Regional Variability of Thermodynamics/Seabreeze Insights from the TRACER Field Campaign

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Building Collaborations Around TRACER Science Objectives

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ARM CLIMATE RESEARCH FACILITY

TEXAS A&M UNIVERSITY

Why should we care about airmass heterogeneity?

- Pre-convective boundary layer development controls updraft size.

- Nonequilibrium convection in the midlatitudes, in the presence of gradients in large scale heating (aka mesoscale boundaries such as seabreeze circulations) and aerosol concentrations can have sustained aerosol effects on deep convective clouds and precipitation (Morrison and Grabowski 2013, Bechtold 2014, Leung 2023).

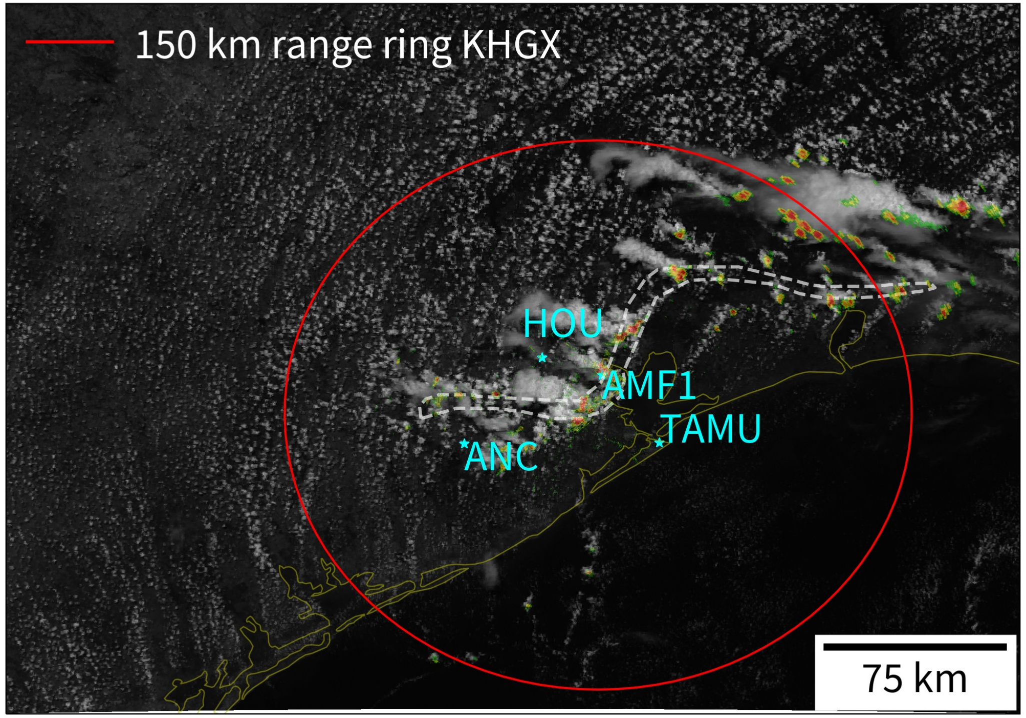
- To disentangle the role of background meteorology and aerosols in convective invigoration (water and ice-phase). Confounding variables?

- An often-overlooked component of aerosol-convection interactions in deep convective clouds is
  - Inflow airmass thermodynamics
  - Inflow airmass aerosol concentration
  - Vertical variability in aerosol concentration

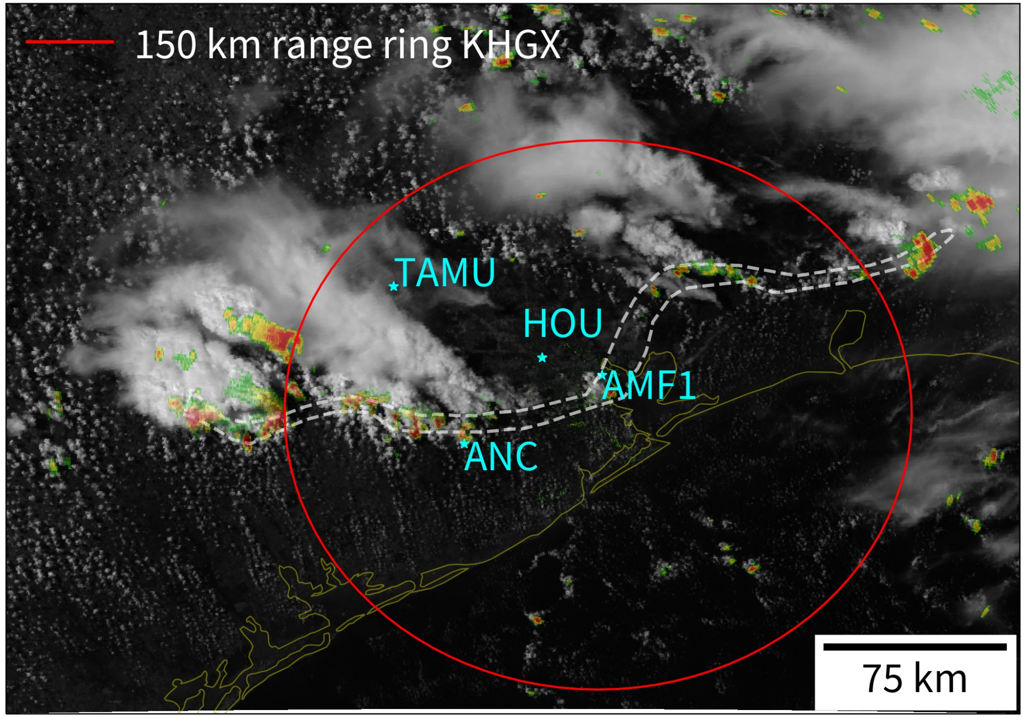
TAMU TRACER sampling strategy

TAMU TRACER IOP 09 (29 July 2022)

