Snow and Vegetation: Remote Sensing and Modeling

(Activities in Land-Atmosphere Interactions
at the University of Arizona, Tucson)

Michael Barlage

Joint Center Funded Work - PI Xubin Zeng

Our Research

- Look for areas of model improvement, especially those which can be explored by remotely sensed data
- Develop new datasets or formulations to solve these problems
- Test new datasets to determine improvements in either model prediction or representation
- Goal: Be a bridge between the modeling and remote sensing community

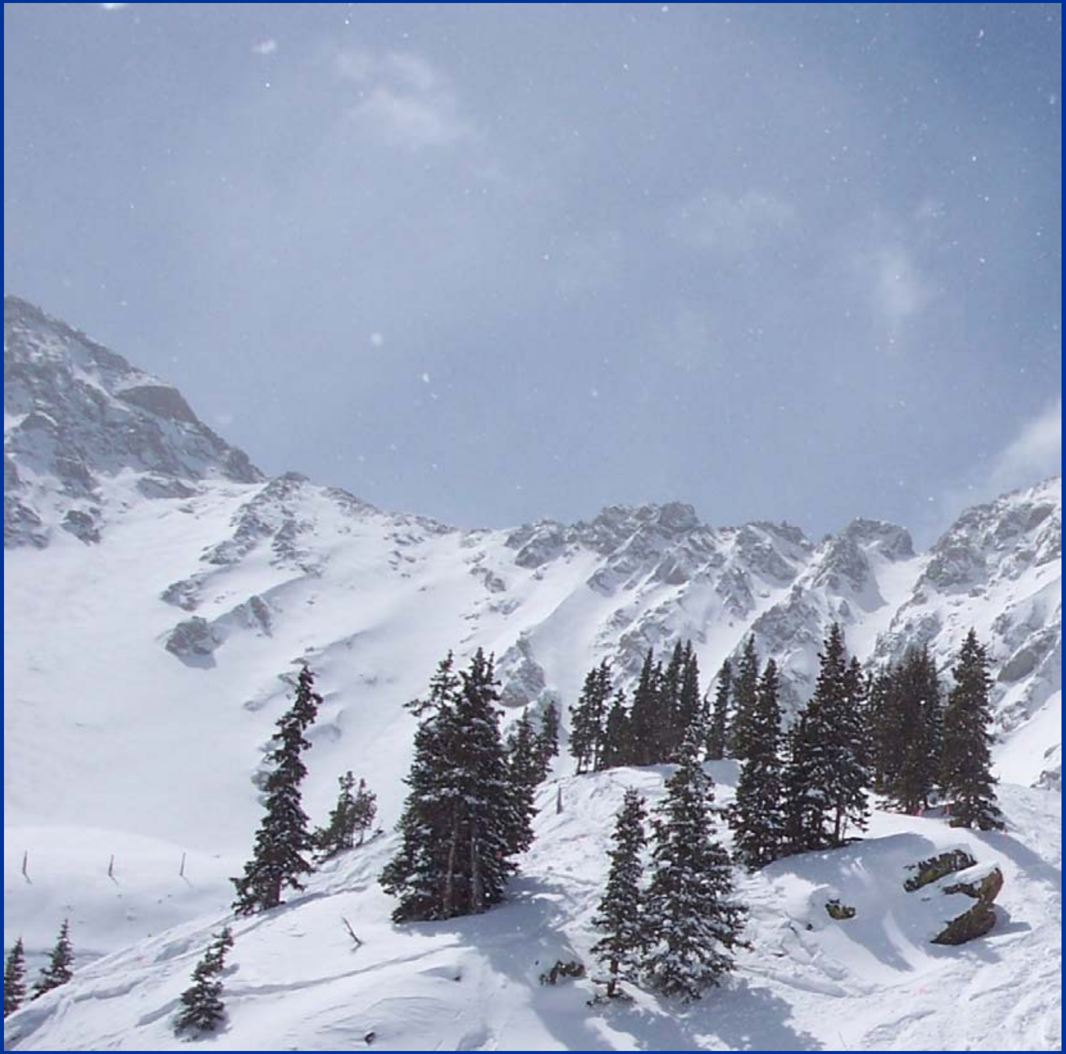
Derivation of a New Maximum Snow Albedo Dataset Using MODIS Data

M.Barlage, X.Zeng, H.Wei, K.Mitchell; GRL 2005

Motivation

- Maximum snow albedo is used as an end member of the interpolation from snow- to non-snow covered grids
- Current dataset is based on 1-year of DMSP observations from 1979
- Current resolution of 1°
- Create new dataset using 4+ years of MODIS data with much higher resolution

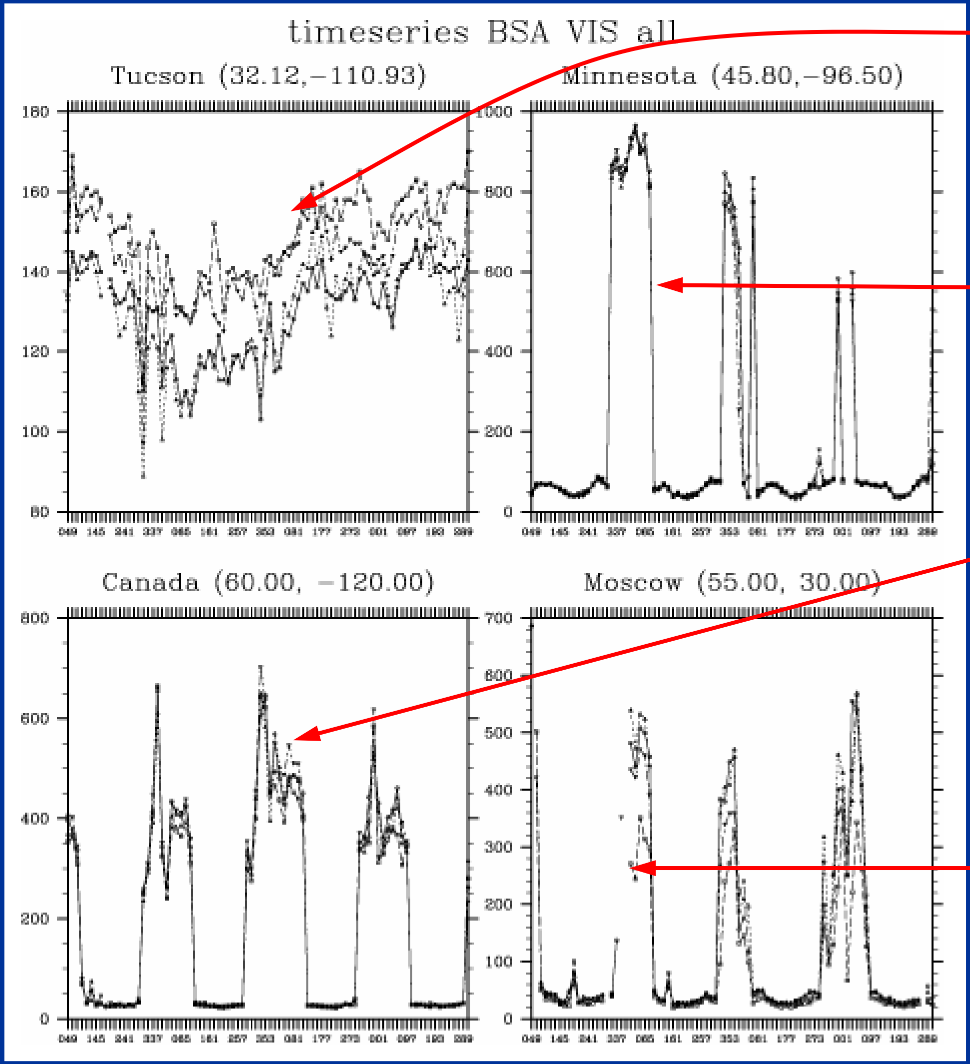
Motivation



MODIS products used:

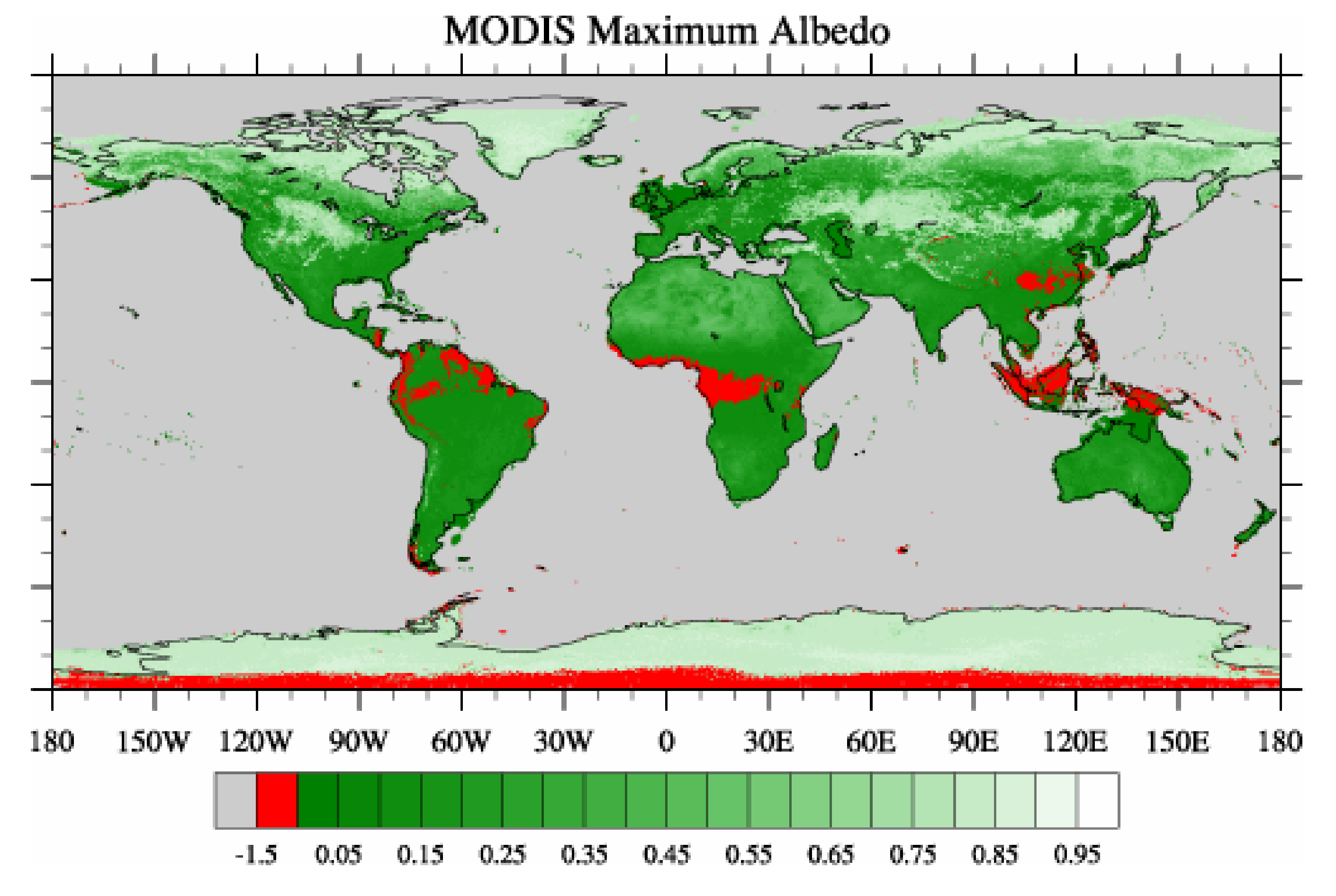
- Broadband Albedo: 0.05° CMG, all available v4; major data component
- Land Cover: 1km global, v4; used to determine fill values outside snow area
- Spectral Albedo/NBAR: 0.05° CMG, all available v4; used to calculate NDSI to determine snow regions, also to mask water

Raw MODIS Albedo Data

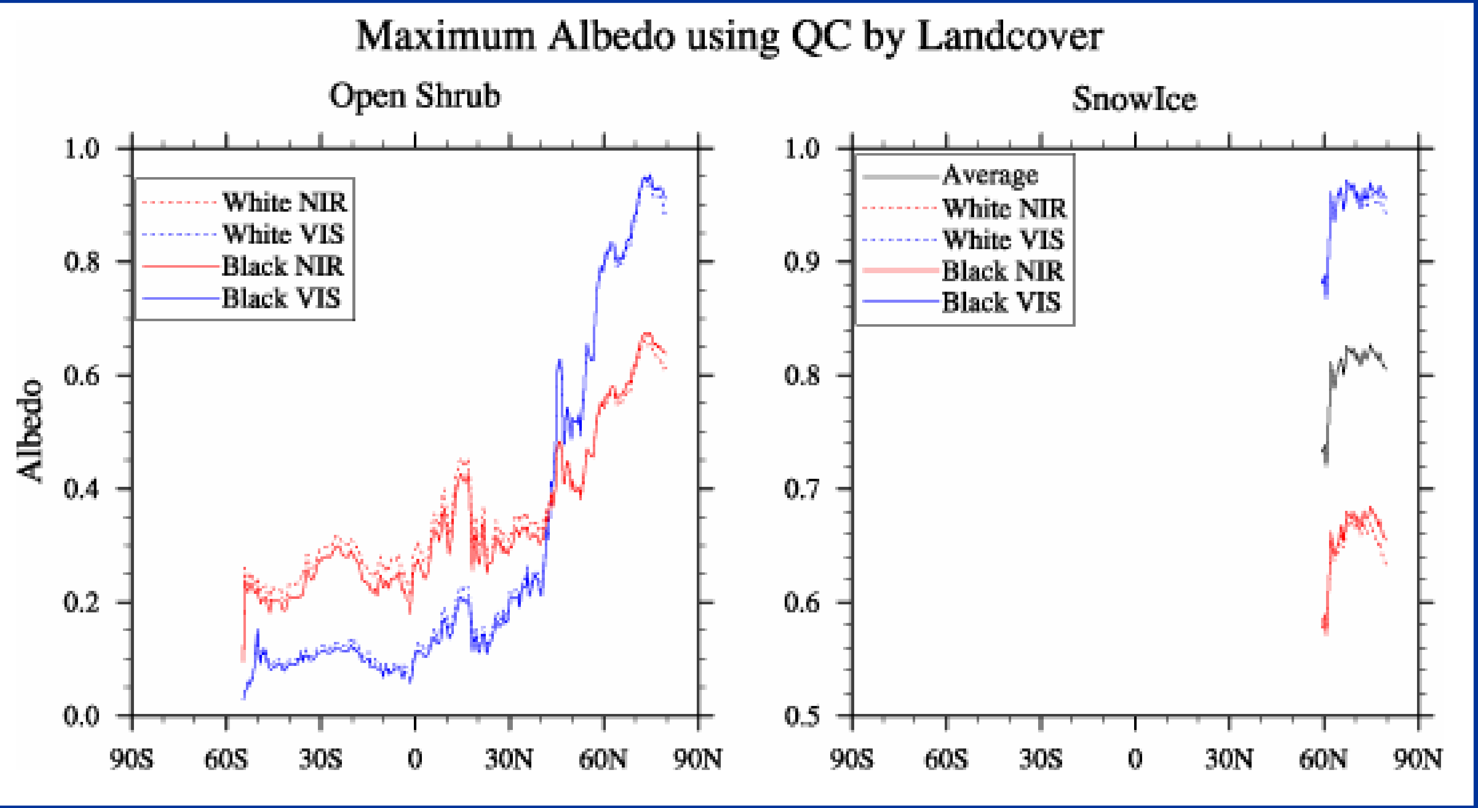


- Tucson: little variation; no snow
- Minnesota: cropland; obvious annual cycle
- Canada: annual snow cycle; little summer variation
- Moscow: some cloud complications

Maximum "Good" Albedo



Albedo and Land Cover

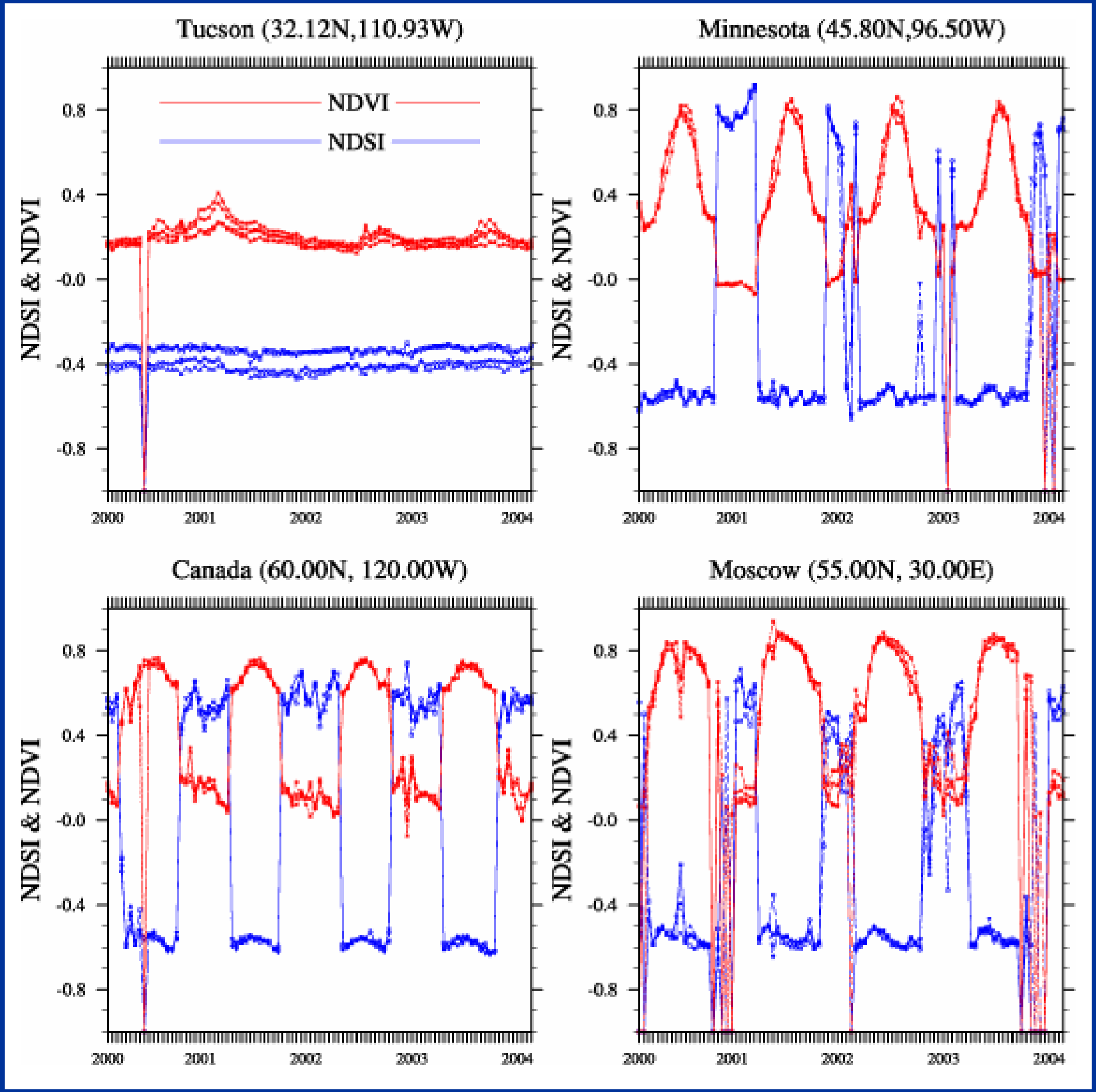


How can you be sure it's snow?

