An approach for developing surface albedo product from seven MODIS land bands at 250m spatial resolution over Canada and the Arctic circumpolar region

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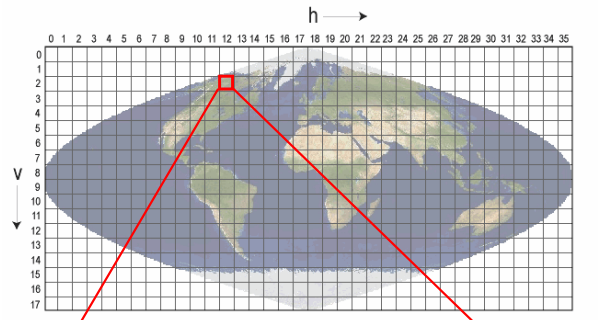
Rationale for developing new algorithm

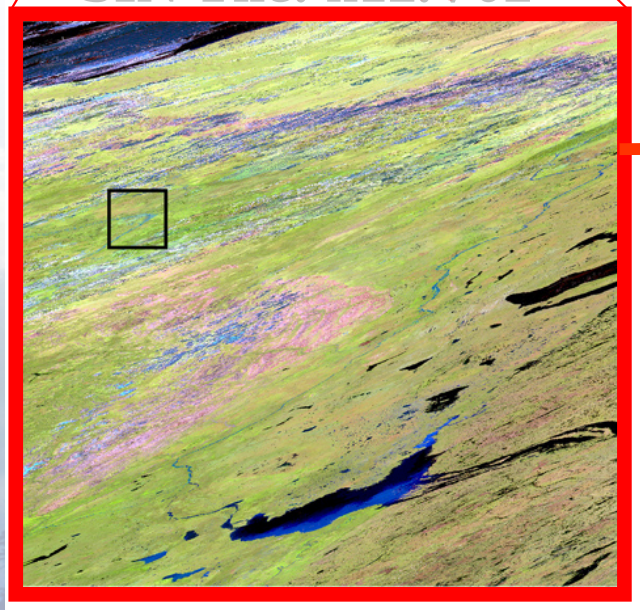
- Serious imagery distortion over Canada and the Arctic Area inherent to MODIS operational sinusoidal (SIN) projection;
- Original data only have two bands with 250m resolution, while GCOS/CEOS require 250m resolution for most surface products;
- New algorithm extends surface albedo retrieval over Arctic ice, water and areas north above 80°N;
- New algorithm improves snow/ice BRDF model;
- Final goal is to generate improved surface albedo/BRDF for all land bands at 250m resolution and 10-day interval over Canada and Arctic Circumpolar Area.

Serious distortion over the North in SIN projection

MODIS Sinusoidal Grid

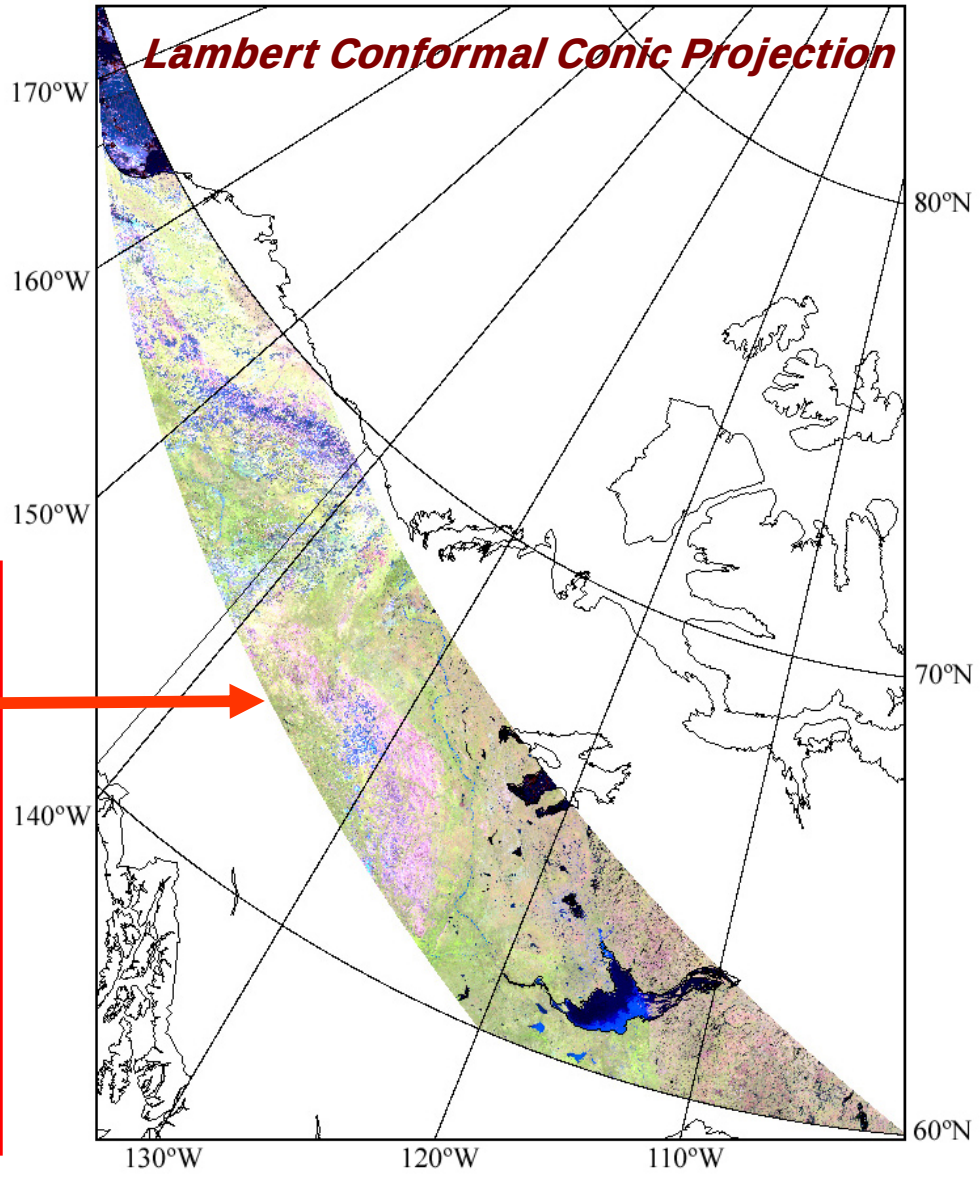


SIN Tile: h12.V02



(a)

Lambert Conformal Conic Projection



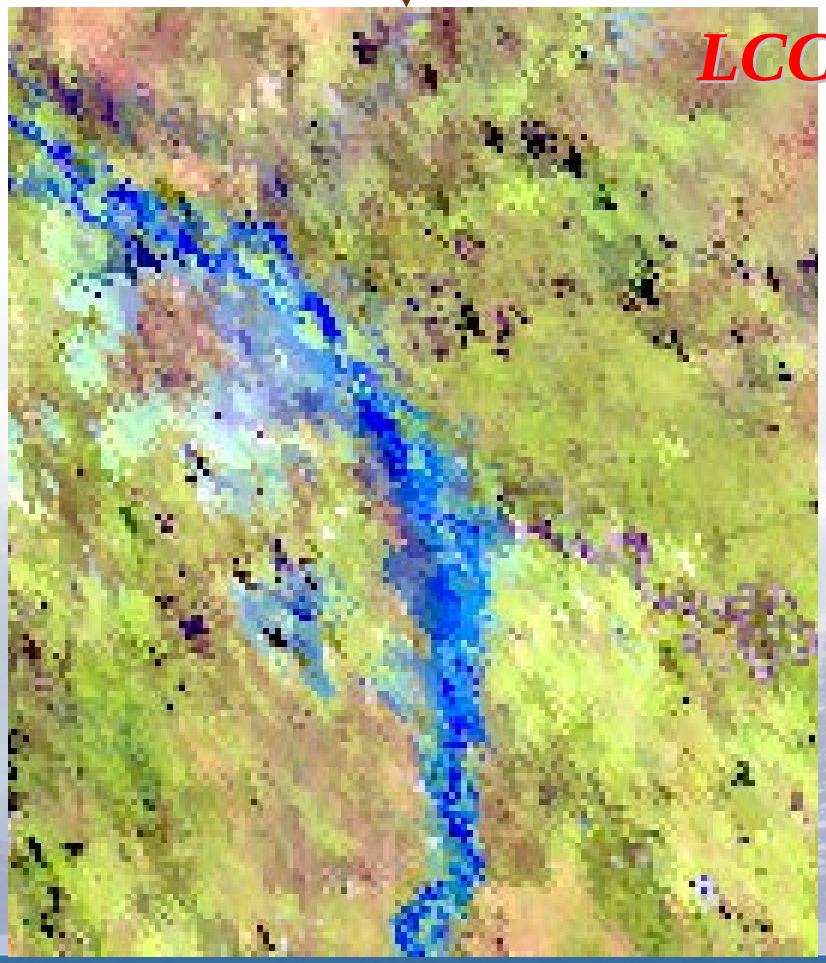
(b)

