



# Consortia Presentation

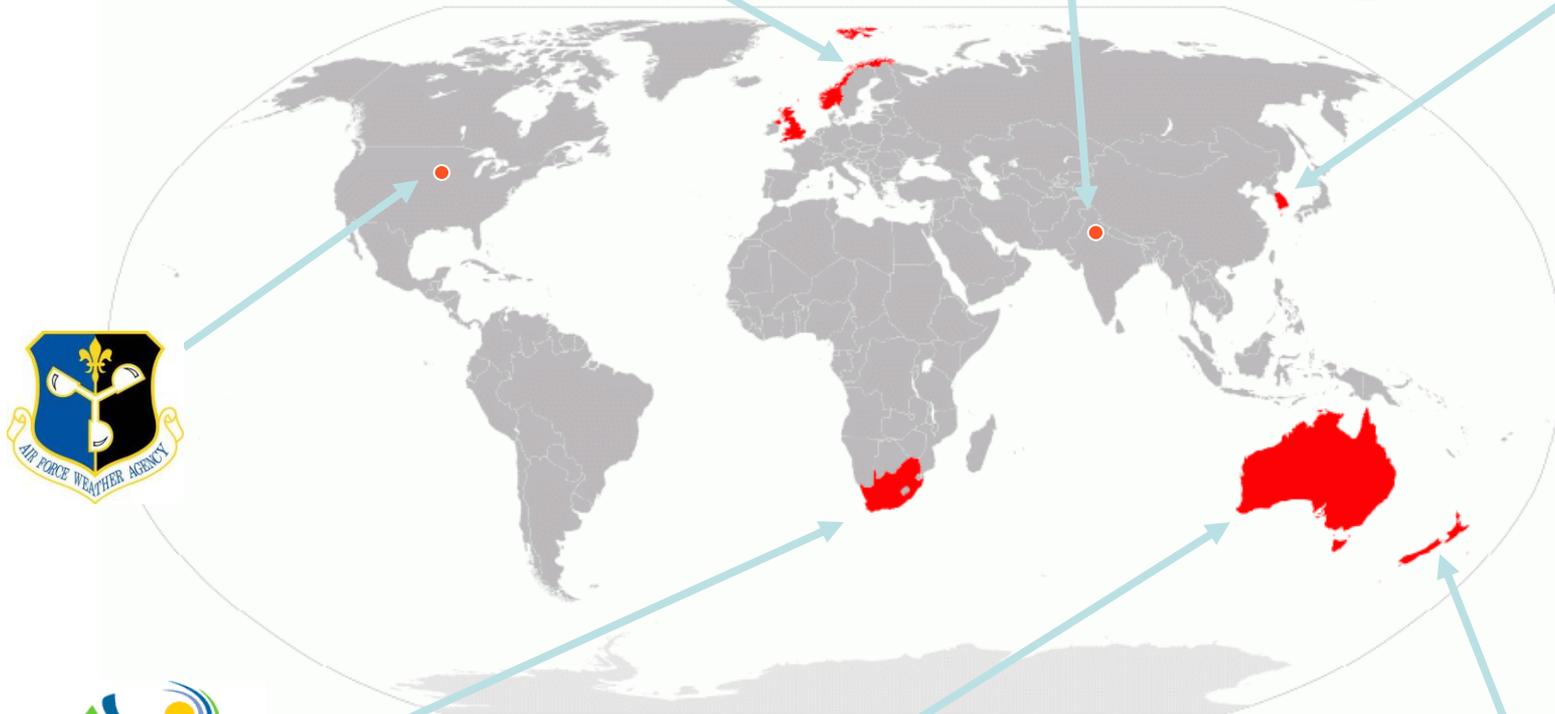
Mike Bush

Jorge Bornemann, Phil Brown, Selena Georgiou, Kirsty Hanley, Humphrey Lean, Adrian Lock, Stuart Webster, Mark Weeks, Steve Willington

35th EWGLAM and 20<sup>th</sup> SRNWP Annual Meeting 2013

30<sup>th</sup> September – 03<sup>rd</sup> October 2013 Antalya, Turkey

# International UM partnership: Operational users 2013



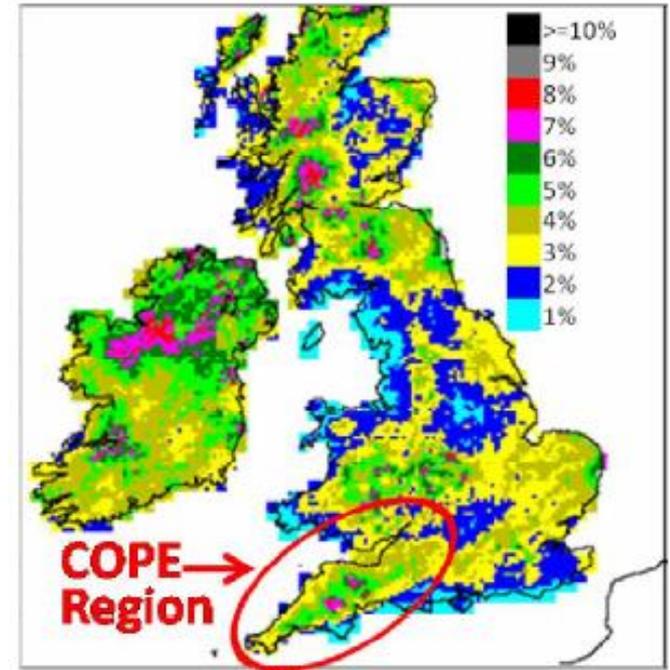
Australian Government  
Bureau of Meteorology



# COPE

**Met Office**

- CONvective Precipitation Experiment
- UK-led project over SW England in June, July and August 2013.
- With typical luck, it turned out to be the driest summer in England since 1996!
- COPE aims to improve QPF forecasts by:
  - Studying the production of precipitation in organized convective systems over SW England
  - Improving the exploitation of data used for operational assimilation
  - Improving the representation of microphysical processes in operational km-scale NWP

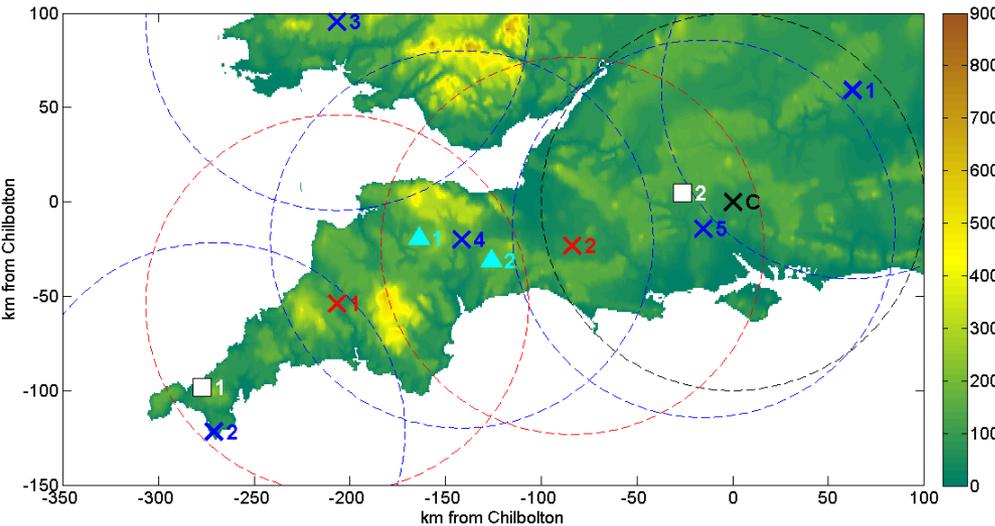




Met Office

# Observations:

FGAM transportable X-band Doppler radar



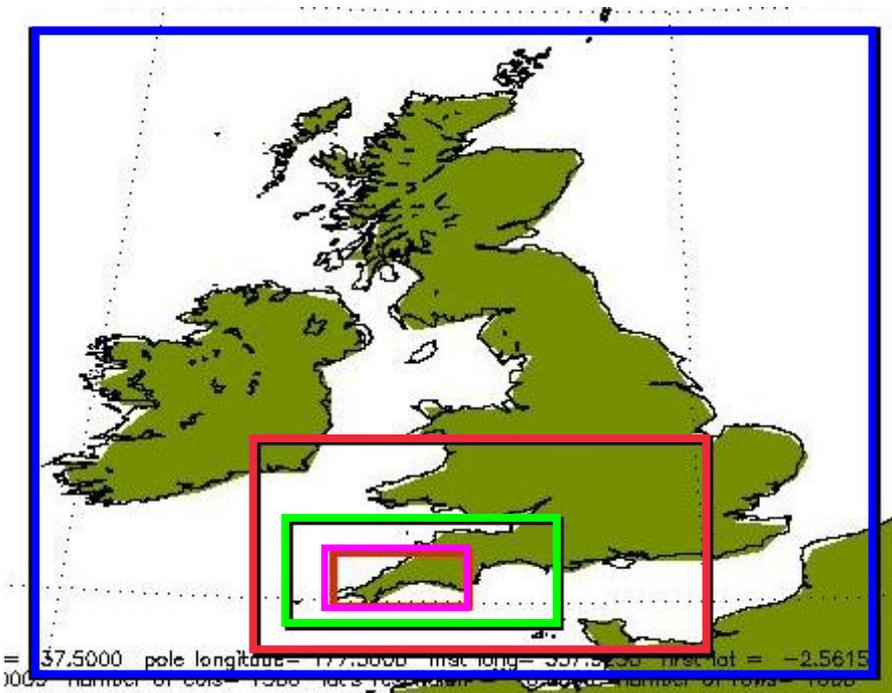
U. Wyoming King Air with WCR/WCL

Plus:

- MO network radars (with dual-polarization and Doppler capability)
- additional radiosondes (Camborne and MRU mobile)
- Doppler lidar (MRU van)
- aerosol surface site

# High Resolution COPE simulations

Set of nested models.



