Modeling Corn Belt Drainage: Seasonal differences driven by hydroclimate controls

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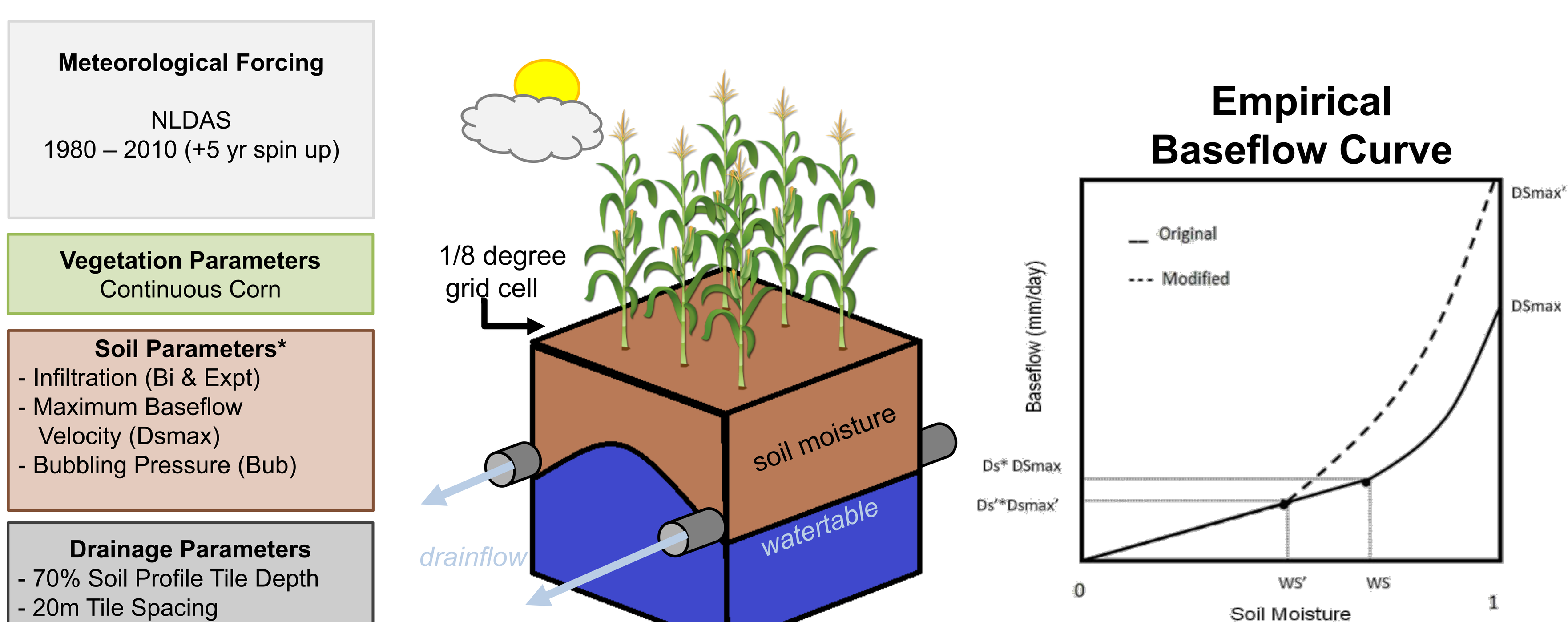
Why Simulate Regional Drainage?

- Corn Belt agriculture depends on tile systems to help transport excess water away from poorly drained fields to improve trafficability and enhance crop yield.
- Field studies on subsurface drainage are limited spatially and temporally.
- Simulation studies can help us understand the regional variability in hydroclimate controls on drainage, such as precipitation and cold processes.
- Seasonal differences in subsurface drainage may influence the effectiveness of best management practices, such as drainage water recycling (DWR), across the region.

