Forest flows and CFD

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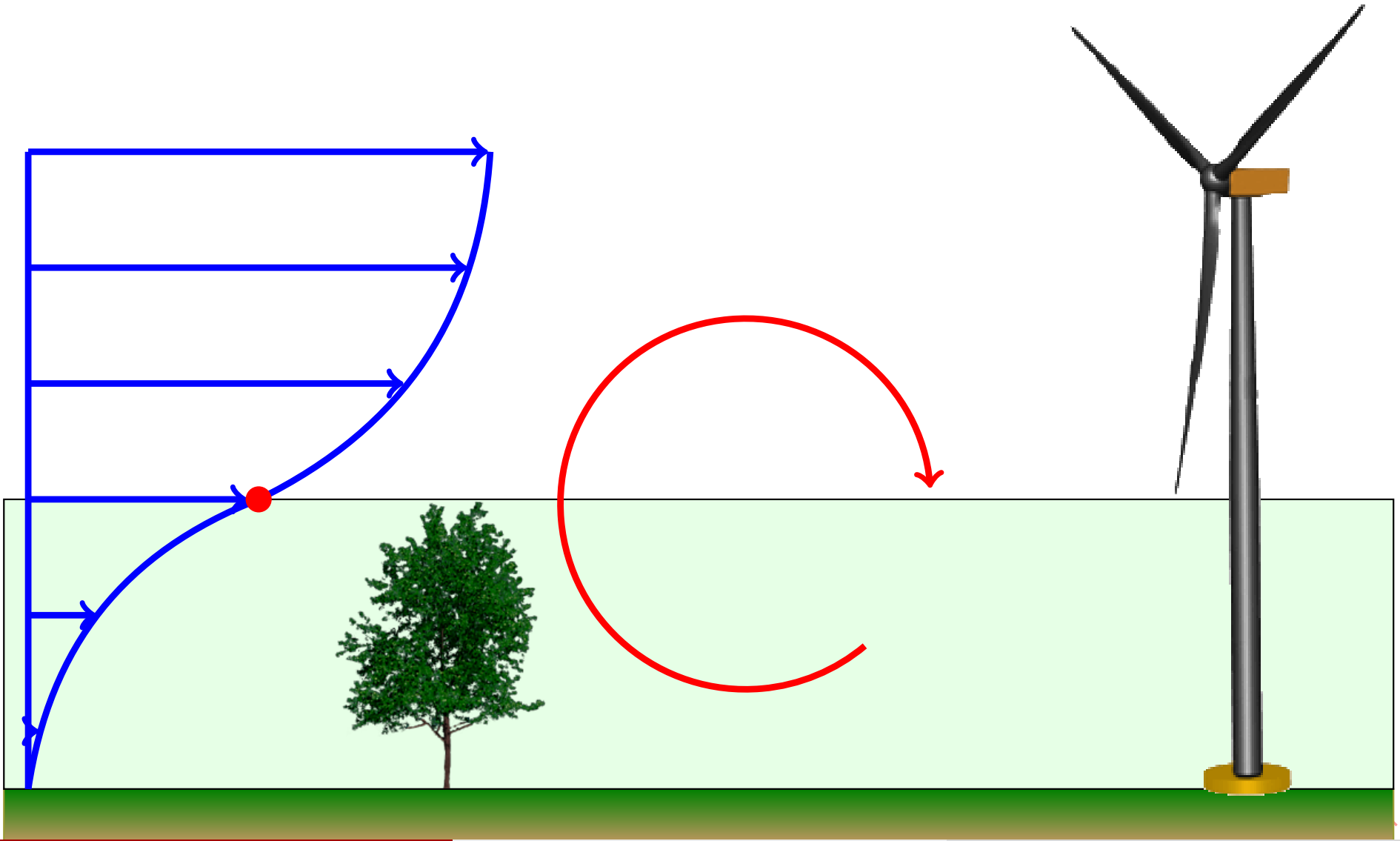
Outline

Motivation

[Finnigan, 2000]



Context

- Modification of RANS $k - \epsilon$ equations to account for forest effects

Canopy model: [Sogachev, 2009]

Momentum:

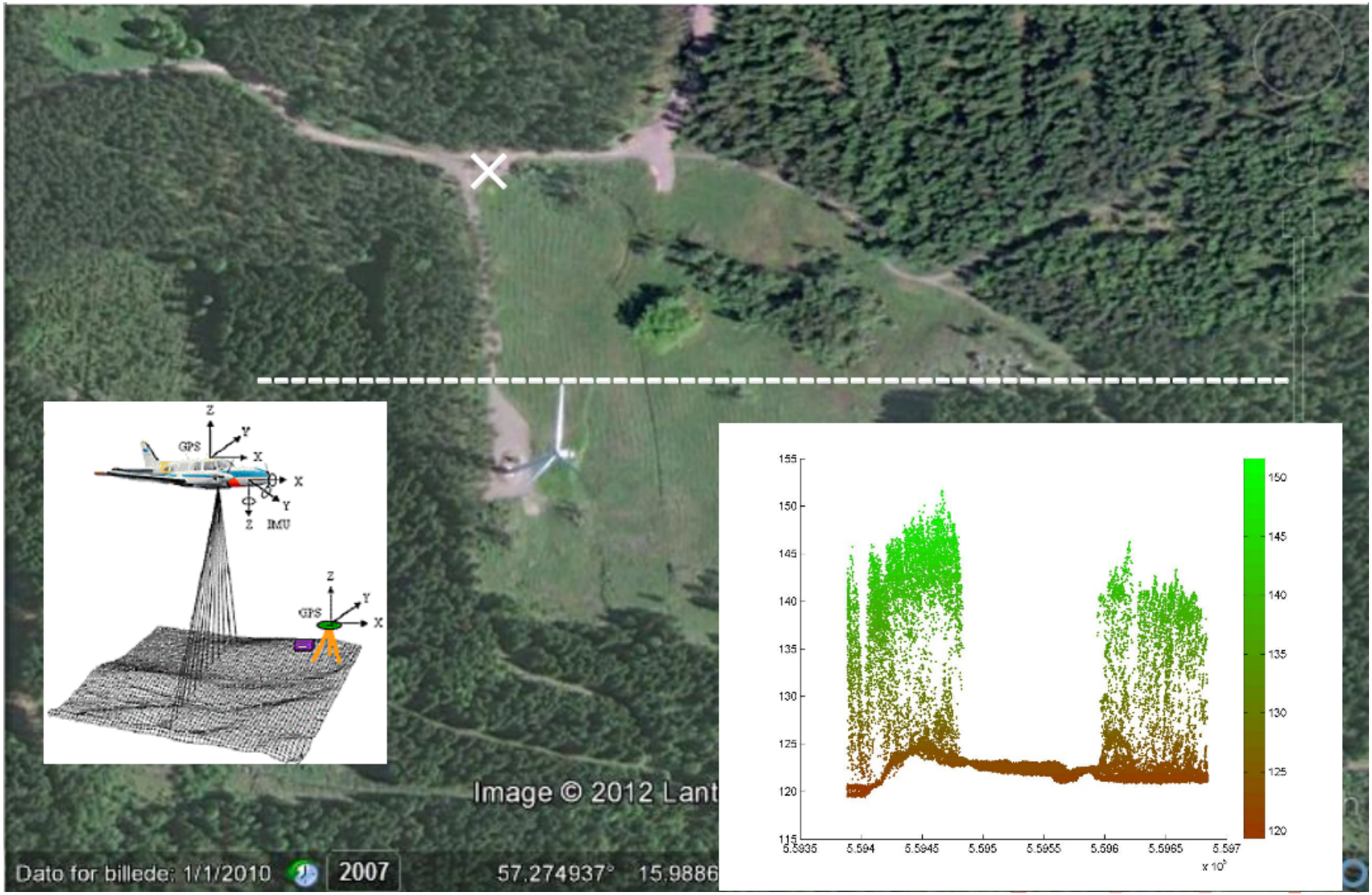
$$\frac{\partial u_i}{\partial t} = ... - C_d LAD(z) u_i |U|$$

Dissipation:

$$\frac{\partial \epsilon}{\partial t} = ... - 12 C_\mu^{1/2} C_d LAD(z) |U| (C_{\epsilon 1} - C_{\epsilon 2}) \epsilon$$

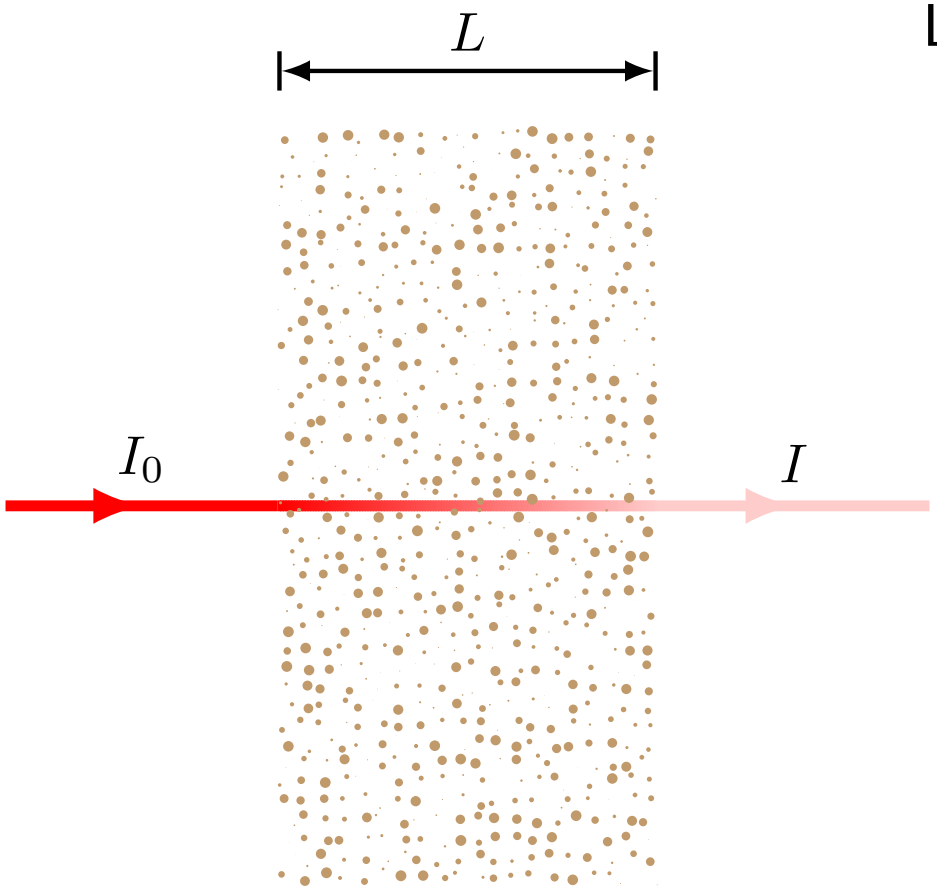
Context

Context


GPS
IMU
GPS
Image © 2012 Lant
Dato for billede: 1/1/2010
2007
57.274937°
15.9886

Theory

The Beer-Lambert law



$$\frac{I}{I_0} = \exp(-\gamma L)$$

Light attenuation in plant canopies: [Monsi and Saeki, 2005]

