Estimating Error in UAV-Based Measurements Using CFD

Hayden Hedworth, John Sohl, Tony Saad

Hypothesis: Mixing from unmanned aerial vehicle (UAV) rotors can affect atmospheric gradients and interfere with vertical measurements.

Objectives: Assess airflow and mixing during vertical flight and identify an optimal flight procedure for data collection, and sensor location.

Background

Vertical measurements of ozone conducted using a rotary-wing UAV (Fig. 1) suggest that turbulent airflow generated by the rotors can cause notable differences between data from ascent and descent (Fig. 2).

Fig. 1: DJI M600 equipped with an ozonesonde

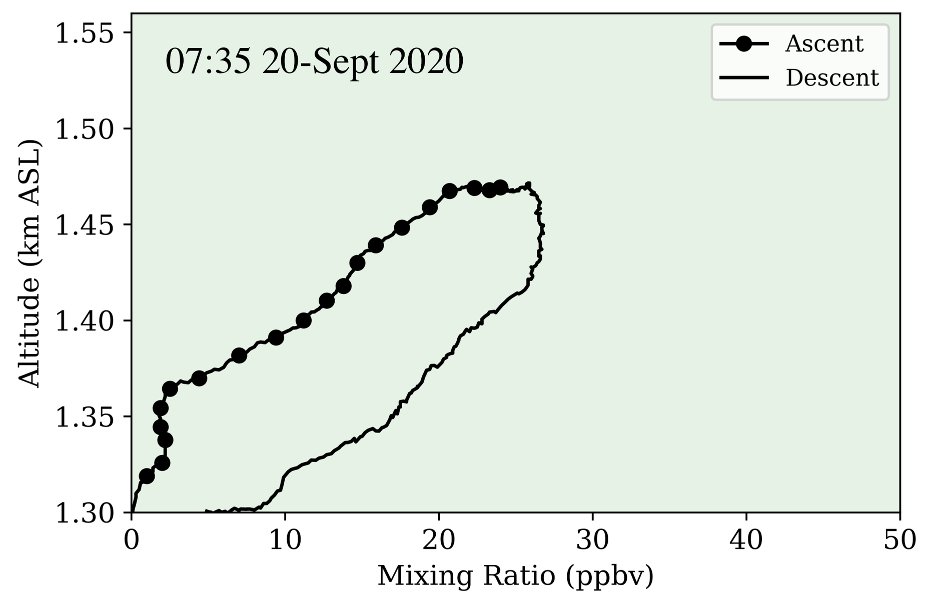

Fig. 2: Morning ozone profiles measured during ascent (dotted line) and descent (solid line)

To investigate and explain these observations, we used an in-house computational fluid dynamics software (Wasatch) to simulate the airflow and scalar mixing around the UAV.

