Developing capabilities for low-altitude rotary and fixed wing sUAS to fill a critical gap in boundary layer observations

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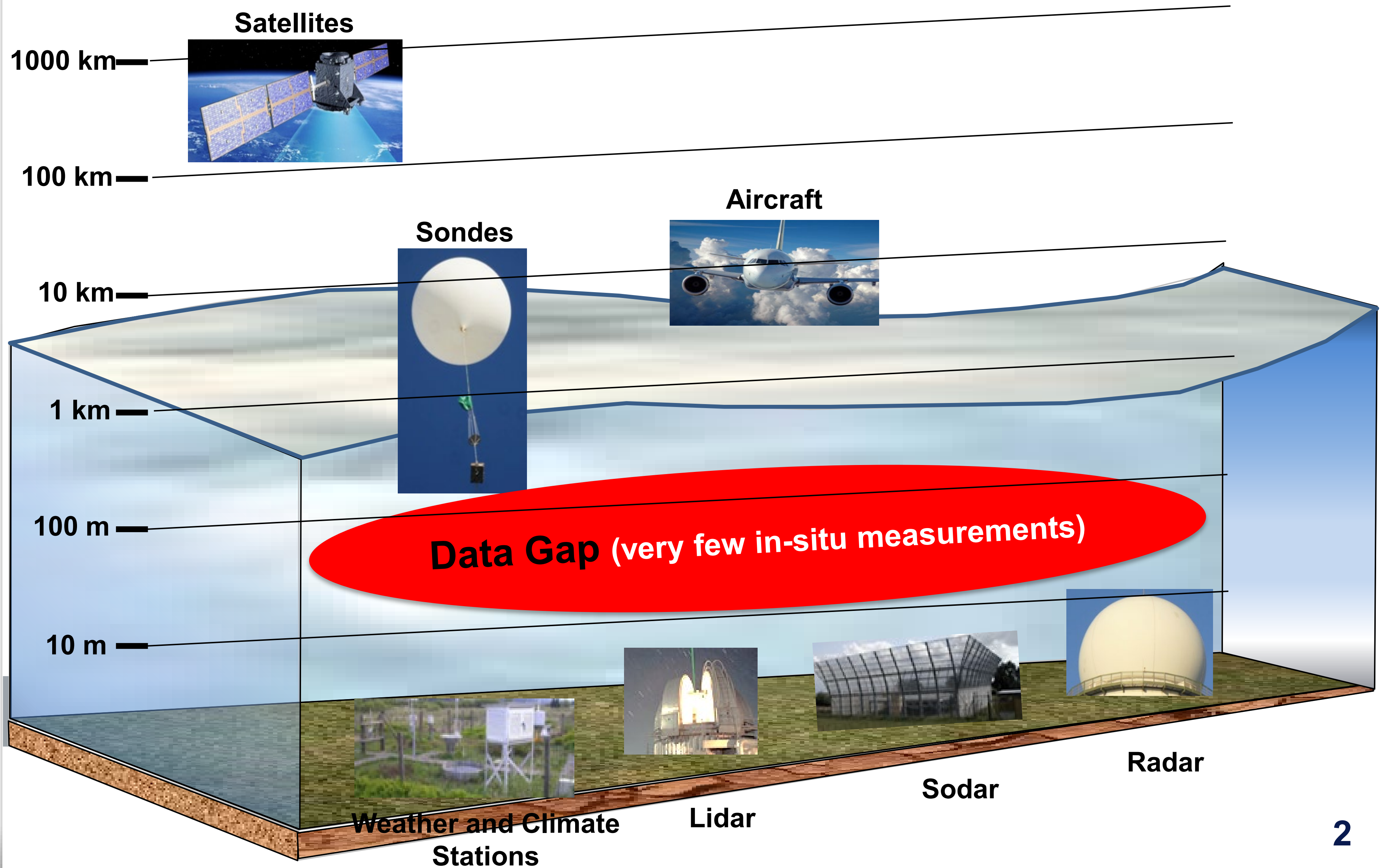
Current and Future Uses of UASs
Norman, OK
29 Oct 2019

1 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE, NOAA
2 CIMMS Cooperative Institute for Mesoscale Meteorological Studies
3 ORAU Further. Together.

Importance of sUAS



Goal: Use sUAS to improve Weather Forecasts

Improve scientific understanding of the physical processes occurring within the planetary boundary layer, using novel observational and modeling techniques, so that these processes can be better represented in weather forecast models

NOAA / ARL / ATDD sUAS Platforms

Model	DJI S-1000	MD4-1000	Meteodrone SSE	BlackSwift S2
				
Registration	N542FC	N536JN	FA3NEYLHN3	FA3PTCFHWM
Manufacturer	DJI	Microdrone	Meteodrone	BlackSwift Technologies
Units in Fleet	1	1	2	2
Vehicle Type	Multi-rotor	Multi-rotor	Multi-rotor	Fixed-wing
Gross Weight	11 kg	3.85 kg	0.7 kg	6.6 kg
Wing Span	1.0 m	1.0 m	0.6 m	3.0 m
Length	1.0 m	1.0 m	0.6 m	2.0 m
Payload Capacity	4.5 kg	1.2 kg	--	2.3 kg
Engine Type	8 electric motors	4 electric motors	6 electric motors	1 electric motor
Autopilot	DJI A2 with iOSD Mk II	Microdrone	Meteodrone	SwiftPilot
Max Speed	10 m s^{-1}	10 m s^{-1}	19 m s^{-1}	24.7 m/s
Loiter Speed	0 m s^{-1}	0 m s^{-1}	0 m s^{-1}	15 m/s
Endurance	15 min	25 min	20 min	80 min
Ceiling	365 m	500 m	3000 m	3000 m

Low Altitude sUAS Observations are Useful for Forecasting

Early Successes

- DJI S-1000 sUAS flown during VORTEX-SE and LAFE (2014-2017) and used to observe incoming air masses and convective activity at the surface
- Use fixed-wing sUAS to scale temperature, water vapor, and winds to forecast scales validated using in-situ measurements
- NOAA now has a wide area COA approved by the FAA
- FAA approval to fly up to 1 km to improve local weather forecasts
- Meteodrones being used in operational NWP at MeteoSWISS provide accurate atmospheric measurements to 1.5 km AGL under windy conditions (up to 40 kt)

Key capabilities we can do operationally now with this technology

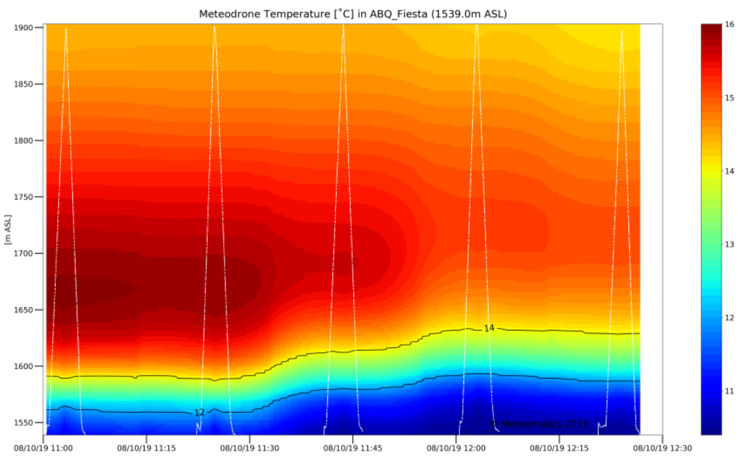
- Operating a fixed-wing sUAS in tandem with multiple rotary sUAS pairs to characterize the pre-convective ABL

- High-precision, fast-response sensors for accurately profiling boundary layer structure in the presence of strong winds

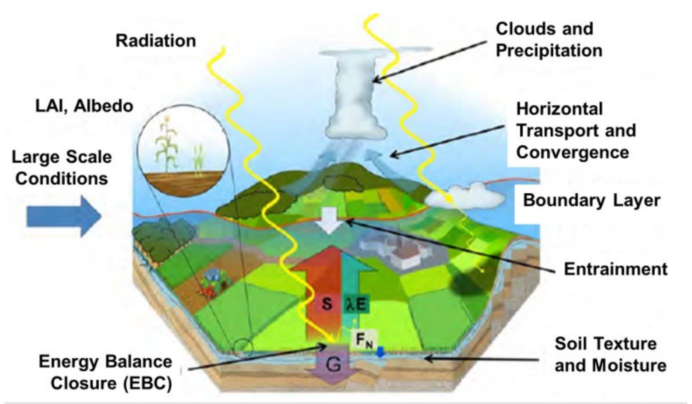
- Vertical takeoff and land (VTOL) sUAS have sophisticated autopilot systems and differential GPS positioning

- Boundary layer profiling up to 1 km

How do small unmanned aircraft systems help improve weather forecasts?



