The Green-OAWL (GrOAWL) Airborne Demonstrator for the ATHENA-OAWL Mission Concept: System Progress and Flight Plans

International Winds Working Group Workshop

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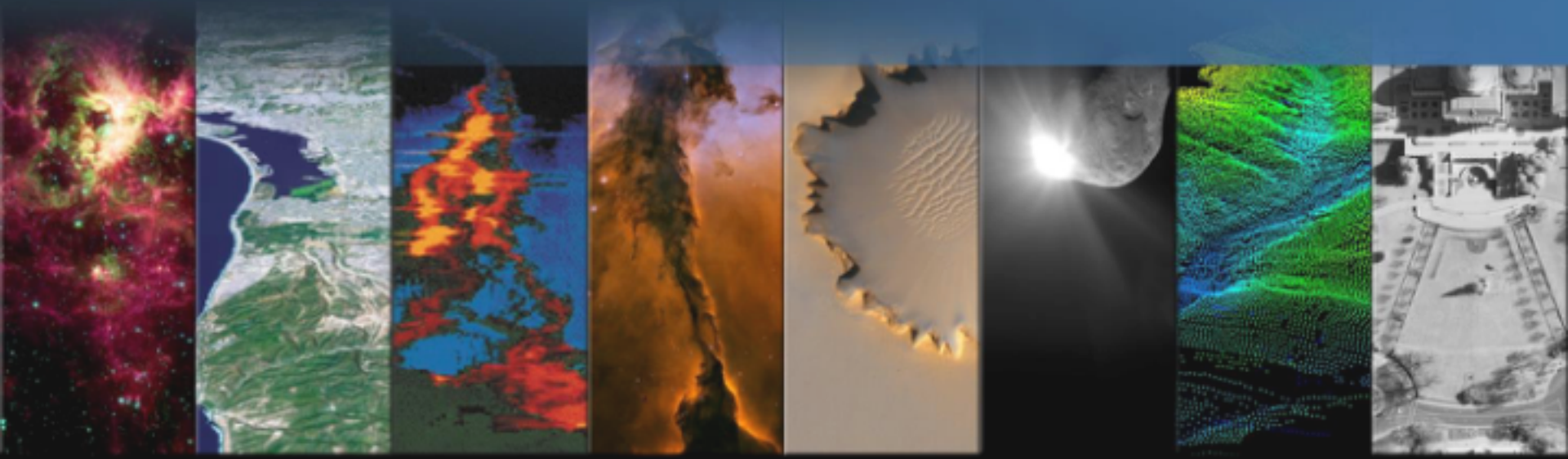
Sara Tucker – Ball Aerospace

Mike Hardesty & Sunil Baidar – NOAA/CIRES/CU



Agility to Innovate, Strength to Deliver

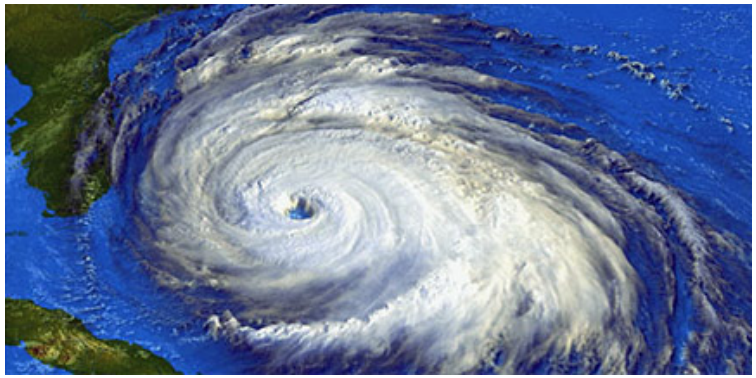
Ball Aerospace & Technologies Corp.

ESTO Earth Science Technology Office

NASA

Space-Based Wind Measurements

- Need more wind observations to feed numerical weather prediction forecast models
  - Baker et al. *BAMS*, 2014
- Global Observing System
  - ✓ ✓ mass observations
  - ✓ water vapor
  - ❑ wind profiles (kinematics) over oceans (esp. tropics)
- A space-based DWL system would provide
  - Direct measurements of altitude-resolved wind profiles
  - Measurement of convergence & divergence



