Eddy Covariance theory and practice: from sensors setup to preliminary data processing

Module: **Setup sito**

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IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
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INTRO

- A lot of options to consider to design an EC station
- Best compromise between reaching the scientific aim and implementation costs
- A good design allows to
  - minimize measurement errors / maximize measurement representativity
  - reduce maintenance, thus reducing the disturbances
  - keep the station efficient over time

What we'll see

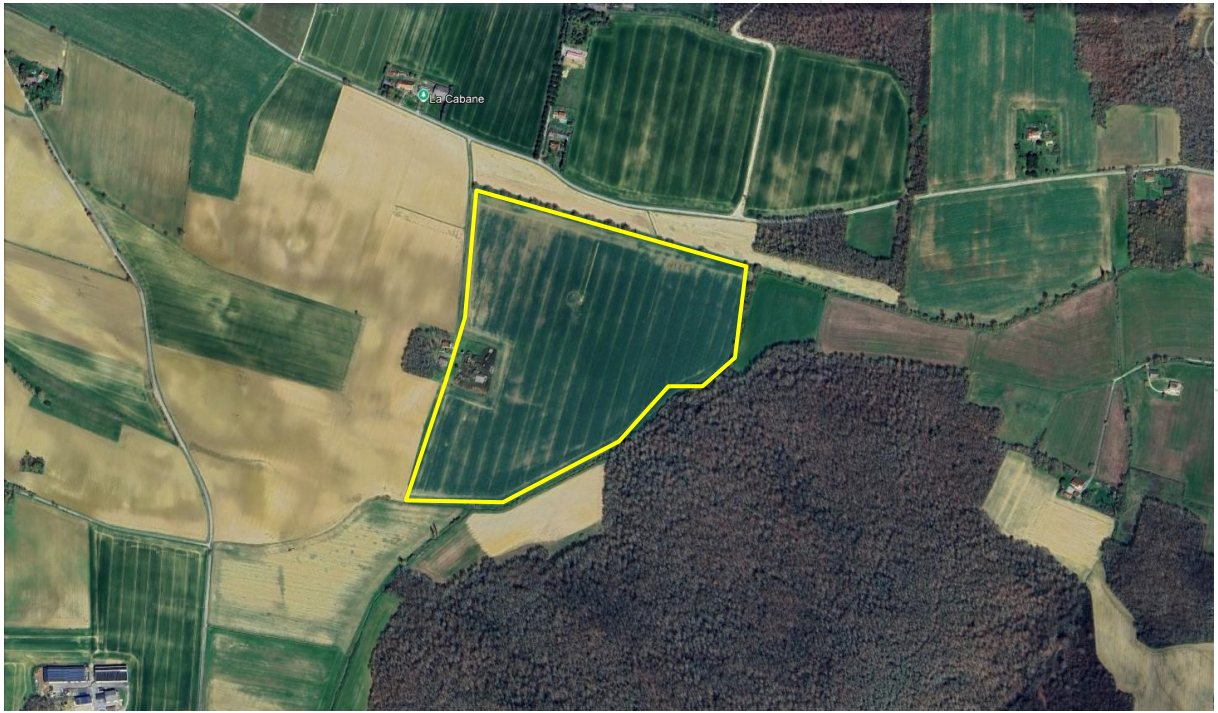
theoretical and practical considerations to optimize the tower positioning and its design

INTRO

1. Tower location
    a. Site selection
    b. Micrometeorological / environmental constraints
2. Tower structure
    a. Tower type / size / height
3. Supporting structures

1. Tower location: site and preventive considerations

Site selection: little room for decision-making!



1. Tower location: site and preventive considerations

Minimize environmental disturbances

- Excessive openings in forests

Mymic the canopy pattern!

