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GOES-R ABI New Product Development

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1. INTRODUCTION*

The current Geostationary Operational Environmental Satellite (GOES) series was inaugurated in 1994 with the launch of GOES-8 and will continue with three more satellites (GOES-N, O, P) past the most recent GOES-12 launched in 2002. The next generation GOES (beginning with GOES-R) will be launched in the 2012 time frame. This new series of satellites will include improved spatial, temporal, spectral, and radiometric resolution. The last two characteristics are manifest by an increased number of spectral bands and increased precision for measurements from those bands. To take advantage of the long lead-time needed to design, build, and test this new and complex satellite system, it is time to do the background work needed to prepare for the development and implementation of products from GOES-R.

Preparations for GOES-R for applications to forecasting mesoscale weather events, including severe storms, tropical cyclones, lake effect snowstorms, and fog outbreaks are well underway. Two approaches are being used for these "Risk Reduction" activities. In the first approach, data from existing operational and experimental satellites are used to create subsets of observations that will be available from GOES-R. Those data are used to create new image products or improve existing products. In the second approach, numerical cloud models are being coupled with radiative transfer models to create simulated imagery. In this article, GOES-R is briefly reviewed, and an example of a risk reduction activity for mesoscale applications based on the first approach is presented. Activities involving the second approach will be presented by other authors at this conference.

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2. PRODUCT DEVELOPMENT

An extensive effort is being undertaken to work towards new and improved products that will be available when GOES-R is launched. Some of the initial product development work has already been reported (Hillger 2004; Hillger et al 2004a, b, and c; Hillger and Schmit 2004).

Focus at the Cooperative Institute for Research in the Atmosphere (CIRA) has been on product development for the Advanced Baseline Imager (ABI, Table 1). Not only will existing products be improved due to the increased (spatial, temporal, spectral, and radiometric) resolutions of the ABI, but new products will be developed that would not have been possible from the current selection of GOES Imager and Sounder bands.

In order to emulate the GOES-R ABI bands, various existing satellite imagery are being utilized. In particular the experimental imagery from the EOS (Earth Observation System) Terra and Aqua MODIS (Moderate-resolution Imaging Spectrometer) instruments cover all but two of the spectral bands that will be available on the ABI (Table 2).

2.1 Fog/Stratus Product History

One of the image products that is an initial focus of the product development work is an improved fog/stratus (low-level water-drop cloud) product. The thought was to develop a two-part product, with a fog/no-fog discrimination part and a fog detail (thickness and particle size distribution) part. However work to date has been on merely discriminating the fog/stratus from many other features in satellite imagery, such as ice clouds, various land-and-water-surface types, and snow and ice on the land.

The basis of fog/status detection is the *fog/reflectivity product* that has long proven useful for discriminating fog/stratus from ice clouds and land and water surfaces due to the lower emissivity, or higher reflectivity, of water-droplets compared to ice crystals in the shortwave window band at 3.9 µm.

At night for the fog/stratus product, the shortwave window band radiance is compared to the longwave window band (10.7 µm) radiance, to qualitatively discriminate low emissivity clouds from other features in the imagery. The fog/stratus product is generally produced only at night, since the same surfaces that have low emissivity have high reflectivity during the day, which often masks the lower temperatures in the shortwave IR band, making that band alone not as good at discriminating fog/stratus from other image features.

The daytime reflectivity product is combined with the nighttime fog/stratus product to effectively do the same fog/stratus discrimination during the day as at night. This product, which determines the added radiance in the shortwave window band caused by more reflective low-level water-droplet clouds, has been used at CIRA since the development of its RAMSDIS (RAMM Advanced Meteorological Satellite Demonstration and Interpretation System; Molenar et al 2000) systems in the 1990s.

A further improvement over the fog/reflectivity product is the *shortwave albedo product* (Kidder et al 2000). The product computes the shortwave albedo by determining the reflected (whether positive or negative) component of the shortwave window band radiance by subtracting the wavelength-adjusted emitted radiance, using the equivalent temperature computed from the longwave window band radiance. This product can be computed day or night, with a radiance deficit at night and a radiance surplus during the day. In either case the result is the albedo, of inversely the emissivity, of clouds in this two-band product. In this product, highly reflective water-droplet clouds are white, and less-reflective ice-crystal clouds and land surfaces are generally darker. A case study of this product will be examined farther along in this paper.

