# An Evaluation of Satellite-Derived Atmospheric Motion Vector (AMV) Characteristics in Tropical Cyclones Using TCI HDSS Dropsondes


**Brian McNoldy**[1], **Christopher Velden**[2], **Sharanya Majumdar**[1]

1 - U. Miami/RSMAS

2 – UW/CIMSS



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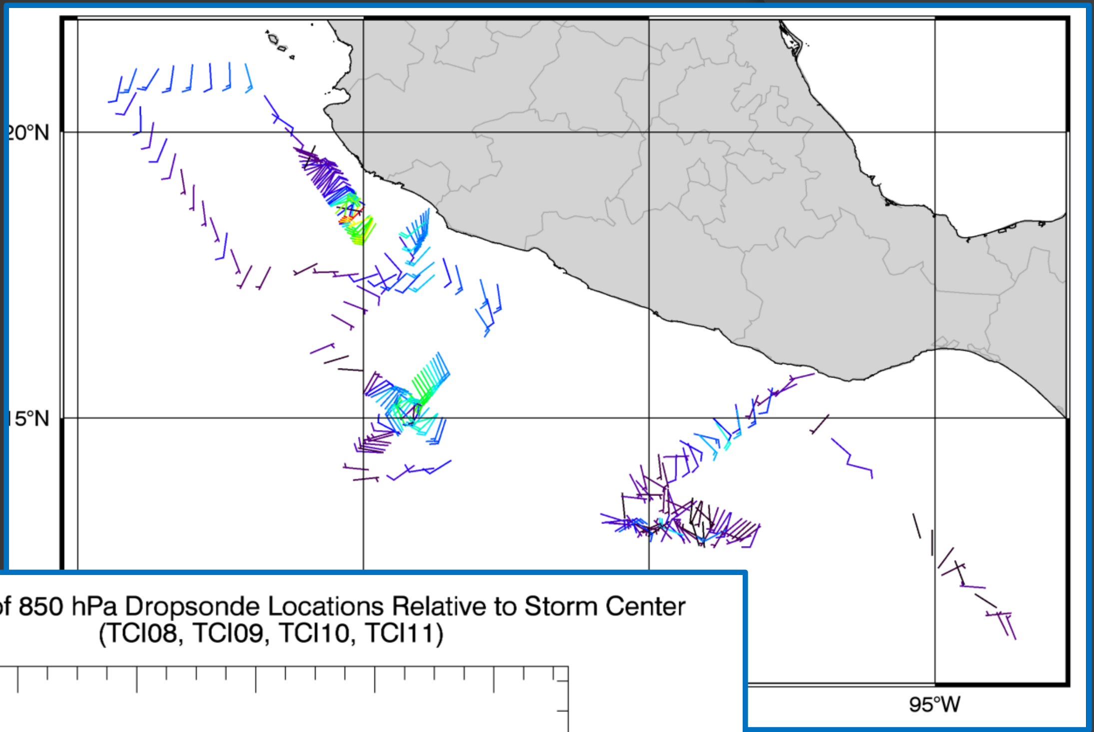
# TCI AMV/Dropsonde Comparisons

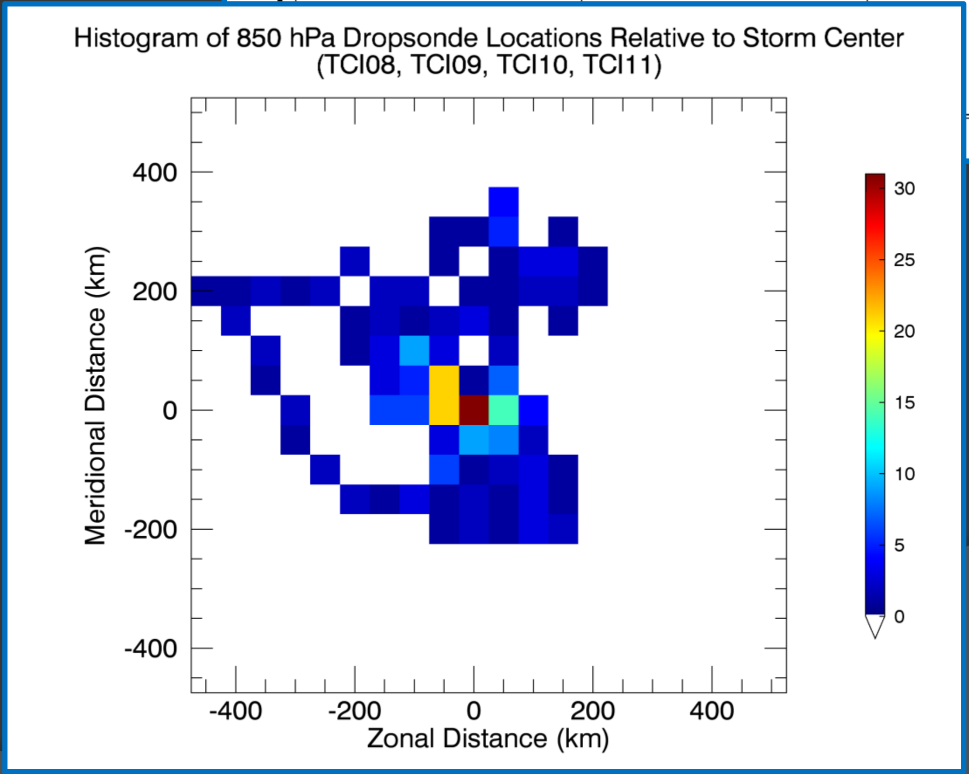
- Project motivation: **How good are AMVs in defining TC outflow**, and can a mix of high-resolution dropsondes with the AMVs better define the 4-D structure evolution?
- First, characterize AMVs by comparing to co-located (space and time) high-altitude HDSS dropsonde wind profiles
  - Focus on 4 TCI flights over Hurricane Patricia in Oct 2015 and two AMV datasets reprocessed by UW-CIMSS from GOES-East
  - Evaluate AMV accuracies and height assignments against dropsonde data averaged in layers of varying thicknesses, from 10 hPa to 300 hPa

