SafeWind


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Deliverable Dp-5.4

"Suitability and feasibility of integrating Limited-Area EPS (LEPS) for WPF applications"

Appendix K

Skill assessment of COSMO-LEPS

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Appendix K: Skill assessment of COSMO LEPS

The COSMO-LEPS system ([K.1] & [K.2]) has been based on the dynamically downscaling of the global VarEPS forecasts provided by ECMWF. One of the rationales for using COSMO-LEPS instead of simpler, purely statistical downscaling methods is that the COSMO model is better capable to simulate small-scale phenomena, and can thus provide some extra, valuable information on the top of the global ECMWF VarEPS system.

The *first Section* of Appendix K discusses results obtained by COSMO-LEPS system [K.3] for the period *DJF 2009* (December 2008 – January & February 2009). The population of the mesoscale system had been 16 members with a horizontal resolution of 10 km. For DJF 2009 period, COSMO-LEPS forecasts have been compared to ECMWF Ensemble Prediction System (EPS) forecasts to assess whether they can add valuable information to the one produced by the EPS. COSMO-LEPS and EPS platforms differ both in membership (16 for LEPS compared to 50+1 of EPS) and resolution (10 km for LEPS compared to 50 km of EPS). To assess the impact of ensemble size, COSMO-LEPS is compared to both the full-size EPS, and to the first 16-member EPS. To alleviate the fact that COSMO-LEPS has a higher resolution, both systems are verified on the same 0.5 x 0.5 degree grid.

In the *second Section (DJFM 2010 period)* COMSO-LEPS scheme with its new horizontal resolution of 7 km is compared to both the old ECMWF EPS of 50 km resolution (period DJ 2010) and to the new (currently) EPS of 32 km (FM 2010 period). It is worth to point out that in the first Section common ECMWF analysis fields were used for the skill assessment (which has been somehow unfair to COSMO-LEPS), while in the second Section, each platform has been verified against its own analysis.

1. Details of the DJF 2009 verification: Old COSMO-LEPS (res: 10 km) Vs Old EPS (res: 50 km)

- *ACC & Useful Forecast Interval (UFI) for surface (10-meter height) wind speeds*

ACC values for IFS High-Resolution Operational Forecast (IFS-OPER), EPS (50 members) Ensemble Mean (EPS-EM50m), EPS (16 members) Ensemble Mean (EPS-EM16m), EPS Control Forecast (EPS-Cntr), COSMO-LEPS Ensemble Mean (CO-EM) and COSMO-LEPS Operational Forecast (taken also as COSMO Control Forecast) are shown in Figure K1.

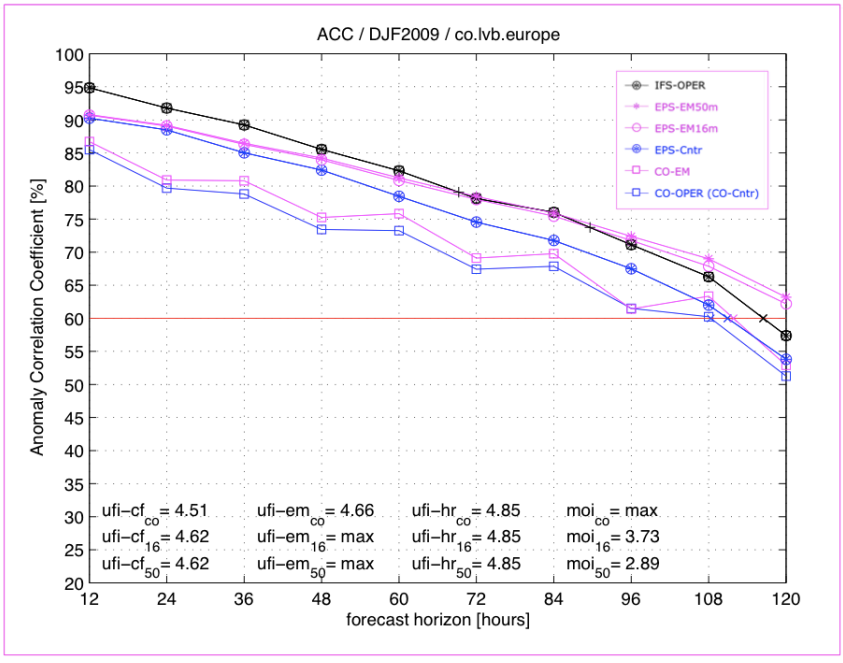

Figure K.1: *ACC values for IFS-OPER, EPS-EM50m, EPS-EM16m, EPS-Cntr, CO-EM and CO-OPER (taken also as CO-Cntr) over Europe during DJF 2009.*

From Figure K.1, it is obvious that both COSMO-LEPS Control (also Operational) Forecast and COSMO Ensemble Mean perform less skilfully than ECMWF EPS's components over Europe for DJF 2009. It is interesting to note that the Ensemble Mean of the limited 16-member EPS has almost the same skill as the full 50-member EPS-EM for all forecast horizons.

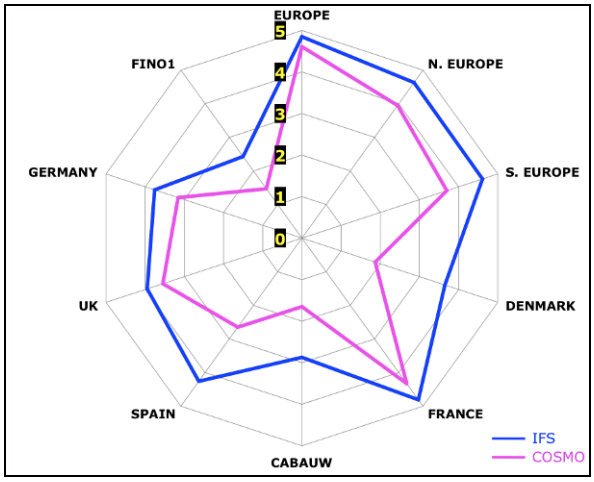

Figure K.2: *Useful Forecast Interval (UFI) values for IFS-OPER and CO-OPER over various European subareas during DJF 2009.*

Besides ACC values, their corresponding UFI (Useful Forecast Interval) and MOI (Minimum Overtaking Interval) values are also shown at the lower part of Figure K.1 valid for Europe. For IFS-OPER, UFI was found equal to 4.85 days compared to 4.51 (days) of COSMO-OPER. For both formulations of EPS (e.g., the 50- & 16-member EPS), UFI for EM reached its maximum value of 5 days, while the corresponding UFI for COSMO-LEPS ensemble mean reached 4.66 days. Based on different values of UFI over a set of European subareas, Figure K.2 is constructed for IFS and COSMO Operational components. From Figure K.2, it becomes clear that IFS keeps its superiority over COSMO not only for large but also for small subareas (of Europe).