2.2 Three-Color Imagery

Because of the much wider selection of bands what will be available with the ABI, one of the ways to utilize the many bands is through three-color RGB (Red, Green, and Blue) compositing, that is widely available in most image processing systems. RGB analysis of MSG (Meteosat Second Generation) imagery is the focus of most of their product development (Gaertner, 2005). [RGB compositing means true color analysis only when the RGB bands are the red, green, and blue colors of the visible spectrum; otherwise the analysis is called “thee-color” or “false-color”.]

One of the primary and most user-friendly RGB products that is created from MSG imagery is called a “natural” color product. This product is a composite of MSG bands at 1.6, 0.8, and 0.6 µm respectively for the red, green, and blue components. In this product, highly reflectively water-droplet clouds are white, less-reflective ice-crystal clouds are blue, and land surfaces are either green or brown depending on the amount vegetative ground cover. This land-surface discrimination is due to the 0.8 µm “green” vegetation band, whereas the water/ice discrimination is due to the 1.6 µm snow/ice band. Again, a case study of this product will be examined farther along in this paper.

Another MSG RGB product that is used to discriminate fog/stratus from snow during the day utilizes the 0.8, 1.6 and 3.9 µm bands. In this case the bands are gamma-adjusted before combining, and the 3.9 µm band is the solar/reflected part only. The emitted part is removed, being pre-processed in a manner similar to the shortwave albedo product already mentioned, before combining it with the other bands in the RGB composite.

2.3 Modifying a MSG RGB product

A number of fog/stratus cases have been collected for use in developing a fog/stratus discrimination product. Much of the analysis has been involved with determining the bands that contain most of the signal that is relevant to the detection of water-droplet clouds. Since the shortwave albedo product contains most of the explained variance in fog/stratus discriminations, it becomes the primary input for developing a new daytime fog/stratus product. And, this is already a component of the MSG RGB daytime snow/fog product discussed above.

The 1.6 µm band is also a prime component of the new product due to the large difference in ice/water reflectivity at this wavelength. Again, this is already a component of the MSG RGB daytime snow/fog product.

However, the third component of the MSG RGB daytime snow/fog product has been changed to the 0.6 µm (red) band instead of the vegetative “green” band at 0.8 µm. This sacrifices the discrimination of different land-surface features, allowing more discrimination of cloud level and type, variations that are harder to otherwise distinguish from each other.

Another feature of the new RGB composite is that the two reflective bands (0.6 and 1.6 µm) are enhanced first by applying an albedo correction. This correction adjusts the image brightness by correcting for non-nadir solar zenith angles. This process is outlined by Kidder et al (2000), and is called the *visible albedo product* when applied to visible band radiances. This processing is in lieu of the gamma-adjustments that are applied to the MSG bands in their equivalent product. The original MSG product with gamma-adjusted bands has not been recreated, rather only the new/modified product will be shown in the case study to follow.

3. A FOG/STRATUS CASE STUDY

A widespread fog case study that was identified with the help of the Portland NWS Office is used as the prime example of the new daytime fog/stratus product. That case was for 11 February 2005 at 1910 UTC (daytime). This case contains many different types of clouds, as well as both snow-covered and snow-free land surfaces. In addition, another daytime MODIS granule was examined for this particular case, as well as two nighttime granules. Only the daytime cases have the visible bands available to generate the proposed product.

Although several fog/stratus cases have been examined, only one will be presented in this paper. Other cases will be available on the poster at the conference.

Figure 1a shows the shortwave albedo product alone, which appears to nicely discriminate fog and stratus, which appear white or light, from land surfaces and ice clouds, which appear dark. Even fog and stratus are discriminated a bit from each other, partly by brightness and otherwise by the texture of the clouds in the product, the fog appearing “flatter” and the stratus with apparent edges or shadows, suggesting their elevated nature.

