High Precision and Resolution PBL Wind Observations From Coherent Doppler Wind Lidar

John W. Cooney[1], Kristopher M. Bedka[2], and Amin Nehrir[2]

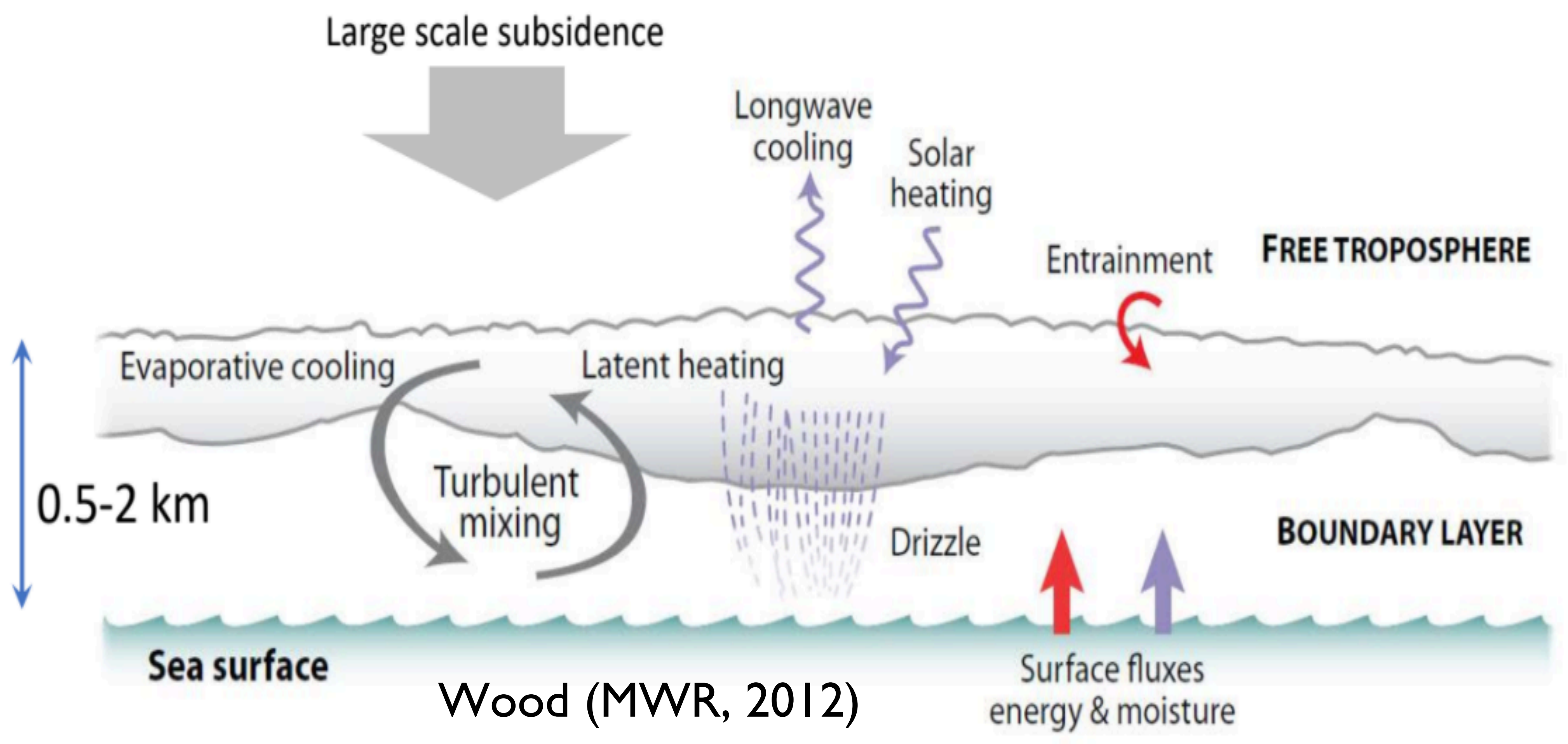
Postdoctoral Fellowship Program at NASA Langley Research Center (LaRC)[1]

and NASA LaRC[2]

john.w.cooney@nasa.gov

Motivation

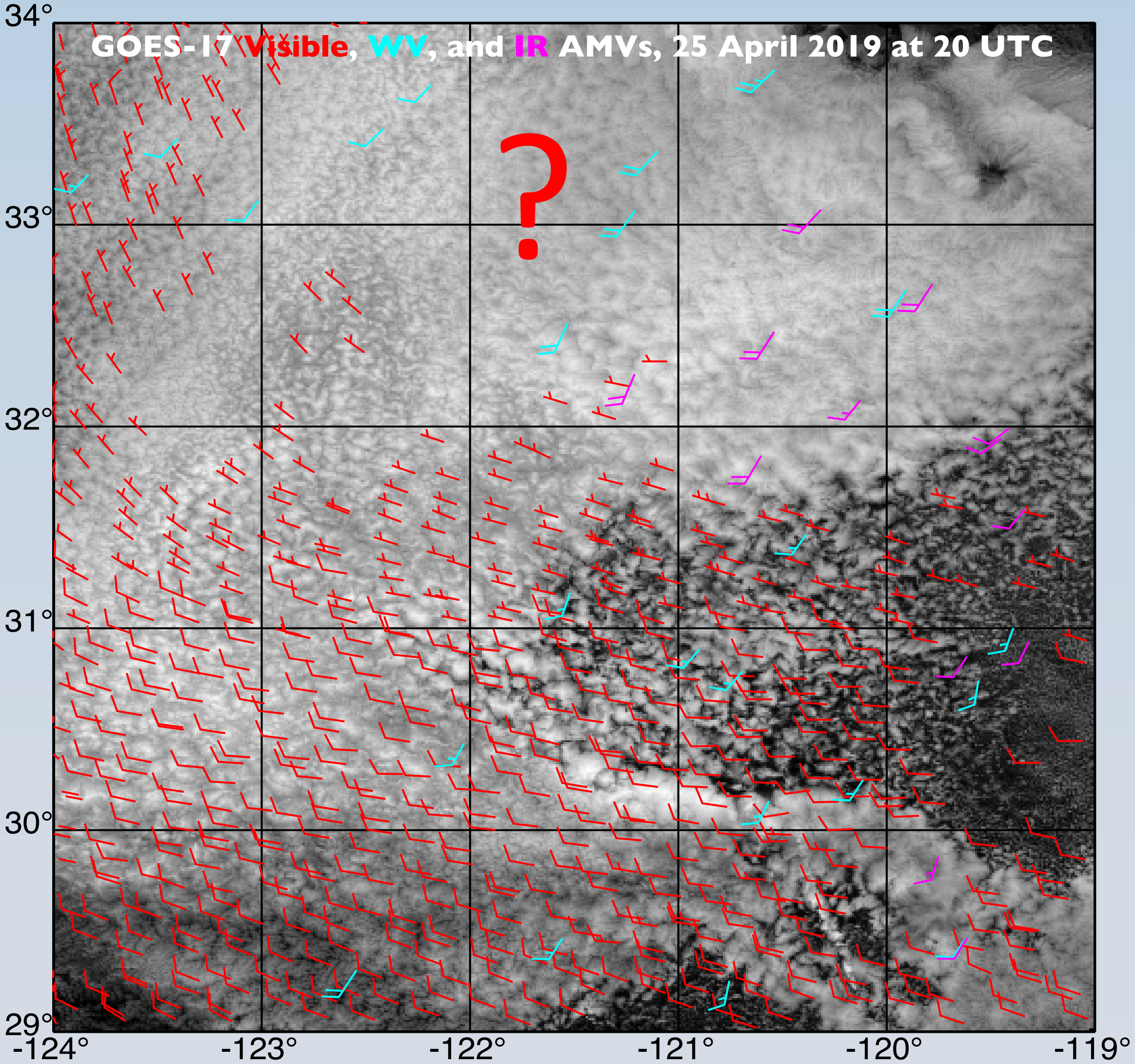
- 2017 Decadal Survey - Uncertainties in initiation and response of clouds is primary source of discrepancy in models
- Clouds are influenced by many dynamic, thermodynamic, and aerosol processes
- Vital to know where, when, and how clouds form, if they precipitate, and how they affect radiative balance
- PBL wind data critical for discriminating tornadic from non-tornadic supercells (Coniglio and Parker, 2020) and forecasting convective initiation/growth
- Process studies require high precision and resolution wind observations, not provided by most existing platforms

