Balloon-based ozone measurements supporting air quality studies in Texas

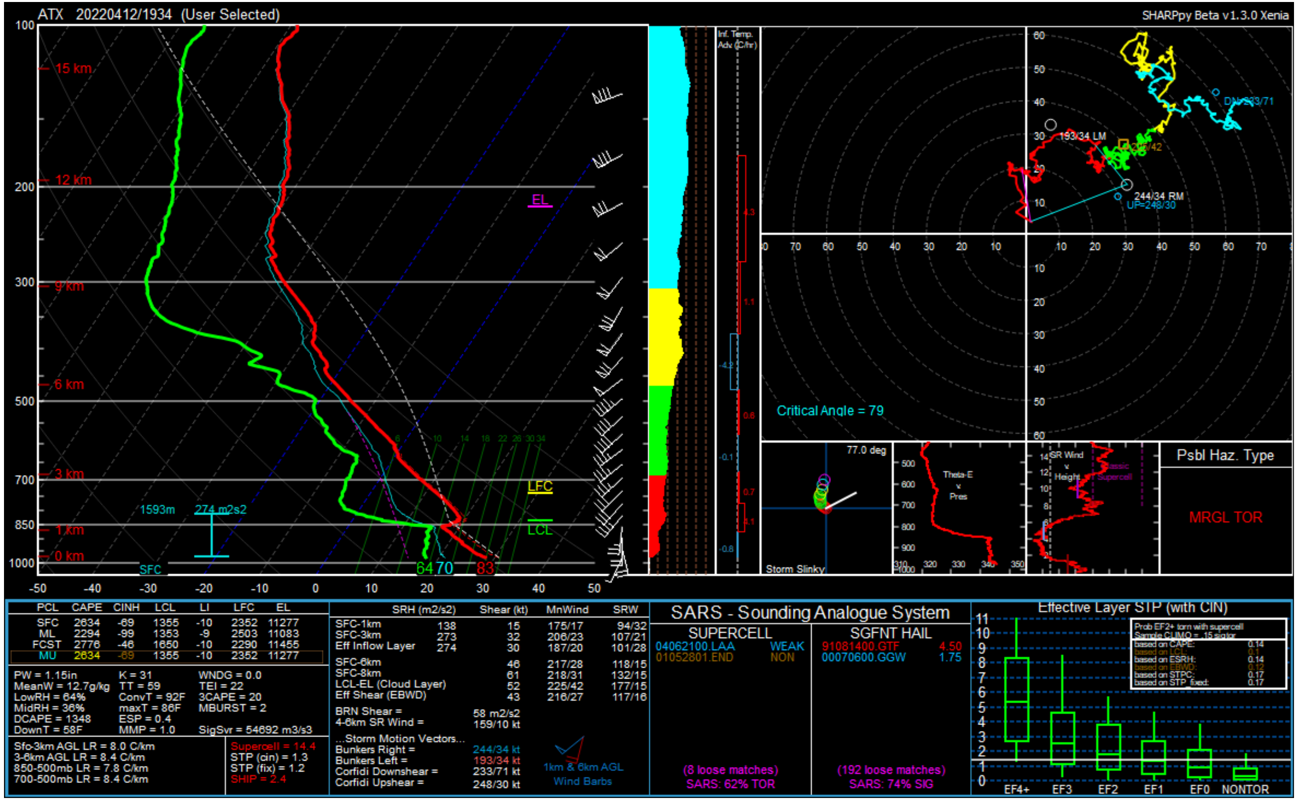
Paul Walter, St. Edward's University
(pauljw@stedwards.edu)

In collaboration with:
University of Houston: James Flynn, Travis Griggs, Alexandra Ulinski, Sergio Alvarez, Nadia Partida, Yuxuan Wang, Subin Yoon, Michael Comas, Wei Li, Xueying Liu,
Ehsan Soleimanian
Baylor University: Sascha Usenko, Rebecca Sheesley, Meghan Guagenti
St. Edward's University: Gary Morris (now at NOAA), Mark Estes, Laufey Jörgensdóttir
UTEP: Nakul Karle, Suhail Mahmud, Rosa Fitzgerald, Tom Gill, Tristan Chavez-Poeschel, Benjamin Ojo
Trinity University: Kristina Trevino, Marilyn Wooten, Zoe Lacey
Texas A&M U. - Corpus Christi: Chuntao Liu
TCEQ: Doug Boyer
NASA: John Sullivan, Alex Kotsakis
Brookhaven National Laboratory: Michael Jensen, Chongai Kuang

Radiosondes
(potential severe weather)

National Weather Service has twice daily soundings (00Z and 12Z) from many sites across the US

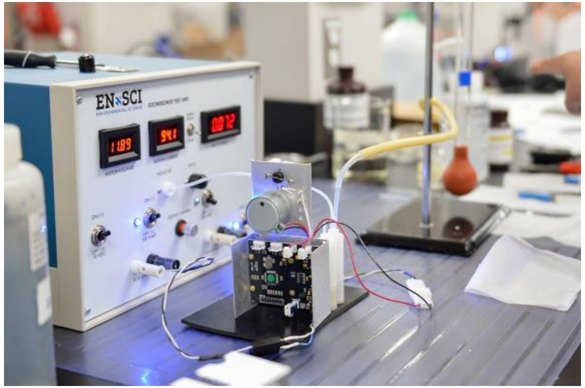
- No regular sounding location in Central Texas or Houston
- St. Edward's University (Austin) and Texas A&M University (College Station) release weather balloons to support forecasting efforts
    - Released weather balloons prior to severe weather (tornadoes) on March 21, 2022 and April 12, 2022.



