Turbulence classification of the atmospheric boundary-layer for Doppler wind lidar networks

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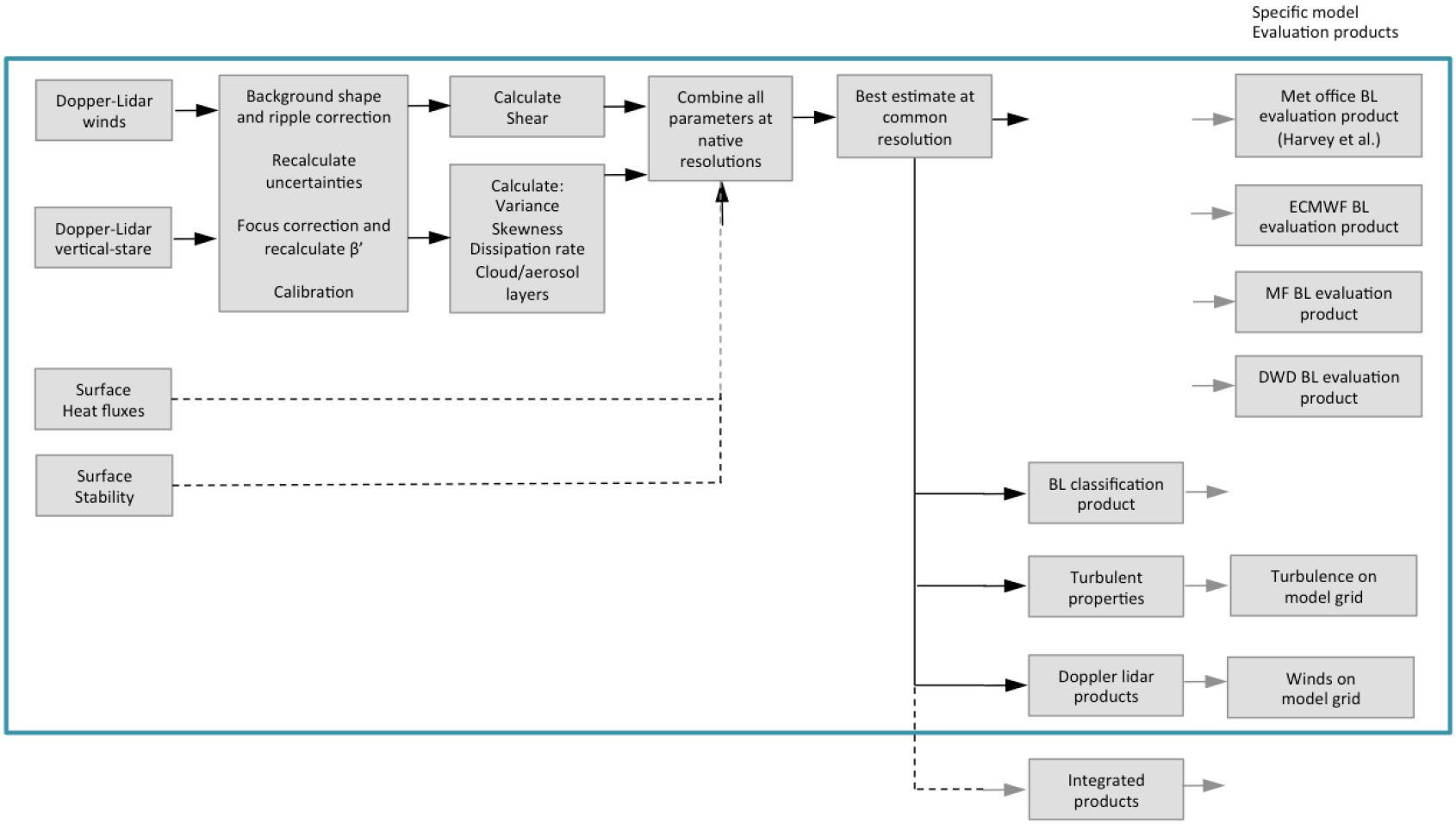
Classifying the boundary-layer (BL)

- **Goals:**
  - Understand complex mixing processes and their evolution using long-term observational data
  - Provide operational products in high resolution at different sites

- **Requirements:**
  - Uniform set of procedures and data formats

- **Benefits:**
  - Identify turbulent regions that are driven by surface fluxes or clouds
  - Systematic evaluation of BL schemes in forecast models

BL classification as a product



Doppler wind lidar (DWL)

