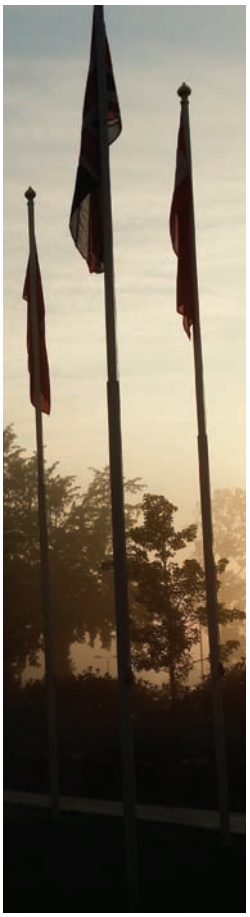
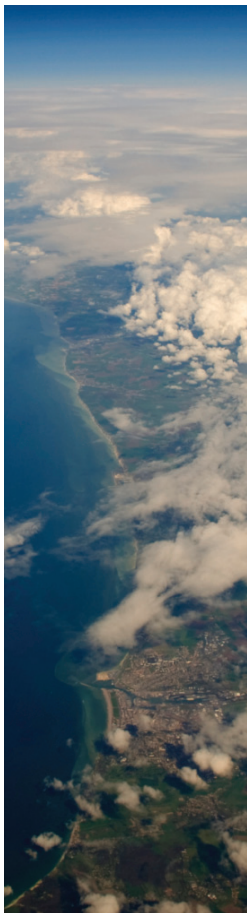
ECMWF

ANNUAL REPORT **2014**


ECMWF

ANNUAL REPORT 2014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Norway


Portugal


Serbia


Slovenia


Spain


Sweden


Switzerland


Turkey


United Kingdom

Member States as of January 2015

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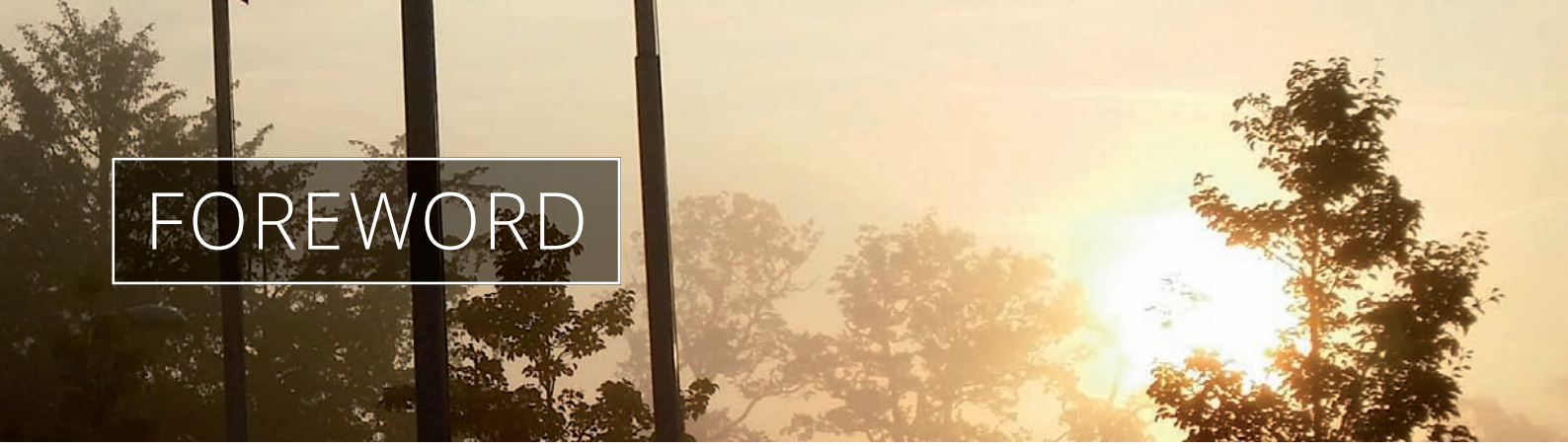


FOREWORD

Another year of advancing weather science to improve numerical weather prediction

The science that is created from investment in ECMWF is an important part of what ECMWF's founders had in mind forty years ago when they decided that weather forecasting would be better served by European nations pooling their resources to complement and support national activities. The pay-back from innovative research has to be measured in terms of decades rather than a single year. Still, in this Annual Report we are able to show how science and innovation has significantly taken us forward this year.

Considering our most valuable asset, it has clearly been a very good year for ECMWF's people. From medals to scientific awards and publications, the spotlights have shone on our men and women. Regarding our forecasts, the scientific upgrades implemented in 2013 have delivered on their promise, with improvements to our prediction of precipitation already noticeable. Our global collaboration with the World Meteorological Organization was exemplified in 2014 by the significant contribution ECMWF made to the first ever World Weather Open Science Conference in Montreal. In terms of research, 2014 was marked by advances in demonstrating the feasibility and utility of a coupled ocean–atmosphere data assimilation approach for our weather predictions. Last but not least, 2014 saw our supercomputing capability significantly enhanced by the operational introduction of our new Cray XC30 facility. Such a large migration of our operations required staff from across the organisation to work together, address issues, come up with innovative answers, and test and re-develop solutions.

Last year we identified four areas that will have a defining role in our future. The development of the next ten-year Strategy was initiated, with the launch of a wide-ranging consultation with our staff as well as with our Member and Co-operating States and other stakeholders. This has helped us to shape a first draft of our next ten-year Strategy, which after further refinement will be adopted by our Member States. The Future Accommodation project focussed on an assessment of our future needs in the light of current constraints. The Scalability Programme has started strongly and has already received recognition and rallied support from across the field.

2014 was a significant year for ECMWF because we signed an agreement on 11 November to implement the Copernicus Climate Change Service and the Copernicus Atmosphere Monitoring Service on behalf of the European Commission. These are what is known at ECMWF as third-party activities. The decision by the European Union to place this European-wide responsibility on ECMWF's shoulders is further evidence that the vision of the Centre's founders – fostering a collaborative approach by setting up an international organisation – was prescient. And it is a further demonstration of the return on the European investment in ECMWF, an investment made on behalf of Europe's citizens.

Alan Thorpe
Director-General

2014 AT A GLANCE

JANUARY

Co-operation agreement signed with CMA

The China Meteorological Administration (CMA) signs a co-operation agreement with ECMWF.

MACC-II General Assembly

The EU MACC-II project (Monitoring Atmospheric Composition and Climate - Interim Implementation) holds its Third General Assembly in Brussels. The project, co-ordinated by ECMWF, has few equivalents worldwide of pre-operational services for atmospheric composition.

FEBRUARY

Co-ordination meeting

ECMWF hosts a meeting of the three committees representing governments and the administration departments and staff from Co-ordinated Organisations. Discussions relate to the salaries, allowances and pensions of all staff working for a Co-ordinated Organisation.

Copernicus Climate Change Workshop

Climate experts gather at ECMWF to discuss the possible scope and content of the Copernicus Climate Change Service.

ERA-CLIM2 project starts

ECMWF hosts the kick-off meeting for ERA-CLIM2, a project to develop new climate reanalysis products with consistent descriptions of the atmosphere, ocean, land-surface, cryosphere, and the carbon cycle.

MARCH

New Director of Computing

Dr Adrian Wander becomes the Director of Computing at ECMWF.

Global Flood Partnership launched

Under the lead of the EC's Joint Research Centre and the Dartmouth Flood Observatory (University of Colorado), the Global Flood Partnership is launched at ECMWF. This unique forum brings together the scientific community, satellite and weather service providers, national flood and emergency management authorities, humanitarian organisations and donors. The aim is to develop a global flood observation and modelling infrastructure for managing and forecasting flood risk at a global scale.

