Relationships between NDVI and soil properties in the Adirondacks

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Outline

- The role of soil properties in responses of forests to climate warming: what do we know and what do we not know?
- Adirondack study of sugar maples
- Remote sensing of vegetation phenology and growth patterns
- MODIS and Landsat instruments
- Preliminary results from MODIS
- Spatial and Temporal Adaptive Reflectance Fusion Model (STAR-FM) for Landsat and MODIS data fusion
- Conclusions and future work

Role of soil properties in responses of vegetation to climate warming

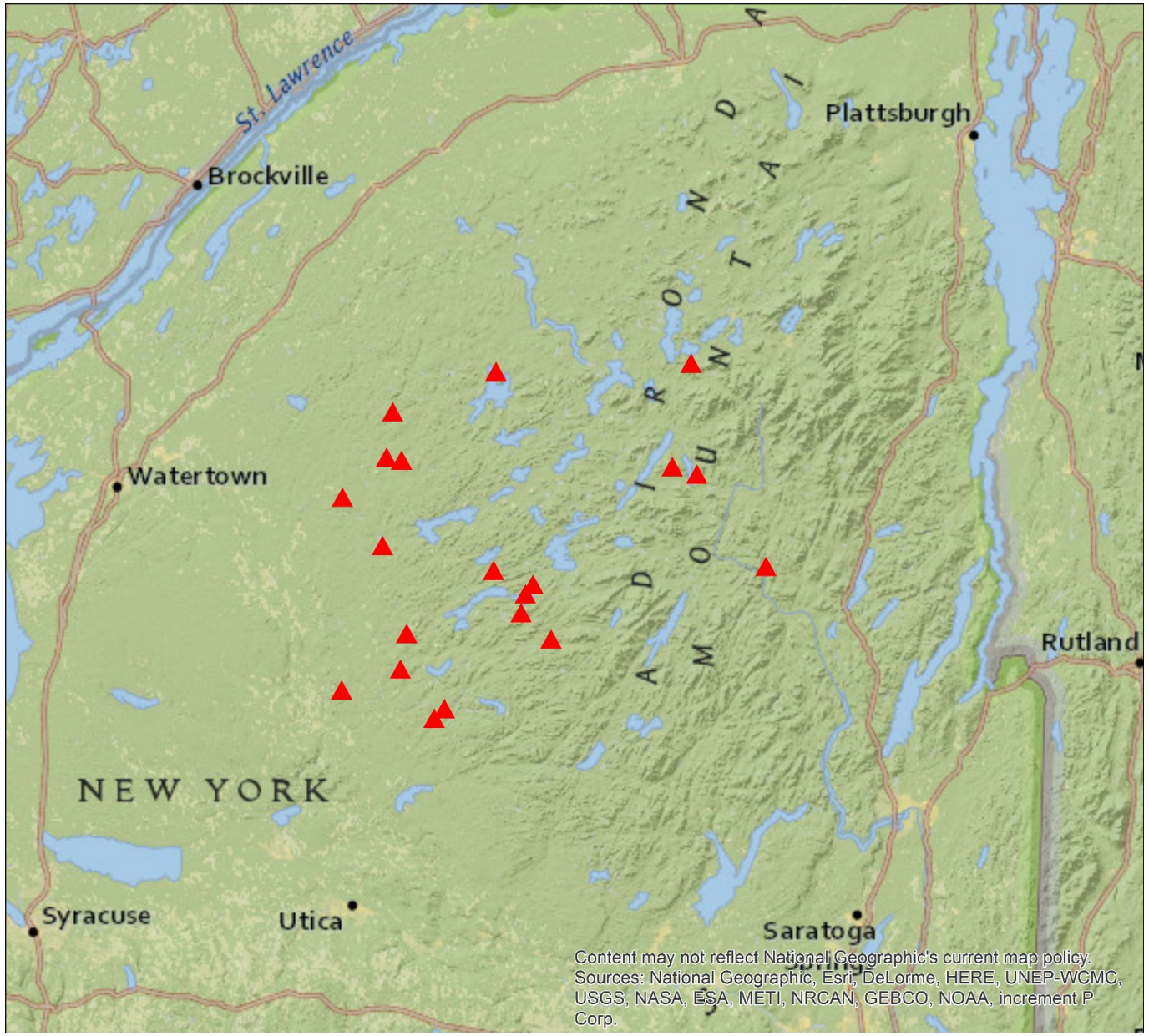
- Considering the broad tolerance of most tree species to variations in soil characteristics, soils should not be a major constraint for the expected (due to recent warming) northward shift of tree species.
- However, observations of tree growth during the last 3-4 decades along the *boreal* and the *alpine* tree lines have demonstrated not only advances of tree species, but also their retreat or no response. Some researches explain this by inadequate soil properties, including permafrost and the lack of available nutrients (Macias-Fauriaa and Johnson 2012; Bogaert et al. 2012; Danby and Hik, 2007; Jobbagy and Jackson, 2000).

Role of soil properties in responses of vegetation to climate warming

- Another important question is how forest phenology changes and whether there were any shifts in carbon allocation.
- Phenology is closely linked to carbon partitioning in tree species as well as to soil respiration (e.g. Barr et al., 2009; Noormets et al. 2009).
- Existing literature on the **role of soil properties** in phenologic shifts due to warming, however, is incomplete and controversial.
- Warming experiments in planted forests demonstrate no difference in phenologic shifts or carbon partitioning at plots with various level of fertilization (N addition) (e.g. Strömgren and Linder, 2002)
- Soil archived studies (Lapenis et al. 2014) show clear responses of carbon allocation patterns to early spring among spruce stands growing on soils with variable degree of acidification.

Adirondack study of Sugar Maple (*Acer saccharum* Marsh).

