A Newly Identified Role of the Deciduous Forest Floor in the Timing of Green-Up

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Ecophysiologic significance of forest floor

- Shelter for decomposers, insects, earthworms, borrowing organisms etc.
- Recycling of above and below ground litter (>90%)
- Retention of nutrients (high content of SOM)
- Retention of water
- Control of carbon dioxide and other gases exchange with atmosphere
- Thermal “blanket”

Unique thermal properties of forest floor

a)low volumetric heat capacity

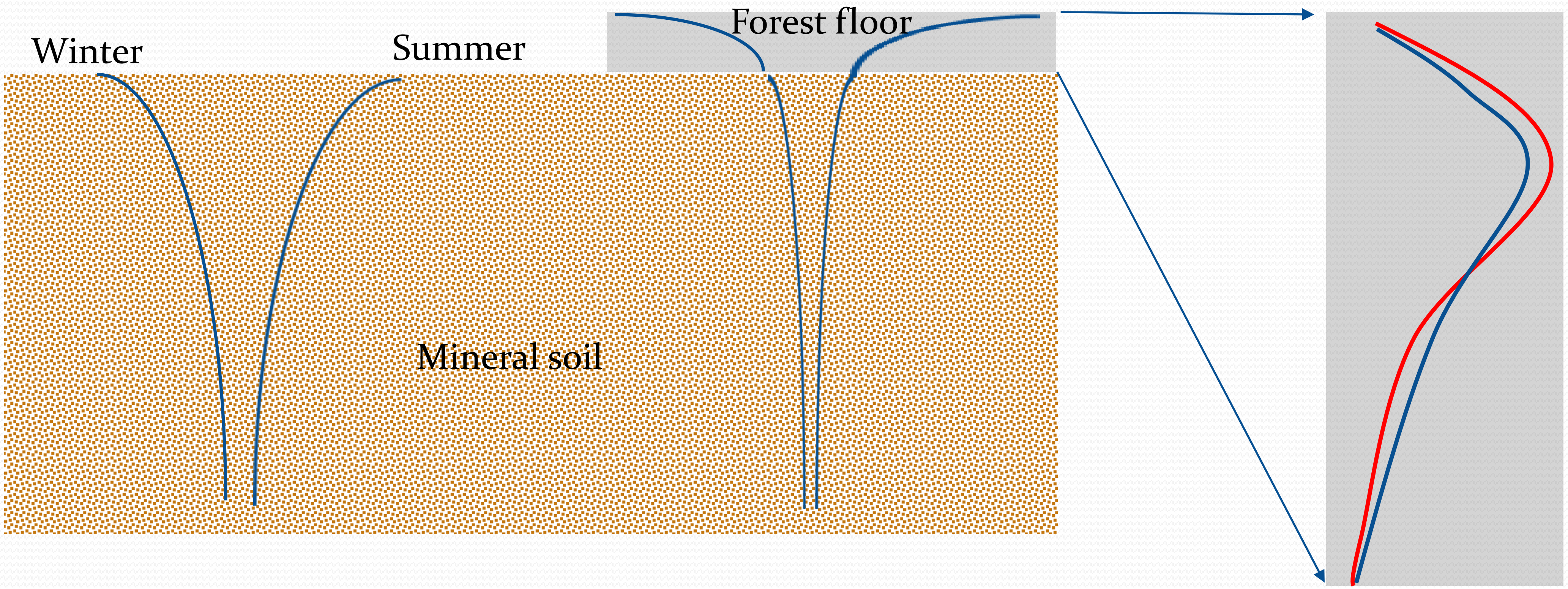
b) low thermal diffusivity.   (like desert soil)

5X times lower D than snow!

$$D = \frac{Heat\ conducted}{heat\ stored} = \frac{k}{\rho \times c}\ [\frac{m^2}{s}]$$

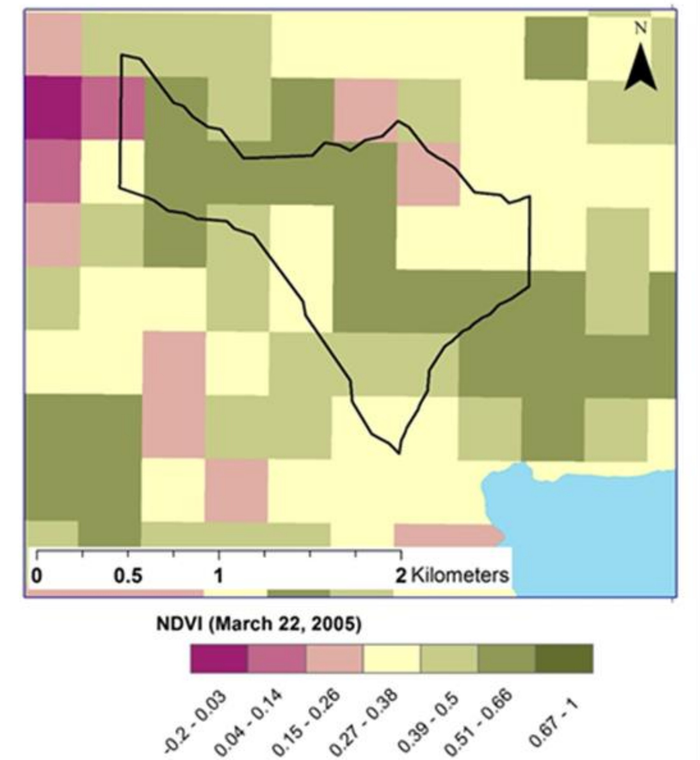
WATER: increases heat conduction and heat storage=>

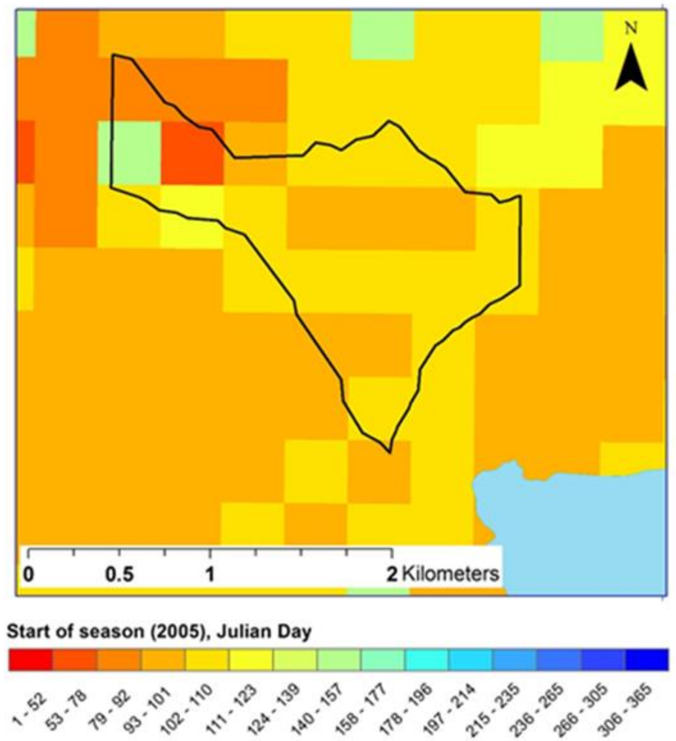
does not change much thermal diffusivity



Problem: Phenology-Temperature relationship cant explain 100% variability in SoS

- Plant phenology studies rarely consider controlling factors other than air temperature.
- Therefore, it is difficult to explain 10 -40 days difference in SoS within a small distance of only a few km where mean annual temperature changes on less than 2 oC!