- *Root Mean Square Error for surface (10-meter height) wind speeds*

RMSE values for the same components as the ones contained in Figure K.1 are shown in Figure K.3. Once more, ECMWF IFS & EPS keep their superiority over COSMO-OPER & COSMO-LEPS. It is worth to point out that COSMO-LEPS ensemble mean provides better forecast guidance than COSMO-OPER's for all forecast horizons.

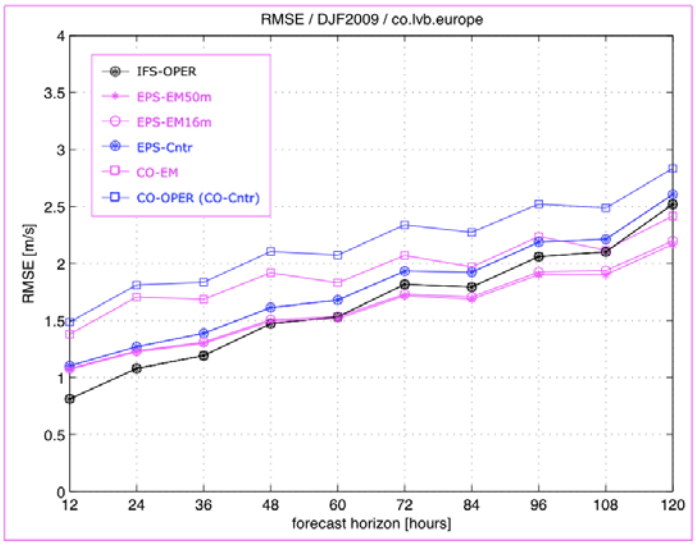

Figure K.3: *As in Figure K.1 but for RMSE values.*

- *Continuous Ranked Probability Skill Score for surface (10-meter height) wind speeds*

Ranked Probability Score's continuous formulation, e.g., the Continuous Ranked Probability Score (CRPS) corresponds to the integral of the Brier Score (BS) for the associated binary probabilistic forecasts at all real value thresholds. Besides the two ensemble prediction platforms (ECMWF-EPS & COSMO-LEPS), CRPSS probabilistic scores have been computed for the EPS and LEPS Control Forecasts, Ensemble Means and their corresponding Operational Forecasts by constructing appropriate "synthetic" Probability Density Functions [K.4].

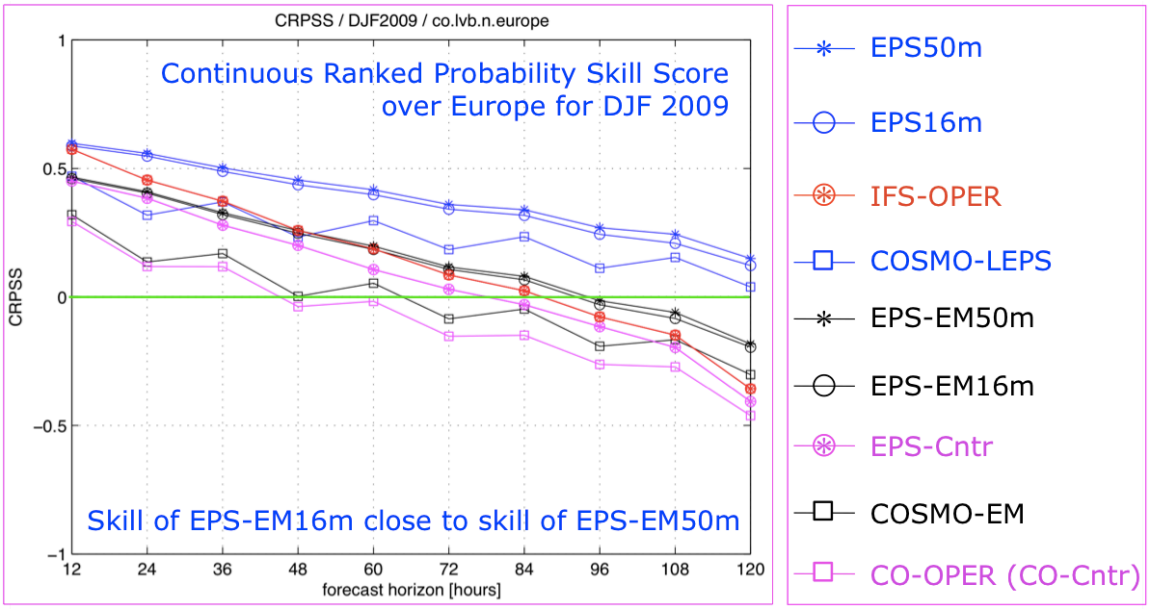

Figure K.4: *CRPSS values for ECMWF-EPS 50 members (EPS50m), ECMWF-EPS 16 members (EPS16m), COSMO-LEPS, IFS-OPER, EPS-EM50m, EPS-EM16m, EPS-Cntr, COSMO-EM and CO-OPER (taken also as CO-Cntr) over Europe during DJF 2009.*

From Figure K.4 it is clear that both EPS and LEPS provide better probabilistic guidance that their corresponding "deterministic" components. Once more, EPS in both of its formulations (16- and 50-member EPS), scores better than COSMO-LEPS. It is surprising that EPS components keep their superiority over LEPS's not only for large areas (as Europe) but for small areas (as FINO1) as well.

