

Evaluation of the level of prediction errors of wind and PV in a future with a large amount of renewables

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Outline

- Methodology to simulate forecast errors in a future with a large amount of renewable energy
- Obtained results : the shape and level of national forecast errors as a function of horizon and installed capacity
- Obtained results in the French prospective project « Towards 100% renewables in France »

FORECAST ERRORS IN A FUTURE WITH A LOT OF PV

Introduction

Need to quantify the additional cost in the French power system due to forecast errors in a future with a large amount of renewable :

1st step:

- What would be the level of forecast errors ?
- Would it depend on the implantation of production means across the country ?

→ **Objective here:** Simulation of the French national forecast error in a future with a large share of PV production

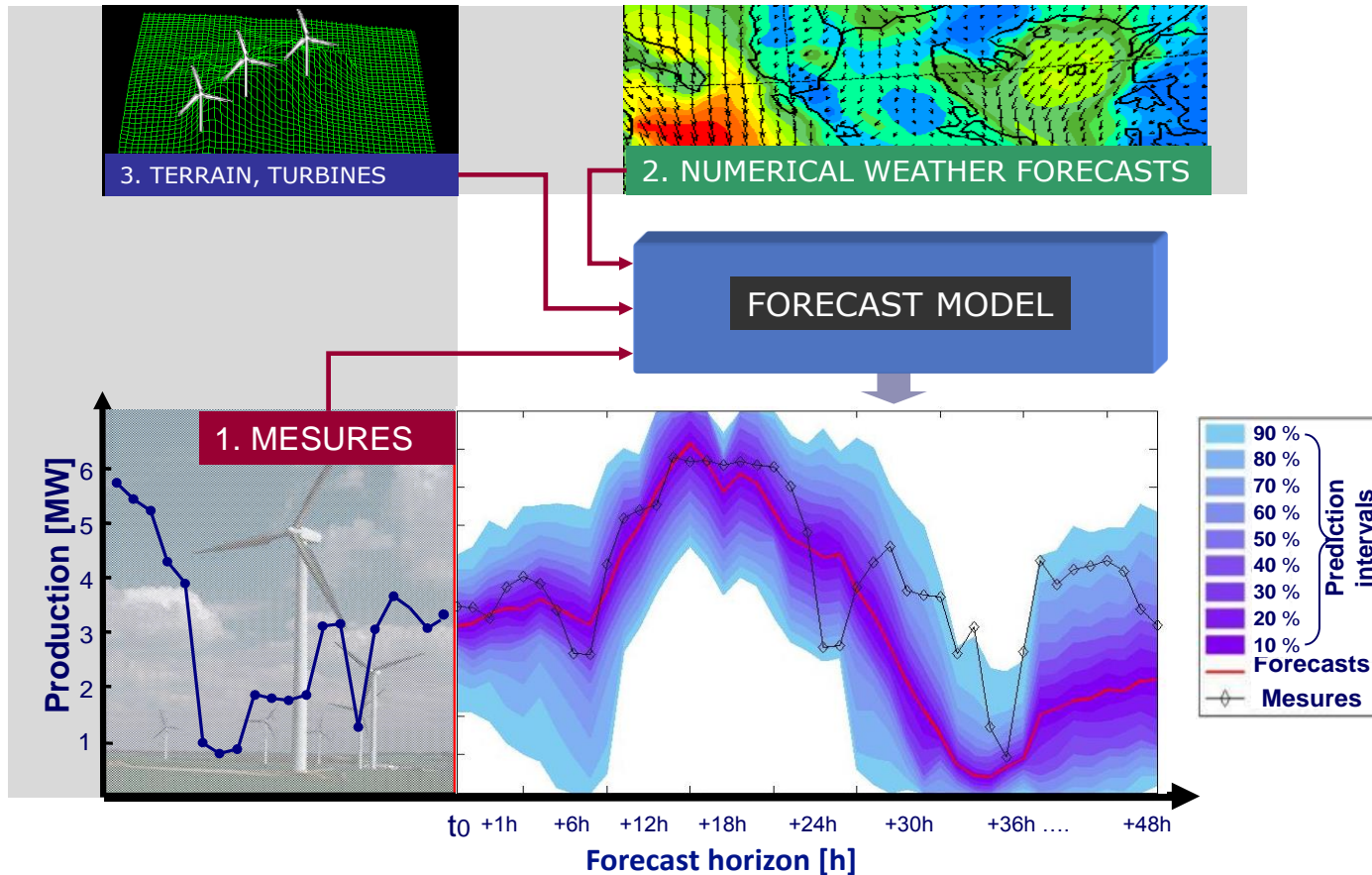
Methodology

1. Simulation of production (PV and Wind) with meteorological data (SODA and MERRA)
2. Simulation of production site implantations (different strategies)
3. For all sites and for several years:
 - Simulation of intra-hourly production variability
 - Simulation of forecast errors with met data and a statistical model
4. Application of step 1-2-3 for many different configurations