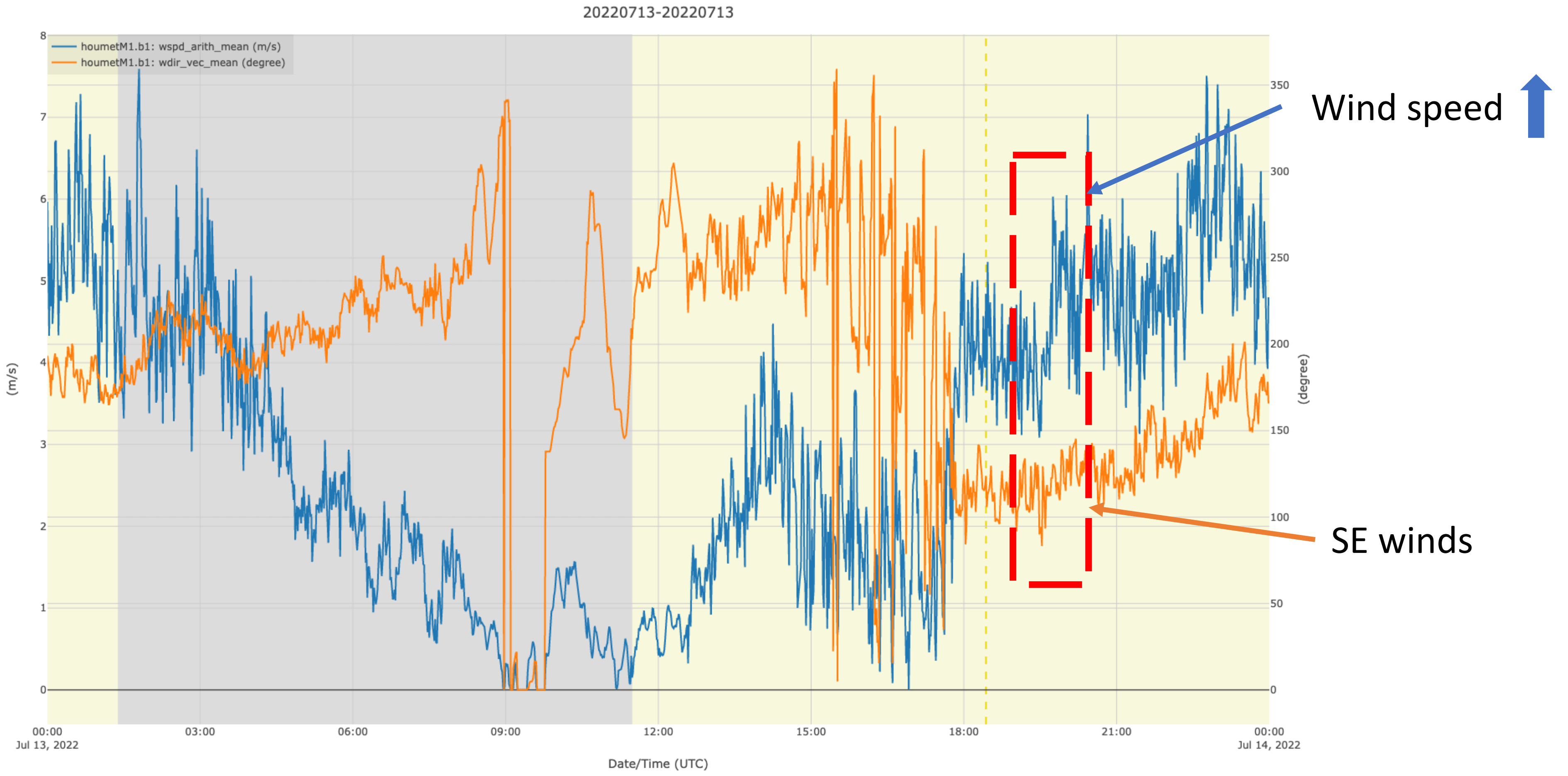
~1730 UTC



~2129 UTC



Meteograms used to classify airmass sampled by radiosondes



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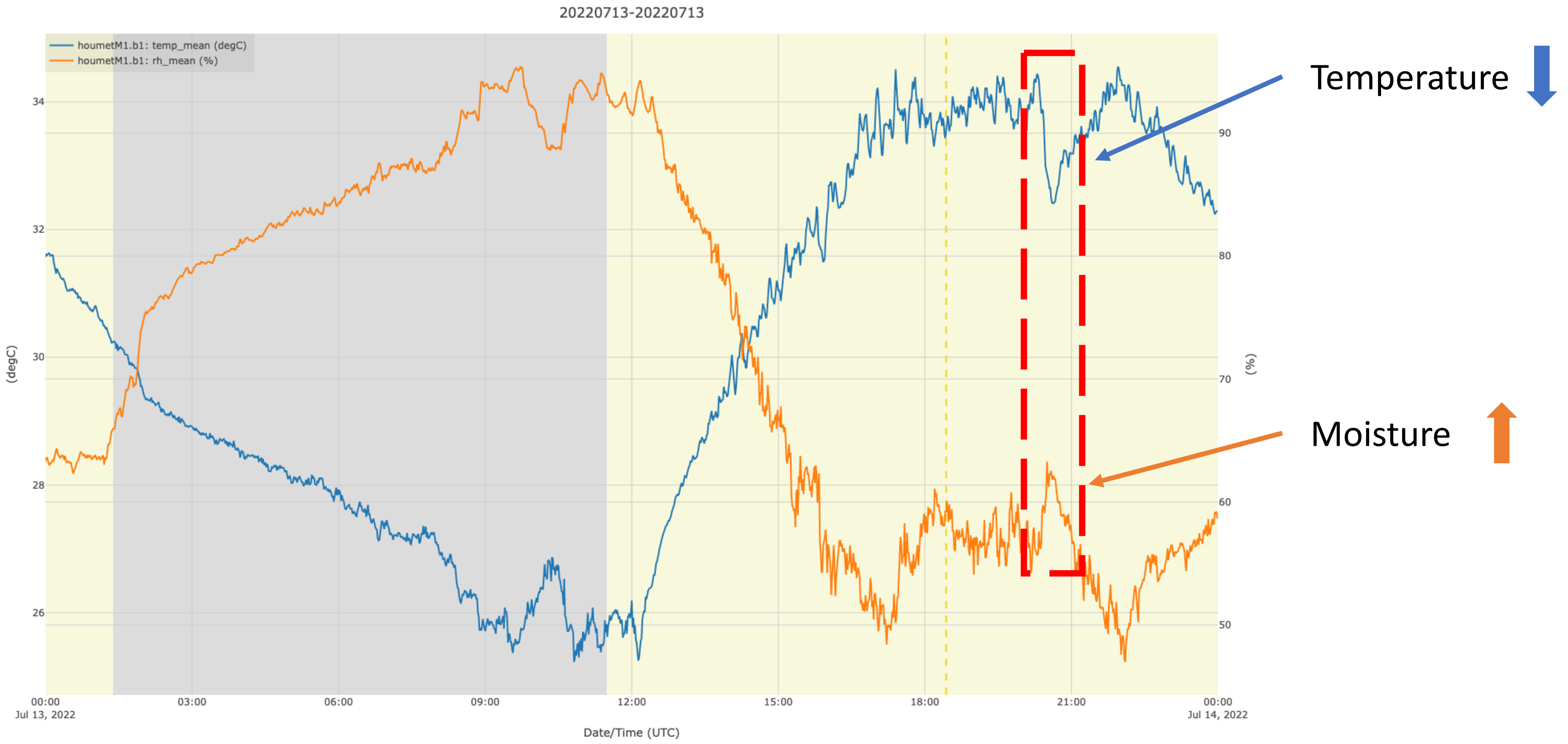
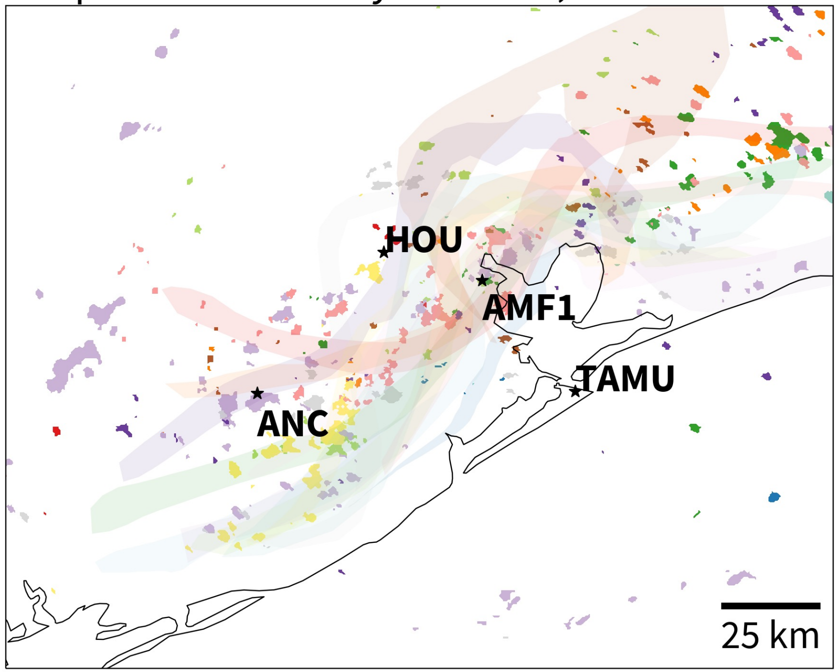


