Importance (?) of Wind Sensor Averaging Times for Predicting Short-Range Dispersal

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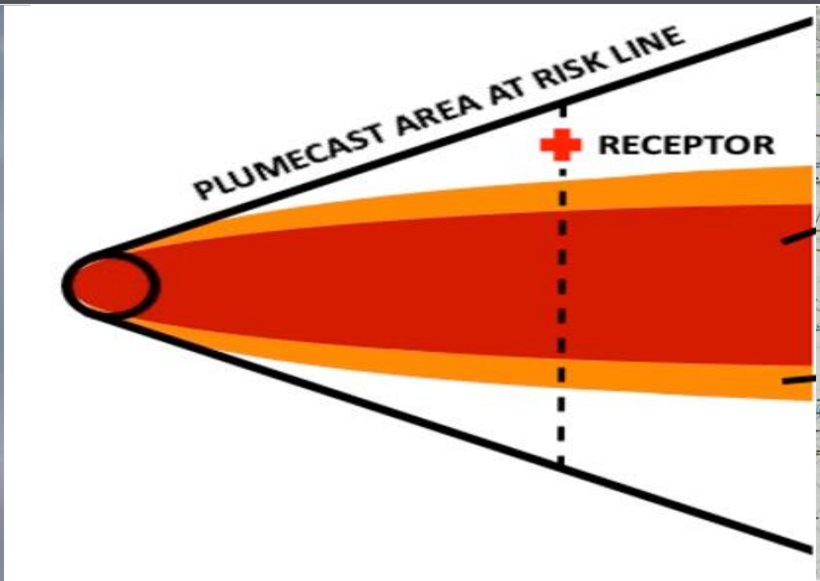

Q. Luo, M. Brettle and R. S. Plant

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Short-Range Dispersal

- Consider an accidental atmospheric release of some potentially-dangerous material

- We focus on its short time / short range dispersal

- Plumecast is a commercial system used to predict risk and safe areas, aiming to support decisions within minutes of an event

- If surface layer is reasonably homogeneous, then observations from a single, local wind sensor can be useful to estimate maximum turbulent spread at scales of up to 10km

