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INTER-COMPARISON & OPTIMAL COMBINATION OF MULTI-MODEL LAF ENSEMBLE SCHEMES FOR WIND PREDICTION

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Abstract summary

The WISENT's (German collaborative project building the knowledge network for energy meteorology) Weather Forecasting Portal (WFP) is an internet application for disseminating products based on NWP models. Using WFP's interface, six and twelve LAF (Lagged Average Forecasting) member ensembles of the NCEP's GFS (Global Forecast System) are constructed. Likewise, six and twelve member LAFs are formulated of the NCAR's WRF (Weather Research and Forecasting) model. Combining GFS with WRF LAFs, twelve ensemble schemes are constructed. The best (optimal) LAF scheme is determined by inter-comparisons among all available formulations. The average performance of each formulation has been assessed considering the level of ensemble spread and the accuracy of single and ensemble forecast components.

Objectives

Although current forecasting technology mainly encompasses deterministic models for the power output, the concept of complementary tools that can be used jointly to traditional forecasts to assess wind predictability has emerged as an important issue. In situations with low predictability the development of probabilistic wind power forecasts becomes very important and requires probabilistic information for decision making. Experiments using different LAF schemes as combinations of GFS [1] and WRF [2] model components have been generated and evaluated.

Setup of GFS LAFs and WRF LAFs (WAFs)

The meso-scale model WRF employed by WISENT [3] is suitable for both research and operations, capable of running on a variety of platforms, either serially or in parallel, with or without multithreading. The chosen methodology for post-processing and optimization of wind energy predictions is the LAF technique [4], which involves the combination of various forecasts that are verified at the same time, but were initiated at sequentially different times (Figure 1).

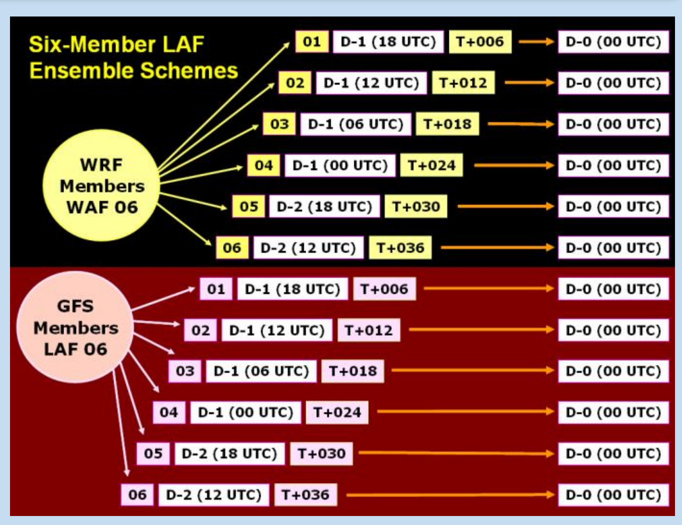

Fig 1: Graphical representation of 6-member LAFs


Fig 2: WRF 2-domain & 2-way nested setup

Investigating the accuracy of wind speed fields produced by WISENT's WRF, we finally utilized a two-domain, two-way nested set-up (Figure 2), with a parent (outer) to child (inner domain) ratio 1:3 (30 & 10 km respectively). In the vertical, 35 full levels were used. GFS LAFs and WRF LAFs (WAFs) at the height of 80 meters were generated and evaluated for the period of MAM (March, April & May) 2007. All LAF formulations were verified for all forecast intervals, i.e. from 06 to 120 hours over 11 wind farms stationed at North Germany.

Combination of LAFs and WAFs

Different configuration LAF schemes as combinations of GFS and WRF single deterministic components were formed. A set of twelve schemes was constructed:

LAF06	The 6-member ensemble scheme constructed using the 6 most recent, lagged GFS model forecasts (i.e. forecasts started at the initial time, and 6, 12, 18, 24 and 30 hours earlier).
LAF12	As in LAF06, but for the 12 most recent lagged GFS model forecasts.
WAF06	As in LAF06, but for WRF model forecasts.
WAF12	As in WAF06, but for the 12 most recent lagged WRF model forecasts.
CMB12	The 12-member ensemble constructed by combining LAF06 and WAF06.
CMB24	As in CMB12 but for the 24-member ensemble combining LAF12 and WAF12.
OLAF06	As in LAF06 but the ensemble-mean (OLAF06-EM) is taken by utilizing normalized weights based on each member's seasonal (inversed) forecast skill.
OLAF12	As in OLAF06, but for the 12 most recent lagged GFS forecasts.
OWAF06	As in OLAF06 but for WRF model forecasts.
OWAF12	As in OWAF06, but for the 12 most recent lagged WRF forecasts.
OPT12	As in CMB12, but combining OLAF06 and OWAF06 forecasts (utilizing equal weights).
OPT24	As in OPT12, but combining OLAF12 and OWAF12 model forecasts.

