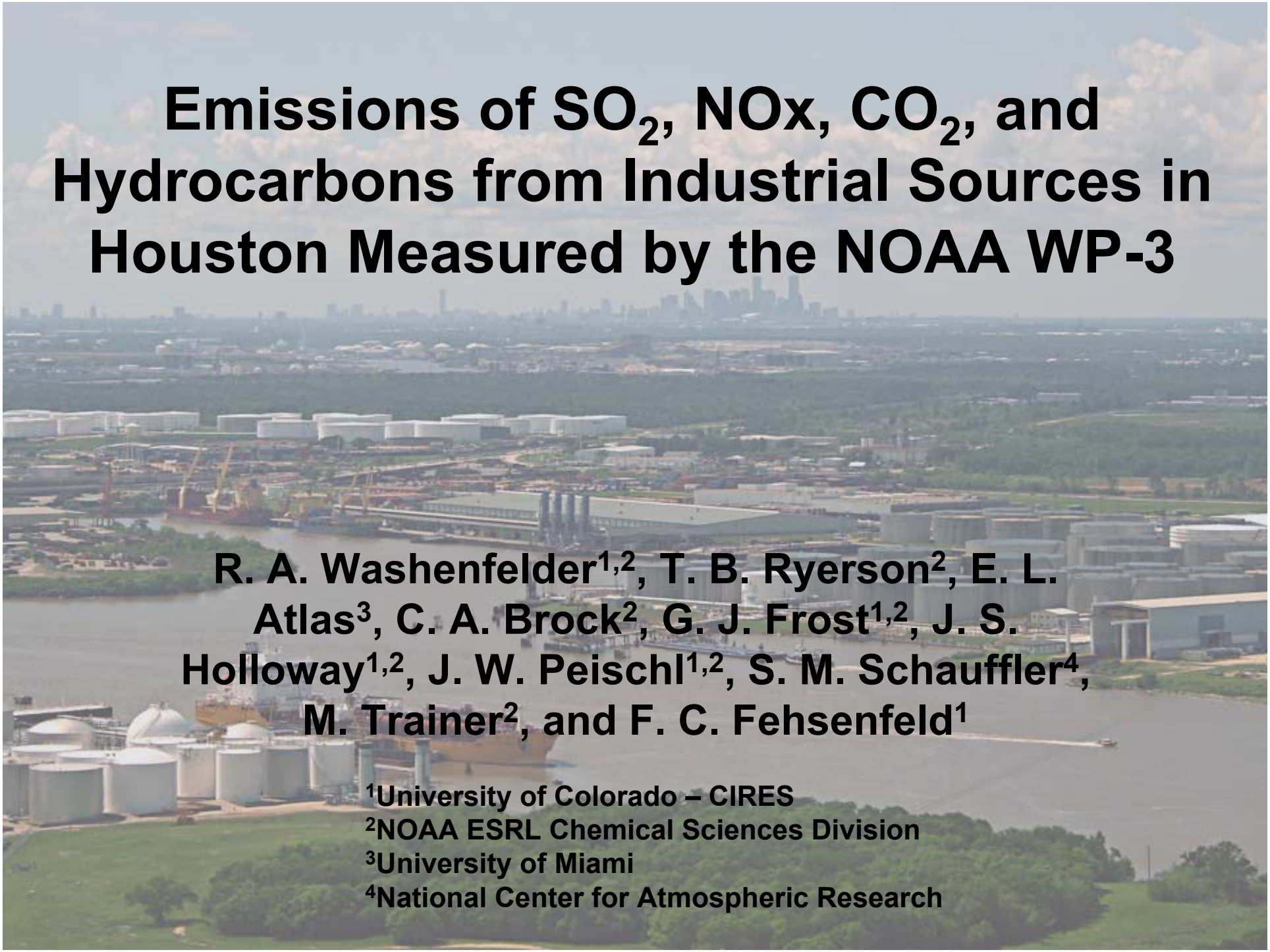
Emissions of SO_2, NOx, CO_2, and Hydrocarbons from Industrial Sources in Houston Measured by the NOAA WP-3



R. A. Washenfelder[1,2], T. B. Ryerson[2], E. L. Atlas[3], C. A. Brock[2], G. J. Frost[1,2], J. S. Holloway[1,2], J. W. Peischl[1,2], S. M. Schauffler[4], M. Trainer[2], and F. C. Fehsenfeld[1]

[1]University of Colorado – CIRES
[2]NOAA ESRL Chemical Sciences Division
[3]University of Miami
[4]National Center for Atmospheric Research

Emission Inventories for Texas

Texas Commission on Environmental Quality (TCEQ) Point Source Emissions Inventory

- Annual average SO_2, NO_x, CO, and VOC emissions

- Includes 1858 fixed-location pollution sources in Texas

- Databases for 1999 and 2004

EPA Continuous Emissions Monitoring

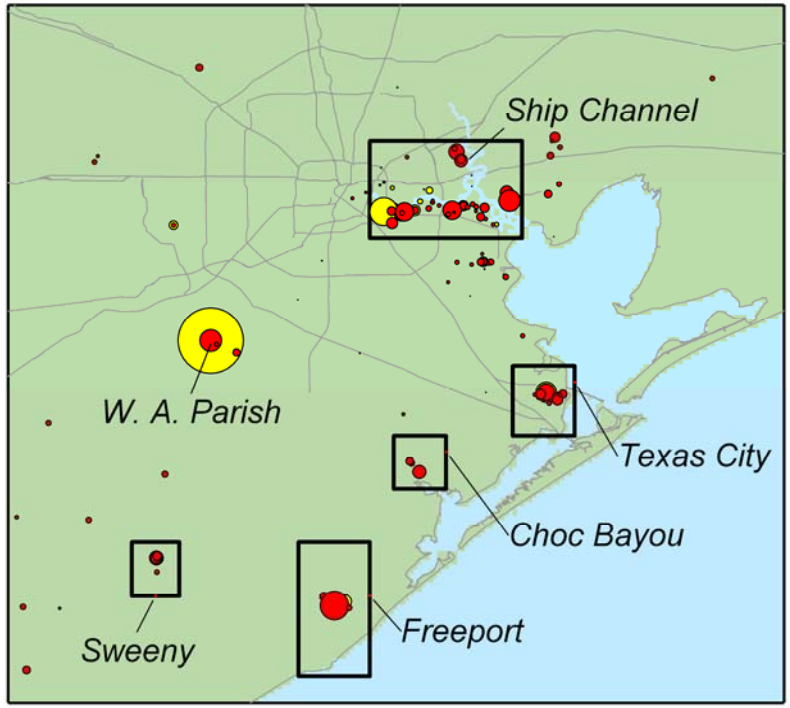
- Hourly measurements of SO_2, NO_x, and CO_2 emissions

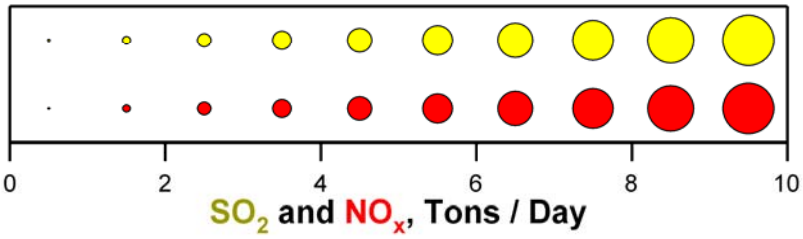
- Includes 130 fossil-fuel power plants and other large fixed-location pollution sources in Texas

Measurements in 2000 identified inaccuracies in the TCEQ Point Source Emissions Inventory (*Ryerson 2003; Wert 2003; Kleinman 2002)*.

