# Current Activities and Future Plans for UAS Research Community Support by **National Center for Atmospheric Research**


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NCAR UCAR | EARTH OBSERVING LABORATORY

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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# UAS Workshop
## 21 - 24 February 2017

108 Participants: Researchers, engineers, program managers, students

US Universities, NCAR, NOAA, Private Company, Foreign, NSF, NASA, Other Federal, DOE

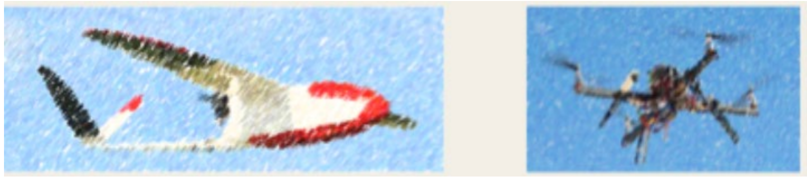
**Goals**

- Identify key areas for UAS research
- Examine ways to improve measurements from UASs
- Discuss new instrumentation for UASs
- **Identify needs for calibration of UAS instruments and verification of UAS based measurements**
- Discuss UAS operations including challenges and opportunities
- **Identify novel ideas for lower atmosphere in situ observations that EOL could support**

# Recommendations and Community Needs (partial list)

**Community building: "Best Practices" and Guidelines**

- **UAS sensor calibration/installation/validation**
- UAS autonomy and operations in the NAS
- Atmospheric observations using UAS, successes and failures



**Weather forecast:**

- FAA requires that remote **pilot in command must assess local weather conditions**
- Especially in BVLOS operations understanding UAS weather is essential
- Local UAS specific weather nowcast and forecast largely not available

**UAS atmospheric sensors**

- **Access to calibration facilities** (temperature, pressure, humidity, wind, radiation, and certain trace gases, …)
- Guidelines for the specification of the sensor performance, including random uncertainty, systematic effects, time response, and operating conditions
- Need for standard, well-characterized PTU sensor module
- **Validation against recognized standards can be done using reference sensors on tall towers** or using a dedicated reference UAS or even a manned aircraft

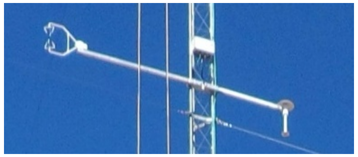
# NCAR/EOL Support of UAS Calibration Testbed

2017 NCAR / EOL Community Workshop Recommendation

- **Reference sensors on tall tower**
- **Wind LIDAR (ISS)**

## New EOL Infrastructure

- Scanning Wind LIDAR
- Guyless Free Standing 30 meter tower
- Initial location: NCAR Marshall (Boulder County) Field site
- Trailer based tower – Portable
- Meteorological sensors:
  - 3-D Wind, Heat, moisture, $CO_2$, Fluxes, PTH, radiation
- Propose 3-sensors levels



## Status

- Leased 12 towers from two companies for CHEESEHEAD field program
- Evaluating operations, maintenance, stability, safety, durability
- Purchase a single tower in 2020 and equip with ISFS sensors

CHEESEHEAD ISFS

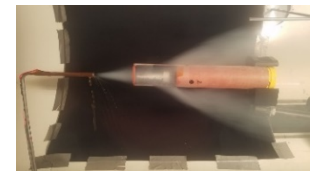
# NCAR/EOL Support UAS Sensor Evaluation & Calibration

**Support community sensor evaluation and calibration**

**EOL Upgrading Infrastructure Easily support wide variety of sensors**

## Low Speed Wind Tunnel

| | |
|---|---|
| Test section: | 89 cm (D) x 152 cm (L) |
| Velocity Range: | 0 m/s to 25 m/s |
| Accuracy: | 0.1 m/s |



## Humidity Chamber

**<u>Thunder Scientific 2500 Specifications</u>**

| | |
|---|---|
| Humidity range | 10% to 95% |
| Humidity accuracy | +0.5% |
| Temperature range | -18°C to 50°C |
| Temperature accuracy | +0.1°C |

## Precision Oil Baths

**<u>Fluke 7060 Specifications</u>**

| | |
|---|---|
| Temperature range | -60°C to 110°C |
| Typical bath stability | +0.002°C |

