# Determining Cloud Type With GOES I-P Series Imagers

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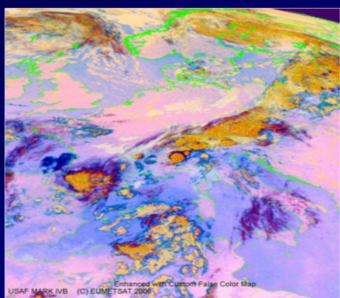
The replacement of GOES imager channel 5 (the 12.0 µm infrared split-window) with channel 6 (the 13.3 µm carbon dioxide channel) has eliminated the use of window channel differencing with GOES channels 4 and 5 from GOES M-P (GOES 12 – 15). Red-green-blue composite image solutions using the water vapor channel in addition to the visible, midwave and longwave infrared channels are described here as substitutes until the GOES-R series imagers introduce improved multi-spectral products. Several studies have shown that water vapor and longwave infrared window channel differences are useful for cloud top height determination and convection prediction. It should be noted that these substitute multi-spectral products may also be produced using imagery from GOES 10 and GOES 11, as well as many international geostationary meteorological satellites.

## EUMETSAT NIGHTTIME IR FOG FALSE COLOR

This multispectal image (MSI) is described in the EUMETSAT MSG Users Guide. It is produced by combining three IR channels into a hybrid math-operation/false color. It uses a 12.0 µm and 10.8 µm difference (DT1), a 10.8 µm and 3.9 µm difference (DT2), and the 10.8 µm channel. All components are emitted infrared channels, but fog and low clouds appear dramatically different from night to day as a result of the additional reflected solar midwave infrared (MWIR) in the 3.9 µm channel.




METEOSAT-8, 2006 Sep 08, 0000Z

This night time product shows fog and low clouds as yellow areas against a pink land surface and light blue sea surface. Mid cloud tops have a gold color, while high clouds appear as orange-red. Thin high clouds allow emissions from the surface and from lower clouds to penetrate the cirrus, which results in colors ranging from dark purple to dark blue.

## ALTERNATIVE SOLUTION

GOES users cannot obtain DT1 with GOES 12 through GOES 15, although it remains available with both GOES 10 and GOES 11 imagers, as well as NOAA AVHRR, so an alternative solution is required to produce an informative nighttime MSI.

Two interesting options are available: use of either the 13.3 µm channel or the water vapor channel for a channel difference in place of DT1. Previous studies have shown that the 6.7 µm and 11 µm difference is correlated to convection, and can be used globally since all geostationary meteorological satellite imagers have channels those two bands (Mosher, 2001).

A 6.7 µm and 11 µm difference (DT3) is useful for determining the height of a feature in the atmosphere. Cloud elements at or above the top of the water vapor layer have little attenuation in the 6.7 µm channel, and have similar temperatures in both channels. DT3 for high cloud tops (or mid cloud tops with little water vapor above them) is small (0 to -15).

Upward emissions from low level features (near the bottom of the water vapor layer) are greatly attenuated in the 6.7 µm band. Low level features (surface or low cloud tops) appear warm (highly emissive) in the 11 µm window channel. Satellite imagers receive 6.7 µm emissions from that same field of view at the top of the higher and colder water vapor layer. Since there is a large difference between water vapor and window channel temperatures, low features may have moderate to large DT3 values (up to -75 or more). The 11 µm and DT3 values allow one to distinguish relative cloud top altitudes.

Mecikalski and Bedka (2006) developed a list of channel differences significant to convective initiation (CI), and MacKenzie and Mecikalski (2006) added the 10.7 – 3.9 micron channel difference to develop a nocturnal CI nowcasting technique. At night, the 10.8 µm - 3.8 µm difference (DT2 , the difference between GOES channels 4 and 2) is used to identify areas of Fog and stratus (positive DT2), Cirrus (negative DT2), and the surface (DT2 near zero).

