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Precipitation on the lee side of the Vosges Mountains: Multi-instrumental study of one case from the COPS campaign

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1) INTRODUCTION

- In the framework of the Convective and Orographically-induced Precipitation Study (**COPS**) campaign (Wulfmeyer et al. 2008, 2011) -> *numerous obs. and models runs available (July-September 2007).*
- COPS area = **low mountains** (Vosges Mountains and Black Forest) **and complex terrain** (crops, forests, towns, etc. ...) between North-Eastern France and South-Western Germany.

Main objectives of this work :

What are lee side precipitation mechanisms ? How can GPS Water Vapour (WV) measurement be helpful to understand key processes in Convection Initiation (CI) and lifecycle ?
Method : Synergic use of GPS, radars, and other observations + analyses/models.

2) MATERIAL AND METHODS

OBSERVATIONS

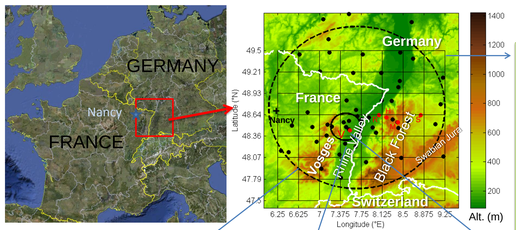


Figure 1 : The COPS area

GPS MEASUREMENT
→ **Network of GPS stations** (black and red dots) for :
• **Integrated Water Vapour amount (IWV)** above each station.
• **3D WV mixing ratio via tomography** (tomographic grid in black) .

Supersite V. Numerous measurements including :
• UHF wind profiler
• Radisoundings

PRECIPITATION MEASUREMENT

DLR POLDIRAD C band radar
• **120 km** range (great circle)
• PPI scans at 2° elevation
• Every **10 min** when operating

LaMP X band radar
• **20 km** range (small circle)
• PPI scans at 5° elevation
• **High res**: 30s / 60m (radial)

ANALYSES

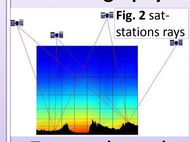
Vienna Enhanced Resolution Analysis (VERA)
(Steinacker et al. 2006; Bica et al. 2007) :
• Interpolates surface based data in order to perform model independent 2D Analysis.
• No a priori but a « fingerprint method » to take into account terrain height heterogeneity (Bica et al. 2005).
• **Resolution : 8x8 km², hourly.**

European Centre for Medium-Range Weather Forecast (ECMWF) Analyses
(Simons et al. 2007; Dee et al. 2011)
• Resolution : **0.5x0.5°** , 21 vertical levels (between 0 and 12 km AMSL).
• Every 6 hours (at 00, 06, 12 and 18 UTC every day).

GPS METEOROLOGY

General principles
• **GPS signals are delayed by the atmosphere**
• About 90 % of this delay comes from induced dipolar moment of atmospheric components → accurately calculated from surface pressure (Saastamoinen 1972, Bevis et al 1985).
• About 10 % remaining are due to Water Vapour permanent dipolar moment : ***Wet Delay*** → **gives total amount of WV along zenith path (IWV) or along each Slant satellite-station path (SIWV)** (Emardson and Derks 2000, Niell 1996).

GPS tomography : from SIWV to 3D WV



• Damped weighted least square inversion to retrieve the best 3D WV field from all the available SIWV (Reverdy 2008, Van Baelen et al. 2011)
• **Tomography results** = Water vapour field with **vertical resolution up to 200 m** (lowest layers) and **horizontal resolution of about 30 km**. Time resolution up to **5 minutes.**

3) CASE STUDY : 18th JULY 2007

GENERAL SITUATION

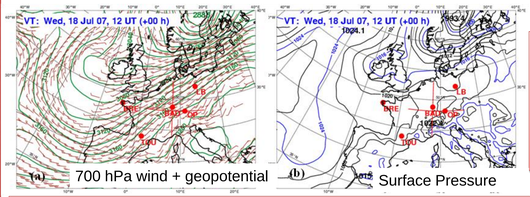


Fig 3. ECMWF Analyses at 12 UT

Between Scandinavian-UK through and SE Mediterranean high pressure :
• Low wind near the surface
• **Surface cold front → could favour lifting.**

Radiosoundings : Moderate CAPE at supersite V (Mixing Layer CAPE about **800 J/kg** at 14 and 17 UT)

