Contribution of personal weather stations for observing deep-convection features near the surface

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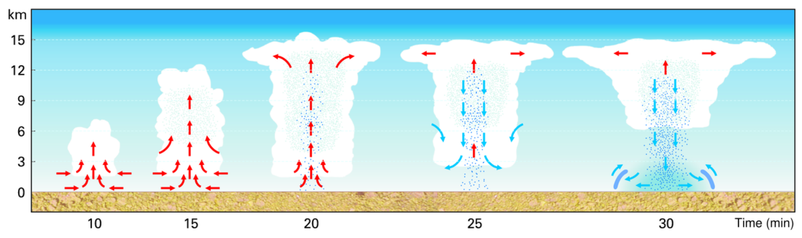
INTRODUCTION



Life cycle of an individual convective cell. Adapted from Malardel [1].

- Rapid changes in temperature, humidity, pressure, wind and precipitation near the surface caused by **thunderstorms** are observed by weather stations.
- Standard weather station (SWS) networks, deployed by national meteorological and hydrological services, miss out on some of these changes, particularly those smaller than the meso-γ-scale (2–20 km).
- The Internet of Things (IoT) makes it possible to get observations from many personal (or citizen) weather stations (PWSs), that do not necessarily comply with WMO standards regarding sensor quality or siting.
- To what extent could PWS observations combined with SWS observations help us to observe more accurately the rapid changes associated with the life cycle of deep convection near the ground?

PERSONAL WEATHER STATION OBSERVATIONS

Personal weather stations (PWSs)

- Large PWS observation datasets are provided by:
  – **weather stations sellers**: companies such as Netatmo, Davis Instruments, etc.
  – **aggregators**: companies such as Weather Underground; weather enthusiasts associations such as Infoclimat in France; meteorological services such as the Met Office with the Weather Observations Website.
- These sources disseminate and display observations via application programming interfaces (APIs) and websites.

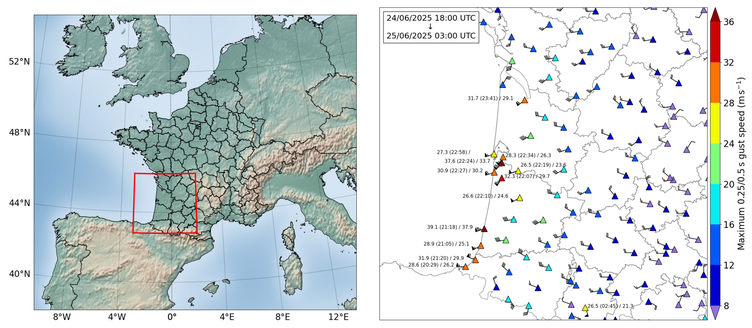
From left to right, some popular PWSs: the Netatmo "Smart Home Weather Station" with the "Smart Rain Gauge" and the "Smart Anemometer", the Davis Instruments "Vantage Pro2" and "Vantage Vue", and the Tempest "Home Weather Station".

Quality control (QC)

- Quality control of PWS observations was shown to be crucial for at least some brands: analyses incorporating raw Netatmo PWS observations of temperature, relative humidity and pressure are objectively degraded [2].
- Multiple QC algorithms exist in the literature, such as Titan [3, 4]. Most of them are based on spatio-temporal comparisons with references, such as neighbouring observations, analyses, or short-term forecasts.
- The MC20 [2] algorithm controls temperature, relative humidity and pressure. It is based on comparisons mostly with SWS observations. It was designed to deal with large physical changes caused by deep convection, and it doesn't consider that the majority of all PWS observations are right even if this leads to filtering out a large proportion of observations.

In the following, PWS observations refer to as Netatmo PWS observations, quality-controlled by the MC20 algorithm.

