The TRacking Aerosol Convection interactions ExpeRiment (TRACER): Initial Science Results on Ongoing Research Activities

Michael Jensen and the TRACER+ Science and Operations Team

Brookhaven National Laboratory

Joint ARM User Facility and ASR PI Meeting

07 August 2023, North Bethesda, MD

@BrookhavenLab

How do aerosols interact with convective clouds and storms?

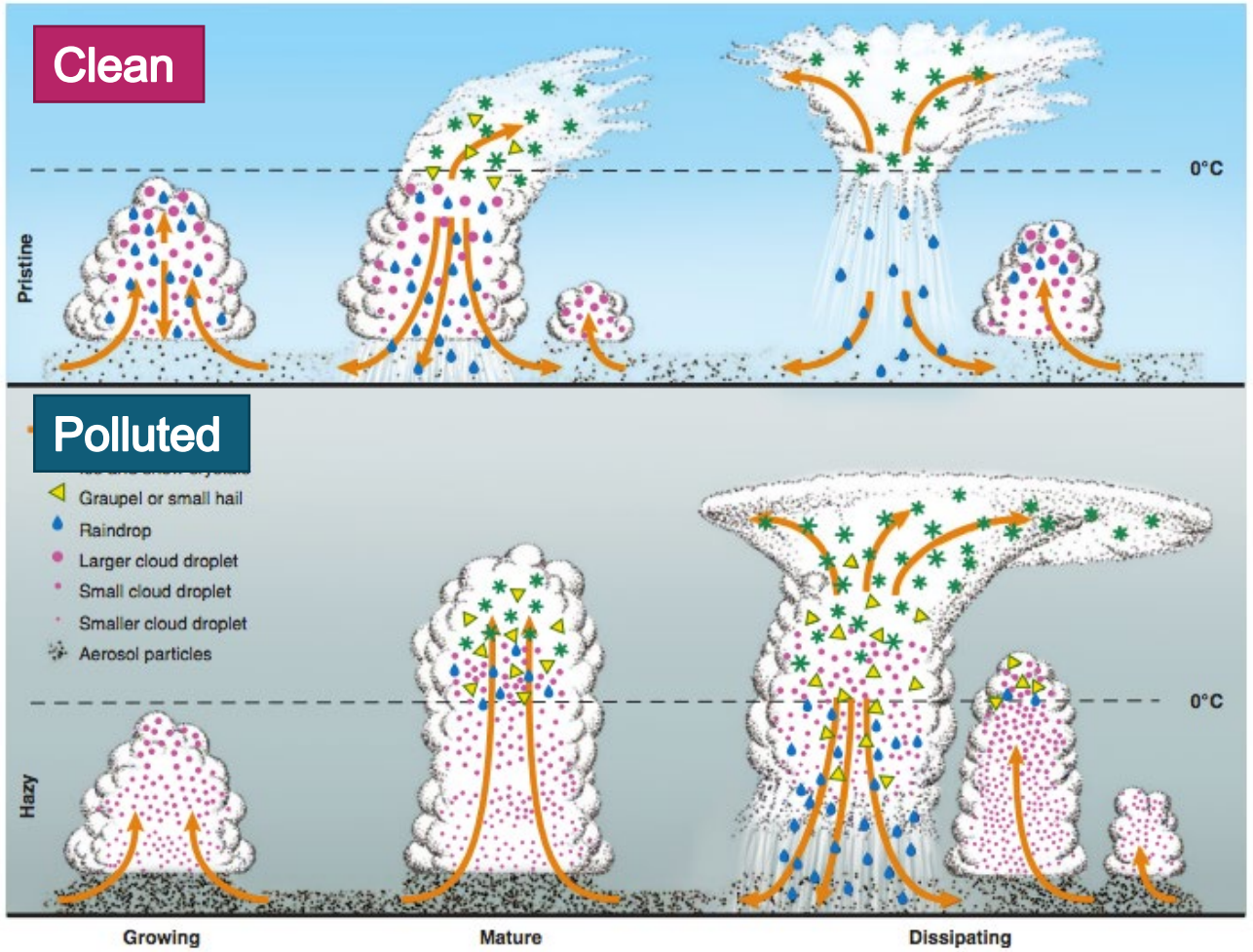
All else being equal, more aerosols > more smaller cloud droplets

Rosenfeld et al. 2008

(abridged) Storm Impacts:

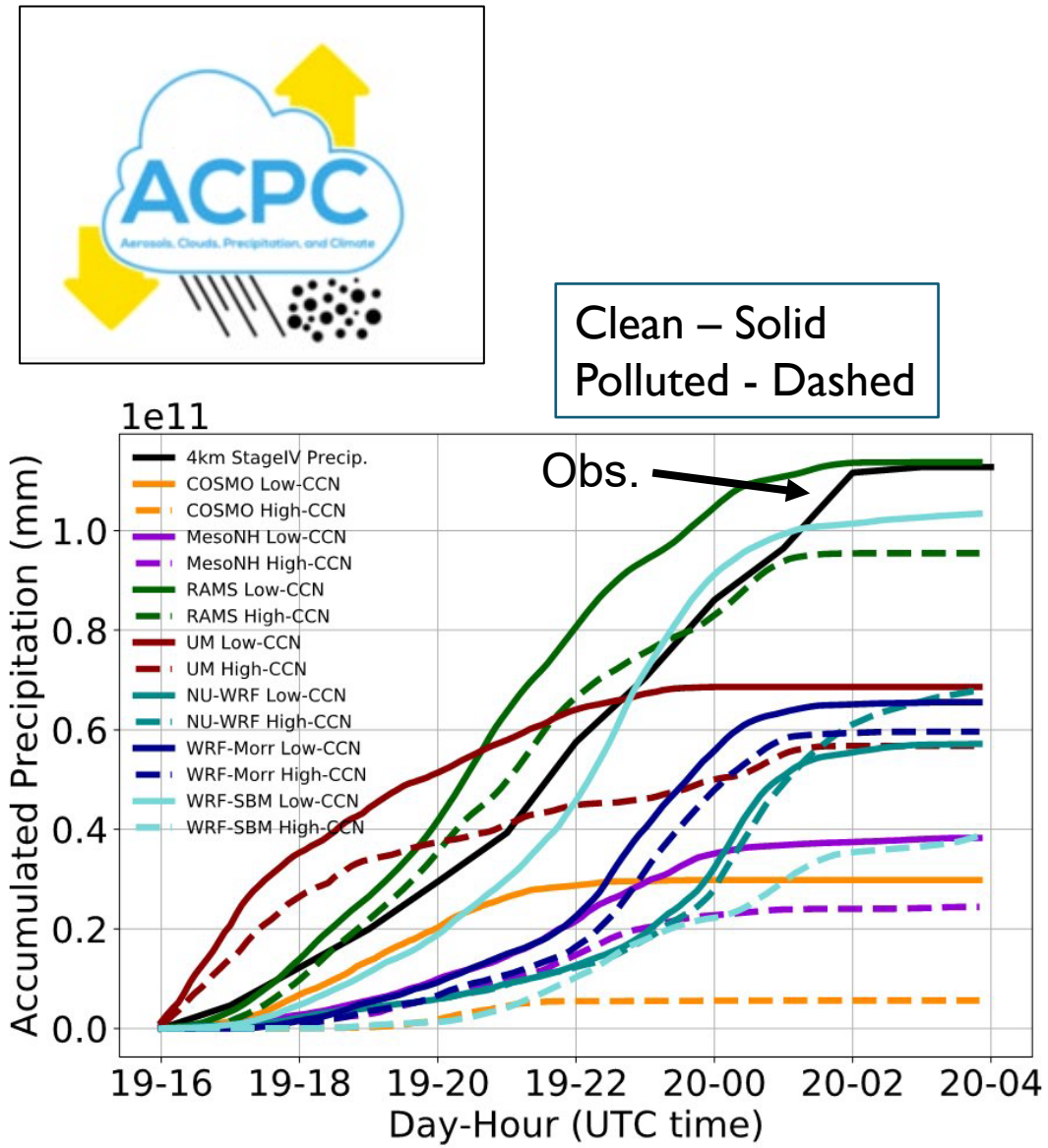
- "Cold-phase" invigoration
  - rain formation suppressed
  - more water lifted above freezing level
  - latent heat of freezing released
  - warms air making it more buoyant
  - stronger storm
- "Warm-phase" invigoration
  - increased droplet surface area
  - more condensational growth
  - Latent heat of condensation released
  - Warms air making it more buoyant
  - Stronger storm

For more information- breakout session #3



Brookhaven National Laboratory

Aerosol, Clouds, Precipitation & Climate - Pilot Study



- The **humid subtropical climate** of the Houston region, with large and diverse aerosol sources, provides an **excellent setting for the study of aerosol-convection interactions**.
- Intercomparison of **7 state-of-the-art** computer models of clouds
- Precipitation differences vary greatly among models
- Most models underestimate the total precipitation by more than 40%
- Aerosol impacts vary significantly

