ECMWF Feature article

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VIEWPOINT

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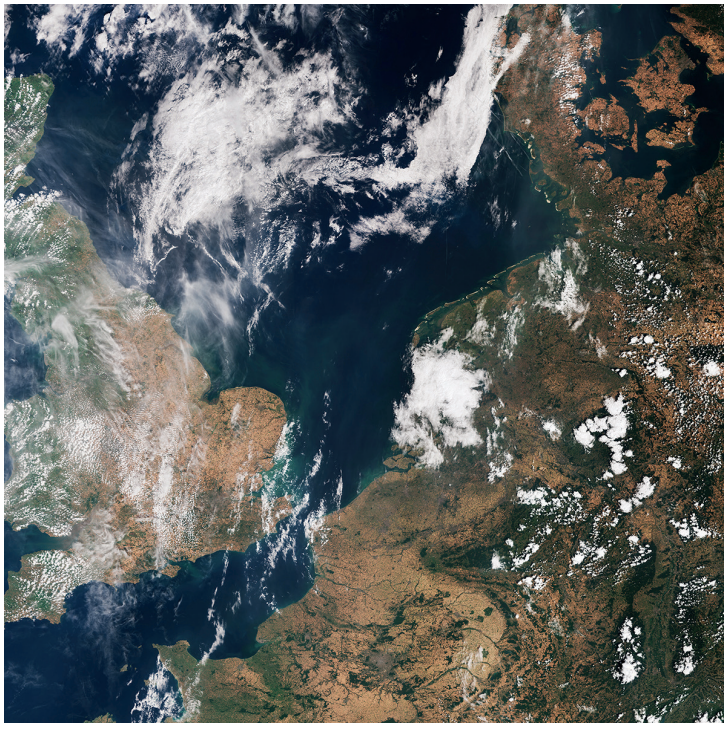

Satellite image of Europe – 25 July 2018 © ESA

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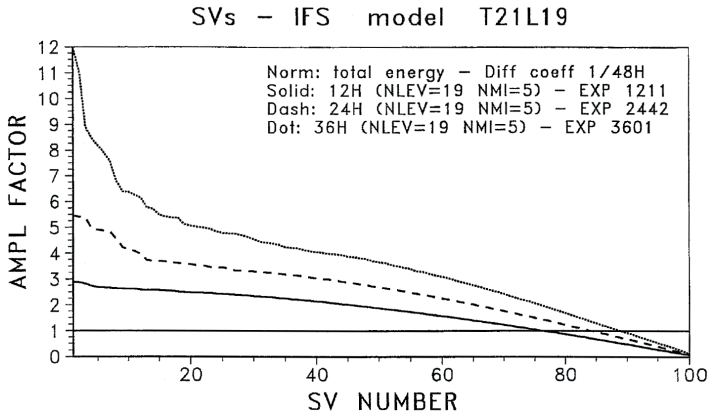
Roberto Buizza talks about probabilistic forecasting and life after ECMWF

Roberto Buizza (interviewed by Georg Lentze)

ECMWF Lead Scientist Roberto Buizza is leaving the Centre after 27 years to take up a position as Full Professor of Physics at the Scuola Superiore Sant'Anna in Pisa. Roberto has been one of the key players in the development of ensemble forecasting at the Centre and in promoting the use of a probabilistic approach to manage weather risk in a range of sectors. He has also worked on ocean reanalysis and coupled data assimilation, and he was the coordinator of the EU-funded ERA-CLIM2 project.

Roberto in Pisa in November 2017.



One of the first singular vector results obtained in 1992. The figure shows the amplification factor of 'well-behaved' leading singular vectors computed with ECMWF's Integrated Forecasting System (IFS) at T21L19 resolution with different optimisation times.

In the eighties, you completed a physics degree with a thesis on plasma physics. How did you come to move from there into numerical weather prediction?

R.B. After I completed my degree, the Centre for Thermonuclear Research of the Electricity Board of Italy (CRTN/ENEL) offered me a position as a scientist, to work on the diffusion of pollution, meteorology and climate. I accepted and it turned out to be a great choice: while working for CRTN, I visited ECMWF to extract data that we were using to assess the impact of weather on the energy sector. At CRTN, we also worked with a limited-area model, and I started to face the predictability questions that would then keep me busy for the rest of my career.

What were the main questions in numerical weather prediction when you joined the Centre in 1991?

R.B. One of the key questions we were facing was how to estimate forecast confidence. We knew that forecast failure was flow dependent, and we were wondering whether we could design an operational method that would give us a flow-dependent, reliable and accurate estimate of the confidence we can have in a forecast. Tim Palmer, Franco Molteni, Čedo Branković, Ernst Klinker and Robert Mureau were working on the development of a prototype ensemble which could be used to give us such an estimate. Joe Tribbia from NCAR was visiting ECMWF for six months. I worked mainly with Franco and Joe to implement a method to initialise an ensemble of forecasts. We decided to use the singular vector (SV) approach. The method was known and was used in simple barotropic or quasi-geostrophic models, but no-one had ever computed singular vectors with a complex primitive equation model with a few thousand degrees of freedom. I remember inspirational discussions, long days debugging the code, a great team spirit, a unique atmosphere – and then the successful implementation of the ECMWF ensemble at the end of 1992. Today, ensembles are used to provide more complete, reliable and accurate forecasts for all forecast ranges, from a few hours to

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months ahead, in practically all the world's national meteorological centres. Ensembles are also used to estimate the uncertainties of analyses.

As you leave the Centre 27 years later, what are the main challenges in predictability today?

