Ship-Based LIDAR Estimates of Marine Mixed Layer Heights during TexAQS 2006

Sara Tucker[1,2], Brandi McCarty[1,2], Alan Brewer[1], Christoph Senff[1,2], Janet Machol[1,2], Scott Sandberg[1], and Richard Marchbanks[1,2]
[1]National Oceanic and Atmospheric Administration, Earth System Research Laboratory
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder
325 Broadway, Boulder, CO 80305, USA, sara.tucker@noaa.gov (303) 497-4684

Background

During the ship-based portion of the 2006 Texas Air Quality Study (TexAQS 2006) , NOAA deployed two lidars on the aft deck of the research vessel R. H. Brown. The High Resolution Doppler Lidar (HRDL) performed continuous measurements of boundary layer winds and relative 2 micron aerosol backscatter. The Ozone Profiling Atmospheric Lidar measured ozone and aerosol profiles.

Using different aspects of the HRDL data, we have developed **new methods** to estimate and visualize mixed layer heights as determined by aerosol layering, vertical velocity variance (mixing strength) profiles, and wind shear. We present an overview of the methods used for estimating these layers and compare the results to aerosol-profile derived estimates of boundary layer heights from the OPAL measurements. We provide examples of marine mixed layer heights, as well as their interpretation, from various conditions encountered during the experiment.

Mixing is usually the result of convection and/or shear-induced mechanical turbulence. Either type of mixing can effect the blending of the surface aerosol layers and other aerosol/pollution layers aloft. Nocturnal low-level jets often cause the mixed layer to stay below the jet, in the region of high shear.

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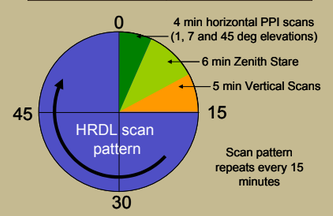
High Resolution Doppler Lidar (HRDL)

HRDL Parameters

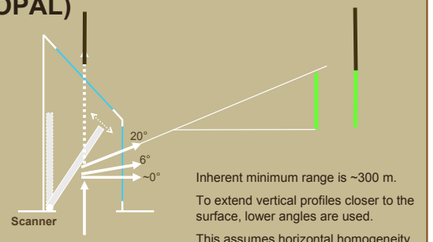
Wavelength	2.02 micron
Pulse Energy	2-3 mJ
PRF	200 Hz
Max Range	4-8 km
Range Res.	30 m
Beam rate	2 Hz
Scanning	Full Hemispheric
Precision	10 cm/s



Some Caveats

- The Ship is a moving platform – we sometimes see "sudden" changes in mixing dynamics when moving from close to shore to open water, or vice-versa
- Ship's stack can affect lidar performance
- Wind shear data: 5-20 m vertical resolution starting at the surface

Ozone Profiling Atmospheric Lidar (OPAL)



Inherent minimum range is ~300 m.

To extend vertical profiles closer to the surface, lower angles are used.

This assumes horizontal homogeneity.

Aerosol Measurements

OPAL aerosol data is measured at the 355-nm wavelength. Data have been corrected for instrument range dependence and calibrated using a clean region of 4500 – 5500 m in the Klett retrieval method.

Types of "Boundary Layer" Heights

- Surface Layer
- Mixing Layer
- Convective Mixing/Boundary Layer
- Aerosol layer (maximum gradient)
- First Aerosol layer (first gradient)
- Shear and shear-induced turbulence mixed layer.

We're interested in two main types of boundary layer height

- The height of the surface-based layer within which aerosols/gases emitted within that layer are mixed → concentration calculations.
- The maximum height of the layers containing larger/concentrated aerosols → radiative transfer studies

MIXED LAYER PRODUCT (preliminary)

Combined mixed-layer product is found by choosing the dominant atmospheric feature:

- aerosol gradients
- vertical mixing (if present)
- wind speed shear and/or
- wind direction shear.

We then use those data to determine the mixed layer height for the given time.

