P2C.4 AN OBJECTIVE ALGORITHM FOR THE IDENTIFICATION OF CONVECTIVE TROPICAL CLOUD CLUSTERS IN GEOSTATIONARY INFRARED IMAGERY

Chip Helms and Christopher C. Hennon*
UNC Asheville, Asheville, NC

Kenneth R. Knapp
NOAA/National Climatic Data Center, Asheville, NC

1. INTRODUCTION

A requirement for tropical cyclogenesis is the existence of a large area of intense and persistent thunderstorms, called "cloud clusters". During a typical hurricane season in the Atlantic, there are usually more than 100 cloud clusters that form and move across the basin. Cloud clusters can be associated with easterly waves, stalled mid-latitude fronts, and/or a large area of atmospheric instability.

Owing to their critical importance in the tropical cyclogenesis process, several recent studies (e.g. Hennon and Hobgood 2003) have compiled a large dataset of cloud clusters for study. Most studies have used manual identification techniques to create the cluster database. This is a very time consuming process. Usually, hundreds or thousands of basin-wide IR imagery are examined individually for evidence of coherent cloud clusters.

This paper describes a simple technique for objectively finding and recording tropical cloud clusters in geostationary IR imagery. The definition of a cloud cluster and the satellite imagery used in the study are described in the next section. This is followed by a brief description of the how the algorithm works. Preliminary results from the 2000 Atlantic hurricane season are presented in section 4. Section 5 describes potential applications for a large dataset of tropical cloud clusters. Finally, section 6 will present a summary and a discussion on future work.

2. DATA AND CLOUD CLUSTER REQUIREMENTS

There is no one single definition of what differentiates a tropical cloud cluster from other types of convection. Lee's (1989) study of tropical cyclogenesis in the Western North Pacific defined a cloud cluster using the following criteria:

1. Independent of other systems
2. At least 4° in diameter; not elongated
3. Must persist for at least 24 hours

* *Corresponding author address:* Christopher C. Hennon, UNC Asheville, Dept. of Atmospheric Sciences, CPO #2450, Asheville, NC 28804; e-mail: chennon@unca.edu

These criteria were adopted for Hennon and Hobgood (2003), and we adopt them here with the following adjustments. First, we lower the size requirement to 2° to capture more potential organized systems. Second, all cloud clusters must be centered over water. Third, we limit our domain to latitudes between 2.5°N and 35°N in the Atlantic basin.

Cloud clusters are found through a testing of the brightness temperature (T_b) data from geostationary satellites. The data were obtained from the HURSAT-Basin dataset developed at the National Climatic Data Center (Knapp 2008a, 2008b). The data are derived from the International Satellite Cloud Climatology Project (ISCCP). Each basin-wide image is available in 3-hour increments at 8 km horizontal resolution. For this study, we use 6-hour increments between images.

3. METHODOLOGY

The algorithm is currently programmed in the Interactive Data Language (IDL). HURSAT Basin T_b data are read into IDL from a netCDF format and sent through a number of testing procedures. The main steps are summarized in Fig. 1. First, all individual pixels are checked and those that do not have a T_b of 230 K or less are eliminated from consideration. This threshold is somewhat arbitrary, although it is well within the range of values seen in deep tropical convection. We do not expect the algorithm to be sensitive to the choice of the deep convection threshold, but formal testing has not yet been completed.

A land/sea mask is then applied to the remaining pixels. All pixels over land are removed. Proceeding forward, the third step eliminates groups of pixels that are irregular in shape by checking concentrations of deep convection surrounding each pixel. Each pixel must have at least 80% of its neighbors (within 1°) passing the T_b threshold. This in effect eliminates pixels that are a part of elongated or other irregularly shaped and sized convective areas. This step is also used to determine whether the remaining clusters of pixels meet the size requirement (at least 2° in diameter) to be considered a cloud cluster.