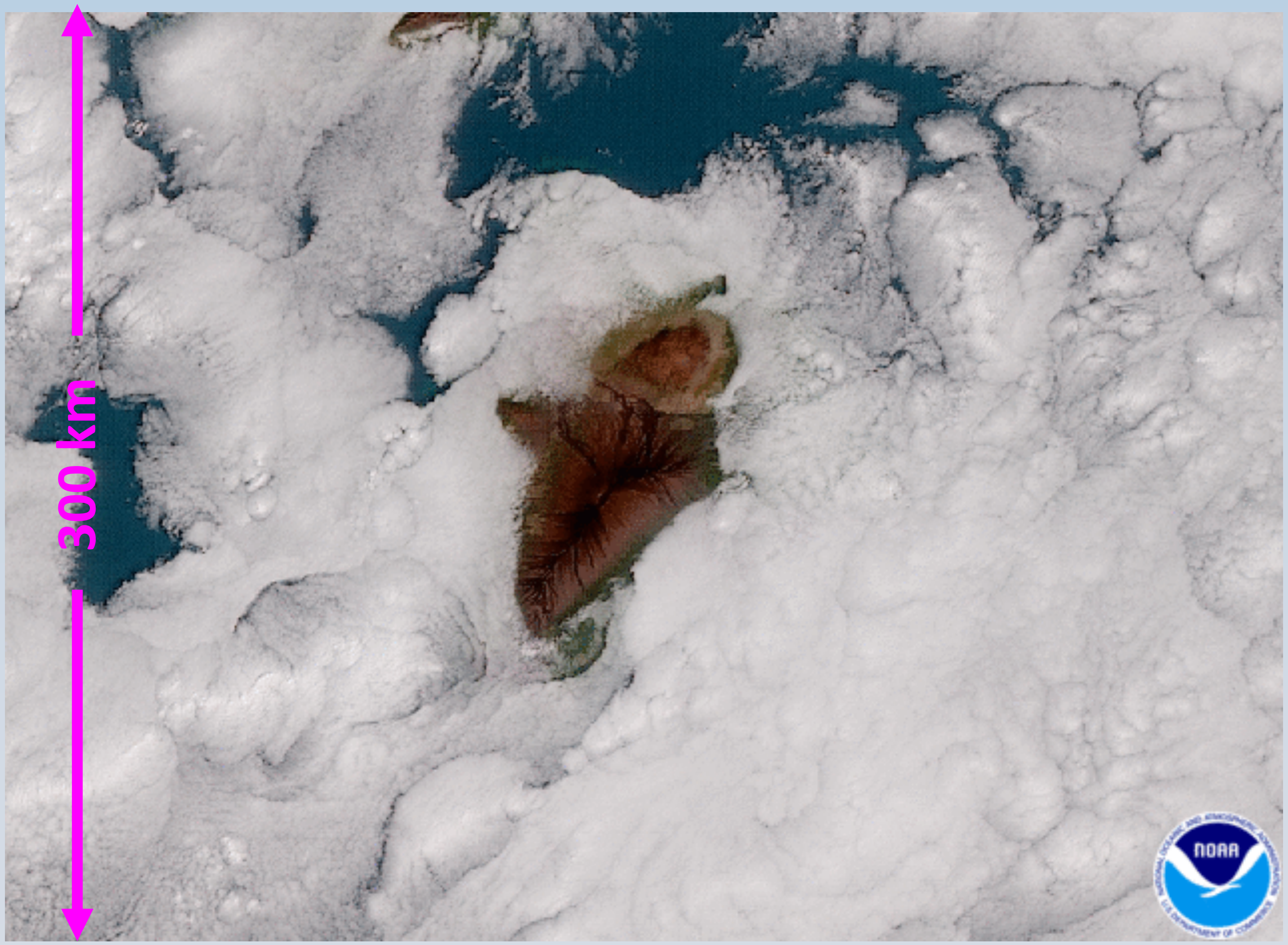


Wood (MWR, 2012)

Current Wind Observing Instruments

1. Radiosonde, Doppler radar, commercial aircraft, and anemometers on land/buoy
2. Scatterometry and passive microwave for ocean surface winds
3. Atmospheric Motion Vectors (AMVs) from GEO or LEO visible, infrared, and water vapor imagery
4. European Space Agency ADM-Aeolus Doppler Wind Lidar
5. Ground-based or Airborne Doppler wind lidars

