Università degli Studi della Basilicata
Scuola di Ingegneria

HyMeX-SOP 1 IOP 8 - Combined use of Raman lidar measurements and MESO-NH model simulations for the characterization of complex water vapour field structures and their genesis

Paolo Di Girolamo[1], Marie-Noelle Bouin[2], Cyrille Flamant[3]

[1] Scuola di Ingegneria, Università degli Studi della Basilicata, 85100 Potenza – Italy , email: paolo.digirolamo@unibas.it

[2]Météo-France /CNRM, 29280 Plouzané, France email:nbouin@ifremer.fr

[3]LATMOS/IPSL, UPMC Univ. Paris 06 Sorbonne Universit´es, UVSQ, CNRS, Paris, France

As part of the Cevennes-Vivarais site, the University of Basilicata Raman lidar system (BASIL) was deployed in Candillargues and operated throughout the duration of HyMeX-SOP 1 (September-November 2012), providing high-resolution and accurate measurements, both in daytime and night-time, of atmospheric temperature, water vapour mixing ratio and particle backscattering and extinction coefficient at three wavelengths.

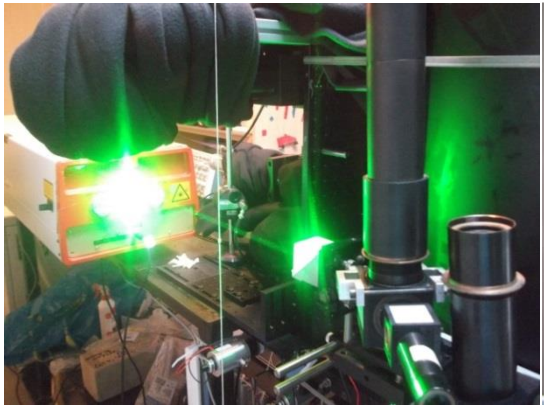
ISTP 2019, Toulouse, 20-24 May 2019

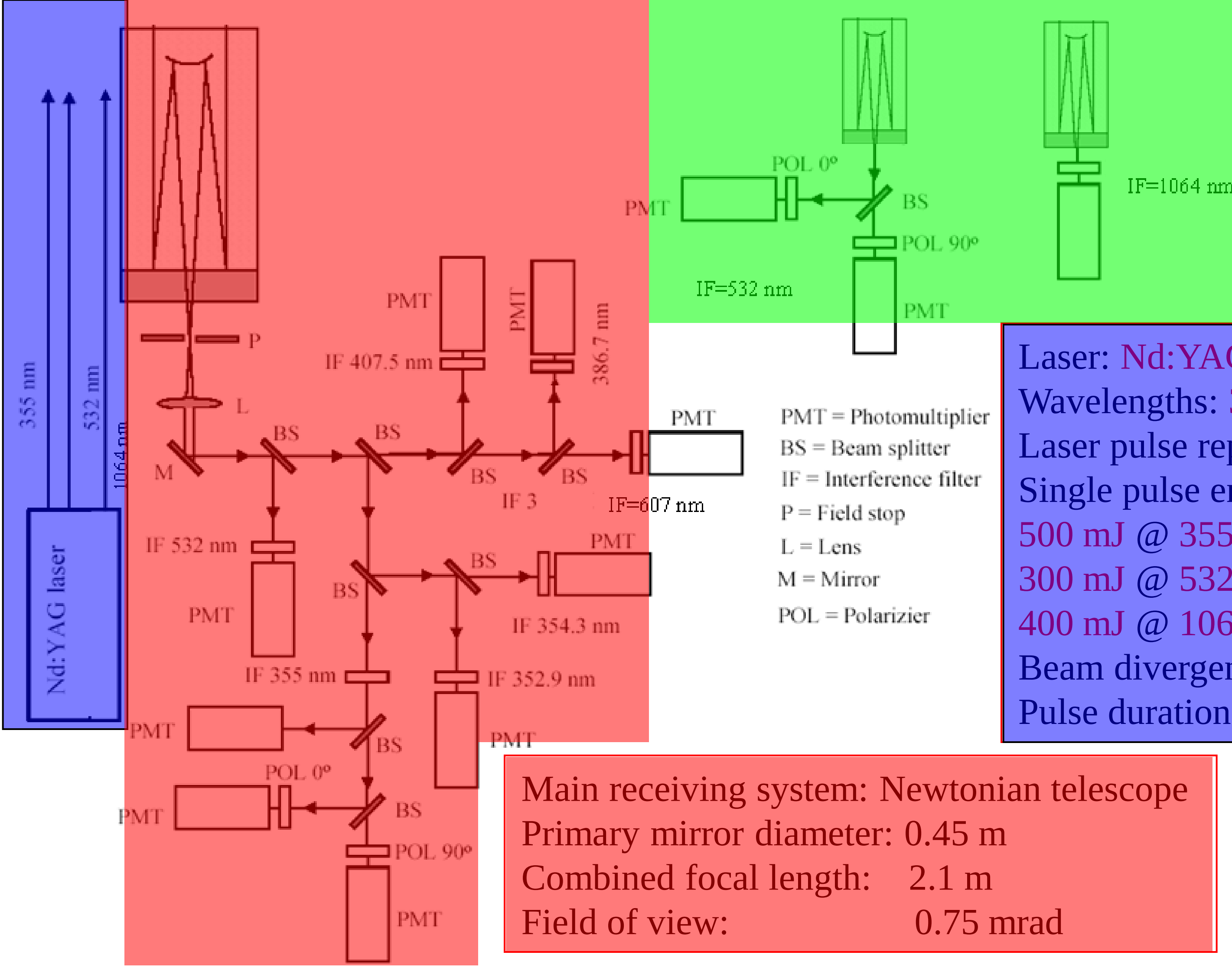
Trasportable Raman Lidar - BASIL $3\beta+2\alpha+2\delta+H_2O+T$

Measured parameters (day and night):

- particle backscattering coeff. @ 355, 532 and 1064 nm **3β**
- particle extinction coeff. @ 355 and 532 nm **2α**
- depolarization ratio @ 355 & 532 nm, **2δ**
- atmospheric temperature (Rotational Raman technique)
- water vapour mixing ratio (Vibrational Raman technique)
- relative humidity from simultaneous measurements of temperature and water vapor mixing ratio

Resol. of raw data: vert. 15-30 m, temp. 10 sec
Resol. of measured parameters: vert. 150 m, temp. 5 min



Laser: Nd:YAG (Quanta Sys.-SYL202)
Wavelengths: 355, 532, 1064 nm
Laser pulse repetition rate: 20 Hz
Single pulse energy:
500 mJ @ 355 nm (average power: 10 W)
300 mJ @ 532 nm (average power: 6 W)
400 mJ @ 1064 nm (average power: 8 W)
Beam divergence 0.5 mrad
Pulse duration 5 ÷ 6 ns

Main receiving system: Newtonian telescope
Primary mirror diameter: 0.45 m
Combined focal length: 2.1 m
Field of view: 0.75 mrad

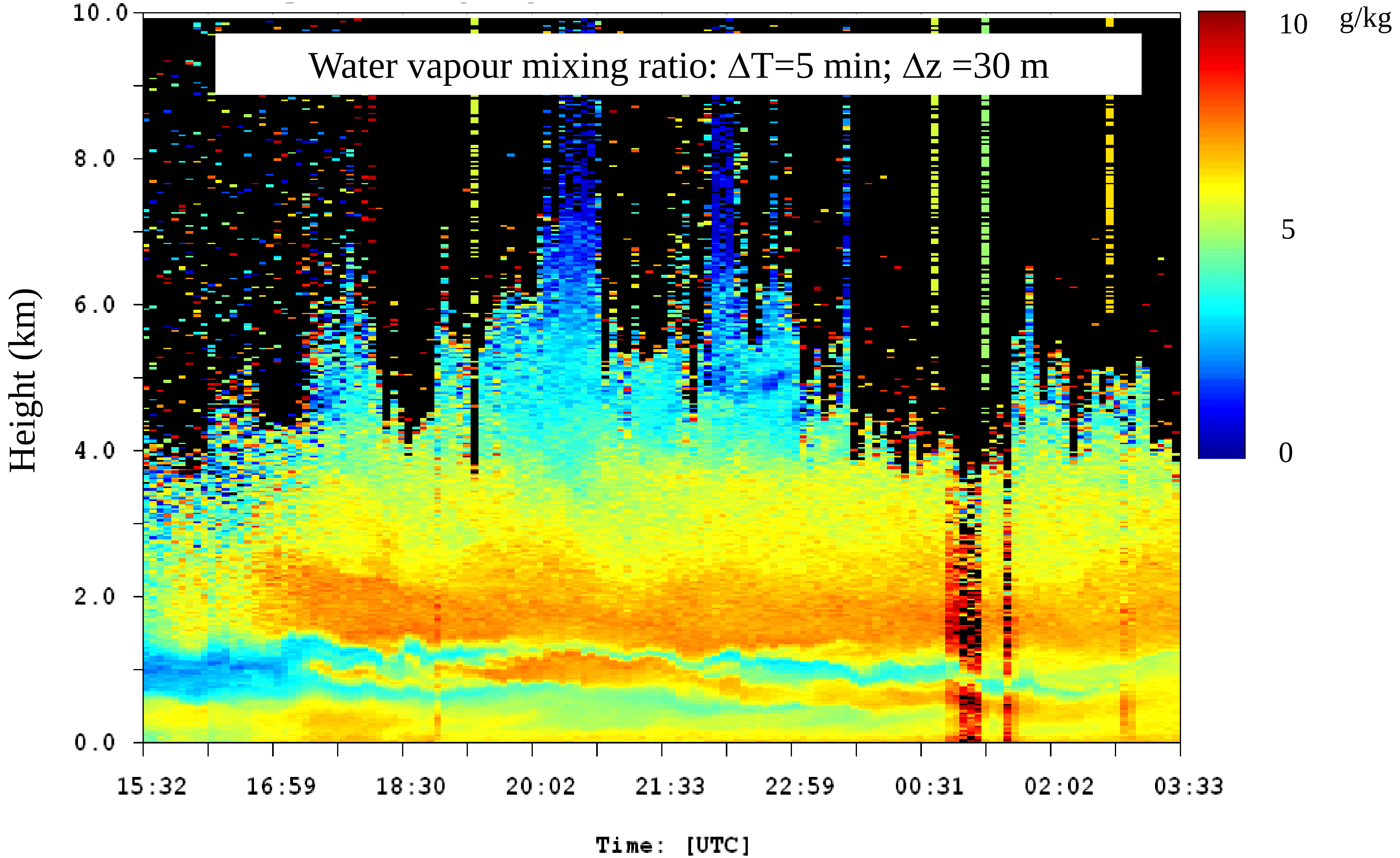
Two small telescopes
Aperture: 0.05 m
Focal length: 0.2/0.6 m
Field of view: 10/3 mrad

SPECTRAL SELECTION: based on Interference Filters

				N_2@355	H_2O@355	N_2@532	Low J RR	Low J RR
Wavelength (nm)	1064	532	355	387	407	607	354.3	352.9
Bandwidth (nm)	1.0	1.0	0.5	1.0	0.25	0,3	0.2	1.0

12 measurement channels: 1064, 532, 532||, 532 H.lvs, 355, 355⊥, 355 ||, 387, 407, 607, 354.3, 352.9