- **Wavelength**: 1.5 µm
- **Max. Range**: 9-10 km
- **Vertical resolution**: 30 m
- **Vertically-pointing**
  - Vertical wind
  - Backscatter
- **Scans** (DBS or VAD)
  - Horizontal wind speed and direction

DWL parameters for BL classification

Attenuated backscatter β

Height of the aerosol layer

Cloud detection

Requires sufficient amount of aerosols as tracer for air motion

Vertical velocity skewness

Source of turbulence

(surface or cloud)

$$s = \frac{\overline{w'^3}}{\overline{w'^2}^{3/2}}$$

TKE dissipation rate ε

Identify turbulent regions

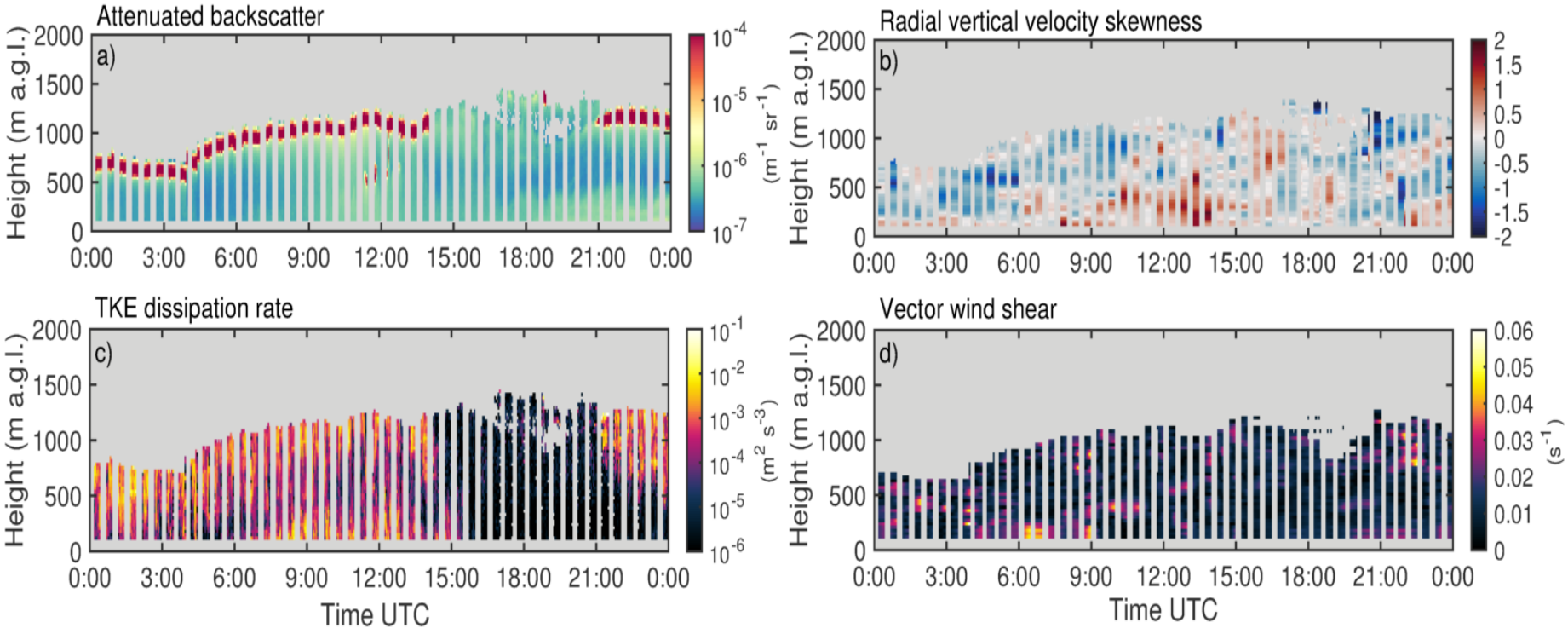
Derived from vertical velocity variance (O'Connor et al., 2010)

