National Aeronautics and Space Administration

Earth System Explorer Mission Concept - Atmospheric Winds (5 of 5)

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Earth System Explorer - Strategic Initiative Leader: Sabrina M Feldman

Objectives: Define a mission architecture and develop the necessary models to enable the first comprehensive, near-global measurements of the 3-D distribution of horizontal winds across the whole troposphere. Specific objectives include: O1) Determine lidar wind retrieval precision, accuracy and coverage; O2) Determine passive atmospheric motion vector (AMV) retrieval precision, accuracy and coverage; O3) Develop and refine a machine learning based data fusion algorithm O4) Determine winds mission data sampling sufficiency for Mesoscale Convective Systems (MCSs).

Background:

- Atmospheric winds (AW) are essential for the transport of mass, heat, moisture, momentum, and chemical species, and enable interactions between components of Earth's climate System
- AW measurements are very limited in the Program of Record (POR). The typical root-mean-squared-error (RMSE) of existing AMVs and Aeolus winds is about 7-8 m/s, unable to meet the AW measurement objectives stipulated in ESAS17.
- The 2017 Earth Decadal Survey (DS) established the Explorer mission line, which calls for PI-led concepts in seven investigation categories, including atmospheric winds.

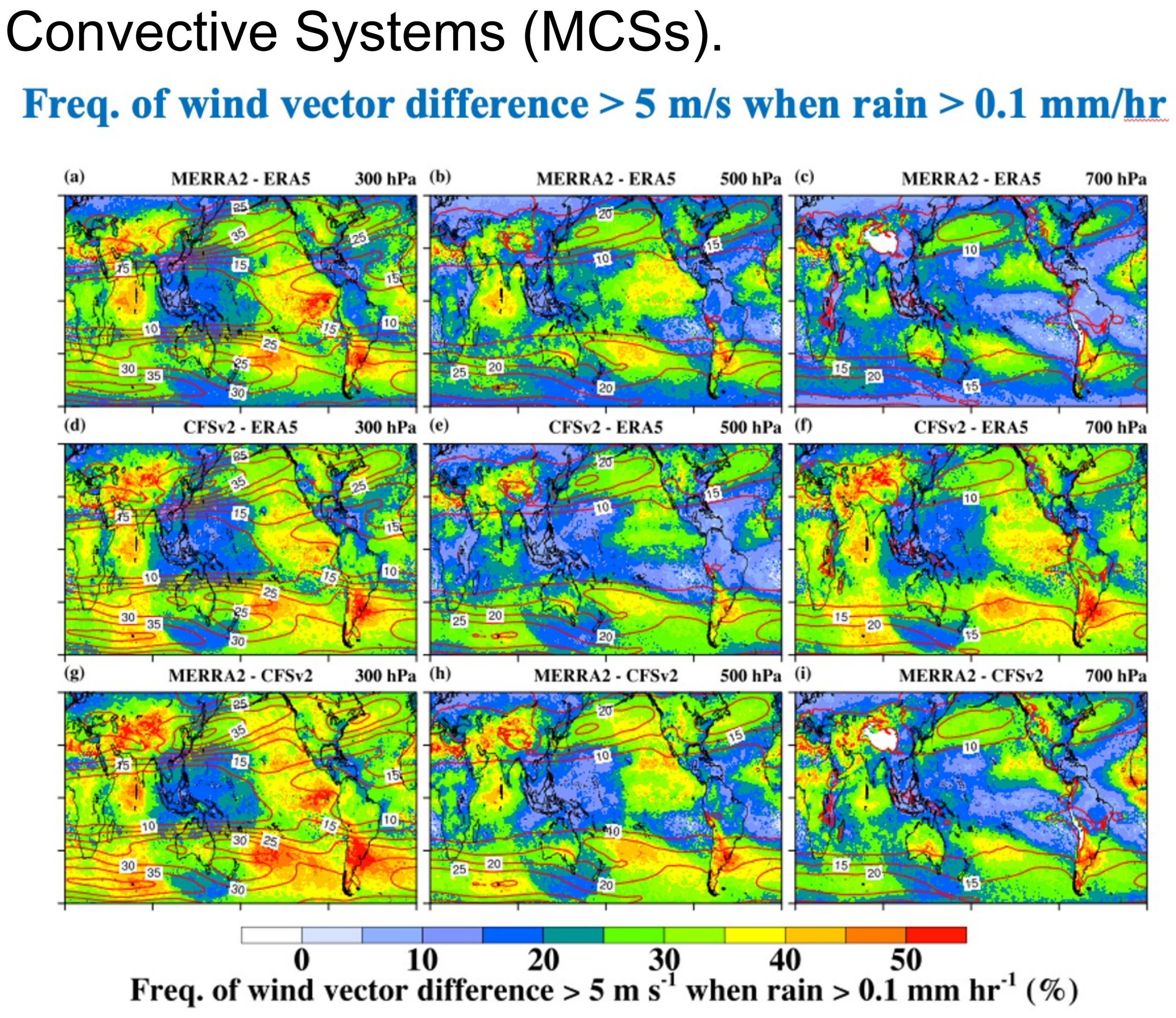


Figure 1. Differences Differences among three atmospheric reanalysis datasets, each created with the goal of producing the best estimate of the atmospheric state. Differences are largest (> 5 m/s) where there is rain occurring, demonstrating the need for winds measurements in and around regions with precipitation.

