Forty years of improving global forecast skill

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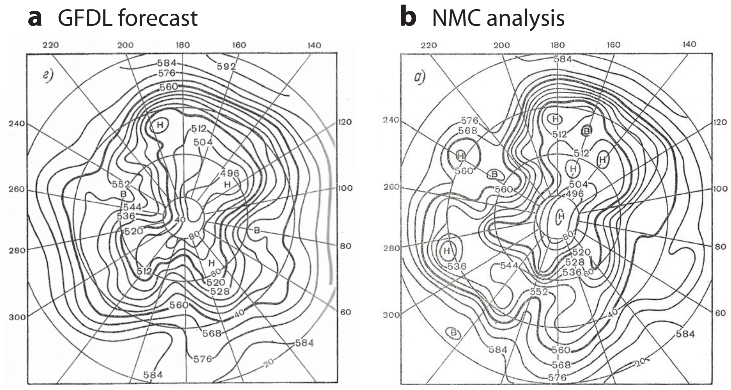


500-hPa geopotential height charts showing (a) the GFDL forecast for day 5, valid for 6 March 00 UTC, and (b) the NMC analysis for 6 March 00 UTC, used for verification.

The Convention establishing ECMWF came into force on 1 November 1975. The Centre's 40th anniversary provides an opportunity to look back at the first ECMWF weather forecast produced in 1975 for the period 1 March to 11 March 1965. To illustrate the impact of 40 years of research conducted at ECMWF, we have repeated this first forecast experiment using the CERA system, which is at the cutting edge of research in data assimilation and forecasting.

A series of medium-range forecasts between 20 February and 20 March 1965 were also produced using the CERA system. Their skill shows that ECMWF has fulfilled the initial promise that a future 6-day forecast would be as skilful as 2 to 3-day forecasts were in the 1970s.

ECMWF's first forecast

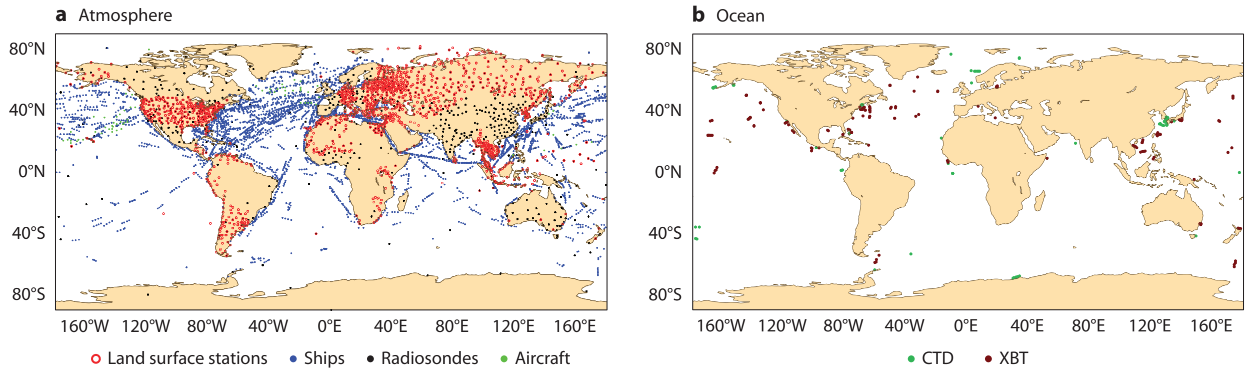
The first global forecast experiments at ECMWF were carried out in the early autumn of 1975 using the general circulation models developed at GFDL (Geophysical Fluid Dynamics Laboratory) and UCLA (University of California, Los Angeles), kindly made available to ECMWF by the two institutes. The two models were used to produce a 10-day forecast starting on 1 March 1965 00 UTC.

The GFDL model was available with two different horizontal resolutions (250 and 500-km grids) and 9 vertical levels, 7 in the troposphere and 2 in the stratosphere. The UCLA model had a lower horizontal resolution corresponding to a grid spacing of 550 km with 6 vertical levels, 5 in the troposphere and 1 level in the stratosphere. Both models were mainly intended for climate simulation studies. They fully represented physical processes, including the radiation effects of H_2O, CO_2 and O_3. In this respect the models were more advanced than typical NWP models in the early 1970s.

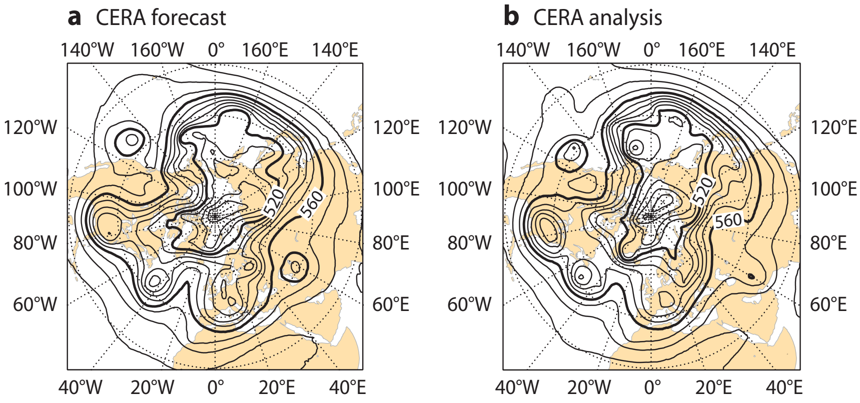
At that time, atmospheric observations used in NWP consisted essentially of surface observations (weather stations and ship reports) and observations from radiosondes. The radiosonde network was very sparse in the tropics and the southern hemisphere, but coverage was rather good at middle and high latitudes in the northern hemisphere.

