Representative Ecosystem Characteristics for Flux Tower Sites defined by Footprint Climatology and Airborne Remote Sensing Observations

N. Kljun*, L. Chasmer, C. Hopkinson,
A.G. Barr, T.A. Black, J.H. McCaughey, and T. Milne

*Email: n.kljun@swansea.ac.uk / Swansea University, UK

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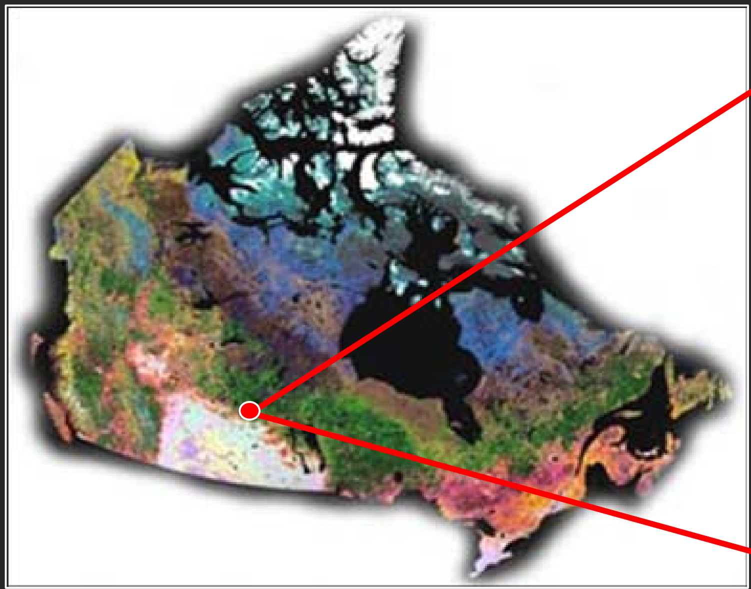
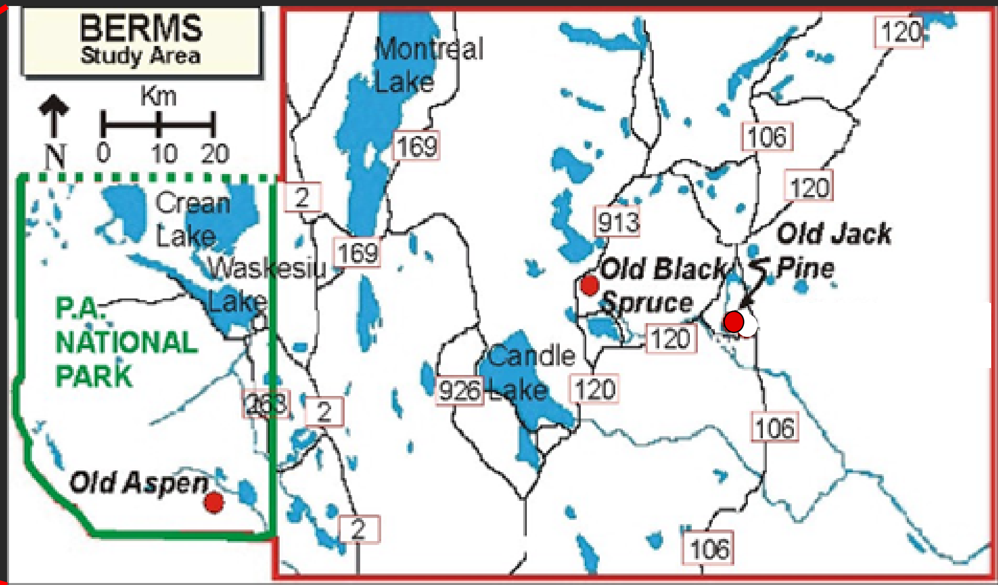
Study Sites

Southern boreal forest, Saskatchewan, Canada





Broad-leaved forest

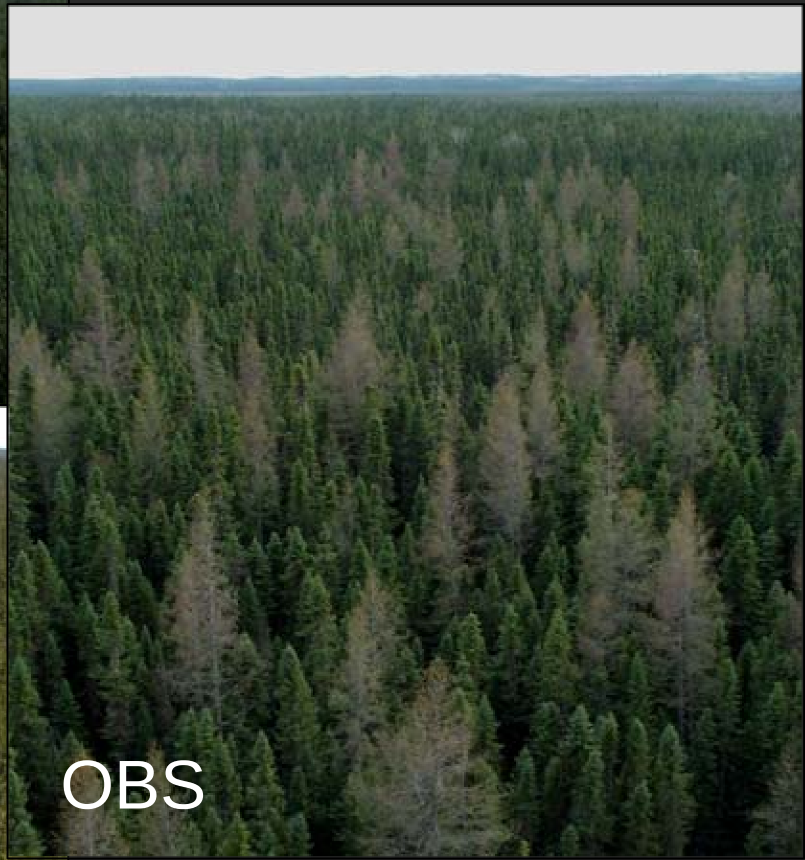
- Old Aspen site (OA)

Conifer forest

- Old Black Spruce site (OBS)
- Old Jack Pine site (OJP)

Study Sites

Study Sites



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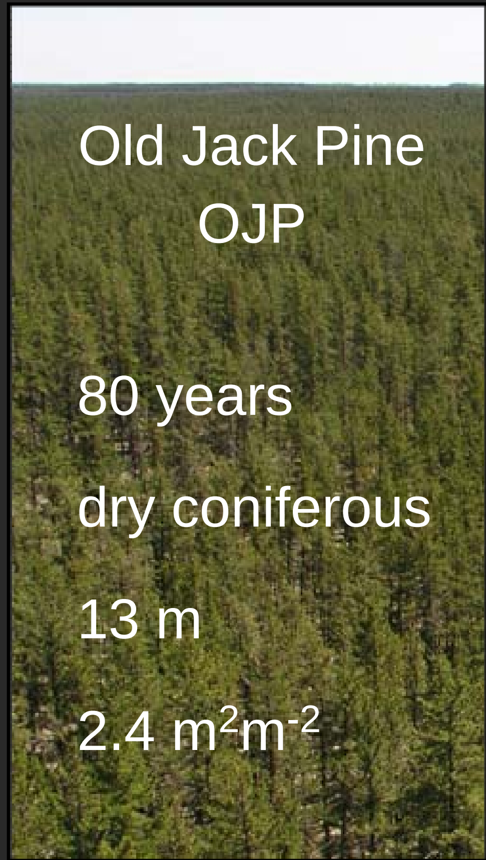


	Old Aspen OA	Old Black Spruce OBS	Old Jack Pine OJP
• Age	85 years	130 years	80 years
• Stand	deciduous	wet coniferous	dry coniferous
• Height	21 m	7 m	13 m
• LAI	5.6 m^2m^{-2}	4.2 m^2m^{-2}	2.4 m^2m^{-2}

Flux Tower Measurements

Eddy correlation system

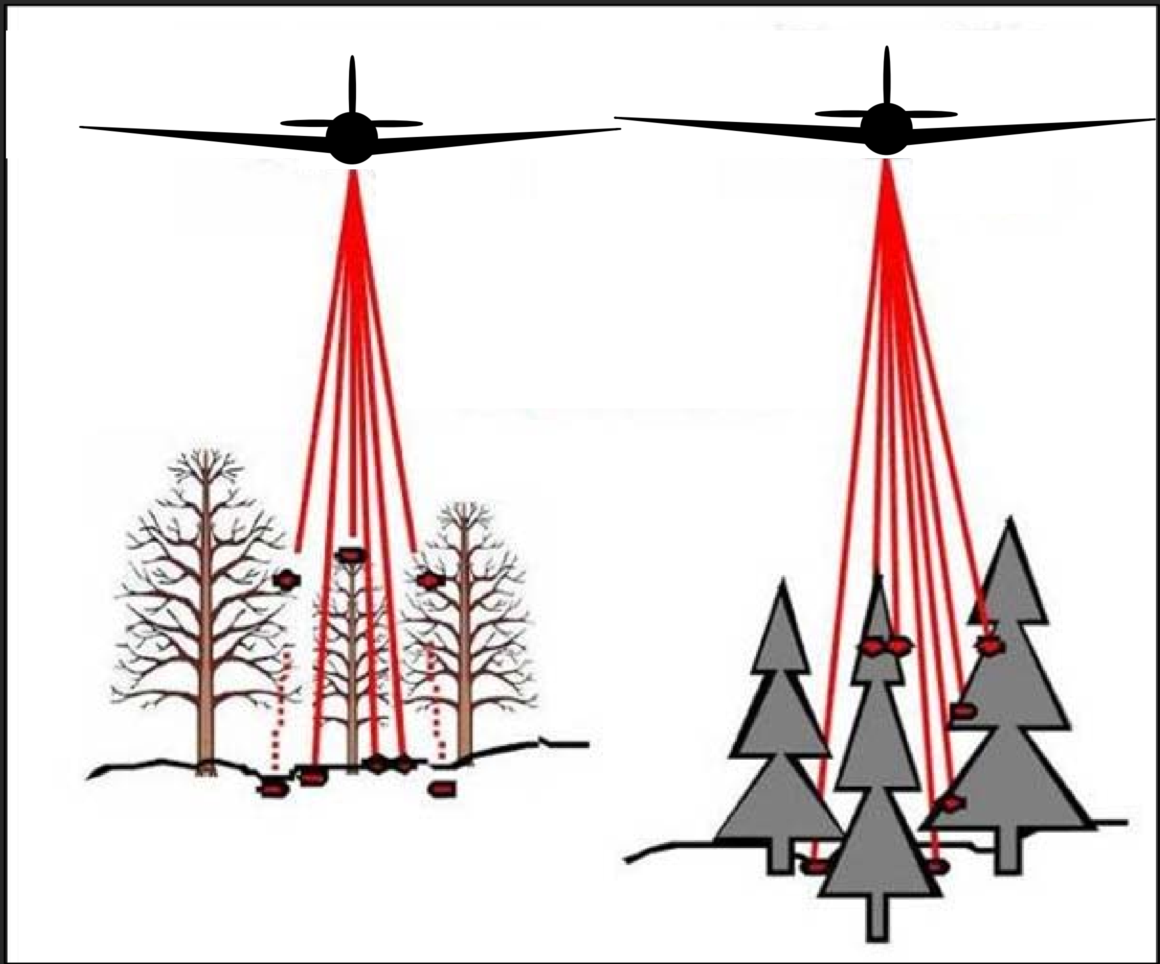
- Measurements since 1993 (former southern BOREAS sites)
- Sonic anemometer
- Closed path gas analyser
- Fine-wire thermocouple
- Standard climate measurements

