Coastal effects on the Baltic Sea wind profile

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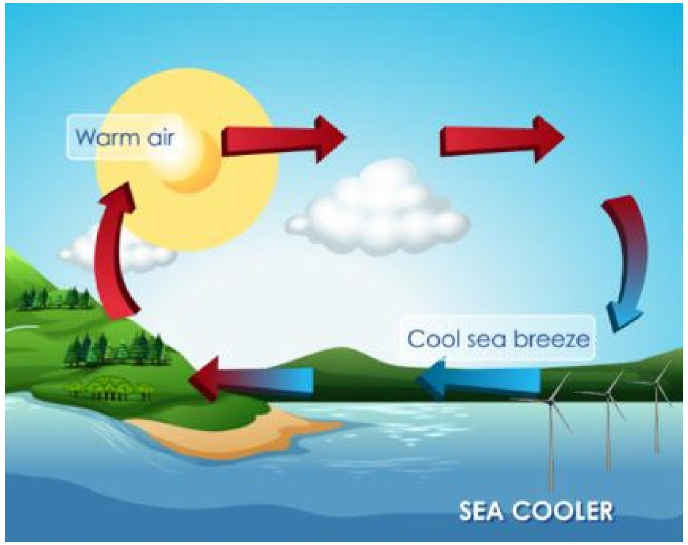
Outline of the presentation

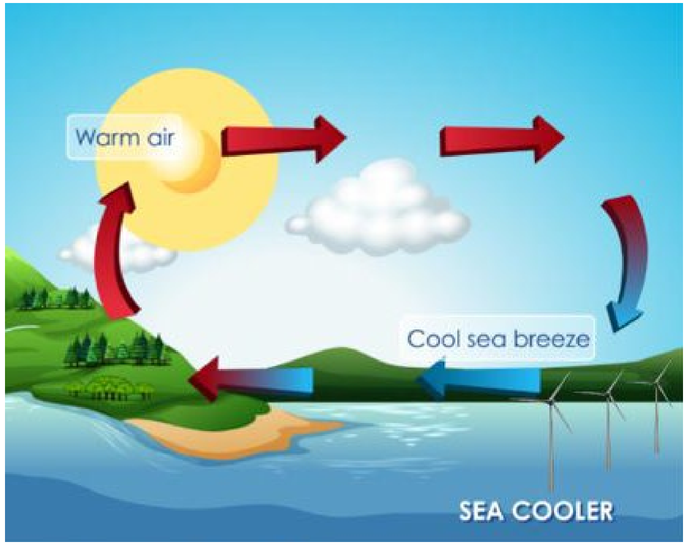
- Processes in the coastal zone affecting the wind profile
- What is the low-level jet?
  - Formation
  - How common are they over the Baltic Sea?
  - Implications for wind power
- How good are reanalyses in describing the Baltic Sea wind conditions?
- Negative profiles and profiles with a local minimum
- Alterations of turbulence under non-idealized wind profiles
- Summary and conclusions

Processes in the coastal zone affecting the wind profile



Sea breeze

Processes in the coastal zone affecting the wind profile



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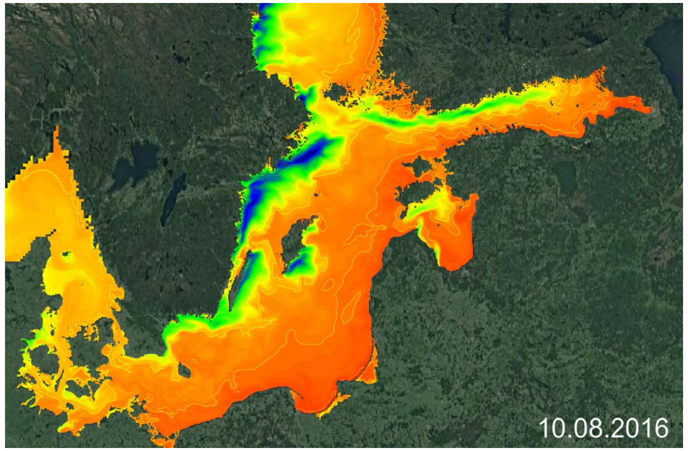

Sea surface temperature (upwelling)

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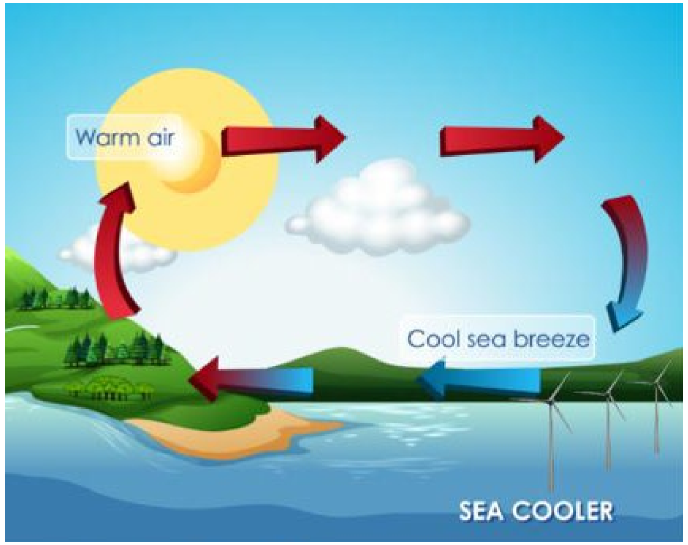

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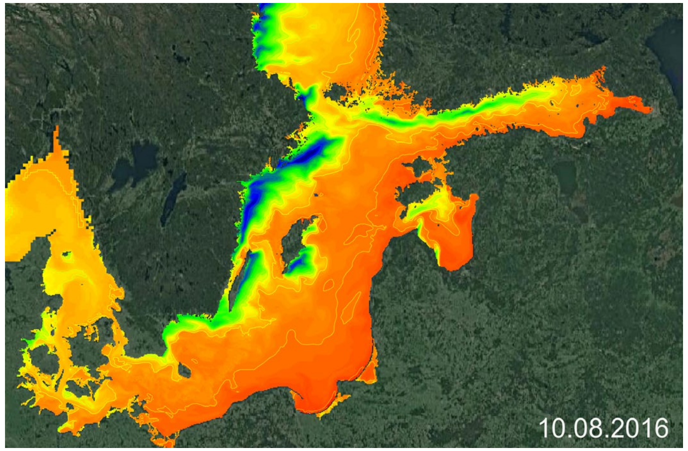

