"Seasonal wind analysis in Limassol, Cyprus, using the ground-based Doppler LiDAR of the CARO National Facility"

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AIM

- Delve into and utilize the data of the only operating Doppler LiDAR instrument in Cyprus
- Analyze the wind patterns that affect the coastal city of Limassol
    - Monthly and seasonal analysis of the average horizontal wind speed and direction
    - Estimate the impact of the island's geomorphology and the Mediterranean sea on the observable wind patterns in Limassol
- Investigate the formation and characteristics of the Mixing Layer for every season

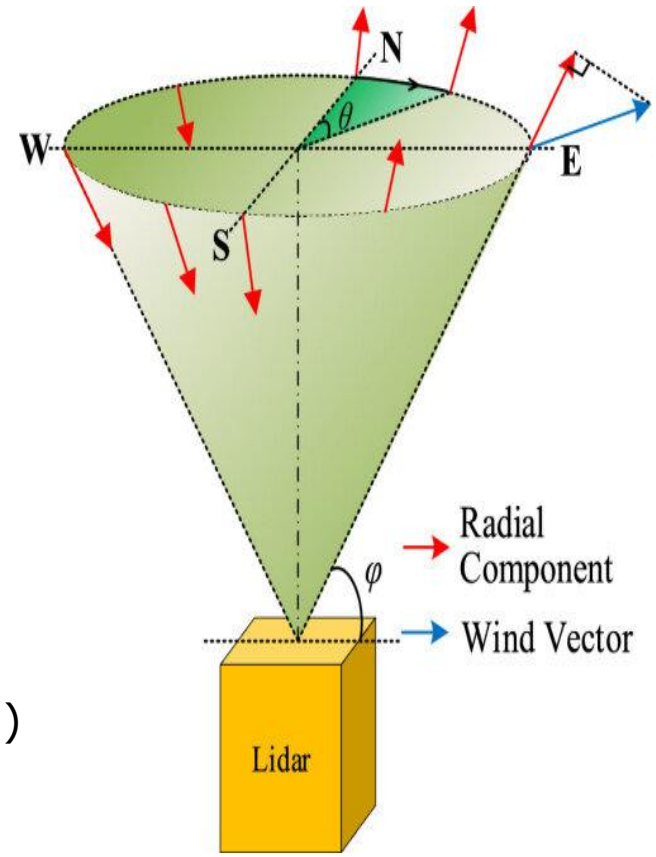
Region of interest

Limassol is a coastal city that lies between the Mediterranean Sea and Troodos Mountain range.

- Katabatic winds
- Land breezes
- Sea breezes

Halo Photonics Streamline XR *Doppler Lidar*

- Active Remote Sensing instrument
- It works by emitting laser pulses and measuring the frequency shift (Doppler effect), of the backscattered light due to the relative motion of air particles
- It provides high-resolution profiles of vertical and horizontal wind speed and direction



2 scanning modes

Stare

Retrieval of the vertical wind speed (w)

Velocity Azimuth Display (VAD)

Retrieval of the horizontal wind speed and direction (u, v)

$V_{HOR} = \sqrt{u^2 + v^2}$

$\theta = \arctan(v/u)$

Operation and Data

- In a day of full operation:
  - Stare mode: measurements were taken for 38400 times and 250 height bins
  - VAD mode: measurements were taken around 97 times for 250 height bins
- Data saved in NetCDF format:
  - Vertical wind speed
  - Advection speed + error
  - Wind direction + error
  - Height
  - Time
- 2 full years of wind data between February 2023 and January 2025 are used

Methodology (1)

Monthly average horizontal wind speed & direction

- The wind speed and direction data of each day that belonged to the same one-hour interval of each height bin are averaged.
- The respective mean values of all the days in a month that belonged to the same one-hour time interval and height bin are averaged.