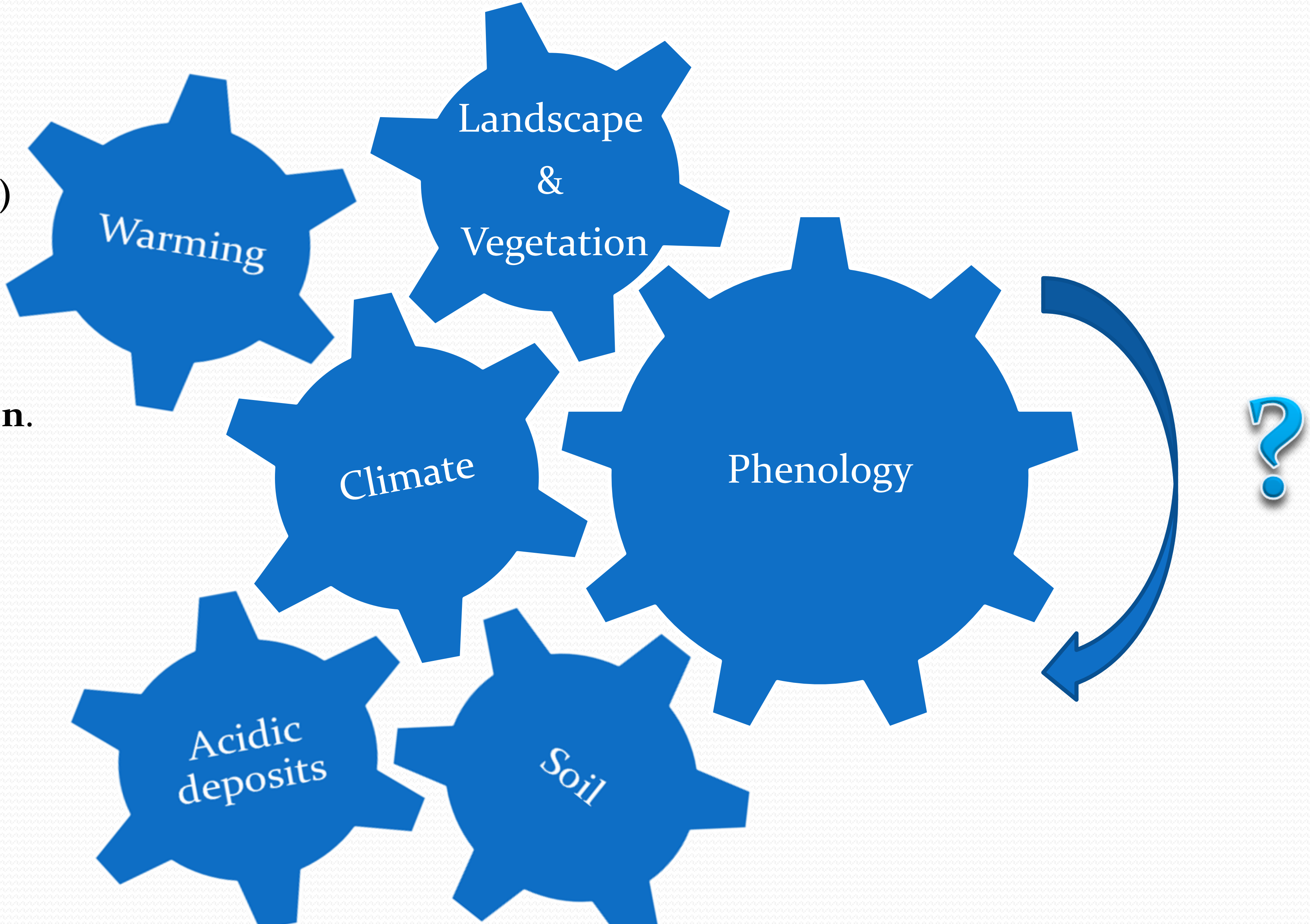


Drivers of Spring Phenology.

