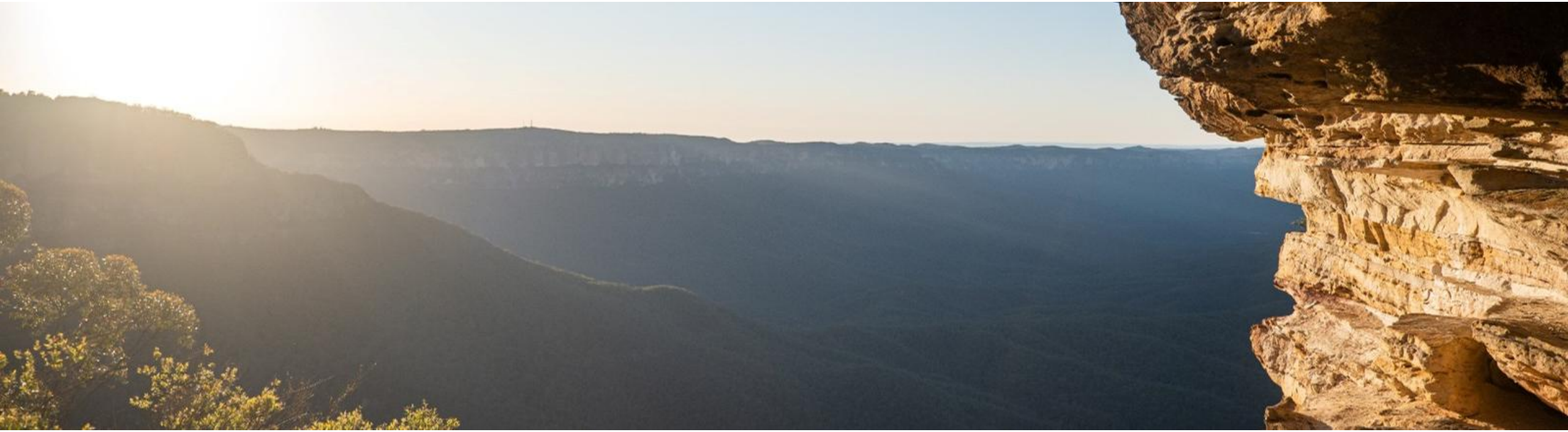


STUDY OF AEROSOL TRANSPORT IN THE TROPOSPHERE AND STRATOSPHERE USING MICRO PULSE LIDAR (MPL) AND CEILOMETER IN NEW SOUTH WALES

CASANZ Clean Air Conference, Cairns QLD

31 August – 2 September 2026

Hiep Nguyen

Department of Climate Change, Energy the Environment and Water

NSW GOVERNMENT

Department of Climate Change, Energy the Environment and Water acknowledges the traditional custodians of the land and pays respect to Elders past, present and future.

We recognise Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to place and their rich contribution to society.

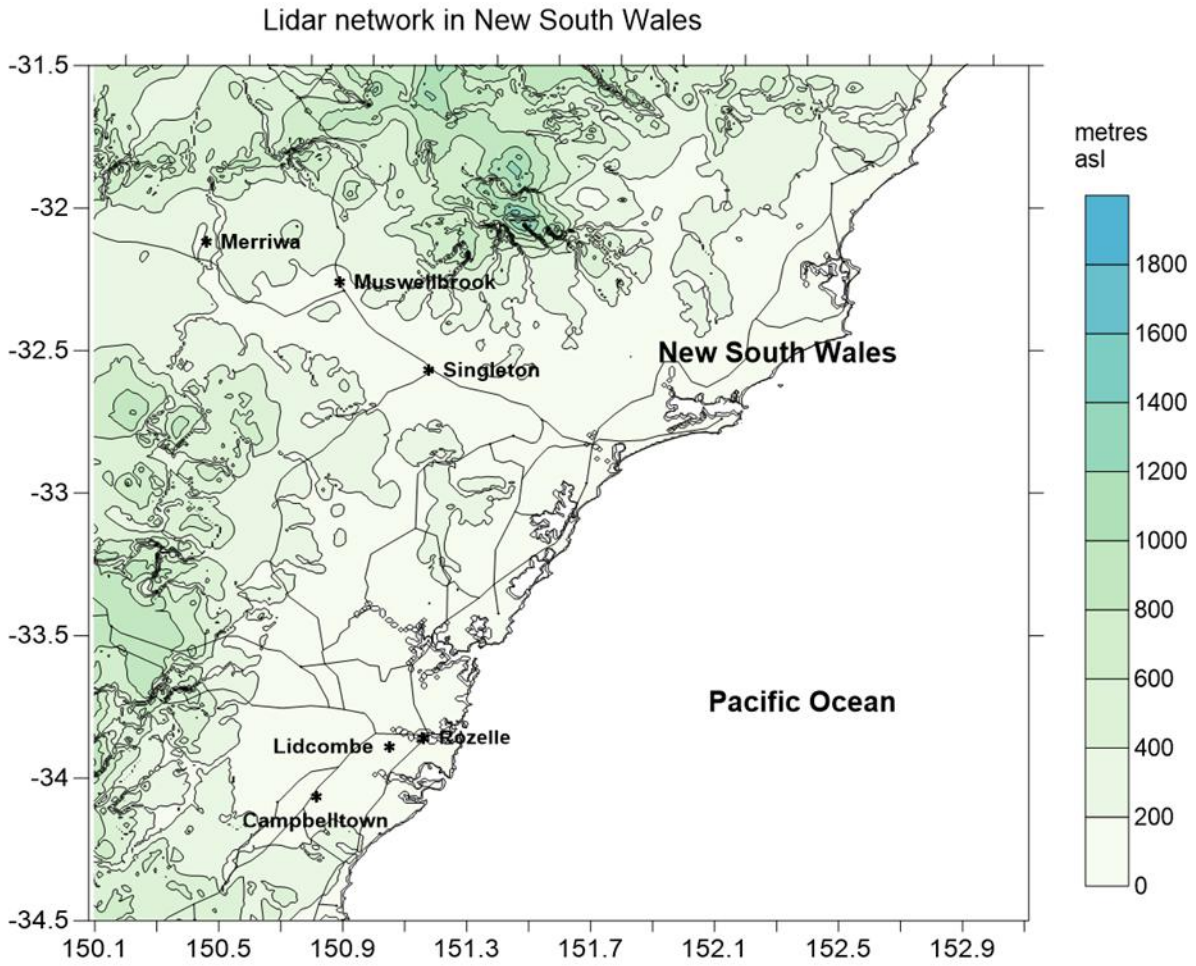
Artist and designer Nikita Ridgeway from Aboriginal design agency – Boss Lady Creative Designs, created the People and Community symbol.