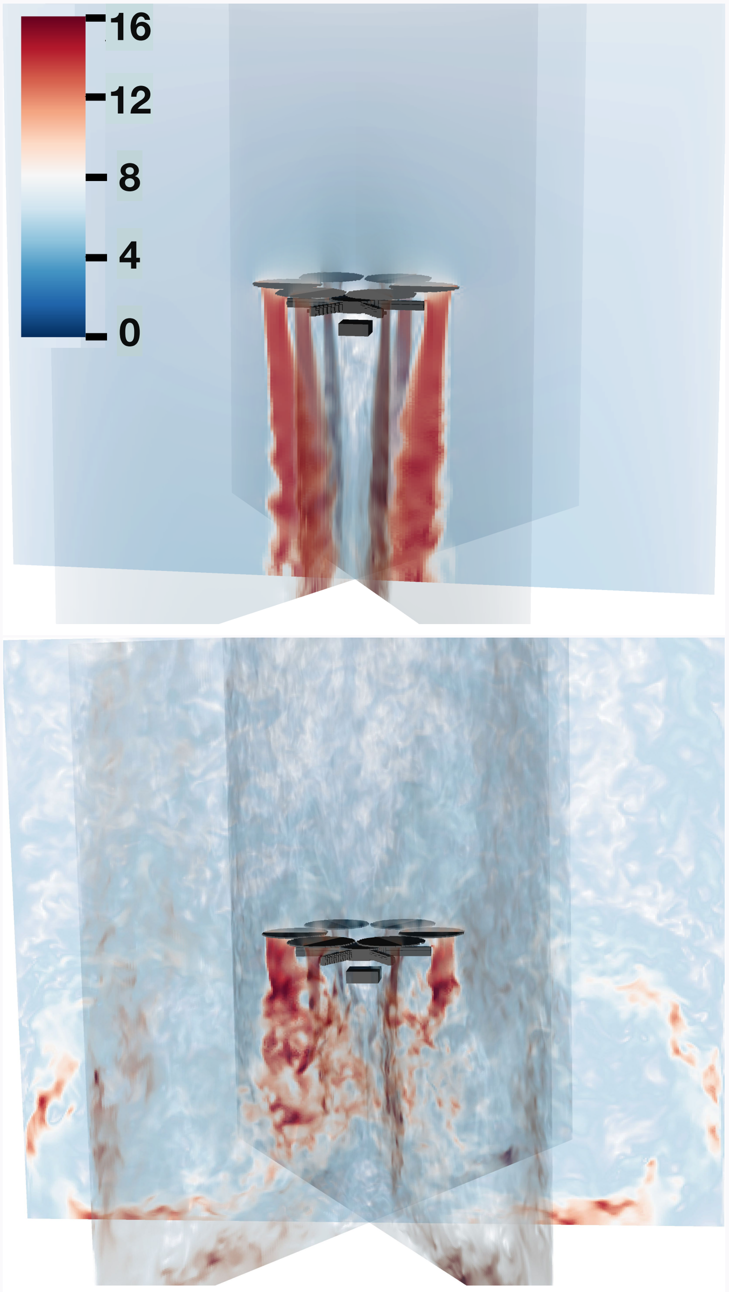

Fig. 3: Airflow (m/s) during ascent (top) and descent (bottom)

Simulations

- Simulate UAV rotors using a source term based on the thrust needed to lift the UAV and payload.
- Simulate ascent and descent by setting the inlet velocity at the top or bottom boundary of the domain.
- Airflow around the UAV during descent is highly turbulent due to the UAV passing through its own wake
- We also simulate a passive scalar to represent ozone.
- Simulate flight through a vertical gradient.
- Evaluate three potential sensor/ intake tube locations (Fig. 4)

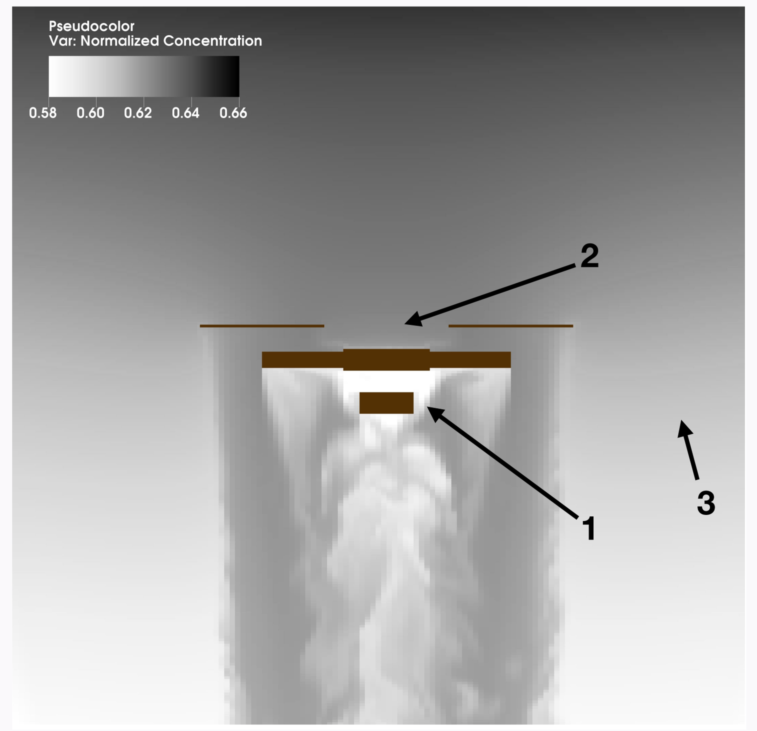

Fig. 4: Scalar profile during ascent with sensor locations marked

Results

We evaluated the relative error caused by the rotors by comparing the actual concentration in the domain to the expected gradient.

