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New Metric for Defining the Time of Extratropical Transition of Tropical Cyclones

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INTRODUCTION

Almost half of all tropical cyclones (TCs) in the Atlantic basin undergo extratropical transition (ET). During an ET event, wind and precipitation fields often expand dramatically, resulting in more widely-felt impacts. While several objective metrics to track and predict ET have been developed, they rely at least partially on internal tropical cyclone structure, for which numerical models show less skill. Further, these metrics fail to account for static stability, which plays a vital role in determining precipitation amounts.

OBJECTIVES

- Develop a coupled dynamic and thermodynamic metric using the Eady moist baroclinic growth rate (EMBGR) to define the time of ET.
- Understand the evolution of the EMBGR when compared to storm precipitation distribution *(left or right of center i.e. L/ROC),* interaction between the mid-latitude trough and tropical system from a vorticity perspective, and the Cyclone Phase Space (CPS).

What is the EMBGR?

$\sigma_{BI} = 0.31\, f\, \frac{\partial \vec{v}}{\partial z}\, N^{-1}$	Measure of baroclincity (EBGR) accounting for vertical wind shear and Brunt-Vaisala frequency, but assumes a dry atmosphere. *Eady (1949) and Hoskins and Valdes (1990)*
$N_m^2 = \frac{g}{T}\left(\frac{dT}{dz} + \Gamma_m\right)$	The Brunt-Vaisala frequency for a moist atmosphere and applicable for situations involving heavy precipitation (e.g. tropical cyclones). *Durran and Klemp (1982)*
$EMBGR = 0.31\, f\, \frac{\partial \vec{v}}{\partial z}\, N_m^{-1}$	Combining the above two terms gives us the EMBGR and is the basis of the ET metric for this research.