The final test is for independence. The single pixel surrounded by the most convective pixels is identified

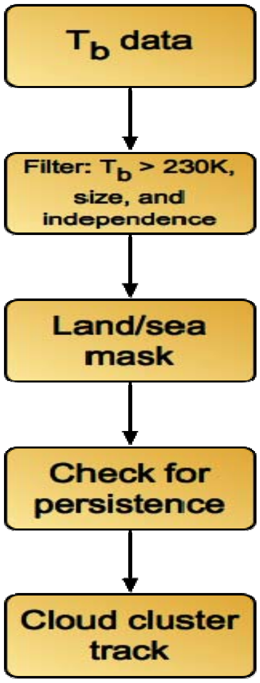

Figure 1. Flow chart illustrating the important steps used by the cloud cluster algorithm.

as a “cloud cluster”. The other remaining pixels are then checked to determine if they are far enough away from the first cloud cluster to be considered an independent system. Obviously, pixels immediately surrounding the cloud cluster are considered part of that cluster and not a separate entity. We use a threshold of 1200 km to check for independence.

The final step is to determine if the newly identified cloud clusters are persistent features or if they are new systems. Each cloud cluster that is identified in each 6-hour period is recorded in a “track file”. This file contains the date/time stamp, latitude, and longitude of the cluster center. Each current track file is checked against the newly identified clusters from the current image. If the new clusters are within a reasonable distance, then they are added on to the previous track. If they are too far away from any previous system, then they are considered newly developed. An allowance is made for clusters whose convection experiences a brief (<12 hour) weakening – they are added to their original track.

At the conclusion of the time period of interest (e.g. a hurricane season from 1 June through 30 November), all tracks are checked to determine the length in hours. Only those that lasted at least 24 hours are retained in the cloud cluster database.

4. RESULTS: 2000 ATLANTIC SEASON

We tested the algorithm on the 2000 Atlantic hurricane season. Cloud clusters were identified and tracked from 1 June through 30 November. Figure 2 shows an example of the T_b field of a cloud cluster. This particular system was the 30th identified cluster of the 2000 season. The track of the cloud cluster is shown in Figure 3. Note that the track tends to jump rather erratically in spots. This was expected, as it is well known that convective maxima in cloud clusters tend to generate in one area and then dissipate and regenerate close by. Since the algorithm is tracking the convection, it picks up on the jumps that are experienced. It should be noted that the algorithm cannot distinguish between cloud clusters and mature tropical systems (tropical depressions, tropical storms, and hurricanes). Thus, all such systems are included in the results presented here. They will be removed from the database at a later time.

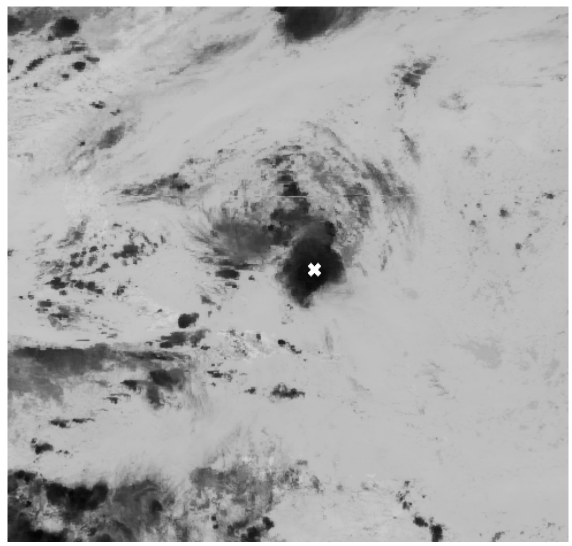

Figure 2. Cloud cluster #30 (2000). Darker areas correspond to colder T_b values. The ‘X’ marks the center.

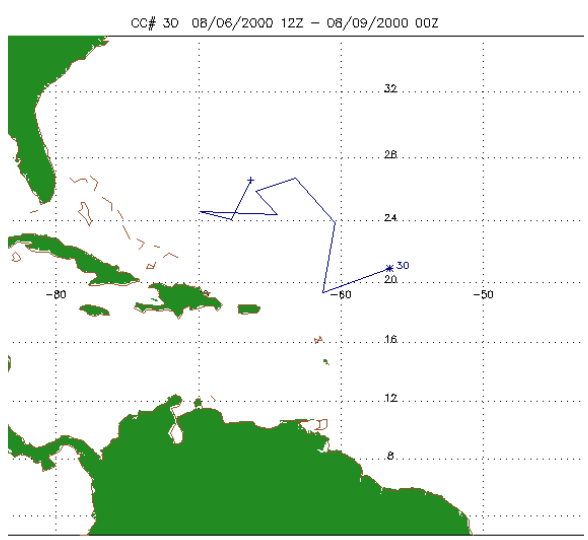

Figure 3. Track of cloud cluster #30 (2000).

