Progress Report on the Global Data Processing System, 2010
United Kingdom
Met Office

1. Summary of highlights

The following upgrades were made to the major components of our Production NWP System during the accounting year April 2010-March 2011. The changes were introduced following 3 parallel suites each of 1 month duration to ensure robust changes at expected quality.

PS24 **14-Jul-10**	Assimilation of ASCAT surface soil wetness Upgrade to NH snow analysis Use v18 RTTOV coefficients PC2 prognostic cloud scheme 8C Boundary Layer scheme Radiation upgrade Upgrade aerosol climatologies
PS25 **11-Feb-10**	Increase VAR inner loop resolution to N216 Covariance statistics update Reintroduction of ice in moisture observation increment operator (VAR+UM) Pragmatic vertical scaling of analysis increments within VAR Track/land checks for marine data, removal of sonde RH cap and use of extra humidities in SURF analyses Increase screen analysis VAR resolution to N216 Improved convective diagnosis parcel perturbations Extend GPSRO and switch on SSMIS UAS channels to constrain Mesosphere Review AIRS channel selection and assumed errors. James Cameron. Improved GPSRO bending angle QC to avoid sharp vertical gradients Assimilate MSG clear sky radiance data in global model Removal of Alaskan glaciers
PS26 **16-Mar-11**	Reintroduce NOAA19 MHS Boundary Layer and land/sea/ice surface changes Implement the JULES land surface model Post implementation PC2 changes Updated concentrations of greenhouse gases McICA treatment of cloud inhomogeneity Revised convection diagnosis Switch on prognostic rain with Abel & Shipway fall speeds Lean/Wenyi SW spectral file Critical convective cloud water option Use opaque lid USSP and 150% launch amplitude

Table 1 - Global Model and Data Assimilation changes

PS24 **14-Jul-10**	Introduce cloudy IASI radiances in NAE Assimilate GeoCloud data outside MOPS coverage area GPSRO bending angle assimilation in NAE and CAM Additional cloudy checks for SEVIRI- Clear Use v18 RTTOV coefficients Radiation upgrade # incremental timestep ; # Improved solar zenith angle correction # Hogan solver; # Use mix-column solver # Fix for "global cloud top" # Modified "Barker" albedo for the open sea + spectral dependence # Use modulus of fluxes for weights in LW equivalent extinction Convection upgrade # New termination condition; Convection diagnosis method 5 # Downdraught version 1; Convective critical cloud water option 1 Increase MSGWINDS data volume for NAE
PS25 **11-Feb-10**	Track/land checks for marine data, removal of sonde RH cap and use of extra humidities in SURF analyses Covariance statistics update Assimilate WindSat Improved Observation Operator for Ground GPS, Review AIRS channel selection and assumed errors Improved GPSRO bending angle QC to avoid sharp vertical gradients Equal β soil moisture interpolation
PS26 **16-Mar-11**	Reintroduce NOAA19 MHS Implement the JULES land surface model Updated concentrations of greenhouse gases Introduce prognostic rain Lean/Wenyi SW spectral file

Table 2- Regional Model and Data Assimilation changes

PS24 **14-Jul-10**	Additional cloudy checks for SEVIRIClear Use v18 RTTOV coefficients Boundary layer changes to resolve valley cooling problems * Entrainment-subsidence coupling fix * Change stability functions to MES tails * Subgrid shear drainage; * NEON parameters for inland water tile Variable errors for MOPS cloud Install additional 12km UK Model with full chemistry for Air Quality Forecasts
PS25 **11-Feb-10**	Track/land checks for marine data, removal of sonde RH cap and use of extra humidities in SURF analyses Fine tuning of MOPS Cloud Weighting Radiation upgrade JULES Science neutral in UKV Improved Observation Operator for Ground GPS Equal β soil moisture interpolation
PS26 **16-Mar-11**	New UKV Covstats Microphysics package Lean/Wenyi SW spectral file Skyview and terrain shading scheme Install additional UK Model as Global Downscaler at 4km resolution

Table 3- Local UK Model and Data Assimilation changes

PS24 **14-Jul-10**	Use v18 RTTOV coefficients (MOGREPS-G - Medium range EPS) Upgrade MOGREPS to use latest model science Change IAU settings (MOGREPS-G) ETKF Upgrade (MOGREPS-G) Increase Resolution (MOGREPS-R - Regional EPS) to 18kmL70 Upgrade to GLOSEA3 (Seasonal EPS) to HadGEM3-AO
PS25 **11-Feb-10**	ETKF Upgrade (MOGREPS-G) Upgrade GLOSEA4 vertical resolution to HadGEM3-AO N96L85 ORCA1L75 Add sea ice assimilation to GLOSEA4
PS26 **16-Mar-11**	Upgrade MOGREPS to use latest model science Introduce daily initialisation of the GLOSEA4 forecast ensemble

Table 4- Ensemble Modelling System changes

PS25 **11-Feb-10**	Introduce new MDT for FOAM altimeter assimilation Introduce recalculated and seasonally varying error covariances to FOAM Upgrade FOAM to use NEMO to vn3.2 Upgrade FOAM to use reference SST for surface relaxation Modification to WAVE Model spectral partitioning scheme Introduce NEMO Shelf trial suite

Table 5 - Ocean and Wave Modelling changes

2. Equipment in use at the centre

2.1 Supercomputing Platform

3 IBM Power 575, p6 systems - comprising two identical 106 node (3392 core) systems for Production resilience and a small 30 node (960 core) system used for collaboration with UK universities.

- Total site peak capacity: 145 TFlops.
- Total Main Memory: 15.5 TBytes
- Total Disk Capacity attached to HPC system (GPFS): 776 TBytes
- Operating system AIX

The Supercomputer is LAN attached to MASS (see 2.3), Front-end IBM system, desktop PCs, UNIX servers and printers.

2.2 Desktop systems for forecasters

"Horace", a Unix based HP workstation system continues to be used by the Met Office at its Guidance Unit in Exeter (Radford, 2000).

A PC-based production system called Nimbus (McHugh *et al.*, 2000) is also in use at front-line Met Office locations in the UK and overseas. This system visualises data for forecasters, and also serves as a production platform for the creation of products and services to some Met Office customers.

A unified display and production system named "Swift", has been developed, which is based on IBL Visual weather. Horace and Nimbus workstations are gradually being phased out as Swift systems are deployed.