During investigation, the total forecast horizon of 120 hours was conveniently spitted into three (3) time intervals:

- *Very Short-Range FOrecast interval (VS-RFO), defined from 6 to 36 hours.*
- *ShOrt-Range FOrecast interval (SO-RFO), defined from 36 to 72 hours.*
- *Early Medium-Range FOrecast interval (EM-RFO), defined from 72 to 120 hours.*

Results

The best (optimal) LAF scheme was determined by inter-comparisons among all available LAF formulations, focusing on the skill of the ensemble mean and the validation & characteristics of each ensemble scheme's spread. Spread evaluation was based on the comparison of the average (over all 11 wind farms) ensemble standard deviation with the error of the ensemble-mean.

In terms of ensemble-mean, the 24-member OPT24 scheme gives the best forecast guidance after T+24h (day1) in the VS-RFO and keeps its superiority in both the remaining SO-FRO and EM-RFO time intervals. In Figure 3, the skill of GFS (LAF06-Con) and WRF (WAF06-Con) Control is plotted together with OPT24's ensemble mean. Controls are becoming similar after day 2.5 (T+60h), but nevertheless both Controls exhibit worse quality characteristics (skill) than the weighted ensemble mean of the 24-member OPT24 scheme (OPT24-EM).

In terms of spread, OPT24 ensemble scheme has the largest spread than any other scheme, while at the same time it matches more to the error of its corresponding ensemble mean (OPT24-EM), revealing a more harmonized, i.e. better tuned overall performance (Figure 4). OPT24's control forecast (OPT24-Con) is plotted as well for comparison.

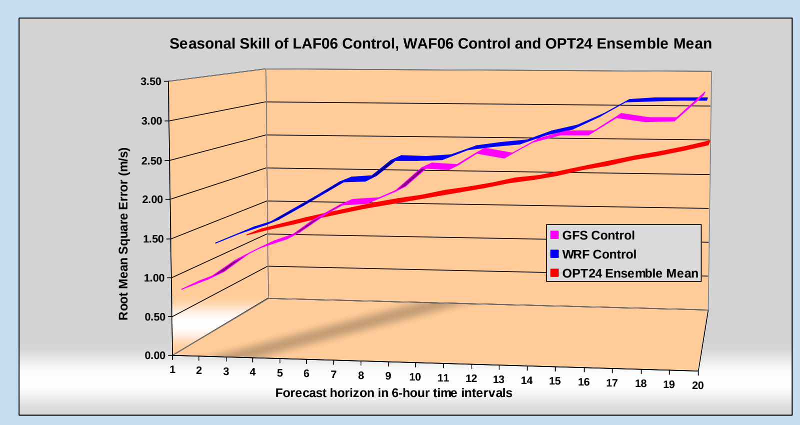

Fig 3: Seasonal skill (RMSE) of LAF06-Con, WAF06-Con and ensemble mean of the OPT24 scheme

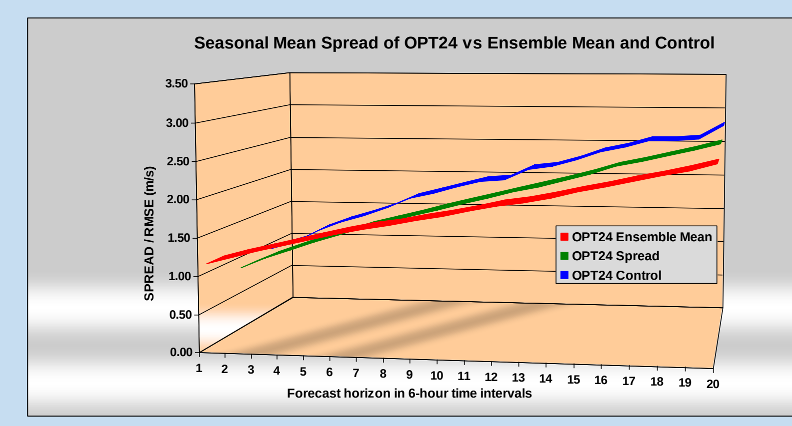

Fig 4: OPT24 scheme's seasonal spread from its ensemble mean. OPT24-EM and OPT24-Con are also plotted.

