Precipitations on the lee side of the Vosges Mountains : 2 case studies from the COPS campaign

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Introduction

The international field campaign COPS (Convective and Orographically-induced Precipitation Study, Wulfmeyer, et al., 2008) took place from 01 June to 31 August 2007 in a low mountain area in southwestern Germany/ eastern France. In this poster we will explore the lee side precipitations during two days of the campaign (July 18th and August 6th), using observations from radars, satellites, radio-soundings, and a network of GPS stations, as well as models simulations and analysis. In particular, we will give a special attention to small scale orographic effects on the development of precipitations, and to the role of water vapor convergence as a precursor to the convective initiation.

Presentation of the campaign and the main instruments deployed :

The overall objective of the COPS campaign is to **improve the Quantitative Pecipitation Forecast** skill of Numerical Wether Prediction models over a region of moderate topography. In that aim, the COPS campaign joigned together people from modelling and experimental communities for a 3 month international project.
The COPS domain streched over a **complex terrain**, included the Vosges Montains, The Rhine Valley, The Black Forest and the Swabian Jura (figure 1). A lot of instruments were deployed during the campaign, especially along a transept of 5 supersite. In this study we will focus on the data over the Vosges and the West part of Rhine valley.

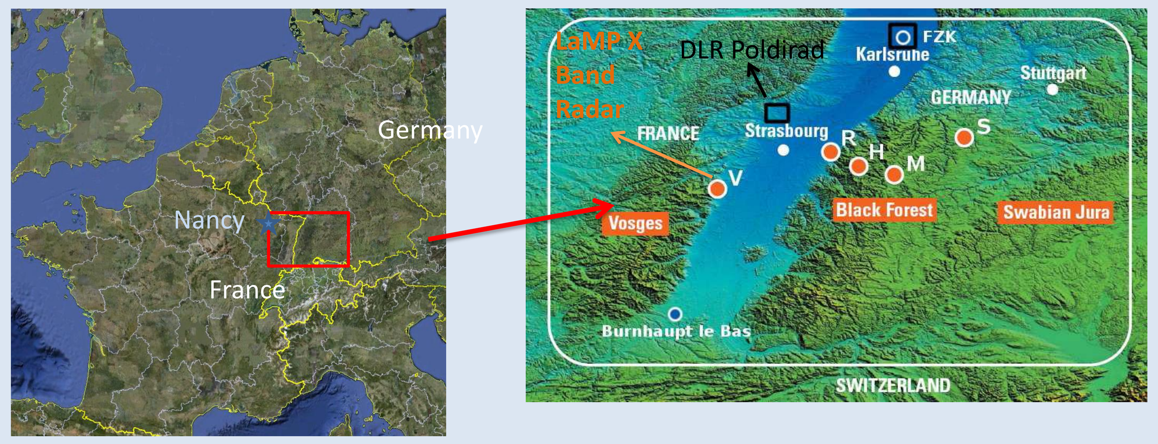

Figure 1. *Left* : the COPS domain (270x150 km) between France and Germany. The Nancy synoptic radiosounding station is situated on the West of the COPS area. *Right* : Zoom on the COPS domain showing the main instrumented locations. The five supersites are in orange.

Radars:

The observations of precipitating systems over the Vosges Mountains have been done with two radars. **The DLR Poldirad radar** is a C band polarimetric radar, with a maximal range of 120 Km. It gives PPI scans every 10 minutes, at a 2° elevation. The **LaMP X band radar** gives images every 30 secondes, with a radial resolution of 60m. It was run at a constant elevation of 5°, till a range of 20 km.

GPS tomography:

- Network of GPS stations in the COPS domain
- The propagation of GPS signal from the satellite to the station is delayed because of the atmosphere.
- These STDs (Slant Total Delays) are calculated for each sattelite – station ray (fig 3)
- Substraction of Hydrostatic delay (estimated using the ground weather stations data) gives Slant Integrated Water Vapour (SIWV)
- A tomography software (Reverdy *et al*, 2009) retrieves hourly the 3D water vapour field from an inversion method (presently using *only* the standard atmosphere as *a priori*).