Marinescu et a. 2021

TRacking Aerosol Convection interactions ExpeRiment (TRACER)

https://www.arm.gov/research/campaigns/amf2021tracer

Who?	DOE ARM, DOE Atmospheric System Research
What?	First ARM "Mobile" Facility C-band Scanning ARM Precipitation Radar, Tethered Balloon System Many Guest Instruments
Where?	Houston Metropolitan Region
When?	01 October 2021 – 30 September 2022 01 June – 30 September 2022 (Intensive Observational Period)

TRACER+ Field Campaigns – Houston, TX Summer 2021-Summer 2022

Tracking Aerosol Convection interactions ExpeRiment (TRACER) – Oct ’21 - Sep ’22
DOE Atmospheric Radiation Measurement (ARM)

TRACER-Air Quality (AQ) – Sep ’21
NASA Tropospheric Composition Research
NASA Health and Air Quality Applied Sciences
Texas Commission on Environmental Quality

TRACER Intensive Operational Period (IOP) – Jun ‘22 - Sep ’22
DOE ARM & Atmospheric System Research

Experiment of Sea breeze Convection, Aerosols, Precipitation and Environment (ESCAPE)
31 May ’22 – 27 Jun ’22
National Science Foundation

Convective cloud – Urban Boundary layer Experiment (CUBE) – Summer ‘22
National Science Foundation

TRACER AQ2 – Summer ’22
Texas Commission on Environmental Quality

DOE-supported sites during TRACER

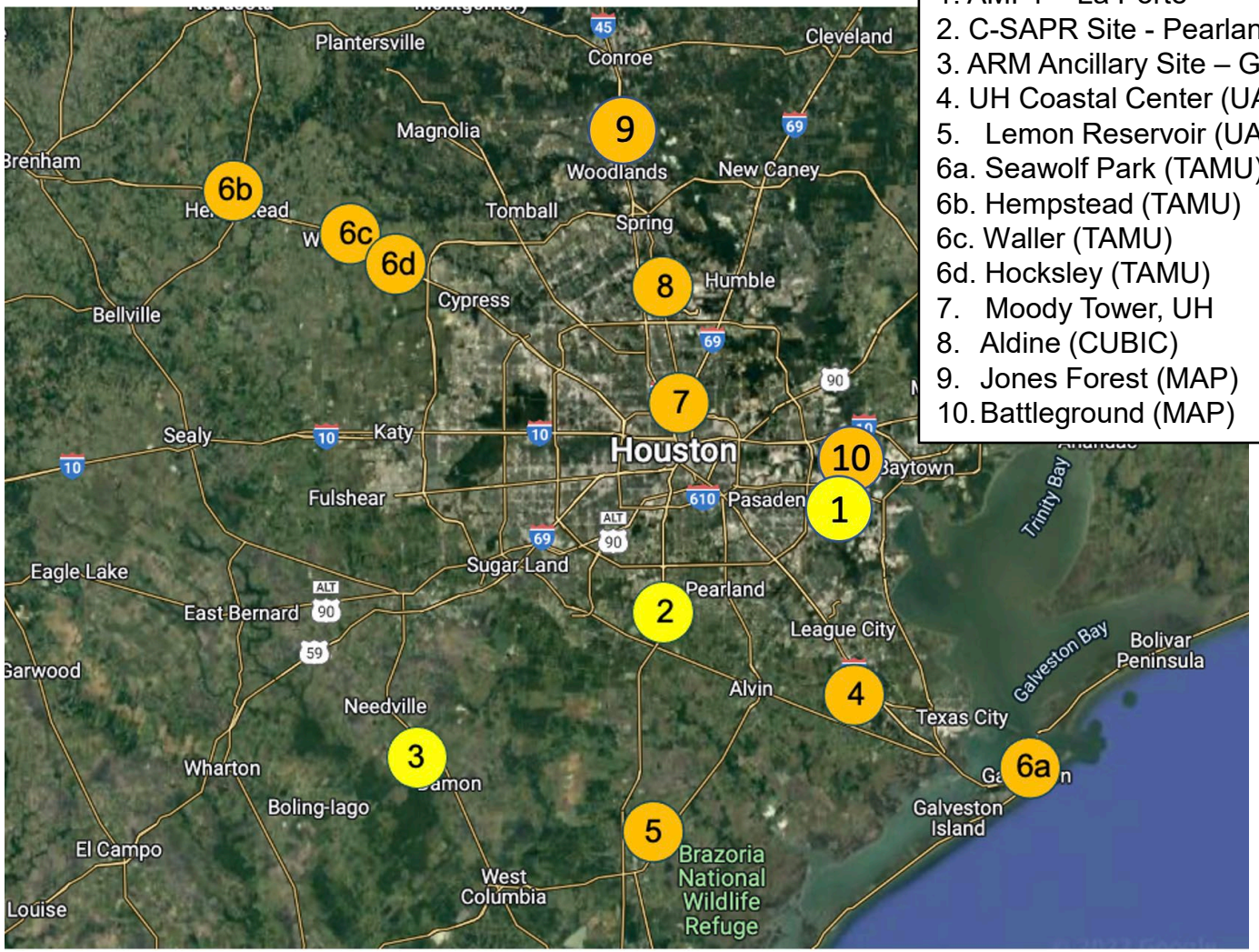
https://www.arm.gov/research/campaigns/amf2021tracer

Capture variability in:

- Convective lifecycle (radar cell-tracking)
- Aerosol loading (more vs. less polluted)
- Boundary layer structure (sea-breeze, bay-breeze, urban heat island)
- Vertical profile (aerosol, thermodynamics)
- Diurnal Cycle
- Seasonal Cycle

Leverage existing measurements:

- TCEQ meteorology and AQ
- Lightning Mapping Array
- GPS (water vapor) network
- NEXRAD radar



1. AMF1 – La Porte
2. C-SAPR Site - Pearland
3. ARM Ancillary Site – Guy
4. UH Coastal Center (UAV, CUBIC)
5. Lemon Reservoir (UAV)

6a. Seawolf Park (TAMU)
6b. Hempstead (TAMU)
6c. Waller (TAMU)
6d. Hocksley (TAMU)

7. Moody Tower, UH
8. Aldine (CUBIC)
9. Jones Forest (MAP)
10. Battleground (MAP)

Daily TRACER IOP Operations

Weather Forecast Briefing

Isolated Convection

Enhanced Operations:
Afternoon sondes at Guy
Additional afternoon sondes at La Porte
C-SAPR Cell-tracking

No Isolated Convection

Normal Operations:
4 sondes/day at La Porte
Discretionary C-SAPR Cell-tracking

TRACER+ PI operational decisions

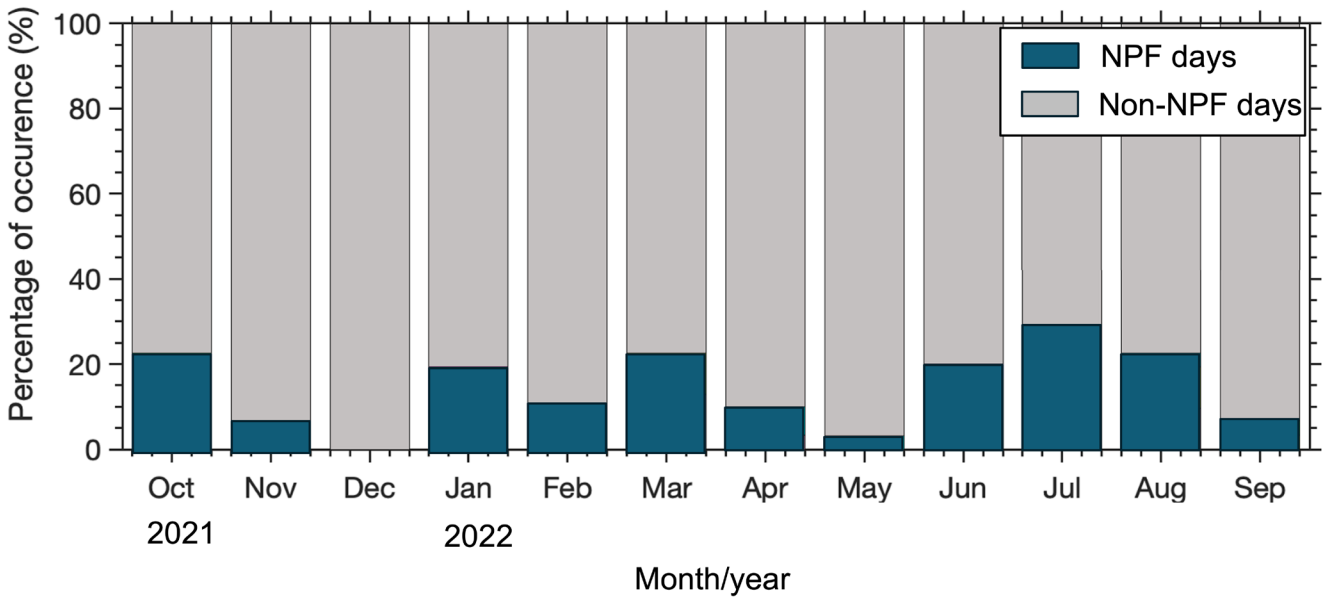
A sampling of measurement and research highlights from TRACER

