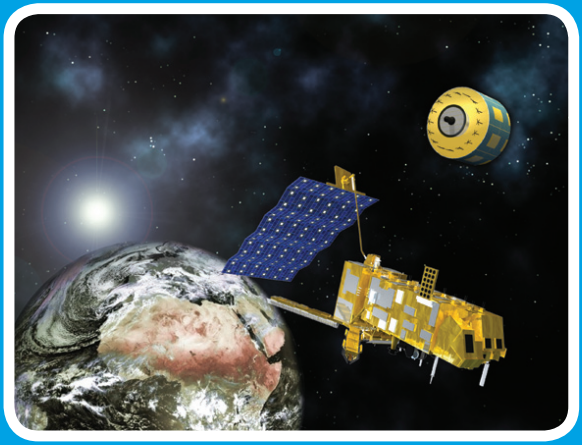
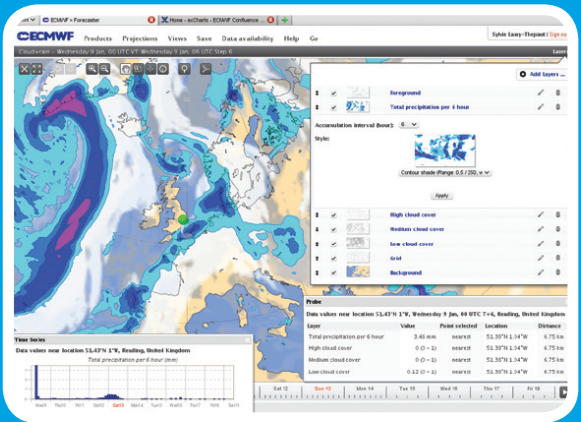
ECMWF

European Centre for Medium-Range Weather Forecasts

Annual Report 2012





ECMWF ANNUAL REPORT 2012

Foreword

ECMWF is a global forecast centre, and our forecasts describe weather all over the world, be it a hurricane in the Atlantic, a flood in the southern Mediterranean region, a heat wave over Russia or heavy snowfall in Finland. However it is the ability to forecast extreme events that is both critical for society and a key measure of the accuracy of a weather centre's forecasts.

Notable events in 2012 that had a significant societal and economic impact included extreme cold and snow affecting much of Europe in both February and December. ECMWF's forecasts provided warnings up to two weeks ahead for the onset of the extreme cold period, as well as good guidance for the individual snow episodes. In Northwest Europe (especially the UK) exceptional rainfall resulted in several extreme flooding events on several occasions throughout the year, again causing major economic impact. ECMWF forecasts provided early indications of these events 5 to 10 days ahead.

Another highlight of 2012 was the weather prediction ECMWF made for Hurricane Sandy. In October 2012 Sandy made landfall at and around New York City and caused considerable damage and lives lost both in the USA as well as earlier in the Caribbean. ECMWF's forecasts of this event were accurate even as far ahead as eight days before landfall. Of course forecasts are not always so good but this success does show the potential for making useful relatively long-range forecasts of extreme and rare weather events. Such forecasts really matter for saving lives and avoiding damage.

During 2012 our supercomputer system was upgraded and now operates with a sustained speed of nearly 10^{14} floating point operations per second – a quite staggering number! However, further advances in meteorology mean that forecast skill would greatly benefit from even higher speeds and capacities. This is why in 2012 we launched the procurement process for a next-generation supercomputer to start operating in 2014.

The ECMWF meteorological data archive is the largest in the world and continues to grow. It now contains around 40 petabytes of operational and research data, with about 45 terabytes being added daily. Over 100 billion meteorological fields are stored in ECMWF's Meteorological Archival and Retrieval System. This provides access to the archive of observations and ECMWF analysis and forecast information, which is used extensively both by ECMWF and internationally for research and model evaluation.

In this annual report we present just some of the output from ECMWF's talented staff in 2012. It is impossible to do justice here to all the activities that are vital to ECMWF's success; those that are not mentioned are no less important. Our work relies on the ongoing operational, research and administrative work that underpins what we do. To achieve all this we also work closely across Europe with 34 Member and Co-operating States, with partner organisations like EUMETSAT and ESA, national meteorological services, academics and many others. We thank our collaborators for their many contributions to what we do. ECMWF is an exemplar of what can be achieved through international scientific and technical cooperation.

Alan Thorpe
Director-General

François Jacq
President of Council

Key events of the year

There were many important developments during 2012 with some of the highlights being the enhancement of the supercomputing and communications infrastructure, the accurate predictions of extreme weather events, and an expansion of both the membership of ECMWF and collaboration with partners. Also 2012 marked the twentieth anniversary of ensemble prediction at ECMWF.

MACC-II general assembly (February-March)

ECMWF hosted the final general assembly of the European project Monitoring Atmospheric Composition and Climate (MACC) combined with the kick-off assembly of its follow-on project MACC-II (MACC Interim Implementation). The event brought together contributors to the MACC project and users of atmospheric environmental services to review the achievements of MACC and the plans for MACC-II.

NCEP joins EUROSIP (June)

ECMWF hosted an event to celebrate NCEP (National Centers for Environmental Prediction, USA) becoming an associate partner in the EUROSIP multi-model seasonal forecasting project. EUROSIP started in 2005, and has so far used data from ECMWF, the Met Office and Météo-France, which is integrated into a common framework. The new partnership enables the creation of operational seasonal forecast products on both sides of the Atlantic.

ECMWF forecast and analysis system updated (June)

An updated version of ECMWF's Integrated Forecasting System was implemented. The new version includes improvements to the forecast model and data assimilation, affecting the high-resolution forecasts and analyses, the ensemble of data assimilations and the ensemble forecasts including their monthly extension.

ECMWF seminar on seasonal prediction (September)

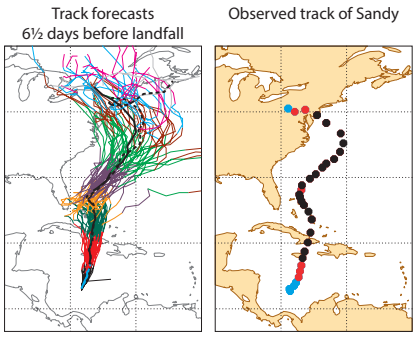
Scientists from around the world attended the ECMWF annual seminar on seasonal prediction. Speakers showed that predictions months ahead now provide better, more valuable information than statistical ones, or climatology. Michel Jarraud (WMO Secretary-General) said, "The past is no longer a trustworthy indicator for the future. Thanks to advances in seasonal forecasting, we can provide users, especially the most vulnerable ones, with better forecasts than statistics based on the past."

