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# INVESTIGATION INTO ENVIRONMENTAL CONDITIONS FOR STORM INITIATION OVER THE OCEAN USING SATELLITE DATA

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## 1. INTRODUCTION

The importance of short term storm initiation forecasts has been recognized by the aviation community for a long time; however, the skill to correctly forecast storm initiation remains poor, even over land where dense, surface-based observational networks are available. Over the ocean, storm initiation forecasts become even more challenging, owing to the lack of surface-based observational networks such as surface mesonets or the WSR-88D radar network. Recognizing the difficulty that the lack of surface-based observations causes, this study strives to utilize satellite-derived environmental parameters to identify favorable conditions for oceanic storm initiation. The environmental fields being evaluated include: 1) Advanced Microwave Scanning Radiometer (AMSR-E) sea surface temperature (SST), 2) convergence/divergence derived from QuikSCAT near-surface winds, 3) Convective Available Potential Energy (CAPE), Convection Inhibition (CIN) and the atmospheric relative humidity as derived from oceanic soundings determined from vertical profiles taken by the Atmospheric Infrared Sounder (AIRS) in combination with the Advanced Microwave Sounding Unit (AMSU) as well as from the National Center for Environmental Prediction (NCEP) Global Forecasting System (GFS) numerical model analysis.

Creating oceanic convection initiation nowcasts in conjunction with extrapolation of existing storms gives the oceanic aviation community, dispatchers and forecasters valued information for enroute planning and strategic avoidance of potentially hazardous convection.

A simple scatter plot approach is employed in this preliminary study to investigate the environmental conditions favorable for convection initiation (CI) over the ocean. A brief description of various datasets and the methodology for data analysis are given in section 2. Section 3 discusses the implications of various scatter plot results. A summary and future work outline is given in section 4.

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## 2. DATASETS AND METHODOLOGY

The domain for this study is the Gulf of Mexico (see Fig.1 for domain size). The time period spans Aug 12 – 23, 2007. During this time period, convective activity was abundant through both initiation of new storms and through the advection of existing storms. A brief description of each dataset used in this study is as follows.

(a) Convective Diagnosis Oceanic and Convective Nowcasting Oceanic

The Convective Diagnosis Oceanic (CDO) product is derived from a fuzzy logic, data fusion technique and is used to detect the presence of mature convection in ocean/remote regions using satellite imagery (Kessinger et al. 2006). To accomplish this, outputs from three independent, satellite-based convection detection algorithms are combined using a fuzzy logic algorithm to create the CDO output field. The CDO interest values range from zero (no convection) to four (convection) with a typical threshold of about 2.0 used to define convective activity. Next, the Convective Nowcasting Oceanic (CNO) system extrapolates the CDO field using an object-tracking methodology (Dixon and Wiener, 1993) to produce 1-hr and 2-hr nowcasts of convection location.

For details of CDO and the CNO system, the reader is referred to Kessinger et al. (2008). An example of CDO compared with the cloud top height product is shown in Fig. 1, where Hurricane Dean was at the middle of our analysis domain; the hurricane was well-captured by the CDO field.

(b) AMSR-E Sea Surface Temperature (SST)

The AMSR-E sea surface temperature (SST) covering the Gulf of Mexico is provided by Naval Research Laboratory (NRL) and has been quality-controlled by removing precipitation and land mass contamination. This dataset could be used to verify

