MS/CS “Green Book’ Report 2024

Section 1: Background

* 1.1 Country

Switzerland

* 1.2 Author(s)

Marco Arpagaus, Jonas Bhend, Oliver Fuhrer, Adel Imamovic, Pirmin Kaufmann, Lionel Moret, Daniele Nerini, Christoph Schmutz, Christoph Spirig, Stefano Zanini

* 1.3 Organisation

Federal Office of Meteorology and Climatology MeteoSwiss (Forecasts Development department, Service and Development Numerical Prediction Department, Forecasting and consulting department).

* Section 2: Summary of major highlights

Section 3: Forecast Products

3.1. Direct use of ECMWF forecast products

* a) Medium Range (e.g. for high impact weather forecasting)

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): None

* b) Extended Range (monthly)

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department):

- ECMWF’s monthly forecasts have been at display on MeteoSwiss’ public website for almost 20 years in the form of a simple monthly outlook showing tercile probabilities for three regions in Switzerland (Fig. 1).

- Two years ago, MeteoSwiss started issuing a weekly bulletin for the energy sector during the winter season. Besides monitoring of temperature and heating degree days over Switzerland we included tercile summary plots of ECMWF’s monthly forecasts over Europe (Fig.2).

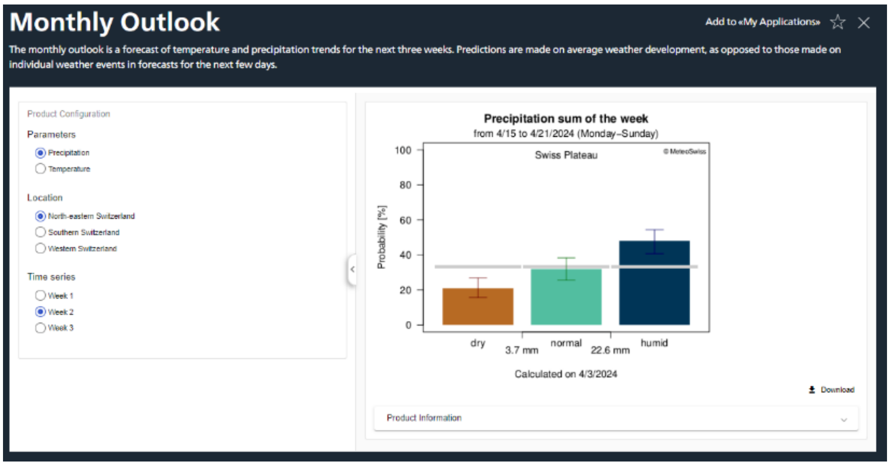


Fig. 1: Screenshot of MeteoSwiss' monthly outlook

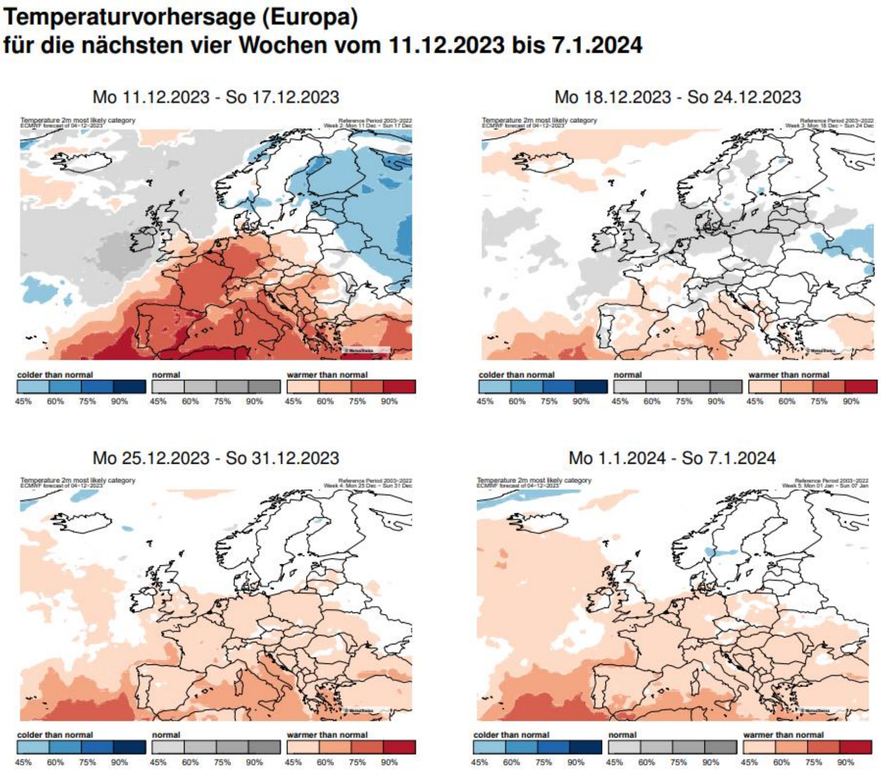


Fig. 2. Monthly temperature forecasts as part of a special bulletin for the energy sector.

* c) Long Range (seasonal)

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): None

* d) CAMS and Fire-related output (ecCharts mainly)

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): None

3.2. Cycle 48r1

* a) Positive impacts of model cycle 48r1

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): The more frequent monthly forecasts are highly appreciated and all our products based on monthly forecasts (including the monthly outlook mentioned above) are now updated daily. Furthermore, we appreciate the decoupling of IFS EXT from IFS, which results in seamless variables across the entire forecast lead time. Analyses have shown that we need a bundle of at least 5 hindcast dates to correct our forecasts for biases, which is why we would greatly appreciate higher hindcast production frequency (e.g. every other day). We note that the dissemination only offers 1 hindcast date ahead (although more are available e.g. from the MARS archive) - this results in us having to use both dissemination and MARS to retrieve the hindcasts.

* b) <u>Negative</u> impacts of model cycle 48r1

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department):

-

c) Systematic changes in forecast output since model cycle 48r1 was implemented

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): None

3.3: Derived Fields

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department):

- Extended range forecasts are postprocessed to be used for the new Swiss drought monitoring and early warning platform, which will go live in Q1 2025. To that end we downscale IFS EXT forecasts to a 2 km grid using a quantile mapping algorithm for temperature, precipitation and sunshine duration. The 2 km grid forms the basis for the following two key products:

a) 1 month rolling sum precipitation forecasts for Swiss 38 warning regions. These are seamlessly combined with the observed precipitation in that region to produce a 6-month past and a 1 month look into the future. A prototype is shown in the following figure (Fig.3).

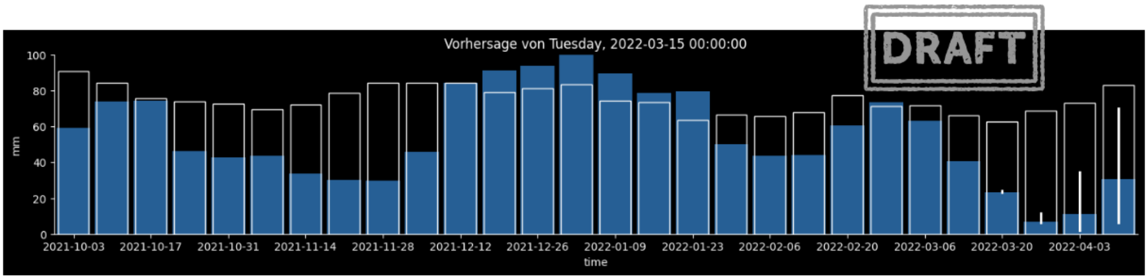


Fig. 3. Observed and forecasted 30 day rolling sum of precipitation amount for a drought warning region in Switzerland (blue). The obs record is 6 month long, the forecast is 4 weeks into the future. The forecast was issued on the 3rd of March 2022. Uncertainty bars show p10 and p90. The white box corresponds to climatology.

b) standardized precipitation indices SPI-1, SPI-6 and SPI-12 forecasts

c) will be used for monitoring meteorological droughts, while **b)** will be used together with hydrological indices as factors for the combined drought indicator CDI. The forecasted CDI will be used to issue warnings on droughts. Given the large uncertainties with respect to forecasting single precipitation events beyond lead week 1, we only show accumulated quantities, which show skill into W4 (ongoing analysis).

3.4: Artificial Intelligence (AI) / Machine Learning (ML) techniques

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): ECMWF model outputs are used routinely as input features to our postprocessing system. This includes various statistical modelling techniques, ranging from multiple linear regression to neural networks. The training is based on either seasonal or full operational archive since 2017. As such, breaking changes in the input data are challenging. As an example, we were not able to re-train our postprocessing models for IFS Cycle 48r1. We are currently migrating the postprocessing models to our new LAM models (ICON-CH1 and ICON-CH2). In the future, we plan to extend and further develop our postprocessing models to include additional variables and improve their performance for severe weather. To reduce the maintenance costs, we are working on further automating the whole ML model lifecycle. In this sense, it will be important to better align our (re)training strategy with the reforecasting approach adopted by IFS.

3.5: Dynamical Adaptation

Pirmin Kaufmann (Service and Development Numerical Prediction Department):
ENS boundary conditions are used to run ensembles of the COSMO limited area model in two resolutions. The COSMO-1E ensemble has 10 disturbed members plus one control run that uses HRES instead of ENS at the boundary. The ensemble has a grid spacing of 1.1 km, 80 levels and runs 8 times per day (every 3 hours) out to 33 hours (45 hours in the case of the 03 UTC forecast). The COSMO-2E ensemble has 20 members plus one control run. Its grid spacing is 2.2 km and it has 60 levels. It runs 4 times per day (every 6 hour) out to 120 hours (5 days). The domains with the respective topography are illustrated in Figure 1. Both ensembles start from a common assimilation cycle KENDA-1, which implements a 40 members ensemble transform Kalman filter. The COSMO model is scheduled to be replaced in operations with similar configurations of the ICON model by the end of May 2024.

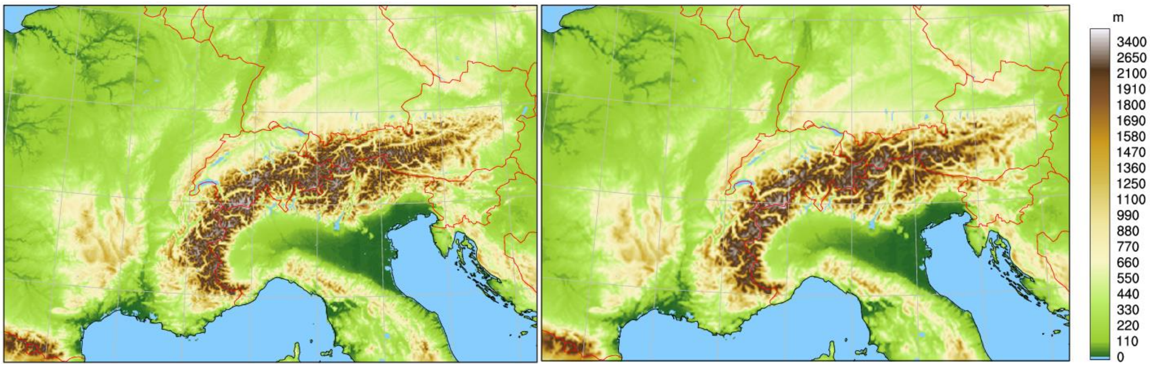


Fig. 4: Model domains and orography of COSMO-1E (left) and COSMO-2E (right)

Trajectories are calculated from HRES forecasts with the Lagrangian tool LAGRANTO (Sprenger and Wernli 2015). It uses HRES forecasts in 0.25° resolution for worldwide calculations and 0.1° resolution for calculations in Europe. The trajectories are started from predefined locations in routine production and can be calculated on-demand for arbitrary location for emergency response. The dispersion of air contaminants is simulated with the Lagrangian particle dispersion model FLEXPART (Pisso et al. 2019) based on HRES forecasts in 0.5° resolution worldwide and 0.1° resolution in Europe. As for the trajectories, the dispersion from predefined locations is simulated routinely with a normed source term, and on demand calculations can be started for arbitrary locations and source terms for emergency response purposes.

3.6: Data-driven (AI) models

* a) ECMWF's real-time AI model initiative

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): If it is about AIFS, we found it very needed. The potential of AI model is so great, we cannot miss it!

* b) Use of AI forecasts for operational purposes

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): We do not use yet AIFS in operation.