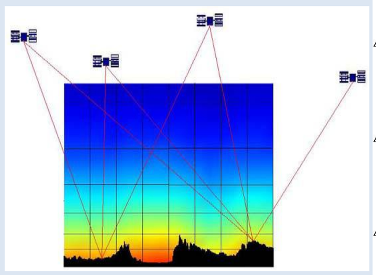

Fig 3. Vertcal cut showing sattelite-stations rays.

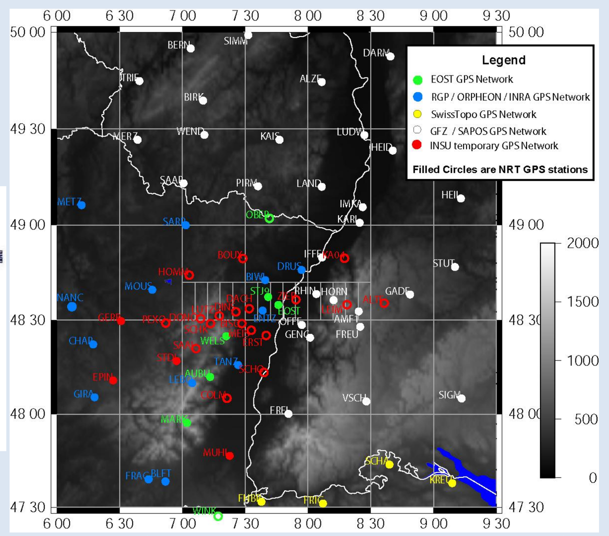

Figure 2. The GPS stations Network during the COPS Campaign. Each station gives STD and also Integrated Water Vapour (IWV) over the station .

VERA (Vienna Enhanced Resolution Analysis) is a new state-of-the-art tool for objective data anlysis. Station data which are irregularly distributed are checked for both gross and systematic errors. Then they are interpolated to a regular grid in an intelligent way. The analyses are given each hour at ground level with an 8 km resolution. The full VERA domain is quite large (1664 km x 1536 km), but here we show the analyses in a smaller area, from 47.5 to 49.0°N and from 6.0 to 9.6°E.

References :

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Reverdy et al., 2009, Water vapour fields retrieval with tomography software, Ann. Meteorol.
Van Baelen et al., 2010 On the relationship between water vapour field evolution and precipitation systems lifecycle, *QJRMS*, submitted
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1st Case study : July, 18th (IOP 9a)

Synoptic situation (figure 4)

Frontal zone SW-NE orientated, in the vicinity of the COPS region could **favour large scale lifting**, even if the situation seems to be more complicated looking to ECMWF vertical wind Analysis and forecast (regions of lifting and subsidence in the cops area, *not shown*). The South-Westerly flow is associated with clouds advection.
Meistrezheim radiosounding : at 1415UTC **CAPE=1320 J/kg**. MesoNH simulation (not shown) for 15UTC predicted **moderate CAPE** over the Vosges Mountains (about 1000-1500 J/kg), and low CAPE over the Black forest.
-> conditions mainly favourable for precipitations

