ECMWF

ANNUAL REPORT 2013

EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

ECMWF
ANNUAL REPORT 2013


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Member States as of July 2014

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FOREWORD

Weather prediction is critical for people and society, and in reviewing ECMWF over 2013 we reflect on our achievements for our Member States and society at large. Are European citizens better prepared for severe weather and able to anticipate the impacts of the weather on their lives? To answer these questions positively, which this Annual Report shows we can, ECMWF depends on the European co-operation that lies at the heart of our success. This co-operation involves having the best scientific minds in Europe working together, focused on solving the toughest scientific problems in numerical weather prediction using supercomputing and data management technology that few nations on their own could have at their disposal. It also involves working in partnership across our Member States and even wider across the world.

Looking back at 2013 allows us to assess our successes and identify those areas where we can improve in future. This is akin to weather prediction itself where looking back and investigating how well our past forecasts performed, we can help remove errors in our prediction methodologies and specifically estimate the degree of confidence we can ascribe to individual future forecasts.

What are the vital statistics of 2013? Some 15 billion observations were ingested into our supercomputer and the predictions were computed at a sustained rate of about 90 teraflops. We disseminated over 1,400 numerical weather forecasts to our 34 Member and Co-operating States including to national weather services and businesses. Our research, computing, forecasts and administration is carried out by ECMWF's 270 staff located in Reading in the UK. In 2013, our weather predictions have continued to improve – we retain the acknowledged world leading position in global prediction out to 10 days and beyond. For example we have gained nearly a half-day predictability of precipitation in the medium-range in our ensemble forecasts. The reanalysis is producing a comprehensive and consistent assessment of the climate of the twentieth century. Our atmospheric composition information, including air pollutants, desert dust, and smoke from wildfires, is used by more than 1,500 users across the world.

As we look forward from 2013 it is becoming clear that there is a range of exciting opportunities. Weather prediction is never static and scientific and technological developments drive us on to achieve bigger and better results. We look forward to utilising more powerful supercomputers but recognise that the computer architecture of the future means that we have to develop our numerical codes to operate efficiently on that architecture. There are great opportunities associated with the Copernicus programme of the European Union, which aims to provide environmental information services to complement and extend what can be achieved for weather analysis and forecasting. As the various components of the Earth system such as the land surface, the oceans, and the cryosphere interact with the atmosphere, there is great benefit to weather forecasts of extending our models to include these other components.

2014 will see the start of ECMWF developing its next ten-year strategy which will come into force at the beginning of 2016. That strategy will include the plan for developing the world-class facilities that ECMWF needs to have at its disposal so that, for example, it can accommodate the data centre that it needs and continue to attract the best staff from across Europe.

Alan Thorpe
Director-General

Gerhard Adrian
President of Council

"A year in which forecasts helped to save lives during episodes of extreme weather."

2013 AT A GLANCE

ATHENS FLOOD (FEBRUARY)
An intense thunderstorm hits Athens causing severe flash floods, believed to be the worst in 50 years. The forecast gave first indications of the potential for heavy rainfall in this area seven days ahead, with a significant chance of rainfall totals well beyond the normal climate range.

FORECAST DATA FROM SANDY AVAILABLE TO RESEARCHERS (FEBRUARY)
ECMWF forecast data for hurricane Sandy becomes available for free download for research use via the TIGGE archive hosted at ECMWF. The archive contains ensemble forecast data from nine global models.

CO_2 FORECASTS AVAILABLE (MARCH)
ECMWF adds a new daily product to its large portfolio of global forecast products available on its website. Global atmospheric CO_2 concentrations are forecast with a five-day lead time. Later in the year, forecasts of dust (i.e. aerosol optical depth) and a UV index are also made available via MACC-II – the European project led by ECMWF that is developing the range of services for the Copernicus programme on the composition of the Earth's atmosphere.

HEAVY SNOW IN NORTHERN FRANCE AND BELGIUM (MARCH)
Exceptionally heavy snow (up to 50 cm) in northern France and Belgium causes major travel disruption and widespread power outages. The Extreme Forecast Index provided a good indication several days ahead of the likely location, timing and severity of the events.

EXTREME COLD IN NORTHERN EUROPE (MARCH/APRIL)
Much of northern Europe suffers from several weeks of exceptionally cold weather. As well as sub-zero temperatures, heavy snowfall and strong winds have a severe impact, including several fatalities. The onset of the cold episode was well predicted two weeks ahead by the monthly forecast.

'DISTINCTIVE CLIMATE SIGNALS IN REANALYSIS OF GLOBAL OCEAN HEAT CONTENT' (MAY)
ECMWF staff co-author an article published in *Geophysical Research Letters* explaining why the sea-surface temperature increases stalled in the 2000s. The study provides insights into making decadal predictions using a coupled atmosphere-ocean model. This illustrates the importance of using ECMWF's reanalysis for climate monitoring and understanding climate change.

FLOODS IN CENTRAL EUROPE (MAY/JUNE)
Several days of heavy rain, combined with saturated soil, lead to extreme flooding in large areas along the major rivers of central Europe. ECMWF's ensemble forecast gave an early indication of heavy precipitation and the high-resolution forecast captured the spatial distribution very well, although the intensity was underestimated.

USING ECMWF'S FORECASTS (JUNE)
This year's workshop theme is 'Integrated use of ECMWF forecast products in decision making and risk management' and allows the usual exchange of ideas and experiences on the use of ECMWF data and

2013 AT A GLANCE

products. For the first time, the meeting is open both to representatives of national meteorological services and also to commercial businesses, partner organisations, universities and research establishments.

MACC-II SUMMER SCHOOL (JUNE)
MACC-II organises its first Summer School in Anglet, France. Users of the services, as well as young scientists and engineers, took part in what is now a regular event.

SEVERE THUNDERSTORMS HIT CENTRAL EUROPE (JUNE)
Severe thunderstorms hit central Europe, particularly Switzerland and Germany. Damaging gusts and flash flooding were reported, and there were many injuries and some fatalities. ECMWF's forecasts gave useful indications of these events, but rainfall was higher than expected in some places.

CRAY CONTRACT SIGNED (JUNE)
A contract for a new high-performance computing facility (HPCF) is signed between ECMWF and Cray UK Ltd. Cray will provide a multi-petaflops supercomputing infrastructure from mid-2014 to mid-2018, with a three-fold increase in sustained performance.

WORKSHOP ON 'POLAR PREDICTION' (JUNE)
The workshop introduces the Polar Prediction Project (PPP) to the wider community, establishes ECMWF's role in polar prediction and provides scientific guidance for future developments. A planning meeting for the Year of Polar Prediction (YOPP) followed.

NEW MODEL CYCLE (JUNE)
The new cycle of the Integrated Forecasting System (IFS) features the long-anticipated upgrade of the vertical resolution from 91 to 137 levels. This affects the high-resolution forecast model, the assimilation process and the Boundary Conditions Optional Programme.

WALTER ZWIEFLHOFER STEPS DOWN AS DIRECTOR OF OPERATIONS (JUNE)
Walter Zwieflhofer leaves the Centre after 32 years, having played a major role in shaping the organisation, especially leading numerous supercomputer and other procurements.

ESTABLISHMENT OF THE FORECAST AND COMPUTING DEPARTMENTS (JULY)
The Forecast Department, created as part of the Centre's reorganisation, aims to ensure that ECMWF's forecasting products meet the needs of Member and Co-operating States, as well as supporting the activities of other service providers. The 24/7 operation of the computing infrastructure and forecast production is under the remit of the Computing Department.