Short term PV-Wind power forecasting: principle

Most models rely on the use of Numerical Weather Predictions (here we used ECMWF IFS)

General principle of wind power forecasting



What is the result of the simulation ?

- Forecast errors at the national level
- Expressed with 1 quantiles or Root mean square error (RMSE, i.e. average error) per horizon ranging from 1 to 24 hours ahead
- As a function of the installed capacity in France (PV/Wind), the dispersion of production sites.



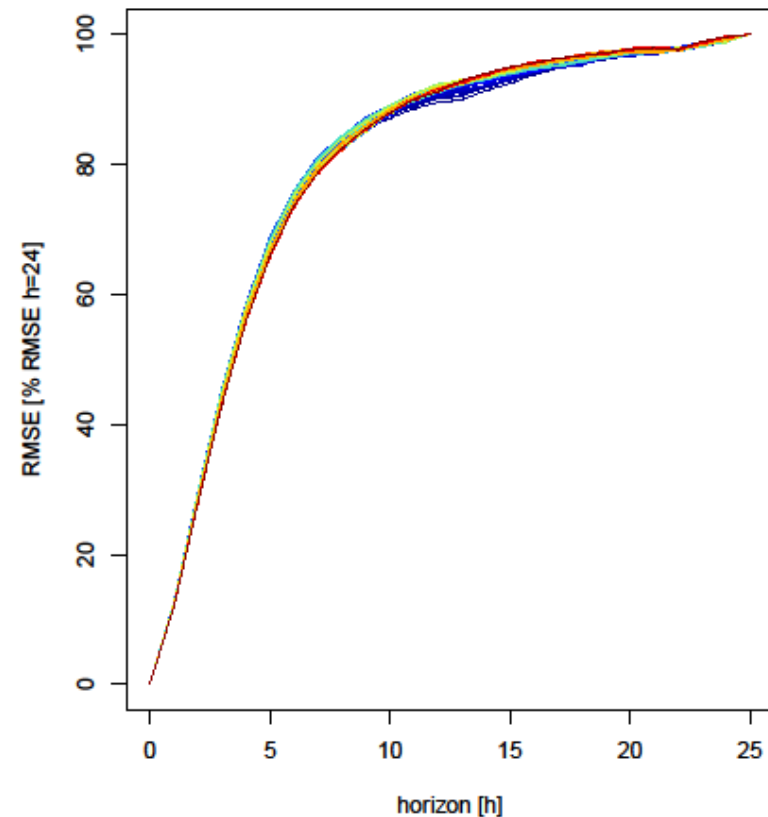
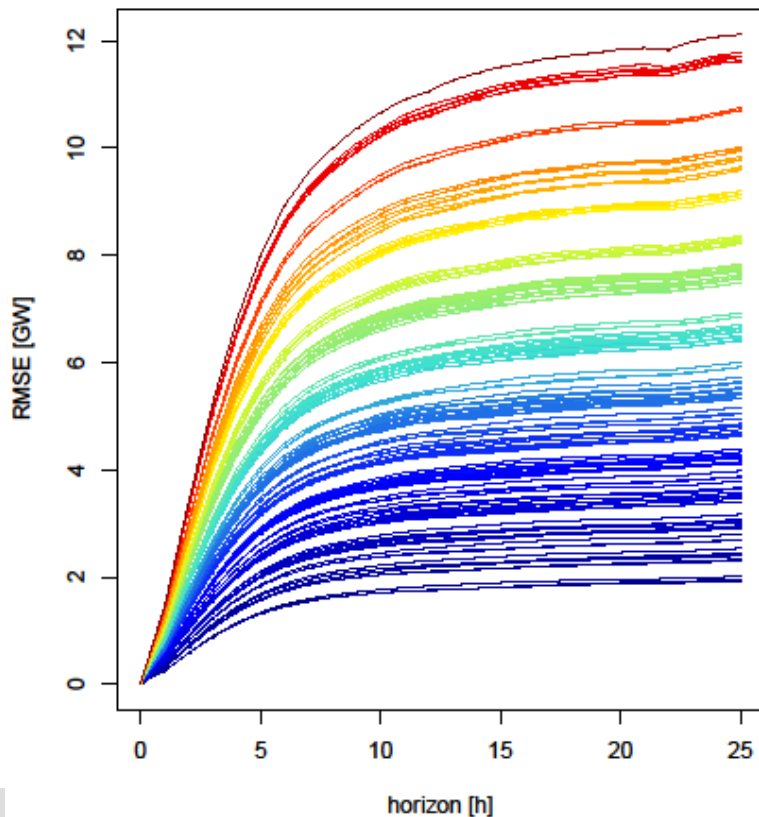
Conclusion : PV and wind power forecast errors at national level approximately a **function of**