OBSERVATIONS ON THE SQUALL LINE CASE OF 24–25 JUNE 2025



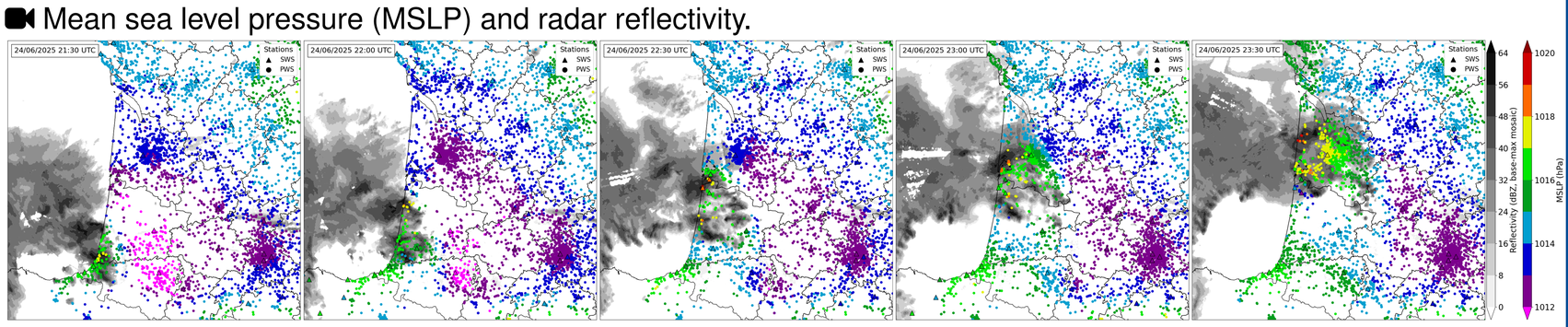
(Left, red) Area of study. (Right) Maximum 0.25/0.5 s gust speed and direction (coloured triangles in m s^{-1} and barbs in kt) observed between 18:00 and 03:00 UTC on 24–25 June 2025. Text indicate the maximum 0.25/0.5 s gust speed, the time of this maximum, and the maximum 3 s gust speed.

- A squall line formed over Spain and propagated northwards.
- 0.25 s gust speed of 37.6 m s^{-1} at 22:24 UTC and 3 s gust speed of 33.7 m s^{-1} at 22:26 UTC observed in Cazaux at 10 m height AGL.
- 2 injured by a falling tree, 4000 households left without electricity and 37 rescue operations carried out by 170 rescuers [5].

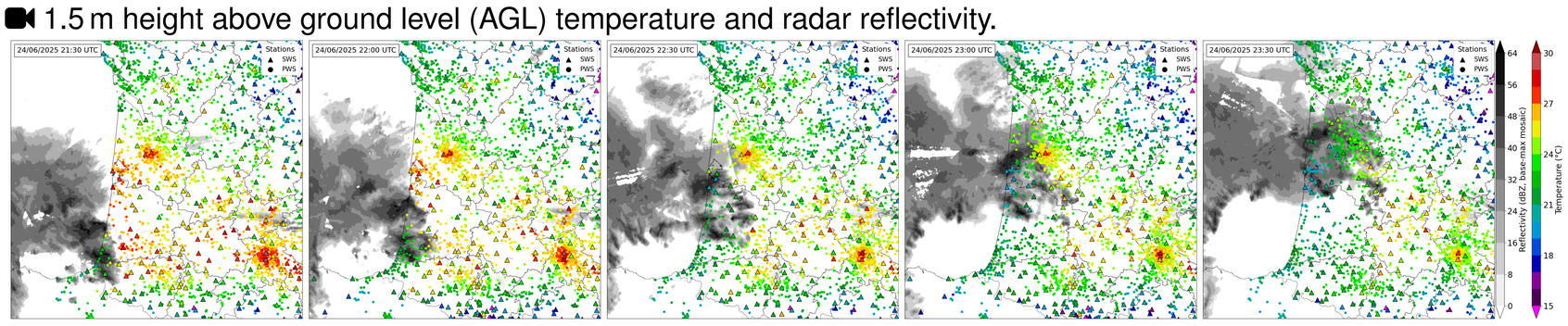
Contribution of PWS observations

- The complex structure of the MSLP field is revealed with two mesohighs and a mesolow at the rear of the squall line.
- MSLP gradients up to 4 hPa $\times$ (16 km)$^{-1}$ are observed at the leading edge of the squall line.
- Spatio-temporal evolution of MSLP, temperature and relative humidity are observed with more detail than with SWS observations only.

