Forecast Product Development at ECMWF

Tim Hewson. Operations Section, ECMWF.

In recognition of expanding use of the internet for forecasting purposes, ECMWF is increasing the range of products that it provides to customers through this medium. One goal has been to take advantage of the user-friendly interactivity that the web can provide. One major undertaking involves product delivery through an entirely new customisable web interface, and development of this facility is described elsewhere in this volume (Raoult, 2010). The present article will summarise other new web-based products, highlighting with examples how they might be used operationally. In line with ECMWF's key goals most of these new products have a severe weather focus, but at the same time should find application in forecasting normal day-to-day weather. An attraction of many of the products is that they utilise clickable maps to allow the user to home in on specific regions and specific weather features, as discussed below.

a) 'Climatological Context' products

National Met Services issue warnings for disruptive weather, and it tends to be the rarity of that weather, within the particular region, that tallies with the level of disruption caused. This is because a region's infrastructure will over time have been developed to cope just with weather within the normal range of variability experienced there. For example UK building regulations require that new constructions be able to withstand wind strengths corresponding to a given return period – values vary geographically. A second example would be highway snow clearing equipment, which for obvious reasons is not commonly found in areas where heavy snowfalls are very rare. With all this in mind ECMWF has put considerable effort into developing a 'model climatology', with which the real-time EPS forecasts can be compared, to provide a measure of event rarity. Although this is, strictly, rarity within the 'model world', it tends to commute successfully into the real world, even if the parameter values themselves sometimes have shortcomings. These principles already underpin the EFI, or extreme forecast index. 'Climatological context' products that have become operational relatively recently have built upon these concepts (see also Zsótér, 2006).

First it should be stressed that our model climatology now differs from that described in Zsótér (2006). Specifically it is based on 450 forecast realisations spanning the last 18 years (80% ensemble runs, 20% control); it is a function of time of year, of geographical location, and of forecast lead time; and it is always based on reruns with the current operational model version. To embrace these concepts we coin the term 'M-Climate', to distinguish from other model climatologies which might not, for example, have a forecast lead time dependance, or might not be entirely based on one model version. Many tests were performed in order to optimise the generation of the M-Climate; the current system is believed to make best use of available resources.

A new web interface for accessing the 'climatological context' products was introduced operationally in summer 2009. The starting point for the user is a map, global or regional, which aims to highlight in simple form using symbols and colours, areas where the weather is forecast by the EPS to be particularly anomalous (relative to the M-Climate). An example of a European map is shown in Figure 1; this is structurally similar to the example in Zsótér (2006). Here southwest Turkey is forecast to be anomalously wet, southeast Greenland anomalously windy, and large parts of Europe anomalously cold – all relative, of course, to what those respective regions would ordinarily experience at this time of year. Colouring and symbols on this map come directly from the EFI.

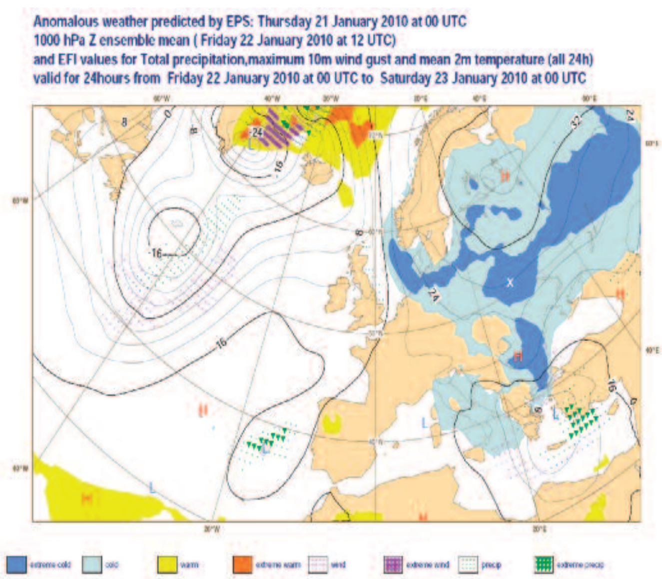

Fig. 1 Example of an 'anomalous weather chart' for the European region.

