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Winds in the upper atmosphere and radio science: A fireside chat

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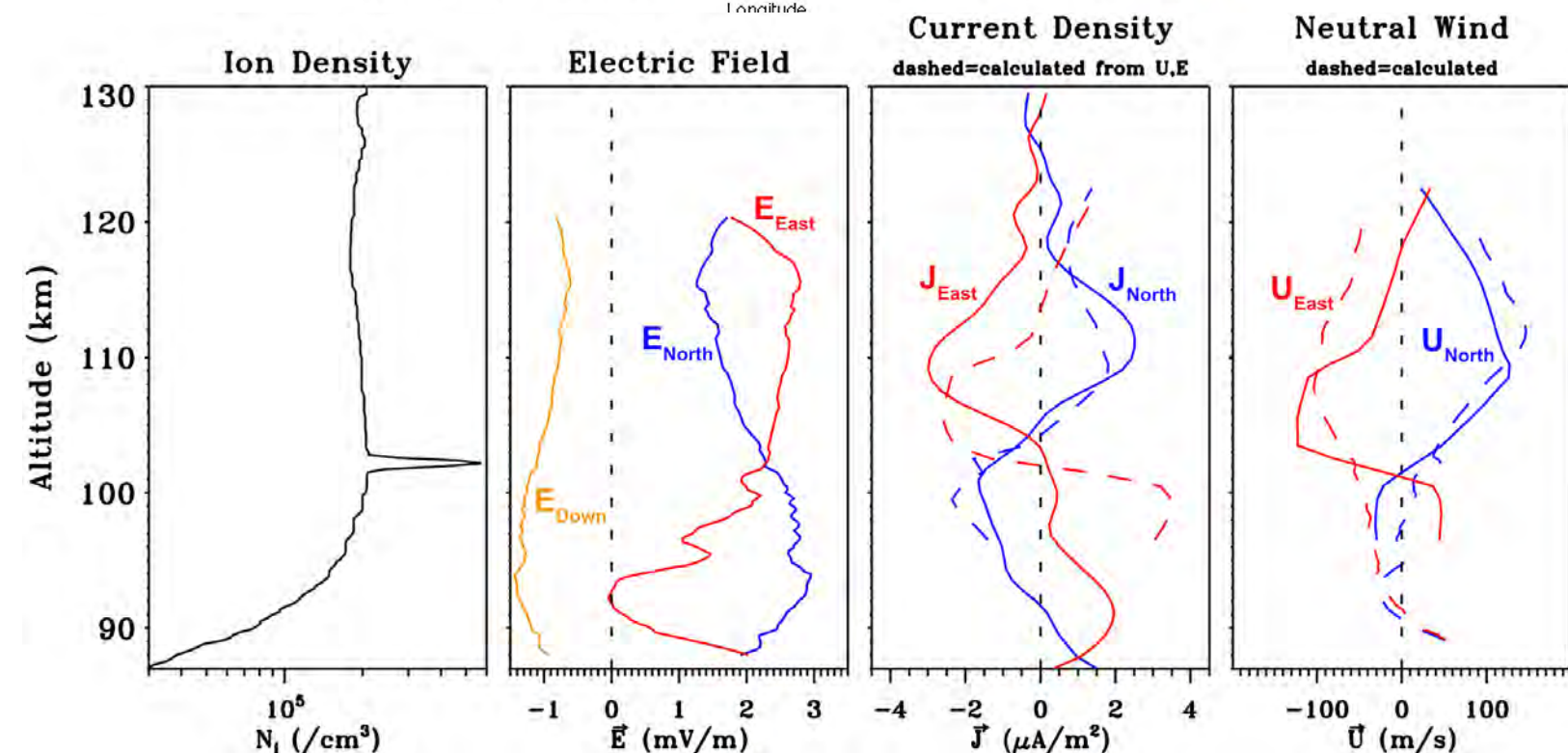
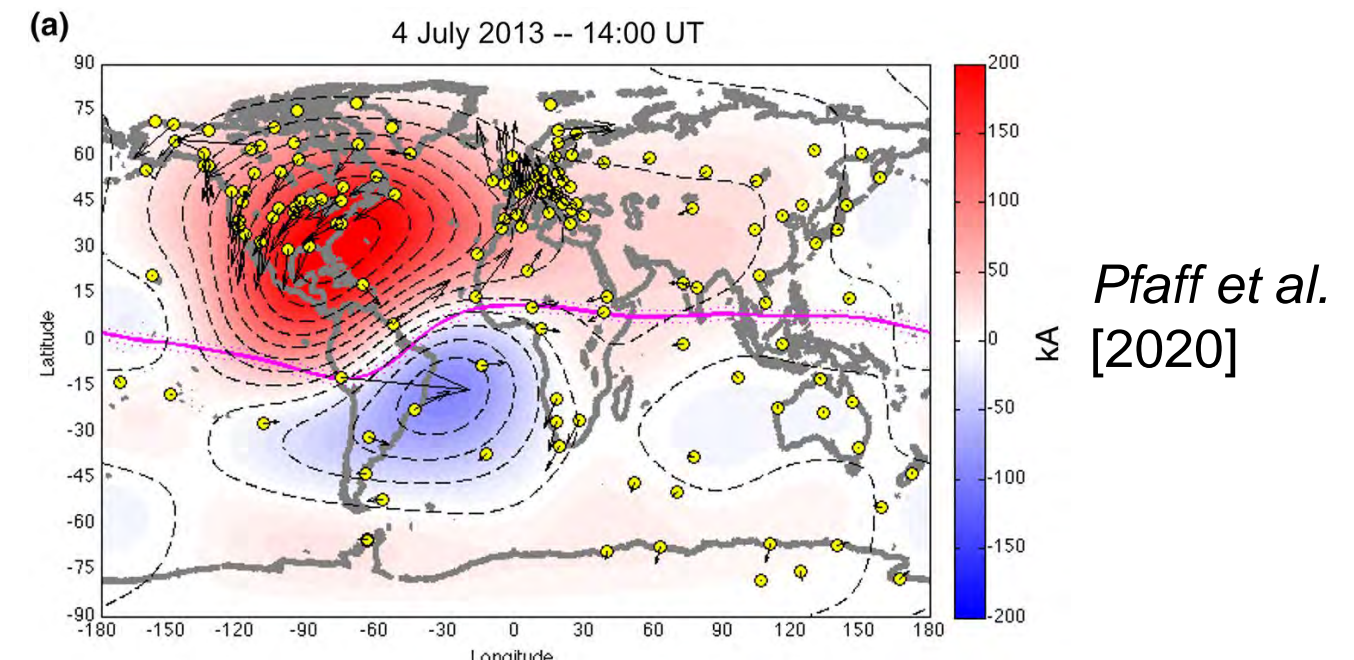
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Introduction

- Wind measurements and radio science are naturally complementary
 - The intertwined nature of the ionosphere and neutral atmosphere require study as a single system
- Science – examples that feature *in situ* wind measurements
 - Daytime Dynamo
 - Equatorial Temperature and Wind Anomaly
- Instruments – instruments under development at UNH
 - Cross-track winds instrument
 - In-track winds instrument
 - Imaging winds instrument
- Science applications utilizing winds measurements
 - LLITED
 - AETHER
 - GDC, and beyond
- The winds - radio science connection – specific collaborations
 - AETHER
 - Rockets from Wallops

