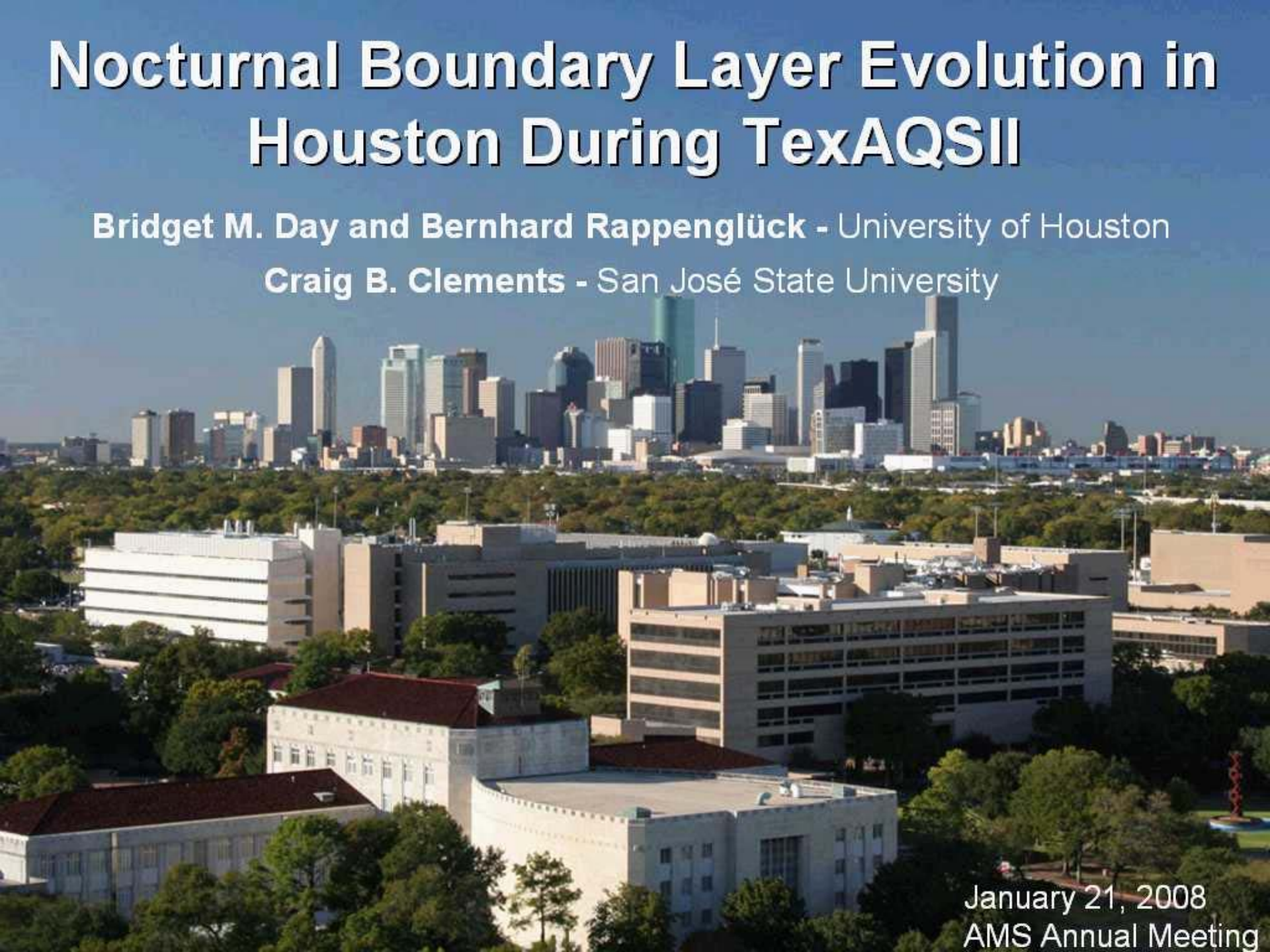
Nocturnal Boundary Layer Evolution in Houston During TexAQSII

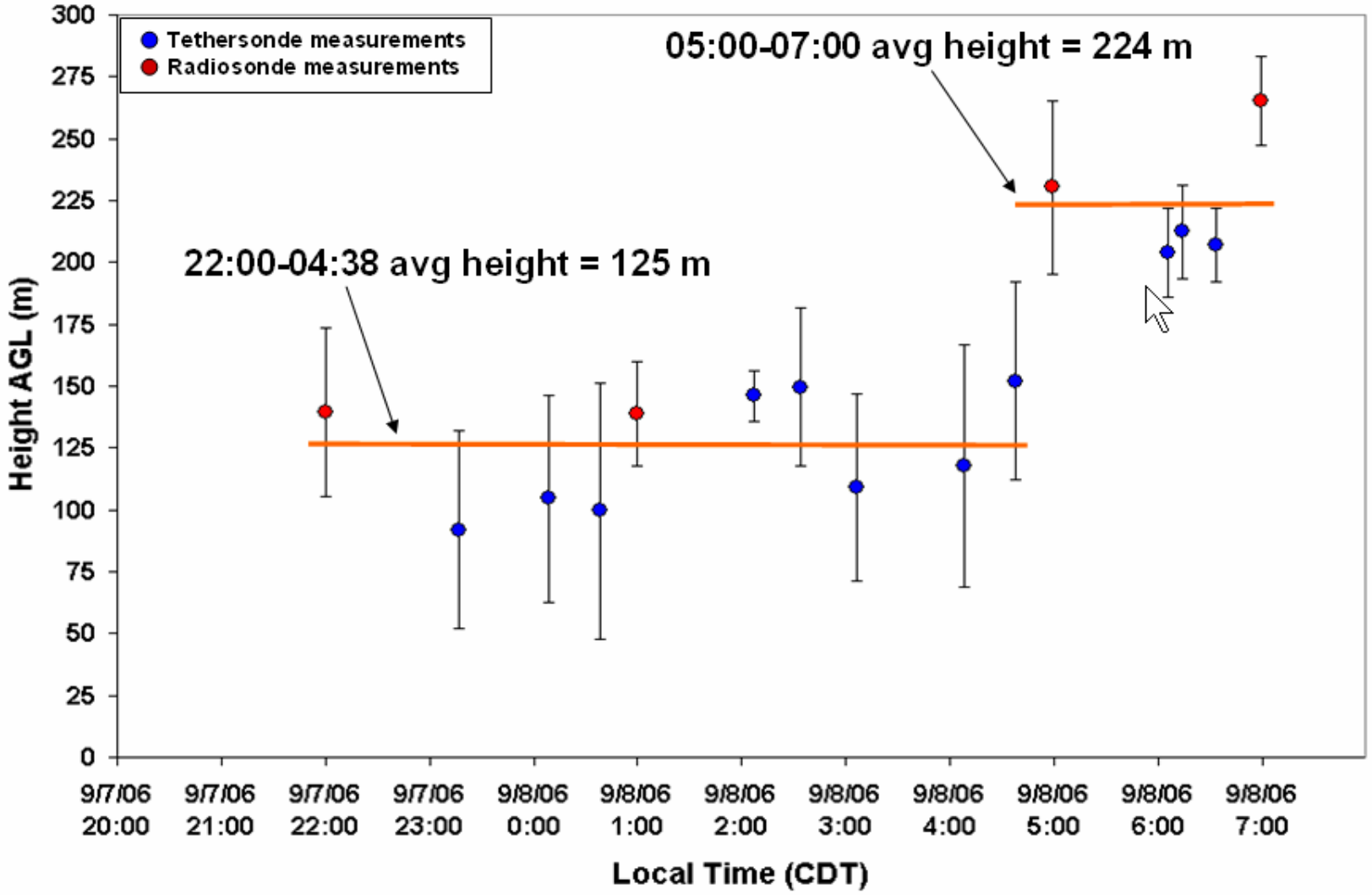
Bridget M. Day and Bernhard Rappenglück - University of Houston

