First Observations from the Winds Cross-Track Instrument on the Dynamo 2 Mission

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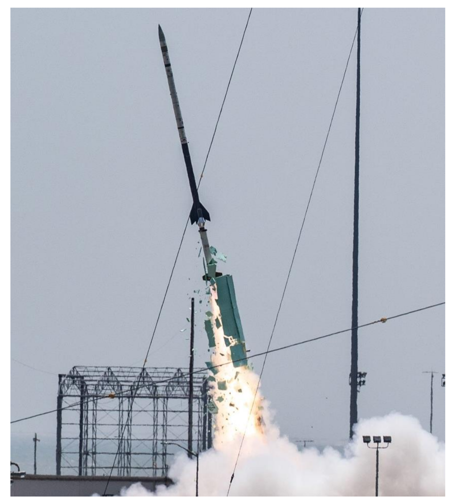


Introduction

The E-region (~90-130 km) is the transition region between neutral and ionized gas populations. Currents formed in this region sustain the global dynamo current system. To study the strong, meridional currents, two sounding rockets were launched as a part of the Dynamo 2 mission.

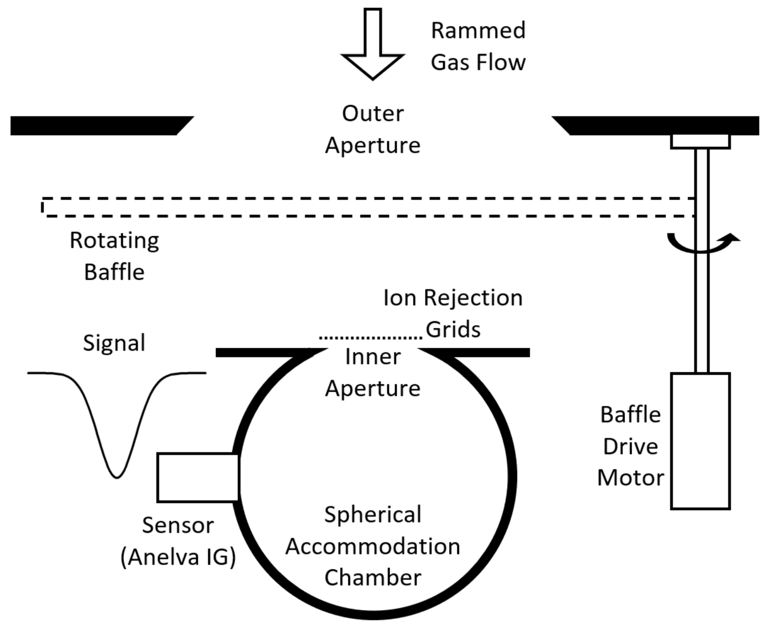
One central science objective was to characterize the Dynamo equation. For this goal, a neutral wind measurement is crucial. The Winds Cross-Track (WCT) instrument, flown for the first time, provided *in situ* measurements of the wind velocity components perpendicular to the spacecraft velocity.

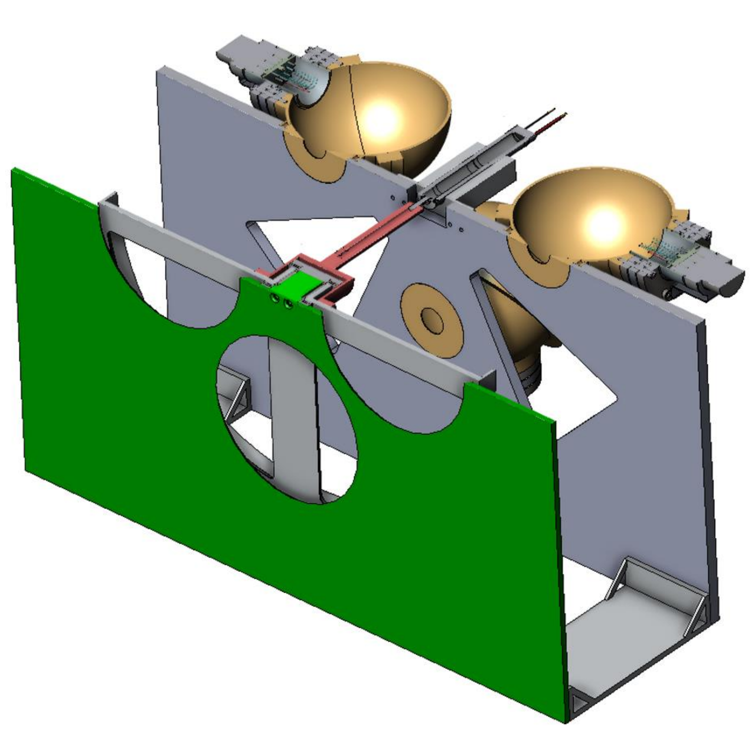
The WCT has high time (8 samples/sec; ~125-250 m spatial resolution) and wind resolution (~1–2 m/s from model results).

