Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure
and Water Management*

Doppler wind lidar measurements during a thunderstorm at Cabauw, The Netherlands

Tiemo Mathijssen, Steven Knoop

On July 9th 2024, a code orange was issued by KNMI for severe thunderstorms in the whole of The Netherlands. Two long-range scanning Doppler lidars at the Cabauw atmospheric research site captured several aspects of the wind field before and during the passing of the storm. This includes wind profiles that show vertical layers, spatial structures in the wind field revealing wind gusts and very strong up- and downwards motion around the shelf cloud. This event shows that Doppler lidars can contribute to the observation of thunderstorms.

Thunderstorm 2024-07-09

On July 9th 2024, a low-pressure system moved northeast across the Irish Sea towards northern England. The accompanying warm front passed over The Netherlands during the night and morning of July 9th, bringing warm and increasingly moist air in a southeasterly flow. In the late afternoon and evening, the cold front reached the southwest and moved northeast across the country. Widespread thunderstorms developed along this cold front, and ahead of it, where the cold and warm air collided.

KNMI had issued a *code orange* for the entire country, warning for thunderstorms with gusts of wind, hail and heavy precipitation.

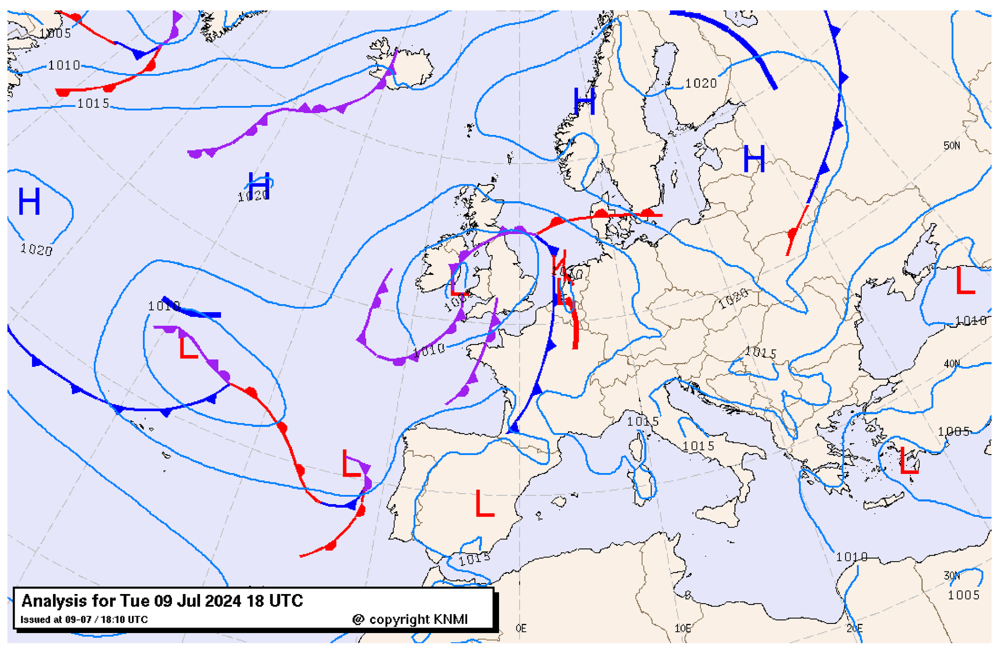

Figure 1: *Weather analysis for 2024-07-09 18 UTC (20:00 local time).*

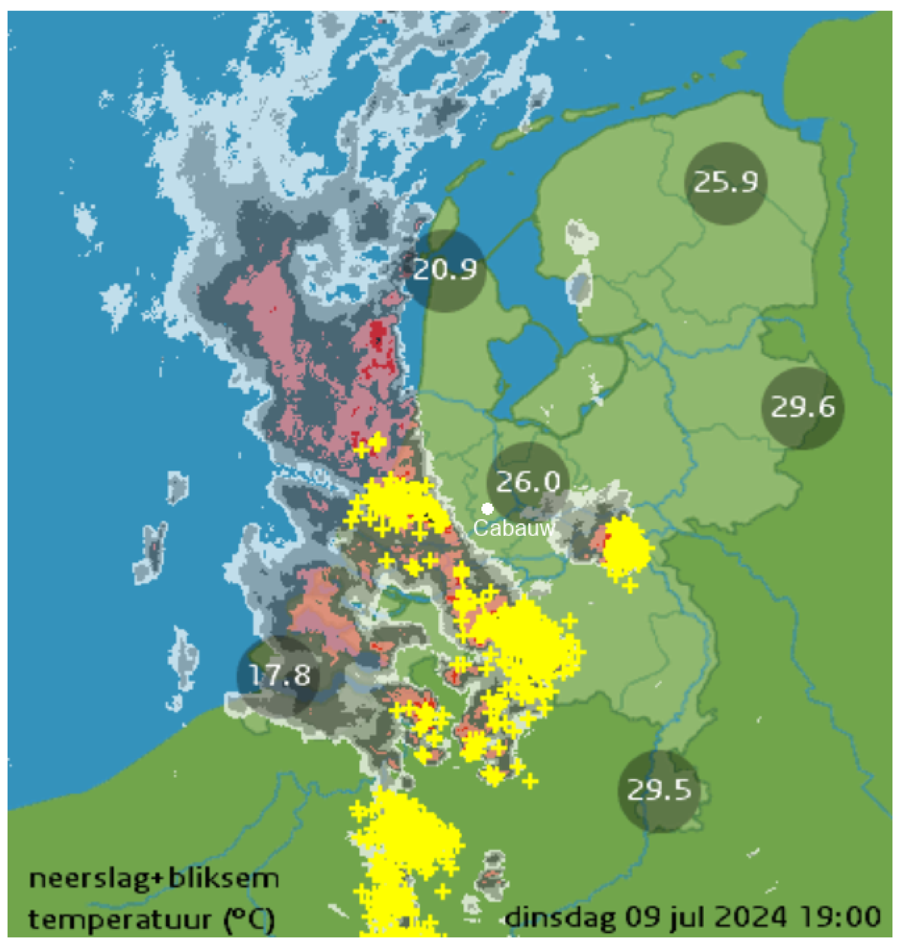

Figure 2: *Weather radar precipitation and lightning detection (yellow symbols) at 17:00 UTC (19:00 local time), half an hour before it started raining at Cabauw.*

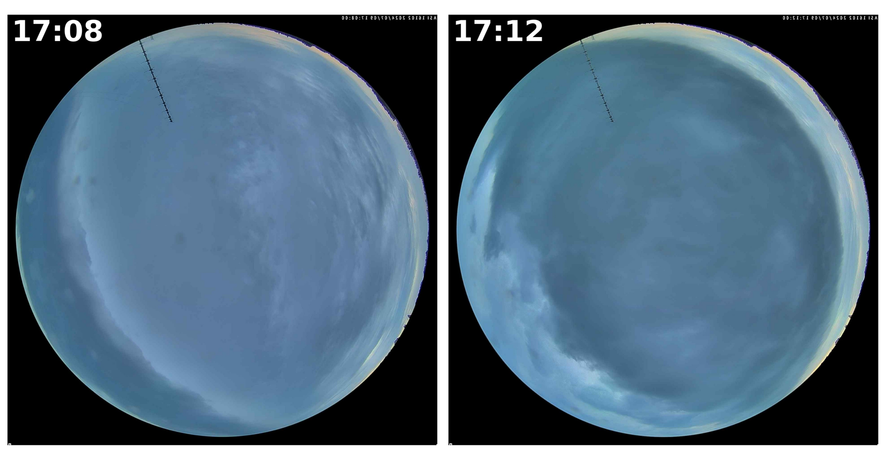

Figure 3: *Total sky imager at Cabauw shows the passing of the shelf cloud, entering on the left at 17:08 and leaving on the right side at 17:12 (time in UTC). See also figure 9.*

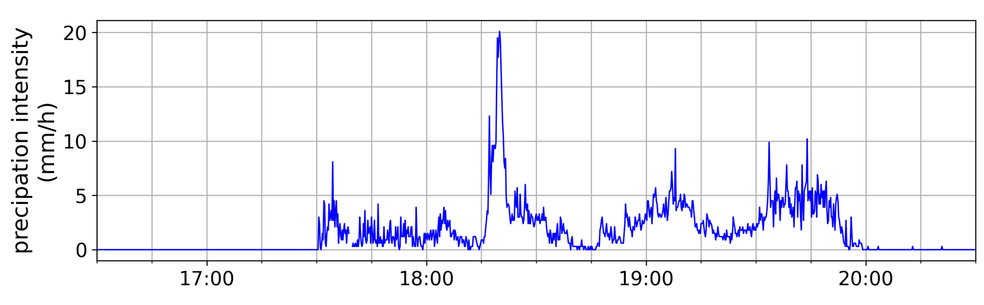

Figure 4: *Surface observation of precipitation intensity at Cabauw. Time in UTC.*

Doppler lidars at Cabauw

KNMI deploys long-range scanning Doppler lidars at the Cabauw atmospheric research site (Vaisala Windcube200S) since 2021 and at Amsterdam Schiphol Airport (Leonardo Skiron3D) since 2025. Theses instruments allow for unattended and continuous 24/7 operation, and data is collected in near-real time.

