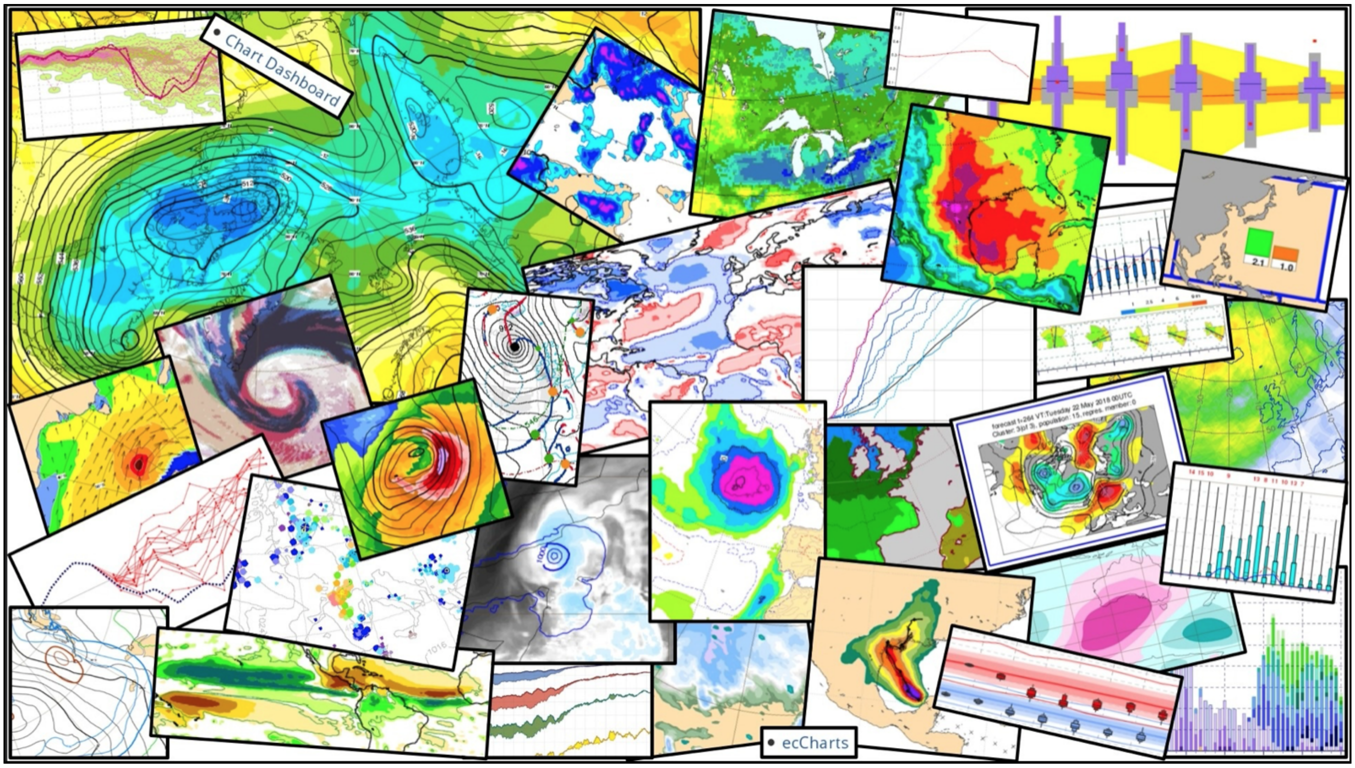
Forecast User Guide

e "Behind good forecast practices are often hidden good theories; equally, good theories should provide a basis for good forecast practices." Profess
or Tor Bergeron, personal communication, 1974



This edition of the Forecaster User Guide applies to the ECMWF Integrated Forecast System (IFS) and meteorological products after June 2023 using IFS Cycles 48r1 and later.

Aim of the Forecaster User Guide

The aim of this User Guide is to help meteorologists make the best use of the forecast products from ECMWF.

In particular the aims of the guide are:

- to give an outline of structure and use of the ECMWF Integrated Forecast System (IFS).
- to increase understanding of the ensemble forecast process.
- to show how the IFS models inter-depend and interact.
- to advise on how best to use the output and how to build up trust in the forecast information. A good forecast that is not trusted is a worthless forecast.
- to introduce and develop new products.
- to reach new sectors of society.
- to satisfy new demands.

The goal of ECMWF is to produce:

- medium-range (day 0 to day 15) forecast products. This output generally differs significantly from that dealing with short-range or seasonal NWP.
- extended range (day 16 to day 42) forecasts products. These concentrate on the probabilities of anomalies from the norm during 5-7 day forecast periods for given location and time of year.
- seasonal forecasts (month 1 to month 7 or 13). These give an indication of likely conditions beyond six weeks ahead. They are run monthly giving forecasts to 7 months ahead, and run quarterly with forecasts extended to 13 months ahead. Output concentrates on the anomalies relative to the seasonal climate.

