Characterization of Boundary-Layer Meteorology During DISCOVER-AQ

Daniel M. Alrick and Clinton P. MacDonald
Sonoma Technology, Inc.
Gary A. Morris
St. Edward's University

for

Texas Air Quality Research Program Workshop
Austin, TX

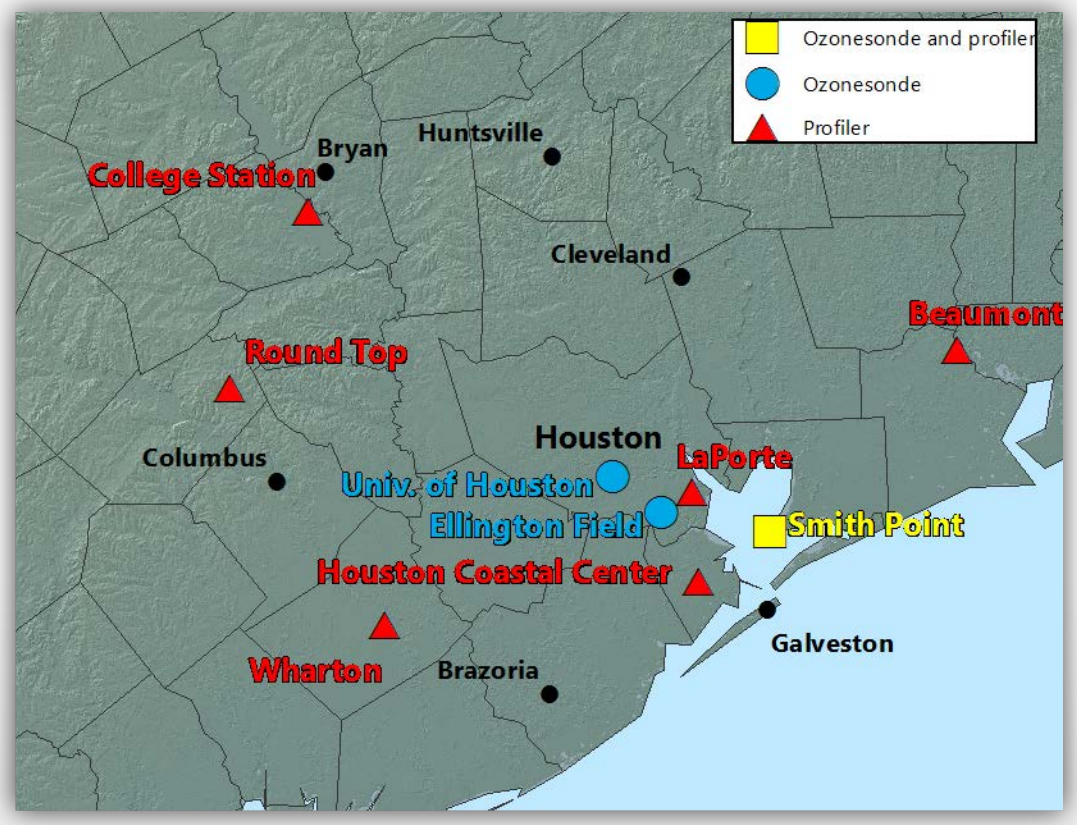
June 18, 2015

Sonoma Technology, Inc.

Our Project Goals

- Characterize key meteorological processes that were observed during DISCOVER-AQ 2013
  - Boundary layer (BL) winds and heights
  - Flight days and high ozone days
- Provide continuous daytime mixing heights from the seven Radar Wind Profilers (RWPs) for future analysis and modeling
  - QC'd RWP winds were provided as part of measurement project and are available.
  - Wind and mixing height data very useful for model evaluation and support interpretation of air quality data.
- Determine the similarities and differences in meteorology and ozone during DISCOVER-AQ as compared to TexAQS-II, and to 10-year averages for ozone profiles.

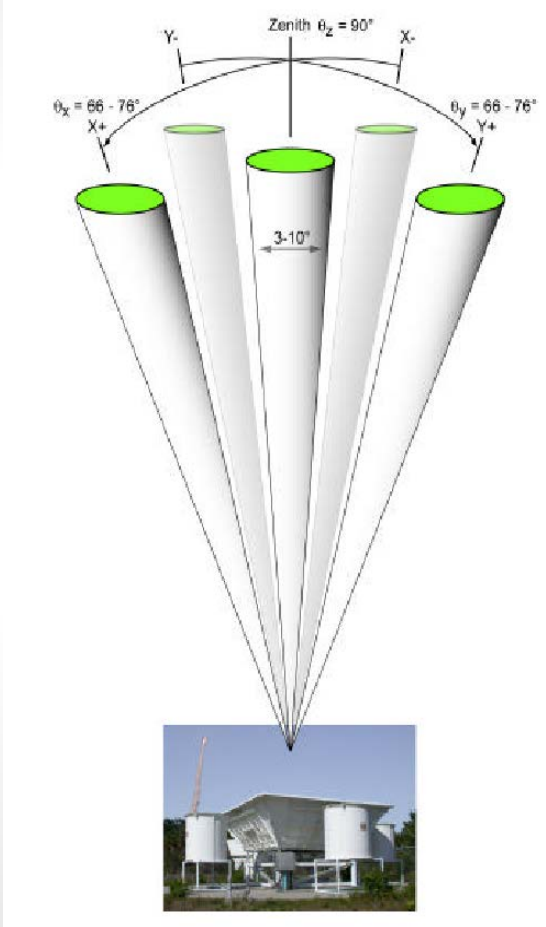
Instrumentation



Locations of RWPs (operated by TCEQ, NOAA, and STI) and ozonesonde launches (Tropospheric Ozone Pollution Project)

About RWPs

- RWP is a vertically pointing clear air radar that measures
  - Hourly or sub-hourly horizontal winds from about 100 to 4000 m agl with a vertical resolution of 60 to 120 m depending on settings
  - Continuous reflectivity (SNR/C_n^2 backscattered signal)
  - Continuous vertical velocity
- How it works
  - RWP emits electromagnetic pulse at the speed of light at vertical and oblique angles.
  - Small amounts of energy are reflected by atmospheric density gradients back toward the RWP.
  - The reflected energy is Doppler-shifted depending on the motion of the air relative to the beam.
  - Horizontal winds at pre-defined heights are calculated using the Doppler data from all beams.
  - The heights are known from the speed of light and the time passed between sending and receiving the signal.