1. Tower location: site and preventive considerations

Minimize environmental disturbances

- Excessive openings over crops

1. Tower location: site and preventive considerations

Minimize environmental disturbances

- Excessive infrastructures
  e.g. walkways over wetlands

1. Tower location: site and preventive considerations

Minimize environmental disturbances

- Spoiling of air

  even sporadic during maintenance

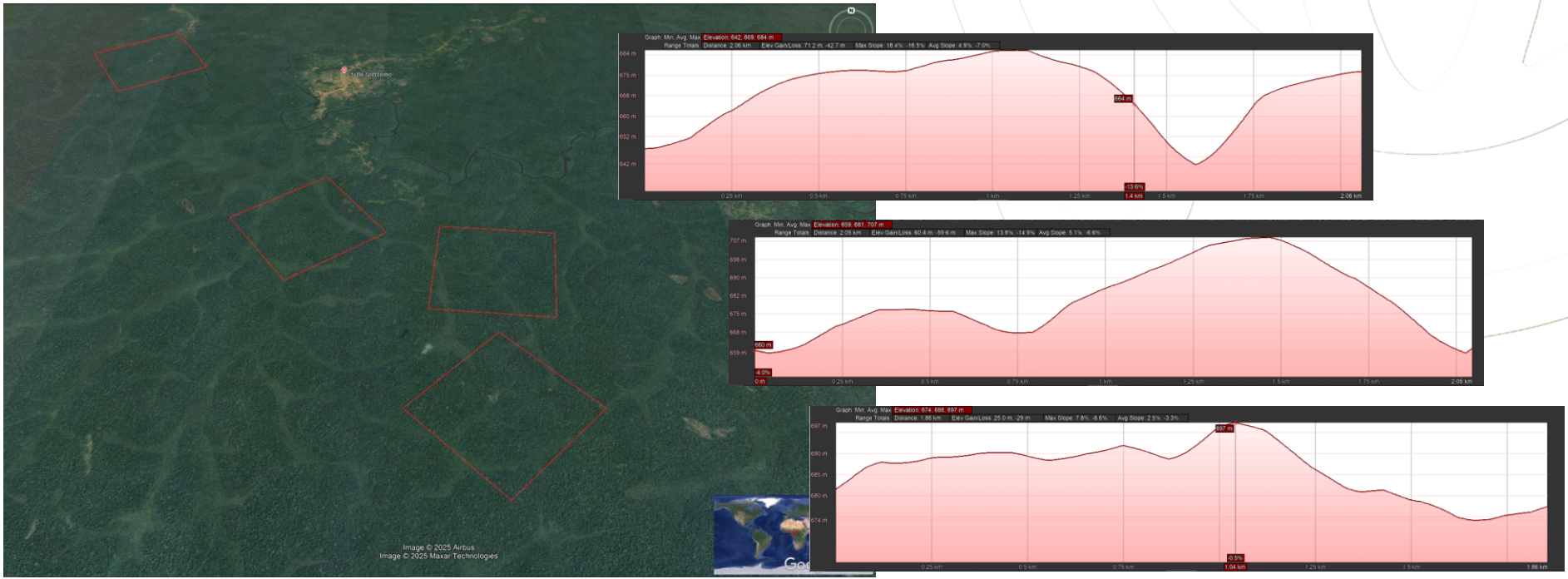
1. Tower location: ideal conditions

Which are the **ideal conditions** for EC measurements?

1. Flat terrain
2. Non-sloping terrain
3. Uniform cover

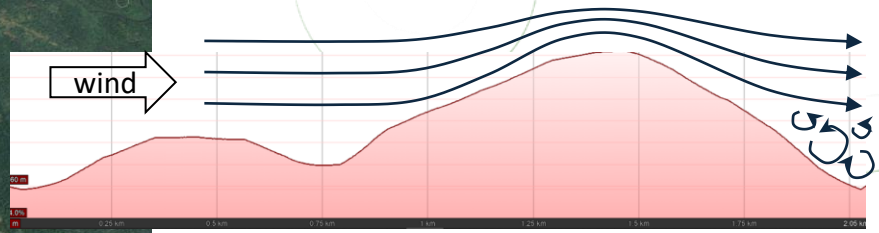
1. Tower location: topographic constraints

1. Flat terrain: avoid the presence of valleys/dips or hills



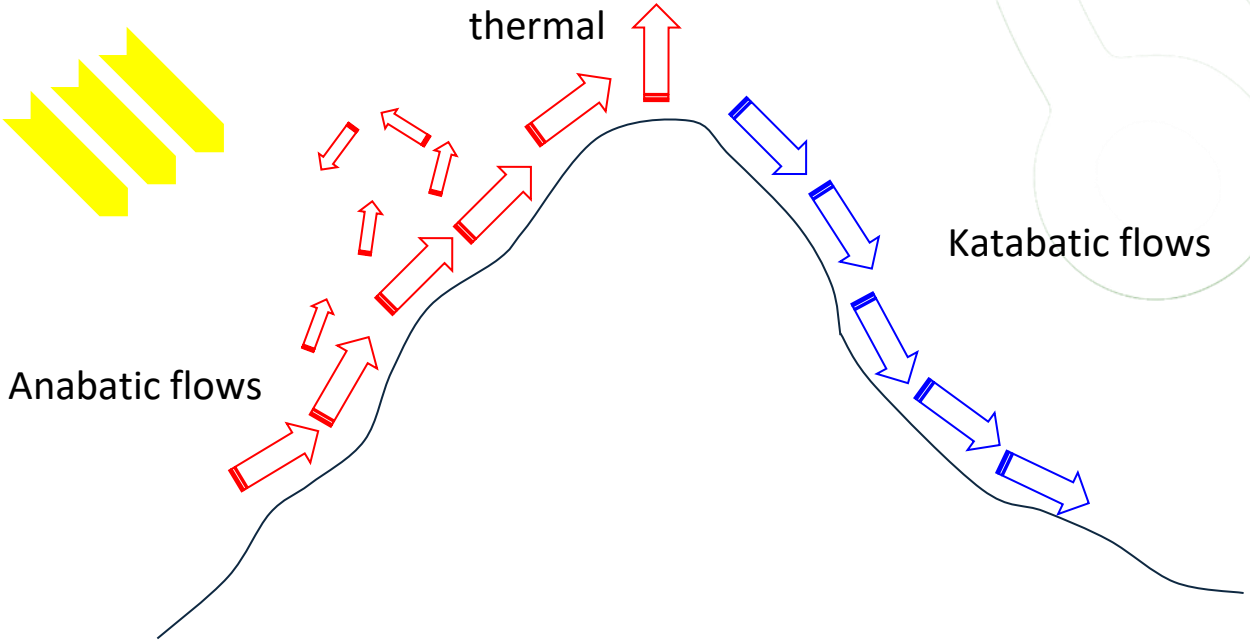
1. Tower location: topographic constraints