The Winds Cross-Track Instrument

The WCT is designed to measure *in situ* the cross-track components of the wind with high resolution. It can also measure the thermal velocity, mean mass and temperature of the neutral gas.

Ambient neutral gas is rammed into the WCT by the spacecraft, where a rotating baffle modulates the incoming gas. The gas then enters an accommodation chamber, where an Ionization Gauge (IG) measures the density of the gas. The signal forms a wake as the flow is modulated, forming a minimum when the baffle is aligned with the wind vector. The displacement of the minimum indicates the cross-track component of the wind.



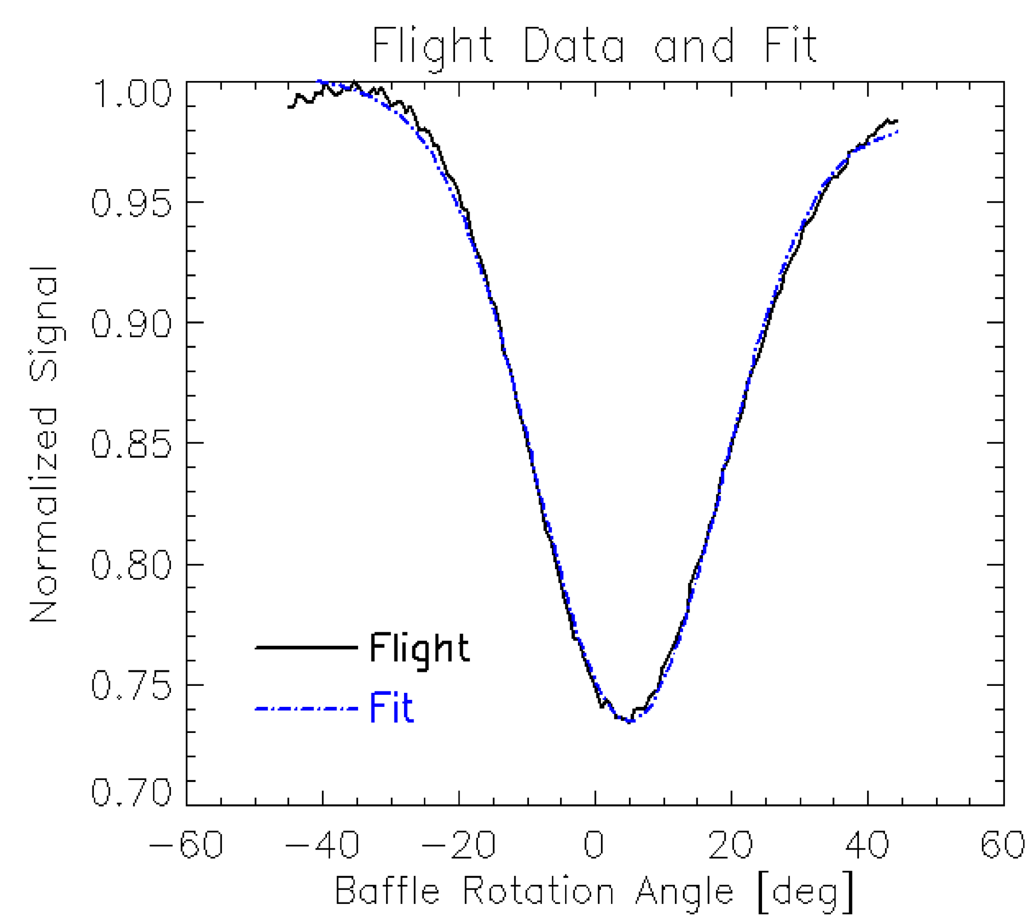


A cutaway of the current WCT design. The motor shaft drives the rotating baffle. Chambers with attached IGs are seen (4 total).

To obtain a full wind vector, the in-track component is also needed. A sister instrument to measure this component, the Winds In-Track, was also flown, though further development is needed.

