A SIMPLE GOES SKIN TEMPERATURE PRODUCT

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1. Introduction[*]

An image product that is easily generated from the GOES split-window bands can be used to monitor surface skin temperature changes. This product is a variant of GOES thermal infrared images, corrected for low-level atmospheric absorption. The small transmittance difference between the split-window bands (band 4, 10.7 μm; and band 5, 12.0 μm, on the GOES Imager) can be used to correct them for the effects of atmospheric absorption, arriving at a skin temperature product.

Atmospheric transmittance calculations for the standard mid-latitude atmosphere show that for the GOES Imager the transmittance at 10.7 μm is about 0.71 and at 12.0 μm it is about 0.57. This translates into a correction factor to be applied to the more transparent 10.7 μm band of approximately two (2) times the temperature differential between the two bands. The resulting product is closer to the actual radiative skin temperature than either of the input bands.

Examples of this product generated from the split window bands of both the GOES Imager and GOES Sounder are shown below. For the Sounder a change in the atmospheric correction factor is needed due to differences in the split-window bands. Also, the split-window difference temporarily disappears from the GOES Imager with GOES-12 and beyond, due to a change of the 12.0 μm band to a more opaque 13.3 μm band intended for cloud detection. A skin temperature

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product is not as easily generated from this larger spectral (and transmittance) separation.

The chief use of the surface temperature product is to determine changes or boundaries in the low-level temperature. Color enhancements are used to quickly quantify the surface temperature and its variations and help track changes over time. Variations in surface heating are inversely related to both surface types and low-level moisture. Also, when compared to shelter temperatures, the skin temperature can be used to indicate the temperature lapse rate near the surface, at times indicating the presence of low-level temperature inversions.

2. Analysis of Skin Temperature

Based on the work of McMillin and Crosby (1984), the split widow bands (band 4, 10.7 μm; and band 5, 12.0 μm, on the GOES Imager) can be used together to correct one of them for the effects of atmospheric absorption. The formula is

$$T_{sfc} = T_{10.7} + \eta \cdot (T_{10.7} - T_{12.0})$$

where

$$\eta = \frac{1 - \tau_{10.7}}{\tau_{10.7} - \tau_{12.0}}$$

and τ is atmospheric transmittance (see Kidder and Vonder Haar 1995, pages 219–225, for details). MODTRAN (Berk et al. 1989) calculations for the standard mid-latitude atmosphere show that for the GOES Imager $\tau_{10.7}$ is about 0.68 and $\tau_{12.0}$ is about 0.57, which means that the correction or scale factor η is approximately 2. This derivation is similar to sea

surface temperature algorithms (McClain et al. 1985), but it is simpler.

Examples of T_{sfc} product images for the GOES-8 (GOES-east) and GOES-10 (GOES-west) Imager are shown in Figure 1. T_{sfc} appears quite similar to the usual $T_{10.7}$ image, but with slightly more noise because it is a combination of two bands and therefore has compounded noise. A color enhancement is used to emphasize variations in temperatures affecting the land and ocean surfaces, whereas gray shades are used for cloud top temperatures.
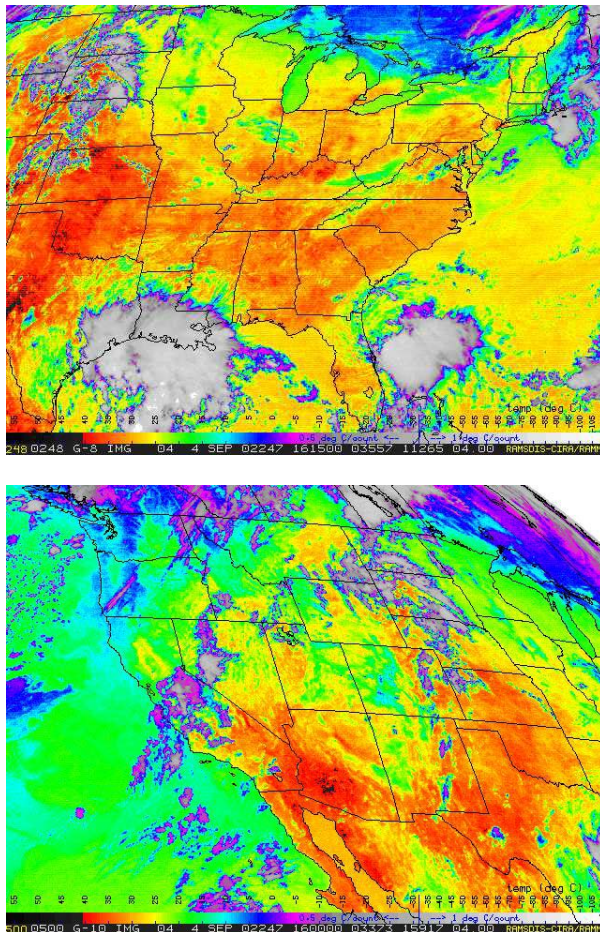

Figure 1: Skin temperature product images for the GOES-8 (top) and GOES-10 (bottom) Imager on 4 September 2002 at 1615 and 1600 UTC respectively. A special "rainbow-color" enhancement is applied to emphasize variations in land surface/skin temperatures. Gray shades are used for clouds.

The time evolution of $T_{10.7}$, $T_{12.0}$, and the temperature correction [$2(T_{10.7} - T_{12.0})$] over Norman OK on a cloud-free day (11-12 May 1998)

are compared in Figure 2. The 00 and 12 UTC soundings are also shown. GOES Imager band 5 (12.0 μm) is more sensitive to water vapor than is band 4 (10.7 μm); i.e. band 5 is more sensitive to the atmosphere than is band 4. When the atmospheric temperature decreases with height, $T_{12.0}$ is normally cooler than $T_{10.7}$, and the temperature correction is positive. When the atmospheric temperature increases with height, the correction can be negative. In any case, T_{sfc} is closer to the actual skin temperature than either $T_{10.7}$ or $T_{12.0}$.
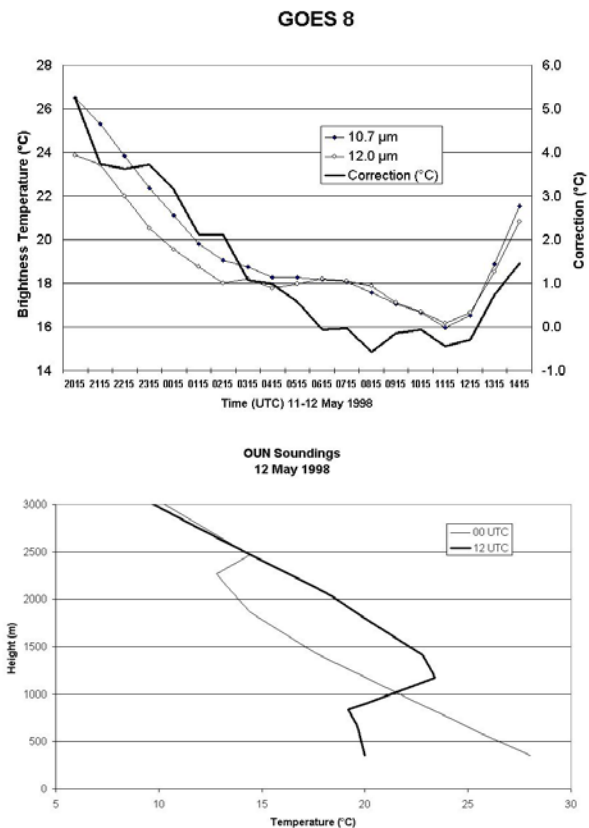

Figure 2: (Top) Time sequence of GOES-8 $T_{10.7}$, $T_{12.0}$, and the temperature correction used for Norman OK on 11-12 May 1998. (Bottom) 00 and 12 UTC soundings at Norman OK on 12 May 1998.

The chief use of the surface temperature product is to determine changes or boundaries in the low-level temperature. T_{sfc} is mostly of value in humid situations to "clear" the water vapor from the satellite signal to reveal the surface (skin) temperature. Color enhancements can be used to quickly quantify the surface temperatures and help track changes.

Unfortunately, the dirty or split-window band-5 on the GOES Imager will disappear temporarily when GOES-12 becomes operational as GOES-east in place of GOES-8. The new band-6 at 13.3 μm, meant for analysis of low clouds, is too opaque to be used together with the window band-4 to produce a skin temperature product. However, there are other satellite instruments that contain the split-window bands that can be used to produce a skin temperature product.