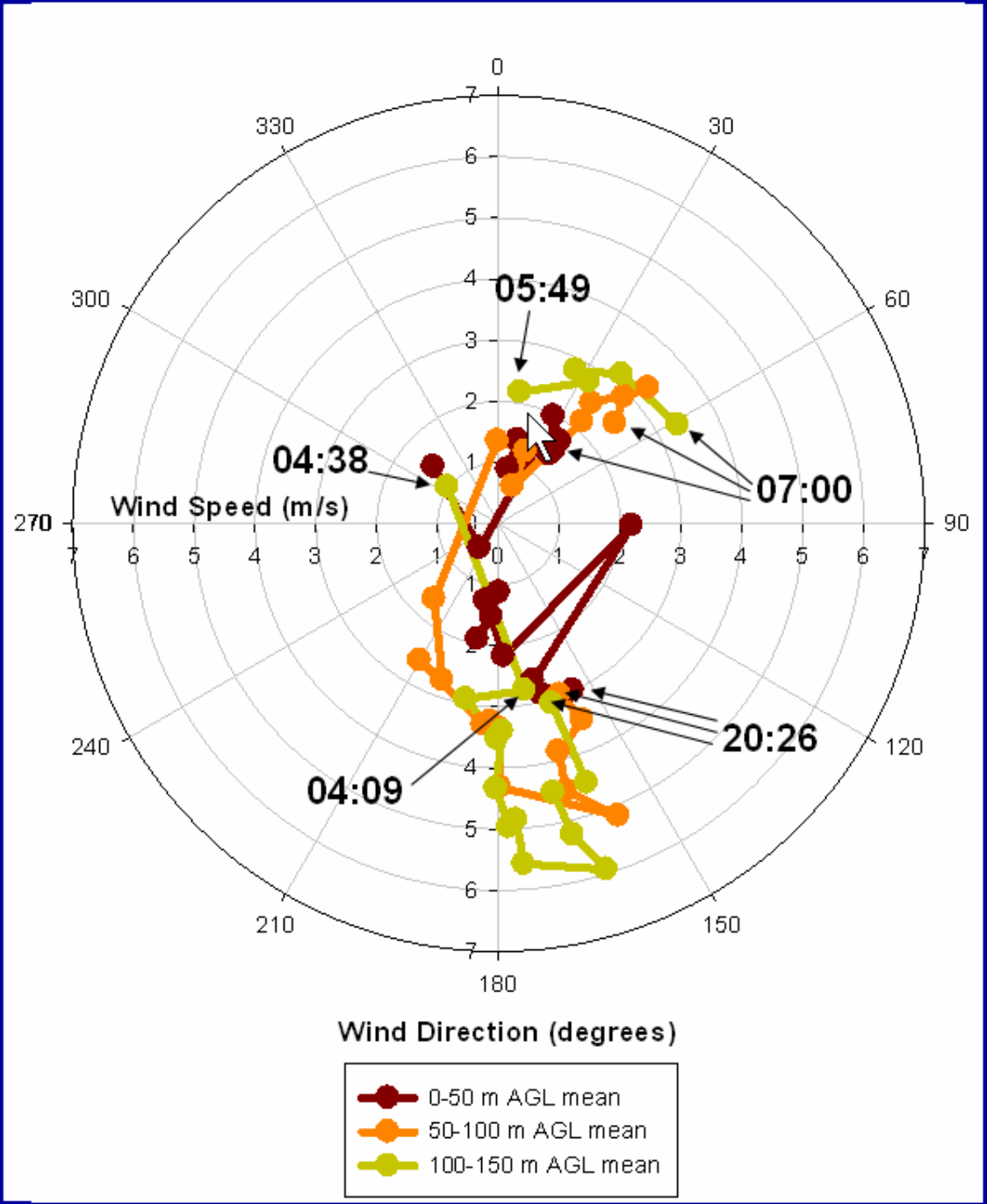
Craig B. Clements - San José State University