L1B Swath Data

SIN Tile

Re-sampled

CCRS Processed



LCC projection

vs.

Downscaling Bands 3-7 to 250m resolution

MODIS bands for land applications

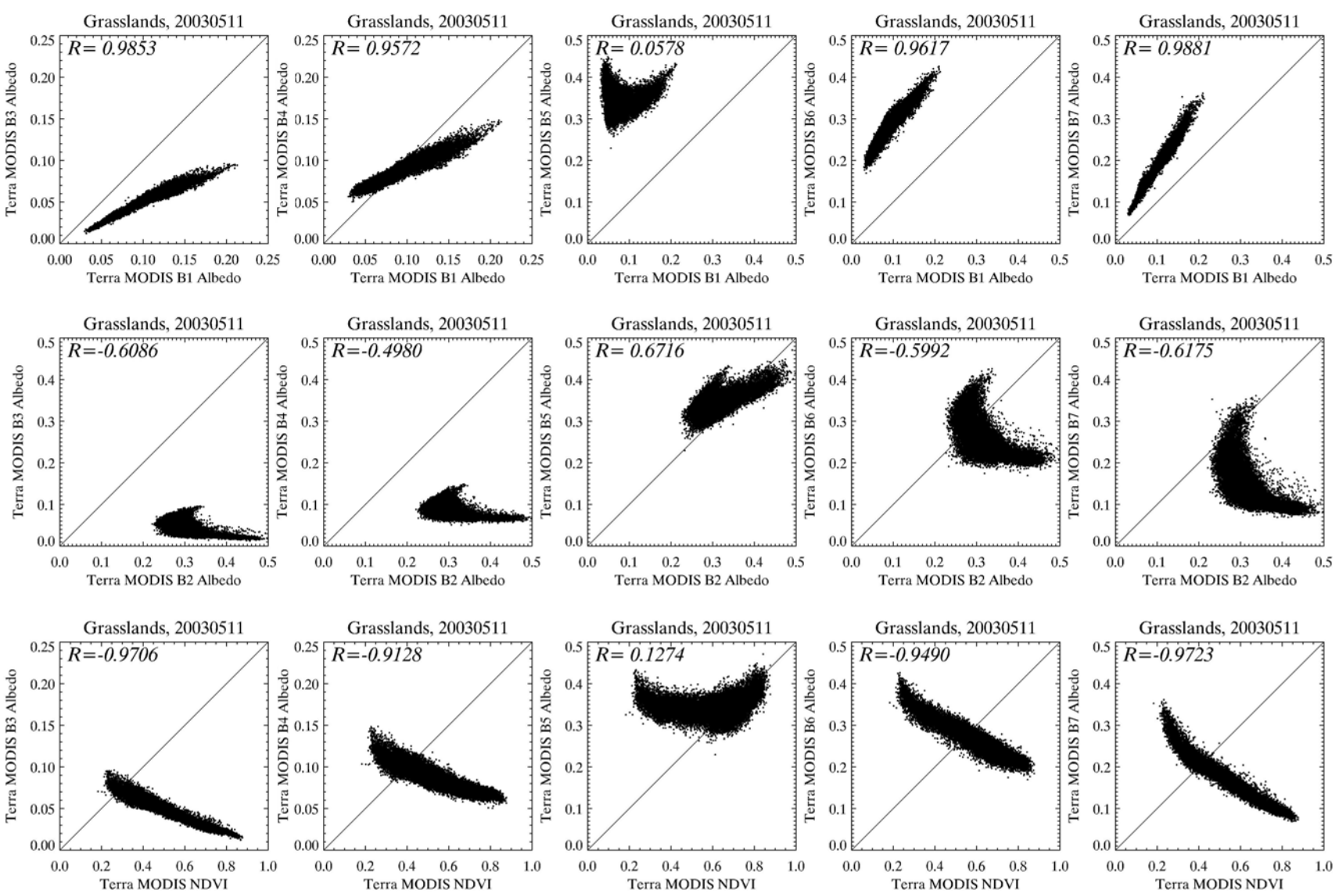
Primary Use	Band (resolution)	Bandwidth (nm)
Land/Cloud/ Aerosols Boundaries	B1 (250m)	620 - 670
	B2 (250m)	841 - 876
Land/Cloud/ Aerosols Properties	B3 (500m)	459 - 479
	B4 (500m)	545 - 565
	B5 (500m)	1230 - 1250
	B6 (500m)	1628 - 1652
	B7 (500m)	2105 - 2155

A method has been developed to enhance the spatial resolution of the MODIS land bands B3-B7 from 500m to 250m. It uses adaptive regression to exploit the observed dependence between B1, B2, and NDVI and B3-B7.

$$B_{i(3-7)} = a_{0,i} + (a_{1,i}B_1 + a_{2,i}B_2)(1 + a_{3,i}NDVI + a_{4,i}NDVI^2)$$

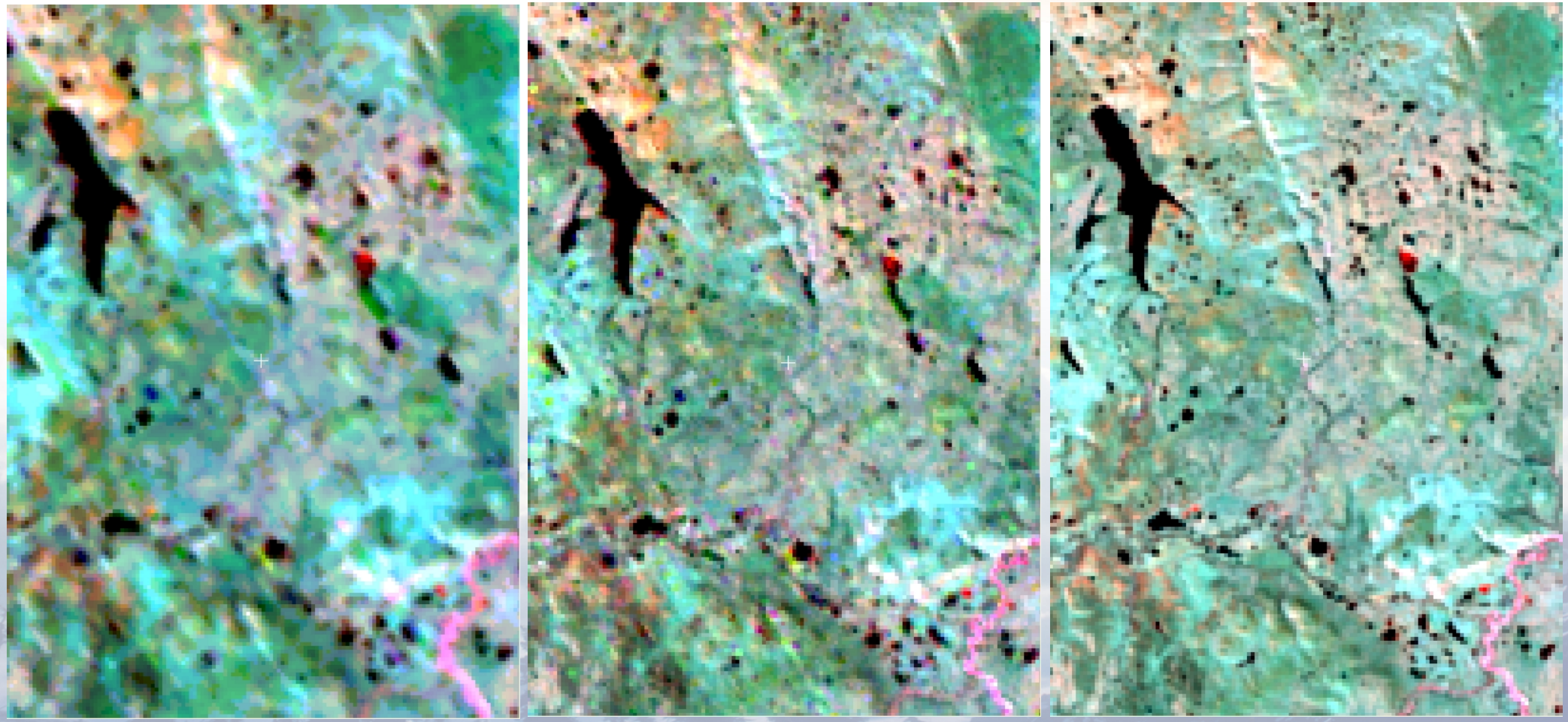
Normalized Difference of Vegetation Index $NDVI = (B_2 - B_1)/(B_2 + B_1)$