During the 2024-07-09 thunderstorm both Doppler lidars were operational at Cabauw. The Skiron3D was performing several scans in a cycle of 3 minutes: VAD scans for wind profiles, low elevation PPI scans for the horizontal structure and RHI scans for vertical cross section of the wind field. The Windcube200S performed a continuous vertical stare scan to measure the vertical velocity.

Figure 5: *Long-range scanning Doppler lidars at Cabauw: (left) Windcube200S, (right) Skiron3D. In the back the 213-m tall tower of Cabauw.*

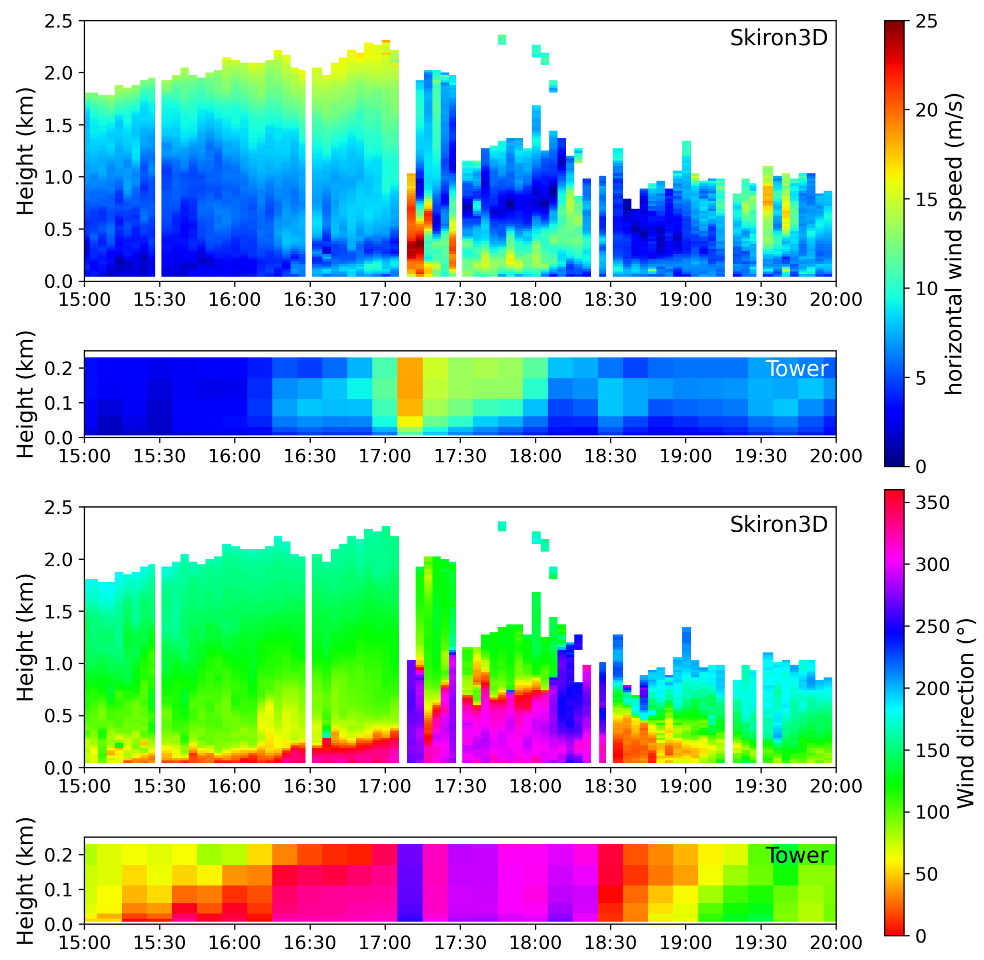

Figure 6: *Horizontal wind speed and wind direction determined from VAD scans of the Skiron3D and from in-situ measurements in the Cabauw tower.*

