Ensemble applications and integration with deterministic post-processing

Ken Mylne

Thanks to Caroline Jones, Rob Neal, Piers Buchanan, Andrew Jones, James Canvin, Andrew Bennett, Stephen Moseley and Jo Robbins.

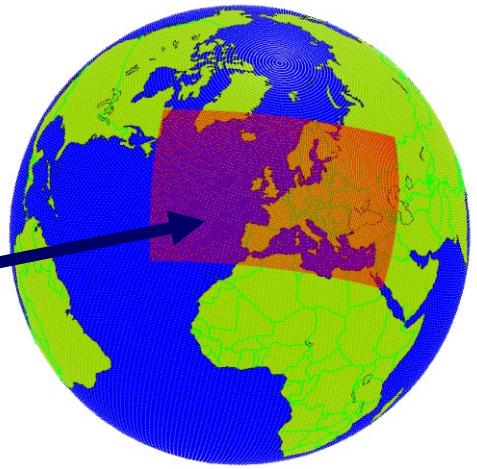
MOGREPS

Met Office Global and Regional Ensemble Prediction System

24 members | Operational since Sept 2008 after 3-years of trials

Global Component (MOGREPS-G)

- 60km, 70 Levels
- T+72h
- Run at 00Z and 12Z
- ETKF for IC perturbations
- Stochastic physics (SKEB2) and random parameters
- Also run at ECMWF out to 15 days **(MOGREPS-15)**

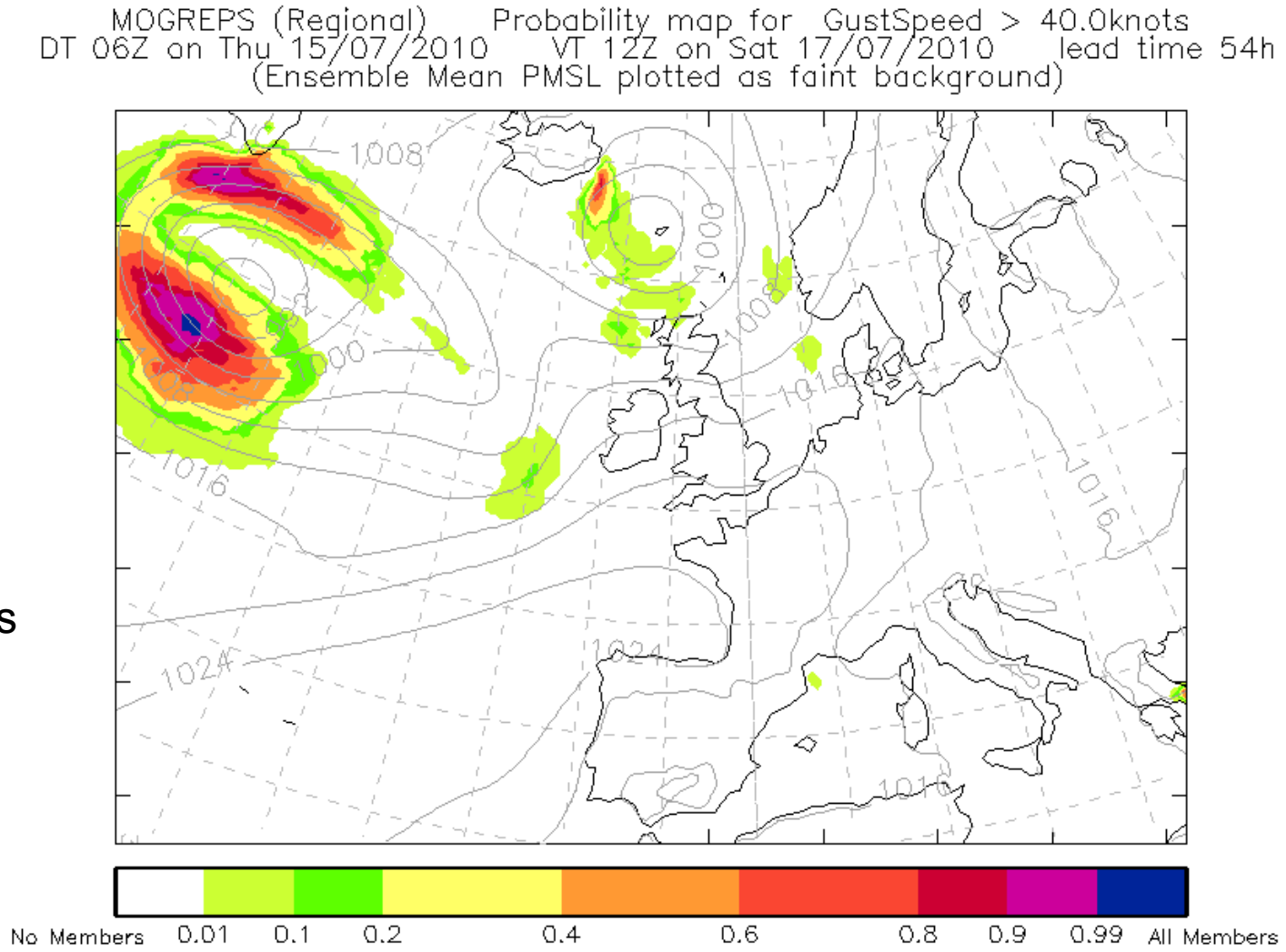


Regional Component (MOGREPS-R)

- Runs over the North Atlantic and Europe (NAE)
- 18km, 70 Levels
- T+54h
- Run at 06Z and 18Z with boundary conditions from MOGREPS-G

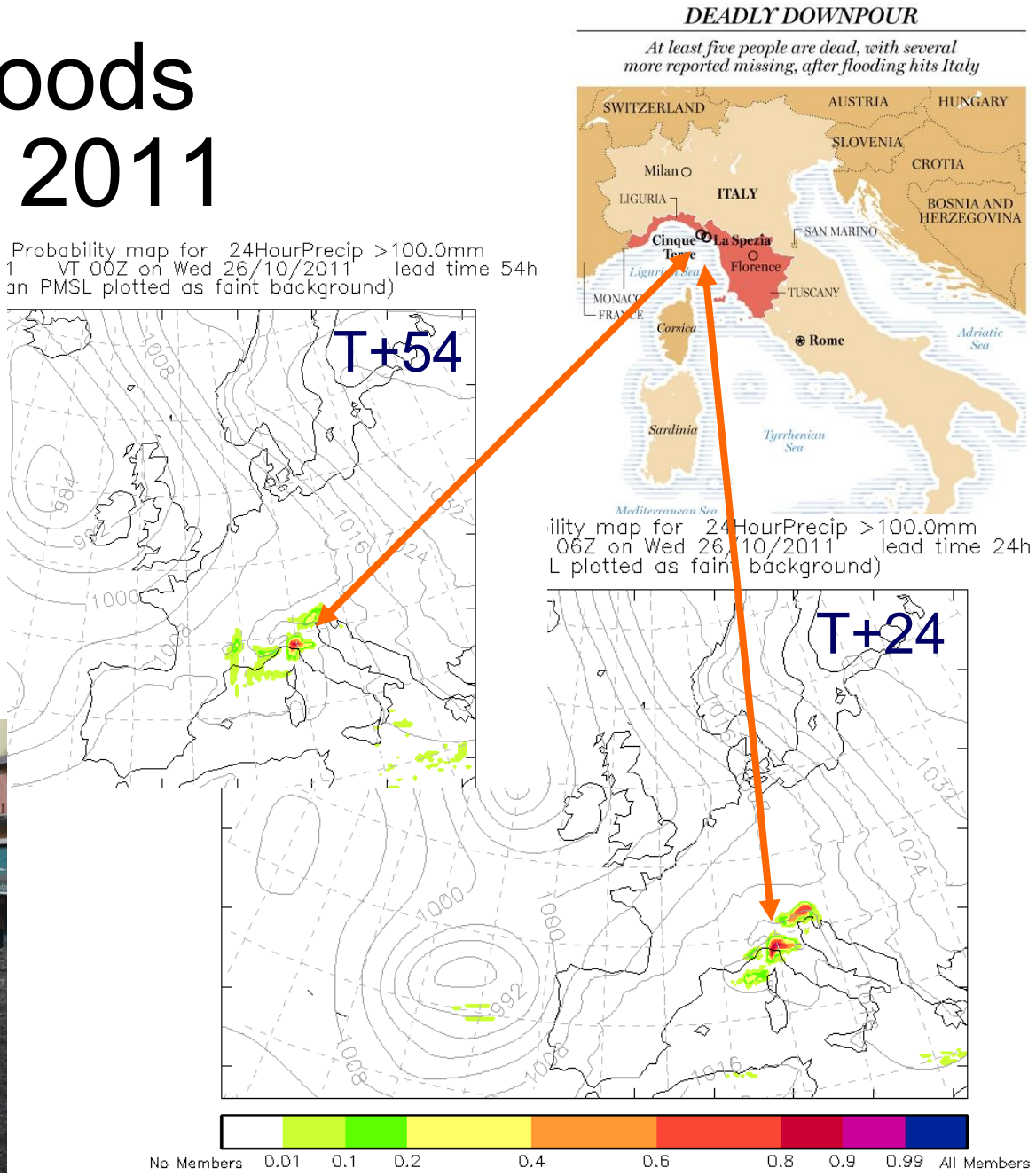
Many web-based products
e.g. Prob of Gusts>40kt

- Probabilities, ensemble mean and spread also stored as GRIB2 files for display on forecaster workstations alongside deterministic forecasts
- Ensemble members in GRIB2 for
  - Exchange
  - TIGGE-LAM
  - Product generation



Italy Floods 26 Oct 2011

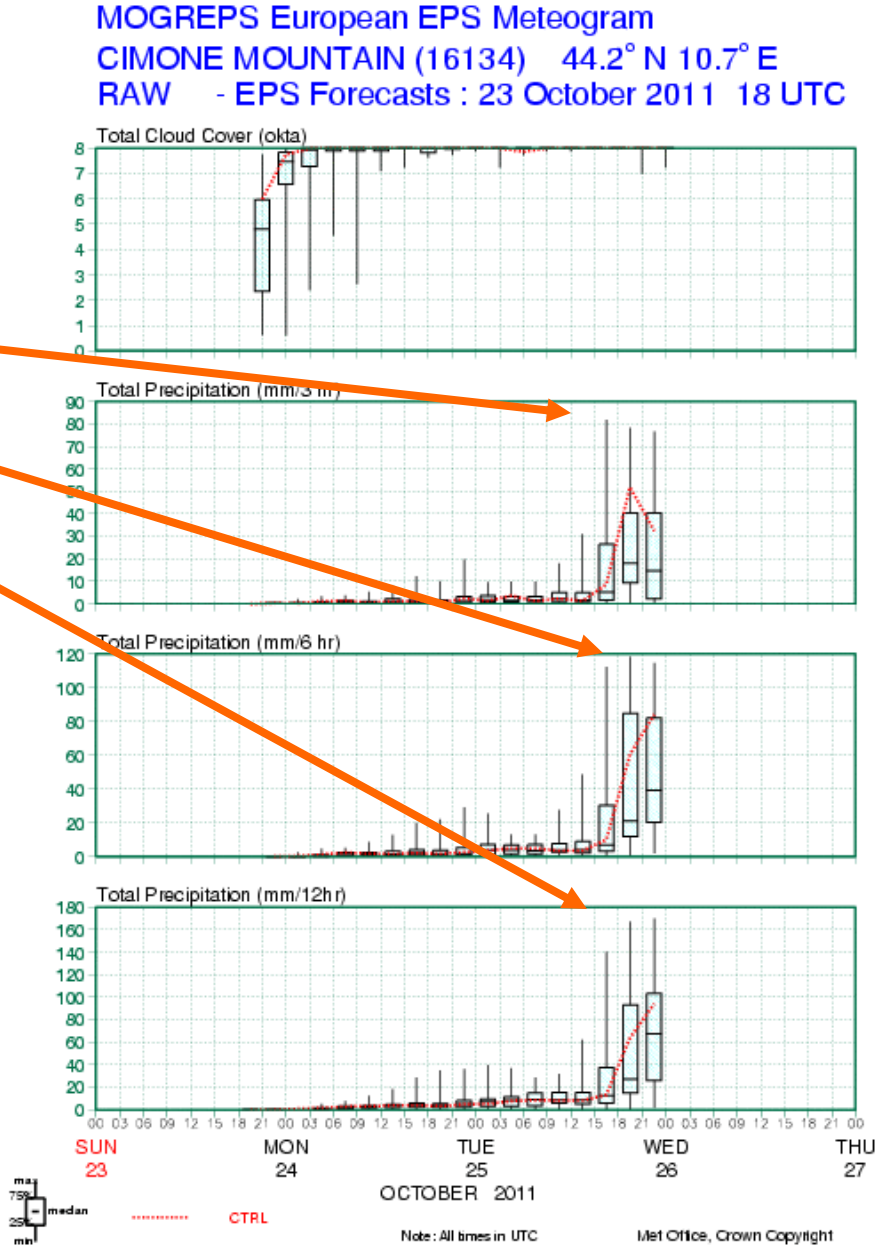
- MOGREPS-R probs of 24h precip>100mm accurately pinpoint severe floods
- Prob>80% at T+54



Italy Floods 26 Oct 2011

2-day Forecast:

- 3h precip up to 80mm
- 6h precip up to 120mm
- 12h precip up to 160mm
  - Median over 60mm
- Observations over 400mm reported