- **Produced energy**
- **Forecast horizon**

WP Forecast errors as a function of horizon

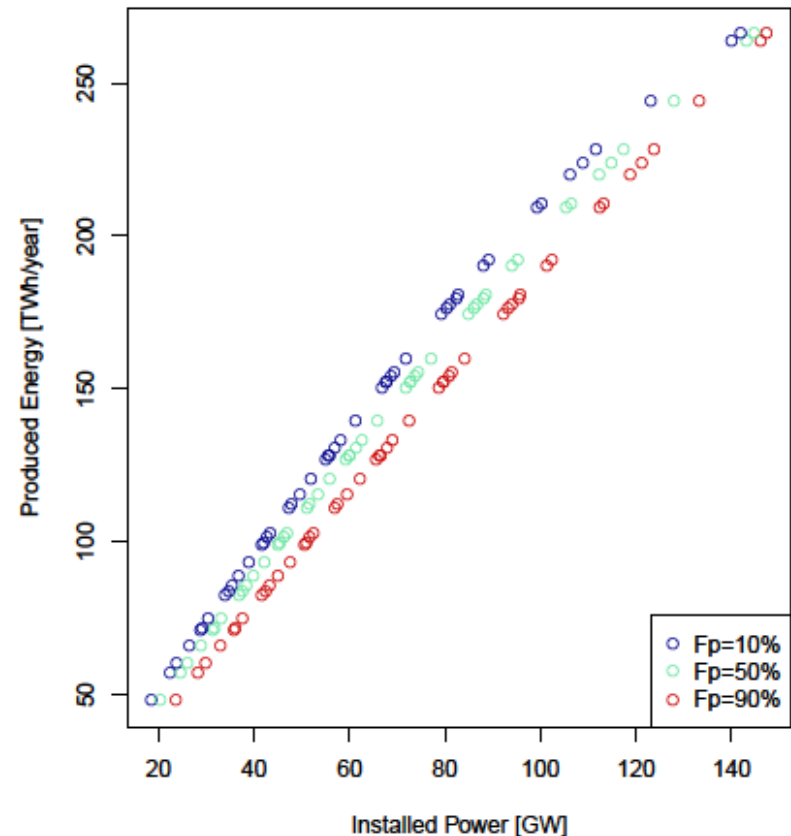
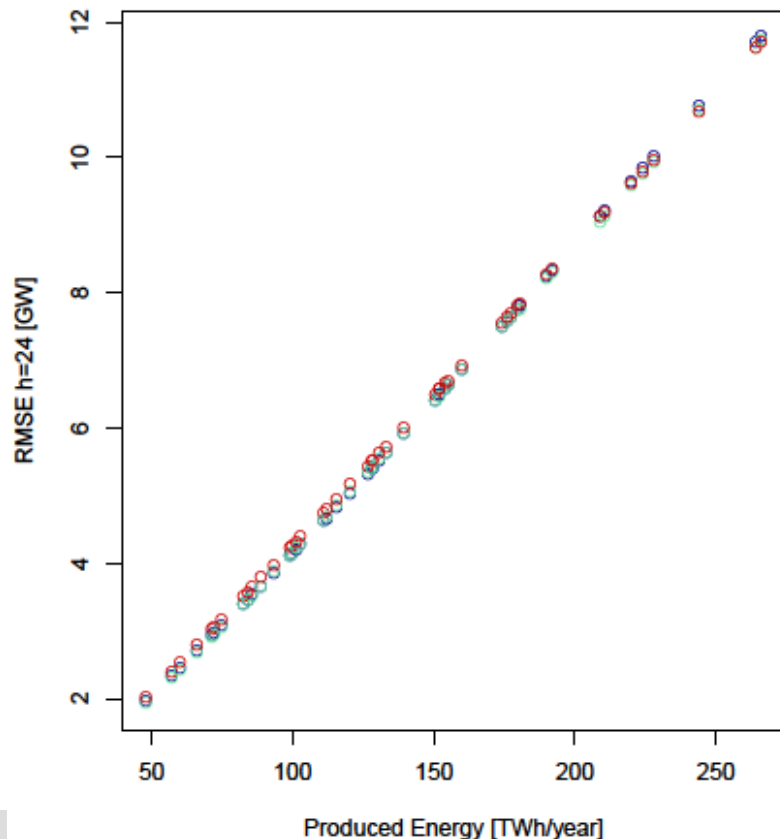
Error level as a function of **forecast horizon** and for different configurations (installed capacity and dispersion of sites)

