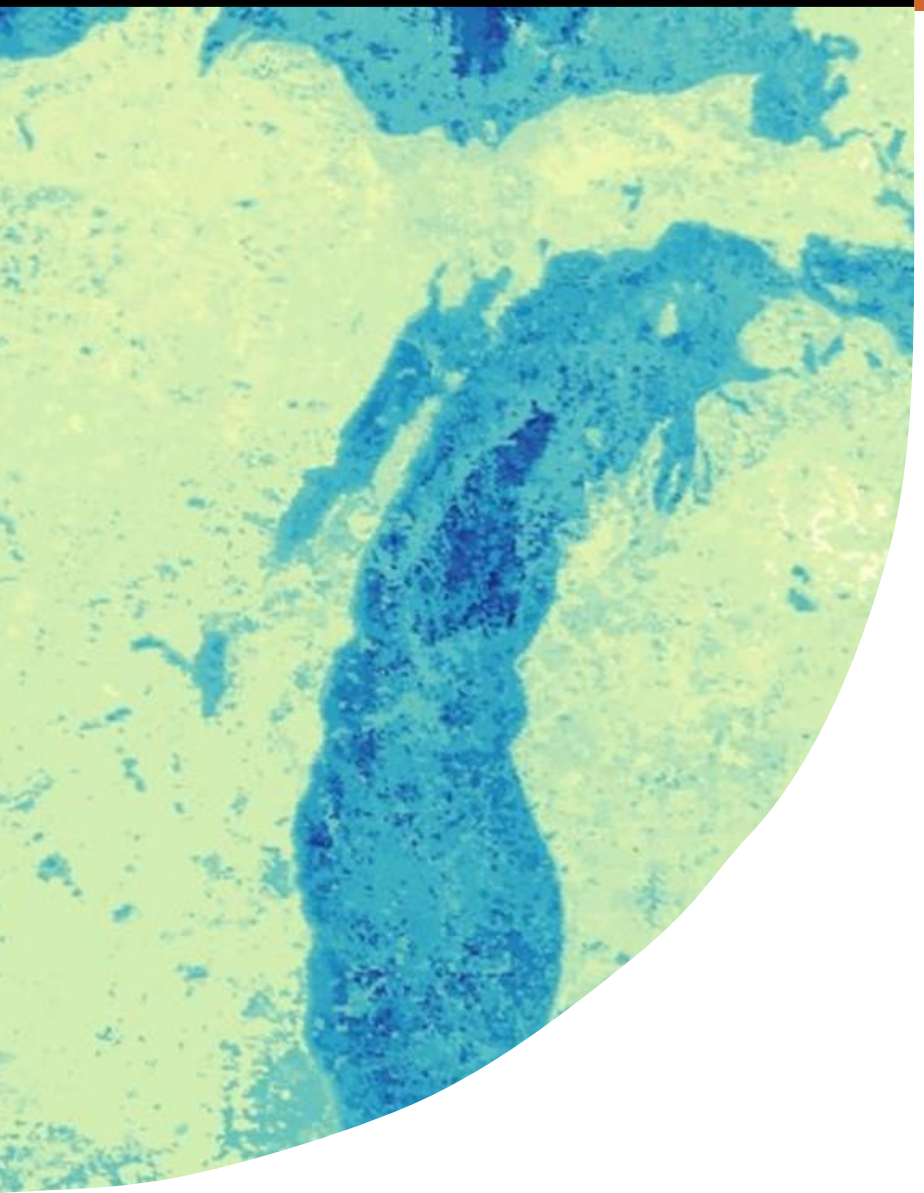
National Aeronautics and Space Administration



Wisconsin Agriculture

Assessing Cover Crop Seeding Dates in Wisconsin's Lake Shore Counties Using NASA Earth Observations

Jovanny Aguilar, Lauren Wick, Aaron Wilson

(Analytical Mechanics Associates)

Virginia – Langley | Fall 2025

Project Partners

Midwest Cover Crops Council

Image Credit: MCCC, Ashley Gallagher

USDA, Natural Resources Conservation Service, Wisconsin

Image Credit: MCCC, Tom Kaspar

University of Wisconsin-Madison

Image Credit: MCCC, Abbey Wick

Community Concerns

Uncertain seeding windows	Economic Risk of Adoption	Water Quality & Soil Erosion
Narrow window between harvest and frost	Equipment costs with no immediate financial benefit	Unfavorable weather leading to runoff and nutrient loss

Image Credit: Daniel H. Smith

Objectives

Image Credit: Daniel H. Smith

Quantify Cover Crop Adoption

Validate Seeding Date Recommendations

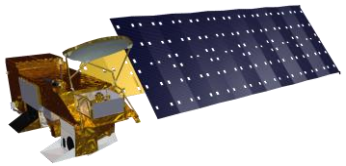
Assess Hydrologic Impact

NASA Satellites & Sensors

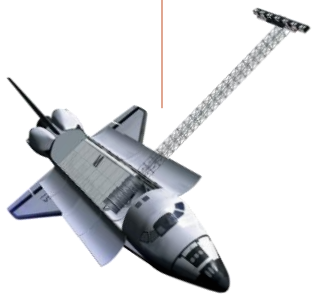
Land Surface Temperature

Terrain & Hydrology

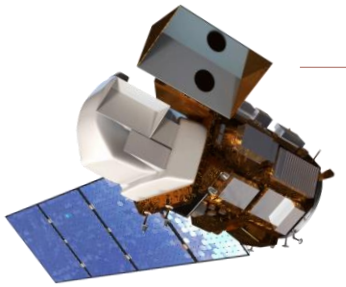
Normalized Difference Vegetation Index (NDVI)



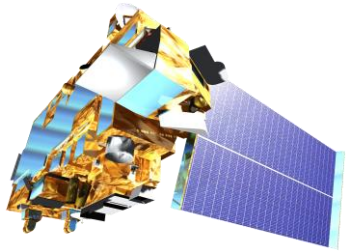
Aqua MODIS



SRTM



Landsat 8 OLI



Terra MODIS

Image credit: NASA

Landsat 9 OLI-2

Study Area

Door – Kewaunee

- Highest cover crop adoption

Manitowoc – Sheboygan

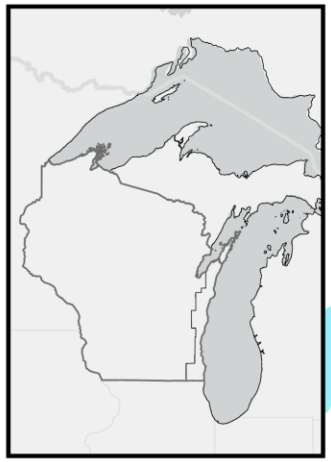
- Highest stability in GDD & first frost trends

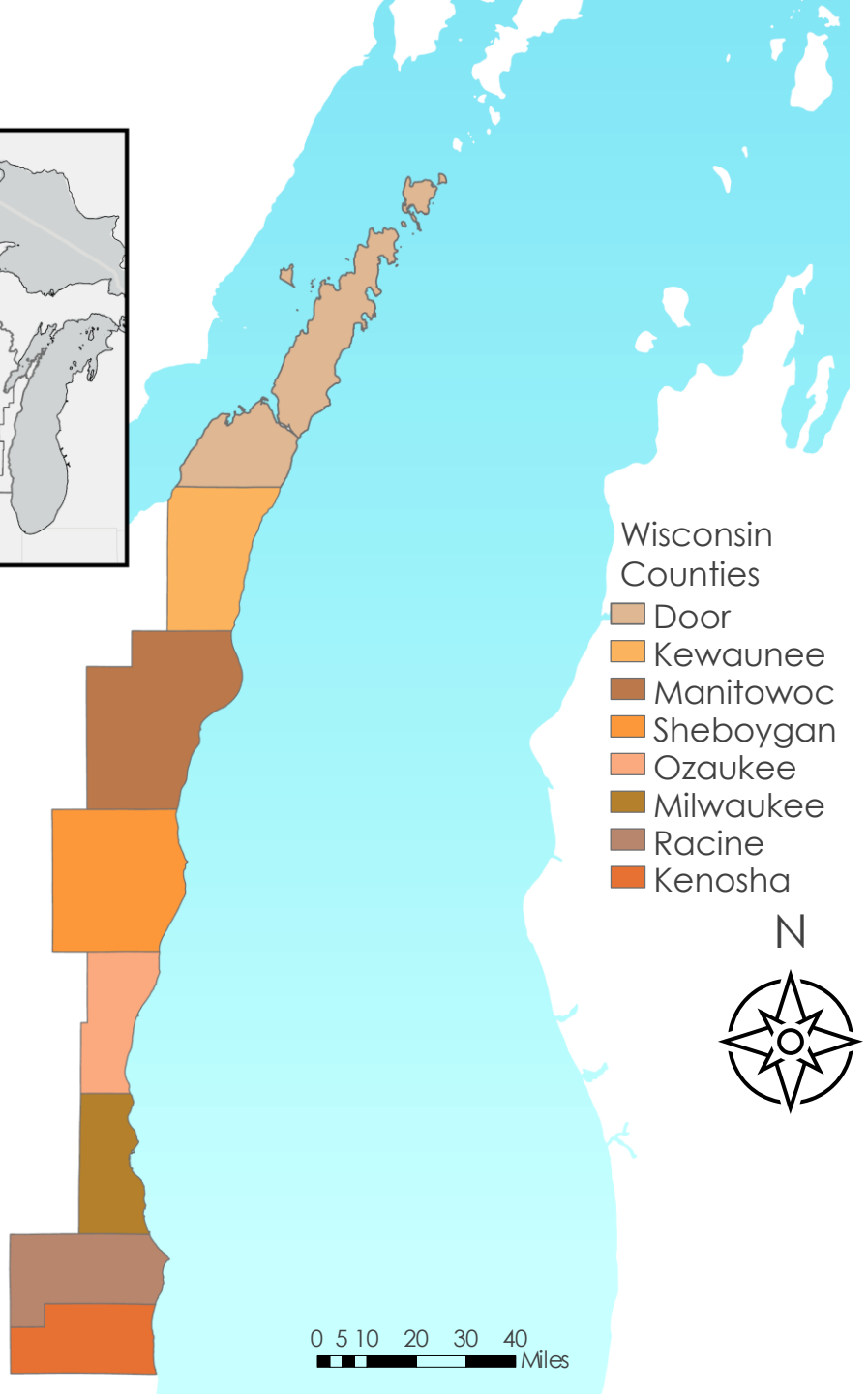
Ozaukee – Milwaukee

- Highly developed, lowest cover crop adoption, & greatest temperature variability

Racine – Kenosha

- Longest growing season & warmest climate





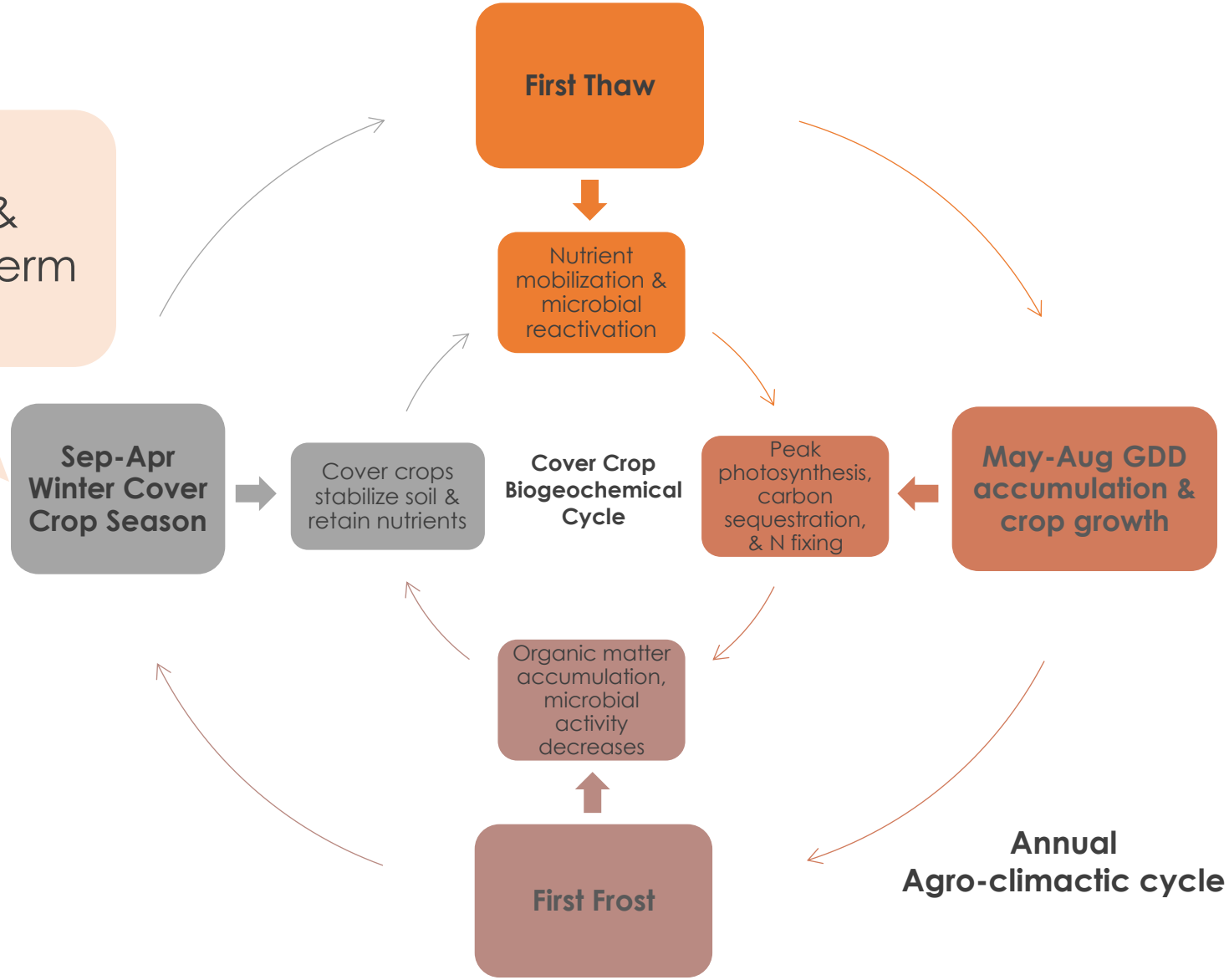
Study Period

2000-2024, capturing year-to-year variability in growing degree days & seeding windows along with long-term climactic impacts

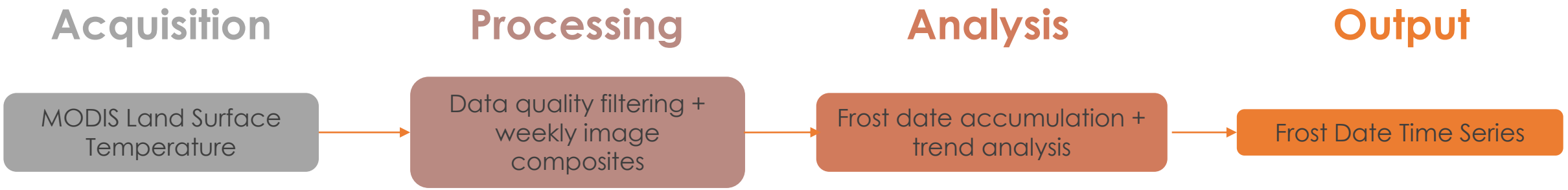
MODIS
- 2003-2024
- Terra: 10:30 AM, Aqua: 1:30 AM