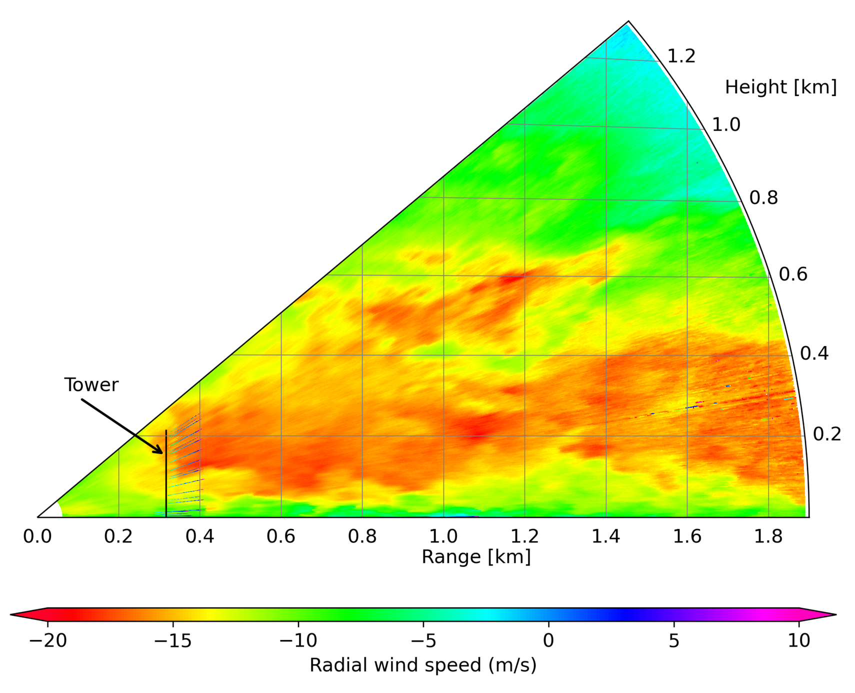

Figure 7: *Skiron3D: radial wind speed from the RHI scan at 320° azimuth angle at 17:14:21 UTC time. The duration of the scan is approximately 10 s. Areas of high wind speed are indicated in red.*