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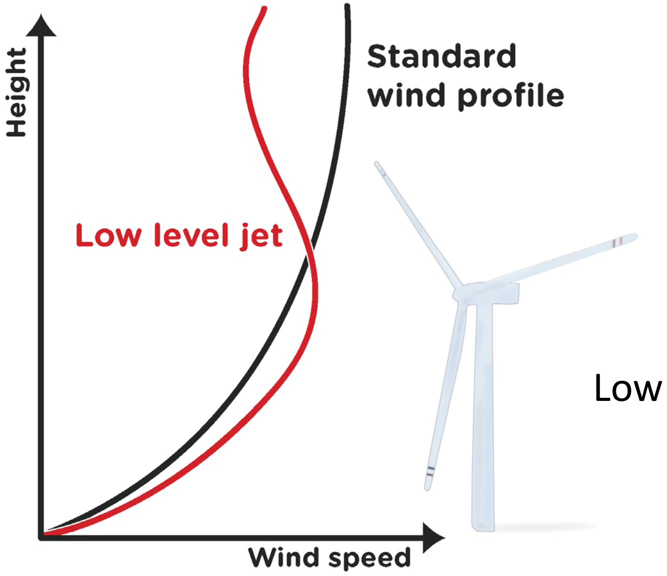

Low level jet

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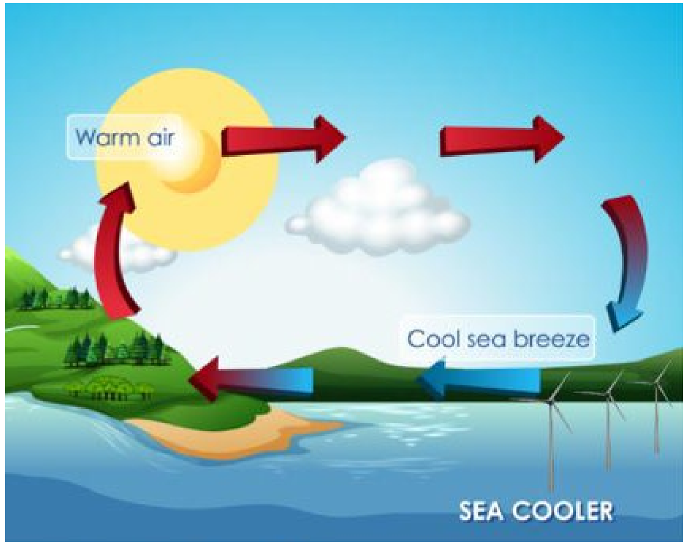
Processes in the coastal zone affecting the wind profile



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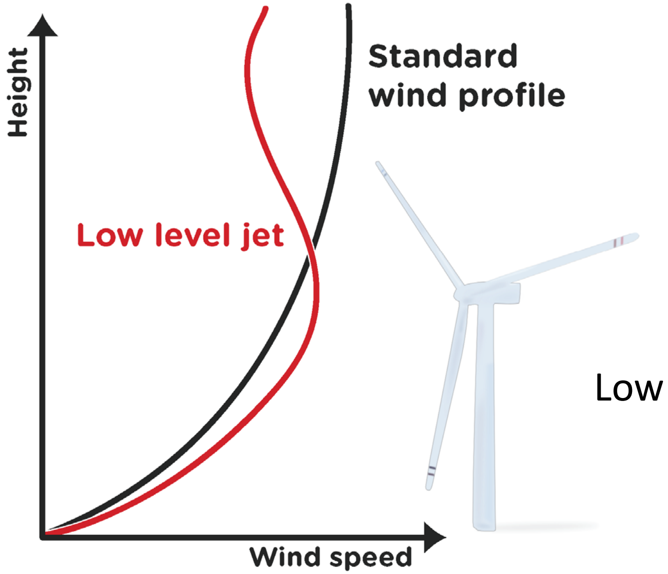
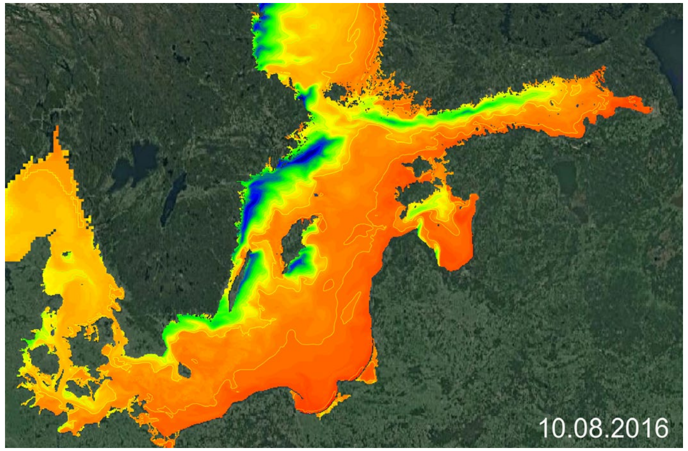


Low level jet



Sea surface temperature (upwelling)

Waves

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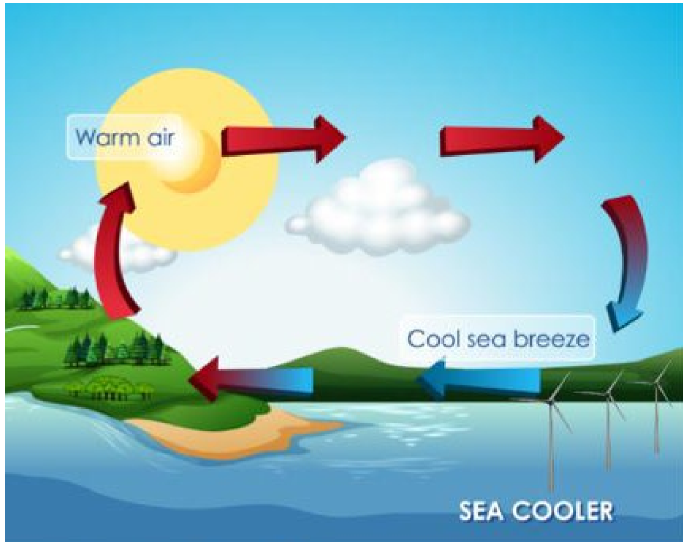

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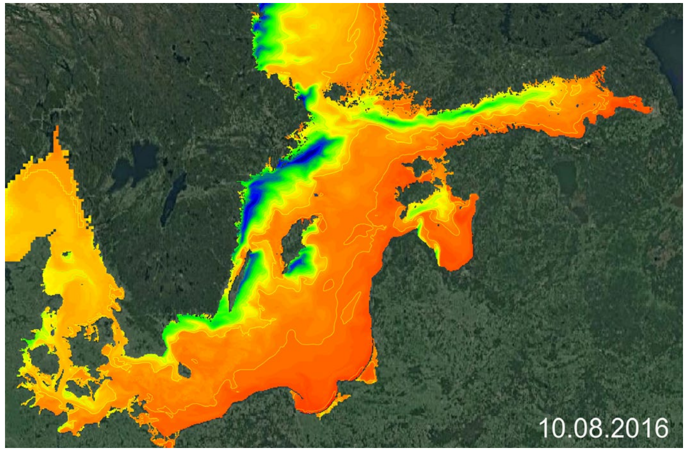

