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A milestone in ECMWF's evolution: changes to the Convention

The European Centre for Medium-Range Weather Forecasts (ECMWF) was founded on 1 November 1975 with the purpose of developing a European capability for medium-range weather forecasting and providing medium-range weather forecasts to its Member States. The Convention establishing ECMWF sets out its core objectives and duties. It restricts membership to the founding 18 Member States.

In April 2005 the Council, the Centre's governing body, in a landmark decision, unanimously agreed to amend the Convention to facilitate ECMWF's activities as leading provider of global medium-range weather forecasts. All Member States must notify their acceptance of the amendments to the depositary of the ECMWF Convention, the Secretariat of the Council of the European Union, before they can enter into force. By the end of 2006, four Member States had done so: Finland, Denmark, Norway and the United Kingdom.

When ratified by all the current Member States, the amended Convention will:

- Allow new Member States to join the organisation
- Enlarge ECMWF's mission to cover the monitoring of the Earth-system
- Broaden the possibility for activities funded externally.



ECMWF – leading the world in weather forecasting

ECMWF has a worldwide reputation for providing the most accurate medium-range global weather forecasts.

The National Meteorological Services of Member States and Co-operating States use them for their own national duties, in particular to give early warning of potentially damaging severe weather events. Scientists and researchers around the world use ECMWF's forecast products to monitor the environment and analyse climate change.

ECMWF uses a highly sophisticated computer modelling technique, called numerical weather prediction (NWP), to forecast the weather from its present measured state up to several days ahead. Its complex calculations require a constant input of meteorological data – air pressure, temperature, wind speed and direction and humidity – collected by satellites and earth observation systems such as automatic and manned stations, aircraft, ships and weather balloons.

The data are fed into ECMWF's databases and assimilated into its advanced numerical weather prediction models which calculate:

- Medium-range forecasts, predicting the weather up to 15 days ahead
- Monthly forecasts, predicting the weather on a weekly basis 30 days ahead
- Seasonal forecasts up to 12 months ahead.

Over the past three decades ECMWF's activities and wide-ranging programme of research and development have played a pioneering role in the remarkable advancement of weather forecasting and data assimilation systems. The organisation's strategy for 2006-2015 underlines its commitment to maintaining the current rapid rate of improvement of its global medium-range forecasts and products, with special focus on the early warning of severe weather events.

A ship leaves Tokyo to sail to San Francisco. Its trip will take ten days. What route should the ship follow to complete the trip in the shortest time, with maximum saving of fuel, avoiding strong head winds and heavy seas which could damage the cargo? Its owners receive ship routing services from European National Meteorological Services based on ECMWF's products.

Our mission

Principal objective

To maintain the current rapid rate of improvement of its global, medium-range weather forecasting products, with particular emphasis on early warnings of severe weather.

Complementary objectives

- Improve the quality and scope of monthly and seasonal-to-interannual forecasts
- Enhance support for Member States' national forecasting activities by providing suitable boundary conditions for limited-area models
- Deliver real-time analyses and forecasts of the atmosphere's composition
- Carry out climate monitoring through regular reanalyses of the Earth-system
- Contribute towards the optimisation of the Global Observing System.

To achieve these objectives, ECMWF:

- Develops numerical methods for medium-range, monthly and seasonal weather forecasting
- Prepares medium-range, monthly and seasonal weather forecasts for distribution to the National Meteorological Services of the Member States and Co-operating States
- Conducts scientific and technical research directed at improvement of these forecasts
- Collects and stores meteorological data.

ECMWF's Member States and Co-operating States

As of 31 December 2006.

Member States

Austria, Belgium, Denmark, Germany, Greece, Finland, France, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Co-operating States

Croatia, the Czech Republic, Estonia, Hungary, Iceland, Lithuania, Morocco, Romania, Serbia and Slovenia.

Co-operation agreements

- World Meteorological Organization (WMO)
- European Centre for the Exploitation of Meteorological Satellites (EUMETSAT)
- European Space Agency (ESA)
- African Centre of Meteorological Applications for Development (ACMAD)
- Joint Research Centre (JRC)
- Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organisation (CTBTO)
- Executive body of the Convention on Long-range Transboundary Air Pollution (CLRTAP)



ECMWF's Member States and Co-operating States



Foreword by the Director

2006 was a year of significant activity and achievement, one in which ECMWF continued to consolidate its reputation as the world leader in global medium-range numerical weather prediction (NWP).

ECMWF's operational forecasting system achieved a high level of performance throughout 2006 – summer was particularly good – helping to maintain the Centre's clear lead over other major NWP centres. The tropical cyclones 3-day forecasts in the Atlantic basin, a key element in the early warning of storms over Europe, were also impressive.

2006 has witnessed other significant improvements to the forecasting system, further securing ECMWF's leading role in the development of forecast and data assimilation systems. The upgrade to the high resolution forecast system in February 2006, for example, which enables meteorologists to extract more information from observations, is also of particular benefit to the forecasting of severe weather, as was the implementation of the Variable resolution Ensemble Prediction System (VarEPS), which provides the capability to extend the forecasts from day 10 to day 15 at a lower resolution. The introduction of a new model cycle in September brought several important model improvements to the Integrated Forecasting System, and represents a significant step towards one of the key objectives of ECMWF's Strategy for 2006-2015: to increase efforts towards a fully unified ensemble system.

The measurements collected by satellites provide a valuable and constantly expanding source of global meteorological data for numerical weather models. The successful launch on 19 October 2006 of EUMETSAT's MetOp-A satellite – Europe's first ever polar-orbiting spacecraft – will facilitate significant improvements in NWP.

Throughout 2006 ECMWF continued to collaborate with Member States, the European Union and the World Meteorological Organization (WMO) in a number of key research programmes and initiatives. As its contribution to the EU's Global Monitoring for Environment and Security (GMES) initiative, ECMWF is co-ordinating the four-year, EU-funded GEMS project which is developing a prototype atmospheric monitoring service for GMES. During 2006 the technical components of the project were put into place: ECMWF contributed significantly to the preparation of the prototype service, GMES Atmosphere Services (GAS).

As part of ECMWF's remit to assist the implementation of WMO programmes,

products disseminated to WMO Members were significantly increased. Specifically, the Council agreed to extend the forecast range of the products distributed on WMO's Global Telecommunications System to day 10 for several parameters and provide global products from the Ensemble Prediction System in support of high impact and severe weather and site-specific forecast products at selected locations, particularly targeting synoptic stations in developing countries.

A landmark in ECMWF's development by any definition was the completion of the new office building in November, providing much needed additional office space for recently developed activities. The building's completion, almost to schedule, was a major achievement in itself, for which the ECMWF project management team deserves special commendation. Staff and consultants of the Research Department are now enjoying their new state-of-the-art environment. Everyone else is set to benefit as well, as the new building has provided a timely opportunity to re-organise the allocation of offices in the old building to locate all sections within a division together.

Following the Council's milestone decision in 2005 to amend ECMWF's Convention, which restricts membership to the current 18 Member States, Denmark, Norway and the UK joined Finland in ratifying the amended Convention in 2006. When it enters into force, the amended Convention will allow ECMWF to accept

'The operational forecasting system's high level of performance throughout 2006 helped ECMWF maintain its lead over other NWP centres'

new Member States. Meanwhile in 2006 two new countries, Lithuania and Morocco, joined as Co-operating States, Morocco being our first African Co-operating State. The ECMWF community is growing fast, and we look forward to the day when 'new' countries are eligible to apply for full Member State status.

The responsibility for providing Europe's citizens with the best meteorological forecasts possible at all ranges – medium, monthly and seasonal – presents a constant challenge to ECMWF. It is faced with increasing costs in running NWP systems, owing to the ever growing complexity of assimilation systems and forecasting models and the need for more powerful computers to run them.

ECMWF's Strategy for 2006-2015 recognises that, in order to maintain its leading position in global NWP, there must be a significant increase in the funding of its High Performance Computing (HPC) budget; specifically to ensure that the current supercomputer system's replacement, scheduled for 2009, is capable of fulfilling the increasingly complex operational and research requirements that will be demanded of it. Accordingly, at its 66th Session,

the Council – ECMWF's governing body – approved an increase in the HPC budget of £3.5 million from 2009 onwards, with a second increase of the same amount from 2011 onwards to be decided in 2007 at the latest.

A key determinant in this decision was the review of ECMWF activities and costs conducted by the Programme Task Team (PTT), which the Council established in July 2006 to consider long-term funding issues. The PTT reported that ECMWF's activities are fully compliant with its mission and conducted very efficiently and with transparency. The PTT also verified that 75% of the Centre's costs result from medium-range forecasting activities; its supplementary activities are developed at a very low cost and its lean administration and management account for less than 10% of the total expenditure.

The PTT also analysed the responses to a questionnaire sent to Member States, which confirmed that ECMWF's products and services are crucially important to the Member States. ECMWF's outputs, it concluded, are highly valued by the Member States for their contribution to a number of socio-economic areas, with medium-range weather forecasts being of highest priority.



Dominique Marbouty
Director, ECMWF

Key events of the year 2006

1 February

The new high resolution system became operational. Access times to products were harmonised to ensure their accessibility from the archive and through dissemination at the same time. Dissemination times were also reviewed and brought forward by an average of 25 minutes.

1-2 February

A subgroup of the Technical Advisory Committee met to consider opportunities provided by computer grid technologies.

6-10 February

ECMWF hosted the first Annual Assembly of the Global Environment Monitoring System (GEMS) project, the principal goals of which were to review progress, update the plan for the next period and provide guidance on financial reporting.

20 February

ECMWF and EUMETSAT held their bilateral meeting, at which the valuable support provided by EUMETSAT in developing the use of satellite data was reviewed.

28 February

Inaugural bilateral meeting with the European Space Agency (ESA) held at ECMWF, following the signature of the Co-operation Agreement on exchange of information and expertise in 2005.

Mid-March

Monitoring activities for the African Monsoon Multi-disciplinary Analysis (AMMA) project special observation period commenced.

15-17 March

A workshop on the future of numerical weather prediction was held in Europe, organised jointly with the UK's Met Office.

30 April

Ute Dahremöller replaced Gerd Schultes, who retired after 20 years as Head of Administration.

Mid-May

A comprehensive survey of the supercomputing market confirmed the evaluation presented to Council for its discussion of the Centre's strategy on its supercomputer requirements.

8 May

The amended Regional Meteorological Data Communications Network contract was signed, detailing the migration process to the new technology.

19-22 June

A Group Earth Observation sponsored workshop was held on the status of and plans for global reanalysis in Europe, Japan and North America and on preparations for a new generation of reanalysis.

28 June



The Norbert Gerbier Mumm International Award was presented to the DEMETER team, at a ceremony in Geneva, in recognition of their paper entitled 'Development of a European Multimodel Ensemble System for Seasonal-to-Interannual Prediction'.

6-7 July

ECMWF's 65th Council session was held in Oslo.

11 July

Visit to ECMWF by Paul Weissenberg, Director, DG Enterprise and Industry, European Commission, who has responsibility for GMES.

- **17 August**

The first of the two IBM Phase 4 clusters of the High Performance Computing Facility successfully passed acceptance on 17 August and immediately began generating operational forecasts.

- **4-8 September**

ECMWF's annual seminar was held on the theme of the impending International Polar Year.

- **12 September**

A new model cycle was introduced featuring a number of important enhancements, including variational bias correction for all satellite radiances and major changes to the physical parametrizations.

- **2 October**

Lennart Bengtsson (Director of ECMWF 1982-1990) was awarded the 51st IMO prize by the World Meteorological Organization for his pioneering research in numerical weather prediction.

- **18 October**

ECMWF hosted a Prediction Application Facilities seminar.

- **20 October**

Pierre-Etienne Bisch, representative of France to the ECMWF Council, chaired the first meeting of the Programme Task Team (PTT). The PTT reviewed in detail the ECMWF programmes and their cost.

- **2 November**

MetOp-A satellite data were processed and operationally monitored, with the results displayed on ECMWF's website just two days after EUMETSAT began distribution.

- **9-16 November**

ECMWF gave a demonstration of SIMDAT at the Technical Conference on the WMO Information System (WIS), held in conjunction with the meeting of the Commission for Basic Systems of WMO in Seoul.

- **20 November**

Lithuania became a Co-operating State following ratification of the Co-operation Agreement by its parliament.

- **22 November**

ESA's Programme Board on Earth Observation decided to support distribution of data from the Soil Moisture and Ocean Salinity Mission (SMOS) in near-real-time, providing ECMWF with invaluable information on land soil moisture and ocean salinity.

- **27 November**

The Centre's new office block was completed. The building provides a new home for a major part of the Research Department and much needed space for new activities.

- **27 November**

ECMWF hosted a meeting at which the results of the recent study on World Climate Research Programme (WCRP) networking opportunities were presented to WCRP stakeholders in Europe.

- **28 November**

Dissemination of products from the second leg (days 11 to 15) of the new VarEPS forecasting system was implemented.

- **1 December**

The Kingdom of Morocco became the first African country to join ECMWF as a Co-operating State.

- **6 December**

ECMWF hosted the Council of EUMETNET, a network grouping of European National Meteorological Services.

- **7-8 December**

ECMWF's 66th Council session was held at the Centre.

- **12 December**

A new cycle of the ECMWF forecast system which implements the assimilation of new satellite data was introduced.