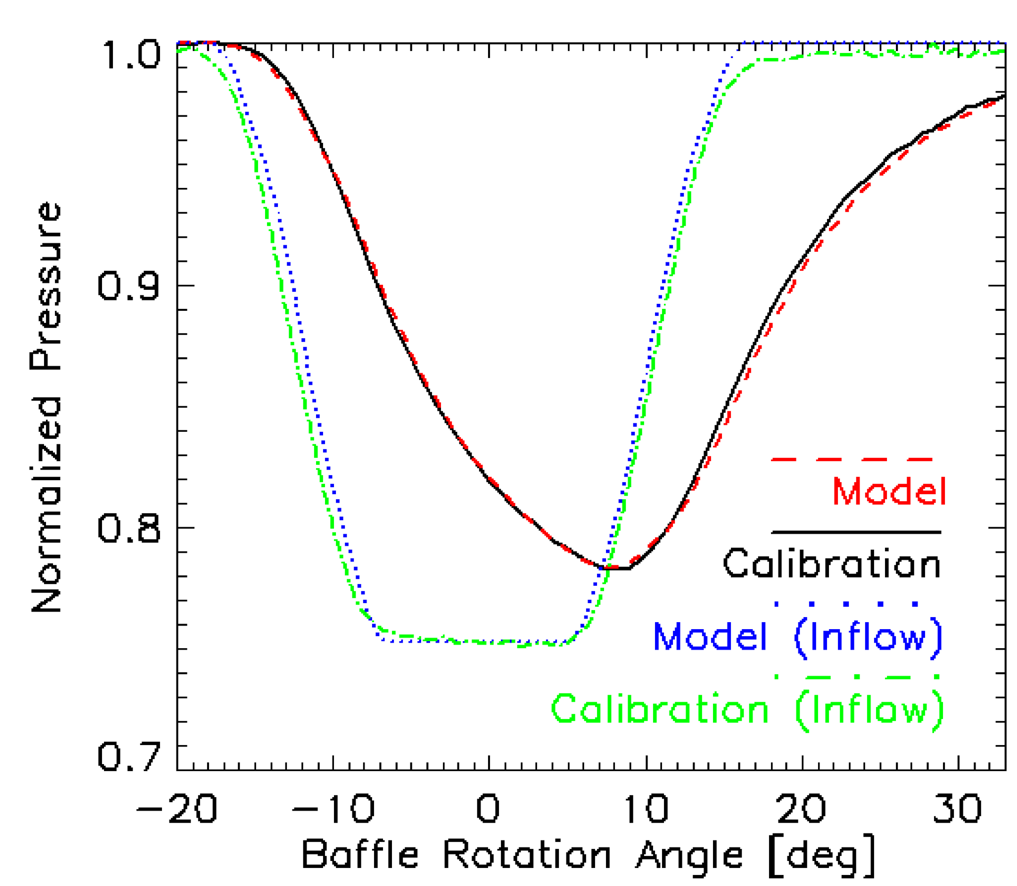
Methodology

Flight data is first separated into samples. An optical sensor monitored the rotation of the baffle wheel and sent a pulse when a blade passed, demarking the sample boundaries. Each sample is fit with a skewed Gaussian. Accounting for other factors, such as the change in density as the rocket changes altitude, would improve this step further.



The fit parameters are then converted to gas measurements. The gas parameters (e.g., wind velocity) were found to depend non-linearly on multiple fit parameters, making a one-to-one conversion difficult. Thus, a machine learning model (Sequential) was trained with a library of model results. The model predicts the gas parameters with an error of ~1-2%.

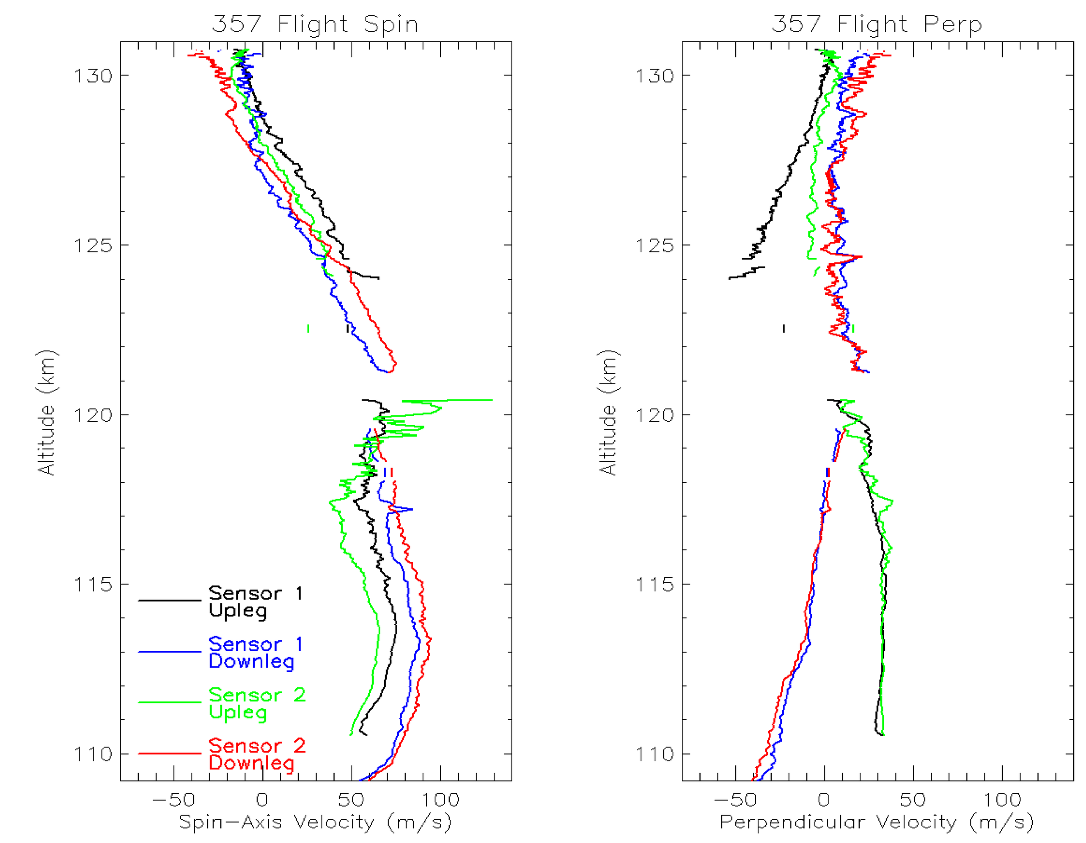
The accuracy of the model was verified with calibration data.



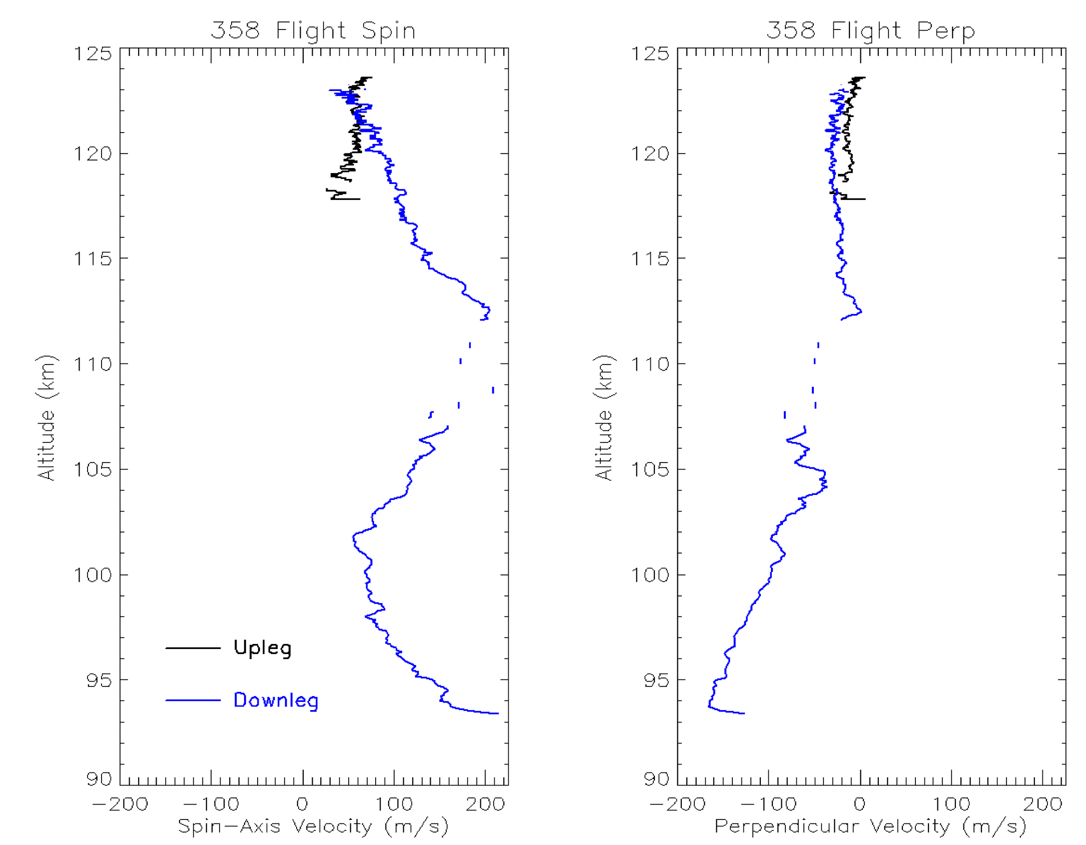
The measured angles are then scaled with the ramming velocity. To get true wind velocities, the rocket velocity is subtracted off.

