An Overview of TRACER (+) Science and Operations

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Brookhaven National Laboratory
TRACER Science and Operations Team
TRACER breakout, ARM/ASR Meeting
24 October 2022

ARM CLIMATE RESEARCH FACILITY

ASR Atmospheric System Research

Cross-cutting Motivations and High-Level Science Objectives

The **humid subtropical climate** of the Houston region, with large and diverse aerosol sources, provides an **excellent setting for the study of aerosol-convection-pollution interactions**.

The **impacts of aerosols on convective vigor** (updraft strength, precipitation amount, mass flux and anvil area) require improved process level understanding.

In the Houston region, **sea-breeze dynamics often interact with local urban and industrial emissions to degrade air quality**. An improved understanding of these pollution challenges is **crucial for public health and environmental equity**.

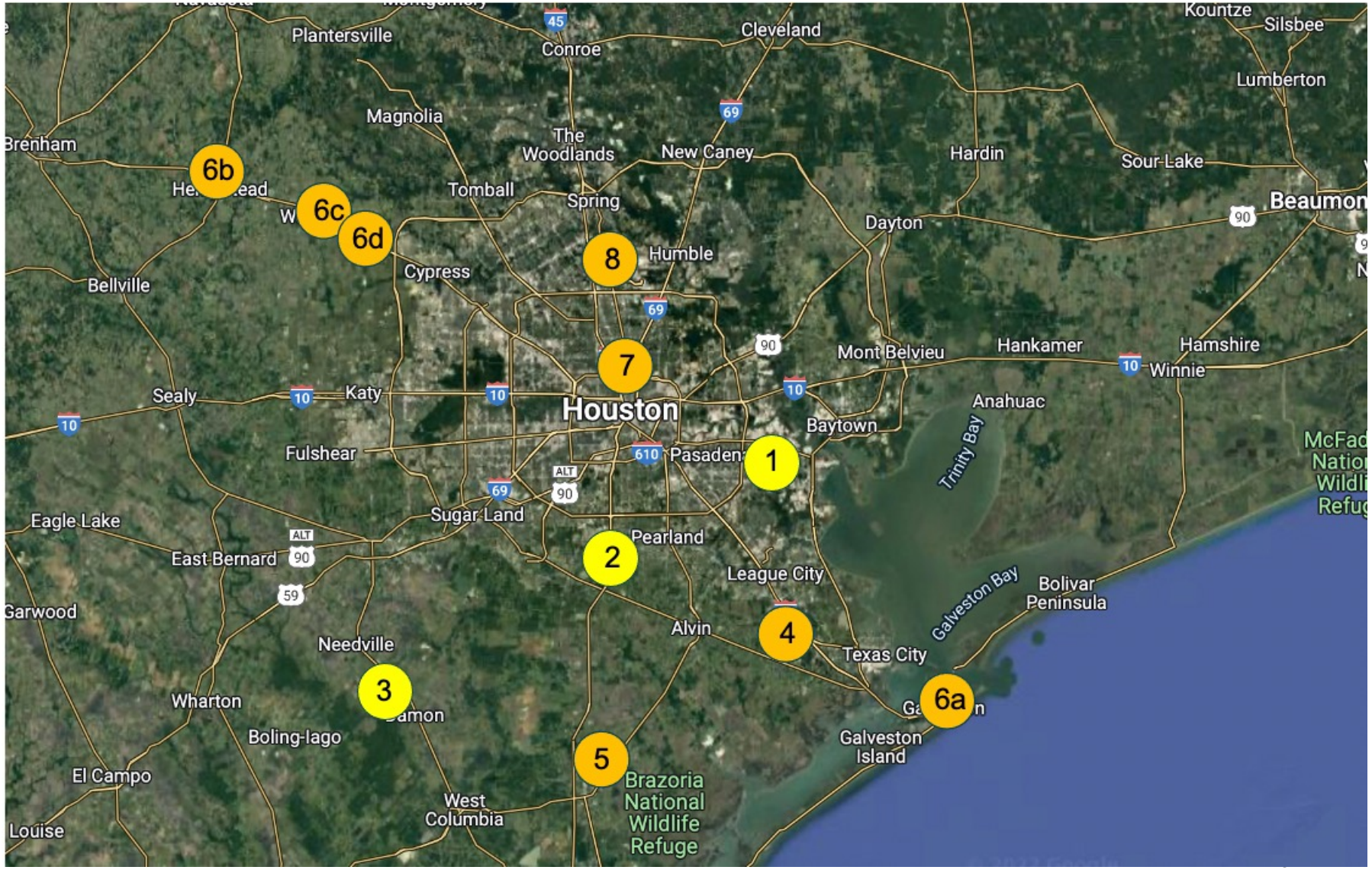
The interaction of coastal and urban circulations play an important role in **convective cloud lifecycle, influencing the dynamics of updrafts and downdrafts, precipitation formation, and lightning occurrence**. An improved understanding of these processes is necessary for accurate forecasting and prediction.

TRACER IOP Deployment

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

01 Oct. ‘21 – 30 Sep. ‘22
IOP June – Sep. 2022

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)



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

TRACER+ by the numbers

5 Participating Agencies (DOE, NSF, NASA, TCEQ, NOAA)
38 TB of Data (so far)
40 Enhanced Operational Days
~ 45 Participating Institutions
~ 50 contributors to daily forecast briefings
122 ARM Intensive Operational Days
150 Tethered Balloon Flights
~ 150 field participants
181 ARM Forecast briefings
188 ARM data streams
~ 395 ARM Operational Days
1885 ARM Sounding launches

