Describing the Marine Atmospheric Boundary Layer using Airborne Doppler Wind Lidar observed backscatter and turbulence

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Science contributions and target questions

- What does an Airborne Doppler Wind Lidar (ADWL) have to offer
  to investigations of the Marine Atmospheric Boundary layer (MABL)?
  - Depth of the MABL defined by aerosols (backscatter), wind profiles and turbulence (spectral width)
  - MABL features: LLJs, OLEs, sea salt spray distribution
  - Ocean surface: breaking waves, foam coverage, ocean wave spectra.

- How organized are MABL Organized Large Eddies?

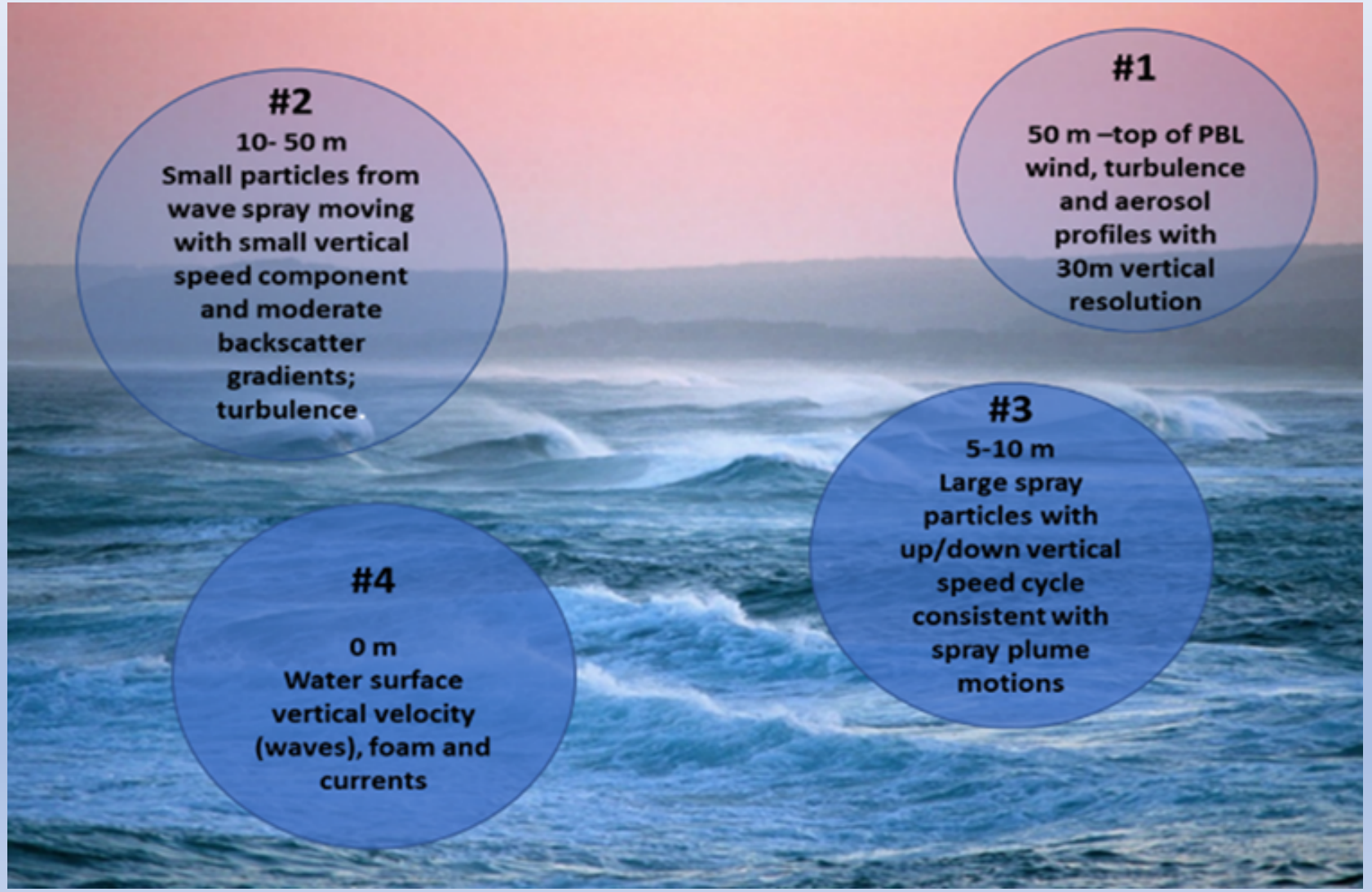
- How can ADWL contribute to PDF based air/sea flux parameterizations?

- What is the “true” wind at the traditional 10 m reference height over water?
  Log and power wind profiles are not suitable for high winds (>15m/s) with highly non-linear interactions between the ocean surface and the lower MABL

Available data sets

- Coherent Airborne Doppler Wind Lidars
  - TODWL (80% MABL) 2001 - 2019
    - Working altitude: 30m to 3km MSL
    - Cruise speed: 50-60m/s
    - DWL: coherent 2 um, 1mJ, 500Hz, side mounted scanner
    - Single shot resolution: ~40m vertical; .1 m horizontal
  - P3DWL (99% MABL) 2008 - 2019
    - Working altitude: 1km to 3km MSL
    - Cruise speed: 120 - 130m/s
    - DWL: coherent 2 um, 2mJ, 500Hz, side mounted scanner
    - Single shot resolution: ~40m vertical; .3m horizontal
  - DAWN (90% MABL) 2014 - 2019
    - Working altitude: 1 km to 13km MSL
    - Cruise speed: 225 - 250m/s
    - DWL: coherent 100mJ, 10Hz, nadir wedge scanner
    - Single shot resolution: ~30m vertical; 25m horizontal

Zonal approach to processing single ADWL shots



Deriving the MABL depth using coherent ADWL

- Three primary data products generated by ADWL used to define MABL depth and kinetic energy intensity profile
  - Backscattered returns from aerosols
    - Confounder speckle
  - Doppler shift along radials
    - Confounder chirp
  - Spectral broadening
    - Confounder FFT limits
- Comparisons made with dropsondes
  - Ri profile (bulk)
  - ThetaE profile