NSW GOVERNMENT

Introduction & research questions

- The NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) has recently installed and operated a Micro Pulse Lidar (MPL) from Cimel (Cimel MPL CE376GPN_2401) to study the characteristics of aerosols above ground and their transport in the troposphere and stratosphere.

- The MPL is co-located with the Vaisala CL61 ceilometer at DCCEEW Lidcombe monitoring supersite.



DCCEEW lidar network in NSW with 6 sites located in the Upper Hunter and the Greater Metropolitan Region of Sydney (GMR).

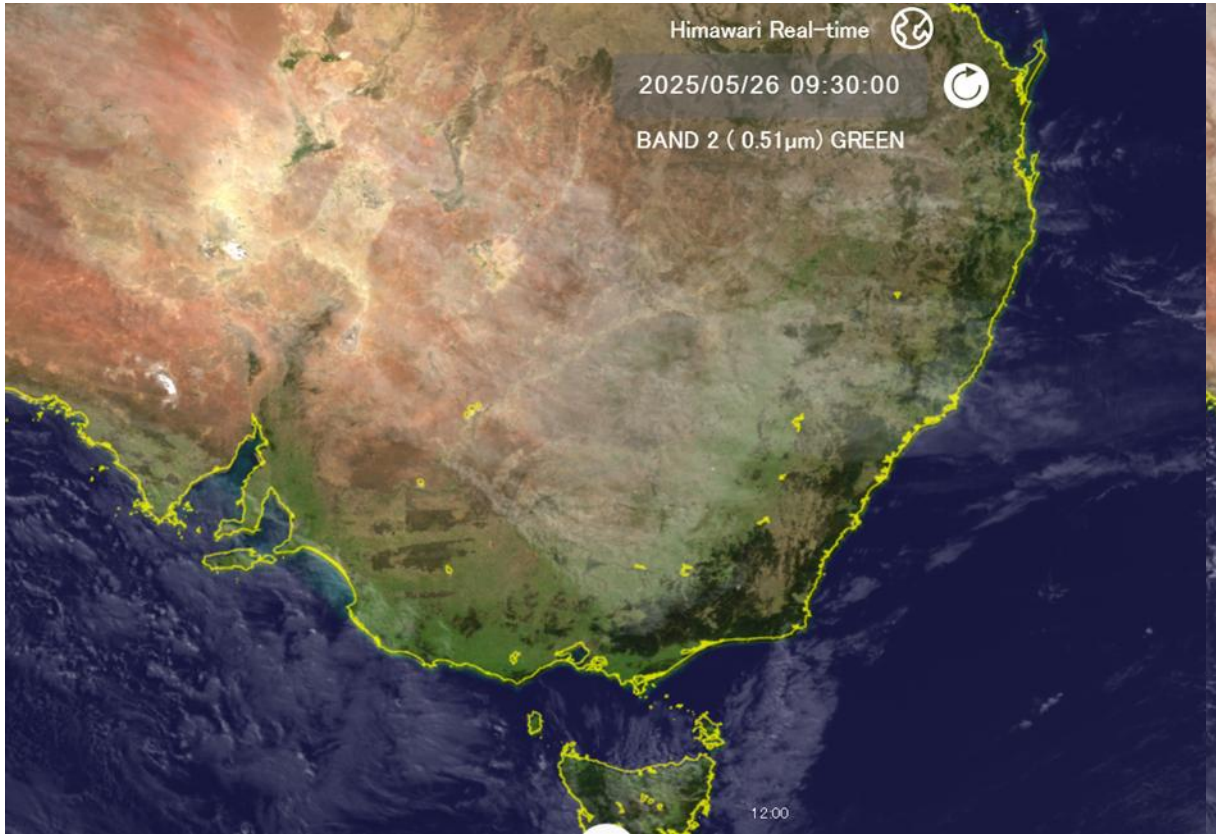
- The purpose is to analyse the transport of pollutants from events such as dust storms and wildfires
- How the pollutants from these events affect air quality and human exposure on the ground?
- Do the upper air data validate the air quality forecast results ?