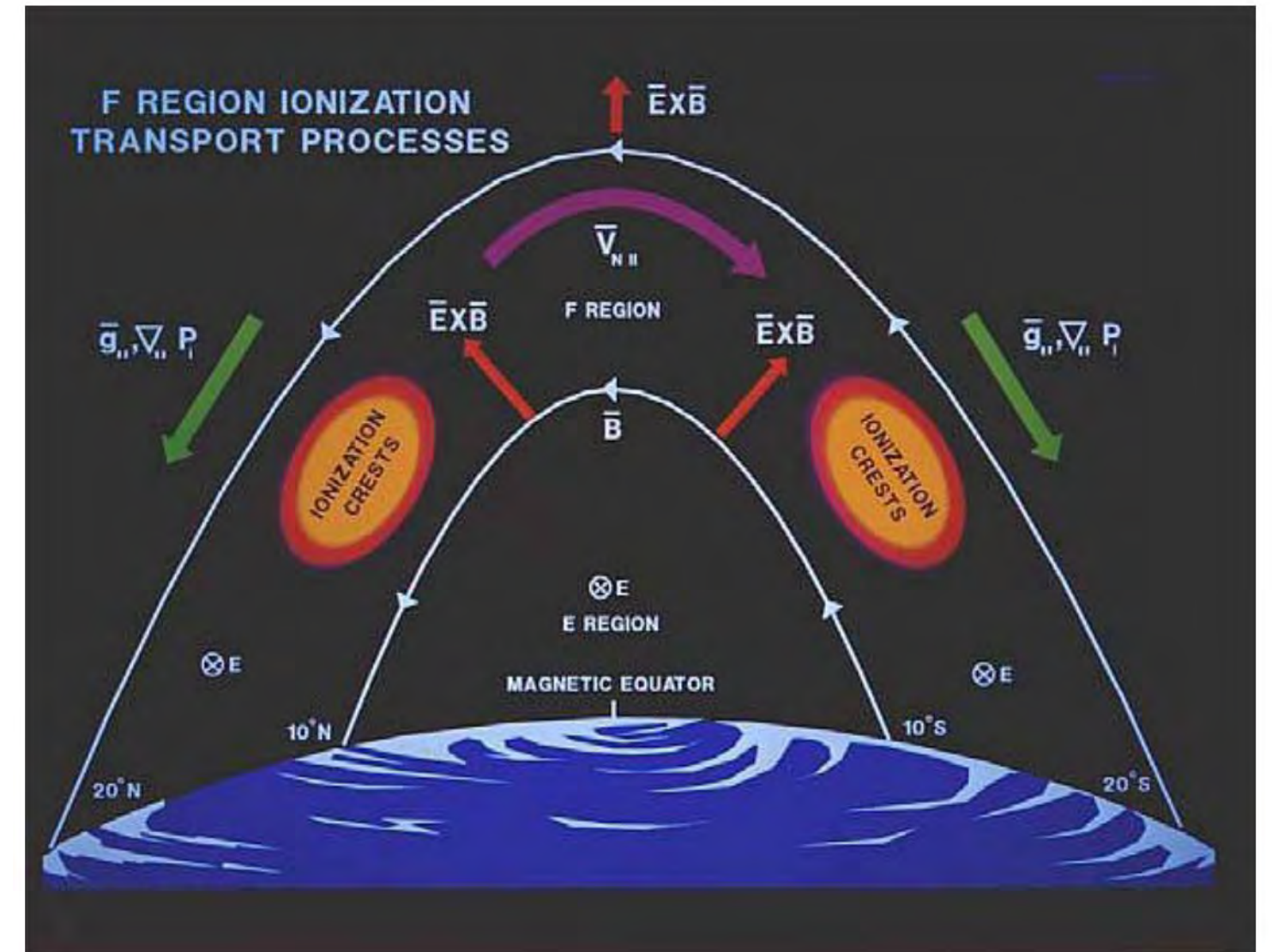
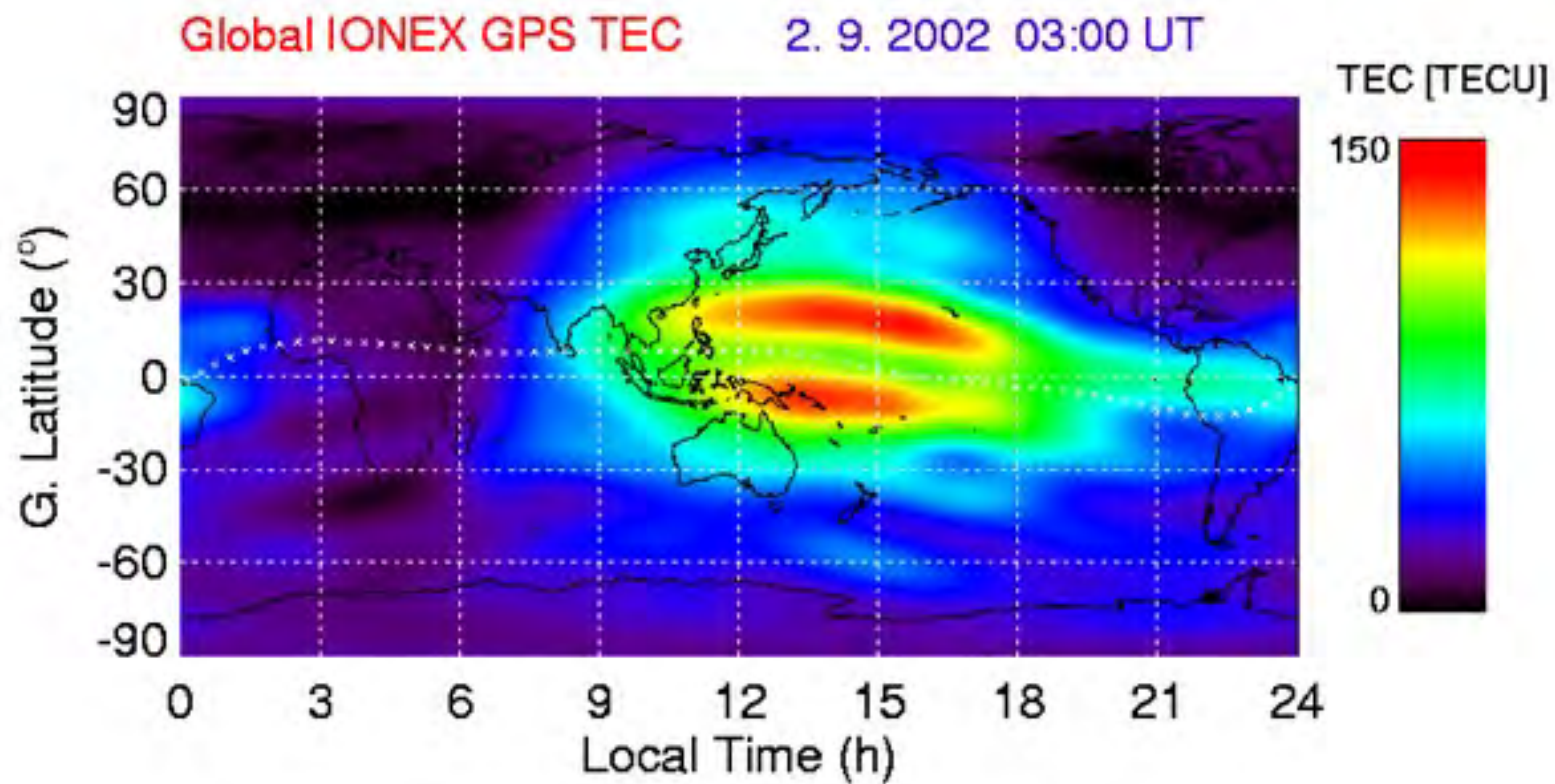
Winds in the Daytime Dynamo

