TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

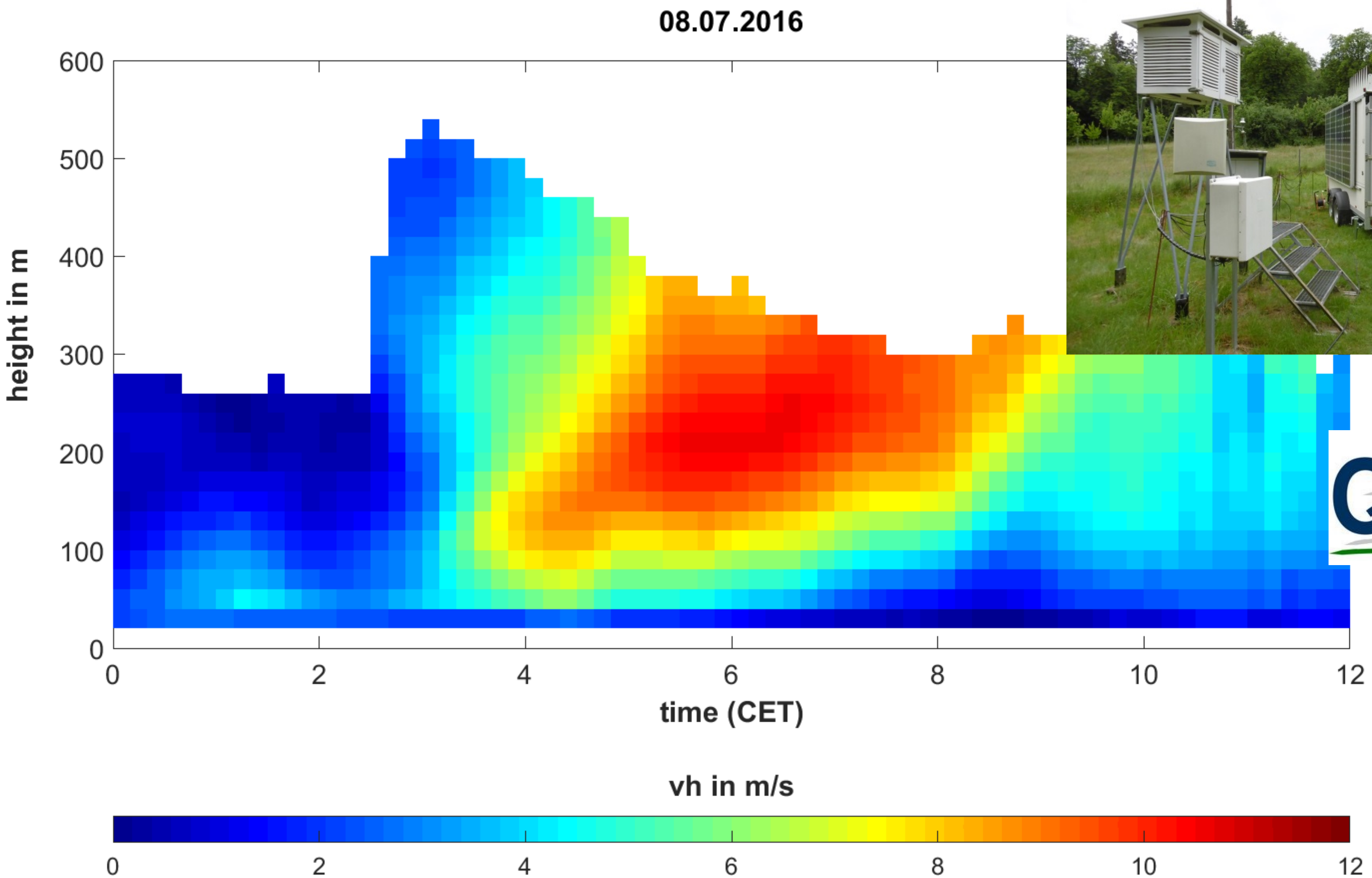
TU Dresden, Chair of Meteorology

Modelling of the atmospheric boundary layer – Applications for wind energy

Astrid Ziemann, Manuela Starke, Valeri Goldberg and colleagues