# Patricia 2015

- 4 flights spanning 20 Oct – 23 Oct
- 257 total dropsondes

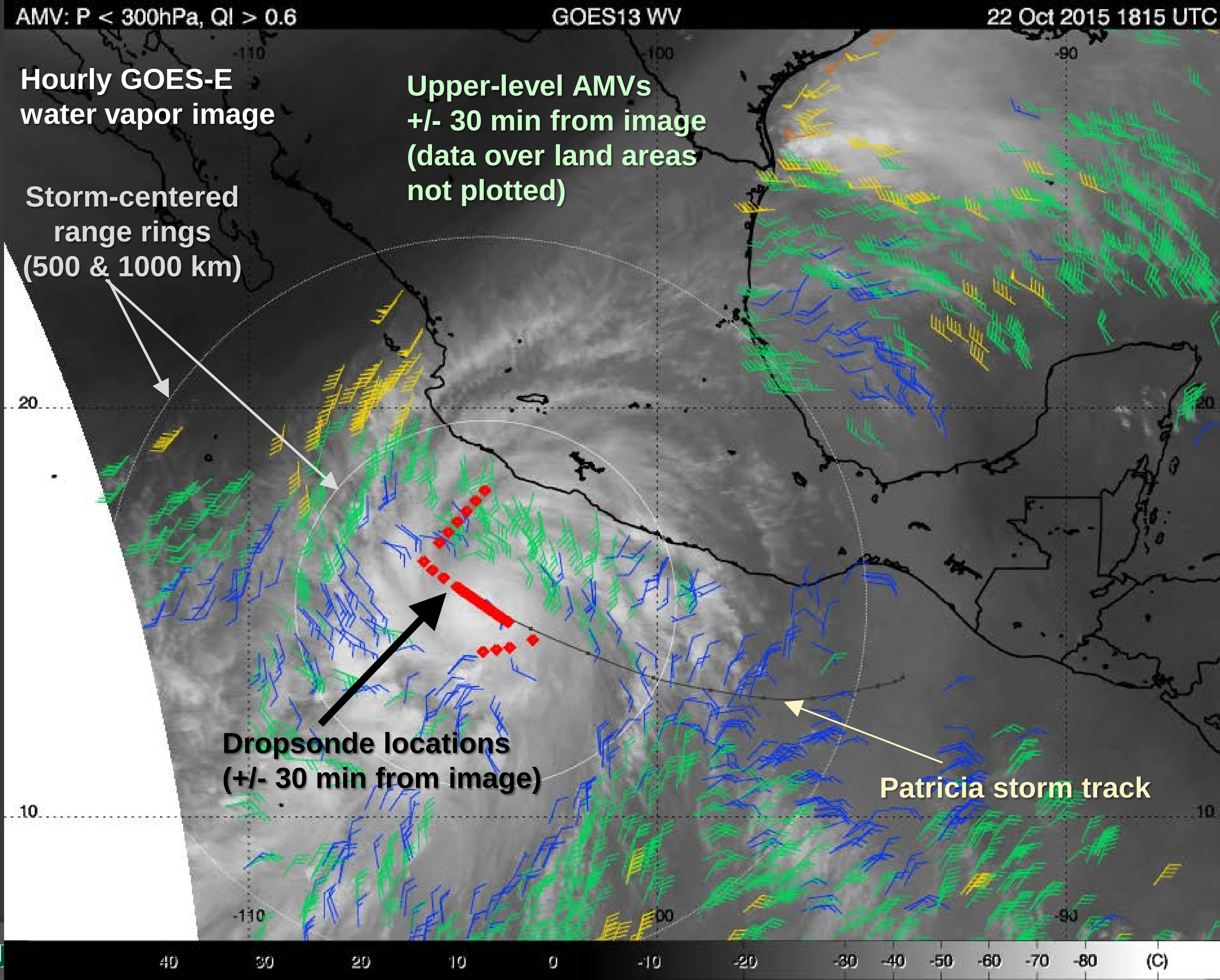


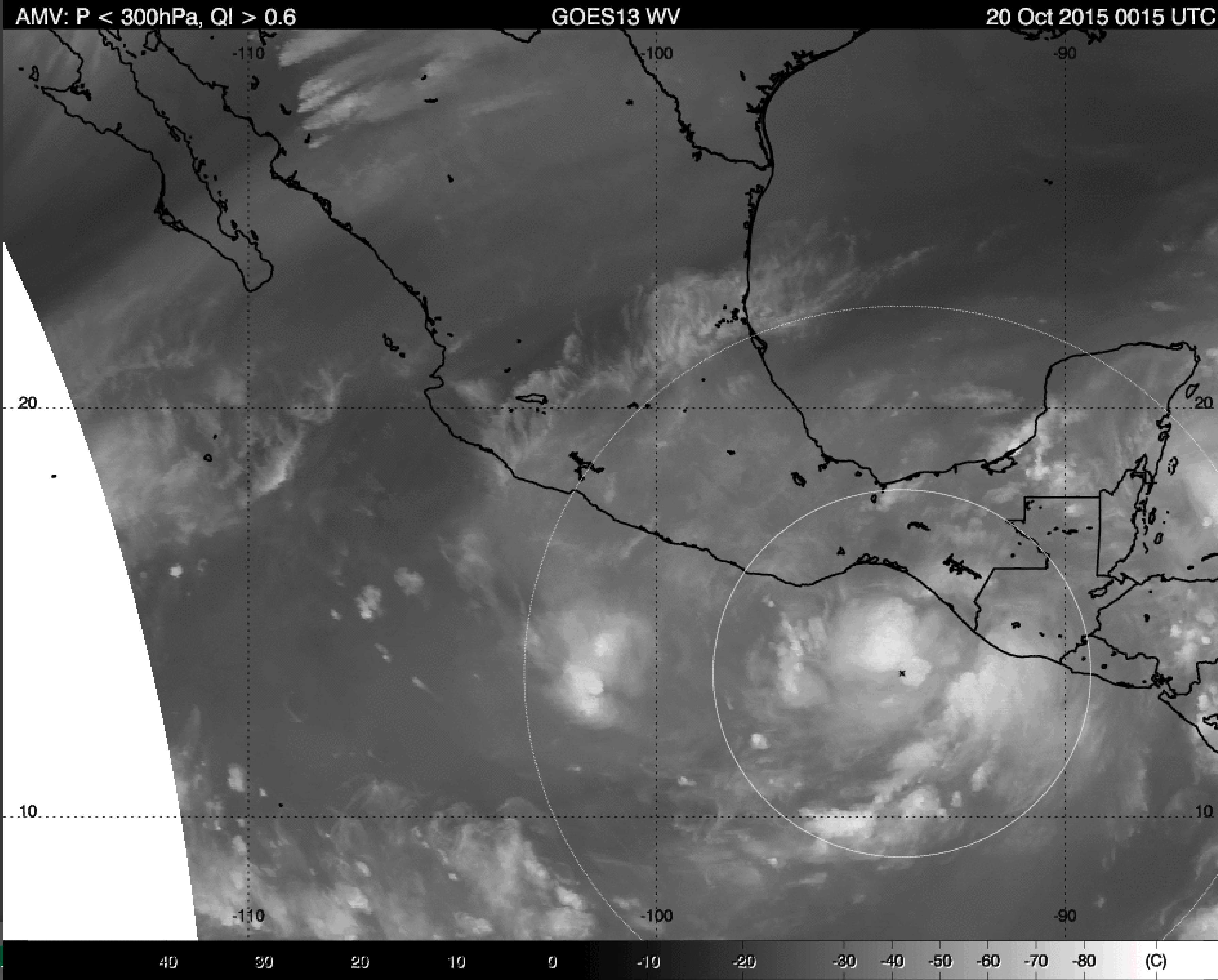

Dropsonde wind measurements at 150 hPa




Storm-centered dropsonde density

- *46 sondes released over Patricia on 23 Oct when intensity peaked at 185 kts, most intense western hemisphere TC on record*


AMV: P < 300hPa, QI > 0.6
GOES13 WV
22 Oct 2015 1815 UTC
Hourly GOES-E water vapor image
Upper-level AMVs +/- 30 min from image (data over land areas not plotted)
Storm-centered range rings (500 & 1000 km)
Dropsonde locations (+/- 30 min from image)
Patricia storm track
-110
-100
-90
20
10
40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 (C)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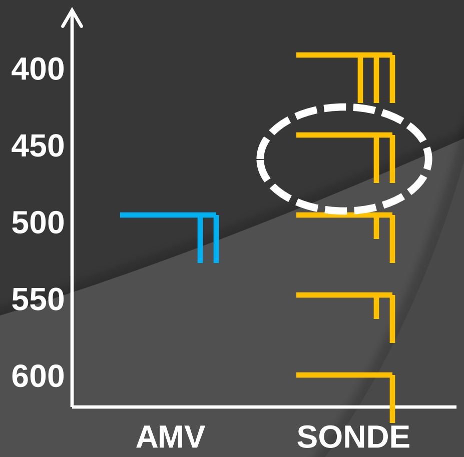
0
-10
-20
-30
-40
-50
-60
-70
-80
(C)

# AMV Match Selection Criteria

- Dunion & Velden (2002) evaluated low-level AMVs against dropsondes in 3 TCs during 1998 season… AMVs used if:
  - Within **60 minutes** of dropsonde
  - Within **1°** of dropsonde
- Velden & Bedka (2009) evaluated AMVs against hi-res rawinsonde soundings from 3 ARM sites… AMVs used if:
  - Within **60 minutes** of sonde
  - Within **50 km** of sonde
- Sears & Velden (2012) evaluated AMVs against G-V dropsondes from 26 flights over Invests/TCs during PREDICT… AMVs used if:
  - Within **30 minutes** of dropsonde
  - Within **½° or 1°** of dropsonde (both tested)
  - AMV Quality Indicator **(QI) ≥ 0.5**
- *This study evaluates AMVs against HDSS dropsondes from WB-57 flights over mature TC cores during TCI-15… Higher-density HDSS allows stricter match criteria:*
  - *Within **30 minutes or 15 minutes** of dropsonde (both tested)*
  - *Within ¼° of dropsonde*
  - *AMV Quality Indicator **(QI) ≥ 0.8***