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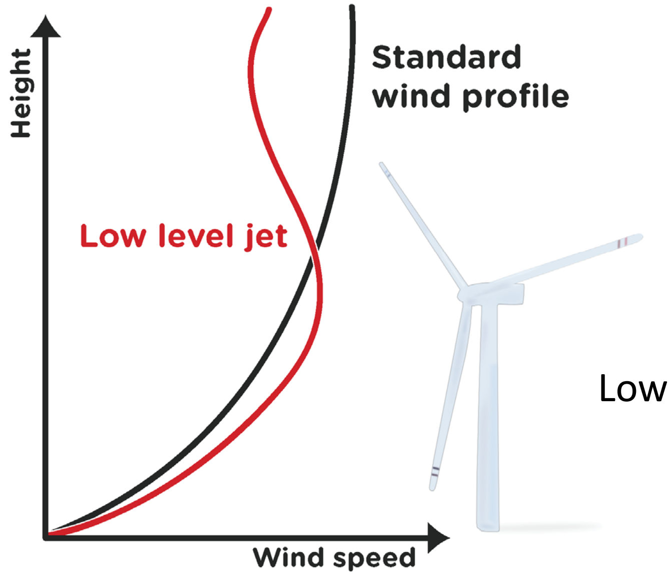

Low level jet

Waves

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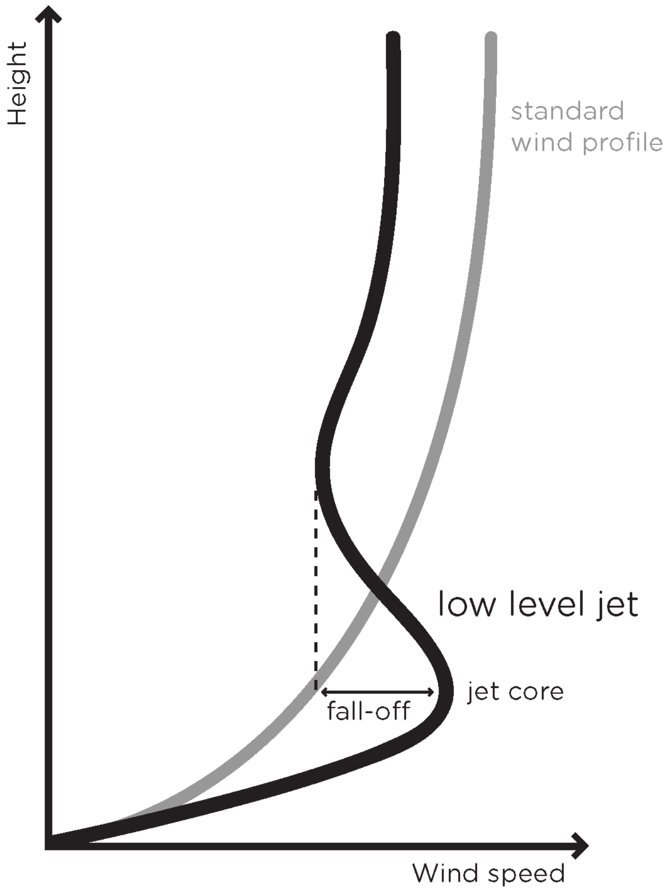
LLJ = low-level jet

What is the LLJ?

- A local maximum in the wind profile
- LLJ definition: fall-off above the core
  - Absolute criterion, relative criterion or a mix
- Typical core height: 50 – 150 m
- Typical core speed: 5 – 10 m/s
- Can be 200 – 300 km wide



LLJ effects on wind power

- Power production
- Loads on the turbines
- Wake recovery rates

Formation of the LLJ

- Over land surfaces (evening):
  - land surface cools → stable stratification → suppression of turbulent transport of momentum → pressure gradient force is unbalanced → speed-up of the wind → an LLJ core is created just above the decoupled lower part of the surface layer

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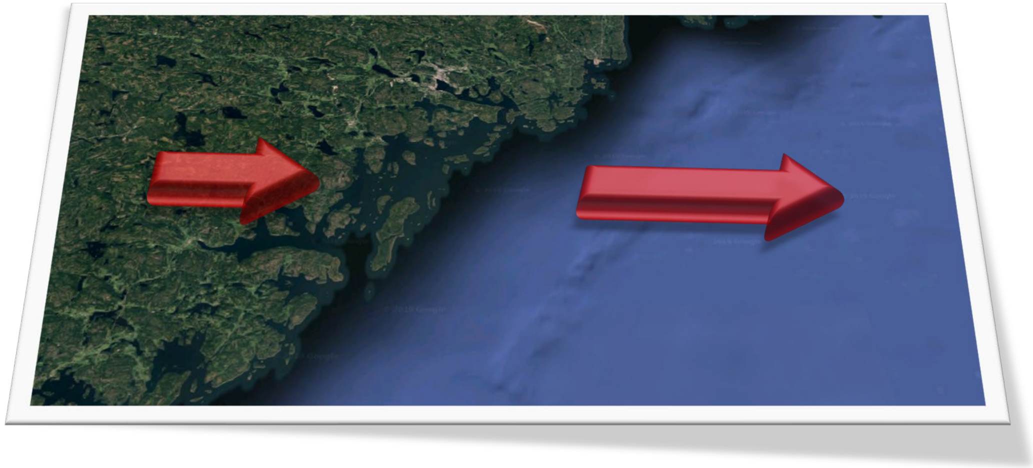
- Over water surfaces (late spring/early summer):
  - advection of warm air over a cold surface → stable stratification → ...
- The LLJ can also form as a consequence of
  - the sea-breeze circulation
  - katabatic winds in complex terrain
  - cold fronts



How common are LLJs over the Baltic Sea?