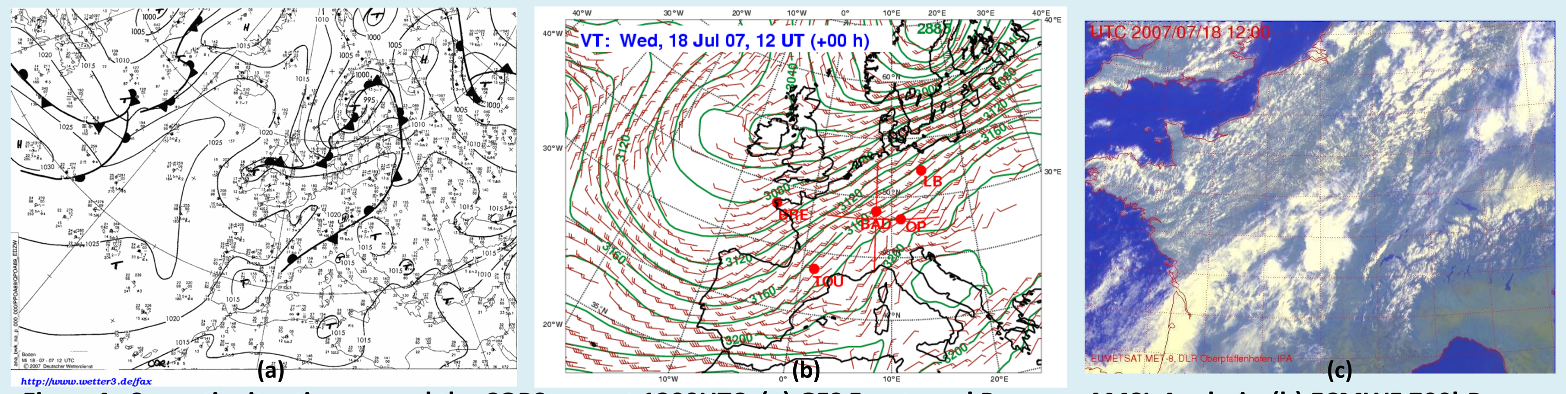

Figure4. Synoptic situation around the COPS area at 1200UTC. (a) GFS Fronts and Pressure AMSL Analysis, (b) ECMWF 700hPa Geopotential and wind analysis , and (c) MSG visble reflectance picture.

Radars observations on the lee side of the Vosges Mountains

- 1st cell initiate along the Bruche Valley at 1640 UTC (fig. 5a. ,top) -> intensifying around 2 small hills on the lee side of the Vosges shown by the X band radar.
-2nd cell initiate on the south, on the lee side of the Vosges Mountains, over a hill at 1810 UTC (fig 5b)
-> The X band radar shows the impact of small scale orography

