

# **A Continental United States High Resolution NLCD Land Cover – MODIS Albedo Database to Examine Albedo and Land Cover Change Relationships**

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**Extra-tropical forests are warm relative to surrounding fields**

**Extra-tropical deforestation produces a cooling effect**

**Boreal deforestation greater cooling; temperate deforestation less cooling**



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## 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.
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- 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<sup>2</sup> 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.

- UNFCCC, 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.



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## Why might extra-tropical forests warm?

Forests are darker (lower albedo) than surrounding herbaceous vegetation

Albedo difference is accentuated in presence of snow

The cooling effect of transpiration is only seasonally active

Crops have lower stomatal resistance than forests (Bonan 1997)

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

The effect of albedo on radiative forcing extends beyond the boundary layer; leads to tropospheric cooling (Davin and de Noblet-Ducoudré 2010).



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## Albedo

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

Summer albedos

| PFT   | Model 1 |      | Model 1 | Model 1 | Model 1 | Model 1 |
|-------|---------|------|---------|---------|---------|---------|
| BDT   | 0.15    | 0.15 | 0.19    | 0.13    | 0.18    | 0.13    |
| NDT   | 0.13    |      |         | 0.14    | 0.13    | 0.13    |
| BET   |         | 0.11 | 0.11    | 0.13    | 0.12    | 0.12    |
| NET   | 0.10    | 0.15 | 0.13    | 0.11    | 0.14    | 0.14    |
| Grass | 0.18    | 0.20 | 0.19    | 0.20    | 0.20    | 0.20*   |
| Crop  | 0.19    |      | 0.20    | 0.16    | 0.20    | 0.25*   |

Adapted from Hollinger et al. (2010). BDT=broadleaf deciduous tree; NDT=needle-leaf deciduous tree; BET=broadleaf evergreen tree; NET=needle-leaf evergreen tree; \*=max of reported range.

A “variance” of  $\pm 0.02$  in albedo produces significant changes in regional climate simulations (He et al. 2012).



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## NLCD Land Cover – MODIS Albedo Dataset

### Dataset Characteristics

#### Albedo

- ❖ 14 years (2000-2013); 46 dates/year ; year 2000 is without January through mid-February
  - maximum of 638 observations/pixel (if no missing values)
- ❖ Only high quality albedo observations included
- ❖ Spatial resolution<sup>1</sup> = 480 m<sup>2</sup>
- ❖ Includes snow-covered & snow-free observations
- ❖ Spatially aligned to NLCD (NLCD albers equal-area projection)
- ❖ Layers of number of observations / pixel for each of 46 dates (total, snow-cover, study period)

#### NLCD

- ❖ Homogenous at 480m<sup>2</sup>
- ❖ All 3eras (2001, 2006, 2011)
- ❖ Elevation, slope, and aspect
- ❖ 14 of 16 NLCD classes (480m<sup>2</sup>); collapsed 4 urban categories into 2

#### Availability

- [www.mrlc.gov](http://www.mrlc.gov) (not yet)