Ozonesondes (air quality measurements)

Ozonesonde prep

- Initial prep (2.5 hours)
- Day-of prep (1.5 hours)
- Launch prep (45 min)

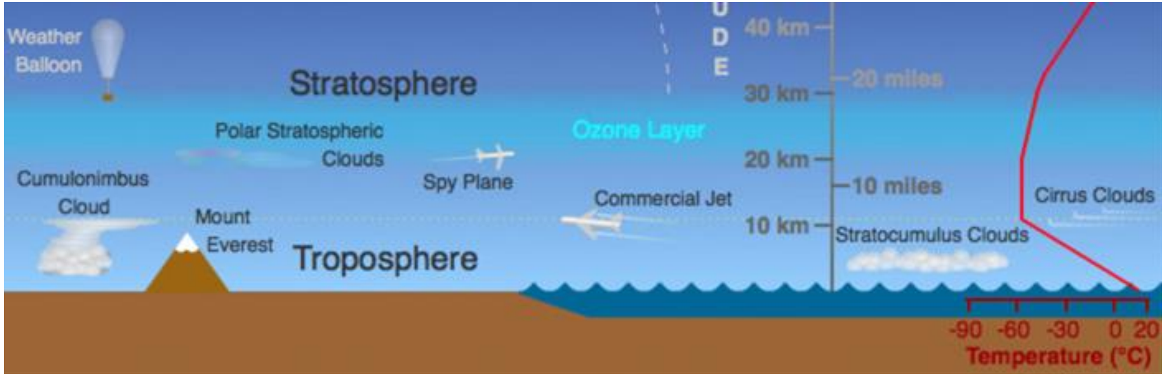


Balloon reaches about 100,000’ (bursts)

- Rises at ~1000’ per min
- Parachute slows descent
- Flight time of ~2-2.5 hours

Ground-level Ozone

a secondary pollutant



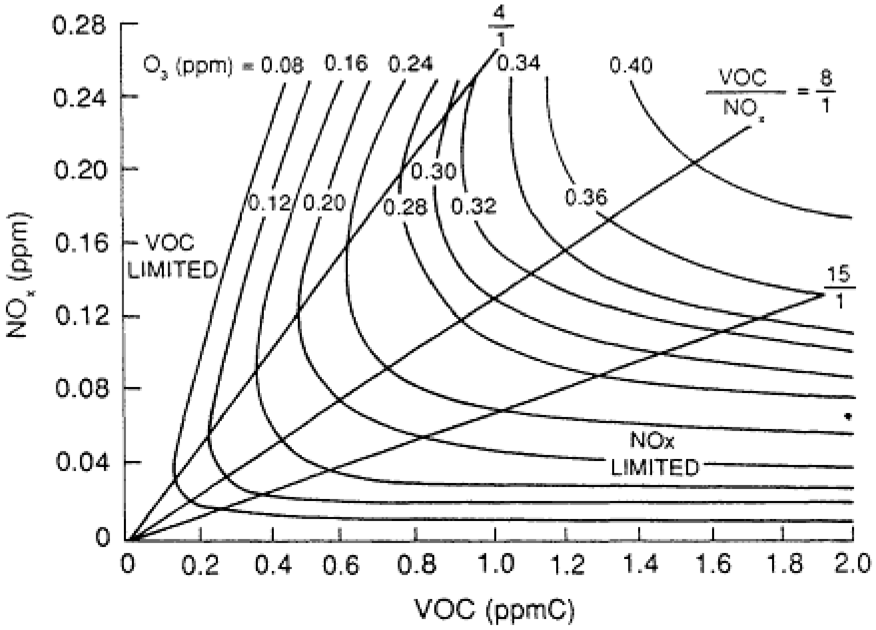
Ground-level ozone formation:

NOx + VOCs + UV → $\mathbf{O_3}$

NOx: NO and NO_2

VOCs: volatile organic compounds

Control strategy to reduce ozone depends upon whether in a NOx-limited or VOC-limited regime



Credit: National Academies of Sciences. https://doi.org/10.17226/1889.

Ground-level Ozone

a secondary pollutant

Ground-level ozone formation:

NOx + VOCs + UV → O_3

MDA8: Maximum Daily 8-hour Average

Ozone design value: 3 year average of each year's 4th highest ozone day

- EPA National Ambient Air Quality Standard (NAAQS) ozone standard of 70 ppv

MDA8 Ozone values for each monitor in October 2022

Area	Monitoring Site	POC	October 2022																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Austin																																	
	Austin North Hills Drive C3/A322	2	72	62	63	73	72	69	62	61	66	62	52	44	65	NV	51	48	42	43	NA	NA	NA	NA	NA	NV	39	48	53	37	39	43	57
	Audubon C38	1	66	54	57	66	64	61	52	52	57	55	46	36	53	54	42	35	NV	37	43	42	48	37	34	27	33	42	47	30	33	35	49
	Dripping Springs School C614	1 N	81	72	81	78	73	77	66	68	68	66	57	45	71	65	51	50	47	51	60	54	62	47	41	38	42	56	52	36	40	46	61
	CAPCOG Lake Georgetown C690	1 N	67	59	57	62	67	65	57	57	66	64	53	40	57	64	51	38	38	39	43	44	53	43	38	27	33	44	50	35	NV	NA	NA
	Lockhart C1604	1 N	55	53	53	56	50	59	50	49	49	49	40	42	49	49	41	35	36	38	45	48	44	35	30	25	26	42	42	30	34	40	50
	St. Edwards University C1605	1 N	61	53	55	61	57	59	46	39	50	52	43	40	55	51	42	38	36	38	39	43	43	37	33	28	34	43	44	33	34	38	47
	CAPCOG Bastrop CAMS1612	1 N	51	47	48	54	50	56	49	49	50	54	41	41	47	54	52	41	39	41	47	53	49	42	36	32	NV	43	50	32	34	41	45
	CAPCOG Elgin C1613	1 N	60	52	53	57	55	61	50	53	56	61	44	47	55	56	50	40	40	45	51	53	48	41	35	33	32	46	49	33	34	39	45
	CAPCOG East Austin C1619	1 N	68	58	60	68	66	69	58	56	60	58	49	45	58	58	49	43	40	40	39	44	44	36	31	26	31	39	49	35	36	40	51
	CAPCOG Round Rock Brushy Creek W C1620	1 N	63	54	53	60	65	60	49	52	60	60	49	40	54	60	48	43	37	38	44	45	49	41	36	30	34	44	51	35	37	40	47
	CAPCOG San Marcos Staples Road C1675	1 N	68	62	61	66	59	71	56	57	61	58	49	52	61	58	46	41	33	39	46	54	48	41	37	32	36	49	48	35	40	43	59