January 21, 2008
AMS Annual Meeting

September 7-8 Nocturnal Inversion Heights 20:26 – 07:00 CDT





September 7-8, 2006
Wind Speed and Direction
20:26 – 07:00 CDT

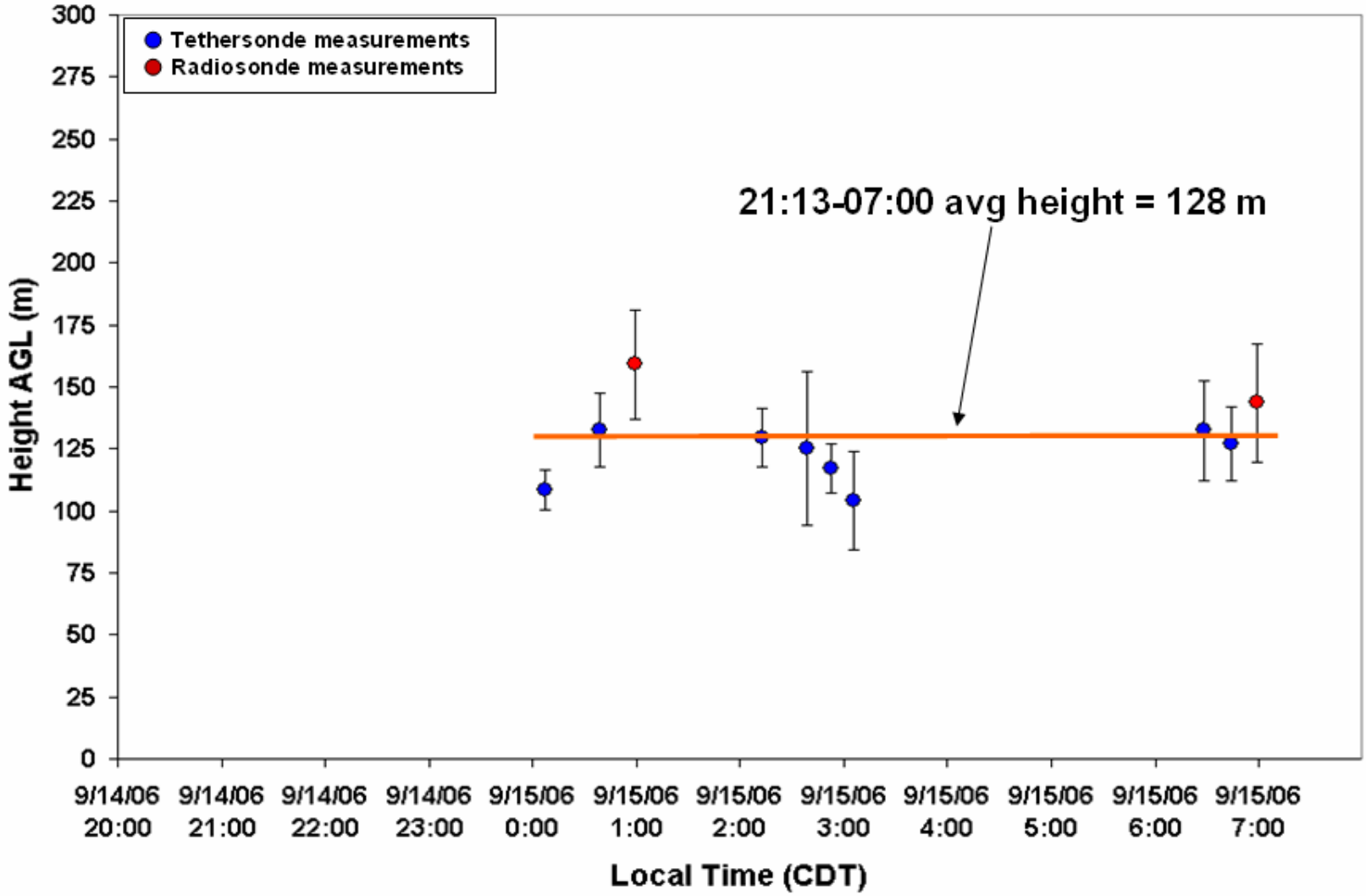
Methods

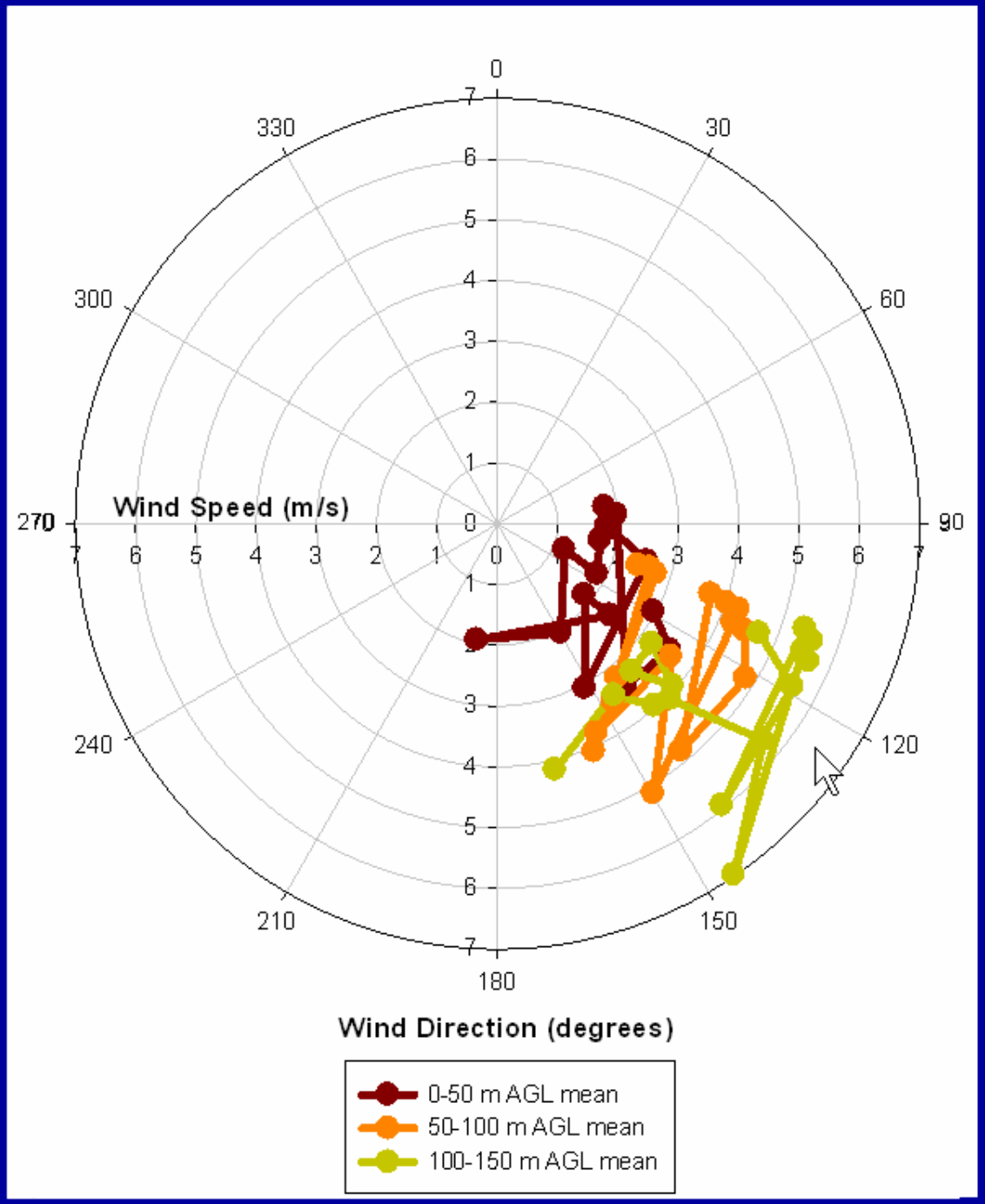
- Winds averaged in 50-m layers
- Tethersonde and radiosonde data represented

Results

- General clockwise circulation overnight
  - Sea breeze to land breeze
- In early morning, winds shift quickly from S to N
  - Wind shift occurs at different times depending on layer

September 14-15 Nocturnal Inversion Heights 21:13 – 07:00 Local Time





September 14-15, 2006 Wind Speed and Direction 21:13 – 07:00 CDT

Results

- Winds southeasterly during entire overnight period
- Synoptic flow overwhelmed local winds
- Higher wind speeds vs. Sept 7-8

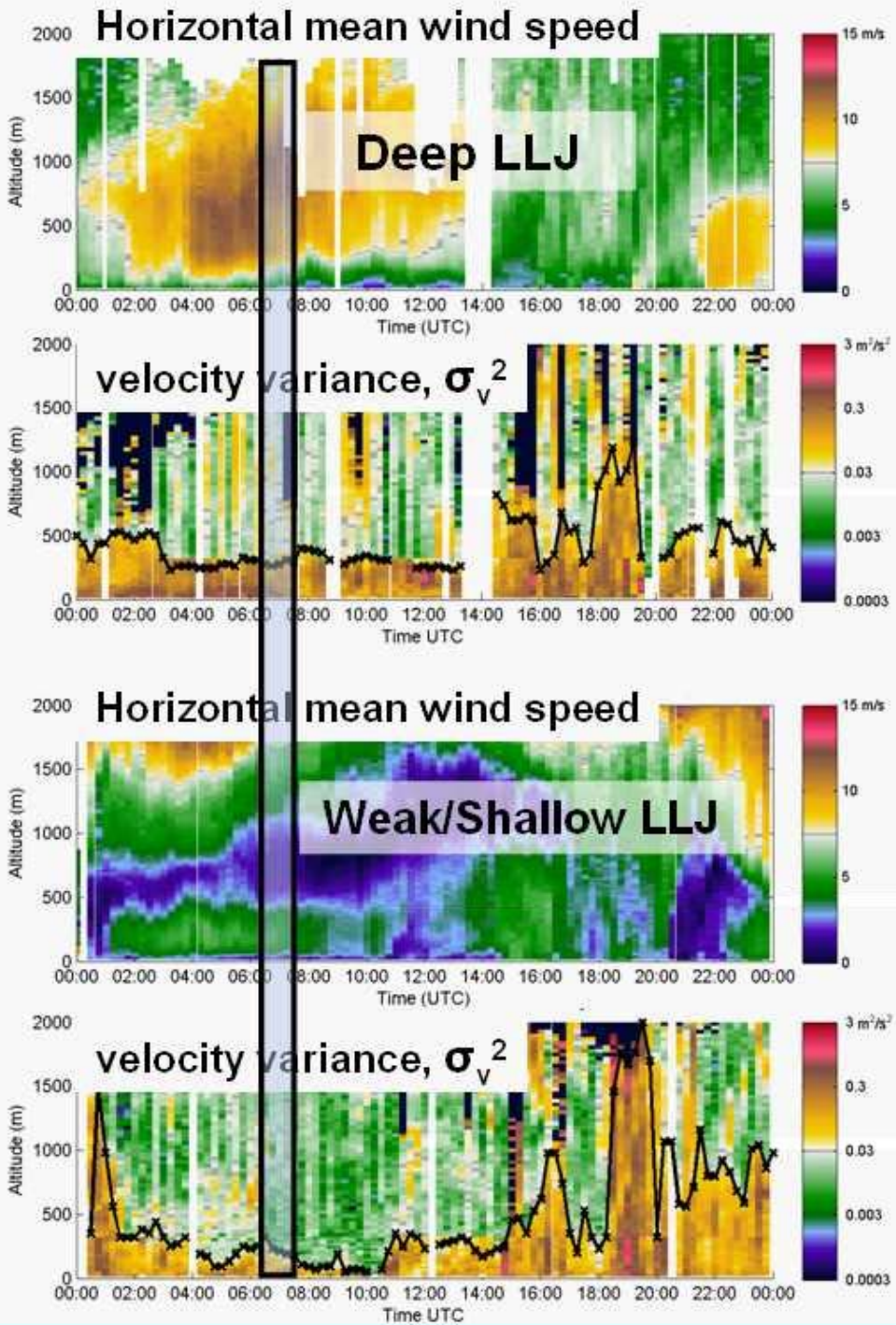
Conclusions

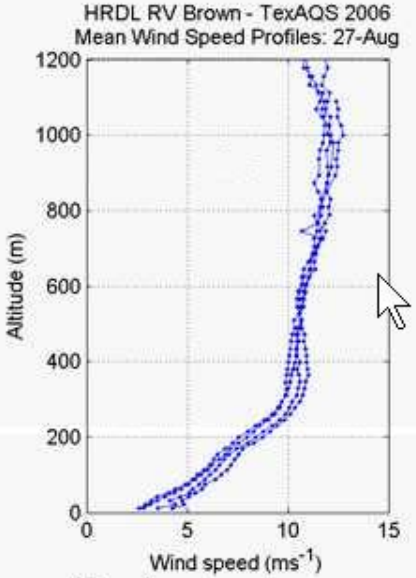
- Houston land-sea breeze circulations
  - Seen on some nights in dataset
  - More evident aloft vs. near surface
- Land breeze development may influence
  - Nocturnal inversion height
  - Vertical temperature profile
- Synoptic winds can dominate local winds

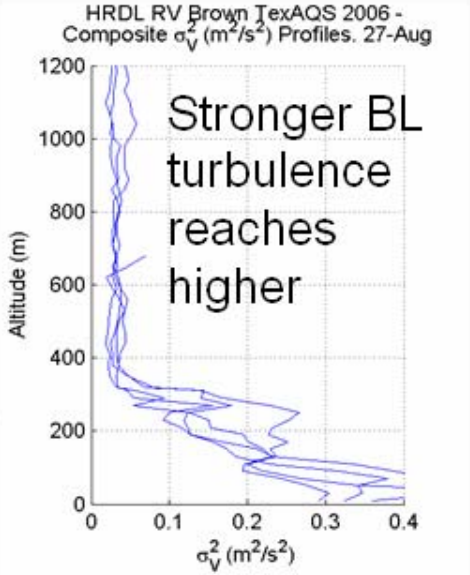
Ship-based lidar measurements of nocturnal mean winds, mixing height and boundary layer dynamics and correlation to Houston ozone measurements during TexAQS II

Sara C. Tucker*, Wm. Alan Brewer, Janet L. Machol*
Robert M. Banta, Christoph J. Senff*, Wayne M. Angevine*
Eric J. Williams*, Brian M. Lerner*, and R. Michael Hardesty
NOAA/ESRL/CSD, *also with CIRES, University of Colorado