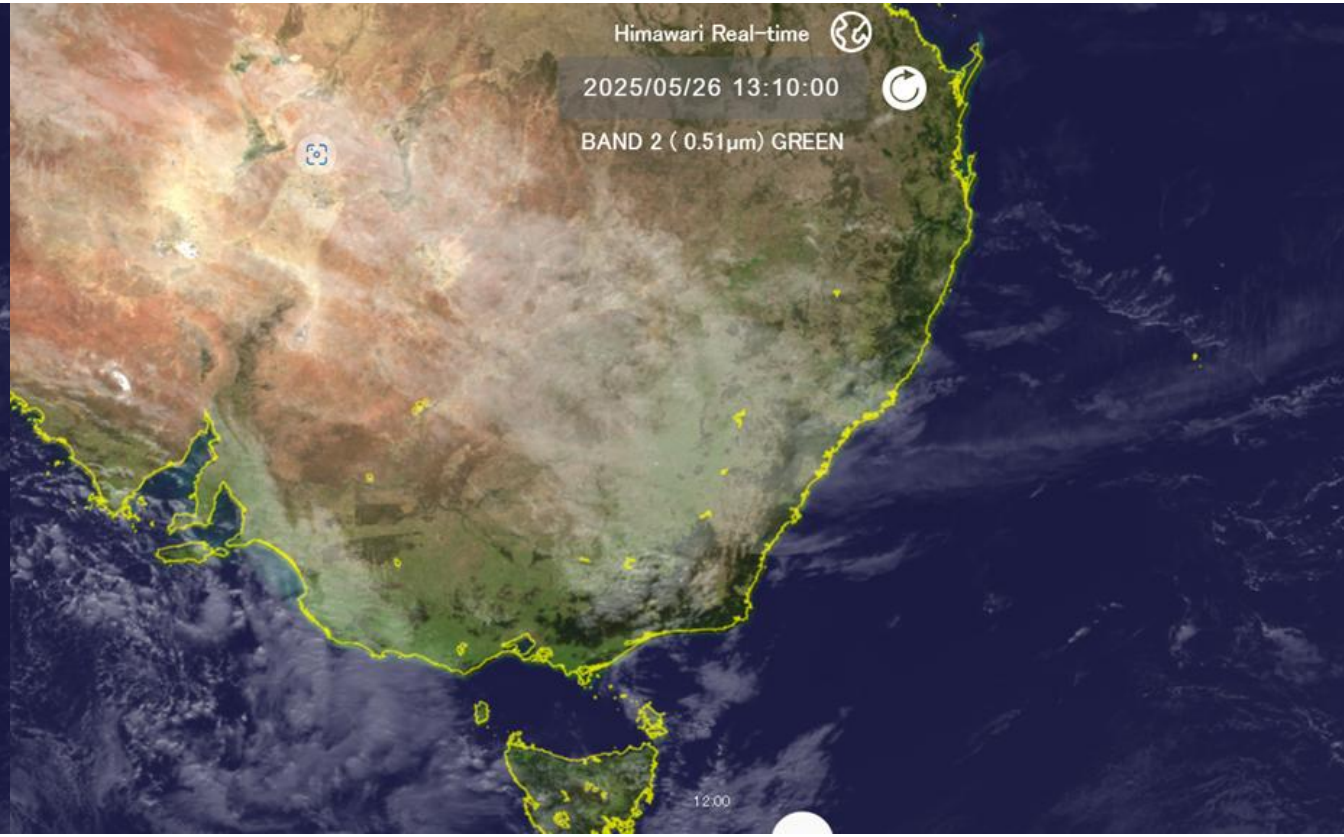
Lidar operation and Data

- The MPL is a powerful lidar with 2 wavelengths (**green** cross, green parallel polarisation at 532nm and red Infrared 808nm). Short powerful pulses of lidars penetrate the atmosphere up to 20km above ground.

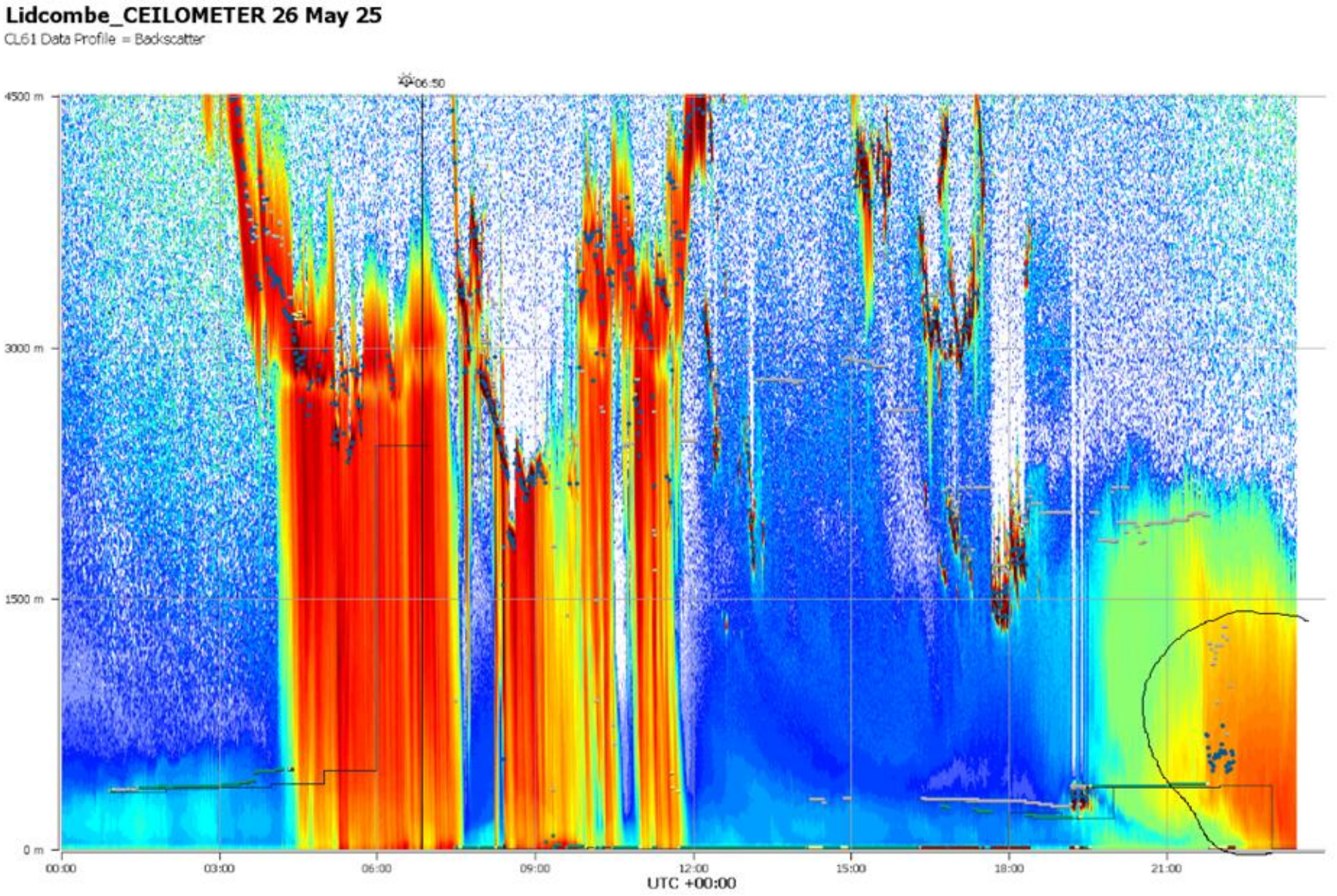
- The MPL can therefore detect intercontinental transport of aerosols at high altitude. The ratio of cross to parallel reflection yield the type of aerosols (wildfire fine or dust coarse).

Dust storm May 2025. Himawari satellite image 26/5/2025 9:30 and 26/5/2025 13:10



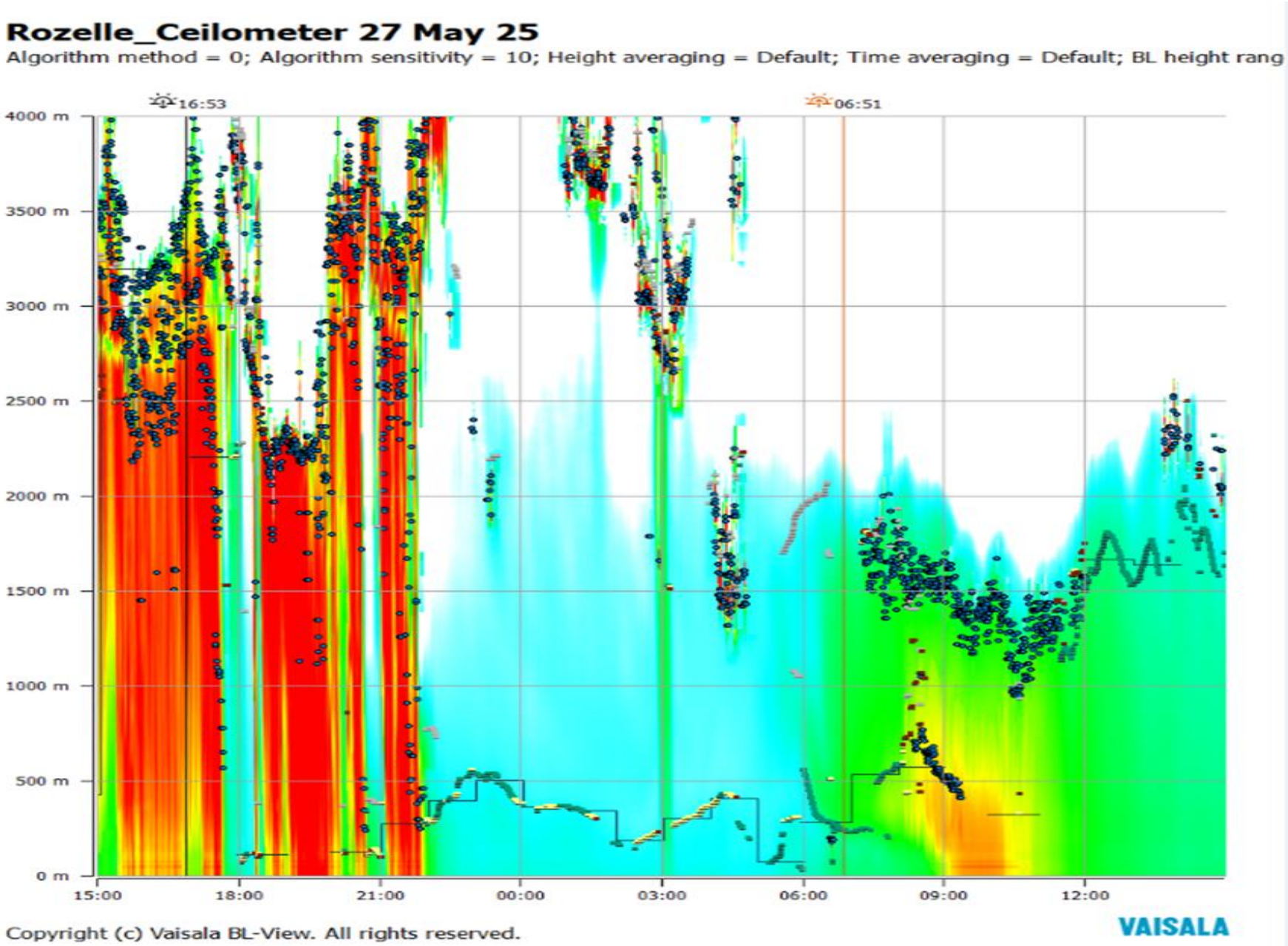


Lidcombe ceilometer



Rozelle ceilometer

Dust plume from 1000m high to ground

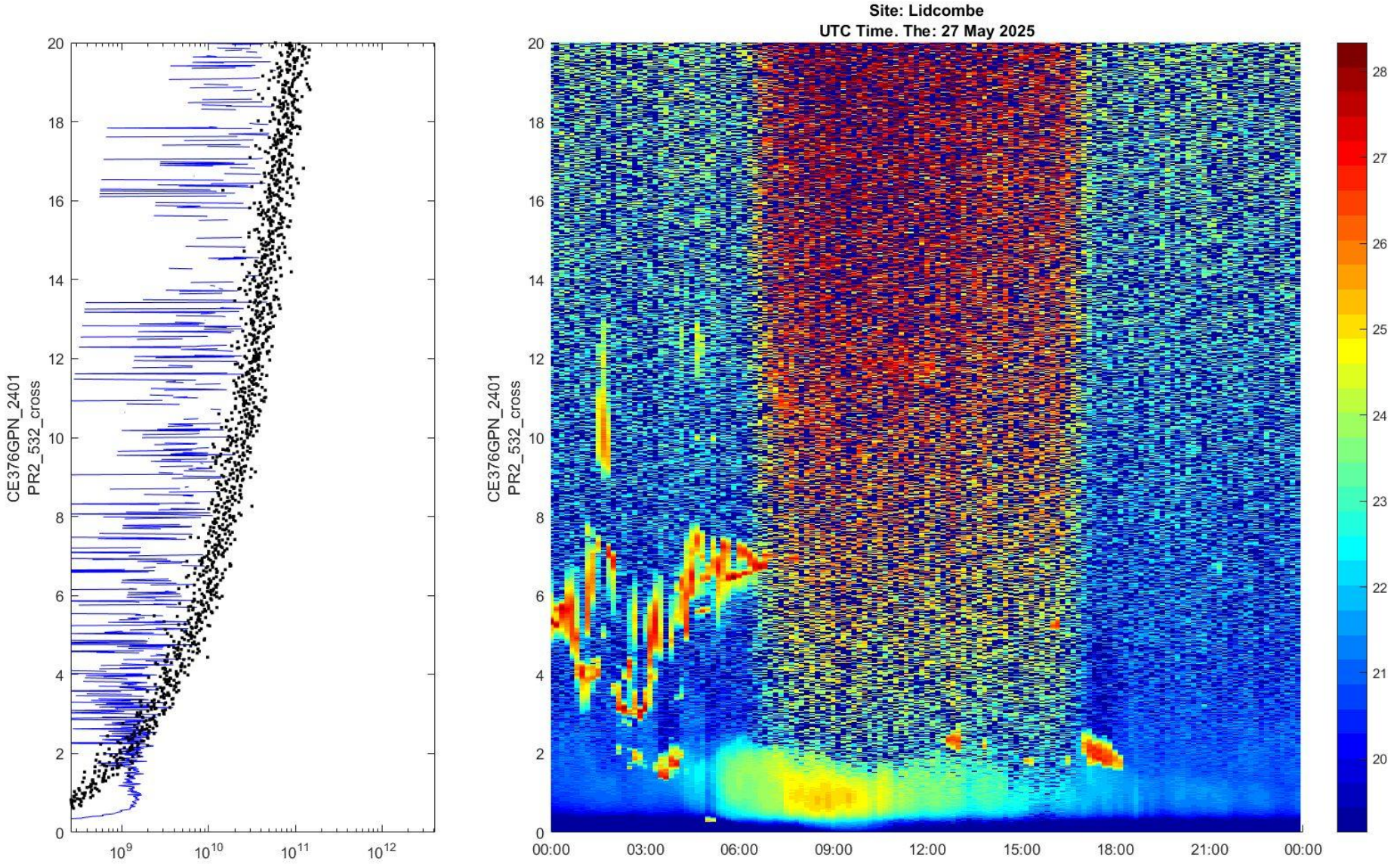


MPL profiles of dust plume

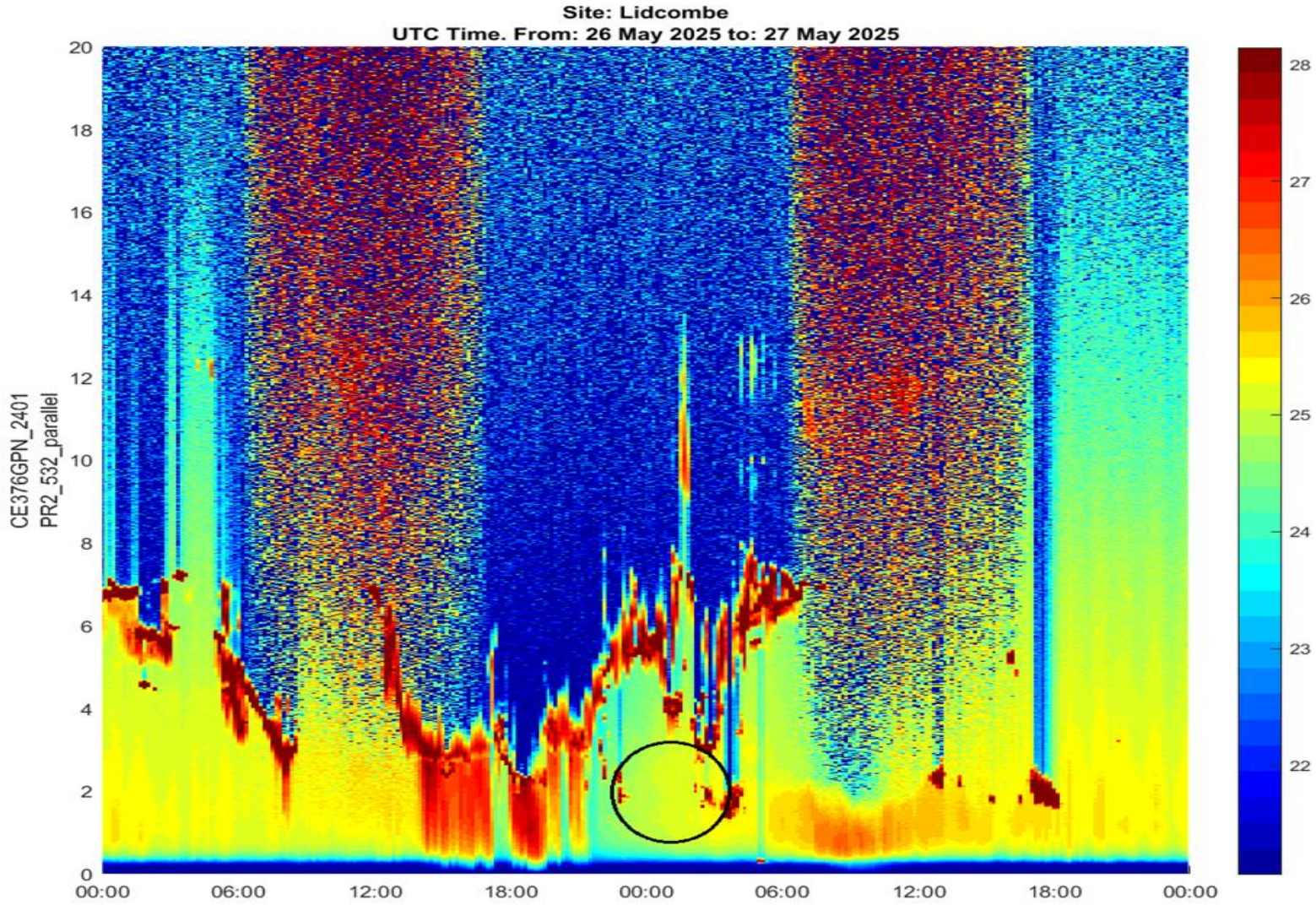
- From 26 to 27 May 2025, the Cimel MPL detected dust plume from ground level up to 2km and at time dust up to 5km

- The profiles on the 27 May 2025 for cross-532, parallel-532, total 532 and red 808 lidar reflections show the dust plumes.

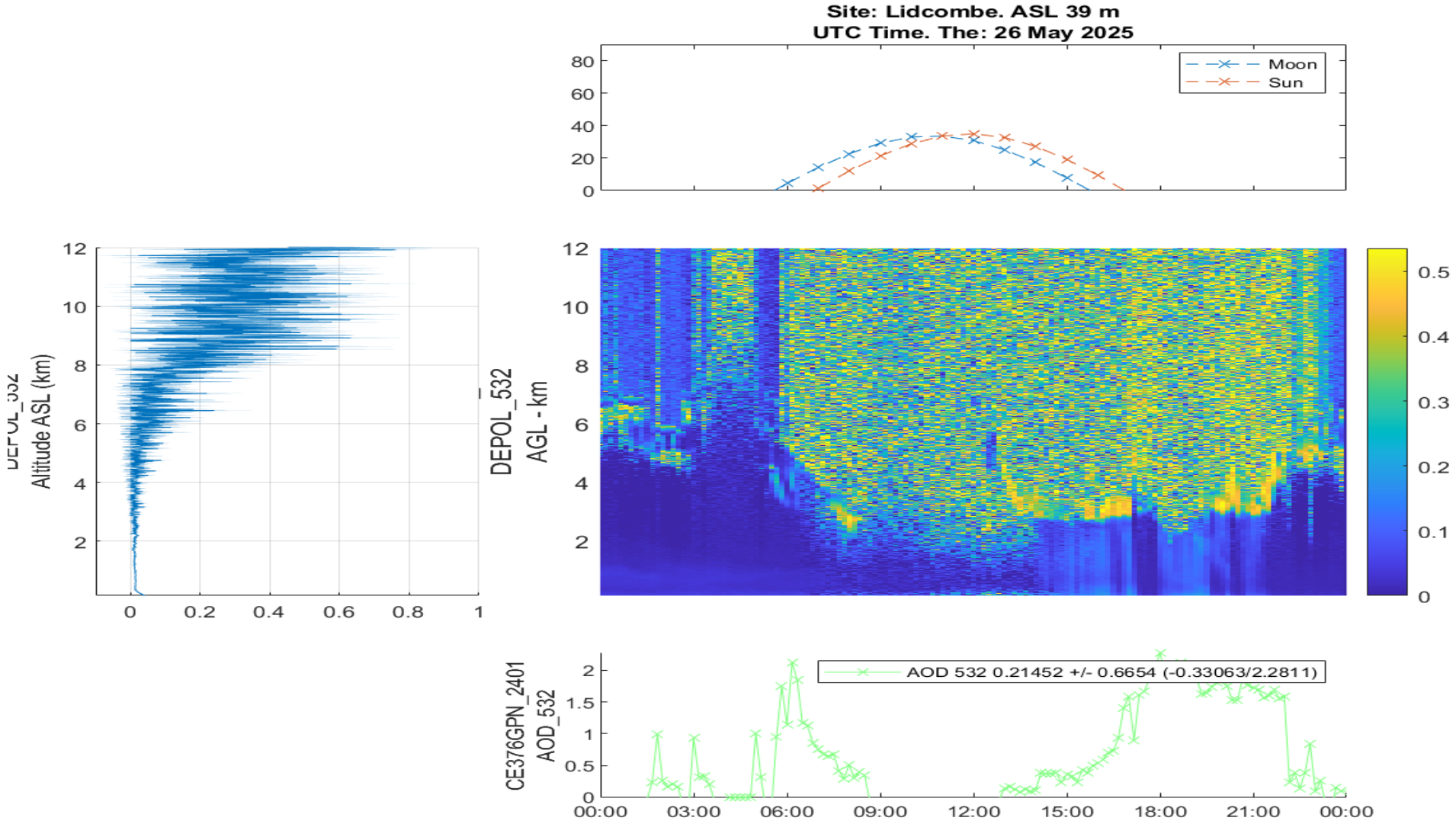
The yellow colour denotes the aerosol densities (in photons), the red colour line is cirrus cloud 3-5km. Noise reflection at night (UTC time) in the middle. **Dust plume lasted more than 10 hours on this day over Lidcombe**. (yellow band at the bottom below the noise layer)



