



HOW TO COMBINE STATE-OF-THE-ART MULTI-SCALE NUMERICAL WIND POWER FORECASTS AND BENEFITS OF A HUMAN METEOROLOGICAL EXPERTISE?

17 october 2018 – Wind Integration Workshop: forecasting session

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COMPAGNIE NATIONALE DU RHONE (CNR)

1 BACKGROUND INFORMATION

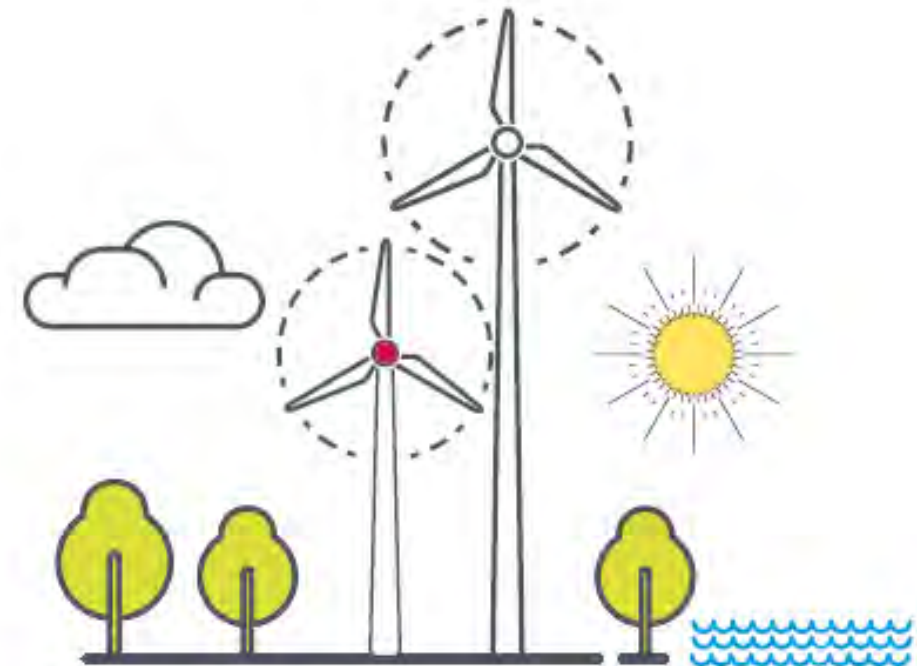
2 METHODOLOGY OF THE EXPERIMENT

- a. Single NWP-based Artificial Neural Networks
- b. Combinations
- c. Confidence index based on expertise

3 RESULTS

Overall performance of different combinations

4 DISCUSSION / CONCLUSIONS

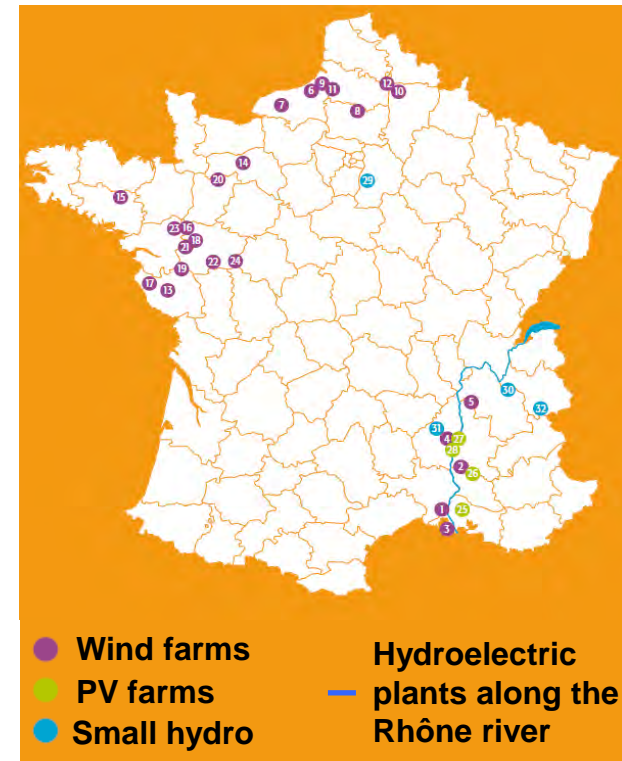
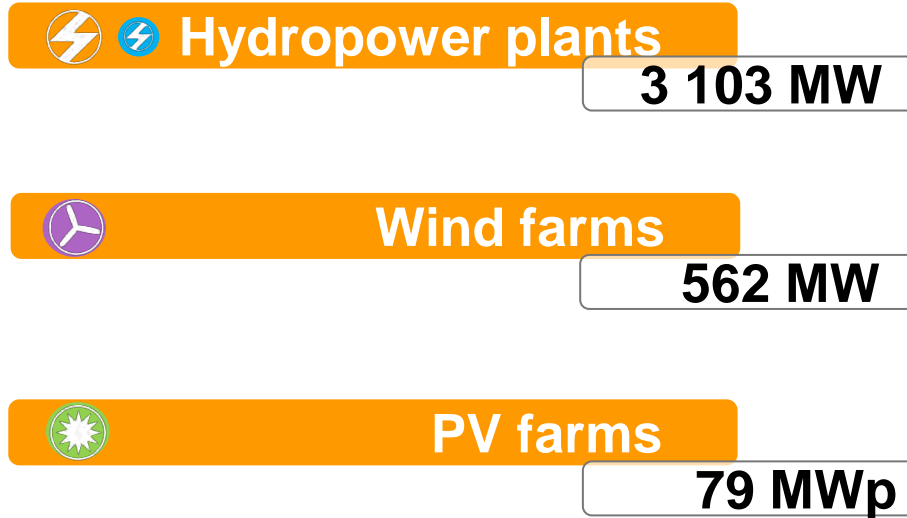




1. BACKGROUND INFORMATION

COMPAGNIE NATIONALE DU RHÔNE ASSETS IN FRANCE

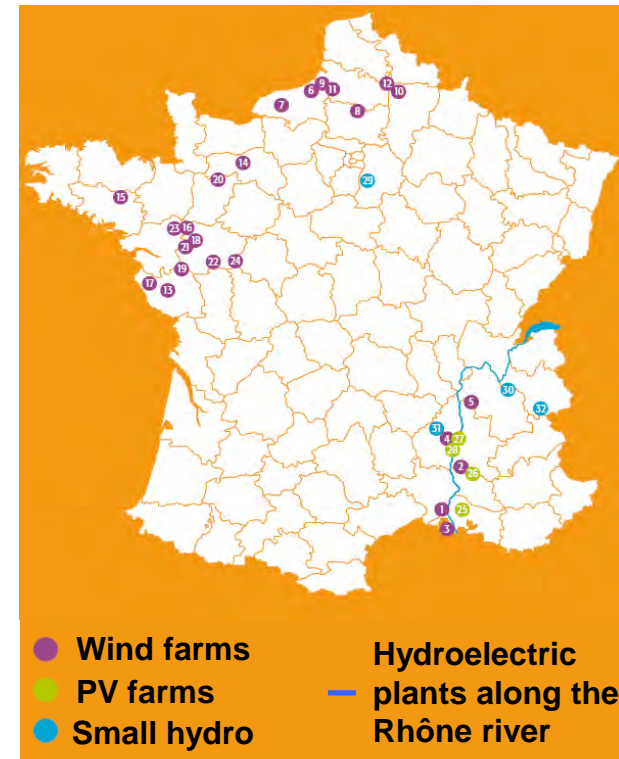
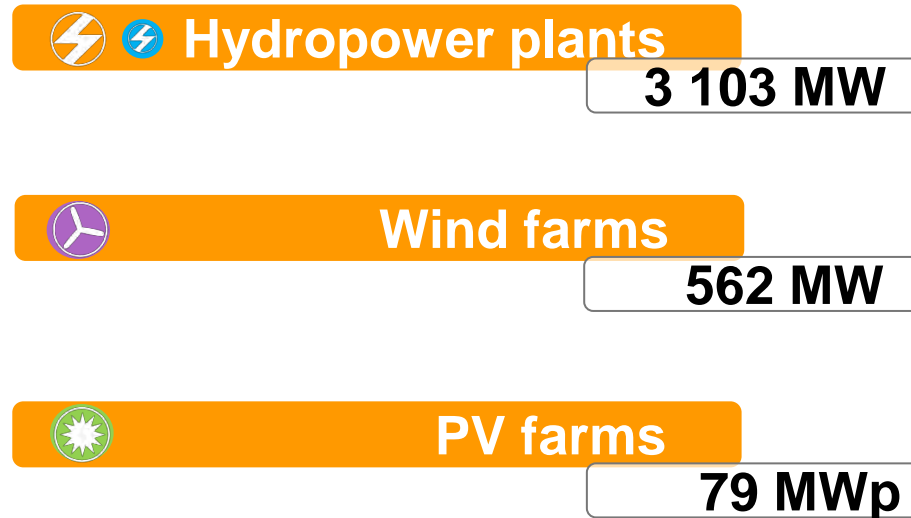
First only renewable electricity producer in France



