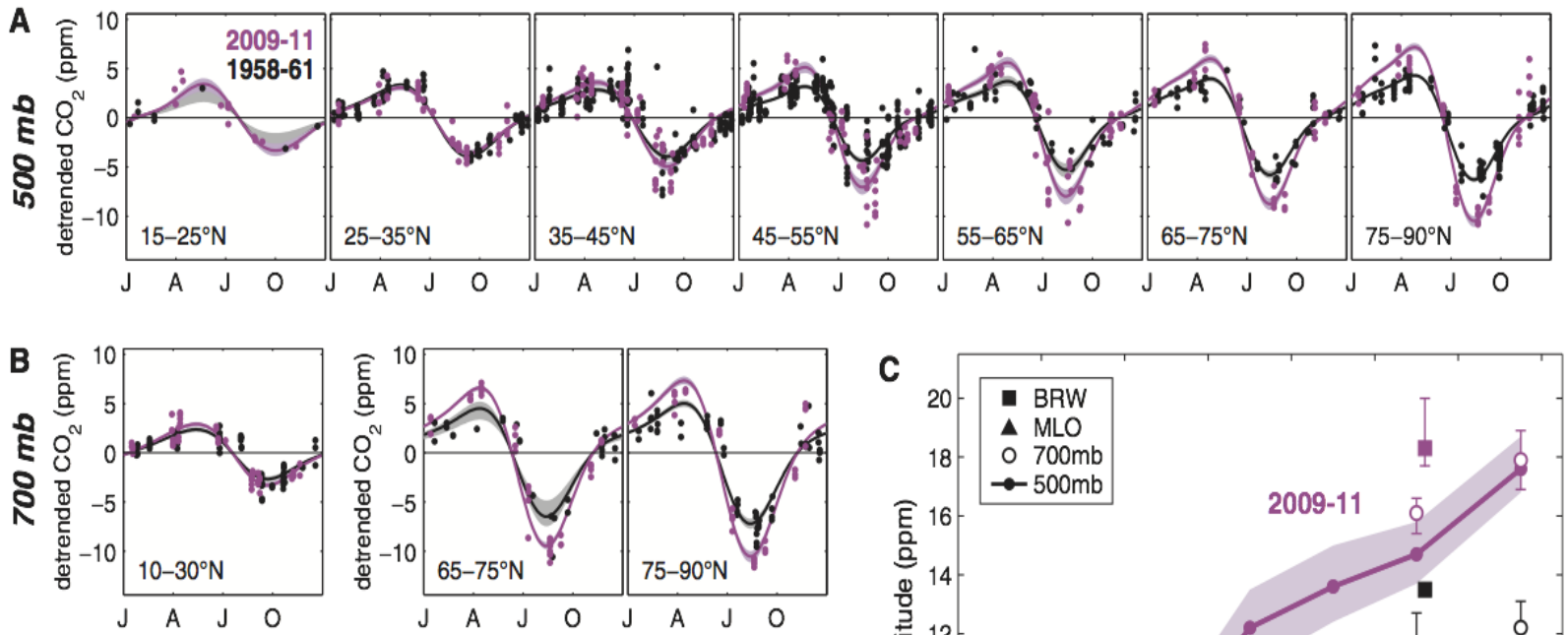
Using Three Decades of Landsat Data to Characterize Changes & Vulnerability of Temperate and Boreal Forest Phenology to Climate Change

Mark A. Friedl, Damien Sulla-Menashe, Eli Melaas, Josh Gray & Curtis Woodcock
Department of Earth and Environment
Boston University

(supported by NASA TE & USGS)

Motivation



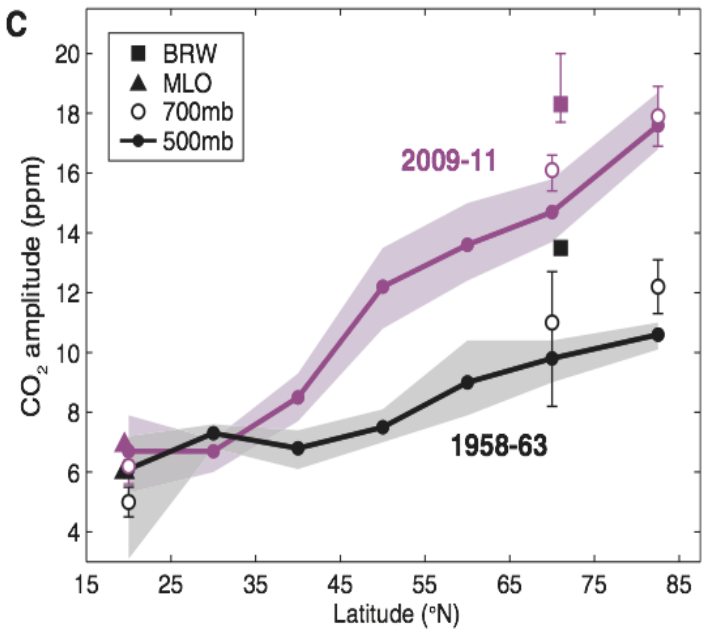
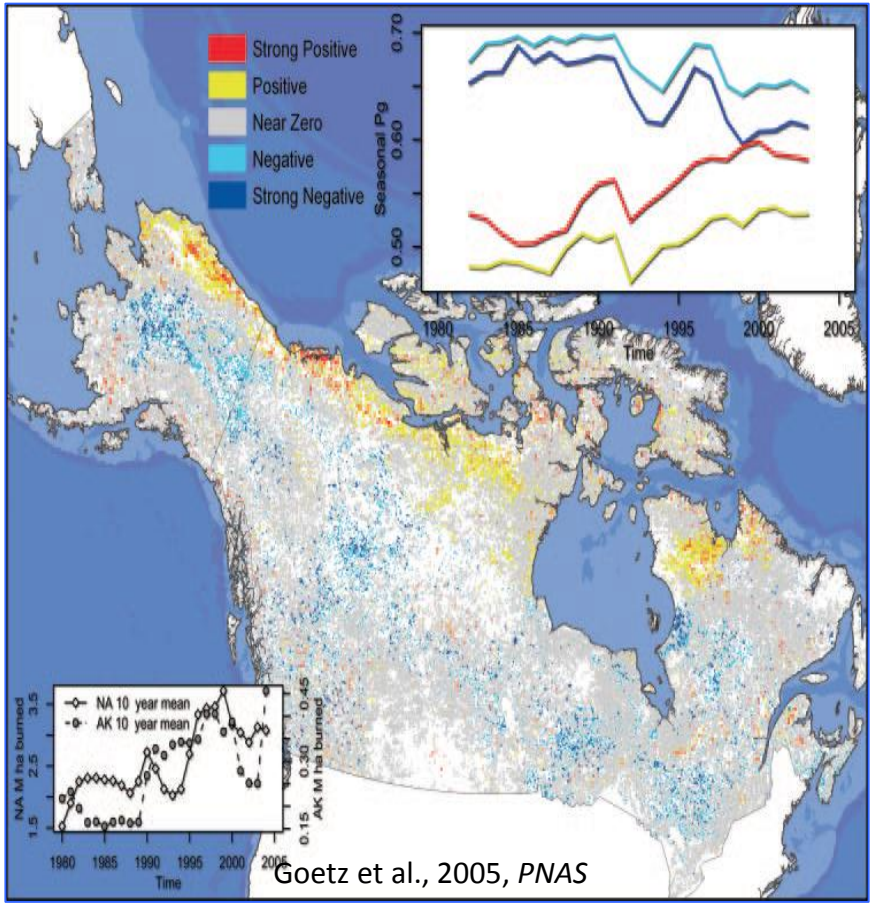


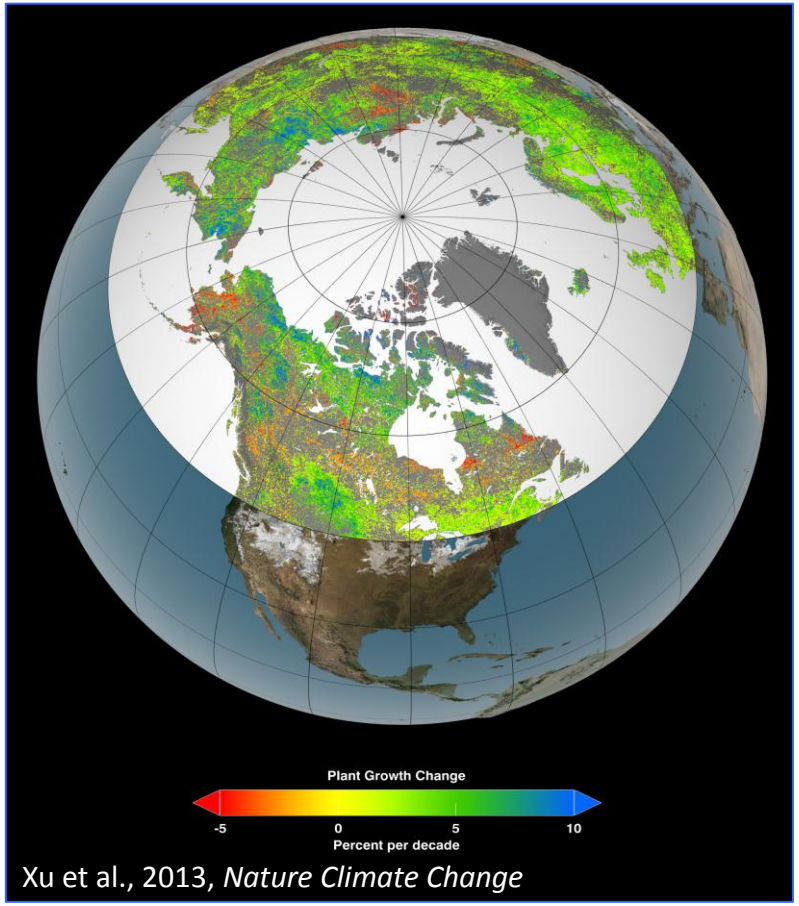
Fig. 2. Seasonal CO_2 cycles observed by aircraft in 1958 to 1961 and 2009 to 2011. Seasonal cycles of CO_2 at 500 mb in the upper row (**A**) and 700 mb in the lower row (**B**) for each latitude band with aircraft data in both periods. Curves show the seasonal cycles fit to the data, with uncertainties indicated by shaded areas. Amplitudes of the seasonal cycle of CO_2 for all locations with data available in both periods (**C**). The IGY aircraft data cover the period 1958 to 1961; the early BRW and MLO data cover 1961 to 1963 and 1958 to 1963. Uncertainties (*55*) are shown by the shaded areas for 500 mb data and by error bars for 700 mb and BRW in 2009 to 2011. Uncertainties for BRW in 1961 to 1963 and MLO in both periods are smaller than the symbol sizes.