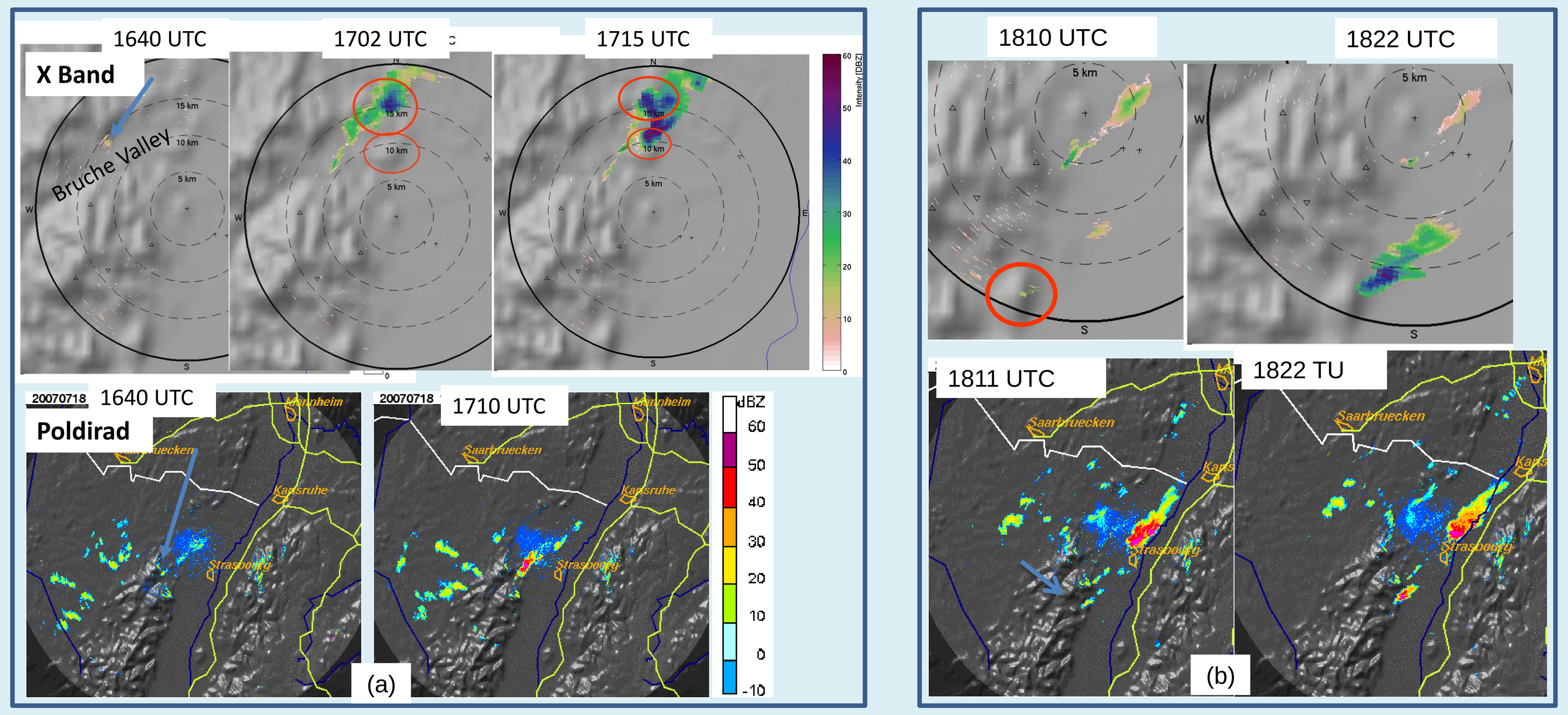

Figure 5. X band radar (top) and Poldirad radar (bottom) reflectivity pictures

Water vapour and wind

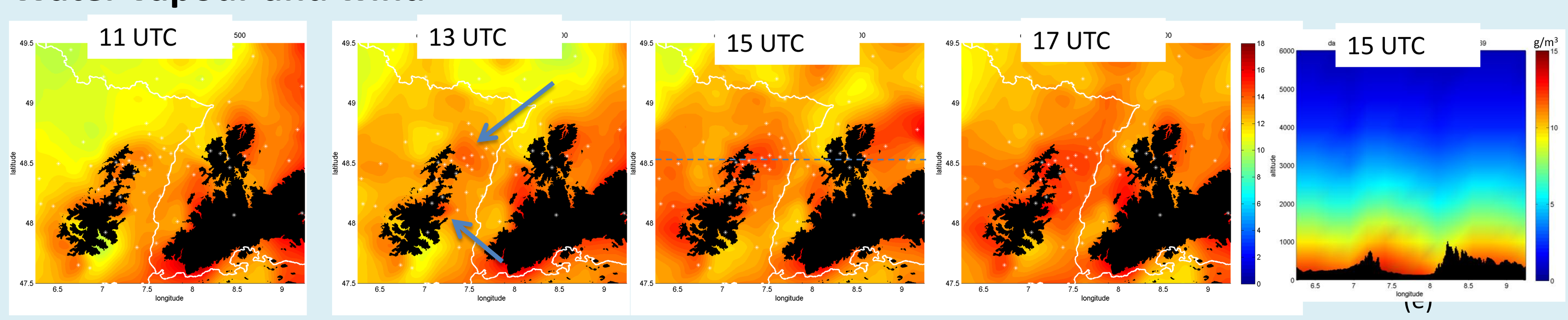

Figure 6. water vapour field at 500m AMSL (a,b,c,d) and at a constant lalitude of 48.57 °N (along the blue dashed line , c) obtained from GPS tomography