Evolution of the forecasting system

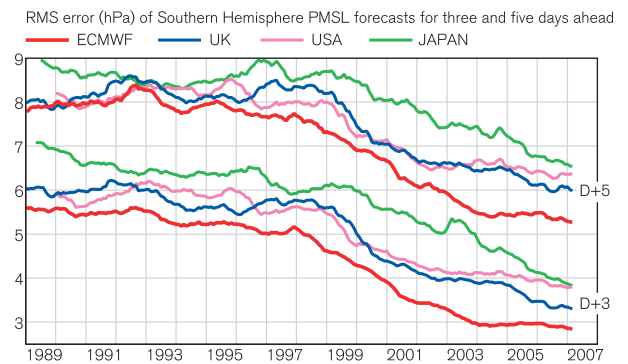
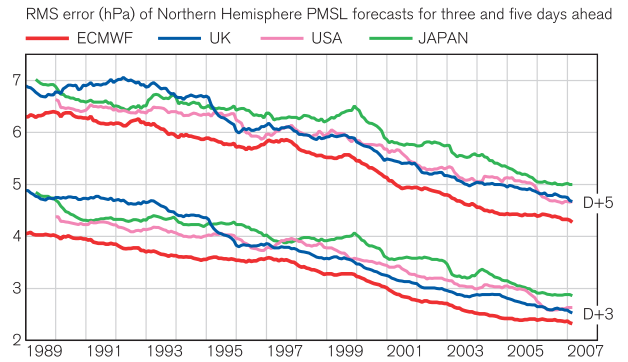
ECMWF is renowned worldwide for providing the most accurate medium-range global weather forecasts. It also provides forecasts to one and six months ahead. The Centre's wide-ranging research programme continues to play a pivotal role in the advancement of weather forecast skill and the use of the rapidly developing satellite and in situ observations of the atmosphere.

Performance of the operational forecasting system

ECMWF maintained a clear lead over other NWP centres in 2006. Skill over the 2005/2006 winter period was maintained at the same level as two winters ago and was significantly higher than winter 2004/2005. Performance over summer 2006 was particularly good.

Probabilistic forecasts generated by the Ensemble Prediction System (EPS) continued to improve in skill throughout 2006. Additionally, the accurate prediction of several severe weather events during this period confirmed that the EPS has benefited significantly from the increase in skill in the high resolution system.

A comparison of three- and five-day forecasts in the northern and southern hemispheres since 1989 by four major forecasting centres. The lower the curve, the more accurate the forecast. ECMWF's is lowest in both cases.



Forecasts of precipitation also improved in 2006. Correlation between forecast and observed 24 hour precipitation amounts over Europe shows a substantial and significant gain in accuracy compared to previous years.

After the exceptional 2005 North Atlantic hurricane season, the 2006 season proved close to normal, despite some noteworthy events. Hurricane Gordon struck north-east Iberia in September and subsequently, as an intense extra-tropical storm, brought severe weather to parts of the UK and Ireland. It was accurately and consistently forecast by the Integrated Forecast System.

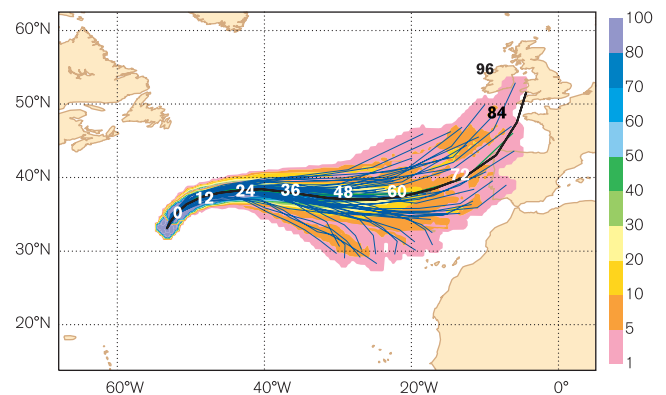
Since the system's resolution increase in February 2006, substantial reductions in core pressure error and improvements in position have been noted for tropical cyclone forecasts. Striking examples of the genesis of tropical cyclones were also witnessed.

Major resolution upgrade of the forecasting system

ECMWF's Integrated Forecast System (IFS) received a major resolution upgrade on 1 February 2006.

Since 2000, the operational global forecasting system has assimilated weather observations such as temperature, humidity and wind speed and direction, at specific grid points 40 km apart across the Earth's surface and at 60 different vertical levels through the atmosphere. Following the increase in resolution, the grid points are now only 25 km apart and the vertical resolution has increased to 91 levels.

Tracking a major storm

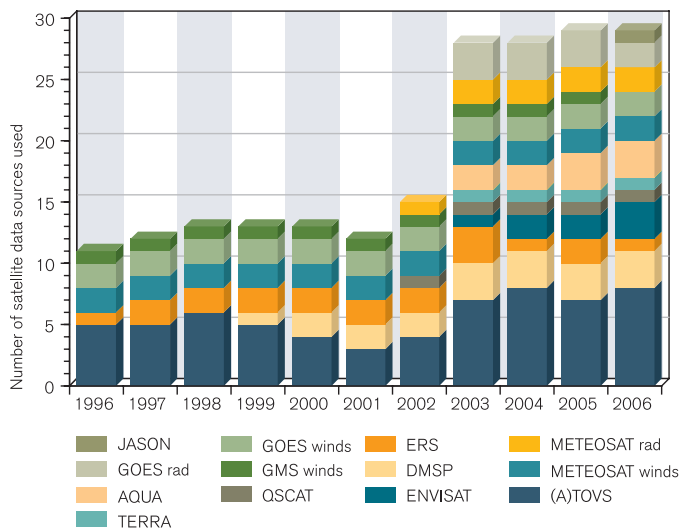


20060917 12 UTC
Probability that GORDON will pass within 120 km radius during the next 120 hours
tracks: black=OPER, green=CTRL, blue=EPS numbers: observed positions at t+..h

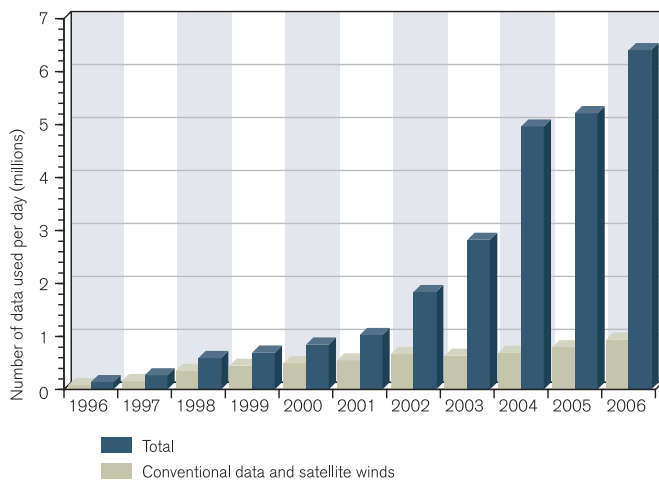
The observations are consequently more detailed and more information can be extracted from them, which in turn enhances forecast accuracy. The higher vertical resolution, for example, makes it possible to measure and forecast thin layers of cloud more accurately, while the greater horizontal resolution enables meteorologists to, for example, pinpoint and track snow storms over the Alps with far greater accuracy.

Hurricane Gordon struck north-east Iberia in September 2006 and subsequently brought severe weather to parts of the UK and Ireland. This map shows the strike probability of the storm as predicted by ECMWF at 12 UTC on 17 September. The blue lines identify the tracks predicted by the ECMWF EPS members, the black line the ECMWF's high-resolution deterministic model, and the shading indicates the ensemble-based probability that the cyclone will pass within 120 km of a location within the next 120 hours. The white/black numbers denote the storm's observed position every 12 hours, up to the time when the stormy remnants of Gordon reached Ireland four days later on 21 September. On 18 September the UK's Met Office issued a press release based on ECMWF's forecast.

The expanding satellite network



6 million data used daily



ECMWF's operational forecasting system sources data from an extensive global network of satellites. The top graph shows how the number of satellites supplying data has increased from 11 to nearly 30 over the last decade. The lower graph shows the number of data - six million - ECMWF assimilates every day.

The increase in forecast skill resulting from the change has been particularly notable for the southern hemisphere. The gap in skill between the ensemble mean and the high-resolution deterministic forecast was also reduced in the early range.

Resolution is also a critical factor in providing early warnings and monitoring the intensity and progress of severe weather events, the majority of which are notable for their local nature, or as localised weather phenomena within larger-scale events. ECMWF accurately predicted, for instance, that the tail-end of Hurricane Gordon would reach Ireland and the UK in September.

Other upgrades to the forecasting system

The introduction of a new model cycle (Cycle 31r1) on 12 September brought several improvements to the IFS, creating a more realistic model. The changes have resulted in better representation of the amount of water vapour in ice clouds and the small reduction in evaporation due to the salinity of sea water. Additionally, a major change was made in the way friction is exerted by the small-scale details of the Earth's rough terrain on the atmosphere, resulting in more accurate predictions of wind speed in the vicinity of major mountain ranges. The effects of deep tropical cloud systems on the wind were also reviewed and made more accurate. As a result of these changes, the atmospheric state simulated by the model is now closer to the best available observations.

In a major change to the data assimilation system, a variational bias correction technique was implemented for all satellite radiances used by our system. Owing to instrument aging and inaccuracies in calibration, most satellite observations are subject to errors known as biases, which require correction to avoid corrupting the critical initial state of the forecasts. In the past, the amplitude of these biases was monitored and corrected by the Centre's scientists. The new technique, known as Variational Bias Correction (VarBC), automates the procedure by selecting a set of bias correction parameters which minimises the average differences between the observations and the short-range forecasts on several days. It also has the ability to discriminate between the systematic errors in the satellite radiances and those in the NWP model. VarBC represents a major and timely gain in efficiency in an era in which several thousands of channels will soon be subject to these corrections.

Another important IFS upgrade, developed in collaboration with DLR, the German Aerospace Centre, was the refinement of the cloud model to represent the ice super-saturated state for the first time and improve the representation of the ice water content. The spread of high level cirrus clouds, which form in ice-saturated regions in the upper troposphere, are of particular interest to aviation forecasting and climatologists; they warm the atmosphere by trapping the radiation reflected from the Earth and therefore have the potential to affect the Earth's climate.

Their formation is significantly increased by the condensation trails, or contrails, of high altitude airplanes. Studies have already shown that the spread of cirrus cloud has increased in busy air routes. The incorporation of ice super-saturation will improve the IFS's ability to forecast areas where aircraft contrails might form, opening up the possibility of directing air traffic away from the most sensitive regions.

Cycle 31r1 was also adopted for the latest reanalysis project, ERA-Interim, and the new version (System 3) of the seasonal forecasting system. The new cycle, therefore, represents a significant step towards a key objective of ECMWF's strategy for 2006-2015: to increase efforts towards a fully unified ensemble system.

Optimising the use of satellite observations in NWP

ECMWF endeavoured to enhance and improve the use of satellite observations in NWP during 2006.

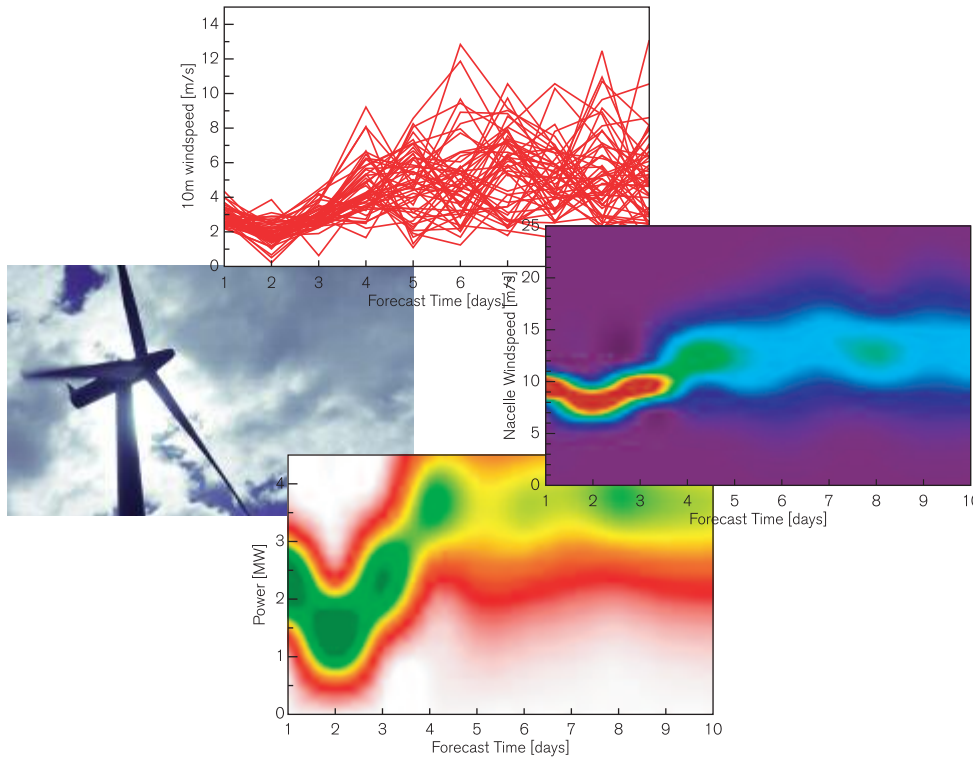
Substantial efforts have been dedicated to the use of GPS radio occultation (RO) bending angle measurements. Such observations are currently available from the CHAMP and GRACE-A satellites, the COSMIC constellation and the GRAS instrument on board MetOp-A. Temperature information can be inferred from these with a unique vertical resolution, considerably improving the thermal representation of the model's stratosphere. RO measurements from CHAMP, GRACE-A and COSMIC were introduced into our operational

ECMWF and EUMETSAT: a rewarding collaboration

"It was good to see how quickly the first applications were developed on the basis of the new flow of MetOp data. I am convinced that the data gathered by the MetOp satellite are crucial to better understanding the Earth's weather, climate and environment. These observations will significantly improve Numerical Weather Prediction. The European Centre for Medium-Range Weather Forecasts has demonstrated its capabilities in assimilating temperature and moisture information from AMSU-A and MHS less than three months after the launch of MetOp."