Graven et al, 2013, *Science;* …. but, see Gray et al., 2014, *Nature*

Changes in Greenness, Productivity(?) & Mortality

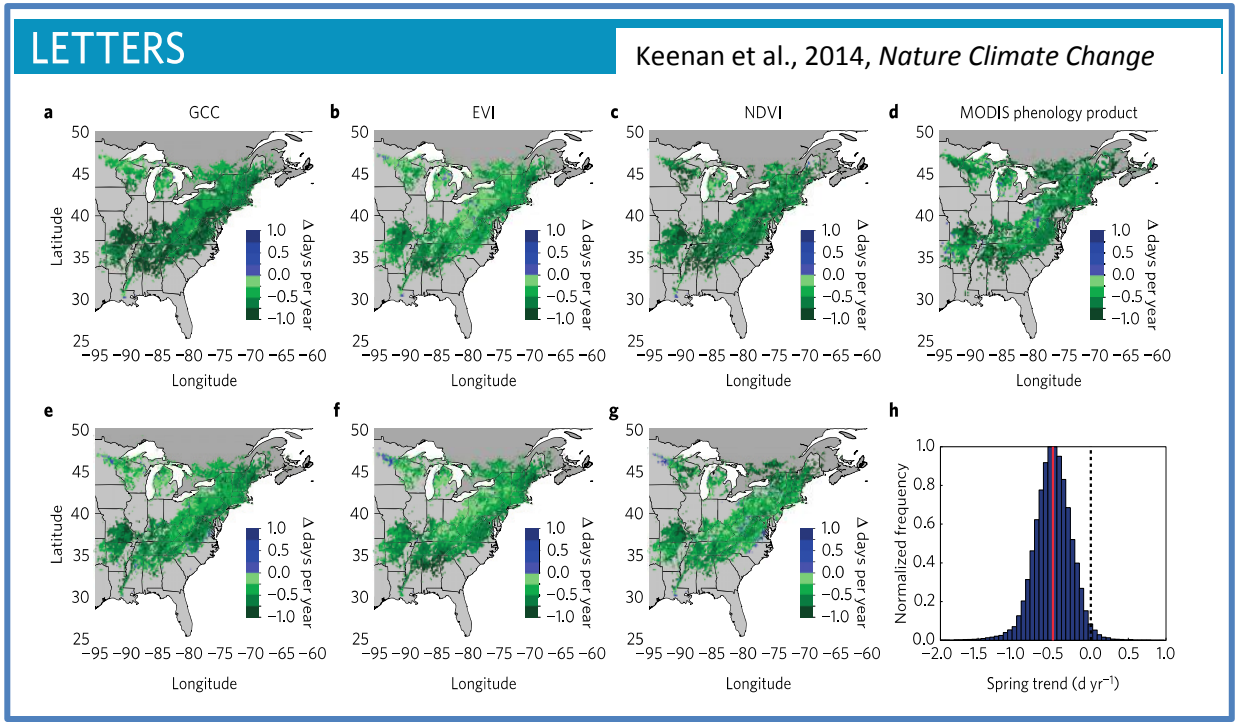


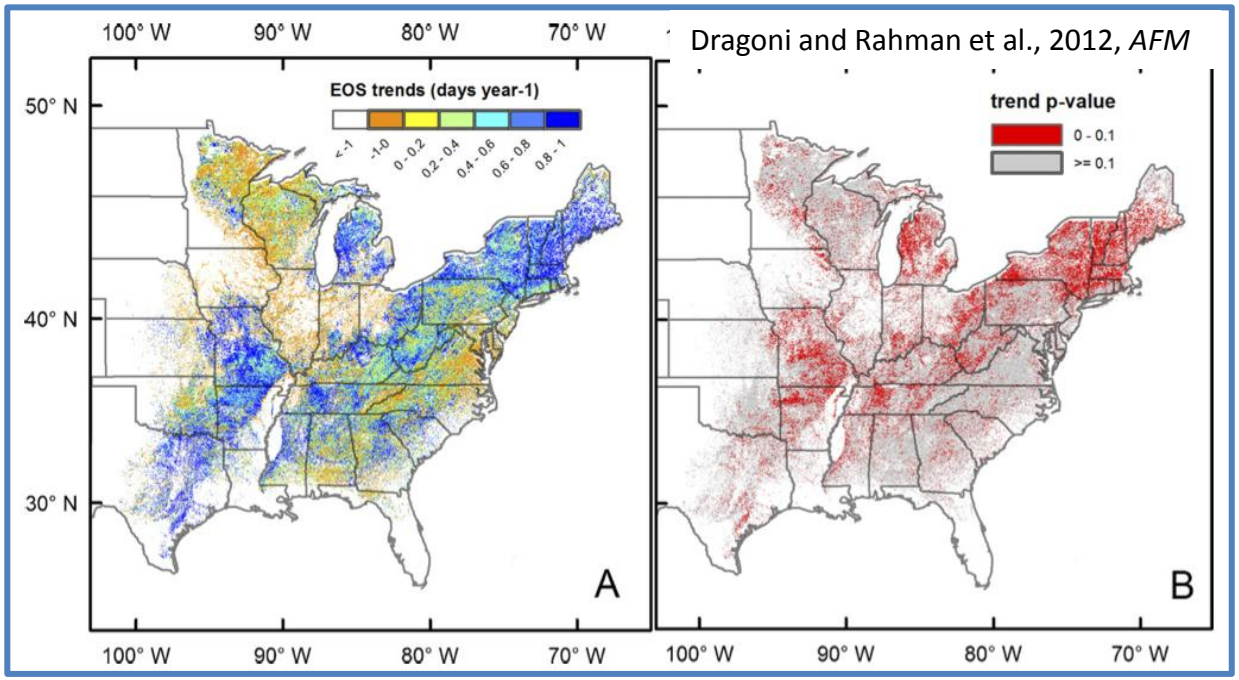
Goetz et al., 2005, *PNAS*



Xu et al., 2013, *Nature Climate Change*

Trends in Growing Season





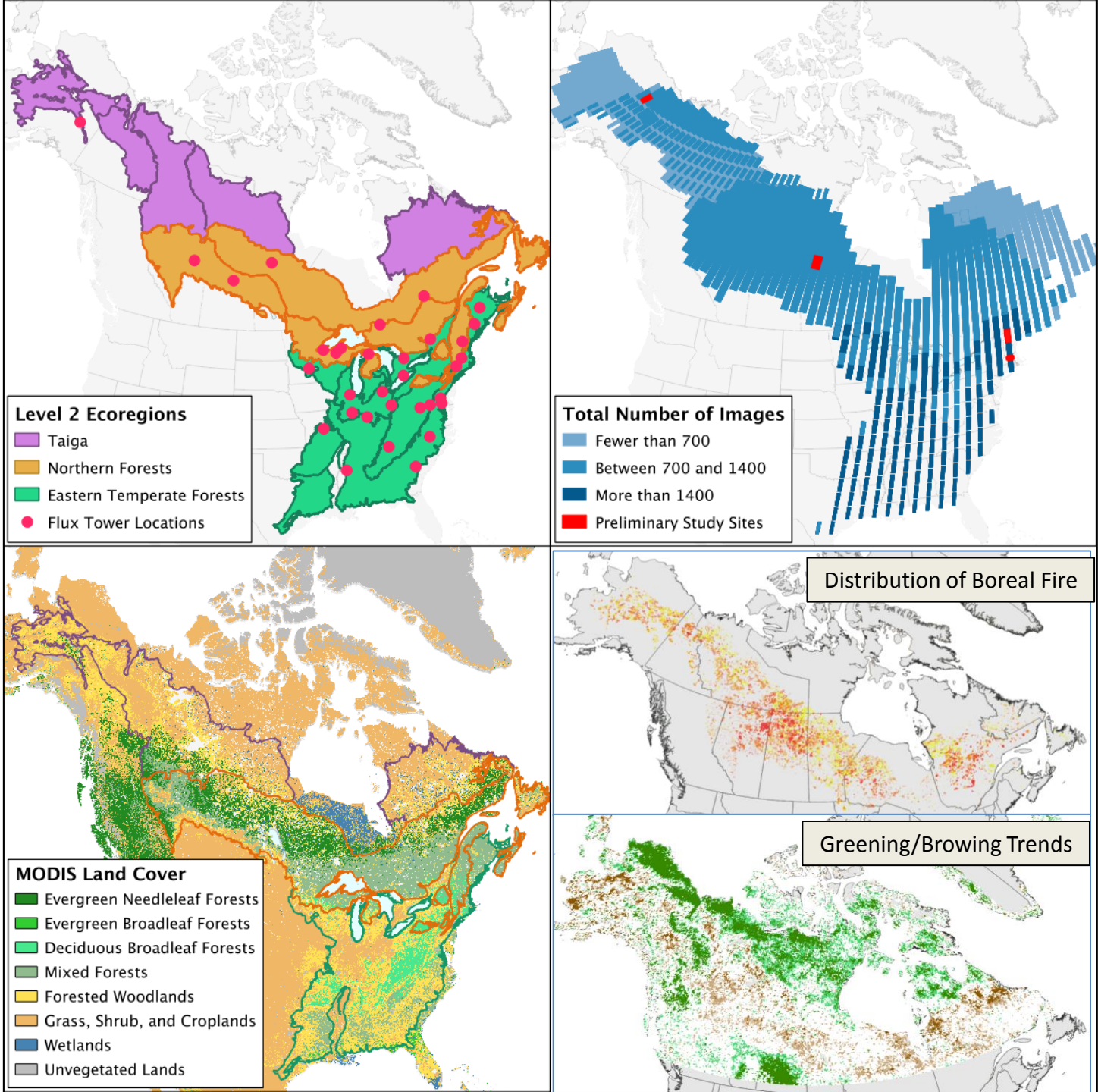
Project Goals

Why use AVHRR (or even MODIS) when you can use Landsat?

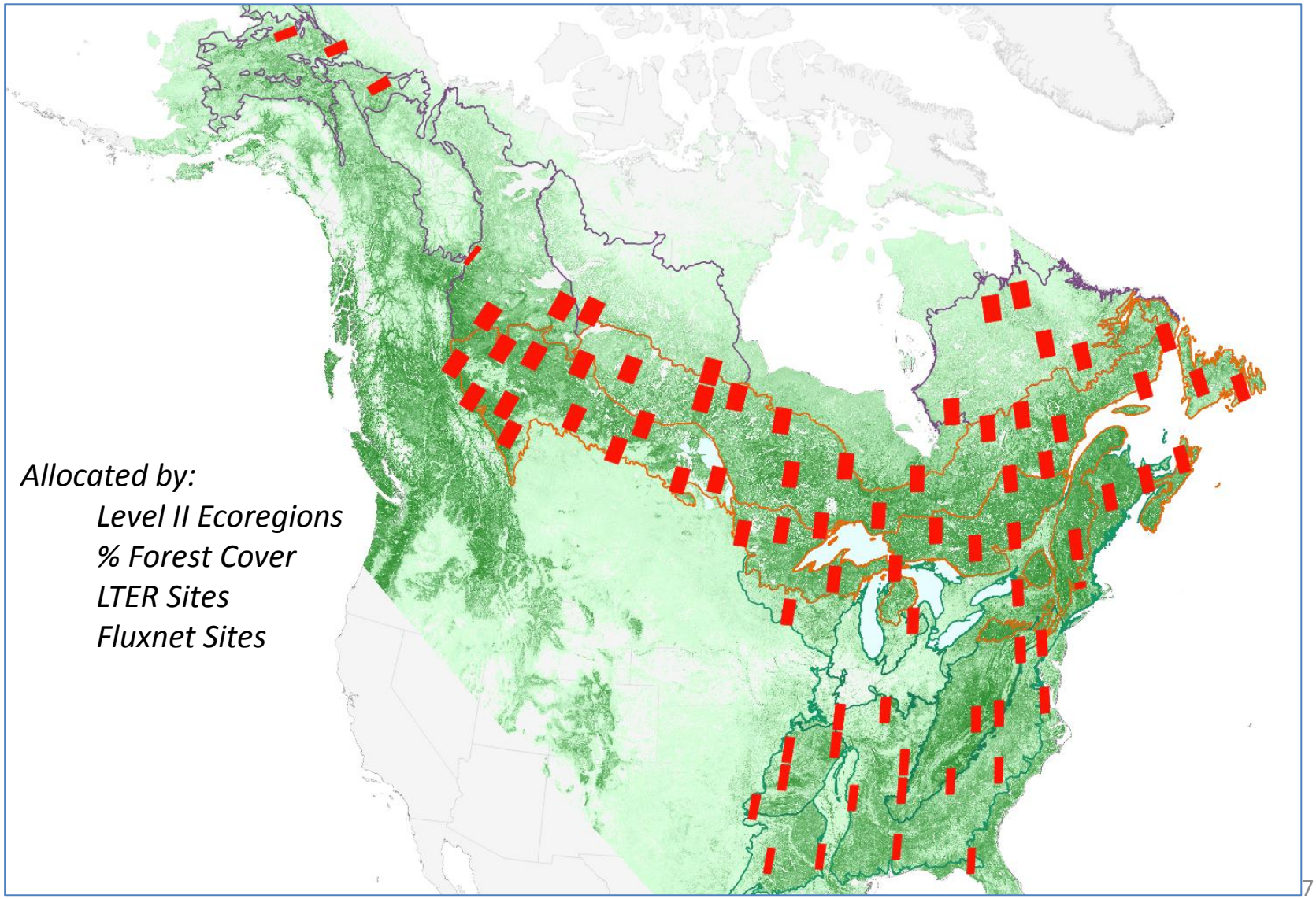
Sample Design:

~ 75 Sites

Pseudo-Random Allocation



Selected Sites (n~80)



Allocated by:

- *Level II Ecoregions*
- *% Forest Cover*
- *LTER Sites*
- *Fluxnet Sites*

Part 1: Trends in Peak Summer NDVI

Are there trends in Landsat NDVI over Boreal Canada?

If so, what is nature, magnitude, and drivers behind trends?

- Two possibilities:
  1. Actual changes on the ground, including role of disturbance?
  2. Artifacts in data?
     - *Changes in sensor-sun geometry*
     - *Subtle differences in calibration of TM5 vs. ETM?*
- Analysis at 16 sites

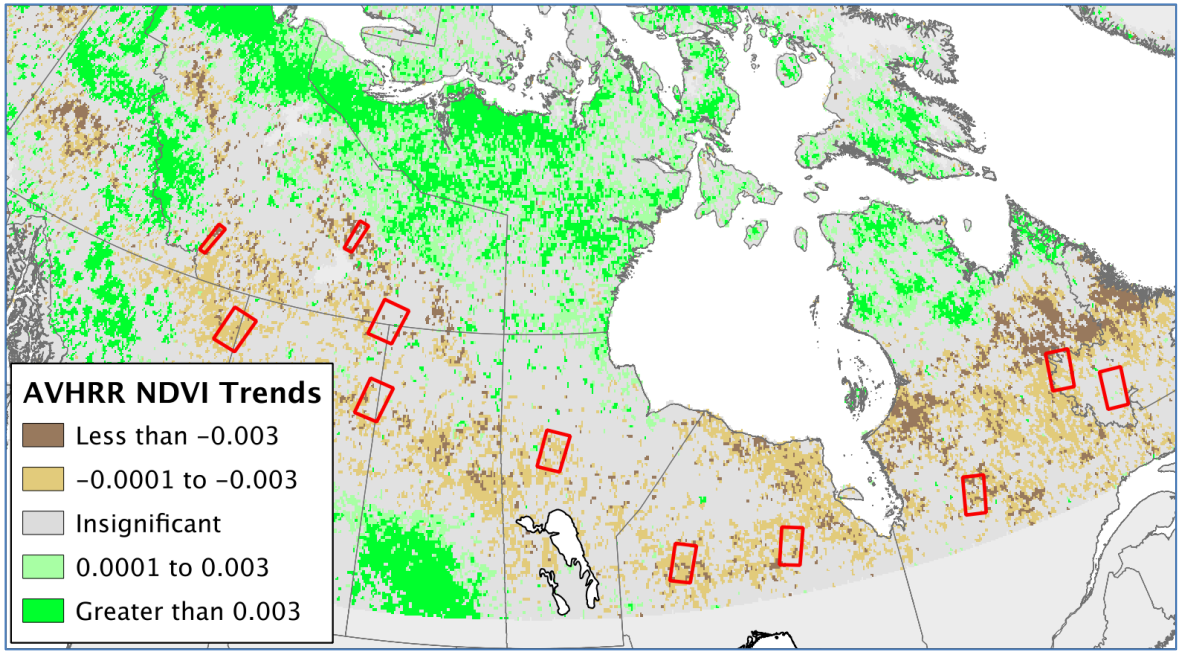
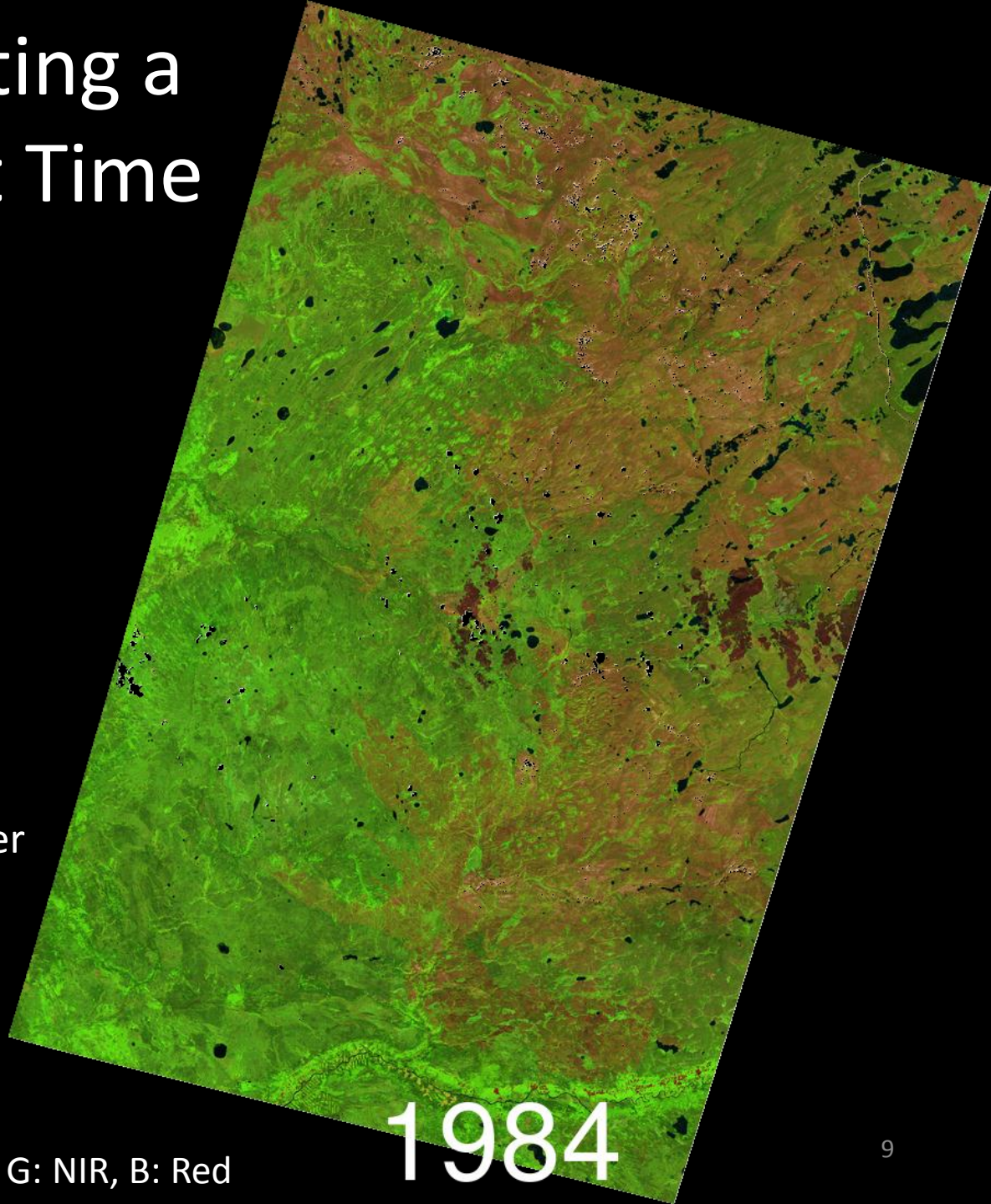


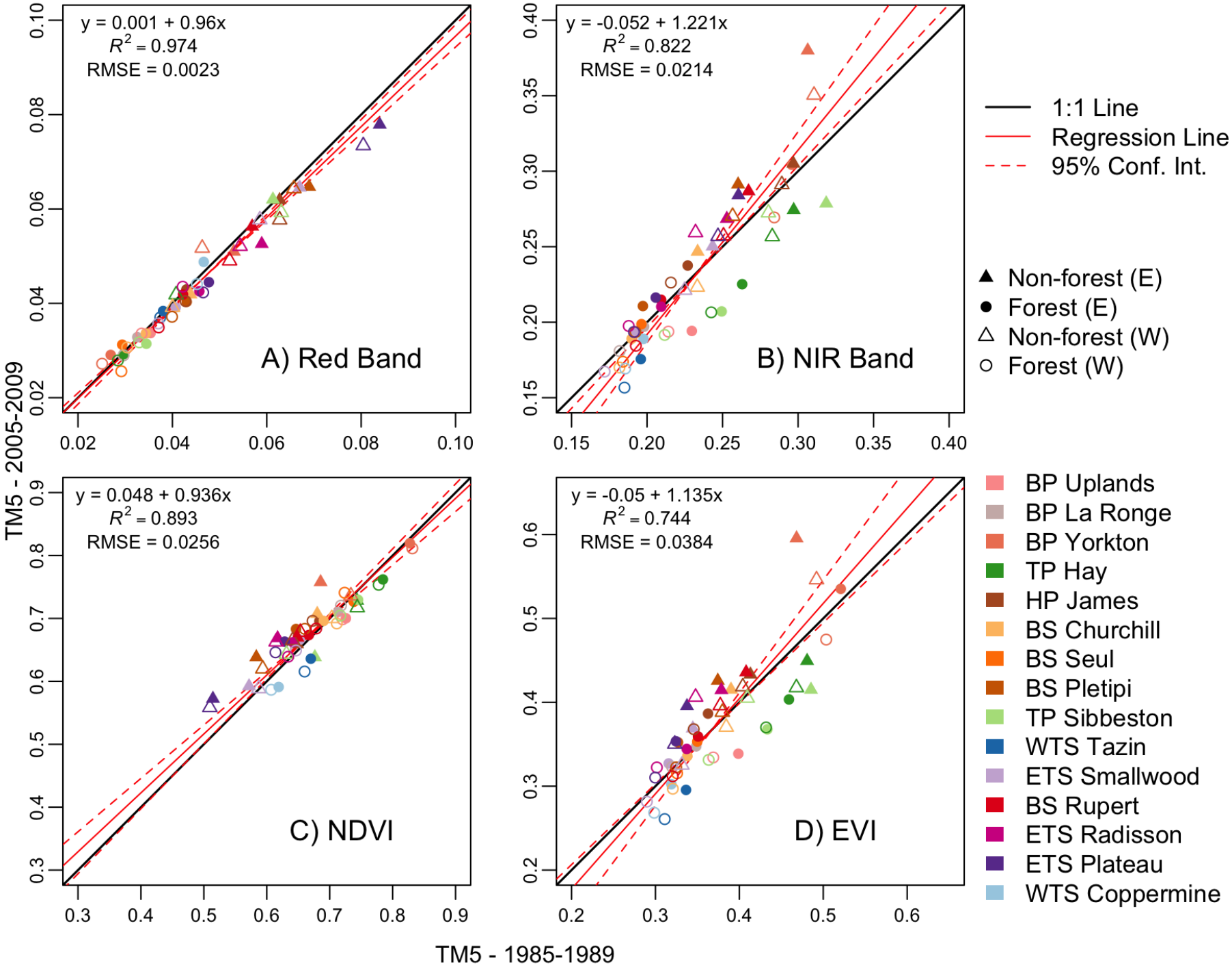
Figure from: Sulla-Menashe et al., in revision, *Remote Sensing of Environment*

