National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

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

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Strategic Focus Area: Earth System Explorer – Science Definition and Technology Maturation
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Objectives: Mature a mission concept for observing the global 3D distribution of atmospheric horizontal winds across the whole troposphere. The proposed work builds on past work on wind OSSEs by the project team. It combines established in-house OSSE modeling capabilities, machine learning data fusion, and passive sounding instrumentation expertise, science leadership from Univ. AZ, and strong technical support from Ball Aerospace. OSSEs quantify the benefit of new observations in the context of the program of record, and provide quantitative support to the decision-making process for identifying the most cost-effective and compelling mission architecture for ESE AW.

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.

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

T2) 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.

T3) Determine data sampling sufficiency for addressing science objectives on mesoscale convective systems (MCSs) using orbit simulators and nature run datasets.

FY23 Progress:

1. Strengthened and refined the science requirements for a 3d winds mission.
2. Improved the optical flow AMV algorithm, and characterized its performance for a diverse set of weather systems.
3. Prototyped a machine learning model for lidar wind and AMV data fusion.
4. Conducted a costing exercise to determine the feasibility of flying a passive mission alongside Aeolus. Found that a Class-C passive only mission fits within the ESE cost cap, while a Class-D mission fits within the expected EV-M cost cap
5. Submitted three manuscripts for publication (see reference below).

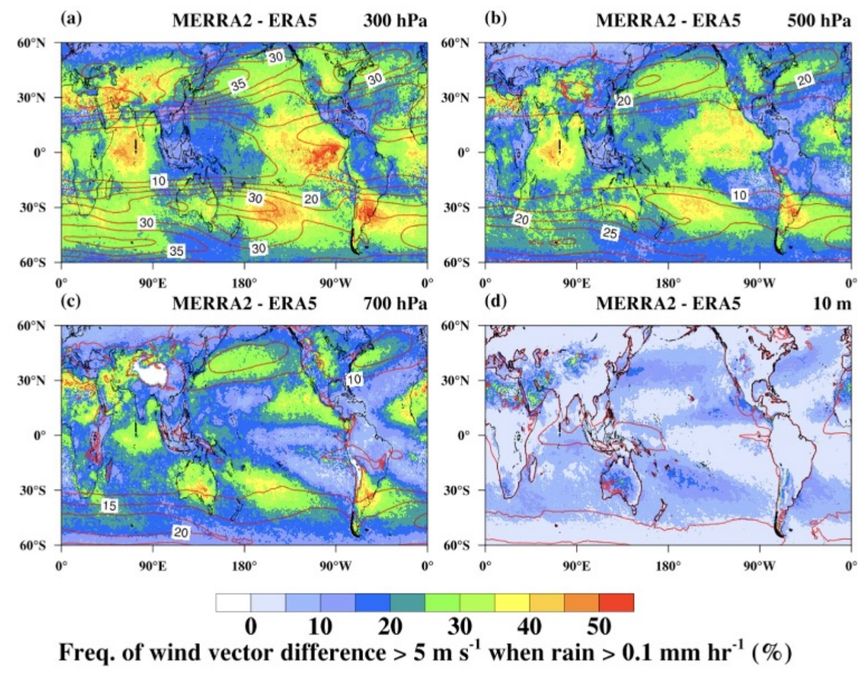

Figure 1.

Frequency (%) of wind vector difference > 5 m s-1 between MERRA2 and ERA5 when IMERG precipitation > 0.1 mm hr-1: (a) 300 hPa; (b) 500 hPa; (c) 700 hPa; and (d) 10 m. Red contour lines are the mean wind speed in ERA5 from 2017-2021.

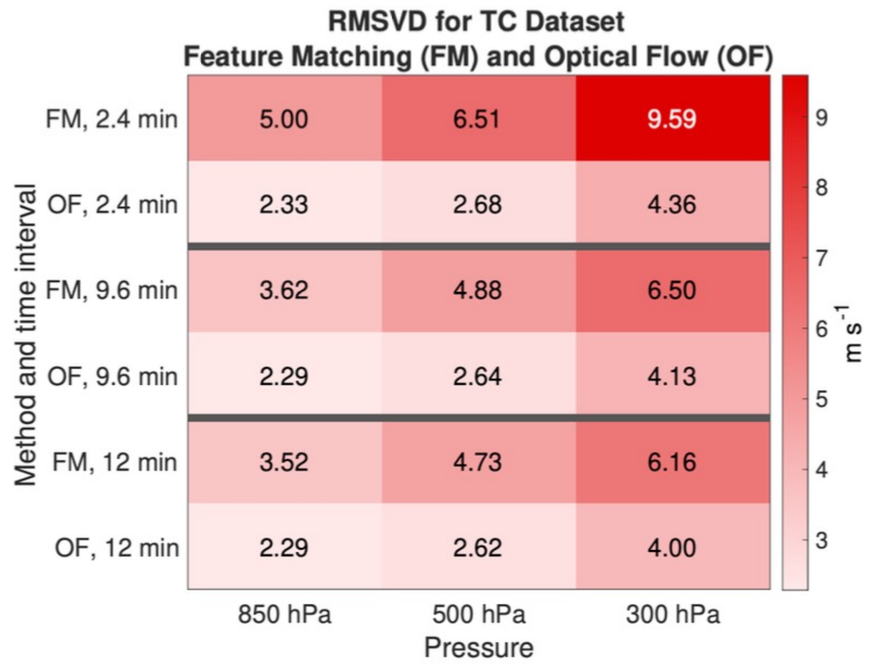

Figure 2.

RMSVD errors obtained using the feature matching (FM) and optical flow (OF) methods are presented for a tropical cyclone (TC) dataset at various time intervals and pressure levels. The optical flow algorithm demonstrates an average improvement of 45.9% in AMV accuracy compared to the feature matching algorithm.

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. They are applicable to the ESE opportunity, future Earth Venture Mission (EVM) opportunities, and future (2027) Decadal Survey opportunities.

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Publications:

Wu, L., H. Su; X. Zeng; D. J. Posselt; S. Wong; S. Chen; and A. Stoffelen, 2023: Uncertainty of Atmospheric Winds in the Reanalysis Datasets. J. Appl. Meteor. Clim., Conditionally Accepted.

Yanovsky, I., D. J. Posselt, L. Wu, and S. Hristova-Veleva, 2023: Quantifying Uncertainty in Atmospheric Winds Retrieved from Optical Flow: Dependence on Weather Regime. J. Appl. Meteor. Clim., Submitted

Zeng, X., H. Su, S. Hristova-Veleva, D. J. Posselt, and co-authors, 2023: Vientos - A new satellite mission concept for 3D wind measurements by combining passive water vapor sounders with Doppler wind lidar. Bull. Amer. Meteor. Soc., Conditionally Accepted.

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