COMPAGNIE NATIONALE DU RHÔNE

ASSETS IN FRANCE

First only renewable electricity producer in France



Context of pricing in France

- ✓ Historical feed-in tariff mechanism (nearly all of CNR assets)
 - ✓ Some of them + new assets : direct sales on the market + remuneration from French State
- Important change for CNR

COMPAGNIE NATIONALE DU RHÔNE

PRODUCTION FORECASTS & HUMAN EXPERTISE

- **Operational wind power production forecasting at CNR :**
 - ✓ Direct sales on the market on behalf of third parties (CNR as aggregator)
 - ✓ Maintenance optimisation

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- **Generation of small hydro, solar and wind power forecasts through APOGEEES ®**
 - ✓ In-house development since 2008
 - ✓ Spatial scale : farm scale
 - ✓ Temporal scale : hourly time-step, lead-time mostly up to 3 days (max 15 days)
 - ✓ Room for meteorological expertise (for wind : through the modulation of wind curves)



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PRODUCTION FORECASTS & HUMAN EXPERTISE

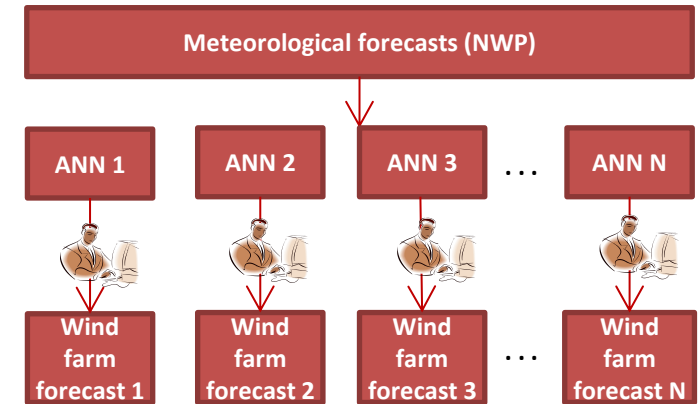
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 - ✓ Room for meteorological expertise (for wind : through the modulation of wind curves)
- **Operational hydro-meteorological forecasting team, historically for the Rhône river basin management**
 - ✓ 5 meteorologists
 - ✓ Daily analysis of various Numerical Weather Prediction models (NWP)
 - ✓ Added-value against raw model outputs



AN EXPERIMENT TO COMBINE EXPERTISE AND AUTOMATIC WIND POWER FORECASTING

Current operation at CNR: downstream expertise

- Modulation of wind curves after a downscaling step
- Manual correction on individual forecasts
 - 😊 Easy and fast to do for a meteorologist
 - 😞 What if the number of farms is exponentially growing?



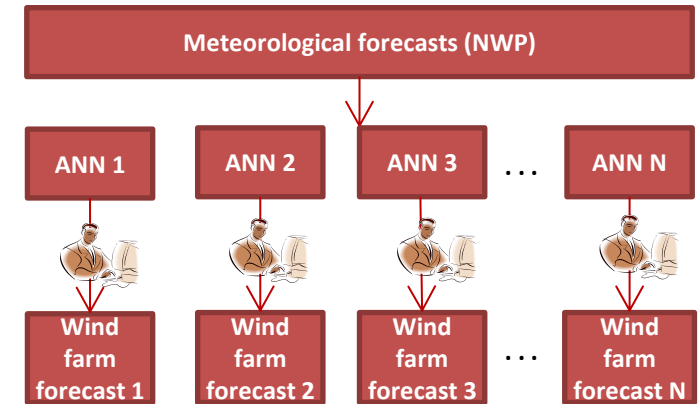
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How to keep benefiting from its meteorological knowledge in a context of growing forecasts demand ?



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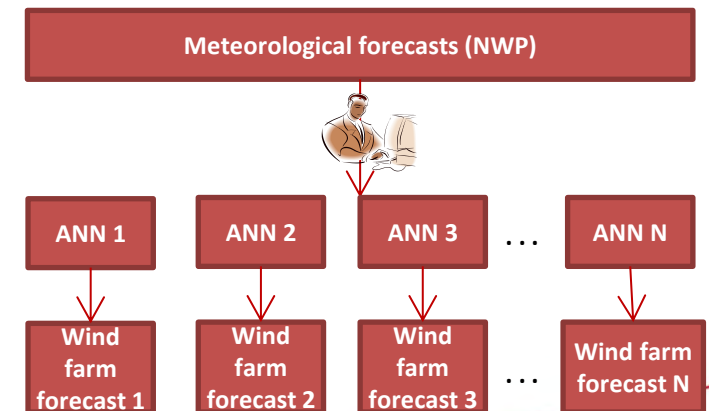
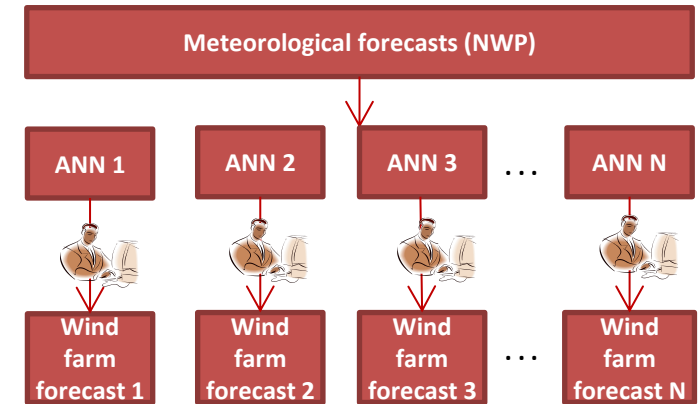
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An experiment to bridge the gap : upstream expertise

- Expertise is performed upstream NWP's forecasts
- Choice of the appropriate scenarios based on confidence indices



