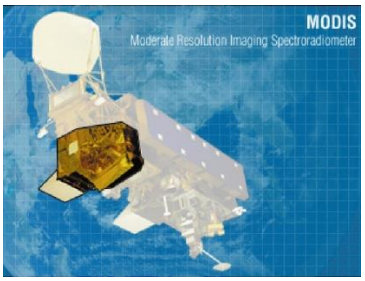
Title:	Mapping snow cover using MODIS
	Part I: The MODIS Instrument
	Part II: Normalized Difference Snow Index
	Part III: Quality Control Procedures and Masks
	Part IV: Apply masks to create a corrected snow map
Product Type:	Curriculum
Developer:	Helen Cox (Professor, Geography, California State University, Northridge): helen.m.cox@csun.edu Maziyar Boustani & Laura Yetter (Research Assts., Institute for Sustainability, California State University, Northridge)
Target audience:	Undergraduate
Format:	Tutorial (pdf document)
Software requirements*:	ArcMap 9 or higher (ArcGIS Desktop) (Parts II, IV), ERDAS Imagine 2010 or higher (Parts I, II, III, IV)
Data:	All data required are obtained within the exercise.
Estimated time to complete:	All parts: 7 hrs.
	Part I: 2 hrs.
	Part II: 2 hrs.
	Part III: 2 hrs.
	Part IV: 1 hr.
Alternative Implementations:	• Parts I and II together provide a standalone exercise producing a snow map • Parts I, II and Part IV (starting at #2) together provide a standalone exercise producing a snow map and comparing it to one produced by NASA • Completing all parts (I through IV) produce a snow map with corrections that is compared to one produced by NASA
Learning objectives:	Part I: • Learn about the MODIS instrument and MODIS data • Download MODIS data
	Part II: • Learn about the Normalized Difference Snow Index (NDSI) • Create a Model in ERDAS Imagine to calculate the NDSI • Create a snow map
	Part III: • Learn how to identify water and forests where snow could be misidentified • Create a Normalized Difference Vegetation Index (NDVI) image • Create masks that will be used to eliminate water and dark forests from the NDSI
	Part IV: • Apply the water, forest, and NDVI masks to eliminate water and forest from the snow map • Re-project the snow map and compare to a MODIS snow product map

*Tutorials may work with earlier versions of software but have not been tested on them



Mapping snow cover using MODIS
Part IV: Apply masks to create a corrected snow map

Objectives

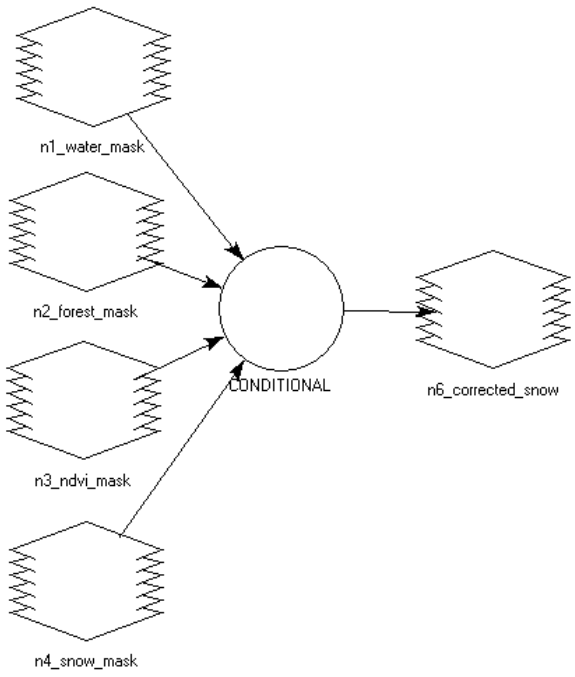
- **Apply the water, forest, and NDVI masks to eliminate water and forest from the snow map**
- **Re-project the snow map and compare to a MODIS snow product map**

Now that the water, forest, and NDVI masks have been created they can be applied to the NDSI image to get the final snow map result. Keep in mind that raster values within the NDSI, water, forest, and NDVI masks are 1= true or 0 = false and the following conditions have already been applied to them.