Airborne Survey: LiDAR Data

- Send and receive laser impulse (four-pulse return)
- Flight at 600 m to 1500 m above ground
- High spatial resolution (35 cm to 1 m) for 4 km x 4 km
- 3D image of forest

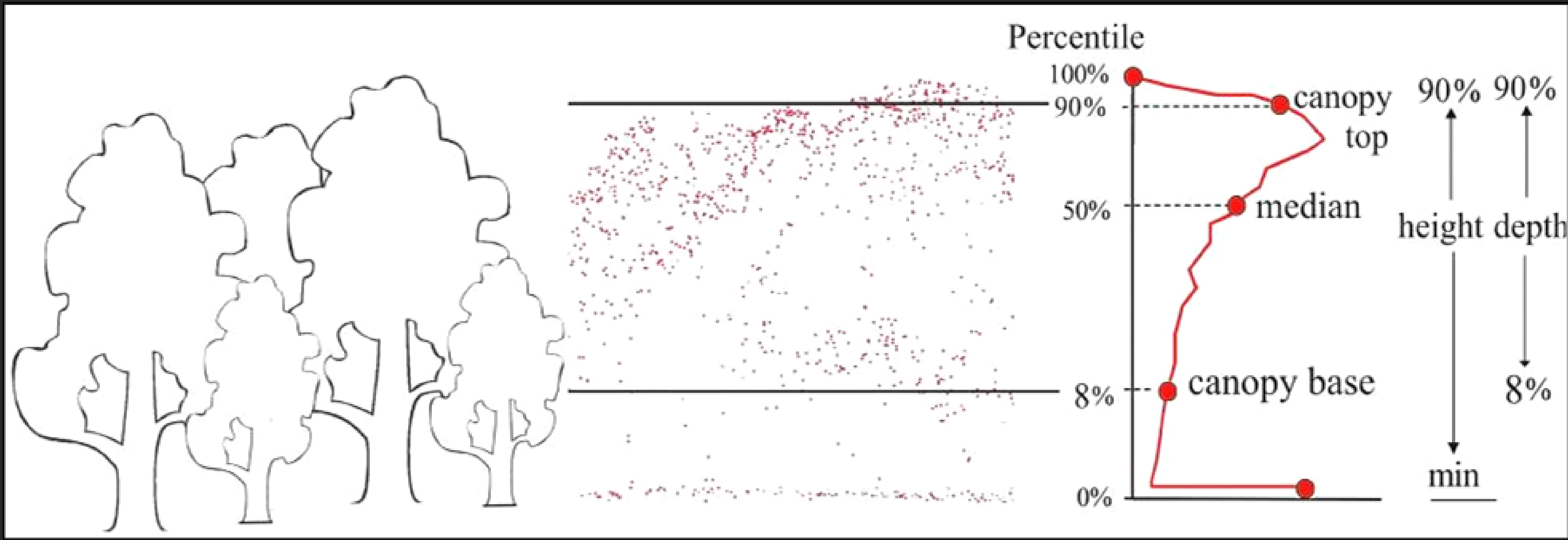
LiDAR Data

Ground returns even from under canopy



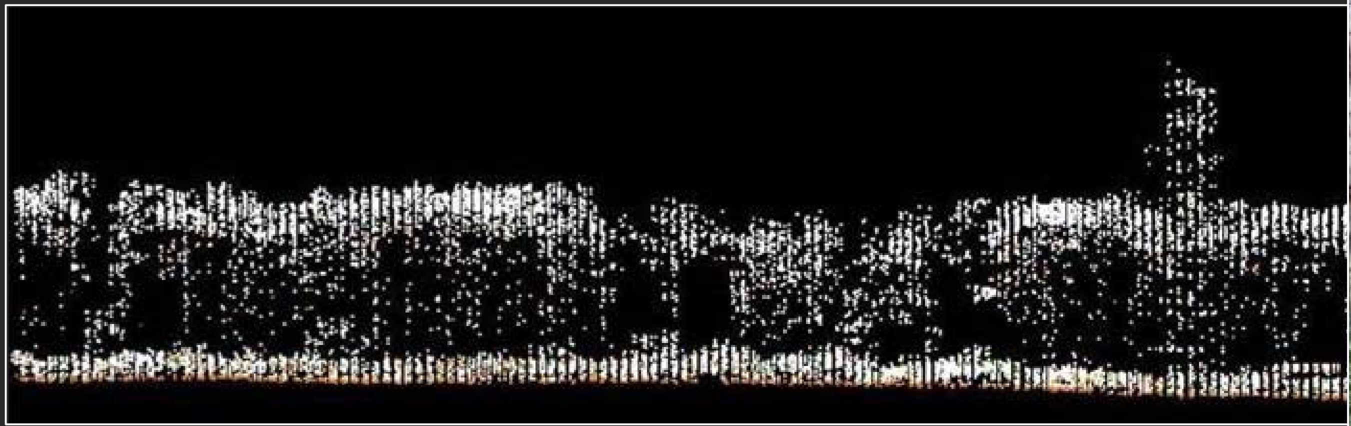
Tree Height, Fractional Cover

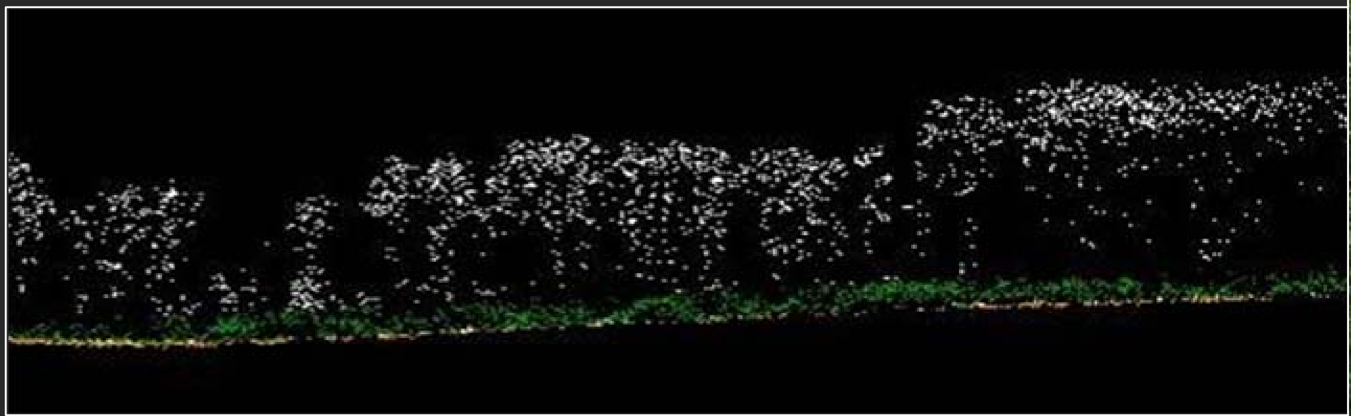
Forest plot LiDAR point clouds Frequency Distribution



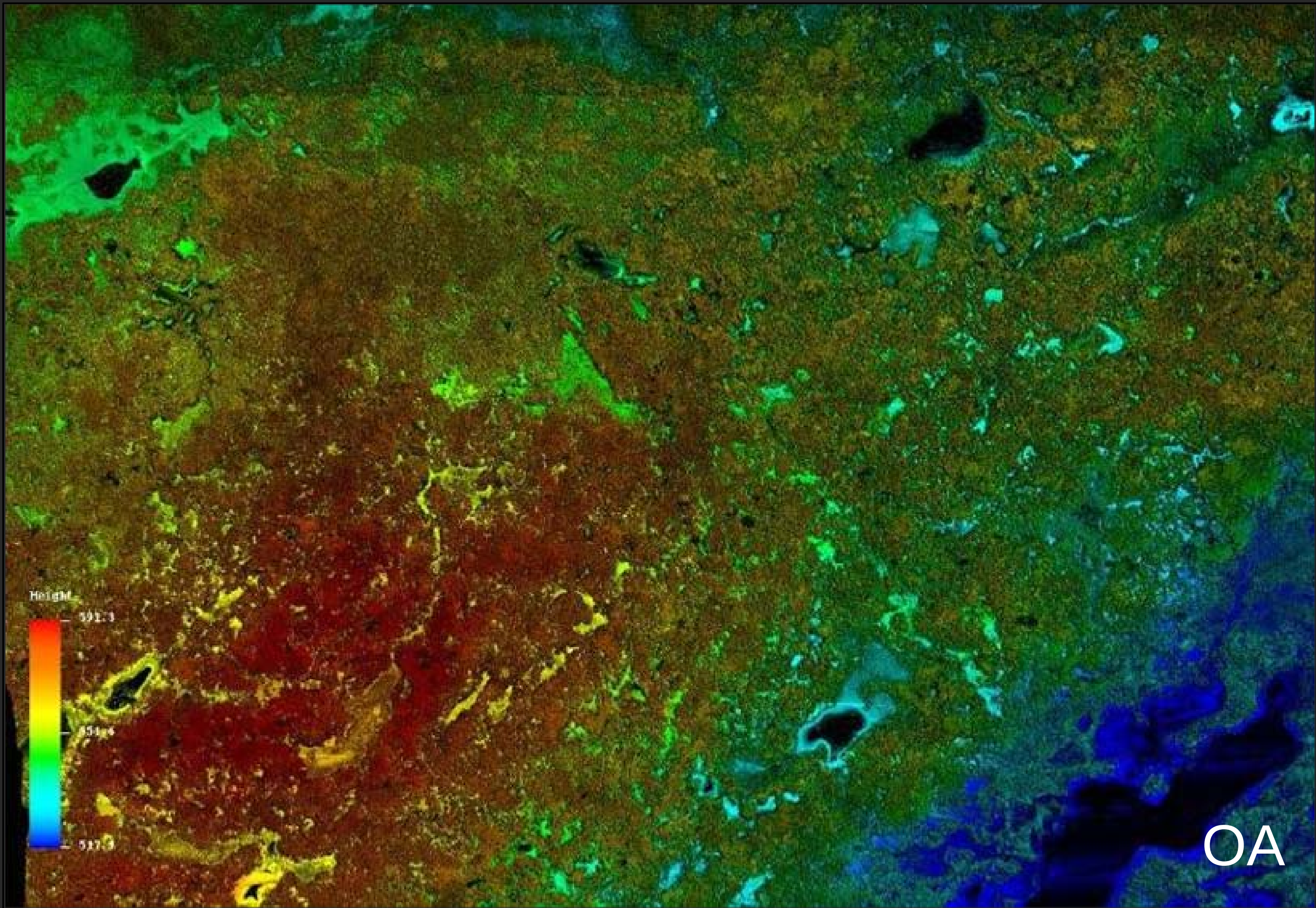
LiDAR Data

Example: Old Aspen site (OA)