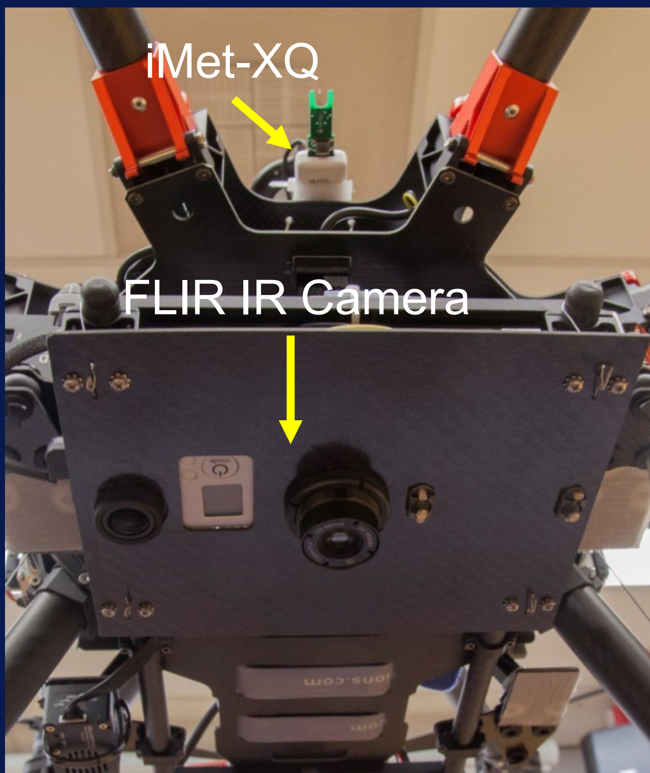
Real-time information on the current state of the atmosphere



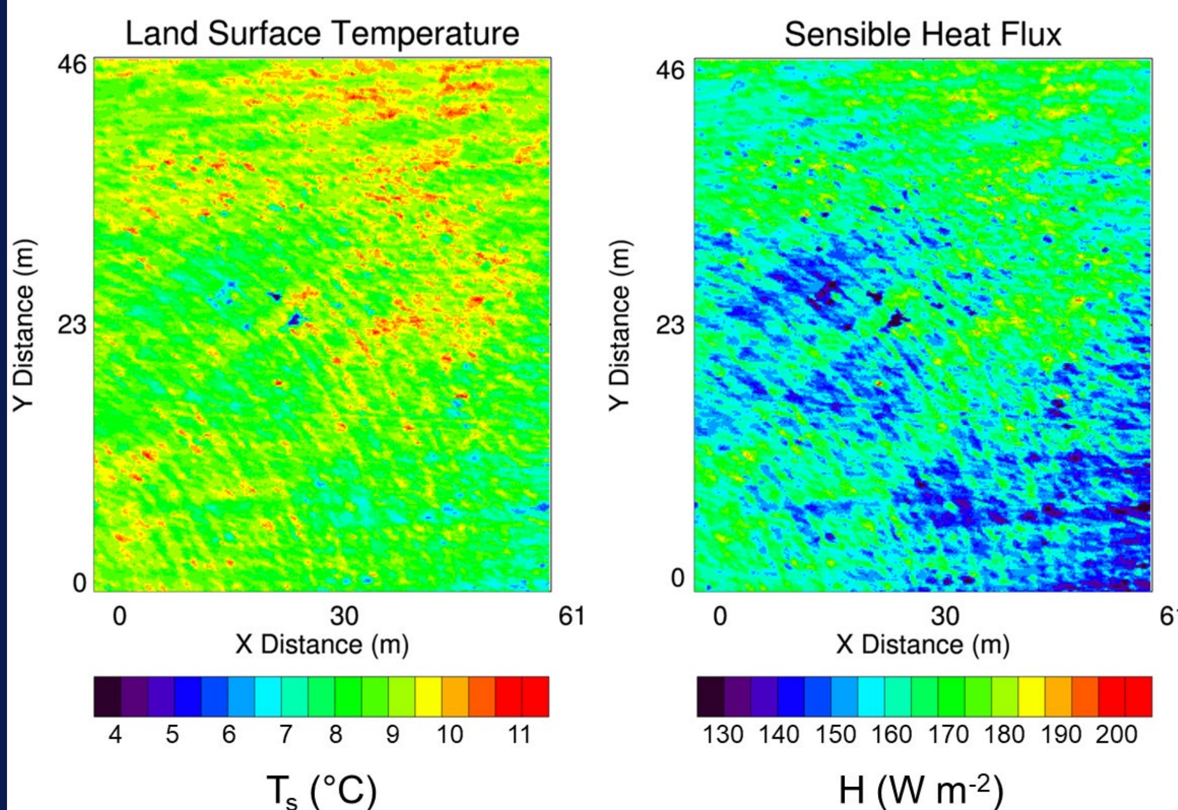
Improve scientific understanding of atmospheric processes

Fluxes from sUAS

Heat flux from sUAS computed as a function of difference between T_{sfc} and T_{air} and empirical constant derived from flux tower