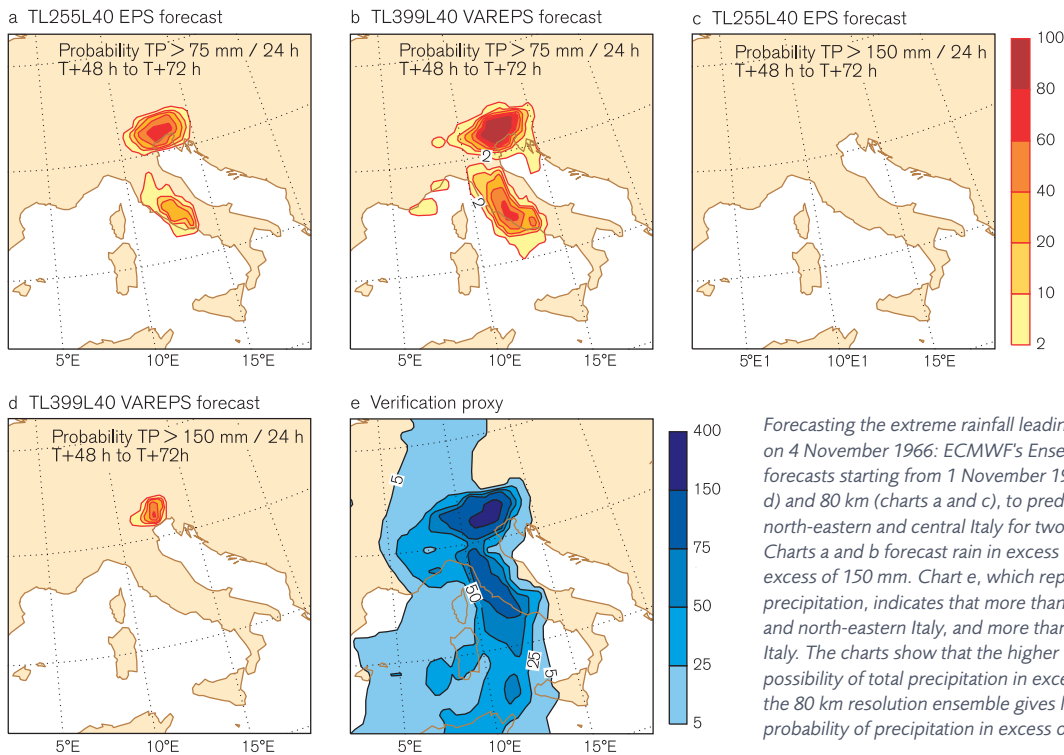
Lars Prahm, Director-General,
EUMETSAT

How much power will a wind farm generate?



Weather-sensitive industries benefit greatly from 'probabilistic' forecasts produced by ECMWF's Ensemble Prediction System (EPS). It runs 51 separate models, known as an ensemble, in which the forecast's initial starting conditions vary subtly to provide 51 possible future scenarios. This example shows how windspeed predictions derived from an EPS forecast can be used to calculate the amount of power a wind farm is likely to generate over a period of 10 days. The most likely windspeed at nacelle height is indicated in red, and the lower probabilities in green/blue.

Forecasting Italy's disastrous 1966 flood



Forecasting the extreme rainfall leading to the catastrophic flood that hit Italy on 4 November 1966: ECMWF's Ensemble Prediction System ran probabilistic forecasts starting from 1 November 1966 at resolutions of 50 km (charts b and d) and 80 km (charts a and c), to predict the likely precipitation over north-eastern and central Italy for two and three days ahead. Charts a and b forecast rain in excess of 75 mm, and charts d and c in excess of 150 mm. Chart e, which represents a proxy of the actual observed precipitation, indicates that more than 75 mm of rain per day fell over central and north-eastern Italy, and more than 150 mm per day over north-eastern Italy. The charts show that the higher resolution forecast (50 km) predicts the possibility of total precipitation in excess of 75 mm/d and 150 mm/d, while the 80 km resolution ensemble gives lower values for 75 mm/d and no probability of precipitation in excess of 150 mm/d.

forecast system on 12 December.

The enhancement of the exploitation of radiances from the three existing Special Sensor Microwave Imager (SSM/I) instruments under cloudy and rainy conditions continued throughout 2006. Improved quality control of the data affected by frozen precipitation has been implemented, together with a better bias correction and a reduction of the interference of the surface wind signal into moisture increments. These enhancements have led to improvements in the humidity forecasts in the tropics. The analysis and forecast error for the tropical cyclones has also been reduced.

First data from the MetOp satellite

EUMETSAT's MetOp-A satellite was successfully launched on 19 October, the first of a series of three polar-orbiting satellites forming the space segment of the EUMETSAT Polar System. Eight of its instruments are directly relevant to global numerical weather prediction (IASI, AMSU-A, MHS, HIRS, AVHRR, ASCAT, GRAS and GOME-2), and ECMWF is striving to make early and efficient use of this abundance of new meteorological data.

The AMSU-A instrument represents part of the ATOVS (Advanced TIROS Operational Vertical Sounder) instrument suite carried on board MetOp. The 15-channel microwave sounder measures atmospheric temperature profiles, even in the presence of non-precipitating clouds. Data from AMSU-A were first made available to NWP users via EUMETCast

on 31 October. They were immediately processed by ECMWF and were being monitored operationally by 2 November, followed shortly by the Microwave Humidity Sounder (MHS) and High Resolution Infrared Sounder (HIRS). Since then, all three instruments have been monitored operationally, providing invaluable feedback on instrument quality to EUMETSAT.

The Advanced Scatterometer (ASCAT) is used to estimate surface vector winds over the global oceans, soil moisture over land and the extent of land and sea ice. Early access to initial data samples allowed ECMWF to contribute actively to the validation of this instrument.

Variable Resolution Ensemble Prediction System

ECMWF's Ensemble Prediction System (EPS) provides forecasters with a range of possible future scenarios which can be used to estimate the probability of specific weather events occurring during the forecast period. A key element of the Centre's operational forecasting system since 1992, it has been upgraded several times.

The EPS is currently undergoing another phased upgrading process that will increase the medium-range forecast range and provide a seamless transition to the monthly forecasts. First, the resolution of the EPS was increased on 1 February 2006, along with that of our other forecasting systems. The new EPS resolution, T399, represents one grid point every 50 km. The second phase of the upgrading process, the extension of the EPS forecast

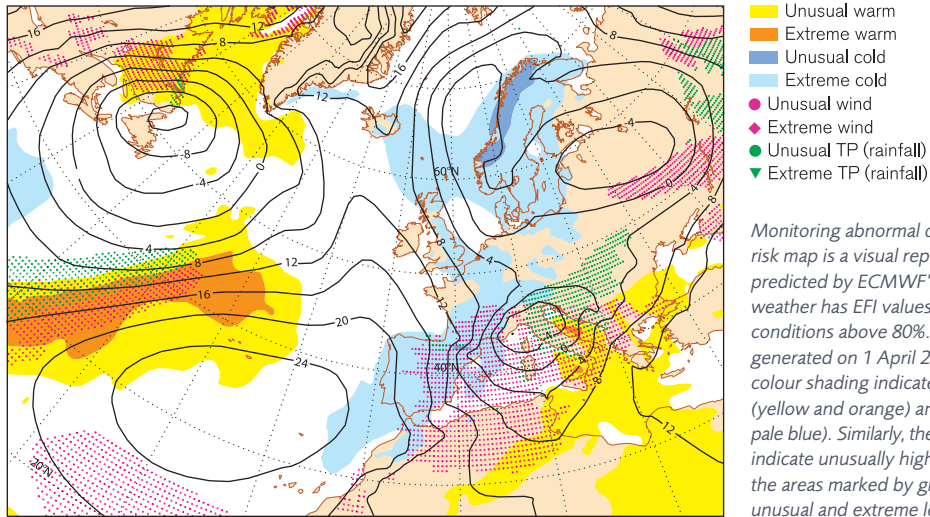
to day 15, was completed on 28 November. This was achieved by changing the model's resolution from 50 km to 80 km for the forecast range days 11-15. In a third phase, the EPS forecasts will continue, once per week, to a forecast range of 32 days and will replace the current Monthly Forecasting System.

Predicting severe weather

The forecasting of extreme weather events has received special emphasis in recent years, following catastrophic events such as Hurricane Katrina and Europe's 2003 heat wave. While the weather phenomena that cause natural disasters cannot be controlled, the loss of life and property can be minimised through better use of improved weather forecasts.

Thanks to ECMWF's delivery of medium-range forecasts twice daily, the Member States' National Meteorological Services can help to better protect citizens' lives and property in Europe and beyond, by providing more effective early warnings of approaching severe weather. ECMWF has recently introduced several new products relevant to severe weather prediction, such as the Extreme Forecast Index (EFI), the tropical cyclone track and strike probability maps and seasonal tropical cyclone frequency.

The gradual improvement of NWP models has similarly improved the prediction of hazardous weather phenomena such as tropical cyclones and squall lines. ECMWF's Ensemble Prediction System can also deliver more reliable and user-specific warnings of



Monitoring abnormal or unusual weather: the extreme weather risk map is a visual representation of unusual weather patterns predicted by ECMWF's Extreme Forecast Index. Unusual weather has EFI values above 50%, and extreme weather conditions above 80%. This example represents a forecast generated on 1 April 2006 to four days ahead (4 April). The colour shading indicates areas of unusual and extreme warmth (yellow and orange) and unusual and extreme cold (darker and pale blue). Similarly, the areas marked by pink dots and diamonds indicate unusually high and extreme winds respectively, while the areas marked by green dots and diamonds experienced unusual and extreme levels of rainfall.

extreme weather events in a probabilistic way. However, the extraction of extreme weather related information from the huge volume of EPS data generated remains a complex and difficult task.

Extreme Forecast Index

ECMWF's Extreme Forecast Index was developed as a tool for identifying where the EPS forecast distribution differs substantially from the model climate distribution. Its major advantage lies in the fact that it is an integral measure referenced to the model climate that contains all the information regarding variability of a weather parameter, such as temperature in location and time. Users can thus identify an abnormal weather situation without having to define specific space and time dependent thresholds.

In 2006, verification demonstrated that, for both precipitation and maximum temperature, use of the EFI increases the ability to detect extreme events, compared to simply taking EPS probabilities at face value. Work, complementary to the EFI, on developing alternative indices to highlight extremes in the EPS distribution also progressed well.

During the year ECMWF collaborated with the German National Meteorological Service to investigate verification procedures for severe weather. Work focused on

precipitation events, using data from Europe's high resolution rain gauge networks to create gridded precipitation fields for verification purposes. An initial study was made utilising the gridded data as a 'perfect' forecast, which is then verified using the original station observations. Work continues, using the gridded data to investigate appropriate scores for severe events, and to investigate further the difficulties associated with the verification of model precipitation, generated by gridded data, against point observations.

Combining the deterministic forecast and the EPS

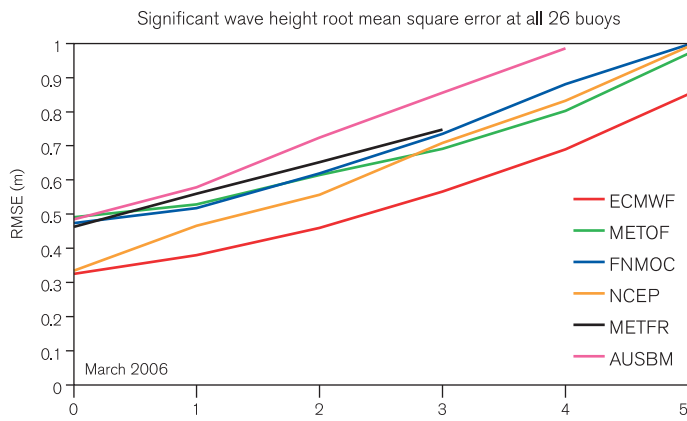
Users sometimes have difficulty deciding which of these two systems is best adapted to their needs. In an effort to solve their dilemma, we have started to develop probabilistic products combining the results of the deterministic forecast and of the EPS. The relative weights to give to the deterministic forecast and to the EPS in such a generalised ensemble were computed for various weather parameters and forecast ranges. Encouragingly, results show these weights to be relatively stable. Work will continue on this theme, with a view to introducing new combined probabilistic products that will eventually replace the current products based on the EPS alone.

Seasonal Forecast System 3

ECMWF has been running a seasonal forecast system since 1997, during which time there have been two versions: Systems 1 and 2. A system consists of the atmospheric and oceanic components of the coupled model, as well as the data assimilation software to create initial conditions for the ocean, the coupling interface linking the two components, the strategy for ensemble generation and the re-forecasts used for calibrating the system and correcting the systematic errors.