Left: absolute value, right: proportion of the value for $h=24$.



WP Forecast errors function of produced energy

Forecast error for $h=24$ as a function of **produced energy** for different configurations (left) and installed capacity as a function of energy produced (right).



Conclusions

1. Simulator of forecast errors implemented and runs for many different scenarios
2. Level of average forecast error at the scale of a country is function of annual produced energy and horizon
3. This is valid for the range of installed capacity studied here (50GW-200GW Wind+PV) and in France
4. Comparison with observations (std. deviation of normalized national WP forecast errors):

COUNTRIES	GERMANY	FINLAND	SPAIN	DENMARK	IRELAND	SIMULATION FRANCE
HORIZON OF 1 HOUR	0.0116	-	0.0133	-	-	0.0101
HORIZON DE 24 HOURS	0.045	0.0751	0.0514	0.0534	0.0827	0.0630

A more realistic case study ?

SIMULATION RESULTS IN THE PROJECT “TOWARDS 100% RENEWABLES IN FRANCE”

Few words on the study « CAP100% RES »

- Is it possible to have 100% of renewable electricity in France ?
- If yes, what would it cost and what would be the « optimal » mix
- Study financed by ADEME
- American example of NREL « renewable Electricity Futures Study » http://www.nrel.gov/analysis/re_futures/
- Optimization of CAPEX+OPEX
- About OPEX:
 - « Unit Commitment/optimal power flow » -
 - hourly
 - Regional spatial scale
 - Interconnections and neighbor countries
 - Estimation of reserve, ...
- About CAPEX
 - Long temporal scales: life length, construction length,
 - Demand planning, Network/storage/production investments coupling gaz/heat,... here mix of neighbor countries given.(not optimized)
 - Territorial constraints