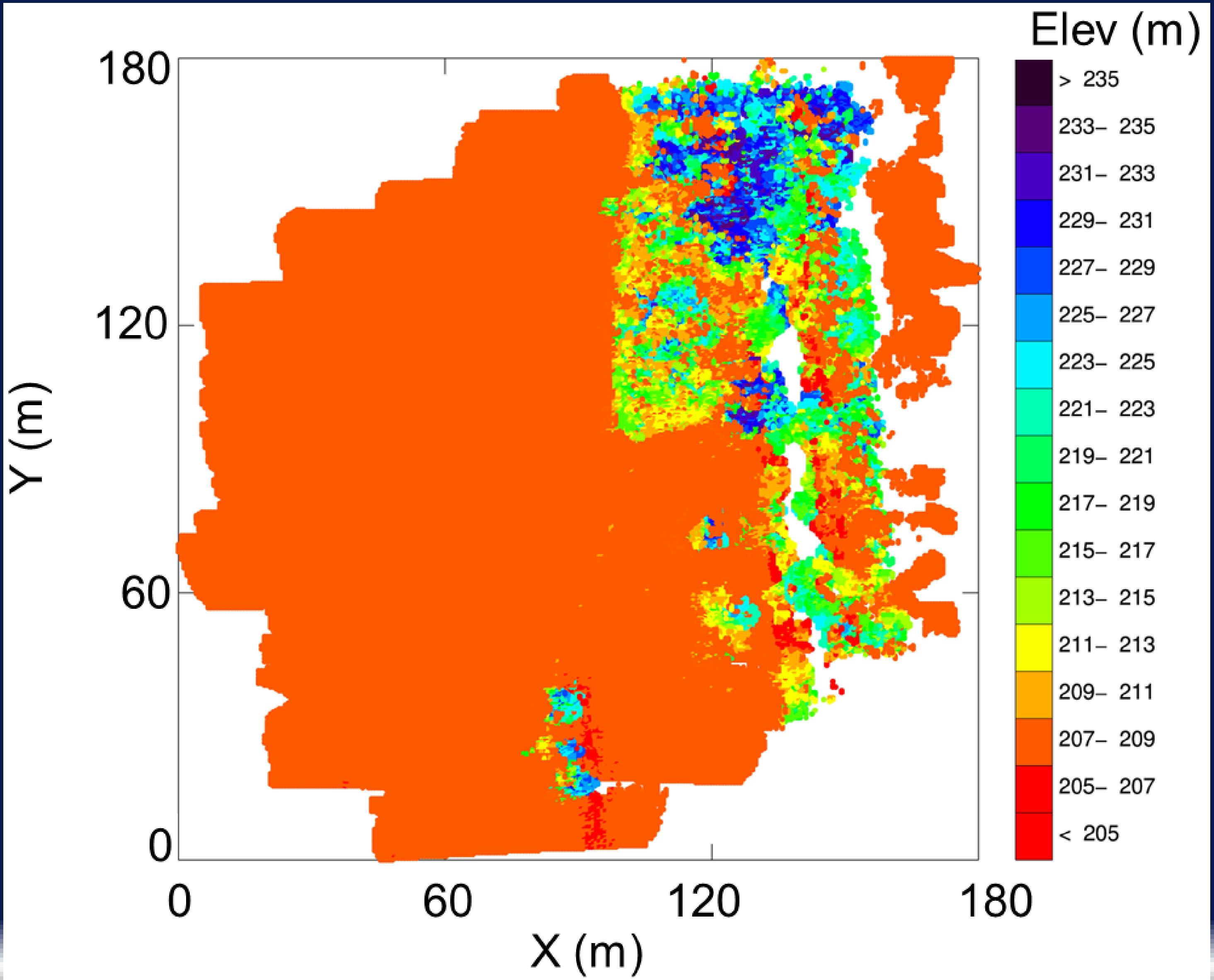


Underside of DJI S-1000 sUAS

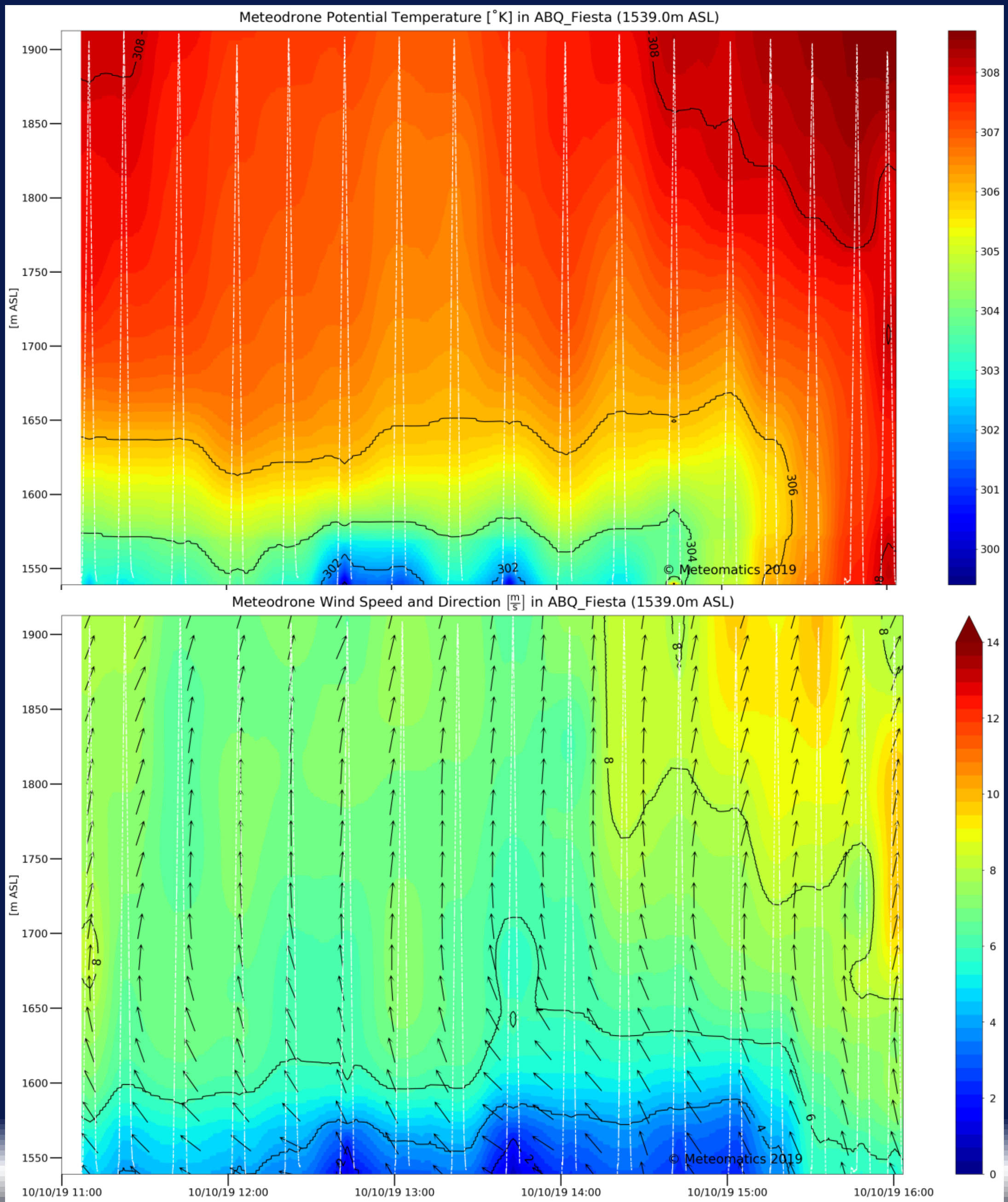


Lee et al. 2017

High-resolution Information on Surface Roughness from MD4-1000 Lidar

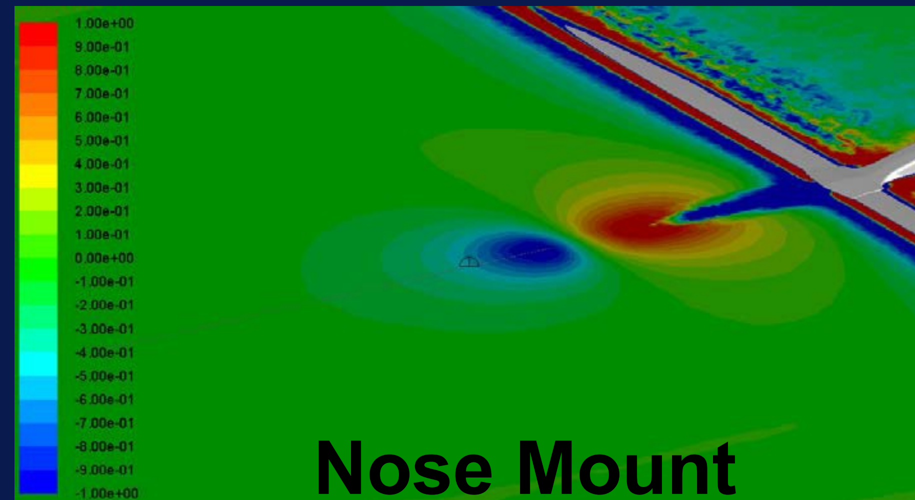


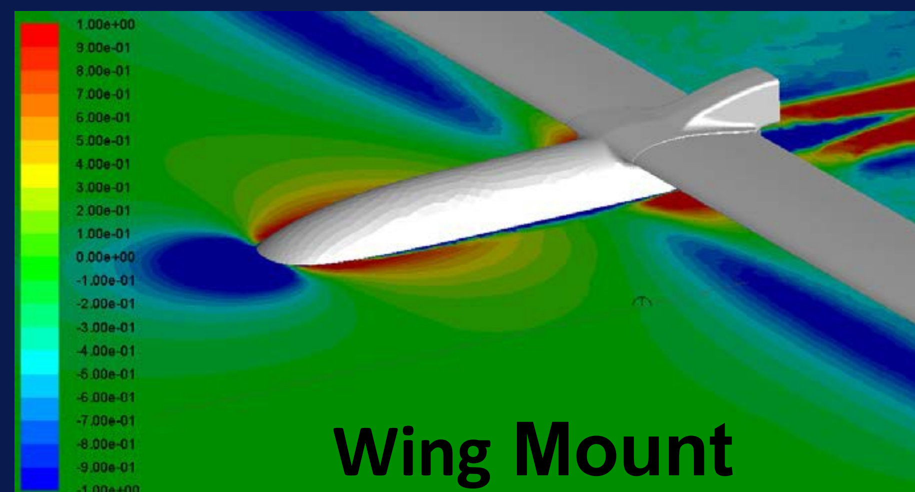
Vertical Profiles of θ and U from Meteomatics



BST MHP Probe for Fast-Response Wind Measurements

AOA = 0, AOS =0
Function = observed |V| - 18 m/s
Range = -1 to +1 m/s

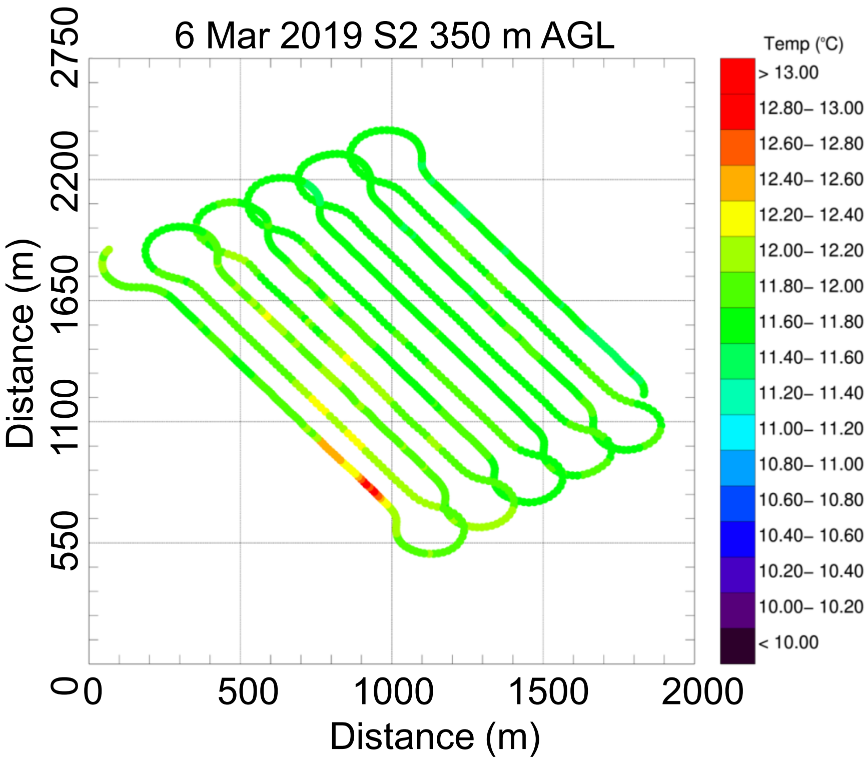


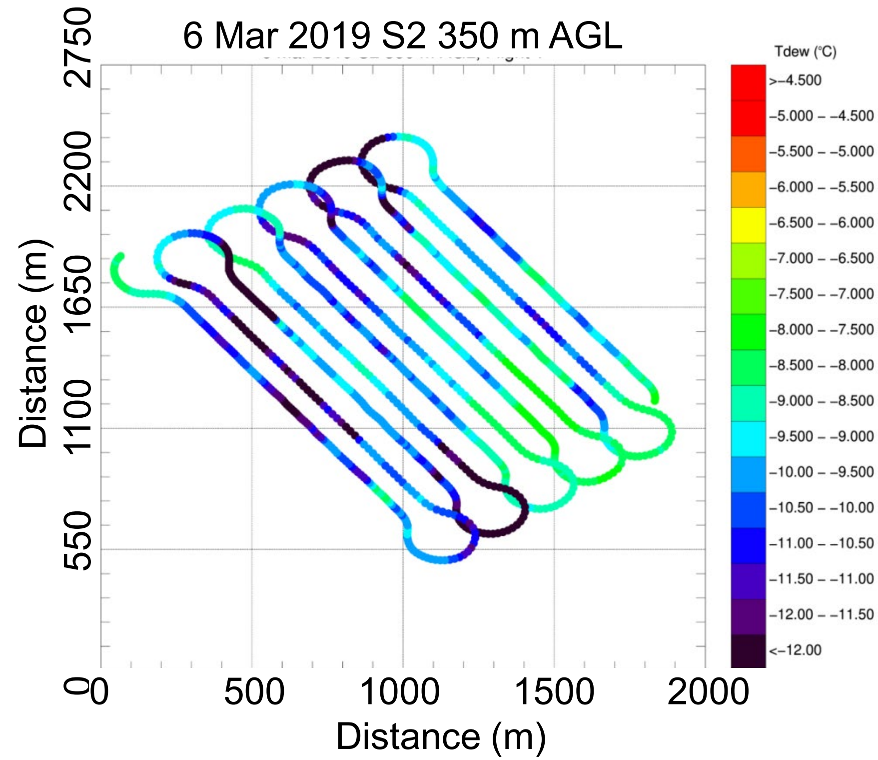


CFD calculations of flow distortion around the S2 Aircraft

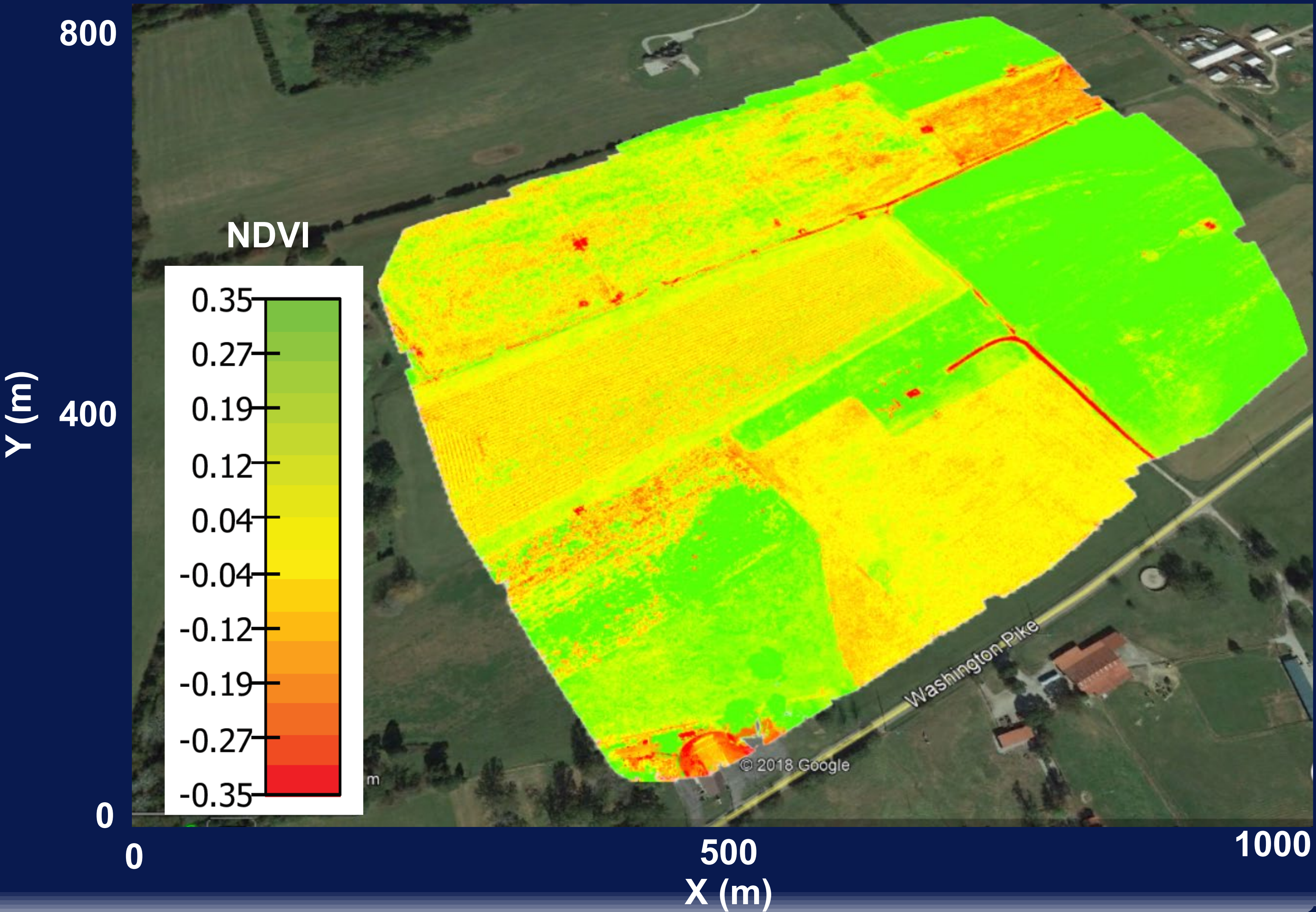
Lawnmower Flights using BST S2

Avon Park BST S2 6 Mar 2019 19:03-19:37 UTC





NDVI from MapIR on BST S2



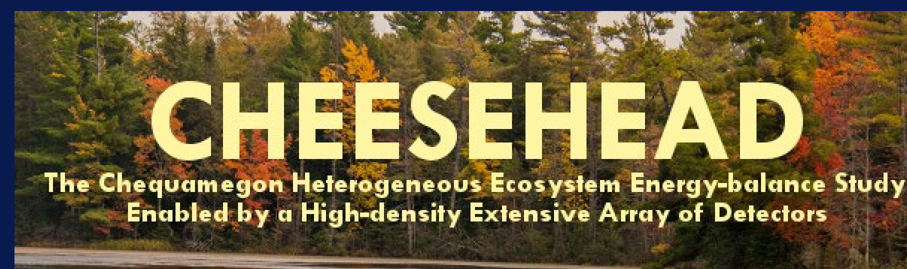
Recent Experiments

Mar-Apr 2016, 2017

Land Atmosphere Feedback Experiment

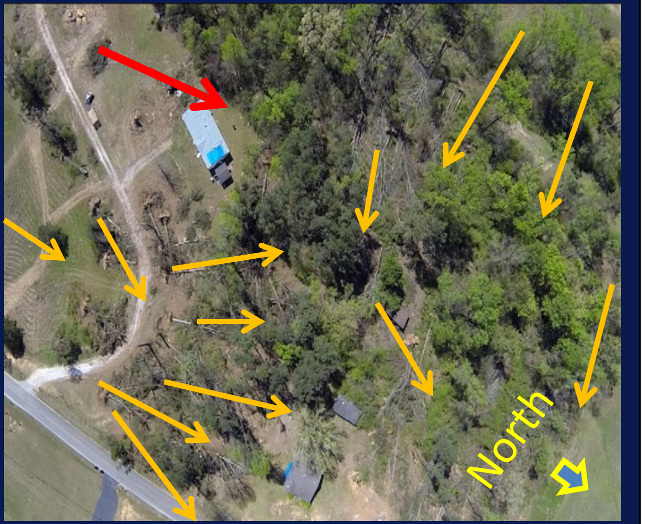
Aug 2017

Aug 2017

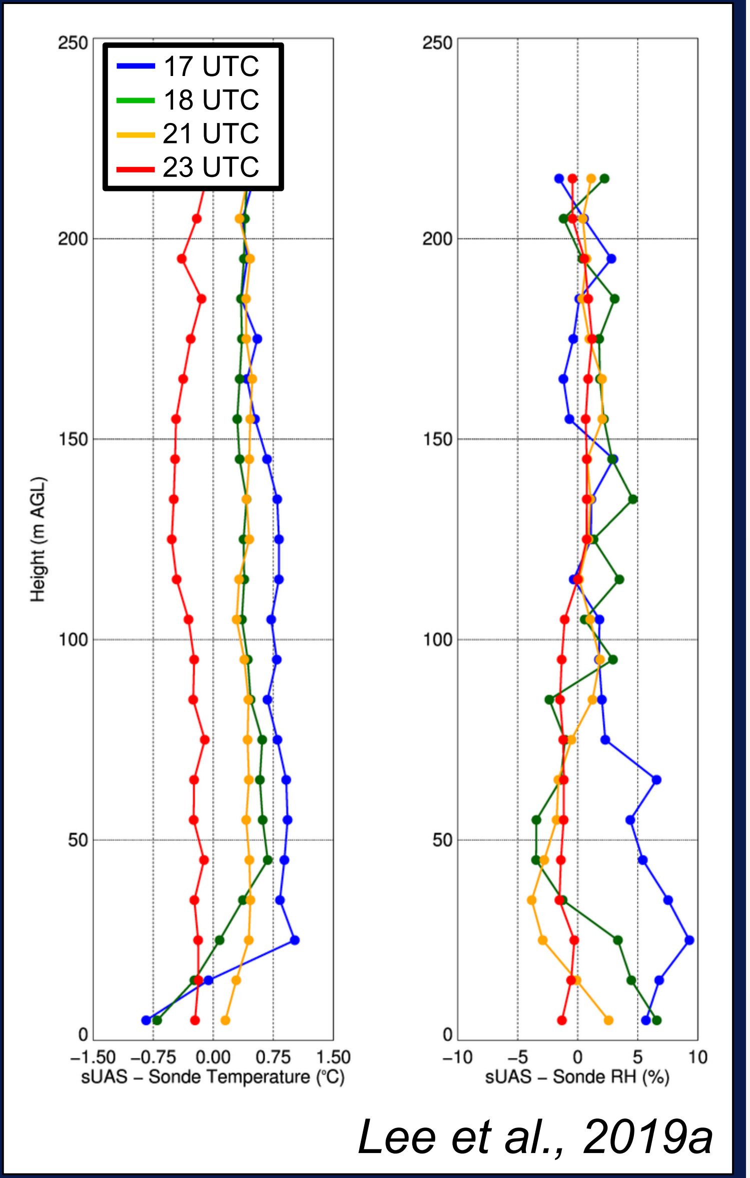


Jul-Sep 2019

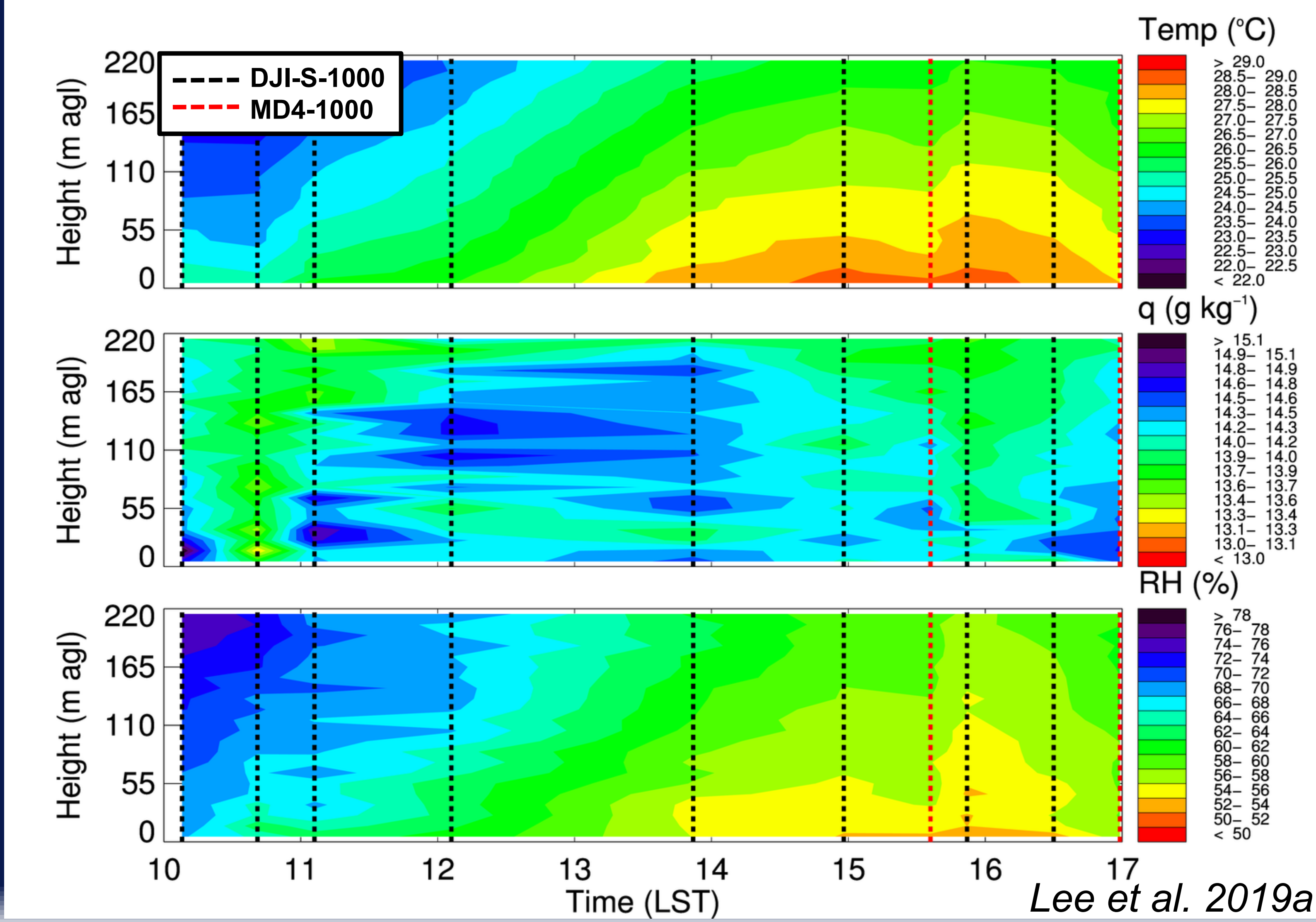
VORTEX-SE


North


FEATHERLITE

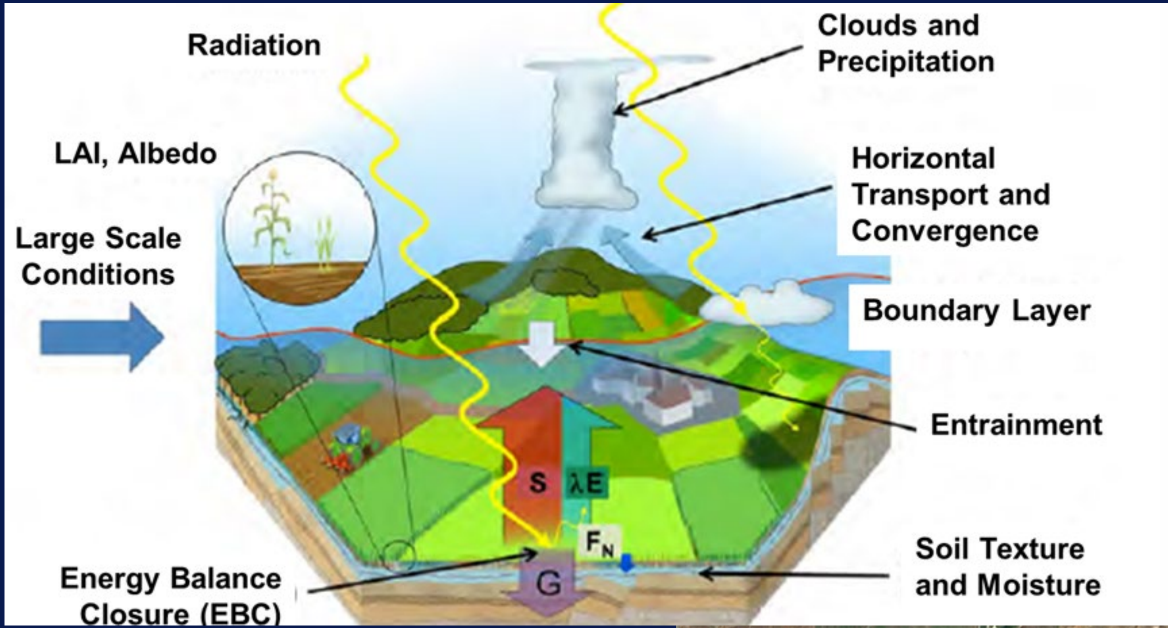

17 UTC
18 UTC
21 UTC
23 UTC
Height (m AGL)
sUAS – Sonde Temperature (°C)
sUAS – Sonde RH (%)
Lee et al., 2019a

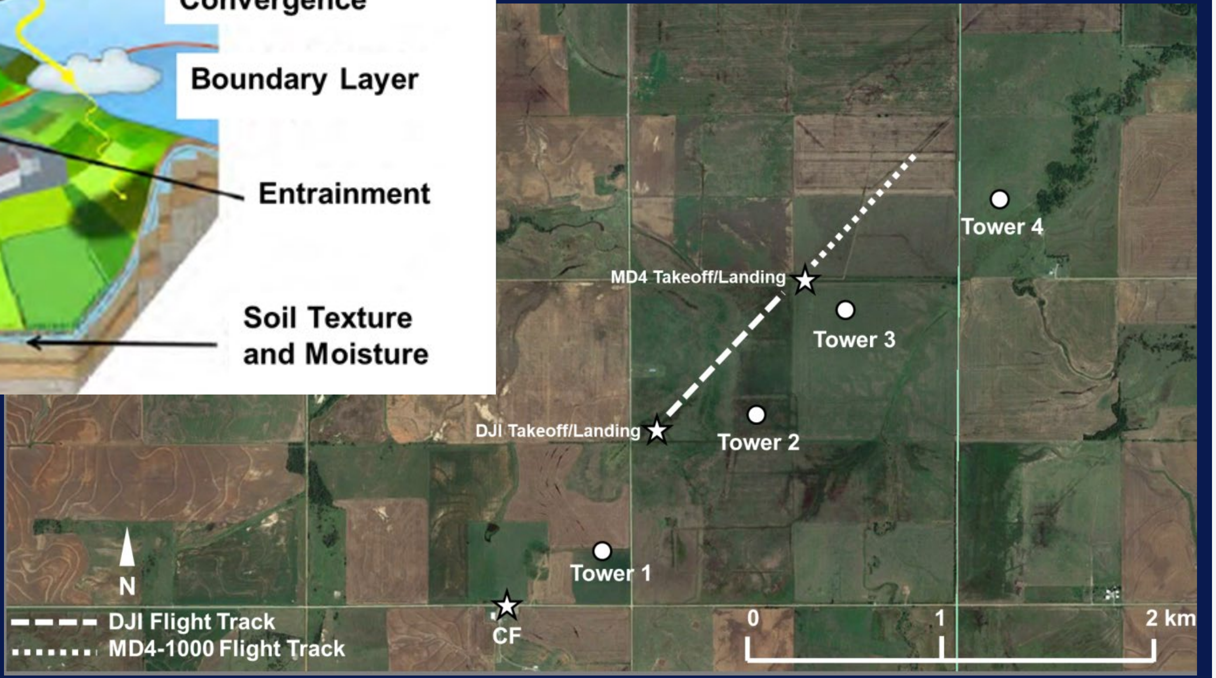
Vertical profiles from sUAS provided critical information on the evolution of near-surface temperature and moisture prior to severe weather events during VORTEX-SE



Lee et al. 2019a

Land Atmosphere Feedback Experiment (LAFE)

