Application and Verification of ECMWF Products 2019

This report should be a maximum of 6 pages and reach ECMWF by the **31 July 2019** via email to Sue Dunning (sue.dunning@ecmwf.int).

Federal Office of Meteorology and Climatology MeteoSwiss

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1. Summary of major highlights

It is expected that a more detailed description of any items included here will appear in section(s) below.

2. Use and application of products

Include, as appropriate, medium-range high-resolution (HRES) and ensemble (ENS) forecasts, monthly forecasts, seasonal forecasts.

2.1 Direct Use of ECMWF Products

Since 2019, MeteoSwiss uses the new model output parameter vertical integral of north/eastward water vapour flux introduced with cycle 45r1 for early warning of flood potential in Switzerland. Exploiting the relationship between flooding and exceptional water vapour transport towards the Alps documented in Froidevaux and Martius (2016), a series of visualizations summarizing the potential for flooding is produced operationally (see Figure 1). The charts are used to support planning at the hydrological unit of the Swiss Federal Office of the Environment. A publication on the alert system is under review in *Weather and Forecasting.*

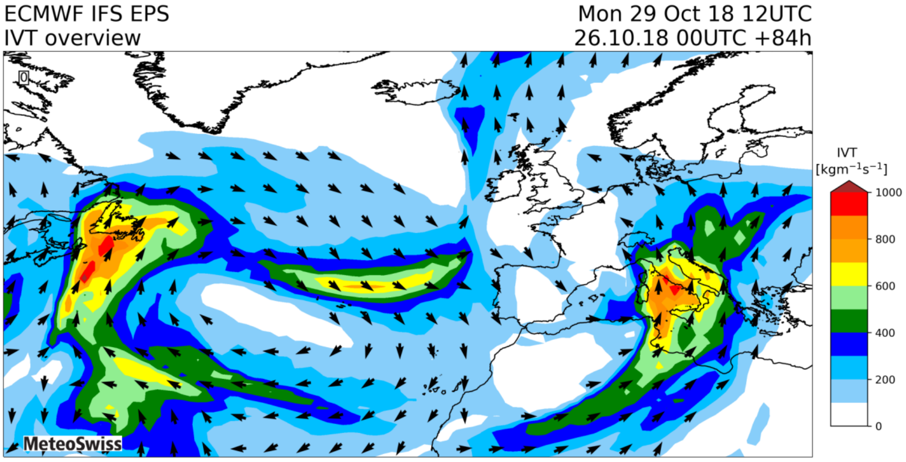

Fig.1: Sample visualization of a situation with potential for flooding in October 2018. Although southern Switzerland was not affected in the event, flooding occurred in various areas in northern Italy.

2.2 Other uses of ECMWF output

Describe the different ways in which you use ECMWF forecasts indirectly, in the following categories:

2.2.1 Post-processing

Statistical adaptation - include post-processing strategies for standard HRES and ENS output.

2.2.2 Derived fields

Since May 2019, MeteoSwiss uses the lightning flash density of the ensemble system to compute the probability of average lightning flash density ≥ 1 flash/ 100 km during the last 1, 3 and 6h. A bilinear interpolation is used to provide forecasts at arbitrary locations.