Cimel MPL profile on 27 2025. PR2_532_cross (green)



Cimel MPL profile on **26 to 27** 2025. PR2_532_parallel. Circle shows the dust first appeared above Lidcombe and then a plume lasted for more than 10 hours)



Depolarisation ratio cross/parallel on **26 May** 2025. For dust 0.2 <Ratio < 0.6

Planetary Boundary Layer Height (PBLH)

- The netdcf files as exported from the Cimel iAAMS software, allow one to extract the lidar energy reflected signal (range corrected) over a daily period with 10 minutes time step this time step can be changed in the data acquisition software configuration).

- Also exported from iAAMS software are the daily PBLH text files containing the PBLH estimate for each of the 4 methods: Gradient method (GM), Log Gradient Method (LGM), Inflection Point Method (IPM) and Variance Covariance Method (VCM)

Planetary Boundary Layer Height (PBLH)

- The VCM is usually the best method for estimating the PBLH. But sometimes the VCM method is not stable, and its estimate is outside the range of plausible normal PBLH values.
- Hence the best estimate is chosen as follow: VCM is chosen first when the PBLH is estimated to be between 100m and 3500m.
- If it is outside this range, use then the LGM estimate when it is within the range (100m to 3500m).
- If none of these 2 methods estimates is within this range, then a median value of all the 4 methods is chosen

Planetary Boundary Layer Height (PBLH)

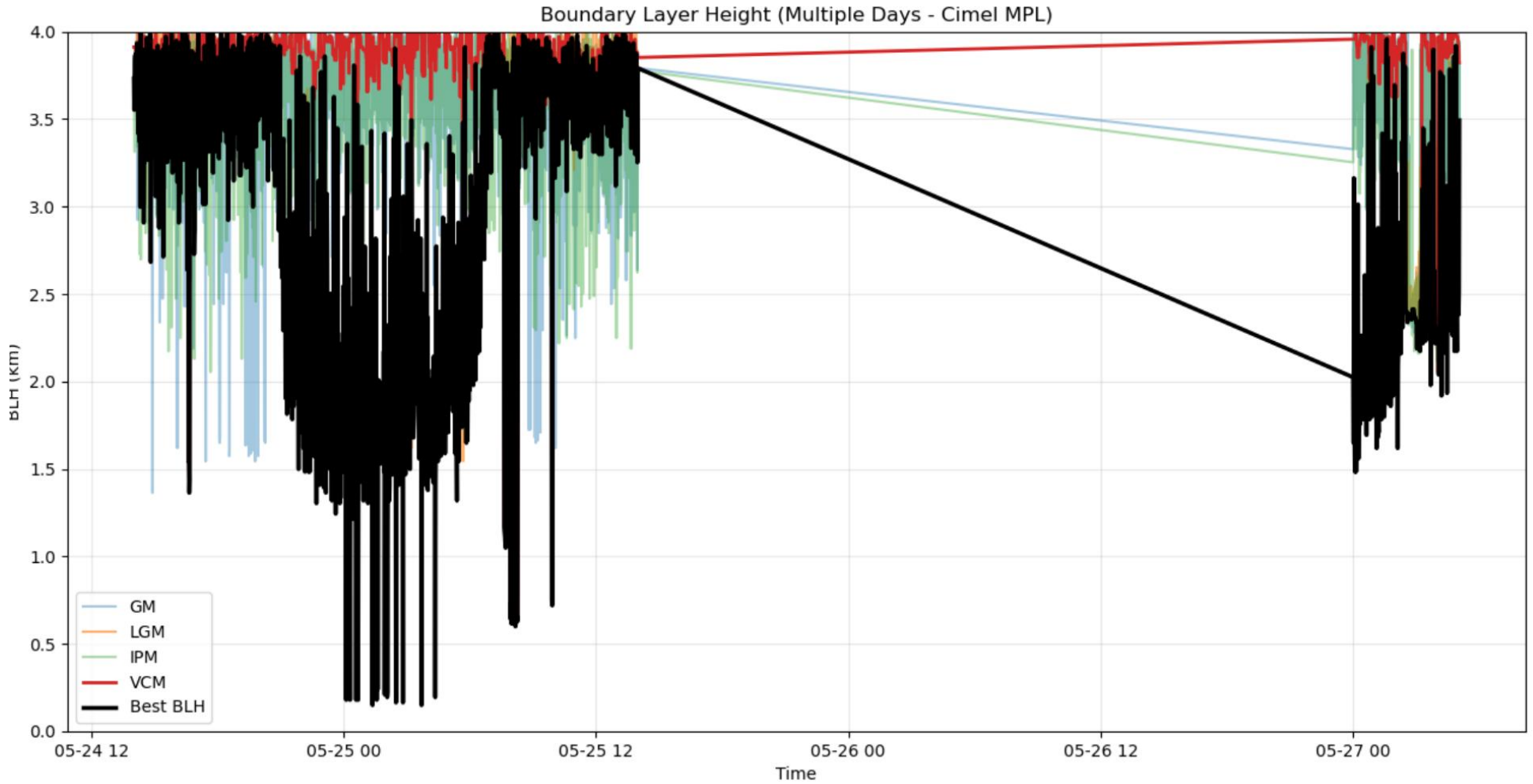


Figure 6 – Time series of PBLH from 24/5/2025 12:00 UTC to 27/5/2025 12:00 UTC as estimated by the 4 methods (GM, LGM, IPM and VCM) and the best estimate.

Planetary Boundary Layer Height (PBLH)

The time series of PBHL in Figure 8 shows a gap between about 25/5/2025 15:00 UTC to 27/5/2025 00:00 UTC due to high loading of aerosols in this period as shown by the strong reflected RCS.