Section 4: Verification

4.1 Raw model output from ECMWF, and other operational models/ensembles

a) Short Range and Medium Range

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): We are routinely evaluating ECMWF IFS and our local LAM against surface observations. As part of this ongoing verification, we noticed improvements due to the resolution change from IFS cycle 47r3 to 48r1 (see Figure 5). The example shown below illustrates a case for which the difference between 47r3 and 48r1 is most pronounced. For many other parameters and verification metrics, the difference is much less pronounced.

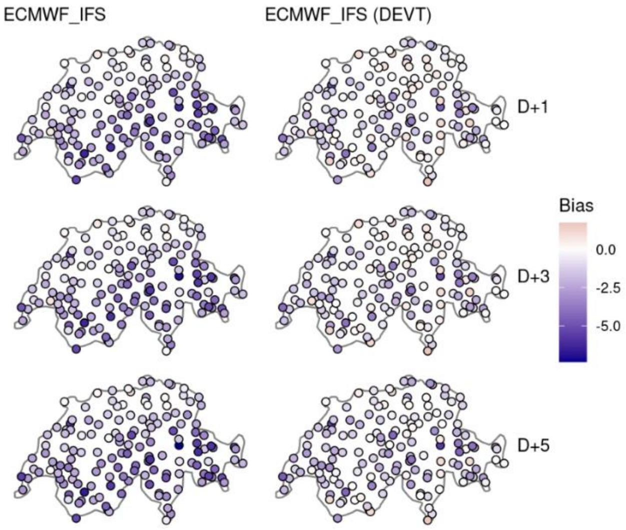
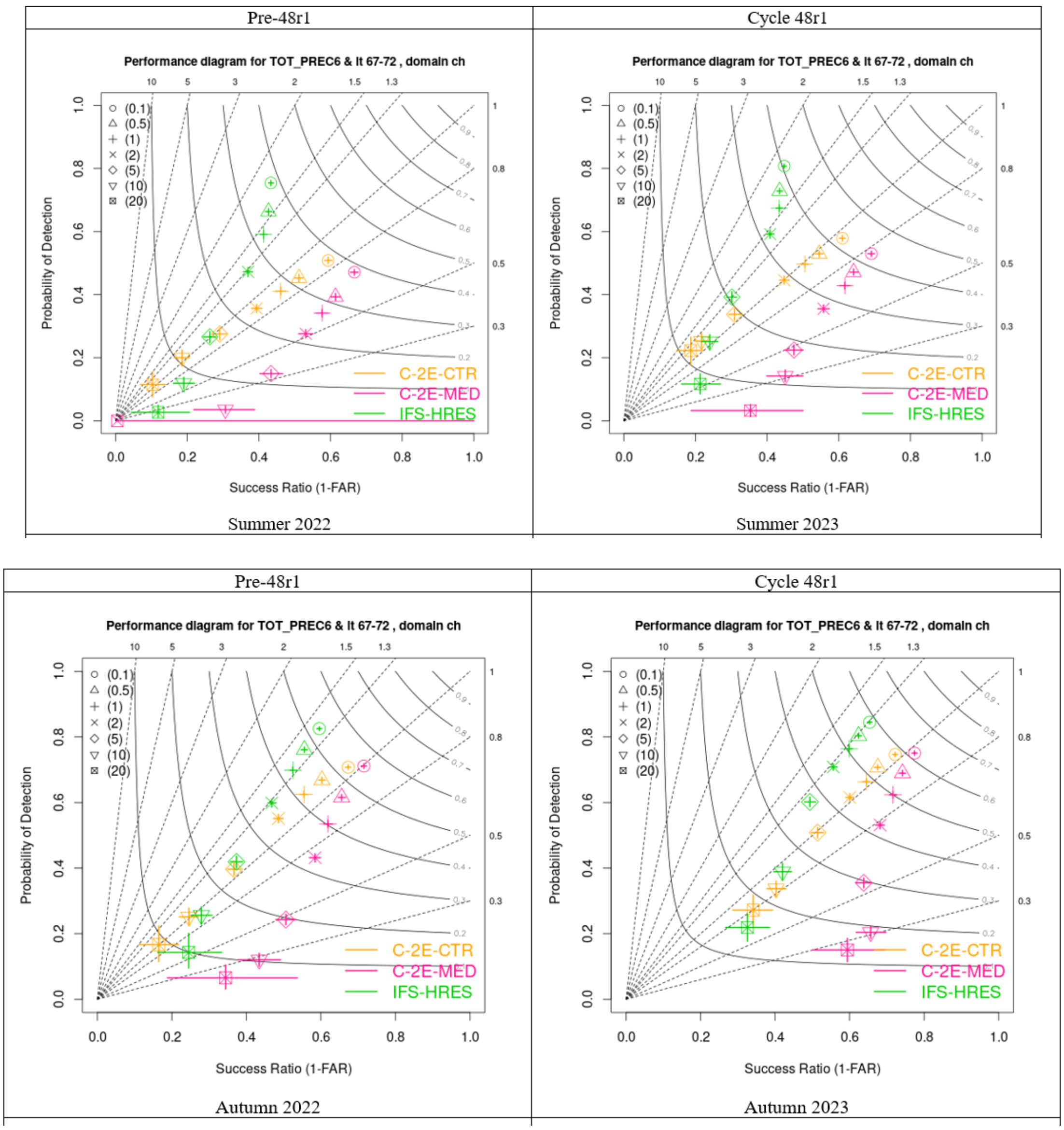