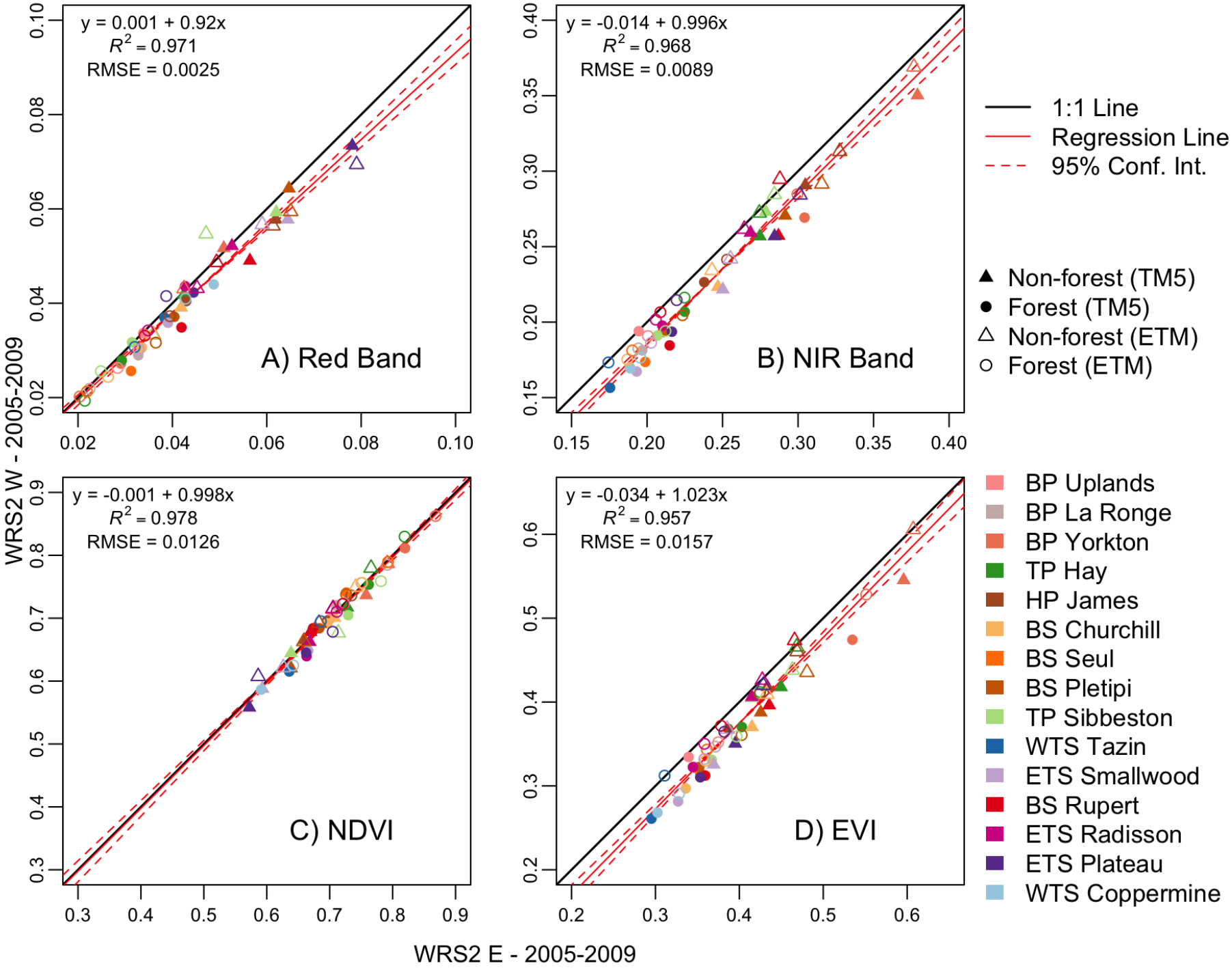
Methods: Creating a 28-year Landsat Time Series

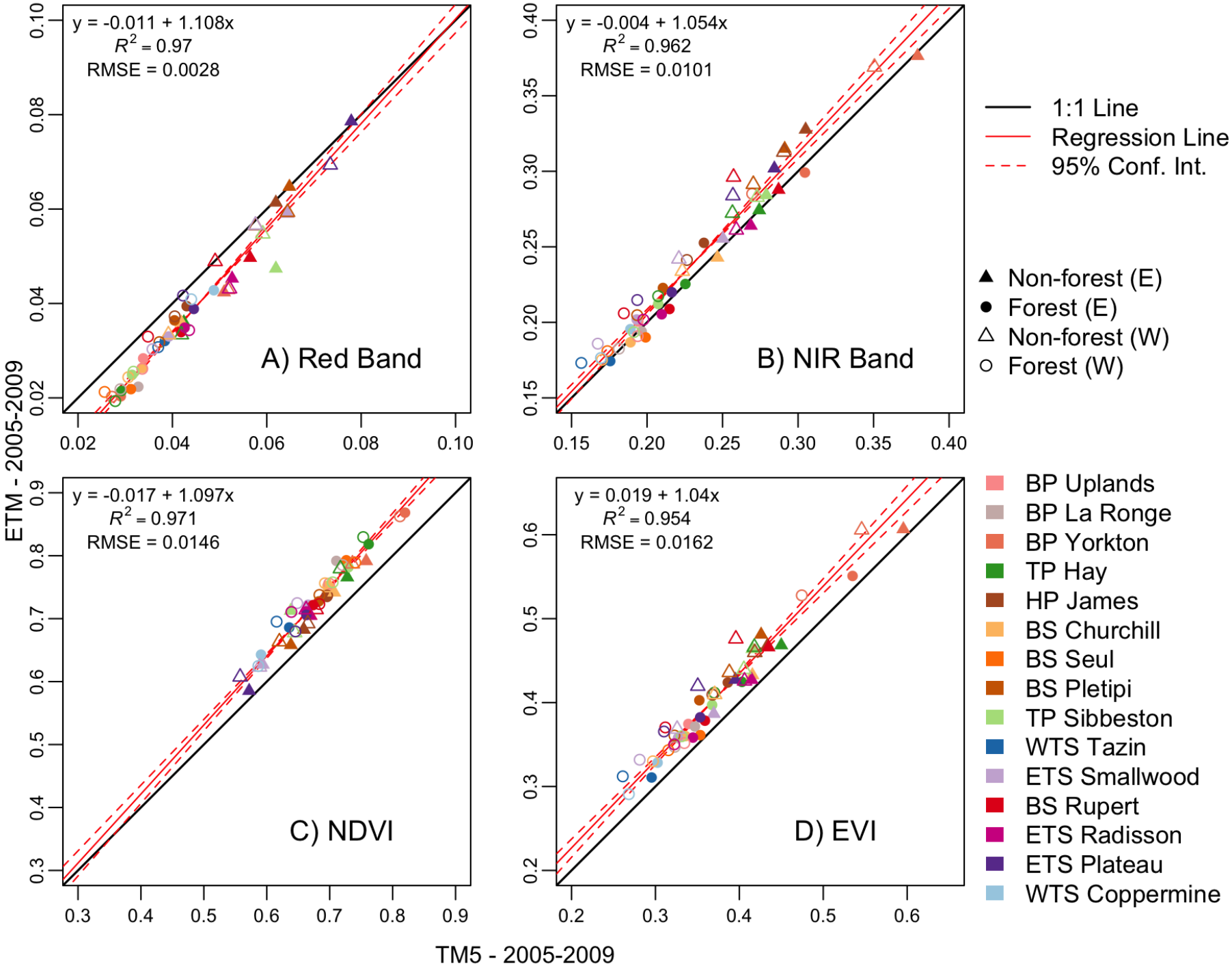
1. Atmospheric correction & cloud screening (LEDAPS, FMASK)
2. CLFDB and YATSM for disturbance
3. Maximum NDVI value composite for peak summer "greenness" (following Goetz et al., and others)