WORKSHOP ON 'OCEAN REANALYSIS INTERCOMPARISON' (JULY)
The workshop considers the consistency between the ocean reanalysis products, an evaluation of whether reanalyses are fit-for-purpose, and the exploitation of reanalyses using the ensemble approach.

INSTALLATION OF DRY COOLERS (AUGUST)
The data centre infrastructure is enhanced by installation of dry air coolers for the HPCF. The new system is expected to reduce annual electricity consumption by an average of about 2 million kilowatt-hours.

ANNUAL SEMINAR ON 'RECENT DEVELOPMENTS IN NUMERICAL METHODS FOR ATMOSPHERE AND OCEAN MODELLING' (SEPTEMBER)
The seminar is part of ECMWF's educational programme and is aimed primarily at young scientists. This year it reviews recent advances and future challenges in high-resolution numerical modelling of the atmosphere and ocean.

2013 AT A GLANCE

ACCESSION AGREEMENT BETWEEN SERBIA AND ECMWF SIGNED (SEPTEMBER)
The accession agreement is signed between the Government of the Republic of Serbia and ECMWF in Belgrade. Serbia will become the 21st Member State after the agreement has been ratified by the Serbian Parliament.

NEW DIRECTOR OF FORECASTS (OCTOBER)
Dr Florence Rabier takes up the post of Director of Forecasts. In her previous role at Météo-France, she was responsible for bringing research through to operational implementation in the NWP models.

WINDSTORM (OCTOBER)
Known as Christian, St Jude and Simone, the windstorm kills 19 people across Europe and creates major disruption to traffic systems. Forecasts predicted the windstorm 4 to 5 days in advance.

WORKSHOP ON 'PARAMETRIC ESTIMATION AND INVERSE MODELLING FOR ATMOSPHERIC COMPOSITION' (OCTOBER)
ECMWF's data assimilation and forecasting system includes atmospheric composition (e.g. reactive gases, greenhouse gases and aerosols). The workshop explored options to optimally define the boundary conditions for atmospheric composition in a near-real-time data assimilation system.

WORKSHOP ON 'METEOROLOGICAL OPERATIONAL SYSTEMS' (NOVEMBER)
The 14th biennial workshop reviewed recent developments and requirements in data management and visualisation. There was a special focus on how to transition developments in research into operational products and services.

FURTHER NEW CYCLE OF THE IFS (NOVEMBER)
The new cycle of the IFS features several significant changes, such as a new convection scheme, and an extension to 91 levels in the ensemble forecast. Also the atmosphere and ocean models are directly linked in the ensemble forecast.

SUPER-TYPHOON HAIYAN HITS PHILIPPINES (NOVEMBER)
Super-typhoon Haiyan, one of the strongest tropical cyclones ever recorded, makes landfall in the Philippines, causing widespread destruction and the loss of over 6,000 lives. From the moment Haiyan formed (three days before landfall), ECMWF provided very consistent and accurate forecasts of its track towards the Philippines.

NEW TROPICAL CYCLONE PRODUCTS (DECEMBER)
New tropical cyclone products are developed in response to requests from users in the Member States. The new products show the predicted track of tropical cyclones out to 10 days (previously only to 5 days), and probability of storms occurring at various lead times during the forecast.

CO-OPERATION AGREEMENT WITH ACMAD RENEWED (DECEMBER)
The Centre's co-operation agreement with the African Centre for Meteorological Applications for Development (ACMAD) is renewed and will remain in force until January 2020.

NEW PRESIDENT AND VICE-PRESIDENT OF THE ECMWF COUNCIL (DECEMBER)
François Jacq (France) and Christian Plüss (Switzerland) step down as President and Vice-President of the ECMWF Council. Gerhard Adrian (Germany) and Miguel Miranda (Portugal) are elected as their replacements, both for a first term of office for one year.

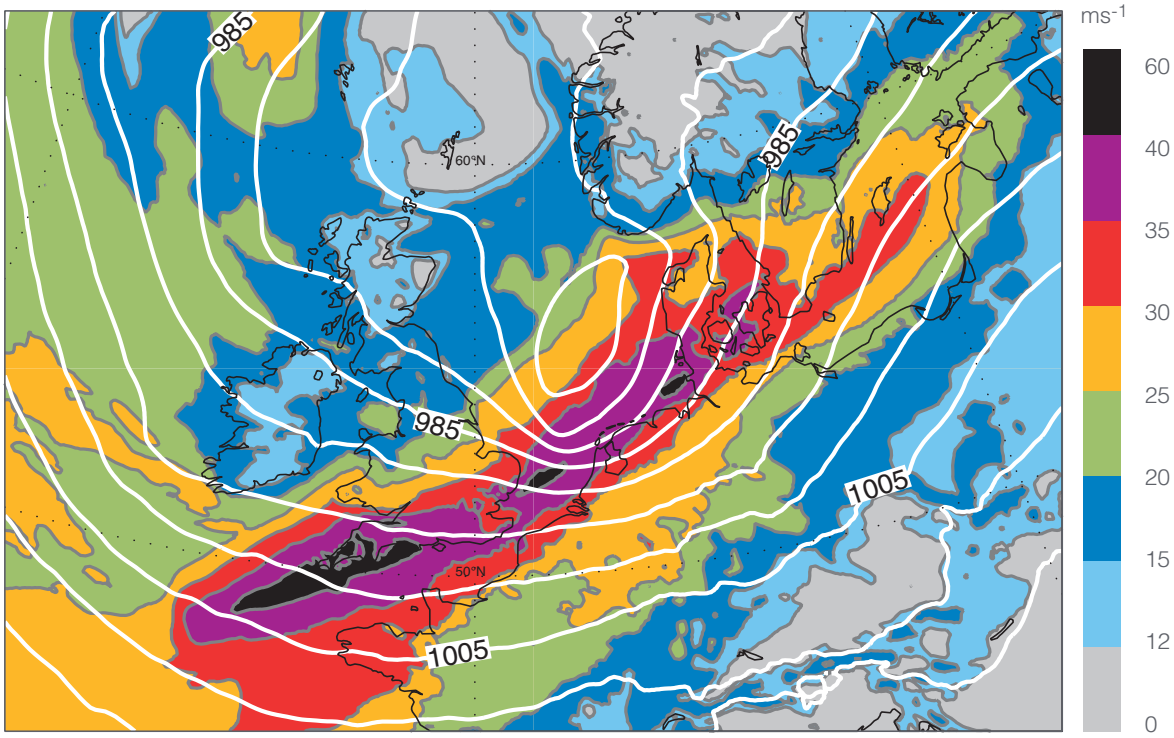
METVIEW ANNIVERSARY (DECEMBER)
The 20th anniversary of the first internal release of Metview is celebrated at ECMWF. Metview is ECMWF's meteorological workstation software for accessing, manipulating and visualising meteorological data, incorporating both an interactive and a batch mode.

2013 AT A GLANCE

STORM XAVER (DECEMBER)
The storm with the storm surge in the North Sea, the highest for 60 years (6 metres at Hamburg), is successfully predicted by the Netherlands based on ECMWF's forecasts.

NEXT-GENERATION NETWORK (DECEMBER)
The Regional Meteorological Data Communication Network was in need of modernisation to meet future requirements. For the new service over 90% of sites are formally accepted, well above the threshold required by the contract with Interoute Communications Limited.

END OF THE ERA-CLIM PROJECT (DECEMBER)
The three-year ERA-CLIM project led by ECMWF comes to an end. The project has improved the available observational record for the 20th century, and developed the observational input and technical infrastructure needed to produce a climate reanalysis going back 100 years or more. ERA-CLIM2 will start in January 2014.