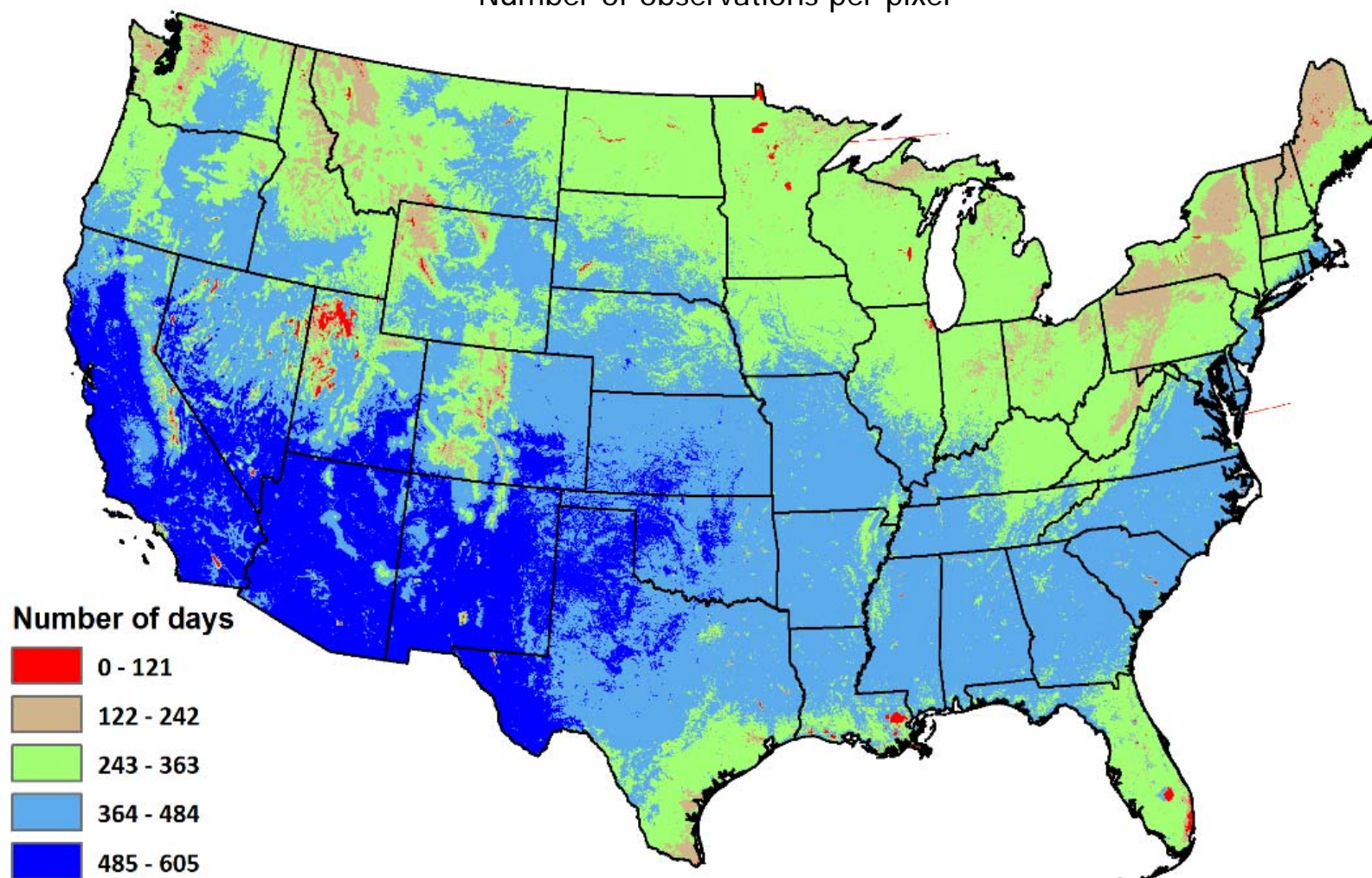
<sup>1</sup> Nominal MODIS spatial resolution do not equal actual spatial resolutions





