Exploration of land cover and cloud 'frequency' from MOD35/MOD06

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Project Summary

I am developing a global 1-km cloud climatology using MODIS data for global biodiversity studies and to inform high-resolution interpolation of precipitation. I am interested in two summary metrics:

1. Frequency of cloudy days (e.g. proportion of cloudy days in MOD35 across all years within each particular month)
2. Summaries of the cloud top parameters (MOD06 optical thickness and effective radius) across all years within each month.

Cloud Mask Frequency Associated with Land Cover

When I summarized the data for tile h11v08 (Venezuela), I was surprised to find a strong association between proportion cloudy days and land cover at fine resolutions in some regions. I first noticed this in the MOD06 product, but recently realized that the root of the pattern is in the cloud flag itself. For example, the following figure illustrates the proportion cloudy days (bits 1-2 either 01 or 10) across all swaths 2000-2012 for tile h11v08 (Venezuela).

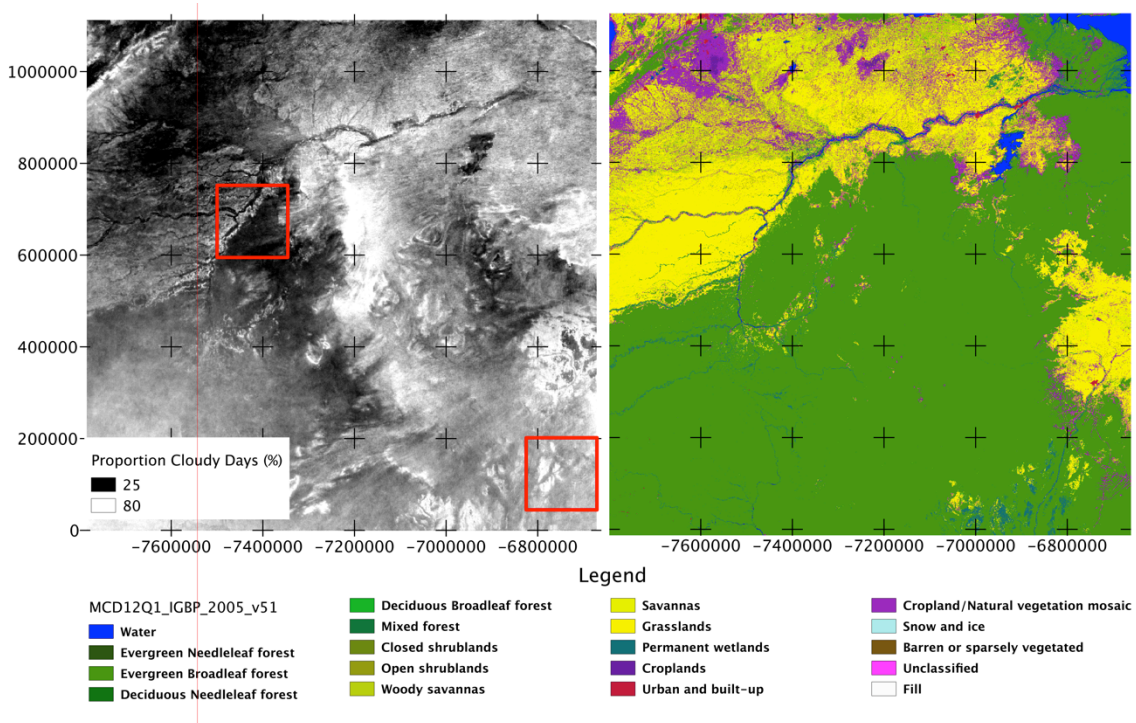

Figure 1: Proportion of "Probably Cloudy" and "Certainly Cloudy" across all January swaths (2000-2012) (left) and landcover from MODIS (MCD12Q1:IGBP) for tile h11v08. Red squares indicate areas shown in

Figure 2. Note the discrete boundaries in cloud frequency at landcover boundaries (especially forest:nonforest).