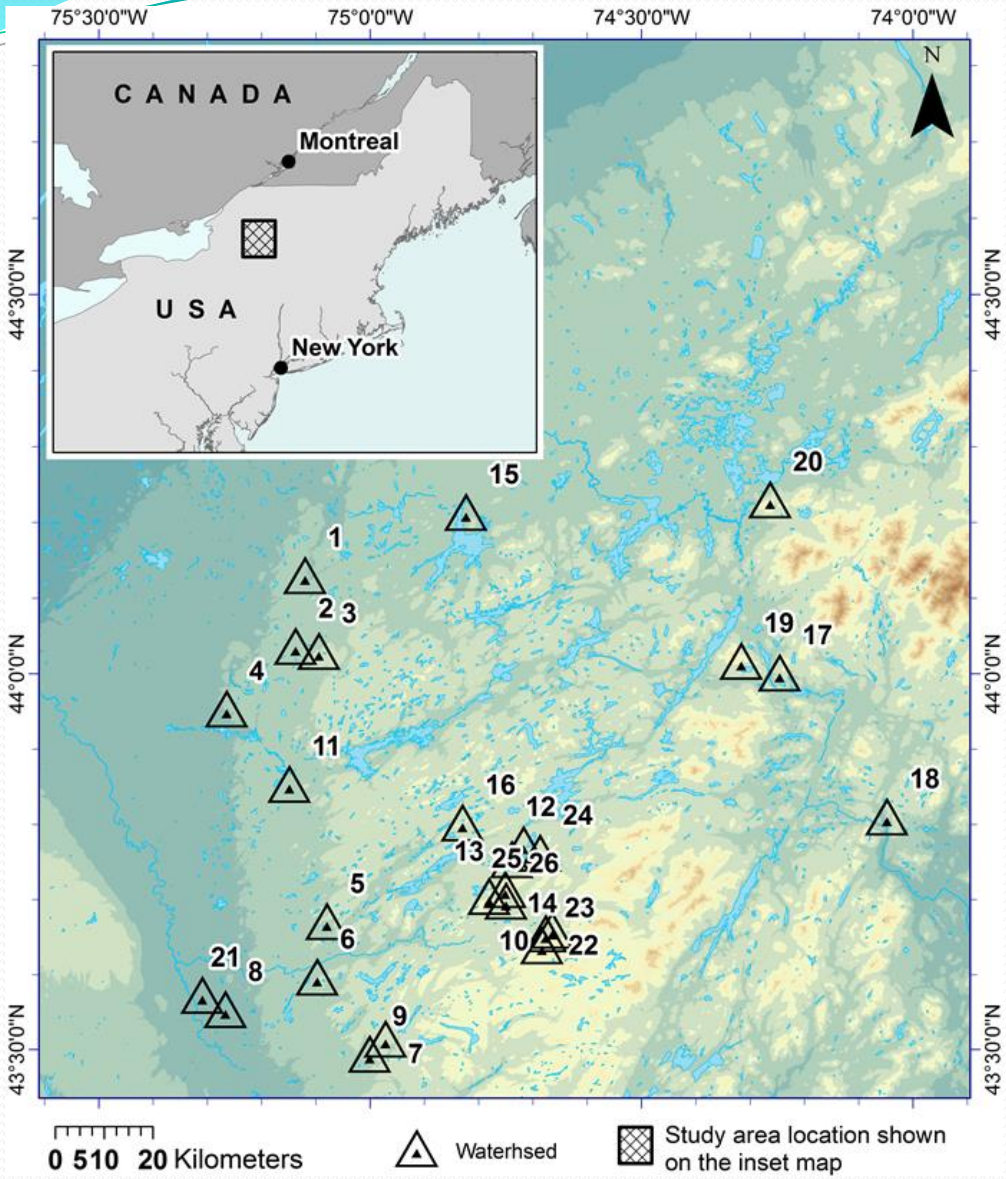
Wielgolaski (2001)
pH- early budbrake

Dahlgren et al. (2007)
K-early flowering?

Arend et al. (2015)
pH – early budbrake
AND early cessesation.



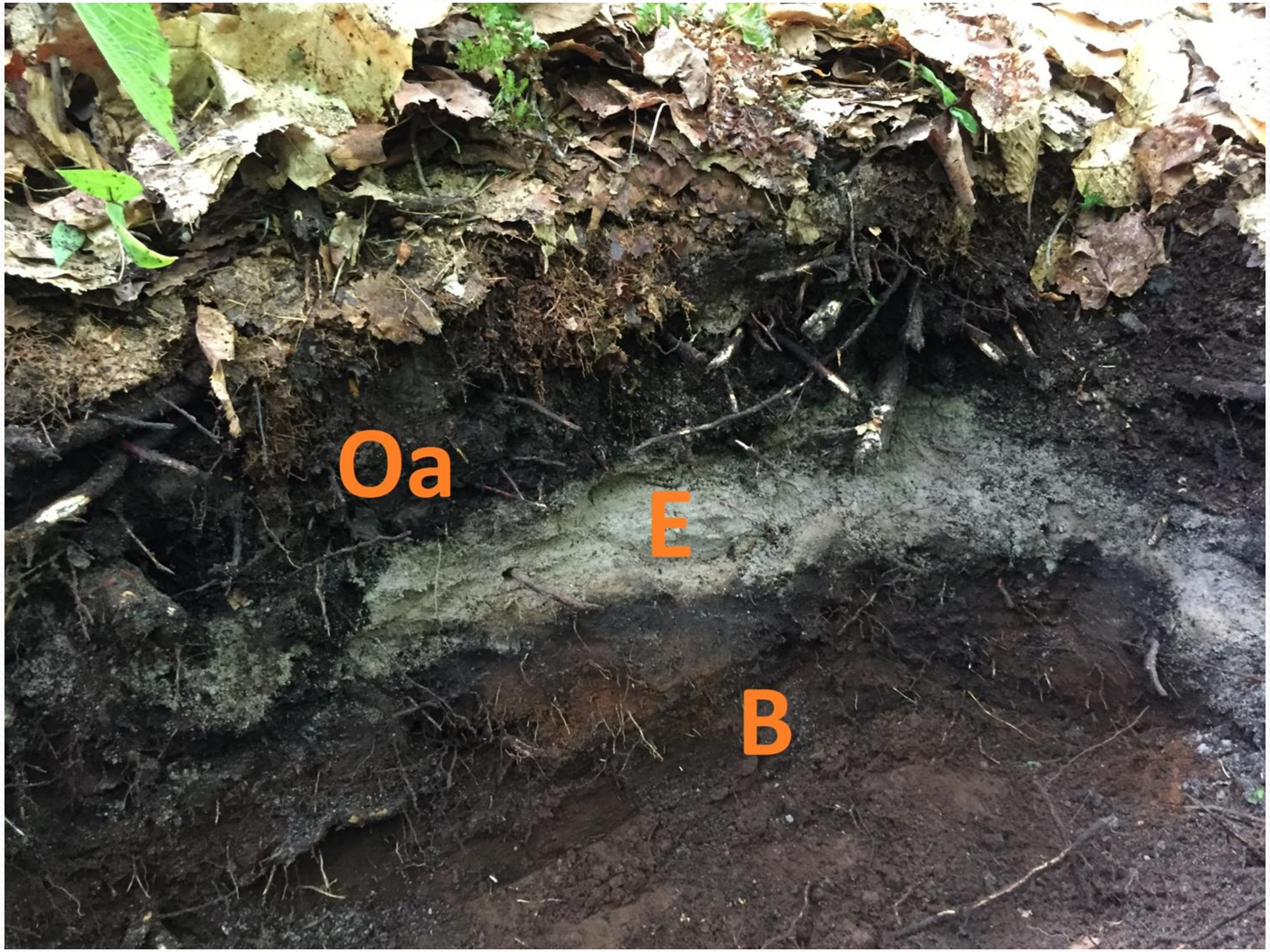
Detail soil survey of 26 Adirondacks watersheds.