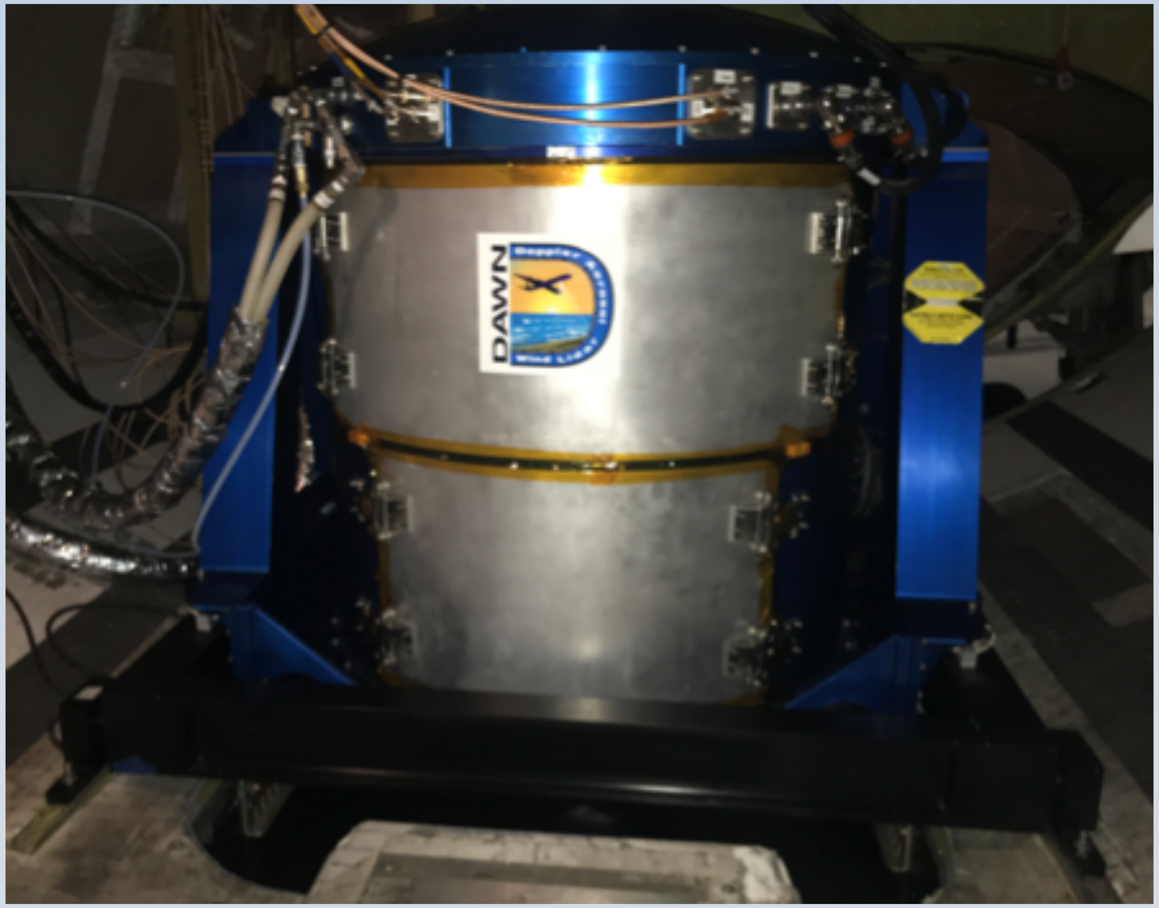




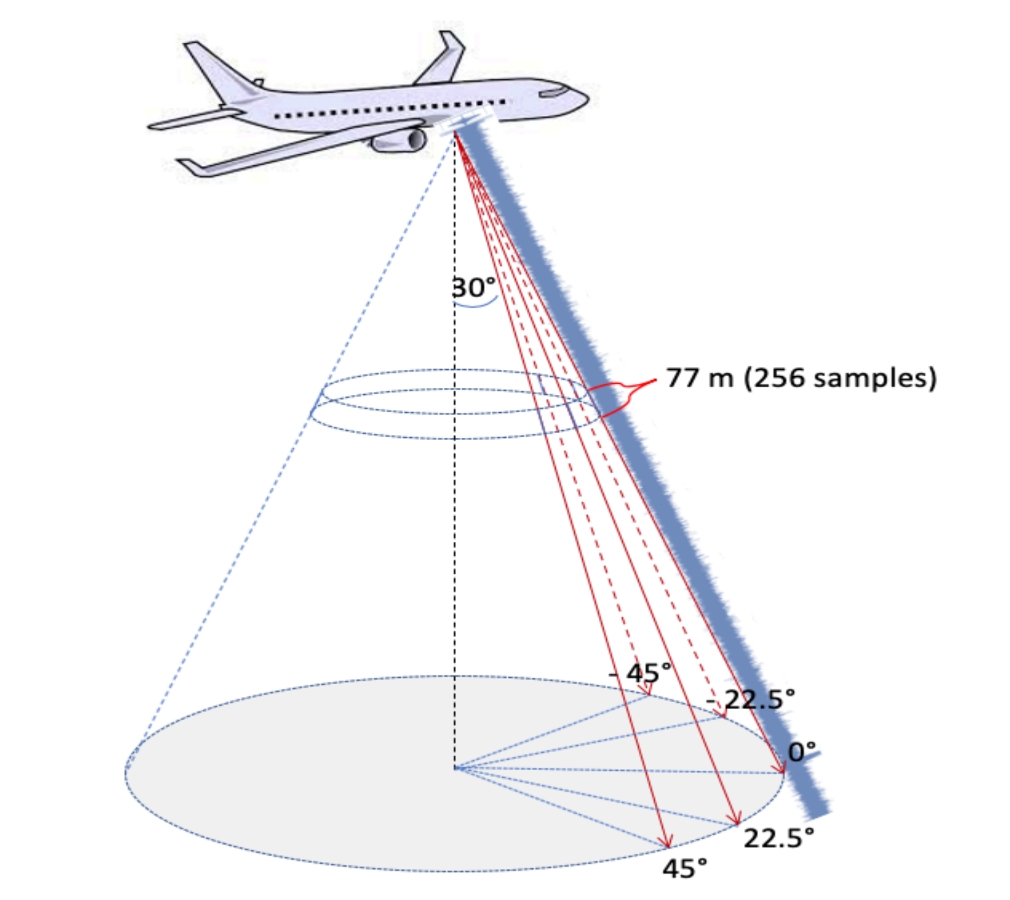
GOES-17 5-Minute Imagery Over The Big Island Of Hawaii

Doppler Aerosol WiNd Lidar (DAWN)

- Coherent-detection airborne lidar with solid-state laser
- 2053 nm wavelength with 10 Hz pulse rate
- Wind detection relies on aerosols which are abundant in PBL and free troposphere
- Vertical profiles of zonal (u) and meridional (v) wind components
- As few as 2 lines of sight needed to retrieve wind vectors, but more are desired
- <1 km horizontal resolution profile spacing possible in PBL
- ~33 m vertical spacing between levels