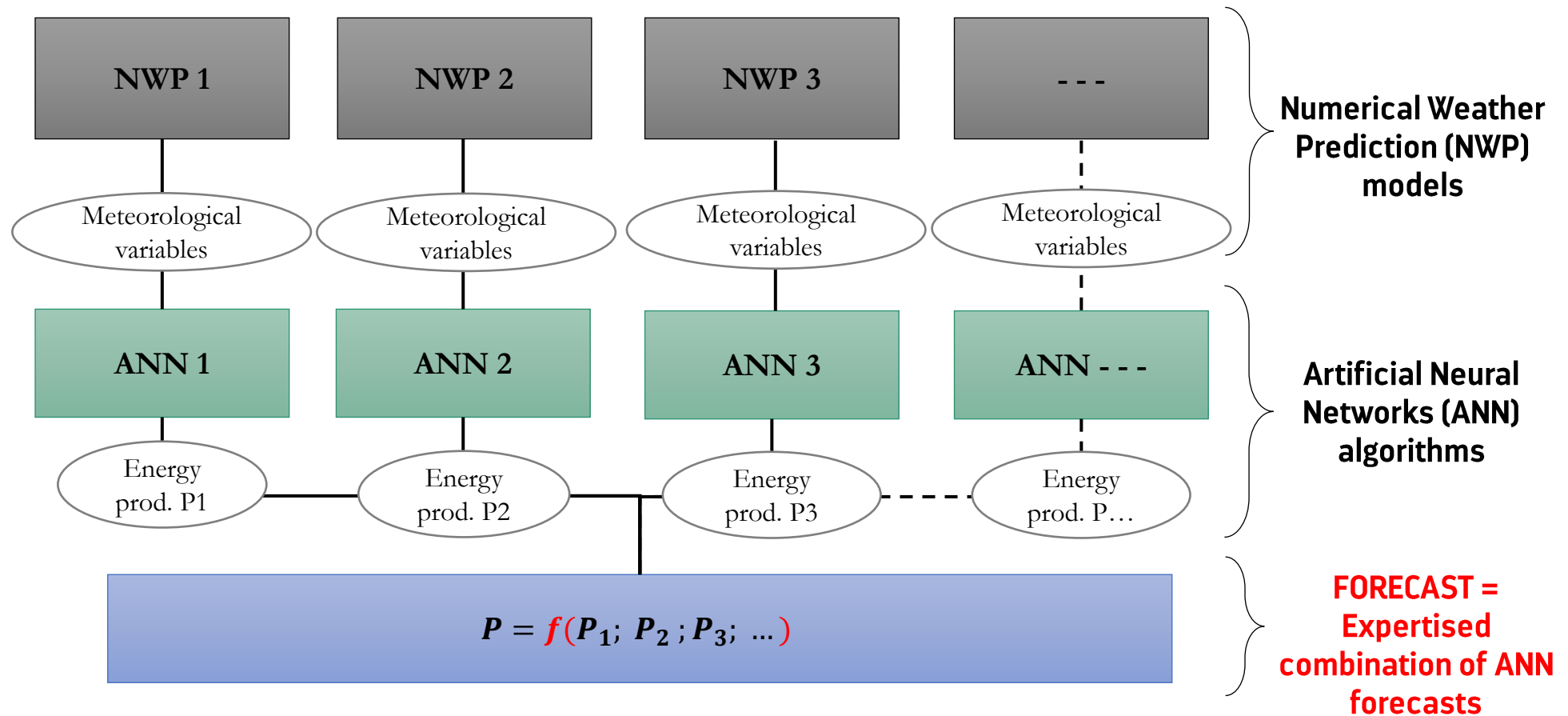
APOGEES- ϕ

Application Pour l'Optimisation de la Gestion
de l'Energie Eolienne & Solaire

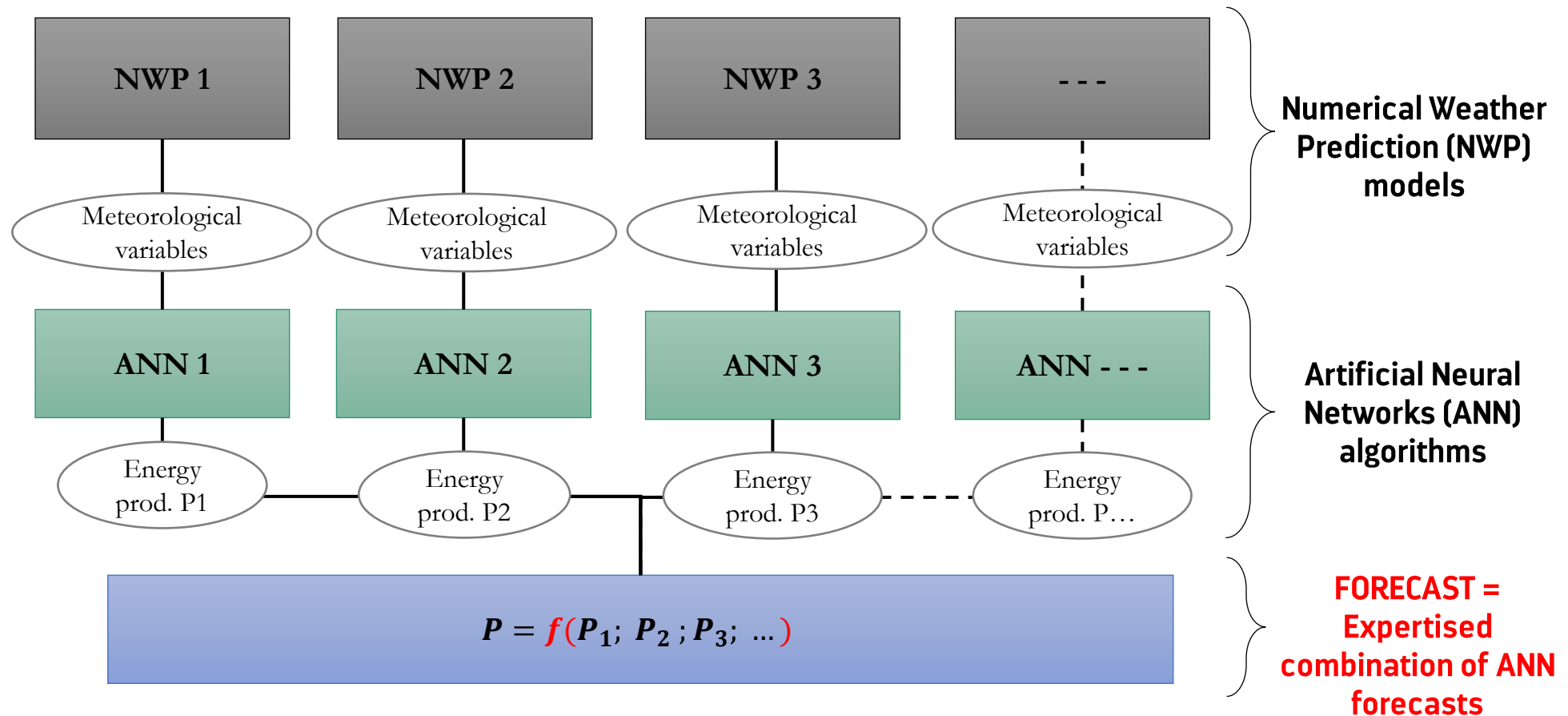
2. METHODOLOGY OF THE EXPERIMENT

Expertised combination of single NWP-based ANNs forecasts

2.a Wind production forecasts using single NWP-based Artificial Neural Networks

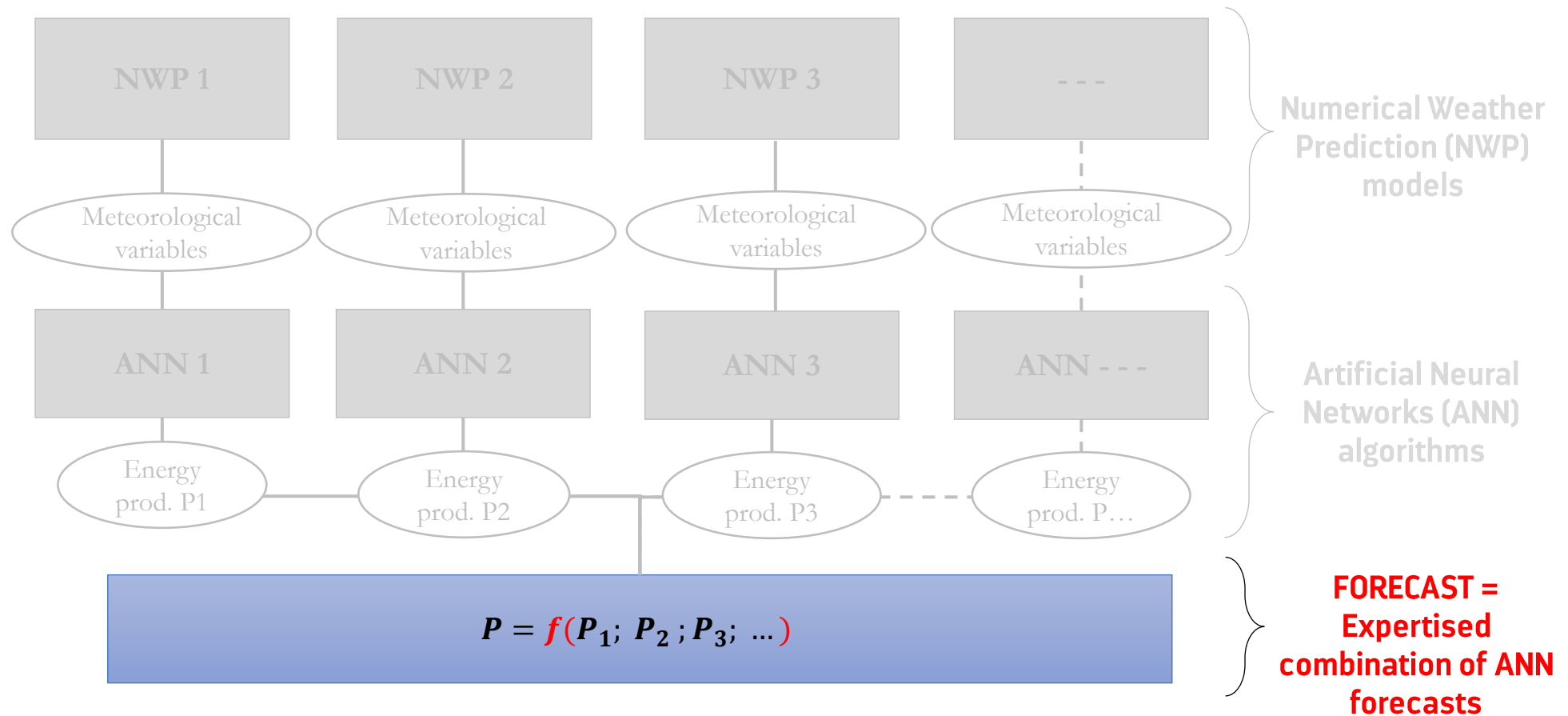


2.a Wind production forecasts using single NWP-based Artificial Neural Networks



- NWPs in this experiment:**
- ARPEGE (Météo France)
 - AROME (Météo France)
 - IFS (ECMWF)

2.b Combinations of single NWP-based ANNs



?

