The L-WAIVE campaign over the Annecy lake: An analysis of water vapor variability in complex terrain

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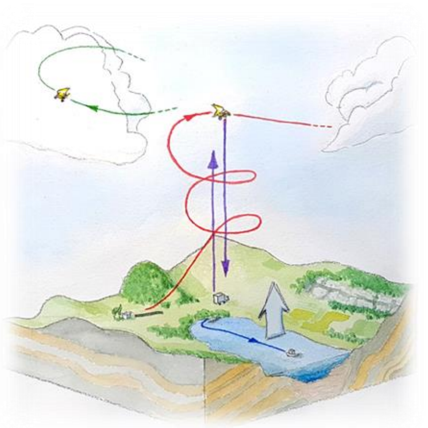
The L-WAIVE field campaign

The field campaign held from 10 to 24 June, 2019

Scientific objectives:

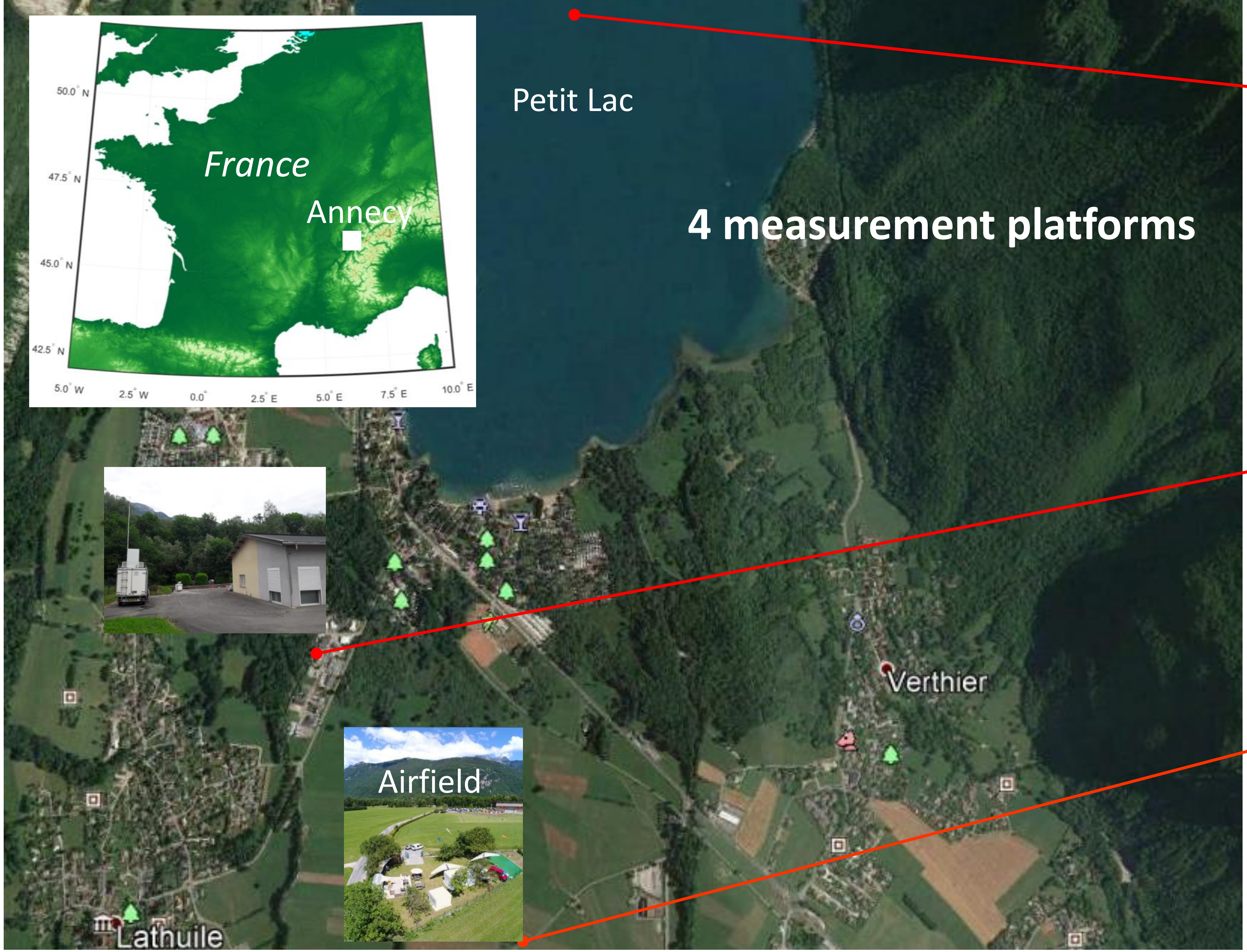
- **Study evaporation processes and their heterogeneity over the Annecy lake, as case study**
- **Test an original approach to measure water isotopes: H_2O, HDO and $H_2{}^{18}O$**
- **Investigate the link between aerosol layers and water vapour at different altitude levels**
- **Construct a reference isotope profile database for a ground/airborne/satellite lidar simulator**



The measurements:

- Vertical profiles of HDO, $H_2{}^{18}O$ and $H_2{}^{16}O$ via Picarro on board an ultra-light aircraft (ULA)
- 2D/3D structure of the low troposphere via a polarized Rayleigh-Mie lidar onboard an ULA
- HDO and $H_2{}^{18}O$ inside and at the surface of the lake via an instrumented boat: sampling by vials on the water surface film and underneath, laboratory analysis
- Vertical profiles of temperature, PH, O_2 and conductivity inside the lake (from 0 to ~-50 m)
- Vertical profiles of atmospheric water vapour mixing ratio, temperature and aerosols via Raman lidar
- Vertical profiles of temperature, relative humidity and pressure via meteorological probe onboard ULA
- Vertical profiles of temperature, relative humidity and pressure in the surface layer via meteorological probe on board drone
- Surface albedo and visible fluxes via pyranometers onboard ULA
- Particle size distribution from FIDAS onboard ULA
- Vertical profile of the wind direction and intensity from a ground-based wind lidar

Field experiment over the « Petit Lac d'Annecy »



x2

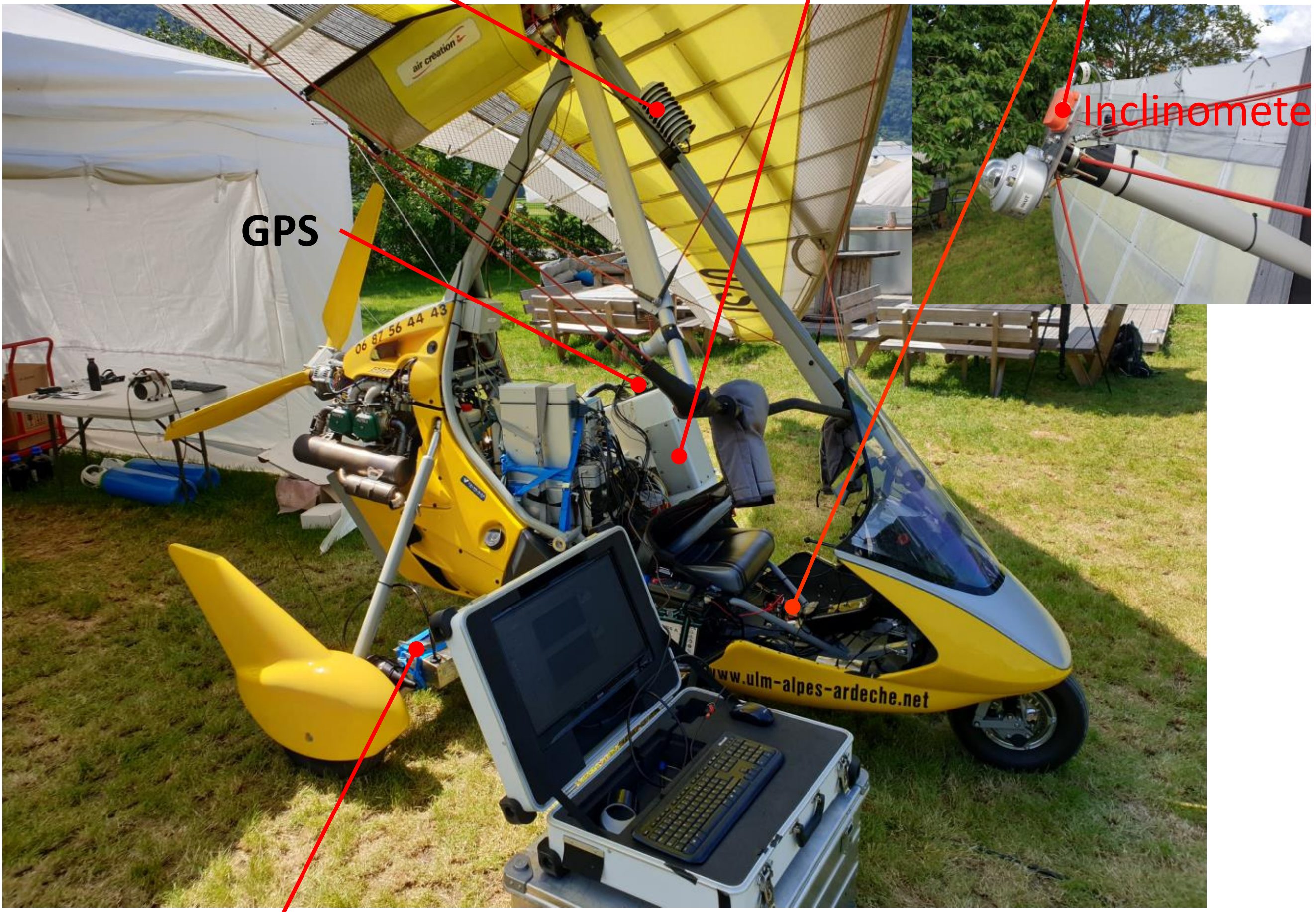
ULA payloads

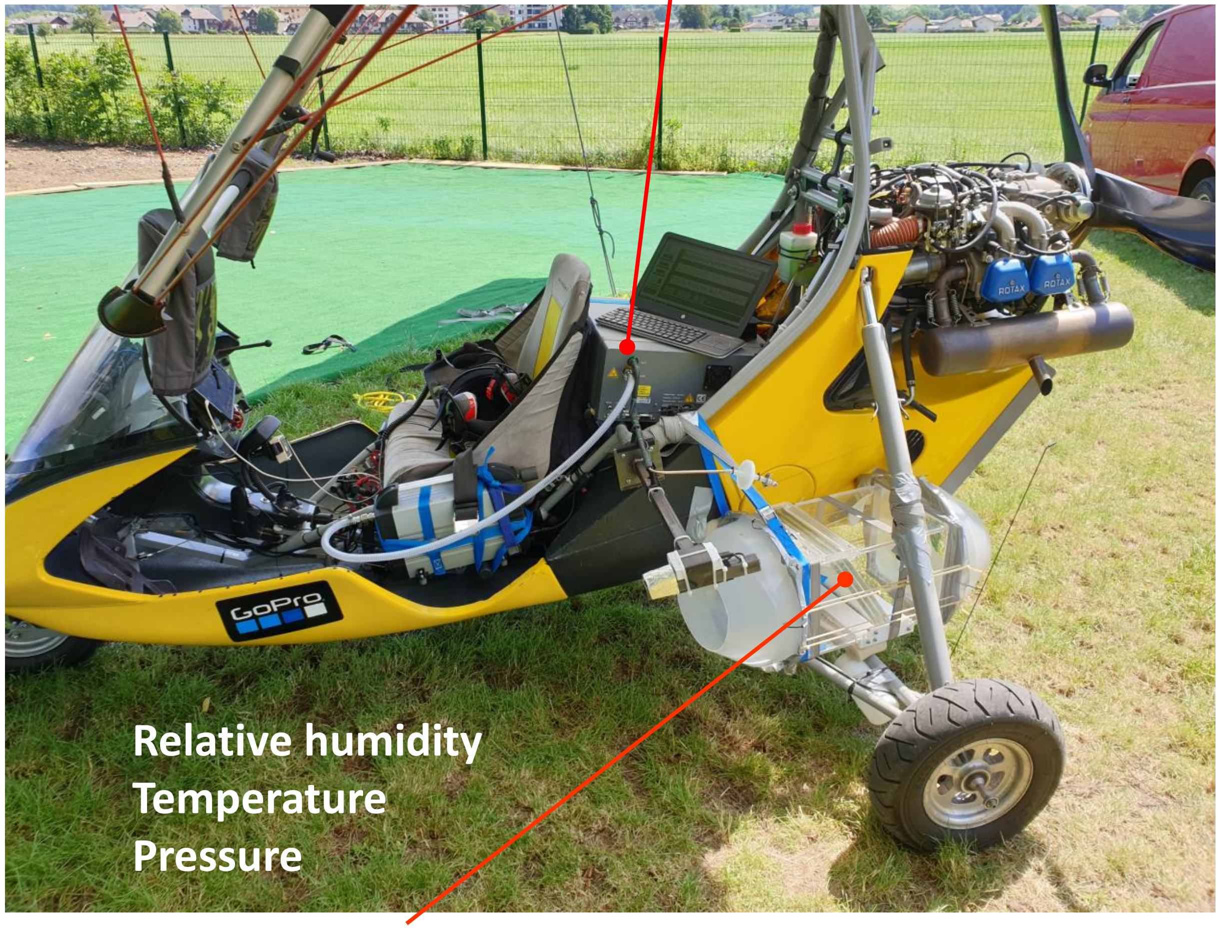
Relative humidity
Temperature
Pressure

Rayleigh-Mie Lidar

Pyranometers
(Upward and
downward
visible fluxes)

Picarro
Water vapor stable isotopes: H_2O, HDO et $H_2{}^{18}O$

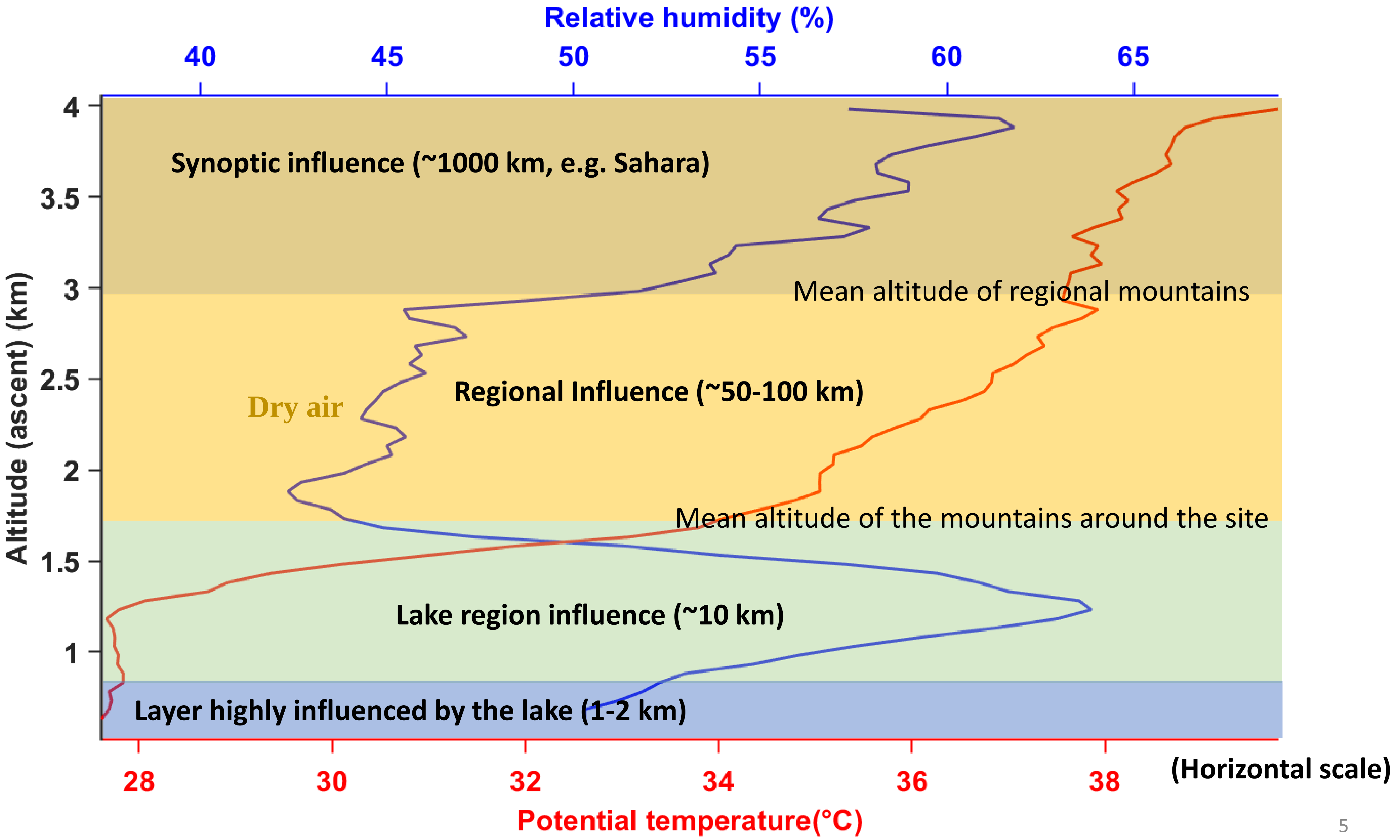




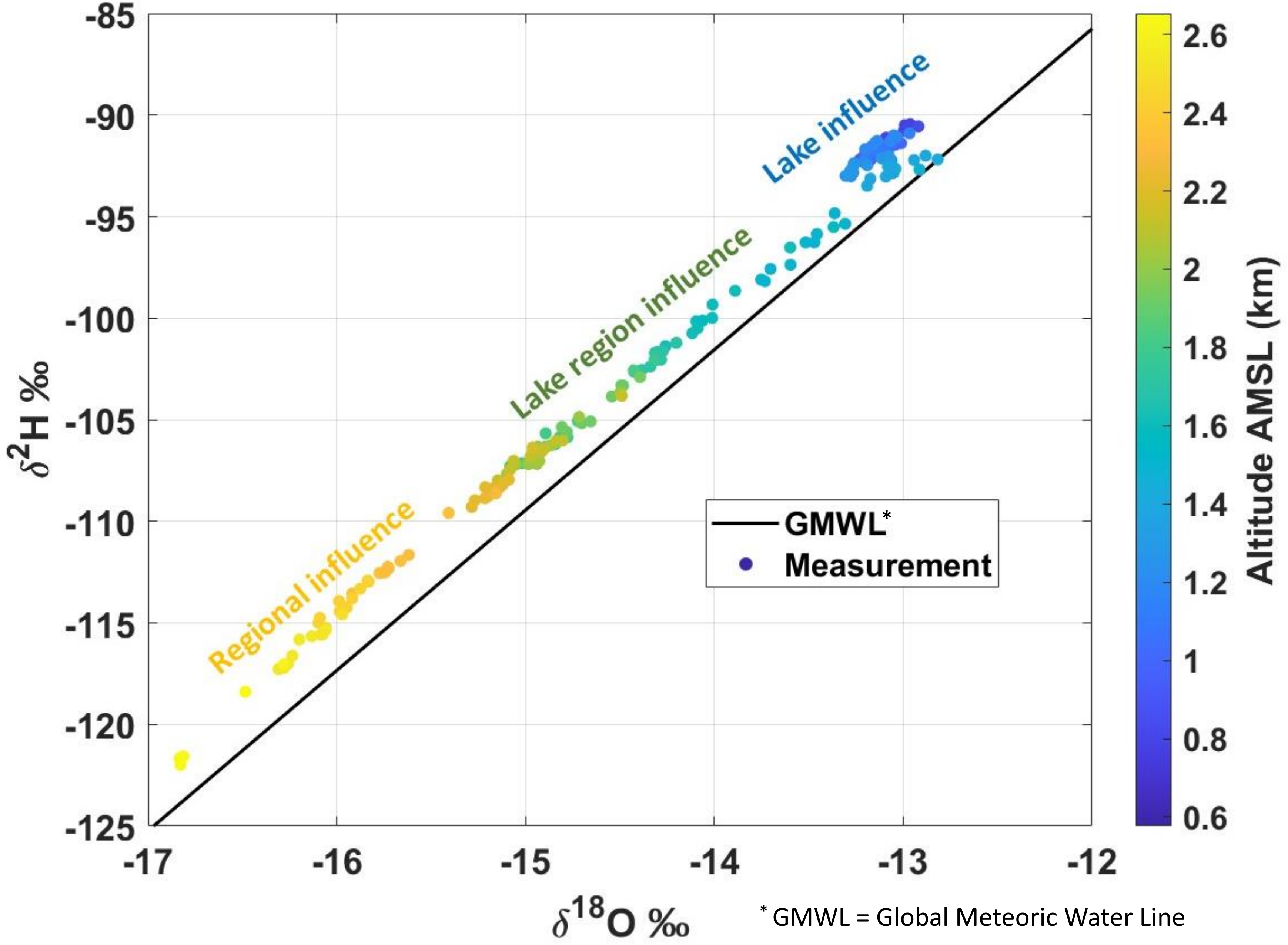
Particle sizer (FIDAS)

