Development of an Operational Land Water Mask for MODIS Collection 6

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Abstract

Introduction

Data from the Moderate Resolution Imaging Spectro-radiometer (MODIS) are processed from Level 0 (raw uncalibrated instrument measurements) to Level 4 (calibrated, and interpreted products) at the MODIS Adaptive Processing System (MODAPS) at NASA Goddard Space Flight Center. There are over 100 algorithms in thematic areas of Land, Oceans, and Atmospheres that are processed some of which utilize a land/water mask to achieve greater accuracy in the interpreted measurements (ex. Land surface temperature, aerosol retrievals, cloud detection, etc.). The original land/water mask that was used, from launch through Collection 3, had a spatial resolution of 1km and was derived from the AVHRR land cover product (1996), GTOPO30, and other come resources at the time. This product was determined by the MODIS Land team to have inaccuracies that caused errors to propagate into downstream data products and was replaced prior to the start of the Collection 4 reprocessing in 2004. The new product, generated by the MODIS Land Cover team at Boston University, was still at 1km spatial resolution but improved on some of the gross misplacement of rivers (Carroll et al, 2009) that were causing known problems in MODIS data products. During subsequent MODIS Land Science team meetings in 2005 – 2008 the team expressed an interest in further improving the land/water mask with finer resolution products that were becoming available and by utilizing the building archive of MODIS 250m data in order to produce more continuous rivers and better define the lakes and coastlines. A team from the University of Maryland led an effort from 2008 – 2009 to create a new global 250m land/water mask to be used for MODIS data processing for future collections. The product was completed and released to the public in August, 2009 (Carroll et al, 2009). The MODIS Science team decided to wait for Collection 6 reprocessing to implement the new land/water mask in order to keep the processing consistent within Collection 5.

The global 250m water map is a binary depiction of the Earth's surface as either land or water. Prior products used in MODIS processing further defined the water into the classes shown table 1. The MODIS Land team decided that the most appropriate configuration for a new Collection 6 land/water mask would be to maintain the categories shown in table 1 and produce a product at 500m spatial resolution to match the spatial resolution of the majority of the products. The team from the University of Maryland accepted this task in June 2010 and completed the project in September 2010. This document describes the methods used to convert the binary mask to a categorical representation consistent with prior collections, describes the differences between the C4/5 and C6 masks, and identifies primary areas of differences in the maps that can propagate into downstream data products.

Table 1 Categories represented in the multi-class water mask for MODIS.

Value	Category
0	Shallow Ocean
1	Land
2	Shoreline
3	Inland Water
4	Deep Inland Water
5	Ephemeral Water
6	Moderate Ocean
7	Deep Ocean

Methods

The base product used in the development of the operational land/water mask for C6 MODIS data production is the Global 250m Water Map (Carroll et al, 2009). This product was further defined with the additional definition of a "shoreline" (defined as the last land pixel before water is encountered) and the differentiation of shallow from deep water. The global relief product ETOPO1 (http://www.ngdc.noaa.gov/mgg/global/global.html) (accessed 06/10/2010) was used to identify the depths in the water to define the categories 0, 4, 6, and 7. The ETOPO1 product was chosen for its global coverage and 1 arc minute spatial resolution. Depth thresholds were identified to be as close to previously used thresholds as possible and were defined as follows: Shallow: 0 – 160 ft; Moderate: 161 – 400 ft; Deep > 400 ft. Deep inland water was defined as anything deeper than 160 ft. The ephemeral water category was not populated in either the at-launch product or the C4/5 product. No attempt was made to populate this category for the C6 product.

Initially the global 250m water map was aggregated to 500m spatial resolution using exact averaging and with the following assumptions:

1) There are exactly 4 250m pixels in 1 500m pixel assuming that all projection parameters remain constant.
2) If 2 or more 250m pixels were identified as water the 500m pixel was labeled as water.

There was a substantial difference in spatial resolution between the MODIS data (~15 arc second) and the ETOPO1 data (60 arc second). An algorithm was developed and implemented that utilized spatial relationship utilities in a Geographic Information System (GIS) to merge the data sets and maintain the finer resolution class boundaries.

The previous steps were automated and produced the first cut result. Each of the 326 MODIS tiles were then opened and evaluated by comparing against visible imagery. Tiles with apparent anomalies were identified for further evaluation. The primary anomaly identified were "slivers" between shoreline and shallow ocean that were not captured in the automated error checking. These occurred in less than 10% of the tiles and were manually converted to the shallow ocean category.