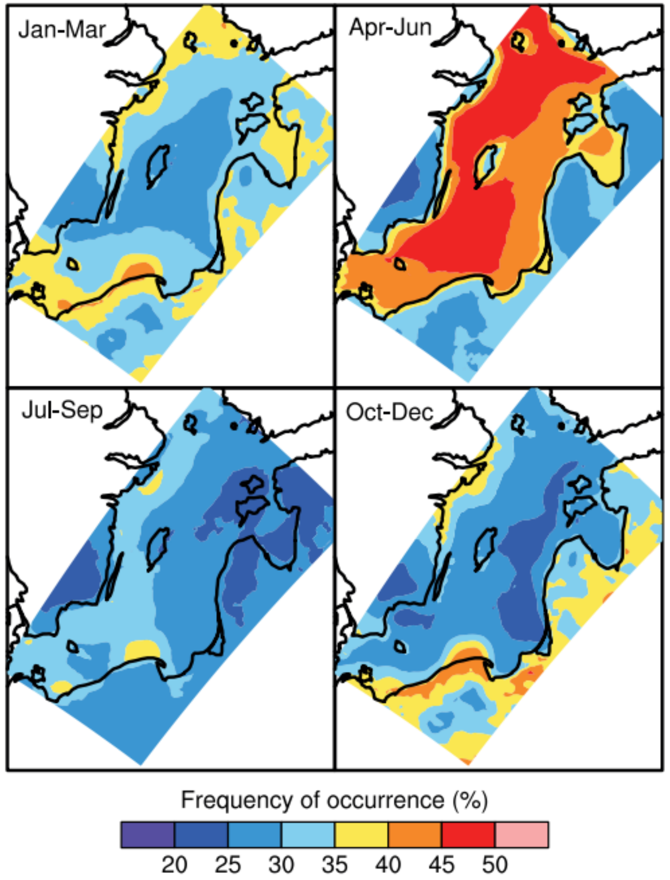


Fig. 10. Frequency of occurrence of LLJs over the southern Baltic Sea from simulations covering the years 2000–2013.

- As expected from theory: LLJs are most common in late spring/early summer

Svensson, N., Bergström, H., Sahlée, E., & Rutgersson, A. (2016). Stable atmospheric conditions over the Baltic Sea: model evaluation and climatology, Boreal Environment Research 21: 387–404

How common are LLJs over the Baltic Sea?

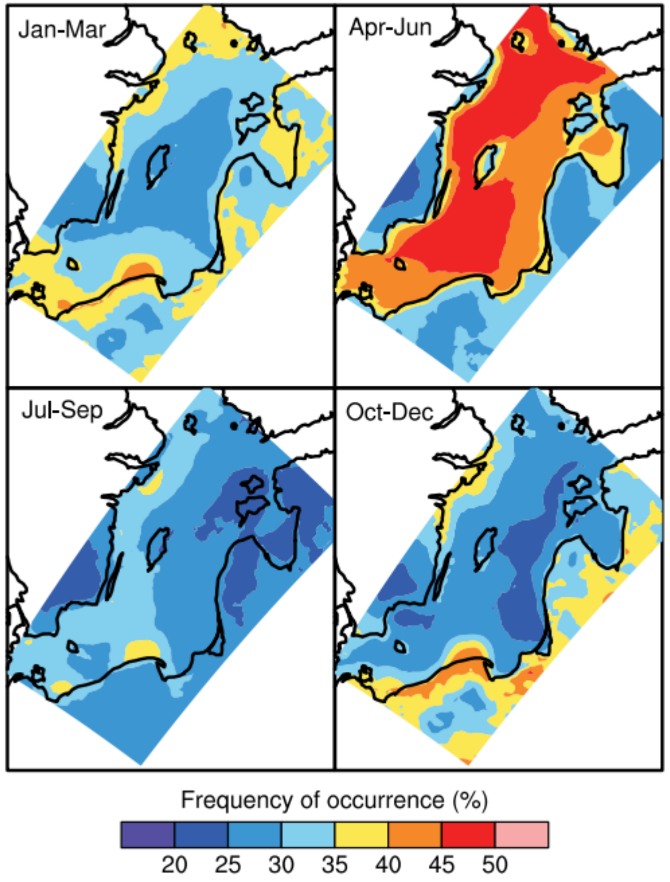
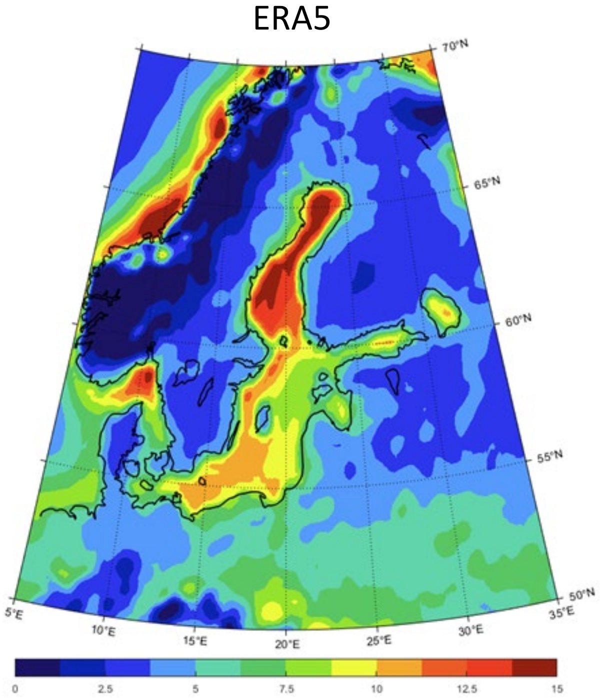
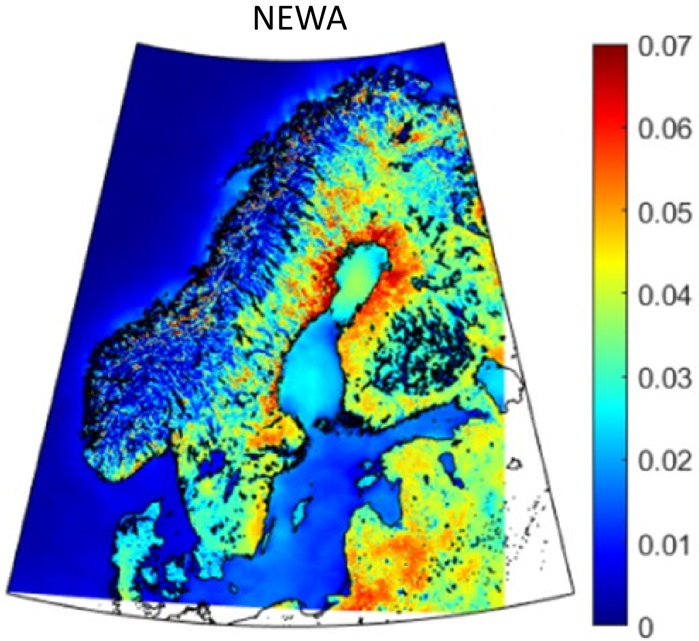


Fig. 10. Frequency of occurrence of LLJs over the southern Baltic Sea from simulations covering the years 2000–2013.

- As expected from theory: LLJs are most common in late spring/early summer
- But can we trust the models?