R.B. I think there are two key challenges from the scientific point of view. The first is how to improve our simulation of model uncertainties. Currently our ensembles are under-dispersive for some key variables, e.g. near-surface variables, and the Ensemble of Data Assimilations underestimates uncertainties in the analysis. The second is that, although we are now using a coupled (atmosphere, land, three-dimensional ocean, ocean waves and sea-ice) model to generate all our forecasts, we still estimate the initial conditions (ICs) in uncoupled/weakly coupled ways. This makes both our analyses and the ICs for forecast ensembles suboptimal. From the user point of view, the key challenge that we are facing is to convince users that it is always more valuable to take decisions using probabilistic rather than single forecasts. Forecasters use ensembles to assess the range of possible future weather scenarios, but my feeling is that they are still not exploiting their full potential. End users are still mainly asking for categorical yes/no information and are often unable to use probabilities in decision-making. We need to work more closely with them and develop tools and products so that they can exploit the full range of ensemble-based information we generate daily.

What do you say to the charge that ensemble forecasts are a cop-out: they are almost never wrong because almost any outcome is liable to be predicted, if only with a small probability?

R.B. Ensembles can be wrong, and they are definitely not a 'cop-out'! Ensembles must be evaluated using metrics designed for probabilistic forecasts. Two key properties that these metrics assess are reliability and accuracy. In a reliable ensemble, a forecast probability of, say, 75% that a weather event will occur means the event should occur 75% of the time when such a forecast is issued. If one verifies such an ensemble forecast for a large enough sample of cases and finds that instead of 75% this event happens only 60% of the time, we can say that the ensemble is unreliable. Another property is accuracy, i.e. how close the ensemble forecast probability distribution is to observations. Using these metrics, we can make quantitative assessments of ensemble forecast skill: poor ensembles will score low using these metrics, while good-quality ensembles will score high.

Today the rationale for ensemble forecasting is widely accepted. Nevertheless, at ECMWF we still produce a higher-resolution analysis and forecast, as well as ensembles. Is there still a case for a higher-resolution analysis and forecast?

R.B. We need to distinguish between the role of a single higher-resolution analysis and the role of a single higher-resolution forecast. In the ECMWF operational suite, the single high-resolution analysis provides the unperturbed state to which we add perturbations generated using the SVs and the Ensemble of Data Assimilations (EDA). We need this analysis since the 51 members of the EDA cannot be completed in time to generate the ensemble initial conditions: we do not have enough computing power to do this. Thus, until we can generate the 51 EDA analyses in time to initialise ensemble forecasts (ENS), the current setup with one analysis run at higher resolution (compared to the EDA and ENS) pays off.

Regarding the role of the single high-resolution forecast (HRES), the key question to ask ourselves is: which among the forecasts ECMWF produces is on average more accurate: the HRES, the ensemble mean, or the ensemble median? If one compares the skill of these forecasts, it turns out that on average HRES is the most accurate only in the short forecast range (the exact forecast time depends on the variable considered). So HRES provides valuable additional information in the short forecast range, up to about forecast day two. What is more, running at least one member at higher resolution than the ensemble is valuable because it helps us and our users to prepare for the future: in line with our Strategy, the horizontal resolution of our ensemble forecasts will at some point increase to about 9 km, and the experience gained with the 9 km HRES since 2016 will help us prepare for that. At the next resolution increase, ideally we should set the resolution of the HRES to what we will be able to afford for ENS at the following resolution upgrade. In other words, we should strengthen the link between the resolutions used in ENS and HRES to guarantee that ENS inherits a well-tested model version.

Beyond ensemble forecasting, what are the key areas in weather prediction where we can expect to see progress in the next 10 years or so?

R.B. As stated in our Strategy, one of the key aspects that ECMWF aims to understand is why it is so difficult to predict regime transitions over Europe in the forecast range from two to four weeks. Europe is also a difficult region for seasonal prediction. We aim to improve the skill of European forecasts of regime transitions in the sub-seasonal range, and of large-scale anomalies in the seasonal range. Recent

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upgrades to our model that have brought coupling to a three-dimensional ocean and a dynamical sea-ice model in all our forecasts were steps in the right direction. We need to continue to investigate which aspects we need to improve to increase forecast skill. For example, is there something missing in our treatment of stratospheric processes and in the way we propagate signals between the stratosphere and the troposphere? Do we need a finer vertical resolution to propagate these signals more realistically? Do we need a higher-resolution ocean capable of resolving the Gulf Stream better, thus improving the development and propagation of atmospheric systems over the Atlantic Ocean? How can we further improve the quality of the initial conditions exploiting all available observations, for example the ones coming from the newly launched Aeolus satellite?

Looking to the future, what will be the focus of your work at the Scuola Superiore Sant'Anna?

R.B. Scuola Superiore Sant'Anna of Pisa, together with Scuola Normale of Pisa and Scuola Superiore IUSS of Pavia, have agreed to start a new inter-university centre that will study the impact of climate change on society and sustainability. I will be working with experts in many different fields, from economics and management to agriculture and health care, from mathematicians and physicists to bioengineers and lawyers. Climate change is an extremely complex problem, which is having a huge impact on society: we want to work on some of the most urgent climate change-related problems using interdisciplinary approaches, and propose possible solutions and ways forward.

Let me close this interview by thanking everyone with whom I have worked during the past 27 years for their openness, kindness, ideas, constructive criticism, and challenging discussions. In particular, let me say a huge thank you to Franco Molteni, one of my closest friends and colleagues: Franco contacted me at the end of 1990 informing me that there was a vacancy in Tim Palmer's group, asking whether I would be interested in applying. This is how it all started. I also want to thank Tim, Adrian Simmons and Dave Burridge, who in 1991 decided to offer that position to me, thus giving me a great opportunity. ECMWF is a great, unique place, and I wish you all the best for the future.

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