Space-based Doppler Wind Lidar

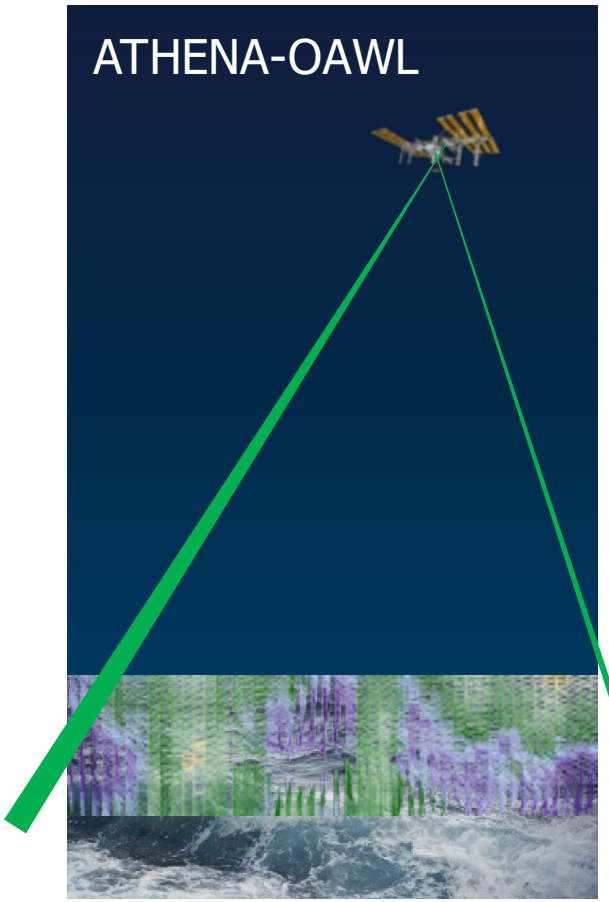
- ESA's Aeolus Mission (ADM) – previous talk
- >30 years of NASA and NOAA investments in wind lidar technology
  - Advancements:
    - Multiple wind lidar mission concepts and system architecture feasibility studies – none flown
    - Multiple ground and airborne demonstration systems
    - Advancements in UV and near-IR laser technology
    - Model-related Advancements (e.g. OSSE's)
  - Challenges
    - Competing technologies within NASA → Hybrid system
      - LaRC: Coherent detection : 2μm wavelengthaerosol backscatter (lower troposphere/boundary layer)
      - GSFC: Direct detection: 355 nm wavelength molecular backscatter (all altitudes, lower precision)
    - Need for more wind scientists asking for the data

US Space-based wind lidar, cont'd

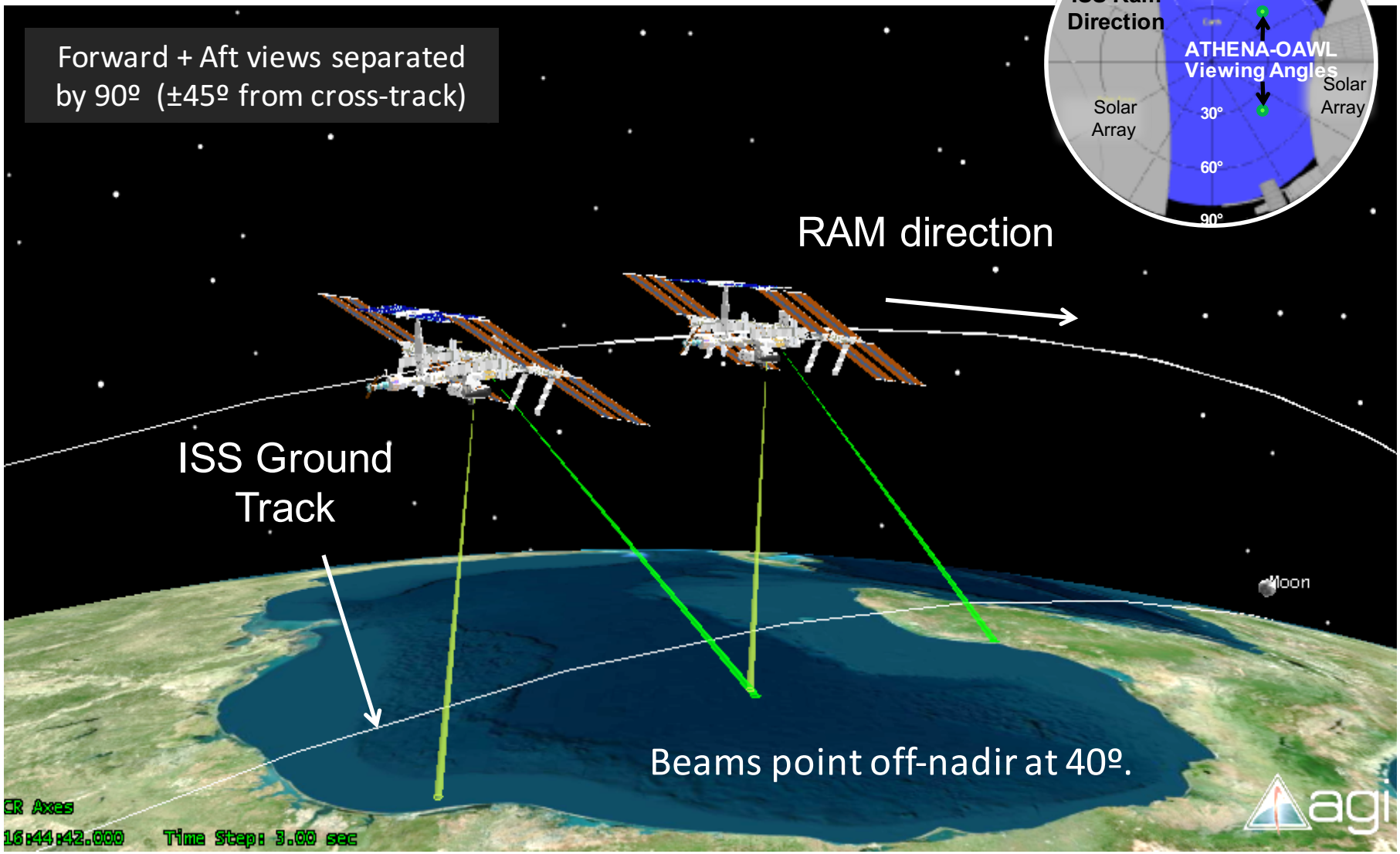
- 2007 Earth Science Decadal Survey:
  - Hybrid of both the LaRC & GSFC systems = high cost
  - Tier 3 mission
- Third option: Direct detection, short wavelength, aerosol lidar
  - 355 nm (aerosol + molecular) and/or 532 nm (aerosol)
  - ESA's Aeolus mission @ 355 nm: aerosol + molecular channels, both direct detection
  - ATHENA-OAWL concept: 532 nm, aerosol