IOP 8 - BASIL, Candillargues, 43°36'40.10"N ; 4° 4'15.80"E, 28-29 September 2012

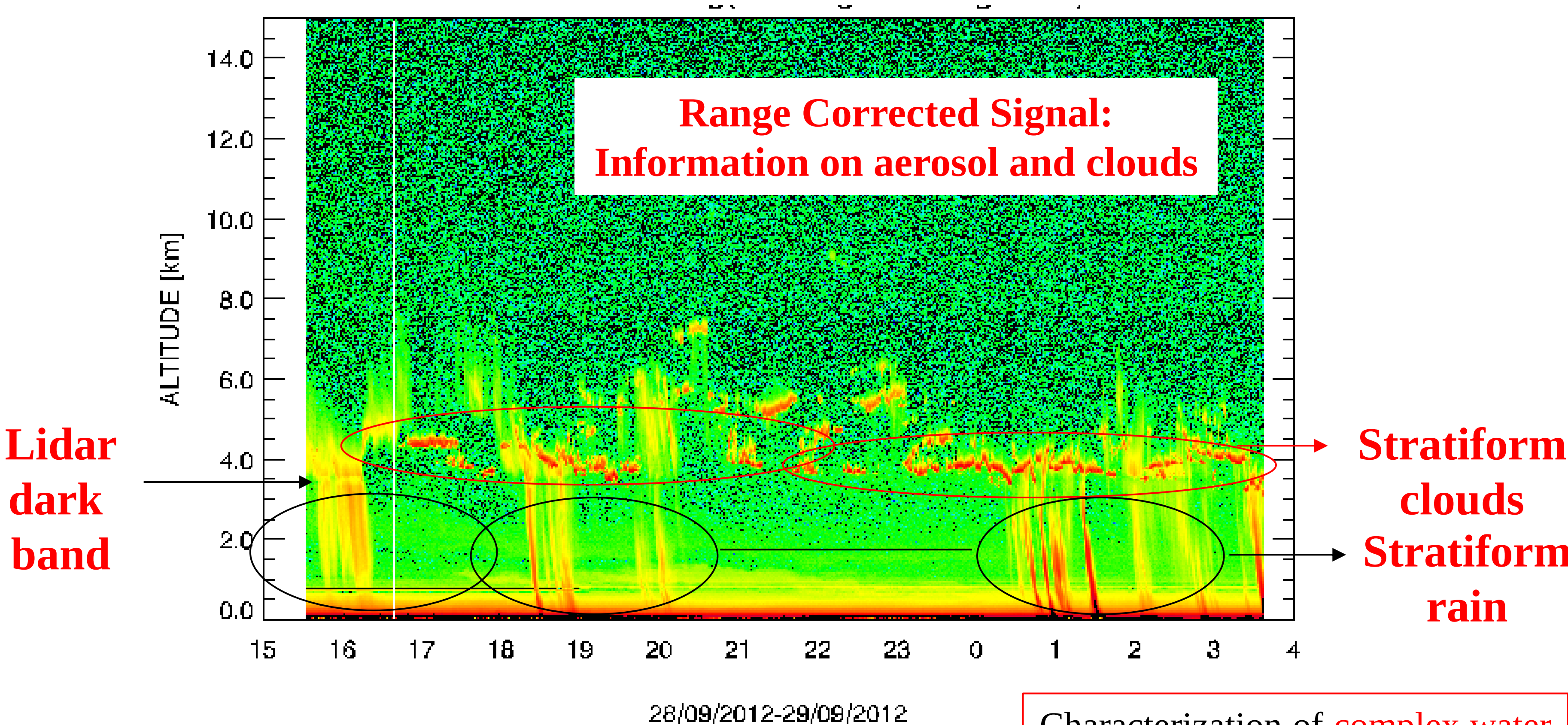


Measurements carried out by BASIL on 28 September 2012 reveal a water vapour field characterized by a quite complex vertical structure.

Goal of research effort: Assessof the origin of the different humidity filaments observed by BASIL on this day based on the comparison with data from MESO-NH model.

IOP 8 - BASIL, Candillargues, 43°36'40.10"N ; 4° 4'15.80"E, 28-29 September 2012

Range Corrected Signal at 1064 nm: ΔT=1 min; Δz =30 m



Raman lidar measurements were run in the time interval between **two consecutive heavy precipitation events**.

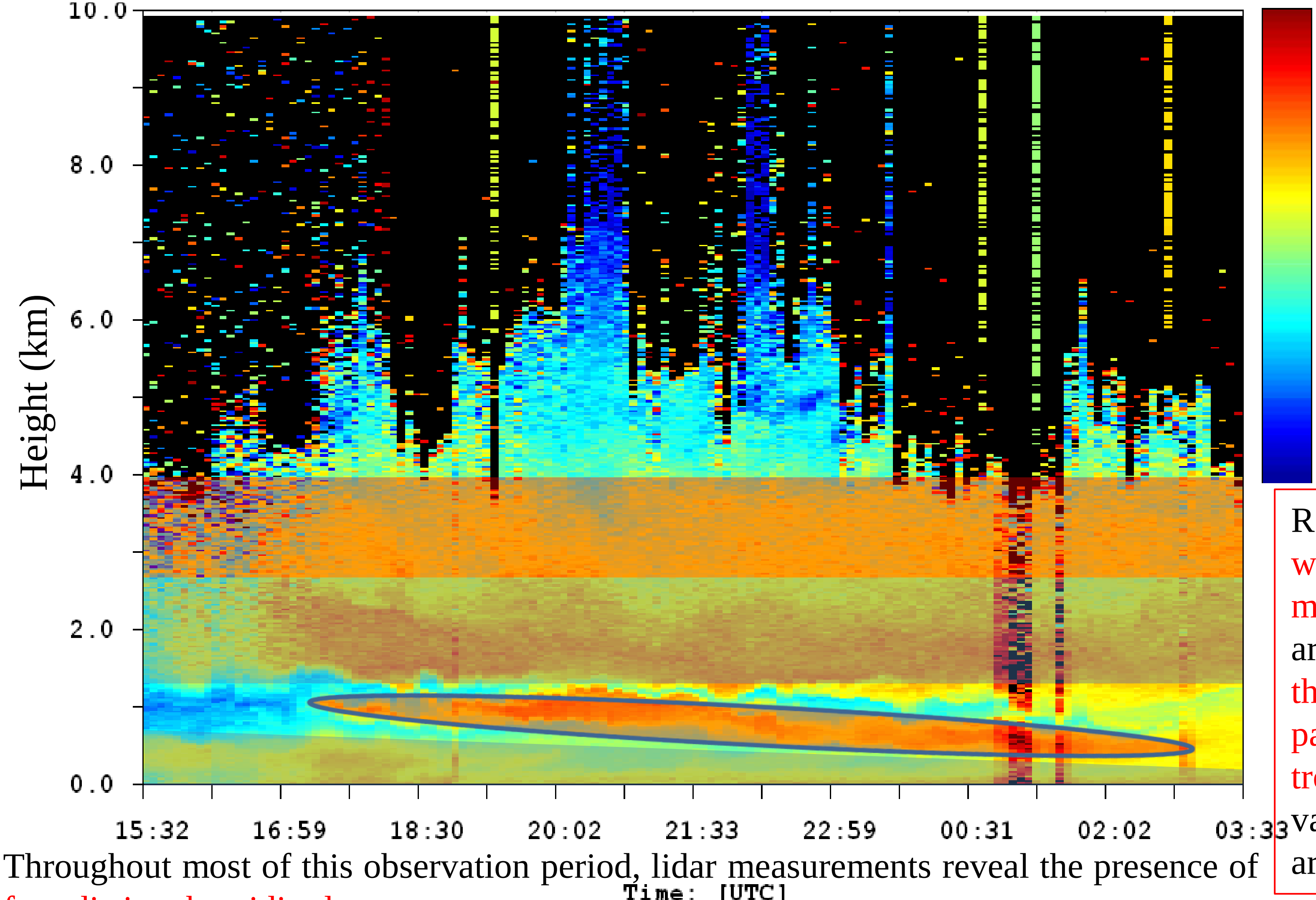
↔

Characterization of complex water vapour field structures and their genesis of the different features is also beneficial for a deeper comprehension of these two HPE events.

Raman lidar measurements by BASIL are possible in the presence of very light precipitation events, like those observed (above) around 16:00 UTC, in the time interval 18:30-20:30 UTC and 00:30-03:30 UTC.

The figure above reveals the presence of Virga events (black ellipses), with most precipitating particle sublimating before reaching the ground (complete subl. observed only during the first event at 16:00 UTC).

IOP 8 - BASIL, Candillargues, 28-29 September 2012, Water vapour mixing ratio: ΔT=5 min; Δz =30 m



Relatively high water vapour mixing ratio values are observed throughout most part of the troposphere, with a value of 3 g kg^{-1} around 6 km.

Throughout most of this observation period, lidar measurements reveal the presence of four distinct humidity layers:

- a surface layer extending up to 0.4-0.8 km a.s.l.;
- a filamentary structure, first observed around 17:30 UTC, progressively descending from ~1 km down to ~0.5 km and a variable vertical extent within the range 100-400 m;
- two upper humid layers: one from 1.3-1.5 km to 2.4-2.8 km, with values of m_{H2O} up to 7.5 g kg^{-1}, and one above up to approx. 4 km, with values of m_{H2O} not exceeding 6 g kg^{-1}.

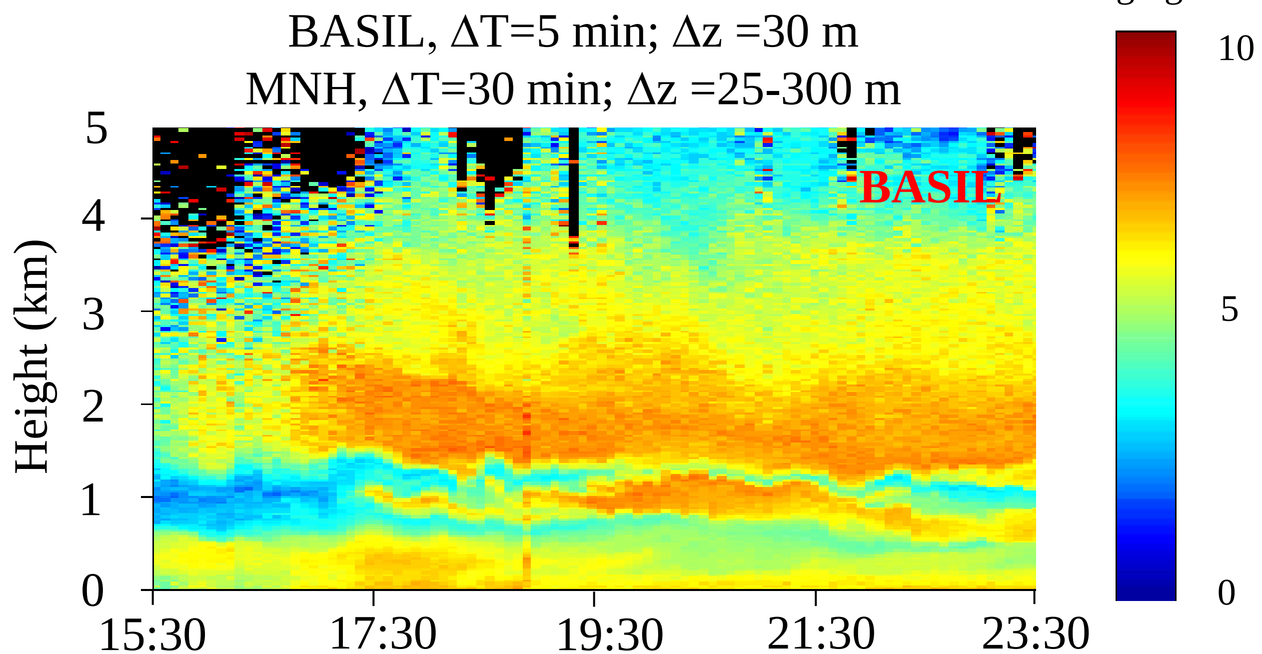
- For the purpose of this analysis the non-hydrostatic numerical research model MESO-NH was run over a 1446 x 1778 km^2 domain (35°-48° N, 8° W-16° E), with a horizontal resolution of 2.5 km.