DAWN Instrument on NASA DC-8

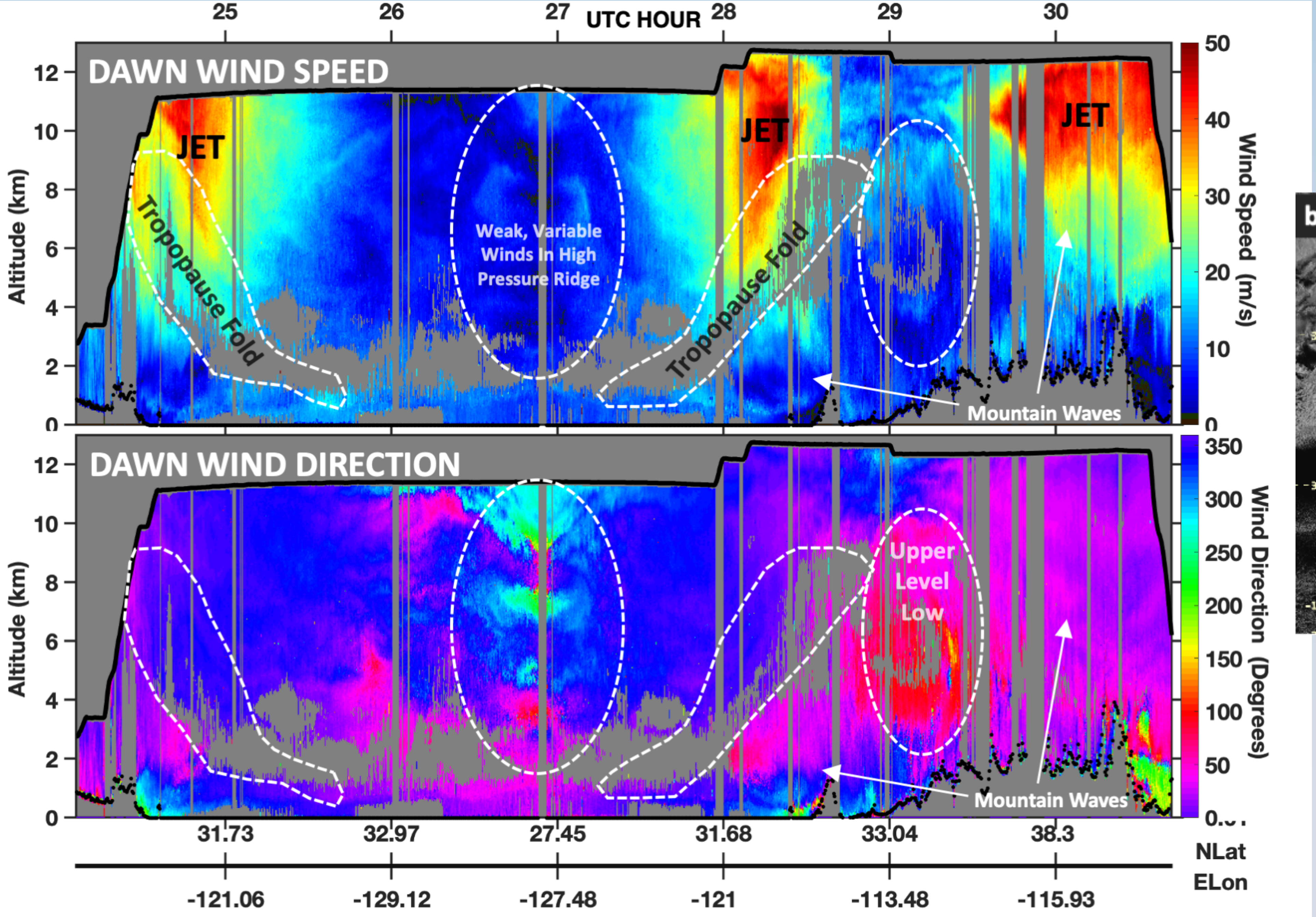


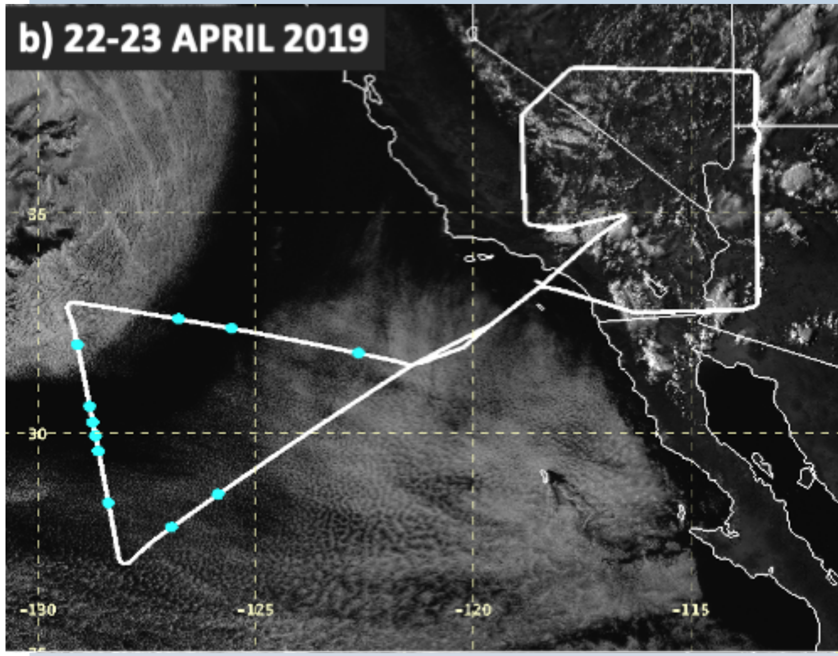
Nominal DAWN Scan Pattern

Kavaya et. al 2014

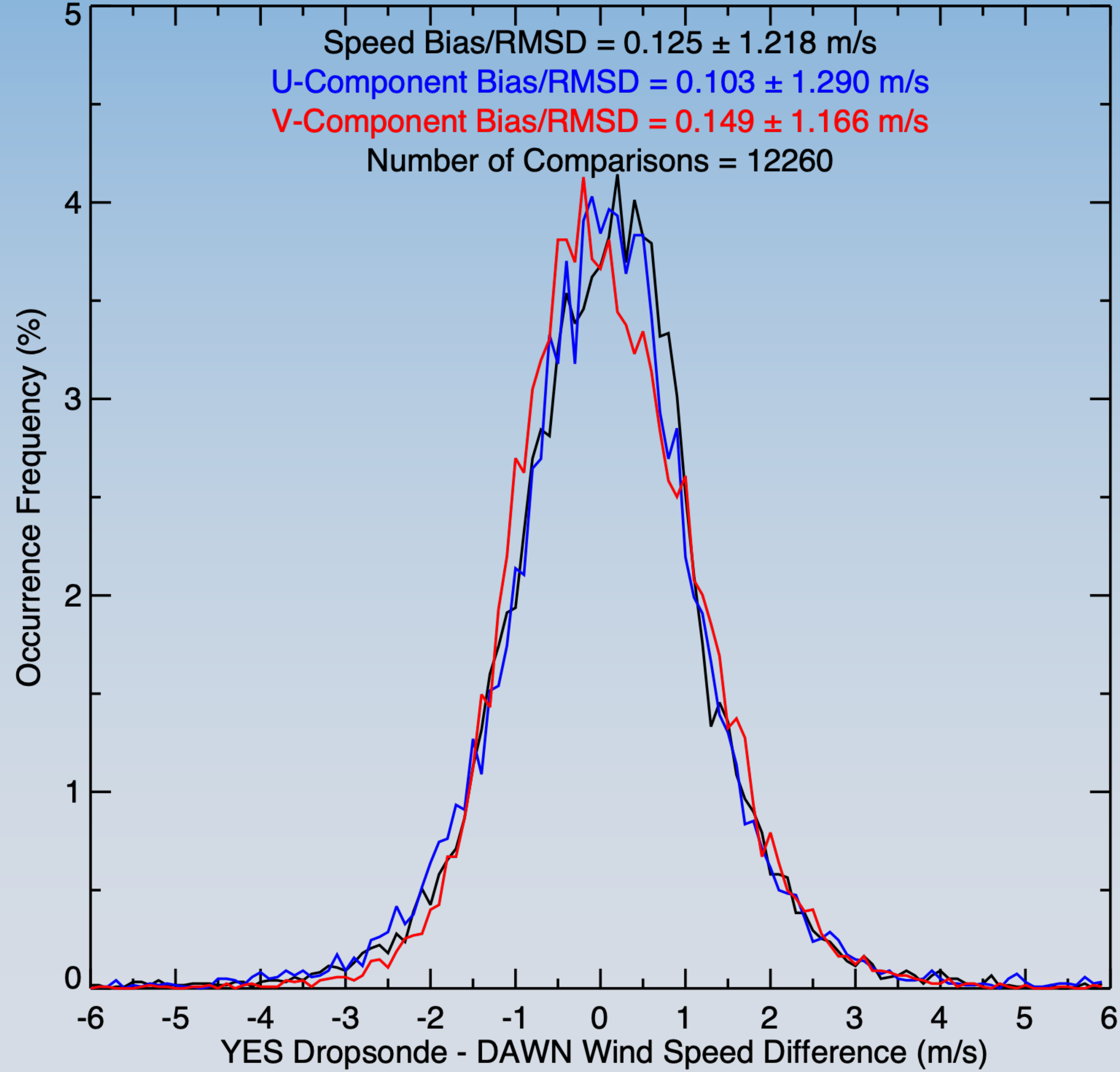
April 2019 NASA Aeolus Cal/Val Campaign

- DAWN and the High Altitude Lidar Observatory (HALO) integrated onto NASA DC-8 and flown for 46 flight hours over the Eastern Pacific in April 2019
- 64 dropsondes used to measure winds and temperature, and validate DAWN/Aeolus
- GOES-17 1-minute observations collected across the entire campaign to support process studies and advanced AMV retrievals

