2.2 IMPROVEMENTS IN GLOBAL CONVECTIVE DETECTION

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1. INTRODUCTION

Thunderstorm detection is required for a large number of applications ranging from global climate studies to aircraft operations. The Aviation Weather Center (AWC) generates High Level Significant Weather forecasts covering 2/3 of the globe which include areas of deep convective activity that will affect aircraft. The generation of these forecasts as well as their verification requires an objective method of global monitoring of convective activity. In addition, a real time diagnostic of thunderstorm convective activity is of great benefit to pilots and dispatchers making aircraft routing decisions. Because thunderstorms have lifetimes ranging from 30 minutes to several hours, continual monitoring methods are needed over the entire globe with update rates of an hour or less. Thunderstorms can be detected directly using radar, lightning detection, and satellite microwave sensors. However, these detection techniques are not continually available over the entire globe.

Algorithms for the indirect estimates of thunderstorm existence and intensity have been developed using geostationary satellite images. Over the past 30 years, a number of algorithms have been developed, especially for rainfall estimation. Many of these algorithms use infrared (IR) temperature thresholds (e.g. Arkin and Meisner, 1987 and Vicente et. al.,1998) to determine the existence of thunderstorm clouds. Rozumalski (2000) has shown that these techniques frequently produce erratic results because cirrus clouds can also have IR temperatures colder than the threshold used to define a thunderstorm. Other cloud classification techniques, such as Tag et. al. (2000) use a combination of IT temperature thresholds, texture, and spectral response of various channels. However the ability of these cloud classification techniques to distinguish between thunderstorms and cirrus significantly degrades without the use of the visible channel, which occur at night.

Recently the possibility of using the difference between the 6.7 micron water vapor (WV) and the 11 micron IR channels to identify deep convection has been identified by several groups. Bessho et. al. (2001) has used the technique to identify cumulonimbus clouds in typhoons. Mosher (2001) has proposed using this technique, herein called the Global Convective Diagnostic algorithm (GCD) to monitor global convection since these two channels are available on the geostationary weather satellites.

2. GLOBAL CONVECTIVE DIAGNOSTIC ALGORITHM

2.1 Physical Basis

The physical concept behind the GCD algorithm is that thunderstorms lift WV and cloud particles to the top of the troposphere. Where there is active uplift to the top of the troposphere, the IR and WV channels will have the same temperature. The wind at the thunderstorm top will transport the cloud ice particles and WV down wind. As the cloud ice particles advect away from the thunderstorm, they will gradually fall because of their mass. WV will also advect away from the thunderstorm, but will not fall. Hence in the cirrus clouds down wind of the thunderstorm, there should be a slight temperature difference between the IR temperature of the cloud particles and the WV channel temperature of the WV. The current algorithm eliminates areas where the IR channel is at least 1 degree C warmer than the WV channel. The 1 degree C threshold was selected because it is the smallest increment of the satellite sensor's brightness counts (using 8 bit satellite images) that all geostationary weather satellites shared in common. The 1 degree C threshold is consistent with the temperature difference realized by a 20 micron ice crystal falling 100 meters in 30 minutes in the average lapse rate at the top of the troposphere).

2.2 Algorithm Methodology

The original test version of the global convective diagnostic algorithm used differences between the global composites of IR and WV images. The use of composites produced problems in the overlap regions between satellites with false identification of cirrus as thunderstorms. Originally it was thought that the overlap problem was caused by limb darkening differences between the two channels. Closer examination revealed that the problems were caused by non coincident pixels where one satellite was providing the IR value in the composite and another satellite was providing the WV value. The algorithm was modified to first take the differences between the channels in the original satellite image projections, and then remap and composite the differences into a global composite. This revised method eliminated the false identification problems in the overlap regions.