ATHENA-OAWL: **A**erosol **T**ransport, **H**urricanes, and **E**xtra-tropical **N**umerical we**A**ther using the **O**ptical **A**utocovariance **W**ind **L**idar

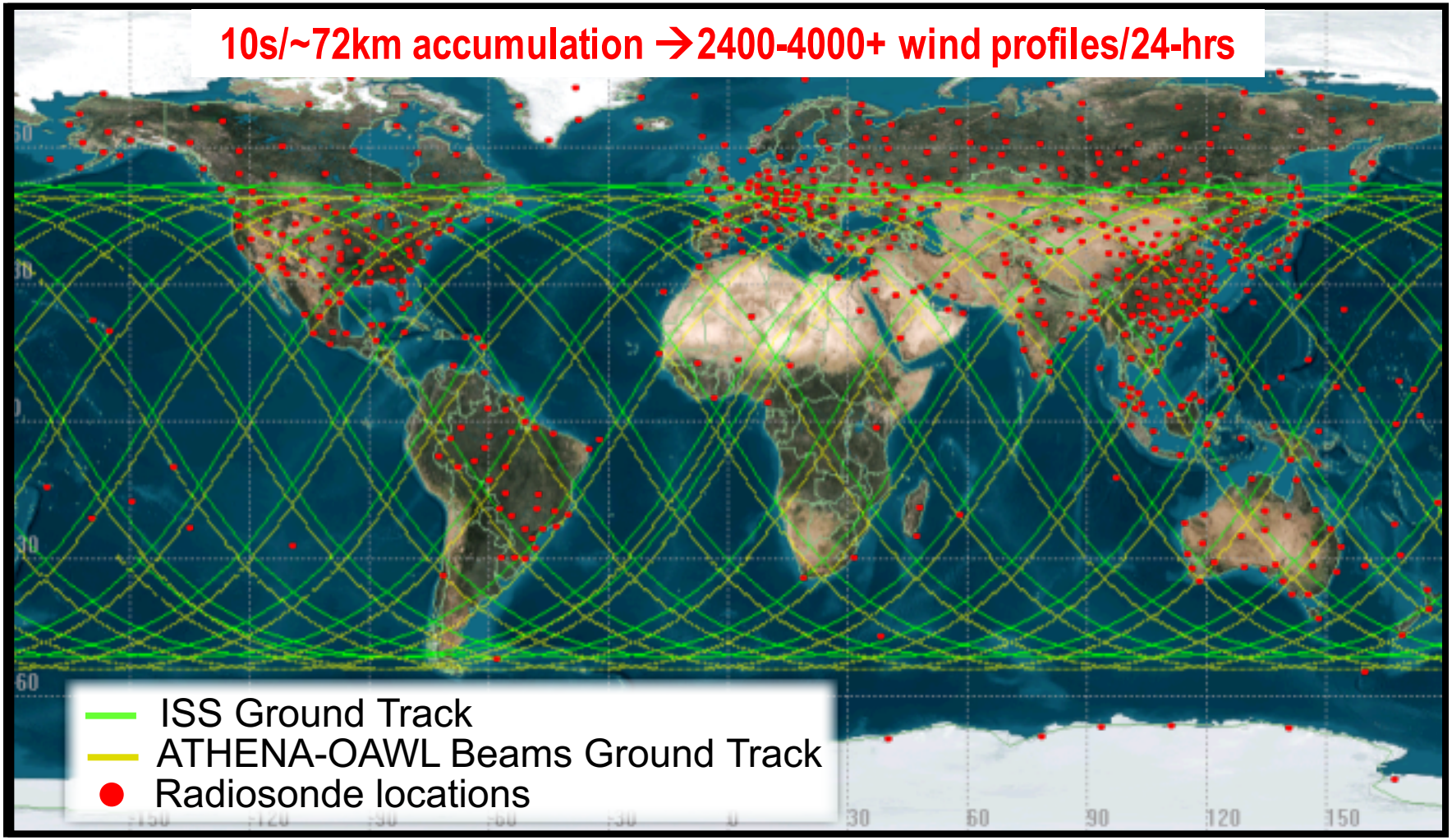
- Path-finding science for next-generation global weather prediction and climate analysis
- *Design to cost approach* to Earth Venture Instrument call building on CALIPSO (now 10 years on orbit) and ISS technologies
- Mission Objectives: Co-located wind and aerosol profiles
  - breakthroughs in modeling and prediction of low and mid-latitude weather and climate.
  - better understand relationships between aerosol radiative forcing, atmospheric dynamics and the genesis and lifecycle of tropical cyclones
  - study impacts of long-range dust and aerosol transport on global energy and water cycles, air quality, and climate.