Turbulence estimation using coherent DWL

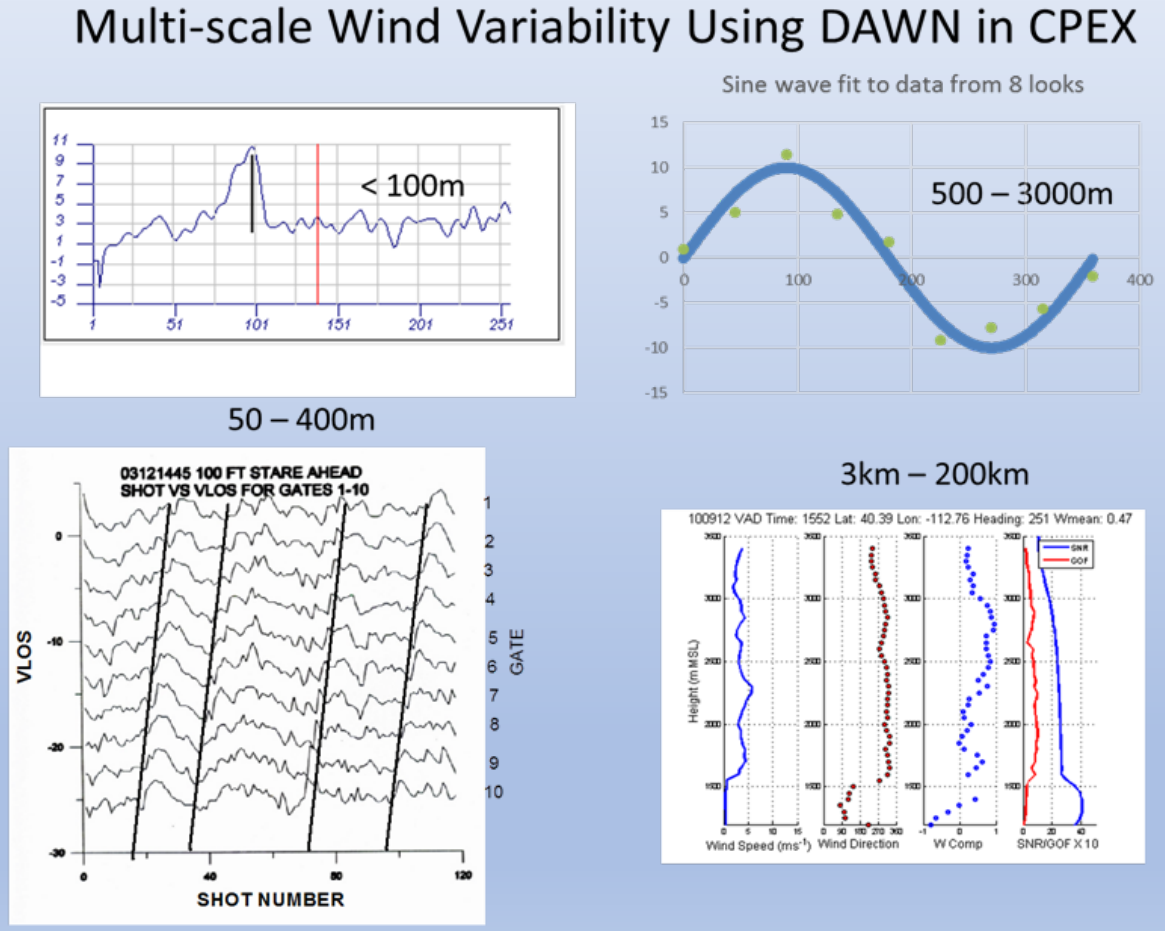
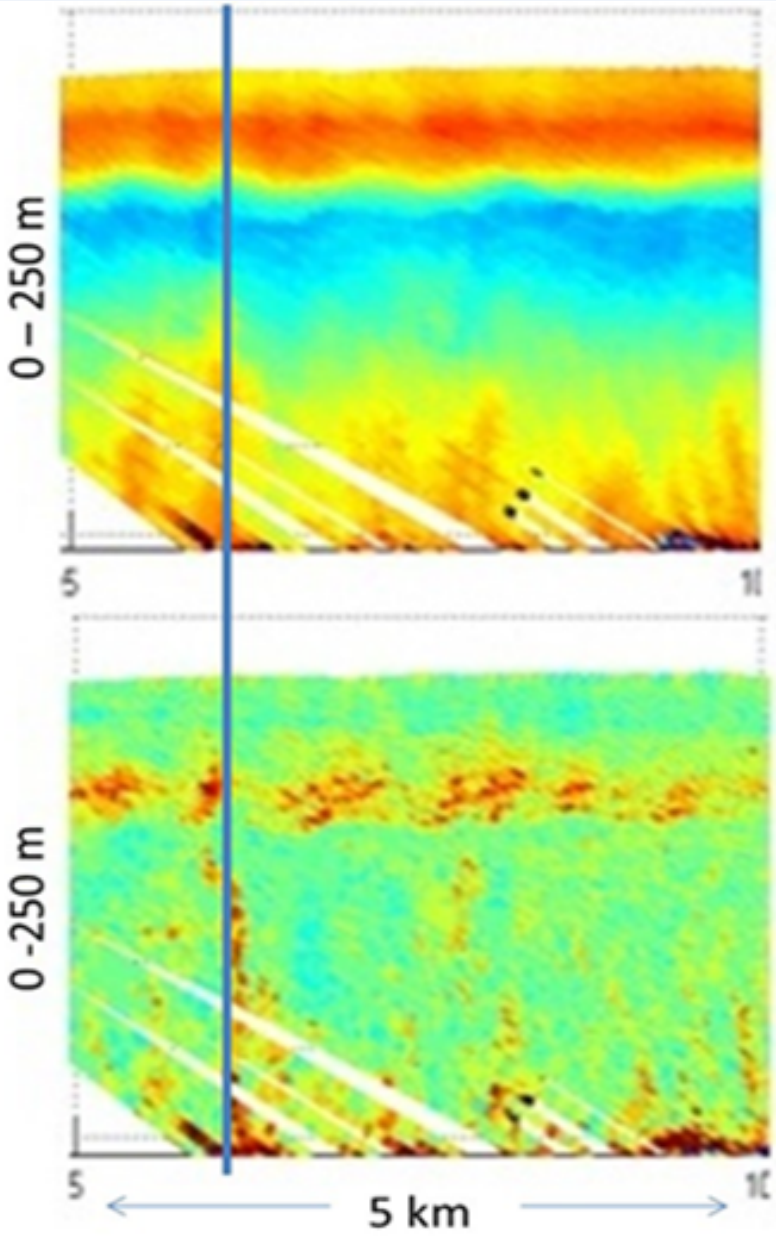
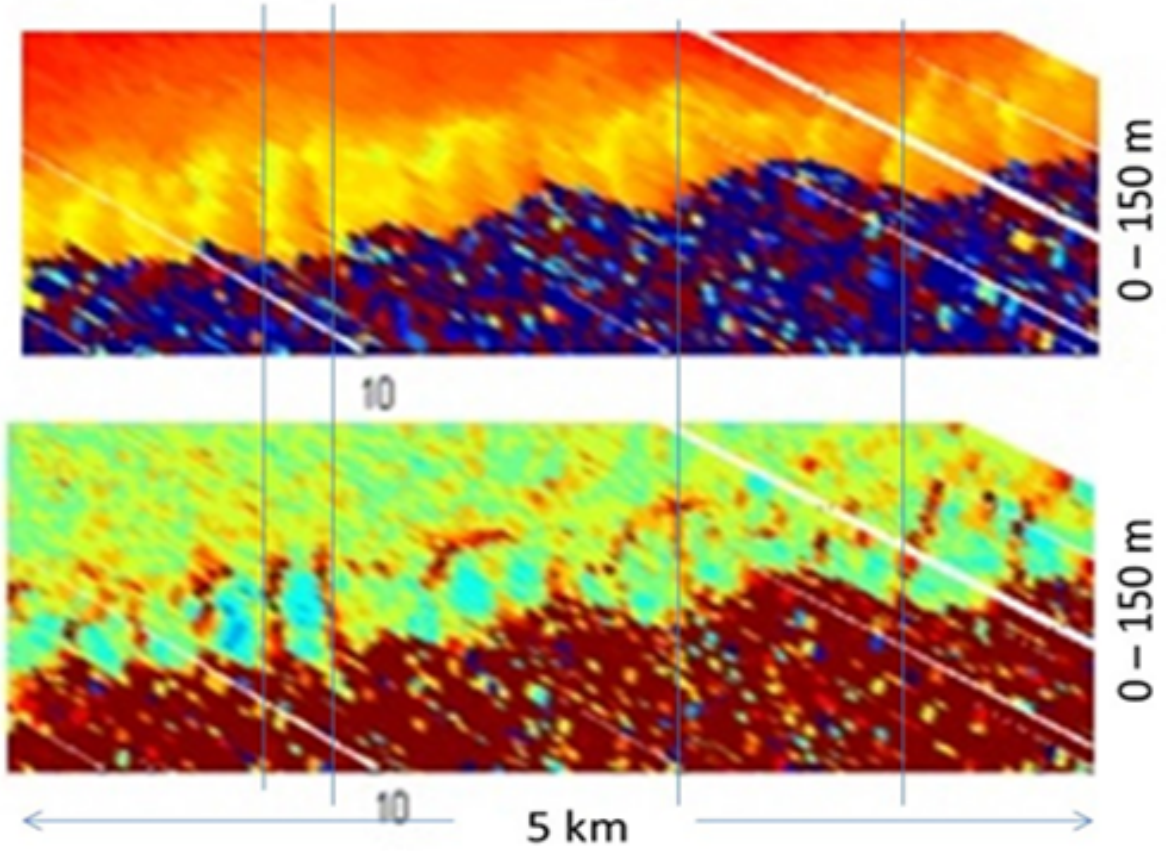


Illustration of the four scales of atmospheric wind variability observed with coherent ADWLs



Focus upon wind convergence structures (top panels) associated with rolls in the marine boundary layer



Channels of turbulence (spectral broadening) being transported from near surface to top of the marine boundary layer. Blue lines to assist visual alignment.