Correlations between $B_{3,4,5,6,7}$ and $B_{1,2}$ and NDVI



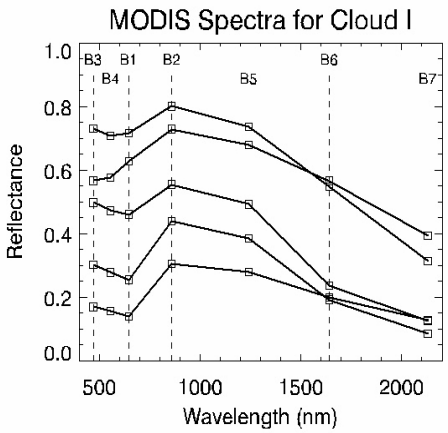
Performance of downscaling

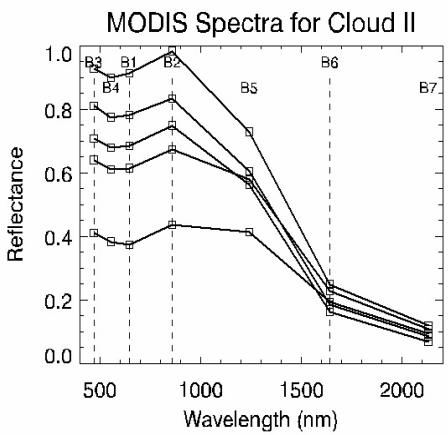
MODIS original 500m → MODIS downscaled 250m **vs.** Landsat aggregated 250m

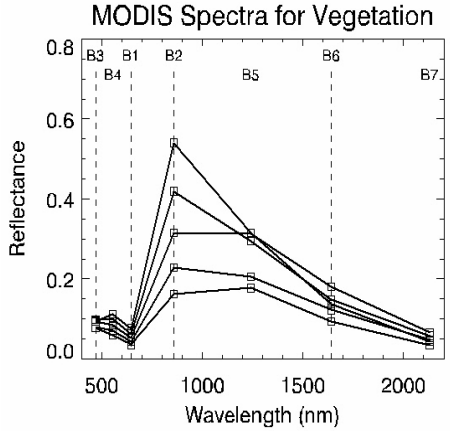


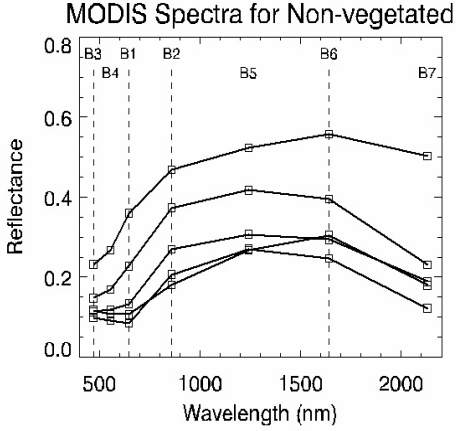
R-B4 (0.55μm) **G**-B6 (1.6μm) **B**-B7 (2.1μm)

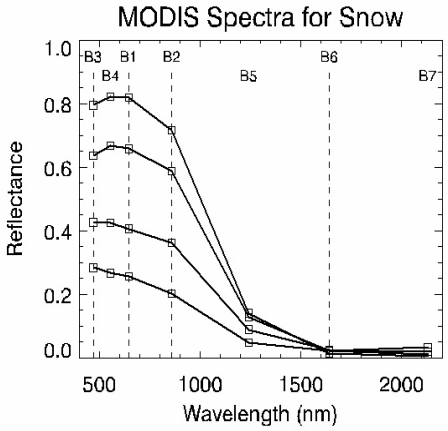
Generating multi-day clear-sky composite
Scene identification using multiple bands

