Low-level jets and their possible impact on wind climatology at hub heights of wind turbines

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Introduction and Motivation

- **Increasing hub height** and **rotor diameter** of wind turbines
- Development of new areas for wind energy, e.g. **forest sites**

How can the **wind climatology** be modelled at **heights > 100 m**?

How does **forests modify the wind field** at hub heights?

Which **special features** of the atmospheric airflow have to be considered?

Special feature of wind field at heights >100 m:
Nocturnal low-level jet (LLJ)

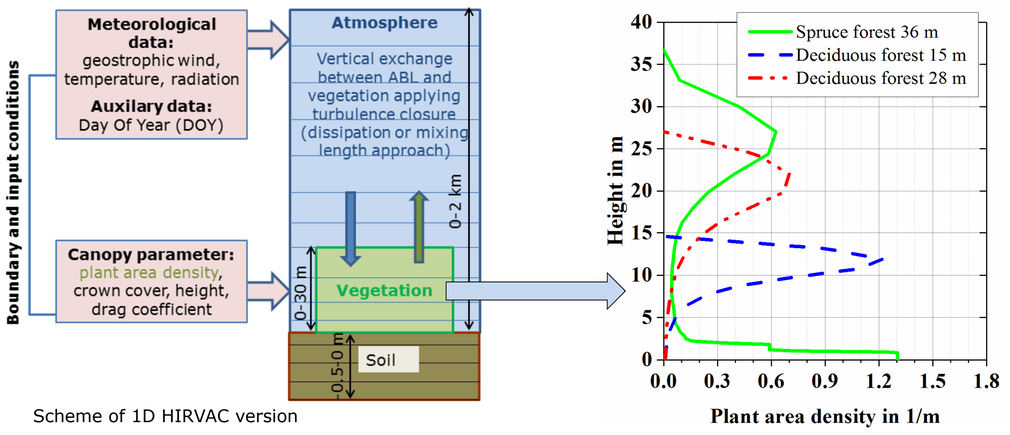
Properties of LLJ:
Frequency of occurence
Maximal height and intensity

Dependency of LLJ on:
Type of landuse
Geostrophic wind speed

Models and Data

Micro-scale model of atmospheric boundary layer HIRVAC2D

- Diurnal variation of flow field depending on vegetation properties



Scheme of 1D HIRVAC version

Meso-scale model in climate mode COSMO CLM (CCLM)

- Seasonal variation of flow field for different scenarios (climate and landuse)

QuWind 100

New wind climatology:
→highly resoluted
→for Germany
→for heights 100 m – 200 m

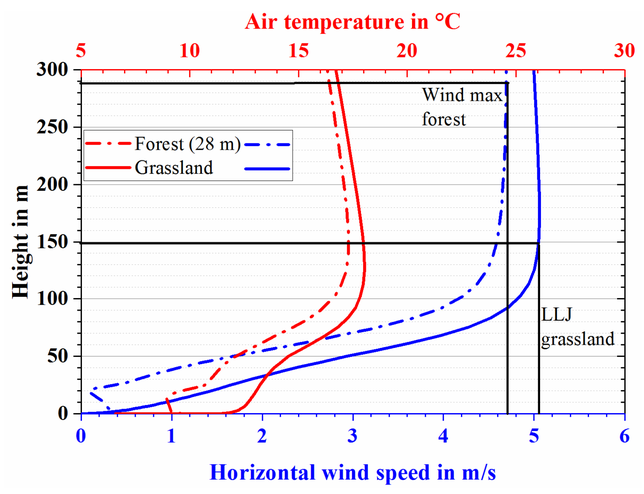
Climate forcing		
Reference	**Present**	**Future**
1981-2010	1981-2010	2021-2050
Reanalysis	Climate projections	
ERAinterim	RCP8.5 from EURO-CORDEX	
Landuse forcing		
Present (2010)	**Future (2030)**	
BBSR (Bundesinstitut für Bau-, Stadt- und Raumforschung), Project CC-LandStraD (Hoymann and Goetzke, 2014)		