Right: Four highest ozone days of 2022

Austin														
	Austin North Hills Drive C3/A322	2	09/29/2022	1100	79	09/13/2022	1000	76	06/29/2022	1200	75	10/04/2022	1000	73
	Audubon C38	1	06/29/2022	1100	68	09/29/2022	1000	67	10/04/2022	1100	66	10/01/2022	1000	66
	Dripping Springs School C614	1 N	06/29/2022	1100	87	05/26/2022	1100	83	03/02/2022	1100	83	10/03/2022	1100	81
	CAPCOG Lake Georgetown C690	1 N	06/29/2022	1200	88	09/29/2022	1100	85	09/13/2022	1000	81	08/11/2022	1200	74
	Lockhart C1604	1 N	05/26/2022	1100	98	06/29/2022	1000	80	06/04/2022	1100	69	05/27/2022	1200	69
	St. Edwards University C1605	1 N	08/12/2022	1100	76	09/12/2022	1100	71	09/29/2022	1000	69	09/13/2022	1000	69
	CAPCOG Bastrop CAMS1612	1 N	05/26/2022	1100	89	06/29/2022	1300	75	06/04/2022	1200	72	03/26/2022	1100	67
	CAPCOG Elgin C1613	1 N	05/26/2022	1100	84	06/29/2022	1100	75	03/02/2022	1000	72	05/27/2022	1100	69
	CAPCOG East Austin C1619	1 N	09/29/2022	1100	79	06/29/2022	1200	78	08/12/2022	1100	75	09/13/2022	1100	74
	CAPCOG Round Rock Brushy Creek W C1620	1 N	09/29/2022	1000	82	06/29/2022	1200	80	09/13/2022	1000	79	07/12/2022	1100	77
	CAPCOG San Marcos Staples Road C1675	1 N	05/26/2022	1100	90	06/29/2022	1000	82	08/12/2022	1100	80	09/12/2022	1100	78

Below: Ozone design value for Austin

Austin						
	Audubon C38	1	63	65	66	**64**
	Austin North Hills Drive C3/A322	2	46 *	66	73	**61**

Ozonesondes in Texas

Austin (2016, 2017, 2023)

San Antonio (2017, 2019, 2020, 2023)

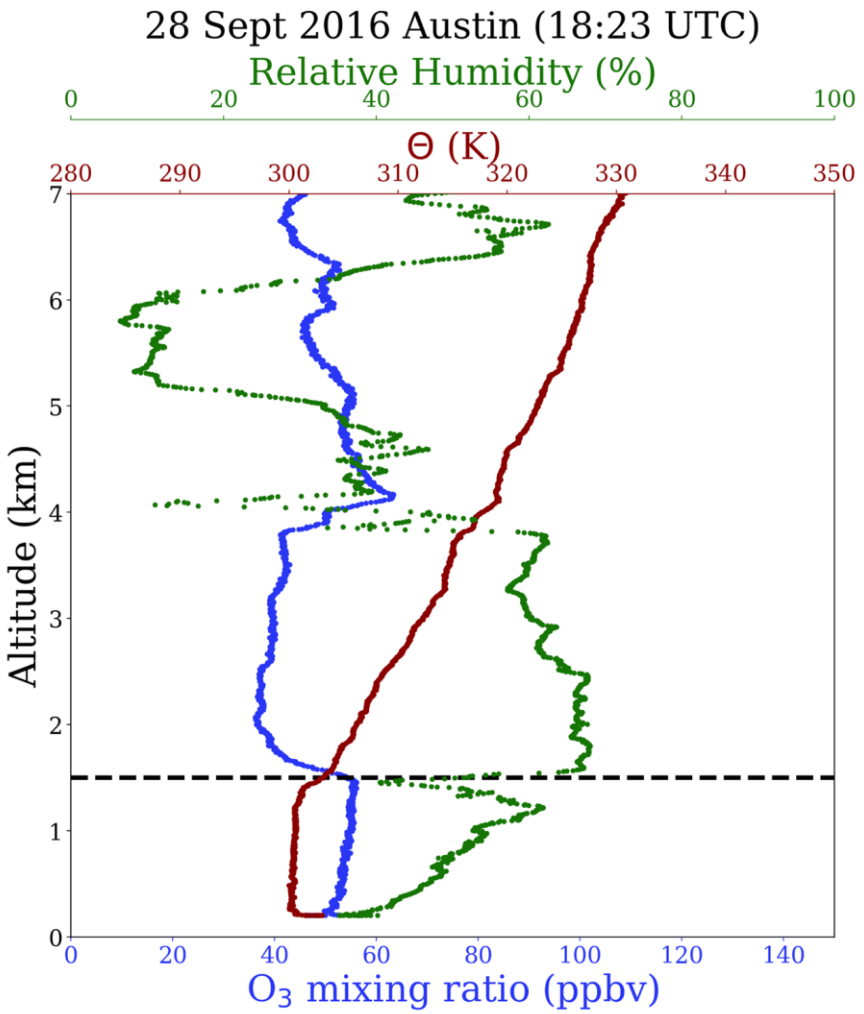
El Paso (2017, 2019, 2020, 2023)

Houston (2021, 2022, 2023)