Model setup – UM vn8.2 PS32  
UKV – 1.5km grid length, 70 levels,  
2D subgrid turbulence scheme,  
BL mixing in vertical.

500m model – 500x400 km

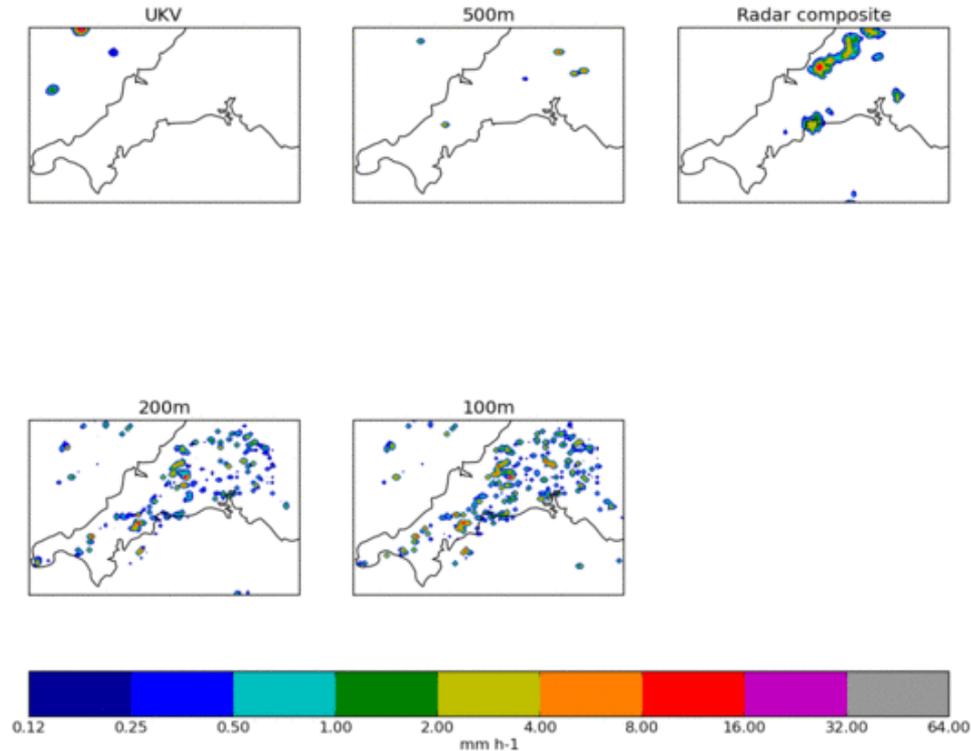
200m model – 300x200 km

100m model – 150x100 km

High res models: 140 vertical levels,  
3D subgrid turbulence scheme,  
 $RH_{crit}$  is 0.97 (0.91) in 1<sup>st</sup> few layers  
decreasing smoothly to 0.9 (0.8) at  
~3.5km.

## 3<sup>rd</sup> August – convergence line

Rainrate at 09:15 (UTC) 03-08-2013



- 03rd August case had a nice line of showers down the centre of the peninsula which the 500m model captured quite nicely.
- The higher resolution models have lots of little showers
- Cells appear to get smaller as grid length is reduced



# NOAA Hazardous Weather Testbed (HWT)

## NOAA HAZARDOUS WEATHER TESTBED

NOAA's Hazardous Weather Testbed (HWT) is jointly managed by NSSL, the [Storm Prediction Center \(SPC\)](#), and the [NWS Oklahoma City/Norman Weather Forecast Office \(OUN\)](#). The HWT is focused on national hazardous weather needs.

The HWT facilities include a combined forecast and research area situated between the operations rooms of the SPC and OUN, and a nearby development laboratory.

During multiple experiments that take place in the HWT throughout the year, researchers and forecasters work side-by-side to evaluate emerging research concepts and tools in simulated operational settings, including experimental forecast and warning generation exercises. In practice, this effort gives forecasters direct access to the latest research developments while imparting scientists with the knowledge to formulate research strategies that will have practical benefits. This collaborative approach ensures an effective, two-way path between research and operations which ultimately improves NWS forecasts and warnings.



- Each year, the NOAA Hazardous Weather Testbed, based in Norman, Oklahoma, USA hosts a spring experiment to assess up-and-coming forecast developments in a simulated operational environment.
- Although Met Office scientists and forecasters have taken part in some previous years, this is the first time we have provided Unified Model forecasts.



# HWT Spring 2013 Experiment

## 2013 Spring Experiment NWP Models and Guidance

The table below lists NWP models and guidance that will be available for testing and evaluation during the 2013 Spring Experiment. Additional details about the configuration of the guidance (e.g. specifics of parameterization schemes, setup of vertical grid, etc.) can be found in the 2013 Spring Experiment Operations Plan.

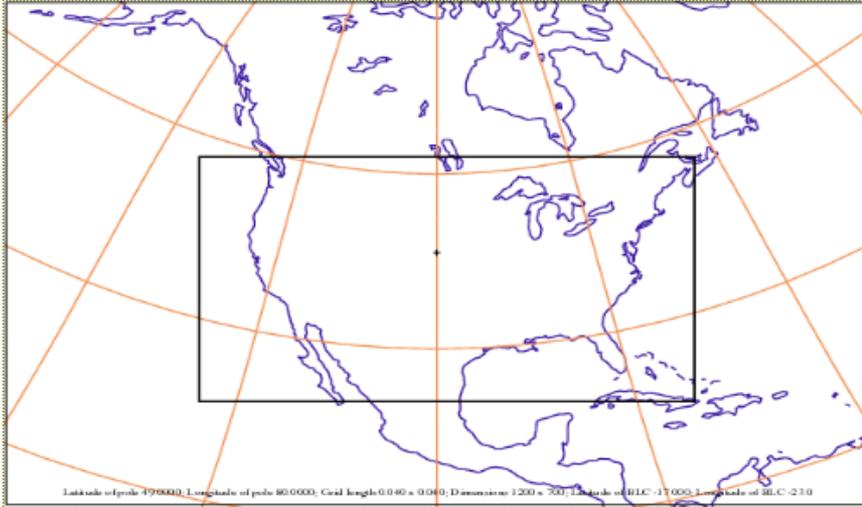
Provider	Init. Time	Model	Grid Space	Domain	Run Time	Notes
CAPS	00 UTC	WRF-ARW/ARPS 27 Member Storm Scale Ensemble Forecast (SSEF)	4km	CONUS	48 hours	Multi-model, Multi-physics, Multi-IC ensemble system with 3DVAR DA including radar
CAPS	12 UTC	WRF-ARW 8 Member Storm Scale Ensemble Forecast (SSEF)	4km	CONUS	18 hours	Multi-model, Multi-physics, Multi-IC ensemble system with 3DVAR DA including radar
AFWA	00 UTC 12 UTC	10 Member WRF-ARW Ensemble	4km	CONUS	36 hours	Single-model, Multi-physics, Multi-IC ensemble system with NO data assimilation
NSSL	Hourly/ 15,17,19 UTC	36 Member WRF-ARW Ensemble	18km	CONUS	0,1 hour/ Out to 03 UTC	Single-model, Multi-physics, EnKF system with data assimilation
UKMET	00 UTC	Unified Model	2.2km 4km	CONUS	36 hours	Unified Model
NSSL	00 UTC	<del>WRF-ARW</del>	<del>4km</del>	<del>CONUS</del>	<del>36 hours</del>	<del>NAM ICs/LBCs</del>
EMC	00 UTC 12 UTC	WRF-NMM	4km	CONUS	36 hours	NAM ICs/LBCs
EMC	00 UTC 12 UTC	HiResWindow WRF-NMM	4km	Central/Eastern US	48 hours	NAM ICs/LBCs
EMC	00 UTC 12 UTC	HiResWindow WRF-ARW	5.1km	Central/Eastern US	48 hours	NAM ICs/LBCs
EMC	00 UTC 12 UTC	NMMB Nest	4km	CONUS	60 hours	NMMB ICs/LBCs
SPC,NSSL,EMC	00 UTC 12 UTC	7 Member Storm Scale Ensemble of Opportunity (SSEO)	~4km	Central/Eastern US	36 hours	Consists of existing CONUS WRF-NMM, HiResW WRF-NMM and WRF-ARW, NMMB Nest, and 2 time-lagged HiResW members
SREF	03,09,15,21 UTC	21 Member Short-Range Ensemble Forecast (SREF)	16km	CONUS	87 hours	Multi-model, Multi-physics, Multi-IC ensemble system
GSD	Hourly	HRRR WRF-ARW	3km	CONUS	15 hours	RR ICs/LBCs includes DDFI Radar