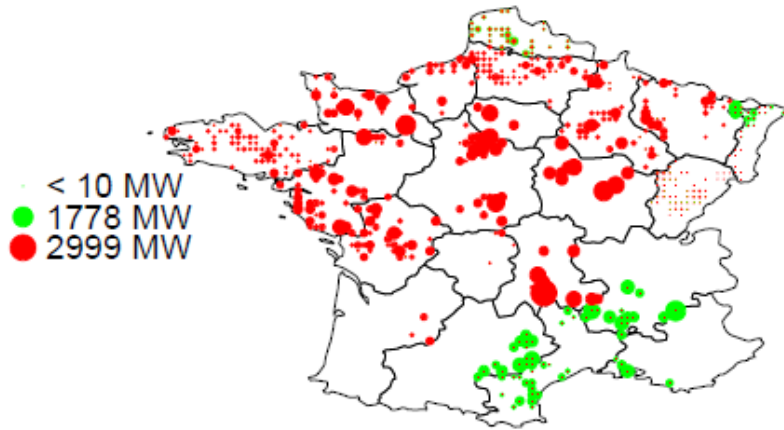


ADEME

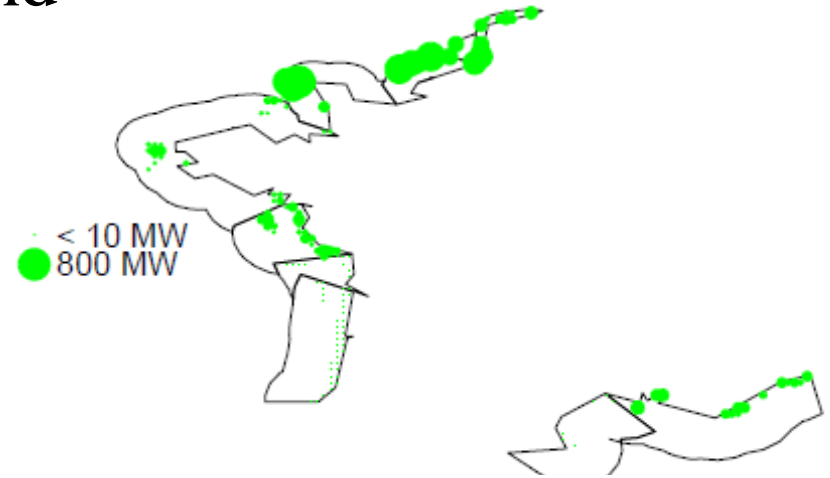


Locations obtained in the central scenario of the project

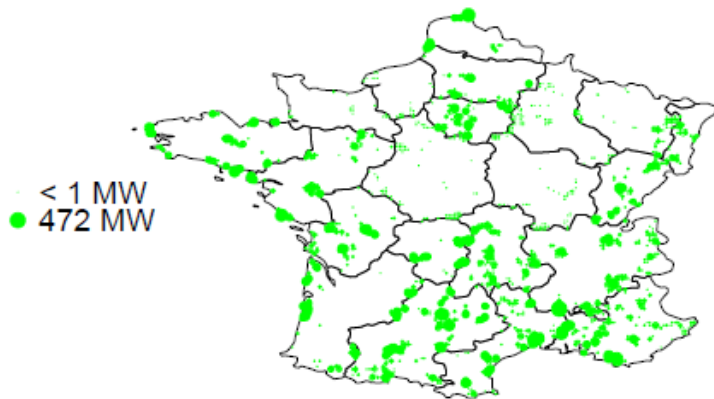
Wind farm locations **new/old** kind



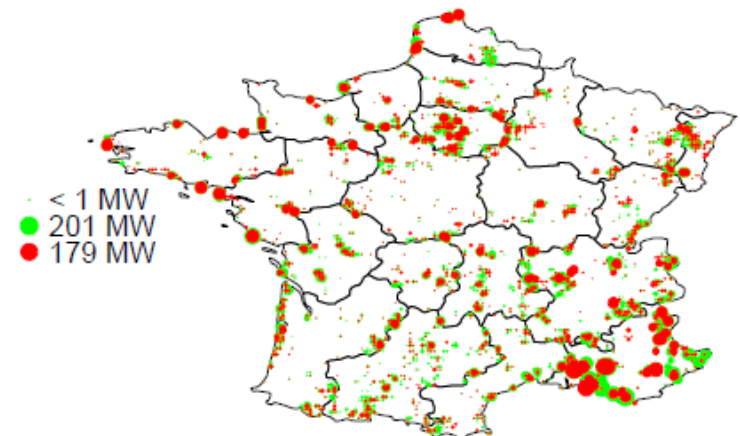