SRTM DEM
- February 11-22, 2000
- Static elevation dataset

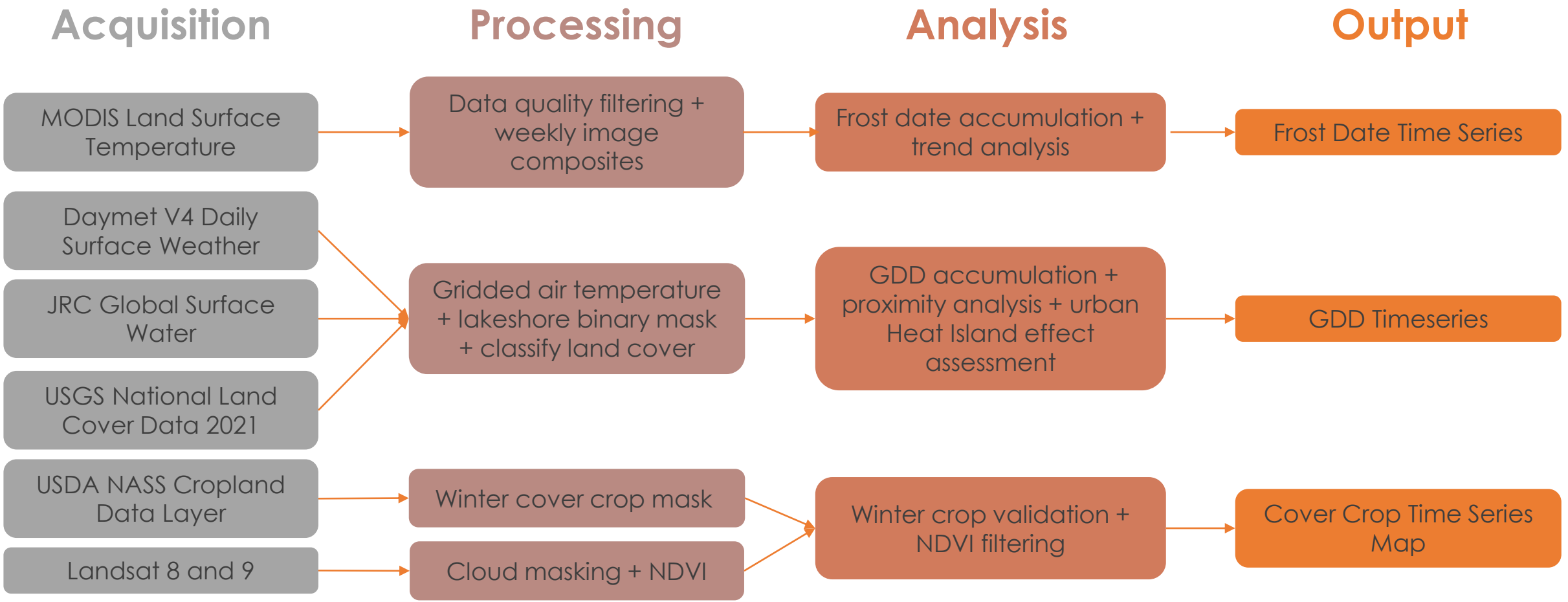
Landsat
- 2003-2024
- 16-day revisit, 30 m resolution



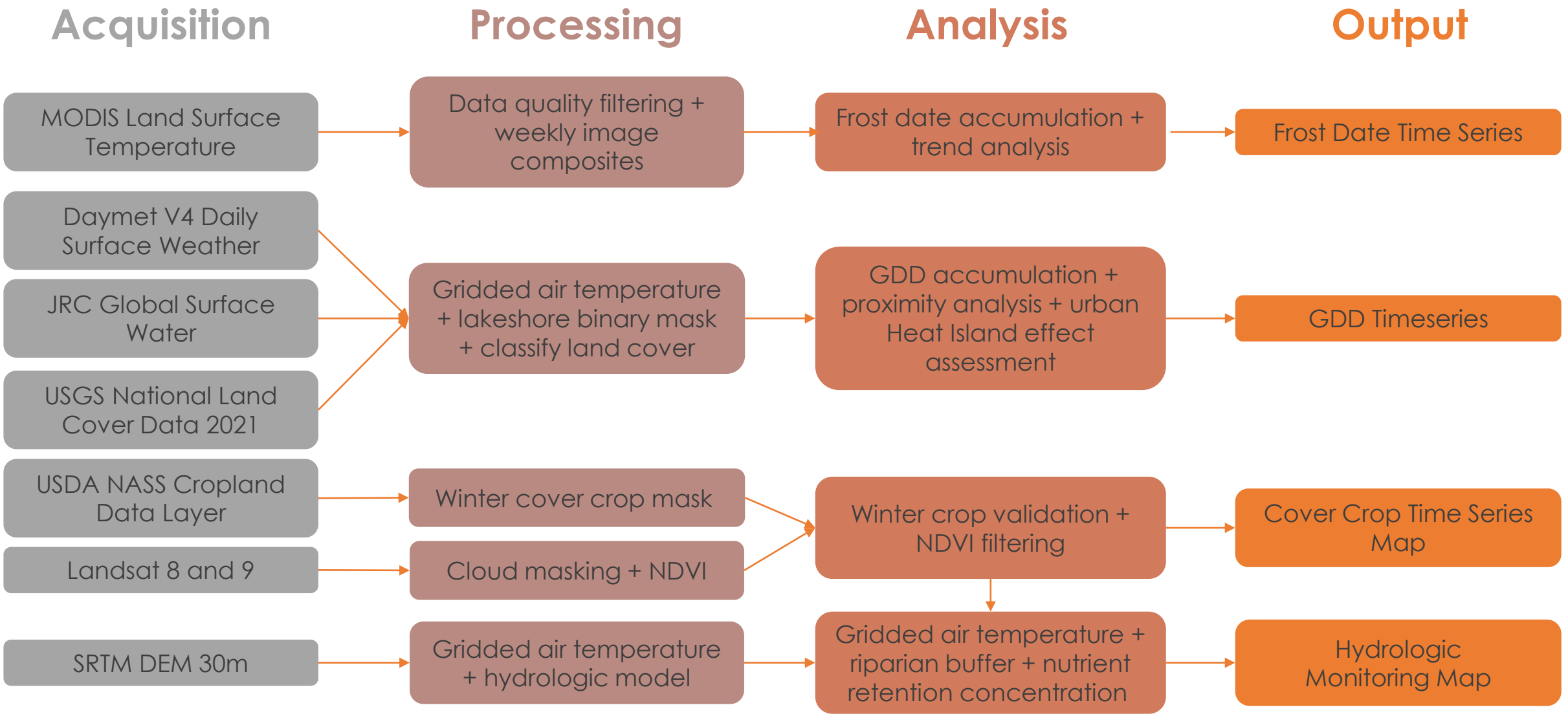
Methodology



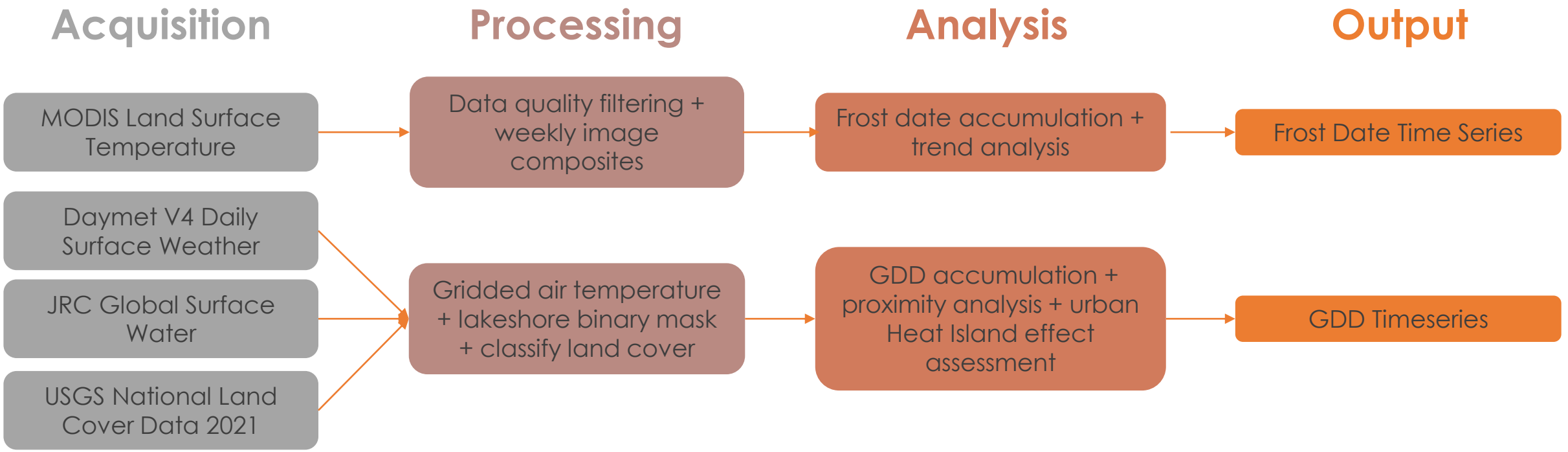
Methodology



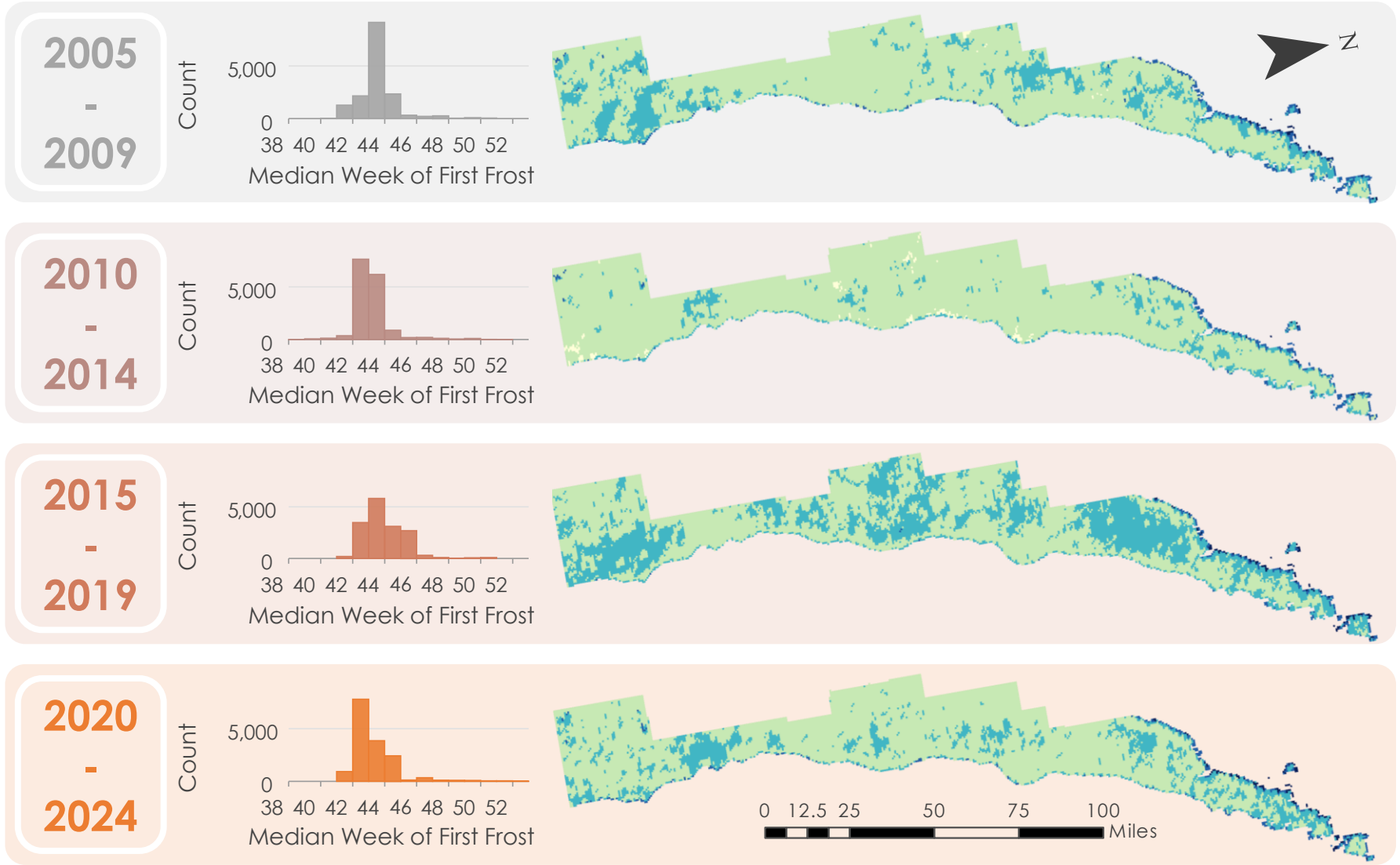
Methodology



Methodology

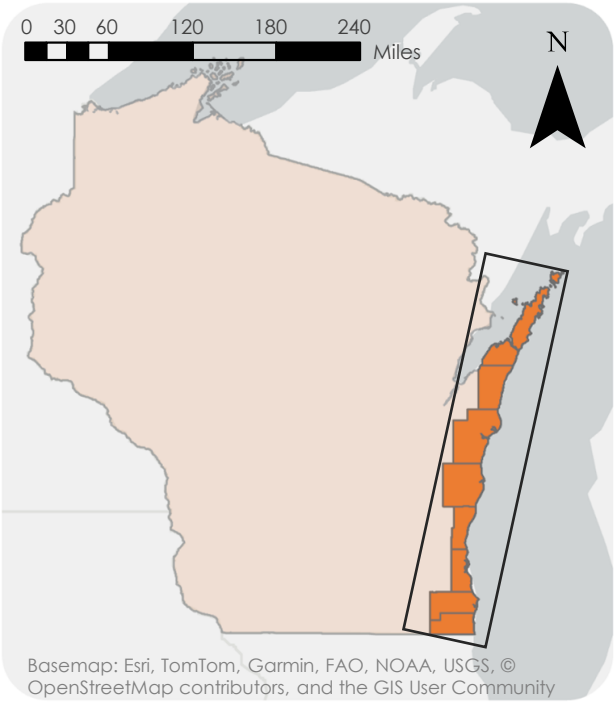


Results – First Frost (32°F) Spatial Analysis

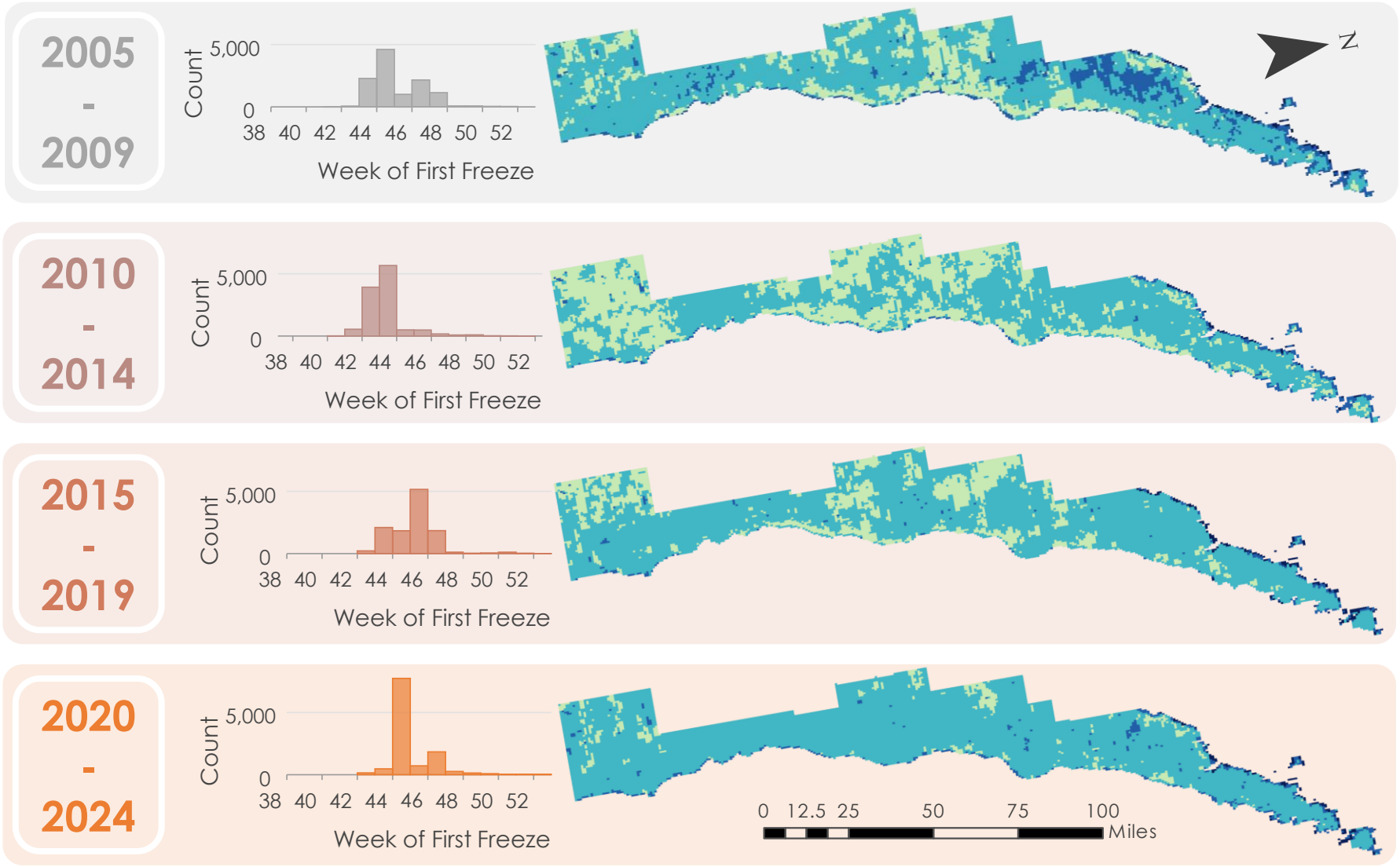


Week of First Frost (32°F)

- 38 – 40 (Mid Sep – Early Oct)
- 41 – 43 (Early Oct – End Oct)
- 44 – 46 (End Oct – Mid Nov)
- 47 – 49 (Mid Nov – Early Dec)
- 50 – 52 (Early Dec– End Dec)



Results – First Hard Freeze (28°F) Spatial Analysis



Week of First Hard Freeze (28°F)

