

# Impact of High-Resolution Data Assimilation of GPS Zenith Delay on Mediterranean Heavy rainfall Forecasting

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# Atmospheric humidity determined by ground-based GPS

- GPS measurements allow to retrieve integrated water vapour

→ **ZTD** : Zenithal Tropospheric Delay (m) → **data assimilated**

$$\Delta L = \int_L 10^{-6} N \cdot dl \quad \text{with,}$$

(*N*, Air index refractivity)

$$N = k_1 \frac{P}{T} + k_2 \frac{P_e}{T} + k_3 \frac{P_e}{T^2}$$

Hydrostatic contribution

Wet contribution



Zenithal Hydrostatic Delay

**ZHD ≈ 2.1m**

Zenithal Wet Delay

**ZWD ≈ 0.15 m**

→ **IWV** : Integrated Water Vapor (kg.m<sup>-2</sup>)

ZWD	IWV	PW
6.5 mm	1 kg.m <sup>-2</sup>	<b>1 mm</b>

← **GPS accuracy**

# GPS Data assimilation methodology

## ZTD GPS observations

EGVAP + RENAG/OHMCV

⇒ Stations selection

⇒ Bias correction of the data

## Assimilation experiments

- Without GPS obs : CTRL
- With GPS obs : GPS

## AROME model

- 2.5 km resolution

→ convection resolved

- Sequential assimilation

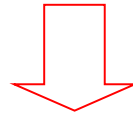
{ 3D-Var analyses

{ 3h- Model forecasts

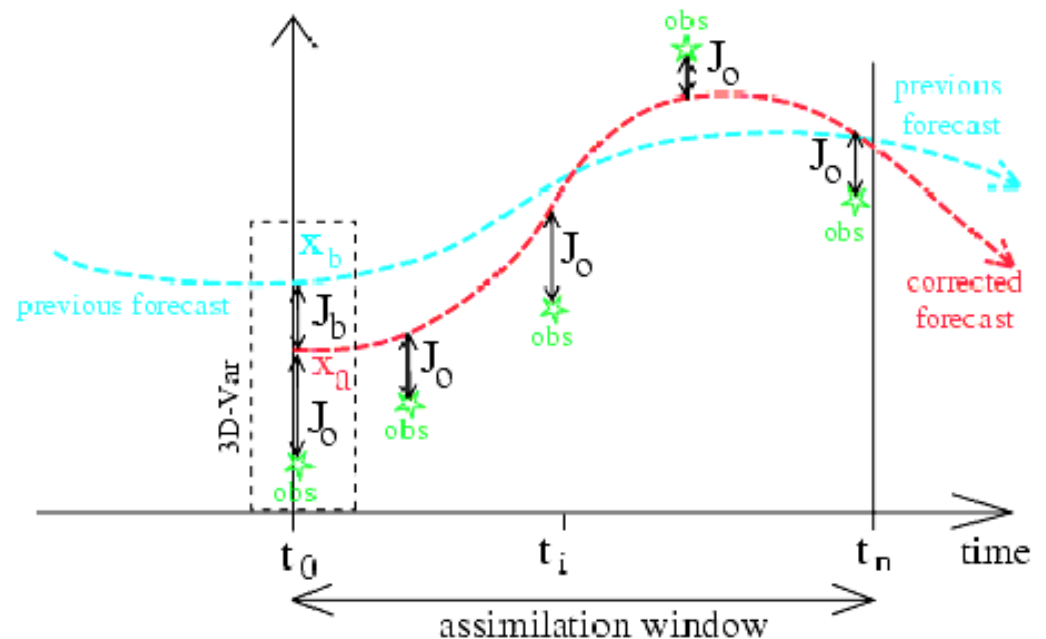
30h-Forecast using analyses from assimilation experiments CTRL and GPS

# Basic concepts of data assimilation

- Background (« ébauche » ( $x_b$ )) : a priori estimate of the real state of the atmosphere
- Selected observations ( $y$ )
- Analysis : best estimation of the true state of the atmosphere at a given time in a model ( 00, 06, 12 and 18UTC)



**Data assimilation** →  
minimizing distance between  
background trajectory and the  
observations



## **1) ZTD GPS observations**

**EGVAP + RENAG/OHMCV**



**Stations selection**



**Bias correction of the data**

# Stations selection and bias correction

Observation operator ( $H(x_b)$ ) : computes the model equivalent observable

Several criteria are used:

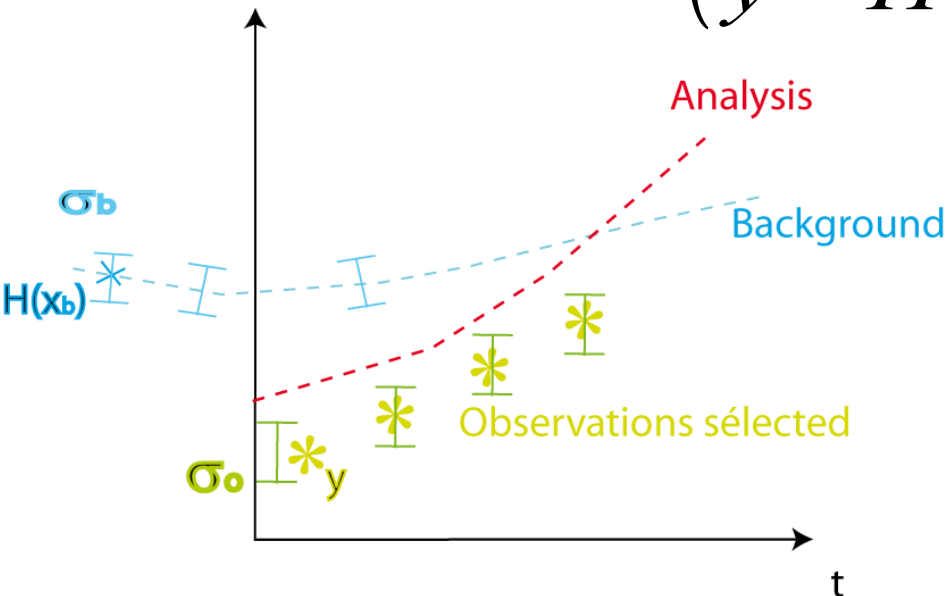
- Gaussian distribution of the ZTD difference  $y - H(x_b)$

→ with Kolmogorov-Smirnov test

- Sufficient availability of data : 40% of data available for the 15 days assimilation period

- Rejection criteria :