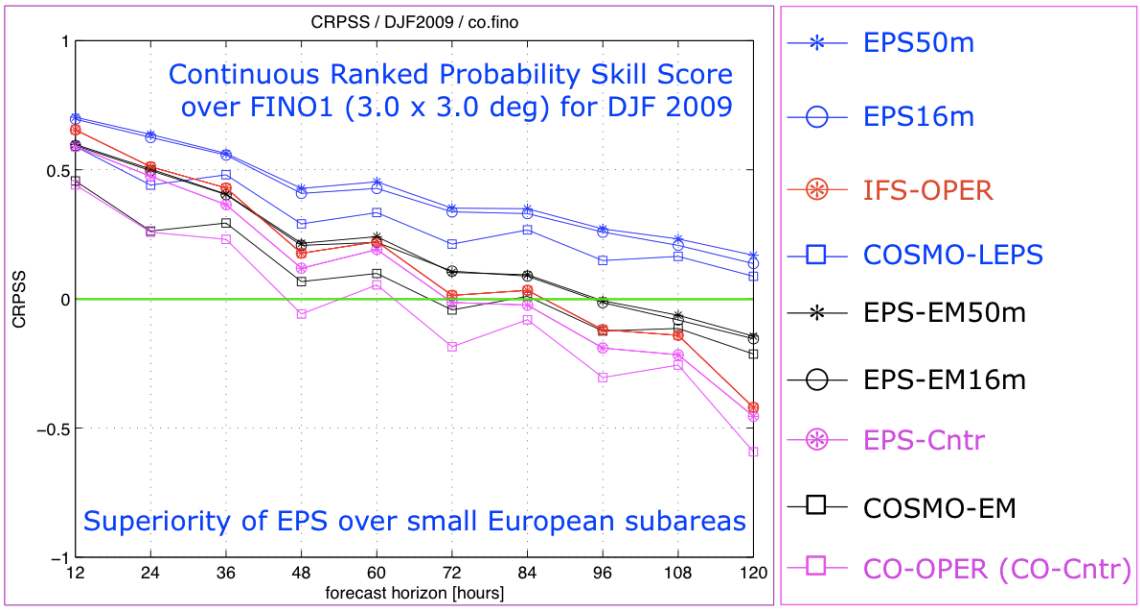

Figure K.5: *As in Figure K.4 but for FINO1 observation platform area (55.5N / 5E / 52.5N / 8E).*

2. Details of the DJFM 2010 period verification

In the following Sections (2a & 2b) of DJFM 2010 period, COSMO-LEPS platform with its new horizontal resolution of 7 km (after 1 December 2009) is compared to both the old ECMWF EPS of 50 km resolution (period DJ 2010) and to the new (currently) EPS of 32 km (FM 2010 period). Each platform is verified against its own analysis. Details of the verification framework can be found in Figure K.6. It is worth mentioning that the resolution of new IFS (during FM 2010) is equal to 16 km.

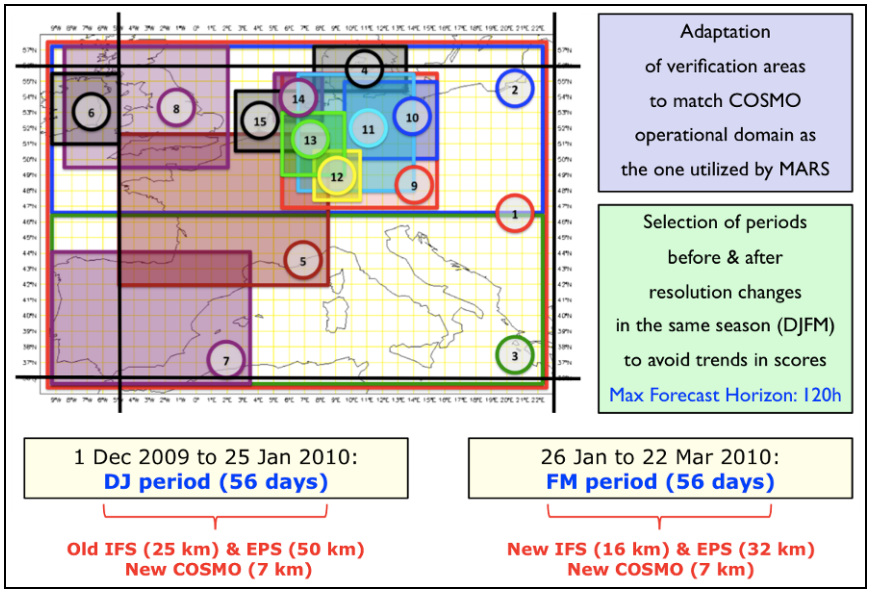

Figure K.6: *Adaptation of European subareas to match COSMO-LEPS domain as it is utilized in ECMWF MARS (Meteorological Archiving System) & definition of DJ & FM periods.*

2a. December 2009 – January 2010 Period (DJ): New COSMO-LEPS (7 km) Vs Old EPS (50 km)

- *ACC & Useful Forecast Interval (UFI) for surface (10-meter height) wind speeds*

ACC values for the High-Resolution IFS, EPS Control Forecast and COSMO Operational Forecast (COSMAN Operational) are shown in Figure K.7. The superiority of IFS over EPS Control and COSMO Operational is evident for all forecast horizons (having the highest UFI value of all).