New high-performance computer in operational use (October)

The new high-performance computer became the primary system for producing ECMWF's operational forecasts on 24 October 2012. The dual-cluster IBM POWER7, installed in several stages during 2012, has a total of almost 50,000 processor cores. It provides ECMWF with a significant increase in computing performance for running enhanced operational forecasts, conducting research and developing forecasting models.

Accurate predictions of Hurricane Sandy (October)

Hurricane Sandy made landfall in New Jersey on 30 October 2012, leaving a trail of devastation both in the Caribbean and in the north-eastern United States. From the time Sandy was forming in the Caribbean, the ECMWF ensemble and high-resolution forecasts gave early indications of the potential for the north-east United States to suffer the impact of Sandy.

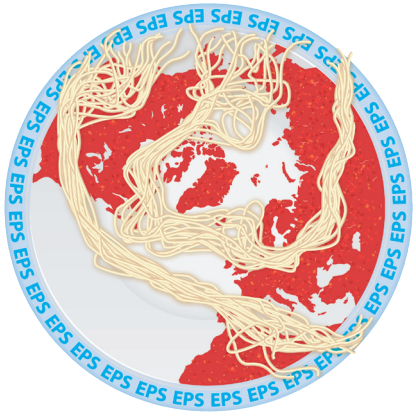


European Flood Awareness System operational (November)

The European Commission announced that the European Flood Awareness System (EFAS) was fully operational. Flood warnings from EFAS contribute to the protection of the European citizen, the environment, property and cultural heritage. As well as ECMWF's ensemble forecasts being a key input, ECMWF is also the computational centre of EFAS, working alongside partners from Sweden, Slovakia, the Netherlands and Spain.

Twenty years of ensemble prediction at ECMWF (December)

ECMWF celebrated 20 years of operational ensemble prediction at ECMWF. On 24 November 1992, the first ensemble predictions were produced as part of the operational forecasting system. The event was marked by a series of presentations from people who helped ECMWF provide the best global, medium-range and monthly probabilistic forecasts, either by developing the operational system or by contributing to the science on which it is based.



Slovenia became a Member State (December)

The Republic of Slovenia became ECMWF's 20th Member State. Slovenia now has full voting rights at the Council, which is the top-level governing body of ECMWF. Also, a portion of the Centre's supercomputer and data archive resources will be allocated to Slovenia for its own use, and Slovenia will have access to all ECMWF products and tools.

New RMDCN contract (December)

ECMWF signed a contract for the provision of the next generation of the Regional Meteorological Data Communication Network (RMDCN). This will provide a highly available and resilient data communication network for the dissemination of ECMWF products. Also it provides the WMO Global Telecommunication System for Europe and the Middle East. ECMWF is responsible for the procurement, implementation and operation of the network.

Improving skill

ECMWF 's reputation for providing the most accurate and reliable medium-range, global weather forecasts is underpinned by a wide-ranging programme of research and development aimed at improving the forecasting system and making full use of satellite data. The monitoring of forecast skill plays a key role in assessing the impact of operational changes and highlighting areas for further development.

In June 2011 a revised set of headline scores was adopted by the Council to monitor trends in forecast performance. The two primary scores and four supplementary scores concerned with the high-resolution and ensemble forecasts showed that high levels of skill were maintained during 2012.

Progress on each of the headline scores is reported to the Member States through the ECMWF Council and committees. An annual review of the performance of the forecasting system, including a comprehensive set of verification scores, is presented each year to the Technical Advisory Committee and subsequently published as a Technical Memorandum. ECMWF also maintains a wide range of verification information on its website.

Comparison with other centres provides a useful reference for assessing the skill of the ECMWF forecasts. A common ground for such comparison is provided by the exchange of scores under the auspices of the World Meteorological Organization (WMO). This exchange focuses on assessment of large-scale weather patterns. The results for 2012 show that ECMWF continues to maintain its lead over other centres. Also, as in previous years, this lead is larger for the southern hemisphere, though the difference in performance between centres is decreasing.

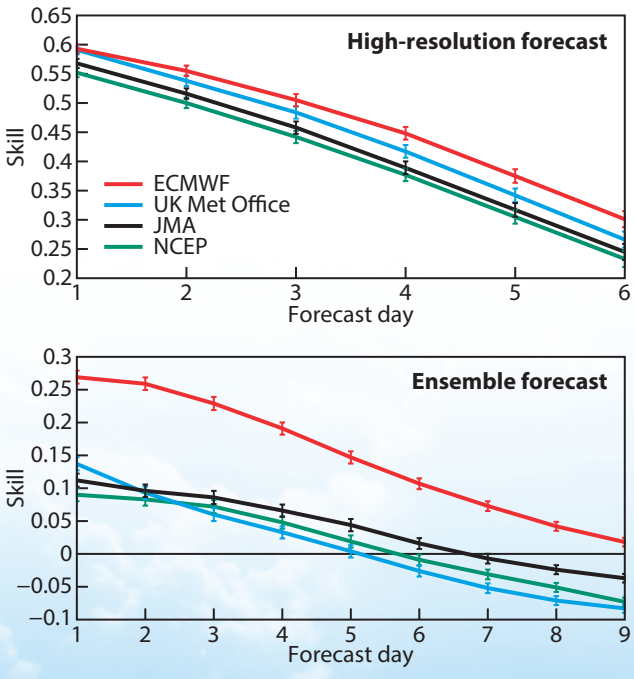
ECMWF has begun a routine comparison of the precipitation forecast skill of ECMWF and other centres for both the high-resolution and ensemble forecasts. Results using ECMWF's supplementary headline scores for precipitation over the last year show a consistent lead for ECMWF compared with other centres. The ECMWF ensemble forecast shows skill out to 9 days, while the forecasts for days 5-6 have skill levels only achieved by other systems at days 2-3.

ECMWF is now working together with WMO to extend the official exchange of scores to include precipitation results and other surface weather variables.

TECHNICAL ADVISORY COMMITTEE

Alan Dickinson,
Acting Chair of the TAC

"At its meeting in October 2012 the Technical Advisory Committee (TAC) congratulated ECMWF on the continued high performance level of its weather forecasting system. The TAC noted the recent improvements in the medium-range forecasts resulting from enhancements to the data assimilation system and modifications to the treatment of convection and clouds. The TAC encouraged ECMWF to continue to develop new verification procedures that relate to weather impact especially for severe events, and to understand local variations in performance. The TAC also encouraged ECMWF to continue developments to maintain its world-leading position in medium-range forecasting."