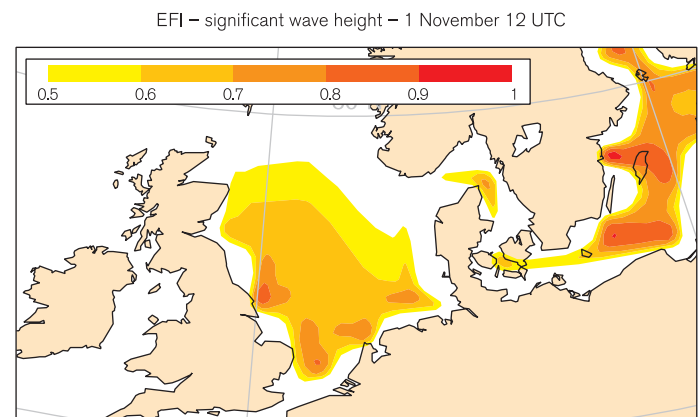
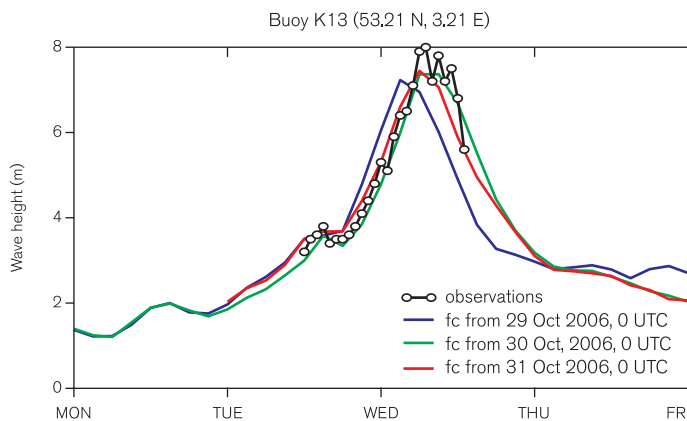
System 2 was introduced in August 2001. Over the last few years work on developing System 3 has proceeded; it is likely to run in parallel with System 2 for a few months before being deemed operationally ready.

The climatology of the atmospheric component of System 3, based on Cycle 31r1 of the IFS, shows substantial improvements with respect to System 2. Research experiments comparing the mean annual frequency of tropical storms for each ocean basin with observations from both systems suggest that System 3 detects more tropical storms and has a better climate than System 2 over all the ocean basins. The likely explanation for this is its increased atmospheric horizontal resolution.



Evaluating ocean wave forecasts: the graph on the left compares the performance of significant wave height forecasts by the major forecasting centres. The lower the curve the better the forecast.

Warning of approaching severe weather: the intense low pressure system illustrated in these images brought a persistent northerly flow over the North Sea, with the resulting high waves and strong storm surge causing damage to shipping and flooding in coastal areas. ECMWF's Extreme Forecast Index gave meteorologists four days' warning of strong winds and waves four days before the event in both the North Sea and the Baltic. The high resolution forecast produced accurate forecasts of both the timing and intensity of the waves, as shown by the time series of forecast and observed wave height at a buoy located in the southern North Sea.



EUROSIP

ECMWF is developing the EUROSIP multi-model seasonal forecasting system in collaboration with the UK's Met Office and Météo France. Processing suites for the French and UK data were run by ECMWF for more than a year. A modest upgrade in the UK forecasting component was made in 2006, requiring the production of corresponding re-forecast data. A multi-model processing suite, which produces a range of graphical multi-model products, is now run daily by ECMWF.

The policy for the distribution of data and products from EUROSIP was discussed at the autumn session of the Policy Advisory Committee (October 2006) and agreed by the Council at the 66th Council session (7-8 December).

Ocean wave forecasting

The state of the sea is an important component of the marine weather forecast, and critical to shipping, fisheries, offshore operations and coastal protection. ECMWF's ocean wave forecasting model is coupled with the atmospheric model and also forms part of the Ensemble Prediction System, providing valuable probabilistic information on sea states to 15 days ahead. ECMWF operates a comprehensive verification system for its ocean wave forecasts and exchanges results with other forecasting centres for comparison.

The resolution of the deterministic ocean wave model was increased from 0.5 degrees to 0.36 degrees in February when the IFS resolution was upgraded. Additionally, wave height data from the altimeter on board the Jason-1 satellite and ASAR data from the ENVISAT satellite were

assimilated into the model for the first time, improving the ECMWF analysis.

Optional project

ECMWF continued production for the Boundary Condition (BC) project throughout 2006. This project provides several Member States with lateral boundary conditions for their short-range applications, based on limited-area forecasting systems. It comprises four short-range forecast suites run at 00, 06, 12 and 18UTC with severe time constraints.

The operational BC suite was reorganised to utilise the more recent 4D-Var analysis, instead of the 3D-FGAT system, and to take advantage of the data produced from the main forecast cycles at 00 and 12 UTC. Verification over the whole extra-tropical northern hemisphere confirmed an overall increase in skill in the BC system as a result of the change, compared to the previous years.



Computing

Running ECMWF's complex weather forecast models in relatively short timescales requires supremely powerful computers and instant access to massive amounts of data. Central to the Centre's activities are its supercomputers and its unique archive of meteorological data, collected over three decades and stored in the Data Handling System.

The High Performance Computer facility

ECMWF has been using IBM computer systems to produce operational forecasts since 2003. Its High Performance Computer (HPC) facility – one of the biggest in Europe – comprises two identical and independent IBM Cluster 1600 supercomputers.

ECMWF's contract with IBM provides for regular upgrades to the system's performance, so that it can run forecasting models faster, cope with regular model upgrades which demand additional computational power, and allow the Centre's researchers to carry out the experiments necessary to develop and refine forecast models.

'ECMWF's user community has access to state-of-the-art computing resources to support their research activities'

The HPC facility received a major upgrade in 2006, when the two clusters of the Phase 3 HPC system were replaced in a phased implementation under Phase 4 of the contract with IBM. One cluster was installed in the new extension to the computer hall; the other was installed at a later date in the original computer hall.

The Phase 3 clusters were decommissioned and replaced one at a time as the new Phase 4 clusters successfully passed their operational acceptance tests. The first cluster did so on 17 August and began generating operational forecasts immediately. Member States were given early access to the new cluster, which quickly took over the workload of the Phase 3 cluster it replaced.

Installation of the second Phase 4 cluster started at the end of August and it passed its operational acceptance test towards the end of 2006. Shortly afterwards, the complete Phase 4 HPC system passed its acceptance tests with flying colours.

Each of the two Phase 4 clusters comprises 155 compute servers with 16 Power5+ processors each. With installation and commissioning complete, the system delivers and sustains almost twice the performance of its predecessor. ECMWF's user community has access to these state-of-the-art computing resources

to support their research activities until 2009, when the entire system is scheduled for replacement with an even more powerful system.

Use of the HPC facility by Member States

50% of ECMWF's high performance computer resources are allocated to research, 25% to producing forecasts and 25% to the research activities of the Member States.

Significant efforts have been expended on providing a steadily increasing number of users from Member States and Co-operating States with support and advice regarding the use of ECMWF's computer facilities. A sizeable number of Member States used a substantial share of their allocation in 2006. All Member States were advised on the migration of their work from Phase 3 to Phase 4 of the HPC facility.

Time-critical applications

ECMWF has developed, and currently monitors, tailored EPS suites for Member States under the 'Framework for Member State time-critical applications', enabling their meteorologists to produce higher-resolution, and therefore more detailed, probabilistic forecasts for their regions. The following suites were updated in February to utilise ECMWF's higher resolution EPS,

and updates on the systems and their performance were given at the Forecast Products Users Meeting in June:

- The new COSMO-LEPS (Consortium for Small-scale Modelling/Limited Area EPS) suite now produces a probabilistic forecast at a resolution of 10 km, instead of the standard 50 km of the global model EPS system
- The Norwegian Meteorological Services Targeted EPS system (TEPS), a specialised version of the ECMWF EPS targeted at the North Atlantic area
- The UK Met Office's THORPEX suite (further technical changes are required before the suite can be declared time-critical).

ECMWF's state-of-the-art supercomputer facilities (below) provided the inspiration for photographer Simon Norfolk's award-winning entry for the Association of Photographers Bursary 2005. The photographs were widely published in magazines in spring 2006 and exhibited at London's Royal Academy of Arts in May 2006.



Special Projects in 2006

Special Projects carried out under the auspices of ECMWF are defined as experiments or investigations of a scientific or technical nature, undertaken by one or more Member States, likely to be of interest to the general scientific community. Users within one of the Member States may apply for computer and archiving resources for a Special Project. European organisations with which ECMWF has concluded a Co-operation Agreement are also eligible for Special Project resources. Special Projects currently in progress are listed on the Centre's website at www.ecmwf.int/about/special_projects.

Data Handling System

Weather forecasting makes use of, and generates, very large volumes of data – observations, analyses and research experiments – that need to be stored for long periods. Our data represent a valuable asset and incomparable archive of world-wide weather observations and weather forecasts over the past 30 years. They are used by researchers in meteorological and environmental studies and are also available for educational and commercial purposes.

For many years ECMWF has operated a dedicated Data Handling System (DHS) in which all ECMWF users can store and retrieve the data needed to perform weather modelling, research in weather modelling or data-mining for weather related data. The ease with which data in the DHS can be accessed is regularly commented upon by visiting scientists and other users of the system.

The IBM High Performance Storage System (HPSS) is the underlying archive system in which all the data are kept. A new version, HPSS 6.2, was implemented in late spring, introducing new features which enhance productivity. Following extensive testing, version 6.2 entered service in October.

During the course of 2006 the DHS's capacity for storing primary data increased by 50% to 4.25 petabytes, with an additional petabyte of storage space available for backup copies of key primary data. By the end of the year there were more than two million files in the Meteorological Archive and Retrieval System (MARS) and about

25 million files in the ECMWF File System (ECFS).

In April 2006 an Invitation to Tender was issued for the replacement of the automated tape library in the disaster recovery building, where copies of data that cannot easily be recreated are kept. ECMWF has selected an IBM TS3500 library, containing LTO-3 tape drives and LTO Ultrium tape cartridges, each of which is capable of holding up to 400 GB of uncompressed data.

Use of GRID Technology

At its 35th session, ECMWF's Technical Advisory Committee (TAC) established a subgroup on the use of grid technology in the meteorological community; an inaugural meeting was convened on 1-2 February. Presenting its findings to the 36th TAC session in October, the subgroup concluded that there was no economic case for establishing a compute grid for running NWP workloads. However, as grid technology links together individual computers into a network of systems accessible from a single portal, the subgroup concluded that data grids showed potential for better collaboration between organisations and for strengthening the European Meteorological Infrastructure (EMI). The need was identified for a technological body to co-ordinate data grid developments within the EMI was identified.

SIMDAT

ECMWF is a partner in the EU-funded project SIMDAT (Data grids for process and product development using numerical simulation and knowledge discovery), and is leading the development of the meteorological application. The objective is to develop an infrastructure, the Virtual Global Information System Centre (VGISC), which offers meteorologists and researchers a virtual view of both all the meteorological data distributed in real-time and the archived databases of the partners, and to provide a secure and reliable mechanism to collect, exchange and share these distributed data.

In November, a prototype of VGISC, developed by ECMWF, EUMETSAT and the German, French and UK National Meteorological Services, attracted considerable interest when it was demonstrated at the WMO Technical Conference, which preceded the session of the Committee for Basic Systems conference in Seoul, South Korea. Eleven sites are currently linked to the prototype.



Data and product distribution

By the end of 2006, ECMWF was disseminating 4,800,000 analysis and forecast products per day to Member States and Co-operating States via its privately managed network and website and to non-members via the WMO's Global Telecommunications System.

Regional Meteorological Data Communications Network

ECMWF Member States, EUMETSAT and the National Meteorological Services within WMO Region VI and beyond – currently 41 sites – have dedicated network access to ECMWF and its forecasting products via the Regional Meteorological Data Communications Network (RMDCN). Throughout 2006, the network continued to provide a stable and reliable service.

ECMWF is in the process of transferring the network's operating system from Frame Relay technology to Multi-Protocol Label Switching technology. The contract with network provider Equant (now OBS) was amended in 2006 to detail the migration process. The transfer has entailed the construction of a new, enhanced network, in parallel with the existing RMDCN network. The lengthy migration phase, which involves individually configuring each of the 41 sites, is scheduled for completion in the first half of 2007. The new RMDCN will bring a number of significant benefits, including higher bandwidth and performance throughout the network and improved cost efficiency.

Meteorological Archival and Retrieval System

There has been considerable interest in the Meteorological Archival and Retrieval System (MARS) from the National Meteorological Services of Portugal, Spain, Brazil and the UK, all of whom are currently evaluating the software. The Australian National Meteorological Service has been running MARS operationally since February 2006.

Support for interim re-analysis, daily climatology and ERA-40 monthly daily forecast accumulations has been added to MARS; ongoing developments include support for GEMS-related data, VarEPS and the ENSEMBLES project.

Web services

ECMWF's website is a major, easily accessible and much appreciated resource for the international meteorological and research community. Users can access a wide range of products and services, computer facilities, MARS, operational and research data, training material, information on special projects and on running experiments with our forecasting system using the prepIFS application.

The ECMWF web servers continued to provide a stable and reliable service throughout 2006. New features and content on the external website included collaboration tools for GEMS and SIMDAT, the web version of the ERA-40 atlas and ECMWF historical documents.