1. Flat terrain: avoid the presence of valleys/dips or hills



1. Tower location: topographic constraints

2. Non-sloping terrain: avoid slopes and steep sides



1. Tower location: fetch

3. Uniform cover

Fetch: minimum along-wind distance to the next inhomogeneity

Adequate to the target surface and it must especially be respected

- for the prevailing wind direction (if any)
- under all atmospheric stability conditions

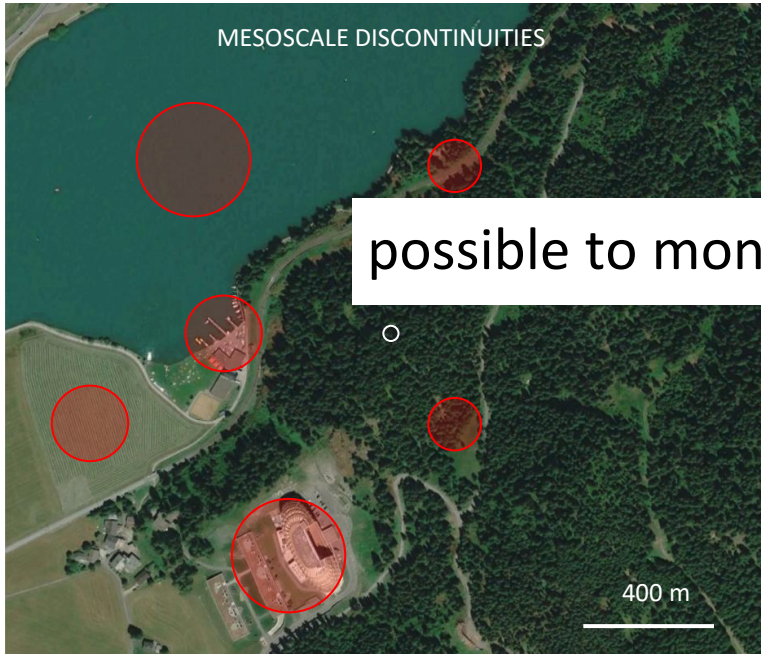
1. Tower location: fetch

What does it means adequate fetch?

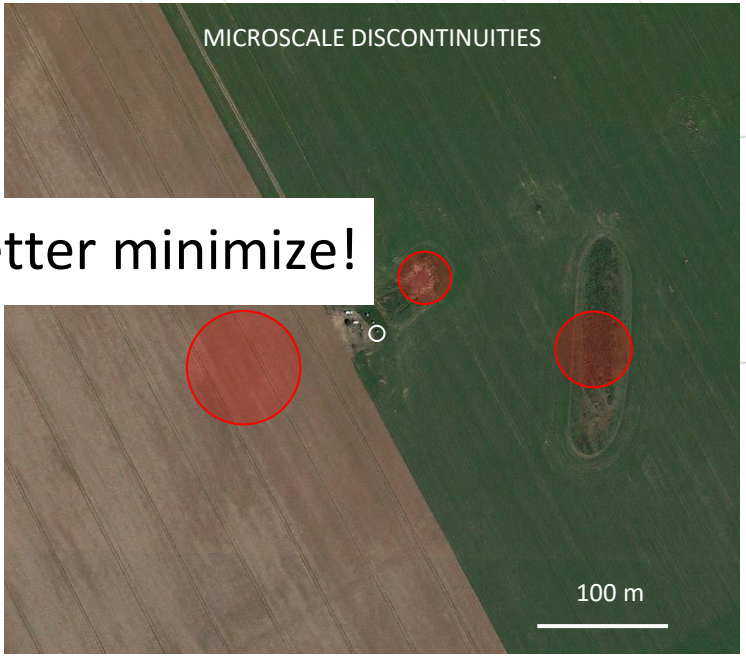
(or which inhomogeneities are of concern)

1. Tower location: fetch

1) Landscape/environment variability



possible to monitor, better minimize!