Methods

Analyzed conditions on each day using

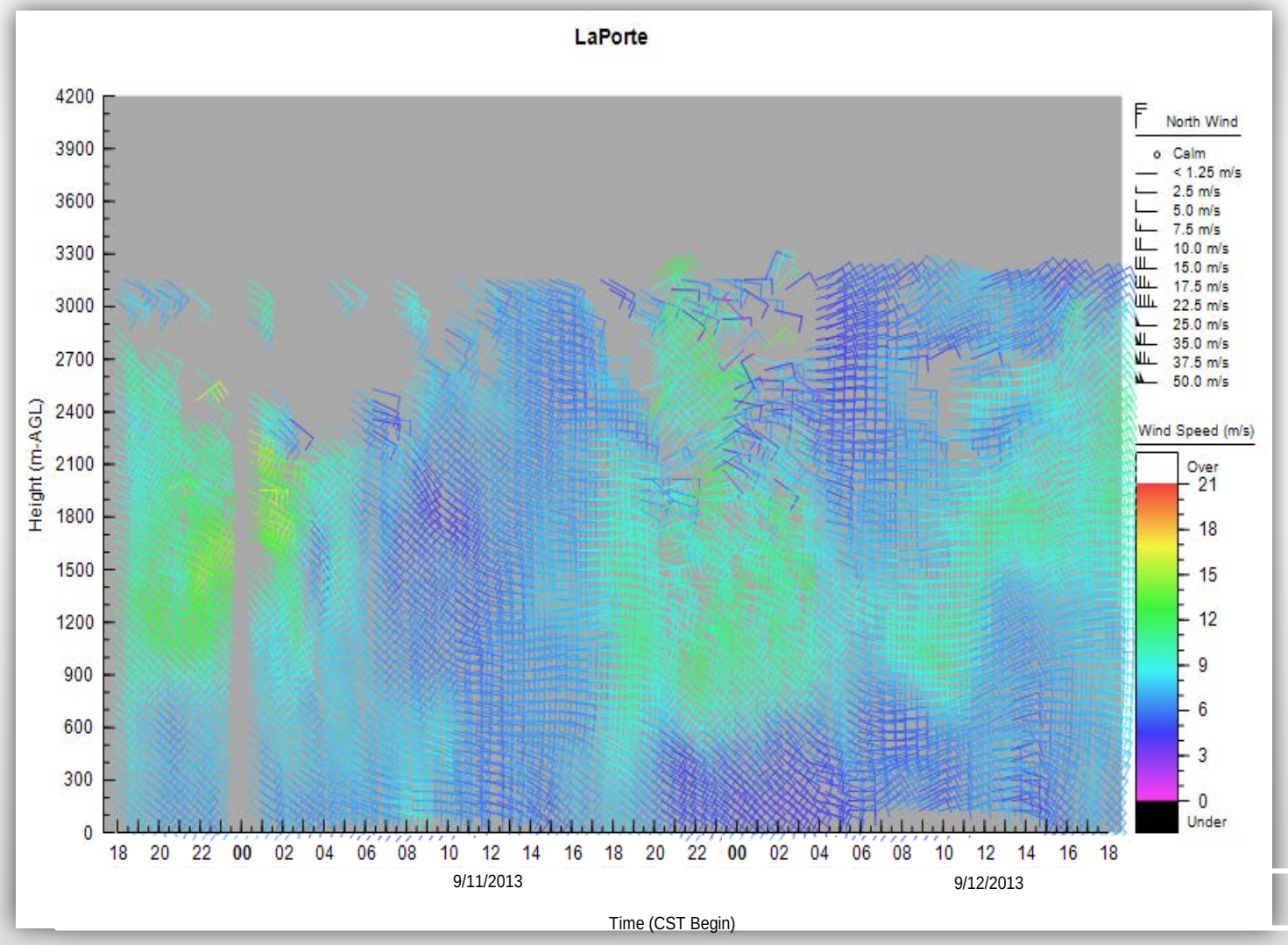
- Upper-level and surface weather maps
- Surface meteorology and ozone data
- Backward trajectories
- Hourly daytime mixing heights derived from RWPs
- Wind data from RWPs
- Ozonesonde profiles
- Regional satellite and radar imagery

Date	Metro-Houston Maximum 8-hr Ozone (ppb)	DISCOVER-AQ Flight Day
8/28/2013	83	
8/29/2013	78	
8/30/2013	78	
8/31/2013	84	
9/4/2013	62	✓
9/6/2013	45	✓
9/11/2013	51	✓
9/12/2013	66	✓
9/13/2013	66	✓
9/14/2013	64	✓
9/24/2013	51	✓
9/25/2013	124	✓
9/26/2013	89	✓
9/27/2013	63	
10/8/2013	85	
10/9/2013	99	

