Global Vector Winds, Wind Turbulence, and ABL Structure from the Coherent WIND-SP Instrument Concept

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WIND-SP (Space Pathfinder)

- Instrument and preliminary mission design funded by NASA through LaRC
- DWL pathfinder concept is a follow-on to White Papers submitted to National Academy of Sciences in 2017 by LaRC and SWA.
- Focus upon atmospheric boundary layer is consistent with National Academy of Sciences Boundary Layer Workshop (10/17) and the 2018 Decadal Survey recommendations. Mid and upper troposphere still well represented with a WIND-SP pathfinder mission.
- Pathfinder mission is being designed to explore various sampling strategies suitable for NASA's lower tropospheric atmospheric processes research and follow-on operational NWP **in the presence of clouds (based upon CALIPSO data indicating >80% of lidar shots have cloud returns globally)**.

Potential contributions from a Coherent Wind Lidar in orbit: technology

- NASA has been investing in airborne and space based coherent DWL technology for several decades
  - LAWS, a component of the original EOS program
  - SPARCLE, a space shuttle demonstration
  - WIND-SP (most recent effort)
  - DAWN, an airborne demonstrator for WIND-SP
- NOAA and the DoD are currently flying airborne coherent Doppler Wind lidars
  - NOAA funded hurricane reconnaissance since 2014
  - ONR funded Atmospheric Boundary Layer research, primarily the marine Boundary Layer

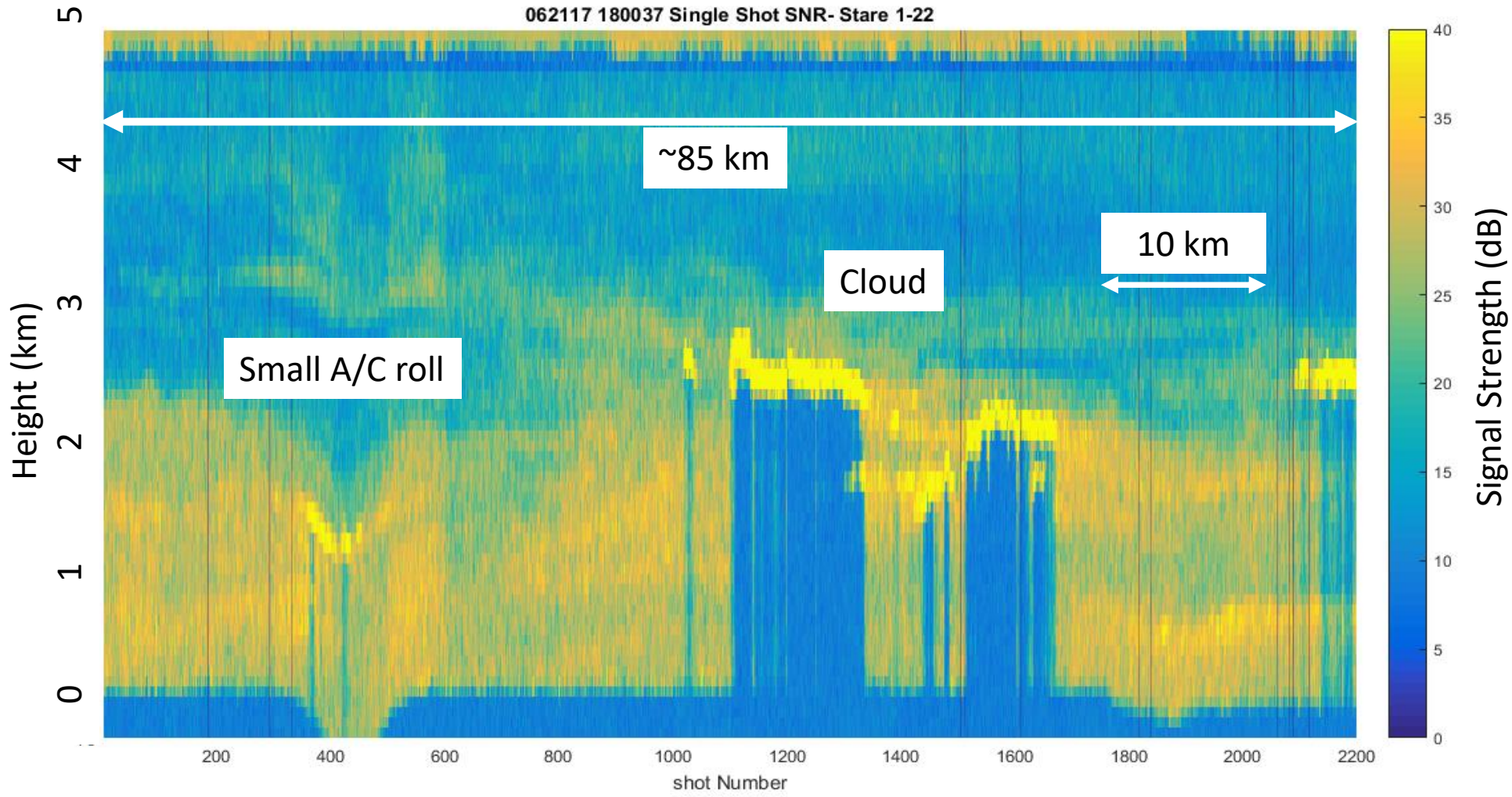
Atmospheric Boundary Layer properties observable from space with a coherent DWL