$$LAI = -\frac{1}{\gamma} \ln\left(\frac{I}{I_0}\right)$$

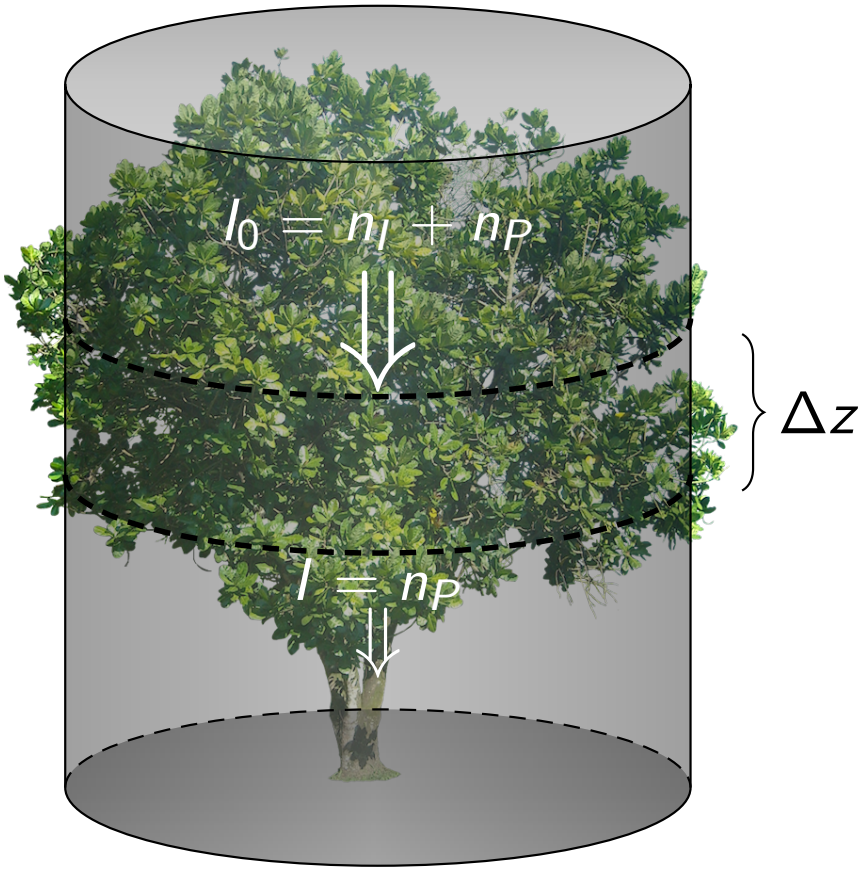
$\Rightarrow$Probability a beam reaches the the canopy depth L

Discrete analogy [Richardson, 2009]:

$$LAI = -\frac{1}{\gamma} \ln\left(\frac{R_g}{R_t}\right)$$

Theory

k^{th} level:



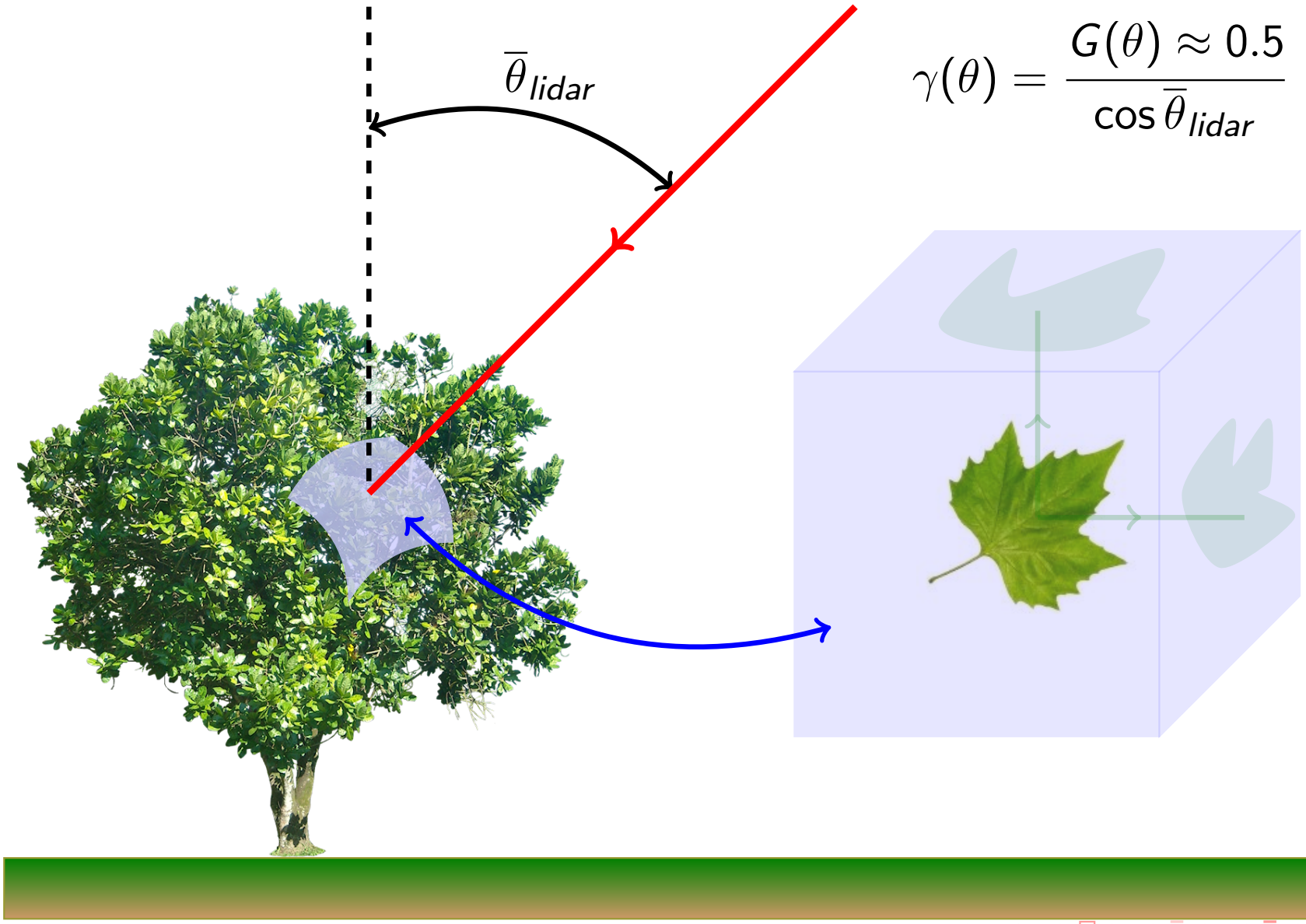
$$LAI = \int_0^z LAD\, dz \Rightarrow LAD = \frac{dLAI}{dz}$$

$$\Downarrow$$

$$LAD(k) = \frac{1}{\gamma \Delta z}\left(\frac{n_I(k)}{n_I(k) + n_P(k)}\right)$$