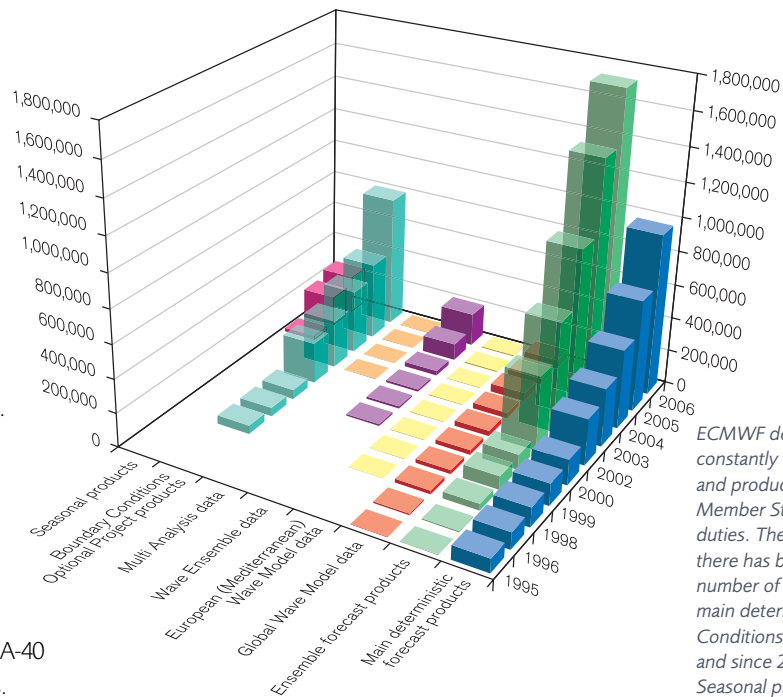
The use of the website continues to grow, with an average growth of 30% per year in the number of pages served. The growth rate of pages served to registered users is even higher.

WMO users

A new page was added to the ECMWF website, to provide a single entry point for the services offered to WMO members. These include a series of graphical products, including EPSgrams, the downloading of data that the Centre makes available on the Global Telecommunications System (GTS) and software to decode WMO formats.

Council also decided to make ECMWF's seasonal forecast products available to the WMO's wider meteorological community via the web. In addition, sea surface temperature forecasts from the seasonal system are disseminated via the GTS to support WMO members running local two-tier global or regional seasonal forecasting systems.

Following a recent invitation from the WMO Secretariat, in acknowledgement of its role as an important provider of global seasonal forecast products, ECMWF was designated a Global Producing Centre for long-range forecasts at the WMO/CBS event in Seoul in November, subject to confirmation by the WMO Congress.



ECMWF develops and disseminates a constantly expanding portfolio of data and products which the meteorologists of Member States use for their own forecasting duties. The figure shows that since 2003 there has been a notable growth in the number of ensemble forecast products, main deterministic products and Boundary Conditions and Optional Project products, and since 2005 an increasing growth in Seasonal products and Wave Ensemble data.

Other activities

ECMWF currently participates in a number of collaborative research programmes run by the European Union and the WMO. The Centre's computer resources and forecasting expertise are helping to improve the accuracy of global forecasting methods, develop new technologies for utilising computer and data storage capacity across distant sites and improve atmospheric monitoring and forecasting for the purposes of environmental and climate research.

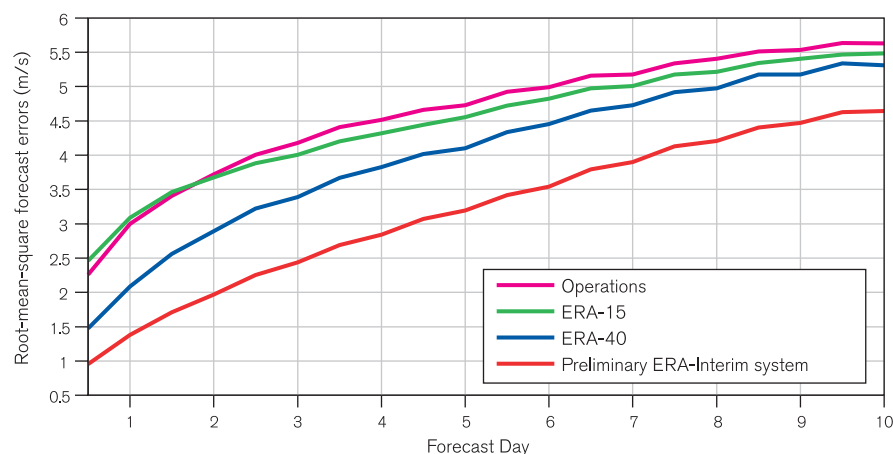
Reanalysis

A powerful new approach to the analysis of the Earth's climate applies the tools and techniques of modern everyday weather forecasting to a process called 'reanalysis'. It involves feeding weather observations collected over past decades into a state-of-the-art forecasting system that is considerably more refined than the systems available when most of the observations were made. Atmospheric and surface conditions are reconstructed for each day of the period over which suitable observations exist.

The success of reanalysis can be measured by the number, variety and quality of applications of its products, which are used in sectors such as agriculture, water management, air quality, health, ecosystems and biodiversity. As reanalysis systems are further refined, their products will increasingly form the backbone of the information essential for climate related policy and decision making in a changing global environment.

In 2006, ECMWF embarked on the ERA-Interim analysis, which will run from 1989 onwards, with observations and boundary fields from its earlier ERA-40 reanalysis and operations. Once it reaches the present day, ERA-Interim will continue in near real-time in 'Climate Data Assimilation System' (CDAS) mode. It will serve as an intermediate reanalysis between ERA-40 and the next extended reanalysis, and complement CDAS activities in Japan and the USA.

Early in 2006 a user-friendly version of the ERA-40 climatological atlas was made available on the ECMWF website. The atlas describes the climate during 1979-2001, the period with the best and most time-consistent product quality for the globe as a whole. The climate over the period is presented for the four



Forecasts made retrospectively from successive reanalyses of past atmospheric observations can be validated to demonstrate the improvements that result from developing better ways of analysing the observations and modelling the atmosphere. The curves show errors in low-level tropical wind forecasts as a function of forecast range measured for dates in 1989 and 1990, from ECMWF's operations at the time and from subsequent ERA-15, ERA-40 and ERA-Interim reanalyses carried out at approximately six-yearly intervals (the lower the curve, the more accurate the forecast).

seasons, the annual average and the inter-annual variability. These products are based on the ERA-40 monthly/diurnal averages, together with six-hourly analysis and forecast fields. A selection of time series, showing, for example, the quasi-biennial oscillation of stratospheric winds, is presented for the full period 1958-2001.

AMMA

ECMWF participates in the component of the African Monsoon Multidisciplinary Analysis (AMMA) project funded by the EU under the Sixth Framework Programme. Its principle goal is to obtain a better understanding of the intra-seasonal and interannual variability of the west African monsoon. The main fieldwork took place during summer 2006; ECMWF's contribution was to maintain a dedicated internet facility for real-time monitoring of the number and quality of observations. AMMA radiosondes were included in our assimilation and forecast suites and their

impact assessed. In the future, more AMMA observations will be used to diagnose and reduce the systematic errors of the IFS model over the Sahelian region.

Observing System Experiments

The goal of the EUMETNET Composite Observing System (EUCOS) programme is to deliver terrestrially based operational observations for the improvement of regional NWP in Europe. To ensure the EUCOS programme evolves and meets customer needs for regional NWP, Observing System Experiments (OSEs) were commissioned in 2006 from selected NWP centres to evaluate and compare the contribution of the components of

the in-situ Observing System and the satellite-based Observing System to numerical weather forecasts.

The experiments ran for a period of 43 days in the winter and 46 days in the summer. The results demonstrated that wind and temperature observations from radiosondes and aircraft had a major impact on NWP, while radiosonde humidity observations and wind profilers had a marginal impact. Furthermore, while wind observations alone from radiosondes did have any notable impact on forecast accuracy, when coupled with temperature observations they significantly and statistically improved forecasts, well within the medium range.

'The success of reanalysis can be measured by the number, variety and quality of applications of its products'



Photograph courtesy of The World Bank

Forecasting public health hazards: Mosquito-borne epidemic malaria infects 500 million people worldwide each year, killing an estimated one million - most of them children. ECMWF's seasonal forecasts are making a major contribution to the EU-funded DEMETER project, which has been assessing the effectiveness of a multi-model ensemble system in real-life decision-making processes. DEMETER has developed a malaria prevalence forecast system that is enabling public health officials in Botswana and surrounding countries to allocate their limited resources effectively in the fight against malaria.

The evaluation of the contribution of the components of the satellite based Observing System was performed in collaboration with EUMETSAT, over the same periods, using the same version of the assimilation system, as the EUCOS study. It confirmed that all the space based instruments are contributing positively to the overall improvement of the ECMWF forecasting system.

During 2006 ECMWF produced a detailed 13 month simulation of its high-resolution IFS model, in support of the optimisation of the Global Observing System. This simulation, called a 'nature run', will be used by research groups throughout the world to simulate the impact of novel observation systems on weather forecast skill, facilitating the decision making process for future investment in costly observation platforms, such as satellite instruments. The dataset

has been distributed to a wide community and is currently being assessed. Results have shown that it can safely be used as a proxy to the real atmosphere.

GMES and GEO

During 2006, ECMWF continued to contribute to the development of the EU's Global Monitoring for Environment and Security (GMES) initiative. GMES aims to make environmental information more readily available to scientists, policy-makers and industry, and to create a European shared information system for exchanging a wide range of information.

ECMWF attended the 6th meeting of the GMES Advisory Council (GAC) in Brussels (31 May), several meetings of the GAC Working Group on 'Future GMES structure and governance' and the GMES conference hosted in Graz by the EU Austrian Presidency. The Centre supported

preparatory activities for new GMES services, such as the atmospheric monitoring service.

The Group on Earth Observation (GEO) is leading a worldwide initiative to build a Global Earth Observation System of Systems (GEOSS) over the next 10 years. ECMWF's contribution to GEO activities in 2006 included the provision of impact studies and simulations concerning the protection of radio frequencies essential for tropospheric sounding, and for passive measurements in particular.

GEMS

As a contribution to GMES, the EU-funded project GEMS (Global and regional Earth-system Monitoring using Satellite and in-situ data) has been established to develop an atmospheric monitoring service which will generate valuable new analysis and forecast products and produce regional

short- and medium-range forecasts indicating air quality and pollution patterns across Europe. The four-year project is co-ordinated by ECMWF, which is also responsible for developing and operating the global forecast system for atmospheric composition.

GEMS was initiated operationally in 2006, when the technical components of the project were put into place. The GEMS Annual Assembly was convened at ECMWF in February (6-10) to review progress since the start of the project and to make plans for the coming 18 months. A report on the project's first year was presented to the European Commission on 28 June.

ECMWF contributed significantly to the preparation of a draft proposal for the prototype service, GMES Atmospheric Services (GAS). An important milestone for the development of GEMS' operational continuation activities was reached when GAS was authorized to proceed at the 7th GAC meeting in Brussels (25 October); a workshop followed in Brussels (December 6-7) to prepare the content of GAS.

ENSEMBLES

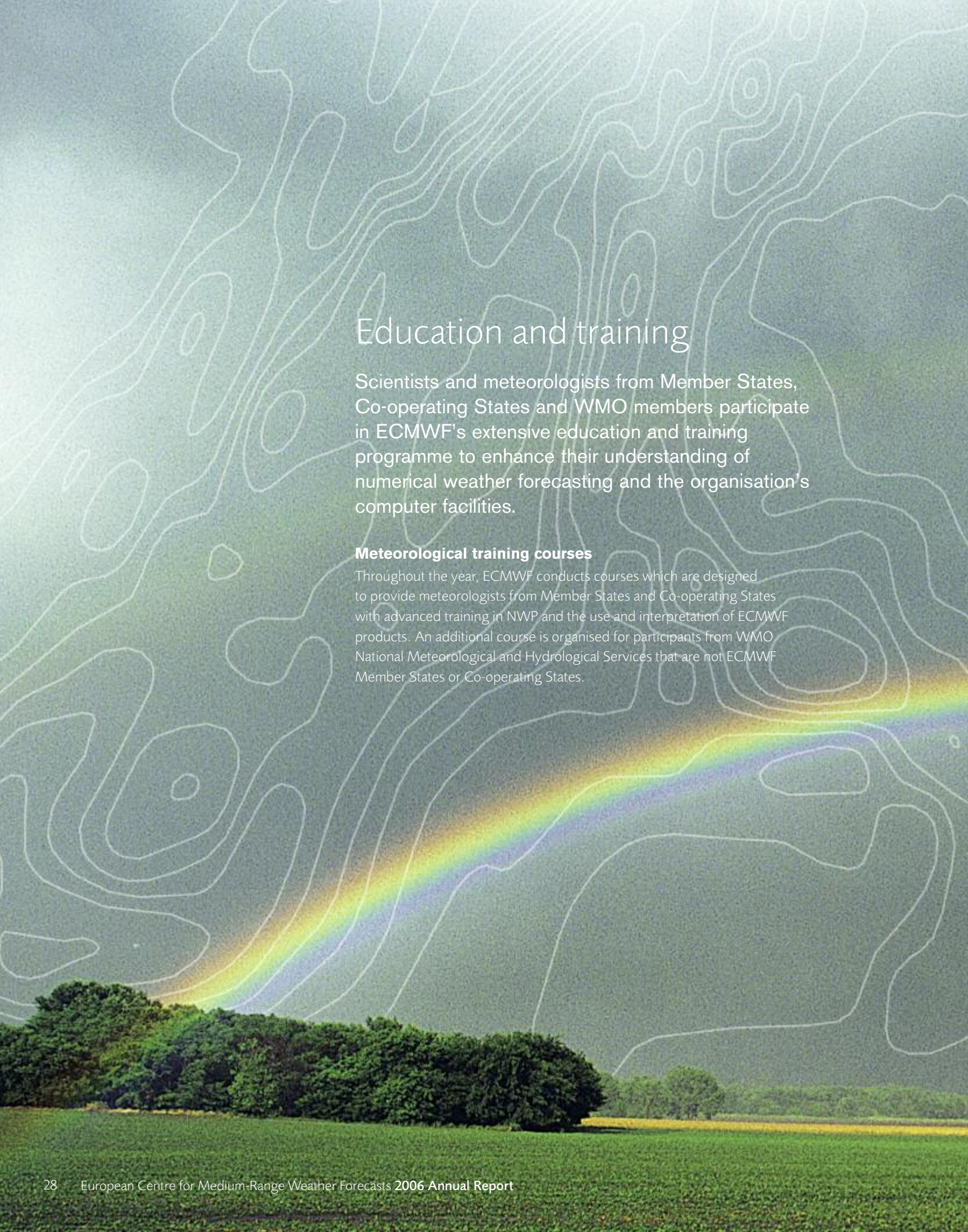
Predictions of climate variability and the human impact on climate are inherently probabilistic, owing to uncertainties in the initial conditions of forecasts, the representation of key processes within models and other factors influencing climate. Reliable estimates of climate change can only be made through ensemble integrations of Earth-system models into which these uncertainties are explicitly incorporated.