EMBGR When Compared to Other ET Metrics

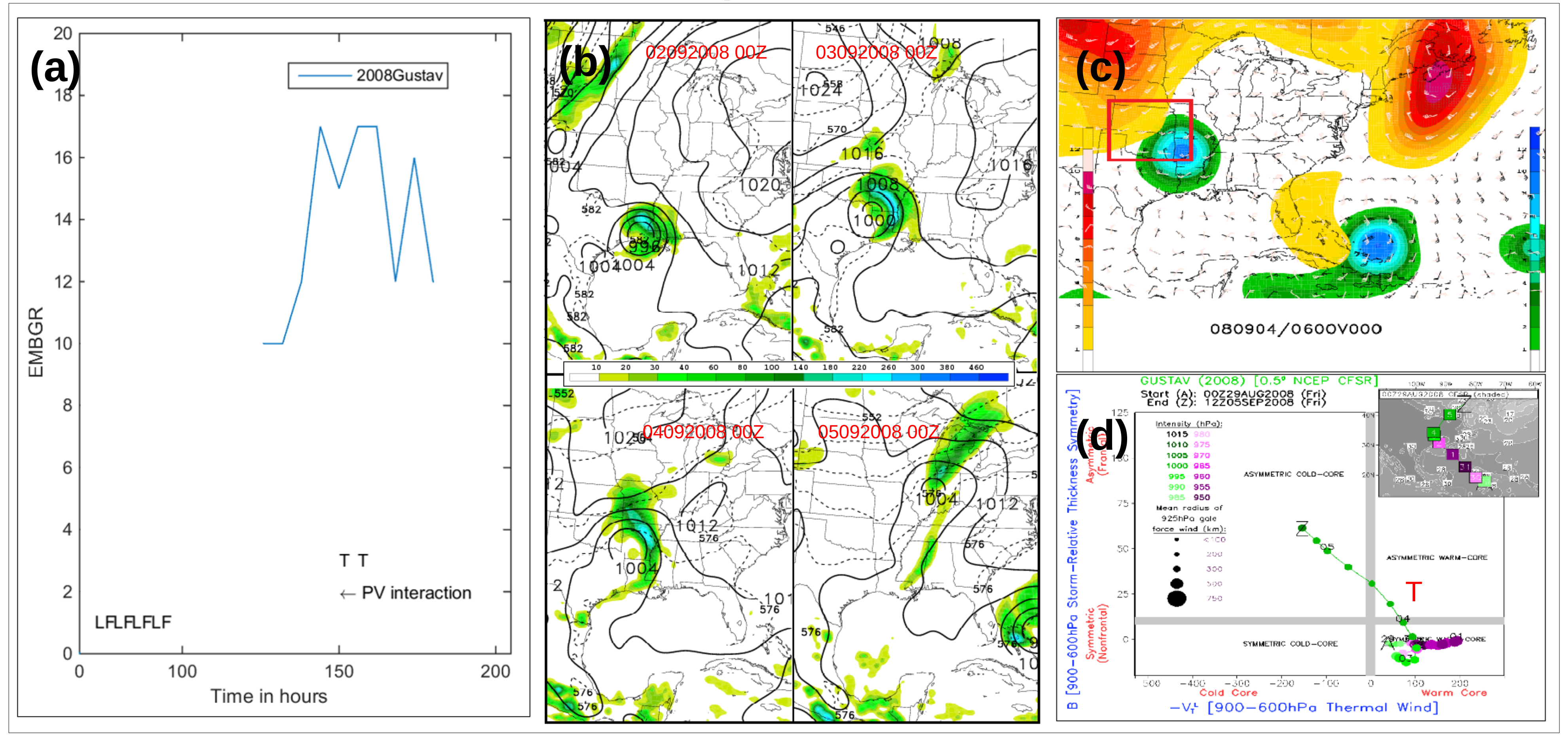

Fig. 1: For Gustav (2008): (a) Evolution of the EMBGR (day^{-1}). Also marked are the time of landfall (LF), PV interaction, warm core asymmetric CPS (T), (b) The shift in precipitation from symmetric or ROC to LOC , (c) PV interaction: Plotted are 200-300 hPa PV (PVU, warm colors), and 850-700 hPa relative vorticity ($\times 10^{-5}\ s^{-1}$, cool colors) , and (d) CPS.

Results, Comments and Future Work

- Most of the 46 cases demonstrated the growth in EMBGR observed prior to ET. This provides a better lead time when compared to CPS or trough interactions (Table 3). Future work will involve expanding the study to all 91 cases.
- EMBGR is a measure of baroclinicity (frontal formation), $\frac{d(EMBGR)}{dt}$ may have a much closer relationship with precipitation distribution than wind field size.
  - ➢ A strong relation could not be drawn between the evolution of EMBGR and area if the outer closed isobar (OCI) after studying 13 cases.
- Systematically demonstrate that the $\frac{d(EMBGR)}{dt}$ predicts LOC precipitation distributions sooner than the TC phase space diagram or other metrics of ET.

FILTERATION PROCESS

- 177 named Atlantic Basin TCs made landfall in the U.S. in between 1979 and 2014.
- 91 of these storms made landfall along the East Coast or Gulf Coast of the United States and moved at least 500 km poleward.
- 79 of these storms interacted with a mid-latitude upper tropospheric trough.
- 46 of these storms entered the asymmetric warm-core region of their respective TC CPS.
  - ➢ This is generally thought of as the start time of ET.

TC and Mid-Tropospheric Trough Interaction		
Before Landfall	Around Landfall (±12 hours)	Post Landfall
15 Storms	*19 Storms*	*12 Storms*

Table 1: A substantial number of TCs interacted with the mid-tropospheric trough around landfall.

PV vs. Phase Space		
PV First TC interacted with a mid-tropospheric trough	Phase Space First TC phase space diagram entered asymmetric warm core	Same Time
30 Storms	*13 Storms*	*3 Storms*
>12 Hours Lead Time	>12 Hours Lead Time	
23 Storms	*7 Storms*	

Table 2: TC interaction with a mid-tropospheric trough is often followed by a TC developing fronts and entering the asymmetric warm core sector of its CPS.