[Hosoi and Omasa, 2006]

Extinction coefficient

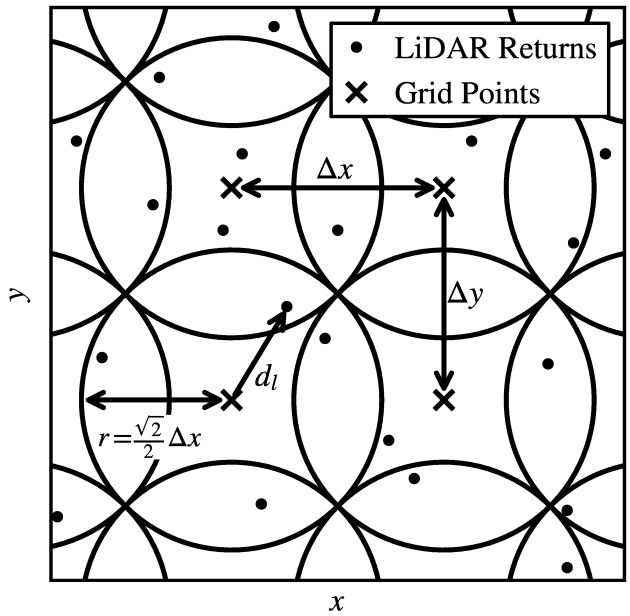


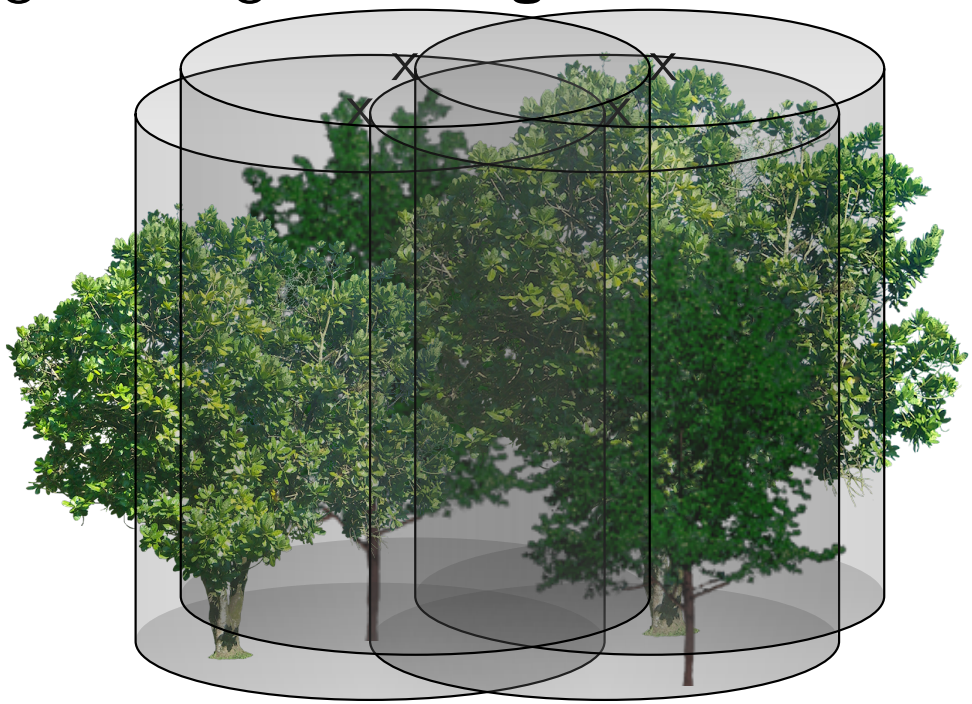
$$\gamma(\theta) = \frac{G(\theta) \approx 0.5}{\cos \overline{\theta}_{lidar}}$$

Algorithm

Steps:

1. **Classification** of LiDAR returns into ground and vegetation points:
   - MCC-LIDAR: multi-scale curvature algorithm [Evans and Hudak, 2007]
2. Local binning **algorithm** for generating a **forest grid**:



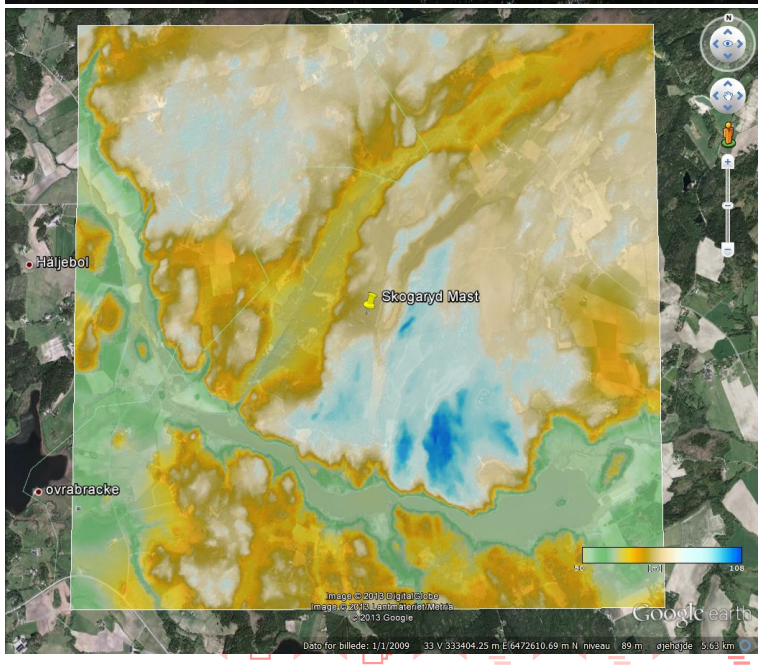


3. **Computation** of the 3D discrete LAD values.

