Monitoring Atmospheric 3D Winds with the HALO Doppler Wind Lidar at the CARO National Facility in Limassol, Cyprus

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Introduction

The Cyprus Atmospheric Remote-sensing Observatory (**CARO**), operated by the *ERATOSTHENES Centre of Excellence*, is a National Facility located in Limassol, Cyprus. CARO is equipped with a suite of active and passive ground-based remote sensing instruments, enabling continuous, high-resolution monitoring of atmospheric processes. Since January 2023, the observatory hosts the HALO Photonics Streamline XR Doppler lidar (Snoopy), a state-of-the-art system capable of capturing the three-dimensional wind field with high spatial and temporal resolution.

This study aims to:

✓ Investigate the **monthly and seasonal horizontal wind patterns** over the coastal city of Limassol using the first two years of the Doppler lidar's measurements, with particular attention to the influence of the island's complex topography and the surrounding Mediterranean Sea.

✓ Estimate the **seasonal mixing layer height** (MLH) based on vertical wind profiles and their variance.

✓ Assess the performance of ESA's Aeolus satellite Level 2B Rayleigh-Clear and Mie-Cloudy wind products by comparing them with ground-based observations. Evaluate their accuracy and suitability for regional wind profiling, and investigate the correlation between measurements taken over land and sea.
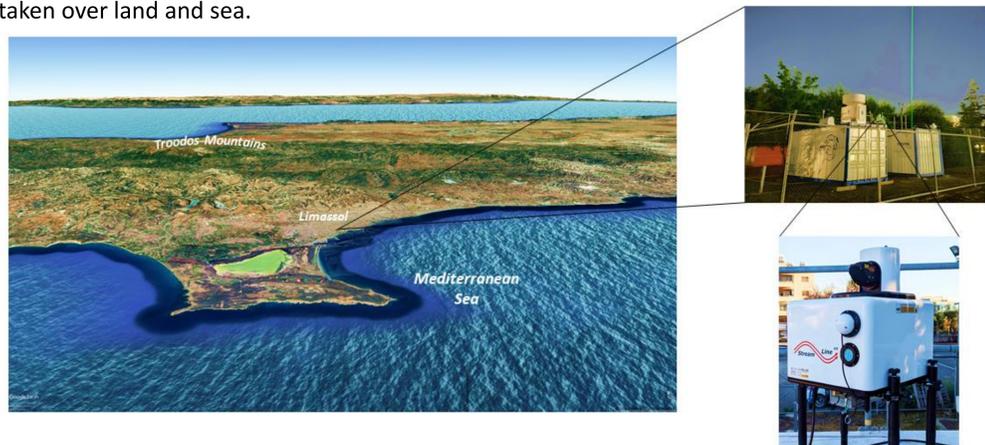
Methodology

