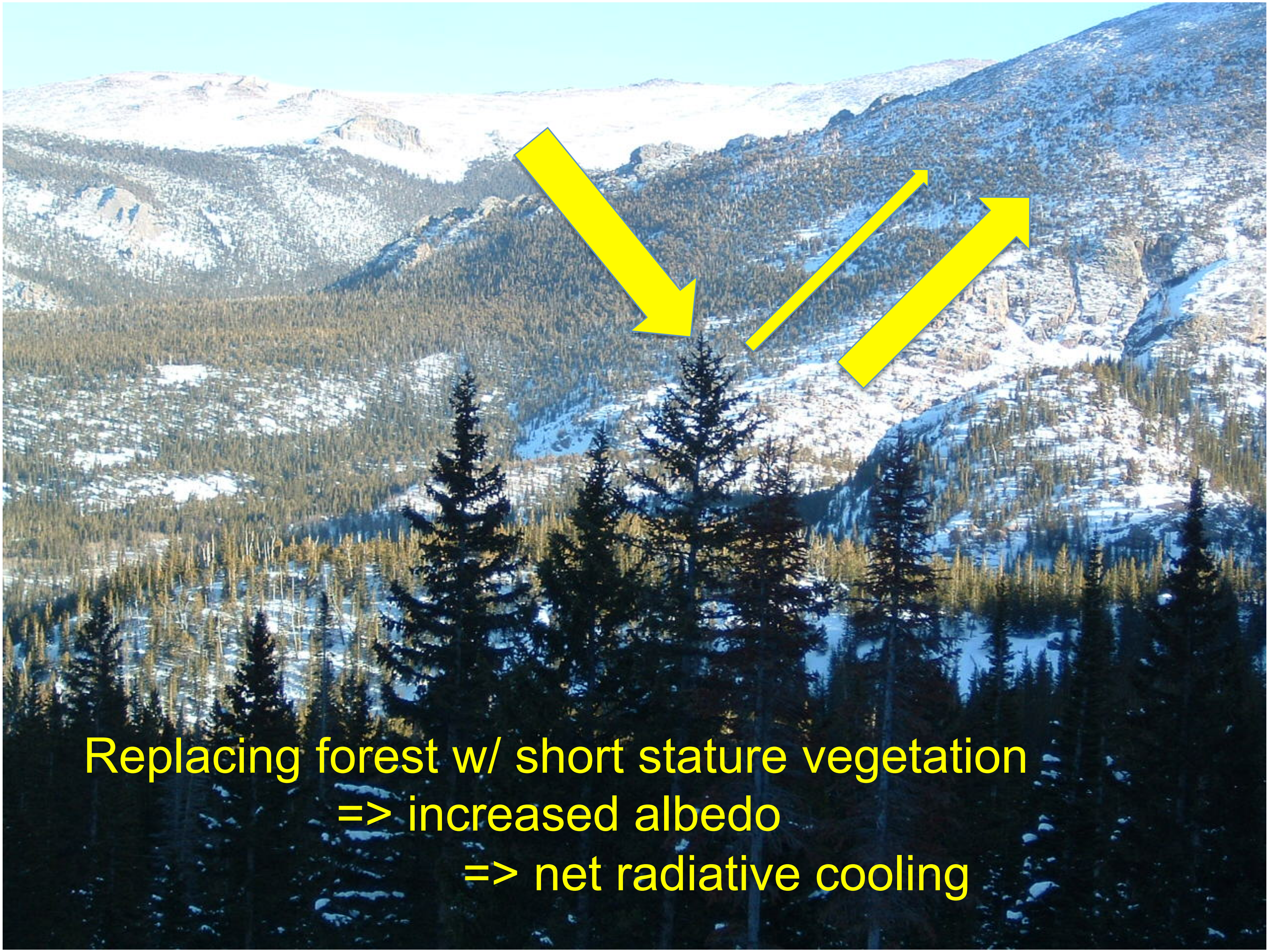
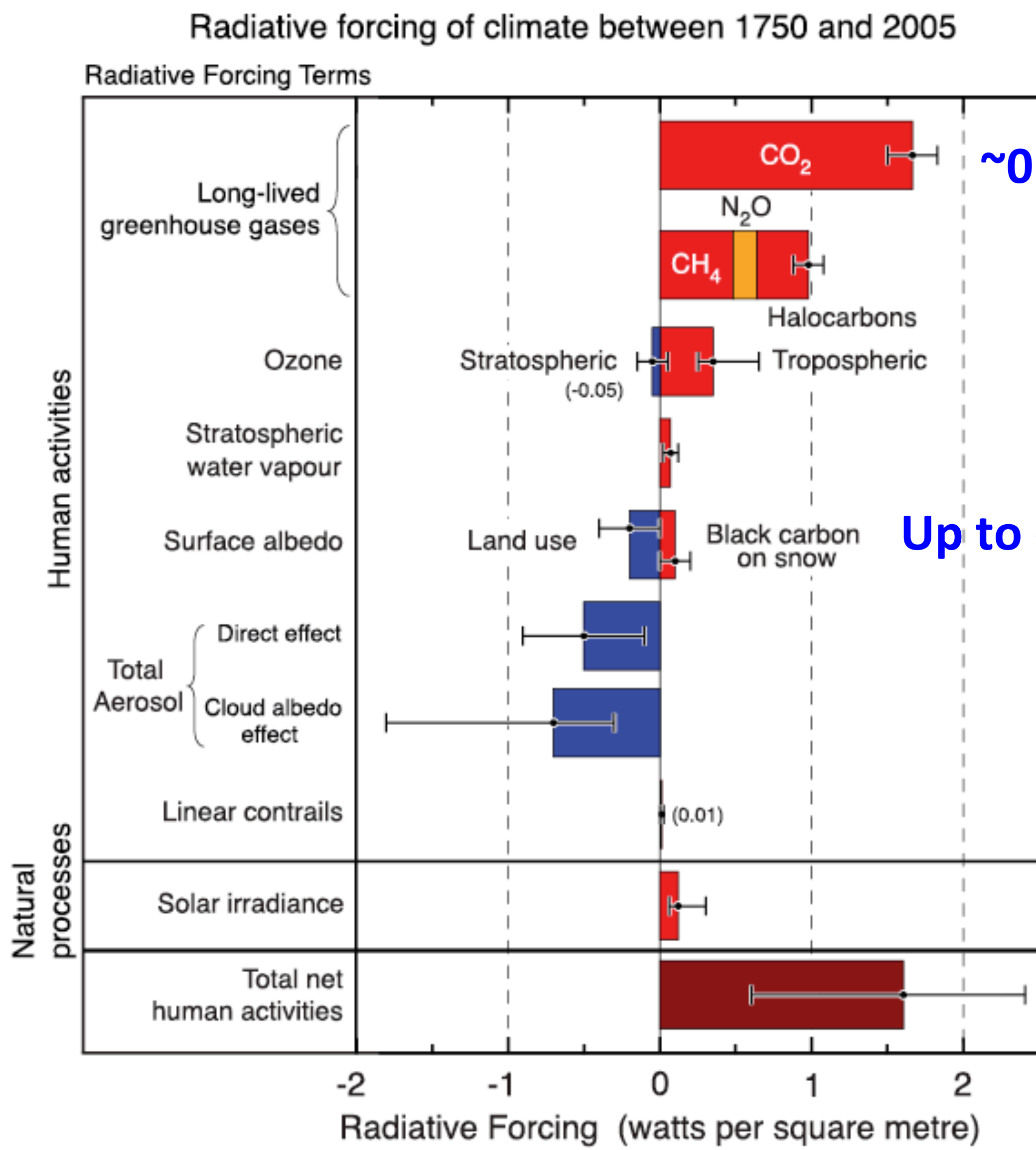
Albedo Trends Related to Land Cover Change and Disturbance: A Multisensor Approach

Jeff Masek, Yanmin Shuai (NASA GSFC)
Feng Gao (USDA ARS)
Chris Williams, Bardan Ghimire (Clark University)
Crystal Schaaf, Zhosen Wang (U. Mass, Boston)
Tao He (U. Maryland)

April 15, 2013


Replacing forest w/ short stature vegetation
=> increased albedo
=> net radiative cooling

Global RF from Land Use Change (IPCC AR4)



~0.6 W/m^2 land use

Up to -0.5 W/m^2 land use

… but could be zero!

From IPCC AR4, Ch. 2

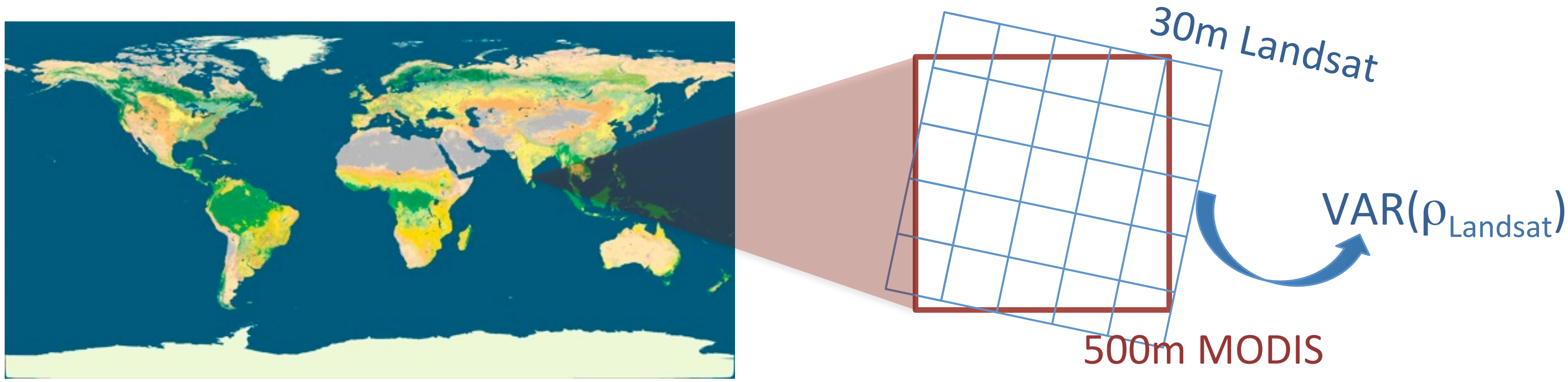
Improved Albedo via Multi-Sensor Fusion

Objective: improved estimates of albedo impacts of land use change and forest disturbance by fusing information from Landsat (spatial resolution) and MODIS (angular information)

- **Global Scale**: Improved Albedo vs. Land Cover LUT
  - *"pure", geographically specific land cover samples*
  - *recalculation of global land use RF since 1500*

- **Landscape Scale:** How do disturbance & LC change affect regional albedo?
  - *30m albedo by combining Landsat reflectance and MODIS BRDF*
  - *application to long-term Landsat LC change maps*

Improved Albedo-Land Cover LUT *(Gao)*



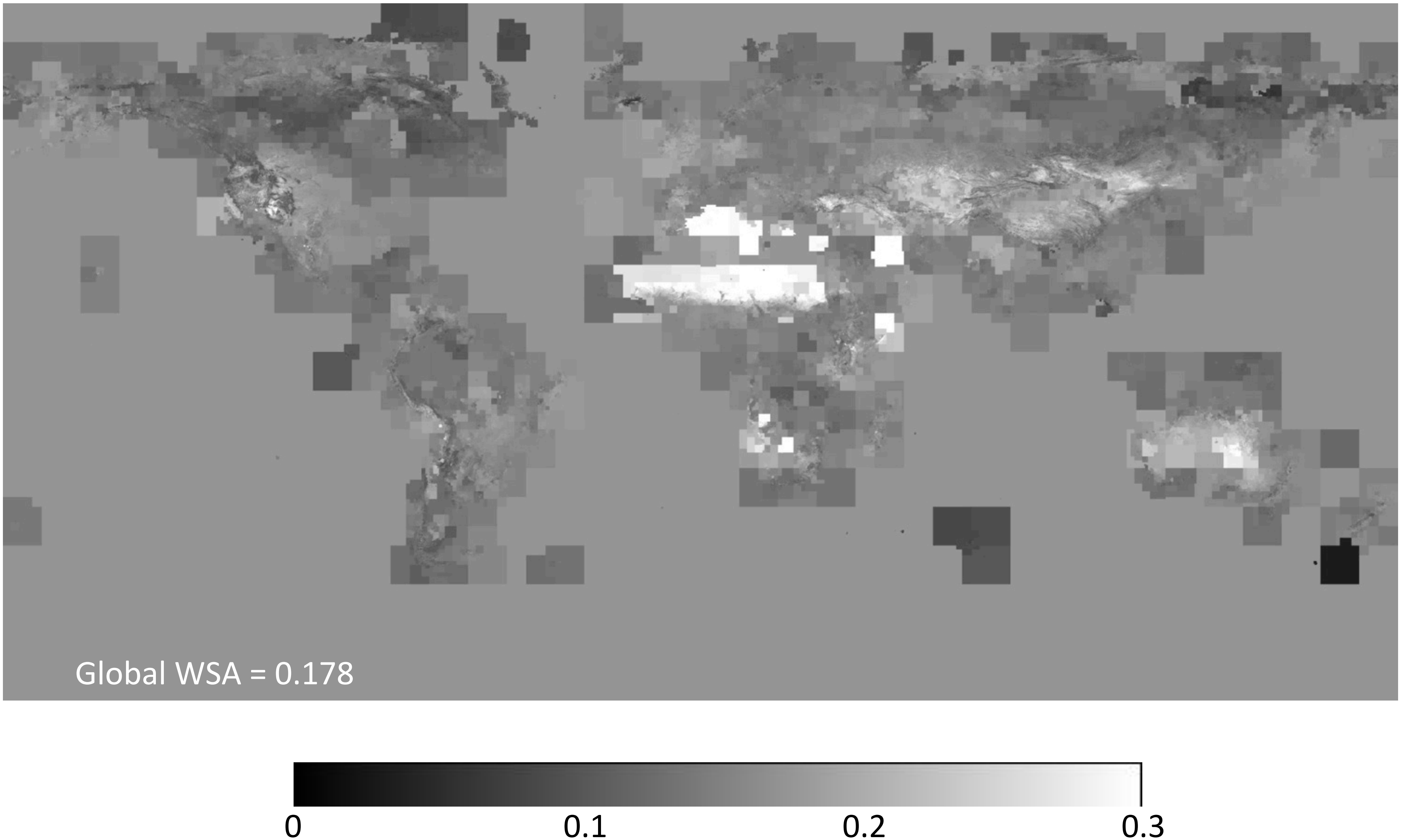
Retrieve "pure" examples of MODIS albedo (MCD43A) for IGBP types (MCD12) by looking for 500m cells with low VAR($\rho_{Landsat}$)

Hierarchical approach: Inherit nearest example to provide example of every IGBP type at every location of globe