- 38 – 40 (Mid Sep – Early Oct)
- 41 – 43 (Early Oct – End Oct)
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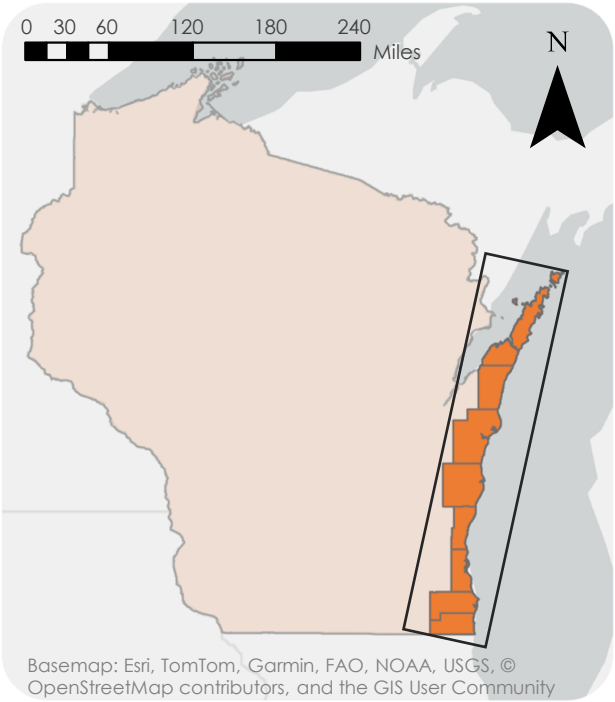
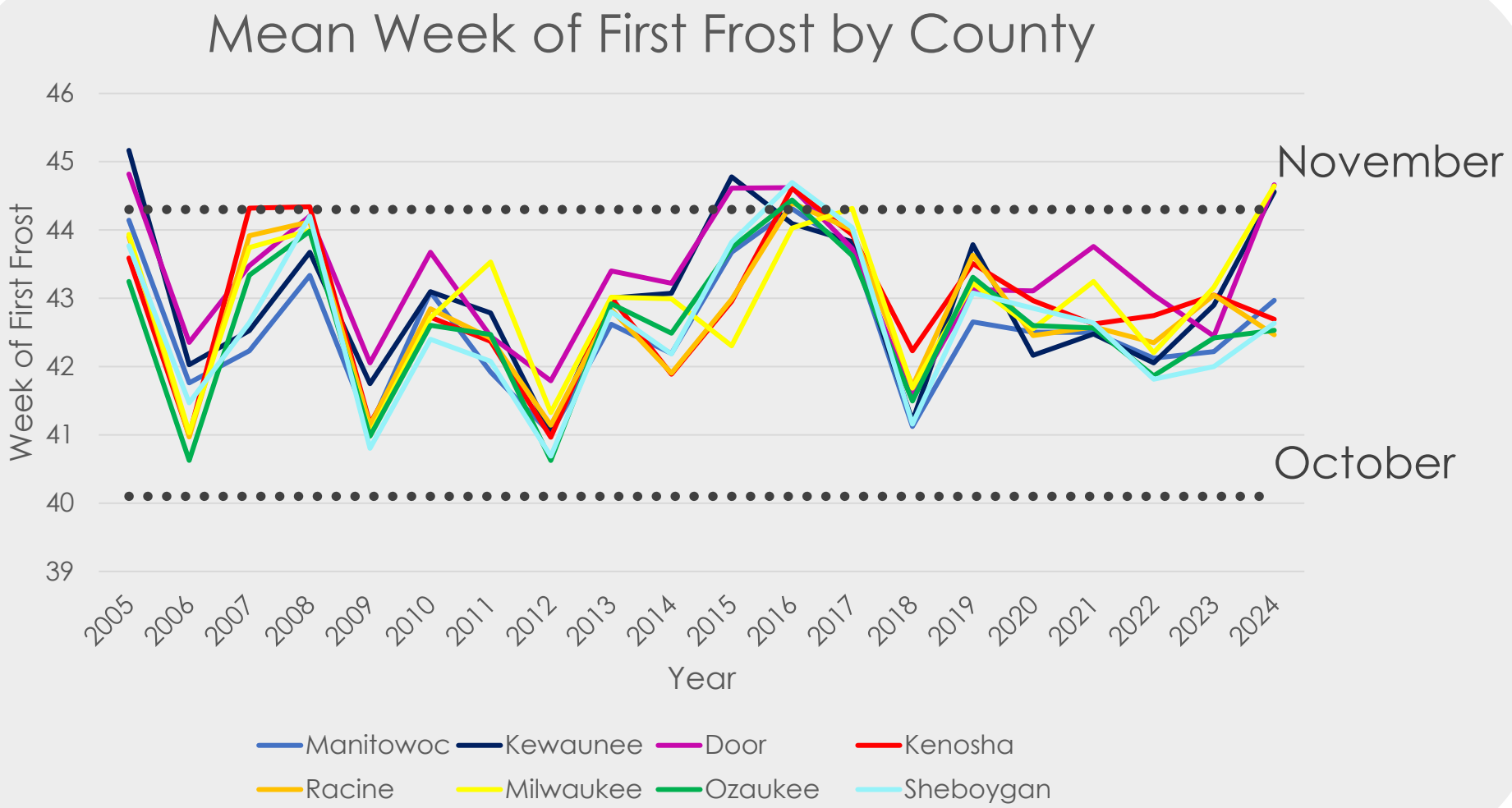
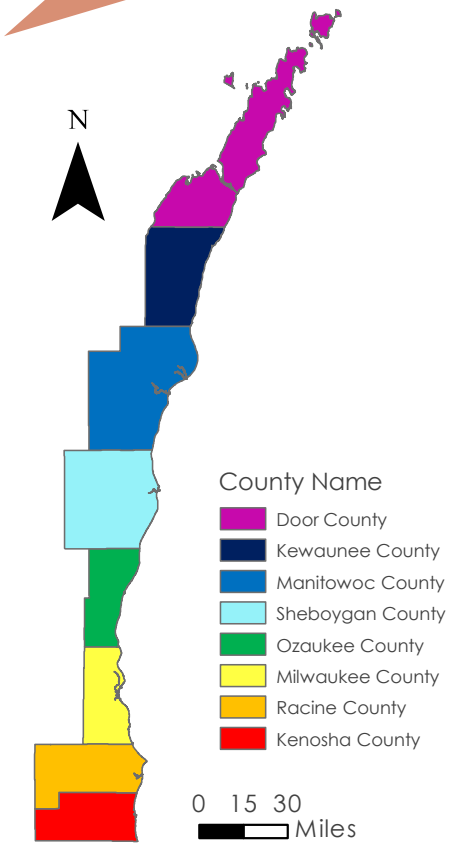


Results – First Frost (32°F) Time Series

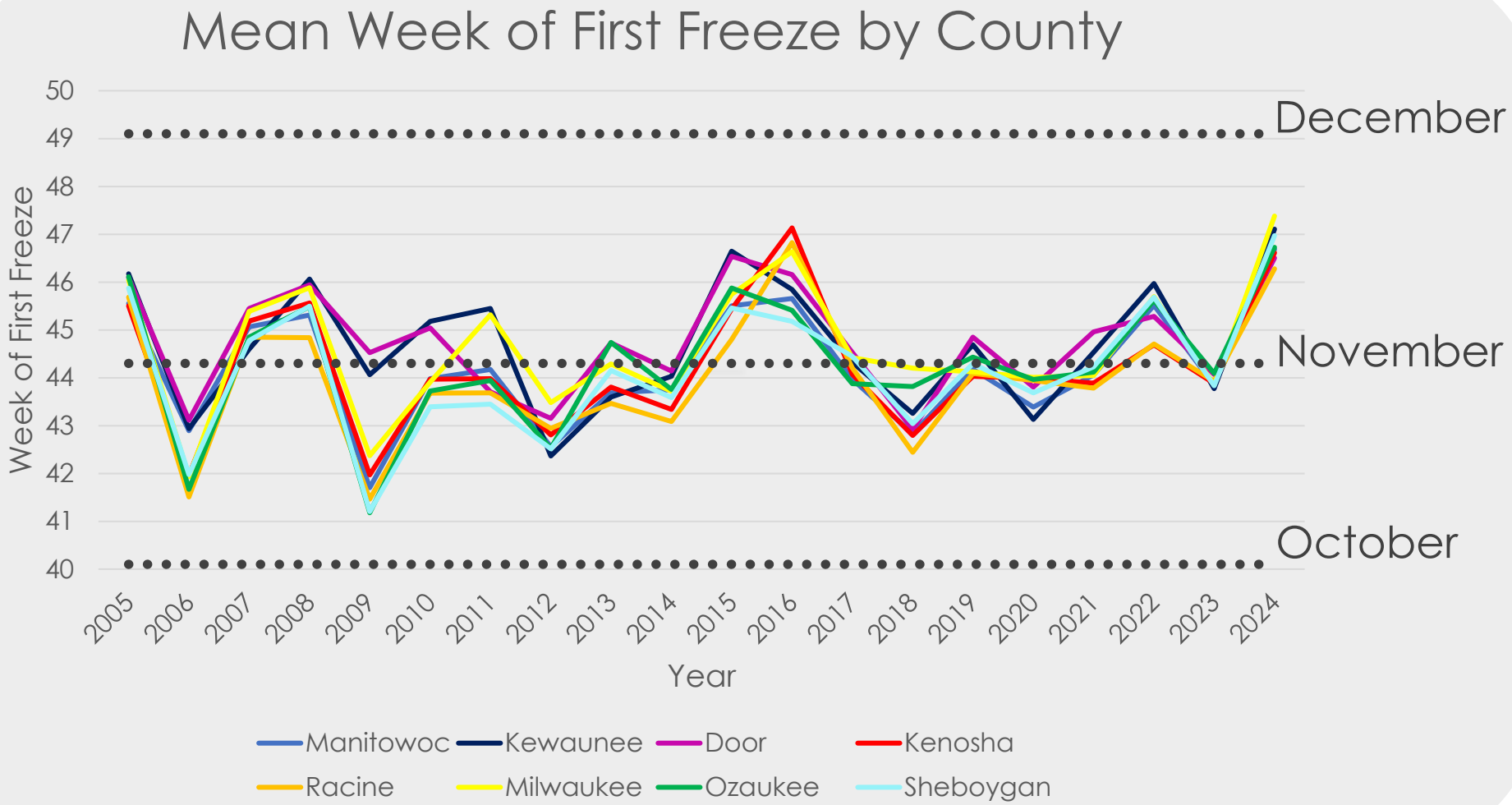


Average R^2 = 0.005

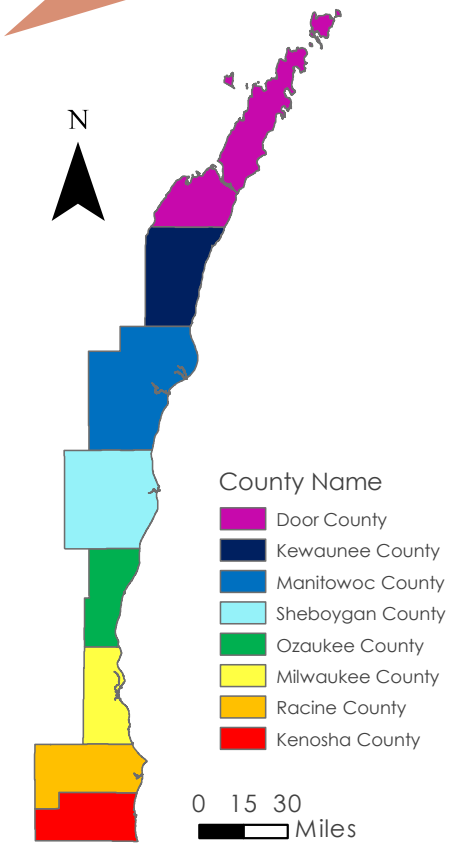


Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC); NASA ORNL DAAC; JRC Global Surface Water 1.4

Results – First Hard Freeze (28°F) Time Series



Average R^2 = 0.046



Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC); NASA ORNL DAAC; JRC Global Surface Water 1.4

Results – First Frost Trend Analysis

Generate Annual First Frost Maps (2005 – 2024)

Trend analysis with Mann-Kendall Test

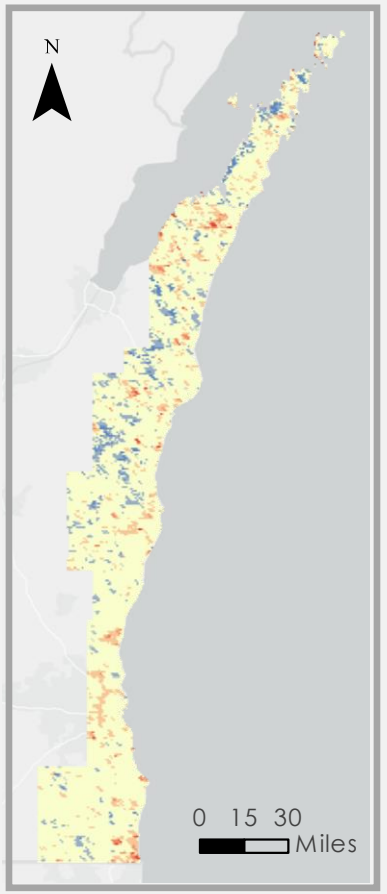
Quantify magnitude of trend with Sen's Slope

Test for statistical significance

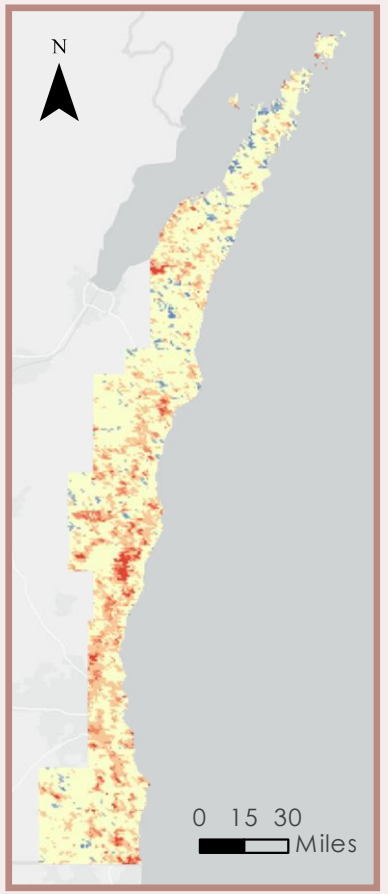
Sen's Slope (Week/Year)

- -0.206 - -0.099
- -0.098 - -0.039
- -0.038 - -0.001
- 0
- 0.001 – 0.118
- 0.119 – 0.156
- 0.157 – 0.286

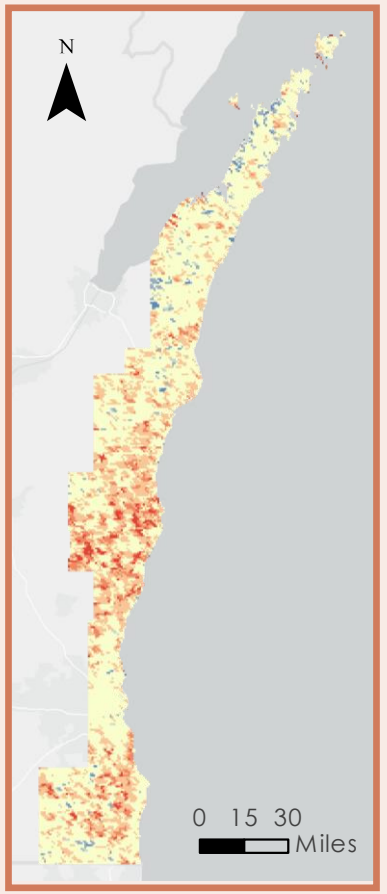
First Frost (32°F)



First Freeze (30°F)



First Hard Freeze (28°F)



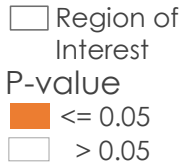
Results – First Frost Trend Analysis

Generate Annual First Frost Maps (2005 to 2024)

