An Alternative View of the Climate Warming Mitigation Potential of U.S Temperate Forests

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Extra-tropical forests hot (warm) relative to surrounding fields

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Extra-tropical deforestation produces a cooling effect

Boreal deforestation greater cooling; temperate deforestation less cooling

Extra-tropical forests are warm relative to surrounding fields

Lee et al. 2011. Observed increase in local cooling effect of deforestation at higher latitudes. *Nature* 479:384.

Davin & de Noblet-Ducoudré 2010. Climate impact of global deforestation: radiative vs. non-radiative … *J. Clim.* 23:97.

Diffenbaugh 2009. Influence of modern land cover on climate of the U.S. *Climate Dynamics* 33:945.

Bala et al. 2007. Combined climate and carbon-cycle effects of large-scale deforestation. *PNAS* 104:6550.

Betts et al. 2007. Biogeophysical effects of land use on climate: Model simulations … *Agric. For. Meteorol.* 142:216.

Brovkin et al. 2006. Biophysical effects of historical land cover changes simulated by six … *Climate Dynamics* 26:587.

Feddema et al. 2005. The importance of land cover change in simulating future climates. Science 310: 1674.

Gibbard et al. 2005. Climate effects of global land cover change. *Geophys. Res. Lett.* doi: 10.1029/2005GL024550.

Brovkin et al. 2004. Role of land cover changes for atmospheric CO^2 increase and climate … *Glob. Change Biol.* 1:1

Bounoua et al. 2002. Effects of land conversion on surface climate. *Climatic Change* 52:29

Betts. 2001. Biogeophysical impacts of land use on present day climate: near-surface … *Atmos. Sci. Lett.* 2:39.

Bonan 1999. Frost followed the plow: impacts of deforestation on climate of the US. *Ecol. Appl.* 9:1305.

Brovkin et al. 1999. Modelling climate response to land cover change. *Glob. Ecol. Biogr.* 8:509.

Bonan 1997. Effects of land use on climate of the U.S. *Climatic Change* 37:449.

Importance of the warming effect of extra-tropical forests

Many organizations promote forestation (afforestation & reforestation) as a climate mitigation strategy.

- UNFCC, IPCC, U.S. federal agencies

Forestation-oriented climate mitigation policies must account for biogeophysical effects in addition to biogeochemical effects (carbon sequestration)

…
Importance of accounting for biogeophysical effects

Betts et al. 2007. Biogeophysical effects of land use on climate: Model simulations … *Agric. For. Meteorol.* 142:216.

Jackson et al. 2008. Protecting climate with forests. Env. Res. Lett. doi:10.1088/1748-9326/3/4/044006

Anderson et al. 2011. Biophysical considerations for forestry in climate protection. *Front. Ecol. Environ.* 9:174.

Why might extra-tropical forests warm?

Forests are darker (lower albedo) than surrounding herbaceous vegetation

Albedo difference is accentuated in presence of snow

Crops have lower stomatal resistance than forests (Bonan 1997)

Forests “trap” heat at night (Lee et al. 2011)

The cooling effect of transpiration is only seasonally active

Why might extra-tropical forests cool?

Snow is not consistent or persistent in many US temperate locations

Albedo differences are also affected by soil color & wetness

Albedo difficult to measure, labile, and differences between forest and cropland albedos are often small (Alton 2009, Hollinger et al. 2010).

Crops have lower stomatal resistance (Bonan 1997) but forests have a higher rate of transpiration (Davin & Noblet-Doucoudré 2010).

Higher surface roughness of forests is generally regarded as a characteristic that promotes heat dissipation.

Expectation

Temperate forests are not a source of heat; transpiration and shading will outweigh overall small differences in albedo throughout the continental US.

Inverse relationship between forest and surface temperature will strengthen with scale. Forest dominance over larger spatial extents will enhance cooling.

The crooked forest of Gryfino, Poland

http://www.amusingplanet.com/2013/06/the-crooked-forest-of-gryfino-poland.html

Methods

Compile MODIS Land Surface Temperature (LST) data for years 2007 – 2012 (Version 5) and conflate with proportion of forest (and other land cover) from NLCD 2001 land cover measured across 6 scales).

MODIS – 8-day composite data from afternoon overpass (MODIS-AQUA); 1 km^2 spatial resolution; utilized daytime and nighttime temperatures; NLCD 30m^2 spatial resolution.

Bivariate regression (forest, scale) and boxplots (forest vs. cropland); controlled for effects of elevation and other factors; analyses conducted seasonally and annually; regressions across 6 spatial scales of forest proportion (1km^2 – 6km^2); "exclusive" wintertime analyses conducted for southeast.

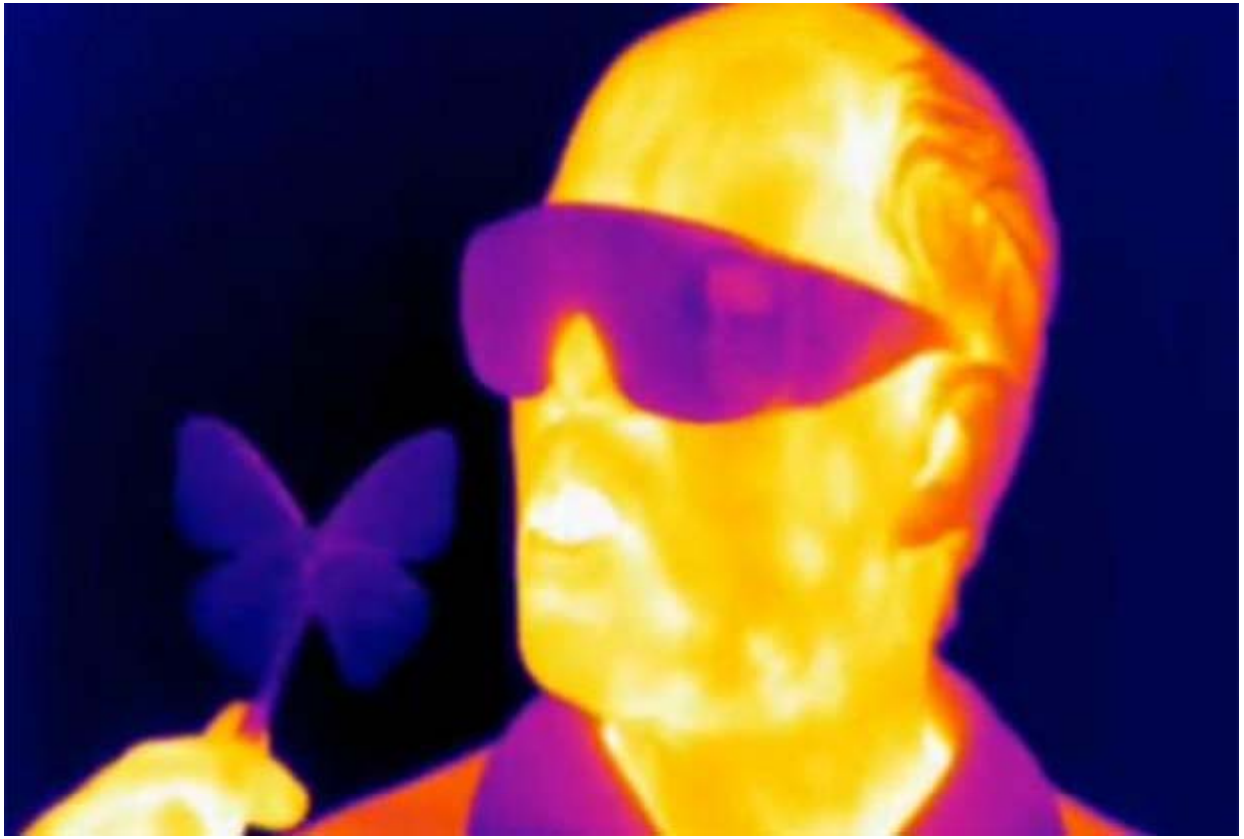
Analyses conducted within 100x200km cells (100km ~= 1° latitude) using only 1 observation within 5km X 5km subgrid to control for spatial correlation.