# UM configurations run for the Hazardous Weather Testbed (HWT)

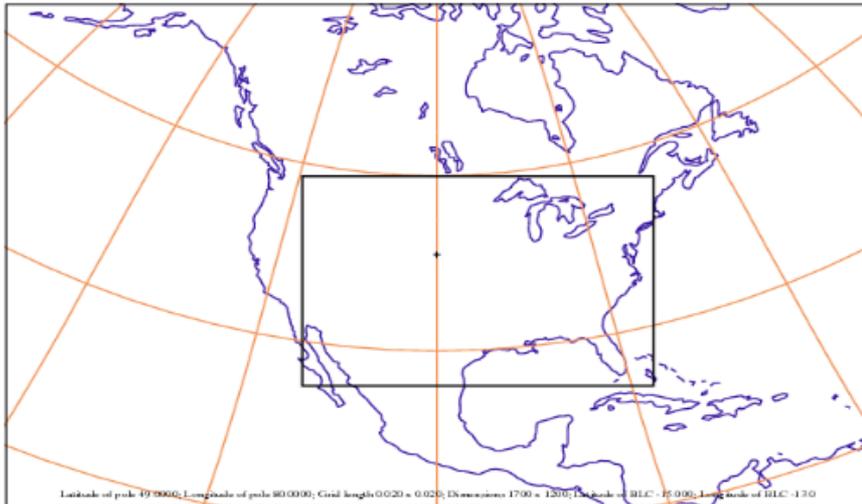
Model domains  
4.4km

4.4km model



2.2km

2.2km model



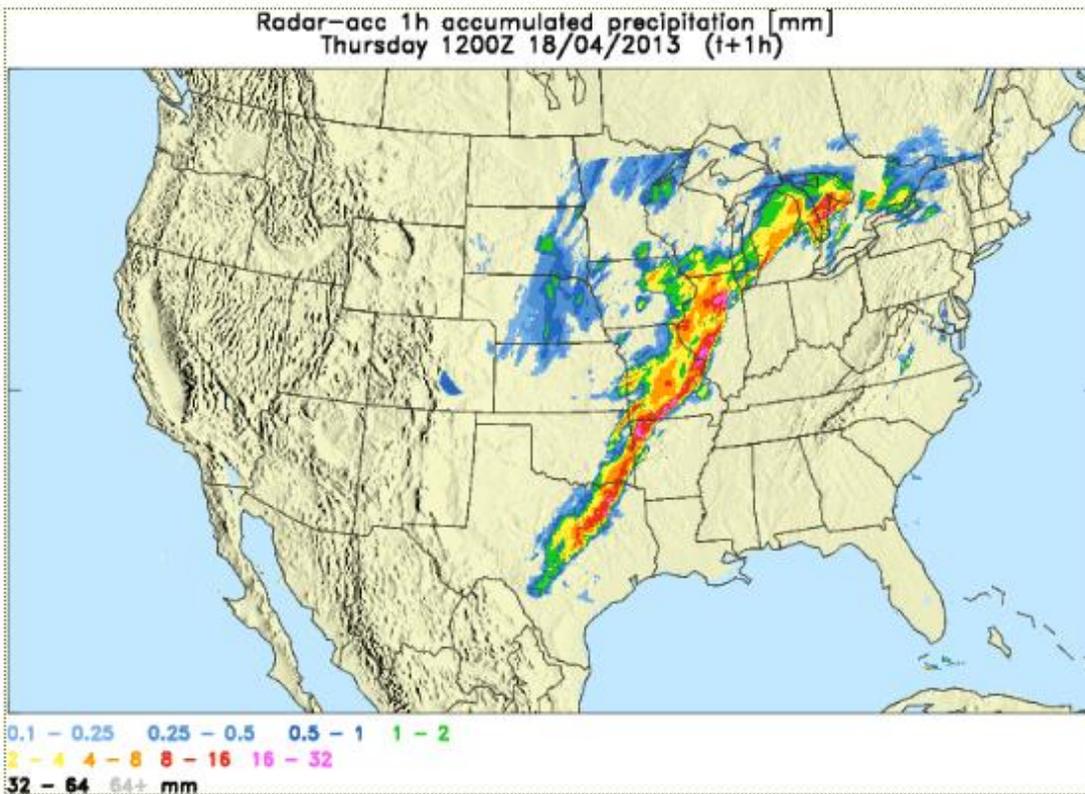
- The 2.2km model was nested inside the 4.4km model.
- The models were run with PS32 configurations, but without data assimilation and without any specific tuning.
- In order to make like-for-like comparisons with the US forecast models additional diagnostics had to be computed
- Simulated radar reflectivity and updraft helicity (used in the US to indicate potentially tornadic supercell storms)



# 4.4km and 2.2km UM models and Radar

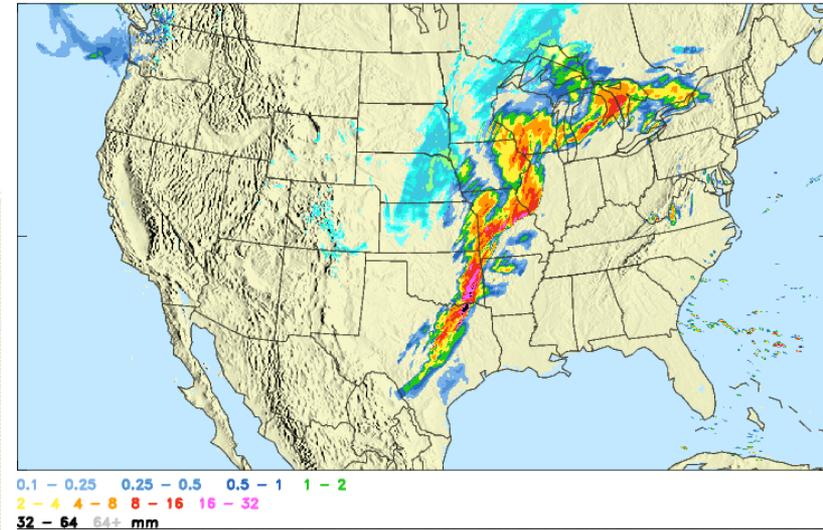
Radar

Radar Hourly accumulation



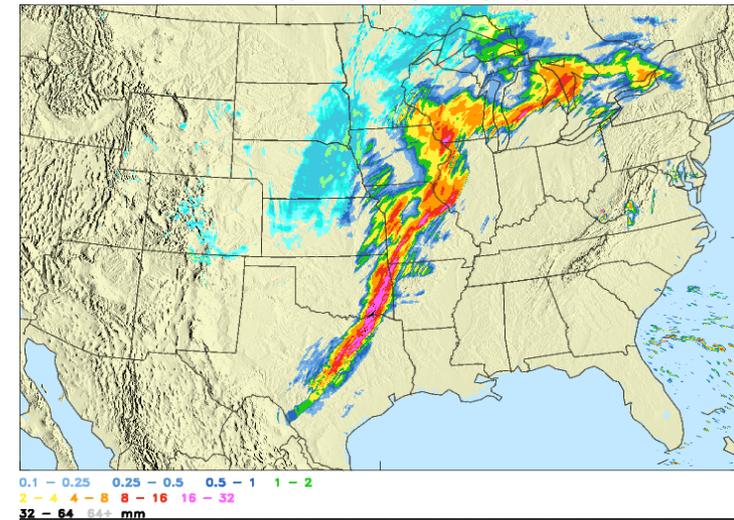
4.4km model

US4-OP 1h accumulated precipitation [mm]  
Thursday 1200Z 18/04/2013 (t+12h)



2.2km model

US2-OP 1h accumulated precipitation [mm]  
Thursday 1200Z 18/04/2013 (t+9h)





# Greyzone physics developments



# Turbulent mixing parametrization in the Greyzone: Basic principle

- Given a turbulent flow of length scale,  $L$ , and grid size  $\Delta x$ :

Unresolved,  $L \ll \Delta x$ :

- a) Traditional NWP 1D parametrization good for vertical mixing
- b) Horizontal turbulent diffusion negligible  
**OK sometimes = standard NWP**

Resolved,  $L \gg \Delta x$ :

- a) Traditional NWP 1D parametrization inappropriate
- b) LES-style 3D turbulence scheme works well  
**Only OK if actually well resolved**