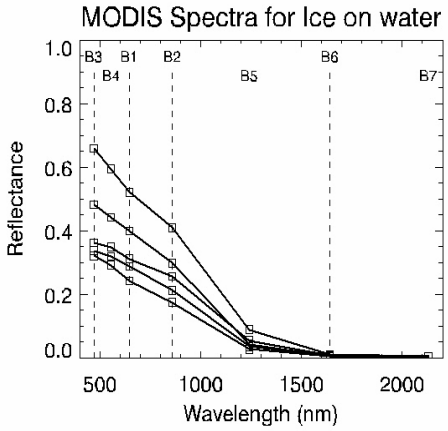


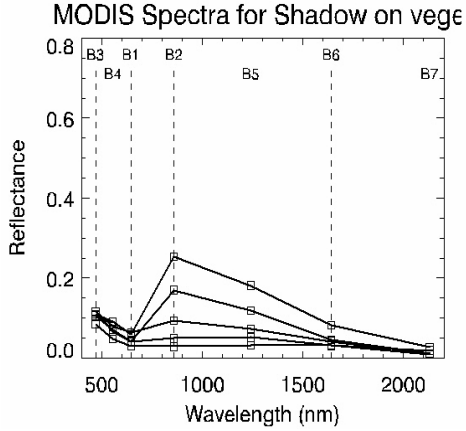


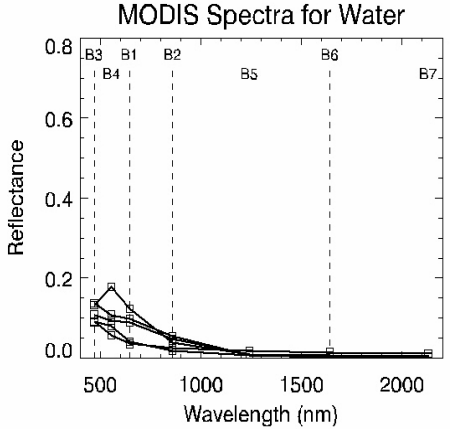






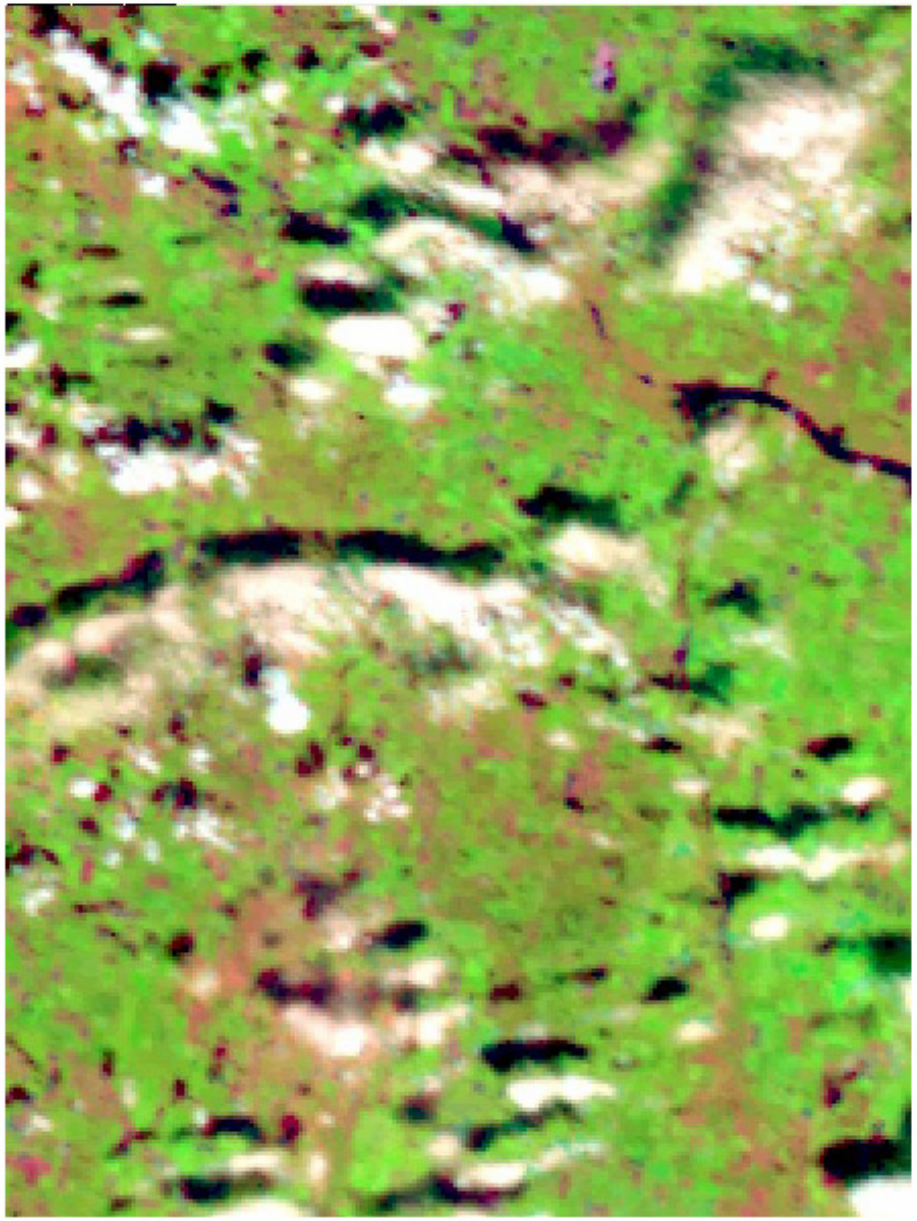




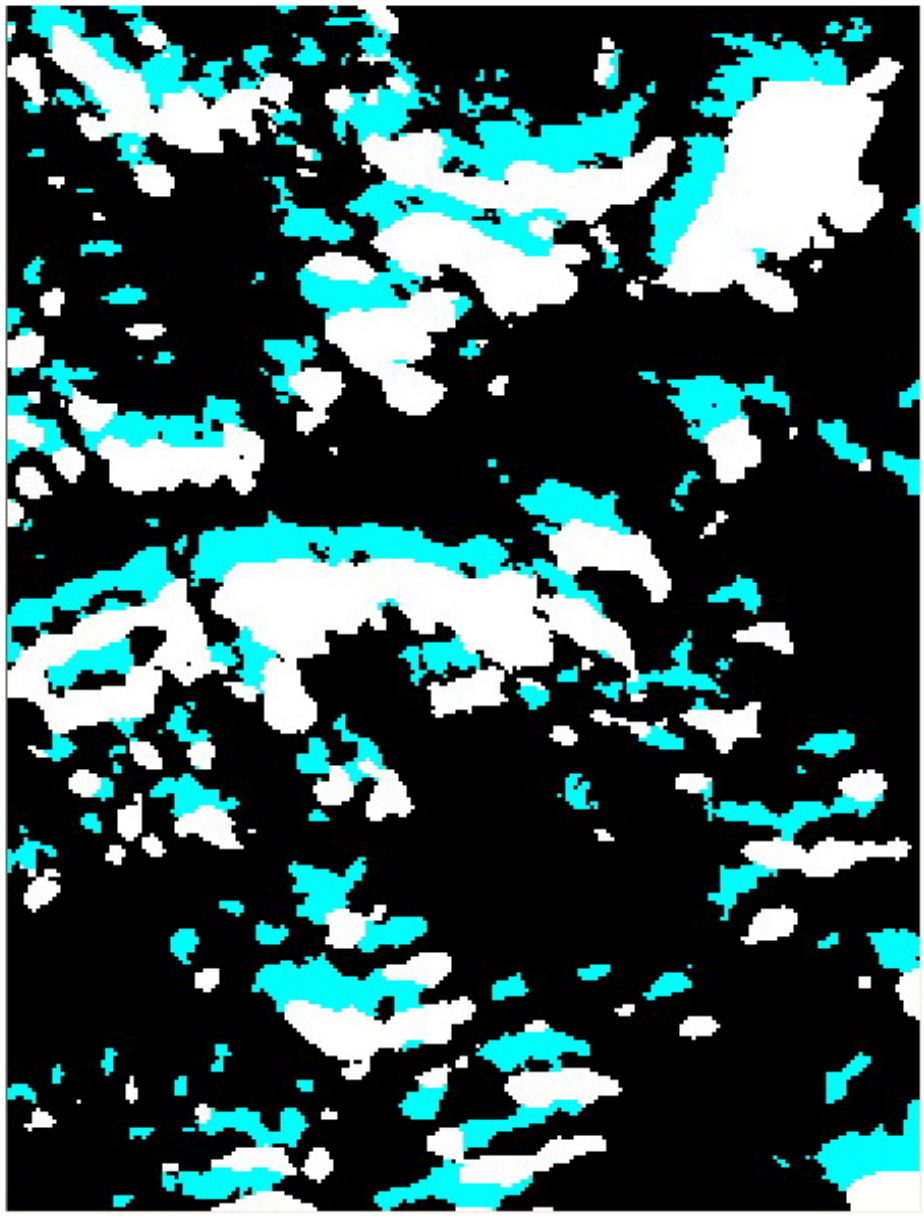


Cloud & cloud shadow detection

(a) MODIS false color image (250m)



(b) CCRS Cloud & Shadow Mask (250m)