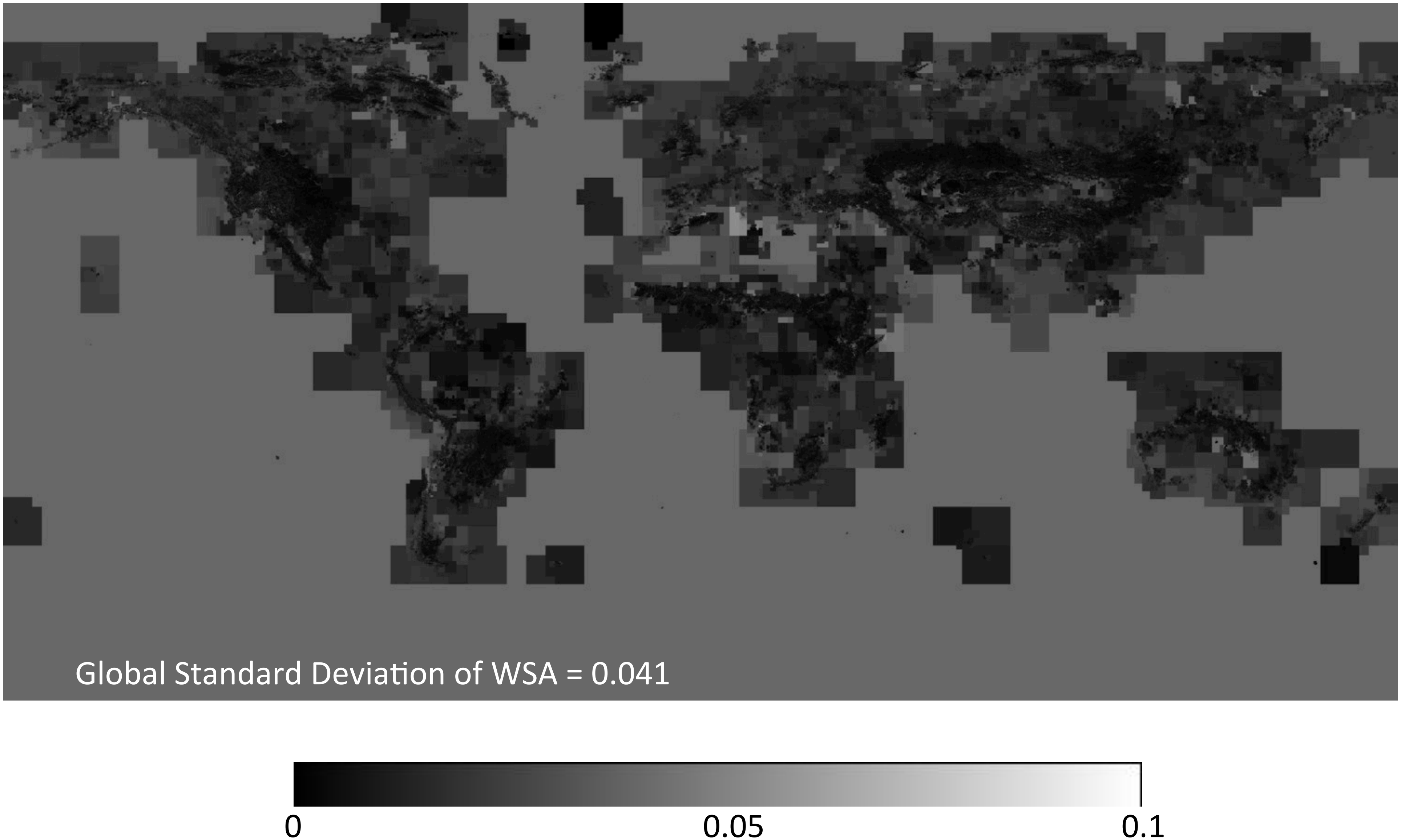
Separate albedo LUT for:

- albedo type {wsa, bsa} & spectral band {vis, nir, sw}
- climatologic date {1-46 8-day periods}
- snow covered & snow-free

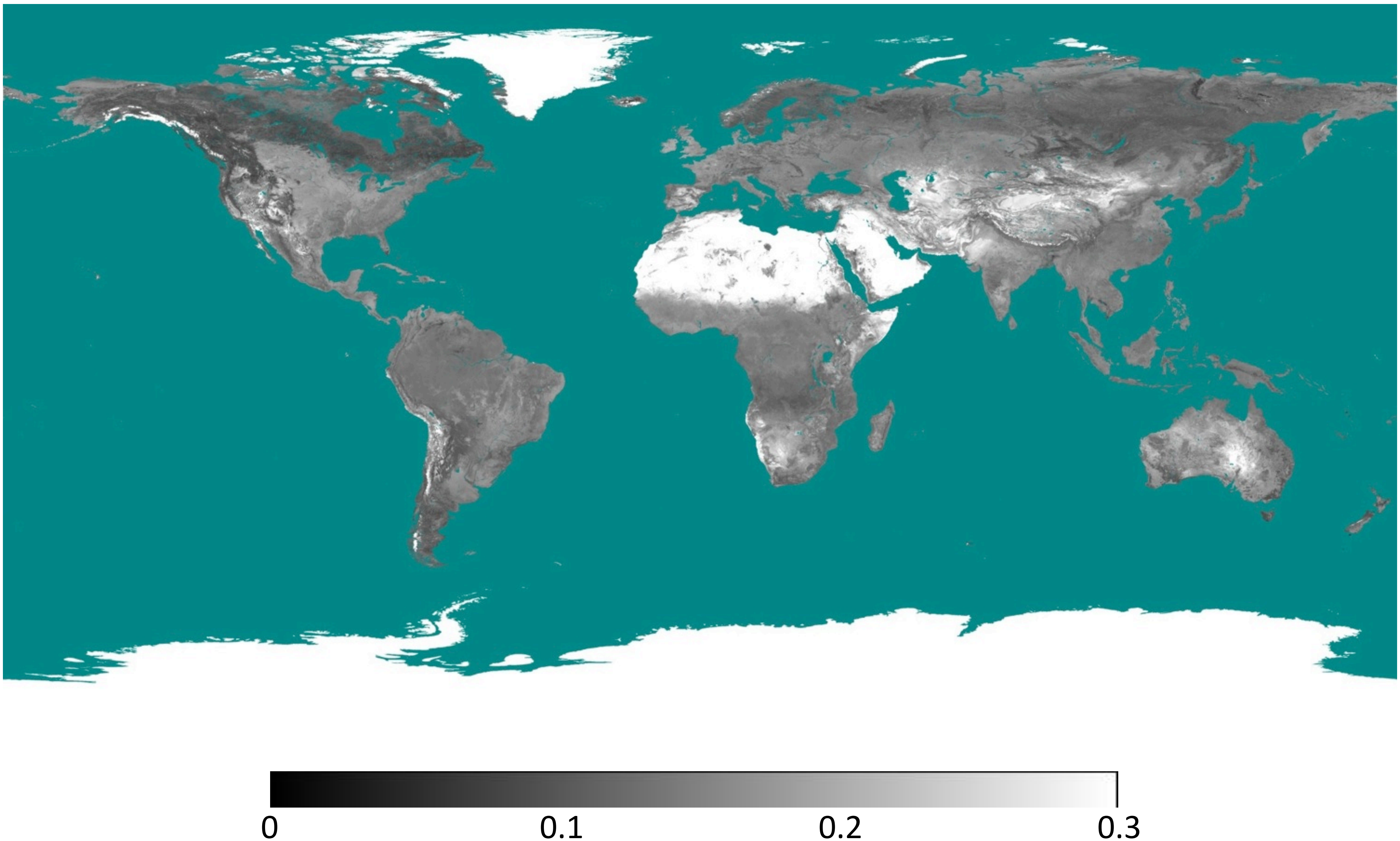
Grassland, Snow-free, Shortwave, WSA, 0.05°
(Albedo)

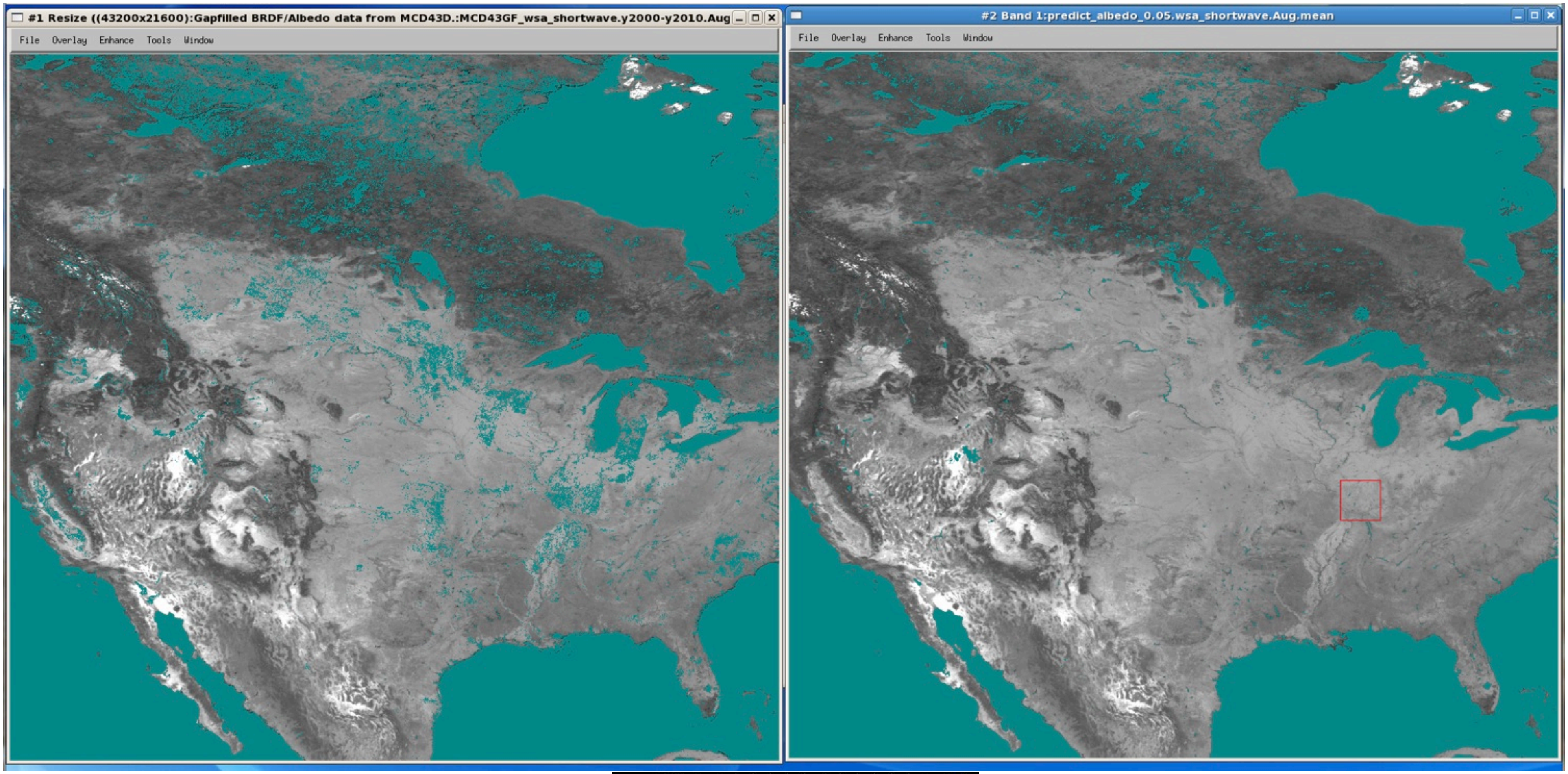


Grassland, Snow-free, Shortwave, Stdev of WSA, 0.05° (uncertainty)

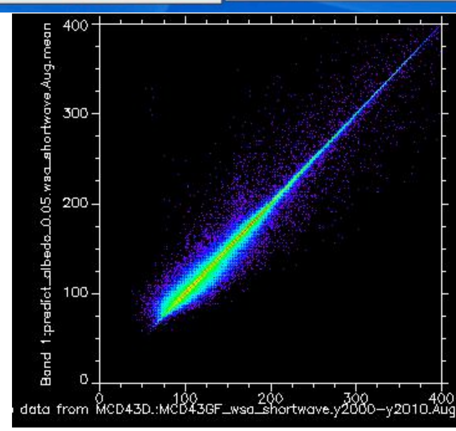


Modeled MODIS white-sky albedo from LUMs
in shortwave on August (2001-2010) at 0.05 degree





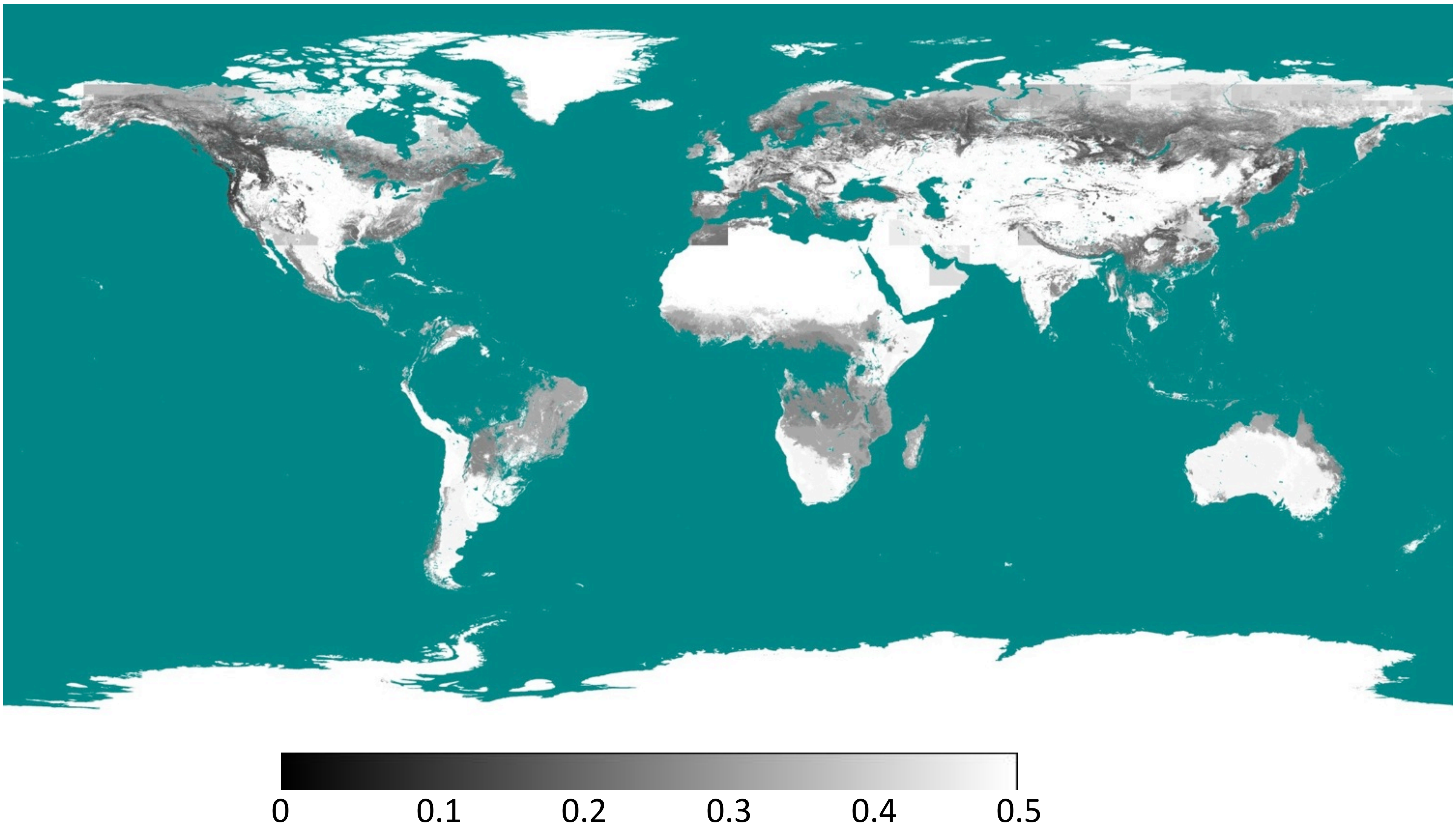
Climatology Albedo



Modeled Albedo

Snow-free WSA
Shortwave
August
0.05 degree

Modeled snow-covered shortwave white-sky albedo in January from LUMs



Global Albedo and Radiative Forcing

(Ghimire, Williams)

Compute blue-sky albedo for each month (*m*), year (*y*) and pixel (*p*) as:

$$\propto_{m,y,p} = \sum_{l=0}^{17} \sum_{s=0}^{1} \sum_{r=0}^{1} f_{l,y} f_s f_r \propto_{l,s,r,m,p}$$

