Shrub Abundance in Alaskan Arctic Tundra from MODIS Reflectance Anisotropy

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Introduction: Increasing shrub abundance has been observed in Arctic tundra over the last 60 years and this is ecologically significant because - unlike trees - shrubs are present over a very large area and able to expand rapidly, with consequences for ecosystem structure and function, albedo, and feedbacks to climate. Although the warming of the climate may result in rapid expansion, currently fractional tall shrub cover is very low at the ~250 m - 1km scales of NASA's moderate resolution imagers (MODIS, MISR) and is rarely >0.1. The difficulty of mapping vegetation at high latitudes using passive solar wavelength remote sensing is well known (e.g., Montesano *et al*. (2009) found that the MODIS Vegetation Continuous Field tree cover product may not be precise enough to allow monitoring of 500 m pixel-level tree cover in the taiga–tundra transition zone, particularly for pixels with less than 20% tree cover). The low shrub cover - together with dark and heterogeneous tundra surfaces (rarely >0.06 in the red wavelengths except where bright lichen species are abundant) and high solar zenith angles (>50° at these latitudes even in summer, resulting in a relatively large diffuse:direct irradiance ratio) - makes the detection and measurement of shrubs from space extremely challenging.

Method: Measures of surface physical structure encapsulated in the anisotropic scattering kernel weights of linear, semi-empirical kernel-driven models of the surface bidirectional reflectance distribution function (BRDF) might be used to map shrubs. Inversion of geometric-optical (GO) models is also being pursued but since cover is so low, the modeled BRF pattern is almost entirely defined by the (calibrated, dynamic) BRDF model used to represent the non-shrub background. MODIS Terra/Aqua red band BRFs accumulated over DOY 169 to 184 2010 were used to invert the RossThick-LiSparseMODIS and Simple Geometric-optical model results using the AMBRALS and Praxis algorithms, respectively. A MISR-derived BRDF was used to represent the non-shrub background. Fourteen sites along the Chandler River on the North Slope of Alaska, have been comprehensively surveyed and provide accurate reference data, based on field belt transects, high resolution imagery, and ground photographs. Multiangle field radiometry provides estimates of typical tundra BDRFs.

Results: The relationships between the site estimates of fractional cover, mean shrub height, and the product of these (a surrogate for woody biomass) and kernel weights are shown in Figure 1. It can be seen that the geometric kernel weight has the strongest and most linear relationship to measured shrub cover, height, and cover x height (used here as a surrogate for aboveground woddy biomass). This may reflect the strong signal from shadowing relative to the relatively minor increase (decrease) in volume scattering (isotropic scattering). The spatial distributions of model fitting error and retrieved parmeters, look count, and geometric kernel weight weights of determination for a large area of the North slope are shown in Figure 2. High RMSE values indicate inversions over MODIS observations that include a high proportion of surface water.