The next step is to rotate into a stationary coordinate system, such as ENU. However, the third component (in-track) was not directly measured. Thus an assumption (e.g., the vertical component of the wind velocity being negligible) will be needed to obtain a full wind vector. This is an area of active work.

Dynamo 2 WCT Flight Data

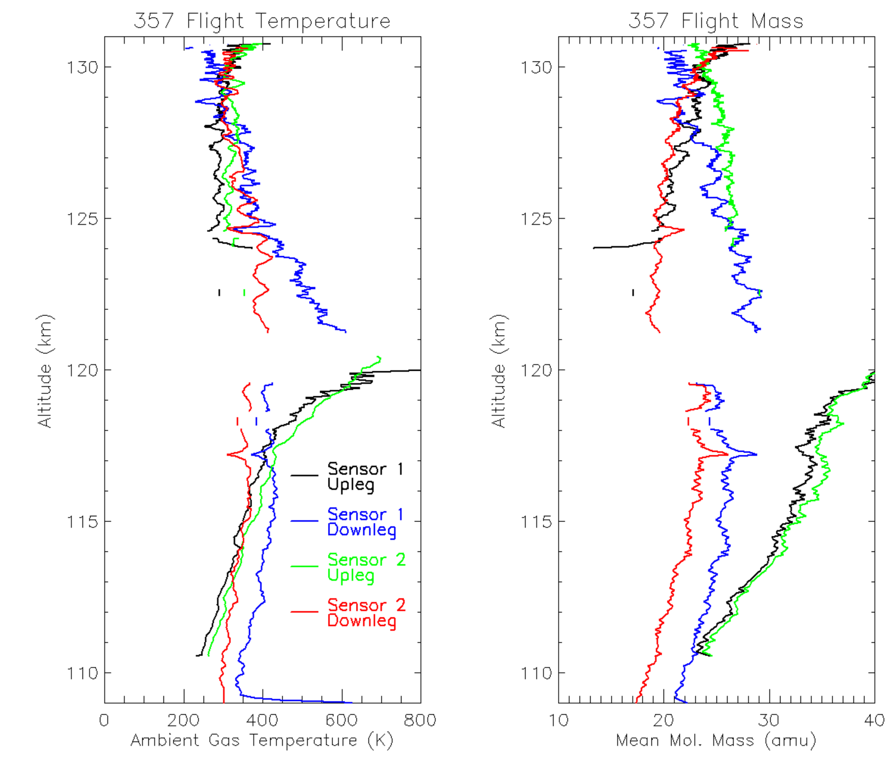


Wind profile in the instrument frame for the July 11 flight. Results from two sensor pairs are split between upleg and downleg. From these two components, velocity magnitude peaks at ~95 m/s between 110-117 km altitude.