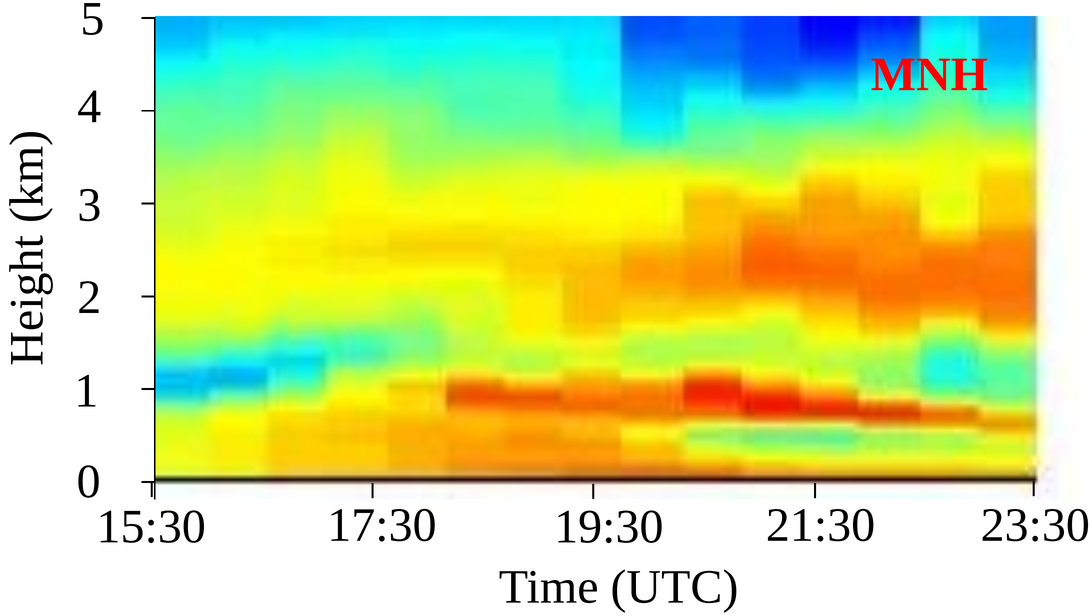
- Back-trajectory analyses from MESO-NH allow revealing that air masses reaching Candillargues at different altitudes levels are coming from different geographical regions.

- The considered MESO-NH simulation started at 00:00 UT on 27 September 2012 and ended at 00:00 UT on 29 September 2012; consequently, back-trajectories can be extended back in time by 40 to 50 hours to 00:00 UT on 27 September 2012.

IOP 8 - BASIL, Candillargues, 43°36'40.10"N ; 4° 4'15.80"E

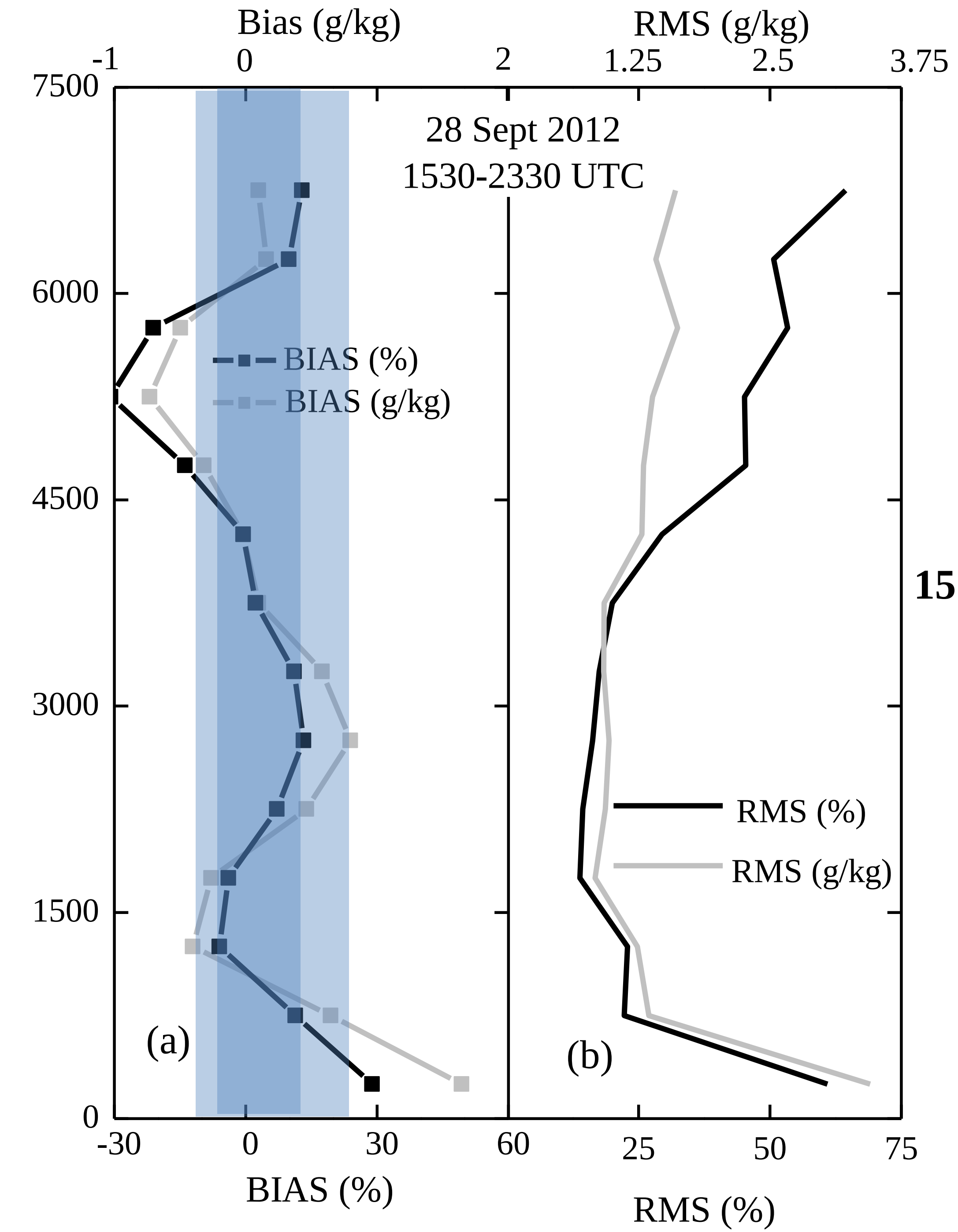
28 September 2012, Water Vapour Mixing Ratio





The four different humidity layers are well riproduced by Meso-NH, both in terms of timing of occurance and mixing ratio values.

only one exception: mixing ratio values within the elevated filamentary structure