EMBGR VS PV		EMBGR VS Phase Space	
EMBGR First	PV First	EMBGR First	Phase Space First
31	8	35	9

Table 3: An increase in the EMBGR was noted in most cases prior to a mid-tropospheric trough interaction or the TC entering its asymmetric warm core sector of the CPS.

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DATASET

- NCEP Climate Forecast System Reanalysis (CFSR) (Saha et al. 2010).
- Modern, global, high resolution (0.5°) and reliable precipitation.

An Example Case: IRENE (2011)

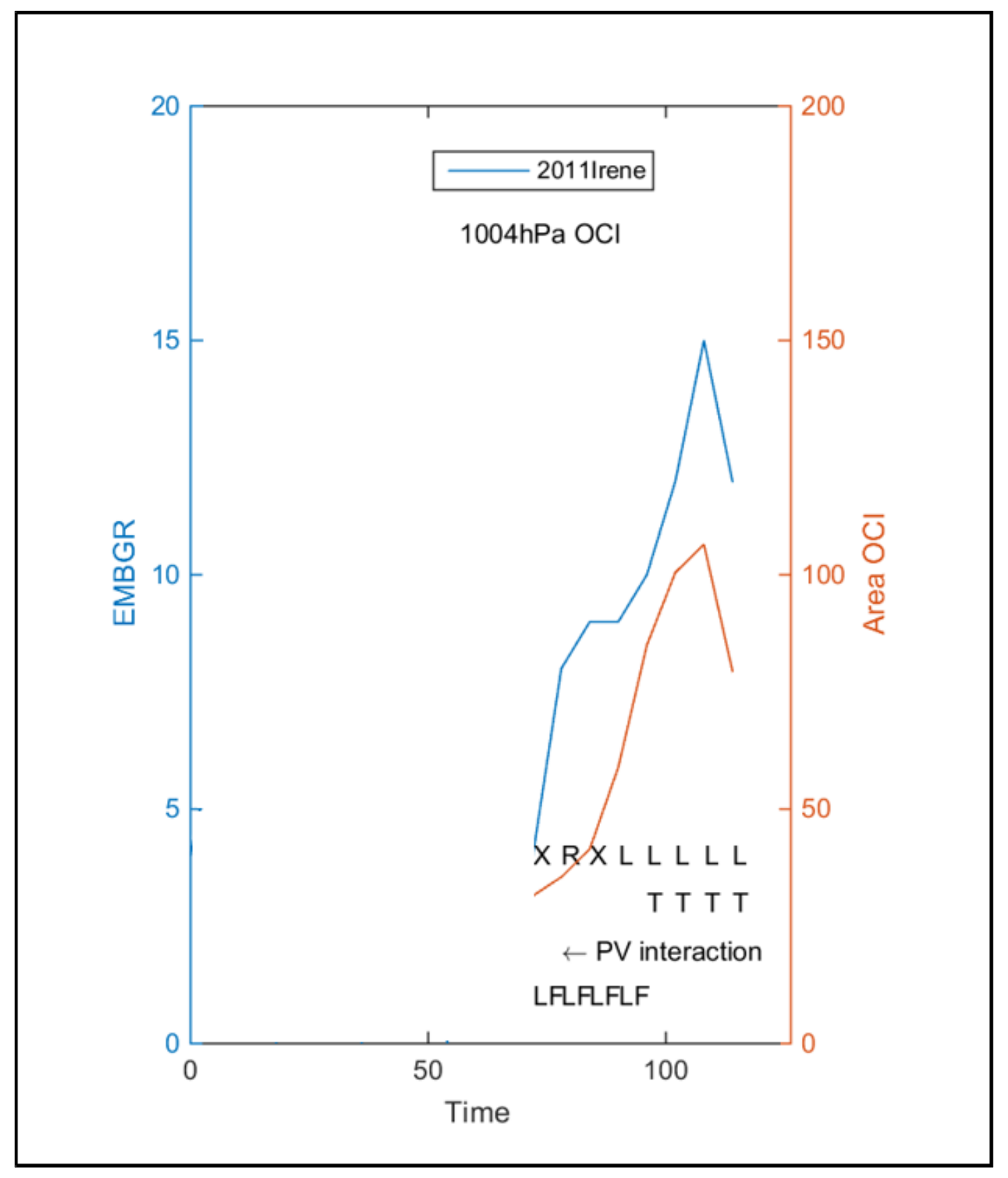


Fig. 2: Plot showing the time evolution (in hours) of the EMBGR (day^{-1}) and area of 1004 hPa OCI. Also marked are the time of landfall (LF), PV interaction, warm core asymmetric CPS (T) and left of track precipitation distribution (L).