Jet and Turbulence Profiles

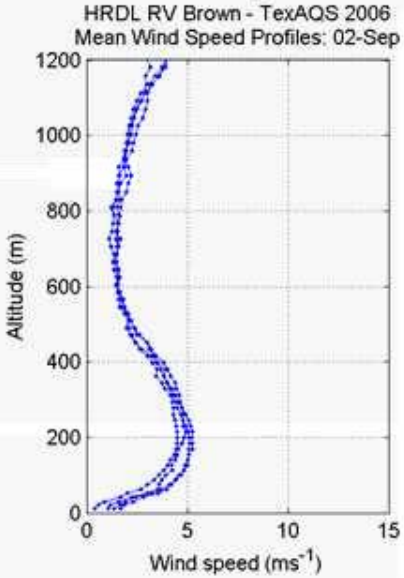


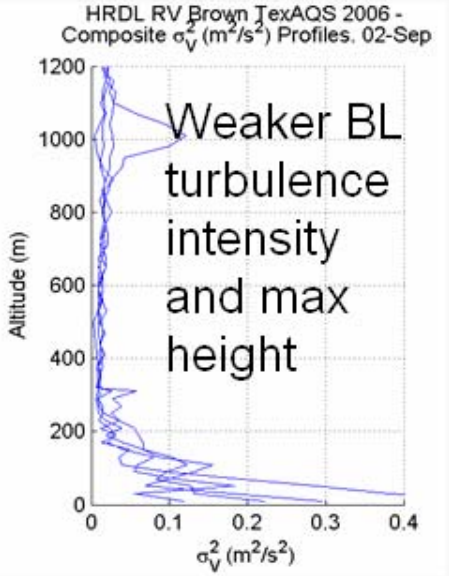




Horizontal mean wind speed

velocity variance





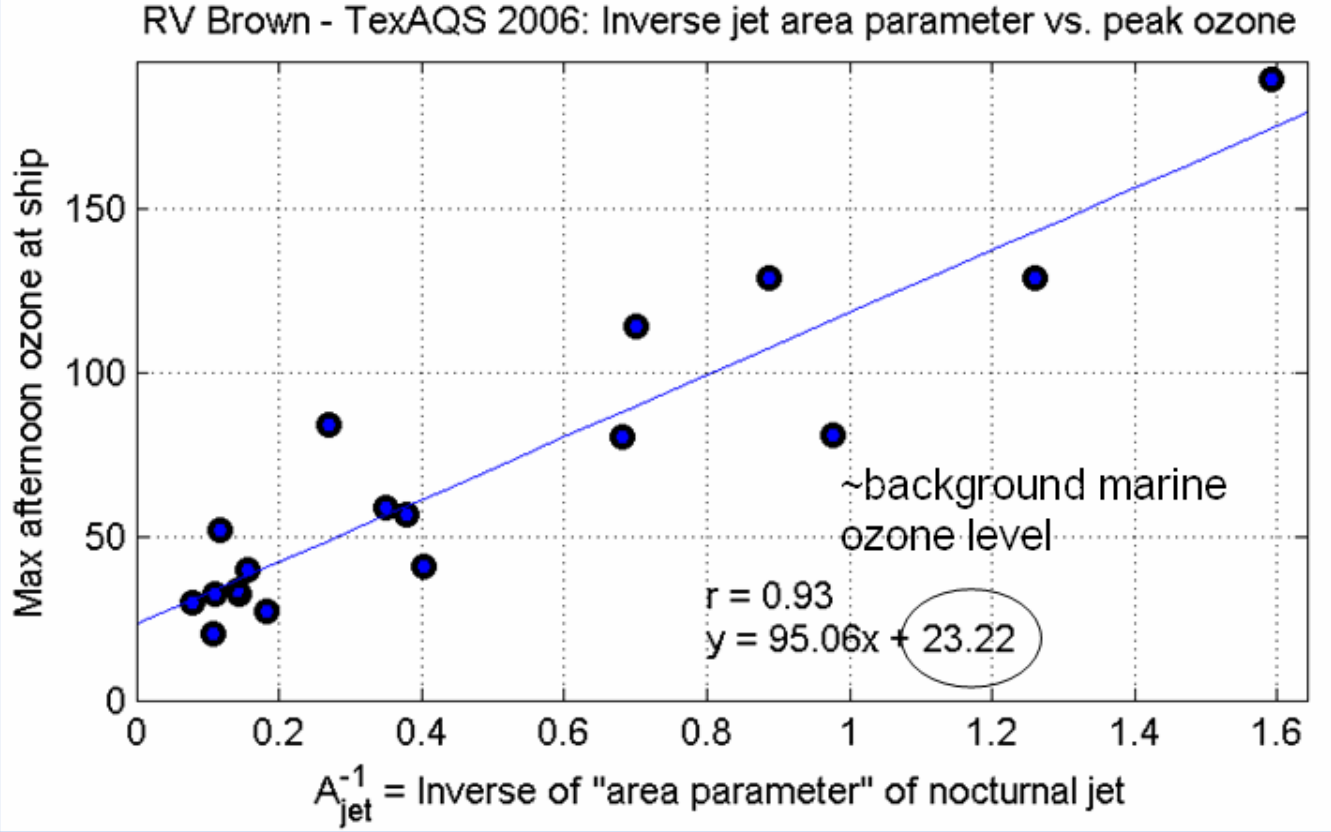
Connecting nocturnal winds to daytime ozone levels

Peak ship based ozone measurement of the day vs. A_{jet}^{-1} the previous night, where

$A_{jet} = V_{max} * H_{max}$

V_{max} = max speed of jet

H_{max} = height of max speed of jet.



Deeper/faster nocturnal LLJs correlate to lower ozone values the following day

– Currently studying the affect the LLJ has on those levels

Conclusions

- The DSLLJ reduces nocturnal ozone/Ox concentration levels via the following mechanisms:
  - Transport of "unpolluted" marine air into the Houston area.
  - Generation of mechanical turbulence that mixes the surface air with the relatively clean air aloft.
  - Transport of surface emitted pollutants that enter the jet layer.
- Deeper/stronger jets clean out a larger/deeper volume for less "residual" ozone/Ox available the next day.
- Surface winds don't tell the whole story.
- Inverse of the jet "area parameter" is a good indicator of peak ozone the following day.

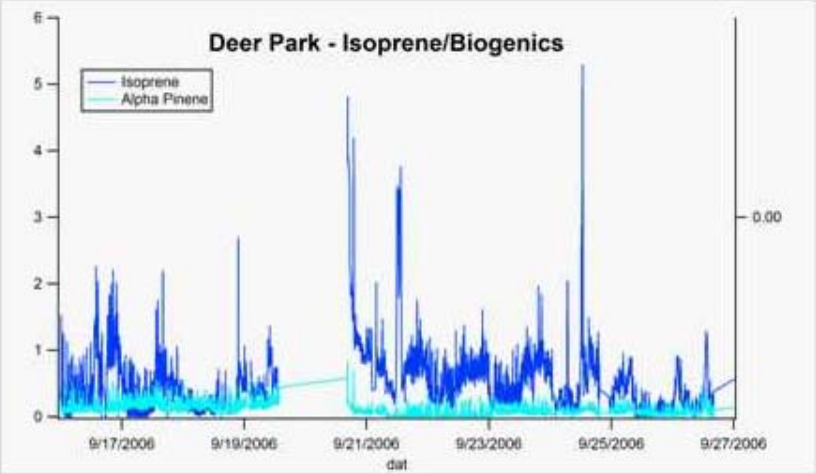
Acknowledgements: NOAA's Air Quality Program & the Texas Commission on Environmental Quality

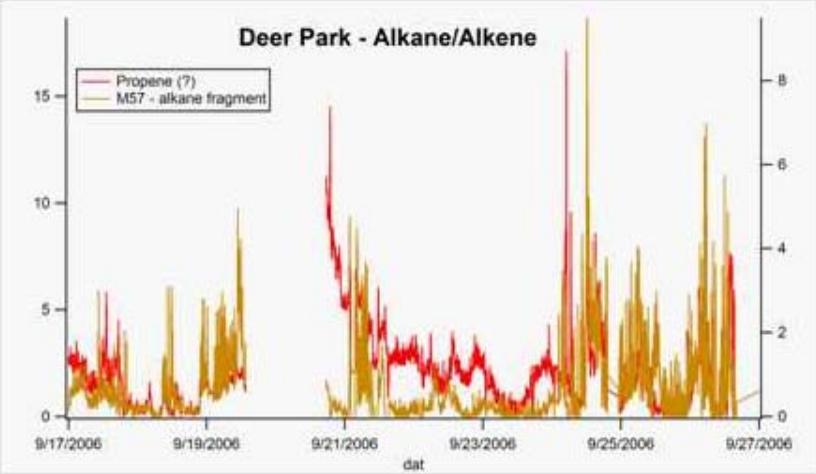
Aerosol and Trace Gas Measurements at Deer Park and Bayland Park in the 2006 Houston Triangle Experiment