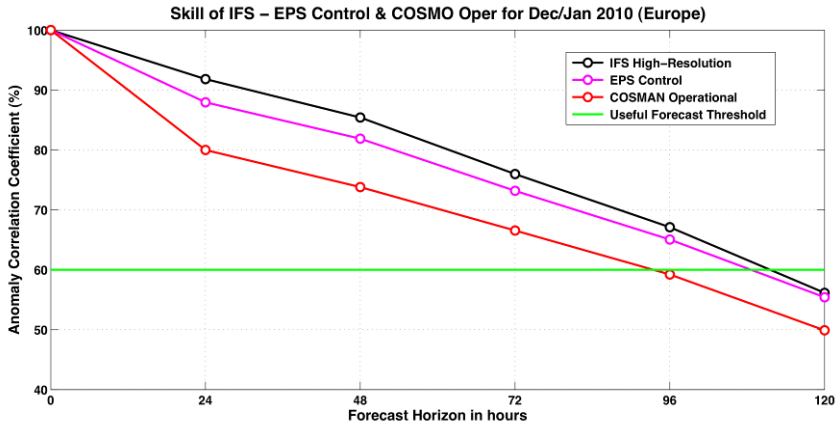

Figure K.7: *ACC values for IFS, EPS Control and COSMO Operational over Europe during DJ 2010.*

- *Continuous Ranked Probability Skill Score for surface (10-meter height) wind speeds*

Continuous Ranked Probability Score (CRPS) values for both EPS (the limited 16- and the full 50-member EPS) formulations are shown in Figure K.8. Scores for the 16-member EPS show comparable performance to the full 50-member one, although the difference in ensemble size is considered significant. Nevertheless, both EPS formulations found to provide better probabilistic guidance over corresponding COSMO-LEPS for Europe and smaller European subareas also.

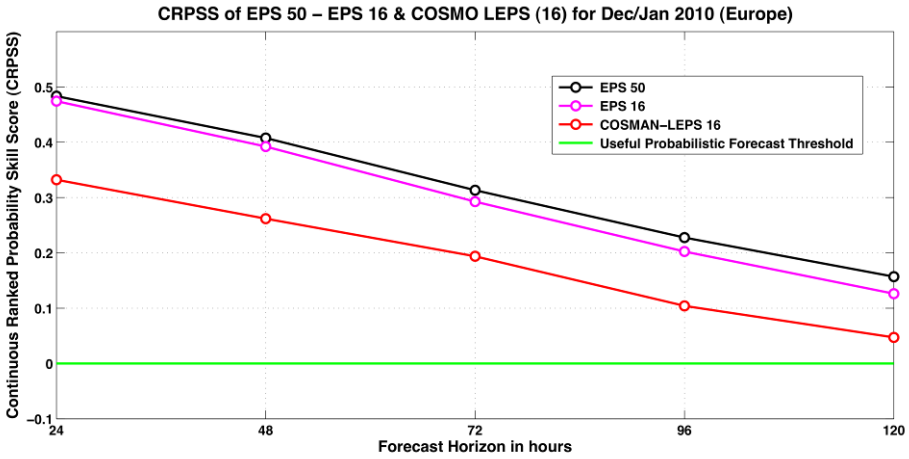

Figure K.8: *CRPSS values for limited 16- & full 50-member ECMWF EPS formulations and COSMO-LEPS over Europe during DJ 2010.*

2b. February – March 2010 Period (FM): New COSMO-LEPS (7 km) Vs New EPS (32 km)

- *ACC & Useful Forecast Interval (UFI) for surface (10-meter height) wind speeds*

ACC values for the High-Resolution IFS, EPS Control Forecast and COSMO Operational Forecast (COSMAN Operational) are shown in Figure K.9 (left). Once more, the superiority of IFS over EPS Control and COSMO Operational is evident for all forecast horizons (having the largest value of UFI). The same is true for all different European verification subareas also.

Furthermore, ACC values for both the ensemble means of ECMWF EPS (16- & 50-member) formulations are contained in Figure K.9 (right). Same wise, ACC scores for the ensemble mean of COSMO-LEPS is plotted also. LEPS EM found to be less skilful compared to both 16- & 50-member EPS EM formulations. Interesting to note once more the similarities in skill that the two 16- & 50-member EPS Ensemble Means seem to share.

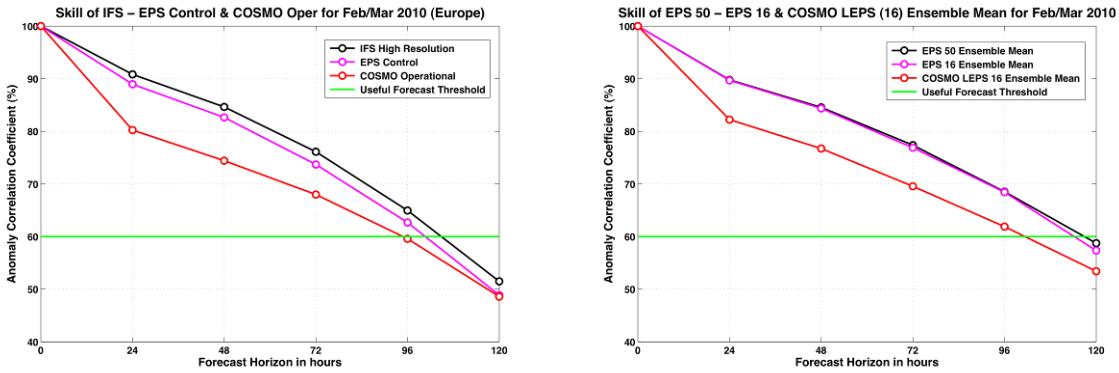

Figure K.9: *ACC values for IFS, EPS Control and COSMO Operational (left) & EPS-16 member EM, EPS-50 member EM and LEPS EM (right) over Europe during FM 2010.*

- *Continuous Ranked Probability Skill Score for surface (10-meter height) wind speeds*

Continuous Ranked Probability Score (CRPS) values for IFS High-Resolution, EPS Control and COSMO Operational Forecast synthetic PDFs are plotted in Figure K.10 (left). Differences in skill between IFS and Control are not considered significant (critical), while probabilities based on COSMO Operational forecast seem unable to provide better forecast guidance than climatology for horizons longer than 24 hours. The red line (corresponding to COSMO Operational Forecast crosses the zero (green) line just after the 24-hour forecast horizon. Furthermore, CRPSS values for EPS (for both the limited 16- and the full 50-member formulations) and for COSMO-LEPS are shown in Figure K.10 (right). Scores for the 16-member EPS show large similarities to the full 50-member one, while both ECMWF EPS formulations found to provide better probabilistic guidance over corresponding COSMO-LEPS for Europe and European subareas.