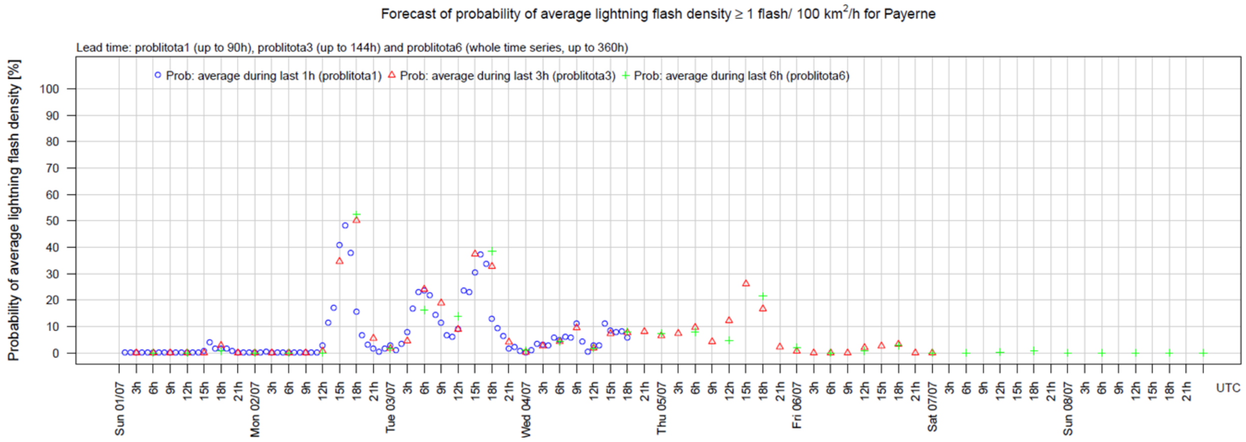

Fig.2: Sample visualization of the probability of average lightning flash density ≥ 1 flash/ 100 km in Payerne (Switzerland) during the last 1, 3 and 6h for the 1st to 8th of July.

2.2.3 Modelling

No changes have been made since last year to the suite of limited-area models. The IFS forecasts serve as boundary conditions for the deterministic model COSMO-1 with 1.1 km grid spacing, driven by HRES, and the ensemble system COSMO-E with 2.2 km grid spacing, driven by ENS. COSMO-1 has 80 levels and runs 7 times per day out to 33 hours and once (base time 03:00 UTC) out to 45 hours. COSMO-E is a 20 member ensemble with 80 levels, with a maximum forecast range of 120 hours. The phase-out of the regional model COSMO-7 with a grid spacing of 6.6 km, covering a larger domain, has been delayed to 2020. Currently work is ongoing to replace the COSMO-7 products by HRES products with best available spatial and temporal resolution. All models are directly one-way nested into IFS with no intermediate step. The domains of the COSMO models and their topography are illustrated in Fig. 3.

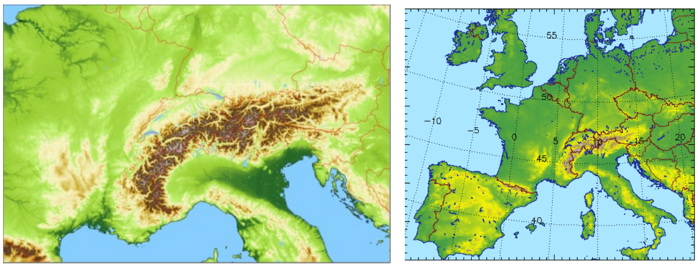

Fig. 3: Domains of COSMO models at MeteoSwiss. Left: COSMO-1 and COSMO-E, right: COSMO-7

All COSMO models have their own assimilation cycle, which is updated in intervals of 3 hours. COSMO-E uses an Ensemble Kalman Filter analysis, COSMO-1 and COSMO-7 use Nudging.

The Lagrangian trajectory calculation tool Lagranto (Sprenger and Wernli 2015) produces routine and on-demand trajectories based on global HRES fields with 0.25° resolution and on 0.1° HRES fields over Europe in parallel with the COSMO-7 trajectory products.

The Lagrangian particle dispersion model Flexpart (Stohl et al. 1998) is used for on-demand calculation of the dispersion of radioactive nuclides based on HRES fields with a resolution of 0.5° worldwide and 0.25° over Europe. The use of hourly 0.1° HRES fields is currently being implemented along with a parallelized version 10.3 of Flexpart (Pisso et al., 2019).