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How good are reanalyses in capturing the wind profile over the Baltic Sea?

- A reanalysis is an optimized gridded description of the atmosphere at a given time
- In Hallgren et al. (2020) we compared state-of-the-art reanalyses with offshore lidar observations in the Baltic Sea

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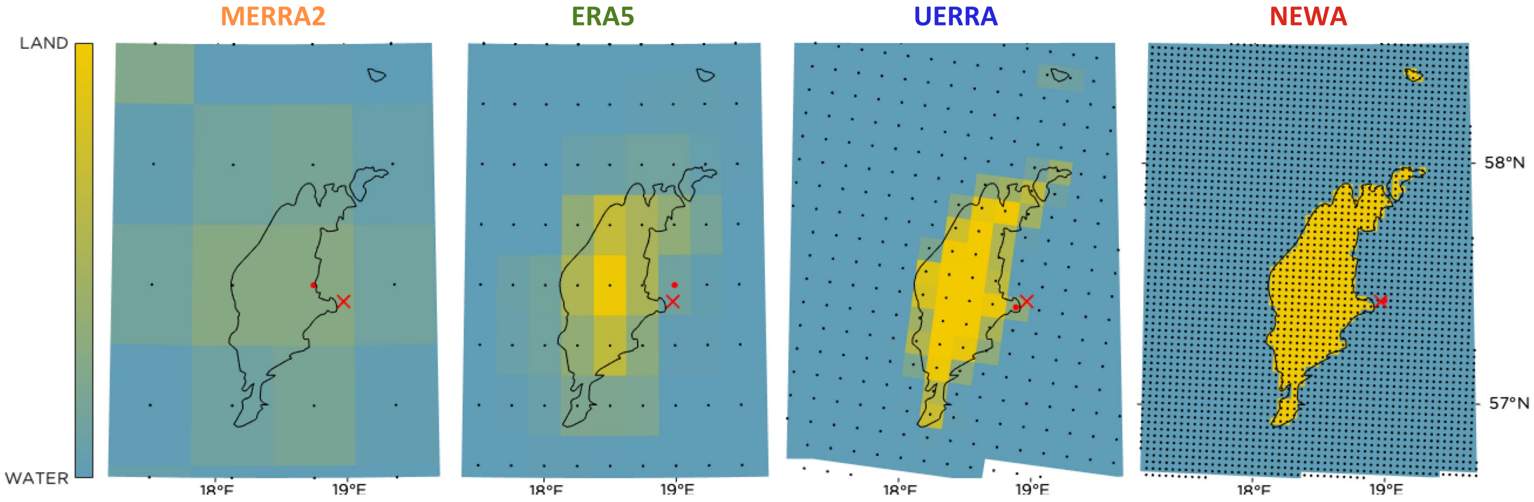
Four reanalyses tested:

- MERRA2: global, 3 h, 40 km x 55 km
- ERA5: global, 1 h, 17 km x 31 km
- UERRA: Europe, 1 h, 11 km x 11 km
- NEWA: Europe, 30 min, 3 km x 3 km



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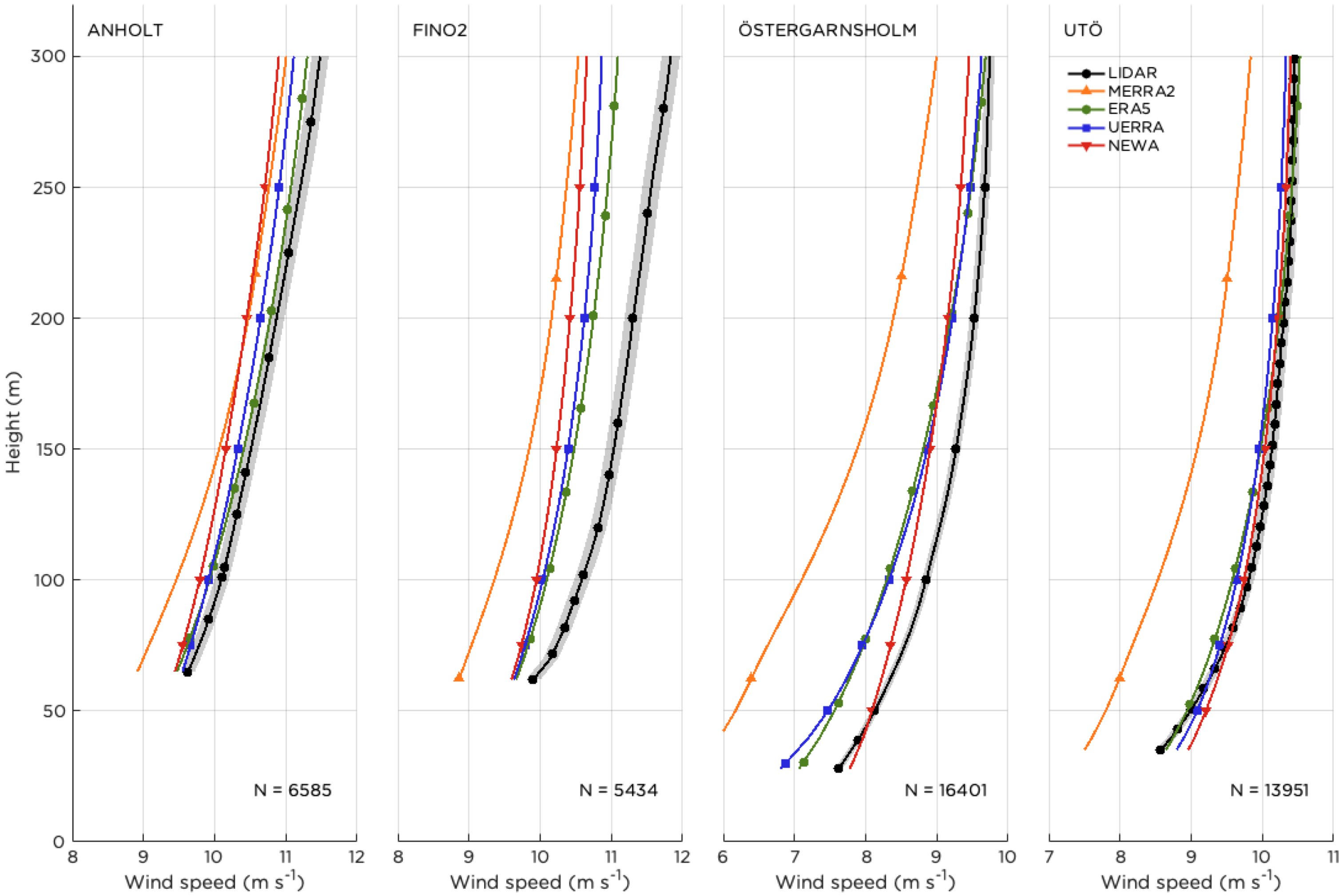

