



“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

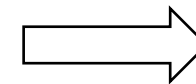
2 scanning modes

Stare

Velocity Azimuth Display (VAD)

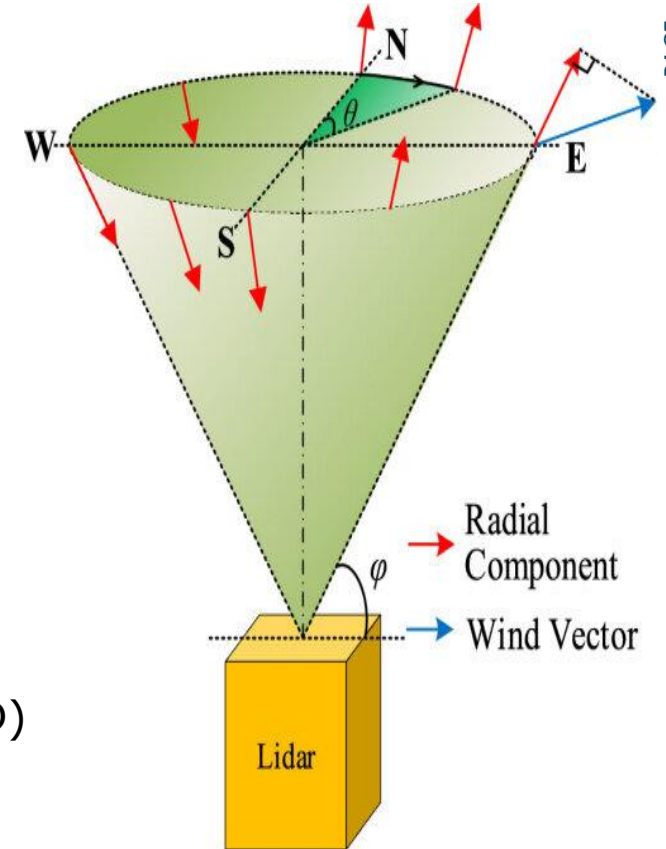