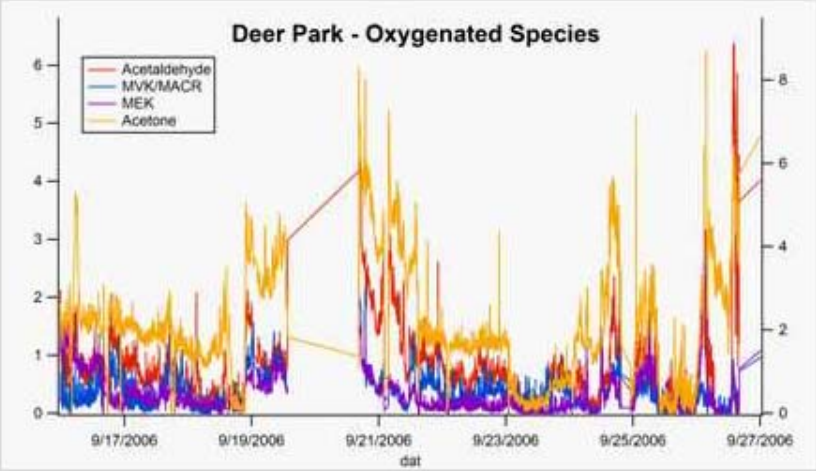
M. L. Alexander[1], X.Y. Yu[2], J. Ortega[1], M. Newburn[1], T. Jobson[4], R. Zaveri[2], J. Neece[5], D. Worsnop[3], J. Jayne[3], T. Onasch[3], M. Canagaratna[3] and C. Berkowitz[2]

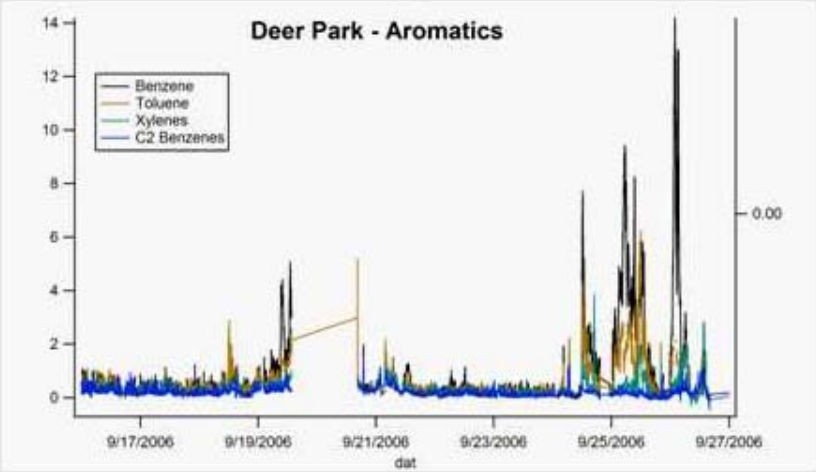
1. William R. Wiley Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory, 3335 Q Street, Richland, WA 99352
2. Atmospheric Science & Global Change Division, Pacific Northwest National Laboratory, 3200 Q Ave., Richland, WA 99352
3. Aerodyne Research Inc. (ARI), 45 Manning Road, Billerica, MA 01821
4. Department of Civil and Environmental Engineering, Washington State University, Pullman, WA 99164-2910
5. Air Quality Planning Division, Texas Commission on Environmental Quality, CP.O. Box 13087, Austin, TX 78711-3087

PTR-MS from Deer Park - Overview







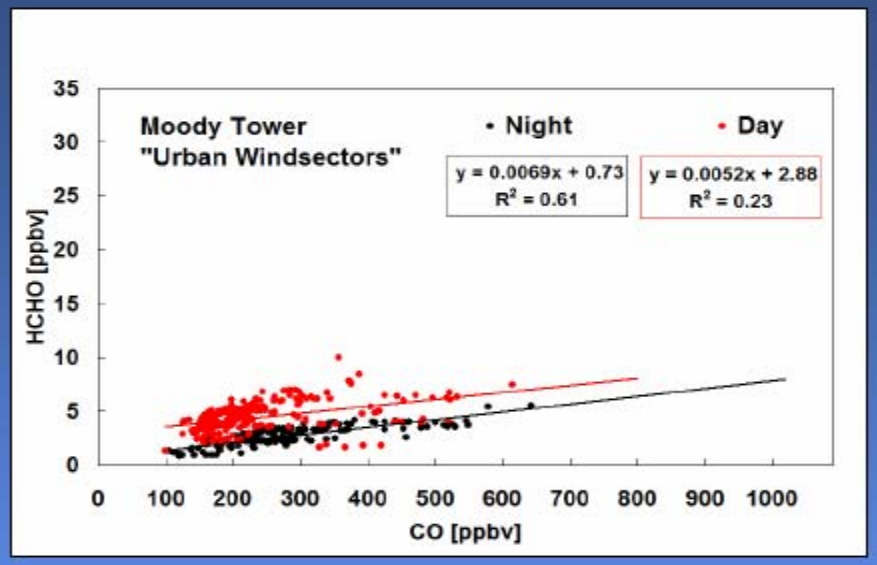


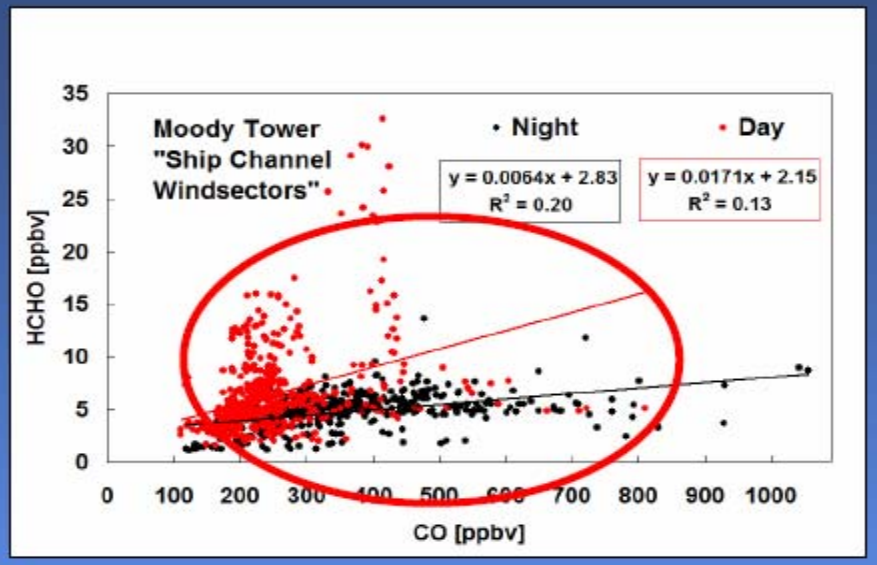
Analysis of Primary vs. Secondary Fraction of Formaldehyde in the Houston Area during TexAQS-II

B. Rappenglueck[1], S. Alvarez[2], D. Byun[1], M. Buhr[3], B. Czader[1], P. Dasgupta[4], M. Estes[5], L. Kauffman[2], S. Kim[1], M. Leuchner[1], W. Luke[6], M. Shauck[2], G. Zanin[2]

[1] Department of Geoscience, University of Houston, Houston
[2] Baylor University, Waco
[3] Air Quality Design Inc., Golden
[4] Department of Chemistry, The University of Texas at Arlington, Arlington
[5] Texas Commission on Environmental Quality, Austin
[6] NOAA-ARL, Silver Spring

