Estimating Error in UAV-Based Measurements Using CFD

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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

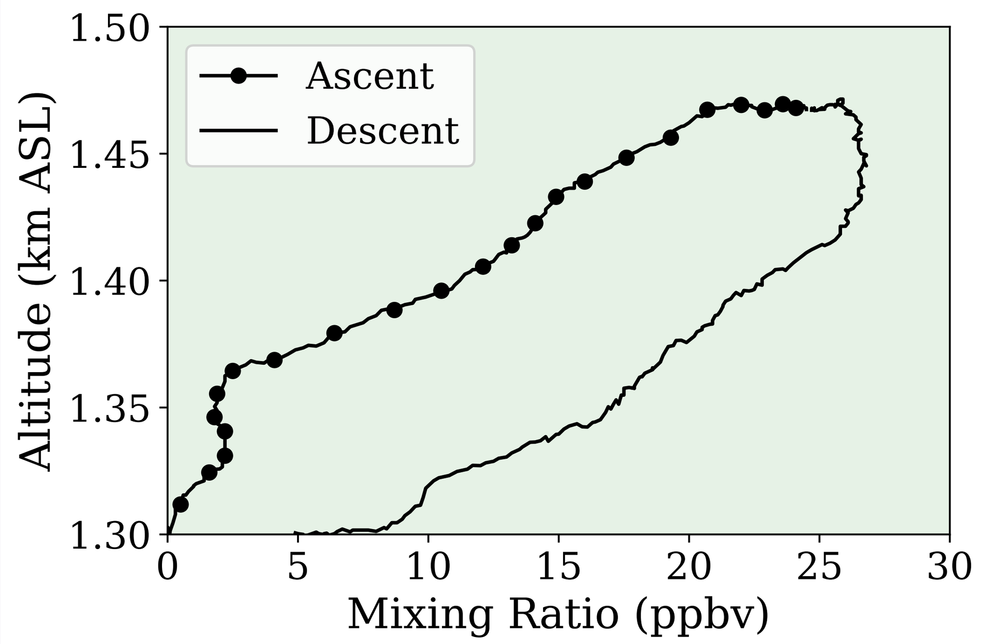

Fig. 2: Morning ozone profiles measured during ascent (dotted line) and descent (solid line)

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.