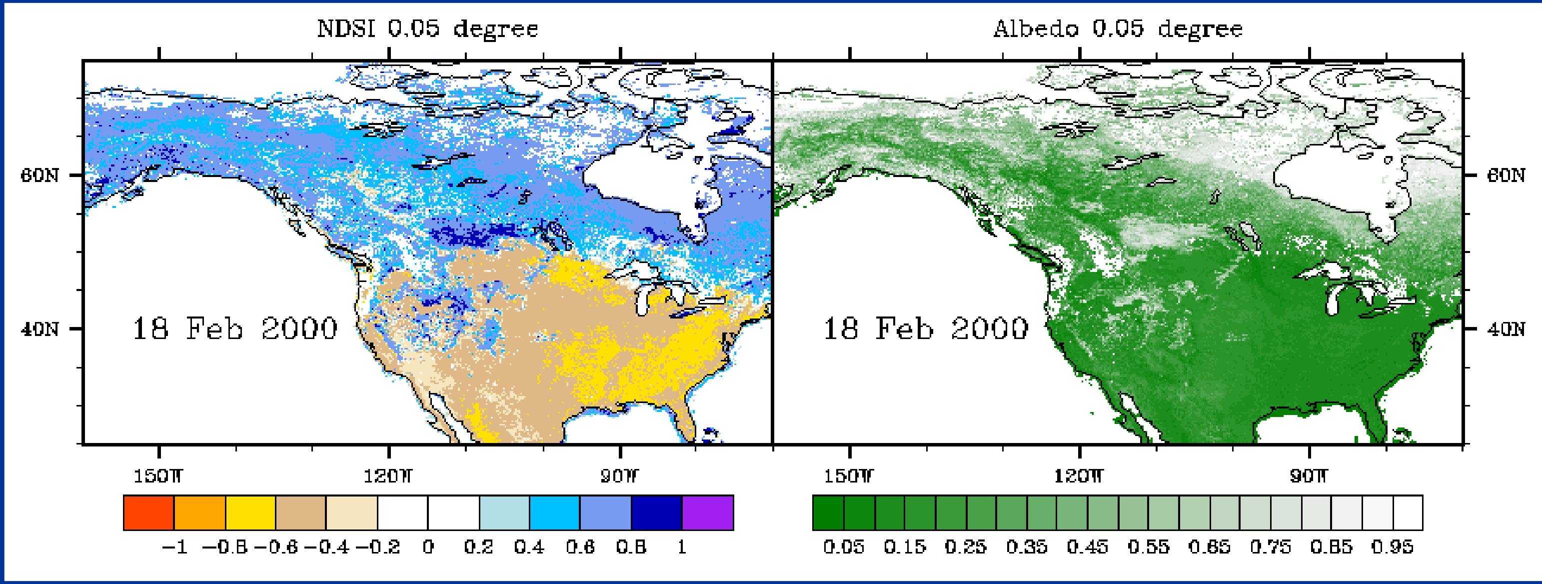
- NDSI: Exploiting the differences in spectral signature between visible and NIR albedo.

$$NDSI = \frac{\alpha_{4(0.55)} - \alpha_{6(1.64)}}{\alpha_{4(0.55)} + \alpha_{6(1.64)}}$$

