A geometry-based approach is presented to identify cloud shadows using an automated cloud classification algorithm developed for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program. These new procedures exploit both the cloud confidence and cloud phase intermediate products generated by the Visible/Infrared Imager/Radiometer Suite (VIIRS) cloud mask (VMC) algorithm. The procedures have been tested and found to accurately detect cloud shadows in global datasets collected by NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor and are applied over both land and ocean background conditions. These new procedures represent a marked departure from those used in the heritage MOD09 cloud mask algorithm which utilizes spectral signatures in an attempt to identify cloud shadows. However, they more closely follow those developed to identify cloud shadows in the MODIS Surface Reflectance (MOD09) data product. Significant differences were necessary in the implementation of the MOD09 procedures to meet NPOESS latency requirements in the VCM algorithm. In this presentation, the geometry-based approach used to predict cloud shadows is presented, differences are highlighted between the heritage MOD09 algorithm and new VIIRS cloud shadow algorithm, and results are shown for both these algorithms plus cloud shadows generated by the spectral-based approach. The comparisons show that the geometry-based procedures produce cloud shadows far superior to those predicted by the spectral procedures. In addition, the new VCM procedures predict cloud shadows that agree well with those found in the MOD09 product while significantly reducing the execution time as required to meet the operational time constraints of the NPOESS system.

### Abstract

Spectral tests have been employed by the MCM (Ackerman et al., 2006; 2002; 1997) and original VCM (Reed, 2002) algorithms to identify cloud shadows, while noting that a geometric approach requires too much CPU to run operationally. Figure 1 shows results produced by these spectral-based cloud shadow tests applied to a MODIS Terra granule collected over the western US on October 30, 2003 at 1835 UTC. (The granule ID is MOD.2003.299.1835.) A false-color image of the region of interest is enlarged in Panel 1A. Large shadows are apparent near clouds located at Points A, B, and C. Panels 1B and 1C show shadows predicted with the spectral tests.

Cloud shadows predicted by the spectral tests with this case study represent the best produced in 40+ MODIS granules analyzed during the course of these investigations. In most cases, the spectral-based tests failed to detect correctly any cloud shadows.

### Results

#### Shadows from Water Cloud

Figure 3 shows results of the geometry-based cloud shadows for the scene containing water clouds in Figure 1. Panel 3A shows results from the VCM algorithm while Panel 3B shows the data contained in MOD09 product. Clouds in the MOD09 product are displayed in yellow while those from the VCM algorithm appear as orange. Shadows appear turquoise for both products.

#### Shadows from Ice Cloud

Cloud shadows are shown for ice clouds shown in the MODIS scene contained in Figure 4, which covers the southwest USA and northern Mexico. These data were collected by MODIS Terra on February 1, 2002 at 1750 UTC (granule ID MOD.2002.032.1750).

Panel B of Figure 4 contains shadow results from the VCM algorithm using the spectral tests. (In this case, the actual VCM cloud mask is not shown separately since the spectral tests detected so few shadows.) Panels C and D in (e) Figure 4 again show the VCM and MOD09 geometry-based cloud shadows. In this case, the VCM projects a slightly larger shadow that is found in the MOD09 product. Upon close examination of the MOD09 product, it is seen that unmasked shadows in the imagery are evident around Points A and B in Panel D, while these edges of undetected shadows are not observed in VCM results shown in Panel C. It appears that using the cloud phase analyses in the VCM to specify the cloud top height of cirrus clouds can provide a more accurate cloud shadow when the clouds are not completely opaque. Smaller shadows in MOD09 product approach occur because the actual CTT is colder than the 11-μm brightness temperature, so the cloud top height is placed too low in the atmosphere.

#### Conclusion

A geometry-based approach has been implemented to identify cloud shadows in a VCM algorithm for NPOESS. The procedures closely follow those used in the MOD09 algorithm. The new VCM cloud shadow procedures exploit both the cloud confidence and cloud phase intermediate products to better classify cloud tops associated with cirrus clouds. Results show that the geometry-based approach used to predict cloud shadows are far superior to those procedures that predict shadows with the spectral tests. In addition, procedures used in the new VCM implementation significantly reduced execution time of the MOD09 approach. The analyses of about 40 MODIS showed the core-time on an IBM computer, running AIX operating system was about 22-seconds per granule. Replacing the spectral test with a direct implementation of the MOD09 algorithm increased this core time to about 200-seconds, while running the VCM with the VCM implementation required about 45 seconds.