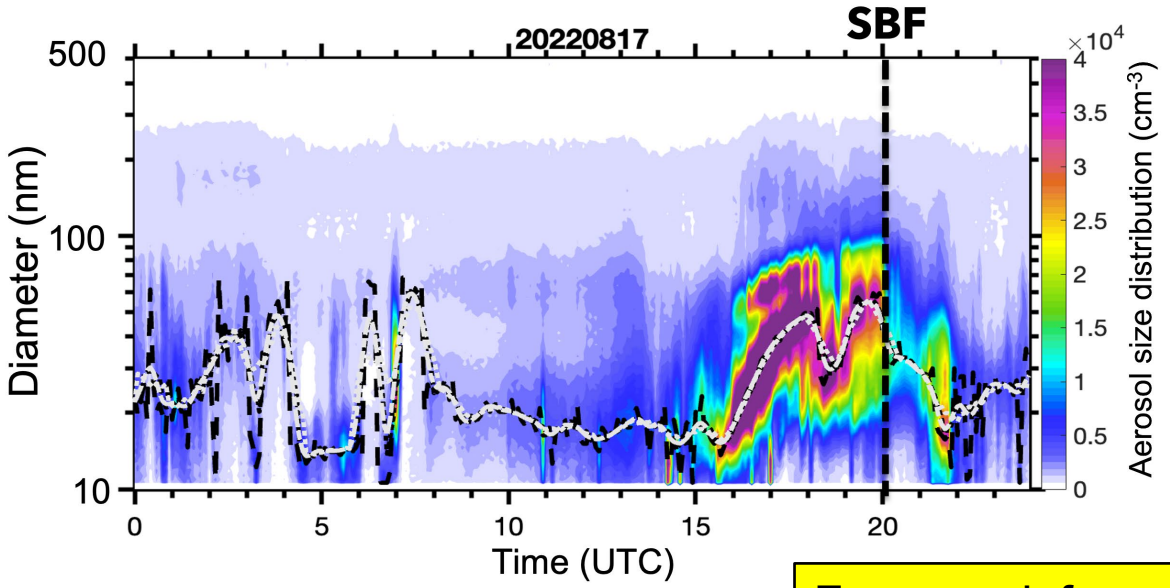
8 August 07:08 AM, ANC site, Guy, Texas

NEW PARTICLE FORMATION (NPF) EVENTS AT TRACER MAIN SITE

Monthly variation of the NPF events (% of occurrence).

- *A total of 53 NPF events (~15%) were observed during the measurement period.*





During summertime changes in aerosol properties coincident with the passing of the **Sea Breeze Front (SBF)** were observed at the M1 site.

For more information see Poster #2-12 Subba et al.

Physical and Chemical Properties of Aerosol Particles at the ANC Site During TRACER IOP

Jing Li[1], Jiaoshi Zhang[1], Xianda Gong[1], Steven Spielman[2], Chongai Kuang[3], Ashish Singh[3], Maria Zawadowicz[3], Lu Xu[1], Jian Wang[1*]
1. Washington University in St. Louis; 2. Aerosol Dynamics Inc.; 3. Brookhaven National Laboratory

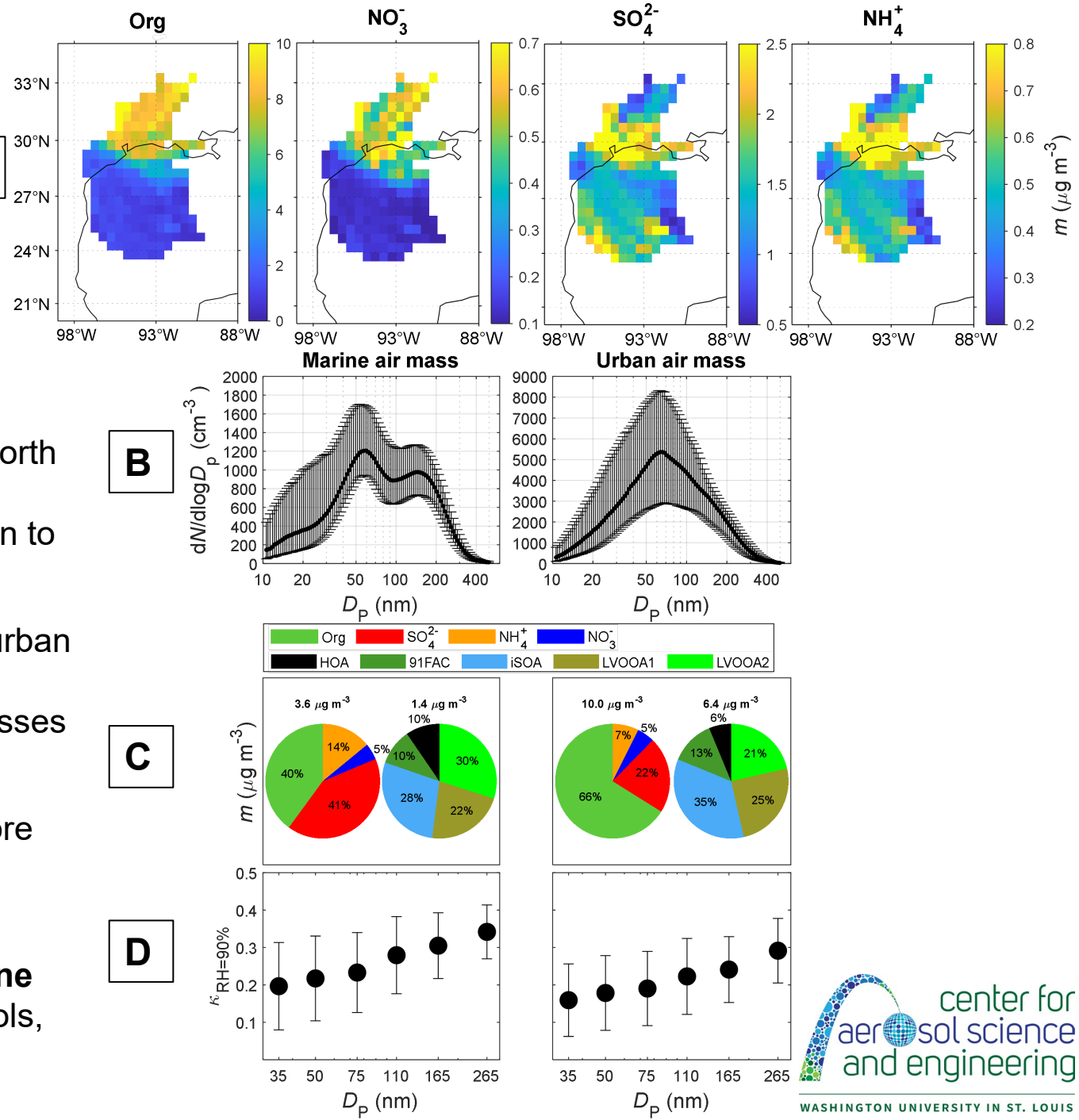
Poster #18 (Session 2, 9:15-10:30 am Tuesday)

A. High organics and nitrate mass concentrations from the north and northeast (i.e., urban areas). Elevated sulfate and ammonium mass concentrations from the south in addition to the north and northeast.

B. Marine aerosols show a **bimodal** size distribution, while urban aerosols show a **unimodal** aerosol size distribution. Both aerosol number and mass concentrations in urban air masses are about **3.5 times** of those in marine air masses.

C. Marine air mass has the largest fraction of sulfate and more oxidized organic aerosols. Organics are dominated by **biogenic SOA**.

D. **Particle hygroscopicity increases with diameter. Marine** aerosols show **higher hygroscopicity than** urban aerosols, consistent with the aerosol compositions.