## EXAMPLES

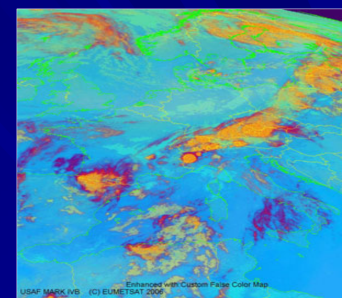
The DT3 product can be used as a substitute for DT1 in the "GOES" Nighttime IR Fog MSI to the right. In the EUMETSAT MSI at left, only select portions of the ranges of each RGB input is used to highlight cloud and surface features, but in the alternative "DT3" MSIs, a linear contrast stretch is applied to the entire range of each input used in the RGB combination.

DT3 can also be used with DT2 and the visible channel to produce a daytime Cloud Type-Height MSI to the lower left. The RGB channel inputs were rearranged and the 10.8 µm channel was replaced with the visible channel to help compensate for the lack of a positive-negative sign change in DT2 values (daytime DT2 values are nearly all negative due to the sun's reflected MWIR contribution). This MSI can be used to show a variety of cloud features described below center.

Finally, it was found by lucky chance that a ratio of water vapor and infrared channels can highlight areas of near-freezing temperatures (lower right), providing there is an above-freezing background, below freezing cloud elements, and the input brightness temperature values are expressed in degrees Celsius (for a positive or negative ratio). This can be used to show areas of thin cirrus, as long as the mixed pixels are below freezing, and the freezing level on the sides of vertical clouds.

## GOES NIGHTTIME IR FOG FALSE COLOR

This MSI is produced by combining three channels into a hybrid math-operation false color. It uses the 6.7 µm and 10.8 µm channel difference (DT1), the 10.8 and 3.9 µm channel difference (DT2), and the 10.8 µm channel. All components are infrared, like the EUMETSAT False color, but fog and low clouds appear different from night to day, and users should understand how reflected solar MWIR affects the MSI.



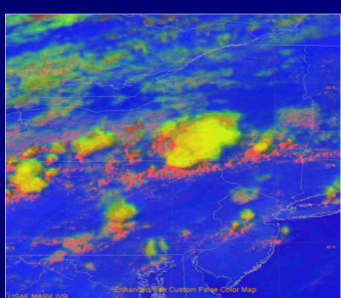

METEOSAT-8, 2006 Sep 08, 0000Z

This night time MSI shows fog and low clouds as pale aqua areas against a light blue land surface and medium blue sea surface. Mid cloud tops have a gold color, while high clouds appear orange or red. Thin high clouds allow IR emissions from lower clouds and the surface to penetrate the cirrus, which results in colors ranging from dark purple to dark blue.

## DAYTIME "CLOUD TYPE – HEIGHT" FALSE COLOR

This daytime MSI uses the visible channel in place of the 10.8 µm input in the following RGB combination:

Red = Visible
Green = DT2 (10.8 µm - 3.8 µm)
Blue = DT3 (6.7 µm - 11 µm)




GOES 12, 2005 Aug 13, 2000Z

The features highlighted by this MSI are described in the table at right.