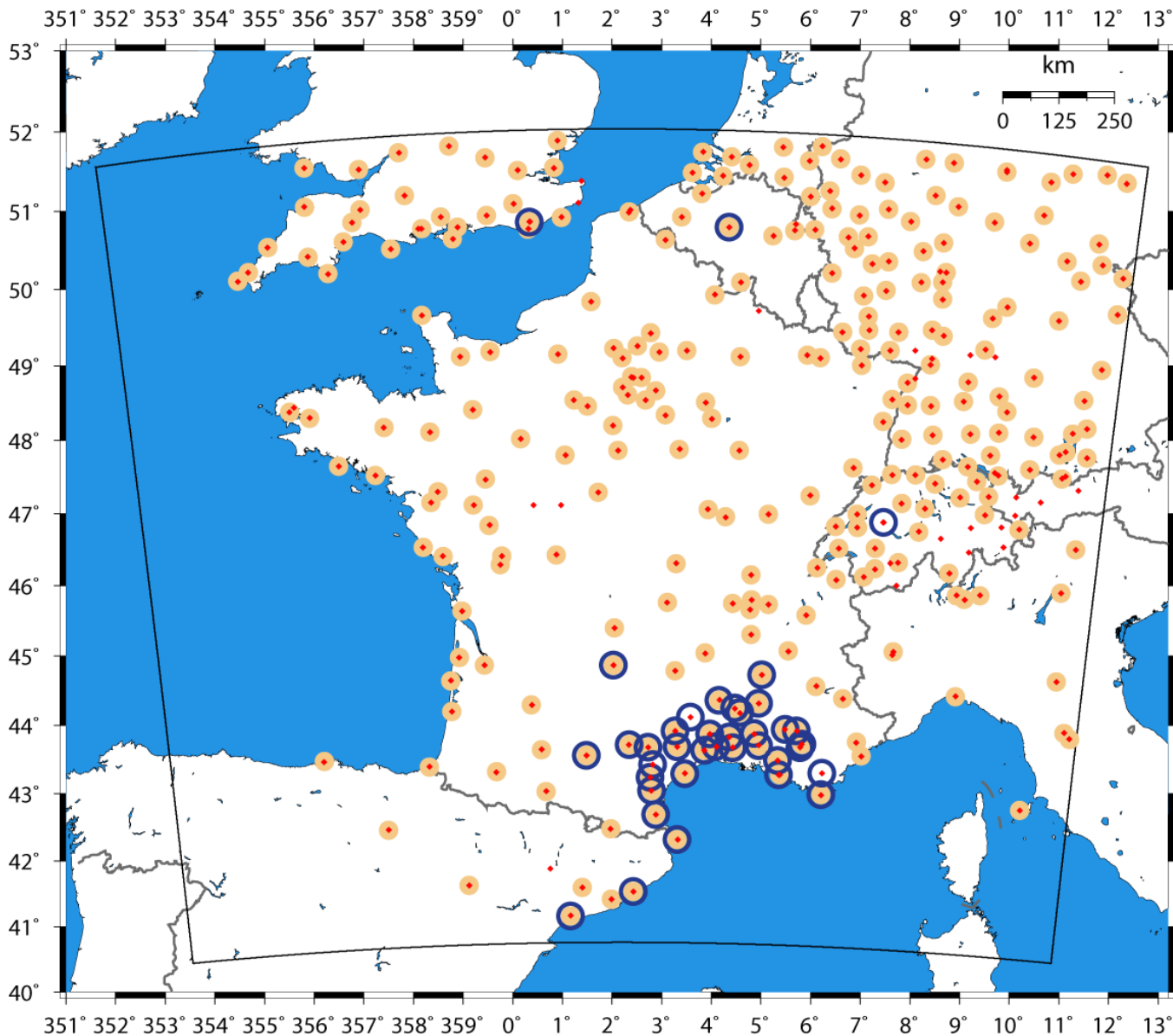
$$(y - H(x_b))^2 > n(\sigma_b^2 + \sigma_o^2)$$



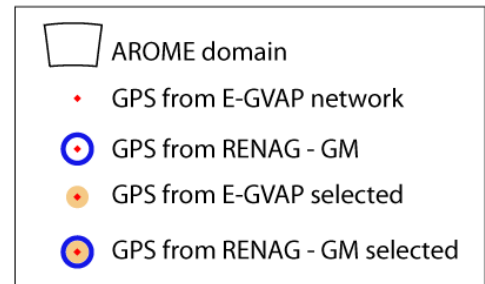
$\sigma_b \approx 12$  mm, *background error*

$\sigma_o \approx 10$  mm, *observation error*

# GPS network and final selection



Stations-centres : 696  
Final selection :  
→ 282 stations / 331



## 2) Assimilation experiments

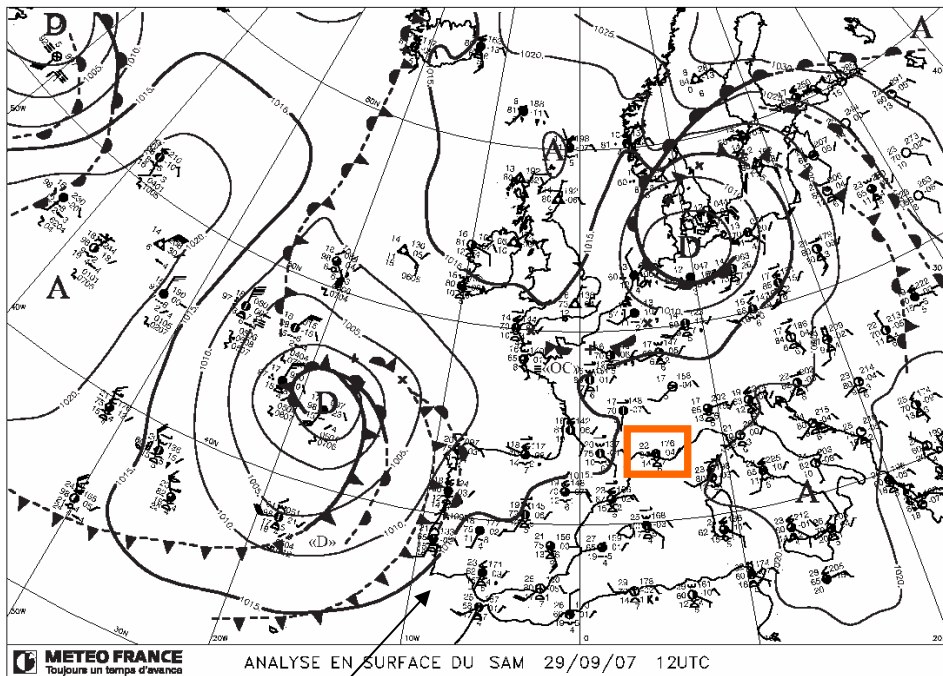
- Experiment **without GPS obs** : CTRL
- Experiment **with GPS obs** : GPS

Data assimilation period between 15<sup>th</sup> - 30<sup>th</sup> September 07

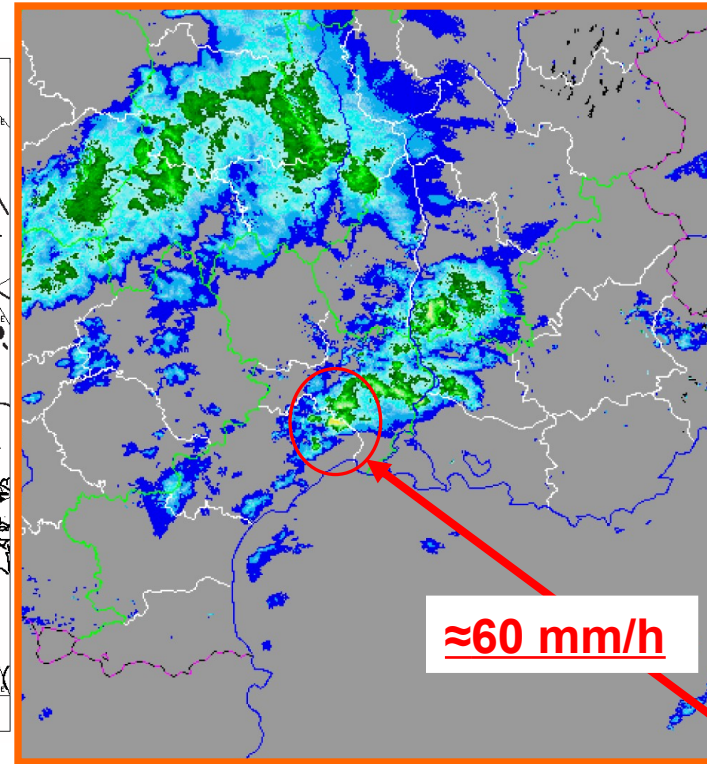
→ we focus on the 29<sup>th</sup>-30<sup>th</sup> September 2007 study case