- The Sq (solar quiet) ionospheric currents are driven by a dynamo set up in the ionosphere
- Winds are important for driving the dynamo
- In this rocket experiment performed at Wallops Island, VA, the current was surprisingly structured as a function of altitude
- The winds were also a surprise: larger than predicted by tidal theory
- The electric fields were also larger than expected, with the overall combined result yielding the observed currents
- This experiment will be repeated for more active conditions this summer



Equatorial Temperature and Wind Anomaly

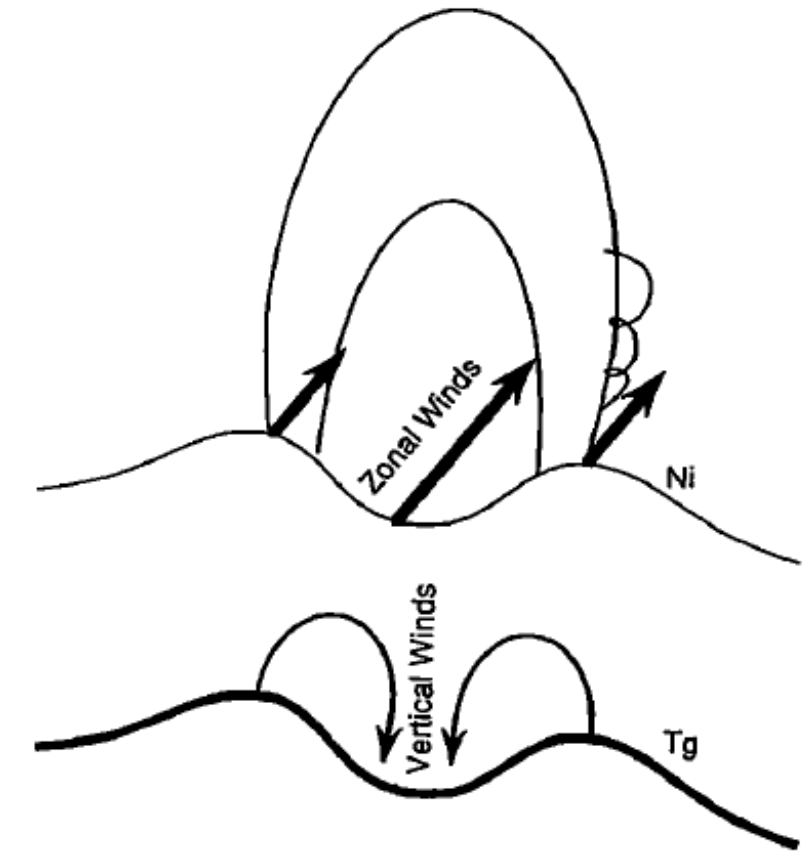
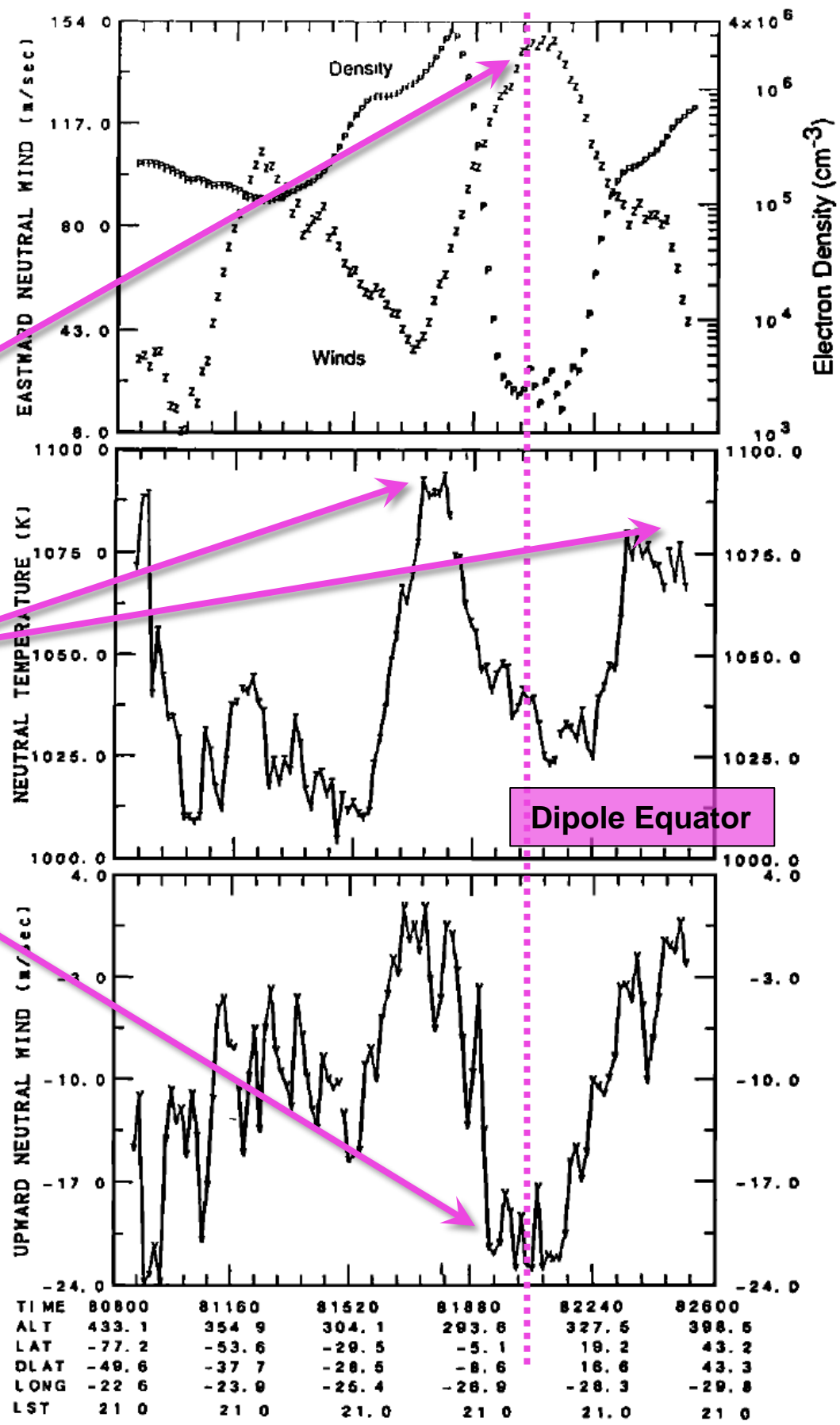
- Begins with the equatorial ionospheric anomaly
- Add some winds and ion-neutral coupling



DE-2 data at dusk: ETWA

- Strong zonal winds at equator
- Neutral temperature enhancements above and below equator
- Downward vertical winds at equator
- No meridional winds available