Derived MABL depths by NASA's DAWN

- DAWN flown at ~12 km flight level
- 2 second stare at 10 Hz= 20 samples per look angle
- 25-30m between shots
- Processed with 77 m gate with a 15 m slide (correlated products)
- Dropsondes for comparisons


0423_022800
0427_185028
0428_001059
Google Earth
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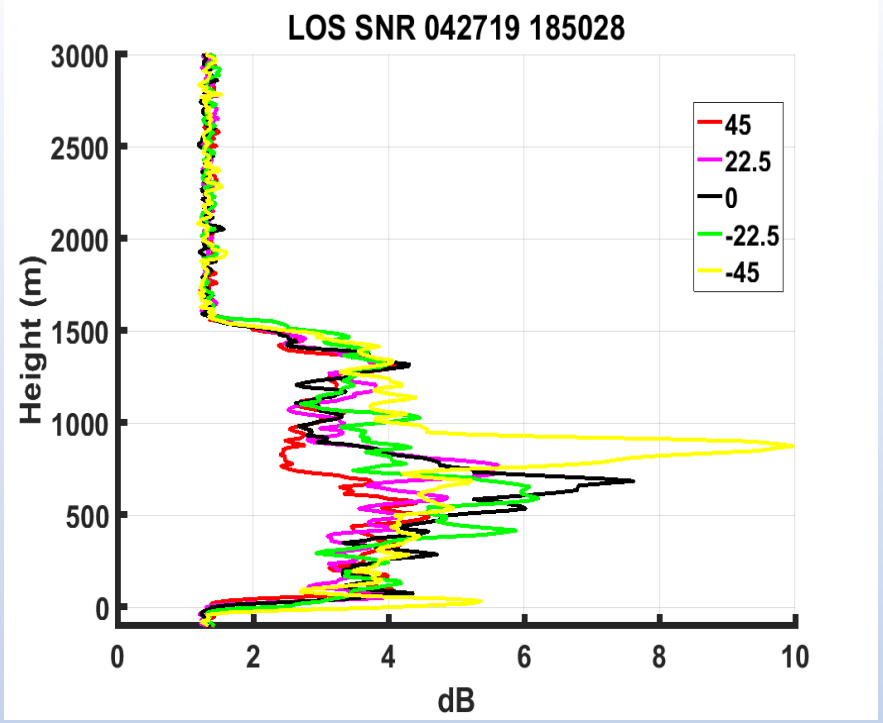
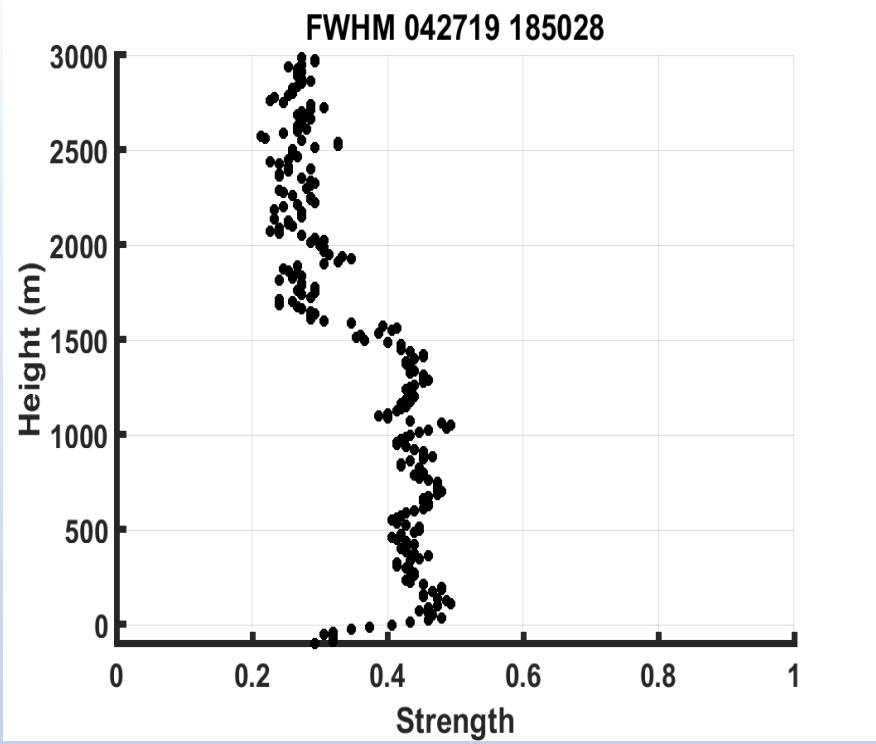
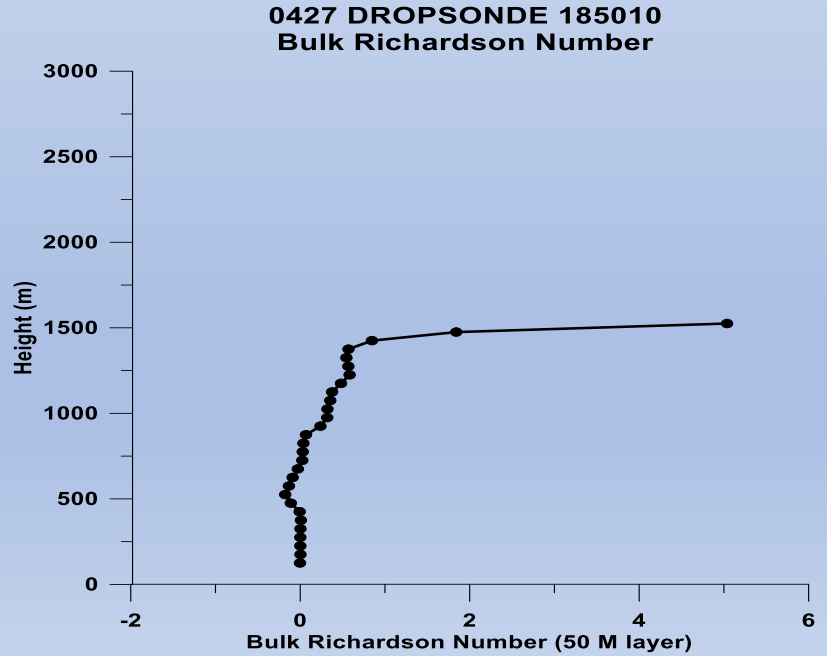
© 2020 INEGI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
N
2200 mi