## "CLOUD TYPE – HEIGHT" FALSE COLOR INTERPRETATION

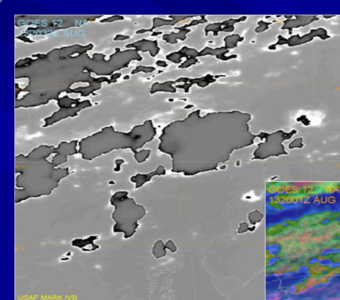
| Components | Features | Values |
|---|---|---|
| Gold/Bright Yellow: | Thick, high, cold, ice crystal/supercooled liquid cloud droplet mix | |
| High Red | Dense Mixed ice crystal/liquid droplets | Albedo: 60 to 79% |
| High Green | Ice clouds, large negative | DT2: -45 to -34 |
| Low Blue | Highest Cirrus tops | DT3: -5 to +/-0 |
| Orange-Brown: | Semi-Transparent Thin, high, cold, ice crystals over Mid-Level Cloud Tops | |
| Med-High Red | Dense Ice crystal cirrus cloud tops | Albedo: 54 to 66% |
| Med Green | Mixed Ice cloud & lower water droplet inputs | DT2: -33 to -23 |
| Low Blue | High Cirrus tops | DT3: -5 to -2 |
| Bright Yellow-Green: | High-Mid Level Cloud Tops, ice crystals | |
| Med Red | Ice crystalline cloud tops | Albedo: 34 to 44% |
| High Green | Ice crystalline cloud tops | DT2: -45 to -40 |
| Med Blue | High-Mid cloud tops | DT3: -11 to -9 |
| Dark Red: | Semi-Transparent Thin, high, cold, ice crystals over Low Warm Cloud Tops | |
| Med-High Red | Mix of cirrus over low-level liquid clouds | Albedo: 48 to 60% |
| Low Green | Average of Liquid droplets and ice crystals | DT2: -19 to -10 |
| Low Blue | High Cirrus tops | DT3: -5 to -2 |
| Dark Green: | Semi-Transparent Thin, high, cold, ice crystals with surface features | |
| Low Red | Low reflectivity: dark surface through cirrus | Albedo: 30 to 40% |
| Med Green | Ice clouds mixed with lower surface inputs | DT2: -22 to -19 |
| Low Blue | High Cirrus tops | DT3: -8 to +/- 0 |
| Pink-Red: | Low Warm Cloud Tops and Developing Convective Clouds | |
| Highest Red | Dense liquid droplet clouds, highly reflective | Albedo: 70 to 95% |
| Low Green | Liquid droplets; low negative inputs | DT2: -15 to -10 |
| High Blue | Low cloud tops; large negative | DT3: -35 to -11 |
| Blue: | Land-Water, no snow-cover or ice cover | |
| Lowest Red | Water/Land, low reflectivity values | Albedo: 6 to 14% |
| Lowest Green | Surface | DT2: -9 to -4 |
| Highest Blue | Surface | DT3: -50 to -45 |
| Purple-Red: | Snow-covered Land/Ice-covered Water | |
| High Red | Snow-covered Land, snow-land-vegetation | Albedo: 70 to 95% |
| Low Green | Surface | DT2: -9 to -4 |
| Highest Blue | Surface | DT3: -50 to -45 |

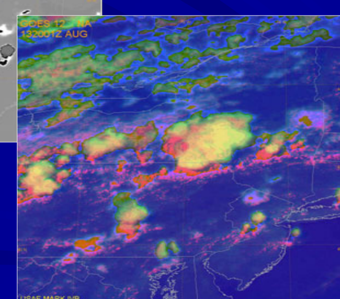
## "CLOUD TYPE - FREEZING BOUNDARY"

This MSI uses a ratio of GOES water vapor and IR window channels (R3/4, example left) to highlight the opaque and transparent cloud areas with near-freezing temperatures. This requires above freezing background areas.

This MSI uses the following combination:

Red = Visible
Green = DT2
Blue = R3/4




### COLOR-FEATURE INTERPRETATION

**Yellow:** Dense Cirrus
**Green:** Thin Cirrus over ground
**Orange:** Cirrus over liquid clouds
**Red:** High/subfreezing liquid Cumuliform clouds
**Bright Blue:** high cloud outline and/or the freezing level on cloud sides
**Purple:** Lower/warm clouds
**Dark Blue:** Surface

GOES 12, 2005 Aug 13, 2000Z

References:

MacKenzie, W.M., and J. R. Mecikalski, 2006: Using multi-spectral satellite remote sensing techniques to nowcast nocturnal convection initiation. 14th Conference on Satellite Meteorology and Oceanography, 30 January-2 February, Atlanta, GA. Amer. Meteor. Soc.,

Mecikalski, J. R., and K. M. Bedka, 2006: Forecasting convective initiation by monitoring the evolution of moving convection in daytime GOES imagery. Mon. Wea. Rev. 134, 49-78.

Mosher, F. R., 2001: A Satellite Diagnostic of Global Convection. 11th Conference on Satellite Meteorology and Oceanography, 15-18 October, Madison, WI. Amer. Meteor. Soc., 416-419.

Acknowledgements

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