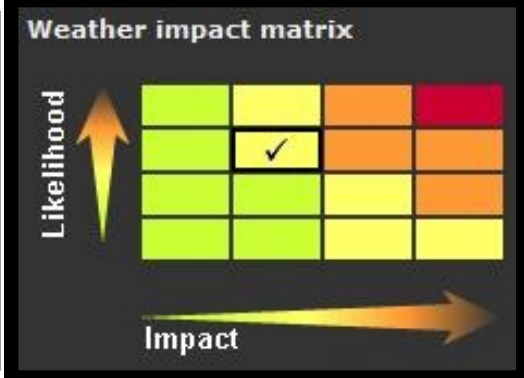
MOGREPS-W

First-guess Severe Weather Warnings for NSWWS

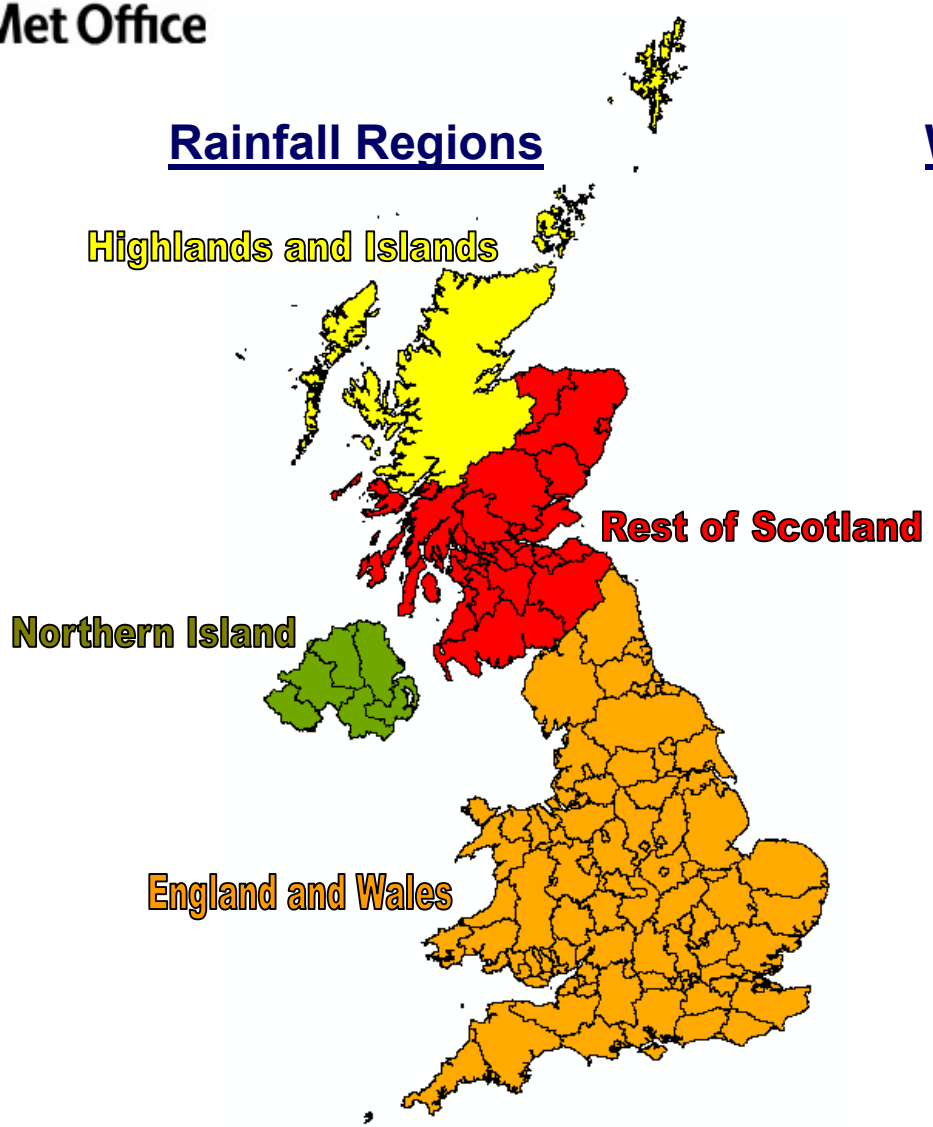
Estimating Impact – a Risk tool

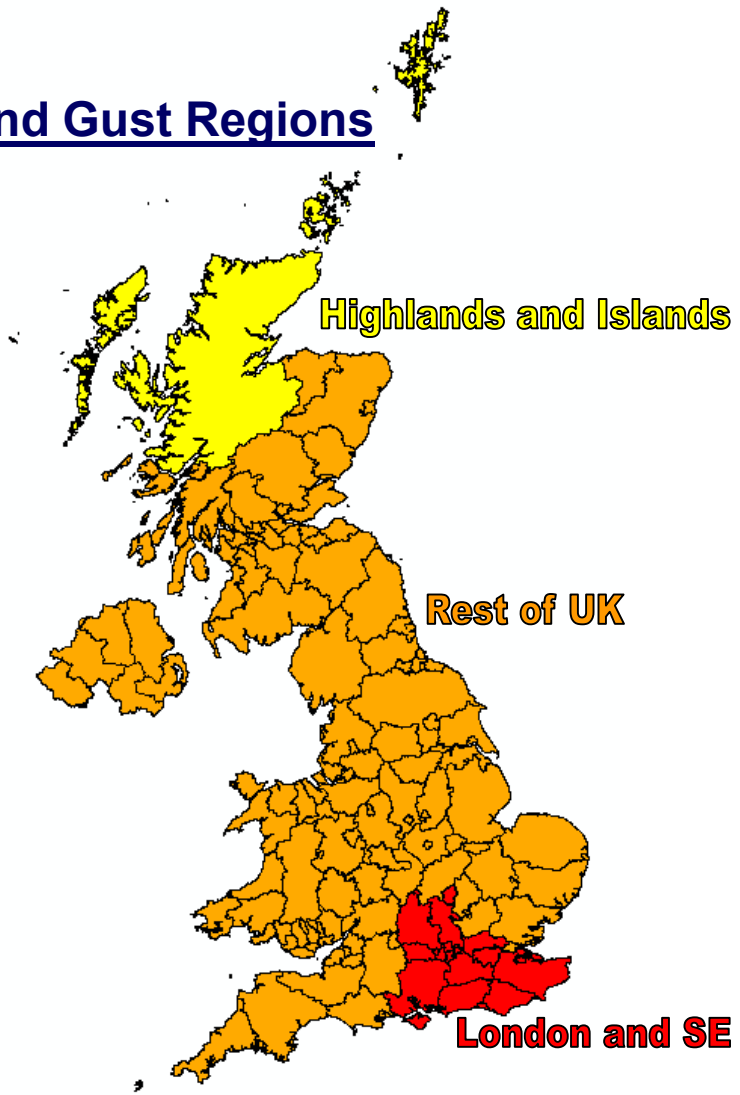
The *New* National Severe Weather Warning Service (NSWWS)

- Alerts/warnings based on **likelihood** and **impact**
  - **Alerts** - issued more than 24 hours ahead
  - **Warnings** - issued up to 24 hours ahead
- Regionally varying impact thresholds
- Alerts/warnings presented by shape areas on a map rather that just by county area



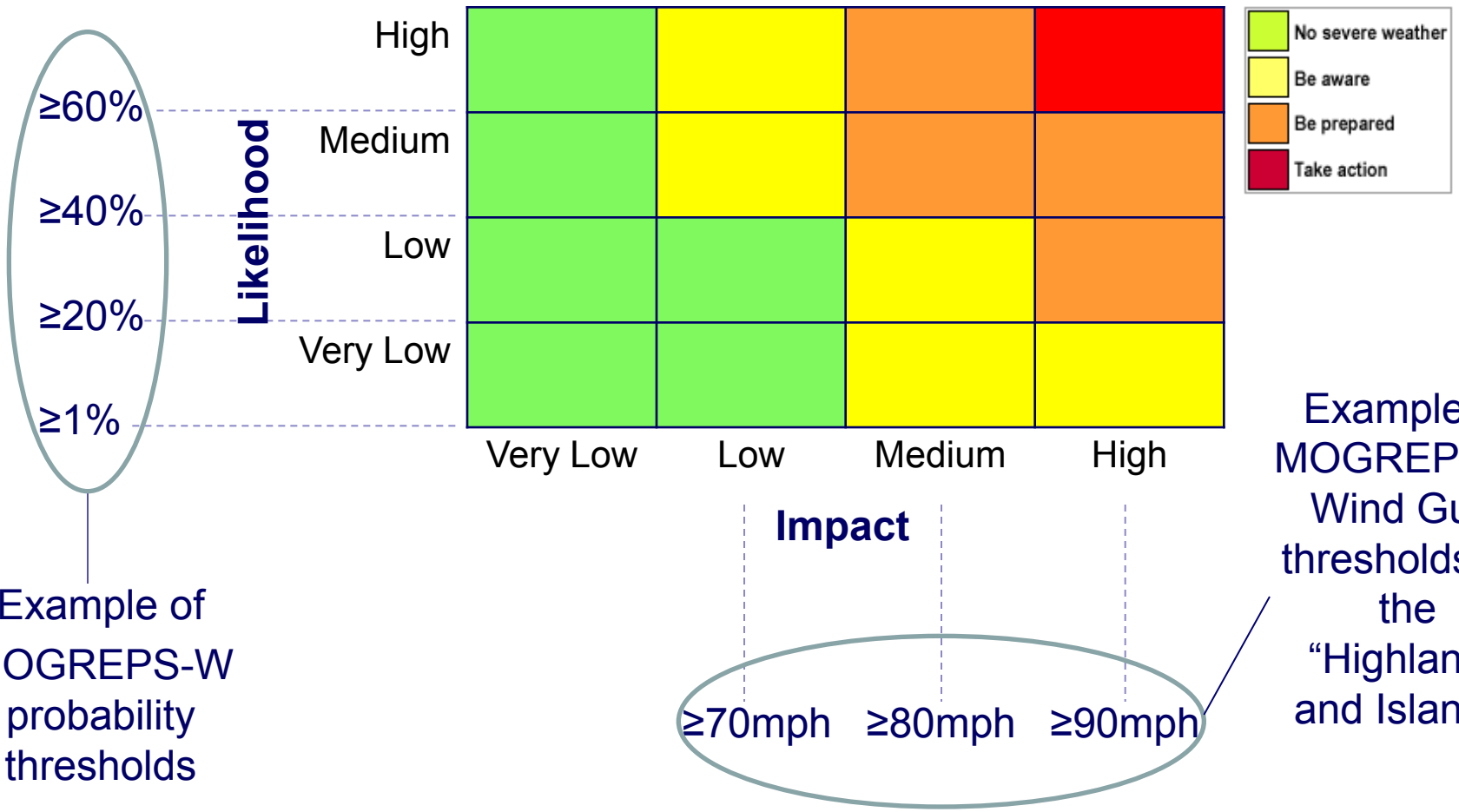
Regional Impact Thresholds





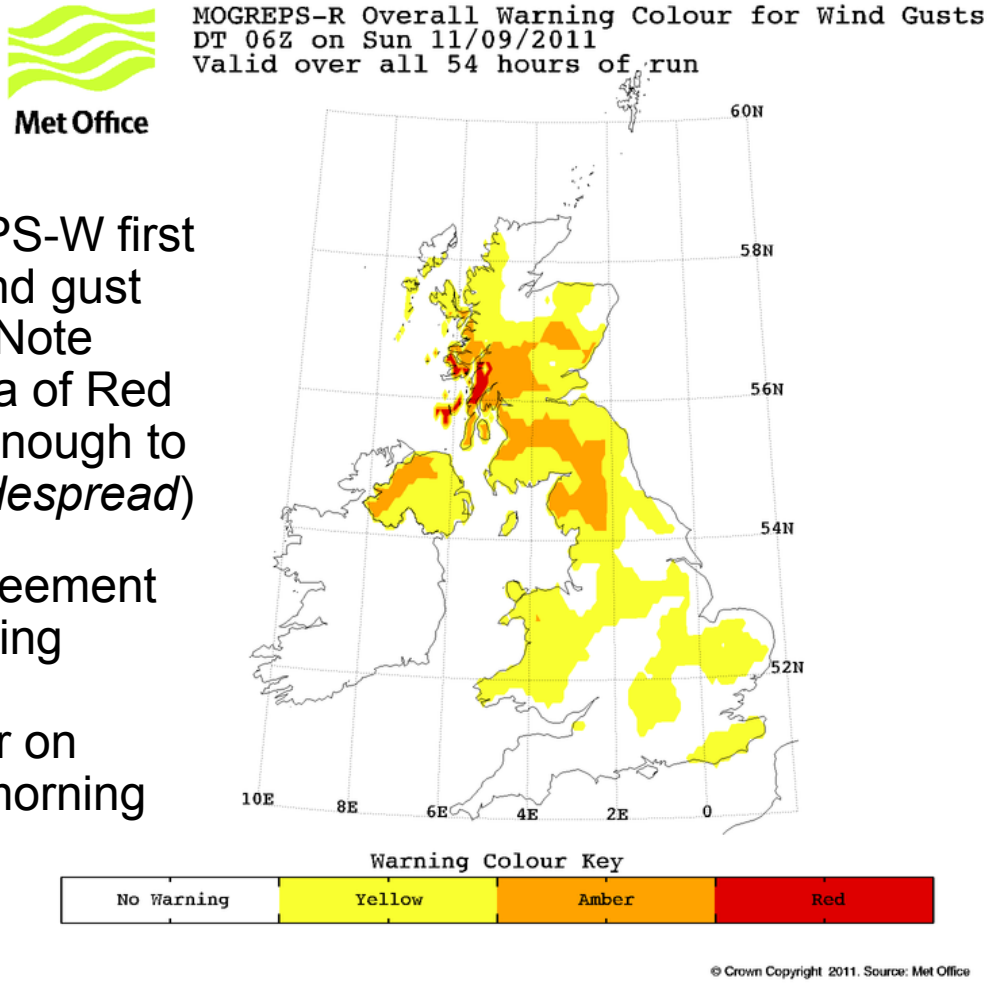
Impact-based MOGREPS-W

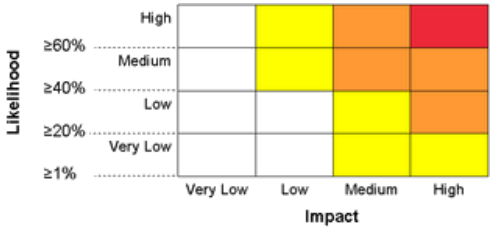
Weather Impact Matrix

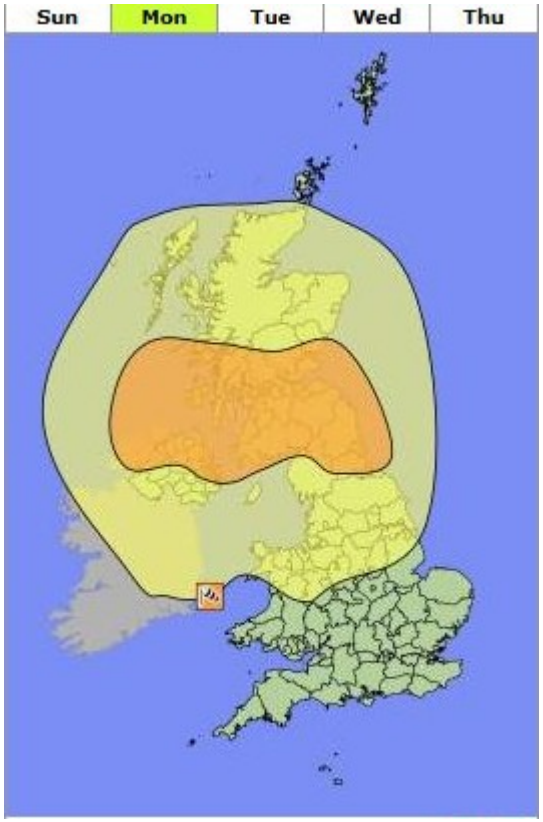


MOGREPS-W Example

Ex-hurricane Katia, 12th Sep 2011





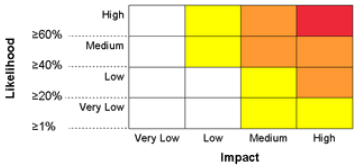


MOGREPS-W first guess wind gust warning. Note small area of Red (but not enough to justify *widespread*)

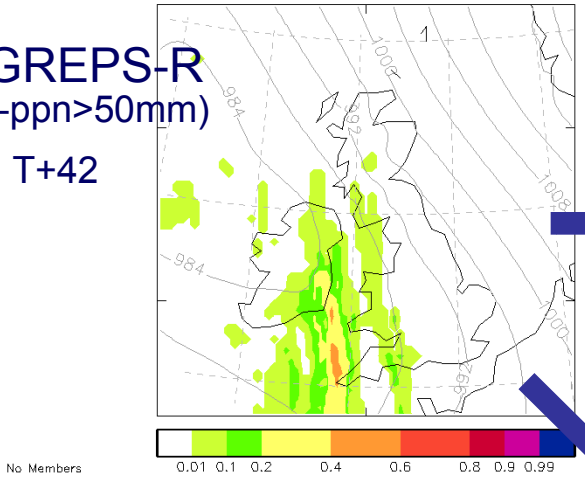
Good agreement with warning issued by forecaster on Sunday morning (right)