The VIC Model Drainage Algorithm

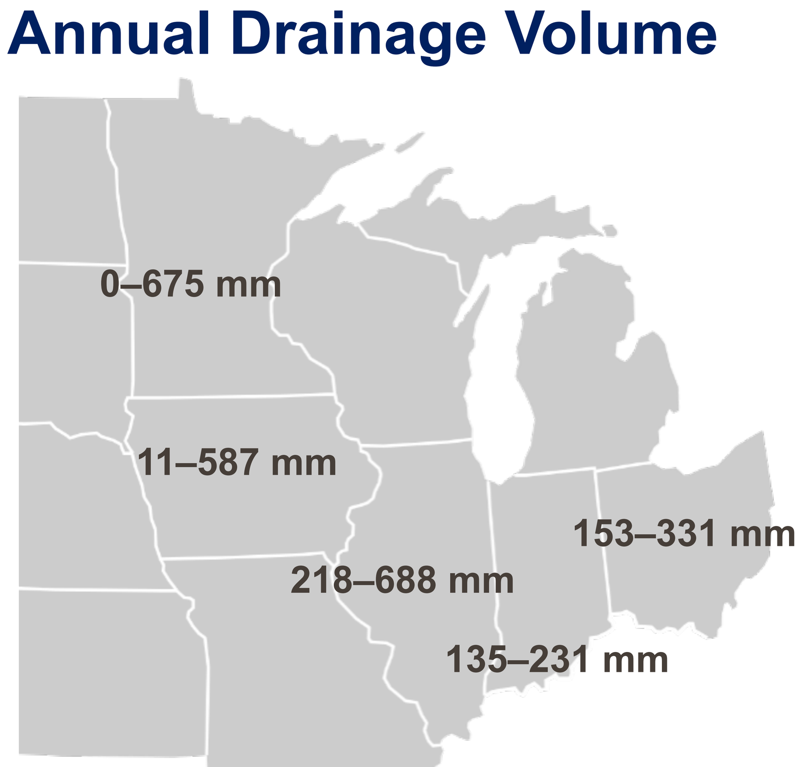


*sub-set of soil parameters focused on in this analysis are derived from POLARIS physical soil properties for counties with >0% sub-surface drainage in domain

The increase in subsurface flow produced by drainage systems is represented by modifying the empirical baseflow curve to match the maximum drainage rate predicted by the ellipse equation, which is impacted by tile depth and spacing.

Observed Drainflow (1987 – 2010)

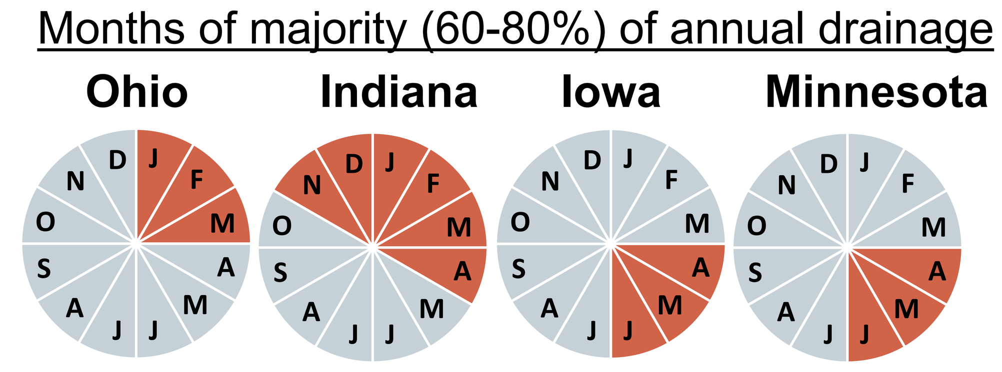
Annual Drainage Volume



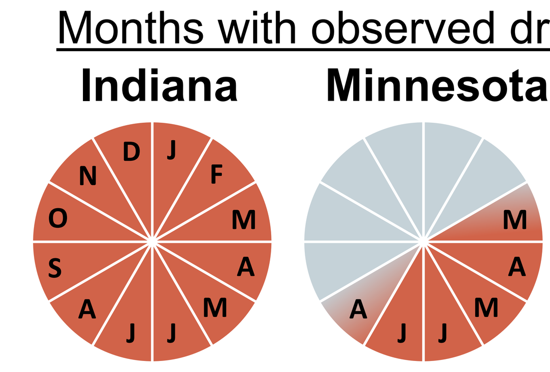
6 – 63% of annual precipitation (Kladviko et al., 2001)