mean BIAS

-5 ÷ 10 % or -0.4 ÷ 0.8 g/kg

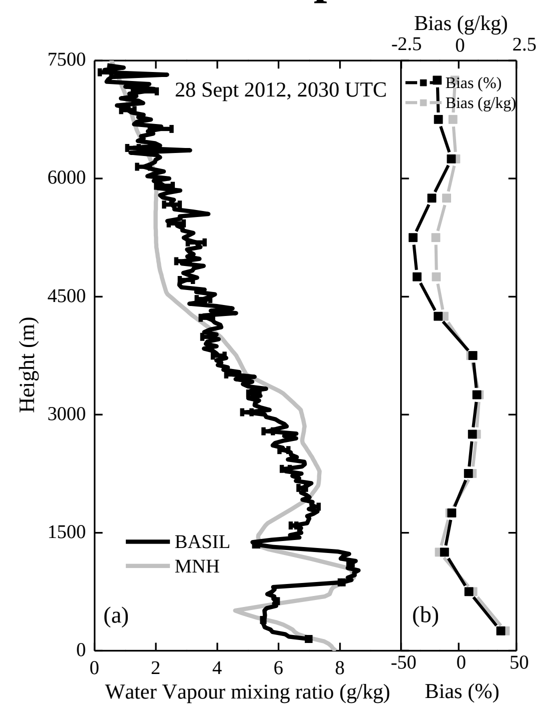
vertically-averaged mean BIAS

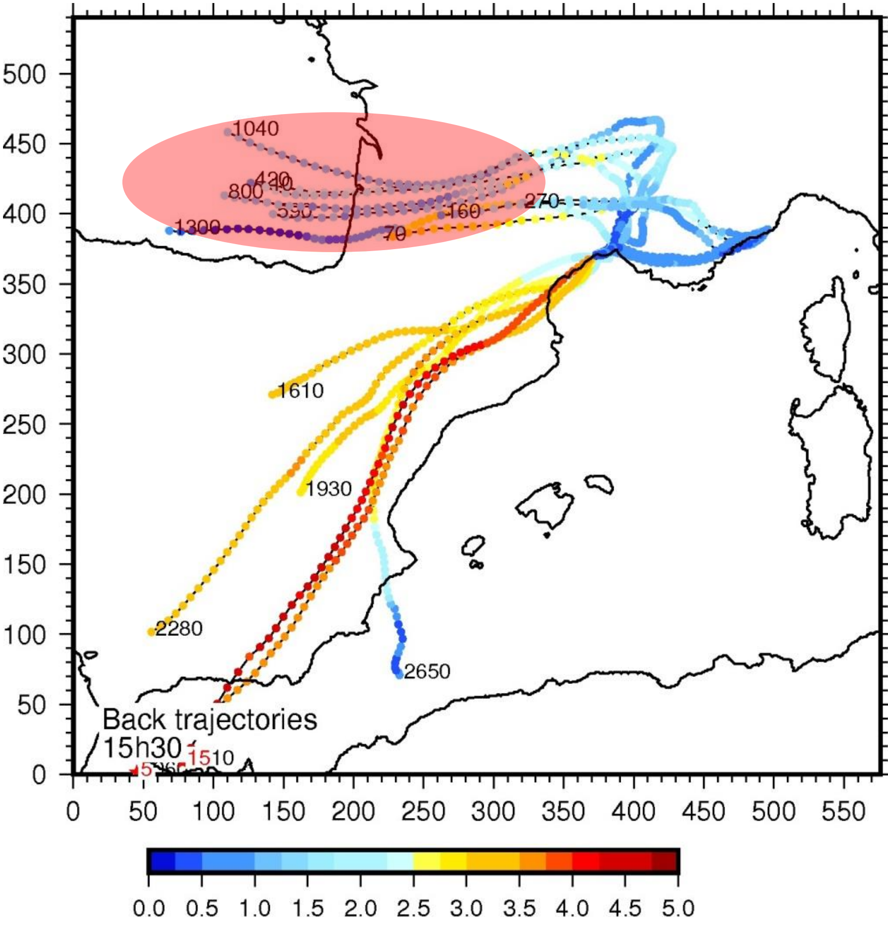
2,9 % or 0,25 g/kg

vertically-averaged mean RMS

29,3 % or 1,35 g/kg

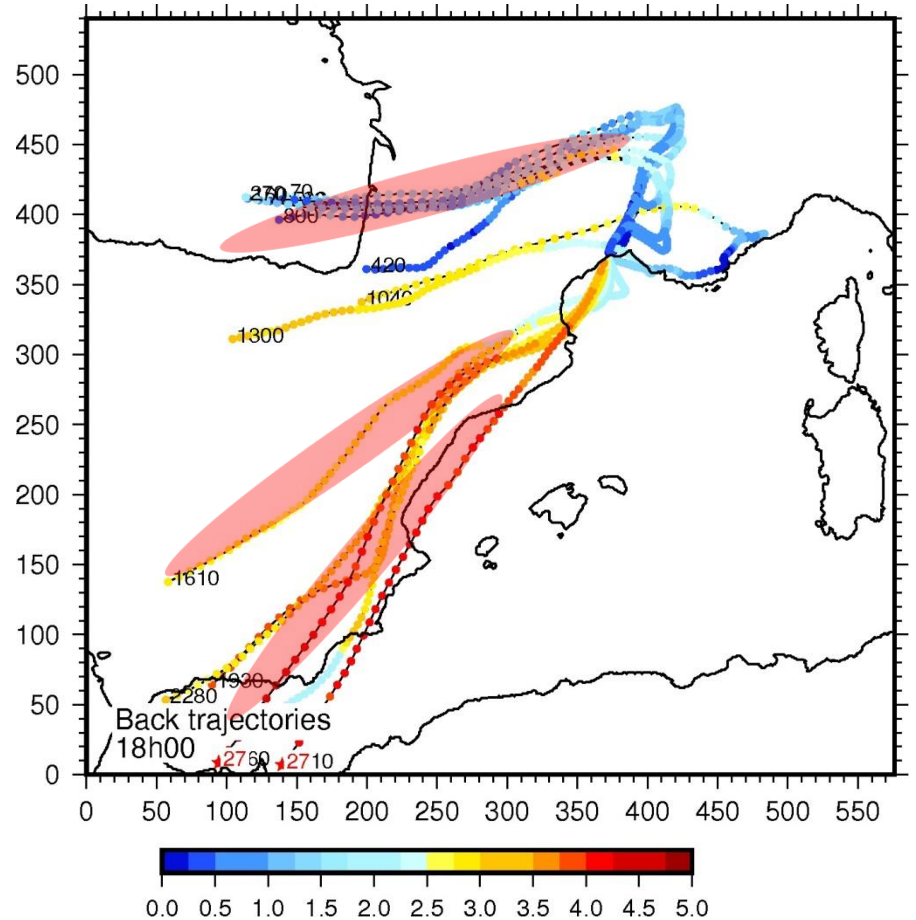
15:30-23:30 UTC → **16 profile-to-profile comparisons**





MESO-NH back-trajectory analysis reveals that:

- air masses within the surface humidity layer originated over the Atlantic Ocean,
- air masses within the elevated filamentary humidity layer are also coming from the Atlantic Ocean, overpassing the sea stretch North of Spain and Southern France at an altitude of ~1 km.

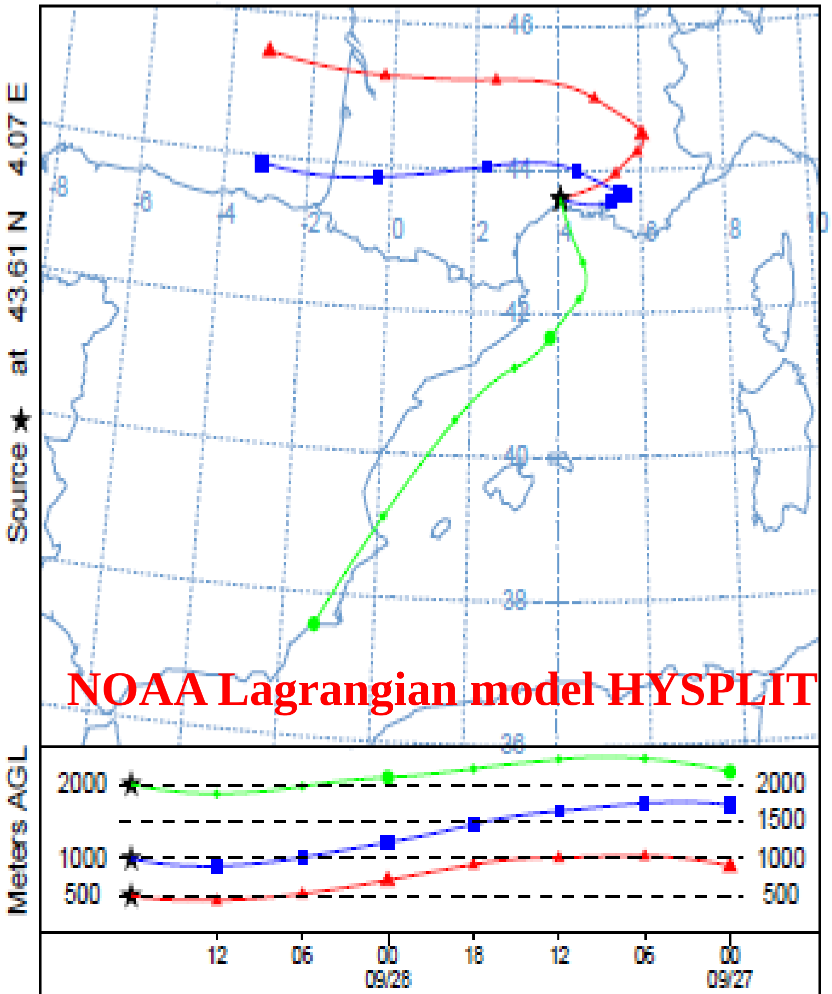


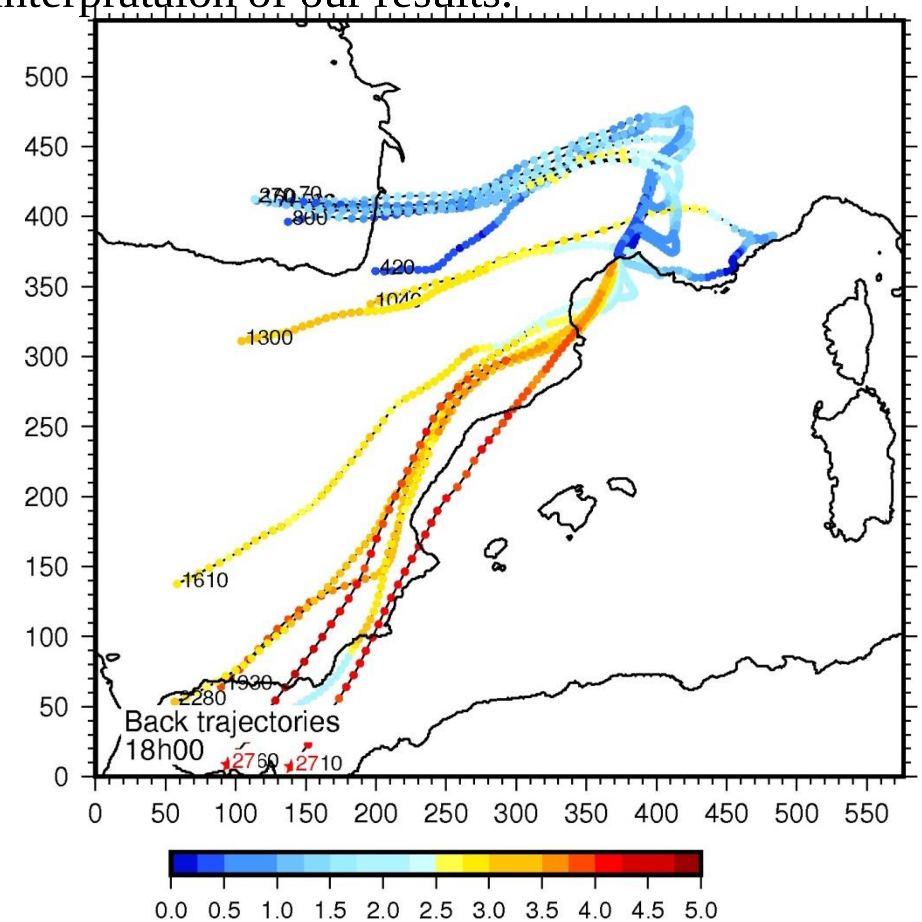
Air masses within the lower of the two upper layers are found to overpass Southern Spain and Marocco, descending from an elevation of 2-3.5 km, while air masses within the uppermost layer (up to 4 km)m are not tracked by MESO-NH.

Back-trajectory analysis from MESO-NH and HYSPLIT ending in Candillargues at 18:00 UTC on 28 September 2012 and starting at 00:00 UTC on 27 September 2012.

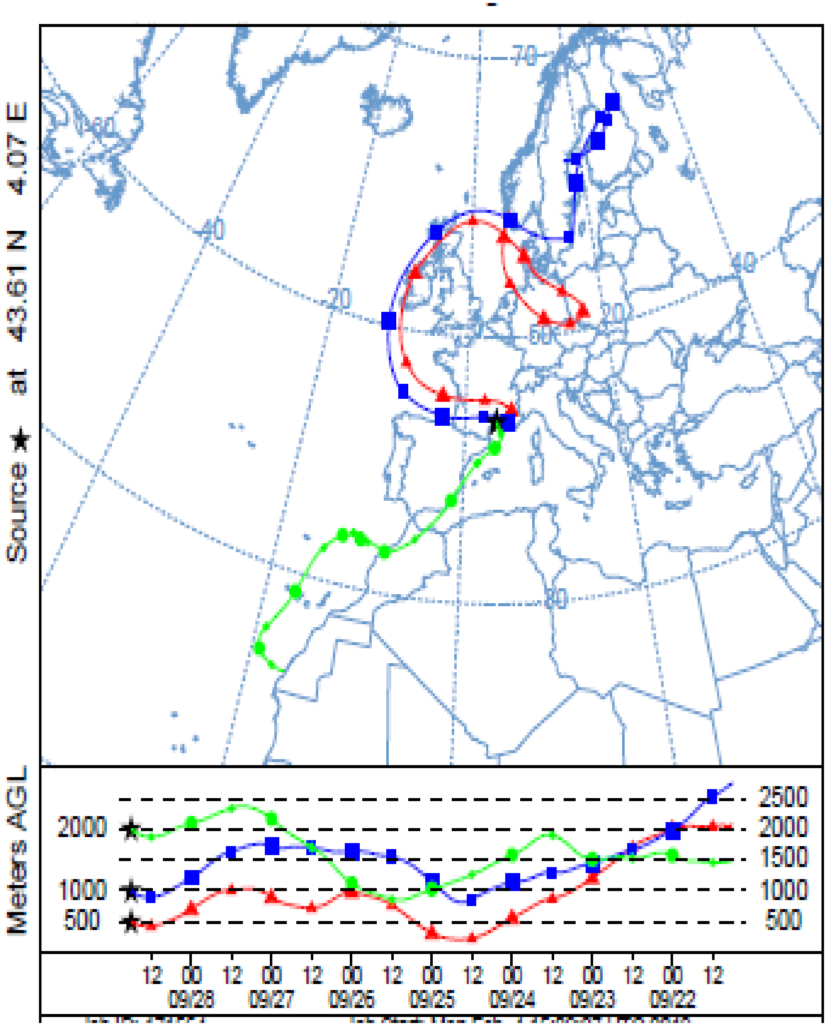
Considered back-trajectories from HYSPLIT are those ending at 500 m, 1000 m, 2000 m and 3500 m, these being the central altitudes of the four humidity layers observed by BASIL.