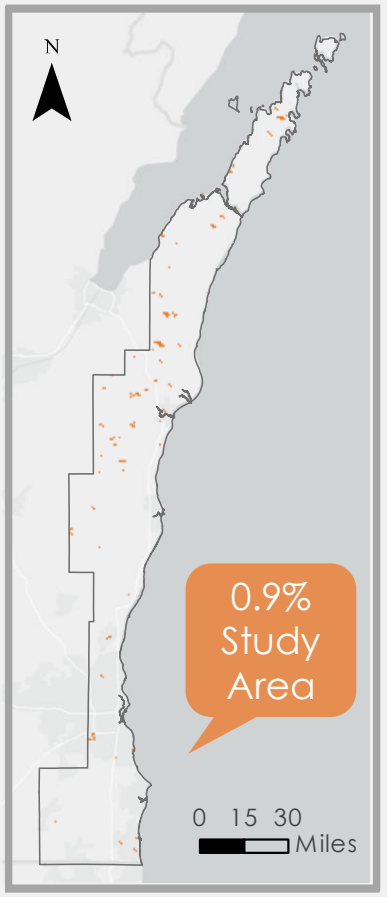
Trend analysis with Mann-Kendall Test

Quantify magnitude of trend with Sen's Slope

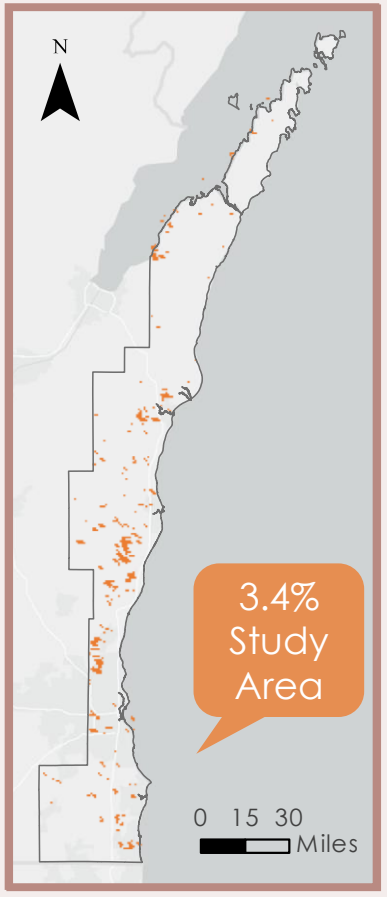
Test for statistical significance



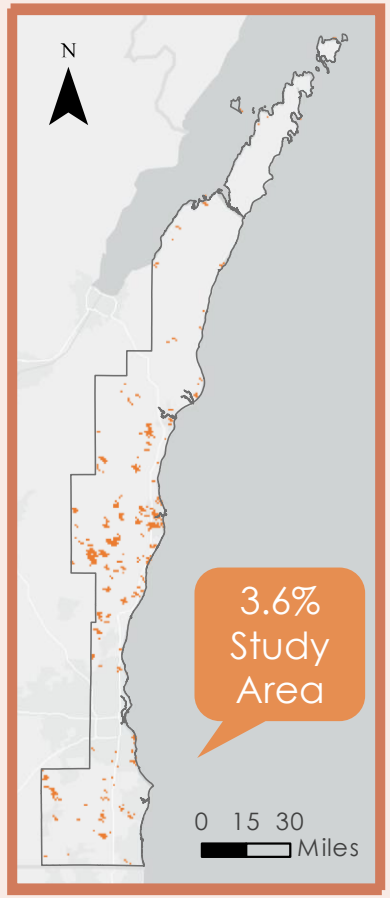
First Frost (32°F)



First Freeze (30°F)



First Hard Freeze (28°F)

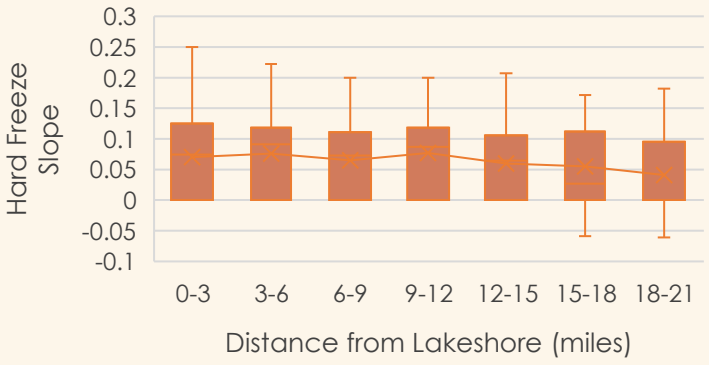


Basemap: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

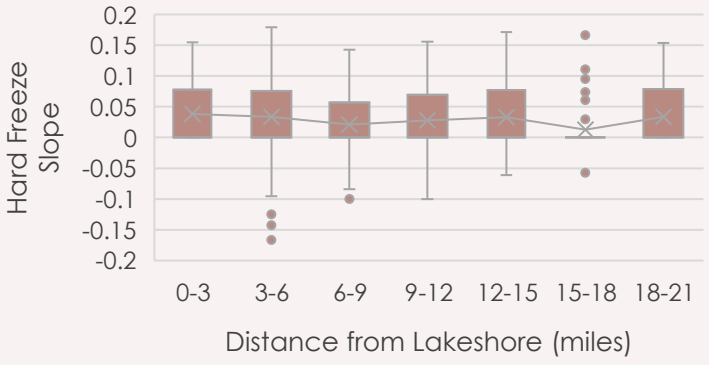
Results – First Frost Trend Analysis by County

First Hard Freeze (28°F)

Sheboygan County – Slope by Distance from Lake Michigan

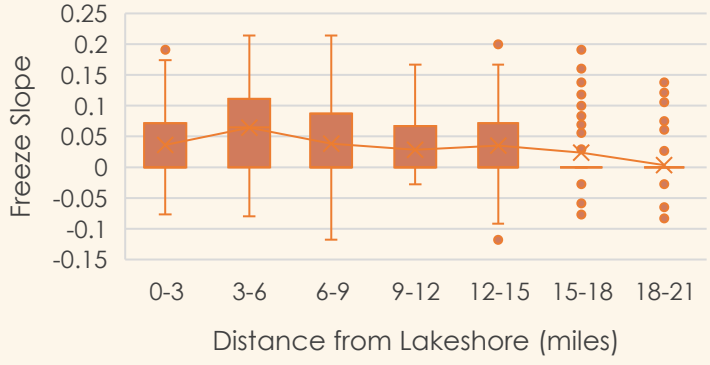


Manitowoc County – Slope by Distance from Lake Michigan

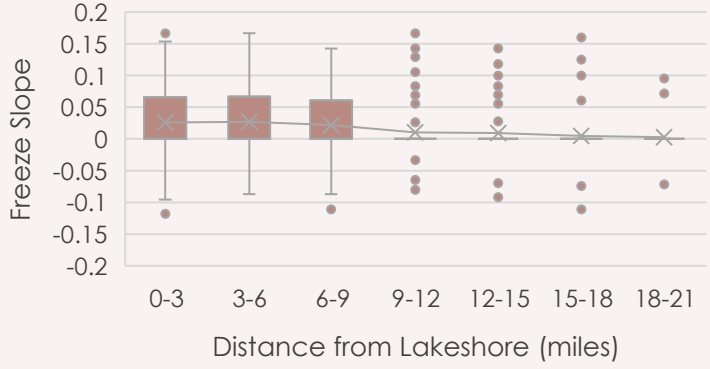


First Freeze (30°F)

Sheboygan County – Slope by Distance from Lake Michigan

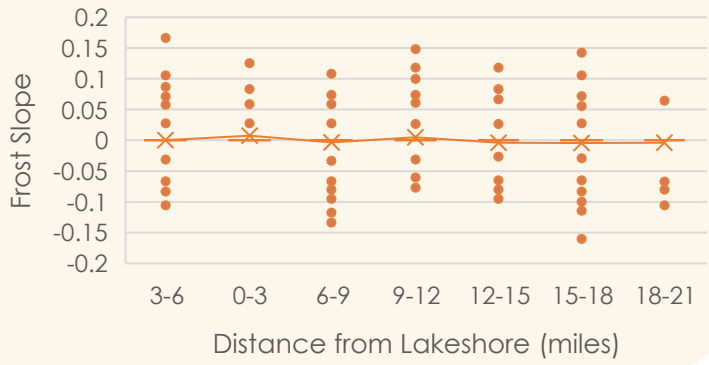


Manitowoc County – Slope by Distance from Lake Michigan

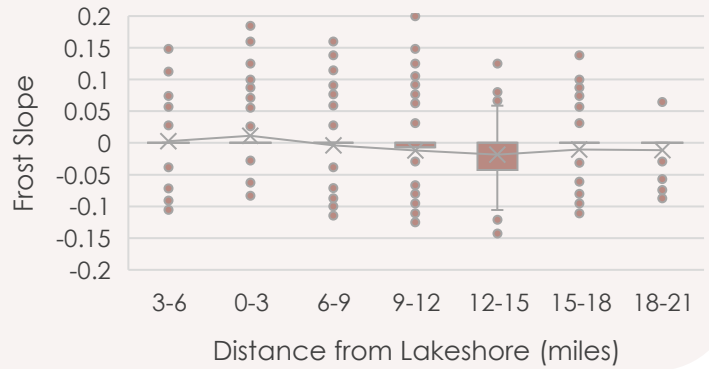


First Frost (32°F)

Sheboygan County – Slope by Distance from Lake Michigan

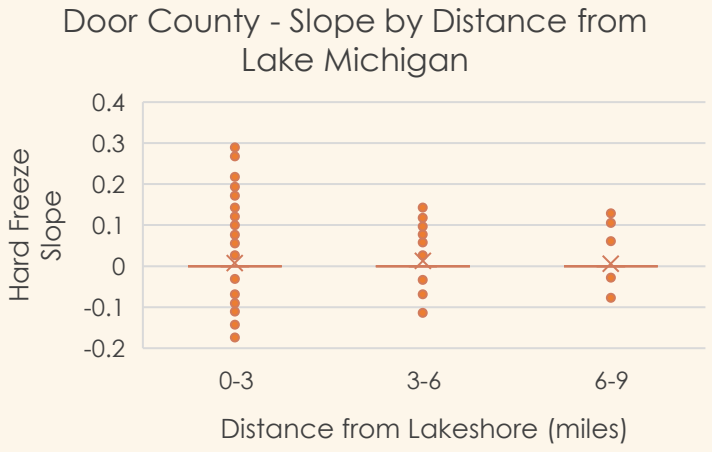


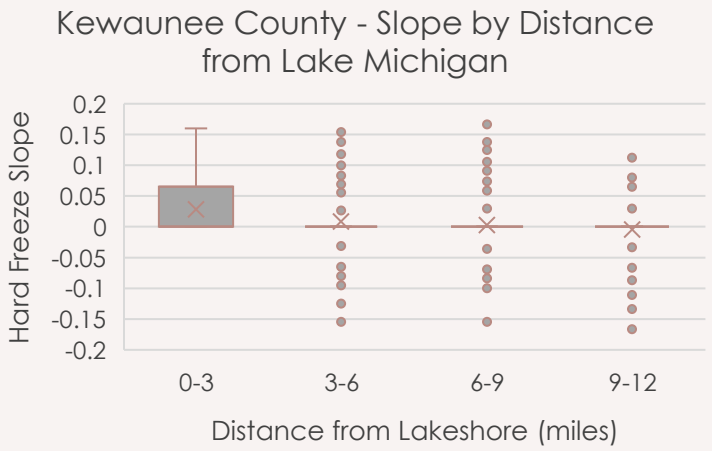
Manitowoc County – Slope by Distance from Lake Michigan



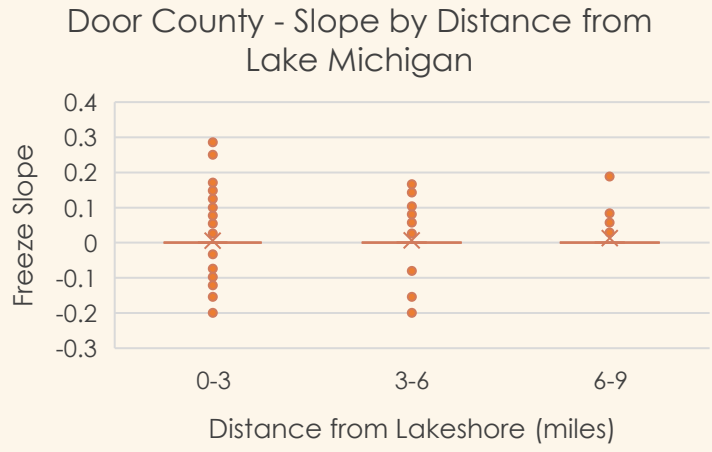
Results – First Frost Trend Analysis by County

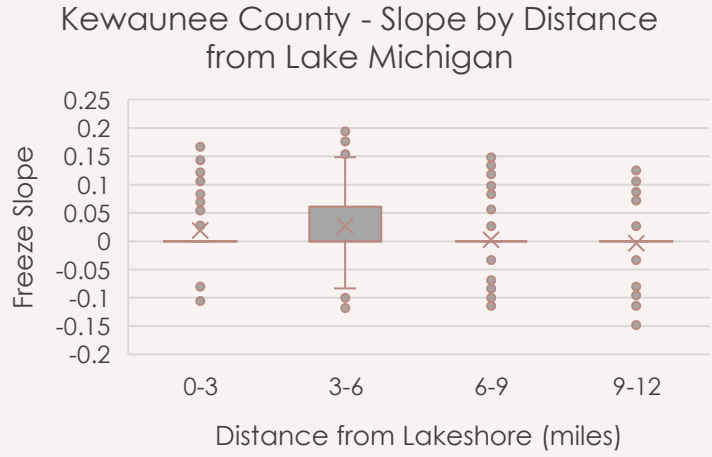
First Hard Freeze (28°F)



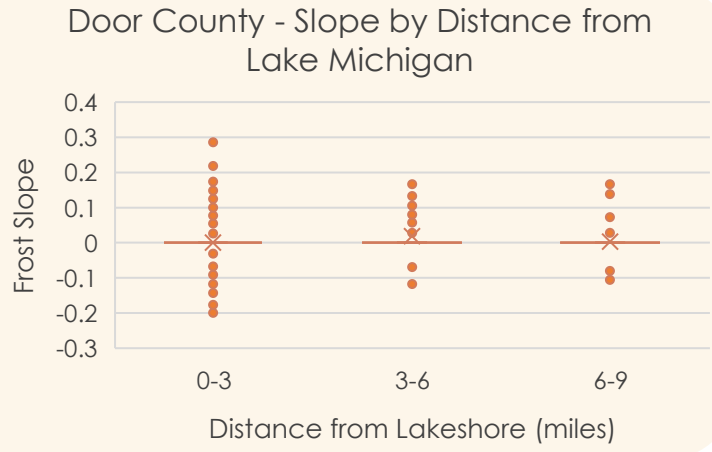


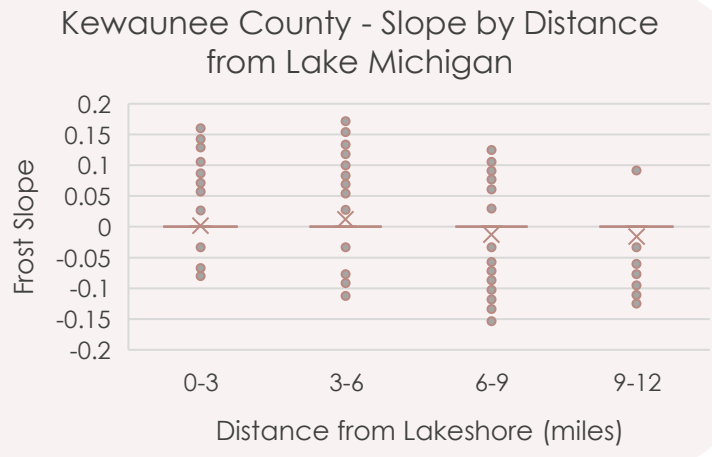
First Freeze (30°F)





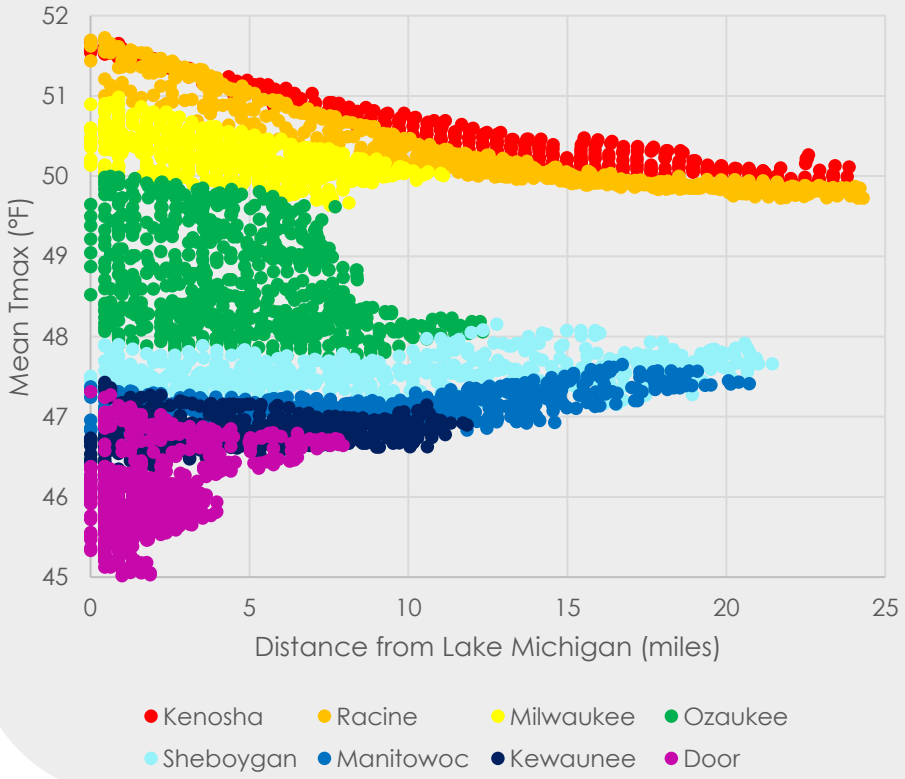
First Frost (32°F)



