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

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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 minute 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 layer, 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 for this whole time period, as well as their interpretation, from various conditions encountered during the experiment.

Aerosol Measurements

OPAL aerosol data is measured at the 305-mm 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 are interested in two main types of boundary layer heights:
- The height of the surface-based layer within which aerosols/gases emitted within that layer are mixed
- Vertical velocity variance/small-scale mixing profiles

HRDL 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)
- Combined shear (wind vectors): Find altitudes where the vector between wind- speeds and wind directions
- Vertical velocity variance/small-scale mixing profiles
- Mixed layer heights do not necessarily match aerosol gradients

OPAL (3 minute) and HRDL

- Mixed layer heights do not necessarily match aerosol gradients
- 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

Example: August 14 – Barbour’s Cut

- RV Brown was in Barbour’s Cut all day – almost all flow is “offshore”
- Nightly low level jet (LLJ) observed
- This day had typical mixed layer behavior for LLJ events

Example: August 29/30 – Gulf of Mexico

- In the gulf for this whole time period she measured: 8/20 – 8/30
- Boundary layer is fairly constant until 22:00 on 8/20
- Covers part of a Saharan dust event with high aerosol layers.

Summary

- Diurnal cycle observed during offshore flow or land conditions
- Mixed layer heights over the Gulf of Mexico are usually around 600 meters
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High Resolution Doppler Lidar (HRDL)

HRDL Parameters

<table>
<thead>
<tr>
<th>Type</th>
<th>Range</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed</td>
<td>2.5 m/s</td>
<td>1 m/s</td>
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<tr>
<td>Polarization</td>
<td>±1°</td>
<td>±1°</td>
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<tr>
<td>Range</td>
<td>45 km</td>
<td>90 km</td>
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<tr>
<td>Field of View</td>
<td>30°</td>
<td>54°</td>
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<tr>
<td>Scanning speed</td>
<td>1 Hz</td>
<td>2 Hz</td>
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<tr>
<td>Minimum range</td>
<td>~5 km</td>
<td>185 m</td>
</tr>
</tbody>
</table>

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.

Mixed layer product (proposed)

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.

Some Caveats

- The Ship is a moving platform – we sometimes see “sudden” changes in mixing dynamics when moving from close to shores 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)

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

Example: August 14 – Barbour’s Cut

- RV Brown was in Barbour’s Cut all day – almost all flow is “offshore”
- Nightly low level jet (LLJ) observed
- This day had 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 she measured: 8/20 – 8/30
- Boundary layer is fairly constant until 22:00 on 8/20
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Summary

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