2.b Combinations of single NWP-based ANNs

1. Equal weights

$$P_{equal} = \frac{1}{3}P_{IFS} + \frac{1}{3}P_{ARP} + \frac{1}{3}P_{ARO}$$

2.b Combinations of single NWP-based ANNs

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$$P_{equal} = \frac{1}{3}P_{IFS} + \frac{1}{3}P_{ARP} + \frac{1}{3}P_{ARO}$$

2. Optimized weights for each lead time

$$P_{optim} = \omega^0_{IFS}P_{IFS} + \omega^0_{ARP}P_{ARP} + \omega^0_{ARO}P_{ARO}$$

ω^0_{IFS} , ω^0_{ARP} and ω^0_{ARO} are optimized for each lead time on historical data

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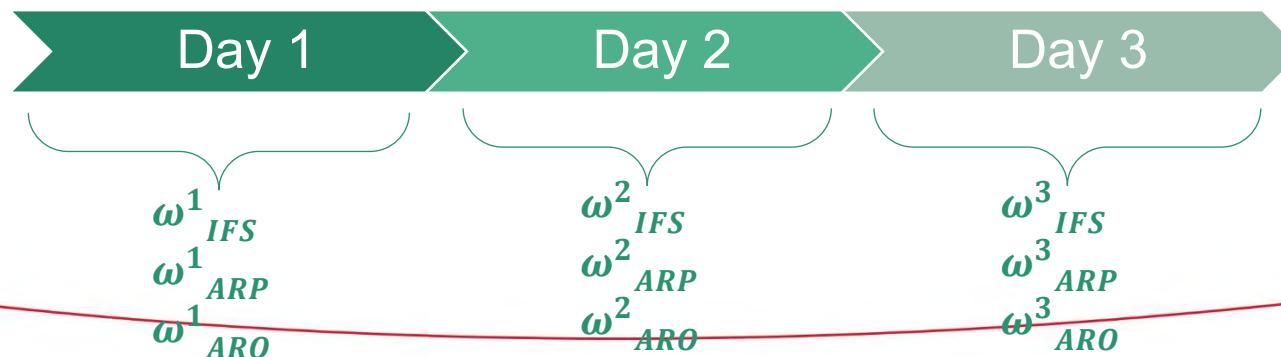
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3. "Perfect forecaster": best possible combination

A *posteriori* analysis, knowing the observed data :



Optimal set of weights for each day (minimizing the absolute error)

2.c Combination based on expertise

4. Combination based on confidence indices given to each NWP

$$P_{expert} = \omega_{IFS}P_{IFS} + \omega_{ARP}P_{ARP} + \omega_{ARO}P_{ARO}$$

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4. Combination based on confidence indices given to each NWP

$$P_{expert} = \omega_{IFS}P_{IFS} + \omega_{ARP}P_{ARP} + \omega_{ARO}P_{ARO}$$

With each “expertised” weight calculated at the regional scale as :

$$\omega_i = \frac{\omega_i^0 C_i}{\sum_{i=1}^N \omega_i^0 C_i}$$

ω_i^0 is the default weight for the i^{th} NWP (e.g. optimized lead by lead)

C_i is the confidence index given by the expert to the i^{th} NWP

→ $0 < C_i < 1$ but $\sum C_i$ does not need to be equal to 1

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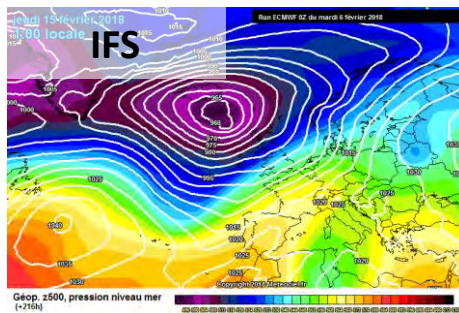
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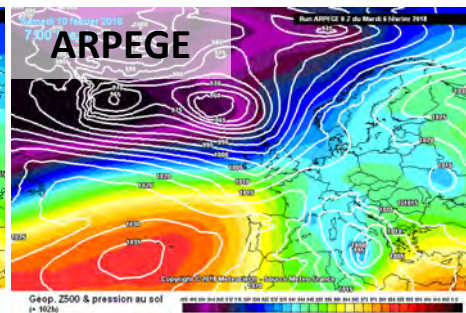
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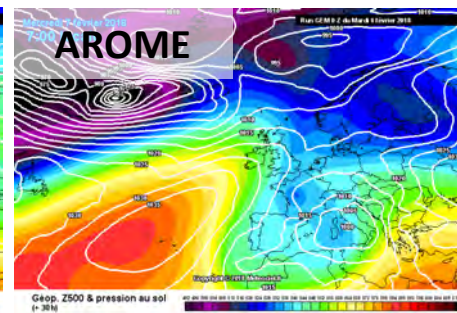
$\rightarrow 0 < C_i < 1$ but $\sum C_i$ does not need to be equal to 1



C = 1
(High confidence)



C = 0.66
(Fair confidence)



C = 0.33
(Poor confidence)

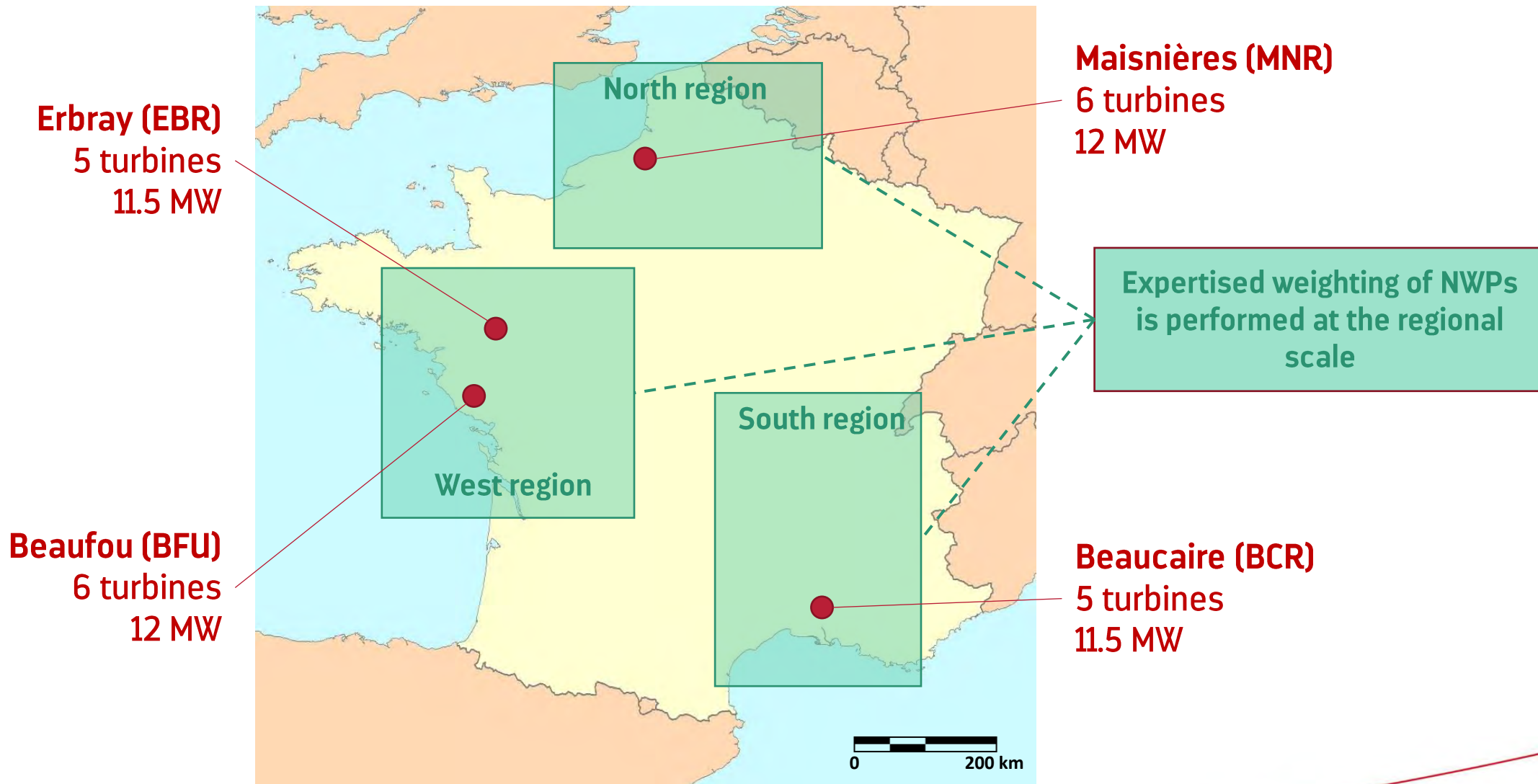
Example of confidence indices given to three NWP for a given meteorological situation