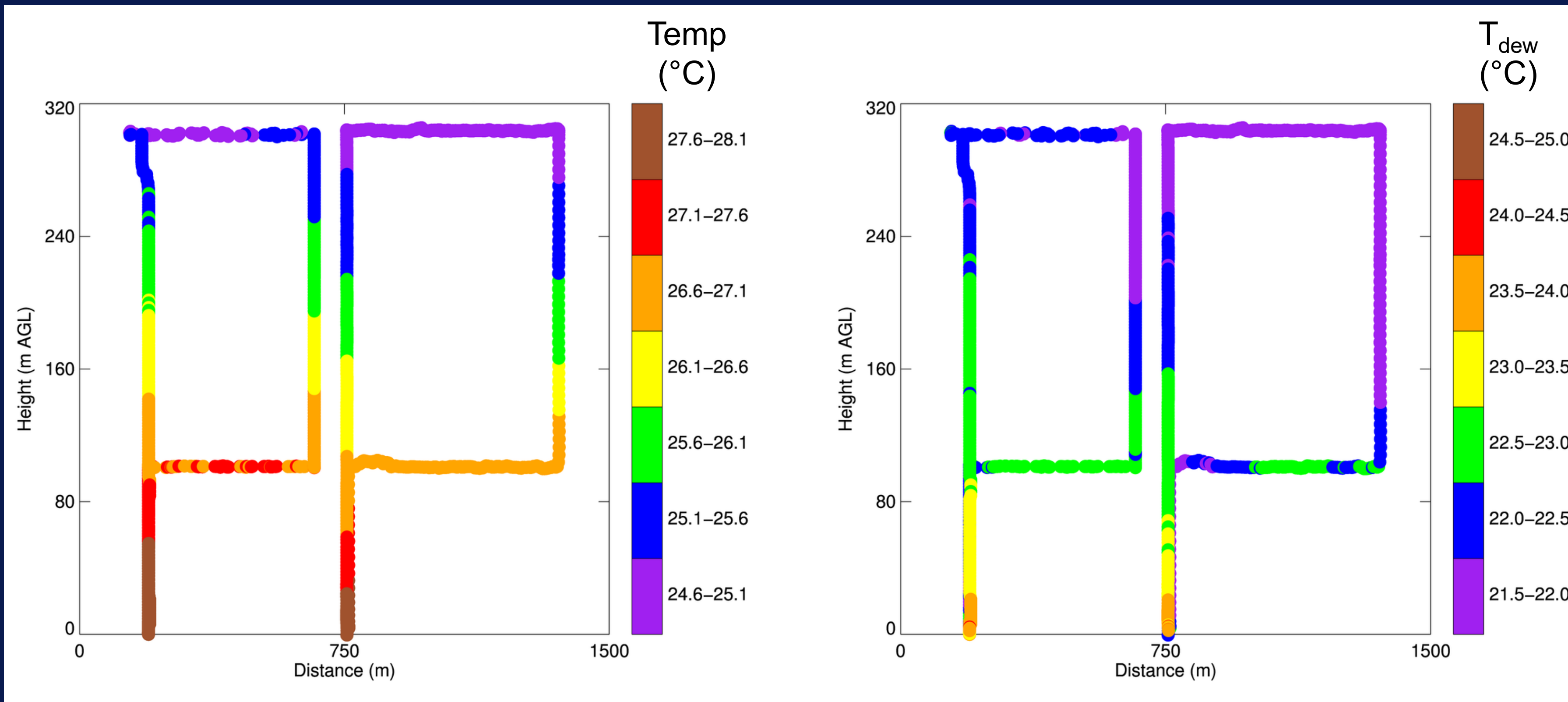




Array of surface weather instruments and PBL profilers to study interactions between the land surface and overlying atmosphere

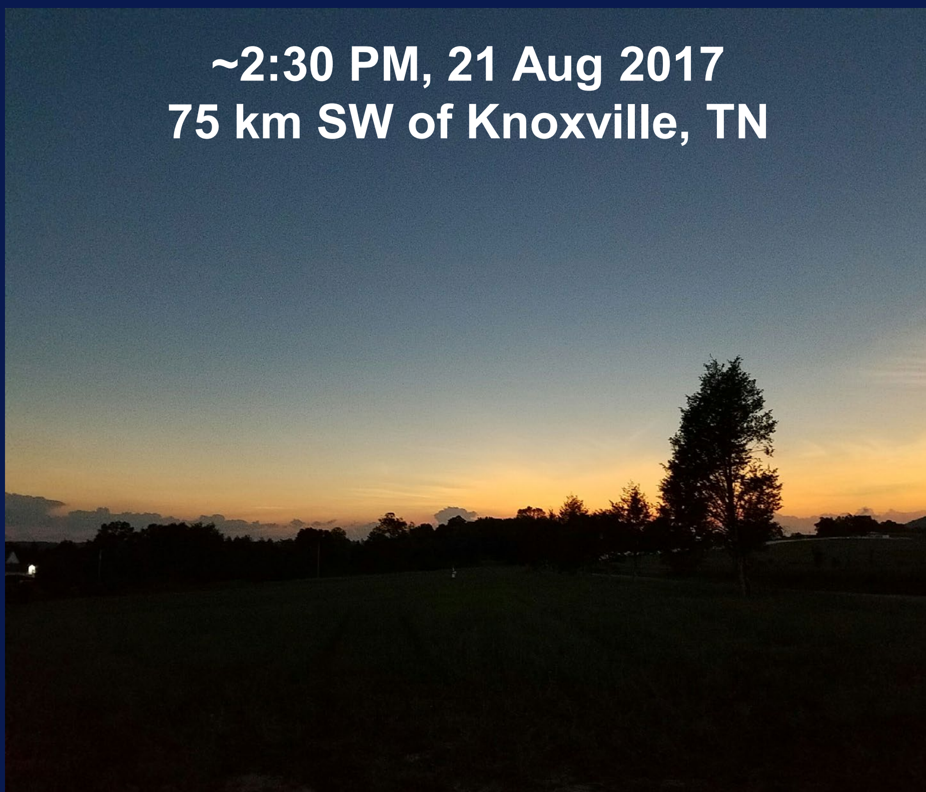
sUAS were used to fill in this gap and measure differences in near-sfc. temp. and moisture

