



Dedicated to innovation in aerospace

METSIS: METeo Sensors In the Sky

08-12-2021 | Dr.ir. Emmanuel Sunil

 11th SESAR Innovation Days





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Outline

1. Background and METSIS Concept
2. Experimental Validation
3. Results
4. Conclusions



What is METSIS?

Small drones have many applications....



Shipping



Mapping



Movie Filming



Infrastructure Management



Wildlife Monitoring



Agricultural



Disaster Management

**And Many
More...**

...but they are vulnerable to wind...



...especially at low altitudes

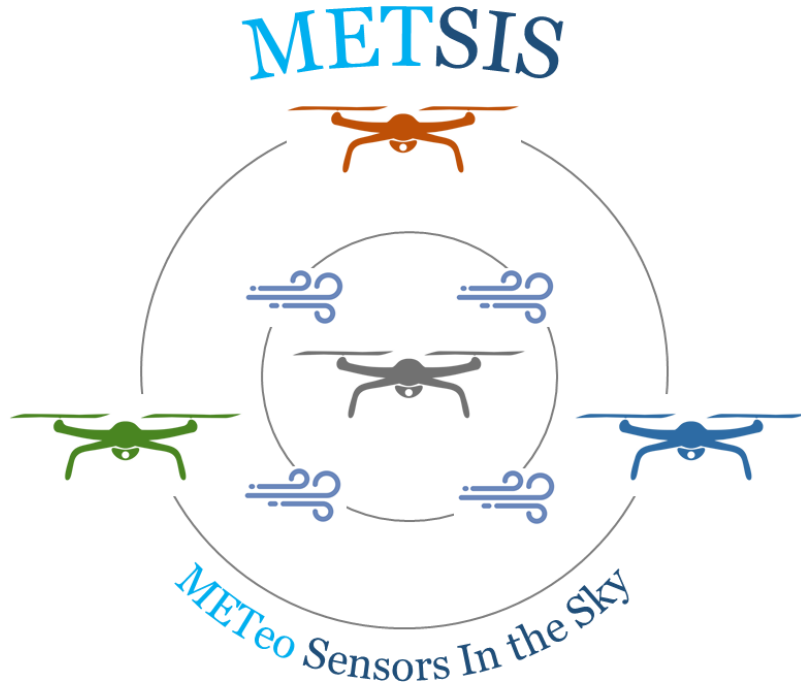
U-space and Weather



**Weather
Information Service**

U2

Collects and presents relevant weather information for the drone operation including **hyperlocal weather** information when available/required.



Investigating the use of drones as an aerial sensor network for low altitude hyper-local wind now-casting

Consortium



Advisory Board

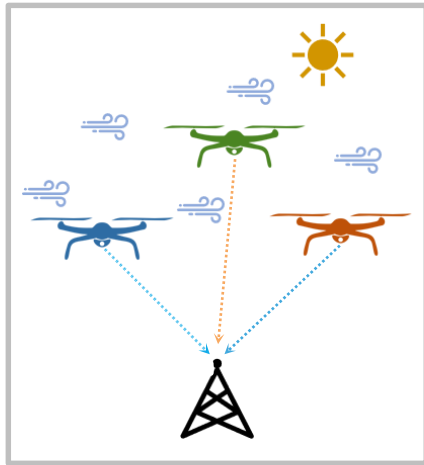


Funding

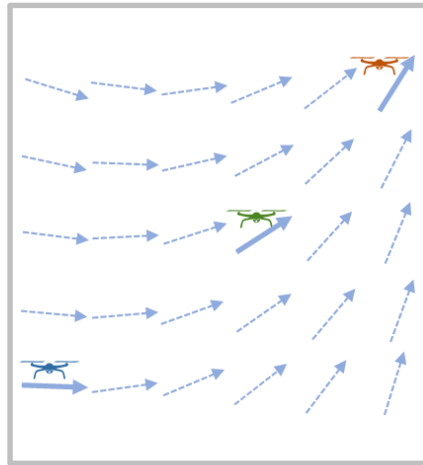


METSIS Concept Overview

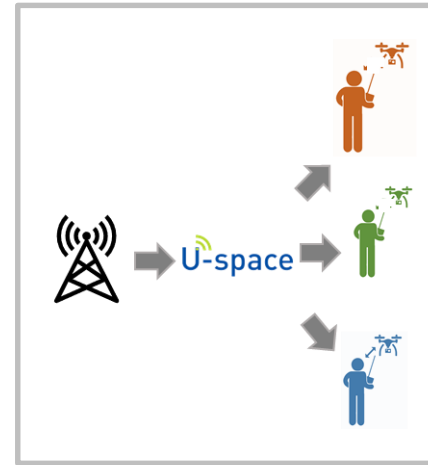
Using drones as an aerial sensor network for low altitude hyper-local wind now-casting