- snow mask=true if the NDSI is >= 0.4
- water mask = true if band 2 is < 0.11
- forest mask = true if band 4 is < 0.10
- ndvi (snow-forest) mask = true if the NDVI = ~0.10

1. Combine the Masks

Create a new model and add the 4 masks as input rasters.

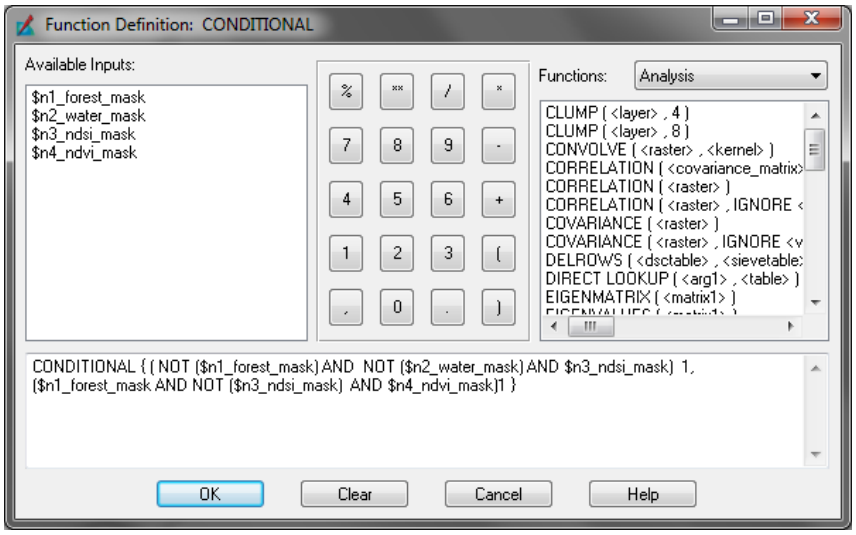


Create a Conditional statement that says if the NDSI mask has identified a pixel as snow it is snow as long as it is not a forest pixel or a water pixel:

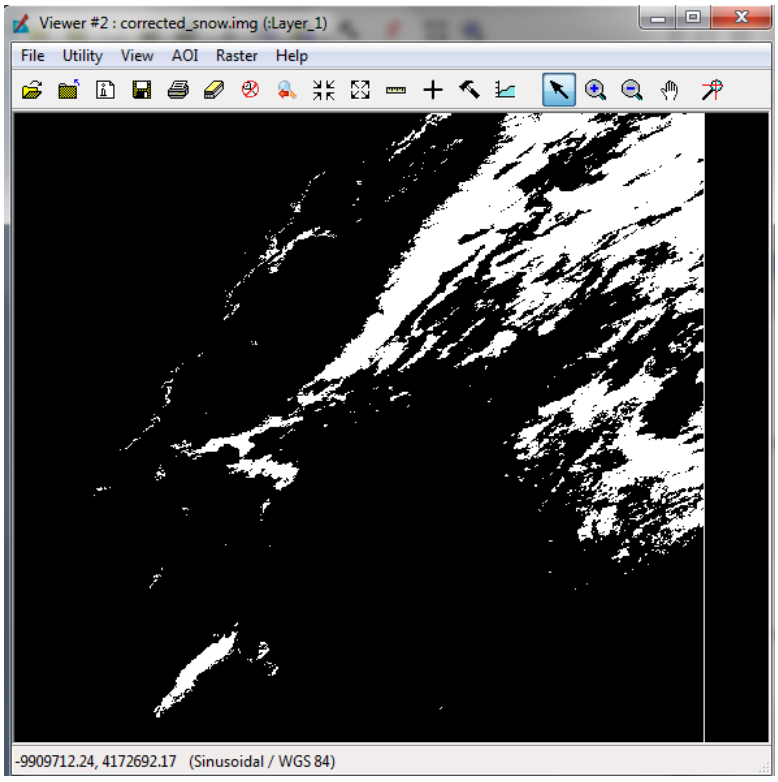
(NOT (forest mask) AND NOT (water mask) AND (NDSI mask)) 1

Create a second test that says if a pixel is identified as snow-forest by the NDVI mask and it is a forest pixel it is snow even if the NDSI mask says it is not snow.