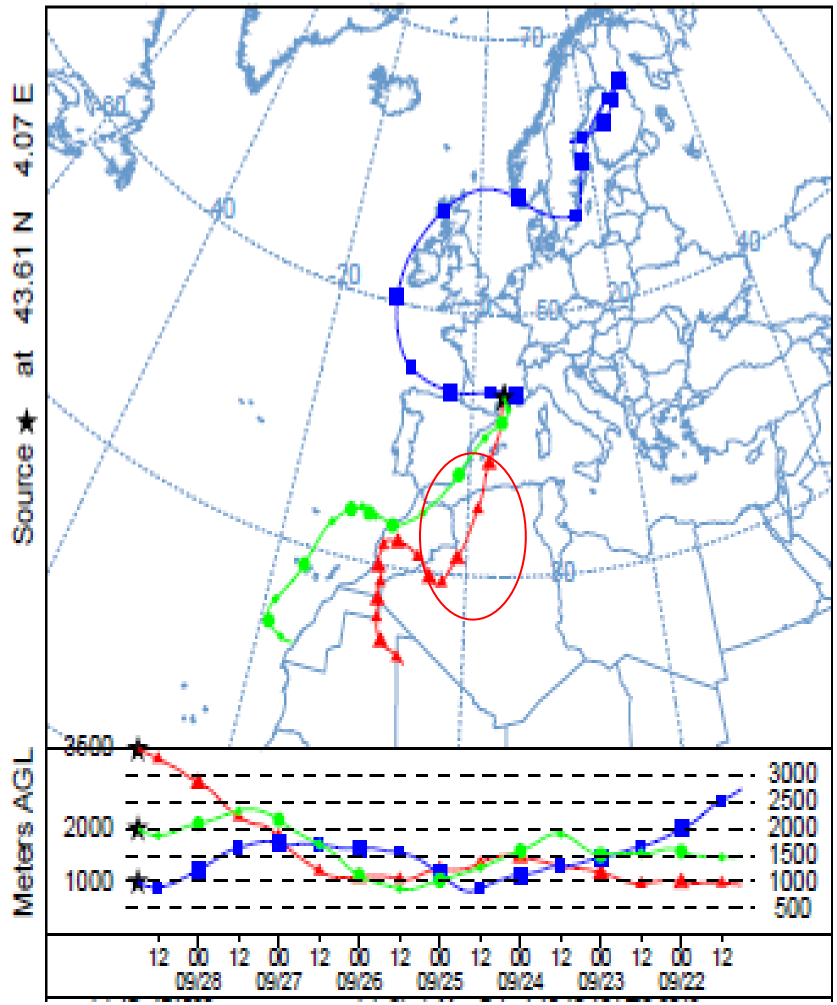
The two back-trajectory analyses are in very good agreement → confidence on the possibility to also use HYSPLIT in support of MESO-NH in the interpratain of our results.





Back-trajectory analysis from HYSPLIT ending in Candillargues at 18:00 UTC on 28 September 2012 and starting 180 hours (7.5 days) earlier at 06:00 UTC on 21 September 2012.

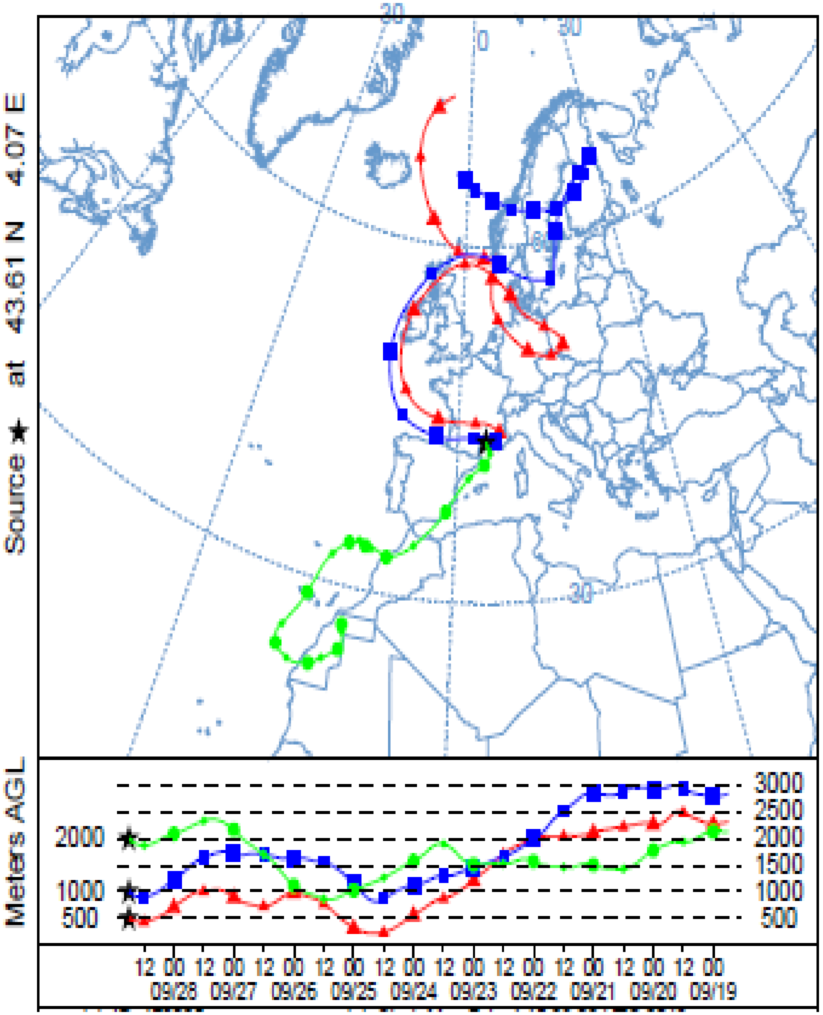


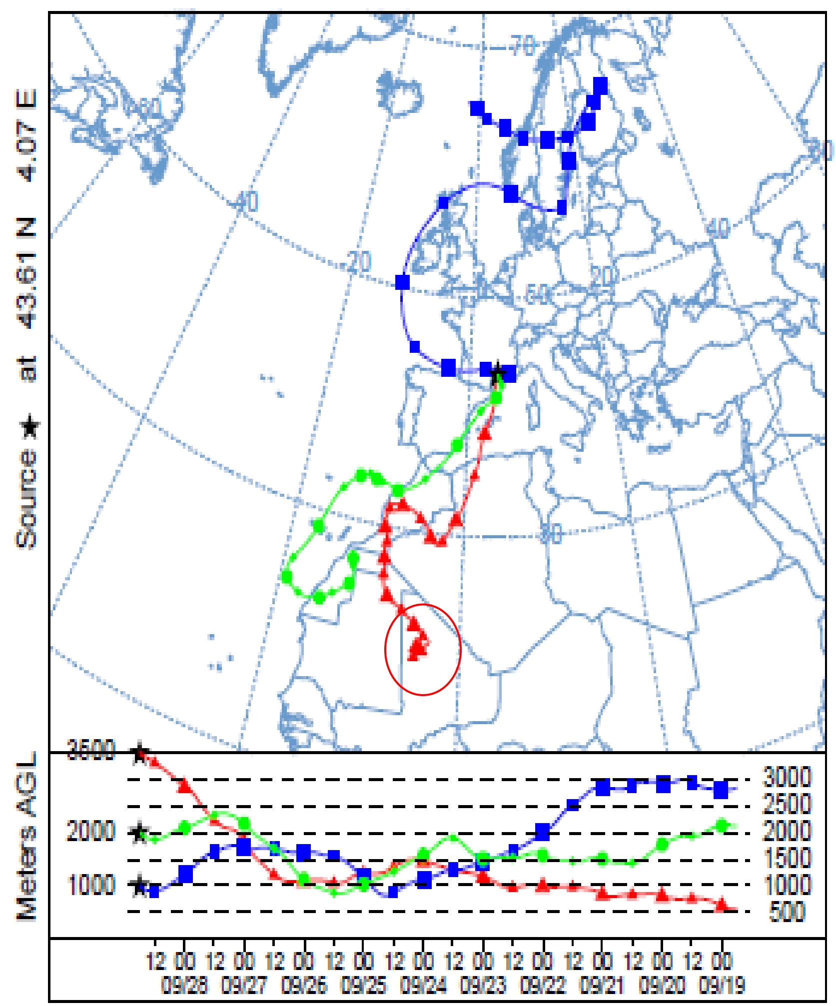


- Air masses within the uppermost layer are found to overpass Algeria.

Back-trajectory analysis from HYSPLIT extended further back in time (10 days)

Back-trajectory analysis HYSPLIT ending in Candillargues at 18:00 UTC on 28 September 2012 and starting 240 hours (10 days) earlier at 18:00 UTC on 18 September 2012.

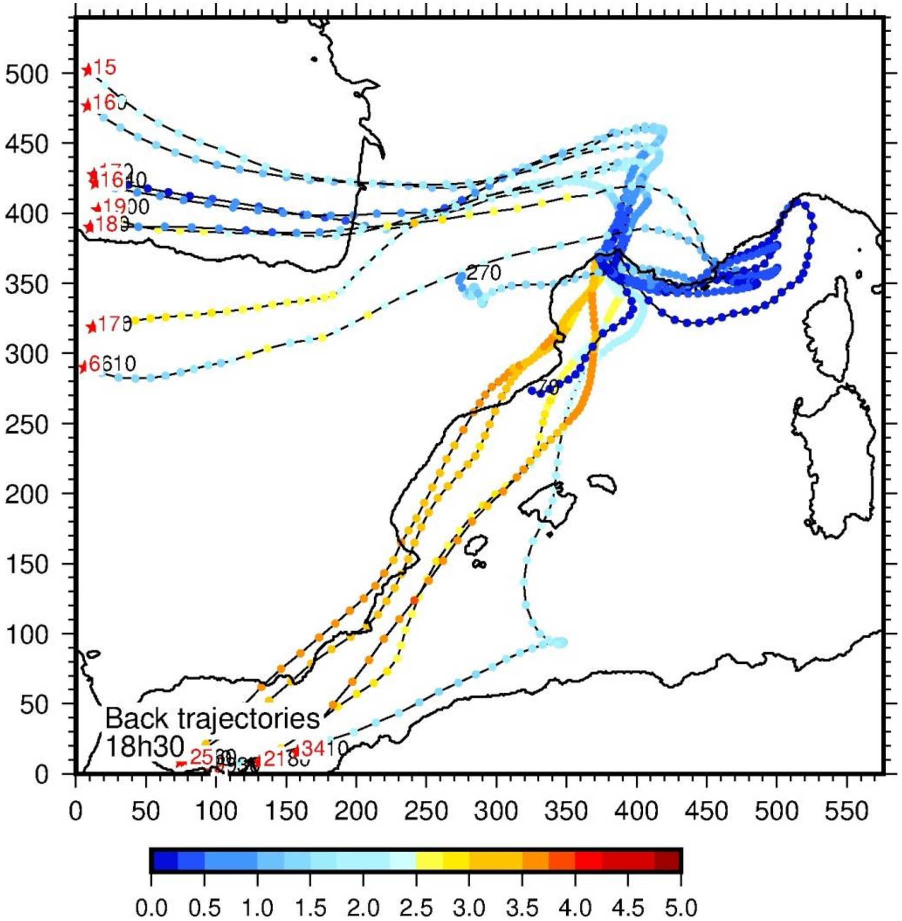




The back-trajectory extended back in time by 240 hours (10 days) reveals that air masses in the uppermost humid layer, which had been found to overpass Algeria, originate over Central Africa (Mali).

