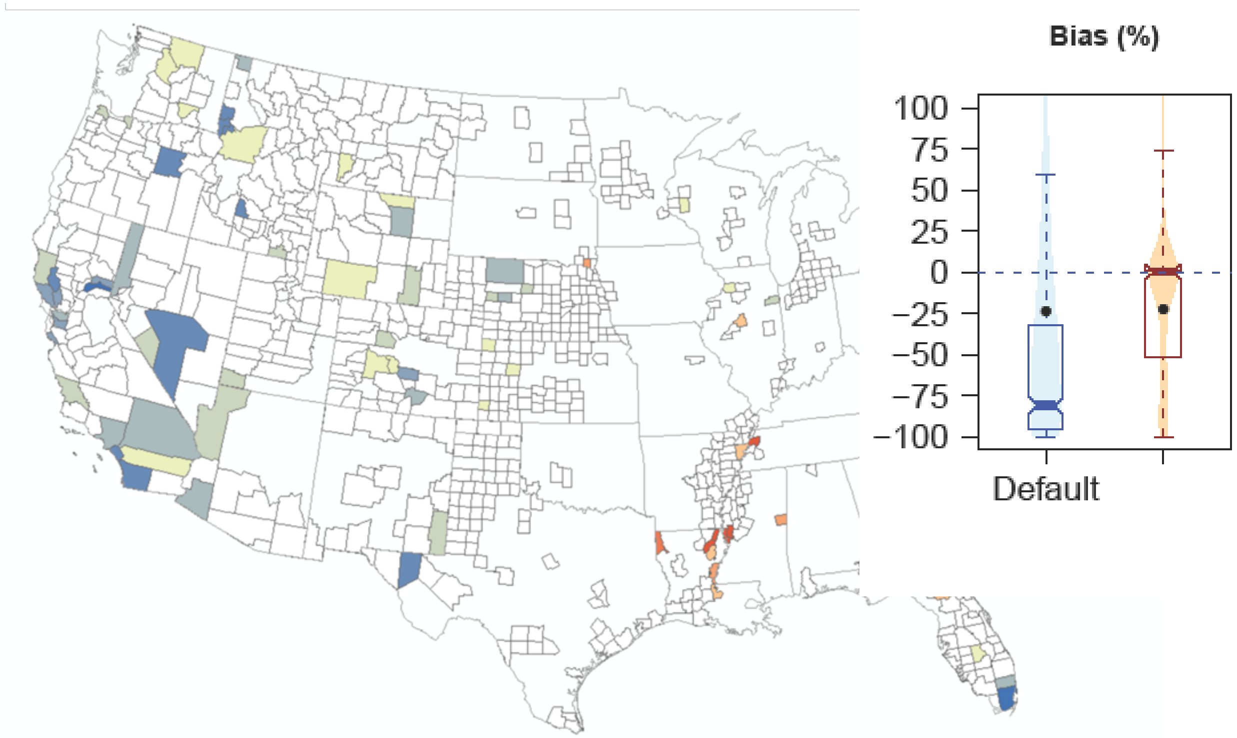


County-level comparison of irrigation model performance: Default Vs Calibrated Bias (%)