## Altitude Chamber

**<u>Thermotron FA-96 Specifications</u>**

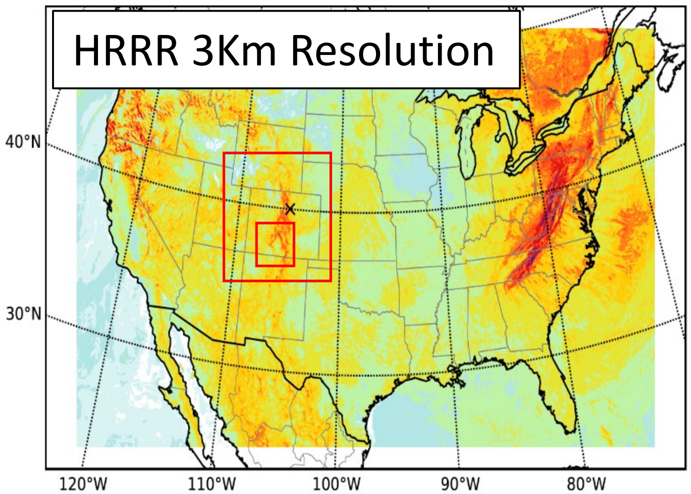
Temperature Range: -73°C to 177°C

Altitude Range: sea level to 30480 m

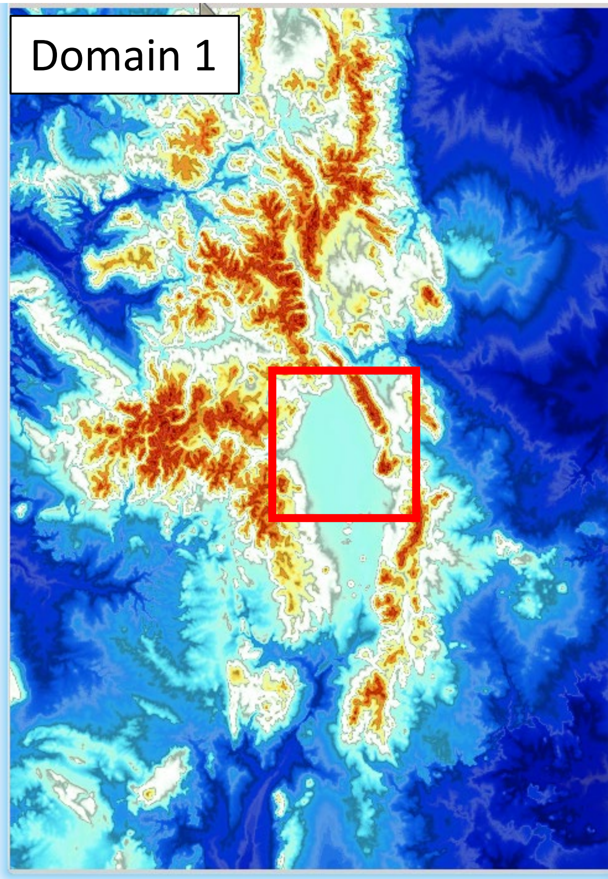
# NCAR UAS Wx Program – Led by Research Application Laboratory