The relative error was minimal during ascent (~4-7%), but much larger errors were observed around the drone during descent (~40-70%) (Fig. 5).

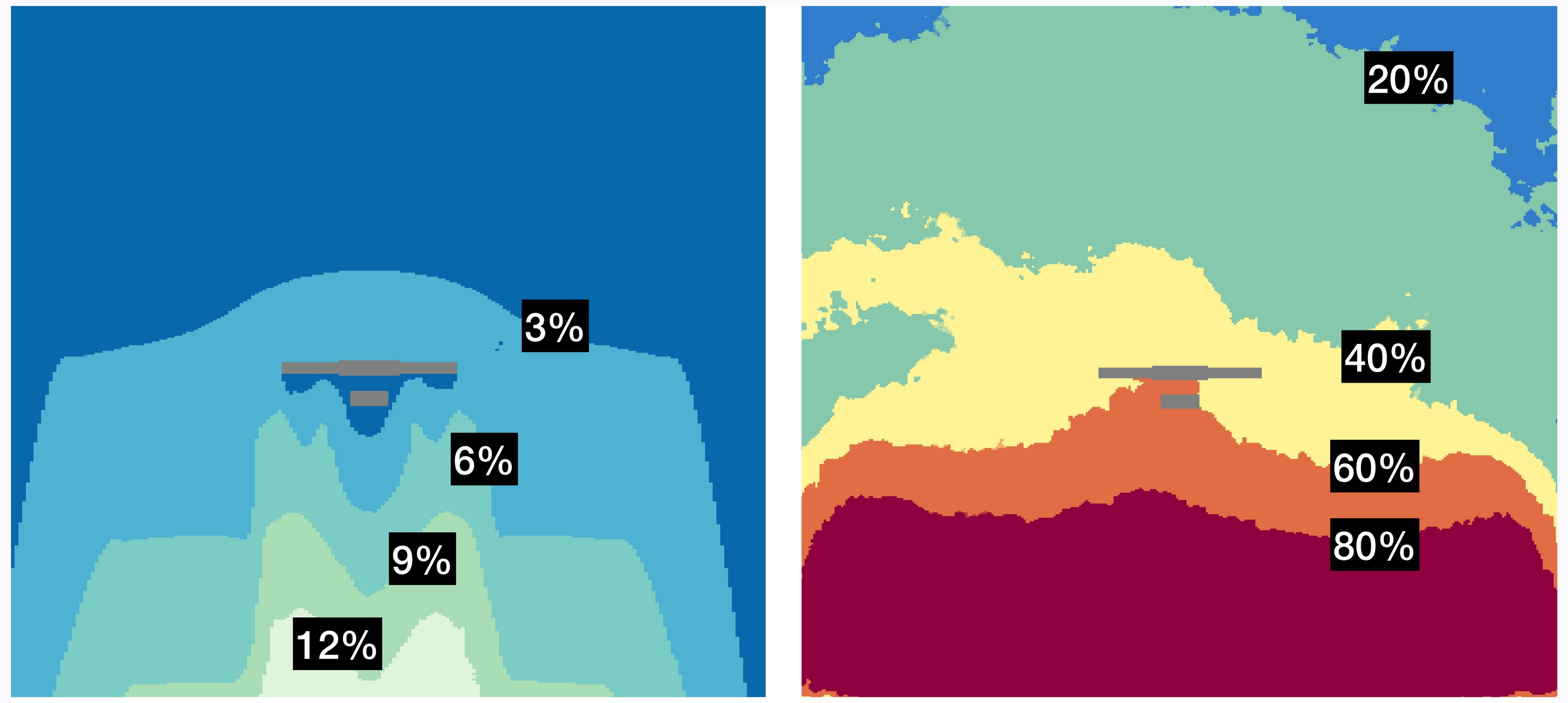

Fig. 5: Relative error map for ascent (left) and descent (right)

Conclusions

- Data should be only be collected during ascent
- Under the UAV is a suitable sensor location.

Funding for this project was provided by the National Science Foundation EAGER program and the Utah Division of Air Quality. Computational resources provided by the Center for High-Performance Computing at the University of Utah.