A new MESO-NH simulation was run starting at 00UTC on 26 September 2012 (24h earlier than the previous simulation).

Backtrajectories are out of the domain for the first time periods of the run (the numbers in red at the domain borders correspond to the time, the 26 September, at which the particle enters the domain).



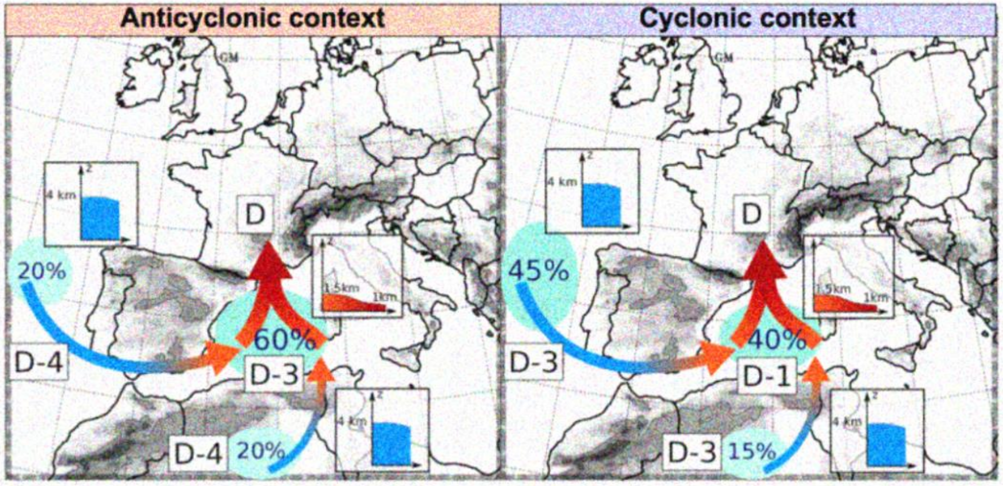
It is possible to run another simulation, on a larger domain and starting, for instance the 25 September at 00 UTC, but the atmospheric forcings should be taken from a global model with a coarser resolution than AROME-WMED, like ARPEGE or ECMWF.

Backtrajectory analysis from MESO-NH simulation are very important for the purpose of estimating the atmospheric water budget associated with the transport of water vapour, but less effective in the assessment of the origin of the air-masses.

The role of Mediterranean evaporation and low-level humidity transport in feeding HPE events was highlighted in a variety of HyMeX papers.

e.g.

- Duffourg and Ducrocq, 2011
- Chazette et al. 2015,
- Khodayar et al. 2018
- Duffourg et al., 2010
- Duffourg et al., 2018
- Lee et al., 2018

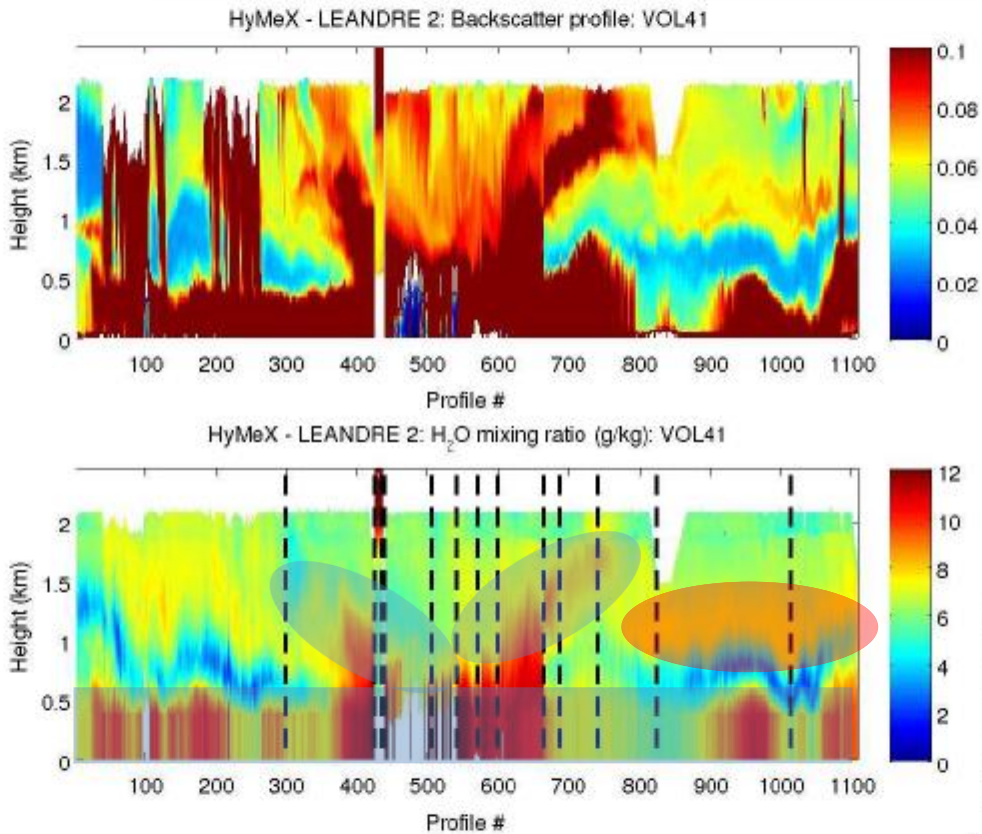


Origin: Atlantic and Tropical Africa // Mediterranean
Transport: Transport in the lower troposphere for 3-4 days,
Subsidence upon reaching the Mediterranean 12-72h before HPEs

Comparison with LEANDRE2 DIAL measurements

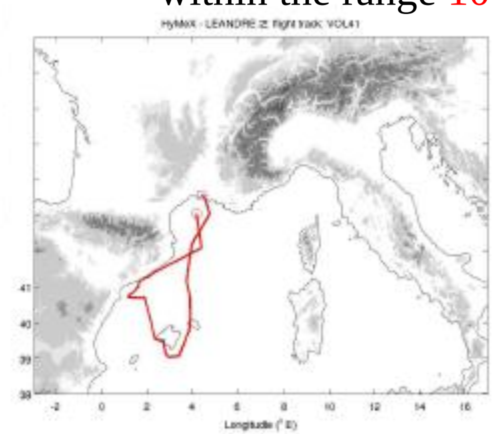
AS41 28/09/12 #8 Survey of moist inflow towards northern Spain (CA & VA) F/F20

Flight AS41 28/09/2012 (1458-2016 UTC)



Identification within L2 data of the four distinct humidity layers observed by BASIL:

- a surface layer extending up to 0.4-0.8 km a.s.l.;
- a filamentary structure, first observed around 17:00 UTC, with a progressively descending trend from ~1 km down to ~0.5 km and a variable vertical extent within the range 100-400 m;



- an upper humid layer from 1.3-1.5 km to 2.4-2.8 km, with values of m_{H2O} up to 7.5 g kg^{-1}.

The exact correspondence, in terms of back-trajectories computation and water budget, between the humidity layers observed by BASIL and those identified in LEANDRE2 measurements has to be verified based on a dedicated simulation effort.

SUMMARY

In this research effort we investigated the origin of the different humidity layers observed by BASIL over the time interval from 15:30 UTC on 28 September to 03:30 UTC on 29 September 2012 based on the use of back-trajectory analysis from MESO-NH and the NOAA Lagrangian model HYSPLIT.

Origin: Atlantic and Tropical Africa
Transport: Transport in the lower troposphere for several days

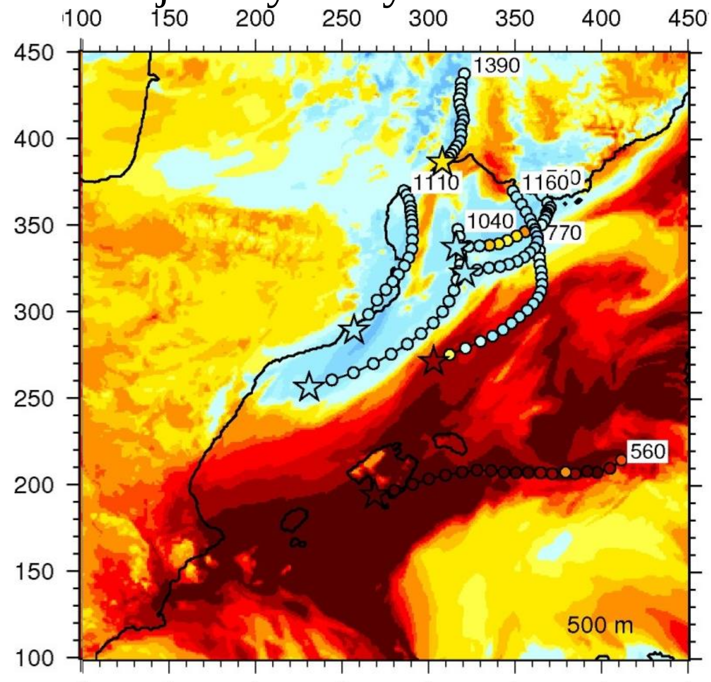
FORTHCOMIN FUTURE STEPS

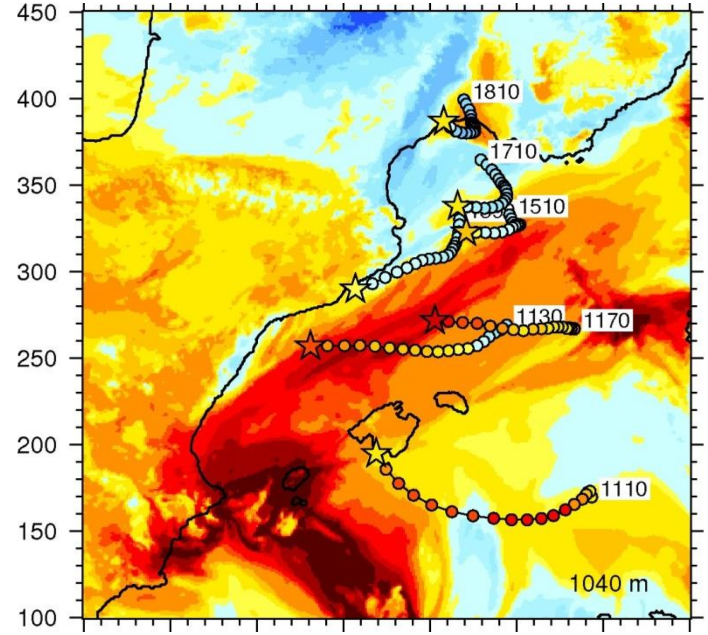
The time series of temperature and potential temperature and other relevant parameters (aerosol characteristics) from BASIL over the same time interval (15:30 UTC on 28 September to 03:30 UTC on 29 September 2012) is to be studied.