Main conclusions:

- The reanalyses underestimate the average wind speed
- MERRA2 suffers from insufficient vertical resolution
- The average wind shear is too low in NEWA, but too high in ERA5 and UERRA
- UERRA is the reanalysis that best captures the LLJs (both seasonality and core features)

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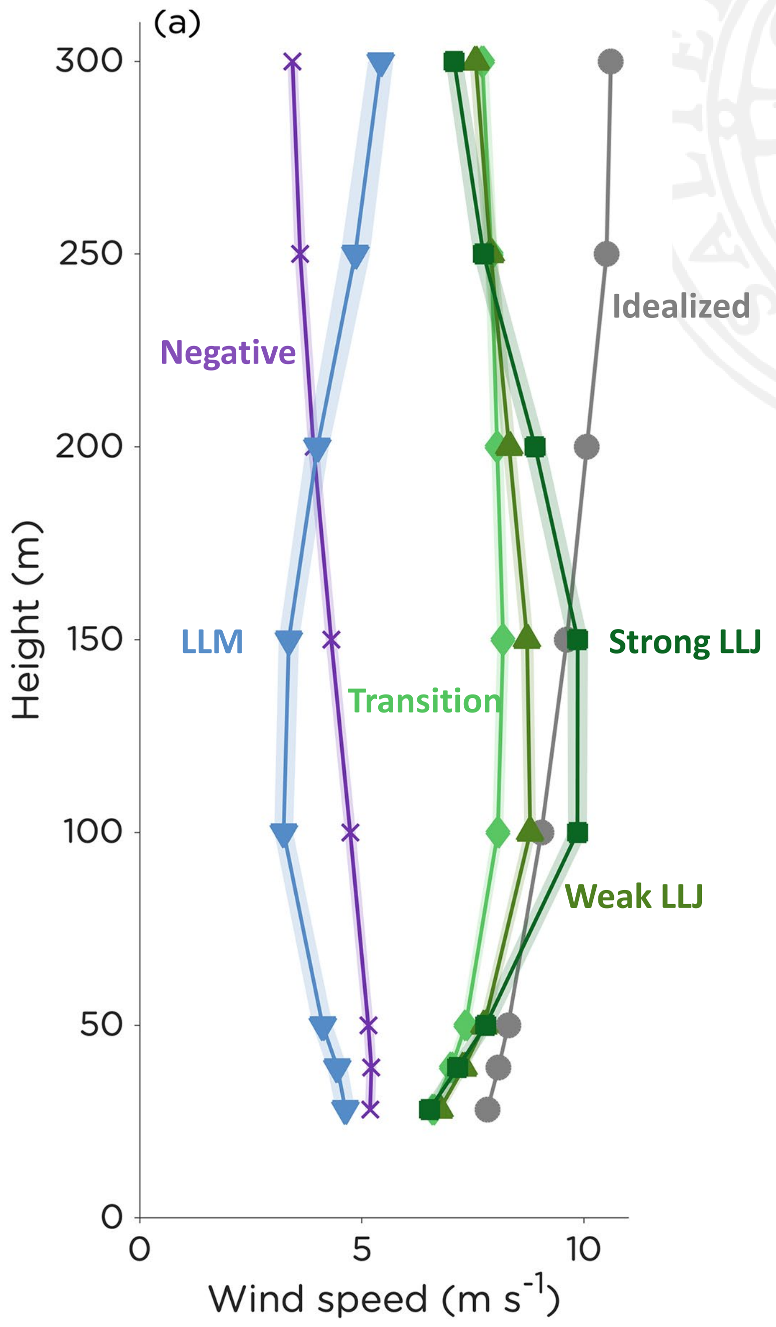
Other types of wind profiles

- LLJs are not the only non-idealized wind profiles that occur
- In Hallgren et al. (2022) we also studied the appearance of negative profiles and low level minima (LLM)

Lidar data from Östergarnsholm



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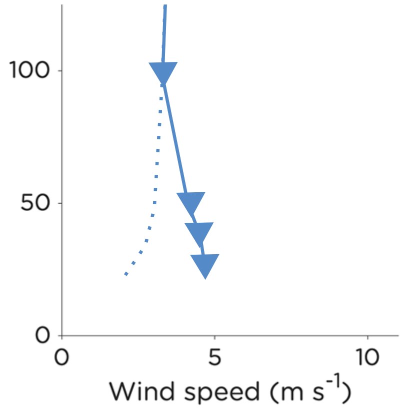
- Swell conditions favorable for the formation of negative profiles and LLMs
  - Waves feed energy into the surface layer → wind speed increases from below



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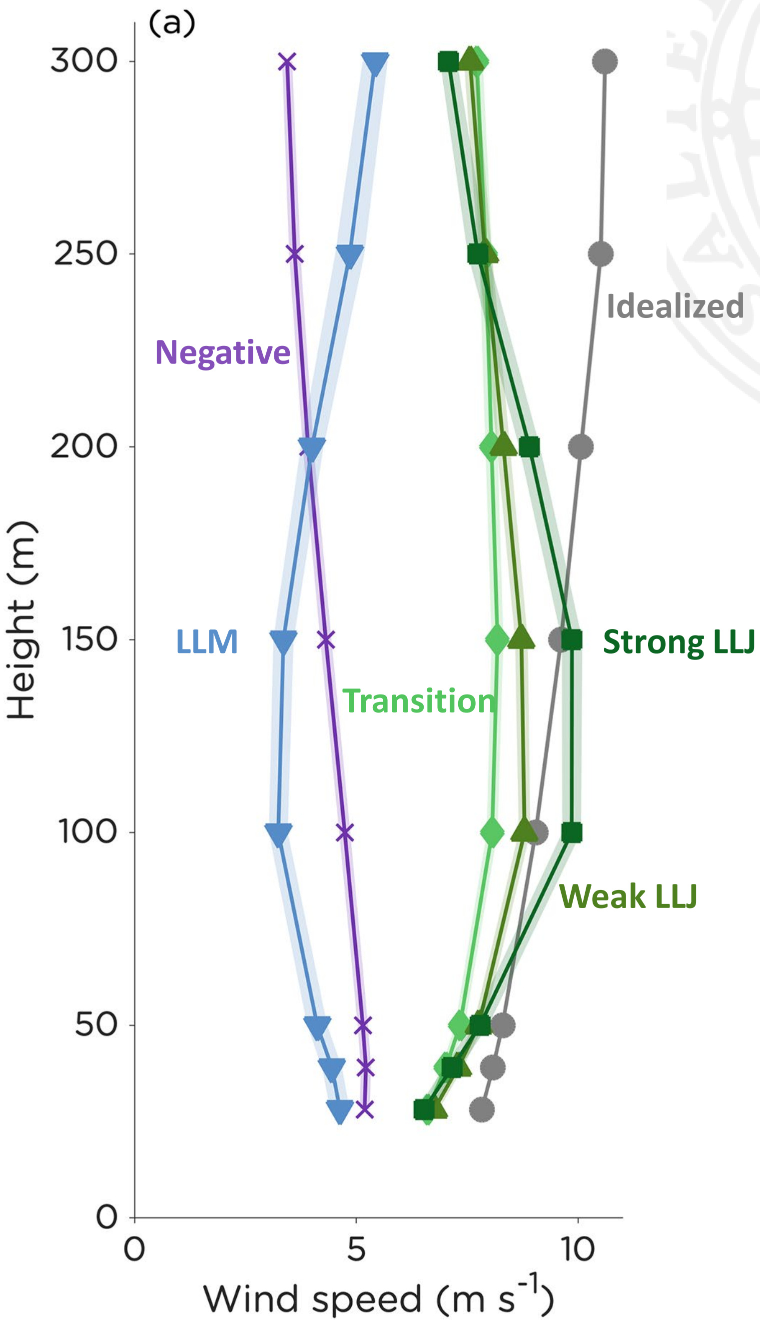