2.3 MASS storage system

The new MASS-R is based on IBM HPSS. An interface known has MOOSE has been developed in-house. Initially the new systems will support an archive rate of 10TB/day. As of March 2011, the archive contains 4PBytes of data to support NWP and |Climate Research. The system is connected to the supercomputer, front-end mainframe and research Unix servers.

3. Data and products from GTS in use

3.1 Observations

Non-real-time monitoring of the global observing system includes:-

- Automatic checking of missing and late bulletins.
- Annual monitoring checks of the transmission and reception of global data under WMO data-monitoring arrangements.
- Monitoring of the quality of marine surface data as lead centre designated by CBS. This includes the provision of monthly and near-real-time reports to national focal points, and 6-monthly reports to WMO (available on request from the Met Office, Exeter).
- Monthly monitoring of the quality of other data types and the provision of reports to other lead centres or national focal points. This monitoring feeds back into the data assimilation by way of revisions to reject list or bias correction.

Within the NWP system, monitoring of the global observing system includes:-

- An automated quality control system with 3 stages, an internal consistency check, a comparison against model first guess and a buddy check against neighbouring observations.
- A real-time monitoring capability that provides time series of observation counts, reject counts and mean/root-mean-square departures of observation from model background; departures from the norm are highlighted to trigger more detailed analysis and action as required;
- Monitoring of satellite observations includes time series of comparisons of observations versus model background for separate channels plus comparisons of retrieved fields versus model background for different model levels http://www.metoffice.gov.uk/research/collaboration/nwp-saf

The global data assimilation system makes use of the following observation types. The counts are based on a snapshot taken on May 9th 2011.

Observation group	Observation sub-group	Items used	Available Data (24 hour period)	% used in assimilation
Ground-based vertical profiles	TEMP PILOT PROFILER	T, V, RH processed to model-layer average As TEMP, but V only As TEMP, but V only	1,360 876 8,948	95 47 32
Satellite-based vertical profiles	ATOVS AIRS IASI SSMI/S	Radiances directly assimilated with channel selection dependent on surface instrument and cloudiness	4,657,687 318,593 323,310 2,729,760	3.5 10 10 0.5
Aircraft	AIREPS AMDARS	T, V as reported with duplicate checking and blacklist	11,576 272,294	73 23
Satellite atmospheric motion vectors	EUMETSAT JMA GOES EUMETSAT	High-resolution IR, VIS and WV winds SEVIRI	1,672,266 294,494 783,568 716,721	0.5 2.5 1.5 4
Satellite-based surface winds	ERS ASCAT WINDSAT	1DVAR wind-speed retrieval	84,474 966,210 1,623,252	4 4 1
Ground-based surface	SYNOP SHIP BUOY	Pressure, wind, temp, RH Pressure and wind Pressure	78,423 14,669 41,890	92 75 67
GPS-RO	Satellite Ground-based	Bending Angle	1895 273,141	86 7

Table 6 Observations in Global Data Assimilation

3.2 Gridded products

Products from WMC Washington are used as a backup in the event of a system failure. The WAFS Thinned GRIB products at an effective resolution of 140 km (1.25° x 1.25° at the equator) are received in 6-hour intervals out to T+72. Fields in this format include geopotential height, temperature, relative humidity, horizontal and vertical components of wind on most standard pressure levels, rainfall, mean sea-level pressure and absolute vorticity.

GRIB data for icing, clear-air turbulence and cumulonimbus, automatically generated from the Met Office global model, is also been transmitted.

4. Forecasting system

The forecasting system consists of:-

Atmosphere Models

- Global atmospheric forecast model at 25km L70 supported by 4D-Var 6 hour cycle data assimilation system
- North Atlantic and Europe regional atmospheric forecast model at 12km L70 supported by 4D-Var 6 hour cycle data assimilation system
- UK Mesoscale (4-km) atmospheric forecast model supported by 3D-Var 3 hour cycle data assimilation system
- UK Mesoscale (4-km) atmospheric forecast model downscaler, reconfigured from the Global atmospheric forecast model.
- UK Mesoscale variable resolution (with inner domain at 1.5-km) atmospheric forecast model supported by 3D-Var 3 hour cycle data assimilation system
- Global atmospheric ensemble forecast model (24 members, 60km L70) with ETKF initial perturbations and Stochastic physics model perturbations.
- North Atlantic and European Regional atmospheric ensemble forecast model (24 members, 18km, L70) driven by the Global EPS.
- Ensemble Seasonal Forecasting System using coupled ocean/atmosphere. (120km L85 atmosphere resolution), with lagged average initial perturbations and Stochastic Physics model perturbations

"Wet" Models

- Global wave hindcast and assimilation/forecast system using WAVEWATCH III® at 60km resolution
- North Atlantic and European Regional wave hindcast and forecast system using WAVEWATCH III® at 12km resolution
- Global ocean model (NEMO) at 0.25degree
- Various Regional ocean models at 1/12 degree
- Various tidal Shelf-seas models – these are being replaced by configurations using NEMO.
- Various Mesoscale sea surge models

Other

- Post-processing system mapping surface variables on to fixed 2 or 5km grids with suitable topographic adjustment and encompassing a Nowcasting system
- Site-specific post-processing system including Kalman Filter statistical correction
- Transport and dispersion model