Compiled 14-year land cover-albedo database based on NLCD and 500m MODIS albedo product.

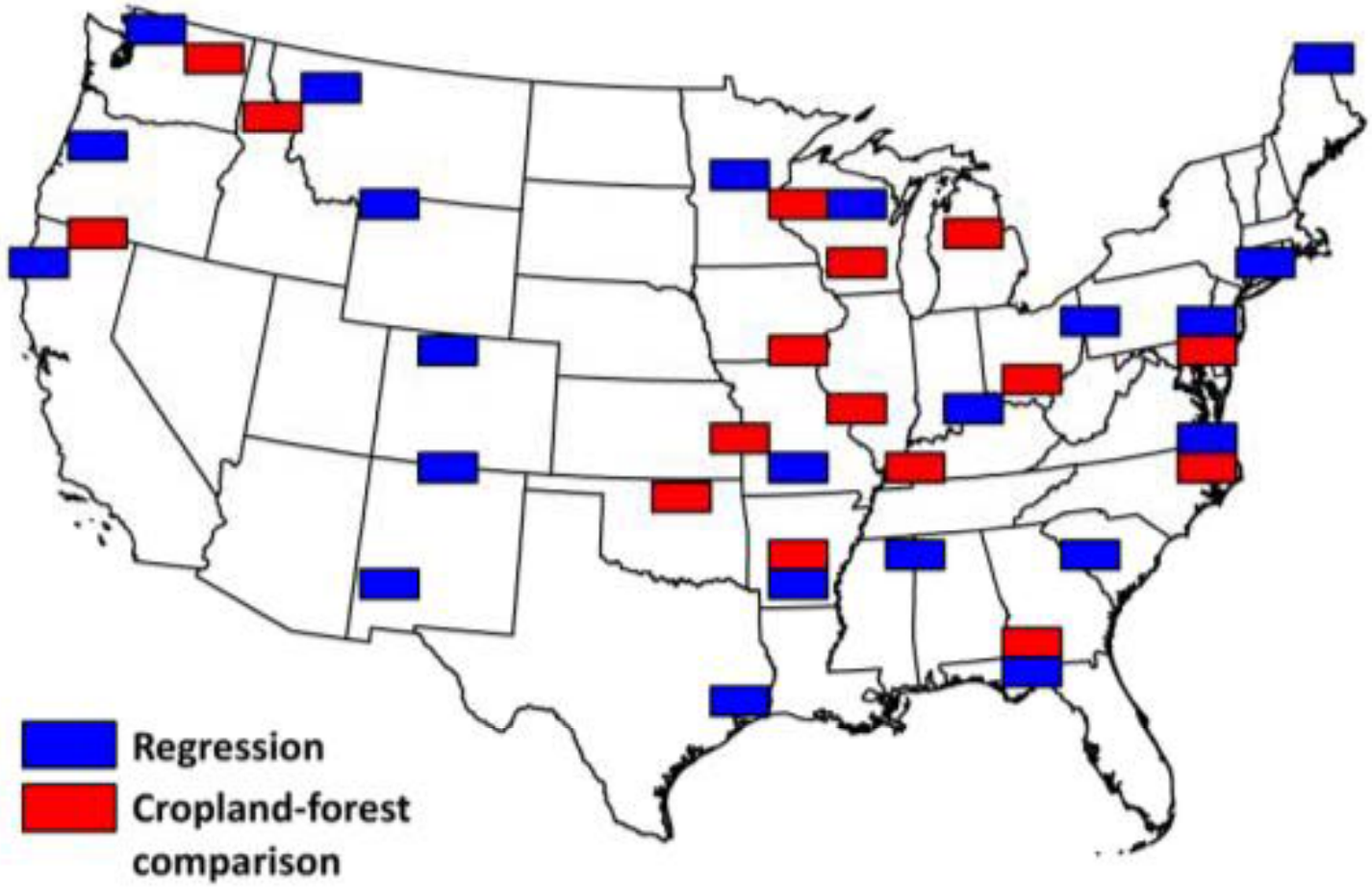
MODIS

Measures “skin” or surface temperature, which ~canopy height for vegetation

Surface temperature is needed to calculate sensible heat (Jin et al. 2004)