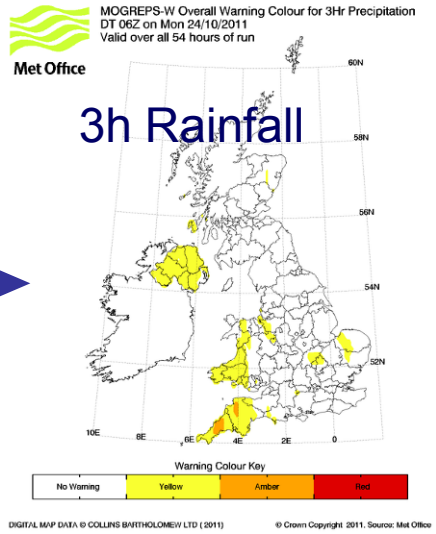
MOGREPS-W Example

Heavy Rain on 24th October 2011



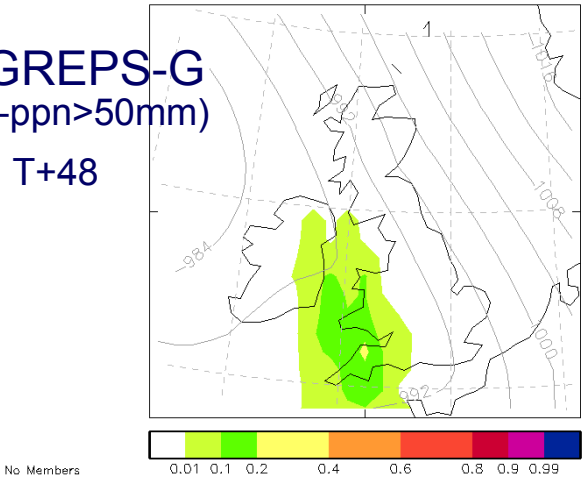
MOGREPS-R
p(24h-ppn>50mm)
T+42

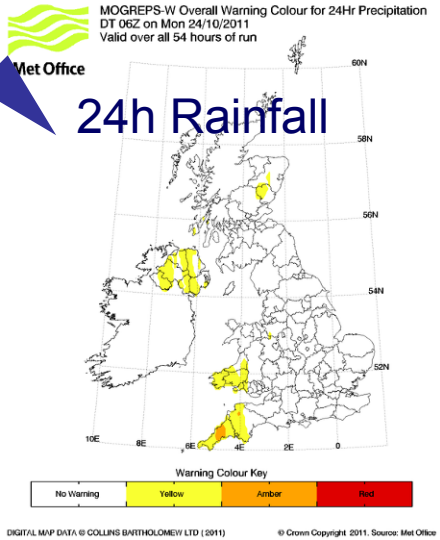




3h Rainfall

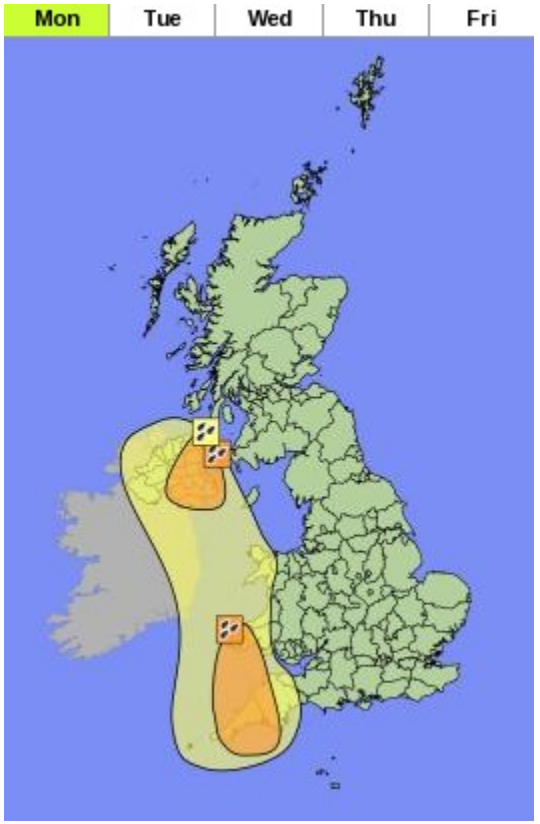
MOGREPS-G
p(24h-ppn>50mm)
T+48





24h Rainfall

Good agreement with warning issued by forecaster (below)

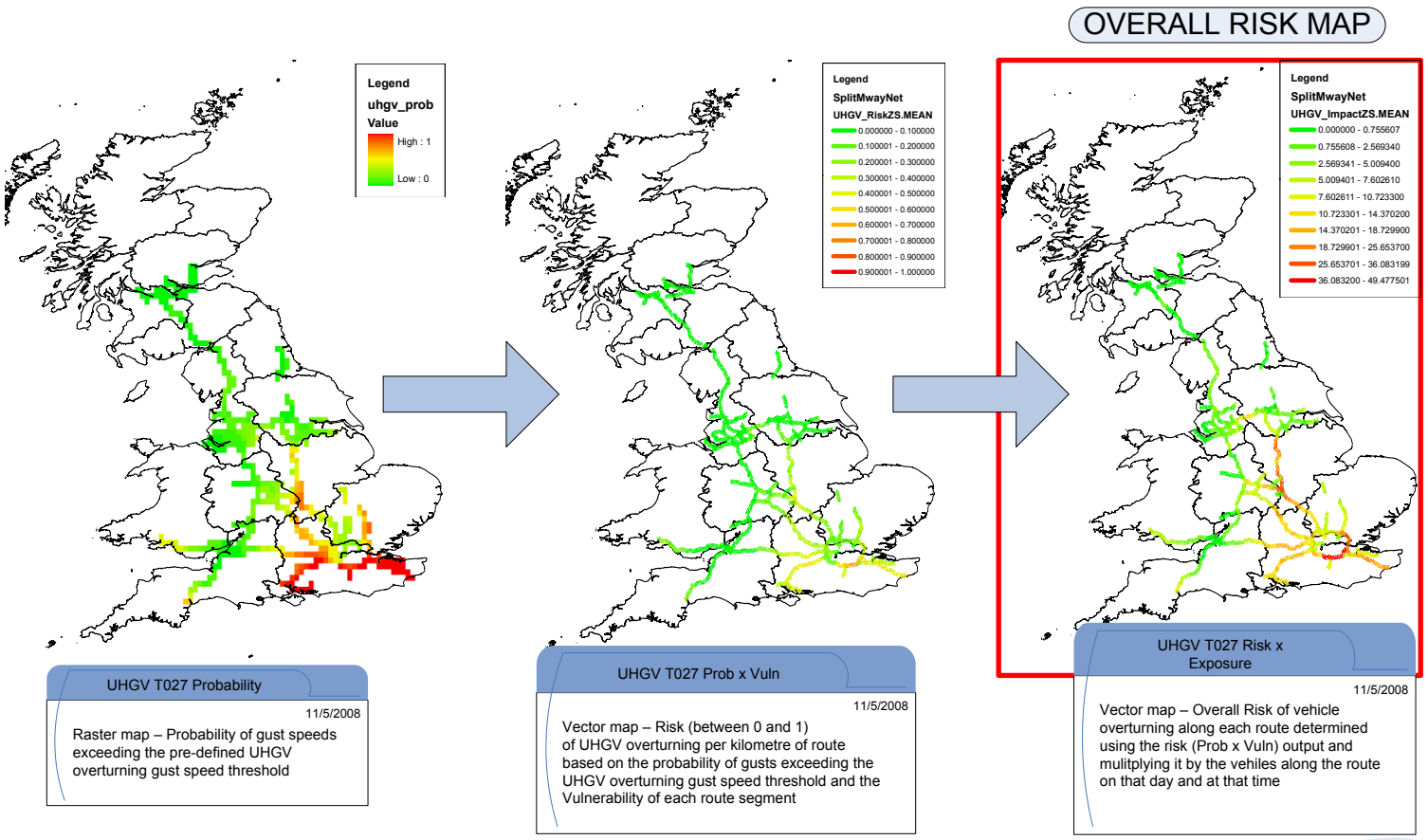


Converting Hazard to Risk

Example for road vehicle overturning due to strong winds

Probability, Vulnerability & Exposure = Risk of Vehicles Overturning

Wednesday, November 05, 2008



UHGV T027 Probability

11/5/2008

Raster map – Probability of gust speeds exceeding the pre-defined UHGV overturning gust speed threshold

UHGV T027 Prob x Vuln

11/5/2008

Vector map – Risk (between 0 and 1) of UHGV overturning per kilometre of route based on the probability of gusts exceeding the UHGV overturning gust speed threshold and the Vulnerability of each route segment

UHGV T027 Risk x Exposure

11/5/2008

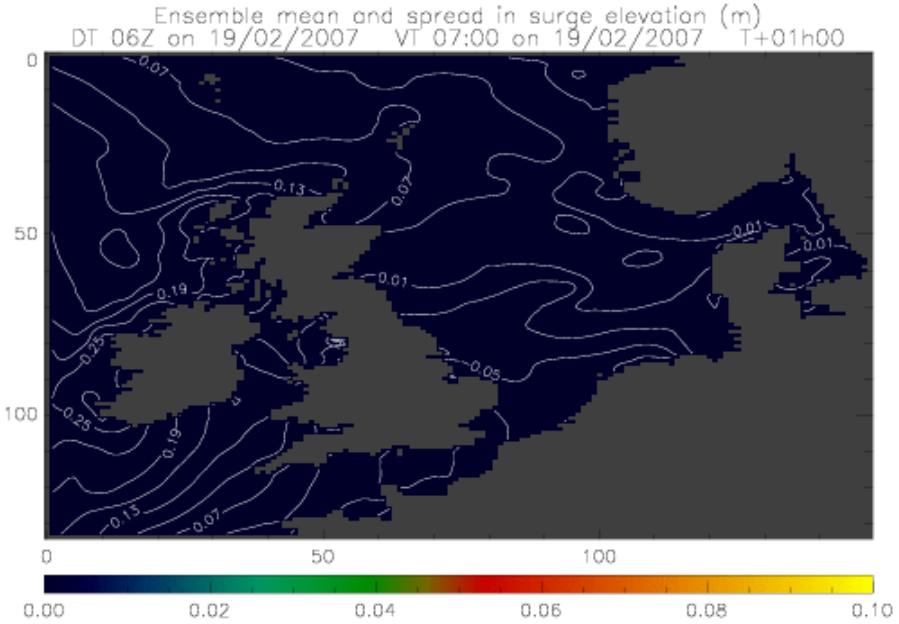
Vector map – Overall Risk of vehicle overturning along each route determined using the risk (Prob x Vuln) output and mulitplying it by the vehiles along the route on that day and at that time

Storm surge ensemble

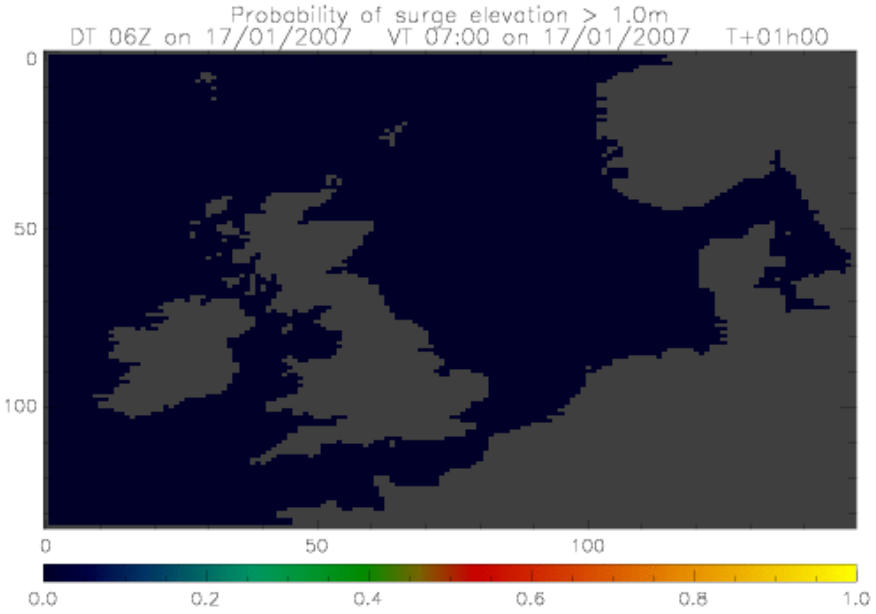
Coupling a surge model to MOGREPS –
In support of coastal flood forecasting by the Environment Agency

Storm surge Ensemble –
recently extended to 7 days

- Storm surge model coupled to MOGREPS-R and MOGREPS-15



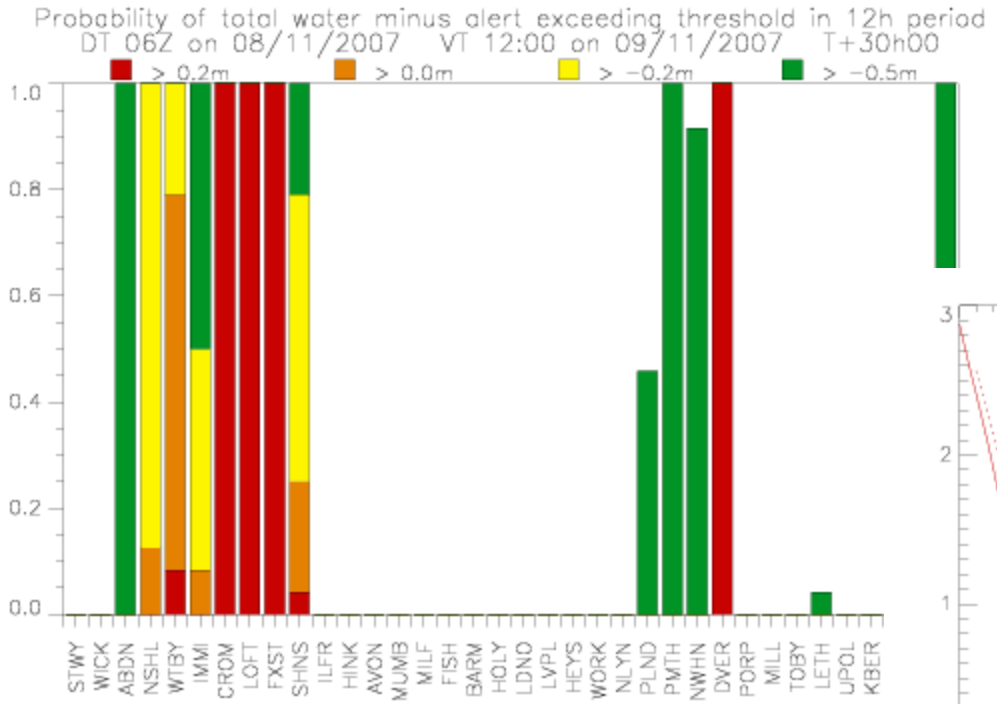
- Mean and spread of surge elevation



- Probability of surge elevation >1.0m

Storm surge ensemble for EA

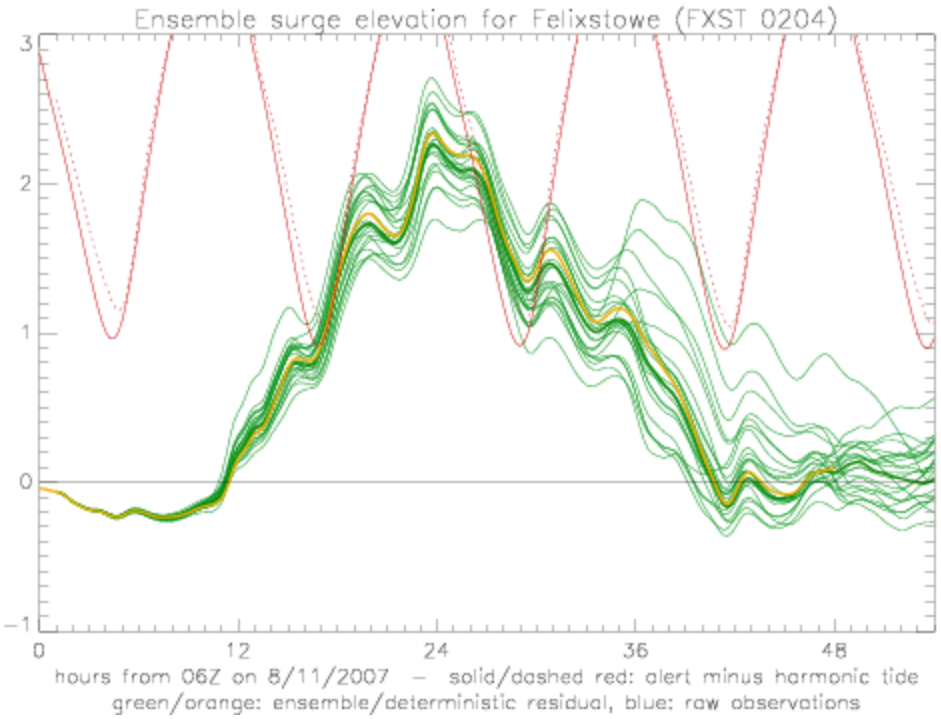
Risk assessed relative to 3 impact thresholds



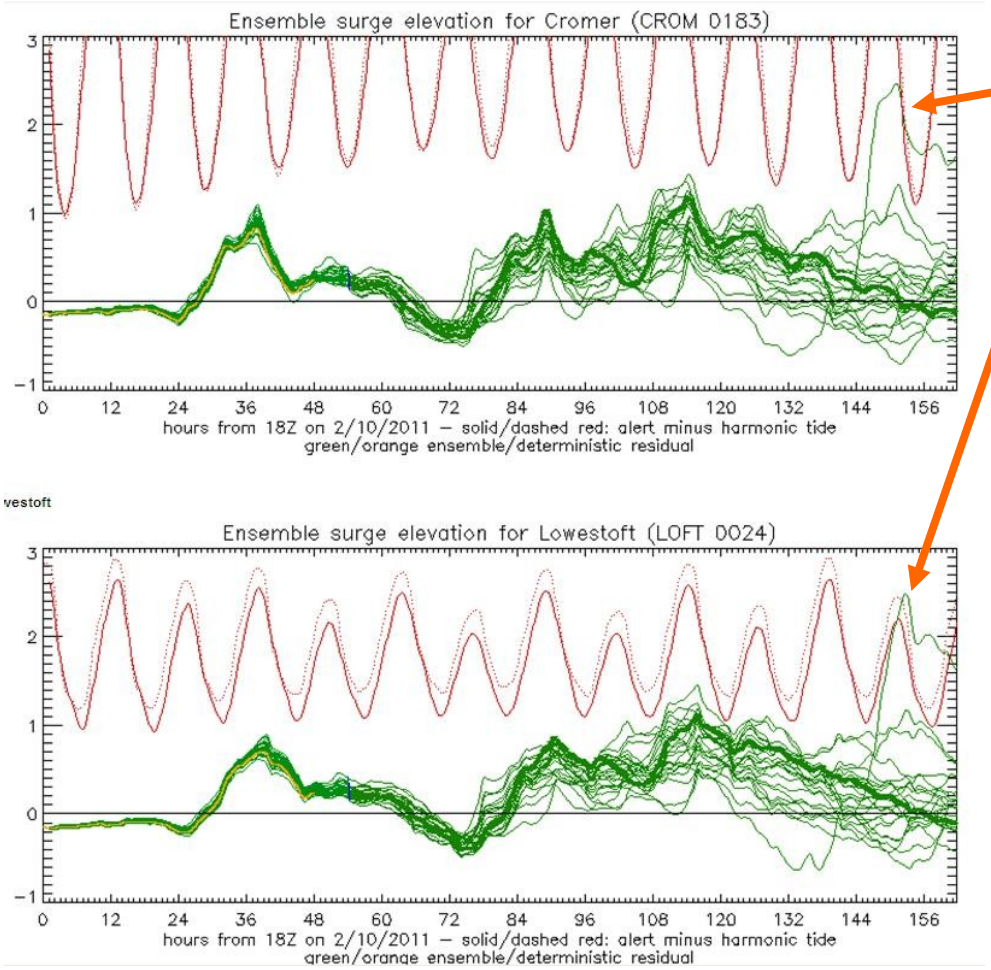
12h ending
1200 (T+30)

Probability of water level exceeding impact levels

Felixstowe



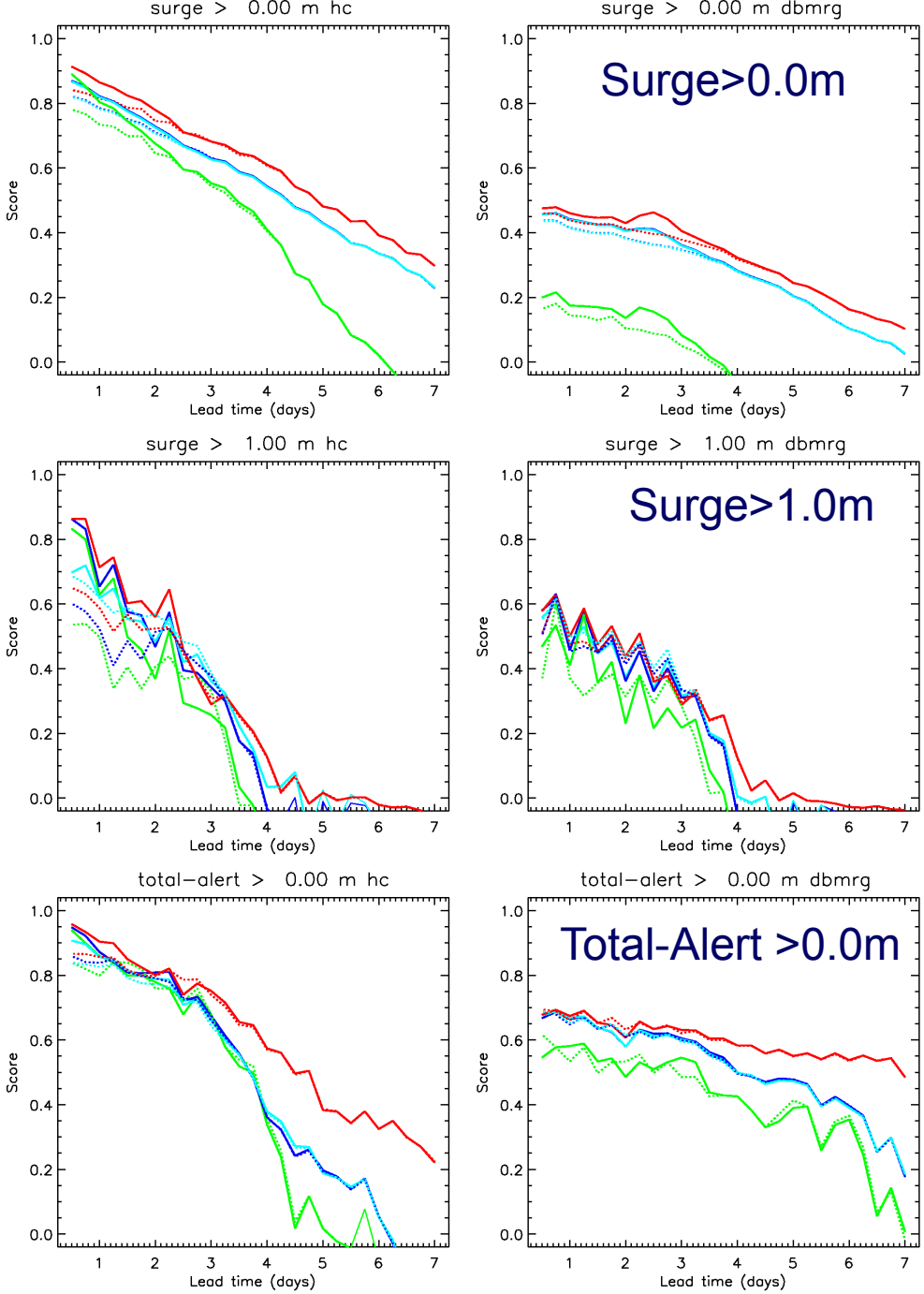
Surge ensemble 7-day forecast from 18Z on 2nd Oct 2011

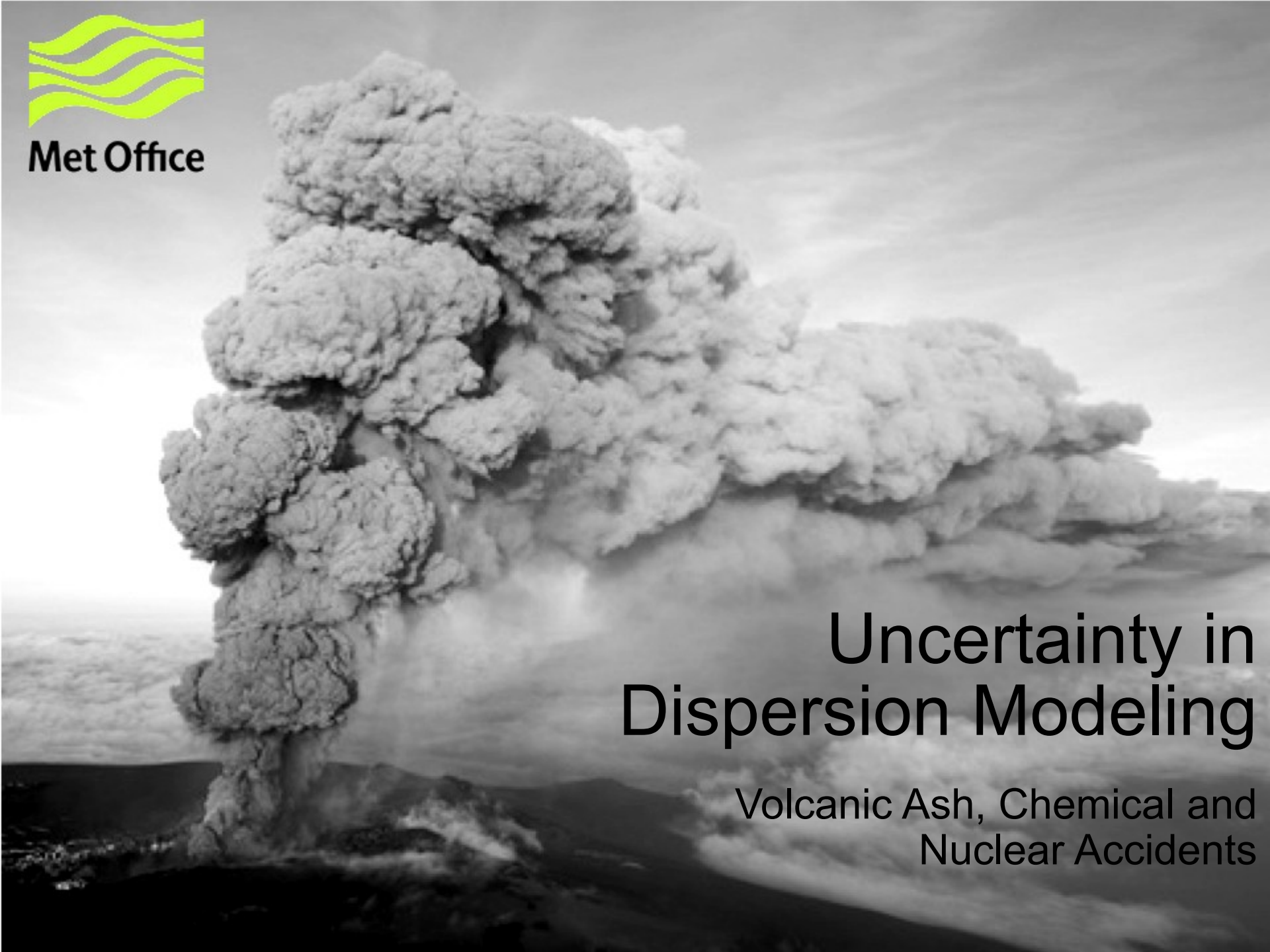


- One member of the ensemble predicts an extreme surge 7 days ahead
  - Classic case of low probability of high impact
- In the event nothing happened – as was most likely –
  - but EA was able to take early preparedness actions at little cost

Brier Skill Score

- Summarises overall skill of probabilistic forecast
- Based on ‘rms error’ of probability, where truth is 0 or 1 in each case
- Ensemble beats dressed deterministic
- Greatest benefit at long lead times

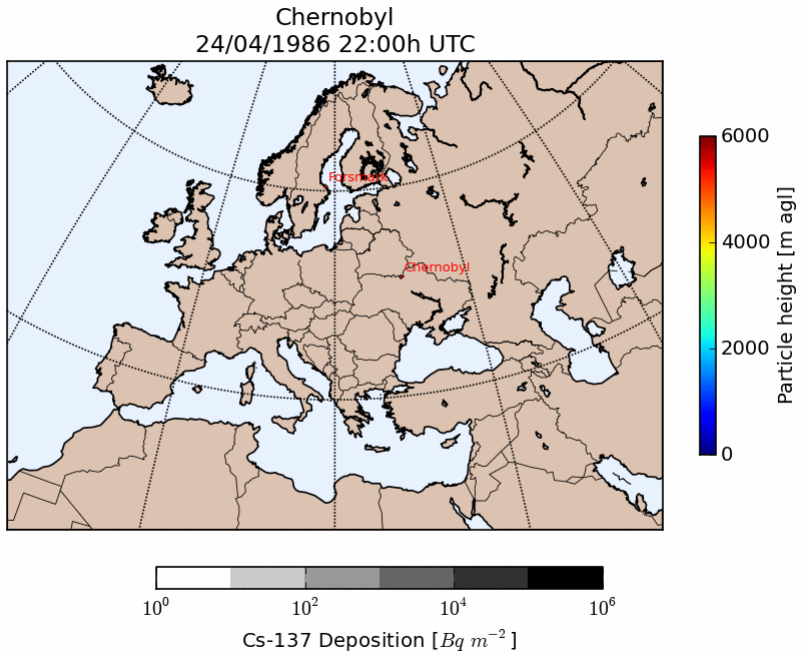



Met Office
Uncertainty in Dispersion Modeling
Volcanic Ash, Chemical and Nuclear Accidents

NAME

Numerical **A**tmospheric-dispersion **M**odelling **E**nvironment

- Development started following the Chernobyl accident
- Initial purpose to give emergency response dispersion predictions for nuclear incidents
- NAME has been and continues to be under constant development
  - Starting in 1999 code completely rewritten
  - Science updates occur continuously
- Used by 12 organizations
- Lagrangian stochastic model
- Model particles are released and followed to predict plume
- Very wide range of physics, functionality and application



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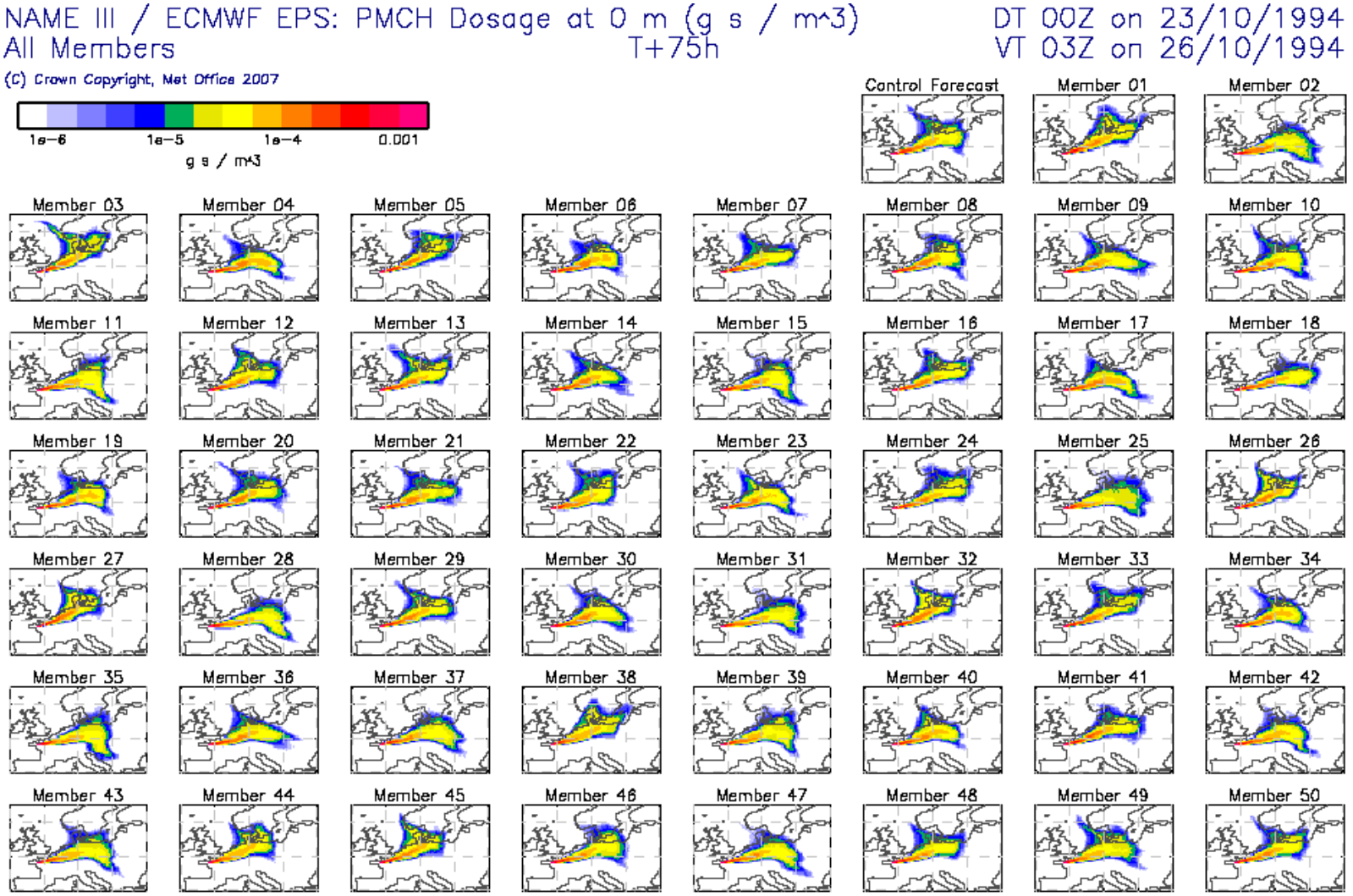
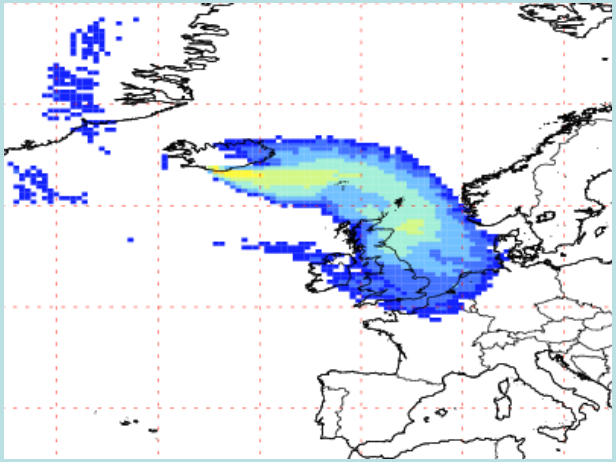
EPS-based dispersion modelling



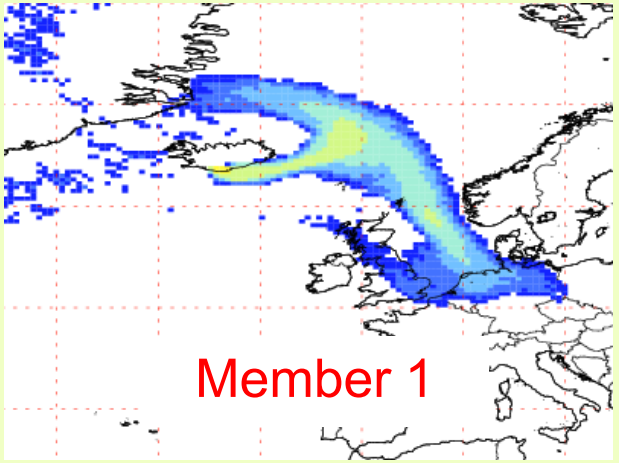
NAME volcanic ash predictions using ECMWF EPS forecasts

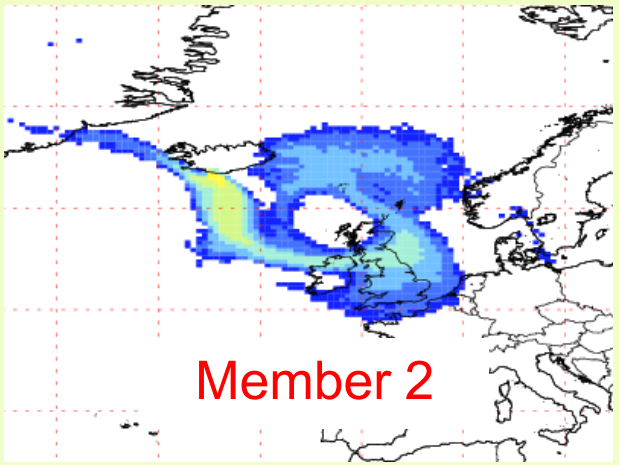
Control forecast



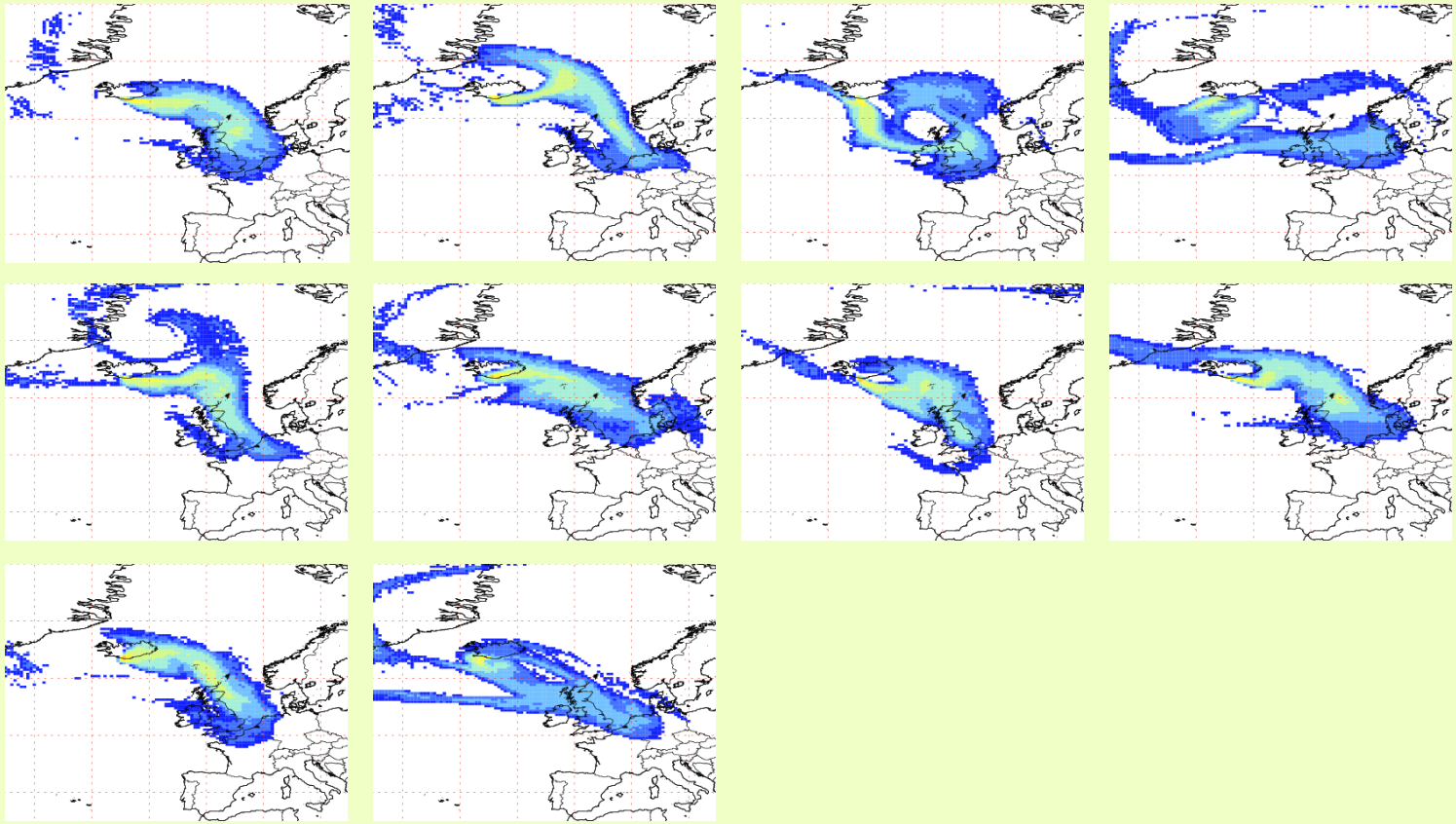
4 day forecast of FL000-FL200 ash concentration valid at 12UTC on 17/05/2010

Perturbed forecasts





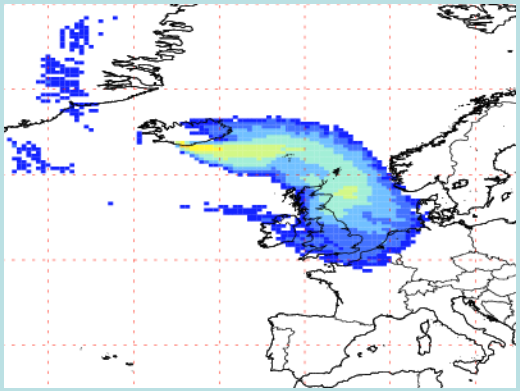
NAME volcanic ash predictions using ECMWF EPS forecasts



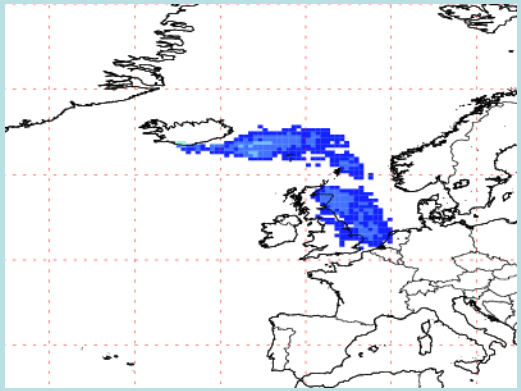
10 members of an ensemble forecast of FL000-FL200 ash concentration valid at 12UTC on 17/05/2010

Ensemble mean, median (and other percentiles …)

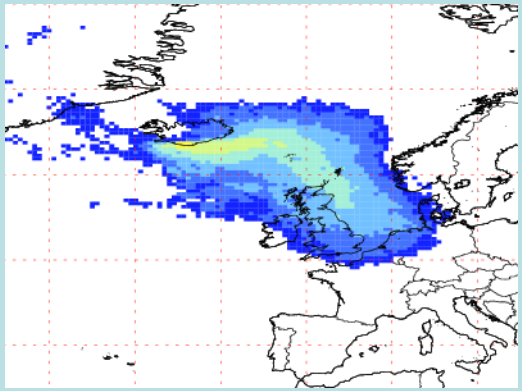
Control

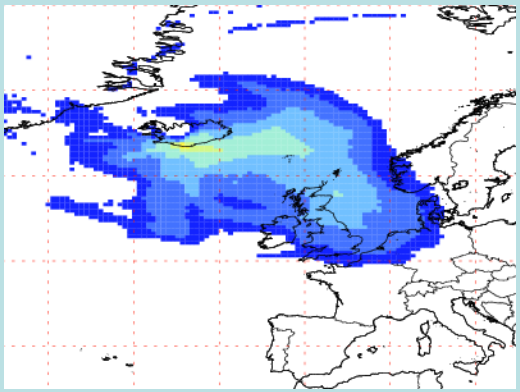


25th perc

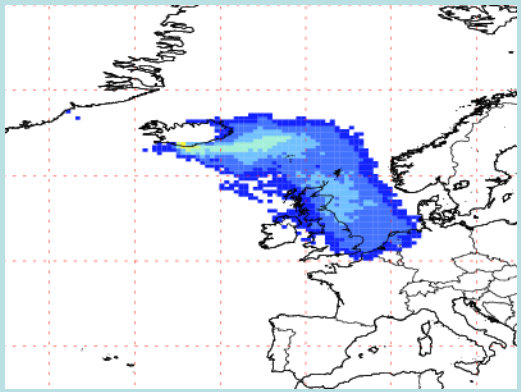


75th perc

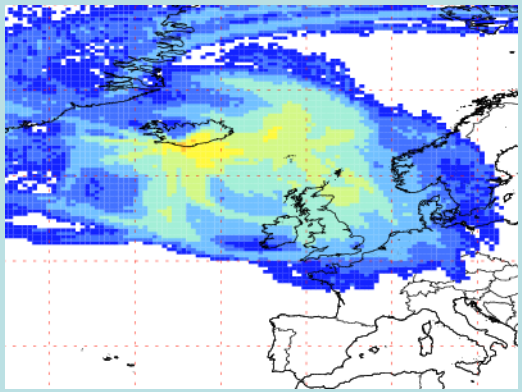




Ens Mean

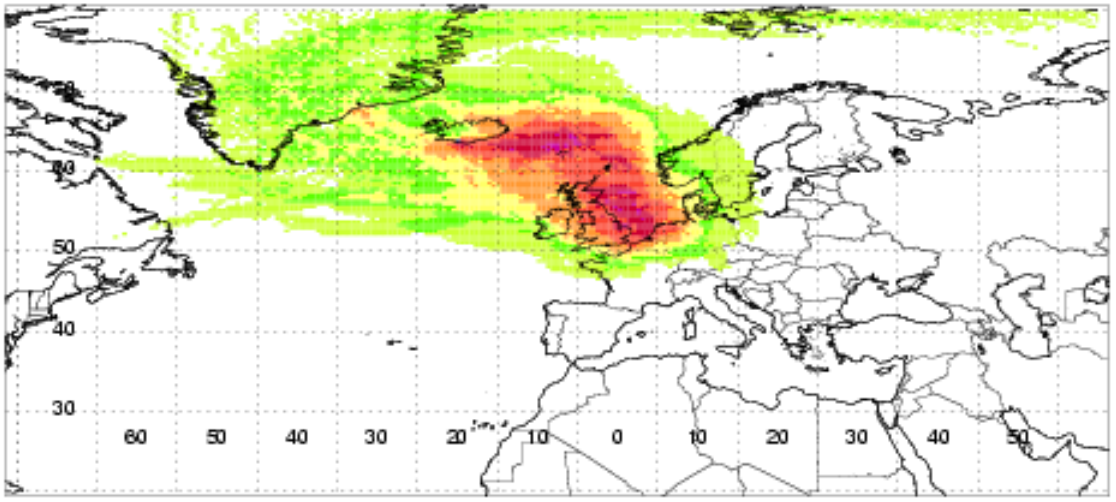


50th perc



100th perc

NAME volcanic ash predictions using ECMWF EPS forecasts



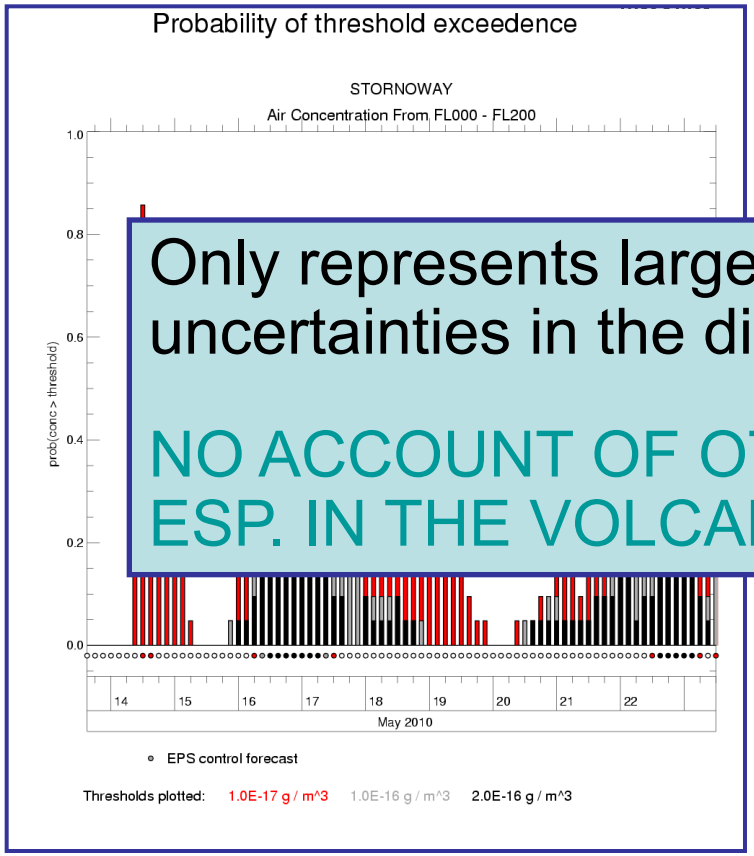
prob(conc > VA threshold) in FL000-200 at T+72