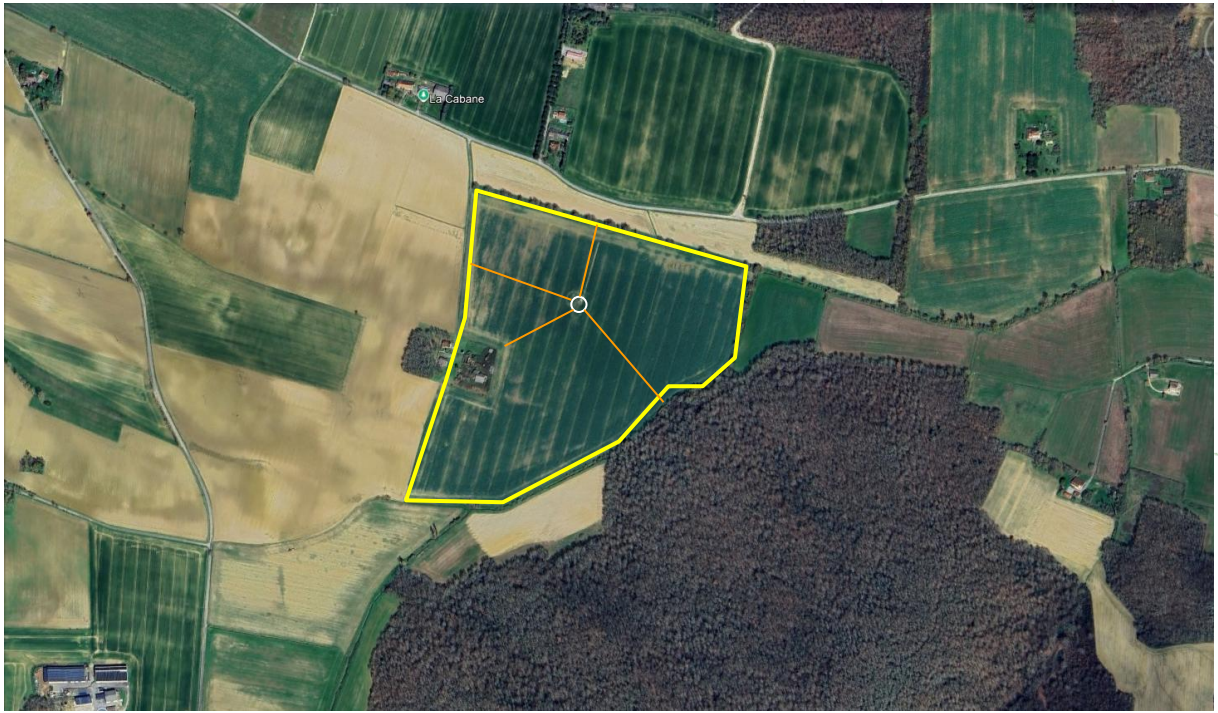
1. Tower location: fetch

2) Vegetation/species composition

1. Tower location: fetch

3) Land cover structure

1. Tower location: fetch



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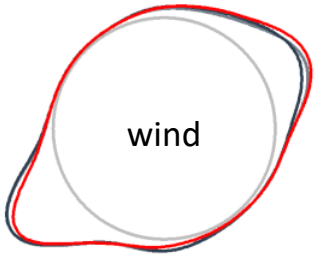

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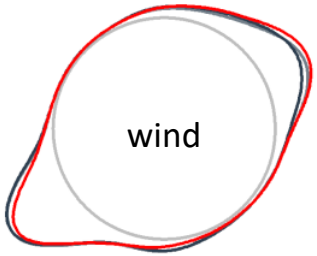

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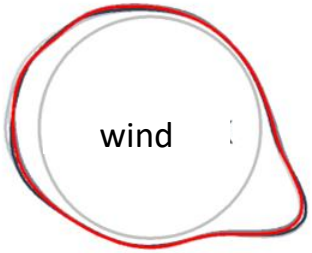

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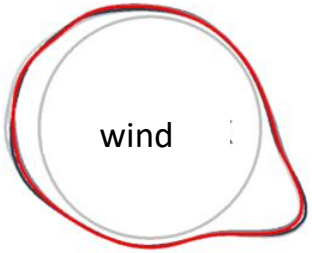


1. Tower location: fetch

Fetch: minimum along-wind distance to the next inhomogeneity.

