Ship-based High Resolution Doppler Lidar (HRDL) measurements in the Gulf of Mexico:

Data summary and observations related to space-based lidar performance

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Working Group on Space-Based Lidar Winds
Miami, Florida, February 5-9, 2007
We agree on a need for global measurements of winds. It is helpful to understand the effect of variability in the small-scale wind fields on expected performance. HRDL measurements are being used to characterize the off-shore winds for use in space-based lidar performance predictions.
<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>Location</th>
<th>Instrument</th>
<th>Experiment Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASAP 2004-Close Connections</td>
<td>??</td>
<td>MOPA</td>
<td>June 22-July 23, 2004</td>
</tr>
<tr>
<td>NEAQS 2004</td>
<td>Northeast U.S. coast (Maine down to Boston)</td>
<td>HRDL</td>
<td>June 30- August 12, 2004</td>
</tr>
<tr>
<td>RICO</td>
<td>Off the coast of Barbuda/Antigua</td>
<td>MOPA</td>
<td>December 29, 2004- January 24, 2005</td>
</tr>
<tr>
<td>ASAP 2005-Emma</td>
<td>Off the coast of Bahamas</td>
<td>MOPA</td>
<td>May 13-25, 2005</td>
</tr>
<tr>
<td>TexAQS 2006</td>
<td>Galveston Bay/Gulf of Mexico</td>
<td>HRDL</td>
<td>August 1- September 11, 2006</td>
</tr>
</tbody>
</table>
Characterization of pollution sources
Study of transport and transformation processes
Study of coastal impacts
Study of radiative effects of aerosols

HRDL measurements made on the Ronald H Brown during TEXAQS 2006
July 28 – September 11, 2006
TexAQS 2006 – Proposed Instrumentation on RV Brown

- Photolysis rates (j-values) Spectral radiometer
- Ozone (O3) UV absorbance
- Ozone NO chemiluminescence
- Carbon monoxide (CO) Nondispersive IR
- Carbon dioxide (CO2) Nondispersive IR
- Sulfur dioxide (SO2) Pulsed UV fluorescence
- Nitric oxide (NO) Chemiluminescence
- Nitrogen dioxide (NO2) Photolysis/chemiluminescence
- Total reactive nitrogen oxides (NOy) Au tube/chemiluminescence
- Peroxyacyl nitric anhydrides (PANs) GC/ECD
- Alkyl nitrates (RONO2) GC/MS
- Nitrate radical (NO3); Dinitrogen pentoxide (N2O5) Cavity ring-down spectrometry
- Nitric acid (HNO3) Mist chamber/IC
- Water vapor (H2O) Nondispersive IR
- Continuous Speciation of VOCs PTR-MS/CIMS
- VOC Speciation GC/MS
- Formaldehyde (HCHO) CHD fluorimetry
- Radon (Rn) Radon gas decay
- Seawater/atmospheric CO2 Nondispersive IR
- Enhanced measurement of radiative fluxes Spectral radiometers
- Aerosol optical depth MicroTOPS
- Irradiance Portable Radiation Package (PRP)
- Size-resolved aerosol composition and gravimetric mass Impactors (IC, XRF, and thermal-optical OC/EC)
- OC/EC On-line thermal optical
- Ionic Aerosol Composition Particle In Liquid Sampler (PILS)-IC
- Aerosol Size and Composition Aerosol Mass Spectrometer
- Organic function groups FTIR
- Aerosol scattering (400, 550, 700 nm) TSI Model 3563 Nephelometer
- Aerosol absorption (400, 550, 700 nm) Radiance Research PSAP
- Aerosol number CNC
- Aerosol size distribution Twin DMAs and an APS
- Aerosol light scattering hygroscopic growth f(RH) Twin TSI 3563 nephelometers
- Aerosol size hygroscopic growth g(RH) Tandem DMAs
- Aerosol light extinction hygroscopic growth f(RH) Cavity ring-down spectrometer
- Total and sub-micron aerosol extinction Cavity ring-down spectrometer
- Ozone/aerosol vertical profiles O3/Aerosol Lidar (OPAL)
- Wind/temperature vertical profiles 915 MHz wind Radar
- High-resolution BL winds/aerosol Doppler Lidar (HRDL)
- Wind profiles/microscale turbulence C-band radar
- Temperature/relative humidity profiles Radiosondes
- Surface energy balance (fluxes) Eddy covariance (bow mounted)
- High resolution BL turbulence structure Doppler mini-Sodar
Characterizations of the Gulf/Bay with HRDL data

- **Winds and turbulence information**: used to determine the potential performance, including errors, based on sample rate/volumes, etc, in space-based Doppler lidar measurements.

- **Cloud coverage**: used to determine the percentage of time a satellite can make measurements at each altitude in this area.