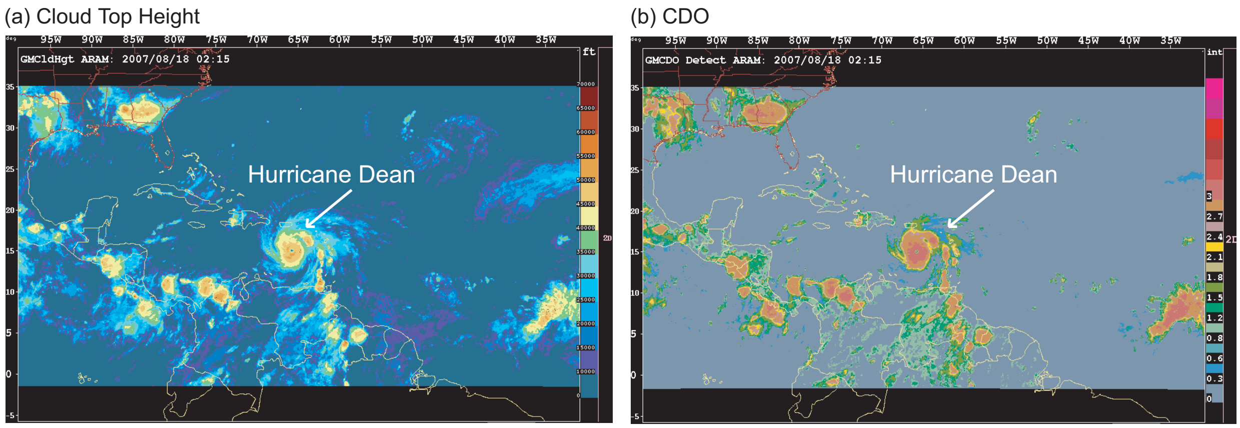


*Fig. 1. An example of a) could top height, and b) CDO at 0215 UTC on 18 August 2007 showing the Gulf of Mexico domain used in this study. Hurricane Dean is right at the middle of the domain.*

a well-known fact that tropical deep convection tends to form over warmer water owing to the abundance of moisture in that region.

(c) QuikSCAT Near-surface Winds

The QuikSCAT near-surface winds, as provided by NRL, contain invaluable information about the nature of the near-surface wind field over the ocean. No other instruments can provide this information at such a high spatial resolution. The QuikSCAT winds have been quality-controlled by utilizing the rain flag for removal of precipitation contaminated winds. Derived fields such as divergence and vertical vorticity are calculated and smoothed for the purpose of this study.

(d) Temperature and Moisture Soundings from AIRS/AMSU

Atmospheric Infrared Sounder (AIRS) and Advanced Microwave Sounding Unit (AMSU) can provide temperature/moisture vertical profiles when the sounder is not blocked by deep clouds. Various convective parameters such as Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN) are derived from these data for various sounding levels. The CAPE/CIN from 925 mb is used in this study.

(e) Global Forecasting System (GFS) Model Analysis

In addition to various satellite-based observational datasets described above, the GFS model analysis is also used to identify favorable environmental conditions for CI over the ocean. Since model analysis data provides a self-consistent frame work for various convective indicators, it will be interesting to compare the same parameters derived from GFS versus that from satellite-based observational data. Considering GFS already assimilates many of the satellite datasets, consistency between the two should be expected.

An interest field derived from GFS data which will be used in this study is the frontal likelihood field. The frontal likelihood field is utilized as a tool to indicate where fronts are located. Details of how the frontal likelihood field is derived can be found in Megenhardt et al. (2004) and in Kessinger et al. (2008).

(f) Methodology

The purpose of this study is to identify the favorable environmental conditions for convection initiation (CI) over the ocean. To achieve this goal, a simple scatter plot approach is employed, to determine if the convective parameters under investigation serve as a good precursor of CI. Namely, we are plotting new convective storms, which are represented by their CDO values over 2.0, against various convective parameters such as the AIRS/AMSU CAPE field. The convective parameters are straight-forward to compute, as described in the earlier part of this section; defining when new storms have formed is the more tricky part. Fortunately, within the Convective Nowcasting Oceanic (CNO; Kessinger et al. 2008) system, the Thunderstorm Identification, Tracking and Nowcasting (TITAN; Dixon and Wiener 1993) algorithm is used to extrapolate/forecast the CDO storm polygons. During the process of tracking the CDO storm polygons, TITAN can identify new storms by