LOS SNR 042719 185028
Height (m)
dB
45
22.5
0
-22.5
-45


FWHM 042719 185028
Height (m)
Strength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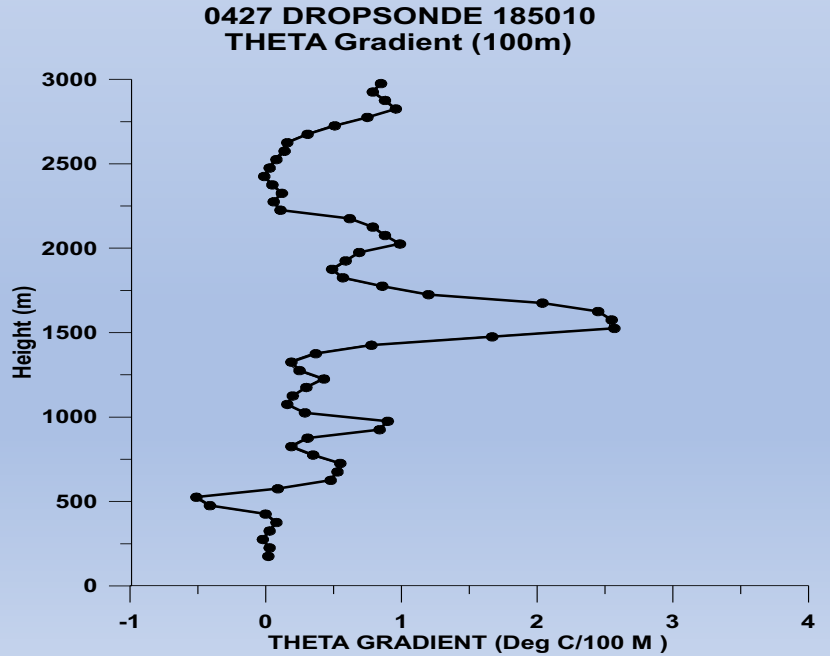
Bulk Richardson Number
Height (m)
Bulk Richardson Number (50 M layer)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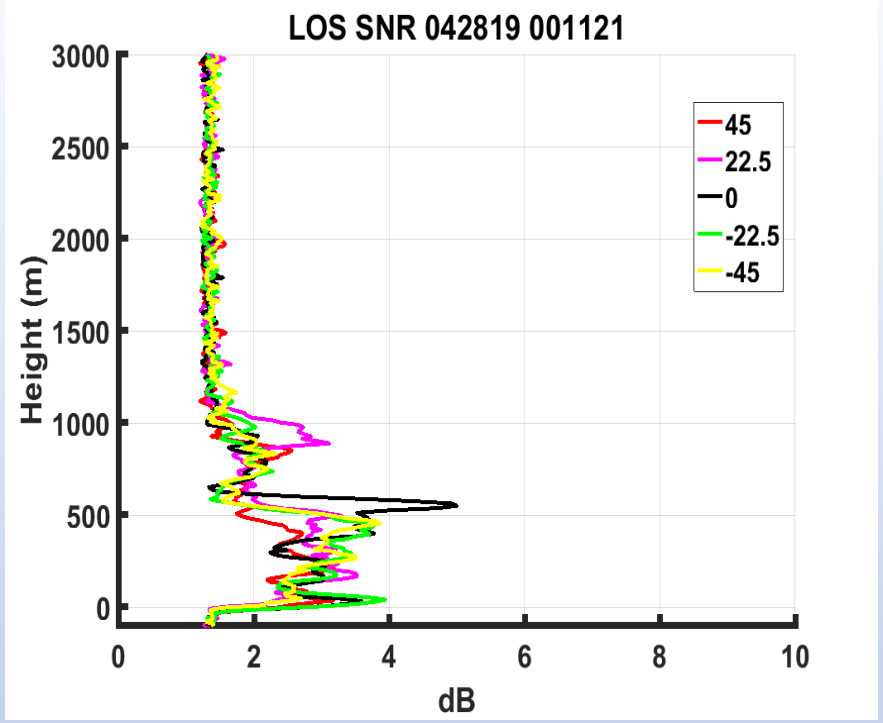
THETA Gradient (100m)
Height (m)
THETA GRADIENT (Deg C/100 M)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Height (m)
dB
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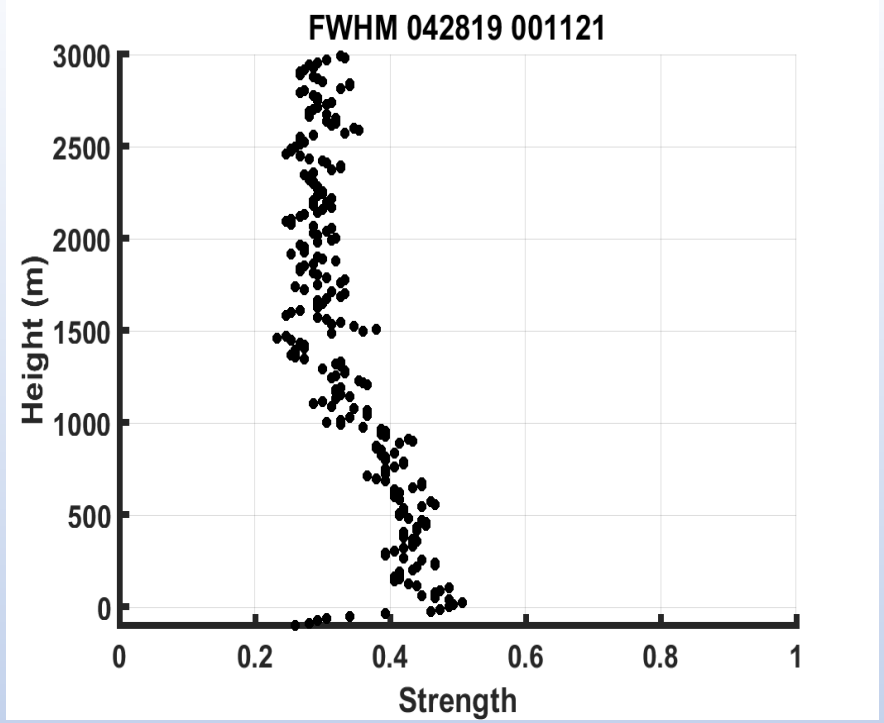
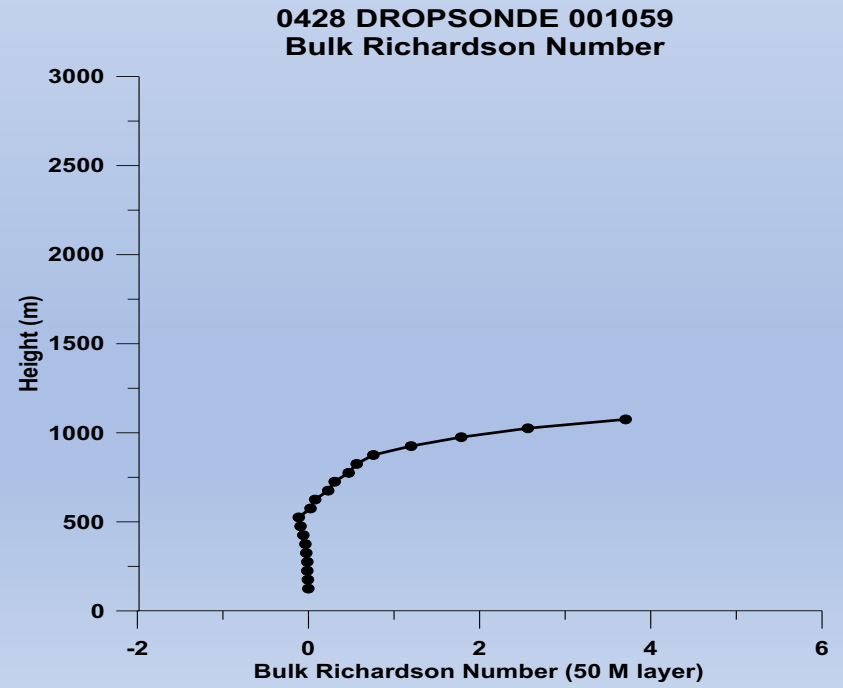
22.5
0
-22.5
-45


FWHM 042819 001121
Height (m)
Strength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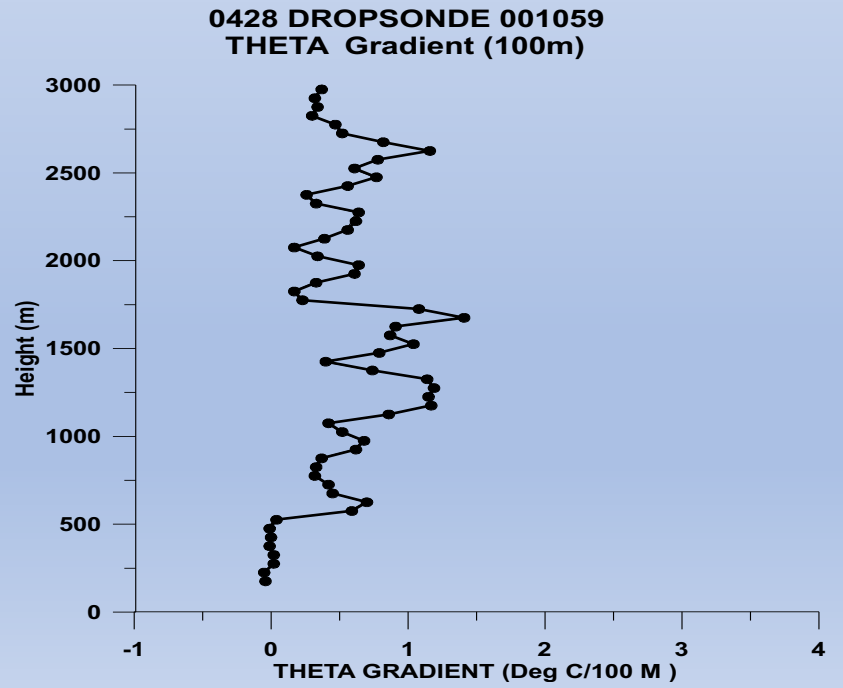
Bulk Richardson Number
Height (m)
Bulk Richardson Number (50 M layer)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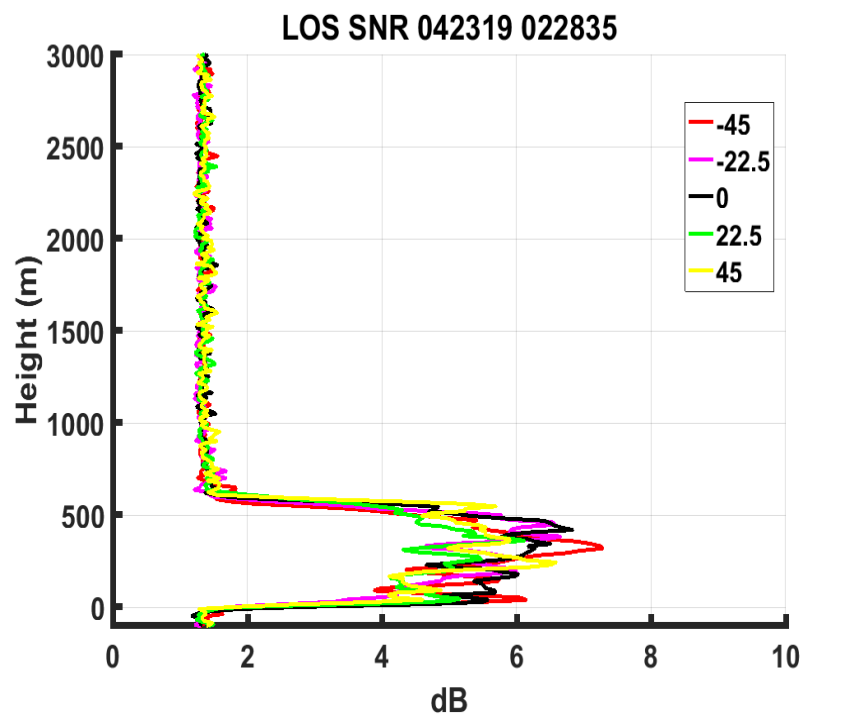
THETA Gradient (100m)
Height (m)
THETA GRADIENT (Deg C/100 M)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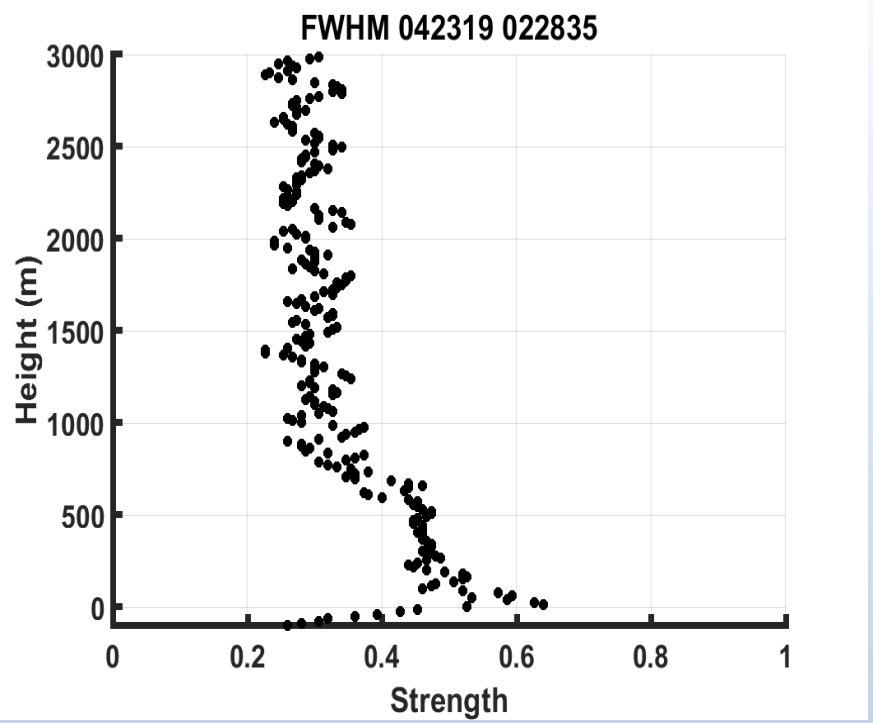
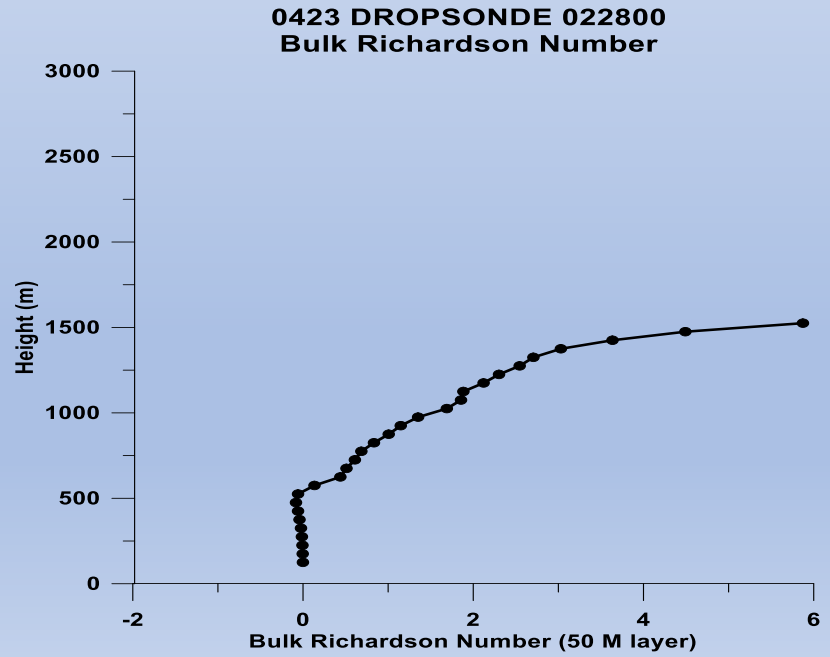
Height (m)
dB
-45
-22.5
0
22.5
45