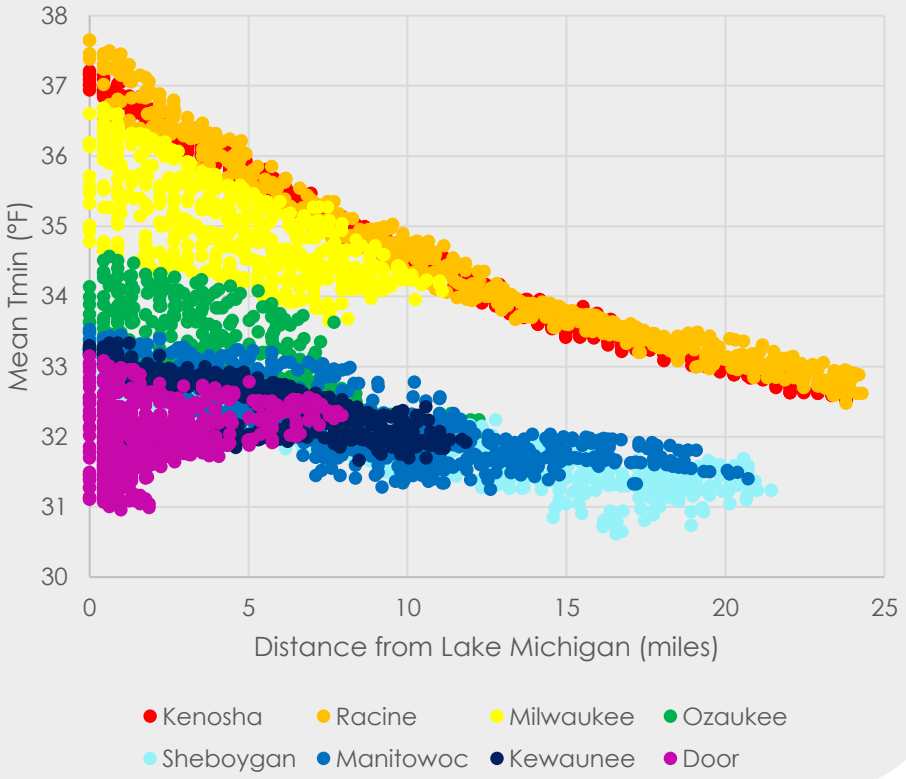


Results – Growing Degree Day Time Analysis

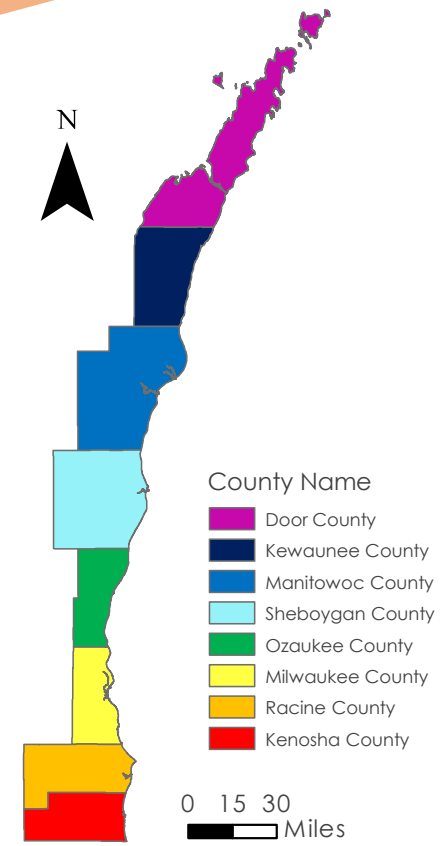
Distance vs Mean Maximum Temperature by County (Sept 1 - Apr 16, 2006 - 2024)



Distance vs Mean Minimum Temperature by County (Sept 1 - Apr 16, 2006 - 2024)



Greatest variability in Milwaukee + Ozaukee county



Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC); NASA ORNL DAAC; JRC Global Surface Water 1.4

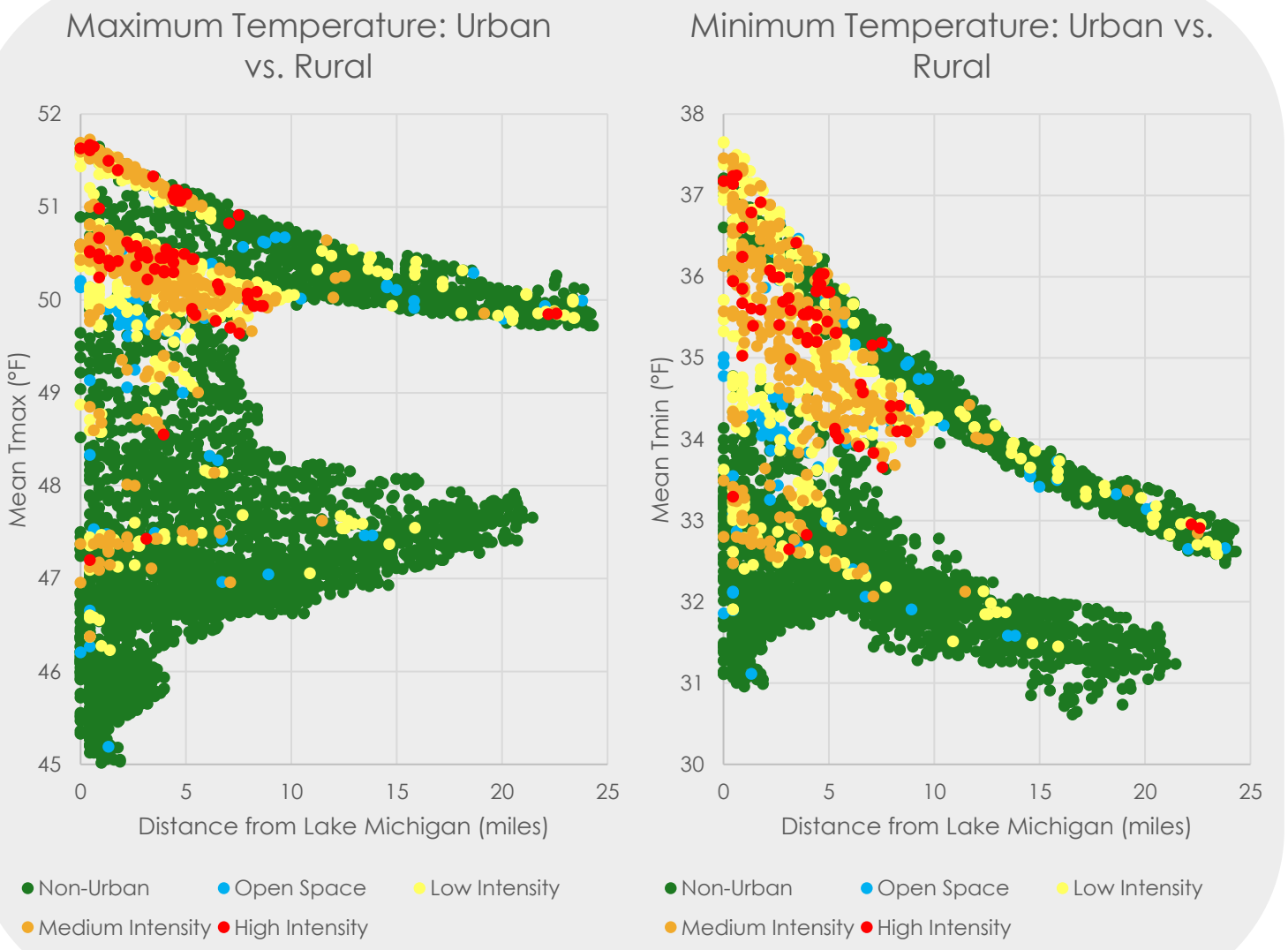
Calculate Distance from Lake Michigan

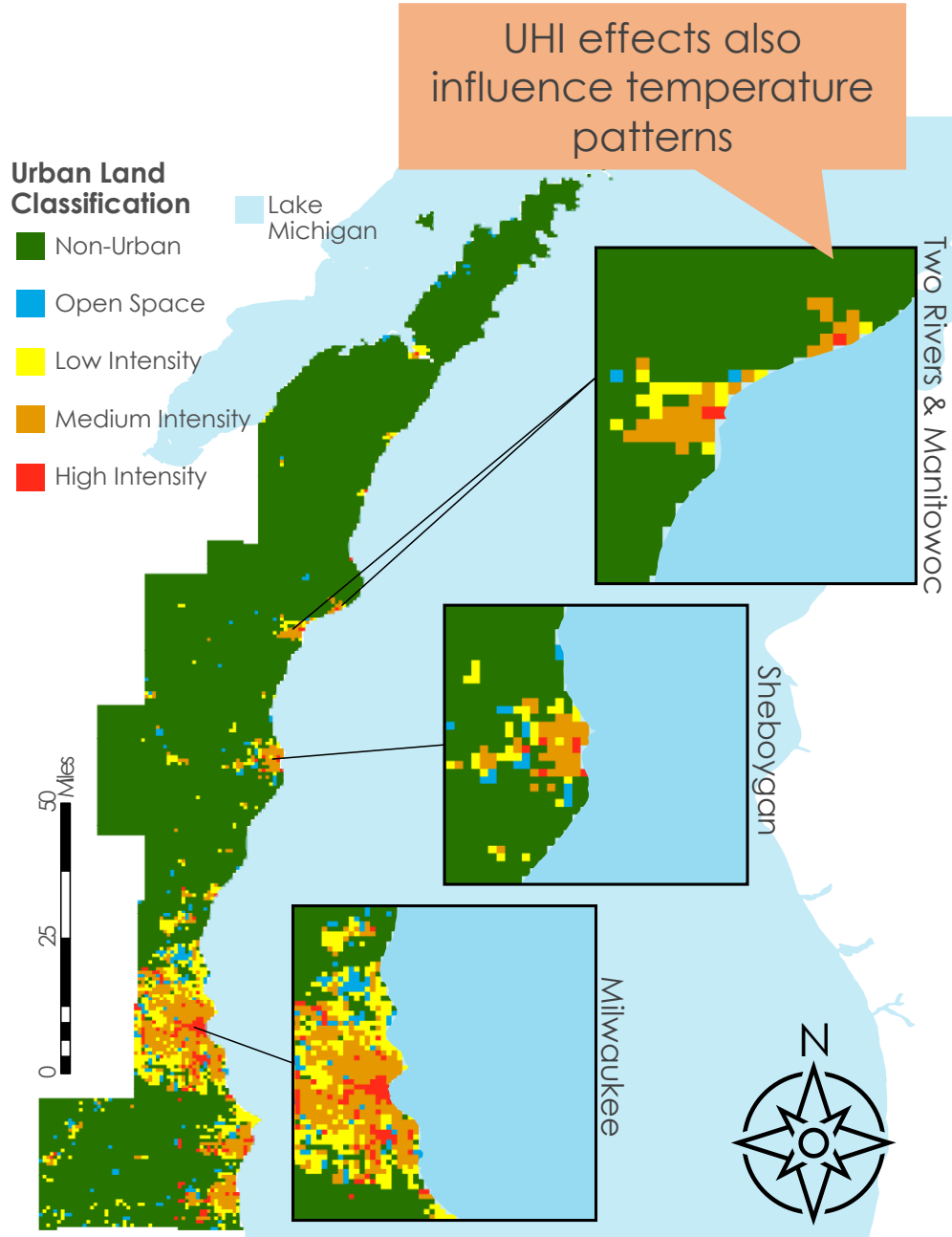
Extract Daily Temperature Data

Compute Mean Seasonal Temperatures

Generate Distance-Temperature Scatterplots

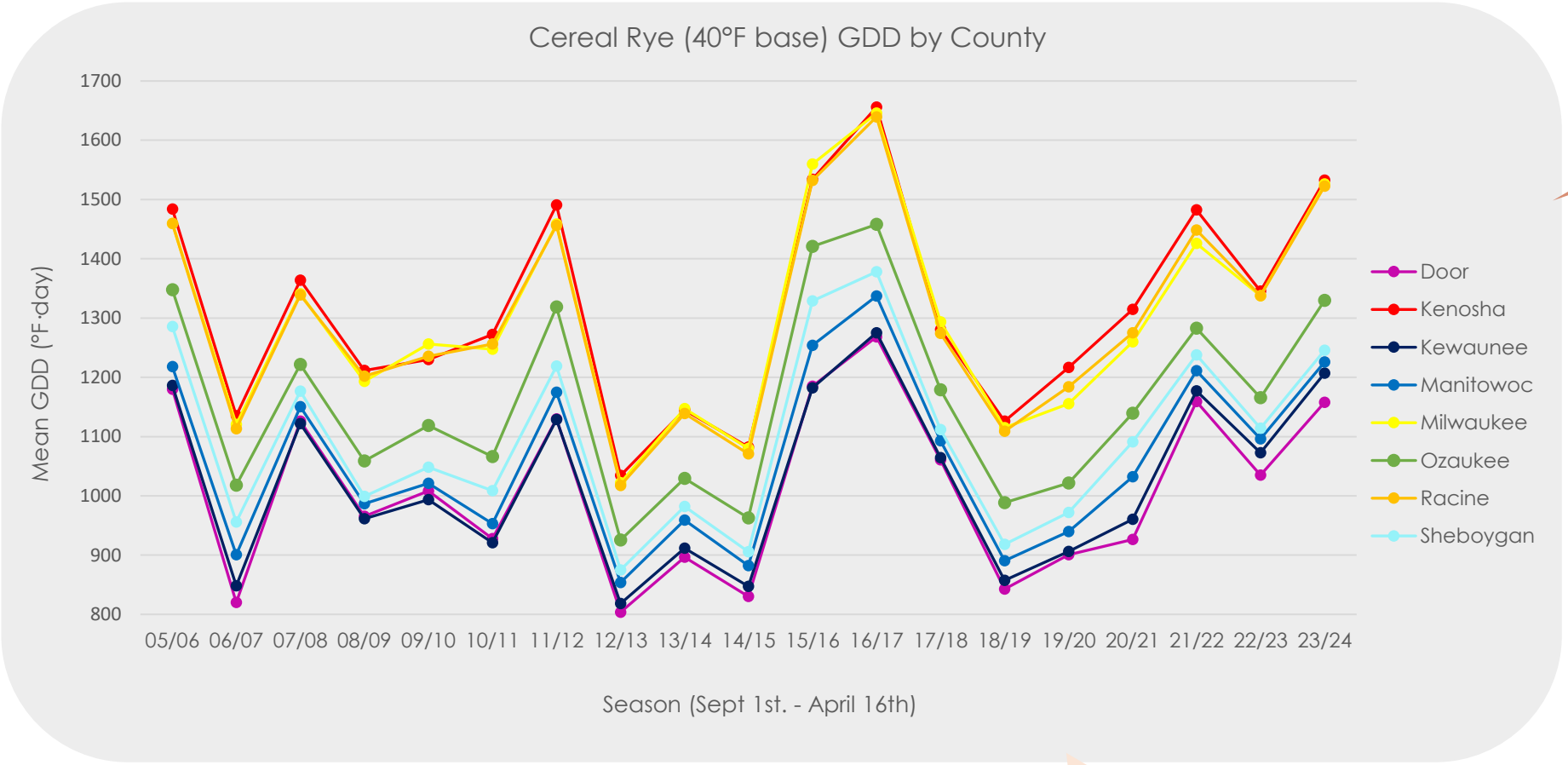
Results – Urban Heat Island Effect



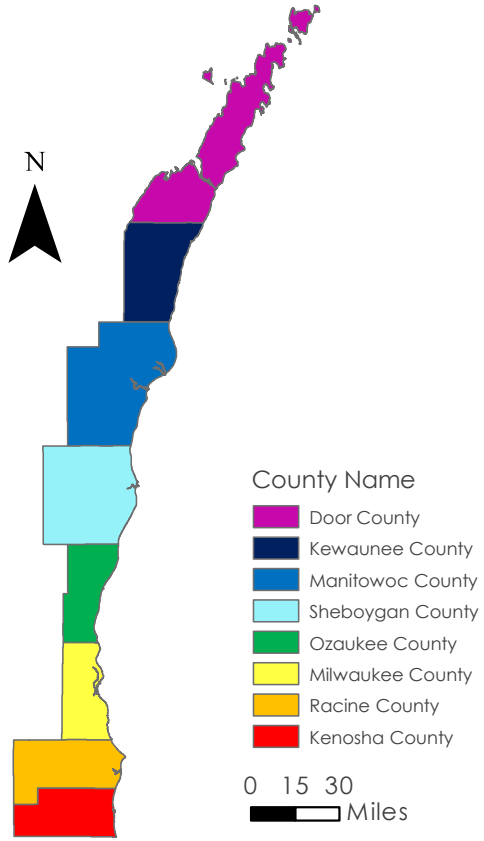


Sources: Esri; Daymet V4 (NASA/ORNL); NLCD 2021 (U.S.G.S); JRC Global Surface Water; U.S. Census Bureau