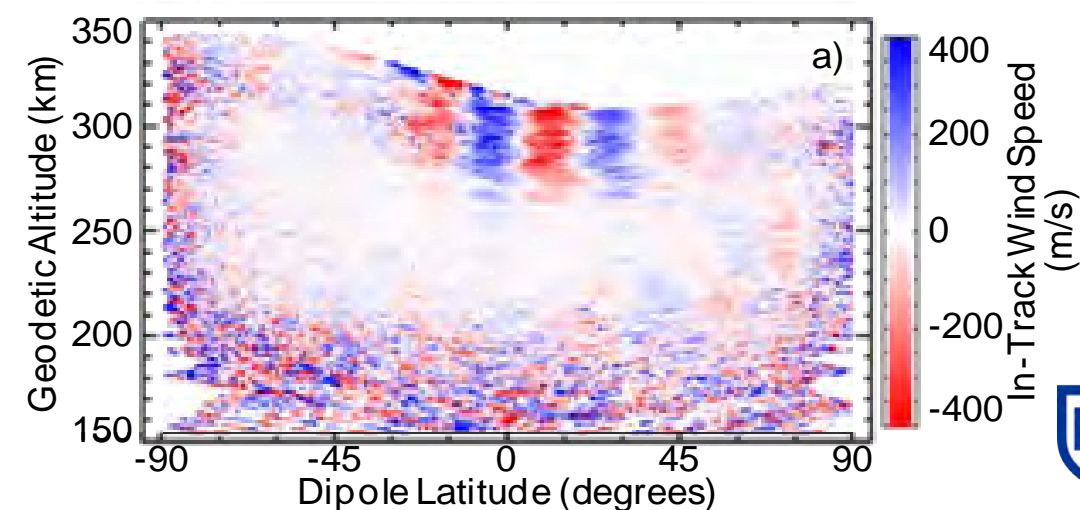
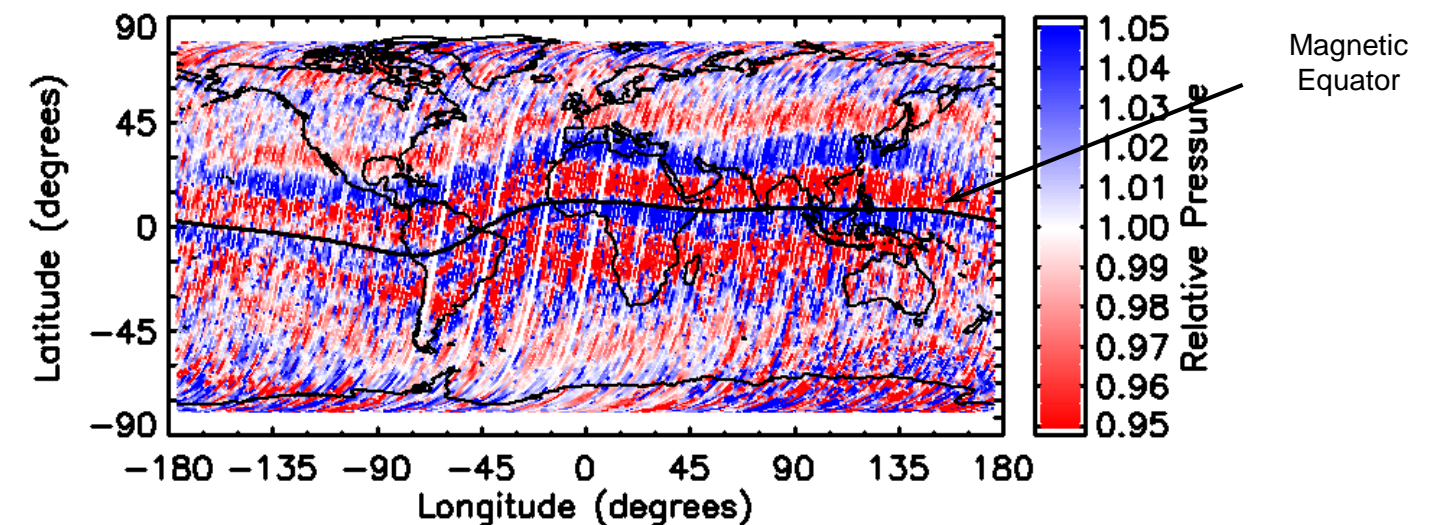
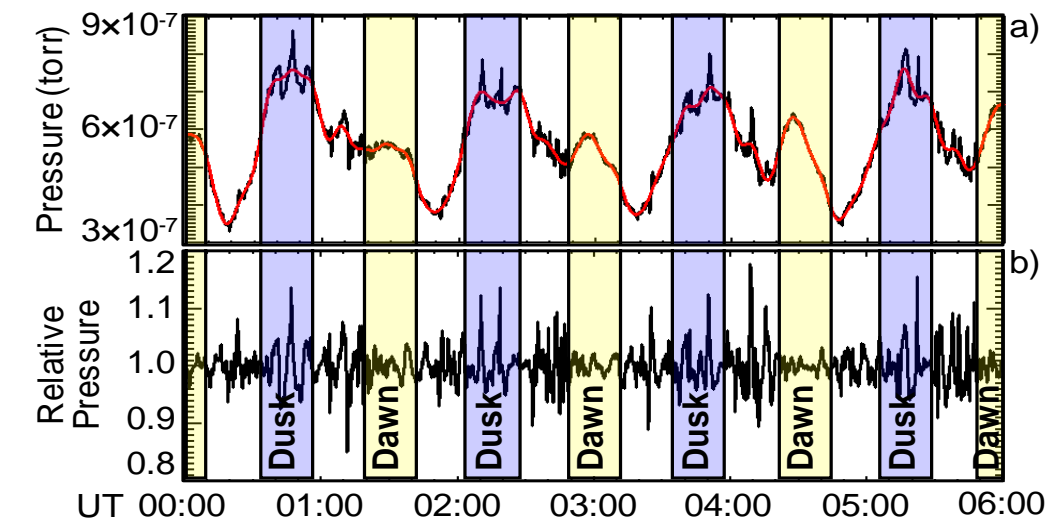
Dynamics Explorer-2 (Orbit 3838, Day 82107)



Raghavarao et al., 1993

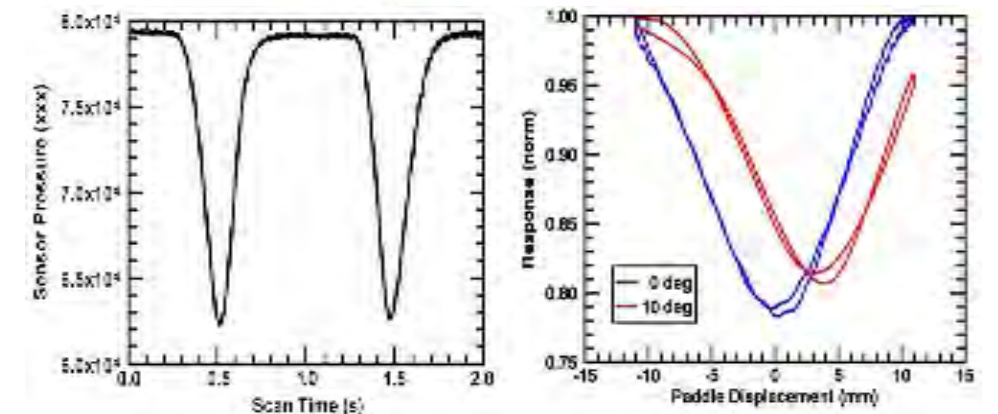
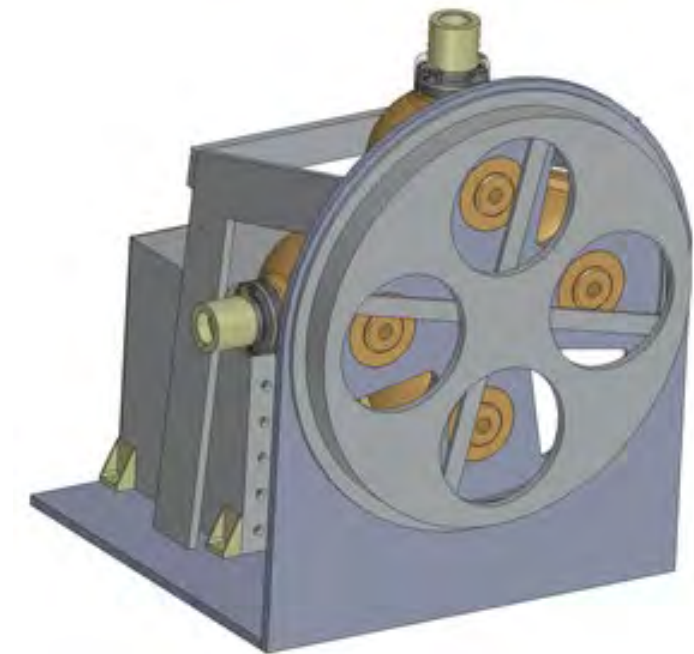
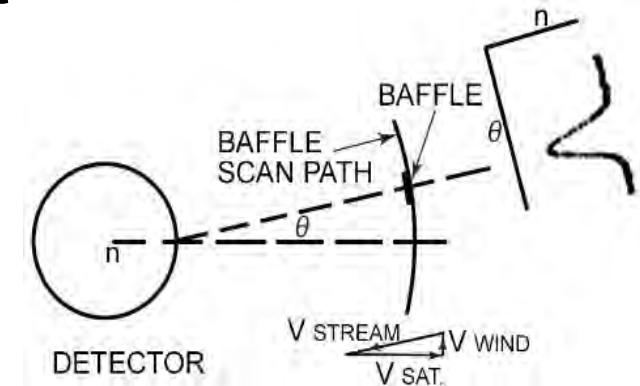
Equatorial Temperature and Wind Anomaly

- The Streak mission flew in 2005-2006 with a single science instrument – a ram pressure sensor based on an ionization gauge (IG)
- The dawn-dusk orbit provided 16 passes per day through the EIA/ETWA region
- Alternating enhancements and diminishments were seen in the IG pressure data
- The pattern in the data showed an obvious connection to the magnetic field, implicating plasma
- Analysis showed that the most likely explanation was the pattern of winds set up by the ETWA phenomenon
 - The meridional component mission from the DE-2 measurements
 - Very fast winds were inferred
 - Tidal structure was revealed in the winds



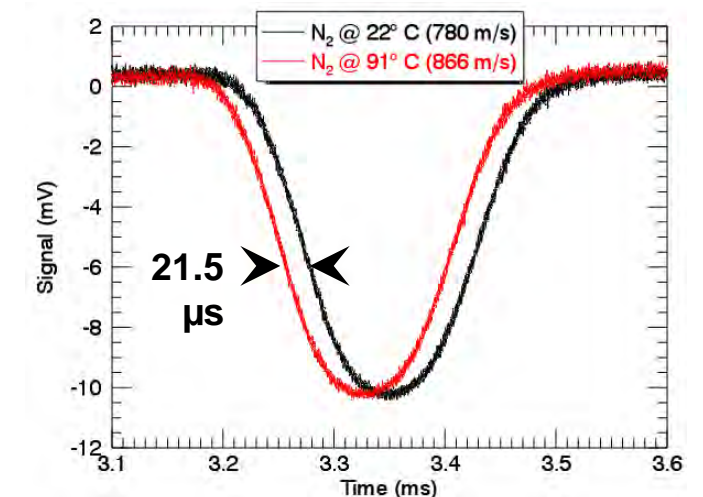
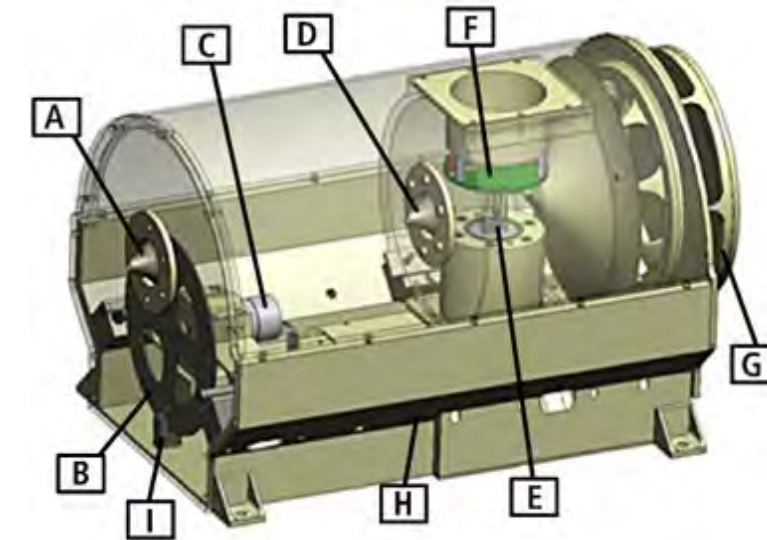
Cross-track winds instrument

- The WCT is based on the principles used on the WATS instrument on DE-2 [Spencer *et al.*, 1981]
- The ambient gas is admitted to an accommodation chamber through a scanning baffle system
- A pressure gauge monitors the chamber pressure
- In development is a new system based on rotating vanes that simplifies the implementation and improves performance
- The similar WCT (with reciprocating vanes) was tested in the laboratory and flown on a test rocket flight



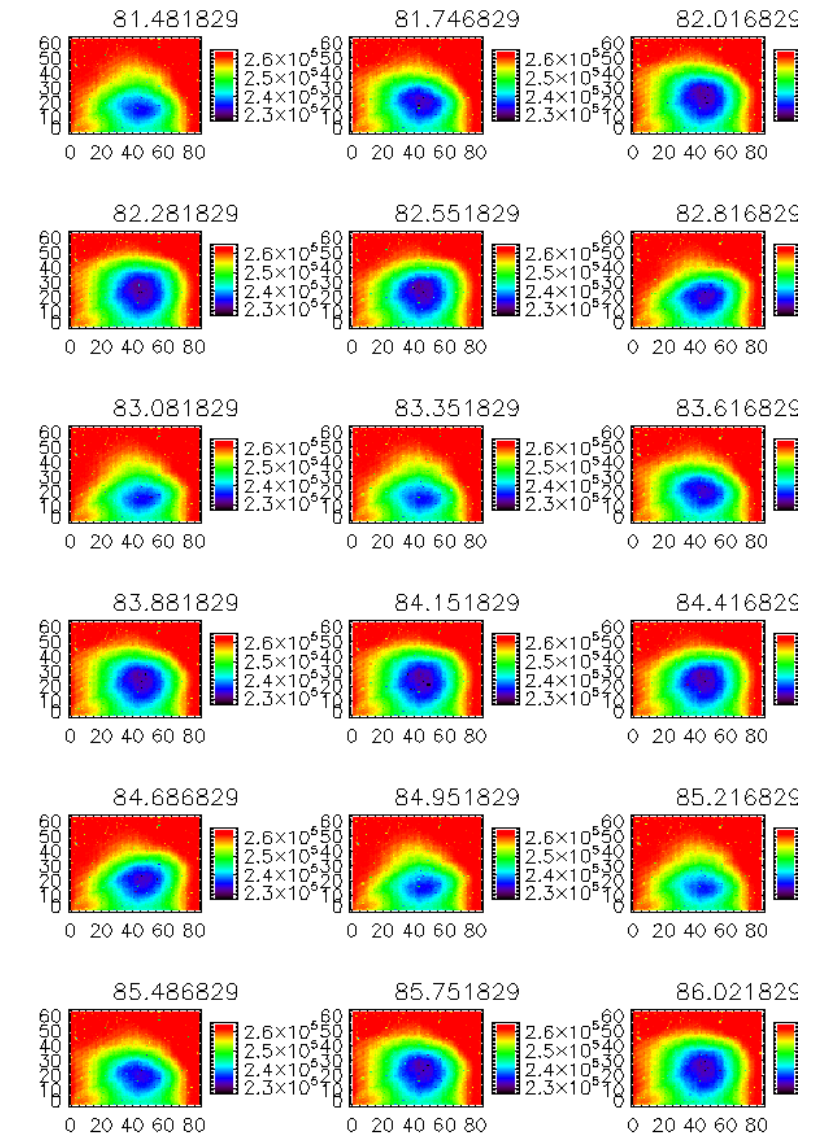
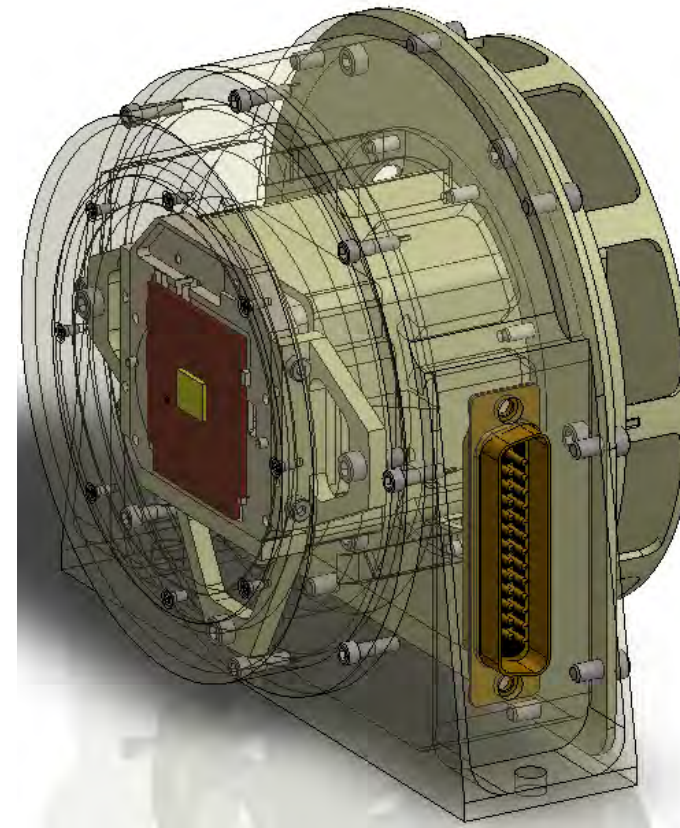
In-track winds instrument

- The WIT is based on a technique used to measure molecular beam speeds in the laboratory
- The admitted gas steam is modulated by a rapidly-spinning chopper wheel
- The admitted “puffs” of gas are measured by a fast pressure sensor to determine their time of flight in the instrument
- The first WIT was tested in the laboratory and flown on a test rocket flight
- Lessons learned are being incorporated in the WIT being prepared for for this summer’s Dynamo2 flights



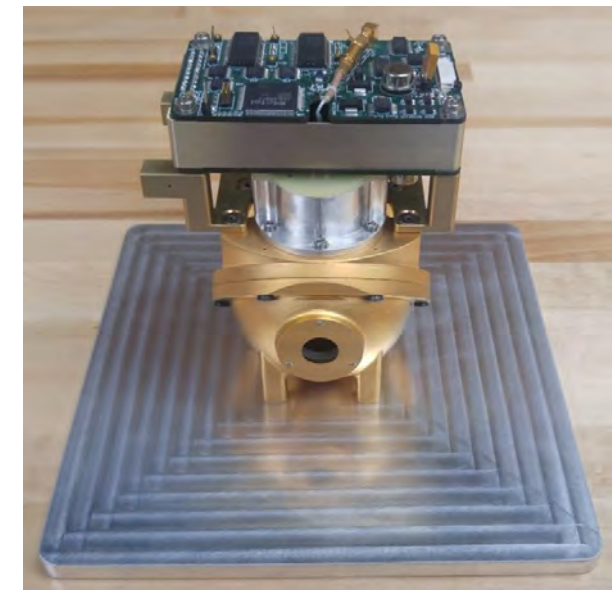
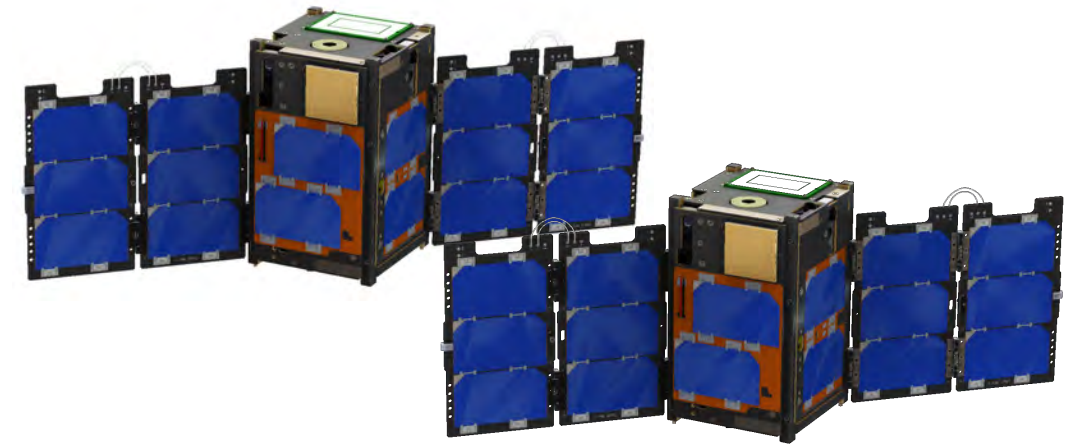
Imaging winds instrument

- Utilizes a pinhole camera geometry
- Rammed gas admitted into the instrument through a small aperture
- A sensitive windowless microbolometer array is used to image the pattern of arriving gas
 - No moving parts
- Very small (12 by 10 by 8 cm) and light (600 g)
- Flew on test rocket in 2017, being prepared for a new flight this summer



