Developments of the ECMWF Integrated Forecasting System

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Evaluation Section
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and colleagues
Contents

- Evolution of scores
- Model cycle 41r1 (12 May 2015)
- Model cycle 42r1 (early 2016)
- High-density observations
The operational forecasting system

High resolution deterministic forecast (HRES):

- Twice a day 16 km 137-level, to 10 days ahead

Ensemble forecast (ENS):

- Twice a day, 32 km (64 km after day 10) 91-level, to 15 days ahead
- 50 perturbed members (account for initial and model uncertainties)
- Mon/Thu 00 UTC extended to 46 days ahead (Monthly Forecast)

Ocean waves: twice a day

- Global: 10 days ahead at 28 km (fully coupled)
- Global: 10 days ahead at 11 km (stand-alone)
- Ensemble: 15 days ahead at 55 km

Seasonal forecast: once a month

- 51 members, 80 km 91 levels, to 7 months ahead
Forecast performance

- 6 headline scores
  - HRES and ENS upper-air skill
  - HRES and ENS precipitation
  - Severe weather: TC position and EFI for extreme wind

- Comparison with reference systems
- Comparison with other centres
- Evaluation for severe weather
- Additional verification and in-depth diagnostics
HRES skill: Z500 NH

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 -180.0 to 180.0)
HRES skill: Z500 NH

HRES - ERA
500hPa geopotential
Anomaly correlation
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
T+0 T+12 ... T+240
oper_an-era_an od-ei oper 0001 | 00UTC,12UTC,beginning

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
Ensemble skill: T850 NH

850hPa temperature
Lead time of Continuous ranked probability skill score reaching 25%
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
Ensemble skill: T850 NH

Skill relative to ‘dressed’ ERA-Interim

Resolution upgrade

EDA-related changes
Ensemble skill: T850 NH

850hPa temperature
Continuous ranked probability skill score
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
DecJanFeb

atmospheric variability +
changes in observing system
Ensemble skill: T850 NH

850hPa temperature
Continuous ranked probability skill score
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
DecJanFeb
Precipitation skill

Supplementary headline score for deterministic precipitation forecast

Supplementary headline score for probabilistic precipitation forecast
HRES precipitation skill

Lead time (days)

HRES

ERAINT

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
Wave height forecasts

DJF 2015, verification against buoys

Wind speed

Wave height

ECMWF
METOF
FNMOC
NCEP
METFR
DWD
BoM
JMA
KMA
Extreme Forecast Index (EFI) – Day 4

EFI skill = 2*ROC-1
Events defined by 95^{th} percentile
Tropical cyclone forecast
New model cycle – 12 May 2015

Cycle 41r1

Description of the upgrade

IFS cycle 41r1 includes a large number of changes affecting all components of the forecasting system. Significant changes to the model physics, assimilation, observation usage and the ensemble configuration have been shown to deliver significant analysis and forecast benefit.

The domain of the high-resolution limited-area wave model will be extended to the entire globe, and will no longer be ‘limited-area’.

The page will be updated as required. It was last changed on 19.05.2015.

For a record of changes made to this page please refer to Document versions.

Further information and advice regarding the upgrade can be obtained from User Support.

Timetable for implementation

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 March 2015</td>
<td>Initial announcement to Member States</td>
</tr>
<tr>
<td>16 March 2015</td>
<td>Availability of test data in dissemination</td>
</tr>
<tr>
<td>12 May 2015</td>
<td>Implementation date</td>
</tr>
</tbody>
</table>

News

19 May 2015

IFS Cycle 41r1 implemented a revised set of forecast output fields for the ocean waves. These were based on a new method to split the 2d ocean wave spectrum into its principal components. The new scheme splits the wave spectrum into one wind waves and up to three swell partitions. The parameters characterising the three swell partitions (significant height, mean wave direction and mean wave period of first, second and third swell partitions) are now supplementing the total swell parameters already produced.