DATA

26 small watersheds (1-4 km^2)
over an area of about 150x150 km.
Vegetation: deciduous forest
(sugar maple, beech, yellow birch, red maple
age from 80 to 150 yr)

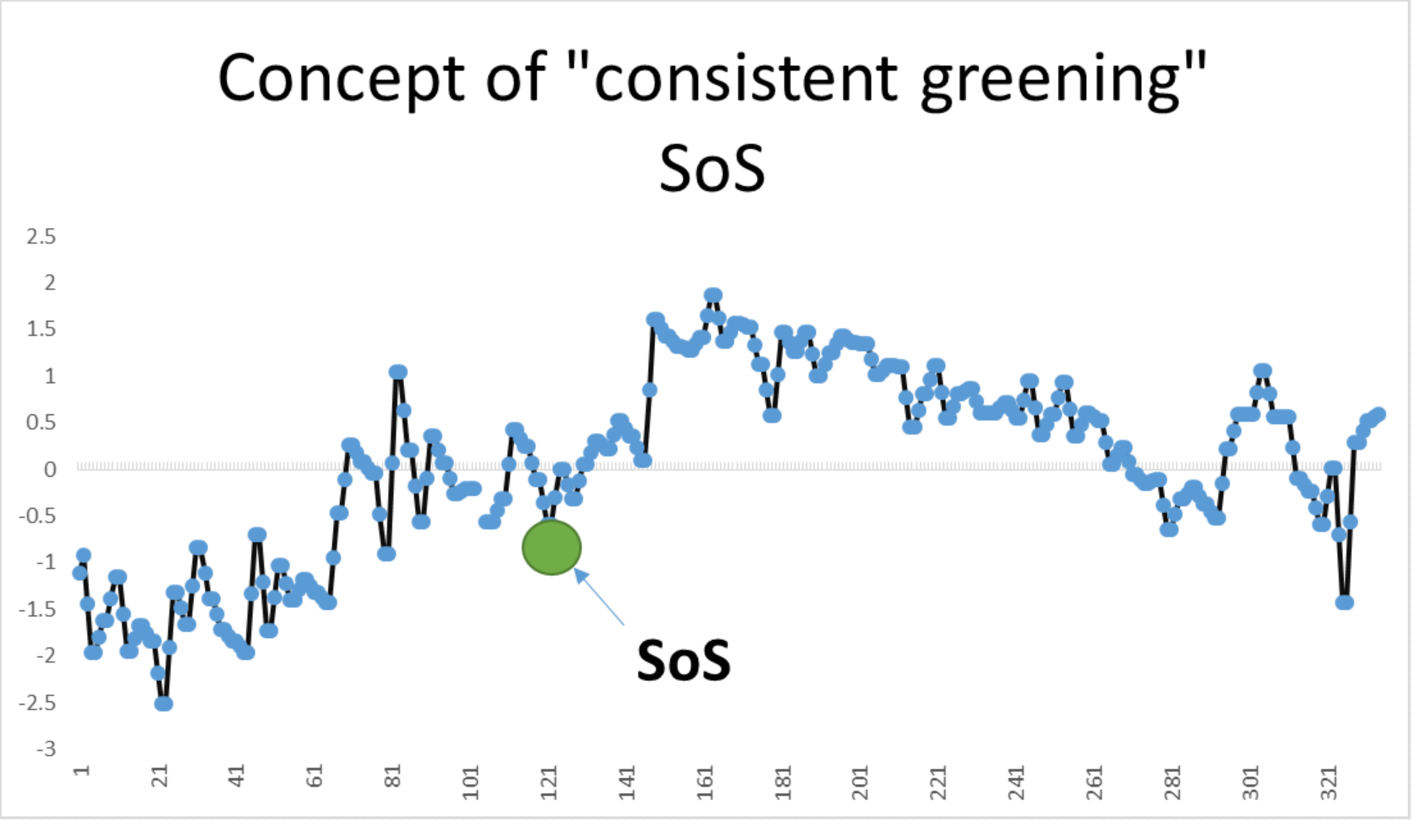
Typical profile of Adirondack Spodosol Soil



In this study we did use data for Oa soil horizon. 3-5 plots per watershed, 10-15 soil profiles per plot.
Oa horizon
holds most of trees roots, and has relatively fast SOM turnover time.
LOI, pH, C%, N%, Ca etc.
11 variables

Surface phenology

MODIS US GS SoS data (MOD13Q1)
SoS,- Start of Season,
the first day
with consistent greening
trends in NDVI record
(250 m)



DATA

Climate data

DAYMET (1x1 km)

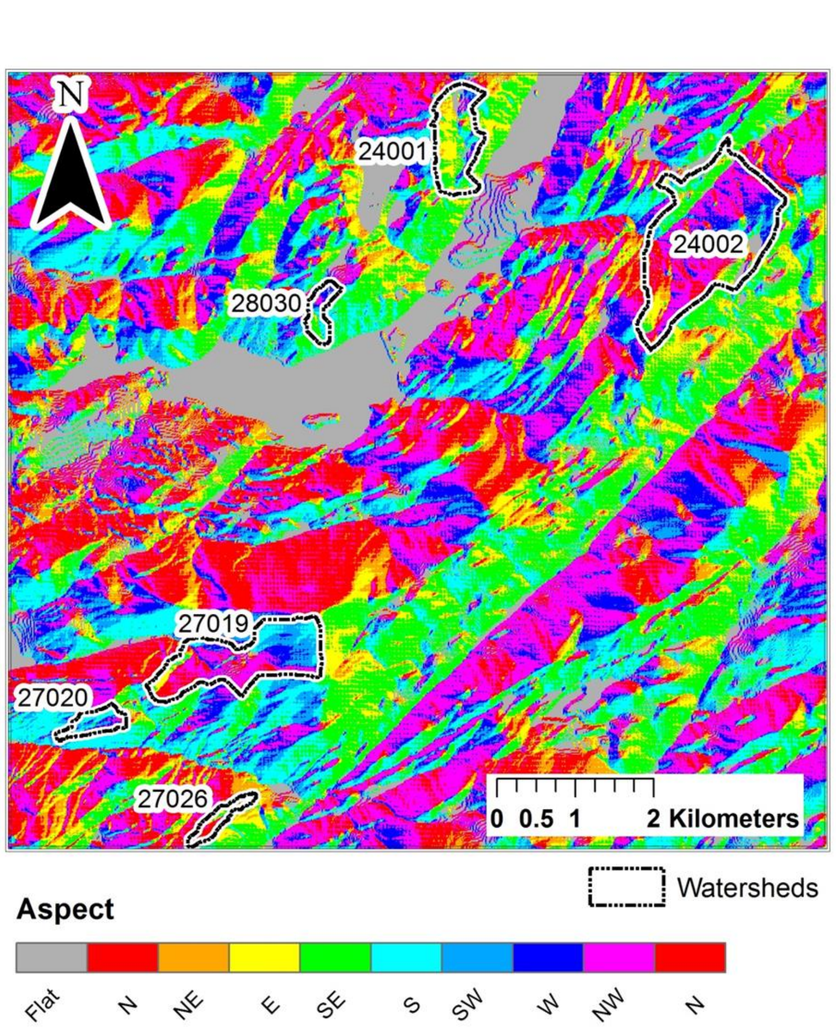
Average, max and min April and March Temperature, and April and March Precipitation.