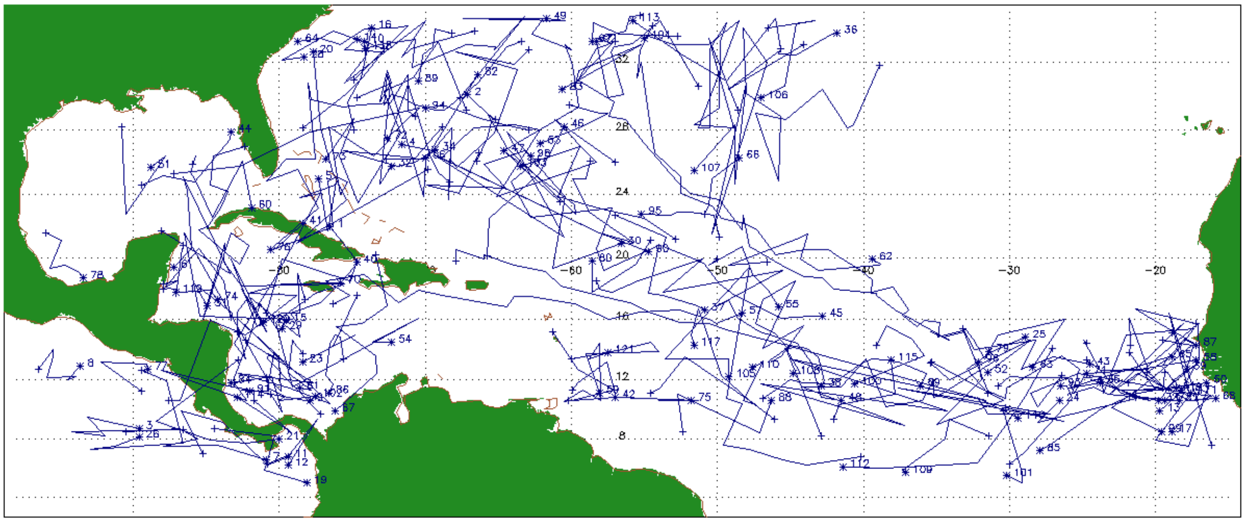

Figure 4. Tracks of all cloud clusters that formed and/or tracked across the Atlantic basin during the 2000 hurricane season (1 June – 30 November).

4.1 ***Season Activity***

Figure 4 shows all of the identified cloud cluster tracks during the 2000 season. The highest concentration of tracks is found in areas where tropical cyclogenesis most commonly occurs: southwest Caribbean, off the east coast of the United States into the central Atlantic, and off the coast of Africa along the climatological easterly wave tracks. There is a curious lack of activity in the Gulf of Mexico. This may or may not be real – it will be investigated further. It is also interesting to note the lack of activity in the southeastern Caribbean Sea centered at 14°N, 65°W. This region has been identified in past studies (e.g. Hennon and Hobgood 2003) as an area where easterly wave convection typically dissipates. Tropical cyclogenesis is also very rare in this part of the basin.

In total, 121 cloud clusters were identified during the 2000 Atlantic hurricane season. This compares quite closely to the number of clusters identified manually in Hennon and Hobgood (2003) – they found 110 over the same period.

4.2 ***Intraseasonal Activity***

The cloud cluster activity identified with the algorithm matches known intraseasonal oscillations in convective activity across the Atlantic basin. Fig. 5 is a bar chart showing the number of identified cloud clusters by month as well as the number that developed into at least tropical depressions. As expected, activity peaks in September and is at a minimum in June, the least thermodynamically

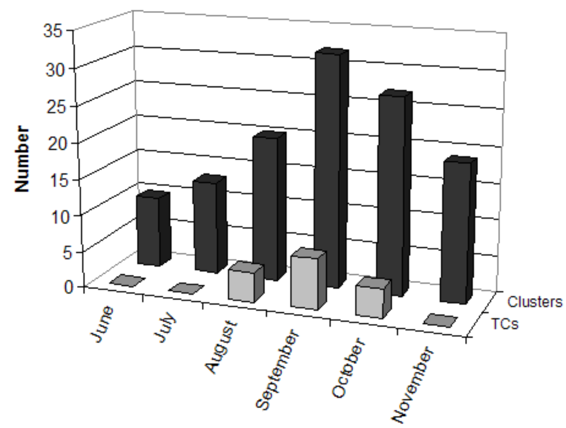

Figure 5. Number of identified cloud clusters (dark) and developing systems (light) by month during the 2000 Atlantic season.

favorable month of the season. Later in the season, intrusions by the westerlies limit TC development, although cloud cluster activity remains high.