Seabreeze fronts tracked in time using spatiotemporal interpolation

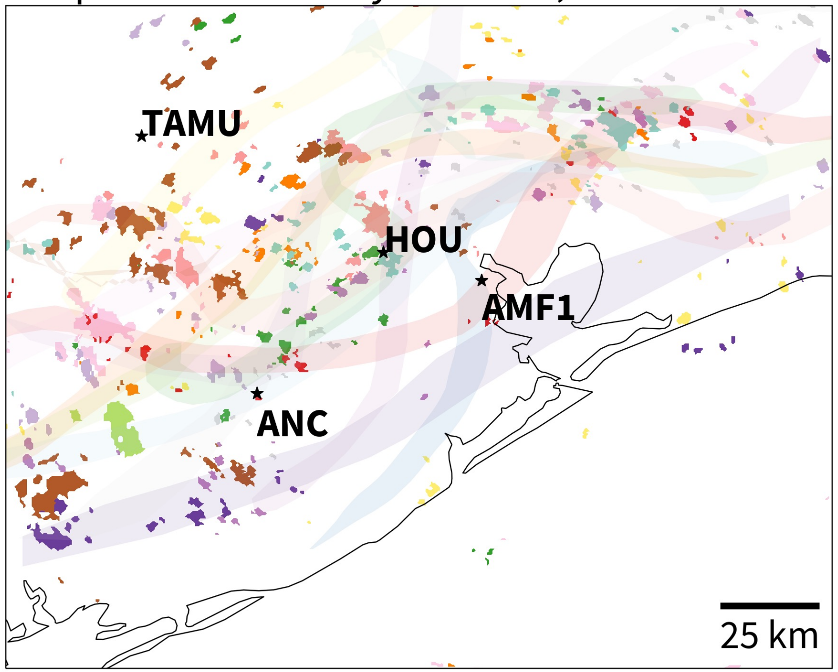
Early afternoon

Composite reflectivity > 35 dBZ, 1730-1830 UTC

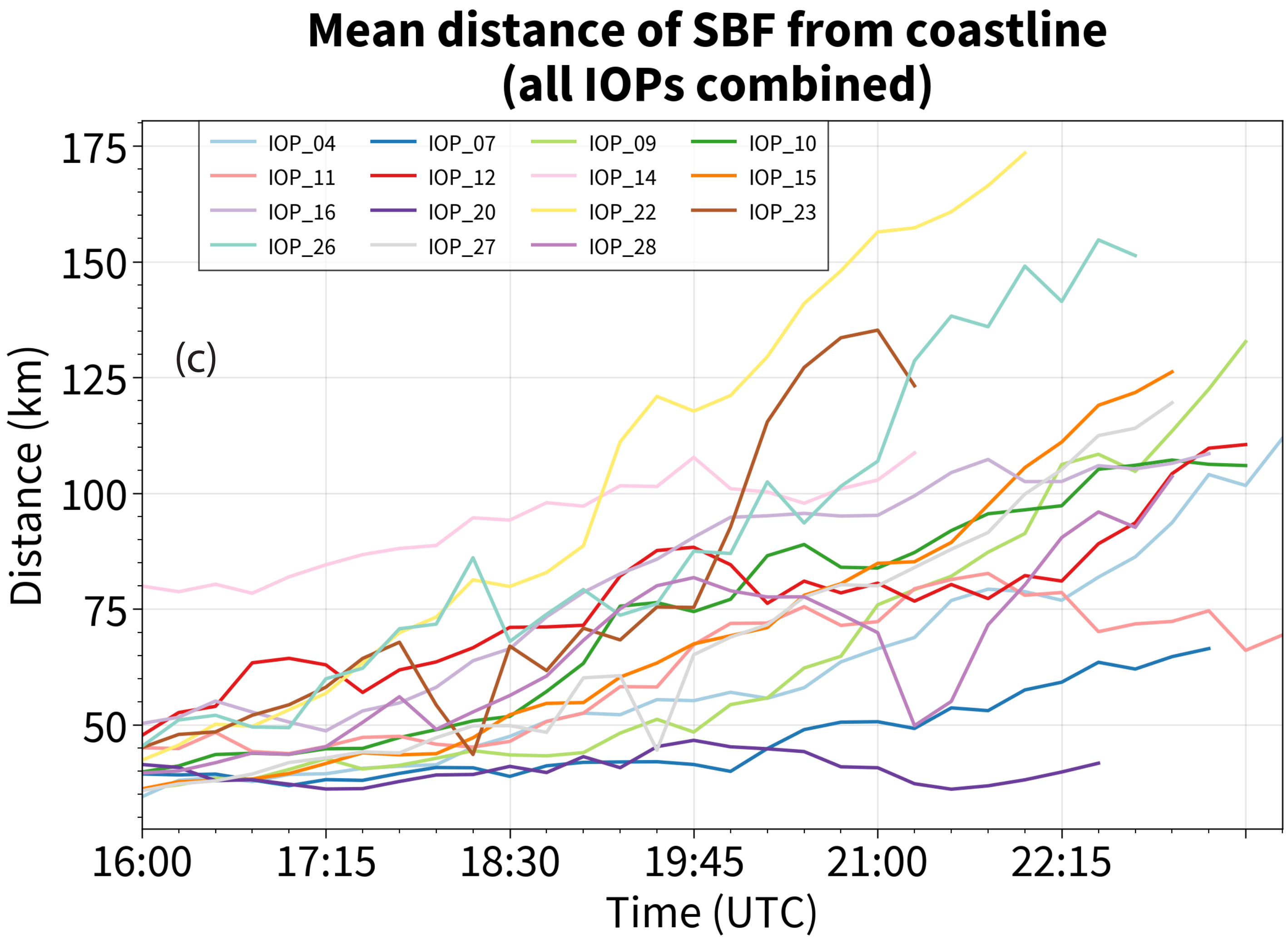


Late afternoon

Composite reflectivity > 35 dBZ, 2030-2130 UTC

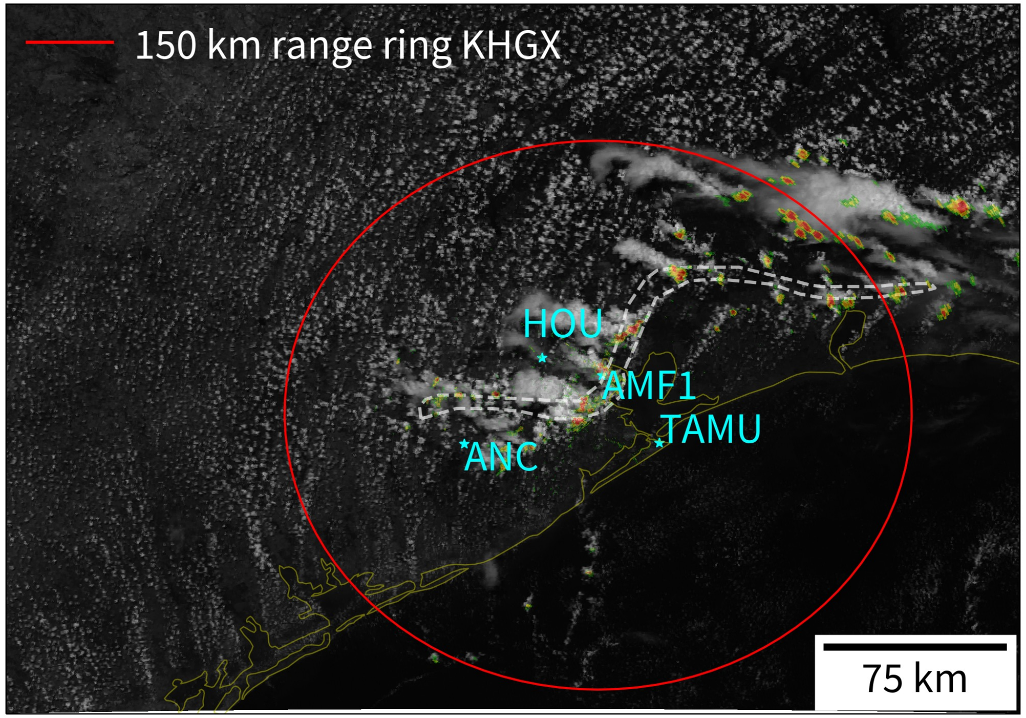


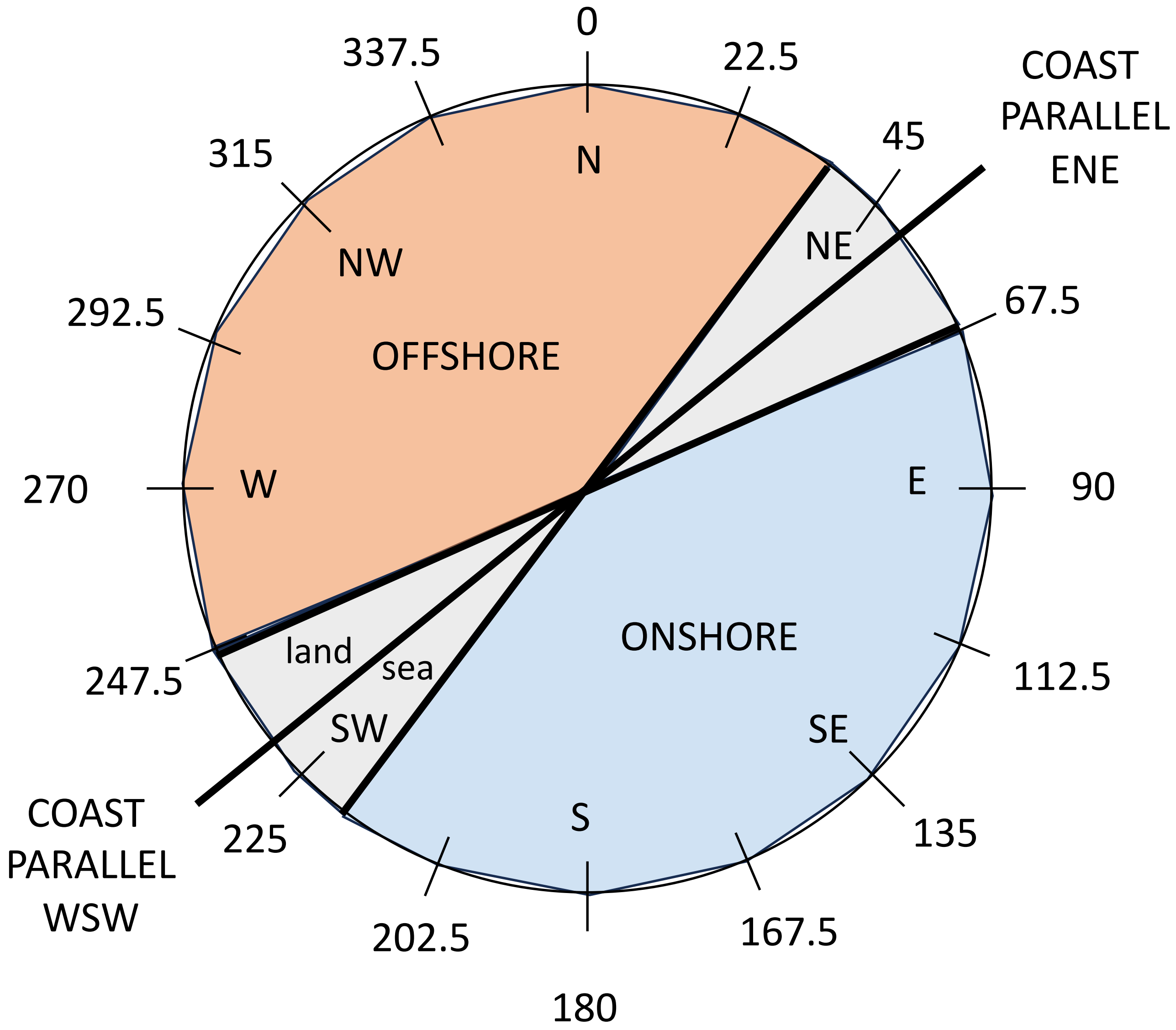
Seabreeze fronts tracked in time using spatiotemporal interpolation