Daily TRACER IOP Operations

Weather Forecast Briefing

Isolated Convection

No Isolated Convection

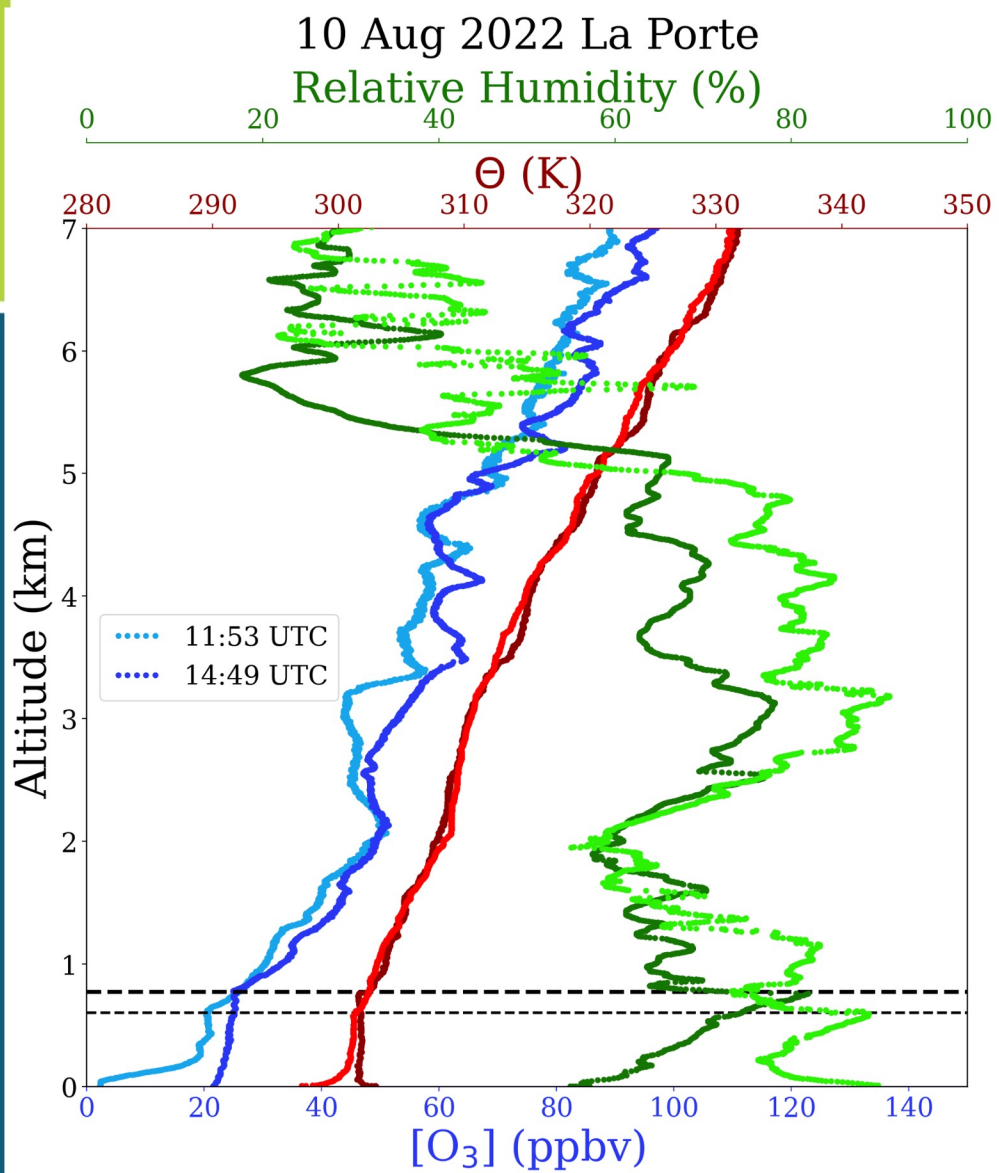
Enhanced Operations:
Afternoon sonde at Guy
Additional afternoon sondes at La Porte
C-SAPR Cell-tracking

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

TRACER+ PI operational decisions

Contributions from TRACER Science and Operations Team

TRACER Sonde



Lighter colors show earlier morning profile

- 11Z profiles show residual layer
- 15Z profiles show developing boundary layer

Data set: 65 ozonesondes from free release balloons at Main site in La Porte, TX

- Twice-daily pair released at 11Z and 15Z (July - Sept.)
  - 17 of 32 days were TRACER enhanced sounding days
  - Radiosondes released at 15Z on 6 additional TRACER enhanced sounding days
  - Some days coordinated with TRACER MAP

Image courtesy of Dié Wang

Dié Wang (BNL, left)

Nadia Partida (UH, center)

Minnie Park (BNL, right)

Baylor University: Sascha Usenko and Rebecca Sheesley
University of Houston: James Flynn, Yuxuan Wang, and Nadia Partitda
St. Edward's University: Paul Walter

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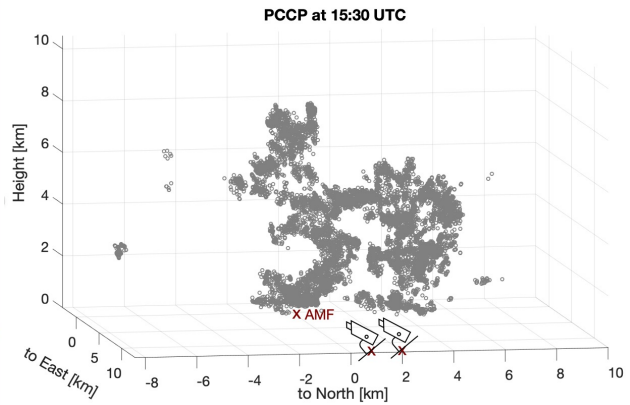
Stereo Camera Observations during TRACER