Two-look, space-based wind lidar



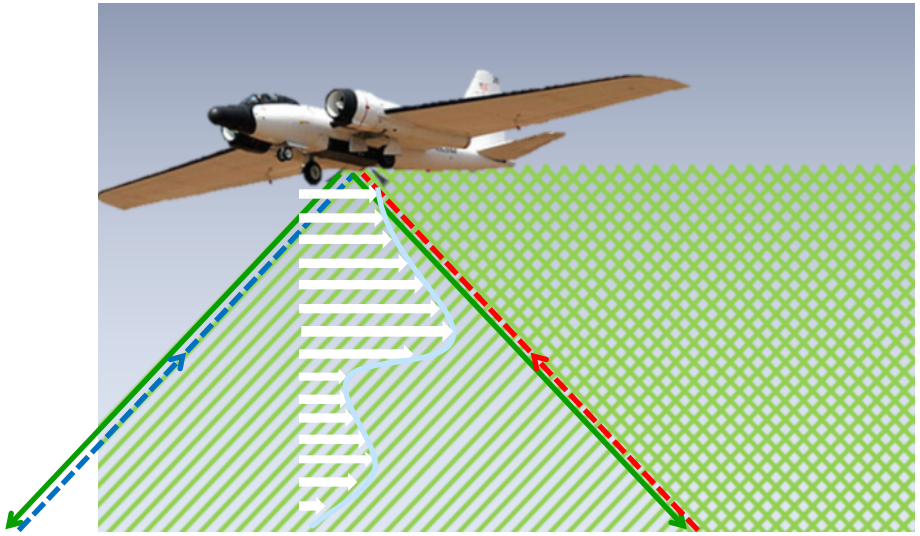
OAWL ISS Coverage (Example 24 hours)



ATHENA-OAWL Venture Tech (AOVT)