3. Verification of ECMWF products

HRES, ENS, monthly and seasonal forecasts are all within scope. ECMWF does extensive verification of its products in the free atmosphere. However, verification of surface parameters is in general limited to using synoptic observations. More detailed verification of these weather parameters by national Services is particularly valuable.

At this point in time (2019) ECMWF would particularly welcome:

- Evaluation of systematic errors in near-surface parameters
- Evaluations related to visibility, humidity, clouds, precipitation type
- Conditional verification results (e.g. 10m wind bias stratified by topographical aspects/cloud cover)
- Comparisons between ECMWF ENS and external LAM-EPS systems (for probabilistic forecasts)

3.1 Objective verification

Describe verification activities and show and discuss related scores.

3.1.1 Direct ECMWF model output (both HRES and ENS), and other NWP models

The routine seasonal model verification at MeteoSwiss includes both HRES and ENS. The surface parameters verified on an hourly basis are precipitation (additionally 12-hourly and 6-hourly), total cloud cover, global radiation, sunshine duration (additionally 12-hourly), 2 m temperature, dewpoint temperature, relative humidity, 10 m wind speed, wind gusts (additionally 6-hourly), wind direction, station pressure, and pressure reduced to mean sea level. Most parameters are available at over 160 stations in Switzerland, except cloud cover, which is derived from longwave radiation measurements at more than 40 stations.

The total cloud coverage over Switzerland typically exhibits a diurnal cycle. Fig. 4 shows that this diurnal cycle was also present in spring 2019 and has been simulated by HRES. However, HRES overestimated the cloud amount at the Swiss stations and the diurnal cycle is slightly shifted in time, with the daytime peak occurring too early. The measured cloud cover on the other hand, as it is derived from long wave radiation, is less sensitive to high clouds and might in fact have a slight negative bias, adding to a small degree to the gap between observation and model.

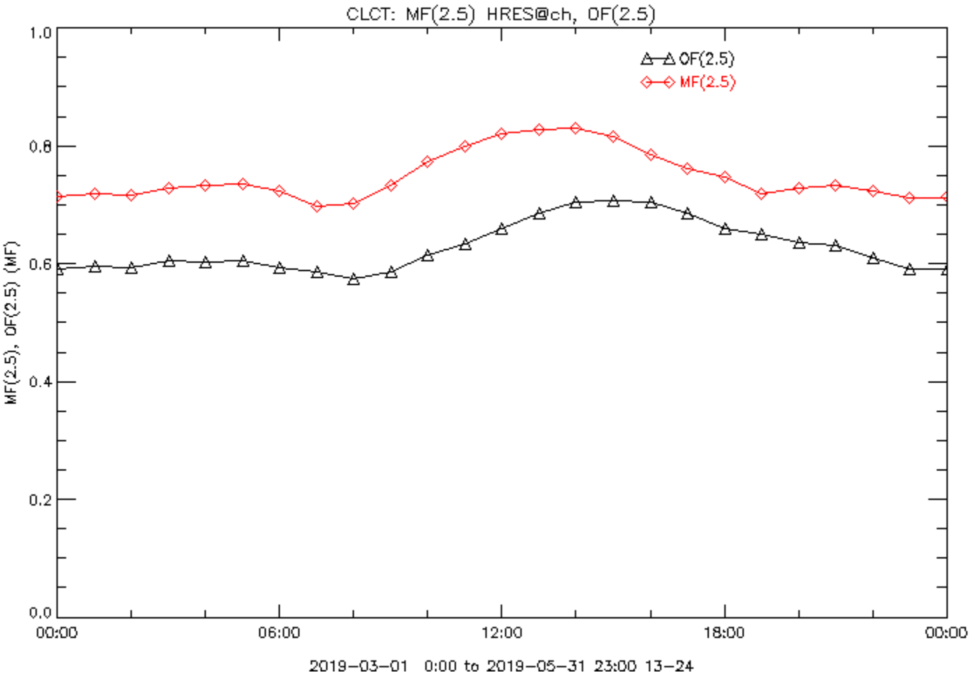

Fig. 4: Diurnal cycle of the frequency of occurrence for hourly cloud amount above 2 okta: HRES (red) and observation (black), spring 2019, at Swiss stations.