Fetch ≠ Footprint

NO!

1. Tower location: fetch

RULE: Maximize the time the system sample the target ecosystem!

aim for 90%

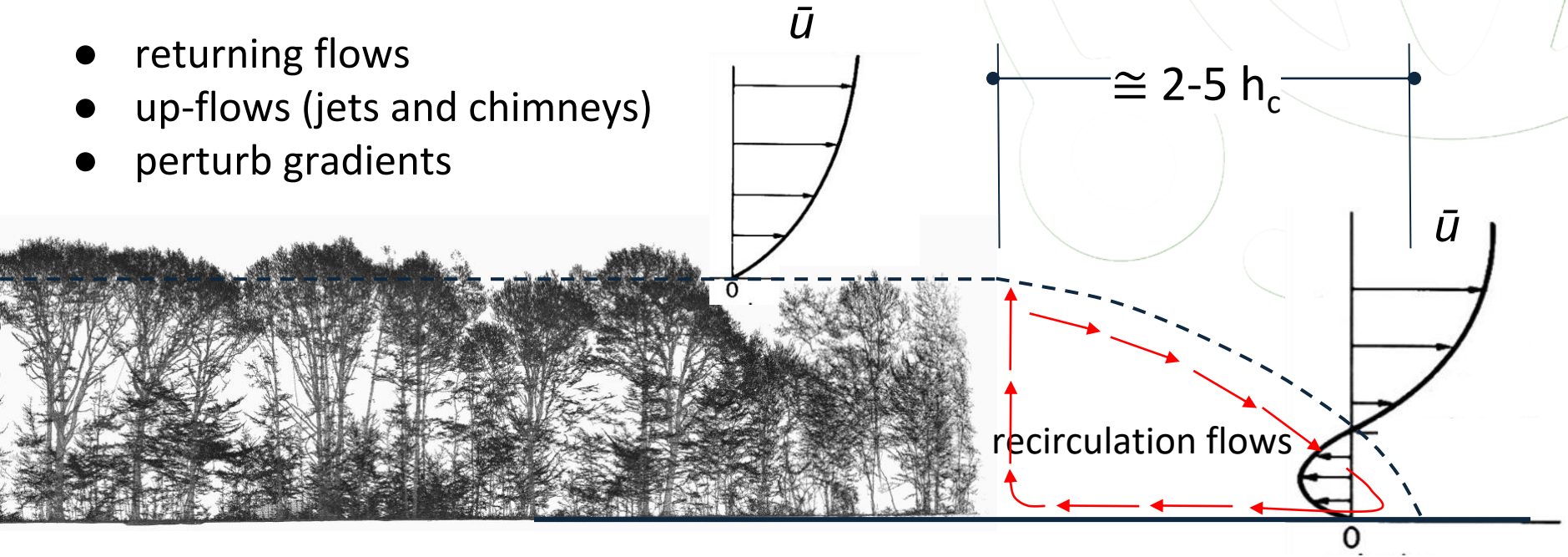
be happy with 80%

settle for 70%

1. Tower location: canopy edges

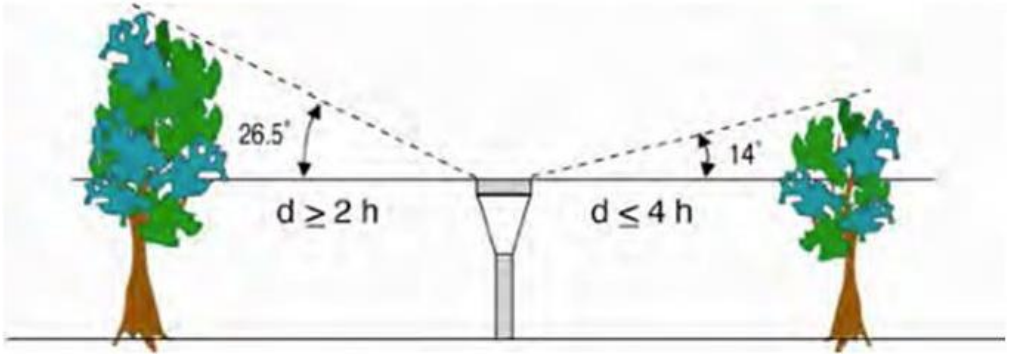
Recirculation areas form at forest openings