# Study case : 29-30 September 07

- Quasi-stationary Mesoscale Convective System (MCS)
  - Storms locally intense reaching 30 to 60 mm per hour
- High daily cumulated rainfall recorded at Vérargues : 220 mm

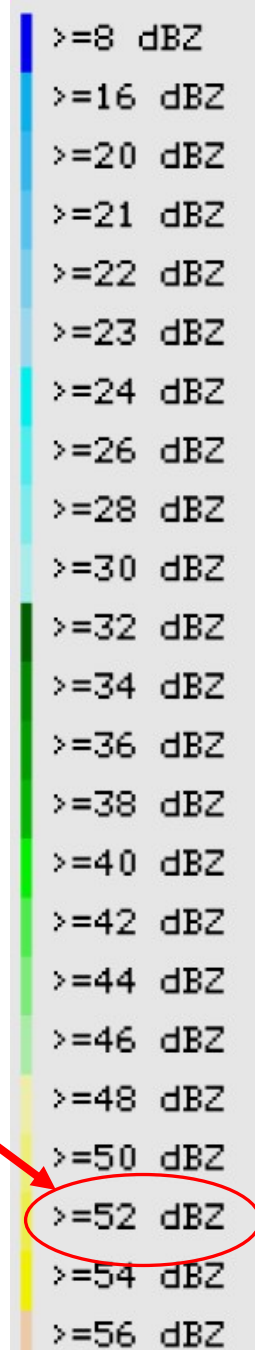


Southwesterly low pressure area



Radar composite image on  
29/09/08 at 18UTC

source : Météo France



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{ 3D-Var analyses  
3h- Model forecasts

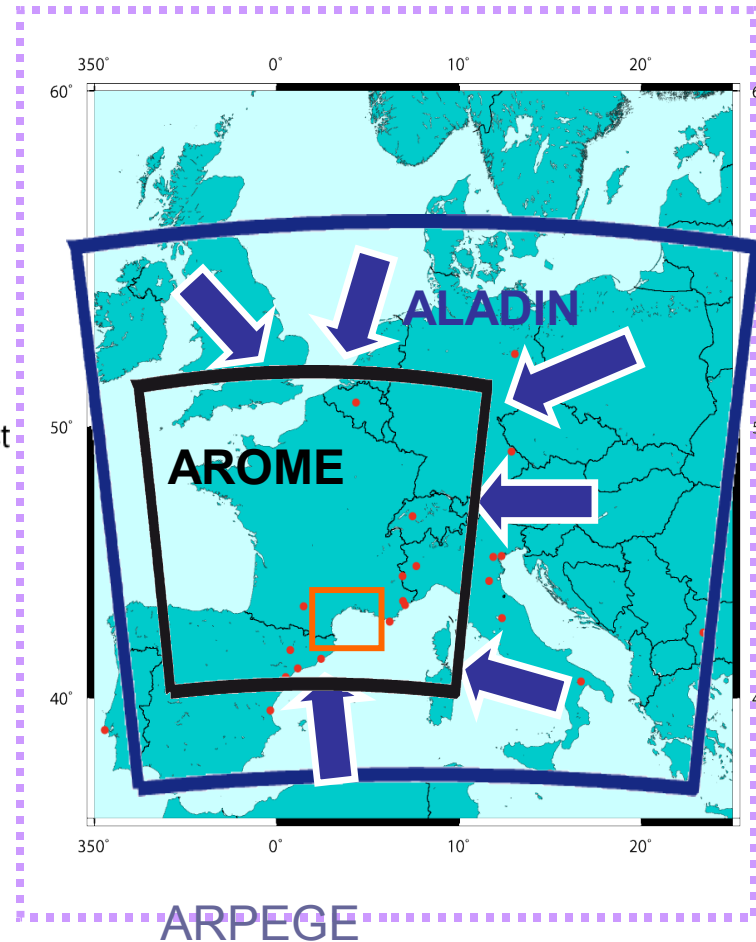
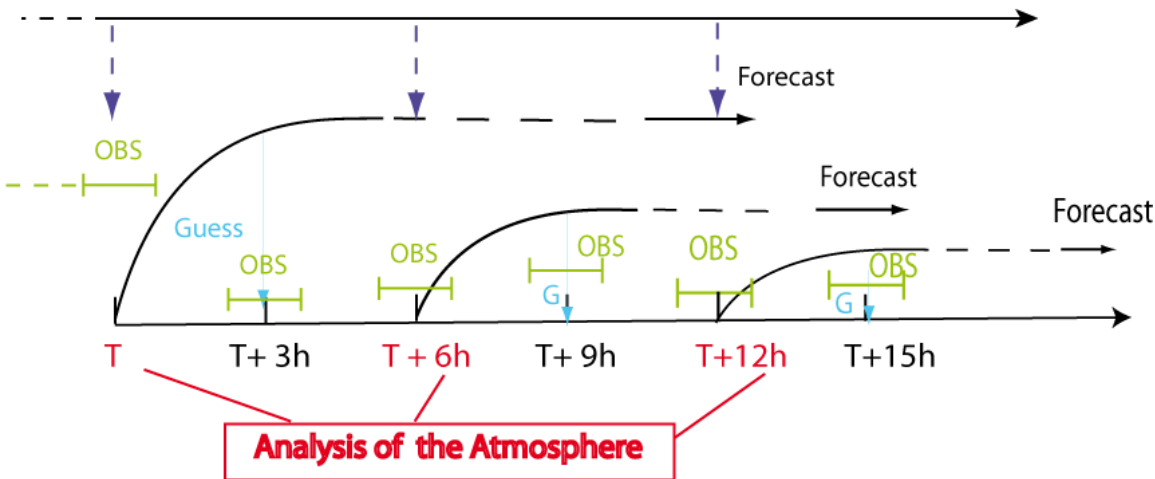
30h-Forecast using analyses from assimilation experiments CTRL and GPS