- 50 stands where Sugar Maple (SM) dominates the canopy. This dataset is similar (identical?) to that used by Sullivan and colleagues in the "Effects of Acidic Deposition and Soil Acidification on Sugar Maple Trees in the Adirondack Mountains, New York" (2013)
- Because of inherent limitations of satellite data we averaged soil data from 50 stands within 20 watersheds. Watersheds were delineated using the USGS NED 10-meter elevation grid (Yvonne H. Baevsky).
- We used the same grid to obtain satellite data used in our study.



Map of 20 Adirondack watersheds with 50 Sugar Maple stands

Adirondack study of sugar maple

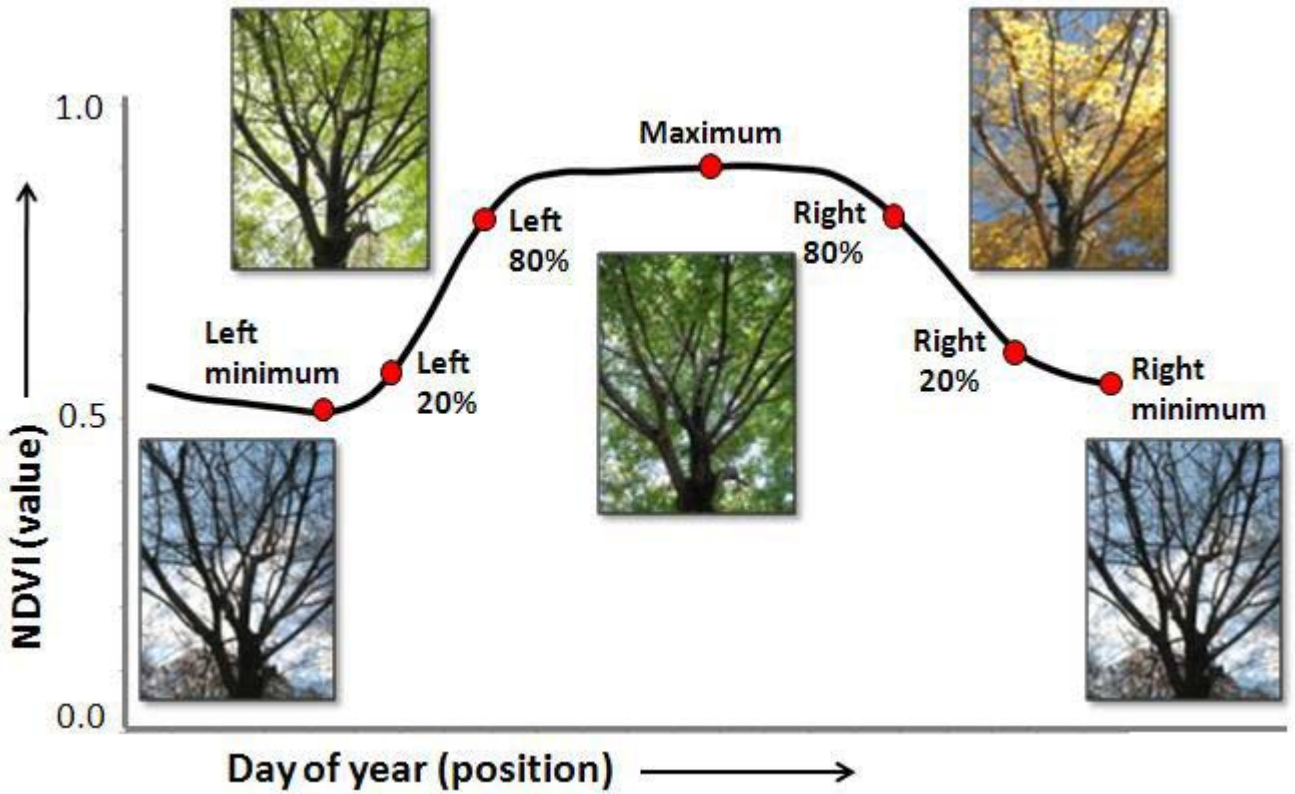
- Soil data were provided for Oe, Upper B and Lower B horizons:

pH in DI H_2O; pH in $CaCl_2$; % Weight Loss on Ignition; Exchangeable Ca; Mg; Na, K; Total Nitrogen; Total Carbon; Exchangeable Acidity; Exchangeable Al ; Exchangeable H; Base saturation; CEC

This dataset with strong soil chemistry gradient allow us to design an experiment where we can use satellite data to test hypothesis about close relationship between soil properties and forest response to warming.

Remote sensing of vegetation growth

- Normalized Difference Vegetation Index (NDVI)