- Profiles of the horizontal wind vector using two perspectives
  - Maximum vertical resolution ~ 25m
  - Nominal resolution more likely around 100m
- Depth of the ABL defined by backscatter gradients
  - Vertical resolution using sliding gates ~ 10m
- Depth of the mixed layer using the spectral width of the information peak in the coherent frequency spectrum
  - Limited to cases where TKE > 1.0 near top of BL
- Shear within the ABL
  - Presence of LLJs
- Presence of rolls within the ABL
  - Allows for selection of appropriate parametrization of the ABL fluxes.

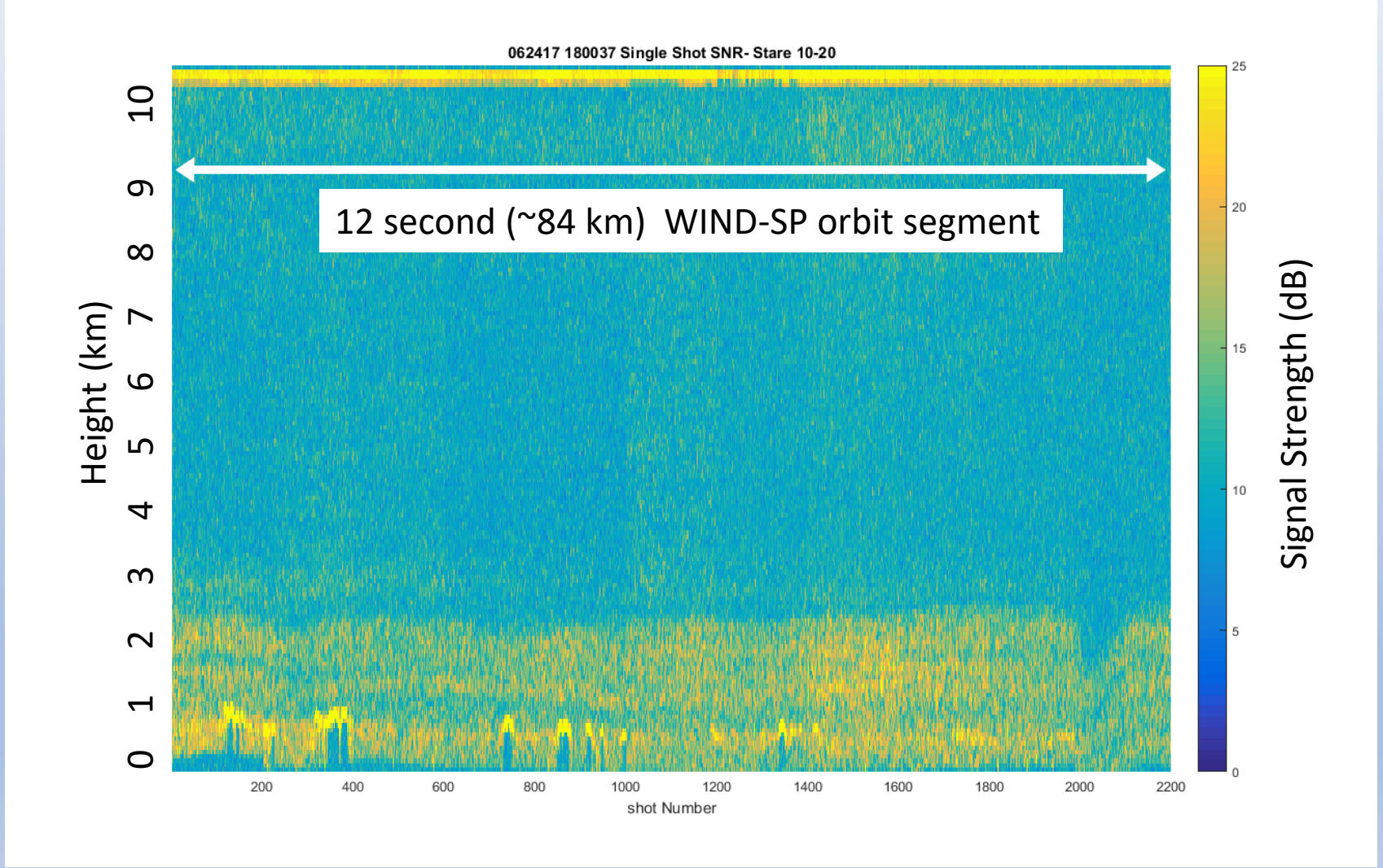
Using airborne DAWN to simulate WIND-SP sampling and representativeness