Mesoscale/Seabreeze flow regimes between 16 and 22 UTC

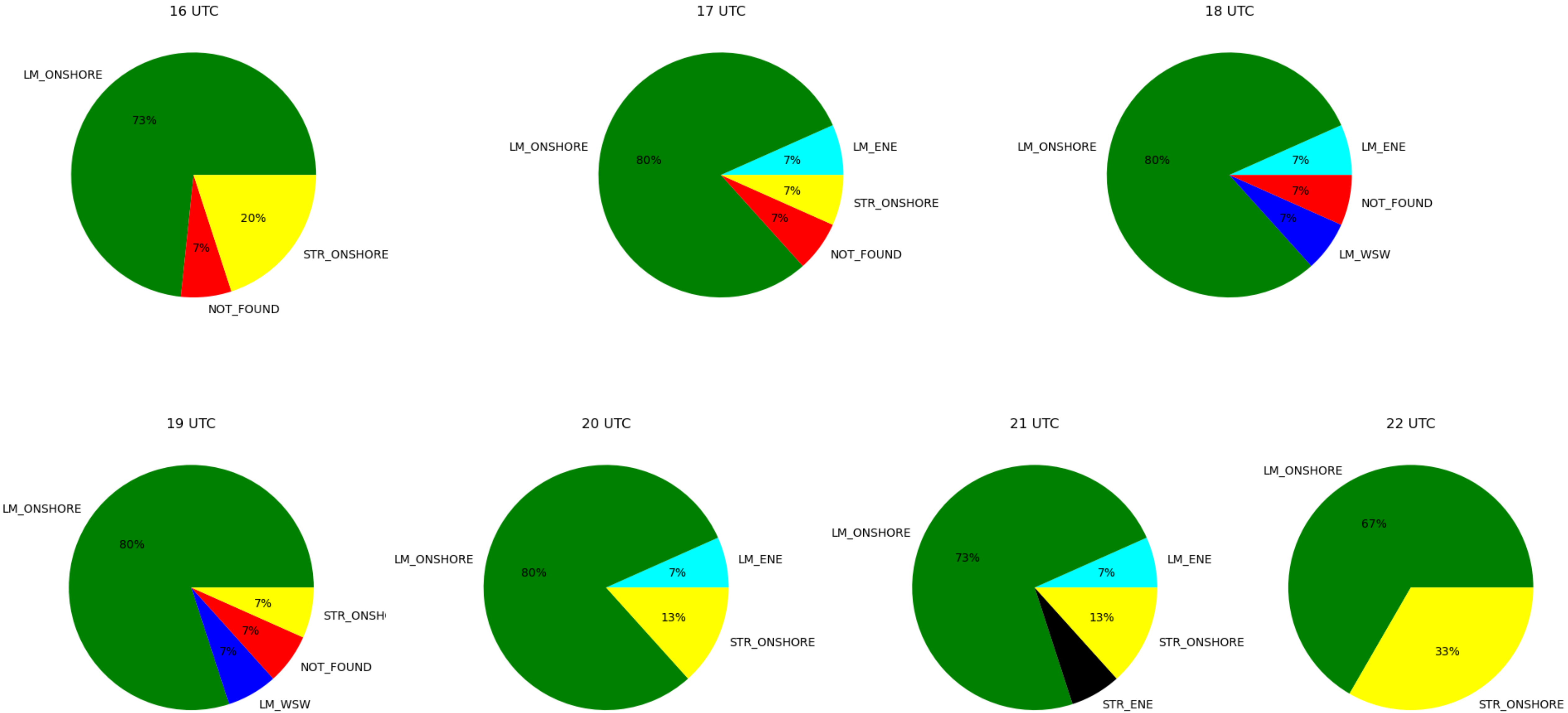
ERA5 850 hPa zonal and meridional winds



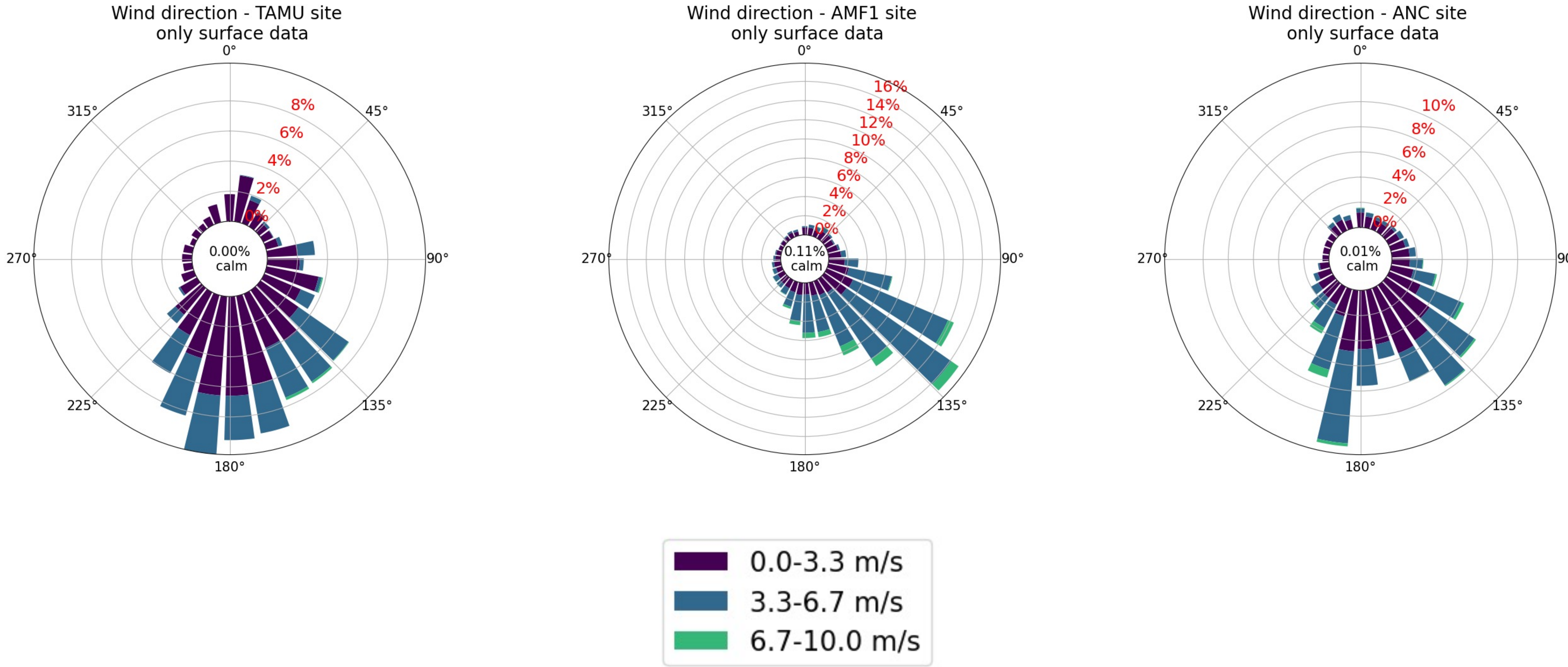


Light to moderate winds (wspd <= 5.14 m/s)
Strong winds (wspd > 5.14 m/s)

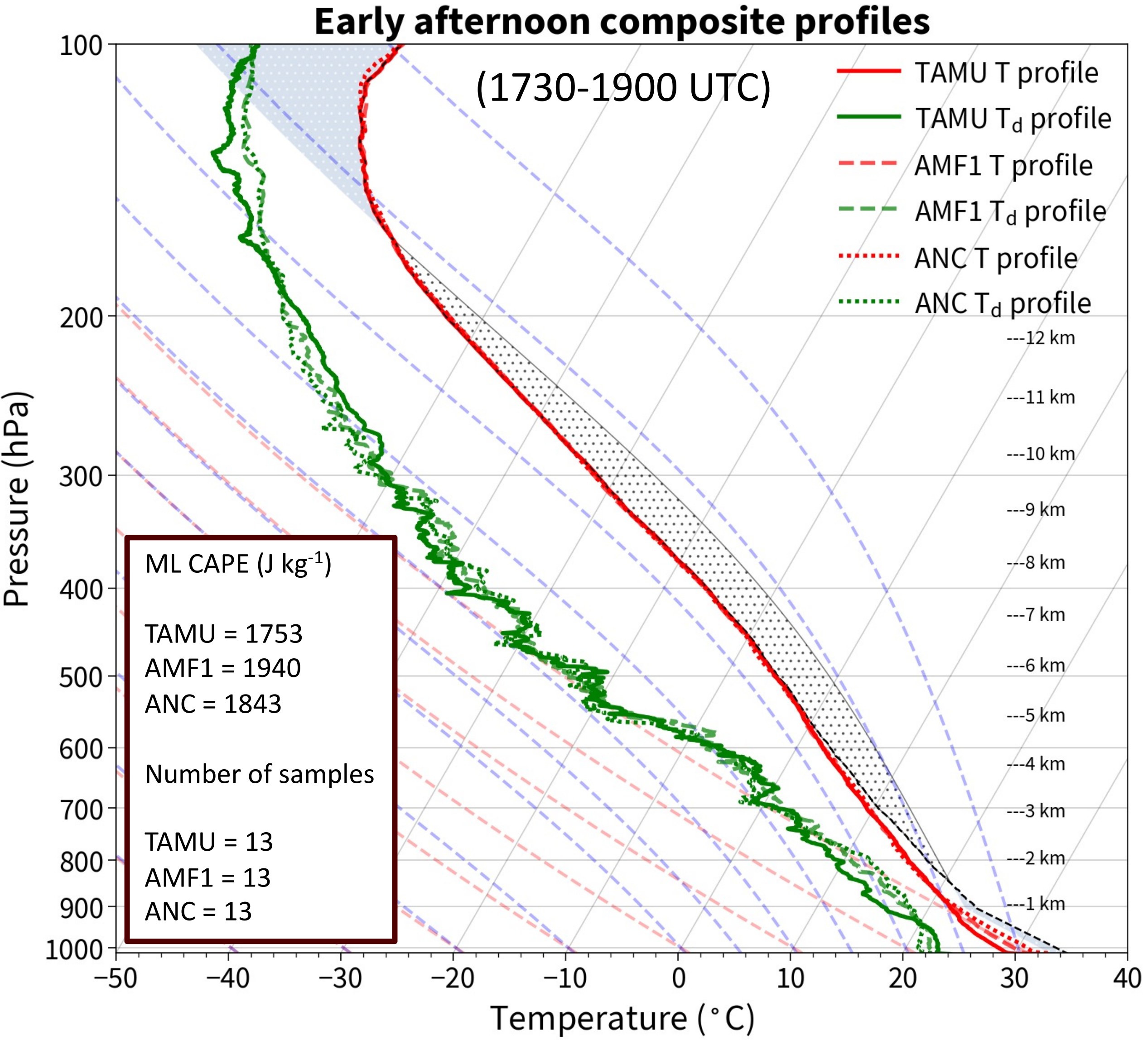
Molina and Chen (2009) https://link.springer.com/10.1007/s00704-008-0028-2