Comparison of precipitation forecast skill for ECMWF and three other global forecasting centres. *The skill of the high-resolution and ensemble forecasts for 2012 for the extratropical regions is shown. Bars indicate 95% confidence intervals. These results show that ECMWF's skill exceeds that of the other forecasting centres.*

Forecasting extreme weather events

Producing reliable medium-range forecasts of extreme weather events and changes in weather regime is a key aim of ECMWF. Such forecasts are used by forecasting services in many countries to provide early warnings to their customers, including civil protection agencies and the public, so they can take action to mitigate the potential for damage to property, loss of life, and reduced economic activity.

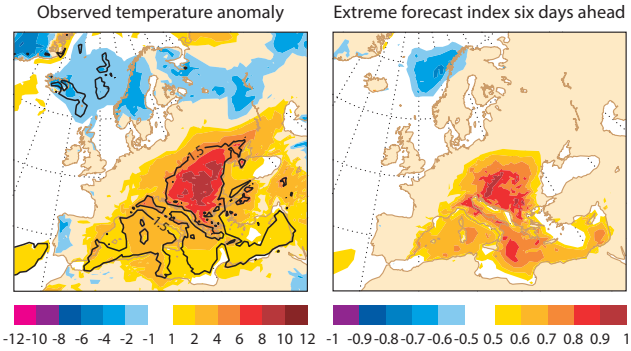
Large parts of Europe were severely affected by a prolonged period of extreme cold during the first two weeks of February 2012. The onset was well captured 12 to 18 days ahead in the monthly forecasts and the sustained cold conditions were consistently predicted.

During the summer a number of heat waves affected southern and eastern Europe. The extreme forecast index (EFI) provided good guidance for all these cases. There was also good guidance from the EFI for the severe snowfall episodes that affected large parts of Europe in February and December 2012.

Months of below-normal rainfall in Western Europe were followed by very wet conditions during April. The EFI gave an early indication 5 to 10 days ahead of the heavy rainfall affecting areas from Iberia to southern Scandinavia, while nearer the event the high-resolution forecast gave an excellent forecast of the location and magnitude of the rainfall. The ECMWF forecasts provided similar guidance for subsequent severe flooding events which affected Northwest Europe (especially the UK) during the rest of the year, as well as for damaging severe rainfall events in southern Spain (September) and Italy (November).

Hurricane Sandy caused many fatalities with extensive losses to property, infrastructure and the economy on the eastern seaboard of the USA in October 2012. Remarkably the ECMWF high-resolution prediction gave an accurate indication of Sandy's landfall eight days in advance even though its track was not that normally taken by a tropical storm. Nearer the event, the ensemble forecast indicated a high level of confidence in the prediction of landfall and intensity.

Not all extreme weather events are forecast as well as Sandy and transitions to periods with heat waves or droughts are notoriously difficult to capture. However, various events in 2012, some of which are illustrated here, give encouragement that there is significant potential for improving our predictive skill.



Heat wave over southeast Europe, 24–26 August 2012, forecasts six days ahead. *Shown are the analysed anomalies of 2-metre mean temperature for the three-day period from 24 to 26 August (left) along with the extreme forecast index (EFI) for 2-metre mean temperatures for the same period from six days ahead (right). Positive values of the EFI for southeast Europe indicated well in advance that higher than normal temperatures were likely.*

Snow across much of Europe in early December 2012. *Extreme cold weather and snowfall caused widespread damage and disruption, including a number of fatalities. In Southeast England there was disruption to road transport, delay to flights and closure of schools. The EFI gave a good indication that there would be heavy snowfall.*

Being innovative

The goal of research at ECMWF is to improve weather forecasts through the introduction of new components of the forecasting system as well as fundamental developments in numerical weather prediction and related areas. Research and development activities are guided by the strategic goals of improving the prediction of severe weather in the medium range and the quality of near-surface parameters.

The world-class research at ECMWF benefits from strong links with the research community and space agencies. These links not only support collaborative research, they also provide a means of monitoring scientific developments to help identify the most promising lines of research. Priorities are also guided by feedback from users and diagnostics from the forecasting system. For example, a report was issued in 2012 about an investigation of poor forecasts of severe weather, often referred to as 'busts', to help understand why they occurred.

In 2012 a major upgrade of the forecasting system improved the use of satellite data, the representation of cloud processes and the description of ocean waves. The reconstruction of short-range forecast error statistics with the latest model version led to a considerable improvement in forecast scores. These statistics determine the weight given to the short-range forecasts in the data assimilation scheme that combines the forecasts with observations. The combination, referred to as the analysis, serves as the starting point for the medium-range forecasts.

Improved estimates of the background errors are also needed as part of the development work to increase the vertical resolution of the forecast model. Preparations for the increase in resolution have required much effort, as nearly all aspects of ECMWF's Integrated Forecasting System (IFS) are affected by such a change. At the same time experiments have continued into exploring the impact of having a very high horizontal resolution.

Research on numerical methods, observing systems, data assimilation algorithms and representation of the Earth's physical processes will provide the basis for further improvements to the forecasts. Whilst consistent improvements of forecast skill remain a challenge, scientific developments of the model and data assimilation, as well as inclusion of components of the Earth's system (e.g. oceans, sea-ice and atmospheric composition), offer great potential.

ELIAS HÓLM

"The background error covariances are a fundamental component of the analysis system. They describe the statistics of errors in the short-range forecast which is combined with observations to produce the analysis. Today's background error covariances are the result of research by many scientists at ECMWF during the last two decades. This research has led to an increasingly realistic statistical description of background errors that now reflects geographical and flow-dependent differences."

MASSIMO BONAVITA

"Current developments make increased use of ensemble data assimilation to supply better estimates of geographical and flow-dependent background errors. These errors help determine the accuracy of new observations presented to the assimilation system and what weight they should be given in the analysis. Being involved in this work has been both demanding and stimulating, and shows what can be achieved when scientists collaborate to a common purpose. Also it has been very satisfying knowing that our activities have a direct and large impact on the quality of the forecasts."

Introducing new products and services

ECMWF and its Member States benefit from a continual exchange of information through numerous workshops, meetings and visits. This leads to the development of new products and services, including some based on probabilistic information that the meteorological services of Member States use in their forecasting tools and applications.