((forest mask) AND NOT (ndsi mask) AND (ndvi mask)) 1

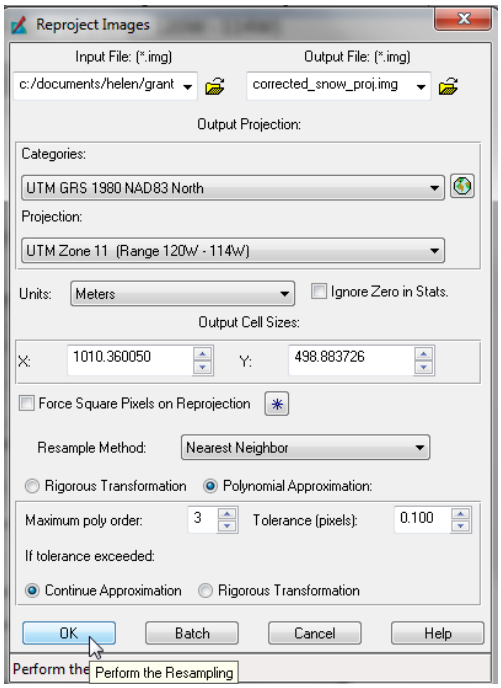


The output should be a raster which will show areas of snow (corrected for errors). Run the model and save the output raster.



2. Project raster

Open the results in Imagine. Re-project the results. Imagine 2010: Raster Tab> Reproject >
(Or Classic Interface: Data Prep> Reproject Images>)
Categories: UTM GRS 1980 NAD 83 North
Projection: UTM Zone 11 (Range 120W - 114W)



Click OK and view the results

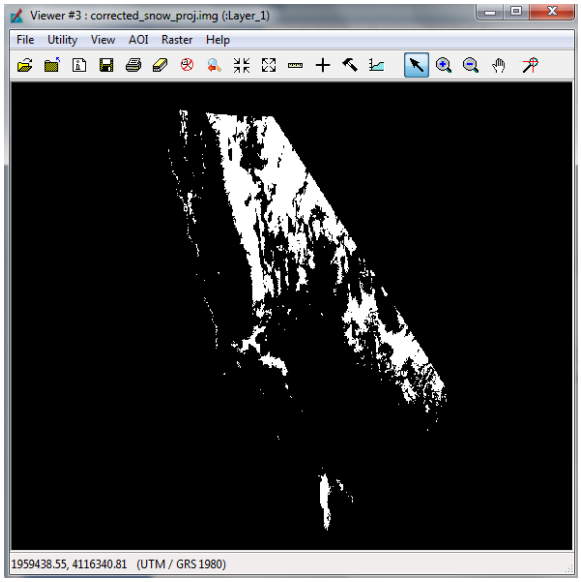
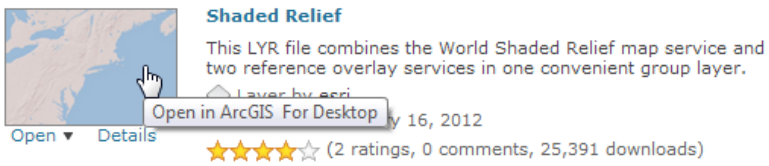


Figure 1. Reprojected final results.