The previous wave products split the spectra into just two components (wind waves and total swell).
Forecast

• New surface climate fields (land-sea mask, sub-grid orography), also affecting number of land and sea points.
• New CO2/O3/CH4 climatologies from latest MACC-II reanalysis produced at ECMWF.
• Revised semi-Lagrangian extrapolation reducing stratospheric noise.
• Cloud scheme change of rain evaporation, auto-conversion/accretion, riming, precipitation fraction.
• Improved representation of supercooled "freezing" rain.
• Modified convective detrainment.
• Activation of the lake model (FLAKE).
• Active use of wave modified stress in coupled mode.
• Revised sea-ice minimum threshold, sea-ice roughness length and consistency between SST and sea ice concentration.
Cycle 41r1 – Meteorological changes

Forecast

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Cycle 41r1 – Meteorological changes

Data assimilation

- Upgrade of inner loop resolutions of 4D-Var to TL255 for each of the three iterations of the outer loops.
- Reduction of number of iterations in 1st inner loop and use of full linear physics package.
- Changed calculation of background error covariances from using EDA samples of perturbations from last cycle (1/3) and climatology (2/3).
- Active use of:
  - SSMIS moisture sounding channels over land and sea-ice;
  - surface-sensitive ATMS channels over land;
  - ASCAT in soil moisture analysis;
  - Altika and Cryosat altimeter wave height data.
- Upgrade of radiance observation operator with RTTOV-11.
- Assimilation of GPS-RO with two-dimensional observation operator.
- Assimilation of high-resolution radiosondes.
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- Assimilation of high-resolution radiosondes.
control-normalised 0001 minus 0067

500hPa geopotential
Root mean square error
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
Date: 20141006 12UTC to 20150510 12UTC
T+24 T+48 ... T+240 | Confidence: [95.0] | Population: 432, 430, 428, 426, 424, 422, 420, 418, 416, 414

RMSE

41r1 - HRES

2%
**41r1 - Scorecard**

<table>
<thead>
<tr>
<th>N.Hem</th>
<th>S.Hem</th>
<th>Tropics</th>
<th>Europe</th>
<th>N.Atl</th>
<th>N.Amer</th>
<th>N.Pacif</th>
<th>E.Asia</th>
<th>Austr.Nz</th>
<th>Arctic</th>
<th>Antarctic</th>
</tr>
</thead>
</table>

- Significant wave height verified against satellite obs

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ECMWF
EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
41r1 – Surface parameters

<table>
<thead>
<tr>
<th></th>
<th>2-m temperature</th>
<th>2-m dewpoint</th>
<th>10-m wind speed</th>
<th>Total cloud cover</th>
<th>24-h precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extratropics</td>
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<tr>
<td>Europe</td>
<td></td>
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<tr>
<td>Tropics</td>
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</tr>
</tbody>
</table>

**2-m temperature, Extra-tropics**

**Total cloud cover, Europe**
41r1 – Heavy precipitation

Oct 2014 – Apr 2015, Europe

SED vs Lead time (days)

>20 mm / 24h

>50 mm / 24h
The future – 42r1 (early 2016)

Increased resolution

Atmosphere: 16 km $\rightarrow$ 9 km (32 km $\rightarrow$ 18 km)
Ocean: 1$\rightarrow$¼ deg
Grid T1279 $\rightarrow$ TCo1279 (‘cubic octahedral’)

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
The future – 42r1 (early 2016)

Increased resolution

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Ocean: 1 → ¼ deg
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Data Assimilation
EDA configuration:
Resolution TL639 forecast/outer loop, TL191/TL191 inner loops.
Timesteps 900s outer loop, 1800s inner loops.
Simplified linear physics used in first inner loop.
New climatological B's evenly sampled from ~41R1 TL399 EDA's every 5.5 days Jan-Oct 2014.
Compute hybrid B by adding samples from latest EDA forecast (weight 0.3) to static climatological B (weight 0.7).
Cycling flow-dependent errors and B:
- Saving on iterations in first minimization (70 down to ca. 30)
- Background error covariance calculation 5 times faster due to new and code optimizations.
4DVAR configuration:
Inner loop resolutions TL255/TL319/TL399
Timesteps inner loops 1200s/1080s/900s.
Conventional data:
Implementation of Sonntag saturation vapour equation in observation operators.