PRECIPITATIONS

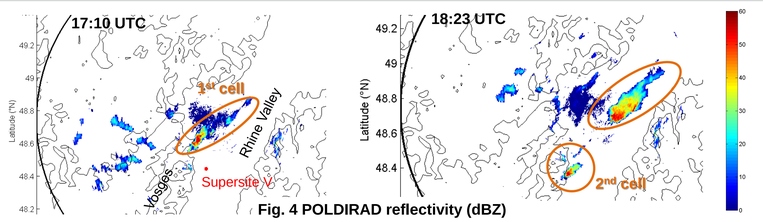


Fig. 4 POLDIRAD reflectivity (dBZ)

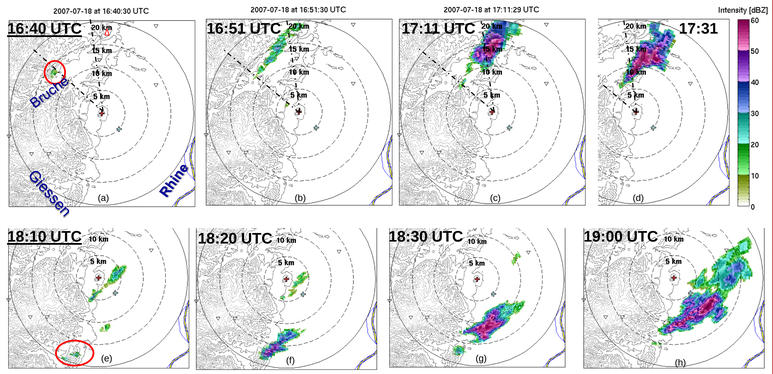


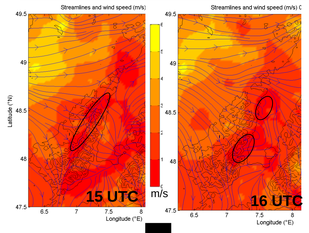
Figure 5. X band radar reflectivity. Top (a-d) = 1st cell. Bottom (e-h) = 2nd cell.
Dashed lines = partially masked area. Blue text = names of the rivers. Red ellipses = CI locations.

→ 2 precipitating cells on the east part (lee side) of the Vosges Mountains, in the late afternoon.
• 1st initiates in the **Bruche Valley**, and growth **over the hills** in the North-Eastern exit of the valley.
• 2nd initiates **over the hill** in the NE of the Giessen Valley exit, and develops over the **Rhine Valley**.
• POLDIRAD RHI and lightning detection network data show that **only the first cell growth up to mature thunderstorm stage** (top of cloud over 8km height, lightning activity detected).

→ Both cases exhibit quite important interactions with local orography.
NB : *No precipitation detected over the crest/windward side of the Vosges Mountains : WHY ?*

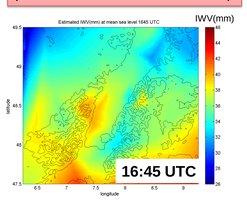
3) CASE STUDY : 18th JULY 2007 (continued)

Fig 6. VERA surface wind field



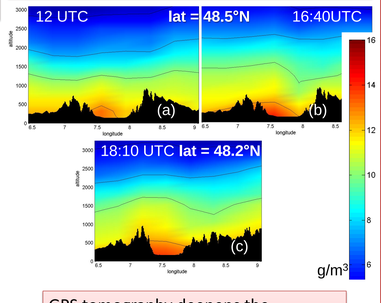
Light wind **convergence line** over the Vosges crest (black ellipse) at 15 UTC → Moves Eastward : over the lee slopes/Rhine Valley at 16 UTC .

Fig 7 . GPS IWV (Estimated at mean see level)



Moist area on the east side of the Vosges mountains at 16:45 UTC (i.e. when precipitation begins) , and it remains till nearly 19 UTC (not shown).

Fig 8. GPS tomography : WV mixing ratio



GPS tomography deepens the information from the 2D IWV map :
• **Moisture accumulation** from 12 UTC near the 1st cell initiation location, **in the boundary layer** (BL).
• **Moist area** near the 2nd Cell initiation location (c) **before the onset of precipitation**, also in the BL.

4) SUMMARY AND CONCLUSION

Precipitation mechanism :
Light synoptic forcing and moderate CAPE + over the lee side of the Vosges Mountains :
• Wind Convergence
• Moist area (both in term of total column and of mixing ratio in the boundary layer)
→ Favour **lee side precipitation.**
+ Interactions with local orography (and probably local valley-breeze systems) lead to the development of **deep** (1st cell) **and shallow** (2nd cell) **convection** with heavy precipitation.

→ To the contrary, no moisture accumulation over the crest, and only weak convergence in the early afternoon : **no precipitation on the crest/ windward side** of the mountain range.

Important role of the 3D Water Vapour field → usefulness of GPS measurement, even if horizontal resolution is quite low.

5) ACKNWOLEDGEMENTS AND REFERENCES

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