ISARRA 2018

15-21 July 2018

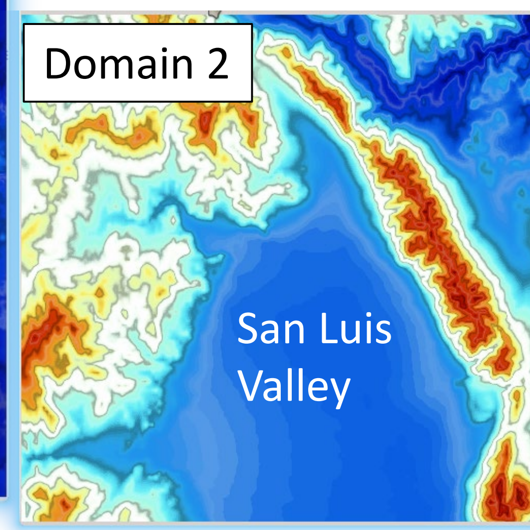



## Real-time WRF-LES




Domain 1
- **1 km model resolution**
- 487 x 637 x 45 gps

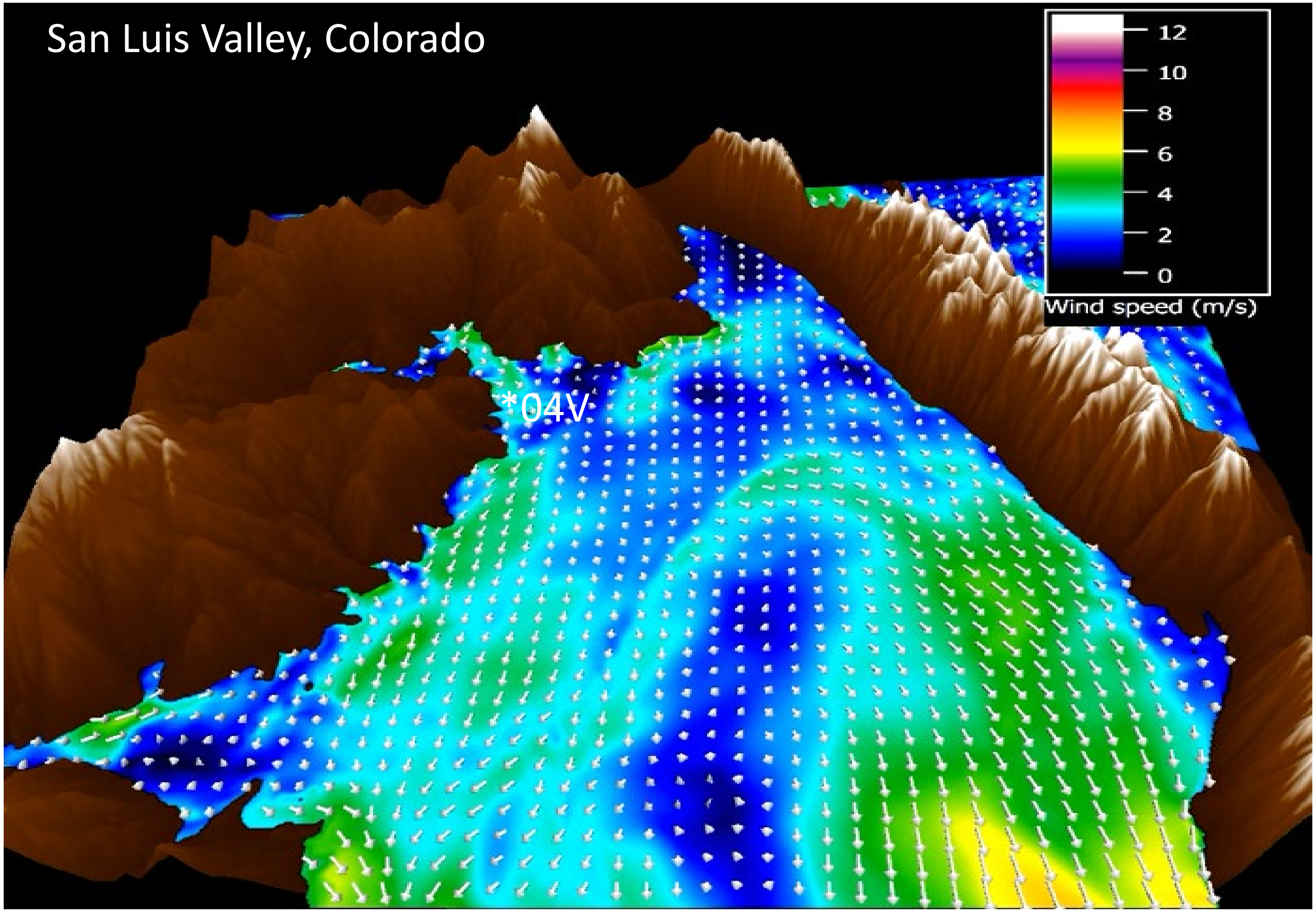
Domain 2 LES Simulatons
- **100 m model resolution**
- 1008 x 972 x 45 gps




Model Physics used in models
- WSM Microphysics
- MYNN2 PBL – D01 Only, D02 = WRF_LES
- NOAH LSM
- Builds on Munoz-Esparza et al 2017, 2018

