

#### **Analysis of convective Overshooting Tops (OTs) within and near the pouch**

PREDICT Science Workshop

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IR image and Overshooting Tops for 20090810 at 0615 UTC



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#### Objective OT Detection Algorithm (from Bedka et al. (2010), adapted to the tropics)

Find relative minima in the 4 km resolution 11 µm brightness temperature (BT) field colder than 215 K.

Compute the mean BT of the surrounding anvil cloud at an ~8 km radius in 16 directions.

At least 9 surrounding pixels must be colder than 225 K to be identified in the anvil. (Note the color scale difference)

Cloud pixel minima 9 K colder than the surrounding anvil are flagged as overshooting. Pixels within 6 km and colder than the OT BT plus 50% of the OT-anvil difference are also flagged as overshooting.



Images courtesy of Kristopher Bedka, Science Systems and Applications, Inc.

Brightness Temperature (K)							
320	200	280	260	240	220	200	180
320	300	280	200	240	220	200	100



### Overview

Genesis

Rapid Intensification





# Applications to TC Genesis: Vortical Hot Tower Proxy

- "Vortical" Hot Towers (VHTs) are vigorous convection, hypothesized to be associated with TC genesis (i.e. Montgomery et al.)
- Cross-section from developing TS Jangmi (2008) from an airborne ELectra DOppler RAdar (ELDORA) between 2310 and 2320 UTC on 24 Sept 2008 (courtesy Lt. Colonel Neil Sanger, United States Air Force).
- No OT algorithm detection of the VHT from the MTSAT-1R scan at 2330 UTC.
  - VHT could be identified when the OT constraints were relaxed to 6.5 K colder than surroundings → VHT was potentially decaying
  - ~30 minutes had elapsed between the ELDORA views and MTSAT-1R image
    - OTs lifetime as short as 10 minutes.
  - Better than 1 hour temporal resolution could have potentially detected this VHT at the 9 K OT-Anvil BT difference.





#### **Can Trends in OTs Predict TC Genesis?**

#### **Developmental Data Sets**

- Cases from the 2009 and 2010 Atlantic hurricane seasons
- Pouches tracked by Mark Boothe (Naval Postgrad School) using 4 different global models:
  - UKMET, GFS, NOGAPS, ECMWF
  - Model consensus tracks also provided for 2010.
- OTs detected within a 200 km radius of pouch center using IR images with 30-minute temporal sampling:
  - GOES-12/13 westward of 40° W, 4 km spatial resolution
  - METEOSAT-9 eastward of 40° W, 3 km spatial resolution
- OTs along the model tracks are averaged over 2 hour time frames.
- No accounting for the diurnal signal necessary.



### Can Trends in OTs Predict TC Genesis?

Comparison between OTs and the vertical component of vorticity

- Case requirements for consideration include:
  - 1)Pouch having a UKMET-analyzed vertical vorticity component observed at 700 hPa when crossing 30° W, or a forecast from the day prior to crossing 30° W
    - UKMET provide greatest number of pouches to analyze.

2)Not already undergoing genesis east of 30°W

 46.6% of the 58 pouches from 2009-2010 sample satisfy the criteria at 30° W



### Can Trends in OTs Predict TC Genesis?

- Moderate correlation (CC=0.58) between the number of OTs/day and the strength of the vertical vorticity component at 30° W
- 77% of pouches with
   ≥ 35 OTs/day
   eventually underwent
   genesis (and 2 of the
   false alarm cases
   were under high
   VWS)
- 0% of the pouches with less than 35 OTs/day developed in the Atlantic.





# Can OTs help predict IF a pouch will develop?

Criteria for forecast genesis (empirically derived from 31 cases in 2009): an average of at least 4 OTs/scan over a 2-hour period

Verification: Genesis at any time subsequent to the forecast, based on NHC Best Track



Independent test on cases in 2010

Commonly-used measure of forecast accuracy is the Pierce Skill Score (PSS):

Probability of Detection – Probability of False Detection



#### Can varying the minimum OT BT better predict **IF** a pouch will develop?

- 200 K: Approximately 16 km above ground level
  - height used by Montgomery and Farrell (1993) and Simpson et al. (1998).
- 205 K: Approximately 14.5 km above ground level
  - Average equilibrium level calculated using the NCEP sounding and surface  $\theta_e$  from Liu and Zipser (2005).
- 225 K with an anvil BT colder than 235 K: Approximately 11 km above ground level
  - Analyzed because the optimal forecast peaked with 215 K OT BTs, the warmest BT analyzed.



#### Finding: 215 K is the optimal OT minimum BT for *IF* a pouch will develop.



#### Comparison to the NHC probability of development product

- During 2009-2010, 7 out of 36 (19.4%) NHC "high chance of formation" (>50%) outlook frames did not verify.
  - 4 of these had available GFS and UKMET pouch tracks
  - 2 of these 4 were not forecast to develop based on the 4 OTs/scan over a 2 hour period OT analysis.
- In 2010, NHC genesis forecasts could not distinguish between 30% and 70% probability of genesis (PoG).
  - The results above suggest the OT product could improve the verification percentage of the NHC PoG forecasts by an additional 5-10%.





### Can OTs Help Predict WHEN a pouch will develop?

Forecast only valid for TCs developing west of 25° W and exceeding tropical depression strength

- A moderate correlation exists between the magnitude of the first detected 2-hour OT/scan average > 4.25 and the time until TC genesis
- A linear regression yields an average genesis forecast error of 1.2 days (TS Claudette was excluded from the regression as its "prospects for becoming a tropical cyclone were never stated to be good" (Pasch 2010))





# **Forecast Modification**

At least two 4.25 OTs/scan thresholds must be reached.