The EU-funded ENSEMBLES project aims for the first time to develop a common ensemble climate forecast system for use across a range of timescales (seasonal, decadal and longer) and spatial scales (global, regional and local). The

ENSEMBLES model system will be used to construct integrated scenarios of future climate changes to provide a basis for quantitative risk assessment of climate change and variability, and also to develop a range of applications for agriculture, health, food security, energy, water resources, insurance and weather risk management.

The project is organised into a number of research themes, of which ECMWF contributes to two significantly: the development of the Ensemble Prediction System and the production of hindcasts on seasonal and decadal timescales. In 2006 ECMWF hosted a joint meeting (8-9 June) to consider the goals achieved to date for both themes and the plans for the third year of the project.

'The GEMS atmospheric monitoring service will generate valuable new analysis and forecast products and produce regional short- and medium-range forecasts indicating air quality and pollution patterns across Europe'



Education and training

Scientists and meteorologists from Member States, Co-operating States and WMO members participate in ECMWF's extensive education and training programme to enhance their understanding of numerical weather forecasting and the organisation's computer facilities.

Meteorological training courses

Throughout the year, ECMWF conducts courses which are designed to provide meteorologists from Member States and Co-operating States with advanced training in NWP and the use and interpretation of ECMWF products. An additional course is organised for participants from WMO National Meteorological and Hydrological Services that are not ECMWF Member States or Co-operating States.

As in previous years, the 2006 courses comprised the following modules:

- **ECMWF products**

(organised by the Operations Department)

- 13-17 March: Use and interpretation of ECMWF products; repeated 5-9 June
- 9-13 October: Use and interpretation of ECMWF products for WMO members.

- **Numerical Weather Prediction**

(organised by the Research Department)

- 22-31 March: Data assimilation and use of satellite data
- 24-28 April: predictability, diagnostics and seasonal forecasting
- 2-12 May: Parametrization of diabatic processes
- 15-24 May: Numerical methods, adiabatic formulation of models.

A total of 148 applications for one or more modules of the meteorological training courses was received from 15 Member States and 11 applications from Co-operating States and organisations with which ECMWF has a working agreement. In addition, applicants were accepted from six non-Member States.

The Centre received 26 applications for the WMO-sponsored course on the use and interpretation of ECMWF products for WMO members, of whom 22 were accepted.

GEMS training session

A separate one day training session, attended by 10 participants, was organised during the GEMS Annual Assembly hosted by ECMWF (6-10 February) to train people involved in the GEMS project.

Computer training course

ECMWF's 2006 computer training course (16 February-10 March) comprised five independent modules:

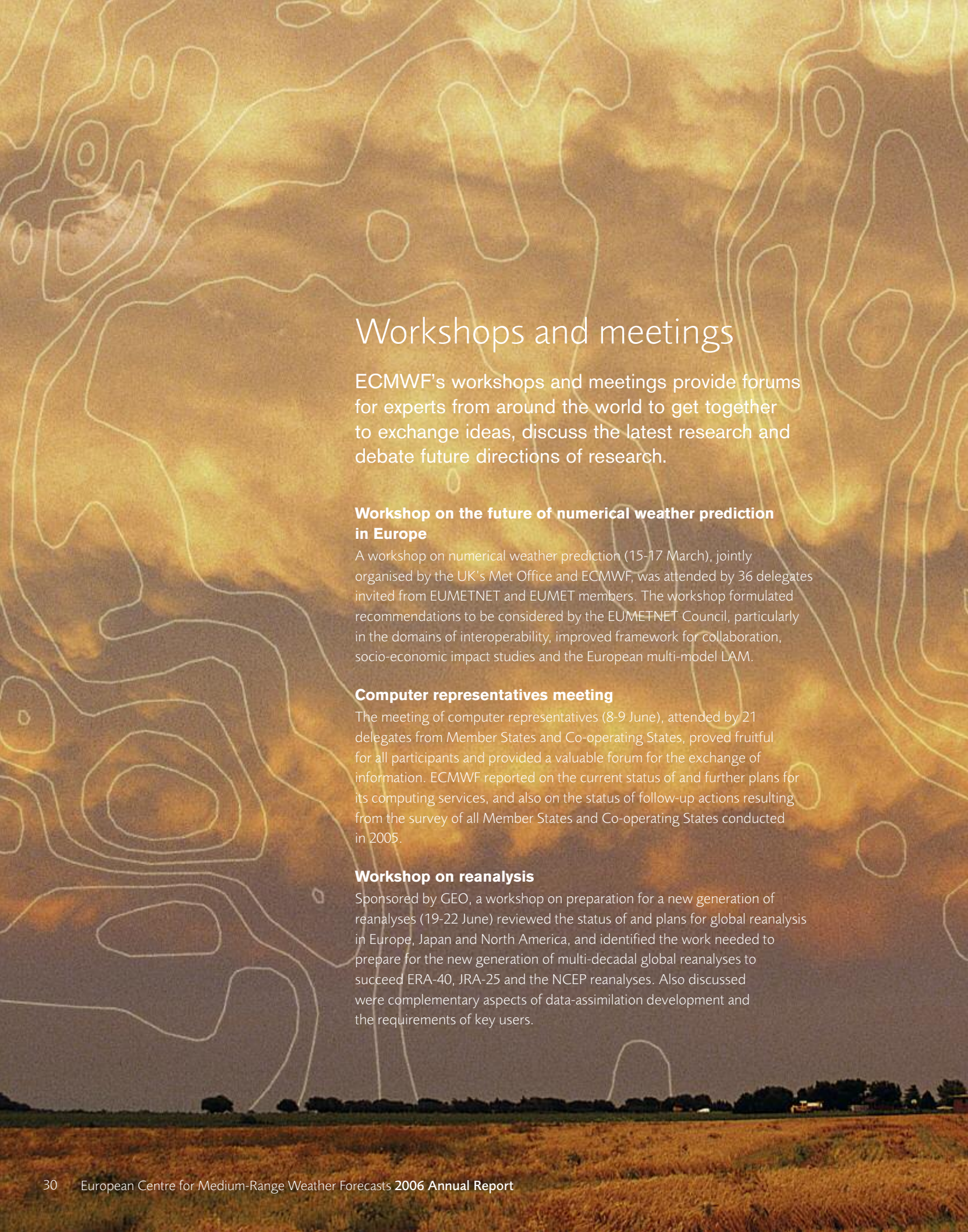
- Introduction to the Supervisor Monitor Scheduler (SMS/XCDP) for workflow management
- Introduction to the Meteorological Archival and Retrieval System (MARS) for new users
- The Meteorological Application Graphics Integrated Colour System (MAGICS)
- The Metview graphics system
- Use of ECMWF's supercomputer resources.

Fifty-seven participants from Member States, Co-operating States and other organisations attended the course.

Annual seminar on polar meteorology

ECMWF's Annual Seminar (4-8 September) took as its theme the impending International Polar Year (IPY). Delegates reviewed the recent advances in knowledge and understanding of polar atmospheric science, together with some of the key issues to be addressed in IPY. Participants from Member States and Co-operating States discussed data assimilation, modelling and predictability challenges that are unique to such high latitudes, including those associated with the land, ocean and cryosphere. Also addressed were the performances of NWP and climate modelling systems in these regions and the nature and causes of observed deficiencies.

'ECMWF's courses provide meteorologists with advanced training in NWP and the use and interpretation of our products'



Workshops and meetings

ECMWF's workshops and meetings provide forums for experts from around the world to get together to exchange ideas, discuss the latest research and debate future directions of research.

Workshop on the future of numerical weather prediction in Europe

A workshop on numerical weather prediction (15-17 March), jointly organised by the UK's Met Office and ECMWF, was attended by 36 delegates invited from EUMETNET and EUMET members. The workshop formulated recommendations to be considered by the EUMETNET Council, particularly in the domains of interoperability, improved framework for collaboration, socio-economic impact studies and the European multi-model LAM.

Computer representatives meeting

The meeting of computer representatives (8-9 June), attended by 21 delegates from Member States and Co-operating States, proved fruitful for all participants and provided a valuable forum for the exchange of information. ECMWF reported on the current status of and further plans for its computing services, and also on the status of follow-up actions resulting from the survey of all Member States and Co-operating States conducted in 2005.

Workshop on reanalysis

Sponsored by GEO, a workshop on preparation for a new generation of reanalyses (19-22 June) reviewed the status of and plans for global reanalysis in Europe, Japan and North America, and identified the work needed to prepare for the new generation of multi-decadal global reanalyses to succeed ERA-40, JRA-25 and the NCEP reanalyses. Also discussed were complementary aspects of data-assimilation development and the requirements of key users.

Security representatives meeting

ECMWF's annual meeting of Member State and Co-operating State Security Representatives on 16-17 May provided a forum for exchanging views and experiences, reviewing the status of the security arrangements at ECMWF and in each Member State and Co-operating State and discussing planned developments. Among the topics discussed were Strong Authentication Systems and the outcome of an external security audit, focused on the perimeter systems, acquisition and dissemination of data. The security audit identified no major vulnerabilities and concluded ECMWF's internet access is well secured.

Forecast products users meeting

The annual meeting for users of ECMWF's medium-range and extended range products (June 14-16) gave forecasters the opportunity to: discuss their experiences with and to exchange views on the use of medium-range and extended range products, including the Ensemble Prediction System (EPS); review the development of the operational forecasting system; and discuss plans for future changes, including the development of new forecast products.

Participants included operational forecasters from National Meteorological Services, commercial providers and academic users involved in developing

products and assessing predictability at different timescales. Examples of the growing range of applications were presented from a variety of sectors, including energy, media, transport, health and water management (e.g. drought planning and flood risk assessment).

Workshop on high performance computing in meteorology

The 12th ECMWF workshop on high performance computing in meteorology (30 October-3 November) was attended by 100 delegates from National Meteorological Services, research institutions and computer vendors from Europe, Asia and the Americas. Topics for discussion included model development, usage of HPC systems and future development in meteorological applications and computer hardware and software. With supercomputer systems delivering petaflops performance becoming a reality by the end of the decade, further increasing their complexity, the effective usage of ever-growing numbers of processors and coping with rising costs will create major challenges.

Workshop on the parametrization of clouds in large-scale models

Hosted by ECMWF (13-15 November), the workshop's purpose was to review the most recent developments in research and to explore new ideas. Even by ECMWF

standards, the workshop was a popular and oversubscribed event. Among the aspects addressed were: cloud microphysics, with consideration of more processes and prognostic variables than currently in the IFS; the statistical nature of cloud schemes; the interaction of clouds with radiation; numerical methods for fast cloud processes in the NWP context; and verification using ground-based and satellite observations with particular emphasis on ice clouds. The main outcome was a set of recommendations for future research directions both at ECMWF and in the wider research community.

Use of the EPS continued to grow throughout 2006, with several examples reported of new applications using EPS data to provide information on confidence and risk assessment. Some users reported positively on the monthly forecast system, which was found to provide useful skill, especially for temperature predictions up to three weeks ahead. The general high quality of ECMWF products was noted in many presentations. Following February's high resolution upgrade, forecasters soon began reporting improvements for severe weather events and for the EPS.

Delegates made it clear at the meeting how many users appreciate and benefit from the products developed at ECMWF. The ease of access and wide range of products available was especially appreciated.

Administrative matters

Personnel

ECMWF's Director, appointed by the Council, is responsible for implementing the organisation's objectives and oversees three departments: Operations, Research and Administration.

At December 2006 ECMWF employed 153 staff members, 67 consultants and 37 contractors. During the year nine staff members were recruited, four left the organisation and eight people retired.