Pre-cleaned Caltech Active Strand Cloud Water Collector (CASCC), modified to efficiently collect cloud water at the airspeed of the ULA

Typical vertical structures above the Annecy lake (example on 14 June 2019)



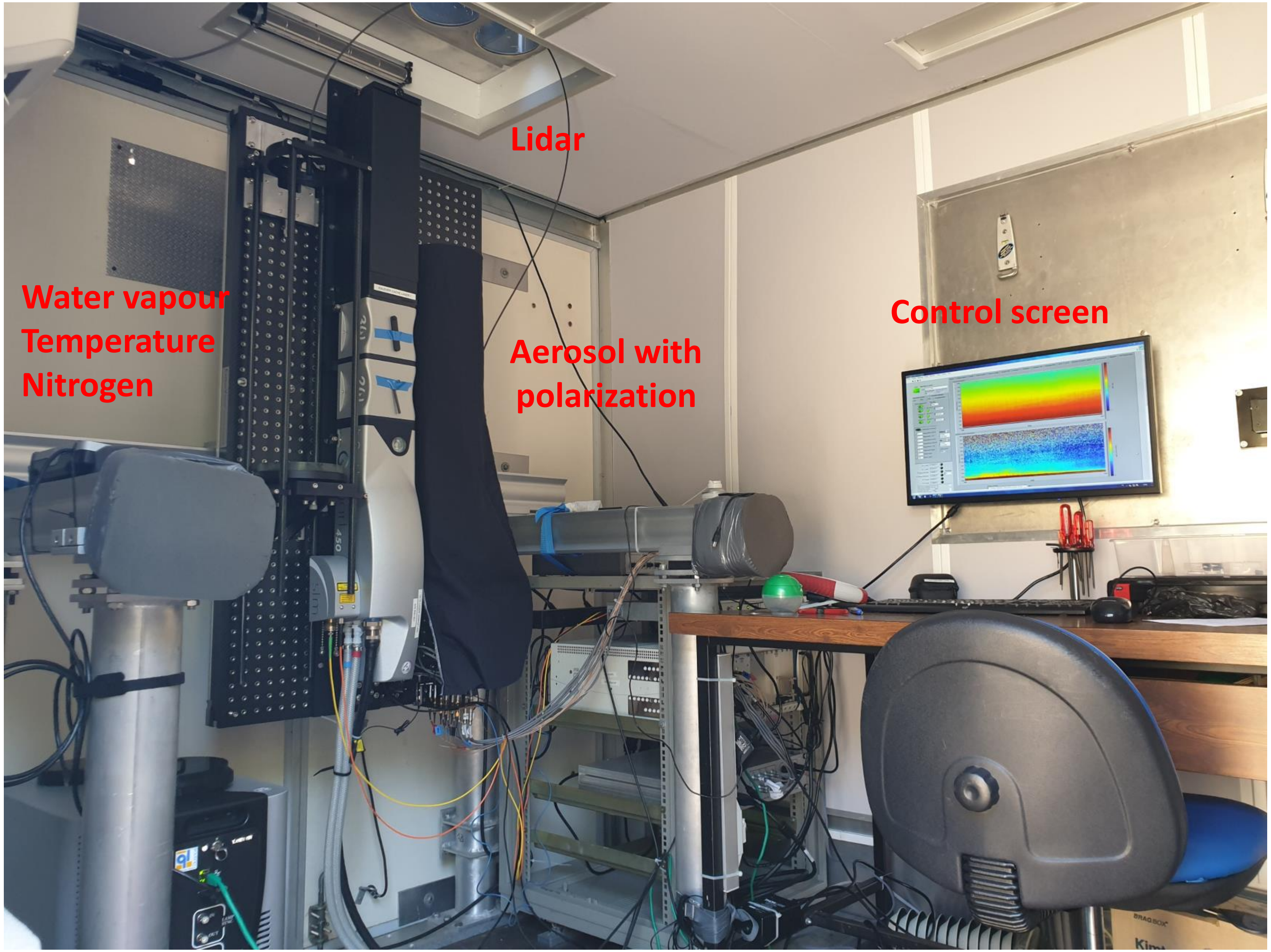
Example of ULA flight on 14 June 2019



* GMWL = Global Meteoric Water Line

Isotopic ratios seem to depend on the area of influence.
Evaporation from the lake and grassland, evapotranspiration from coniferous forest occur in the local area (1).
The intermediate area (2) is probably influenced by the vegetation evapo-transpiration and the lake, while the regional air (3) is partly influenced by the Mediterranean basin.