Step 1: Airborne drones measure instantaneous wind states and transmit data to a ground station

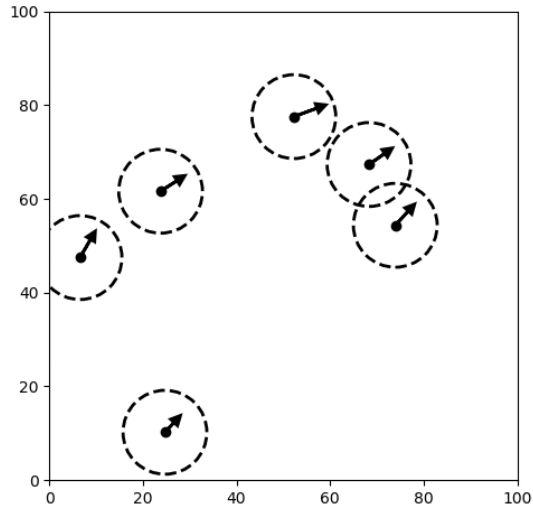


Step 2: Ground station uses the Meteo Particle Model (MPM) to estimate the wind field in real time

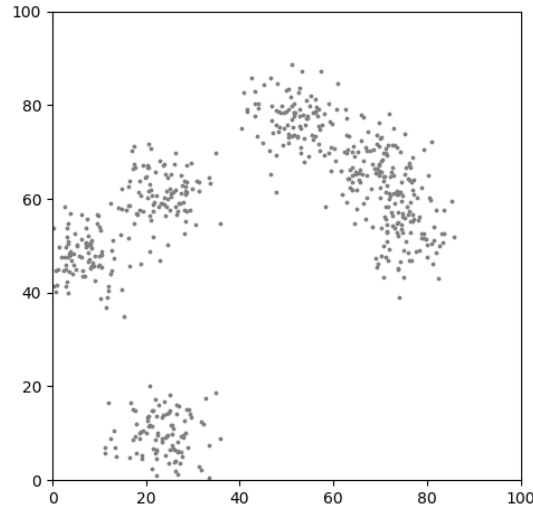


Step 3: The ground station communicates wind field data to drone operators via the U-space weather information service

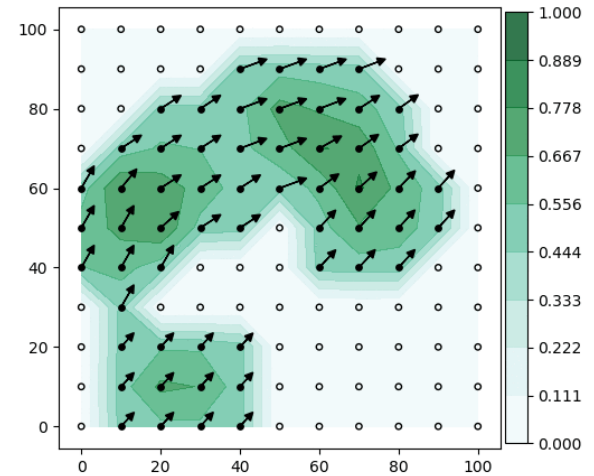
Previous Research: Meteo Particle Model (TU Delft)



Wind Measurements



Particle Generation



Wind Field Estimation



Project Objectives

Focus of this presentation

1. Determine the **accuracy** of the METSIS concept in the presence of static obstacles to estimate low altitude winds below 500 ft
2. Determine how low-altitude wind information should be communicated to drone operators within a **U-space** system



METSIS Benefits

- **Low cost and real-time** wind speed and direction estimates for very low level airspace
- Data can be used to **optimize drone trajectories** w.r.t wind
- Contribute to **U-space Weather Information Service**
- Data can be used as for **non-drone applications**
 - Additional input to national meteorological systems
 - Ship-Helicopter Operation Limitations (SHOL)

Experimental Validation

Experimental Testing: NLR Drone Center





Four Drones and Sensors



METSIS Drone and Sensor

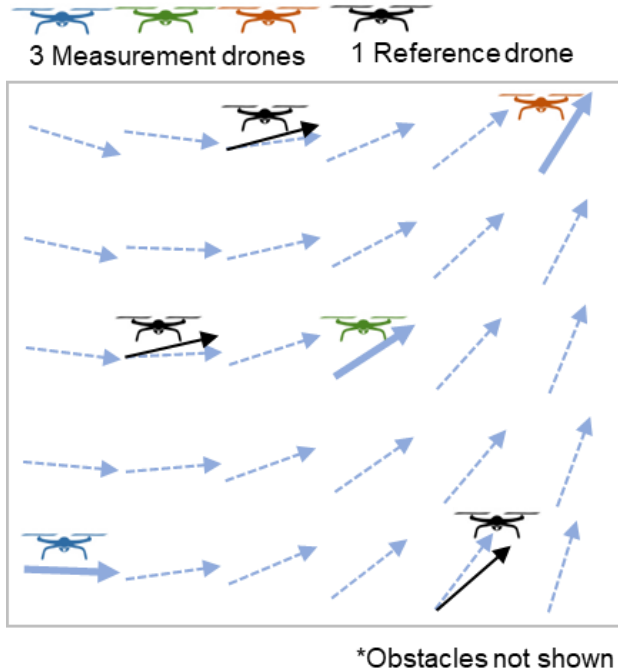


Anemoment Trisonica Mini
Ultrasonic Wind Sensor

Aluminum Pole

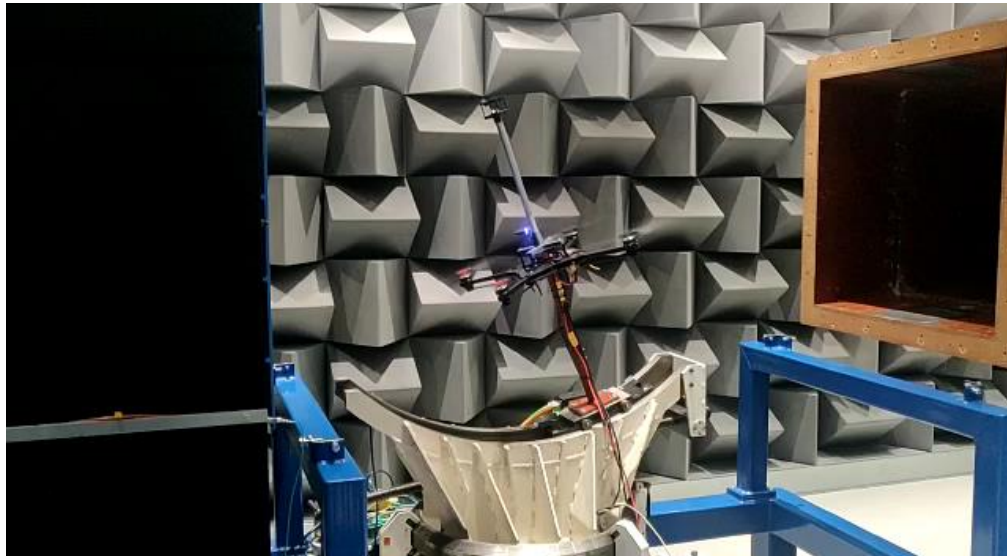
Foxtech Hover 1
Drone

Accuracy Through Comparison



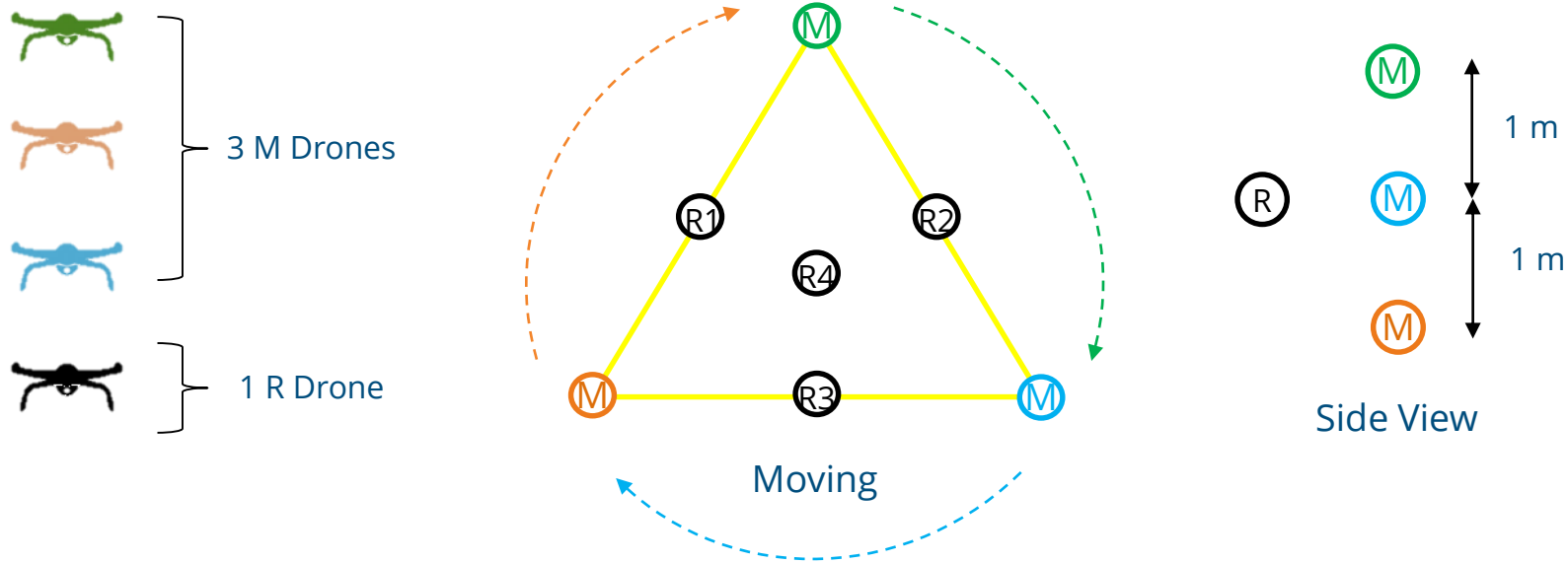
- **3 Measurement drones:** feed METSIS network
- **1 Reference drone:** Use as reference measurement
- **Accuracy:** Difference between reference measurement and METSIS network estimate at reference drone locations

Wind Tunnel Testing: NLR Anechoic Wind Tunnel



- 3 Wind tunnel speeds: 3, 6 and 9 m/s
- 9 Angles of attack: -2° to 18°
- 2 Drone propeller speeds: 0% and 50 %

Predefined Topology: Equilateral Triangle



Note:

- Measurement drones at the 3 corners of the triangle with slightly different altitudes (for safety)
- Accuracy is measured at 4 "accuracy locations" by reference drone: R1-R4
- During static scenarios, the measurement drones fly a circular path

Flight Test Scenarios

- 4 Altitudes (up to 100 meters)
- 3 Distances between drones
- 2 Drone speeds
- 2 Obstacles



Obstacle 1: Van + Trailer



Obstacle 2: Trees

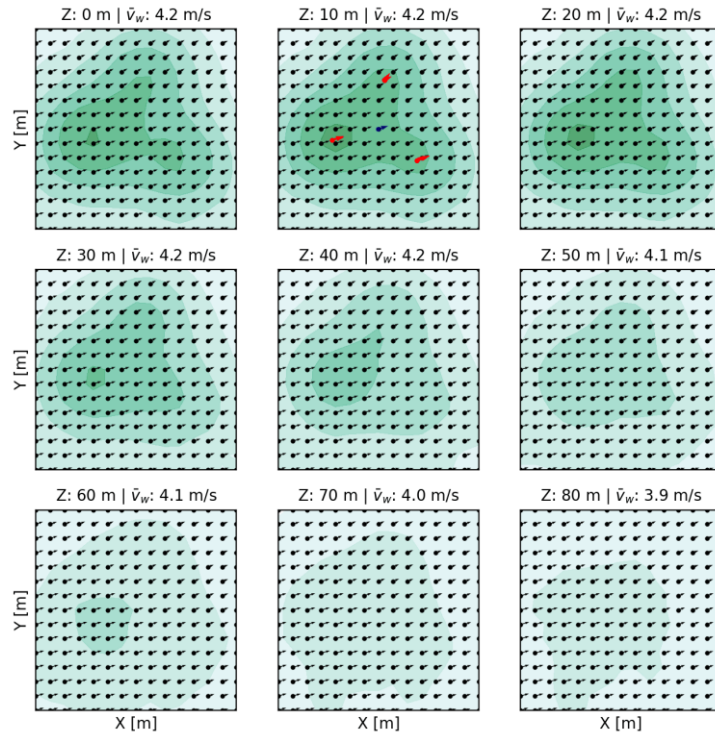


Flight Test Video

Results

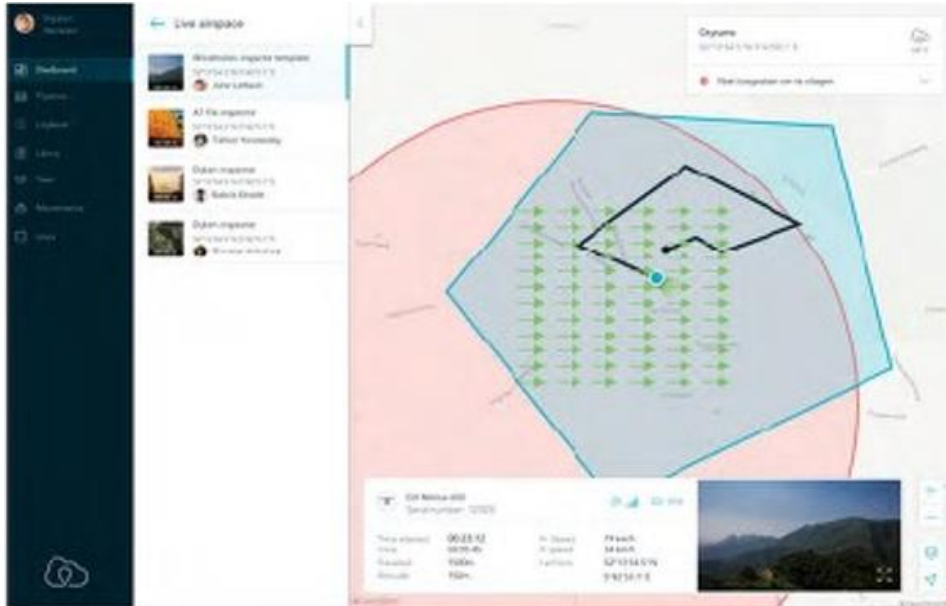
METSIS Output: Wind Contour Plots

Scenario 1, Tri: 60m, alt: 10m, spd: 0m/s
 $t_{sec} = 37.0$



- Separate estimate for each altitude
- Green color indicates confidence interval
- Confidence highest at the altitude and location of drones