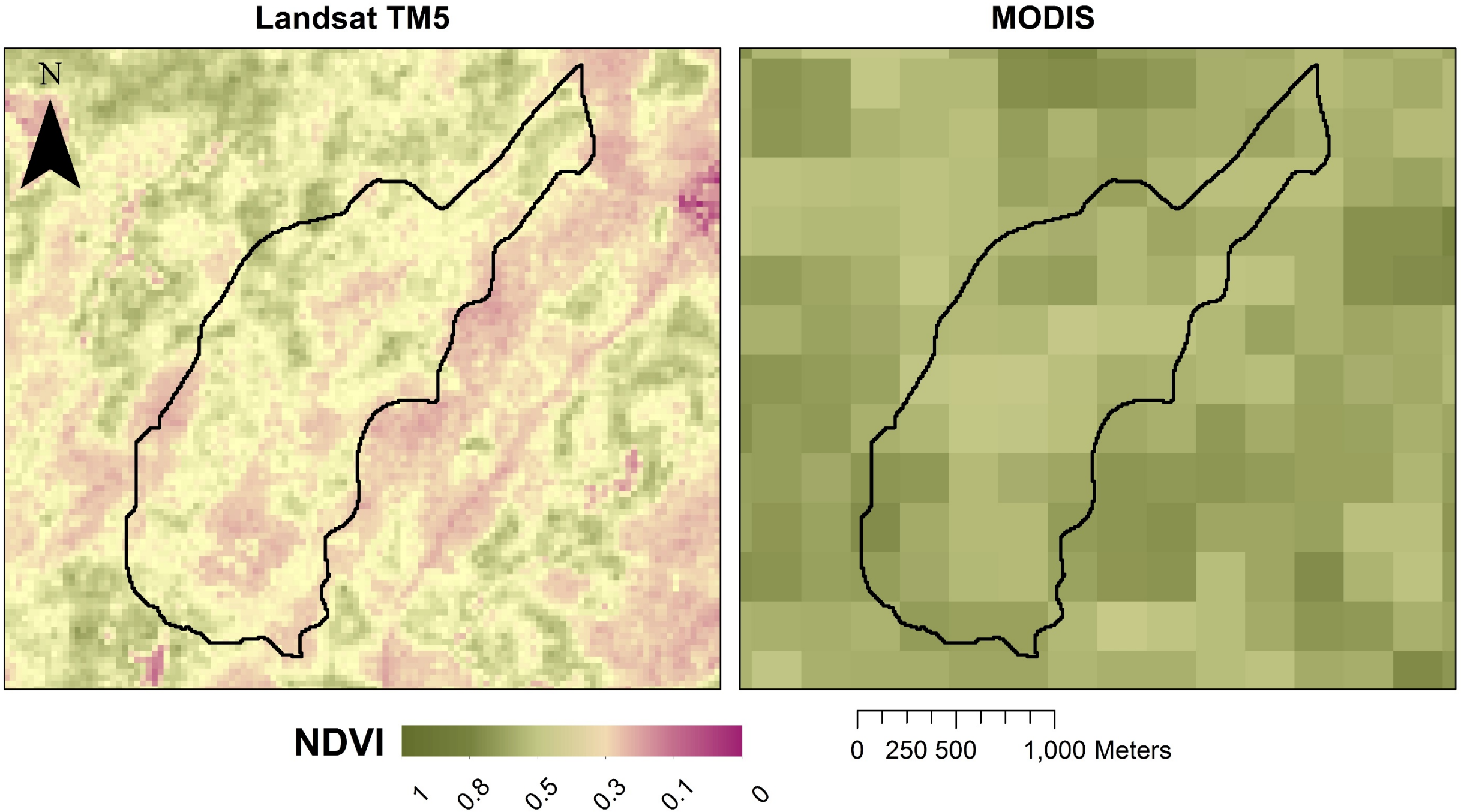
MODIS and Landsat instruments

- Landsat
  - Resolution: (30x30 m); Revisit: twice a month (23 scenes per year). TM5 data available since 1982 (USGS). NDVI can be readily calculated from the two spectral bands (3 – RED and 4 – nearinfrared)

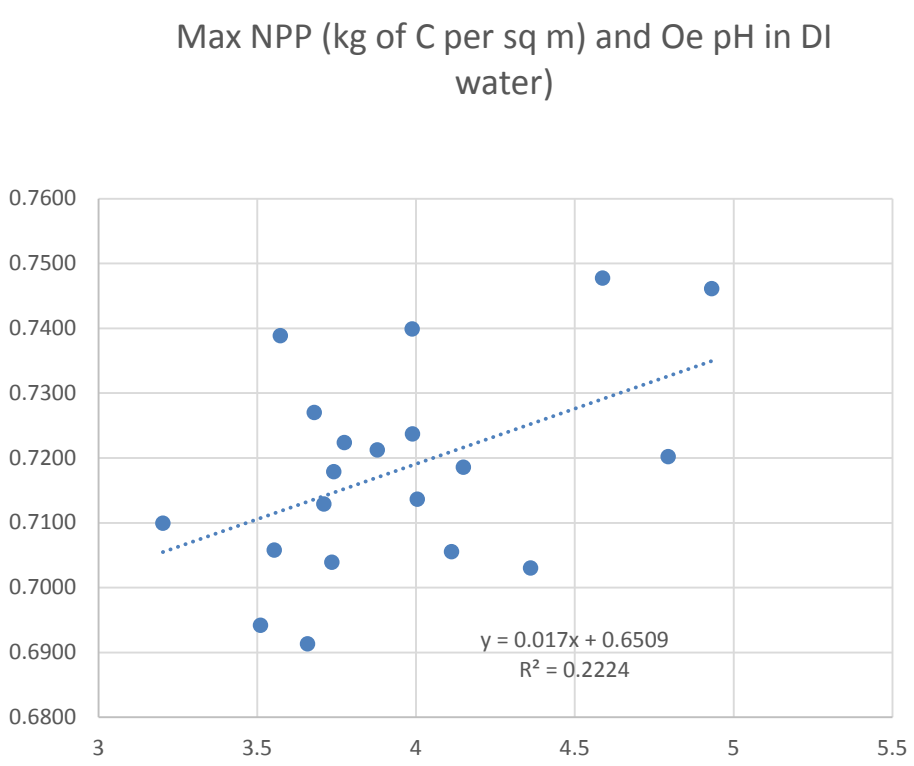
- Moderal Resolution Imaging Spectroradiometer (MODIS)
  - Resolution (250x250 m or 500x500 m); Revisit: daily (365 scenes per year); Data available since 2000, NDVI is a standard product. **Biome –BGC model is used to calculate GPP, NPP.**
  - We can use NDVI from either Landsat or MODIS to model phenology.
  - Problems: clouds, snow.