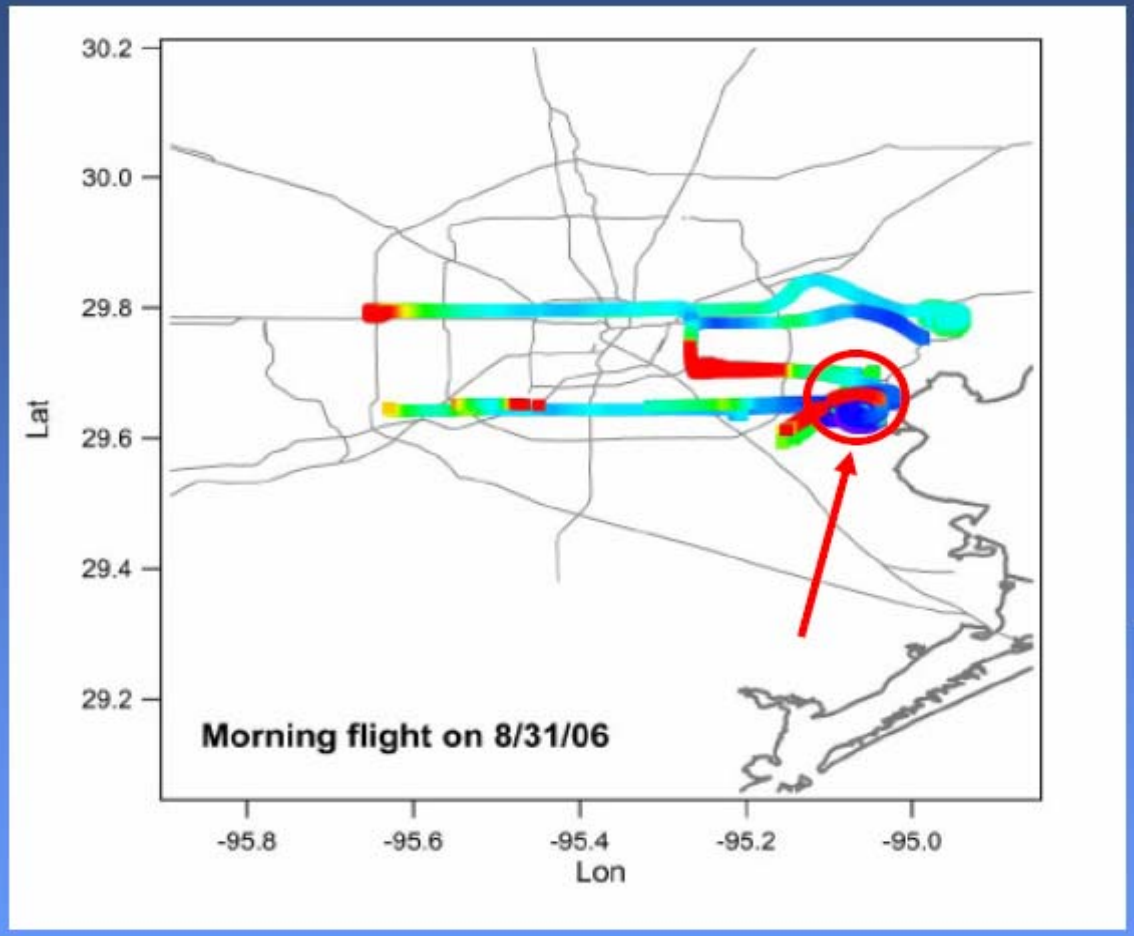
Correlations

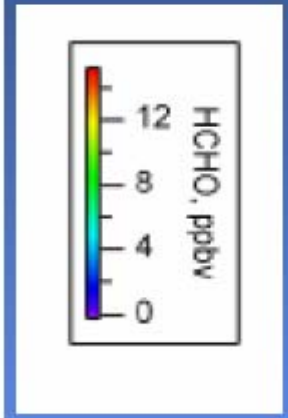




- "Ship Channel" data higher scatter, also during nighttime during nighttime (other sources than traffic may contribute)

Airborne Measurements

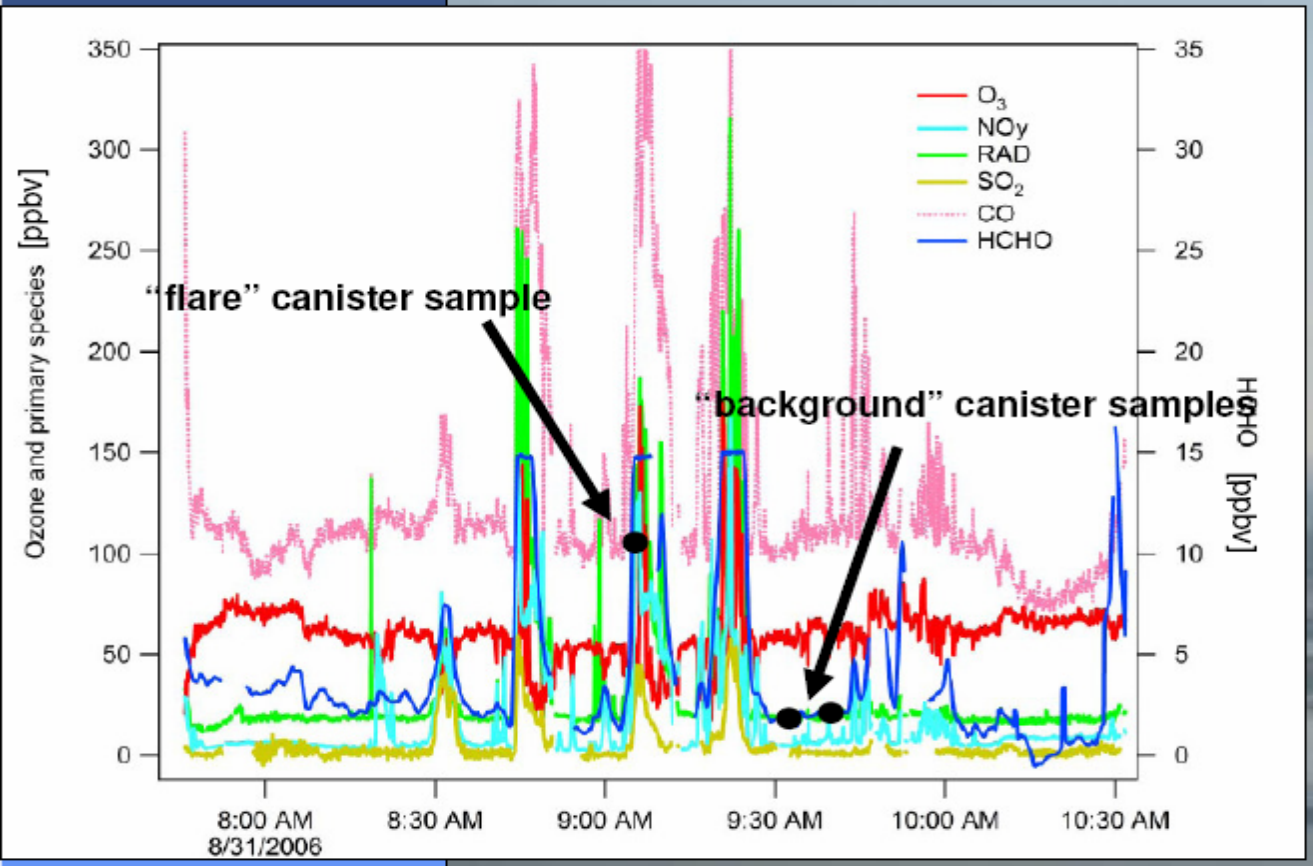




Airborne Measurements

Flare Flight

Airborne Measurements



Flare Flight; 3 cross sections – about 1000 ft a.g.l.

Correlations

Other Correlations ("nighttime"):

	HCHO<>CO	HCHO<>NO_2	HCHO<>SO_2	HCHO<>Ethylene
Moody Tower ("Urban")	0.0069 (R2=0.61)	0.060 (R2=0.19)	0.058 (R2=0.02)	0.46 (R2=0.18)
Moody Tower ("Ship Channel)	0.0064 (R2=0.20)	0.064 (R2=0.28)	0.062 (R2=0.04)	0.23 (R2=0.09)
HRM3	0.0024 (R2=0.10)*	0.098 (R2=0.32)	0.802 (R2=0.18)*	0.24 (R2=0.09)
Lynchburg Ferry	0.0054 (R2=0.11)*	0.184 (R2=0.32)	0.797 (R2=0.05)*	0.21 (R2=0.09)

Baylor Aircraft (BU)	
"background 1"	0.0031
HCHO	0.4 ppbv
CO	127.7 ppbv
Ethylene	1.1 ppbv
"background 2"	0.0041
HCHO	0.5 ppbv
CO	132.8
Ethylene	2.9 ppbv
"Flare"	0.0230
HCHO	8.8 ppbv
CO	383.3
Ethylene	6.9 ppbv

*closest TCEQ site taken

In flare:

- HCHO/CO ~ 5-7 times higher than in background
- HCHO/CO ~ 3 times higher than traffic induced HCHO/CO ratios
- Ethylene values relative moderate

Conclusions

- "Background" HCHO values range between 2.9 (Moody Tower) - 6.6 ppbv (Lynchburg site). Maximum values are between 31.5-52.4 ppbv
- Best correlation of HCHO with CO. Primary emissions of HCHO estimated to be up to 0.7% of the CO emissions.
- Diurnal HCHO variations indicate "Ship Channel" impact.
- Indications that flare emissions may be up to 2-5% of flare CO emissions.
- CMAQ simulates well HCHO at Moody Tower; results indicate:
  - during daytime photochemical production dominates
  - nighttime HCHO formation, most likely through olefin- O_3 reactions
  - non-negligible HCHO emissions

The role of background versus locally contributed ozone during the TexAQS2 field campaign

James Tobin and John Nielsen-Gammon
Department of Atmospheric Sciences
Texas A&M University

Background Ozone

- Mean statistics by background station

Cleanest background associated with SSE flow detected in Brazoria County.

STATION	PEAK	BKGD	N	SPD	DIR
039-1003	62.30	25.03	256	3.43	166.68
039-1016	61.22	30.32	305	3.16	151.83
167-0014	62.82	32.19	242	3.51	148.49
201-0029	62.16	38.76	46	3.24	89.35
201-0066	53.02	32.72	228	2.73	122.43
245-0022	63.71	35.26	220	2.23	108.24
339-0078	81.50	49.55	153	2.47	55.73
339-0089	82.31	49.24	42	3.73	51.24

Dirtiest background associated with NE flow detected in Montgomery County.