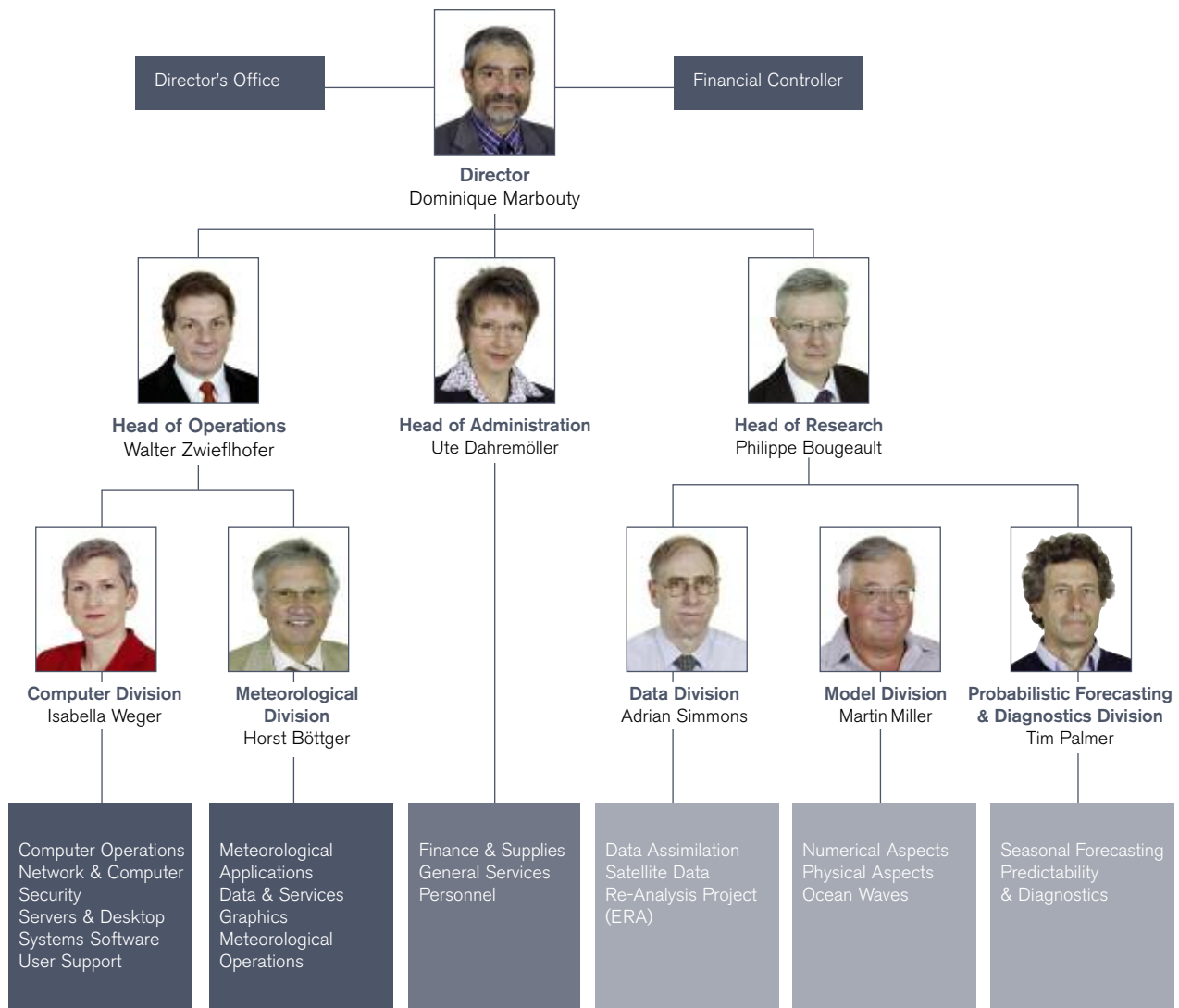
Staff and consultants' nationalities

ECMWF operates an equal opportunities policy. The Centre recruits staff and consultants solely on the basis of their qualifications and experience, and not on their gender, marital status, race or religion.

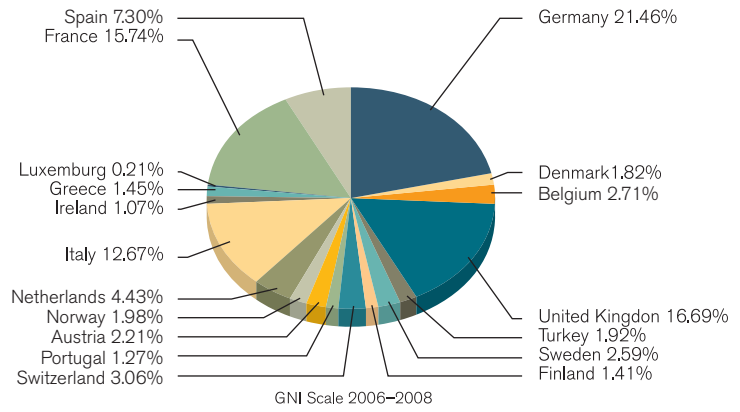
Proportion of female staff employed by ECMWF 2002–2006

Grades/Year	2002	2003	2004	2005	2006
B-grades	51%	47%	48%	49%	50%
A-grades	11%	13%	14%	16%	17%

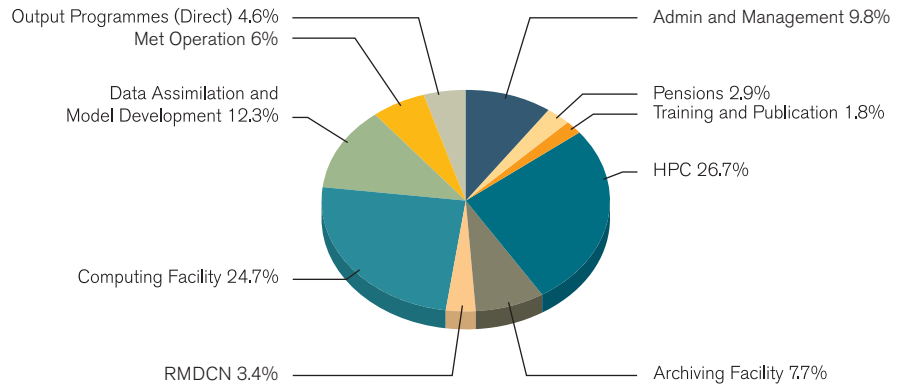
The ECMWF Organisation at 31 December 2006



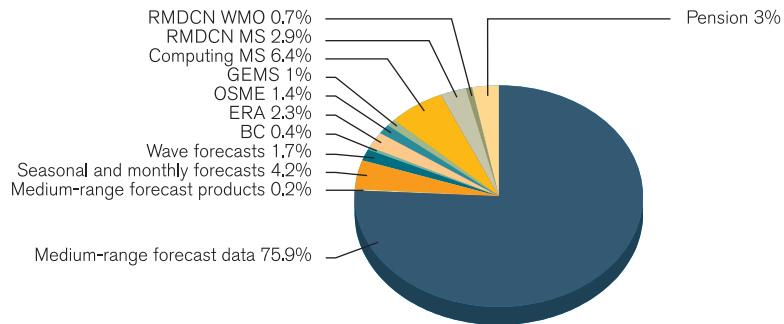
ECMWF Budget 2006



ECMWF Accounts 2005 by Infrastructure Programmes
Net Expenditure £28m (excl. externally funded projects)



ECMWF accounts 2005 by output programmes
Net expenditure £28m (excluding externally funded projects)





The Centre's long-awaited new block provides a new home for a major part of the Research Department and much-needed space for new activities.

The Funded Pension Scheme

At the 65th session the Council approved the Finance Committee's recommendation that long-term consultants from Member and Co-operating States (i.e. with an uninterrupted contract exceeding two years) should be permitted to enrol in ECMWF's Funded Pension Scheme, with effect from 1 January 2007.

Finance

ECMWF's budget for 2006 totalled £29,340,300, which included contributions from Member States and Co-operating States amounting to £27,885,700. The main expenditure was on the high performance computer infrastructure and staff.

Facilities

A milestone in ECMWF's development was the completion of the new office building on 27 November 2006, providing much-needed office space to accommodate new activities such as Seasonal Forecast, RMDCN and GEMS. Designed to integrate with the original style of architecture of the existing buildings, the new block provides well-furnished modern offices, communal areas on each floor, three new meeting rooms and a bright and spacious atrium.

The new building's completion almost to schedule was a major achievement, given that the ECMWF project management team took over the responsibilities of the main contractor in May 2006, when the company went into receivership only three-quarters through the construction work.

Staff and consultants of the Research Department are now resident in the building. This has provided an opportunity to reorganise the allocation of offices in the old building, so that all sections within a division are located at close quarters.

Programme Task Team

At its 65th session (July 2006) the Council agreed to set up a Programme Task Team (PTT) to consider long-term funding solutions for the Centre.

The PTT's report to Council at its December session stated that:

- 75% of the cost was allocated to medium-range forecast data
- ECMWF had developed supplementary activities at very low costs
- ECMWF carries out its activities very efficiently

- The Centre's lean administration and management account for well below 10% of its costs
- The overall percentage of expenditure on core activities was 96.4%
- The overall ratio of expenditure on principal goals compared to expenditure on supplementary goals is 87.5% to 12.5% (ECMWF's strategy aims at a minimum of 80% to 85%)
- The level of reporting to its governing bodies was appropriate.

The PTT also analysed a questionnaire sent to Member States which confirmed that ECMWF's products and services are critically important to the Member States. ECMWF's outputs, it concluded, were highly valued by the Member States for their contribution to a number of socio-economic areas, with medium-range weather forecasts being of highest priority.

As a result of the work of the PTT the Council approved at its 66th session (December 2006) an increase of the budget for the High Performance Computing Facility.

Appendices

The ECMWF Council and its committees

The Council

As ECMWF's governing body, and comprising two representatives from each Member State, the Council adopts measures that implement the Convention. Its responsibilities include admission of new members, authorising the Director to negotiate and conclude co-operation agreements, determining the annual budget and the scale of financial contributions of the Member States, adopting the Financial Regulations and the Staff Regulations and pursuing the Centre's long-term strategy and programme of activities.

ECMWF's 65th Council Session

The 65th session was held in Oslo, Norway (6-7 July), at which the Council, among other decisions:

- Authorised the Director to conclude an agreement with Morocco for scientific and technical co-operation
- Decided to allow consultants from Member States and Co-operating States with an uninterrupted contract exceeding two years to enrol in the Centre's Pension Scheme
- Decided to set up a Programme

Task Team (PTT) to consider long-term funding issues, designating Pierre-Etienne Bisch as its Chair

- Decided to add products to ECMWF's catalogue of real-time products and reduce information charges for small service providers, and approved the enhancement of product dissemination for WMO members
- Supported the Centre's engagement with the GEO initiative and agreed to the provision to GEO of data sets specifically linked to its activities.

ECMWF's 66th Council Session

The 66th session was held at the Centre's headquarters in Reading, UK (7-8 December), at which the Council, among other decisions:

- Approved an increase of the budget for the High Performance Computing Facility by £3,446,000 from 2009, and a second increase from 2011 (to be decided by December 2007 at the latest), to allow the Centre's 10-year Strategy to be implemented without delay
- Increased the Member States' contributions to the 2007 budget by 5.5% to maintain the level of resources and cope with increased electricity and pension costs.

- Noted the findings of the PTT's report, which: confirmed that almost 75% of the Centre's costs are allocated to medium-range forecasts and that the Centre develops supplementary activities at a very low cost; verified that the Centre has a lean administration and management with expenditure well below 10% of the total cost; presented the results of a questionnaire which demonstrated the importance and variety of applications of ECMWF products and services and the high regard in which they are held by the Member States in contributing to a number of socio-economic areas, with medium-range weather forecasts being of highest priority
- Unanimously adopted the updated Four Year Programme of Activities for the period 2007-2010
- Tasked the Director to develop further ECMWF's co-operation with the European Commission on the basis of opportunities such as GEMS and global and regional reanalysis
- Authorised the Director to negotiate a Co-operation Agreement with Montenegro.



Participants gathered in Oslo, Norway, in the summer for the 65th Council session (picture courtesy of Detlev Frömming).

Member States' representatives to Council Sessions



President: Anton Eliassen (Norway)



Vice-President: Adérito Vicente Serrão (Portugal)

State	Representatives	Advisers
Belgium	Henri Malcorps, Werner Verschueren	
Denmark	Peter Aakjaer, Leif Laursen	
Germany	Wolfgang Kusch, Gerhard Adrian	Detlev Frömming, Christian Sperling
Spain	Jesus Patan	
France	Pierre-Etienne Bisch, Alain Ratier Philippe Veyre	Jean-Louis Gaumet
Greece	Dimitrios Skourgias, Ioannis Papageorgiou Maria Katsimardou-Refene	Emmanouil Kefalopoulos, Eleni Georgopoulou
Ireland	Tom Sheridan, Declan Murphy	
Italy	Massimo Capaldo, Pierluigi Cascioli	
Luxembourg	Claude Alesch	
The Netherlands	Frits Brouwer	
Norway	Anton Eliassen, Øystein Hov	Lillian Svendsen
Austria	Fritz Neuwirth	
Portugal	Adérito Vicente Serrão	
Switzerland	Daniel Keuerleber-Burk	
Finland	Pekka Plathan, Mikko Alestalo	
Sweden	Maria Ågren, Jörgen Nilsson	
Turkey	Adnan Ünal, Kemal Dokuyucu Can Oguz	
United Kingdom	Mark Hutchinson, George Pankiewicz Alan Dickinson	Phil Evans, Jim Sharp

Programme Task Team

At its 65th session (July 2006) the Council agreed to set up a Programme Task Team (PTT) to consider long-term funding solutions for the Centre.