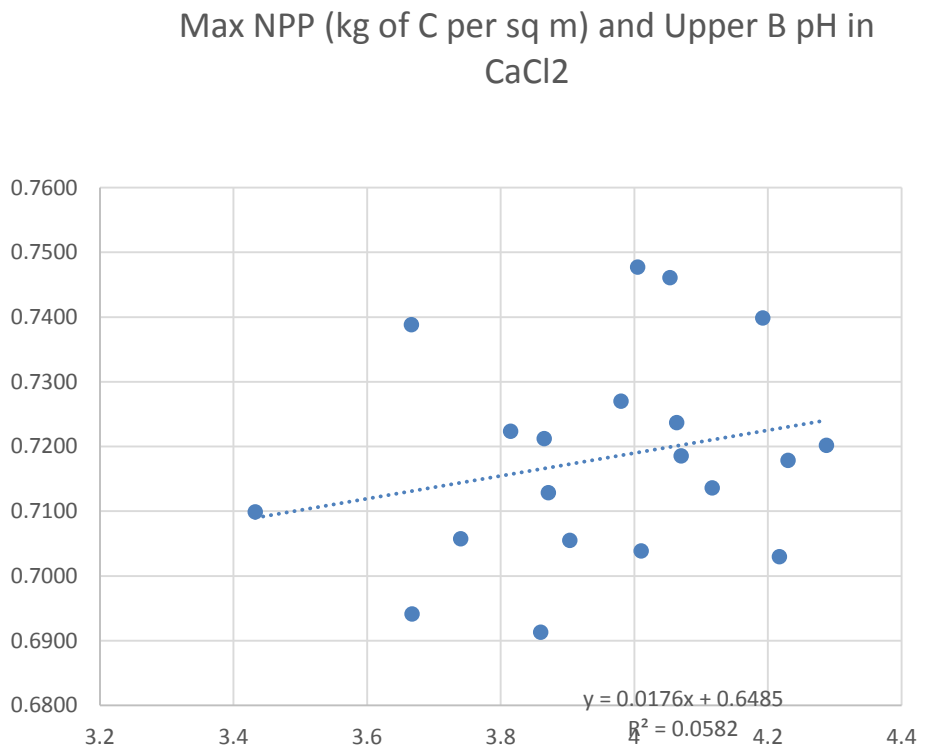
MODIS and Landsat instruments

- For each watershed we identify pixel with max NDVI and min NDVI values as well as mean for all pixels within watershed.