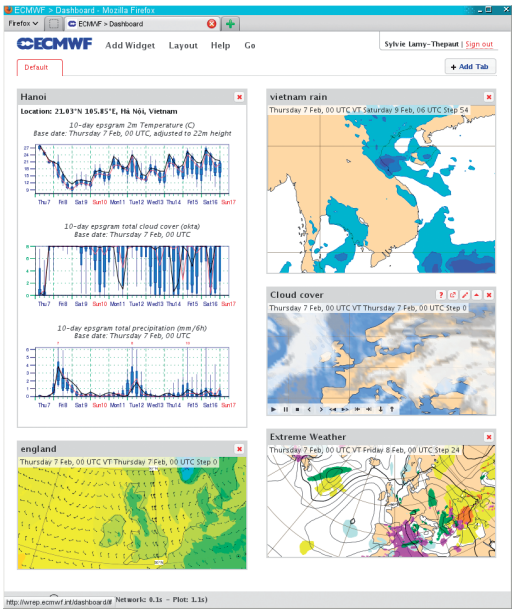
In response to user requests, in June 2012 ECMWF implemented a new suite of web applications, called ecCharts, to provide fast access to ECMWF's medium-range forecast data as soon as the information is available. The rich user interface offers an interactive set of tools for viewing and exploring the meteorological situation in far greater detail than has previously been possible on ECMWF's website. As a result, users can prepare tailored material focused on their specific areas of interest. This fully-supported 24-hour ECMWF service has received good feedback and is becoming increasingly popular amongst forecasters.

In 2012 ECMWF introduced several new products to meet the requirements of users. These include new convective indices to help with the prediction of thunderstorms and an extension to products based on the extreme forecast index (EFI), including additional parameters concerned with maximum and minimum near-surface temperatures, snowfall and significant height of ocean waves.

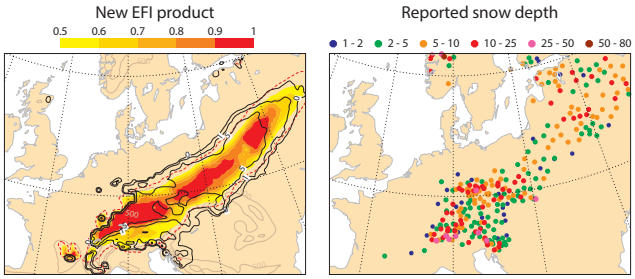
The annual *Forecast Products Users' Meeting* gives users of ECMWF forecasts the opportunity to discuss their experiences with the medium-range and extended-range products and to present feedback on their use and future requirements. Participants appreciated the enhancements made in 2012, including the extended range of parameters (e.g. new convective indices) and additions to the EPSgrams (e.g. low, medium and high clouds and wind gusts). Participants also suggested additional products, with the focus on more information about weather elements.

Visits to 13 Member and Co-operating States in 2012 by ECMWF staff and the biennial *Workshop on Meteorological Operational Systems* provided opportunities for discussions about users' experiences with the recently introduced ecCharts and their suggestions for new products.

ECMWF will continue to strengthen collaboration and communication with users of forecasts in Member States to develop new products that meet their demanding needs.



The ecCharts dashboard application. *Users can organise and configure their favourite products in a set of folders presented as tabs at the top of the page.*



An EFI product for the early snowfalls affecting Europe in October 2012. *On the left is shown a product based on the extreme forecast index and other information for snowfall for day 3 of the forecast valid on 28 October 2012. The coloured shading gives an indication of the likelihood of snow (the higher the value the more likely the event) whereas the contours indicate how extreme the event might be (the higher the value the more extreme the event). On the right is the observed snow depth (in cm) reported at 06 UTC on 28 October. The forecast gave a clear indication that snow was likely with at least a 10% probability of extreme snowfall.*

Collaborating with others

ECMWF collaborates extensively with the meteorological community, worldwide but particularly within Europe, with a focus on developing elements of ECMWF's forecasting capability. Collaboration with its expanding membership, space agencies, research community, European institutions and the WMO underpins ECMWF's achievements and helps sustain its core mission.

The TIGGE data archive, which consists of ensemble predictions from global forecasting centres, is used to study ensemble forecasting and predictability, and to develop products to improve the prediction of severe weather. During 2012 the number of active users increased by 21% to 86 and the volume of retrieved data increased by 31%. As well as supplying its own forecast data, ECMWF provides the infrastructure for the TIGGE archive.

ECMWF, as the computational centre of the European Flood Awareness System (EFAS), works alongside partners from Sweden, Slovakia, the Netherlands and Spain. EFAS became fully operational in 2012 and provides assessments of flood risk using ECMWF's ensemble forecasts as a main input.

Two EU-funded projects being led by ECMWF involved wide-ranging collaboration in 2012. ERA-CLIM, which involves nine European institutions, aims to prepare a climate reanalysis of the twentieth century. Also MACC-II (Monitoring Atmospheric Composition and Climate - Interim Implementation), the pre-operational Copernicus Atmosphere Service, has 36 partners.

ECMWF has continued to work closely with space agencies, particularly EUMETSAT and ESA. This collaboration has improved the accuracy of weather forecasts by fully exploiting satellite data. A study in 2012 showed that the ECMWF forecast system would have failed to predict the course of Hurricane Sandy if data from polar-orbiting satellites had not been available.

EUMETSAT

"Our partnership with ECMWF is essential. Not only does the Centre extract the best value from our observations for its numerical forecasts, but it also has unique capabilities to measure their impact, and is a major source of requirements for our future satellite systems."

Alain Ratier
Director-General, EUMETSAT

WORLD FOOD PROGRAMME SUPPORT

The United Nations World Food Programme (WFP) has been given access to ECMWF forecasts to help boost its preparedness planning and operational capacity. WFP's Analysis and Early Warning Team first used the forecasts in the remote area of Yida in South Sudan where flooding had made getting help to 60,000 refugees almost impossible. This allowed WFP to better time costly airdrops and organise supply pipelines so minimising disruption to its life-saving work. WFP also shared the forecast with other UN agencies. UNOPS (United Nations Office for Project Services) timed crucial construction work on building a new runway and staff from UNHCR (United Nations High Commissioner for Refugees) prioritised which relief supplies to send in first based on the weather forecasts.

"ECMWF experts have helped us every step of the way and have been incredibly generous in giving us access to their industry-leading technology and information. This is of great value to us in our first initiative in this important area.

Increasingly, anticipating extreme weather is critical to WFP's emergency preparedness and emergency response. We have now extended forecasts to areas like the Middle East where the plight of refugees from the Syrian conflict was exacerbated by an extreme winter. Knowing when heavy rain and snow were on the way allowed WFP staff in Jordan to quickly rent extra shelters to protect people during food distributions and to prioritise their work in challenging conditions."