Example Products from LiDAR Survey



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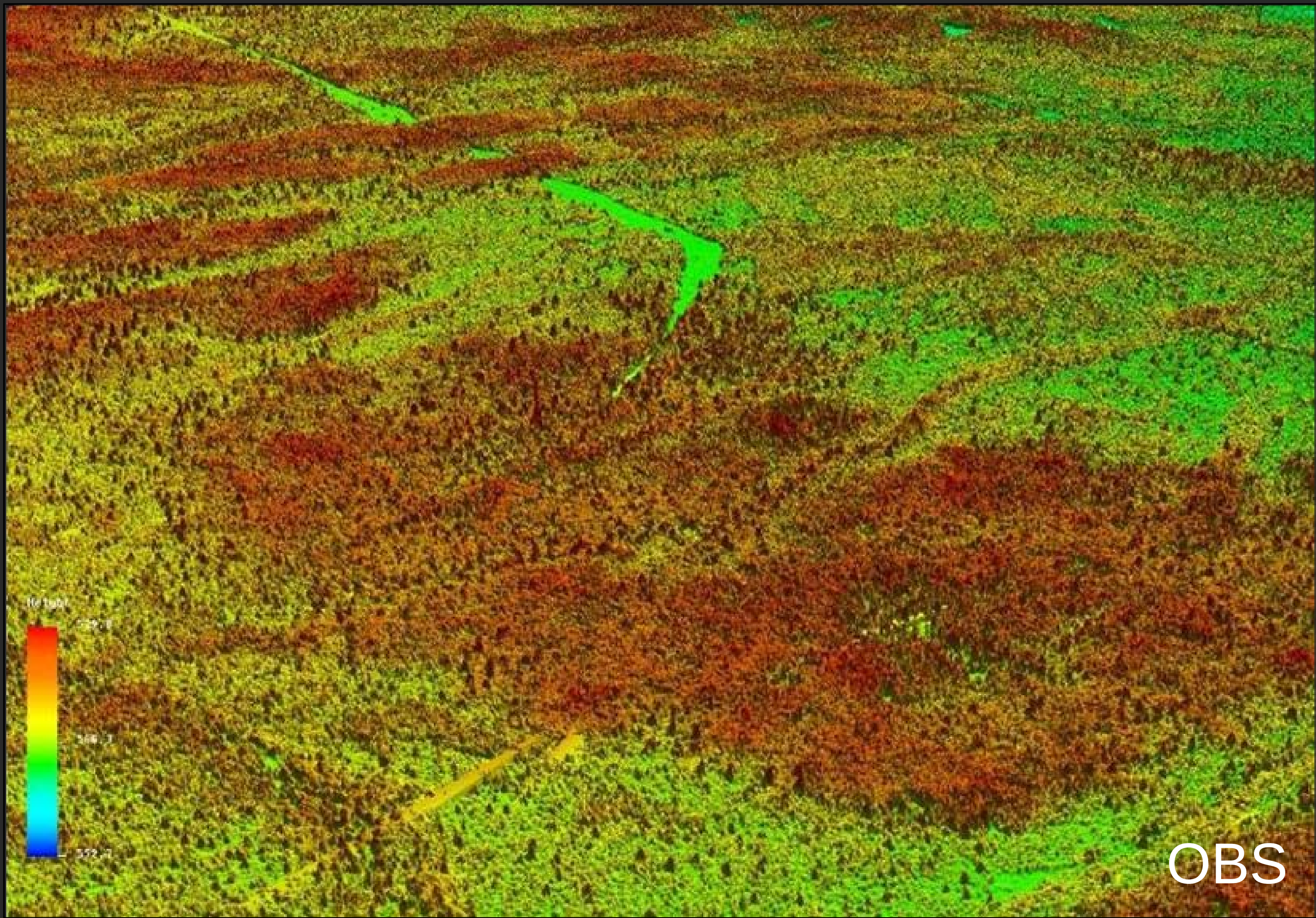

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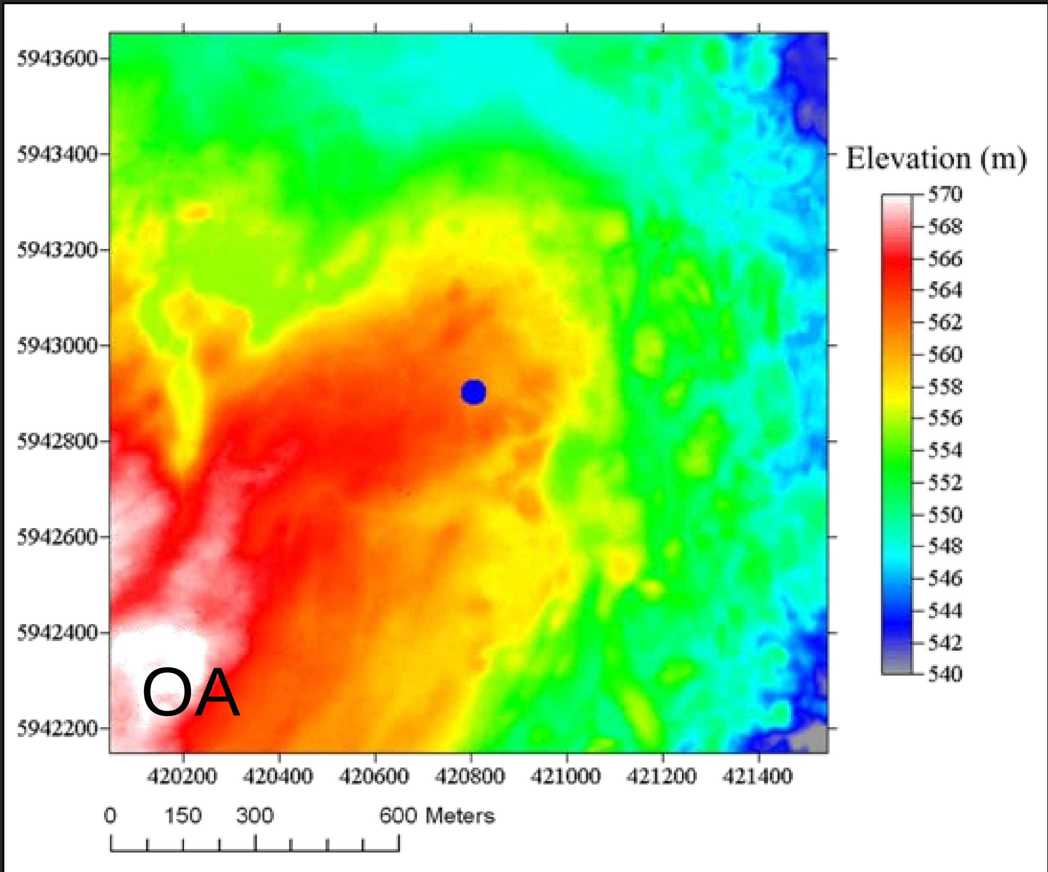
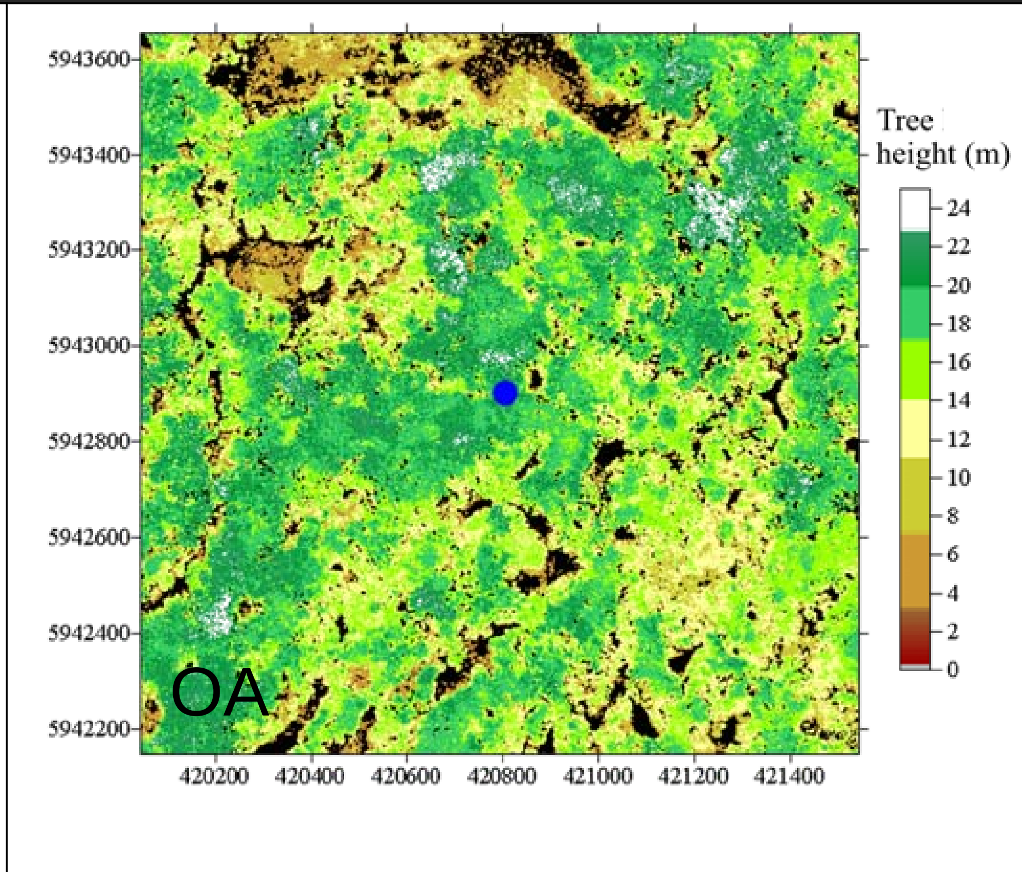
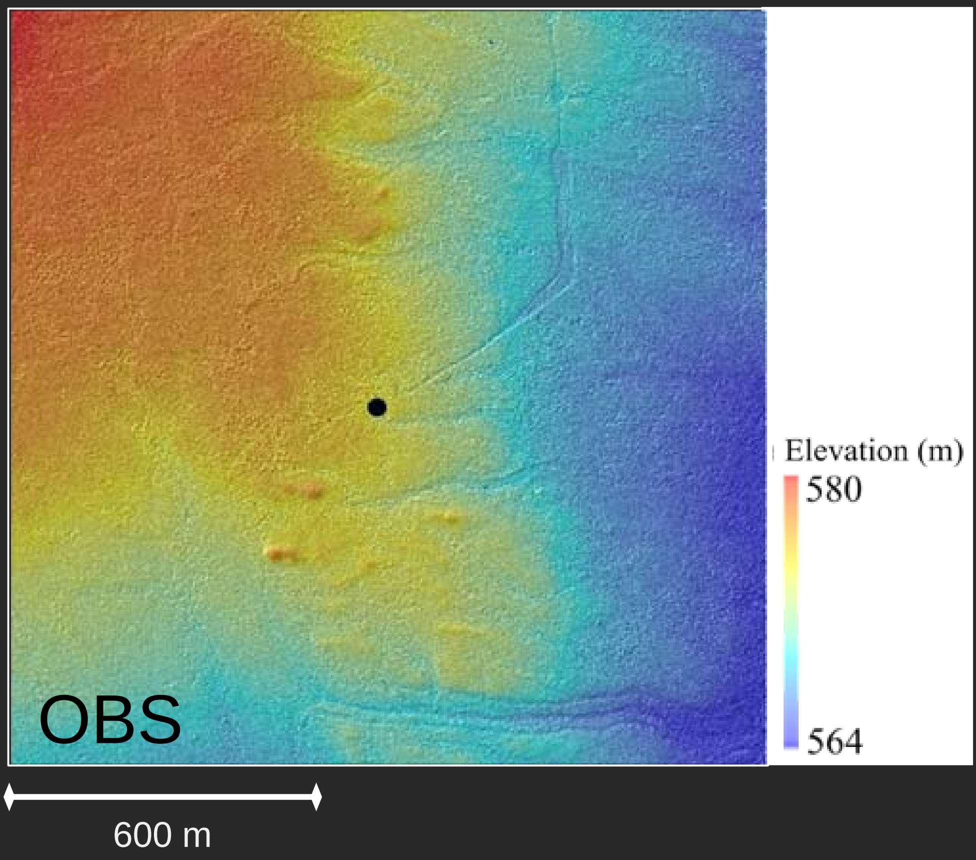