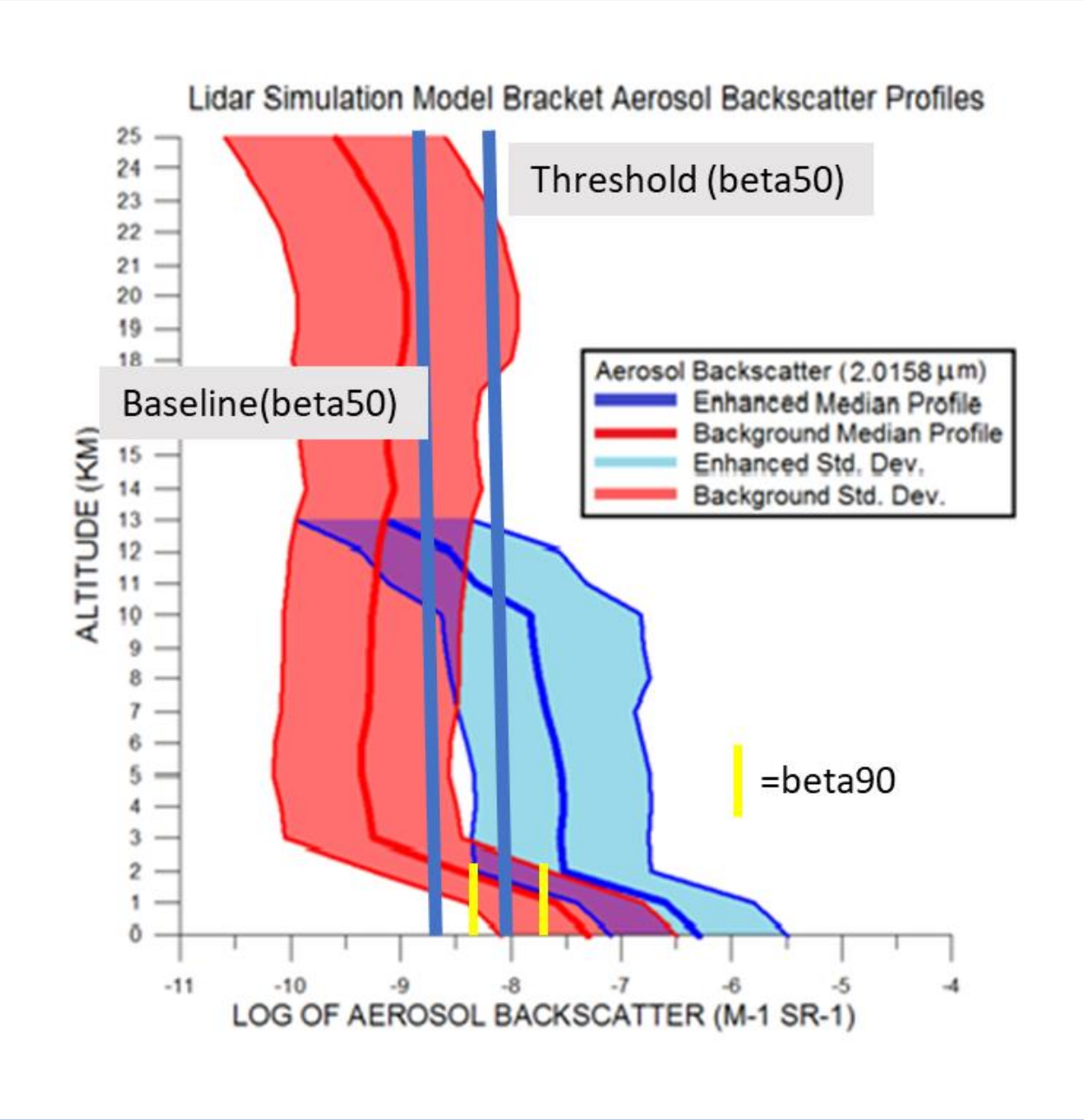
- WIND-SP design evolves from the DAWN instrument
- Data quality expectations are based upon proven DAWN performance
- Ongoing analyses of DAWN data taken during CPEX (2017) has WIND-SP focus
- DAWN's optical power allows for single shot processing from 10 km and thus provides an excellent representation of the winds over the planned WIND-SP 10km flight segments.
- Using only 2 of the 5 looks by DAWN during the CPEX allows for evaluation of the 2 looks planned for WIND-SP.