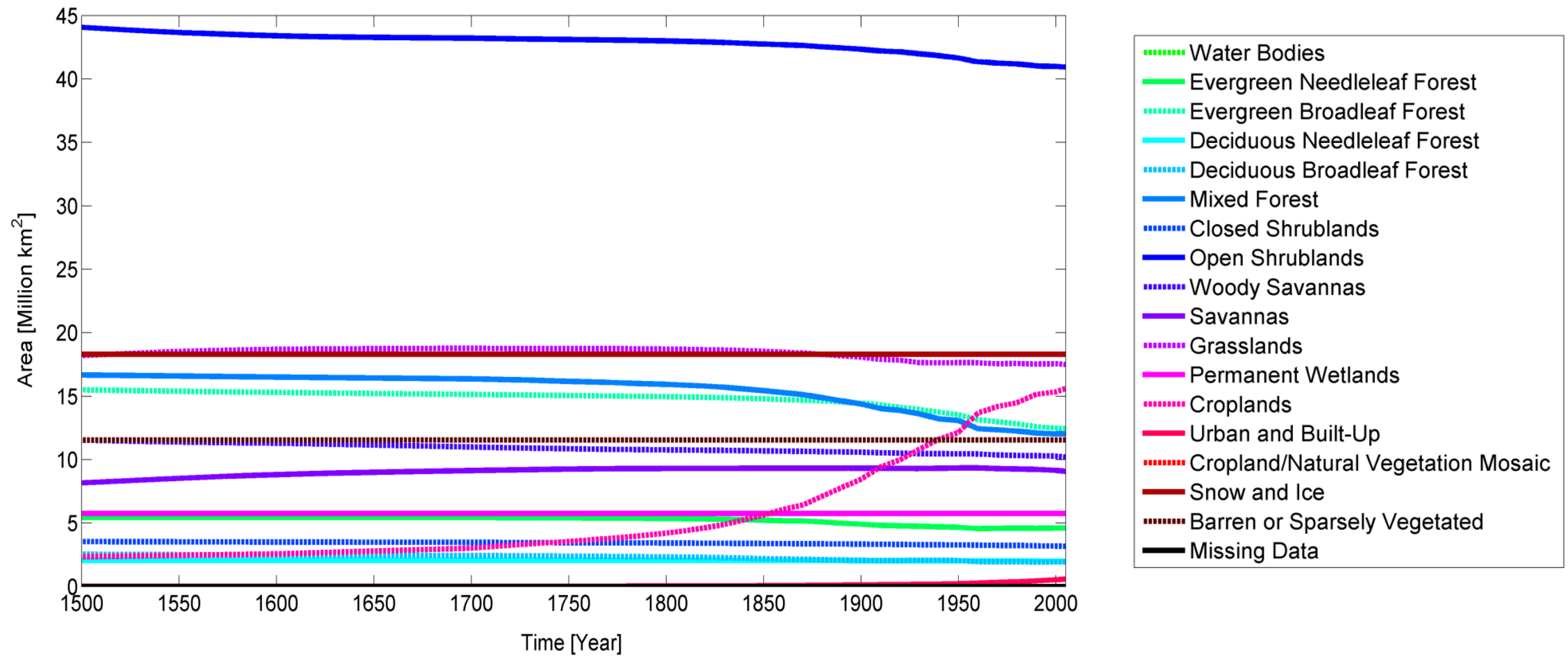
$f_{l,y}$ is fraction (*f*) of a given land-cover class (*l*) at year (y),
f_s is fraction of snow-covered (*s*=0) and snow free (*s*=1) (NCEP/NCAR reanalysis)
f_r is fraction of diffuse (*r*=0) and direct (*r*=1) radiation (NCEP/NCAR reanalysis)

Albedo maps from 1500 to 2005 are then converted into surface radiative forcing (F_s) using incoming solar radiation (*I*) from NOAA-CIRES Reanalysis as:

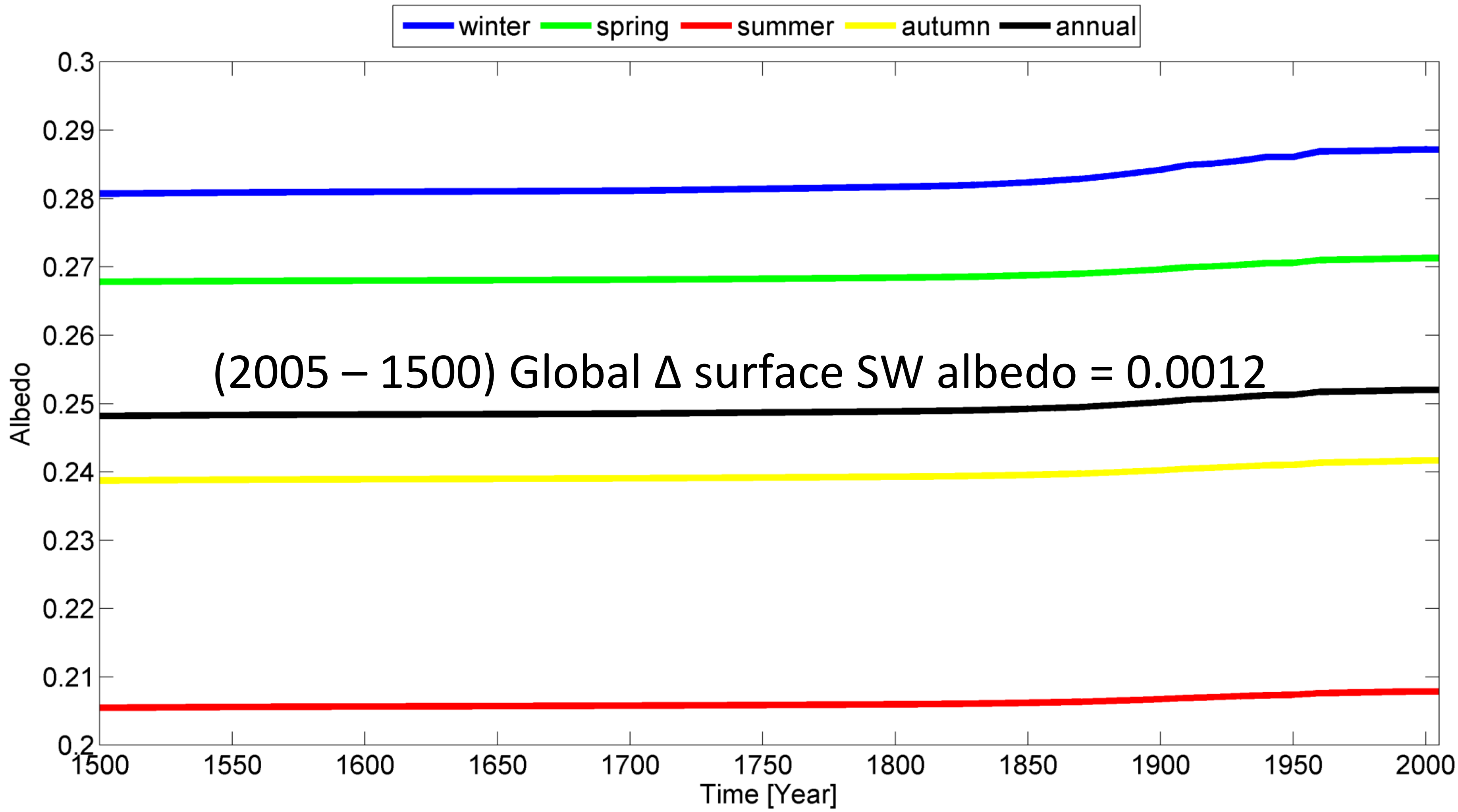
$$F_s = \propto_{m,y,p} I$$

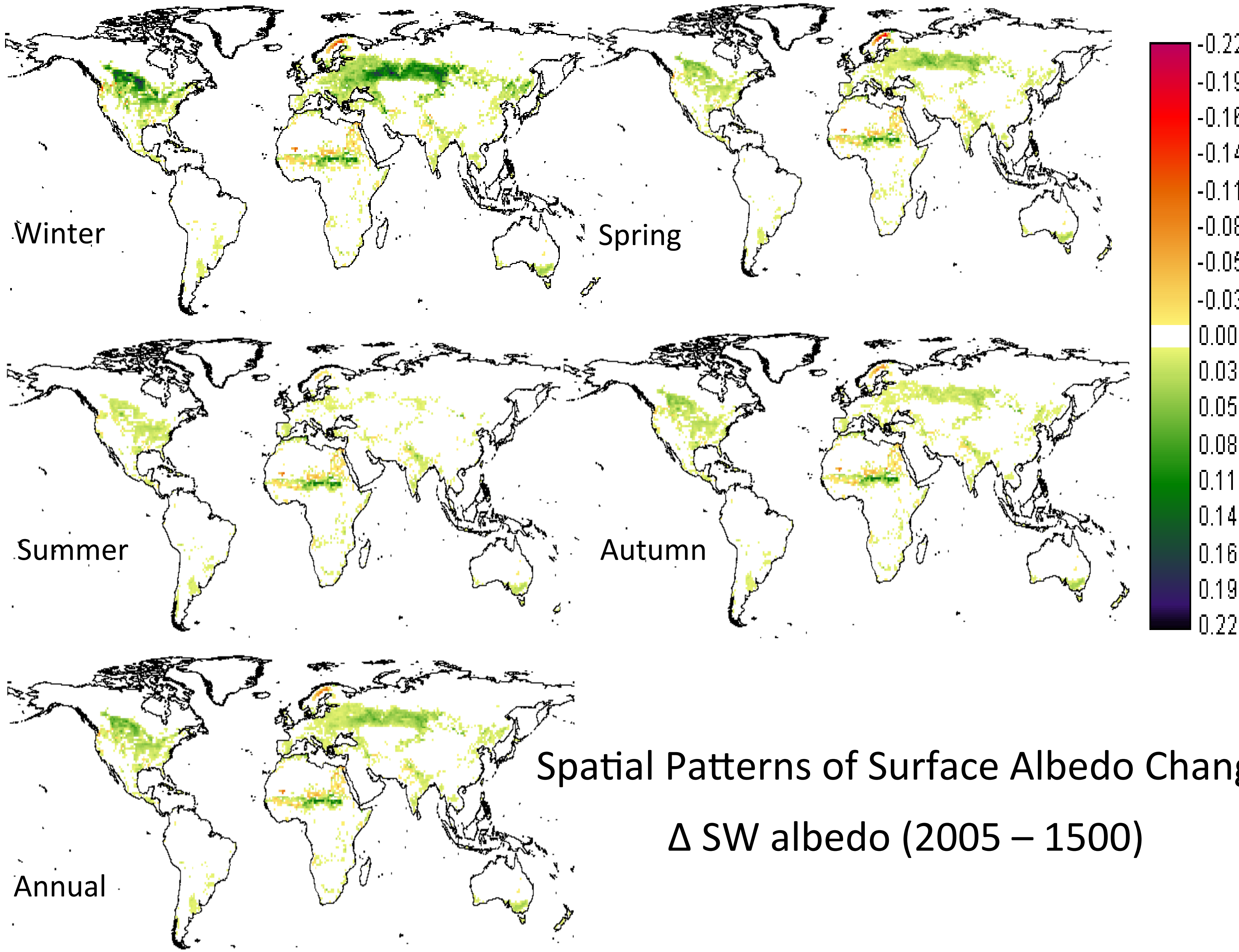
Global Land Cover History 1500-2005

Hurtt et al (2006) LU Harmonization cross-walked to IGBP land cover types



Global Albedo Change 1500-2005



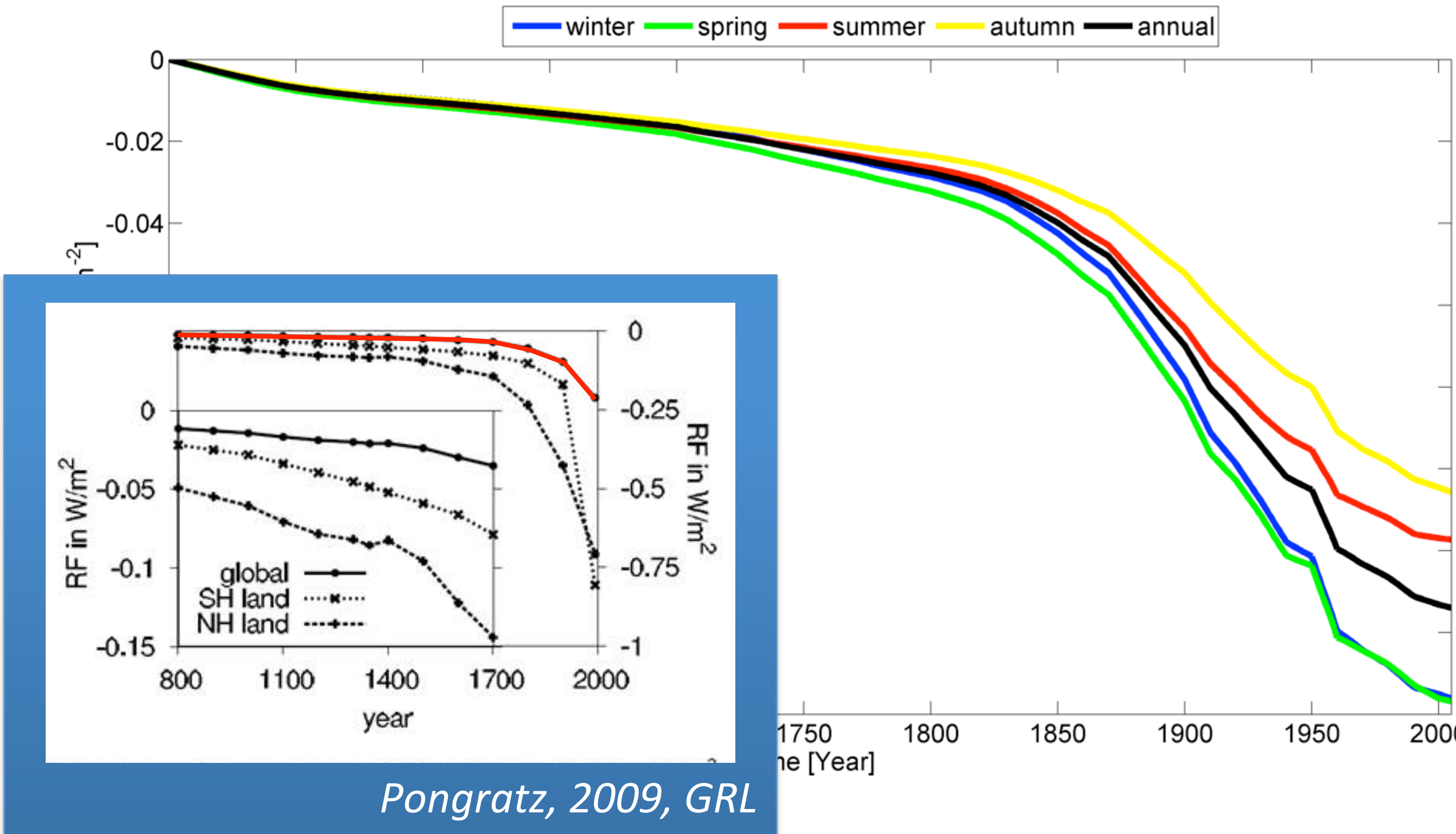


Spatial Patterns of Surface Albedo Change

Δ SW albedo (2005 – 1500)