center for aerosol science and engineering
WASHINGTON UNIVERSITY IN ST. LOUIS

Wind-Driven Emissions of Coarse Mode Particles in an Urban Environment

See poster 4-22 Petters

ASR Atmospheric System Research

Motivation

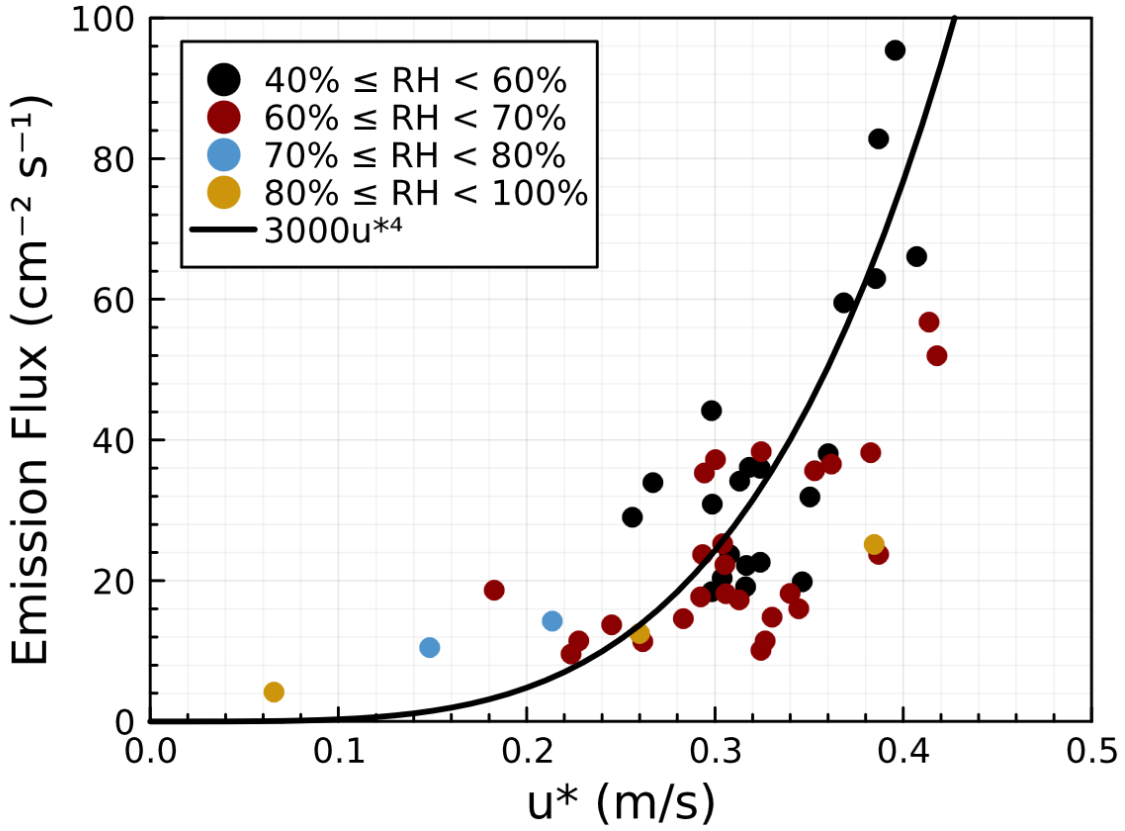
- Particle emissions are important for understanding the aerosol number, CCN, and INP budgets.

Approach

- Use coherent Doppler Lidar backscatter and vertical velocity fluctuations to obtain the particle number flux $D > 0.5$ µm during the IOP of the TRACER campaign.

Impact

- Backscatter fluxes are all positive (upward) and statistically significant.
- Backscatter could be related to particle number concentration.
- Emission number flux scales with friction velocity.
- **Urban surfaces are a potentially important source of coarse particles.**



Variation of the daily averaged emission flux with surface-derived friction velocity. Colors show data stratification by relative humidity. The solid line illustrates a power law dependency of the emission flux.

[Petters, M. D., Pujiastuti, T., Rasheeda Satheesh, A., Kasparoglu, S., Sutherland, B., and Meskhidze, N.: Wind-Driven Emissions of Coarse Mode Particles in an Urban Environment, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-951, 2023.]

ARM Tethered Balloon Operations during TRACER

Ancillary Site (Guy, TX)

- 11 days b/t 03 -14 June (46 flights)
- 13 days b/t 02-14 July (32 flights)
- 13 days b/t 02-14 Aug (44 flights)
- 12 days b/t02-14 Sept (28 flights)

Total 49 days, 150 flights

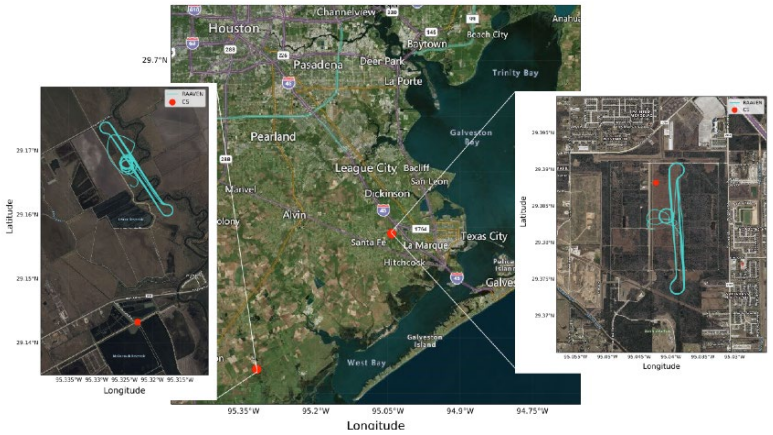
Profiling/loitering

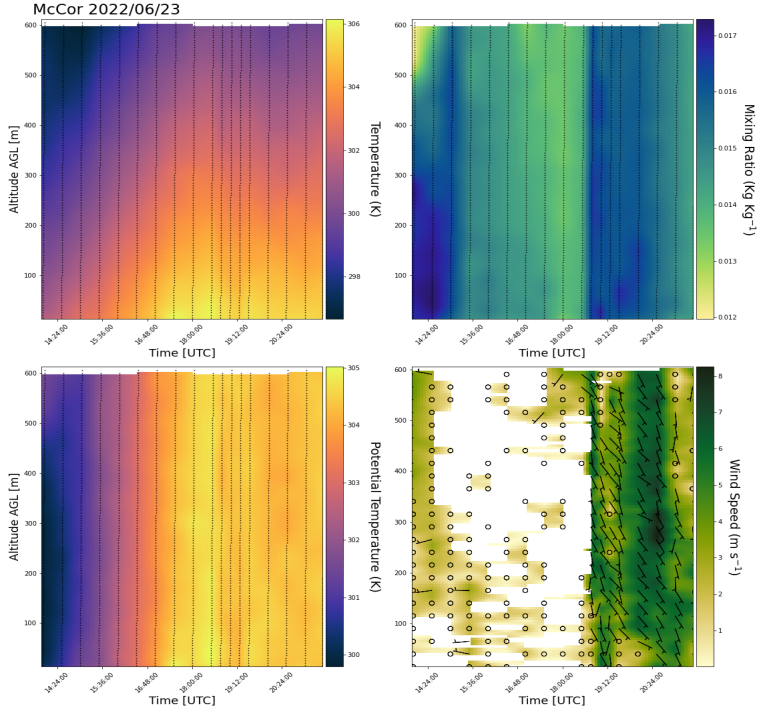
Various instrument combinations

- Aerosol
- Atmospheric State
- Trace Gases

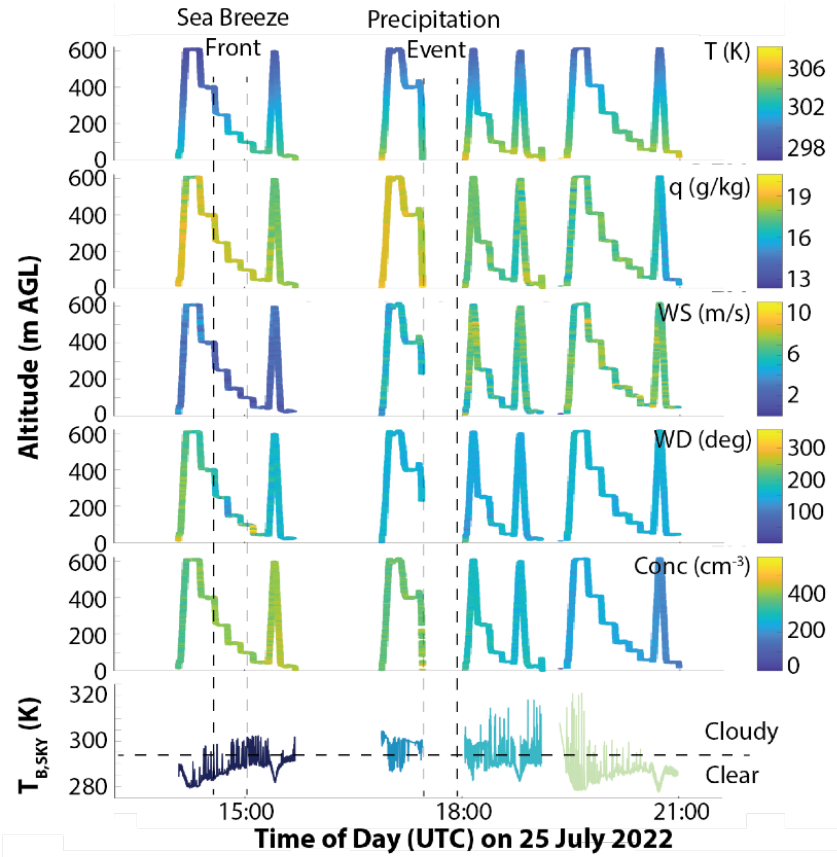
See Poster #1-13 Dexheimer, V-2 Cheng, V-7 Gautam

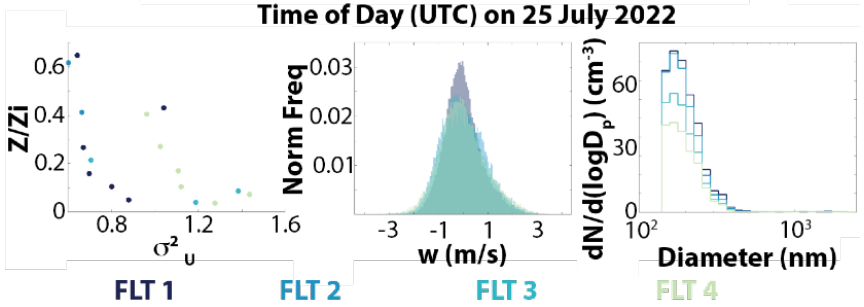
TRACER-UAS: Locations and Initial Results