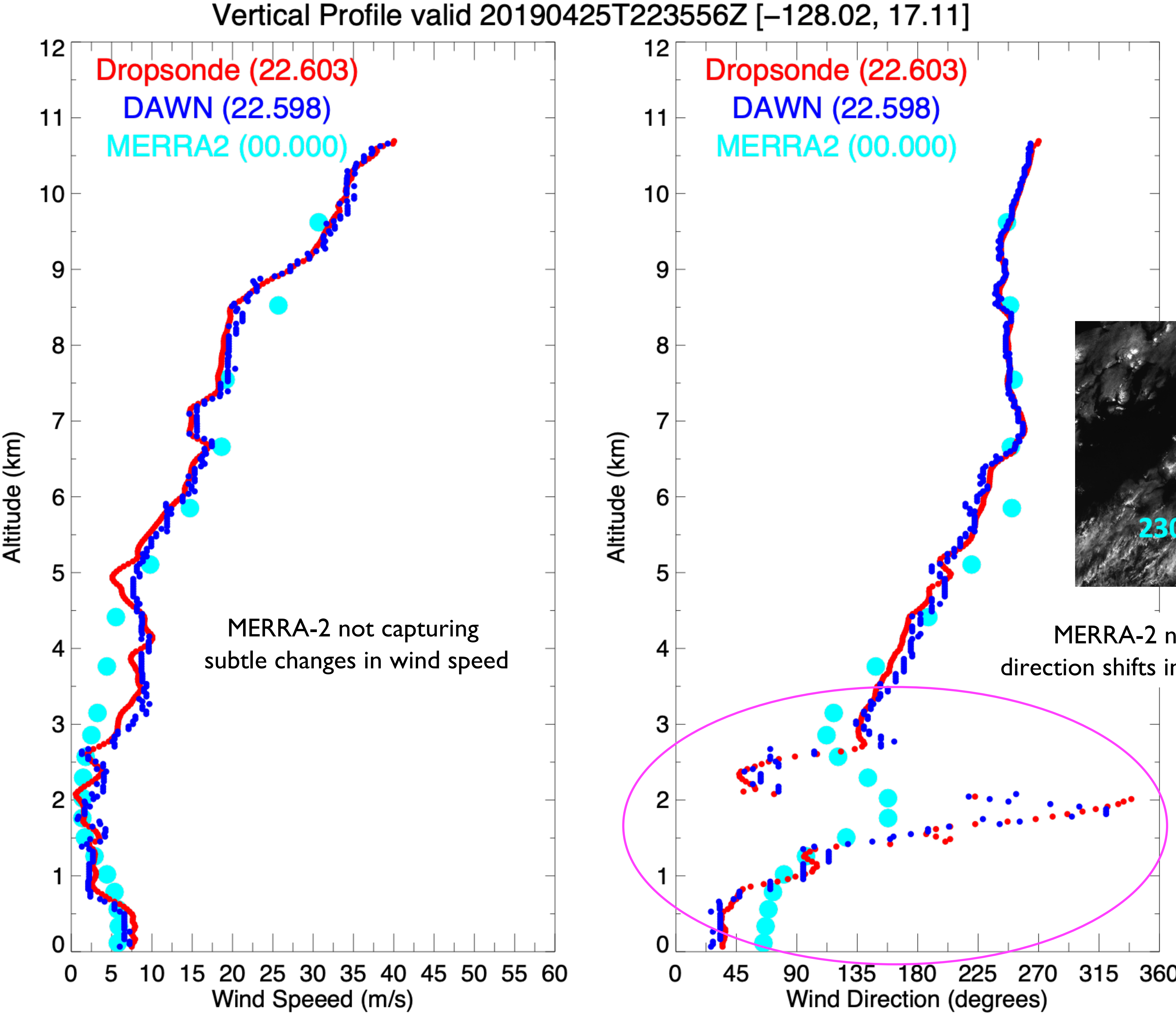


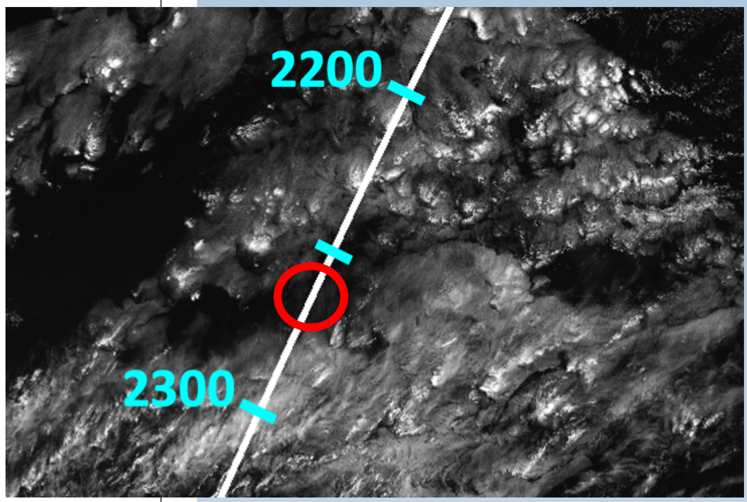


DAWN and Dropsonde Comparisons



DAWN, Dropsonde, and MERRA-2 Comparison

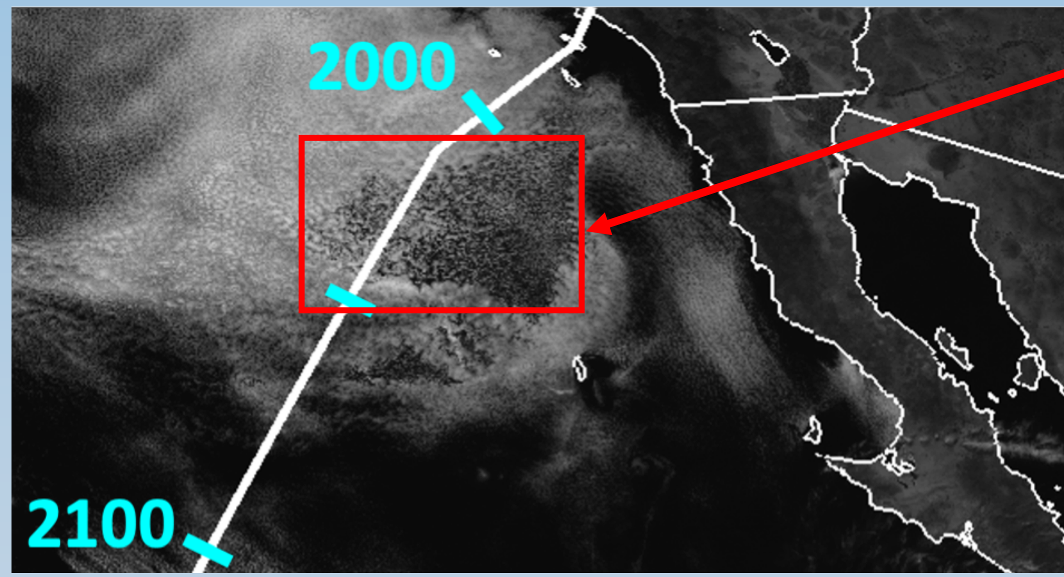




MERRA-2 not capturing subtle changes in wind speed

MERRA-2 not capturing wind direction shifts in slow speed conditions

Lidar Wind Profiling To Understand PBL Clouds

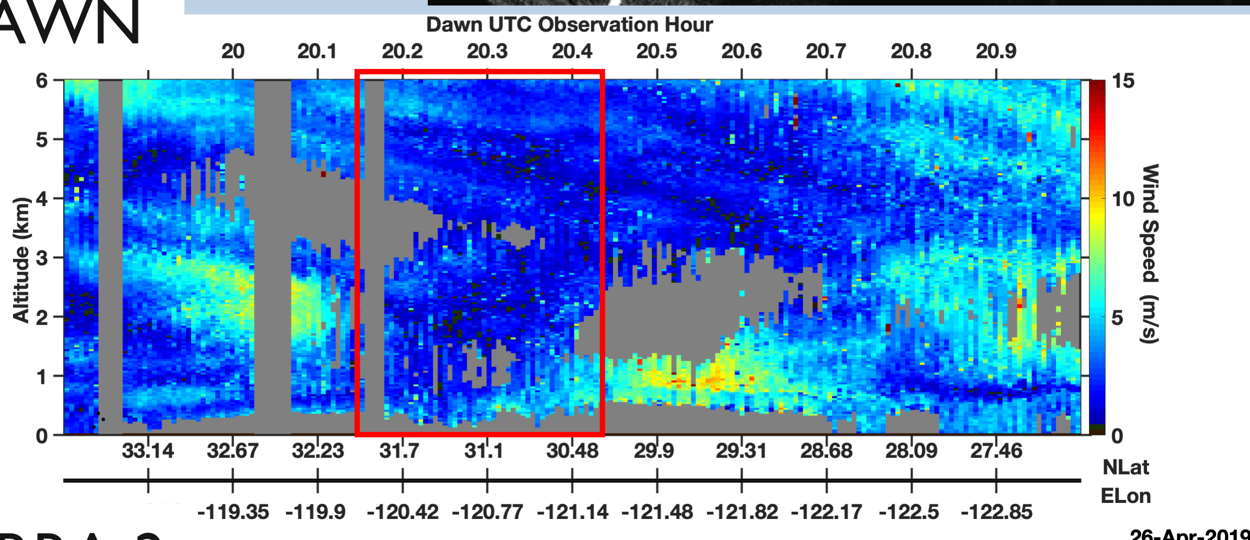


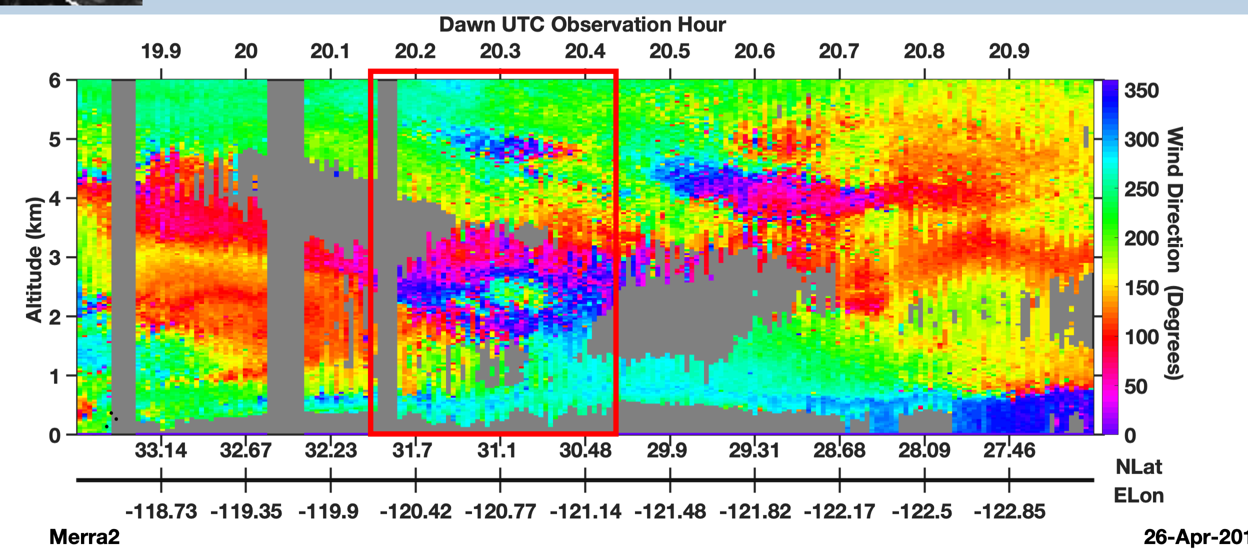
What is causing stratocumulus clouds to change appearance here?