# 3D-Var sequential assimilation in AROME

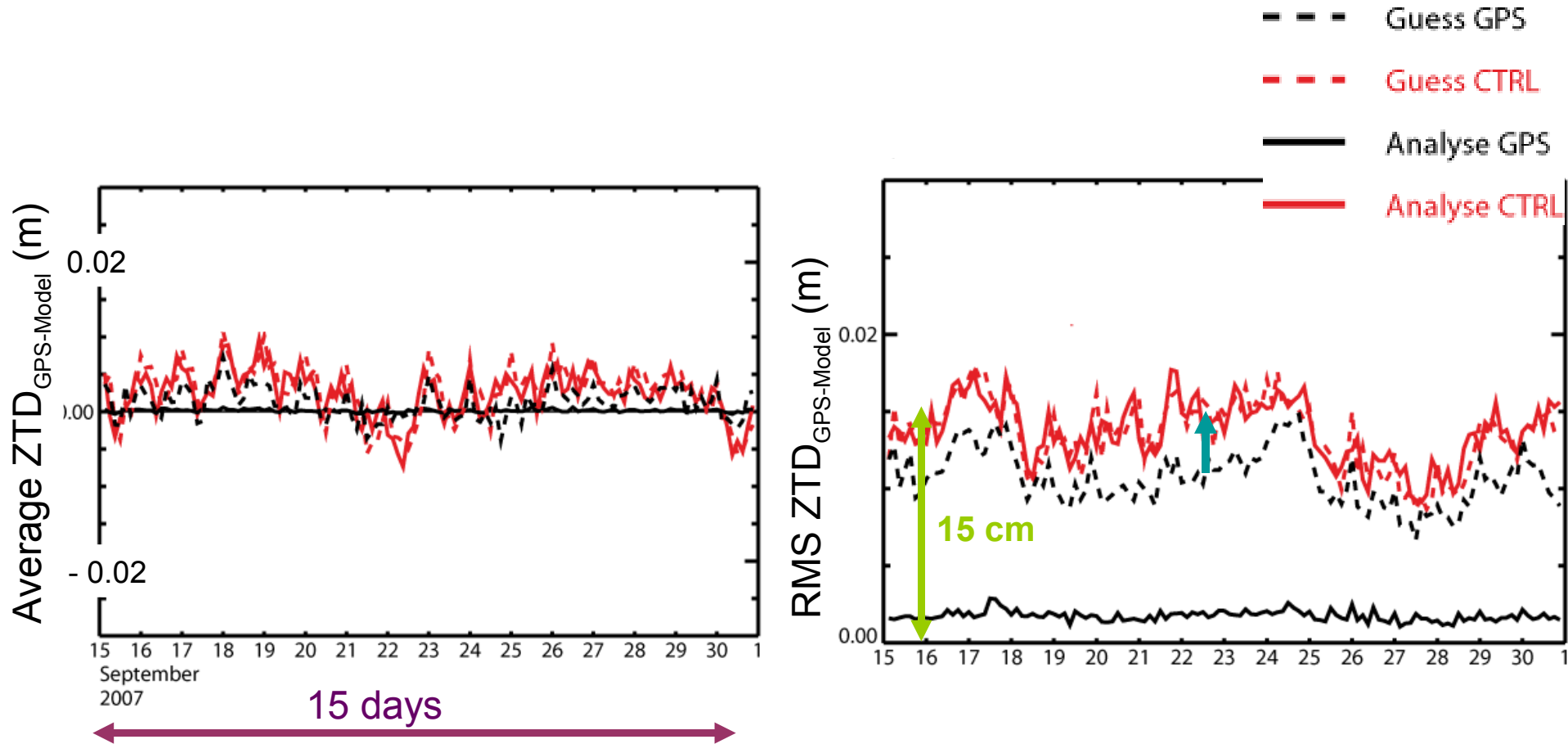
Assimilation window in Arome : each 3h GPS observations are assimilated

Lots other data are assimilated in AROME

Lateral conditions from Aladin forecasts (9.5 km)



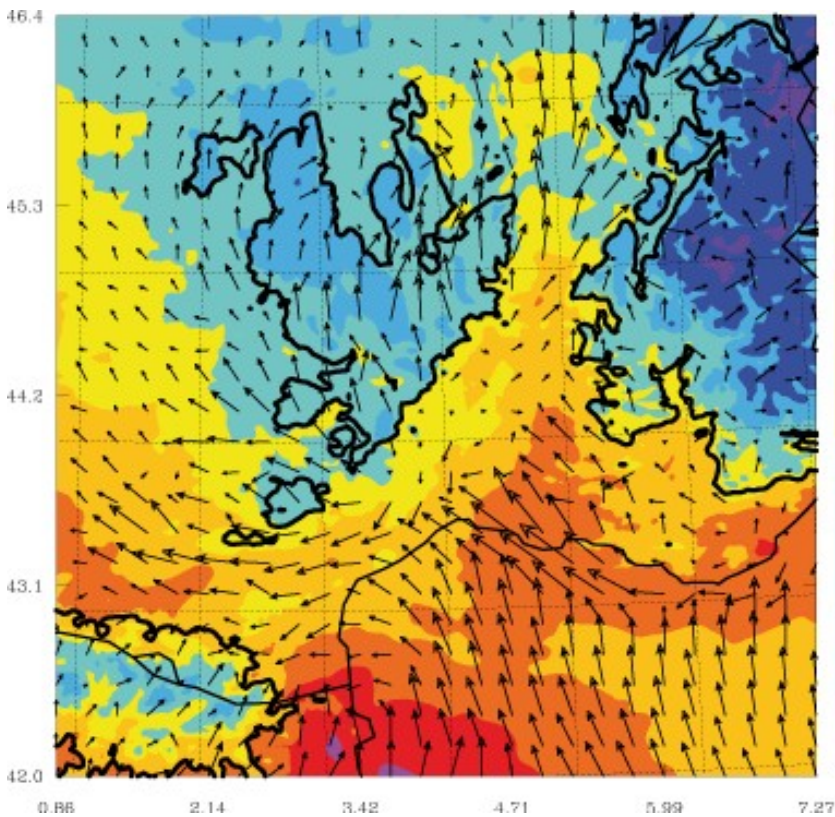
# Impact on the analysis : CTRL / GPS



- Average of  $ZTD_{\text{obs-model}} \approx 0 \rightarrow$  data are well unbiased
- GPS analysis provides a precise ZTD estimate
- Initial GPS information partially disappears after 3h

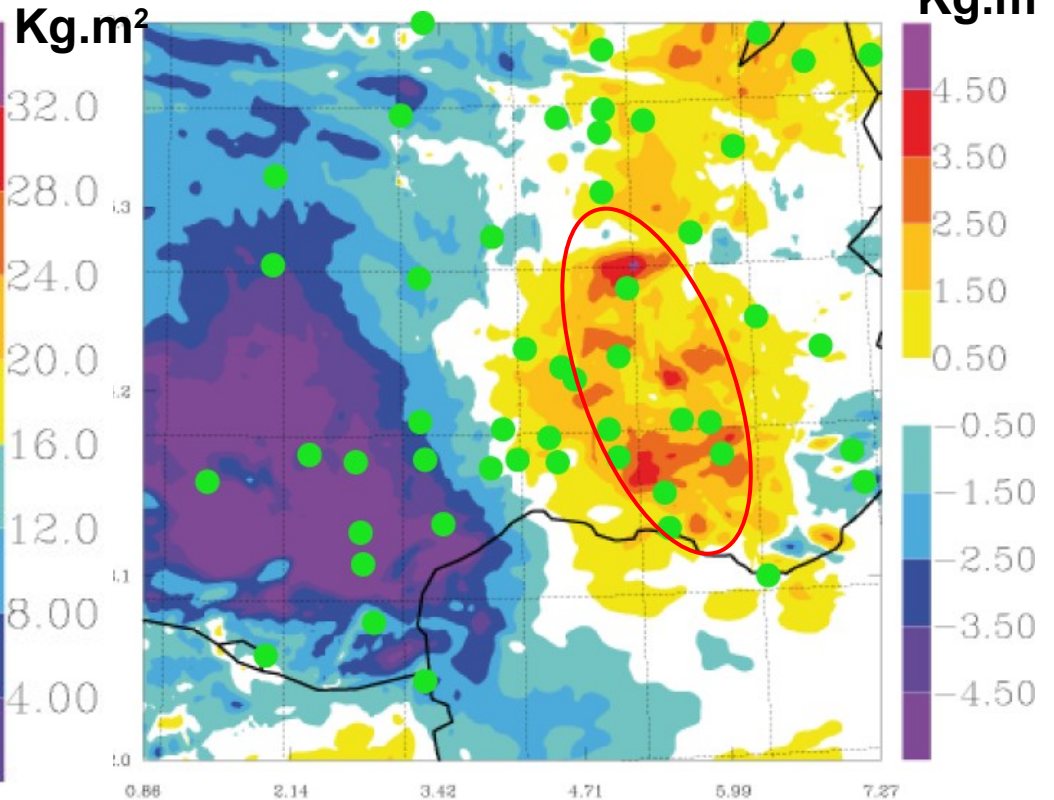
# Integrated Water Vapor (IWV) on 29/09/2007: 12UTC