Example of Single Shot Returns from DAWN during CPEX (~20m between shots; ~60m vertical resolution)



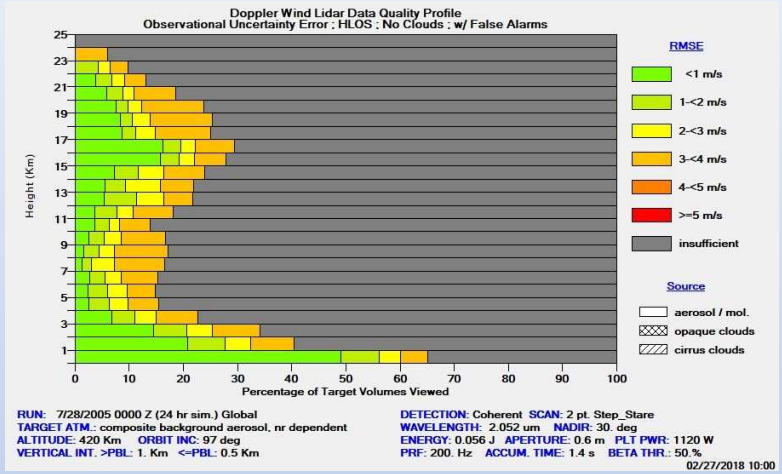
Example of DAWN's mapping the ABL from 10km FL

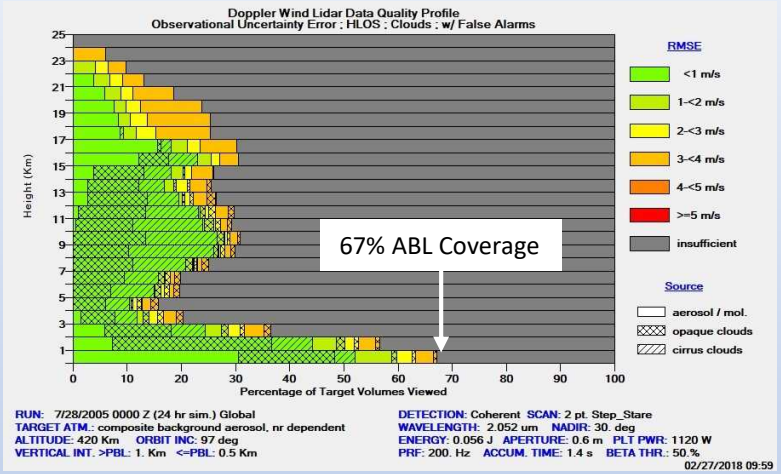



Lidar Simulation Model Bracket Aerosol Backscatter Profiles
Threshold (beta50)
Baseline(beta50)
Aerosol Backscatter (2.0158 µm)
Enhanced Median Profile
Background Median Profile
Enhanced Std. Dev.
Background Std. Dev.
=beta90
ALTITUDE (KM)
LOG OF AEROSOL BACKSCATTER (M-1 SR-1)