Windstorm "Christian". Information from the ensemble forecast gave a signal for the windstorm 4 to 5 days in advance. Also the high-resolution forecast gave a good indication of the strength of the gusts. The figure shows the maximum wind gust between 00 and 24 UTC and mean-sea-level pressure at 12 UTC on 28 October for the high-resolution forecast from 12 UTC on 26 October 2013.

"Our aim is to improve our models and data assimilation and enhance our ensemble products at the medium and monthly ranges. 2013 has seen a half-day gain in predictability of precipitation in the medium range."

IMPROVING OUR FORECASTS

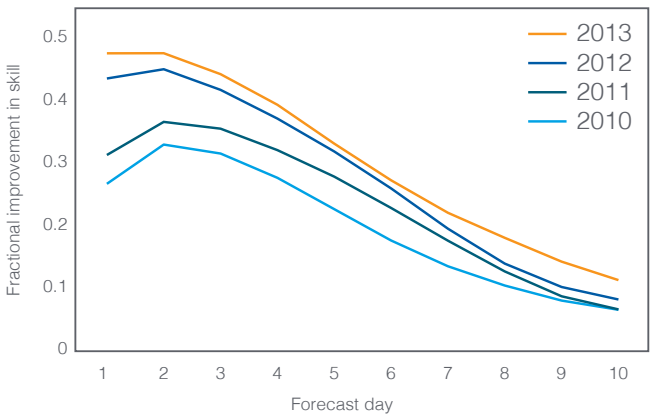
We evaluate forecast performance using headline scores that assess the overall performance of ECMWF's forecasts. This provides information to both users and model developers on the quality of our forecasts.

To isolate the impact of improvements we have introduced into our modelling system, we compare today's forecasts with those that would have been made with the system in operational use in 2006. This shows that in each year since 2010 the forecasts have improved because of new science introduced into the model.

For the ensemble forecast (ENS), we compare forecasts with those from other global centres for numerical weather prediction (NWP). In 2013 ECMWF has maintained its world-leading position. The ENS has also seen a noticeable increase over the past year in the skill of predicting precipitation. This amounts to around a half-day gain in predictability in the medium range.

There has been significant progress in predicting extreme events over the past few years. Examples include good forecasts of the heavy rain causing floods in Athens in February, heavy snowfall in northern France and Belgium on 12 March, exceptionally cold weather over much of Europe in March and early April, heavy rain in central Europe in May and June, and strong winds affecting Europe in October and December. Of course forecasts are not always as good, so investigating extreme events and getting feedback from users is essential.

The tropical cyclone position error has decreased and reached its lowest value so far. Also the skill of 10-metre wind speed as indicated by the Extreme Forecast Index (EFI) remains high compared with the skill over the last ten years.



High-resolution forecast performance. There has been a steady increase in skill of the current high-resolution forecasts from forecasting system improvements compared with those made using the forecasting system of 2006 (ERA-Interim) for calendar years 2010, 2011, 2012 and 2013. Curves represent the fractional improvement in the anomaly correlation coefficient at 500 hPa in the extratropical northern hemisphere.

Ensemble forecast performance. There has been a gain of half a day in the last year in the skill of the ensemble forecast in predicting precipitation. The curve shows the lead time at which the continuous ranked probability skill score for 24-hour precipitation for the extratropical northern hemisphere reaches 0.1 (12-month running average).

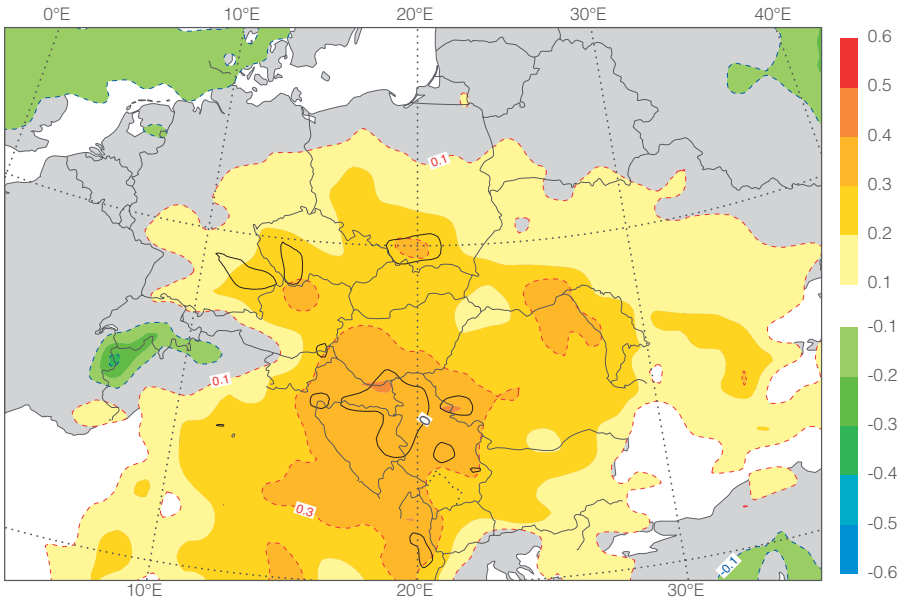
IMPROVING OUR FORECASTS

FLOODS IN CENTRAL EUROPE

(END OF MAY AND EARLY JUNE)

Several days of heavy rain, combined with saturated soil, led to extreme flooding in large areas along the major rivers of central Europe. ECMWF's forecasts signalled an extended period of unusually heavy precipitation more than ten days in advance. Closer to the event, the signal became stronger and more focused on the affected region, capturing the spatial distribution very well. However, the total amount of precipitation was underestimated in the forecasts over the northern Alps, where precipitation was enhanced as air was forced to rise over the mountains. Follow-up studies have shown that increasing the horizontal resolution of the model and revising the representation of cloud processes (both planned for forthcoming upgrades) significantly improve this aspect of the forecasts.

This event was the first real test for the operational European Flood Awareness System (EFAS), for which ECMWF runs the computational centre. EFAS provides real-time flood forecasts up to ten days ahead and our ensemble forecasts provide some of the meteorological input. Over the last week of May, EFAS forecasts showed a rapidly increasing probability of exceeding flood warning thresholds for wide areas in central Europe. Overall, EFAS performed well in most of the affected areas, although some peak discharges were underestimated.



Forecast from 00 UTC on 21 May 2013 for the five-day period 31 May to 5 June.
Extreme Forecast Index (shaded) shows areas at increased risk of anomalously wet conditions (higher values indicate higher risk). Positive values of the Shift-of-Tails (black contours) indicate where the most extreme precipitation might occur.

ADVANCING WEATHER SCIENCE

ECMWF scientists' mission is to push the boundaries of known research to improve how we predict the weather and its impacts. Meeting our users' evolving needs by carrying out ground-breaking new science which is introduced into our current system is what makes ECMWF's predictions the best in the world. Key to the Centre's success is its collaborative approach to research, including with space agencies, the research community across the world, and national meteorological services.

An evaluation of short-range forecasts against analyses shows a decreasing error in the specification of the state of the atmosphere at the start of the forecast – known as the initial state error. Significant gains have been made by improving the data assimilation and thereby extracting more information from the observations. Reducing the initial state error and improving the model contribute about equally to improvements in the skill of the medium-range forecasts.

In November 2013 we implemented a new convection scheme based on observational, theoretical and experimental studies. This addressed a long-standing problem of forecasts of the onset of precipitation from deep convection occurring too early during the day. Improving forecasts of the diurnal cycle of convection was a major breakthrough. Comparisons with radar and satellite observations show that the diurnal cycle of convection and the variability of convection over land are now more realistically represented, with typical rainfall maxima now being forecast to occur in the late afternoon or early evening.

