Using Airplane and Ozoneonde Profiles to Estimate Boundary-Layer and Buffer-Layer Depth

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Definitions

- **Planetary Boundary Layer (PBL)** — The layer that interacts with the surface on a time scale of hours. It may be clear or stratus-capped.

- **Buffer Layer (BuL)** — The layer overlying the PBL that interacts with the PBL on a time scale of up to several days. Here the BuL encompasses the cumulus cloud layer, the residual layer (i.e. the previous day’s PBL), and overlying shear-mixed layers. *The BuL does not always exist.*

- **Free Troposphere (FT)** — The region above the BuL/PBL. It is stably-stratified and is not turbulently mixed throughout, but may have embedded intermittently turbulent layers and may contain cloud layers.
Criteria for Estimating PBL Height

• Constant potential temperature lapse rate from surface up to PBL top, \( h \); i.e. top is where lapse rate exceeds \( \sim 3 \) C km\(^{-1}\).

• Water vapor and ozone mixing ratios within PBL are \( \sim \) constant on large scales and have small-scale fluctuations.

• If RH reaches \( \sim 95\% \) and stays constant or increases, clouds likely
Criteria for Estimating BuL Height

- Potential temperature lapse rate within BuL decreases ~ exponentially to ~ constant lapse rate.
- Water vapor and ozone mixing ratios within BuL change ~ exponentially to “background” free-tropospheric value.
- Increased large-scale and decreased small-scale fluctuations.
Contrasts between PBL, BuL, and FT

- **PBL** -> Well-mixed vertically; well-defined eddy aspect ratio of 0.65 in middle of convective PBL
- **BuL** -> Intermittently mixed vertically via cumulus convection or shear
- **FT** -> Layered structure with limited (in space and time) vertical mixing. Layers are mostly uncoupled with extensive horizontal scales (up to 10’s or 100’s of km), and vertical scales of ~ 10 m to ~ 1 km.
Ozonesonde soundings from Beltsville (left) and Edgewood (right)
Edgewood soundings:
left - airplane
right - ozonesonde
Diurnal variation at Aldino

- BL beneath early morning sounding
- BL top at ~700 m at 10:16 LST
- BuL top ~1300 m -> 1400 m
## Determination Statistics of Aircraft and Ozonesonde PBL and BuL Heights

<table>
<thead>
<tr>
<th></th>
<th>Number of Soundings</th>
<th>Number of indeterminate PBL heights</th>
<th>Number of questionable PBL heights</th>
<th>Number of indeterminate BuL heights</th>
<th>Number of questionable BuL heights</th>
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</thead>
<tbody>
<tr>
<td>Aircraft Soundings</td>
<td>253</td>
<td>36</td>
<td>17</td>
<td>58</td>
<td>12</td>
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<tr>
<td>Ozonesonde Soundings</td>
<td>63</td>
<td>8</td>
<td>7</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Distribution of Heights for BL and BuL

Bin size = 300 m

BuL $h = 2527 \pm 784$ m

PBL $h = 1122 \pm 625$ m
Summary

• 21% of the PBL and 28% of the BuL aircraft soundings were indeterminate or questionable.
• 24% of the PBL and 8% of the BuL ozonesonde soundings were indeterminate or questionable.

Comments:
1. Ozonesondes covered greater depth and had slower instrument response
2. Aircraft incorporates horizontal variation during soundings
3. Ozonesondes started nearly at surface; aircraft from ~300 m above surface
High-Resolution Doppler Lidar (HRDL) measurements \( w \) from LIFT on 5 August 1996; a typical fair-weather day.
High-Resolution Doppler Lidar (HRDL) measurements $w$ from LIFT on 20 August 1996. $z_i = 960$ m, $U = 6.8$ m/s, $\Delta U = 3.1$ m/s, $\partial \theta / \partial z = 1.2$ C/km in FT.
High-Resolution Doppler Lidar (HRDL) measurements from LIFT on 12 August 1996; CBL modulated by fair-weather cumulus.