Retrieval of the vertical wind speed (w)

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.

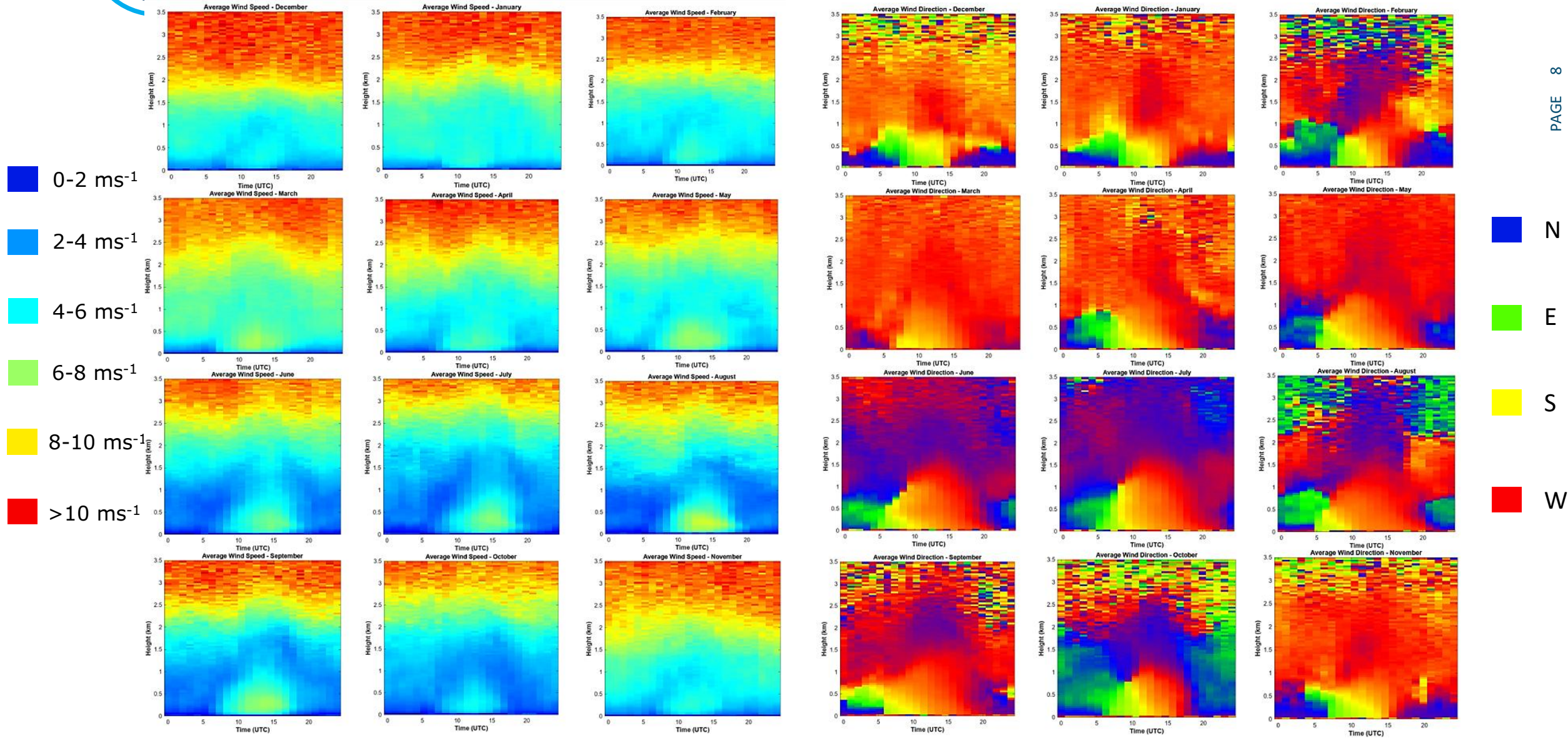
Semiannual average horizontal wind speed & direction