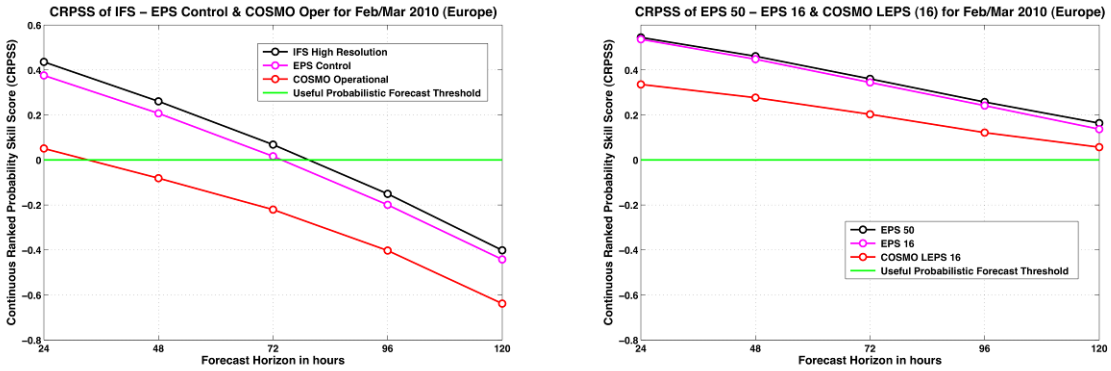

Figure K.10: *CRPSS values for IFS, EPS Control and COSMO Operational "synthetic" Probability Density Functions (left) & EPS limited 16- & full 50-member formulations and COSMO-LEPS (right) over Europe during FM 2010.*

- *EPS Spread from the Ensemble Mean and Skill of the Ensemble Mean (Spread / Skill relationship)*

In a perfect EPS, the time-mean ensemble spread about the ensemble-mean equals the time-mean RMS error of the ensemble-mean. Concerning the last changes in IFS & EPS taken place on 26 January 2010 onwards, the impact on the EPS spread found to be minimal [K.5]. The EPS has been tested for 58 cases in January and May 2009 and over the period 4 October to 3 November 2009. The overall benefit of the new T639 EPS is reflected in the results for the probability scores that are consistently improved for 500 hPa height anomalies and 850 hPa temperature anomalies, although as mentioned above, EPS spread has been in general unchanged. The EPS ensemble-mean errors are consistently lower, resulting in some overestimation of spread in terms of 500 hPa height and a better tuned spread in terms of 850 hPa temperature. Nevertheless, EPS spread in general still remains smaller than EPS EM skill (e.g., EM's RMSE), reflecting to the known deficiency of EPS concerning its under-dispersion as clearly seen in Figure K.12 (left), denoted by the gap between the two black lines.

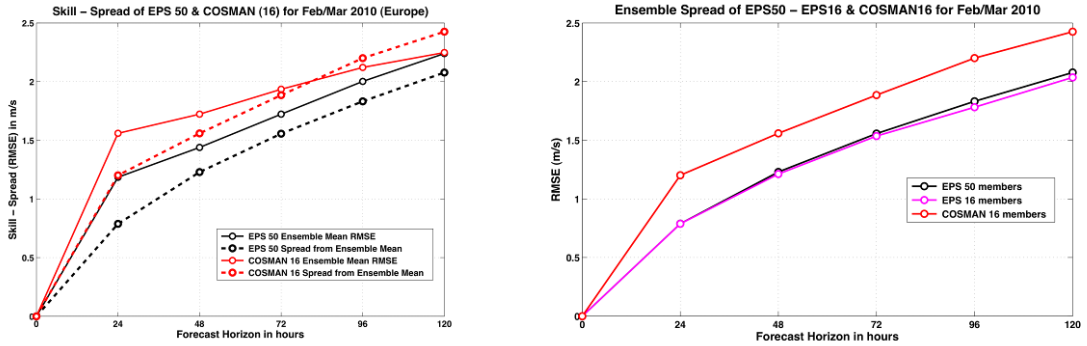

Figure K.12: *Spread – Skill relationship for ECMWF EPS & COSMO-LEPS (left) & Spread from the ensemble mean for ECMWF EPS 16- & 50-member formulations and COSMO-LEPS over Europe during FM period (right).*

Based on Figure K.12 (right) it becomes obvious that COSMO-LEPS Spread (from the ensemble mean) gets higher values than both EPS 16- & 50-member formulations for all forecast horizons. This characteristic of COSMO-LEPS can be of great value when atmosphere enters into its chaotic non-linear regime and most ensemble members are likely to be drawn towards model's climatology [K.6]. In such cases, a larger spread may reflect to the capability of EPS to include the "extreme" solution as one of its ensemble members. It should be pointed out that the larger spread of COSMO-LEPS corresponds to a larger error of its ensemble mean that makes also LEPS under-dispersive for most of forecast horizons. LEPS becomes over-dispersive after the 72-hour forecast horizon. Nevertheless, COSMO-LEPS appears not only to have larger spread (compared to EPS's) but most importantly a more "harmonized" relationship between Spread & Skill values as clearly seen in Figure K.12 (left), denoted by the smaller gap between the two red lines.

- *Talagrand Rank (Bin) Histograms*

In an ideal EPS system the long term "Talagrande distribution" [K.7] should be flat with equal number of verifications in each interval. Keeping this in mind, Talagrand Rank Histograms (TRHs) are constructed for the COSMO-LEPS and its corresponding EPS 16-member formulation.