Results

The product generated from this work is natively in MODIS Sinusoidal grid and tiling scheme and available at 500m spatial resolution. To fulfill the needs of the production team an additional product was generated that is a global depiction of the result in Lat/Lon (Geographic) projection on WGS-84 datum (figure 1).

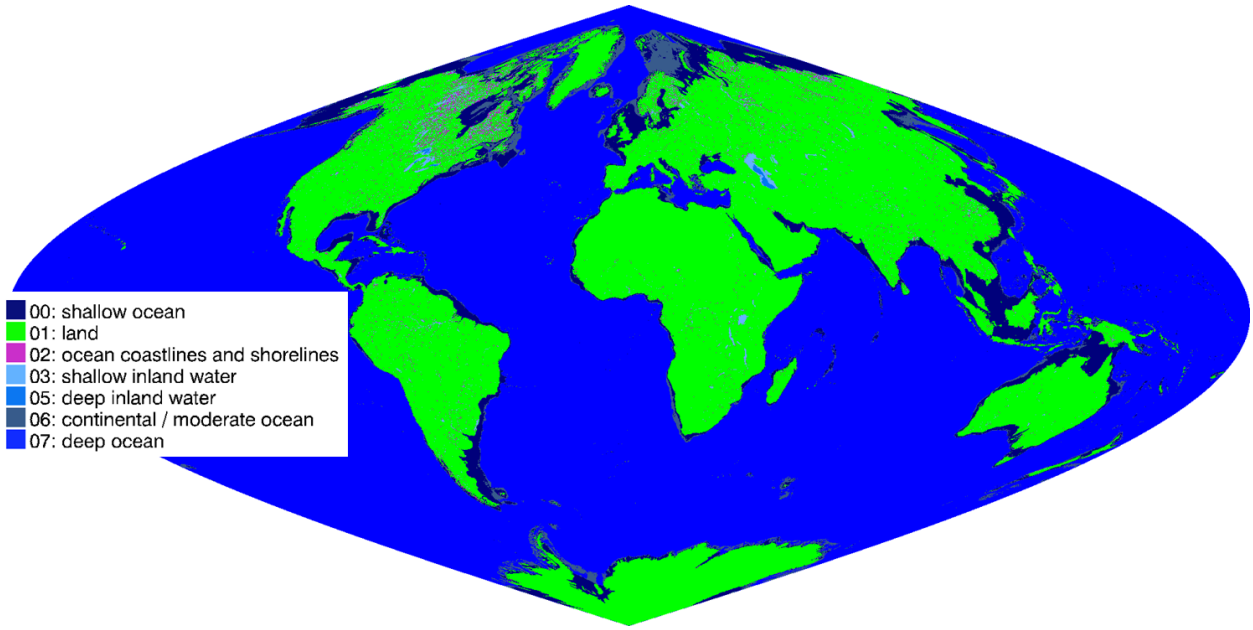

Figure 1 Global 8 category water mask at 500m resolution for the MODIS C6 data reprocessing.

Some of the fine details seen in the 250m product have been lost due to the coarseness of the spatial resolution but overall the spatial fidelity remains good (figure 2,3). The continuity of rivers is lost when the width of the river is less than 500m which is expected and is simply a limitation of the resolution that we are working at.

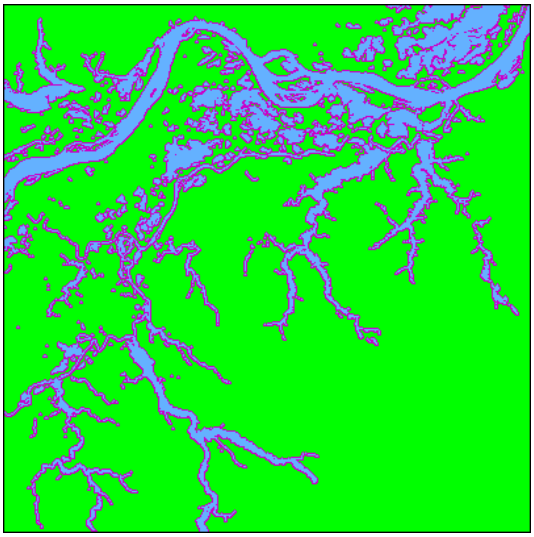

Figure 2 Amazon River, Brazil South America.