So the pattern of "cloud" frequency appears to be strongly influenced by land cover, occasionally ranging from >70% cloudy over non-forest to <30% cloudy over forest across the boundary (<3km apart). While differences in cloud properties over various ecosystem types is expected, the fine-scale detail present in the cloud mask climatologies suggests there is a landcover artifact, probably associated with the different processing paths for different land cover types (e.g. vegetation and 'desert'). For example, the following figure shows two smaller regions within tile h11v08. The most extreme example of the relationship is apparent in the bottom row of Figure 2, which shows areas <5 km across with the classic 'fishbone' deforestation pattern having increased 'cloud' frequencies.

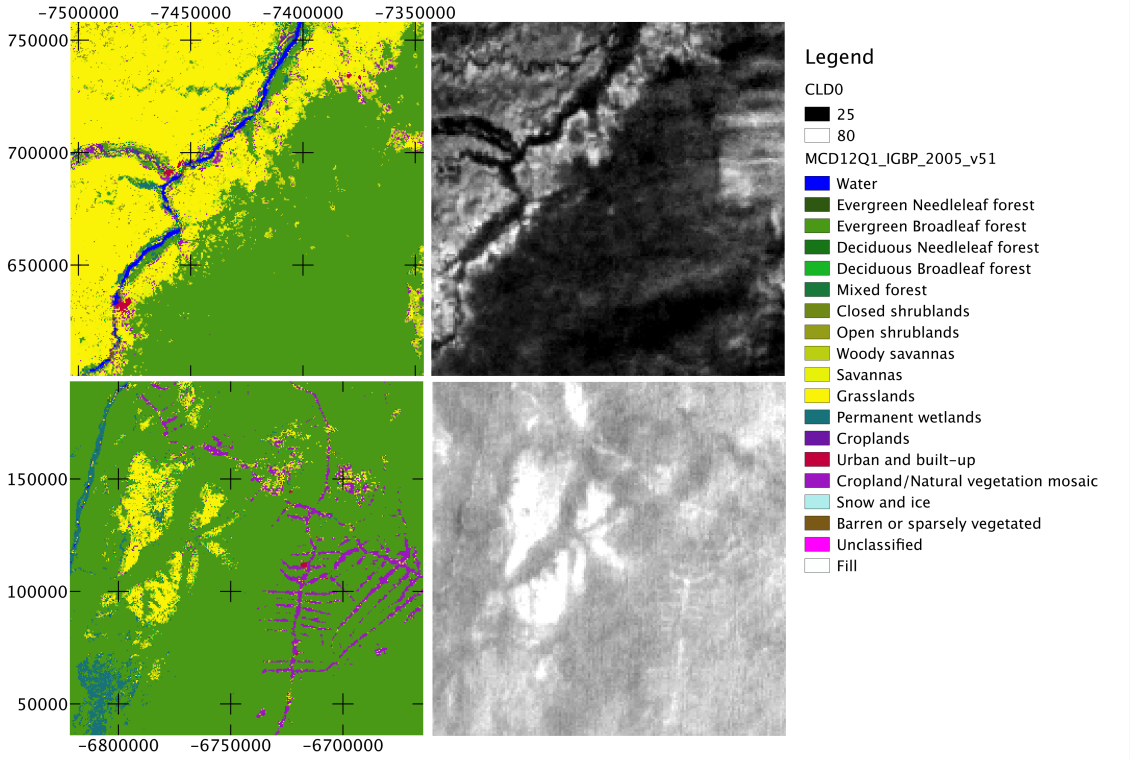

Figure 2: Comparison of land-cover and cloud frequencies at finer resolutions for two regions within tile h11v08 (see figure one for locations). Note that areas of non-forest ('savannas' in the northwest and deforested areas in the southeast) have far higher proportions 'cloudy' days.

Broader Implications

The implications of this land-cover artifact in the cloud mask are much broader than just the MOD06 cloud product. Because MOD35 is used in most higher-level MODIS products, these artifacts will affect the quantity of available observations for many products (e.g. MOD13 vegetation indices and MOD11 land surface temperatures).

See below for the proportion of missing data in the MOD43A4 (BRDF reflectance) product over 2010-2012 for the southeastern corner of h11v08.