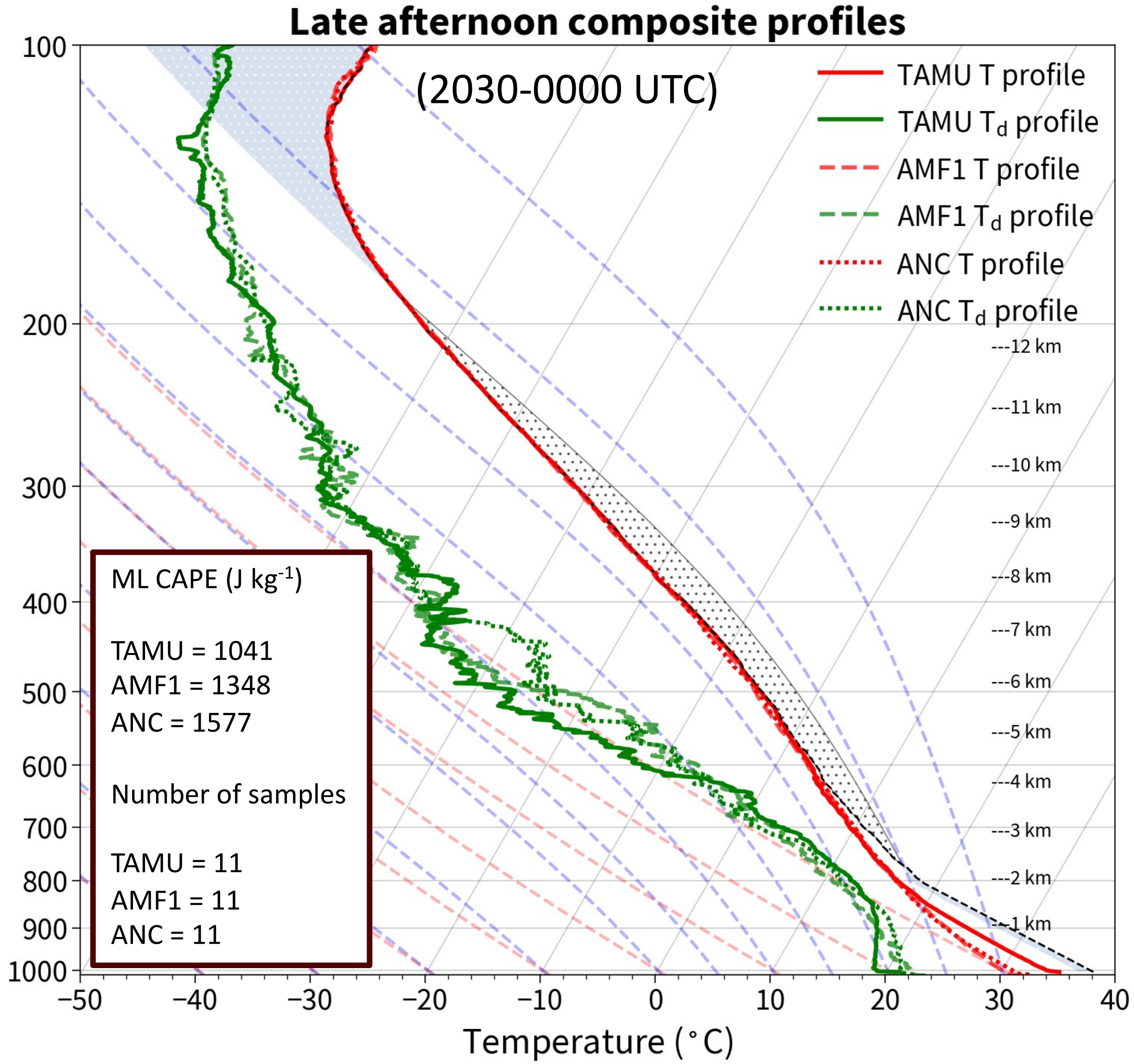

16 UTC
LM_ONSHORE
73%
20%
7%
STR_ONSHORE
NOT_FOUND
17 UTC
LM_ONSHORE
80%
LM_ENE
7%
7%
7%
STR_ONSHORE
NOT_FOUND
18 UTC
LM_ONSHORE
80%
LM_ENE
7%
7%
7%
NOT_FOUND
LM_WSW
19 UTC
LM_ONSHORE
80%
7%
STR_ONSH
7%
7%
NOT_FOUND
LM_WSW
20 UTC
LM_ONSHORE
80%
LM_ENE
7%
13%
STR_ONSHORE
21 UTC
LM_ONSHORE
73%
LM_ENE
7%
13%
STR_ONSHORE
STR_ENE
22 UTC
LM_ONSHORE
67%
33%
STR_ONSHORE