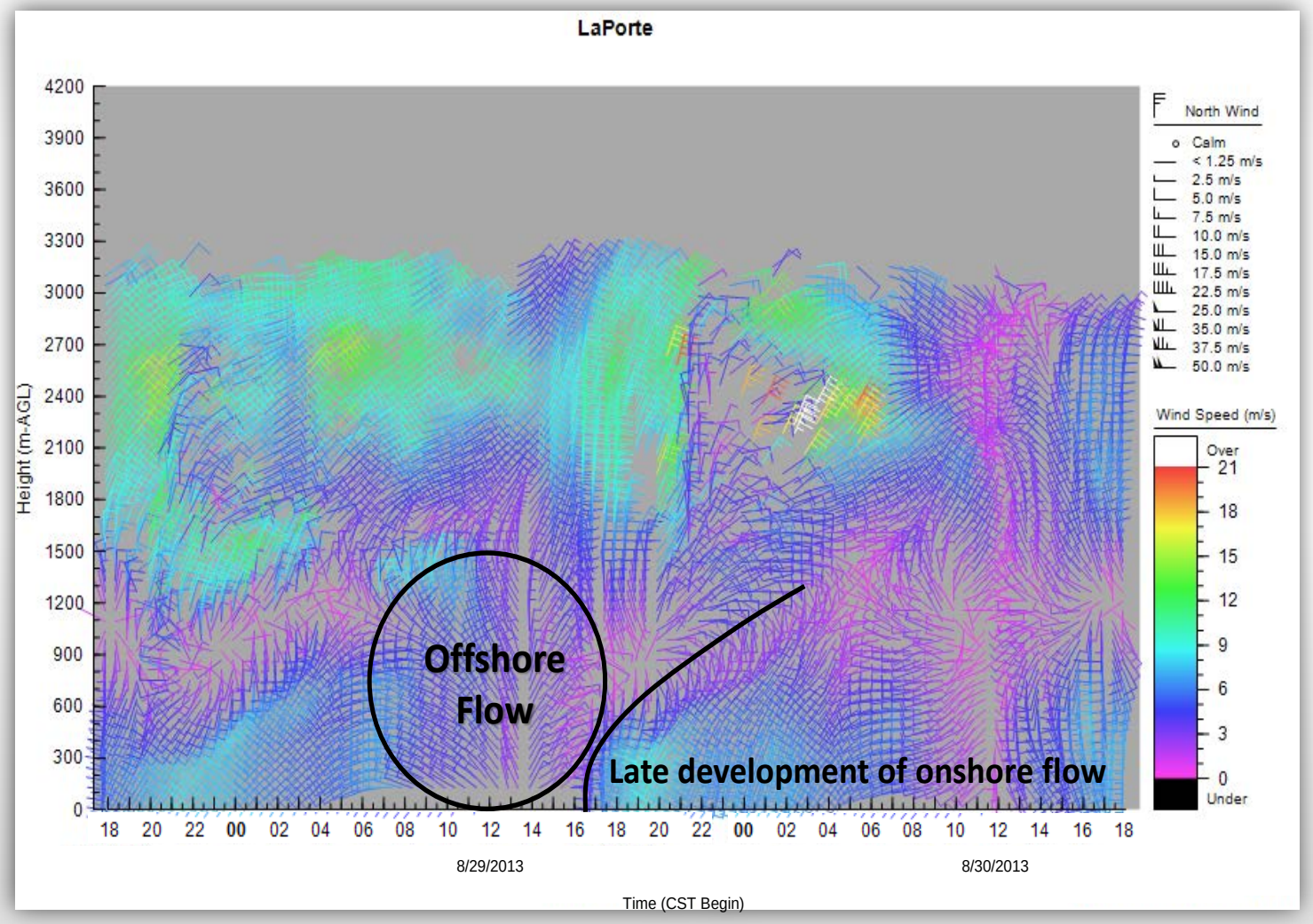
Key Findings from BL Analysis

- Two general meteorological regimes
  1. Large-scale onshore flow and lower ozone concentrations
  2. Weak large-scale flow with complex local flows and generally higher ozone concentrations
- Modest to large spatial differences (coast vs. inland) in BL vertical wind profiles (especially on days with weak synoptic forcing) and mixing height evolution
- High ozone days
  - Low mixing heights through mid-morning, followed by rapid increase in mixing height inland and continued low mixing heights at the coast
  - Short transport distances with recirculation (land/bay/gulf breeze)
  - Offshore flow undercut by a shallow marine layer in the afternoon