The global composite is generated by remapping each satellite difference image into a 10 km resolution

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latitude-longitude equidistance projection with a parallax correction assuming a 10 km cloud top height. The parallax correction is accomplished by increasing the radius of the earth by 10 km in the navigation subroutines computing coordinate transformations. Image data close to the earth edge beyond approximately 65 degrees from the satellite subpoint are excluded from the composite. Where there is overlap between satellites, the most timely data are selected for the composite.

2.3 Requirement for space and time coincident differences

The requirement for space and time coincident differences of IR and WV images is a problem with the Meteosat satellite at 0 degrees longitude. During daylight the visible and IR channel data must share the same communications bandwidth, with the net result being that the WV image is sent only every 3 hours during daylight hours, and every ½ hour during the night hours. The IR is continually sent every ½ hour. The Indian Ocean Meteosat at 63 degrees longitude provides both IR and WV images every half hour. In overlap regions where both European and Indian Ocean Meteosat data are available, the Indian Ocean satellite is given preference. This problem will be corrected in the coming years with the next generation of Meteosat.

2.4 Stability Filter

While convection is the most common process lifting air parcels and clouds to the top of the troposphere, it is not the only lifting mechanism which generates high clouds. Ageostrophic motions around jet streams cause cirrus clouds. Cyclone lifting mechanisms (i.e. slantwise ascent) cause extensive cirrus shields around the mid latitude storms. The IR-WV channel difference also detects non-convectively produced cirrus clouds where they are being generated. Since these cirrus clouds are not associated with thunderstorms, a filter is desired to remove them from the GCD. Several meteorological filters have been tried. A stability index filter appeared to have the most success in elimination of non-convective areas of active uplift. The global GFS forecast model 4 layer Lifted Index (LI) is being used in the current algorithm to eliminate areas not associated with convection. The most current GFS run with forecast times closest to GCD time (generally the 6 hour forecast) is used as the filter. Areas with a positive LI of +1 or greater are eliminated from the composite. The gridded GFS model data are converted to an image in the same projection as the satellite image, and then used to eliminate areas not conducive to convection.

The use of the LI filter assumes that the GFS model has forecast the state of the atmosphere correctly for the entire globe. Preliminary monitoring of the algorithm for areas incorrectly eliminated by the LI filter has shown few problems. The most common problem has been convection in the cool season in regions of warm air advection where the GFS 4 level LI cannot diagnose the instability associated with elevated convection.

2.5 GCD Processing and Visualization

The GCD is produced routinely every half hour at the AWC and is made available to AWC forecasters. GCD visualization depends on user interest. While a pilot might wish to see only convective areas, meteorologists frequently wish to view the IR images in addition to the GCD. Both the GCD images and the GCD combined with the global IR composite are available on the web. Figure 1 shows the GCD combined with the global IR composite. Sectors are also generated for various sections of the world. Sectors for the Conus, Atlantic, North Atlantic, Pacific, North Pacific, Indian Ocean, tropics, South America, Africa, Asia, Australia, Europe, and the world are currently available. The South American and African sectors are shown in Figs. 2 and 3, respectively. GCD sectors are available at http://aviationweather.gov/gcd/.