# Realtime Prediction for LAPSE RATE with WRF-LES

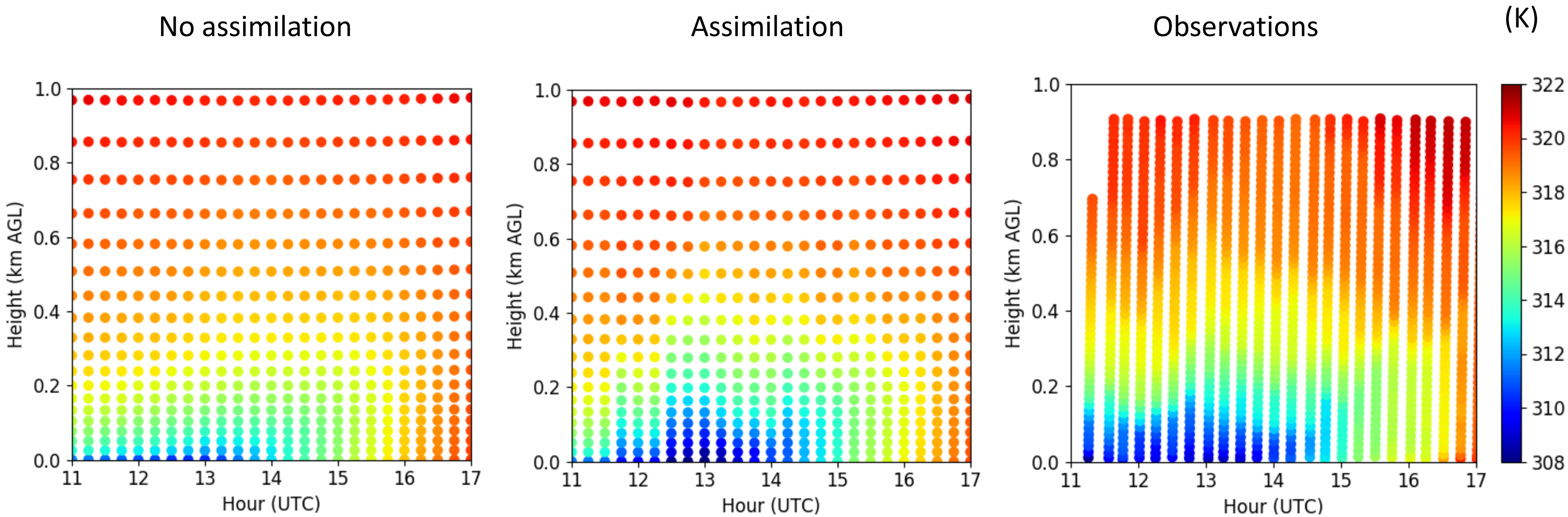
12 hour run valid: 06:00 – 18:00 UTC (00:00 – 12:00 LT) ~300 ft AGL



# Evaluation & Data Assimilation Experiments ISARRA 2018

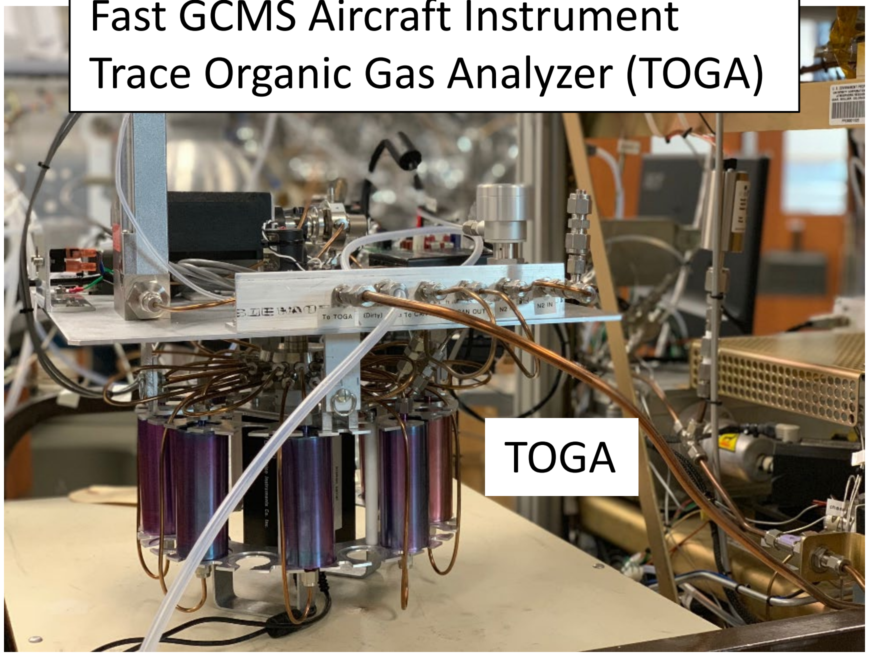
No Assimilation | Assimilate UKY UAS Data | OU Coptersonde Data

Theta (K)