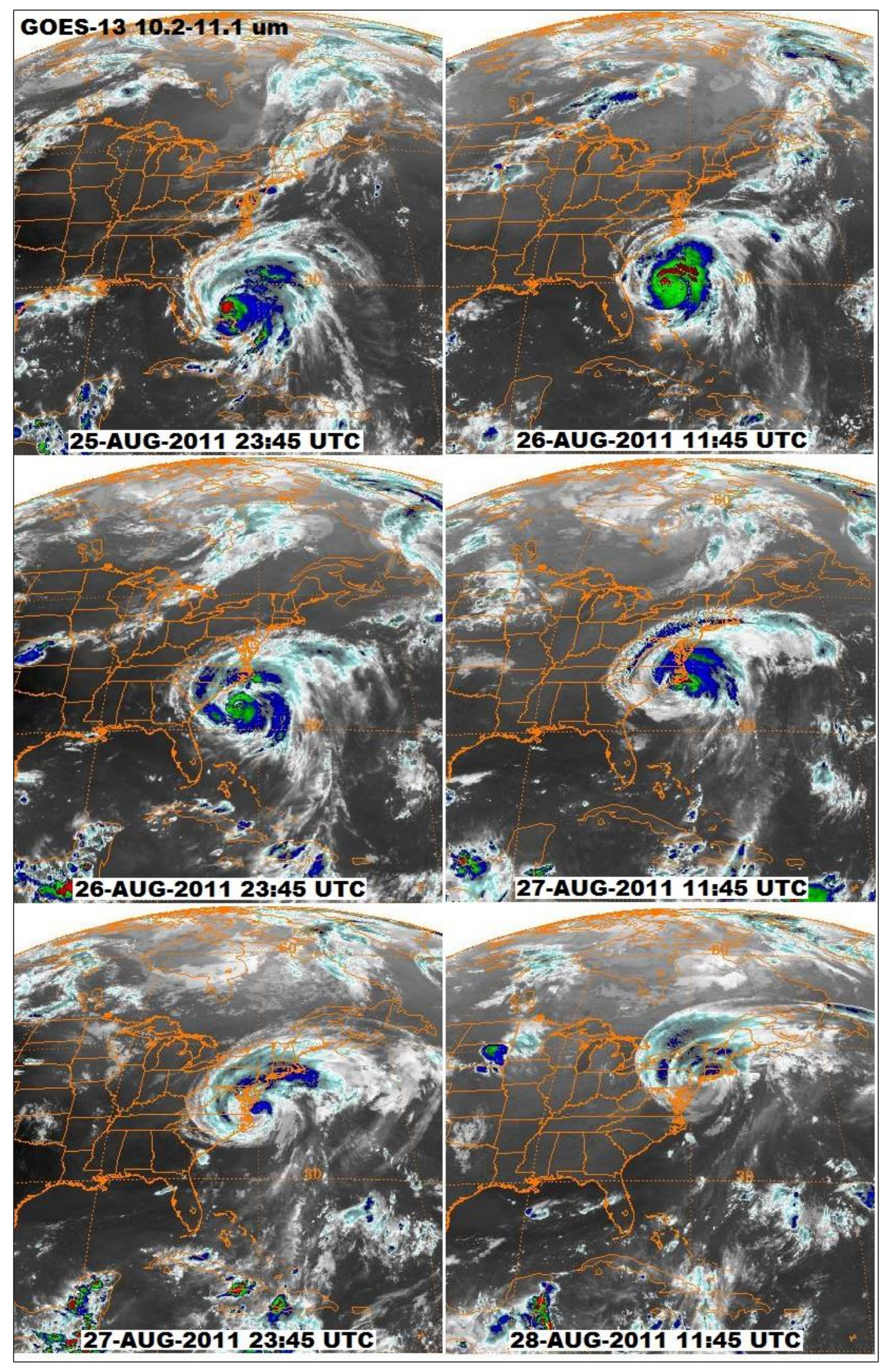