Global ALCC Radiative Forcing Change 1500-2005

(2005 – 1500) Global Δ RF surface = -0.13 W m^{-2}

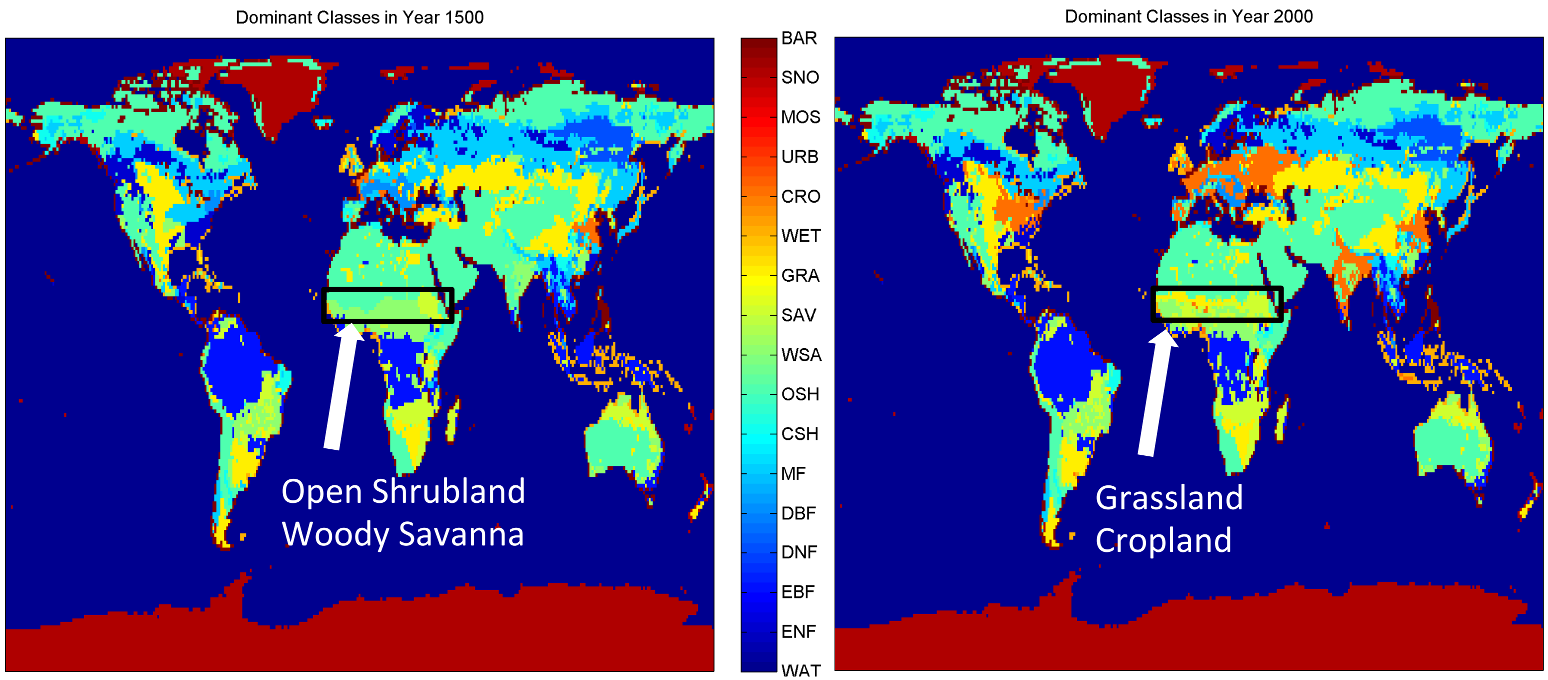


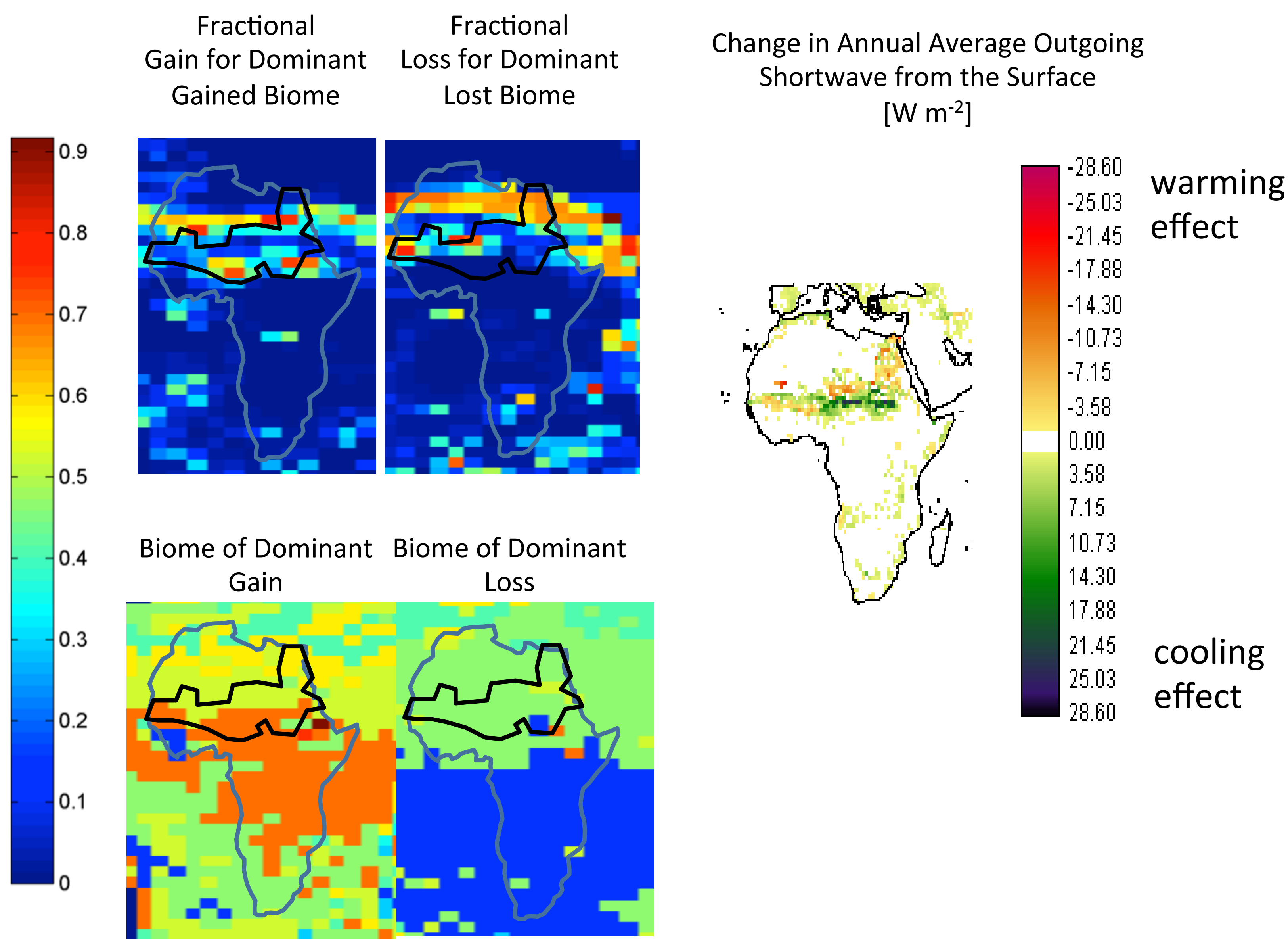
Pongratz, 2009, GRL

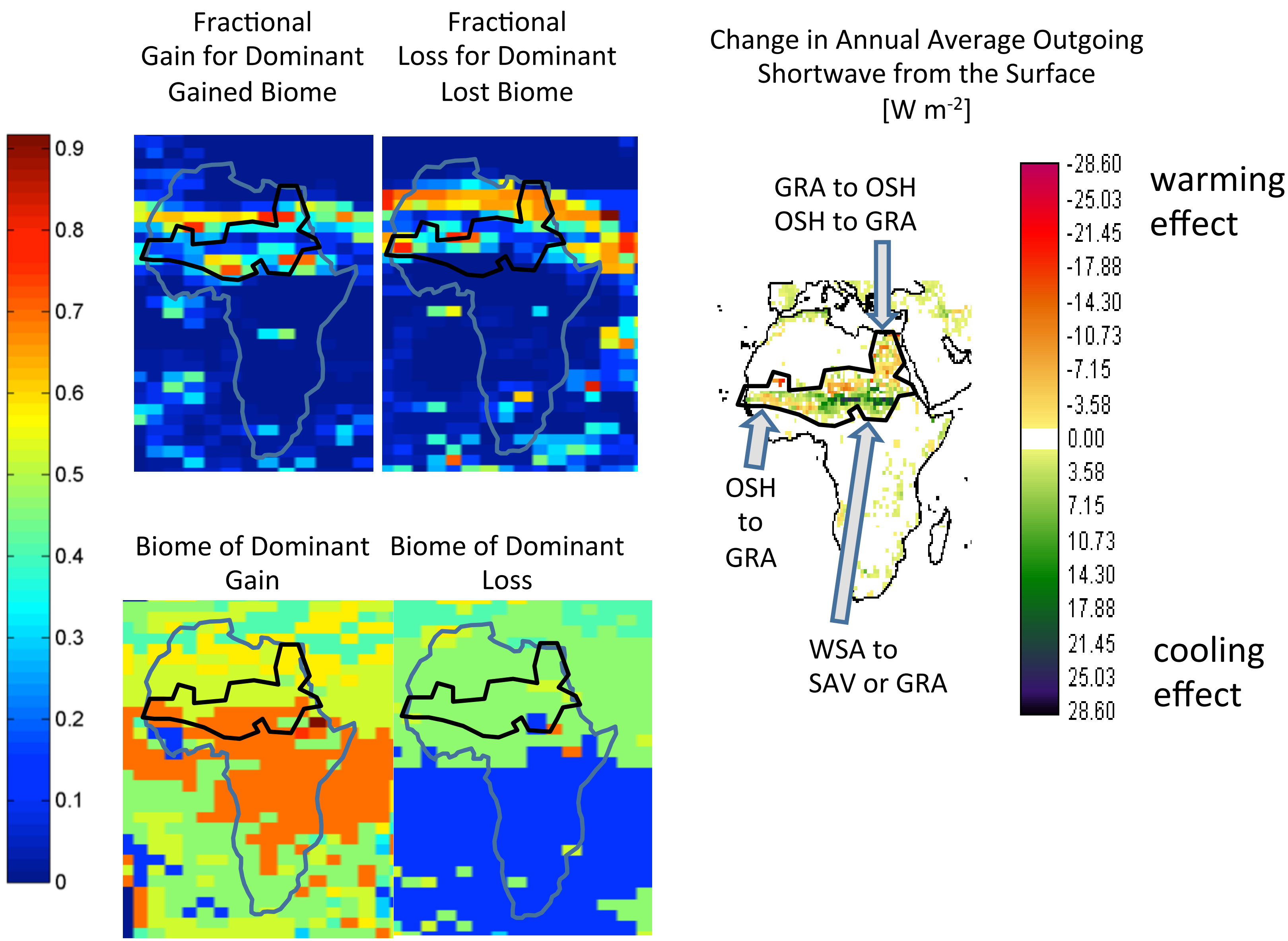
Recent Assessments of Global ALCC Forcing Since ~1700

This study:	**-0.12 W/m2 (*-0.13 since 1500*)**
Pongratz (2009):	-0.18 W/m2
Betts et al (2007):	-0.18 W/m2
Brovkin et al (2006):	-0.14 W/m2
IPCC AR4 (2007):	-0.50 to -0.08 W/m2 (various data sets)