Seasonal average horizontal wind speed & direction

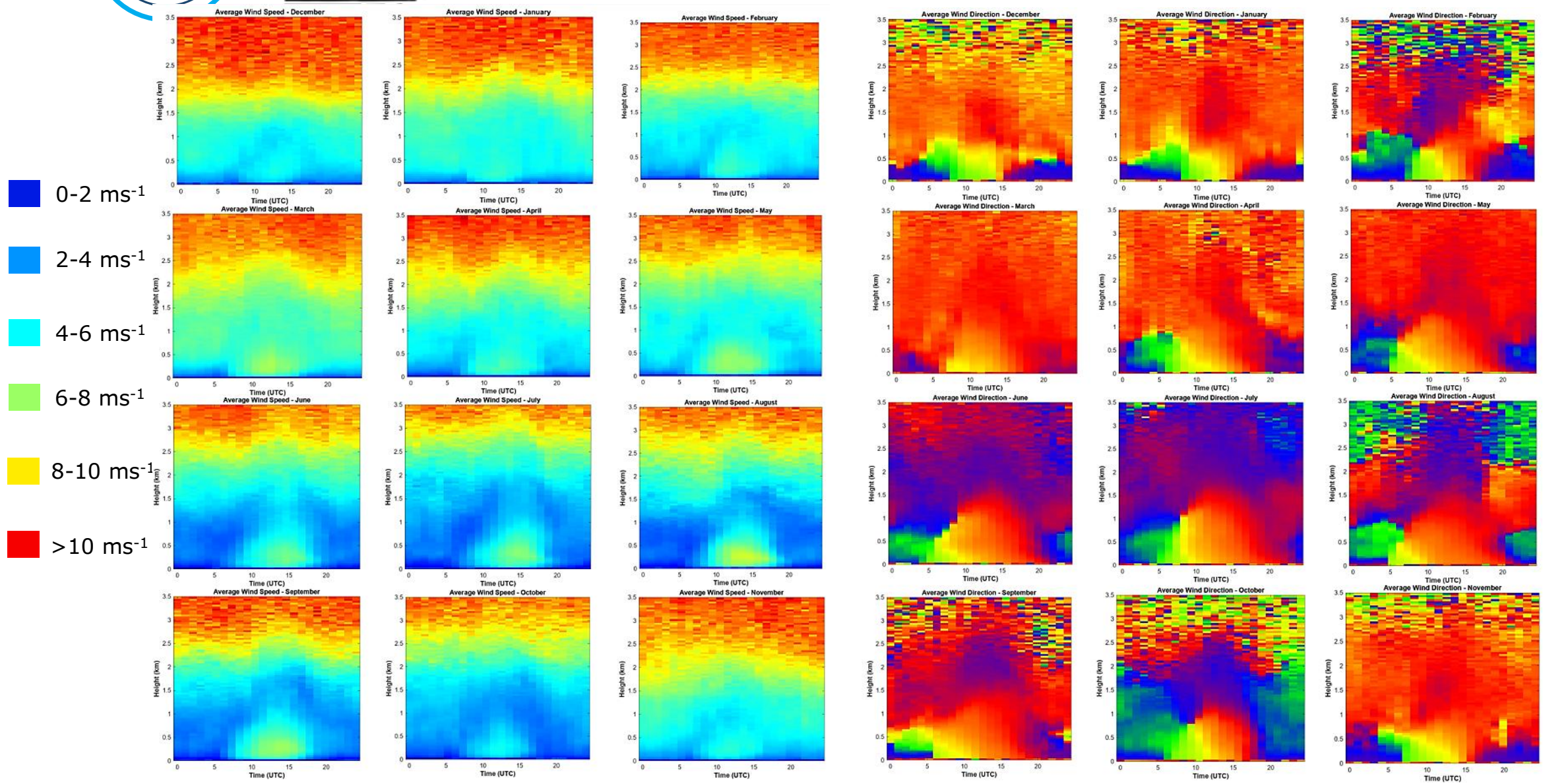
- 4 seasons: - Winter (Dec. to Feb.) => 180 days
  - Spring (Mar. to May) => 184 days
  - Summer (Jun. to Aug.) => 184 days
  - Autumn (Sep. to Nov.) => 182 days
- The same process as the previous one is followed.