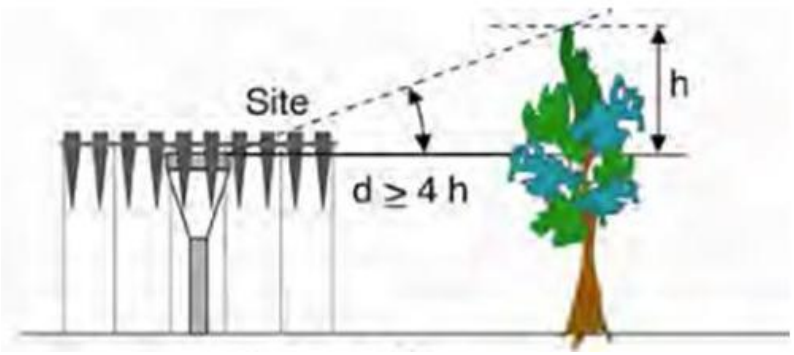
- returning flows
- up-flows (jets and chimneys)
- perturb gradients



1. Tower location: canopy edges

Not only important for EC!

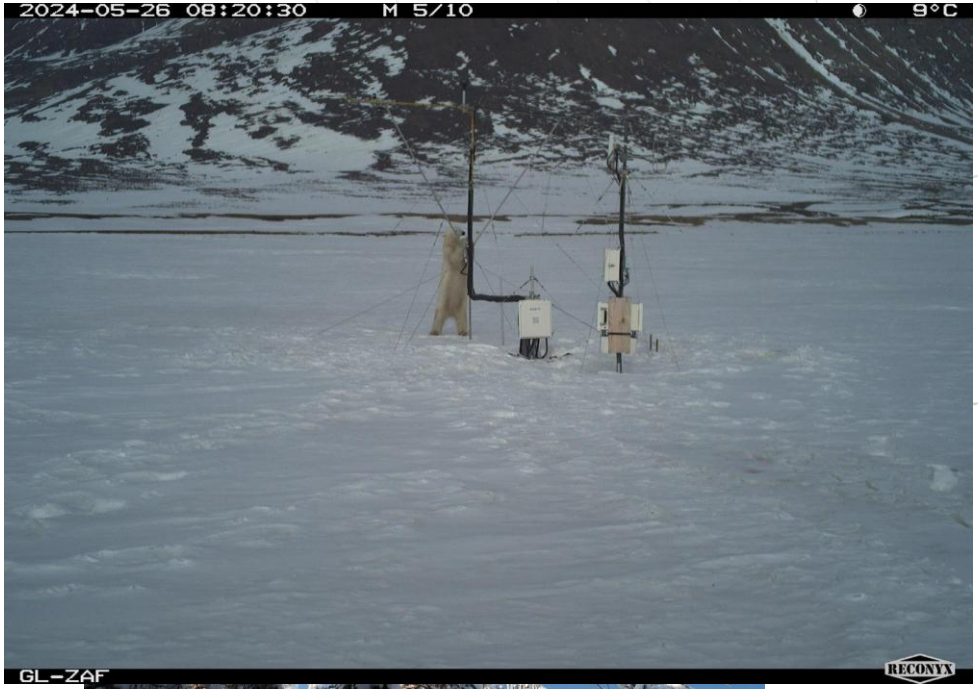




2. Tower design

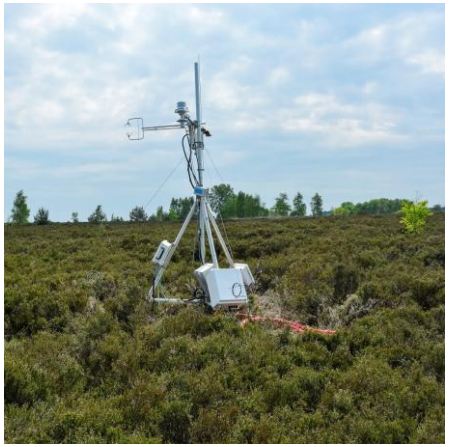
Robustness and safety of the tower to withstand the elements and typical local conditions

- temperature variations
- heavy rainfall
- strong wind
- aerosol (salty)
- cattle/wildlife



2. Tower design

Tower **type** driven by, and adequate to, the target ecosystem




2. Tower design

Tower **oscillations**

- Avoid movements that covaries with turbulent fluctuations of w and c (harmonic motions, not between 1 and 20 Hz)
- Movements speed should be < 0.02 m s^{-1}
- Movement span < 1 mm m^{-1}
- Human induced oscillations not impact on measurements directly, discard data anyway

2. Tower design

Guy wires

PRO

improve stability especially under high winds

CONS

risk of tower damages in case of falls

2. Tower design

Tower **base**/foundations

minimize local soil and environmental alteration

2. Tower design

Tower **size**

- Trade-off #1: stability *vs* local environmental impact
- Trade-off #2: slenderness *vs* instrument hosting
- Trade-off #3: safety/accessibility *vs* flow distortions

- General criterion for openings: mimic the local average inter-distances among plants

2. Tower design

Tower **height**

h_c = canopy height
d = displacement height: 2/3 * h_c
z_0 = roughness length: 0.15 * h_c
h_m = measurement height ≅ d + 4(h_c - d) [!]