Approach and Results:

Utilize a spectrum of observing system simulation experiment (OSSE) methodologies to explore the trade space that consists of active and passive winds measurement techniques. Evaluate the results by quantifying uncertainties in simulated retrieved winds for various weather systems.

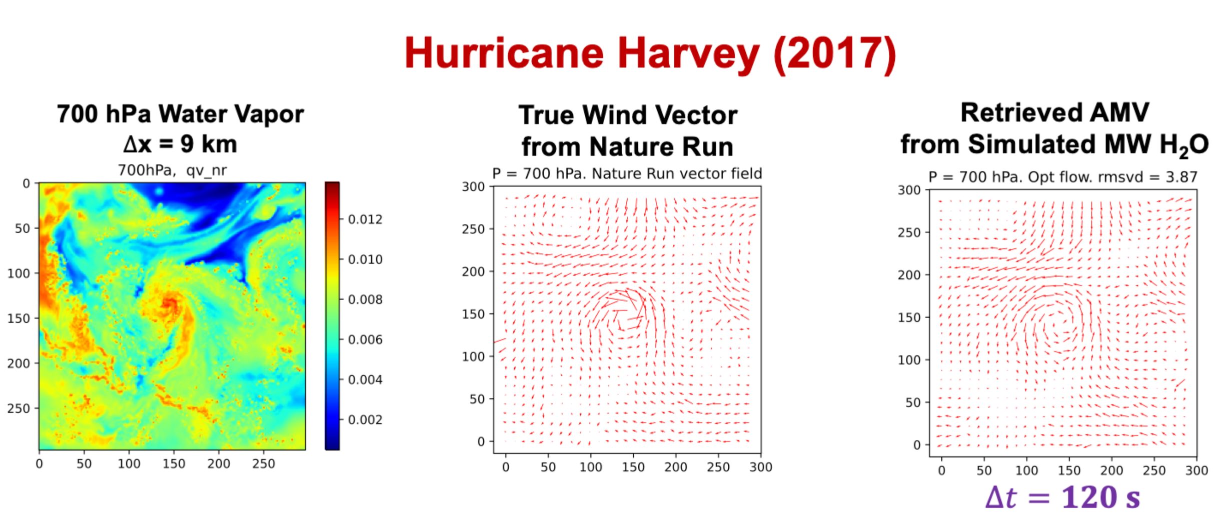
Technical approach:

T1) Determine the wind lidar retrieval precision, accuracy and coverage using STK and Ball's lidar simulator.

T2) Determine AMV retrieval precision, accuracy and coverage from IR and MW instruments using optical flow feature tracking of water vapor images retrieved from candidate sounders.

T3) Develop and use a machine learning data fusion algorithm for active and passive winds that leverages the coverage of AMVs and the accuracy of lidar.

T4) Determine data sampling sufficiency for addressing science objectives on mesoscale convective systems (MCSs) using orbit simulators and nature run datasets.



Root Mean Square Error of Wind Vector Relative to the Nature Run (m/s)

	850 hPa	700 hPa	500 hPa	300 hPa
qv_NR	3.70	3.52	3.16	3.65
qv_MW	4.07	3.87	3.47	4.75

Figure 2. Water vapor geographic distribution (upper left), along with the nature winds (upper center) and winds retrieved from the optical flow algorithm applied to water vapor images (upper right). The RMS errors relative to the nature run for various vertical layers is tabulated at bottom. All results are valid for a simulated hurricane.