Regional Patterns: Africa

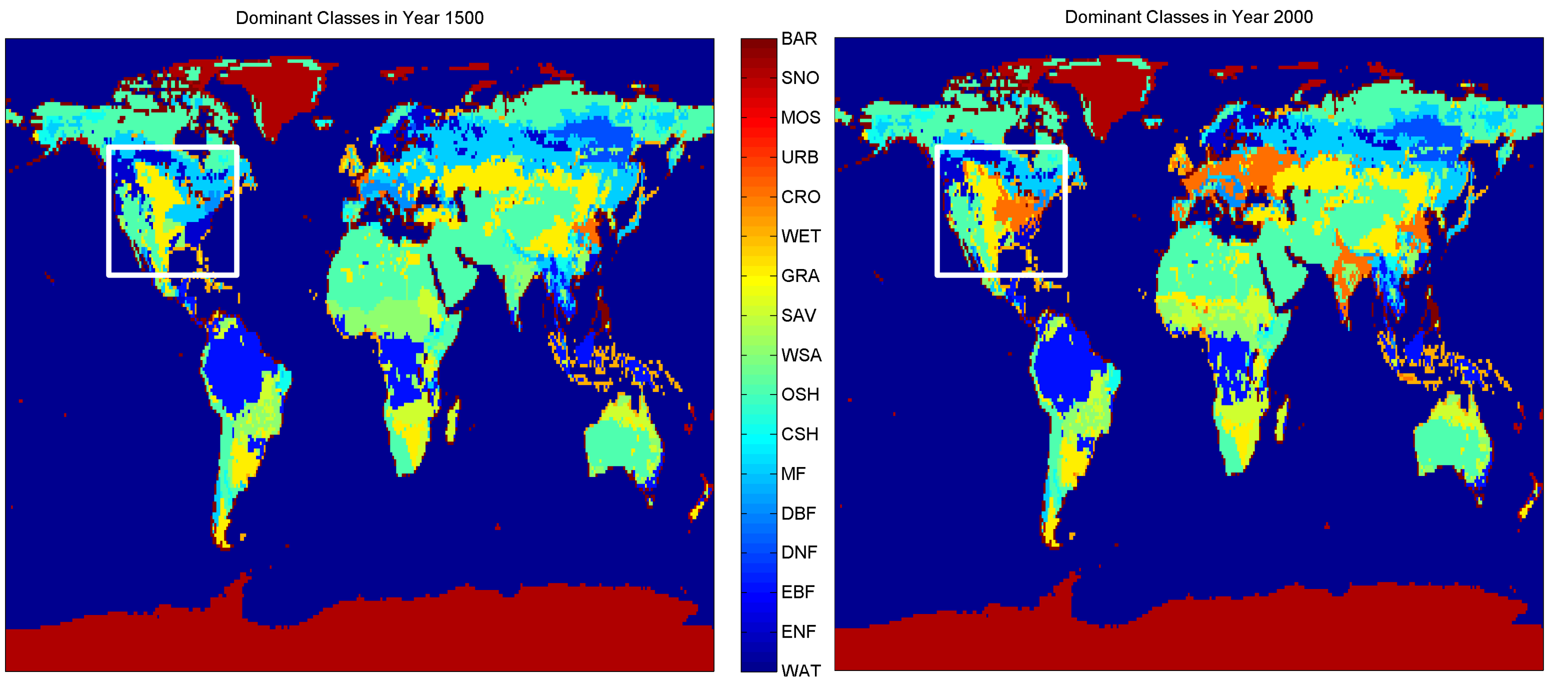


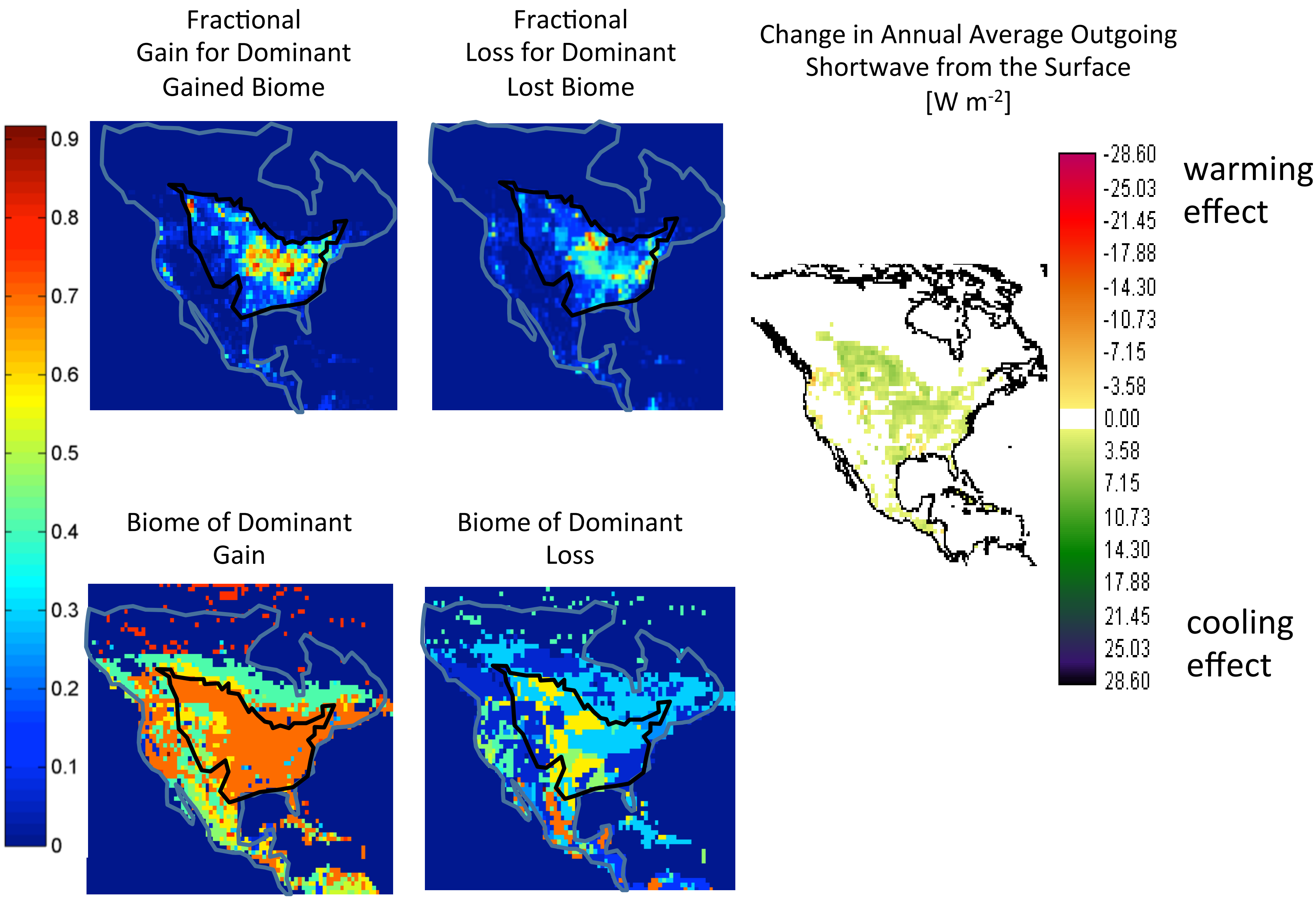

Fractional Gain for Dominant Gained Biome
Fractional Loss for Dominant Lost Biome
Biome of Dominant Gain
Biome of Dominant Loss
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Change in Annual Average Outgoing Shortwave from the Surface [W m-2]
-28.60
-25.03
-21.45
-17.88
-14.30
-10.73
-7.15
-3.58
0.00
3.58
7.15
10.73
14.30
17.88
21.45
25.03
28.60
warming effect
cooling effect

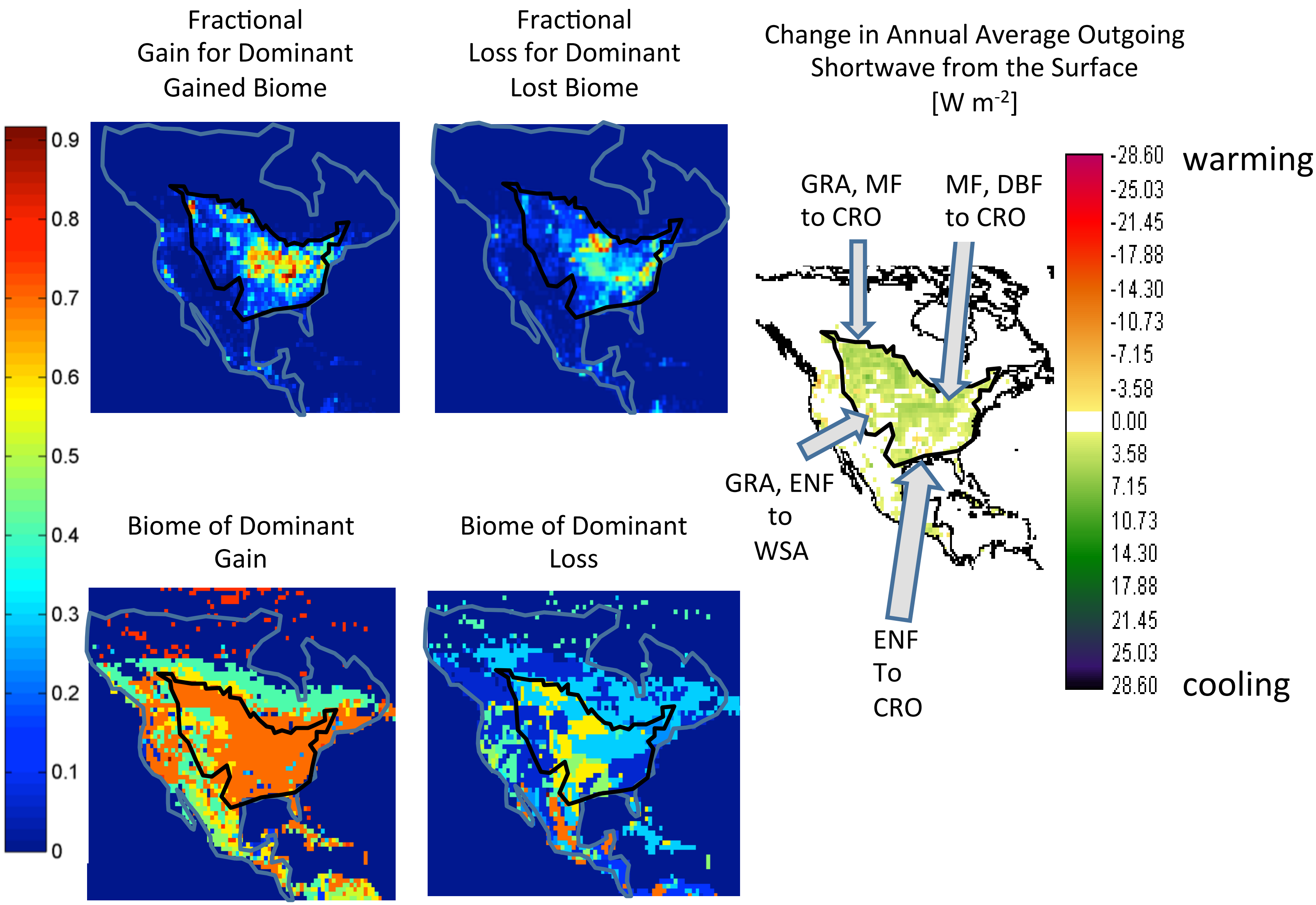


Fractional
Gain for Dominant
Gained Biome
Fractional
Loss for Dominant
Lost Biome
Biome of Dominant
Gain
Biome of Dominant
Loss
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Change in Annual Average Outgoing
Shortwave from the Surface
[W m-2]
GRA to OSH
OSH to GRA
OSH
to
GRA
WSA to
SAV or GRA
-28.60
-25.03
-21.45
-17.88
-14.30
-10.73
-7.15
-3.58
0.00
3.58
7.15
10.73
14.30
17.88
21.45
25.03
28.60
warming
effect
cooling
effect

Regional Patterns: North America




Fractional
Gain for Dominant
Gained Biome
Fractional
Loss for Dominant
Lost Biome
Change in Annual Average Outgoing
Shortwave from the Surface
[W m-2]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Biome of Dominant
Gain
Biome of Dominant
Loss
-28.60
-25.03
-21.45
-17.88
-14.30
-10.73
-7.15
-3.58
0.00
3.58
7.15
10.73
14.30
17.88
21.45
25.03
28.60
warming
effect
cooling
effect

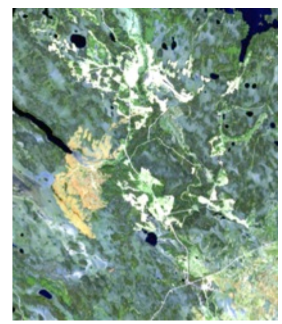


Fractional
Gain for Dominant
Gained Biome
Fractional
Loss for Dominant
Lost Biome
Change in Annual Average Outgoing
Shortwave from the Surface
[W m-2]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Biome of Dominant
Gain
Biome of Dominant
Loss
GRA, MF
to CRO
MF, DBF
to CRO
GRA, ENF
to
WSA
ENF
To
CRO
-28.60
-25.03
-21.45
-17.88
-14.30
-10.73
-7.15
-3.58
0.00
3.58
7.15
10.73
14.30
17.88
21.45
25.03
28.60
warming
cooling

3. Landscape-Scale Albedo Evolution *(Shuai)*

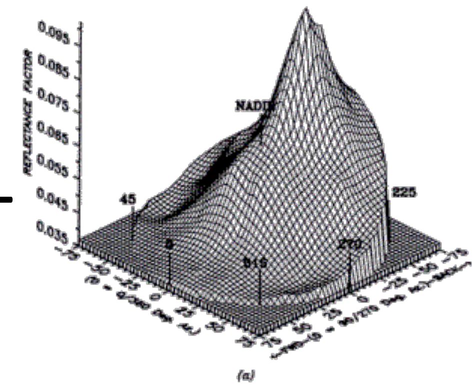
How does disturbance and land cover change affect regional albedo?

Derive 30-meter albedo by combining:
- *30m Landsat nadir reflectance*
- *500m MOD43 BRDF (Shuai et al., 2011)*



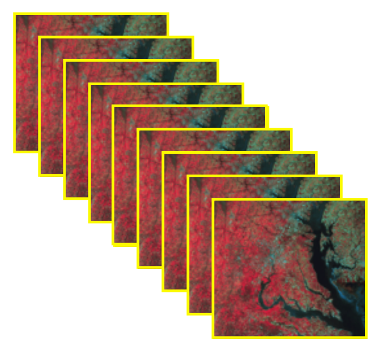
Landsat nadir SR

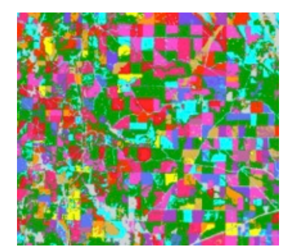
+



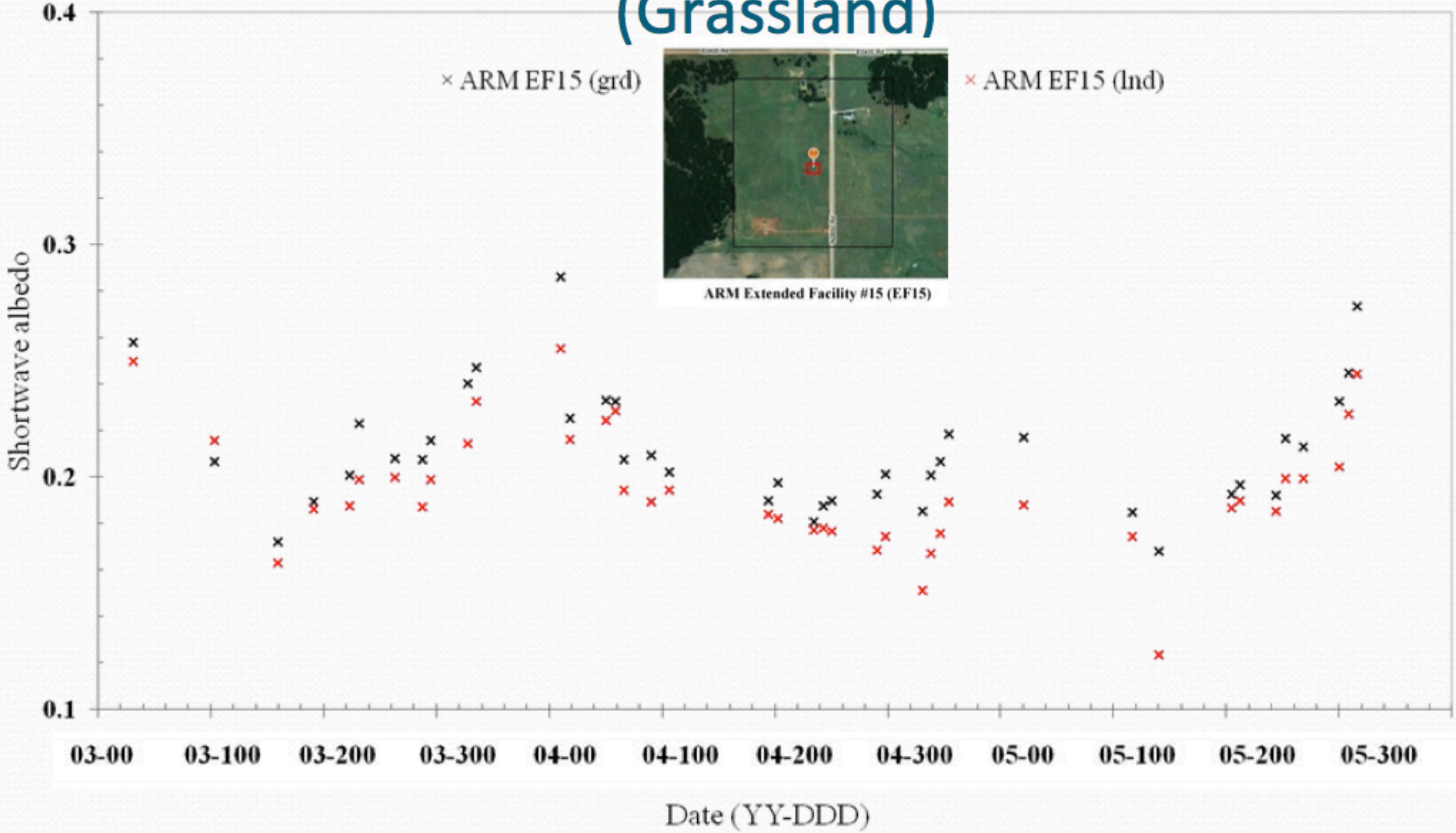
MODIS BRDF

Generate per-pixel time series albedo using Landsat archive, and relate to forest disturbance type, severity

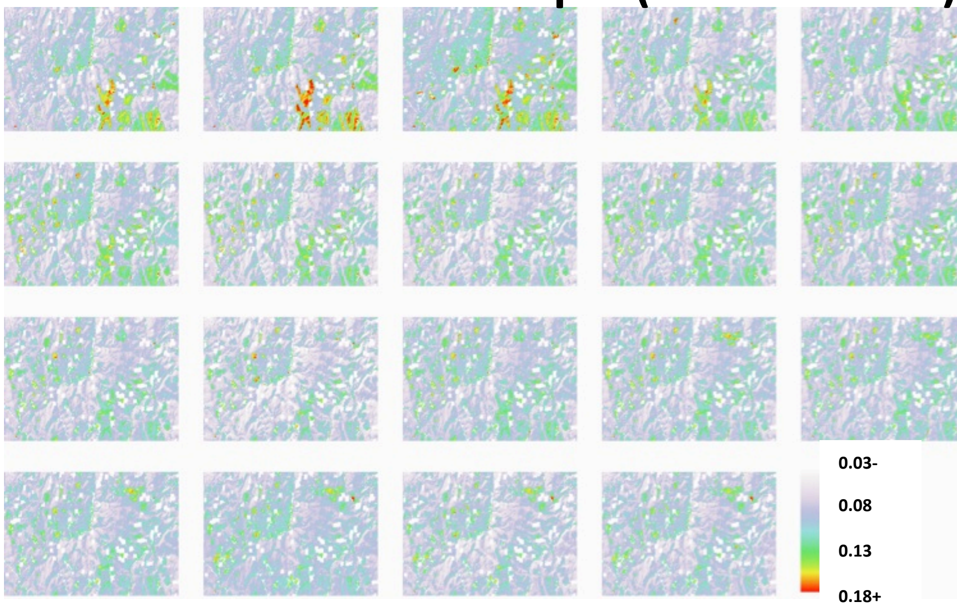


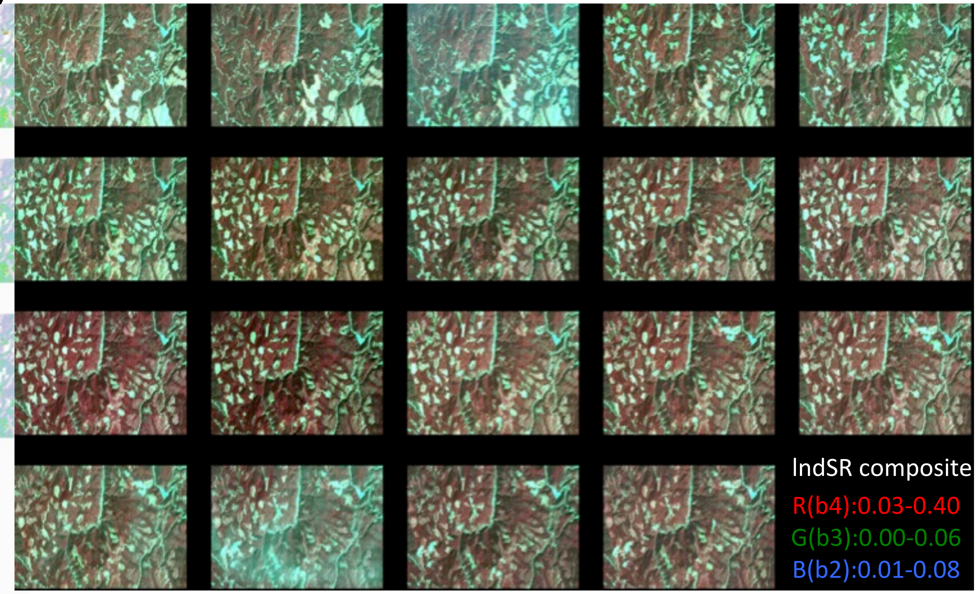


Temporal albedo over ARM EF15 site (Grassland)



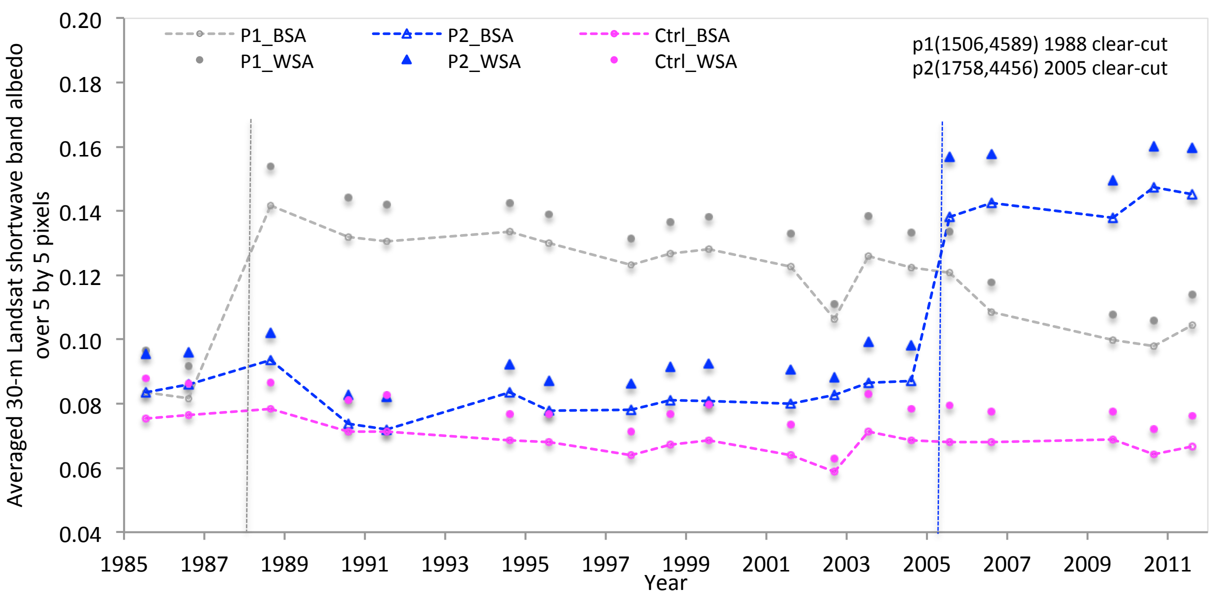
Clear Cut Harvest Example (Mid-Summer)



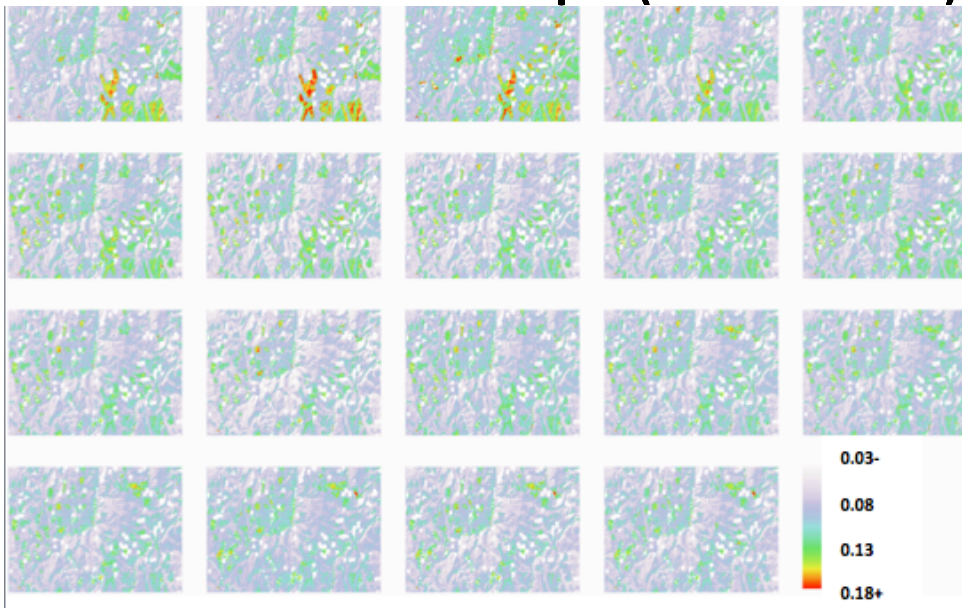


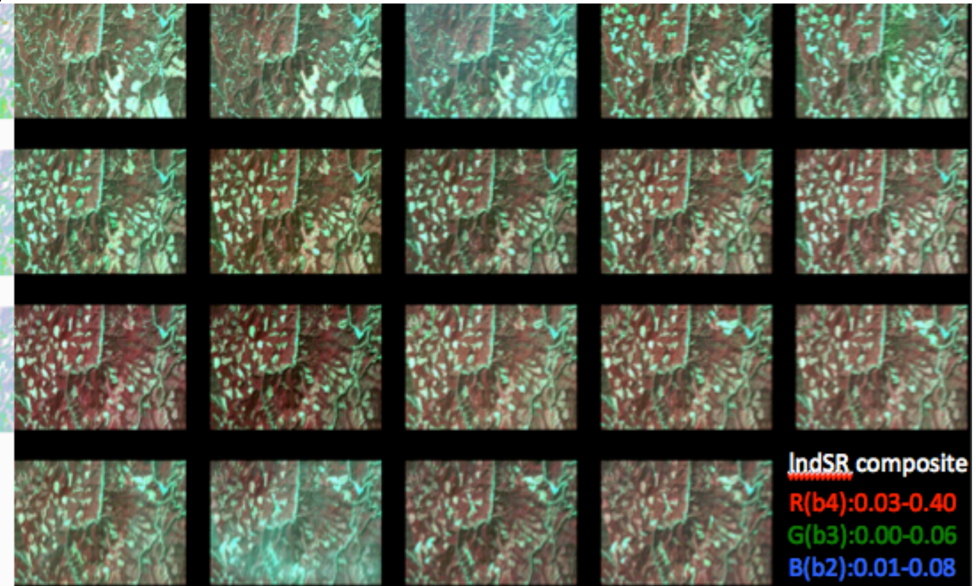
Black Sky Albedo

1985/200	1986/219	1988/241	1990/214	1991/201
1994/225	1995/212	1997/233	1998/220	1999/207
2001/220	2002/255	2003/202	2004/221	2005/207
2006/226	2009/234	2010/237	2011/224	



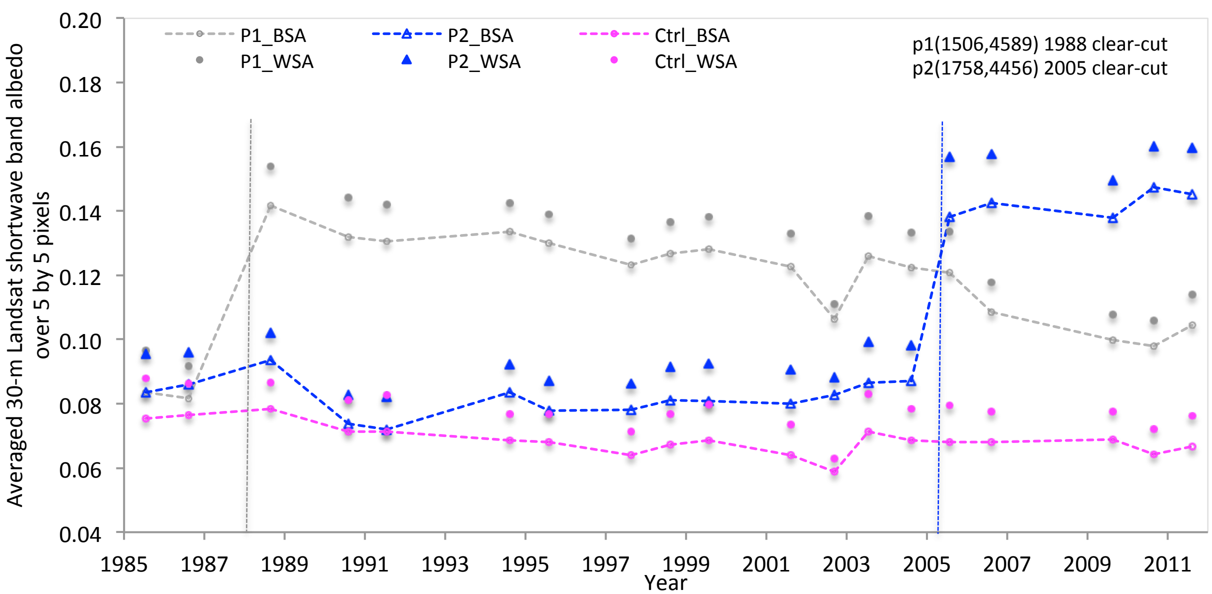
Clear Cut Harvest Example (Mid-Summer)



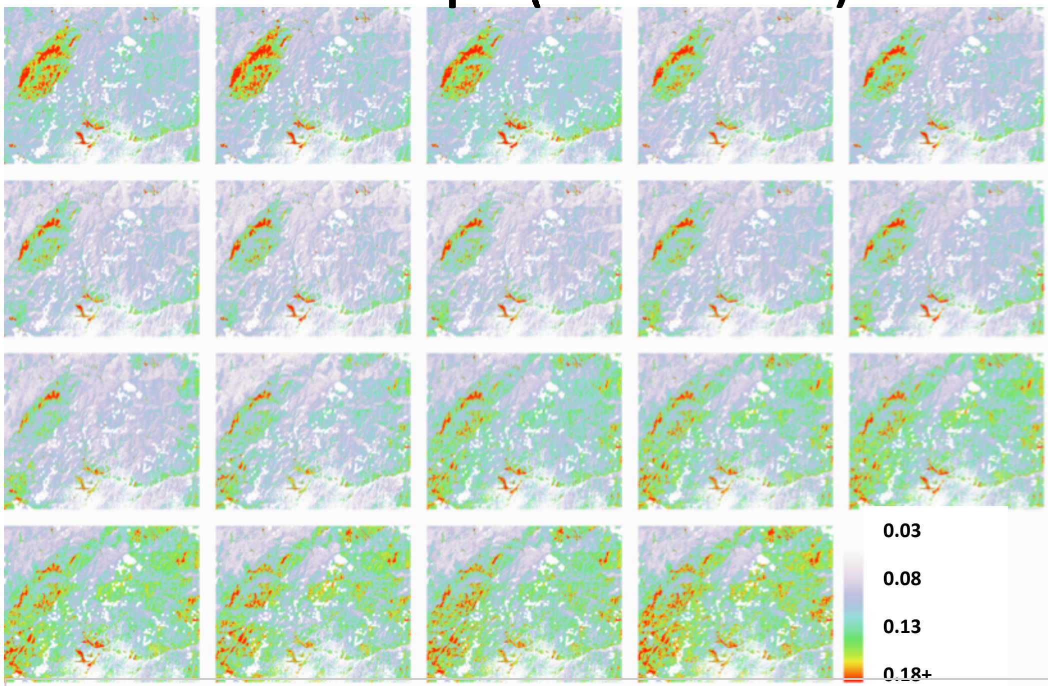


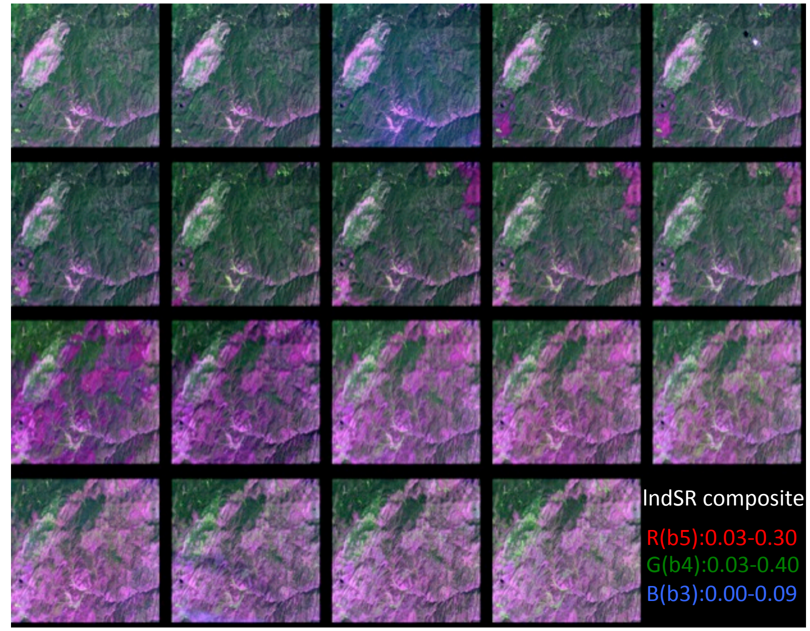
1985/200	1986/219	1988/241	1990/214	1991/201
1994/225	1995/212	1997/233	1998/220	1999/207
2001/220	2002/255	2003/202	2004/221	2005/207
2006/226	2009/234	2010/237	2011/224	