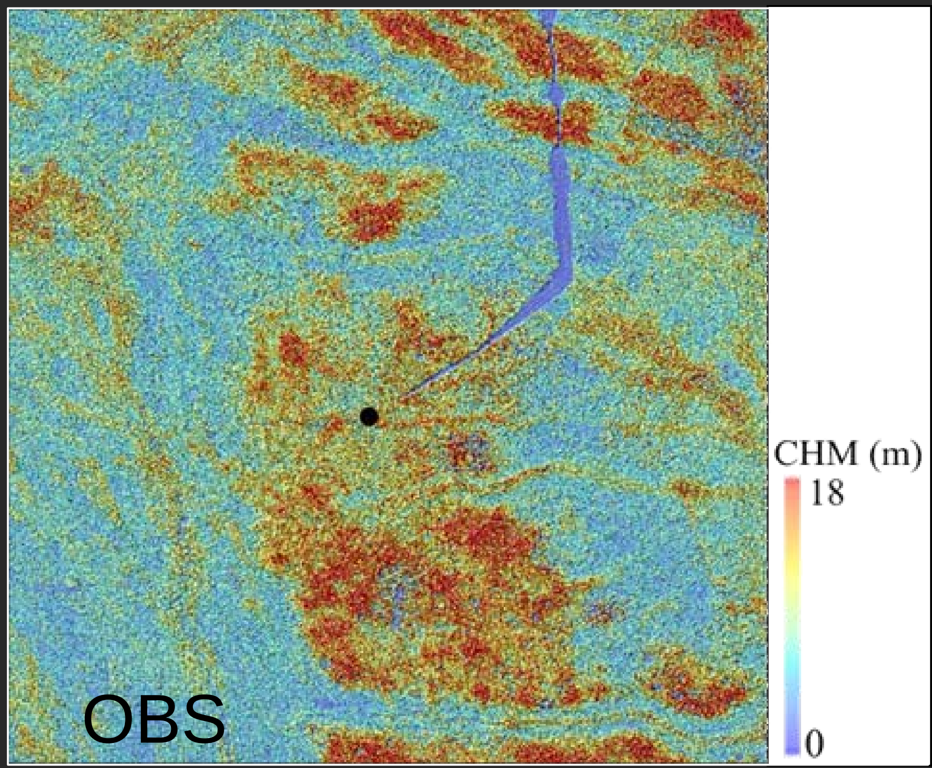
Elevation



Tree Height

Example Products from LiDAR Survey





Elevation

Tree Height

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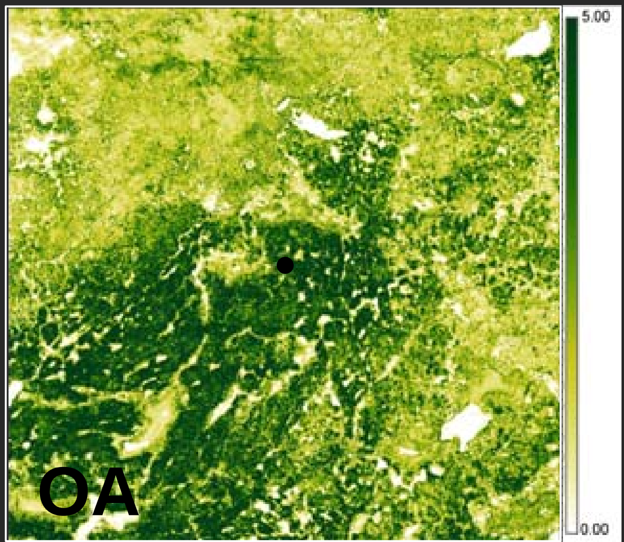
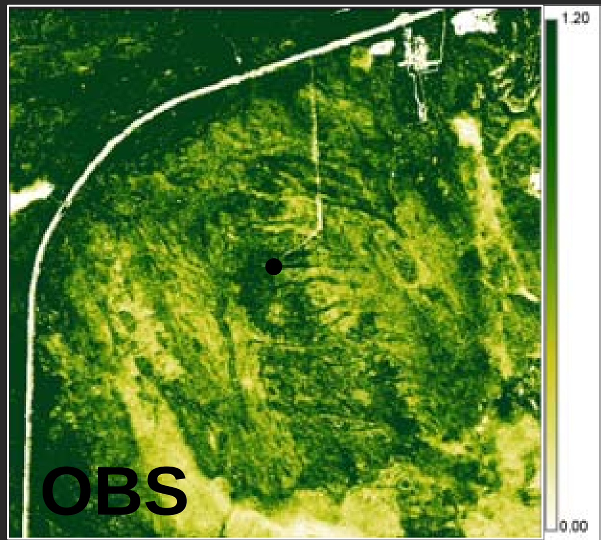
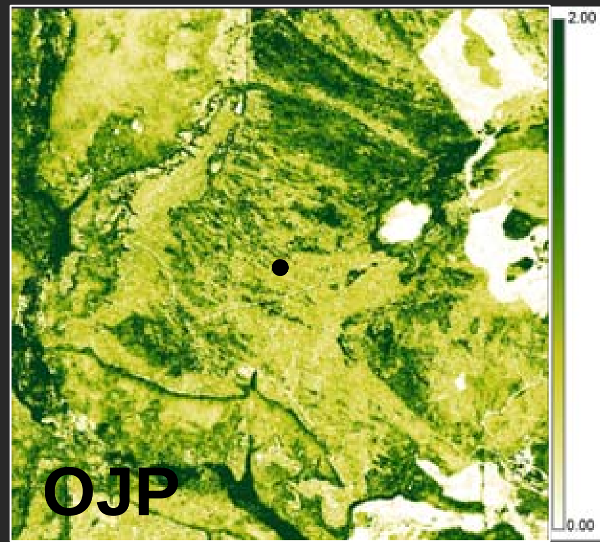
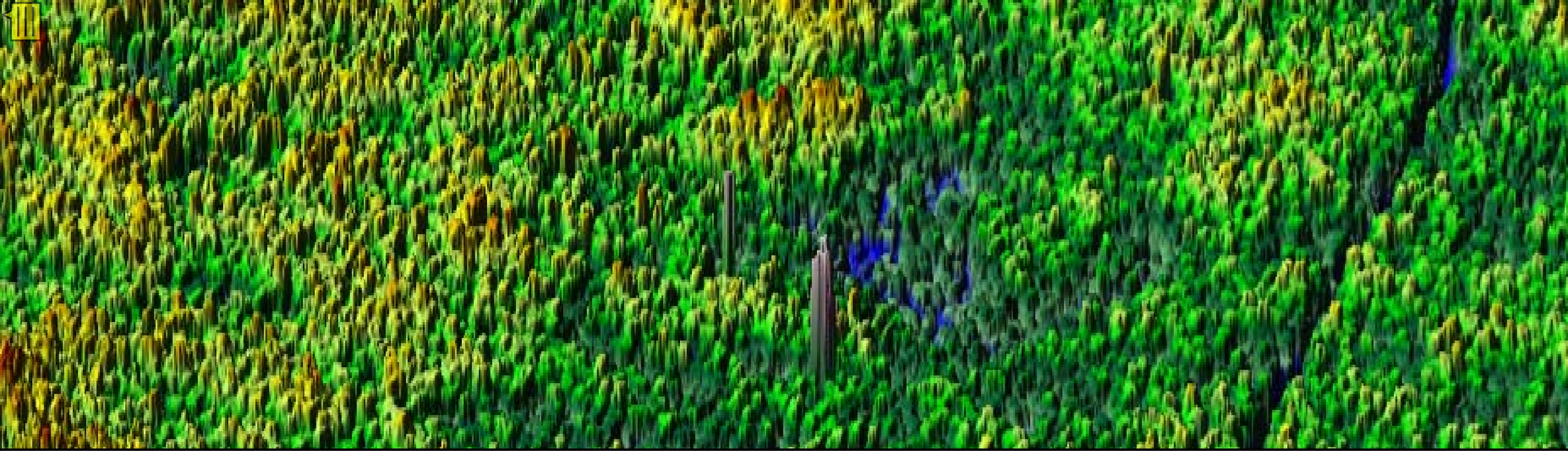