TIGGE-LAM archive to improve regional ensemble forecasts

The World Weather Research Programme launches a new tool to improve regional ensemble forecasts of high-impact weather. TIGGE-LAM is an extension of the THORPEX Interactive Grand Global Ensemble (TIGGE) archive that includes weather forecasts from limited-area model (LAM) ensembles. Data from seven European ensemble systems is now available in a standard format through a single web portal hosted by ECMWF.

APRIL

New ECMWF website goes live

ECMWF launches its new website, designed to support traditional web content as well as specialised functions such as forecast charts and data access. The new site offers an opportunity to improve the usability, relevance, quality and accessibility of web content.

First Sentinel launch

Sentinel-1A is successfully launched on a Soyuz rocket from Europe's Spaceport in French Guiana. The Sentinel-1 mission is the first of six families of dedicated missions that will make up the core of Europe's Copernicus environmental monitoring network.

Scalability workshop

The workshop defines objectives for collaboration between numerical weather prediction centres, high-performance computing centres, academia and hardware providers – critical to the success of ECMWF's Scalability Programme. Discussions include common areas of research, the potential for shared computer code development, and future benchmarking strategies.

Metview interface to 3D interactive graphics

The latest version of Metview

We send more than 4 terabytes of data daily to 277 destinations in 61 countries

is released, with an interface to an external tool called VAPOR (Visualization and Analysis Platform for Ocean, Atmosphere, and Solar Researchers). In addition to 1D and 2D visualisation techniques, Metview now offers cutting-edge interactive 3D graphics.

Graphical products on the new website

The new catalogue of graphical products on ECMWF's website introduces faceted navigation with improved search functionalities.

MAY

Regional Meteorological Data Communication Network migrated

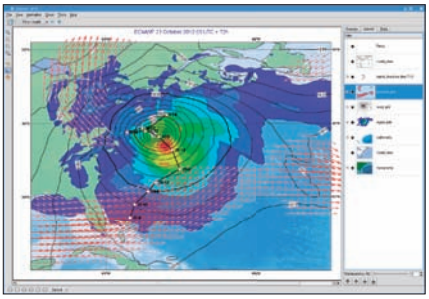
The RMDCN begins using the new network operated by Interoute Communications Ltd. The network has been modernised to meet future requirements for higher data volumes, increasing bandwidths and the continuing demand for membership from the wider WMO community.

Severe flooding in the Balkans

Weeks of wet conditions followed by exceptionally intense rain lead to disastrous and widespread flooding in the Balkans, in particular in Bosnia-Herzegovina and Serbia. Critical flooding is also reported in other regions including southern Poland, Slovakia, and the Czech Republic. Early warnings were provided by the European Flood Awareness System.

End of NWP training course for 2014

ECMWF's NWP training programme draws to a close for the year, having attracted over 130 participants



from 25 countries, from Member and Co-operating States and other national meteorological services and universities, including in South Korea, China, Brazil and Australia. Improvements this year include a brand new module on 'Advanced numerical methods for Earth-system modelling', a redesigned 'Data Assimilation' module, online training materials, and poster sessions at each training event.

Metview's new user interface

Metview's new interface makes it easier and quicker for users to work with the meteorological workstation, offering a clearer layout and enhanced search functions.

JUNE

Second OpenIFS user meeting

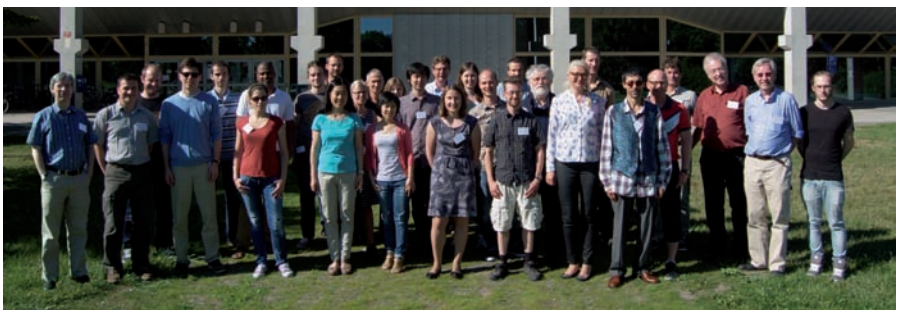
Users of ECMWF's OpenIFS gather at Stockholm University for a day of lectures and two days of practical sessions using Metview and the Single Column Model (SCM). OpenIFS aims to provide a long-term, sustainable and easy-to-use version of ECMWF's Integrated Forecasting System (IFS) for education and research at universities and research centres.

Annual user meeting

More than 80 professionals from national meteorological services, businesses and international organisations meet at ECMWF to learn about new developments, exchange ideas on the use of ECMWF data, and share their experiences. For ECMWF, the meeting is a valuable opportunity to gather feedback on its forecast performance and services.

New Weather Room opens

ECMWF officially opens its new Weather Room. Previously the Library, this new room provides a real-time working environment with state-of-the-art video displays.



2014 AT A GLANCE

It also provides a flexible space for informal meetings for small groups, a reception point for seminars and meetings and an interactive discussion space for group talks and education sessions.

New scalable acquisition and pre-processing system (SAPP) launched

In response to changes in computing architecture and a sharp increase in satellite data in recent years, ECMWF introduces a new acquisition and pre-processing suite. The new SAPP system is part of a wider project to develop a Continuous Observation Processing Environment aimed at building a more scalable, efficient and effective system for successive processing stages involving filtering observations and complex quality control procedures.

Severe convective storms in western Europe

Severe convective storms affect western Europe throughout the summer, with strong wind gusts and heavy rain causing a number of fatalities and widespread damage. The study of these cases, along with user feedback, indicates there would be benefit in developing severe weather products focussed on forecasting deep convection.

JULY

ECMWF Fellowship Programme launched

ECMWF launches its Fellowship Programme to foster and formalise links with individuals who are carrying out pioneering scientific and technical research in areas relevant to the Centre's strategic goals. Professors Tilmann Gneiting, Rupert Klein and Tim Palmer become the first ECMWF Fellows.

AUGUST

MACC-III starts

The EU MACC project begins a new eight-month phase, providing pre-operational services while the Copernicus Atmosphere Monitoring Service is being set up.

World Weather Open Science Conference (WWOSC)

WWOSC, the first scientific conference of its kind, takes place in Montreal, Canada. As well as weather science, discussions focus on social sciences and the economic impacts of weather in many sectors, such as energy, health and insurance. Increasing collaboration between government services, academia, the private sector and professional organisations is another topic.

SEPTEMBER

Annual Seminar on 'Use of satellite observations in NWP'

Both early-career scientists and experts attend presentations on the use of satellite data by leading scientists at ECMWF and from around the world.

First operational forecasts on new Cray

The first operational forecasts are produced on 17 September following the successful migration of ECMWF time-critical operational suites. The new Cray high-performance computing facility provides ECMWF with the computing power needed to implement the next major step in its strategy, namely the upgrade in horizontal resolution.

OCTOBER

Climate symposium

EUMETSAT and the World Climate Research Programme hold a symposium entitled 'Climate Research and Earth Observations from Space – Climate Information for Decision Making', with ECMWF Director of Research Erland Källén on the organising committee. The findings and recommendations are to be published in the Bulletin of the American Meteorological Society (BAMS).

First reanalysis of 20th century released

The first ECMWF reanalysis of the 20th century, ERA-20C, is released. Produced as part of the ERA-CLIM project, it covers the period January 1900–December 2010, with three-

hourly products describing the spatial and temporal evolution of the atmosphere, land surface and ocean waves.

25 years of IFS/ARPEGE

The coding of the first version of the IFS/ARPEGE model was initiated at ECMWF in 1987 as a joint project between ECMWF and Météo-France. Many scientific projects, sub-projects, and operational and research options have since been built around this initial code, for both data assimilation and forecasting aspects.