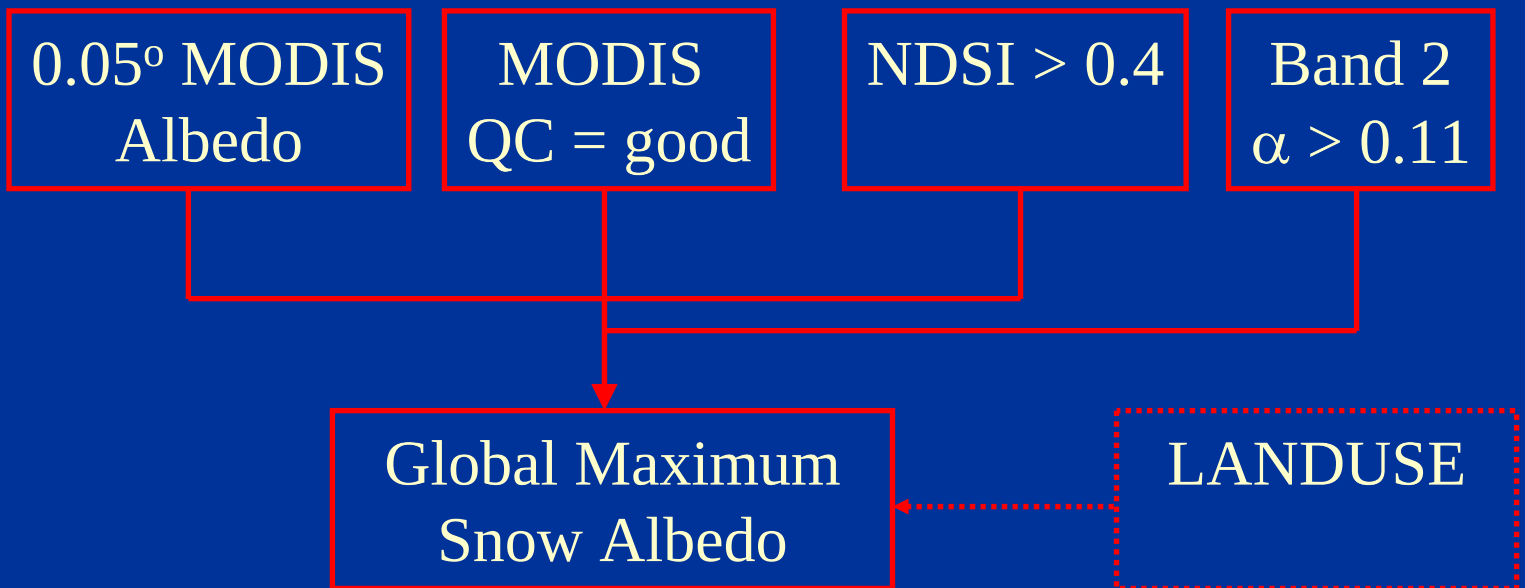
NDSI and NDVI



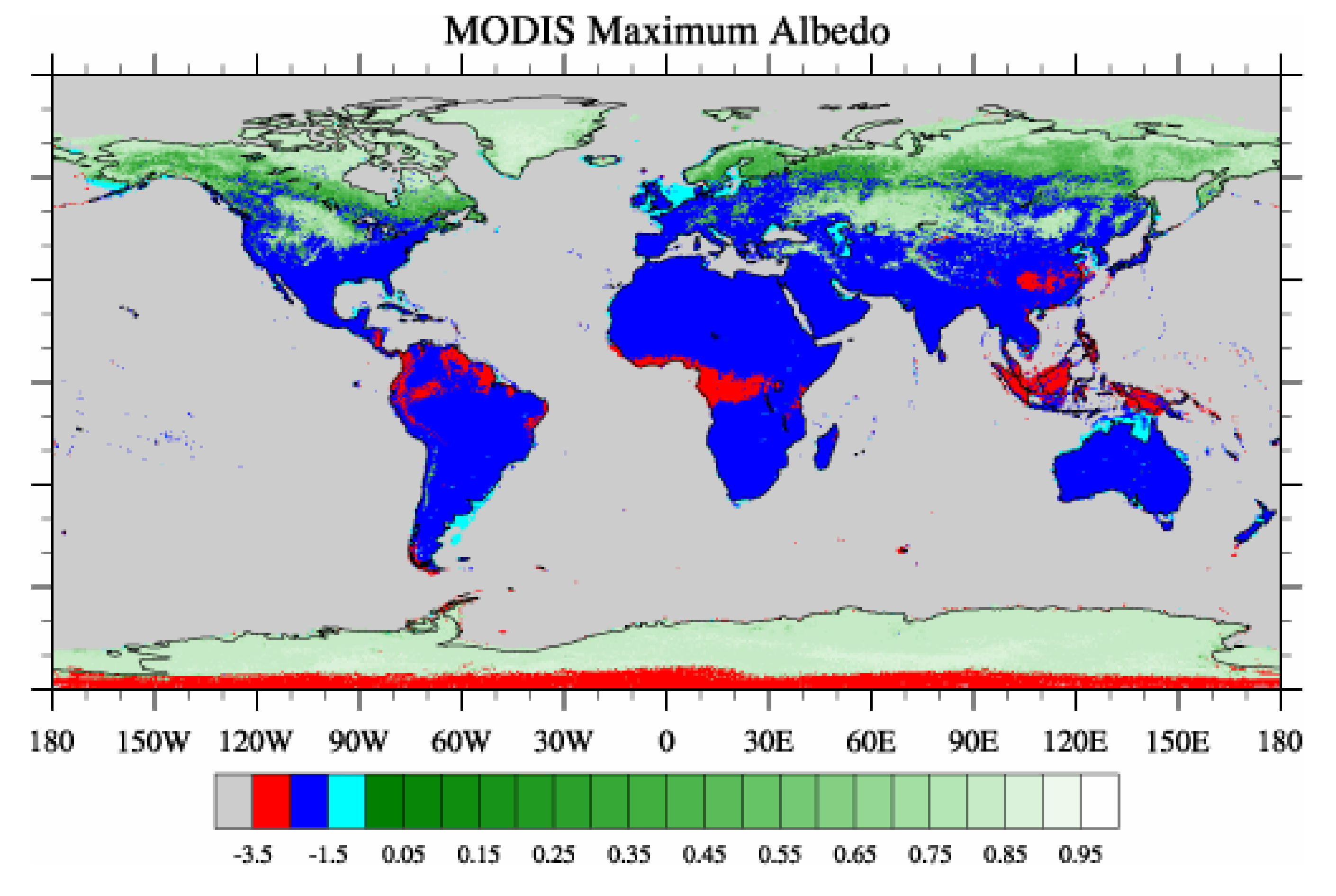
NDSI and Snow Albedo



Current Logic Structure

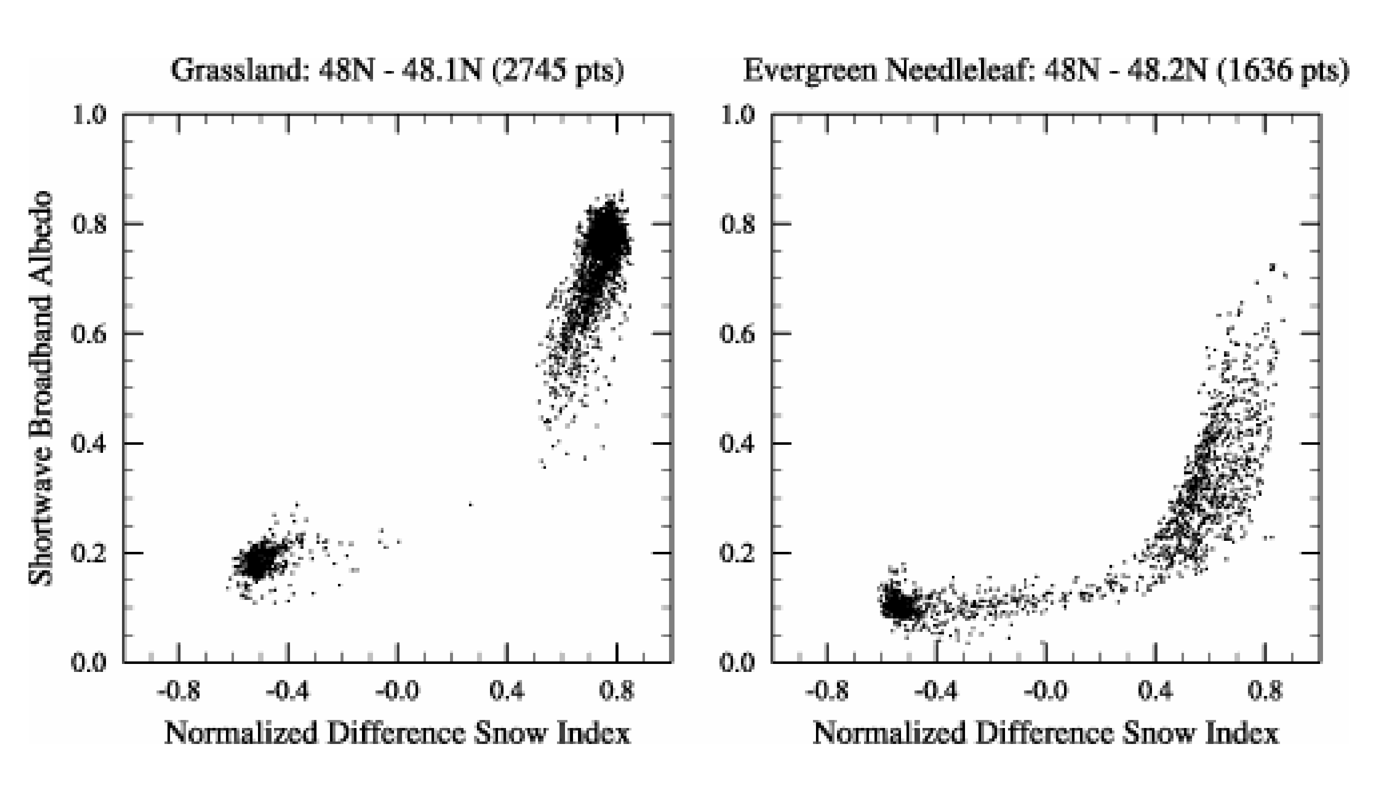


Maximum Snow Albedo

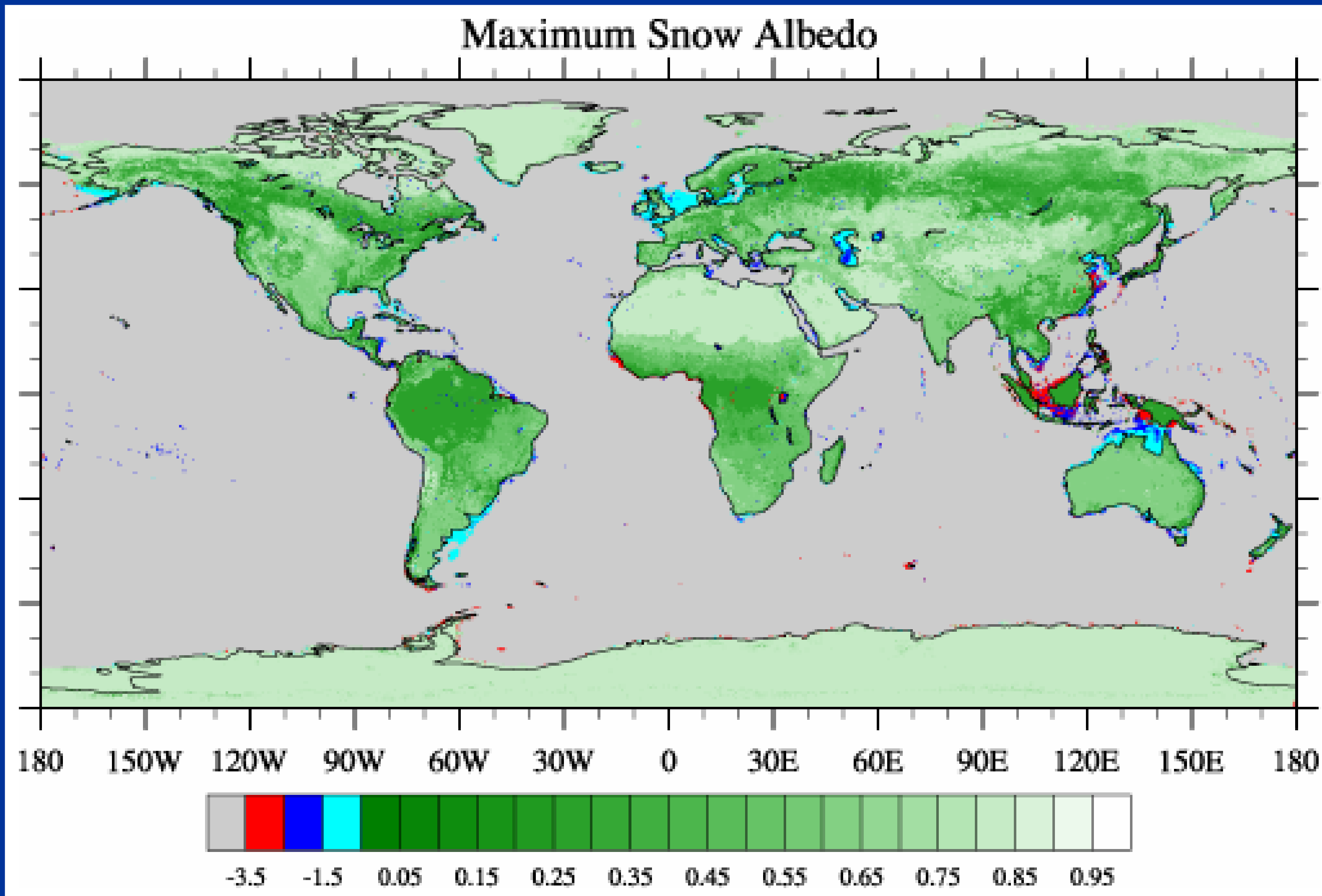


Merging Land Use and Albedo

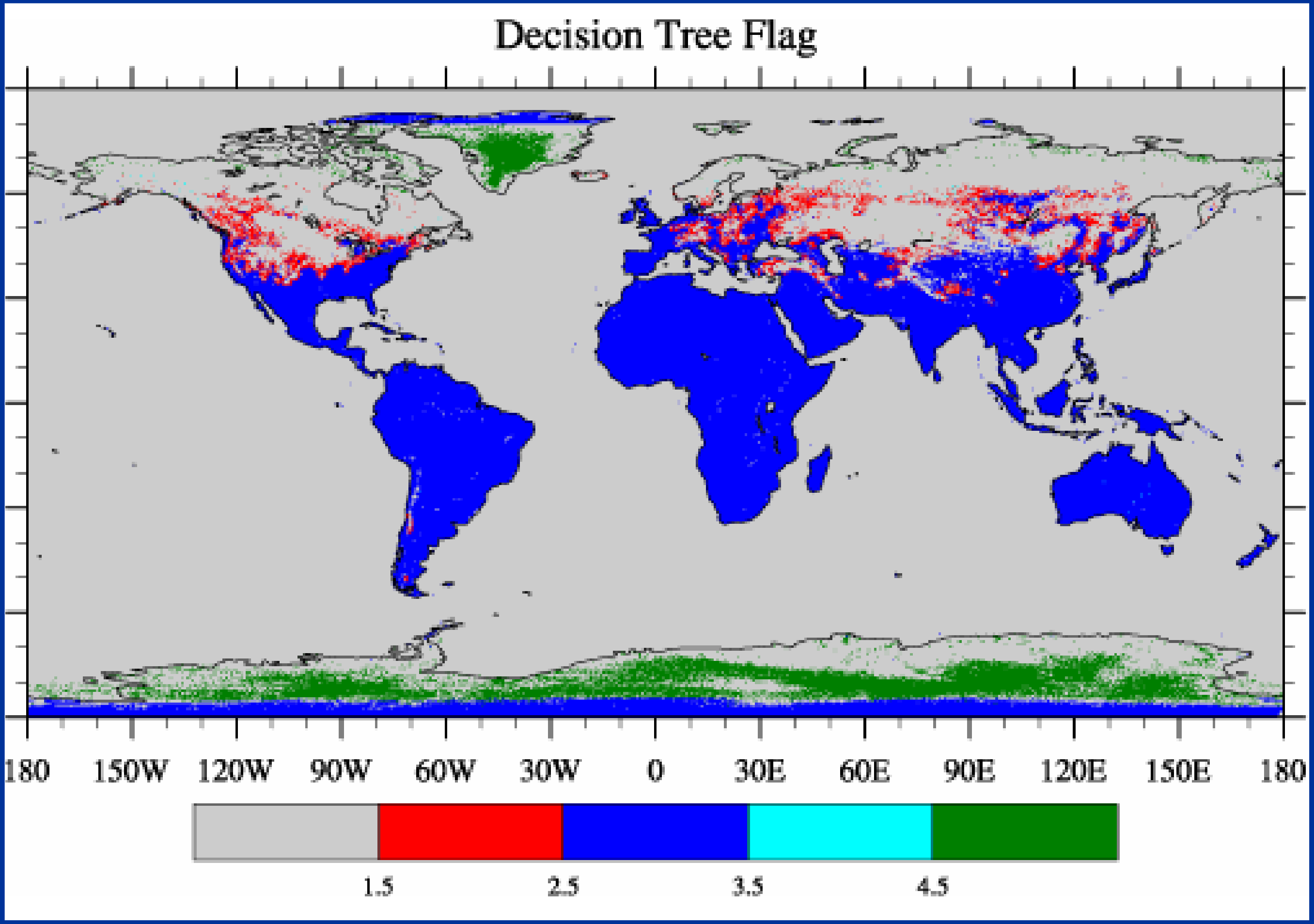
High spread in albedo among same land use type…
What value to use?



Final 0.05° Maximum Snow Albedo



Data Flag Layer

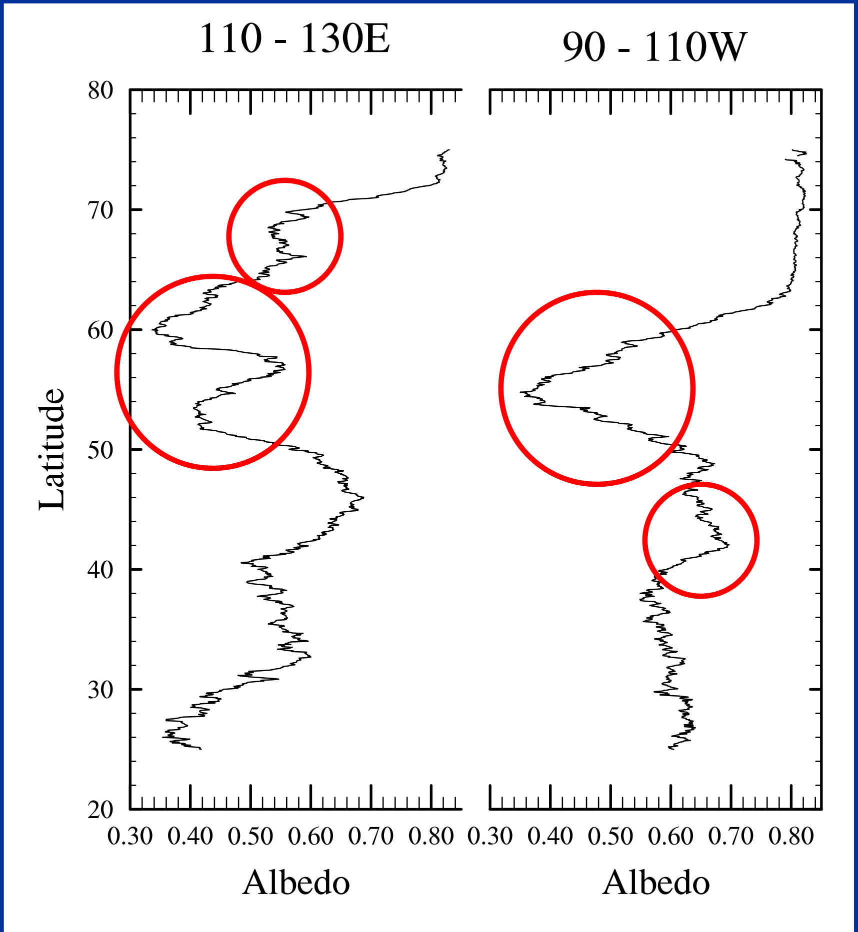


Decision Tree:

- Grey: "Good" snow-covered albedo
- Red: Fill with average of same land cover in 2° area surrounding
- Blue: If red filter < 100 values, fill with latitude average
- Light blue: If higher, replaced non-snow covered value
- Green: Albedo > 0.84 decreased to global ice average of 0.84

Comparison with RK

0.05deg MODIS



RK Figure 5

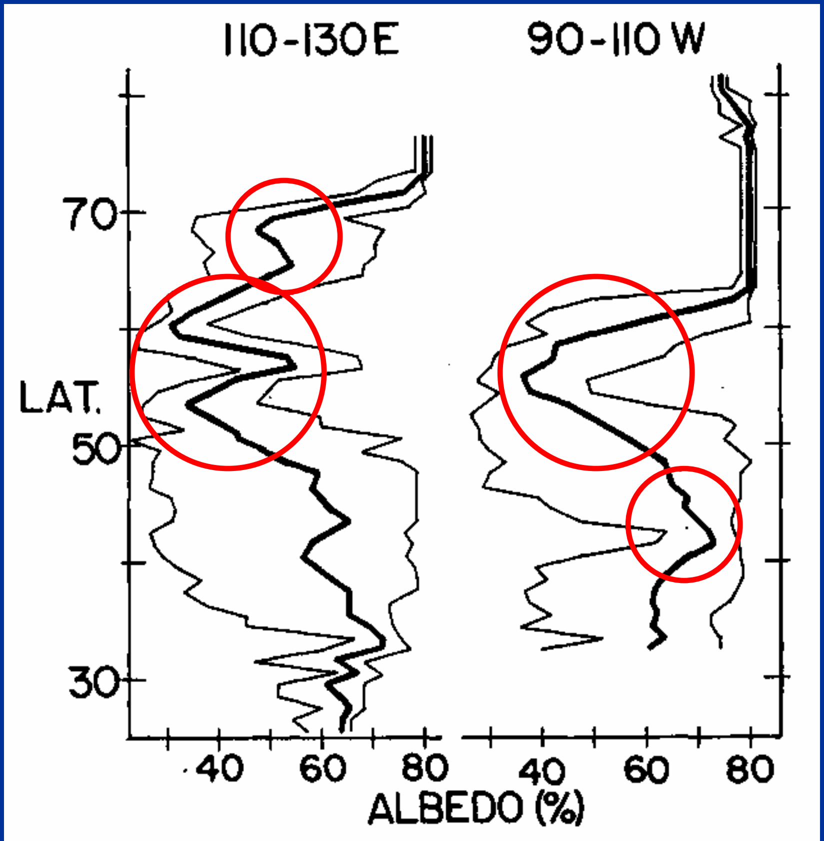


FIG. 5. Maximum surface albedo of seasonally snow covered lands in 1° latitudinal steps averaged across two 20° wide longitudinal swaths (heavy lines). The range in albedo for the 20 cells in each latitudinal zone is shown with thin lines.

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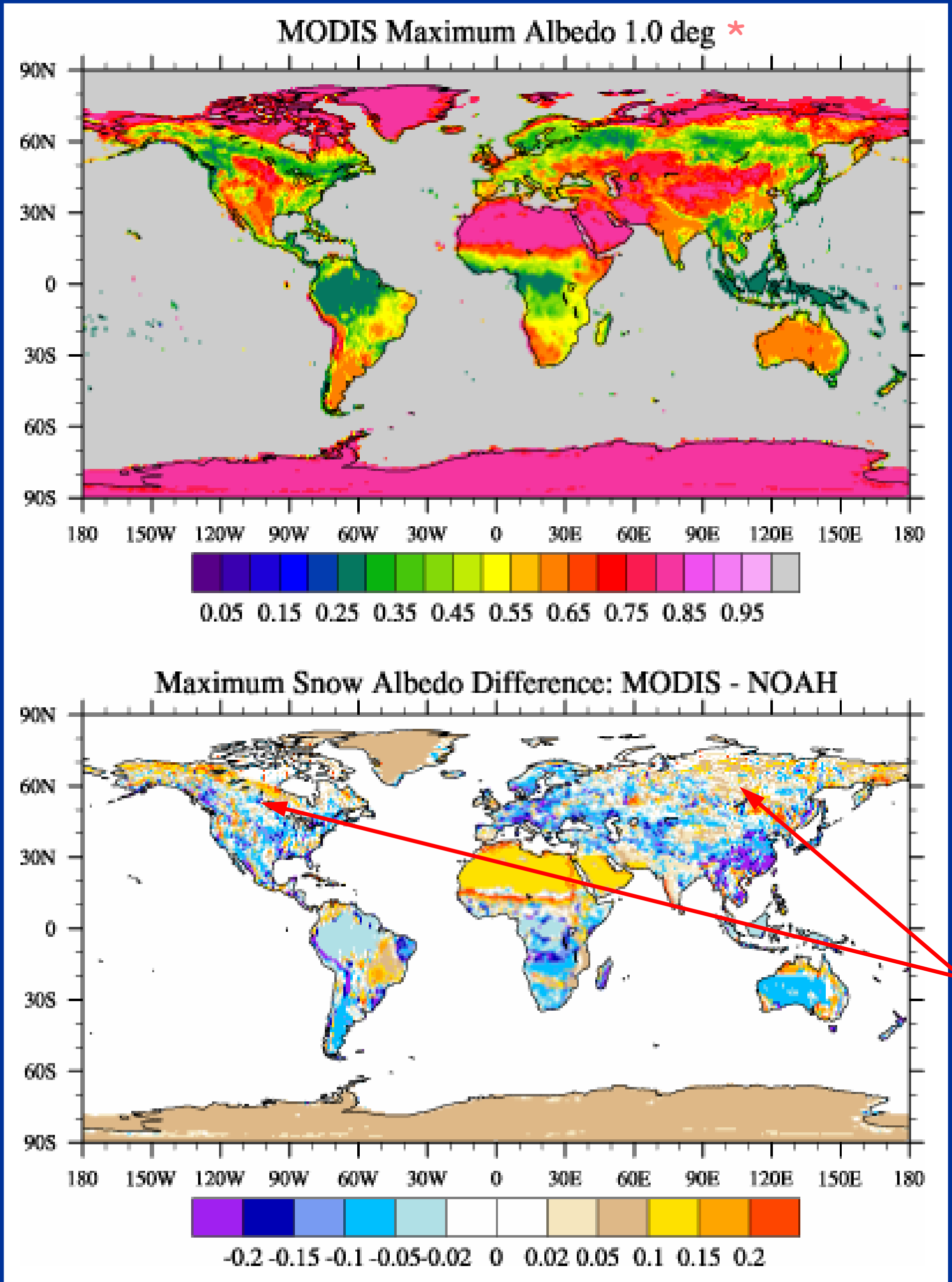
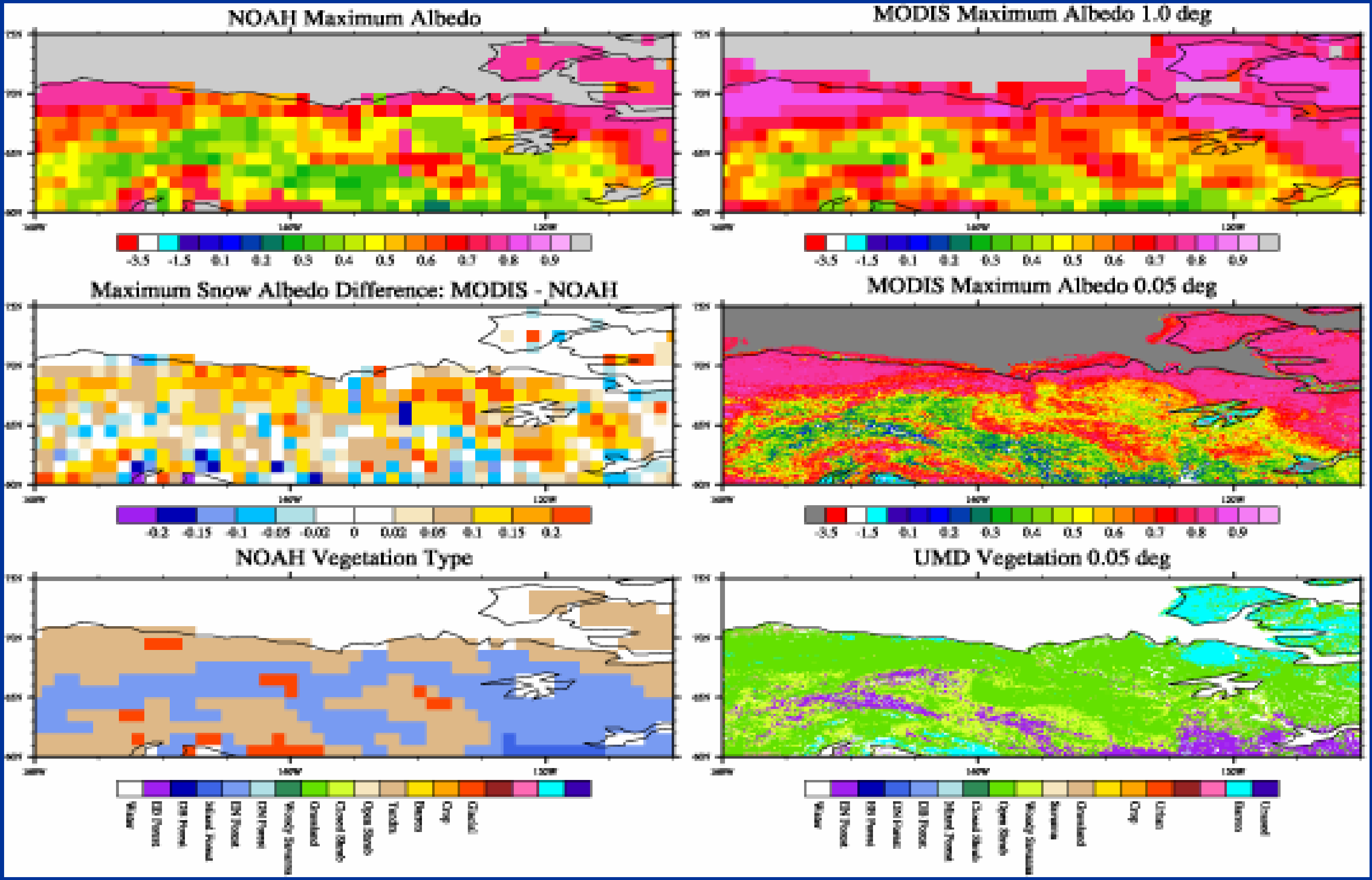