1710 UTC 15 Aug 2017

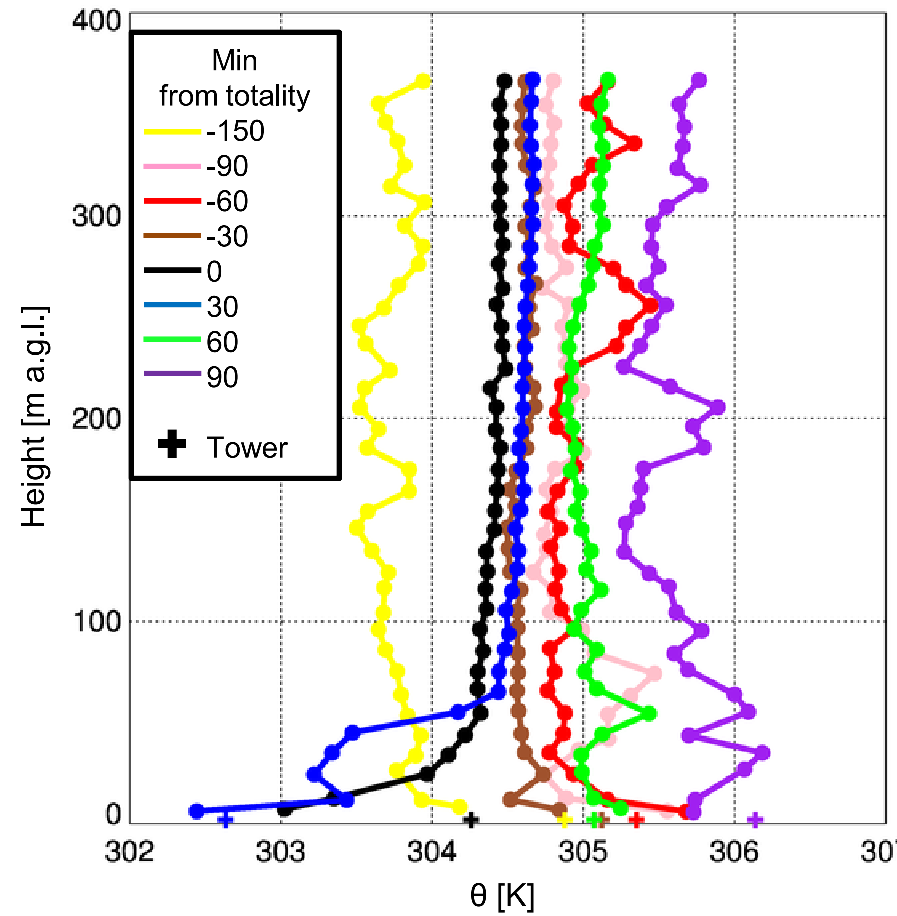


Great American Eclipse

…as observed by us

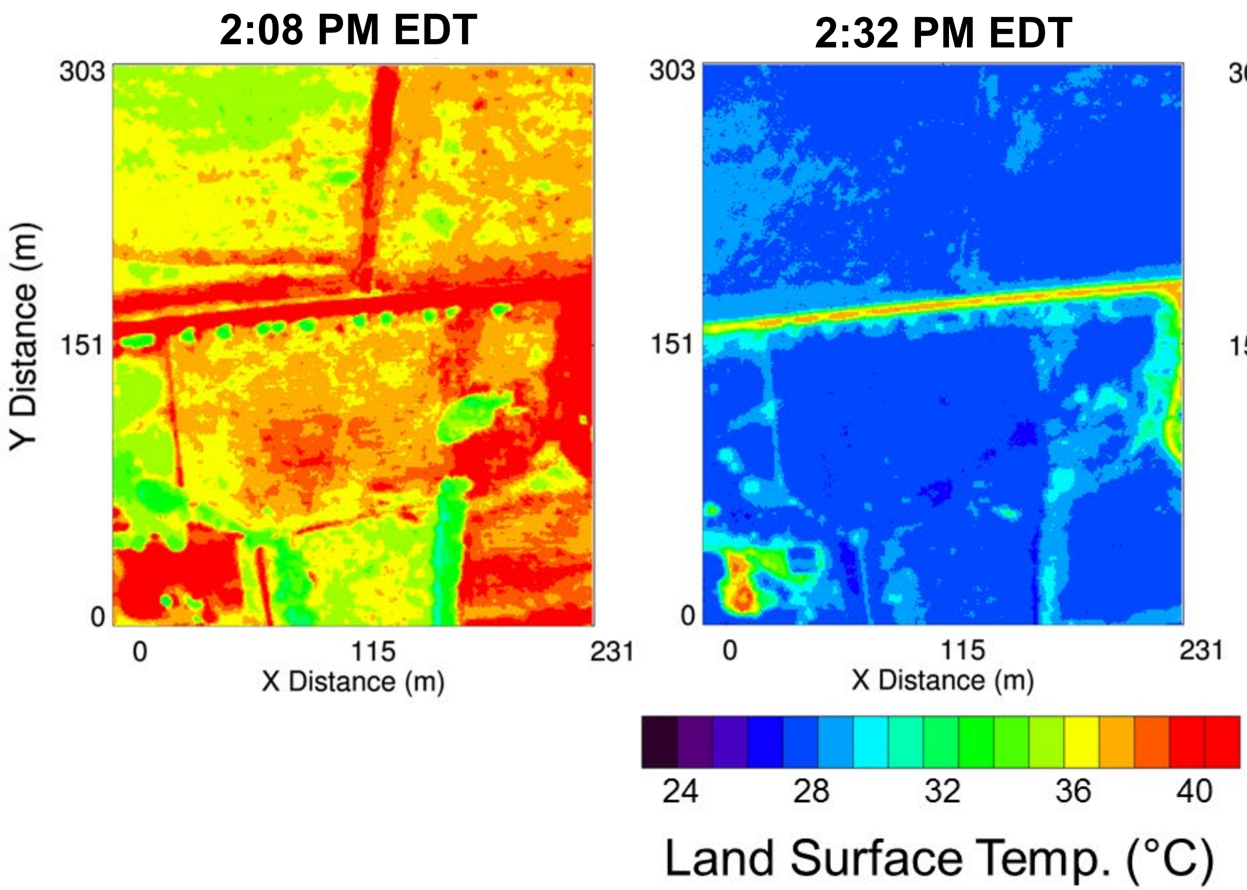


…and as observed by our sUAS



Buban et al., 2019

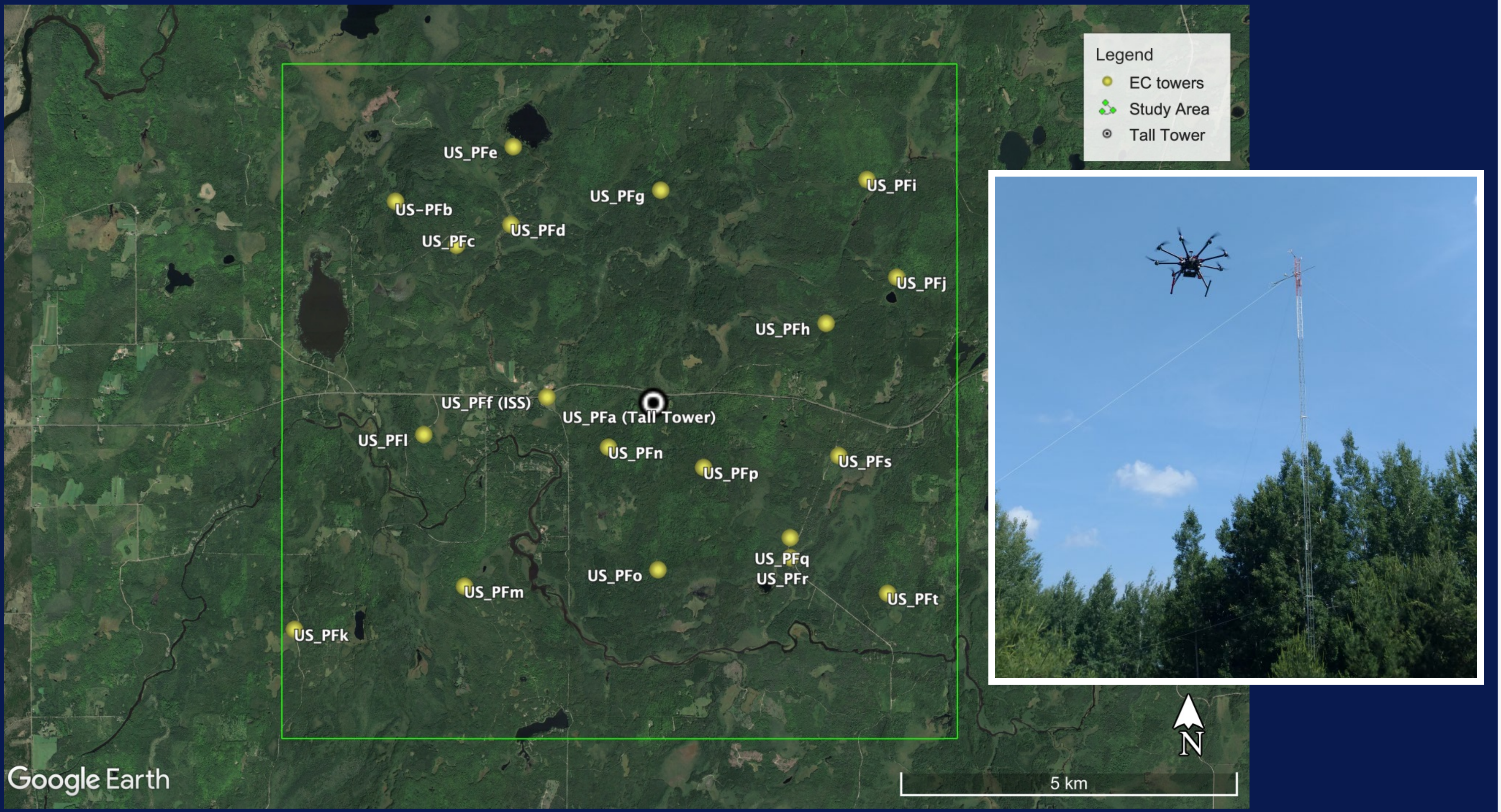
sUAS Surface Temp. Before, During and After Eclipse



Buban et al., 2019

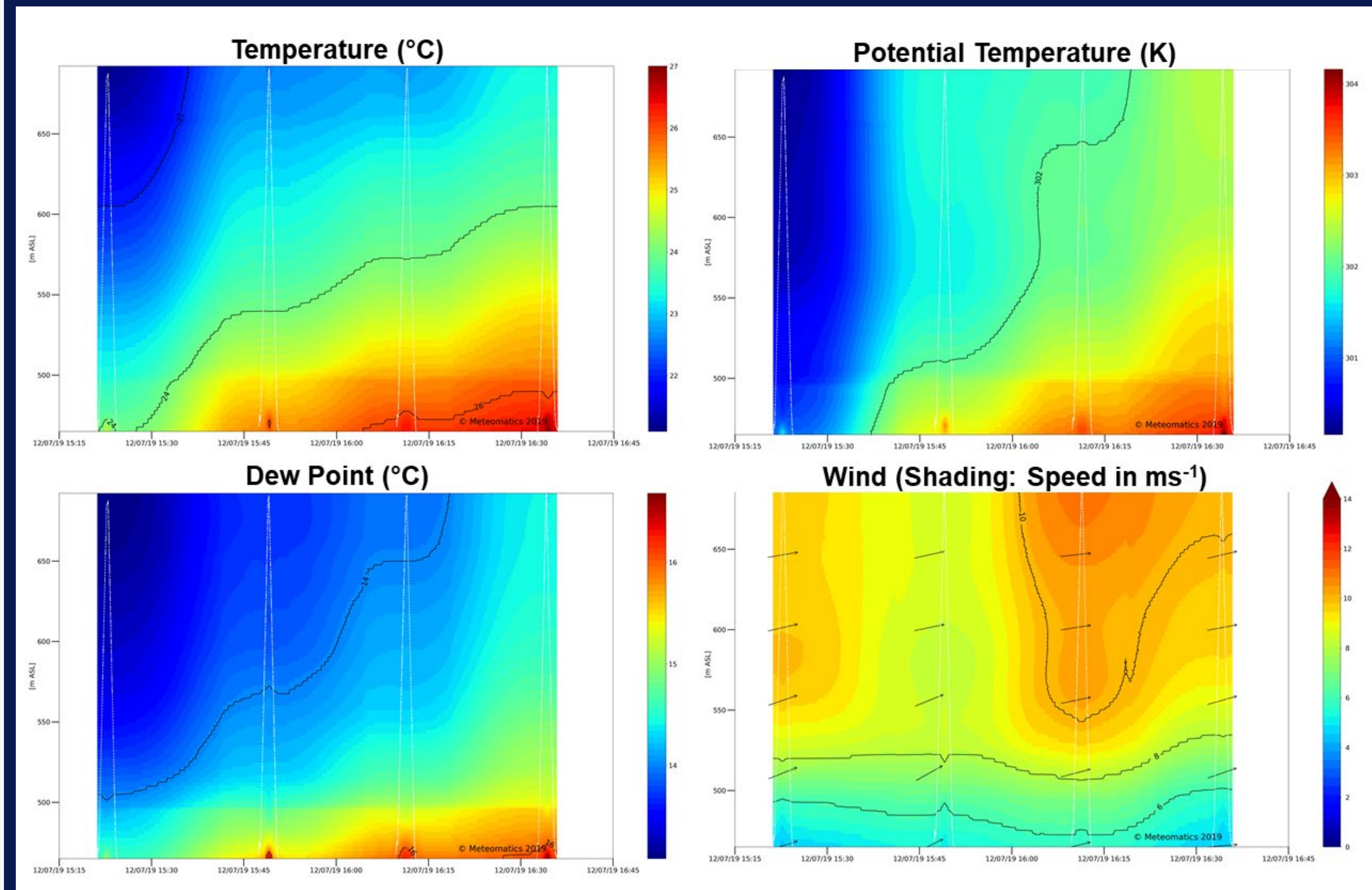
Rapid cooling and re-heating of land surface on afternoon of eclipse