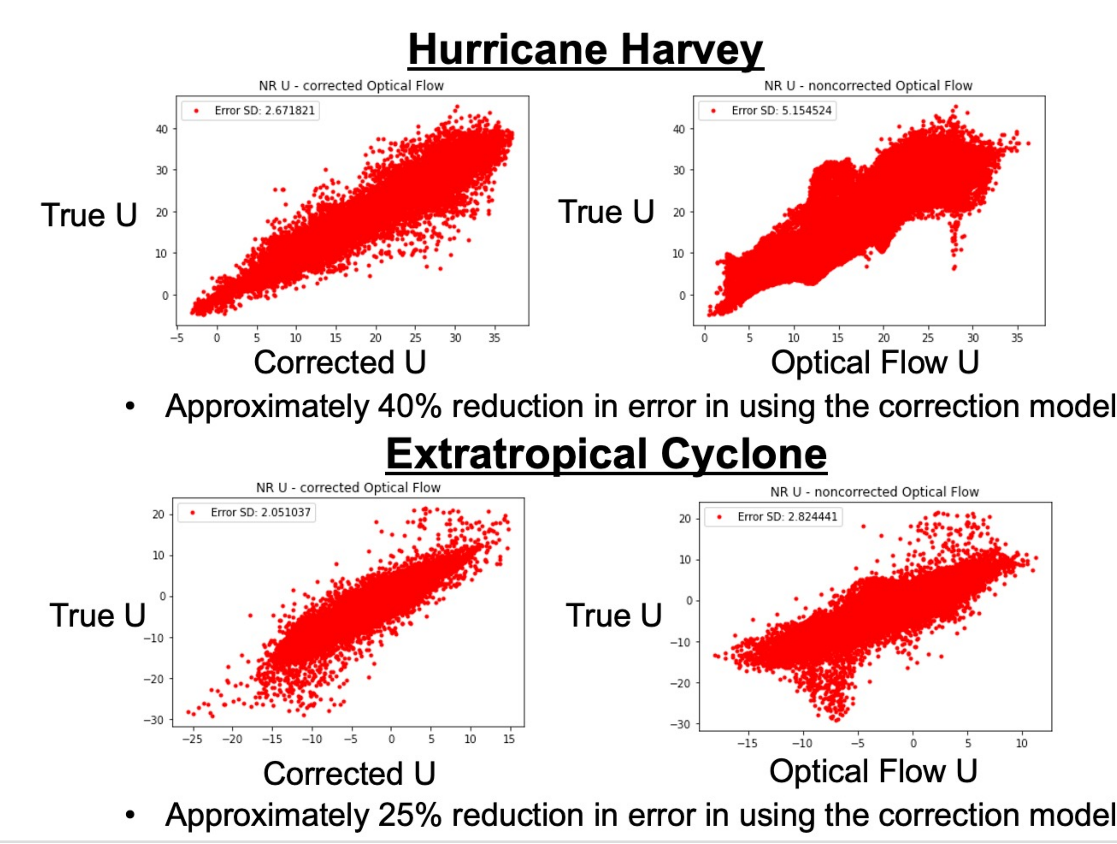


Figure 3. Analysis of the nature run ("true") u (west-east) direction winds vs those retrieved from the optical flow algorithm (right column) and vs those that have been corrected using information from a notional doppler wind lidar (left column).

FY22 Progress:

1. Optimized an optical flow algorithm and demonstrated significantly reduced AMV retrieval errors.
2. Developed a ML model for lidar wind and AMV data fusion.
3. Won a NOAA Broad Agency Announcement project to conduct trade space analyses for future NOAA winds missions.
4. Quantified uncertainty in current atmospheric winds analysis datasets, demonstrating space-based winds mission needs.
5. Built an end to end doppler wind lidar simulator.

Significance/Benefits to JPL and NASA: This proposal focuses on concept and technology maturation for Atmospheric Winds (AW). The concepts and technologies being matured under this initiative align directly with (and flow down from) NASA's observing system science and application priorities as described in the 2017 NASA Earth Science Decadal Survey for Earth Science and Applications from Space (ESAS17). They also align with JPL's and 8X's strategic plans, and offer new opportunities for utilizing JPL's key capabilities and product lines. This investment is urgently needed to ensure that JPL has high quality, selectable concepts for future NASA Earth System Explorer calls.

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