Point Cloud of Cloud Points on September 9, 2021



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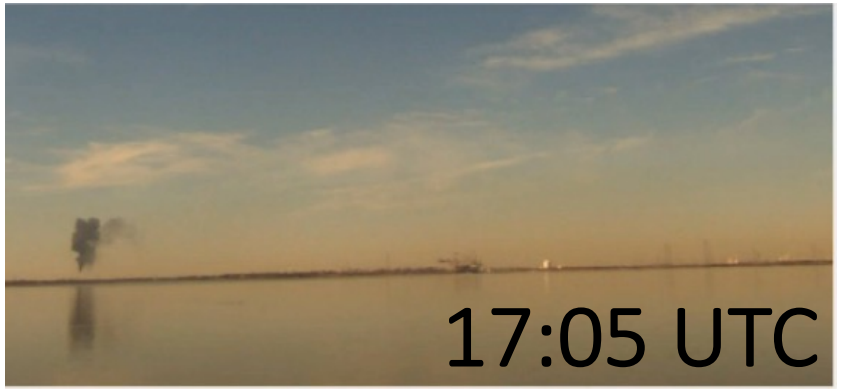
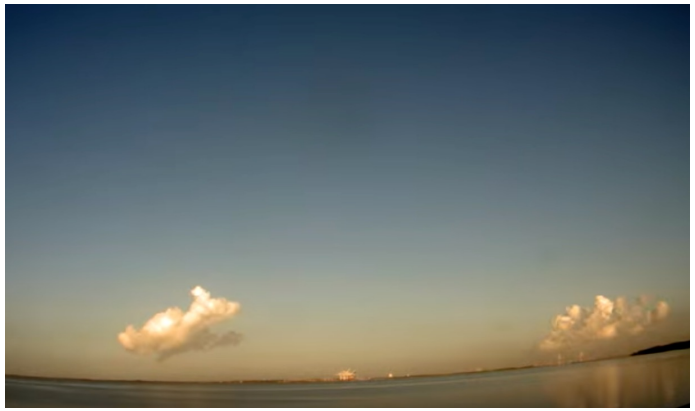
Industrial Plume on February 14, 2022



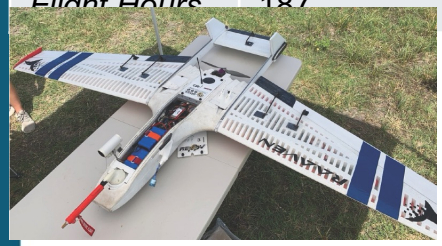
Isolated plumes forming atop chemical plants on June 22, 2022

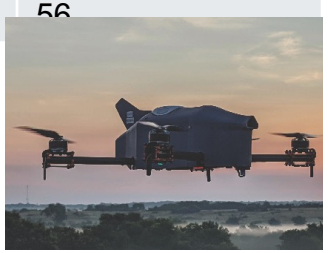


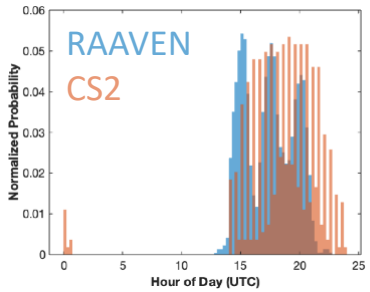
TRACER-UAS

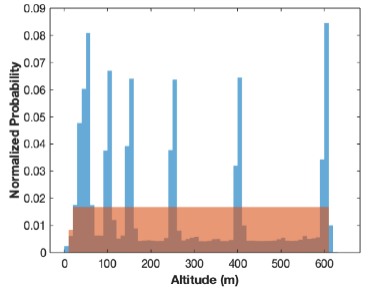
Flight Statistics:

Aircraft	CU RAAVEN	OU CopterSonde2
Flight Days	47	33
Flights	131	546
Profiles	251	544
Flight Hours	187	56