Cyclone Hudhud causes fatal blizzard in Nepal

More than 40 people are killed as a devastating blizzard hits the Annapurna massif in north-central Nepal. The forecasts gave a strong indication of extreme snowfall in the region more than a week in advance. The track of cyclone Hudhud was consistently well predicted, even in forecasts initialised during its early stages, and this led to the high predictability of the snowfall event.

NOVEMBER

Joint HEPEX/H-SAF workshops

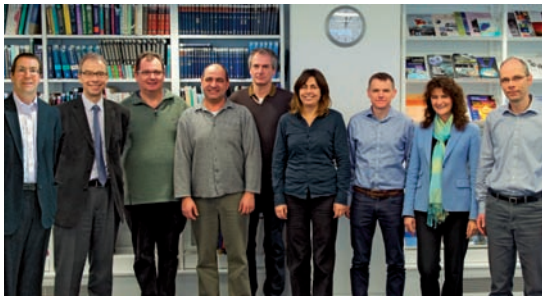
Experts in hydrological product development, satellite data assimilation and hydrological forecasting from both research and operational centres meet at ECMWF for a week of workshops and presentations. The emphasis is on improving the implementation of satellite products in NWP systems and hydrological models.

Copernicus delegation agreement signed

The European Commission and ECMWF sign a delegation agreement for ECMWF to implement both the Copernicus Climate Change Service and the Copernicus Atmosphere Monitoring Service until the end of 2020. The two services represent an investment by the EU of €291 million over seven years and will draw on contributions from across Europe.

Active assimilation of BUFR reports

ECMWF starts actively assimilating BUFR reports (binary code) in the operational forecasting system. These replace certain observations no longer being exchanged on the Global Telecommunication System in the traditional alphanumeric codes. Forecast scores are expected to improve as the quantity of BUFR data acquired and processed gradually increases.



Closing symposium of THORPEX

The ten-year THORPEX research programme, in which ECMWF has been heavily involved from the outset, draws to a close. Many legacy activities continue, such as TIGGE and follow-on research programmes.

DECEMBER

Additional clustering time periods available

ECMWF starts to disseminate and archive clustering products for three additional time windows. ECMWF clustering is one of a range of products that summarise the large amount of information in the ensemble forecast. The clustering gives an overview of the range of different large-scale (synoptic) flow patterns over the North Atlantic and Europe that may occur during the forecast period.

CHARMe system launched

The EU-funded CHARMe project holds its final review meeting and launches the CHARMe system for sharing information about climate datasets. ECMWF developed one of the tools, the Significant Event Viewer, a web-based graphical tool for associating time series of climate variables with relevant events.

ADVANCING WEATHER SCIENCE

Research and development

ECMWF scientists are constantly pushing the boundaries of existing research to improve the way we predict the weather and its impacts. Applying cutting-edge science to our forecasting system helps to make sure that ECMWF's predictions meet the evolving needs of our users, and that they continue to be world leading. Key to the Centre's success is our collaborative approach to research, including working with space agencies, national meteorological services and the research community worldwide.

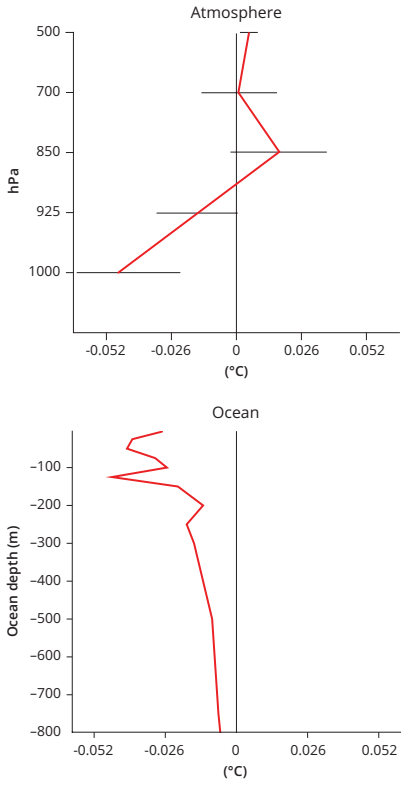
2014 was a very important year for data assimilation, the combination of a short-range forecast with the latest observations to achieve the best possible representation of the current state of the atmosphere. ECMWF scientists are exploring advances in both variational and ensemble-based methods. In 2014, good progress was made in experiments with ensemble Kalman filter (EnKF) formulations of data assimilation. Tests of hybrid variational-EnKF algorithms have shown encouraging results.

The year also saw the first demonstration of the feasibility of coupled ocean–atmosphere data assimilation. A coupled system was developed over a period of three years and will be applied in a new climate reanalysis of the 20th century. It is capable of capturing observed coupled processes, better exploiting the potential of near-surface satellite observations, and providing good-quality initial conditions for coupled forecasts.

Forecast quality depends on the suitability of the numerical methods used. A problem with forecasts of Sudden Stratospheric Warmings (SSW) was traced to errors in the vertical advection, which were in turn found to originate in the semi-Lagrangian numerical scheme used in the Integrated Forecasting System. A modification of the semi-Lagrangian departure point was developed, leading to significant improvements in the forecasting of SSW events in both the short and medium range.

A new approach to the representation of higher-order nonlinear terms in the forecasting system's governing equations brought improvements with respect to kinetic energy distributions. This has led to better representations of extreme weather phenomena, such as high-intensity rainfall near steep orography and high wind speeds in the vicinity of jet streams and weather fronts.

Higher model grid resolutions are one of the key drivers of better forecasts. Experiments were carried out to examine the behaviour of the model and the analysis at a horizontal grid length of approximately 8–10 km. A new grid representation was developed that will allow a higher resolution to be introduced efficiently in 2015/16.



▲ **Better fit with observations.** Vertical profile of the difference in background temperature root-mean-square error between the coupled and uncoupled assimilation systems with respect to conventional temperature observations over the tropics for September 2010 for the atmosphere and the ocean. The horizontal lines are error bars. The negative difference in the lower atmosphere and in the upper ocean shows that the coupled assimilation system produces a background closer to observations near the air–sea interface. This illustrates the benefits of atmosphere–ocean coupling in the assimilation process.

"Today's weather forecasts and climate predictions are likely to evolve towards seamless weather–climate–impacts forecasting."

WWOSC End of Conference Statement

OPEN SCIENCE CONFERENCE

ECMWF's collaborative approach to research is illustrated by its active role in international weather science meetings. The first ever World Weather Open Science Conference, which took place in Montreal from 16 to 21 August 2014, is a case in point.

ECMWF Director-General Alan Thorpe co-chaired the International Organizing Committee of the event, which attracted 1,000 meteorologists, forecasters, social scientists and application developers from over 50 countries. Twenty delegates from the Centre attended the Conference. Diverse scenarios for the development of weather science and its applications in various fields were proposed, often focusing on the prediction of extreme weather hazards.

The scientific goal of achieving seamless predictions – using integrated modelling systems for all time scales, from a few minutes to weeks, months and years ahead – received strong support from participants. The Conference explored the integration of meteorology with hydrology, for flood forecasting, and with atmospheric chemistry, for air quality forecasting. Both areas are important subjects of research at ECMWF.

The WMO World Weather Research Programme is a key vehicle for transnational collaborative research projects that help address the issues raised at the Conference. ECMWF staff, along with many colleagues around the world, will play a major part in three new programmes: polar prediction, subseasonal-to-seasonal forecasts, and high-impact weather.

The Conference led to international scientific collaboration on a White Book to be published by the WMO in mid-2015. ECMWF staff contributed to 12 of the 25 collaborative papers brought together in the publication.

IMPROVING OUR FORECASTS

Forecast quality

To provide the best possible input for our Member States' national forecasts, our global numerical forecasts must be of the highest quality. We monitor the quality of our forecasts by routinely evaluating performance using a set of headline scores and benchmarks.

Forecasts from other global centres also serve as a useful benchmark and show that ECMWF maintained its world-leading position in 2014.

Comparing forecasts against those made by the version of the forecasting system used in 2006 (ERA-Interim) allows us to identify the impact of changes made to the system. Recently, a 'dressed' ERA-Interim forecast was obtained by constructing a Gaussian probability distribution based on past forecast errors around each forecast. This has proven to be a rigorous benchmark for probability forecasts, highlighting a substantial increase in the relative skill of probabilistic forecasts for 850 hPa temperature.

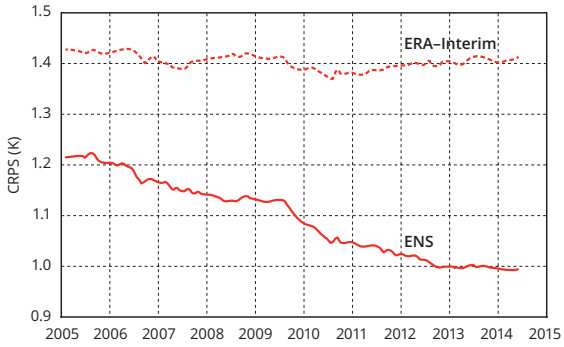
Recent upgrades to the forecasting system have brought about anticipated improvements in predicting precipitation, noticeable over 2014, continuing the long-term trend in increased skill.

Skill in predicting extreme events has also continued to improve. The tropical cyclone position error has stabilized at a low level, at almost half of what it was ten years ago. For the 10-metre wind speed and 24-hour precipitation indicated by the Extreme Forecast Index (EFI), the skill has reached its highest value so far.

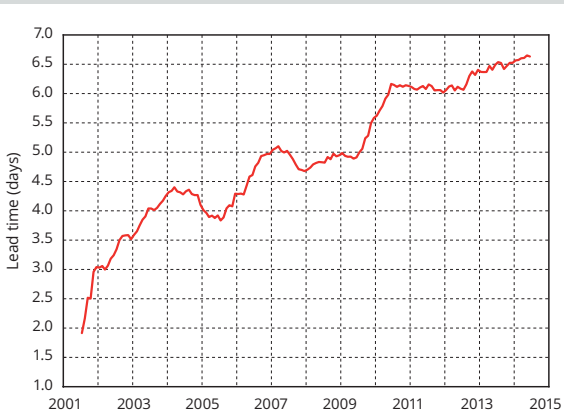
A major project in 2014 was the migration of all forecasting suites to the new Cray XC30 high-performance computing facility, which we started using for operational forecasts in September. Other technical projects during the year have also benefitted the forecasting system. The scalable acquisition and pre-processing (SAPP) system introduced in June has improved several aspects of pre-processing observation data.

ENSEMBLE FORECAST

▼ **Probabilistic skill of the ensemble forecast (ENS) relative to the dressed ERA-Interim forecast.** Results for temperature at 850 hPa in the northern hemisphere extratropics show that the relative skill has increased substantially in recent years for ENS compared to the fixed ERA-Interim system. The figure shows the 12-month running average values, based on the Continuous Ranked Probability Score (CRPS).



▼ **Ensemble forecast performance.** The positive long-term trend continued during 2014 as a result of upgrades to the forecasting system. The curve shows the lead time at which the Continuous Ranked Probability Skill Score (CRPSS) for 24-hour precipitation for the extratropical northern hemisphere reaches 0.1 (12-month running average), after which a forecast is of little value.



Accounting for uncertainty in forecasts is ultimately about enabling better decision-making

In November we started actively assimilating observations in BUFR format, a binary format promoted by the World Meteorological Organization (WMO). Forecasts will benefit from the higher quality and quantity of observations available. We supported Member States in their migration to using these observations by providing detailed quality monitoring results to the WMO, the EUMETNET Observations Programme and the EUCOS web portal.

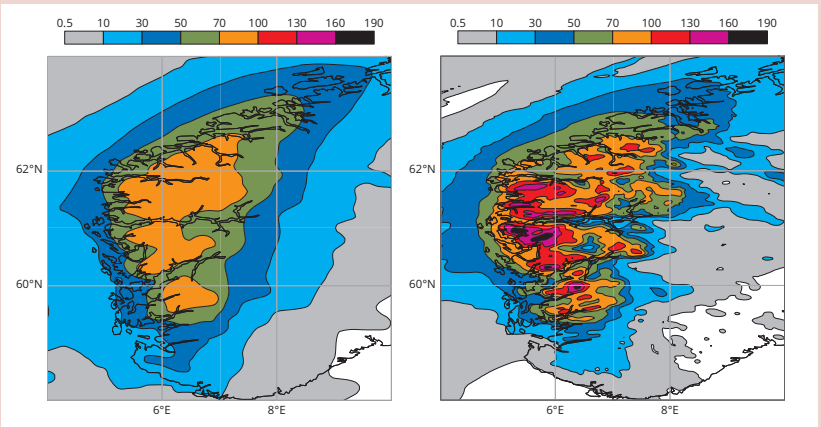
SEVERE EVENT CATALOGUE

In June we introduced a new portal to facilitate communication with forecast users. In the 'Forecasting Issues' section, we list issues we are aware of that affect the forecasts. We explain the cause of the problems and actions being taken to solve them. The idea behind the 'Severe Event Catalogue' is to collect and share material about severe weather cases to help with further evaluation. By evaluating single cases, we can gain better insight into the characteristics of extreme event forecasts and get ideas for further statistical investigations.

Cases so far include heavy rainfall/snowfall, convection, windstorms, tropical cyclones, and heat waves. They are chosen for the severity of the events and not in terms of forecast performance. The national meteorological services (NMSs) also investigate severe events affecting their countries and have access to additional material for verification. The Severe Event Catalogue is designed to facilitate the sharing of knowledge with NMSs for such cases. By the end of 2014, it listed details for 26 extreme events that occurred during the year.

Extreme flooding in Norway

One event was the extreme rainfall that led to severe floods in south-western Norway in October 2014. With information about the event and various forecasts from ECMWF and other centres presented on a single page, forecasters can better understand the meteorological conditions and good and bad aspects of the forecasts. ECMWF's Extreme Forecast Index gave a strong signal for extreme precipitation a few days ahead, but forecasts underestimated the intensity of the rainfall. Forecasts for 28 October from the Norwegian and Swedish meteorological services, using a high-resolution limited-area model (AROME), showed higher peaks in the intensity and a more detailed structure in the rainfall, confirming the value added by higher resolutions and limited-area models.



▼ **Forecasts of 24-hour precipitation from ECMWF (left) and the AROME model (right).**

MORE POWER

High-performance computing

Producing world-leading medium-range weather forecasts and cutting-edge research in numerical weather prediction requires one of the most advanced high-performance computing facilities. The demand for more accurate and reliable forecasts and for better early warnings of severe weather events, such as windstorms, tropical cyclones, floods and heat waves, can only be met by continual improvements of ECMWF's Integrated Forecasting System (IFS). Finer model grid resolutions, a more realistic representation of physical processes in the atmosphere, and the assimilation of more observations are the main drivers for better computational performance.

ECMWF's latest high-performance computing facility (HPCF), two Cray XC30s with over 160,000 processor cores in a resilient configuration, is one of the most powerful supercomputers in Europe. It has been producing ECMWF's operational forecasts since September 2014.

The two clusters of the Cray HPCF provide ECMWF and Member States with about three times the performance of the previous HPCF. To achieve the number of floating point operations (such as adding or multiplying two numbers) this system is capable of every second, the entire population of the UK would need to work continuously for just under two years.

2014 marked the culmination of three years of hard work, from carrying out a market survey, issuing an invitation to tender and selecting, customizing and installing the facility to preparing it for operational use. Cray delivered the first cluster, which had been built to order, to ECMWF in November 2013. In parallel with the physical installation, the IFS and all of the associated software had to be migrated. The sustained efforts of many people across the Centre led to the successful migration of the operational suites on 17 September 2014.

Installing a new HPCF is not a straightforward affair. There is only enough power and cooling capacity on-site to run three clusters of the size used in our HPCF. This means that one cluster of the new system is installed alongside the two clusters of the old HPCF. When the new cluster is accepted and is shown to be able to run the IFS properly, one of the clusters of the old HPCF can be powered down. This allows the installation and acceptance testing of the second cluster of the new system.

Numerical weather prediction has always been closely linked to supercomputing. A first international workshop on making NWP processes more scalable in preparation for the exascale era of supercomputing was held in April 2014.

▼ **Celebrating the successful migration of the operational suites to the new Cray HPCF.** Mike Hawkins (ECMWF), Peter Bauer (ECMWF), Erland Källén (ECMWF), Anne Glover (European Commission), Fiona Burgess (Cray UK Ltd), Alan Thorpe (ECMWF), Rob Varley (Met Office, UK), Peg Williams (Cray Inc, USA), Florence Rabier (ECMWF), Nyall Farrell (ECMWF), Adrian Wander (ECMWF) and Isabella Weger (ECMWF).

Developments in numerical weather prediction are intrinsically linked to developments in computing

RESOURCES FOR MEMBER STATES

Member States have access to 25% of the HPCF. Some of these computing resources are used for Member State time-critical applications. These include suites which prepare boundary files, extract data and run forecasting systems for national meteorological services including Météo-France, the UK Met Office and Germany's Deutscher Wetterdienst (DWD).

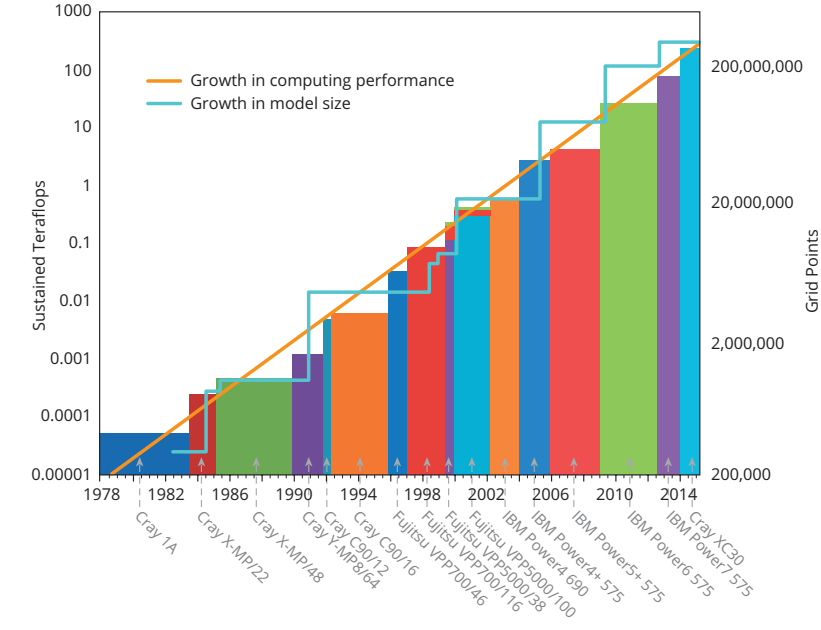
ECMWF also runs more than 2,500 jobs from over 200 different users, including Iceland running its HARMONIE limited-area model four times a day and Greece running its Wave Area Model twice a day.

A new Member State time-critical application approved in 2014 was for Portugal to run the ALADIN limited-area model twice a day.

Also in 2014, Germany's DWD asked for its geo-redundant backup computer centre to be implemented at ECMWF. The backup suite runs twice a day and executes both the DWD global model and its COSMO-EU model. Data will be sent to Potsdam if the emergency production is activated. The suite was set up by DWD in close co-operation with ECMWF. Data transfer tests to verify the suitability of the infrastructure for the challenging requirements were performed. The new MSPDS data transfer facility is used to enable the monitoring of data transfers by ECMWF and DWD operators.

The continued increase in the number of suites clearly demonstrates the success of the framework for Member State time-critical applications. Supporting these applications requires considerable human resources, especially when new suites are set up and migrated to a new HPCF.

A large part of the HPCF resources made available to Member States is used for research carried out by national meteorological services and research institutes. Seventeen Special Projects in six Member States involving investigations likely to be of interest to the scientific community were also initiated in 2014.



HPCF growth versus grid size of ECMWF's high-resolution forecast model. The Cray XC30 clusters are the latest in a series of HPCFs acquired to provide the computing power required for continual improvements in forecasts.

IMPROVING USERS' EXPERIENCE

ECMWF's users range from forecasters in national meteorological services to climate scientists, university students and users in private companies. We rely on feedback from users to ensure we tailor our events and products to their diverse and changing needs.

In 2014, we continued our extensive programme of events and training and launched new technical features to make it easier to work with ECMWF data.

Events and education

Providing training to experts from Member and Co-operating States is an essential part of what we do – enabling our partners to get the most from ECMWF's services and develop an advanced understanding of forecasting. Over 130 people took part in our numerical weather prediction (NWP) training courses in 2014.

We also welcomed over 750 external participants to workshops and seminars at ECMWF. Topics included high-performance computing and scalability; using ECMWF forecasts; the use of satellite data in NWP; and hydrological applications for the emergency management and water resources sectors.

Metview

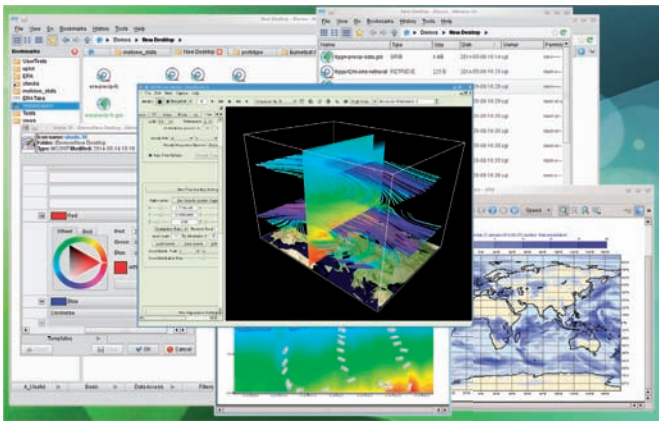
Metview is ECMWF's freely available workstation software for accessing, manipulating and visualising meteorological data. It is used in many weather services of ECMWF's Member and Co-operating States, as well as various other organisations and countries. 2014 saw the introduction of Metview's new user interface, providing some significant benefits to users, such as a tabbed interface, improved navigation between folders and new search functions.

Another addition during the year was the link to the VAPOR software for 3D visualisation. Metview can now convert GRIB data, a format widely used for meteorological data, into the format required by the VAPOR 3D visualisation system. This allows users to explore the 3D structure of meteorological features, and to see them change over time. This high-quality 4-dimensional visualisation of ECMWF forecast products could be a valuable aid for training and research.

Analysts at ECMWF were also given the ability to send Metview plots directly to the screens in the Weather Room, aiding discussions about weather situations.

VAPOR is a product of the Computational and Information Systems Laboratory at the National Center for Atmospheric Research.