Fig. 5. Bias in maximum hourly wind speed during the day for ECMWF IFS-ENS Cycles 47r3 with 18km horizontal resolution (left) and 48r1 with 9km horizontal resolution illustrating the benefit of increased spatial resolution in the Alps (southern and eastern Switzerland). The bias for forecasts of 1 to 5 days ahead has been computed for a common period in May and June 2023, for which both 47r3 and 48r1 were available.

Pirmin Kaufmann (Service and Development Numerical Prediction Department):
The routine seasonal model verification at MeteoSwiss includes both HRES and ENS. The hourly surface parameters verified are precipitation (hourly, 6-hourly, and 12-hourly sums), total cloud cover, incoming longwave radiation, incoming shortwave global radiation, sunshine duration (hourly and 12-hourly), 2 m temperature, dewpoint temperature, relative humidity, 10 m wind speed, gusts (hourly and 6-hourly), wind direction, station pressure, and pressure reduced to sea level. These parameters are available at about 160 SwissMetNet stations in Switzerland. Most of these parameters are obtained directly from partnering weather services around Switzerland at approx. 620 stations within the COSMO model domain. Longwave radiation is not available, and cloud amount coverage is too spurious to be used for verification. Figure 6 shows the performance of the precipitation forecast of HRES in comparison to the COSMO-2E model in a performance diagram (Roebber 2009). The measurements are 6-hourly sums from the Swiss automatic rain gauge network, the forecasted value is the sum from lead time 66 to lead time 72 from all 4 model runs per day. The left column are results from before the introduction of 48r1, the right column after. The top row shows the results for summer (left 2022, right 2023), the second row for autumn (left 2022, right 2023), and the bottom row for winter (left 2022/23, right 2023/24). For COSMO-

2E, the control run (orange) and the ensemble-median (pink) are shown. COSMO-2E is smoothed by a 3 by 3 spatial averaging filter to somewhat alleviate the double penalty effect. Note that more spatial averaging would be needed for a fair comparison on the scale of HRES. The strong tendency of HRES to overestimate the frequency of occurrence for low thresholds is visible in all panels, as the green symbols are clearly above the main diagonal for low thresholds. However, when comparing the same season (same row) before and after the introduction of Cycle 48r1, there is at least for autumn and winter an improvement of the frequency bias, the values of which are indicated by the dashed lines. For all three seasons, the symbols move towards the right, indicating a higher success radio and thus a smaller false alarm ratio, and towards the top, indicating a higher probability of detection. The COSMO models seem to be able to benefit from this improvement of the HRES forecast. I cannot be excluded with certainty however that all three seasons were simply easier to forecast in 2023/24 than in 2022/23. For higher thresholds, both HRES and the control run of COSMO-2E get closer to the diagonal or even drop below, indicating an underestimation of the frequency of occurrence. The very low frequencies for the ensemble-median of COSMO-2E is an artefact of taking the median of a skewed distribution. In terms of critical success index (CSI, also called threat score; curved lines depict equal CSI), the HRES is better than the COSMO-2E control run for several medium thresholds. This is probably due to a double penalty effect, as COSMO-2E shows more structure in its fields even after a 3 by 3 averaging (5 by 5 averaging would be needed to obtain the same spatial smoothness as HRES). For the highest threshold however, the success ratio (x-axis) and the probability of detection (y-axis) of the COSMO-2E control run are both clearly higher than those of HRES, leading to a better CSI.