Semiannual average horizontal wind speed & direction

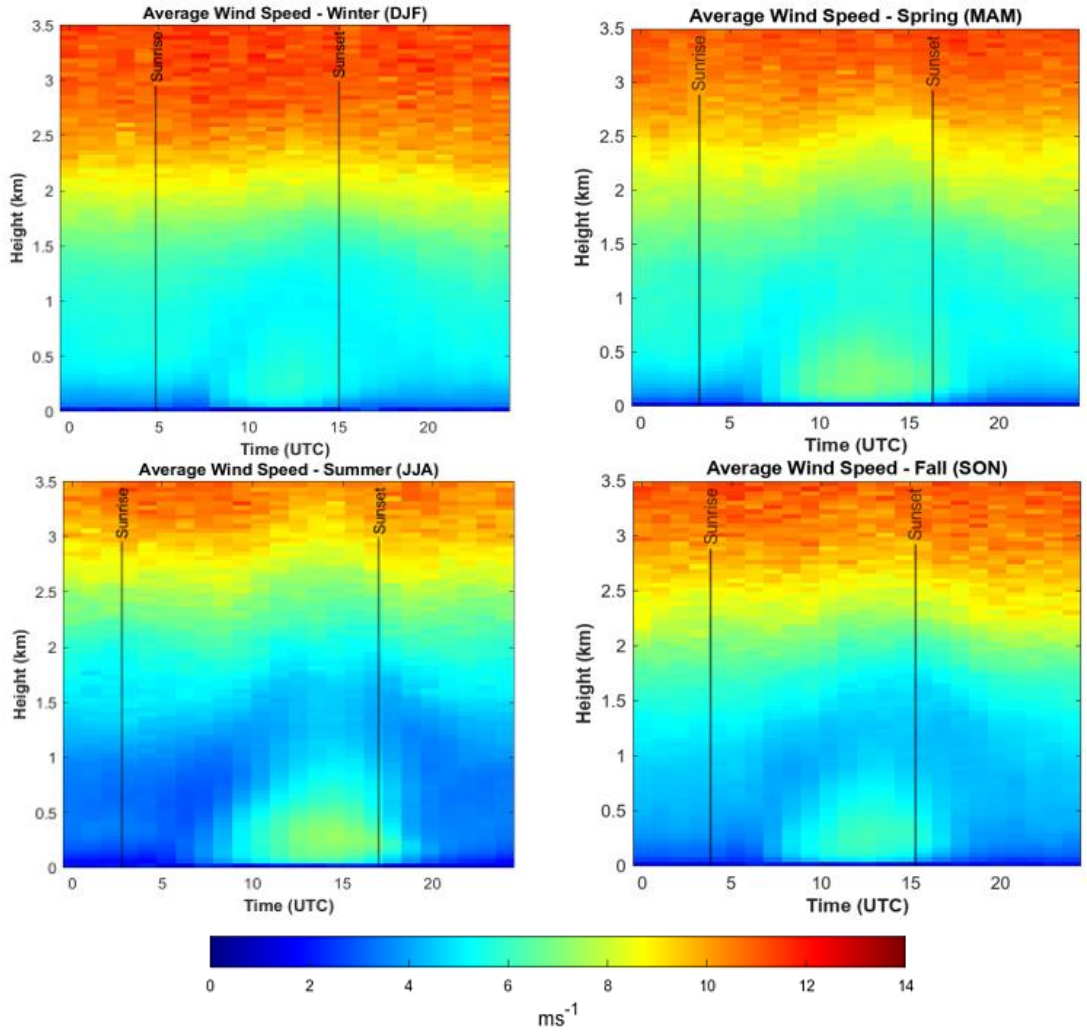
- 2 seasons: - Cold (Nov to Apr) => 362 days
  - Warm (May to Oct) => 368 days
- The same process as the previous ones is followed.