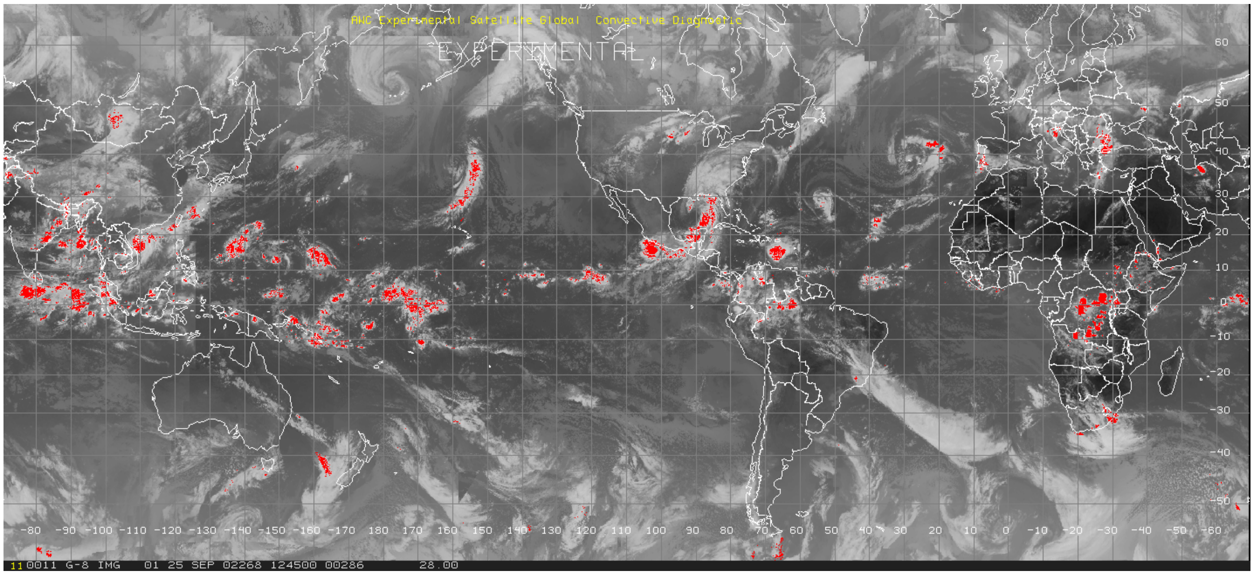

Figure 1 Global Convective Diagnostic (GCD) in red overlaid on global infrared image for Sept. 25th 12:45Z.

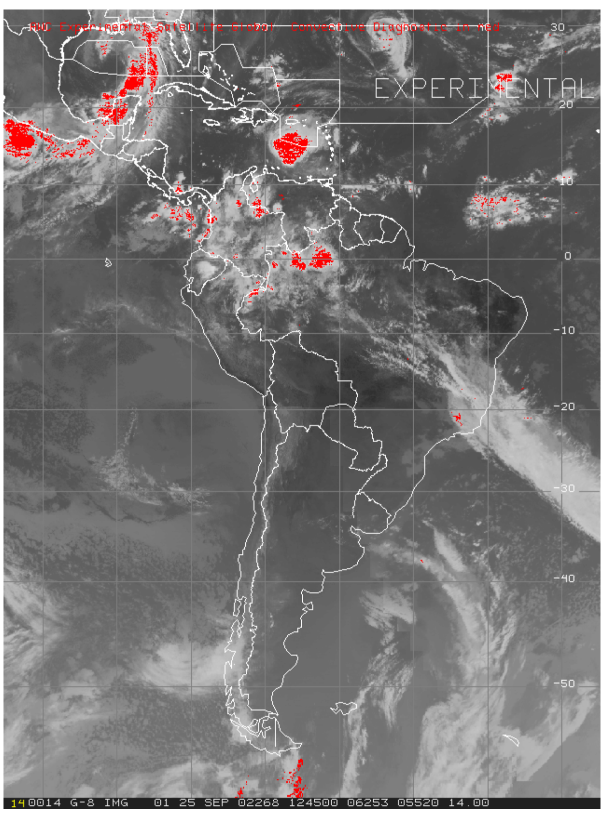

Figure 2. South American GCD sector for same time as Figure 1.