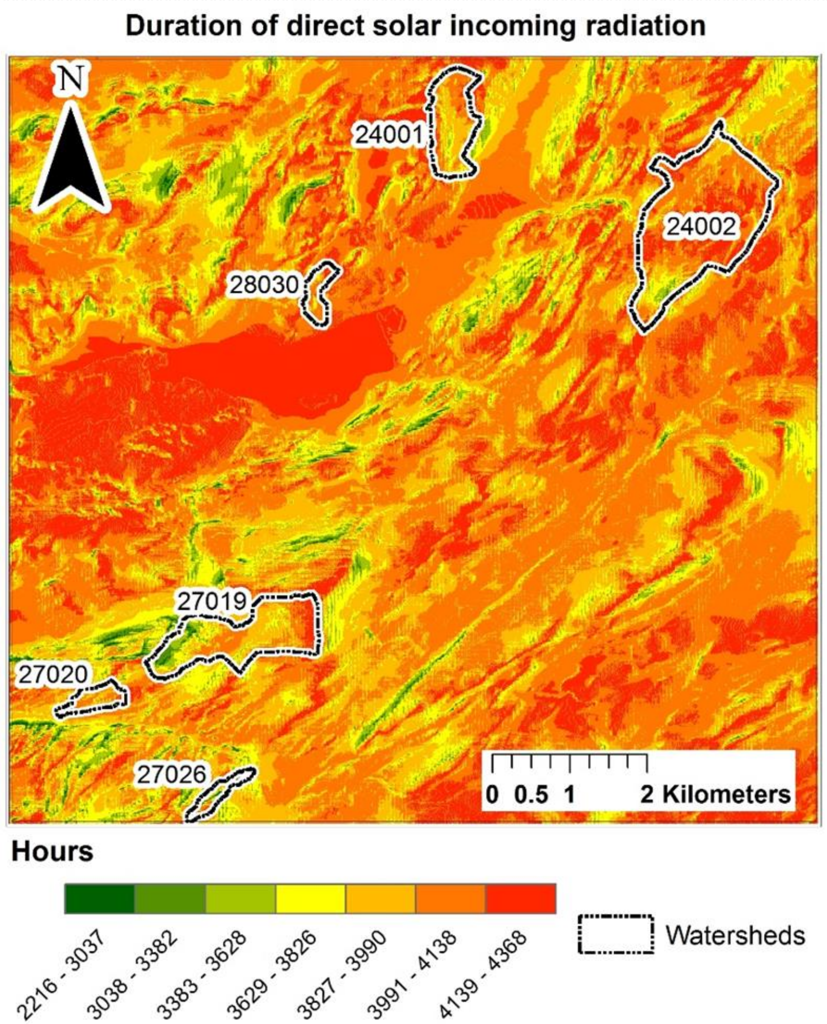
+ Direct and diffuse incoming solar radiation (estimated from GIS DEM analysis).

Landscape Factors (DEM,10 m)

DATA

1)Size of Watershed, 2)Elevation, 3)Slope, 4)Aspect, 4)Photoperiod





METHODS

- Statistical analysis
- Process-based modeling

3 Step Statistical Analysis:

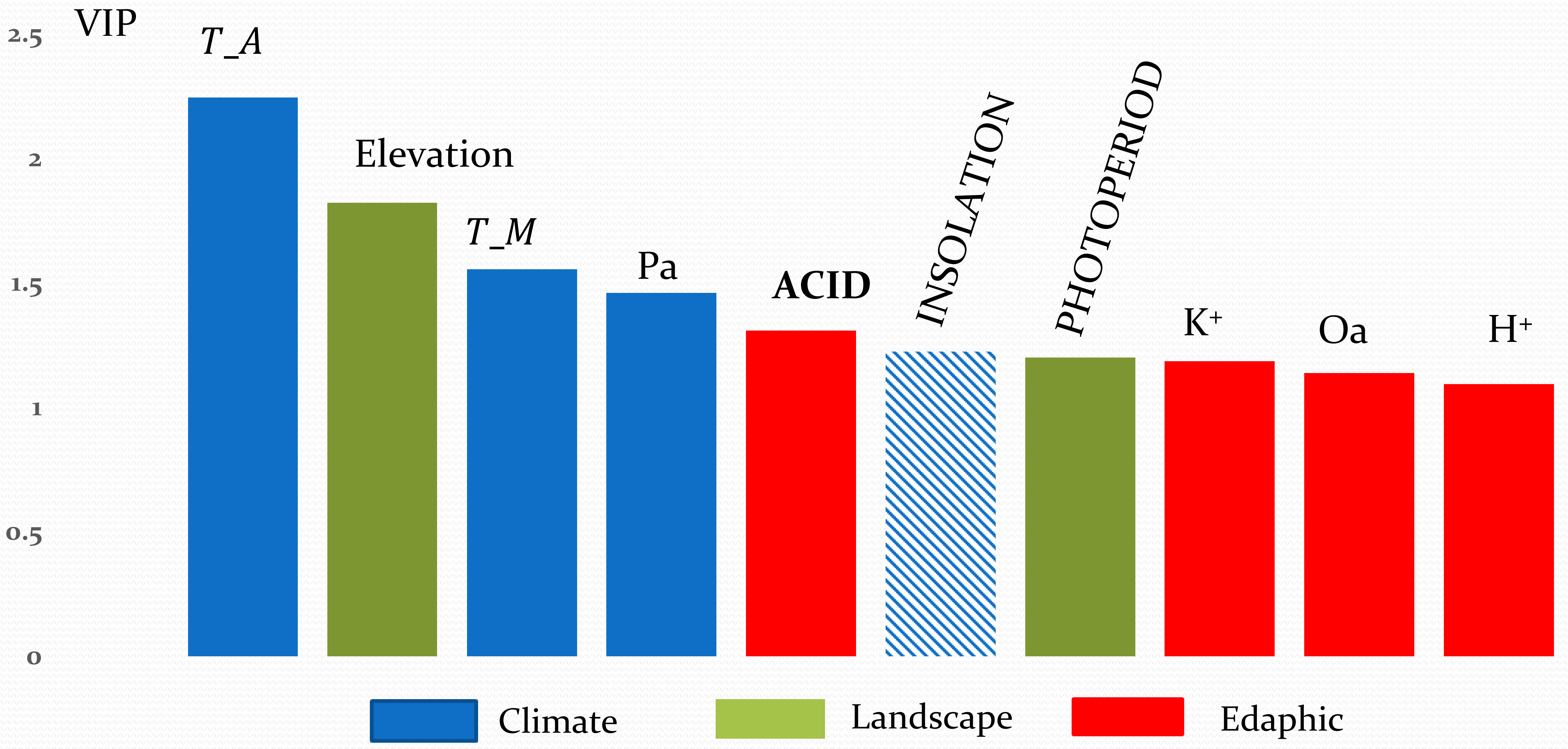
1) Variable selection criteria: Variance Importance in Projection (VIP). projection into principal components

2) Partial Less Square Regression model. We did use NIPALS (**N**onlinear **I**terative **P**artial **L**east **S**quares) algorithm with v-fold cross validation.