Application of MODIS Maximum Snow Albedo to NCEP Land Surface Model

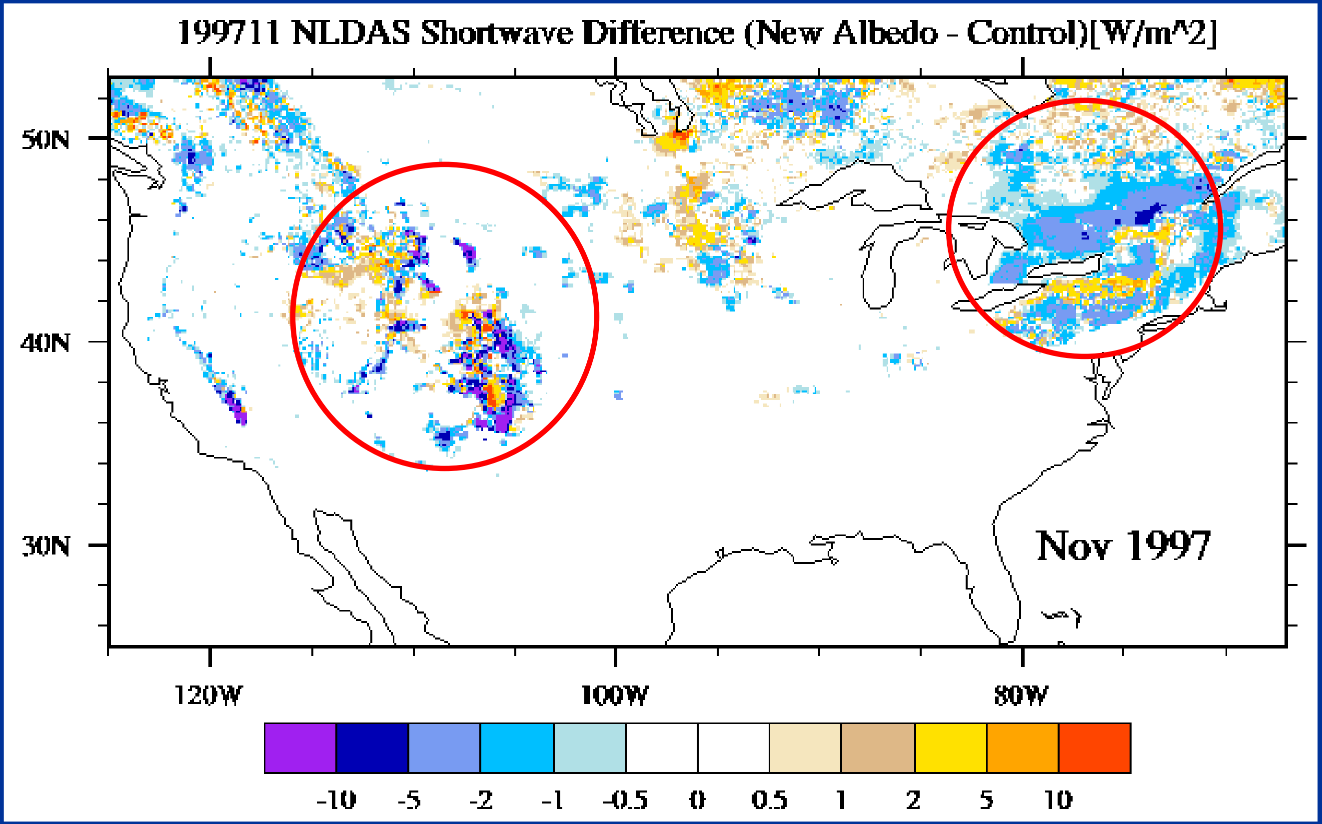
Up to 0.2 difference in high/mid latitudes can greatly affect surface energy balance, snow depth, and snow melt timing

*Note: 0.05° maximum albedo dataset downscaled to 1° to compare with NOAH data

High-resolution Improvements



Application of MODIS Maximum Snow Albedo to NLDAS



Over 10 W/m^2 difference in southern Canada and mountain regions of United States

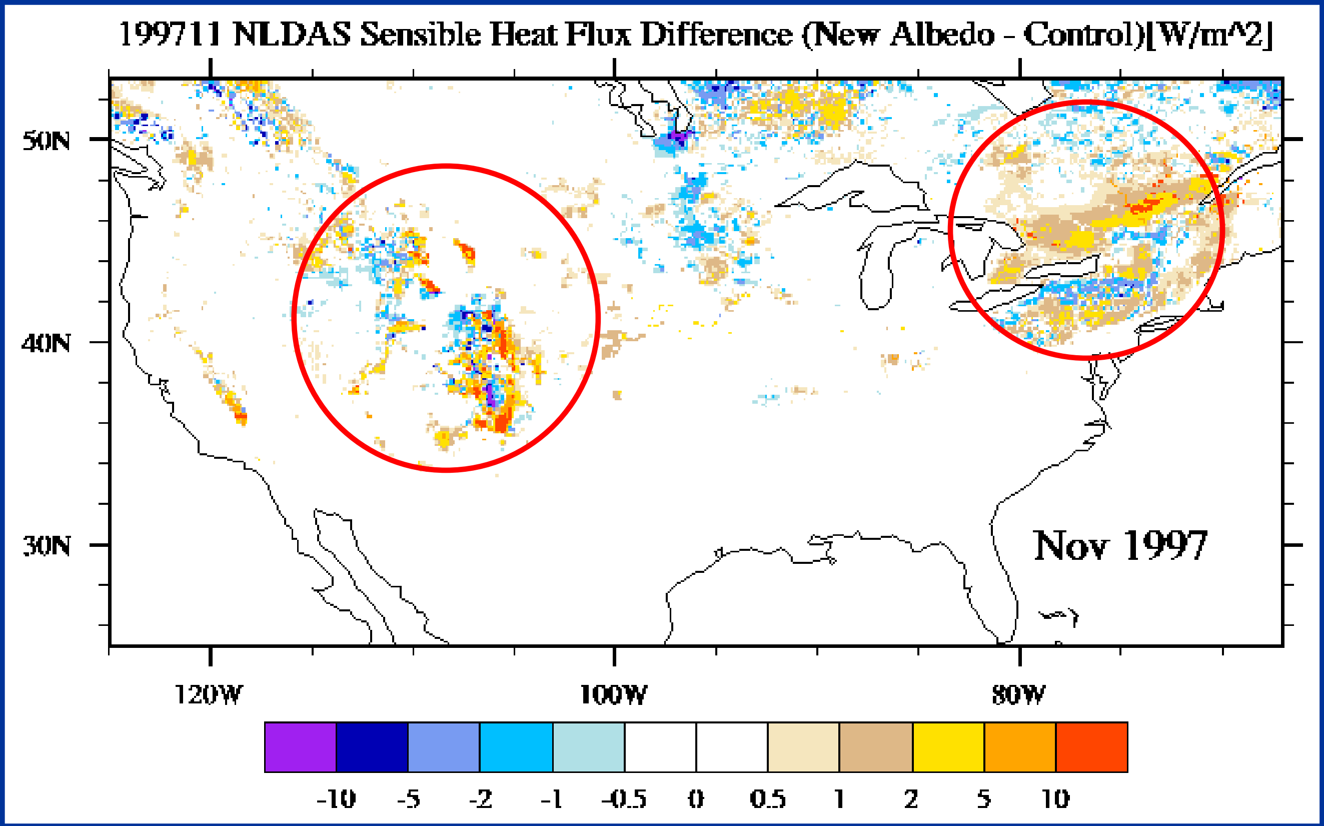
*Note: 0.05° maximum albedo dataset downscaled to 0.125° to use in NLDAS

Upward Shortwave Difference

North America Land Data Assimilation System: 0.125° NOAH model forced with EDAS output

•Winter simulation: From Nov. 1997 to May 1998

Application of MODIS Maximum Snow Albedo to NLDAS



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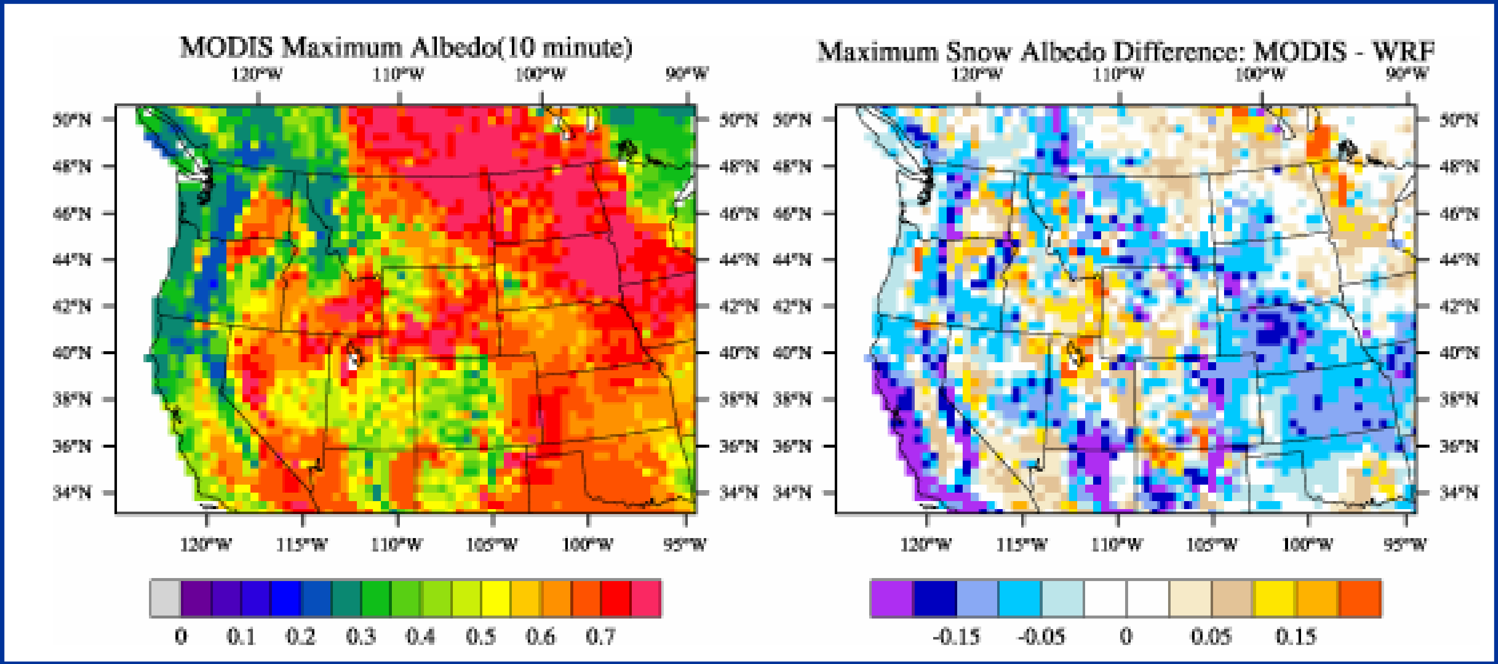
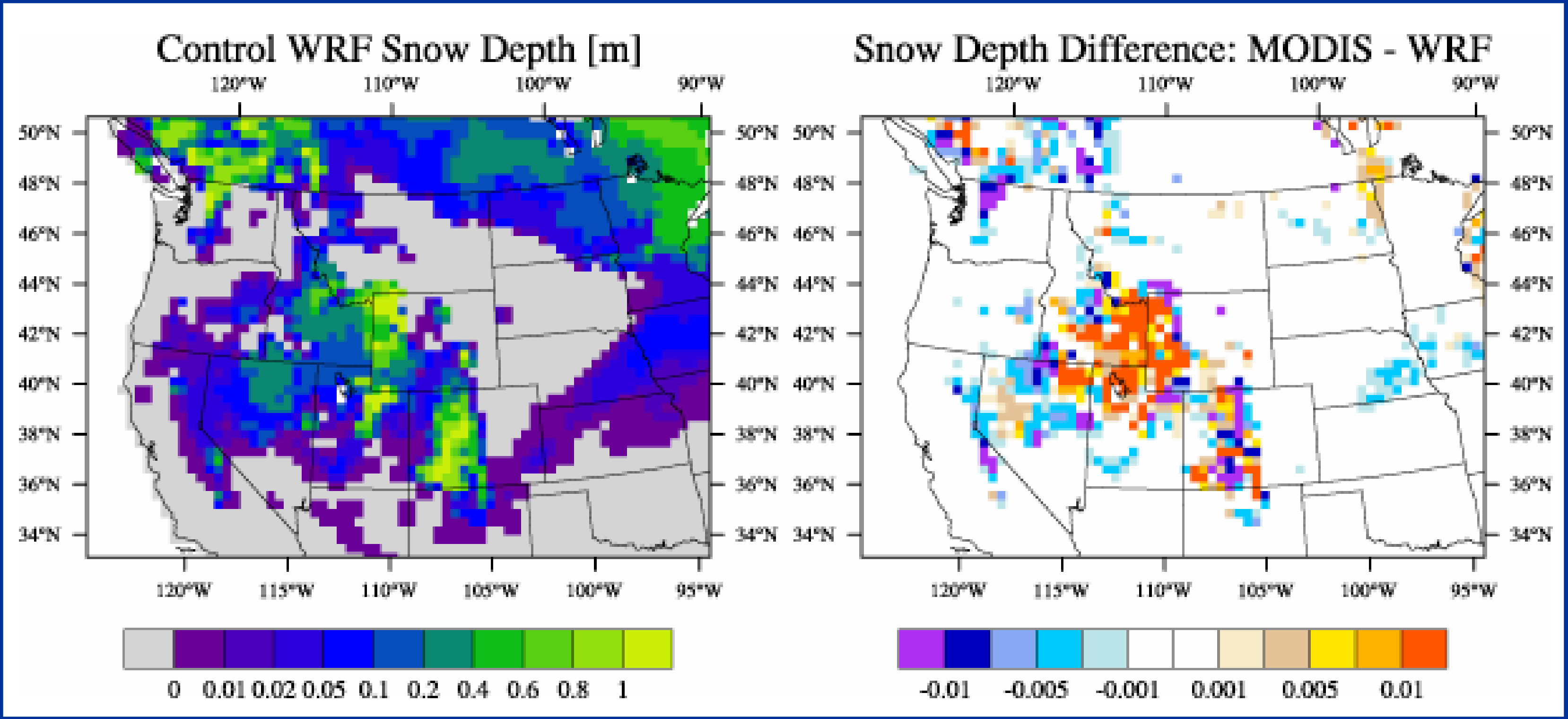
Application of MODIS Maximum Snow Albedo to WRF-ARW/NOAH



Maximum Snow Albedo and Difference

- WRF-ARW Model: 10min(0.144°) input dataset converted from 0.05° by simple average; model run at 40km; initialized with Eta output;
- Winter simulation: 24hr simulation beginning 00Z 10 Feb 2005
- Significant albedo change of greater than 0.05 over most of the Western U.S.

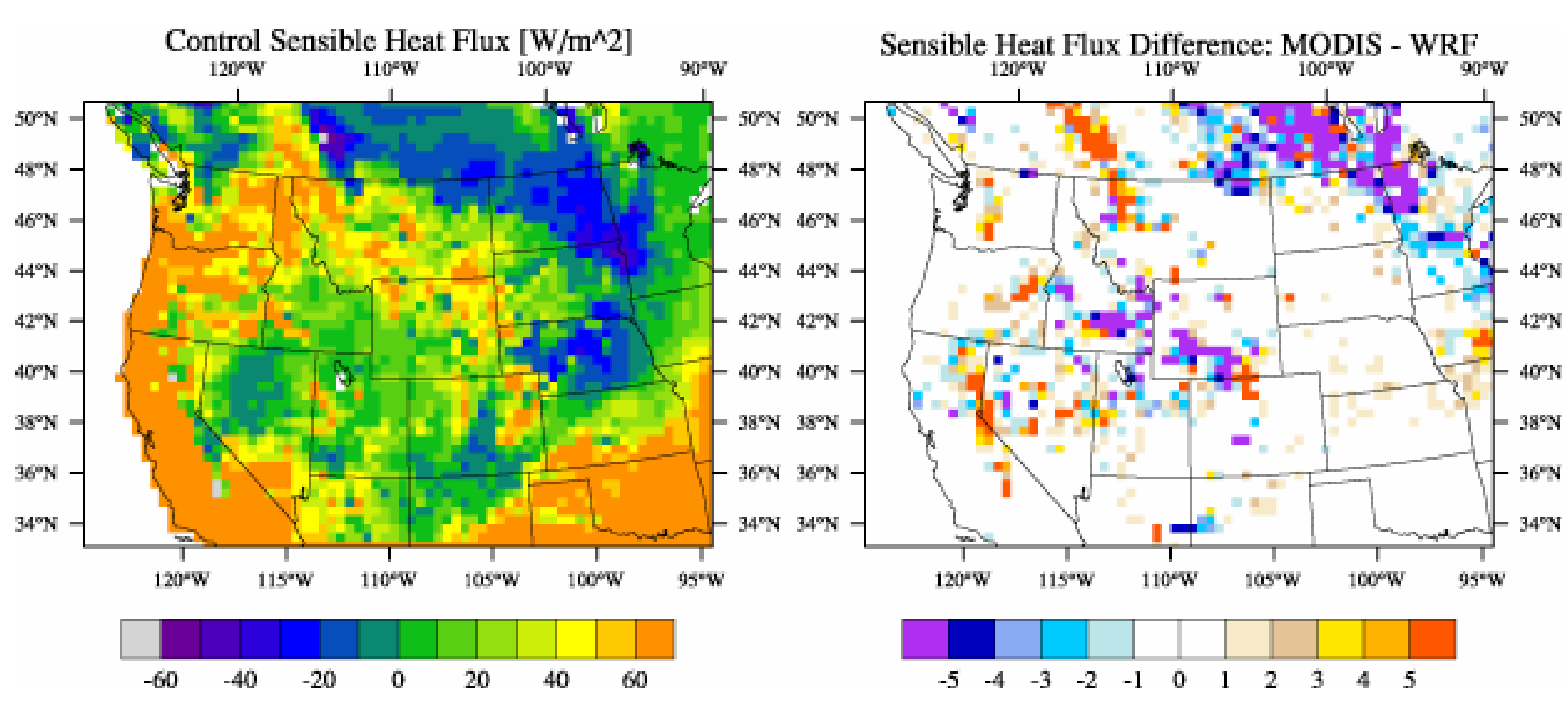
Application of MODIS Maximum Snow Albedo to WRF-ARW/NOAH