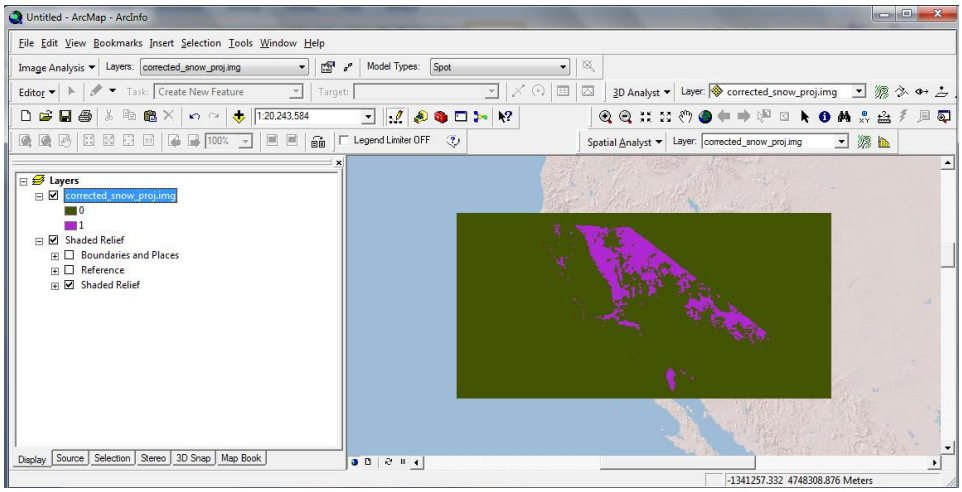
3. ArcMap View with Base Map

Move your projected image into ArcMap and add a base map with terrain and shaded relief.

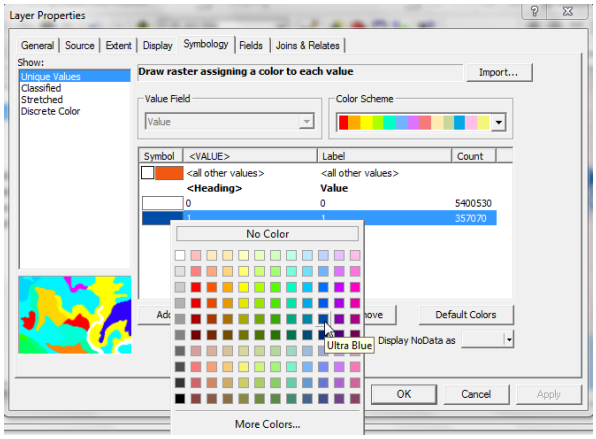
(You can just open ArcMap and drag the .img file of your projected image into the left-hand panel and drop it there.) To add a base map use the + symbol and choose a base map with terrain, or use ArcGIS online to select one.



In ArcMap move the snow map to be above the shaded relief map so it is not hidden.



Change the symbology of the projected snow map to unique values (right click on the name, select “Properties”, select the “symbology” tab, select “unique values” and press “Add all values”. If you receive a message “Unique values do not exist. Do you want to compute unique values?, select “yes”). Then make 0 = no fill and select a color for 1= snow by double-clicking on the color swatch.



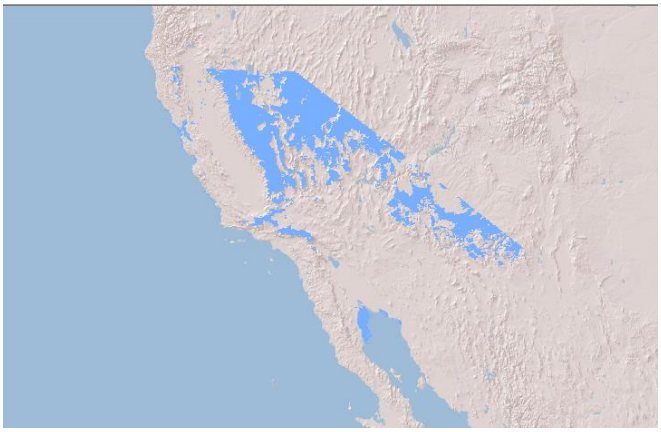
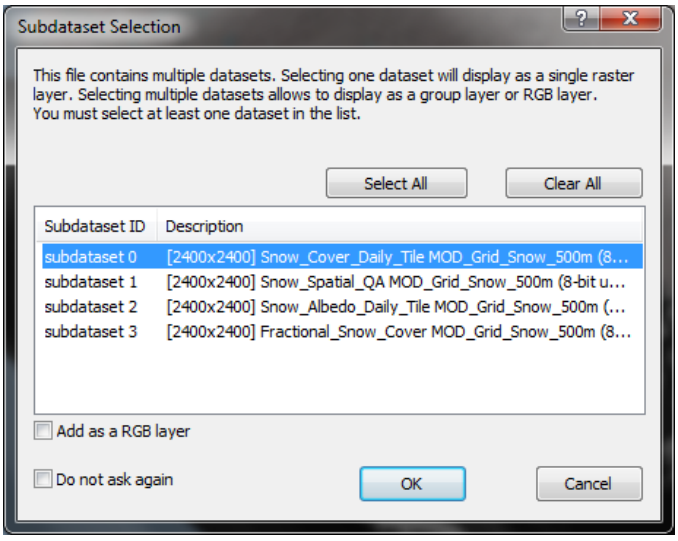