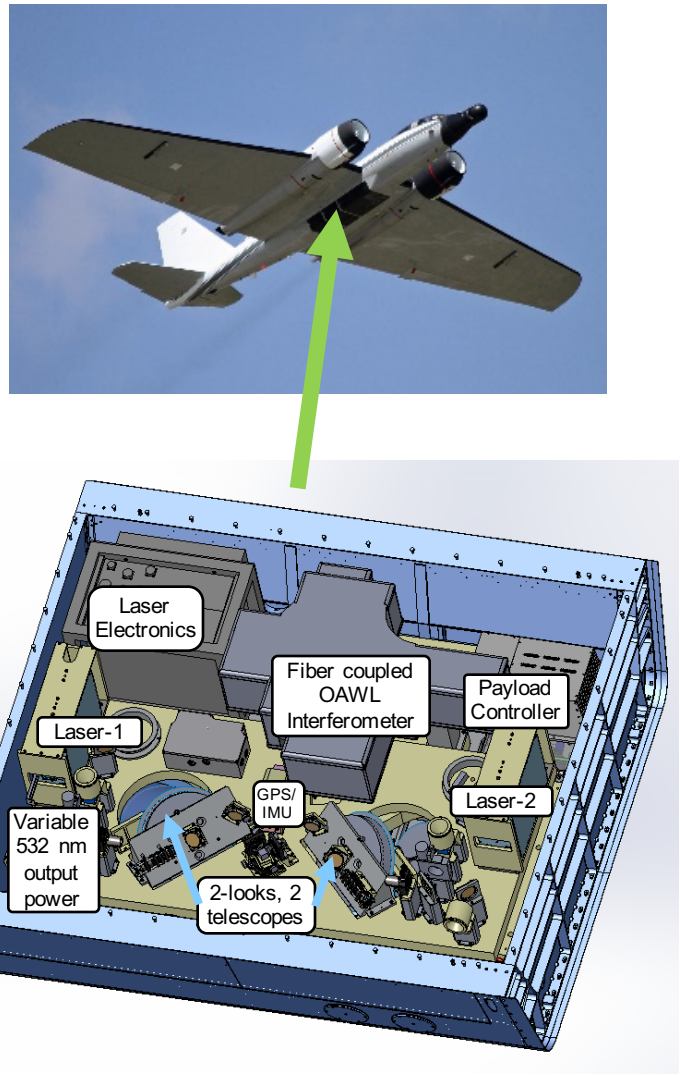
The Green-OAWL Airborne Demonstrator

- **ATHENA-OAWL** EV-I 2013 Mission Concept was rated Category 3
- Thus eligible for EV-I "Venture Tech" funding.
- AOVT Goals
  - Update OAWL to a two-look, 532 nm "**Green OAWL" (GrOAWL)** airborne system
  - demonstrate measurement performance from ground and aircraft
  - Provide measurement validation
  - Scale system performance to space, (e.g. Aeolus)
  - Raise OAWL TRL for next EV-I proposal



OAWL: Optical Autocovariance Wind Lidar

- A direct detection, aerosol, Doppler wind lidar…
- Operates at both the 355 nm (UV) and 532 nm (green) wavelengths
- Uses a field-widened, quadrature channel, Mach Zehnder interferometer to resolve the Doppler shifts.
- Current configuration:
  - Two-look (two laser, two telescope) airborne system
  - In the NASA WB-57 "bomb-bay" pallet
  - Remotely operated



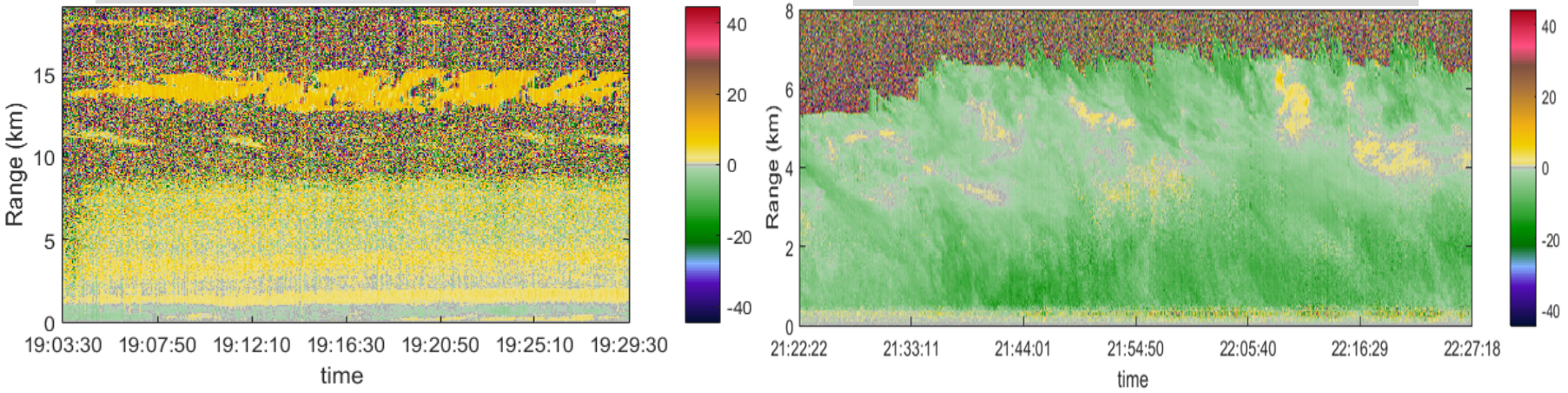
March/April 2016: ground testing of new system