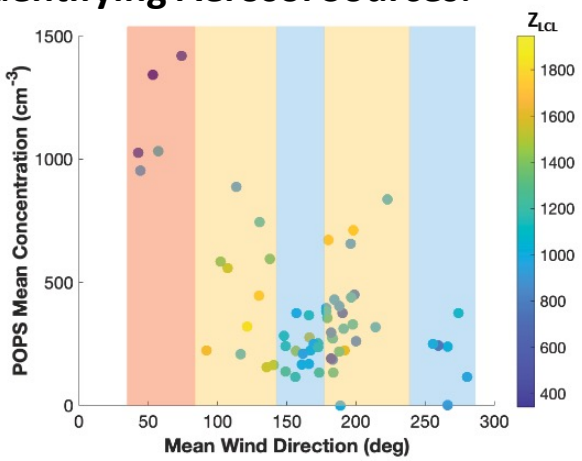


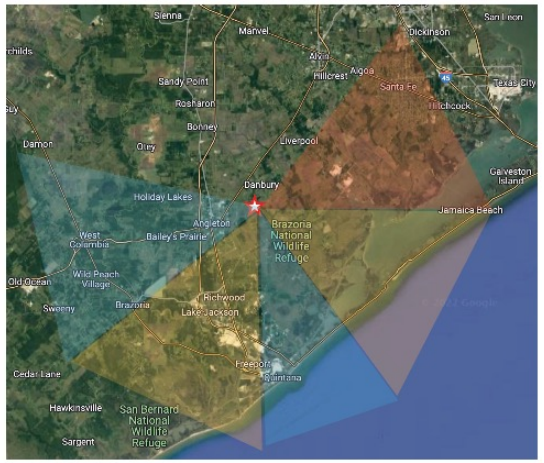




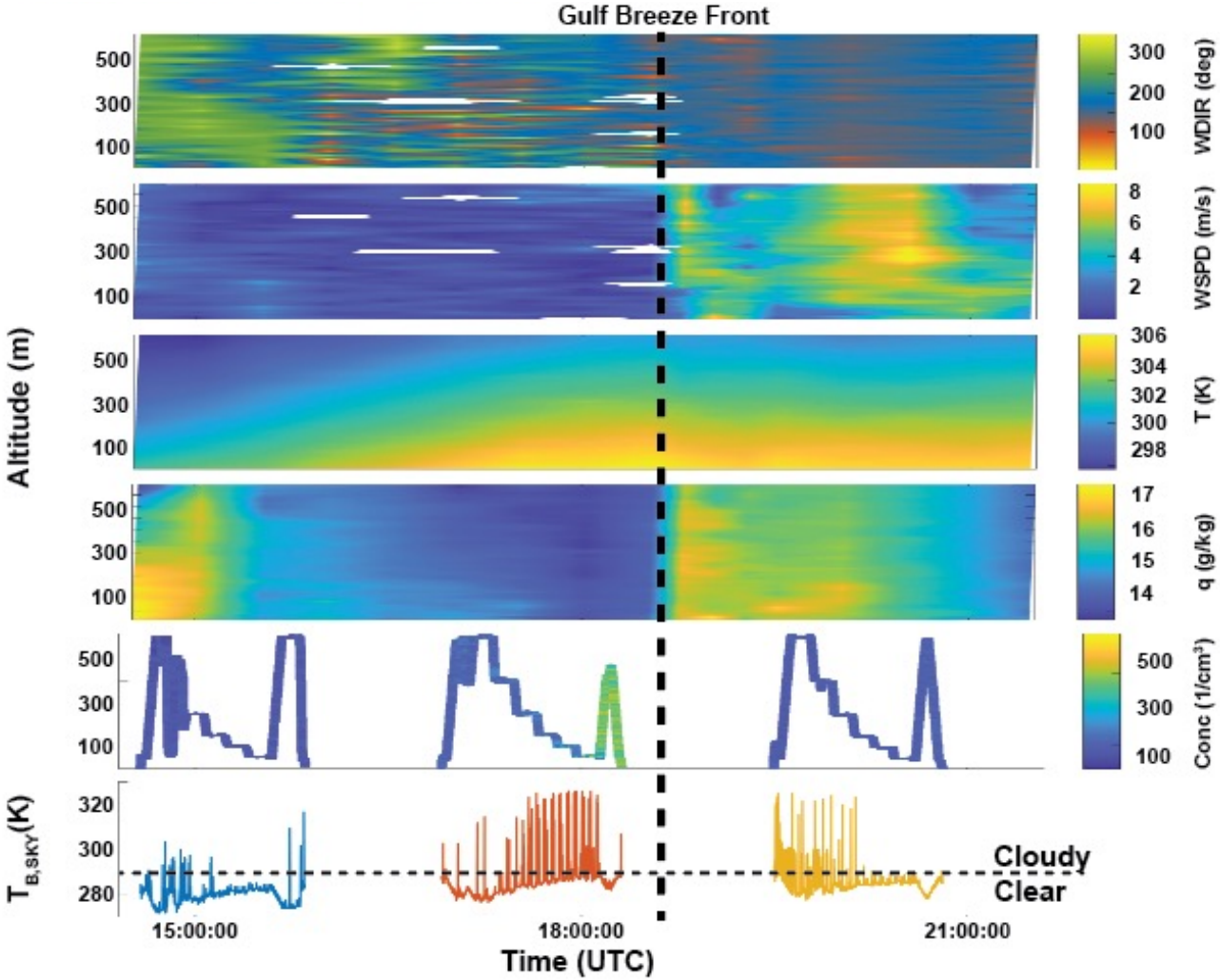


Identifying Aerosol Sources:





Example Flight Day (23 June):

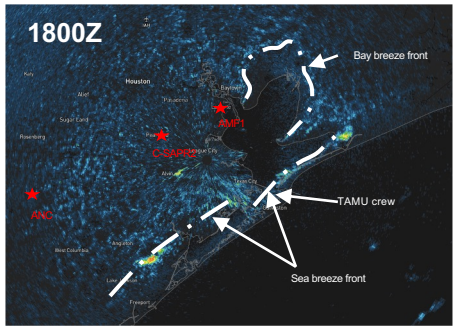


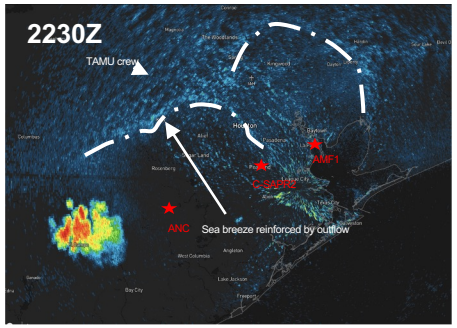
For more info, see poster or contact Gijs de Boer (gijs.deboer@colorado.edu)

TAMU TRACER: Targeted Mobile Measurements to Isolate the Impacts of Aerosols and Meteorology on Deep Convection

Anita D. Rapp, Sarah Brooks, Chris Nowotarski
M. Sharma, E. Nielsen, M. Etten-Bohm, S. Thompson, B. Chen, R. Li, and B. Hendrickson

Aerosol instrumentation measured particle size, concentration, vertical profiles, CCN, and INP