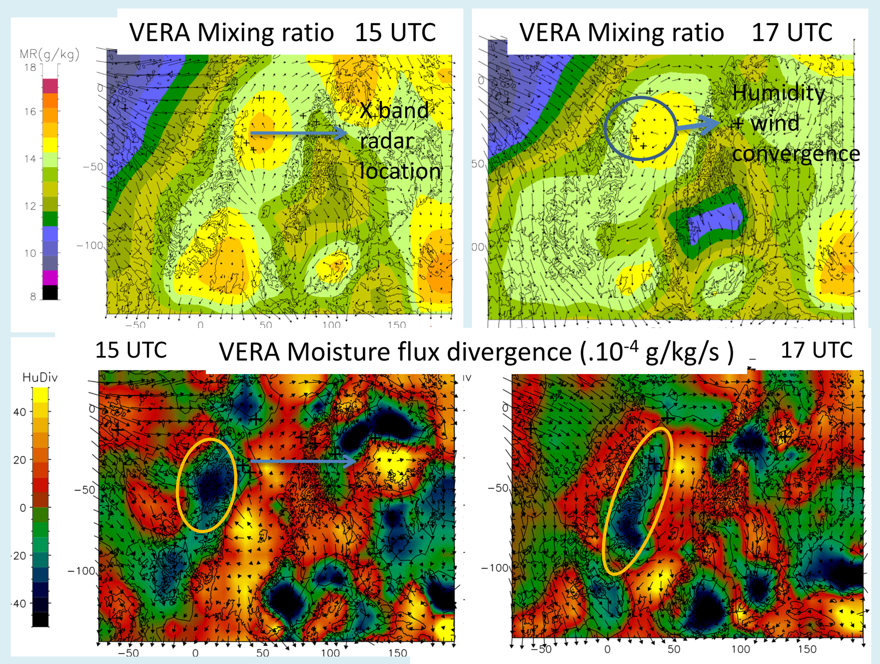

Figure 7. VERA wind field (arrow), mixing ration (a,b) and Moisture flux divergence(c,d) in the COPS region. The thin lines indicate orography.

- *From 13UTC* **moisture accumulation** on the lee side of the Vosges (fig 6. b) around the 1st cell location, **near the ground** an then up to 1.5km (6.e).
- Analysis also show these **damp areas** (fig 7. a,b).
- *15UTC* : moisture convergence over the Vosges BUT no moisture accumulation (fig6. e). Hence the **moisture is certainly advected est of the Vosges** (and is a part of humidity seen around 1000m with GPS).
- *17 UTC :* **Moisture and wind convergence** in the vicinity of the small hill where the 1st cell grows.

-> local convergence of moisture and wind at the ground + advection of moisture + orography + moderate CAPE and vicinity of a front explain convective initiation and growth.

2nd Case study : August, 6th (IOP 14a)

Synoptic situation

At 12 UTC, the COPS domain is situated in the vicinity of a convergence zone, in front of a cold front. The Front itself is associated with precipitations and convective storms. ECMWF analyses also predicted **large scale lifting** along the convergence line.
The Meso NH predictions (not shown) give **cape around 1500 J/kq at noon** over the Vosges mountains and seem to be associated with the propagation of the front.
- MSG pictures show some shallow cumulus over the East part of the Vosges mountains.
-The brightness temperature (and the lightings detected at high altitudes) indicates **very deep convection** over the Rhine valley at 16UTC (T_b< 215K at 10.8 µm).

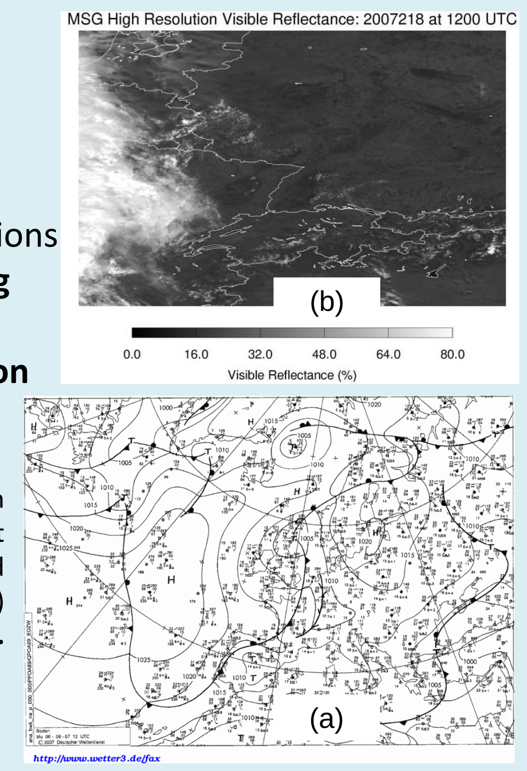

Figure8. Synoptic situation around the COPS area at 1200UTC. (a) GFS Fronts and Pressure AMSL Analysis, (b) MSG visble reflectance picture.