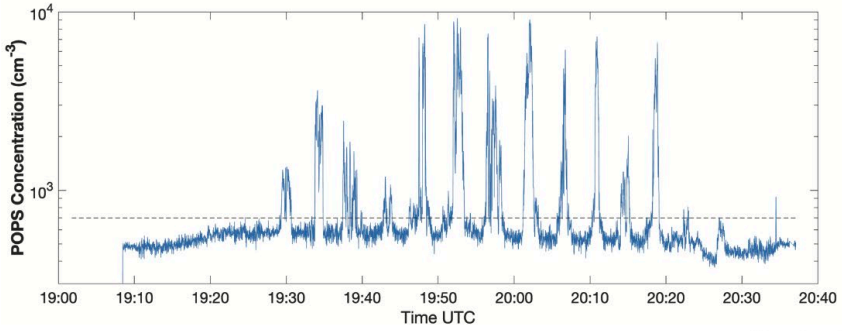


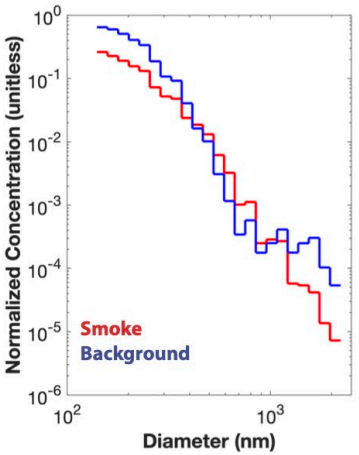
CopterSonde Gulf Breeze

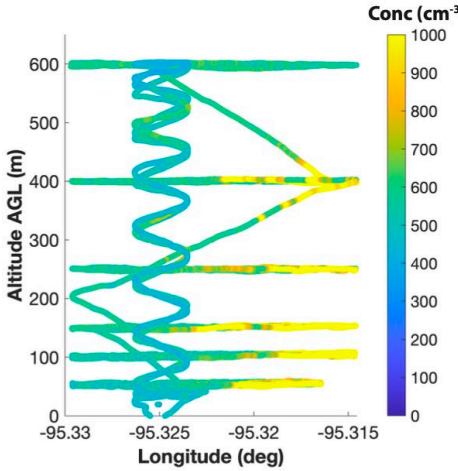




Typical RAAVEN Flight Day





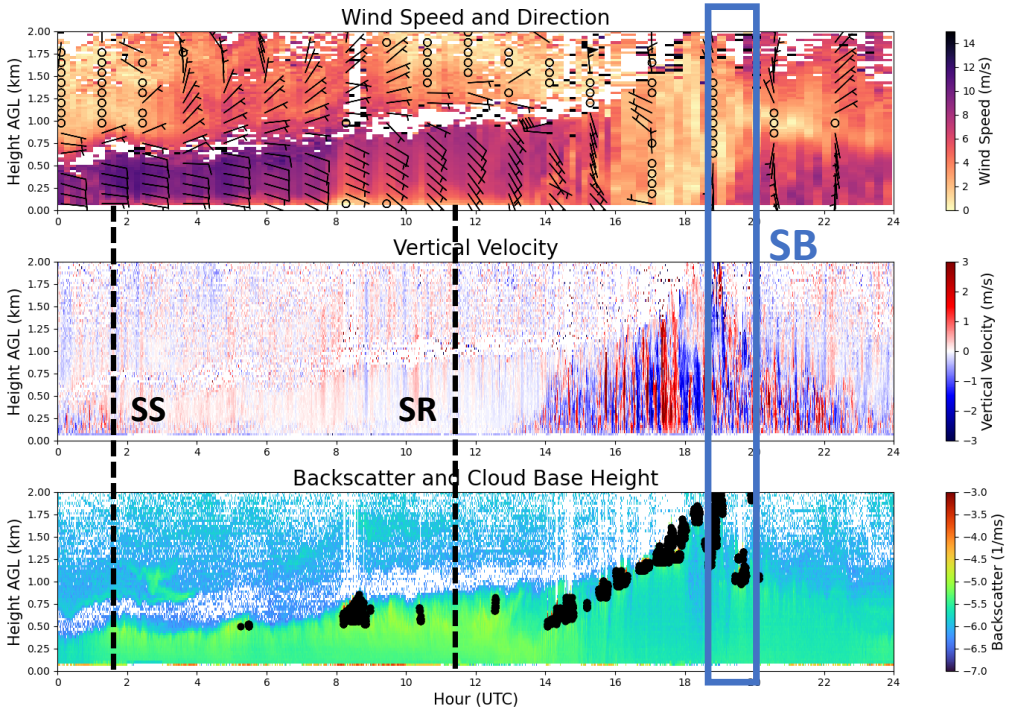


Wildfire plume sample

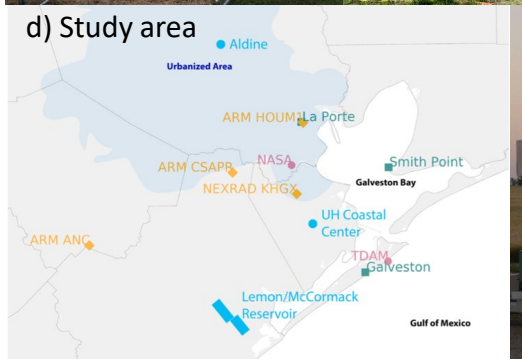
Team members present: **de Boer (CU), Lappin (OU)** – Let's talk about collaboration opportunities! **Poster #21** in Poster Session 1

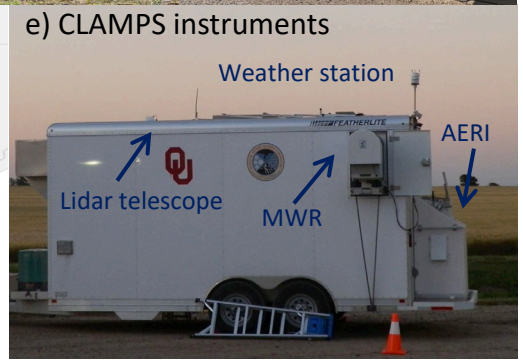
TRACER CUBIC Project (PI: P. Klein)

- Three mobile profiling systems were deployed and operated during the TRACER IOP
- Collection of high temporal resolution kinematic and thermodynamic boundary-layer profiles
  - Example from 07/12/2022 at the Coastal Center:



For More Information Check Out Michelle Spencer's Poster 37 in Session 1





TRACER CUBIC Data Availability and Observed Weather Conditions

Events during 1 June – 30 September, 2022	Number of Cases
Days with good data coverage (C2 no lidar for 24.5 days)	114
Days with Baybreeze (BB) and/or Seabreeze (SB) Circulations	39 (plus 13 questionable SB days)
Cases with local convection initiation due to BB/SB	16
Nocturnal low-level jet with $U_{LLJ} > 10$ m/s	21
Land/urban circulations	14

Tracking Lifecycle of Convective Storms during TRACER

Multisensor Agile Adaptive Sampling (MAAS) framework:

- Uses NEXRAD, GOES observations
- Automatically Steers CSAPR2 & CHIVO
- Track convective cells
- Follows pre-determined criteria