Chair: Pierre-Etienne Bisch (France)

Member States' representatives:

Germany: Wolfgang Kusch, Detlev Frömning, Christian Sperling
Spain: Manuel Palomares
France: Pierre-Etienne Bisch, Alain Ratier
Netherlands: Frits Brouwer, Piet de Wildt
Austria: Fritz Neuwirth
Sweden: Maria Ågren, Jörgen Nilsson
United Kingdom: Phil Evans

The Council is advised in its work by the following six committees, which consist of experts from the Member States.

Policy Advisory Committee (PAC)

The PAC provides the Council with opinions and recommendations on any matters concerning ECMWF policy submitted to it by the Council, especially those arising out of the Centre's four-year programme of activities and long-term strategy.



Chair: Massimo Capaldo (Italy)
Vice-Chair: Fritz Neuwirth (Austria)

Member States' representatives:

Germany: Wolfgang Kusch, Detlev Frömning, Christian Sperling
Spain: Bartolomé Orfila, Manuel Palomares
France: Alain Ratier
Italy: Massimo Capaldo
Austria: Fritz Neuwirth
Finland: Mikko Alestalo
Sweden: Jörgen Nilsson
United Kingdom: George Pankiewicz, Alan Dickinson, Phil Evans

Finance Committee (FC)

The FC provides the Council with opinions and recommendations on all financial matters submitted to the Council and exercises the financial powers delegated to it by the Council.



Chair: Laurence Frachon (France)
Vice-Chair: Monika Köhler (Austria); succeeded Fabrice Carton (Belgium)

Member States' representatives:

Germany: Detlev Frömning, Christian Sperling
France: Jean-Louis Gaumet, Laurence Frachon
Italy: Antonio Bartolini, Pierluigi Cascioli
Austria (also representing Belgium, The Netherlands, Switzerland and

Luxembourg): Monika Köhler (Austria)
Fabrice Carton (Belgium)
Netherlands: Piet de Wildt (observer)
Greece (also representing Spain, Portugal and Turkey): Michael Georgiadis
Spain: Manuel Palomares (observer)
Ireland (also representing Denmark, Norway, Finland and Sweden): Eamon Murphy, Jim Logue
United Kingdom: Liz Ritchie, Paul Mundy, Phil Evans

Scientific Advisory Committee (SAC)

The SAC provides the Council with opinions and recommendations on the draft programme of activities of the Centre drawn up by the Director and on any other matters submitted to it by the Council. SAC members are appointed in their personal capacity and are selected from among the scientists of the Member States.



Chair: Thor Erik Nordeng
Vice-Chair: Gerhard Adrian

Members:

Gerhard Adrian
François Bouttier
Luigi Cavaleri
Martin Ehrendorfer
John Eyre
Hans Huang
Dr Heikki Järvinen
Hennie Kelder
Thor Erik Nordeng
Ernesto Rodriguez-Camino
Julia Slingo
Michael Tjernström

Technical Advisory Committee (TAC)

The TAC provides the Council with advice on the technical and operational aspects of the Centre including the communications network, computer system, operational activities directly affecting Member States, and technical aspects of the four-year programme of activities.



Chair Kristiina Soini (Finland)

Vice-Chair: Alan Dickinson (United Kingdom)

Member States' representatives:

Belgium: Daniel Gellens
Denmark: Leif Laursen
Germany: Helmut Ladwig, Dieter Schröder
Spain: Pablo del Rio, Fermin Elizaga
France: Bernard Strauss, Matteo Dell'Acqua
Greece: Dimitrios Kapniaris
Ireland: Jim Logue
Italy: Sergio Pasquini
Luxembourg: Claude Alesch
Netherlands: Toon Moene
Norway: Jens Sunde, ar Skålin
Austria: Georg Kaindl, Yong Wang
Portugal: Teresa Abrantes, Maria Monteiro
Switzerland: Stefan Sandmeier
Finland: Kristiina Soini, Pertti Nurmi
Sweden: Ilmar Karro, Håkan Borg
Turkey: Fatih Büyükkasabbasi
United Kingdom: Alan Dickinson, Nick Graham

Co-operating States' representatives:

Croatia: Ivan Cacic, Cedo Brankovic
Czech Republic: Martin Janousek
Hungary: Zoltán Dunkel, Istvan Ihász

Iceland: Kristjan G. Bjarnason, Halldor Bjornsson
Romania: Victor Pescaru
Serbia: Ljiljana Dekic
Slovenia: Jure Jerman

TAC Subgroup on Use of GRID Technology



Chair Roar Skalin (Norway)

Member States' representatives:

Denmark: Leif Laursen
France: Bernard Strauss, Jean-François Estrade
Germany: Helmut Ladwig, Dieter Schröder
Italy: Sergio Pasquini, Pier Francesco Coppola
Netherlands: Toon Moene, Gerard Cats
Norway: Jens Sunde, Roar Skålin
Sweden: Ilmar Karro, Esa Falkenroth
United Kingdom: Alan Dickinson, Bob Ellis

Co-operating States' representatives:

Hungary: Zoltán Dunkel, László Kullmann
Slovenia: Jure Jerman

Advisory Committee for Data Policy (ACDP)

The ACDP provides the Council with opinions and recommendations on matters concerning ECMWF Data Policy and its implementation.



Chair: Lillian Wester-Andersen (Denmark),
Vice-Chair: Colin Cuthbert (United Kingdom)

Member States' representatives:

Belgium: Valérie Schraepen
Denmark: Lillian Wester-Andersen
Germany: Klaus Haderlein, Detlev Frömming
Spain: Francisco Pascual, Manuel Palomares
France: Jean-Louis Gaumet, Christine Mengus
Ireland: Liam Campbell
Netherlands: Ton Donker
Norway: Lillian Svendsen
Austria: Monika Köhler
Finland: Lea Leskinen
Sweden: Gunlög Wennerberg, Marcus Flarup
United Kingdom: Colin Cuthbert

Co-operating State representative:

Romania: Ion Victor Pescaru

Advisory Committee for Co-operating States (ACCS)

The ACCS provides the Council with opinions and recommendations on the Centre's programme of activities, and on any matter submitted to it by the Council.



Chair: Jozef Roskar (Slovenia)

Vice-Chair: Ion Sandu (Romania)

Co-operating States' representatives:

Croatia: Cedo Brankovic
Hungary: László Bozó
Serbia: Dragan Jovanovic
Slovenia: Jozef Roskar

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483 Ferranti, L. and P. Viterbo: The European summer of 2003: sensitivity to soil water initial conditions (January 2006)

484 Jung, T., L. Ferranti and A.M. Tompkins: Response to the summer 2003 Mediterranean SST anomalies over Europe and Africa (February 2006)

485 Jung, T., S.K. Bulev, I. Rudeva and V. Soloviev: Sensitivity of extratropical cyclone characteristics to horizontal resolution in the ECMWF model (February 2006)

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487 Bauer, P., P. Lopez, A. Benedetti, D. Salmond and E. Moreau: Implementation of 1D-4D-Var assimilation of precipitation affected microwave radiances at ECMWF, Part 1: 1D-Var (February 2006)

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490 Eden, C. and T. Jung: Wind-driven eddies and plankton blooms in the North Atlantic Ocean (March 2006)

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495 Bormann, N. and J.-N. Thépaut: Assimilation of MIPAS limb radiances in the ECMWF system. Part I: Experiments with a 1-dimensional observation operator (August 2006)

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504 Richardson, D., J. Bidlot, R. Buizza, L. Ferranti, A. Ghelli, G. van der Grijn and E. Zsoter: Verification statistics and evaluations of ECMWF forecasts in 2005-2006 (November 2006)

505 Weissmann, M. and C. Cardinali: The impact of airborne Doppler lidar observations on ECMWF forecasts (November 2006)

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- No. 26 Betts, A.K., J.H. Ball, A.G. Barr, T.A. Black, J.H. McCaughy and P. Viterbo: Assessing land-surface-atmosphere coupling in the ERA-40 reanalysis with boreal forest data (August 2006)
- EUMETSAT/ECMWF Fellowship Programme Research Report
- No. 16 Healy, S.B., J.R. Eyre, M. Hamrud and J.-N. Thépaut: Assimilating GPS radio occultation measurements with two-dimensional bending angle observation operators (August 2006)
- ESA Reports
- Abdalla, S. and H. Hersbach: The technical support for global validation of ERS Wind and Wave Products at ECMWF (April 2004 – June 2006). Final Report for ESA contract 18212/04/I-OL
- Seminar and workshop proceedings
- Seminar on polar meteorology, 4-8 September 2006
 - Workshop on ECMWF/GEO Workshop on atmospheric reanalysis, 19-22 June 2006
- ECMWF Strategy 2006-2015 (August 2006)
 - ECMWF Newsletter was published in Spring (No 107), Summer (No 108), Autumn (No 109) and Winter (No 110)
 - Global Data Monitoring Report, published monthly by ECMWF
 - Global Earth-system monitoring, 5-9 September 2005 (February 2006)
 - Application and verification of ECMWF products in Member States & Co-operating States (September 2006)

Externally-funded projects and services in 2006

Project Acronym	Project Name	ECMWF role
ADM/ AEOLUS	Development and production of aeolus wind data products	subcontractor
AMMA	African Monsoon Multidisciplinary Analysis	contractor
ARM	Model validation studies	subcontractor
ASSET	Assimilation for ENVISAT data	contractor
BOSS4	Building Operational Sustainable Services for GEMS	contractor
DEISA	Distributed European infrastructure for supercomputing applications	contractor
eDEISA	Extended distributed European infrastructure for supercomputing applications	contractor
EGPM-Simulator	Development of an end-to-end tool to simulate the performance of the European contribution to the GPM (EGPM) mission (EGPM II)	contractor
ENSEMBLES	Ensemble-based predictions of climate change and their impacts	contractor
ENVISAT II	Technical support for global validation of ENVISAT data products	contractor
EPS/IASI PHASE 3	Support of ECMWF to EPS/IASI development phase 3 (EPS/IASI 2), WP3	contractor
ERS Validation II	Technical support for global validation of wind and wave products (ERS II)	contractor
EUMETSAT fellowships		contractor
EURORISK PREVIEW	Prevention, information and early warning pre-operational services to support the management of risks	contractor
GEMS	Monitoring using satellite and in-situ data	coordinator
GEOLAND	GMES products & services, integrating EO monitoring capacities to support the implementation of European directives & policies related to "land cover & vegetation"	contractor
HALO	Harmonised coordination of the atmosphere, land and ocean, integrated projects of the GEMS backbone	coordinator
H-SAF	Satellite Application Facility on support to operational hydrology and water management	contractor
JRC HPC facilities	Provision of flexible dedicated High Performance Computing facilities	contractor
MERSEA	Marine Environment and Security for the European Area	contractor
Microwave Radiometer	Mission requirement for a Post-EPS microwave Radiometer	contractor
NWP SAF IOP	Development & Implementation of certain activities within a EUMETSAT satellite application facility on numerical weather prediction	subcontractor
OSE EUCOS	Observation System Experiment	subcontractor
OSE EUMETSAT	Observation System Experiment	contractor
SIMDAT	Data grids for process and products development using numerical simulation and knowledge discovery	contractor
THORPEX	Vaisala Cooperative post-doctoral Research Fellowship Program	contractor

date from	to	Funded by	ECMWF budget (€)	Total budget (€)
01/10/2004	31/01/2008	ESA	1,026,923	n/a
01/01/2005	31/12/2008	EC	372,780	11,700,000
01/01/2005	31/12/2006	US DOE	\$ 199,998	n/a
01/01/2003	30/06/2006	EC	315,008	1,800,000
01/12/2006	01/06/2009	EC	149,997	11,800,000
01/05/2004	30/04/2008	EC	709,800	14,000,000
01/06/2006	31/05/2008	EC	131,200	4,500,000
11/02/2004	30/06/2006	ESA	59,999	250,000
01/09/2004	31/08/2009	EC	1,124,475	15,000,000
01/01/2006	31/12/2007	ESA	327,000	480,000
01/01/2006	31/12/2007	EUMETSAT	262,939	262,939
01/04/2004	30/06/2007	ESA	379,000	379,000
ongoing		EUMETSAT	n/a	
01/04/2005	31/12/2008	EC	215,000	14,300,000
01/03/2005	28/02/2009	EC	4,691,000	12,500,000
01/01/2004	31/03/2007	EC	450,000	10,000,000
01/02/2004	30/04/2007	EC	404,000	900,000
01/09/2005	31/08/2010	EUMETSAT	220,000	3,000,000
01/08/2006	31/03/2009	JRC	433,182	433,182
01/04/2004	30/09/2007	EC	326,400	24,400,000
01/04/2006	30/11/2006	EUMETSAT	48,860	48,860
01/03/2004	28/02/2007	EUMETSAT	586,221	2,500,000
03/05/2005	31/07/2007	EUCOS	59,000	n/a
01/08/2005	31/07/2007	EUMETSAT	236,000	236,000
01/09/2004	31/08/2008	EC	819,000	11,000,000
01/10/2004	30/09/2006	WMO	82,000	n/a





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