Scientific Facility at the technical department of Lathuile



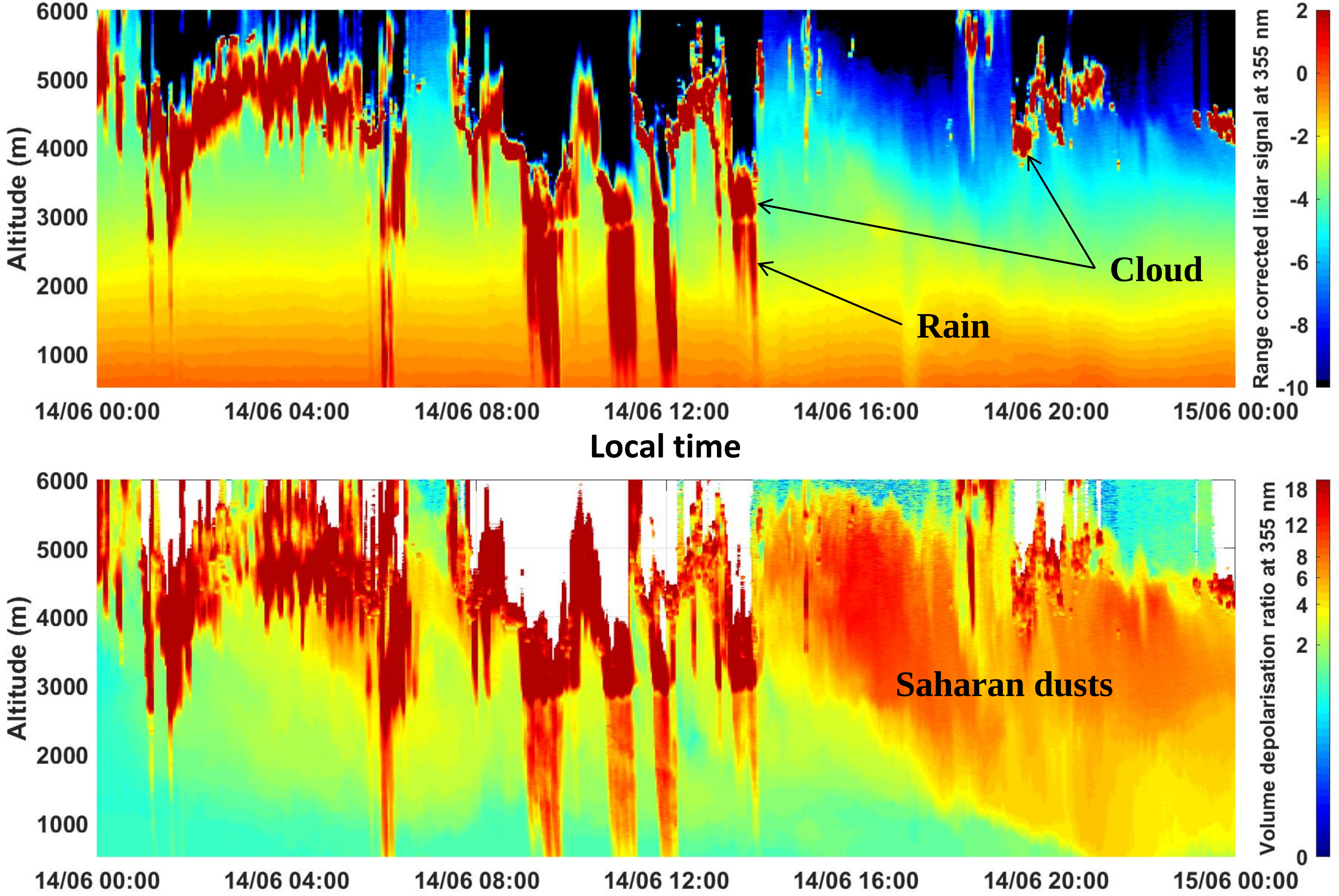
Laser electronic

Acquisition unit

Wind lidar

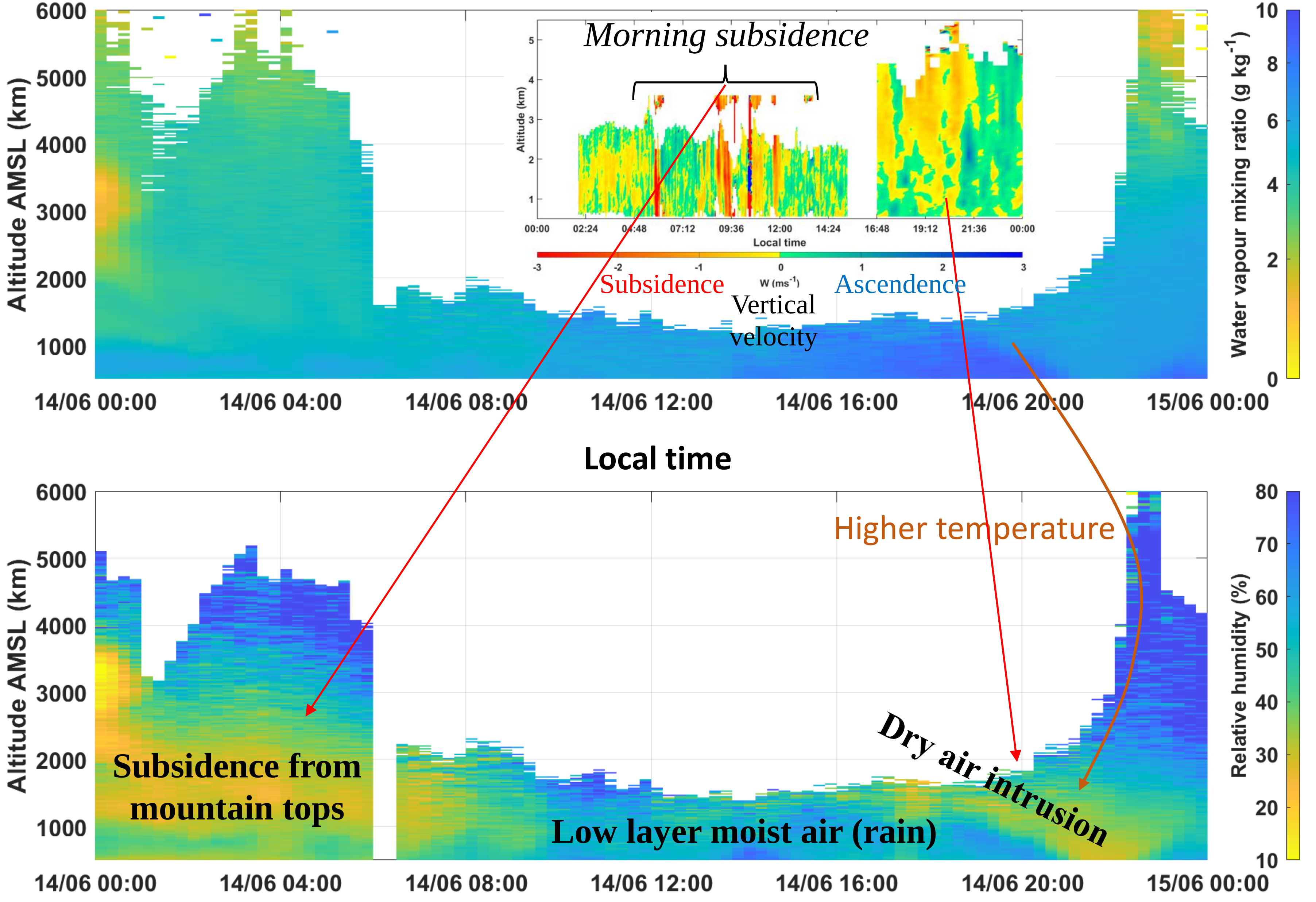
Drone with GPS, water vapour, temperature and pressure

