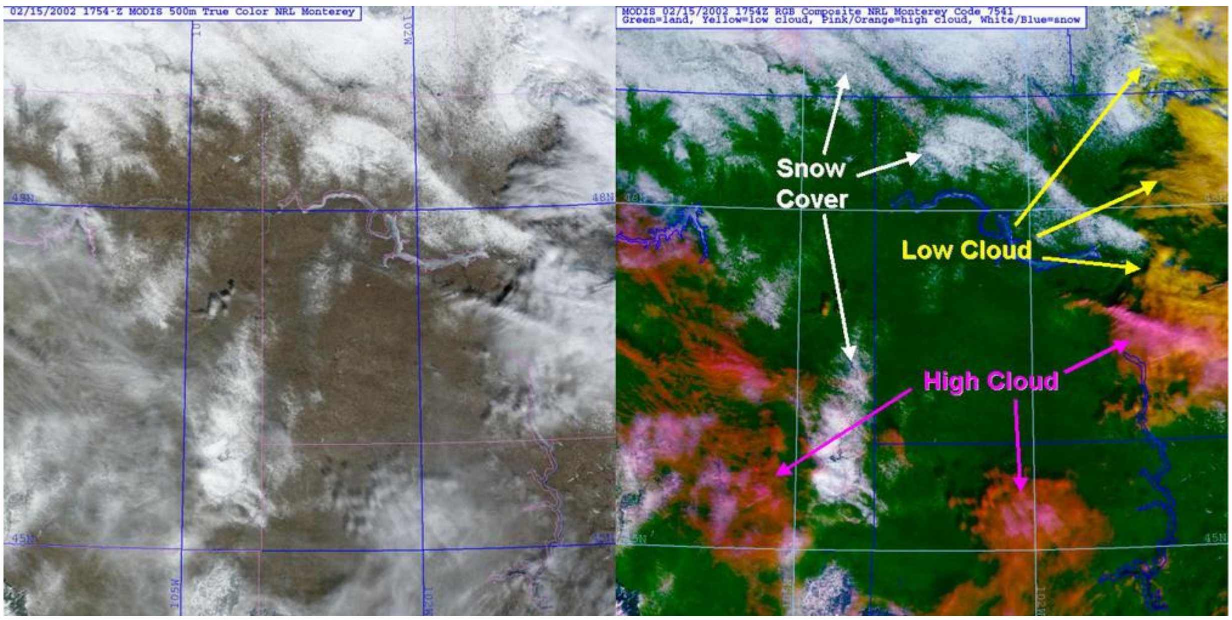
Satellite Product Tutorials:

Snow and Layered Clouds



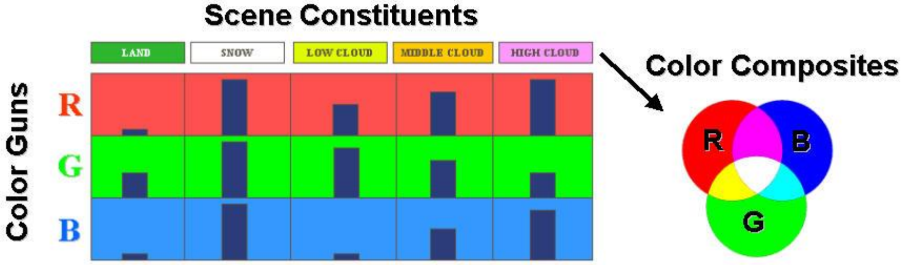
Above: The multi-layer cloud and snow product is actually another version of the daytime cloud/snow product that provides additional information on the cloud levels of the scene—in terms of roughly where the clouds reside in the atmospheric column. The basic guidelines for interpretation of the colors in this enhancement are as follows: green = land (clear sky, devoid of snow cover), white/bluish-white = snow cover, yellow = low level liquid-phase clouds, and orange/magenta = mid/high level ice phase clouds. Other products on *NexSat* provide quantitative information pertaining to the actual heights of these clouds in the atmosphere. The multi-layer cloud and snow product cannot see below thick clouds to report snow cover, but can often detect snow under thin cirrus and depict both pieces of information simultaneously.