Radars Observations

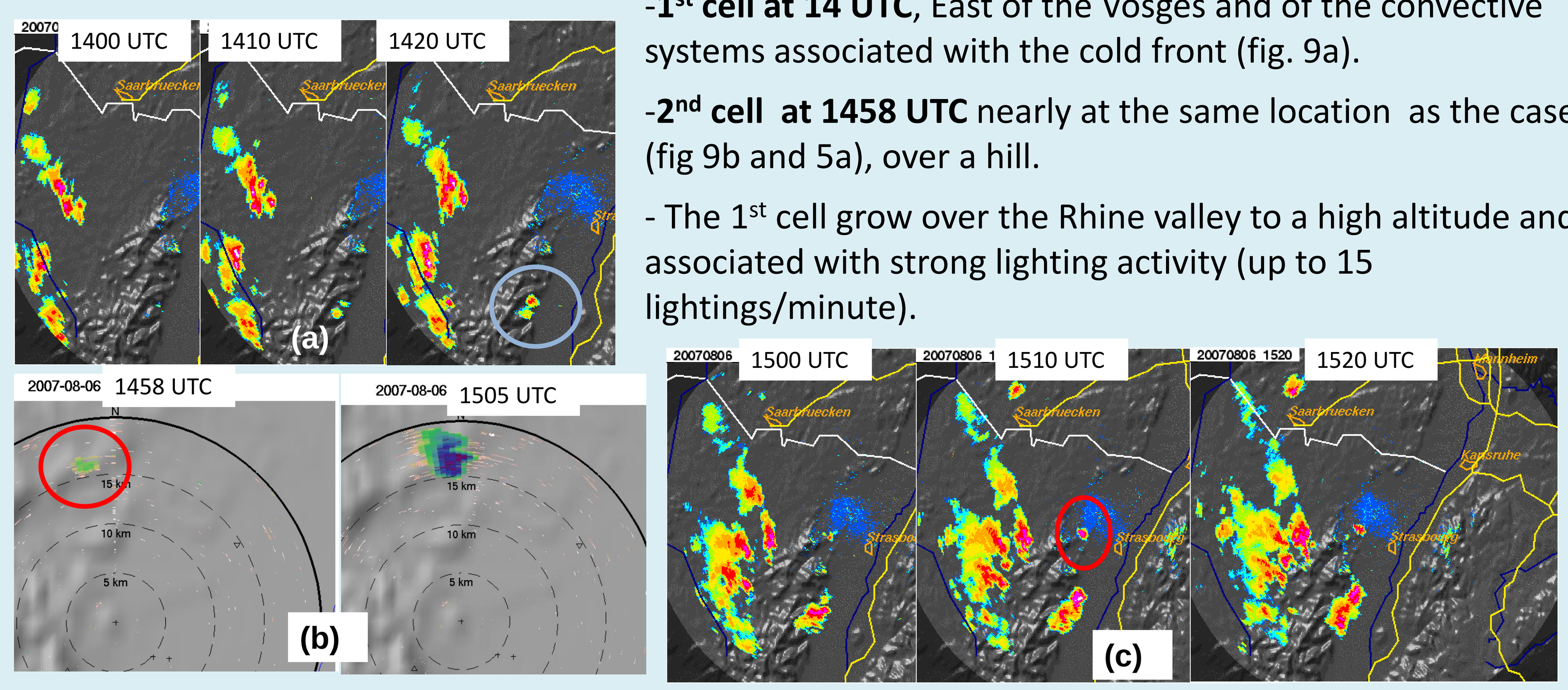

Figure 9. Poldirad (a,c) and X band (b) radar reflectivity

-**1st cell at 14 UTC**, East of the Vosges and of the convective systems associated with the cold front (fig. 9a).
-**2nd cell at 1458 UTC** nearly at the same location as the case 1 (fig 9b and 5a), over a hill.
- The 1st cell grow over the Rhine valley to a high altitude and is associated with strong lighting activity (up to 15 lightings/minute).