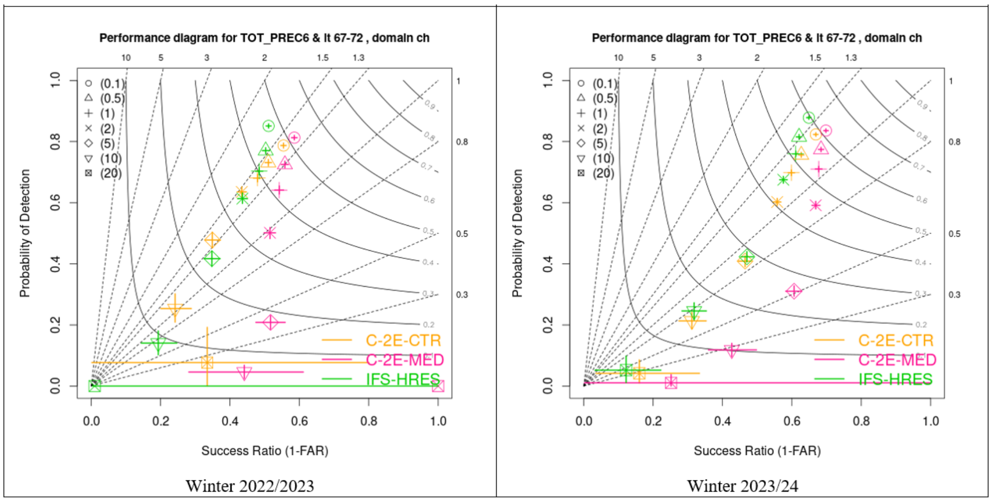


Fig.6: Performance Diagram for the forecasts of COSMO-2E control run (orange), COSMO-2E ensemble median (pink), and HRES (green), for 7 thresholds (different symbols). Forecast value: 6-h sum of precipitation from lead time 66 to 72 from 4 runs per day at Swiss stations.

b) Extended Range (Monthly) and Long Range (Seasonal)

Christoph Schmutz (Forecasting and consulting department): Weekly forecasts: The available weekly forecasts for the extended range are a precious source for MeteoSwiss' forecast service, as they are used to assess the weather tendency expected, in particular for the forecast ranges d+8 to d+14 and d+15 to d+21. Since the computation frequency of these products (maps and meteograms) has been increased form twice a week to daily, the forecasting range (Monday to Monday) is kept fixed. However, for its use in the forecast service, it would be very useful to having these products available for a fixed leadtime range also, e.g. the weekly forecast range should move day by day forward according to the daily updating cycle.

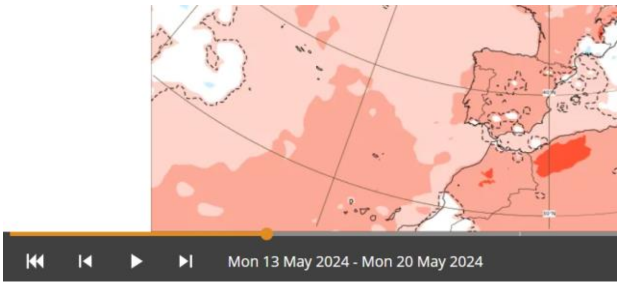


Fig.7: forecasted weekly temperature deviation from model climatology. The forecast period is currently kept fixed form Monday to Monday. Useful would be a version with fixed lead time.

4.2 <u>Post-processed</u> products and/or tailored products delivered to users

Christoph Schmutz (*Forecasting and consulting department*): (CAT (Clear Air Turbulence): Especially when it comes to estimating whether a SIGMET should be issued, forecasters consult various turbulence products from different models. It is noticeable that the ECMWF product CAT generally predicts significantly lower values than the DWD product, for example. It is not possible to say whether this is an effective underestimation, as turbulence reports (Special Air Report) are quite rare. Is the CAT product verified and are the verification results available?