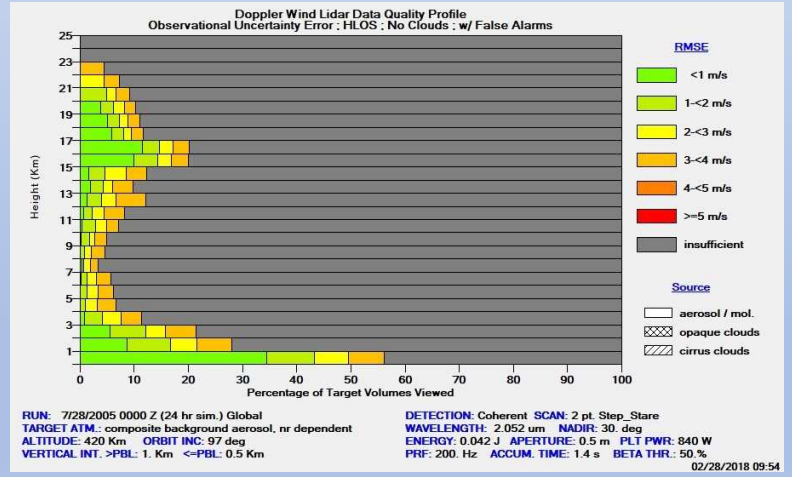
Composite background, 1.4 S (design cloud gap ~10km)