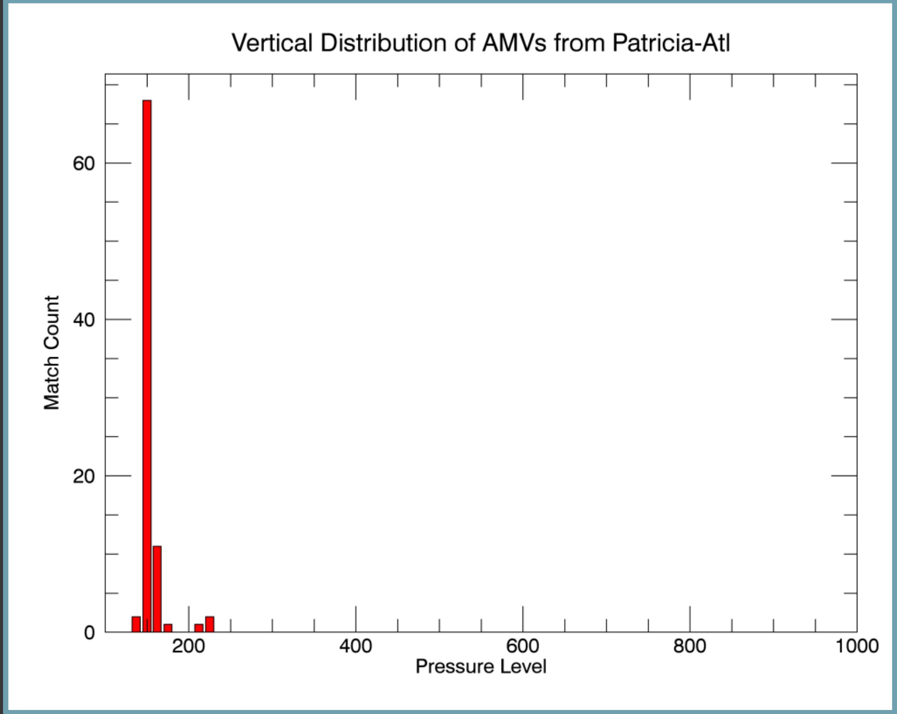
# AMV-Dropsonde Match Statistics

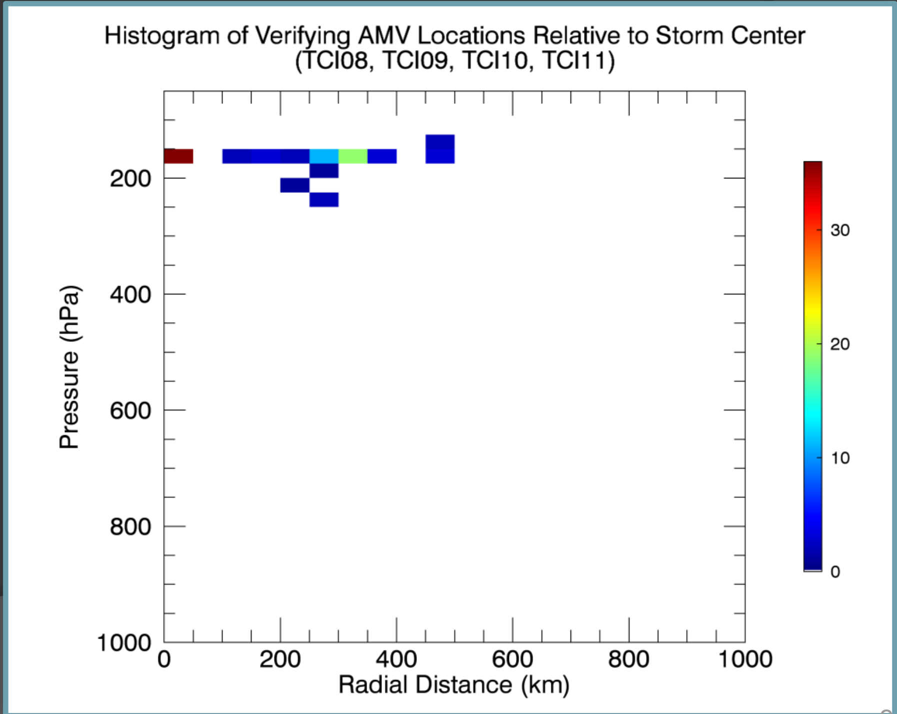
- Following previous studies, routine statistics were calculated based on Nieman et al. (1997) and Velden and Bedka (2009)
  - **Vector difference (VD)**
    - $(VD)_i = \sqrt{(U_i - U_s)^2 + (V_i - V_s)^2}$
  - **Bias**
    - $(BIAS) = \frac{1}{N}\sum_{i=1}^{N}\left(\sqrt{U_i^2 + V_i^2} - \sqrt{U_S^2 + V_S^2}\right)$
  - **Mean vector difference (MVD)**
    - $(MVD) = \frac{1}{N}\sum_{i=1}^{N}(VD)_i$
  - **Vector standard deviation (VSD)**
    - $(VSD) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[(VD)_i - (MVD)]^2}$
  - **Vector root-mean-square error (VRMS)**
    - $(VRMS) = \sqrt{(MVD)^2 + (VSD)^2}$
  - **Vector height--level of best fit (LBF)**
    - Level where AMV-sonde VD is minimized, within 100 hPa of AMV height



# Routine (Real-Time) AMV datasets produced by CIMSS

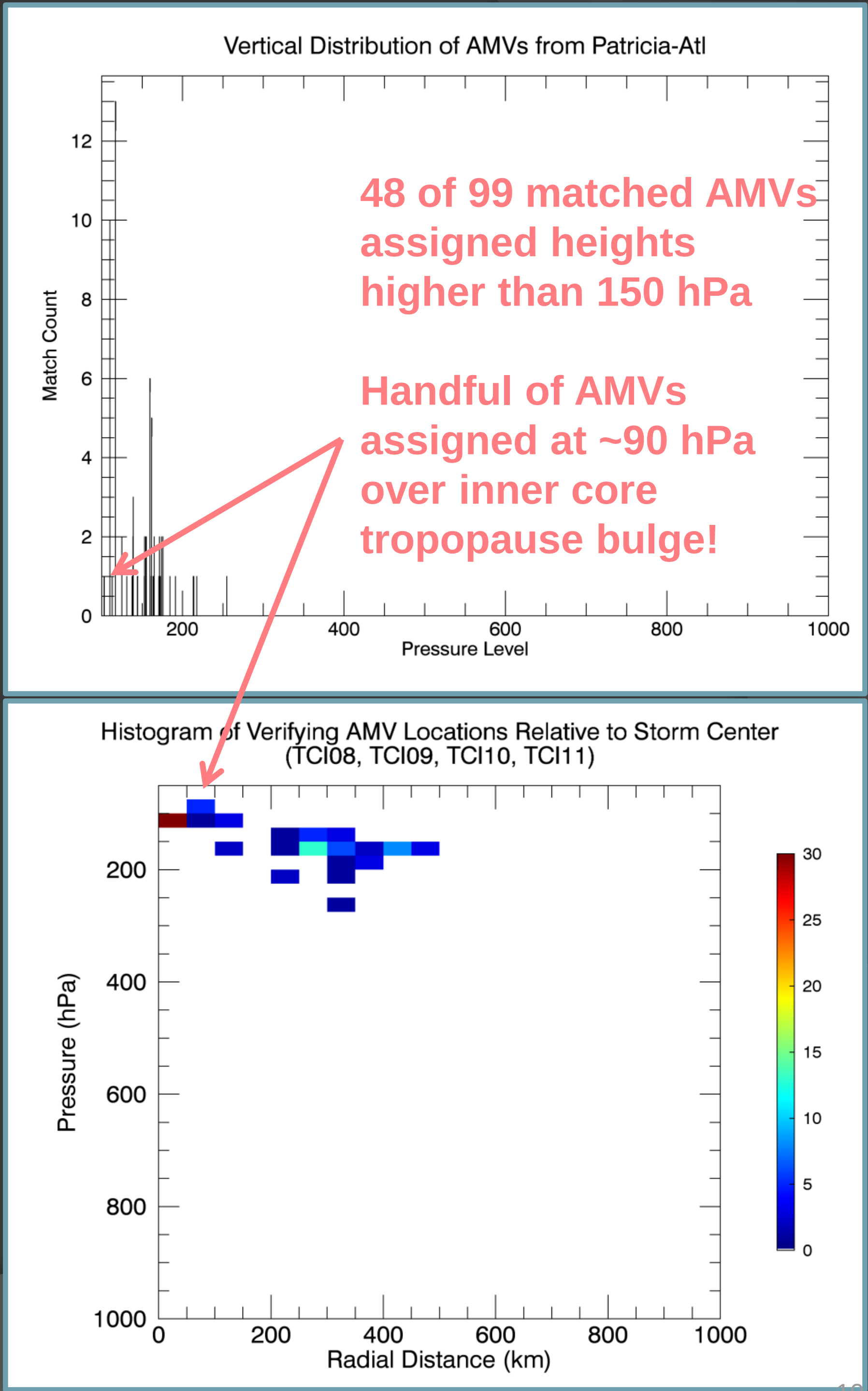
- Full-disk datasets derived every 60 minutes
- Processing methods not tailored to TC scales
- AMV height assignment "cap" at 150 hPa
- Time window for comparison: +/- 30 mins
- AMV Quality Indicator ≥ 0.8
- Total of 85 qualifying AMV-dropsonde matches, all in upper-level outflow within 500 km of Patricia's center



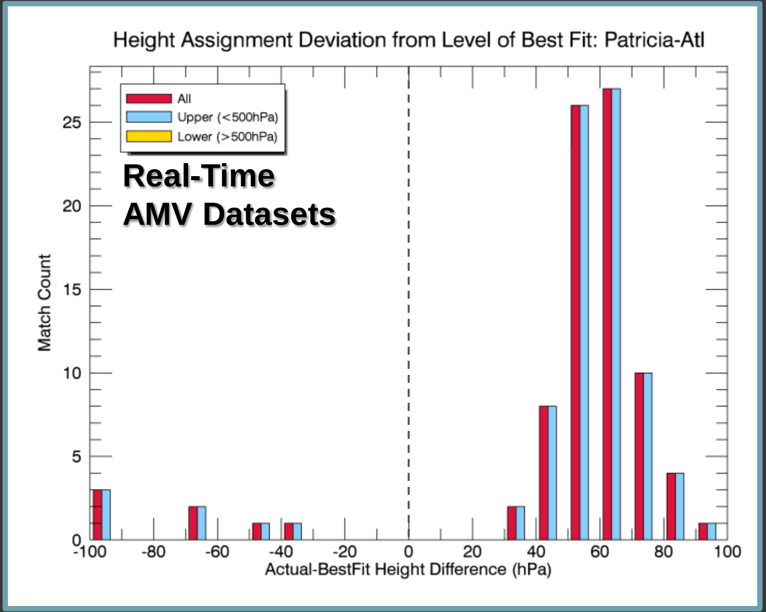
# AMV datasets reprocessed by CIMSS for TCI

- Focused datasets produced every 30 mins using novel processing strategies for TCs
- AMV height assignment upper bound “cap” removed
- Time window for comparison: +/- 15 mins
- AMV Quality Indicator ≥ 0.8
- Total of 99 qualifying AMV-Dropsonde matches, all in upper-level outflow within 500 km of Patricia’s center

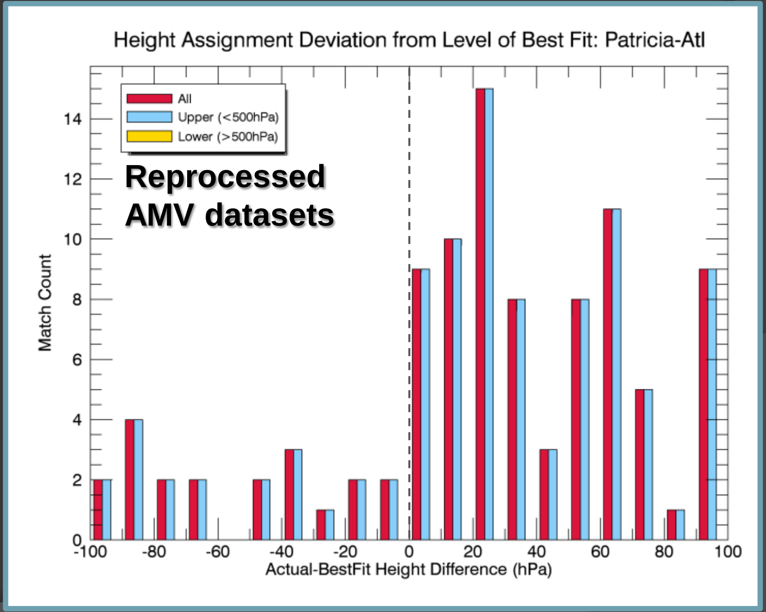


# How good are the AMV height assignments? What are the levels of 'Best Fit' based on TCI sondes?

- Search for minima in AMV-Sonde vector difference within 100 hPa of the original AMV height assignment (i.e., what is the best height assignment an AMV could be given that most closely matches a collocated dropsonde wind profile).
  - Negative values: AMVs assigned too high in atmosphere
  - Positive values: AMVs assigned too low in atmosphere




Ave LBF: **+51.6 hPa** (σ=38.4)

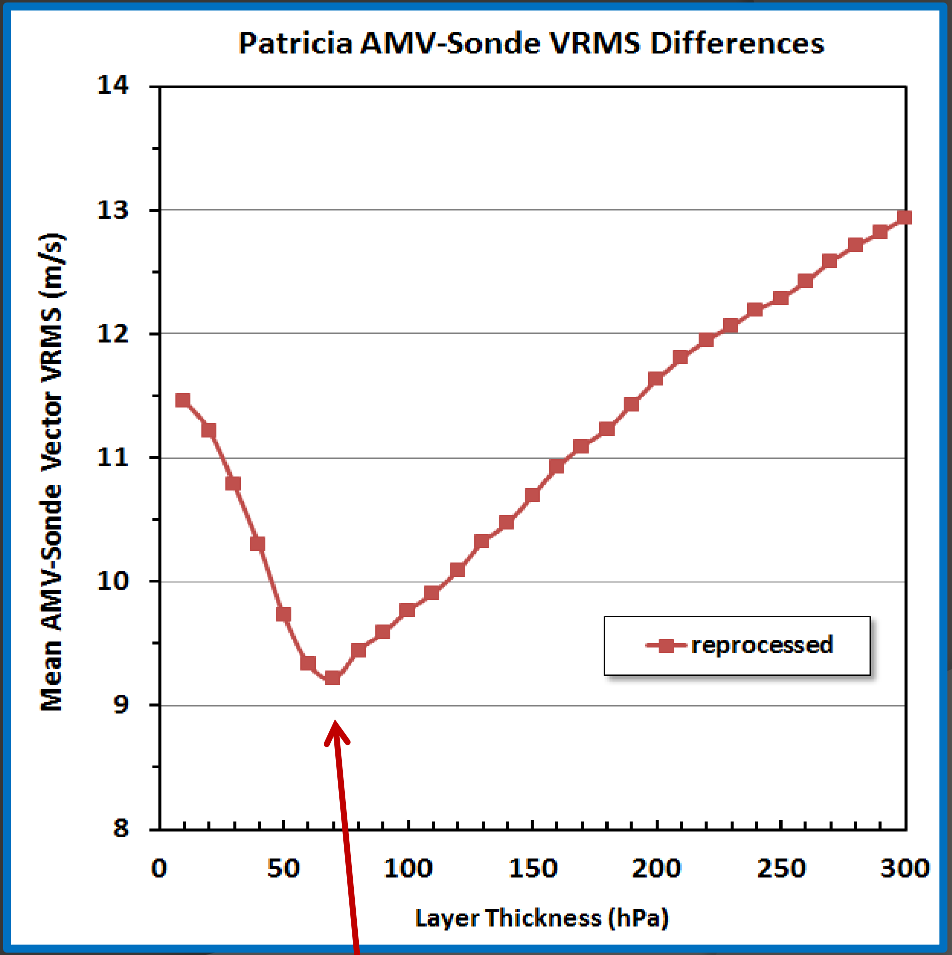



Ave LBF: **+24.2 hPa** (σ=48.4)

# Are AMVs better represented by layers?

## i.e. layers of 'Best Fit' based on TCI dropsonde wind profiles

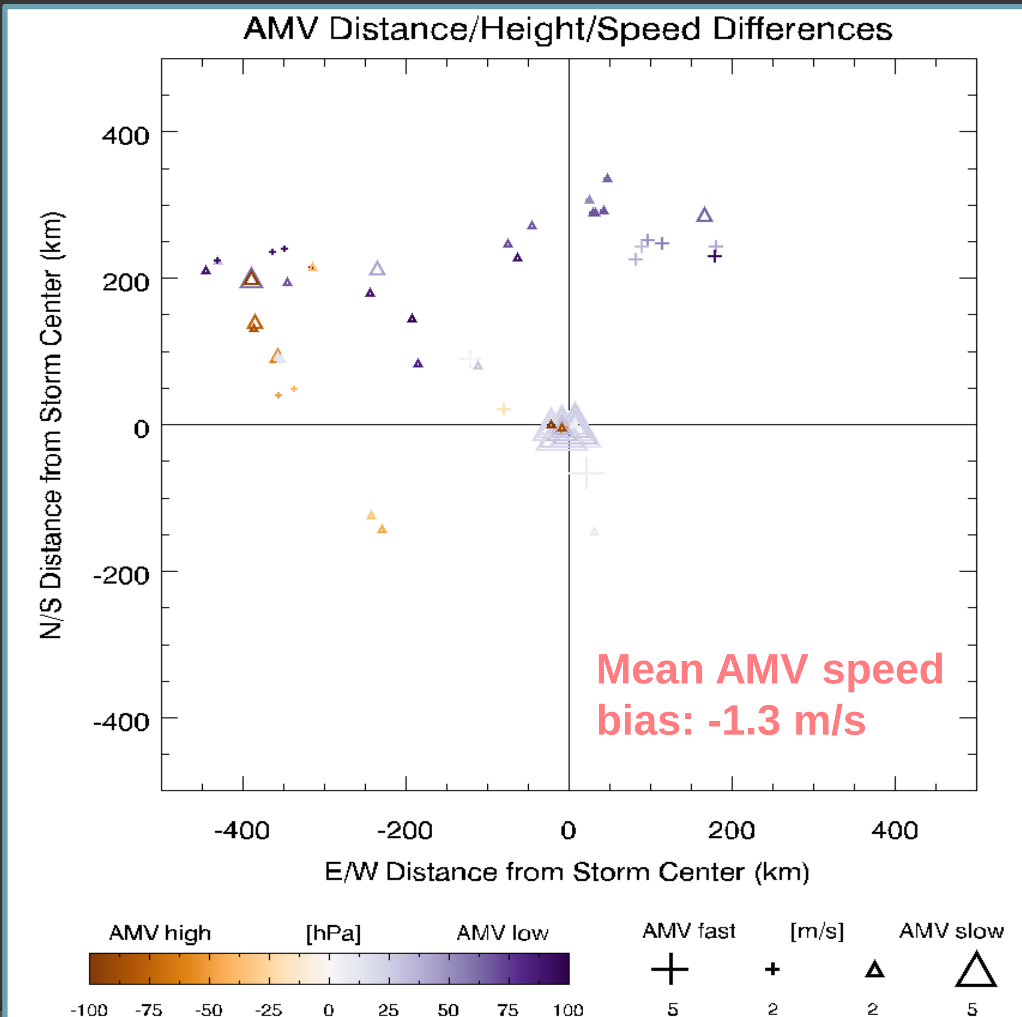
- Compare reprocessed AMVs to vertically-averaged winds derived from varying layers in sonde profile, from 10-300 hPa thick
- Outflow AMVs better represent thin layer of motion rather than a discrete level
  - Clouds being tracked are 3D and represent a volume
  - Lowest VRMS errors for ~70 hPa thick layer

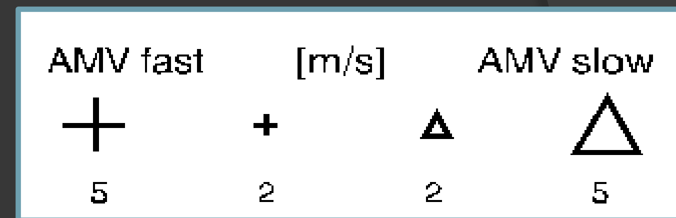



Minimum at **70 hPa** (9.2 m/s)

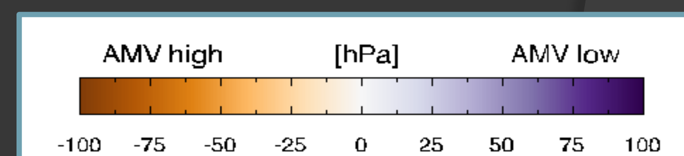
# Storm-centered Differences

- Plan view of reprocessed AMV height and speed differences vs TCI dropsondes (70 hPa layer)



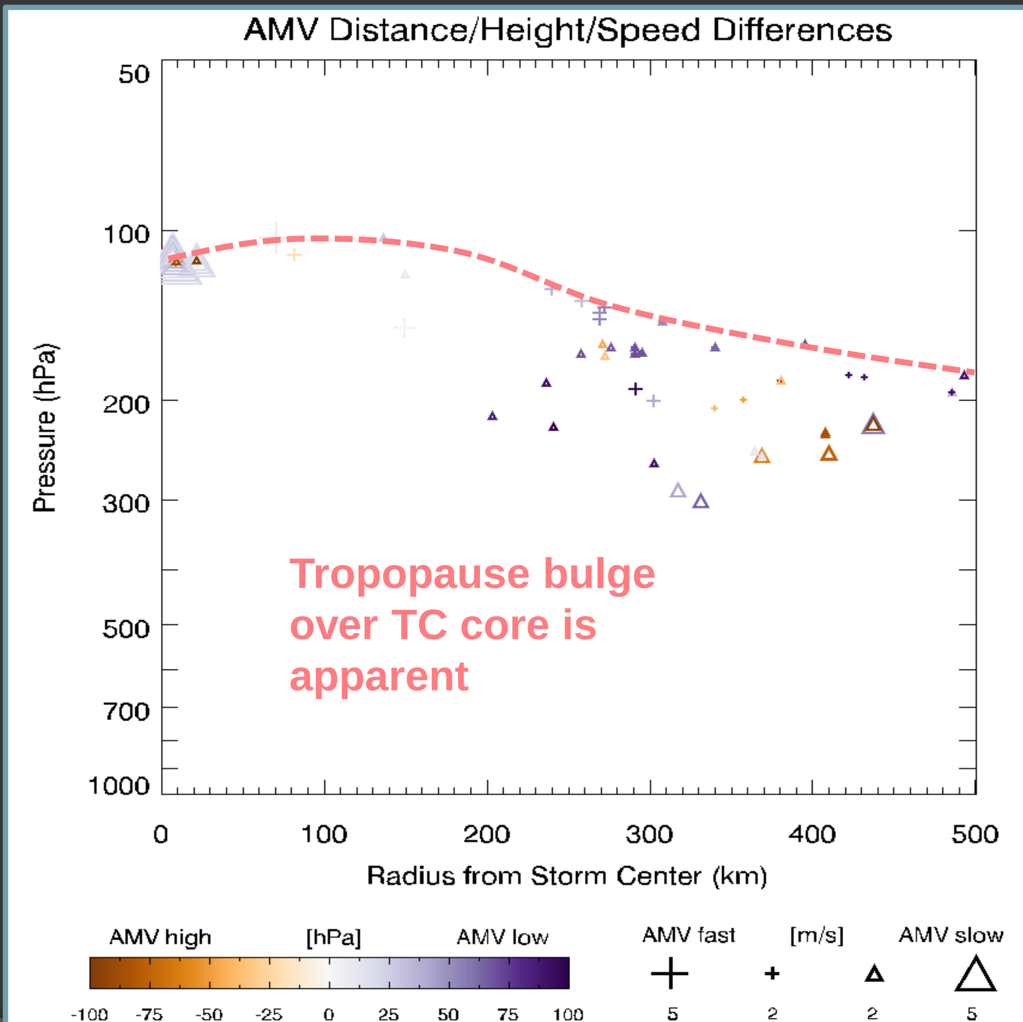

**SHAPE:**
**sign of speed difference**
**SIZE:**
**magnitude of speed difference**

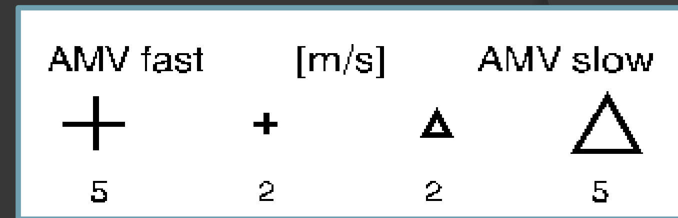



**COLOR:**
**magnitude of LBF difference**

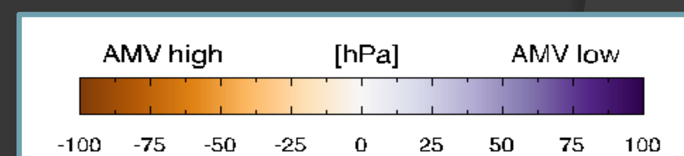
# Storm-centered Differences

- Vertical x-sec view of reprocessed AMV height and speed differences vs TCI dropsondes (70 hPa layer)




**SHAPE:**
**sign of speed difference**
**SIZE:**
**magnitude of speed difference**




**COLOR:**
**magnitude of LBF difference**

# Summary

- TCI's HDSS high-density, high-altitude dropsondes provided **unprecedented coverage** over inner core and outflow layers of intense TCs
  - Allows for interrogation of upper-level AMVs with strict spatial and temporal sonde wind matching criteria
- Routine 150 hPa AMV height assignment "cap" inadequate for TC processing
- Reprocessed AMVs are an improvement
  - Error statistics from TC outflow layer are expectedly higher than in general large-scale environments (tight gradients in speed/direction and vertical shear)
- AMVs best represent motion/wind in a thin layer of the troposphere, rather than a discrete height
  - Layer thickness depends on cloud type and altitude

# Questions?

- bmcnoldy@miami.edu

- TCI Website & Data:
  - https://www.eol.ucar.edu/field_projects/tci

- Funding for this research is from the Office of Naval Research (Ron Ferek)