FWHM 042319 022835
Height (m)
Strength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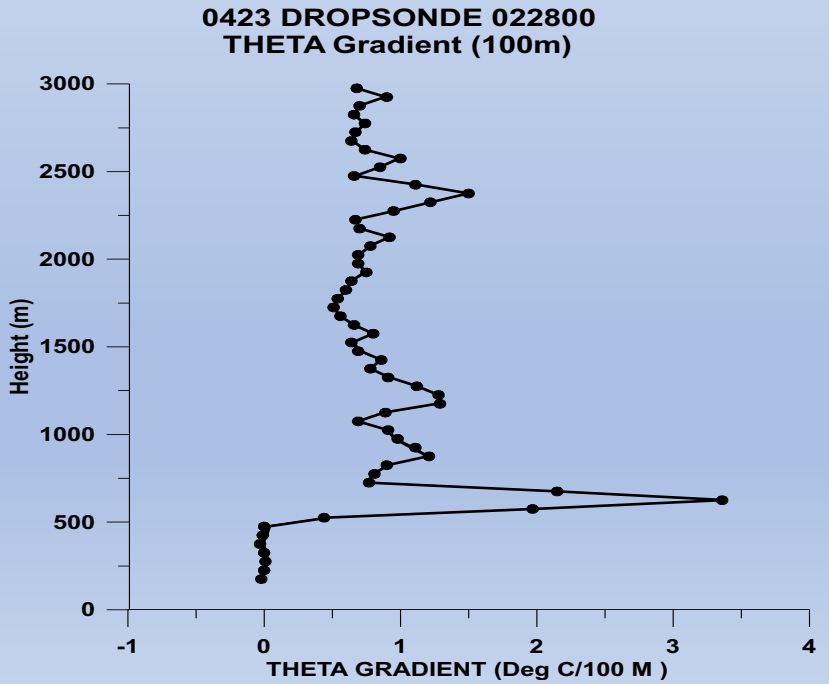
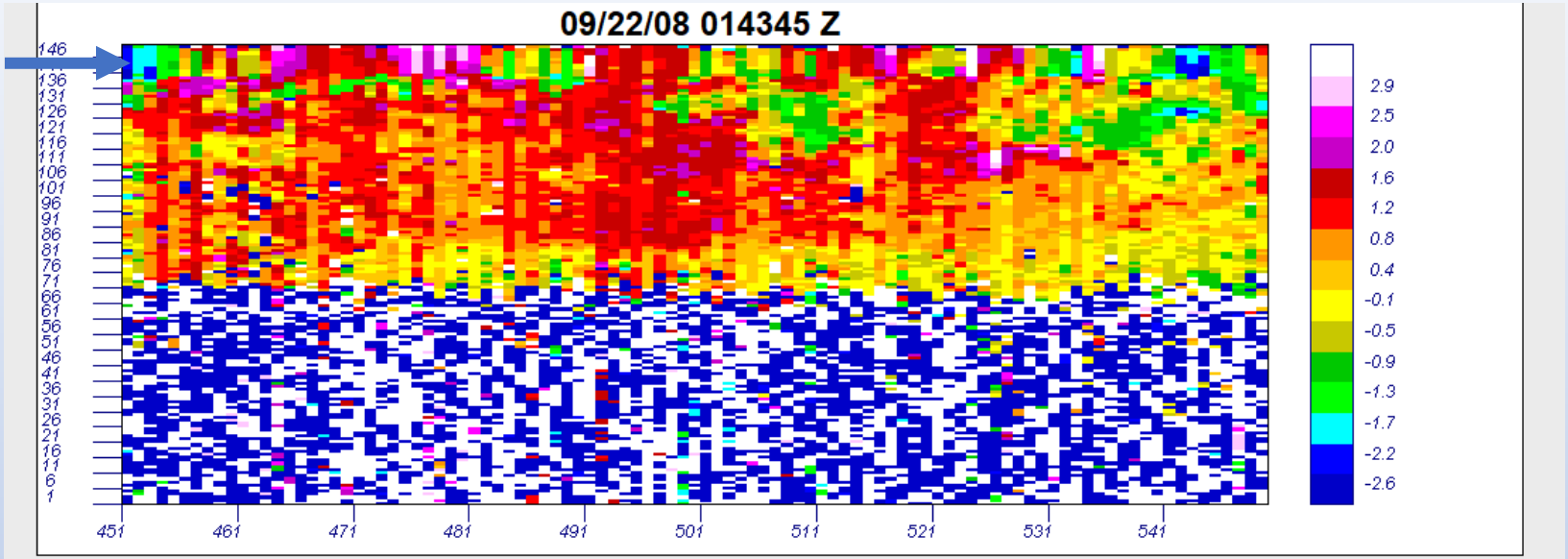
Bulk Richardson Number
Height (m)
Bulk Richardson Number (50 M layer)


0423 DROPSONDE 022800
THETA Gradient (100m)
Height (m)
THETA GRADIENT (Deg C/100 M)

Derived MABL depths by NRL's & NOAA's P3DWL

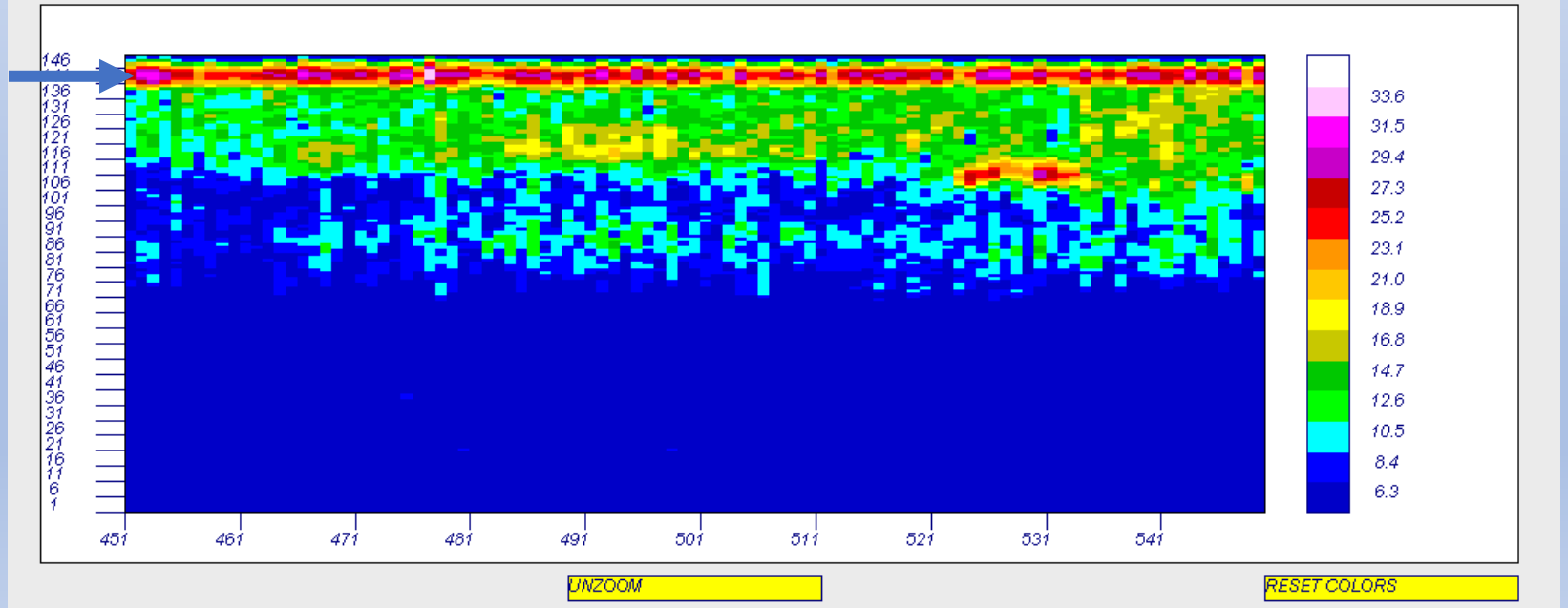
- P3DWL flown at 3 km flight level
- 30 second stare at 160 Hz= 200 samples per look angle
- 18m between shots
- Processed with 80 m gate with a 15 m slide (correlated products)
- Dropsondes for comparisons