How cloud shadow screening works

Before

After

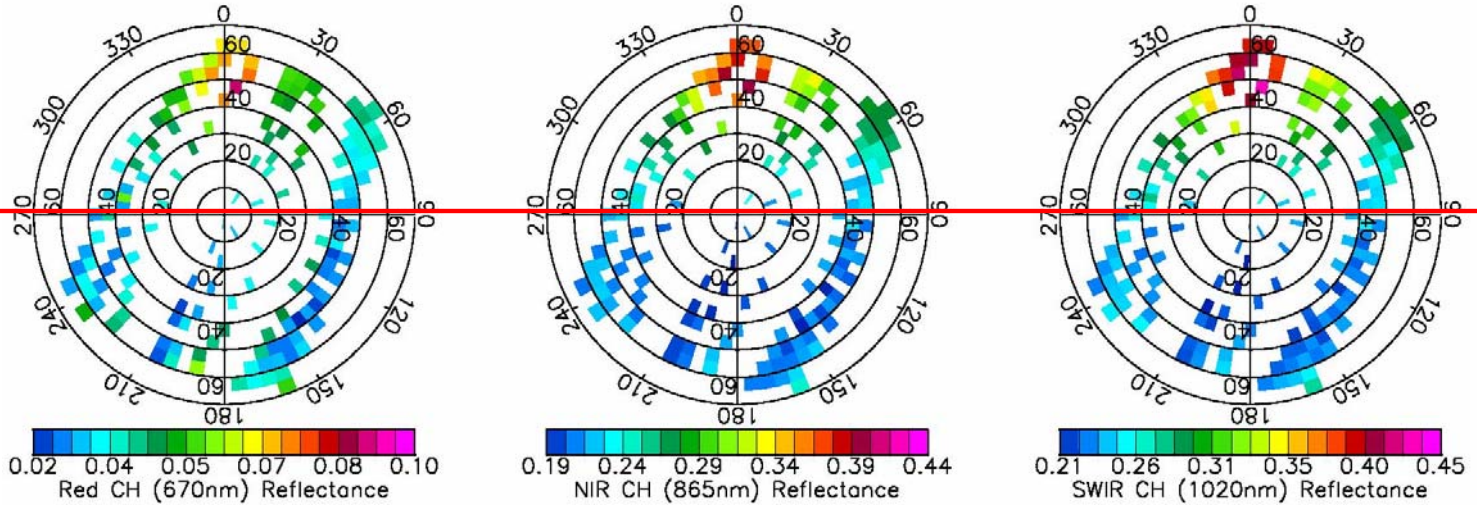
Consideration of BRDF effects

POLDER (POLarization and Directionality of the Earth's Reflectances)

Tree Cover, needle−leaved, evergreen — Lat: 65.03 Lon:−126.38
Solar Zenith Range:42.3−47.3, Ave=45.0 (degree); Date:20060702−20060731

BH

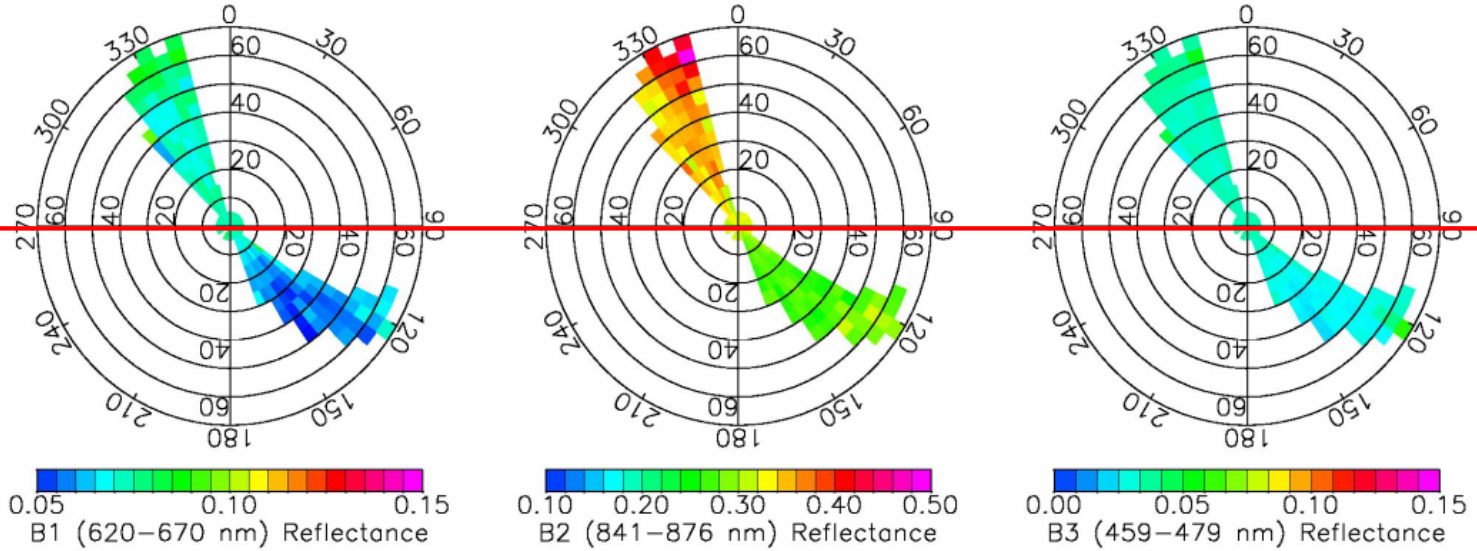
FH



BH

FH

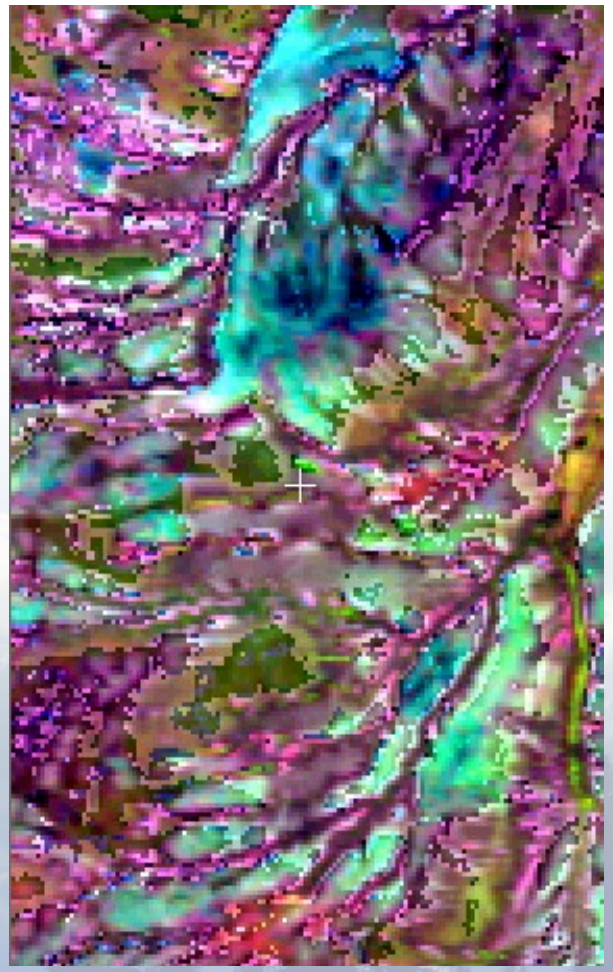
Terra/MODIS, Grassland, May 2003 — SZA: 11.3−34.1, (ave=22.6) NDVI: 0.5−0.7



