CREATION OF ERSATZ GROUND REFERENCE DATA FOR VALIDATING IMPROVEMENTS IN THE MODIS SNOW AND ICE PRODUCT SUITE

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1. INTRODUCTION

We reported earlier [1] on efforts to reduce the so-called "cloud fringe" problem. Here the fringes of certain snow fields are labeled as "cloud" whereas close inspection of the data indicates that the correct labeling is a non-cloud category such as snow or land. Noting that the labeling of image pixels as cloud is done without any regard to spatial context, we investigated utilizing image segmentation for providing a spatial context through which the MODIS Cloud Mask Product determination of cloud can be overridden whenever appropriate.

Quantitative measures are needed to evaluate our results to help guide our efforts and validate our results. Since gathering comprehensive reference data by coincident ground surveys is impractical, we decided to develop a photo-interpretive tool that we could use to edit the MODIS standard snow map product to produce an ersatz ground reference. This tool allows an analyst to compare visualizations of Landsat TM scenes with registered visualizations of sub-sections of MODIS scenes and edit the snow map product as indicated.

Our original idea was to use the photo-interpretive tool to simply override the cloud mask. However, it soon became clear that this type of tool could be made to do much more than override the cloud mask. Our visual inspection of the coincident Landsat TM and MODIS data indicated that we could visualize a more accurate mapping the snow fields and lake ice, even through high clouds. With this realization we decided to expand the capabilities of the tool to fully edit the MODIS Snow and Ice product to broaden the usefulness of the result.

Our Snow-Ice Map Editing Tool, called "snow_ice_edit," requires that the MODIS Snow and Ice product be recomputed without the MODIS Cloud Mask Product being applied. It also requires that the cloud masked and non-cloud masked Snow and Ice product be projected through WGS 84 / UTM projection since the Landsat TM product is normally supplied in this projection. This recomputation and projection is performed in a separate program that we call "swath_snow_ice." The snow_ice_edit program also requires hierarchical segmentations of the MODIS data (bands 1, 2, 4 and 6) and of the MODIS derived NDSI data from the RHSEG program [2].

2. THE SWATH_SNOW_ICE PROGRAM

The MODIS Snow and Ice Product generation algorithm is described in [1] and [3]. The algorithm requires the calculation of the normalized difference snow index (NDSI) and the normalized difference vegetation index (NDVI) from MODIS bands 1, 2, 4 and 6. The algorithm includes a surface temperature screen test that requires the computation of land surface temperature from MODIS bands 31 and 32. The algorithm also requires a Land/Sea Mask provided by the MODIS MOD03 product to differentiate between snow and lake ice. To ensure the best match between the standard MODIS Snow and Ice product and the recalculated product, the swath_snow_ice program uses the CLOUD_OBSCURED flag and other flags from the standard MODIS Snow and Ice product. The calculated product matches the standard product to better than 99.999% accuracy. The snow_ice_edit program also utilizes cloud mask details to help determine whether the cloud mask should be removed at certain locations. The swath_snow_ice program facilitates this by producing a modified cloud mask product from the Cloud Mask and Cloud Mask Quality Assurance data from the MODIS MOD35_L2 product that distinguishes thin cirrus and high cloud detection. To enable the geometric overlaying of sub-sections of the MODIS data and products on the Landsat TM imagery data, the swath_snow_ice program must project the MODIS data and products into the WGS 84 / UTM projection, which is the standard Landsat TM projection. To do this the swath_snow_ice program needs the Latitude and Longitude data from the MODIS MOD03 product output in both swath format (i.e., the original data format) and projected format. The HDFLook program (available from http://www-loa.univ-lille1.fr/Hdflook/) can be used to output MODIS product data in both swath and projected format.