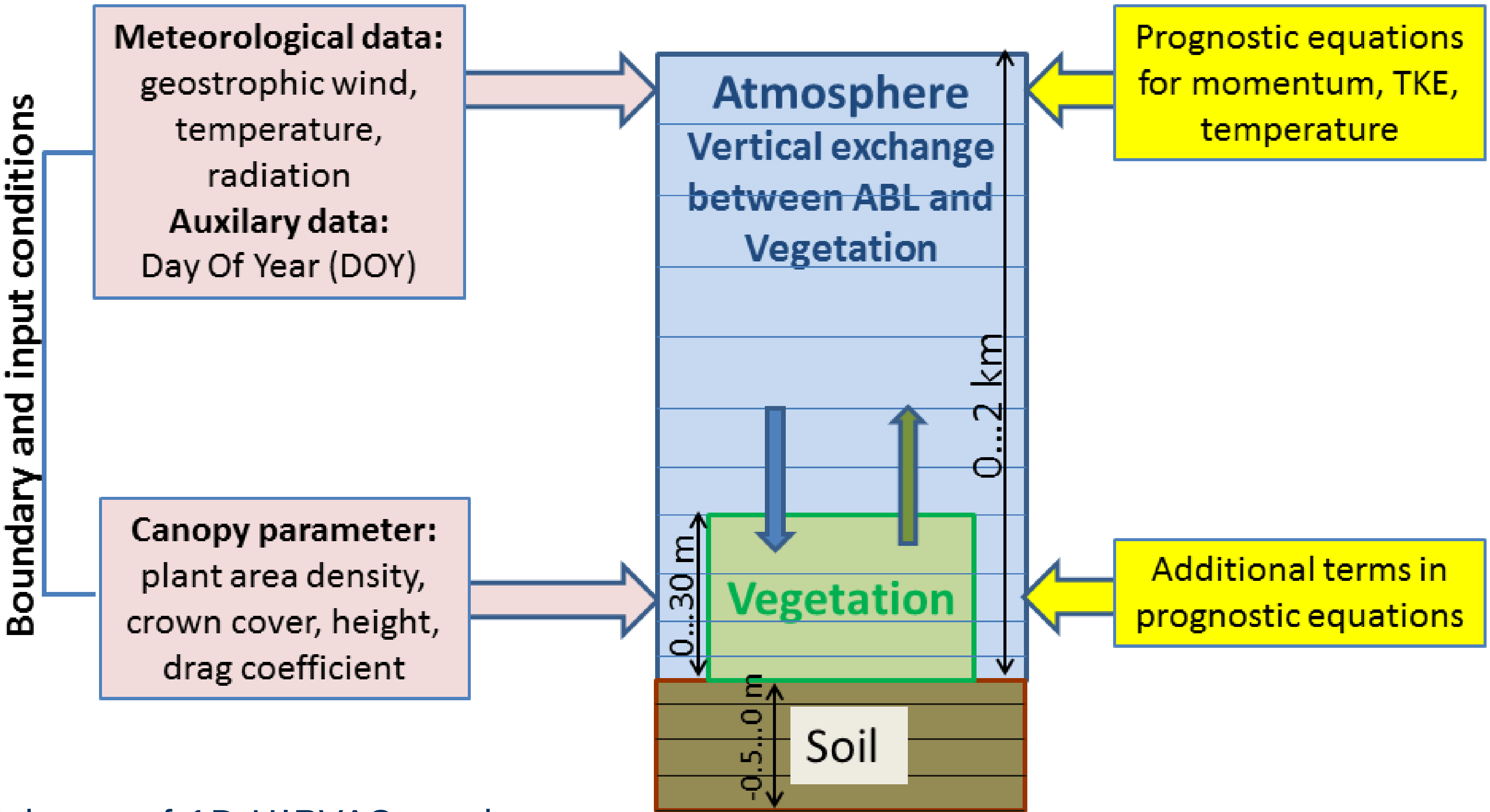
Phenomenon during clear nights: low-level jet
Measurement at forest clearing

→ Increase of wind speed over several hours



Starke, 2016

High Resolution Vegetation-Atmosphere Coupler (HIRVAC)