Vector wind shear

Indicates shear driven turbulence

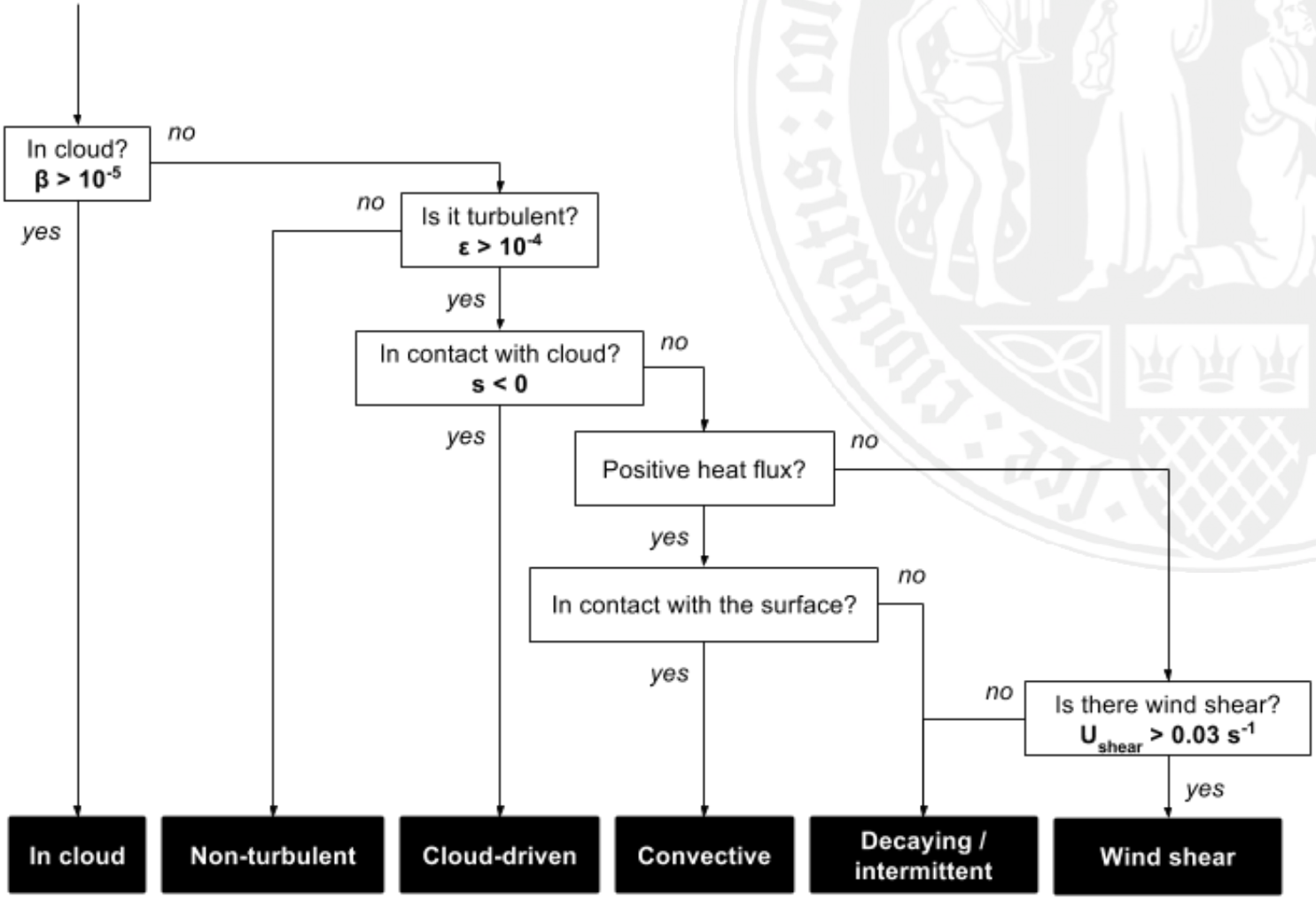
$$U_{shear} = \frac{\sqrt{\delta u^2 + \delta v^2}}{\delta z}$$