CSAPR2 scan bundles

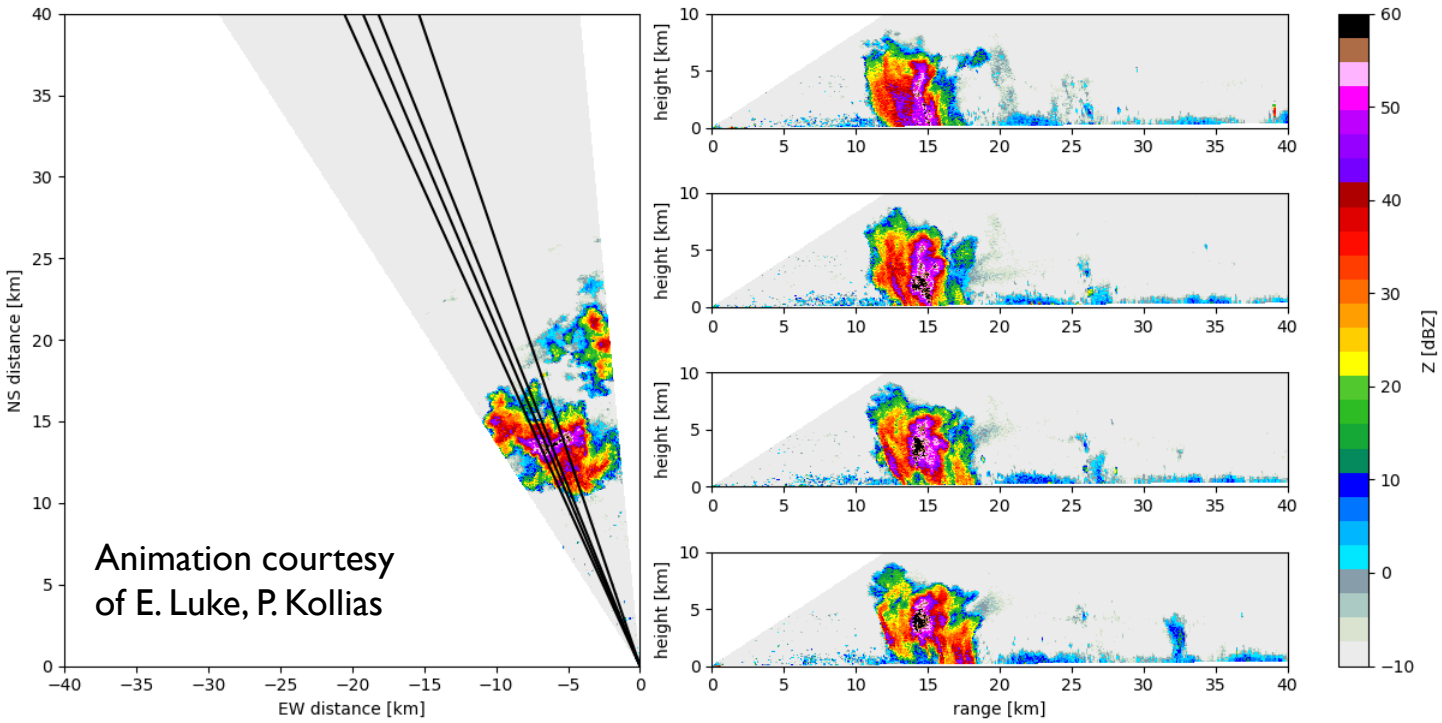
- 3 PPIs, 4-6 RHIs
- ~ 2 minutes
- Jun 04 – Sep 20
- Sampled 1330 cells, 17, 708 bundles

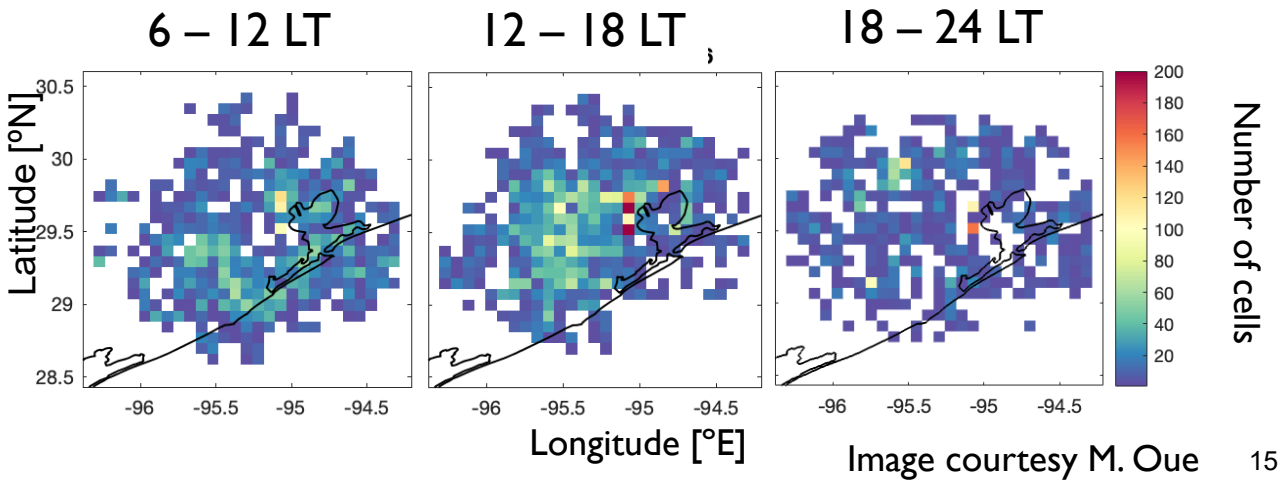
CHIVO scan bundles

- 3-4 RHIs
- ~ 30 seconds
- Aug 07 – Sep 30
- Sampled 75,730 scan bundles

See poster #1-3 9M. Oue

(Lamer et al. JTECH under review)





Lagrangian analysis of Polarimetric Radar & Lightning Mapping Array during TRACER

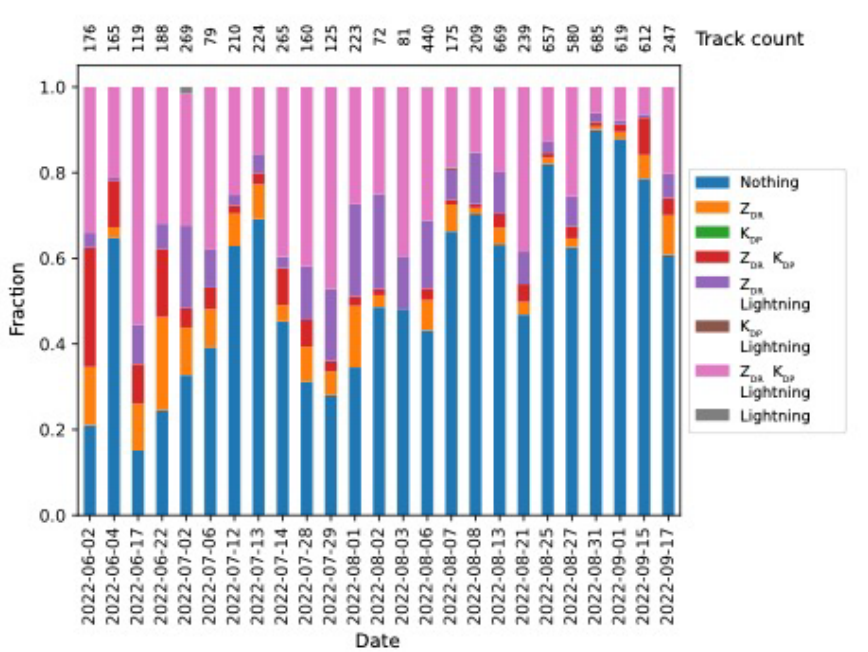
Eric Bruning, Kelcy Brunner, Marcus van Lier-Walqui (PI), V. Chandra, T. Logan, Toshi Matsui, Taka Iguchi

ASR Atmospheric System Research

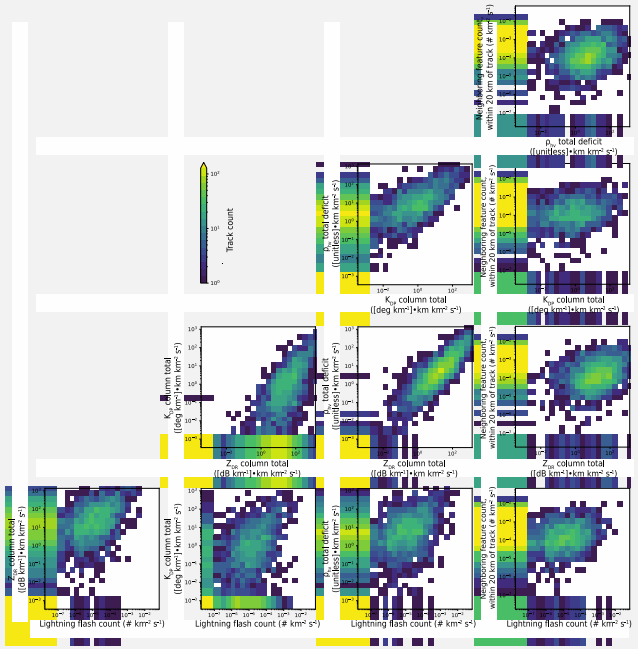
Columbia University in the City of New York

See poster 2-46 van Lier-Walqui

Isolated cells tracked from NEXRAD radar using TOBAC were analyzed with respect to polarimetric signatures and lightning flash activity

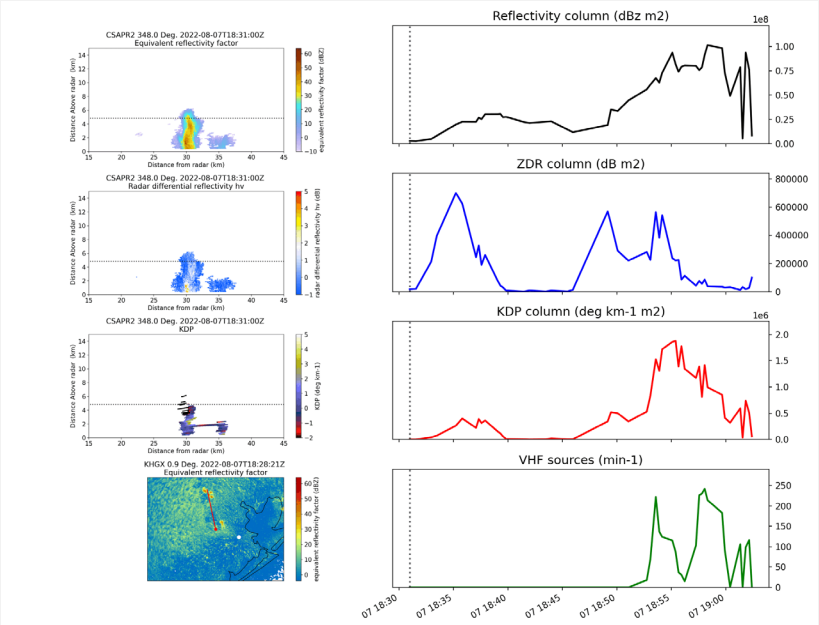


There is strong day-to-day variability; signals make sense physically (e.g. no lightning without KDP columns)