3) All edaphic variables with VIP>1 were tested on mediation by climatic and landscape factors.

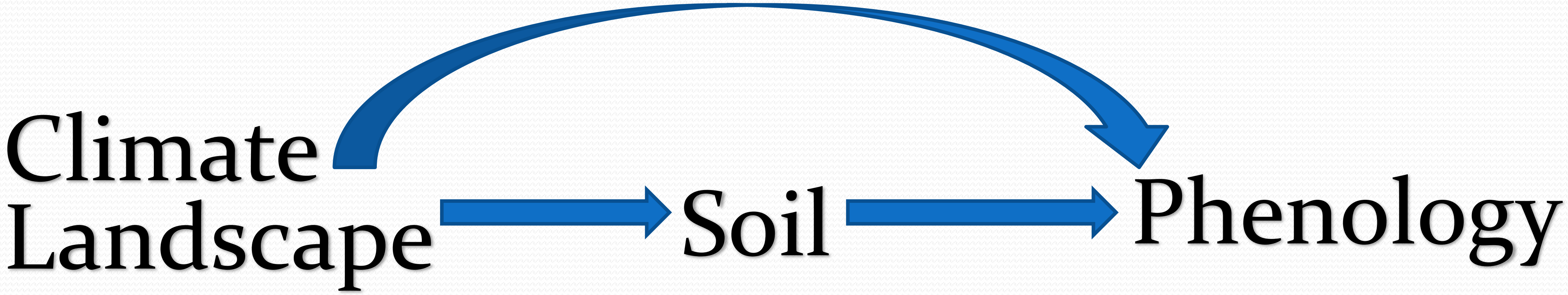
RESULTS

Variable Importance in Projection (VIP>1)
Describe >85% of SoS spatial variability

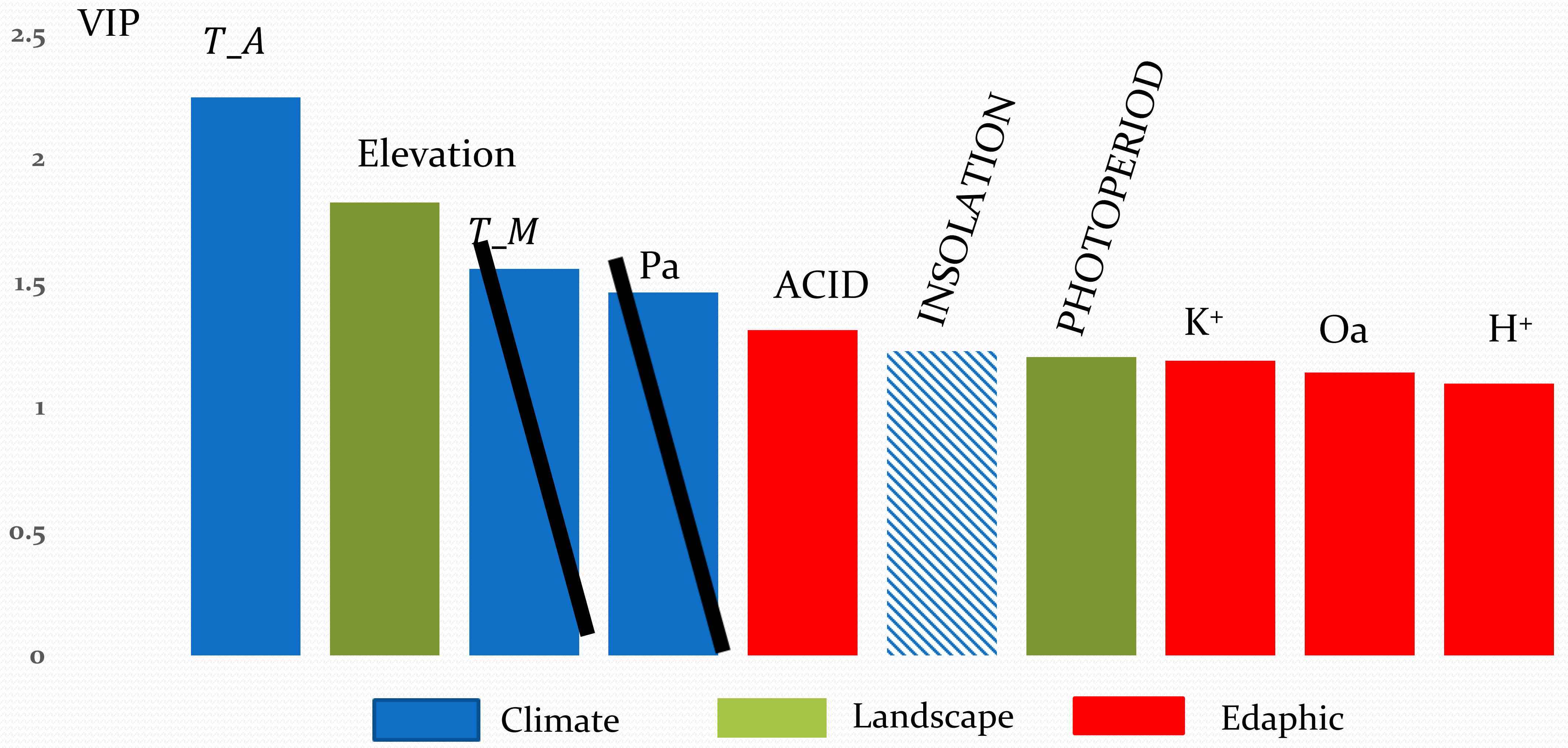


Mediation of Edaphic Factors by Climate and Landscape Variables or “Chicken or Egg” Dilemma.

- We did use approach proposed by Judd and Kenny (1981) for estimate of indirect effect as difference between two regression coefficients.