Surface



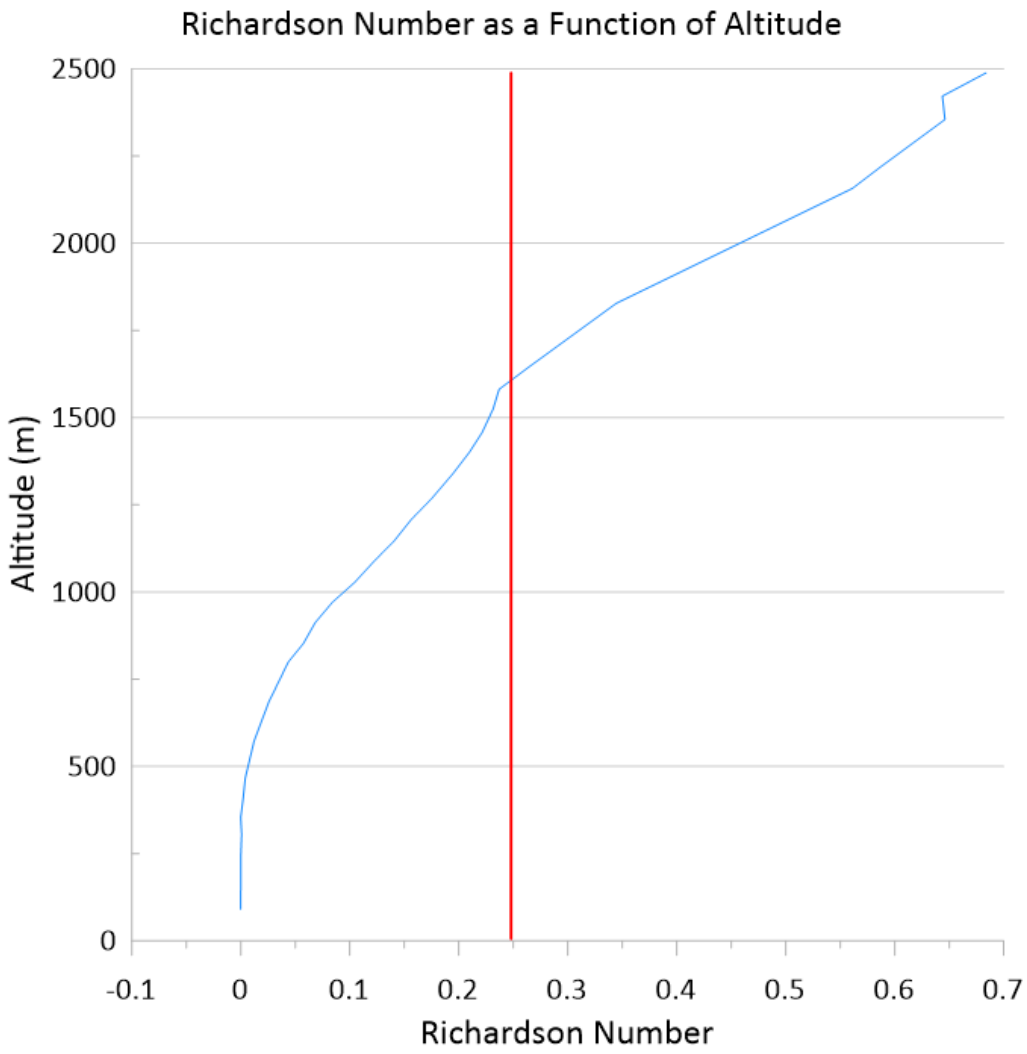
LOS wind speed (m/s)