IWV from GPS experiment



Wind speed at 32 m

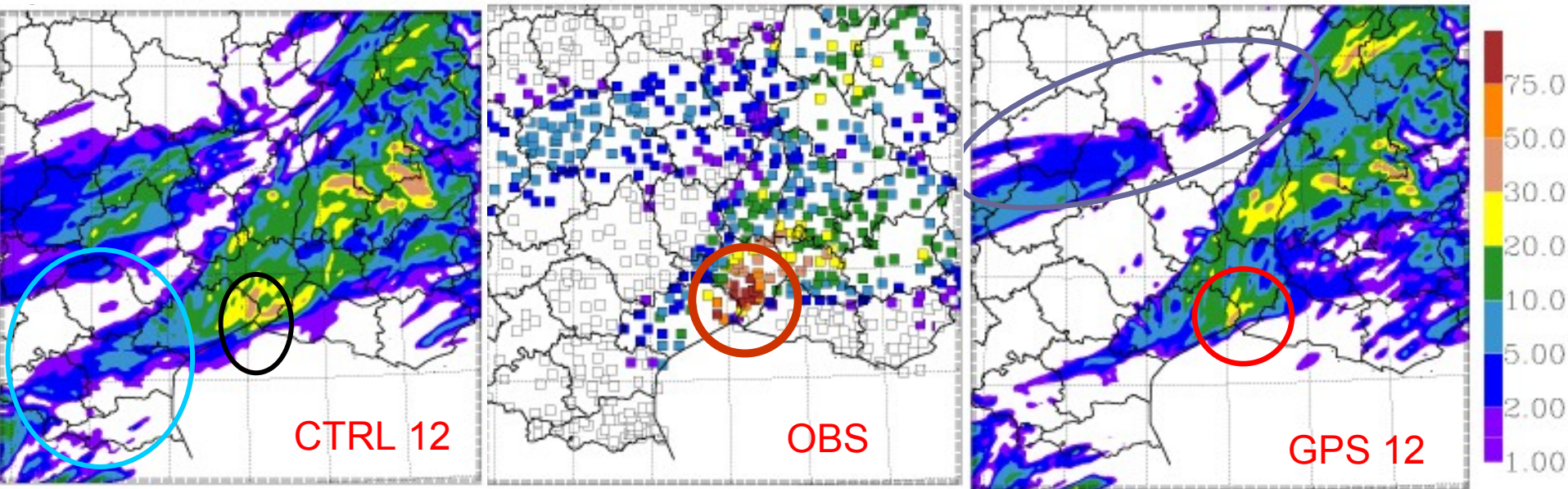
$IWV_{GPS} - IWV_{CTRL}$



GPS dryer

GPS wetter  
about 3 mm in  
average

# Cumulated 24h rainfall forecast : OBS / CTRL12 / GPS12



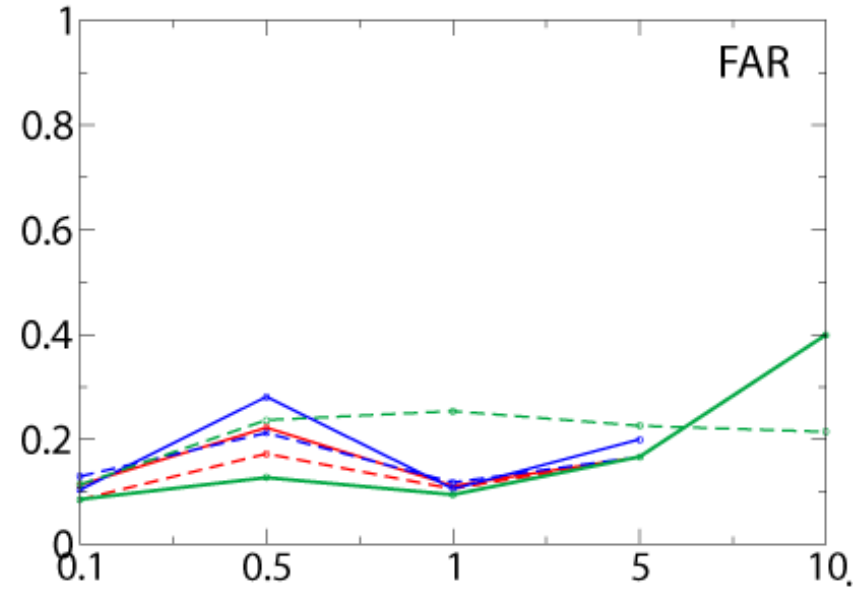
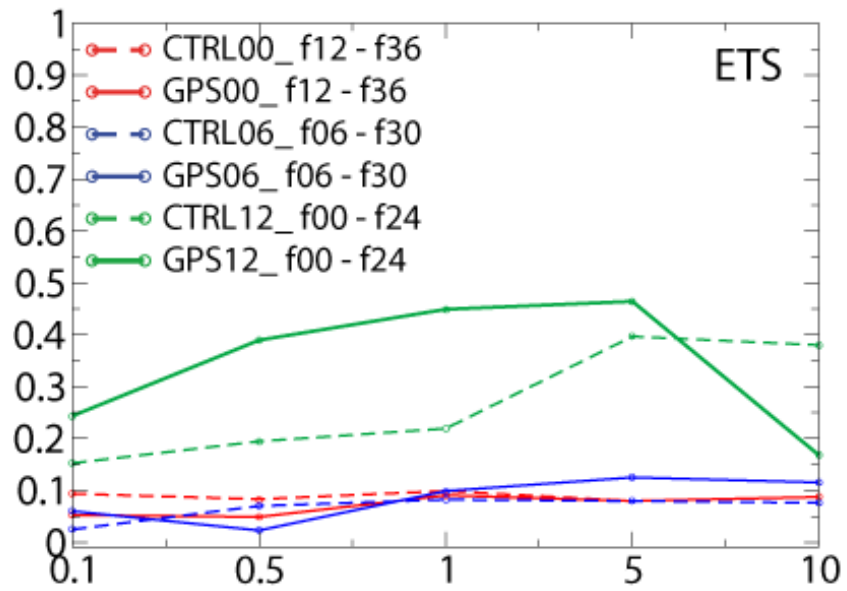
## For the CTRL experiment :

- Good localization of the heavy precipitation core
- Little overestimation of slight precipitation

