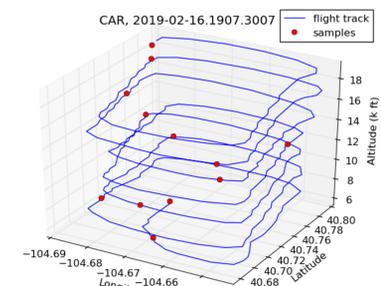
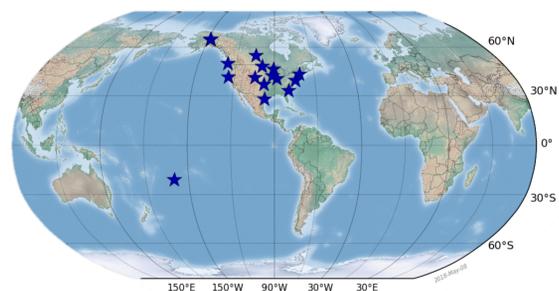


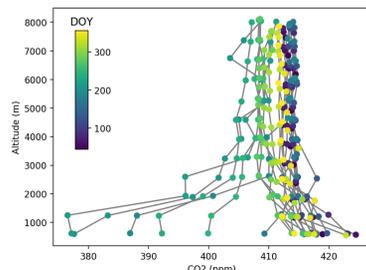
NOAA Greenhouse Gas Aircraft Network

- 13 sites in N. Am. currently
- 15+ yr record at each site
- Private pilots flying small aircraft
- 1-2 profiles per month
- Afternoon sampling to ensure well-developed BL
- 12 flask samples per profile are collected at pre-determined altitudes
- Samples are analyzed for 55+ trace gases and isotopes



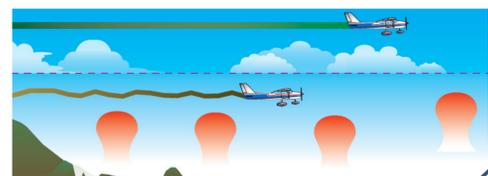
Flight paths are designed to hold altitude steady while a flask is filling and to collect flasks over a fixed point on the ground.

Lower altitude samples reflect surface fluxes and mixing depth. Higher altitude samples reflect seasonal and long-term distributions and synoptic transport.



Motivation

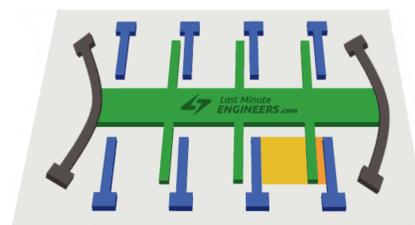
- Atmospheric trace gas measurements are interpreted with transport models to infer surface fluxes.
- Systematic errors in simulated boundary layer depths can lead to large biases in estimated trace gas surface fluxes.
- Validation data for PBL height is sparse and often challenging to interpret.
- Turbulence measurements made during aircraft network profile flights are a direct reflection of the physical mixing process.



Accelerometer Prototype

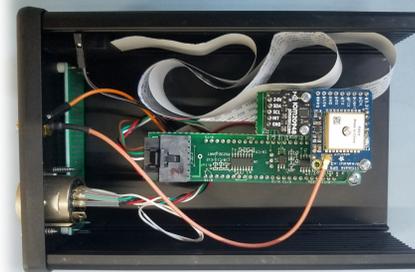
Micro Electro-Mechanical Systems (MEMS) Inertial Measurement Units (IMU)

- Use integrated circuit processing techniques to combine micrometer to millimeter size springs, fixed plates and a suspended proof mass. The movement of the proof mass between the fixed plates creates capacitive changes that are translated into a measure of the proper acceleration within the rest frame of the accelerometer
- Small, low cost, low power sensor for the detection of general and low frequency vibrations at moderate g-forces which makes them a good solution for detecting turbulence in small aircraft.



Components

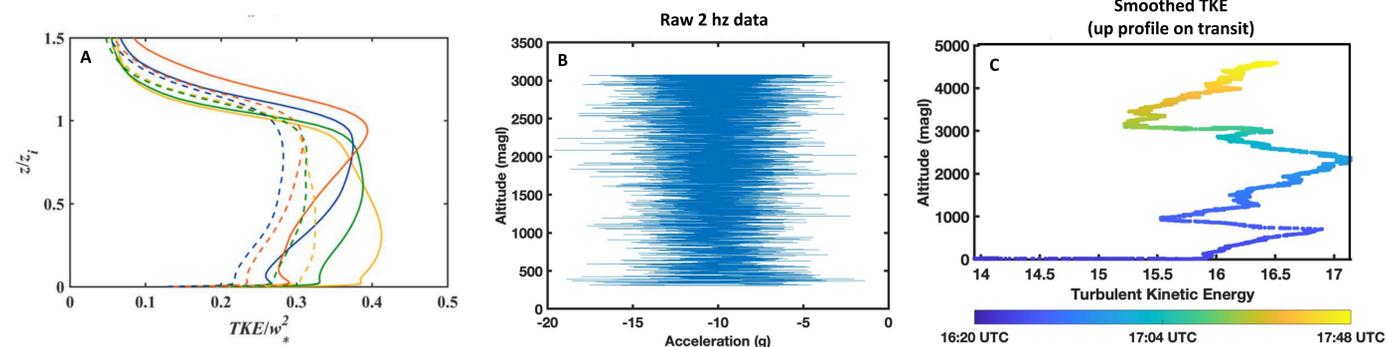
- Microcontroller – Teensyduino v3.6
- GPS – Adafruit Ultimate GPS
- Inertial Measurement Unit – TDK ICM-20948 9-DOF IMU
- Custom designed board to integrate the components



- Future operational unit would have IMU on printed circuit board (PCB), allowing for integration into existing network equipment, which already has power, GPS, and data logging.

