Economic value of GLAMEPS-LAEF over Belgium

Geert Smet

Norrköping, 5-8 April 2011

Outline

1. Introduction

2. Economic value: general framework
   - Binary variables
   - Continuous variables

3. Economic value of GLAMEPS-LAEF over Belgium
   - Verification scores

4. Summary/Conclusions

Figure: Enercon E-126 wind turbine: largest to date with hub height of 135m, rotor diameter of 126m and total height of 198m (Source: Wikipedia).

Introduction

- Relative economic value usually defined for binary events, e.g. $T_{2m} < 0\,°C$, rain vs. no rain, etc.
- However, wind power or energy demand forecasting $\Rightarrow$ relative economic value for 'continuous' variables needed.

Economic value: general framework

Income I (of the decision maker's company)

$$I = f(AV) - Loss(AV, PV)\,,$$

with

$$\begin{aligned} AV &= \text{Actual Value}\,, \\ PV &= \text{Predicted Value}\,, \\ f(AV) &= \text{some (irrelevant) function of } AV\,, \\ Loss(AV, PV) &= \text{Loss in income depending on } PV\,. \end{aligned}$$

Economic value: general framework

Risk neutral decision maker:

$$\frac{d\overline{Loss}(PV)}{dPV} = 0\,,$$

with

$$\overline{Loss}(PV) = \int Loss(AV, PV)p(AV)dAV\,,$$

leads to optimal PV given $p(AV)$ (probabilistic weather forecast).

Economic value: general framework

Relative economic value V_{ref} :

$$V_{ref} = \frac{\overline{Loss}_{ref} - \overline{Loss}_{fc}}{\overline{Loss}_{ref} - \overline{Loss}_{perfect}} .$$

Essentially unique loss function:

$$\begin{aligned} Loss(AV,PV) &= (L-C)\delta_{AV-PV,1} + C\delta_{PV-AV,1} \\ &\quad + (L_m - C)\delta_{PV+AV,2}\,, \\ &= L[(1-cl)\delta_{AV-PV,1} + cl\delta_{PV-AV,1} + (\frac{L_m}{L} - cl)\delta_{PV+AV,2}]\,. \end{aligned}$$

determined by 3 parameters C,L and L_m (with $cl = C/L$).

Binary variables

The static cost-loss model

Minimizing expected mean loss $\overline{Loss}(PV)$:

$$\text{Choose } PV = 1 \text{ if}$$
$$p(AV = 1) > \frac{cl}{1 - L_m/L + cl} = \frac{C}{L - L_m + C}.$$

Continuous variables

We can do two things:

- Choose some threshold value to reduce AV to a binary event, e.g. $T_{2m} < 0\,^{\circ}\mathrm{C}$, rain vs. no rain, $S_{10m} > 5\,m/s$, etc.
- Keep AV, PV continuous. Then, there are essentially an infinite amount of possible loss functions.

Continuous variables

The ‘linear’ case

$$Loss(AV, PV) = C(PV - AV) + Lmax(AV - PV, 0)\,,$$
$$= L \begin{cases} cl|PV - AV| & \text{if} \quad PV - AV \geq 0 \\ (1 - cl)|PV - AV| & \text{if} \quad PV - AV \leq 0 \end{cases} .$$

This is a weighted mean absolute error: $cl = 1/2$ gives the MAE (up to an overall multiplication by a constant $L/2$).

Continuous variables

The 'linear' case

Cost-loss model for wind energy production forecast

- Roulston, Kaplan, Hardenberg, Smith (2003) : *Using medium-range weather forecasts to improve the value of wind energy production.*
- Pinson, Chevallier, Kariniotakis (2007): *Trading wind generation from short-term probabilistic forecasts of wind power.*

Cost-loss model for electricity demand forecast

- Smith,Roulston and von Hardenberg (2000): *End to end ensemble forecasting.*

Continuous variables

The 'linear' case

Minimizing expected mean loss $\overline{Loss}(PV)$:

$$\text{Choose } PV \text{ such that } Pr(AV > PV) = cl\,.$$

Remarks:

- If $cl = 0$, only 'underforecasting' ($AV > PV$) is penalized $\Rightarrow$ choose PV big enough.
- If $cl = 1/2$, median forecast minimizes MAE.