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

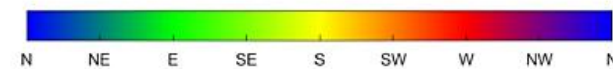
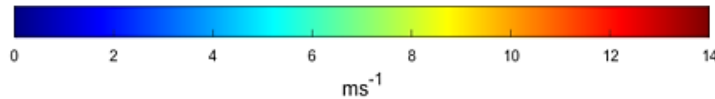
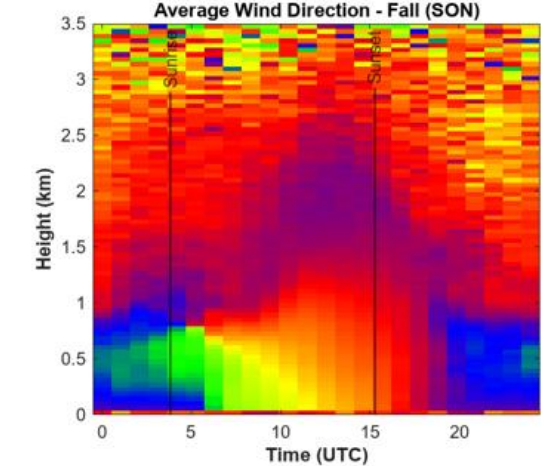
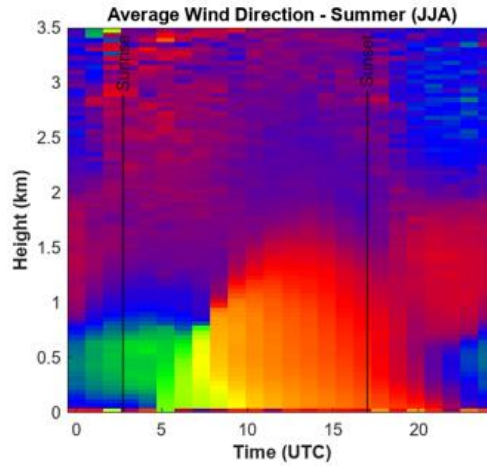
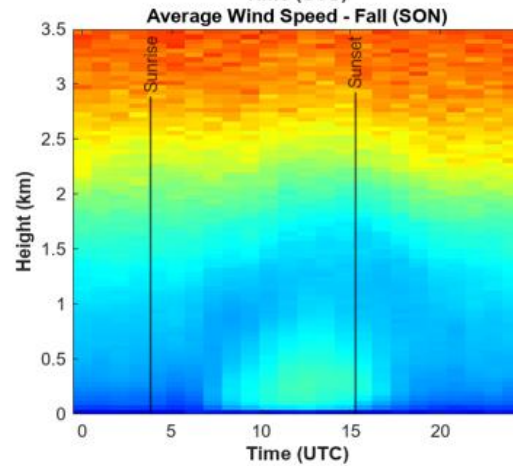