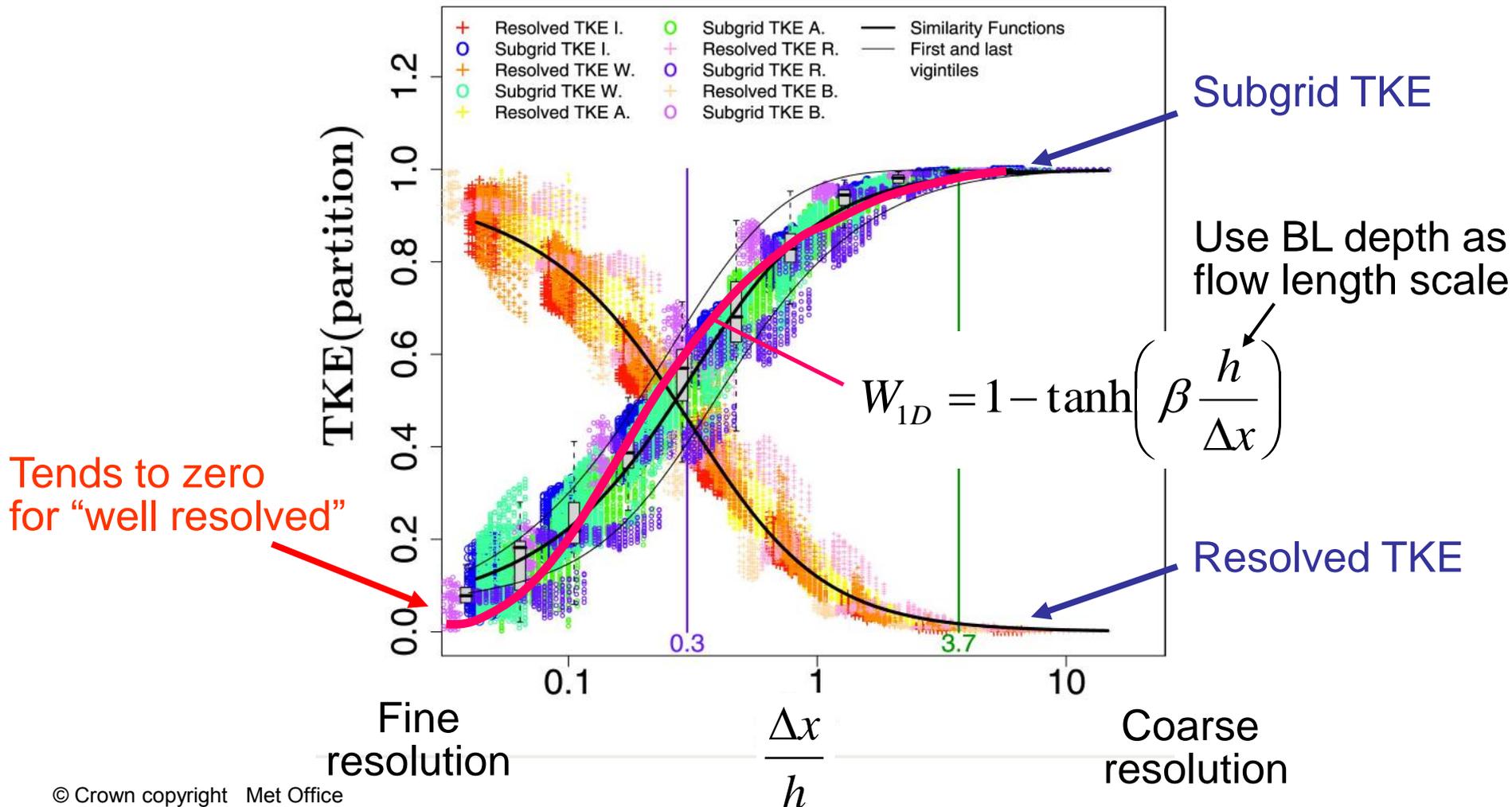
Grey zone,  $L \sim \Delta x$ :

Have some plausible combination of the two (given  $L$  will vary greatly even if  $\Delta x$  is typically uniform)

# Grey zone parametrization

Fit to Honnert et al (2011)

(b)  $0.05 \leq \frac{z}{h} \leq 0.85$

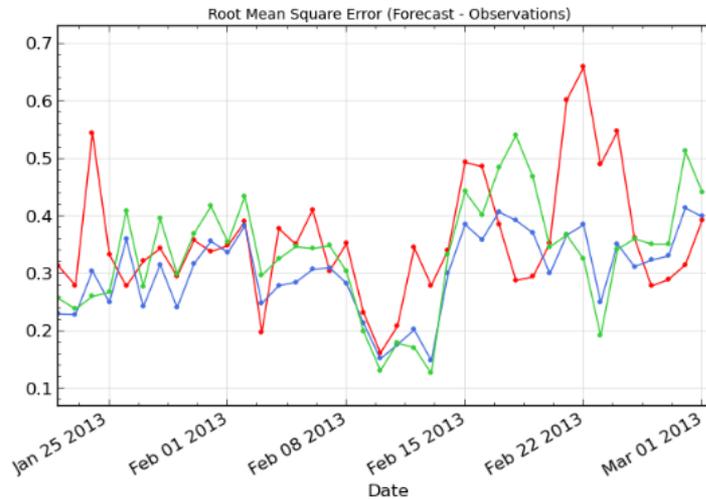
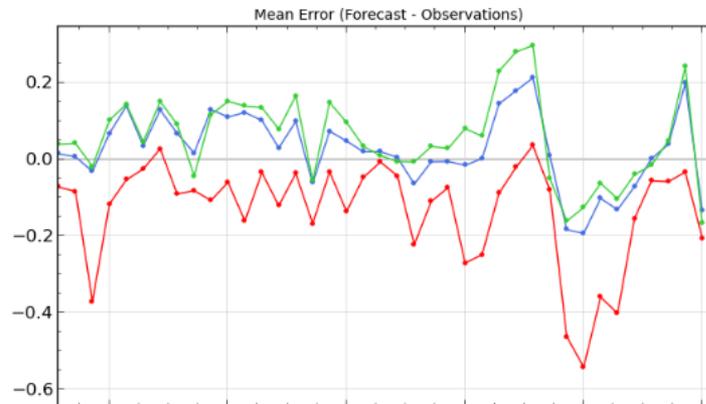




# Poor Sc forecasts from UKV in February 2013

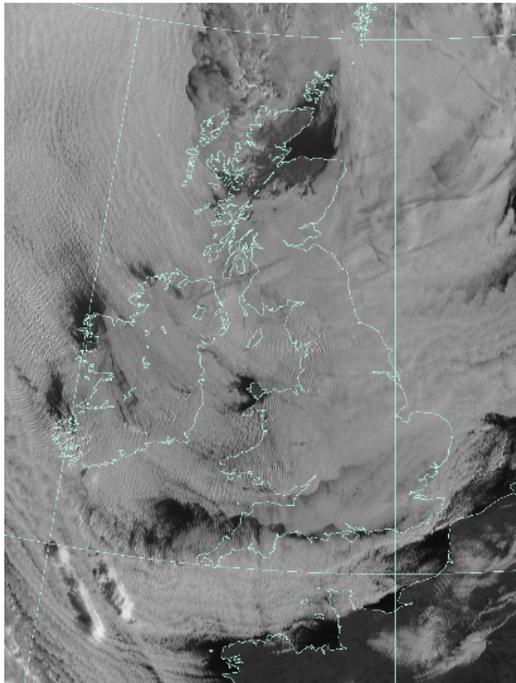
Total Cloud Amount/Cover (fraction), Combined stations, LND SYN - Auto

UK-UKV - T+3      UK-EU - T+0      UK-GM - T+0

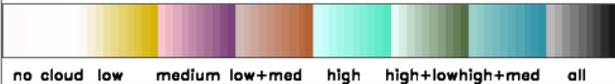
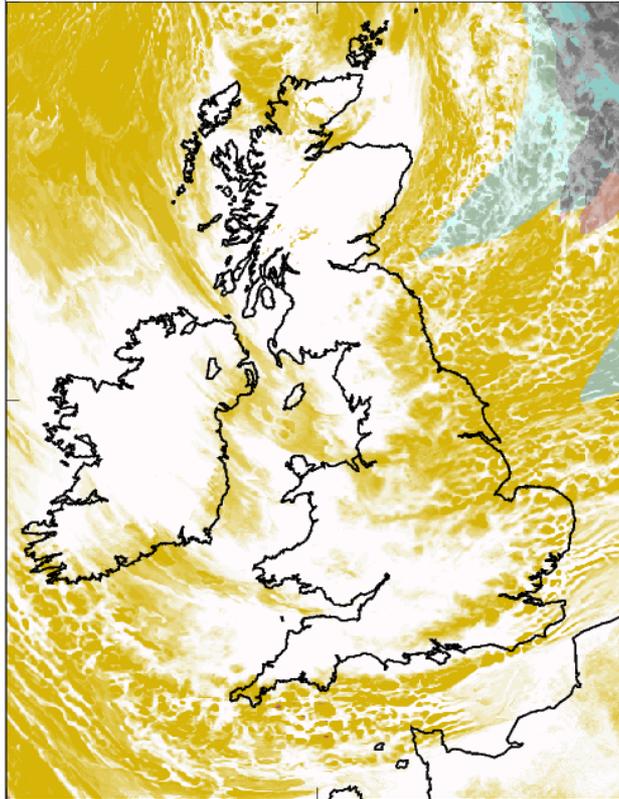




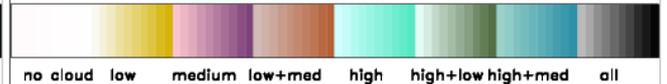
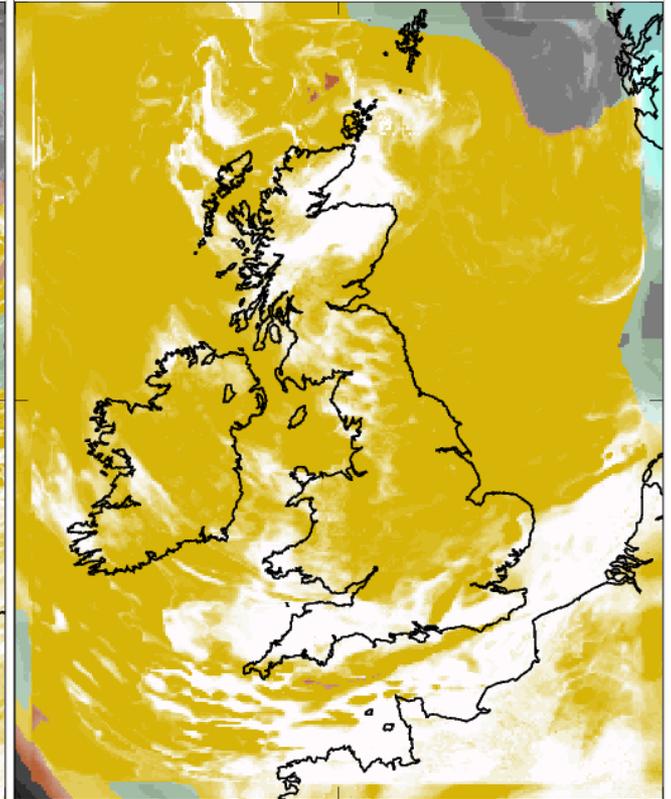
# Satellite image, UKV and UK4