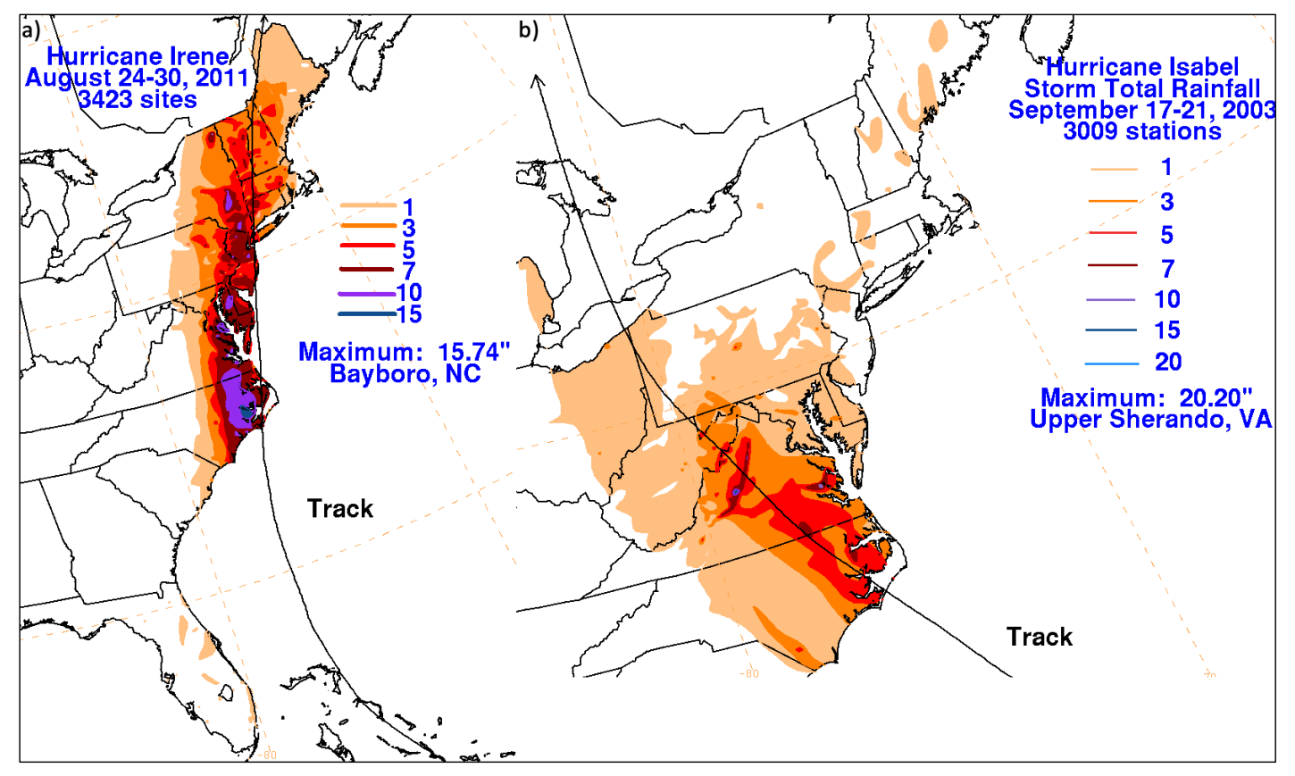