The Ensemble of Data Assimilations (EDA) was extended from 10 to 25 members in November 2013. This provides a more realistic description of flow-dependent errors of our short-range forecast, so we now make better use of observations. This results in a significant improvement in weather forecast skill. The improved data assimilation, alongside an improving model and novel satellite science, means we now use more satellite data in cloudy and precipitating areas.

ECMWF also provides forecasts of ocean waves. With the inclusion of mixing associated with growing and decaying waves, biases presently found in sea-surface temperatures in summer hemispheres are substantially reduced.

During 2013 we started a research programme to improve the scalability and numerical efficiency of the Integrated Forecasting System (IFS) and data handling. This will provide algorithms and code structures for a variety of potential future high-performance computer architectures.

Radio Occultation Meteorology Satellite Application Facility (ROM-SAF) workshop hosted by ECMWF.

"ECMWF's role is to address the critical and most difficult research problems in medium-range NWP that no one country could tackle on its own."

John Hirst, Chief Executive, UK Met Office

NEW MODEL CYCLES IN 2013

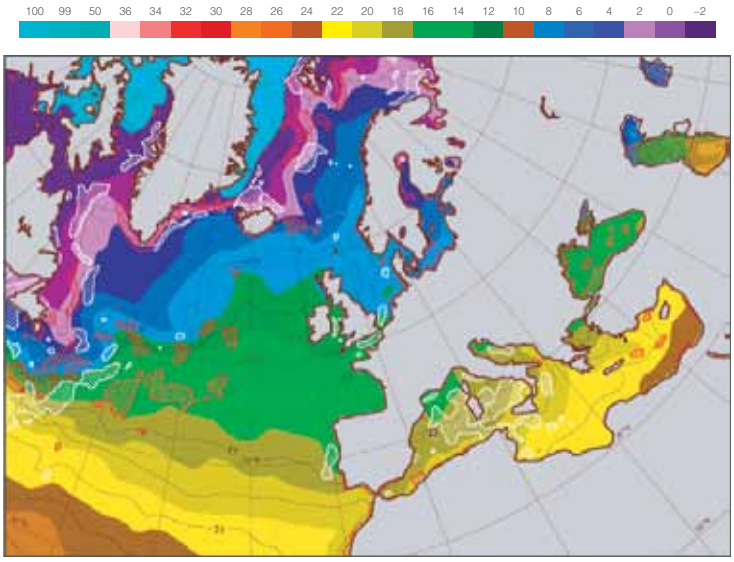
Each implementation of scientific advances is referred to as a new model cycle.

In June Cycle 38r2 came into operational use. The main innovation was the increase in the number of vertical levels from 91 to 137 for the high-resolution forecast (HRES), the Ensemble of Data Assimilations (EDA), the main assimilation (4DVAR) and the Boundary Conditions Optional Programme. The cycle enabled a better representation of physical processes such as those associated with clouds, inversions and vertically propagating gravity waves.

Cycle 40r1 of the IFS was implemented in November 2013. It features improvements in the use of satellite data and the revised convection scheme.

There were also changes to the model that reduced forecast errors in the two-metre temperature and improved the prediction of winds in the boundary layer. These changes were beneficial for the predictive skill of HRES in the northern hemisphere, especially during autumn and winter. In addition, the temperature and humidity forecasts are significantly improved in the lower troposphere in the tropics.

The number of vertical levels used for the ensemble forecast (ENS) was increased from 62 to 91 in Cycle 40r1. This enhanced the representation of clouds, boundary layers and the interaction between troposphere and stratosphere. The interaction between the atmosphere and ocean was improved by coupling the atmosphere and ocean models from the start of the forecast. These changes, along with others affecting the estimation of initial uncertainty, resulted in a general improvement in ENS probabilities. There was also a positive impact on the skill of the monthly forecast.



Linking the atmosphere and ocean in the ensemble forecast. The direct link between atmosphere and ocean in the ensemble forecast (ENS) from the start causes the ocean temperature to change more realistically; this can make the weather forecast more accurate. The solid shading shows sea-surface temperature (SST) and sea ice cover from a 10-day forecast using Cycle 40r1. Stippling shows where SST differs more than 1°C from what it would have been with the previous model configuration – red denotes warmer with Cy40r1 and white colder. The western Mediterranean, for example, is colder with the new configuration because strong northerly winds during the forecast period have effectively cooled it down.

“Weather predictions from ECMWF offer substantial input to forecasts provided to European citizens.”

IMPROVING USERS’ EXPERIENCE

Key to ECMWF’s success is its ability to meet its users’ needs. The focus in 2013 has been on improving usability of computing resources, encouraging feedback, and strengthening training activities.

Enhanced access to ECMWF’s general-purpose computer resources by Member and Co-operating States was achieved by replacing the ECGATE service with an infrastructure based on Linux clusters. Users have benefitted from improved usability of the system and considerably more computer resources.

The seven visits to Member and Co-operating States have provided valuable feedback about how to improve services. Moreover, a survey of users was conducted to understand their requirements, with returns from users in 64 countries.

In June the annual users’ meeting attracted an international group of 90 people. With ECMWF forecasts now being used by a broad range of organisations, this year the meeting brought together representatives of national meteorological services, businesses, partner organisations, universities and research establishments. Invited speakers illustrated the impact of weather information in the financial and energy sectors, new technologies for providing forecasts, and the use of ECMWF’s meteorological data for humanitarian relief operations.

We have put increased effort into providing flexible learning, improved educational tools and new training opportunities. This included running a series of seminars on the web, referred to as Webinars, and three e-Learning events aimed at reaching out to a wider audience. Also participants in NWP training have been given the opportunity to understand the working of the model physics by running forecasts. We have introduced a new course, run in partnership with EUMETSAT, to provide an overview of the use of satellite observations in operational NWP.

The OpenIFS project, started in 2011, maintains a portable version of ECMWF’s forecasting model that can be used for education and research by universities. It provides academic researchers with a world-class NWP model and increases familiarity with a range of ECMWF products, promotes ECMWF research aims and fosters further collaborations with external researchers. In 2013, 12 licensed institutes used the model for research and education. Experience indicates that the aims of the project, to develop and promote research, teaching and training on NWP and related topics with academic and research institutions, are being met.

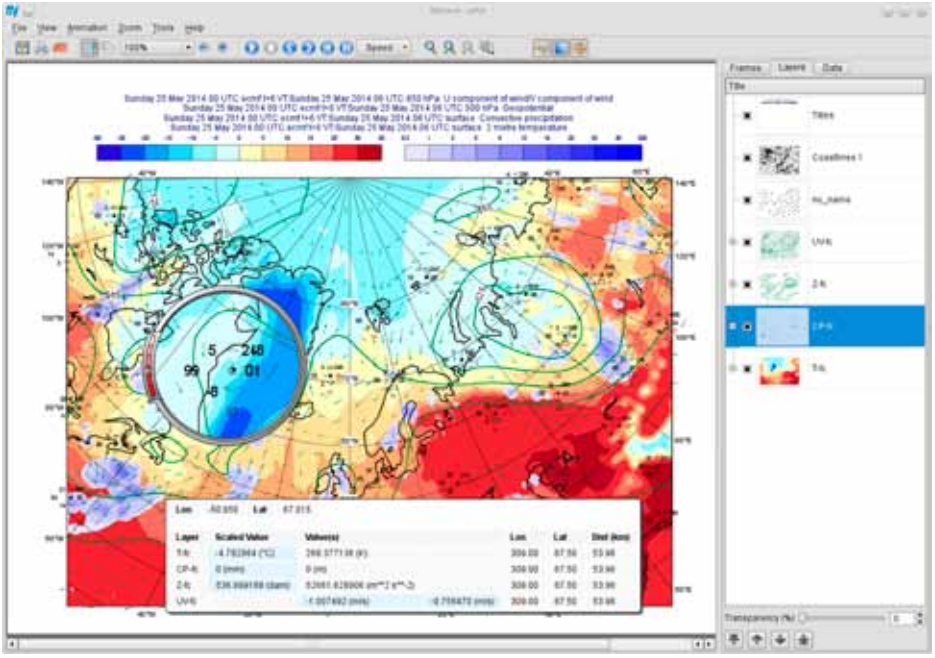
TWENTY YEARS OF METVIEW

The 20th anniversary of Metview was celebrated at ECMWF in December 2013. Metview is ECMWF's meteorological workstation software for accessing, manipulating and visualising meteorological data, and providing powerful interactive and batch modes. It is used by analysts and researchers, inside and outside ECMWF, to analyse observations and NWP data.