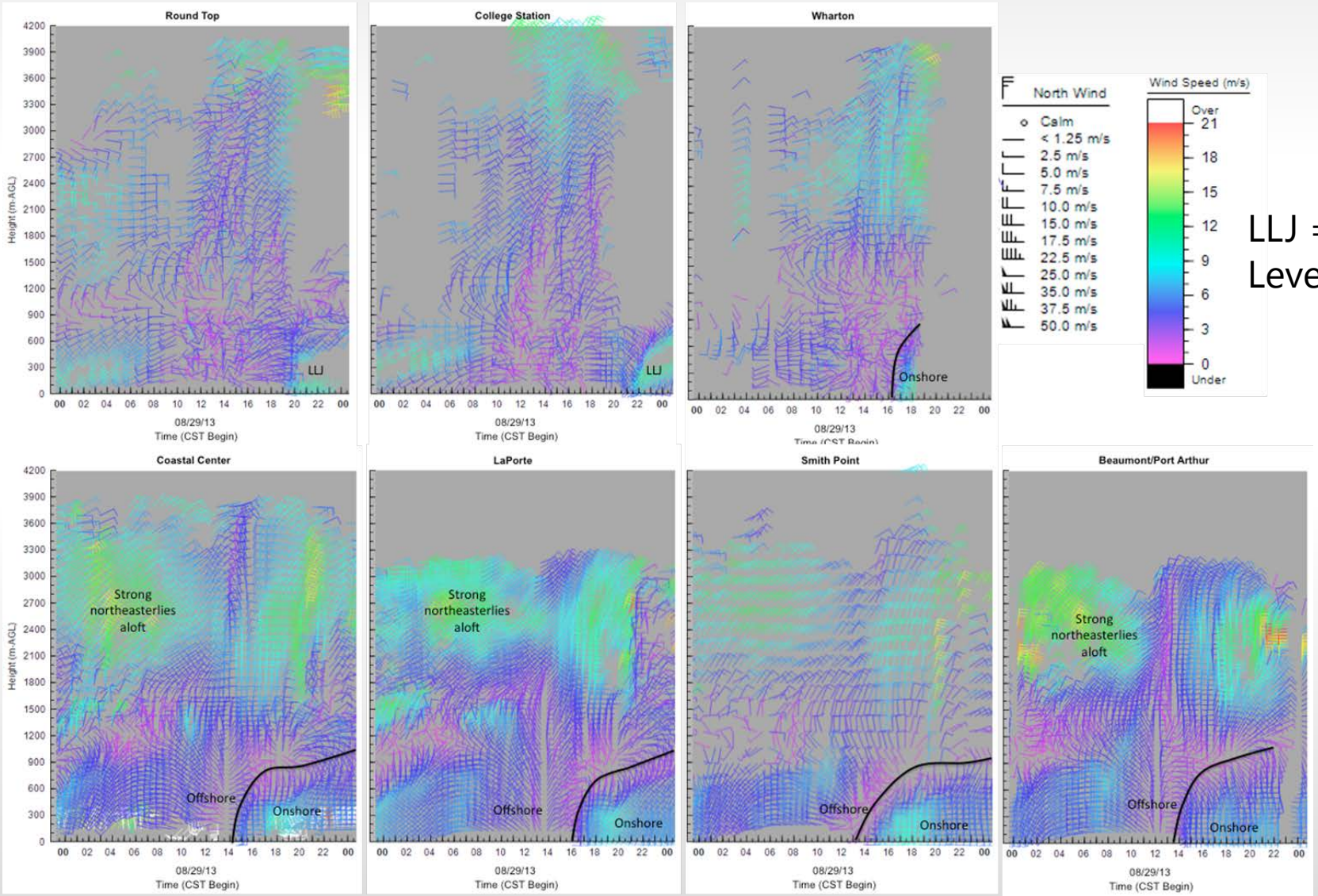
Onshore Flow Regime – Example



Recirculation Regime – Example



Recirculation Regime – Example

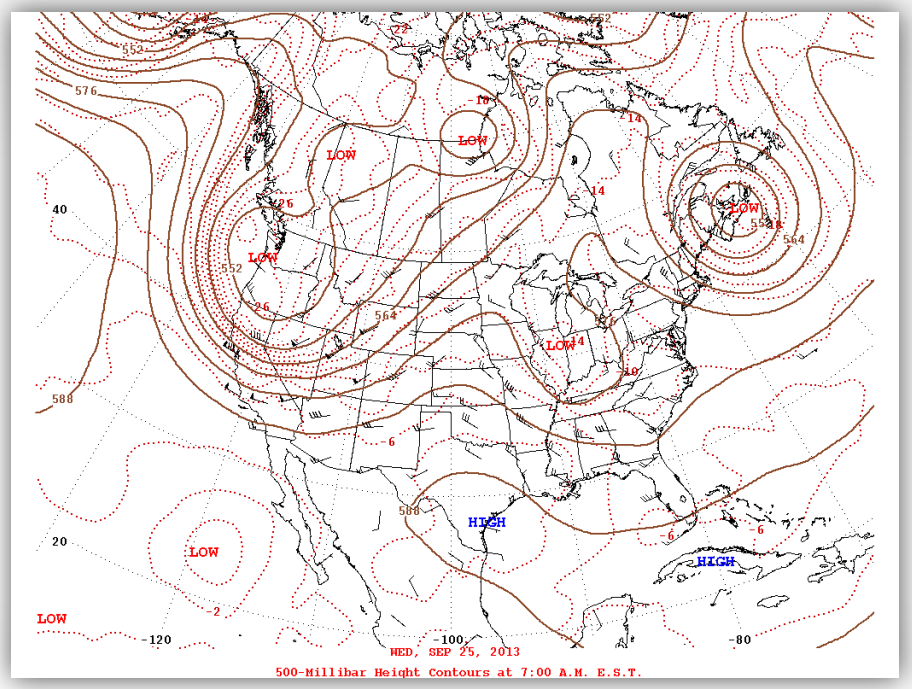


LLJ = Low-Level Jet

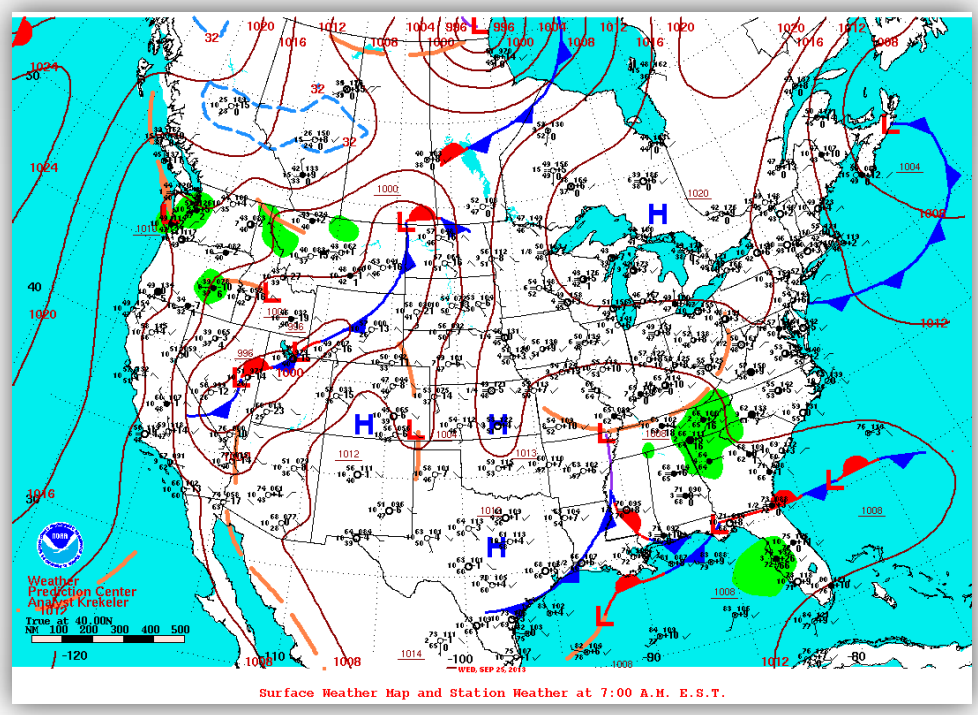
High Ozone Levels on Sept. 25, 2013

- Regional maximum 8-hr ozone of 124 ppb
- Light large-scale offshore flow following cold front passage
- Dry, continental air mass resulting in strong nocturnal temperature inversion
- Recirculation during the day as a weak Bay and Gulf breeze developed