CHEESEHEAD

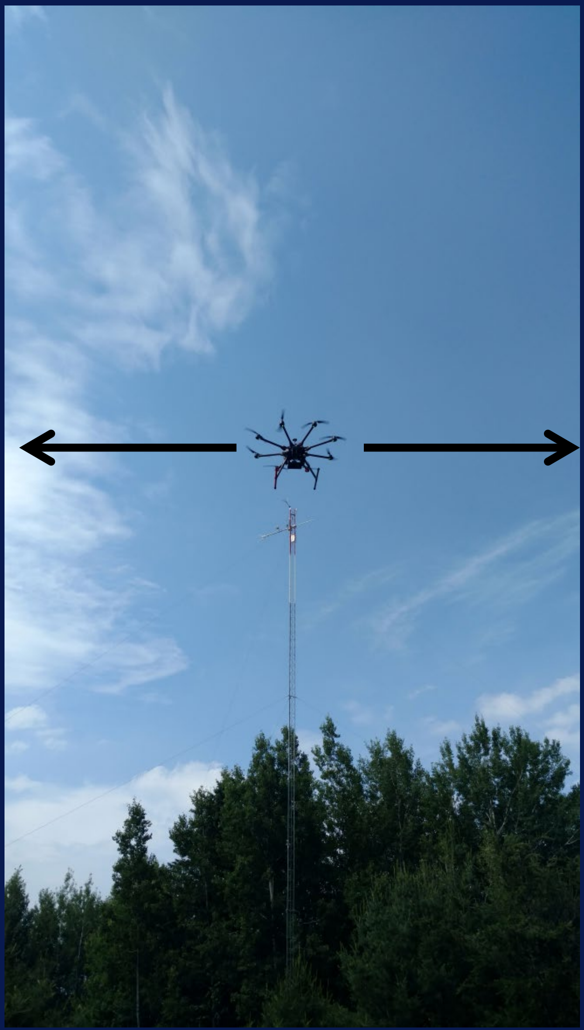


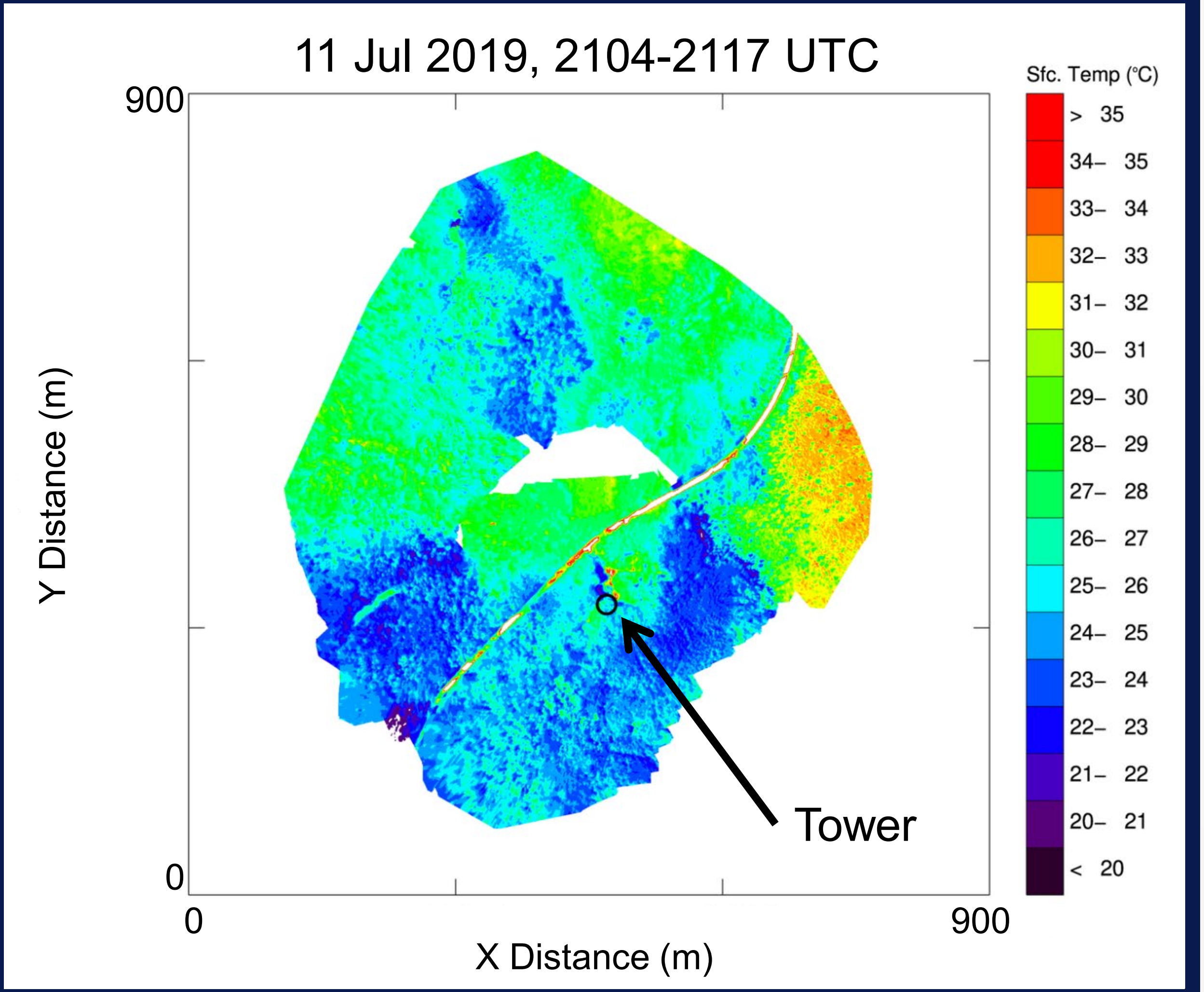
sUAS used to help scale point observations

During CHEESEHEAD, sUAS provided information not only above met. towers…

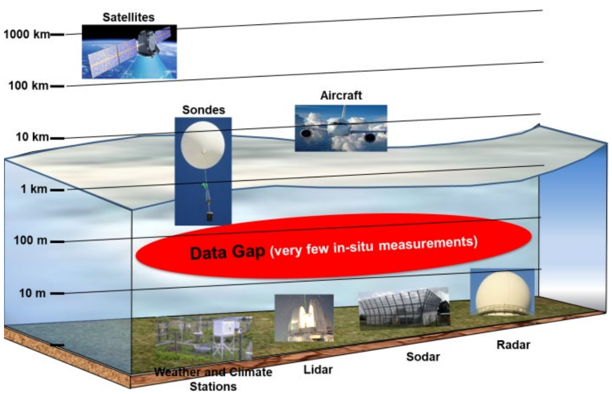


…but also provided information on the horizontal variability in temp. and moisture surrounding the towers.

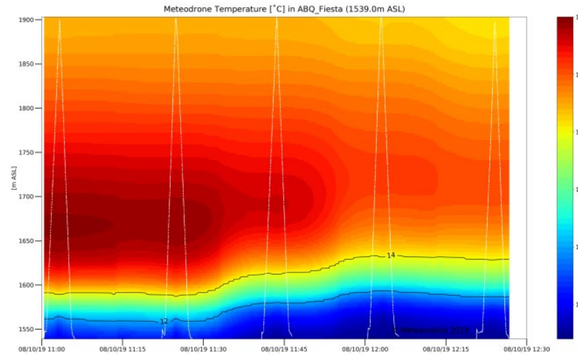


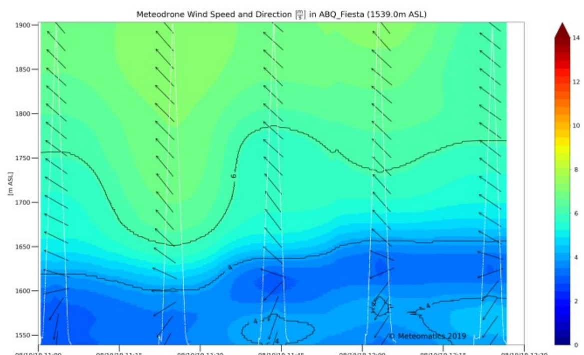


Small Unmanned Aircraft Systems Observations Help Improve Forecasts

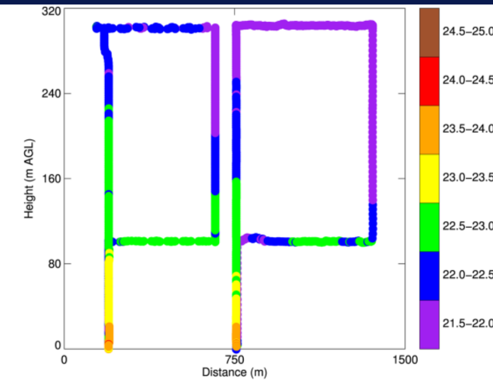


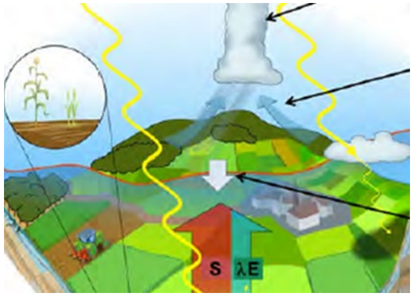
sUAS help close a significant observation gap in Earth's atmosphere





sUAS provide critical, real-time information that assist in making critical forecast decisions





sUAS used to study interactions between the surface and atmosphere and improve how these are represented in forecast models

Future Directions / Opportunities for Collaboration

- Evaluate surface fluxes from BST S2 and scale fluxes to larger (i.e. ≥4 km) spatial scales more appropriate for mesoscale models
- NOAA/ESRL collaboration to scale sUAS measurements from SurfRad sites
- Expand profiling capabilities to sample trace gases and compute fluxes of these species
  - CO_2, CH_4, O_3…