Skogaryd

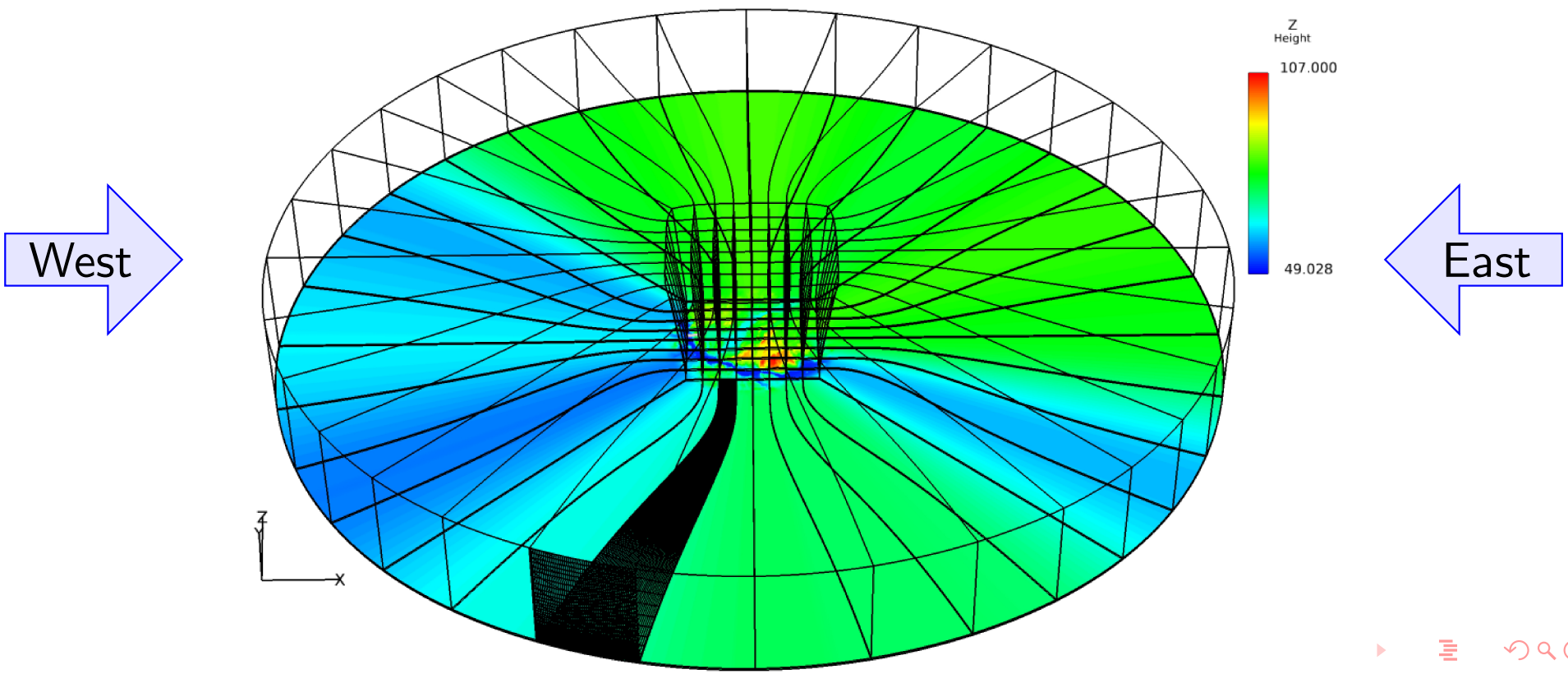
A tall **pine tree** forest, $h \approx 30 - 35m$.
Grid:

- $Resolution = 10m$
- $Searching\ radius = 10m$
- $Vertical\ resolution = 1m$
- $L \times L = 5km \times 5km$
- 499×499
- Instrumented mast [Dellwik,2013]