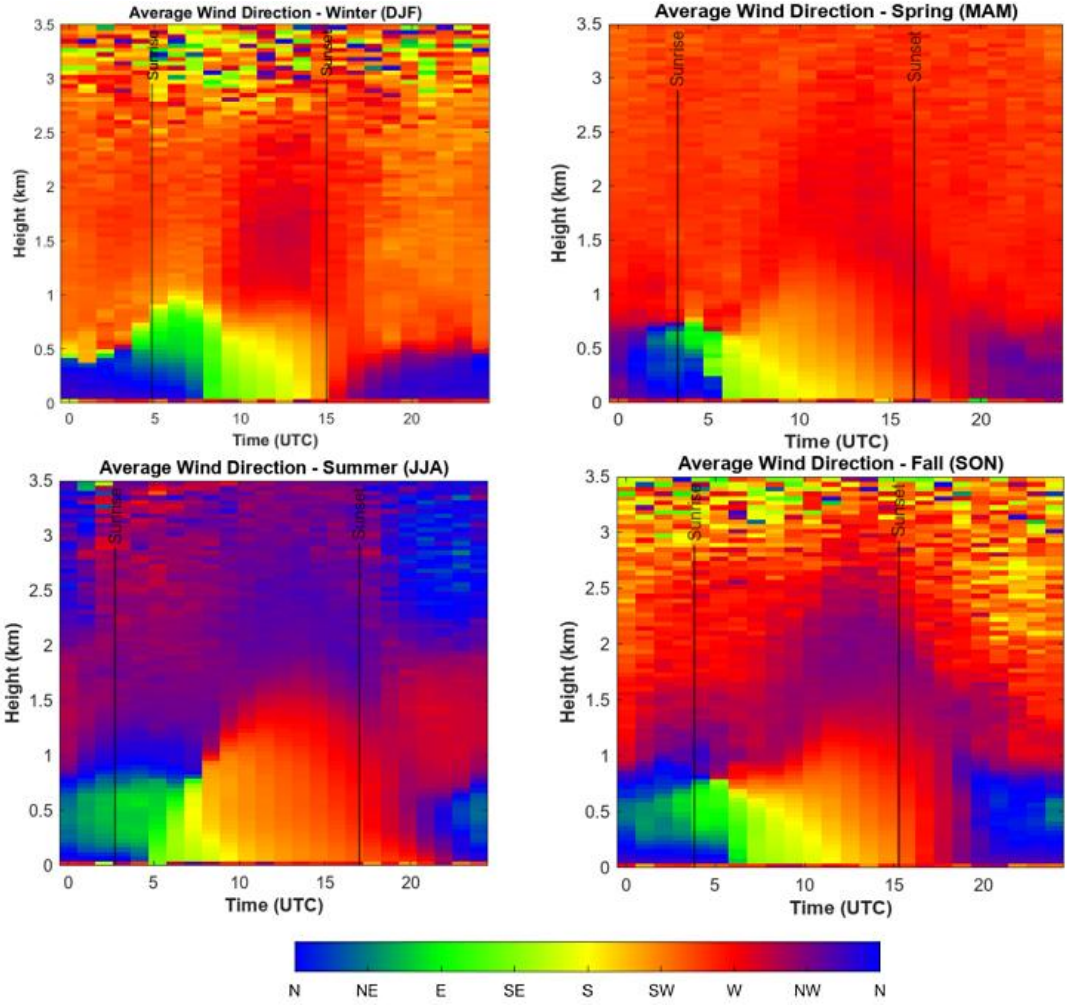
* The NaN values were excluded from the calculations