Plumecast

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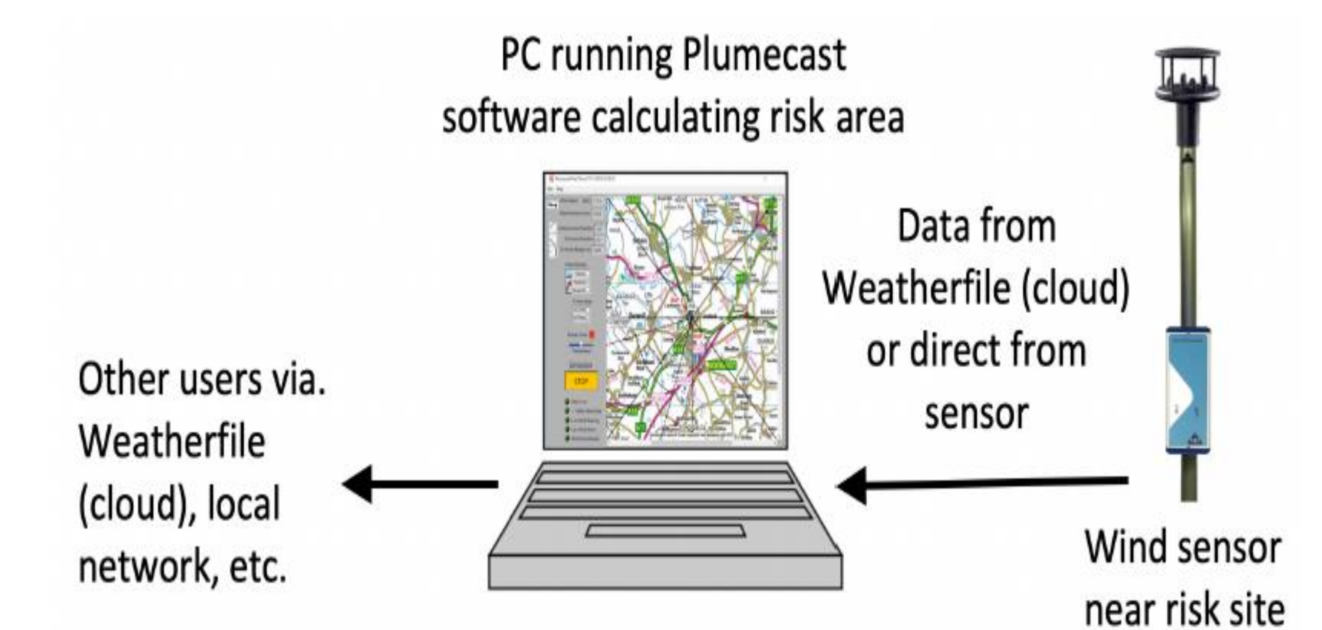
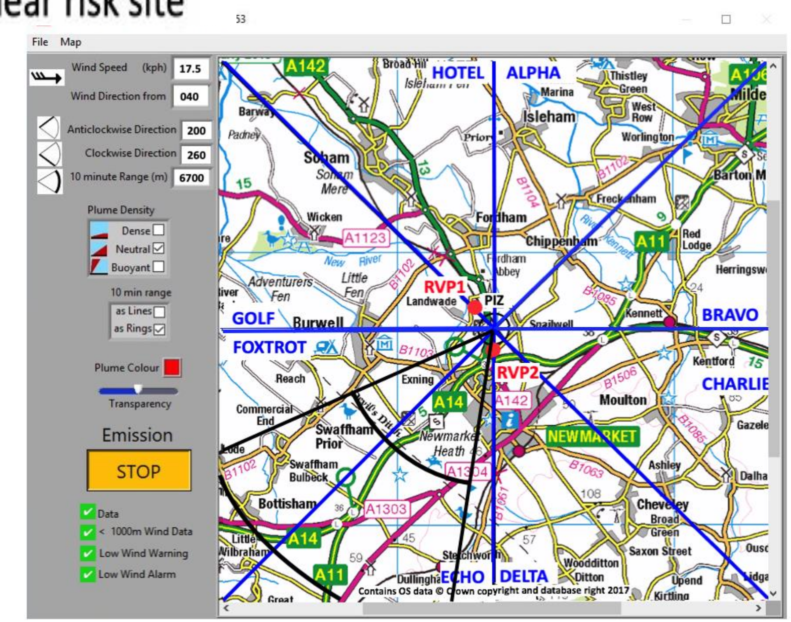


- Sensor communicates with PC, making rapid updates to risk area if release should occur

- Range rings show how far a plume would travel in 10 min



Sensor requirements

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- High frequency data can capture the full turbulent fluctuations, but may limit the choice of sensor

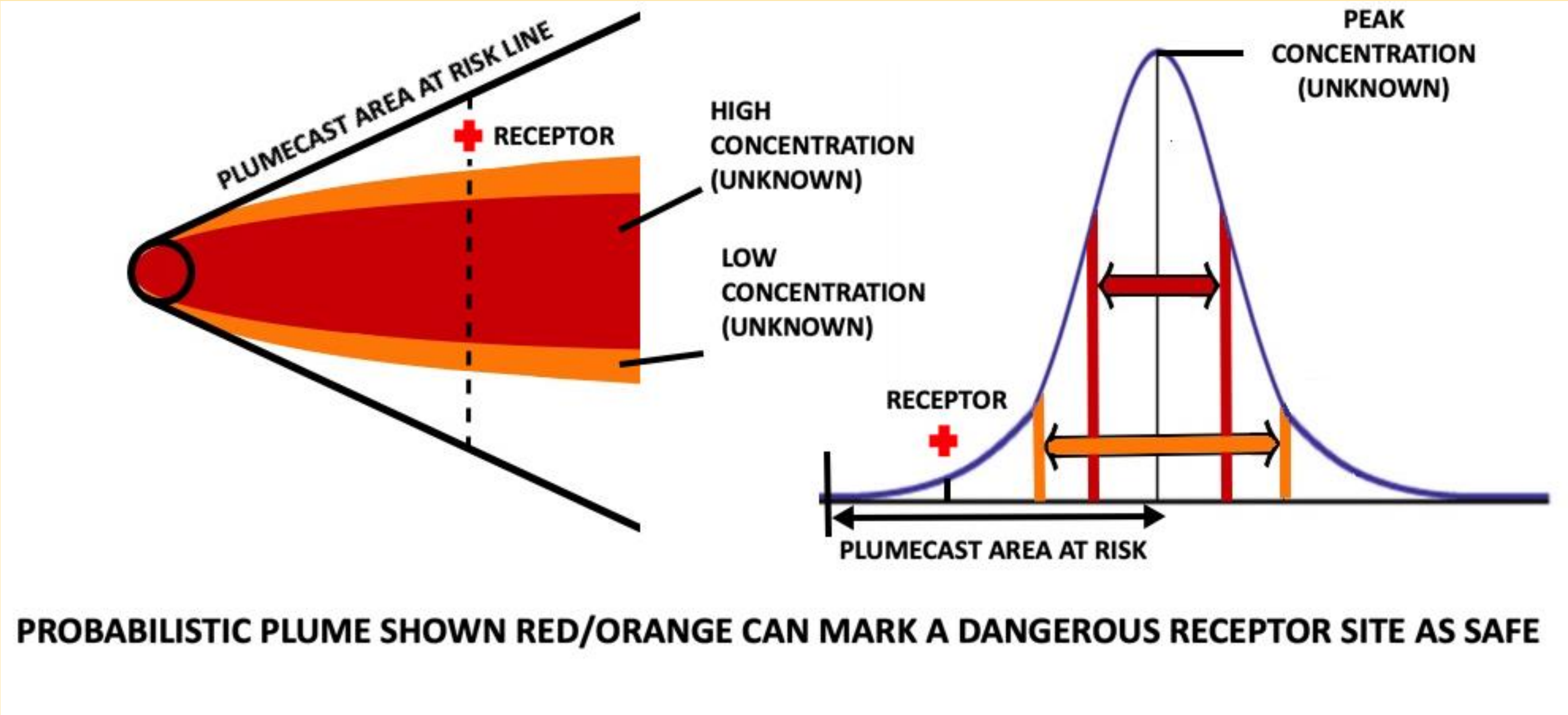
- Here we take 10Hz observational data recorded over several months and investigate degrading it

  - Average the 10Hz data to lower frequencies
  - Sample the 10Hz data at lower frequencies

- What measurement averaging periods / sampling periods are appropriate for a reliable system?

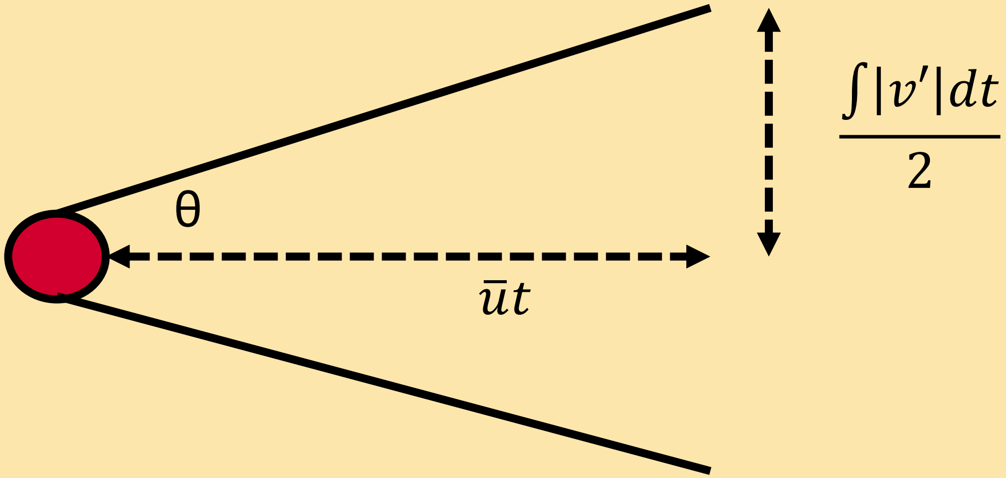
At-Risk Area

- A Gaussian plume or random walk model aims to provide guidance on concentrations within a spreading plume
- The “at-risk area” instead asks where concentration might be non-zero



Calculations

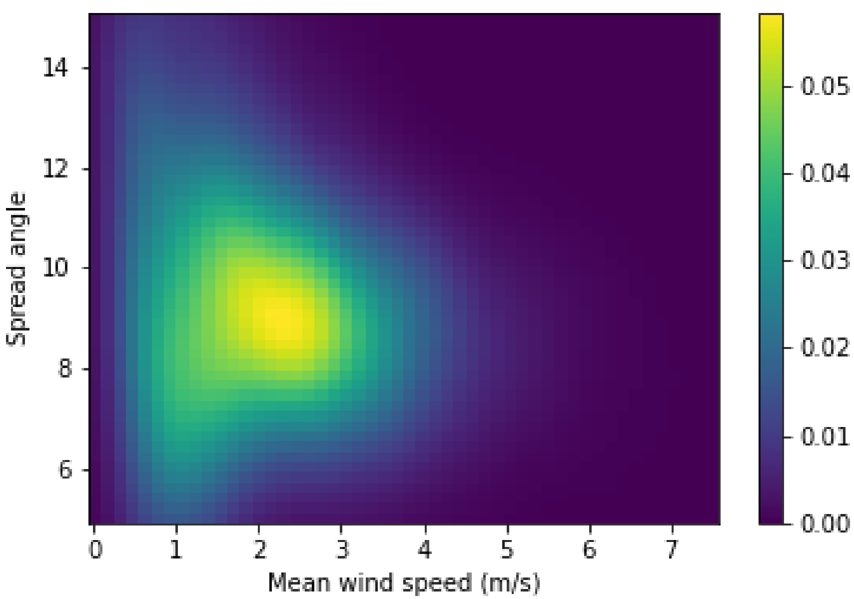
- Divide data into chunks (10min here, but have repeated for others, up to 1h)
- Determine mean wind in period
- Rotate measurements into along and across directions
- Calculate spread angle



- i.e. limit of spread occurs for a parcel experiencing all cross-wind fluctuations of one sign and none of the opposite sign

Instruments and spread

- Data from UoR observatory
- Using a Gill Wind-master Prosonic anemometer at 3m
- 84 complete days of data between12 Jan and 30 Apr 2024



- Don’t find clear systematic variations of the spreading angle with wind direction, rainfall rate, time of day etc
- Some increase, and clear increase in variability, for smaller wind speeds