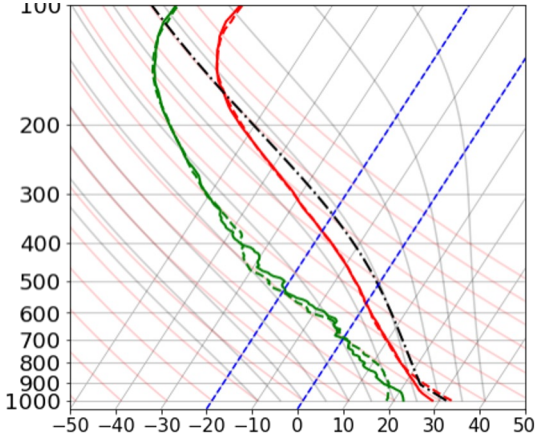


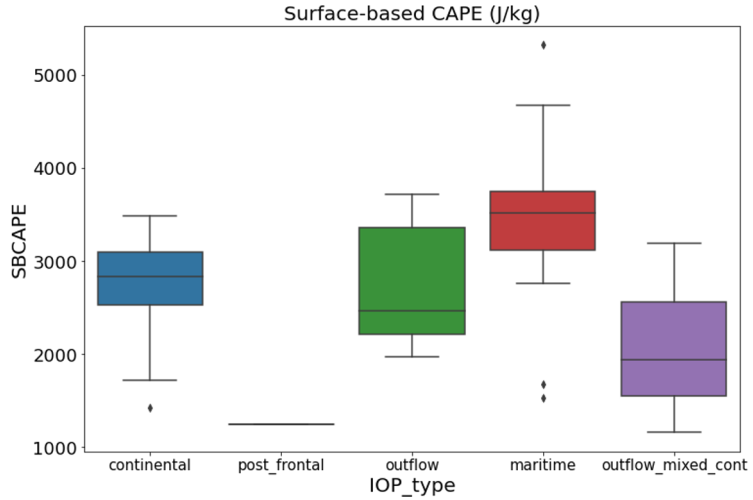
Atmospheric thermodynamic and dynamic profiles measured with iMet-4 radiosondes

TAMU IOP SUMMARY

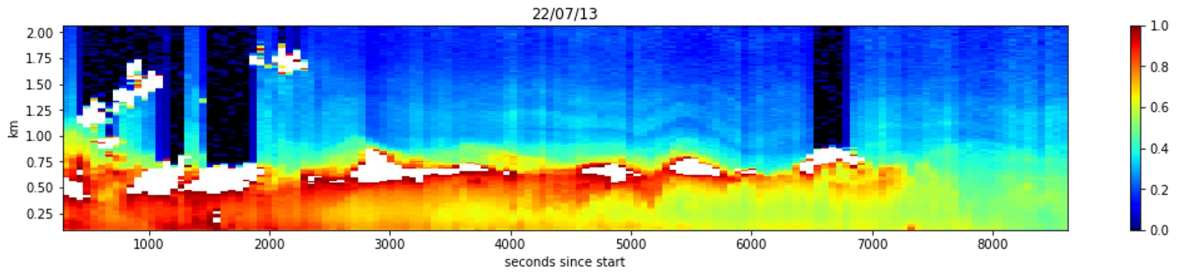
Total number of IOP days	22 joint radiosonde/aerosol 7 radiosonde only 10 aerosol only	June – 5 July – 2, 6, 3 August – 10, 2 September – 6, 5
Type of air mass sampled	Continental – 32 Maritime – 16 Convective outflow – 6 Outflow recovery – 3 Post frontal – 1	Continental – NW Houston Maritime - Galveston

Composite profiles
Dashed – continental, Solid – maritime





Lidar



This work is supported by DE-SC0021047, AFC07023, AFC07055

Sea-breeze Dynamics during TRACER IOP

Dié Wang[1], Michael Jensen[1], Emily Melvin[2], Noah Smith[3], Ayman Abdullah-Smoot[4], Natalia Pszeniczny[5], Siddhant Gupta[1]

[1]Brookhaven National Laboratory, [2]Georgia Institute of Technology, [3]Occidental College, [4]Texas Southern University [5]General Douglas MacArthur High School

Motivation:

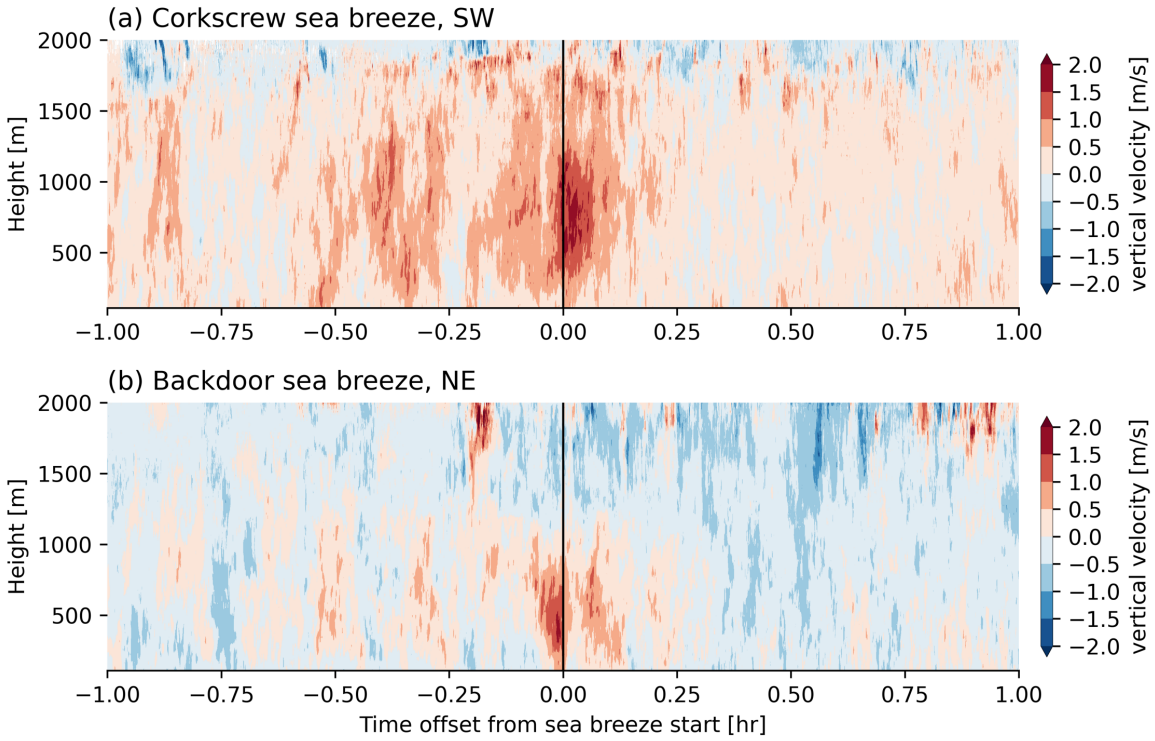
Understanding structures of different types of sea breezes (SB) and lifecycle characteristics of SB induced convective clouds.