UKV op Cloud amount  
Friday 0900Z 22/02/2013 (+6h)

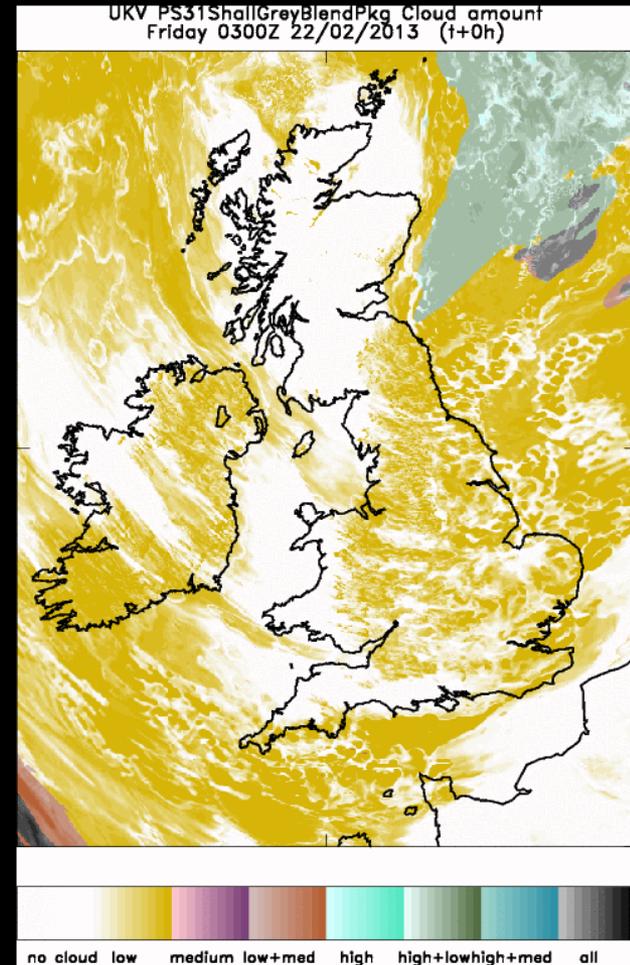
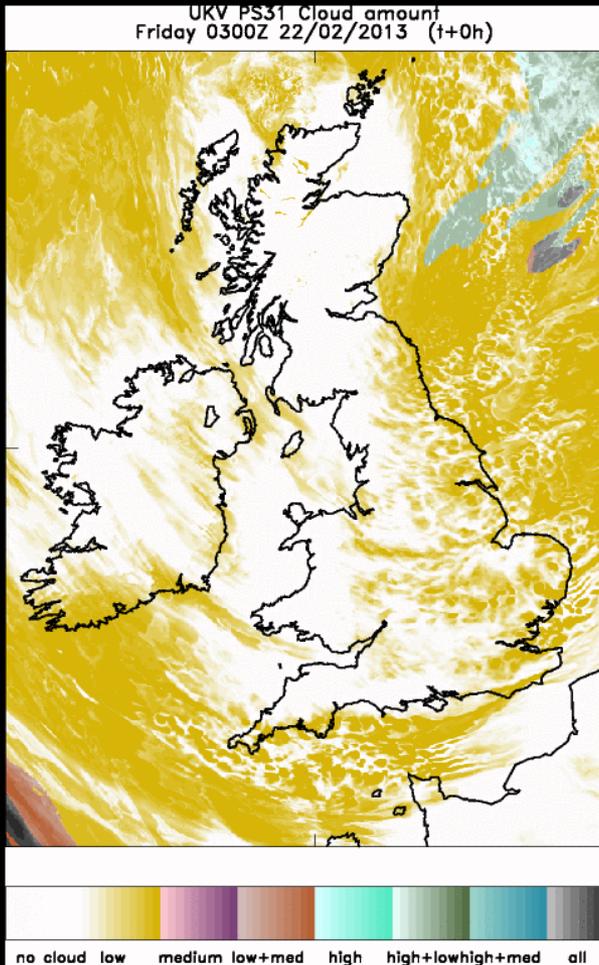


UK4 op Cloud amount  
Friday 0900Z 22/02/2013 (+6h)





# UKV OP and Greyzone turbulence test

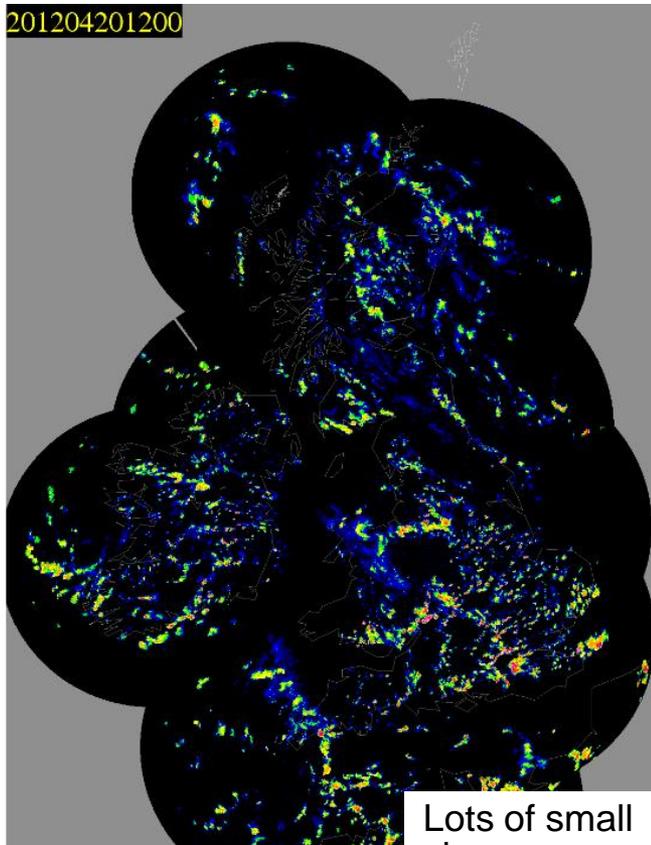


# Convective showers

20<sup>th</sup> April 2012 (DYMECS)

UKV (1.5km grid)

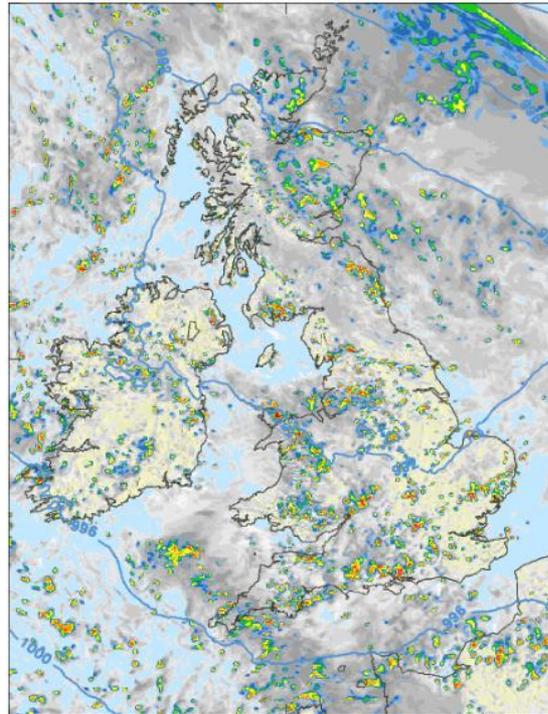
Radar



Lots of small showers

PS31 control

UKV PS31 Precipitation rate [mm/hr] and cloud  
Friday 1200Z 20/04/2012 (+9h)

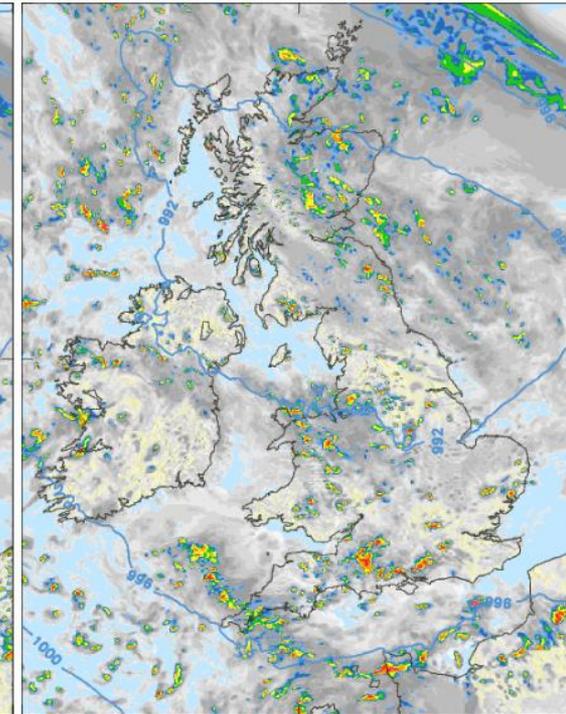


0.1 - 0.25 0.25 - 0.5 0.5 - 1 1 - 2  
2 - 4 4 - 8 8 - 16 16 - 32  
32+ mm/hr

Some small showers

Blended BL

UKV PS31 Blend Precipitation rate [mm/hr] and cloud  
Friday 1200Z 20/04/2012 (+9h)