David Kaatrud
Director of Emergencies

Supporting users

ECMWF is a user-driven organisation. Its strategy, plans and activities are determined by the requirements of weather forecasters in the ECMWF Member and Co-operating States and other users of its forecasts. ECMWF runs many activities intended to support users, obtain feedback, provide access to data and software, and spread expertise.

ECMWF has an extensive education and training programme to introduce users to its computing and archive systems and help scientists develop their knowledge of numerical weather prediction. In 2012 the annual seminar provided an opportunity for forecasters and early-career scientists to learn about recent advances in seasonal prediction.

The OpenIFS project provides a version of ECMWF's forecasting model that academic institutions can use for research and education. In 2012 the Department of Meteorology at Stockholm University became the first institution to use the OpenIFS as a teaching aid.

Each year ECMWF offers training courses on the *Use and Interpretation of ECMWF Products* to assist forecasters in Member and Co-operating States. In 2012 an online forum was introduced to support group activities and discussion of weather events. There was some very positive feedback about the course: "I am looking forward to exploring the new products and putting into practice the things that I have learned" and "This week was very inspiring".

A similar course is also run for forecasters worldwide who access ECMWF products available to Members of the World Meteorological Organization. This year the course included two seminars, broadcast over the web to an international audience, that covered applications of long-range weather forecasts.

ECMWF runs time-critical applications on its computing infrastructure for Member States, with ECMWF staff monitoring the tasks. For example, ensemble forecasts are produced for the COSMO Consortium and UK Met Office. In 2012 two new applications were introduced and a faster web-based interface was implemented.

ECMWF has a unique set of global numerical weather prediction data in its archives. For example, reanalysis data based on reprocessing past observations to produce a consistent record of the state of the atmosphere is widely used for research and commercial activities. The number of users who have downloaded reanalysis data from the ECMWF website has increased by 35% during 2012, to about 12,000.

POWER OUTAGE AT THE DANISH METEOROLOGICAL INSTITUTE

"It's a great service ECMWF has provided us by letting us run the Danish weather model on their supercomputer, and we are pleased that they take the trouble."

Henrik Feddersen
(Senior Scientist at DMI)

"On 21 August there was a power outage at DMI. Staff at ECMWF worked with DMI to ensure that its forecasting model could be run at ECMWF with priority and in a timely manner until DMI's service was restored."

Isabella Weger
(Head of Computer Division, ECMWF)

ANNA GHELLI

"I feel privileged to coordinate and teach at the ECMWF training courses on the use and interpretation of ECMWF products. Working with students from all over the world is an enriching experience and makes you understand the importance of ECMWF products for the work of meteorological services around the world."

Enhancing computing and telecommunications

Producing ECMWF's weather forecasts requires extremely powerful computers and instant access to massive amounts of data. Key to the Centre's activities are its supercomputers and unique archive of meteorological data. Also the efficient distribution of a wide variety of data produced by ECMWF is essential to support operational activities in the user communities as well as research and development.

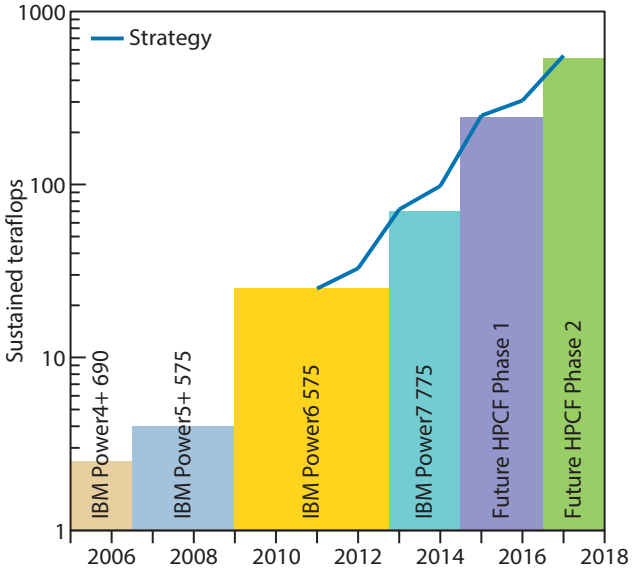
The high-performance computing facility (HPCF) continues to provide a reliable service to ECMWF's users with 99.7% availability over the last 12 months.

As part of a two-phase service contract with IBM for the supply of the HPCF, the migration of operational services to the Phase 2 system started in October 2012. The upgraded HPCF, consisting of 2 POWER7 clusters with a total of almost 50,000 processor cores, 100 terabytes of memory, and 3 petabytes of usable disk capacity, provides ECMWF with the necessary compute resources for its operational and scientific activities until mid-2014.

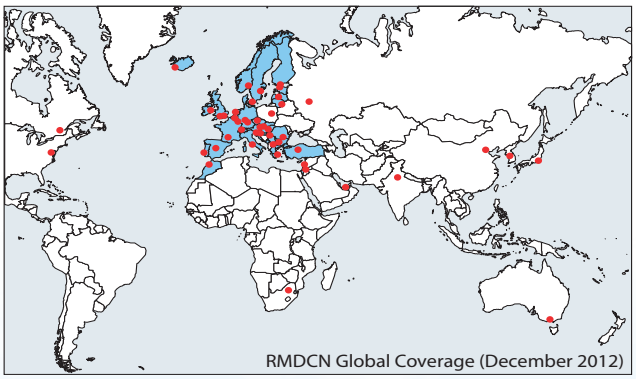
In June 2012, the Council endorsed the work done by its advisory committees in scrutinising the scientific basis, technical options and funding possibilities for the procurement of the HPCF for the period from mid-2014 to mid-2018, to enable ECMWF to keep its leading position in global medium-range weather prediction.

ECMWF issued an invitation to tender for the provision of the next HPCF on 16 October 2012. To implement the ECMWF strategy, a sustained computational performance of around 250 teraflops is required in 2014, followed by a further performance increase in 2016. This is in line with historical growth and continues the rate of HPCF upgrades essential to deliver forecast improvements of one day per decade.

The Regional Meteorological Data Communication Network (RMDCN) is used to disseminate ECMWF products and provides the WMO Global Telecommunication System for Europe and the Middle East. Following an invitation to tender for the provision of a new network, issued in February 2012, ECMWF concluded, in December 2012, a contract for a state-of-the-art network infrastructure for the RMDCN. The migration, scheduled to be completed in February 2014, will deliver a network with higher connection speeds to meet future requirements.