Results

Micro-scale model HIRVAC2D

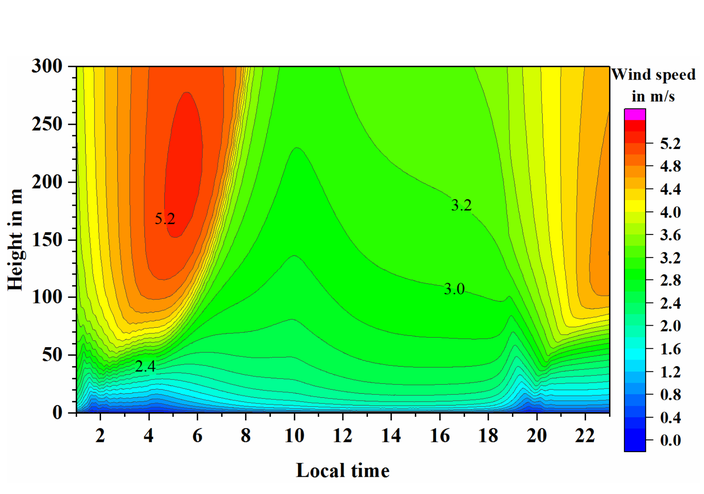
Vertical profiles at 4:00 local time on 19th June:

→ **LLJ** over **grassland**: **lower height**
→ Decreasing **wind speed differences** with height between **grassland and forest**



Development of LLJ over grassland on 19th June:

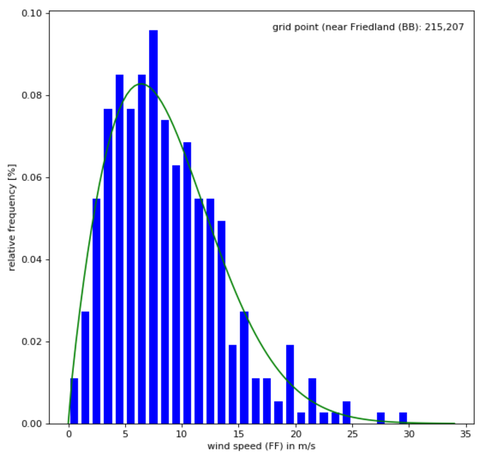
→ 60% **higher wind speed** at nighttime jet axis in comparison to logarithmic wind profile
→ 4x **higher wind power**

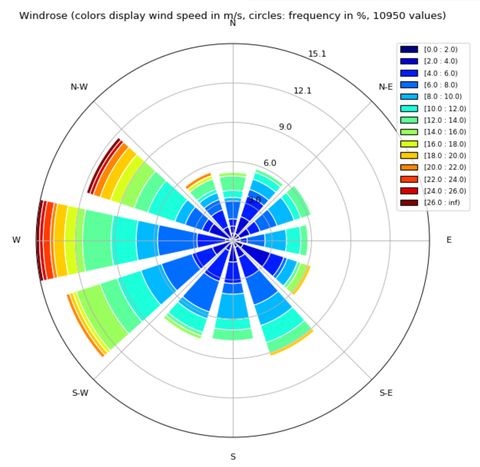


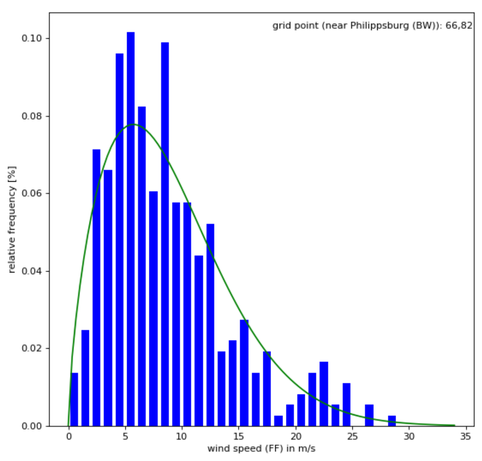
Meso-scale model CCLM

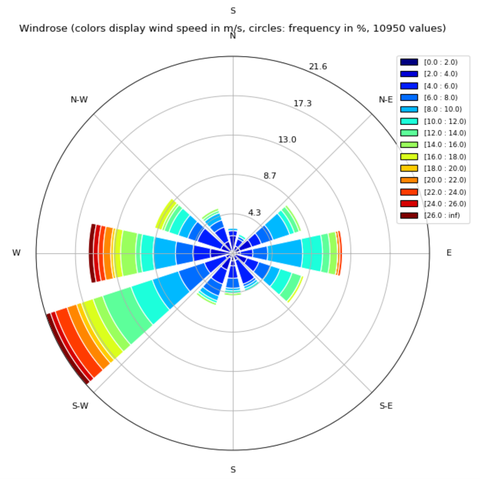
Wind climatology (geostrophic wind speed, 850 hPa, 0:00 UTC) over 30 years (1981-2010) - CCLM-output at two exemplary grid points:

→ Influence of **location properties** on frequency distribution and wind rose:
- topography
- regional and local circulation pattern
- frequency of weather conditions