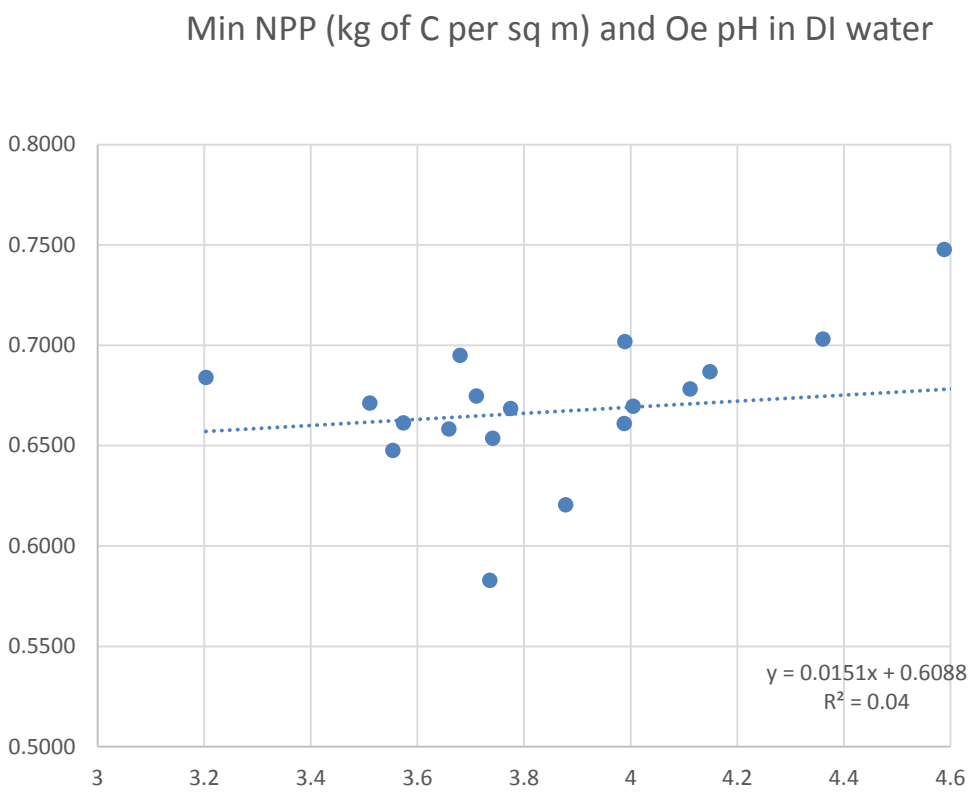

Landsat TM5
MODIS
N
NDVI
1
0.8
0.5
0.3
0.1
0
0 250 500 1,000 Meters

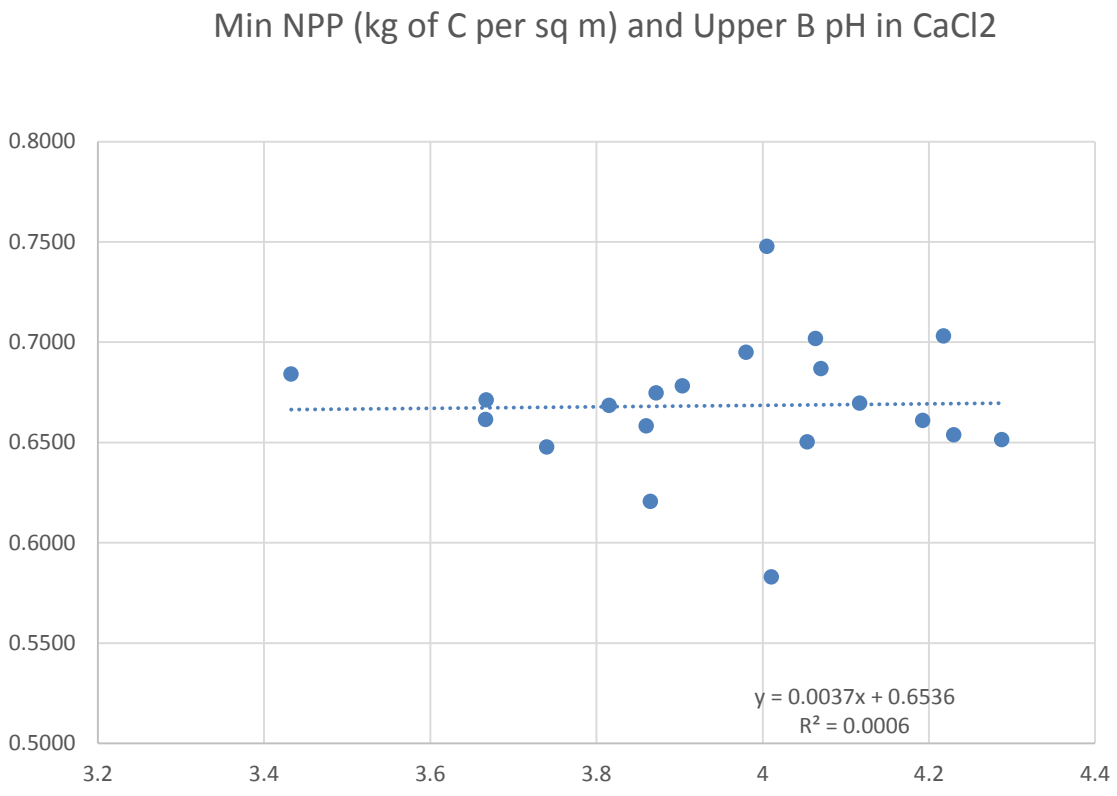
Preliminary data (MODIS)





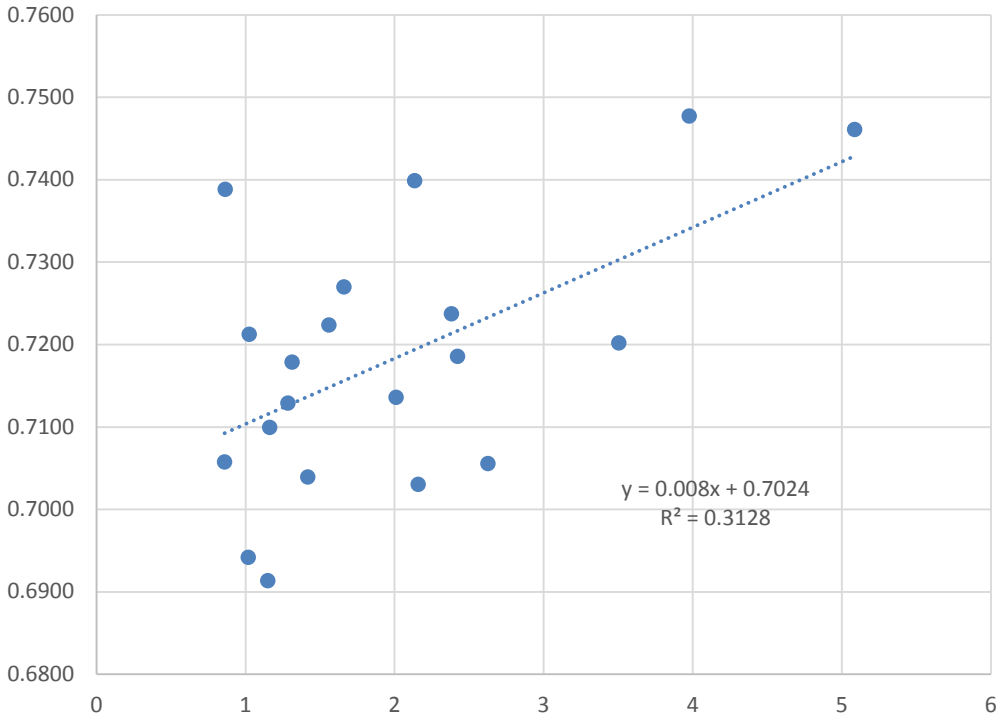
Preliminary data (MODIS)