3. THE RHSEG PROGRAM

The RHSEG (Recursive Hierarchical Segmentation) program [2] produces a hierarchical set of image segmentations. This segmentation hierarchy is a set of several image segmentations of the same image at different levels of detail in which the segmentations at coarser levels of detail can be produced from simple merges of regions at finer levels of detail. A unique feature of a segmentation hierarchy that distinguishes it from most other multilevel representations is that the segment or region boundaries are maintained at the full image spatial resolution for all levels of the segmentation hierarchy. Two different RHSEG segmentations can be utilized by the snow_ice_edit program: A multi-band segmentation on the solar zenith angle corrected reflectance data from MODIS bands 1, 2, 4 and 6, or a single-band segmentation on the NDSI calculated from the MODIS data.

4. THE SNOW_ICE_EDIT PROGRAM

The snow_ice_edit program provides a graphical user interface (GUI) that provides various image displays and action options. The image display panels can be panned and zoomed, and the panning and zooming of each image display panel tracks all the others so that the same geographical area is displayed in every panel. Analyst

experience has shown that the Landsat TM RGB (bands 5, 4 & 2), MODIS RGB (bands 6, 4 & 1), the modified cloud mask map and the pseudo colored region segmentation map are the most useful displays. In addition, the output revised snow and ice map reflects the current revision of the snow and ice map. Through the program GUIs the analyst can select various sub-regions in the output revised snow and ice map, including all or a portion of the cloud masked areas and particular RHSEG region objects at various hierarchical levels. Also, all RHSEG region objects with mean >= threshold can be selected. This thresholding option is most useful with the NDSI segmentations. Other area selection facilities are also provided. The cloud mask can be removed from selected areas by replacing the output revised snow map in the selected areas with the values from the calculated snow and ice map without cloud masking. Particular selected areas can also be relabeled to categories such as No Snow, Lake, Cloud, Lake Ice, or Snow.

5. EXAMPLE OF USING SNOW_ICE_EDIT

We have been testing the snow_ice_edit program on a MODIS data set covering western North America from 2 Dec. 2000 (granule A2000337.1900.005). The Landsat TM scene LE70420312000337EDC00, also from 2 Dec. 2000, falls roughly in the center of this MODIS scene (Fig. 1). The corresponding sub-section of the MODIS scene is shown in Fig. 2, the original (calculated) Snow and Ice product map is shown in Fig. 3. In Fig. 3 (and also Fig. 6), green is “No Snow,” white is “Snow,” and purple is “Cloud.” Note the clouds around the fringe of the snow fields in the original Snow and Ice product map.

The snow_ice_edit program was first invoked using the RHSEG segmentation on the multiband MODIS data. Analyst experience has shown that this segmentation is most useful for editing the cloud mask. The analyst found that region object #2683 at hierarchical level 6 best matched the spatial extent of the cloud area in the north central section of the MODIS image (grey region in Fig. 4) and relabeled this area as cloud (see Fig. 6). Other cloud mask areas were removed because they were determined to be thin high clouds (that can be seen through) or bright sandy soil. Then the snow_ice_edit program was re-invoked with the RHSEG segmentation on the NDSI data. Analyst experience has shown that this segmentation is most useful for editing the snow cover areas. The analyst found that selecting all region objects with region mean >= 0.21 (highlighted in red in Fig. 5) best represented the snow field spatial distribution as seen in both the Landsat TM RGB and MODIS RGB images. The relabeling of these areas as Snow is reflected in the revised snow and ice map in Fig. 6.

Nearly 200 Landsat TM scenes are required to cover the entire MODIS scene. There is significant overlap between the paths and rows of the Landsat TM scenes, but this overlap is useful for keeping the editing consistent between the paths and rows. We find that the Landsat TM scenes are still useful verification even when they are from a few days before or after the MODIS scene.

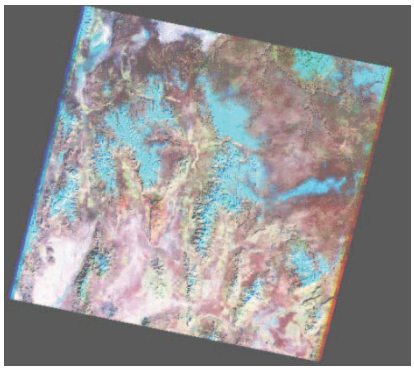

Fig. 1. Landsat TM RGB image.