3. RESULTS

OVERALL PERFORMANCES OF THE DIFFERENT COMBINATIONS

WIND POWER FORECASTING FOCUS ON 4 WIND FARMS



OVERALL PERFORMANCE RESULTS

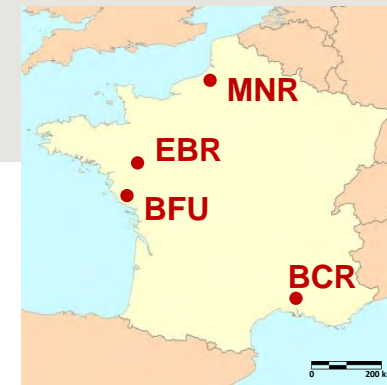
EVALUATION OVER LEAD TIMES (DAY AHEAD)

Evaluation of the overall forecasting performance

- May 2018 → July 2018 (3 months)
- Mean relative MAE scores : MAE / production capacity
- Every DA lead time (+23h to +47h)
- 00hUTC runs of NWP only
- Comparison of standard (no expertised) and expertised combination of NWP-based ANN

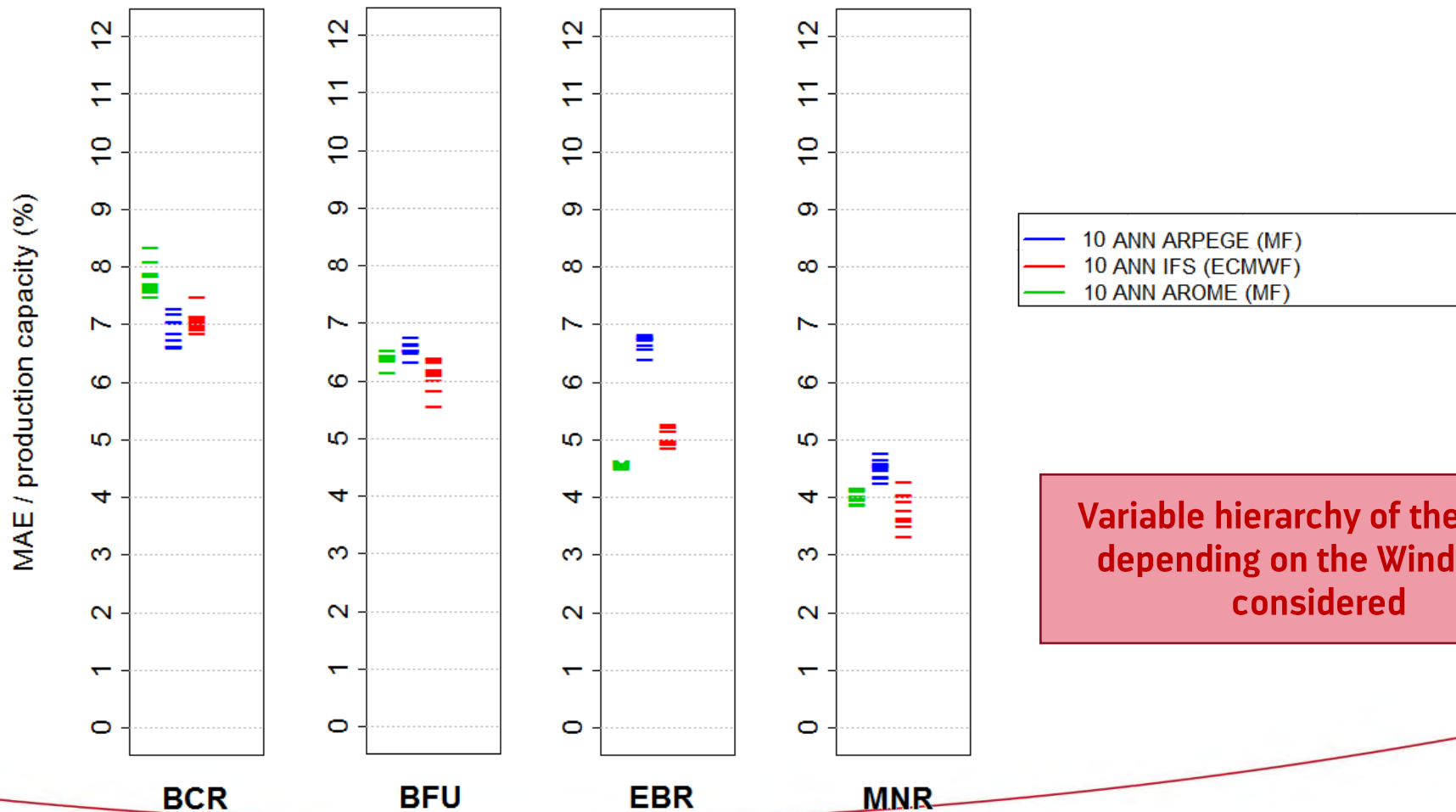
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Relative MAE

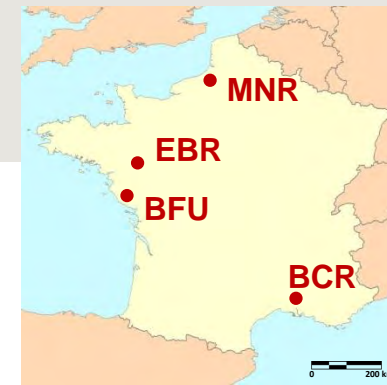
Average performance over day-ahead lead times



Variable hierarchy of the NWPs depending on the Wind Farm considered

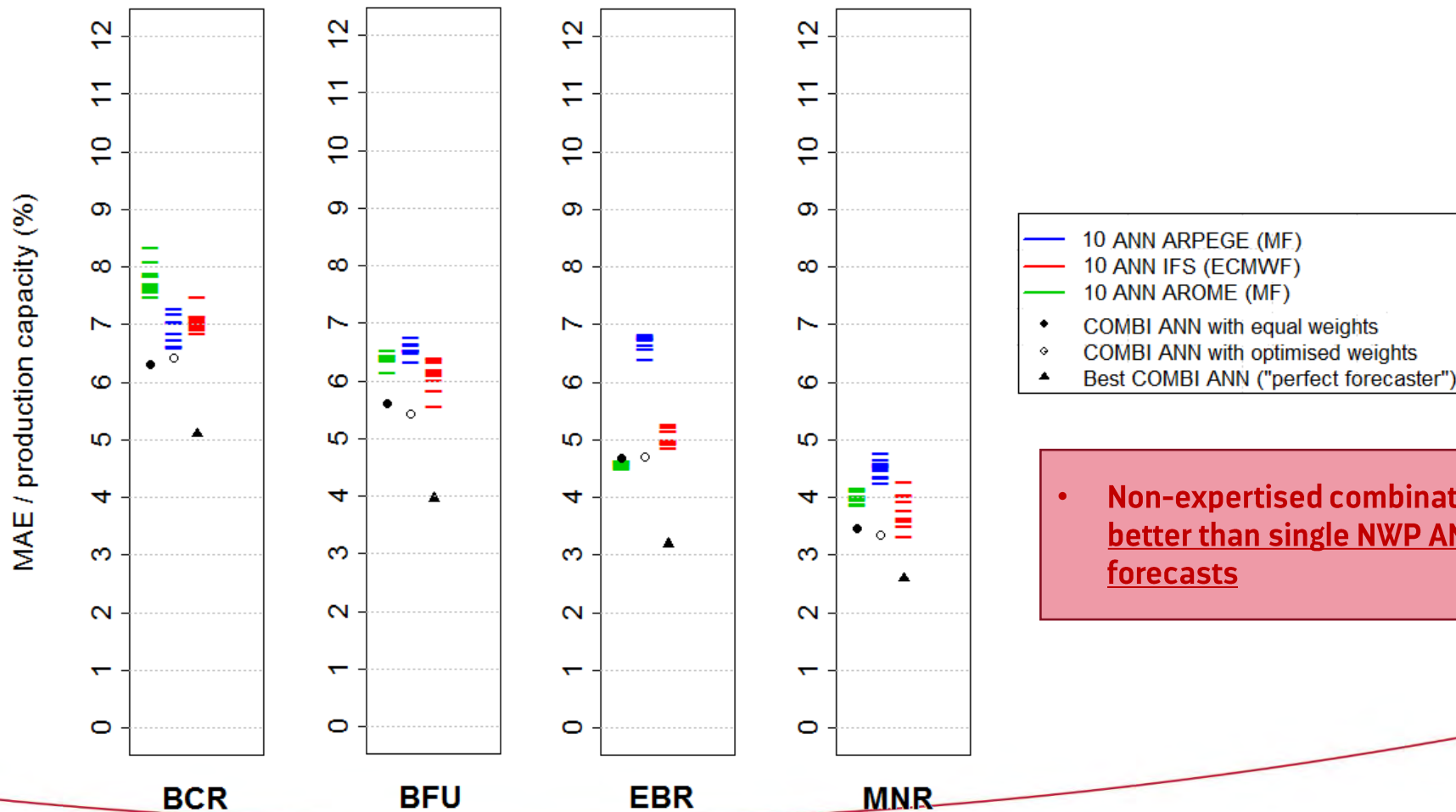
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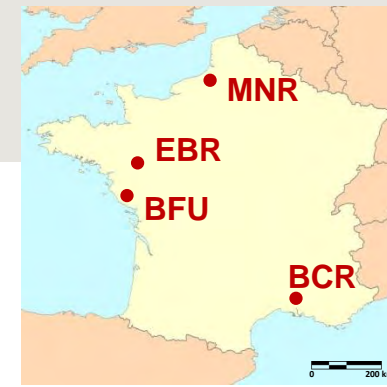
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• Non-expertised combinations are better than single NWP ANNs forecasts