Surface and Aloft Conditions



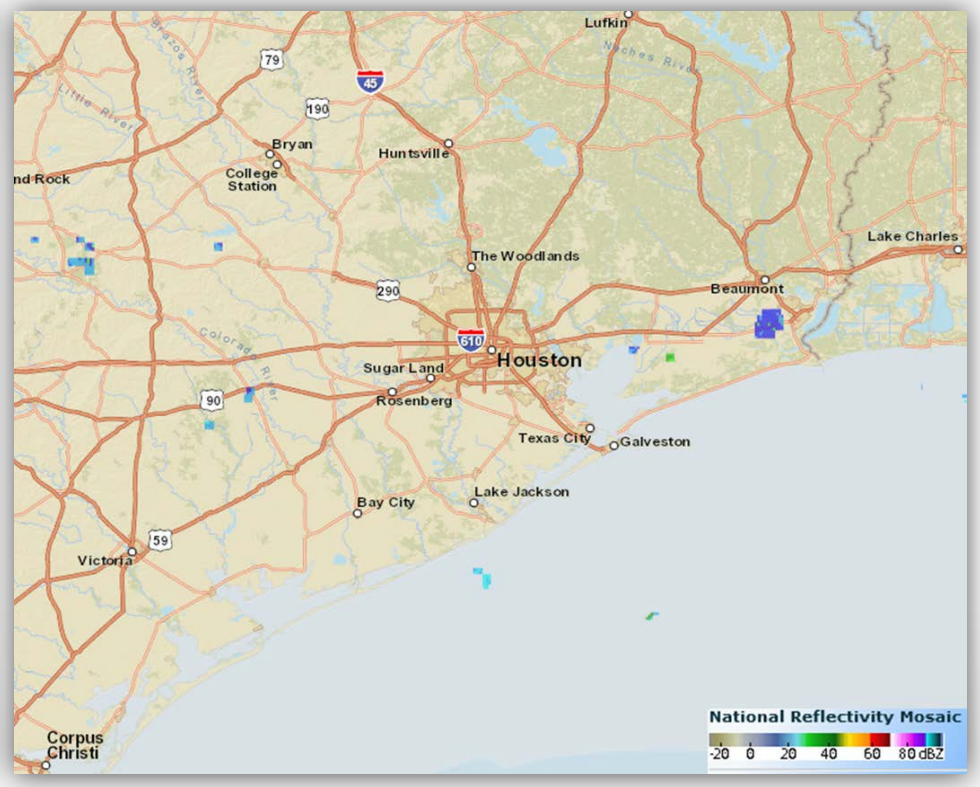
500 mb map
Upper-level ridge over Texas



Surface map
Weak cold front moving southeast of Houston

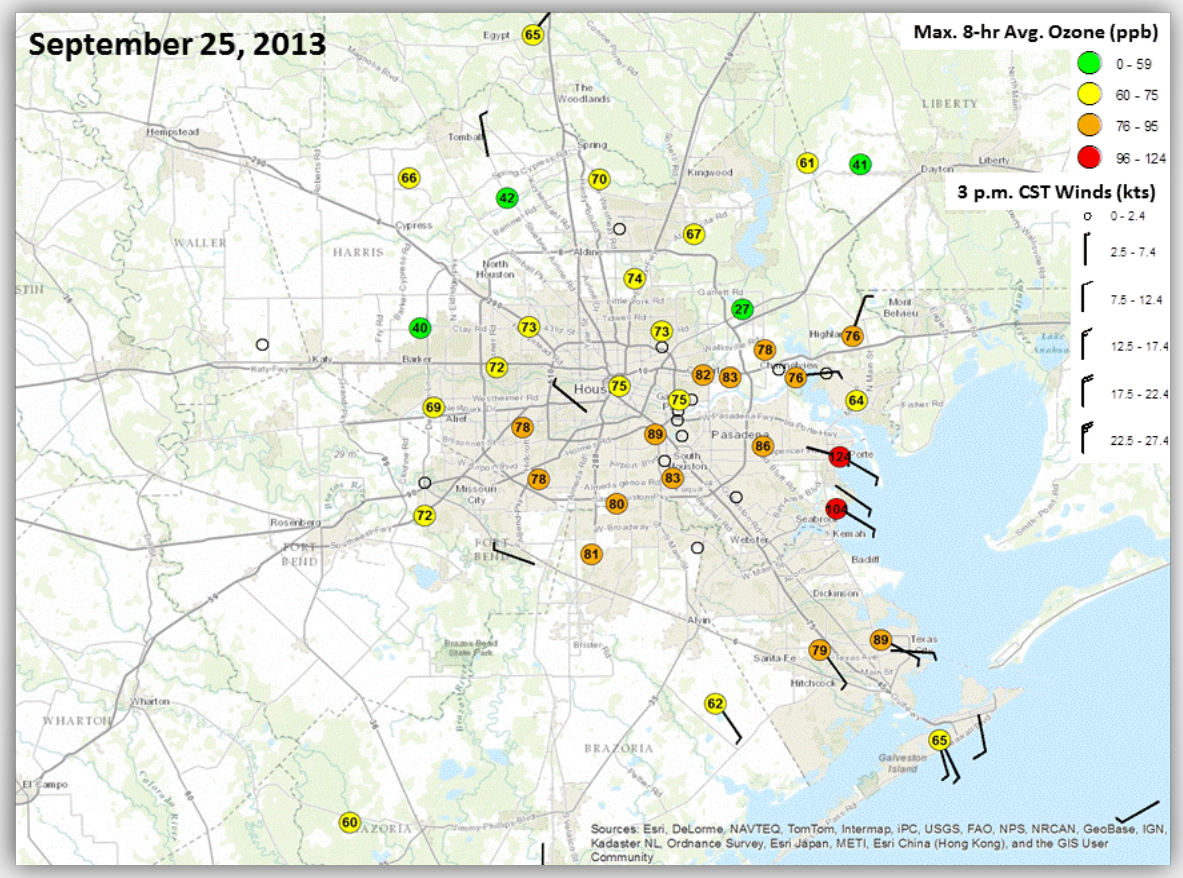
Satellite and Radar

Visible satellite
Clear skies



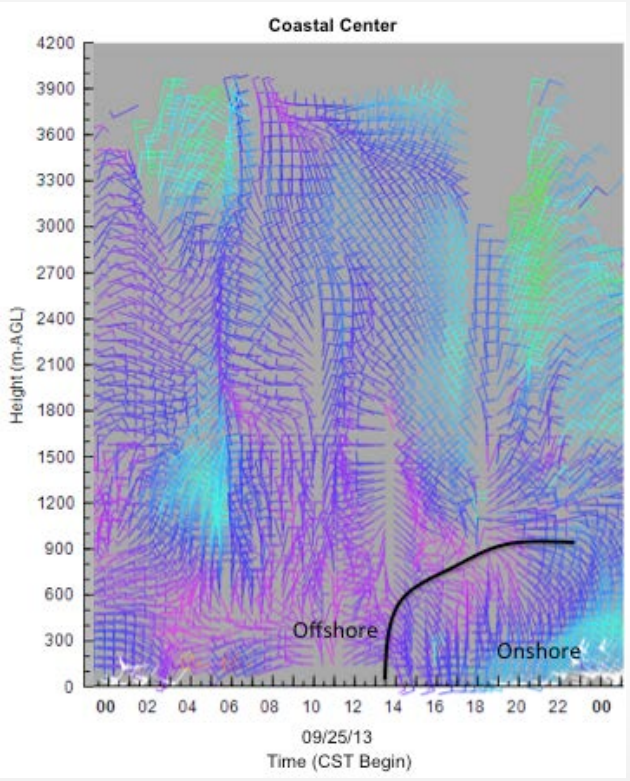
Regional radar
No precipitation in the area

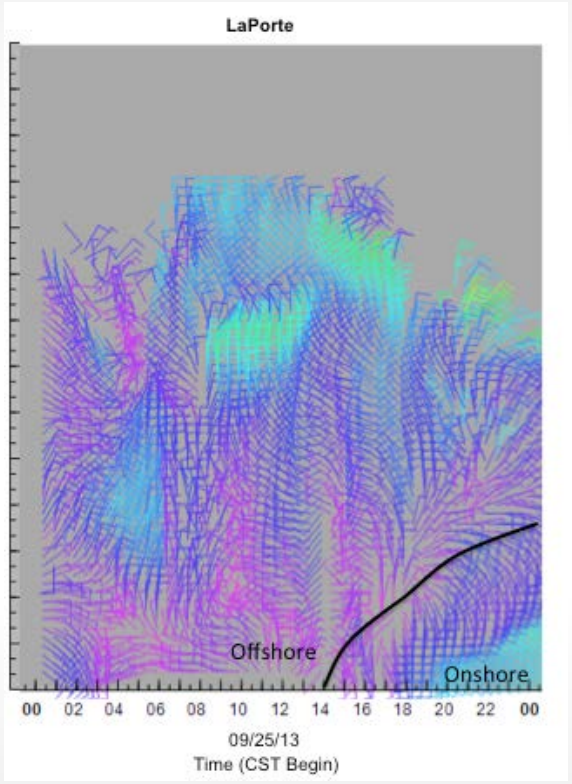
Surface Winds and Ozone

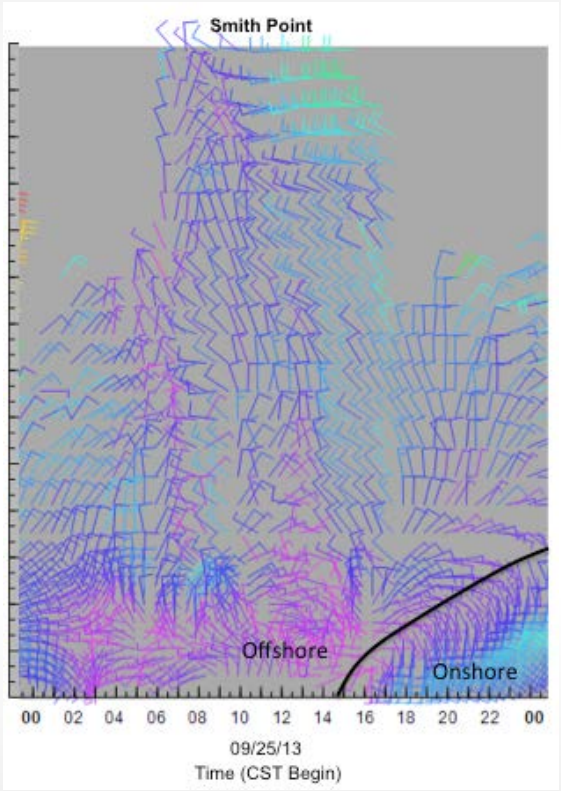


- Calm to light offshore winds away from the coast, light onshore winds along the coast and Bay
- Highest ozone concentrations occurred near the wind shift boundary