Covariability btw lightning and polarimetric radar is weaker than, e.g., btw KDP/ZDR, indicating additional information in lightning

Analysis of CSAPR2 and CSU-CHIVO radars will provide additional context to interpret these relationships and their variability

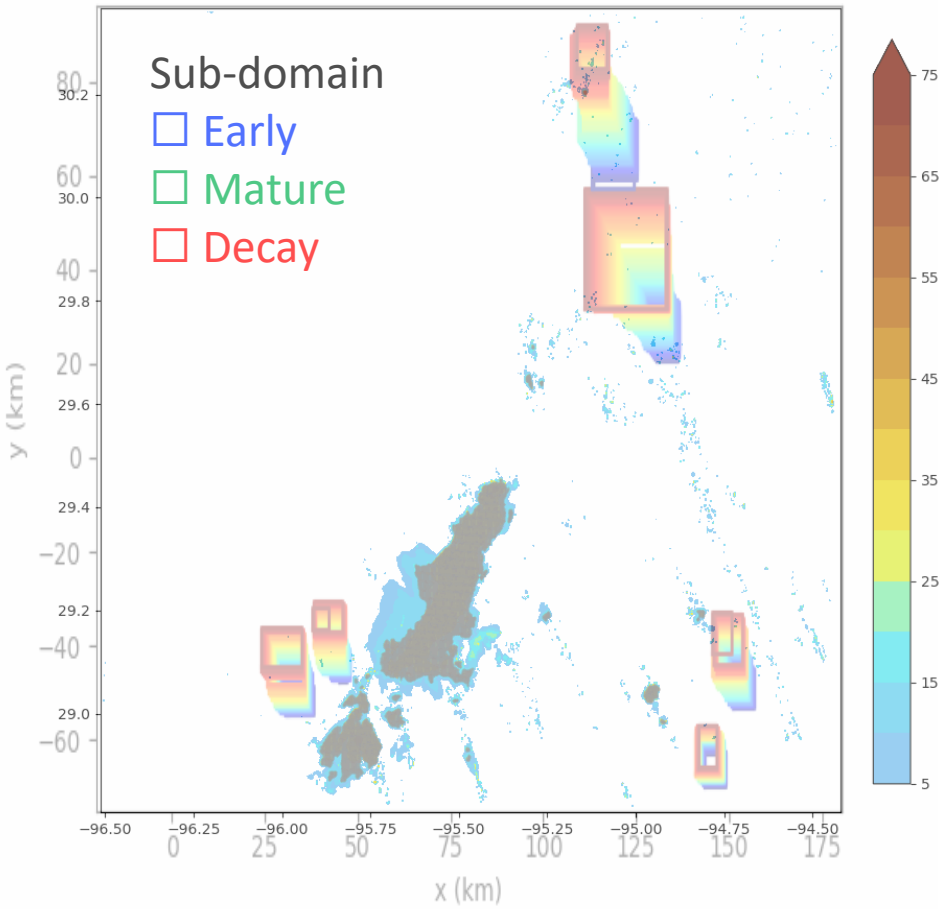


Joint Cell-Thermal Tracking

Toshi Matsui, Daniel Hernandez Deckers, Taka Iguchi, Marcus van Lier-Walqui,
Kelcy Brunner, Eric Bruning, Ann Fridlind, and Ted Mansell

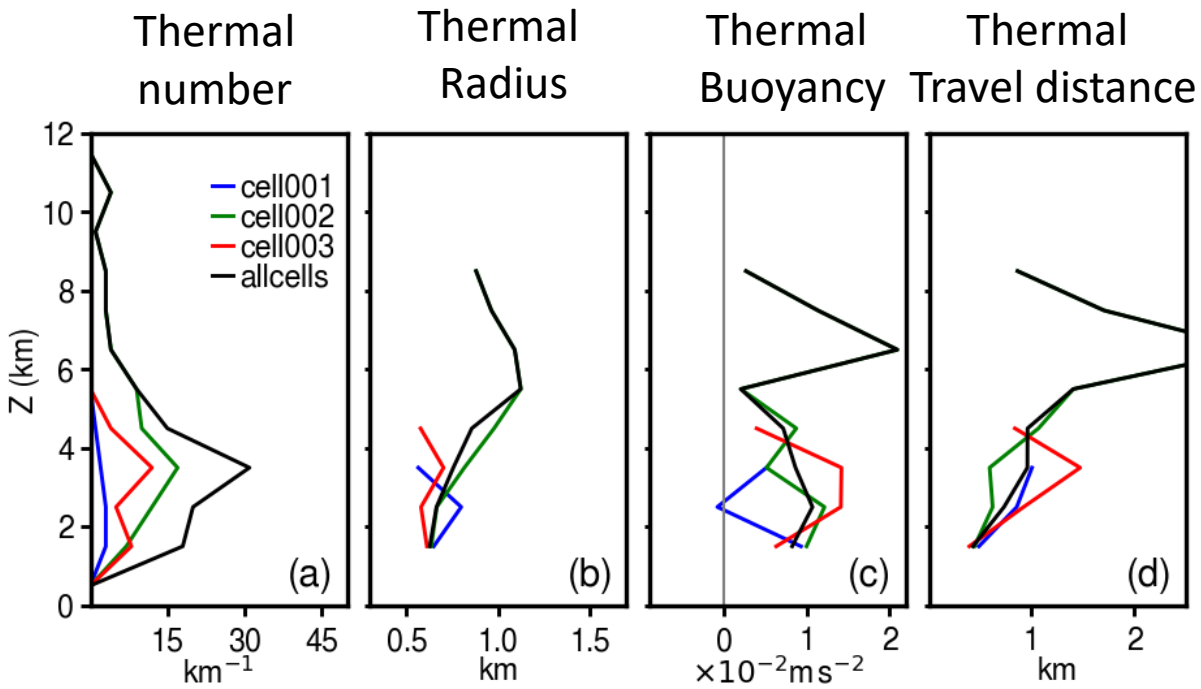
See poster 2-48 Matsui

TOBAC cell tracking animation and
Defined sub-domains of isolated deep cells



Joint Cell-Thermal Tracking Analysis

1. TOBAC cell tracking
2. Define subdomain of tracked cell
3. Thermal tracking for each sub-domain
4. Tracked thermals from isolated deep convection



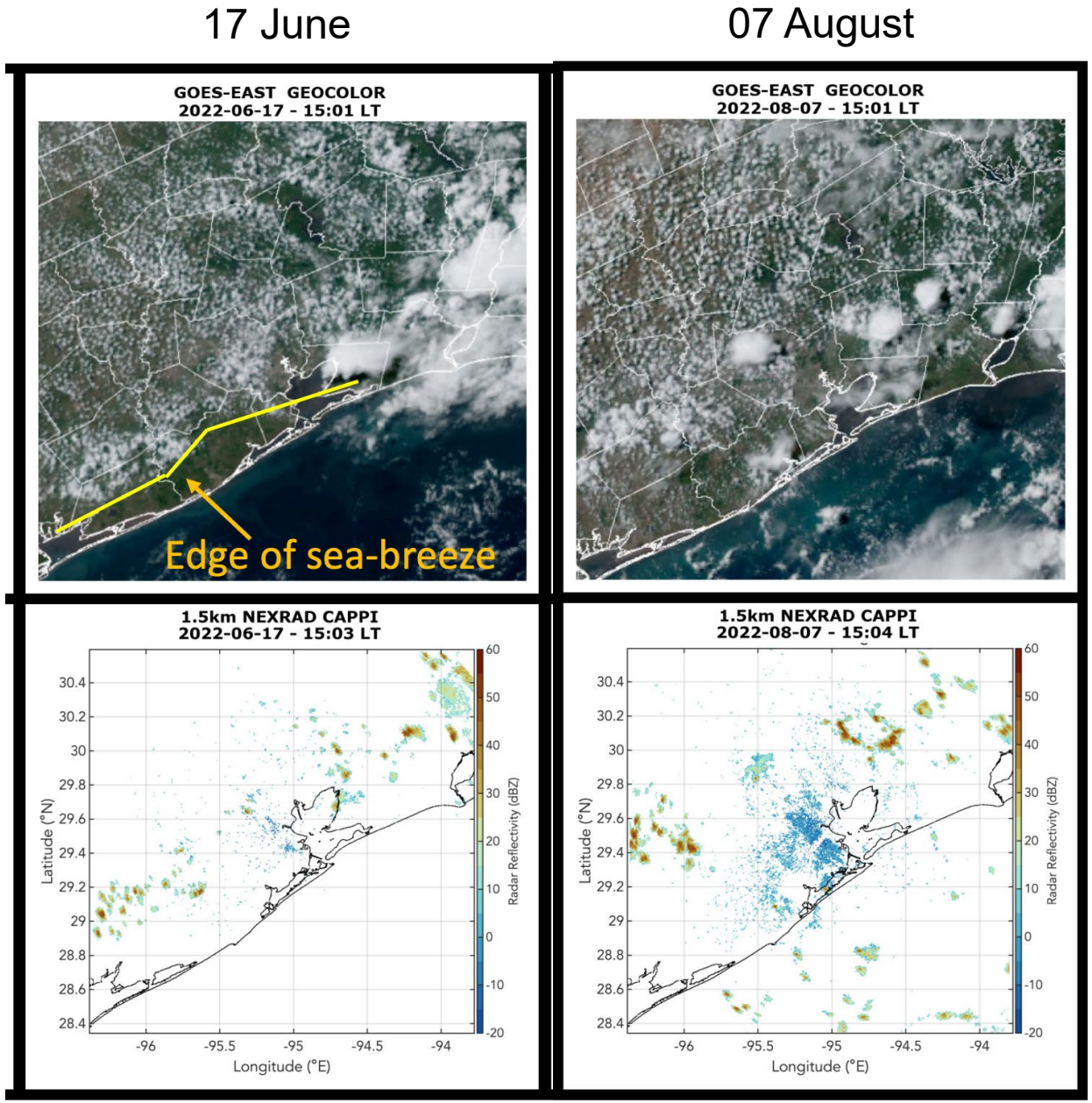
ACPC TRACER Model Intercomparison Project

