Monitoring snowfall and river ice with the MODIS false color composite

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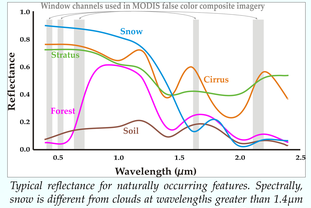
Introduction

The rural nature and low population density of Montana create difficulties in the evaluation of snowfall and river ice. Remote sensing provides the best opportunity to appropriately determine the transition of snow cover and river ice in remote areas, however, visible imagery does not clearly differentiate snow from clouds.

The Great Falls WFO (Weather Forecast Office) has been assessing the use of the MODIS (Moderate Resolution Imaging Spectroradiometer) false color composite created by the Short-term Prediction Research and Transition (SPoRT) Center at NASA/Marshall Space Flight Center to monitor snow cover and river ice. It is expected the false color composite can lead to improved assessments of flooding potential during post event conditions where rapid melting and runoff are anticipated.

MODIS False Color Composite

MODIS false color imagery composites one visible and two infrared channels to highlight features with infrared signature differences. Snow and clouds have reflective differences above 1.4μm, especially near the 1.6μm and 2.13μm MODIS channels. Compositing a visible channel with these two infrared channels creates an image that clearly distinguishes snow and clouds.



Typical reflectance for naturally occurring features. Spectrally, snow is different from clouds at wavelengths greater than 1.4μm and particularly near the 1.6μm and 2.3μm MODIS channels.

Comparison to Other Satellites

MODIS offers an increase in spatial as well as spectral resolution over GOES (Geostationary Operational Environmental Satellites) and AVHRR (Advanced Very High Resolution Radiometer). The result is a detailed view of surface and atmospheric features.

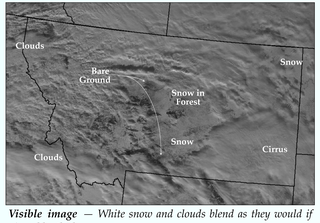
Great Falls is at a relatively high latitude and at the edges of both GOES East and West. The remapping of data results in a north-south and east-west blurring of details. GOES imagery can be looped to show stationary snow features vs. moving clouds, however, there are still issues with semi-stationary clouds such as fog, lenticular formations, and orographically induced stratus.

	MODIS	AVHRR	GOES
Spatial Resolution (meters)	500	1000	1000
Channels used to produce snow products	7	3	1 broadband
Images per day	1-2	3-6	20

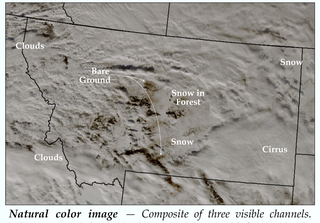
Comparison of features with MODIS, AVHRR and GOES

Assessment Samples

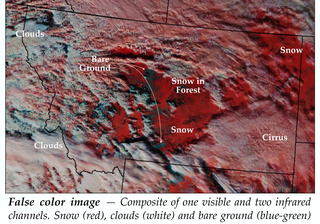
Snap-shot comparison of snow and cloud cover as seen by MODIS visible, natural color and false color.



Visible image *— White snow and clouds blend as they would if viewed by the human eye.*

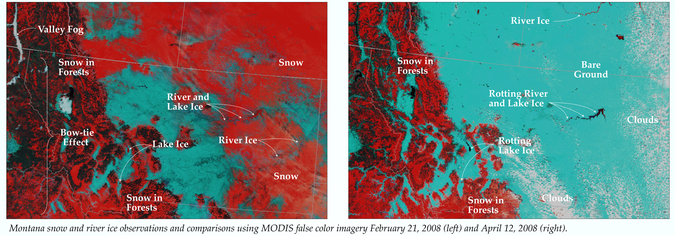


Natural color image *— Composite of three visible channels. White snow and clouds blend, again, as they would if viewed by the human eye.*



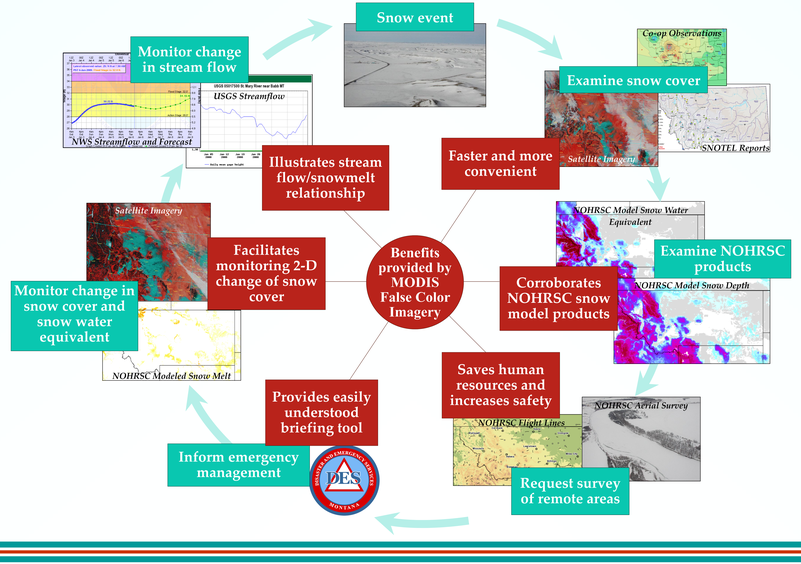
False color image *— Composite of one visible and two infrared channels. Snow (red), clouds (white) and bare ground (blue-green) are distinct.*