3. AVHRR and other instruments

Although presented as GOES products, nearly the same spectral bands are present on the 19-band Sounder on GOES-8 and GOES-10, on the Advanced Very High Resolution Radiometer (AVHRR) on polar-orbiting NOAA satellites, and on the Moderate Resolution Imaging Spectroradiometer (MODIS) on EOS AM-1 / Terra and EOS PM-1 / Aqua. Because the bands are different, a recomputed correction factor is necessary: $\eta \approx 3$ (Price 1984). Table 1 lists the wavelengths, transmittances, and scale factors for each of these instruments. Although the spectral bands vary slightly the scale factor more than doubles for the GOES Sounder and MODIS.

Table 1: Wavelengths, Transmittances and Scale Factors for Various Satellite Instruments.

Satellite and Instrument	Wavelength (um)		Transmittance		Scale Factor
	λ_1	λ_2	τ_1	τ_2	η
GOES-8/11 Imager	10.7	12.0	0.71	0.57	2.1
GOES Sounder	11.0	12.0	0.65	0.57	4.4
NOAA AVHRR	10.8	12.0	0.68	0.57	2.9
EOS MODIS	11.0	12.0	0.65	0.57	4.4

Examples of T_{sfc} product images for the GOES-8 (GOES-east) and GOES-10 (GOES-west) Sounder are shown in Figure 3. In this case the scale factor is much larger (4.4) than for the GOES Imager or for the NOAA AVHRR instrument, but about the same as would be use for the MODIS split-window bands.
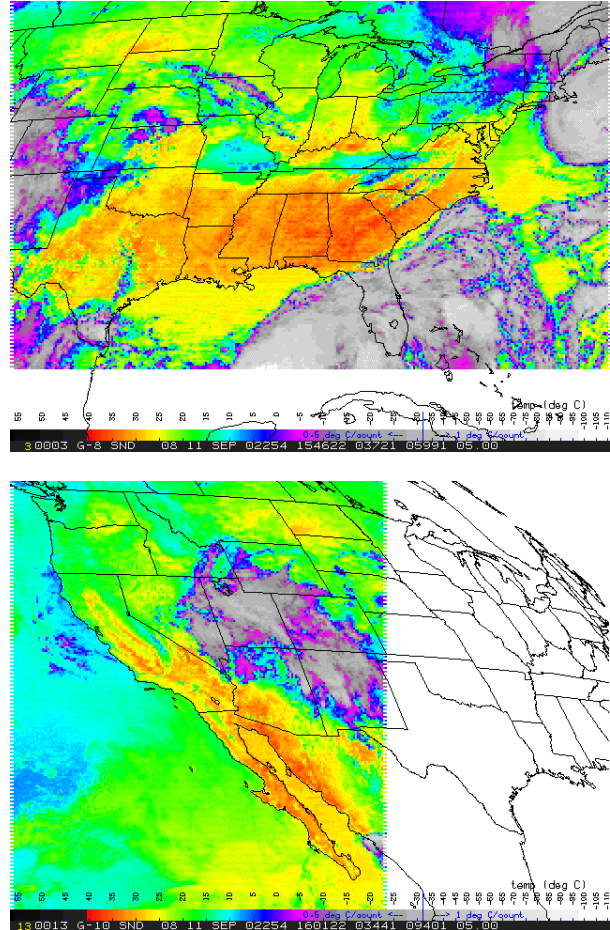

Figure 3: Skin temperature product images for the GOES-8 (top) and GOES-10 (bottom) Sounder on 11 September 2002 at 1546 and 1601 UTC respectively. A special "rainbow-color" enhancement is applied to emphasize variations in land surface/skin temperatures. Gray shades are used for clouds.

4. Summary and Conclusions

A simple surface/skin temperature product that can be constructed from GOES Imager data (or AVHRR or MODIS data) has been presented as a tool to improve weather analysis and forecasting. This product is being tested on a continuing basis using both GOES-east (GOES-8) and GOES-west (GOES-10) imagery on RAMDIS systems at CIRA and made available on RAMDIS On-Line at: http://www.cira.colostate.edu/RAMM/rmsdsol/ROL EX.html. This is the type of product that should be available to forecasters: simple, easily-produced, reliable, and physically based.

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