Figure 2. Final Snow Mapping results for January 4, 2011 displayed with reference map. Blue indicates areas of snow.

How well did the results turn out?

Notice that there are still some pixels along the coast and in the San Francisco Bay that are classified as snow. This misclassification may be caused by large pixel sizes (500m) of mixed cover types interfering with each other and causing false readings of snow.

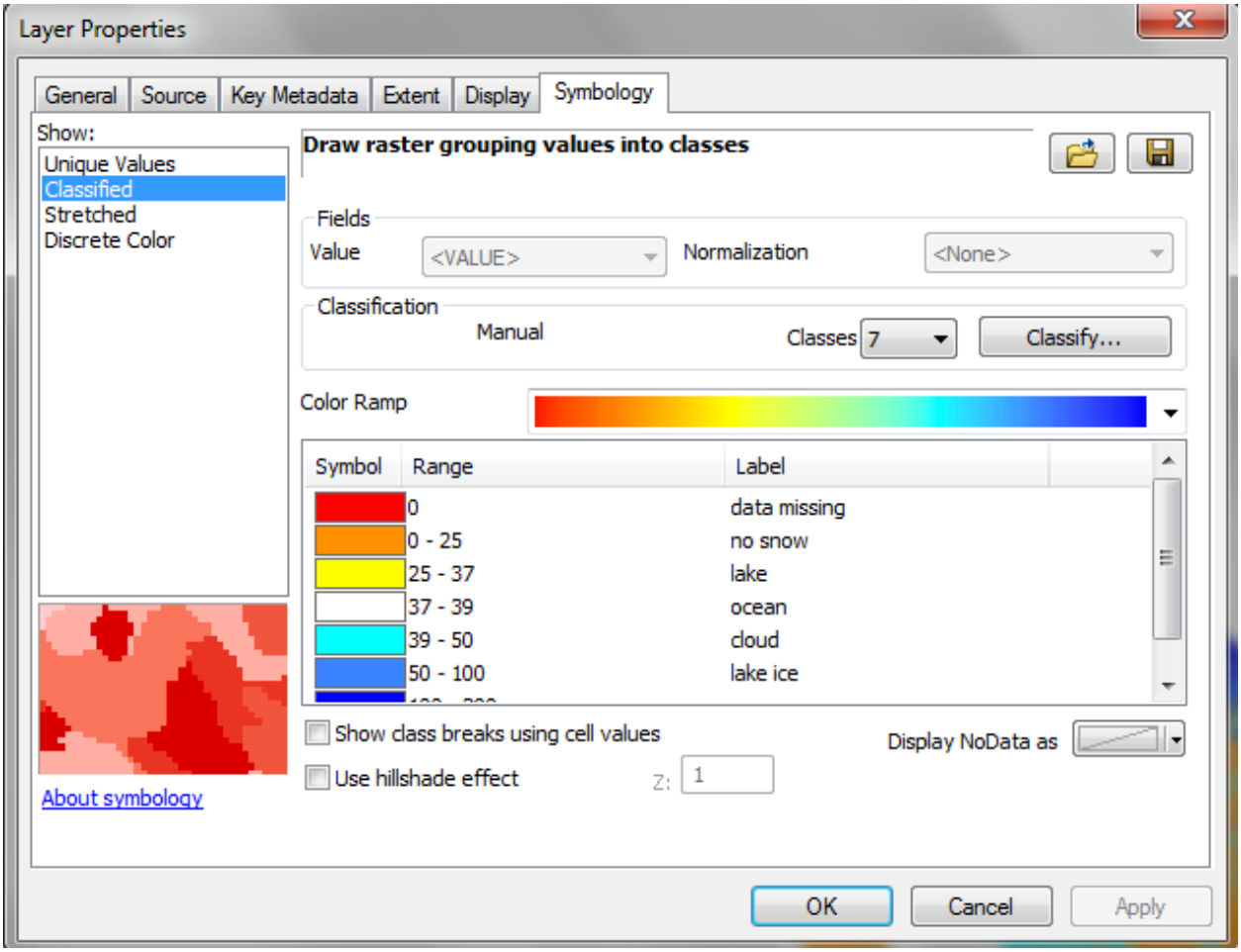
You will now add the MODIS 10A1 snow product map that you downloaded in Exercise 1. Information about this product is at: http://nsidc.org/data/docs/daac/modis_v5/mod10a1_modis_terra_snow_daily_global_500m_grid.gd.html. The data includes snow cover, snow albedo, fractional snow cover, and Quality Assessment (QA) data in compressed Hierarchical Data Format-Earth Observing System (HDF-EOS) format along with corresponding metadata. MOD10A1 consists of 1200 km by 1200 km tiles of 500 m resolution data gridded in a sinusoidal map projection. For this exercise you will use the snow cover (or "Tile" field). Add this to ArcMap by dragging the HDF file into the left-hand pane. On the Subdataset Selection box that appears select the first option Snow Cover Daily Tile.