Black Sky Albedo



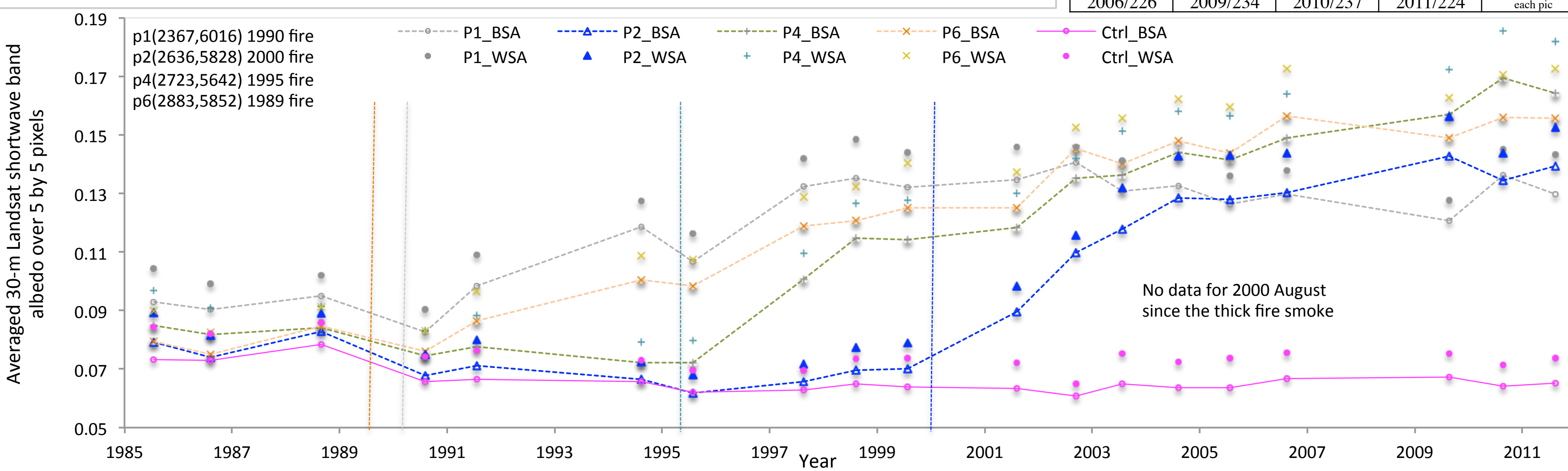
Burned Area Example (Mid-Summer)



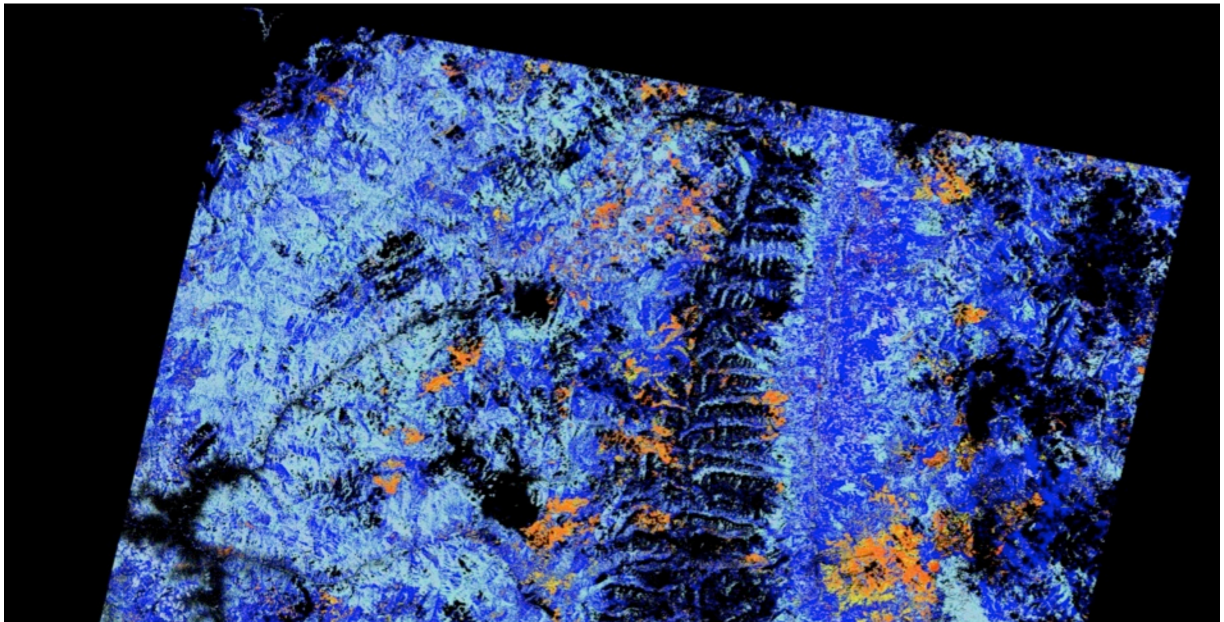


1985/200	1986/219	1988/241	1990/214	1991/201
1994/225	1995/212	1997/233	1998/220	1999/207
2001/220	2002/255	2003/202	2004/221	2005/207
2006/226	2009/234	2010/237	2011/224	YYYY/DOY for each pic

Temporal White Sky Albedo (WSA) in the upper panel, with lndSR band5,4,3 composite in the upper-right panel and plots for individual forest disturbance in the lower graphic, show the evolution of WSA and surface reflectance (vegetation water content).



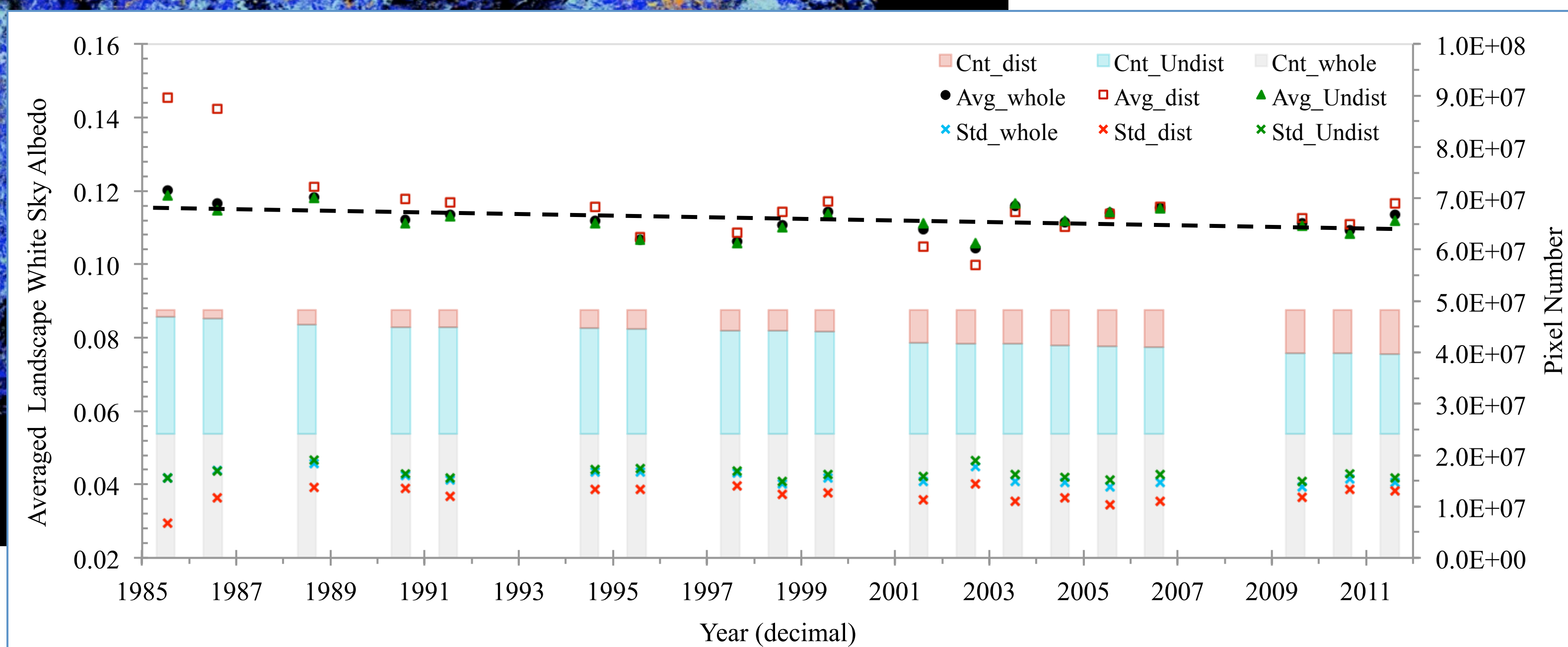
Significant summer albedo (WSA) trends, 1985-2011 based on temporal regression & T-test



No significant trend

Negative trend

Positive trend



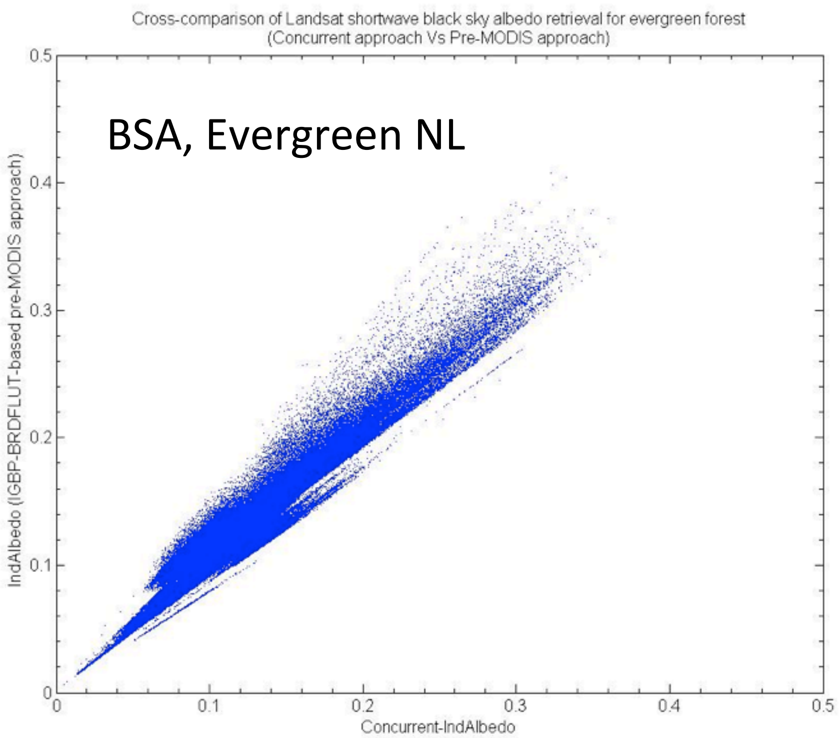
Next Steps

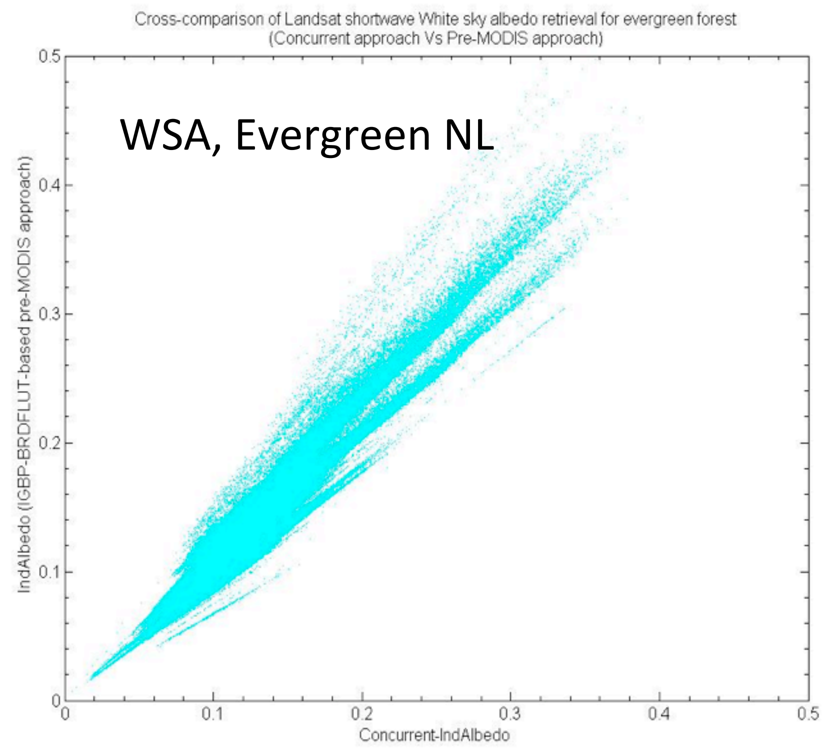
- Provide uncertainties for global albedo & RF trajectories
- Extend to 2100 using IPCC RCP scenarios
- Incorporate snow-covered albedo into landscape analyses & provide annualized RF
- Integrate albedo into USFS Forest Vegetation Simulator (FVS)

Thank You

Backup

Comparison Between "Concurrent" and "BRDF LUT" Methods
(Montana, 5/10/2006)



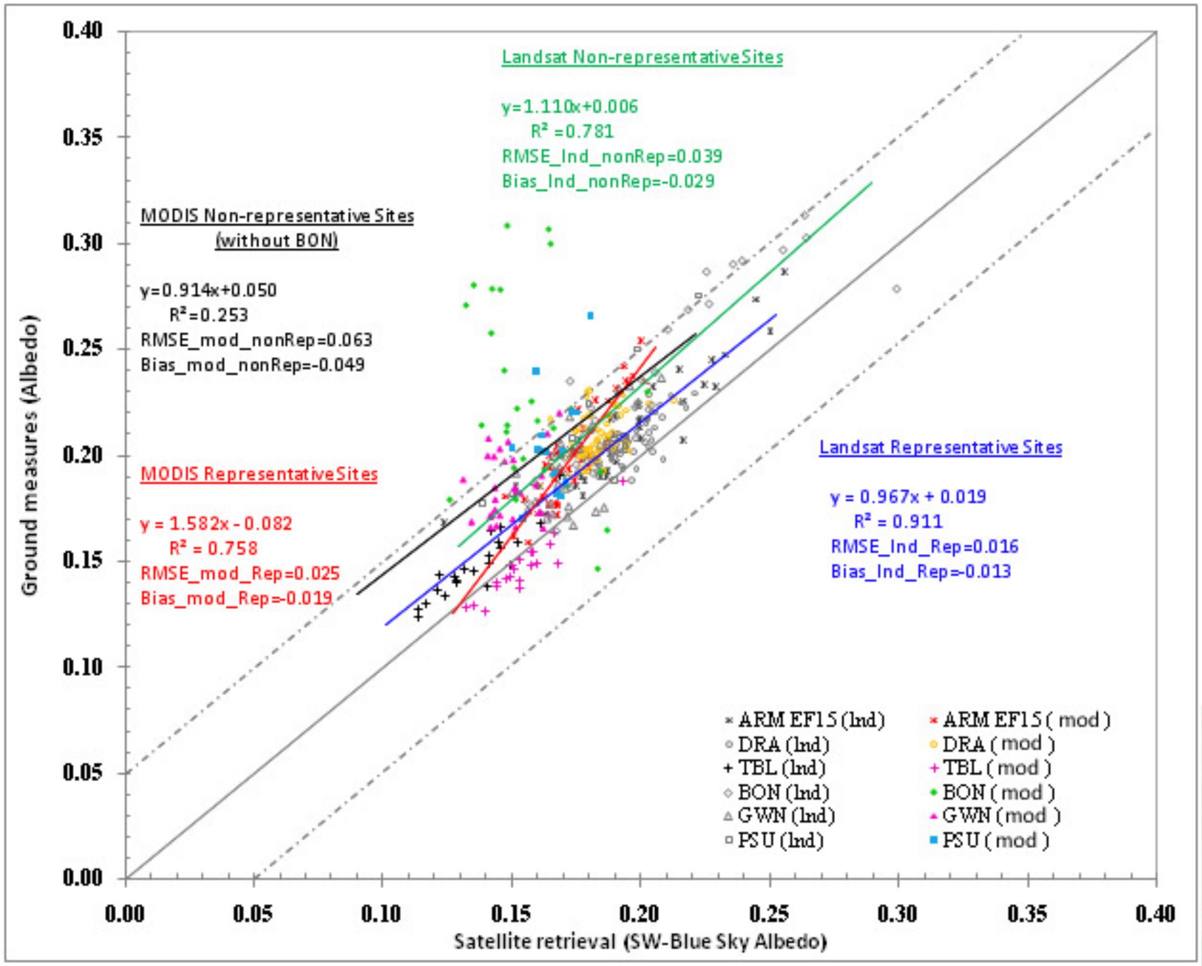


- Direct and diffuse incoming solar radiation for surface radiative forcing
  - Determine albedo induced surface radiative forcing by overlaying (multiplying) direct and diffuse solar radiation maps with corresponding albedo change maps.