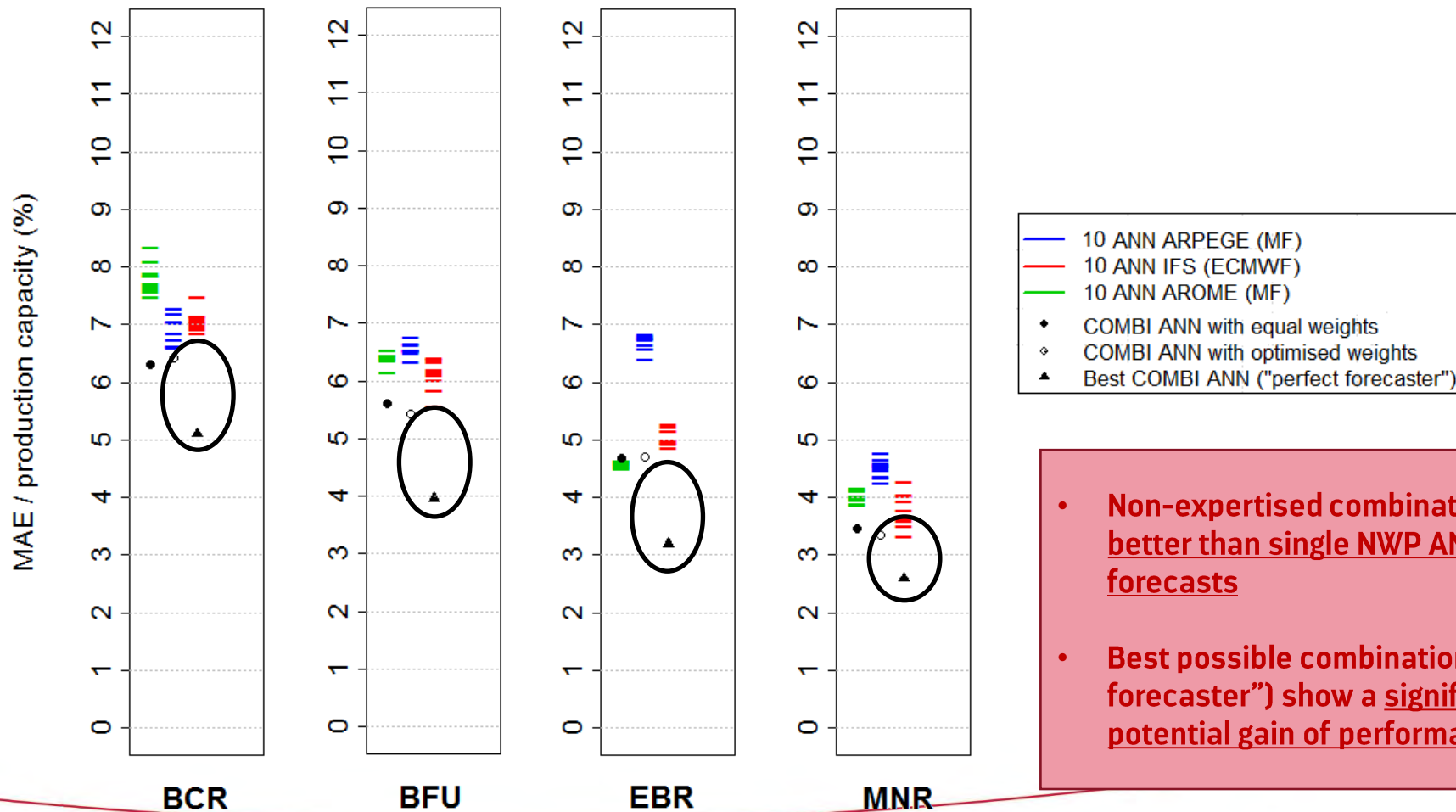
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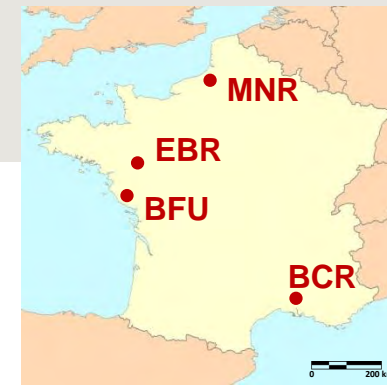
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- **Non-expertised combinations are better than single NWP ANNs forecasts**
- **Best possible combination ("perfect forecaster") show a significant potential gain of performance**

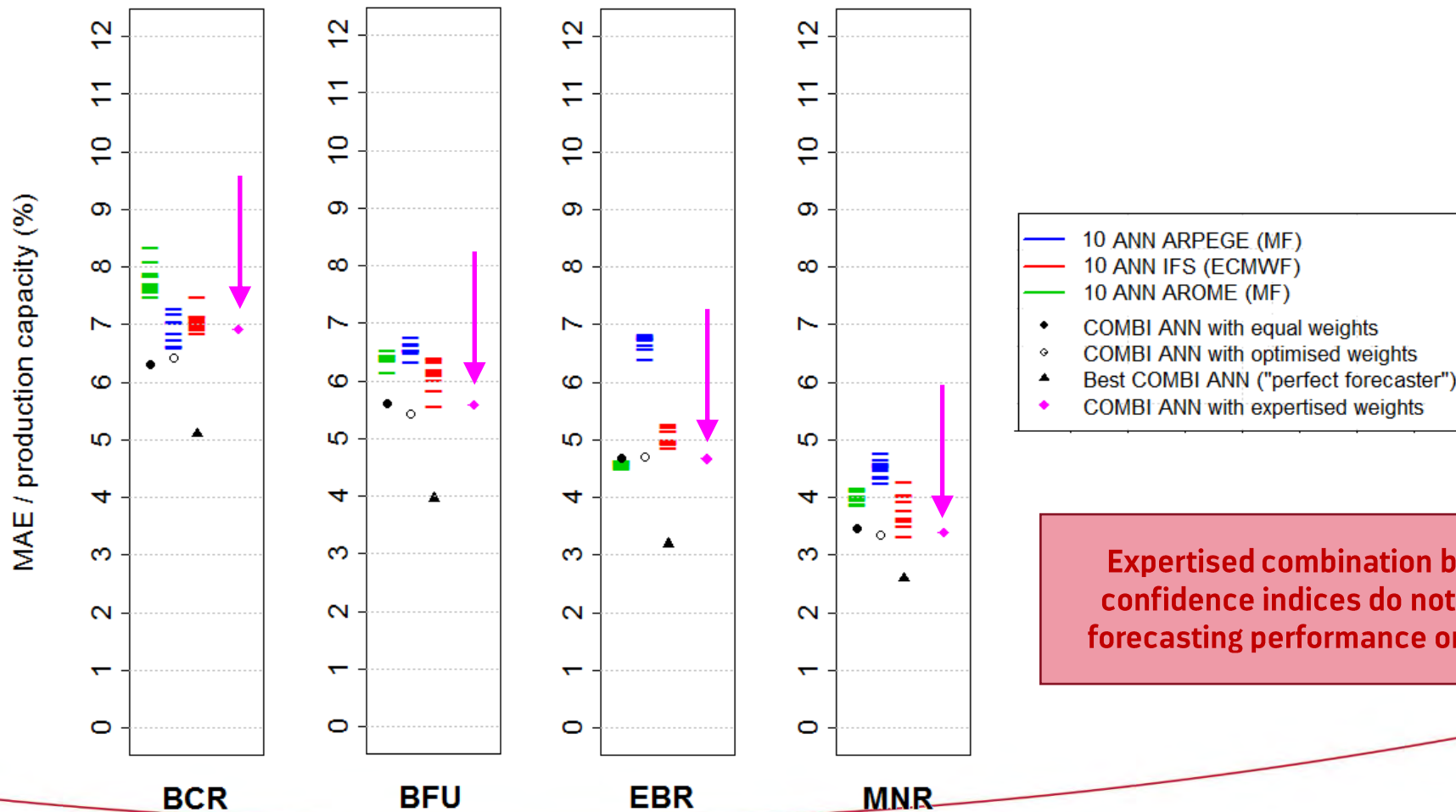
OVERALL PERFORMANCE RESULTS

EVALUATION OVER LEAD TIMES (DAY AHEAD)