- **Aerosol measurements**: used to determine the expected levels of return signal available in this region
  - **Closure** in aerosol studies at 355 nm using ozone profiling lidar (OPAL), cavity ring-down, and in-situ instruments. Will attempt to scale the backscatter and extinction numbers to HRDL wavelength for comparison studies.
  - **Comparisons** with CALIPSO and HSRL
## High Resolution Doppler Lidar (HRDL)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>2.02 micron</td>
</tr>
<tr>
<td>Pulse Energy</td>
<td>2-3 mJ</td>
</tr>
<tr>
<td>PRF</td>
<td>200 Hz</td>
</tr>
<tr>
<td>Max Range</td>
<td>3-8 km</td>
</tr>
<tr>
<td>Range Res.</td>
<td>30 m</td>
</tr>
<tr>
<td>Beam rate</td>
<td>2 Hz</td>
</tr>
<tr>
<td>Precision</td>
<td>10 cm/s</td>
</tr>
<tr>
<td>Scanning</td>
<td>Full Hemispheric</td>
</tr>
</tbody>
</table>

- New pump diode arrays
- New crystal thermal control
Typical scan sequence

- 4 min horizontal wind profile scan (1, 7 and 45 deg PPI)
- 6 min Zenith Stare
- 5 min Vertical Scans

TEXAQS 2006
>775 hours of wind data
Basic HRDL Data Products during TexAQS 2006

- Mean wind speed and direction.
- Average return signal strength
- Small scale mixing strength

posted every 15 minutes during the cruise to:
http://esrl.noaa.gov/csd/ors/data_pages/TexAQS06/hrdl/
HRDL: TexAQS 2006 data posted to web page

HRDL RV Brown TexAQS 2006 - Vertical Velocity Variance $\sigma_w^2$ (m$^2$/s$^2$) Profiles
12:00 09/02/06 to 00:00 09/03/06

Altitude (m)

0 500 1000 1500 2000 2500

Hours UTC

Initial day # 245 2006

0 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00

Color scale:

0.0003 0.003 0.03 0.3 3
HRDL TexAQS: Additional products from post-processing

- Aerosol and mixed layer (i.e. Boundary layer) heights
- Horizontal small-scale mixing strength
- Vertical profiles of relative aerosol strength (layering information) – maybe this will lead to backscatter(?)
- Speed and directional shear information and statistics
- Information about boundary layer dynamics such as rolls, surface streaks, etc.
TexAQS 2006 – HRDL mean wind speed profiles
Land breeze?  
Sea breeze?
TexAQS 2006 – Directional Shear Distributions

Height Distributions of Peak Wind Direction Gradient.

Distributions of maximum $\Delta_{WD}$ in lowest 1 km

Directional difference $\Delta$(deg)
Wind Speed Profiles
TexAQS 2006 – Wind Speed Shear Distributions

Height Distributions of Peak Wind Speed Gradient.

Distributions of maximum $\Delta_{WS}$ in lowest 1 km

Frequency of shear

Frequency of altitude

Speed difference $\Delta$(m/s)
New improvements to scanner controls allow this scan to be part of the automatically repeated pattern. This means we can provide information on:

- Return signal strength
- Aerosol & cloud layer(s)
- Mixing heights
- Turbulence
- Gravity waves
HRDL: Zenith/Vertical stare Data Aerosol layer(s)
Zenith Stare Signal Return

“Hey, what do the aerosol layers look like?”
HRDL-TexAQS 2006: Zenith Return Signal Strength

Saharan dust events
HRDL RV Brown TexAQS 2006 - Vertically Staring Data
02-Sep-06 19:00 - 19:59 Signal Strength (wbSNR) (dB)

Initial day # 245 2006
Lat: 29.659 Lon: -94.981

HRDL RV Brown TexAQS 2006 - Vertically Staring Data
02-Sep-06 19:00 - 19:59 Range-corrected relative signal intensity

SNR
Zenith Stare Signal Return
Relative backscatter
HRDL RV, Brown, TexAQS 2006
Vertical Velocity Variance $\sigma_w^2$ (m$^2$/s$^2$) - All Locations at $z = 200.00$ m
HRDL TexAQS – Estimates of boundary layer height

Mixed layer BL height

UTC time (hours)
HRDL TexAQS – Estimates of boundary layer height
HRDL RV Brown TexAQS 2006 - Vertically Staring Data
31-Jul-06 19:00 - 19:59 Range-corrected relative signal intensity

HRDL Lat: 26.318
Lon: -87.84
Surface Dynamics
Why are we interested in surface streaks?

• We have observed increases in horizontal velocity variance linked to the streaks → corresponding increases in vertical variance likely.

• Effects on the surface energy budget (modeling)

• Usually Correspond to directional shear – which also adds to coherent bandwidth
Up next…

- Boundary Layer Heights
- Quantify the effects of these conditions on space-based lidar CNR & wind estimates.
- Comparisons of HRDL with HSRL and CALIPSO – characterize the relationship between 1 and 2 micron backscatter in this area.
- Streak Analysis and integration of HRDL data with models
T = 95° F
RH = 97%
Thank you
extras
Estimating Velocity Variance

\[
\sigma^2_{v-\text{atmospheric}} = \sigma^2_{v-\text{total}} - \sigma^2_{v-\text{instrument}}
\]
“RHI” Scans: Shear visualization (can see turbulence too)