The user can delve deeper into the model output by clicking on such a map, to bring up one of several products. One of these, labelled 'efi distribution', shows information from several sets of EPS runs, for wind, temperature and precipitation, in cumulative distribution function (CDF) format. An example is shown in Figure 2, for the location of the white cross in Figure 1 (~51N, 27E). Older forecasts are shown in lighter blue, the second most recent forecast in purple, and the most recent in red. Note how the magnitude of the negative EFI increased then stabilised (right hand bars), and also how there was initially a lot of uncertainty in the forecast, denoted by a relatively shallow slope on the oldest CDF (light blue). With time confidence grew, denoted by the CDF curves getting steeper, and run-to-run variability decreased, which will ordinarily, but not always, be the case. Also shown on the top panel, for comparison, is the M-climate CDF for T+24-48 (black line), along with the minimum and maximum parameter values found at that location in that 450-realisation M-climate dataset (legend). Evidently there is high confidence of unusually cold conditions at this location, consistent with colouring on Figure 1. Some users may be more familiar with PDFs (probability density functions) than CDFs. The two are just different ways of representing the same data – the connection is explained on Figure 3.

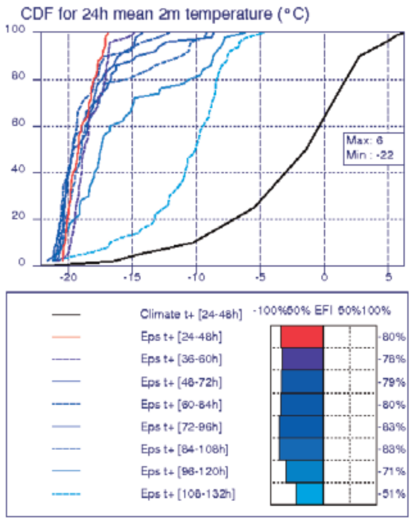

Fig. 2 Example temperature CDFs for the date and lead time shown on Figure 1, at the location marked on Figure 1 with a white cross.

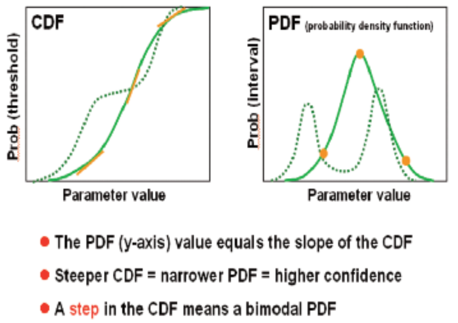

Fig. 3 The connection between CDF's and PDF's – illustrated with a hypothetical example.

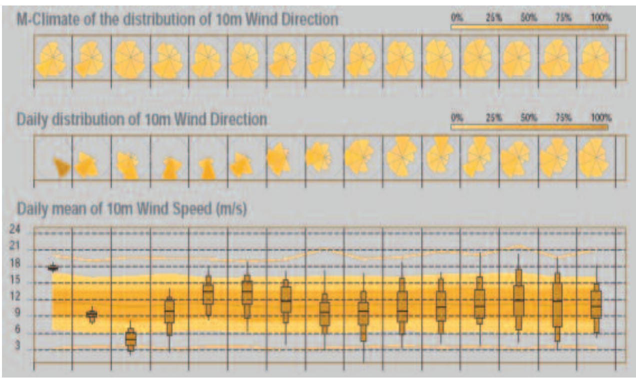

Fig. 4 Example of forecast winds with M-Climate information, for DT 00Z 21st Jan 2010, for a location over the Faeroe Islands. On the speed plot, lines and shading boundaries represent M-climate percentiles of 1,10,25,50,75,90 and 99; whilst boxes and whiskers denote, respectively, in the EPS forecasts, percentiles of 10,25,50,75,90, and the extremes.