Relative MAE

Average performance over day-ahead lead times



Expertised combination based on confidence indices do not improve forecasting performance on average



4. DISCUSSION / CONCLUSION

SUMMARY AND PERSPECTIVES

DISCUSSION / CONCLUSIONS

About the presented experiment

- A new *upstream* way of expertise, based on regional confidence indices given to NWP, is tested
- New approach designed to keep benefiting from expertise in a context of growing number of forecasts
- Trial made on 3 months show:
 - A significant potential improvement of performance (◀ perfect forecaster ▶)
 - Actual performances unfortunately not better than automatic forecasts on average
- Possible explanations:
 - Sampling effect: 3 months only of trial
 - Low wind conditions during the trial
 - Regional discretisation
 - Overconfidence of forecasters ?
 - New approach → still need to gain experience

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Ongoing development / perspectives

- Continue the trial over a longer period
- Assessment of the results at the regional scale
- Expansion to solar production forecasts
- Introduction of ensemble meteorological models

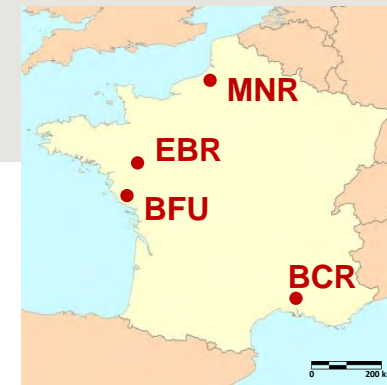
L'énergie au cœur des territoires

cnr.tm.fr



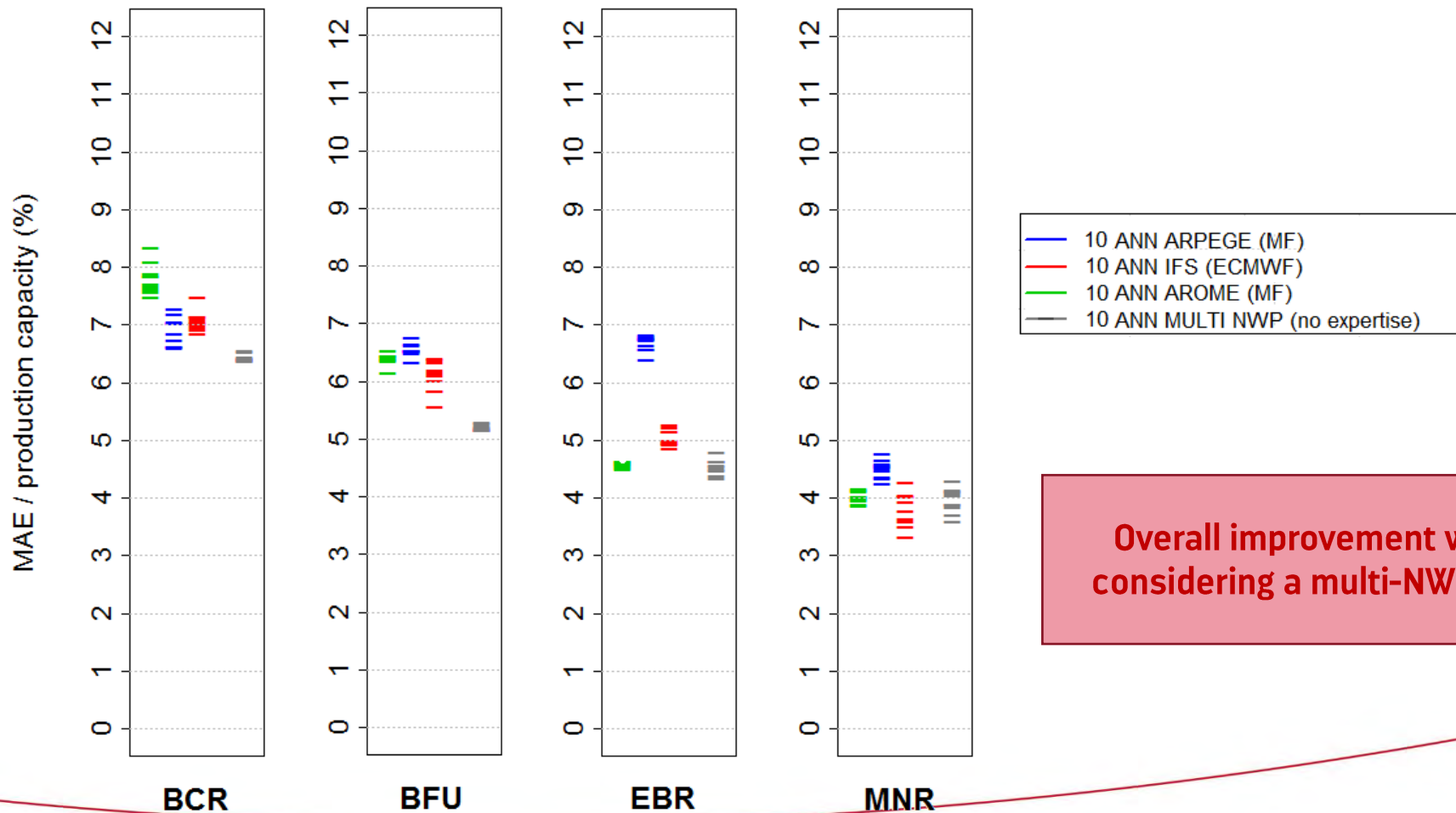
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Relative MAE

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Overall improvement when considering a multi-NWP ANN

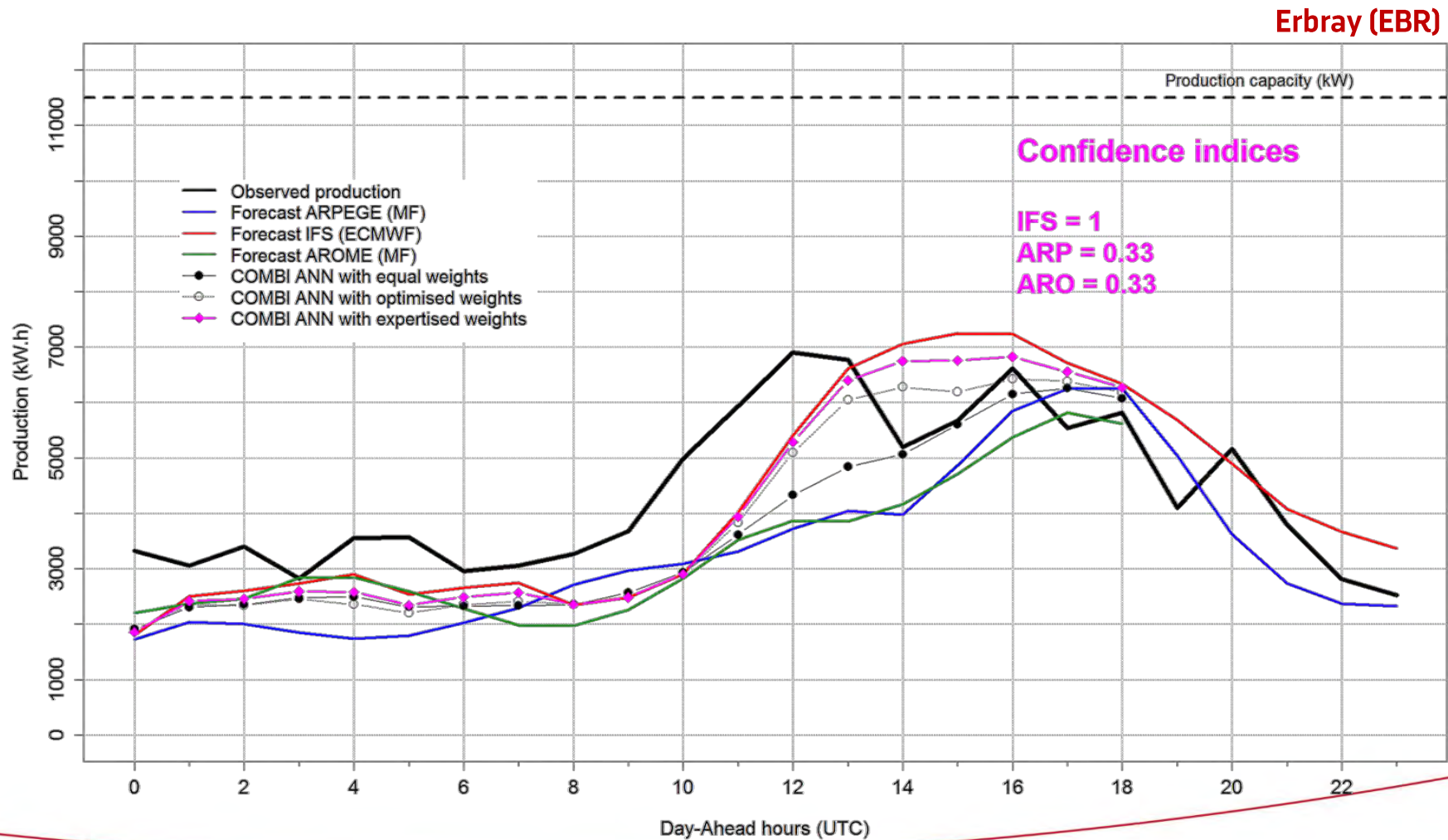
CASE STUDY

HOW EXPERTISE CAN IMPROVE FORECASTING PERFORMANCE ?