Metview was launched as a co-operative project between ECMWF and INPE/CPTEC (Brazil) with assistance from Météo-France. Its graphical user interface and powerful Macro language made it the easiest way to handle ECMWF's data.

Metview offers a single unified interface bringing together many technologies developed at ECMWF for handling and visualising meteorological data. These include access to the MARS data archive, handling of the most important meteorological data formats, grid-point interpolation, and high-quality plotting.

The future of Metview includes some exciting developments. A revised user interface will enable new users to learn Metview even more easily and give experienced users quicker access to its functionality. Metview's powerful data manipulation capabilities can now be interfaced with the 3D visualisation provided by the VAPOR software.



Screenshot of Metview. Metview's advanced plotting capabilities bring together data from different sources in a single display. Metview will continue to support research, monitoring and training at ECMWF while tackling the challenges of increased model resolution and data volumes.

"Our HPCF ingests 40 million observations a day, hosts the largest meteorological archive in the world, and is for shared use with Member States."

MORE POWER

The ECMWF computer facility runs the world's most sophisticated medium-range prediction model of the global atmosphere and oceans, and contains the world's largest archive of NWP data. Without the most advanced high-performance computing facility (HPCF), we cannot improve the forecasting system and make full use of the ever-increasing amount of satellite data.

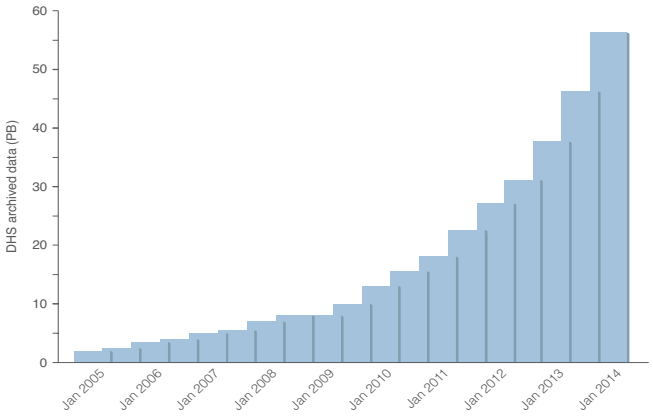
A state-of-the-art HPCF is crucial for ECMWF to exploit scientific advances and keep its position as the provider of the world's best medium-range global weather predictions.

In 2013, the HPCF processed 370,000 parallel jobs and over a million serial jobs per week. 25% of the computer resources are made available to Member States. The HPCF is based on IBM POWER hardware and the migration from POWER6 to POWER7 technology, which was completed in 2013, has provided an almost three-fold increase in sustained performance.

To ensure the HPCF continues to meet the needs of its Member States, a contract was signed with Cray UK on 24 June 2013 for the provision of a new HPCF from mid-2014 to mid-2018. The new Cray system will provide an increase in sustained performance in line with the needs of the strategy for the next two years. The first of the two Cray clusters was delivered on 6 November 2013. We expect the new facility to be ready for operational use from mid-2014.

At the end of the year, the volume of primary data residing in the Data Handling System (DHS) was about 57 petabytes, with a growth rate of about 50% over the previous year. We are enhancing the DHS by increasing storage capacity and taking various actions to manage the growth rate, including archiving less non-operational data and introducing higher compression rates. Member States are allocated 10% of the storage capacity.

Signing the contract between ECMWF and Cray UK Ltd. The contract was signed by Ulla Thiel (Vice-President of Cray Europe) and Alan Thorpe (Director-General of ECMWF) on 24 June 2013. Members of the ECMWF and Cray teams involved in contract negotiations are standing behind the two signatories.



Growth in archived data at ECMWF. The data archive contains observations, analyses and forecasts from the Integrated Forecasting System and various research experiments. In the last year the amount of data increased by 51%.

A CENTURY OF CLIMATE DATA

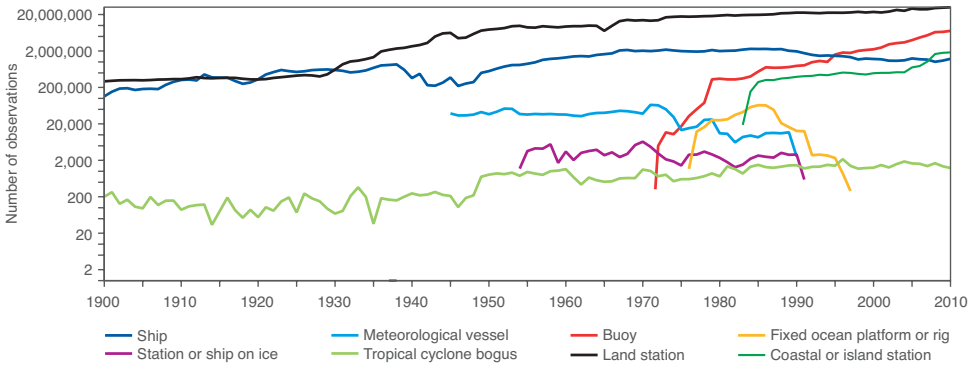
ERA-CLIM was a project conducted by ECMWF together with eight other institutes in Europe, Russia and Chile. It improved the available observational record for the 20th century, and developed the observational input and technical infrastructure needed to produce a climate reanalysis going back 100 years or more. The project was funded under the EU's Framework Programme.

A large portion of the project was dedicated to data rescue, with a focus on early upper-air observations in sparsely observed regions critical for climate (e.g. in the tropics and at high latitudes). This has already resulted in a huge increase in the digitised instrumental record for the early 20th century, more than doubling the total number of pre-1957 weather observations from kites and early radiosondes ready for reanalysis.

ERA-CLIM also kick-started an important international initiative to rescue satellite data by investigating the availability of data records from pre-operational satellites and their potential use in future climate reanalyses. The project produced the first comprehensive inventory of early satellite data for reanalysis, including priorities for data rescue.

Finally, a set of major new atmospheric and land-surface reanalyses were produced at ECMWF, generating three-hourly global fields spanning the period 1900–2010. These datasets, with a combined volume of several hundred terabytes, will be publicly available via the internet. Similarly, the approximately 1 billion input observations used in these reanalyses will be freely accessible via the newly developed Observation Feedback Archive.

The next step is ERA-CLIM2, which is partly funded under the EU's Framework Programme. It will produce reanalyses of the global atmosphere, ocean, land surface, cryosphere and the carbon cycle. The project will start in 2014 and be led by ECMWF in partnership with 32 institutions.