Monthly Average Wind Analysis

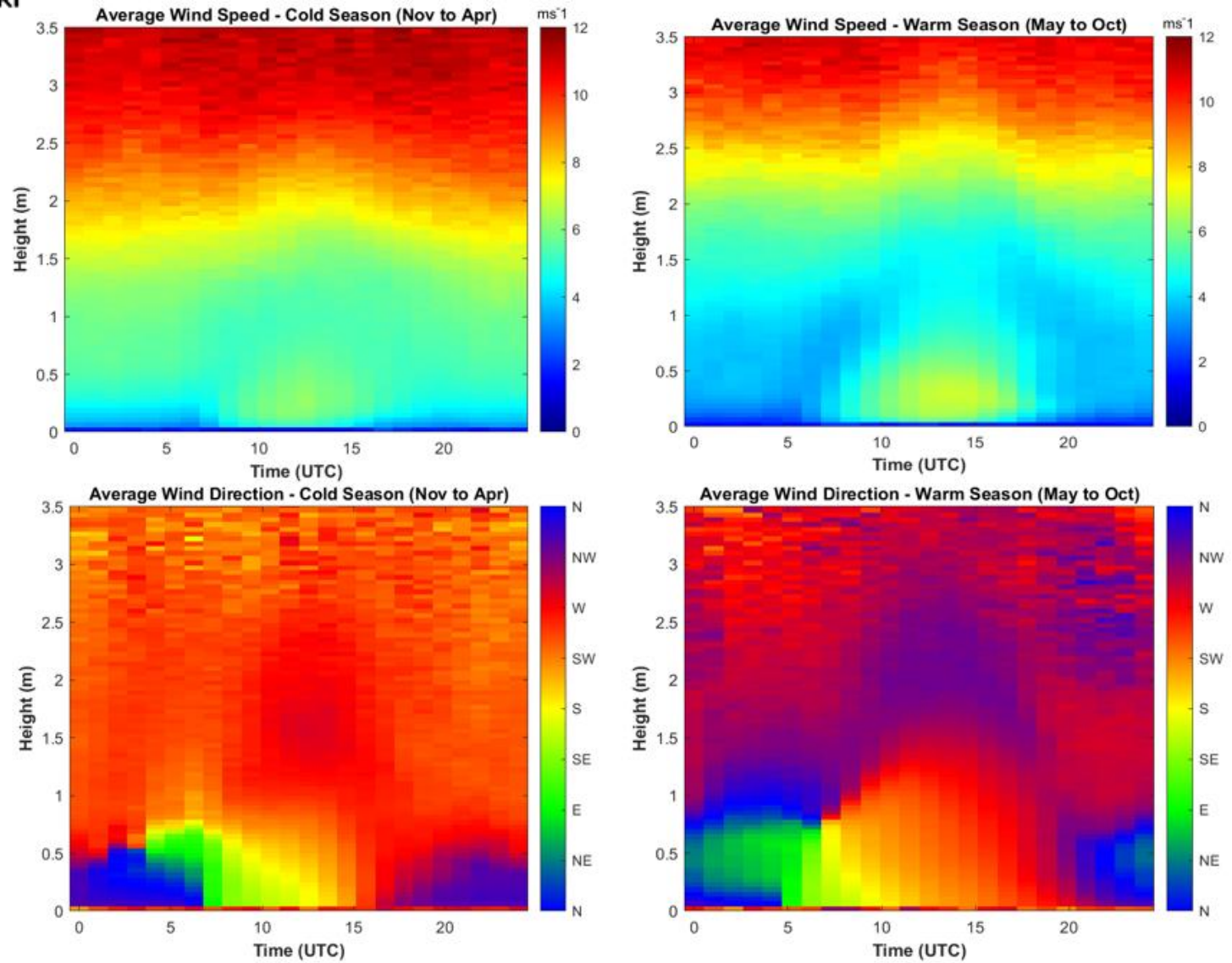


Seasonal Average Wind Analysis





Semiannual Wind Analysis



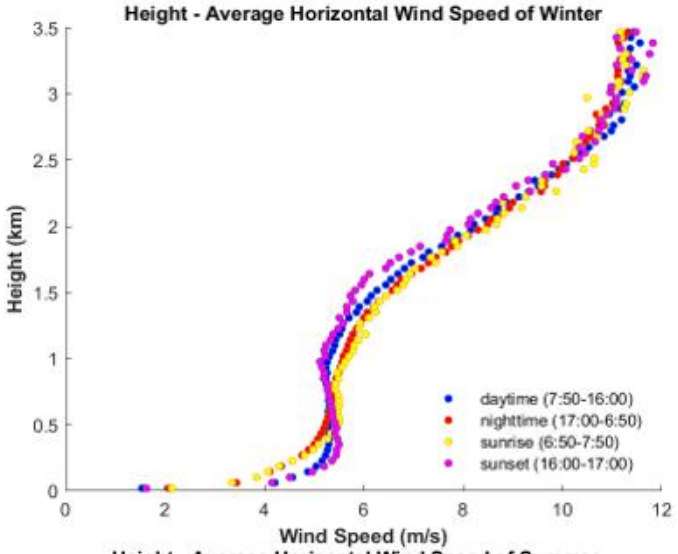
Methodology (2)

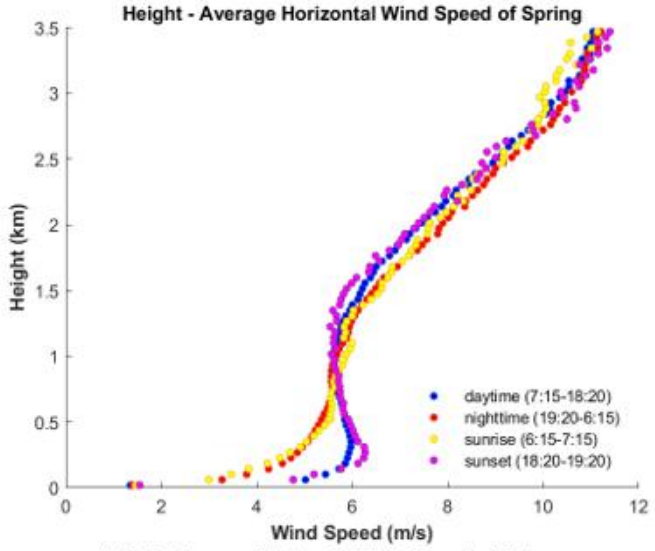
Height-averaged horizontal wind speed & direction