Water vapour and wind

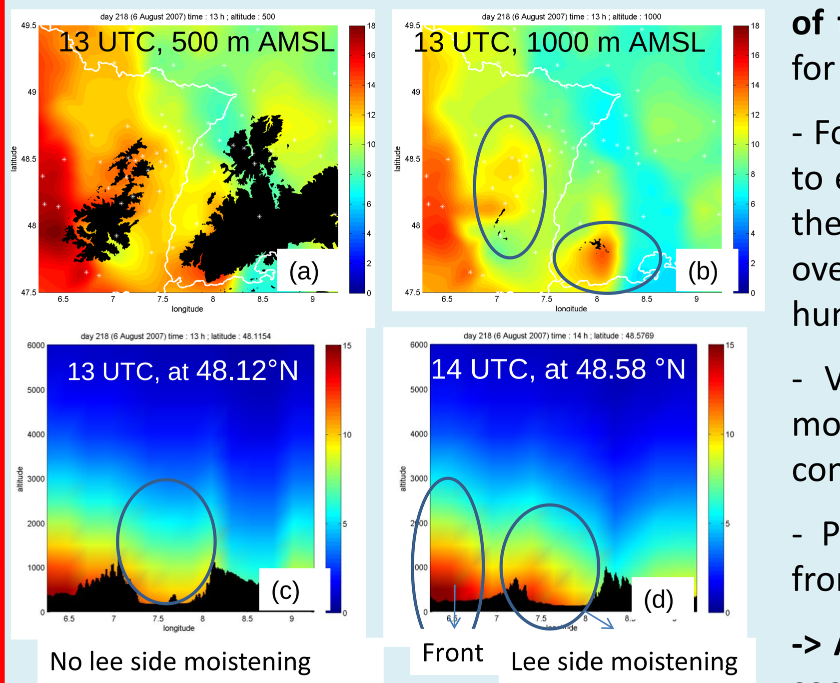

Figure 10. Water vapour field from GPS tomography.

- GPS tomography shows a **moistening of the lee side of the Vosges** (fig. 10 a,b), before the front, especially for the 2nd cell (fig 10 d).
- For the 1st cell, the GPS tomography does not allow us to explain why convection occurs on the lee and not on the crest. (**Note** that *another thunderstorm* develops over the Black forest, at 1654 UTC – first lighting- where humidity is seen from 13 UTC, fig. 10b)
- VERA also show this moistening (not shown) and moisture convergence (fig. 11. a,b,c) in the region were convection occur *but also* on the crest.
- Potential temperature analysis show the **cold front** from 13-14 UTC (fig 11d).

-> As in case 1, moisture, convergence, and orography seem to play an important role, with a stronger forcing here due to the cold front.

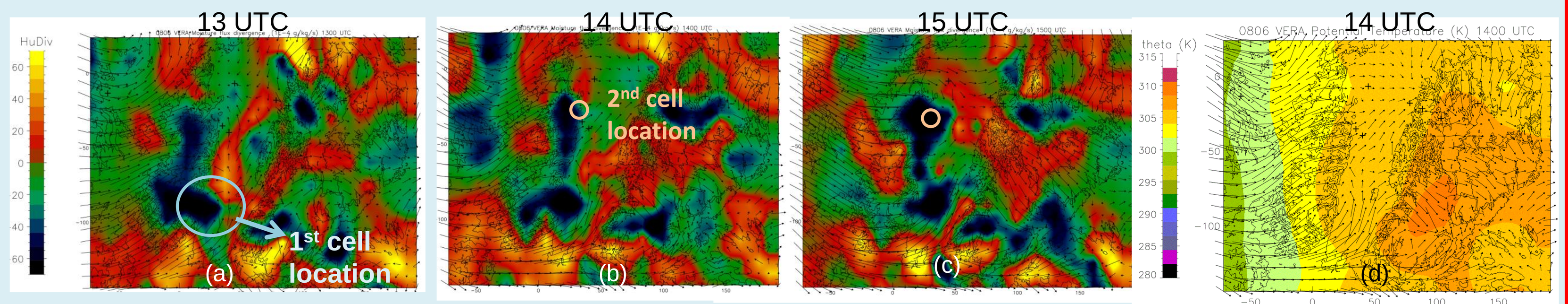

Figure 11. VERA wind and moisture flux divergence (a,b,c), and potential temperature (d)

Conclusion and perspectives

- These 2 case studies show the importance of the knowledge of water vapour field for the understanding of convective initiation and growth. In that aim, GPS tomography appears to give very interesting information, even if resolution is limited. The high resolution radar shows the impact of small scale orography on convective developpment.
- We also have to natice the importance of the wind field : in the case 1 (1st cell) the moisture is advected on the lee side because of strong enough wind over thes Vosges montains.
- Especially for case two, further investigations (for example with the 3D wind data from doppler radars) are needed to understand WHY convection began *only* on the lee side.