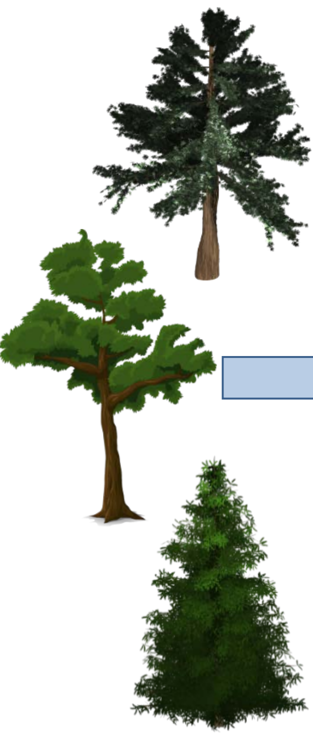
Scheme of 1D HIRVAC version

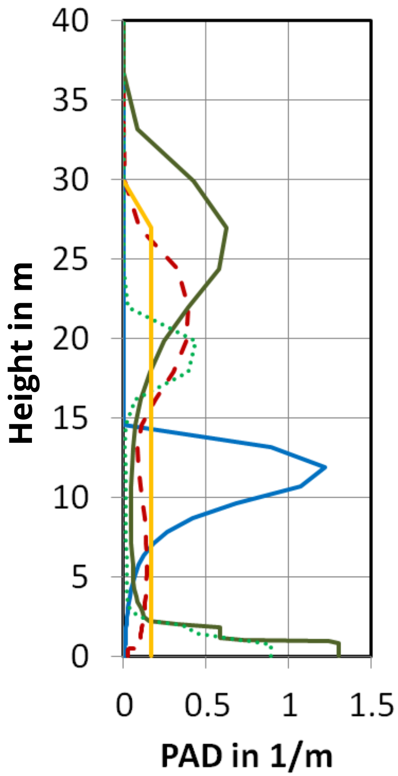
Ziemann, 2017

HIRVAC2D – vegetation parameters and effects on the wind field

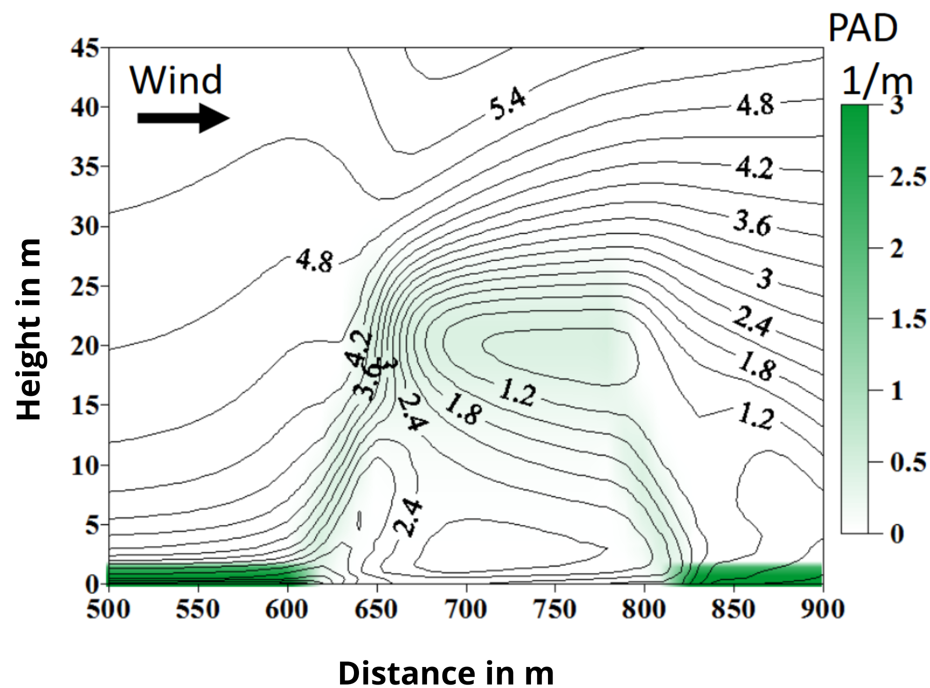
→ Height of vegetation (HP)
→ Profils of plant area density (PAD)

→ Horizontal wind speed in m/s





Starke, 2017



Ziemann and Wilson, 2015

Recent projects with HIRVAC applications → wind field

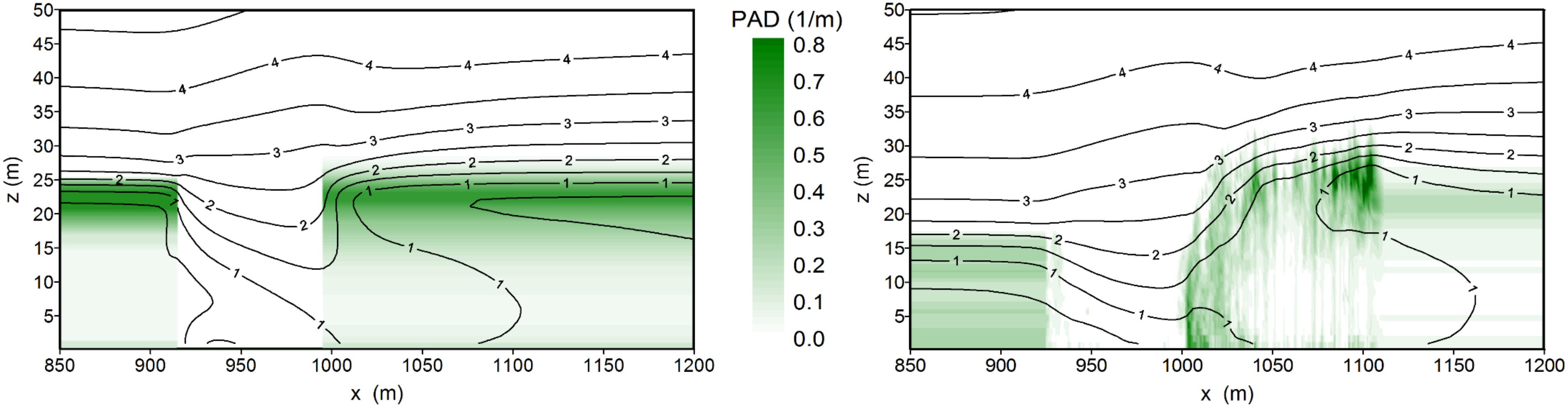
DFG Deutsche Forschungsgemeinschaft

➢ Example 1: DFG priority program 1276 **Metström**

Project **TurbEFA** (Turbulent Exchange processes between Forested areas and the Atmosphere)

→ to investigate the effects of forest edges and inhomogeneities in forests on the turbulence of atmospheric flows and their representation in numerical models

Model results: dependence of wind speed on the vegetation structure



Queck et al., 2014: DOI 10.1127/metz/2014/0567

- Horizontal wind speed in m/s (lines), background: Plant Area Density (green area)
- HIRVAC2D simulation along a forest clearing
- Results from calculations with homogeneous (left) and measured (right) distribution of vegetation

→ Heterogeneous vegetation → more variable gradients of wind speed

Recent projects with HIRVAC applications → wind field

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

QuWind 100

- Example 2: BMWi 6. Energy Research Programme

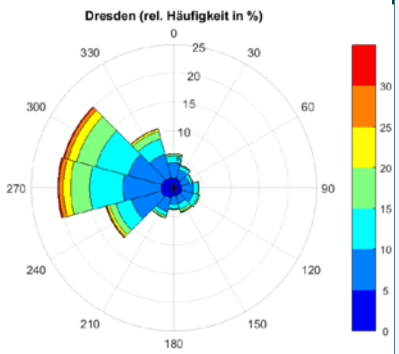
Project **QuWind100** (Quantitative wind climatalogy for wind energy applications at heights above 100 m)