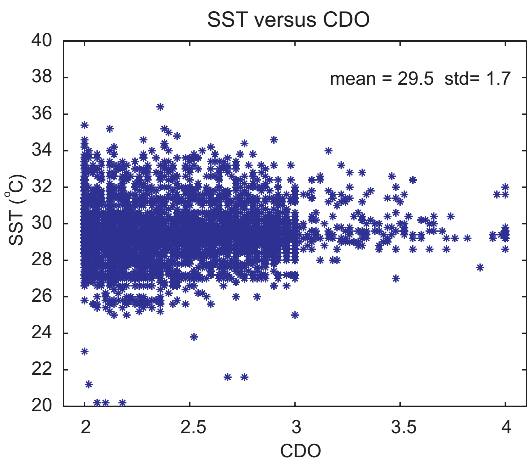


*Fig. 2. Scatter plot of AMSR-E SST versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

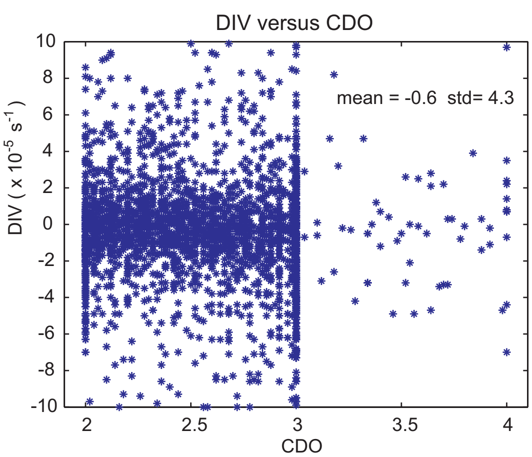


*Fig. 3. Scatter plot of QuikSCAT near-surface divergence versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

their first occurrence. Using these TITAN-identified new storm polygons, the CDO field can be thresholded to remove all storms except for the new ones. Then, scatter plots of new storm CDO versus various environmental convective parameters can be easily created, as shown in the next section.

## 3. Analyses of Various Scatter Plots

### (a) AMSR-E SST

Although it is a well-know fact that new storms tend to form over warm water in the ocean, it would be interesting to verify it and know the distribution of SST for newly initiated storms in the Gulf of Mexico. Fig-

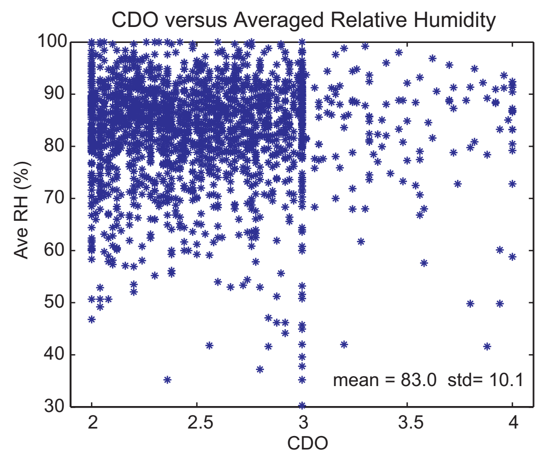


*Fig. 4. Scatter plot of averaged relative humidity versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

ure 2 shows a scatter plot of SST versus CDO associated with new storms for the Gulf of Mexico domain during August 12-23, 2007. Notice that most new storms formed where SST is greater than 26.0 $^{o}$C. The approximate normal distribution of SST has a mean of 29.5 $^{o}$C and a standard deviation of 1.7 $^{o}$C. Since summer and warm SST conditions are prevalent during the period of interest, the high SST average values associated with new storms is an expected result.

### (b) QuikSCAT Near-surface Divergence

Surface convergence associated with surface boundaries has long been recognized as a precursor of CI over the land. Over the ocean, surface-based CI studies have been lagging due to lack of observational data. Thanks to QuikSCAT near–surface wind measurements, the relation between surface convergence and CI over the ocean can be studied. A scatter plot of QuikSCAT-derived near-surface divergence versus CDO of newly initiated storms is shown in Fig. 3. It was found that new storms were associated with both near-surface convergence and divergence, with a slight bias toward convergence, as indicated by the mean divergence associated with all the new storms being -0.6 x $10^{-5}$ $s^{-1}$.