Major Emission Sources in Houston

2004 TCEQ Point Source Emissions Inventory





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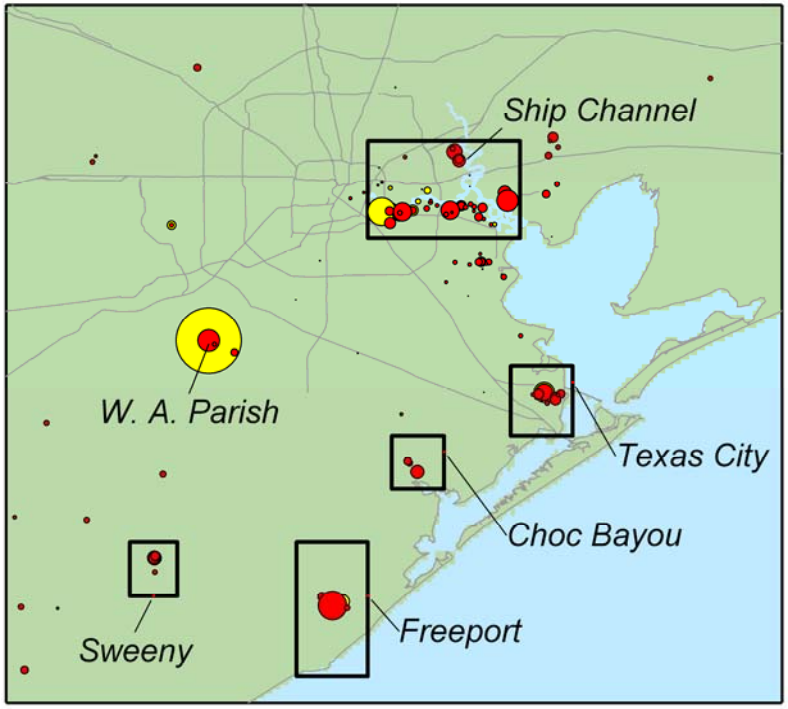
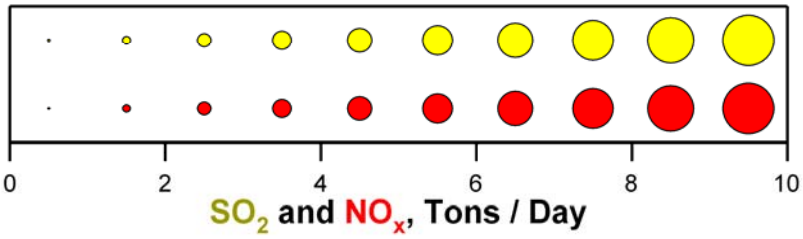




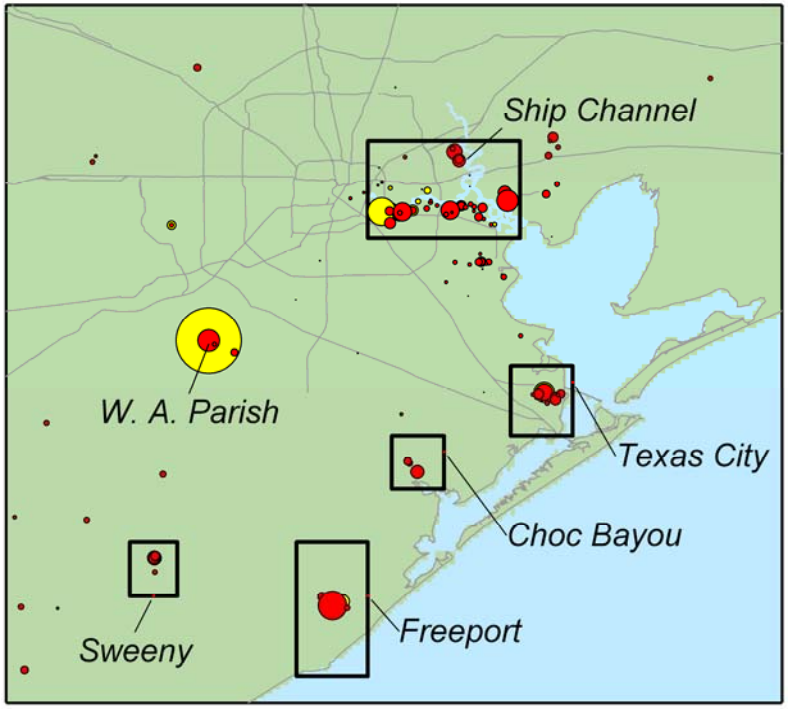
Reported Emissions in Tons / Day

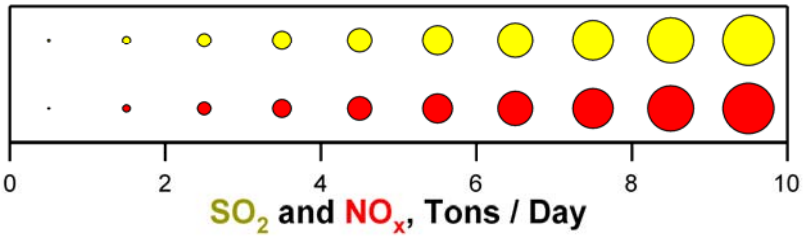
	SO_2	NO_x	CO	VOCs
W.A. Parish	**147**	17	20	0.4
Chocolate Bayou	0.2	10	6	**4.1**
Freeport	7	32	5	**4.1**
Sweeny	6	11	4	**3.8**
Texas City	16	23	11	**18.4**
Ship Channel	**68**	**99**	**46**	**55.7**
Ship Traffic[1]	1.2 - 12	12 - 120	0.2 - 2	

[1]Eric Williams (Presentation A13I-07)