Figure 1b shows the “natural” color MSG three-color product, produced from ABI-equivalent MODIS bands at 1.6, 0.86, and 0.6 µm respectively for the red, green, and blue components. This product too appears to discriminate fog and stratus from land surfaces and ice clouds. Snow and ice clouds are cyan, low clouds are white, vegetated land surfaces are green, and non-vegetated land is brown.

Finally, Figure 1c shows the new daytime fog/stratus product based on the MSG RGB daytime snow/fog product, but modified as mentioned above. Of the three products, this product appears to better discriminate clouds from land, and between different levels and types of clouds. Snow is orange/red; high-level cirrus/ice clouds are yellow/orange; low-level stratus/water clouds have a blue tint; and fog (on the ground) is whiter than stratus clouds that are off the ground (in addition to the texture difference noted for the shortwave albedo product). Most land surfaces are green, the color discrimination of different land types being sacrificed for cloud level and type discrimination.

4. SUMMARY

A new daytime fog/stratus product has been developed, based on both the GOES shortwave albedo product as a component, and RGB compositing that is widely use with MSG imagery. In the fog/stratus case study presented, the fog and stratus appear to be better discriminated from land surfaces, both snow-covered and snow-fee, as well as from ice clouds.

Many more fog/stratus cases are available where this product has been tested. Some of those additional cases will be presented on the poster at this conference.

A limiting factor with the use of MODIS polar-orbiting imagery is that it does not have sufficient time resolution to view the new product in motion, in an image loop. Therefore the next step is to apply this new product algorithm to MSG imagery and provide the result to potential users for testing and further development.

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REFERENCES

Gaertner, V., 2005: Best practices for RGB compositing of multi-spectral imagery, EUMETSAT draft paper.

Hillger, D., M. DeMaria, and L. Grasso, 2004: GOES-R Risk Reduction Activities at CIRA, *CIRA Newsletter,* 21, spring, 10-11, 15.

Hillger, D.W., M. DeMaria, and R. Zehr, 2004a: Advance mesoscale product development for GOES-R using operational and experimental satellite observations. *49th Annual Meeting (Weather and Environmental Satellites),* SPIE, 2-6 August, Denver CO, 9-p.

Hillger, D., M. DeMaria, and J. Purdom, 2004b: Analysis of simulated GOES-R data and products for mesoscale meteorology. *13th Conf. Sat. Meteor. Ocean.,* AMS, 20-24 September, 9-p.

Hillger, D.W., and T.J. Schmit, 2004: Quantization noise for GOES-R ABI bands. *13th Conf. Sat. Meteor. Ocean., AMS,* 20-24 September, 9-p.

Hillger, D.W., M. DeMaria, J.F.W. Purdom, and C.D. Barnet, 2004c: Risk reduction activities for future GOES-R instrumentation. *4th International Asia-Pacific Environmental Remote Sensing Symposium (Applications with Weather Satellites II)*, SPIE, 8-11 November, Honolulu HI.

Kidder, S.Q., D.W. Hillger, A.J. Mostek, and K.J. Schrab, 2000: Two simple GOES Imager products for improved weather analysis and forecasting. *Nat. Wea. Dig.*, 24(4), December, 25-30.

Molenar, D.A., Schrab, K.J., Purdom, J.F.W. 2000: RAMSDIS Contributions to NOAA Satellite Data Utilization**.** *Bull. Amer. Meteor. Soc.*, 81(5), 1019-1030.

Table 1: GOES-R ABI Bands and Bandwidths

ABI Band	Central Wavelength (µm)	Wavelength Range (µm)	Band Explanation	Spatial Resolution (km) @ nadir
1 (blue)	0.47	0.45 - 0.49	Visible/reflective	1
2 (red)	0.64	0.59 - 0.69	Visible/reflective	0.5
3	0.865	0.846 - 0.885	Reflective	1
4	1.378	1.371 - 1.386	Cirrus	2
5	1.61	1.58 - 1.64	Snow/ice	1
6	2.25	2.225 - 2.275	Particle size	
7	3.90	3.80 - 4.00	Shortwave IR window	2
8	6.19	5.77 - 6.6	Water vapor	
9	6.95	6.75 - 7.15	Water vapor	
10	7.34	7.24 - 7.44	Water vapor	
11	8.5	8.3 - 8.7	Water vapor, SO2	
12	9.61	9.42 - 9.8	Ozone	
13	10.35	10.1 - 10.6	Longwave IR window	
14	11.2	10.8 - 11.6	Longwave IR window	
15	12.3	11.8 - 12.8	Longwave IR	
16	13.3	13.0 - 13.6	Longwave IR	