Subtle changes in wind speed and direction above cloud top, coupled with moisture and aerosol variability observed by HALO (not shown)

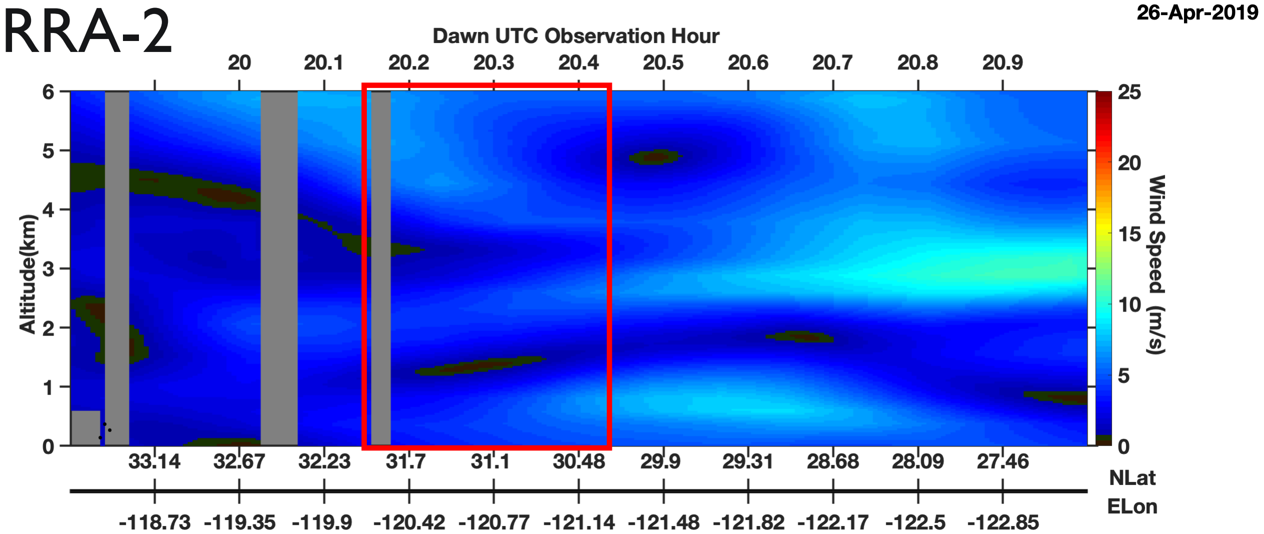
The high-resolution wind lidar data reveals a wealth of other interesting patterns important for modulating clouds that cannot be resolved well by reanalyses