The MIGSI instrument for the LLITED mission

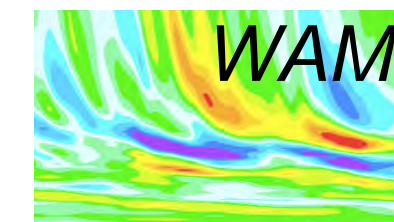
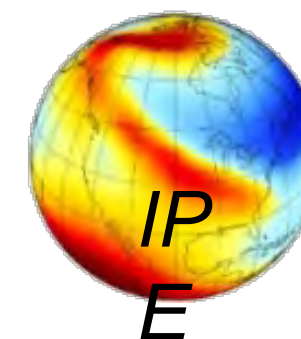
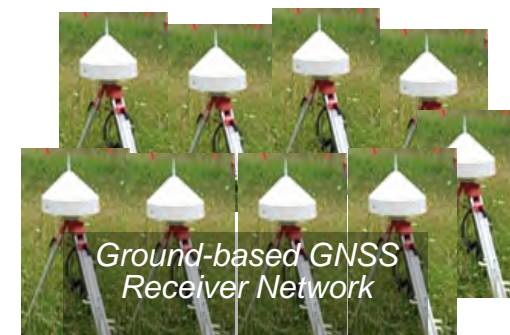
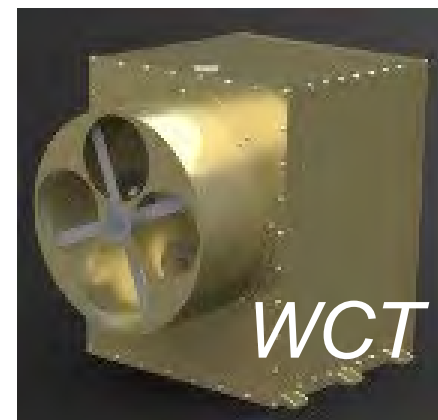
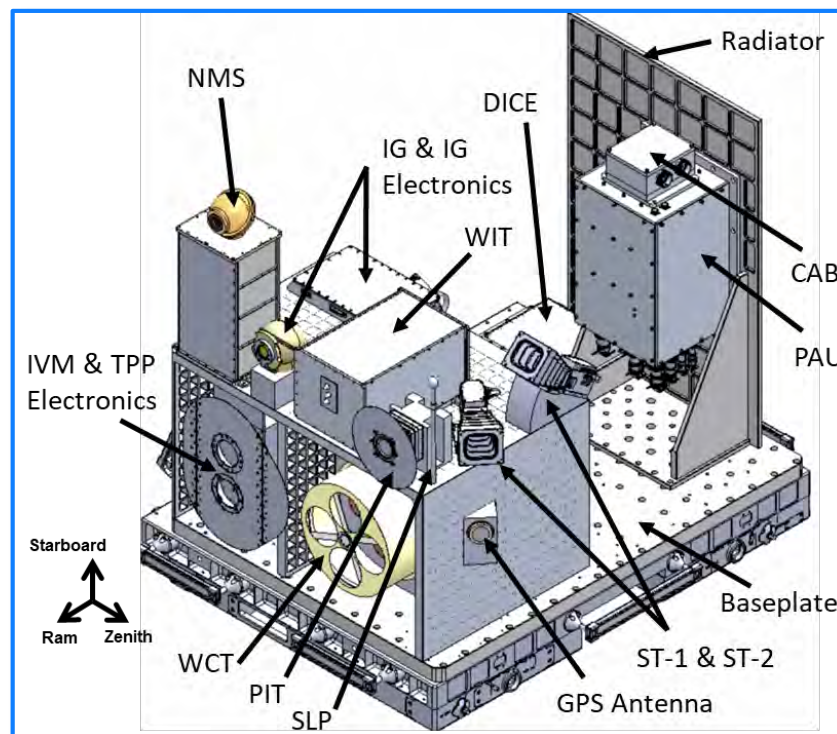
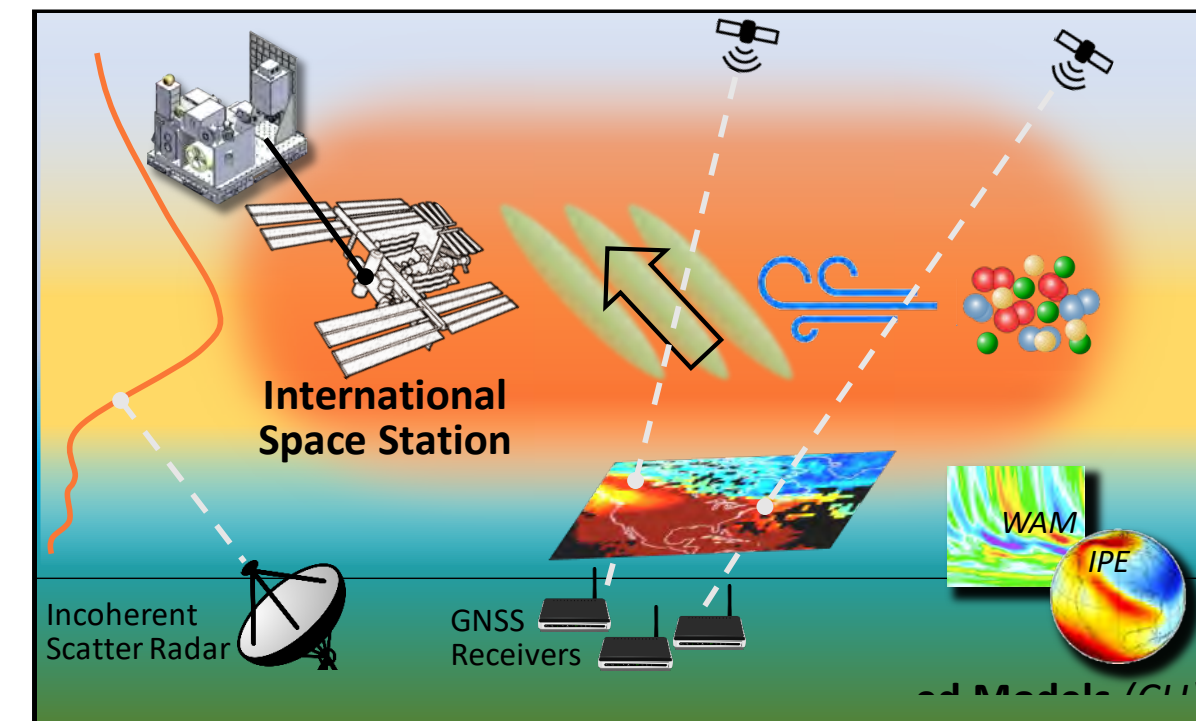
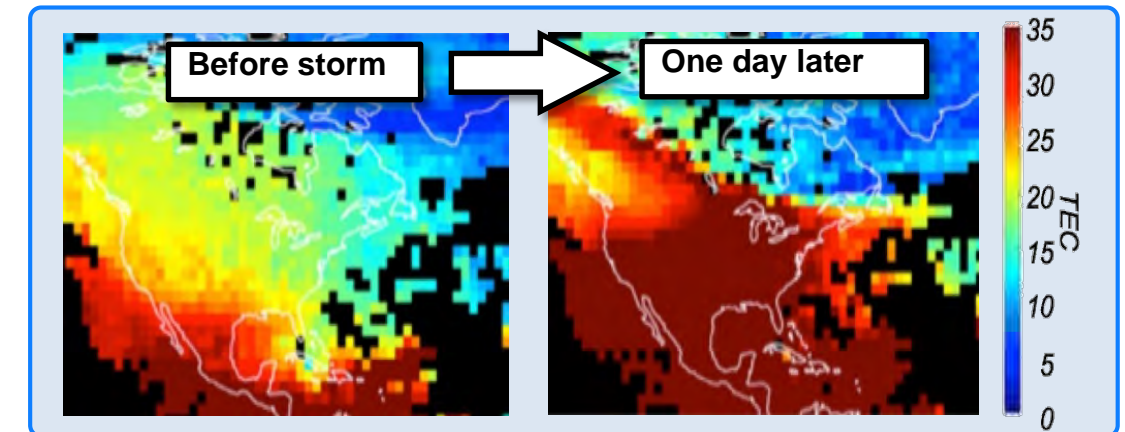
- The LLITED mission is based on a two-cubesat exploration of two interesting thermospheric phenomena
 - Equatorial Temperature and Wind Anomaly (ETWA)
 - Midnight Temperature Maximum
 - Rebecca Bishop is PI
 - Hoping to be launched in 2021
- MIGSI is a pressure sensor similar to what was flown on Streak, but smaller
- Will have the same ambiguities that Streak had, but has some complementary instruments
 - Langmuir Probe (A. Barjatya)
 - GNSS receiver
- Will provide good opportunities for collaborative radio science