Organizers: Steve Saleeby, Jiwen Fan

Project Goals

- Identify model deficiencies and measure performances.
- Use TRACER data for case study assessment.
- **Examine processes leading to model biases and large model spread in order to help reduce uncertainty in ACI.**
- Open to new participants.

For more info see poster #1-45 Saleeby et al.
And presentation in TRACER breakout session.



TRACER at this Meeting

Breakout Session #2 Monday 07 August 4:15 – 6:15

Building Collaborations Around TRACER Science Objectives

- Variability of aerosol/CCN properties
- Regional variability of thermodynamics/sea breeze
- Convective updraft microphysical properties
- TRACER Model Intercomparison Project (MIP)

29 TRACER-related posters

Thank you to all the contributors so far!

J. H Flynn (U. of Houston [UH]), L. M. Judd (NASA Langley,) P. Kollias (Stony Brook U.[SBU]/BNL), C. Kuang (BNL), G. McFarquhar (U. Oklahoma [OU]), H. Powers (Los Alamos NL [LANL]), P. Ramamurthy (City College of New York [CCNY]), J. Sullivan (NASA GSFC), A. Aiken (LANL), P. Argay (LANL), D. Bahrt (Hammelman Comm. [HC]), D. Boyer (Texas Comm. on Env. Quality [TCEQ]), S. Brooks (Texas A&M U. [TAMU]), E. Bruning (Texas Tech U.), R. Calmer (U. Colorado [CU]), C. Cappa (U. California - Davis [UCD]), R. K. Chakrabrty (Washington U. St. Louis [WUStL]), V. Chandrasekar [Colorado State U. [CSU]), S. China (Pacific Northwest NL [PNNL]), D. Collins (U. California - Riverside [UCR]), S. M. Collis (Argonne NL [ANL]), S. Crowell (OU), R. Dal Porto (UCD), M. Deng (BNL), D. Dexheimer (Sandia NL [SNL]), A. J. Drager (BNL), X. Du (UCR), M. K. Dubey (LANL), A. M. Dzambo (OU), G. de Boer (CU), M. Etten-Bohm (TAMU), J. Fan (ANL), R. Farley (UCD), Y.-C. Feng (PNNL), A. Fridlind (NASA GISS), J. Galewsky (U. New Mexico), H. Gamarro (CCNY), V. P. Ghate (ANL), S. E. Giangrande (BNL), J. E. Gonzalez (CCNY), R. Griffin (Rice U.), T. Griggs (UH), M. Grover (ANL), S. Gupta (BNL), J. Hu (OU), R. C. Jackson (ANL), K. L. Johnson (BNL), S. Kasparoglu (North Carolina St. U. [NCSU]), P. Klein (OU), A. Kotsakis (U. Space Research Association), M. Kumjian, (Pennsylvania State U. [PSU]), K. Lamer (BNL), K. Lenninger (National Weather Service [NWS]- Houston), J. Li (UWStL), I.A. Lindenmaier (PNNL), T. Logan (TAMU), E. P. Luke (BNL), O. L. Mayol-Bracer (BNL), T. Matsui (U. Maryland/NASA GSFC), A. A. Matthews (PNNL), F. Mei (PNNL), N. Meskhidze (NCSU), E. Nielsen (TAMU), C. Nowotarski (TAMU), D. Oaks (HC), R. Oktem (LBNL), M. Oue (SBU), J. Park (BNL), M. D. Petters (NCSU), A. G. Pessoa (HC), J. Puthuserry (WUStL), M. K. Rahman (CCNY), A. Rapp (TAMU), D. Rosenfeld (Hebrew U. of Jerusalem), A. Ryzhkov (National Severe Storms Laboratory[NSSL]/OU), R. Sheesley (Baylor U. [BU]), J. Snyder (NSSL), P. Stier (U. Oxford), A. Theisen (ANL), T. Subba (BNL), S. Usenko (BU), S. van den Heever (CSU), M. van-Lier-Walqui (Columbia U.), A. Varble (PNNL), N. Wales (LANL), D. Wang (BNL), Y. Wang (UH), L. Wood (NWS), M. Zawadowicz (BNL)

Questions?

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Extra Slides

29 TRACER-related Posters (1)

Sheesley et al., “Case Studies of VOC composition and chemistry during TRACER”
de Boer et al., “TRACER-UAS: Campaign overview and first results”
Galewsky, “Water Vapor Isotopic Measurements during the TRACER IOP and their co-variability with aerosols.”
Gorkowski et al.,”Humidity and convective effects on aerosols: Long range dust and organics in PyroCB Updrafts
Jensen et al.,” A Tour of Events of Interest during the TRACER campaign”
Smith et al.,”On the dominant role of sulfate chemistry on new particle formation in Houston during TRACER”
Dexheimer et al., “Investigating the influence of lapse rate atmospheric stability on total aerosol and ozone concentration using TBS measurements during TRACER”
Zawadowicz et al., “Characterization of submicron aerosol composition and hygroscopicity during TRACER.
Van Lier-Walqui et al., “Lagrangian analysis of isolated cells during TRACER from LMA and and radar”
Matthews et al.,”TRACER and SAIL field campaign radar data quality and calibrations”
Spencer et al., “Using fuzzy logic algorithm to evaluate PBL height evolution during TRACER-CUBIC”
Saleeby et al., “Model intercomparison project of simulated “golden” convective cases observed during the TRACER campaign”
Deng et al., “Sea breeze circulation and sea breeze lifecycle: An example from TRACER”
Matsui et al., “Simulating isolated storms observed during TRACER using NU-WRF EPIC, a high-resolution weather model with polarimetric radar forward-simulator and prognostic electrification.”
Sharma et al., “Spatiotemporal variability in convective cells & their thermodynamic/aerosol environments during TAMU TRACER”
Cheng et al., “Investigating the vertical profile of size-resolved aerosol chemical composition and mixing state during TRACER”

29 TRACER-related Posters (2)

Gautam et al., “Investigating secondary organic aerosols under convective clouds during TRACER campaign”

Khorshidian et al., “Cloud formation and precipitation over Texas during TRACER campaign period: Improving WRF-Chem-SBM simulations using observation nudging technique.”

Kumar et al., “Correcting for biases in filter-based aerosol light absorption measurements over ARM’s SGP and La Porte, TX”

Subba et al., “Investigating the spatio-temporal controls of summertime sea breeze circulation on the atmospheric aerosol environment in the Houston coastal region.”

Li et al., “Physical and chemical properties of aerosol particles in the rural areas near Houston, TX.”

Hill and Creamean, “Lessons from long-term measurements of ice nucleating particles at ARM sites”

Fan et al., “How do high values of supersaturation in convective cores determine convective invigoration by aerosols?”

Petters et al., “Wind-driven emissions of coarse mode particles in an urban environment”

Jackson et al., “Using layerwise relevance propagation to determine predictors of aerosol regimes in Houston using OpenCRUMS”

Wang, D., Exploring the impact of aerosols on deep convective clouds in Houston: A causal ML approach”

Oue, M., “Analysis of convective cell evolution using high-temporal, high-vertical resolution cell tracking observations by C-band polarimetric radars.”

Sherman et al., “CMAC across ARM: Corrective moments for radars deployed by the world’s largest climate research facility”

Shilling and Levin, “Using machine learning to QC merged aerosol particle distributions from the MERGEDSMPSAPS VAP”