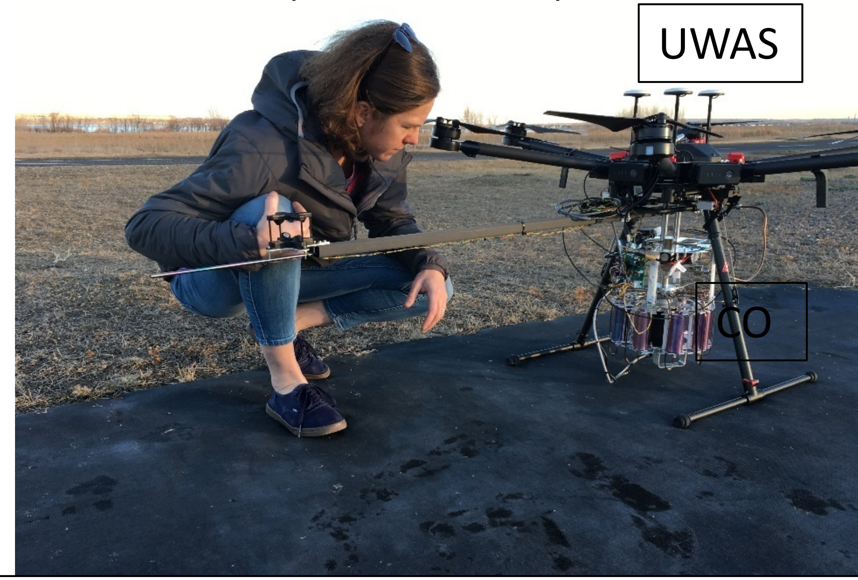



- Bias in winds driven by lack of cold pool in model.
- Data Assimilation performed using DART Ensemble Kalman Filter
- DA reduces warm bias – which reduces strength of drainage winds.

# Unmanned Whole Air Sampler (UWAS)




Developed by Dr. Elizabeth Asher
NCAR Postdoc (ACOM & EOL)