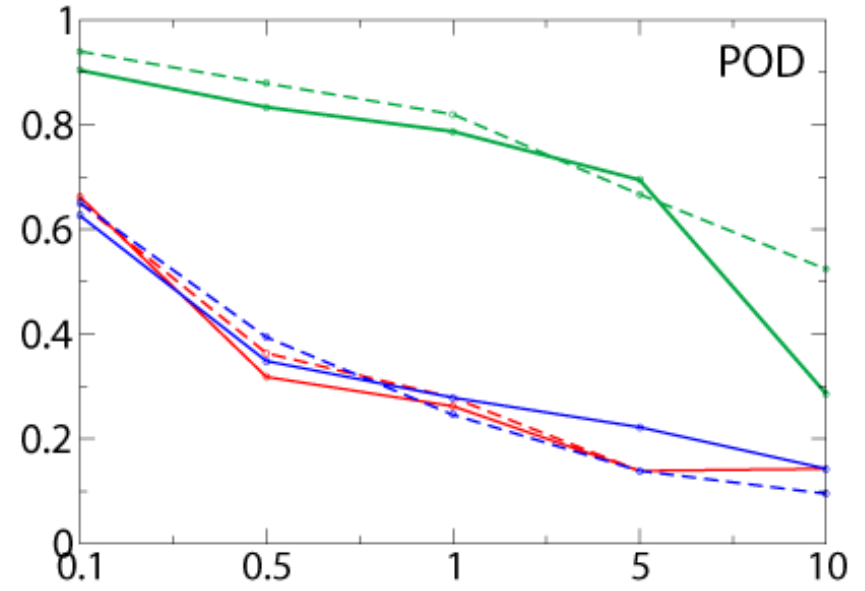
## For the GPS experiment :

- GPS12 improves the general mesoscale feature
- Better forecast of slight precipitation
- GPS12 underestimates heavy rains
- $\approx 25$  mm instead of 50 mm in certain area

# Quantitative **24h cumulated** Precipitation Forecast (QPF) scores



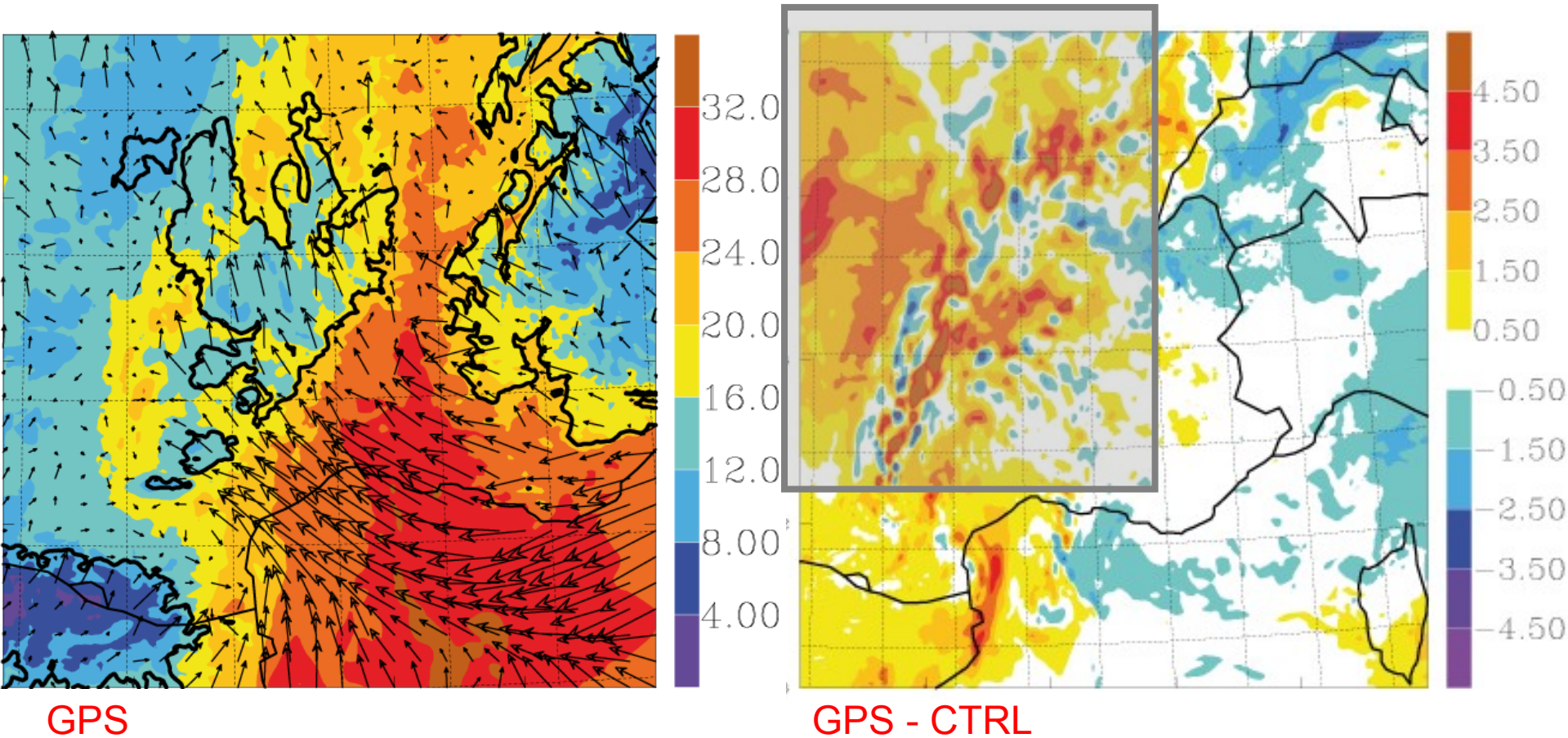
- **Analysis at 12UTC better than at 00 or 06 UTC**
- **Less false alarms with GPS for thresholds < 7 mm**
- **GPS detects better slight precipitations**
- **Impact with GPS experiment visible until 12h after the analysis**



# Discussions and perspectives

- One of the first experiment of GPS data assimilation with AROME, which allows to assimilate a lot of GPS data
- A good fit of the AROME analyses to the GPS data
- Impact on the short range AROME forecast : neutral to slightly positive
  - Improvement mainly found on slight precipitation on the study case
  - In this study case there is still a problem with high precipitation quantification
- How to improve the results ?
  - Optimal model physics for this kind of assimilation ?
  - Optimal density of GPS network ?
  - Larger impact found on the COPS campaign cases (Eastern France), certainly due to assimilation of upstream data
    - lack of upstream data for the Mediterranean heavy precipitation cases ?