The other M-Climate – related product available to the user shows conventional 15-day EPSgrams, but with climatological information added. Figure 3 provides an example for a model sea point near the Faeroe Islands. This just shows 10m wind, though many other parameters are routinely provided. On the speed plot the horizontal lines and shading denote percentile values in the M-Climate (1,10,25,50,75,90,99%), again enabling this single EPS forecast, represented in box-and-whisker format, to be placed into a climatological context. For example the confident forecast for day 1 lies between the 90th and 99th percentiles, implying that a windy day with a rarity of 1 in 10 days to 1 in 100 days is being predicted. One can also gain insight from this product into how the EPS system drifts with lead time; though this is generally very small it can be significant locally. Note that day 1 data relates closely to analyses and so should be more representative of 'truth'. Comparing wind direction at days 1 and 15 on Figure 3 some slight differences emerge: the frequency of NE'lies increases for example, which could indicate model drift. However one must also be aware that at day 1, due to minimal EPS spread, we effectively only have 90 realisations. By day 15 we genuinely have 450 realisations, so sampling also comes into play. Thus only if the trend with lead time is particularly striking should it be considered as drift-related; this is not really the case on Figure 3 for wind direction or speed.

In addition to climatological context products, the clickable map interface (example in Figure 1) provides a 'one-stop-shop' for accessing also standard 10-day and 15-day EPSgrams, as well as wave EPSgrams for anywhere in the world.

b) ‘Synoptic Feature’ Products

A key focal point of forecasting activity in the extra-tropics is arguably the fronts and cyclonic features that one sees regularly plotted on synoptic charts. The reason for this is that they correlate closely with most forms of high impact weather. In connection with this ECMWF has received requests from many users to automate the identification and tracking of these features in its own numerical model output. The principle was that this would clearly assist the forecaster, for whom performing a thorough synoptic analysis of 52 separate 15 day forecasts every 12 hours is plainly impossible.

Conveniently, algorithms developed at the UK Met Office over the last decade or so have made the automation process tractable, and from summer 2009 a range of related products from the ECMWF suite have been provided to member states in test mode. Following feedback this product range is continuing to develop and evolve, with operational implementation planned for the first half of 2010. A recent article (Hewson, 2009) describes in detail the origins of these products, and gives advice to forecasters on how to use them in real world situations. For brevity we will not repeat the contents of that article here, but instead highlight some more recent developments of the product suite.

Output from the deterministic model has recently been added to all synoptic feature products, enabling the forecaster to form a view of likely outcomes that is not based just on EPS members. Ordinarily one would give rather more weight to this unperturbed, higher resolution run, so including it in the mix is of course vital. In addition, to provide a quick-look but quantitative measure of the thermal evolution of the troposphere, the 1000-500hPa thickness pattern has been added to all the automated synoptic chart products. To a trained eye this field can provide clues to likely screen temperatures, to whether any precipitation will be rain or snow, and also to the strength of upper level jets. An example synoptic chart from a deterministic run is shown in Figure 5. The chain of cyclonic systems and the elongated front extending from Spain to the Black Sea would be liable to produce snow, given the close proximity of the 528dm thickness line. Synoptic conditions are similar, if much colder, around the Great Lakes in North America.

‘Dalmatian feature charts’ show as spots all the cyclonic features in the IFS for a given lead time, using colour to signify attributes of those features. The range of such charts has been expanded so that we now also represent mean sea level pressure and 1000-500hPa thickness at the feature point, and also maximum winds at 1km altitude within pre-defined radii of 300 and 600km. A mean sea level pressure example is shown on Figure 6, panel A. This figure also includes snapshots (panels C and D) from a tracking product activated by clicking on a synoptic feature on a map, and thus shows how the two product types can be used together to infer the general evolution in the ensemble of what in this case was an elongated double-centred cyclonic feature at analysis time (panel B).