Simulation Snow Depth and Difference

- Only small differences in simulated snow depth
- Note pattern of snow cover

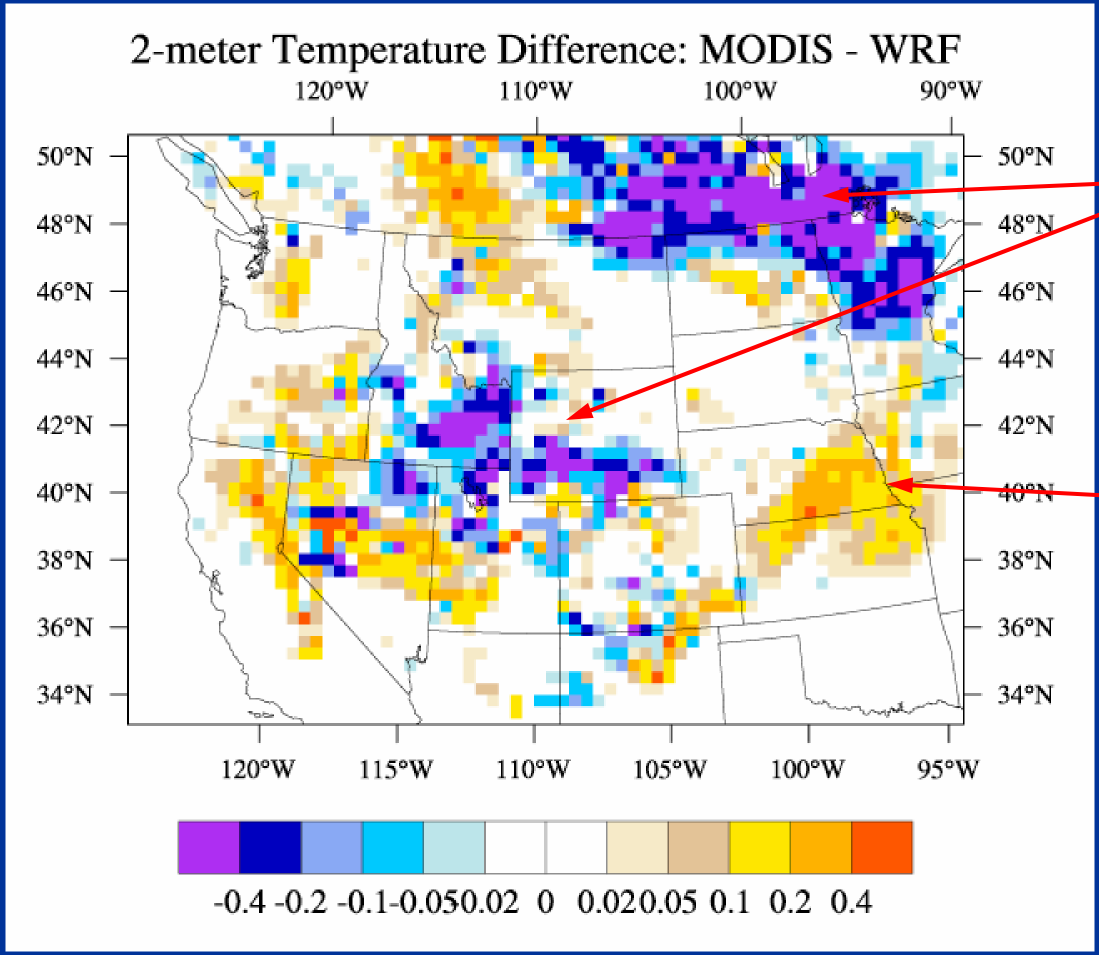
Application of MODIS Maximum Snow Albedo to WRF-ARW/NOAH



Simulation Sensible Heat Flux and Difference

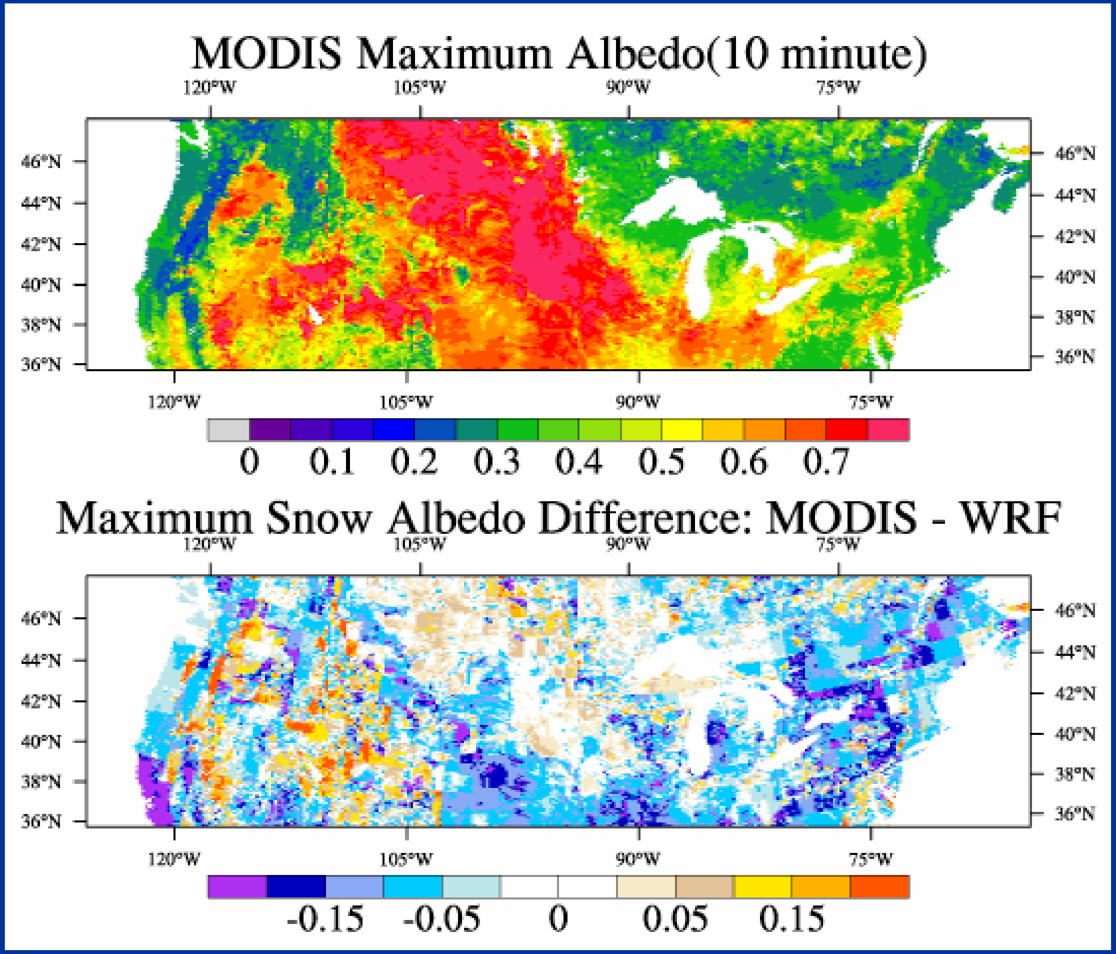
- Up to 5 W/m2 differences in SHF
- Mostly decreases due to lack of snow in lower Plains

Application of MODIS Maximum Snow Albedo to WRF-ARW/NOAH



- Up to 0.5 C decreases in 2-m temperature in regions of high snow cover and significant albedo change
- Greater than 0.1 C increase in 2-m temperature even when snow depth is less than 1cm

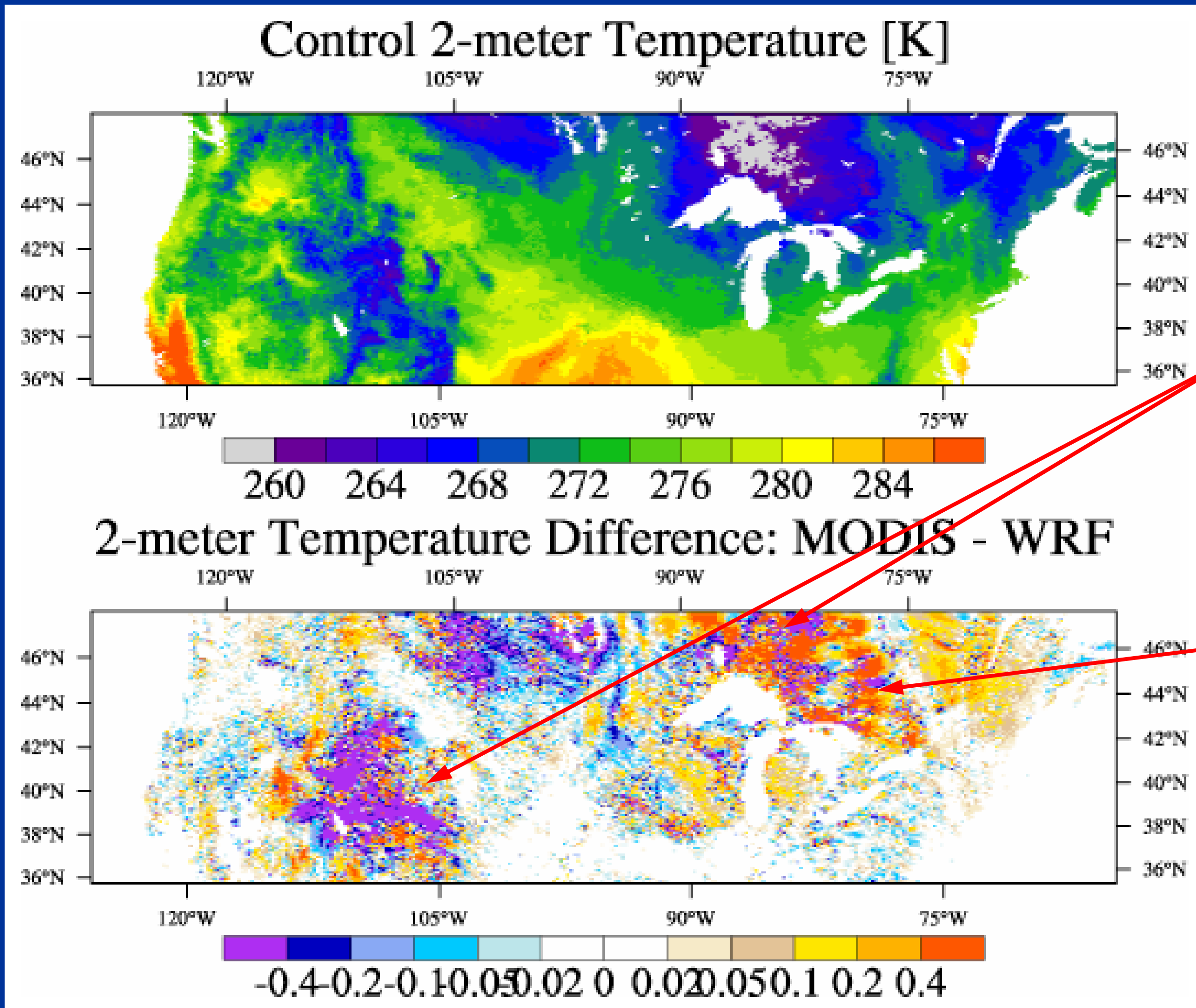
Application of MODIS Maximum Snow Albedo to WRF-NMM/NOAH



- WRF-NMM Model: 10min(0.144°) input dataset converted from 0.05° by simple average; model run at 12km; initialized with Eta output;

- Winter simulation: 24hr simulation beginning 12Z 31 Jan 2006

Application of MODIS Maximum Snow Albedo to WRF-NMM/NOAH



- Again we see up to 0.5 C decreases in 2-m temperature in regions of high snow cover and significant albedo change
- Also see greater than 0.5 C increase in 2-m temperature in several regions

What's next?

- Working with Ken Mitchell's group on validation beyond sensitivity tests in coupled systems such as WRF
- Implement into operational GFS and NAM

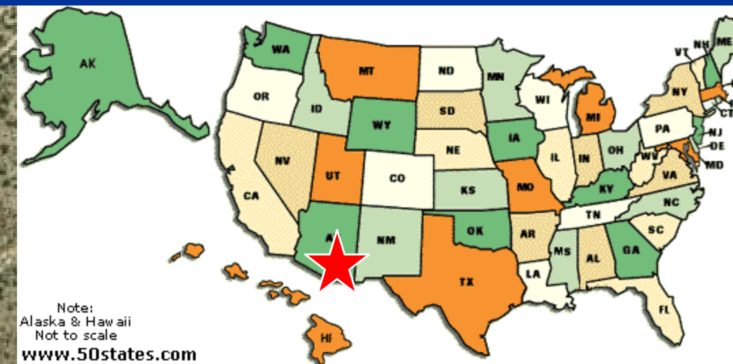
Application and Derivation of Global Green Vegetation Fraction Using NDVI

J.Miller, M.Barlage, X.Zeng, H.Wei; GRL 2006
Zeng et al. 2000; Zeng et al. 2003

Introduction

- Use satellite Normalized Difference Vegetation Index (NDVI) data to improve land surface model representation of vegetated surface
- Derive global 2km green vegetation fraction(GVF) using MODIS data
- Compare with existing Noah GVF
- Implement into NLDAS

Tucson Landscape



Remote Sensing Products Used

- NDVI(MODIS/AVHRR): 1-2km global, v4, 2000-2004 available; filled product of Eric Moody
- Land Cover(MODIS): 1 minute global, v4

GVF calculation

Zeng et al. 2000

- Use NDVI = $\dfrac{r_2 - r_1}{r_2 + r_1}$

where r_1 and r_2 are the 1km MODIS red and NIR reflectance

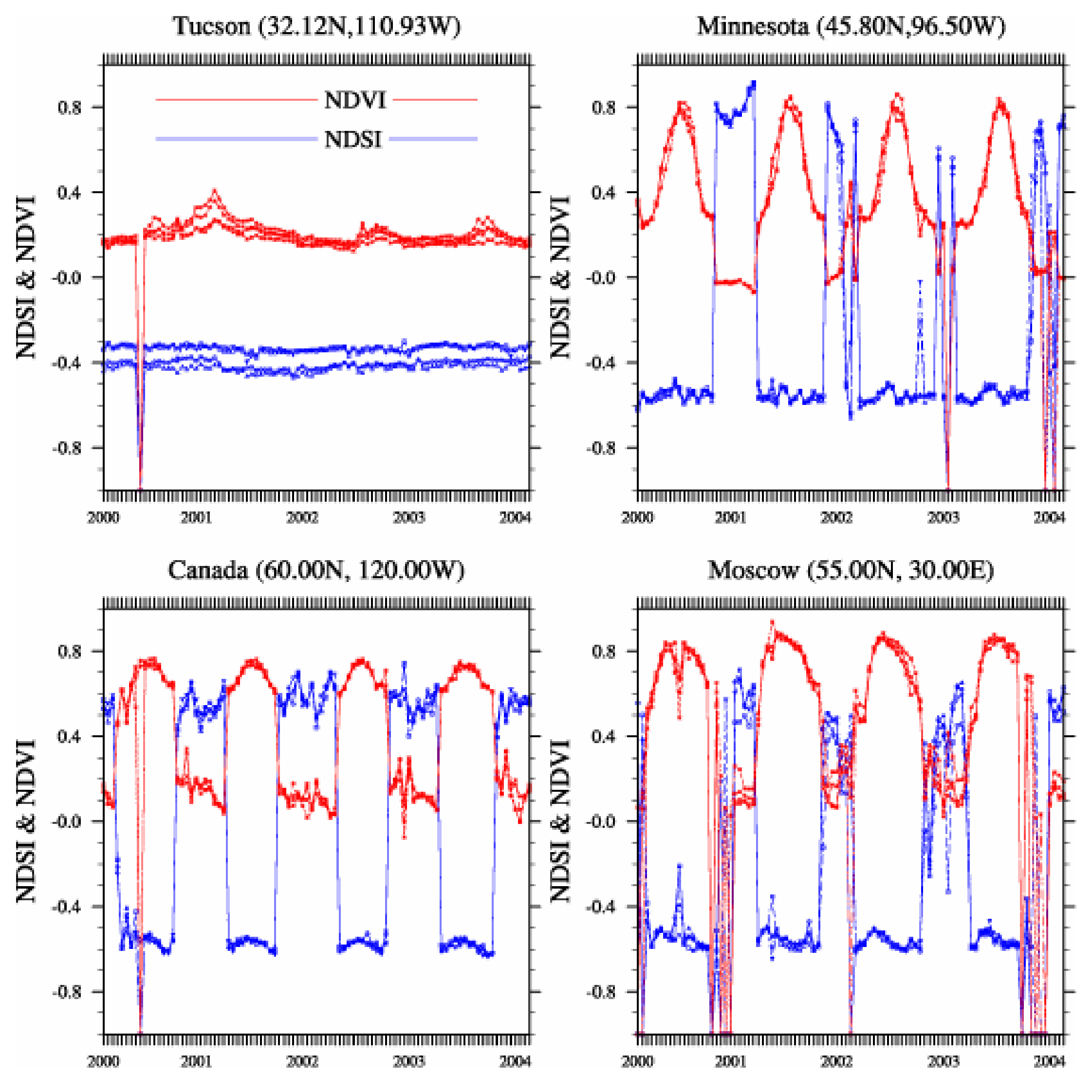
- For each reflectance:

$$r_i = GVF \cdot r_{i,veg} + (1 - GVF) \cdot r_{i,soil}$$

- Combine equations to obtain seasonal max:

$$GVF = \frac{NDVI_{\max} - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$

NDSI and NDVI



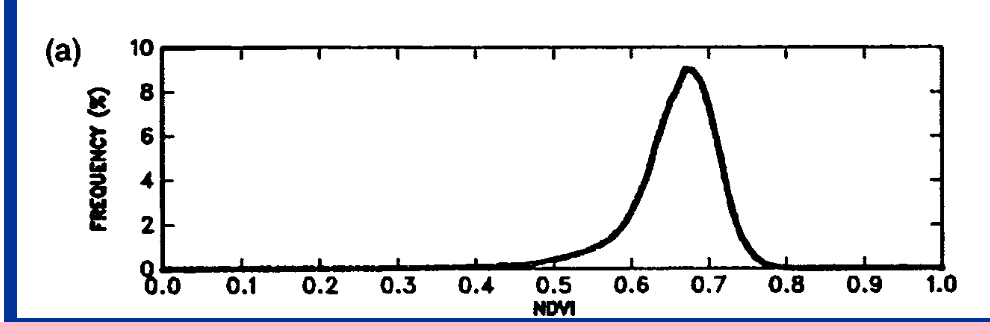
GVF calculation

Zeng et al. 2000

$$GVF = \frac{NDVI_{\max} - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}}$$