2000 m

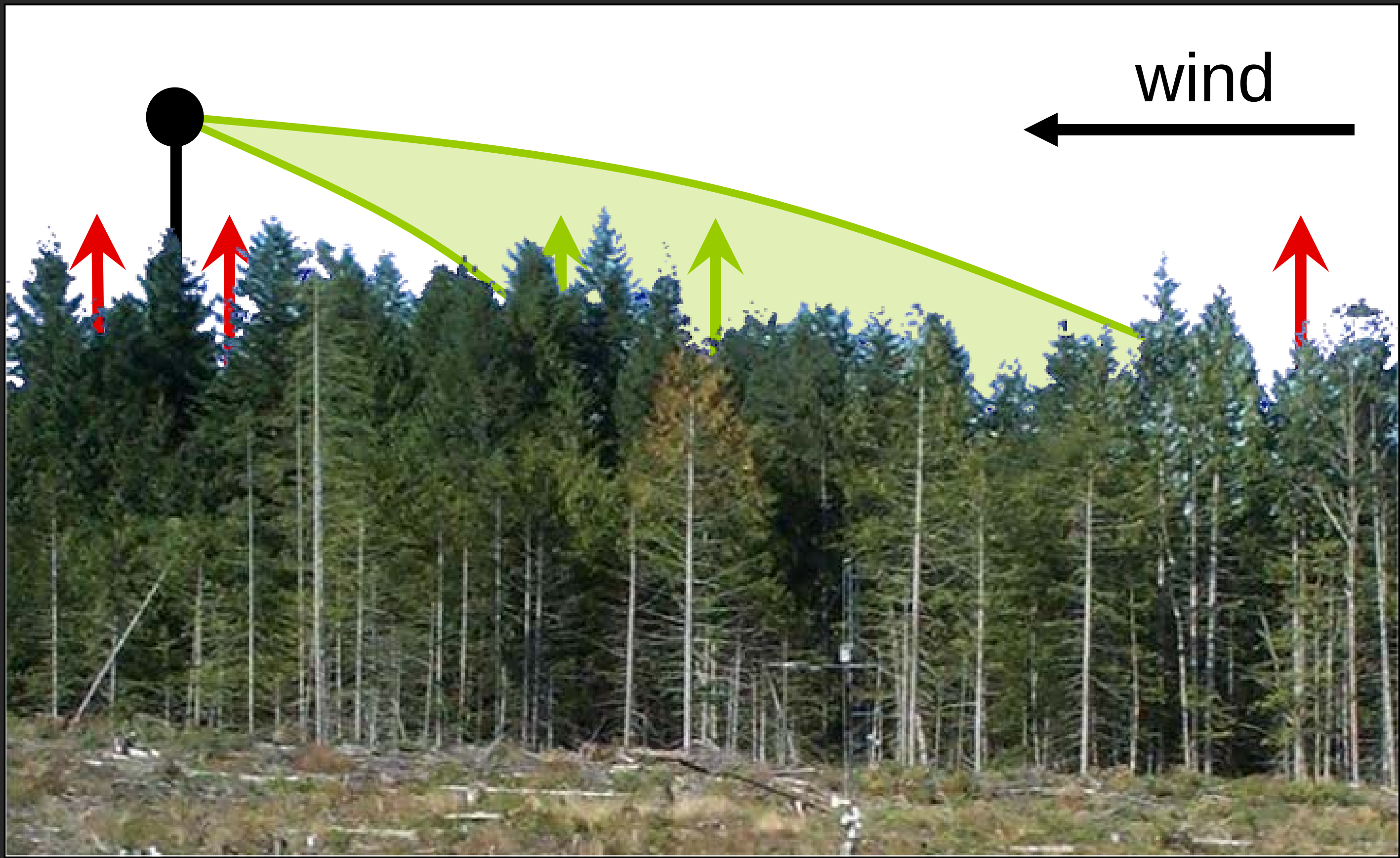
LAIe LAIe LAIe



Footprint Estimates

Which Area Contributes to Measurement?

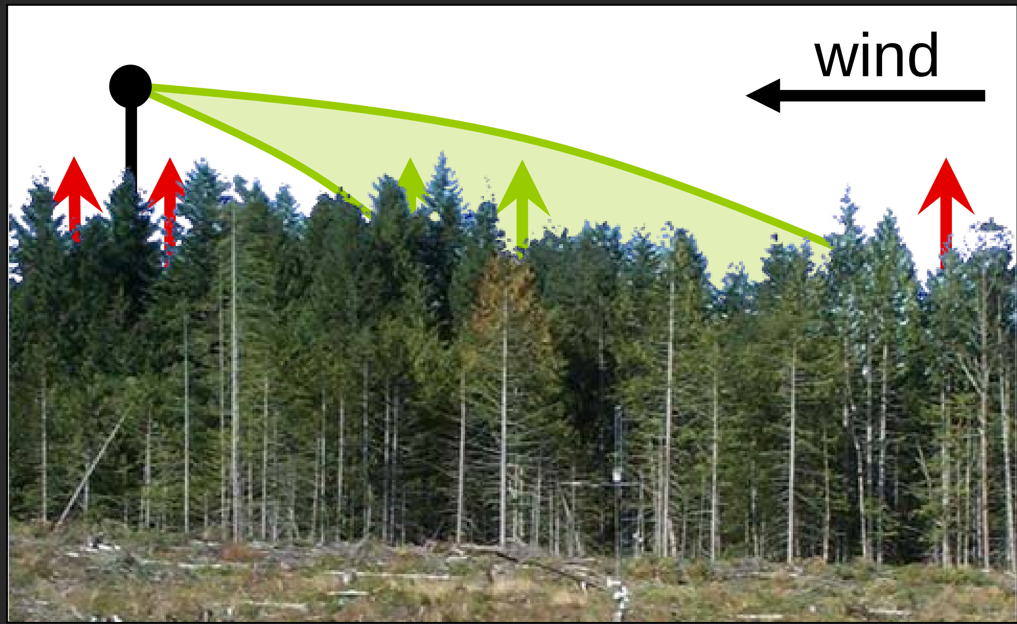
Footprint: spatial extent of the area contributing to the measured quantity



Which Area Contributes to Measurement?

Footprint depends on

- Height of measurement
- Surface properties
- Atmospheric flow characteristics (wind speed, wind direction, turbulence...)



Footprint Estimates

Footprint description

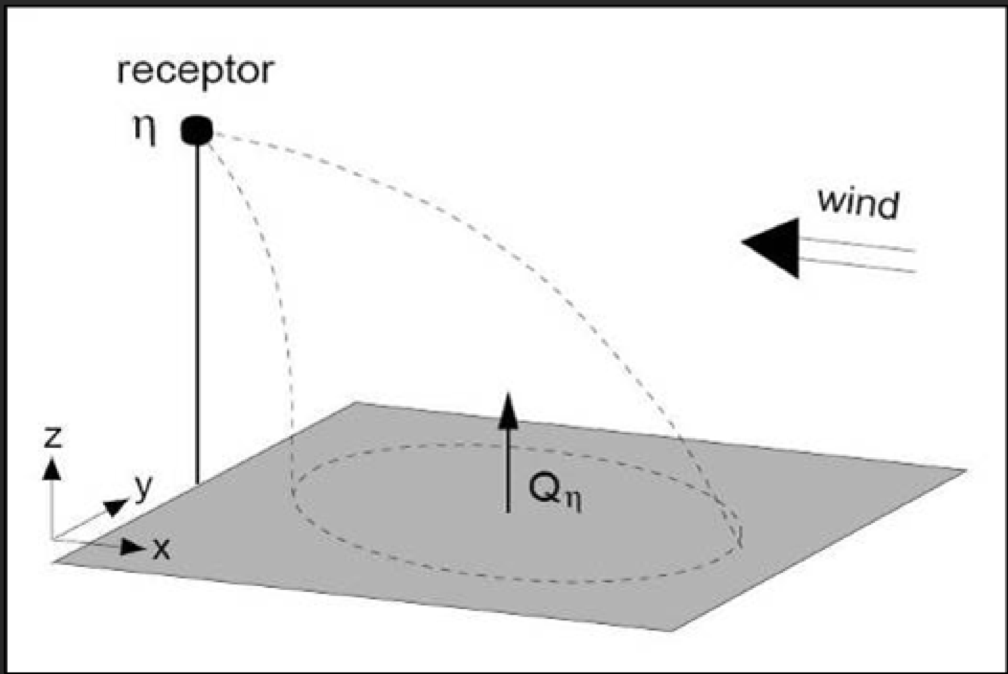
$$\eta(r) = \int_R Q_\eta(r + r')\, f(r, r')\, dr'$$

η: Measured value at *r*

Qη: source emission rate at *r+r'*

R: Domain of integration

f: Transfer function (footprint function)



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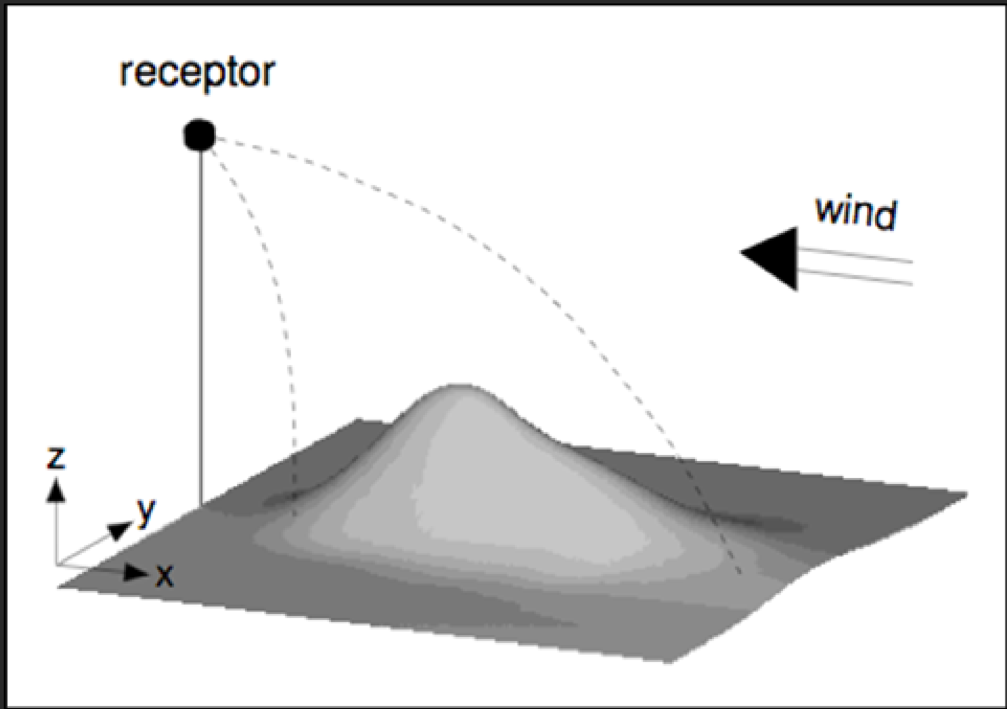


Footprint Estimates

Footprint description

$$\eta(r) = \int_R Q_\eta(r + r')\, f(r, r')\, dr'$$

- Analytical models $\rightarrow$ only valid for SL, homogen. surfaces
- Lagrangian stochastic particle models $\rightarrow$ CPU-intensive
- Parameterisations of above models
- Large-eddy simulations $\rightarrow$ CPU-intensive

Lagrangian Stochastic Particle Models

Langevin equation (Thomson 1987):