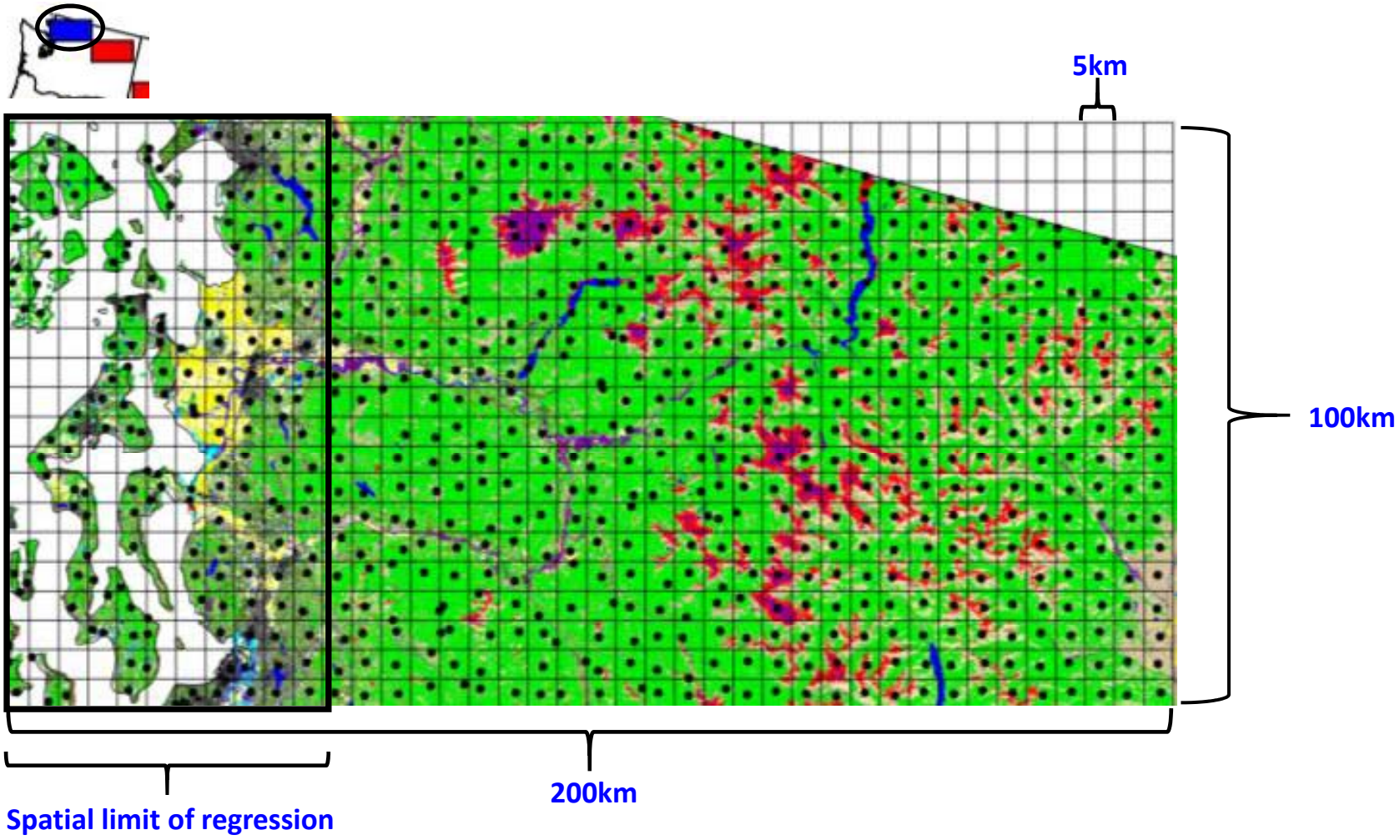


Methods



Methods

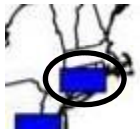
Bivariate regression (forest, scale)