Stratocumulus topped BL

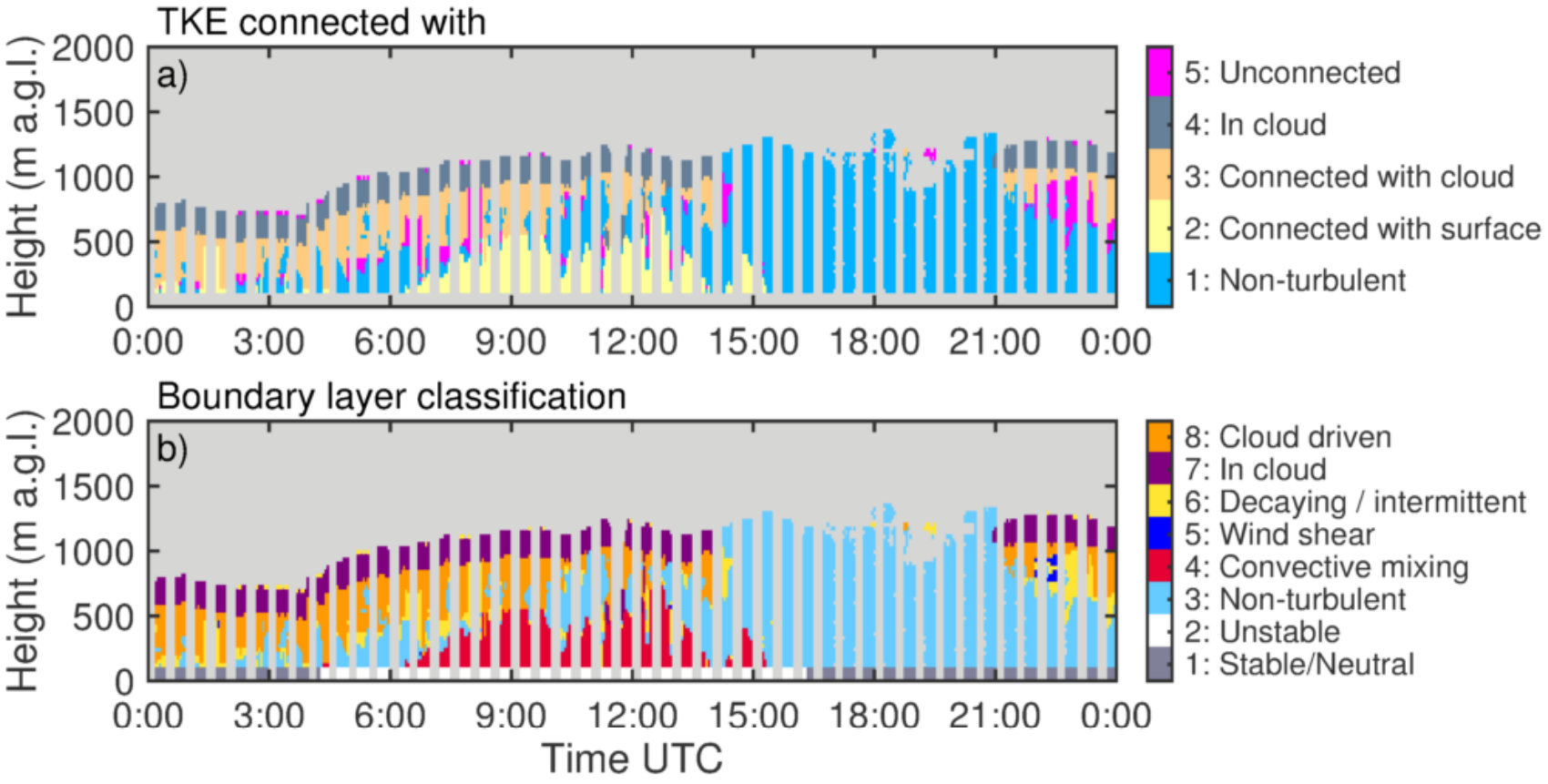


- Case study from Hyytiälä (Finland), 22 September 2016

Decision tree for BL types



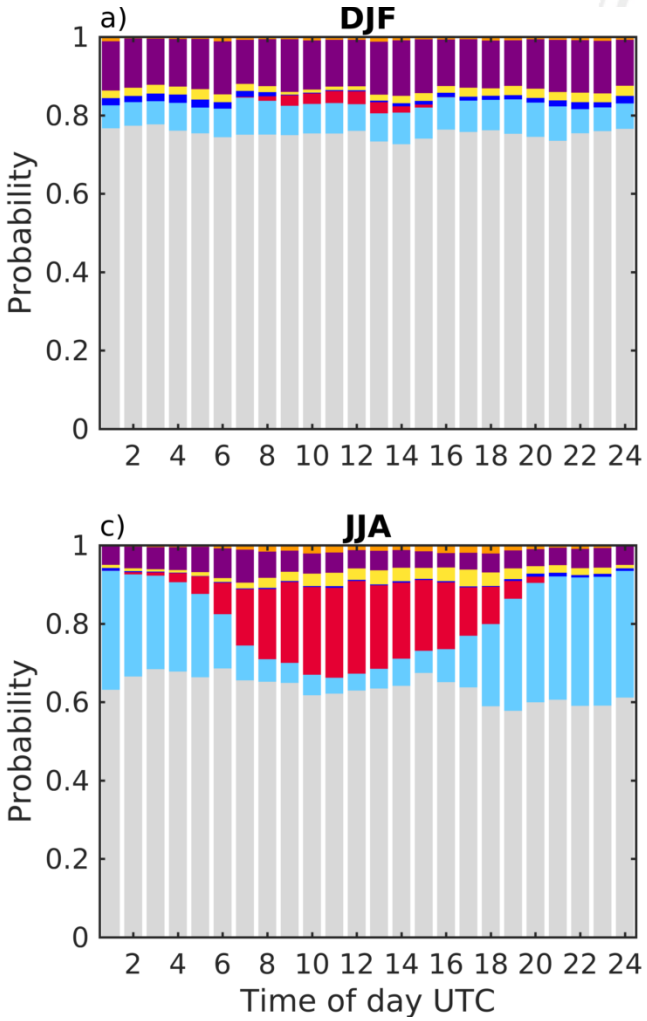
Stratocumulus topped BL



Diurnal development of BL types