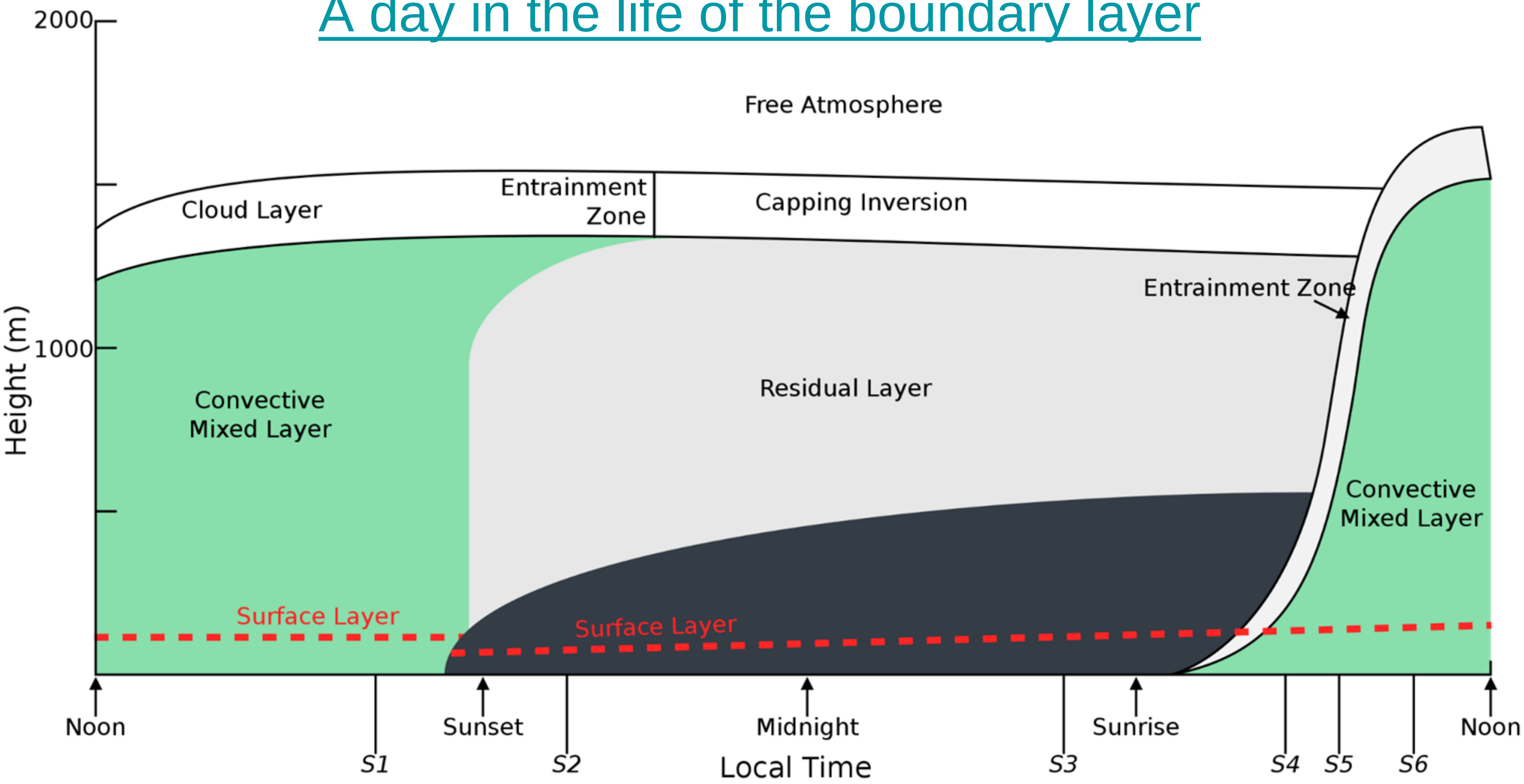
- Houston has a long track record since 2004

Corpus Christi* (2021, 2022)