The available observations were processed by the NMC (National Meteorological Center) to compute the atmospheric analyses used to initialize and verify the forecast on 1 March 1965 00 UTC. It is likely that the NMC analysis was based on a Cressman scheme which used the operational forecast from NOAA (National Oceanic and Atmospheric Administration) and the Australian Met Service as the background, which was corrected using the observations.

Here we focus only on the results of the GFDL model-run at 250 km resolution, which was found to be the most accurate forecast. Although, as shown in the figures, the GFDL model indicates the large-scale weather patterns reasonably well in its 5-day



Observations assimilated by the CERA system for 1 March 1965 from (a) the atmosphere and (b) the ocean using Conductivity Temperature Depth (CTD) and Expendable BathyThermograph (XBT) measurements. A total of 126,703 atmospheric observations and 2,407 ocean observations were assimilated.



500-hPa geopotential height charts showing (a) the CERA forecast for day 5 (valid for 6 March 00 UTC) and (b) the CERA analysis for 6 March 00 UTC used for verification.

forecast, it fails to predict important synoptic features, such as cyclones. A more detailed assessment of the GFDL model shows that even the low-frequency part of the prediction had limited skill, suggesting that the forced Rossby waves had errors, presumably due to the incomplete representation of physical processes such as moist convection.

Today's forecast

ECMWF has been developing a coupled atmosphere–ocean reanalysis system for the production of a 20th century reanalysis (*ECMWF Newsletter* No. 144, p. 15). To repeat the first ECMWF forecast experiment, we ran this system, called CERA, at the operational resolution of ECMWF's Integrated Forecasting System (IFS), coupling a 16 km grid to the ocean NEMO model at a 1-degree resolution and with meridional refinement at the equator. We produced an analysis every six hours from 15 February to 1 April 1965, and 10-day forecasts for each day at 00 UTC.

The different types of atmospheric and ocean observations assimilated by the CERA system for 1 March 1965 come from the BUFR data used in the atmopsheric reanalysis ERA-40 and the EN4 ocean dataset, respectively. It is thought that the same kind of atmospheric data was used by the NMC to provide the analysis for 1 March 1965 00 UTC. In addition to assimilating conventional observations, the CERA system constrains the air–sea interface with a nudging scheme towards the monthly sea-surface temperature analysis HADISST2.

The figures show the CERA 500-hPa geopotential height forecast for day 5 and the CERA analysis for 6 March 1965 00 UTC used for verification. In the CERA forecast, the cyclone over the Atlantic is well predicted, as are other important synoptic features.

Improvement in forecast skill

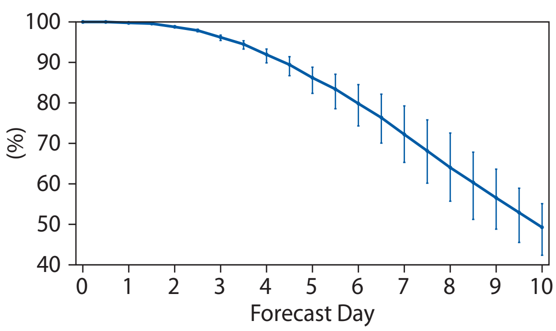
In the 1970s, a series of 2-week forecasts were produced using the GFDL model for 12 winter cases selected from the period 1964–69. Using the NMC analysis for verification and the anomaly correlation as a measure of skill, the 1.5-day forecast of 500 hPa geopotential height over the northern hemisphere has a skill score of 80%, and the 3.5-day one has a skill score of 60%. These two thresholds represent subjectively a good forecast and a useful prediction of the large-scale weather situation.

Twenty-nine medium-range forecasts produced by the CERA system for 00 UTC between 20 February and 20 March 1965 have been used to compute similar forecast skill scores. The anomaly correlation of the CERA 500-hPa geopotential height forecast has been calculated as a function of lead time for the northern hemisphere extratropics with respect to the CERA analysis. The 80% anomaly correlation skill level is reached at 6 days and the 60% level at 8.5 days. This means that the use of a modern ECMWF assimilation and forecasting system extends those skill levels by 4.5 and 5 days, respectively.

It is interesting to note that the general forecast skill obtained using the non-space observing system of the northern hemisphere extratropics in 1965 is not far removed from present forecast skill, which can draw on a number of space-based observing systems. However, the 1965 observing system is unlikely to have captured intense fine-scale weather systems, and outside the northern hemisphere extratropics it was not even close to the performance of present-day space-based observing systems.

When ECMWF was created, it was hoped that a future 6-day forecast would be as accurate as 2 to 3-day forecasts were in the early 1970s. The numerical experiments carried out with the CERA system show that the results of 40 years of research have allowed ECMWF to fulfil this commitment, even for the poorly observed period of 1965.

Despite the fact that here we have only examined a limited number of forecasts over a short period, the results obtained highlight the impressive progress in modelling and data assimilation at ECMWF from the beginning of operational predictions in 1979 to the present.



Anomaly correlation of the CERA 500-hPa geopotential height forecast for the northern hemisphere extratropics with respect to the CERA analysis, based on the 29 forecasts produced by the CERA system for 00 UTC from 20 February to 20 March 1965.