Why We're Interested…

The cloud/snow product is particularly relevant during the winter months, when snowfall occurs across the CONUS domain. The advantages of imagery-based (as opposed to digital masks of snow cover which are often at much coarser spatial resolution and remove the meteorological/terrain context from the scene) snow cover products are many. Specifically, they appeal to the interests/needs of forecasters (for example, monitoring the progress of a major winter storm), resource managers (monitoring the snow pack over a watershed), search and rescue (assisting pilots in mountainous terrain), the DoD (target identification/obscuration, surface trafficability, and pilot safety as exemplified during Operation Enduring Freedom, where military helicopter pilots often needed to negotiate the rugged and perilous high mountain valleys of northeastern Afghanistan), and climate research (monitoring global snow cover trends).

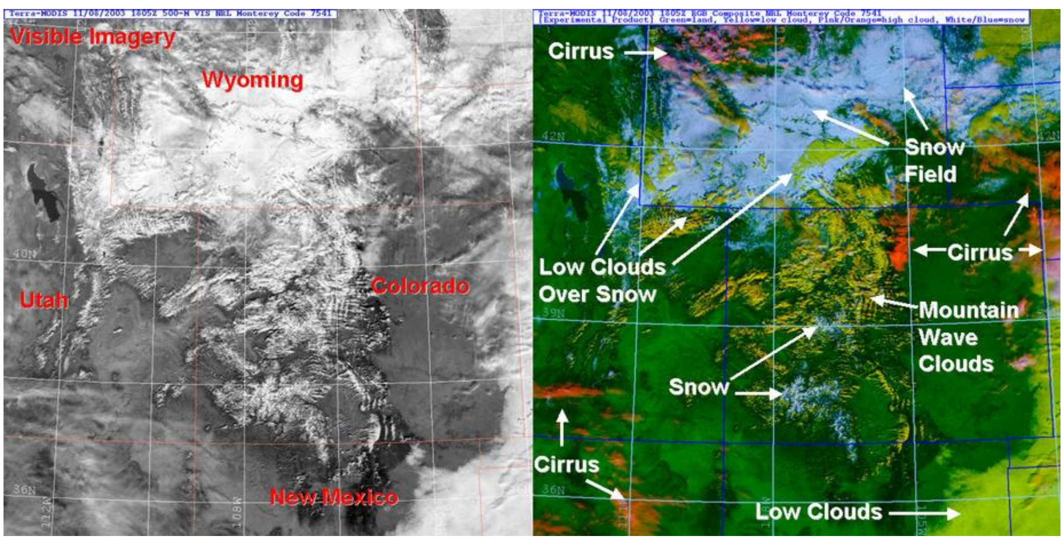
How This Product is Created…

Discriminating between cloud and snow cover over complex terrain using conventional visible (where both are highly reflective and thus appear bright) and infrared (where both can have similar temperatures and resulting poor thermal contrast) satellite imagery can be extremely challenging, even to experts in field of satellite imagery interpretation. Even when adding the shortwave infrared channels (e.g., 1.6 and 3.9 micron, which provide improved discrimination of snow from clouds due to preferential absorption by snow cover), analyses are not entirely free of cloud/snow ambiguity due to the spectral behavior of certain varieties of cirrus. Additional channels available to the Moderate-resolution Imaging Spectroradiometer (MODIS), and particularly the 1.38 micron "cirrus detection" channel, improve the handling of this problem.



Channels offering unique information about the features of interest are combined into a single product. In the cartoon above, shows how this combined information is fed into the R/G/B "color guns" with varying strength of response (height of the blue bar, with a full bar implying high strength) for land, snow, and different levels of cloud. We note, for example, that all three of the color guns respond strongly to snow, while the blue color gun responds only weakly to land. As shown in the composite key to the right of the table, strong contributions from all color guns produces a white tonality (the intersection of the R, G, and B circles in the diagram), while removal of blue information while maintaining strong red & green contributions produces a yellow tonality (the intersection of only the R and G circles). In this way, the composite technique effectively reduces ambiguities associated with any single piece of information, and in so doing, yields an improved delineation of cloud and snow.