4.1 System run schedule and forecast ranges

Run	Model	Forecast range	Run start time	Boundary values
QU18	Global atmosphere update	T+9	0:15	
QZ18	Regional atmosphere update	T+9	0:15	QG18
ED18	NAE Surge Ensembles	T+36	1:00	EY18
QY00	Regional atmosphere (NAE)	T+60	1:30	QG18
QV00	UK 1.5km atmosphere	T+6	2:05	QY00
QD00	Regional marine (NAE)	T+60	2:30	QY00
QG00	Global atmosphere	T+144	2:40	
Q400	UK 4km atmosphere	T+6	3:05	QY00
EG00	Global ensemble	T+72	3:25	QG00
QM00	UK 12km Air Quality		4:15	QG00
QW00	Global Wave	T+144	4:15	QG00
Q403	UK 4km atmosphere	T+36	4:20	QY00
QV03	UK 1.5km atmosphere	T+36	4:25	QY00
Q500	UK 4km Global Downscaler	T+120	4:45	QG00
EN00	Global FOAM NEMO	T+144	5:00	QG00
Q600	OSTIA SST Analysis		5:50	
ES00	New Shelf Seas	T+48	6:15	QG00/QY00/EN00
QZ00	Regional atmosphere update	T+9	6:15	QG00
QQ00	Regional Shelf-seas	T+144	6:20	QG00/QY00/EN00
QU00	Global atmosphere update	T+9	6:55	
QY06	Regional atmosphere (NAE)	T+60	7:30	QG00
EY06	Regional ensemble (NAE)	T+52	8:05	QY06
QV06	UK 1.5km atmosphere	T+6	8:10	QY06
Q406	UK 4km atmosphere	T+6	8:30	QY06
QD06	Regional Wave	T+60	8:30	QY06
QG06	Global atmosphere	T+60	8:45	
Q409	UK 4km atmosphere	T+36	9:30	QY06
QV09	UK 1.5km atmosphere	T+36	9:30	QY06
Q506	UK 4km Global Downscaler	T+60	10:15	QG06
EO00	Seasonal Forecast	T+6months	12:15	QG00
QU06	Global atmosphere update	T+9	12:15	
QZ06	Regional atmosphere update	T+9	12:15	QG06
ED06	NAE Surge Ensembles	T+36	13:00	EY06
QY12	Regional atmosphere (NAE)	T+60	13:30	QG06
QV12	UK 1.5km atmosphere	T+6	14:05	QY12
QD12	Regional Wave	T+60	14:30	QY12
QG12	Global atmosphere	T+144	14:40	
Q412	UK 4km atmosphere	T+6	15:05	QY12
EG12	Global ensemble	T+72	15:25	QG12
QW12	Global Wave	T+144	16:15	QG12
Q415	UK 4km atmosphere	T+36	16:20	QY12
QV15	UK 1.5km atmosphere	T+36	16:25	QY12
Q512	UK 4km Global Downscaler	T+120	17:00	QG12
QU12	Global atmosphere update	T+9	18:15	
QZ12	Regional atmosphere update	T+9	18:15	QG12
QY18	Regional atmosphere (NAE)	T+60	19:30	QG12
QV18	UK 1.5km atmosphere	T+6	20:05	QY18
EY18	Regional ensemble	T+52	20:15	QY18
QD18	Regional Wave	T+60	20:30	QY18
QG18	Global atmosphere	T+60	20:45	
Q418	UK 4km atmosphere	T+6	21:05	QY18
QV21	UK 1.5km atmosphere	T+36	21:55	QY18
Q518	UK 4km Global Downscaler	T+60	22:15	QG18
Q421	UK 4km atmosphere	T+36	22:20	QY18

Table 7 – Production Schedule

4.2 Medium-range forecasting system

Global Data assimilation

Analysed variables	Velocity potential, stream function, unbalanced pressure and relative humidity.
Analysis domain	Global
Horizontal grid	Same as model grid, but resolution is 0.555º latitude and 0.833º longitude
Vertical grid	Same levels as forecast model
Assimilation method	4D variational analysis of increments (Rawlins et al.,2007); a Perturbation Forecast (PF) model and its adjoint represent model trajectories during the data window. The PF model operates on the assimilation grid and is based on the full forecast model but simplified to provide fast linear calculations of small increments for fitting observations. In particular the PF model omits most physics schemes. Data is grouped into 6-hour time windows centred on analysis hour for quality control. A pre-conditioning step at lower resolution provides an approximate solution in order to allow timely convergence at full assimilation resolution.
Covariance statistics	Climatological model error statistics are based on the differences between an ensemble of short range Unified Model forecasts at resolution (0.562º latitude, 0.376º longitude), processed by a covariance model applying balance and other constraints. Each member is generated using an initial increment taken from an ensemble of perturbed analyses.
Assimilation cycle	6-hourly
Initialisation	Increments are not initialised explicitly, but gravity-wave noise is reduced by use of a weak constraint penalising filtered increments of a pressure based energy norm, similar to the method of Gauthier and Thepaut (2001). The initialised increments are inserted directly at T–3.

Global Forecast model *(0-6 days)*

Basic equations	Non-hydrostatic finite difference model with height as the vertical co-ordinate Full equations used with (virtually) no approximations; suitable for running at very high resolution
Independent variables	Latitude, longitude, eta (η), time
Primary variables	Horizontal and vertical wind components, potential temperature, pressure, density, specific humidity, specific cloud water (liquid and frozen)
Integration domain	Global
Horizontal grid	Spherical latitude-longitude with poles at 90º N and 90º S. Resolution: 0.234º latitude and 0.352º longitude. Arakawa 'C'-grid staggering of variables.
Vertical grid	70 levels Charney-Philips grid staggering of variables The normalised vertical co-ordinate η is hybrid in height, varying from $\eta = 0$ at the surface to the top level at $\eta = 1$, where zero vertical velocity w is applied. The lowest level is purely terrain following and there is a smooth (quadratic) transition to a specified number of 'flat' upper levels where the height of each point at a level is constant. Model top is 80km

Integration scheme	Two time-level semi-Lagrangian advection with a pressure correction semi-implicit time stepping method using a Helmoltz solver to include non-hydrostatic terms. Model time step = 600 s.
Filtering	Spatial filtering of winds and potential temperature in the vicinity of the poles
Horizontal diffusion	Second order diffusion along η surfaces of winds, specific humidity and potential temperature
Vertical diffusion	Second-order diffusion of winds only between 500 and 150 hPa in the tropics (equatorward of 30º)
Orography	GLOBE 1km orography dataset The model mean orography is calculated using the 1km dataset and then filtered to remove grid-scale and near-grid-scale structure using a sixth-order low-pass implicit tangent filter which is constrained so that the filtering is isotropic in real space. The sub-grid orography fields used by the flow-blocking and gravity wave drag scheme characterise the orography on scales between the model grid-scale and about 6km, which is typically the shortest scale that forces gravity waves. The 1km dataset is therefore filtered to remove the scales less than 6km before the sub-grid fields are derived. The sub-grid orography fields used by the orographic roughness scheme (which represents the effects of scales less than 6km) are calculated from 100m resolution data for the UK and most of Europe. These fields are derived globally by using the GLOBE dataset standard deviation field which has been scaled by a least squares fit between this dataset over Europe and the fields derived from the 100m dataset.
Surface classification	Sea: global sea-surface temperature (SST) analysis performed daily; Sea ice: analysis using NCEP SSM/I.

Physics parameterisations:

The science configuration of the model is Global Atmosphere 3.1 (GA3.1) as described in Walters *et al.* (2011). The highlights of this configuration are as follows:

a) Surface and soil

- Joint UK Land Environment Simulator (JULES: Best *et al.* 2011 and Clark *et al.* 2011).
- Uses a single aggregate tile for surface energy balance.
- 4 layer soil model using van Genuchten (1980) soil hydrology.

b) Boundary layer

- First order turbulence closure
- Unstable boundary layers use a K-profile scheme with non-local fluxes of potential temperature and momentum and a subgrid inversion diagnosis to parametrize entrainment fluxes at the boundary layer top
- Stable boundary layers use a local stability dependent formulation
- Existence and depth of unstable layers are diagnosed initially by moist adiabatic parcels and then adjusted to limit the buoyancy consumption of turbulence kinetic energy
- The resulting diffusion equation is solved using a monotonically-damping second-order-accurate unconditionally-stable numerical scheme
- The kinetic energy dissipated through the turbulent shear stresses is returned to the atmosphere as a local heating term.

c) Cloud

- Prognostic cloud fraction and prognostic condensate cloud scheme (PC2, Wilson *et al.* 2008).
- The prognostic variables are liquid water content, ice water content, liquid cloud fraction, ice cloud fraction and total cloud fraction.
- Calculate the impact of each of the physical processes in the model on the cloud fields and then advect the updated cloud fields using the model winds.

d) Precipitation

- Wilson and Ballard (1999) microphysics scheme, coupled with the PC2 cloud scheme.
- Prognostic rain, with one iteration for every two minutes of timestep.
- Abel and Shipway (2007) rain fall speeds.

e) Radiation

- Edwards and Slingo (1996) radiation scheme with a configuration based on Cusack (1999) with a number of significant updates.
- The correlated-k method is used for gaseous absorption with 6 bands and a total of 21 k-terms in the SW, and 9 bands and 33 k-terms in the LW.
- Full radiation calculations made every 3 hours with corrections applied for changing solar zenith angle and cloud fields as described in Manners (2009).
- Sub-grid cloud structure represented using the Monte Carlo Independent Column Approximation with a configuration described in Hill (2011).
- The direct effect is included for climatologies of the following aerosols: ammonium sulphate, mineral dust, seasalt, biomass-burning, fossil-fuel black carbon, fossil-fuel organic carbon, and secondary organic (biogenic) aerosols.

f) Convection

- Mass flux scheme based on Gregory and Rowntree (1990) including updraughts and downdraughts, and including momentum transport.
- Different entrainment/detrainment rates and closures for shallow and deep convection.

g) Gravity-wave drag

- Orographic scheme representing sub-grid orography and flow blocking.
- Non-orographic scheme representing the effects of gravity waves in the stratosphere and mesosphere.

Ensemble prediction system (0-15 days)

The ECMWF Ensemble Prediction System (VAREPS) is utilised for medium-range forecasting. During 2010-11 the 15-day Met Office Unified Model EPS, MOGREPS-15, has been upgraded to a fully operational system to provide an additional medium-range ensemble capability for use in multi-model ensemble production and to meet some customer requirements. MOGREPS-15 is run on the computing system at ECMWF using initial conditions generated at the Met Office in Exeter.

The 24-member ensemble is run twice a day (0000 and 1200 UTC), using a global model with a nominal grid length of 60 km. Initial condition perturbations are provided using an ETKF (Ensemble Transform Kalman Filter) method. The model also includes stochastic physics schemes to account for the effect of model errors on forecast uncertainty. Output from the EPS is post-processed twice daily to provide forecasters and customers with numerous chart displays including spaghetti diagrams, ensemble means, individual ensemble members and tracks of tropical and extra-tropical cyclones. Charts are generated showing grid-point probabilities of a wide range of variables including wind-speed, precipitation accumulations and temperature anomalies. Clustering of ensemble members is also provided. A smaller range of products is also generated from ECMWF VarEPS data, and some experimental multi-model ensemble products are produced.

In addition Site-specific ensemble forecasts of temperature, wind speed, precipitation cloud cover and sunshine are stored in our site-specific database for 10000 sites worldwide. A Kalman Filter MOS (Model Output Statistics system) is employed to correct for local biases, and derive maximum and minimum temperatures, for over 300 sites world-wide. Ensemble probabilities are calibrated to optimise performance using Rank Histogram verification (Hamill and Colucci 1997). Operational verification shows that the Kalman Filter MOS leads to significant improvements in probabilities compared to direct ensemble output; the calibration adds a small further improvement for certain products. Site-specific ensemble data are also stored from the ECMWF VarEPS and also include significant wave heights for ocean points.

MOGREPS-15 is also used to drive a storm surge model for waters around the British Isles, and is combined with output from a short-range surge ensemble system to provide seamless forecasts out to 7 days ahead. This system, which is run under contract to the Environment Agency, has been successfully trialled during 2010 and will be made fully operational in 2011.

The VarEPS is scanned daily for probabilities of severe weather (severe gales, heavy rain or snow) and issues automatic alerts to forecasters when defined probability thresholds are exceeded. This system is calibrated to assess probabilities required to support the UK National Severe Weather Warning Service. Verification shows that 3- to 4-day forecasts of severe weather have useful probabilistic skill. Most of the skill comes in the form of low-probability warnings.

Output from MOGREPS-15 is also being written to the TIGGE (THORPEX Interactive Grand Global Ensemble) database. The TIGGE database includes a standard set of ensemble forecast outputs from several operational numerical weather prediction centres, and provides an invaluable resource for research into ensemble prediction, especially the benefits of using multi-model ensemble techniques.

4.3 Short-range forecasting system - North Atlantic-European (NAE) model (0-48 hours)

Regional Data assimilation

The data-assimilation scheme for the NAE model is similar to that for the global model, except in the following:-

Analysis variables	as in the global model, but includes aerosol content
Analysis domain	as model integration domain
Horizontal grid	1/3 model resolution
Vertical grid	as model levels
Assimilation method	4DVAR (as global model); plus latent heat nudging scheme of MOPS precipitation data
Assimilation cycle	6 hours
Data	In addition to the data referenced in Table 6 which might be applicable to a regional domain, we also use - Surface visibility observations (Clark *et al.* 2008) - a 3-dimensional 'MOPS' cloud fraction analysis, derived from satellite imagery and surface reports, is assimilated (Macpherson *et al.,* 1996). Outside of the MOPS domain, a cloud top height derived from SEVIRI is also assimilated.