Methods:

- Identify SB boundaries using radar and satellite images and determine SB timing based on ARM surface meteorological data.
- Classify SB events based on surface gradient wind direction.
- Quantify SB dynamics, thermodynamics, and associated cloud and radiation properties using multi-platform datasets.

Preliminary Results:

- 46 SB events are identified during the TRACER IOP with the majority being corkscrew SB embedded in southwesterly winds.
- Corkscrew SB promotes stronger, deeper, and wider updrafts within the boundary layer compared to backdoor SBs that are formed in northeasterly gradient winds.
- A higher cloud fraction is observed during corkscrew SB events compared to that during backdoor SB events.



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Polarimetric radar & lightning analysis and high-resolution simulations to support TRACER science goals

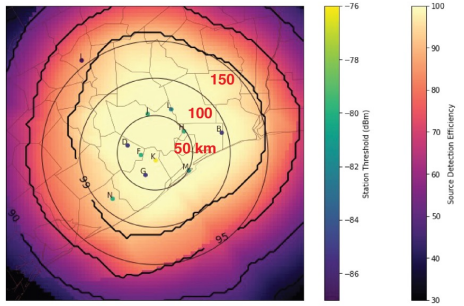
Marcus van Lier-Walqui, Toshi Matsui, Taka Iguchi, Eric Bruning, Kelcy Brunner,

Jessica Souza, Ann Fridlind

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

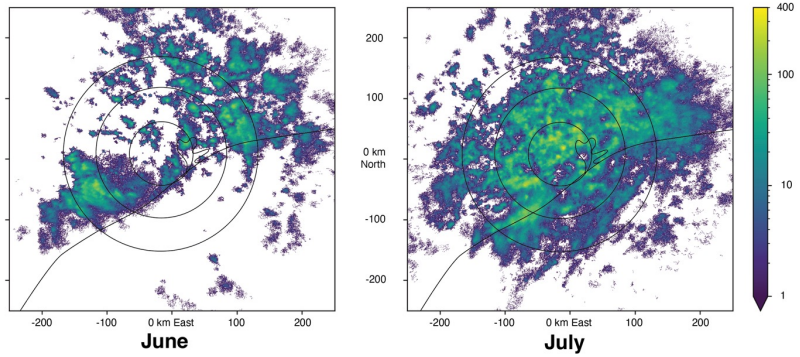
Initial lightning statistics from the Houston Lightning Mapping Array

Detection Efficiency (centered on CSAPR)

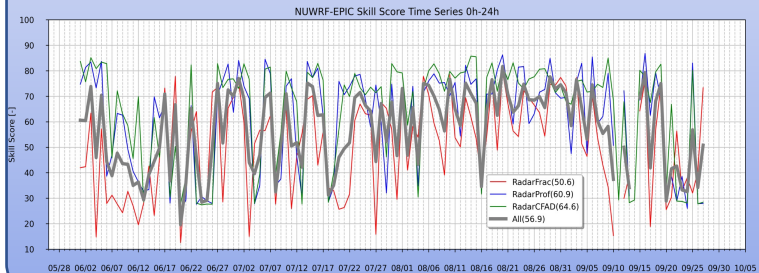


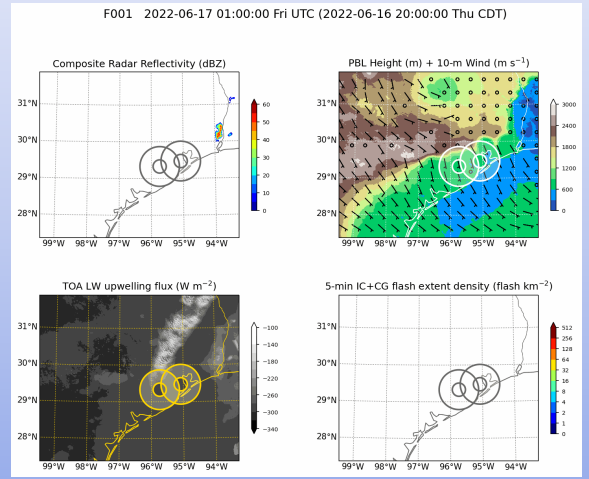
Estimated (Chmielewski and Bruning, 2016, JGR) flash (black contours, %) and source (shading, %) detection efficiency for the receiver thresholds (color symbols) at each Houston LMA station (letters)

Monthly Flash Count (500 m grid, centered on KHGX, range rings from CSAPR)