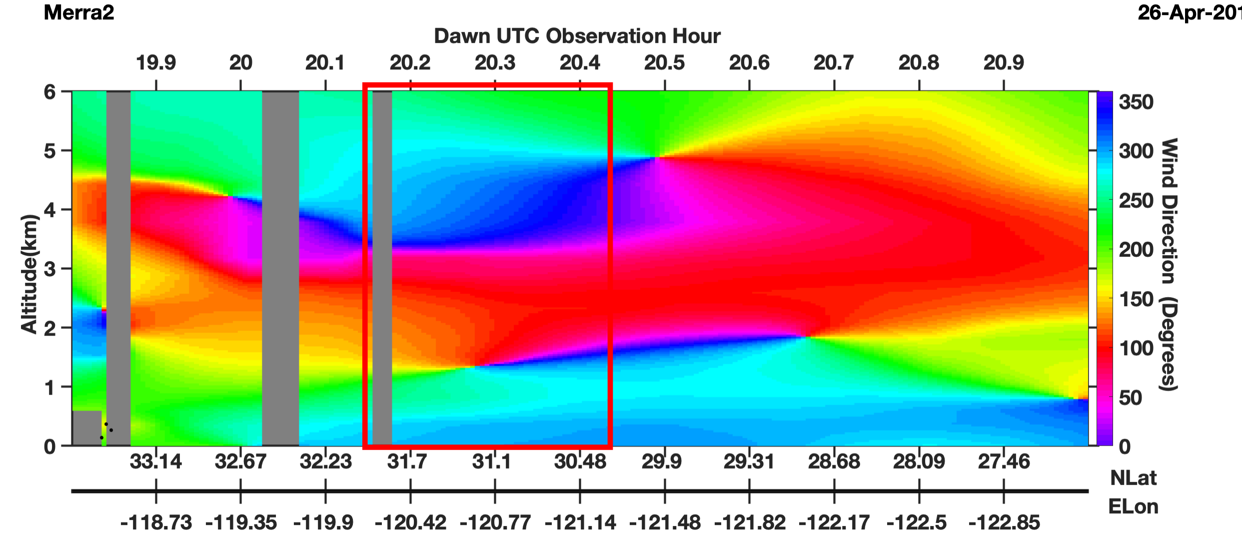
DAWN



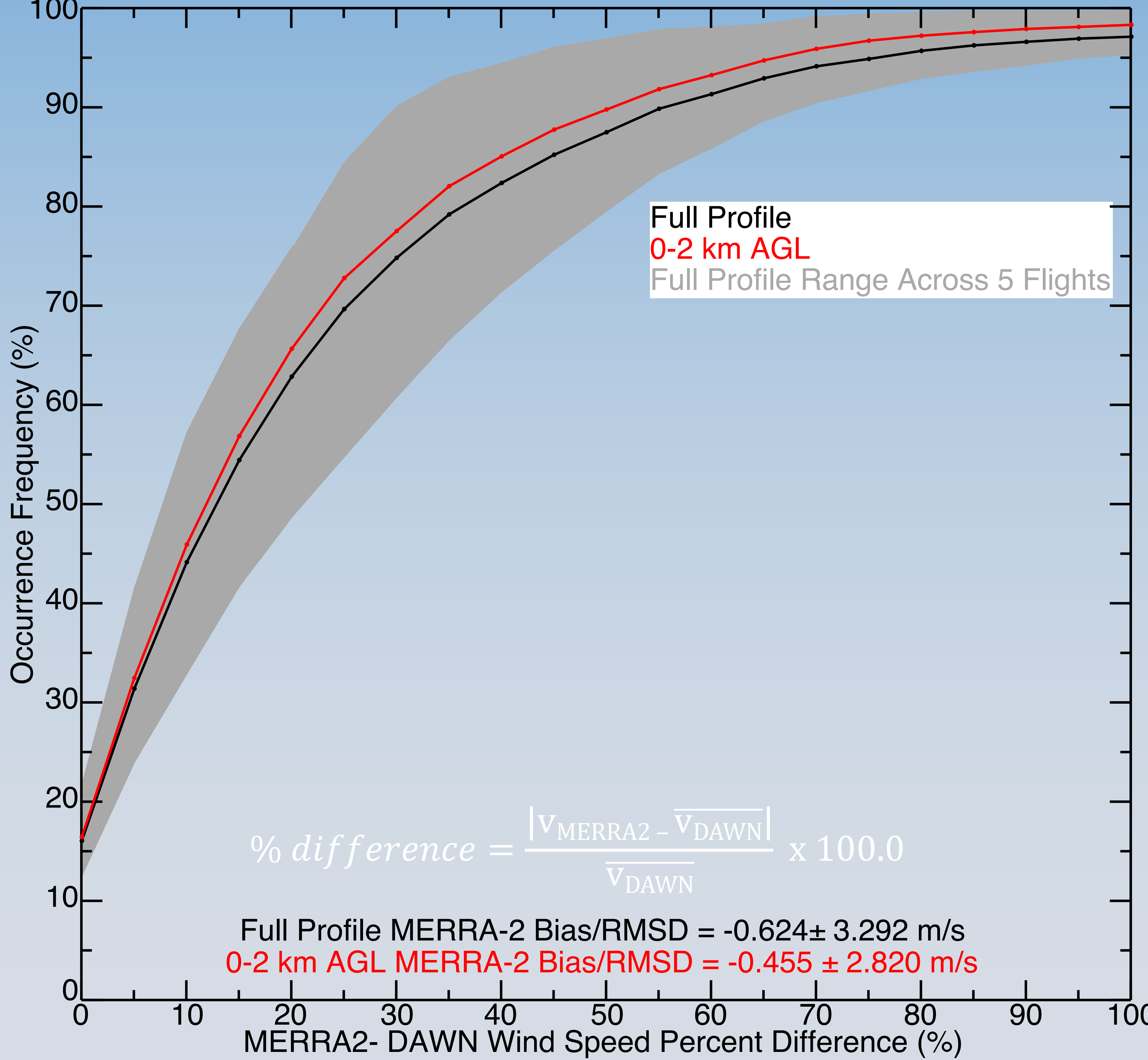


MERRA-2

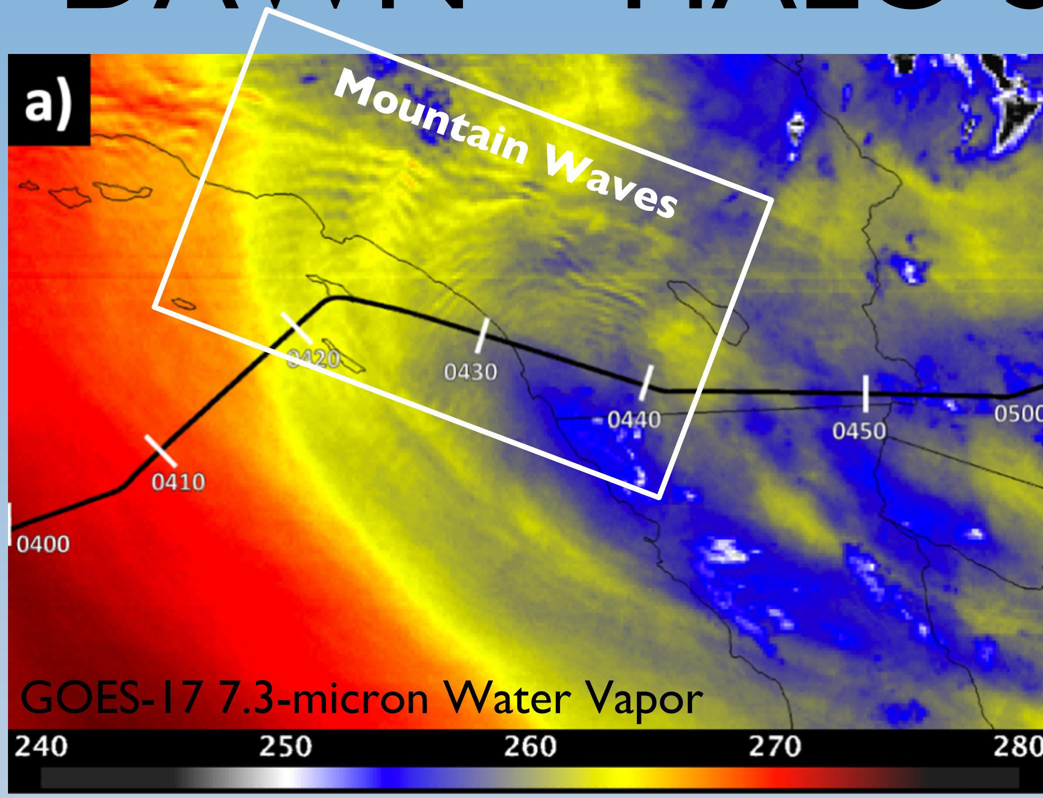


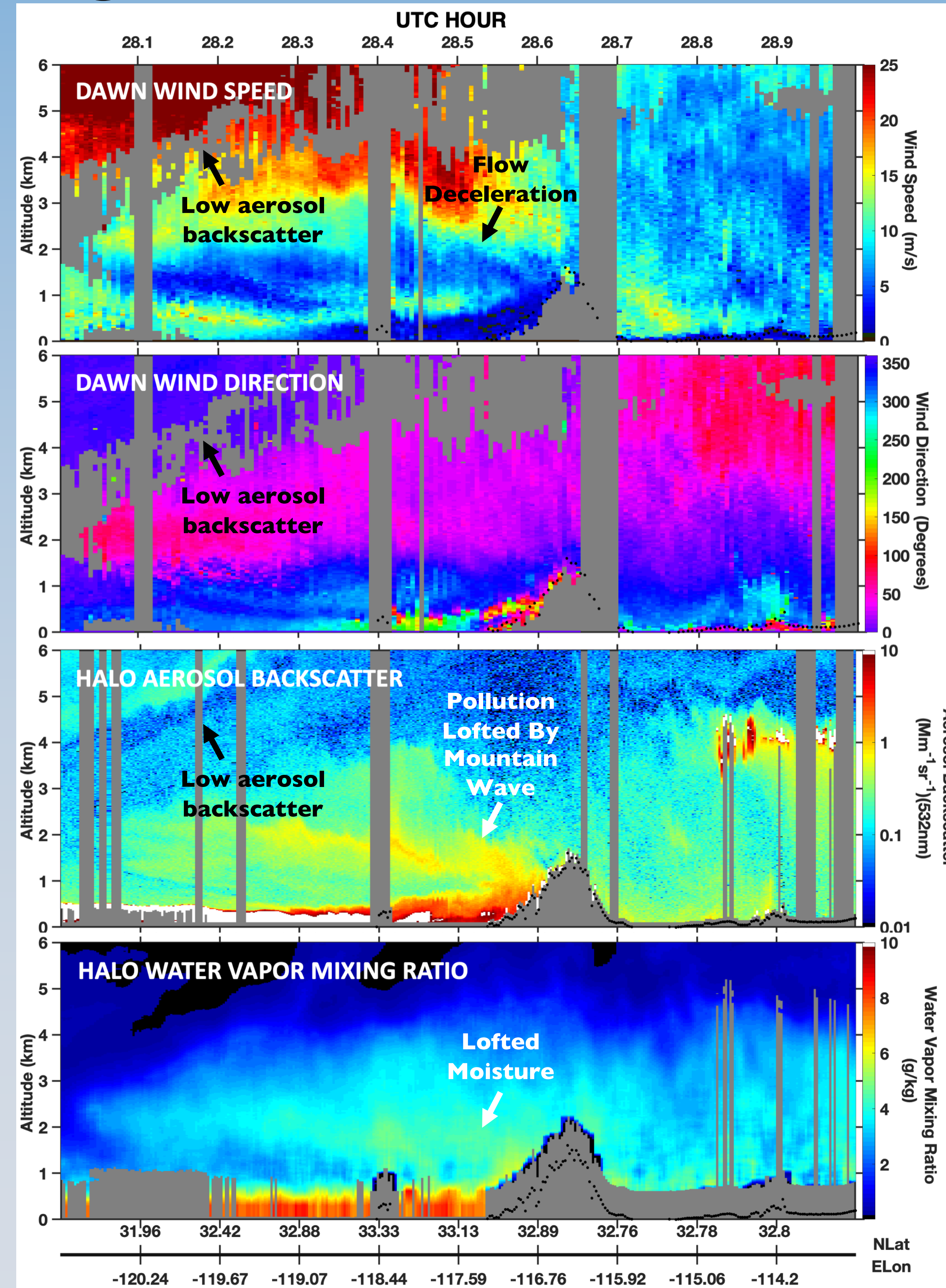


DAWN and MERRA-2 at MERRA-2 Resolution



DAWN + HALO Synergistic Observations

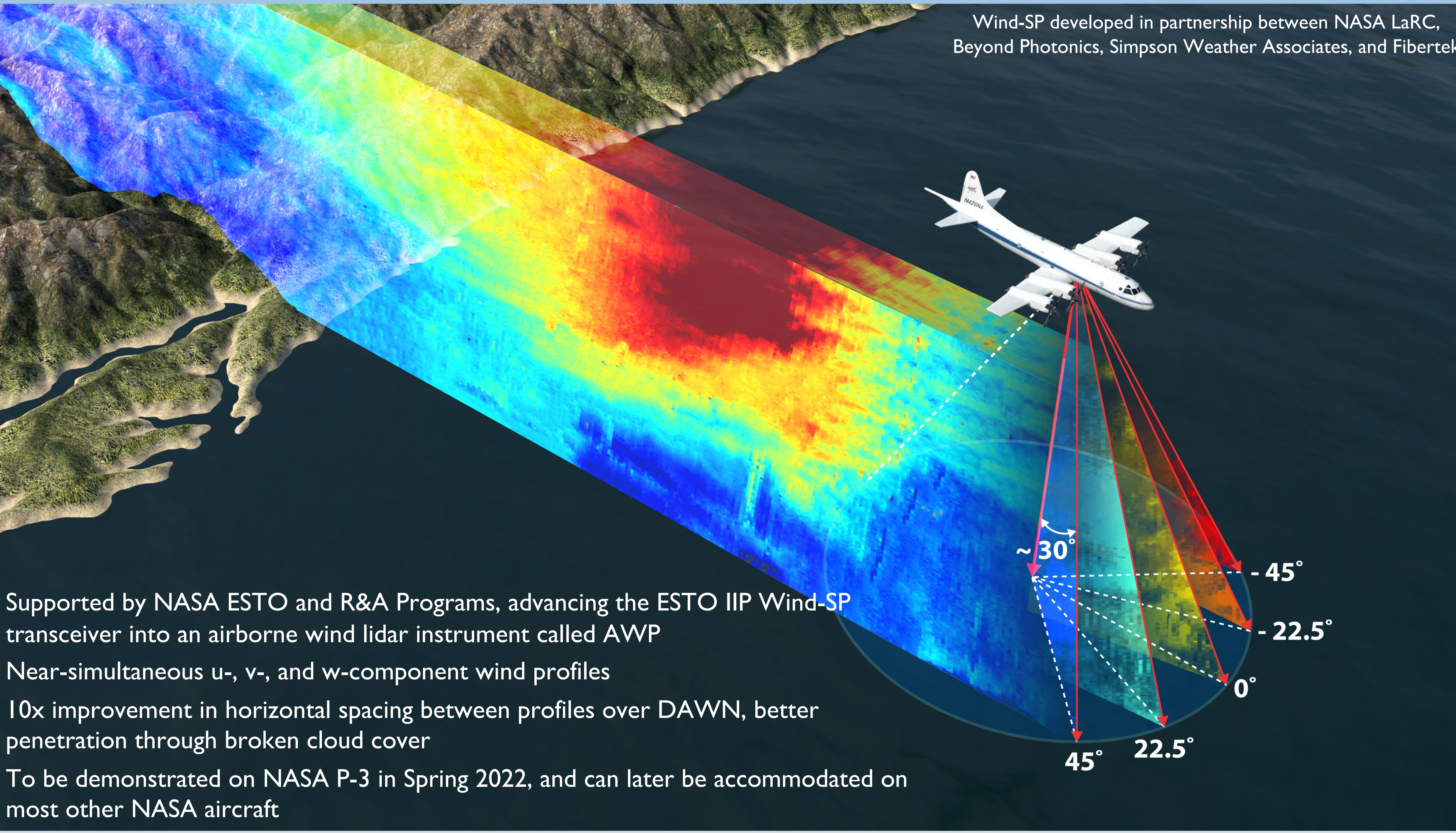




- Simultaneous, detailed observations of winds, water vapor, aerosols, clouds, and precipitation are needed to fully understand the PBL and how it couples to weather and climate
- Airborne platforms provide the detail, measurement quality and revisits not possible from satellite
- Example shows DAWN and HALO observations of complex mountain wave patterns within and above the PBL observed by GOES-17

Next-Generation Lidar Aerosol Wind Profiler (AWP)

Wind-SP developed in partnership between NASA LaRC, Beyond Photonics, Simpson Weather Associates, and Fibertek



- Supported by NASA ESTO and R&A Programs, advancing the ESTO IIP Wind-SP transceiver into an airborne wind lidar instrument called AWP
- Near-simultaneous u-, v-, and w-component wind profiles
- 10x improvement in horizontal spacing between profiles over DAWN, better penetration through broken cloud cover
- To be demonstrated on NASA P-3 in Spring 2022, and can later be accommodated on most other NASA aircraft

Summary and a Look Ahead

- High precision and resolution measurements are required to augment models and derive a complete understanding of complex, rapidly evolving atmospheric processes within and above the PBL
- Wind profiling is a key part of understanding dynamics, clouds, precipitation, and PBL processes, as outlined in the 2017 Decadal Survey
- Recent Aeolus Cal/Val flight campaign showed that DAWN and HALO together provide detailed and precise observations within and above the PBL
- DAWN, HALO, APR-3, and HAMSR will be flown together in the 2021 NASA Convective Processes EXperiment - Aerosols and Winds (CPEX-AW) to derive the best estimate of the 4-D atmospheric state for studying convection and aerosols, and for satellite AMV/lidar
- Advanced airborne 3-D wind lidar (AWP) instrument development and space-borne wind lidar tech development ongoing at LaRC and with partners

QUESTIONS/COMMENTS: john.w.cooney@nasa.gov

References

- Barton-Grimley, R., A.R.Nehrir, S. Kooi, J. Collins: Validation of the High Altitude Lidar Observatory XCH4 Measurements during the 2019 ACT-America Campaign. In preparation for Atmospheric Measurement Techniques.