Annual Drainage Timing

Months of majority (60-80%) of annual drainage



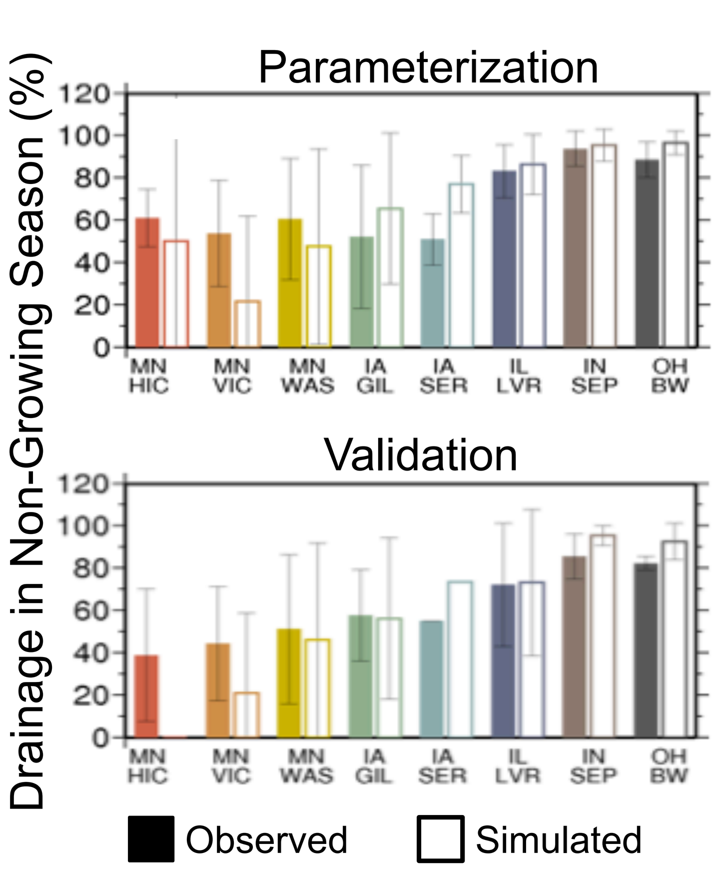
Months with observed drainflow



King et al. (2014)
Kladivko et al. (2004)
Cook and Verma (2012)
Helmers et al. (2005)
Randall et al. (2004)
Strock et al. (2004)

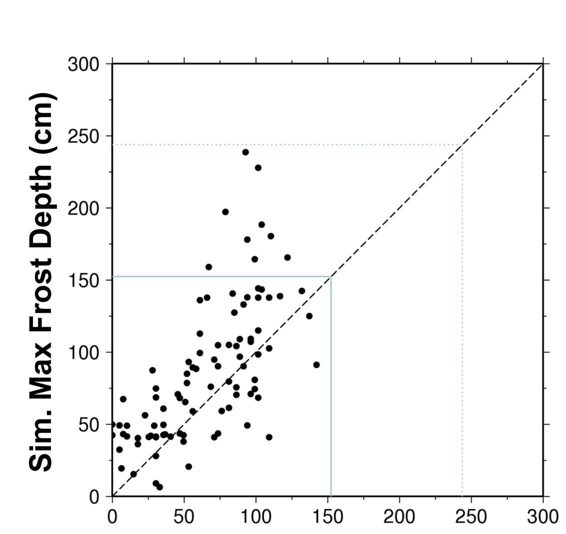
Historical observations from eight field sites across the Corn Belt show the variability in annual drainflow volume (depth in mm) and timing. Sites in the northwest tend to have shorter drainflow seasons that start later in the spring than sites in the southeast.

Field Site Validation of the VIC Model



Left: The VIC model best predicts drainage seasonality, but simulated shorter drainage seasons due to starting later in winter/spring than observed.