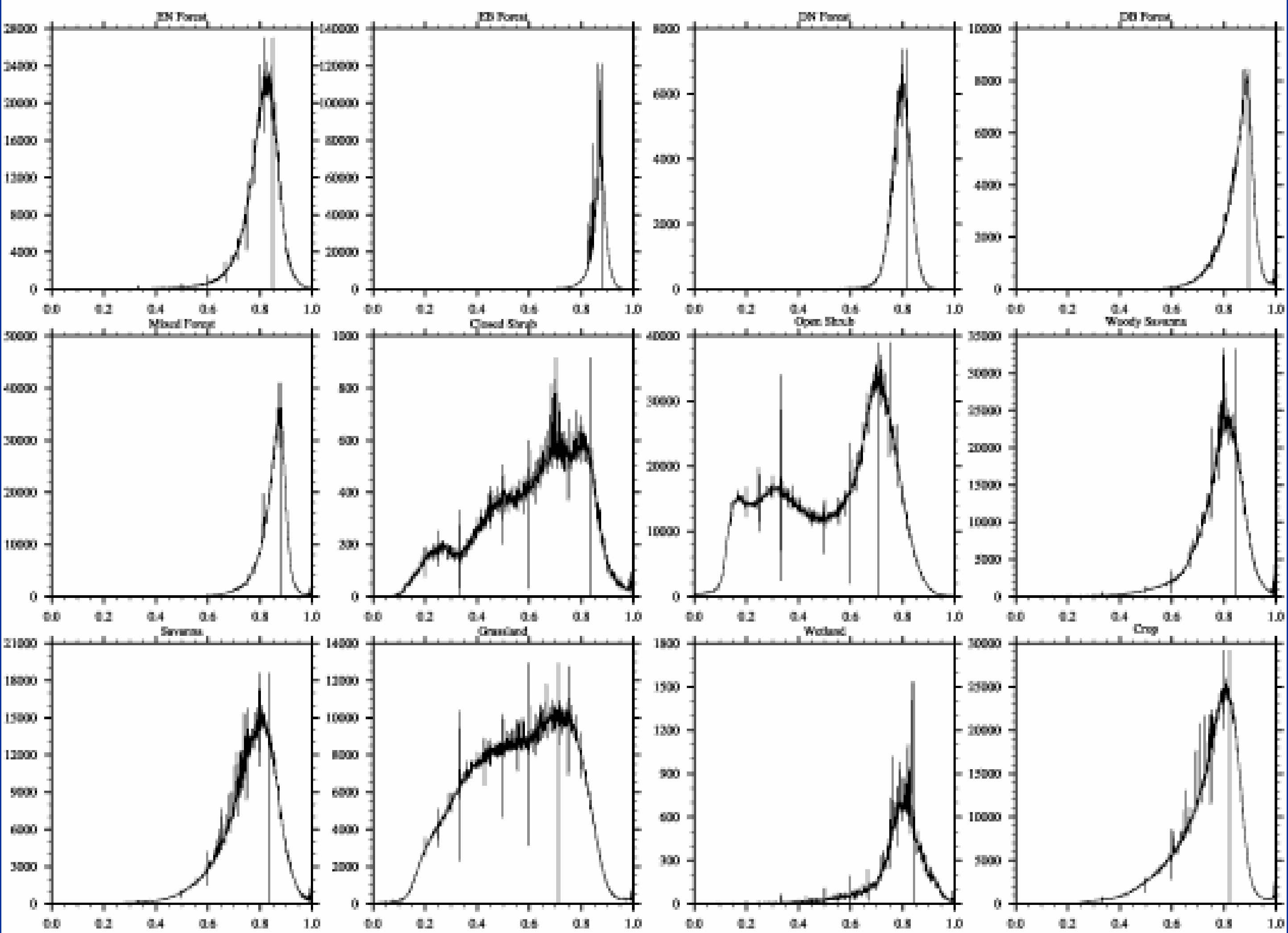
	IGBP land	Pixel%	$NDVI_{veg}$	GVF
1	Evergreen needleleaf forest	5.03	0.63	0.90
2	Evergreen broadleaf forest	9.39	0.69	0.93
3	Deciduous needleleaf forest	1.52	0.63	0.92
4	Deciduous broadleaf forest	2.50	0.70	0.90
5	Mixed forest	4.86	0.68	0.88
6	Closed shrubland	2.01	0.60	0.72
7	Open shrubland	13.96	0.60	0.39
8	Woody savanna	7.87	0.62	0.86
9	Savanna	7.21	0.58	0.81
10	Grassland	8.53	0.49	0.71
11	Permanent wetland	1.02	0.56	0.85
12	Cropland	10.89	0.61	0.86
14	Natural vegetation	10.80	0.65	0.85
16	Barren	14.22	0.60	0.11

To find $NDVI_{veg}$ and $NDVI_{soil}$, we introduce 2km IGBP land type classifications

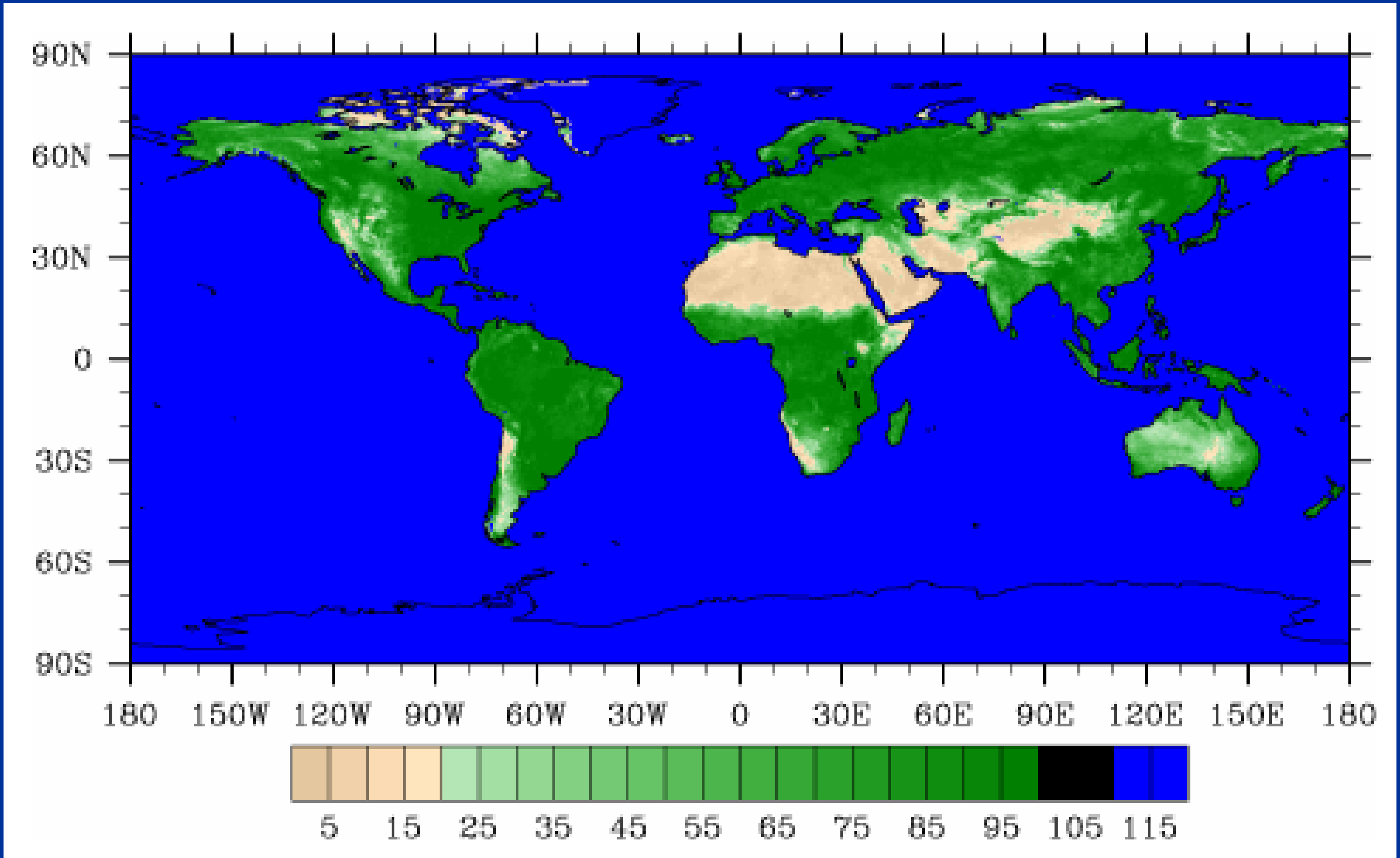


Histogram of evergreen broadleaf

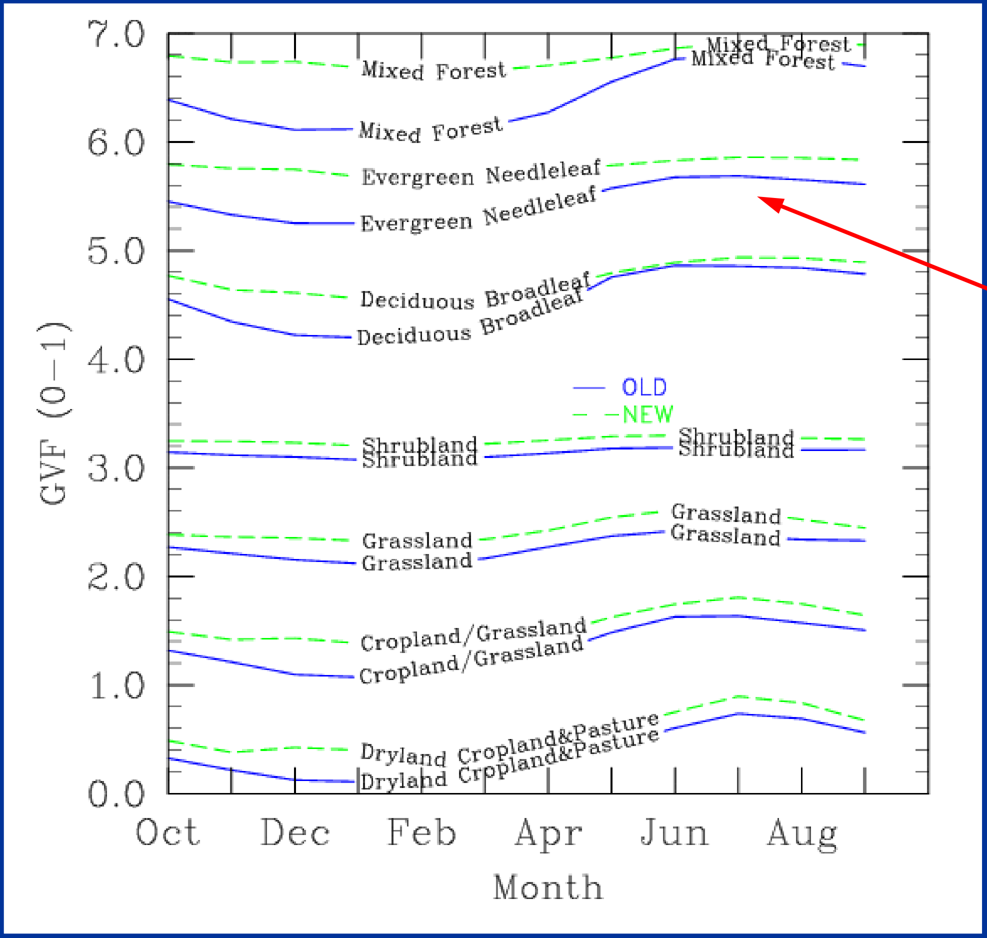
MODIS NDVI Histograms



Global GVF Data



NLDAS GVF Data



GVF for the 7 most prevalent land cover types in NLDAS

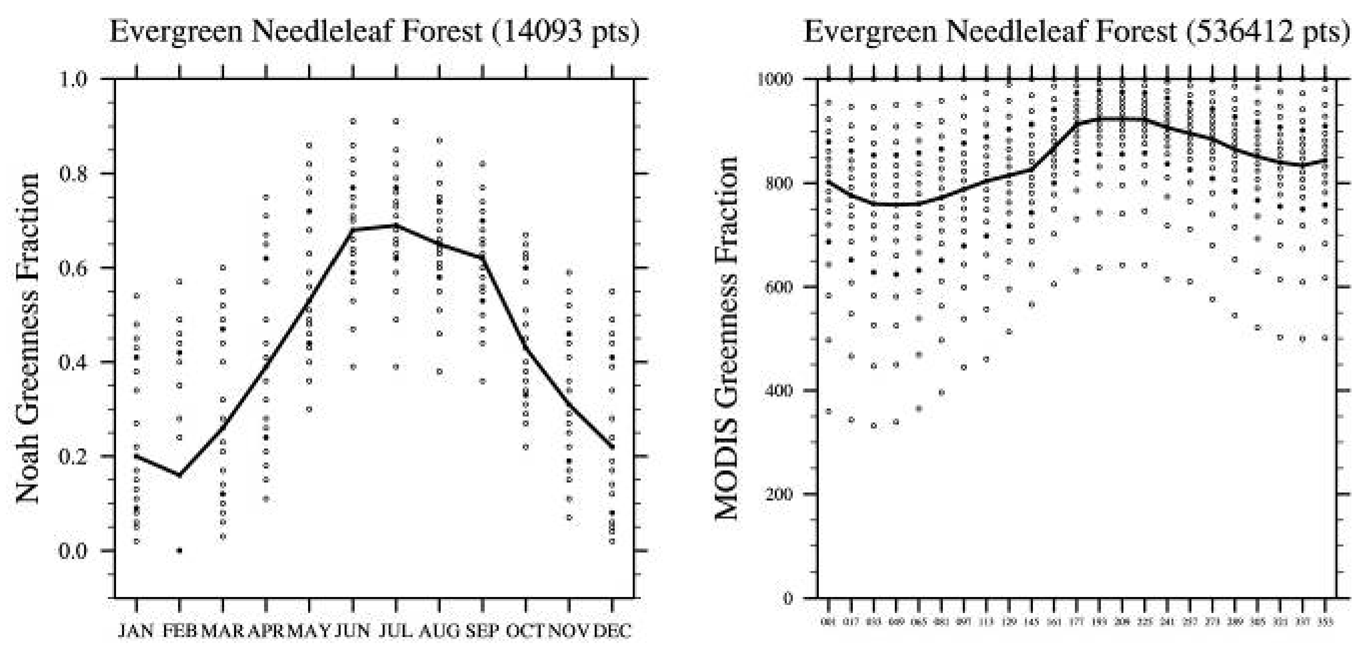
- More realistic annual variation in GVF for needleleaf forest land cover