Results – Growing Degree Day Time Series



Average R^2 = 0.025

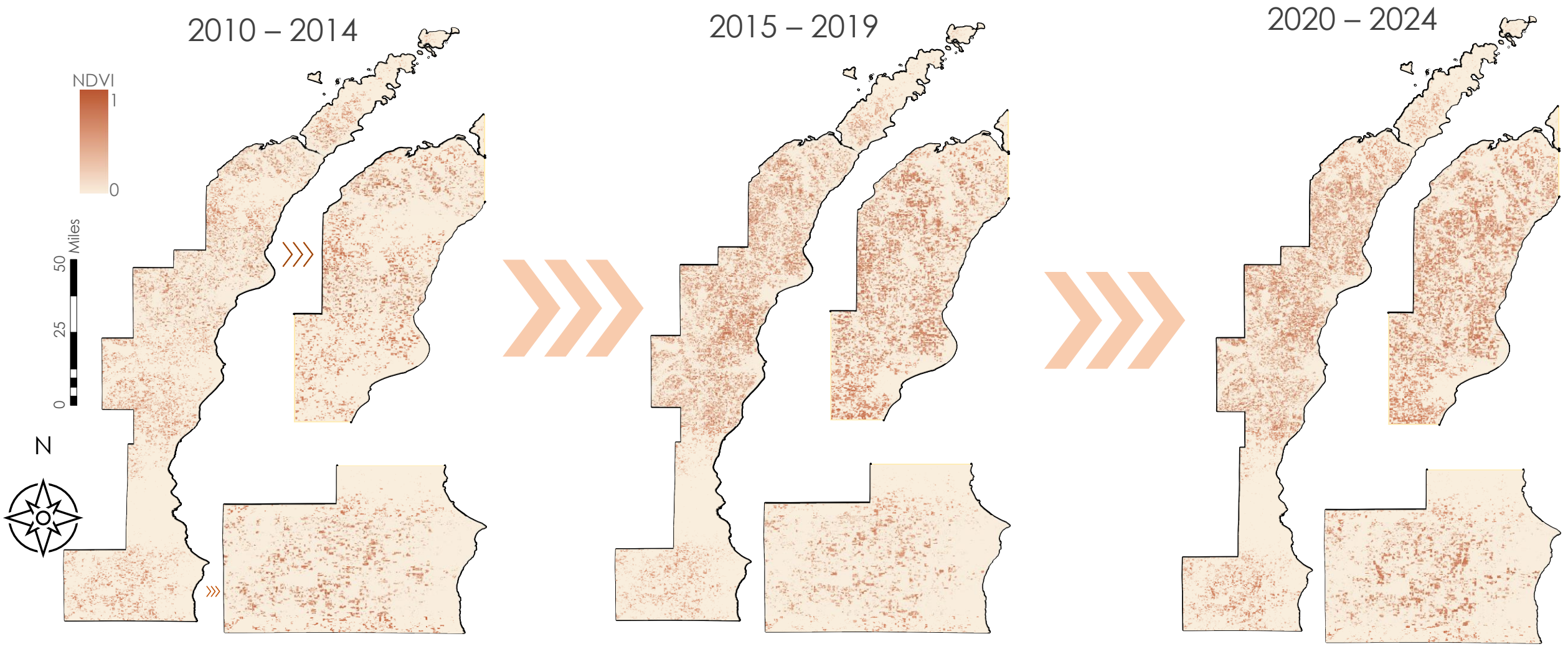


Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC); NASA ORNL DAAC; JRC Global Surface Water 1.4

$T_{avg} - T_{base} = GDD$

Kenosha & Racine county exhibit greatest GDD volatility

Results – Mean Cover Crop Adoption Map

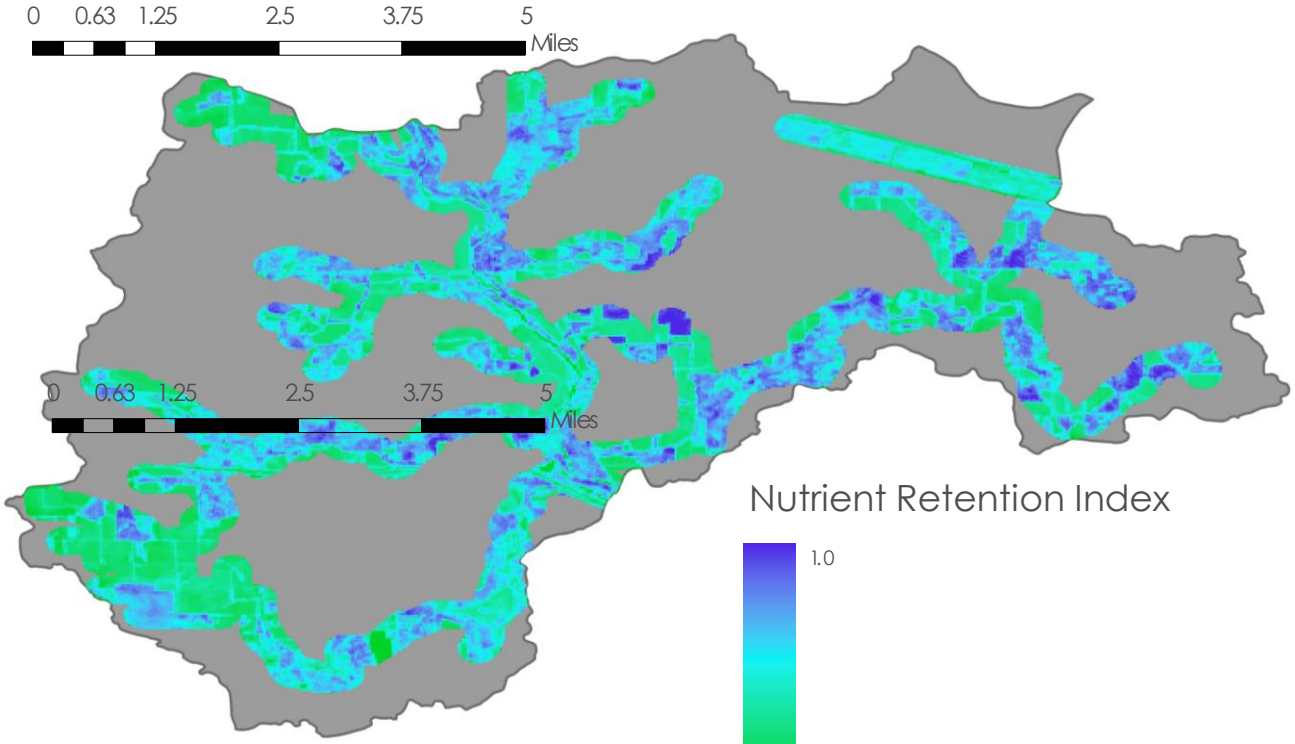


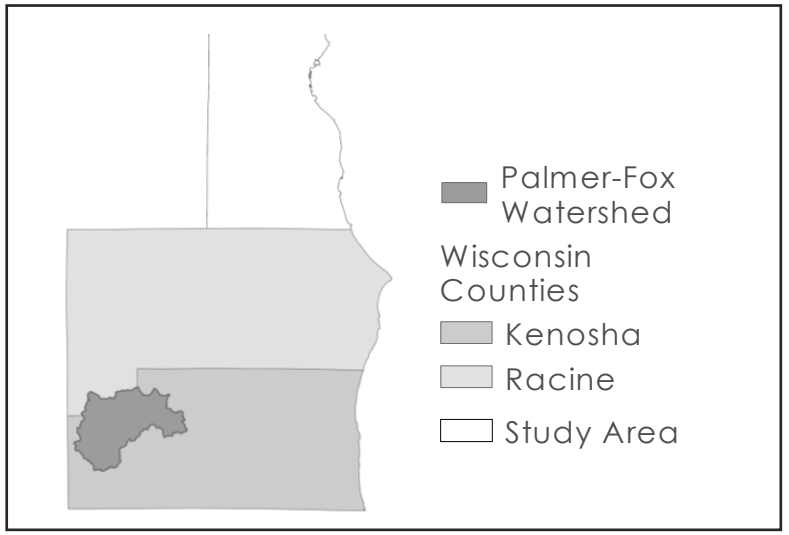
Pixel Count: 1,296,267
Square Miles: 450

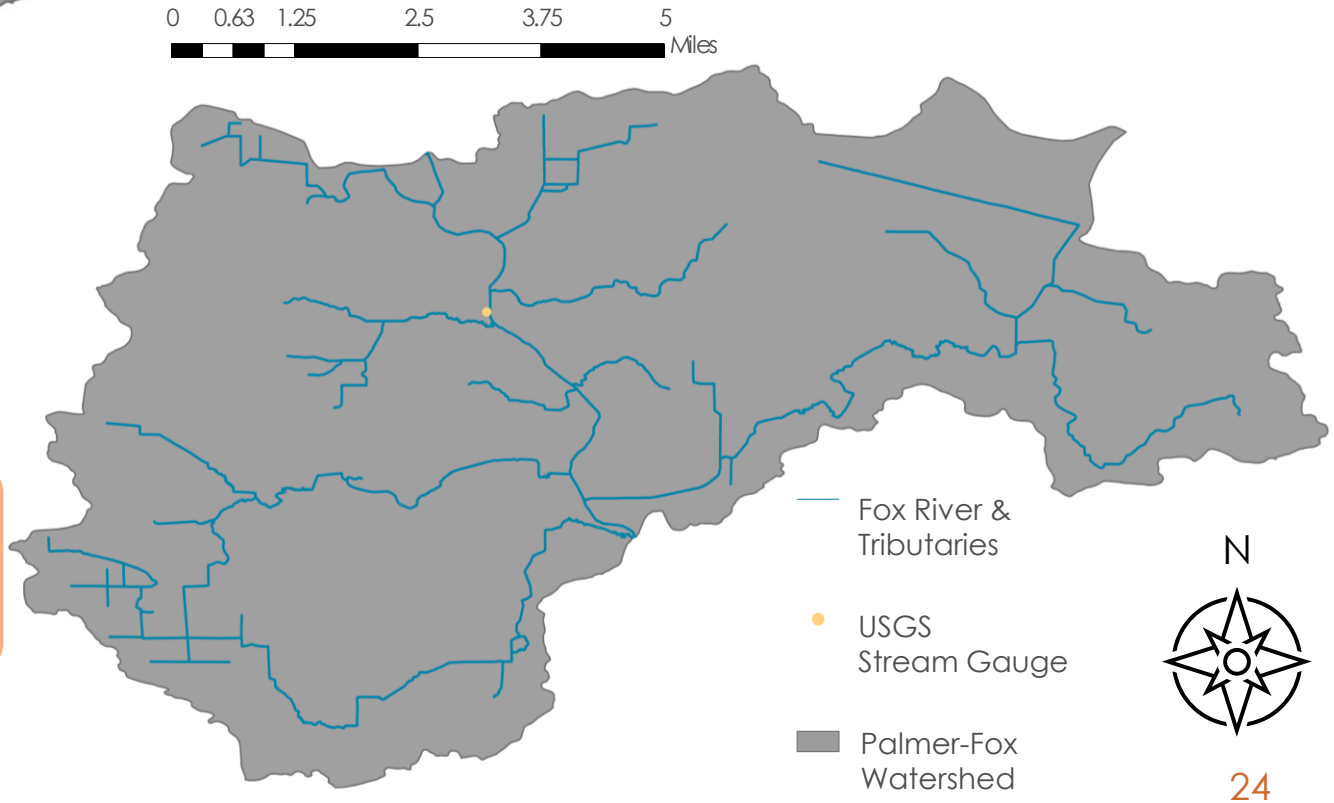
Pixel Count: 1,972,300
Square Miles: 685

Pixel Count: 2,280,503
Square Miles: 793

Results – Hydrologic Model



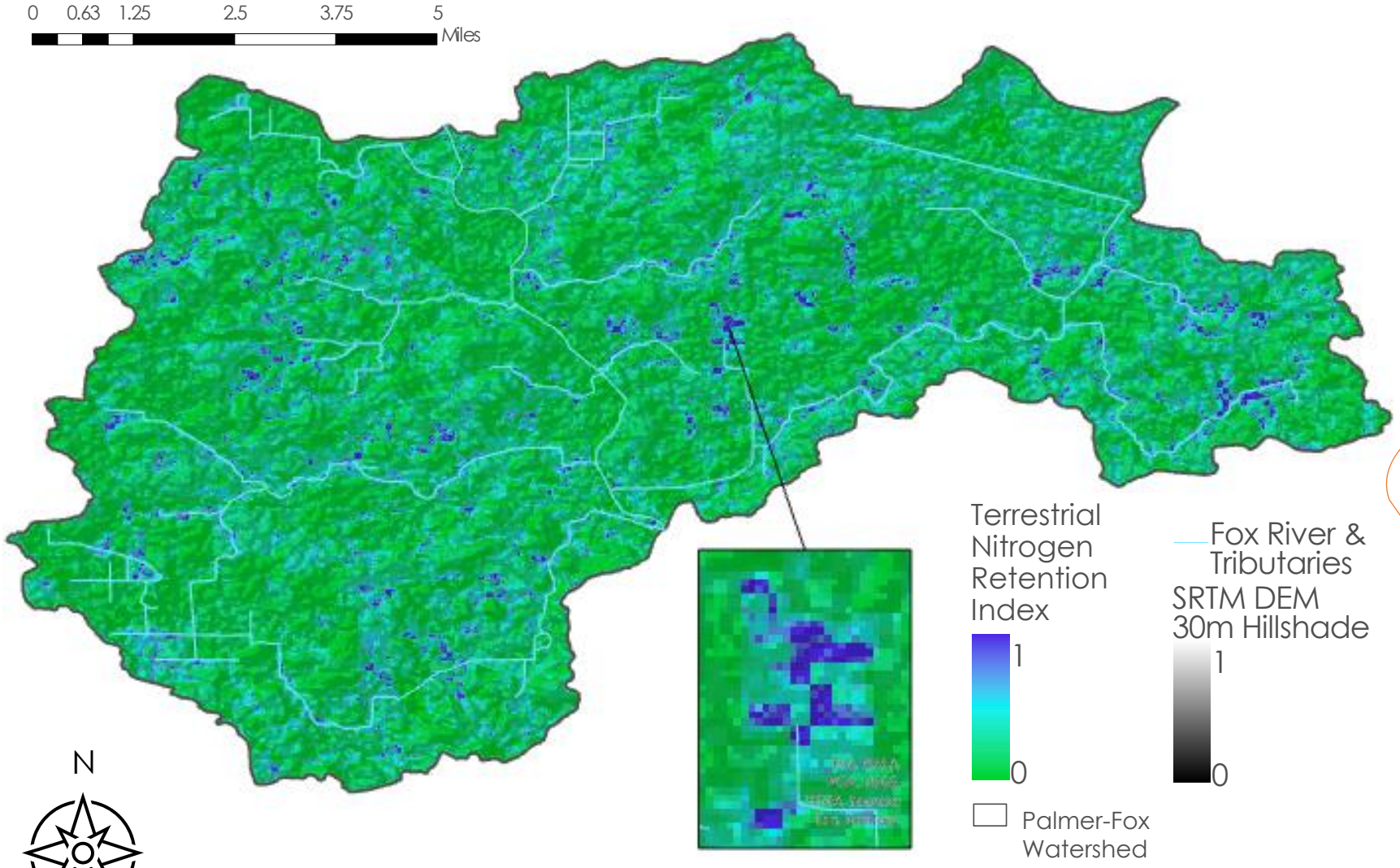


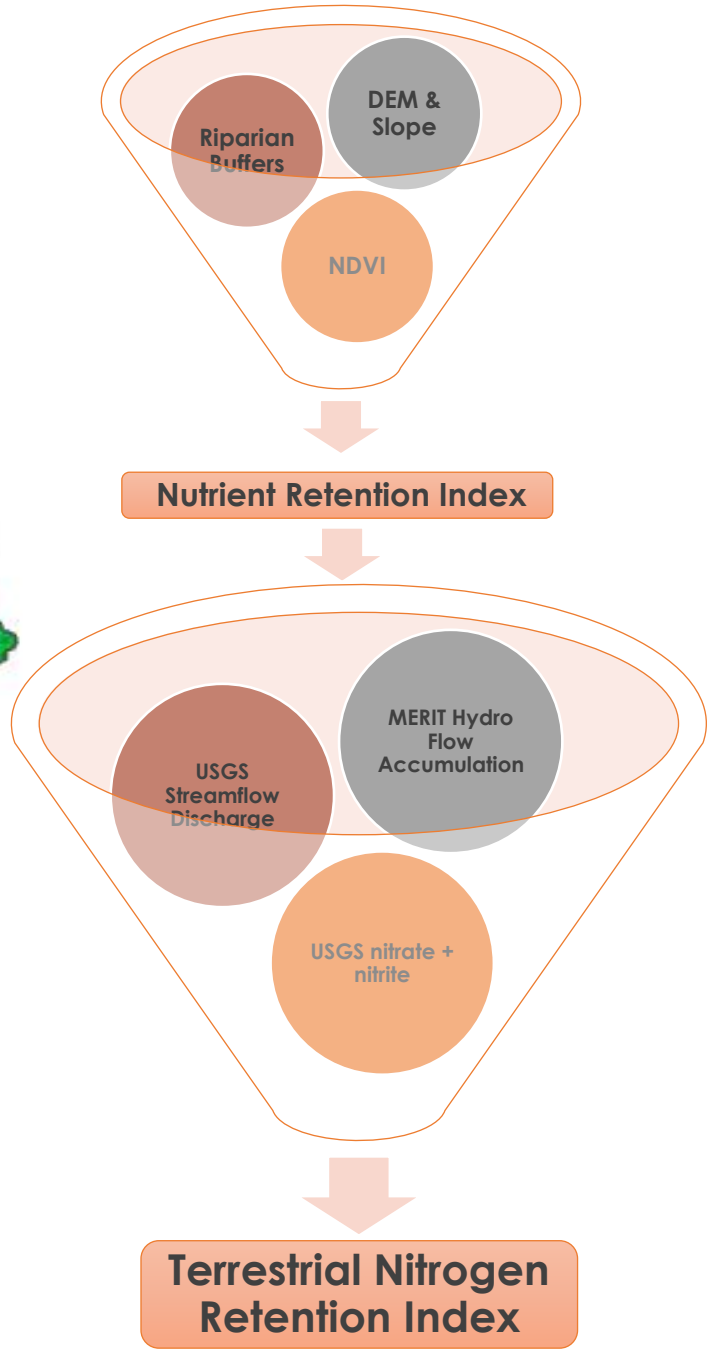


Fox River Riparian Zone NRI: Pixel-weighted SRTM DEM 30m, slope, masked cover crop NDVI, and riparian buffers