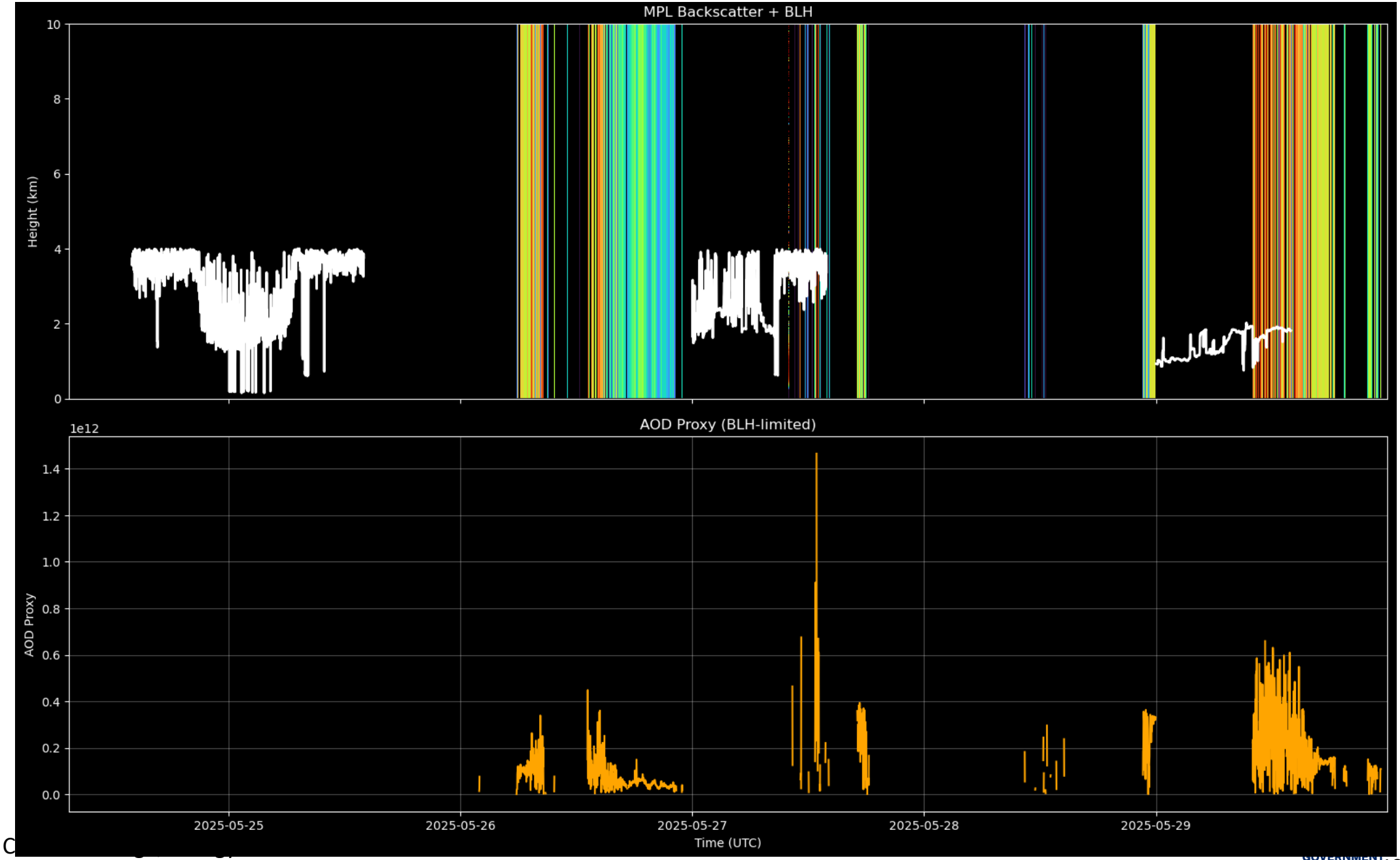
The algorithms in the 4 methods to estimate the PBLH cannot determine the boundary of the aerosols and hence no PBLH estimate can be found.

This can be seen by calculating the proxy AOD as shown next for the period from 24 to 31 May 2025. The top graph of Figure 9 shows the PBLH and the RCS “curtain” of reflected lidar signal while the bottom graph shows the corresponding calculated proxy AOD during this period.

Other strong RCS reflection such as due to rain or cloud also makes the algorithm to determine the PBLH fail in finding the boundary

Top:
Planetary Boundary Layer Height (PBLH) and Range Corrected Signal time series from 24 to 30 May 2025