▲ **Annual Seminar 2014 Group photograph**



▲ **The Metview user interface and a VAPOR 3D plot**

We work with users to develop products and training that are innovative and best meet their needs

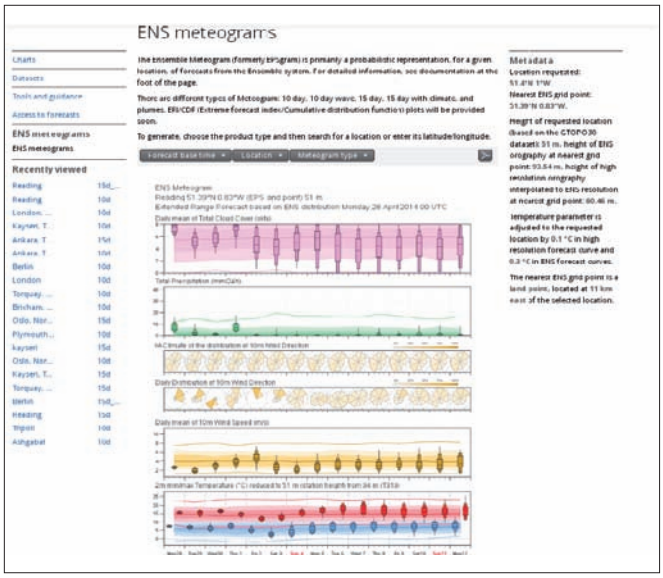
Graphical products on the new website

Graphical products are a popular feature on ECMWF's website, with most being updated daily and remaining available for several days. They are offered for various time steps, geographical areas and parameters.

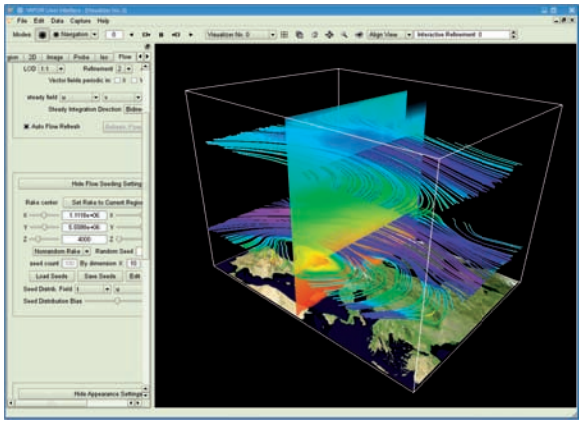
When we launched the new ECMWF website in April 2014, the catalogue of web charts was one of the redesigned features. Finding charts is easy thanks to a powerful search engine and a faceted search that lets users quickly refine their selection criteria. Future plans include more interactive features such as zoom, pan and click.

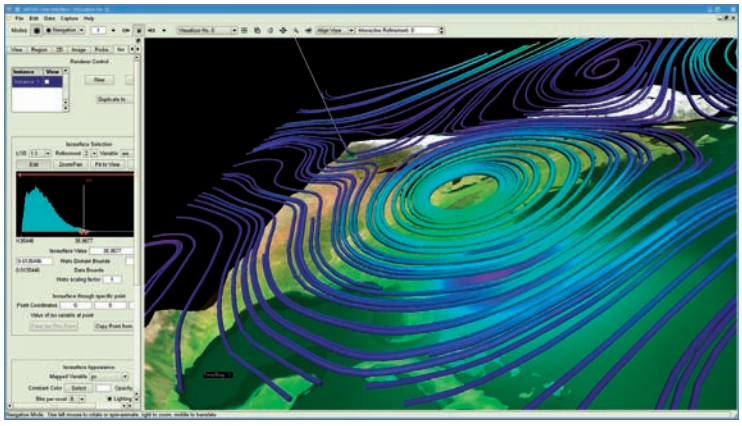
We also introduced two new types of ensemble meteogram (ENSgram) – a 15-day meteogram with climate, and a 10-day plume meteogram. ENSgrams show probabilistic forecasts for a single place selected by the user.

To make it easier to add new features and update content, we redesigned the underlying web infrastructure and also reviewed and improved the release process. This benefits other web applications too. It allows us to integrate new products on the ecCharts interactive web application for forecasters, new datasets on the ECMWF Data Server, and new charts packages on the website.



▲ **The new '15-day with climate' ENSgram.** This meteogram has supplementary model climate information for each parameter shown as bands and lines in the background – specifically the median and other selected percentiles (as denoted on the legend). This helps forecasters to interpret the data and identify extreme values.





▲ **VAPOR 3D plots**

PEOPLE

275 people representing 30 countries: truly international collaboration

Attracting and retaining people who can advance the science and technology behind weather prediction is one of the Centre's key objectives as well as one of its strengths.

In 2014, the Centre employed 275 people representing 30 nations. ECMWF staff wrote or co-authored more than 100 peer-reviewed scientific papers and attended dozens of conferences and workshops around the world. Forty visiting scientists came to the Centre for collaborative work with ECMWF staff.

In July, ECMWF launched a new fellowship programme to foster collaboration with renowned international scientists. The first three ECMWF Fellows appointed are Tilmann Gneiting, leader of the Computational Statistics Group at the Heidelberg Institute for Theoretical Studies (HITS) and Professor of Computational Statistics at the Karlsruhe Institute of Technology (KIT); Rupert Klein, Professor of Scientific Computing at the Free University of Berlin; and Tim Palmer, Royal Society Professor of Climate Physics at the University of Oxford.

"Being a Fellow is a great honour for me and has certainly intensified our collaboration. It's also a great opportunity for my group, several of whom have become involved in joint work," Professor Gneiting said.

A number of ECMWF staff received special recognition for their achievements.

Dr Peter Janssen, the Head of the Marine Prediction Section, was awarded the Fridtjof Nansen Medal by the European Geosciences Union (EGU). The medal is awarded for distinguished research in oceanography.

Dr Florence Rabier, Director of Forecasts, was made a Chevalier de la Légion d'Honneur, France's highest honour, in recognition of her outstanding contributions to meteorology.

The American Meteorological Society (AMS) elevated Dr Anton Beljaars, the Head of the Physical Aspects Section, to the prestigious rank of AMS Fellow, in recognition of his fundamental contributions to understanding atmospheric turbulence and land and ocean surface processes.

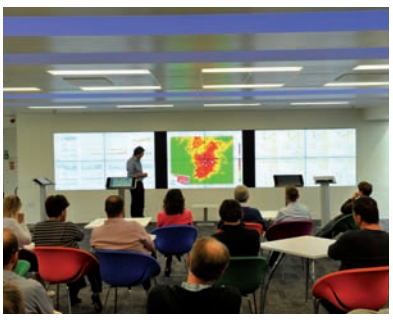
Deputy Director of Computing Isabella Weger was selected as one of HPCwire's 'People to watch 2014', a list drawn up by the well-known outlet every year to pay tribute to the best and brightest minds in HPC from around the world.

ECMWF staff are prepared to go the extra mile. Twenty-two of them swam, ran and cycled a total of nearly 200 km in a triathlon in March, raising more than £1,800 for charity in the process.

Collaborative working

The newly configured Weather Room opened in June 2014 and has proved to be a highly valued and appreciated addition to the Centre's working and collaborative facilities. It operates as a real-time working environment with state-of-the-art video displays, allowing staff from across the organisation to work together. It also provides a flexible space for informal meetings for small groups, a reception point for seminars and meetings and an interactive discussion space for group talks and education sessions.

The room is also used for a weekly weather talk which brings together staff from the Centre to learn about and discuss current topics relating to forecasts or scientific developments.



◀ (left to right) Professor Tilmann Gneiting; Dr Peter Janssen; ECMWF staff take part in the Green Park charity triathlon; ECMWF staff attend the weekly Weather Room talk.

DEVELOPING EUROPEAN **INFRASTRUCTURE**

Satellites

Satellites now provide most of the data used in our NWP models, although the other components of the observing system are still critically important. Our partnerships with space agencies in Europe (EUMETSAT and the European Space Agency, ESA) and worldwide (China, Japan and the USA) as well as our membership of the European Meteorological Infrastructure (EMI) continue to be highly beneficial.

