Landsat-based Upper Great Lakes Forest Phenoclimatology, 1984-2013

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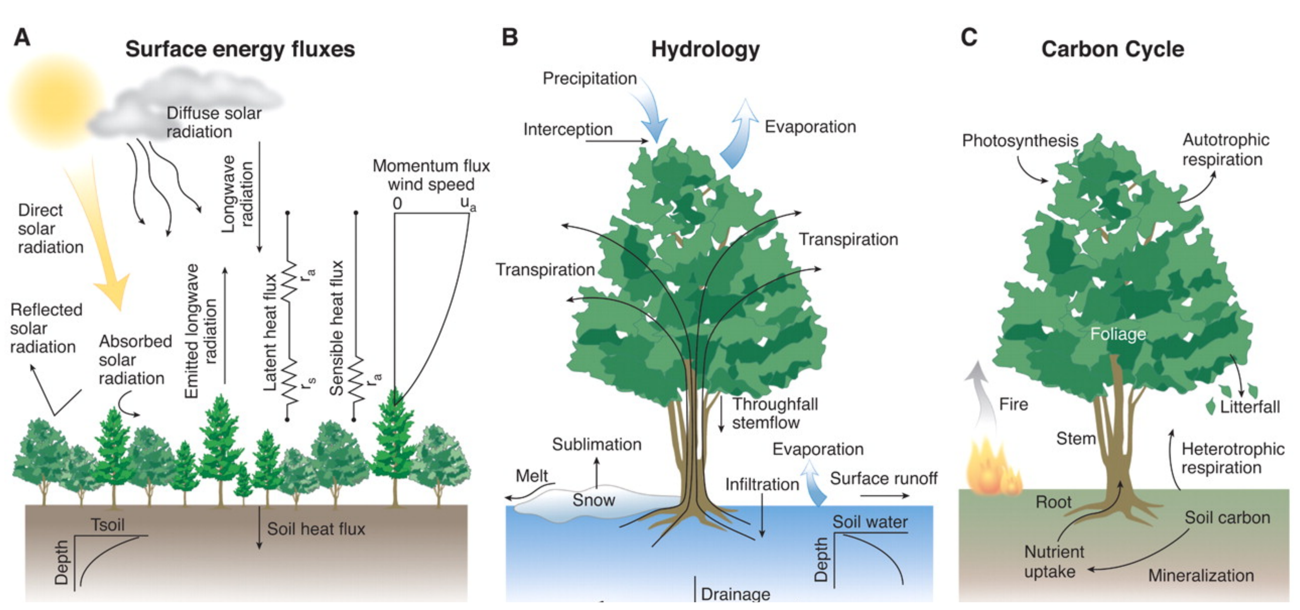
Problem

Land-surface models (LSMs) use bulk state/exchange parameters for coarse vegetation categories.

Some use a "mean" NDVI-based phenological curve, and some use mechanistic phenology models, but no LSMs use observation-based, climate-sensitive dynamic phenology in forest areas.



from Bonan [2008, *Science*]

Objectives

1. regional climatology and climate trends
2. regional forest phenology
3. relationships between climatology and phenology
4. improved maps of forest phenology accounting for weather/climate influences on interannual phenological variability.