*not focused on air quality

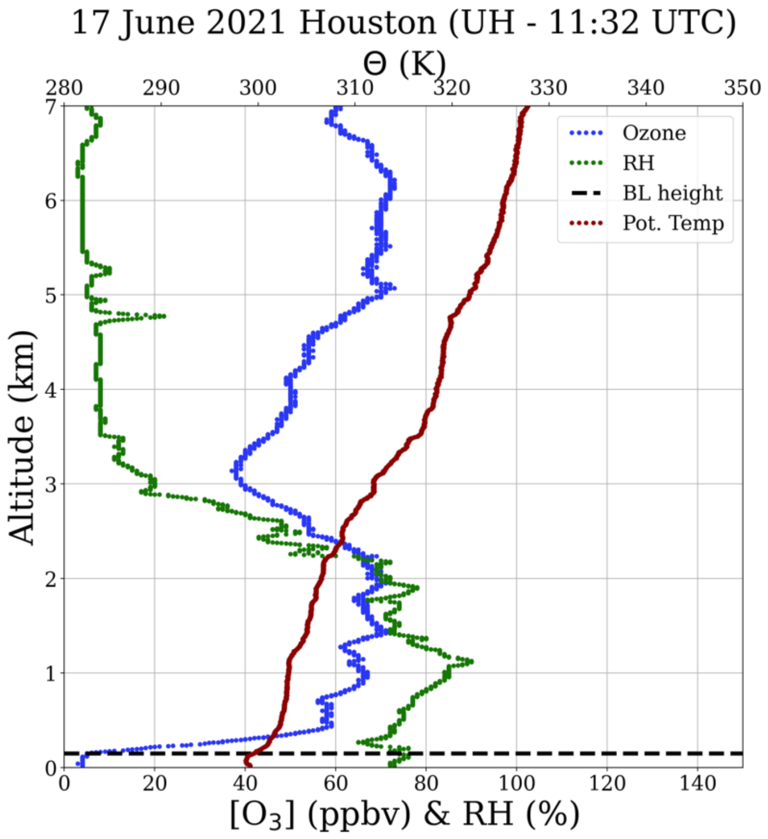


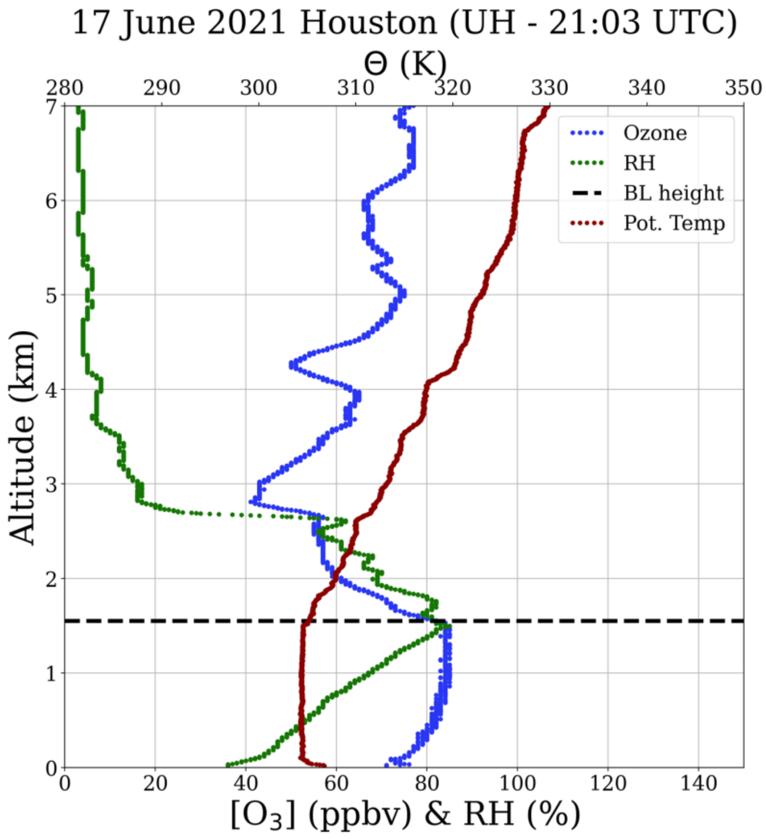
A day in the life of the boundary layer



Credit: NikNaks (Own work, based on [1]) [CC BY-SA 3.0], via Wikimedia Commons

Ozone leftover from the previous day



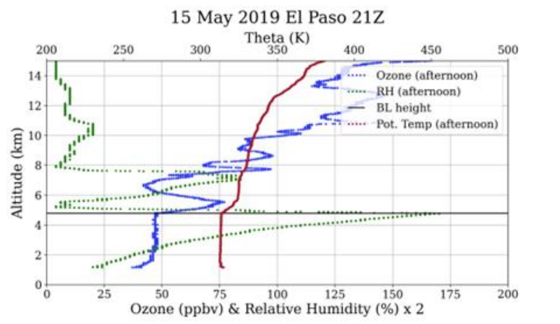


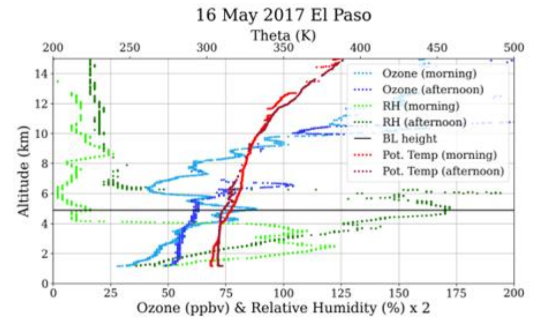
Residual layer contribution to afternoon ozone

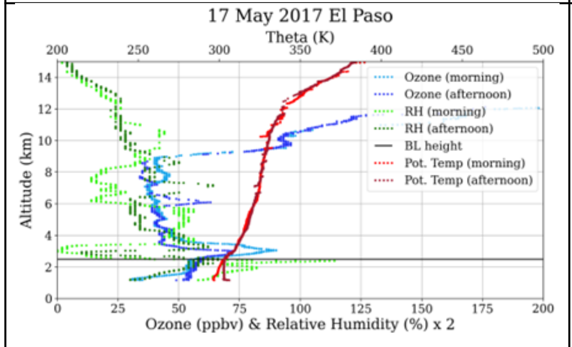
Potential to identify transport of biomass burning influences

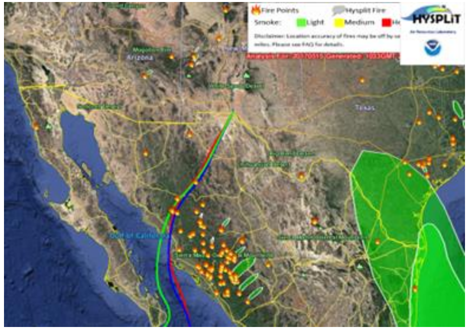
Ozone enhancement above the boundary layer (El Paso)

- Goes away on May 16 and PM2.5 sharply increases
- Back trajectories perhaps consistent with biomass burning influences









Particulate matter ($PM_{2.5}$) at surface monitors

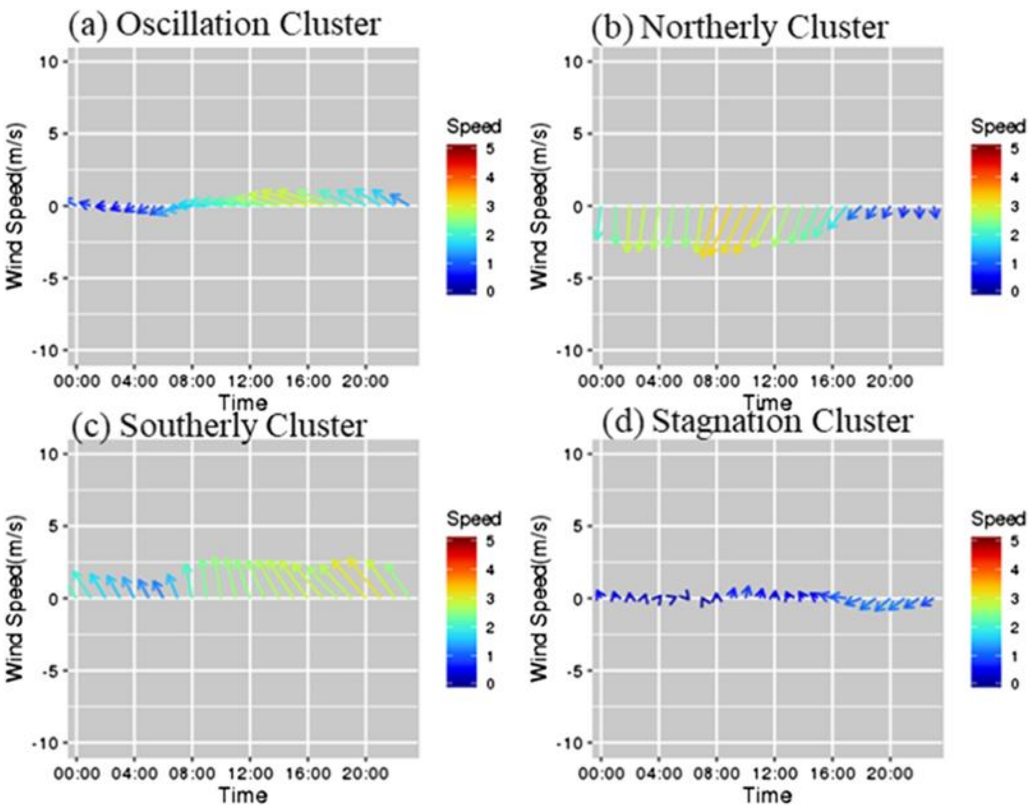
	Peak hourly $PM_{2.5}$ ($\mu g/m^3$)				Lowest Visibility (miles)
	C12	C37	C41		C37
15 May 2017	9.5	17.8	17.3		12.44
16 May 2017	**109.1**	**166.0**	**176.3**		**1.29**
17 May 2017	8.1	17.0	15.3		14.21
18 May 2017	10.3	15.4	12.3		14.45

Wind patterns on high ozone days

High ozone days are often observed in post-frontal conditions

- Clear skies
- Nearly stagnant winds
    - Some recirculation

San Antonio (August- October 2013): Hourly wind direction and speed clusters



Credit: Li et al (2020) https://doi.org/10.1029/2020JD033165

Power of coincident measurements to characterize high ozone events

Large field campaigns in Houston area in 2021-2022

2021 NASA TRACER-AQ

- Funds for supporting measurements from TCEQ

2021-2022 DOE TRACER

- Funds for supporting measurements from TCEQ

TRacking Aerosol Convection ExpeRiment- Air Quality

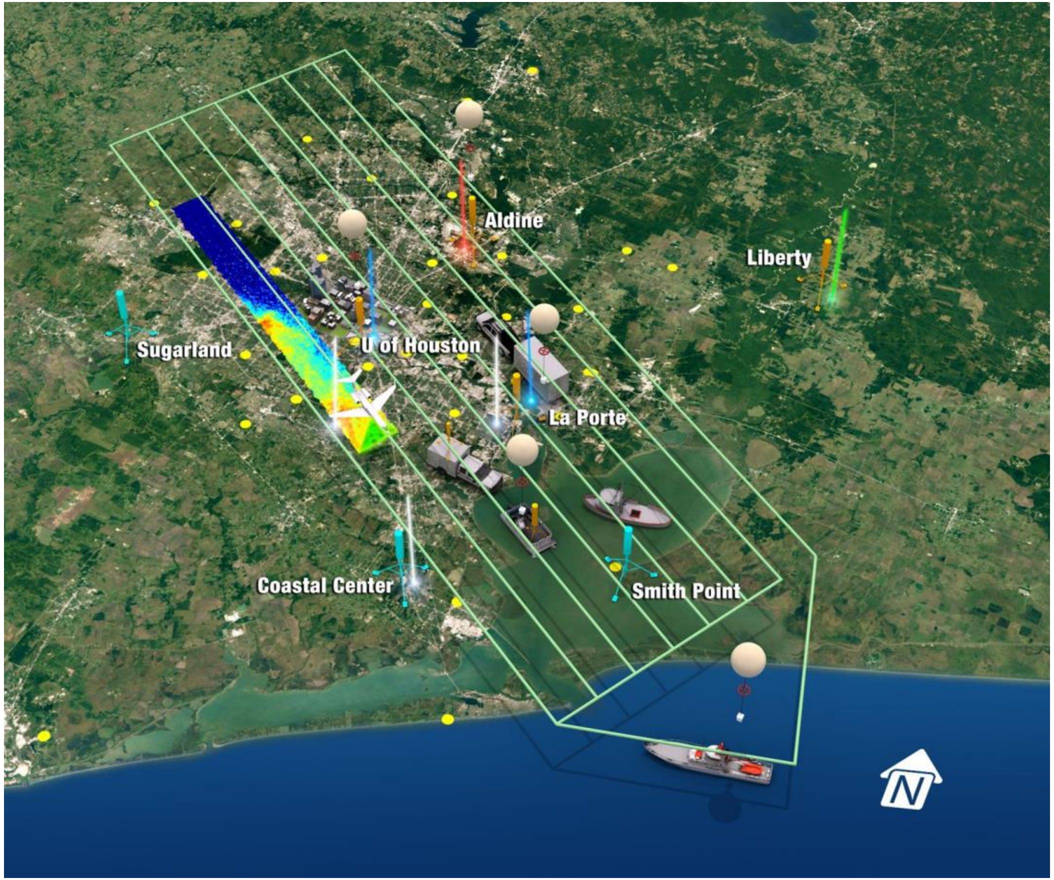
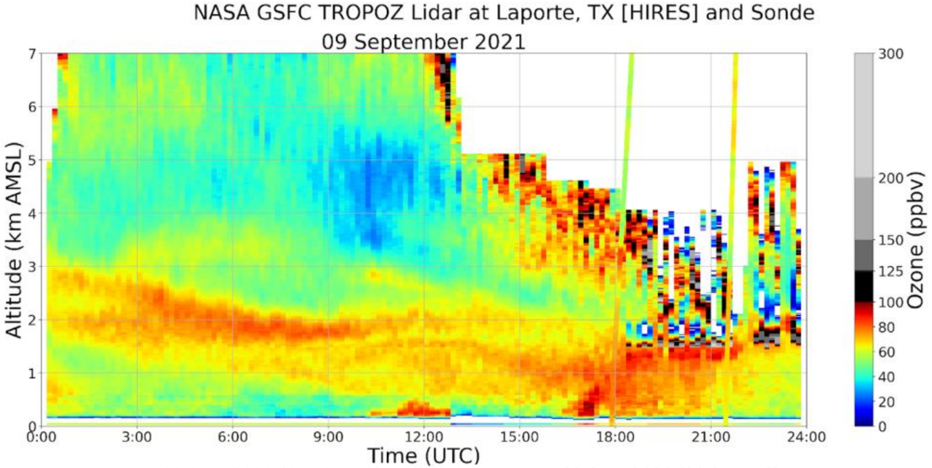
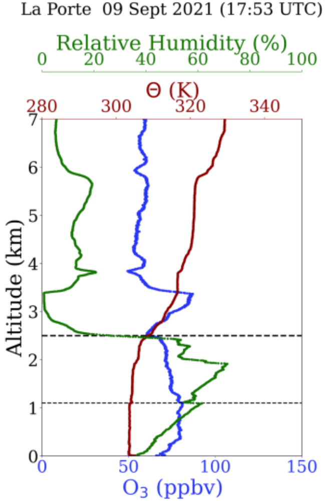


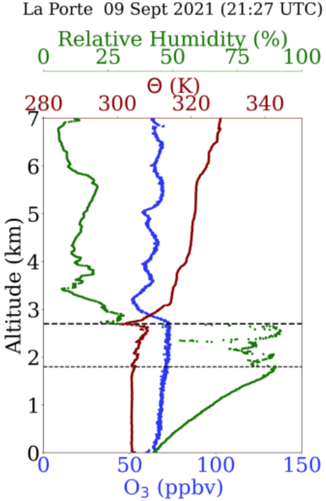
Image credit: Tim Marvel (NASA LaRC)

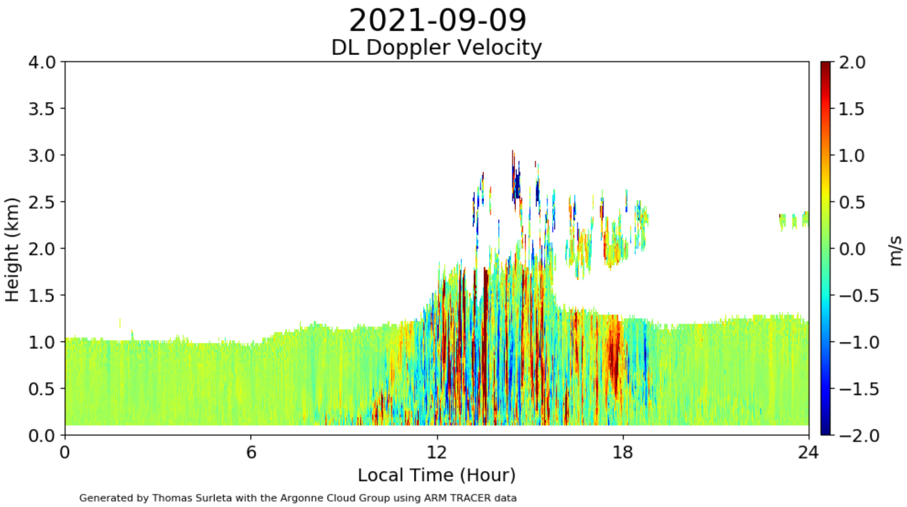
September 9, 2021 Houston-Galveston-Brazoria

Residual layer impact on boundary layer



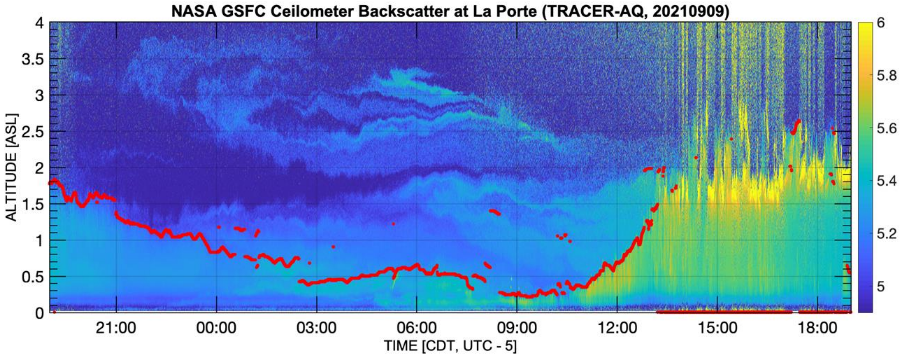






DOE ARM Doppler lidar (Mentor: Rob Newsom)

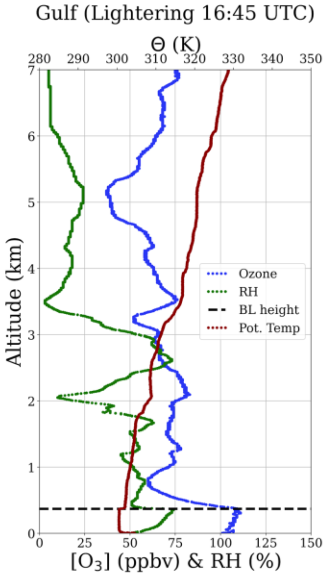
Image generated by Thomas Surleta. Courtesy of TRACER PI Mike Jensen.

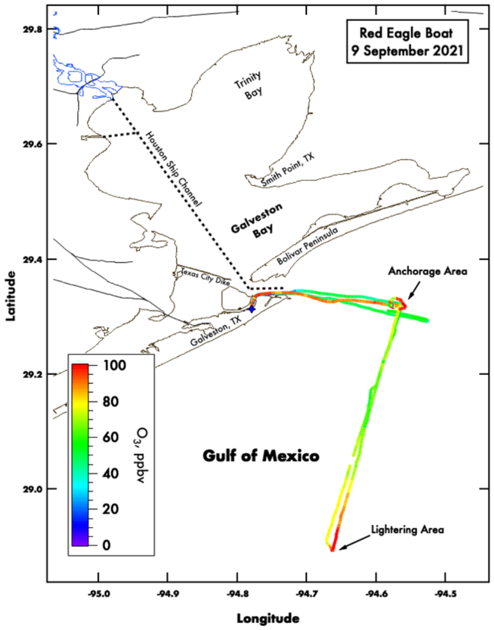


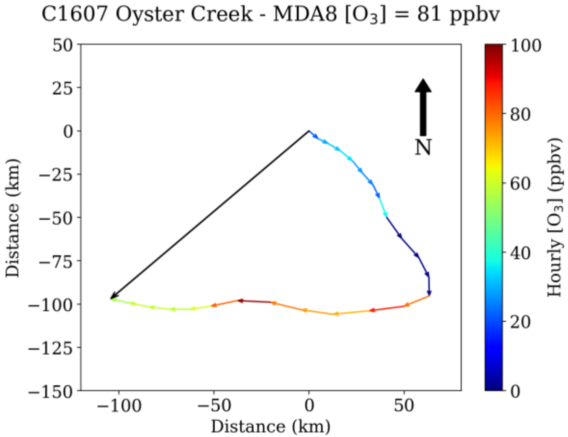
NASA GSFC Ceilometer (John Sullivan)

September 9, 2021
Houston-Galveston-Brazoria

Ozone transported over water then recirculated







Coming to Austin in 2023

Two spectrometers part of global NASA networks making total column measurements

Pandora: Trace gases: Ozone, NO_2, Formaldehyde

AERONET (Cimel): Aerosols

Pandonia Global Network

AERONET

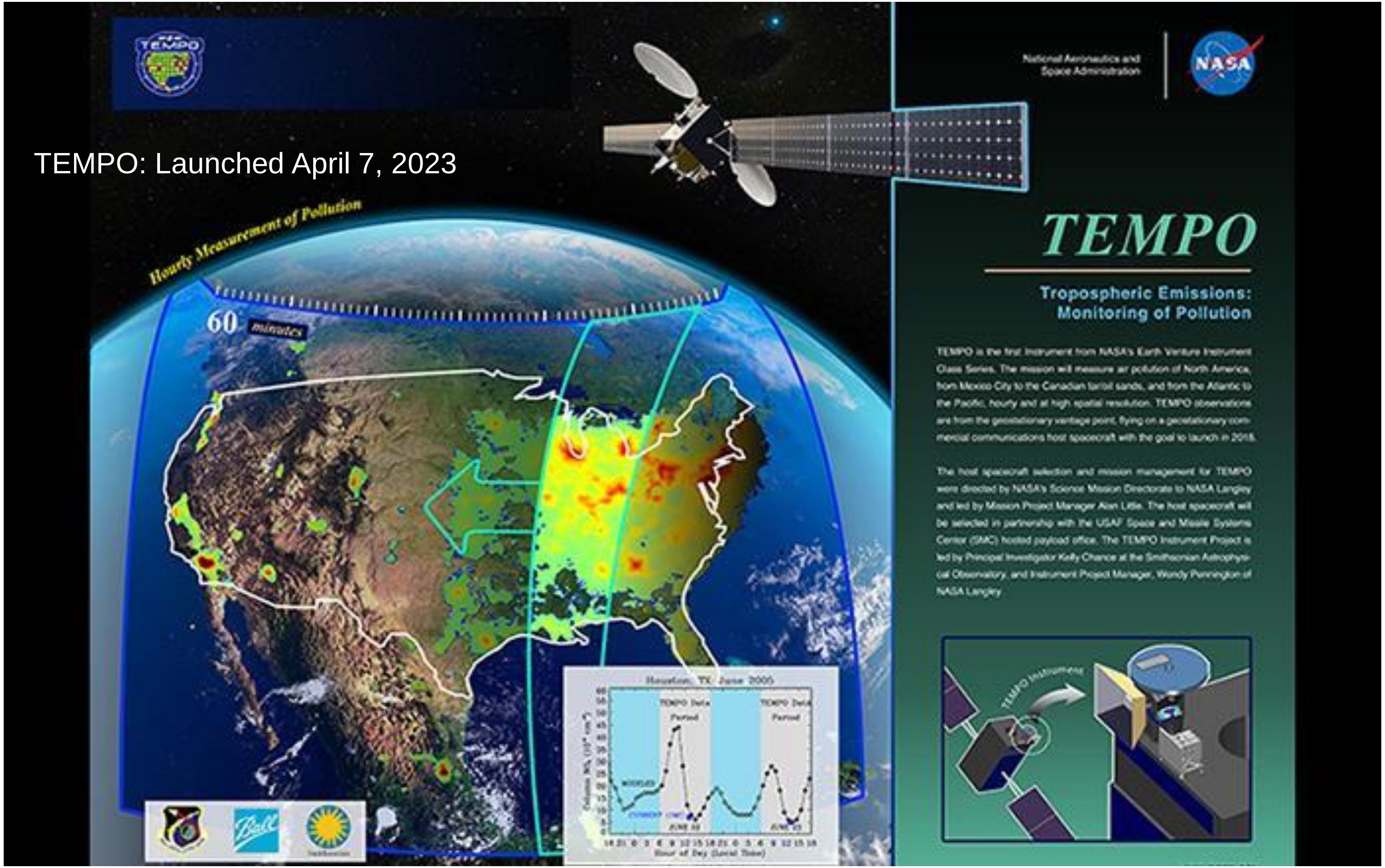
October 2023 Measurements (CAPCOG, *pending*):

- Mobile Air Quality Lab 3 (MAQL3)
  - Validate CAPCOG monitors
  - Map ozone and precursors between monitoring sites
- 16 ozonesondes
- Collaboration between University of Houston, Baylor University, and St. Edward's University

Coming in 2024: EPA–CAPCOG

- 7 continuous particulate matter monitors
- Speciated particulate matter monitor
- Collaboration includes St. Edward's University and Huston-Tillotson University

Satellite Measurements in 2023+



Temporal resolution ~1 hr (O_3); spatial resolution ~4.5-8 km

Tropospheric **E**missions: **M**onitoring of **Po**llution (TEMPO)

Spatiotemporal variability of the boundary layer

Ozone, NO_2, HCHO, aerosols