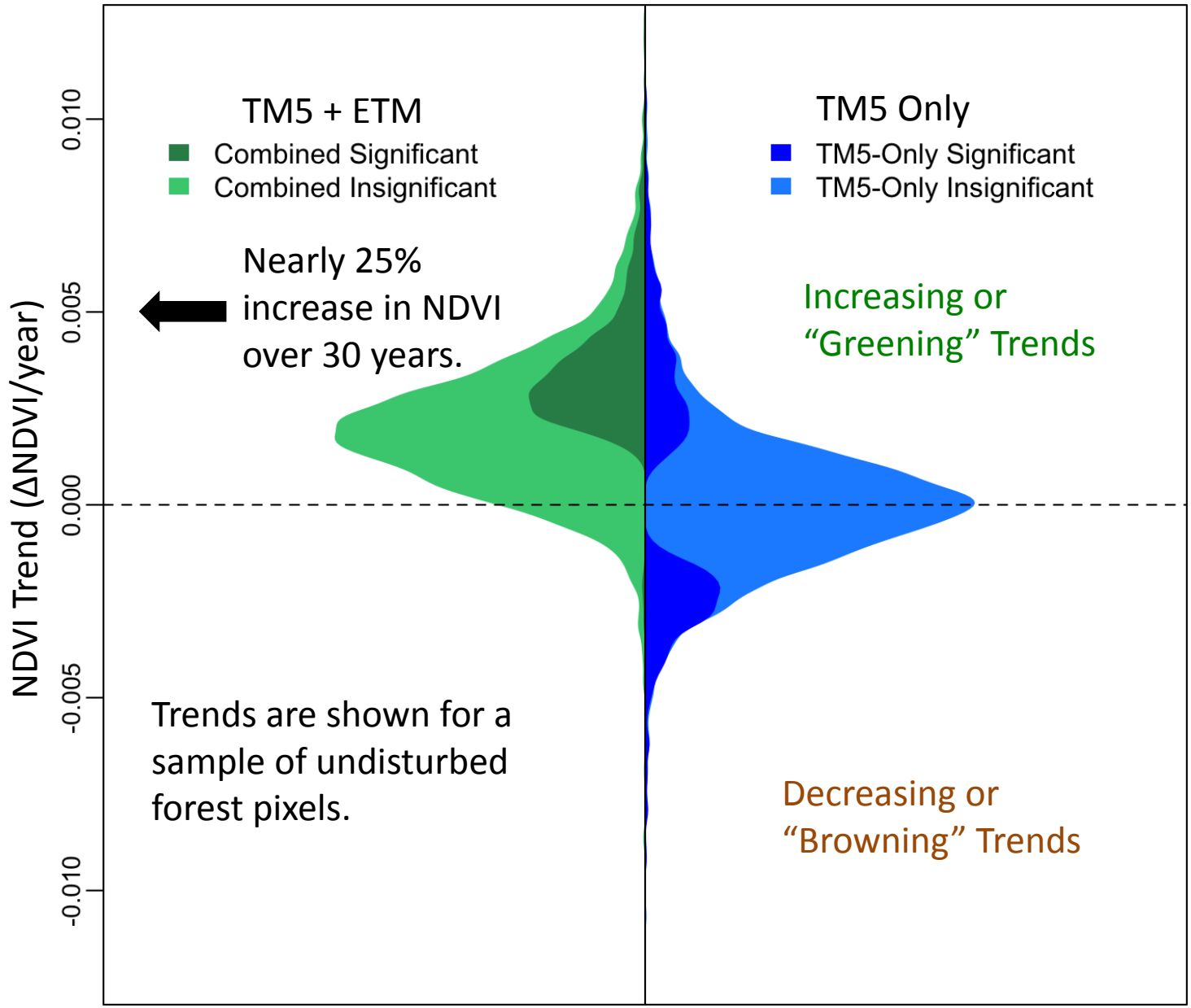
R: SWIR, G: NIR, B: Red


y = 0.001 + 0.96x
R^2 = 0.974
RMSE = 0.0023
A) Red Band
y = -0.052 + 1.221x
R^2 = 0.822
RMSE = 0.0214
B) NIR Band
y = 0.048 + 0.936x
R^2 = 0.893
RMSE = 0.0256
C) NDVI
y = -0.05 + 1.135x
R^2 = 0.744
RMSE = 0.0384
D) EVI
TM5 - 2005-2009
TM5 - 1985-1989
1:1 Line
Regression Line
95% Conf. Int.
Non-forest (E)
Forest (E)
Non-forest (W)
Forest (W)
BP Uplands
BP La Ronge
BP Yorkton
TP Hay
HP James
BS Churchill
BS Seul
BS Pletipi
TP Sibbeston
WTS Tazin
ETS Smallwood
BS Rupert
ETS Radisson
ETS Plateau
WTS Coppermine


y = 0.001 + 0.92x
R^2 = 0.971
RMSE = 0.0025
A) Red Band
y = -0.014 + 0.996x
R^2 = 0.968
RMSE = 0.0089
B) NIR Band
y = -0.001 + 0.998x
R^2 = 0.978
RMSE = 0.0126
C) NDVI
y = -0.034 + 1.023x
R^2 = 0.957
RMSE = 0.0157
D) EVI
WRS2 W - 2005-2009
WRS2 E - 2005-2009
1:1 Line
Regression Line
95% Conf. Int.
Non-forest (TM5)
Forest (TM5)
Non-forest (ETM)
Forest (ETM)
BP Uplands
BP La Ronge
BP Yorkton
TP Hay
HP James
BS Churchill
BS Seul
BS Pletipi
TP Sibbeston
WTS Tazin
ETS Smallwood
BS Rupert
ETS Radisson
ETS Plateau
WTS Coppermine

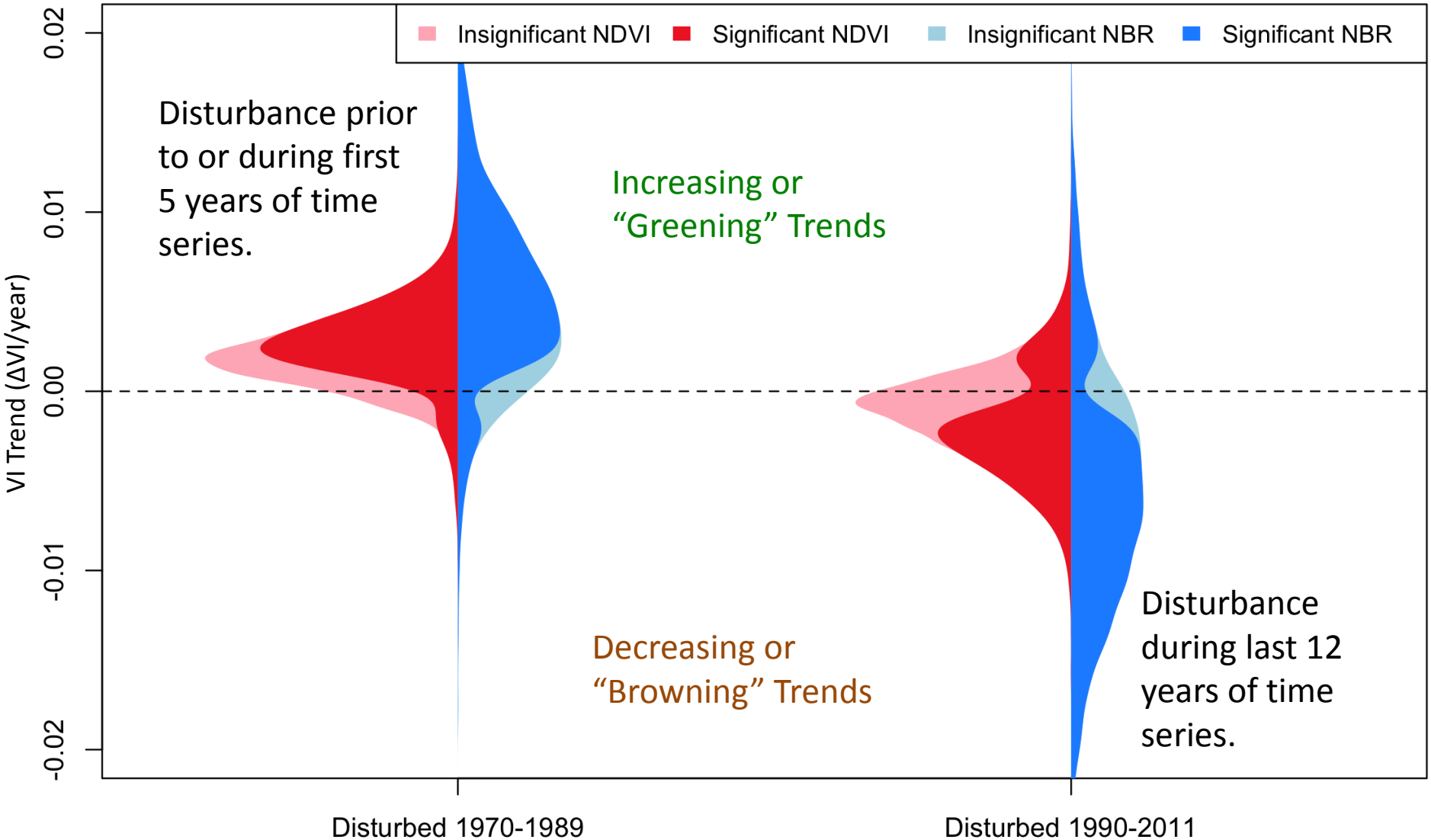

y = -0.011 + 1.108x
R^2 = 0.97
RMSE = 0.0028
A) Red Band
y = -0.004 + 1.054x
R^2 = 0.962
RMSE = 0.0101
B) NIR Band
y = -0.017 + 1.097x
R^2 = 0.971
RMSE = 0.0146
C) NDVI
y = 0.019 + 1.04x
R^2 = 0.954
RMSE = 0.0162
D) EVI
ETM - 2005-2009
TM5 - 2005-2009
1:1 Line
Regression Line
95% Conf. Int.
Non-forest (E)
Forest (E)
Non-forest (W)
Forest (W)
BP Uplands
BP La Ronge
BP Yorkton
TP Hay
HP James
BS Churchill
BS Seul
BS Pletipi
TP Sibbeston
WTS Tazin
ETS Smallwood
BS Rupert
ETS Radisson
ETS Plateau
WTS Coppermine

Results: Effects of Red Band Bias

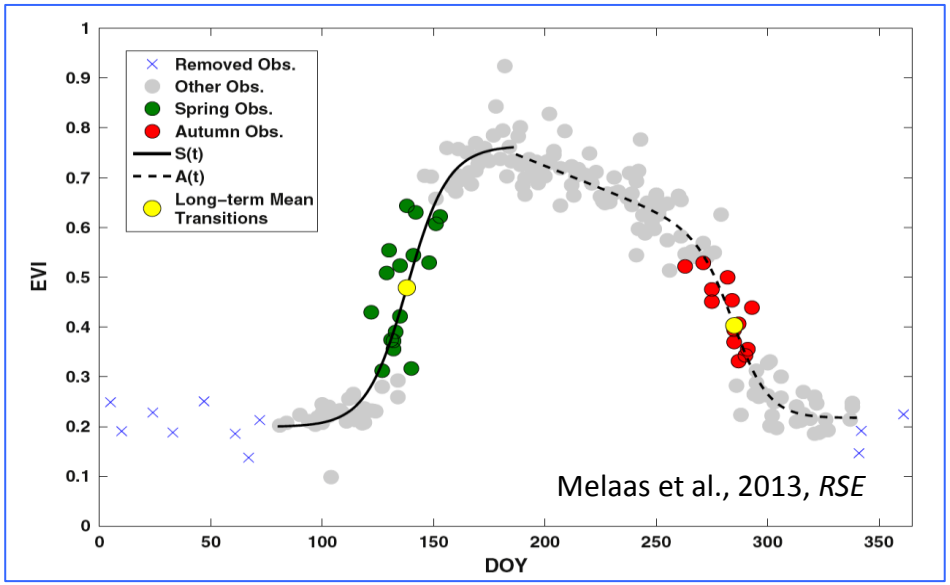


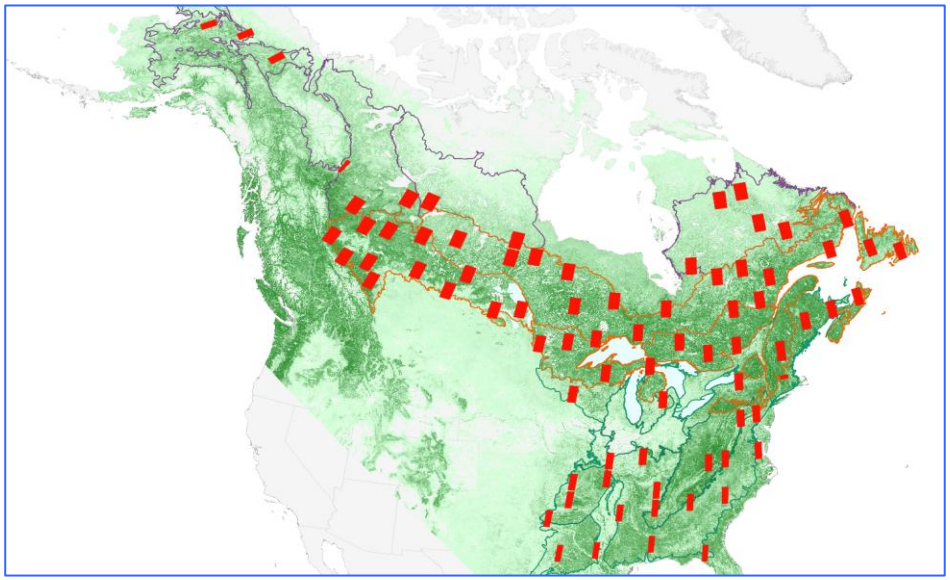
Sulla-Menashe et al., in revision, *Remote Sensing of Environment*