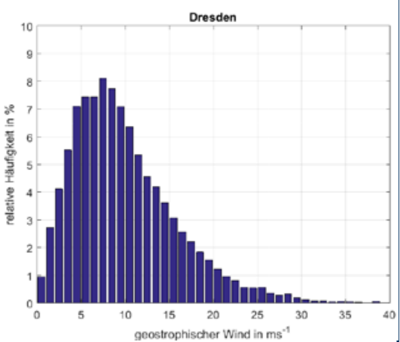
→ to model a wind climatology for Germany for present and future climate and landuse

Project QuWind100

Meso scale

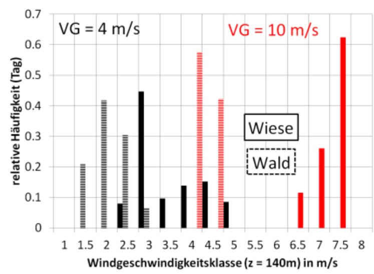
CCLM-Daten



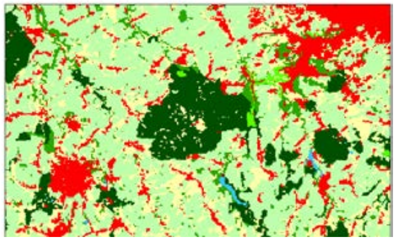


Micro scale

HIRVAC2D



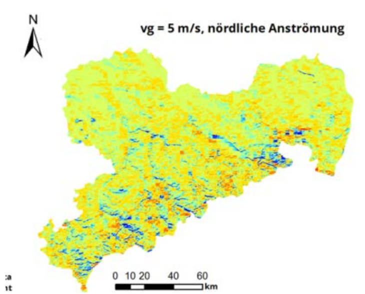
Landuse (LU)-Data



Sensitivity

LU-Classes

WiTraK



Grid-based wind atlas for heights between 100 m and 200 m

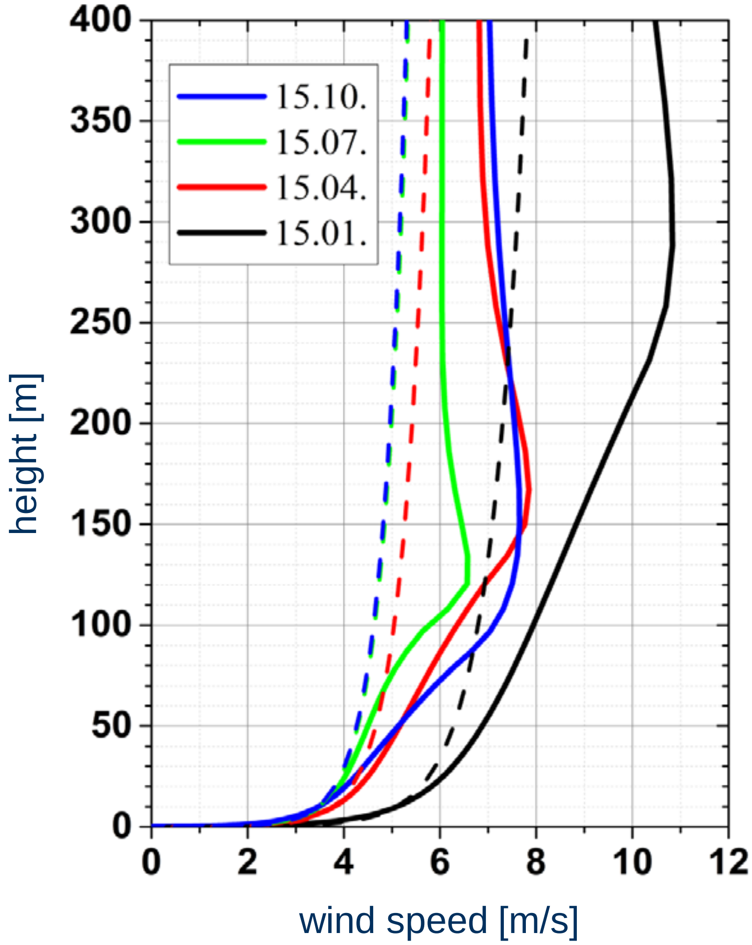
Adopted from Starke, 2019

Model results: nocturnal low-level jet

Low-level jet (LLJ) → important phenomenon of the wind field at typical hub heights of wind turbines:

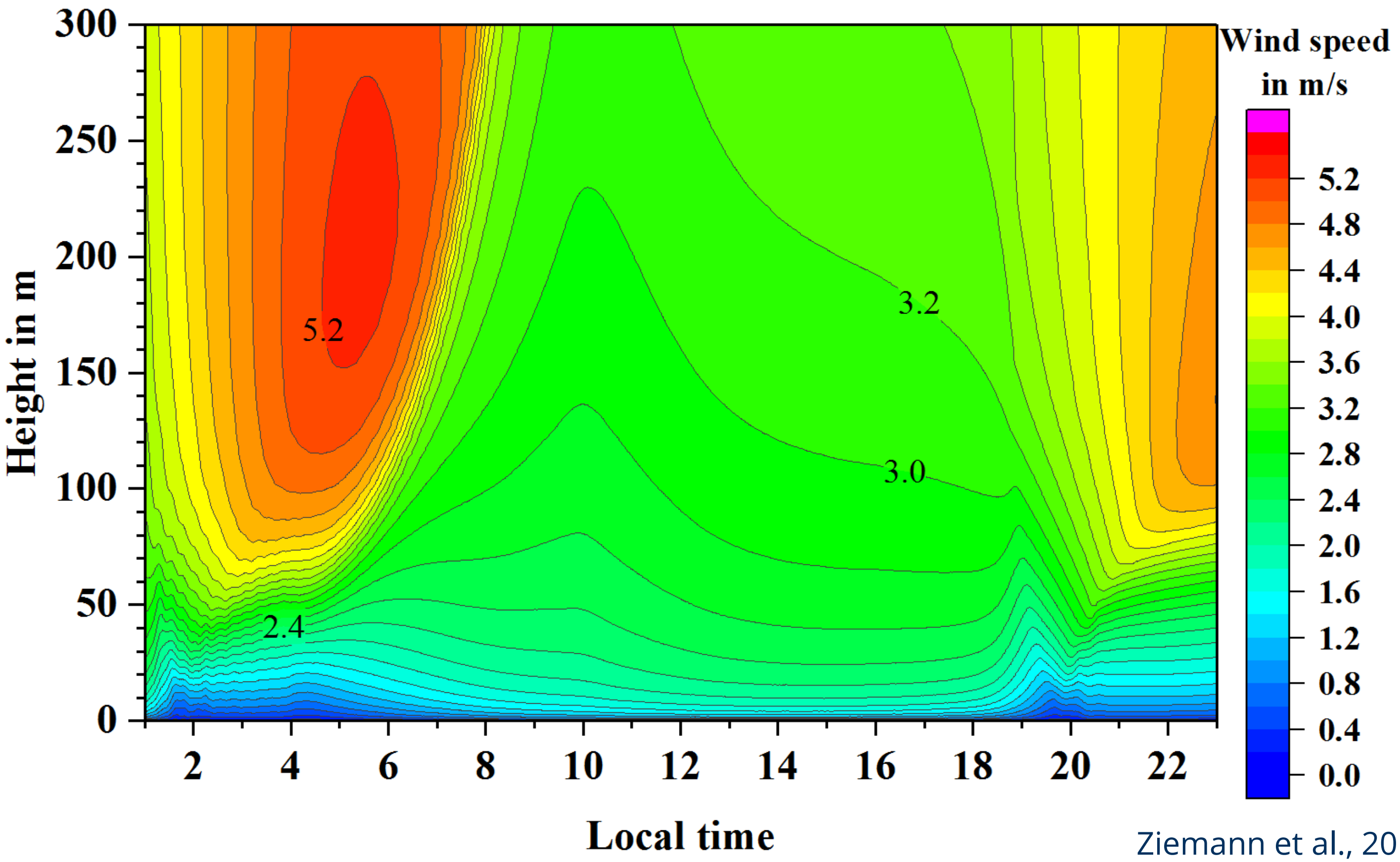
- **Frequent phenomenon**: in 10-20% of all nights in Germany
- **Increasing wind speed** in comparison to the log. wind profile (dashed line)
- Attention: **wind shear** within the swept rotor area

HIRVAC simulation (morning hour) over grassland:
→ **height and max wind speed** are dependent on day of the year