0.1 - 0.25 0.25 - 0.5 0.5 - 1 1 - 2  
2 - 4 4 - 8 8 - 16 16 - 32  
32+ mm/hr

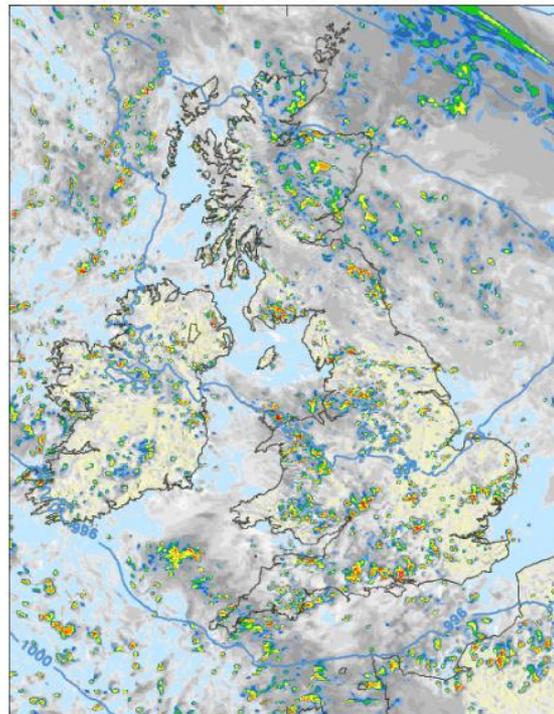
Hardly any small Showers!

# Shallow cumulus parametrization

- Traditional parametrization gives more or less uniform drizzle
- Not popular with forecasters (could post-process), but is using it actually wrong?

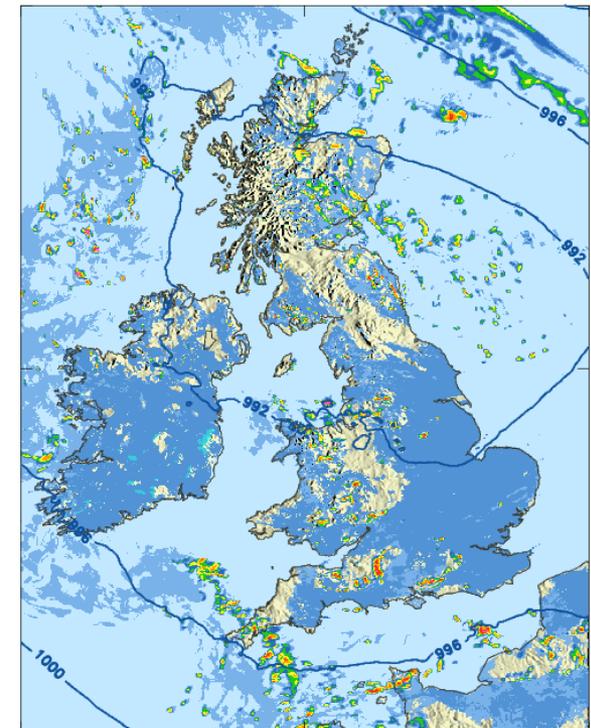
UKV

UKV PS31 Precipitation rate [mm/hr] and cloud  
Friday 1200Z 20/04/2012 (t+9h)

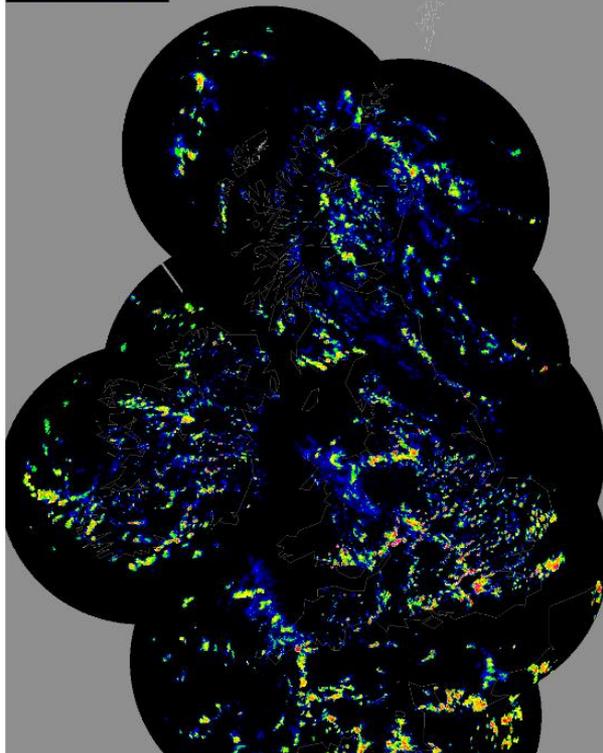


Blending + Shallow Cu param

UKV PS31ShallBlend Precipitation rate [mm/hr] and PMSL  
Friday 1200Z 20/04/2012 (t+9h)



201204201200

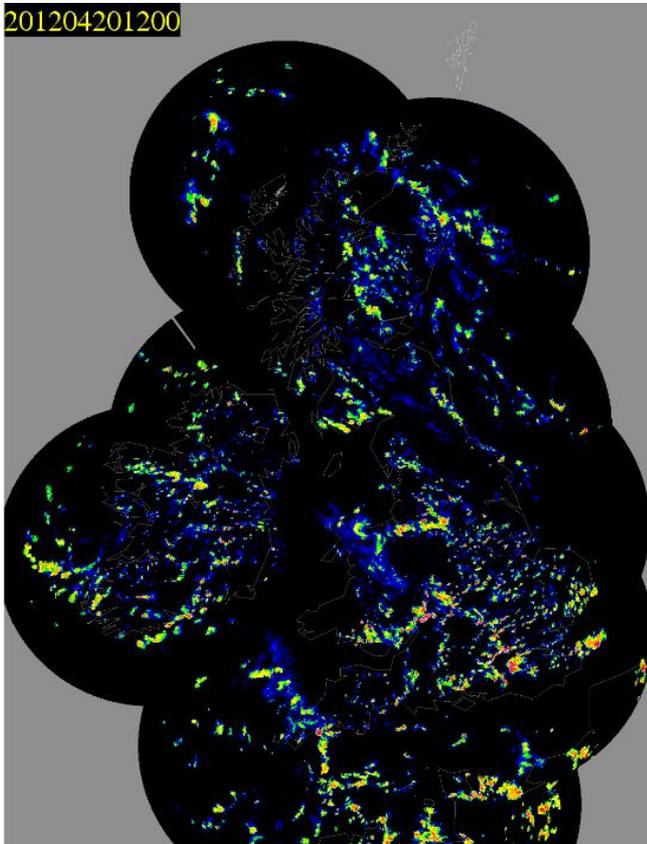


# Grey zone “shallow” cumulus parametrization

20<sup>th</sup> April 2012 (DYMECS)

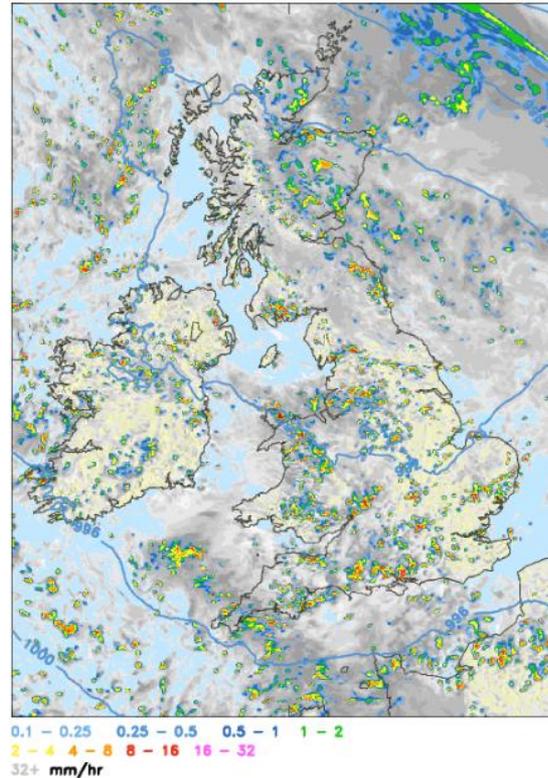
UKV (1.5km grid)

Radar



PS31 control

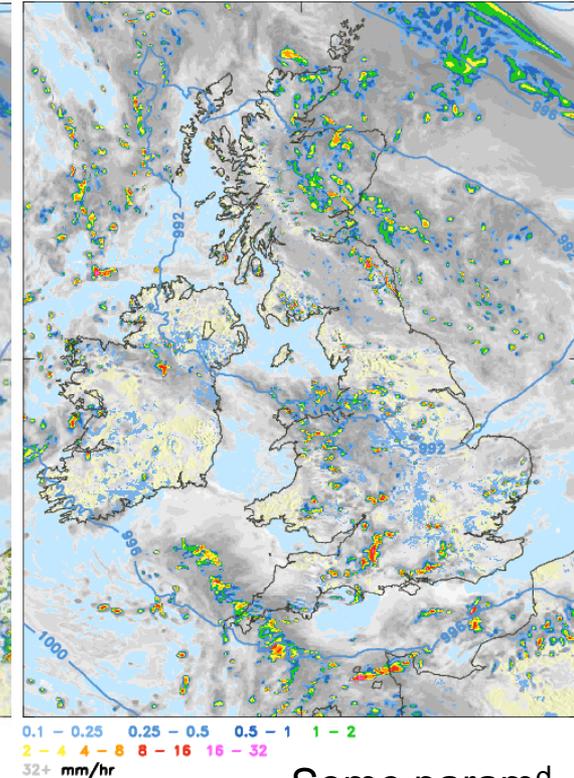
UKV PS31 Precipitation rate [mm/hr] and cloud  
Friday 1200Z 20/04/2012 (+9h)



Some small  
showers

Grey shallow cu

PS31ShallGreySmEntrBlend Precipitation rate [mm/hr] and cloud  
Friday 1200Z 20/04/2012 (+9h)



Some param<sup>d</sup>  
showers



# Summary

- Pragmatic blending, using BL depth as a length scale, appears to work plausibly
  - Gets around having to choose between 3D Smagorinsky or 1D boundary layer parametrization at any given resolution
  - Appears to suppress near grid-scale motions (“noise”)
  - If near grid-scale contains shallow convection (as in UKV) then a shallow cumulus parametrization is needed
- “Grey zone” shallow cu closure (using cloud top height as a length scale) seems to work OK too
- Needs to be tested far more widely and analysed more quantitatively



Met Office



# ENDGame

- See ENDGame Poster

ENDGame was formulated by the Dynamics Research team: Nigel Wood, Thomas Allen, Terry Bailes, Markus Gross, Thomas Melin, Chris Smith, Andrew Stanforth, John Thuburn and Mohamed Zerrouk (University of Exeter). Subsequently, many people in the Met Office have worked on its development and implementation, particularly the physics (APP), the global (GMEB) and the regional (RMEB) teams.

ENDGame is built on the foundation of New Dynamics (introduced operationally in 2002) and aims to be more robust and accurate whilst maintaining or improving conservation and efficiency. Since ENDGame is an evolution of New Dynamics, much has not changed:

- 1) Same equation set and variables (6-m)
- 2) Same horizontal staggering (Arakawa G-grid)
- 3) Same vertical staggering (Chamey/Phillips)
- 4) Semi-implicit/Semi-Lagrangian

The major changes are:

- 1) Improved (implicit) solution procedure (more implicit, approaching Crank-Nicolson) and reduced off-capping (alpha time-weights, all equal to 0.55).
- 2) Iterated approach allows much simpler Remondot problem (7 points) and (cf. 45 point)
- 3) Much simpler (red/black) pencil tone plus greatly reduced communications and leads to improved scalability
- 4) Same Semi-Lagrangian (SL) advection for all variables (cf. Eulerian continuity equation + SL in New Dynamics) and removal of "horizontal spilling in the vertical" for the advection
- 5) Coriolis terms based on mass flux variables (removal of explicitly treated vertical Coriolis terms) improves Rossby mode propagation and leads to improved accuracy
- 6) No polar filtering or horizontal diffusion, control near the poles achieved by implicit damping of wglung (improved scalability and accuracy)
- 7) Vertipoles (cf. u, w and all scalars) means not solving Remondot problem at singular point of grid. Together with improved energy properties gives improved scalability and accuracy

### High Resolution models:

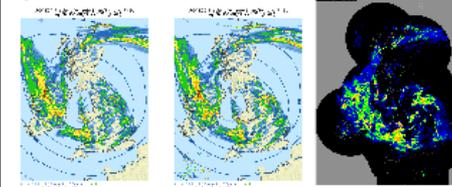


Figure 1: New Dynamics UKV

Figure 2: ENDGame UKV

Figure 3: Radar Image

Testing of Limited Area models such as the 1.5km variable resolution UKV model is still an early stage, but initial results are encouraging. Precipitation forecasts for the 10 region (UK) case of 28 June 2012 show New Dynamics (Figure 1) and ENDGame (Figure 2) run together with the verifying radar image (Figure 3). The runs are very similar, although there are differences in the details, such as convective precipitation cells in the bottom left hand corner of the domain (falling earlier in the ENDGame run (they appear one hour later in the New Dynamics run, not shown)).

### Idealised experiments: Big-bubble Little-bubble test

Described in Robert 1993 (JAS, 50, 1995-1973). A small, negatively buoyant bubble slumps down around a large rising bubble. The plot shows cross-section of potential temperature at various times. New Dynamics (Figure 4) has a few problems with noise, which is absent in ENDGame (Figure 5).

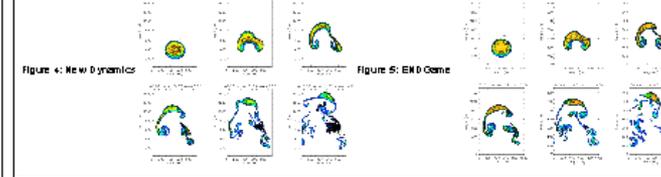


Figure 4: New Dynamics

Figure 5: END Game

### Global model:

The current operational Global WWP model has a horizontal resolution of N512 (~25km in mid-latitudes) and has a configuration of model settings known as G43.1. G43D66.2 refers to a version of the model with the ENDGame dynamical core and related physics settings. The operational implementation of ENDGame will see the resolution of the model being increased to N768 (~17km in mid-latitudes) at the same time as the dynamical core and physics changes.

ENDGame is less diffusive than New Dynamics and this leads to improved levels of Eddy Kinetic Energy at all resolutions (Figure 6). Wind speed biases (Figure 7) are reduced and tropical cyclones (TCs) have reduced track errors (Figure 8) and are systematically deeper (Figure 9), giving stronger winds (Figure 10). Resolution has relatively little impact on track errors compared with the model configuration change (ENDGame plus physics changes) but has more impact on the intensity.

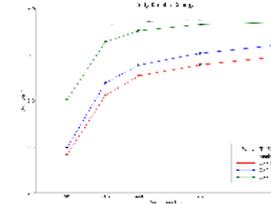


Figure 6: Eddy Kinetic Energy

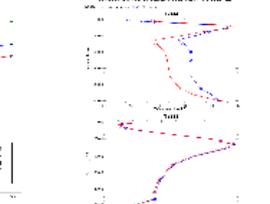


Figure 7: Wind speed bias (top) and RMS Vector Error (bottom)

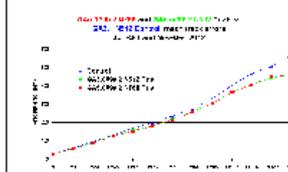


Figure 8: TC mean track error

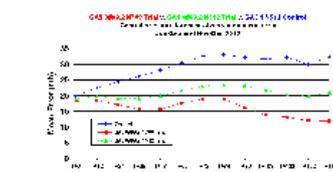


Figure 9: Central Pressure Mean Error

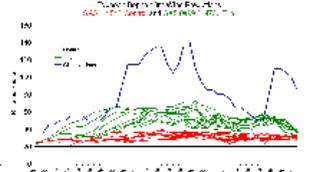
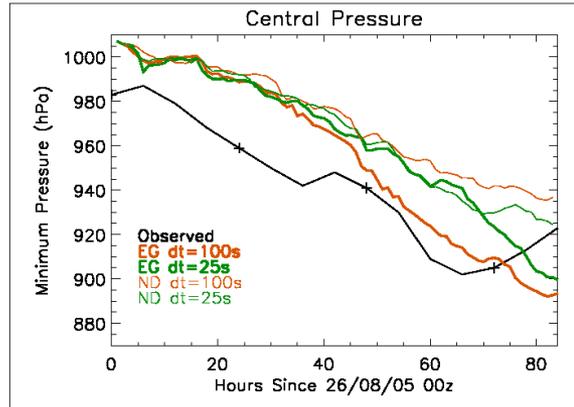


Figure 10: Typhoon Bopha 10m wind predictors

The ENDGame dynamical core is due to become operational at the Met Office in 2014, first in the Global model and then in the limited area model configurations. The Global model change will be accompanied by a change in model resolution from N512 to N768 and an update to the model physics. ENDGame is an evolution of the New Dynamics and aims to be more robust and accurate whilst maintaining or improving conservation and efficiency. ENDGame is less diffusive than New Dynamics resulting in increased Eddy Kinetic Energy. This leads to more intense development of storms and improved wind biases.