Major Emission Sources in Houston

2004 TCEQ Point Source Emissions Inventory





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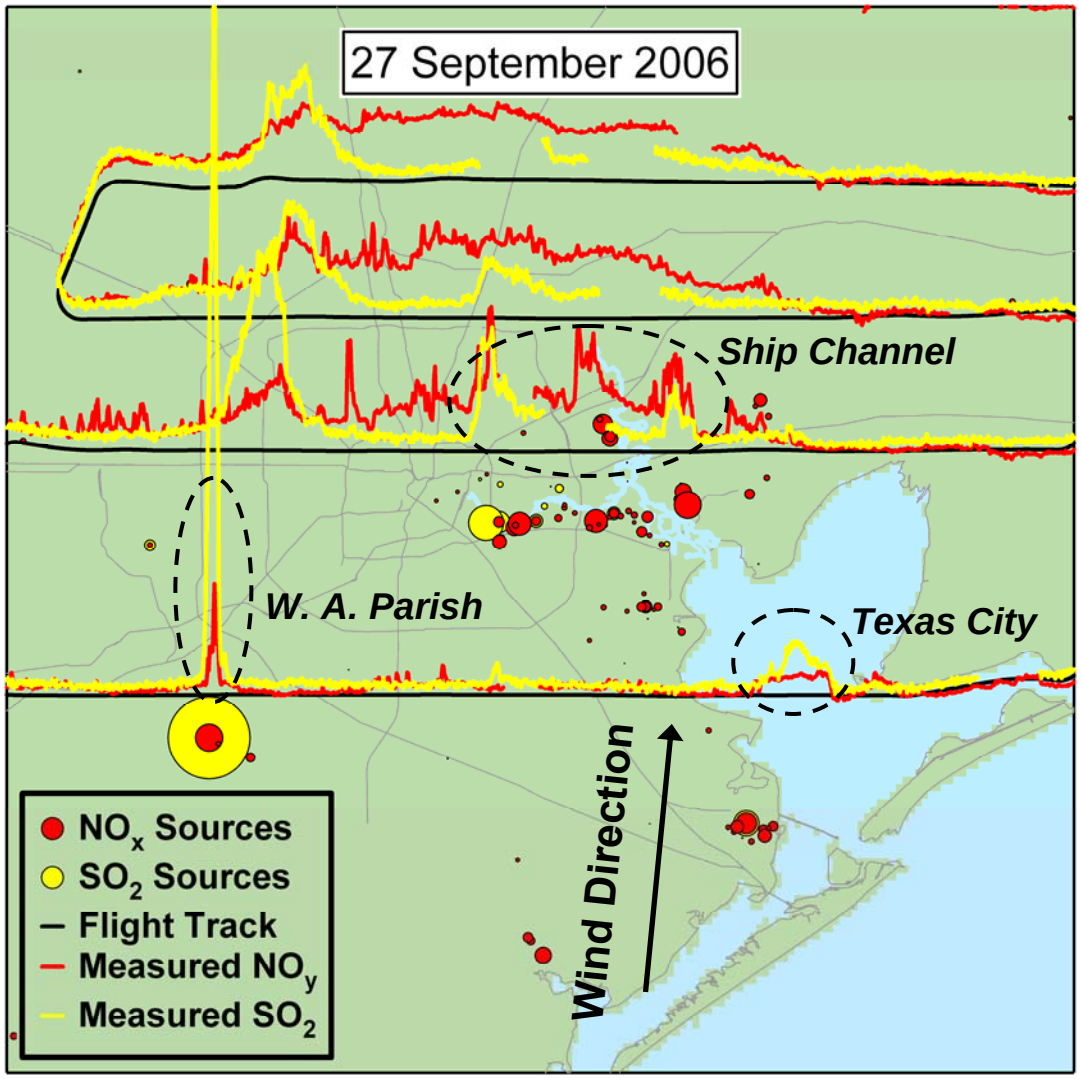
Measurements by the NOAA WP-3 Aircraft



Continuous Measurements:

NO, NO_2, and NO_y

SO_2

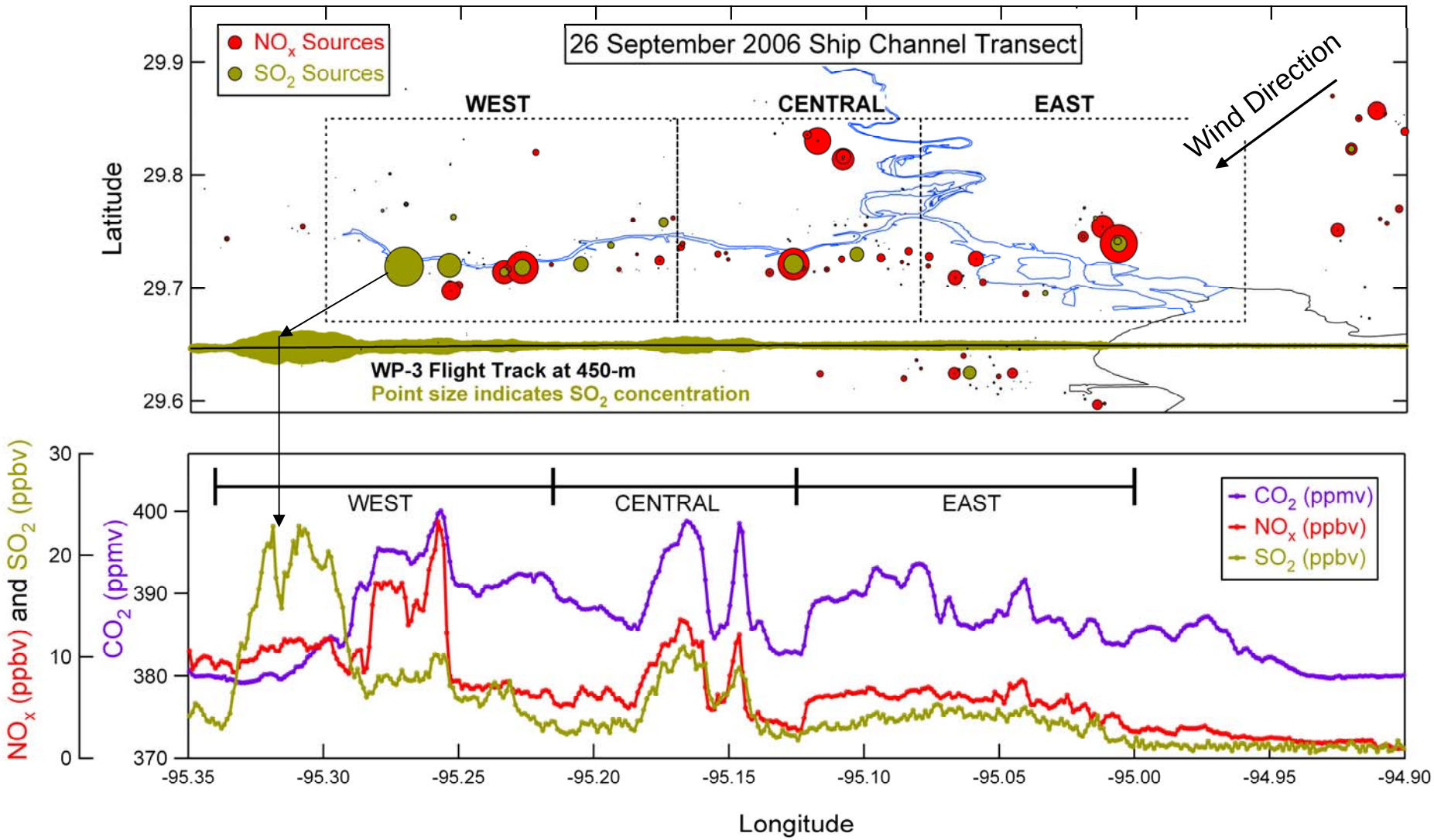
CO

CO_2

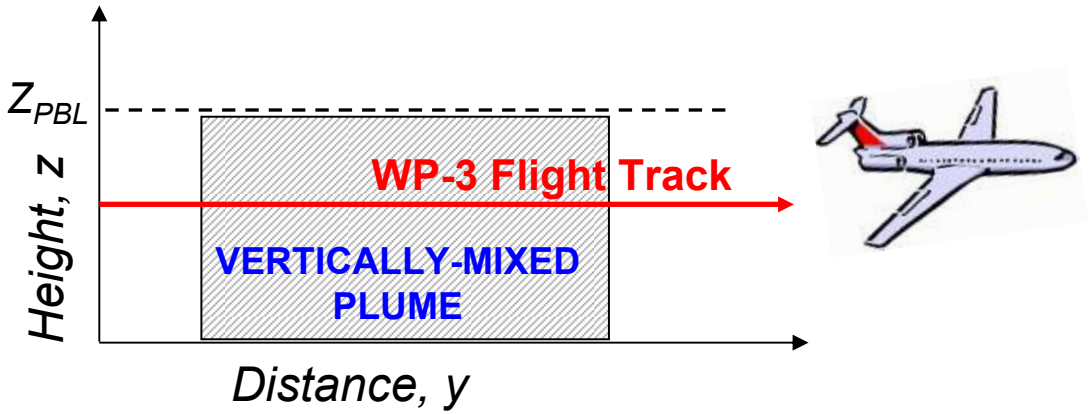
Discrete Measurements:

Speciated Hydrocarbons
(80 samples per flight)