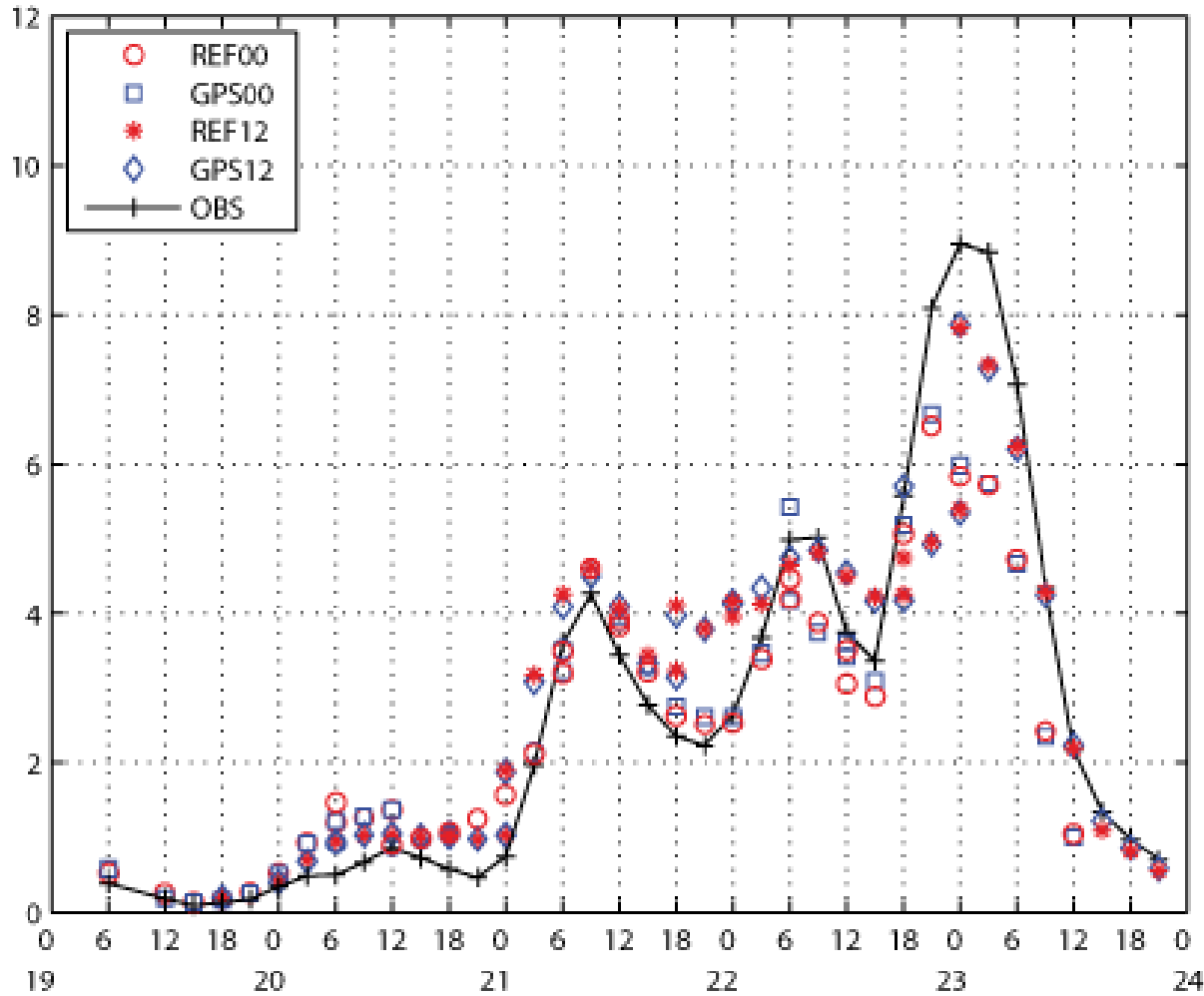
# Integrated Water Vapor (IWV) : Analysis on 22/11/07



Forecasts of the model more unstable for this case

IWV differences are still consistent : about 3mm in average

# November case : 6h cumulated precipitation



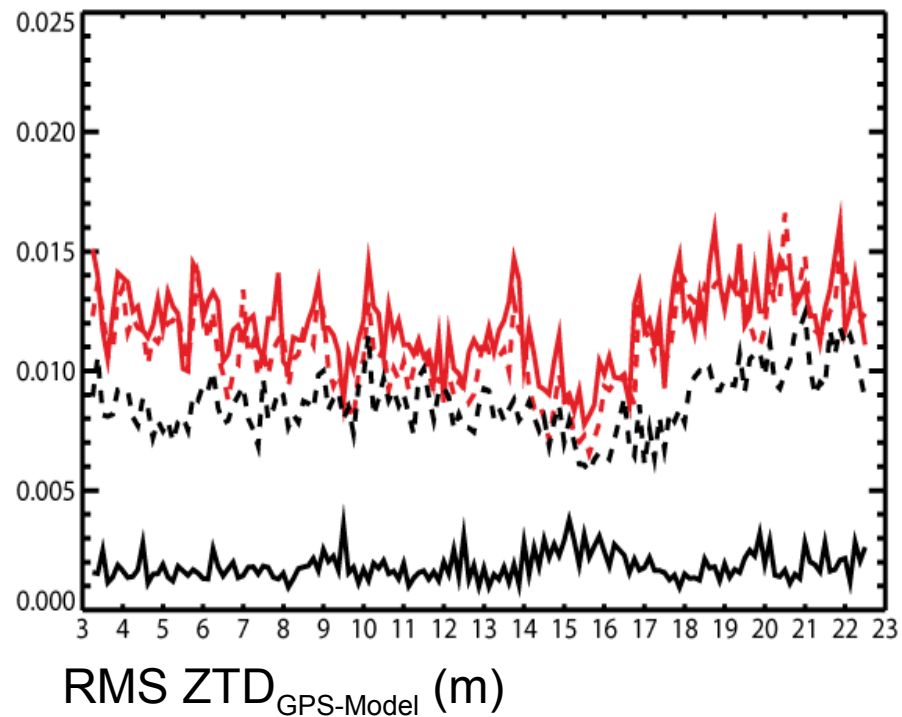
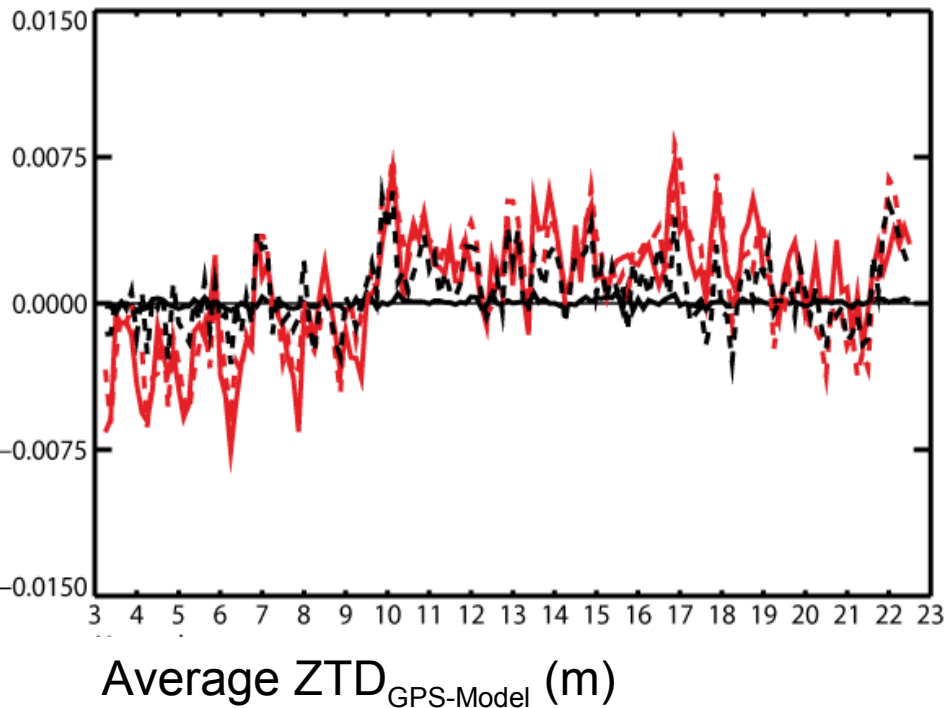
- Analyses at 00 and 12 UTC similar
- GPS and CTRL experiments very closed