- An hourly precipitation rate analysis, derived from radar, is assimilated by latent-heat nudging (Jones and Macpherson, 1997, Macpherson, 2001).
- A reconfigured global soil-moisture analysis (based on screen nudging) and ASCAT soil wetness.

Regional Forecast model

The NAE model is identical to the global model in all respects, except the following:-

Integration domain	From the North American Great Lakes to the Caspian Sea, central Greenland to northern Africa (approximately 70º N to 30º N, 70º W to 50º E, but distorted due to rotated grid).
Horizontal grid	Spherical rotated latitude-longitude with pole at 37.5º N, 177.5º E. Resolution: 0.111º.
Vertical grid	70 levels and 80-km top
Time step	300s
Horizontal diffusion	None
Vertical diffusion	None
Orography	A simpler and more robust sub-gridscale orography scheme; Orographic roughness parameters derived from 1-km (based on 100-m) data.
Boundary values	Specified from global forecast model with the previous data time (T–6, i.e. forecasts from 1800, 0000, 0600 and 1200 UTC).

Physics parameterisations: mostly same as global model. The main exception is the continued use of the diagnostic (Smith, 1990) scheme instead of PC2 (prognostic).

Regional Short-range ensemble prediction system

MOGREPS (Met Office Global and Regional Ensemble Prediction System) provides a 24-member regional ensemble, MOGREPS-R, covering the North Atlantic and Europe (NAE domain) with a grid-length of 18 km, running twice daily (0600 and 1800 UTC) to 36 hours ahead. A global ensemble, MOGREPS-G, with grid-length of 60-km is run twice daily (0000 and 1200 UTC) to 72 hours to provide the boundary conditions for the regional ensemble. Initial condition perturbations are provided through the ETKF (Ensemble Transform Kalman Filter) method calculated using the global ensemble. Two stochastic physics schemes are employed to account for model error in assessing forecast uncertainty. Products are provided to forecasters in real-time on an internal web-based system. Chart-based products include ensemble mean and spread, probabilities for a wide variety of variables and thresholds including many surface parameters relevant to the short-range forecast, spaghetti diagrams, postage stamp charts and clustering. Site-specific forecast products are generated through the FSSSI and new SSPA databases, and include ensemble meteograms, plumes and wind-roses.

MOGREPS-R is also used to drive a storm surge ensemble system for waters around the British Isles under contract to the Environment Agency.

4.4 Short-range local forecasting system (0-24 hours)

Local Data assimilation (for both 4km and variable resolution 1.5km models)

Analysis variables	as in the NAE model
Analysis domain	as model integration domain
Horizontal grid	model resolution (3km fixed resolution analysis grid is used for the variable resolution model)
Vertical grid	as model levels
Assimilation method	3DVAR; plus latent heat nudging scheme of MOPS precipitation data

Assimilation cycle	Analysis increments are introduced gradually into the model using an Incremental Analysis Update (Bloom *et al.,* 1996) over a 2-hour period (T−1 to T+1), while increments from rainfall data are added by nudging.
Data	similar to NAE

Local Forecast models

The UK 4-km model is identical to the NAE model in all respects, except the following:-

Integration domain	The British Isles and all surrounding sea areas, near-continental Europe (approximately 62º N to 48º N, 11º W to 5º E)
Horizontal grid	Spherical rotated latitude-longitude with pole at 37.5º N, 177.5º E. Resolution: 0.036º.
Vertical grid	70 levels and 40-km top
Time step	100s
Horizontal diffusion	Fourth order diffusion along η surfaces of winds, specific humidity and potential temperature.
Vertical diffusion	None
Orography	A new simpler and more robust sub-gridscale orography scheme.; Orographic roughness parameters derived from 100-m data.
Boundary values	Specified from NAE forecast model with the previous data time (T–3, i.e. forecasts from 0000, 0600, 1200 and 1800 UTC).

Physics parametrizations:-

a) Convection	As NAE except the CAPE closure timescale is not constant but depends on the magnitude of the CAPE. Large values of CAPE effectively inhibit the parameterised treatment of deep convection so that it is explicitly resolved by the dynamics.

The UKV 1.5km model is identical to the 4km model, except the following:-

Integration domain	The British Isles and all surrounding sea areas, near-continental Europe (approximately 60º N to 48º N, 11º W to 3º E in the inner area, 62º N to 46º N, 13º W to 5º E in the full domain)
Horizontal grid	Spherical rotated latitude-longitude with pole at 37.5º N, 177.5º E. Resolution: Variable; 0.0135º in the area of interest stretching to 0.036 º in the borders.
Time step	50s
Horizontal diffusion	None, instead a Smagorinsky Subgrid Turbulence scheme is used.
Vertical diffusion	None, however a local Richardson Number based boundary layer parametrization extends from the top of the non-local Boundary Layer to the top of the model to allow mixing.
Orography	No subgrid orographic scheme is used.

Physics parametrizations:-

a) Convection	Convection is explicitly resolved.
b) Gravity wave Drag	Gravity wave drag is explicitly resolved

4.5 Nowcasting and very short-range forecasting systems (0-6 hours and beyond)

UKPP - UK Post Processing System for Nowcasting and Product generation

The UKPP post-processing system produces analyses and forecasts of precipitation and other surface weather parameters. These include precipitation type, visibility, cloud amount, cloud base and cloud top height, wind speed and direction, temperature, gust intensity, towering convection and probabilities of snow, lightening and fog for the period T+0 to T+6 hours, operating on an hourly cycle. Forecasts are normally produced by merging an extrapolation forecast with the UK 4km NWP model forecast at a resolution of either 5 or 15 km. Rainfall forecasts are also produced on the half hour at 5 km, and at quarter hourly intervals at 2-km resolution. A set of soil moisture products is also produced at 5-km resolution. The Nimrod cloud and precipitation analyses are used as inputs to the mesoscale model assimilation scheme.

For the forecast period beyond T+6, the system provides 4km forecast model products in a consistent format to the Nowcast products, which is update 6 hourly in line with forecast model product delivery. A parallel system is now in place to post-process the 1.5km model. A seamless product is also available with a transition to the coarser resolution models beyond T+36. Trial ensemble products are also being fed from MOGREPS to provide a one-stop shop for Model fields.