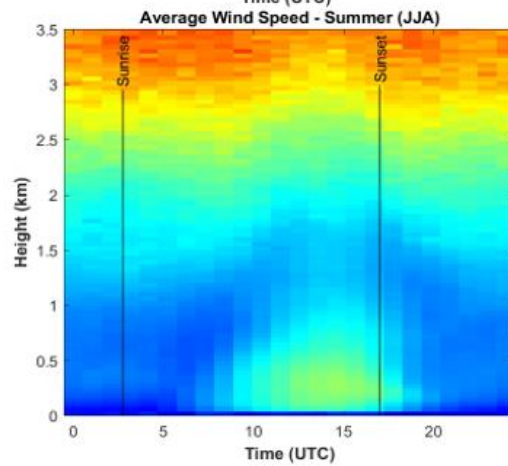
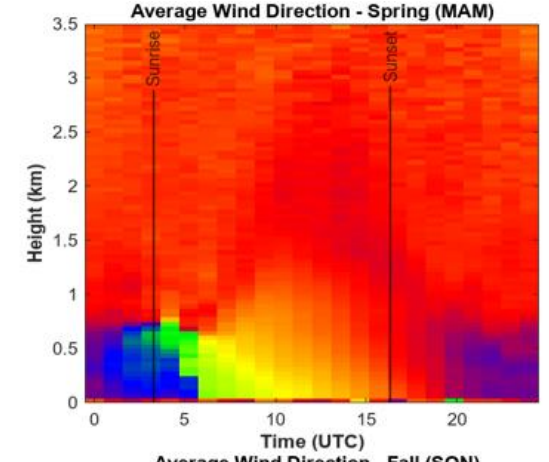
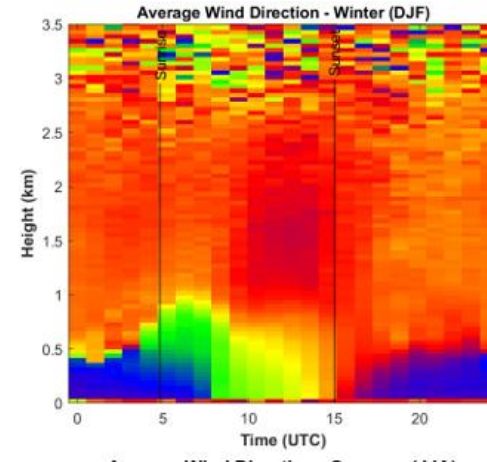
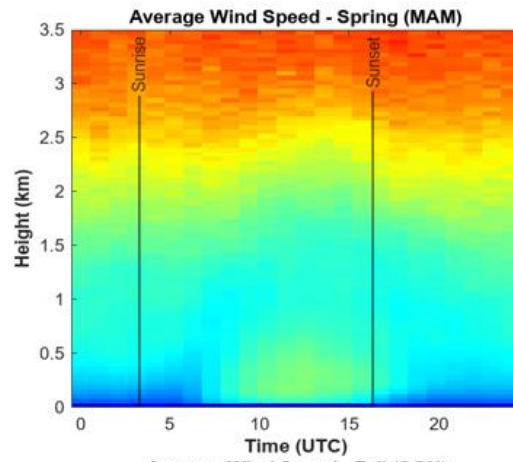
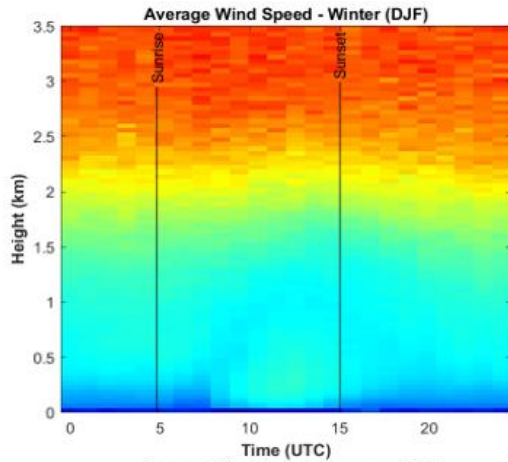
* The NaN values were excluded from the calculations