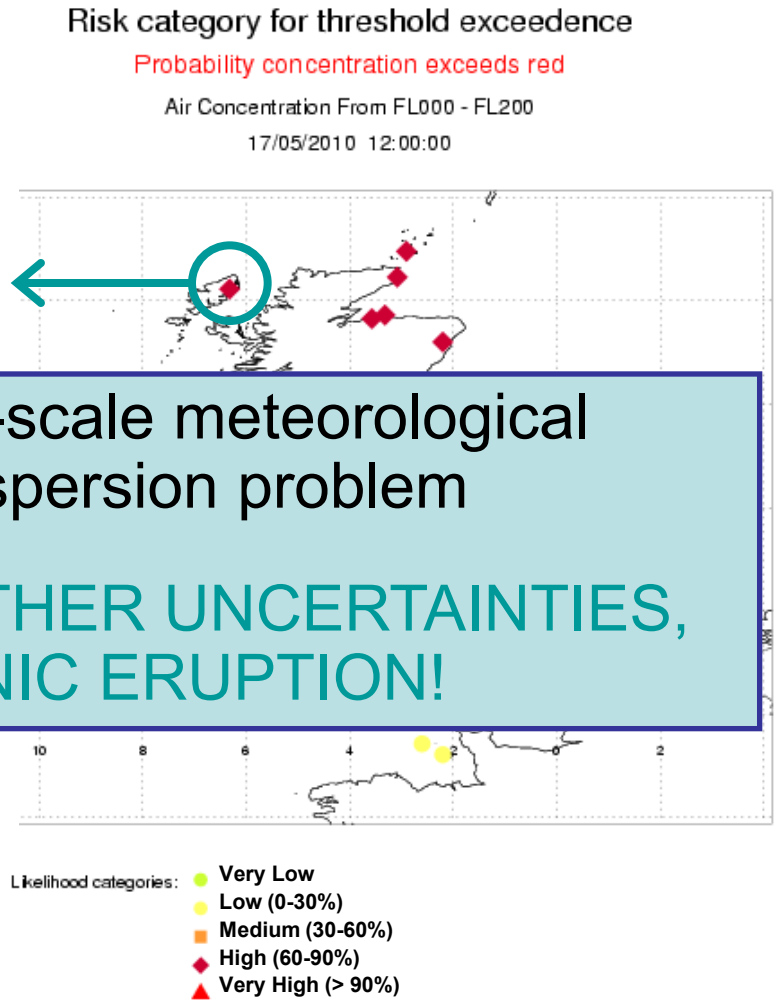
N.B. meteorological uncertainty only!

Probability of exceedence (%)

No Members 10 20 30 40 50 60 70 80 90 99 All Members

Site-specific products





Only represents large-scale meteorological uncertainties in the dispersion problem

NO ACCOUNT OF OTHER UNCERTAINTIES, ESP. IN THE VOLCANIC ERUPTION!

Dispersion Summary

Use of EPS is a powerful tool to understand the *atmospheric forecast uncertainty* in long-range dispersion

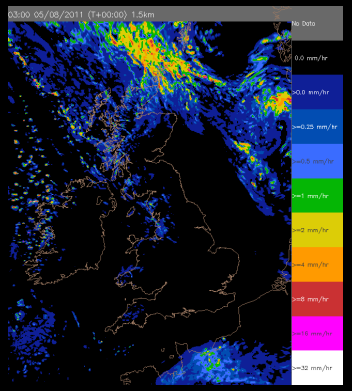
Full probabilistic prediction also requires:

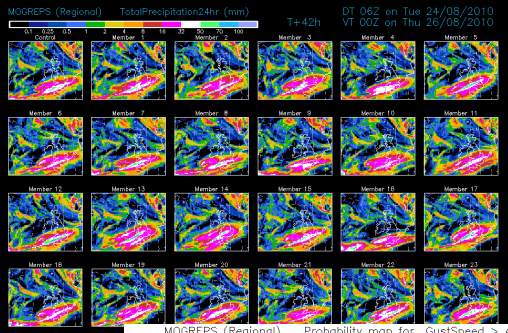
- Source-term uncertainty
- Model uncertainty

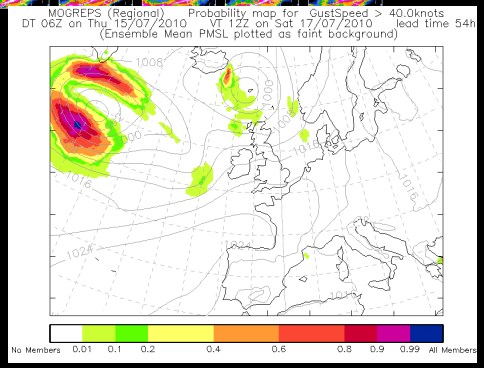
Current research is aiming towards a complete probabilistic prediction

Integrating Post-Processing of Ensemble and Deterministic NWP

Parallel systems







- Deterministic production systems
  - First-guess for charts and guidance
  - Site-specific forecasts for web and products
- *Supplementary* ensemble information
  - ECMWF EPS and MOGREPS
  - Lower resolution
  - Probabilistic risk information for forecasters
  - First-guess early warnings
  - A few customer-specific applications
- NWP Science strategy is ensembles for everything
  - How do we integrate applications?

Site-specific forecasts

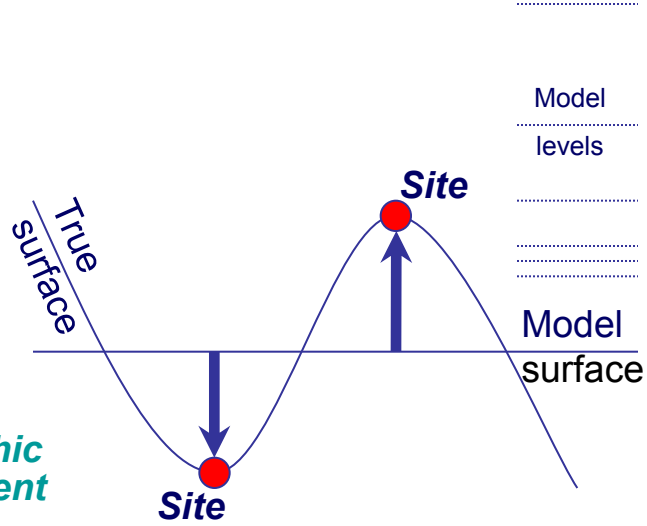
“Best Data” provides a single source of forecast data for all products

- SSPA - Site-specific forecasts
  - 5000 UK sites
  - 10000 sites worldwide
  - Kalman filter bias corrections (where obs available)
    - Reduces effect of resolution differences
  - Cascade of models by lead-time
    - ***Single Value***
      - UKV/UK4
      - NAE
      - MOGREPS Mean
    - ***Multi Value (Percentiles)***
      - MOGREPS-UK
      - MOGREPS-R
      - MOGREPS-15

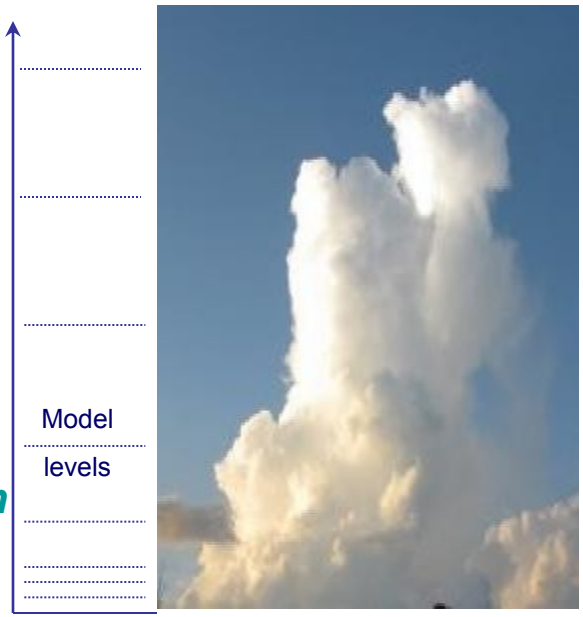
Ensemble starting to be used for “deterministic” Best Data

Ensemble spread adjusted to assure consistency

SSPS Overview
Site-specific extraction from the grid

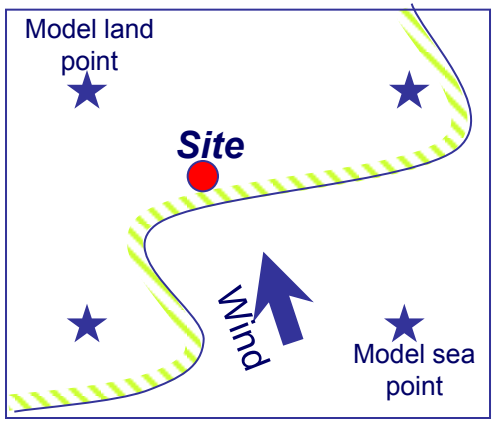


Orographic Adjustment



Convection Diagnosis Procedure

- Same method is used for deterministic & ensembles: Global and regional MOGREPS and ECMWF



Coastal Adjustment

Best Data Blending

Continuous updating of best deterministic

To start – 15 days out

- BestData(T+360) = MOGREPS-15(T+360) Mean

12 hours later

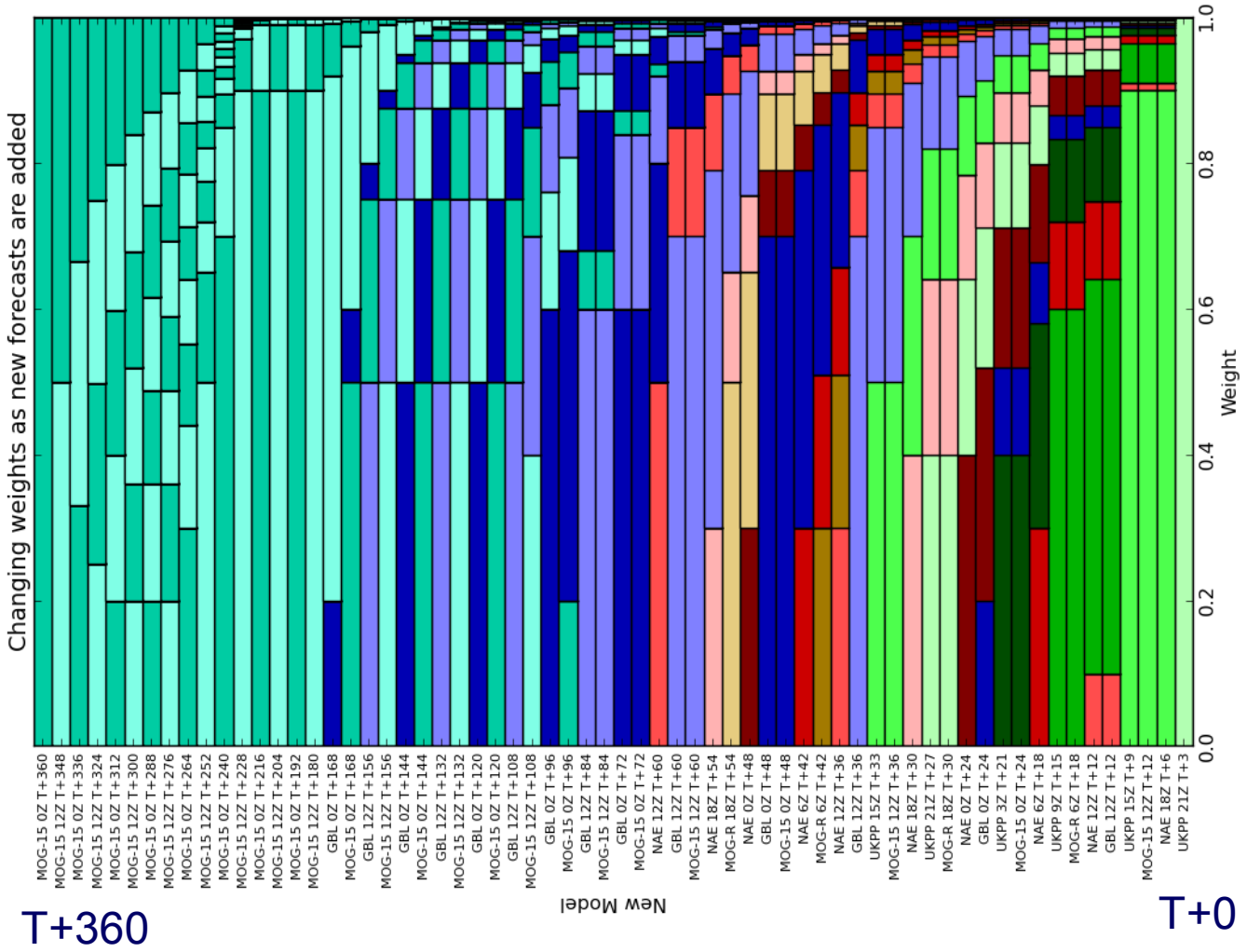
- BestData(T+348) = 0.5*MOGREPS-15(T+348) Mean + 0.5*BestData(T+360)

Current BestData = a * latest forecast + (1-a)* previous BestData

- ‘a’ varies with lead time and model combination

- At shorter range blend in:
  - MOGREPS-R
  - Higher resolution deterministic models including UKV
  - Nowcasts
- Coming soon – ECMWF data included in blend!