two looks (separate days), two wavelengths

Look 1: 12 March 2016

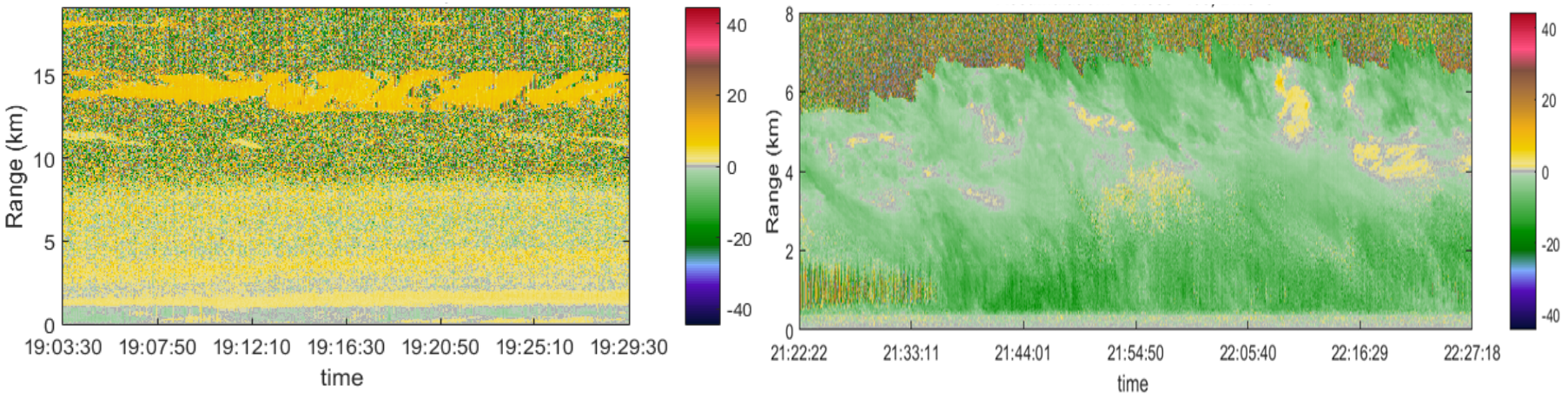
Look 2: 24 April 2016

532 nm



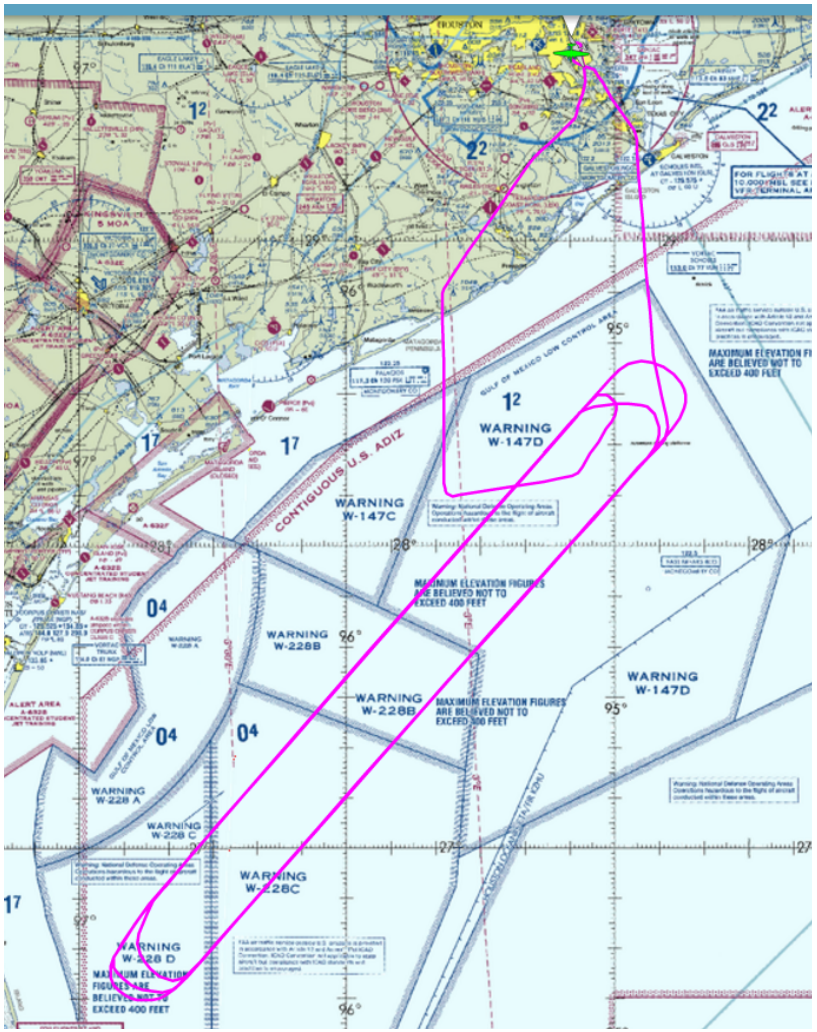
30^{o} Elevation facing west over Boulder foothills