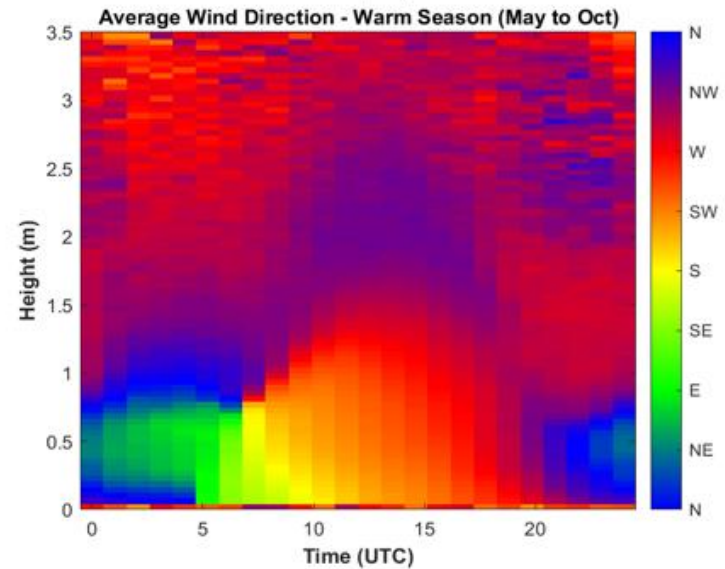
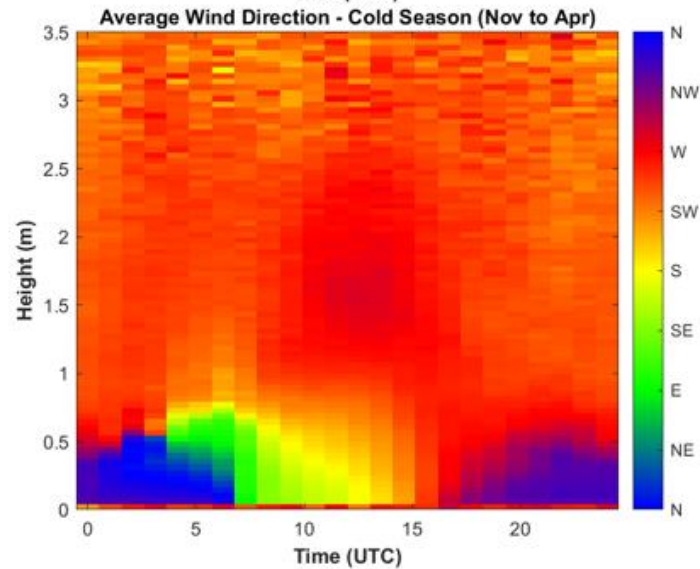
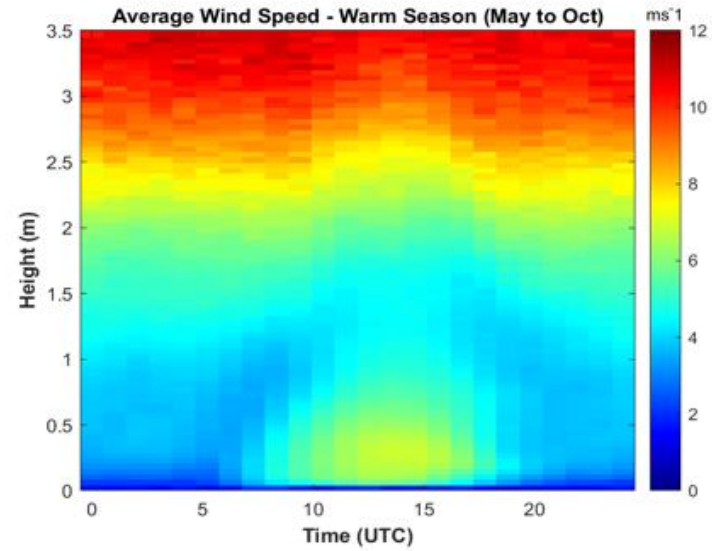
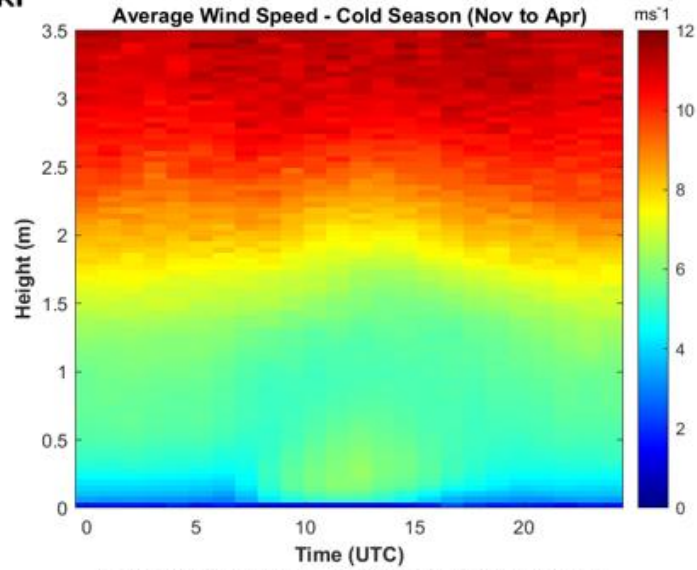
Monthly Average Wind Analysis



