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 biscalpbral, 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 Wilma in 2005. This cross-section 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.

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, 1999). The CDO hides the location of a forming/dissipating eye, which lies beneath the 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).

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

<table>
<thead>
<tr>
<th>Correlation Coefficients</th>
<th>No lag</th>
<th>6hr lag</th>
<th>12hr lag</th>
<th>18hr lag</th>
<th>24hr lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_{IR-WV} (&lt;=0°C)</td>
<td>.626</td>
<td>.642</td>
<td>.719</td>
<td>.701</td>
<td>.712</td>
</tr>
<tr>
<td>T_{IR-WV} (-1°C-0°C)</td>
<td>.675</td>
<td>.682</td>
<td>.749</td>
<td>.734</td>
<td>.732</td>
</tr>
<tr>
<td>Avg T_{IR}</td>
<td>.631</td>
<td>.630</td>
<td>.663</td>
<td>.679</td>
<td>.664</td>
</tr>
</tbody>
</table>

Shown at left is a scatter plot of T_{IR-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 avg. IRW Tb is presented for reference. The IR-WV correlations exceed the avg. 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.

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