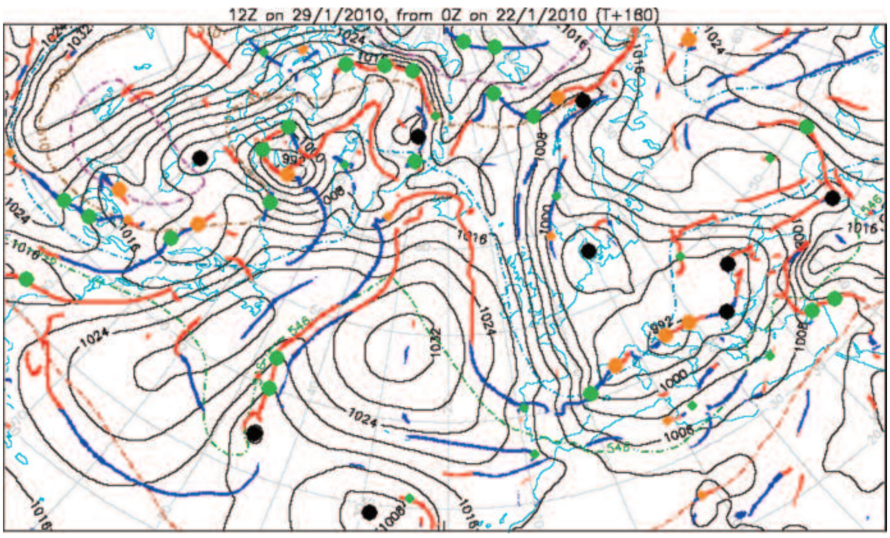

Fig. 5 Snapshot forecast synoptic chart from one EPS member, with 1000-500hPa thickness lines included (dash-dot style; 564,546,528,510,492dm). Warm and cold objective fronts are shown in red and blue respectively, barotropic lows in black, frontal waves in orange and diminutive waves in green. Frontal features lying on thermally weak fronts are shown by smaller spots.

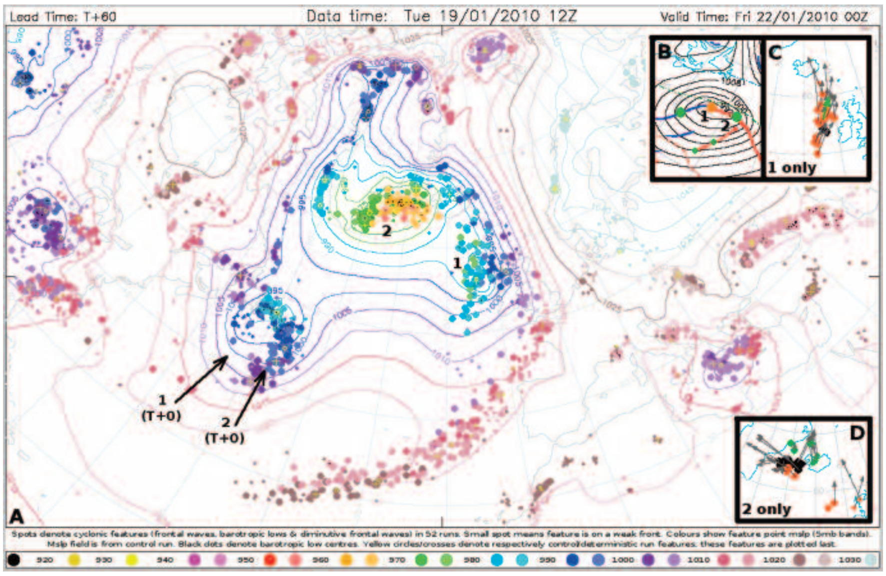

Fig. 6 Segments of web-based synoptic feature products from one IFS run. Panel A: 'dalmatian chart' showing all cyclonic features in one set of IFS runs, at T+60h from DT 12Z 19/1/2010, coloured by mean sea level pressure at the feature point (see legend). Panel B: control run synoptic chart snapshot for same DT (T+0), near Newfoundland (key as on Figure 5). The later position, at T+60h, of the frontal wave '1', as identified by the tracker, is shown on panel C, together with subsequent 12h movement vectors. Panel D shows the same for diminutive wave '2' on panel B. So on the large panel A the cluster of features NW of Ireland mostly relate back to '1' and the generally deeper low W of Iceland mostly comes from feature '2'. Evidently both were predicted to take a track that was cyclonically curved. The real outcome for feature 2 was rapid development, as predicted by a 'median' EPS feature solution; feature 1 however decayed, to lie at the end of the T+60 EPS feature range.