Seasonal Average Wind Analysis



Semiannual Wind Analysis



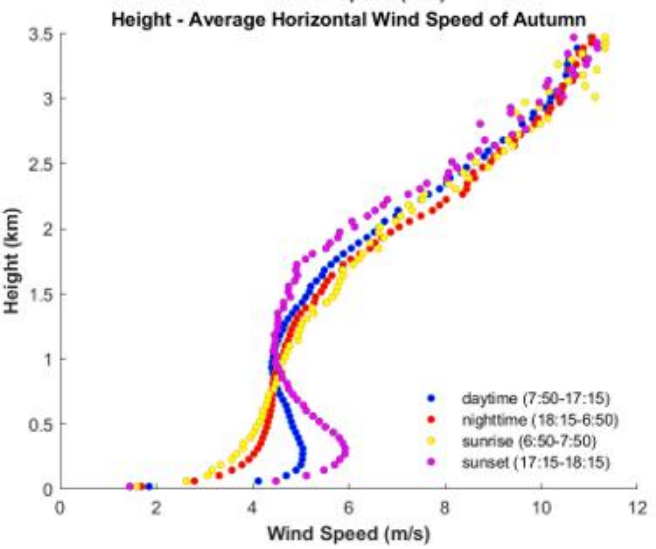
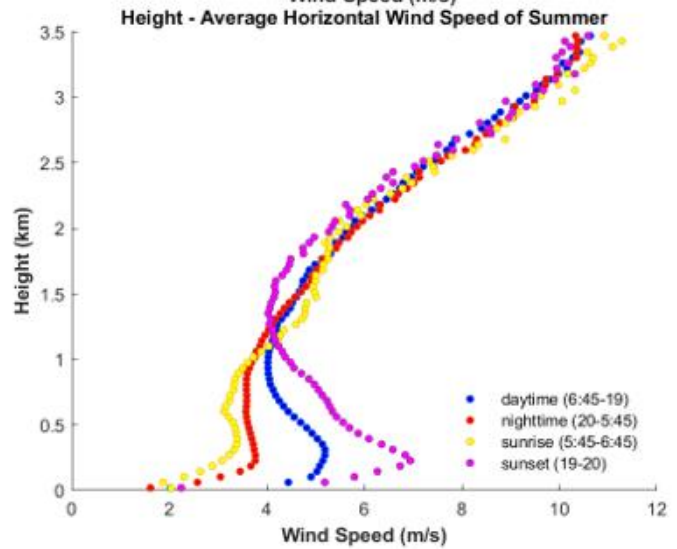
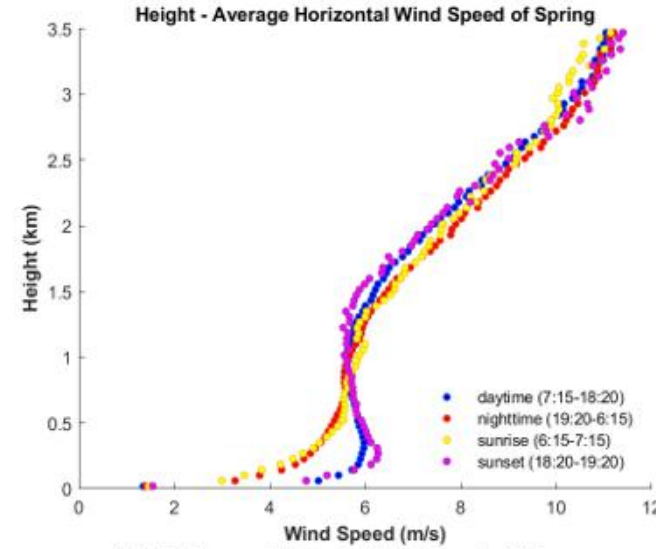
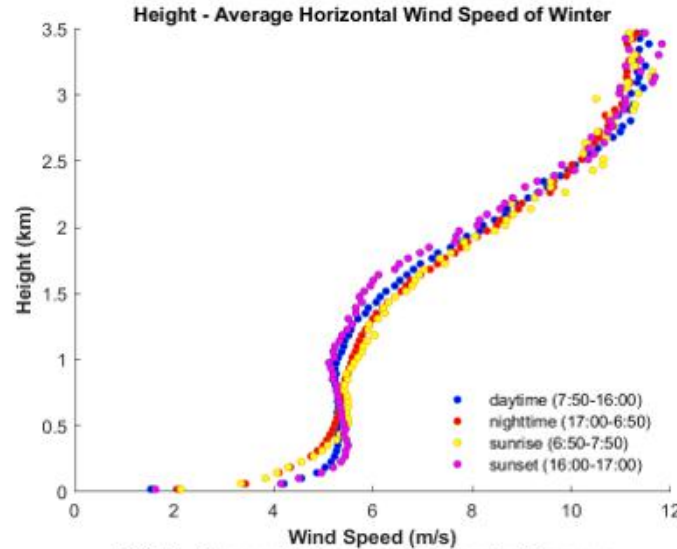
Methodology (2)

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



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

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

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Methodology (3)