Example of lidar-derived aerosol sampling on 14 June 2019



The spatio-temporal location of aerosols by lidar makes it possible to identify the presence of air masses of potentially different origins and therefore with a different moisture history.

Example of lidar-derived moisture on 14 June 2019



The intrusion of dry air (RH < 30%) ~20h LT is linked to the arrival of the desert dust episode.

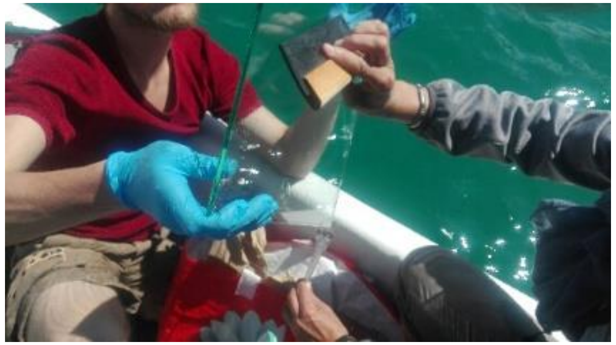
During night time, the dry air is associated with the subsidence of the high altitude air flowing from the surrounding mountain tops.

Ship-borne plateform equipped with atmospheric and sub-surface instruments

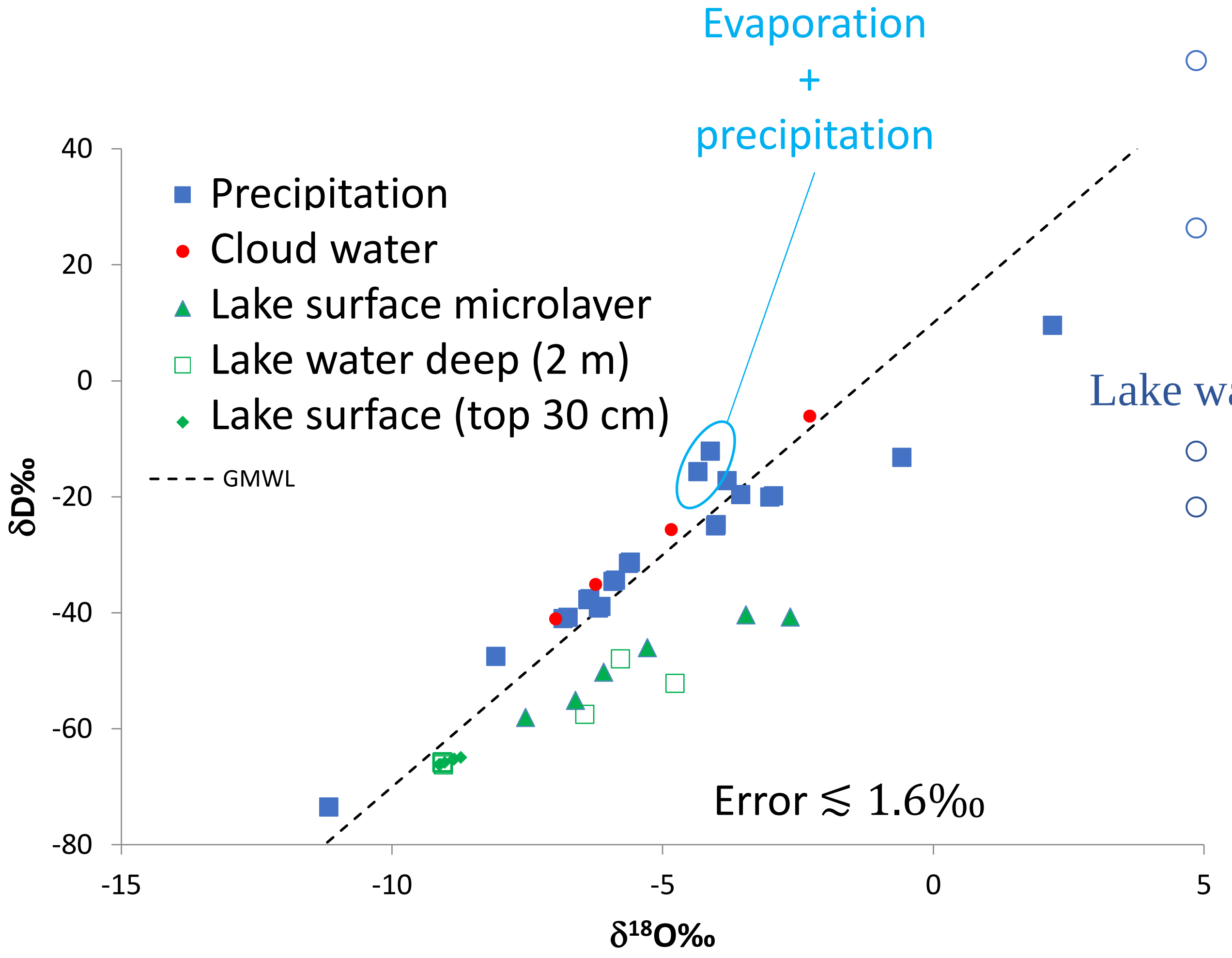
Mainly samples of surface water and at 2 m depth
Measurements of water isotopes in the air above the lake (~20 cm and 2 m)

