P1.25

A comparison of GOES and MODIS imagery in operational forecasting

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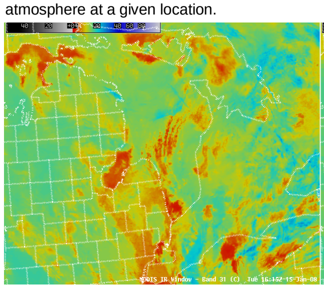
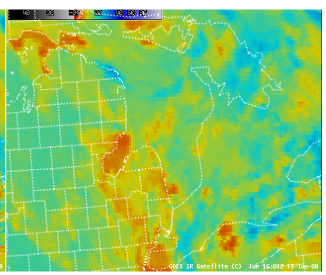
Overview

At the present time, geostationary satellites provide the bulk of satellite information used by National Weather Service (NWS) offices. While these data are consistent and reliable, and quite beneficial to weather forecasters, at times data from polar orbiters may provide a better representation of the atmosphere. The Moderate-resolution Imaging Spectroradiometer (MODIS) instruments on board the Aqua and Terra satellites provide high, one-kilometer spatial resolution imagery at multiple bands. For certain situations this imagery can provide more detail about the current atmosphere than that rendered by the Geostationary Operational Environmental Satellite (GOES). In turn, this enhanced detail enables operational forecasters to more accurately predict future weather patterns and phenomena. To assist forecasters in their quest for greater accuracy, the Space Science and Engineering Center (SSEC) began sending MODIS imagery and products to NWS Forecast Offices in a format that could be displayed with the Advanced Weather Information Processing System (AWIPS), the primary display package of the NWS.

Tasked with providing accurate weather forecasts and issuing timely warnings to save lives, the NWS is the primary consumer of United States satellite data within an operational setting. The AWIPS software package allows NWS forecasters to render model data, plot surface and upper air observations, view radar slices, and display satellite imagery with Display Two Dimensions (D2D), a graphical user interface. Using AWIPS, meteorologists have the ability to load various channels and products from geostationary satellites, most notably GOES, on multiple scales, including, but not limited to, northern hemisphere, continental United States, and regional, specific to the location of the weather forecast office. AWIPS, the primary NWS forecast tool, retrieves nearly all relevant weather data (including satellite), from a satellite-based delivery system known as NOAAPORT, decodes it, and stores it in network Common Data Form (netCDF) format.

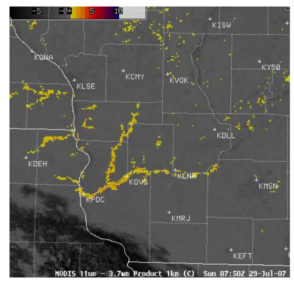
During a standard shift, a NWS forecaster may use satellite imagery to determine the movement of an upper-level cloud deck, watch fog formation and erosion, track particulate resulting from wildfires, check for the formation of a cumulus field, and discover features not well diagnosed with forecast models. To accomplish these tasks, the forecaster uses the visible, water vapor, and infrared (IR) window channels. Although geostationary satellites do not offer IR images at high, one-kilometer resolution across the United States and suffer from parallax error, the reliable and consistent nature of the imagery makes them a constituent part of the short-term forecast process. Other satellite products available in AWIPS include: scatterometer winds, valuable in hurricane forecasting; GOES Sounder lifted index, surface temperature, total precipitable water, and effective cloud amount, useful in evaluating thunderstorm potential; GOES operational wind vectors, for determining prevailing winds at different heights above ground; and GOES soundings, for vertically profiling the entire atmosphere at a given location.

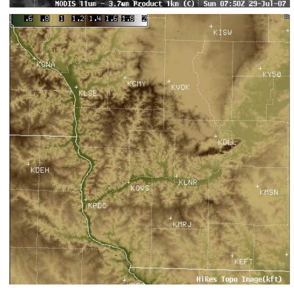




Although GOES provides data and imagery that are very useful to forecasters, compared to polar orbiters, it does not always provide the optimal perspective. Forecasters in Alaska and nearby polar regions cannot use geostationary satellites due to their degraded resolution at very high latitudes. Even in the middle latitudes, GOES does not render the nuances of deep convection with as much detail as some current polar orbiters. Additionally, the GOES satellites only have a limited number of channels. Satellites equipped with a MODIS can detect, among other features, mountain turbulence, eddies in sea surface temperature, thunderstorm signatures, surface moisture gradients, narrow valley fog, and surface ice accumulations (Bachmeier, 2007). Furthermore, products derived from MODIS can indicate cloud phase and more accurately represent the temperature of thin clouds. The two satellites that are equipped with such spectrometers are Aqua and Terra, both polar orbiting satellites. While their spatial coverage of polar regions is sufficient, their temporal resolution across the middle and equatorial latitudes is less than desirable for consistent use in operational settings. However, with proper training, forecasters can learn to use MODIS imagery and products in special situations.