## NLCD Land Cover – MODIS Albedo Dataset

Number of observations per pixel



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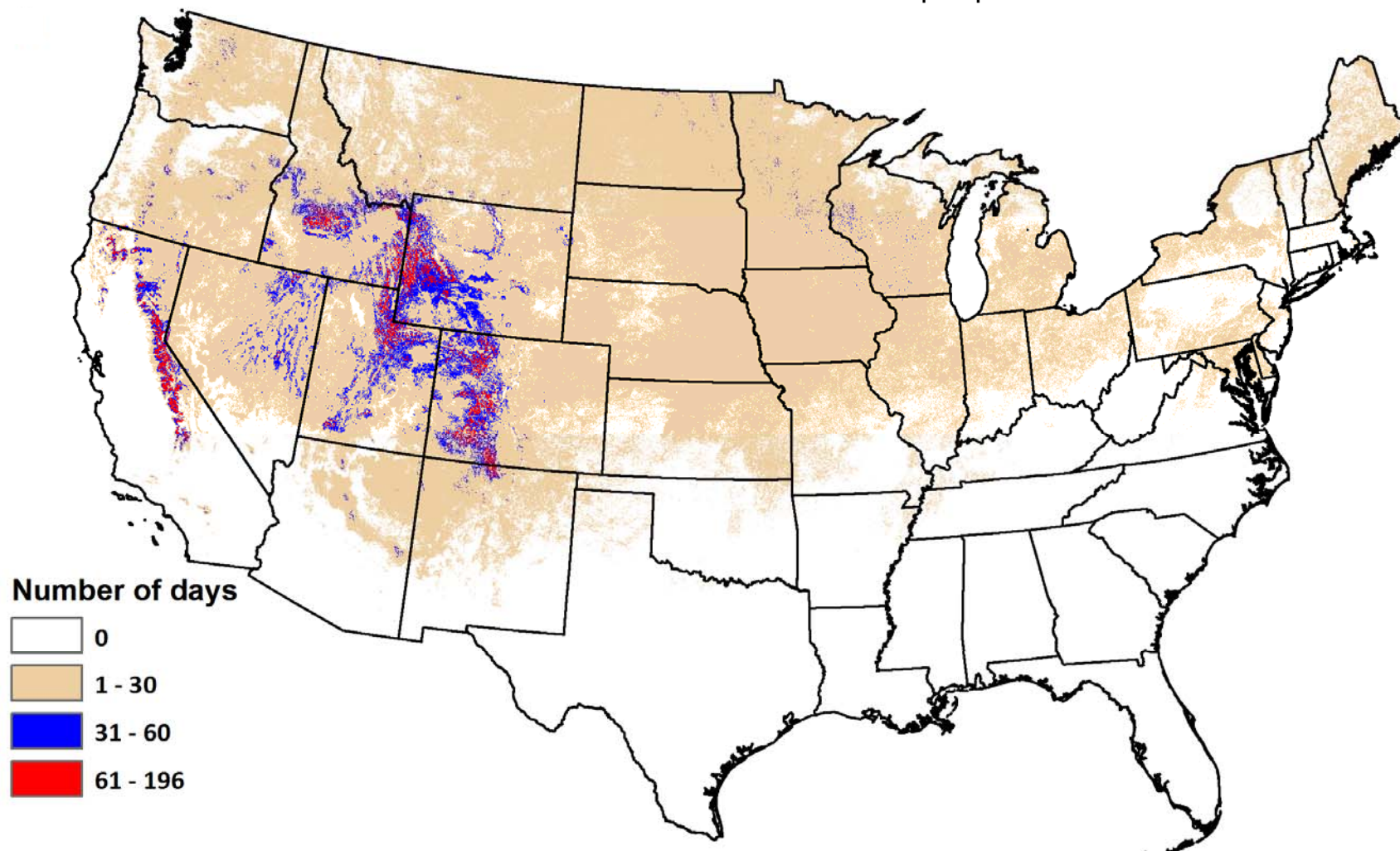
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## NLCD Land Cover – MODIS Albedo Dataset

Number of snow-covered observations per pixel



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## NLCD Land Cover – MODIS Albedo Dataset

### Analysis

#### Albedo

- ❖ Components of variance for static NLCD classes
- ❖ Effect of land-cover change on albedo