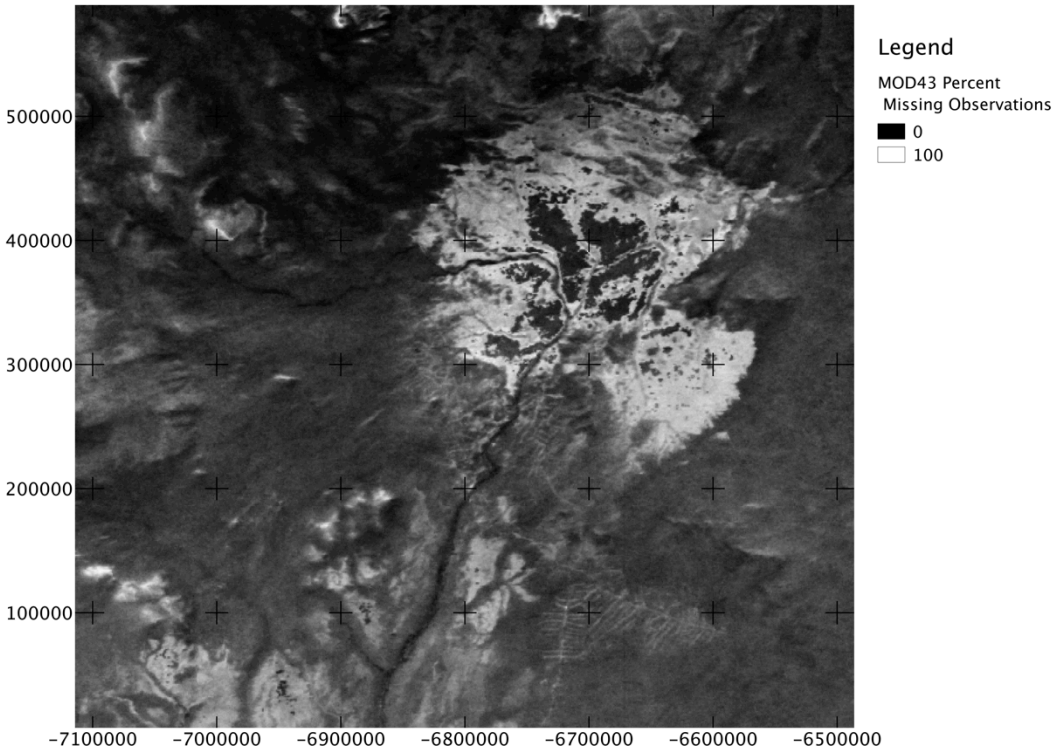

Figure 3: Proportion missing data across all MOD43A4 images between 2010 and 2012 for (enlarged) region shown in bottom row of Figure 2. Missing data in this product are likely due primarily to the cloud mask. Note the similar correlation with land cover, including the 'fishbone' deforestation pattern in the southeast corner. The proportion of missing data can vary more than 50% over ~2km across land-cover boundaries, with >70% missing (cloudy) over non-forest and only 20% missing (cloud) over forest.

Updated MOD35 (Collection 6) Product

Fortunately, according to the updated MOD35 ATBD[1], the algorithm has been updated in several ways that should reduce this problem. Collection 6 will use "NDVI background maps" rather than the AVHRR-based ecosystem maps to identify which pixels should be classified as desert. Specifically, they will use a global 5-year mean of 16-day NDVIs (Moody, et al.) and define desert pixels as those with a NDVI background < 0.3. They also changed some of the tests for identifying clouds in these regions. Apparently[2], these changes will:

1. Greatly reduce the fraction of pixels processed as desert
2. Decreases frequency of "probably cloudy" and "probably clear" results in vegetated regions under conditions of clear skies

[1] http://modis-atmos.gsfc.nasa.gov/_docs/MOD35_ATBD_Collection6.pdf

[2] http://modis-atmos.gsfc.nasa.gov/_docs/MODIS_Aqua_C6_Cloud_Mask_Updates.pdf