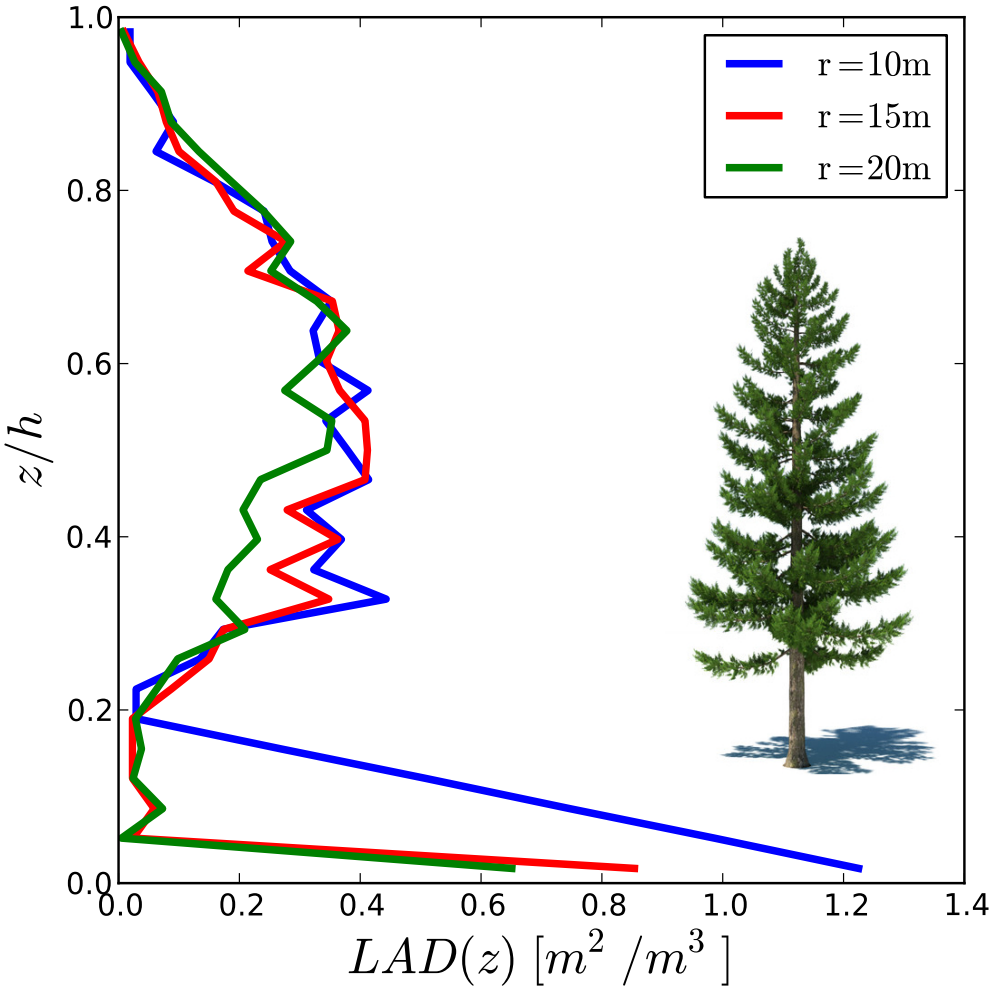


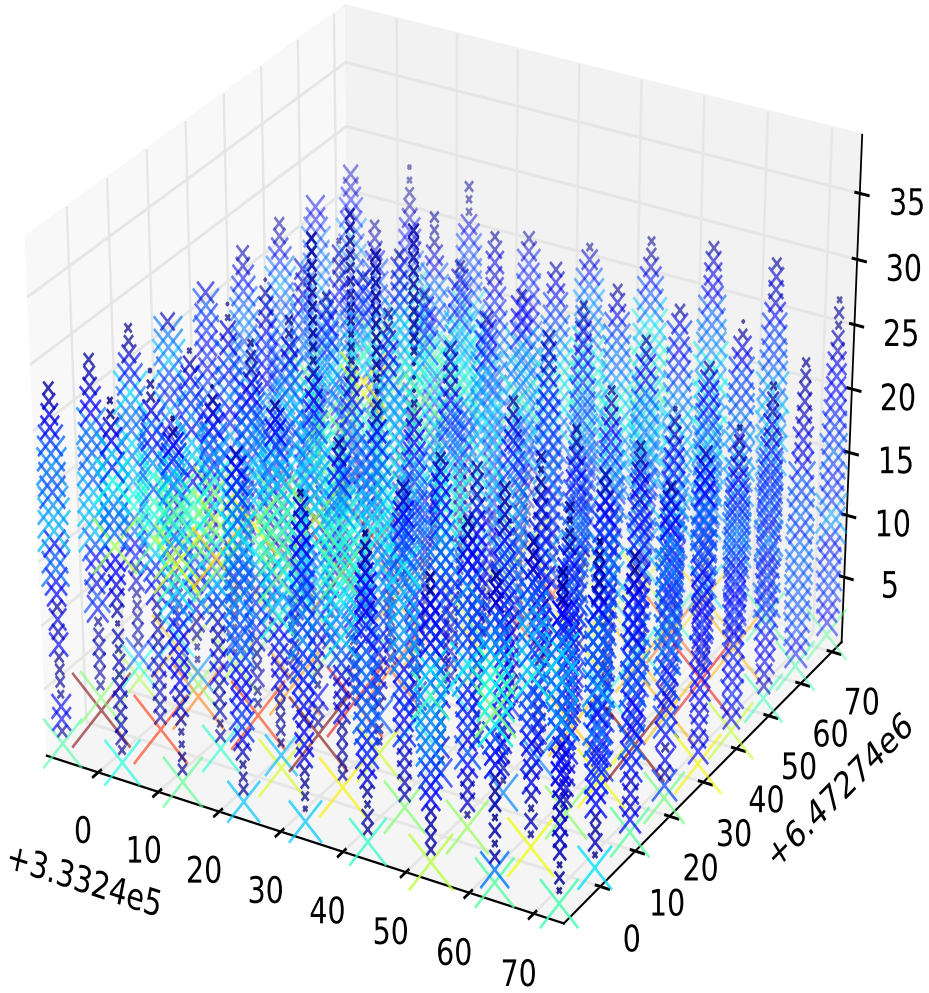
CFD model

- Finite-volume flow solver EllipSys3D [Michelsen, 1982, Sørensen, 1995]
- $k - \epsilon$ model + diffusive terms [Sogachev, 2012]
- $\tau = cst$, steady-state, neutral, no Coriolis force
- Computational grid: $10m$ resolution / ≈ 22 million cells



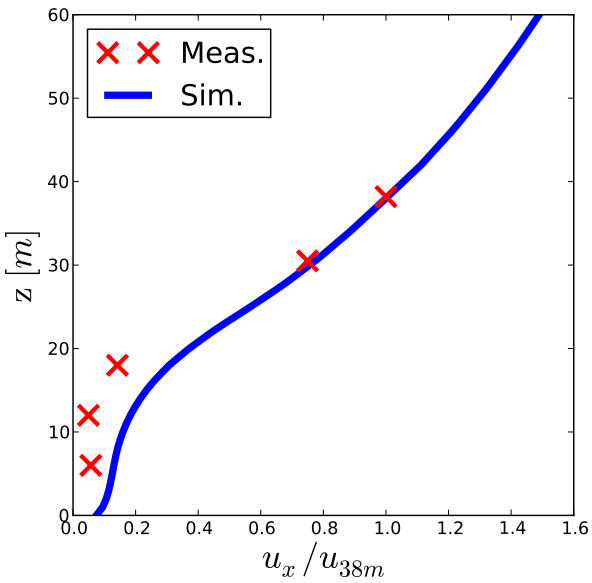
Results

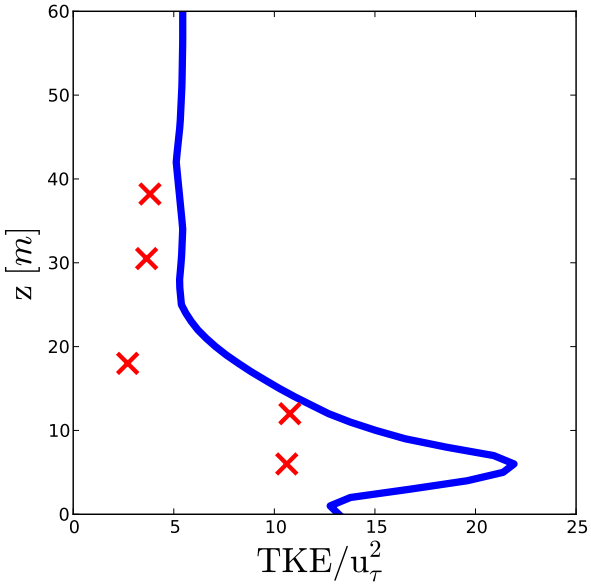

r =10m
r =15m
r =20m
z/h
LAD(z) [m^2 /m^3]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