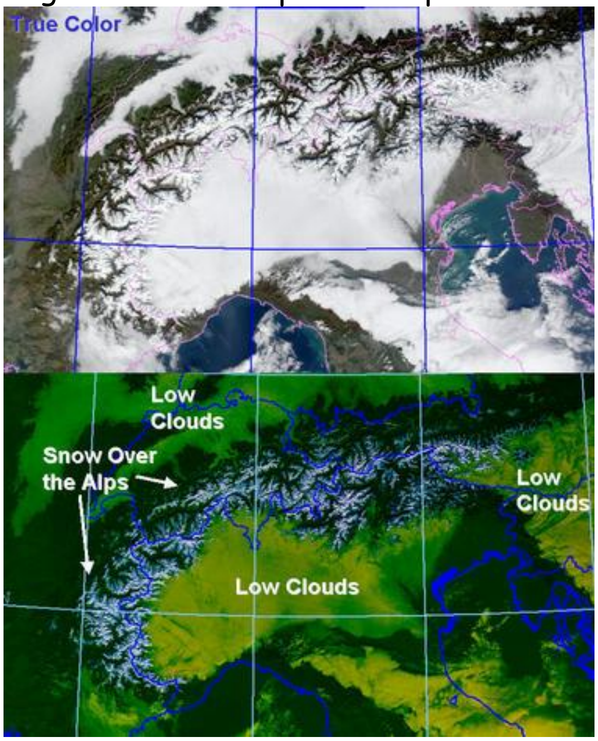
How to Interpret…



An example of this technique is shown above for a complex cloud/snow scene over the Rocky Mountains. The visible image in the left panel of this example provides little insight on the snow distribution, and particularly any differences between the bright regions over southern Wyoming and western New Mexico. In the right panel, the snow/cloud enhancement reveals an extensive snowfield in Wyoming and a low cloud deck in New Mexico. The 1.38-micron near infrared vapor channel on MODIS enables discrimination between cirrus clouds (pink/magenta) and lower tropospheric clouds, giving some indication of regions where multi-layered clouds exist.

Features to Look For:

Snow cover over mountains tends to form readily recognizable "dendritic" patterns (similar in structure to the branches of a snow flake), as snow-covered mountain peaks interleave with snow-free and/or heavily forested valleys carved into them. An example clearly illustrating this pattern is shown below, for a region over the Alps in Europe.



Over the Great Plains, a heavy snowstorm may leave behind the appearance of a "brush stroke" of snow cover across the terrain. Cloud cover span the color range from yellow (low) to orange and magenta (high thin/thick). It is useful to cross reference NexSat products to gain a better understanding of the strengths and limitations of each product. For example, the brightest magenta (high, thick) clouds in the current cloud/snow product should match well with the bright magenta clouds analyzed of the cirrus product, as well as the analyzed cloud top heights of the convective cloud top height product.

Some Things to Watch Out For:

1) Some clouds may appear white (false snow)…most often occurring in clouds transitioning between low and high cloud levels (e.g., parts of thunderstorms as they develop vertically).
2) Some snow areas may appear magenta (false high cloud), particularly over very high mountain peaks, due to unintentional contributions from the 1.38 micron cirrus channel at high altitudes. (This effect is minimized by including a height-dependent threshold in the algorithm, but sometimes bright snow-covered mountain tops can still give rise to problems).
3) Sun glint regions over water and certain desert scenes may appear yellow (false low cloud). We intend to add a glint mask here; for now please cross reference with those glint zones drawn upon the true color products.
4) Some low and warm cloud layers may have green tint (false land)
5) The product loses its discrimination capability at high latitudes where low sun angles, although this generally is not an issue for the NexSat domain.

Looking Toward the NPOESS Era…

The Visible/Infrared Imager/Radiometer Suite (VIIRS) will enable similar cloud/snow detection capabilities through adoption of many of the same channels featured on MODIS. In addition, the day/night band will provide an extension of cloud/snow-cover detection at night, providing an entirely new snow depiction beyond what any contemporary observing system can provide independently.

Did You Know…?

Detection of cloud layers presents one of the single greatest challenges to passive satellite remote sensing. By absorbing heat emitted from the earth and reflecting sunlight at different heights in the atmosphere, clouds can actually heat and cool the air at these levels—changing the state of the atmospheric state over time and ultimately impacting future weather patterns and cloud formations. Next-generation active sensors (lidar and radar, which send out short pulses of energy and “listen” for the echo return off clouds and the earth’s surface) will provide key information critical to understanding the three-dimensional structure of global cloud layering and its role in the radiation balance of the earth/atmosphere system.

Want to Learn More?

Visit the National Snow and Ice Data Center (NSIDC)

Scientific Papers

Pavolonis, M., J., and A. K. Heidinger, 2004: Daytime cloud overlap detection from AVHRR and VIIRS, Journal of Applied Meteorology, 43, 762-778.

Miller, S. D., T. F. Lee, and R. Fennimore, 2005: Satellite-based imagery techniques for daytime cloud/snow delineation from MODIS and AVHRR, Journal of Applied Meteorology, 44, 987-997.

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