Future developments in this field will include adding products related to rain and snow, using in some cases an assignment of areally-integrated precipitation totals to cyclonic features. In addition there are plans to add facilities for selecting a 'representative EPS member', based on EPS handling of a particular feature of interest, in terms of its track or absolute depth or some other attribute. In this light we hope to enable the user to identify on a dalmatian chart a feature that appears to be 'mid-range', in terms of its handling, to hover over the spot to identify the member, and to click to animate the synoptic-scale evolution in that member.

c) Pseudo imagery products

In summer 2009 a range of pseudo imagery products were added to the web interface, for standard infra-red (IR) and water vapour (WV) channels. These are computed from the deterministic run only, using a radiative transfer algorithm ('RTTOVS'). We overlay 850mb wet bulb potential temperature fields on the IR imagery, partly to help the forecaster distinguish frontal cloud from convective cloud. On the WV imagery the mean sea level pressure field is overlaid, enabling connections between surface cyclonic developments and upper level forcing to be subjectively deduced. All these products are provided at high temporal resolution (3h) in the short term, to help the forecaster compare directly with real imagery, and provide pointers to when the deterministic model evolution may be going astray, in regard to handling of clouds and/or convection and/or upper level forcing. Figure 7 panels A to C illustrate use of a pseudo IR product in diagnosing a model error, whilst panel D is an example of a pseudo WV image.

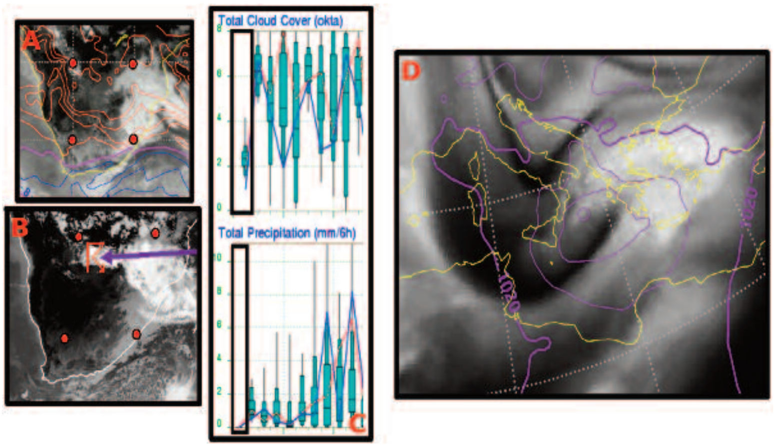

Fig. 7 Panel A: T+6h Pseudo IR image product over southern Africa from Nov 2009, with 850mb wet bulb potential temperature overlaid (2C interval, pink=10C). Panel B: Actual IR image verifying Panel A. Arrow points to thundery activity reported from beneath convective cloud - this was absent from the pseudo image. Panel C: Meteogram segment for same location as the thunderstorm symbol – shows that the EPS also failed to capture the rain and convective cloud on this occasion. Panel D: an unrelated segment from a pseudo WV image product (for validity time T+9h = 21UTC 21 January 2010), with mean sea level pressure contours overlaid (5hPa interval) – note the V-shaped dark zones implying upper trough(s), and a related cyclone in the Mediterranean which lead to copious rainfall.

d) Other developments

Other new products are also being developed at ECMWF. In one project improved clustering techniques are being employed; these partly utilise recognised atmospheric modes, such as 'Greenland Blocking', to classify weather system behaviour in the North Atlantic-European sector. The range of tropical cyclone products is also being extended to include genesis prediction maps, using the EPS. Work is also underway to assign return periods to very rare events forecast by the EPS; this will involve applying extreme value theory to hindcast data.

References

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