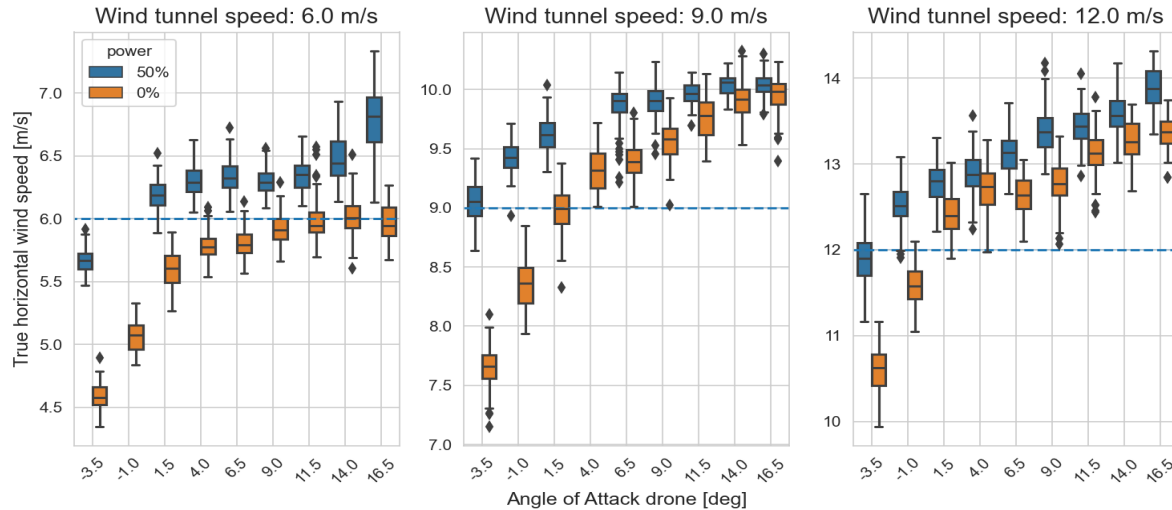
Real-Time Data Transmission to AirHub



- Every 30 seconds
- HTTP POST
- Data in JSON format

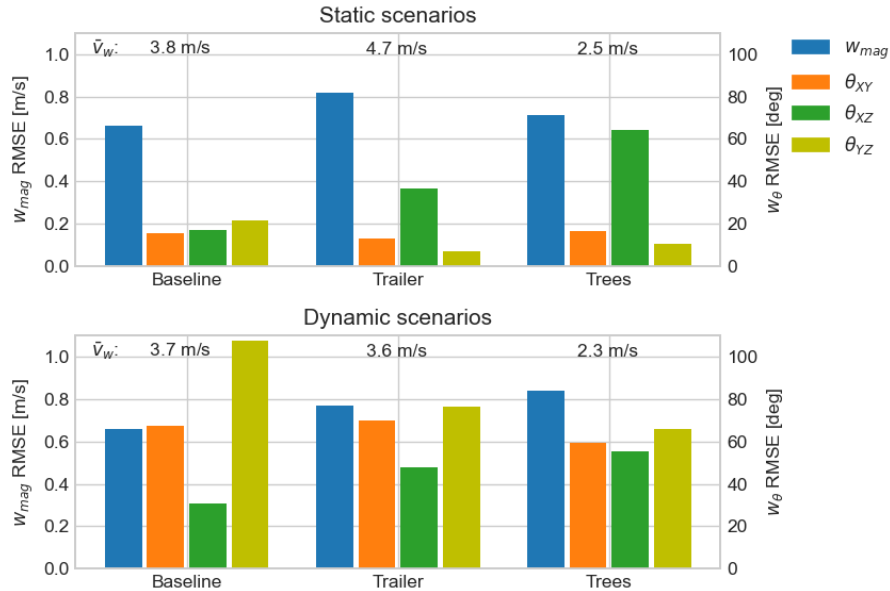
Wind Tunnel Results for Anemometer

Horizontal Wind Speed



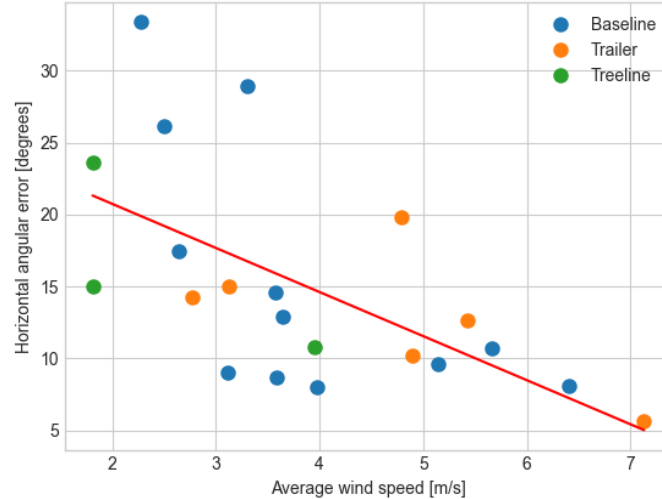
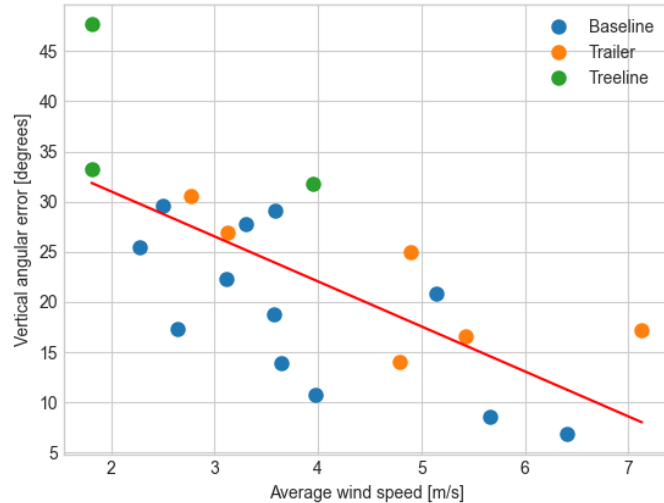
- Sensor accuracy degrades with angle of attack
- **Propeller induced flow** negatively affects sensor accuracy, especially at low wind speeds