Fig. 6 shows the cloud cluster tracks for June 2000. During this early phase of the hurricane season, vigorous activity is climatologically confined to the western portions of the basin. Sea surface temperatures have not yet warmed enough in the east to support cloud cluster activity. This is consistent with the results shown in Fig. 6. Note that only 11 cloud clusters were identified during the entire month, and all occur in the western Atlantic or eastern Pacific basins.

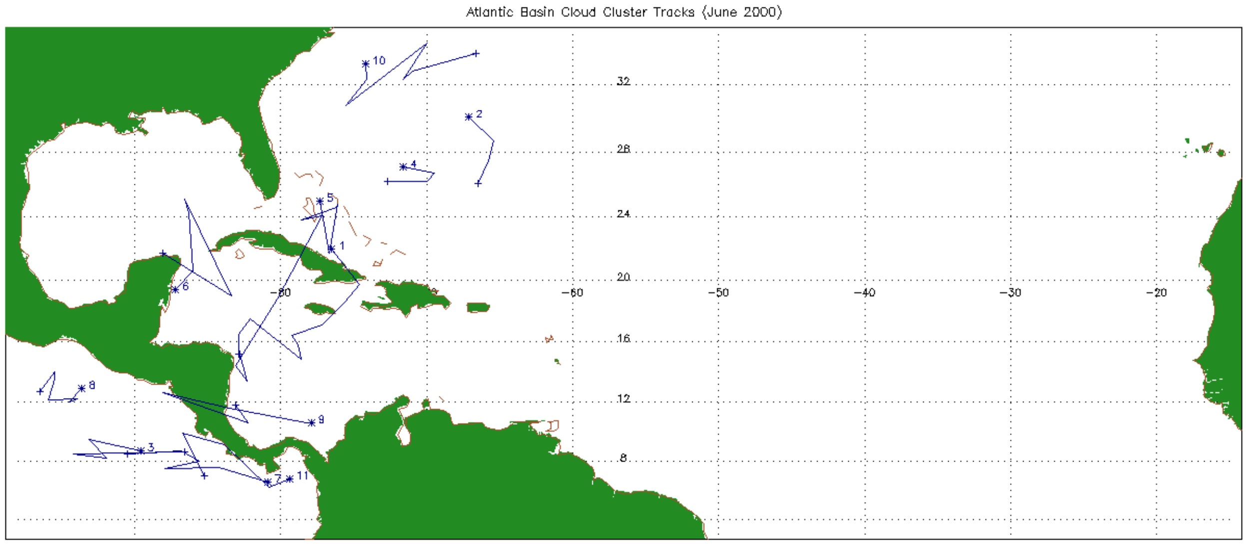

Figure 6. Tracks of cloud clusters that developed during June 2000.

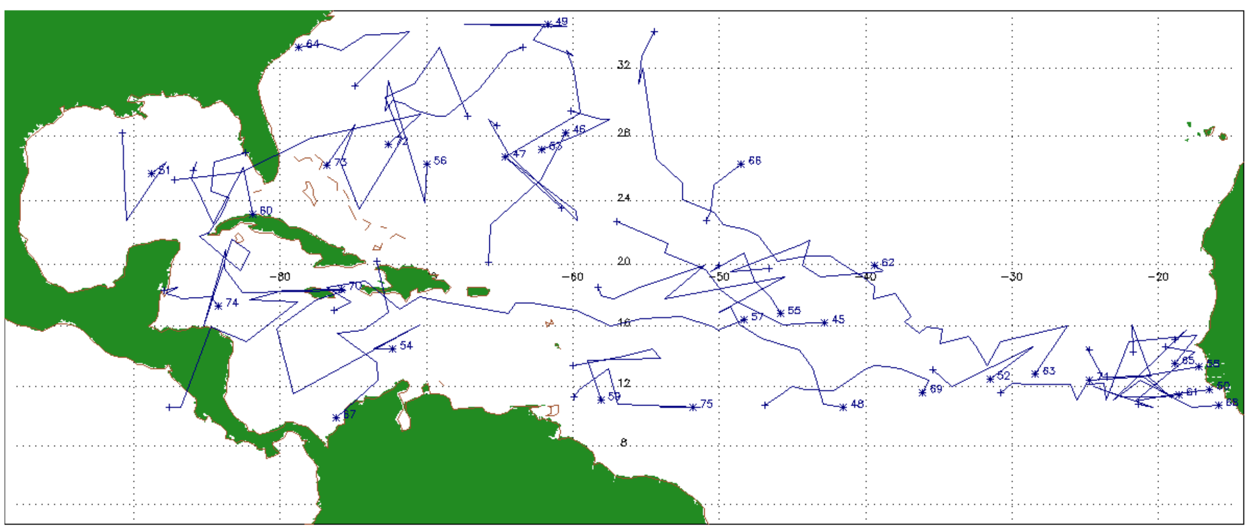

Figure 7. As in Fig. 6 except for September 2000.

September is the climatological peak of the Atlantic season with development occurring across the entire basin, including the far eastern portions off the African coast. This is reflected in the identified cloud cluster activity, as shown in Fig. 7. In total, 32 cloud clusters were tracked during the month.

5. APPLICATIONS

The work described here has several potential applications, both operationally and in the research community. There have been several studies in the past that have used cloud clusters to identify factors that favor tropical cyclogenesis. Each of those studies used a limited dataset of clusters (usually a few years, in one basin) that were developed through manual identification techniques. This algorithm will provide a long (~30 years) time series of *global* cloud clusters that can be applied to tropical cyclogenesis studies.

As subsequent years of activity are cataloged, the long time series will also make it possible to detect changes in cloud cluster activity with time. Since cloud clusters are necessary precursors for TC development, it would be interesting to know how they are changing in a warming world. In a recent paper on changes in TC intensity and frequency in an enhanced greenhouse gas climate, Emanuel et al. (2008) note that changes in the amplitude and frequency of cloud clusters are not considered in their simulations; but that finite-amplitude instability dictates that they should be an important factor.

The algorithm described here can also be run in an operational setting. Areas of concern ("Invests") could be readily identified, especially if combined with other data such as global analysis fields or other satellite information.

6. SUMMARY AND FUTURE WORK

A simple algorithm for identifying tropical cloud clusters is described. The algorithm searches for cloud clusters in the HURSAT Basin IR imagery by identifying patterns in the T_b data. The 2000 Atlantic hurricane season produced 121 cloud clusters that persisted for at least 24 hours. Of those, 19 developed into a tropical system.

A cloud cluster database spanning over 30 years could be applied to several areas of research, including: intraseasonal and interannual studies, impacts of a warming world on cloud cluster activity, and case studies for use in tropical cyclogenesis research.

We have a number of areas for future development of the algorithm. After changes to improve the speed of the algorithm, the first priority will be the completion of the data record in the Atlantic. We will then expand the dataset to include all ocean basins. Other enhancements to the algorithm core will be made to more smartly identify cloud clusters and their tracks.

7. Acknowledgments

Chip Helms' work was supported by a grant from the Undergraduate Research Program Advisory Council at UNC Asheville.

8. References

Emanuel, K., R. Sundararajan, and J. Williams, 2008: Hurricanes and global warming. *Bull. Amer. Meteor. Soc.,* **89**, 347-367.

Hennon, C.C., and J.S. Hobgood, 2003: Forecasting tropical cyclogenesis over the Atlantic basin using large-scale data. *Mon. Wea. Rev.,* **131**, 2927-2940.

Knapp, K.R., 2008a: Hurricane Satellite (HURSAT) data sets: Low-Earth orbit infrared and microwave data. *28th AMS Conference on Hurricanes and Tropical Meteorology,* Orlando, FL.

Knapp, K.R., 2008b:Calibration assessment of ISCCP geostationary infrared observations using HIRS. *J. Atmos. Ocean. Tech.*, **25**, 183-195.

Lee, C.S., 1989: Observational analysis of tropical cyclogenesis in the Western North Pacific. Part I: Structural evolution of cloud clusters. *J. Atmos. Sci.,* **46**, 2580-2598.