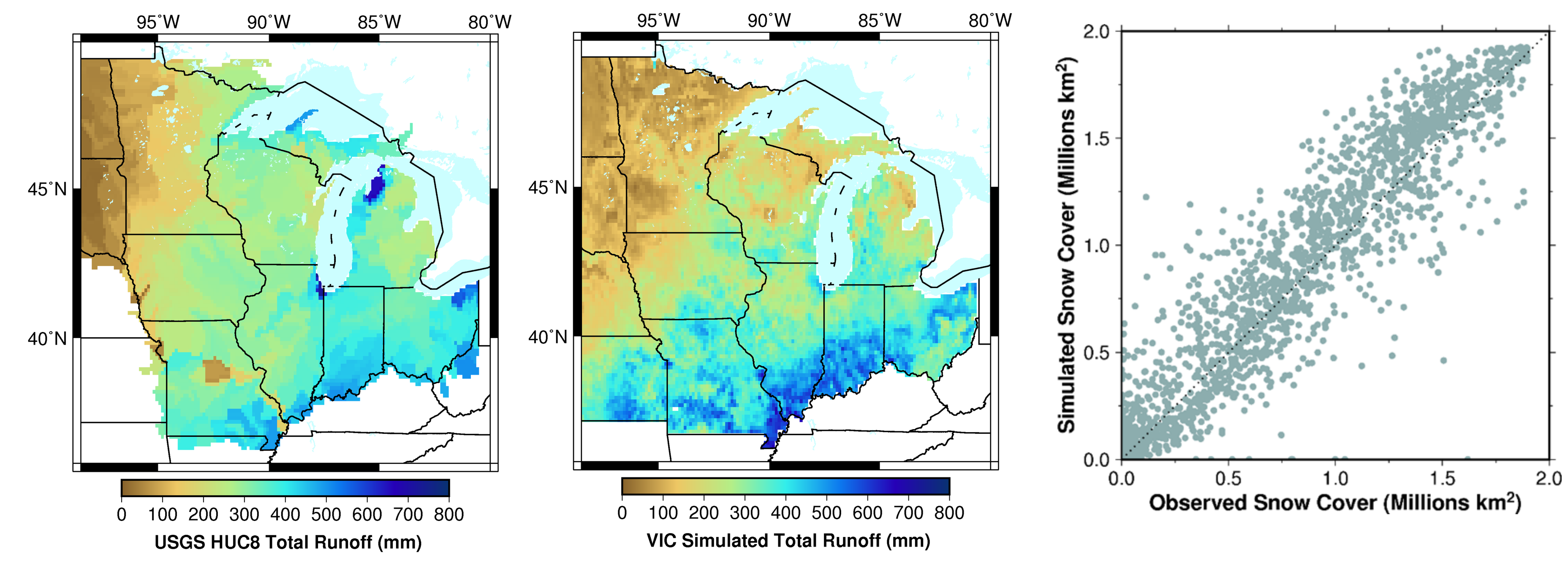
Right: Cold season processes such as snow cover and frost depth were evaluated. Although frost depths appear to be over-simulated, the frost tubes only extend 152 cm, shallower than the deepest frost recorded in MN.



Frost tube length 152 cm (Haugen, 1998)

Deepest frost front recorded in Minnesota >244 cm (MnDOT, 2016)