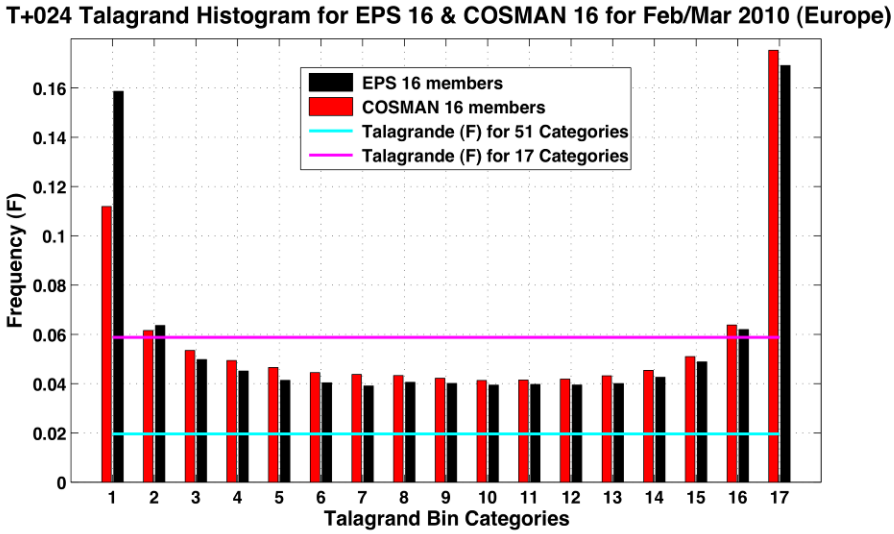

Figure K.13: *T+024 TRH for LEPS & 16-member EPS over Europe during FM 2010. Talagrande distribution for a 16-member EPS (i.e., 17 bins) is denoted by magenta line while the cyan line corresponds to a 50-member EPS (i.e., 51 bins).*

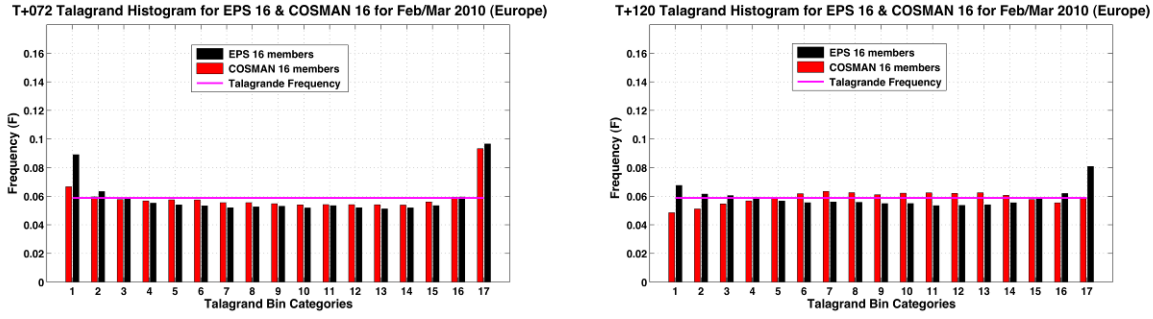

Figure K.14: *As in Figure K.13, but for T+072 (left) & T+120 (right).*

Such TRHs referring to a common number of ensemble members are presented in Figures K.13 (for T+024) and K.14 (for T+072 & T+120 hours). It is interesting to see that COSMO-LEPS at the beginning (T+024 hours) has smaller number of outliers to the left but larger number to the right than its corresponding EPS (16-member formulation). As the forecast horizon increases, COSMO-LEPS manages to show a considerable dropping of the total number of outliers (both to the left and to the right sides) outperforming EPS (16-member formulation). This is a very good sign that COSMO-LEPS largest spread is managing to capture more "extremes" belonging to both (left & right) outer bins.

A closer investigation focusing on the full 50-member formulation of ECMWF EPS reveals that COSMO-LEPS manages to stay closer to its optimal Talagrande distribution concerning the total number (sum of left and right outer bins) of outliers. This means that COSMO-LEPS appears to have a better chance in capturing possible extreme values falling in the outer left & right bin categories.

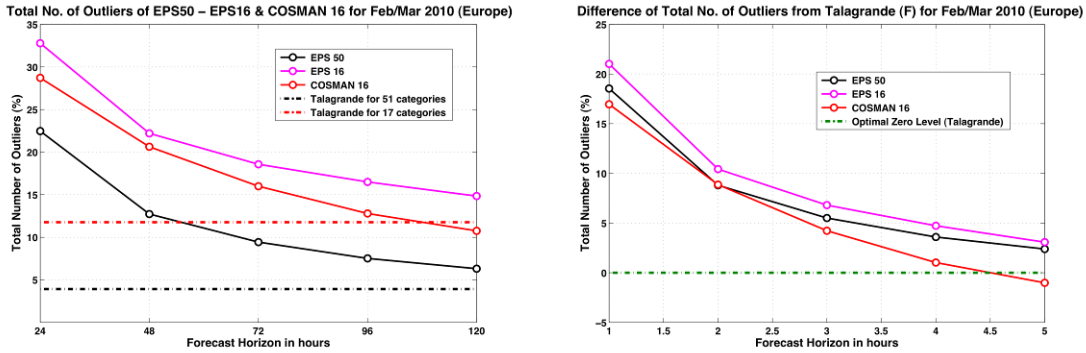

Figure K.15: *Total number (sum of left and right outer bins) of outliers for ECMWF EPS (16- & 50-member) formulations & COSMO-LEPS (left) and differences of total number of outliers from its corresponding Talagrande distribution (right) over Europe during FM 2010.*

It is important to point out though, that Figure K.15 does not provide the user with the complete picture. For instance, in cases that atmosphere moves to its chaotic non-linear regime, then someone is more interested on the events taking place to the right side of the spectrum (e.g., events linked to windstorms with possible destructive power). This is the reason behind plotting Figure K.16 focusing on the left outer bin events (left graph) and Figure K.17 focusing on the right outer bin (right graph), which contains all extreme values possible linked to windstorms.