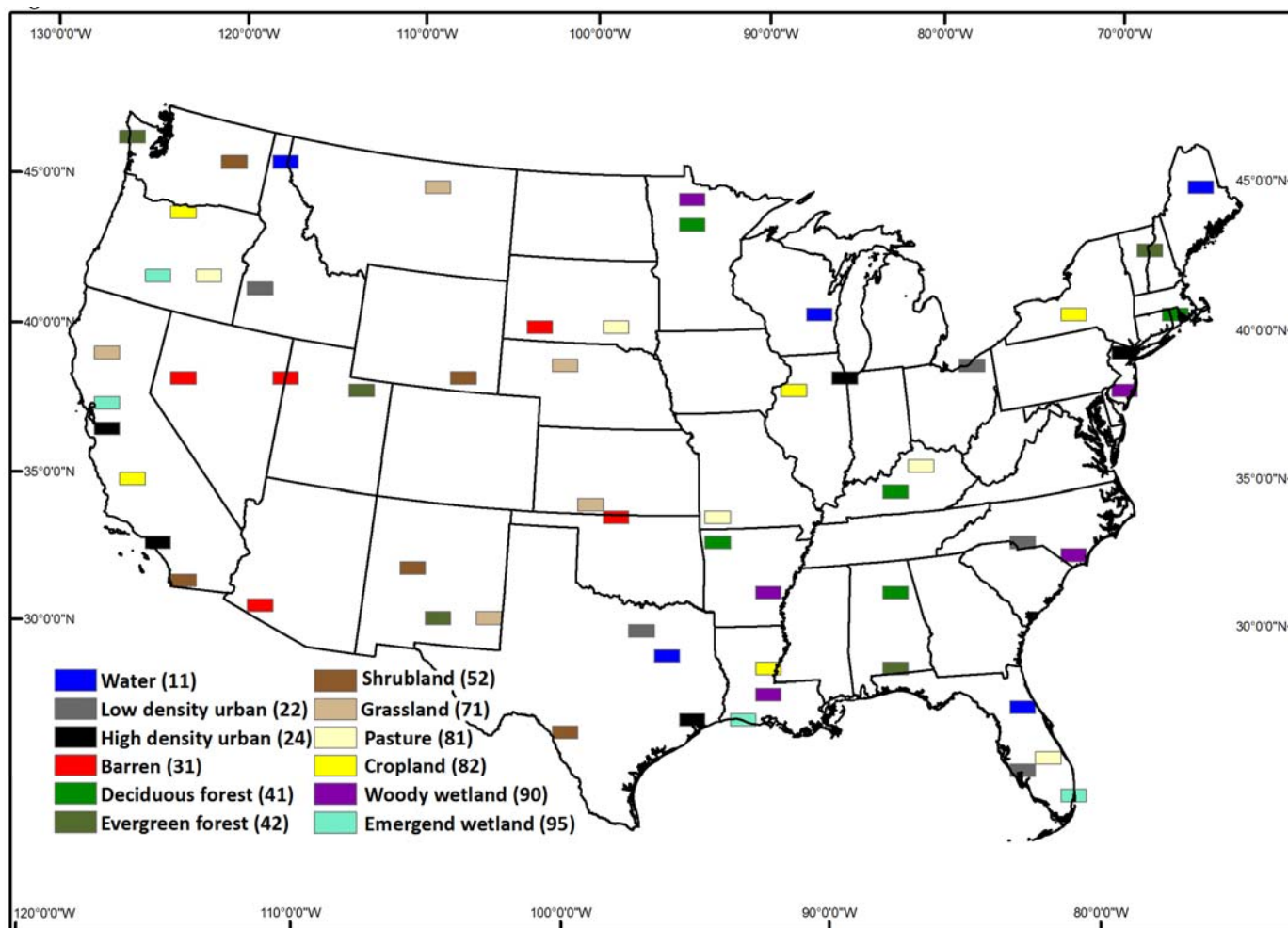
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## NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance



Variance components

1. Year
2. Tile (geography)
3. Year\*tile
4. Pixel (within tile)
5. Year\*pixel(within tile)
6. Day of year (season)

Selection

1. 5 tiles / NLCD class
2. 50 pixels / tile



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## NLCD Land Cover – MODIS Albedo Dataset

### Albedo components of variance

| Source                         | DF   | Type III SS | Mean Square | F value | Pr > F |
|--------------------------------|------|-------------|-------------|---------|--------|
| <b><i>Evergreen Forest</i></b> |      |             |             |         |        |
| Tile                           | 4    | 0.491       | 2.3728      | 153.37  | 0.0001 |
| Year                           | 12   | 0.057       | 0.0048      | 28.81   | 0.0001 |
| Tile*year                      | 48   | 0.279       | 0.0058      | 33.02   | 0.0001 |
| Pixel(tile)                    | 245  | 4.414       | 0.0180      | 101.42  | 0.0001 |
| Pixel*tile(year)               | 2940 | 0.536       | 0.0002      | 1.89    | 0.0001 |
| DOY                            | 45   | 0.496       | 0.0555      | 574.90  | 0.0001 |
| <b><i>Deciduous Forest</i></b> |      |             |             |         |        |
| Tile                           | 4    | 1.332       | 0.3330      | 24.54   | 0.0001 |
| Year                           | 12   | 0.227       | 0.0189      | 137.78  | 0.0001 |
| Tile*year                      | 48   | 0.249       | 0.0052      | 37.43   | 0.0001 |
| Pixel(tile)                    | 245  | 3.449       | 0.0139      | 103.26  | 0.0001 |
| Pixel*tile(year)               | 2940 | 0.410       | 0.0001      | 1.45    | 0.0001 |
| DOY                            | 45   | 23.083      | 0.5130      | 5328.78 | 0.0001 |

Examined for all 14 NLCD classes with static labels across the three NLCD eras (2001, 2006, 2011) using 250 pixels/NLCD class.

All factors were significant; pixel-to-pixel variability [pixel(tile)] was often the third most significant factor following the expected dominant factors of season (DOY) and geography (tile).



