Tropical Cyclone Convection and Intensity Analysis using Differenced Infrared and Water Vapor Imagery
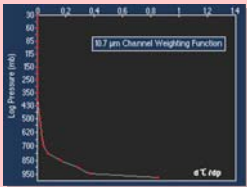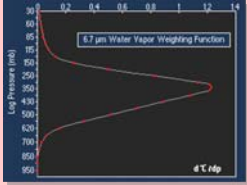
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Motivation and Background

A technique to identify and quantify intense convection in tropical cyclones (TC) using bispectral, geostationary satellite imagery is explored to take advantage of the greater temporal availability over microwave imagery (MW) from polar orbiting satellites. This technique involves differencing the Water Vapor (WV) and Infrared Window (IRW) channels available on all current geostationary satellites. As shown in the weighting functions at left, the WV will typically be colder than the IRW during tropospheric clear sky conditions. With thick, opaque cloud conditions during intense, active convection penetrating the tropopause, however, the IR channel temperature can be equal to or colder than the WV due to the re-emitted absorbed radiation from stratospheric water vapor (Schmetz et al, 1997).
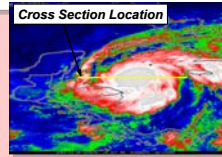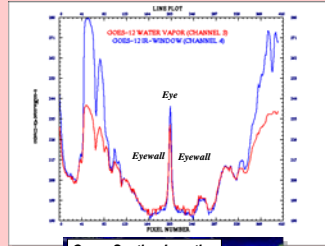
The most intense convection in a TC lies within the storm eyewall. In this region the IR-WV differencing can result in colder cloud top temperatures being measured in the IRW channel than the WV channel, as shown in the East-West cross-section during Hurricane Wlma in 2005. This cross-section clearly shows the colder IRW temperature values observed within the TC eyewall. At this time, Hurricane Wilma was near its maximum intensity (MSLP ~885mb). It is important to note the warmer IRW values away from the eyewall region and within the eye itself. In these regions the clouds are less opaque (or missing entirely) resulting in temperature measurements more in line with the expected atmospheric conditions.

Cross Section Location

Qualitative Analysis and Product Usage

One potential and powerful use of the IR-WV differencing technique could be in the identification of the TC storm center storm center which lies underneath a convective dense overcast (CDO) cloud shield (Velden and Olander, 1999). The CDO hides the location of a forming/dissipating eye region in minimal hurricanes/typhoons. TC forecasters will either use MW imagery (if available), or forecast interpolation/extrapolation to obtain a storm center point (the latter often being highly uncertain). The example below demonstrates the potential for identifying a "hidden" storm center with convective bands/gradients in the IR-WV difference field (dashed arcs)

Central Dense Overcast… where is the center?

Storm Center
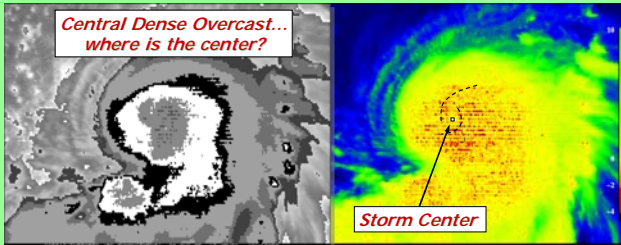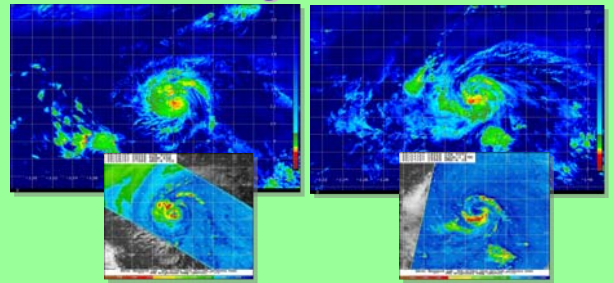
Another possible use is as a "poor-man's" microwave imager. A set of corresponding IR and WV images are differenced, with a specific image enhancement applied to the derived field. The enhancement is an attempt to mimic the 85/89 Ghz channel MW images from the NRL-Monterey webpage. Areas of intense convection regions are identified in strikingly similar regions between the IR-WV and MW images. The two IR-WV images above are obtained from MTSAT during Typhoon Yutu in 2007.

Quantitative Statistical Analysis
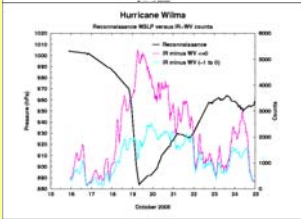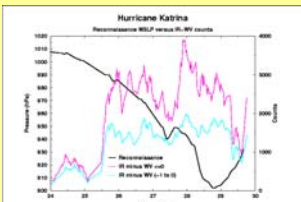
Time series of two Tb_{IR-WV} parameters (see explanation below/right) vs. reconnaissance measurements of center MSLP for Hurricanes Katrina and Wilma (left, top and bottom).
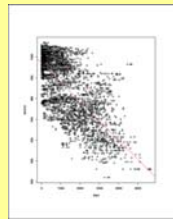
Correlation Coefficients

	No lag	6hr lag	12hr lag	18hr lag	24hr lag
Tb_{IR-WV} ($<=0°C$)	.626	.642	**.719**	.701	.712
Tb_{IR-WV} ($-1°-0°C$)	.675	.682	**.749**	.734	.732
Avg Tb_{IRW}	.631	.630	.663	.679	.664

Shown at left is a scatter plot of TbIR-WV (<-0°C) versus MSLP for all cases in our sample (~50 storms). Shown above is a statistical regression analysis of two selected IR-WV difference parameters vs. collocated aircraft reconnaissance measurements of TC MSLP for our 50 storm sample. The ave. IRW Tb is presented for reference. **The IR-WV correlations exceed the ave. IRW, indicating skill.** The time lag indicates the number of hours the IR-WV analysis time precedes the reconnaissance MSLP measurement. **The highest correlations at 12-hr indicates a potential predictive quality of the IR-WV difference parameters.**

Tb_{IR-WV} ($<=0°C$) : All IR-WV temperatures differences less than 0°C
Tb_{IR-WV} ($-1 -0°C$) : All IR-WV temperatures differences between -1°C and 0°C
Avg Tb_{IR} : Average IR temperature
All parameters represent Tb values taken 0-132km from the TC center.

Potential Applications

○ *Advanced Dvorak Technique (ADT)* (Olander and Velden, 2007)

The ADT is an automated version of the satellite-based Dvorak Technique used operationally by TC analysis centers world-wide to estimate current intensities. The method presented above has the potential to help the ADT automated storm center determination, and improve the intensity estimation in Central Dense Overcast situations.

References

- Olander, Timothy L. and Velden, Christopher S. : **The Advanced Dvorak Technique: Continued development of an objective scheme to estimate tropical cyclone intensity using geostationary infrared satellite imagery**. *Weather and Forecasting*, Volume 22, Issue 2, 2007, pp.287-298.

- Velden, Christopher S. and Olander, Timothy L. : **Bispectral satellite technique for delineating intense convection: Applications to tropical cyclones**. In: Conference on Hurricanes and Tropical Meteorology, 23rd, Dallas, TX, 10-15 January 1999 (preprints), v.1. Boston, MA, American Meteorological Society, 1999, pp.431-434.

- Schmetz, Johannes; Tjemkes, S.A.; Gube, M. and van de Berg, L. : **Monitoring deep convection and convective overshooting with Meteosat**. Adv. Space. Res., Volume 19, 1997, pp. 433-441.