For precipitation, there is a considerable positive frequency bias for the occurrence of weak and moderate precipitation in HRES (Figure 5). The frequency bias is positive for the COSMO models as well, but to a smaller degree. As COSMO-1 tends to overestimate the precipitation amount in the Alps, its frequency bias is larger than that of the coarser COSMO-E.

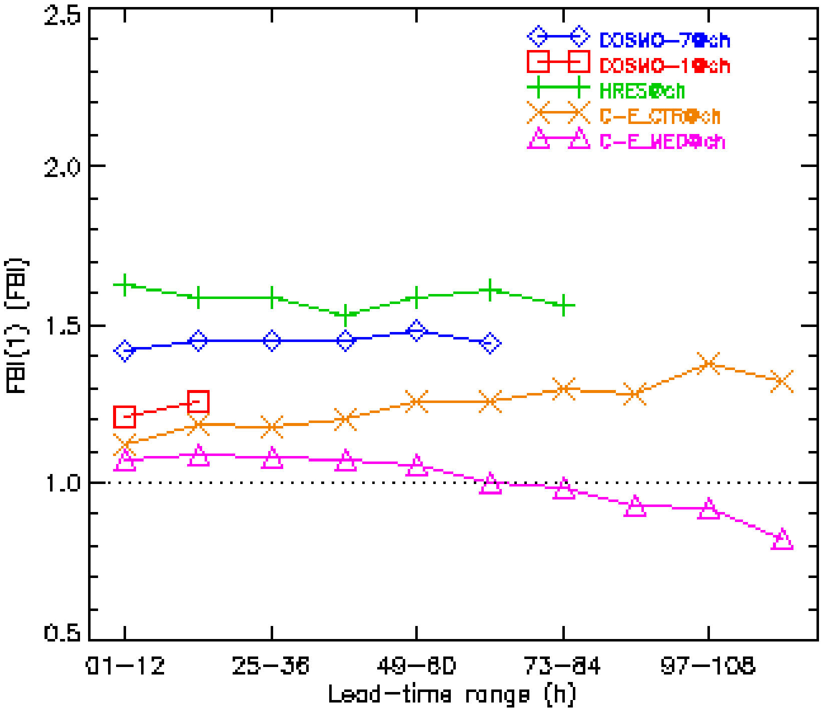

Fig. 5: Frequency bias of 6-hourly precipitation above 1 mm for HRES (green), COSMO-7 (blue), COSMO-1 (red), COSMO-E Control (orange), and COSMO-E Median (purple), in function of 12-hourly lead time ranges, for spring 2019, at Swiss stations.

Fig. 6 compares the reliability of the ensemble systems COSMO-E and ENS during spring 2019. The forecast event is precipitation larger than 1 mm/6 h. The lowest COSMO-E probabilities are fairly accurate, but for the higher probabilities, COSMO-E is over-confident. ENS shows a somewhat similar behaviour, while it overestimates the probabilities even more than COSMO-E. This is an often seen behaviour of the two ensembles also in other seasons.