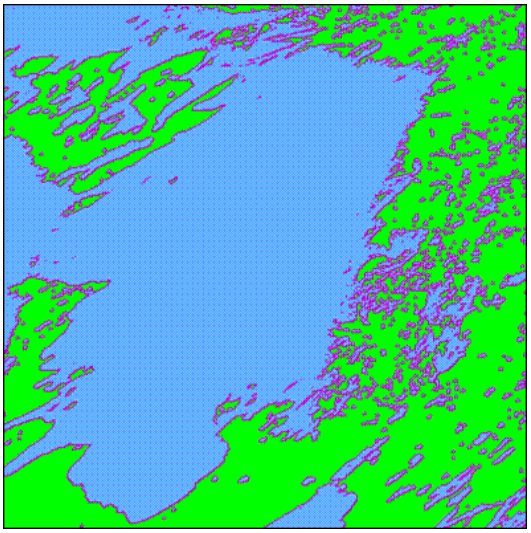

Figure 3 Large and small lakes in Canada North America.

The Land Data Operational Product Evaluation (LDOPE) team evaluated the new C6 land/water mask by comparing with the C4/5 land/water mask. Results of that evaluation are available online at http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/newPage.cgi?fileName=C6_waterMask_250m . A confusion matrix showing areas of agreement and disagreement was created and is shown in table 2. The overall agreement on a global scale is nearly 94%, however substantial disagreement in specific classes does occur. The C6 mask shows 2.33% of the continental surface as water (inland lakes, ponds, reservoirs and rivers) compared to 1.45% represented as water in the C5 mask. For the shallow inland water class, there is 41% agreement between the two masks. Nearly 38% of the pixels identified as shallow inland water in the C6 mask were previously identified as "land" in the C5 mask. If we consider land and shoreline together, 54% of the pixels identified as shallow inland water in the C6 mask were previously identified as land or shoreline in the C5 mask. This difference can be accredited to the substantial difference in spatial resolution between the C5 mask (1km) and the underlying 250m MODIS water map. Primary areas of difference in inland water occur in the high northern latitudes where 2 factors result in more water being identified.

1) Improved spatial resolution from 1km (C4/5) to 500m (C6) result in more lakes and narrower rivers identified in the new C6 mask.
2) An error in the projection software resulted in a substantial shoreline shift in the C4/5 product that was corrected in the C6 product.

Table 2 Confusion matrix comparing C5 vs C6 water mask. Class 4, Ephemeral water, is not populated in either mask so has been omitted from the table.

	C5 Mask	0	1	2	3	5	6	7	
C6 Mask		Shallow Ocean	Land	Shoreline	Shallow Inland	Deep Inland	Mod. Ocean	Deep Ocean	Total
0	Shallow Ocean	66,064,777	2,494,034	3,179,627	165,235	809	45,889,107	956,637	118,750,226
1	Land	541,970	646,883,341	4,862,811	1,204,525	8,095	16,423	192	653,517,357
2	Shoreline	545,582	12,370,392	2,519,087	895,621	984	6,010	379	16,338,055
3	Shallow Inland	72,016	5,411,904	2,366,318	5,893,698	623,283	43	-	14,367,262
5	Deep Inland	123	558	915	614,639	245,001	-	-	861,236
6	Mod. Ocean	5,270,037	86,763	211,545	3,962	-	36,370,514	7,586,840	49,529,661
7	Deep Ocean	1,814,187	5,129	12,196	57	-	7,549,884	836,966,734	846,348,187
	Total	74,308,692	667,252,121	13,152,499	8,777,737	878,172	89,831,981	845,510,782	

Delineation of shoreline is also different between the C5 mask and the new C6 mask. Nearly 5% of the pixels identified as "shallow ocean" were previously identified as either land or shoreline. The impact of using the ETOPO1 bathymetry data set can be seen in the delineations between shallow, moderate and deep ocean. The C6 mask shows 38% more pixels as shallow ocean as compared to the C5 mask with the majority of the reclassified values coming from the

moderate ocean class. There are some differences at the intersection of deep ocean and moderate ocean but these differences represent less than 1% change from C5 to C6.

A map showing the density of "differences" between the 2 maps is shown in figure 4. High concentrations of change can be seen to the west of Hudson Bay in the Canadian Shield as well as along the coastlines.