### (c) Averaged Relative Humidity

Moisture content in the atmosphere is one of the most crucial ingredients for CI, as demonstrated by numerous observational and numerical modeling studies. Figure 4 shows a scatter plot of averaged

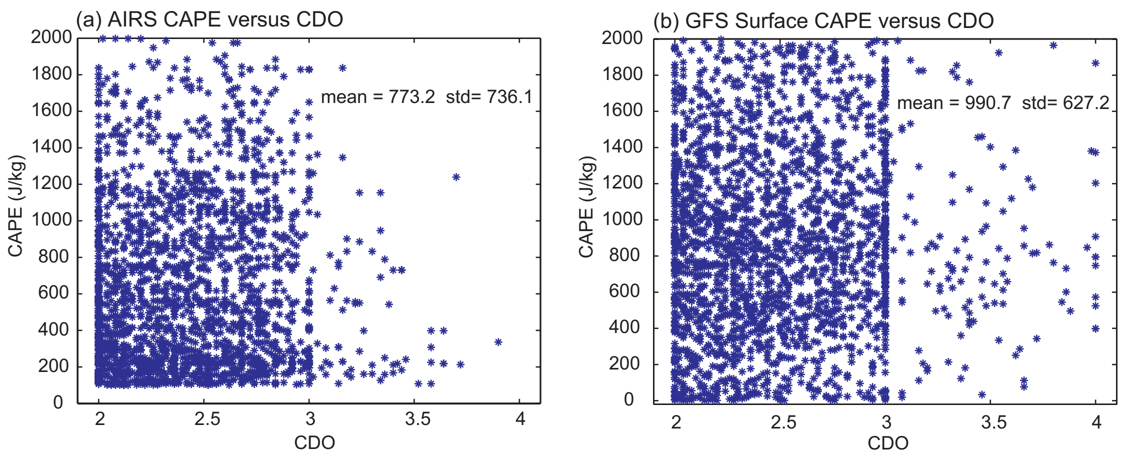


*Fig. 5. Scatter plot of a) AIRS/AMSU CAPE for 925 mb, and b) GFS surface CAPE versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

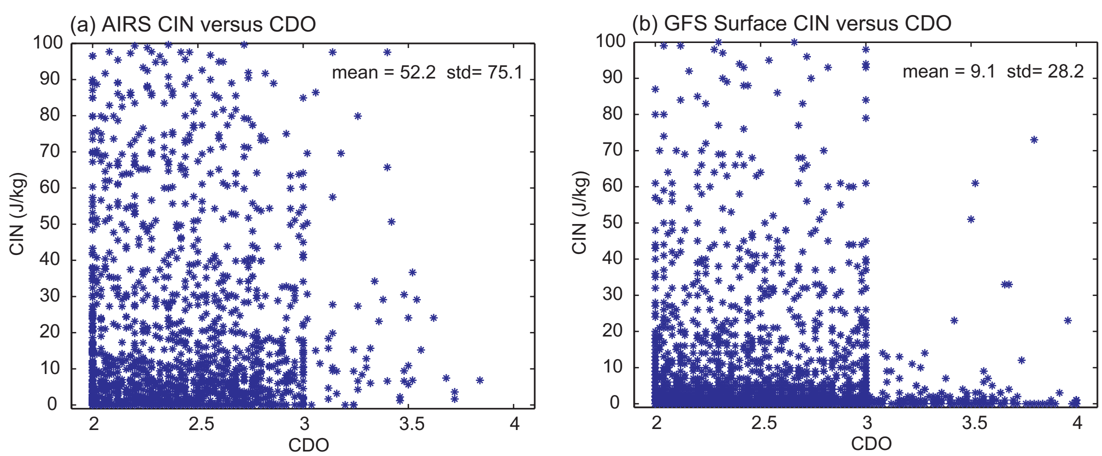


*Fig. 6. Scatter plot of a) AIRS/AMSU CIN for 925 mb, and b) GFS surface CIN versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

relative humidity above the top of boundary layer from GFS analysis versus CDOs of new storms. Clearly Fig. 4 illustrated that new storms tends to form in an environment rich in moisture; and rarely new storms can form when averaged relative humidity was less than 50%. The mean of all averaged relative humidity associated with CI is ~83%, with a standard deviation of ~10%.