HPCF capacity at ECMWF. *The blue line illustrates the computing capacity required to implement the strategy, expressed in sustained teraflops. The coloured bars show the resulting requirements for the replacement HPCF from mid-2014 and the historical evolution of HPCF performance.*



The sites linked by the RMDCN. *Fifty sites (46 national meteorological centres, ECMWF, 2 EUMETSAT sites and 1 disaster recovery site in the Netherlands) are connected to the network. The shaded countries indicate ECMWF Member States and Co-operating States. South Africa and Canada were connected to the RMDCN in 2012.*

Providing extended-range and long-range forecasts

ECMWF's Integrated Forecasting System is used to provide 1-month forecasts twice a week, 7-month forecasts every month, and 13-month forecasts every season. Because predictive skill can arise from the inertia of the oceans and land surfaces, a coupled ocean-land-atmosphere ensemble forecasting system is used to generate these products.

ECMWF's extended-range forecasts are produced twice a week as an extension of the medium-range forecasts. In 2012 these forecasts were successful in indicating the likelihood of European heat waves and periods of cold temperatures several weeks in advance.

The Madden-Julian Oscillation (MJO) is the major fluctuation in tropical weather on weekly to monthly timescales. It is most evident in the Indian and western Pacific Oceans, but it also influences Euro-Atlantic flow regimes. For example, there is evidence of a link between the MJO and the North Atlantic Oscillation (NAO), which is particularly important for the prediction of European weather. Results obtained in 2012 have indicated significant improvements in simulating the MJO and NAO, and this has increased the skill of monthly forecasts over the Euro-Atlantic region.

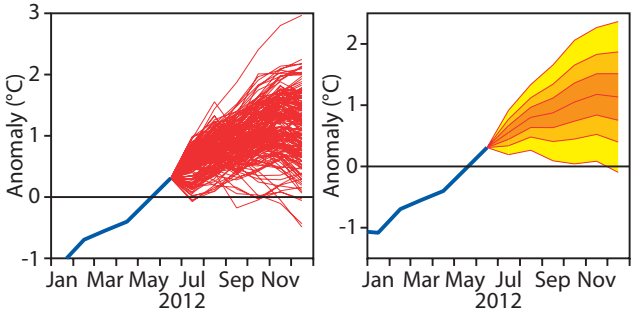
Long-range forecasts, using an atmospheric model coupled to an ocean model from the start, are produced on the first day of the month and cover a seven-month period. Every quarter these forecasts are extended, in experimental mode, to 13 months. Following the operational implementation, in November 2011, of the new seasonal forecasting System 4, the accuracy and reliability of the extended-range forecasts has further improved.

The largest known source of year-to-year climate variability is the El Niño Southern Oscillation (ENSO). This is a coherent, large-scale fluctuation of ocean temperatures, rainfall, and air pressure across the tropical Pacific. System 4 has performed as expected with more reliable ENSO predictions than its predecessor, System 3.

ECMWF hosts and co-ordinates EUROSIP, a multi-model seasonal forecasting system that uses data from ECMWF, the UK Met Office and Météo-France. In 2012 NCEP (National Centers for Environmental Prediction, USA) became an associate partner. This collaboration enables the creation of enhanced seasonal forecast products by merging data from European and American forecasting systems into multi-model products.

LAURA FERRANTI

"ECMWF seasonal forecasts are increasingly used in a range of applications to improve weather-related risk management. The skill of these forecasts now exceeds that of statistical models. In September 2012 scientists from around the world attended the ECMWF seminar on seasonal prediction. It was a great opportunity to review scientific developments and learn about the value of seasonal forecasts."



Multi-model forecast showing the El Niño plume products. *The 13-month forecast from 1 July 2012 indicated a transition to an El Niño state (i.e. warm Pacific sea-surface temperatures) in late 2012 and this has been confirmed. The likelihood of this transition was first apparent in the forecast from 1 November 2011.*
Left: plumes of anomaly sea-surface temperatures from the forecast centres that contribute to EUROSIP.
Right: the corresponding multi-model probability distribution; 50% of the plumes lie within the two central divisions.

Celebrating twenty years of ensemble prediction

On 24 November 1992 the first ensemble forecasts were produced at ECMWF. Today the ECMWF ensemble forecasts are much more reliable and skilful than they were two decades ago. Worldwide, ECMWF is recognised as providing the best global, medium-range and monthly probability forecasts. In December 2012 we celebrated this achievement.

When ECMWF began operational weather prediction in 1979 the forecasts did not include uncertainty estimates. It was recognised, however, that providing this kind of information would help users of forecasts in activities such as risk management and decision-making.

Initially the techniques available for specifying the uncertainty in the initial conditions of a forecast were not sufficiently developed to provide useful results. But research led to improved techniques and the implementation of ECMWF's first ensemble prediction system in November 1992. At that time, ensemble forecasts were issued 3 times a week with 33 individual forecasts (called members) at a resolution of about 250 km for up to 10 days.

Ground-breaking research, which improved ways of assessing uncertainty not only in the initial conditions but also in the representation of physical processes, led to a rapid development of the ensemble forecast. In 2012 the ensemble forecast was produced twice a day with 51 members at a resolution of about 30 km for the first 10 days, and at a resolution of about 60 km for the next 5 days. Twice weekly the ensemble was extended to 32 days.

The skill of the ensemble forecast has been improving more rapidly than the high-resolution forecast. There is confidence that further improvements will come from:

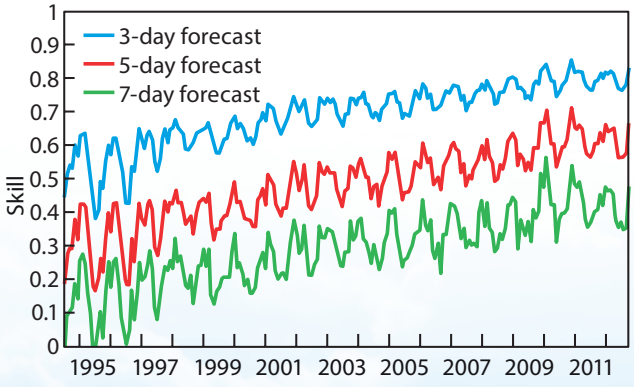
- Improving the simulation of physical processes, taking model uncertainty into consideration.
- Enhancing the definition of the ensemble of initial states.
- Introducing a more accurate and higher-resolution ocean model.

Key for these developments will be close collaboration within the scientific community.

On 3 December 2012 we celebrated 20 years of operational ensemble forecasting at ECMWF and the achievements of the many scientists who have contributed to developing ECMWF's world-leading ensemble forecast.