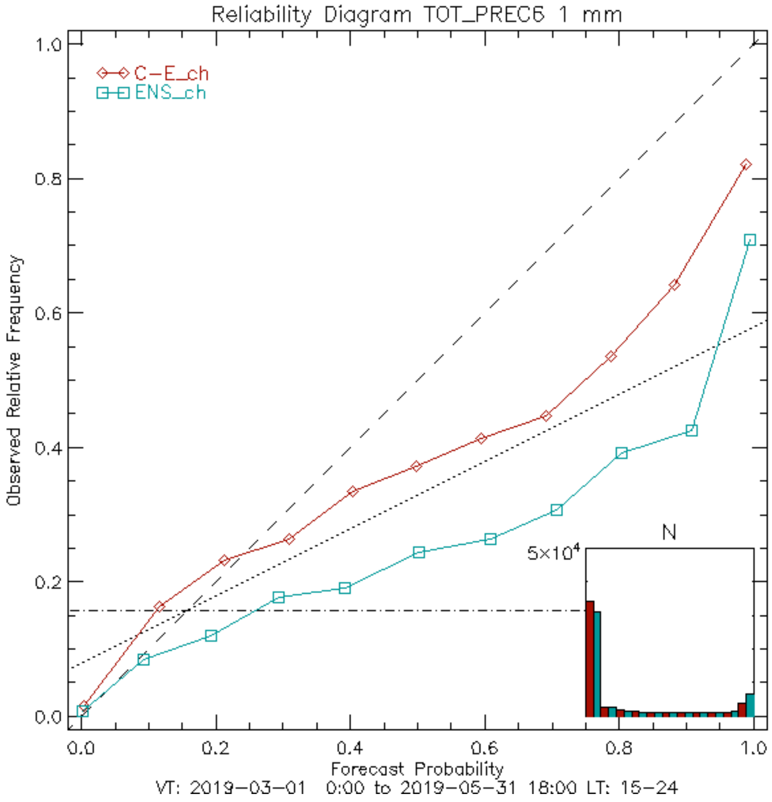

Fig. 6: Reliability diagram of 6-hourly precipitation ≥ 1 mm for spring 2019. Comparison of COSMO-E (brickred) and ENS (teal). Lead times +15 h to +24 h of all 00 and 12 UTC forecasts, at Swiss stations.

3.1.2 Post-processed products and end products delivered to users

MeteoSwiss is in the process of developing a new postprocessing system to deliver automatic forecasts. This system aims at providing calibrated probabilistic seamless point forecasts anywhere in Switzerland. In addition, comprehensive verification along the processing chain is being set up to support the development and motivate and justify changes to the system. NWP sources currently combined in the postprocessing consist of the ECMWF ENS and MeteoSwiss high-resolution limited-area models COSMO-E (ensemble) and COSMO-1 (deterministic).