Tower **height**

z_m = dynamic measurement height ≅ h_m - d

2. Tower design

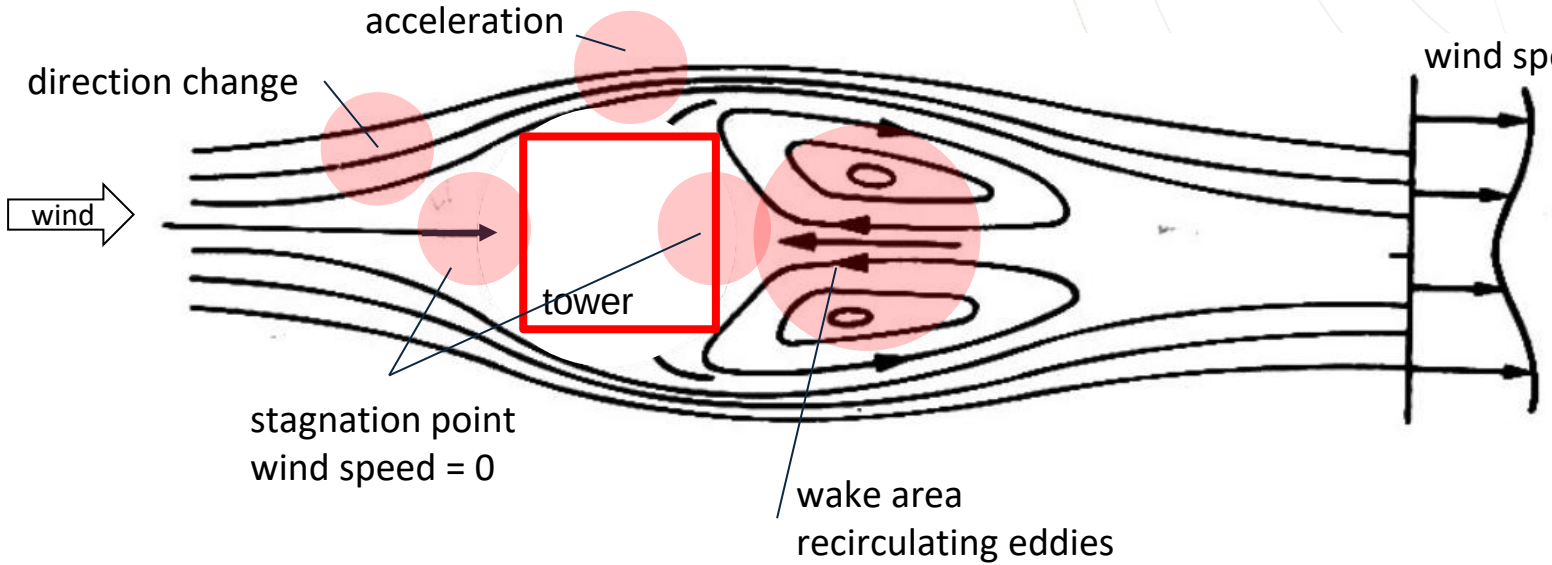
Physical impact on surrounding **air flows**