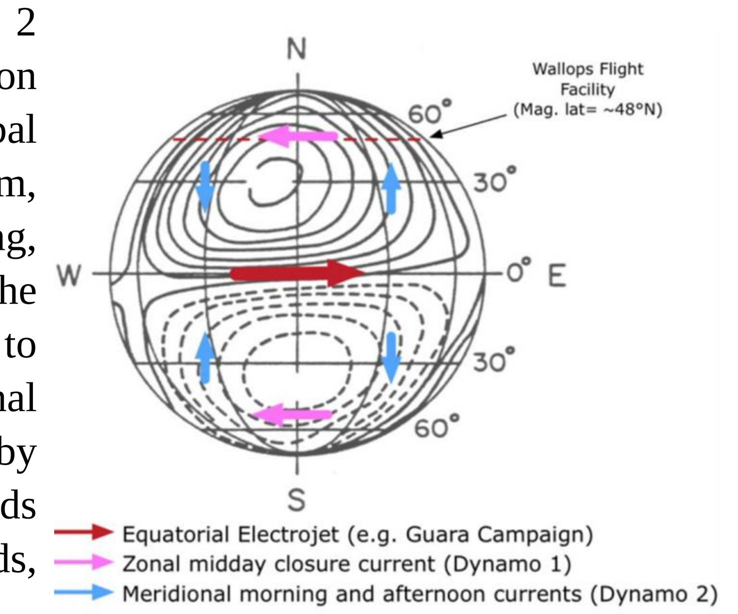
Wind profile in the instrument frame for the July 7 flight. For this flight, one sensor failed, so only one sensor pair is shown. The angle between rocket orientation and the velocity vector exceeded 15° for the first portion of the upleg, and is thus excluded. The velocity magnitude has two peaks, one at ~200 m/s near 112 km and the other at ~230 m/s near 95 km.

Measurements of gas temperature and mean molecular mass for the July 11 flight. Deviations between sensors indicate further work is needed but being within the correct value range is promising. Work is in progress.



The Dynamo 2 Mission

The goal of the Dynamo 2 Sounding Rocket Mission was to study the global Dynamo current system, specifically the strong, meridional currents. The central objective was to determine if the meridional currents were caused by enhanced neutral winds and/or large electric fields, or tidal motion alone.

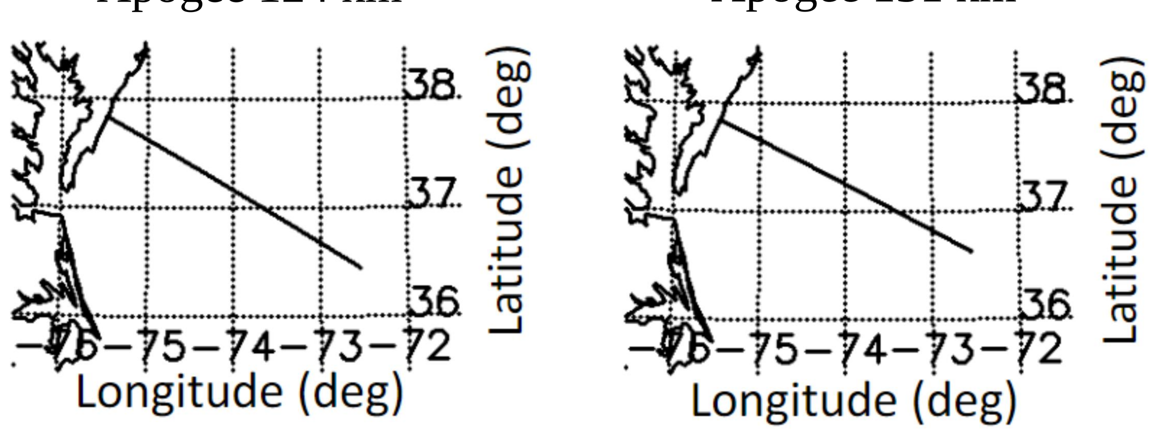


Measurements to support this objective included neutral wind and density, electric fields, plasma density, and currents.

Two sounding rockets were launched successfully in July 2021 from Wallops, VA for the Dynamo 2 mission.

July 7, 2021
Apogee 124 km

July 11, 2021
Apogee 131 km



Summary and Future Work

Key Points:

- The Winds Cross-Track instrument took successful measurements of the neutral wind during its maiden spaceflight
- The WCT is capable of measuring wind velocity, gas temperature, and mean molecular mass at high time resolution (8 samples per second)
- For the July 7th flight, from the cross-track wind velocity components, the wind velocity magnitude peaks twice above 200 m/s at altitudes of ~95 and 112 km

Future Work:

- Work to find the in-track component, or a reasonable assumption, will provide a full 3D wind profile
- Slate of minor improvements, such as accounting for density changes and optimizing the machine learning model, to improve the accuracy of the wind measurements
- Improvements to the consistency of the temperature and mean molecular mass calculations of the ambient gas

Acknowledgments

The authors look forward to incorporating these results into the larger science of the mission and are thankful to all members of the Dynamo 2 team for a successful mission.