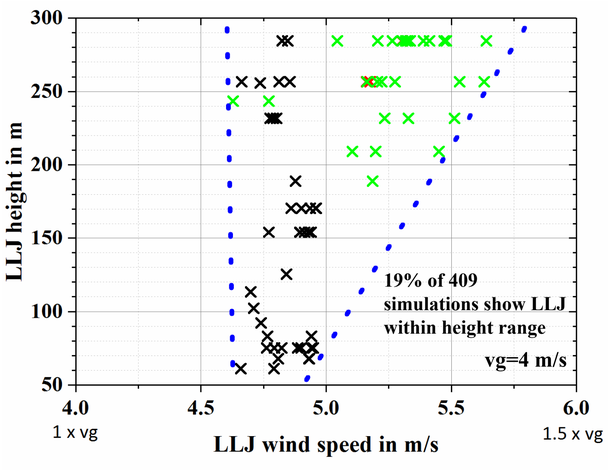


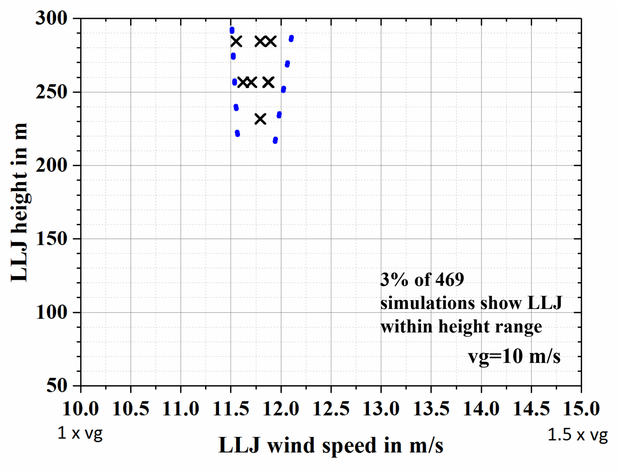




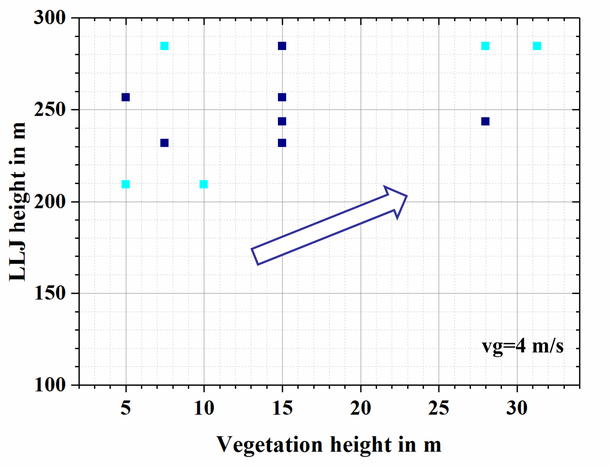
Maximal height and wind speed of nocturnal LLJ event ($vh_{max} - vh_{min} >= 0.5$ m/s, $vh_{max}/vh_{min} >= 1.05$) dependent on

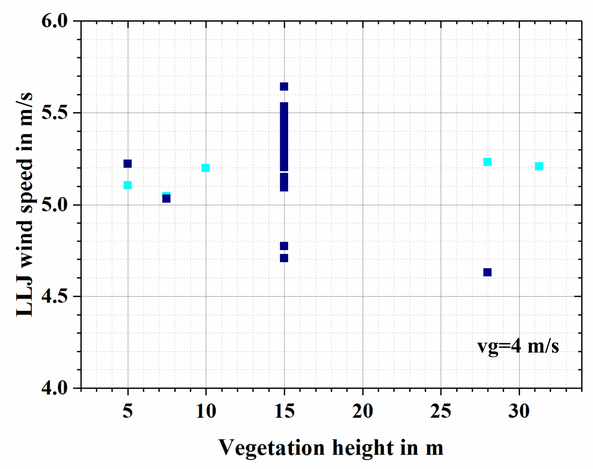
→ type of vegetation: grassland (black), deciduous (green) and coniferious (red) forest
→ geostrophic wind speed vg





→ vegetation height and crown cover (50% light blue, 90% dark blue, here for deciduous forest)





Influences on LLJ properties

- Geostrophic wind speed: vg ↑ → LLJ height ↑
- Landuse/vegetation parameters:
  - grassland in comparison to forest: number of LLJ ↑
  - forest in comparison to grassland: LLJ height ↑ (wind speed ↑)
  - forest height ↑ → LLJ height ↑

Impact of LLJ on wind power in Germany

- Frequent (25-35%) wind speed range: 4 m/s ≤ vg ≤ 8 m/s → ideal conditions for developing of LLJ events during clear nighttime → significant influence on wind power at heights between 100 m and 200 m

Further information and contact

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