The IFS configurations are:

- the 10-day High Resolution forecast (HRES)
- the 15-day ensemble forecast (ENS).
- the 46-day extended range forecast including the extended range control member.
- the 7 or 13 month seasonal forecast.

The ECMWF model output is delivered in the form of charts or GRIB format datasets. It is readily available to forecasters via:

- imports into their own work station environments.
- on the web as Opencharts.
- using the highly interactive ecCharts (ECMWF members and Co-operating States) web-based application

The ECMWF IFS is upgraded at roughly yearly intervals to incorporate improved representation of physical processes and/or resolution changes. New products increasingly aid early warning of severe or hazardous weather. Information on the latest upgrade is given below.

Structure of the this guide

The User Guide is broadly divided into two parts. Sections 2 to 5 describe the structure of the ECMWF Integrated Forecasting System. Sections 6 to 11 describe how the IFS may be used to best advantage by forecasters.

There are links to more detailed descriptions of processes, mainly at the end of each section. Separate online ECMWF training resources explain aspects of the ECMWF IFS more visually.

A key component of the work at ECMWF is education and training. Further educational material is available through the web site:

- Webinars (recordings).
- Slidecasts (slides and audio recordings).
- Tutorials.
- Training lectures (presentations in PDF)).

ECMWF Newsletters issued quarterly give information on IFS models and applications and ECMWF plans.

A glossary is included in an Appendix.

Section2: The ECMWF Integrated Forecasting System (IFS)

Section 2 describes in broad, non-technical terms the ECMWF Integrated Forecast System (IFS). This comprises the global atmospheric model, the wave and the oceanic dynamical models, and the data assimilation systems. It gives an overview of the way the atmospheric model uses sub-gridscale parameterisations for processes within the atmosphere and at the surface. There are large differences in energy fluxes between land or sea and the atmosphere. Thus the definition of the model coastline by the land-sea mask is extremely important. This is especially true for meteograms in coastal areas or on islands.

Numerical weather prediction (NWP) output is complicated by its often counter-intuitive and non-linear behaviour. Understanding model processes enables forecasters to assess model output critically.

Section3: Availability and interpolation of NWP output

Section 3 gives an overview of the way ECMWF graphical forecast products are presented to the forecaster. It gives some insights into ways the analysed and forecast data may be reduced in accuracy by the way it is presented.

Section4: NWP evolution versus reality

Section 4 discusses model error growth with time and the relationship between predictability and scale. An indication is given of how anomalies propagate downstream and gives some pointers towards recognition of these in the analysis.

Section5: Forecast ensemble (ENS) - rationale and construction

Section 5 describes the way the members of the ensemble are generated. The use of ENS allows assessment of uncertainty in the model forecast by giving a range of results. Each ensemble member starts from slightly perturbed initial data. Consequently each evolves a little differently from the other members of the ensemble to give a range of possible forecast results. The variation seen within the ensemble forecasts gives an indication of predictability of the atmosphere.

Model climates are an important product produced within the IFS. These are: M-climate for ENS, ER-M-climate for Extended Range ENS, S-M-climate for Seasonal forecasting. They are a wholly model-based assessment of worldwide climatology based on analyses and re-forecasts over a period of 20 or 30 years.

Section6: Using ENS forecasts

Section 6 discusses the reliance that can be placed upon the ensemble as the forecast lead-time increases. Each ENS slightly perturbed member evolves a little differently from the others and gives a range of possible forecast results. The variation seen within the ensemble forecasts gives an indication of predictability of the atmosphere. The use of probabilities or other risk assessments is an essential part of building forecasts useful to the customer. This section emphasizes the benefit of using ensemble products to get the best description of evolution and uncertainty of a forecast.

Section7: Dealing with uncertainty

Section 7 concentrates on methods that may be used to assess confidence in model results.   This section gives guidance on interpretation of latest and previous ENS output to allow insight into the uncertainty of the forecast. It also gives guidance on assessing the skill of a forecast and how to use run-to-run variability in the forecasts to best advantage. The continuing role of the human forecaster is emphasized.

Section8: ENS products - what they are and how to use them

Section 8 concentrates on making best use of the extensive range of products that are available. The IFS produces a very wide range of products which is delivered in the form of charts or GRIB format datasets. It is readily available to forecasters via:

- imports into their own workstation environments,
- on the web as Opencharts,
- using the highly interactive ecCharts (ECMWF members and Co-operating States) web-based application.