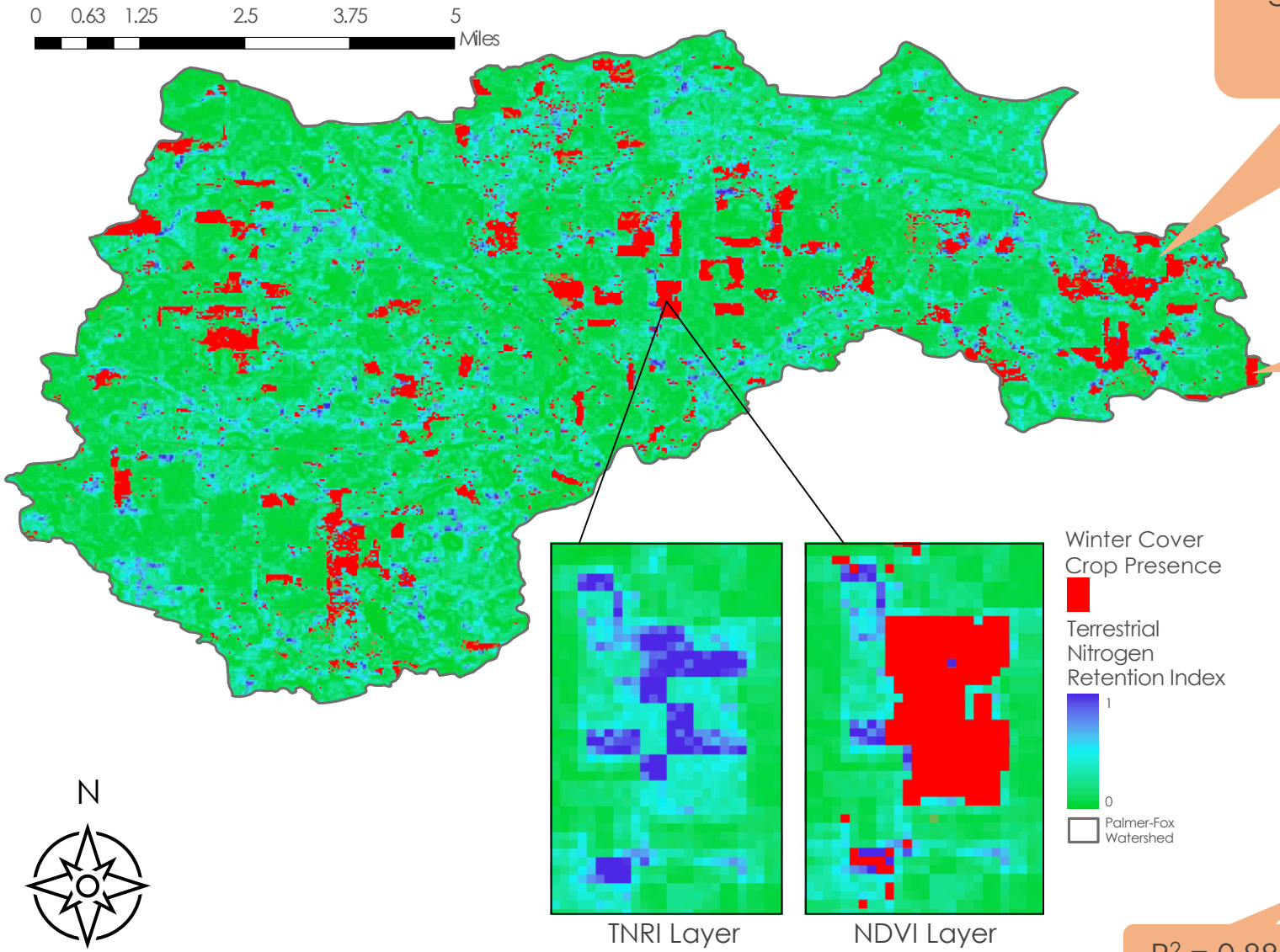
Differentiate areas of terrestrial nitrogen retention vs nitrogen deposited into Fox River

Results – Hydrologic Model



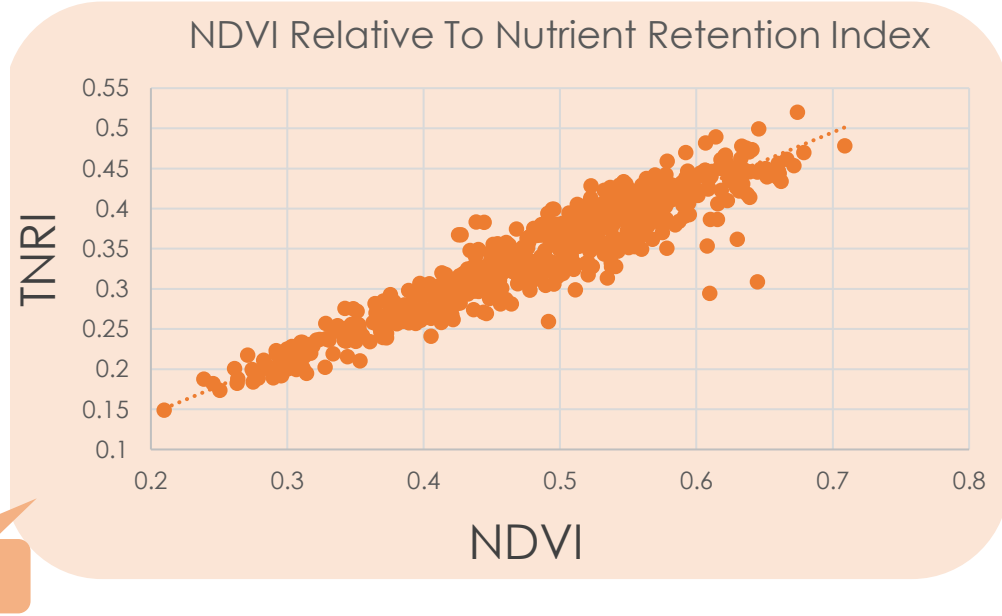


Results – Hydrologic Model



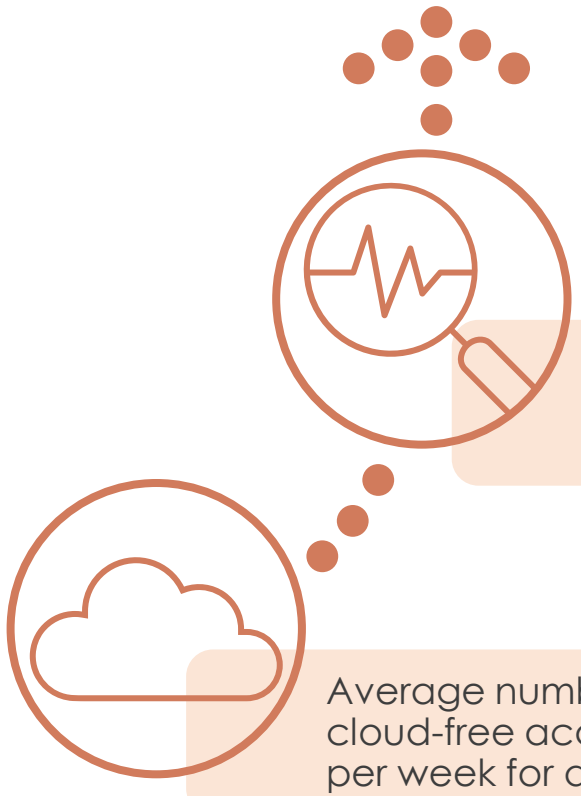
High TNRI leads to improved soil health, water quality, and mitigates erosion

Cover crop adoption zones (red) overlap over 50% of high TNRI values (blue), indicating high cover crop NDVI (0.5+) leads to more productive terrestrial nitrogen retention



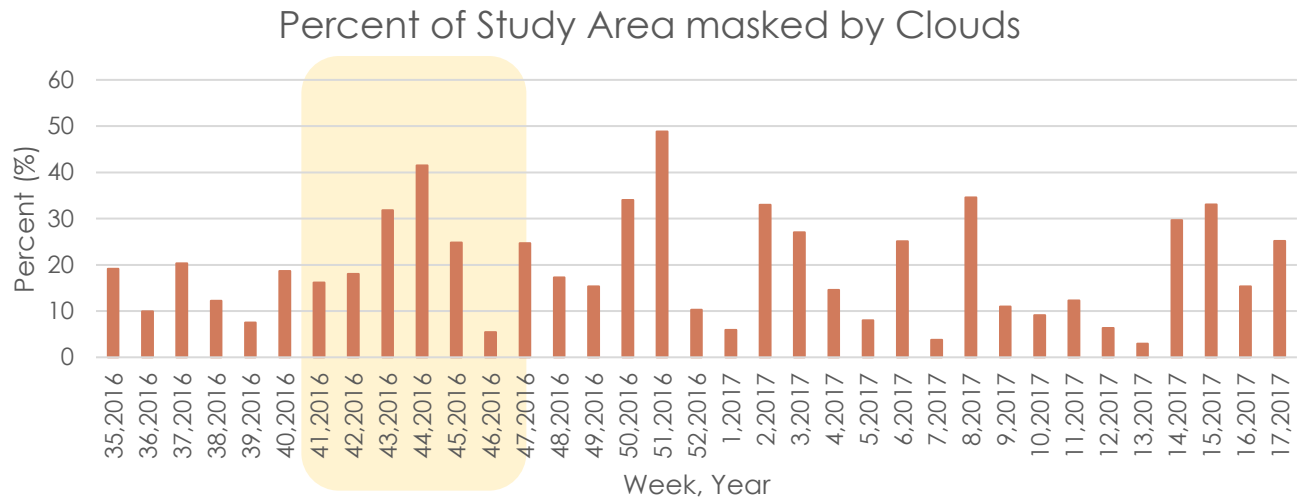
Uncertainties – First Frost Time Series

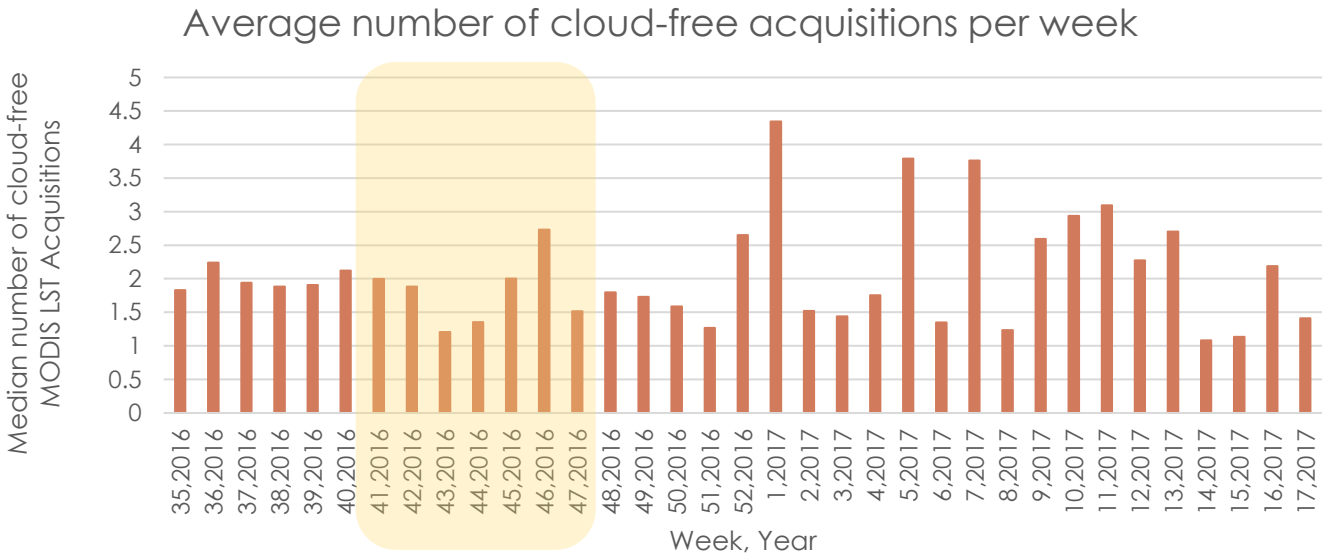
Cloud Cover Analysis



Percent of study area masked by clouds by week

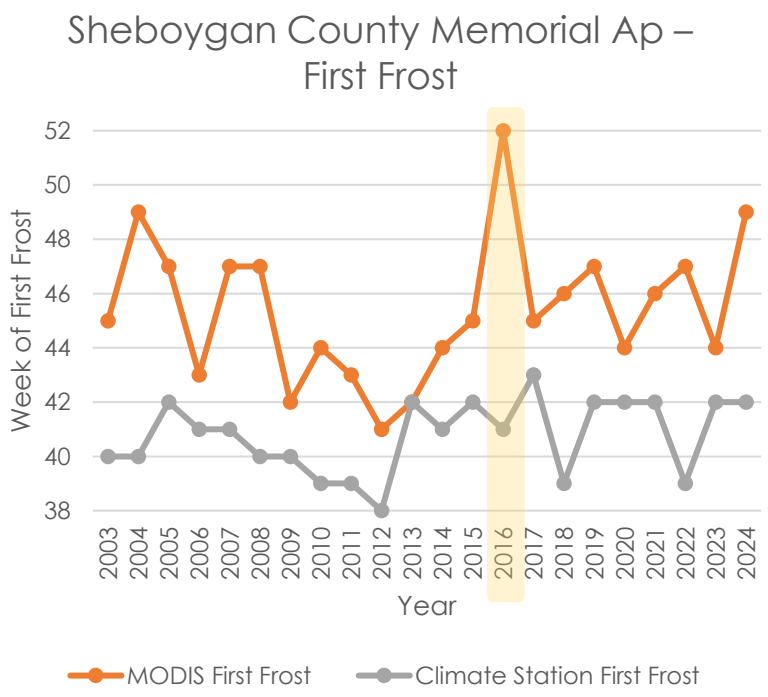
Average number of cloud-free acquisitions per week for a given pixel