EMS SILVER MEDAL AWARD

Tim Palmer was awarded the European Meteorological Society (EMS) Silver Medal for 2012 for his pioneering work on predictability of weather and climate and for his outstanding skills and commitment to communicating the underlying concepts to non-specialists and the general public. Tim worked at ECMWF between 1986 and 2011; he is now a Royal Society Research Professor in Climate Physics at the Department of Physics of the University of Oxford, with close collaboration with ECMWF. He received the award from Dominique Marbouty, President of the EMS and former Director-General of ECMWF, at the EMS Annual Meeting in Łódź, Poland, in September 2012.



Improvement in the skill of the ensemble forecast. *ECMWF ensemble forecasts are much more reliable and skilful than they were when they were first produced, two decades ago. These results for the 500 hPa geopotential height indicate that for the northern hemisphere extratropics there have been gains in predictability of between one and a half and two days per decade (e.g. the five-day forecast is now as skilful as the three-day forecast in the mid-1990s).*

Recruiting and retaining excellent staff

ECMWF's reputation as a world leader in numerical weather prediction is a direct consequence of its ability to recruit and retain staff who are leaders in their field and who work together to develop our research and improve the quality of our forecasts. In 2012 a new employment framework was agreed.

ECMWF recruits from across its Member and Co-operating States. In 2012 we received 412 applications from 48 different countries, and welcomed 36 new employees from 15 countries. We now have 32 different nationalities at the Centre, working across all disciplines.

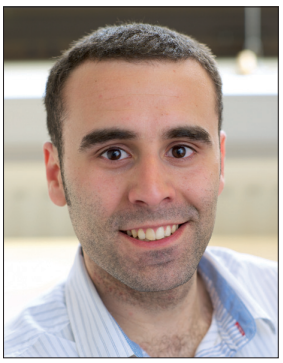
ECMWF has developed a new user-friendly online job application portal to be launched in 2013. This will provide more information about what it is like to work at ECMWF as well as the recruitment process and our employment conditions.

In 2012 we reviewed our employment framework, especially in relation to people working on projects, and have agreed changes including new integrated Staff Regulations that will allow consultants from Member States and Co-operating States to become full staff members and ensure that the Centre's employment conditions are in line with international best practice.

A comprehensive survey of our employees, covering how they see their life and work at ECMWF, was carried out in September 2012. The survey focused on key areas such as line management, communication, engagement and culture. 78% of employees responded and this has provided us with a solid basis for identifying the main areas to concentrate on next in our efforts to provide the best work environment for our employees.

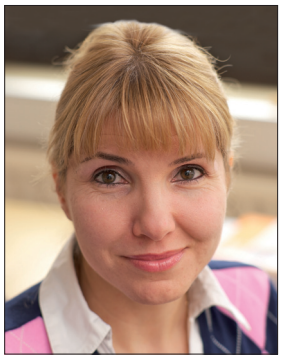
MEMBER & CO-OPERATING STATES

XAVIER ABELLAN



"Before coming to ECMWF I worked in user support at the Barcelona Supercomputing Centre for five years. Joining the User Support Section at ECMWF seemed a natural step as I could build upon my previous experience whilst developing my expertise in another international organisation. I find it particularly rewarding using my knowledge to help users overcome problems and get the most out of the Centre's resources."

MARIJANA CREPULJA



"Having worked in operational meteorology in Serbian and Czech Meteorological Services and experienced giving a presentation at an ECMWF workshop I thought ECMWF would be a stimulating place to pursue my career. Settling into work was much helped by the professional and friendly colleagues. At the Centre I work on acquisition and pre-processing of satellite data for chemical processes modelling and enjoy being part of the new and unique MACC atmospheric service in Europe."

Investing in European weather forecasts

ECMWF is financed principally by its Member and Co-operating States, with external funding supporting core research as well as contributing to complementary goals. ECMWF continued to invest in its staff, infrastructure and systems to provide the highest quality products to its Member and Co-operating States.

Member and Co-operating States contributed £40.9 million out of the Centre's £50.4 million funding and the Centre's success in attracting research funding from the EU and other international organisations has continued with over £5.4 million earned in 2012. Revenues from the sale of data and products amounted to almost £3.8 million.

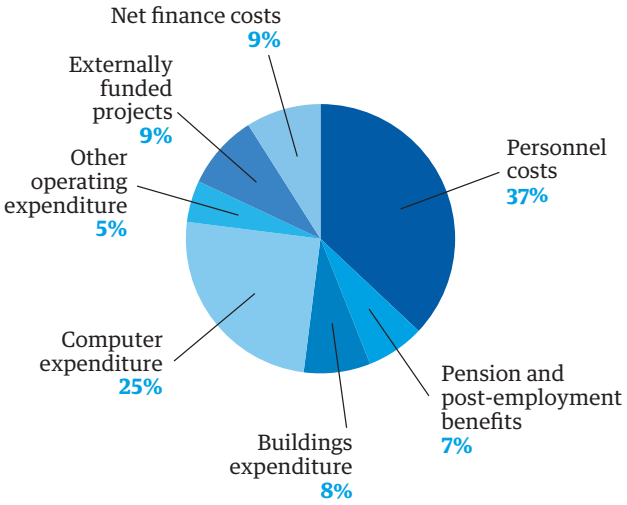
2012 is the first year in which ECMWF produced financial statements in accordance with International Public Sector Accounting Standards (IPSAS), which is in line with best practice. IPSAS has been adopted by many other international organisations.

The main impact of IPSAS is that income and expenditure have been accounted for on an accruals basis, fixed assets have been capitalised and depreciated over their useful lives, and full pension costs have been included in the Statement of Financial Performance. This means that, as expected, the accounts are presented in a very different way to that previously used. Whilst accrual accounts show a deficit of £4 million, in cash terms the Centre produced a surplus of £1.4 million for the year and a reconciliation of these results is provided in the Financial Statements.

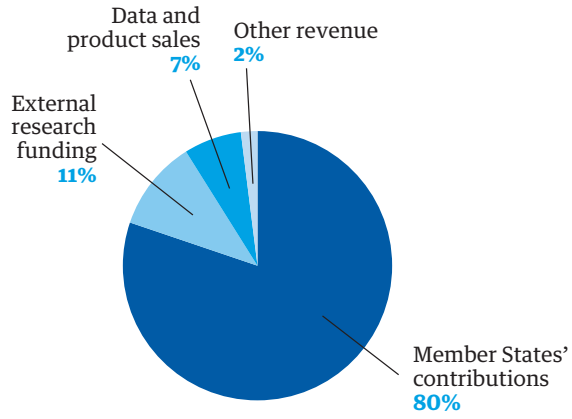
The Centre's future pension obligations have been valued at £150 million and are now shown as a liability in the Statement of Financial Position, whereas the value of its pension investment accounts (£18.2 million) is shown under assets. ECMWF's net pension fund obligations are guaranteed by the Member States.