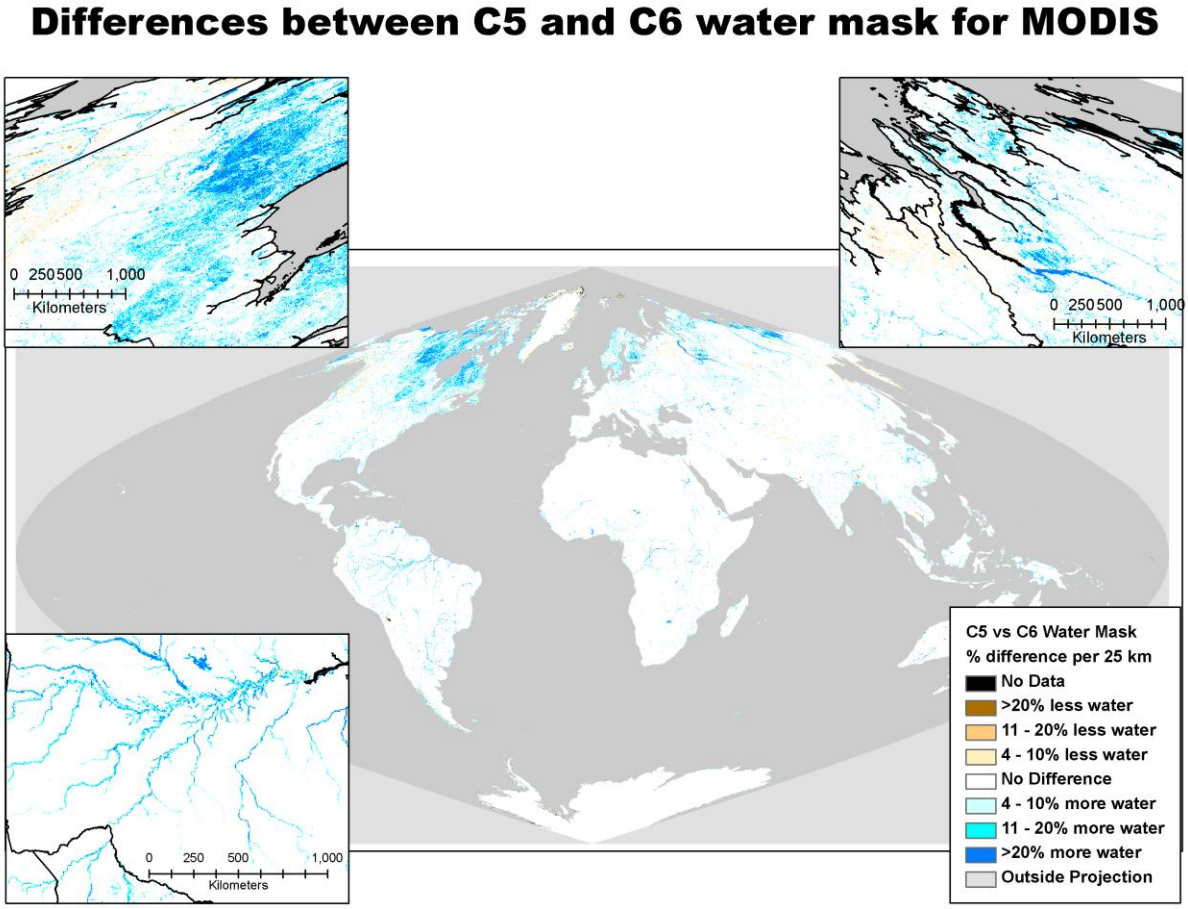

Figure 4 The differences between the Collection 5 vs the Collection 6 water mask for MODIS. Differences are represented as percent difference per 25km grid cell for visibility with more water shown in shades of blue and less water shown in shades of brown.

Conclusions

The Collection 6 land/water mask represents a substantial improvement in accuracy in the representation of water for the MODIS data processing stream. There will be impacts to downstream products that utilize the land/water mask in algorithm pathway logic (i.e. algorithms that operate one way if it is land and a different way if it is water) and this will propagate all the way downstream. While it is expected that the overall global impact because of this change will be minimal the local changes could be significant in some regions such as the Canadian shield where more areas are now identified as water. This watermask is implemented in the L1B product for MODIS and hence has an impact on all products from Land, Atmospheres and

Oceans which use the L1B as input to downstream processes. Individual products will need to be evaluated to determine the direct impact on the C6 offereings.