355 nm



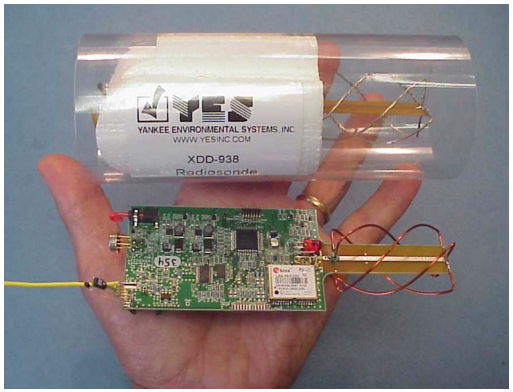
May/June 2016: Airborne Flight Testing

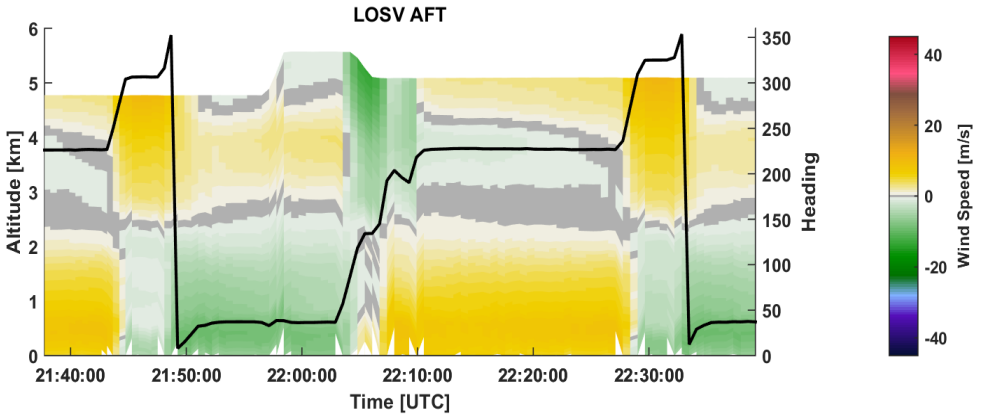
- System operated remotely on the NASA WB-57 jet
- Flew racetrack patterns over the Gulf of Mexico to provide
  - Revisit times: ~1hr/loop
  - Views of the atmospheric regions from opposite sides
    - More validation for models
    - Study of variability
  - Comparison with dropsondes for winds validation



Validation effort (NOAA/CIRES)

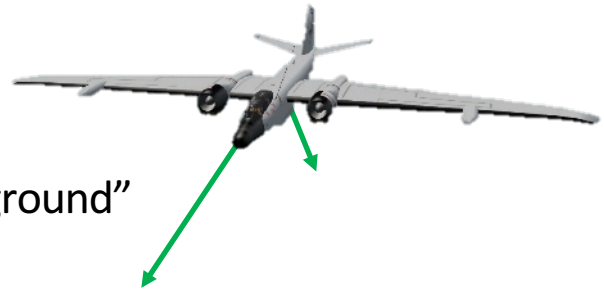
- Validation Focus on radiosondes
  - Balloon-sondes launched from NOAA NWS station at Corpus Christi
  - High Definition Sounding System (HDSS) dropsondes
    - Yankee Environmental Systems with support from Office of Naval Research
    - automated dropsonde system on WB-57
    - Dropped 40+ sondes total over multiple flights
- Comparison with NOAA High Resolution Rapid Refresh (HRRR) model winds projected onto the flight path



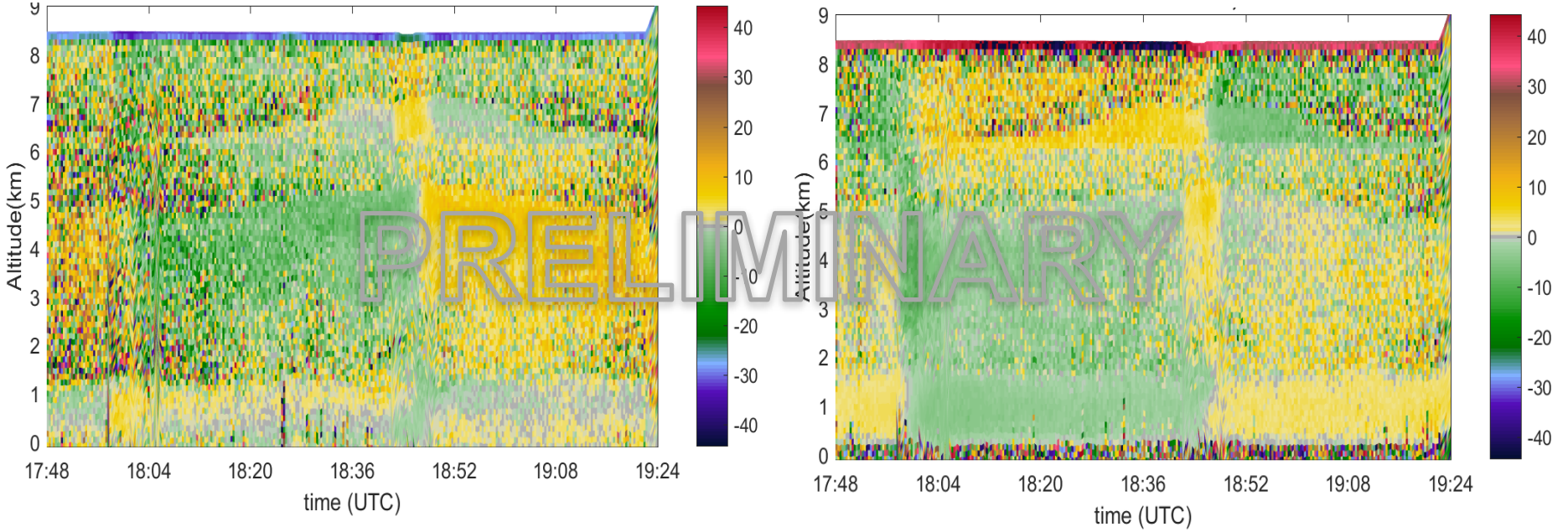


Simultaneous two-look airborne profile results

- Preliminary data
- 532 nm wavelength with only 300 mW per laser
- 8.5km altitude, 12 km slant path to the surface
- Very low aerosol backscatter conditions: below “background”
- Daytime operation with scattered clouds