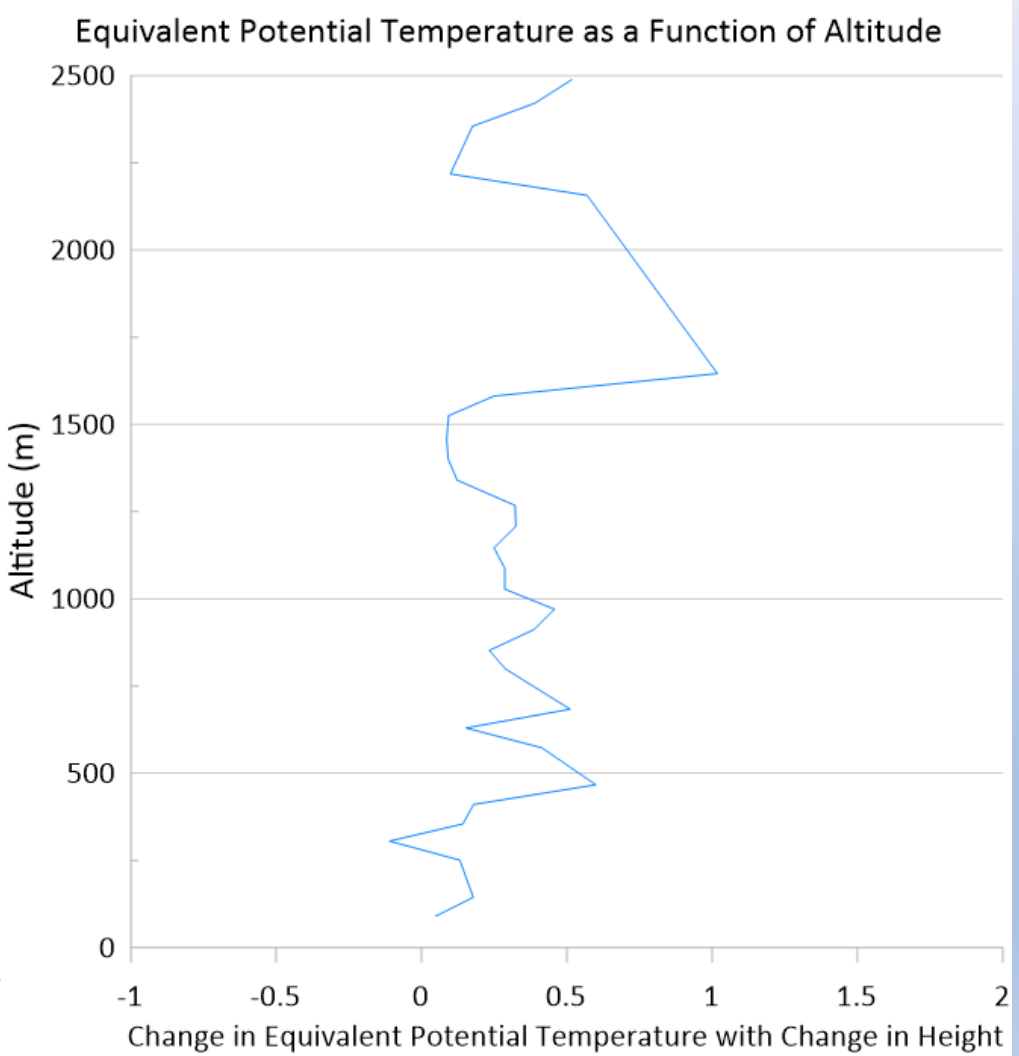
Surface



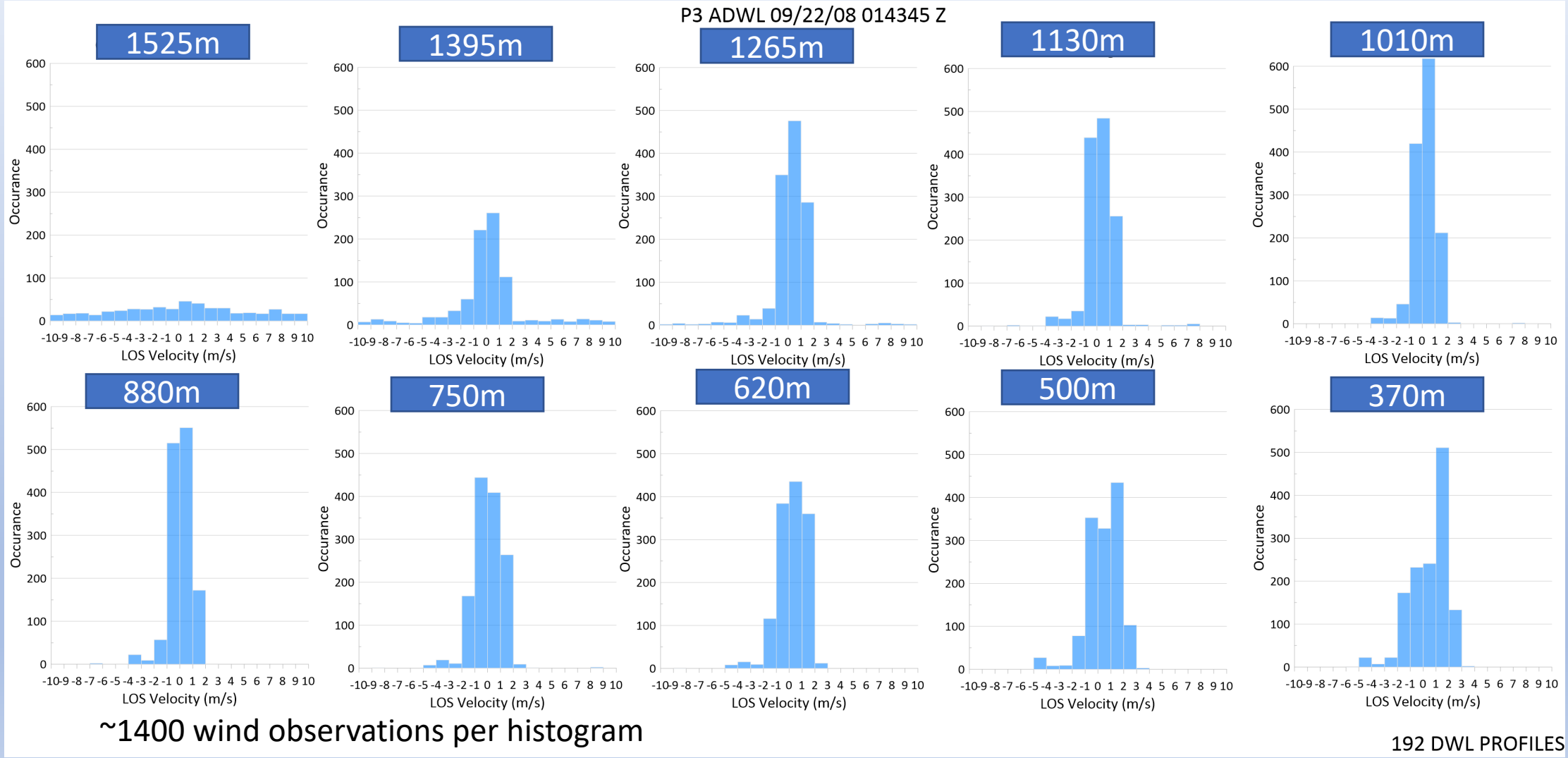
LOS signal to noise ratio (dB)

MABL depths derived from dropsonde





Wind variability as function of altitude within MABL

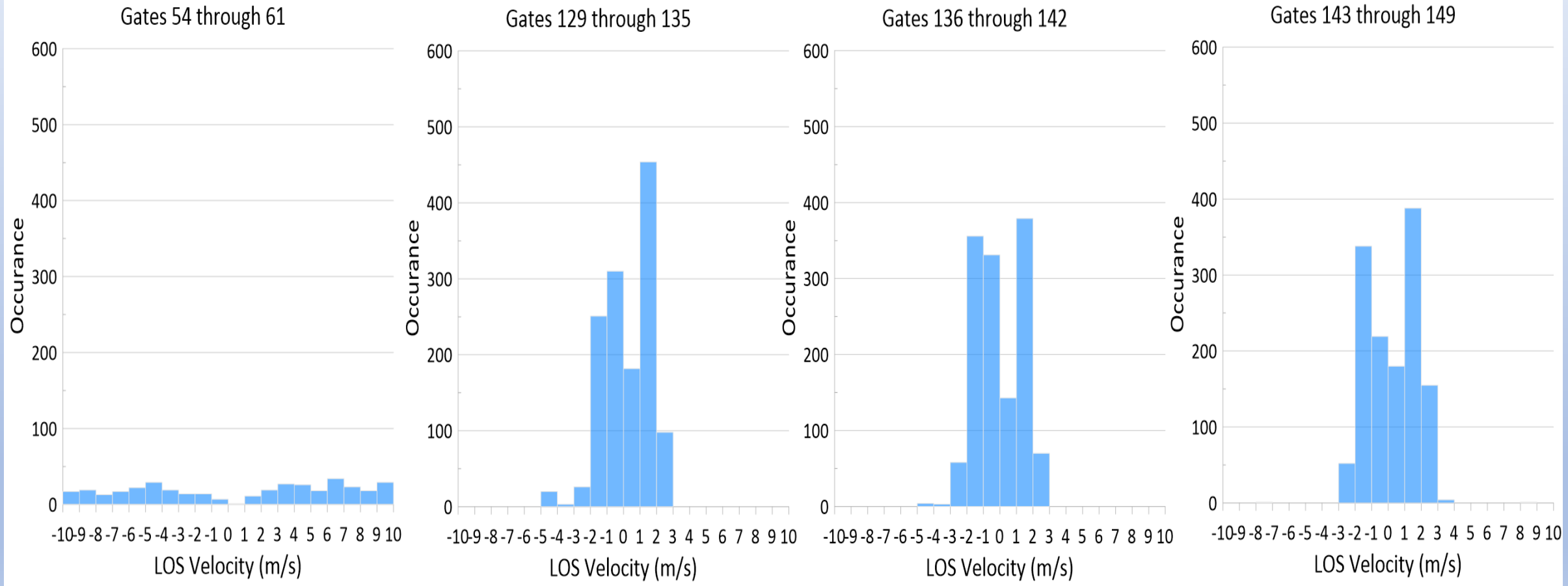


Summary

- An airborne DWL can provide estimates of the depth of the MABL based upon both aerosol distributions as well as turbulent kinetic energy.
- The vertical and horizontal resolutions can resolve MABL wind variability on scales ranging from 10’s to 1000’s of meters.
- In addition to providing precise and high resolution information on the structure and dynamics of the MABL for process investigations, coherent ADWL data can be used for simulating observation errors in OSSEs and for space-based instrument concept trade studies.

Backup Slides

P3 ADWL 09/22/08 014345 Z



192 DWL PROFILES