Grid	There are several configurations, one covering the UK, and one covering the European area. Both are set up on Transverse Mercator projections, the UK domain covering a domain approximately 44° N to 64° N, 12° W to 13° W, and the European domain extending from 30° W to 43° E at 60° N and from 10° W to 25° E at 35° N.
Data Inputs	Imagery from the UK and European radar, Meteosat and MSG visible and infrared imagery, NWP model fields (UK model for UKPP, NAE model for EUPP and Global Model GLPP) and surface weather reports
Forecast time step	5 minutes for precipitation forecasts (to T+6); 60 minutes for other fields.

4.6 Specialized numerical models

Global ocean model – FOAM (Forecasting Ocean Assimilation Model)

Model type	The FOAM system (Storkey *et al* 2010) is based on the NEMO ocean community code (Madec 2008). It uses a linear free-surface and an energy- and enstrophy-conserving form of the momentum advection. The lateral boundary condition on the momentum equations is free slip. The horizontal momentum diffusion uses a combination of laplacian and bilaplacian operators. The tracer equations use a TVD advection scheme and the tracer diffusion operator is laplacian and along-isopycnal. The vertical mixing uses a single-equation TKE scheme with an algebraic expression for the mixing length based on the local density. Sea ice is simulated using the LIM2 ice model.
Integration domain	Global
Horizontal grid	A tripolar curvilinear Arakawa-C grid giving 0.25º x 0.25º resolution at the equator and increasing resolution towards the poles
Vertical grid	50 geopotential (z) levels with partial cells at the seabed and high resolution near the surface, including a 1m surface cell.
Data assimilation	Developed from the Analysis Correction scheme of Lorenc *et al*. (1991), including a 2-component inhomogeneous 3-D error covariance model. Temperature and salinity profile data, sea-surface temperature data (in-situ and satellite) and altimetric sea-surface height are assimilated. Analysis steps are performed once per day. Altimeter data are assimilated by displacement of isopycnal surfaces (an extension of the Cooper & Haines 1996 scheme). A pressure correction technique (Bell et al. 2004) is employed to improve the dynamical balance near the

	equator and analyses performed with large correlation scales are used to attempt to remove large-scale biases in the satellite surface temperature data.
Surface fluxes	From the global NWP model, 6-hourly

Wave hindcast and forecasting system: global wave model

Model type	3rd generation spectral phase averaged WAVEWATCH III® (Tolman, 2009)
Integration domain	Global
Grid	Spherical latitude-longitude from 80.2778ºN to 79.166ºS Resolution: 5/9º latitude, 5/6º longitude
Frequency resolution	25 frequency components spaced logarithmically between 0.0412 Hz and 0.406 Hz
Direction resolution	24 equally spaced direction components
Data assimilation	None.
Integration scheme	Fractional time-stepping method. Advection timestep is frequency dependent (max of 450s), intra spectral timestep = 1800s, source term integration timestep = 60s. Spatial advection scheme is the 2nd order scheme of Li (2008).
Boundary forcing	Winds at 10 m, updated hourly
Surface classification	Sea-ice analyses as in the global model
Physics parameterisations	Source terms (input and dissipation) of Tolman & Chalikov (1996) Non-linear interactions calculated using discrete interaction approximation (DIA) (Hasselman et. al, 1985) Shallow-water terms are included (shoaling, bottom friction, refraction). Surf breaking tem of Battjes & Janssen (1978).

Regional ocean models – FOAM (Forecasting Ocean Assimilation Model)

Model type	The FOAM system is based on the NEMO ocean community code (Madec 2008). It uses a linear free-surface and an energy- and enstrophy-conserving form of the momentum advection. The lateral boundary condition on the momentum equations is free slip. The horizontal momentum diffusion uses a combination of laplacian and bilaplacian operators. The tracer equations use a TVD advection scheme and the tracer diffusion operator is laplacian and along-isopycnal. The vertical mixing uses a single-equation TKE scheme with an algebraic expression for the mixing length based on the local density.
Integration domain	(1) North Atlantic; (2) Mediterranean; (3) Indian Ocean
Horizontal grid	(1)North Atlantic 1/12° x 1/12° rotated grid, approx 20N - 80N, 90W - 20E (2) Mediterranean 1/12° x 1/12° regular lat-lon grid, 30N - 47.5N, 05.5W - 42E (3) Indian Ocean 1/12° x 1/12° regular lat-lon grid, 25S - 31N, 33E - 106E
Vertical grid	50 geopotential (z) levels with partial cells at the seabed and high resolution near the surface, including a 1m surface cell.
Data assimilation	Developed from the Analysis Correction scheme of Lorenc *et al*. (1991), including a 2-component inhomogeneous 3-D error covariance model. Temperature and salinity profile data, sea-surface temperature data (in-situ and satellite) and altimetric sea-surface height are assimilated. Analysis steps are performed once per day. Altimeter data are assimilated by displacement of isopycnal surfaces (an extension of the Cooper & Haines 1996 scheme). A pressure correction technique (Bell et al. 2004) is employed to improve the dynamical balance near the equator and analyses performed with large correlation scales are used to attempt to remove large-scale biases in the satellite surface temperature data.

Surface fluxes	From the global NWP model, 6-hourly
Boundary data	From global FOAM

Wave hindcast and forecasting system: regional wave model

The local wave model uses the same physics as the regional wave model. Two configurations are run: a 4 times daily 60hr forecast using 12km NAE wind forcing and a 2 times daily 144hr forecast using global 40km winds.. At this time the effects of currents and surge are not included.

Model type	3rd generation spectral phase averaged WAVEWATCH III® (Tolman, 2009)
Integration domain	North-West European continental shelf
Grid	Rotated spherical latitude-longitude from approx 25º N to 66º N and 68º W to 42º E. Resolution: 1/9º latitude, 1/9º longitude
Boundary forcing	1) 10-m winds from the mesoscale NWP model, updated hourly (for 60-hour forecast, four times daily); winds from the global NWP model for 144-hour forecast (twice daily) 2) Spectral values at lateral boundaries from the global wave model, updated hourly
Surface classification	Sea ice as in global model.
Physics parameterisations	Identical to the global model.

Shelf-seas forecast model

The NEMO ocean model (Madec 2008) has been adapted for shelf seas and a configuration of this model is running for the NW European shelf area (O'Dea *et al* 2010). The models run once daily for a 24-hour hindcast, followed by a 144-hour forecast.