A more detailed way of analysing the ensemble spread is to construct a so called *Talagrand Diagram (TD)*. TD is constructed from the notion that in an ideal ensemble the verifying analysis is equally likely to lie between any two ordered adjacent members of the ensemble. Such a diagram is presented in Figure 5 concerning the 6-member GFS LAF scheme for the SO-RFO time interval. Its obvious U-shape is due to over-representation of cases when the verification falls outside the ensemble (40.31%).The same U-shaped formulation can be seen in Figure 6 concerning the 6-member WRF WAF scheme for the SO-RFO time interval, where 40.29% of the values are outside the ensemble "cloud".

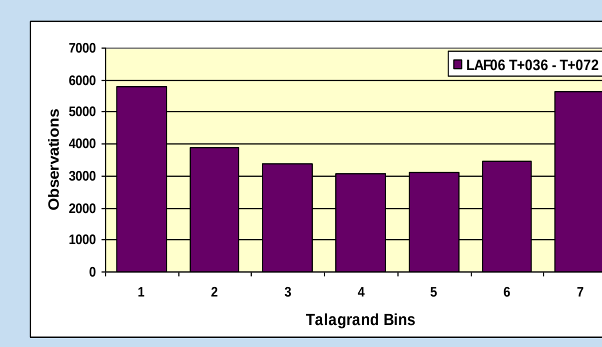

Fig 5: TD for LAF06 for the SO-FRO interval

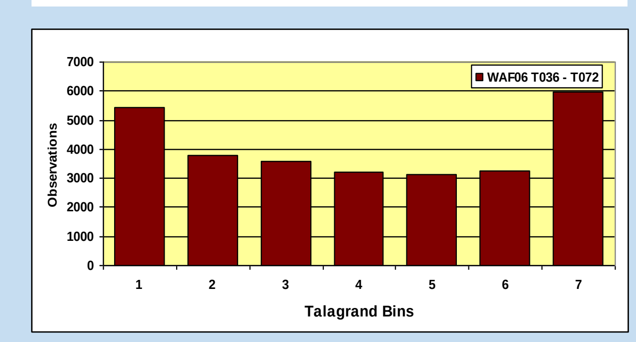

Fig 6: As in Figure 5, but for WAF06 scheme

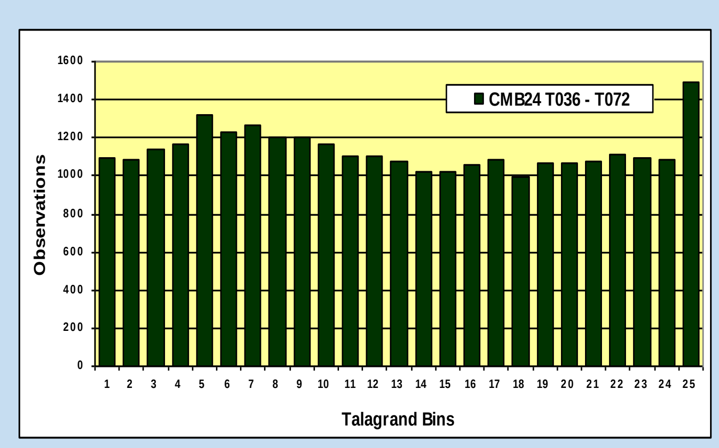

Fig 7: As in Figure 5, but for CMB24 scheme

Investigating the effect of the ensemble size, we construct the graph of Figure 7 concerning the 24-member CMB24 scheme (valid for the OPT24 formulation as well). For CMB24, the no. of ensemble members has been quadrupled (from 6 to 24). This leads to a non U-shaped formulation, meaning that only a small portion of the analysis (actually 9.14%) lies outside the ensemble "cloud".

Conclusions

The 24-member OPT24 formulation comprising 12 GFS LAFs and 12 WRF WAFs was found to be the best (optimum) ensemble scheme. Its weighted ensemble-mean (OPT24-EM) gives the best forecast guidance after T+24h (day1) in the VS-RFO and keeps its superiority in both the remaining SO-FRO and EM-RFO time intervals. Furthermore, OPT24-EM exhibits better quality characteristics than both the GFS's and WRF's control forecasts.

In terms of spread, OPT24 has the largest spread than any other scheme, while at the same time it matches more to the error of its corresponding ensemble mean (OPT24-EM), revealing a more harmonized (i.e. better tuned) overall performance.

References

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2. *The Weather Research & Forecasting Model (http://www.wrf-model.org).*
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4. *Hoffman, R.N. and E. Kalnay, 1983: Lagged Average Forecasting, and Alternative to Monte Carlo Forecasting. Tellus, 35A, 100-118.*