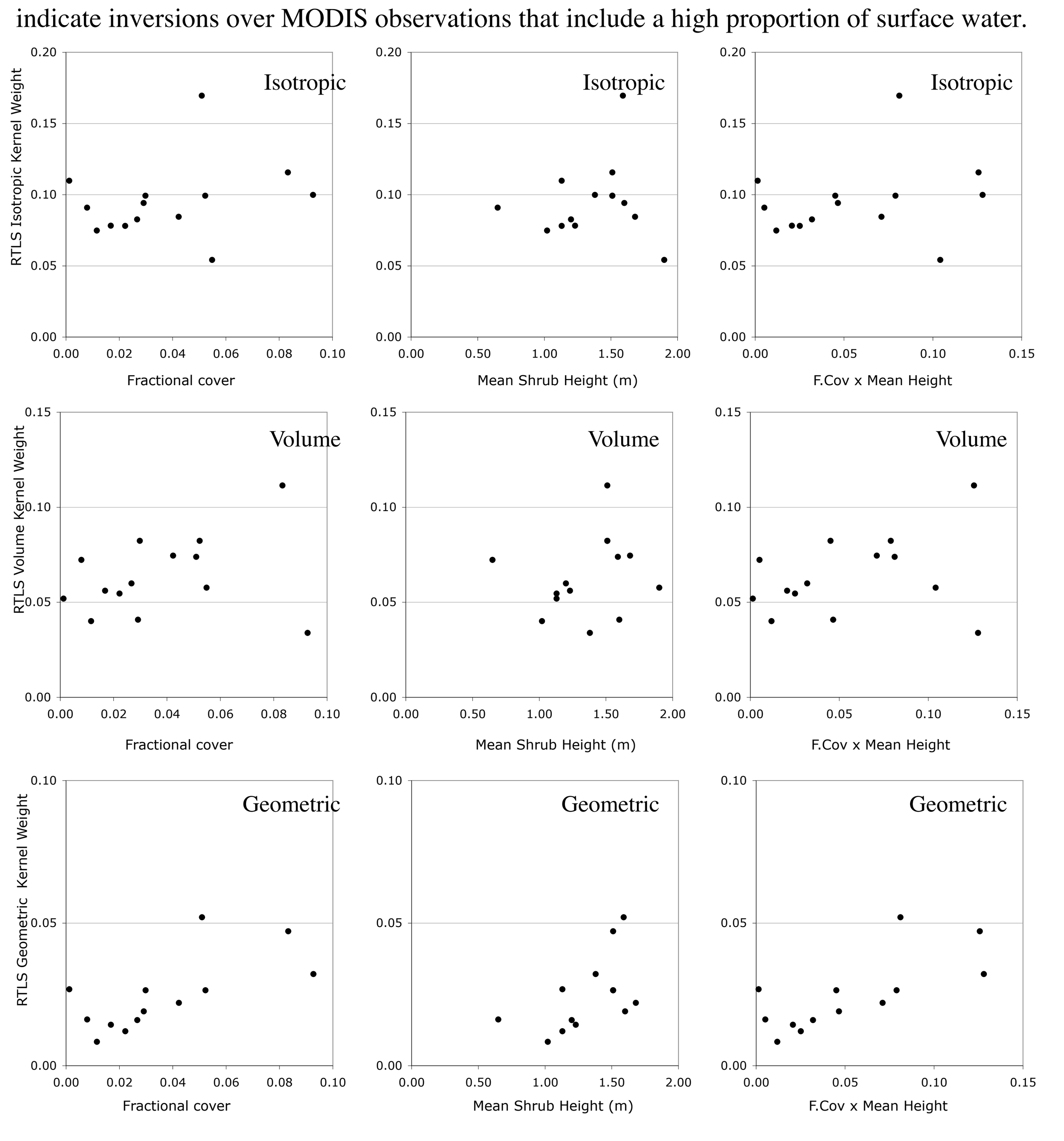


Fig. 1 Relationships between RossThick-LiSparse (RTLS) BRDF model kernel weights from model adjustment against red band MODIS bidirectional reflectance factors.