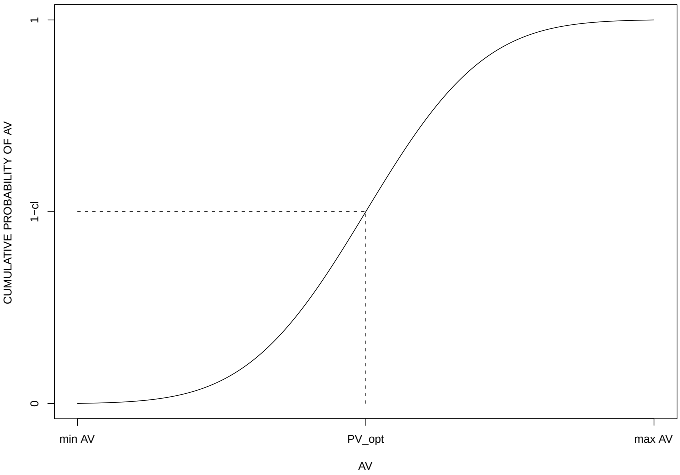


Figure: Optimal PV given p(AV)

Economic value of GLAMEPS-LAEF over Belgium

- Scores are averaged over 10 standard stations in Belgium.
- Verification period: 01/03/2010 - 31/12/2010.
- Only T_{2m} (2m temperature) and S_{10m} (10m wind speed) for now.

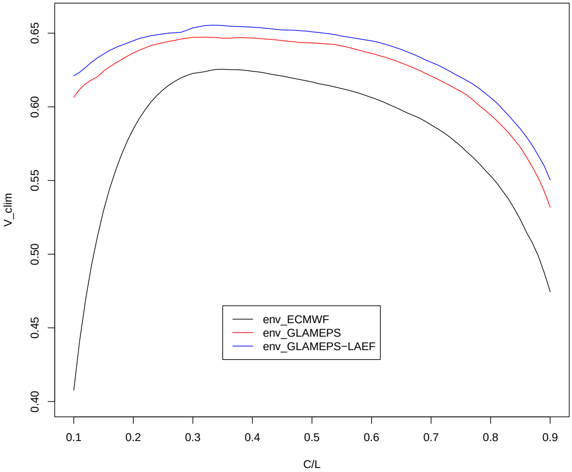


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run = 00h, lead time = 30h).

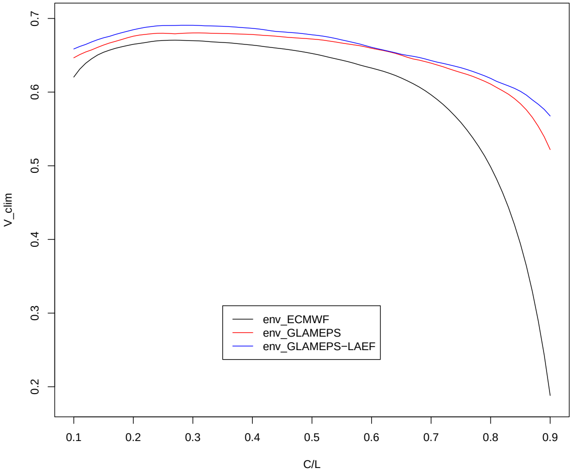


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run = 00h, lead time = 12h).

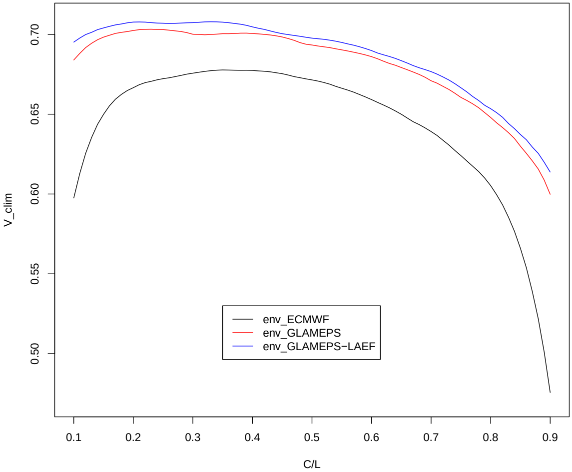


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run = 00h, lead time = 18h).

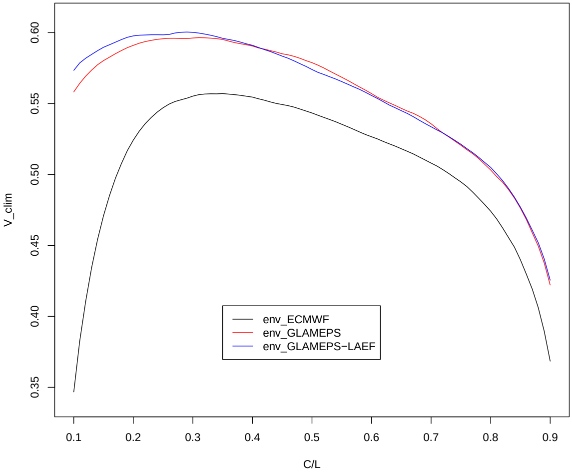


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run = 00h, lead time = 24h).