Diversity of surface pressure observations available for reanalysis. Shown is the number of surface pressure observations used each year in one of the ERA-CLIM reanalyses. As well as illustrating the diversity of observing systems providing surface pressure, it shows that in the last ten years buoys have become the second largest source of data.

OUR PEOPLE

Attracting and retaining people who can advance the science and computing behind weather prediction is one of the Centre's key objectives as well as one of its strengths. Our priority has been meeting the challenges of being both a research institute and a 24/7 operational service, and achieving the high standards our Member and Co-operating States need from us. We accomplish this through close working relationships between our staff and colleagues in our national meteorological services, as well as within the international research community.

The Centre's staff are at the forefront of scientific and technical developments and regularly contribute to ongoing global debates. One such example is an article by Magdalena Balmaseda, Kevin Trenberth and Erland Källén published in Geophysical Research Letters, addressing the key issue of why the sea-surface temperature increases stalled in the 2000s, which is acknowledged to have made a substantial contribution to the global warming debate.

The widespread involvement of ECMWF in the international research arena through membership of many influential groups and conferences is another illustration of how the expertise of ECMWF staff is recognised and appreciated. Notable examples include Erik Andersson's chairing of the Scientific Evaluation Team of the EUMETNET observation programme; Jean-Noël Thépaut's co-chairing of the WMO Working Group on Numerical Experimentation; Florian Pappenberger's co-leadership of HEPEX (Hydrological Ensemble Prediction Experiment); Peter Bauer's membership of the ESA Scientific Advisory Committee; and Anton Beljaars's activities in the Earth Explorer EarthCare.

We introduced a new organisational structure on 1 July 2013, aiming to enhance our overall effectiveness whilst placing users at the heart of our activities. The new structure offers a clear definition of management roles and responsibilities and their contributions to the running of the Centre.

MARK RODWELL AWARDED THE BUCHAN PRIZE

The Buchan Prize is awarded annually to a member of the Royal Meteorological Society for a paper published in the previous five years in one of the Society's journals and judged to contain the most important original contribution to meteorology. Mark Rodwell received the prize at the Society's AGM in 2013.

Mark joined ECMWF in 2003. During his career, Mark has developed a number of penetrating diagnostics to help understand the weather better. These include diagnostics that link the monsoons to the subtropical anticyclones and regions of desert, and diagnostics to understand climate variability over the North Atlantic and the factors that affect it.

In addition, Mark's diagnostics have helped improve the numerical forecasting systems for predicting weather and helped identify reasons for occasional forecast failures.

"Since joining, I have worked on diagnostics with many people at the Centre. These diagnostics are essential for assessing the performance of the forecasting system as a whole, and for identifying key residual errors that would otherwise limit progress. It is great that the Royal Meteorological Society recognises the importance of diagnostics."

Mark Rodwell

Mark Rodwell receiving the Buchan Prize. The prize was presented to Mark by Joanna Haigh, President of the Royal Meteorological Society

"The European Meteorological Infrastructure is a huge shared resource for the benefit of European society."

DEVELOPING EUROPEAN INFRASTRUCTURE

ECMWF is a member of the European Meteorological Infrastructure (EMI) alongside national meteorological services (NMSs); EUMETSAT, a global operational satellite agency; and EUMETNET, an organisation that facilitates co-operation between NMSs. The EMI members supply ground-based measurements, space-based observations and NWP models.

Satellites now provide most of the data used in our NWP models, although more traditional observations are still critically important. Our partnerships with space agencies in Europe (EUMETSAT, ESA) and worldwide (China, Japan and USA) continue to be highly beneficial.

In 2013, we worked particularly closely with EUMETSAT in maximizing the benefit from its operational satellites and preparing future European operational space programmes.

In recent years there has been an increase of 5 satellite instruments utilised at ECMWF per year on average. We currently monitor data from more than 70 instruments, and use data from over 50 of these to produce the forecast.

Sharing of developments by satellite agencies and other meteorological services is paramount to improve the use of satellite data, and we are involved in three of EUMETSAT's Satellite Application Facilities (SAFs) – centres of excellence for processing satellite data.

During 2013 experiments at ECMWF have highlighted the importance of the European Metop polar-orbiting satellites. New results show improved forecasts when data from two satellites (Metop-A and Metop-B) are available compared to one (just Metop-A). This strengthened the case for maintaining two satellites in orbit for as long as possible.

ECMWF helps ensure that maximum benefit is gained from European investment in observation and modelling capabilities.

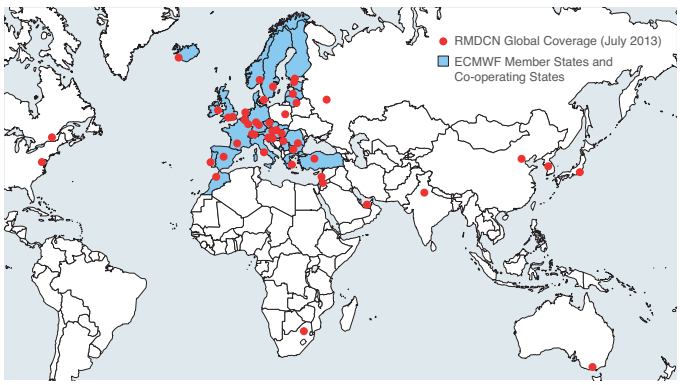
DATA COMMUNICATIONS

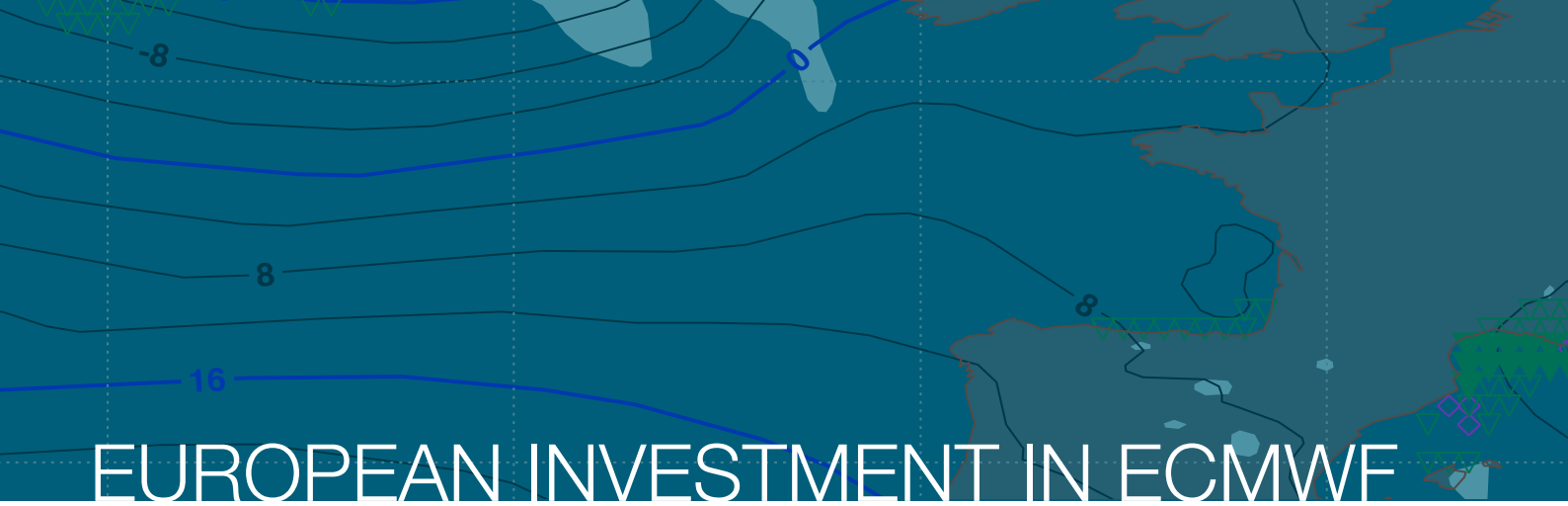
The Regional Meteorological Data Communication Network (RMDCN) was established in the late 1990s to provide a highly reliable and managed data communications network in order to:

- Improve the infrastructure for disseminating ECMWF products to its Member and Co-operating States.
- Improve the GTS of the World Meteorological Organization (WMO) in the region of Europe and the Middle East (WMO Regional Association VI).