Fig. 3: GOES 13 IR images showing Irene (2011) during ET.



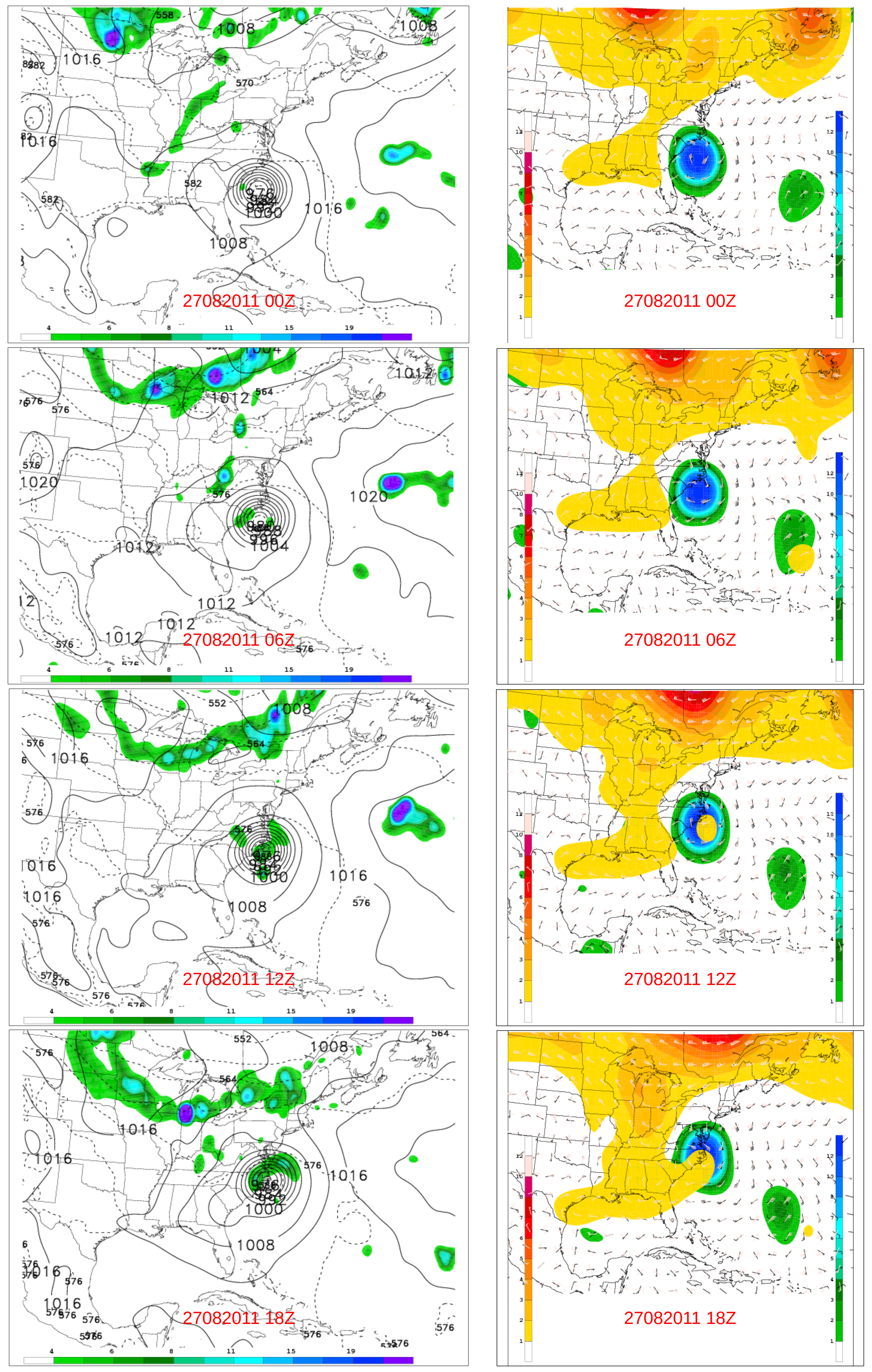


Fig. 5: Evolution of the EMBGR (day^{-1}) and PV interaction for Irene (2011).