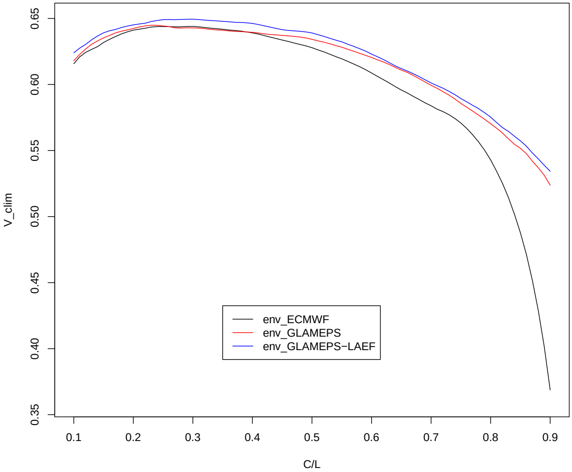


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run $=$ 00h, lead time $=$ 36h).

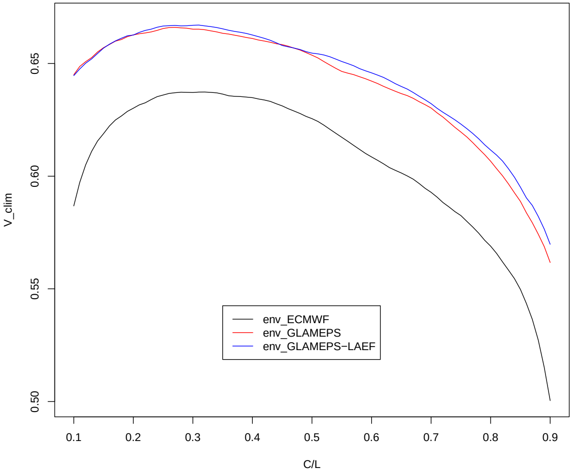


Figure: Relative economic value with respect to (sample) climatology for T_{2m} (run = 00h, lead time = 42h).

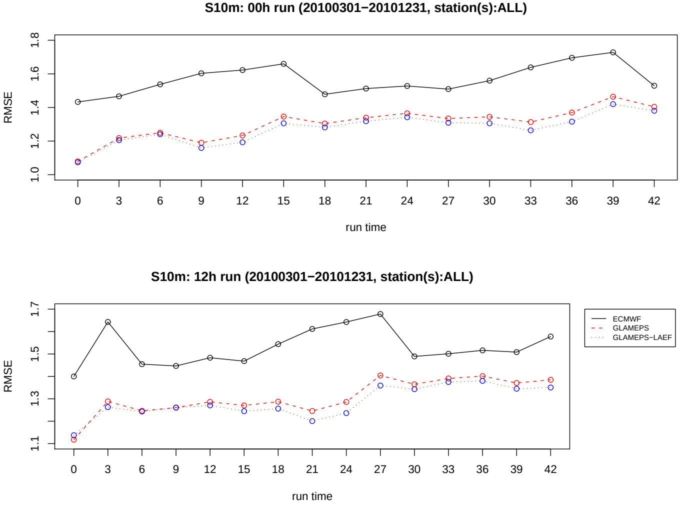


Figure: RMSE of ensemble means for S_{10m}.

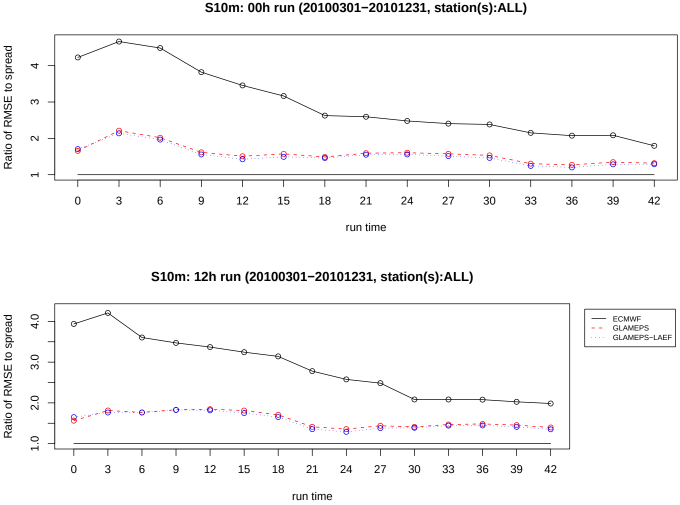
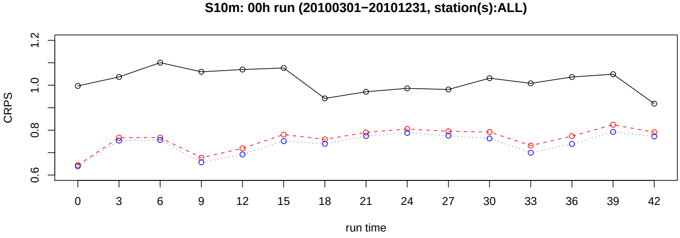


Figure: Ratio of RMSE to SPREAD for S_{10m}.