Increase from 3 to 5 iterations for SL departure points

Ensemble Prediction
Prepare SKEB for horizontal resolution upgrade and spectral viscosity (passive)
Enable computation of singular vectors on cubic grid (technical/passive)
New ozone scheme (Monge-Sanz et al., 2011, ACP) (passive)
Changes for relaxation and multi-year runs (technical)
Revised options for vertical diffusion in stratosphere (passive except for type longrange)

Numerical Aspects
Increase 3 to 5 iterations for SL departure points
Redefine convective adjustment timescale by grid area
Algorithmic and structural improvements in the mass fixing package.

Physical Aspects
Radiation-surface LW/SW updating
Radiation-surface LW tiling
Surface snow fixes
New freezing rain physics and additional diagnostic for accumulation
VDF/convection cleaning and detrainment of snow
Resolution dependent non-orog GWD
Increased erosion rate for convective points
TL/AD non-orog GWD
TL/AD snow fix
Updates for Single Column Model
TL/AD surface & VDF
New snowfall sublimation and ice deposition physics options (passive)
New MACC aerosol climatology (passive as switched off)
Lake fractional ice + update lake “soil” T
Increased roughness over snow/veg
Option for CRM superparametrization
Changes to allow Single precision

Chemical Aspects:
Removal of all code related to coupled chemistry set-up; Composite Implementation of new UV processor providing better UV forecasts
Various model improvements for C-IFS
Assimilation of new satellite data (GOME-2 SO2 (for volcanic eruptions), PMAP)
Enterprises for relaxation and multi-year runs (technical)
New ozone scheme (Monge-Sanz et al., 2011, ACP) (passive)
Changes for relaxation and multi-year runs (technical)
Revised options for vertical diffusion in stratosphere (passive except for type longrange)
41r2 – evaluation results


Z: SH –90° to –20°, 500hPa

Z: NH 20° to 90°, 500hPa

TC01279_TL399_41R2 – TL1279_TL255_41R1

TL1279_TL399_41R2 – TL1279_TL255_41R1
HRES skill: Z500 NH

HRES - ERA
500hPa geopotential
Anomaly correlation
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
T+0 T+12 ... T+240

42r1: gain of 0.15-0.2 fcst days
High-density observations for verification

24h Precipitation to 06h 15 February 15
SYNOP (blue), HDOBS (red)
High-density observations for verification

Verification against different datasets

Verification against up-scaled observations (NEXRAD)
Forecast users web space

https://software.ecmwf.int/wiki/display/FCST/Forecast+User+Home

- Severe Event Catalogue
- Known IFS forecasting issues
- Planned changes to the forecasting system
- Forecast evaluation (main ECMWF web site)

Feedback on cases or issues: forecast_user@ecmwf.int
Summary

- IFS further improved, both HRES and ENS
- Maintaining overall lead among global models
- Increasing focus on high-impact weather in the medium-range
- New cycle in 2016 (16 km → 9 km and many other changes) a major step in forecast skill
Met Office Index (WMO exchange of scores)
control-normalised 0067 minus 0001
500hPa geopotential
Anomaly correlation
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
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control-normalised 0001 minus 0067
850hPa temperature
Continuous ranked probability score
NHem Extratropics (lat 20.0 to 90.0, lon -180.0 to 180.0)
Date: 20141101 00UTC to 20150510 00UTC
00UTC T+24 T+48 ... T+360 | Confidence: [95.0] | Population: 181
ENS scorecard

<table>
<thead>
<tr>
<th>Region</th>
<th>Level</th>
<th>CRPS</th>
</tr>
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<tbody>
<tr>
<td>Europe</td>
<td>850hPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500hPa</td>
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<tr>
<td></td>
<td>1000hPa</td>
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<tr>
<td>N. Hemisphere</td>
<td>850hPa</td>
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CF scorecard

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<th>RMSEF/SDF</th>
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<tbody>
<tr>
<td>Europe</td>
<td>850hPa</td>
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<tr>
<td></td>
<td>200hPa</td>
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</table>
Smoother distribution of gridpoints

Standard reduced Gaussian grid  Octahedral reduced Gaussian grid
41r2 – evaluation results


Z: Europe 35° to 70°; 10° to 40°, 500hPa

Europe

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS