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

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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

- 46 sondes released over Patricia on 23 Oct when intensity peaked at 185 kts, most intense western hemisphere TC on record
Hourly GOES-E water vapor image

Storm-centered range rings (500 & 1000 km)

Dropsonde locations (+/- 30 min from image)

Upper-level AMVs (+/- 30 min from image) (data over land areas not plotted)

Patricia storm track
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
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 $\geq 0.8$
- Total of 99 qualifying AMV-Dropsonde matches, all in upper-level outflow within 500 km of Patricia’s center

48 of 99 matched AMVs assigned heights higher than 150 hPa

Handful of AMVs assigned at ~90 hPa over inner core tropopause bulge!
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)

Mean AMV speed bias: -1.3 m/s

**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)

Tropopause bulge over TC core is apparent

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?

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- TCI Website & Data:
  - [https://www.eol.ucar.edu/field_projects/tci](https://www.eol.ucar.edu/field_projects/tci)

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