Sentinel missions

In April 2014, ESA successfully launched Sentinel-1A, the first in a series of satellites that will make up the core of the EU's Copernicus environmental monitoring network.

ECMWF is implementing two of the six associated services: the Copernicus Climate Change Service (C3S) and the Copernicus Atmosphere Monitoring Service (CAMS). The delegation agreement for the implementation of the two services was signed in November 2014, placing our Member and Co-operating States at the heart of this ground-breaking programme.

CAMS provides information on global atmospheric composition by monitoring and forecasting constituents such as carbon dioxide, methane, ozone, carbon monoxide and aerosols. C3S will provide information on the past, current and future climate as well as on climate drivers, such as carbon dioxide, and impacts, such as sea level rise.

Weather forecasting would not be possible without individual countries collecting observations and sharing them internationally

Both services will use data provided by the six families of Sentinel satellites as well as other sources to support the comprehensive analysis and prediction of atmospheric composition and climate change. The satellites will for example provide global observations of sea and land surface temperature and sea level, and they will measure methane, ozone and other long-lived greenhouse gases as well as aerosols.

Near-real-time capabilities will provide information during extreme events that could endanger health and safety.

Vital feedback

ECMWF's collaboration with space agencies is crucial for the successful delivery of satellite services. In particular, ECMWF provides information on the impact of satellite observations on forecast quality; supports the preparation of new missions through observation simulation experiments; and is a key participant in user consultation processes for new satellite systems. ECMWF thus helps to ensure that maximum benefit is gained from European investment in new observation capabilities.

◀ **Successful launch.** Sentinel-1A was launched on a Soyuz rocket from Europe's Spaceport in French Guiana on 3 April 2014 (image © ESA - S. Convaja, 2014).

EUROPEAN INVESTMENT IN **ECMWF**

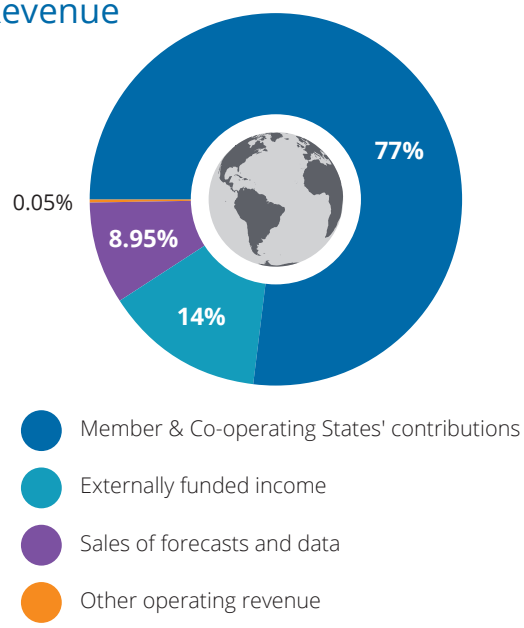
ECMWF is financed principally by contributions from its 34 Member and Co-operating States, which in 2014 totalled £42.0 million out of the Centre's funding of £54.5 million (net of internal tax). Revenue from sales of data and products provided additional income of £4.7 million, while funding of £7.7 million from external organisations supported research and the other goals of the Centre. ECMWF continued to invest in its staff, infrastructure and systems to provide the highest-quality products to its Member and Co-operating States.

ECMWF's budget remains on a cash basis and the Financial Statements include a reconciliation of the results under IPSAS and in cash terms. Under cash accounting, the Centre generated a surplus of £1.0 million in 2014, which is available either for future investment or distribution to Member States according to a decision to be made by the Council in 2015.

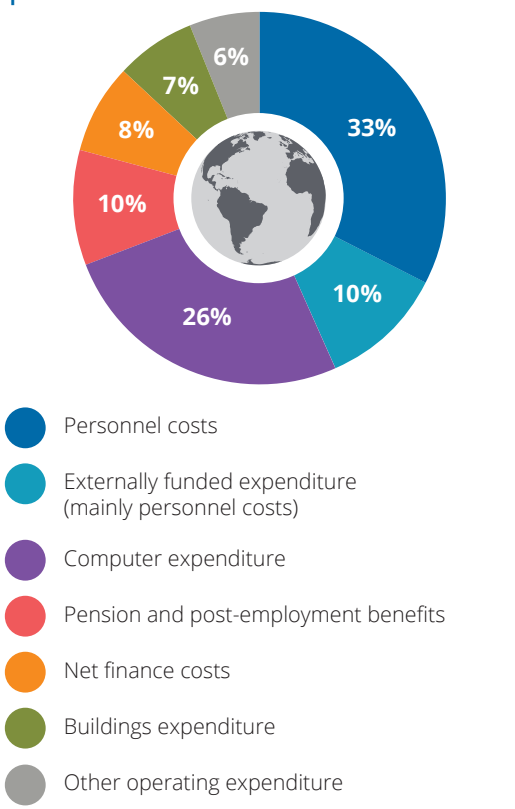
The Centre's future pension and post-employment medical cost obligations have been valued at £181.3 million and are fully guaranteed by the Member States.

The main areas of expenditure were remuneration and related items (£24.2 million; £18.9 million net of internal tax), pension and post-employment benefits (£5.5 million), computer expenses (£15.1 million) and buildings (£3.8 million). Net finance costs were £4.9 million. Costs associated with externally funded research projects amounted to £7.5 million (£6.0 million net of internal tax, of which £5.0 million were personnel costs). Capital investment, principally in IT and infrastructure, totalled £2.3 million.

Revenue



Expenditure



Statement of Financial Performance for the year ended 31 December 2014

Revenue	£k	£k
	2014	2013
Member & Co-operating States' contributions	41,997	41,184
Taxes	6,827	6,705
Externally funded income	7,700	6,876
Sales of forecasts and data	4,748	4,450
Other operating revenue	19	45
	61,291	59,260
Expenditure	**£k**	**£k**
Personnel costs	24,223	23,667
Pension and post-employment benefits	5,547	5,825
Buildings expenditure	3,847	3,837
Computer expenditure	15,086	14,769
Other operating expenditure	3,283	3,115
Externally funded expenditure [1]	7,524	7,037
	59,510	**58,250**
Operating surplus	**1,781**	**1,010**
Net finance costs	(4,859)	(6,087)
Net deficit for the year	**(3,078)**	**(5,077)**

Reconciliation of IPSAS and Cash Results	£k	£k
Net deficit for the year	(3,078)	(5,077)
Assets capitalised in the year	(2,261)	(3,620)
Depreciation in the year	2,457	2,279
Spend on commitments from previous years	1,847	2,136
Commitments carried forward to future years	(2,092)	(1,847)
Finance costs for post-employment benefit	4,681	6,260
Post-employment benefit	(556)	(37)
Accruals	(181)	678
Prepayments	210	344
Change in inventory	(81)	391
Other IPSAS timing differences	67	527
Surplus per cash accounts	**1,013**	**2,034**

1 Externally funded expenditure is inclusive of optional programme expenditure

Member States' Contributions	£k
	2014
Austria	898
Belgium	1,129
Denmark	759
Finland	595
France	6,363
Germany	8,139
Greece	743
Iceland	32
Ireland	498
Italy	5,016
Luxembourg	95
Netherlands	1,888
Norway	934
Portugal	539
Slovenia	115
Spain	3,415
Sweden	1,081
Switzerland	1,105
Turkey	1,159
United Kingdom	6,044
	40,547

Co-operating States' Contributions	£k
	2014
Bulgaria	53
Croatia	72
Czech Republic	209
Estonia	24
Former Yugoslav Republic of Macedonia	10
Hungary	153
Israel	205
Latvia	35
Lithuania	47
Montenegro	4
Morocco	93
Romania	202
Serbia	45
Slovakia	97
	1,249
Single Additional Contributions	201
Total Member & Co-operating States' Contributions	**41,997**

WORKING **TOGETHER**

Collaborating with our Member and Co-operating States

ECMWF routinely pursues extensive scientific and technical collaboration, in particular with national meteorological services in Member States, space agencies, the European Commission and the World Meteorological Organization (WMO). We work with the worldwide meteorological scientific community and participate in partnerships on projects funded by the European Union.