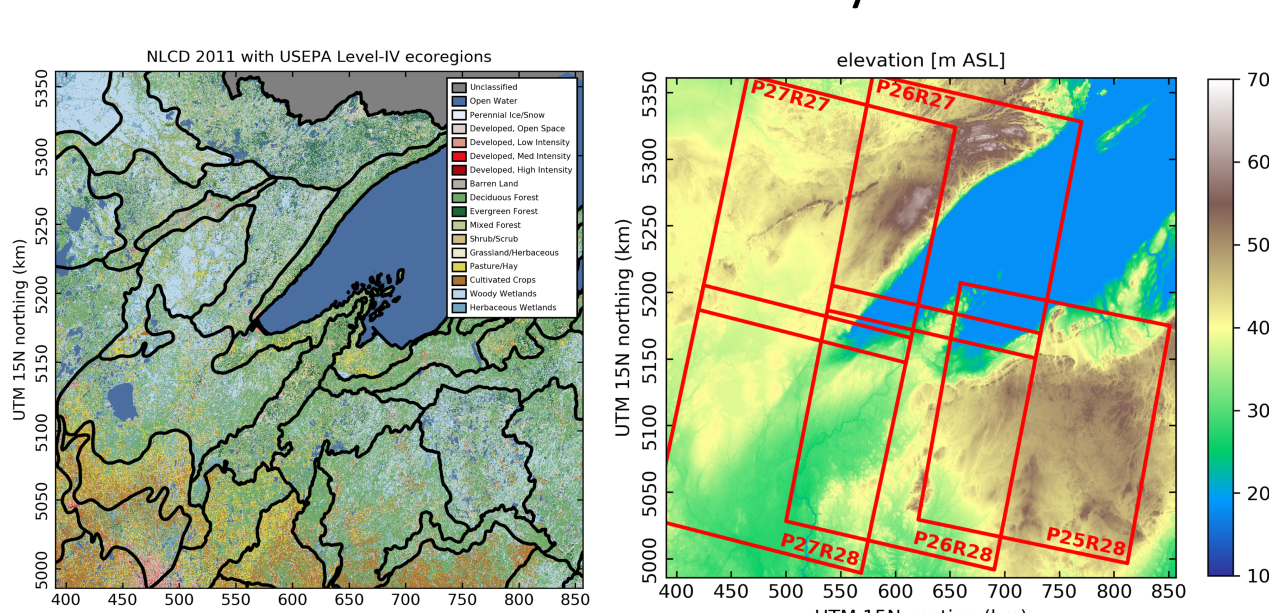
Study Area

202,000 km^2 around western Lake Superior

Mixed boreal and sub-boreal forest

5 Landsat footprints (~130M px, excluding overlaps)

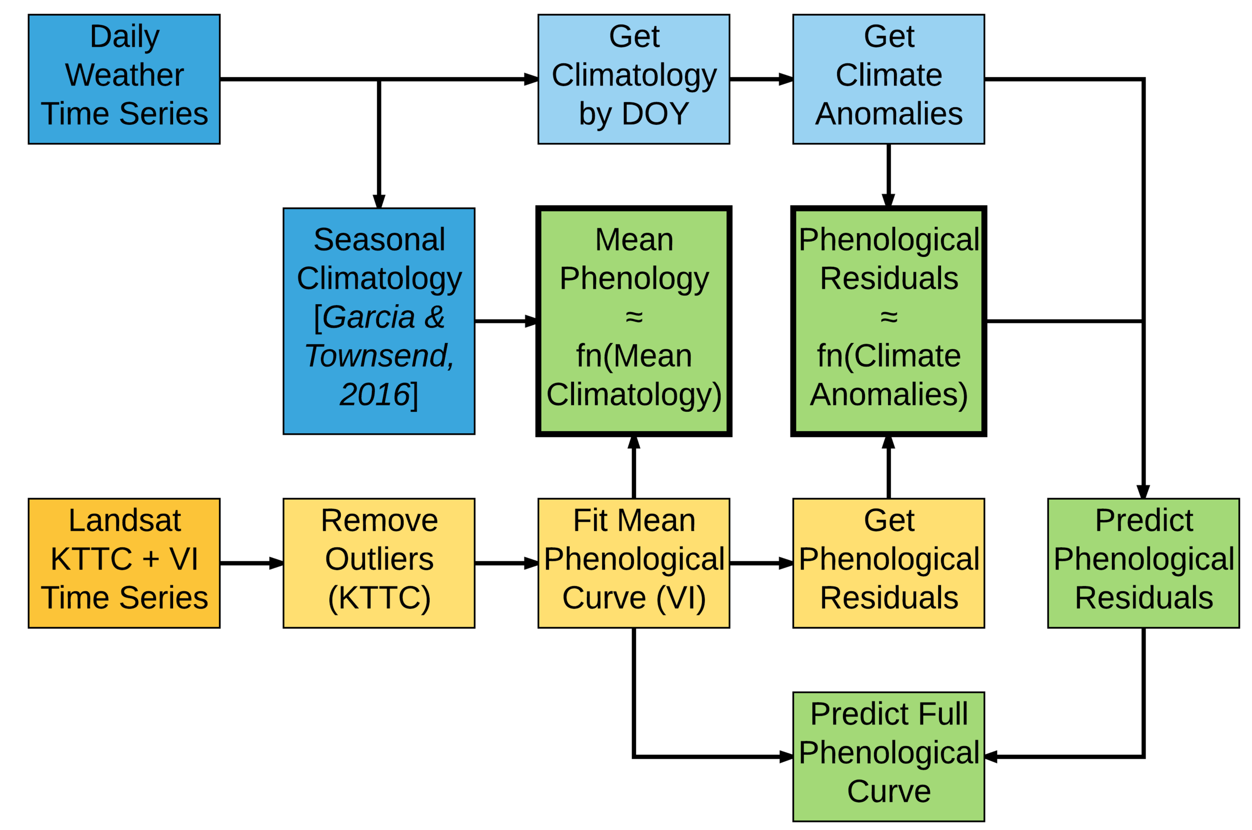
200-250 scenes each over 30 years



Computational Services and Resources

Wisconsin – University of Wisconsin–Madison; HT Center for High Throughput Computing; Open Science Grid