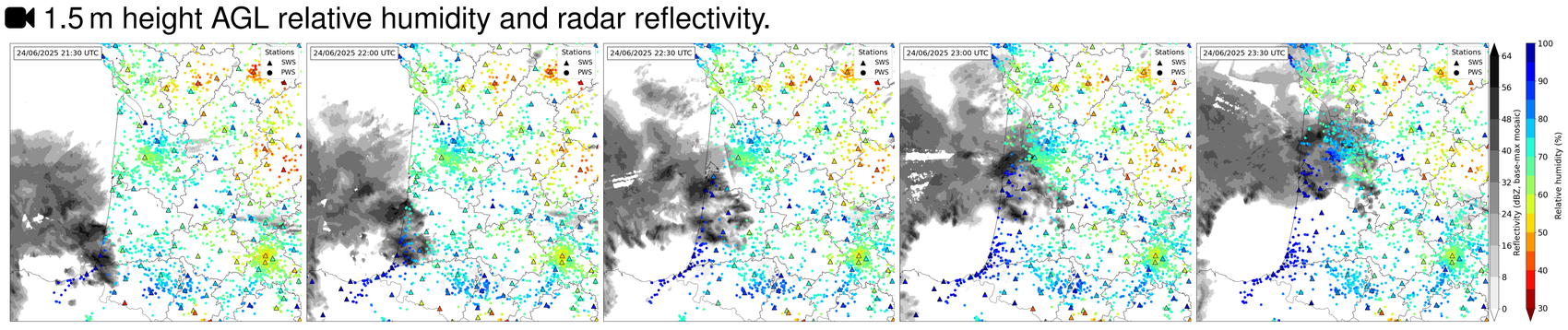
Mean sea level pressure (MSLP) and radar reflectivity.



1.5 m height above ground level (AGL) temperature and radar reflectivity.



1.5 m height AGL relative humidity and radar reflectivity.



ONGOING AND FUTURE WORK

European collaboration

- An ECMWF-EUMETNET project called "IoT observations for numerical weather prediction" has been launched to negotiate with data providers, collect and exchange data.
- Since the summer of 2025, PWS observations, primarily from Netatmo and Infoclimat, have been disseminated in real time through the EUMETNET OASIS API.

	Stations	Pressure	Temperature	Relative humidity	Rainfall	Wind
Count	313 301	312 228	246 962	246 909	103 261	51 530
% of stations		99.7 %	78.8 %	78.8 %	33.0 %	16.5 %

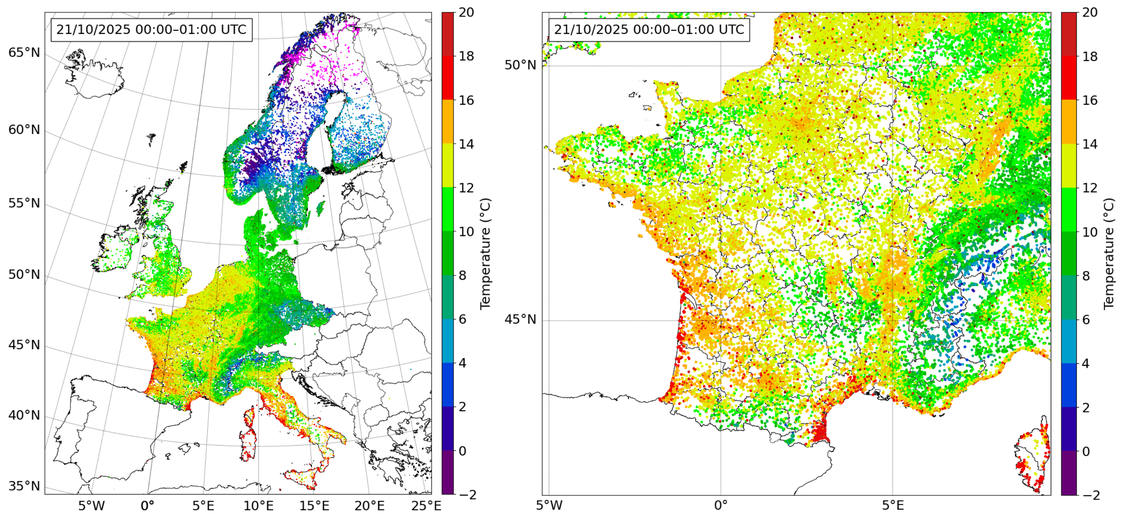
Statistics for observations received on 21 October 2025, between 00:00 and 01:00 UTC. The station count is the number of unique identifiers. The count for each variable is the number of stations that emitted at least one observation.

Objective comparison of MC20 with others QC algorithms over a long period

- Evaluation with a separation between stormy and non-stormy days.

Benefits of the assimilation of PWS observations in the AROME-France model

- Evaluation with the new 4DEnVar system, following on from Demortier et al. [6, 7].



Observations of temperature disseminated through the EUMETNET OASIS API over (left) Europe and (right) France and neighbouring countries on 21 October 2025 between 00:00 and 01:00 UTC.

REFERENCES AND ACKNOWLEDGEMENTS

[1] Malardel, S. *Fondamentaux de météorologie 3e édition*. Cépaduès, 2022.
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[4] Coney, J. et al. "How useful are crowdsourced air temperature observations? An assessment of Netatmo stations and quality control schemes over the United Kingdom". *Meteorological Applications* 29.3 (2022). DOI: 10.1002/met.2075.
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