Profiler Data

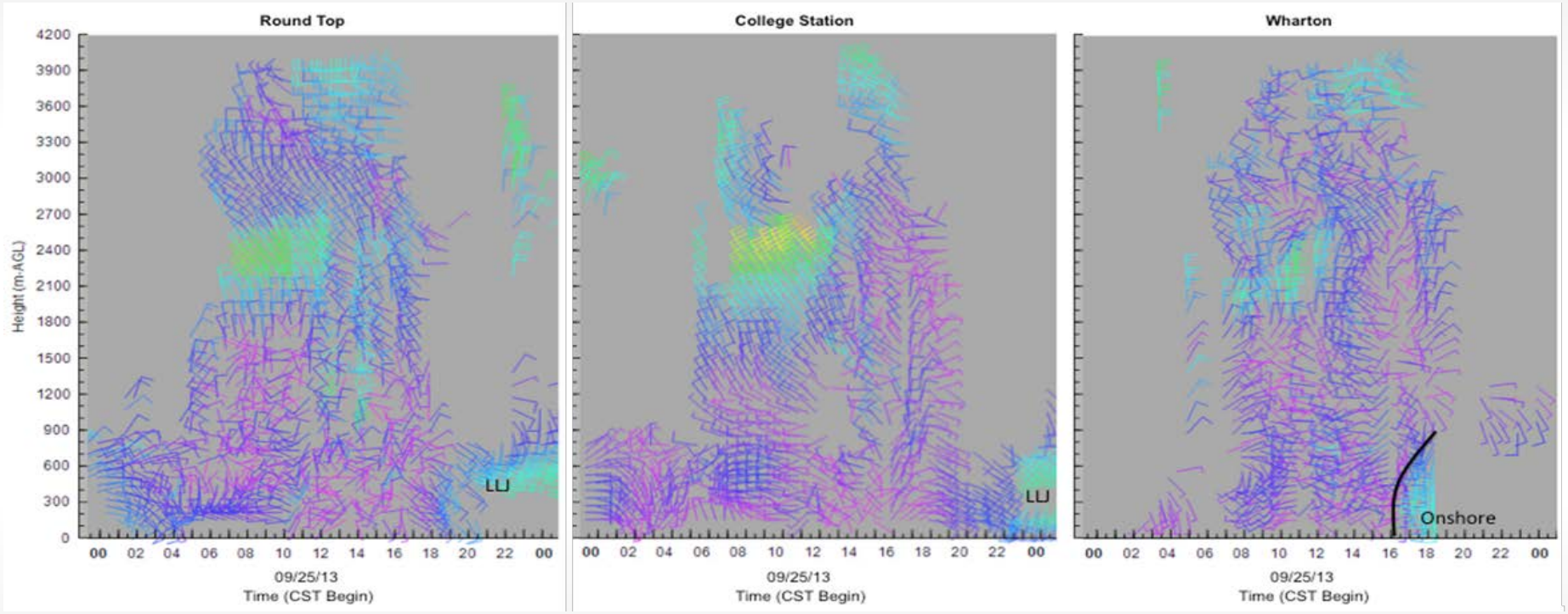






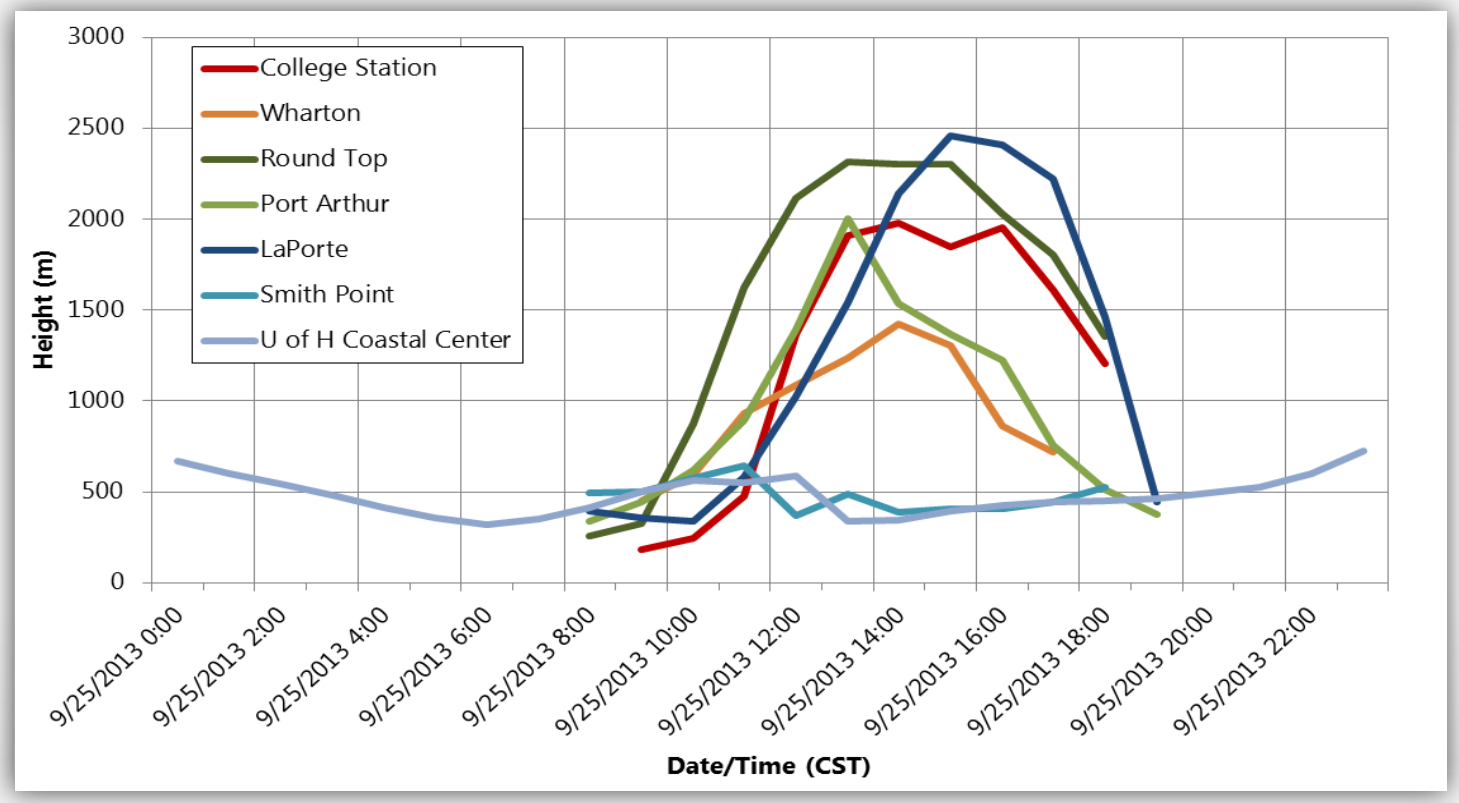
- Coastal profilers showed weak offshore winds through early afternoon
- Shallow onshore winds developed at the surface, gradually deepening overnight
- Highest ozone concentrations occurred near the surface wind shift