Accelerometer Data

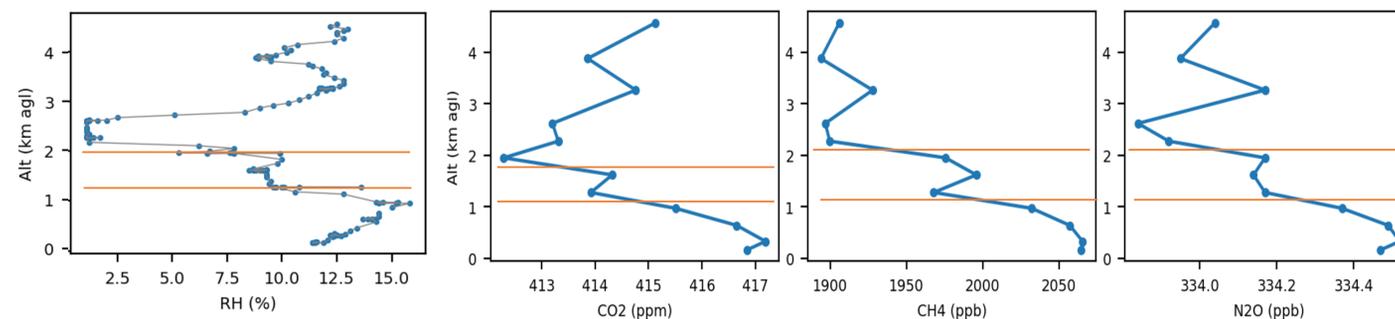
- Obtained data from 17 flights at 3 sites (CAR, SGP, HIL/WBI) from Jan-Oct 2020
- Theoretical framework for data interpretation from Zhou et al. (2019), which gives profiles of vertical and horizontal velocity variation from a set of WRF LES numerical simulations of the convective boundary layer (panel A)
- Case study: Oklahoma (SGP) flight on 2020-08-28 (panels B & C)



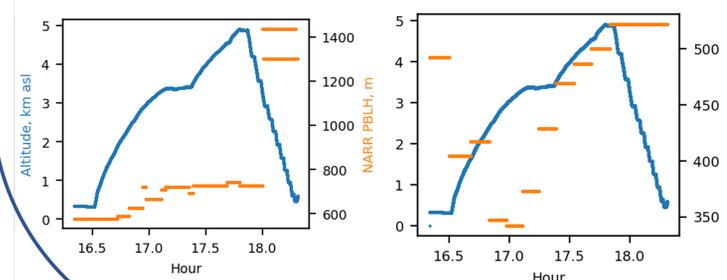
(B) Raw 2 Hz accelerometer data is not useful. (C) To make sense of the data, we convert to velocity for each axis and then compute the velocity variance a 1000-point moving window. TKE is the sum of the wind variances of the three wind velocity components. According to Zhou et al. (2019) TKE is at a maximum at the top of the the turbulent boundary layer.

Comparisons with other coincident BLH measures

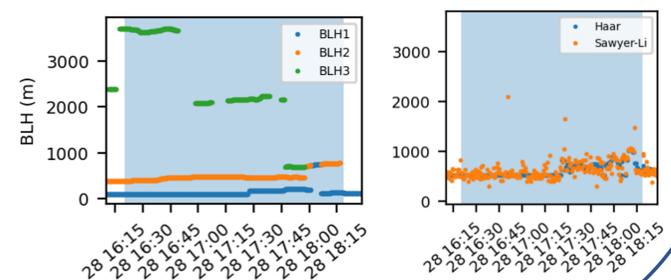
Measured humidity and trace gas profiles (down profile on spiral)



Reanalysis from two models (up and down profile)



DOE ARM Ceilometer and micro-pulse Lidar (down profile)



Radiosonde at DOE ARM site results in BLH estimates of 1600-2100 m by various methods

References

Zhou, Y., Li, D., & Li, X. (2019). The effects of surface heterogeneity scale on the flux imbalance under free convection. *Journal of Geophysical Research: Atmospheres*, 124. <https://doi.org/10.1029/2018JD029550>.

Varanis, M., Silva, A., Mereles, A., Pederiva, R. (2018) MEMS accelerometers for mechanical vibrations analysis: a comprehensive review with applications. *J. Braz. Soc. Mech. Sci. Eng.* <https://doi.org/10.1007/s40430-018-1445-5>.

Hanly, Steve. Accelerometers: Taking the Guesswork out of Accelerometer Selection, <https://blog.endaq.com/accelerometer-selection>.