S or SE surface winds at ARM and TAMU sites

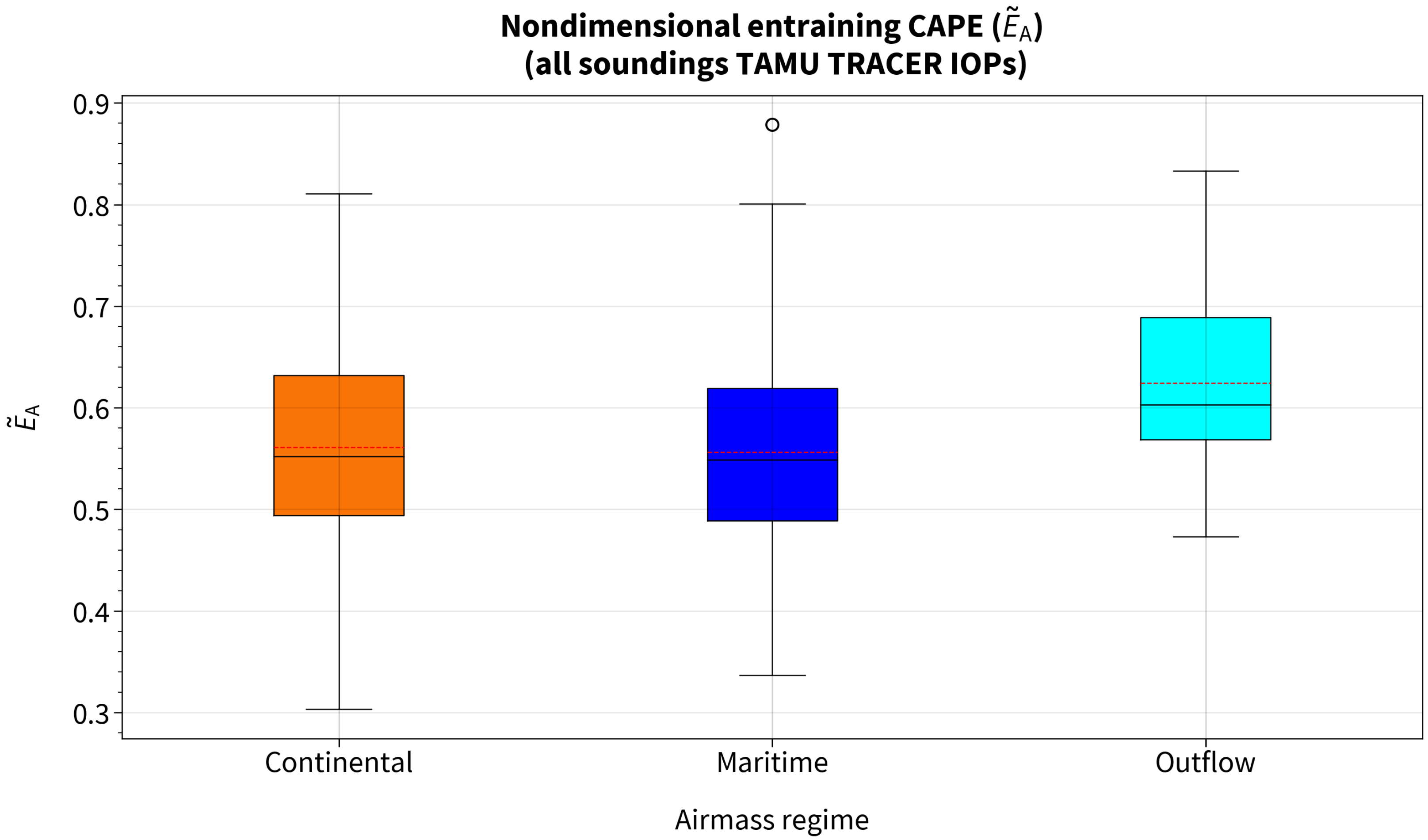


Drier PBL in late afternoon led to lower ML CAPE in continental airmass



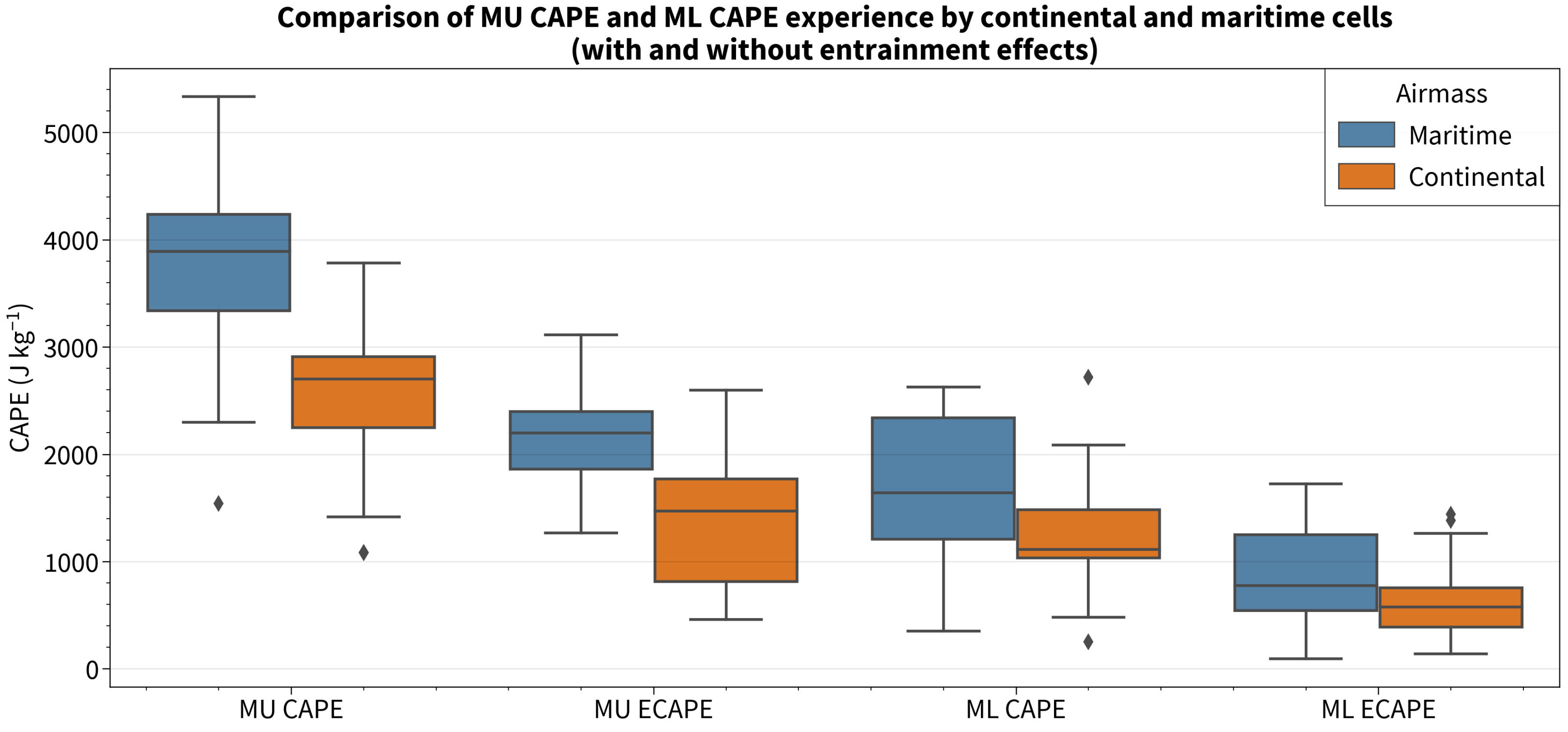


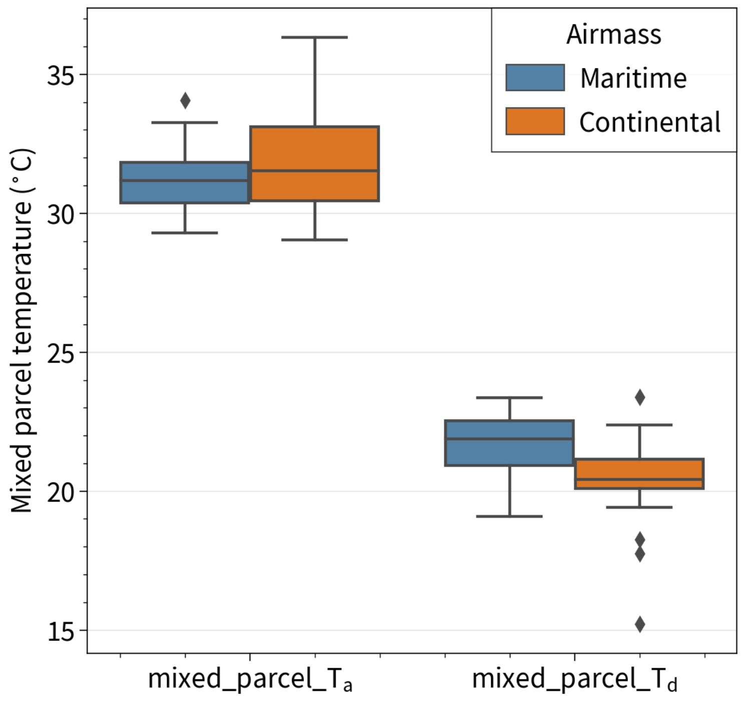
$$\frac{ECAPE(diluted\ parcel)}{CAPE\ (undiluted\ parcel)} \sim 50 - 75\%$$



Refer Peters et al. (2023) for ECAPE calculation
https://doi.org/10.48550/arXiv.2301.04712

Mixed-layer parcel combined with entrainment drastically reduces parcel buoyancy



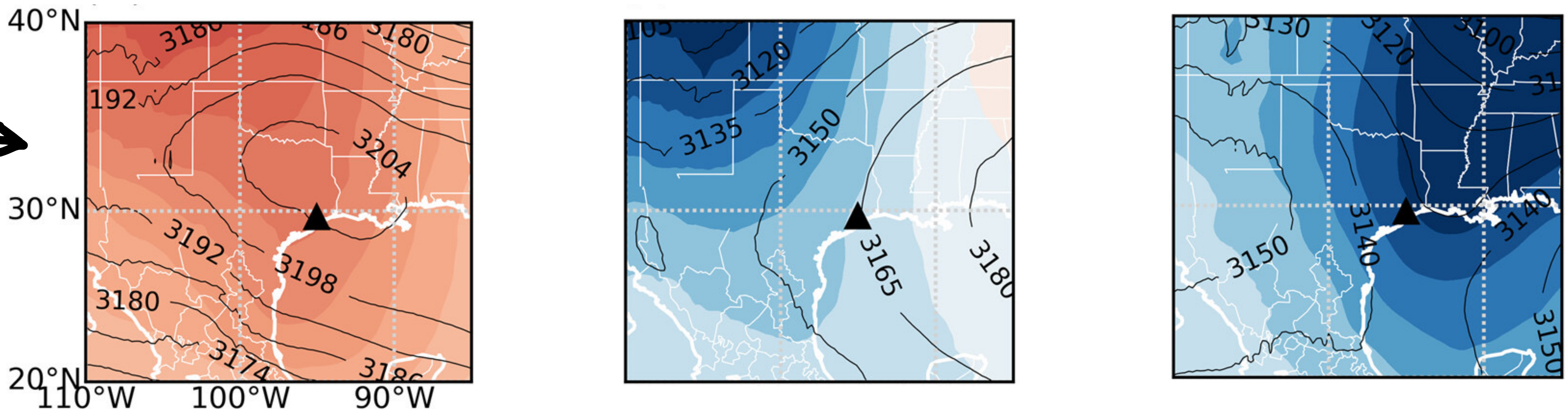


Anticyclonic synoptic pattern favors seabreezes

ERA-5 reanalysis data 23 years (2000-2022)
700 hPa geopotential height anomalies