Winter

Summer



Hyytiälä

Diurnal development of BL types

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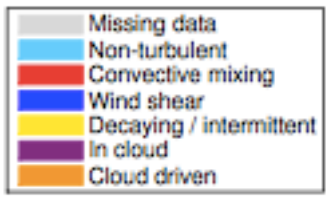
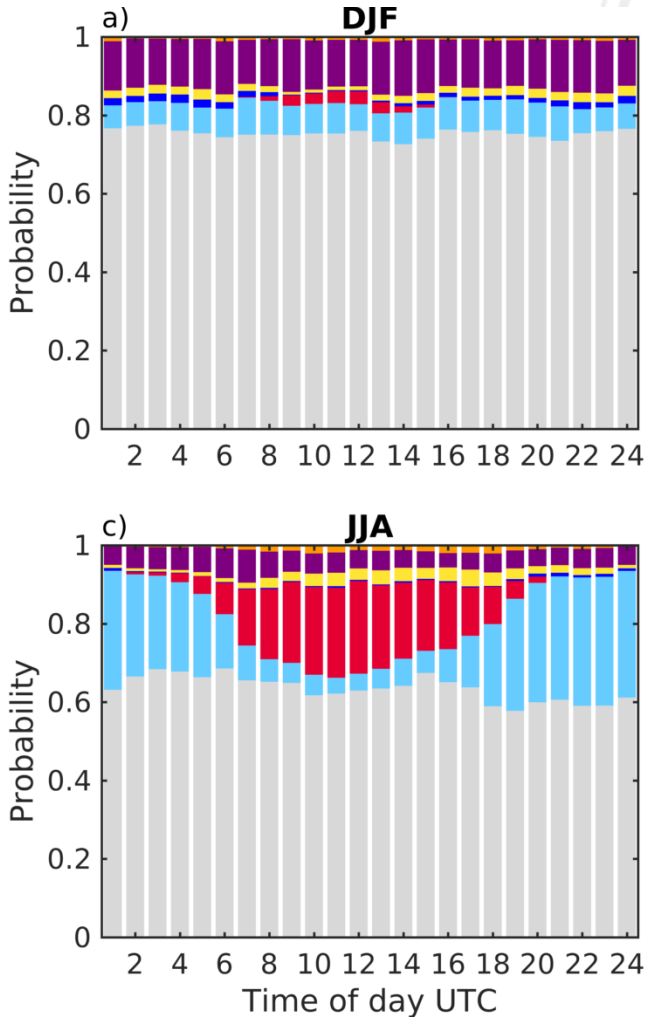
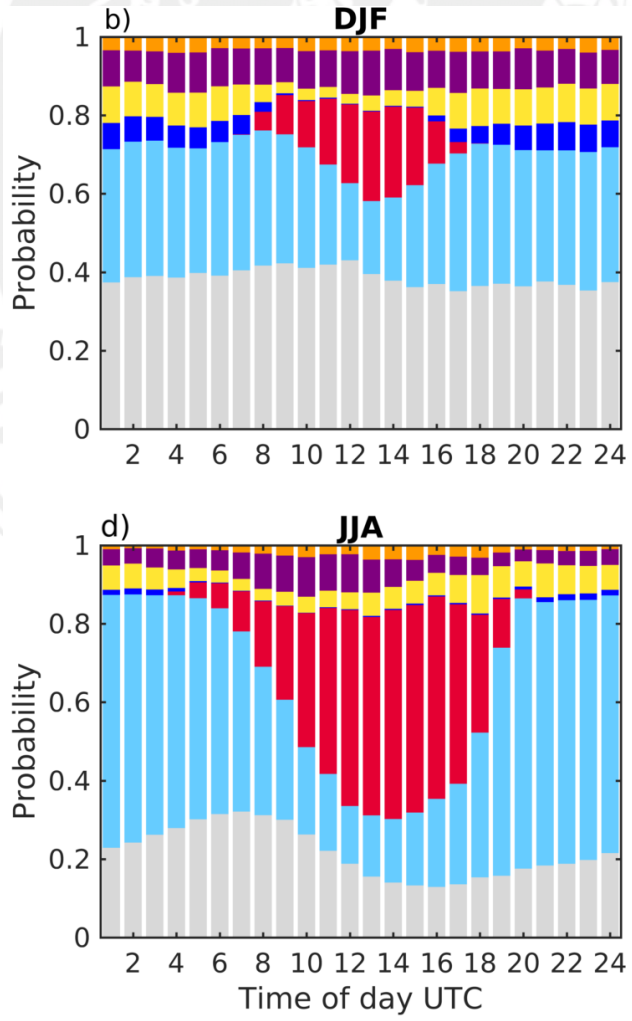