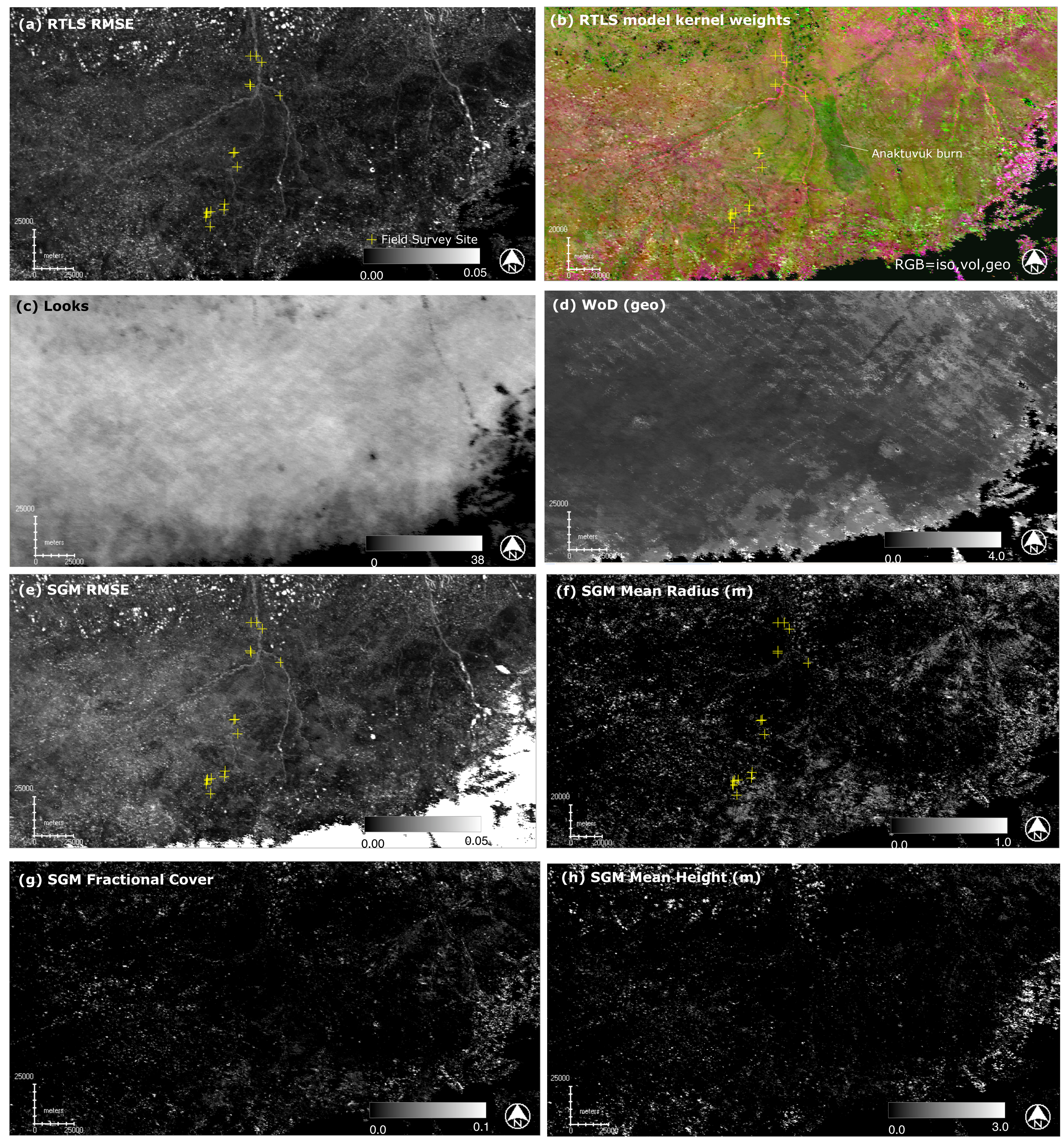


Fig. 2 RTLS and GO model results using MODIS Terra/Aqua red band BRFs accumulated from DOY 169 to 184 in 2010. (a) RTLS model fitting Root men Square Error (b) RTLS model kernel weights, RGB = iso, vol, geo with 2 St.Dev. scaling (c) number of looks (d) Weight of Determination for the RTLS geometric kernel weight (e) Simple Geometric Model Root men Square Error (f) SGM mean crown radius (g) SGM fractional cover (h) SGM mean height.

We can assess noise amplification in retrieved kernel weights using the Weights of Determination (Lucht & Lewis, 2000). The WoD values for the geometric kernel weight are generally <2.0 (maximum = 1.4 for the sites). The retrieved MODIS/SGM mean crown radius, mean crown *b*/*r* ratio, fractional cover, and mean canopy height appear to have no relation to the site reference values (but note that for all but three of the sites the retrieved crown radius were close to zero, indicating that the algorithm found no reason to darken the modeled BRF by adding shrubs).

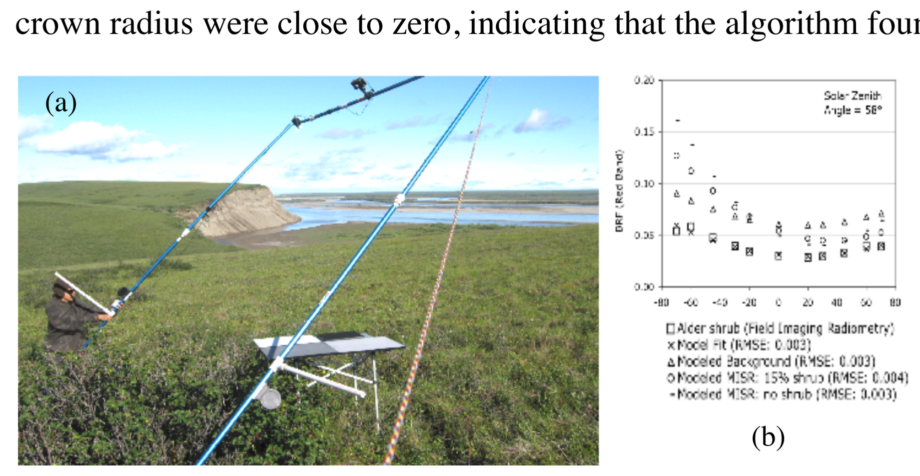


Fig. 3 Multiangle radiometry in tundra(a) tilting frame (b) typical results

Fig. 4 Fractional Cover at the 14 Field Sites

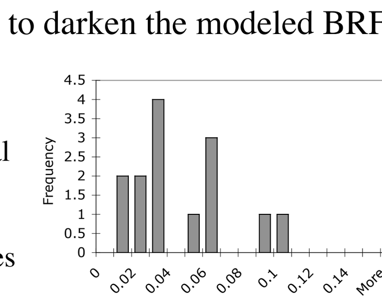
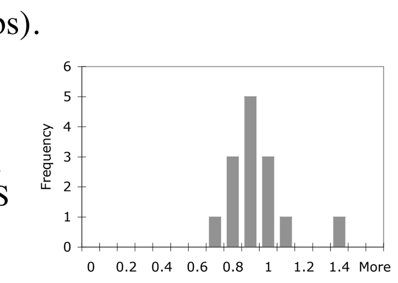


Fig. 5 Weights of Determination For the RTLS Geometric kernel weight



Conclusions: These results indicate that the RTLS BRDF model geometric kernel weight has potential for mapping shrub abundance even where fractional cover is very low and contrast between shrub crowns and the background is very low. More work is required to see whether geometric-optic modeling can be used to map shrubs over dark tundra backgrounds.

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