Simulations

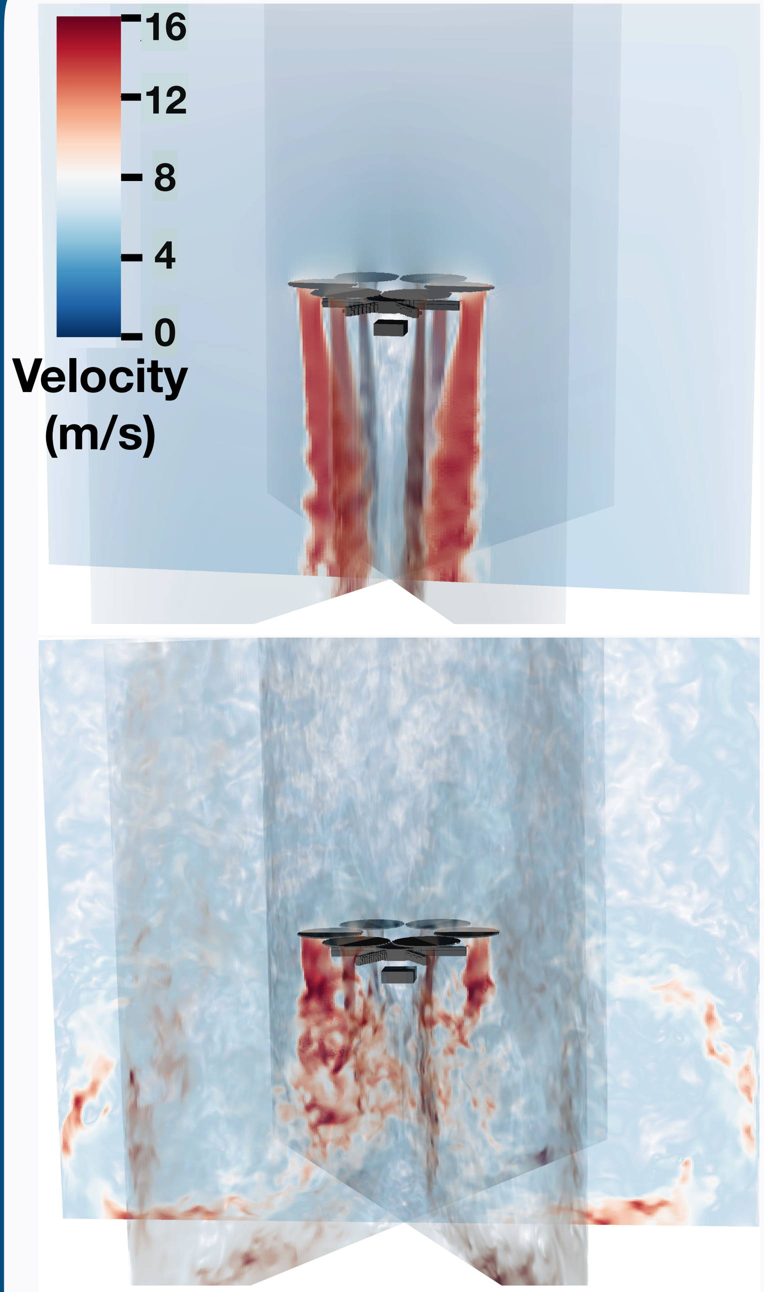

Fig. 3: Airflow (m/s) during ascent (top) and descent (bottom)

- 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)

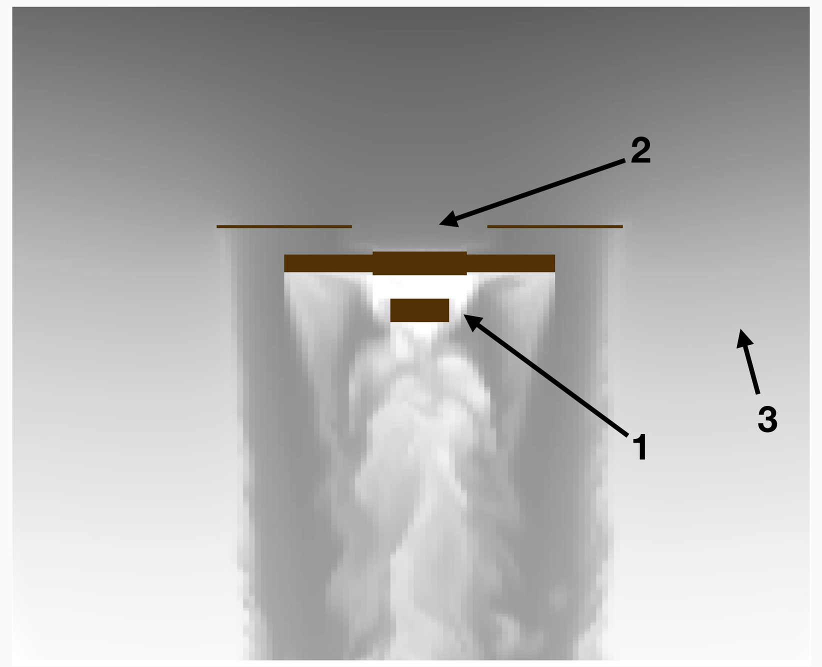

Fig. 4: Scalar profile during ascent with sensor locations marked

Results

Simulations produced a profile similar to our experiments (Fig. 5).

The relative error was minimal during ascent (4-7%), but much larger around the drone during descent (40-70%) (Fig. 6).