Complex sets of weights by lead-time

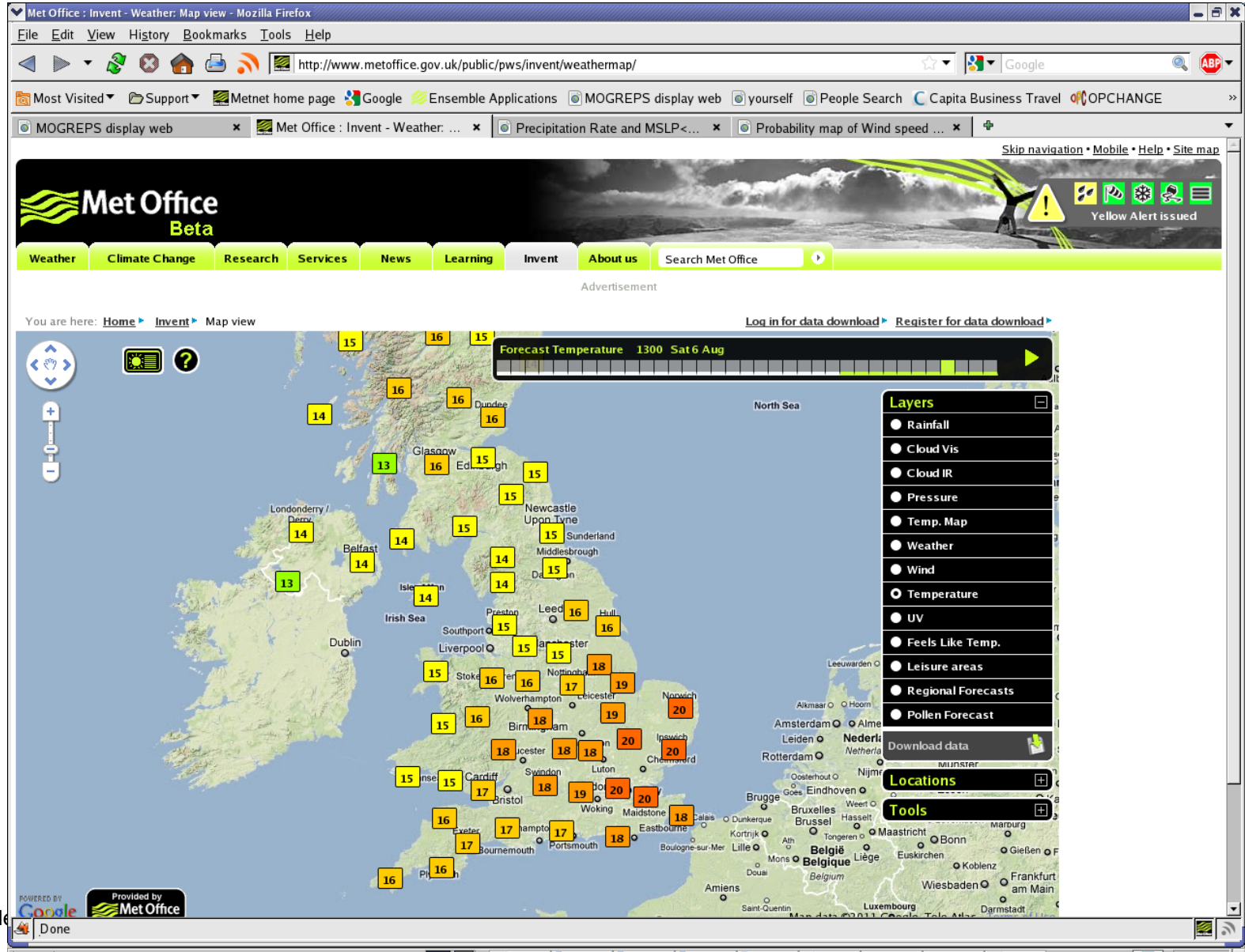


Ensemble Best-Data Stored as Percentiles

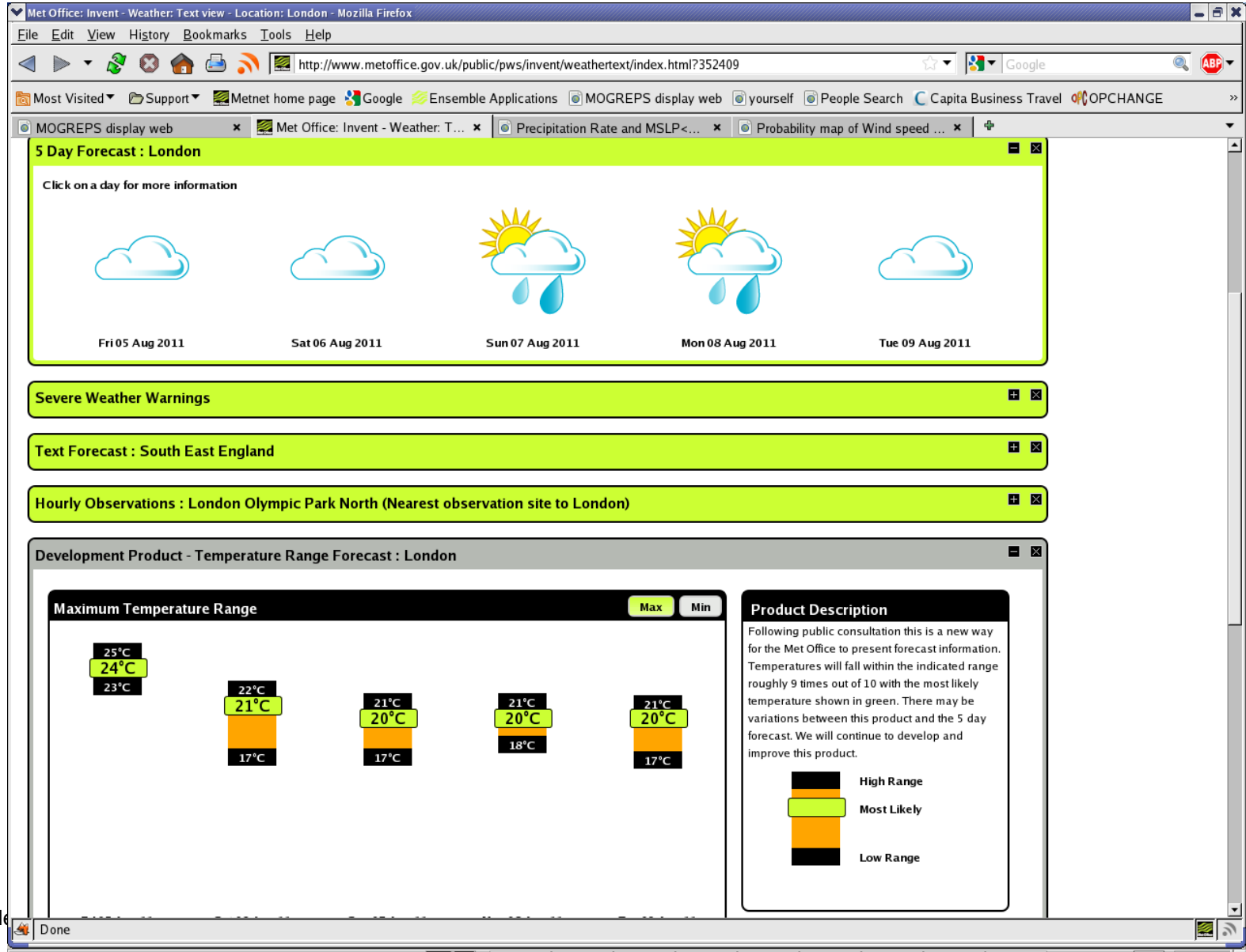
%	Min	5%	10%	20%	25%	30%	40%	50%	60%	70%	75%	80%	90%	95%	Max
T	-3.1	-2.9	-2.8	-2.3	-1.8	-1.7	-1.6	-0.7	-0.4	0.0	0.1	0.9	1.5	2.5	4.6

- Allows interpolation of probability for any threshold
- Independent of ensemble size or combination of data sources
- Using blend of multiple sources including hi-res deterministic models ensures consistency of:
  - Most probable
  - Uncertainty measures

Best Data Temperatures



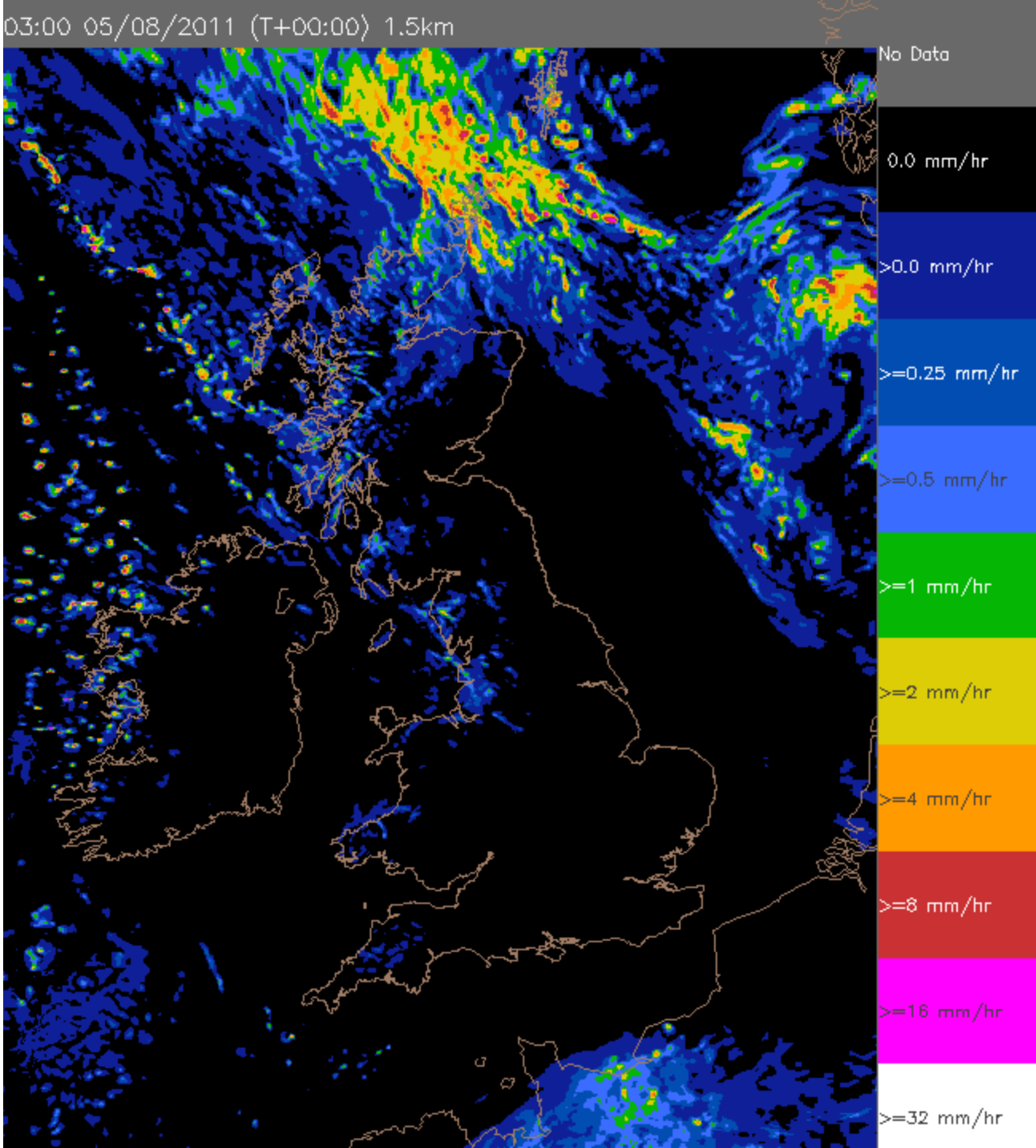
Detail for London



Integrating Gridded Data
UK Post-Processing (UKPP)

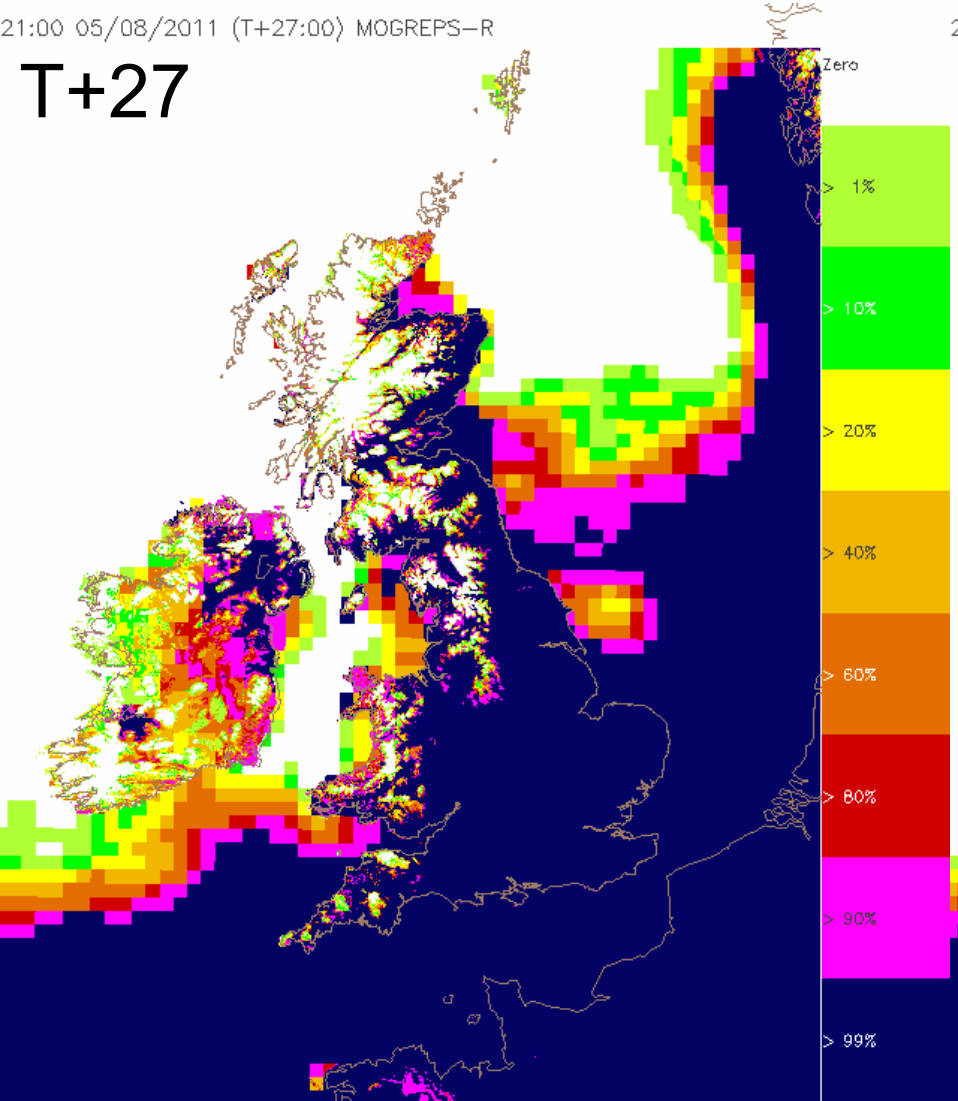
UKPP

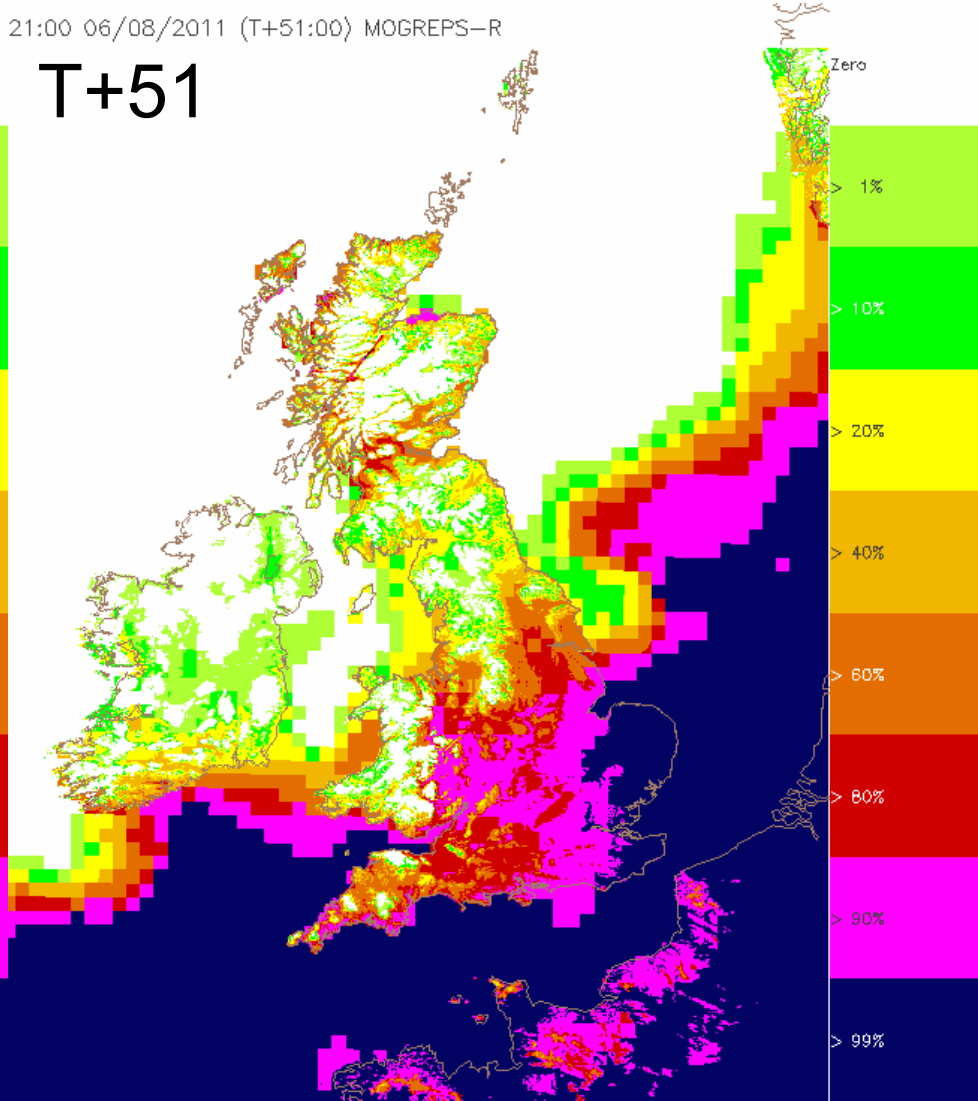
- UKPP processes NWP outputs on a common 2km grid
- Orographic downscaling is applied to lower-resolution models
- Now applying downscaling to MOGREPS-R
  - Post-processing of MOGREPS-UK will be done on UKPP grid