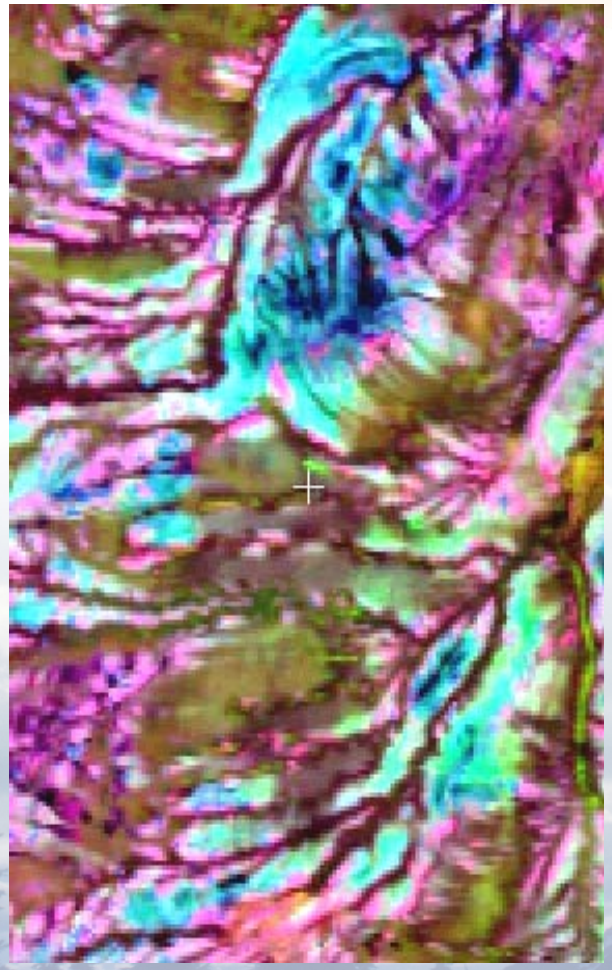
Two-value clear-sky compositing

Economic scheme to consider BRDF effects during clear-sky compositing step

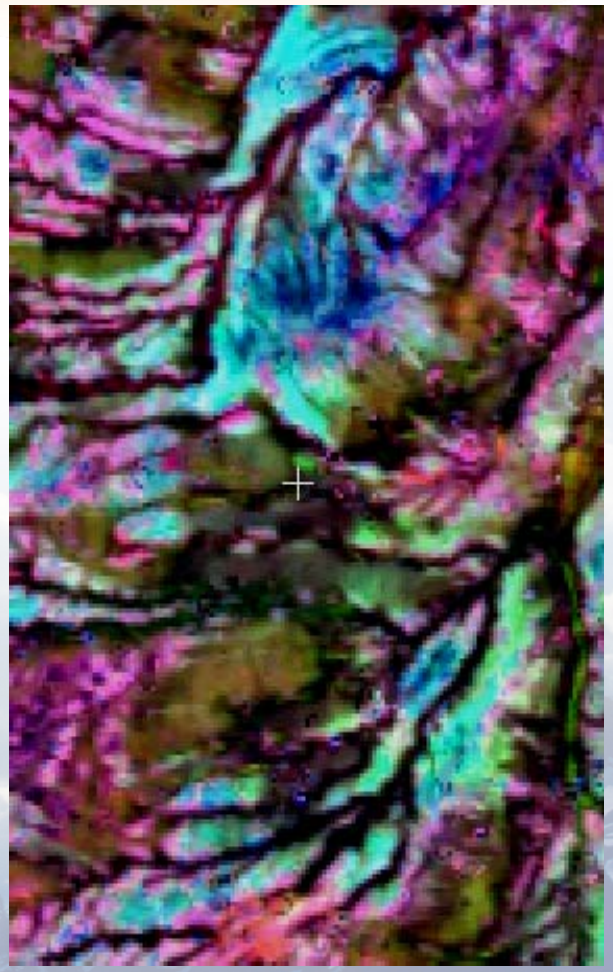
Separate composite for backward scattering (BH) and forward scattering (FH)



(a) 1-value composite



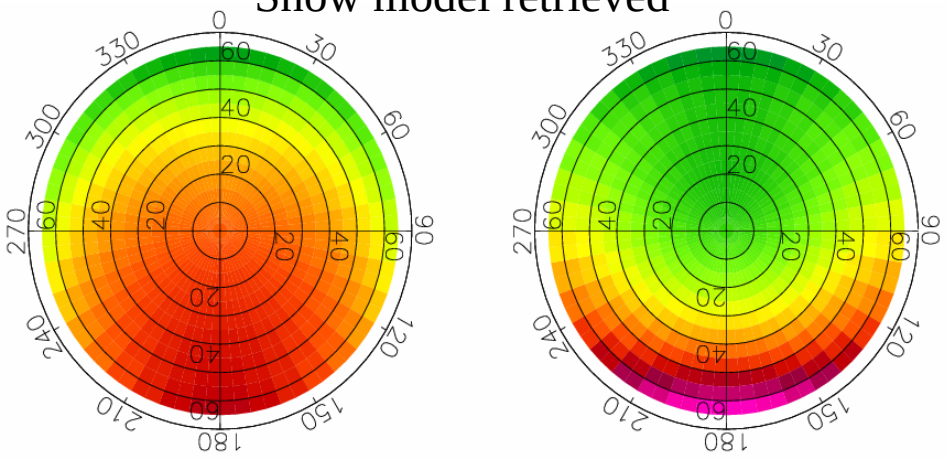
(b) BH composite



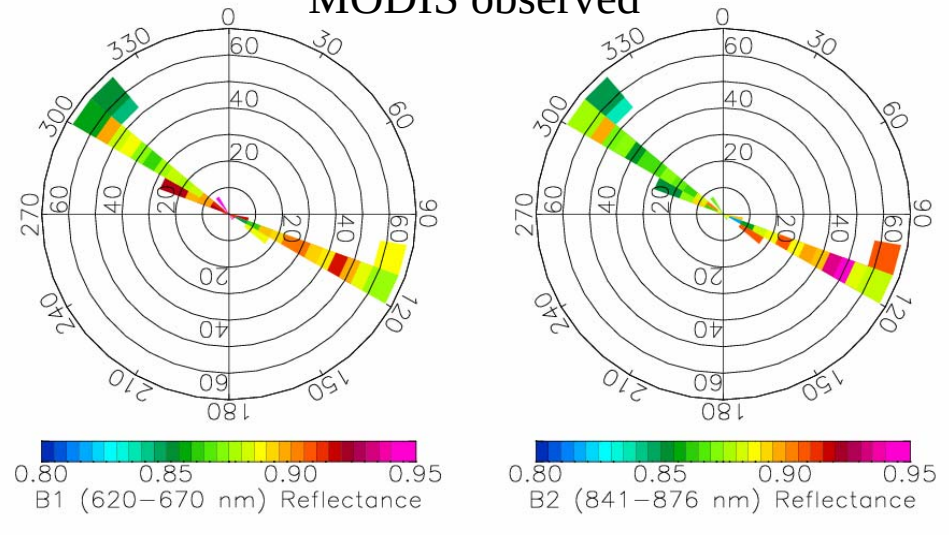
(c) FH composite

Snow BRDF model applied to MODIS data including snow grain size effect

Snow model retrieved



MODIS observed



Ross-Thick-Li-Sparse MODIS BRDF model is not applicable for snow. Maxs and Mins are reversed

$$R(\theta_s, \theta_v, \phi) = R_0(\theta_s, \theta_v, \phi) e^{(-A\sqrt{\gamma d})}$$

R_0 – *Reflection function of a semi-infinite non-absorbing snow layer*

$$A = \frac{0.66(1+2\cos\theta_s)(1+2\cos\theta_v)}{R_0(\theta_s, \theta_v, \phi)}$$

$$\gamma = 4\pi\chi / \lambda$$

d – *snow grain size*
χ – *imaginary part of refractive index of ice*
λ – *wavelength*

Kokhanovsky and Zege (2004)

Combined Land / Snow BRDF model

Modified *RossThick-LiSparse* kernel-driven model (Maignan et al., 2004) for land and snow model (Kokhanovsky and Zege, 2004) are linearly combined for mixed surface conditions. They are weighted by snow fraction α [0.0~1.0]