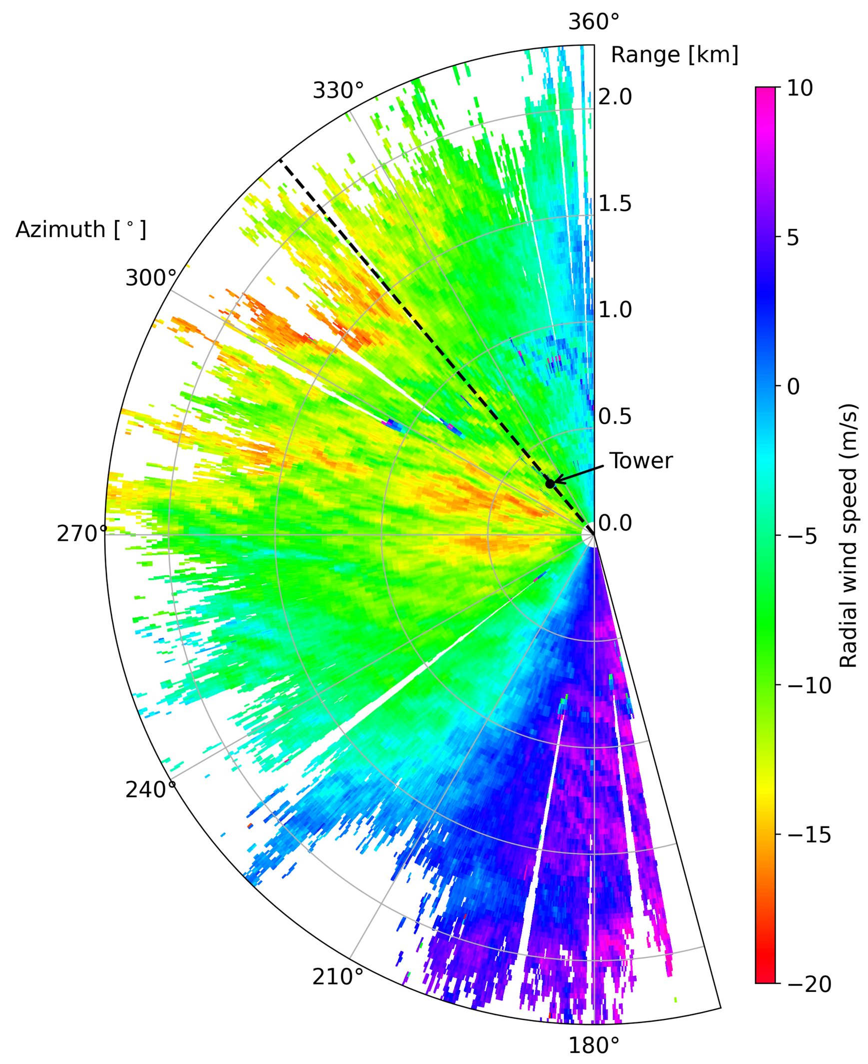

Figure 8: *Skiron3D: radial wind speed from the PPI scan at 0.5° elevation angle at 17:14:34 UTC time. The duration of the scan is approximately 32 s. The beam at 2 km range is at a height of 21 m and therefore the radial wind speed is related to the near-surface wind. The dashed line indicates the direction of the RHI scan shown in figure 7.*

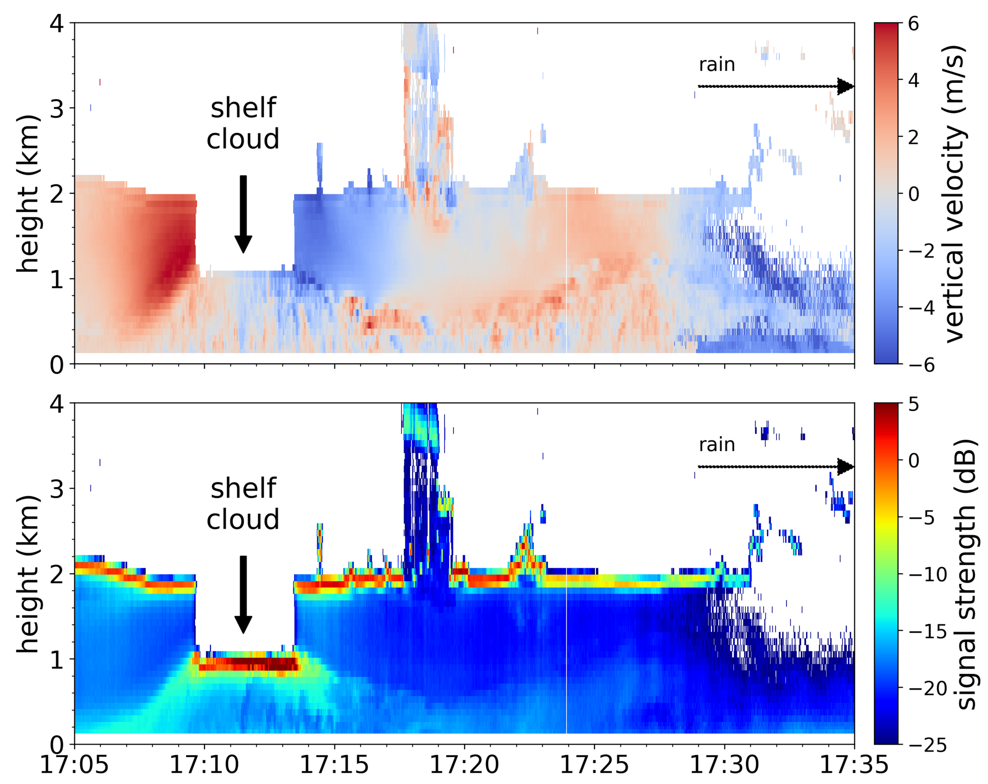

Figure 9: *Vertical stare measurements of the Windcube200S, showing the vertical velocity and signal strength (carrier-to-noise signal). The temporal and vertical resolutions are 1 s and 75 m, respectively. A signal strength of -5 dB or larger indicate the cloud base. Very strong upwards (downwards) motion before (after) the shelf cloud is observed.*

Summary & Outlook

Two long-range scanning Doppler lidars at Cabauw provided wind field observations during the 2024-07-09 thunderstorm. Wind profiles shows the different vertical layers and indicate wind shear. Even during the period of rain, wind data is retrieved. The horizontal and vertical cross sections of the wind field obtained by the low elevation PPI and RHI scans, respectively, provide insight in the spatial structure of the wind field and reveal areas of high wind speed. Continuous vertical stare measurements clearly show the very strong up- and downwards motion around the shelf cloud.

This work shows that Doppler lidars can capture several aspects of a passing thunderstorm, complementary to weather and cloud radars, and in-situ observations of wind.

Ruisdael observatory

Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands. Contact: tiemo.mathijssen@knmi.nl, steven.knoop@knmi.nl
Cabauw atmospheric research site is part of the Ruisdael Observatory (https://ruisdael-observatory.nl/). The Skiron3D Doppler lidar is supported by aviation.