The RMDCN is currently undergoing modernisation to meet the future requirements of ECMWF's Member States and the wider meteorological community. We signed a contract with Interoute Communications Limited in December 2012 to provide the operational service of the RMDCN from early 2014 for a period of nine years.

A pilot network consisting of six sites was accepted in the first half of 2013, with all further sites being connected to the new network during autumn 2013. Over 90% of sites were formally accepted by the contractual deadline of 20 December 2013, well above the threshold of 70% for successful acceptance. The transfer of operational traffic from the existing network to the new one takes place early in 2014.





EUROPEAN INVESTMENT IN ECMWF

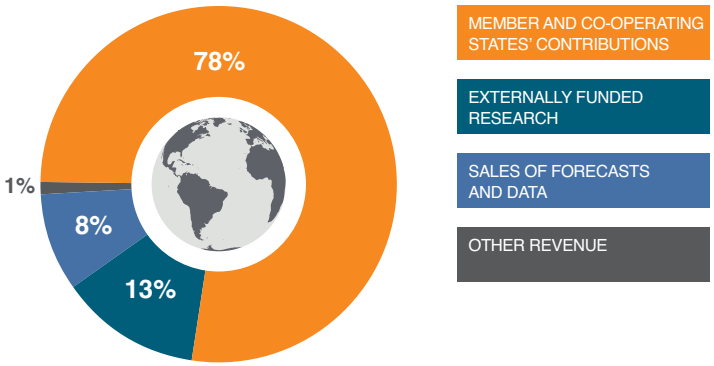
ECMWF is financed principally by contributions from its 34 Member and Co-operating States, which in 2013 totalled £41.2 million out of the Centre's funding of £52.5 million (excluding Centre tax). Revenue from sales of data and products provided income of almost £4.5 million, while funding of £6.8 million from external organisations supported both core research and the complementary 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 £2 million in 2013, which is available either for future investment or distribution to Member States according to a decision to be made by the Council in 2014.

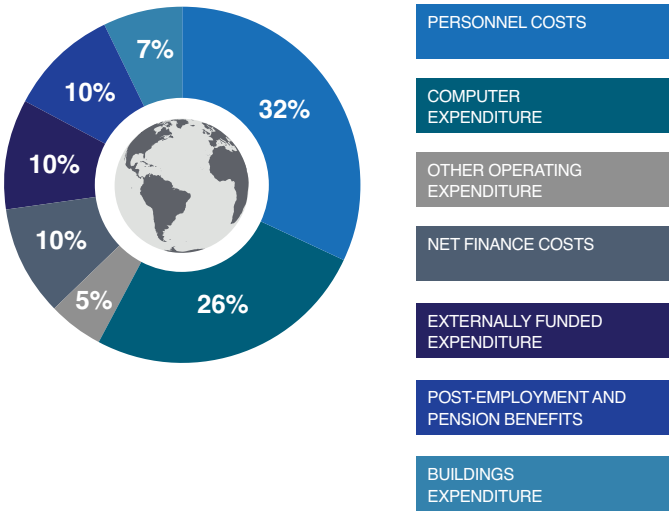
The Centre's future pension obligations have been valued at £137 million and are shown as a liability in the Statement of Financial Position, whereas the value of its pension investment accounts (£20 million) is shown under assets. ECMWF's net pension fund obligations are guaranteed by the Member States.

The main areas of expenditure were remuneration and related items (£23.7 million; £18.4 million net of internal tax), pension schemes (£5.8 million), computer expenses (£14.8 million) and buildings (£3.9 million). Costs associated with externally funded research projects amounted to just over £7 million (£5.6 million net of internal tax) and pension finance costs (net) were £6.1 million. Capital investment, principally on IT and infrastructure, totalled £3.6 million.

ECMWF FUNDING 2013



ECMWF COSTS 2013



> "Investing the funds provided by European taxpayers in a cost-effective way is critically important to ECMWF."

SUMMARY STATEMENT OF FINANCIAL PERFORMANCE FOR THE YEAR ENDED 31 DECEMBER 2013

Revenue	£k	£k
	2013	2012
Member & Co-operating States' contributions	41,184	40,868
Taxes	6,705	6,393
Externally funded projects	6,876	5,766
Sales of forecasts and data	4,450	3,793
Other operating revenue	45	20
	59,260	**56,840**
Expenditure	**£k**	**£k**
Personnel costs	23,667	22,265
Pension and post-employment benefits	5,825	4,321
Buildings expenditure	3,837	4,767
Computer expenditure	14,769	15,160
Other operating expenditure	3,115	2,537
Externally funded expenditure	7,037	5,669
	58,250	**54,719**
Operating surplus	1,010	2,121
Net finance costs	(6,087)	(5,497)
Net deficit for the year	**(5,077)**	**(3,376)**
Reconciliation of IPSAS and Cash Results	**£k**	**£k**
Net deficit for the year	(5,077)	(3,376)
Assets capitalised in the year	(3,620)	(1,814)
Depreciation in the year	2,279	2,015
Spend on commitments from previous years	2,136	2,609
Commitments carried forward to future years	(1,847)	(2,136)
Finance costs for post-employment benefits	6,260	5,333
Post-employment benefits	(37)	(1,292)
Accruals	678	(17)
Prepayments	344	(611)
Change in inventory	391	(77)
Use of surplus from 2011	0	1,000
Other IPSAS timing differences	527	(264)
Surplus per cash accounts	**2,034**	**1,370**

Member States' Contributions	£k 2013
Austria	880
Belgium	1,108
Denmark	745
Finland	583
France	6,239
Germany	7,981
Greece	729
Iceland	31
Ireland	488
Italy	4,918
Luxembourg	93
The Netherlands	1,851
Norway	915
Portugal	528
Slovenia	112
Spain	3,349
Sweden	1,060
Switzerland	1,084
Turkey	1,137
United Kingdom	5,927
	39,758

Co-operating States' Contributions	
Bulgaria	52
Croatia	71
Czech Republic	205
Estonia	23
Former Yugoslav Republic of Macedonia	9
Hungary	150
Israel	201
Latvia	34
Lithuania	46
Montenegro	4
Morocco	91
Romania	198
Serbia	44
Slovakia	95
	1,225
Single Additional Contributions	201
Total Member & Co-operating States' contributions	41,184

WORKING TOGETHER

ECMWF pursues extensive scientific and technical collaboration, in particular with the national meteorological services in the 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. For example, we have worked with scientists at Stockholm University and Helsinki University to improve various aspects of the NWP model. Also in 2013, we exchanged information with the Czech Republic, Austria and Germany about the summer floods in central Europe and with the Netherlands on the December windstorm and its associated storm surge. 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.

On 27 September 2013 an accession agreement was signed between ECMWF and the Republic of Serbia. Once the agreement has been ratified, Serbia will officially join our other 20 Member States.