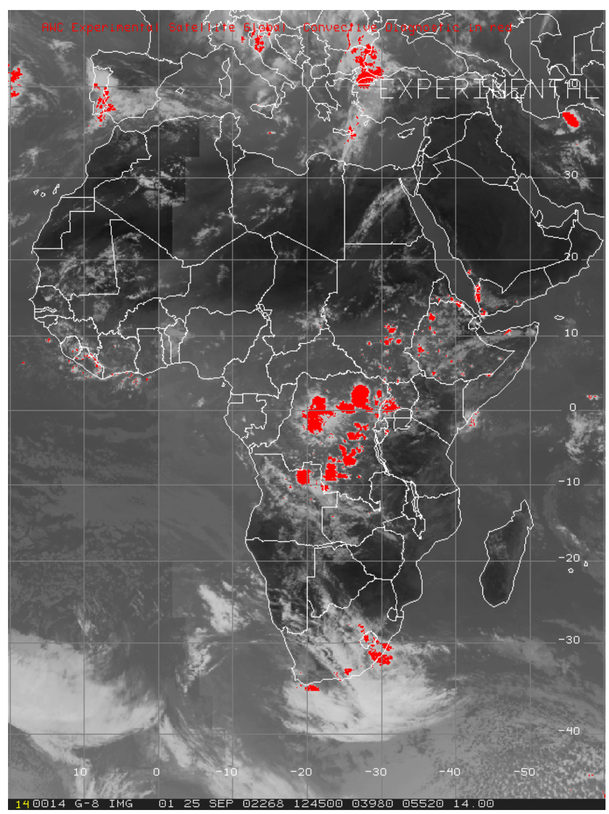

Figure 3. Africa GCD sector for same time as Figure 1.

3. GCD Results

3.1 Verification

During the development of the algorithm, remotely sensed lightning was used for ground truth of thunderstorm existence. The National Lightning Detection Network (NLDN) as described by Cummins et.al. (1998) was augmented with data from the Canadian Lightning Detection Network (CLDN), and network data from Japan, France, and Germany. Global Atmospheric, Inc. (GAI) processed these data with a long range detection algorithm described by Cramer and Cummins (1999). Nierow et.al. (2000) showed these long range data to be useful with range of 2000-4000 km and location accuracy of 16-32 km.

A more formal verification is being undertaken utilizing the Real Time Verification System (RTVS) developed by the Forecast Systems Lab (FSL). The ground truth data is the radar/lightning based National Convective Weather Diagnostic (NCWD) described by Magenhardt et.al.(2000). A US sector with 20 km grid spacing is generated for the verification effort. The methods used for convective verification are described by Mahoney (2000).

Verification statistics are available from 7 September 2001 to 30 September 2002 at http://www-ad.fsl.noaa.gov/fvb/rtvs/conv.index.html. The GCD Probability of Detection yes (PODy) was 0.44, the Probability of Detection no (PODn) was 0.99, the True Skill Statistic (TSS) was 0.43 and the bias was 2.78. To show the comparative level of skill (even though it is for a different product and a different period of observations), the Convective SIGMET verification for the initial time of the forecast period for 2001 had a PODy =.44, PODn=.99, TSS=.42 and Bias=1.39. The verification shows that the Global Convective Diagnostic has a reasonable level of skill, but that the GCD overestimates the area of convection.

3.2 Thresholds

The large bias obtained from the verification suggests that the threshold may be too high, allowing too large an area of clouds to be selected as being convective. The 1 degree C threshold was selected because of the limitations of the global geostationary satellites having only 8 bit data available. The GOES satellites currently have 10 bit data available, so a GCD experiment was performed for the GOES-East area over the US and verifying the GCD with the corresponding NCWD. Figure 4a-c show the GCD for IR-WV thresholds of 1, ½ , and 0 degree C. The extent and bias of the detected GCD is reduced with the smaller thresholds without significant loss of detection skill until the 0 degree C threshold is reached.

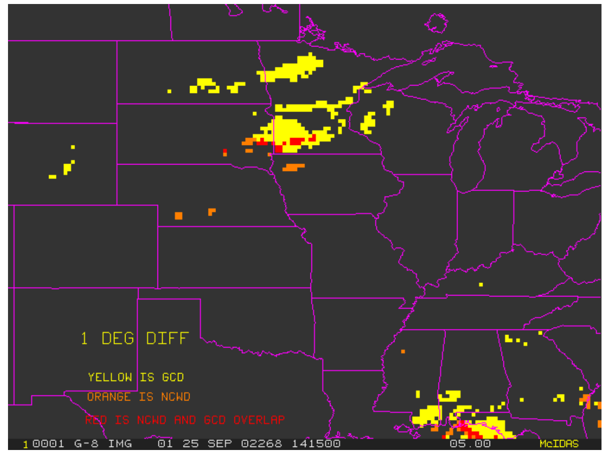

Figure 4a. GCD in yellow with a 1 degree threshold. The NCWD (radar) is in orange and where they both overlap is shown in red.