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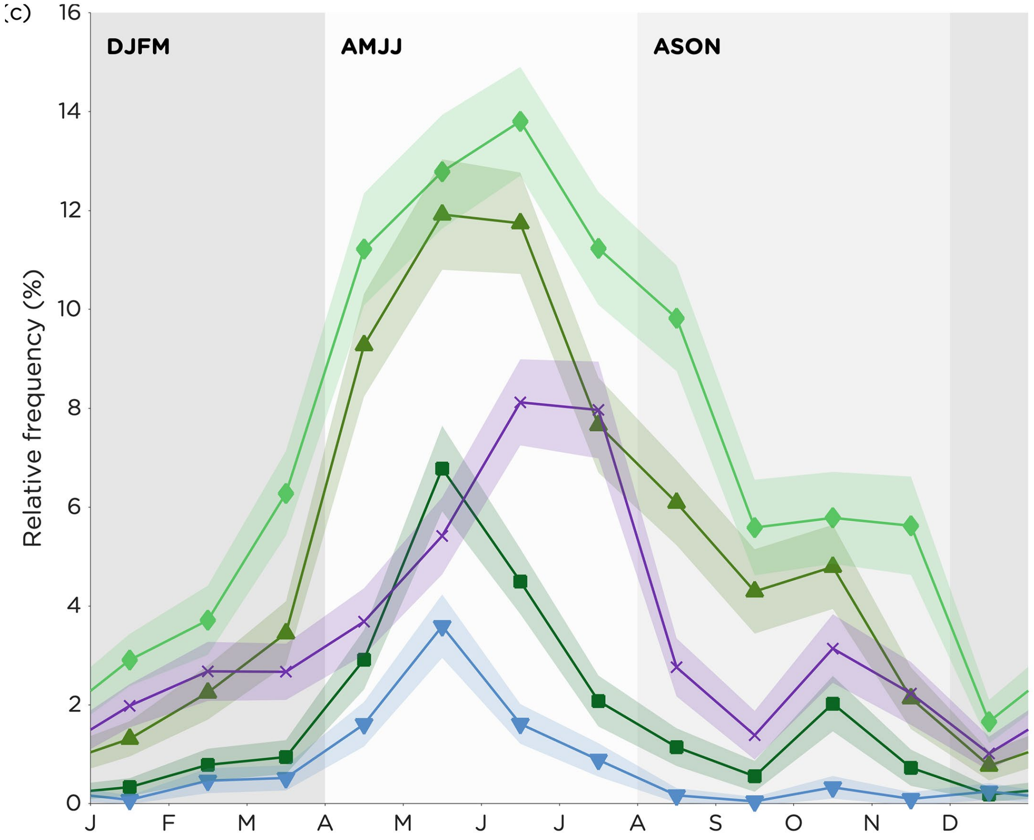
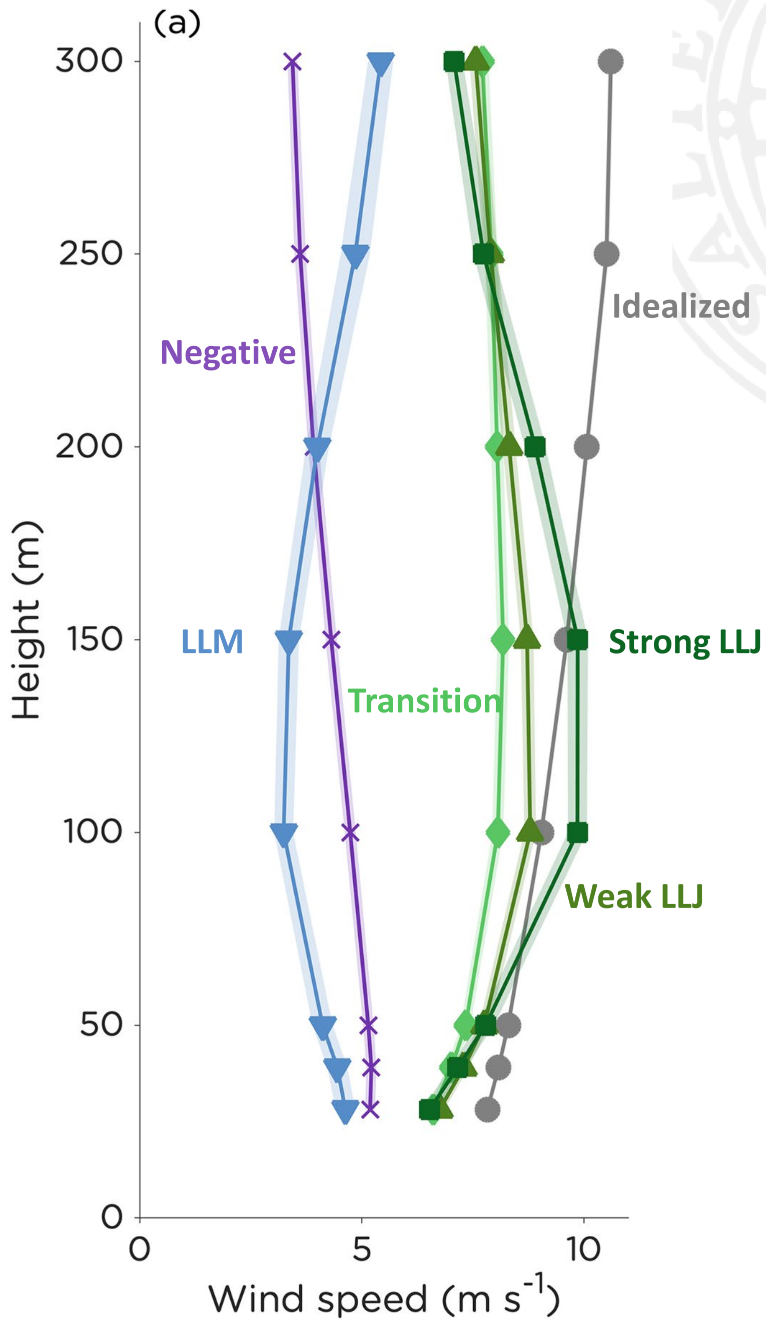
Other types of wind profiles