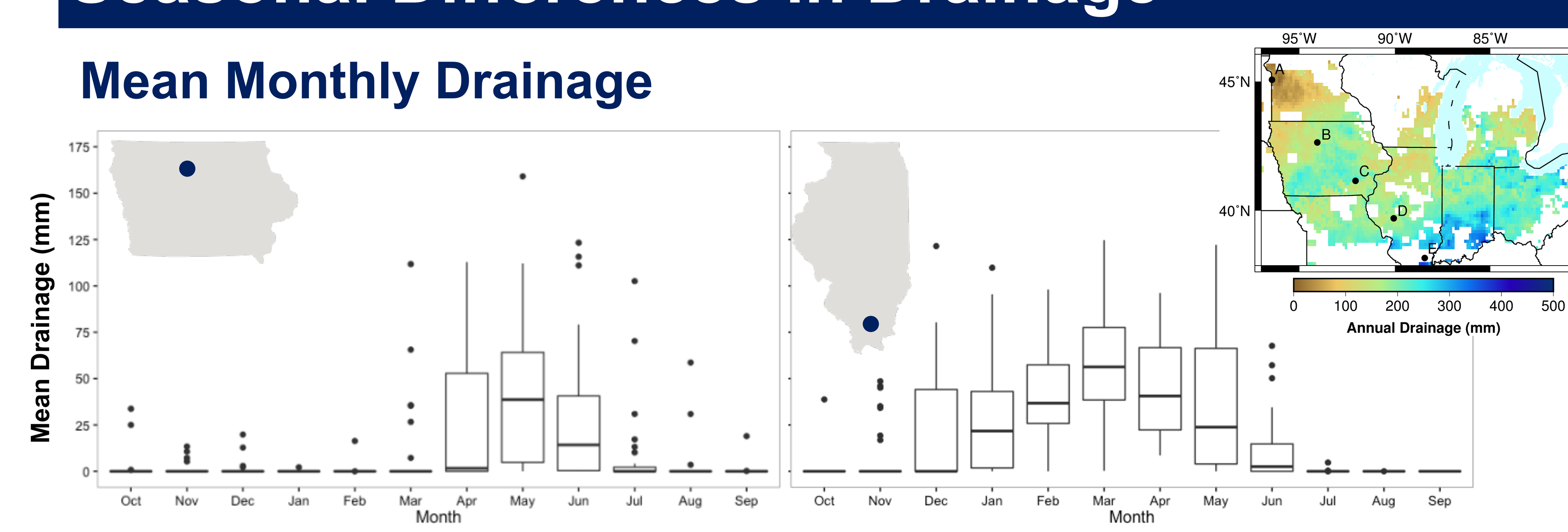
Regional Validation of the VIC Model



Simulated total runoff (baseflow + overland flow) is less in the northwest and greater in the southeast compared to USGS total runoff (normalized streamflow). Simulated daily snow coverage for the region does not have a strong bias compared to remotely sensed data.

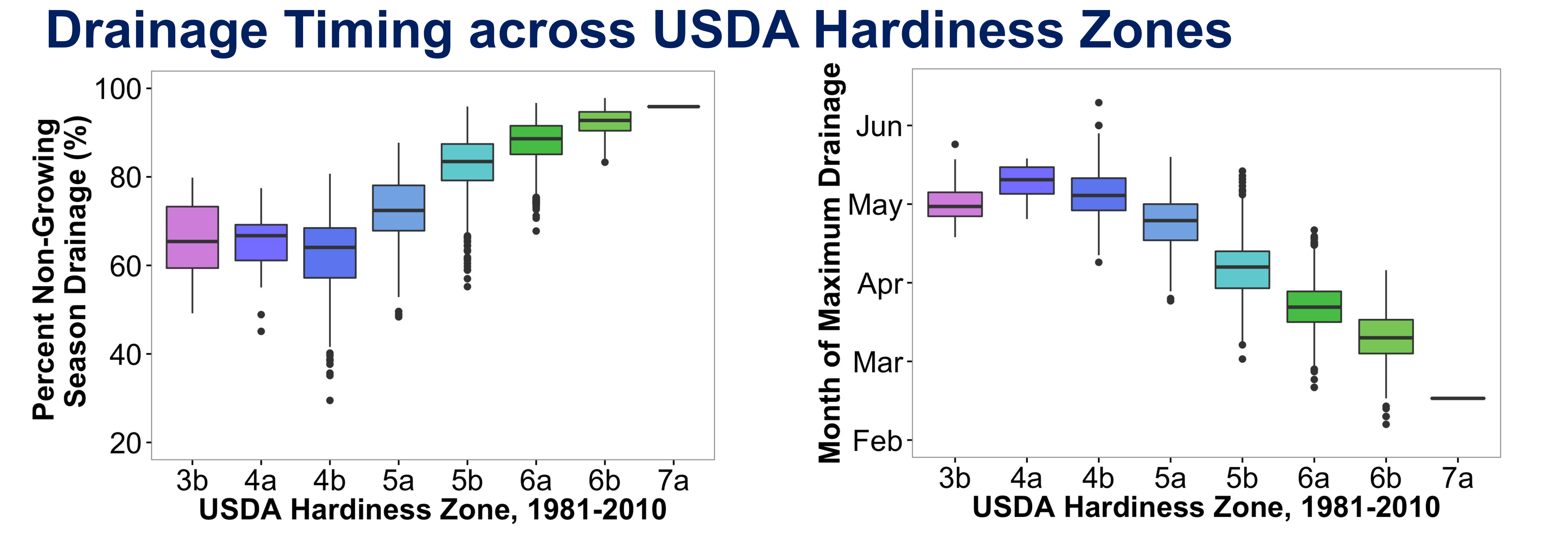
Seasonal Differences in Drainage

Mean Monthly Drainage



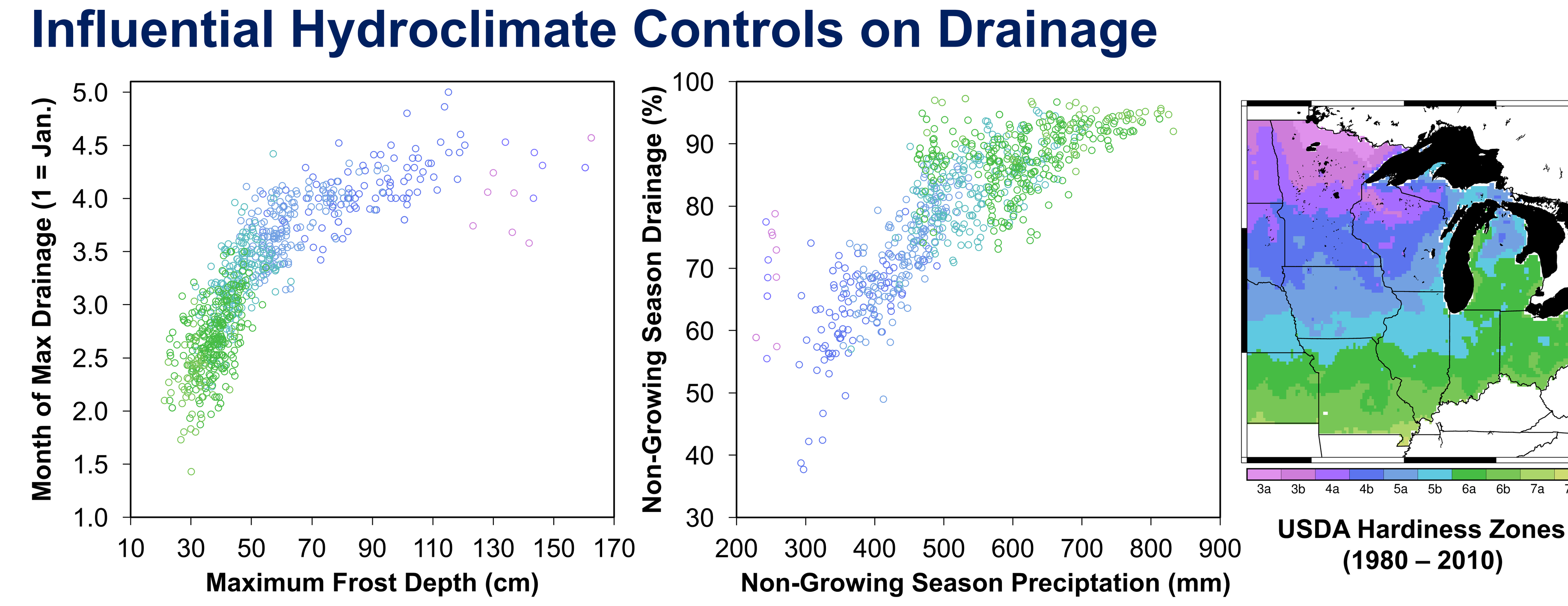
Patterns in simulated monthly drainage varying from 3 months in the north to 7 months in the south. Simulated drainage occurs primarily during the non-growing season in the south, whereas drainage in the north primarily occurs after April 1st.

Drainage Timing across USDA Hardiness Zones



Broader trends in drainage timing divided by USDA Hardiness Zone. The colder, northwestern Corn Belt has the lowest amount of drainage in the non-growing season, October 1 – May 31, and latest peaks in drainage.

Influential Hydroclimate Controls on Drainage



The strongest Spearman correlations between hydroclimate factors and drainage timing metrics were maximum frost depth correlated with month of maximum drainage (ρ= 0.90) and precipitation correlated with drainage volume in the non-growing season (ρ= 0.82).

Conclusions

- Maximum frost depth and precipitation during the non-growing season (Oct 1 – May 31) are the strongest predictors of drainage timing.
- Cold season processes (e.g. frozen soils, snow melt) are more influential in colder, northern regions of the U.S. Corn Belt and contribute to shorter, more variable seasons of subsurface drainage.
- The VIC model could be used to help determine feasibility of drainage best management practices at a broad scale based on hydroclimatology.

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Acknowledgements

This is part of a regional collaborative projects supported by USDA-NIFA Award Numbers 2011-68002-30190 and 2015-68007-23193.

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