Additional thresholds counted if no threshold is exceeded in the previous 0.5 days.

If at least two occur, genesis is forecasted 1.5 days earlier, assuming genesis not forecasted earlier than 24 hours in the past.

If two do not occur by the originally forecasted genesis, genesis is forecasted 1.5 days later.

- Forecast error reduced to 0.75 days
- 81% of correctly forecasted genesis cases develop within <u>+</u> 24 hours of forecast.
- 33% when accounting for all 27 cases forecasted to undergo genesis.
- 63% of the modified pouch forecasts developed within <u>+</u> 24 hours of forecast.



Positive (negative) values indicate where the forecasted time of genesis preceded (followed) actual genesis



### Case Study: Hurricane Karl (2010)

"The genesis of Karl was not forecast particularly well." (Stewart 2010)





#### OT Product as a Potential Predictor in the CIRA Tropical Cyclone Formation Probability (TCFP) Model

- TCFP estimates the probability of genesis within a 5° of latitude by 5° of longitude region based on 10 input parameters
- Experiments with OT averages every 1, 3, 6, 12 and 24 hours prior to the synoptic times within radii of 200, 300, 400 and 500 km
- No combination produced a higher TCFP Brier Skill Score (BSS) than the TCFP BSS without the OTs.
  - BSS decreases by 4.8%
  - Probability of genesis within 24 hours decreases with the addition of the OT information for genesis events.
- However, the OT predictor was given the most weight of any variable by the model, and the Relative Operating Characteristic Skill Score (RSS) increased by 7.1%
  - Pits the POD against the POFD using a set of increasing probability thresholds

Suggests OTs may positively contribute to a multivariate TC genesis prediction scheme, but further study is needed



# **Genesis:** Conclusions

- OTs appear to be a good proxy for the stronger part of the VHT spectrum.
- An excellent relationship exists between pouches exceeding 35 OTs/day and eventual TC genesis.
- 63% of tracked 2009 and 2010 Atlantic pouches exceeding a threshold of at least 4 OTs/scan along either the UKMET or GFS track eventually underwent TC genesis.
- Genesis time can be reasonably forecasted (less than 1day mean forecast error) based on a modified relationship between the value of the first exceeded OT/scan threshold and the number of days until genesis.



# **Genesis:** Future Work

- Will continue OT analysis in 2011 and test a threshold of 5 OTs/scan (more accurate in a more recent dependent test of 2009-2010 data).
- Potential for better performance in the TCPF model should the forecast period be extended to 48 hours.
  - Twice as many maximum OTs/scan are observed within 48 hours of genesis than 24 hours.
  - Research suggests 1-2 days can often elapse between increase in VHTs and genesis.
- The OT product will be demonstrated in real time to NHC during the 2011 Atlantic hurricane season as part of the GOES Proving Ground project.



### Can Trends in OTs Help Predict TC Rapid Intensification (RI)

Recent research suggests VHTs play an important role in TC intensification.

Many theories of RI can be tied to an increase in vigorous TC core convection (and by proxy, OTs).

- TCs undergoing RI experience greater local sea surface temperature and ocean heat content then non-RI TCs.
  - Most important predictors in the current Rapid Intensification Index (RII)
  - Convection in regions with strong ascending large-scale motion increases monotonically with SST
- Vertical wind shear is another important indicator of intensification changes
  - Second most important predictor in the RII
  - Asymmetric deep convection (and perhaps OTs) can indicate a sheared TC and inhibited RI.



#### OT RI Index independent comparison to the RII

Forecast from 1995-2008: exceeded threshold of **3 OTs/scan** with a BT less than or equal to 215 K within a **200 km** disk of the TC center for 3 hours.





Forecast from 1995-2008: exceeded threshold of 4.5 OTs/scan with a BT less than or equal to 215 K within a 300 km disk of the TC center for 3 hours.

Forecast from 1995-2008: exceeded threshold of **4 OTs/scan** with a BT less than or equal to 215 K within a **200 km** disk of the TC center for 3 hours.





#### Potential Addition to a Probabilistic Forecast Model

Logistic Regression: Discriminative model where fitted coefficients for the predictors are obtained through an iterative least squares approach (See Rozoff and Kossin (2011) for more information)

- Optimal OT predictors:
  - 3-hour average within 50 km
  - 6-hour average within 200 km
- Overall improvement in forecast observed when added to the 7 optimal predictors in Rozoff and Kossin (2011)
  - evident by higher Brier Skill Scores



This increase in forecast skill is in addition to the increase in the Brier Skill Score associated with current RII.



# **RI: Conclusions and Future Work**

#### **Conclusions:**

- Independent test of all 2006-2007 Atlantic TCs shows skill comparable to the RII scheme, except for the 35 kt RI threshold.
- Addition of OTs as a predictor to a logistical regression model slightly increased the BSS at the 25 kt and 35 kt RI thresholds.

#### Future Work:

- OT product will be part of the 2011 NHC GOES-R Proving Ground demo.
- Correlate OT analyses to lightning data, potentially collaborating with scientists at CIRA and the Univ. of Washington.
  - OT data lost during satellite eclipses, which can last from 0-3 hrs.
  - Lightning data could act as a proxy for OTs.