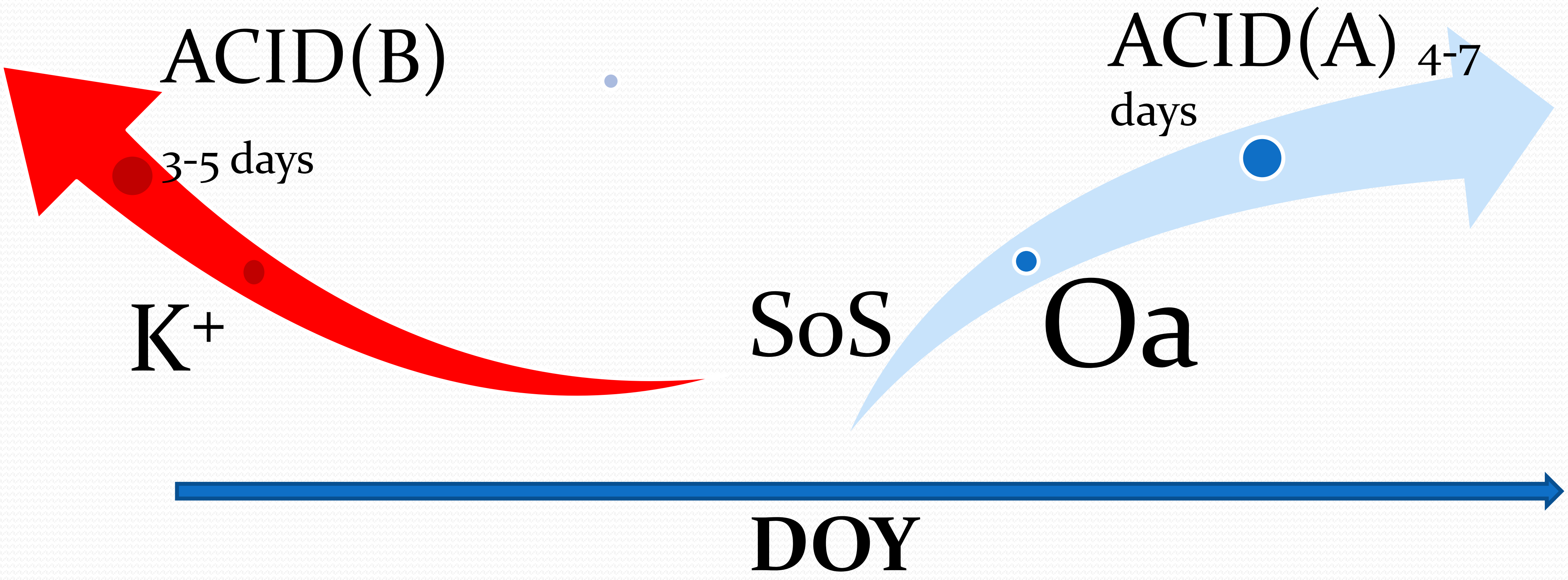


Variable Importance in Projection (VIP>1)
Final model describes >82% of SoS spatial variability



Contribution of Edaphic Factors to Phenology

- SoS dates move forward with increase in K^{+}, and delay with increase in Oa and Al^{3+}



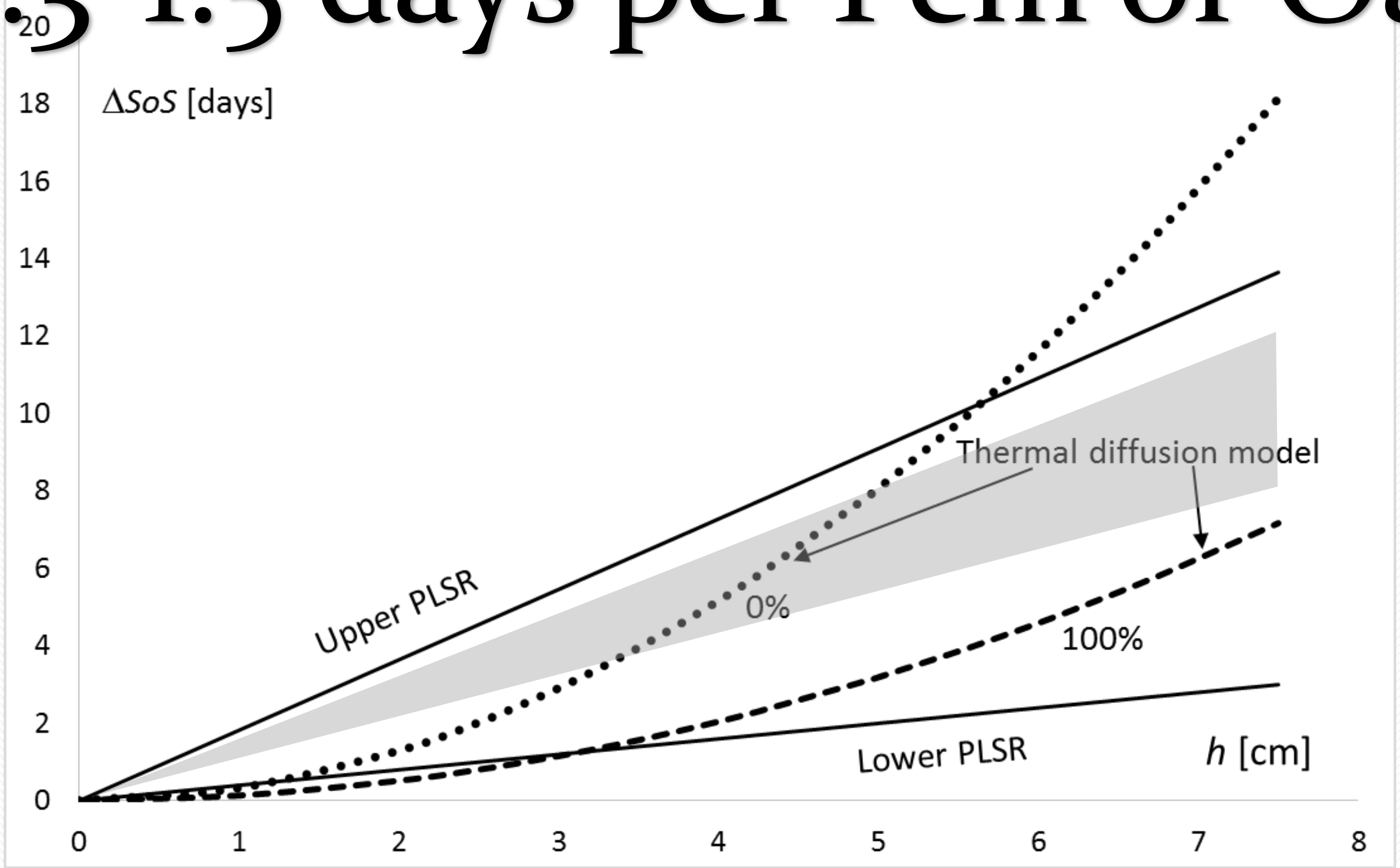
Possible Physical and Biochemical Mechanisms of Phenology Control by Edaphic Factors.

- **K^+:** early SoS can be caused by fertilization effect of potassium (It works as regulator of NSC transport (Lemoine et al., 2013) and starch synthesis (Murata&Akazawa, 1969).
- **ACID:** delay in SoS can be caused by obstructive effect of Al^{3+} on development of fine roots and tree growth (Shortle &Smith , 1988)
- **Oa :** delay in SoS can be caused by delay of thermal signal in forest floor after winter dormancy.

Process-based modeling.

Comparison of Thermal Diffusion Model with PLSR.

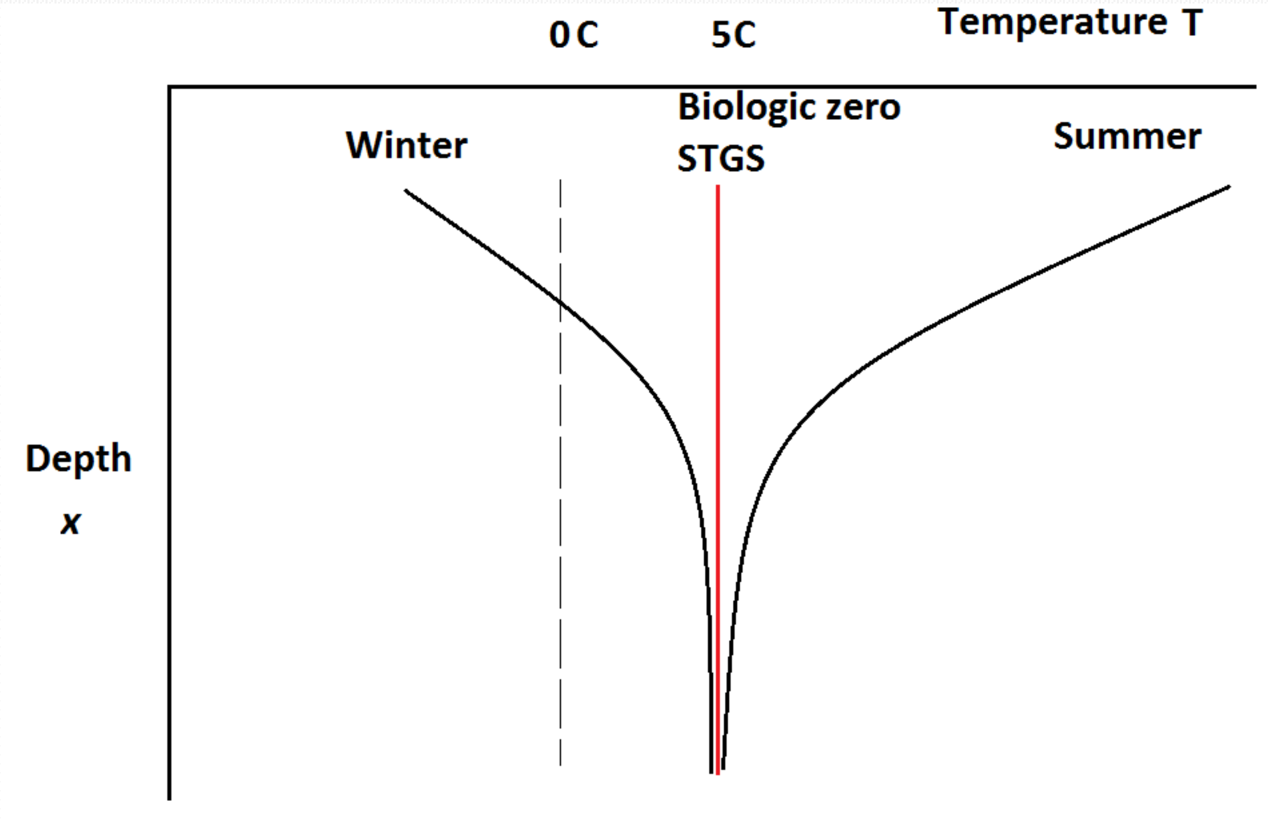
1.3-1.5 days per 1 cm of Oa

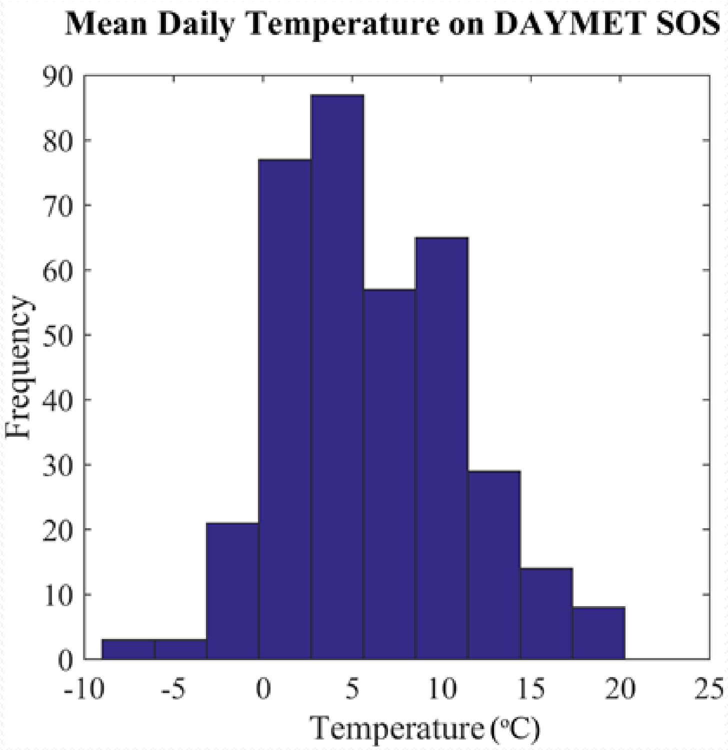


CONCLUSIONS

- Our work points to an additional new role of the forest floor as a modulator of the climatic drivers controlling the rate of spring soil warming and the recovery of trees from winter dormancy. This conclusion is supported by a robust statistical analysis as well as by a process-based model.
- Our findings provide new insights regarding the effects of chemical recovery from past soil acidification and increases in climate warming on forest phenology and productivity.
- Future studies. Use soil archives to see if effect of changes in edaphic factors can be detected in forest phenology.

Process based modeling. Thermal diffusion model.





$$\frac{\partial T(x,t)}{\partial t} = \kappa \frac{\partial^2 T(x,t)}{\partial x^2}$$

- $\Delta t = h/\omega d$

- $d = \sqrt{\frac{2\lambda}{\omega}} = \sqrt{\frac{\lambda\tau}{\pi}}$