Fog Product



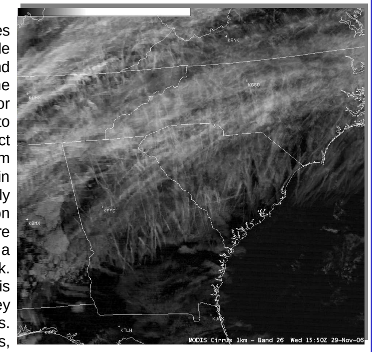


Another weather hazard affecting coastal and island communities alike is fog. Both GOES and MODIS offer a fog product, roughly derived from subtracting the standard IR window from the 3.9 or 3.7 micron band. The fog product not only serves as a useful indicator for the presence of fog and dense fog, but it can also be used to locate areas of thick stratus. A key benefit of the MODIS product is its high resolution, making it easy to locate narrow bands of fog forming in river and mountain valleys. Additionally, MODIS can detect changes in the density of a low cloud deck due to the presence of manmade polluters, such as power plants. Operational forecasters find these abilities significant for two reasons. First, it allows them to determine which portions of their area of responsibility susceptible to fog and dense fog. Second, forecasters may adjust temperatures in those regions as a result of the presence of fog or low cloud, which may inhibit the sun from providing daytime warming until later in the morning or earlier in the afternoon. The delay in receiving the MODIS product does not tend to hinder the forecast process as information about a cloud deck is usually not critical for weather warning purposes. As long as the product arrives by the time a forecast is due, it can be incorporated.

Fire Detection

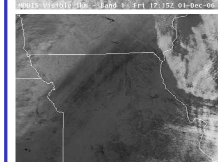
While both GOES and MODIS contain a fire detection channel around four microns, the MODIS 3.7 micron band is able to depict the structure of a large, ongoing fire. The GOES 3.9 micron band is only able to hint that a fire exists in the vicinity of an anomalously warm pixel, and due to poor spatial resolution, is unable to depict the core temperature of a fire as accurately as MODIS. Therefore, for the early detection of small wildfires, MODIS shows a key advantage over GOES, especially when fire growth is not rapid.

Cirrus Band



The cirrus band of MODIS provides another unique perspective not available on GOES. Thin clouds have a profound effect on temperature, particularly in the summer, when they serve as a filter for the sun. As a result, forecasters seek to determine how thin clouds may impact their area. In standard bands from GOES, such as the infrared window, thin clouds are difficult to detect, particularly in polar climates where there is snow on the ground, or in areas where there are multiple layers of clouds— for example, a layer of thin clouds above a stratus deck. While the life cycle of a cirrus cloud is unclear, thunderstorms are one of the key players in the production of cirrus clouds. Strong convection can produce cirrus, which may slowly dissipate in the atmosphere as it is advected upstream following the demise of the complex. Since storms often diminish overnight, coincident with the formation of fog and low cloud, a forecaster must not only contend with how the morning fog will affect daytime heating and thunderstorm chances later in the day, but also how the cirrus cloud cover will limit the amount of sun reaching the low cloud deck to dissipate it. Since visible imagery and infrared bands may be contaminated with other cloud, a forecaster may seek to find an alternative source of determining the presence of cirrus cloud.

The higher resolution of MODIS imagery can also be employed to find jet contrails. In one of the best examples, a MODIS pass over Georgia indicated a mixture of clouds on the visible band. However, the cirrus band display indicated several prominent contrails resulting from aircraft. Such contrails are usually not noted in GOES imagery. The impact of jet contrails on surface temperature is difficult to study, but contrails appear to cause notable impacts on high and low temperatures alike, and, since jet contrails are manmade, they are not forecasted by operational models or incorporated into temperature prediction schemes (Bachmeier, 2007).



Cloud Top Temperature Product

MODIS also offers a cloud top temperature product which can be utilized instead of the standard infrared window to determine the temperature of clouds that are not opaque, such as cirrus. In addition, the cloud top temperature product can be used to determine areas where high clouds exist, particularly at night when the cirrus band is not useful. This product is ultimately the best diagnostic tool in determining the temperature of a cloud, even though the IR window is capable for thick cloud.

Snow and Ice Band

Ground snow and ice also play a significant role in temperature. A heavy snow pack can prevent temperatures from warming strongly during the day, and can aid in a nighttime plummet. MODIS has a snow and ice band which can assist in finding areas of frozen precipitation that has already fallen and accreted on the surface. In contrast, GOES has no such band. However, fallen snow can be located quite easily on a visible band without a cloud deck above. In the event that there are clouds in the vicinity of the snow pack, the snow and ice band from MODIS can assist in determining areas where the surface is visible and contrast those with regions covered with cloud. Freezing rain accumulations are much more difficult to detect, yet the MODIS snow and ice band is able to successfully depict ice on the surface, which is useful in preparing a post-event analysis of a winter storm.

References

Bachmeier, Scott. Personal interview. 4 June 2007.