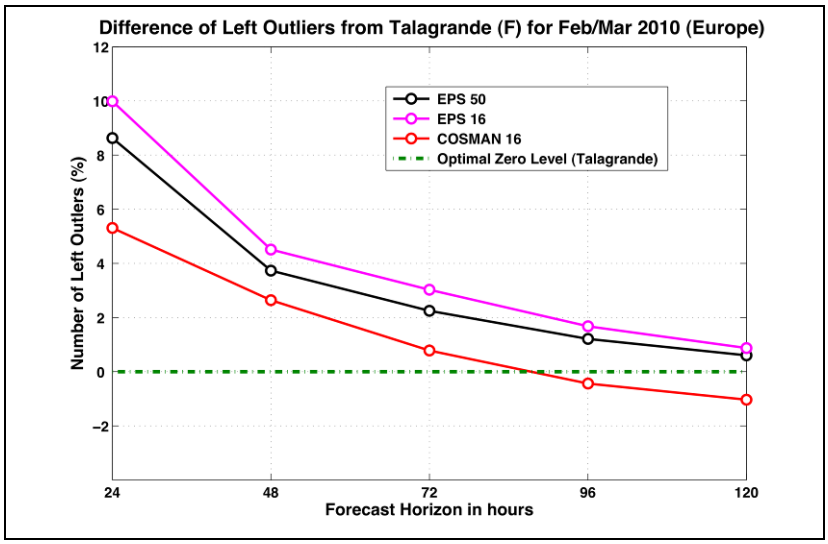

Figure K.16: *As in Figure K.15 (right) but for the left side outliers.*

From Figure K.16, it is obvious that COSMO-LEPS does a better job in forecasting extreme values for the left outer bin, since the number of misses (cases that analysis falls in the left outer bin) is smaller than both the 16-member and 50-member EPS formulations for all forecast horizons. It should be noted here that the left outer bin extremes are not considered as real extremes since they are linked to very light wind speeds (with no potential destructive power).

Investigating “real” extremes, Figure K.17 is constructed. It becomes obvious that ECMWF EPS (especially with its full 50-member formulation) outperforms LEPS for T+024 and T+048. It seems that a balance is reached at T+72. For horizons belonging to the early Medium-Range (i.e., T+72 to T+120), COSMO-LEPS provides the user with a scheme that has better chances to capture a potential “real” extreme event (falling in the right outer bin).

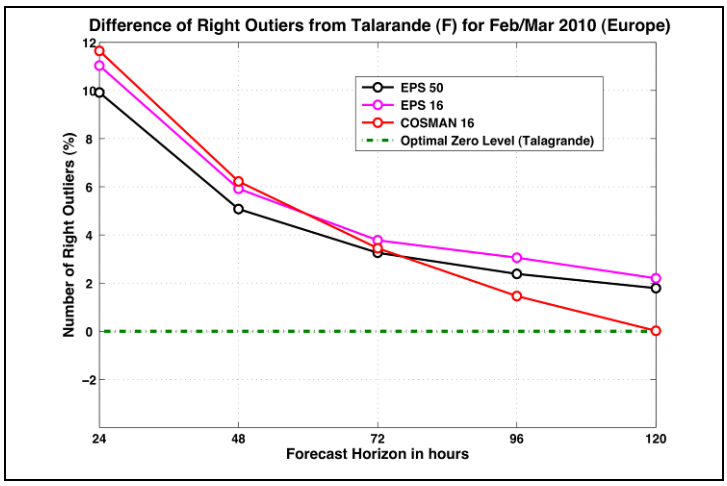

Figure K.17: *As in Figure K.16 but for the right side outliers.*

The value of EPS capability to capture extremes (by utilising an appropriate useful spread) can be seen in the example that follows contained in Figures K.18 – K.19 & K.20. In Figure K.18, T+000 ECMWF IFS & EPS and COSMO LEPS analysis values against FINO1 observations at 103-meter height for 3 February 2010 12 UTC are plotted, fitted in a time window of +/- 6 hours. The 3-hour observation maximum (well above the critical shut-off value of 25 m/s) is denoted by a red dot while a blue dot denotes the 10-min average observation value corresponding to 12 UTC. A black diamond corresponds to the IFS analysis value at 100 meters, while a cyan diamond to the COSMO Operational value at 100 meters. ECMWF EPS (50) members are denoted by a black "x" symbol, while the 16 members of COSMO-LEPS are denoted by blue "x" symbols. It becomes clear that COSMO-LEPS has a more "active" (i.e., larger) spread even at T+000 analysis, although it seems that it is projected mainly onto weaker values.

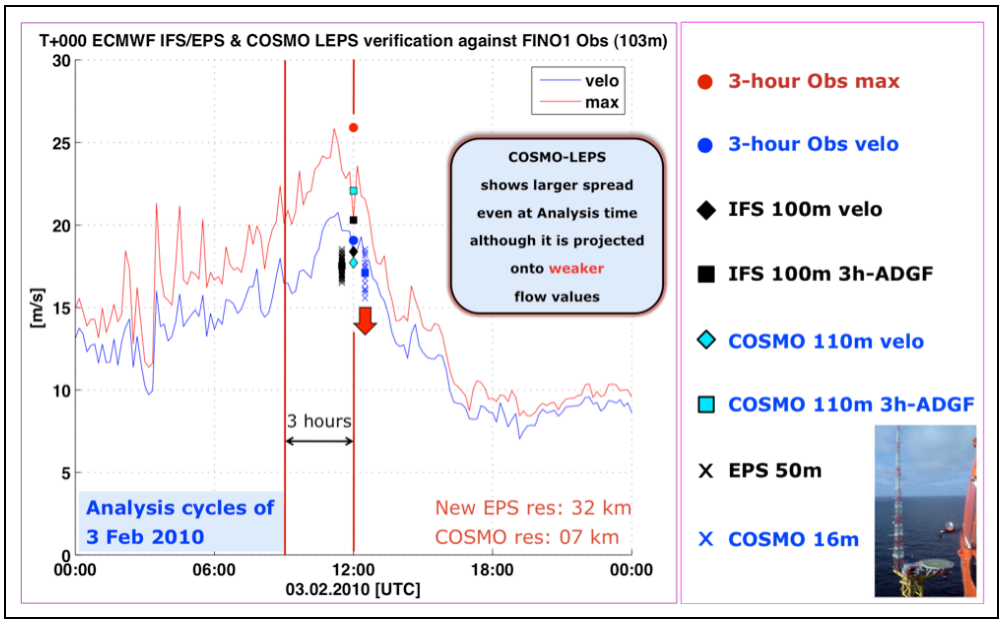

Figure K.18: *T+000 ECMWF IFS & EPS and COSMO LEPS analysis values against FINO1 observations (at 103-meter height) for 3 February 2010 12 UTC contained in a time window of +/- 6 hours. The 3-hour observation maximum is denoted by a red dot, while a blue dot denotes the 10-min average observation value corresponding to 12 UTC. A black diamond corresponds to the IFS analysis value at 100 meters, while a cyan diamond to the COSMO Operational value at 100 meters. ECMWF EPS (50) members are denoted by a black "x" symbol, while the 16 members of COSMO-LEPS are denoted by blue "x" symbols.*