(d) AIRS/AMSU and GFS CAPE/CIN

AIRS/AMSU provides vertical profile of atmospheric temperature and humidity, that can be used to calculate standard convective parameters such as CAPE/CIN. For comparison, GFS surfaced-based CAPE and CIN fields are also obtained. The CAPE/CIN versus CDO scatter plots from both AIRS/AMSU and GFS are shown in Figs. 5 and 6, respectively. It is not surprising that both CAPE fields from AIRS/AMSU and GFS demonstrate no clustering in their distributions, which is reinforced by the large standard deviation in Fig. 5 a and b. This results suggests that new storm formation can occur over a wide range of positive CAPE values. Considering the AIRS/AMSU CAPE is for air parcels at 925 mb while the GFS CAPE is surface-based, the mean value of CAPE from AIRS/AMSU and GFS are fairly similar.

CIN fields from both AIRS/AMSU and GFS show clear trends that new storms tend to form in low/zero CIN regions, although high CIN values do not exclude CI. Convection initiation is the tug of war be-

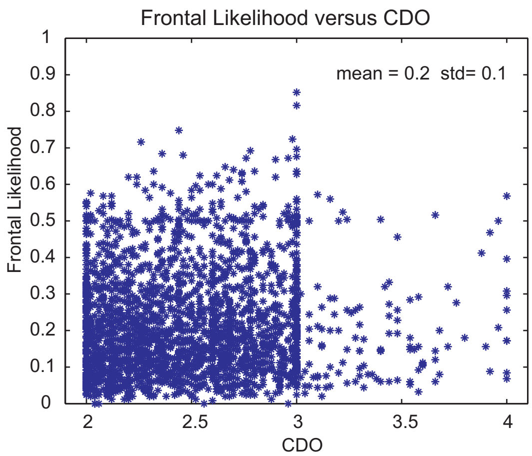


*Fig. 7. Scatter plot GFS-derived frontal likelihood interest field versus CDO associated with new storms for the Gulf of Mexico domain from Aug 12-23, 2007.*

tween two opposite forces, one is the upward forcing, and the other is the cap which needs to be penetrated before new storms can form. When forcing is strong, large CIN can still be destroyed.

(e) Frontal Likelihood Field

One method to find out if frontal forcing plays an important role in storm initiation is to look at the scatter plot of frontal likelihood field versus CDO of new storms. Frontal likelihood field is an interest field derived from GFS model data and is designed to indicate the position of fronts. High frontal likelihood interest values correspond to front locations (Megenhardt et al. 2004). A scatter plot of frontal likelihood interests versus CDO of new storms is shown in Fig. 7. It was found that there was no clear trend of frontal likelihood versus CDO. This result suggests that frontal forcing might not be the sole important forcing mechanism in new storm formation over the Gulf of Mexico in August 2007.

## 4. Summary and Future work

In this preliminary study, a simple scatter plot approach is employed to study the relation between various environmental conditions and new storm formation over the Gulf of Mexico domain for a relatively short period in August 2007. Various satellite-based convective parameters were derived, which include 1) AMSR-E SST, 2) QuikSCAT divergence, 3) AIRS/AMSU CAPE/CIN, 4) GFS surface CAPE/CIN, and 5) GFS-derived averaged relative humidity and frontal likelihood field. It was found that CIN and averaged relative humidity were potentially good discriminators of atmospheric conditions needed for convection initiation to occur, while CAPE and frontal likelihood field might not be good discrminators. Future work will expand this work to other environmental parameters and other domains and over longer time periods, and hopefully, consistent results with this paper will be obtained.

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