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): As part of the routine evaluation of our automated forecasts, we also evaluate our postprocessed forecasts used in the local forecast on the MeteoSwiss mobile app and website. The postprocessing run operationally is based on the ensemble model output statistics (EMOS) paradigm and combines information from our limited area NWP systems (COSMO-1E and COSMO-2E) and ECMWF IFS.

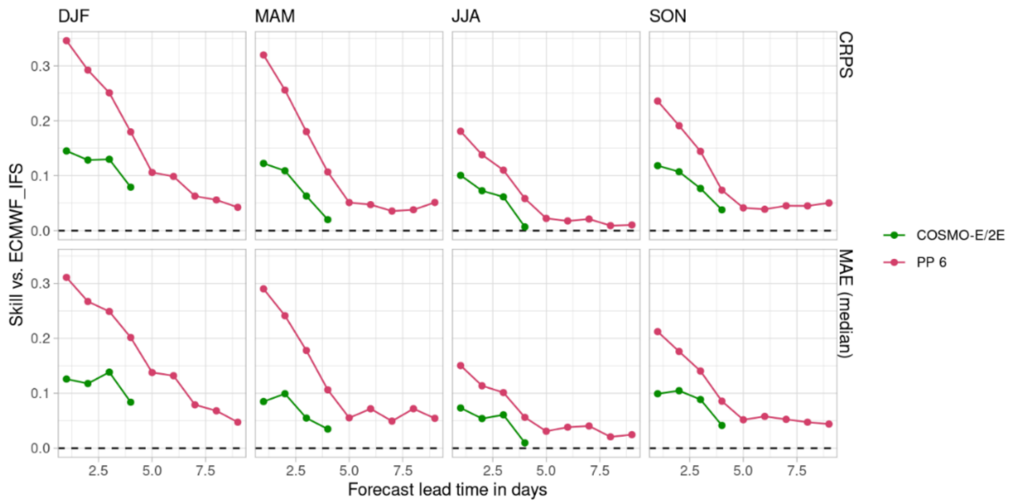


Fig. 8: Skill scores for daily precipitation by forecast lead time computed on automatic MeteoSwiss rain gauge observations in Switzerland. The skill scores have been computed for forecasts issued between 2021-03-01 and 2023-02-28. Positive values indicate that the LAM (COSMO-2E, in green) and postprocessed (in red) forecasts outperform ECMWF IFS.

4.3 <u>Subjective verification</u>

4.4 Case Studies

a) Case Study 1

b) Case Study 2

Section 5: Output Requests

a) Product request 1:

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): Finer-grained classes of weather regimes for IFS-EXT, e.g. following the works by former ECMWF fellow Christian Grams, see. E.g. *https://www.ecmwf.int/en/newsletter/165/meteorology/how-make-use-weather-regimes-extended-range-predictions-europe*

b) Product request 2:

Christoph Spirig, Jonas Bhend, Adel Imamovic, Daniele Nerini, Lionel Moret (Forecasts Development department): Lead time aligned IFS-EXT tercile maps (e.g. W2 tercile maps with W2 being W2 w.r.t. to forecast reference time) along with the existing calendar week aligned tercile maps (with W2 being next calendar week running from Mo to Su).

Section 6: References

Pisso, I., Sollum, E., Grythe, H., Kristiansen, N. I., Cassiani, M., Eckhardt, S., Arnold, D., Morton, D., Thompson, R. L., Groot Zwaaftink, C. D., Evangeliou, N., Sodemann, H., Haimberger, L., Henne, S., Brunner, D., Burkhart, J. F., Fouilloux, A., Brioude, J., Philipp, A., Seibert, P., and Stohl, A., 2019: The Lagrangian particle dispersion model FLEXPART version 10.4. Geosci. Model Dev., 12, 4955–4997, https://doi.org/10.5194/gmd-12-4955-2019. Roebber, P.J., 2009: Visualizing multiple measures of forecast quality. Wea. Forecasting, 24, 601-608, https://doi.org/10.1175/2008WAF2222159.1 . Sprenger, M. and H. Wernli, 2015: Geosc. Model Dev., 8, 2569–2586, DOI: 10.5194/gmd-8-2569-2015