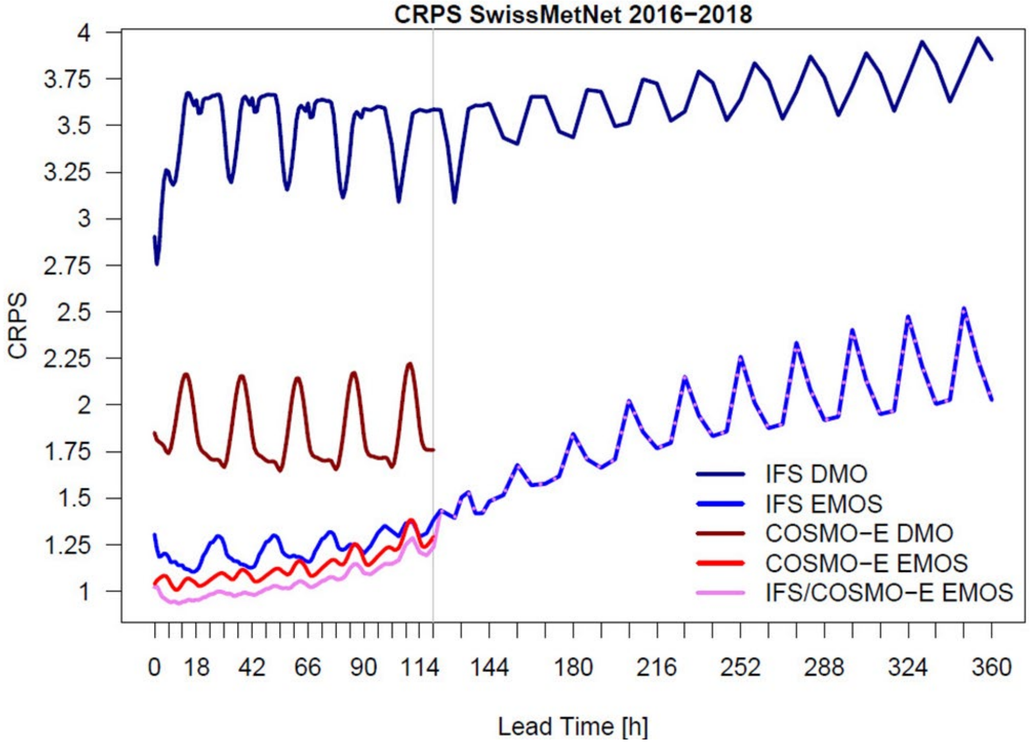

Fig.7: Continuous ranked probability score (CRPS) of near-surface temperature forecasts at 140 MeteoSwiss stations for the years 2016-2018. Please note that no lapse rate correction has been applied to the direct model output. Also, no interpolation to hourly temperatures has been added to mitigate the degradation of ECMWF ENS in temporal resolution with longer leadtimes.

Forecast performance of multi-model temperature forecasts with COSMO-E and ECMWF ENS extending to +360h are shown in Figure 7. These forecasts are calibrated against observed near-surface temperature at 140 stations in Switzerland. Postprocessing considerably reduces forecast biases for both ECMWF ENS and COSMO-E, with postprocessed COSMO-E forecasts slightly outperforming postprocessed ECMWF ENS forecasts throughout the common forecast horizon (out to +120h). Multi-model combination further enhances the performance of the forecasts, thus illustrating the benefits of model combination.

3.1.3 Monthly and Seasonal forecasts

ECMWF EXT forecasts have been used to support early-warning systems in various sectors (also see application with integrated water vapour flux in Section 2.1). As part of the H2020 project Heat-Shield, MeteoSwiss provides forecasts for the early warning of heat stress for European workers. A prototype alert system has been developed and forecasts are made routinely available through a public web portal http://heatshield.biometeo.it/en/.