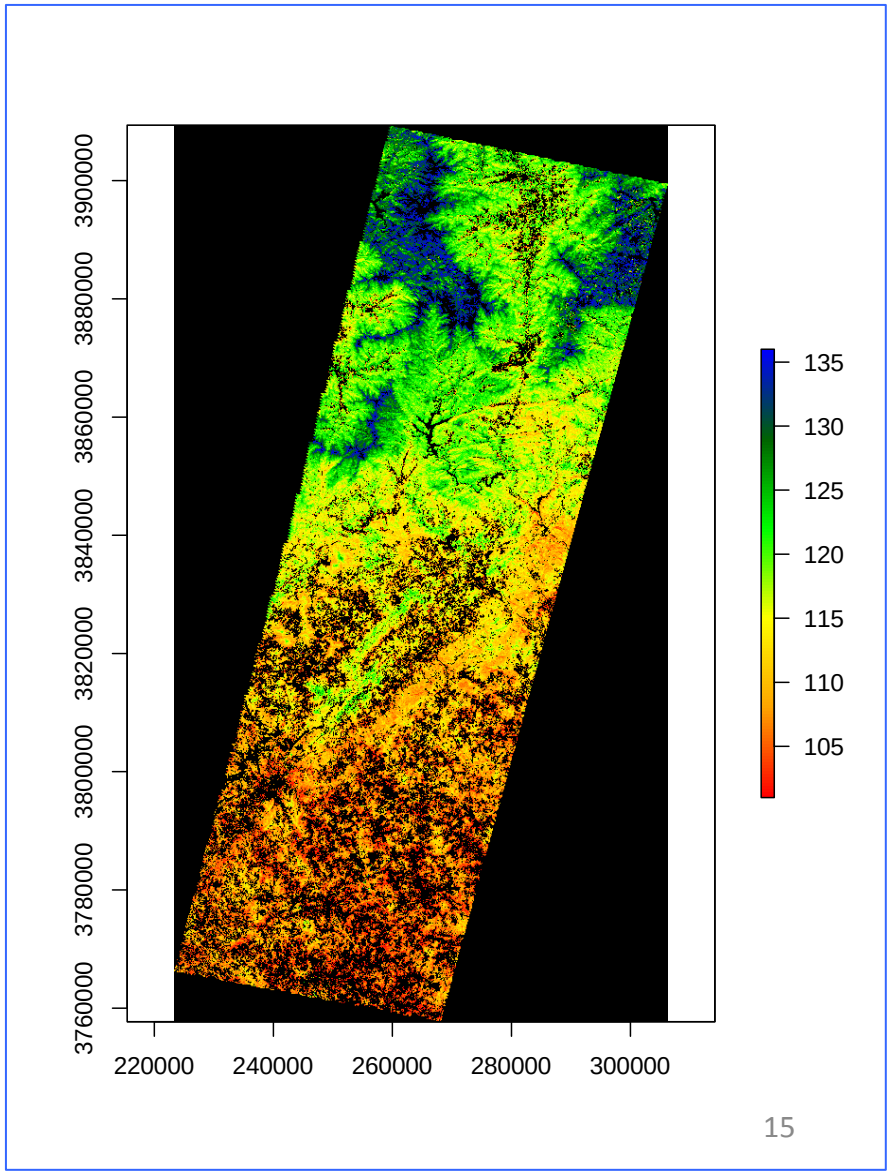
Results: Disturbance

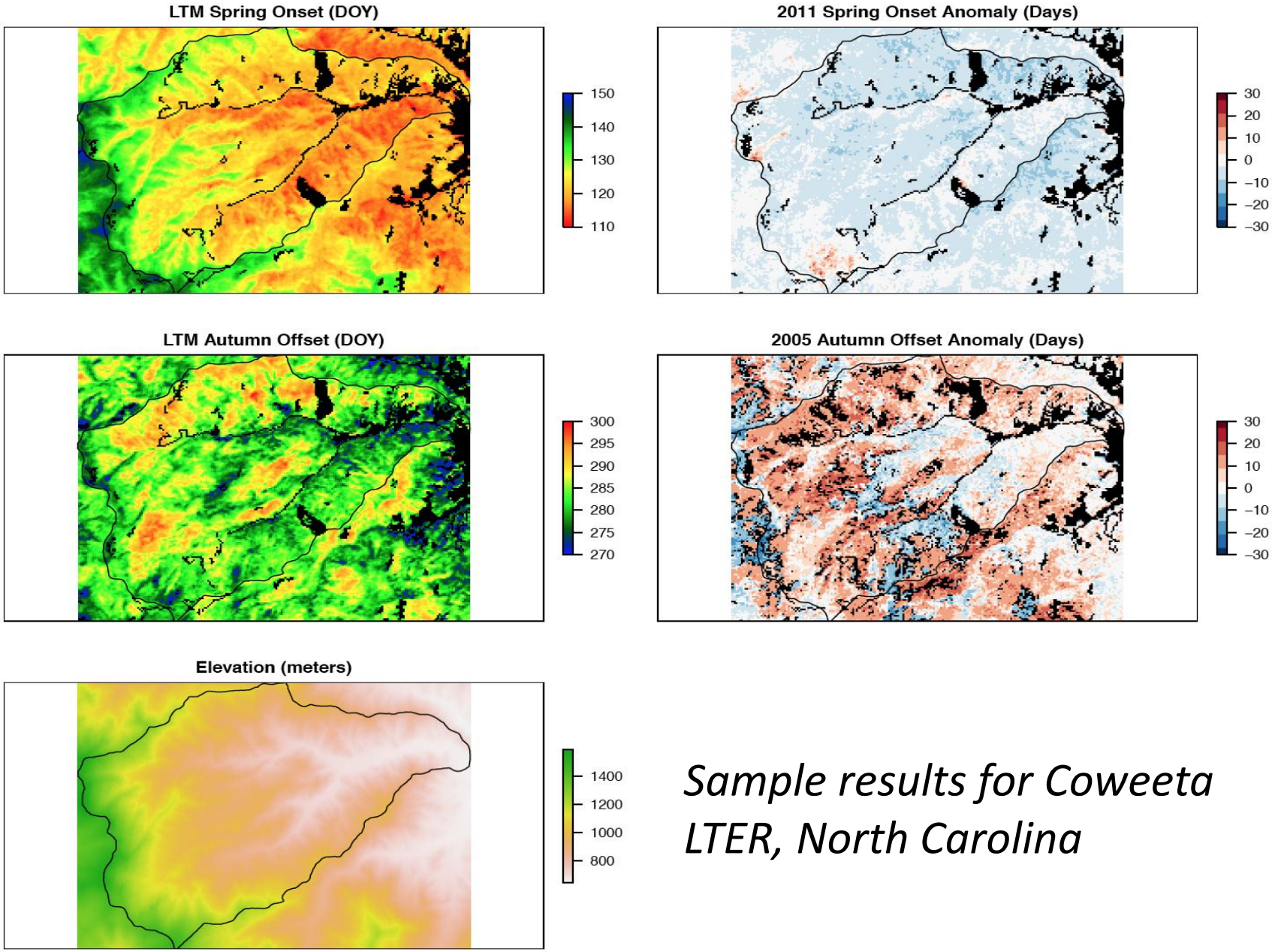


Part 2: Trends in Growing Season Length



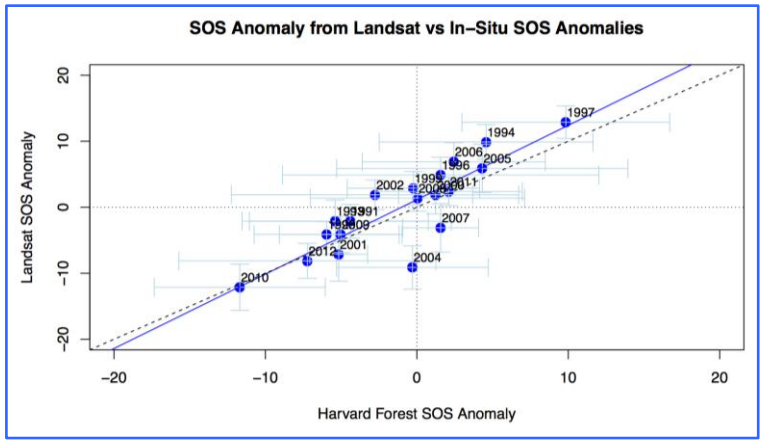


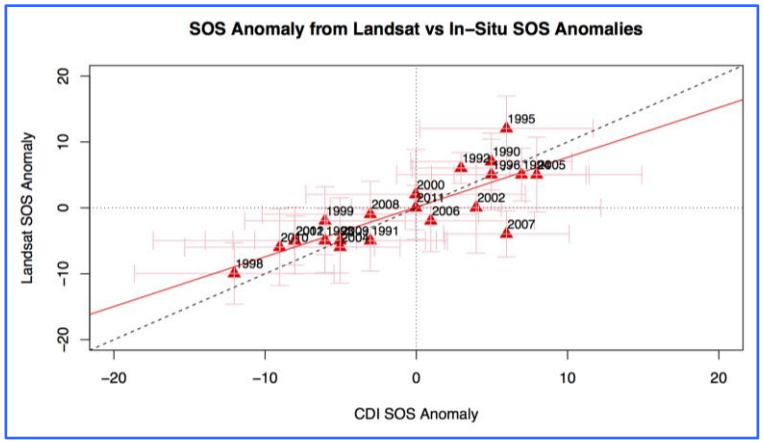


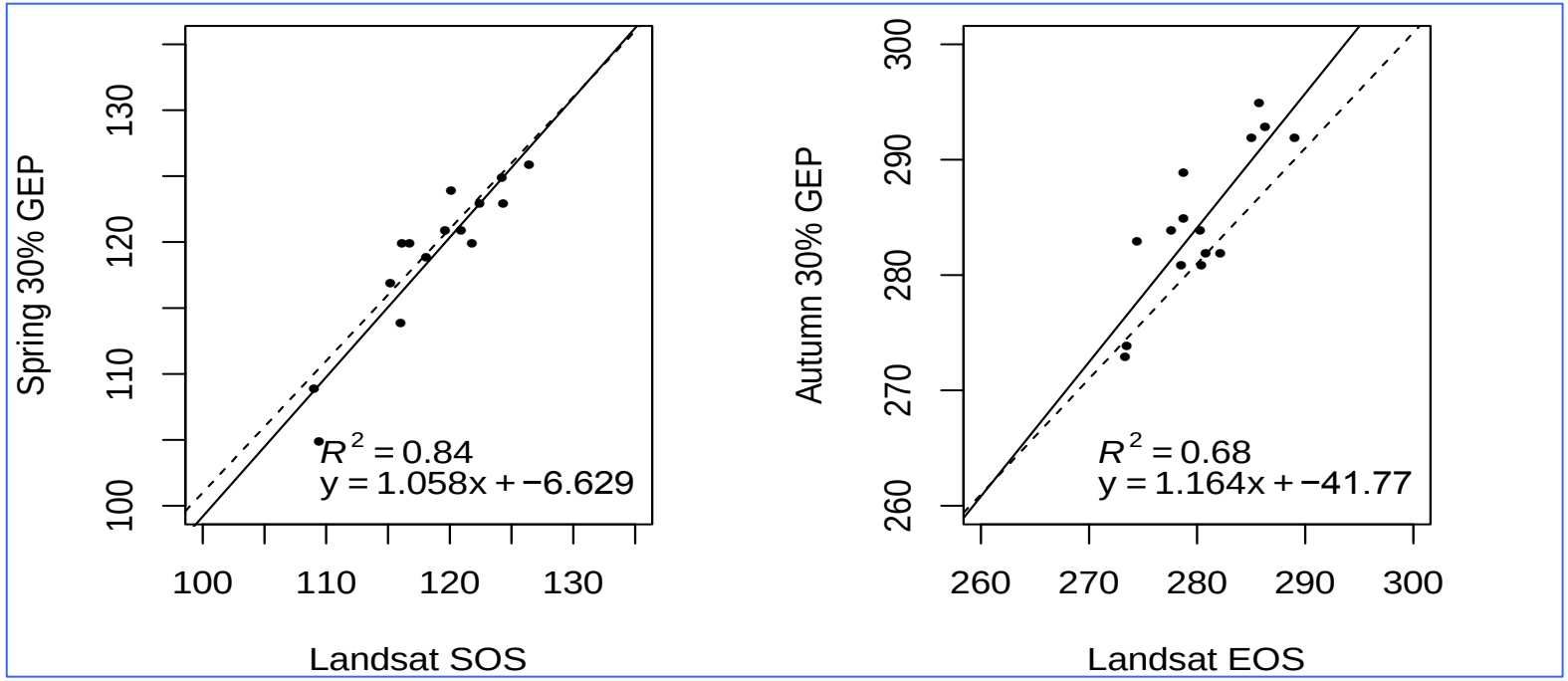


Sample results for Coweeta LTER, North Carolina