Anticyclonic regime – westward shift of the Bermuda high – minimal synoptic influence –seabreeze convection peak (July and August)

Anticyclonic | Pre-trough | Post-trough



Wang et al. (2022) https://doi.org/10.1029/2021JD035920

Sea-breeze Variability during TRACER

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

Motivation:

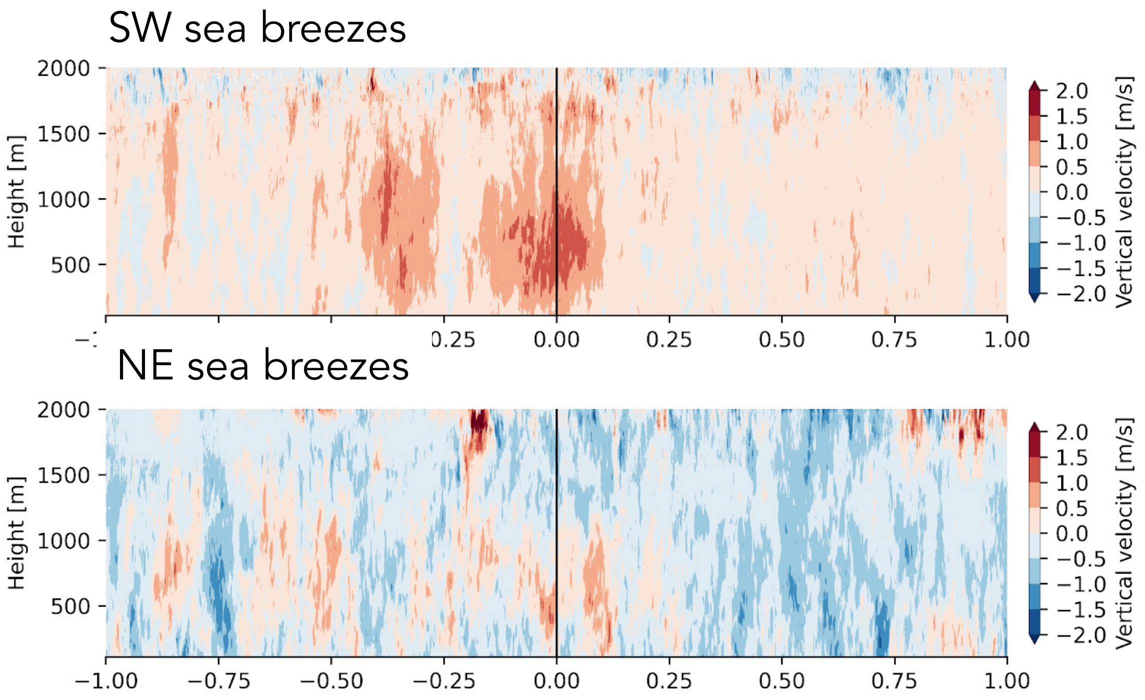
Understanding the structure of the sea-breeze circulation and the lifecycle of the associated convective clouds.

Methods:

Using measurements collected from multiple observational platforms to quantify the cloud, aerosol, thermodynamic, dynamic, and radiation properties associated with sea-breeze circulations.