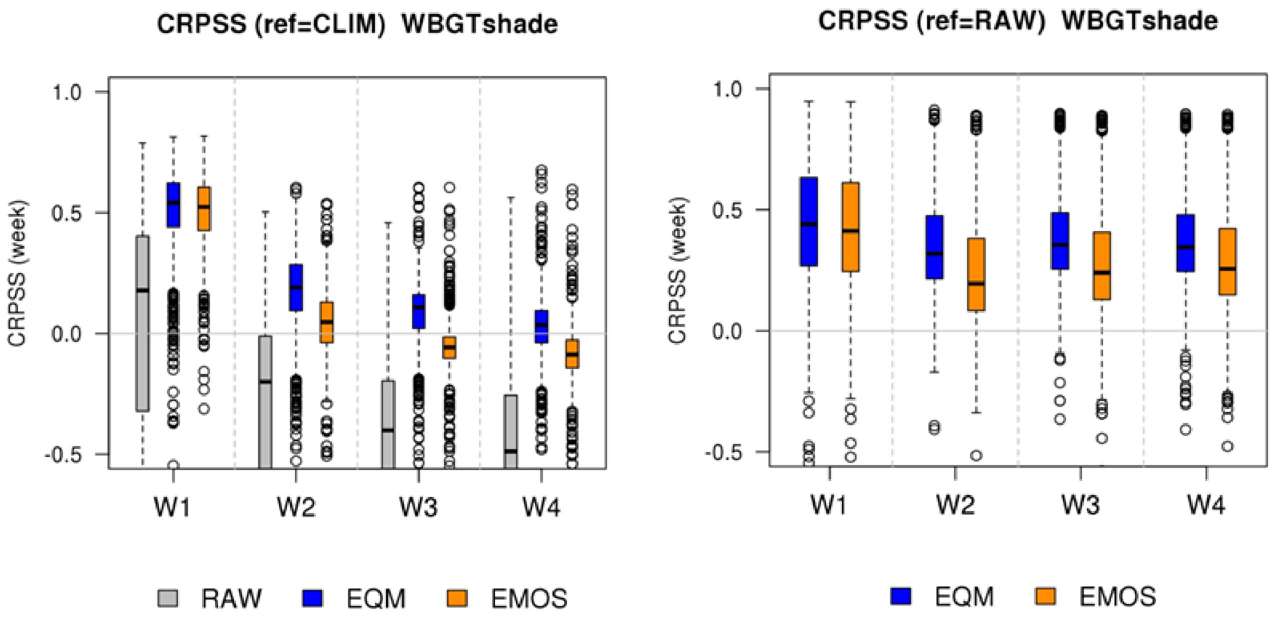

Fig.8: Continuous ranked probability skill score (CRPSS) of forecasts of the wet-bulb globe temperature for April to September 2018 at roughly 1564 stations in Europe. Skill has been computed with respect to a constant climatological forecast (left panel) and the direct model output (right panel). Forecasts of daily maximum and dew-point temperature from ECMWF EXT have been calibrated with empirical quantile mapping (blue) and ensemble model output statistics (orange) using the available 20 years of reforecasts. The box-and-whiskers illustrate the distribution of skill at individual stations. Week 1 denotes day 5-11 of the forecast.

Verification of the heat stress index wet-bulb globe temperature (WBGT) show that skilful heat stress alerts can be issued for the majority of European stations up to 4 weeks in advance (Fig. 8, left panel). Calibration of the underlying variables used to compute WBGT significantly enhances forecast accuracy almost everywhere (Fig. 8, right panel), empirical quantile mapping outperforms ensemble model output statistics in particular at longer lead times.

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

3.2.2 Case studies

Severe weather events/non-events are of particular interest. Include an evaluation of the behaviour of the model(s). Reference to major forecast errors, even if they are not in a "severe weather" category, are also very welcome.

4. Requests for additional output

Include here any particular requests you may have for new or modified ECMWF products.

5. Feedback on ECMWF "forecast user" initiatives

We invite comments on how useful you find the information provided on ECMWF's "Forecast User Portal", see: (https://software.ecmwf.int/wiki/display/FCST/Forecast+User+Home), and on any changes you would like to see. The web-based "Forecast User Guide" was introduced in May 2018 (https://confluence.ecmwf.int/display/FUG/Forecast+User+Guide) and we would particularly welcome feedback on that.

6. References to relevant publications

Froidevaux, P. and **O. Martius**, 2016: Exceptional integrated vapour transport toward orography: an important precursor to severe floods in Switzerland. *QJRMS*, **142**, 1997-2012

Sprenger, M. and **H. Wernli**, 2015: The LAGRANTO Lagrangian analysis tool – version 2.0. *Geosci. Model Dev.*, **8**, 2569–2586, https://doi.org/10.5194/gmd-8-2569-2015

Stohl, A., M. Hittenberger, and **G. Wotawa,** 1998: Validation of the Lagrangian particle dispersion model FLEXPART against large scale tracer experiments. *Atmos. Environ.*, **32**, 4245–4264

Pisso, I., and coauthors, 2019: The Lagrangian particle dispersion model FLEXPART version 10.3. *Geosci. Model Dev. Discussion*, https://doi.org/10.5194/gmd-2018-333

(7. Structure of these Reports)

ECMWF is reviewing the way in which contributions such as these are gathered and collated. We have made some simple changes to the structure this year, as can be seen above. Please provide any comments you have on the whole process (e.g. schedule for collecting input, report content, report layout, TAC summary). Comments entered in this section will be examined and used by ECMWF, but will be removed prior to publishing your reports on the ECMWF website.