Profiler Data



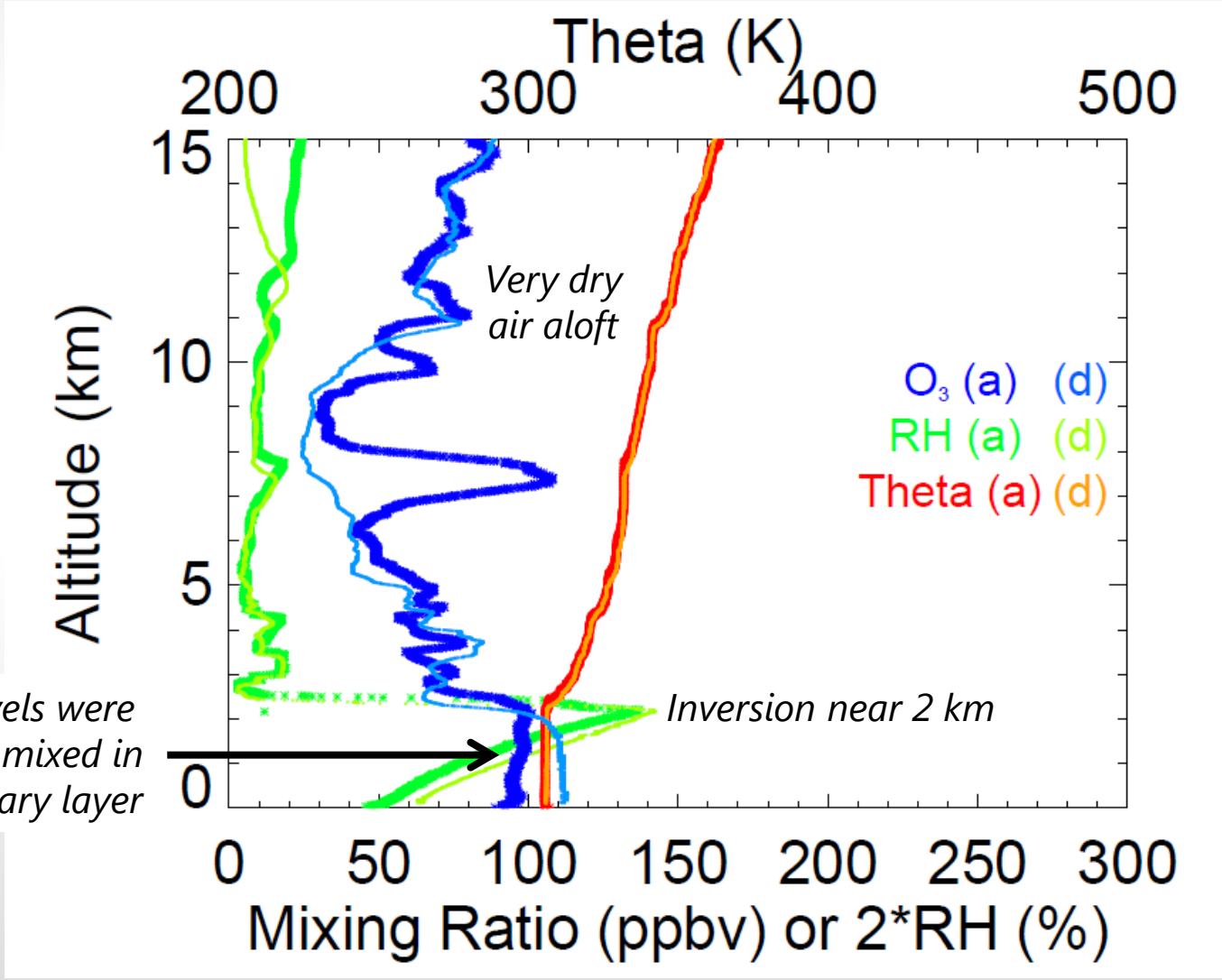
- Inland profilers showed light and variable winds through much of the day
- South-southwesterly low-level jet developed after sunset, followed by more pronounced onshore flow the next day

Mixing Heights



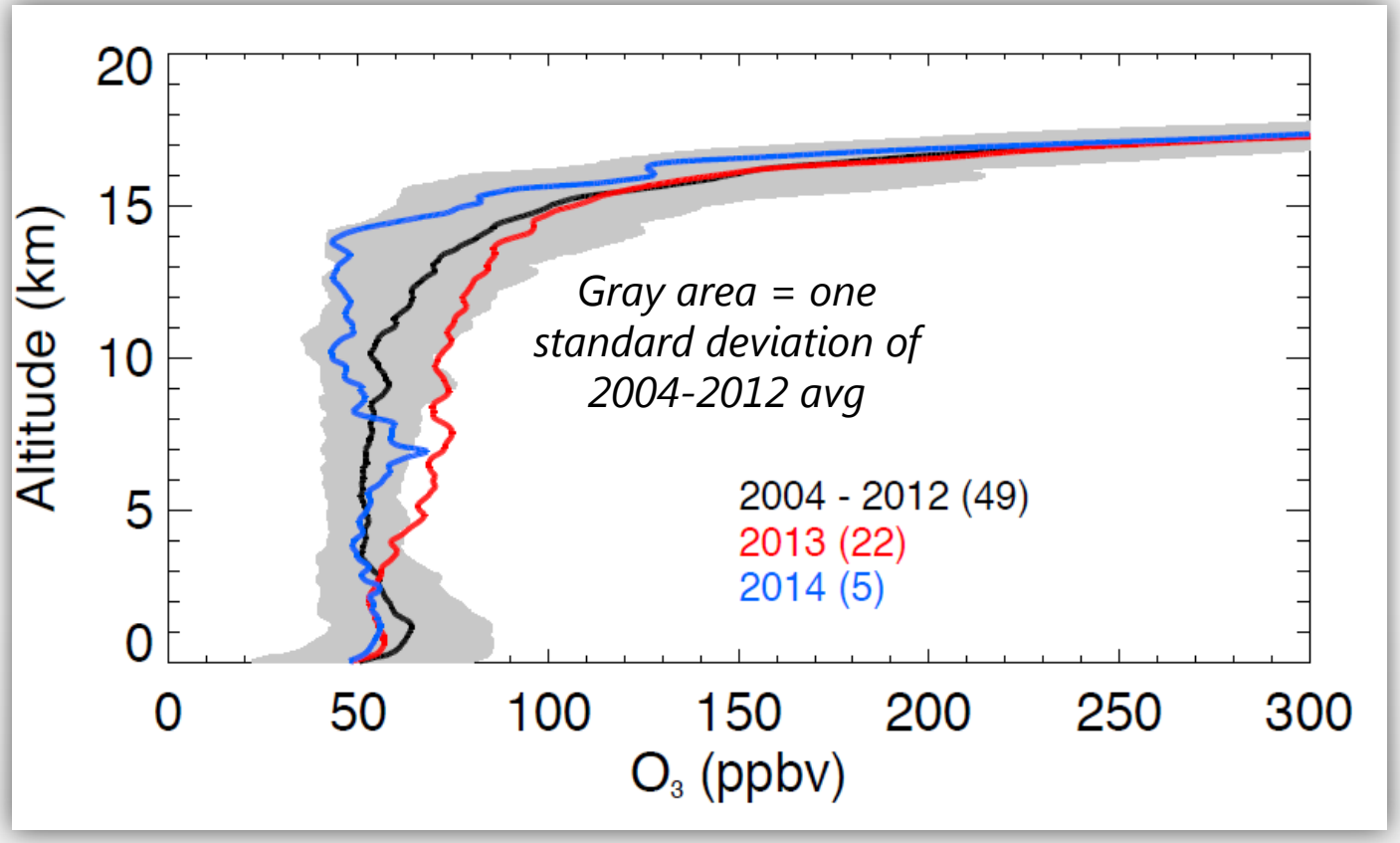
- Mixing heights remained low (near 500 m) through mid to late morning
- Rapid increase in mixing heights inland due to strong heating, dry air mass
- Mixing heights were low all day at the immediate coast