2018-05-14 example

- All NWP runs of 00hUTC
- Day Ahead lead times



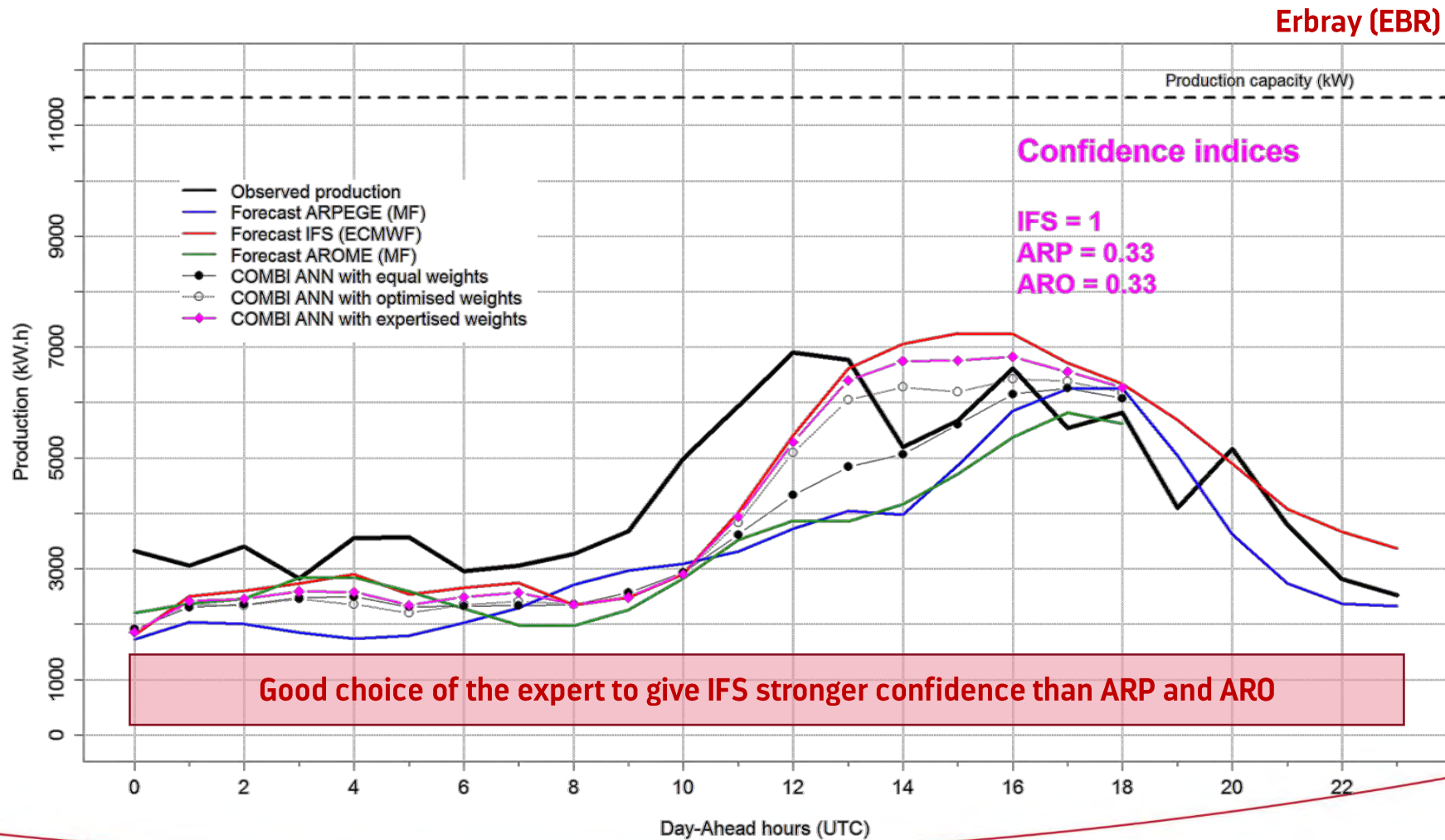
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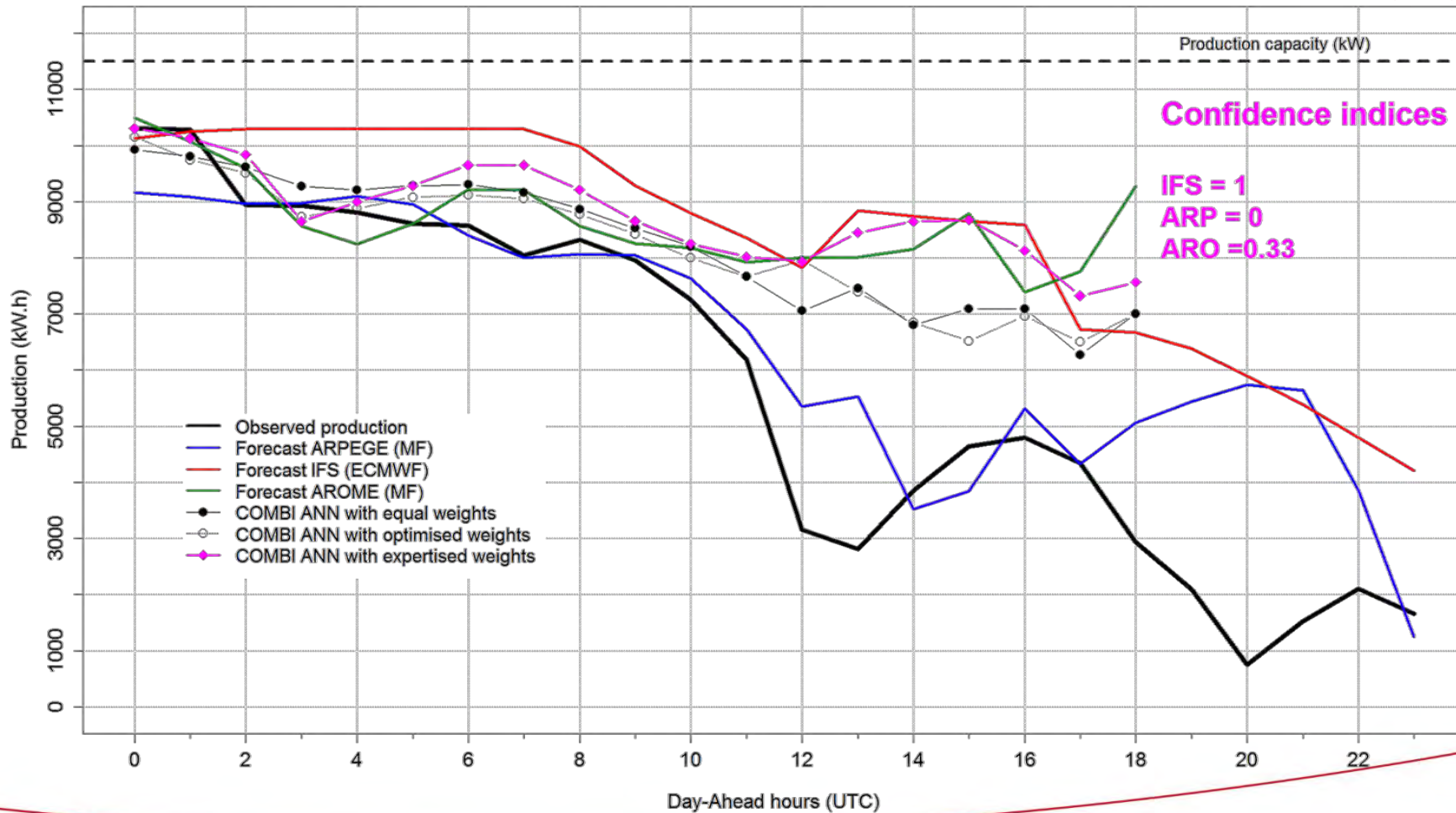
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Beaucaire (BCR)



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