Degrading data, an example

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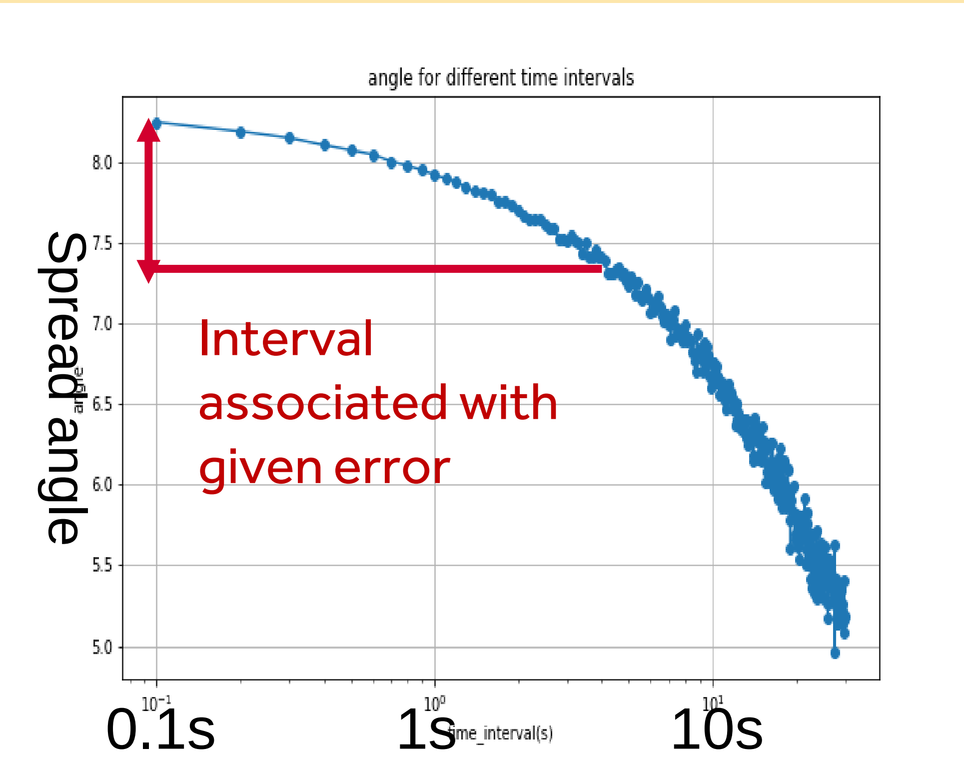
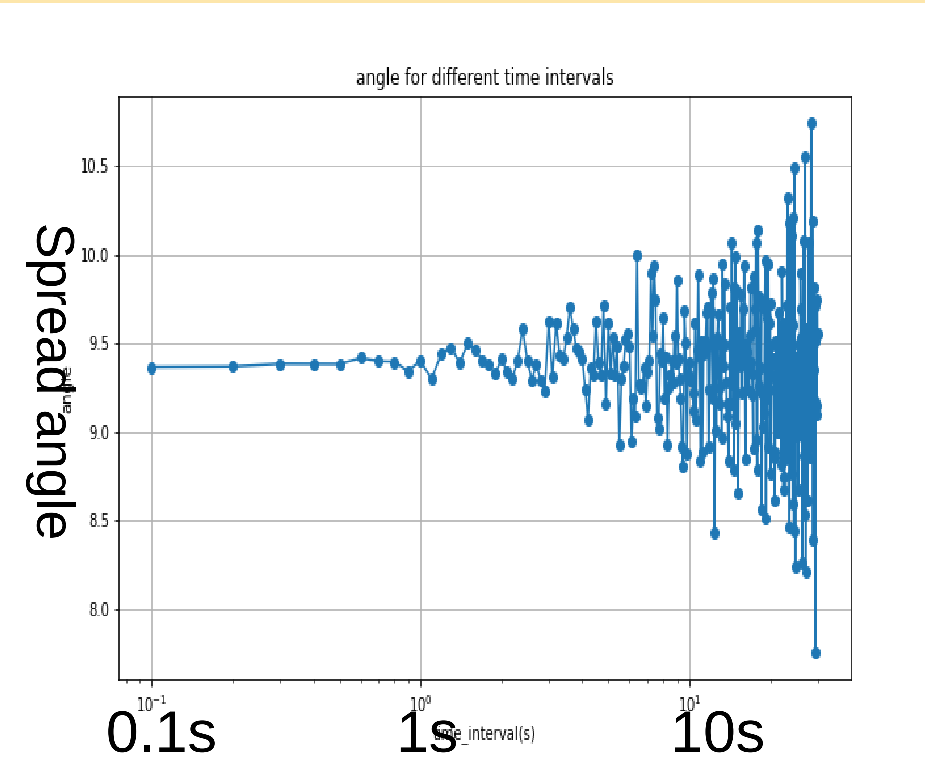
Averaging