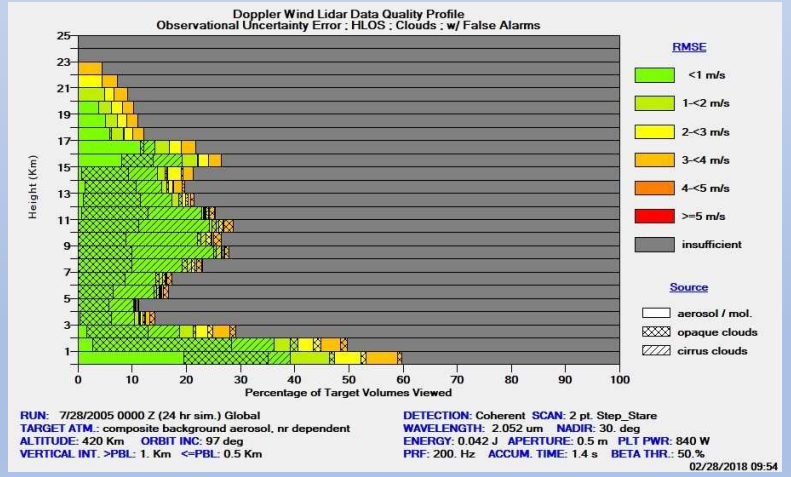
Baseline



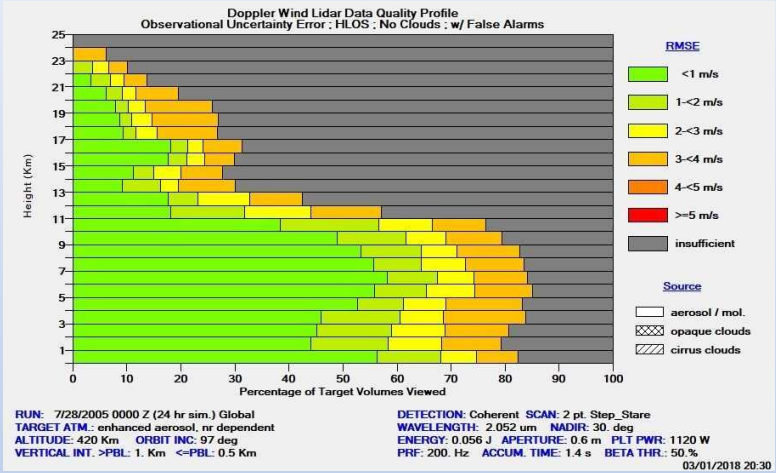


Threshold

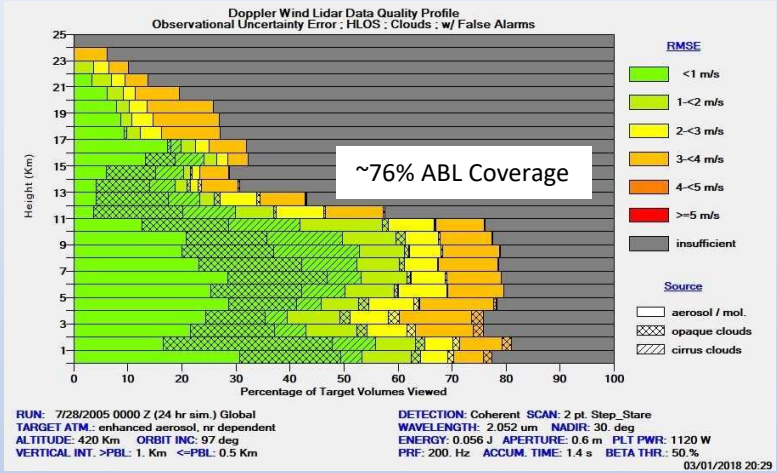


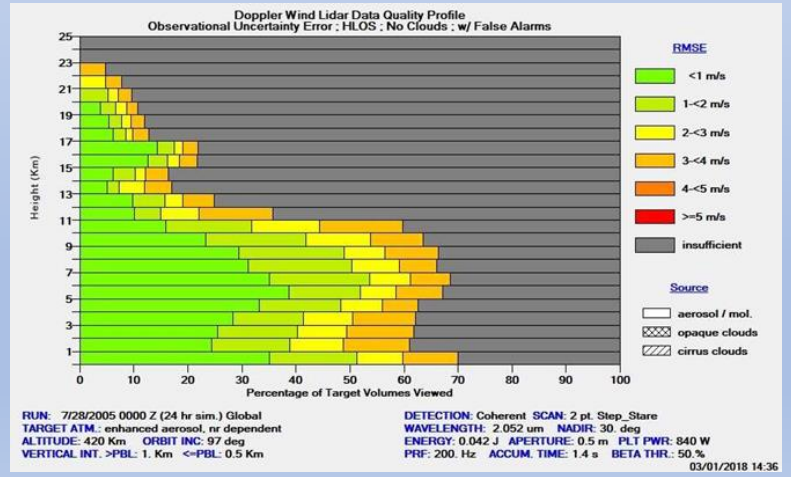


Enhanced, 1.4 second integration

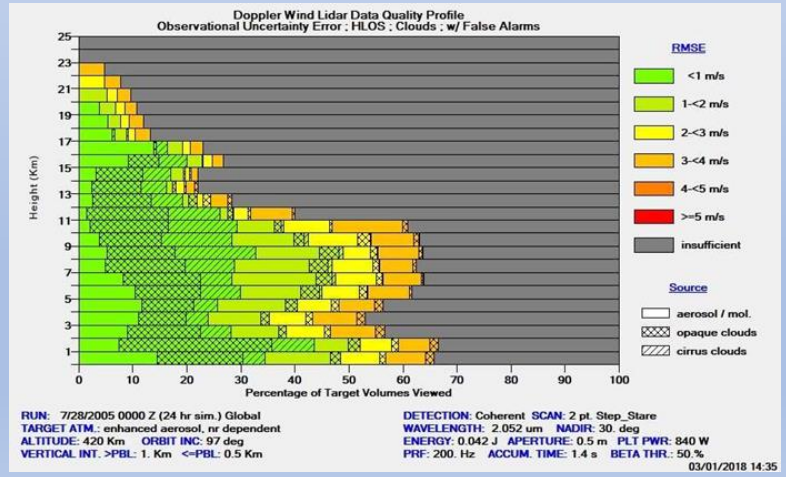


Baseline





Threshold



Summary

Performance simulations of WINDSP in a polar (or ISS) orbit as well as DAWN derived performance expectations promise accomplishment of the following **science and technology objectives**:

- Investigate inter-hemispherical transports via LLJs: How prevalent and energetic are LLJs over the oceans?
- Develop improved parameterization schemes for PBL depths and growth rates for use in global weather and climate models…especially for marine BLs.
- Investigate the role of vertical shear of the horizontal wind in regions of deep convection and in tropical cyclone maintenance and suppression.
- Investigate wind speed and directional shear on the global trans-oceanic transport of pollution.
- Investigate two look vs single look comparisons for a range of atmospheric conditions
- Validate global attenuated backscatter distributions used to design WINDSP and establish coverage expectations, especially over oceans
- **Develop techniques for taking advantage of synergisms between the DWL and scatterometers (ASCAT), CYGNSS, AMVs and other wind observing systems such as ACARS, rawindsondes, buoys, etc.**