Offshore wind farms



PV plants

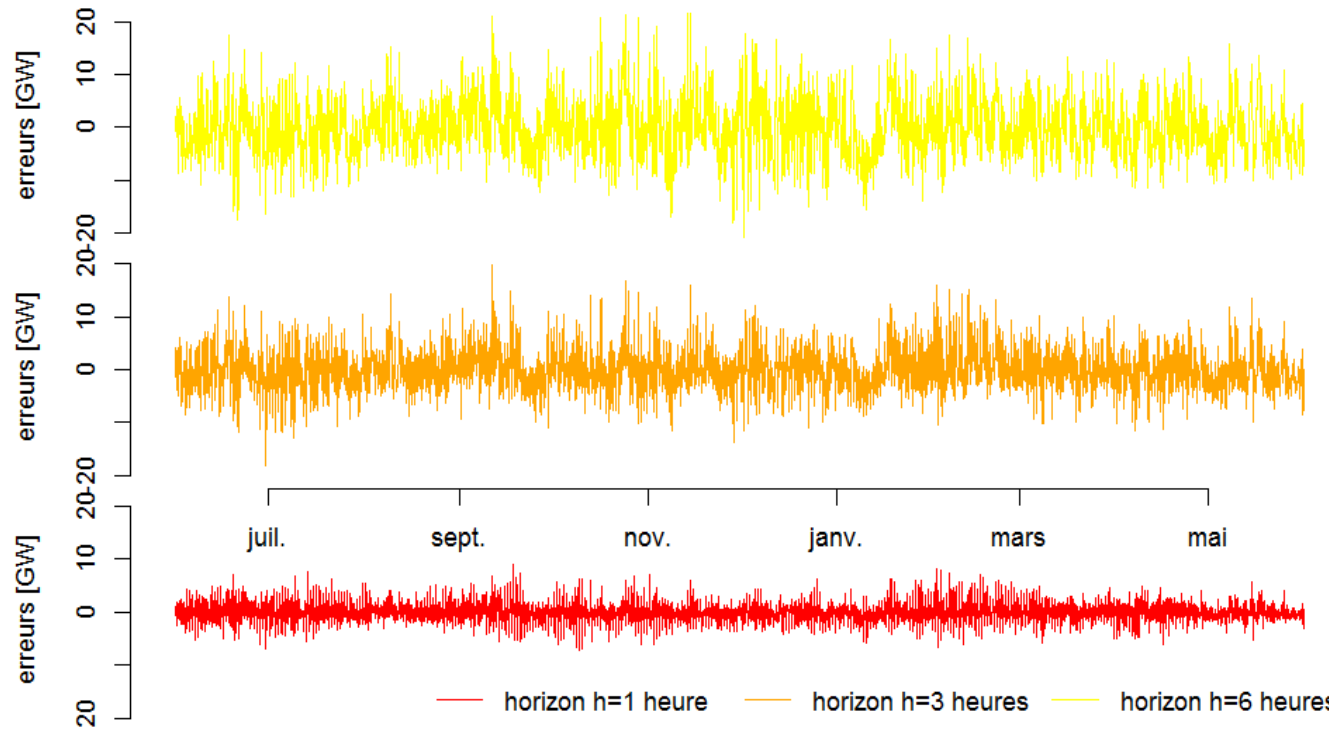


PV **industrial/rooftop** les



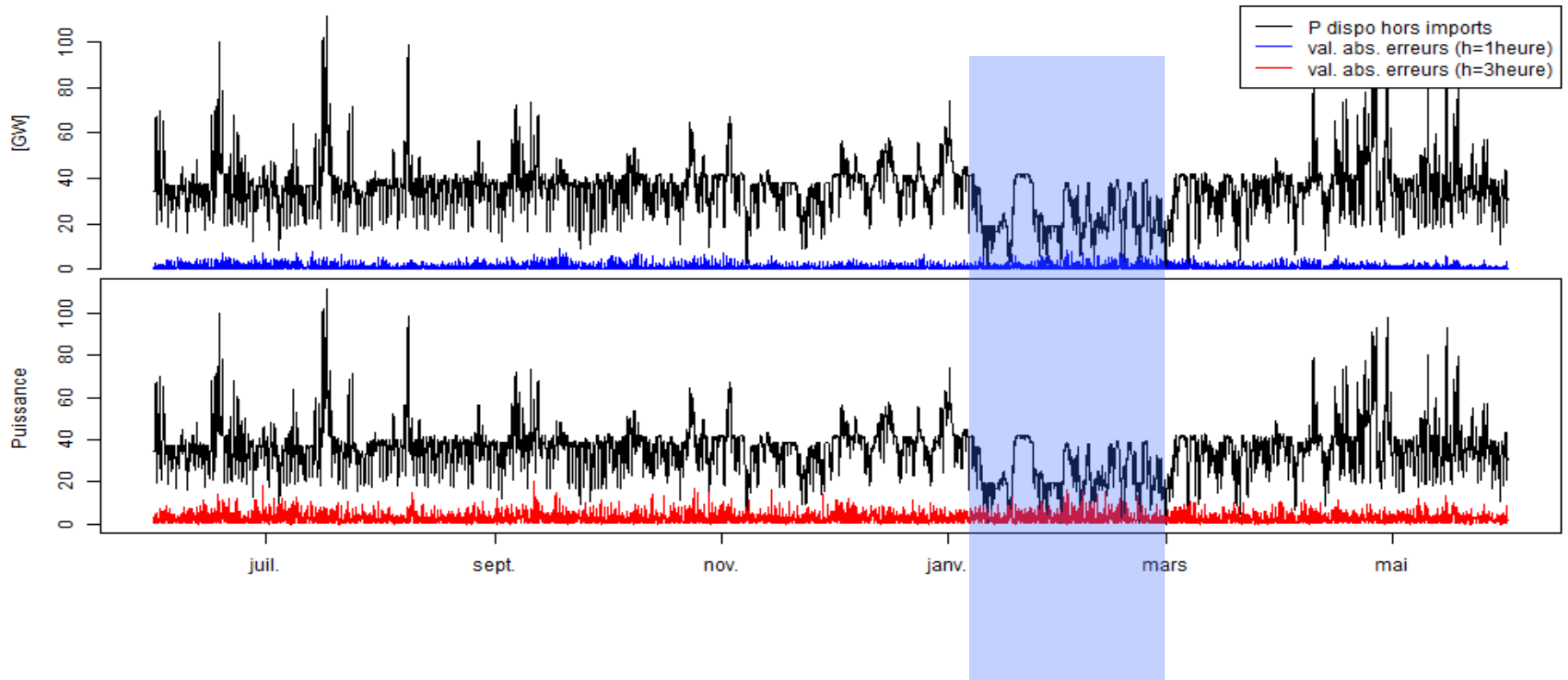
Forecast errors at a national level

- 3 different horizons,
- mixed techno :
 - PV :
25.4+37.6 GW
 - WP onshore
22.9+73.6 GW