River Ice Monitoring Samples

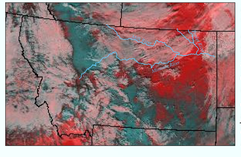


Montana snow and river ice observations and comparisons using MODIS false color imagery February 21, 2008 (left) and April 12, 2008 (right).

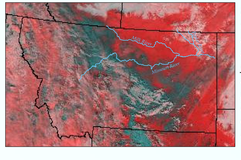
Assessment of Flooding Potential



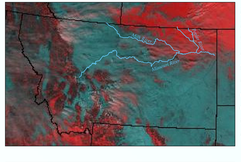
2004 Case Assessment



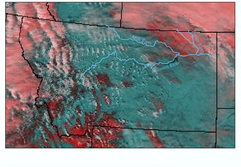
February 19, 2004
Widespread snow cover over northeast/east Montana. Observations show areas with snow depths of 2 feet or more and snow water equivalents of 6 to 8 inches. Significant flooding of Milk and Poplar Rivers forecasted with melt. Extensive briefing of emergency management officials begins.



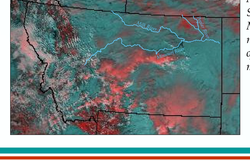
March 4, 2004
Snow melt beginning. Imagery shows significant loss of snow south of Missouri River. No flooding reported, however snow water content was not as great in this area as in northeast Montana. Concerns for flooding continue for northeast Montana.



March 11, 2004
Melt not occurring uniformly. Snow south of Missouri and Milk Rivers virtually gone while widespread snow remains north. Skewed spatial distribution of melt and influx of water to rivers expected to reduce chances of significant river flooding.



March 18, 2004
Imagery and observations show melt has slowed. Snow now gradually retreating north of the Missouri and Milk Rivers. Slowing of melt will allow more gradual influx of water to rivers, further reducing the chance of significant flooding.



March 25, 2004
Snow cover north of the Missouri and Milk Rivers nearly gone. During the course of the snowmelt event, only minor flooding occurred.

Findings

Advantages of false color composite

- Complete overview of snow cover extent
  - High spatial and spectral resolution
  - Information for areas void of surface data
  - Indicates primary areas of concern when complemented with supplemental data from ground measurements
  - Often eliminates need for field surveys during potentially dangerous situations
- Observation of snow cover transition
  - Speed and extent of snowmelt provide insight to areas with possible flooding concerns
- View of ice on rivers and lakes
  - Ice formation and degradation provide insight on locations of possible ice jams and related flooding
- Corroborates information provided by NOHRSC (National Operational Hydrologic Remote Sensing Center) snow models

Disadvantages of false color composite

- Cloud cover blocks view of surface
  - Visible and infrared spectrums
  - Significant snowfall/snowmelt can occur under cloud cover and full extent may not be viewable for days
- Images per day limited
  - Polar-orbiting satellite provides only a few images daily
- 'Bow-tie' effect blurs images
  - Satellite field of view overlap produces data repetition at image edge
  - Algorithm to remove this effect will be available soon

Conclusions

The Great Falls WFO did find the MODIS false color image useful in monitoring snow cover and river ice extent. It was used as a complement to other tools such as the NOHRSC snow water equivalent data and soil saturation and temperature conditions. It was felt the imagery did lead to improved assessments of flooding potential during post snow and ice events where rapid melting and runoff were anticipated; the imagery provided information for rural and remote areas, allowing staff to quickly determine and focus on those areas of greatest concern. Further, the imagery often eliminated the need for field surveys not only saving time and resources but also keeping personnel safe during potentially dangerous situations.

References

Adolphson, J., et. al., 2005: "Minor Flooding on the Milk River After an Extreme Winter in Northeast Montana" Preprints, 19th Conference on Hydrology, Amer. Meteor. Soc., San Diego CA, 4.3

Hall, D. K. and G. A. Riggs, 2007: "Accuracy assessment of the MODIS snow products", Hydrol. Process., 21, 1534-1547

Jedlovec, G. and P. J. Meyer, 2005: "MODIS Composite Imagery for Snow Detection - Training Module", http://weather.msfc.nasa.gov/sport/sport_training.html

Miller, S., 2003: "High/Low Cloud and Snow Discriminator – Focus Tutorial" NRL Monterey, Marine Meteorology Division, http://nrlmry.navy.mil/sat_training/high_low_cloud/modis.html