In Figure K.19 the evolution of EPS and LEPS spread is shown after 72 and 96 hours. EPS spread for T+072 seems more homogenous (with smaller gaps in between its members). LEPS seems more "active" but with distinct gaps in between (mainly due to its limited number of ensemble members). Nevertheless, LEPS manages to provide the user with a member very close to the observation value (denoted by the blue dot), while EPS misses to do so. The same holds for T+096 forecast horizon, where LEPS manages to include FINO1 observation inside its minimum and maximum value. On the contrary, the FINO1 observation is falling in the outer (right) bin category for EPS. This is considered of great importance since both IFS and COSMO Operational forecast fail to provide the user with a useful forecast guidance and ensemble platforms seem the only mean to fill the gap between deterministic components and analysis, as shown in Figure K.20, which is an expansion of Figure K.19 (right). It is obvious that COSMO-LEPS due to its relatively larger and more "active" spread manages to outperform EPS in filling the gap between deterministic forecasts and analysis.

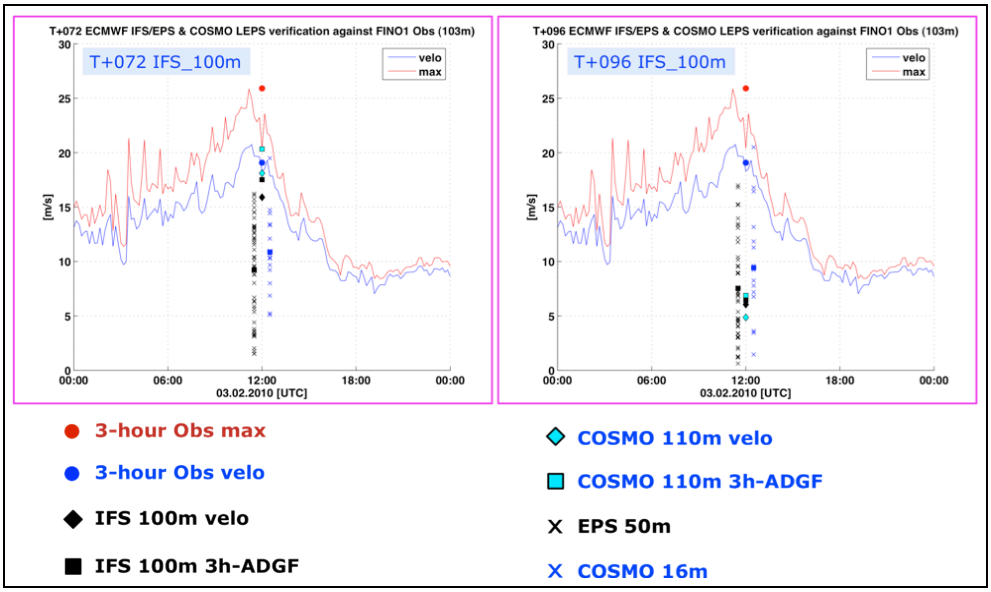

Figure K.19: *As in Figure K.18 but for T+072 (left) and T+096 (right) forecast horizons.*

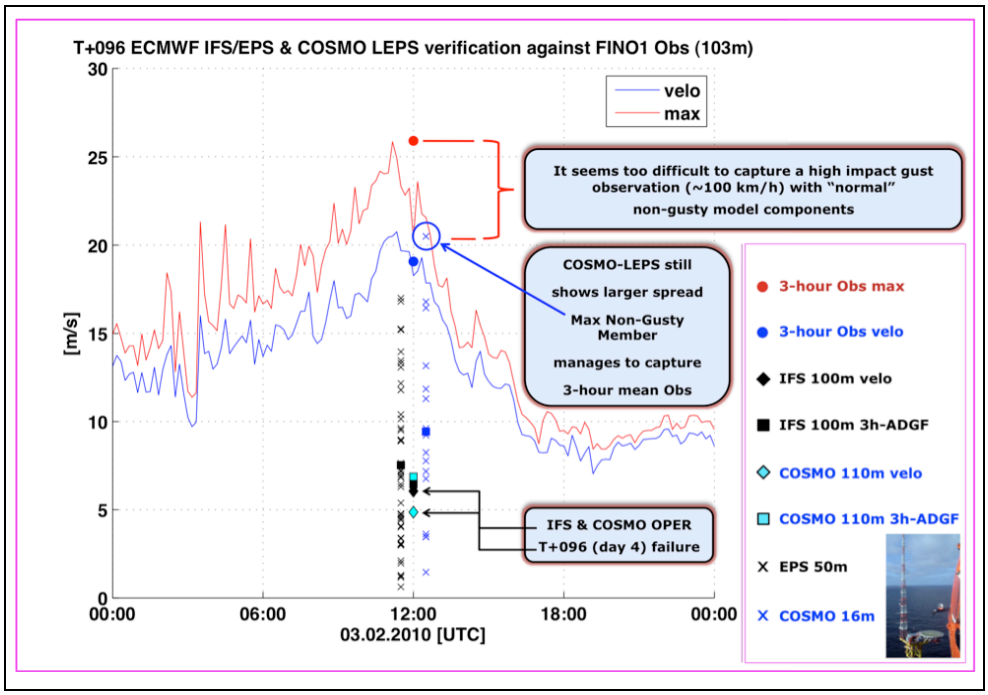

Figure K.20: *As in Figure K.18 but for T+096 forecast horizon, i.e., expansion of Figure K.19 (right).*

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