Table 2: Comparison of 16-band GOES-R Advanced Baseline Imager (ABI) with EOS MODIS bands

GOES-R ABI		MODIS	
Band number	**Central wavelength (μm)**	**Band number**	**Central wavelength (μm)**
1 (blue)	0.47	**3 (blue)**	0.47
2 (red)	0.64	**1 (red)**	0.64
3	0.86	**2**	0.86
4	1.38	**26**	1.38
5	1.61	**6**	1.64
6	2.26	**7**	2.13
7	3.9	**22**	3.96
8	6.15	**No equivalent**	No equivalent
9	7.0	**27**	6.7
10	7.4	**28**	7.3
11	8.5	**29**	8.55
12	9.7	**30**	9.7
13	10.35	**No equivalent**	No equivalent
14	11.2	**31**	11.0
15	12.3	**32**	12.0
16	13.3	**33**	13.3

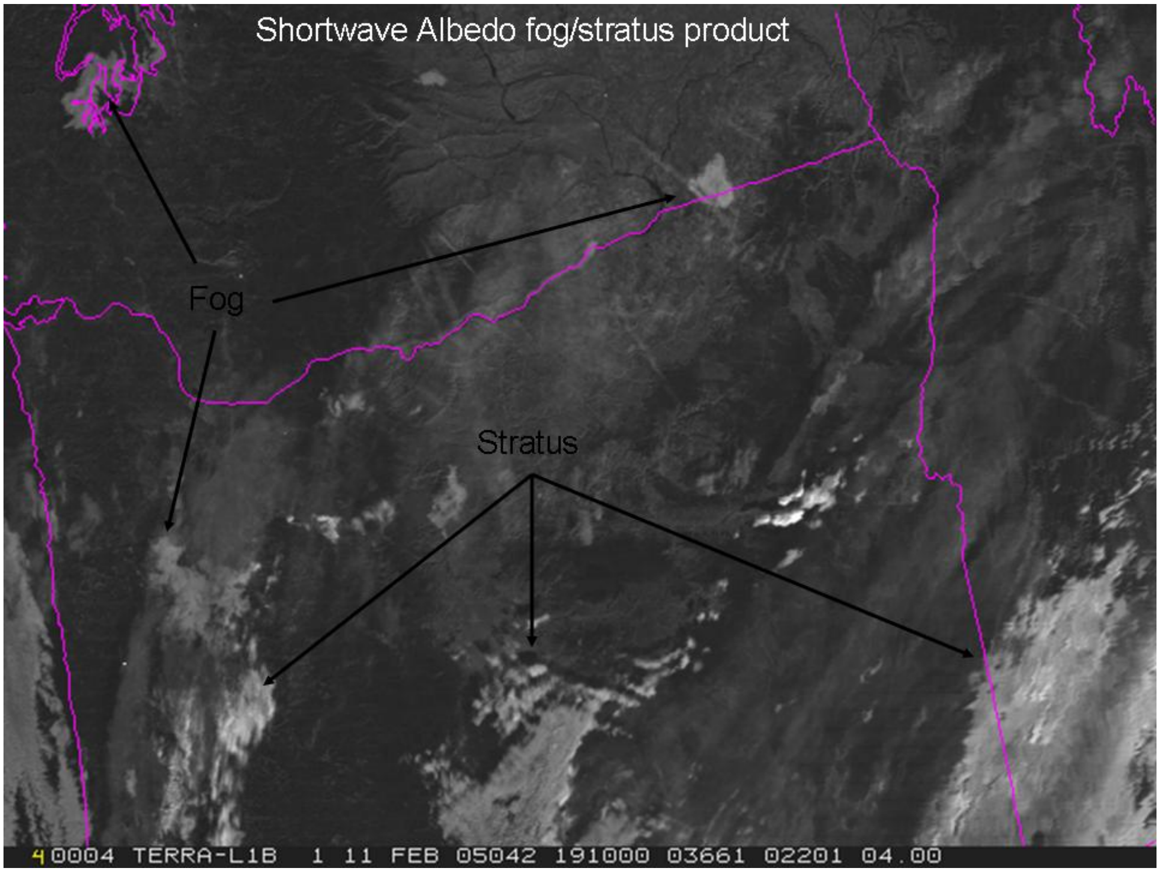

Figure 1a: Shortwave Albedo Product showing patches of fog and stratus in southern Washington and Oregon at 1910 UTC (daytime) on 11 February 2005. Fog and stratus are white/light, whereas ice clouds and most land surfaces are dark.

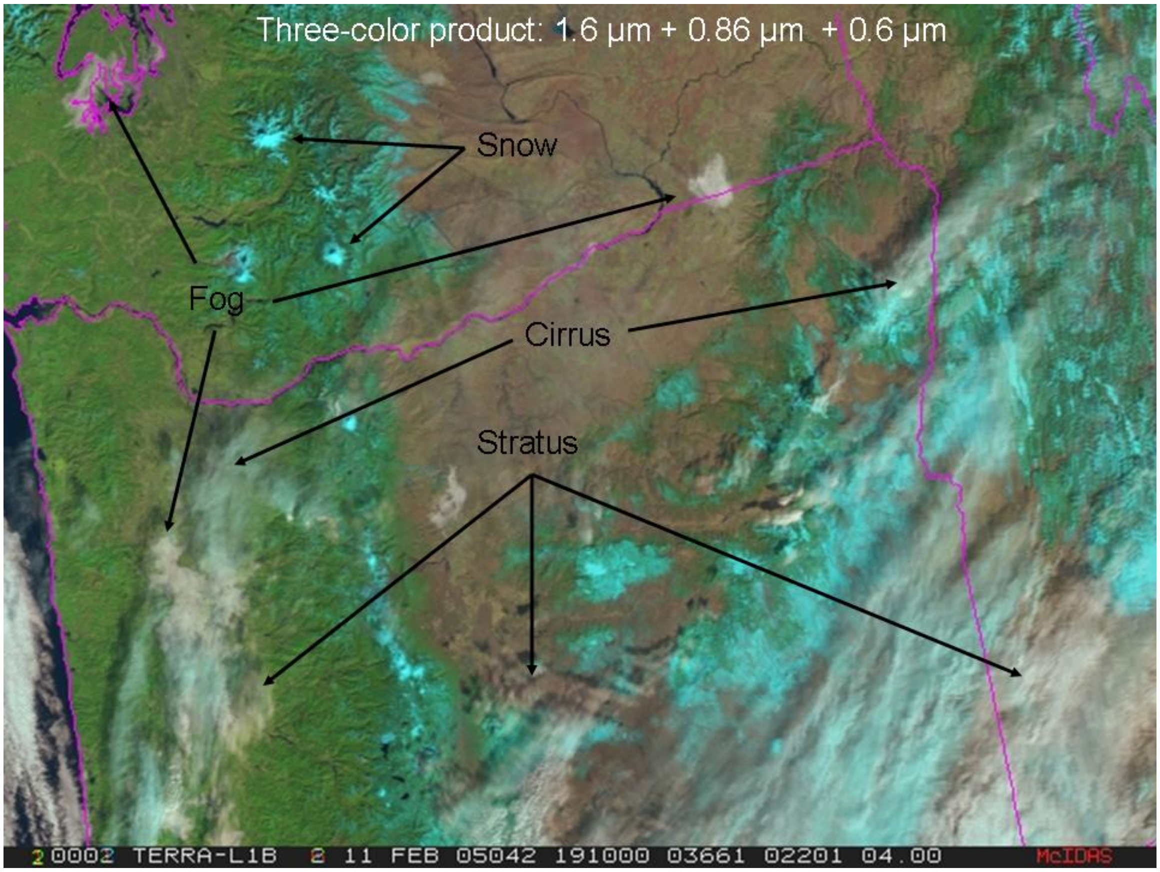

Figure 1b: MSG "natural" Three-Color Product showing patches of fog and stratus, as well as snow and groundcover, for the same scene as in Figure 1a. Snow and ice clouds are cyan, low clouds are white, vegetated land surfaces are green, and non-vegetated land is brown.

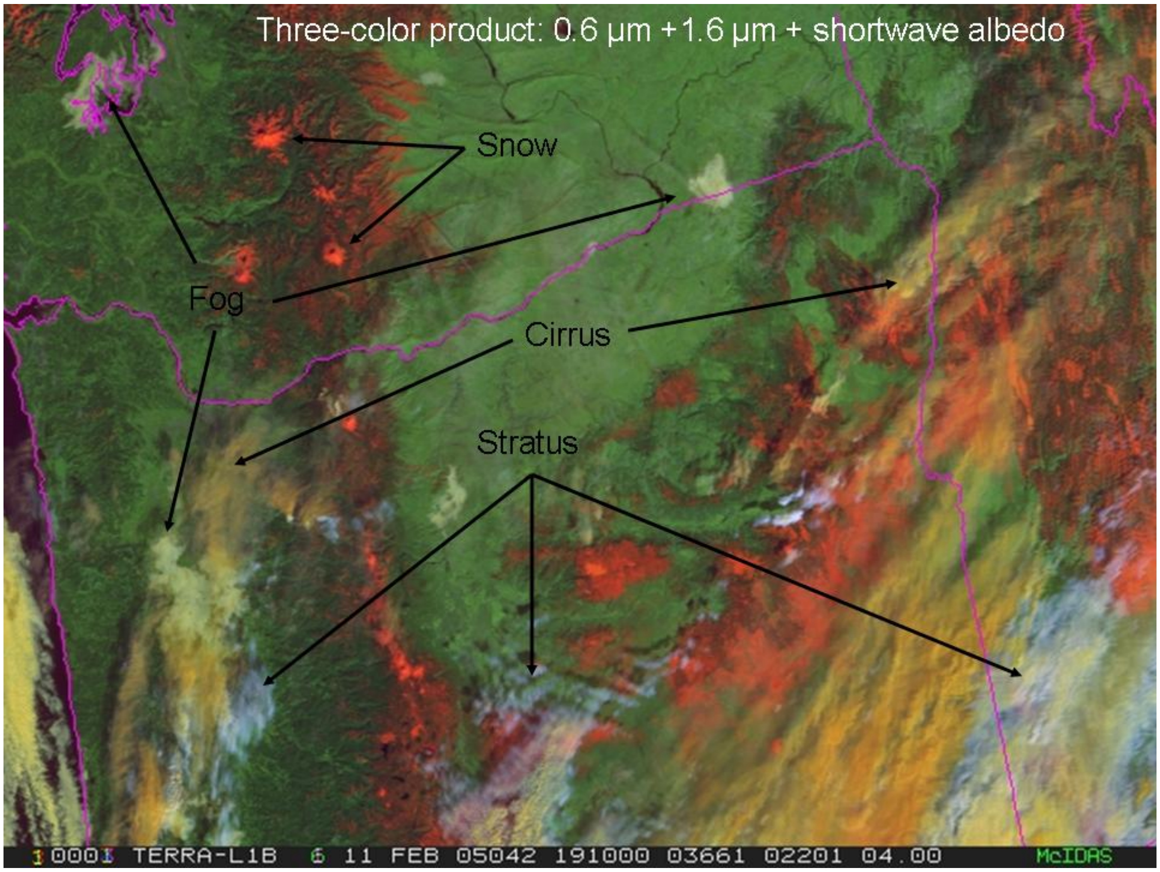

Figure 1c: New Fog/Stratus Three-Color Product that better discriminates clouds from land, and between different levels and types of clouds, for the same scene as in Figure 1a and 1b. Snow is orange/red; high-level cirrus/ice clouds are yellow/orange; low-level stratus/water clouds have a blue tint; and fog (on the ground) is whiter than stratus clouds that are off the ground. Most land surfaces are green, the color discrimination of different land types being sacrificed for cloud level and type discrimination.