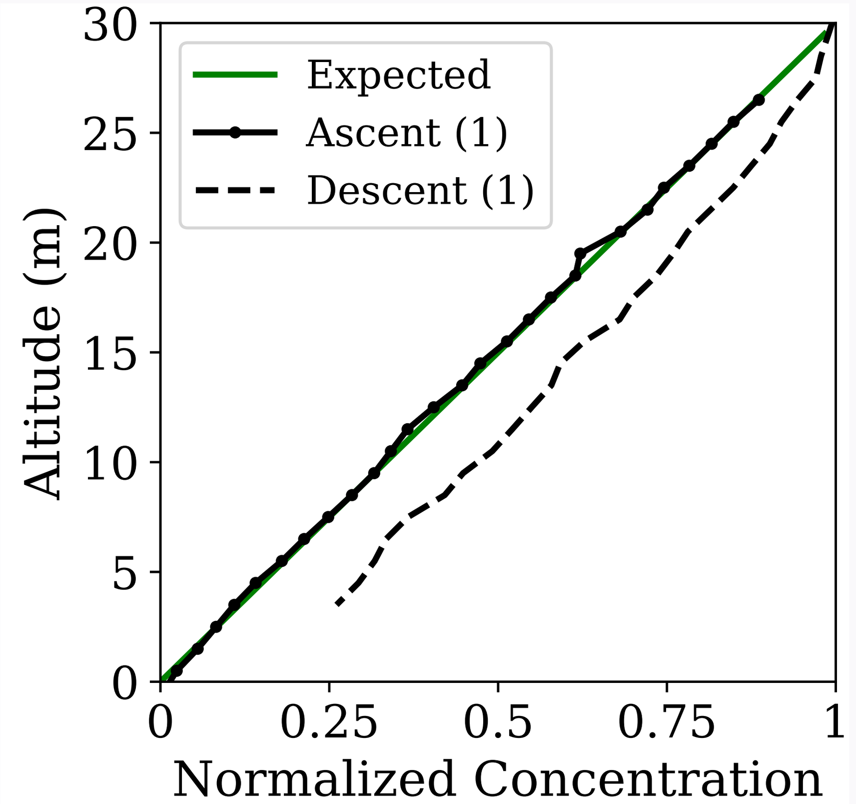

Fig. 5: Simulated ozone profile

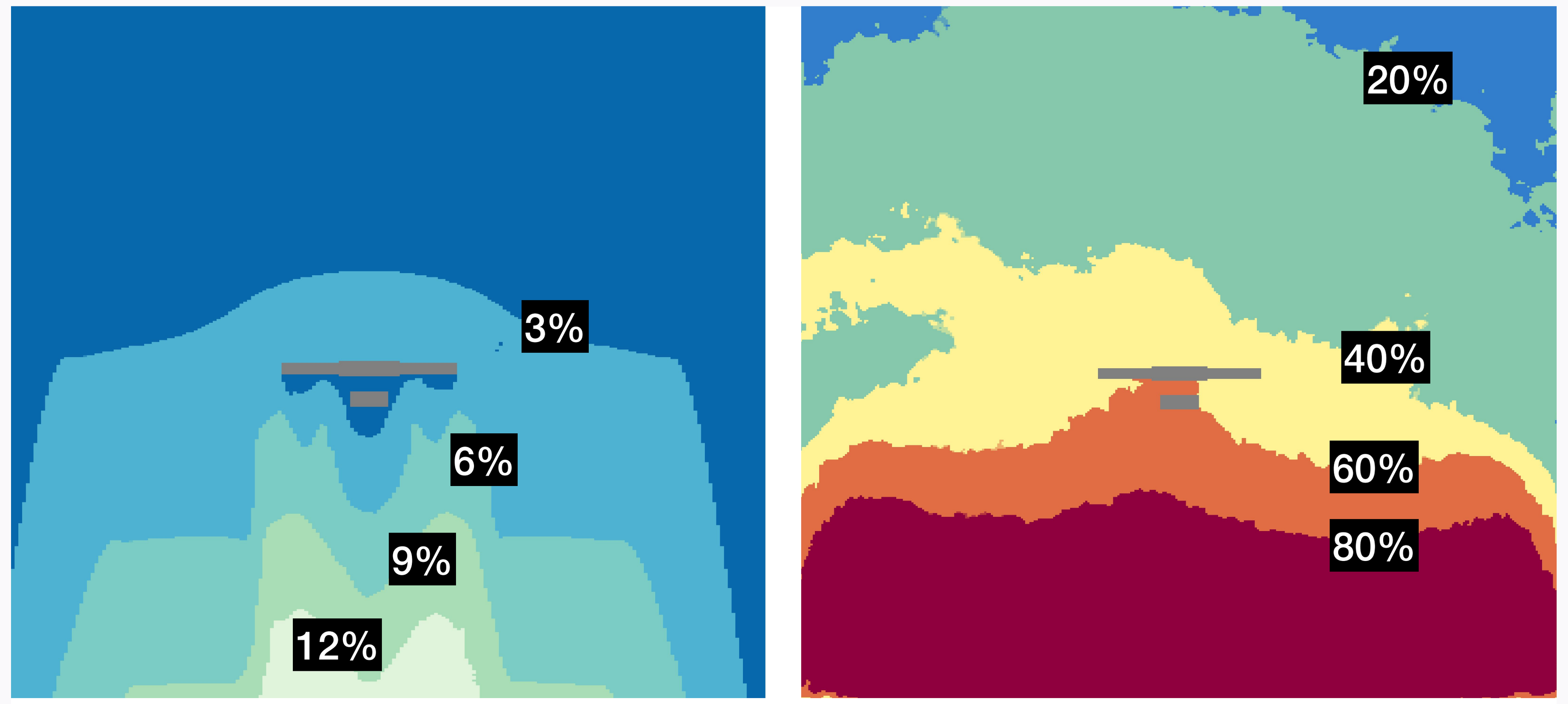

Fig. 6: Relative error map for ascent (left) and descent (right)

Conclusions

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

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