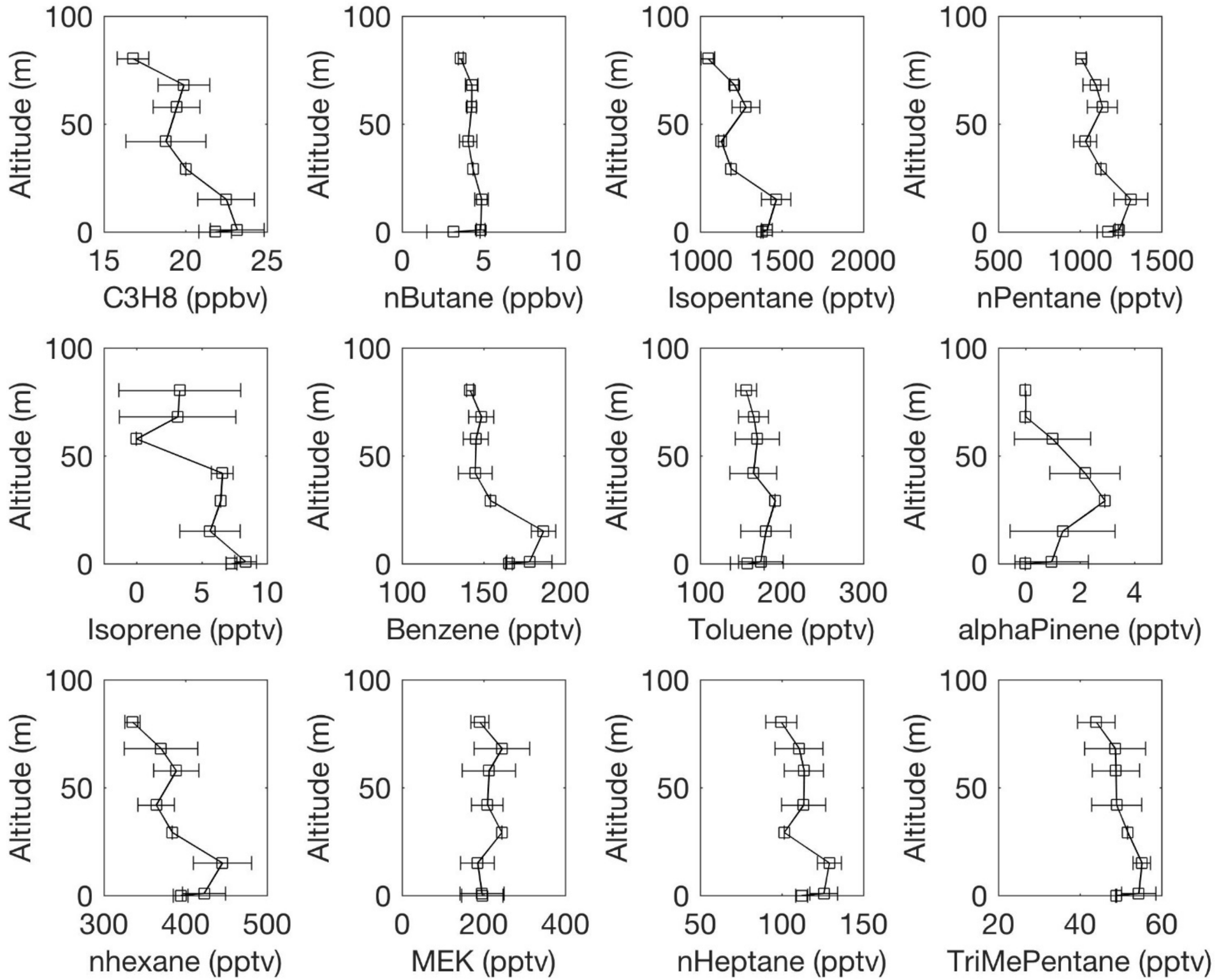



TOGA's small sample sizes (< 14 mL) rapid measurements (every 2 min) and large analytical measurement range make it a good match for UWAS.

- Collects 8 air canisters per flight (may collect ≤15)
- VOC measurements range <10 ppt - ~50 ppb
- 1:30 min. sampling period; duplicate subsamples
- 1Hz T, RH, P, 2D winds, system P and flow
- Computer programed or piloted flights

# UWAS Results VOC profile in Broomfield, CO

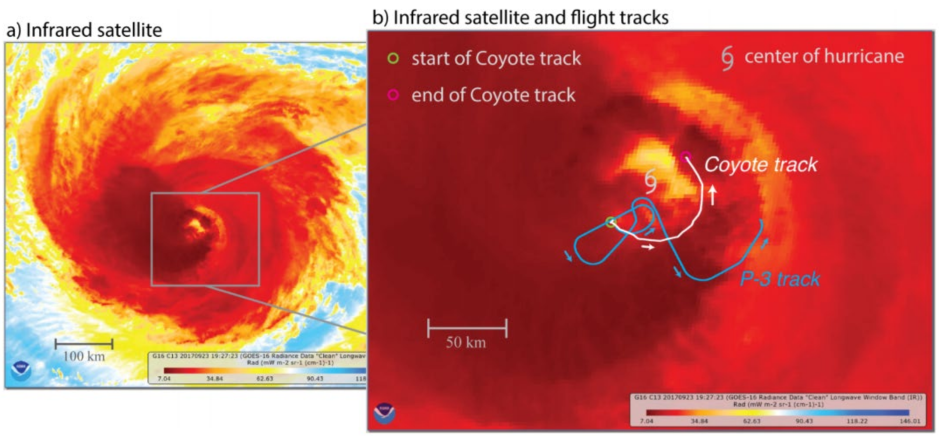
1st Flight November 29, 2018 4:08 pm



# NCAR Collaboration with NOAA - UAS Coyote (Engineering/Science )


Dr. Joe Cione

UAS Coyote




Hurricane Maria Infrared Sat Image
23 Sept 2017
NOAA P-3 Flight Track (Blue)
Coyote Flight Track (White)

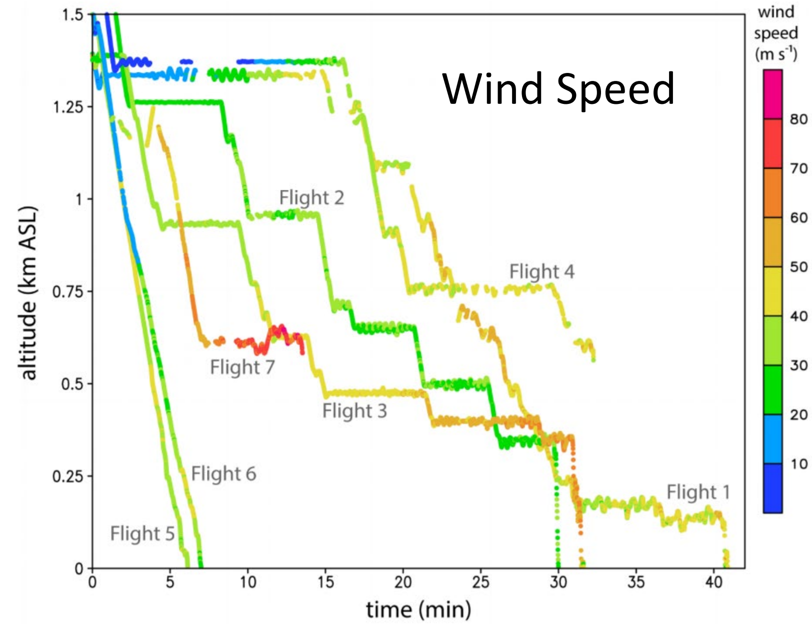



Fig. 6. Summary of all wind speed data collected during Coyote sUAS flights in 2017–2018 (colored dots, m s$^{-1}$) as a function of time and height above sea level (ASL). Flights 1–4 and 7