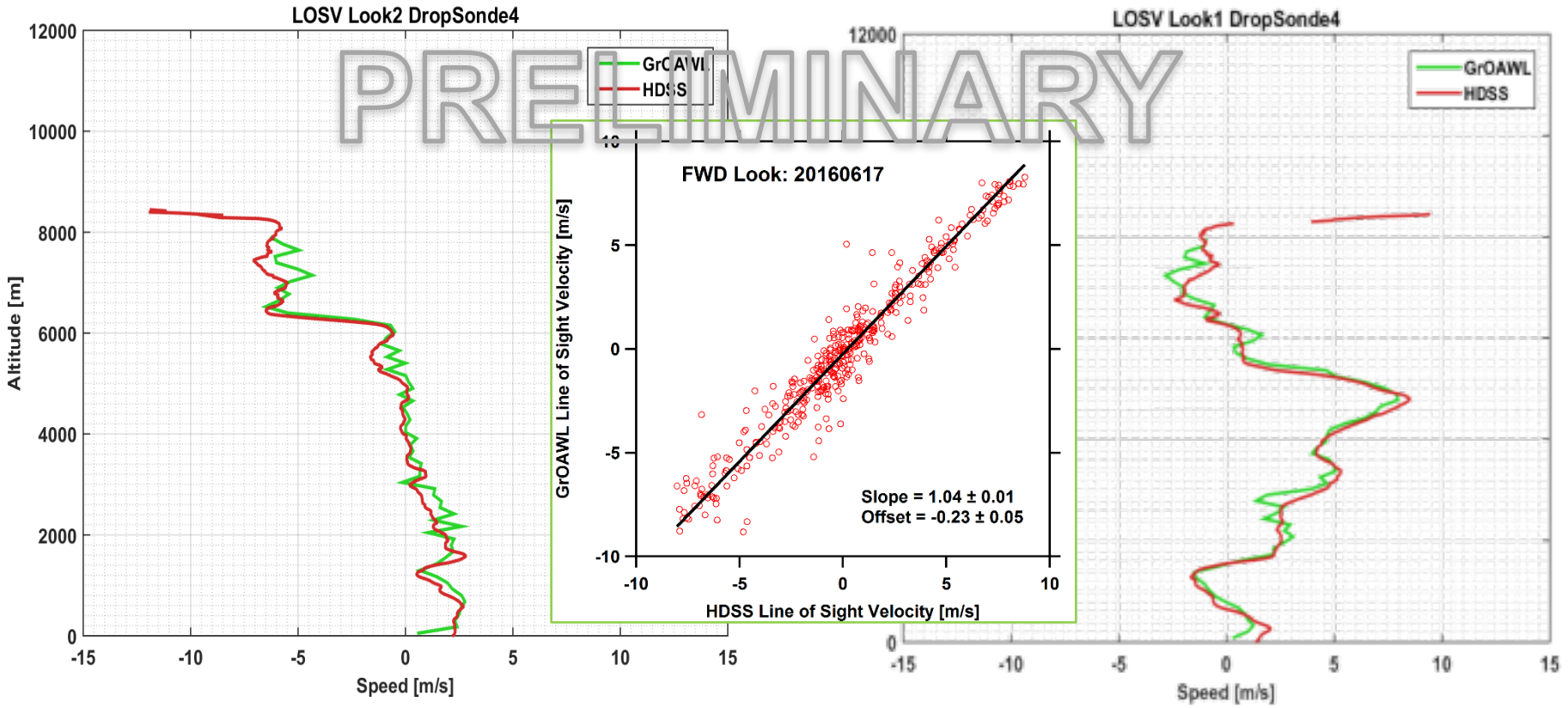


Look 1 (fwd) **17 June 2016** Look 2 (aft)



Preliminary Validation Results

- Neither the dropsonde (HDSS) nor lidar (GrOAWL) data are finalized – data and comparisons are preliminary.
- Representativeness must be taken into account in any comparison
- Yet, already seeing good comparisons with slope fits close to 1



Conclusions and Future plans

Ground/Airborne missions

- The GrOAWL airborne demonstrator has been built with two looks
- Initial two-look measurements from the NASA WB-57 aircraft
  - Post-flight validation, evaluation, and scaling to space just starting
  - Initial validation comparisons are promising
- Next: Ground validations for aerosol transport studies
  - Dual wavelength
  - Depolarization channels
- Next airborne measurements TBD

In support of space missions

- 2017: Airborne Aeolus CalVal
  - OAWL is the only U.S. 355 nm Aerosol wind lidar
  - Use 355 nm OAWL for validating Aeolus' 355 nm aerosol channel
- ATHENA-OAWL Earth Venture Instrument proposal
- 2017 Earth Science Decadal Survey
- We need wind scientist inputs:
  - Need for wind lidar data
  - Help refine wind lidar mission