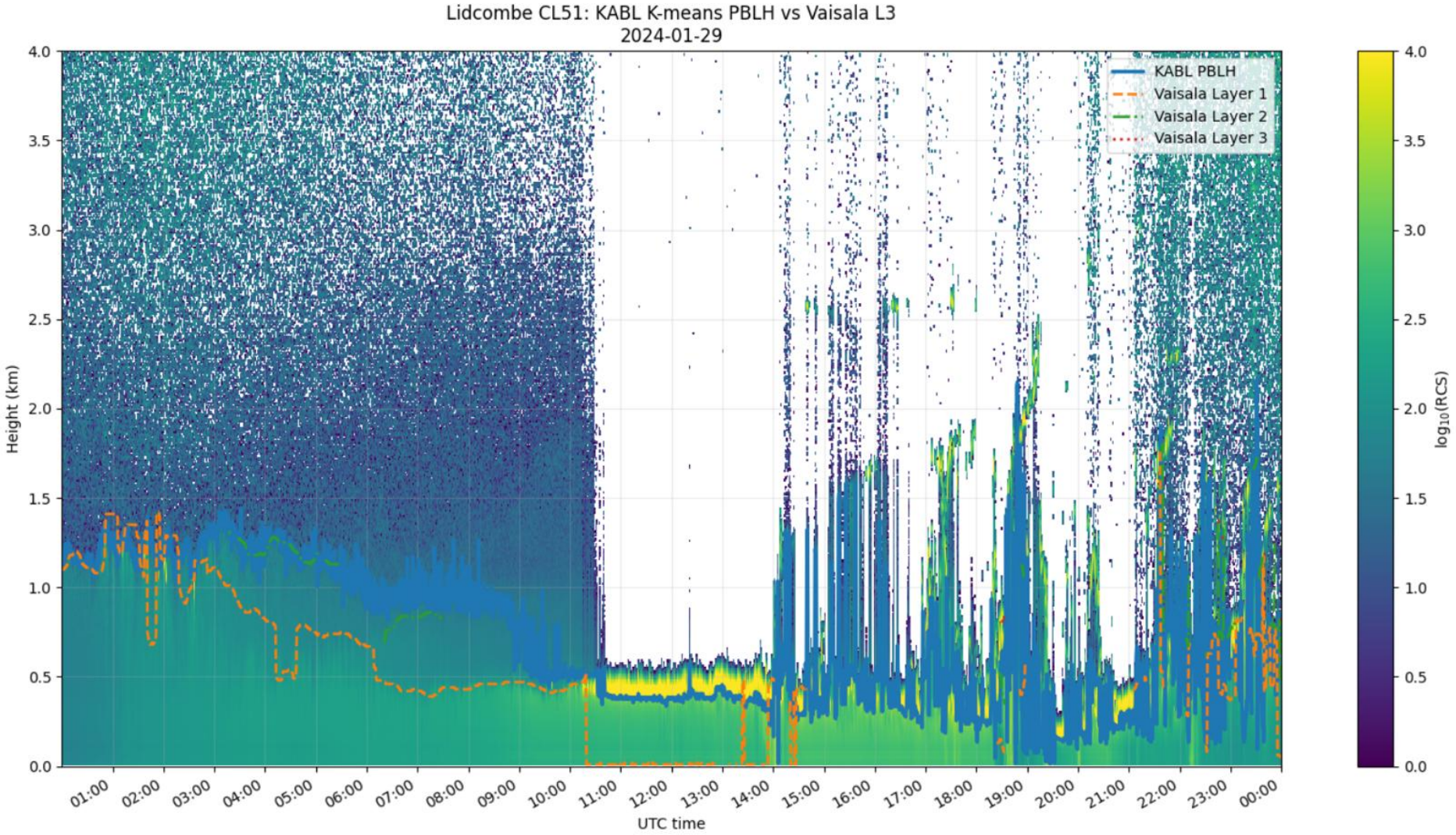
Bottom:
AOD from RCS



Manufacturer algorithm (Cimel) PBLH analysis

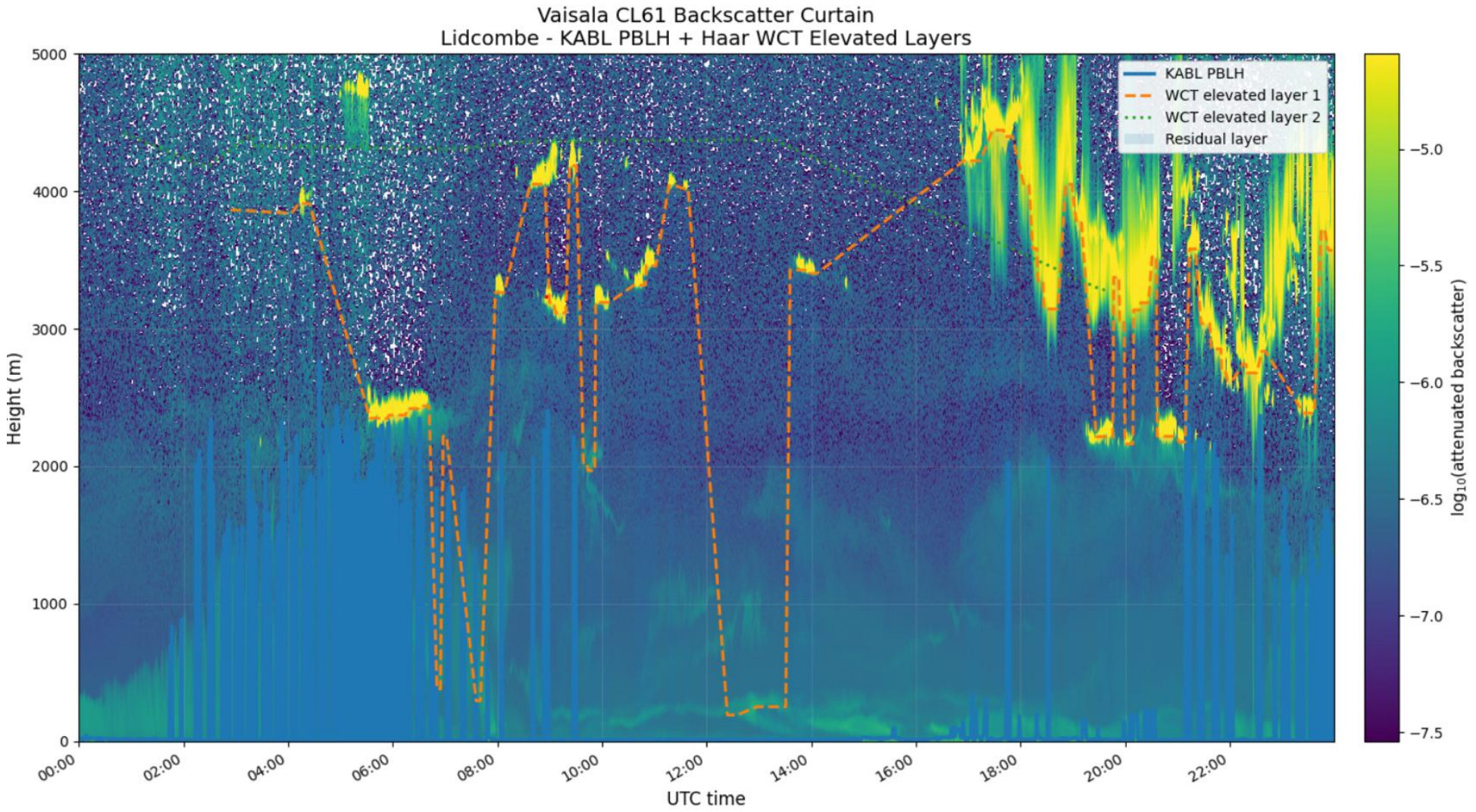
- Not guaranteed provide the best estimate of PHBL
- Other algorithms can be better
- KABL K-mean Atmospheric Boundary Layer – Publicly available Python package. This is ML based implementation for one single layer

Comparison with ceilometer Vaisala CL51



CL51 (PBLH) and RCS Range Corrected Signal at Lidcombe. Much lower maximum height ~ 2.5km

Comparison with ceilometer Vaisala CL61



CL51 (PBLH) and RCS Range Corrected Signal at Lidcombe 26/08/2026.

Lower maximum height ~ 4.5km

Conclusion

- Micro Pulse Lidar (MPL) enhances the upper air data to higher level in the stratosphere and with polarisation can distinguish the aerosol as from wildfire or from dust storm

- MPL complement with ceilometer which has a number of sites installed including the 3 sites in the Upper Hunter to support methane emission project to validate greenhouse estimates (CH4) from coal mines.

Conclusion

- The algorithms to determine the PBLH can give different PBLH estimates. A comparison and evaluation of the methods is desirable. Wavelet Covariance Transform (WCT) as well as ML-based methods is promising.

- Comparison of MPL measurement of Planetary Boundary Layer Height (PBLH) with that of the Vaisala CL61 ceilometer and prediction from air quality models such as WRF-CMAQ, WRF-Chem.