With default parameters



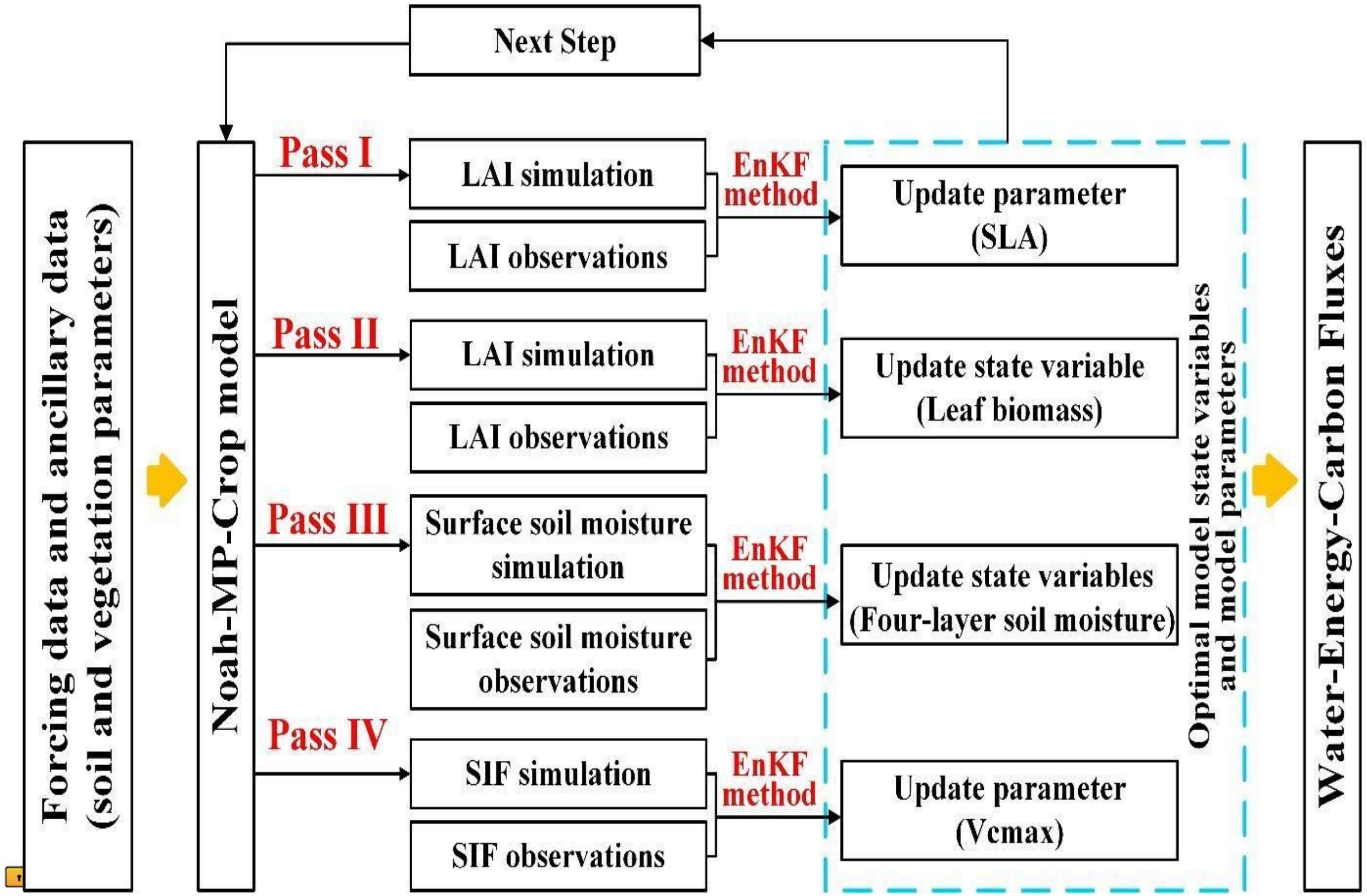
With calibrated parameters



- Irrigation scheme generally underestimated irrigation water
- Calibration improvements low biases, especially over the heavily irrigated counties of the CONUS.

Irrigation and Ag modeling allows for assimilating more and new land-related data

Develop a multi-pass land data assimilation scheme (MLDAS) based on EnKF and Noah-MP-Crop to jointly assimilate satellite soil moisture and crop data: leaf area index (LAI), and solar-induced chlorophyll fluorescence (SIF).