Hurricane Maria Infrared Sat Image
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# LOwer Troposphere Observing System - LOTOS

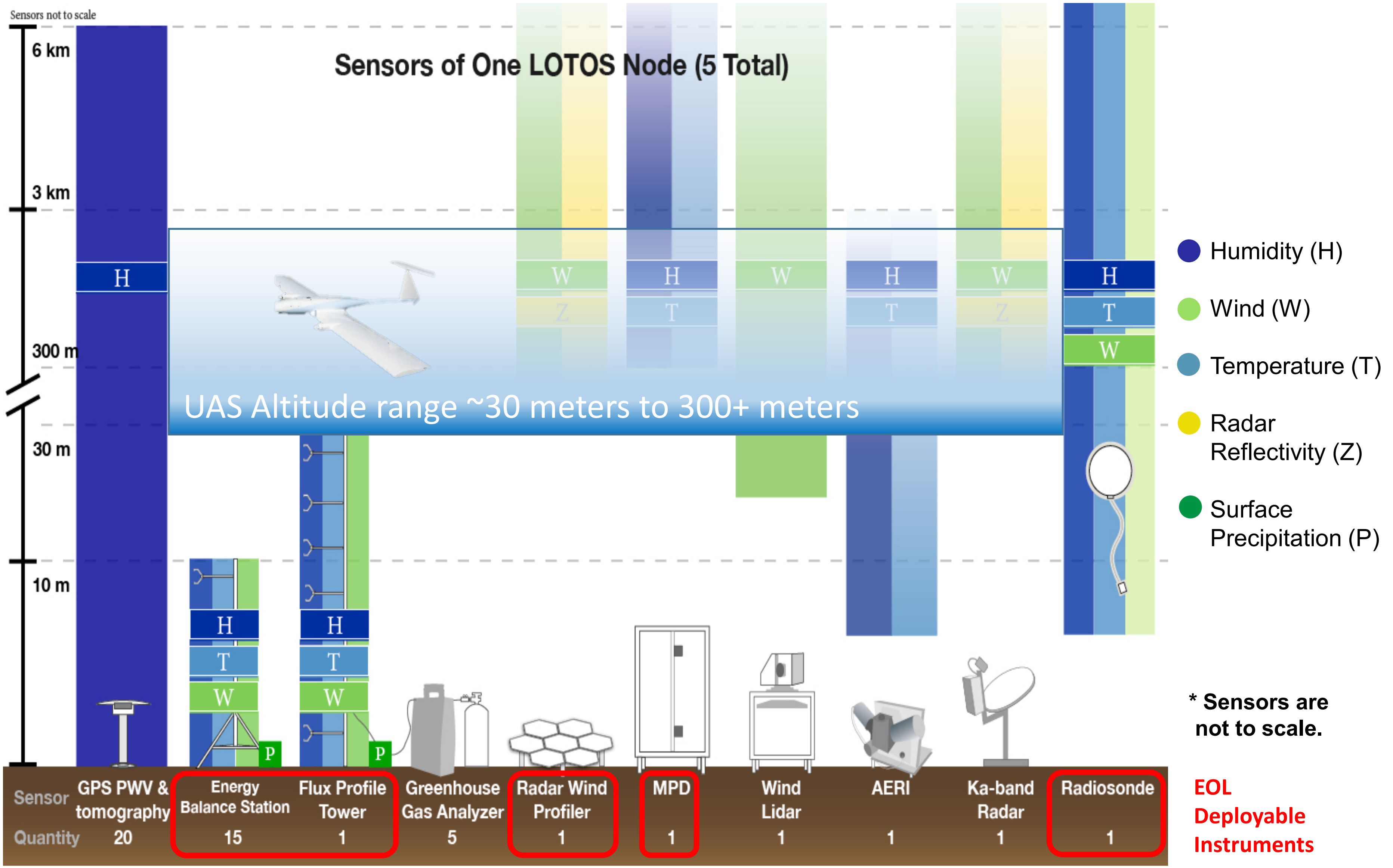
**LOTOS** as a configurable and scalable integrated suite of automated and unattended ground-based in-situ and remote sensors for weather and climate research.