- Identify the presence of cold air pools and investigate their role in the evolution of weather conditions on this day.

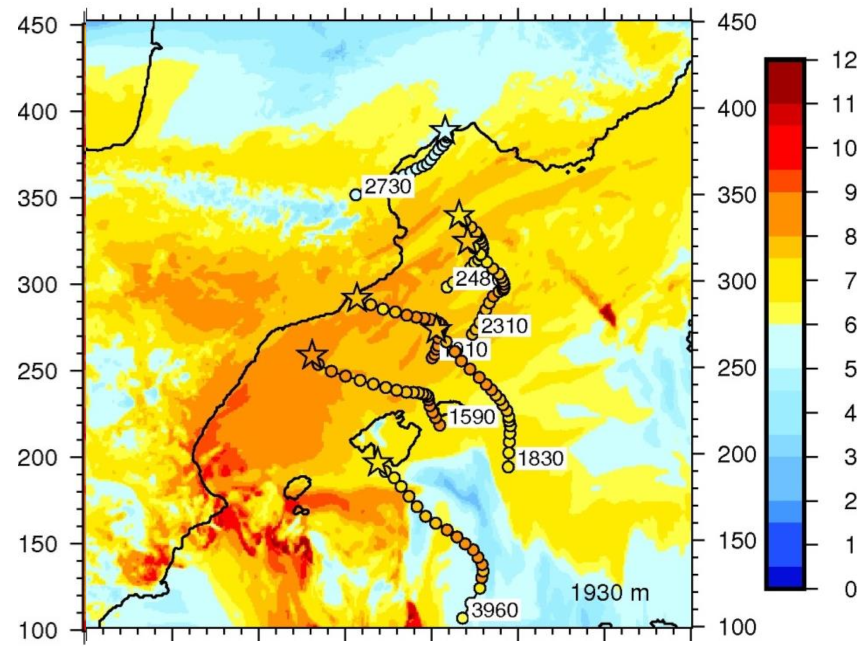
- Investigate the evolution of aerosol compositional and microphysical properties.

Back-trajectory analysis from MESO-NH at 18:00 UTC on 28 September 2012

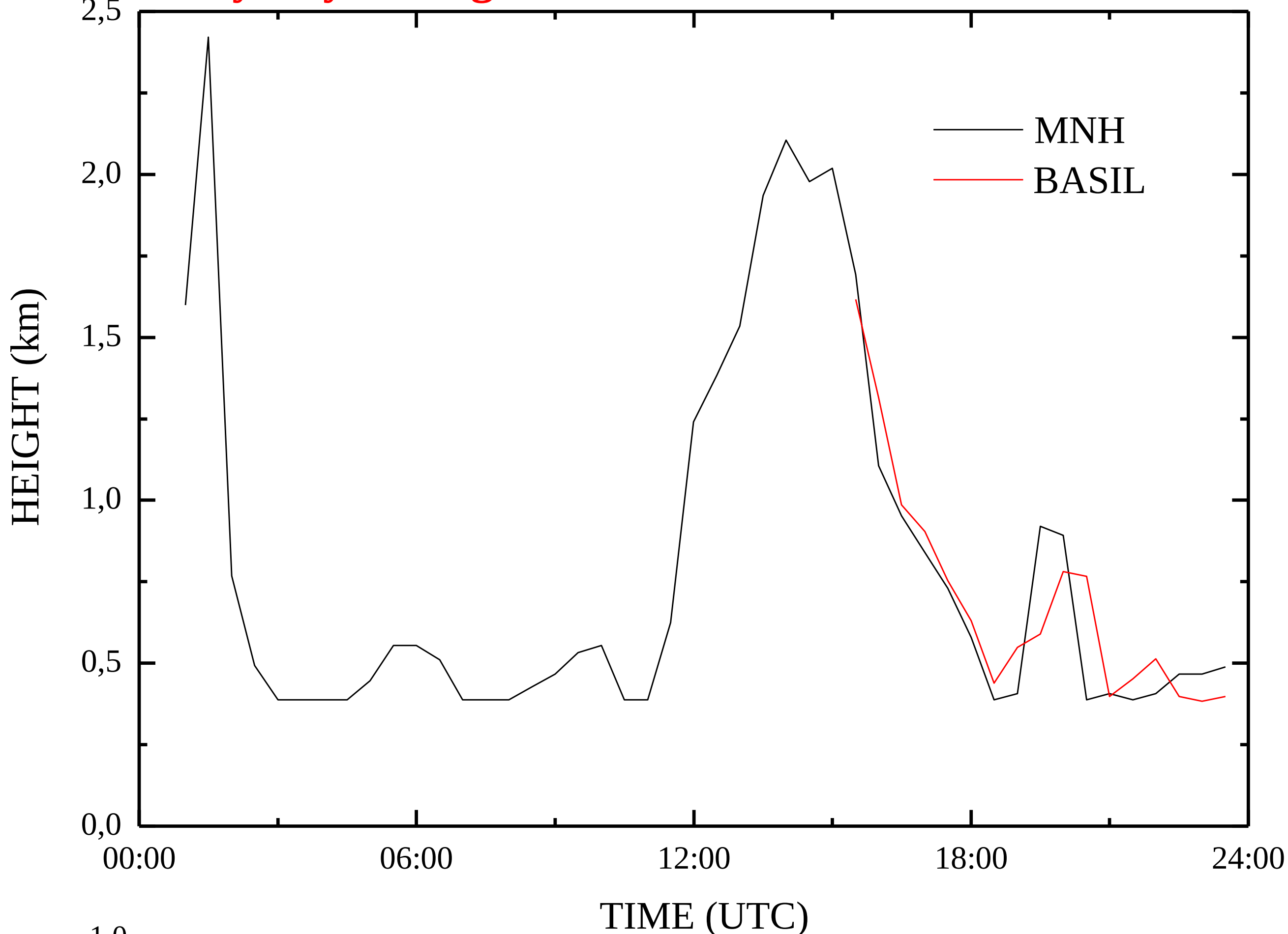


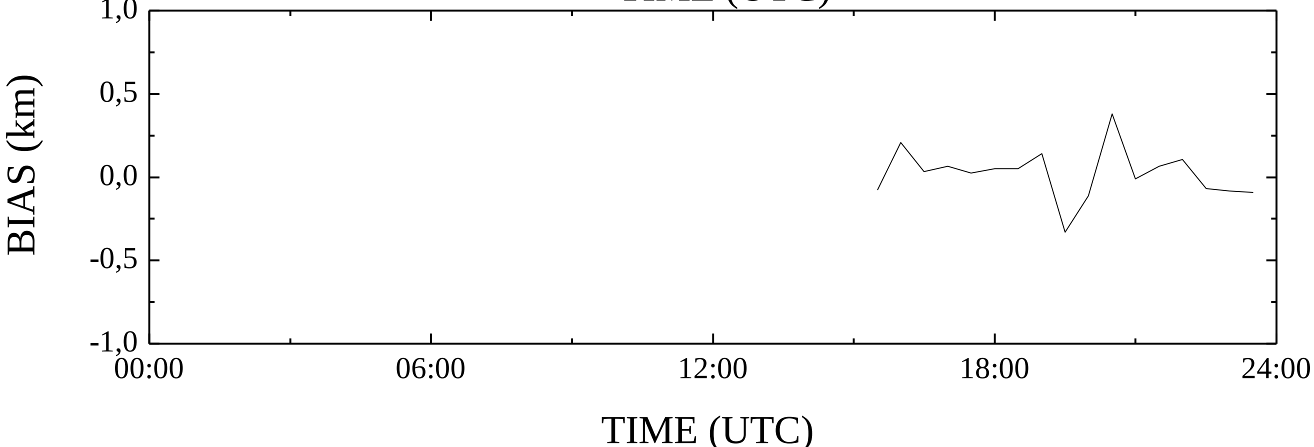


Considered back-trajectories are those ending as close as possible to the altitude levels of 500 m, 1000 m, 2000 m and 3500 m, these being the central altitudes of the four humidity layers observed by BASIL.



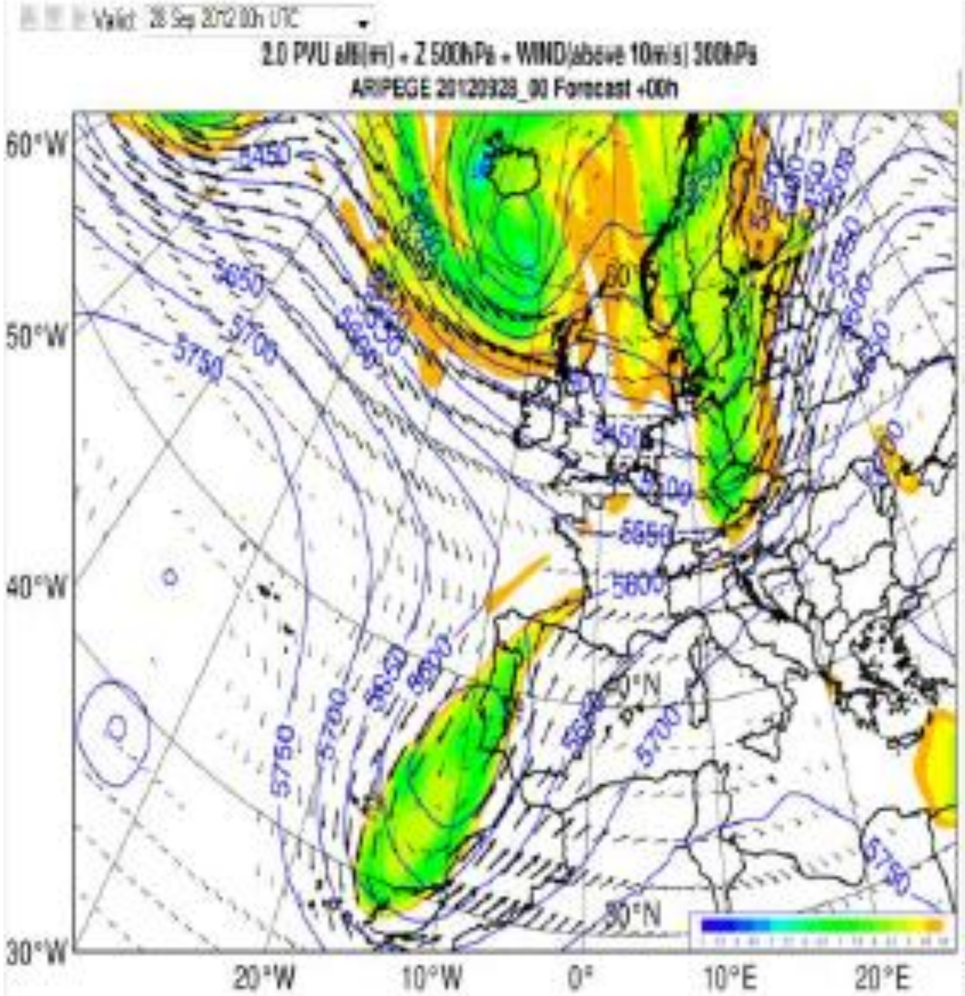
Boundary Layer Height estimate from BASIL and MESO-NH