- Systematically higher in all land cover categories

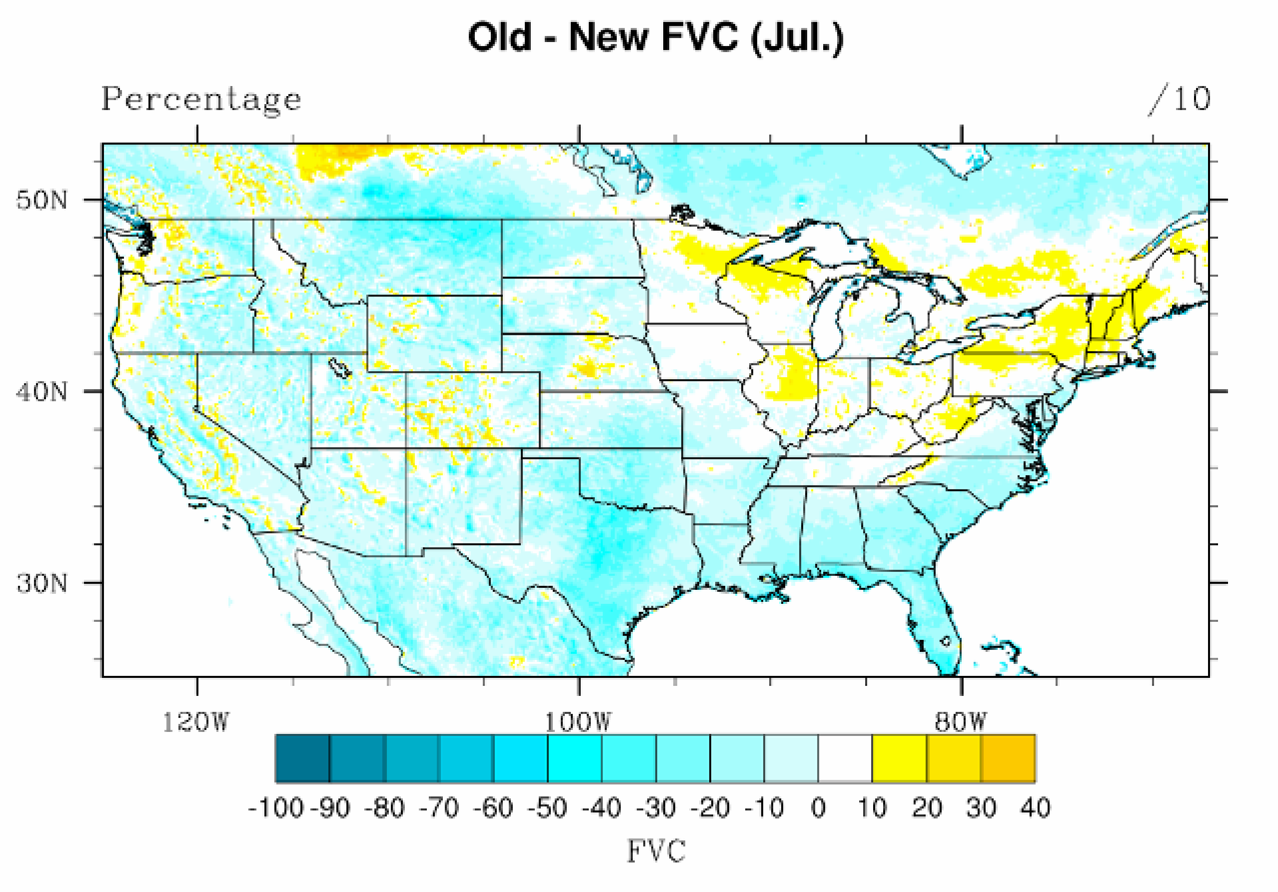
NLDAS GVF Data

Noah 1/8 degree monthly

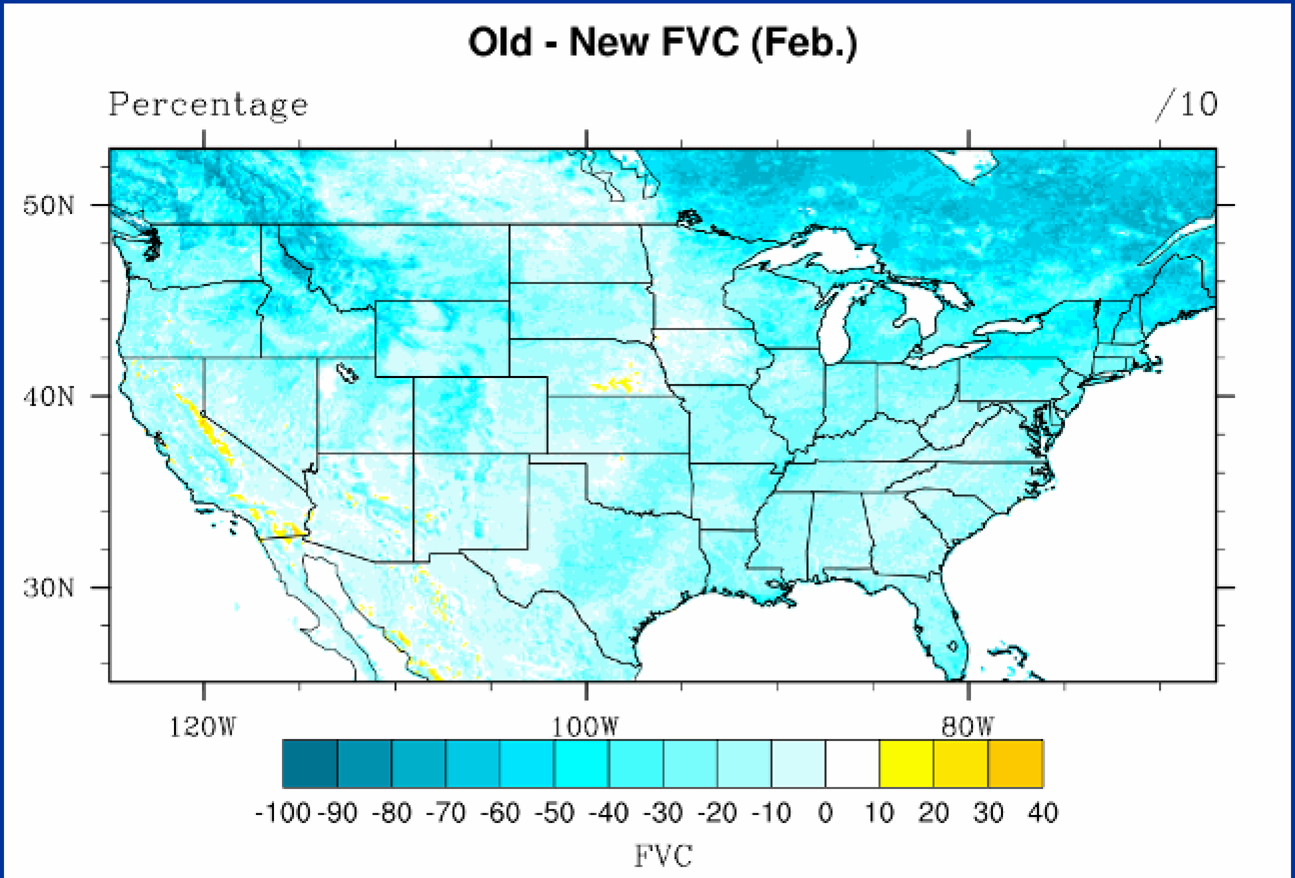
MODIS 2km 16-day



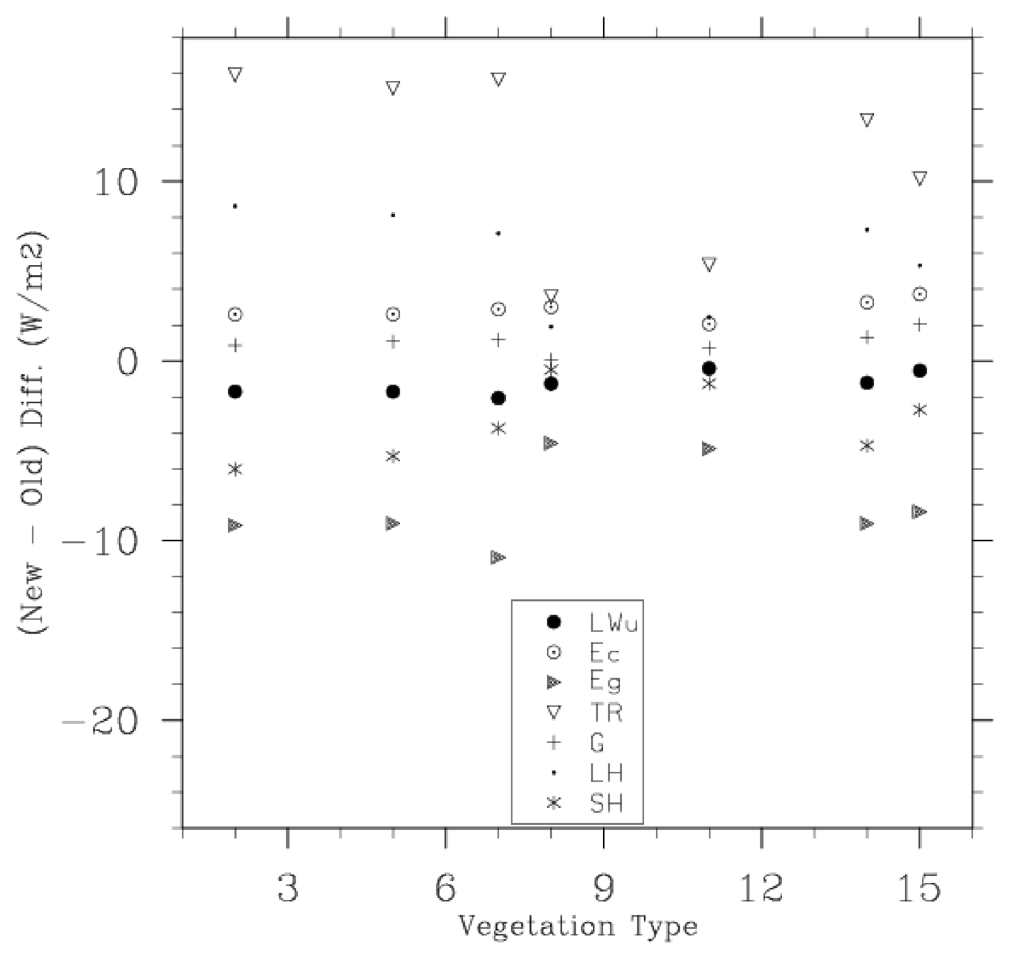
NLDAS GVF Data



NLDAS GVF Data



NLDAS GVF Results



- Addition of new GVF dataset results in an increase of transpiration (~15W/m2) and canopy evaporation (~3W/m2)
- Balanced by a decrease in ground evaporation (~10W/m2)
- Overall increase in LHF(~8W/m2) is balanced by decreases in SHF(~6W/m2) and Lwup(~2W/m2)

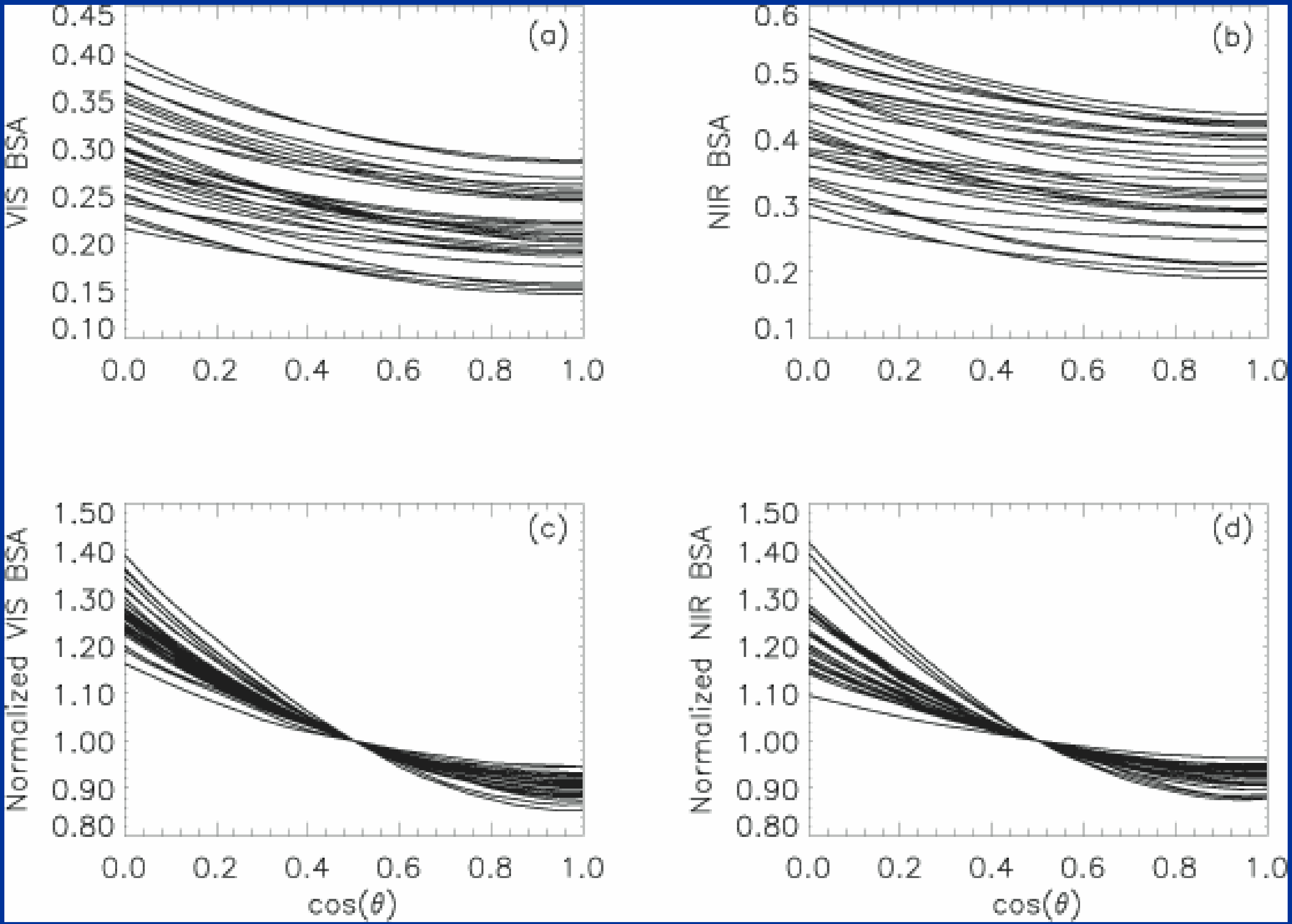
Conclusions and Ongoing Work

- Inclusion of GVF makes a significant difference to land surface representation
- Removes annual variation in GVF for forest land cover types
- Technique can be used at any resolution
- Initial results indicate surface energy budget redistribution which could be important in future
- Use 12-year AVHRR data and 1km MODIS

Solar zenith angle dependence of desert and vegetation albedo

Z. Wang,M.Barlage,X.Zeng,R.E.Dickinson,C.Schaaf; GRL 2005
Z.Wang, X.Zeng, M.Barlage; JGR 2006

MODIS Zenith Angle Dependence



- MODIS albedo as a function of cos(θ) at 30 desert sites globally

- Similar shape in both black-sky and white-sky dependence

Zenith Angle Dependence Formulations

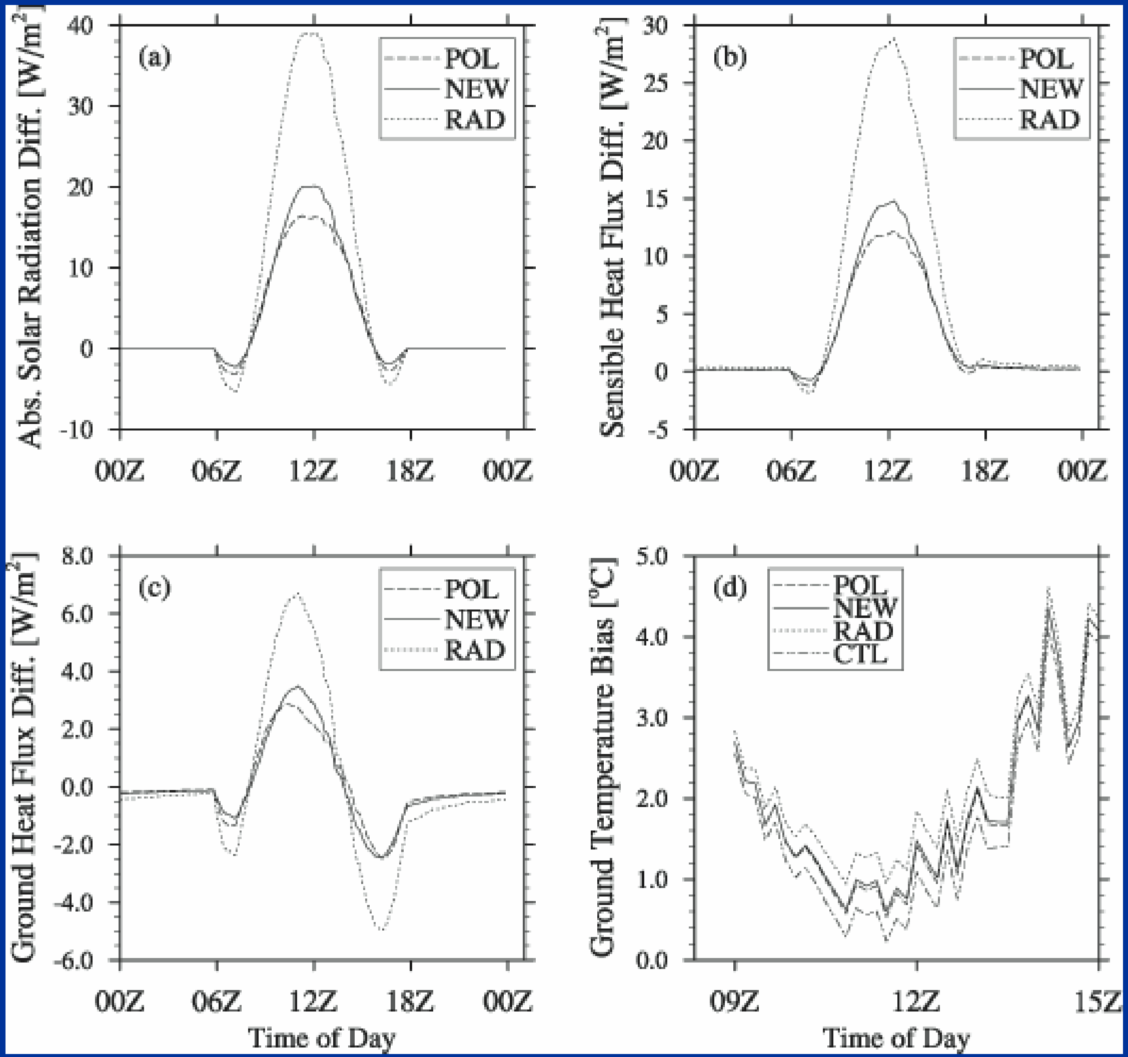
$\alpha(\theta) = \alpha(60°) * \{1 + B_1 * g_1(\theta) + B_2 * g_2(\theta) \}$ Two parameter model

$\alpha(\theta) = \alpha(60°) * [1 + C] / [1 + 2C * \cos(\theta)]$ One parameter model

- Two parameter model B_n parameters are determined for using the 30 desert locations and are found to be $B_1 = 0.346$ and $B_2 = 0.063$