Model products may be deterministic, probabilistic, or in the form of anomalies from normal as defined by model climates. ENS output is shown in an easy-to-use form as:

- charts, plumes, meteograms (and wave meteograms).
- charts showing the evolutions of tropical cyclones and extra-tropical depressions.
- charts giving an indication of the variability and uncertainty among the basic model forecasts. These also compare the latest model output with its predecessors.

The model climates are used extensively to highlight locally extreme weather conditions for time of year and for forecast lead time. The Extreme Forecast Index (EFI), pioneered at ECMWF, compares the forecast probability distribution with the corresponding model climate distribution. The Shift of Tails (SOT) index complements the Extreme Forecast Index (EFI) by giving information about how extreme an event might be. This is done by comparing the tail of the ENS distribution with the tail of the M-climate**.**

The overall aim is to allow assessment of uncertainty to provide the customer with the best and most useful guidance possible.

Section9: Physical considerations when interpreting model output

Section 9 gives pointers towards features which can have an impact on model output. This allows users to modify and improve forecasts for issue to customers. Some other short-comings of the models are noted. These will be addressed in the future but meanwhile they need to be considered by the forecaster. It is through forecaster user feedback that important points will be identified and addressed. The importance of critical assessment of model output by human forecasters cannot be understated.

Section10: Interfaces for displaying model output

Section10 gives an outline of the way forecast data may be presented to the user. ECMWF Web Charts (Open Access) give easy access to ECMWF IFS output. The more flexible and interactive ecCharts allows users to pick-and-mix the IFS data.

Section11: Conclusion

Section11 highlights the continuing importance of the forecaster in providing a consistent and useful product to the customer.

Section12: Appendices

Section12 contains additional detail on statistical concepts for verifying model forecasts, the current structure of IFS, and a list of acronyms.

Comments on application of IFS and the Forecaster User Guide

The forecaster is not a computer.   Instead, the forecaster is employed to add value to model forecasts, and to identify and quantify uncertainties. Forecasters should provide a balanced assessment of the probability of an event that is relevant to customer requirements.

Daily operational forecasting work is largely a matter of assessing, interpreting, combining and correcting NWP information.   Also vital is the ability to identify quickly those products that are particularly relevant for a given synoptic situation.   In the medium-range especially, the use of statistical know-how counts as much as synoptic experience.

Forecasters, and other users, should not simply follow NWP guidance. They should act quite differently by:

- surveying and questioning results from many sources.
- producing forecasts with fewer details.
- assessing the uncertainty. All forecasts have uncertainty, and that uncertainty increases with forecast lead-time.
- ideally, not giving sudden “U-turns” in guidance.

Latest cycle of Integrated Forecast System (IFS) model upgrades.

Some major changes were made to the IFS with the introduction of Cy48r1 in June 2023. These are:

- For the medium range ensemble forecast system:
    - the horizontal resolution is increased to 9 Km
    - the vertical resolution remains unchanged at 137 model levels.
    - the number of ensemble members remains unchanged at 50 members plus a control member.
    - the horizontal and vertical resolutions are identical to those of the High Resolution (HRES).
    - the medium range ensembles are run twice daily from Day0-Day10 and slightly later from Day-0 to Day15.
- For the extended range ensemble forecast system:
    - the horizontal resolution remains unchanged at 36 km.
    - the vertical resolution is increased to 137 model levels. This is the same vertical resolution as the medium range ensemble and the High Resolution (HRES) model.
    - the number of ensemble members is 100 members plus a control member.
    - the extended range ensemble is run daily from Day0-Day46.
- A multi-layer snow scheme was introduced.

Note: The extended range forecasts are not just an extension of the medium-range forecasts but are completely separate forecast systems. However, both start from very similar analyses. There are two sets of re-forecasts, one for the medium range and one for the extended range.

The HRES and unperturbed (control) ensemble member of the medium range ensemble (CTRL):

- have the same horizontal and vertical resolution.
- are meteorologically equivalent.
- are equally skilful on average.

However, they can diverge on a day-to-day basis due to small technical differences and also the chaotic nature of the atmosphere. Nevertheless the HRES will continue for the time being for ease of use by customers and users.

Full details of the current Integrated Forecast System (IFS) is given in the official ECMWF IFS documentation of CY48r1.

Users are advised to keep themselves updated about changes and improvements to products and model processes through the ECMWF Newsletter and web site (e.g. via the Forecast User portal)

This User Guide has been compiled by Bob Owens, with assistance from Tim Hewson, and with contributions from many other scientists and ex-forecasters at ECMWF. It is an updated version of the "User Guide to ECMWF Forecast Products" written originally by Anders Persson and published in 2011 (that had minor adjustments in 2013 and 2015).

The User Guide should be cited as follows: Owens, R G, Hewson, T D (2018). ECMWF Forecast User Guide. Reading: ECMWF. doi: 10.21957/m1cs7h

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