MOGREPS Downscaled 2m Temperature Prob(Tmax>15C)

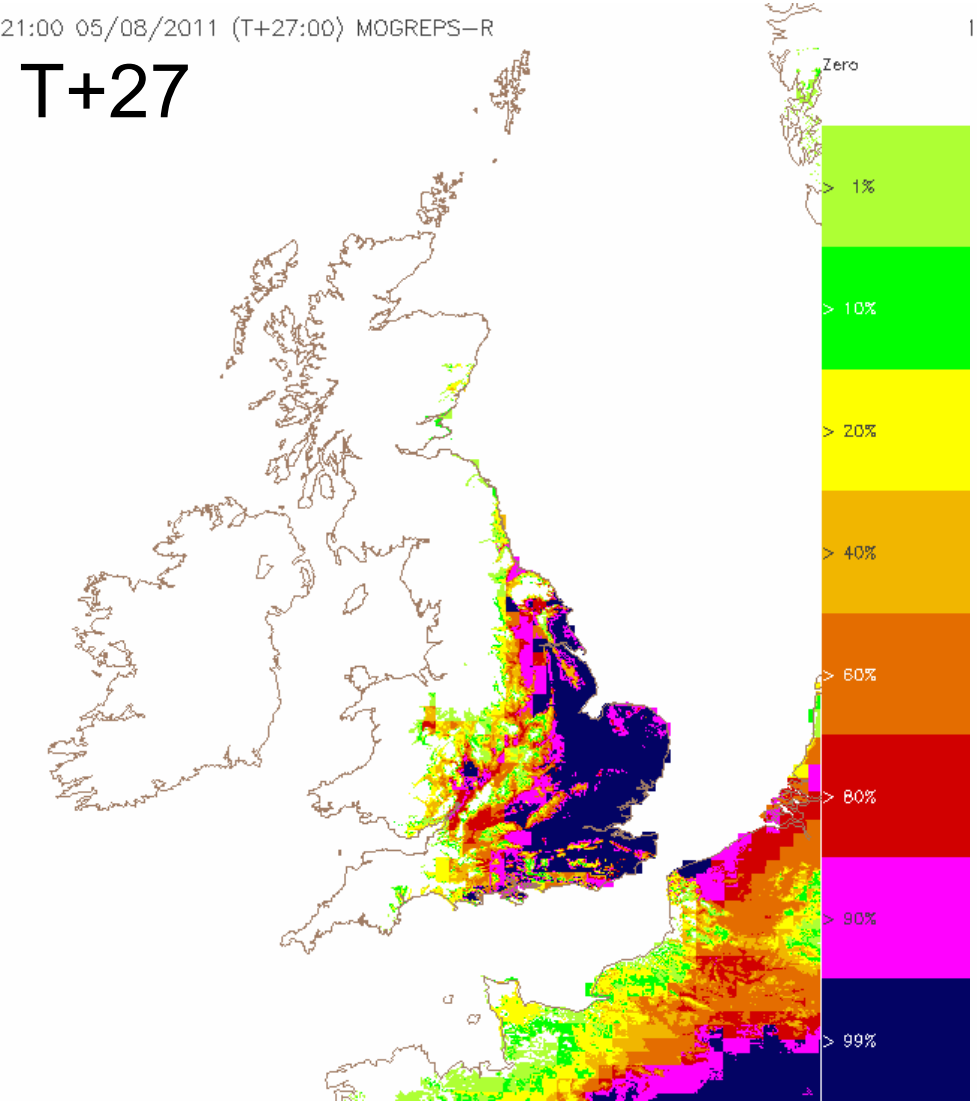
Temperatures adjusted to high-res orography

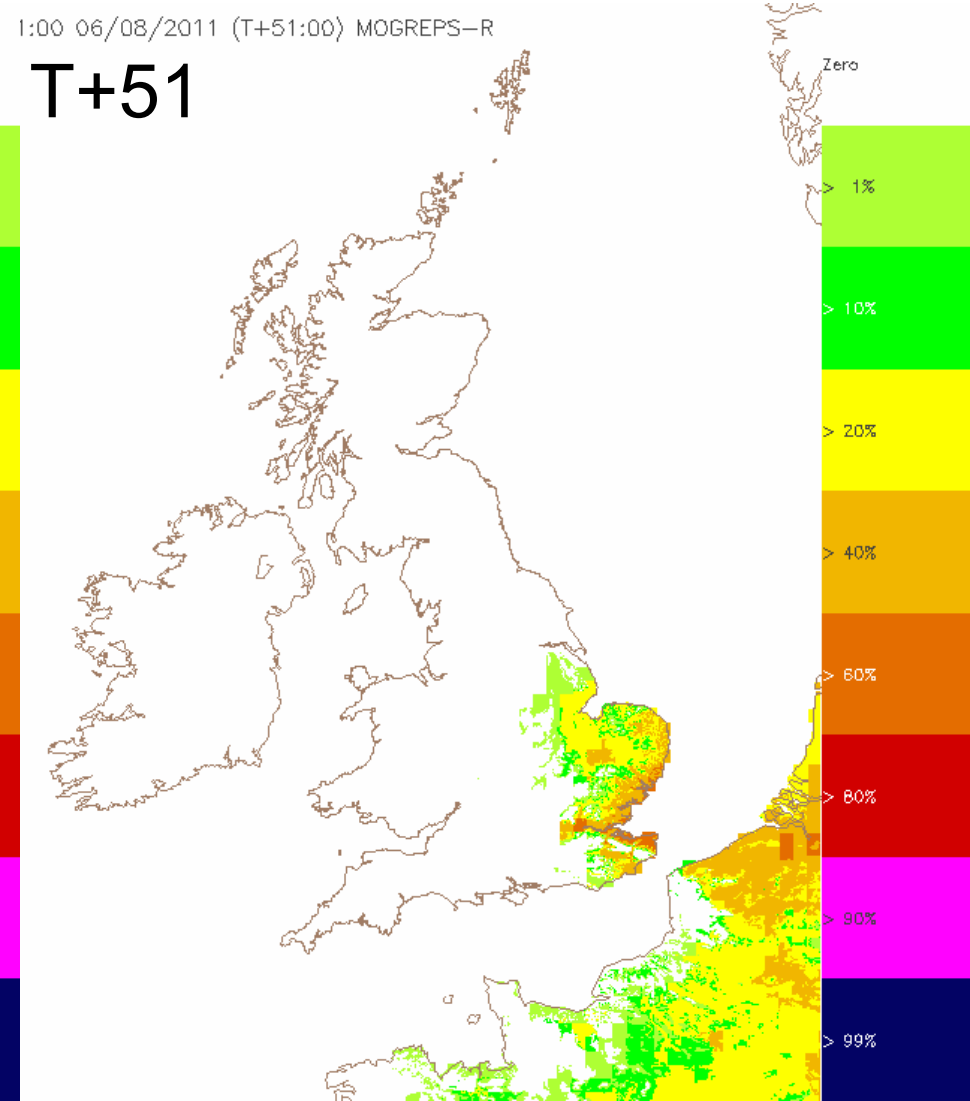




MOGREPS Downscaled 2m Temperature Prob(Tmax>20C)

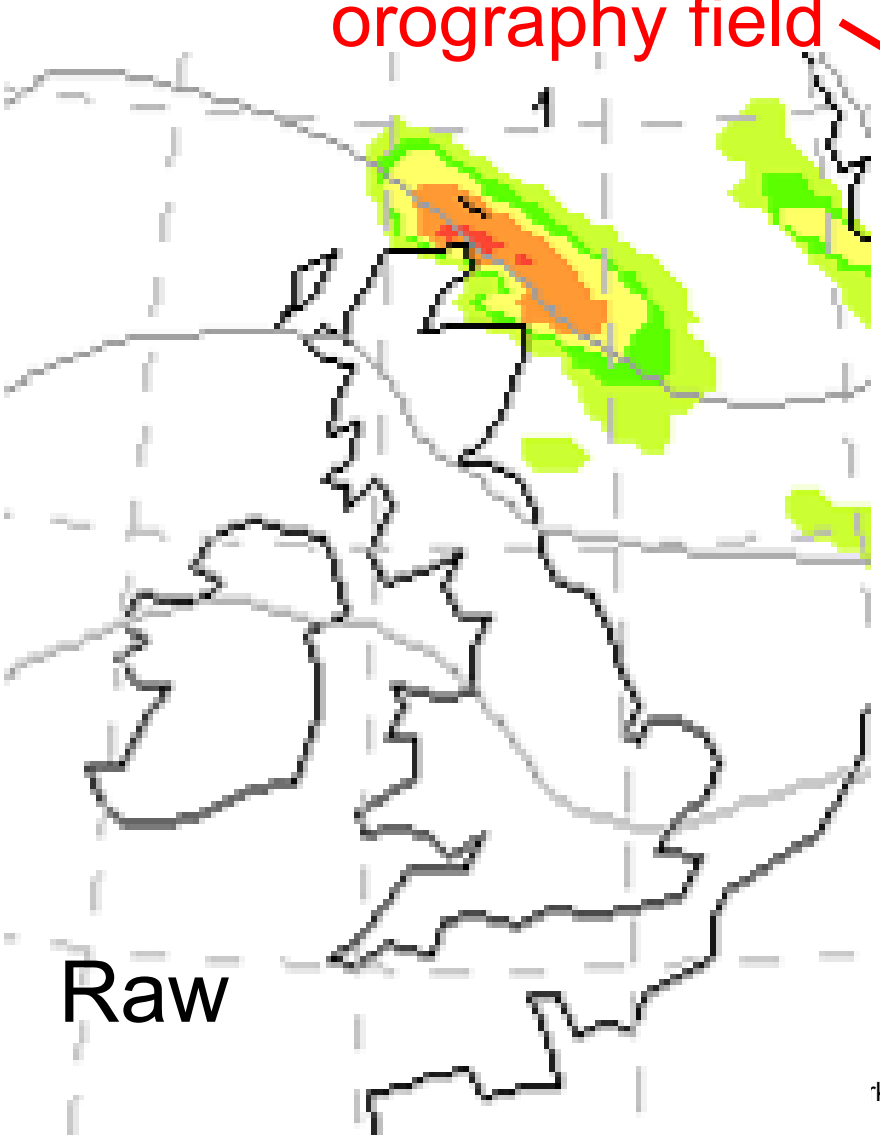
Temperatures adjusted to high-res orography



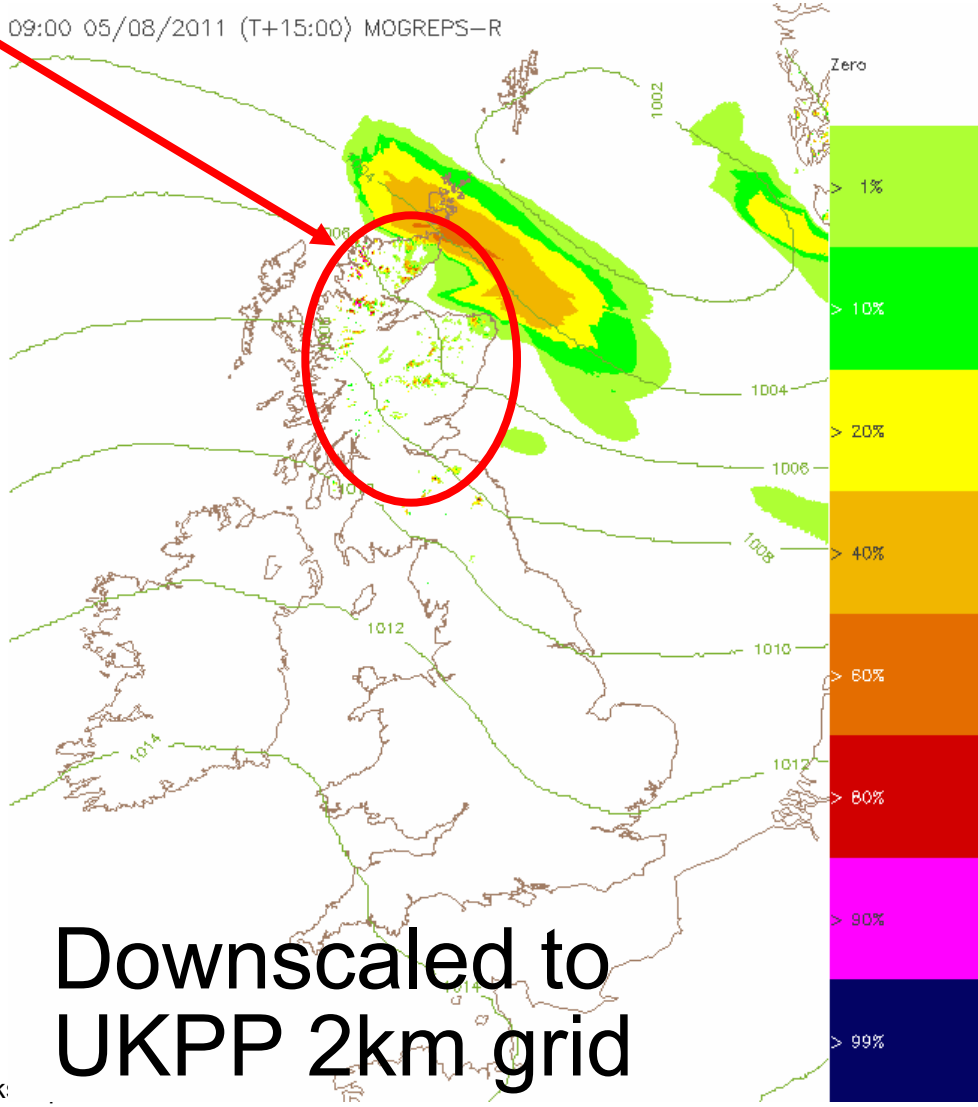


MOGREPS p(WS>22kt)

Benefit of downscaling using hi-res orography field



Raw



Downscaled to UKPP 2km grid

Summary

- Historically we have had:

"Operational" Deterministic Models		"Supplementary" EPS

- Finally we are getting integration:
  - Common post-processing
  - Compatible formats
  - Blended Best Data

Blended Probabilistic NWP

- MOGREPS-UK will be integrated from Day 1

Conclusions

- Ensemble forecasts are still widely considered to be a *nice to have* supplement to the deterministic forecast
- Integrated post-processing provides a consistent picture of the *complete* forecast
- Coupling of ensembles to a variety of impact models provides effective *risk* assessment