Overview of METSIS Accuracy



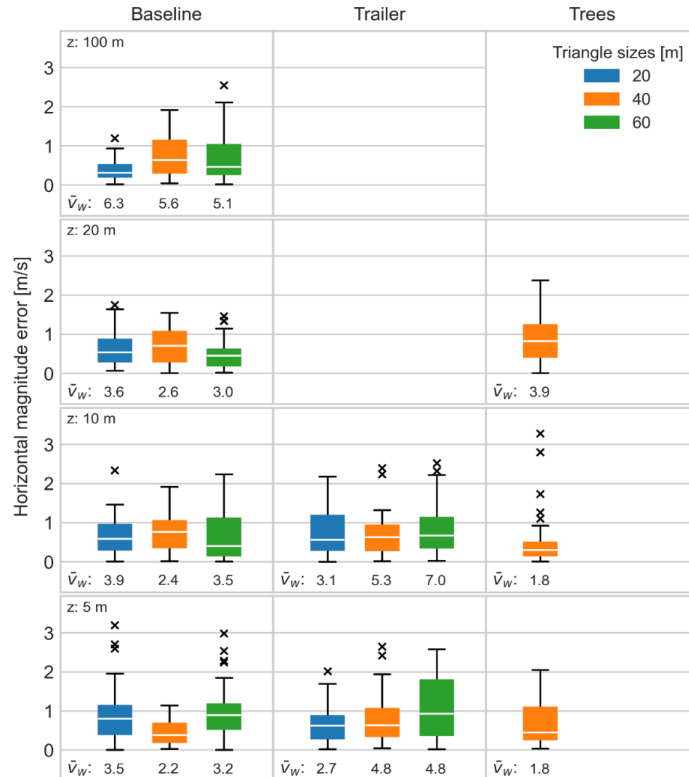
- WMO standard:
 - 0.5 m/s error for $\bar{V}_w < 5$ m/s
 - 5° for wind direction
- Wind speeds during the experiment were low (< 7 m/s)
- On average, **wind speed is reasonably accurate** for both static and dynamic conditions $\rightarrow$ very promising!
- Wind direction is less accurate** than the WMO standard, particularly in the dynamic conditions $\rightarrow$ caused by propeller induced flow over the sensors during dynamic conditions and low wind speeds.

Wind Speed vs. Angular Accuracy (Static Only)



Angular error decreases with increasing wind speed.
Therefore the low average wind speeds during the experiment affected the average direction accuracy in the previous bar charts

Effect of Obstacles



Horizontal Magnitude - Static Drones

- Wind speed was much lower below the tree line as expected
- No significant difference in horizontal speed error as a results of obstacles for all altitudes and distances between drones
- Same conclusion found for:
 - Vertical speed error
 - Vertical angular error
- The horizontal angular error increased below the tree line. This may be connected to the lower wind speeds below the tree line.

Conclusions

METSIS: METeo Sensors in the Sky

- **Concept:** Using drones as a low-cost aerial sensor network for low-altitude **hyper-local wind now-casting**
- **Experimentally tested** using four drones
- **Results:**
 - Concept is **feasible!**
 - Accuracy is promising but needs to further improved





Recommendations for Future Research

- **More scenarios** over multiple experiment days to have more conclusive answers to primary research questions. Independent wind measurements for validation.
- **Increase scalability:** use indirect wind measurement methods that do not require dedicated anemometer
- **Increase accuracy:** optimize MPM parameters, e.g. using PSO
- **Increase utility:** Use METSIS wind nowcasts for computing wind optimized drone trajectories
- Looking for enthusiastic partners to continue this project in **SESAR 3!**

Thank you for your attention!

Questions?

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