- 4 time periods within a day:
  - Daytime (one hour after sunrise till one hour before sunset)
  - Nighttime (from sunset till sunrise)
  - Sunrise
  - Sunset

Seasonal height averaged wind analysis

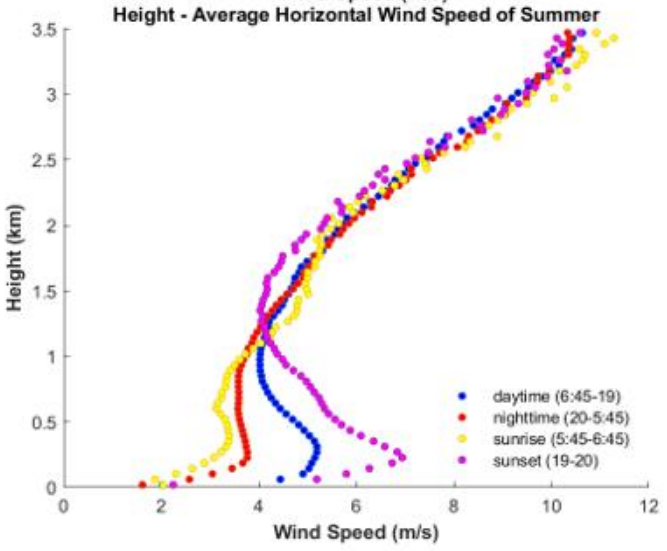
Not much variance during winter

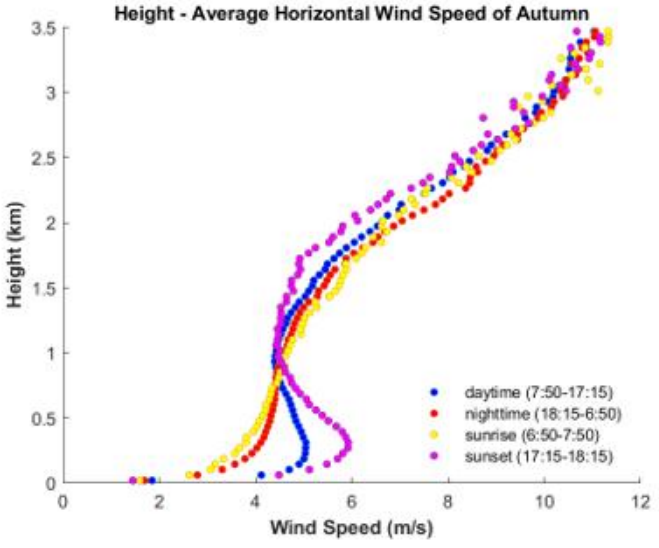




- Stronger winds during daytime at the surface
- Not significant differences at higher altitudes

Significant difference in wind speed at low altitudes. Quite stronger during daytime ➡ sea breeze





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Methodology (3)