Most important for forests, but short-canopy vegetation impacted as well

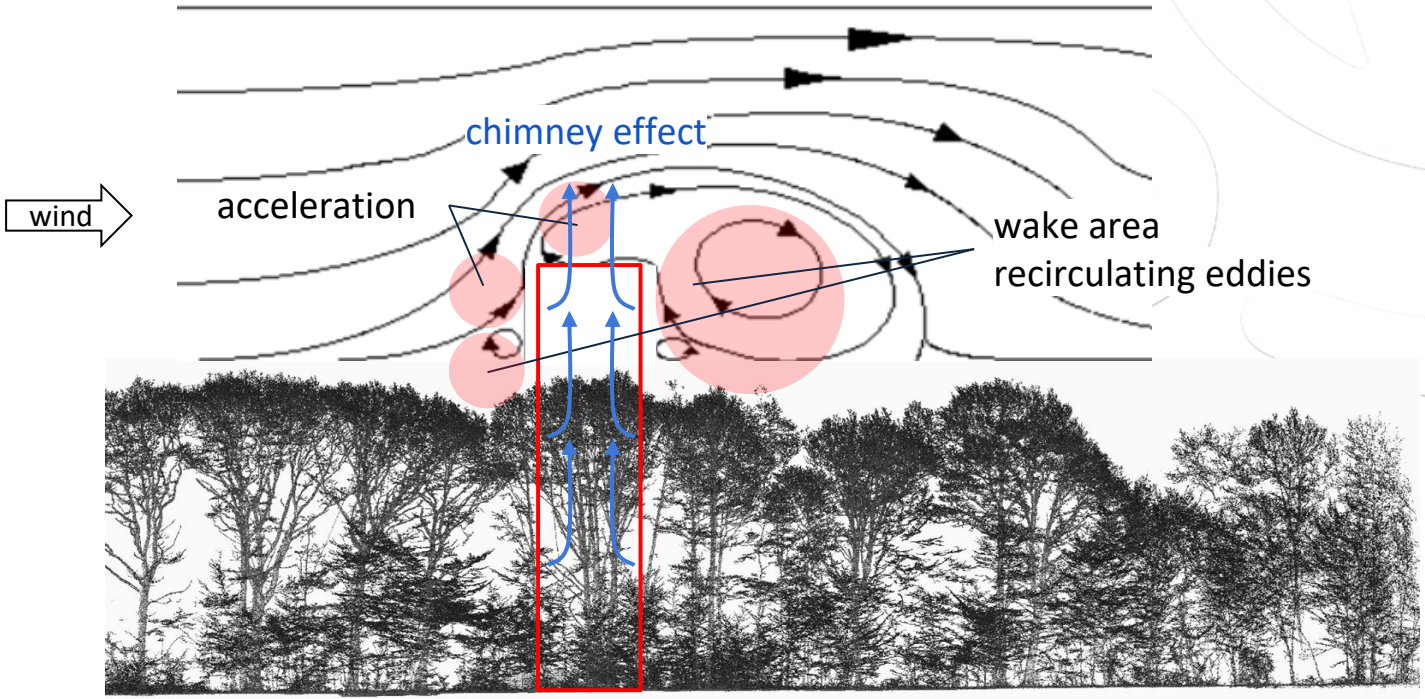
Main types of flow distortion

- streamlines
- recirculation
- wakes
- chimney effect

Types of flow distortion: streamline and wakes



Types of flow distortion: chimney effect



3. Supporting structures considerations

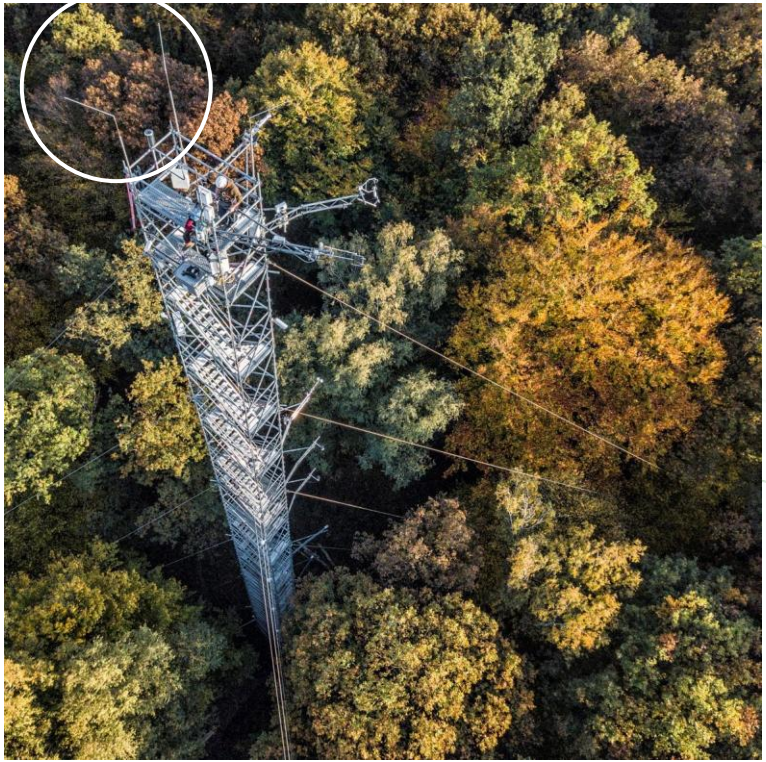
Sensors: consider future installation of additional instrumentation

3. Supporting structures considerations

Lighting protection

(+ grounding)

Signal lights



3. Supporting structures considerations

Shelter

Impact on

- turbulence
- surface reflectivity

$d_{t\text{-}s} \geq 3\text{-}5 * h_s$

3. Sensors and supporting structures considerations

Profile measurements

next topic..

ITINERIS

THANKS!

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