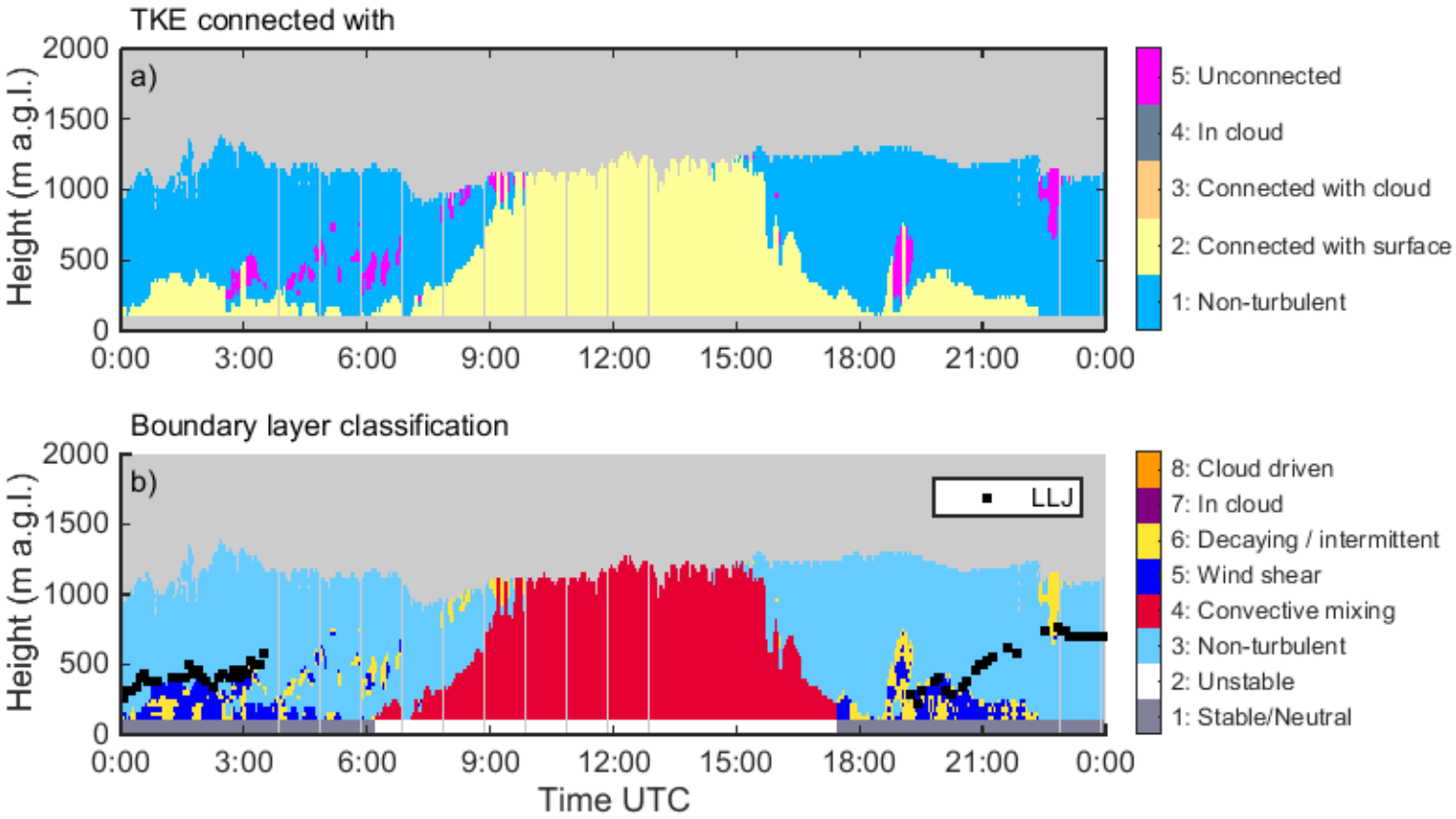


Hyytiälä



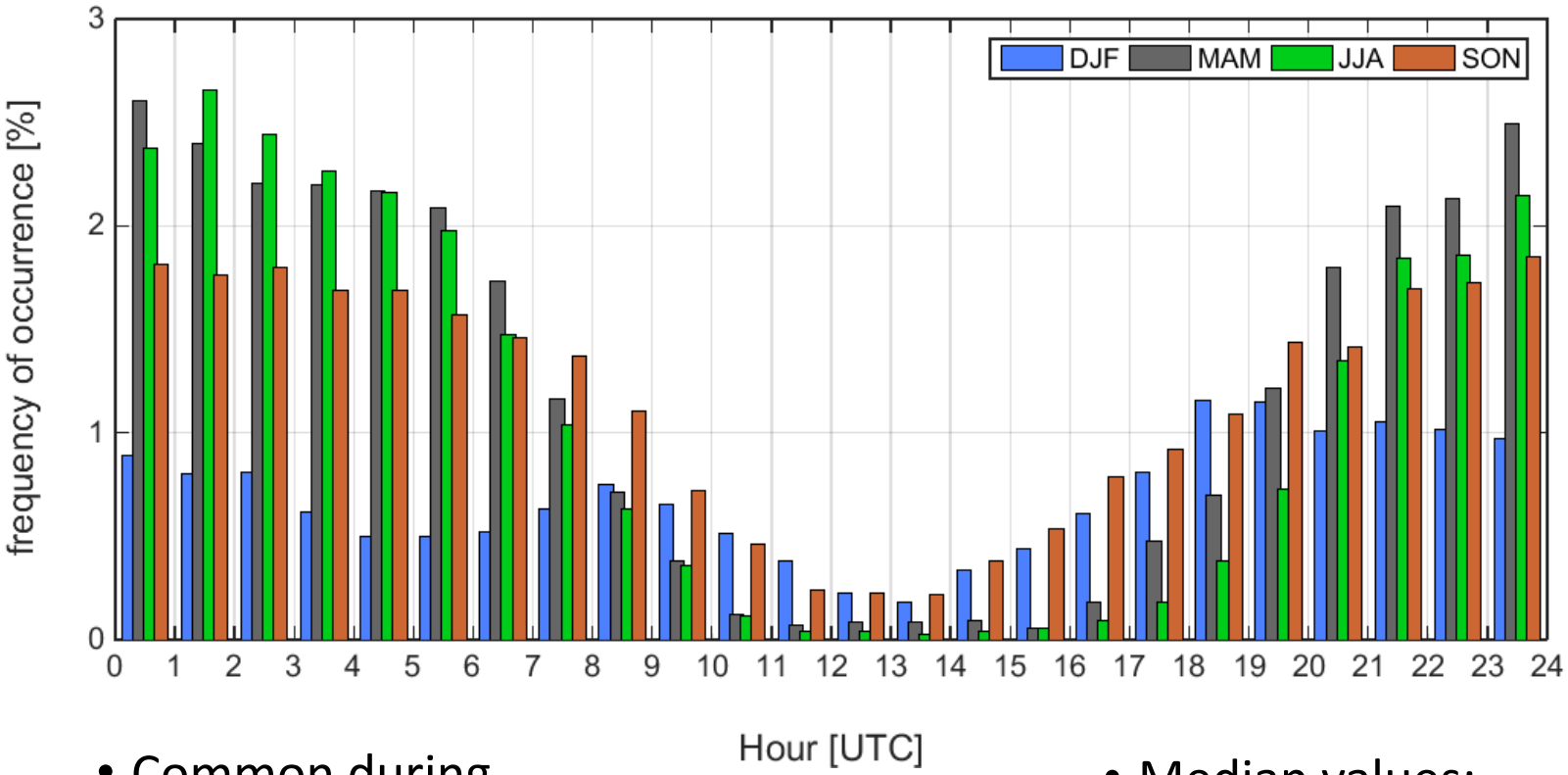
Jülich

Convective BL with nocturnal low level jets



- Case study from Jülich (Germany), 9 March 2016
- Low level jet (LLJ) identification by Tuononen et al. (2017)