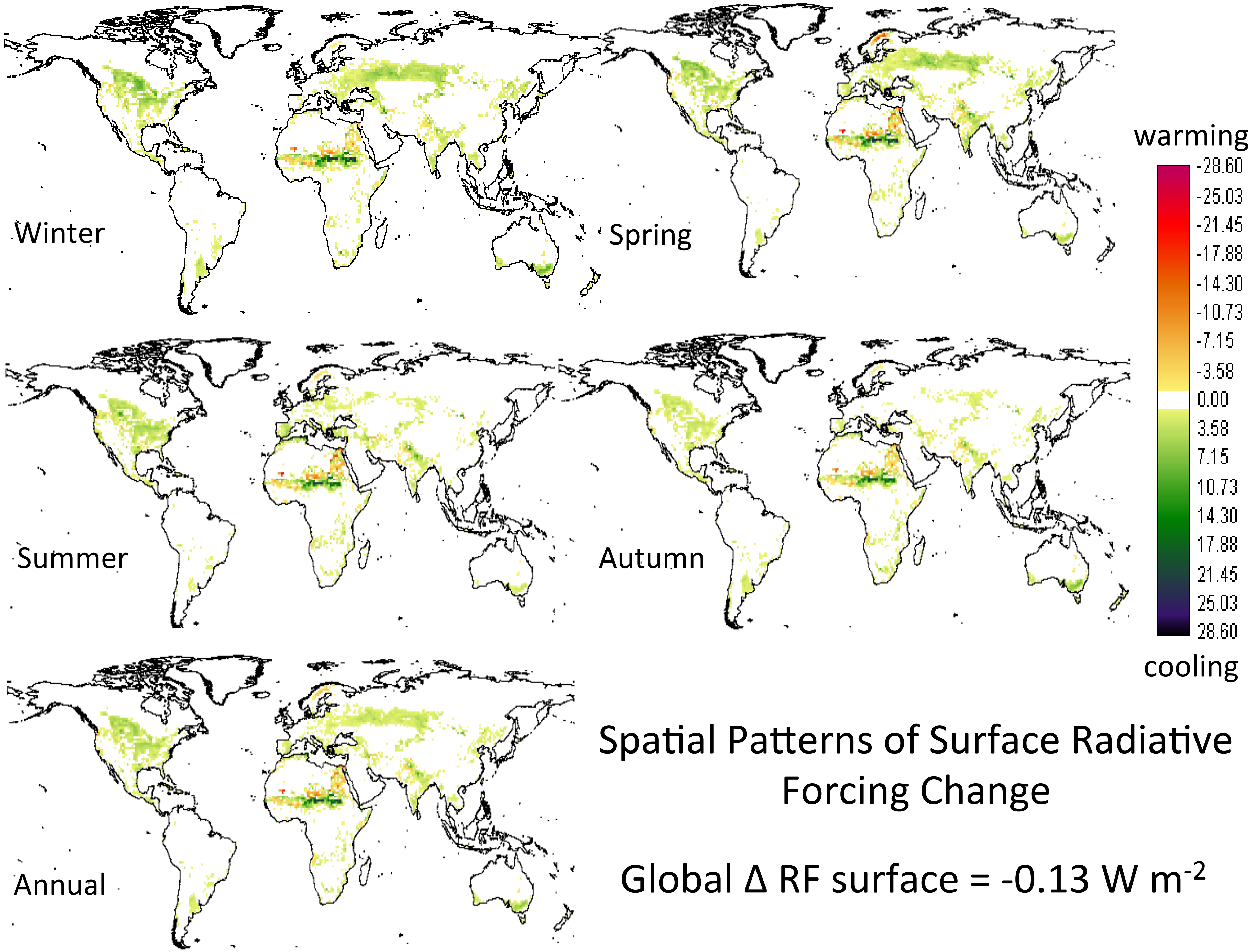
$$\Delta F_{surface,month} = -I^{\downarrow}_{surface,month,year}\left(\alpha_{surface,month,2000} - \alpha_{surface,month,YYYY}\right)$$

  - NCEP/NCAR reanalysis 1 product for direct and diffuse solar radiation
  - Same data source for forecast
  - Also source for snow cover climatology

Comparison of Landsat and MODIS Albedo with In-Situ SURFAD



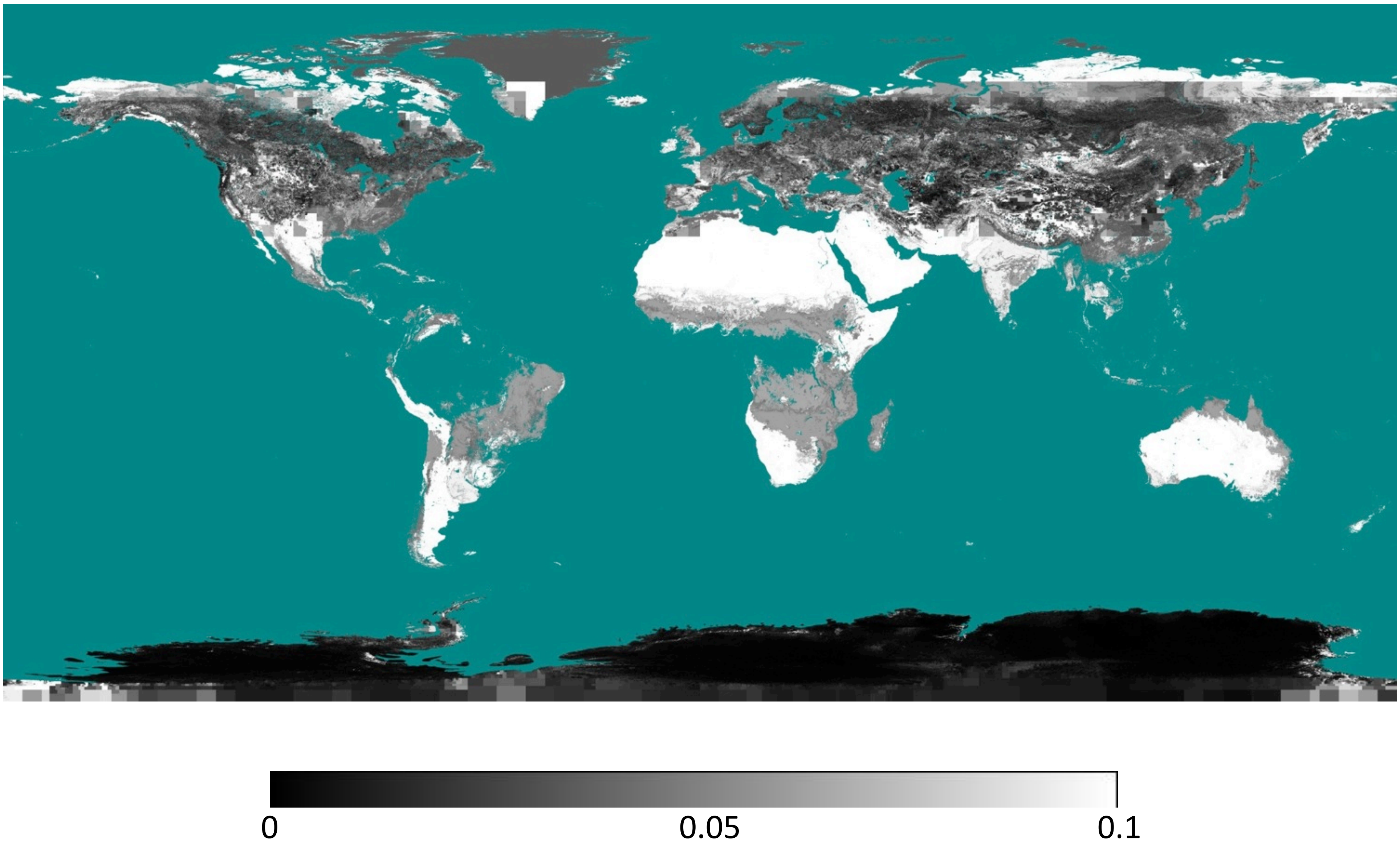
Bondville (BON)



Spatial Patterns of Surface Radiative Forcing Change

Global Δ RF surface = -0.13 W m^{-2}

Uncertainty of the modeled snow-covered shortwave white-sky albedo in January from LUMs

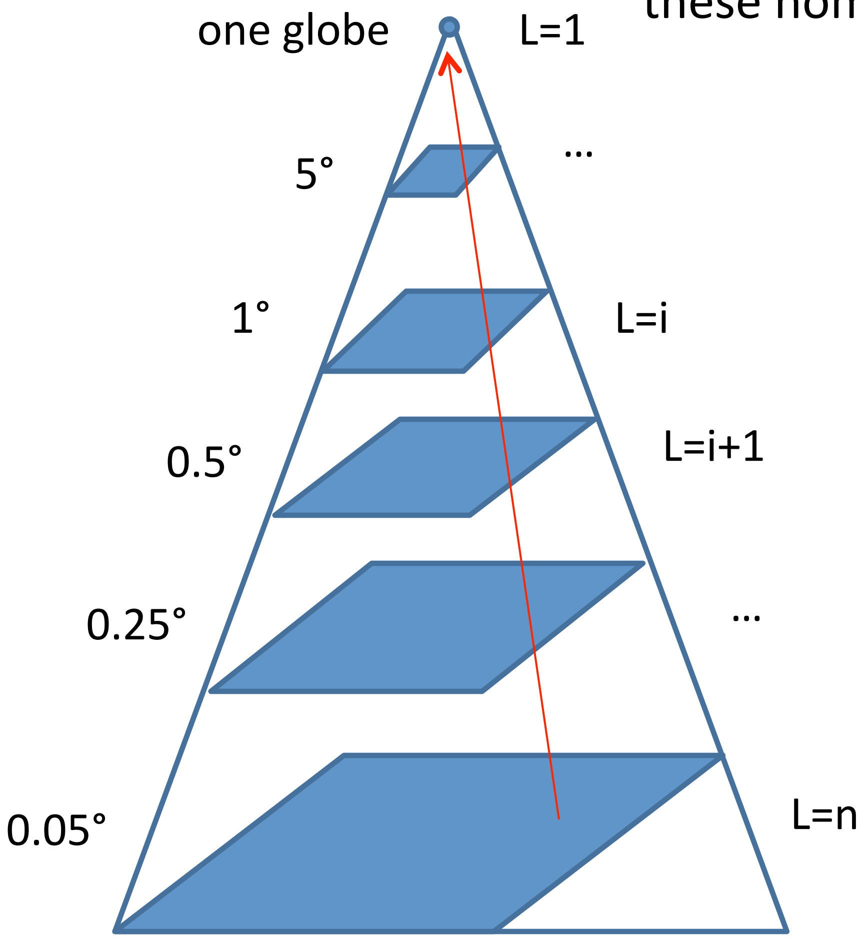


Hierarchical Albedo LUT for IGBP Land Cover Types

1. Use Landsat global GLS2000 to identify homogenous land cover examples at MODIS 500m resolution

2. Extract MODIS albedo climatology for these homogenous examples

3. Propagate values to coarser scales to support modeling scenarios (ie. future landcover != current landcover)



The albedo LUT is presented as:

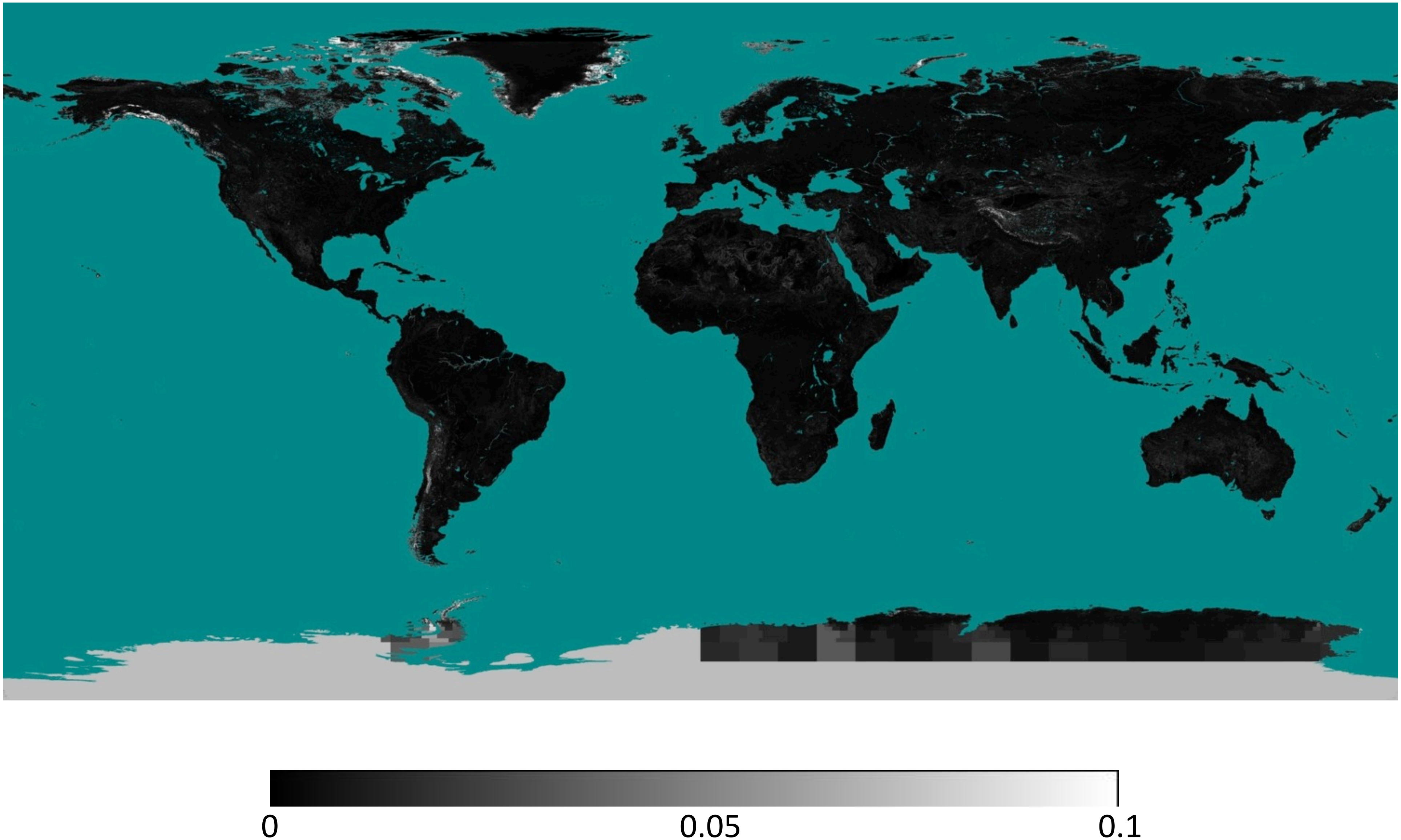
$\rho(i, j, L)$ where:

i = land cover type

j = geographic location (pixel)

L = resolution level

Uncertainty of the Modeled WSA from albedo LUMs in shortwave on August (2001-2010) at 0.05 degree



Significant albedo (WSA) trends, 1985-2011 based on temporal regression & T-test

No significant trend

Negative trend

Positive trend