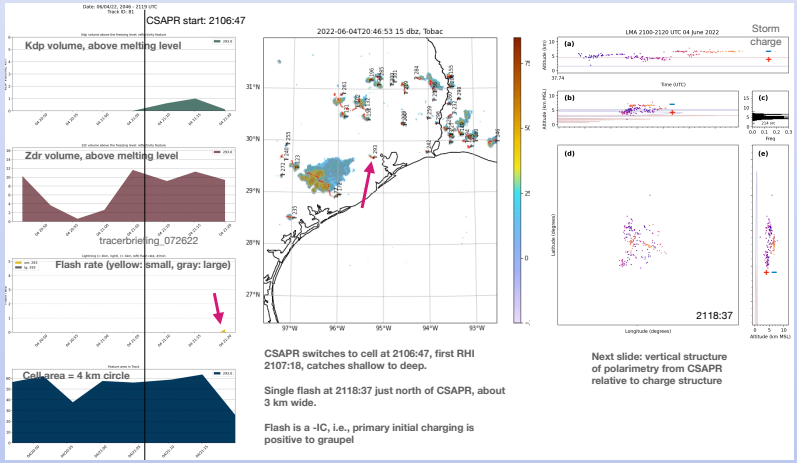


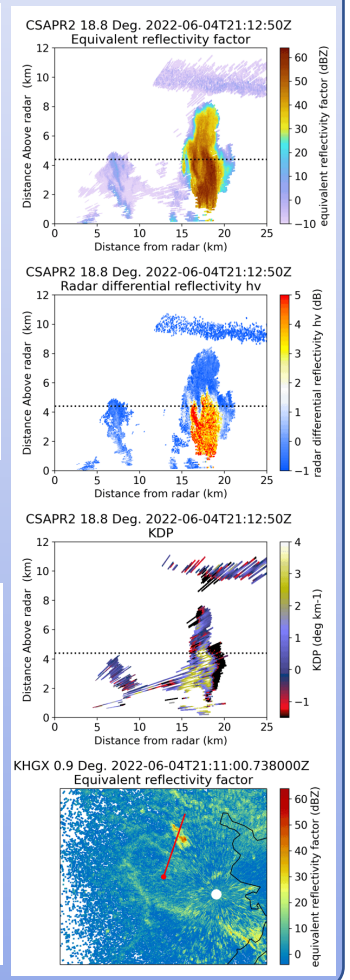
NU-WRF with enhanced capability of Electrification, Polarimetric radar Instrumental simulator, and Cloud condensation nuclei (NU-WRF EPIC)





Ongoing analysis of tracked cells using DOE radars, NEXRAD, and LMA

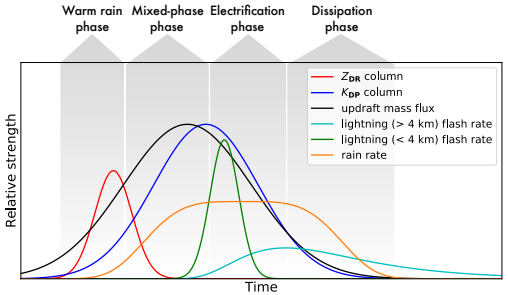




Refine conceptual hypothesis of cell/thermal lifecycle

A Conceptual Model of Cell/Thermal Lifecyle…

- Help organize analysis of observations
- Provide basis for meaningful comparison to simulations
- Help direct observational resources towards achievable & high impact targets
- Contextualize possible aerosol effects by life cycle phase & associated observables



ESCAPE Aircraft Measurements

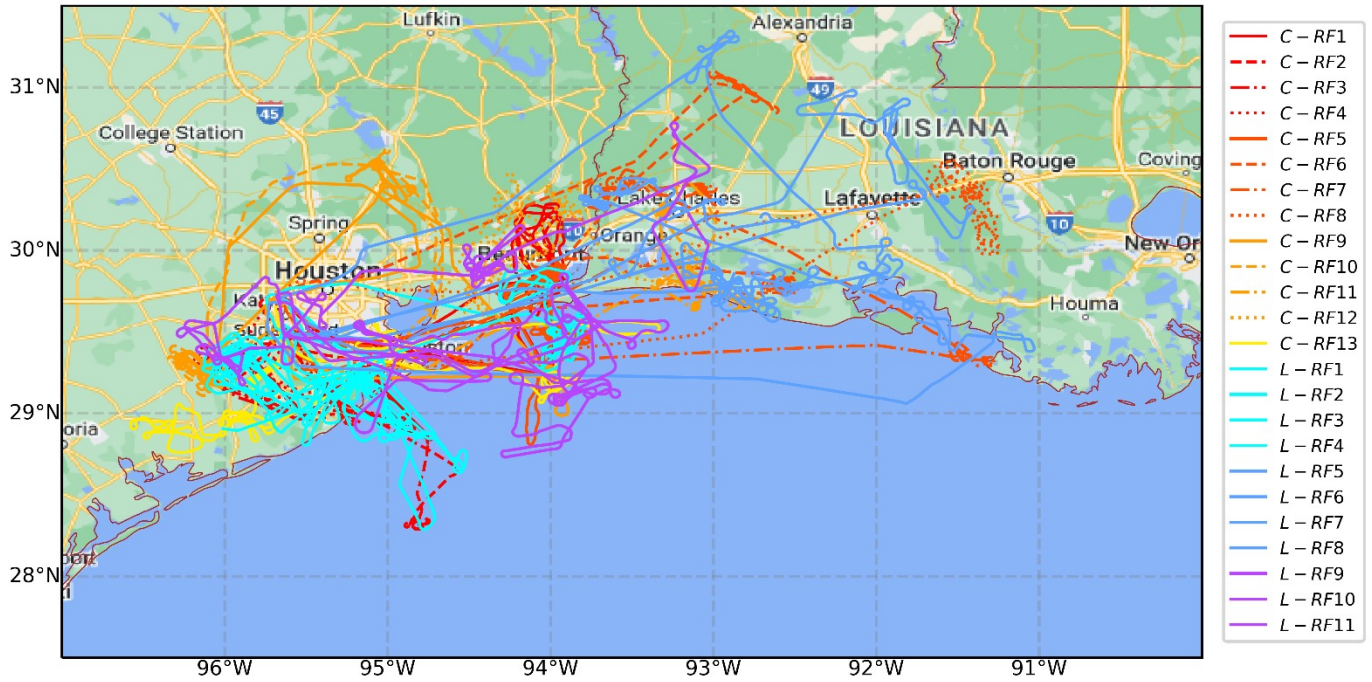
G. McFarquhar & S. Patil/University of Oklahoma; P. Kollias, Stonybrook; M. Wolde/NRC; R. Bruintjes and P. Lawson/SPEC; R. Shaw MTU; Others

Motivation:

Use high temporal & spatial resolution aircraft remote & in-situ data to investigate role of meteorology & aerosol in altering deep convection intensity and evolution