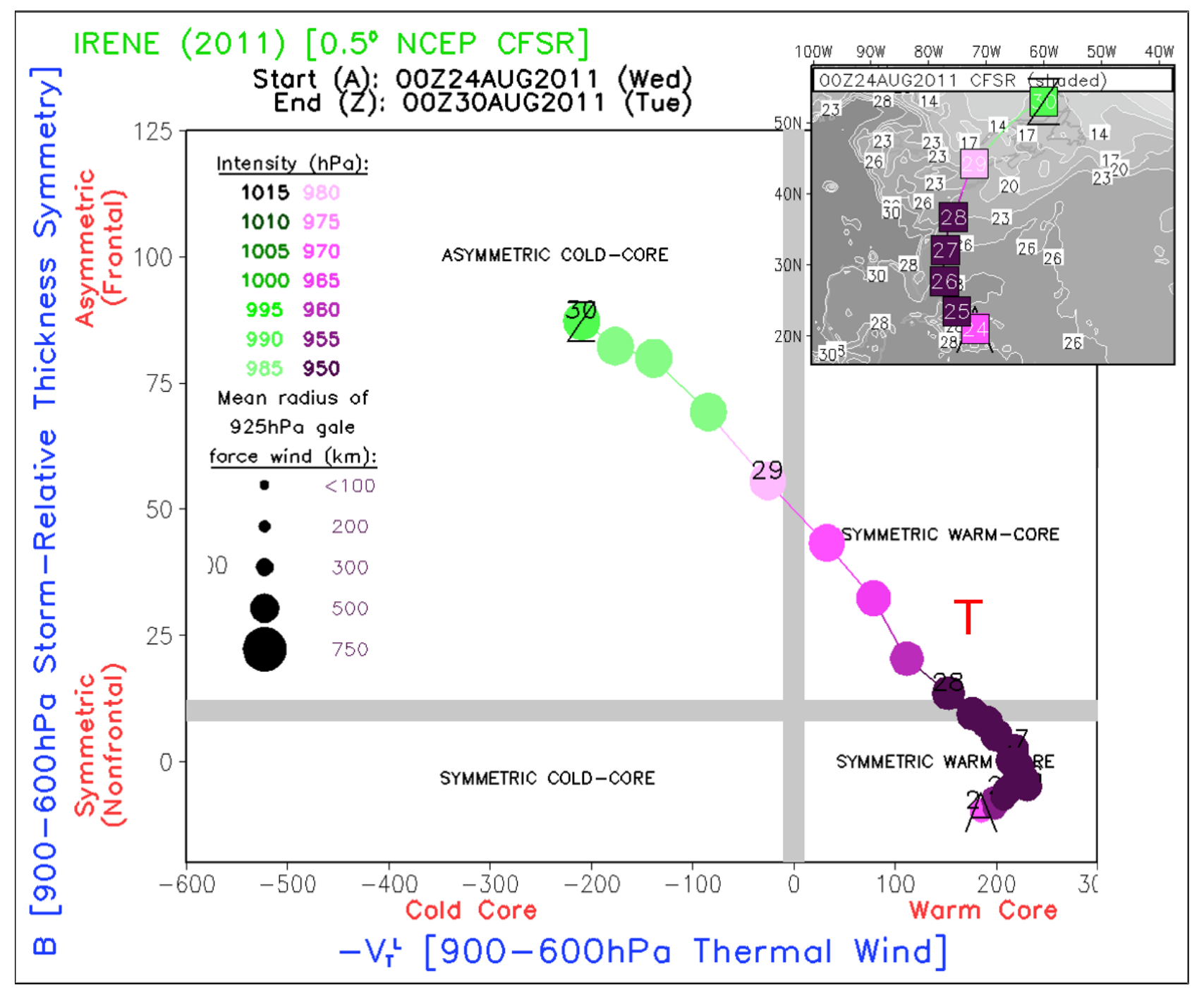


Fig. 6: CPS of Irene (2011). The EMBGR increased over time before PV interaction or asymmetric CPS.

← Fig. 4: Total storm precipitation from (a) Irene (2011) and (b) Isabel (2003).

Irene (2011) was an intensifying ET and has a LOC precipitation distribution (Atallah et al. 2007).