The Tile data should be interpreted as follows:

Value	Description
0	data missing
1	no decision
11	night
25	no snow
37	lake
39	ocean
50	cloud
100	lake ice
200	snow
254	detector saturated
255	fill

In ArcMap the layer should be a gray scale image with the snow shown in a light grey. You should change the symbology so that each different land cover class above is shown in a different color. To do this, right click on the MOD10A layer in ArcMap and select Properties->Symbology. Select Classified and 7 (or more) classes. With “Natural Breaks” it should select the break values correctly or you can set them manually through the “Classify” option. Edit the labels so that they show the correct land cover type rather than the range of values. (You should be able to change the symbology more easily using “Unique Values” but this does not appear to function correctly with this HDF file.)



Your image should now look like this:

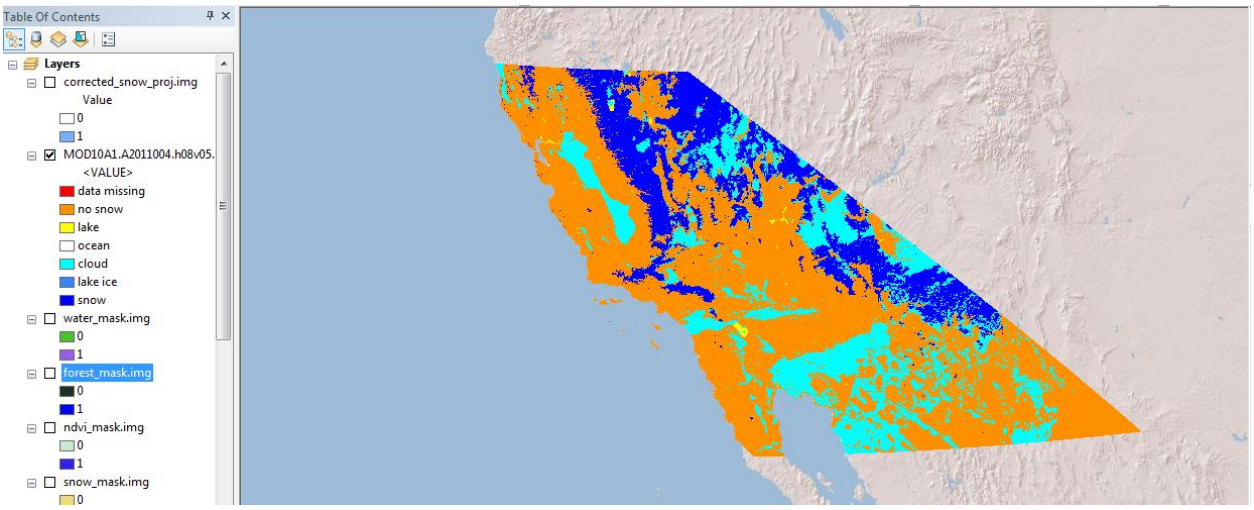


Figure 3. MODIS product snow map used for comparison. In this example, snow is shown in dark blue.

Now display your snow map on top of this. By repeatedly turning it on and off you should be able to flicker between your map and the NASA product.

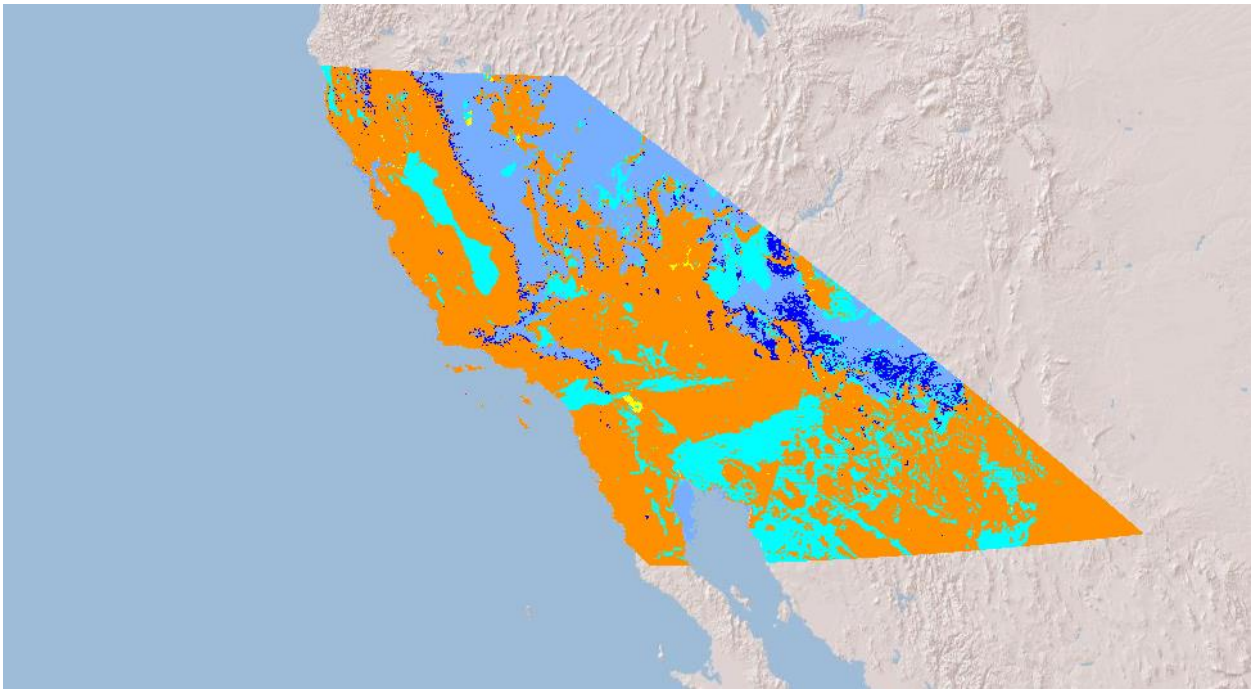


Figure 4. Comparison between NASA snow product (multi-colors, snow in dark blue) and ours (light blue-grey).

Toggle back and forth between the MODIS 10A1 layer and your snow map (or change the transparency) to compare the results. For the most part the data should agree, with minor areas of discrepancy.