Ziemann, 2015

Model results: development of nocturnal low-level jet



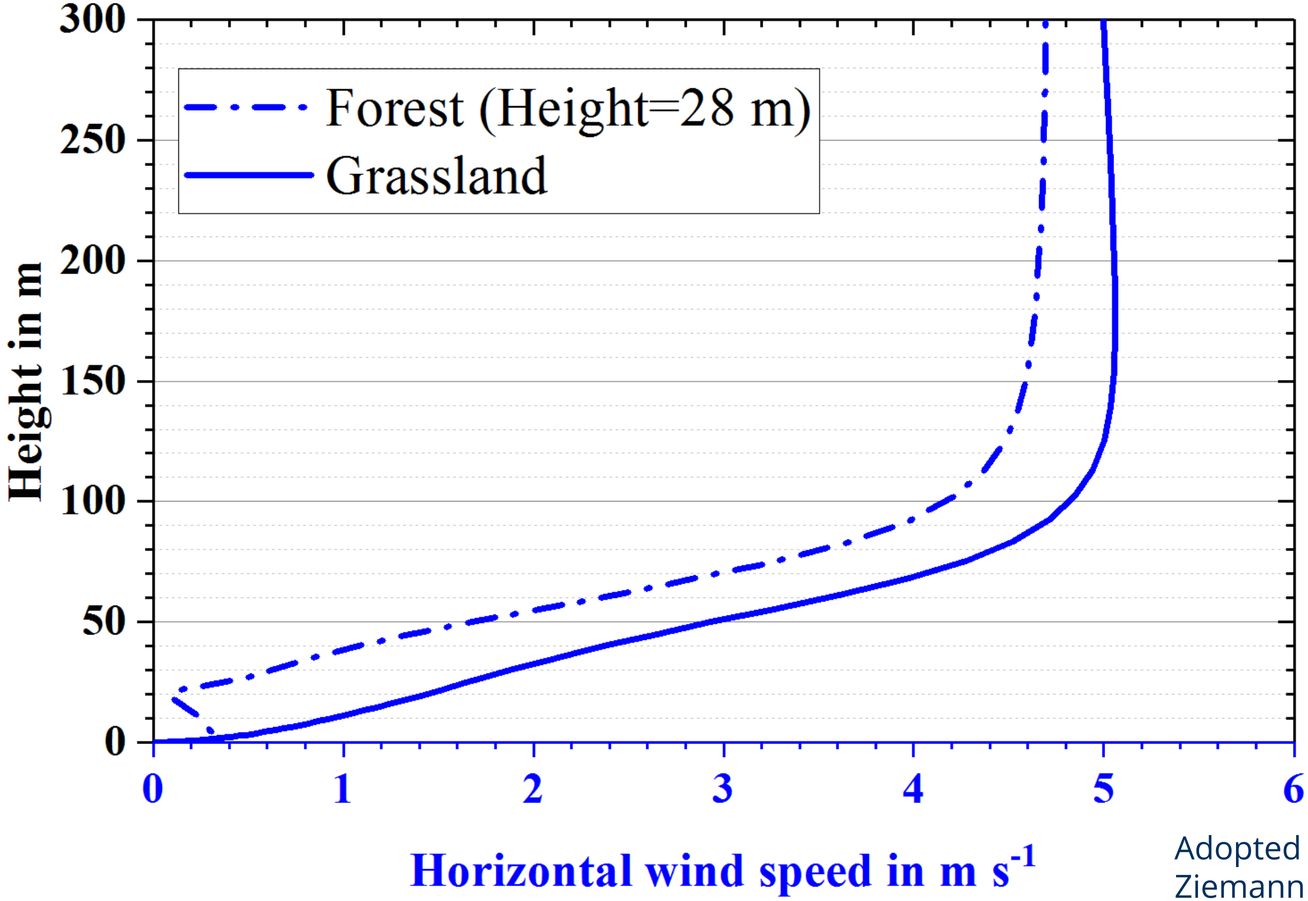
LLJ over grassland on 19th June

vg=4 m/s

Ziemann et al., 2019: https://doi.org/10.5194/asr-16-85-2019

→ **Maximum** wind speed about 1.3 vg
→ 6-7 hours after sunset

Model results: dependence of low-level jet on landuse



Vertical profiles at 4:00 local time on 19th June

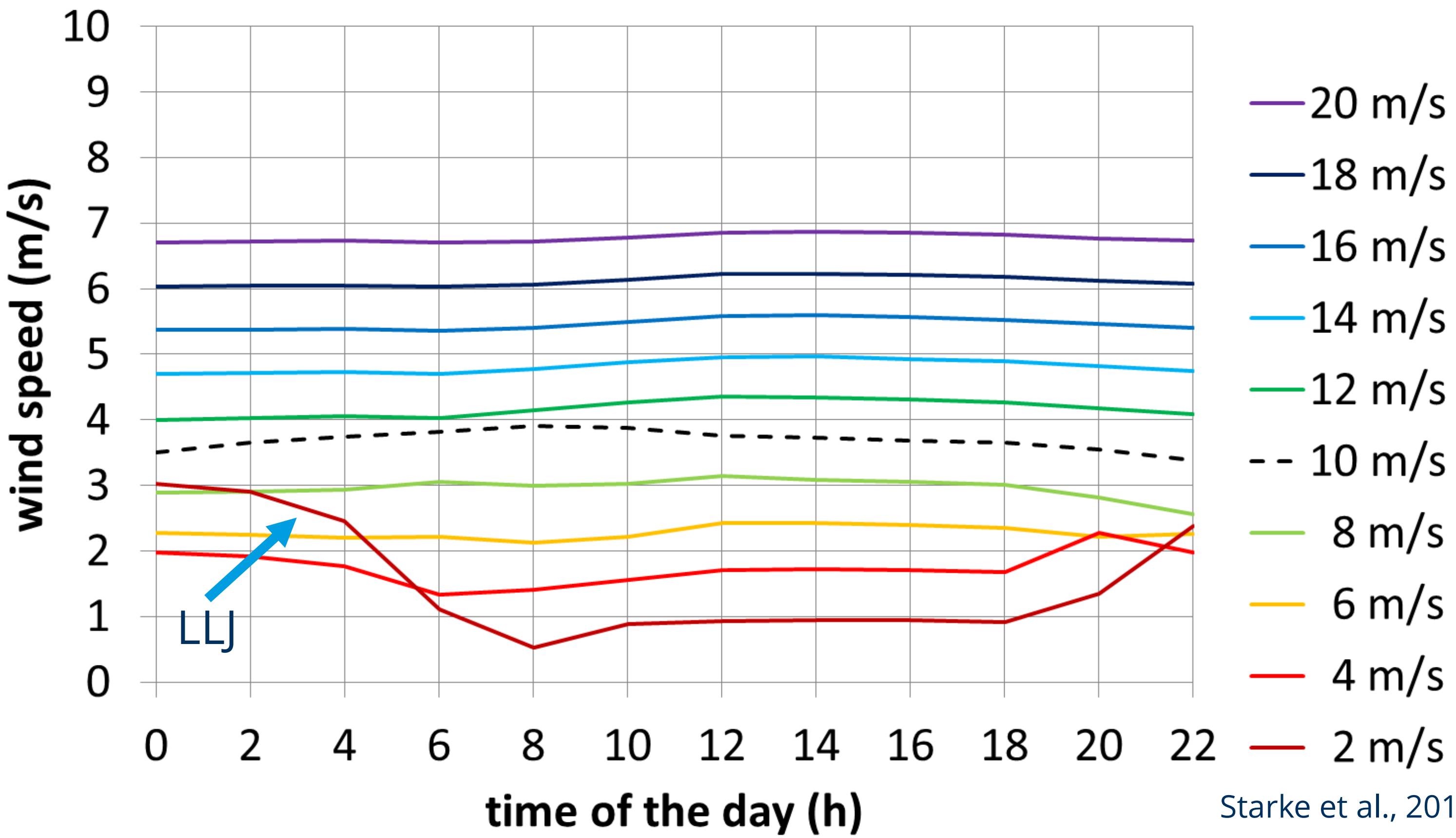