As well as providing NWP data and products, we collaborate closely with our Member and Co-operating States to develop modelling capabilities, design new products, and evaluate forecast quality. We support researchers in the Member States in their wider use of ECMWF's forecasts and resources, and strive to strengthen the already good collaboration with the academic community.

As part of this drive, the OpenIFS project makes an open, easy-to-use version of ECMWF's Integrated Forecasting System available for education and research at universities and research centres. 2014 was an especially good year for the OpenIFS, with the second user meeting being held in June at the Meteorological Institute of Stockholm University. The 36 participants from six European countries enjoyed using Metview and the single-column version of the IFS and discussing the results of exercises with ECMWF staff.

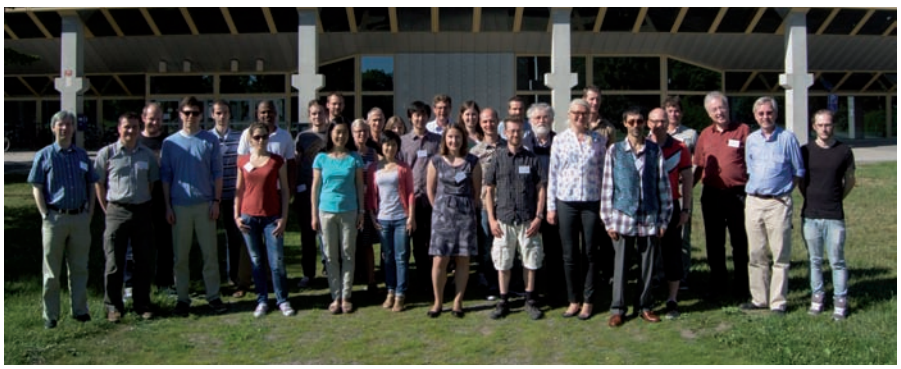
The Centre also works closely with meteorological services outside Europe. The China Meteorological Administration (CMA) and ECMWF signed a co-operation agreement in January 2014 and held their first bilateral meeting in April. It was agreed to co-operate in six areas across numerical weather prediction, observations and computing.

March 2014 saw the launch of a major international database available through a web portal hosted by ECMWF. The TIGGE-LAM database is an extension of the THORPEX Interactive Grand Global Ensemble (TIGGE) archive to include weather forecasts from limited-area model (LAM) ensembles. TIGGE has become a focal point for a range of research projects, including research on ensemble forecasting, predictability and the development of products to improve the prediction of severe weather.

The Centre's involvement in TIGGE is part of its role in the ten-year THORPEX research programme, which held its closing symposium in November 2014 in Geneva. Officially adopted at the 14th World Meteorological Congress in 2003, THORPEX was intended to improve the accuracy of one-day to two-week high impact weather forecasts. Nine members of staff at ECMWF were awarded Certificates of Appreciation at the November symposium for their contributions to this international collaborative project.

Our long-standing partnerships with space agencies, especially EUMETSAT and ESA, continue to be beneficial. We also enjoy strong scientific and technical co-operation

▼ **OpenIFS Workshop 2014.** Attendees of the OpenIFS Workshop in Stockholm.



ECMWF is a member-state organisation in which 34 countries pool their resources

with space agencies in the USA, Japan and China. ECMWF receives funding from the EU's Framework Programme for a number of research projects, and we work with EU organisations such as the European Environment Agency (EEA) and the Joint Research Centre (JRC). In addition, ECMWF is the computational centre of the European Flood Awareness System (EFAS). We also have close working relationships with the WMO in areas concerned with medium-range and long-range forecasts, verification, data formats, international exchange of data, and observation monitoring.

What is clear today is that no one individual, group or nation can go it alone – meteorology is a huge global enterprise that demands co-operation and collaboration if society is to have advance warning of extreme weather so that people can get out of harm's way

▼ **Nine members of staff received Certificates of Appreciation at the THORPEX symposium in Geneva.** David Richardson, Alan Thorpe, Baudouin Raoult, Manuel Fuentes, Peter Bauer, Carla Cardinali, Mark Rodwell, Florence Rabier and Martin Leutbecher.

SCALABILITY

Collaboration is crucial to the success of ECMWF's Scalability Programme, which was launched in 2013 to help prepare the Integrated Forecasting System for the exascale era of massively parallel supercomputing. A first international workshop held at the Centre in April 2014 defined objectives for collaboration by identifying common areas of fundamental research, exploring the potential for shared code components and defining future benchmarking strategies.

As part of the programme, ECMWF is the coordinator of the €4-million ESCAPE project. ESCAPE (Energy-efficient Scalable Algorithms for Weather Prediction at Exascale) will bring together 12 meteorological services, research institutes and hardware companies. Its aim is to develop world-class, extreme-scale computing capabilities for European operational numerical weather prediction.

In addition to collaborating with Member States, ECMWF will work in partnership with various consortia and other organisations such as HIRLAM, ALADIN, COSMO, NEMO, NEMO-VAR, high-performance computing (HPC) centres and hardware companies. Vendors will have an important role in the design process and by providing advice and access to the latest computing architectures. The collaboration with HPC centres will allow ECMWF to run its development codes on emerging novel computer hardware so that informed decisions can be made about them.

The Scalability Programme will provide accurate, efficient and scalable algorithms and code structures to cater for a variety of potential future high-performance computer architectures. It is likely to result in a revolution in the way numerical weather prediction is done.

LOOKING TO THE **FUTURE**

Making innovations in technology work for numerical weather prediction

Progress in numerical weather prediction (NWP) has been intimately connected with progress in supercomputing since the first numerical forecast was made about 65 years ago. More computing power has enabled us to increase the skill and detail of our forecasts. But with current supercomputer architectures, it will soon be impossible to deliver the required performance at a reasonable cost.

Future, more energy-efficient systems with exascale capabilities – performing at least a billion billion calculations per second – will rely on parallel processing at levels to which current NWP codes are not adapted. There is therefore a need to make NWP processes and algorithms scalable so that they will work efficiently on tomorrow's high-performance facilities.

This work has already started. ECMWF launched its Scalability Programme in 2013, and significant progress was made in 2014. Research on how to make data assimilation, numerical methods and the entire NWP processing chain more scalable is being conducted. ECMWF is now involved in a number of scalability-related projects under the EU's Horizon 2020 Research and Innovation programme.

This is a collaborative effort. It brings together meteorological services, research institutes and hardware companies. A quiet revolution in numerical weather prediction is under way, and ECMWF intends to play a leading role in it.

HOW WE **WORK**

Organisation of ECMWF at June 2015

Policy Advisory Committee

Scientific Advisory Committee

Technical Advisory Committee

COUNCIL
21 Member States

Finance Committee

Advisory Committee for Data Policy

Advisory Committee of Co-operating States

DIRECTOR-GENERAL
Alan Thorpe

DIRECTOR OF COMPUTING
Adrian Wander

DIRECTOR OF FORECASTS
Florence Rabier

DIRECTOR OF ADMINISTRATION
Nyall Farrell

DIRECTOR OF RESEARCH
Erland Källén

DIRECTOR OF ECMWF COPERNICUS SERVICES
Juan Garces de Marcilla


Bulgaria


Croatia


Czech Republic


Estonia


Former Yugoslav Republic of Macedonia


Hungary


Israel


Latvia


Lithuania


Montenegro


Morocco


Romania


Slovak Republic

Co-operating States as of January 2015

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