Low level jet occurrence in Jülich

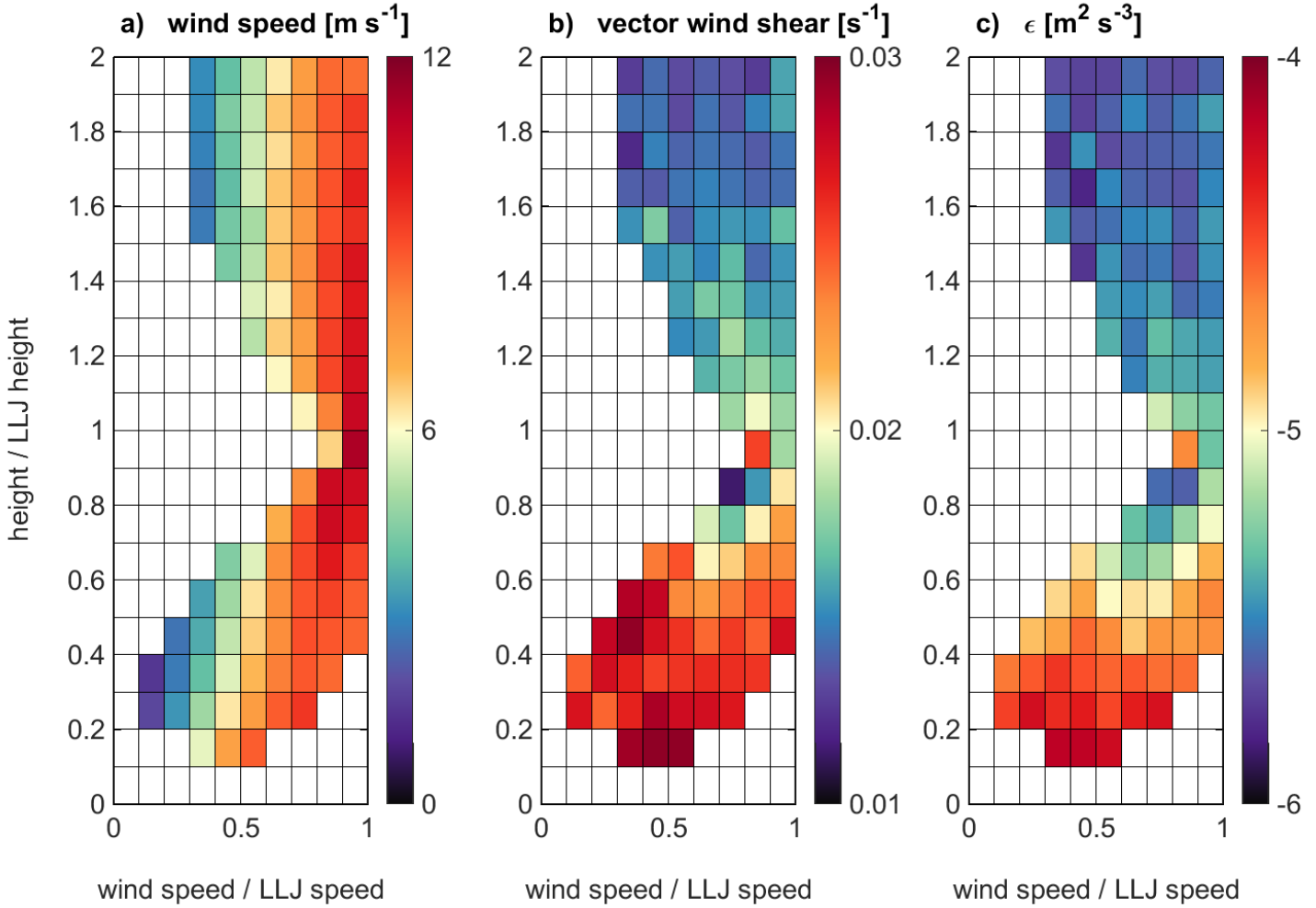


- Common during nighttime
- Stable surface layer

- Median values:
  - LLJ **speed**: 8.82 m/s
  - LLJ **height** 375 m

BL turbulence associated with LLJs

- Relevant for wind energy applications
- Over 15% of all LLJs occur below 200 m



Summary and Outlook

- DWL based BL classification provides main sources causing mixing
- Long term statistics of different sites can give insights in BL development
- Nocturnal LLJs play important role through shear driven turbulence
- Perform forecast model BL evaluations, combine with Cloudnet products..
- Manninen, A., Marke, T., O'Connor, E. J., Tuononen, M.: Boundary layer classification with Doppler lidar, to be submitted