vg=4 m/s

Adopted from
Ziemann et al., 2019:
https://doi.org/10.5194/asr-16-85-2019

→ **LLJ** over **grassland**: **lower height**

→ **More LLJ events** for **grassland**

Model results: dependence of wind speed on daytime

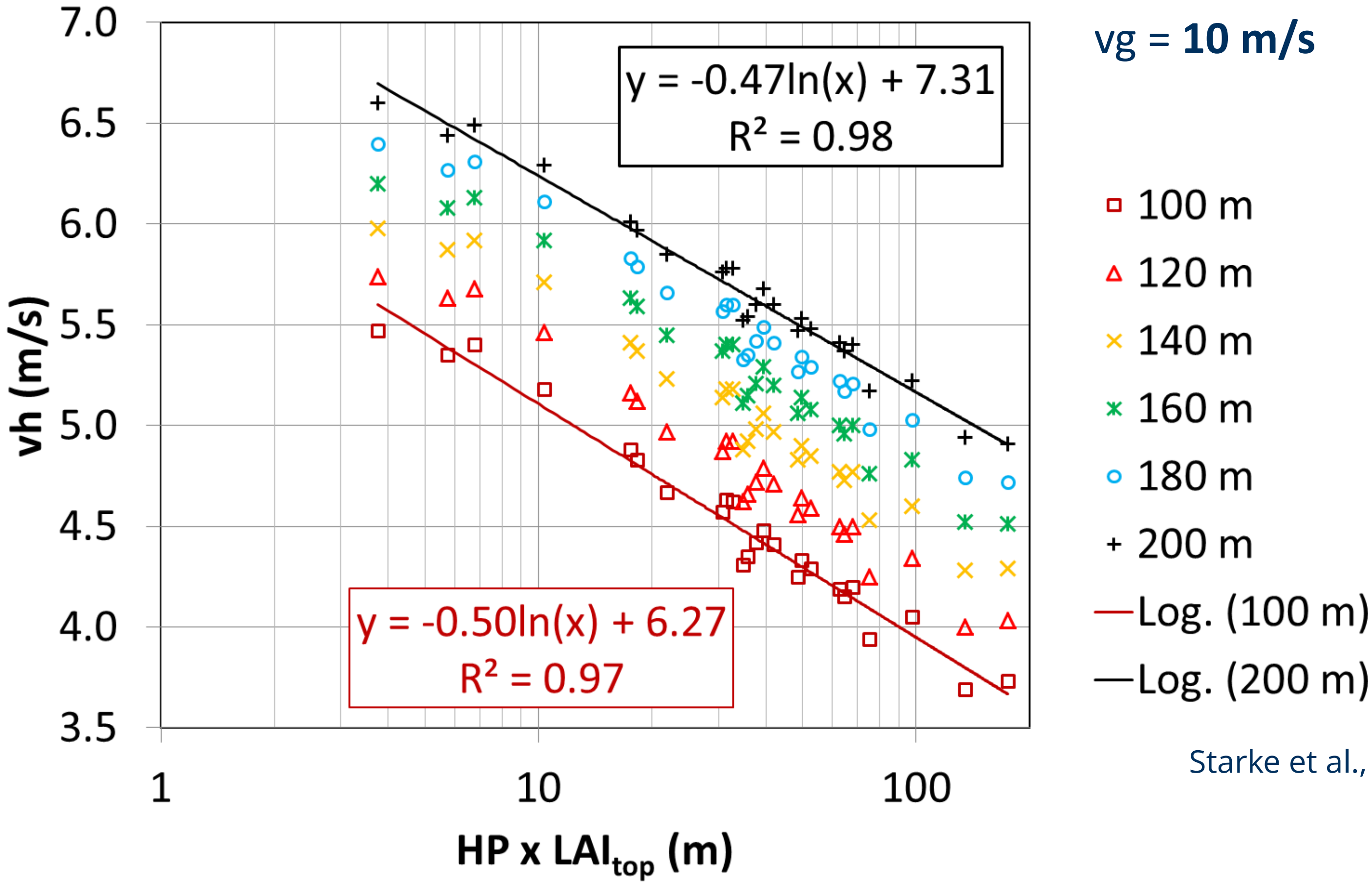


Starke et al., 2017

- Diurnal variations of wind speed at 100 m AGL induced by different wind speeds vg (colors), Vegetation: a 28 m high deciduous forest