MIGSI EM

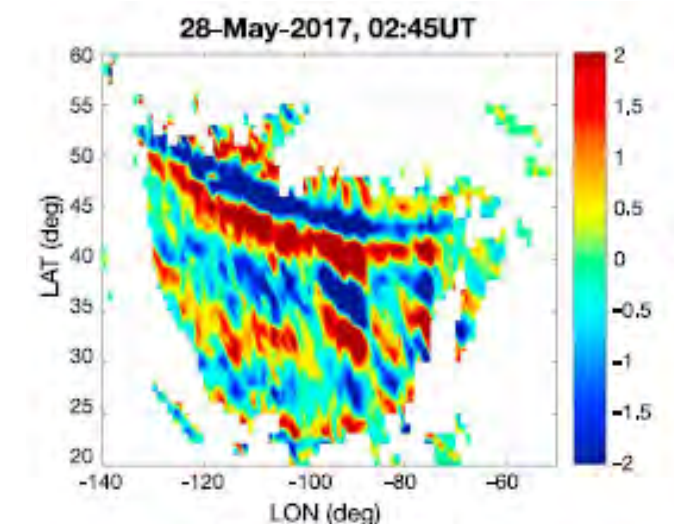
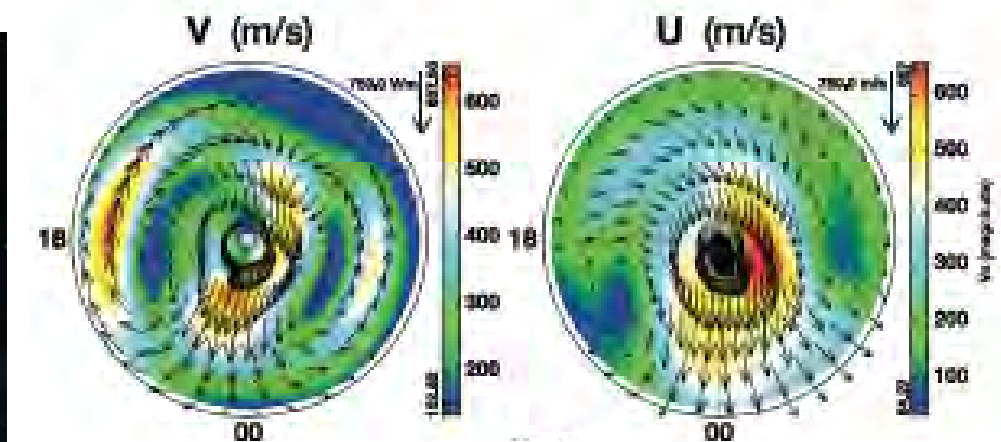
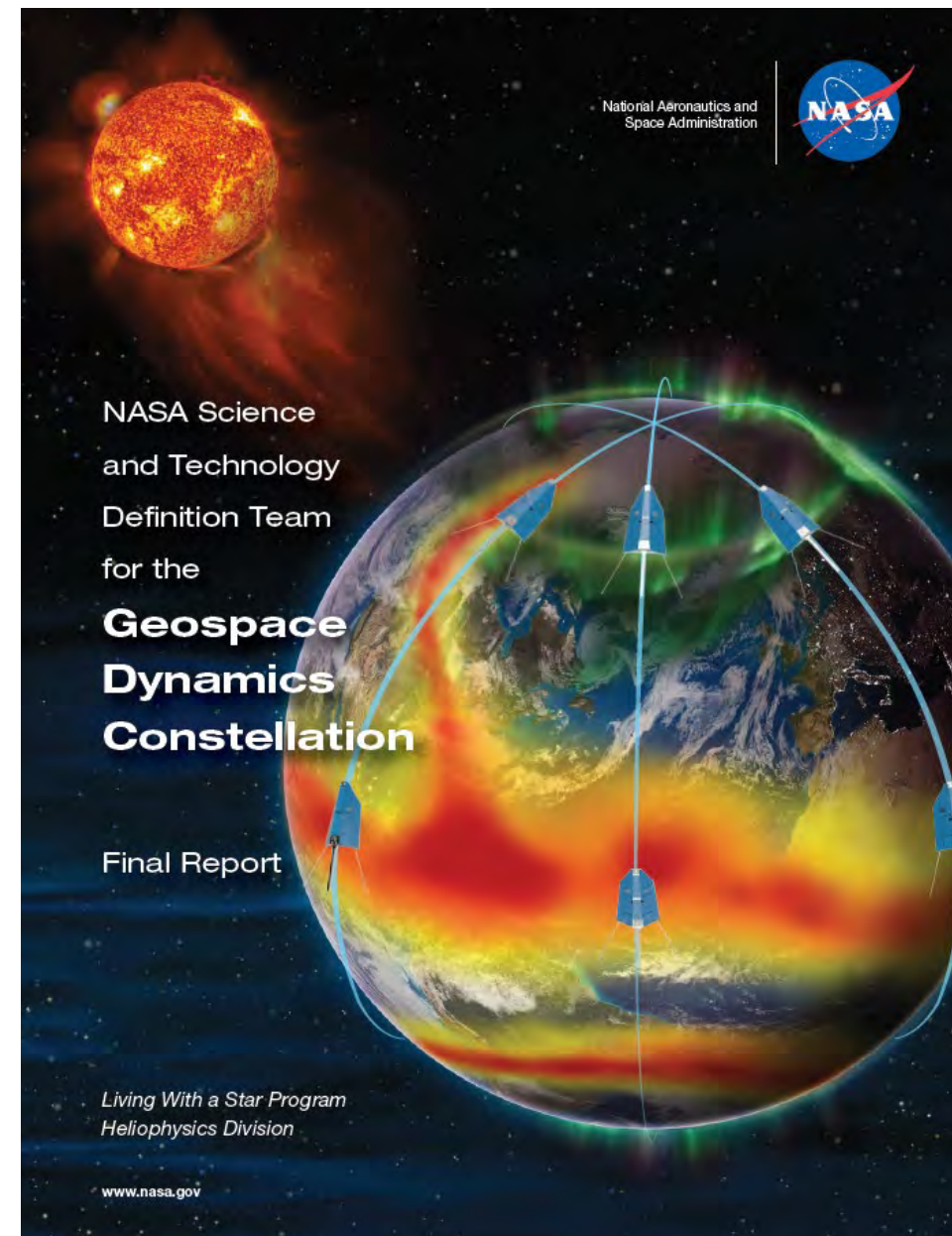
The AETHER mission

- The AETHER mission would investigate the causes of large plasma buildups caused by geomagnetic storms
- In situ neutral and plasma instruments are flown on the ISS including neutral winds instruments
 - Neutral winds are a key measurement objective
- Relies heavily on ground-based instruments and modeling
- Status – AETHER is presently completing a (competitive) Phase A study in preparation for a down-select early in the calendar year



The GDC mission and beyond

- GDC requires good winds measurements
- Ground-based radio science is a key element
- Missions like DYNAMIC are less developed, but also require winds measurements



Specific collaboration opportunities

- AETHER, if it flies, will provide significant opportunities for radio science collaborations
- The millstone Hill ISR is already included
- The global GNSS receiver array is already included
- Opportunities for further radio science collaboration opportunities will be abundant for this mid-latitude mission
- Several sounding rockets are launched from Wallops Island every year
- The midlatitude I-T system is a target for some of these rockets
- Past missions have involved radio science observations, usually with portable experiments
 - Sporadic-E has been a frequent target
- If I did my geometry right, the ionosphere over Wallops Island can be seen from Millstone Hill down to an altitude of about 150 km