10Hz 1Hz 0.1Hz

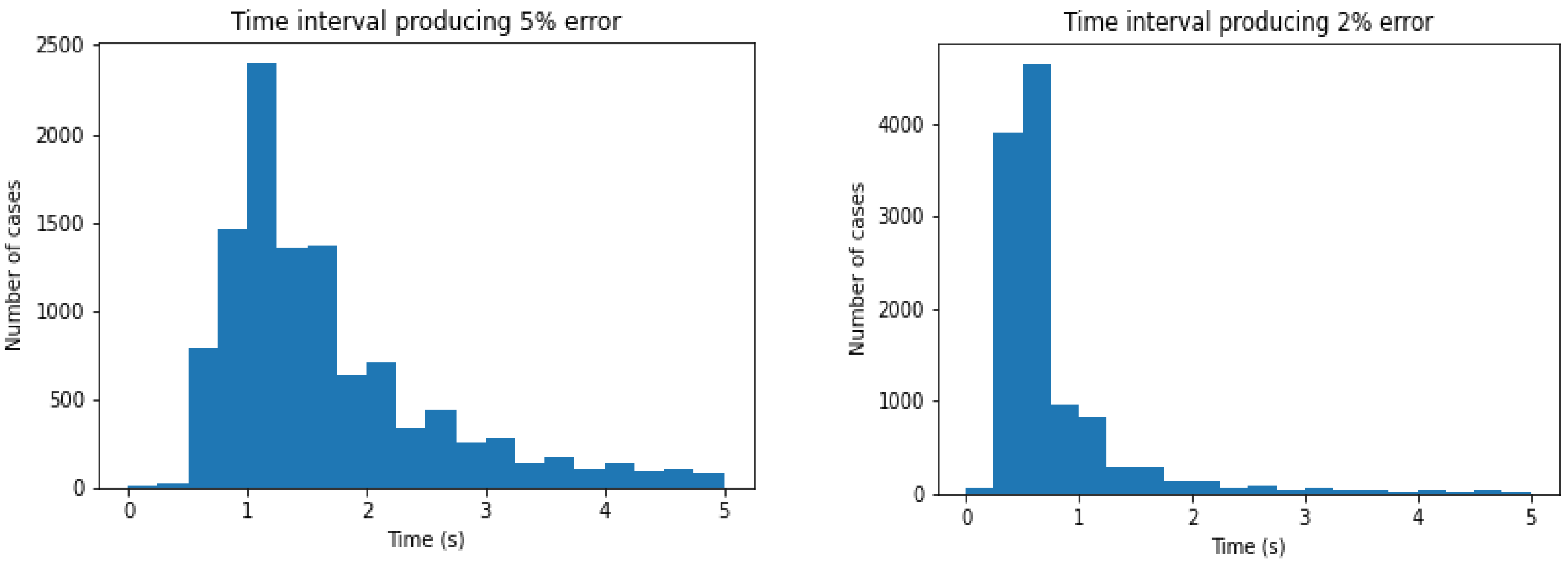
Sub-sampling



10Hz 1Hz 0.1Hz

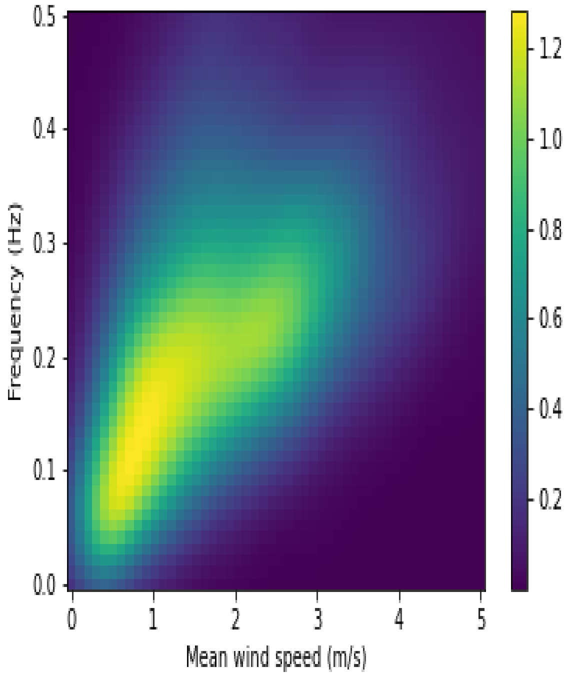
Acceptable level of averaging

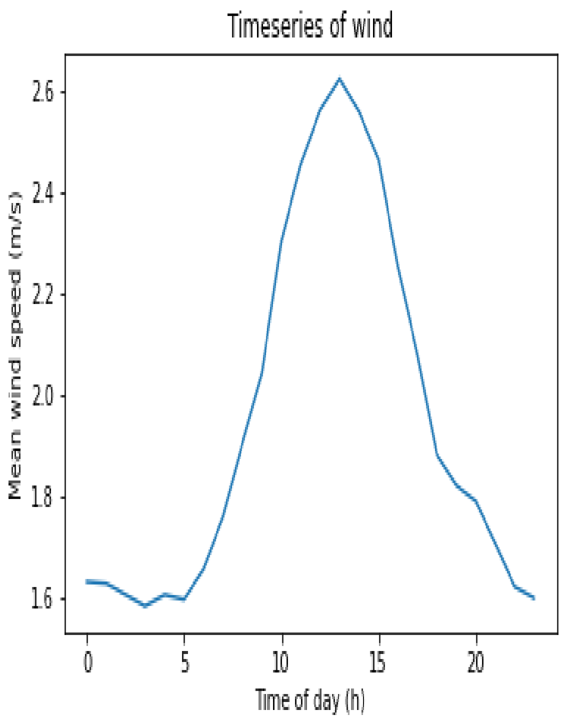
To keep error in $\frac{\int |v'| dt}{2}$ to within 5% (left) or 2% (right)

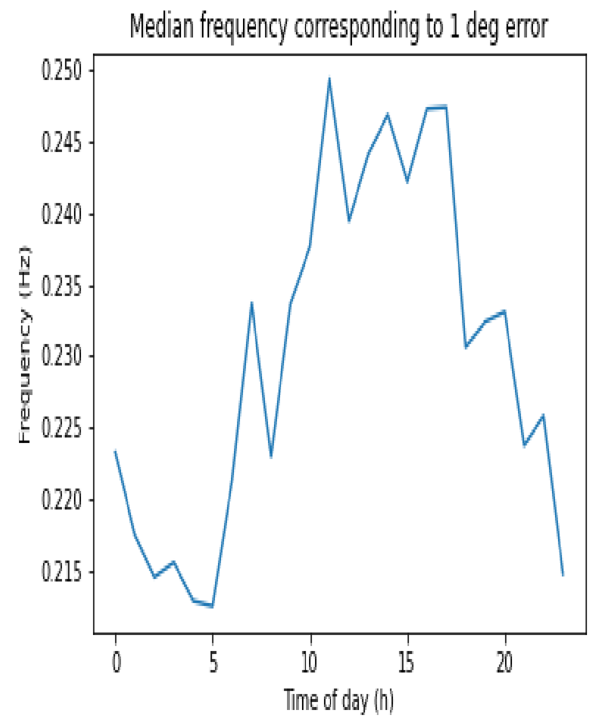


- 5% accuracy is available for data averaged to correspond to 1Hz in 75% of cases
- 2% accuracy needs data corresponding to 2Hz in the median

Factors affecting averaging level







- Here we look at the frequency corresponding to the averaging that leads to an error of 1 degree in the spreading angle θ
- Reduction in how much averaging is acceptable for given error at higher wind speeds
- Modest diurnal cycle may be due to stability but also consistent with the (related) diurnal cycle of surface-layer wind at the site

Sampling vs averaging

- All the qualitative comments and (non-)dependencies above hold true if we subsample the 10Hz data rather than average it to lower time resolutions

- Slightly more degradation is acceptable for given error measures

- e.g. 2% accuracy in $\frac{\int |v'| dt}{2}$ can be obtained with data sampling of 0.8Hz in the median (compared to 2Hz)

Summary

- In general it is good news for the Plumecast strategy
- Errors of 5% in the key turbulence metric can be achieved with confidence using a 1 Hz sensor
- Some modest variations of error characteristics found across diurnal cycle, consistent with variations against wind speed
- Caveat: here we are considering errors due to the data collection strategy, taking 10 Hz as a reference truth
- The sensors have other systematic errors