→ **More LLJ events** for **smaller** values of **vg**

Model results: dependence of wind speed on vegetation parameters

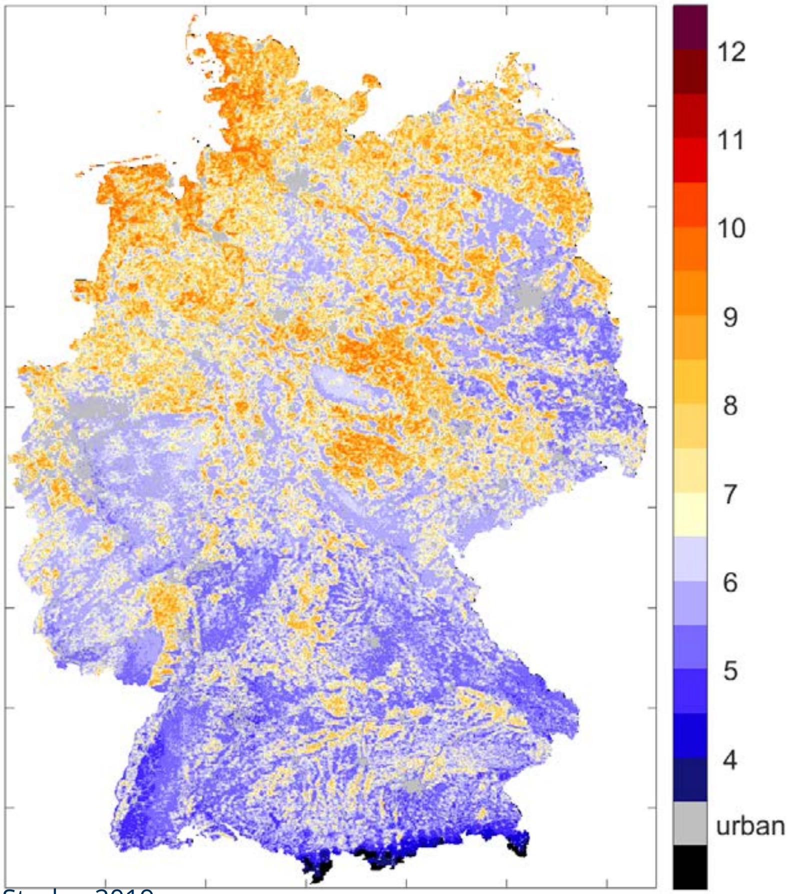


Starke et al., 2017

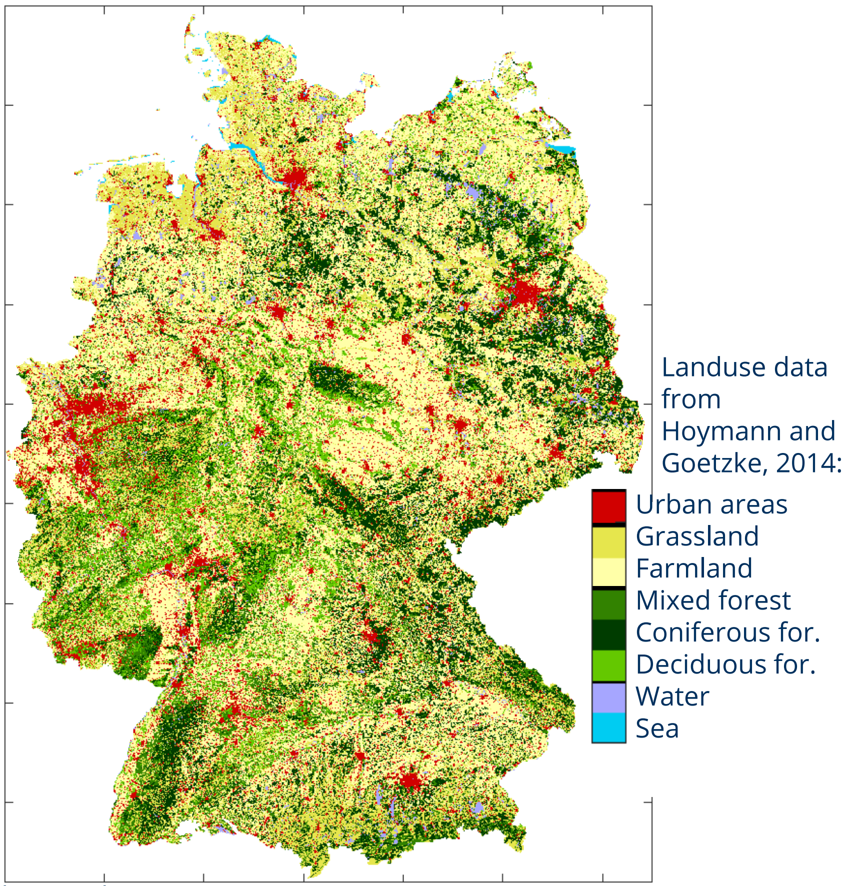
- Daily averaged wind speed vh at different heights AGL (colors) and vegetation properties (height HP and leaf area index crown LAI_{top})

Wind atlas for Germany: exemplary results (only influence of LU, 100 m AGL)

Averaged wind speed (m/s) for winter season present time (left) und landuse (right)



Starke, 2019



https://doi.org/10.1007/s13147-014-0290-y

Open questions

- **Heterogeneous** environmental **conditions** (terrain, landuse, vegetation parameters) → challenges for **wind power assessment**, estimation of **mechanical loads** and **short-term prediction** of wind fields
- **Evaluated models** and parametrizations (→standardized models) are needed to simulate the wind field at hub heights with all important temporally and spatially variable features, especially **low-level jets.**
- **How the properties of low-level jets are modified by a complex terrain with a heterogeneous landuse?**
- Combination of suitable models for special process studies and enhanced parameter/sensitivity studies (wind climatology)
- Model comparison with adequate **measurements** (WindForS)

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Thank you for your attention!