Model type	Non-linear free surface, baroclinic total variation diminishing (TVD) advection scheme, k-epsilon turbulent mixing;
Integration domain	North-West European continental shelf
Horizontal Grid	Spherical latitude-longitude from 40º N to 65º N, and from 20º W to 13º E. Resolution 7km latitude, 7km longitude
Vertical Grid	33 levels, using a hybrid S/sigma/z vertical co-ordinate
Data assimilation	Satellite and in-situ sea surface temperature data are assimilated using a methodology developed from the Analysis Correction scheme of Lorenc et al. (1991),
Boundary forcing	1) Hourly winds and pressures, 6-hourly averaged heat flux from global NWP model; 2) Deep-ocean temperature and salinity profile, barotropic current and elevation from the Atlantic FOAM model; 3) River inflows – daily climatology, data provided from Environment Agency; 4) Tidal elevations from 15 harmonic constituents.
Surface classification	No sea ice; no wetting or drying.
Ecosystem model	The physical model has been coupled with a generic ecosystem model, ERSEM-2004 (Blackford *et al.*, 2004). The ERSEM code is driven by temperature, salinity and diffusivity from the physical model. ERSEM has 100 biological, pelagic and benthic state variables with multiple classes of phytoplankton and zooplankton. The model also considers bacteria, dissolved and particulate organic matter and nutrients.

Storm-surge model

A depth-averaged storm-surge model, developed by the Proudman Oceanographic Laboratory, is run operationally on behalf of DEFRA (the Department of the Environment, Food and Rural Affairs) for the Storm-Tide Forecasting Service. The model is implemented on a grid at 1/9º by 1/6º resolution covering 48º N to 63º N, 12º W to 13º E and is forced at the deep-ocean boundaries by

15 tidal harmonic constituents. The model is run 4 times daily, using hourly values of surface pressure and 10-m winds from the mesoscale NWP model to provide a 36-hour forecast. The model is also run twice daily in a 24-member ensemble driven from MOGREPS-R, and will be extended to 7 days using forcing from MOGREPS-15 during 2011.

Transport and dispersion model

A model for medium- to long-range transport and dispersion (NAME) is available to be run in the event of a major atmospheric release of hazardous pollutants. Applications include nuclear emergencies, volcanic eruptions, major chemical releases or fires, and the airborne transport of the foot and mouth virus. With a comprehensive chemistry scheme it is also used for understanding and predicting air quality and for episode studies. The model provides forecasts of concentrations in the boundary layer and at upper levels, as well as wet and dry deposition to the surface. It uses analysis and forecast fields from the global and mesoscale atmospheric models maintained in on-line archives. The NAME model may be run at any time in hindcast or forecast mode. The model can also be used to compute three-dimensional trajectories.

Model type	Three-dimensional Lagrangian particle Monte Carlo model simulating the medium- or long-range transport, dispersion and deposition of airborne pollutants
Domain	Global or UK mesoscale, nested as required.
Model grid	Identical to the global, UK mesoscale, or crisis-area mesoscale models; The transport model can access fields from three input models simultaneously with an option to use the best resolution available at every particle position. The output grids are user defined and of any resolution.
Meteorological input	Meteorological fields from the global or UK mesoscale models and high-resolution rainfall rates derived from radar.
Integration scheme	Forward Euler solution of the stochastic differential equations governing the particle positions, with time step determined by the diffusion scheme near to the source, but with an option for definition by the user at longer ranges.
Parameterisations	Range of random walk schemes used to represent mixing due to turbulence, utilising profiles of velocity variances and time scales. Parameterisations include: low-frequency wind meandering, plume rise, gravitational settling, the venting of pollutants from the boundary layer by strong convection, and small-scale entrainment at the boundary-layer top. Loss processes include: radioactive decay, wet and dry deposition, and Foot and Mouth virus loss due to high temperature and low humidity. A detailed chemistry scheme (37 species) includes both dry and aqueous phase reactions.
Special features	Utilises high-resolution rainfall rates derived from radar products for detailed wet deposition over north-west Europe. Source attribution scheme for identifying the origin of material at a given receptor; Can handle multiple and complex sources.

4.7 Monthly/Seasonal forecasts (1-6 months)

Seasonal forecasts to 7 months ahead are generated each month using GloSea4, the Met Office ensemble prediction system for seasonal forecasting. GloSea4 became operational in September 2009. A summary of the system can be found here:

http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/glosea4

5. Verification of prognostic products

Statistic	Level	Area	Verified vs.	T+24	T+72	T+120
RMS error(m)	Z 500	N.Hem	Analyses	7.14	21.55	42.97
RMS error(m)	Z 500	S.Hem	Analyses	8.91	27.73	54.25
RMS error(m)	Z 500	N.America	Observations	10.15	22.24	42.22
RMS error(m)	Z 500	Europe	Observations	10.52	23.01	45.25
RMS error(m)	Z 500	Asia	Observations	12.67	21.76	37.09
RMS error(m)	Z 500	Aus/NZ	Observations	8.95	17.80	32.83
RMSVW error (m/s)	W 250	N.Hem	Analyses	3.61	7.89	12.68
RMSVW error (m/s)	W 250	S.Hem	Analyses	3.55	8.57	14.24
RMSVW error (m/s)	W 250	N.America	Observations	5.80	9.90	15.03
RMSVW error (m/s)	W 250	Europe	Observations	5.20	9.43	15.11
RMSVW error (m/s)	W 250	Asia	Observations	5.71	8.87	12.64
RMSVW error (m/s)	W 250	Aus/NZ	Observations	5.44	8.61	12.57
RMSVW error (m/s)	W 850	Tropics	Analyses	1.74	2.72	3.37
RMSVW error (m/s)	W 250	Tropics	Analyses	3.09	5.43	7.02
RMSVW error (m/s)	W 850	Tropics	Observations	3.79	4.38	4.90
RMSVW error (m/s)	W 250	Tropics	Observations	5.18	6.70	7.93

Table 8: Standard WMO Verification for calendar year 2010

6. Plans for the future

6.1 Computer systems

Phase 2 of the IBM HPC (Power 7 IH) will be installed during early 2012.

6.2 Forecasting Research and Development Key Deliverables during 2011

Satellite Applications

- Deliver a system for assimilating IASI and AIRS near–surface channels over land.
- OPS code and report on preliminary trials for assimilating surface cloud observations alongside SEVIRI cloud retrievals into regional NWP models
- Deliver a system for using variable observation errors in 4D-Var.
- Enhanced Radio Occultation Processing Package version 6 (ROPP-6) ready for release to users.
- Report on the impact of changes in the water vapour continuum arising from the CAVIAR consortium on satellite remote sensing .