Measurements Downwind of the Houston Ship Channel



Calculation of Absolute Fluxes



$$Net\ Flux = v \cos\alpha \int_{0}^{Z_{PBL}} n(z)\,dz \int_{-y}^{y} X_m(y)\,dy$$

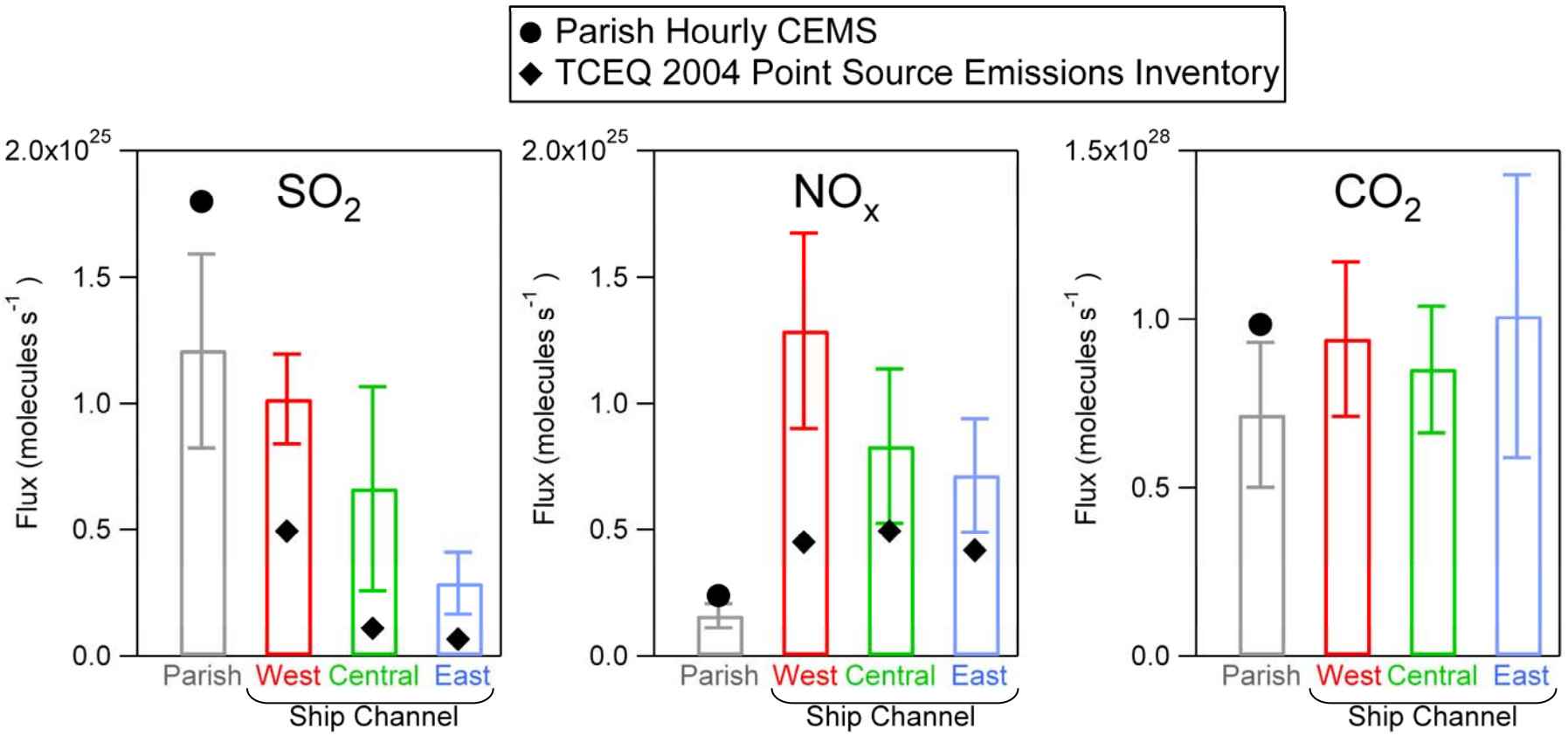
y is the cross-wind coordinate
z is the vertical coordinate
v is a constant, uniform windspeed
α is the angle between aircraft track and the direction normal to the wind direction
X_m is the measured mixing ratio enhancement of species *m*
n is the number density of the atmosphere

Assumptions:
- Wind speed and emissions are constant between the time of emission and measurement.
- Boundary layer (BL) is well-defined and well-mixed.

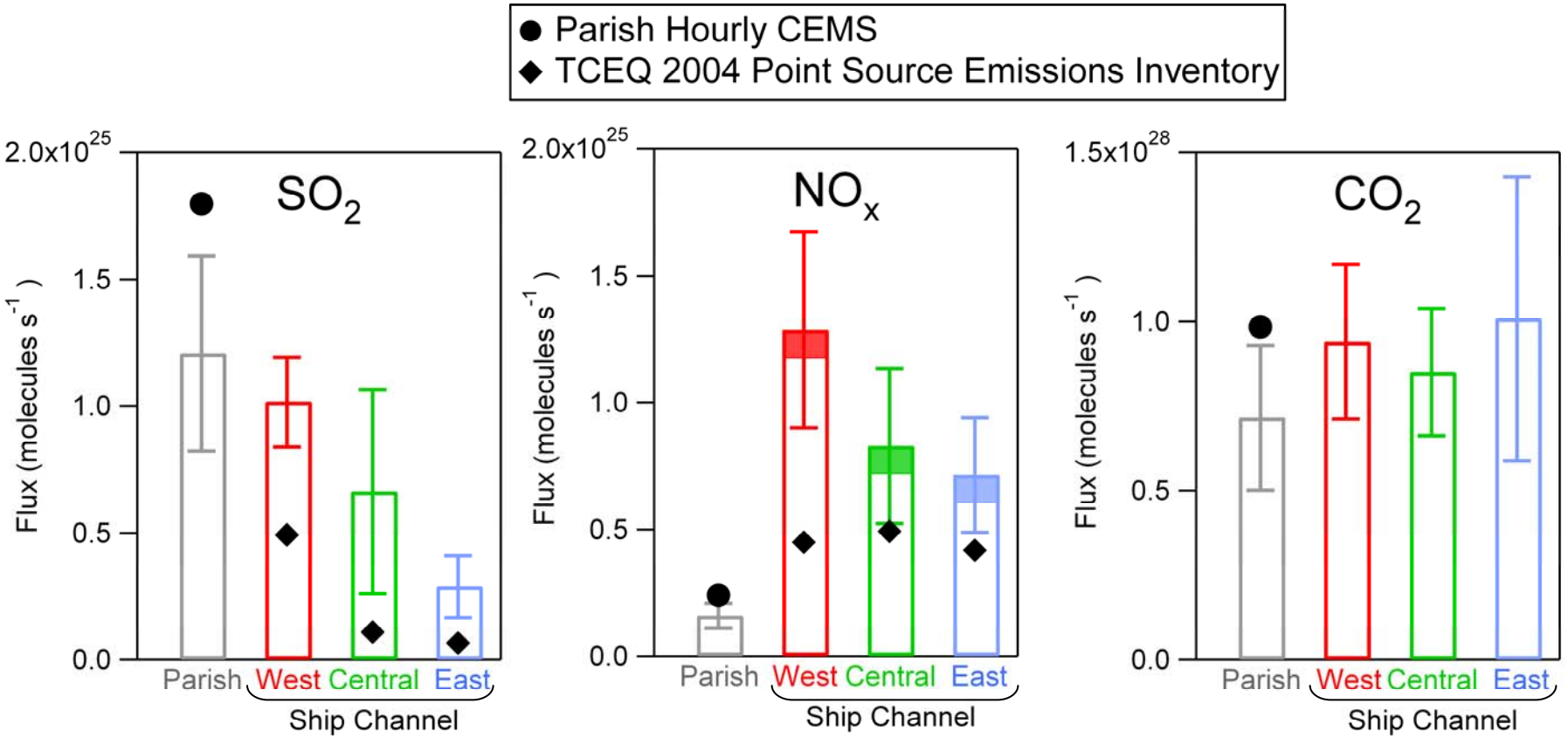
The close ship channel transects presented here may not be fully mixed, and this is a potential source of error.

White et al., 1976

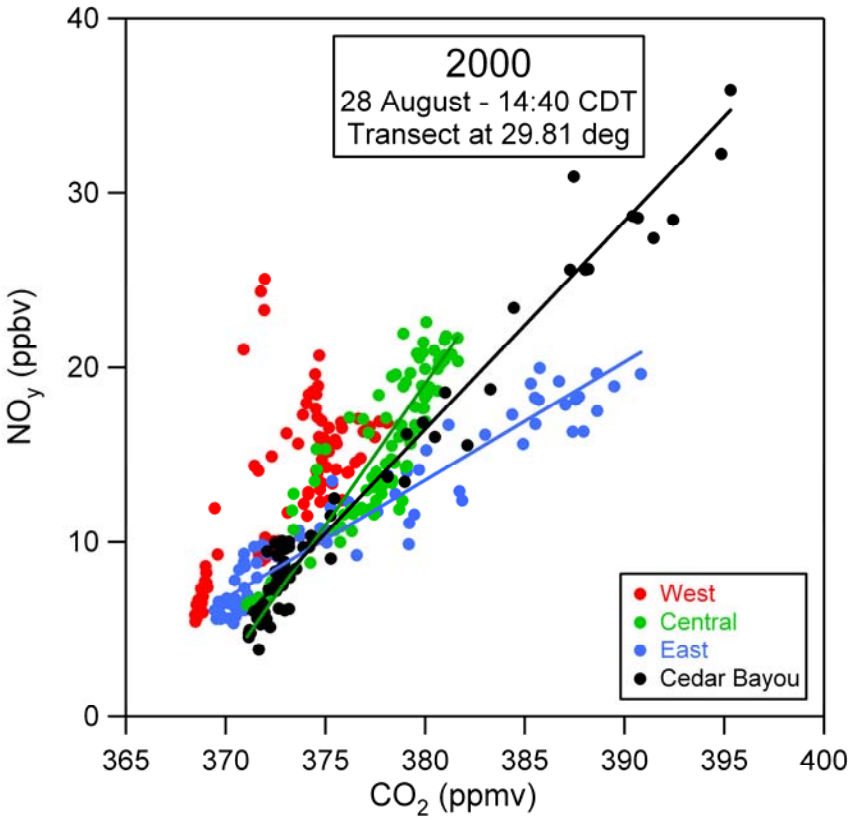
Absolute Fluxes From the Houston Ship Channel

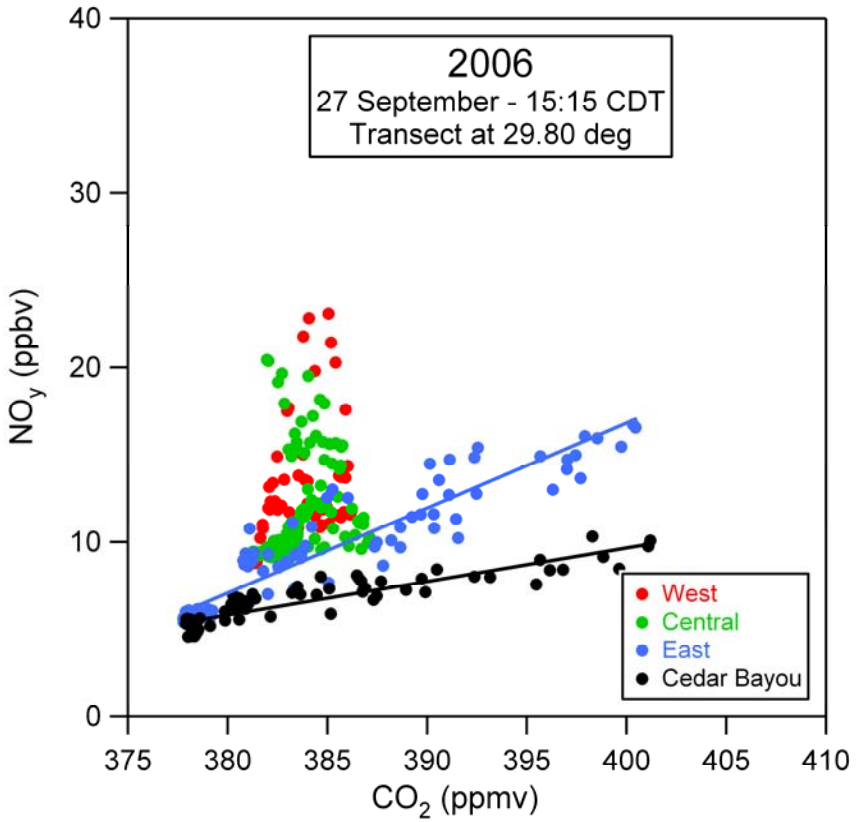


Absolute Fluxes From the Houston Ship Channel



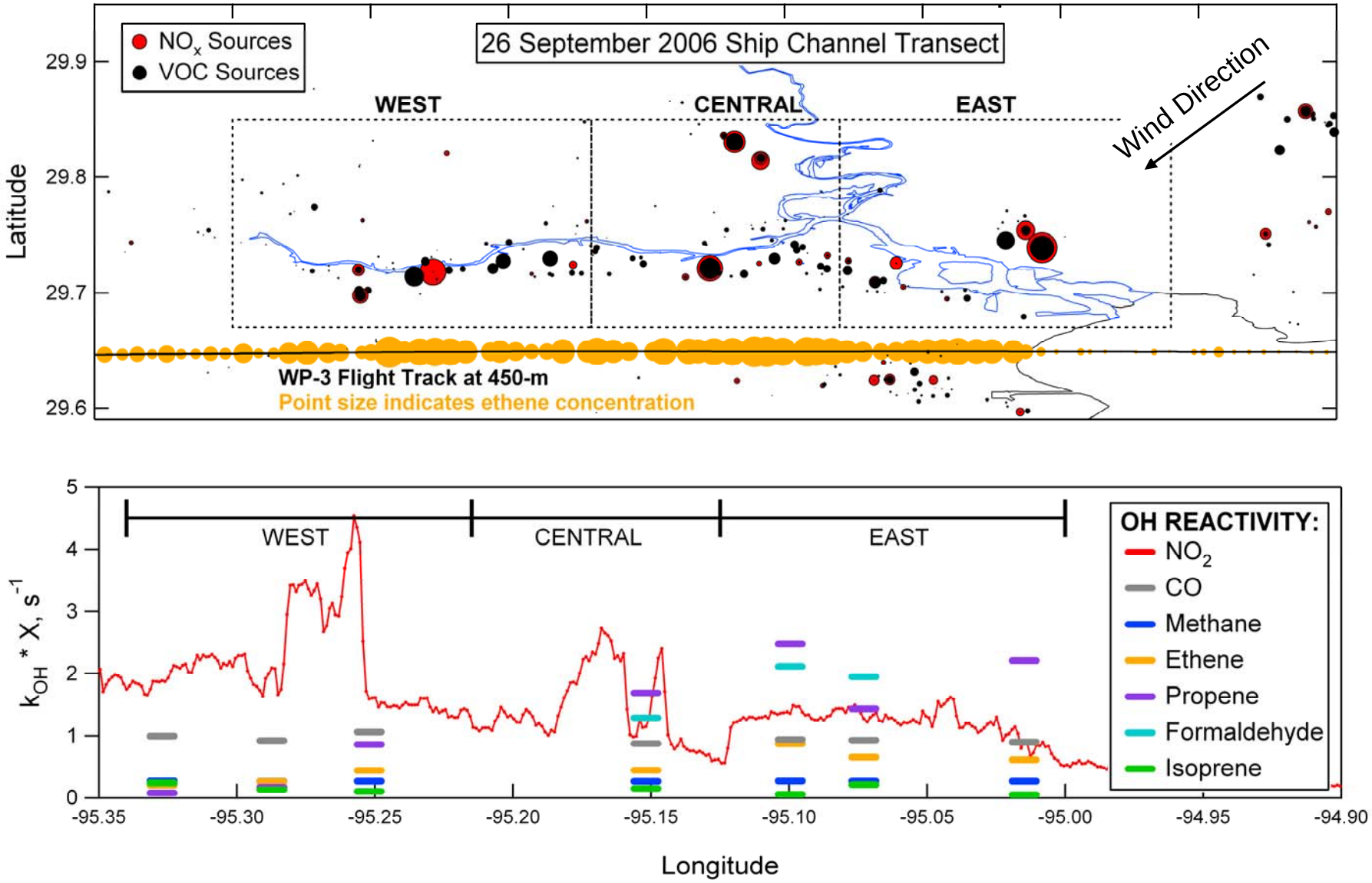
Evidence of NO_x Reductions



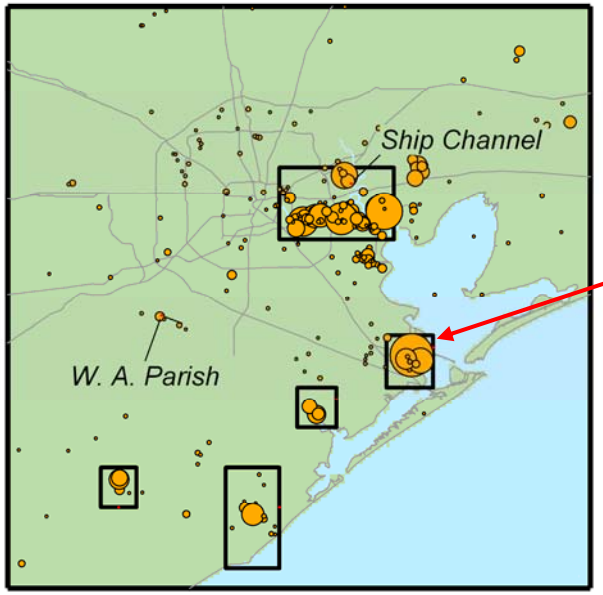


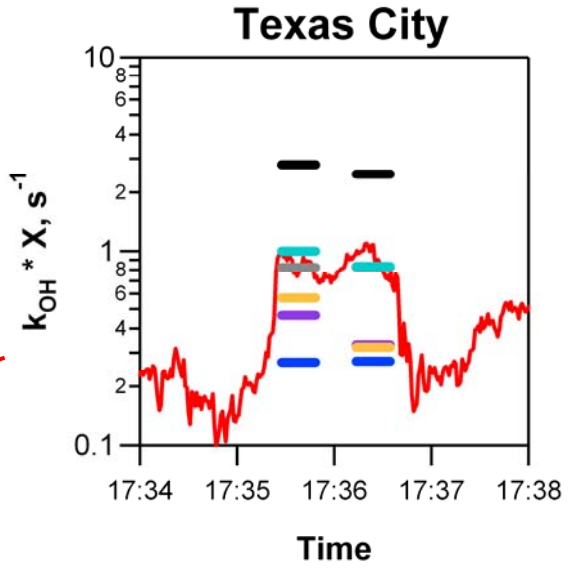
	NO_y / CO_2 Ratio	
	2000	**2006**
● **Central Ship**	**1.62 ± 0.16**	**—**
● **East Ship**	**0.72 ± 0.07**	**0.49 ± 0.05**
● **Cedar Bayou**	**1.21 ± 0.12**	**0.20 ± 0.03**

Contributors to Ozone Formation



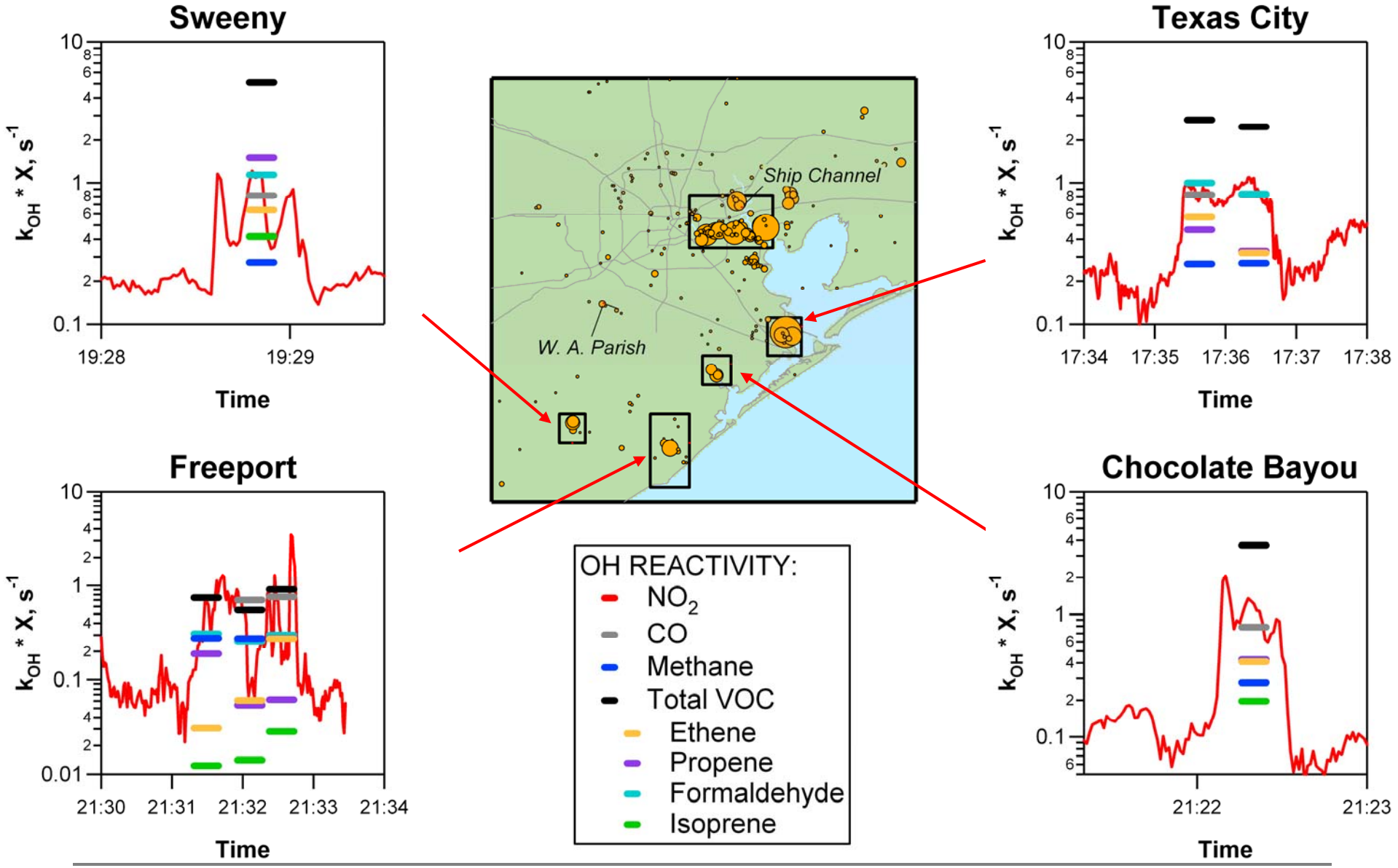
Ozone Precursors at Other Industrial Complexes



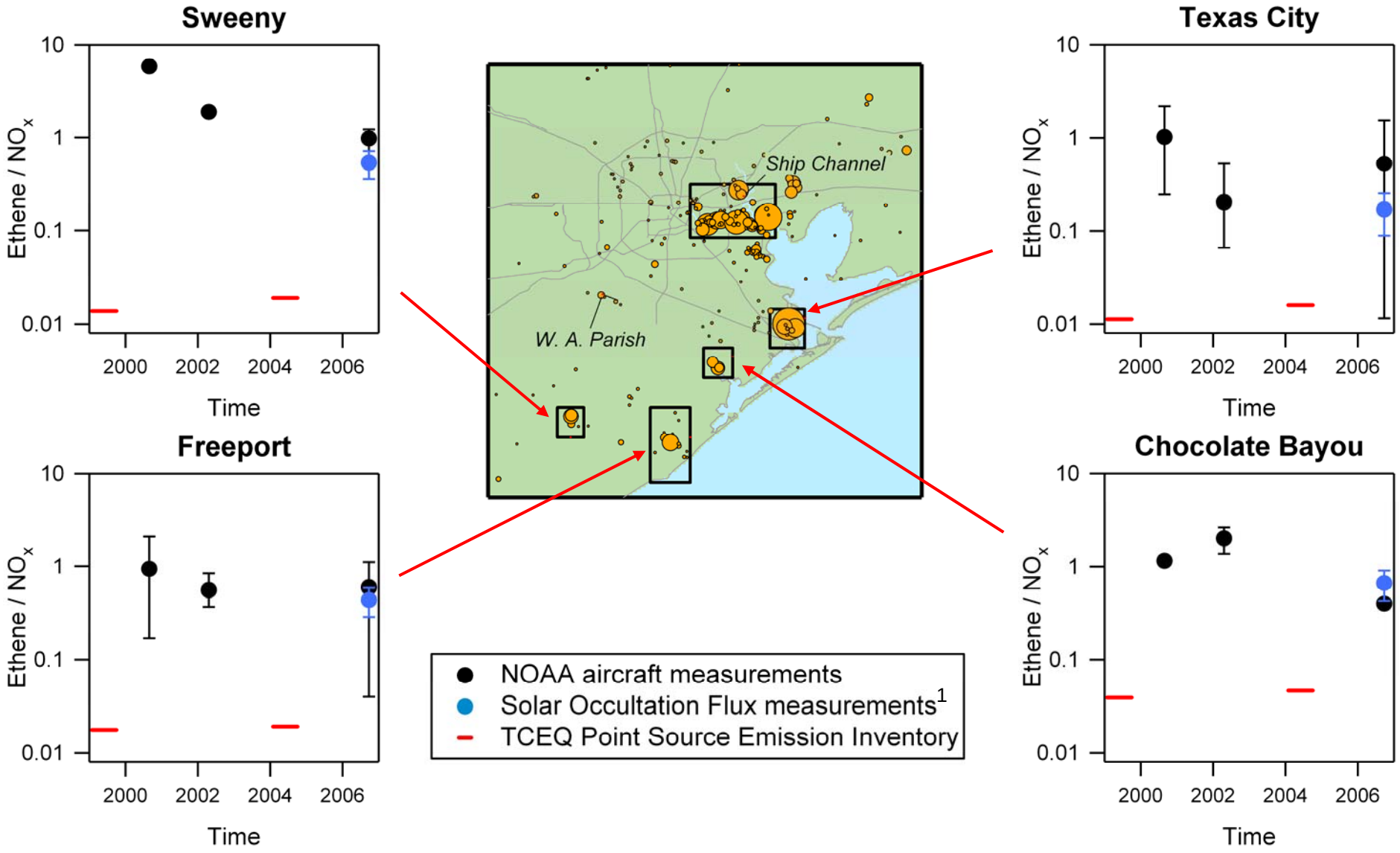


OH REACTIVITY:
- NO_2
- CO
- Methane
- Total VOC
- Ethene
- Propene
- Formaldehyde
- Isoprene