ECMWF and the China Meteorological Administration (CMA) have established scientific collaboration in a variety of areas. This relationship has now been formalised through a co-operation agreement. In addition, we are in talks with the US National Weather Service to identify how best to enhance the existing interactions.

Most of our information about the current weather now comes from satellites. Our long-standing partnerships with space agencies, especially with EUMETSAT and ESA, are crucial for us to benefit fully from satellite data. In return, we provide valuable feedback on the quality of the instruments and regular reports on their impact on global NWP. We also enjoy strong scientific and technical co-operation with space agencies in the USA, Japan and China.

ECMWF receives funding from the EU's Framework Programme for a number of research projects. For example, we are co-ordinating the MACC-II project, which is developing the pre-operational Copernicus atmosphere monitoring service. We are also leading the ERA-CLIM2 project, which will produce a climate reanalysis by combining information from past meteorological observations with modern forecast models. This activity is increasingly seen as critical to understanding the basis for future climate change scenarios.

We work with organisations of the European Union, in particular with 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. These activities emphasise the importance of international collaboration and the global impact of the work of ECMWF.

WORKING TOGETHER

MACC-II: LEARNING FROM USERS

Led by ECMWF and operated by a consortium of 36 partners from 13 countries, the role of the European project MACC-II (Monitoring Atmospheric Composition and Climate - Interim Implementation) is to deliver the pre-operational Copernicus Atmosphere Monitoring Service.

Copernicus services are user-driven, so making sure that pre-operational services meet the evolving user needs and that feedback is effectively taken on-board are key aspects and a substantial fraction of MACC-II's activities.

A meeting was held involving policy users and MACC-II providers on 27 and 28 November 2013 in Brussels. Representatives from the European Environment Agency as well as from the Environment Directorate-General, in charge of the revision of the new air quality policy package until 2030 (adopted in December 2013), were among the participants.

MACC-II products comprise analyses of European air quality, estimates of surface fluxes of greenhouse gases as well as data on the stratospheric ozone layer. These products provide reliable and transparent information in support of monitoring and developing environmental policies as well as of statutory reporting.

Key to MACC-II's success is its partnership approach, where expertise from a number of meteorological services, environment agencies and leading atmospheric research institutes is combined to ensure that users are at the heart of each product. This approach empowers the users to follow a holistic approach to the Earth's environment for evidence-based policymaking.

"Isolationism has no place in pure or applied meteorology … By developing and putting into operation methods for medium-range weather forecasting, which is the essential mission of the Centre, it [the Centre] will fill a gap in the working programme of our national weather services and thus make an important contribution to the benefits the weather services generate for their national economies."

Erich Süssenberger opening the first Council session in 1975

LOOKING TO THE FUTURE

COPERNICUS

The European Union has a flagship programme called Copernicus to provide environmental information services based on existing observational data and new satellite missions as well as on modelling capabilities. These operational services will provide authoritative quality-controlled information to policy-makers, businesses, and other stakeholders. ECMWF is aiming to take a leading role in the Copernicus Atmosphere Monitoring and Climate Change Services. It also contributes to the Emergency Management and Marine Monitoring Services.

STRATEGY

By the end of 2015, ECMWF will have developed its next strategy to cover the period from 2016 to 2025. When preparing the strategy the Centre will consult widely to listen to the views of its stakeholders on what its next strategy should focus on. There are many new scientific, computing and funding opportunities that this new strategy will be built upon.

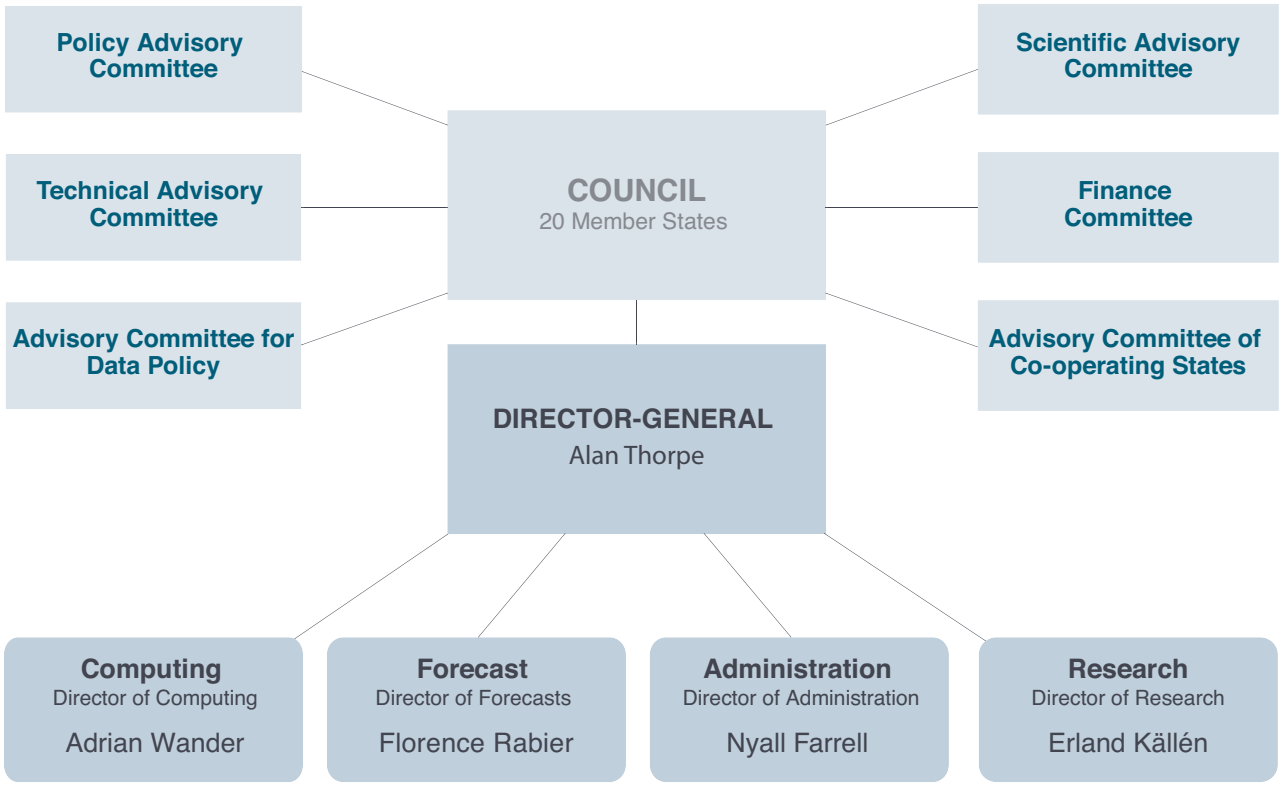
SCALABILITY

ECMWF is taking the lead on a major international collaborative programme on scalability to enable modelling codes to be developed to operate effectively and efficiently on massively parallel supercomputers. The collaboration involves national weather services, universities and computer vendors. The programme will operate over the next four years at least. It is part of European developments in e-infrastructure.

FUTURE ACCOMMODATION

ECMWF has started a project to identify new accommodation in the Reading area that will provide a modern working environment for its staff and an energy-efficient supercomputer data centre. Significant developments at ECMWF make it the right time to find new accommodation to support this ongoing European success story over the next 30 years.

ORGANISATION OF ECMWF
at July 2014



Bulgaria 

Croatia 

Czech Republic 

Estonia 

Former Yugoslav Republic of Macedonia 

Hungary 

Israel 

Latvia 

Lithuania 

Montenegro 

Morocco 

Romania 

Serbia 

Slovak Republic 

Co-operating States as of July 2014

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