Instruments:

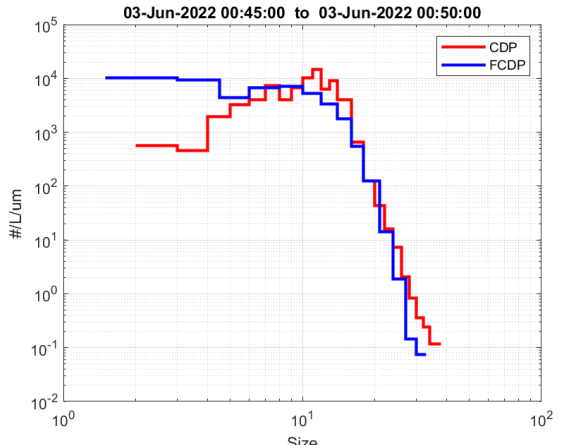
Convair-580: Aerosol (CCN, UHSAS, SP2, CPC, CVI, CFDC), In-situ cloud (CDP, FCDP, 2D-S, CIP, PIP, HVPS, HOLODEC, RICE, Nevzorov), State/Vapor (Licor, T, Edgetech, AIMMS-20), Radar (W-band, X-band, Lidar)
Lear: In-situ cloud (2D-Gray, 2D-S, HVPS-4, FFSSP, FCDP, Hawkeye), turbulence (AIMSS-20) and radar (KPR)

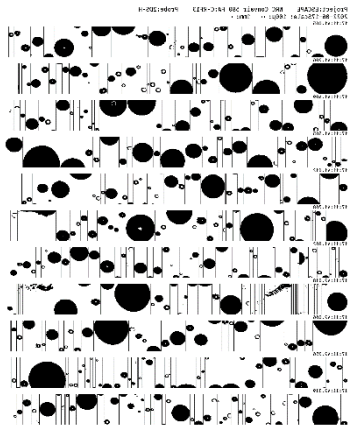


Unique Set of Data

• 13 Flights of Convair-580 and 11 flights of SPEC Learjet made in large variety of conditions

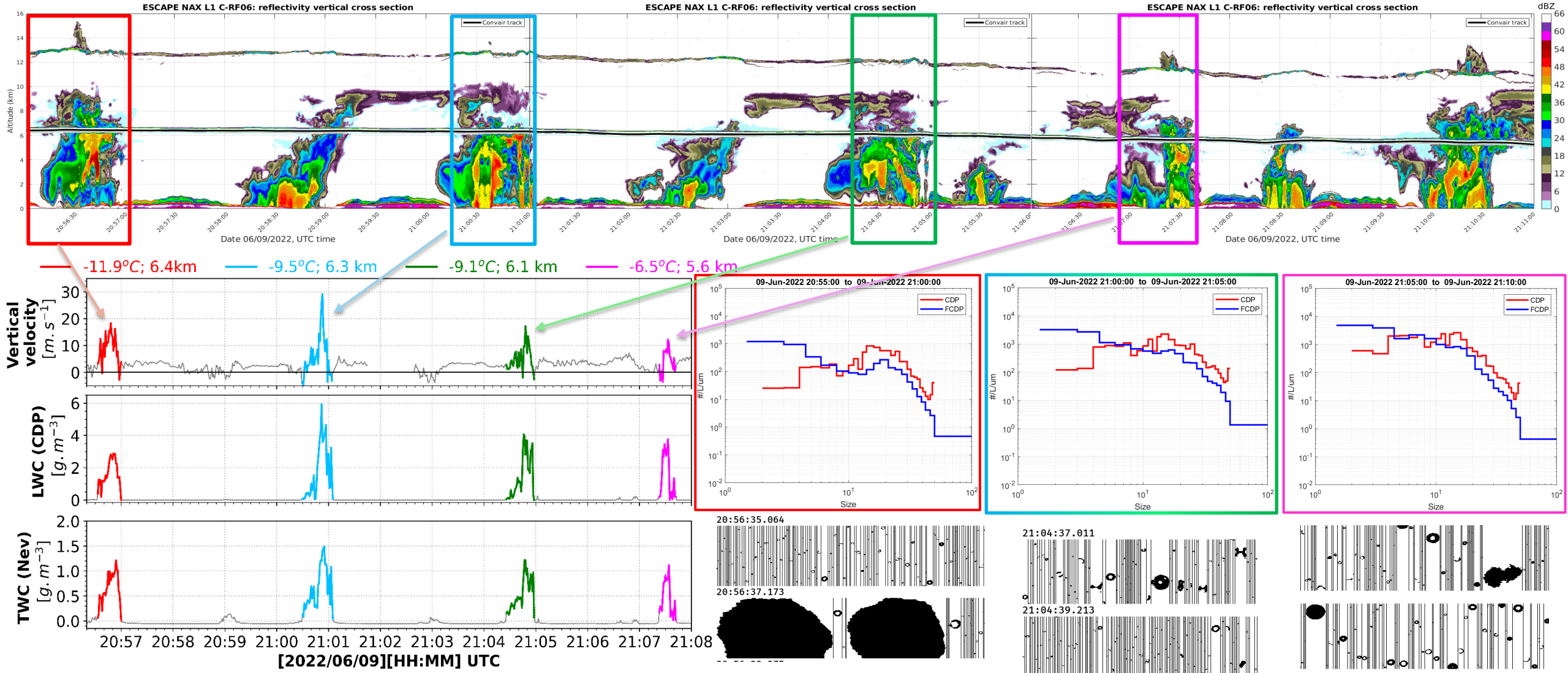
Compare SDs between all probes & algorithms





Example of Observations in Heavy Updrafts, 9 June 2022, C-RF06

- X band radar observations from repeated traverses through same cell at different temperatures.



- Non quality controlled data show ***w*** up to 30 m s^{-1}, ***LWC*** up to 6 g m^{-3}.