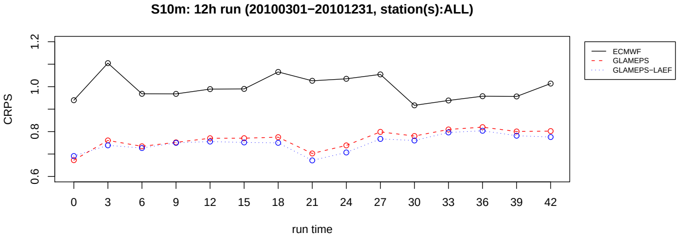


Figure: CRPS for S_{10m}.

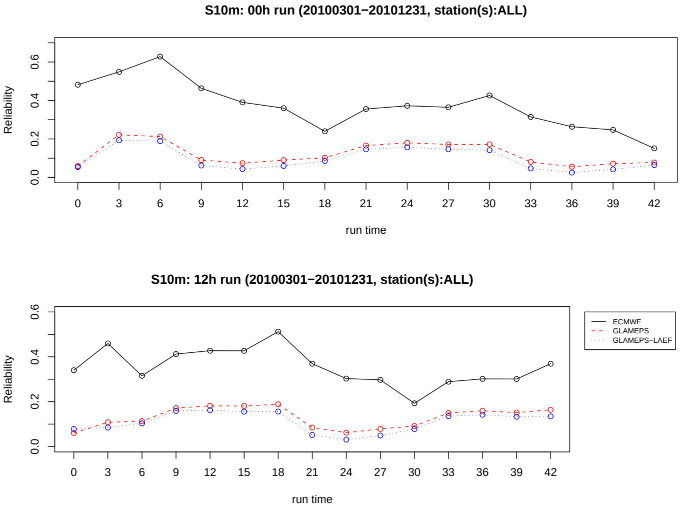


Figure: Reliability component of CRPS for S_{10m}.

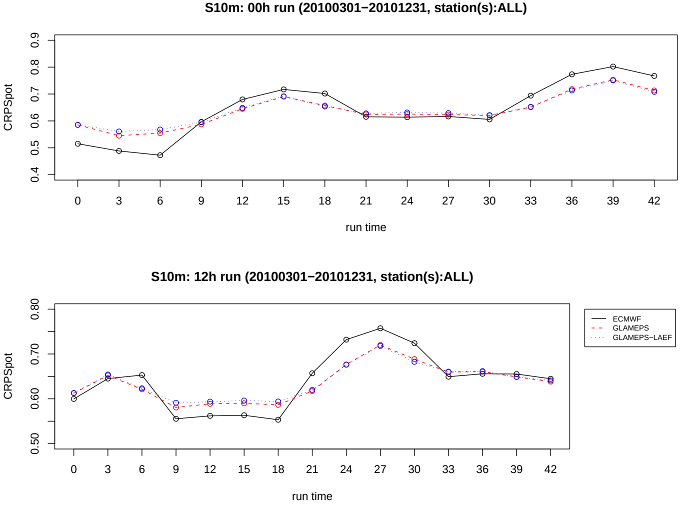


Figure: Potential CRPS for S_{10m}.

Summary/Conclusions

- Relative economic value score for continuous variables.
  - Very useful for the energy market (windpower, energy demand).
  - No (arbitrary) thresholds needed.
- GLAMEPS scores significantly better than ECMWF.

Summary/Conclusions

- Adding LAEF adds value to GLAMEPS, both for T_{2m} and S_{10m}.
  All scores (CRPS, Reliability, RMSE, SPREAD, relative economic value) improve at most lead times.
- Robustness exercise (largest negative impact if removed):
  - T_{2m}: 'EuroTEPS'
  - S_{10m}: AladEPS/(LAEF/'EuroTEPS')

Summary/Conclusions

- Adding ECMWF to GLAMEPS-LAEF does not give better results.
  - Improves scores for T_{2m} at some lead times and decreases scores for other lead times.
  - Worse scores for S_{10m} at most lead times.
- Including 50m, 100m, 150m wind speed in output could be relatively easy way to increase value/usefulness of the weather models.

THANK YOU

Appendix:CRPS

Continuous Ranked Probability Score

$$CRPS(forecast) = \frac{1}{ncases} \sum_{i=1}^{ncases} \int_{x=-\infty}^{x=+\infty} \left(F_i^f(x) - F_i^o \right)^2 dx$$

- F_i are cdf's, with F_i^o usually a (Heaviside) step function.
- Lower CRPS is better.