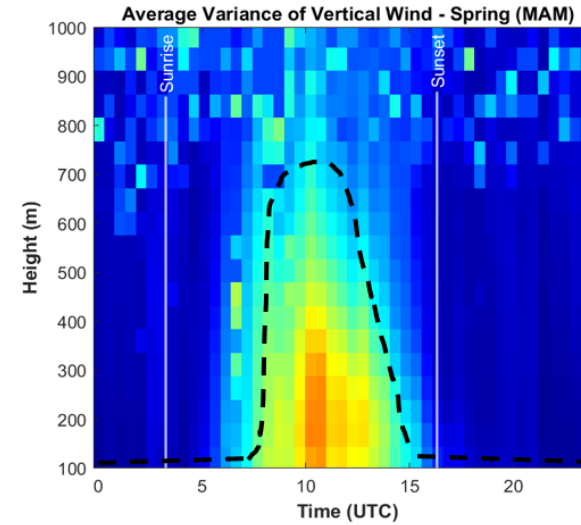
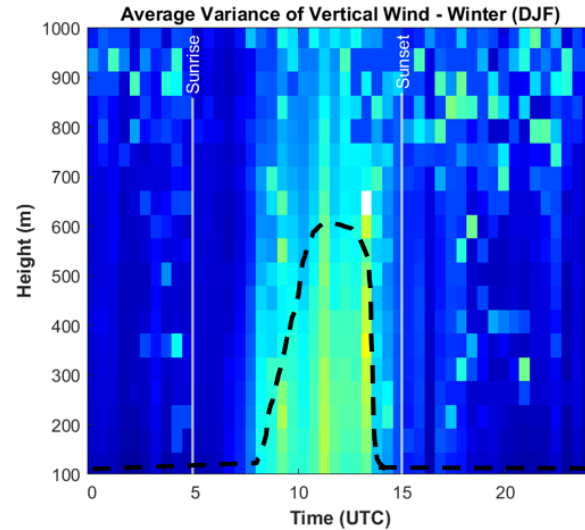
Average seasonal Mixing Layer

- 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 $\rightarrow 0.45 \text{ m}^2/\text{s}^2$
 - Spring and Autumn $\rightarrow 0.40 \text{ m}^2/\text{s}^2$
 - Summer $\rightarrow 0.35 \text{ m}^2/\text{s}^2$

Mixing Layer Results

Winter

Duration: 5.5 hours
Max height: ~ 600m

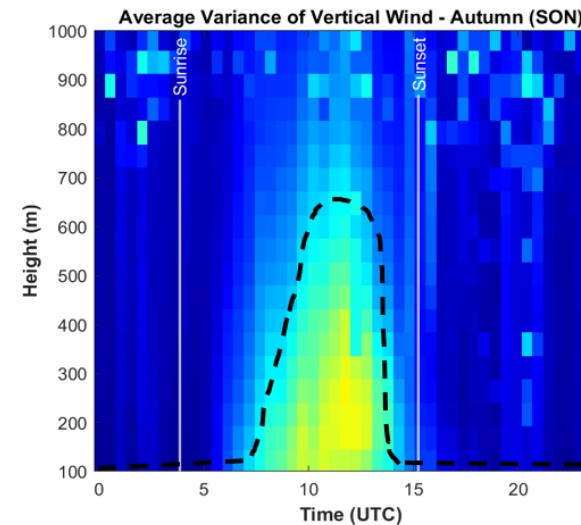
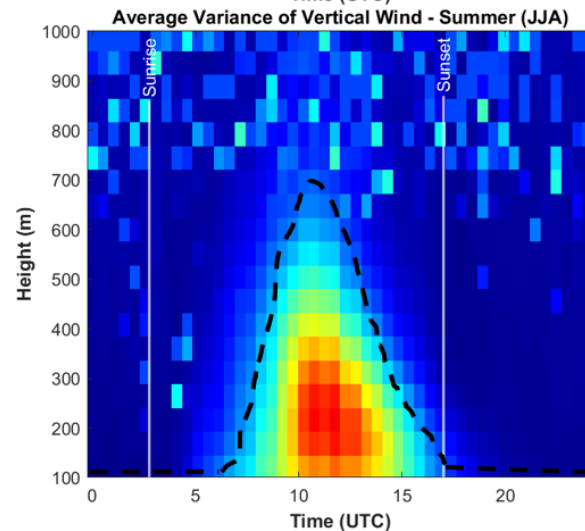


Spring

Duration: 8.5 hours
Max height: ~ 750m

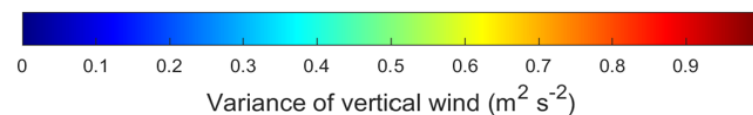
Summer

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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