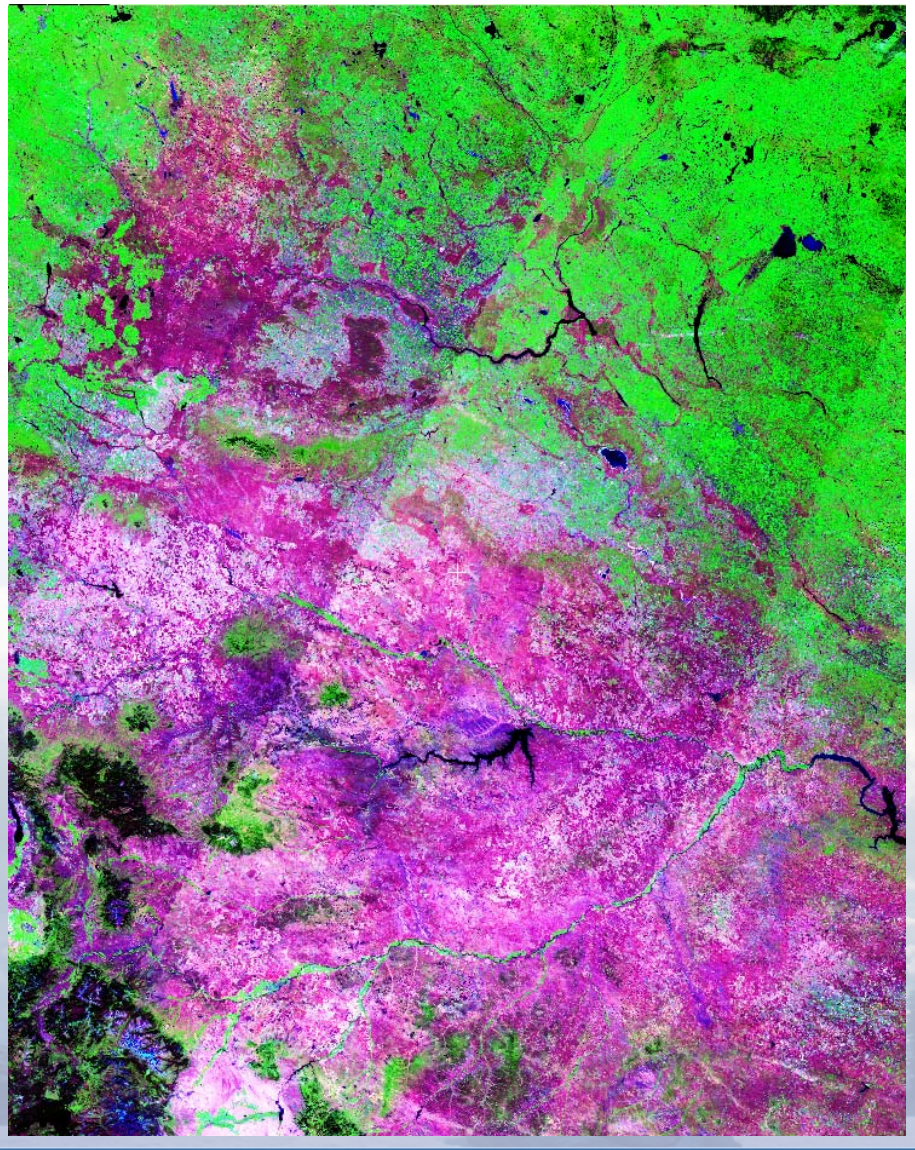
$$f(\theta_s,\theta_v,\phi)=(1-\alpha)\left(a_0+a_1 f_{vol}(\theta_s,\theta_v,\phi)+a_2 f_{geo}(\theta_s,\theta_v,\phi)\right)+$$

$$\alpha\left(a_3 R_0(\theta_s,\theta_v,\phi)e^{(-A\sqrt{\gamma d})}\right)$$

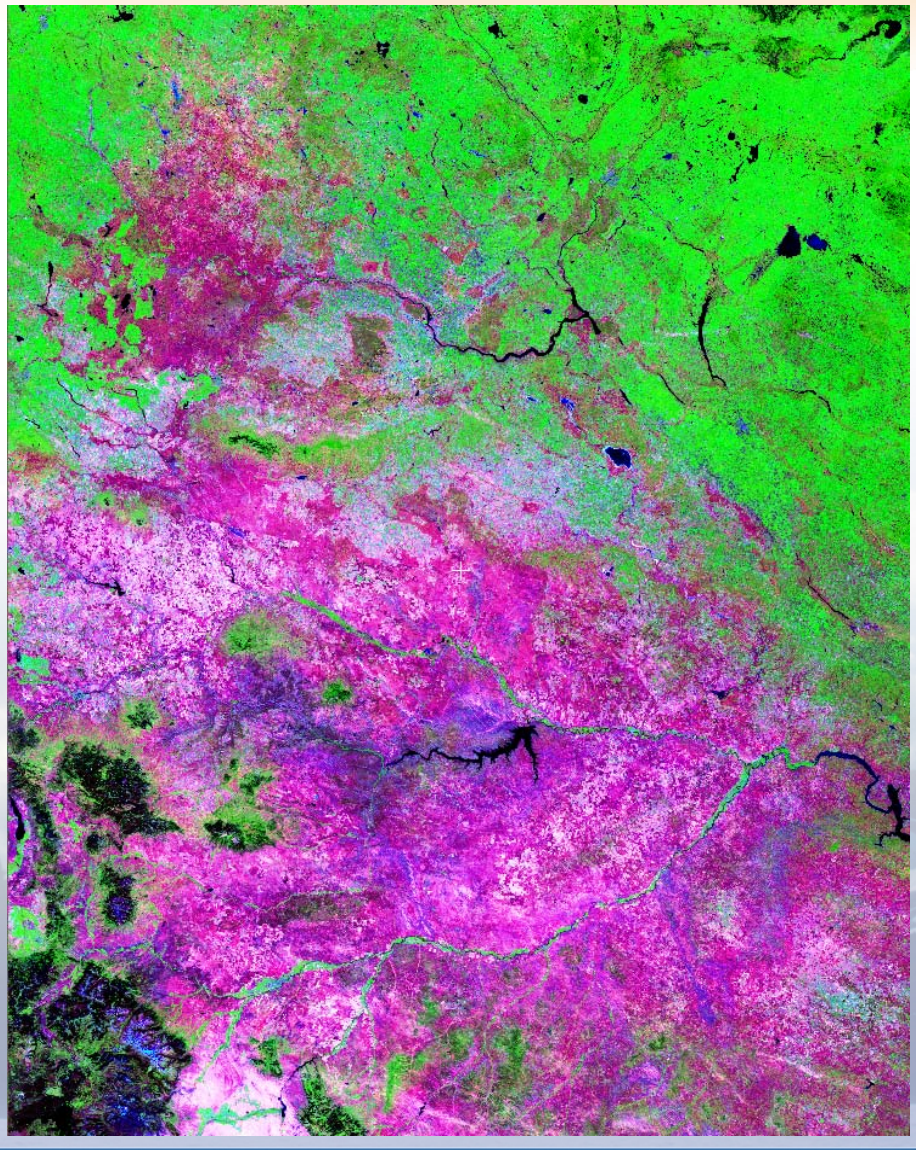
Five parameters $a_0, a_1, a_2, a_3, \alpha, d$ are determined from MODIS observations using a land cover based algorithm (Luo *et al.*, 2005)