Lagrangian particle position $\mathbf{x} = (x, y, z)$

Lagrangian particle velocity $\mathbf{u} = (\overline{u} + u', v', w')$

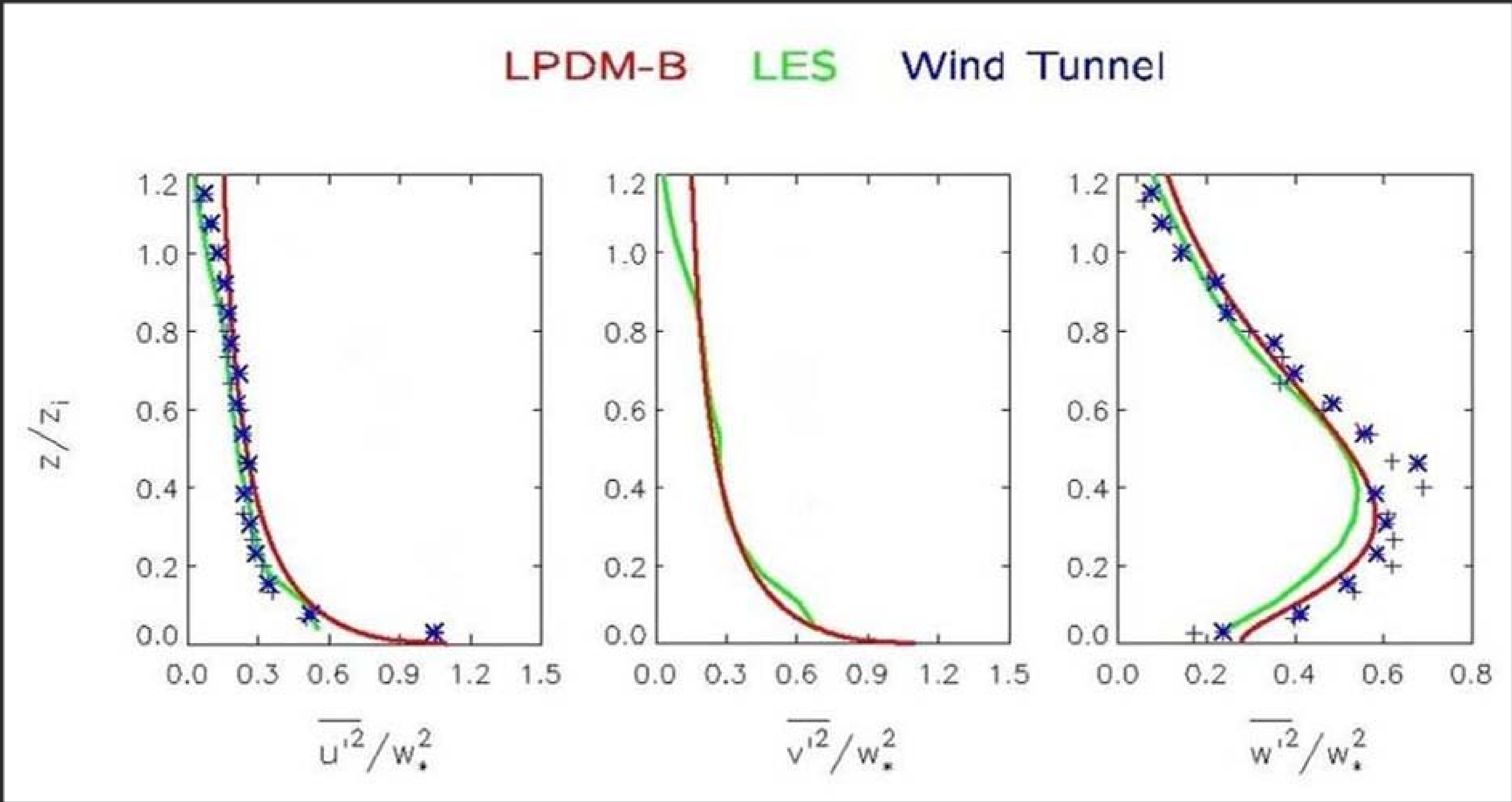
$$\mathrm{d}u'_i = a_i(\mathbf{x}, \mathbf{u}, t)\,\mathrm{d}t + b_{ij}(\mathbf{x}, \mathbf{u}, t)\,\mathrm{d}\xi_j$$
$$\mathrm{d}\mathbf{x} = \mathbf{u}\,\mathrm{d}t$$