**LOTOS is designed to provide:**

- Quasi-3D sensing of the lower troposphere plus mapping of spatial distribution of properties at the Earth's surface
- Full kinematic and thermodynamic profiling at five nodes
- Multiple observations of exchange processes across the land-surface interface and between BL and the free atmosphere

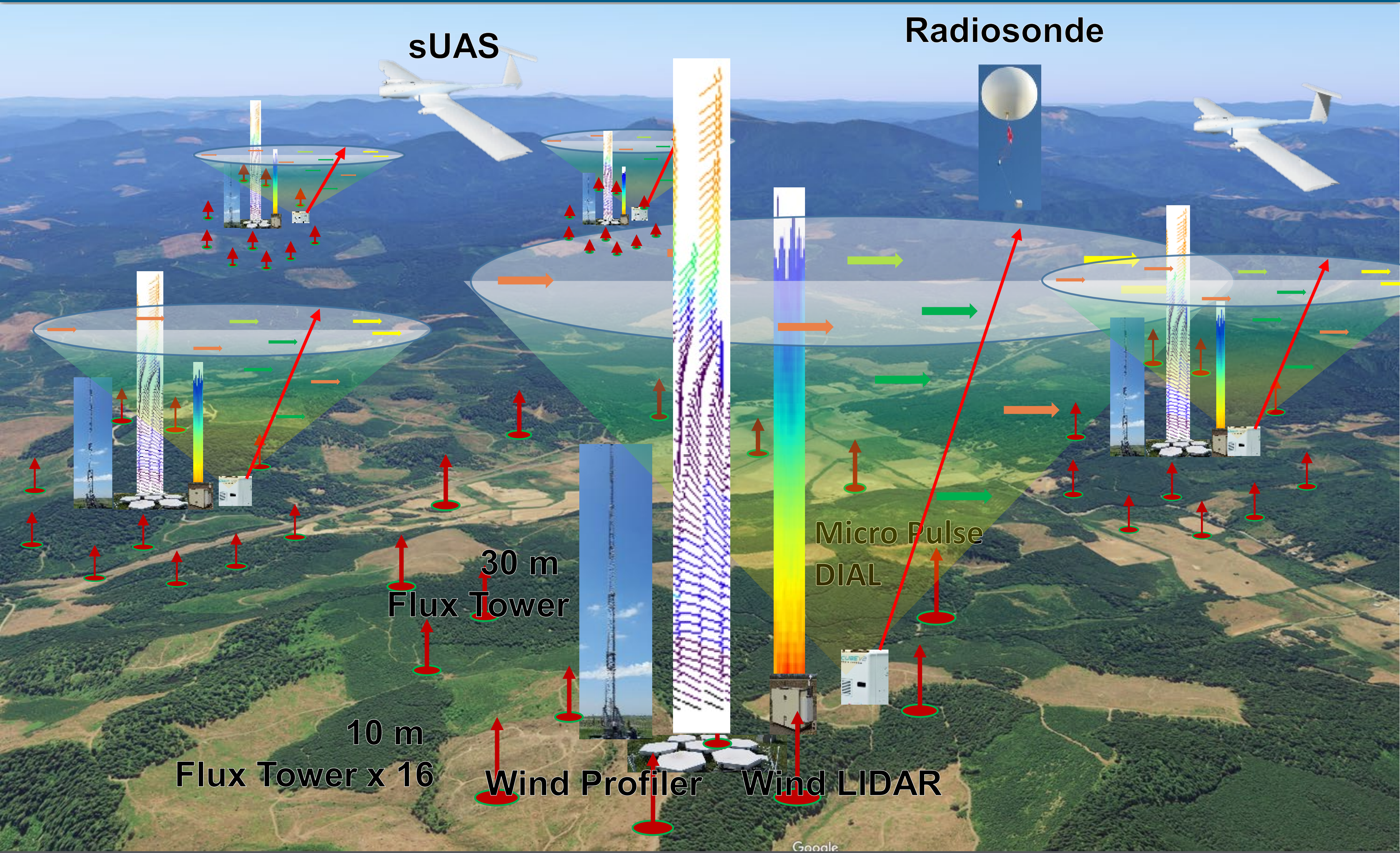
# Instrumentation at each Node

**Complementary in-Situ and Remote Sensors**




**Vertical measurement ranges of the LOTOS sensors at each of the five nodes.**

# LOTOS: Future of 3D Boundary Layer Observations



# NCAR Team

## Thank you for your attention

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