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10.1029/2020MS002394

Key Points:

- The Multipass Land Data Assimilation Scheme (MLDAS) is proposed based on the Noah-MP-Crop model
- Leaf area index (LAI), soil moisture (SM), and solar-induced chlorophyll fluorescence (SIF) measurements are assimilated into the MLDAS to predict sensible heat flux (*H*), latent

Improve the Performance of the Noah-MP-Crop Model by Jointly Assimilating Soil Moisture and Vegetation Phenology Data

Tongren Xu[1], Fei Chen[2], Xinlei He[1], Michael Barlage[2], Zhe Zhang[3], Shaomin Liu[1], and Xiangping He[1]

[1]State Key Laboratory of Earth Surface Processes and Resource Ecology, School of Natural Resource, Faculty of Geographical Science, Beijing Normal University, Beijing, China, [2]National Center for Atmospheric Research, Boulder, CO, USA, [3]School of Environment and Sustainability, University of Saskatchewan, Saskatoon, SK, Canada

Hydroclimatic impacts of crop irrigation

Impact of irrigation on air temperature simulated by Earth system models:

- Insignificant (Fowler and Helvey 1974)
- 0.5 C^{o} reduction(Sacks et al 2009)
- 3.7 C^{o} reduction (Kueppers et al 2007)
- 10 C^{o} reduction (Lobell et al 2009)

- Why such discrepancies in ESM simulations?

Environmental Research Letters

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Memory of irrigation effects on hydroclimate and its modeling challenge

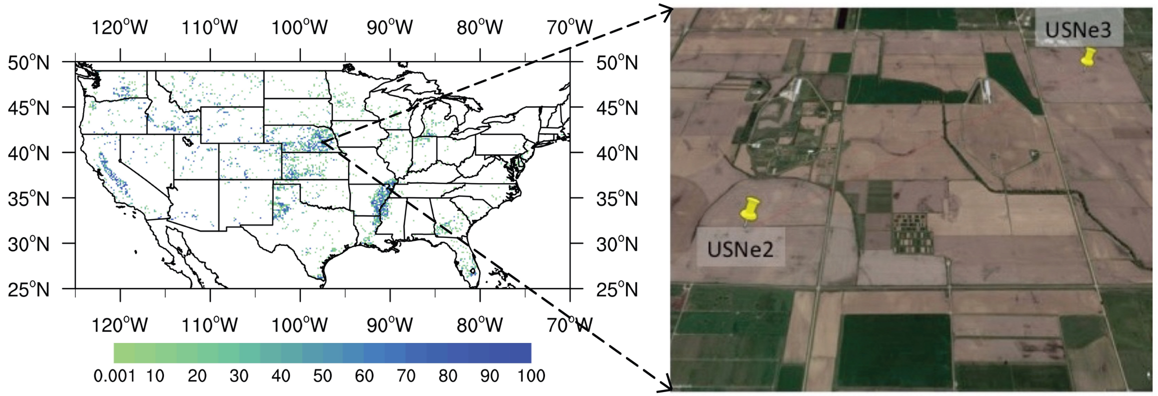
Fei Chen[1,2], Xiaoyu Xu[3,4,6], Michael Barlage[1], Roy Rasmussen[1], Shuanghe Shen[3], Shiguang Miao[4] and Guangsheng Zhou[5]