BRDF normalization for composite imagery

10-day composite of surface reflectance



BRDF normalized



CCRS MODIS Data Processing Flow Chart

MODIS **Swath** Data (Level 1B): *B1,B2@250m; B3-B7@500m*

↓

Adaptive Regression Downscaling: *B1-B7 all@250m*

↓

Map Re-projecting: *LCC or LAEA*

↓

Cloud/Shadow identification

↓

Compositing: *1-day,10-day, or monthly*

↓

Atmospheric Correction

↓

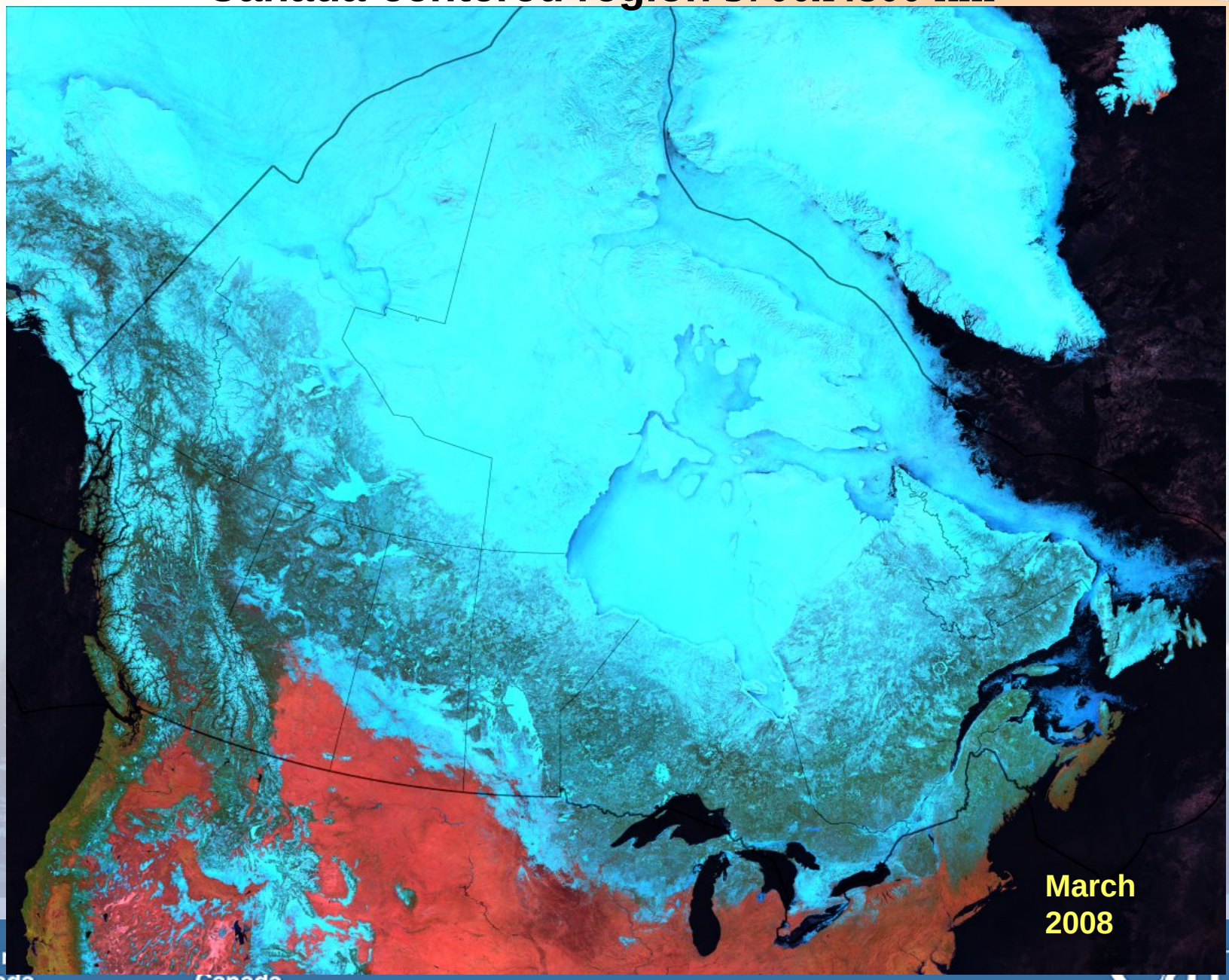
BRDF Normalization

↓

Surface Albedo Products

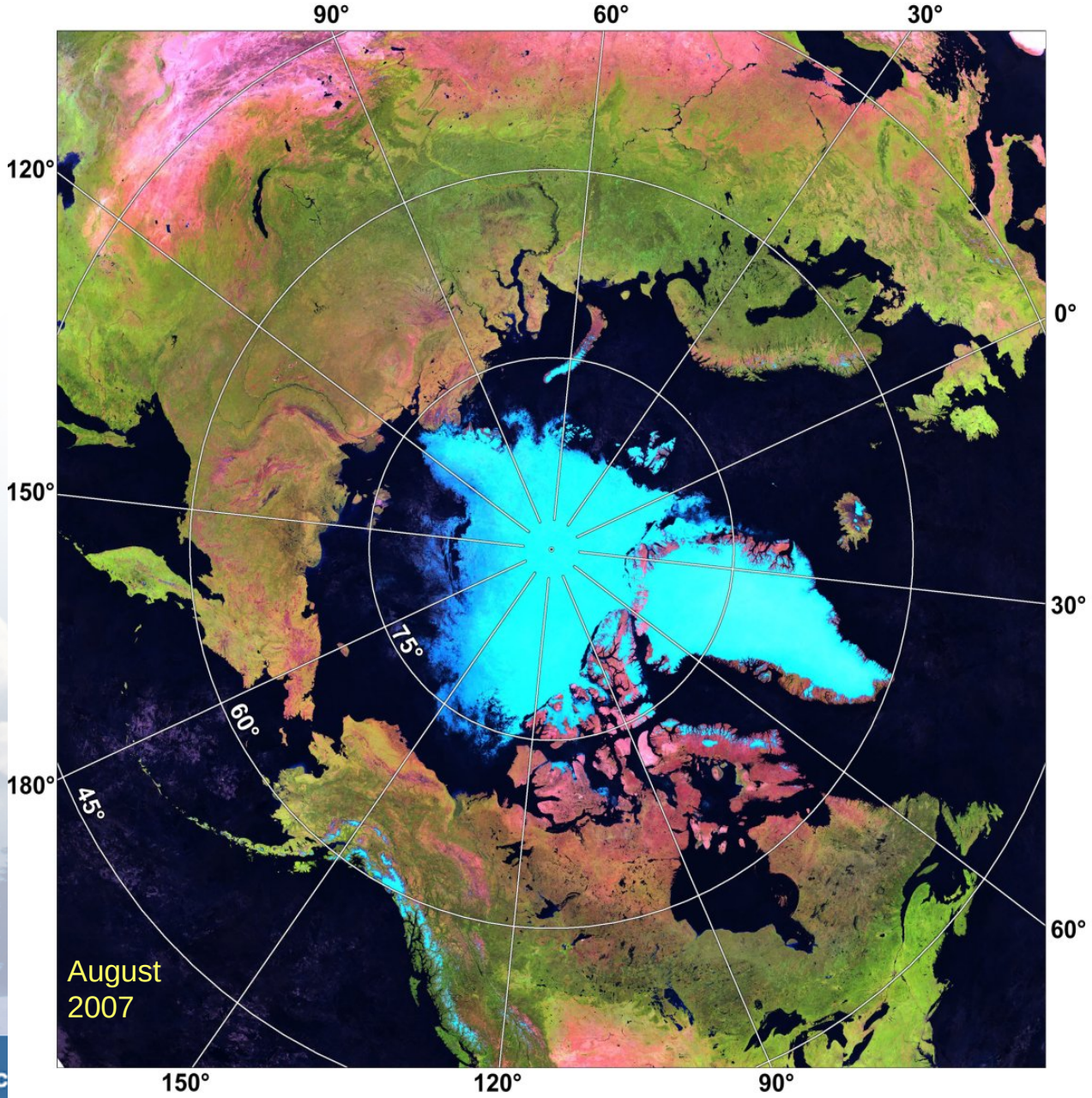
Examples of 250m surface albedo data

Canada-centered region 5700x4800 km^2



Examples of 250m surface albedo data

Arctic Circumpolar Area 9000x9000 km²



Summary

- An independent technology was developed at the Canada Centre for Remote Sensing (CCRS) for generating Canada wide and the Arctic Circumpolar region clear-sky surface composites and albedo based on observations from MODIS/TERRA.
- The MODIS Level 1B swath data were used as input to circumvent the problems with image distortion in Canada and Circumpolar regions inherent to the sinusoidal (SIN) projection utilized in the standard MODIS data products.
- The MODIS 500m land bands B3 to B7 are downscaled to 250m using an adaptive regression and normalization scheme for compatibility with 250m bands B1 and B2.
- To account for surface bi-directional properties, separate clear-sky composites are produced for sun-satellite relative azimuth angles within 90-270 degree (forward scattering) and outside this interval (backward scattering).
- A land/snow combined BRDF model is being developed to produce spatially continuous albedo/BRDF product that includes all surface types (land, water, snow/ice).
- The new product presents an important spatial enhancement to meet GCOS 250-m spatial requirement for terrestrial parameters.