Lidar products and methods for mixed layer height estimation

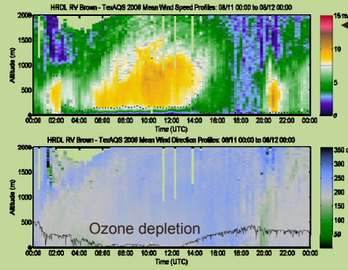
HRDL (15 minute estimates)

- Horizontal Mean Wind profiles
  - Speed and directional wind shear: Search for altitudes where shear is greater than 1.5 (m/s)/m (speed shear) or greater than ~1 deg/m (directional shear) for several meters
  - Combined shear (wind vectors): Find altitudes where the vector between wind-vectors is large.
- Vertical velocity variance/small-scale mixing profiles
  - If surface mixing is present, find where the mixing strength falls below 0.2 m^2/s^2.

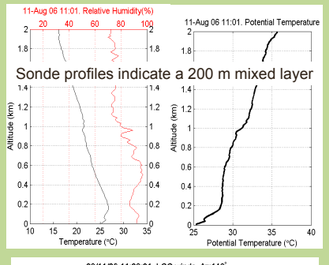
OPAL (3 minute) and HRDL

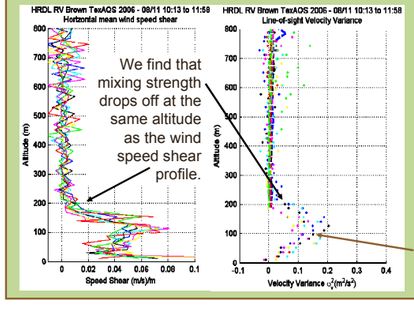
- Vertical profiles of relative aerosol strength.
  - Typically use the Haar wavelet method to detect aerosol gradients.
  - HRDL vertical stare resolution is 30 meters. OPAL resolution is 5 meters.

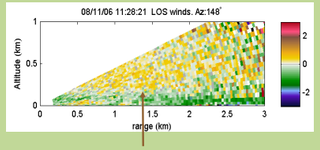
Radar profilers often have difficulty measuring wind and or BL data below 300-500 meters. In zenith stare mode, HRDL's minimum range is 185 meters, but by scanning we can gather turbulence and speed/directional shear information down to the surface. During nocturnal low-level jets (LLJ), low-altitude information is extremely important for estimating the mixed layer height. Here we use the wind speed shear and velocity turbulence/mixing estimates to determine the boundary layer height.



This time/altitude plot of mean wind speed shows the LLJ as a green to yellow area. Dots show where the wind speed shear is greater than 1 (m/s)/m