6h cumulated precip Average (mm)

# Impact on the analysis : CTRL / GPS

*November*

- Guess GPS
- Guess CTRL
- Analyse GPS
- Analyse CTRL



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➡ Stations selection

## Assimilation experiments

- Control experiment without GPS obs : **CTRL**
- Experiment with GPS obs **GPS**

## AROME model

- 2.5 km resolution

➔ **convection resolved**

- Sequential assimilation

{ 3D-Var analyses  
Model forecasts

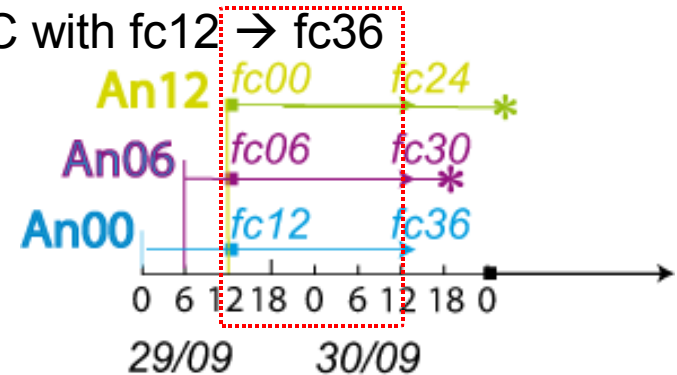
Forecasts using analyses from assimilation experiments **CTRL** and **GPS**

# Assimilation experiments on 2 study cases

- Data assimilation period between 15th - 30th September 07
- 29<sup>th</sup> September 2007
  - Prevision du 29 à 00h ...Analysis 00 UTC with fc12 → fc36
  - Analysis 06 UTC with fc06 → fc30
  - Analysis 12 UTC with fc00 → fc24

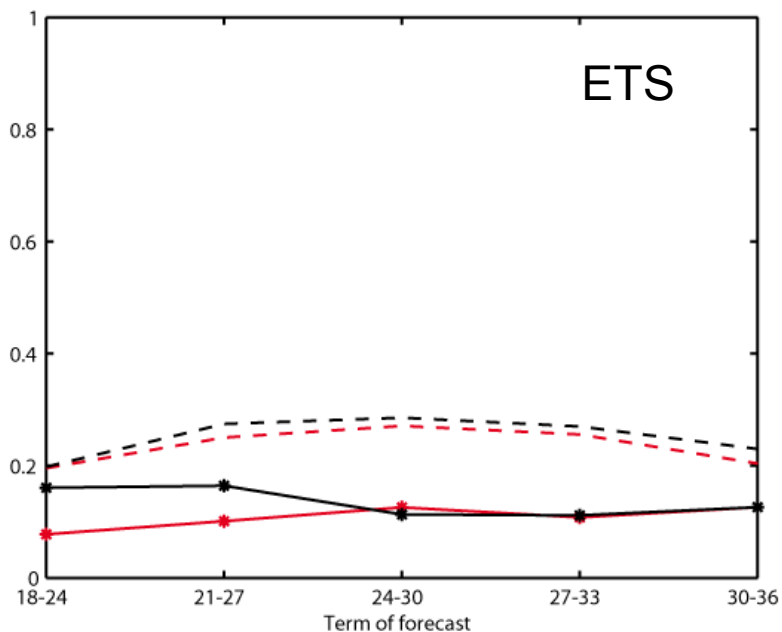
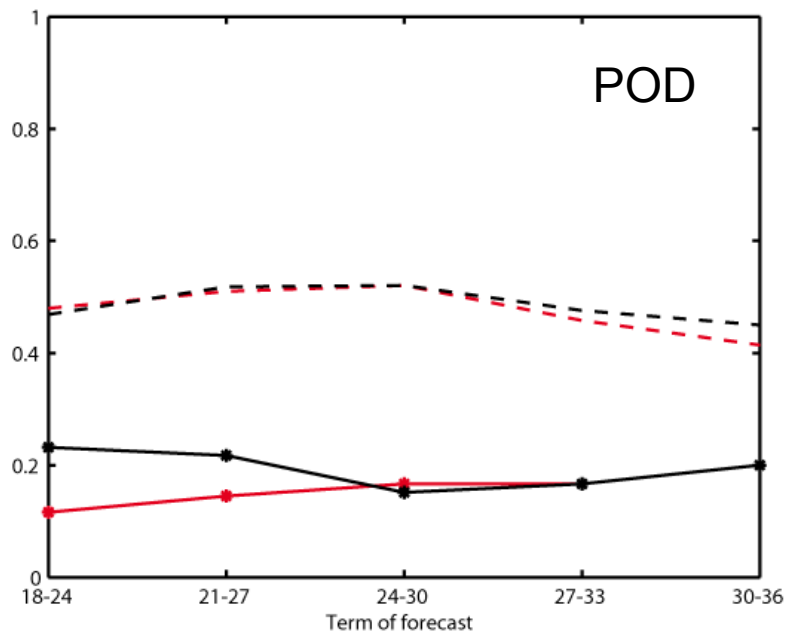
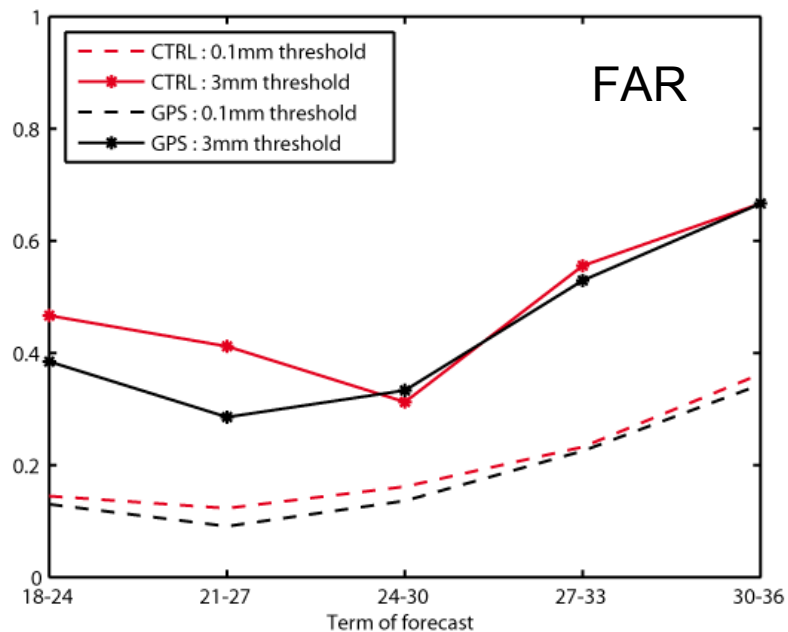
We look to cumulated 24h rainfall

between 29/09 - 12UTC to 30/09 - 12UTC



- 19<sup>th</sup> – 22<sup>nd</sup> November 2007
  - Analysis at 00, 06 and 12 UTC with 36h forecasts each 3h

# QPF scores function of term of forecast (12UTC analysis)



- CTRL less accurate in the first terms of forecast
- Improvement with GPS experiment 12h later than the analysis