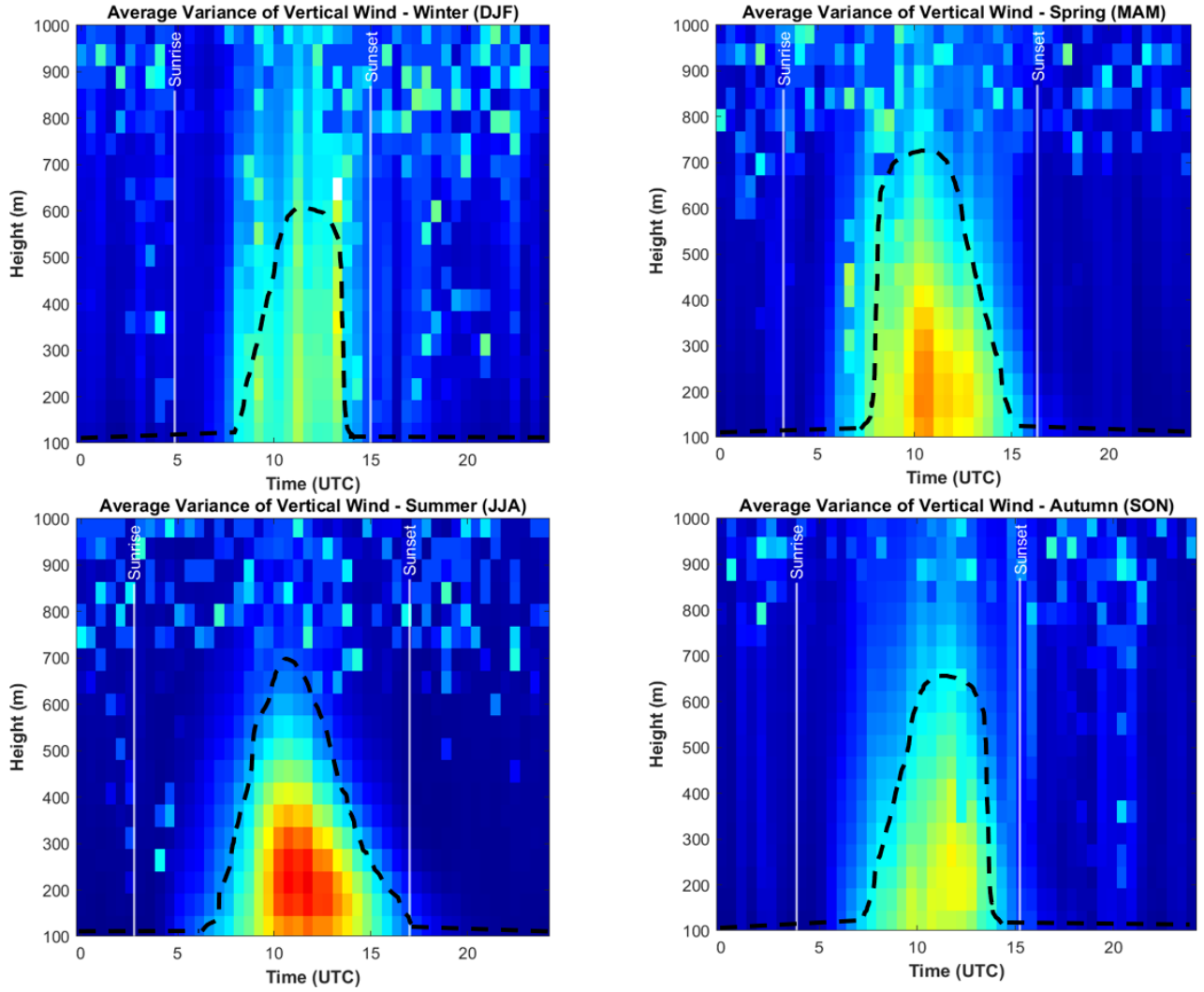
Average seasonal Mixing Layer

- A full year of vertical wind data between February 2023 and January 2024 are used
- The analysis is performed for the 4 conventional seasons, i.e. Winter, Spring, Summer and Autumn
- The variance of the vertical wind (σ_w^2) is calculated along the time dimension within each 30-minute interval for each height bin (similar to Bühl 2015, Vakkari et al. 2015 and Dewani et al. 2023)
- The respective mean variance values of all the days in a season that belonged to the same 30-minute interval and to the same height bin are averaged
- A variance threshold-indicator is empirically chosen for each season: - Winter → 0.45 m^2/s^2

  - Spring and Autumn → 0.40 m^2/s^2

  - Summer → 0.35 m^2/s^2

Mixing Layer Results



Winter
Duration: 5.5 hours
Max height: ~ 600m

Spring
Duration: 8.5 hours
Max height: ~ 750m

Summer
Duration: 10 hours
Max height: ~ 700m

Autumn
Duration: 7.5 hours
Max height: ~ 650m

Conclusions

- Distinct patterns between day and night for both wind speed and direction
  - Stronger winds during the day compared to night at low altitudes, especially during warm period
  - Wind direction follows a pattern of NESW near the surface. Westerlies dominate at high altitudes, especially during cold season
- The local topographical factors influence the observed wind patterns. Both sea and land breezes occur
- The Mixing Layer experiences seasonal variations in depth and duration, which are mainly attributed to solar heating

Thank you for your attention!

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