- Bedka, K. M., A. R. Nehrir, M. J. Kavaya, and Co-Authors: Airborne Lidar Observations of Wind, Water Vapor, and Aerosol Profiles During The NASA ADM-Aeolus Cal/Val Test Flight Campaign. In preparation for Atmospheric Measurement Techniques.
- Coniglio, M. C., and M. D. Parker, Insights into supercells and their environments from three decades of targeted radiosonde observations. Mon. Wea. Rev., doi: https://doi.org/10.1175/MWR-D-20-0105.1.
- Cui, Z., Z. Pu, G. D. Emmitt, and S. Greco, 2020: The Impact of Airborne Doppler Aerosol Wind (DAWN) Lidar Wind Profiles on Numerical Simulations of Tropical Convective Systems during the NASA Convective Processes Experiment (CPEX). J. Atmos. Oceanic Technol., 37, 705–722, https://doi.org/10.1175/JTECH-D-19-0123.1.
- Greco, S.; G. D. Emmitt, M. Garstang, and M. Kavaya, 2020: Doppler Aerosol WiNd (DAWN) Lidar during CPEX 2017: Instrument Performance and Data Utility. Remote Sens. 2020, 12, 2951.
- Greco, S., G. D. Emmitt, A. DuVivier, K. Hines, and M. Kavaya, 2020: Polar Winds: Airborne Doppler wind lidar missions in the Arctic for atmospheric observations and numerical model comparisons. Provisionally accepted to Remote Sensing.
- Natonal Academies of Sciences, Engineering, and Medicine. Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space. Washington, DC: The National Academies Press, doi: https://doi.org/10.17226/24938, 2018.
- Kavaya M.J., Beyon J.Y., Koch J.G., Petros, M., Petzar P.J., Singh U.N., Trieu B.C., and Yu, J. The doppler aerosol wind (DAWN) airborne, wind-profiling coherent-detection lidar system: Overview and preliminary flight results. J. Atmos. Oceanic Technol., 31:826–842, 2014.
- Nehrir A.R., Kiemle, C., Lebsock, M. D., and Co-authors, 2017: Emerging Technologies and Synergies for Airborne and Space-Based Measurements of Water Vapor Profiles. Surv Geophys 38, 1445–1482, November 2017. https://doi.org/10.1007/s10712-017-9448-9
- Turk, F. J., Hristova-Veleva, S., Durden, S. L., Tanelli, S., Sy, O., Emmitt, G. D., Greco, S., and Zhang, S. Q., 2020: Joint analysis of convective structure from the APR-2 precipitation radar and the DAWN Doppler wind lidar during the 2017 Convective Processes Experiment (CPEX), Atmos. Meas. Tech., 13, 4521–4537, https://doi.org/10.5194/amt-13-4521-2020
- Wayman E. Baker. Lidar-measured wind profiles: The missing link in the global observing system. Bull. Amer. Meteor. Soc., 95:543–564, 2014.

Extra Slides