Conclusions (2 of 3)

- Onshore winds, leading to background ozone observed in Harris, Brazoria, and Galveston counties, typically favor lower background and peak ozone values.
- Northeast winds, leading to background ozone observed in Conroe, typically favors higher background and peak ozone values.

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Evaluation of Meander-Like Wind Variance in High-Resolution WRF Model Simulations of the Stable Nocturnal Boundary Layer

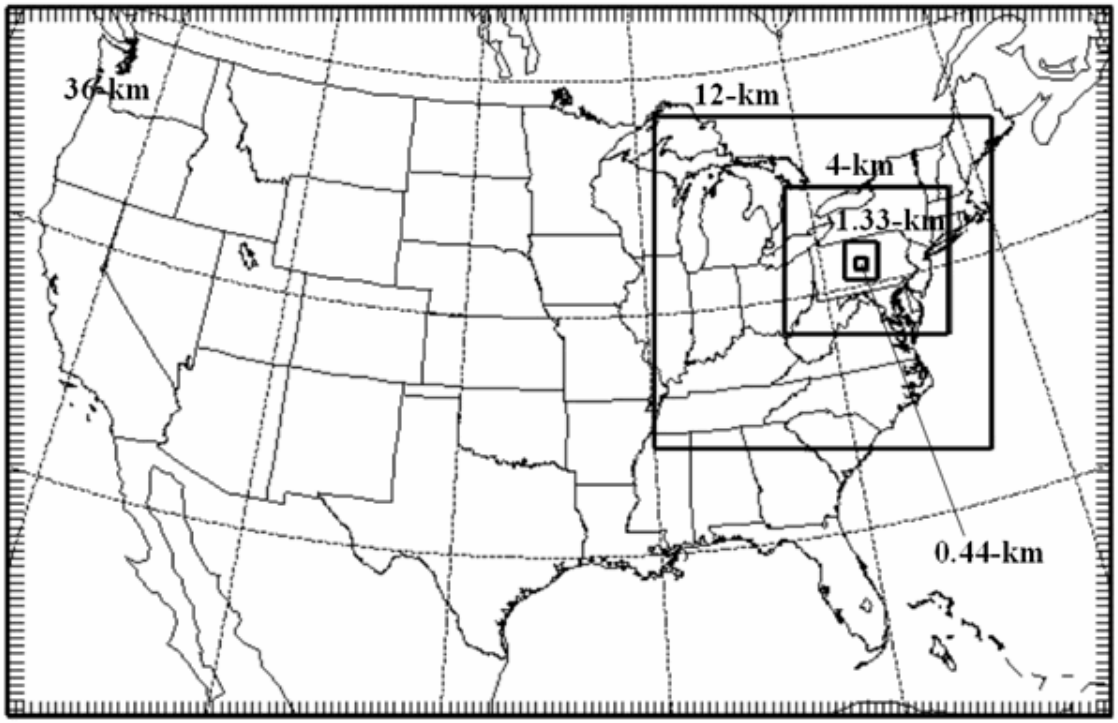
Nelson Seaman[1], Brian Gaudet[1], Aijun Deng, Scott Richardson[1], David Stauffer[1], John Wyngaard[1], and Larry Mahrt[2]

Penn State University[1] & Oregon State University[2]

WRF Horizontal Grid Configuration

- WFR-ARW is configured with 5 nested-grid domains:

Domain No.	Horiz. Res. (km)	No. of Points
1	36.0	141 X 91
2	12.0	130 X 127
3	4.0	193 X 169
4	1.333	121 X 121
5	0.444	151 X 151



- All inner grids use one-way nested grid interfaces.

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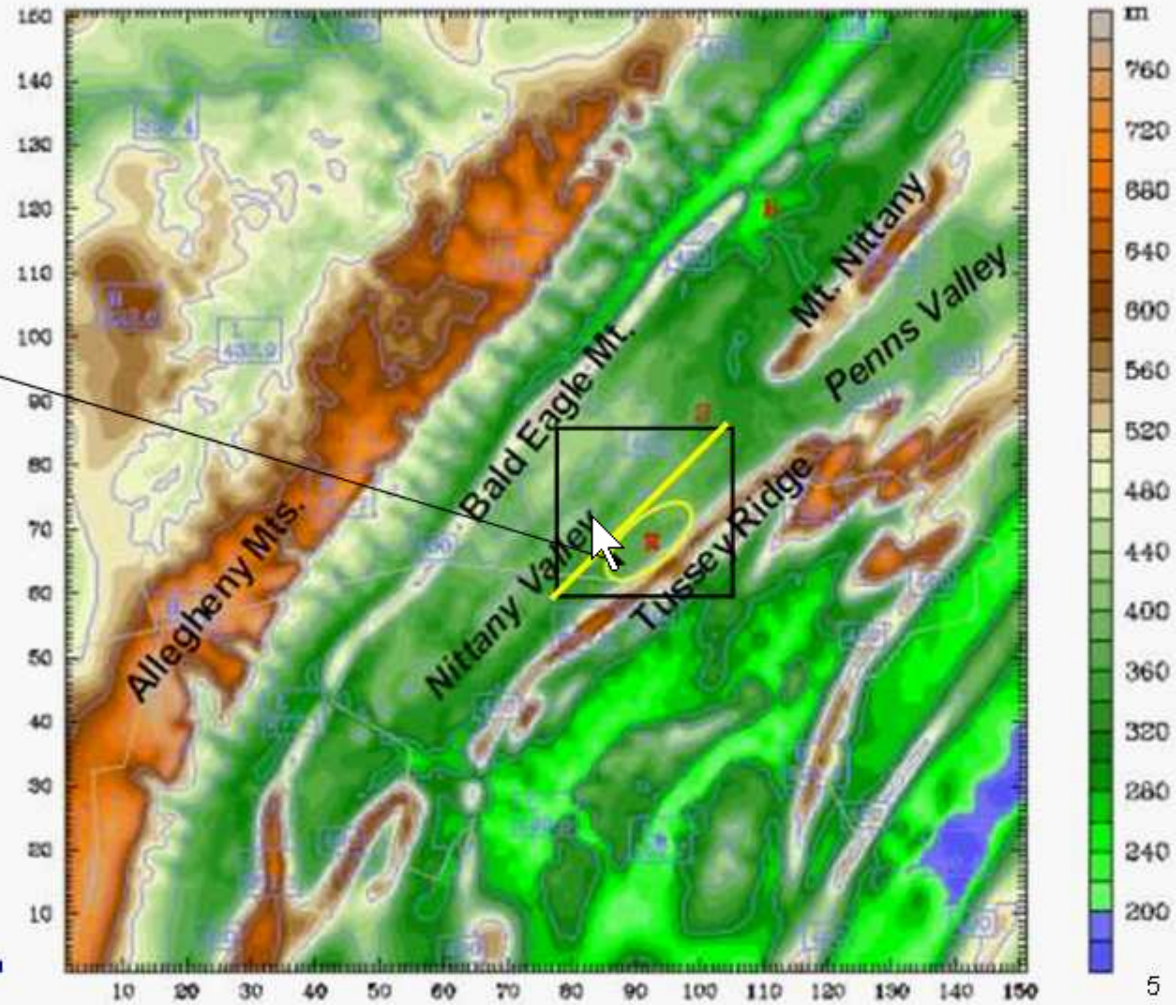
444-m Innermost WRF Domain
(DTED-1 Terrain Database, ~90 m Resolution)

Terrain (m) shown on color bar at right;
(R = Rock Springs, S = State College, B = Bellefonte)

Field Site (ellipse):

Extensive PSU-owned agricultural land at Rock Springs, PA

- **Sub-kilometer resolution is necessary to resolve fine-scale terrain important for shallow SBL flows.**
- **Small box shows sub-domain for diagnostics.**
- **Gold line indicates location of cross section.**