- All non-idealized wind profiles: peak in spring/summer (combining to 40% of the time in May)





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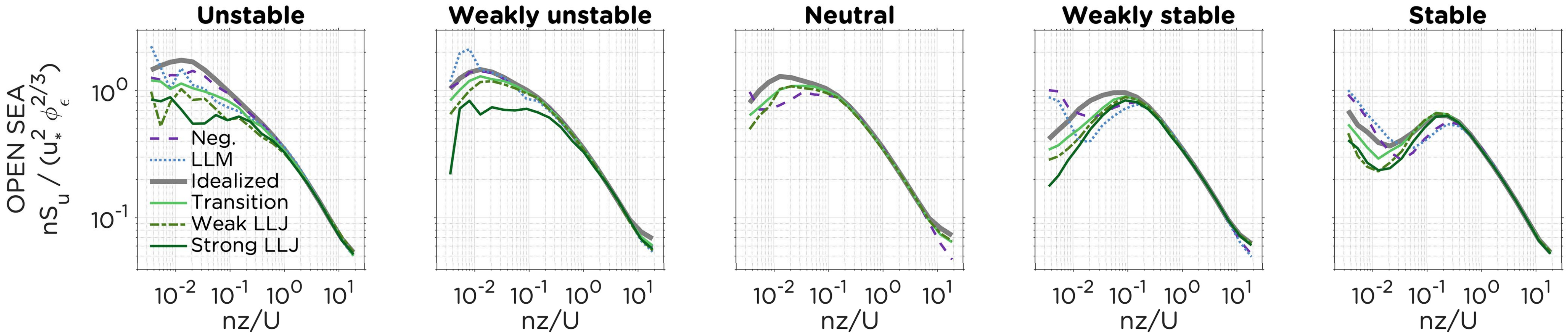
Are non-idealized wind profiles affecting the turbulence?

- Comparing turbulence measurements (10 m met mast) during non-idealized and idealized lidar wind profiles



Median of normalized turbulent *u* power spectra plotted against normalized frequency

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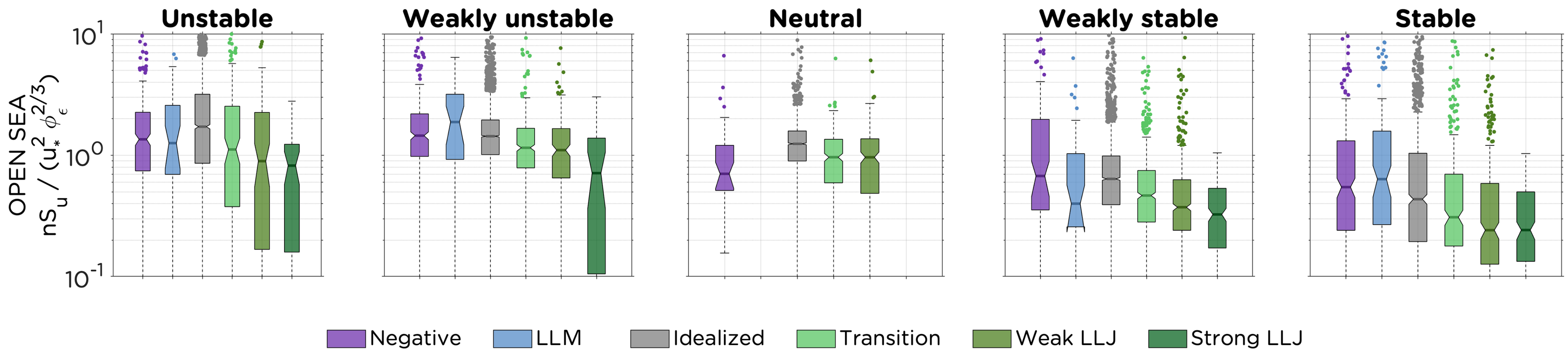
Are non-idealized wind profiles affecting the turbulence?

- To study the possible suppression of large swirls, we select the low frequency nz/U = 0.01 and analyze the distributions



- We conclude that: “There were **indications** that the **strong shear zone** of low-level jets **could cause a relative suppression of the variance for large turbulent eddies** […], in the layer below the jet core”

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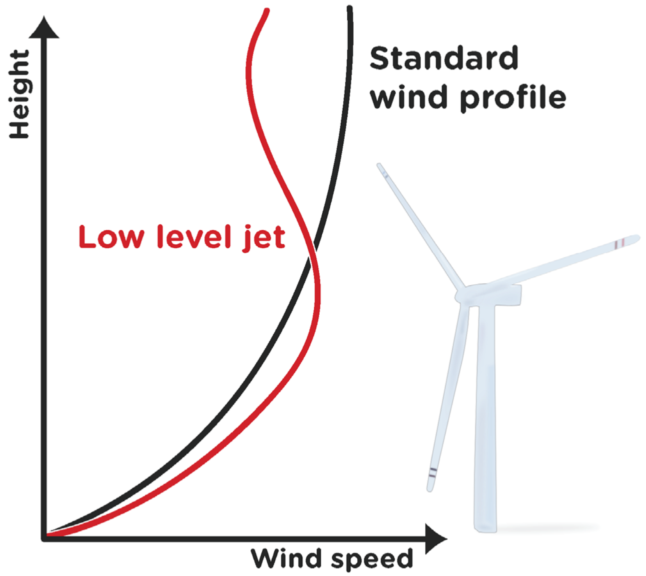
Summary and conclusions

- The wind over the Baltic Sea is highly affected by processes in the coastal zone
- State-of-the-art reanalyses underestimate the average wind speed
- Non-idealized wind profiles (LLJs, LLMs and negative profiles) are frequently occurring over the Baltic Sea
- There is a peak in occurrence of these profiles in spring/summer
- There are indications that LLJs can cause a relative suppression of the variance for large turbulent eddies



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Thank you for your attention!

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