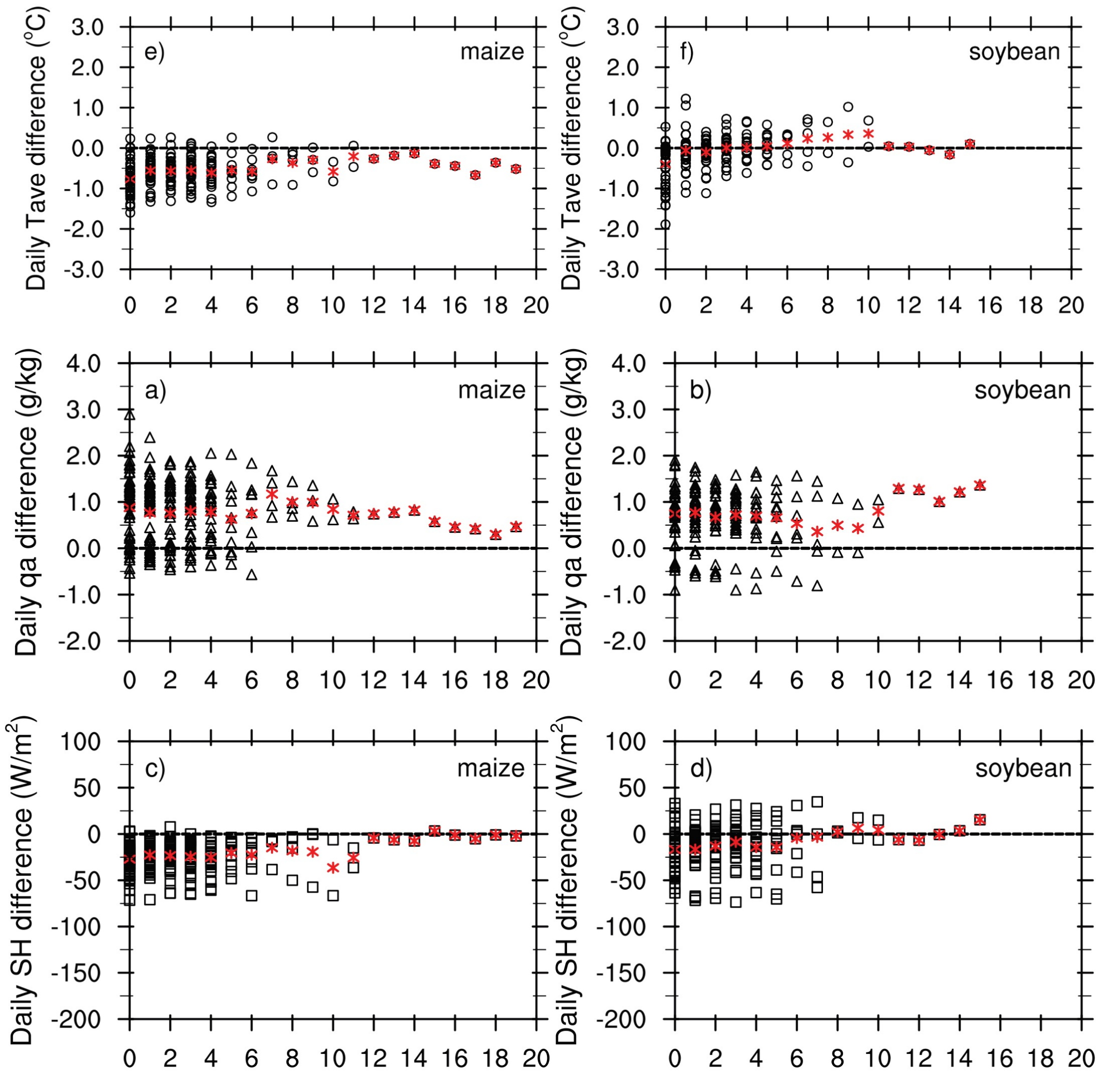
RECEIVED
3 January 2018

REVISED
13 March 2018

Hydroclimatic impacts of crop irrigation

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





- Irrigation reduce air temperature by ~1 C^o, increase water vapor by 1 g/kg, reduce sensible heat flux by 25 W/m2; the memory last ~ 10 days
- Bigger impact and longer memory for corn

Lessons learned

- Capturing the timing of irrigation (important for land-atmosphere interactions, PBL) is more challenging than modeling the irrigation amount
- Calibration of key irrigation model parameters seems necessary; need to develop parameter regionalization strategies
- Need more observations to evaluate and constrain models
- How to transition irrigation models from field to regional to global scales?
- How to transition irrigation models from one region to another? Human-, and crop specie – dependent
- How to reduce uncertainties in modeling irrigation in ESMS?

Thank you!

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