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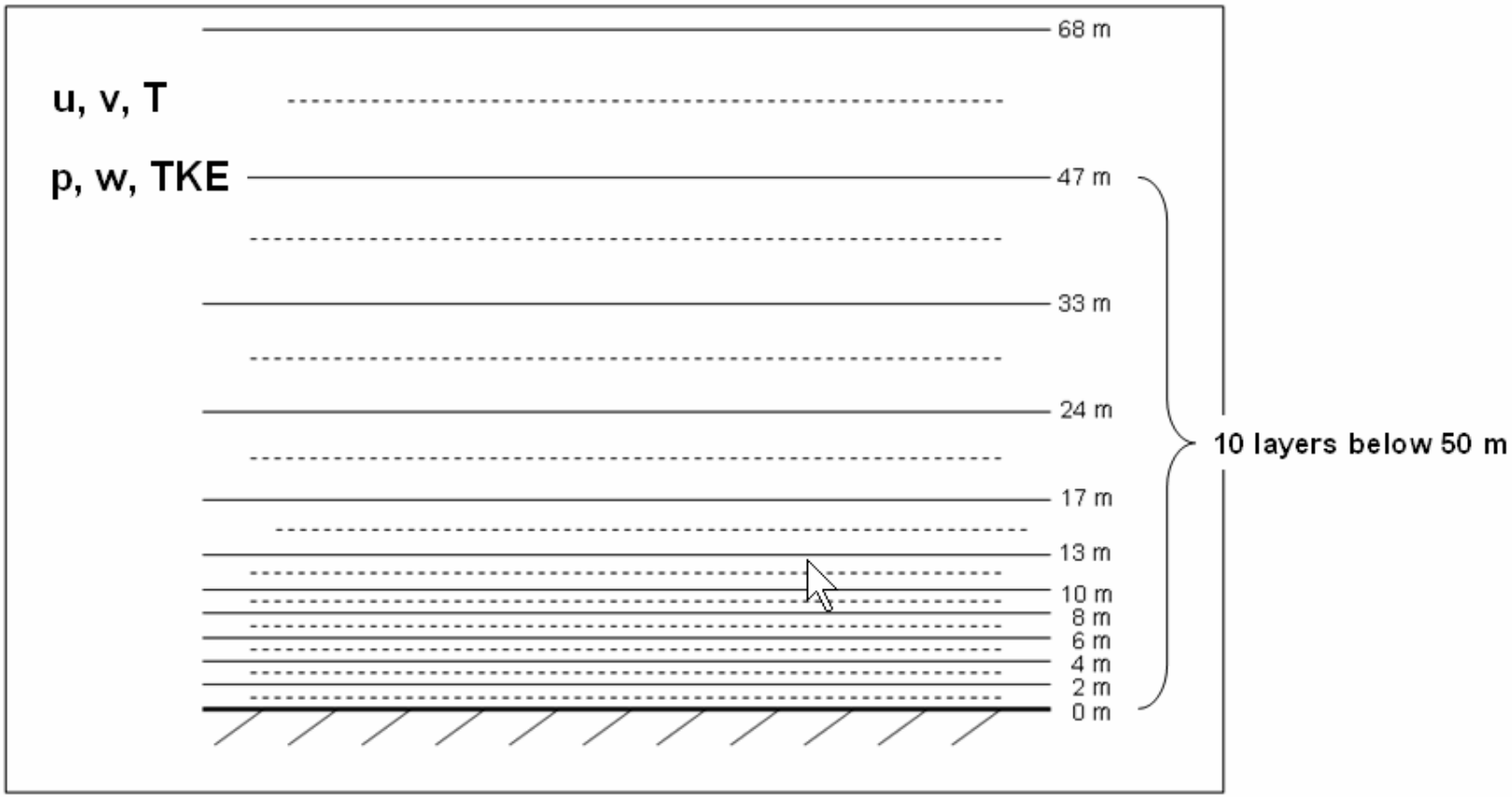
WRF Vertical Grid Configuration

- WRF is configured with 41 layers; model top is at 50 hPa.
- Lowest five layers are 2 m thick, gradually increasing upwards.
- 10 layers below 50 m AGL.



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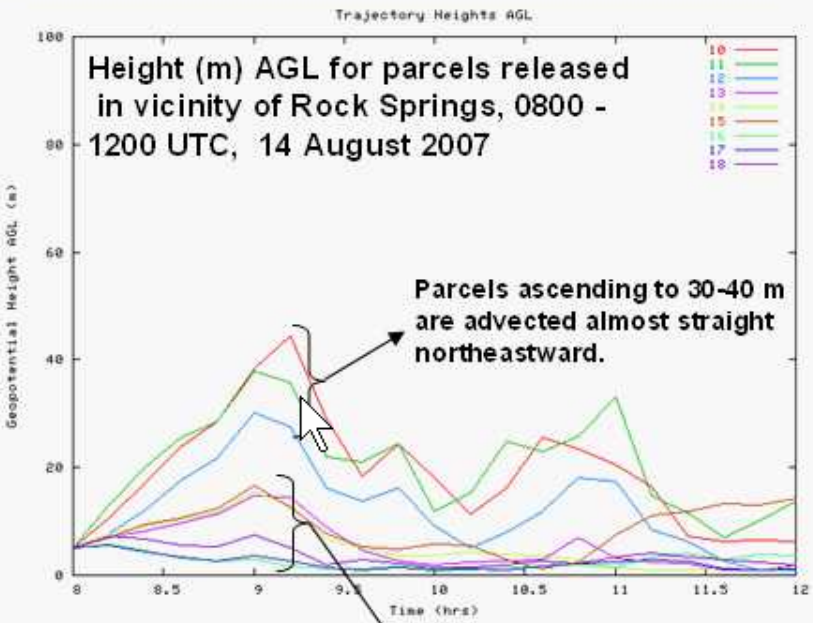
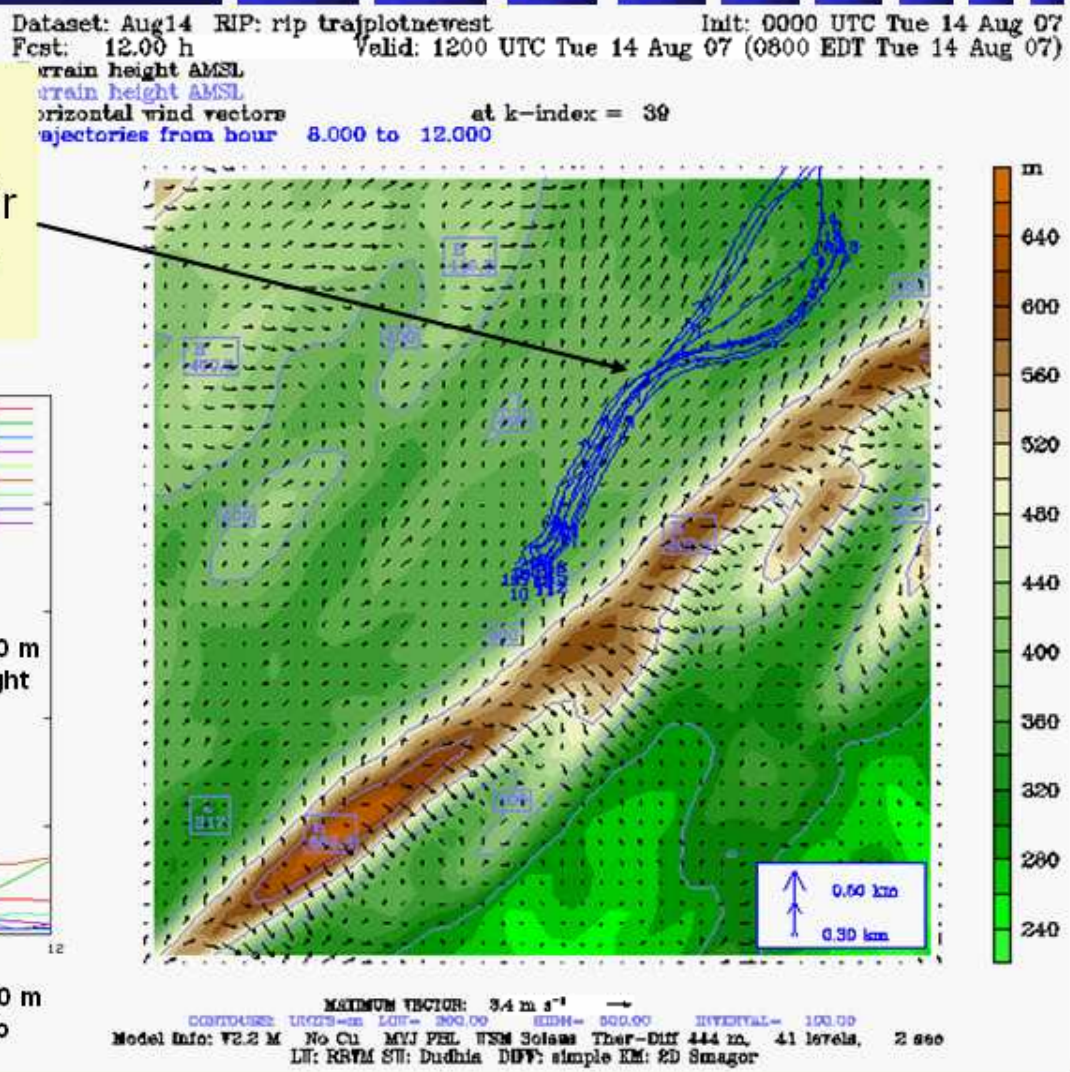
Meandering Trajectories in Nittany Valley

14 Aug. 2007, 0800-1200 UTC, Released at 5m AGL on 444-m WRF-ARW Sub-Domain

Fluctuation of near-surface winds in WRF near Rock Springs, PA, due to transient gravity waves and cold-air drainage, yields **meandering plume trajectories.**