Ozone Precursors at Other Industrial Complexes

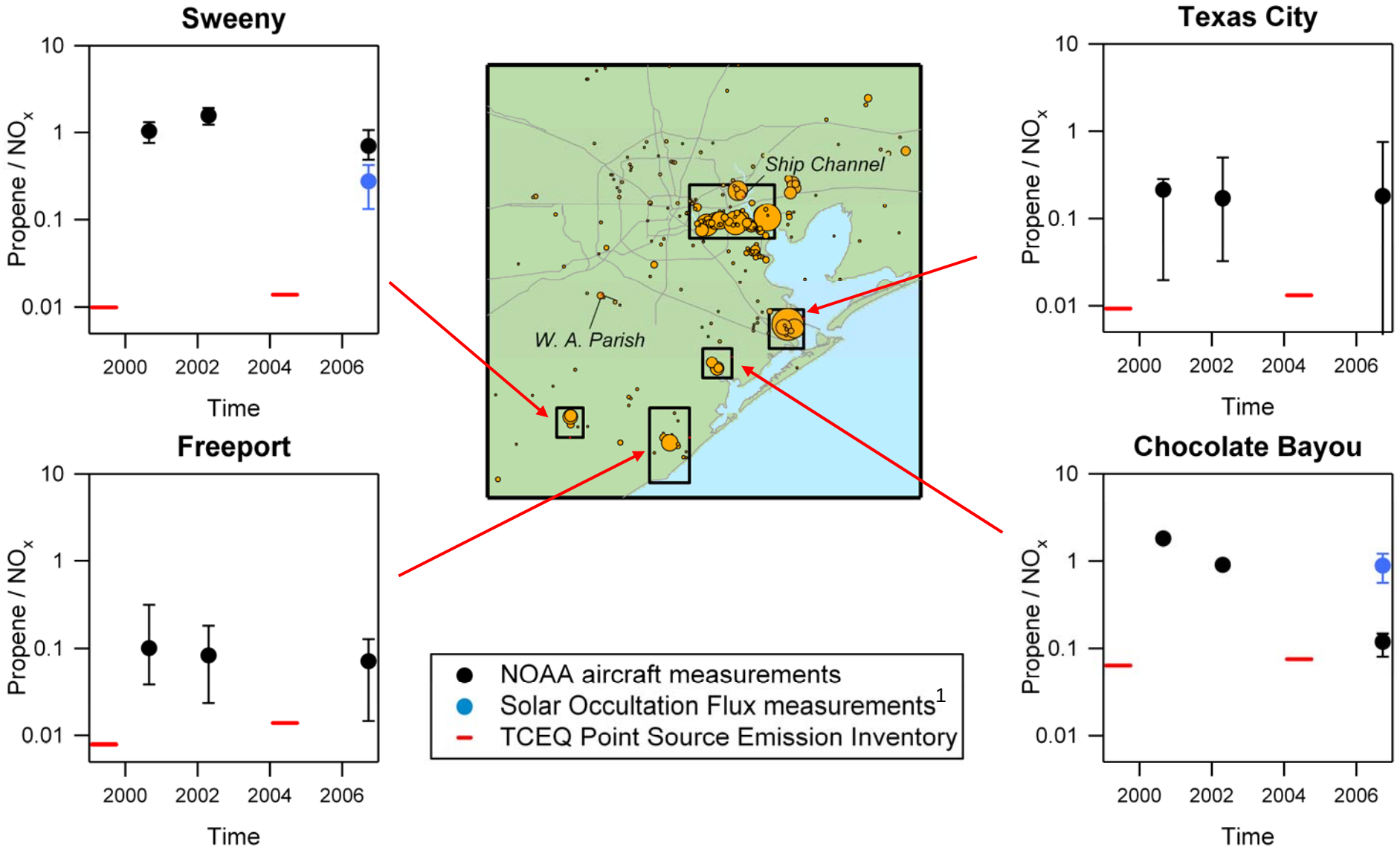


Comparison to Emissions Inventory: Ethene / NO_x



[1]Johan Mellqvist

Comparison to Emissions Inventory: Propene / NO_x



[1]Johan Mellqvist

Conclusions for the Houston Ship Channel

- Major source of NO_x, SO_2, and CO_2 for the Houston urban area.

- NO_x and SO_2 emissions are underestimated in the TCEQ 2004 Point Source Emissions Inventory

- Significant NO_x reductions have occurred between 2000 – 2006 for the East Section of the ship channel and Cedar Bayou

- Ethene and propene make a large contribution to O_3 formation.

Conclusions for the Isolated Industrial Complexes

- The TCEQ 2004 Point Source Emissions Inventory underestimates ethene / NO_x by factors of 10 – 50 and propene / NO_x by factors of 10 – 50 compared to 2006 aircraft measurements.

- Ethene emissions from Sweeny decreased between 2000 – 2006.

- For other industrial complexes, the day-to-day variability and within-plume variability exceeds the interannual trend in VOC emissions.

ADDITIONAL MATERIAL

Description of Measurements Onboard the WP-3

SO_2: UV-pulsed fluorescence; ±0.3 ppbv

NO, NO_2, and NO_y: NO/O_3 chemiluminescence, with photolysis to convert NO_2 to NO. NO_y measured by catalytic conversion of all nitrogen oxides to NO on a 300°C gold surface in the presence of CO; ±0.1 – 0.5 ppbv.

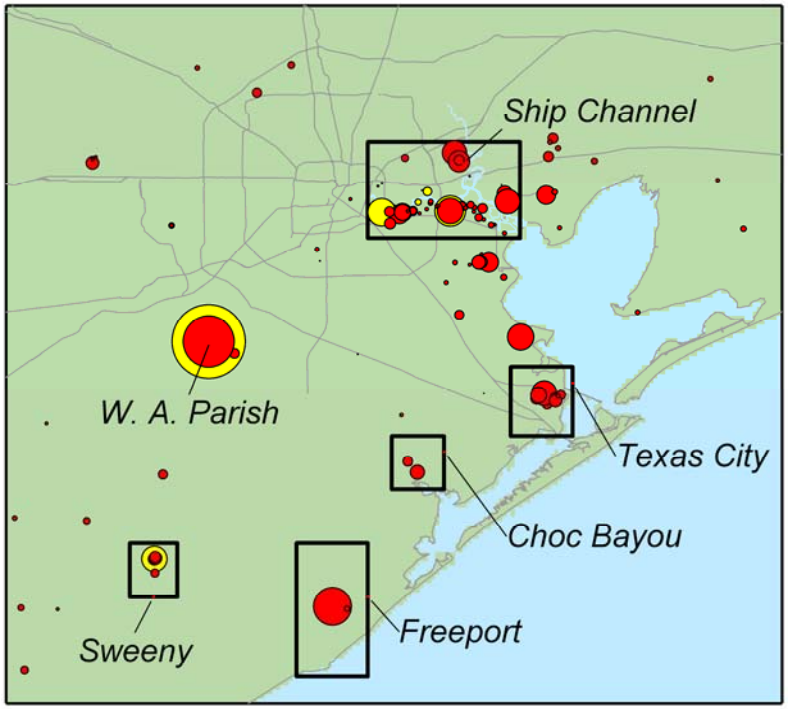
CO_2: Non-dispersive infrared absorption using a modified LICOR; ±0.4 ppmv.

CO: Vacuum ultraviolet fluorescence; ±0.3 ppbv.

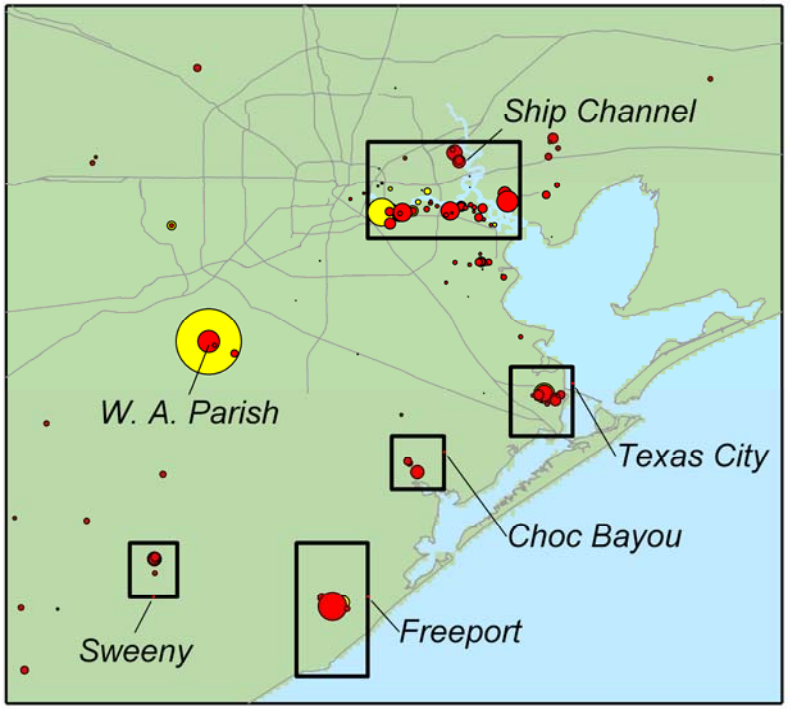
Speciated hydrocarbons: Whole air samples, analyzed by GCMS and GCFID.

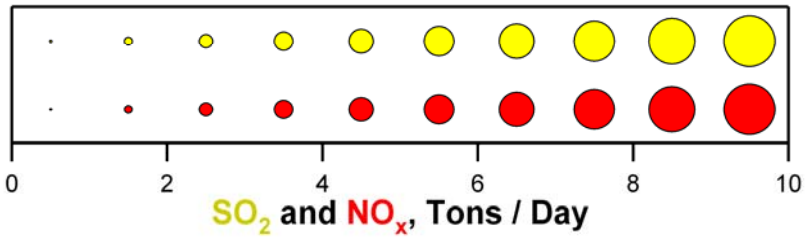
Reported Emissions Reductions

1999 TCEQ Point Source Emissions Inventory



2004 TCEQ Point Source Emissions Inventory





Reported Emissions Reductions

Reported Emissions Change 1999 - 2004

	SO_2	NO_x	CO
W.A. Parish	**-21%**	-87%	-17%
Chocolate Bayou		-16%	+17%
Freeport	+3%	-41%	-16%
Sweeny	-71%	-38%	-78%
Texas City	-44%	-49%	-71%
Ship Channel	**-31%**	**-36%**	**-44%**

2004 TCEQ Point Source Emissions Inventory