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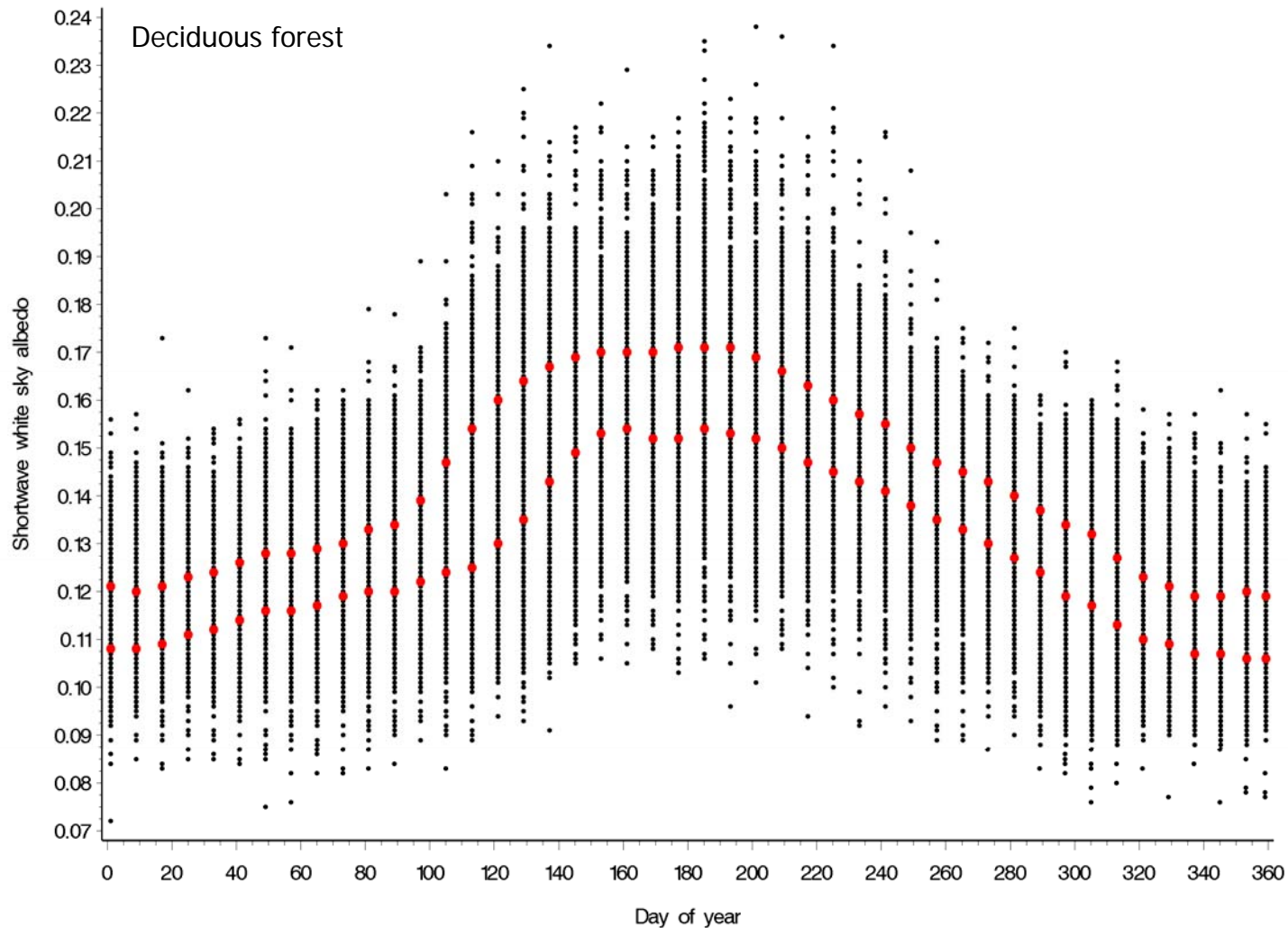
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## NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance



● = inter-quartile range

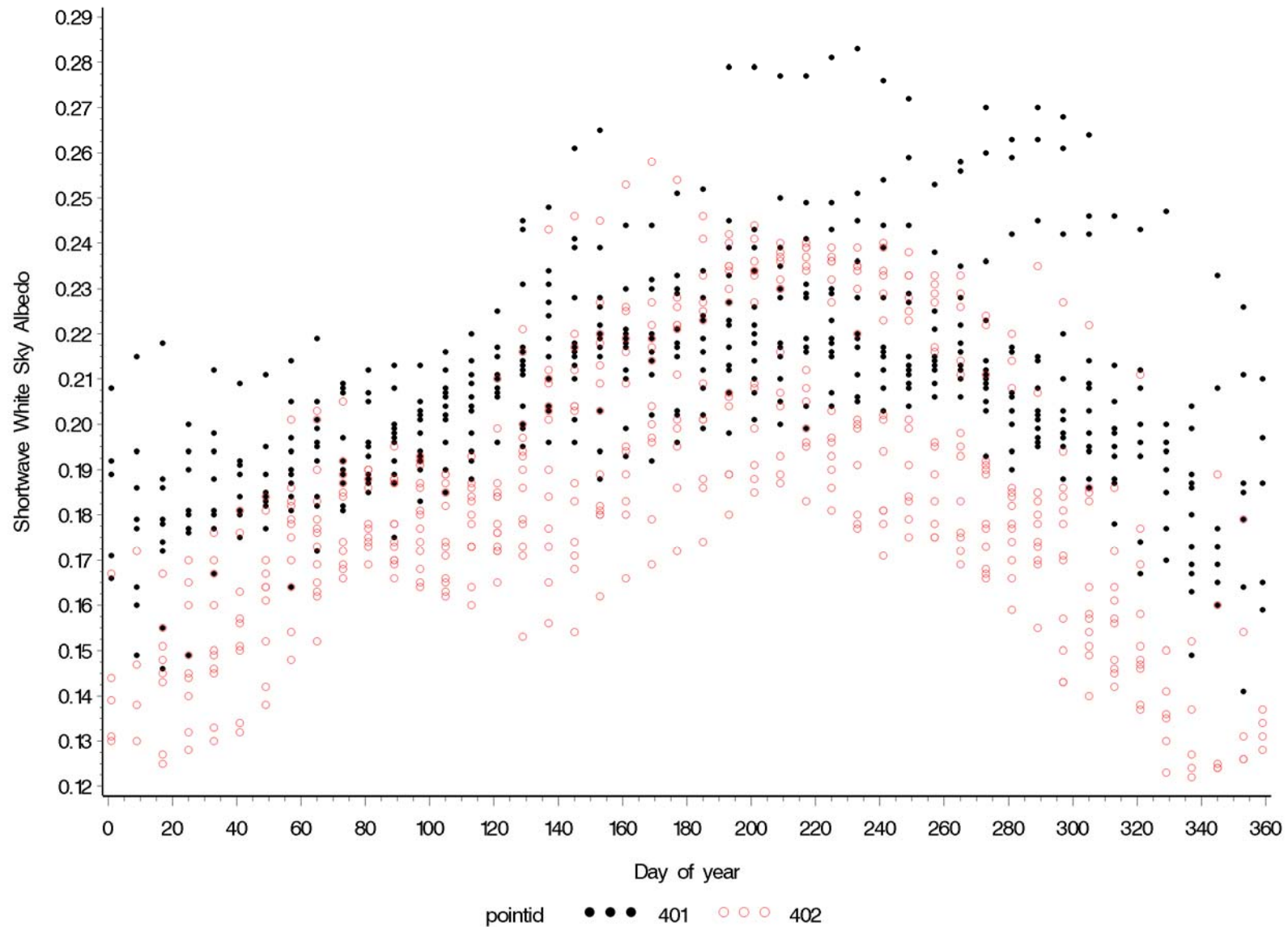


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Figure 5



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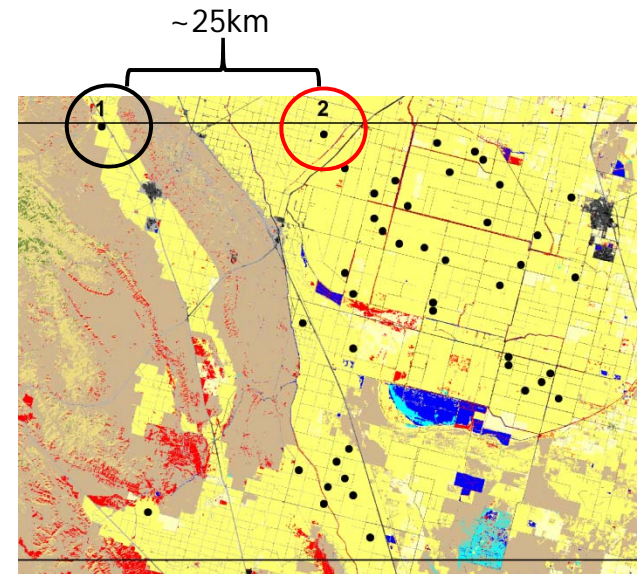
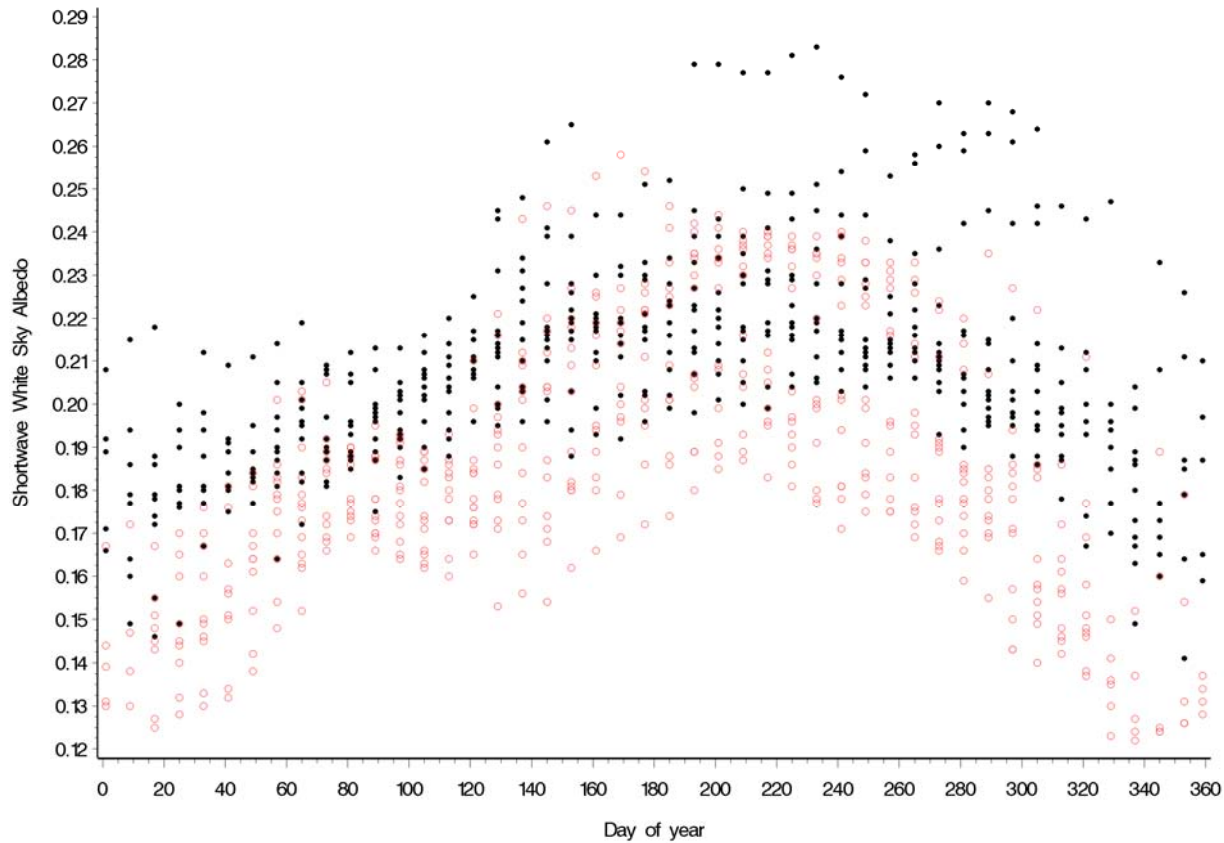




## NLCD Land Cover – MODIS Albedo Dataset

Albedo components of variance

13-year albedo profiles for two cropland pixels ~25km apart



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## NLCD Land Cover – MODIS Albedo Dataset

Effect of land-cover change on albedo

Time series regression of albedo using land-cover change pixels

| Change  | # models | # sig. models | # non-sig. models | Min Change | Max Change |
|---------|----------|---------------|-------------------|------------|------------|
| 41 > 71 | 15       | 9             | 6                 | 0.002      | 0.015      |
| 42 > 71 | 13       | 10            | 3                 | 0.001      | 0.030      |
| 41 > 52 | 4        | 0             | 4                 | 0.001      | 0.010      |
| 42 > 52 | 20       | 15            | 5                 | 0.002      | 0.039      |
| 42 > 82 | 8        | 8             | 0                 | 0.014      | 0.064      |

Notes: 41 > 71 = deciduous forest to grassland; 42 > 71 = evergreen forest to grassland; 41 > 52 = deciduous forest to shrubland; 42 > 52 = evergreen forest to shrubland; 42 > 82 = evergreen forest to cropland.