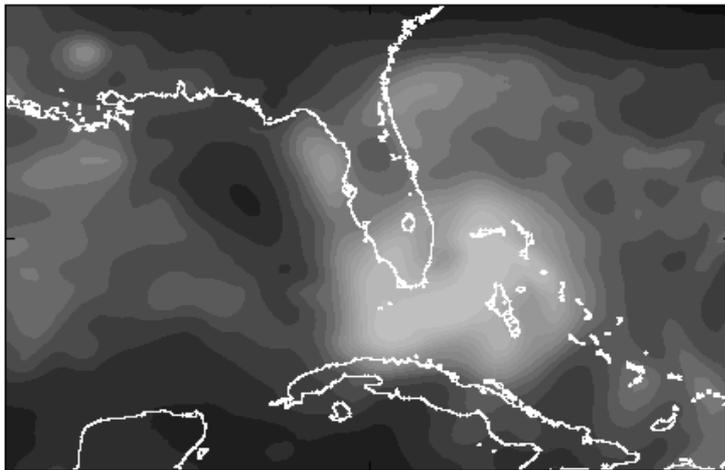
# 4km Hurricane Katrina simulations



## New Dynamics

## ENDGame

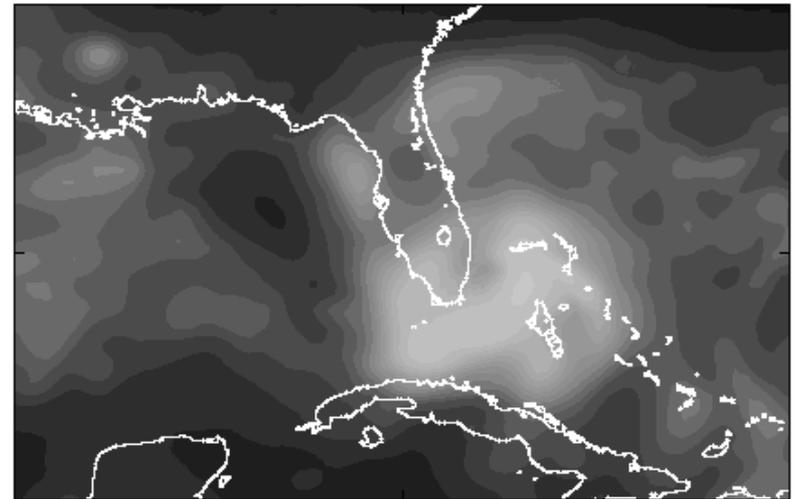
26/8/05 01:01 ND dt=100s  
Outgoing Longwave Radiation (TOA)



Number of points = 555 X 361  
Domain Size = 2219km X 1443km

70 100 130 160 190 220 250 280

26/8/05 01:01 EG NEW dt=100s  
Outgoing Longwave Radiation (TOA)



Number of points = 555 X 361  
Domain Size = 2219km X 1443km

70 100 130 160 190 220 250 280



# Operational changes



# Parallel Suite 31 Highlights

- **Parallel Suite 31 16/01/13**
- **MOGREPS-G**
  - Resolution increase (N400; ~33km)
  - More members to T+9
  - Driving MOGREPS-UK
- **UKV/MOGREPS-UK physics package**  
See talk given last year linked from:  
[http://srnwp.met.hu/Annual\\_Meetings/2012/index.html](http://srnwp.met.hu/Annual_Meetings/2012/index.html)
- **Introduction of the Euro4 downscaler model**  
enabling the future retirement of the 12km NAE model



Met Office

# Parallel Suite 32 Highlights

- **Parallel Suite 32 30/04/13**
- Global model
  - Introduction of data from CrIS and ATMS instruments on board NASA's NPP polar orbiting satellite, giving improved verification scores
- UKV, MOGREPS-UK and Euro4 models
  - Implementation of different ice crystal and snow fall speeds with the result that forecasts of high cloud have been improved without affecting precipitation (as verified against satellite imagery)
  - Low cloud forecasts at short range have been improved due to cloud assimilation changes

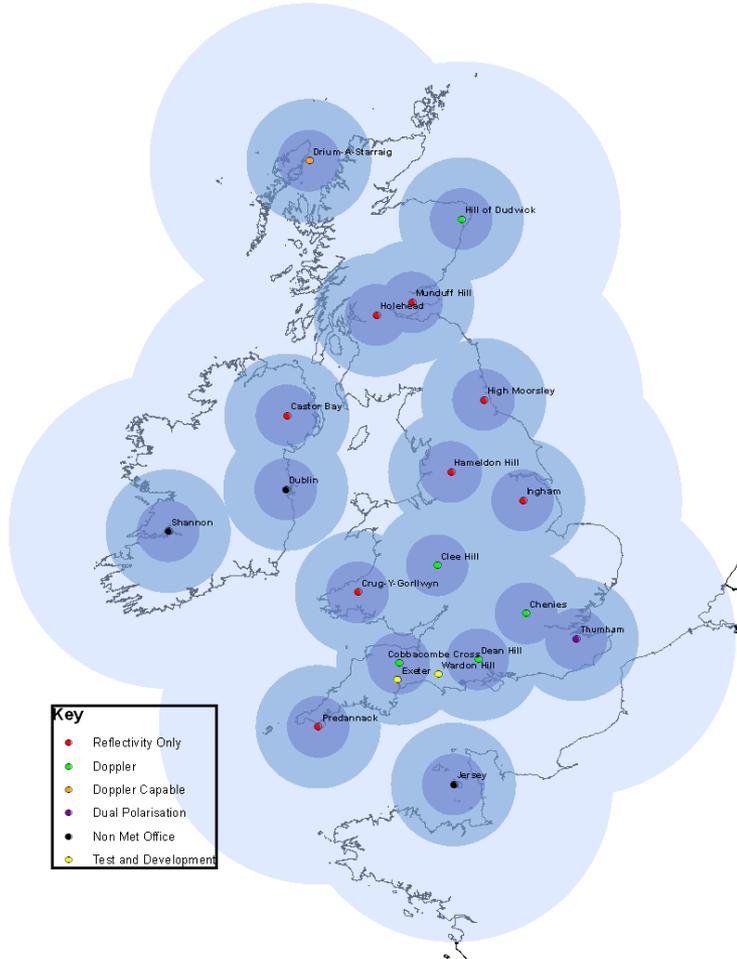


# Weather radar renewal project (2011- 2015)

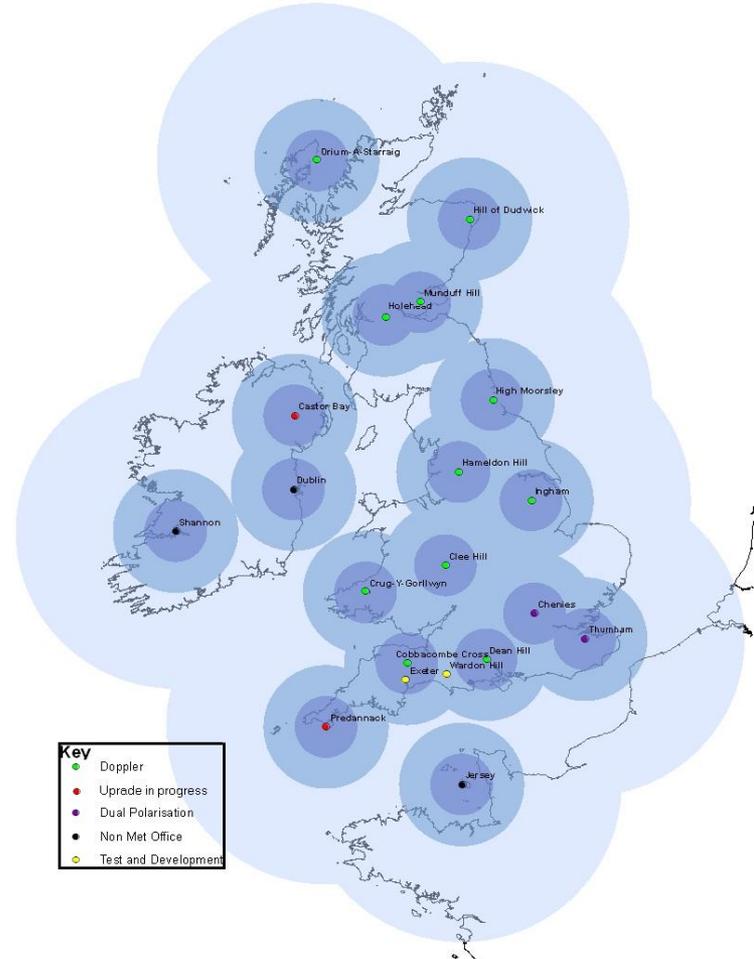
15 Operational Radar:  
6 Doppler Radar  
1 Dual Polarisation Radar

15 Operational Radar:  
15 Doppler Radar  
4 Dual polarisation Radar  
2 undergoing dual polarisation upgrade

UK Weather Radar Network



UK Weather Radar Network





# Future Plans



**Met Office**

# PS33 Rose



- Rose provides a common solution for managing, configuring and running suites of scientific applications.
- Rose will replace
  - the Suite Control System (SCS).
  - All GHUI-based User Interfaces - . UMUI, OPSUI, etc
  - UM scripts.
- Rose provides
  - A simple application configuration
  - Suite utilities to run Rose apps within cylv
  - Commands to install and run
  - Web based Output viewer
  - GUI for editing applications and suite configurations
  - Suite versions control and discovery GUI
- Due for operational implementation in Winter 2013/2014



**Met Office**

# PS34/PS35 Outlook for the UKV

- **DA changes (see talk by Bruce Macpherson)**
- **PS34 (Spring 2014)**
  - New multilayer Snow scheme (the current snow scheme is a zero-layer scheme and suffers from excessive ground heat fluxes which can lead to warm biases).
  - New Murk sources
- **PS35 (Summer 2014)**
  - ENDGame dynamical core
  - Grey Zone Turbulence
  - Warm rain microphysics (scale aware)
  - I. A. Boutle et al. QJRMS Early View. “Spatial variability of liquid cloud and rain: observations and microphysical effects”

<http://onlinelibrary.wiley.com/doi/10.1002/qj.2140/abstract>



# Questions?



Photo: A tornado in Kansas on the evening of the 18th May 2013  
(taken by Steve Willington whilst storm chasing!)