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# Multi-scale shear impacts during the genesis of Hagupit (2008)

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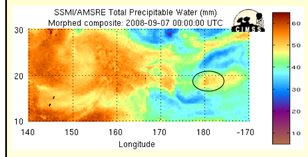
## Introduction

### What makes pre-depression Hagupit (2008) an interesting case study?




- Marsupial Pouch appeared around Sep 7th, ~10 days prior to its TD designation (JTWC)
- Development was delayed due to interactions with upper-level trough (Sep 13th – 14th)
- *Organized deep moist convection* observed with high spatial and temporal resolution by ELDORA radar and dropsondes during the period of shear impacts (T-PARC/TCS-08 campaign) (Bell and Montgomery 2010)
- After all, Hagupit survived through the high-shear environment and eventually formed into Typhoon

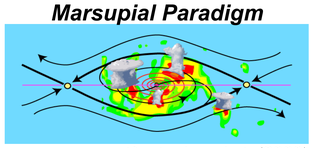
### Here we show complex shear impacts on TC genesis, analyzing multi-scale interactions

- ***From*** synoptic scale wave surrounding pre-depression Hagupit, ***to*** meso-$\gamma$ scale convective cells in the pouch
- Where both vertical wind shear (upper-level vs. low-level) and horizontal shear were present

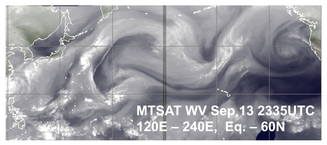
## Results

### Synoptic Scale

***Marsupial Paradigm***



Dunkerton et al. (2009)

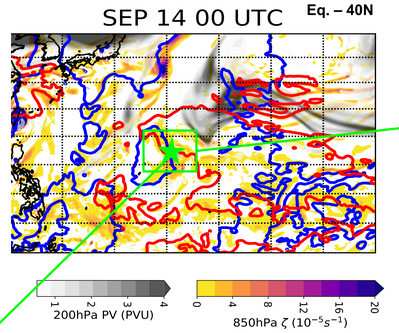



Tracking the sweet spot (center of the Marsupial Wave Pouch)

**Cross section of $v = 0$ & $u = C_p$**

Trough from PV intrusion

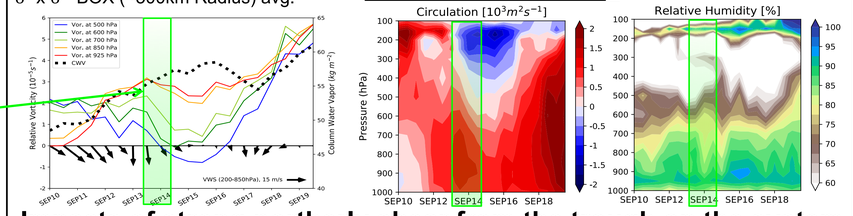
**Dry northerly air with anomalously high PV at 200hPa**




Blue: $v = 0$, Red: $u = C_p$ $(-5.5\ m\ s^{-1})$

### Meso-$\alpha$ scale

Data: ECMWF YOTC, 6° x 6° BOX (~300km Radius) avg.



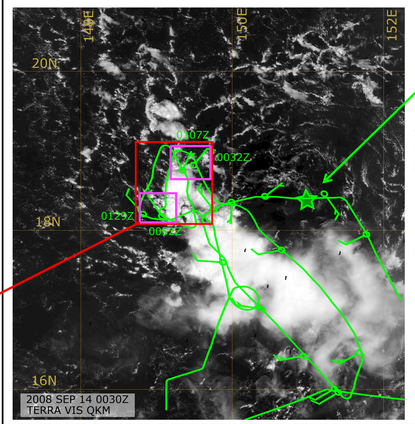

**Impacts of strong northerly shear from the trough on the system**

- Mid-level circulation decreased, Low-level circulation persisted
- RH at low-level shows dry-air intrusion, but CWV kept increasing (overall convection was still saturating the column)

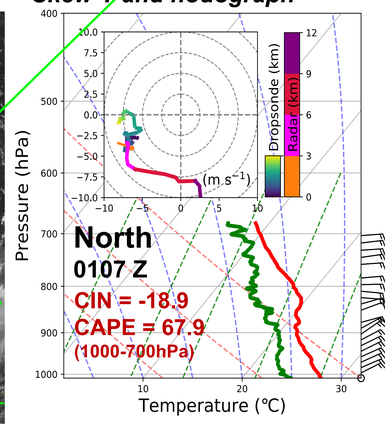
**The marsupial pouch was shallow, but it protected the low-level vortex**

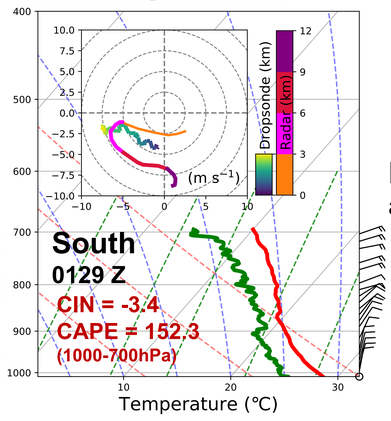
### Meso-$\beta$ scale

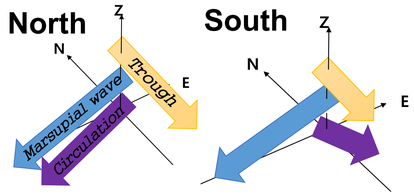
***Flight track & Dropson Locations***




***Skew-T and hodograph***

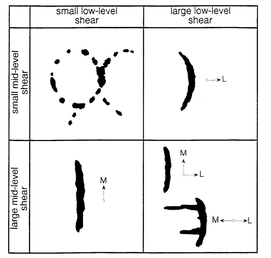


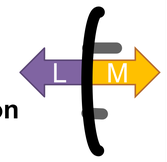




**North vs. South: Different Wind and Thermodynamic Profile**

- Wind for trough, marsupial wave, and low-level circulation
- Both CAPE and CIN favor more convection south (relatively down-shear) than north (up-shear)



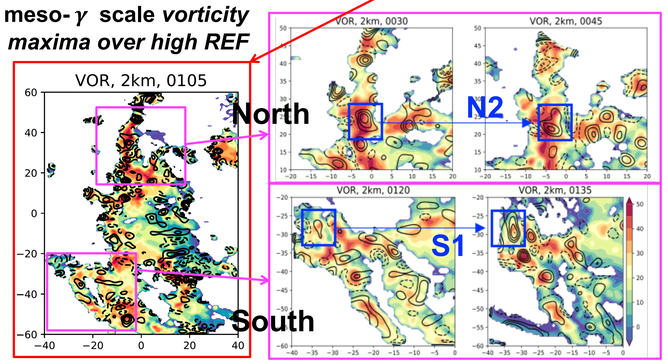

Lemone et al (1998)




**The Role of Shear in Organizing Convection**

- Low-level shear: cold-pool dynamics
- Mid-level shear: trailing secondary bands

***meso-$\gamma$ scale vorticity maxima over high REF***

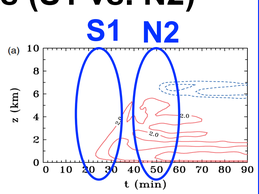



SAMURAI was used for synthesizing radar data with 500m resolution

### Vorticity Budget Analysis (S1 vs. N2)

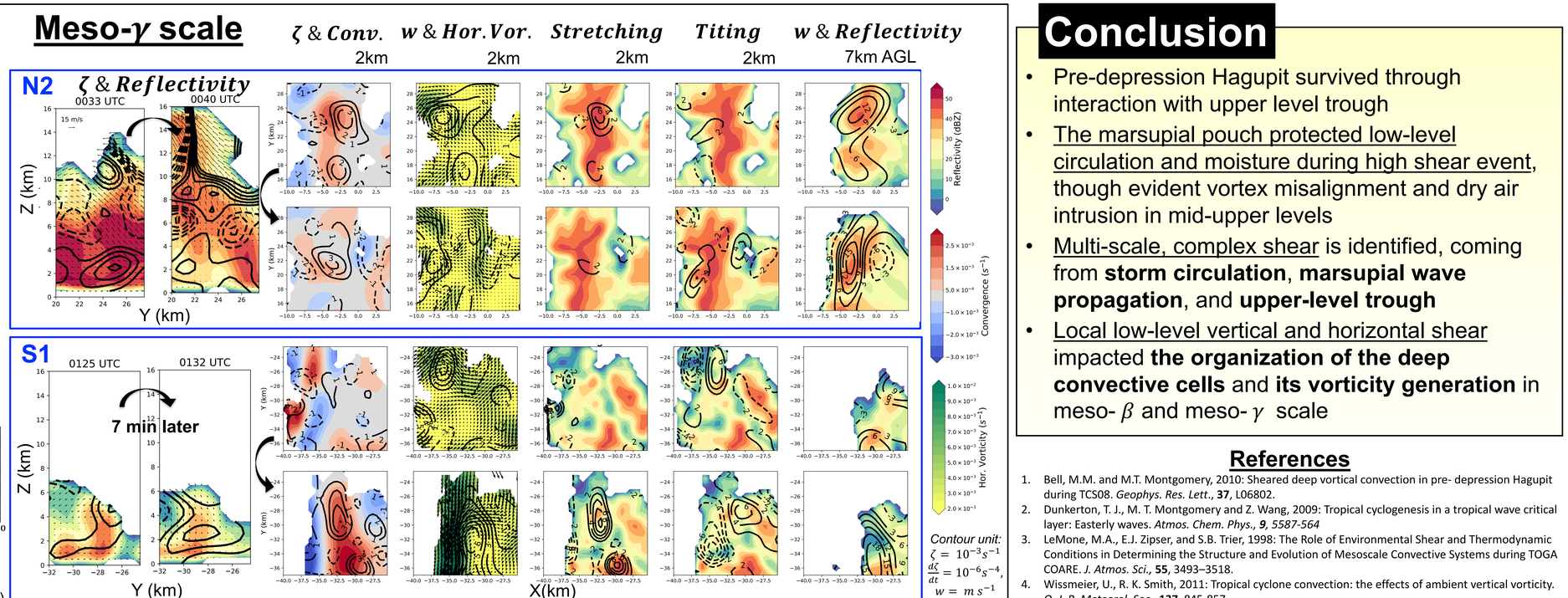
Tilting-dominant vs. Stretching-dominant can be explained by the different low-level shear and the evolutional stage

- **S1 is young, and N2 is mature in the evolutional stage**
- **Low-level shear is much stronger in South**




***convective cell from Idealized simulation***
Wissmeier and Smith (2011)

### Meso-$\gamma$ scale




*Contour unit:* $\zeta = 10^{-3} s^{-1}$, $\frac{d\zeta}{dt} = 10^{-6} s^{-4}$, $w = m\ s^{-1}$

## Conclusion

- Pre-depression Hagupit survived through interaction with upper level trough
- The marsupial pouch protected low-level circulation and moisture during high shear event, though evident vortex misalignment and dry air intrusion in mid-upper levels
- Multi-scale, complex shear is identified, coming from **storm circulation**, **marsupial wave propagation**, and **upper-level trough**
- Local low-level vertical and horizontal shear impacted **the organization of the deep convective cells** and **its vorticity generation** in meso-$\beta$ and meso-$\gamma$ scale

### References

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