Min & max change = minimum and maximum differences in mean albedo across all models per change class after separating into before and after change groups.



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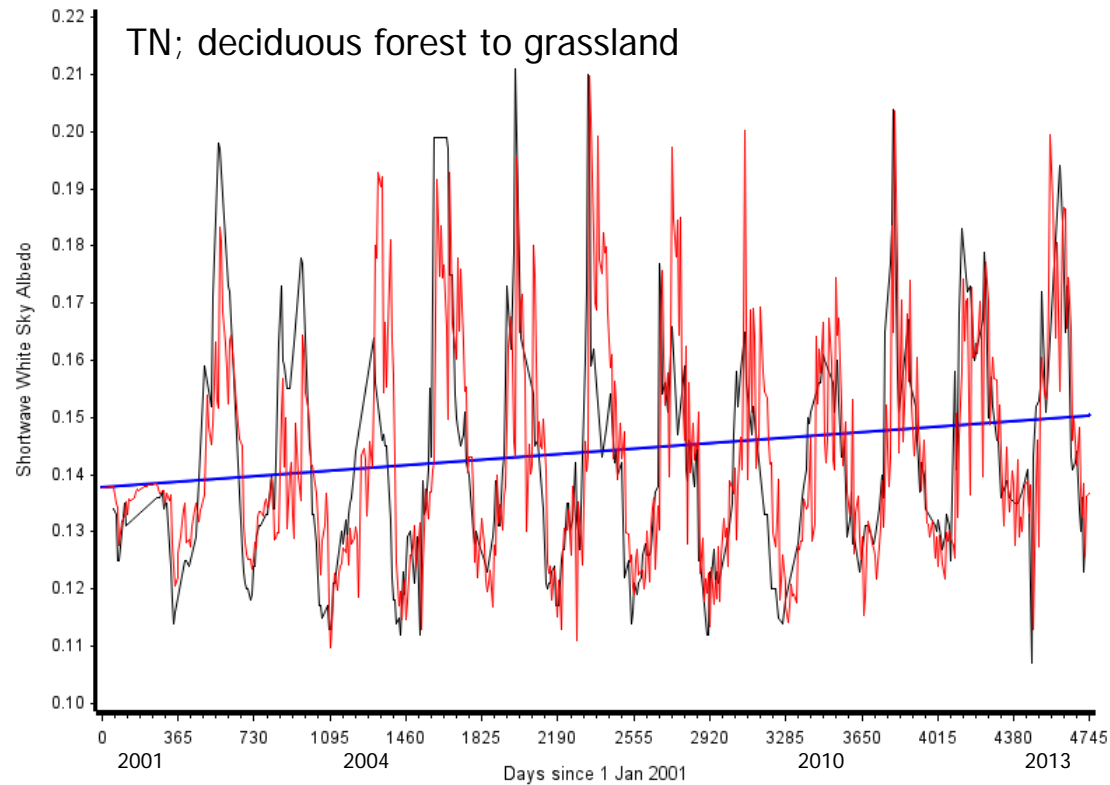
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## NLCD Land Cover – MODIS Albedo Dataset

Effect of land-cover change on albedo

Time series regression of albedo using land-cover change pixels



$$\text{Albedo} = 0.1378 + 0.0000026718(\text{date})$$

$\text{Pr} > |t| < 0.0001$  (intercept);  $= 0.2626$  (slope)



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## NLCD Land Cover – MODIS Albedo Dataset

### Summary

1. Compiled high resolution, long-term (14 years) land cover – albedo using NLCD and MODIS.
2. There are several components to variance in albedo; non-stationarity in features within a land cover class was consistently a significant factor in albedo variability in addition to the expected factors of season and geography; topographic factors were never significant.
3. Land-cover change (so far) does not always result in distinct changes in albedo, and before and after (land-cover change) mean albedos tend to smaller than those reported in the literature.



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## NLCD Land Cover – MODIS Albedo Dataset

### Questions

Wickham J, Barnes CA, Wade TG. in press. 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 wintertime 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.



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