 - WP offshore
10 GW

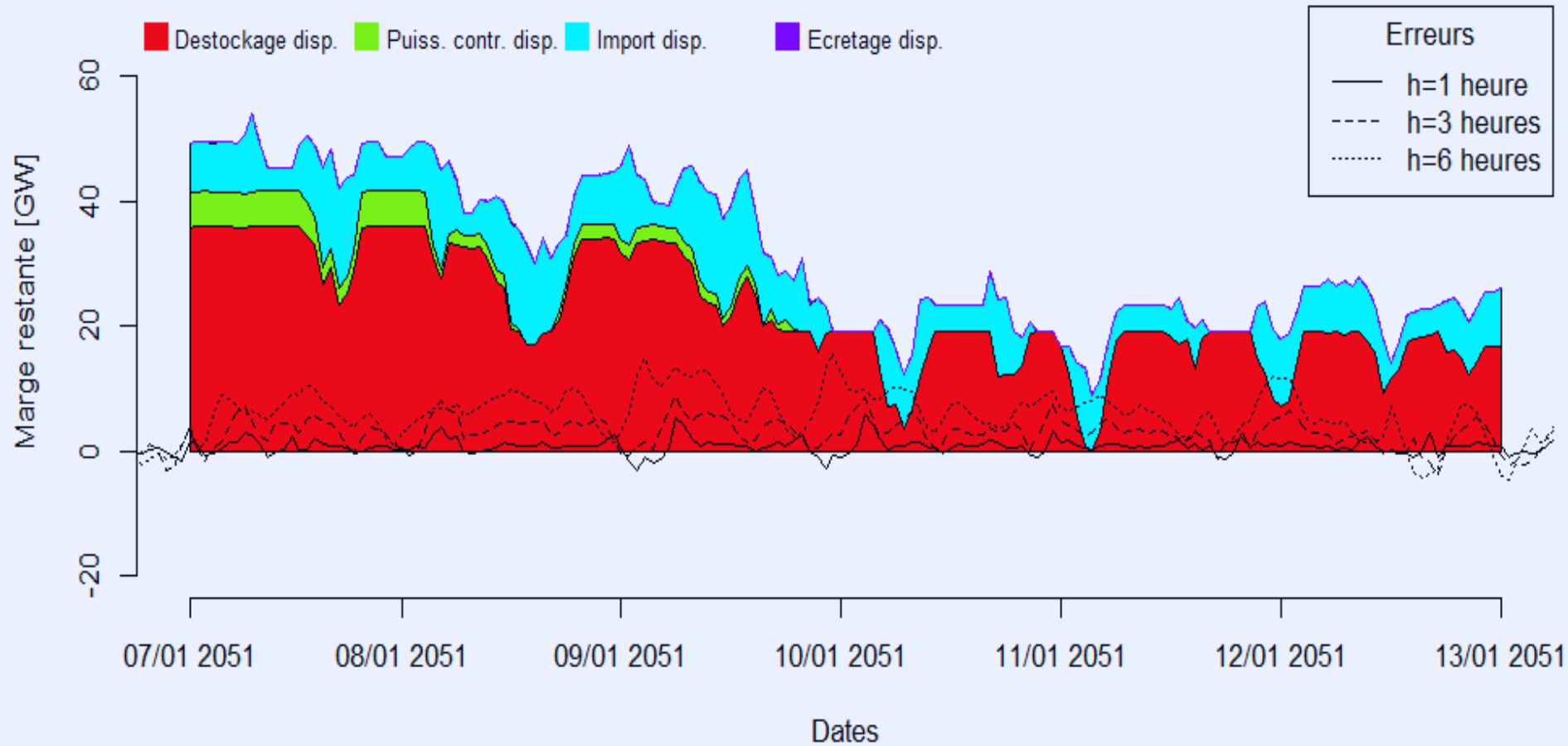


	MIN (GW)	1 ^{ER} QUART (GW)	MED (GW)	MOY (GW)	3 ^{EME} QUART (GW)	MAX (GW)
H=1 HEURES	-7.3	-0.769	-0.073	-0.0006	0.7	9.0
H=3 HEURES	-18.1	-2.3	-0.27	0.032	2.1	19.8
H=6 HEURES	-20.7	-3.7	-0.418	-0.045	3.3	21.6

