



# Benefit of higher resolution analysis and mesoscale observing networks in the UK Models

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# Outline

- ❑ Purpose
- ❑ Background
- ❑ Trial Configurations
- ❑ Results
  - General
  - A forecast bust
- ❑ Other ad-hoc studies
- ❑ Summary



# Purpose

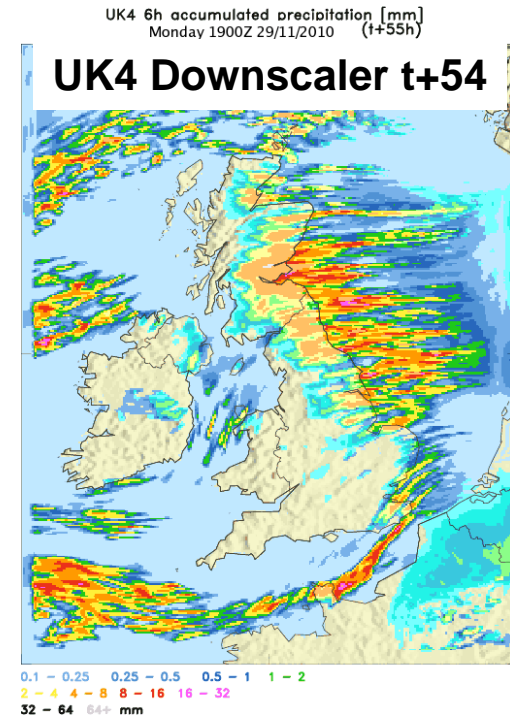
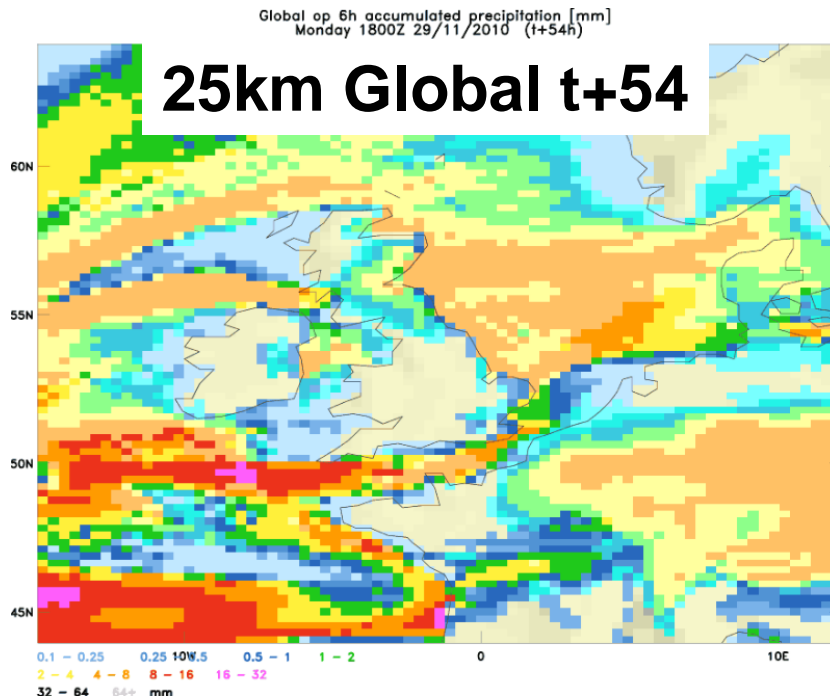
**Local hi-res DA**