Correlated part depending on turbulent velocity a_i

Uncorrelated random contribution b_{ij}

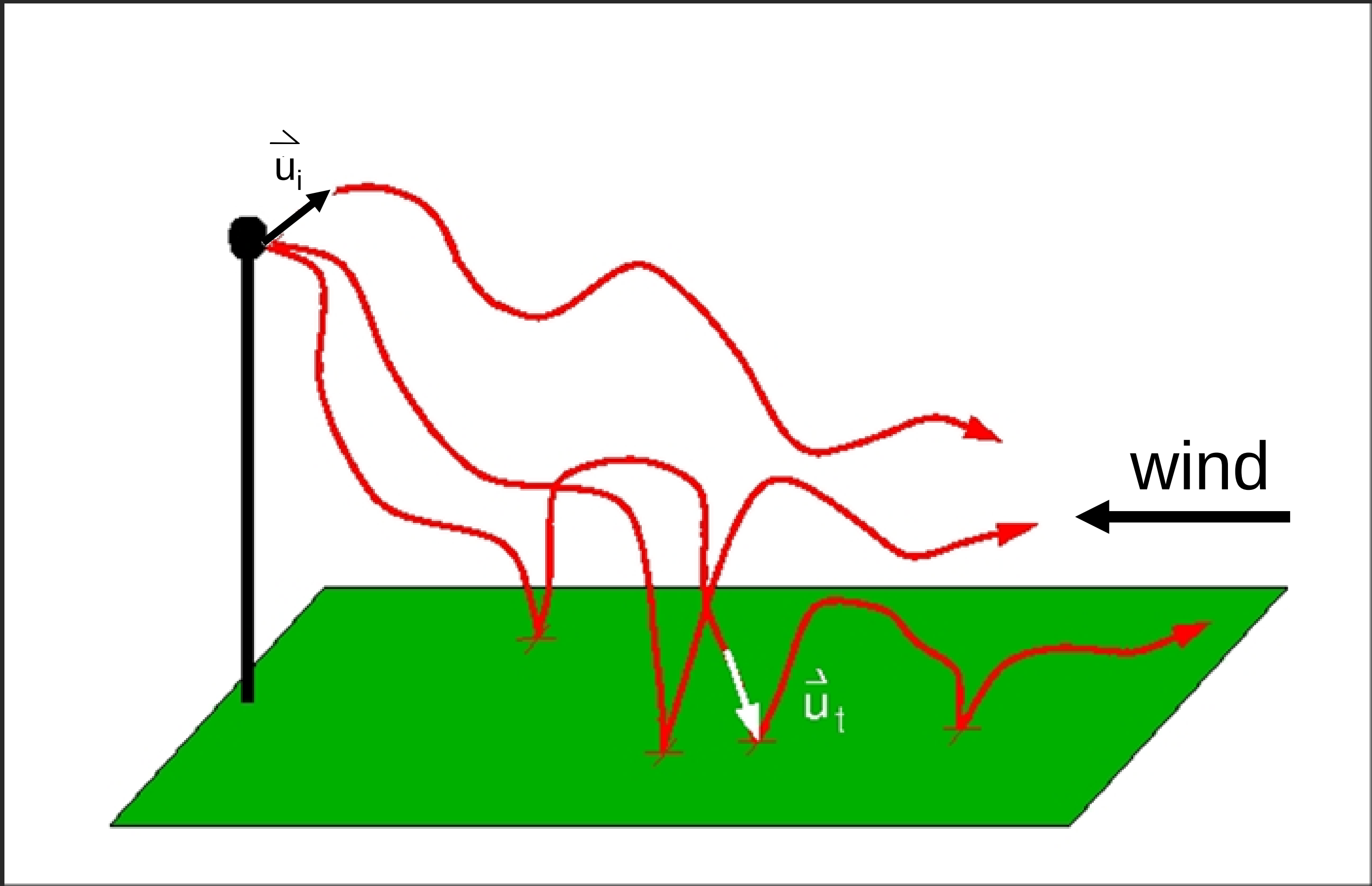
Lagrangian Stochastic Particle Models

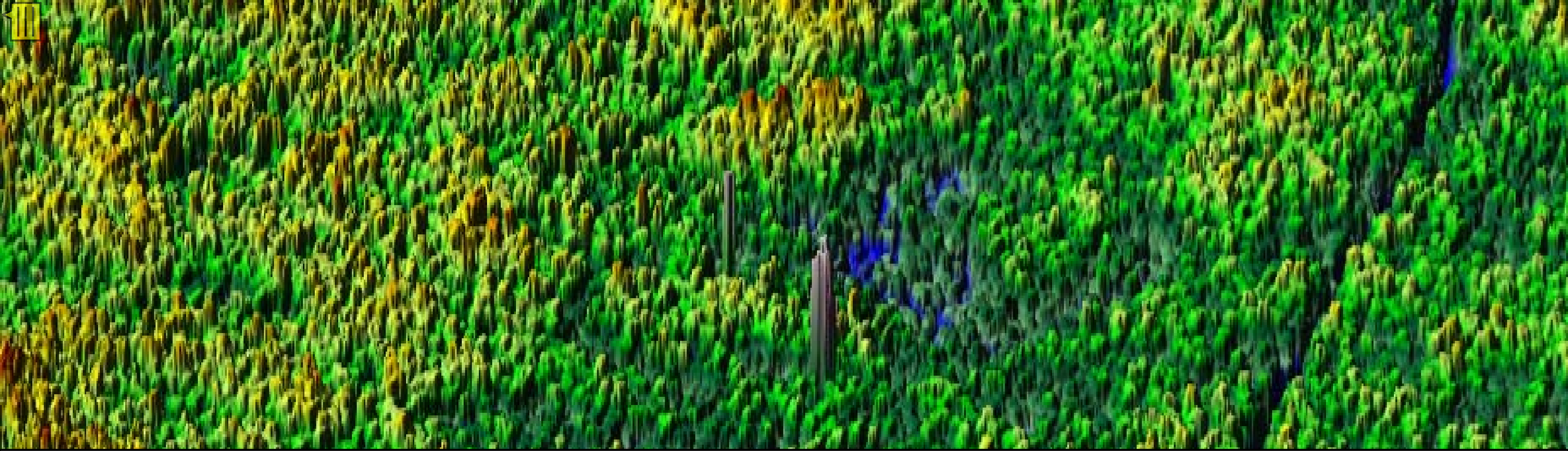
Turbulence profiles as input



Lagrangian Stochastic Particle Models

Track particles





Combination of LiDAR and Flux Tower Data

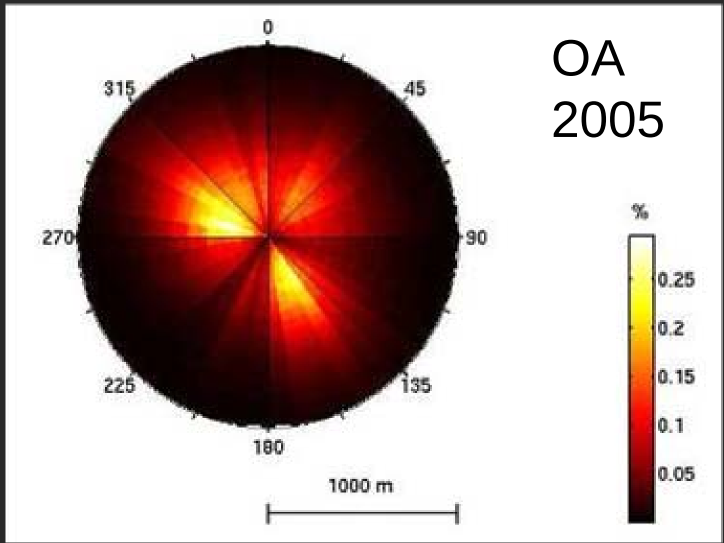
Combination of LiDAR Data and Flux Data

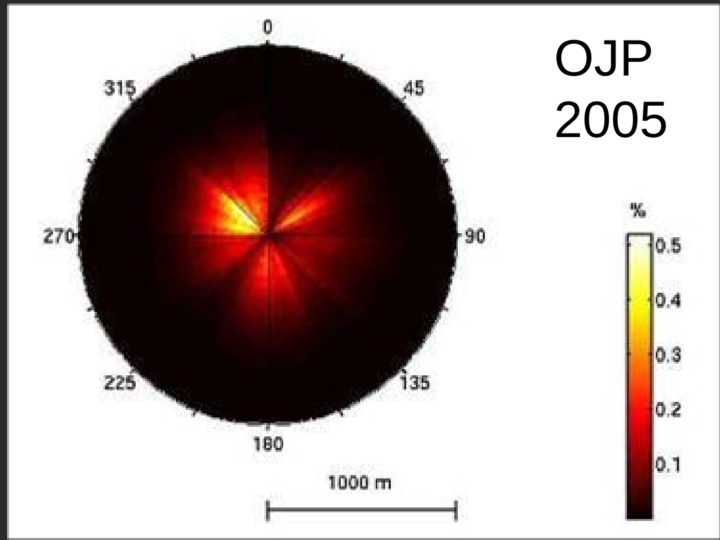
- Footprints (Kljun et al. 2004) for each 30 min flux data point (growing season, daytime)
- Extract canopy characteristics within footprints

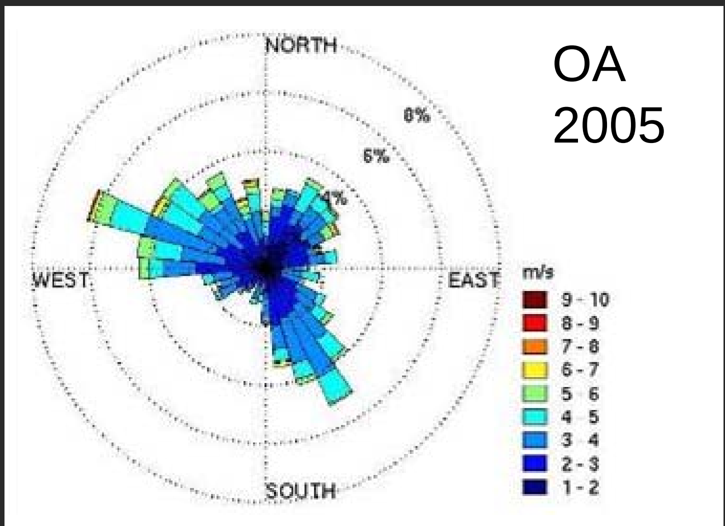
→ tree height, canopy depth, LAIe and elevation per 30 min sampling period

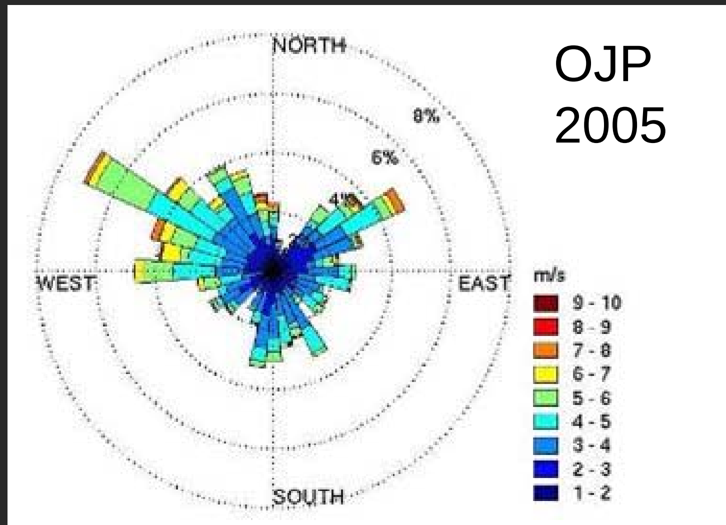
→ Comparison of CO_2 fluxes and canopy characteristics

Example Footprint Climatology



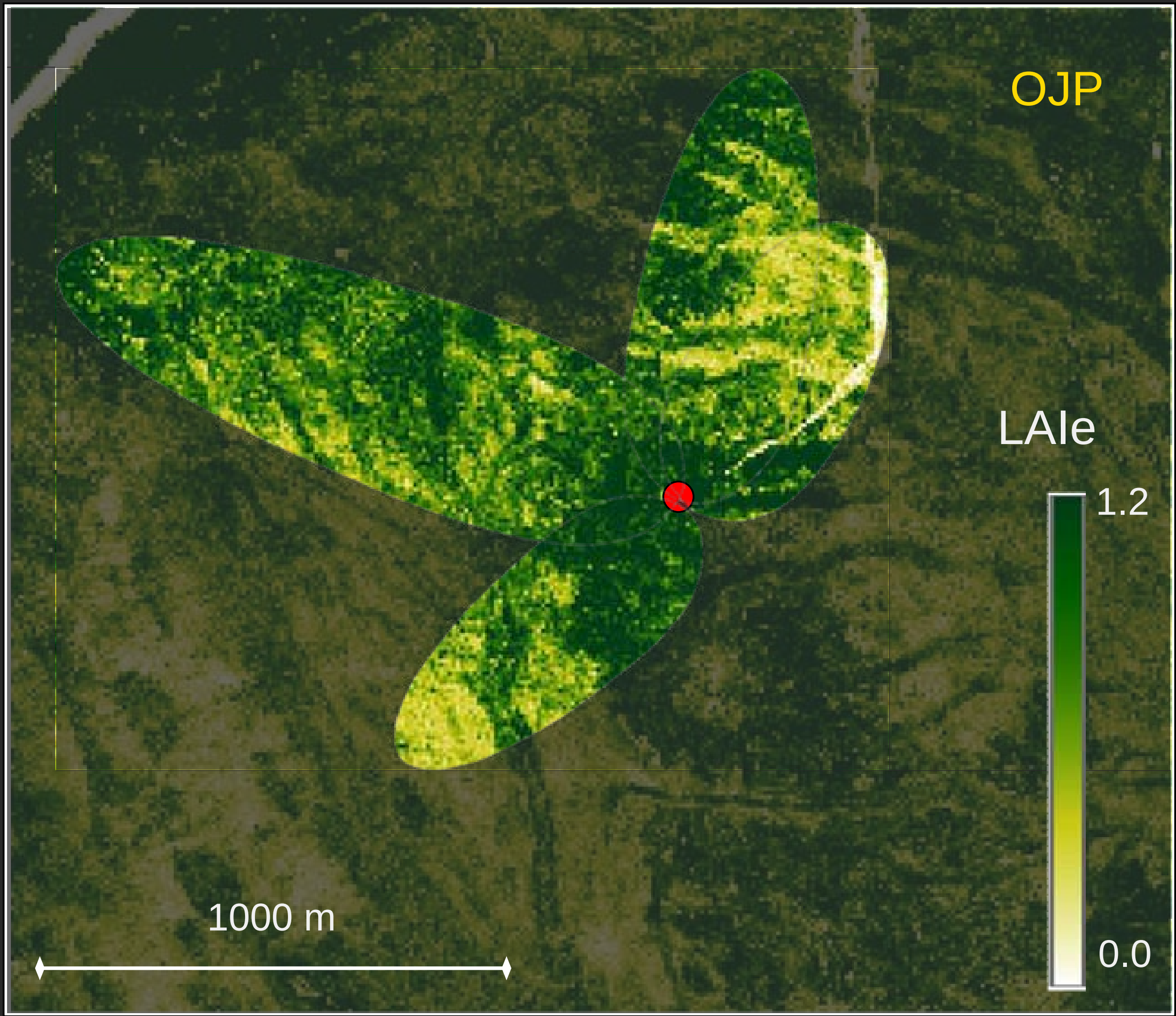






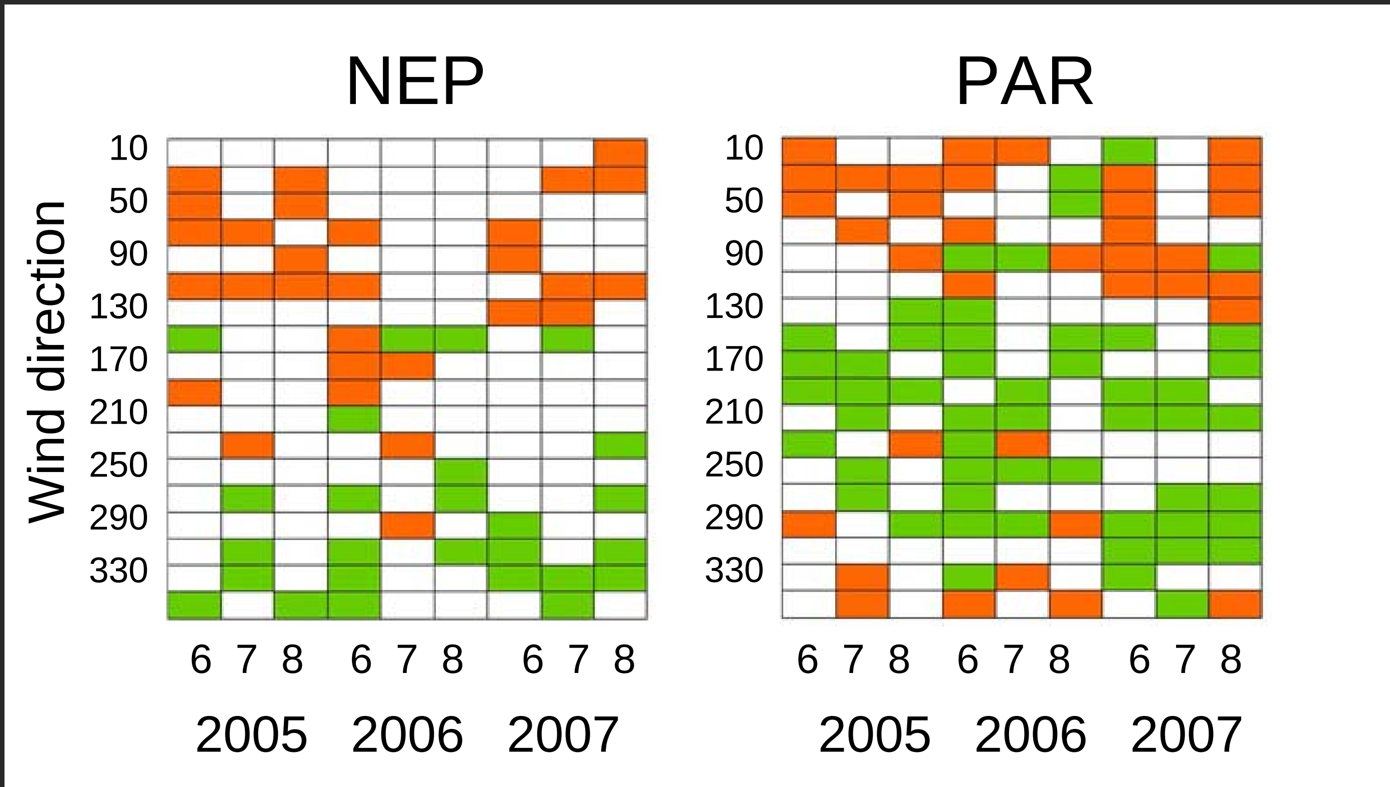
Growing season, daytime

Example Footprints



Impact of Vegetation Characteristics: OJP

Significant deviation from mean (360°)