Horizontal Wind Analysis Over Limassol
→ **Time range:** February 2023 – January 2025
→ **Resolution:**
  • Time: 24 one-hour bins
  • Height: 48 m per bin
→ For each month and season, the daily wind speed and direction measurements of matching time and height bins were averaged.
→ **Seasons** are defined as: Winter (Dec–Feb), Spring (Mar–May), Summer (Jun–Aug), and Autumn (Sep–Nov).
→ **Semi-annual wind**: Cold season (Oct–Mar) and Warm season (Apr–Sep).
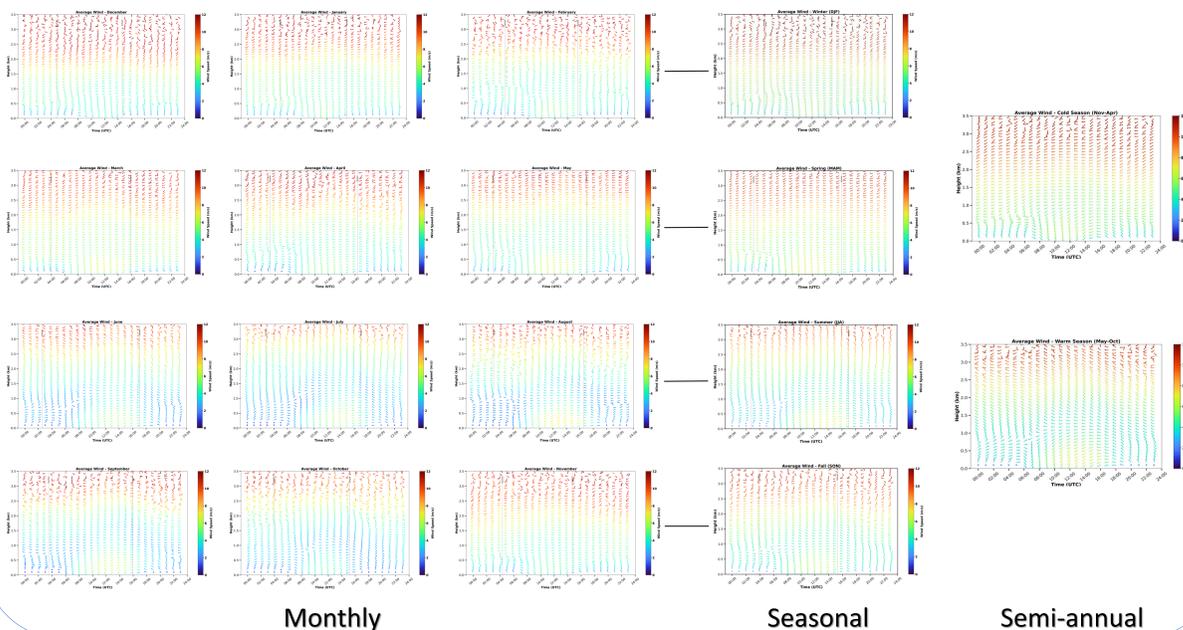
Mixing Layer Height
→ **Time range:** February 2023 – January 2025
→ First, the variance of the vertical wind in every 15-minute range was calculated for each day and then the average variance was calculated for each season.
→ Thresholds used:
  Winter: $0.45\ m^2/s^2$ Spring: $0.4\ m^2/s^2$ Summer: $0.35\ m^2/s^2$ Autumn: $0.4\ m^2/s^2$
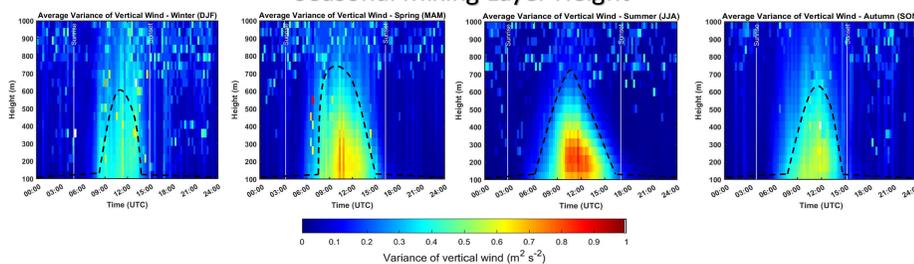
Aeolus – DL comparison
• **Time range:** February - April 2023
• **Max distance:** 100 km
• **Max time difference:** 4 minutes
→ The Level 2B Rayleigh-Clear and Mie-Cloudy HLOS measurements of Aeolus 2B15 baseline were retrieved, excluding measurements of heights above 3 km and with errors higher than 8 and 4 m/s, respectively. The HLOS wind from the ground-based DL was also calculated.
→ Total of 24 overpasses:
  ➢ 12 ascending → 30 (15 + 15) Rayleigh-Clear and 14 (6 + 8) Mie-Cloudy
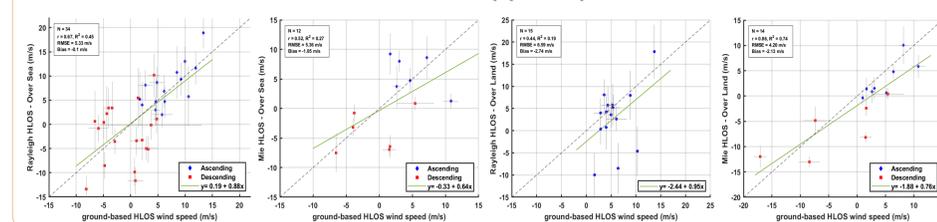 ➢ 12 descending → 19 (19 + 0) Rayleigh-Clear and 12 (6 + 6) Mie-Cloudy
    └ Measurements over land
    └ Measurements over sea

Results

Wind Analysis

Monthly   Seasonal   Semi-annual

Seasonal Mixing Layer Height

AEOLUS – Snoopy Comparison

Conclusions

Wind Analysis
➢ Distinct diurnal patterns are observed for both the wind speed and wind direction.
➢ The months, as well as the seasons, indicate the existence of **two six-month periods**: the cold one and the warm one. These two periods can adequately describe the expected behaviour of the wind in Limassol.
➢ The local topography influences the observed directional patterns of the wind; both sea (during the day) and land breezes (during the night) are observed.

Mixing Layer
➢ The intensity as well as the extent of the Mixing Layer presents a seasonal variation as expected, as it highly depends on the exposure to the Sun.

Seasons Features	Winter	Spring	Summer	Autumn
Max. Height	~ 600 m	~ 750 m	~ 700 m	~ 650 m
Duration	5.5 hours	8.5 hours	10 hours	6.5 hours

Aeolus Comparison
➢ All the comparisons showed a **moderate to poor correlation** with ground-truth measurements. However, in each case there were measurements that presented good correlation, therefore different atmospheric conditions may affected satellite's capabilities.
➢ The limited dataset doesn't permit a solid conclusion as to how the satellite performed in the region.