**- why bother ???!**



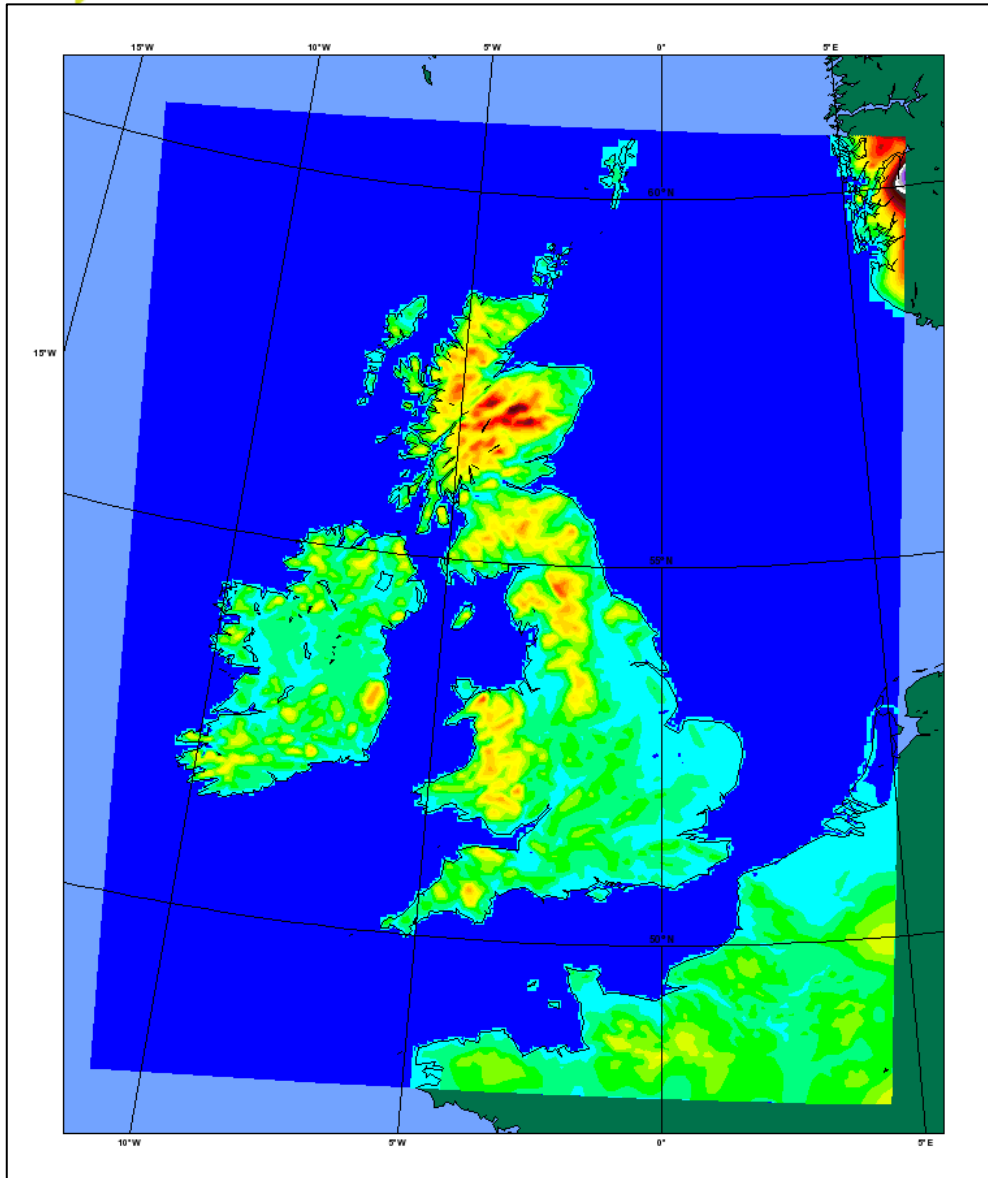
# UK4 Downscaler

- Set-up in November 2010 as quasi-operational model in response to requests from forecasters for **longer range hi-res guidance** during the early wintry weather.
- Runs from **reconfigured Global Analysis** (no local DA)
- Convenient Baseline to measure impact of local DA





# UK4 Vital Statistics



- Resolution:
  - 0.036 degrees gridlength (4 km approx.)
  - 70 Levels (29 in boundary layer)
- LBCs
  - Run from **25km Global model lbc** since Jan 2012 (was regional NAE model previously)



# UK4 Data Assimilation

- ❑ **3DVAR (with FGAT) + IAU** for all observations including MOPS cloud fraction *except*
  - Latent Heat Nudging for radar-derived surface rain rate
  