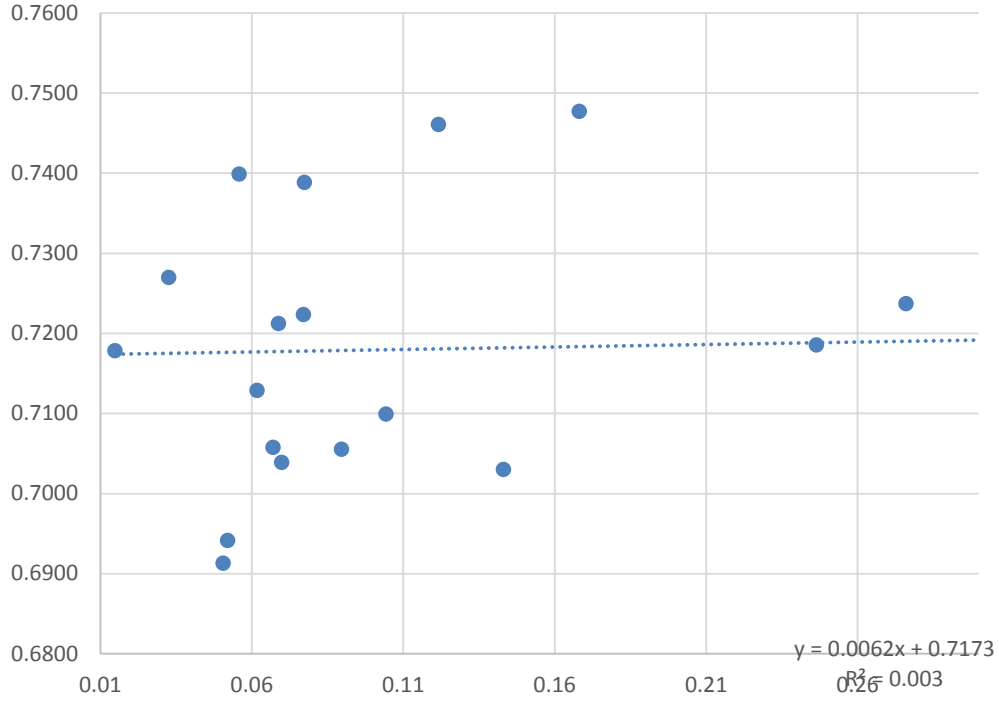


Preliminary data from MODIS

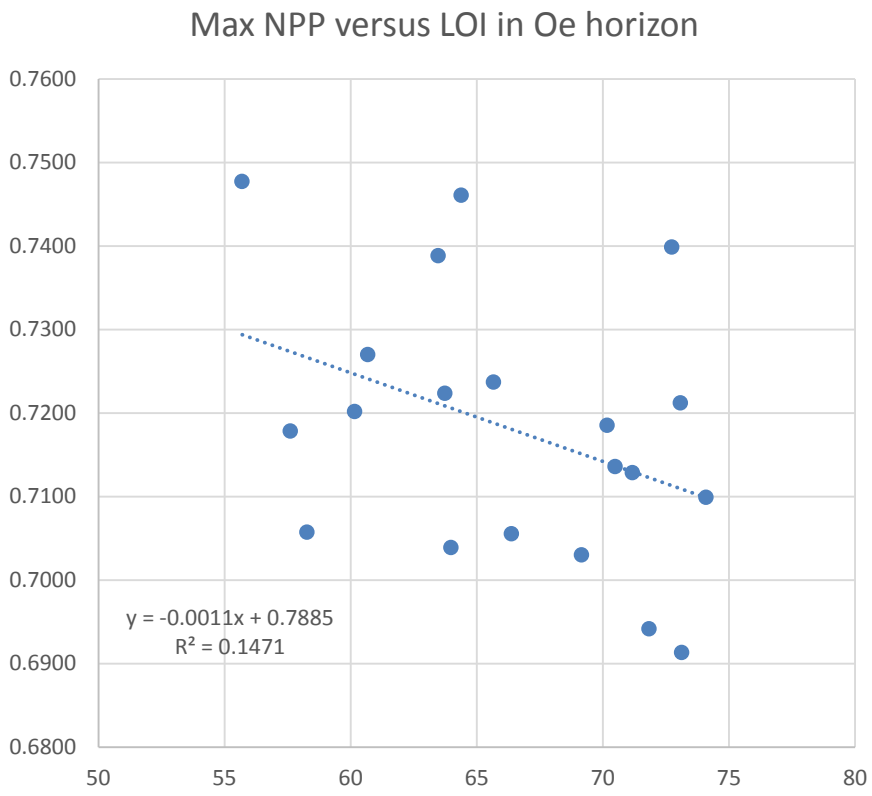
Max NPP (kg of C per sq m) and Oe exchangeable Mg [cmol/kg]

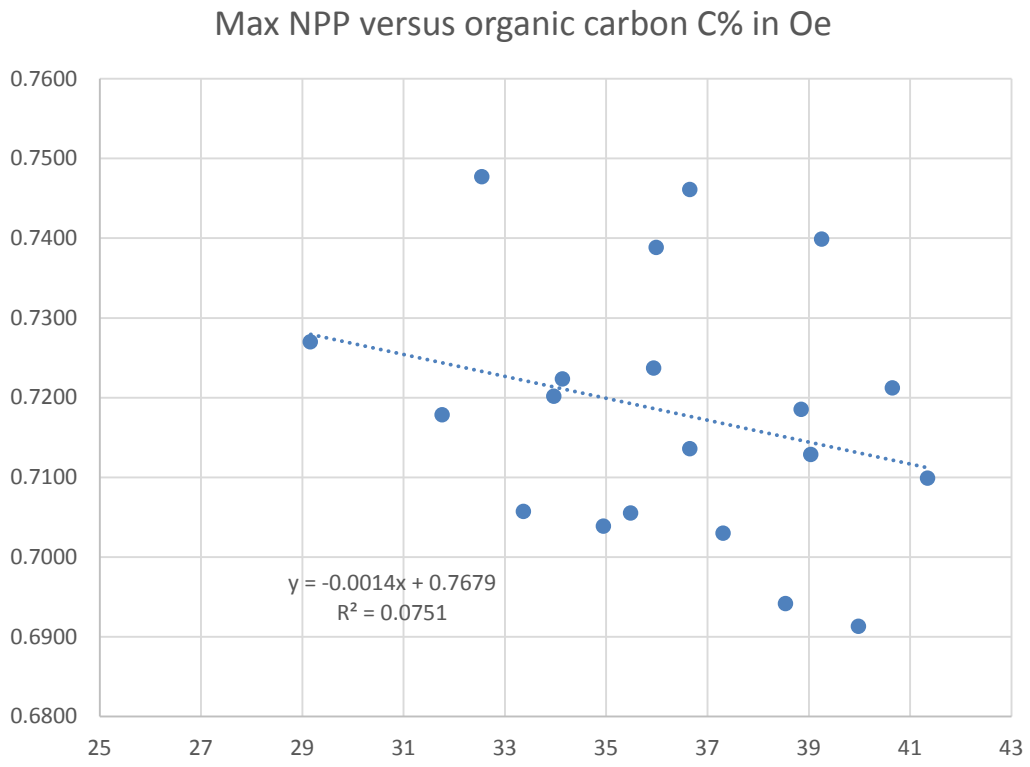


Max NPP (kg of C per sq m) and UpperB exchangeable Mg [cmol/kg]

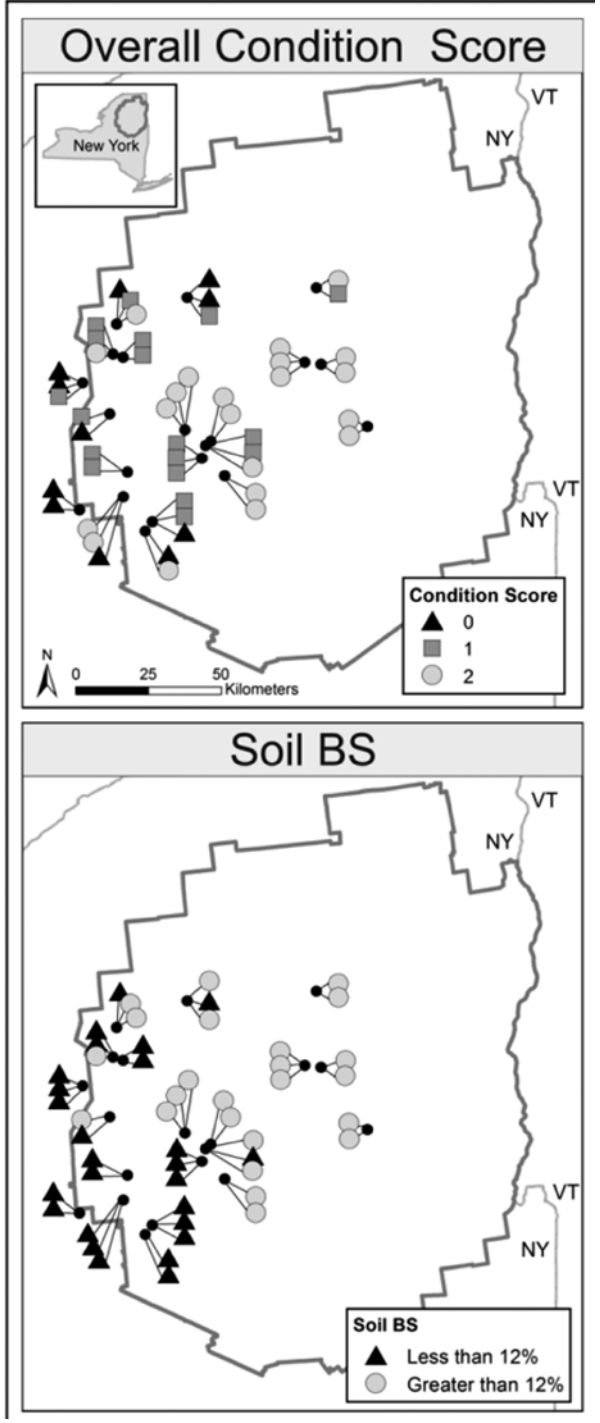


Preliminary data (MODIS)

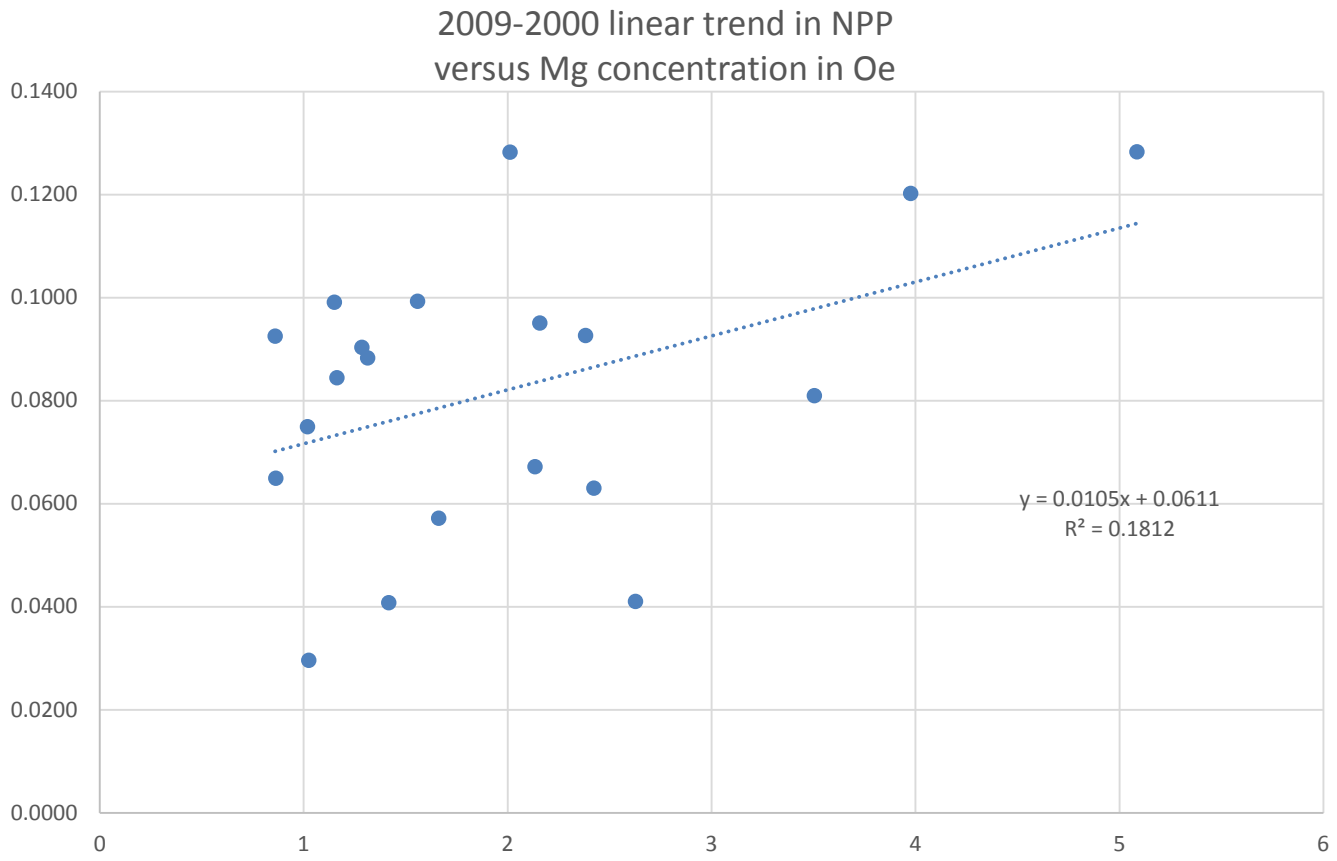




Preliminary data (MODIS) confirm previous results by Sulivan and colleagues (2013) about close correlations between SM growth patterns (in our case it is annual NPP) and soil saturation with bases (in our case, the most significant variable is Mg).



