Operational and research activities at ECMWF now and in the future

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An independent intergovernmental organisation established in 1975

Currently:
21 Member States
13 Co-operating States
How ECMWF was established

Start of operational activities
1978  Installation of first computer system (CRAY 1-A)
1979  Start of operations
       N48 grid point model – 200km
Current system

Cray XC30
  Two identical systems for resiliency
  3.5 Petaflops peak performance ($3.5 \times 10^{15}$)
Operational Model - T1279 (16km)
Ensemble Prediction System - T639 (31km)
Evolution of ECMWF scores

Adapted and extended from Simmons & Hollingsworth (2002)
Physical aspects, included in IFS
Data assimilation
Variational data assimilation
Predictability, diagnostics and extended-range forecasting

The atmosphere is a chaotic system

- Small errors can grow to have major impact (butterfly effect)
- This limits detailed weather prediction to a week or so ahead
- Slowly evolving components of the climate system can give predictability at longer timescales
Forecast skill and improvement

500hPa geopotential
Root mean square error
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
D+6 (2-year running mean)
Z500 Time series of ACC=80% N hemisphere

HRES and ERA Interim 00,12UTC forecast skill
500hPa geopotential
Lead time of Anomaly correlation reaching 80%
NHem Extratropics (lat 20.0 to 90.0, lon -160.0 to 180.0)

Operational forecasts
Reforecasts from reanalysis
Z500 N hemisphere HRES v ERA-I

HRES - ERA
500hPa geopotential
Anomaly correlation
NHex Hem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
T+0 T+12 ... T+240
oper an-era_an_od-el oper 0001 | 00UTC,12UTC,beginning

Graph showing the comparison of HRES and ERA for Z500 in the Northern Hemisphere Extratropics from 2000 to 2014, with specific anomaly correlation markers at various time points.
Meteorological Operations

Mean sea level pressure
Anomaly correlation
Europe (lat 35.0 to 75.0, lon -12.5 to 42.5)
T+72
Future Research Activities

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Outline

Model physics
Increasing resolution
Ensemble prediction
Data assimilation
Focus on improved cloud parametrization:

- Super-cooled liquid layers in mixed phase stratiform cloud (37r3)
- Ice water content in cirrus (38r1)
- Reduction of drizzle occurrence
Horizontal resolution

Atmosphere:

Vertical: 91 → 137 levels in 2013
Increased resolution in 2015
   16 km → 8-10 km
Cubic octahedral grid

Ocean:

1° → ¼°
42 vertical levels → 75 levels

In the future:
5 km ensemble prediction system (2025)
Computing requirements:
60 MW!! (scalability)
Kinetic energy spectra at 200 hPa

\[ (KE)^{5/3} \]

\[ 200 \text{ hPa} \]

-3

-5/3

T1279lin
T1279cub
T2047lin

wavenumbers
HPCF performance vs Strategy

- IBM Power4+ 690
- IBM Power5+ 575
- IBM Power6 575
- IBM Power7 775
- Cray XC30

Sustained Teraflops:
- IBM Power4+ 690
- IBM Power5+ 575
- IBM Power6 575
- IBM Power7 775
- Cray XC30

Years: 2005 to 2018
Scalability activities

Preparation for future HPC architectures (2018 onwards)
- Data assimilation (OOPS)
- IFS dynamical core
- Model code optimisation
- Other code optimisations (observation handling)
Strategy for IFS dynamical core

- Fully compressible equations
- Retain semi-implicit, semi-Lagrangian schemes
- Retain spectral transform technique
- Improve parallelisation/scalability by implementing unstructured grids
ENsemble prediction System (ENS)

EDA, singular vectors and ENS
Stochastic physics
91 levels in the vertical T639
Coupled to the ocean model from the start of the forecast
Monthly forecasting
  MJO skill scores
Seasonal forecast System 4
  EUROSSIP including NCEP
Applications of ENS
  Flooding/drought prediction
Wind storm 9-11 January 2015

Observations Friday 9th January

Signal from 4-5 days ahead in the Extreme Forecast Index (EFI)

EFI from Monday 5th January 00UTC
Performance of the monthly Forecasts since 2002

Hindcasts covering the period 1995-2001

Tropics

N. Extratropics

MJO Bivariate Correlation

NAO Correlation

ECMWF Analysis VT: Thursday 23 April 2009 00UTC 500hPa Geopotential

System = 2 - Method = 1 - Ensemble number = 4

ERA

Day 12-18
Data assimilation

Variational assimilation
Ensemble of Data Assimilations (EDA)
Ensemble Kalman Filter (EnKF)
Surface analysis
Aeolus Doppler wind Lidar (launch 2017) (ESA Earth Explorer Mission)
Aeolus Doppler wind lidar

Aeolus wind profile impacts
Conclusions

Forecasts will continue to improve
Initial error reduction
Model improvements

By 2025:
Ensemble prediction at 5km resolution
High impact weather up to two weeks ahead
Large scale patterns and regime transitions up to four weeks ahead
Global scale anomalies up to a year ahead
Reanalysis (ERA)

Climate monitoring in near real time
Verification data set for reforecasts
ERA-20th century reanalysis in preparation
Ocean reanalysis
Global Warming since 1957
Anomalies of monthly-means relative to 1989 – 2001 average

2 metre temperature anomaly (K)

Stagnation?
Time evolution of ocean heat content

ORAS4 OHC $10^{22}$ J

Upper 300m
Upper 700m
Total Depth


0 5 10 15 20

$10^{22}$ Joules

Global

Agung
El Chichón
Pinatubo
1997-98 El Niño

0.4 0.5 0.7 1.0 W m$^{-2}$
Atmospheric composition

Modelling and data assimilation
Monitoring and evaluation
Impact on NWP – aerosols
July 2013

Canadian smoke over Europe
GFAS

Ceilometer, obs. & simul.

CO @ 500 hPa