Process

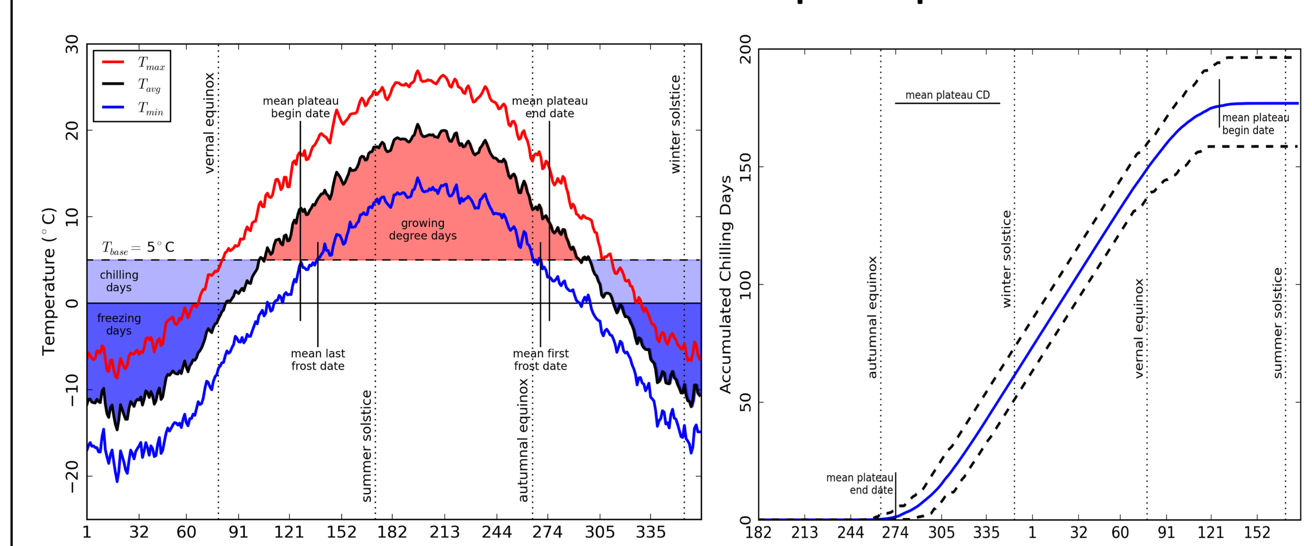


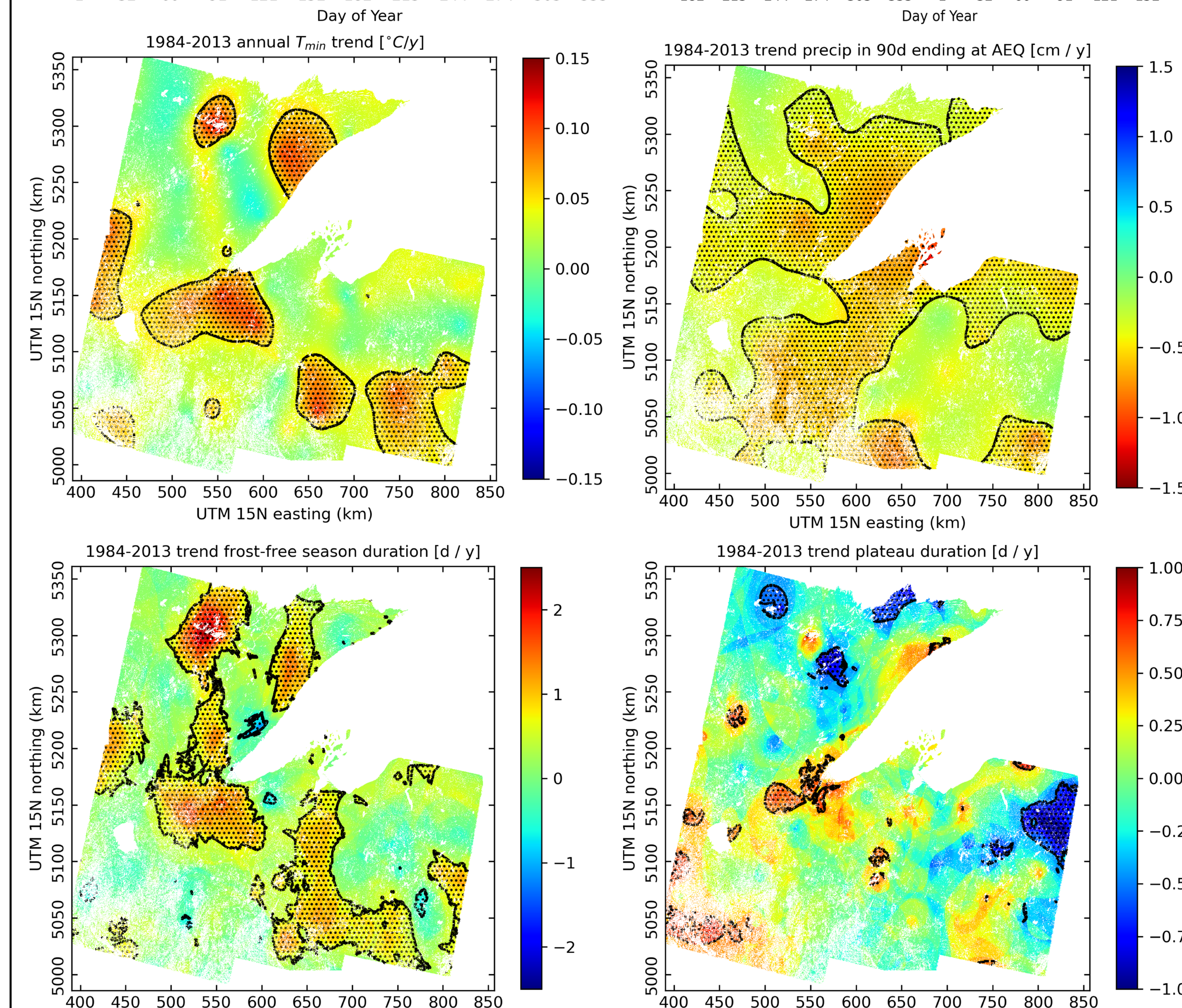
1984-2013 Climatology

see *Garcia and Townsend [2016, JGR–Atmos.]*

From gridded daily obs, calculated indicators include:

- Freezing days (FD) and Chilling days (CD)
- Growing degree days (GDD)
- Last spring frost and first autumn frost
- Beginning and end of the CD plateau
- Seasonal mean temperatures
- Seasonal and annual total precipitation