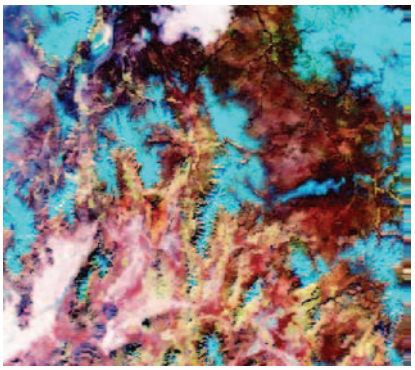

Fig. 2. MODIS RGB image.

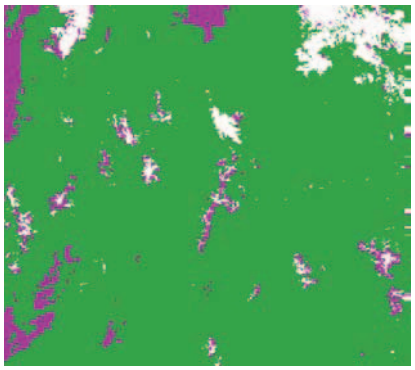

Fig. 3. Original Snow and Ice Map

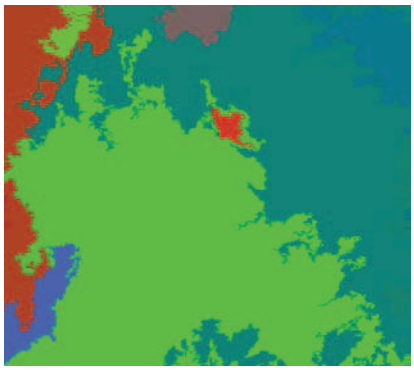

Fig. 4. Pseudo colored MODIS RHSEG segmentation at hierarchical level 6.

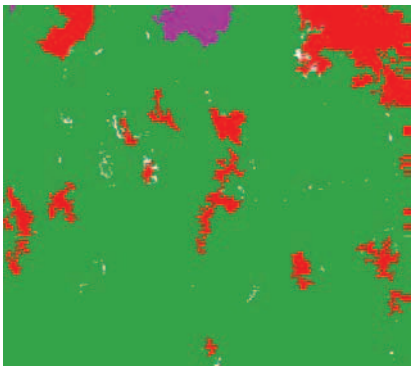

Fig. 5. Snow and Ice map with highlighted (red) NDSI RHSEG segmentation.

Fig. 6. Revised Snow and Ice Map.

6. CONCLUDING REMARKS

We have described and demonstrated an analyst interactive tool for editing the MODIS Snow and Ice product map to produce an ersatz ground reference. Our experience with the portion of the scene edited to date is that the spatial extent of the snow fields is somewhat underrepresented in the current Snow and Ice product. The cloud mask can also be underrepresented, but more often "snow" or "no snow" can be seen through high clouds. In the later case, we have chosen to eliminate the cloud mask for areas in which we can easily see through the clouds (mainly "high clouds"). We are looking forward to using the edited snow and ice maps for validation of our future Snow and Ice Product improvement schemes.

7. REFERENCES

[1] J. C. Tilton, D. K. Hall, and G. A. Riggs, "Enhancement of the MODIS Snow and Ice Product Suite Utilizing Image Segmentation," *Proceedings of IGARSS 2008*, Boston, MA, USA, 7-11 July 2008, Vol. 4, pp. 1069–1072.

[2] J. C. Tilton, "RHSEG Version 1.45," *Disclosure of Invention and New Technology: NASA Case No. 15,898-1*, July 30, 2009.

[3] G. A. Riggs, D. K. Hall, and V. V. Salomonson, "MODIS Snow Products User Guide to Collection 5," http://modis-snow-ice.gsfc.nasa.gov/sug_c5.pdf, Nov. 2006.

[4] J.-M. Beaulieu and M. Goldberg, "Hierarchy in Picture Segmentation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol.11, No. 2, pp. 150-163, 1989.