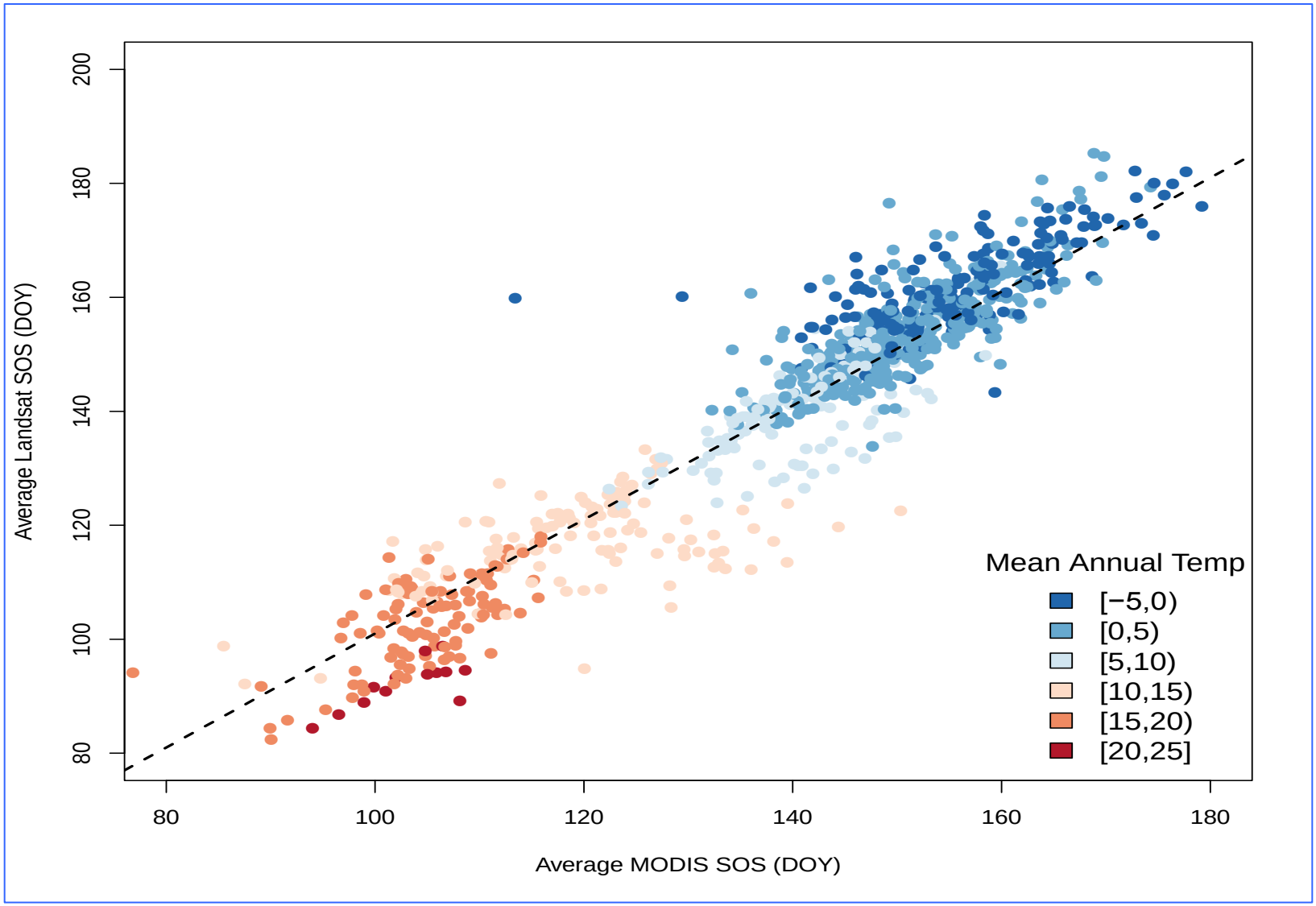
Algorithm Assessment



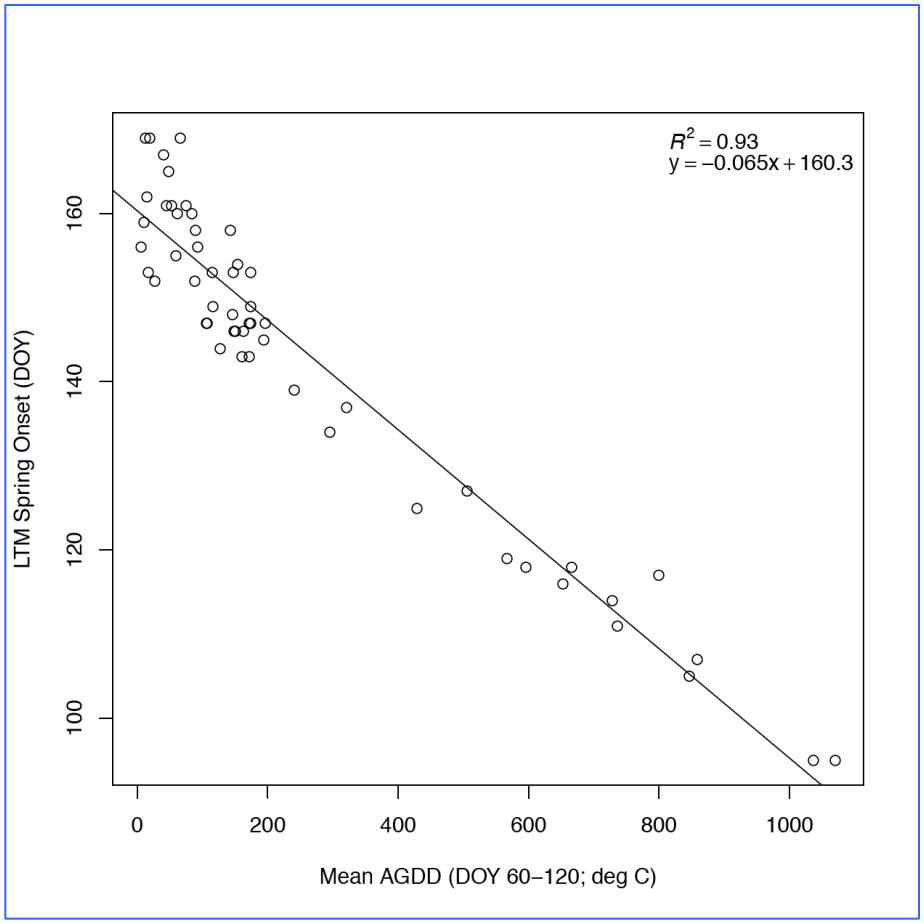


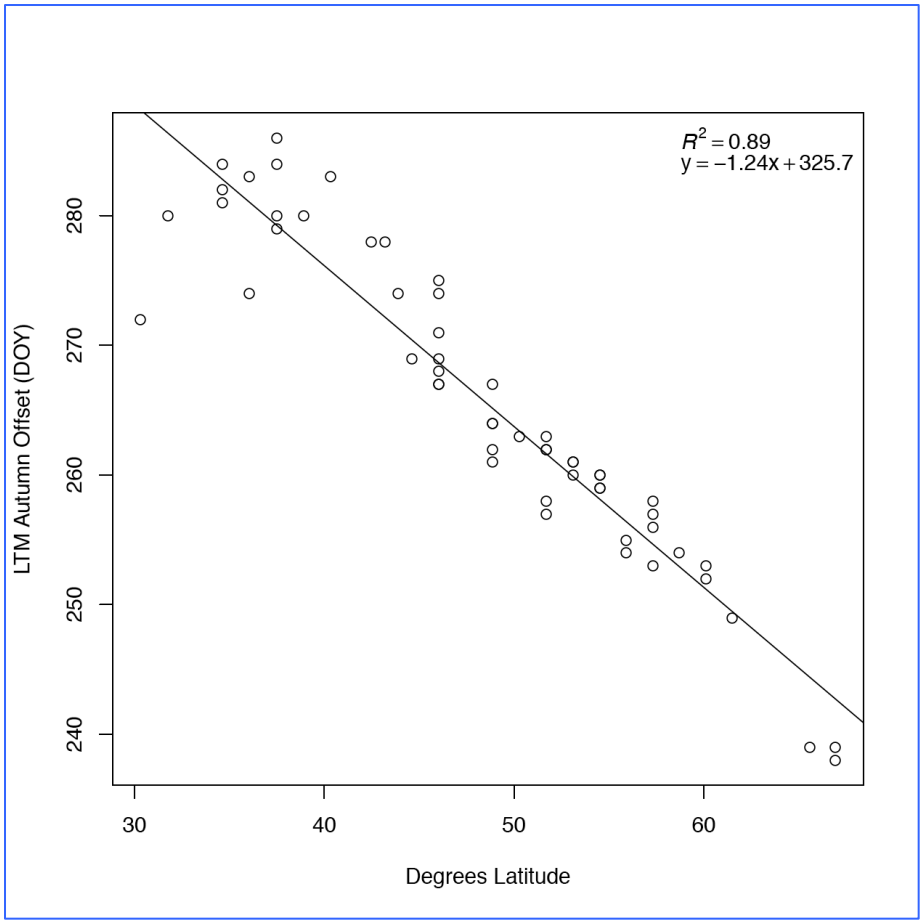


Comparison w/MODIS

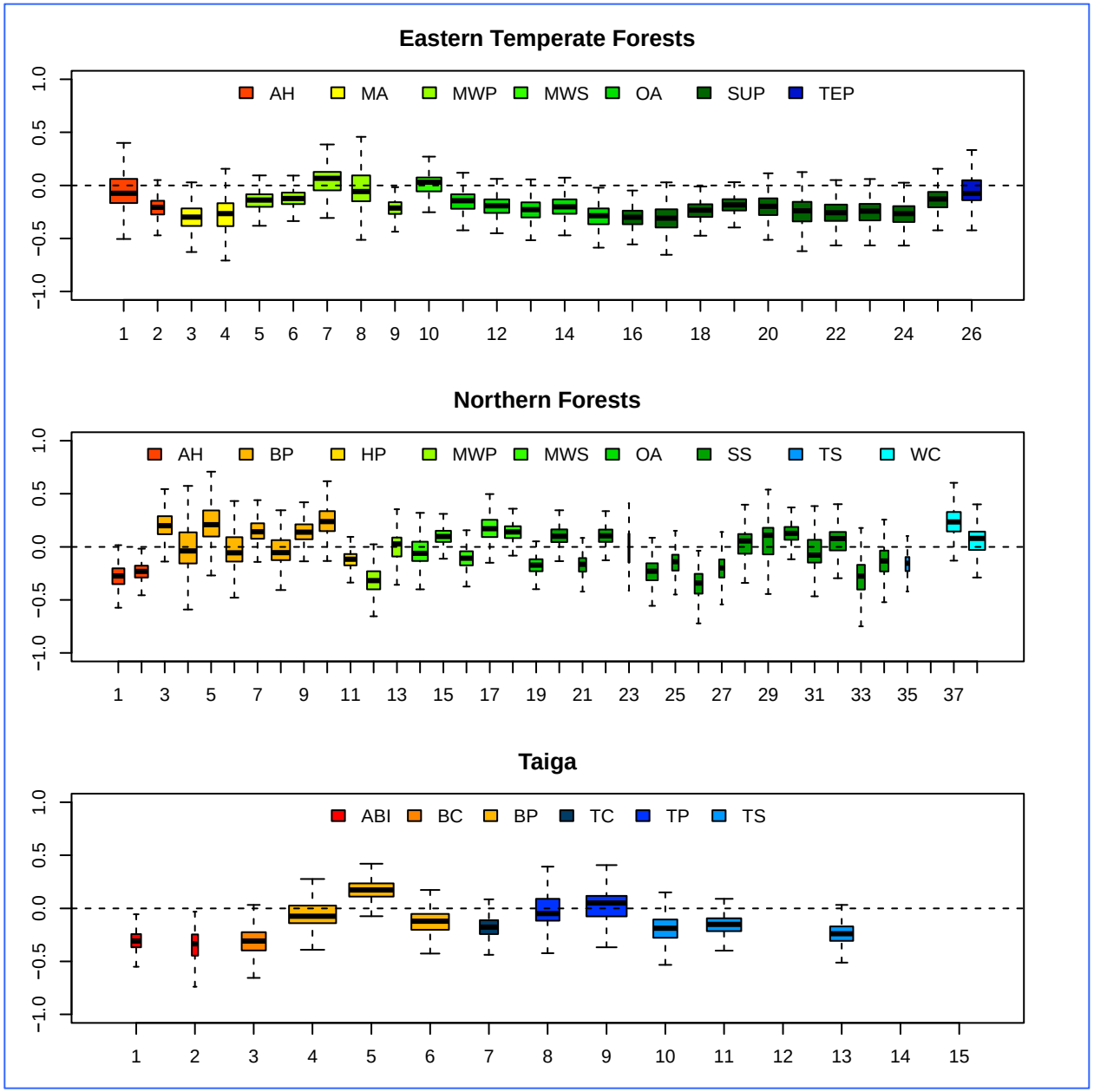


Mean SOS vs AGDD, EOS vs Latitude

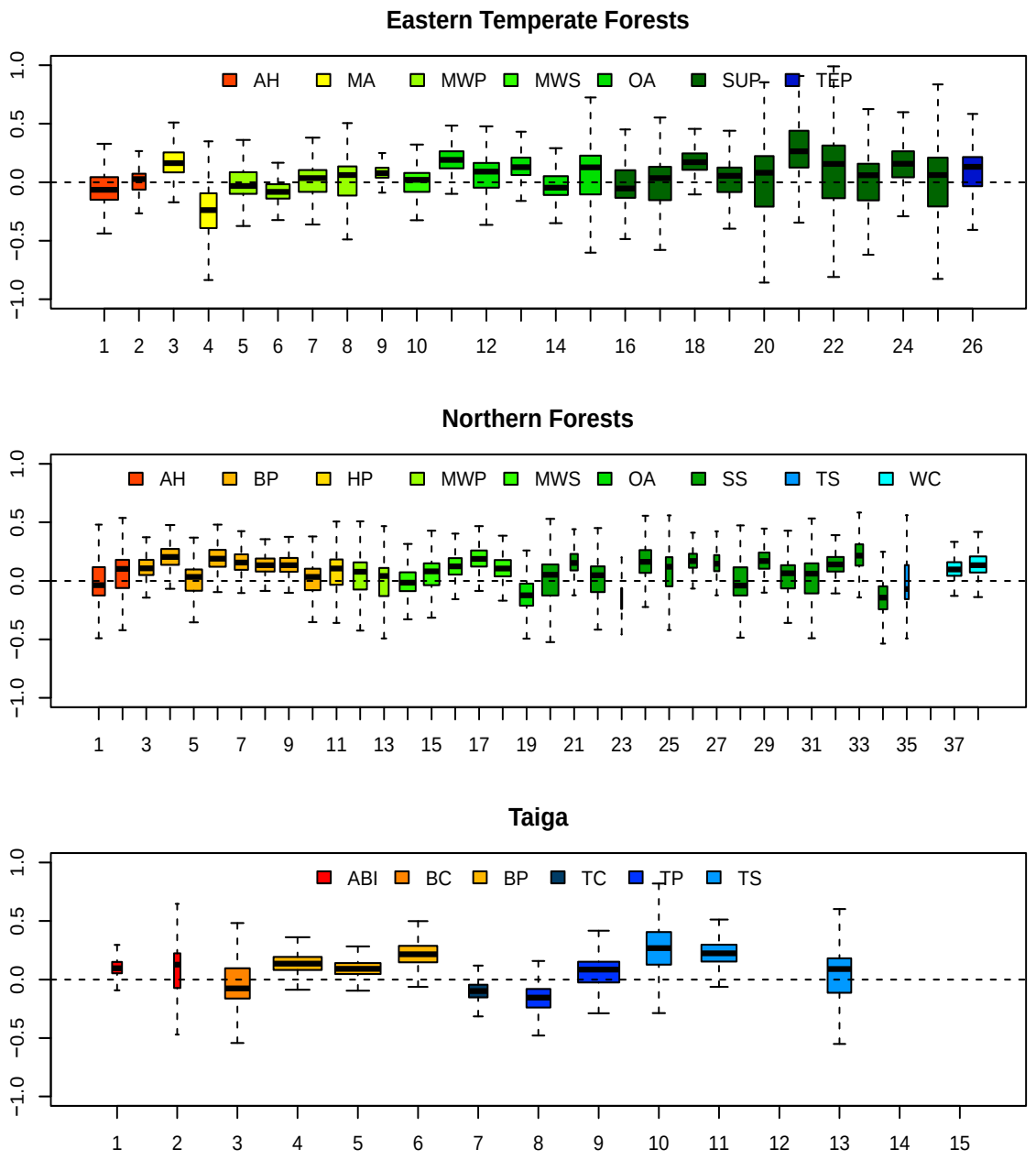


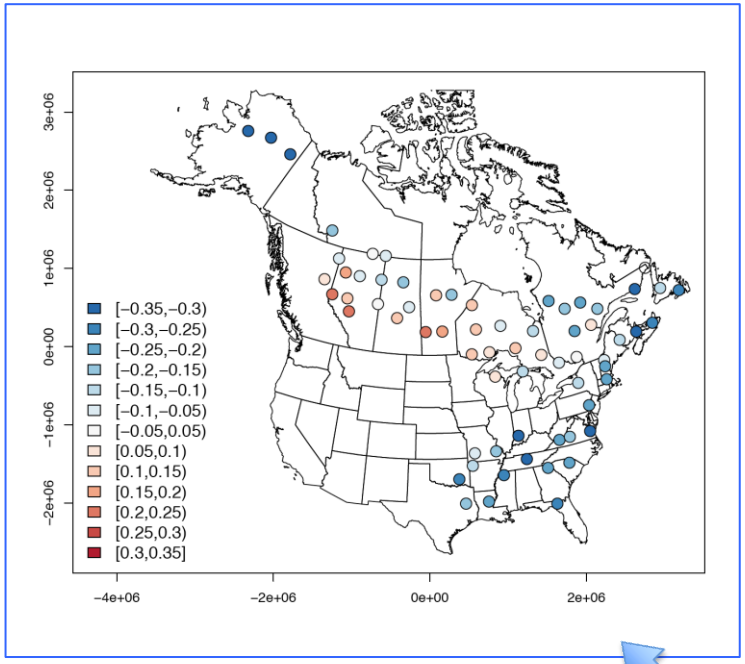


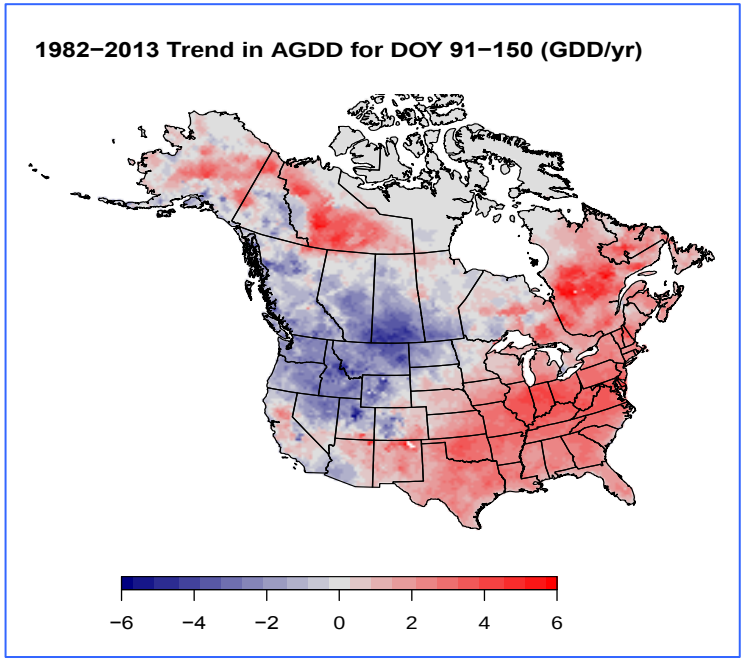
Trends in SOS Stratified by Site and Ecoregion



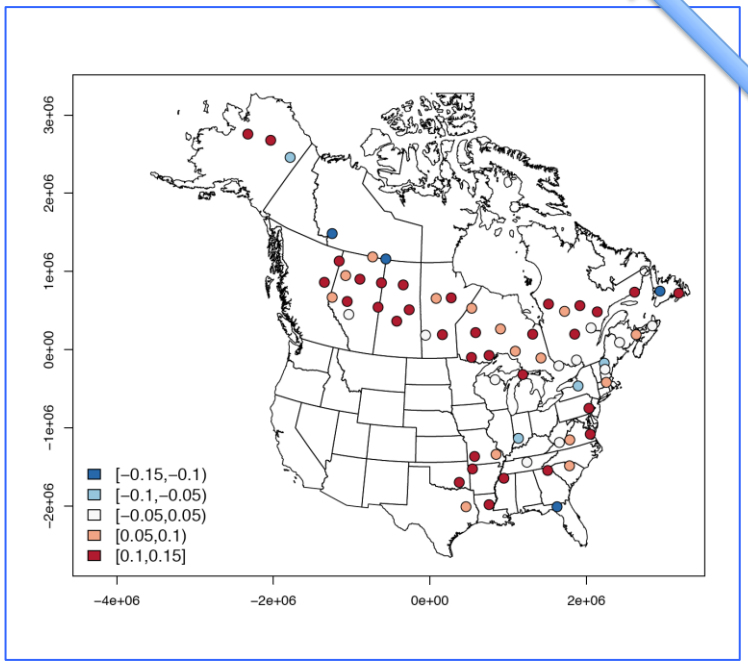
Trends in EOS, Stratified by Site and Ecoregion







Spring trends in AGDD from NARR



Trends in Spring

Trends in Autumn

Questions?