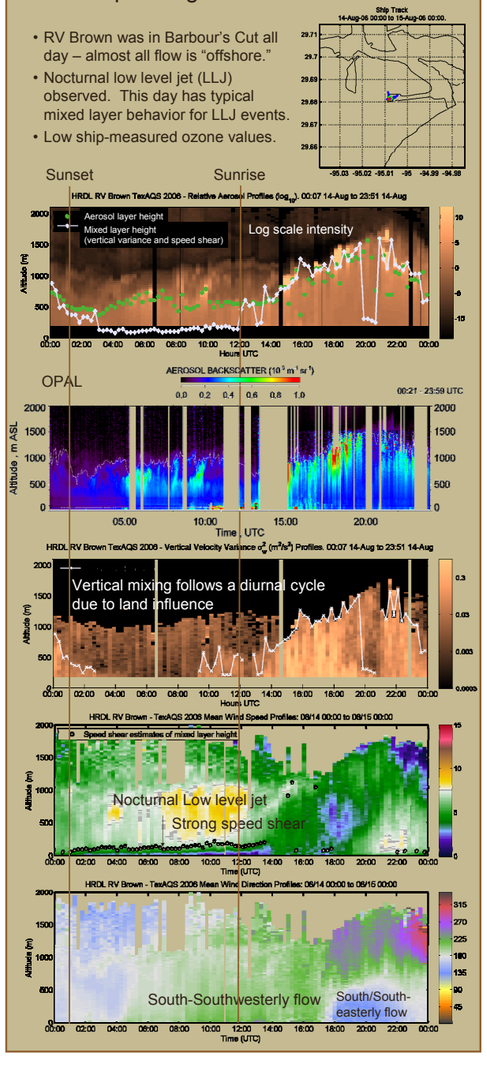




Using HRDL elevation scans, we can calculate high vertical resolution estimates of mixing strength that peak at ~125 m and drop down to near 0 at 200 m.

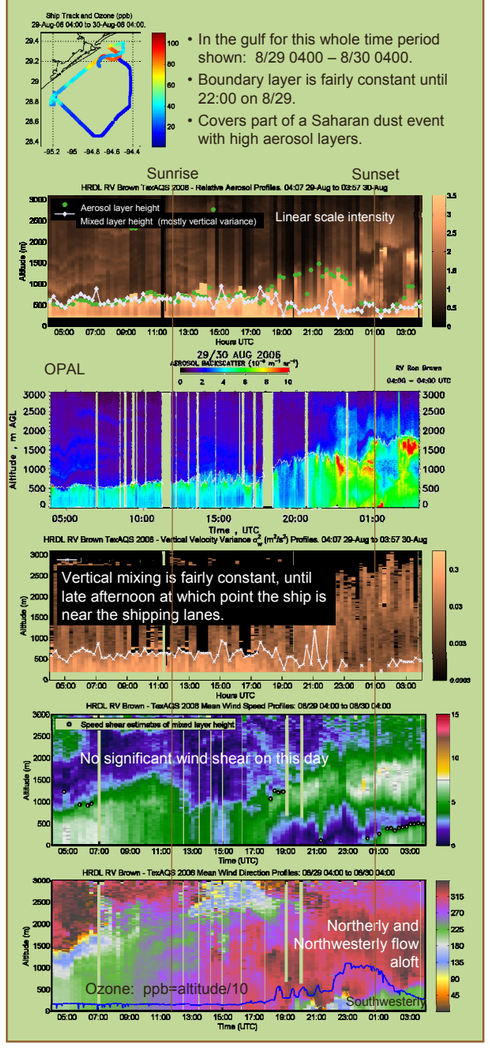
Example: August 14 – Barbour's Cut

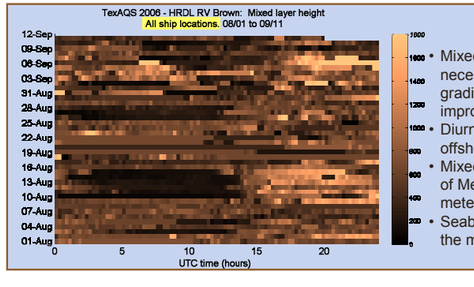
- RV Brown was in Barbour's Cut all day – almost all flow is "offshore."
- Nocturnal low level jet (LLJ) observed. This day has typical mixed layer behavior for LLJ events.
- Low ship-measured ozone values.

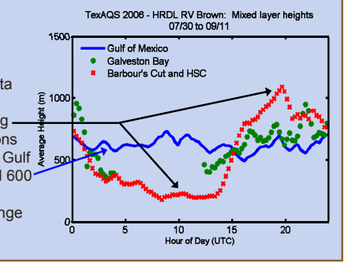


Example: August 29/30 – Gulf of Mexico

- In the gulf for this whole time period shown: 8/29 0400 – 8/30 0400.
- Boundary layer is fairly constant until 22:00 on 8/29.
- Covers part of a Saharan dust event with high aerosol layers.





Summary

- Mixed layer heights do not necessarily match aerosol gradients – using velocity data improves the estimate.
- Diurnal cycle observed during offshore flow or land conditions
- Mixed layer heights over the Gulf of Mexico are usually around 600 meters.
- Seabreezes can quickly change the mixed layer height.