positive deviation from mean

negative deviation from mean

Impact of Vegetation Characteristics: OJP

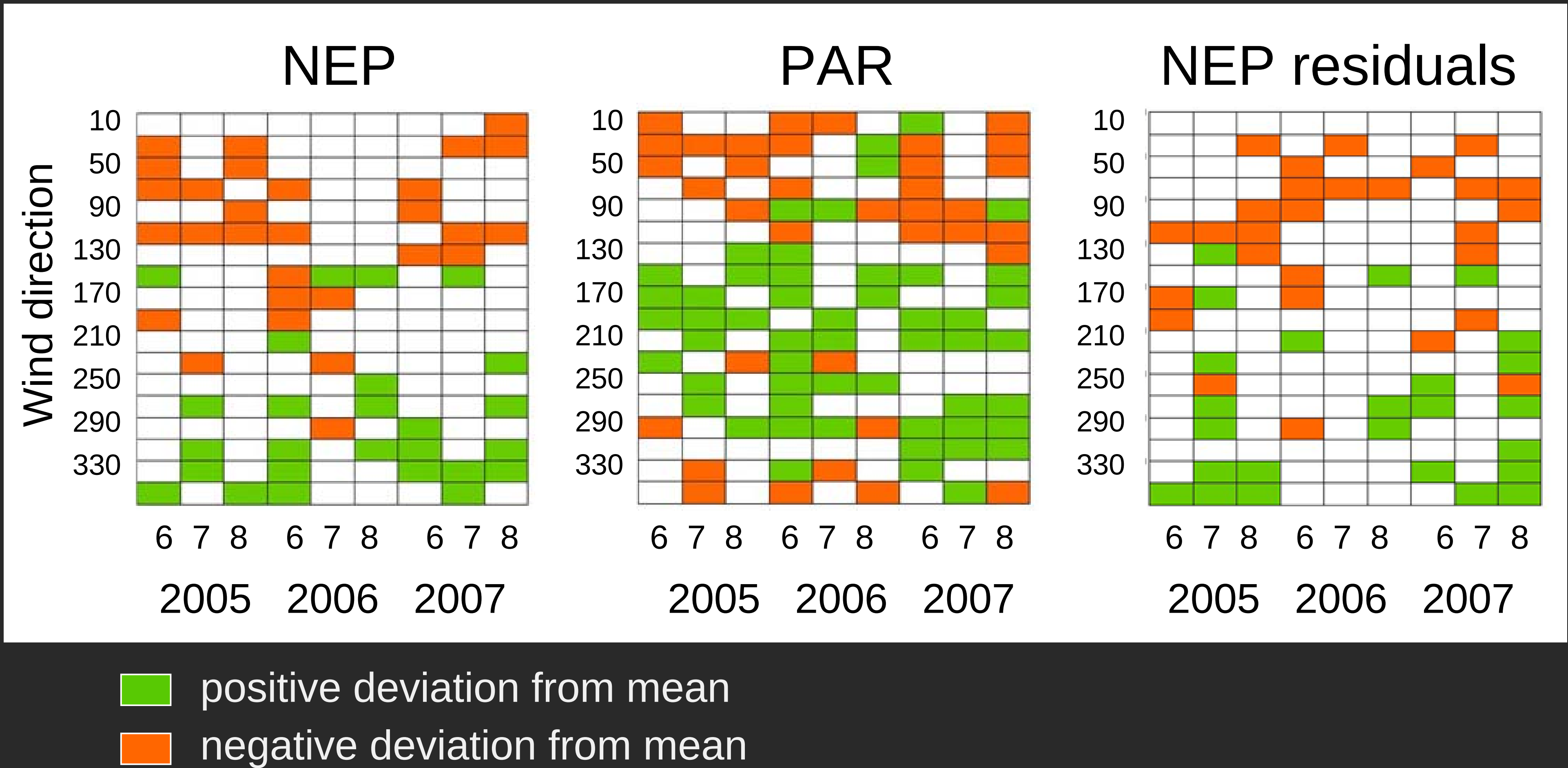
Calculate residual values:

NEP residuals = NEP measured – NEP modelled

NEP modelled = f(PAR, Tair, soil moisture)

Impact of Vegetation Characteristics: OJP

Significant deviation from mean (360°)



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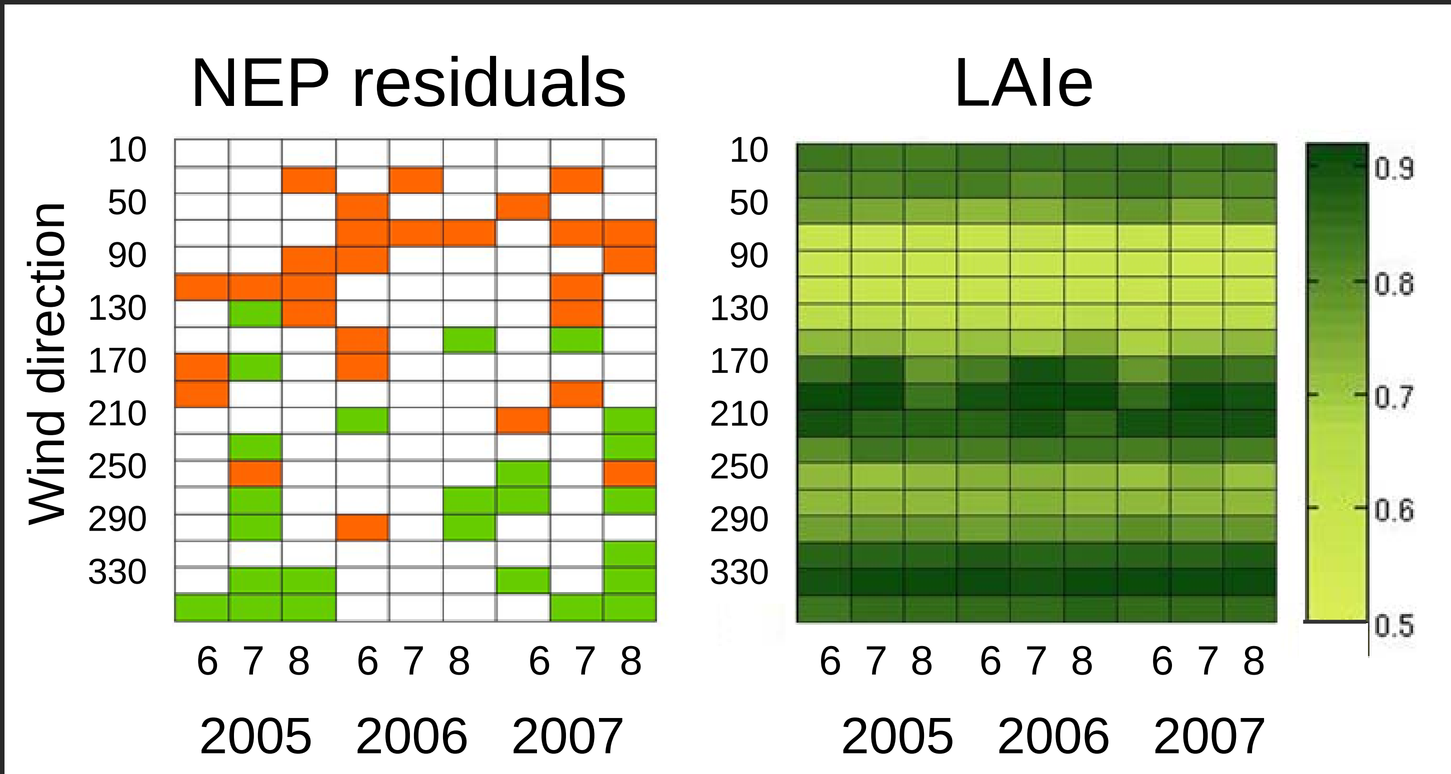
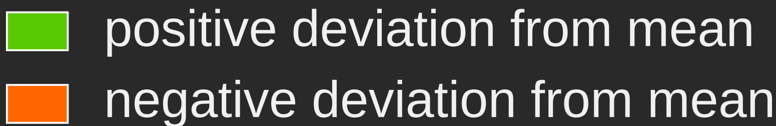
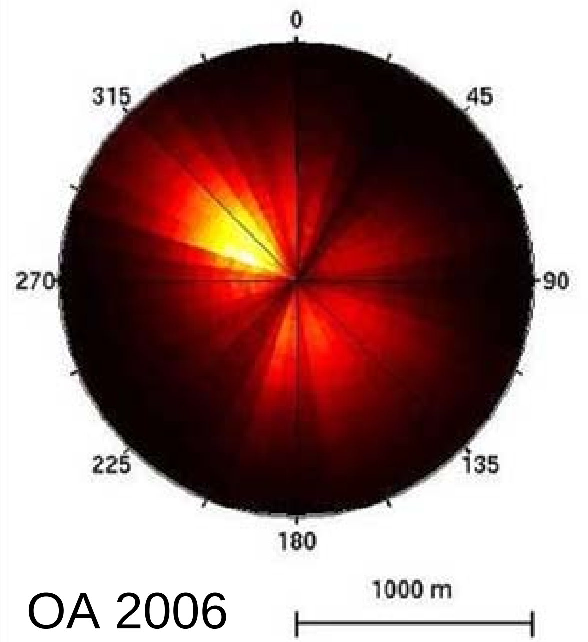




Impact of Vegetation Characteristics

Deviation from average LAIe for top 50% of growing season fluxes

LAIe	OA	OBS	OJP
2005	-3%	-9%	+40%
2006	-8%	-3%	0%
2007	-3%	-3%	-9%
2008	-6%	4%	
Average [m^2/m^2]	4.0	1.0	0.8



OA 2006

Summary

- LiDAR data sets for flux tower sites offer a lot of additional information on vegetation canopy and topography
- Tool to overlay footprints with maps from LiDAR data and to extract vegetation characteristics within footprints
- Vegetation structure can have significant impact on CO_2 fluxes - even at predominantly homogeneous sites
- When upscaling fluxes - weight site characteristics or annual fluxes for site representativeness?

Acknowledgements

- NERC (funding)
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- Applied Geomatics Research Group (LiDAR survey BERMS)

THANK YOU!