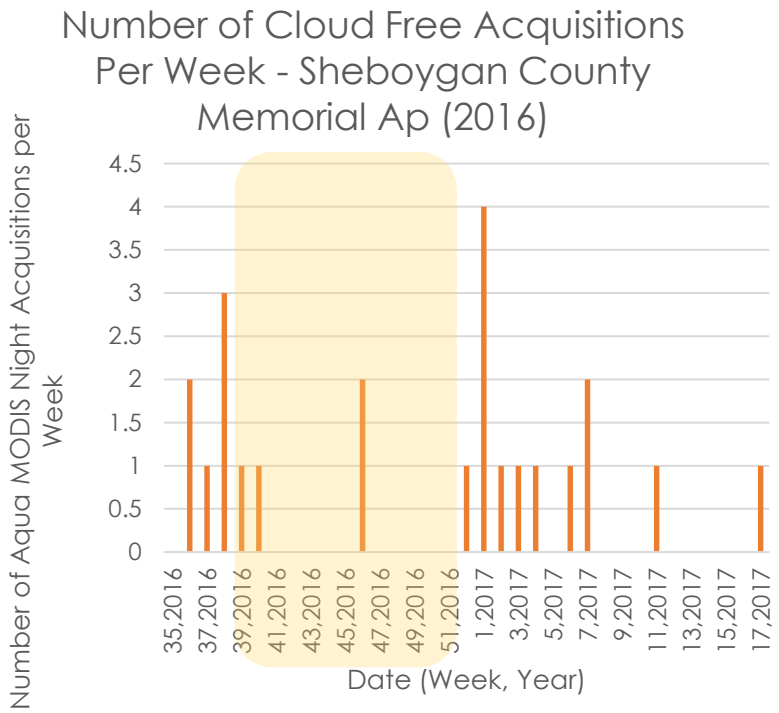


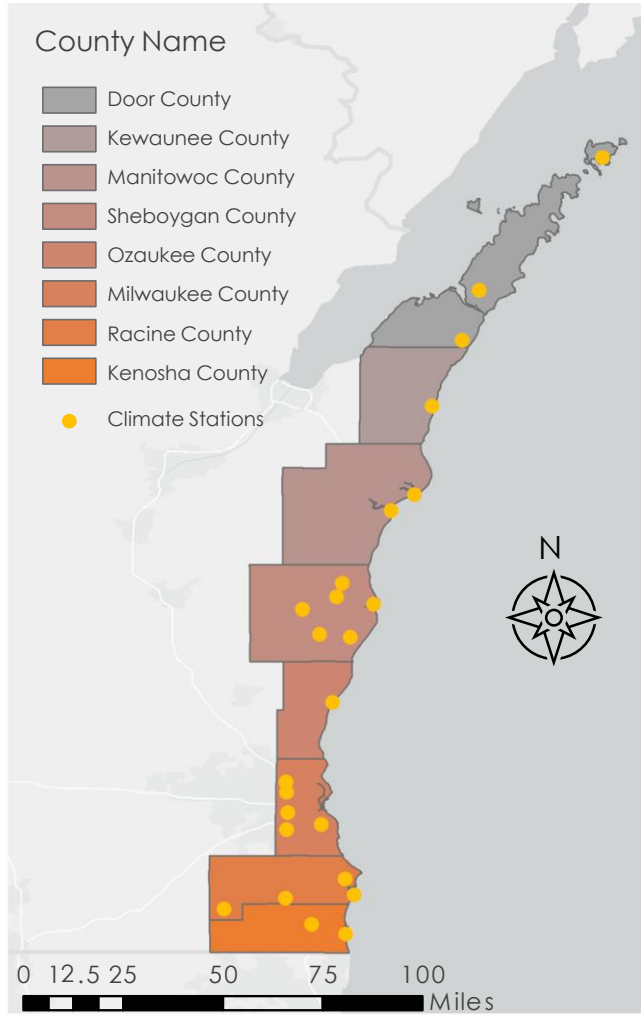


Uncertainties – First Frost Time Series

Access Climate Station Daily Temperature Data → Identify Week of First Frost → Plot Climate Station Locations over MODIS output → Extract MODIS pixel values at climate stations

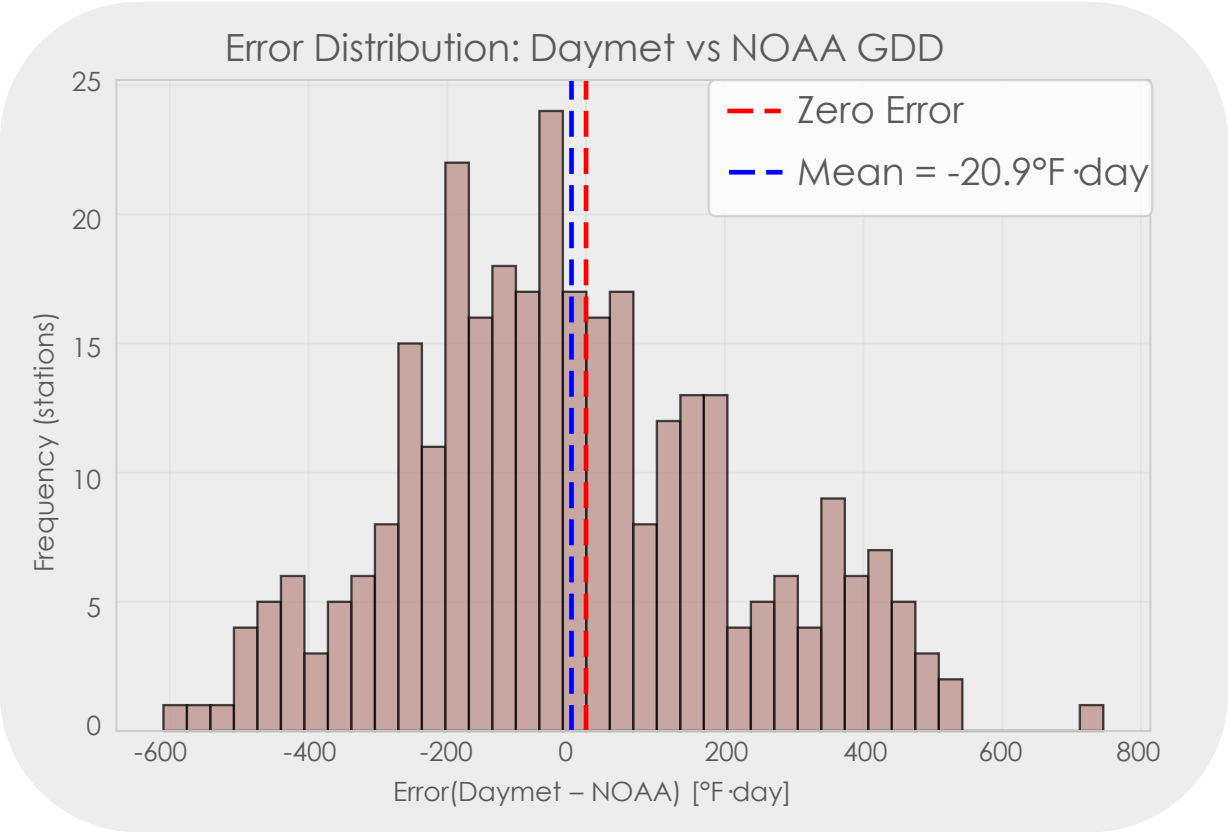


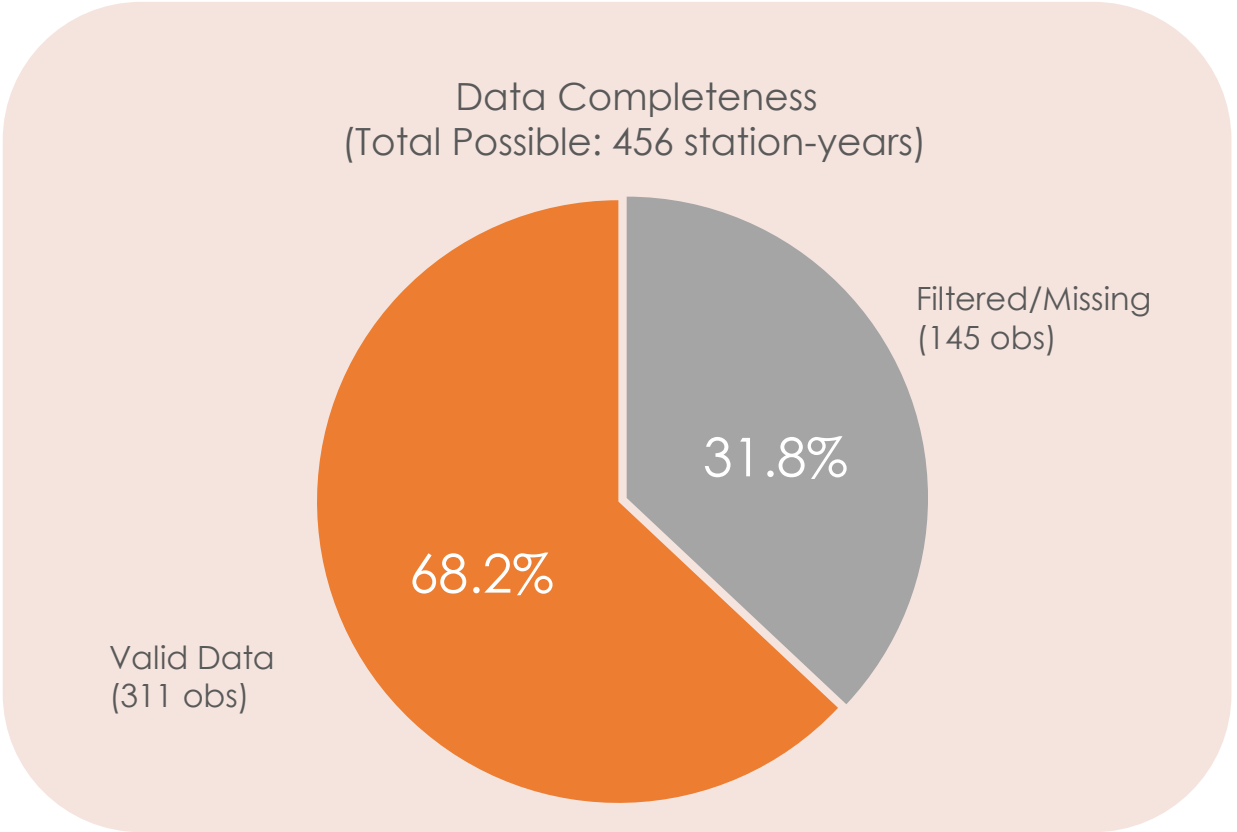


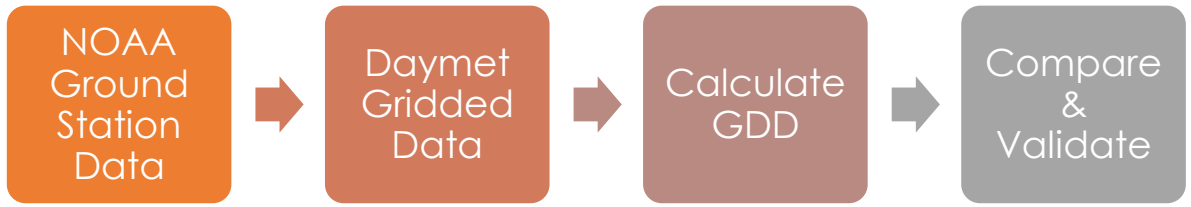


Basemap: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Uncertainties – Growing Degree Days







Station-years & Filtering			
24 stations	19 years	456 total	Filter >20 days missing

Uncertainties – Growing Degree Days

Validation Metric	Result
Mean Bias	-20.9°F ·day
Relative Error	15.8%
Sample size(n)	311

Notes on statistical comparison:

Linear Regression analysis between NOAA & Daymet

Daymet shows moderate agreement with ground stations (r = 0.499)

Systemic underestimation of ~20.9°F ·day

Uncertainties – Hydrologic Model

Biogeo-chemical

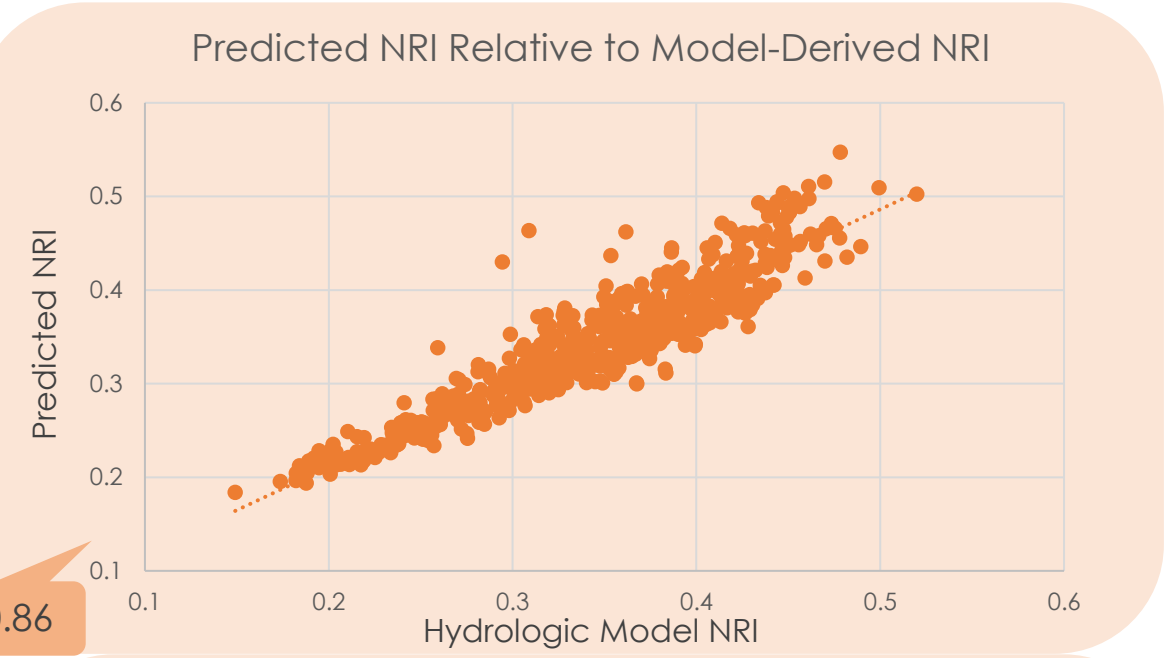
- Cover crop phenology variability
- Soil chemistry data
- Subsurface hydrology

Spatial

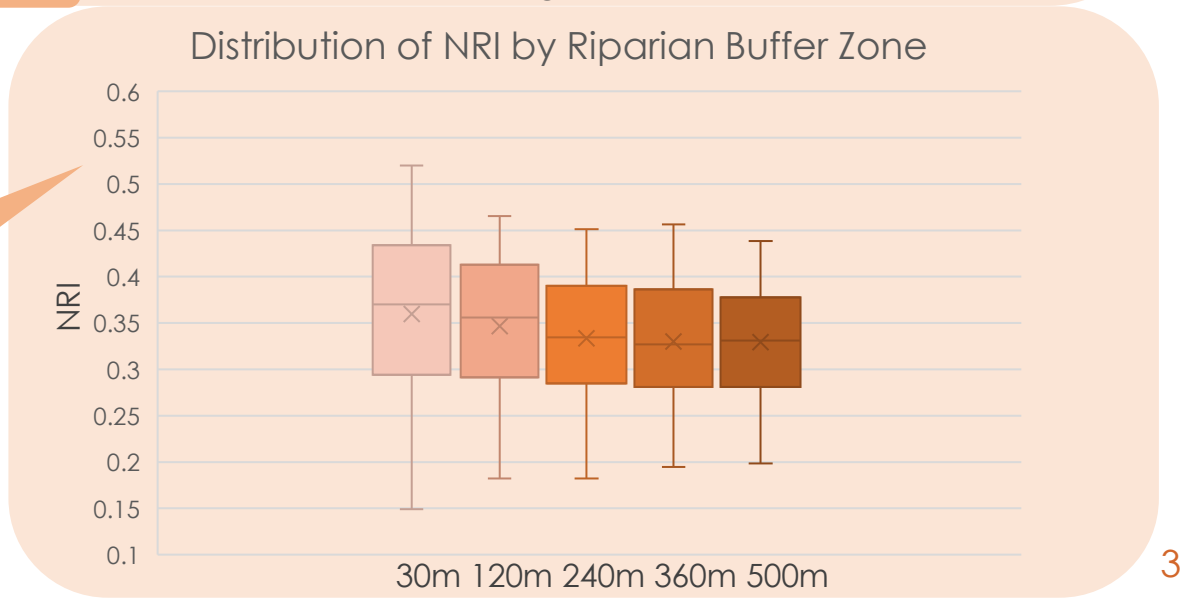
- Static SRTM DEM & MERIT DEM
- Winter cover crop zones vary in management
- 1 watershed as proxy

Temporal

- Study period prioritizes peak winter cover crop growth
- Absence of year-to-year variability



Significantly higher retention within 30 m buffer



Conclusions

Image Credit: MCCC, DeAnn Presley

Key Findings

First Frost: Increasing trend in week of first freeze along lakeshore

Growing Degree Days: Southern counties accumulate ~300°F·day more GDD with high inter-annual variability

Cover Crop Adoption: Increased cover crop adoption over 20-year period

Hydrologic Impact: Strong correlation between cover crop adoption and terrestrial nutrient retention productivity/water quality

Feasibility and Partner Implementation

Seeding Dates
Historical, annual frost date trends inform future growing seasons

Lake Effect
Cover crop GDD decreases further inland

Cover Crop Adoption
Spatial representation of cover crop accumulation

Environmental Impact
Framework to monitor cover crop impact on water quality

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