Data Assimilation

- Operationally-feasible N320 inner-loop 4D-Var configuration ready for implementation testing.
- To have implemented one or more upgrades to the operational global 4D-Var algorithm, giving demonstrable cost-benefit to forecast products. Candidates include: 'Version 1' hybrid', moist control variable.
- To have implemented one or more upgrades to the use of observations within global 4D-Var, giving demonstrable cost-benefit to forecast products. Candidates include: introduction of METARS surface pressure obs; thinning updated for N216 inner loop.
- Report on use of Doppler winds in 4D-Var.
- Report demonstrating use of variational bias correction in regional reanalysis.
- Complete development & testing of revised initial condition perturbation mechanism and increased ensemble size for MOGREPS-G. Upgrade ready for implementation in time for mid-life upgrade.
- Report on design of new climatological convective scale covariance model.
- To have implemented one or more upgrades to the operational UK 1.5km DA algorithm, giving demonstrable cost-benefit to forecast products. Candidates include: new humidity control variable, separate insertion of large scale information & revised fine scale covariances.

- To have implemented one or more upgrades to the use of observations within the operational UK 1.5km DA algorithm, giving demonstrable cost-benefit to forecast products. Candidates include: radar radial winds, radar reflectivity, revised observation errors, introduction of OpenRoad sensor data.
- Report/paper on significant model error investigation.
- Capability for routine running of hourly updated NWP-based very short range forecasts.
- EKF assimilation of screen-level obs and ASCAT soil wetness ready for pre-operational trials.

Ensemble Forecasting Development

- Report on evaluation of MOGREPS ensemble spread – investigate relationship with Global Model error.
- Both MOGREPS-R and MOGREPS-G will have major upgrades to provide 4 cycles per day with 12 members per cycle; 24-member forecast products will be generated by lagging of the last two cycles. Resolution increases will be implemented following the mid-life computer enhancement.
- New 2.2km MOGREPS-UK ensemble ready for implementation following mid-life computer enhancement.
- A first-guess severe weather warning system, MOGREPS-W, based on MOGREPS-R which has been successfully demonstrated in research will be implemented following upgrade to meet the needs of the revised National Severe Weather Warning Service.

Global Model Development and Diagnostics

- Report on the outcomes of collaborative diagnostics project on the Asian Monsoon with ECMWF.
- Evaluate the changes to the tropical cyclone initialisation scheme currently being tested by KMA in our version of the UM with a view to implementation if beneficial.
- Report describing the impact of stochastic parameterizations on atmospheric processes and their effect on model performance across timescales and resolutions.
- Upgrades to model physics fully tested and ready for parallel suite prior to operational implementation (PS30 – GA 4.0).
- Report on extensive coupled ocean-atmosphere trials on NWP (1-15 day) timescales.

Regional Model Development and Diagnostics

- UKV Improvements to fog, drizzle and stratocumulus ready to implement in PS27
- Implement agreed changes to the Warnings Verification System with interim assessment report.
- Determine a best available probabilistic forecast as a combination of all available forecast products
- Report on outcome of UKV case studies highlighting problems seen and potential improvements
- Regular improvements to operational regional and local models resulting in improvements to high impact weather forecasts indicated by proven contribution to NWP index during the previous year.
- Report on performance and systematic behaviour of cloud and fog forecasts over the UK using spatial datasets and methods
- Full strategic intervention capability built into 6 hourly EPS cycle for PS29.
- Report on outcome of UKV case studies highlighting problems seen and potential improvements to the model.

Model Infrastructure

- UM Release UM Release 8.0 with functionality to support a multiple dynamical cores
- UM Release 8.1 with more efficient build facility including installation of JULES from its own repository.
- Working NWP trial with demonstrated with new system.
- Report on UM performance and scalability on Power 7.
- Annual major release of verification codes (ABV/SBV) available for operational use.

- Annual major release of data assimilation codes (OPS/VAR) available for operational and external use

Model Physics

- Modify parametrization schemes to produce improved forecasts of boundary layer cloud
- Report on analysis of high resolution CASCADE runs including ideas for improving parametrizations.
- Submit series of scientific papers on the Eyjafyoll eruption to JGR Special Issue.
- Report on the impact of vertical resolution and vertical soil heterogeneity within JULES and the UM system.
- Scientific report on the exploitation of observations from CONSTRAIN in comparison with sensitivity tests of LES and/or UM to key ice and mixed-phase cloud parameters.
- Review lessons learnt from COLPEX cold-air pooling experiment for high-resolution modelling and post processing.
- Report on progress on determining optimal configurations of model at various resolutions.
- Review progress with parametrization issues in global model seamless prediction system (days to decades – CAPTIVATE project).

Post-processing

- Upgrade MOGREPS-W, exploiting regional impact-related thresholds.
- Report on benefit of lagging KFMOS deterministic and ensemble (temperature) forecasts.
- Ensemble forecasts downscaled in UKPP using physical and/or KF techniques.
- Parallel quasi-operational trial and evaluation of blending scheme and STEPS
- Case study report on the benefit of integrating the 3dVOM into the vehicle overturning risk and impact modelling capability
- Capability for product generation from MOGREPS-UK ready for PS29 including showcase of new probabilistic products from UKV output.
- Ensemble post-processing system prepared for 4-cycles per day lagged ensemble production following PS29.
- Deliver improved visibility and cloud diagnostics in SSPS.

Dispersion Modelling

- Release NAME version with GRIB 2 capability (to retain ability to run using ECMWF ensemble data) and with improved optimisation.
- Report on exploratory investigations into visibility diagnostics schemes using predictions from offline code and AQUM. Deliver recommendations for visibility diagnostic schemes**.**
- Release NAME version with improved parametrizations of urban effects on dispersion.
- Report illustrating the impact of the ExTC scheme on ozone production during episode conditions.

Ocean, wave and surge forecast models

- New verification procedures part of standard practice for wave group
- To deliver the V2 Operational Processes Manual
- OSTIA re-analysis dataset completed, evaluated and a paper submitted
- Submit paper documenting NEMO NW European Shelf system
- Report on issues identified by operational monitoring of ocean models within the FY
- Deliver validated & documented V2 version of MyOcean systems in line with MyOcean project schedule.
- Surge ensemble forecasts will be extended operationally from 2 days to 7 days ahead.

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