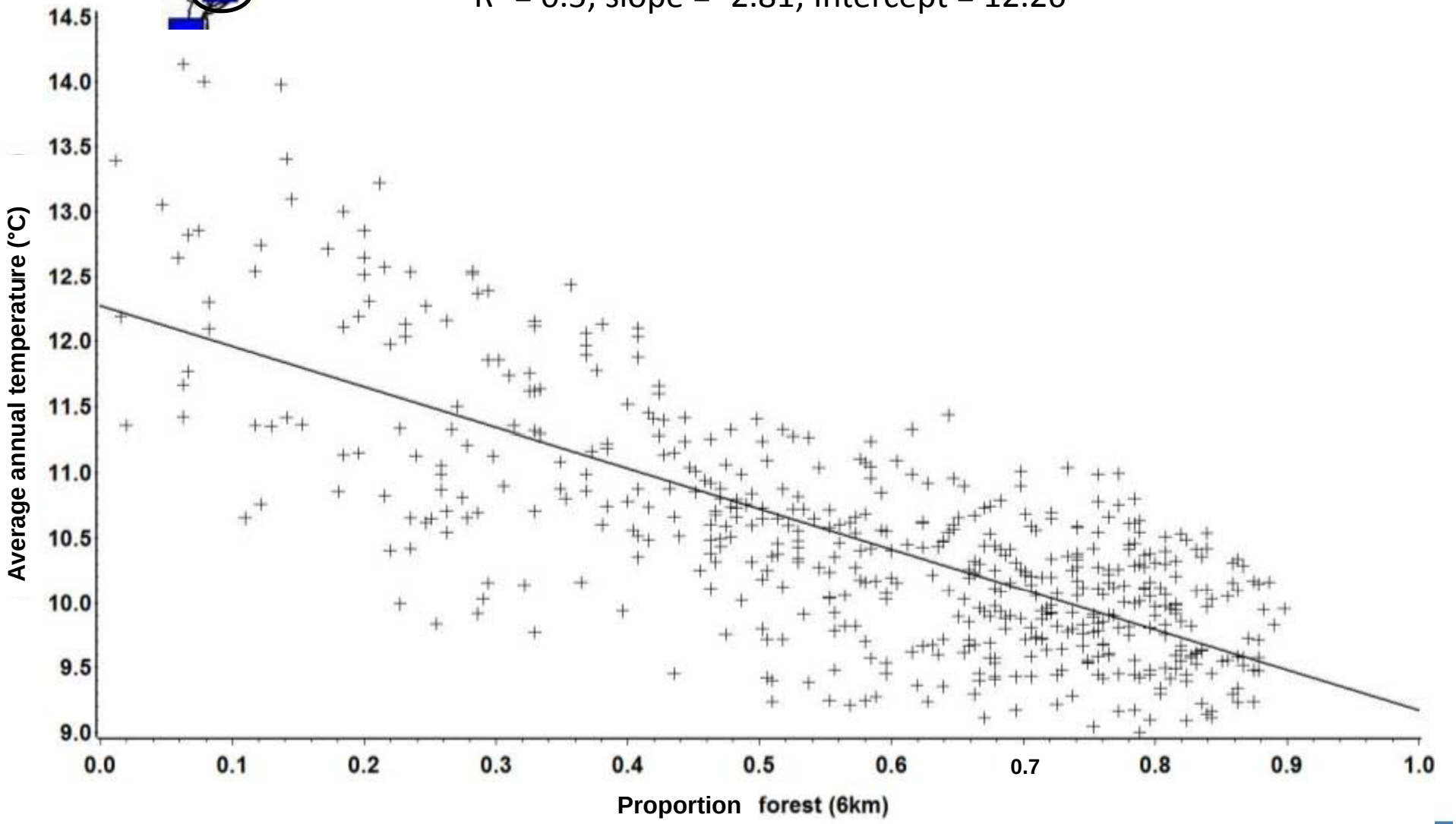


Average annual temperature vs. proportion of forest

Elevation ≤ 100m

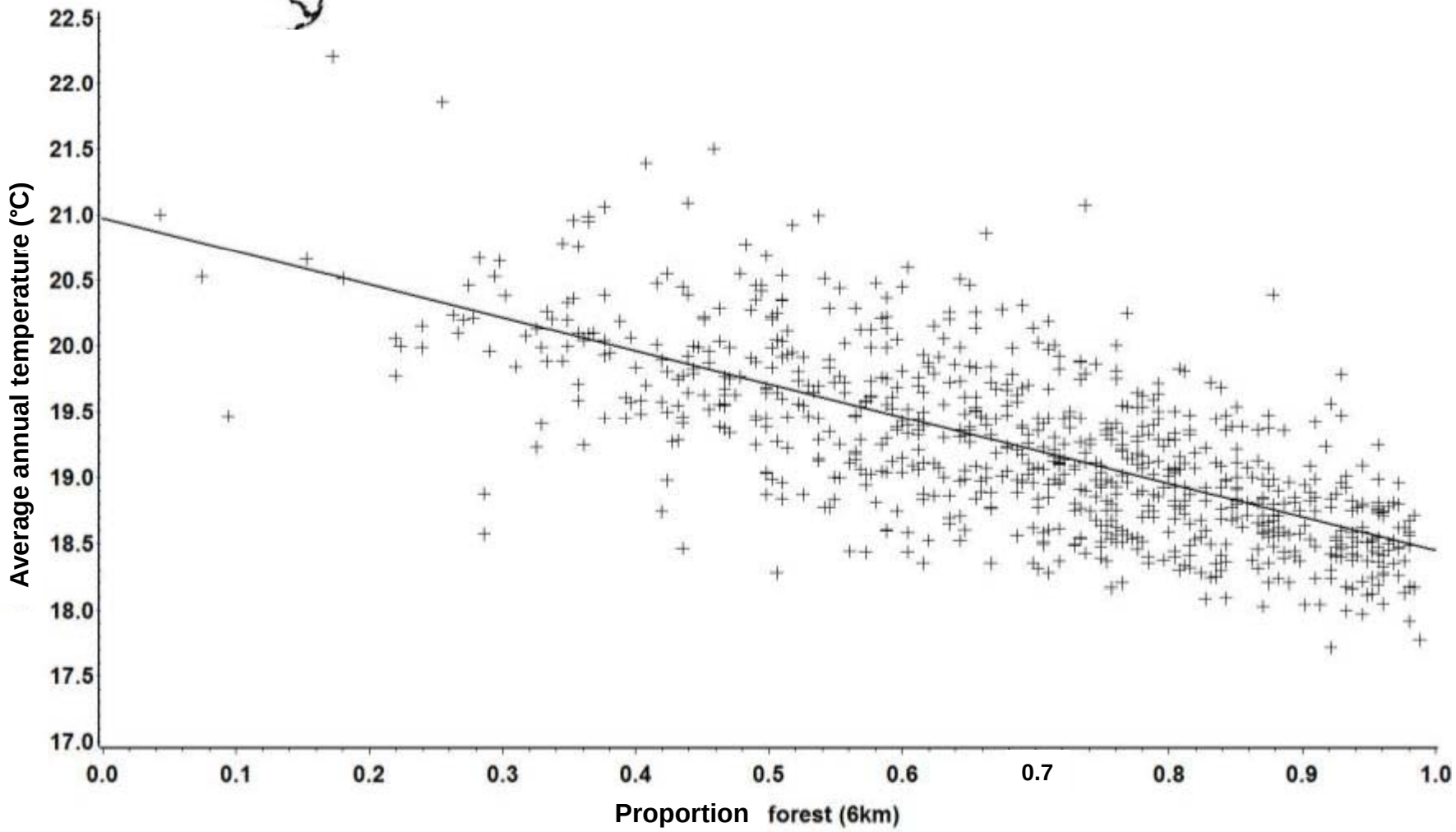
R^2 = 0.5; slope = -2.81; Intercept = 12.26





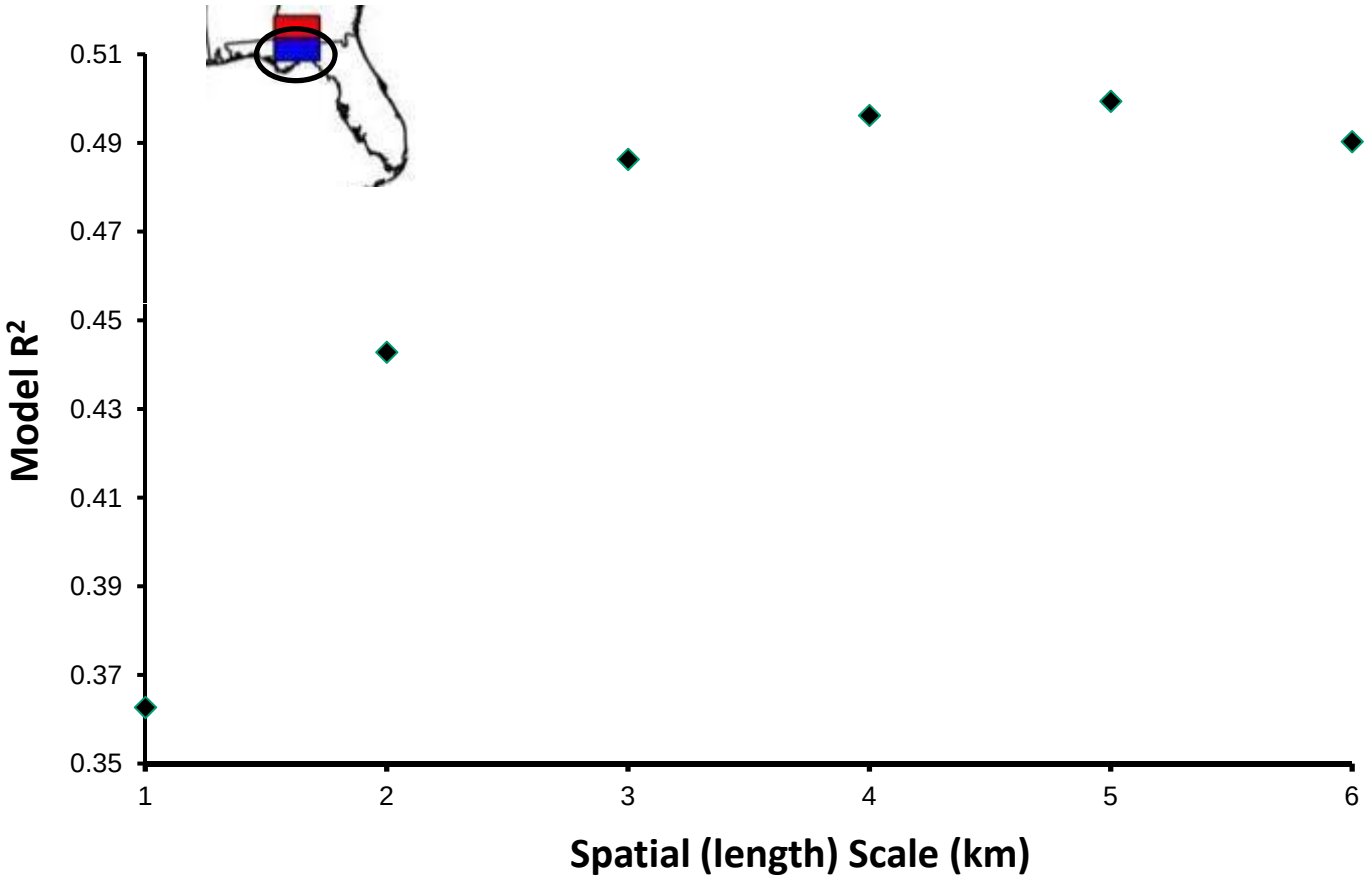
Average annual temperature vs. proportion of forest

R^2 = 0.49; slope = -2.52; Intercept = 20.97

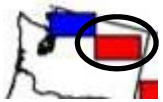


Average annual temperature vs. proportion of forest

Model R^2 vs. spatial scale



Cropland vs. Forest Surface Temperatures



Surface temperature (°C)

45
40
35
30
25
20
15
10
5
0
-10
-5
-15

Day

Night

Forest Crop
Annual

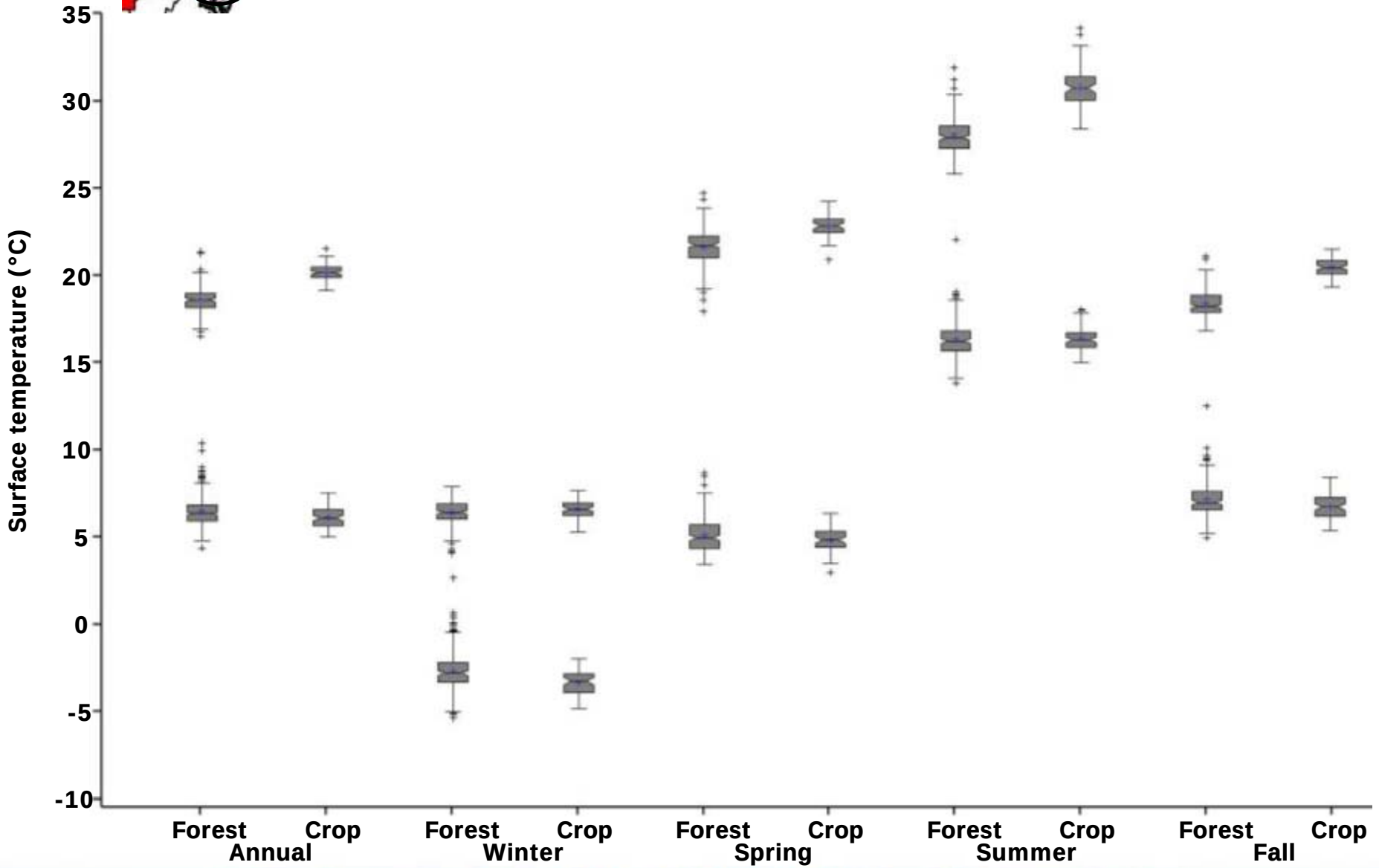
Forest Crop
Winter

Forest Crop
Spring

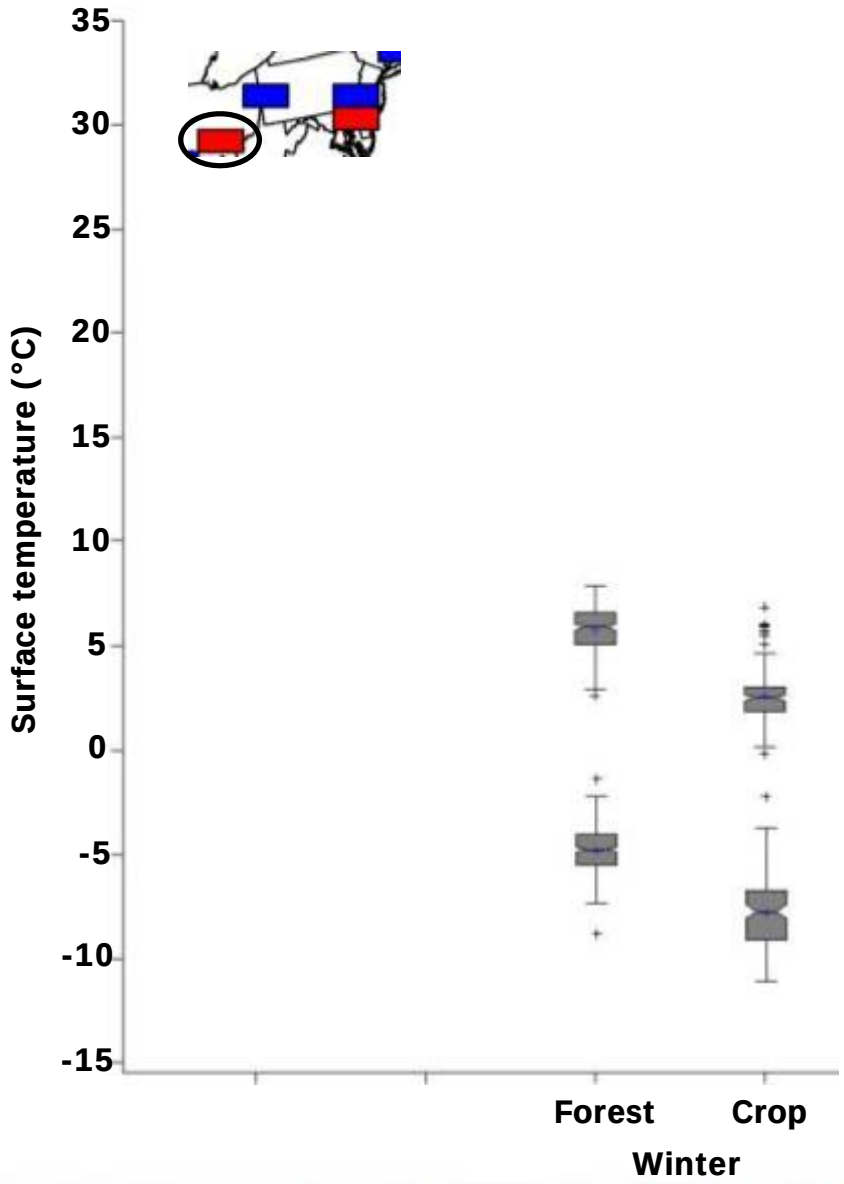
Forest Crop
Summer

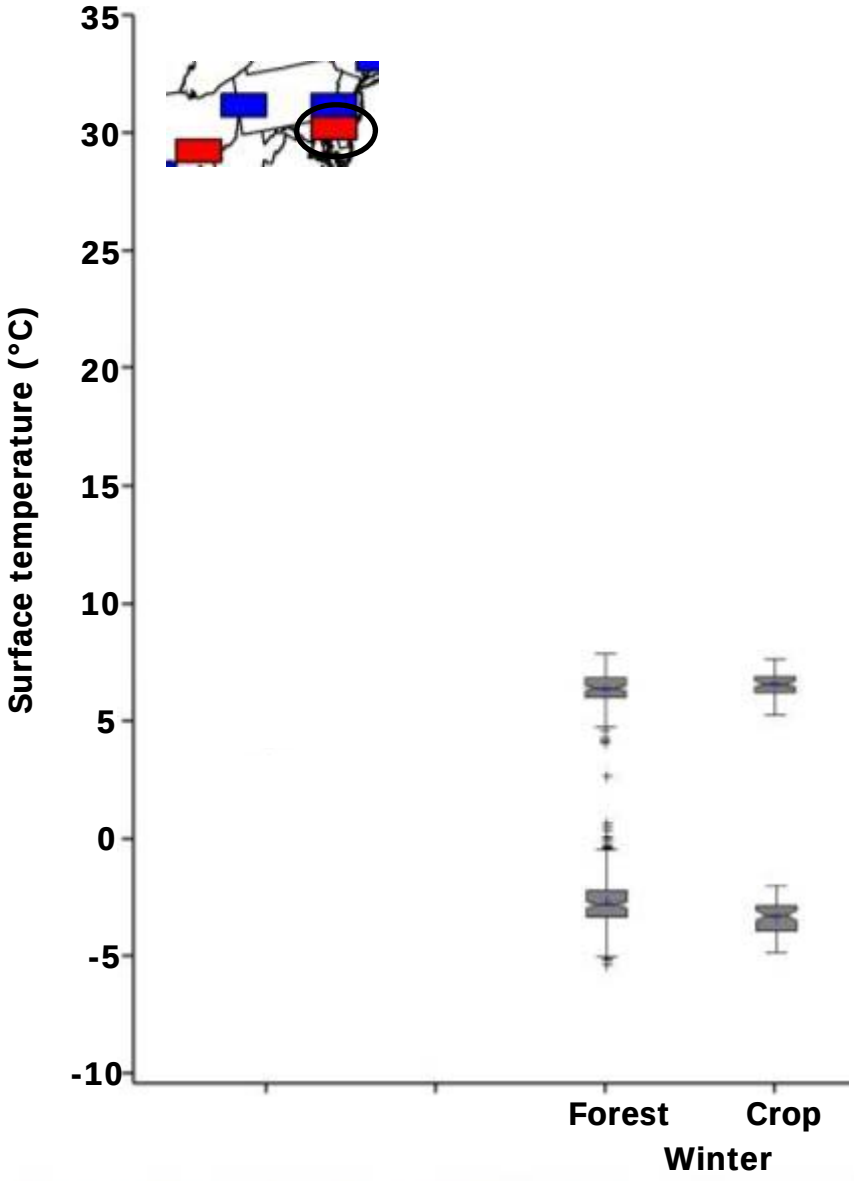
Forest Crop
Fall

Cropland vs. Forest Surface Temperatures

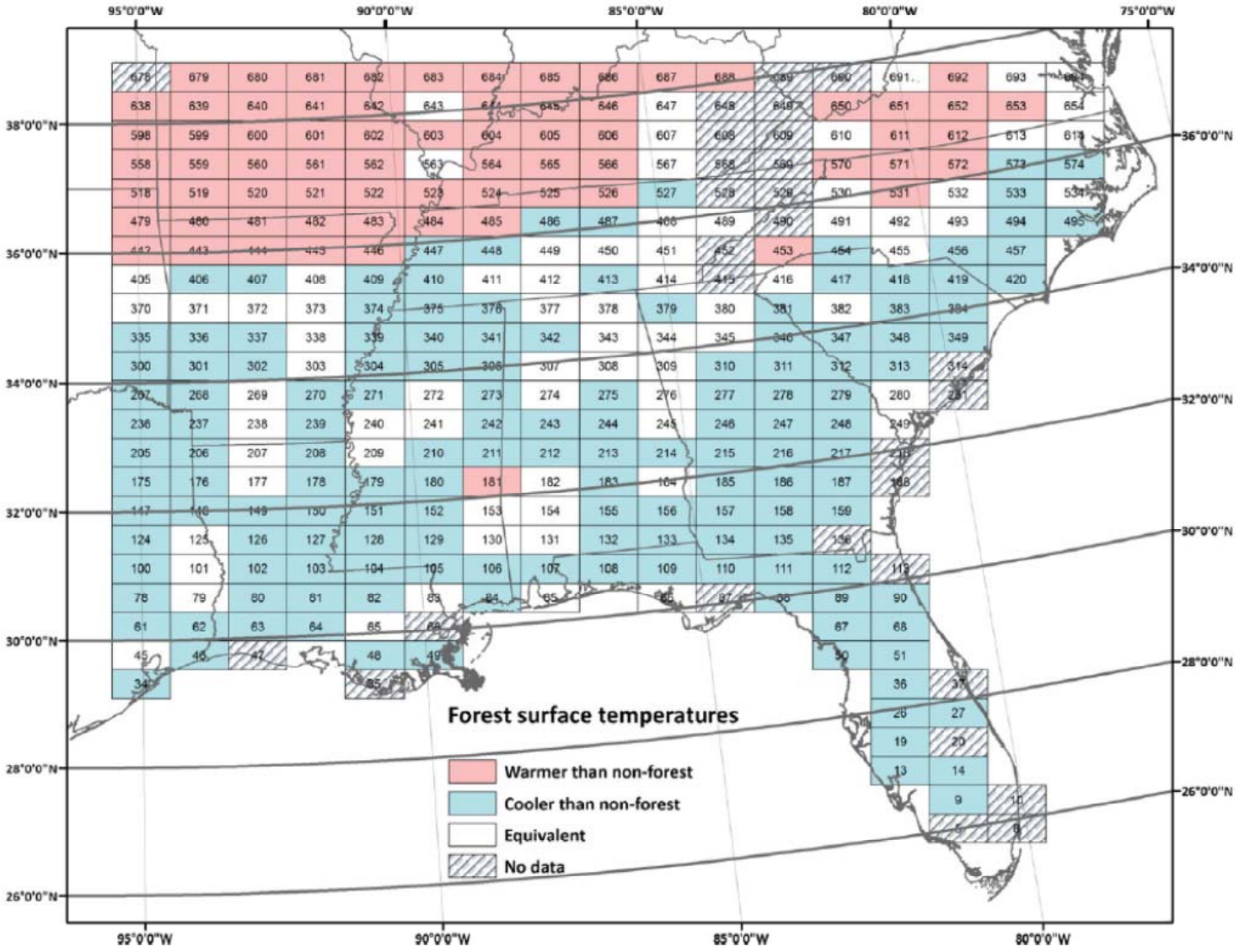


Cropland vs. Forest Surface Temperatures

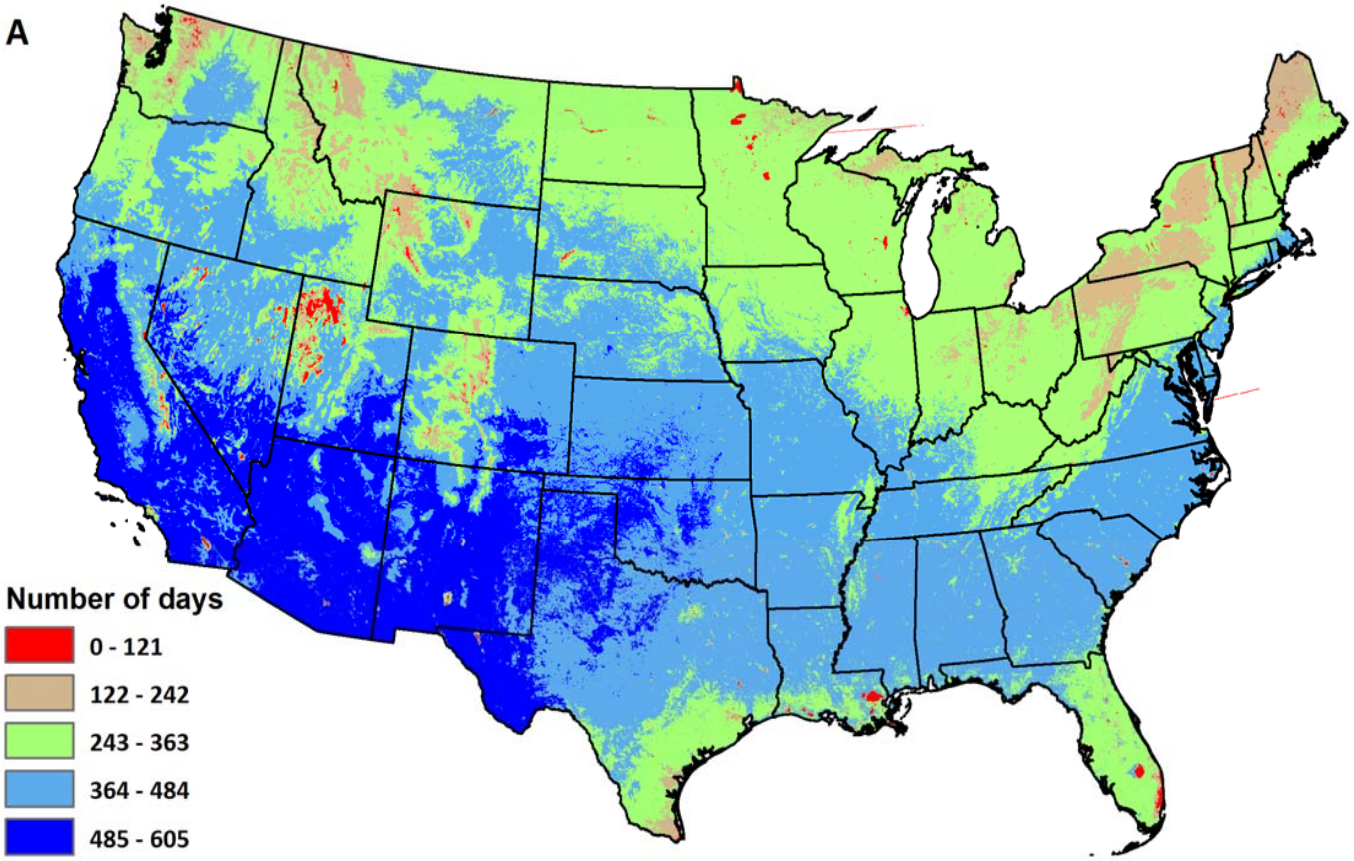




Forest vs. Non-forest Winter Surface Temperatures



NLCD Land Cover – MODIS Albedo Dataset



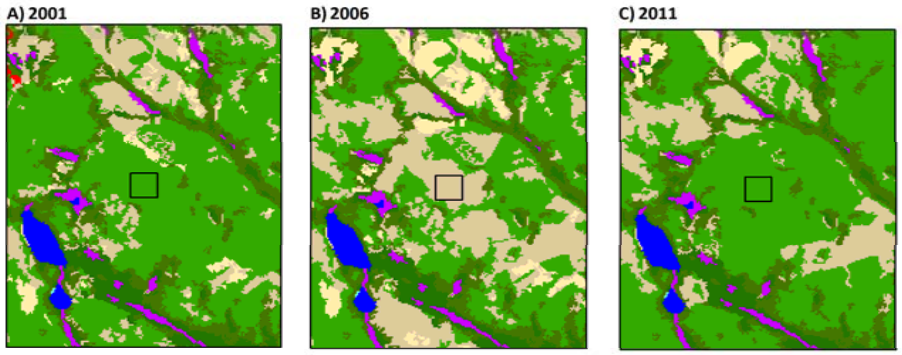
Dataset Characteristics

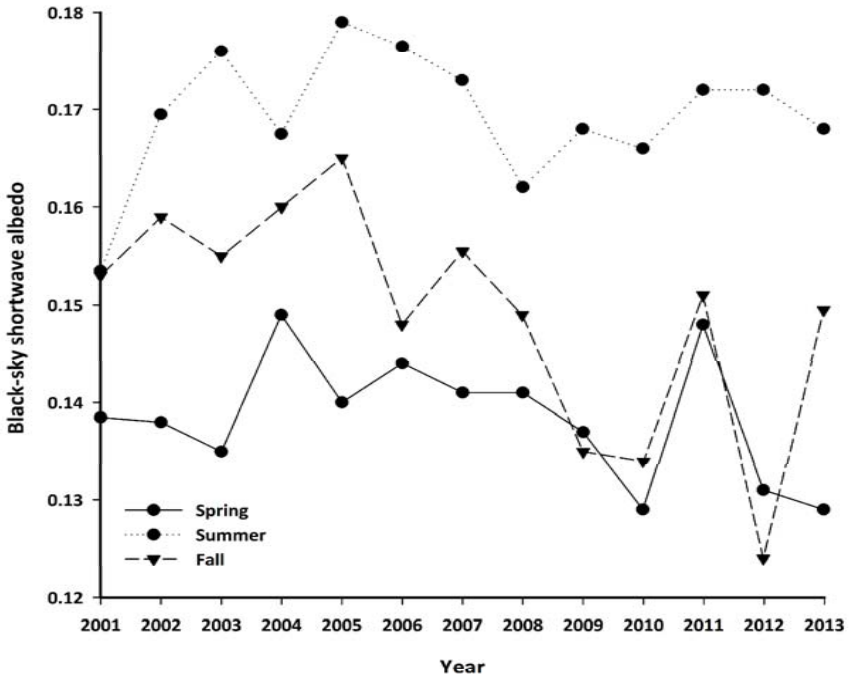
Albedo
- Only high quality albedo obs.
- 14 years; 46 dates/year
- 500 m^2
- Snow-covered & snow-free
- Spatially aligned to NLCD
- Layers of # of obs. / pixel

NLCD
- Homogenous at 500 m^2
- All 3eras (2001, 2006, 2011)
- 14 of 16 NLCD classes

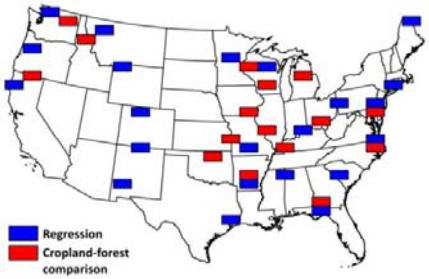
Availability
- www.mrlc.gov (not yet)

NLCD Land Cover – MODIS Albedo Dataset





Summary



1. There were no positive significant relationships between forest proportion and surface temperatures. The slope was either zero or inverse. Forest surface temperatures were cooler annually and in all seasons except winter

2. The significance and strength of the inverse relationship tended to increase with the spatial scale over which forest proportion was measured.

3. Croplands surface temperatures tended to be warmer than forest surface temperature. Forest daytime surface temperature were much cooler than croplands and cropland surface temperatures were only slightly warmer during nighttime.

4. Forests surface temperatures tended to be cooler in all seasons, including winter south of 36°N.

Questions?

Wickham J, Barnes CA, Wade TG. in review. Combining NLCD and MODIS to create a land cover-albedo dataset for the continental United States. Remote Sensing of Environment.

Wickham J, Wade TG, Riitters KH. 2014. An isoline separating relatively warm from relatively cool forest surface temperatures for the southeastern United States. Global and Planetary Change 120:46-53.

Wickham J, Wade TG, Riitters KH. 2013. Empirical analysis of the influence of forest extent on annual and seasonal surface temperatures for the continental United States. Global Ecology and Biogeography 22:620-629.

Wickham J, Wade TG, Riitters KH. 2012. Comparison of cropland and forest surface temperatures across the conterminous United States. Agricultural and Forest Meteorology 166-167:137-143.