Preliminary data (MODIS). Trends in NPP during 2000-2009 period

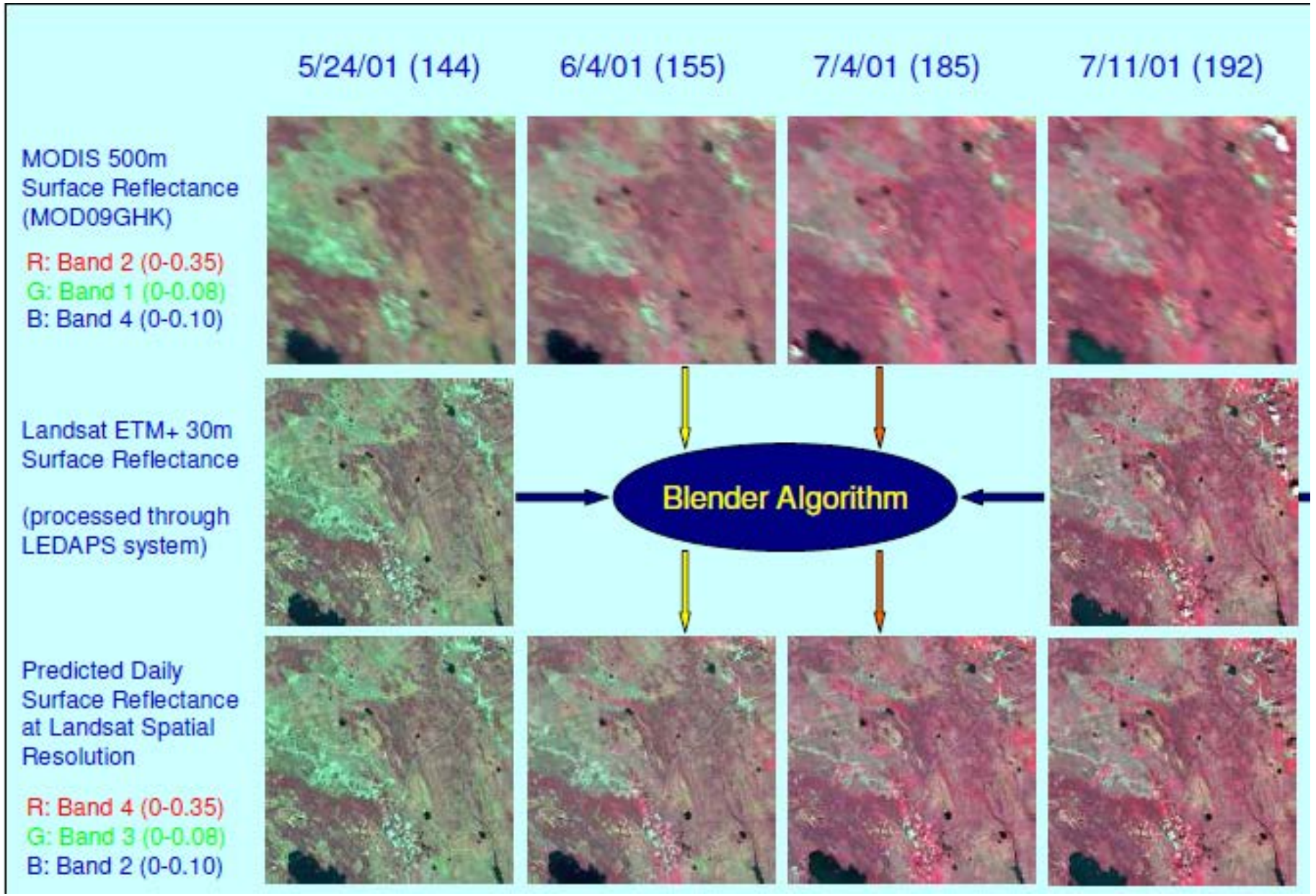


Preliminary data (Landsat).

- Work in progress.

Spatial and Temporal Adaptive Reflectance Fusion Model - STARFM (developed by Feng Gao)

- Outputs predicted reflectance images with the spatial resolution of Landsat and the temporal resolution or MODIS
  - Uses a pair of Landsat and MODIS images
  - Takes advantage of Landsat spatial and MODIS temporal resolutions
- We are producing a synthetic 30m resolution dataset for every 8 days. Available Landsat images will be used for validation



From: Gao, Masek, Schwaller, & Hall, n.d., On the Blending of the MODIS and Landsat ETM+ Surface Reflectance. Retrieved from: http://modis.gsfc.nasa.gov/sci_team/meetings/200503/posters/land/hall.pdf

Conclusions

- Soil properties (pH, BS%, Ca, Mg as well as LOI and organic carbon) of Oe horizon correlate well with the average (2000-09) Mean and Max estimates of NPP of SM
- Soil exchangeable chemistry, however, does not show any correlation with minimum annual NPP within watersheds.
- Trends in NPP (mean and maximum NPP) show a) overall increase during 2000-2009 period, and, b) close correlation with concentration of exchangeable Mg in Oe horizon. The greatest increase in NPP was observed over locations high BS in Oe horizon. The same data show no significant correlation with exchangeable chemistry of B horizon.
- These are preliminary conclusions which will be evaluated using the constructed synthetic data combined with existing Landsat data (possibly at the scale of stands rather than watersheds).