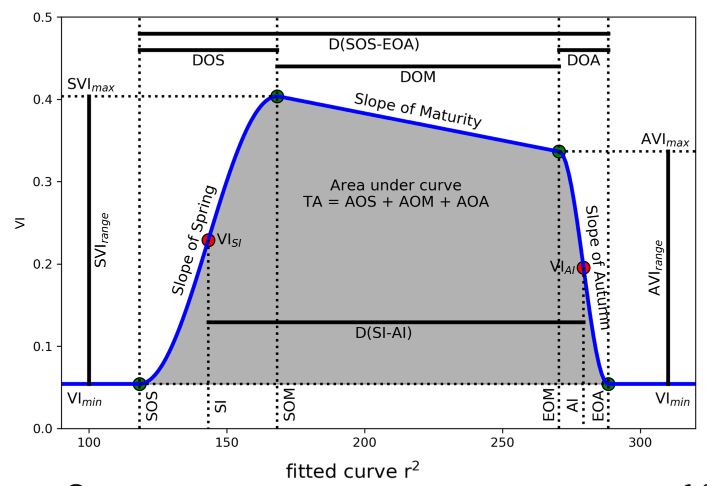


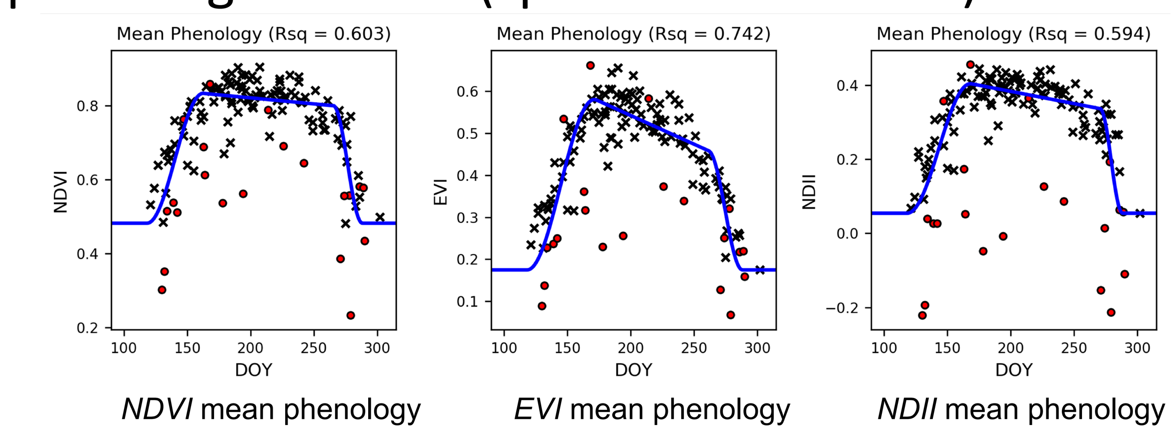
Phenological Modeling

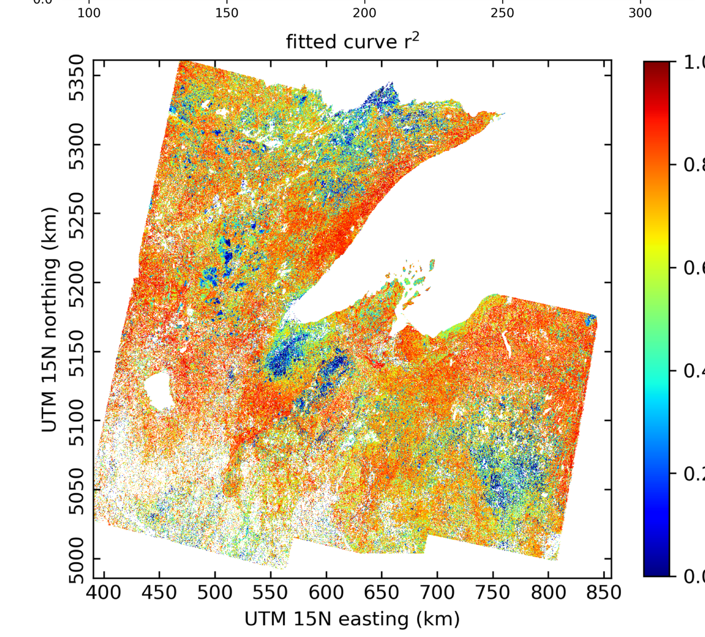
Use standard Landsat vegetation indexes:

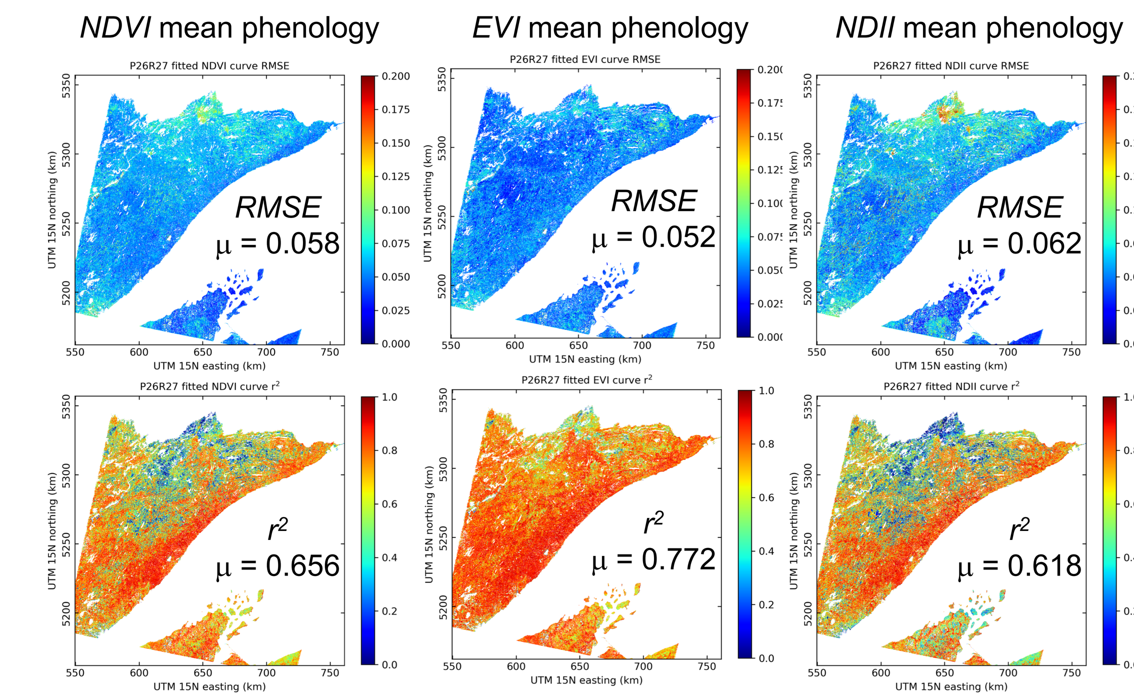
KTTC (3 components) → identify outliers and keep for later analysis

NDVI, EVI, NDII → fit mean phenological curve (special formulation)









Most studies ignore, or do not attempt to explain, the VI (phenological) residuals. For this, we use PLS regression (PLSR) against date-specific climate anomalies:

- maximizes covariance, instead of minimizing correlation
- incorporates the response variable (V), not just the predictors (W)
- does not assume predictors are error-free, unlike OLS regression
- similar to Multiple Linear Regression, but handles predictor collinearity
  → able to handle many predictor variables with few response variables

$$\begin{bmatrix} W_{1,1} & \cdots & W_{m,1} \\ \vdots & \ddots & \vdots \\ W_{1,n} & \cdots & W_{m,n} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_m \end{bmatrix} = \begin{bmatrix} V_1 \\ \vdots \\ V_n \end{bmatrix}$$