Ozonesonde Data from U of H at 2:00 p.m. CST



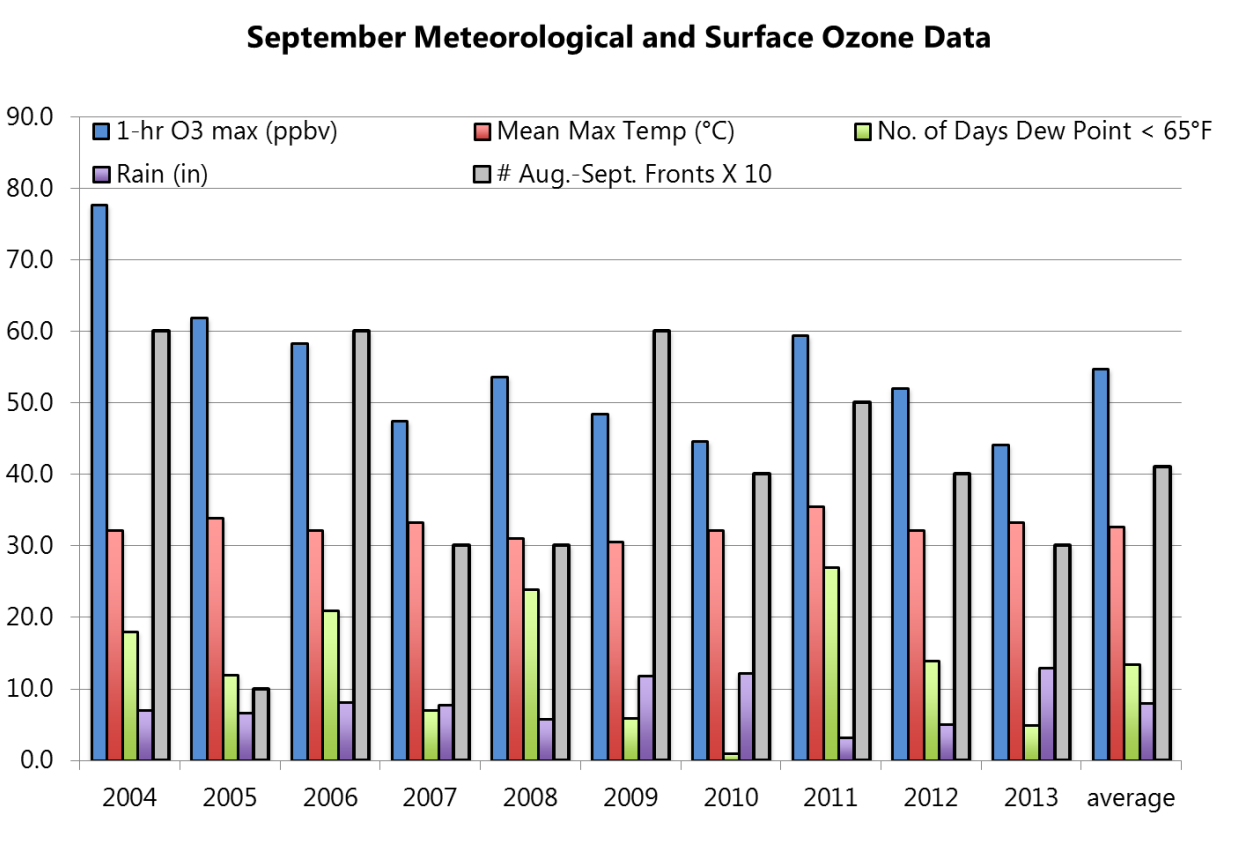
Ozone levels were high, well-mixed in the boundary layer

September Ozone Profiles



- Stronger vertical gradient of ozone in 2013 compared to 2014 and previous years
- Lack of frontal passages in 2013 prevented mixing of tropospheric ozone

Overall Weather Conditions



- Ozone levels have generally been higher in years with more late-summer frontal passages and lower humidity days (e.g., 2006, 2008, 2011)
- In comparison, September 2013 had fewer frontal passages and low-humidity days compared to the 10-yr average

Concluding Remarks

- DISCOVER-AQ period was characterized by a mix of onshore flow days and generally lower ozone, and weak large-scale flow days with recirculation and higher ozone.
- Complex BL meteorological characteristics that vary in time, horizontally (coast to inland), and vertically.
- Meteorological conditions in Sept 2013 were unusual compared to recent years.
  - Lack of frontal passages
  - Strong vertical gradient in ozone
  - Higher humidity levels
- However, daily case studies of 2013 support overall conceptual model for high ozone in Houston.
- Day-by-day characterization of DISCOVER-AQ conditions are available in report, and RWP wind and mixing height data are available from TCEQ.

Contact Us

Daniel Alrick
Meteorologist
dalrick@sonomatech.com

Clinton MacDonald
Manager, Measurements
clint@sonomatech.com

STi
Sonoma Technology, Inc.
Environmental Science and Innovative Solutions
707.665.9900 sonomatech.com @sonoma_tech