Preliminary Results:

- **~60** sea-breeze cases were identified during the TRACER IOP. Under surface wind conditions of SW and NE, sea breezes tend to occur more frequently.
- SW sea breezes promote stronger, deeper, and wider updrafts compared to NE sea breezes
- Sea-breeze induced convective clouds are isolated, shorter-lived, and smaller in size. NE sea breezes show a lower cloud top compared to other sea breeze cases

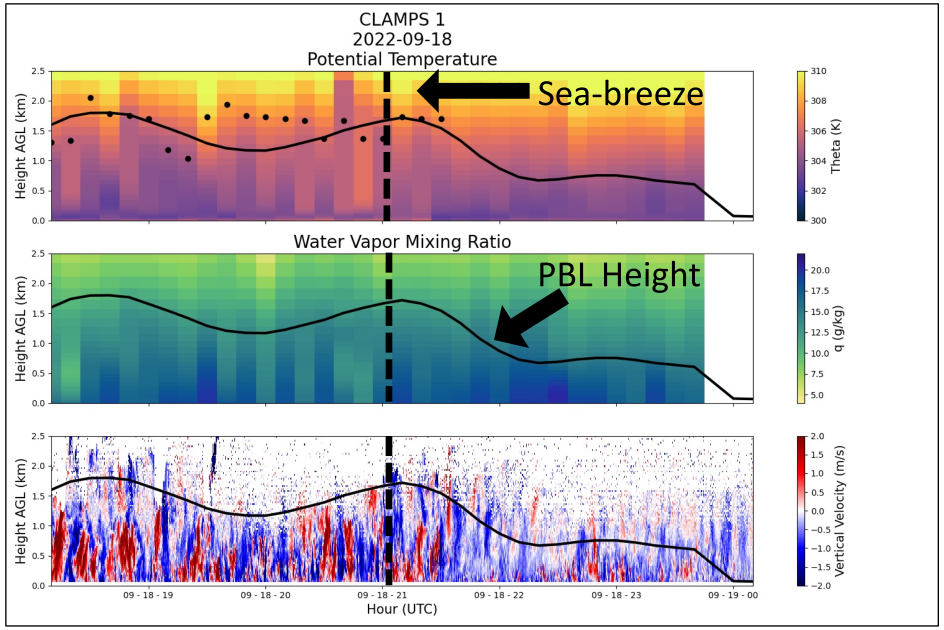


CUBIC and UAS

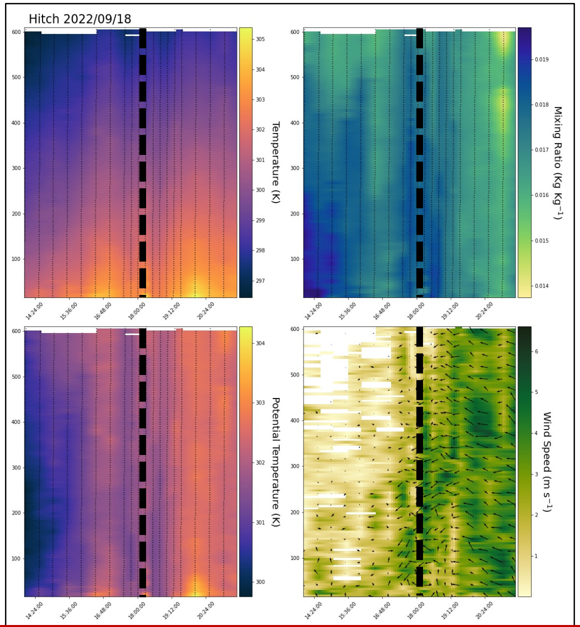
Check out posters **37** and **21**!

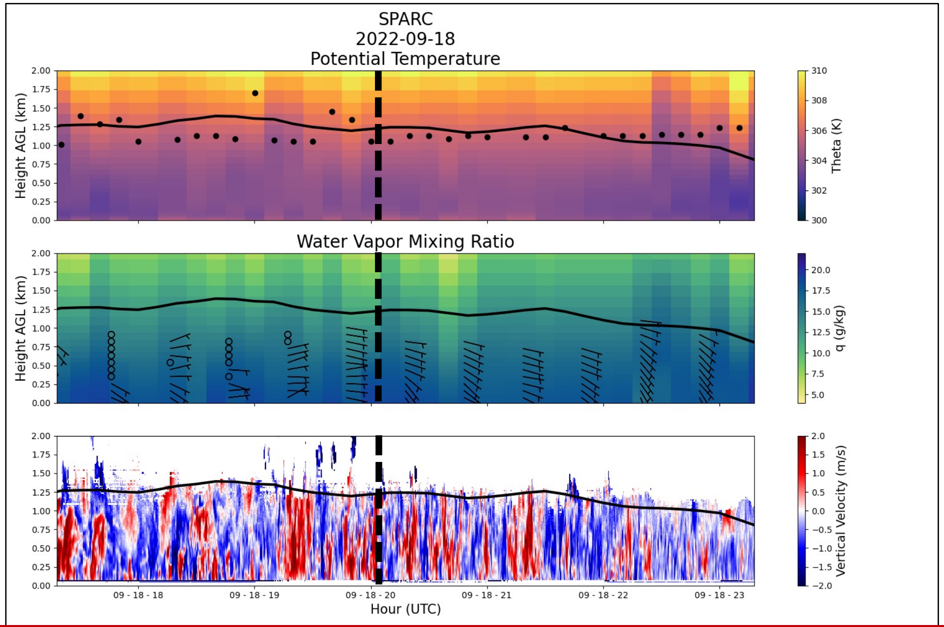
Sea-breeze effects on PBL vary across the greater Houston area

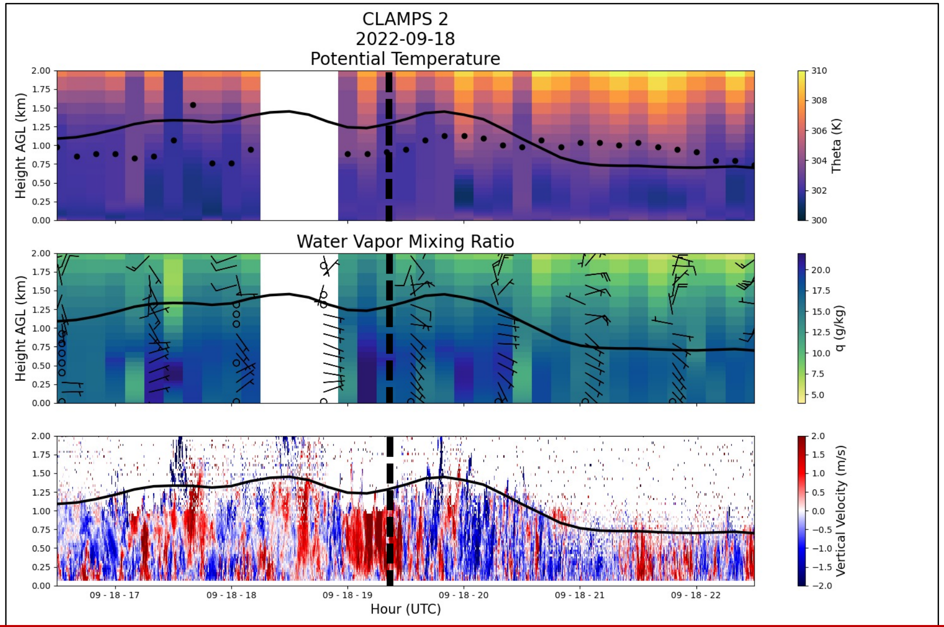
- Three mobile profiling systems deployed
- UAS flights near the coast
- Timing, depth, and inland penetration of sea-breeze vary greatly from case to case



PBL height, thermodynamic, and kinematic responses to sea-breeze from each site on 9-18-2022







Michelle Spencer, Francesca Lappin, Petra Klein, Elizabeth Smith, Tim Wagner, and Gijs de Boer

Key Takeaways

- Mesoscale boundaries of varying degree of thermodynamic properties were found to exist at the fixed and mobile sites. Convective outflow, anvil shading, and urban heat island effects may result in complex evolution of the boundary layer during the course of the day.

- TRACER Aerosol-Convection studies need to embrace the spatiotemporal heterogeneity in thermodynamics across the sea and bay-breeze fronts.

- Investigate the covariability of environmental instability and aerosol concentration during active seabreeze IOP days.

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