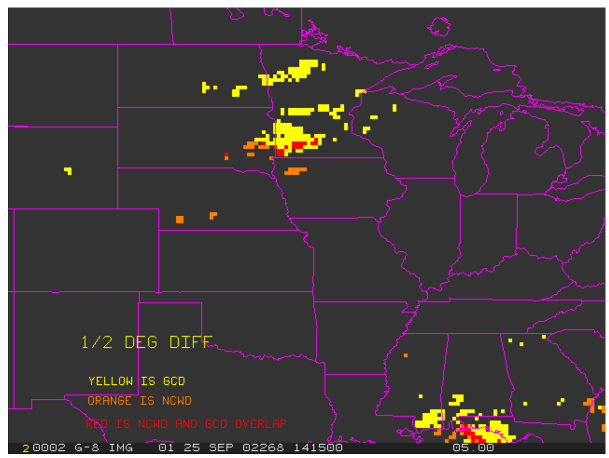

Figure 4b. GCD with ½ degree threshold.

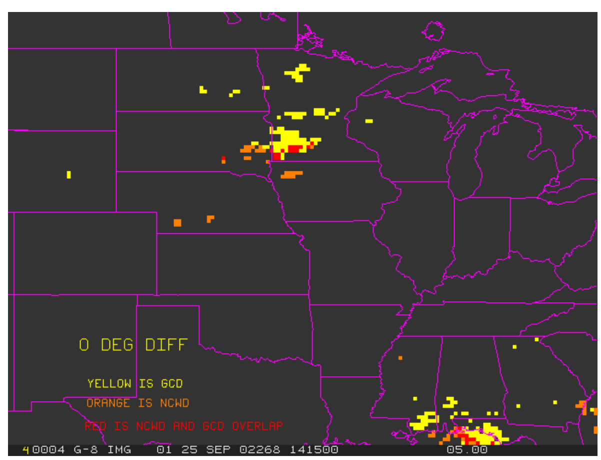

Figure 4c. GCD with 0 degree threshold.

4. SUMMARY

A Global Convective Diagnostic product has been developed at the AWC using the temperature difference between the IR and WV channels from geostationary satellite images. The physical concept behind the algorithm is that in areas of active uplift to the top of the troposphere, the temperature of the clouds detected by the IR channel will be the same as the temperature of the WV detected by the 6.7 micron channel. As WV and clouds advect away from the areas of uplift, the cloud particles will slowly fall, but the WV will not. This will result in the IR channel being slightly warmer than the WV channel. In the current algorithm pixels are eliminated as non-thunderstorm which have temperature differences of 1 degree C. or warmer. The temperature differences are remapped and combined into a global composite with a parallax correction of 10 km. Data beyond approximately 65 degrees from the satellite subpoint are eliminated from the composite. Where two satellites have overlap, the data from the more recent image are used in the composite. Since other phenomenon, such as ageostrophic motions around jet streams, can cause cloud formation at the top of the atmosphere, a filter of the GFS Lifted Index (LI) was applied to the data. Areas with a positive LI of 1 degree Cor greater are eliminated from the composite. Verification shows the diagnostic to have reasonably good skill (True Skill Statistic= .42) in detecting areas of convection, but to overestimate the areal extent (Bias=2.78). Experiments performed with reducing the threshold temperature below 1 degree C showed that lower thresholds reduce the bias without significantly reducing the skill score until the 0 degree threshold is reached.

3. REFERENCES

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