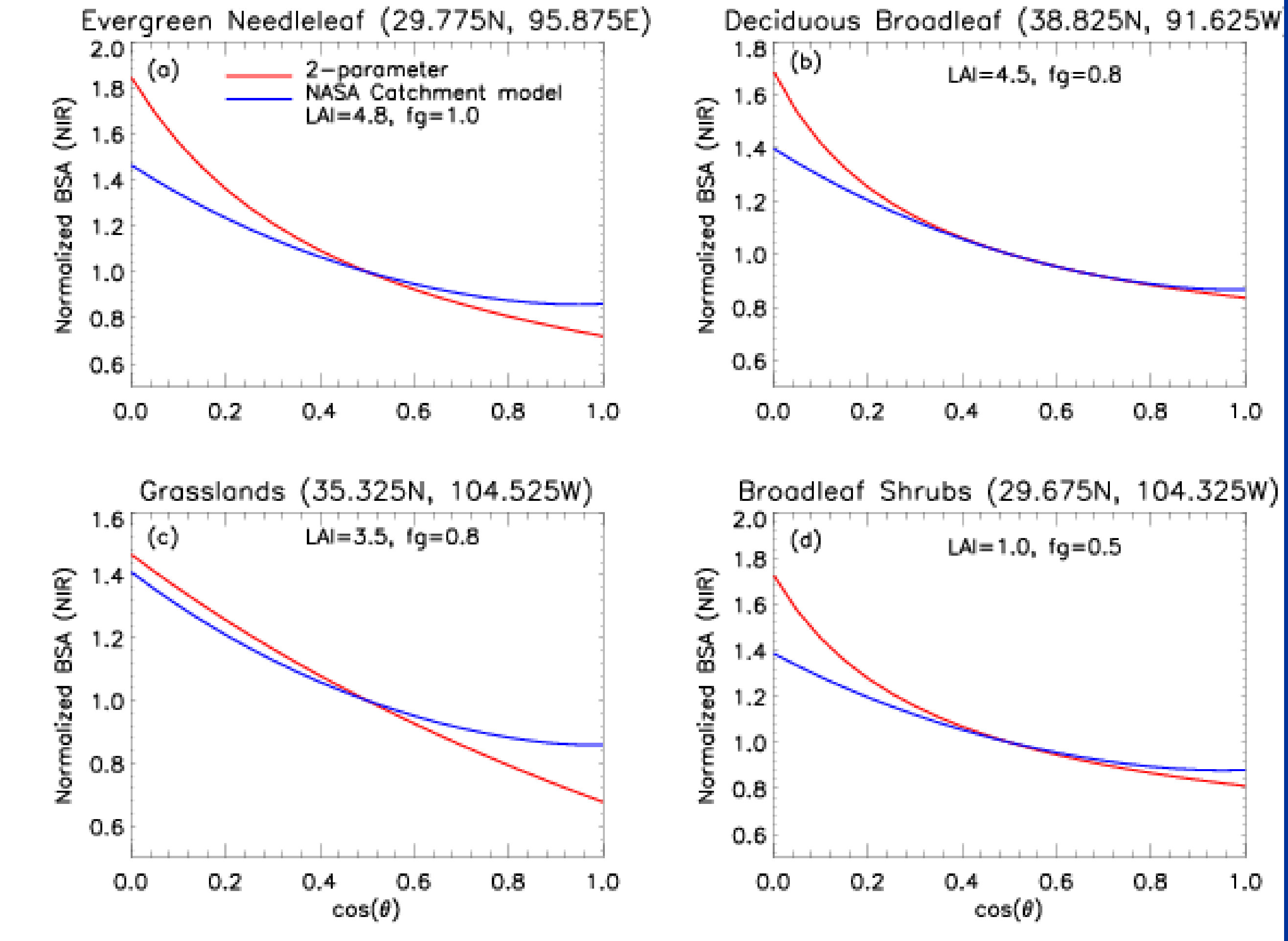
- C parameter in one parameter model is assumed to be 0.4

Model Tests with Zenith Angle Dependence

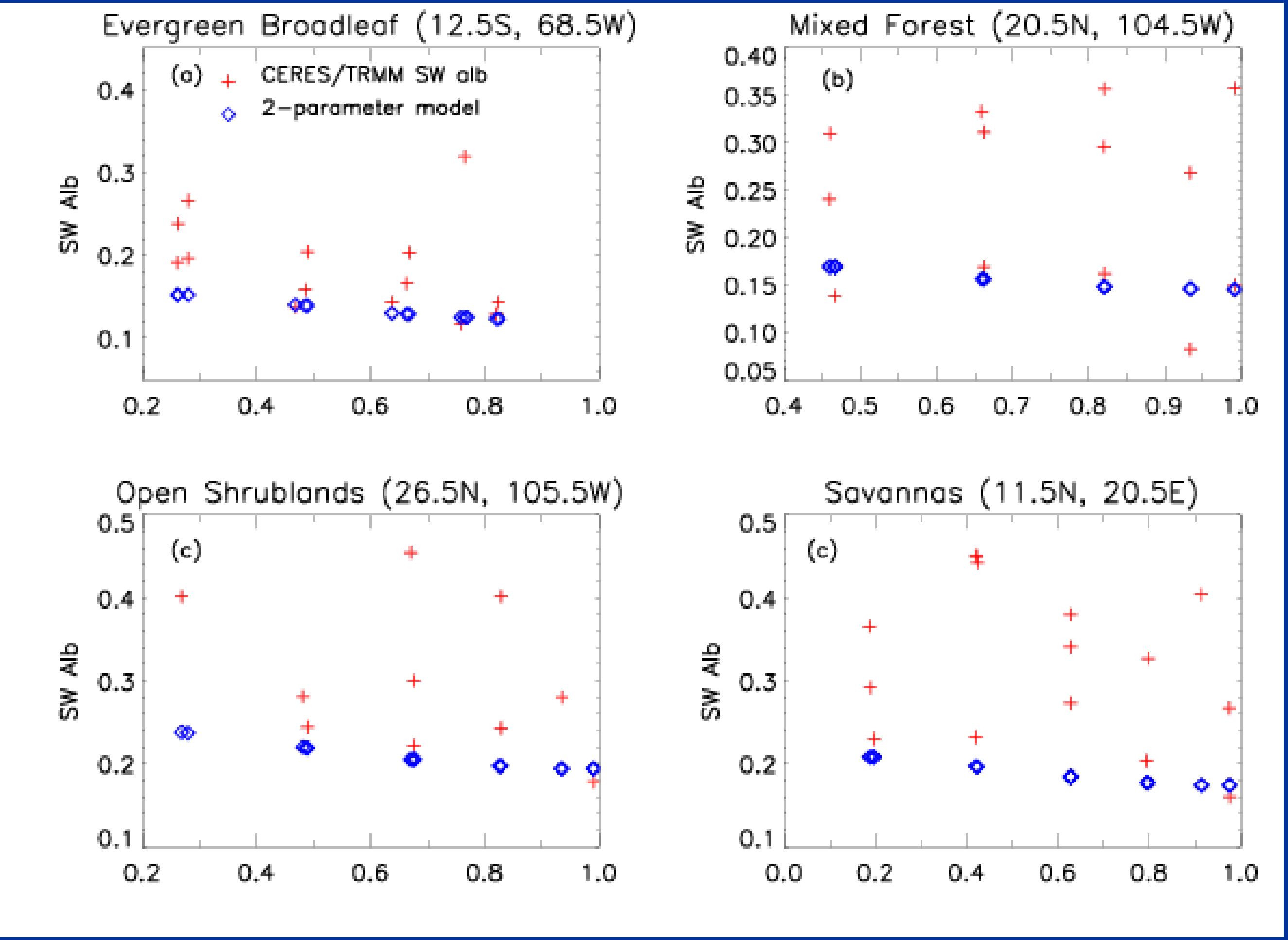


- Sensitivity tests of the new formulation using the Noah model over HAPEX-Sahel site
- Albedo dependence on zenith angle increases absorbed solar by 20 W/m^2 which is balanced by increases in sensible and ground heat flux

Use MODIS albedo/BRDF data to identify deficiencies in the solar zenith angle dependence of land surface albedo in the NCAR, NCEP, and NASA land models (e.g., NASA Catchment model below, in red)

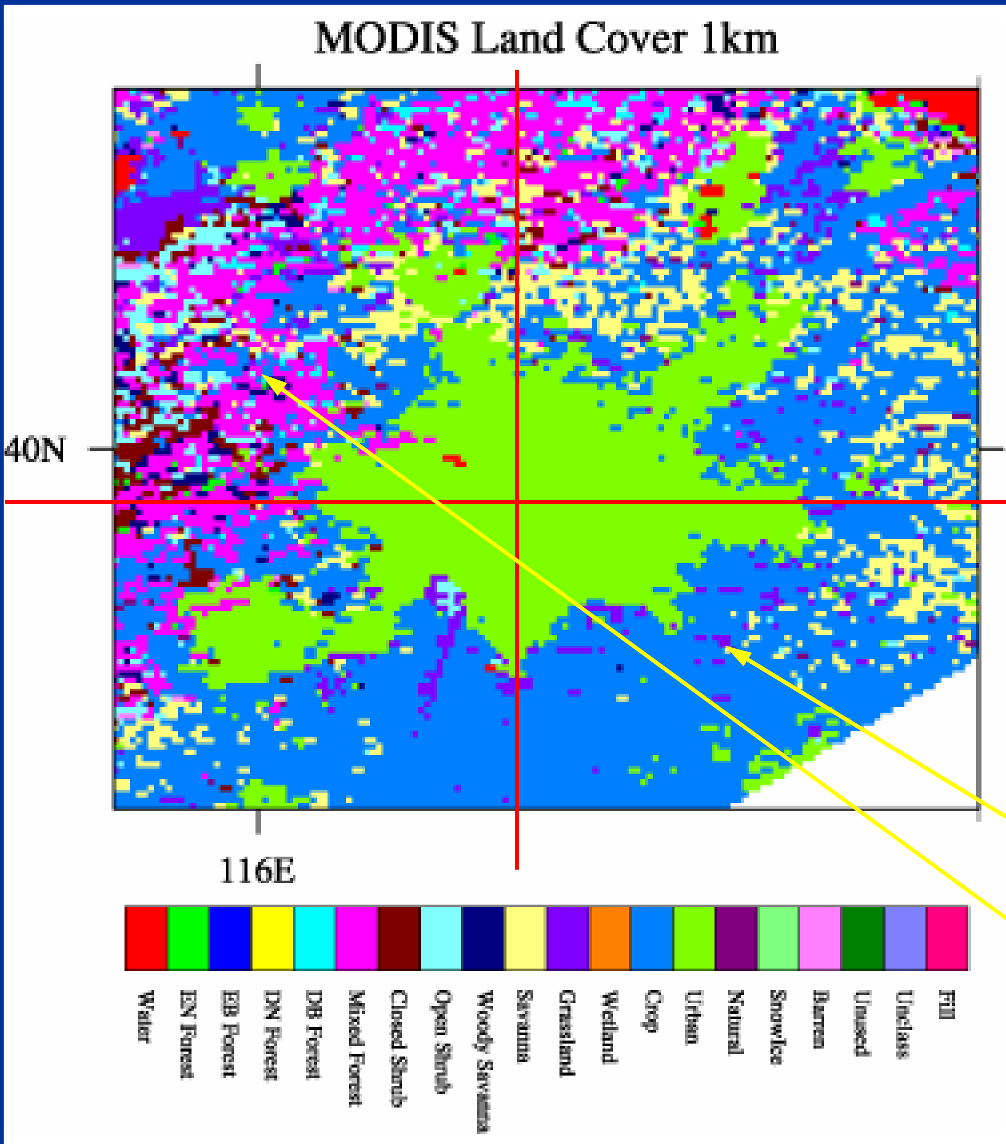


Use MODIS albedo/BRDF data to identify deficiencies in the solar zenith angle dependence of land surface albedo in the CERES, ISCCP, and UMD surface solar flux datasets (e.g., CERES dataset below, in red)



Other Current Activities

Beijing in MODIS's eyes
(with Prof. Mingyu Zhou)



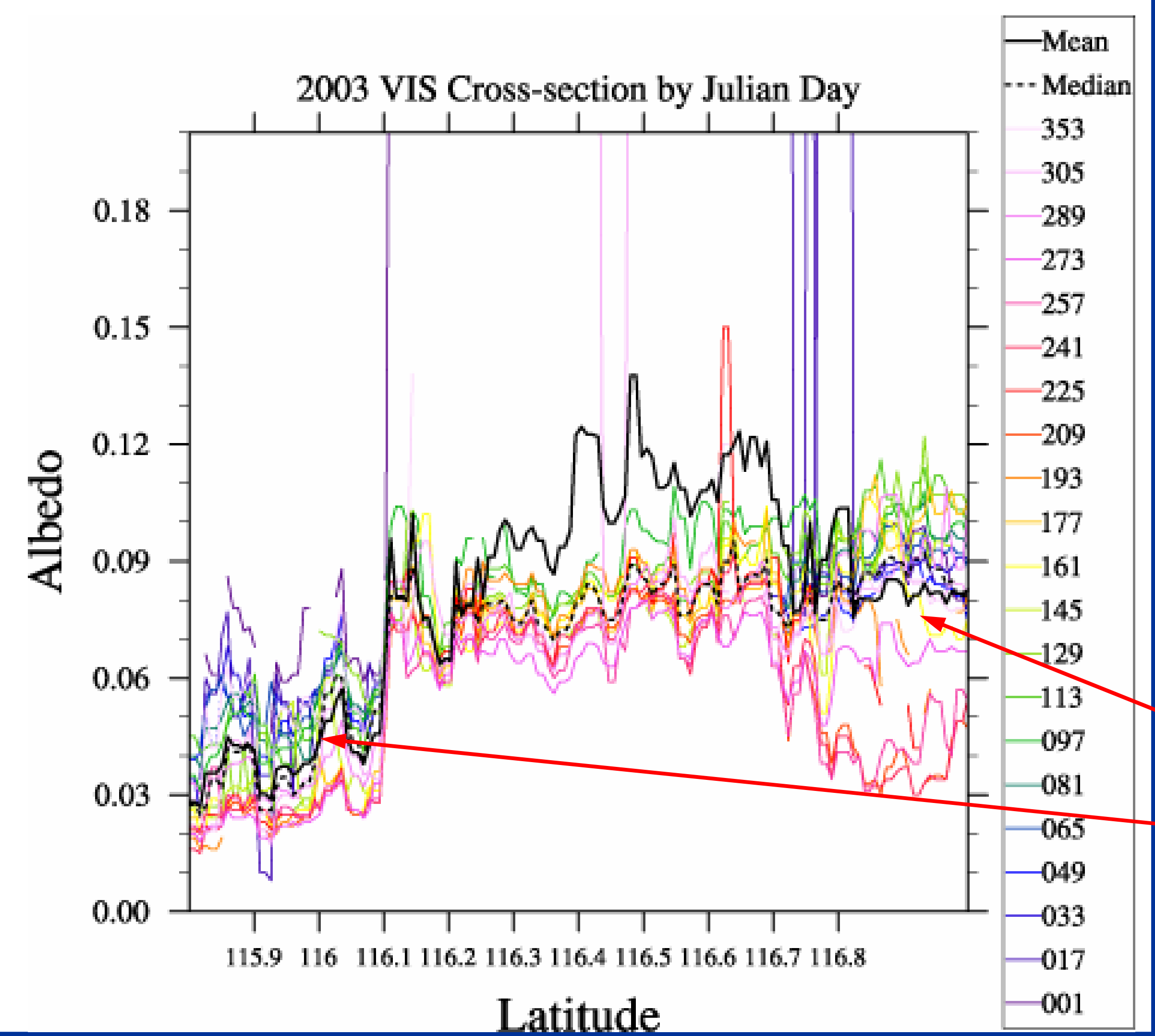
Cross-sectional Views

- 116.4°E
- 39.9 °N

Land Cover Types

- Crop
- Mixed Forest

39.9 °N West-East Beijing Cross-section of MODIS Albedo

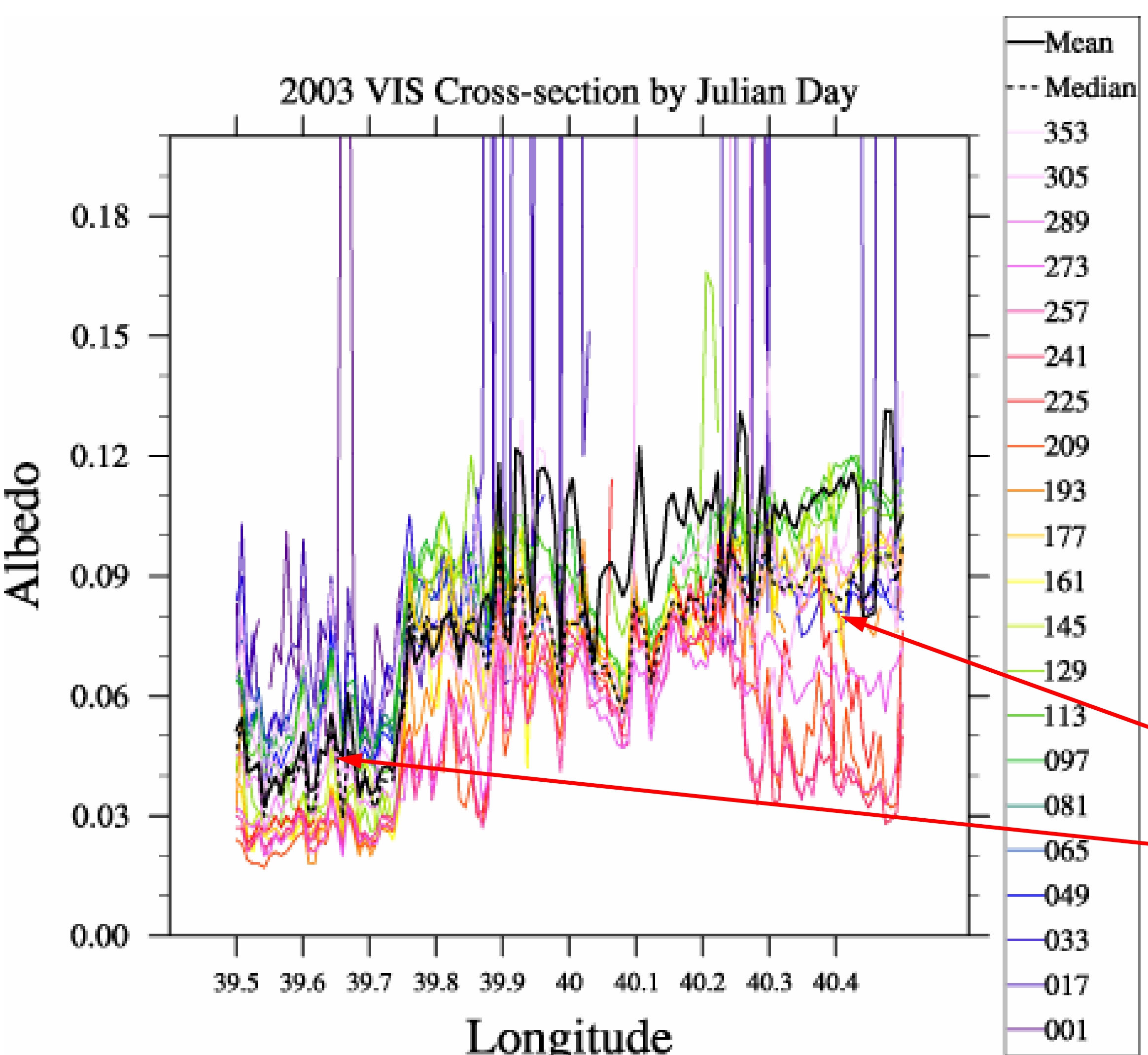


- Significant annual variation in crop albedo
- Small urban variation
- Sharp transition at urban edge

Land Cover Types

- Crop
- Mixed Forest/Rocky

116.4 °E North-South Beijing Cross-section of MODIS Albedo



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Land Cover Types

- Mixed Forest
- Crop