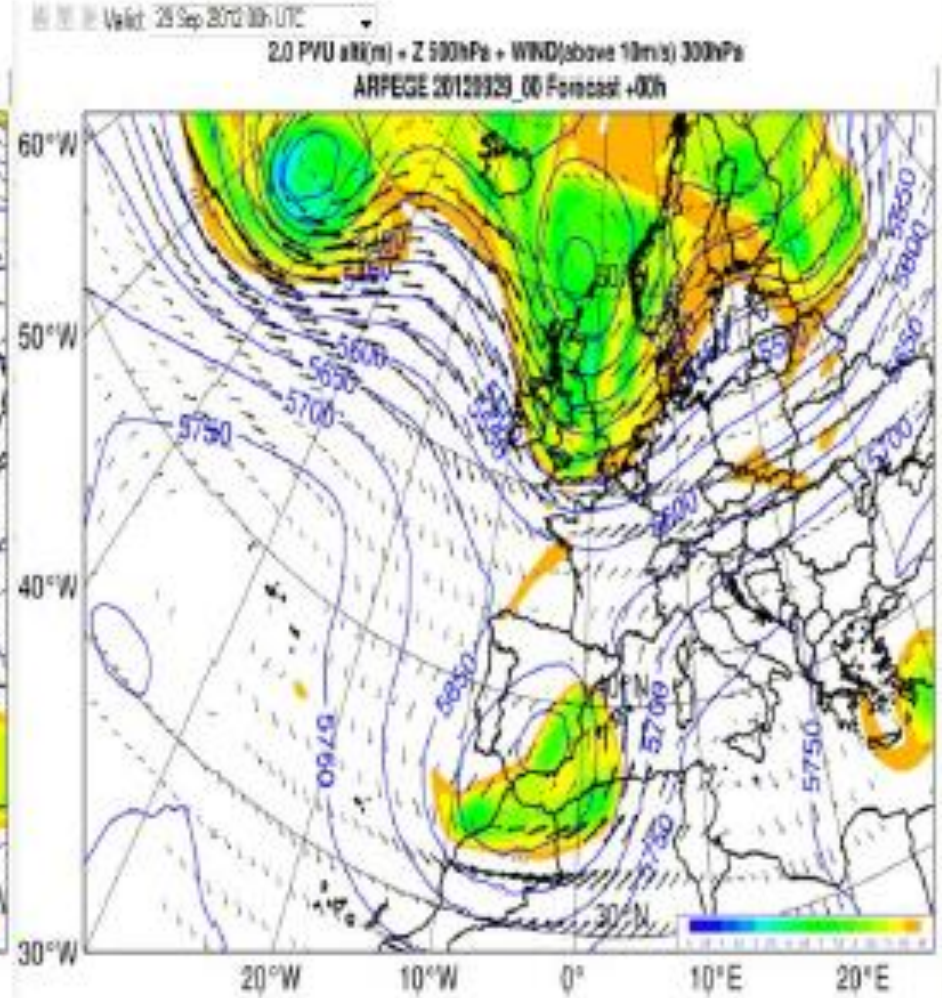


$BIAS_{MNHvsBASIL}$ = -21 m

$RMS_{MNHvsBASIL}$ = 150 m



ARPEGE analysis
28-00UTC



ARPEGE analysis
29-00UTC

For the purpose of this analysis the non-hydrostatic numerical research model MESO-NH was run over a 1446 x 1778 km^2 domain (35°-48° N, 8° W-16° E), with a horizontal resolution of 2.5 km. Back-trajectory analyses from the model allow revealing that air masses reaching Candillargues at different altitudes levels are coming from different geographical regions. The considered MESO-NH simulation started at 00:00 UT on 27 September 2012 and ended at 00:00 UT on 29 September 2012; consequently, back-trajectories can be extended back in time by 40 to 50 hours.

Research effort aim:

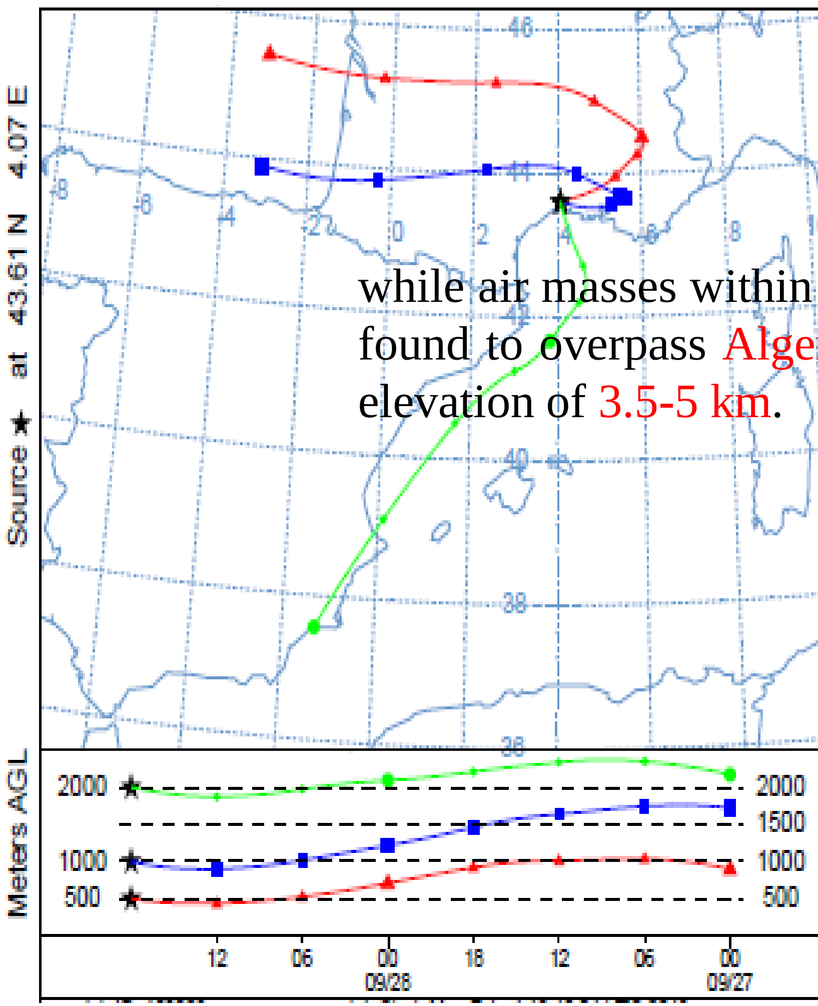
Assessing the origin of the different humidity filaments observed by the Raman lidar BASIL on this day.

↓

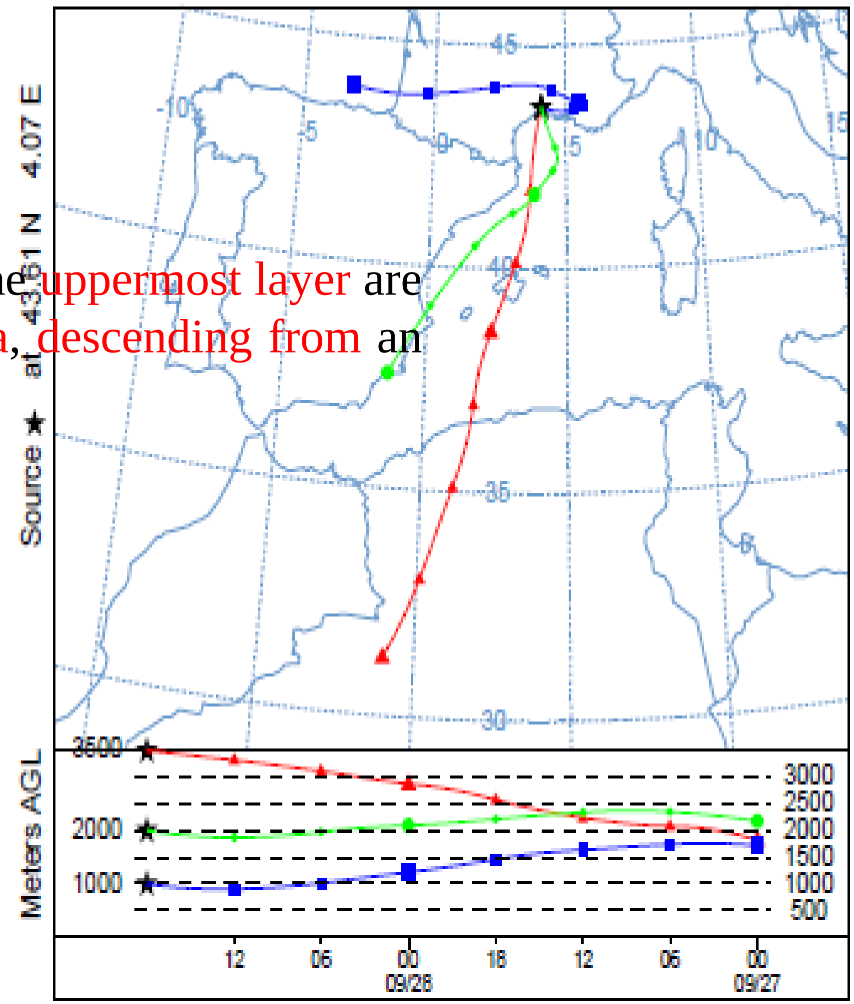
Comparisons between the Raman lidar data and MESO-NH simulations.

Back-trajectory analysis from MESO-NH and HYSPLIT ending in Candillargues at 18:00 UTC on 28 September 2012 and starting at 00:00 UTC on 27 September 2012.

The two back-trajectory analyses are in very good agreement



while air masses within the uppermost layer are found to overpass Algeria, descending from an elevation of 3.5-5 km.



in the atmosphere (e.g. HPE in France, HPE over the Adriatic associated with Bora and Sirocco; e.g. Duffourg and Ducrocq, 2011, Chazette et al. 2015, Khodayar et al. 2018 ….), and observation (GPS, aircraft during SOP1, lidars).

Please note that the stages shown in the figures (colored dots) are every hour and not every 30 min for the first 2 days of the run (26 and 27 September).

, and the results (parameters and their time evolution) at Candillargues would probably be different

was highlighted through back-trajectories computation

Low-level moisture origin and transport

evaporation and

At present my plan is to analyse the

I also plan to analyse BASIL measurements of the particle backscattering and extinction coefficient at different wavelengths over the same time interval (from 15:30 UTC on 28 September to 03:30 UTC on 29 September 2012) to possibly

Can you trace back any aerosol related parameter with your model configuration ?

ST-Heavy Precipitation - Sources and transport of water vapour

Role of Mediterranean evaporation and transport of water vapour

Assessment of the origin of the different humidity filaments observed by the Raman lidar BASIL on this day based on the comparison with data from MESO-NH model.

of the sounded air parcels and their possible modifications along their route. water vapour field characterized by a quite complex vertical structure