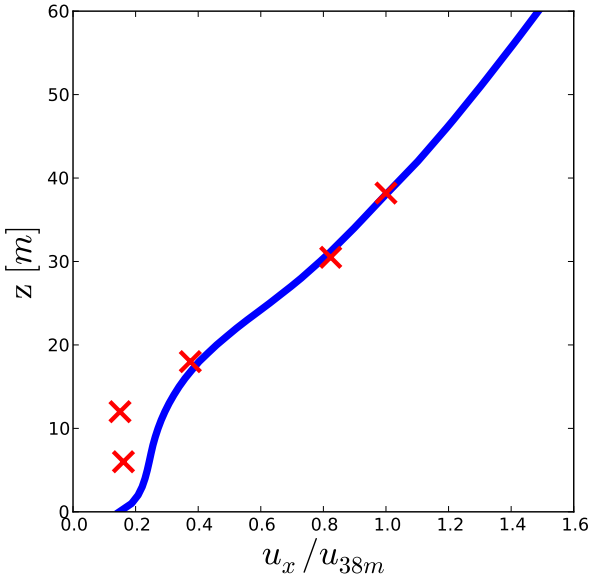

+3.3324e5
+6.47274e6

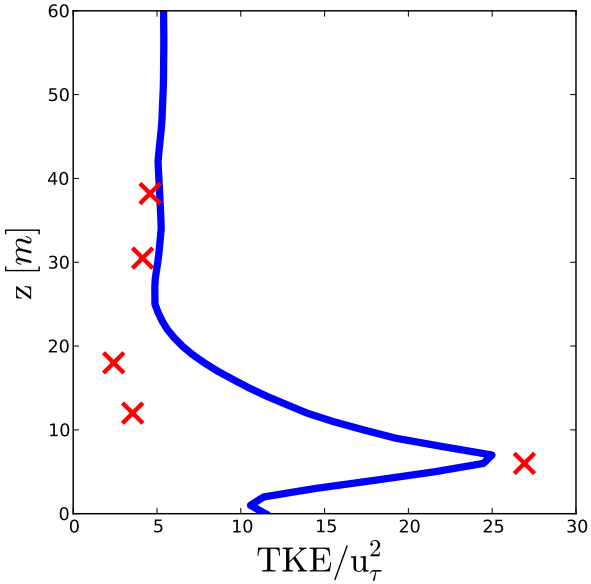
Results

West



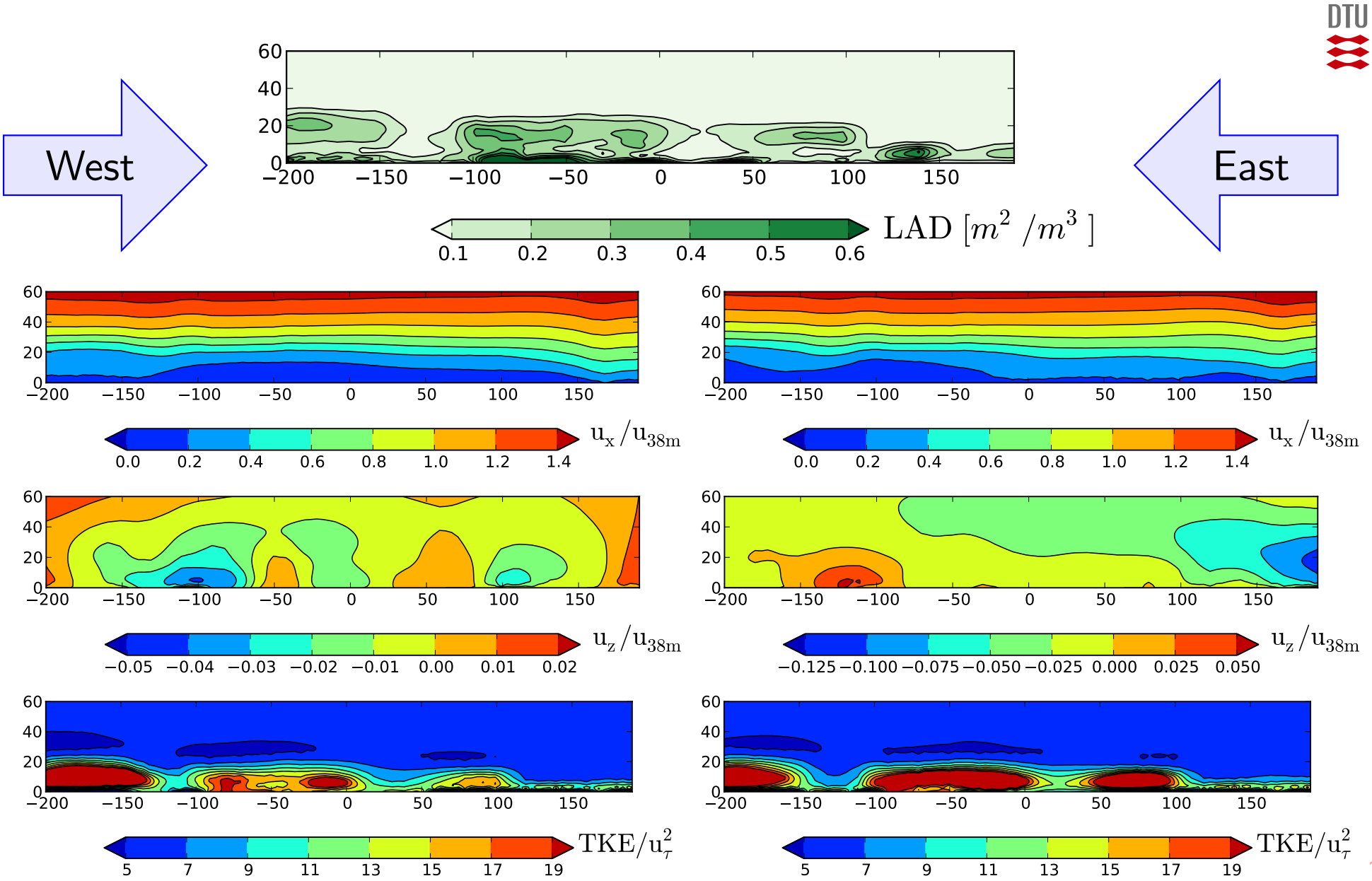






East

Results



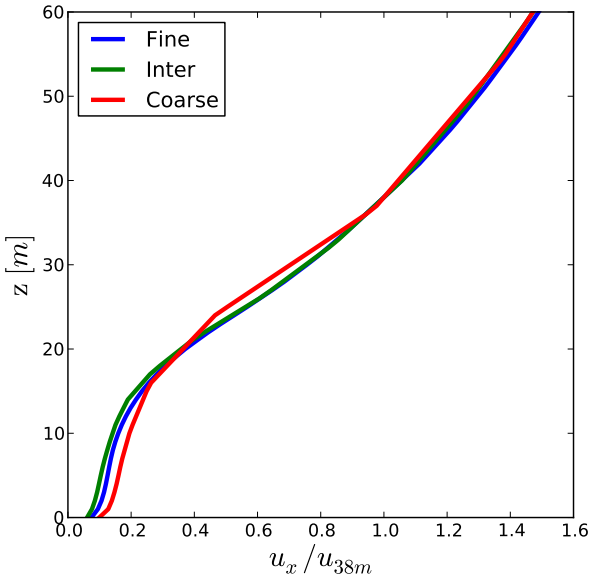
Conclusion

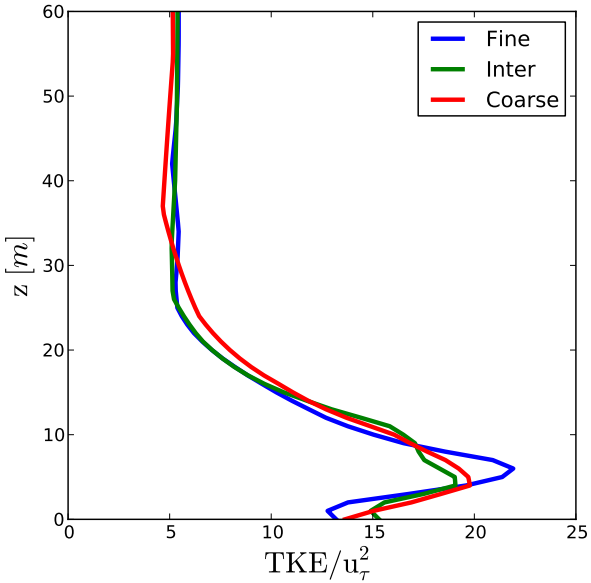
- A 3D forest **gridding methodology** proposed
- **Coupling** with Ellipsys3D
- Future work:
  - Complete sensitivity analysis
  - Validation of forest properties (Gothenburg University $\rightarrow$ allometry)
  - Other sites
  - Addition of Coriolis + temperature effects

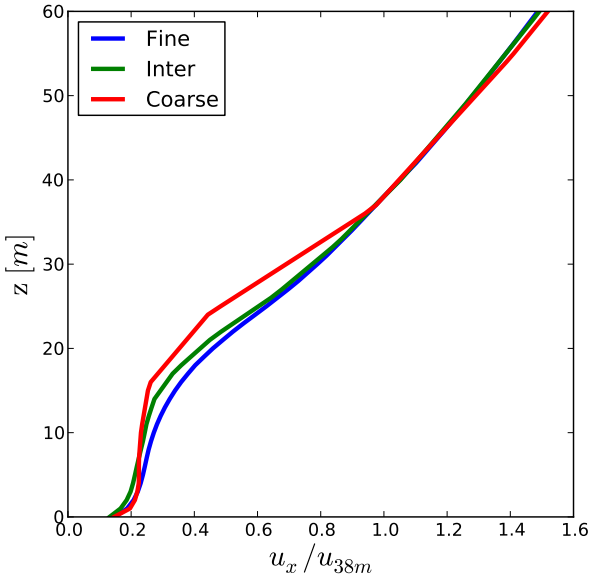
Thank you for your attention!

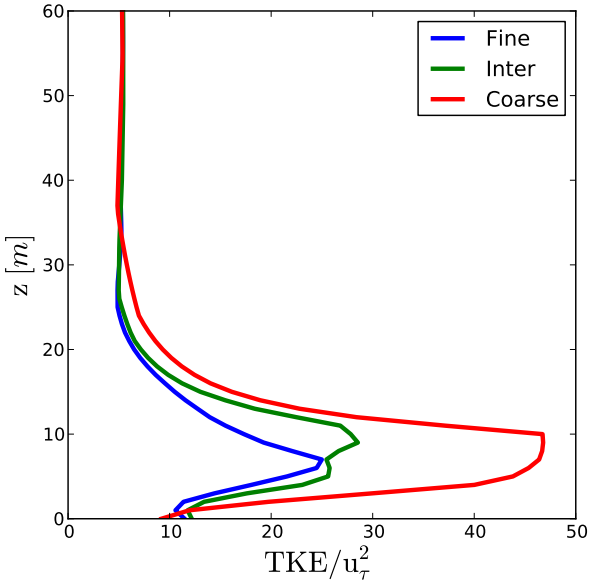
Grid independence

West









East

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