The main areas of expenditure were related to remuneration and related items (£22.3 million; £17.2 million net of internal tax), pension schemes (£4.3 million), computer expenses (£15.5 million) and buildings (£4.8 million). Costs associated with externally funded research projects amounted to £5.6 million (£4.4 million net of internal tax) and pension finance costs were £5.7 million. Capital investment, principally on IT and infrastructure, totalled £1.8 million.

ECMWF COSTS 2012



ECMWF FUNDING 2012



Financial information

ECMWF's Financial Statements of Account for 2012 have been audited by the Board of Auditors and will be presented to the ECMWF Council for approval at its summer session in 2013. The following tables are an extract from those draft Statements of Account.

Summary Statement of Financial Position as at 31 December 2012 (£k)

CURRENT ASSETS	
Cash and cash equivalents	14,013
Receivables	6,538
Prepayments and accrued revenue	912
Inventory	607
	22,070
NON-CURRENT ASSETS	
Property, plant and equipment	16,735
Pension investment accounts	18,274
	35,009
TOTAL ASSETS	**57,079**
CURRENT LIABILITIES	
Payables	11,208
Deferred revenue	383
	11,591
NON-CURRENT LIABILITIES	
Employee benefits	150,181
TOTAL LIABILITIES	**161,772**
NET LIABILITIES	**(104,693)**
General reserve	2,395
Retained surpluses	7,644
Net surplus/(deficit) for the year	(3,986)
Actuarial adjustments	(19,397)
IPSAS adjustment reserve	(91,349)
	(104,693)

Summary Statement of Financial Performance for the year ended 31 December 2012 (£k)

REVENUE	
Member & Co-operating States' contributions	40,868
Taxes	6,393
Externally funded projects	5,413
Sales of forecasts and data	3,793
Other operating revenue	373
	56,840
EXPENDITURE	
Personnel costs	22,265
Pension and post-employment benefits	4,321
Buildings expenditure	4,767
Computer expenditure	15,473
Other operating expenditure	2,935
Externally funded projects expenditure	5,569
	55,330
Operating surplus	**1,510**
Net finance costs	(5,496)
Net deficit for the year	**(3,986)**

Reconciliation of IPSAS and Cash Results (£k)

Net deficit for the year	**(3,986)**
Assets capitalised in the year	(1,814)
Depreciation in the year	2,015
Spend on commitments brought forward from 2011	2,609
Commitments carried forward to 2013	(2,136)
Finance costs for post-employment benefits	5,333
Post-employment benefits	(1,292)
Use of surplus from 2011	1,000
Other IPSAS timing differences	(359)
Surplus per cash accounts	**1,370**

Member States' Contributions (£k)

Austria	869
Belgium	1,094
Denmark	735
Finland	576
France	6,160
Germany	7,880
Greece	720
Iceland	31
Ireland	482
Italy	4,856
Luxembourg	92
Netherlands	1,828
Norway	904
Portugal	522
Slovenia	9
Spain	3,306
Sweden	1,047
Switzerland	1,070
Turkey	1,122
United Kingdom	5,852
	39,155

Co-operating States' Contributions (£k)

Bulgaria	51
Croatia	70
Czech Republic	202
Estonia	23
former Yugoslav Republic of Macedonia	9
Hungary	148
Israel	199
Latvia	34
Lithuania	45
Montenegro	4
Morocco	90
Romania	195
Serbia	44
Slovakia	94
Slovenia*	51
	1,259
Single Additional Contributions	**454**

** Slovenia became a Member State on 1 December 2012*

Looking to the future

The Centre's strategy for the period up to 2020 is based on the vision of ECMWF being the acknowledged world leader in global, medium-range numerical weather prediction. In other words, it will provide the best possible forecast products to our member countries, particularly to national weather services, for the benefit of society.

The principal goal of this strategy is to improve the Centre's global medium-range weather forecasting systems to provide reliable forecasts of severe weather events. We will furthermore endeavour to meet requirements for high-quality near-surface weather forecast products such as precipitation, wind and temperature.

ECMWF will also strive to do the following:

- Improve the quality of its monthly and seasonal forecasts.
- Support climate monitoring with state-of-the-art reanalyses of the Earth-system.
- Contribute towards the optimisation of the Global Observing System.
- Deliver operationally global analyses and forecasts of atmospheric composition.

After extensive discussion with its advisory committees and Council, each year ECMWF updates its four-year programme of activities and from that we produce a more detailed annual plan for the forthcoming year. The backdrop to these activities is the delivery of ECMWF's Strategy 2011–2020. In addition, in 2012 we developed a new integrated framework to describe ECMWF's activities. This framework involves eight key objectives that cover all aspects of the work of the Centre. Associated with these objectives are detailed work plans describing the developments that will take place in 2013.

Underpinning the many planned developments is a continued commitment for ECMWF to be a user-focused organisation where all activities are driven by the requirement to improve forecasting systems and hence the quality of the forecasts. The emphasis will be on meeting the needs of member countries whilst reinforcing partnerships, particularly with space agencies, and maintaining strong links with the research community.

ECMWF'S EIGHT KEY OBJECTIVES

1. **Forecasting system development**: improve the forecasting system through development of model components and techniques to be introduced in upcoming new model versions.
2. **Science and innovation**: carry out innovative research with a long-term goal of improving and developing forecasting techniques.
3. **Data, products and services**: develop state-of-the art forecast products, data services, evaluation tools and visualisation for users (including those for other aspects of the natural environment).
4. **High-performance computing**: ensure provision of world-leading high performance computing and associated specialist facilities to meet ECMWF's and Member States' needs.
5. **Human resources and management**: develop and implement the strategy, policies and processes necessary to ensure that ECMWF attracts, retains and motivates the staff to achieve our goals.
6. **Infrastructure**: provide the physical infrastructure, IT and business services needed to support our staff and the delivery of our goals.
7. **Finance and control**: develop and utilise finance and management information systems to meet ECMWF's reporting obligations, provide an effective control environment and support informed decision-making.
8. **Partnership**: develop effective partnerships with meteorological services, universities and other organisations that help ECMWF to deliver its goals.

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