- ❑ VAR grid is uniform 4km resolution over whole domain



# Trial Configurations



# UK4 DA trial cycling

- ❑ 8 three-hour cycles per day
  
- ❑ **Verified Forecasts to T+24 at 00, 06, 12, 18 UTC**
  - Chosen for consistency with **Downscaler forecast times**
  - Observation cut-off ranges from **hh+150min** to **hh+180min**
  - Lateral boundaries from **hh** run of 25km Global model
  - Intermediate cycles at 03, 09, 15, 21 UTC
  
- ❑ *Note: this is not our operational configuration where we run our long UK forecasts to T+36 at 03, 09, 15, 21 UTC*





# UK4 Impact Trials

**A. Full local DA (Control)**

**B. Partial local DA**

- omitting 'non-conventional' **UK4 only** Obs types  
(see following slide)

**C. Downscaler**

- run from **reconfigured Global Analysis**

**D. Other Obs Configurations where relevant**

**A** vs **C** : total benefit of full high-res DA system

**A** vs **B** : benefit of 'local-only' obs types

**B** vs **C** : benefit of higher-res analysis



## **UK4 – extra observations not assimilated in global model**

- MOPS cloud fraction profiles (3-hourly, 4.5km resolution)***
- radar-derived surface rain rate (hourly, 5km resolution)***
- visibility from SYNOPs (hourly)***
- $T_{2m}$  &  $RH_{2m}$  from Highways Agency roadside sensors (hourly)***
- Doppler radial winds (3-hourly)***

**These observations were denied to the 'Partial Local DA' trial**



Met Office

# Trial Periods

Forecasts to T+24 at 00Z, 06Z, 12Z & 18Z

Period	Dates	No. of Forecasts
July 2011	Jul 1 <sup>st</sup> → Aug 10 <sup>th</sup>	4x40=160
November 2011	Nov 1 <sup>st</sup> → Dec 14 <sup>th</sup>	4x44=176
January 2012	Jan 3 <sup>rd</sup> → Feb 10 <sup>th</sup>	4x38=152
March 2012	Mar 10 <sup>th</sup> → Mar 31 <sup>st</sup>	4x21=84

Period picked at Random

Period picked due to specific (SCu) event



**Met Office**

# Results



# UK Index Metric

(and small data samples)

Variable	ETS Threshold
1.5m Visibility	200m, 1000m, 5000m
6 hour ppn accumulation	0.5mm, 1.0mm, 4.0mm
Cloud Cover	0.3, 0.6, 0.8
Cloud Base Height	100m, 500m, 1000m
1.5m Temperature	$\frac{1-RMS^2}{RMS^2(pst)}$
10m wind	$\frac{1-RMS^2}{RMS^2(pst)}$

- Weighted Basket of Indices
- Combo of **ETS** & RMS scores
- Trials often have very few events for eg 200m vis and 4.0mm precipitation thresholds
- A few events may completely swamp the genuine signal...
- May need a couple of months to get reliable stats for vis and ppn. Depends on weather, season, domain size...



# Verification by Period

		UK Index Benefit		
Period	Days	of <i>full local DA system</i>	of <i>extra obs types not assimilated in the global model</i>	of <i>hi-res DA alone</i>
July 2011	40	<b>+2.54%</b>	<b>-0.96%</b>	(2.54--0.96) = <b>+3.50%</b>
November 2011	44	<b>+1.17%</b>	<b>+0.28%</b>	(1.17-0.28) = <b>+0.89%</b>
January 2012	38	<b>+0.78%</b>	<b>-0.18%</b>	(0.78--0.18) = <b>+0.96%</b>
March 2012	21	<b>-4.83%</b>	<b>-4.47%</b>	(-4.83 -- 4.47) = <b>-0.36%</b>