Lake water collection : 3 types of samples

Deep water samples	Collected at 2m deep in amber glassware capped vials
Surface samples	A 30 x 30 cm glass plate is immersed into water for a minute, then slowly removed from water vertically. The water falling in a continuous flow is not sampled. Then, the dropwise water is collected in HDPE capped flaks
Surface microlayer samples (photo)	After the above procedure, the remaining water (on both faces of the glass plate) is sampled using a rubber scraper in amber glassware capped vials



Isotopic ratios of water samples

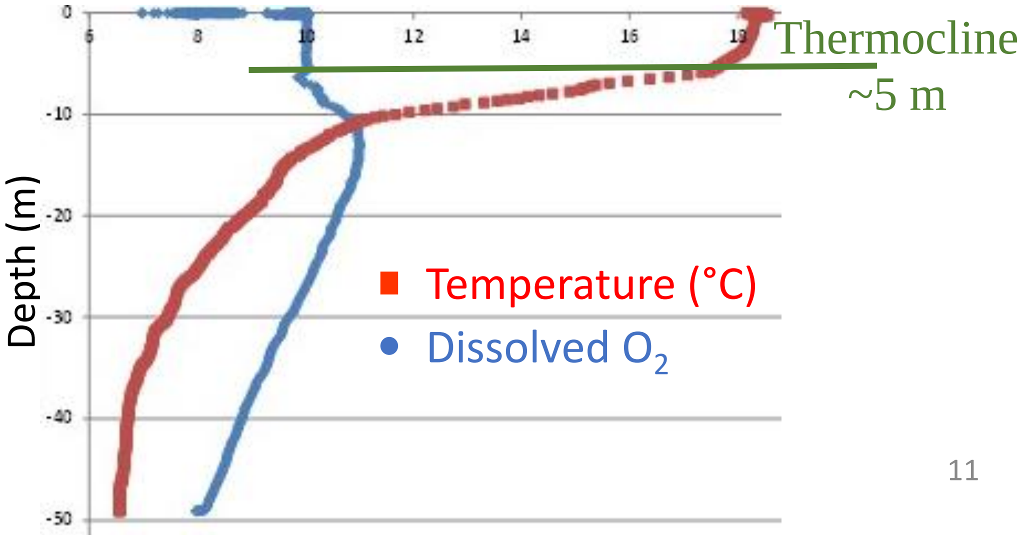


Cloud water and precipitation:

- The 4 cloud samples are on the GMWL - Global Meteoric Water Line. This may indicate thermodynamic equilibrium. This also validates the sampling protocol elaborated during the campaign.
- Very good agreement between cloud water and precipitation samples, both close to the GMWL line except for the highest values in precipitation.
- the highest values in precipitation are significantly lower than the GMWL line, probably due to evaporation process of rain droplets. (heavy isotope enrichment d^{18}O)

Lake water:

- Samples taken close to the surface are affected by evaporation
- No difference between surface and 2 m samples (mixing in the uppermost layer above the thermocline)



Water samplings

Sampling (Vol. collected)	Date (June 2019)	pH	Conductivity (µS/cm)
Cloud water (44 – 50 mL) collected at 2.5 to 3 km of altitude	20 and 21	6.5 – 7.2	-
Rain « dusty » (23 mL)	14 morning (4h UTC)	7.6	53
Rain « dusty » (313,4 mL)	15 morning	7.41	23
Rain (and hail) « clean » (343,8 mL)	15 afternoon	6.08	9
Rain « clean » (400 mL)	21-22 Night	6.85	53
Lake water (7 samples)	13, and 16 to 21	8.28 – 8.51	285 - 362

- Cloud and rain: substantial influence of the dust event (non-polluted water pH ~5.6)
  (chemical content analysis on-going)

- Lake water: typical of unpolluted lake

Perspectives

- ❑ Complete the data analysis using the synergy between the different experimental platforms, e.g. assess how much equilibrium there is between cloud/rainwater and water vapour.
- ❑ Set initial conditions for water vapour isotope DIAL simulator for airborne and spaceborne missions.
- ❑ Use conclusions for the construction of two new campaigns over an industrial site and in the Norwegian fjords (Bergen).

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