Forecast errors with respect to available flexibilities



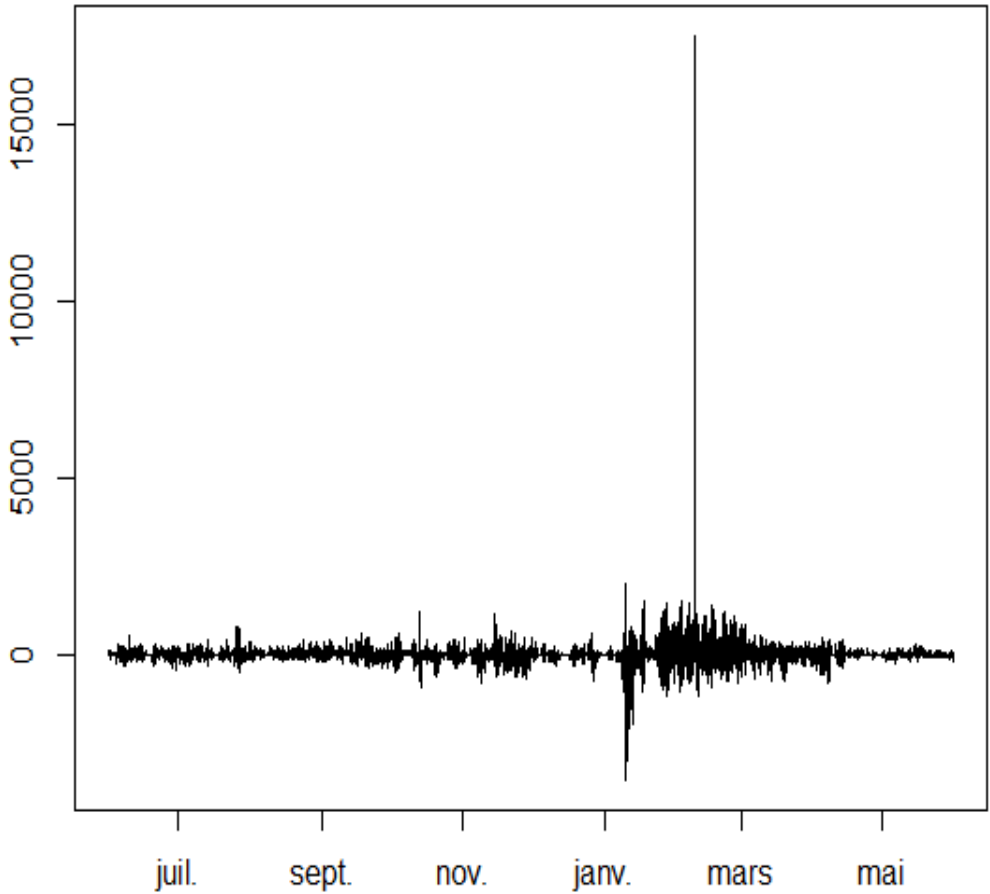
Forecast errors with respect to available flexibilities



Handling these errors ? Proportion of total system cost ?

Scalar product between errors (1 hour ahead) and Lagrange multipliers of the unit commitment/optimal investment

« cost » : Errors * Lagrange multipliers [keuros]



	Sum of positive costs
Horizon of 1 hour	451 Millions euros
Horizon of 3 hours	1146 Millions euros
Horizon of 6 hours	1596 Millions euros
System cost	Around 50 Billion euros

Conclusions and further work

- We proposed a model to simulate
 - location of renewable production means
 - Production
 - Forecast errors (possibility to improve the models)
- We used it to study the forecast error at the level of France
 - further work could be done at the level of Europe
- A further analysis of the cost of forecast errors in a mix with high renewable penetration should be performed.
- Regional scale needs to be analyzed (e.g. congestions)

Thank you for your attention !
Questions ?