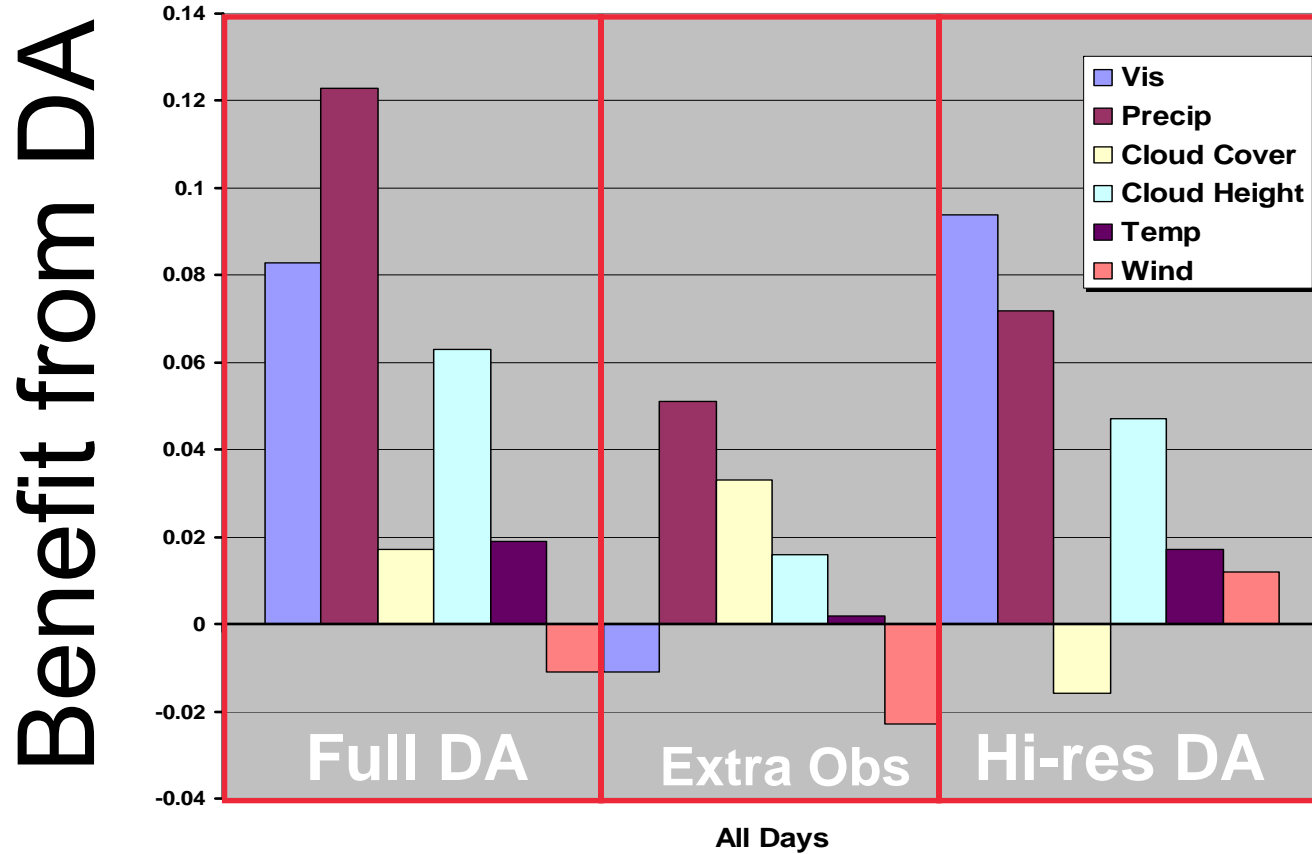
**Cf. typical annual UK Index progression of 2% per annum**



# Verification by Element

		Full DA vs Downscaler							
		Colors indicate best setup for element/period							
Period	Trial	Full DA		Partial DA			Downscaler		
Period	Trial	vis	precip	cloud amount	cloud height	temp	wind	Wind	Overall
Jul 2011	DS	+0.268	+0.151	+0.019	+0.019	+0.078	+0.006	+2.54%	
Nov 2011	DS								
Jan 2012	I								
Mar 2012	I								
Nov 2011									
Jan 2012	T								
Jul 2011	N								
Nov 2011	N								
Mar 2012	N								
Jan 2012	N								
Jul 2011	N								
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Mar 2012	N				</				

# November 2011







# Precipitation

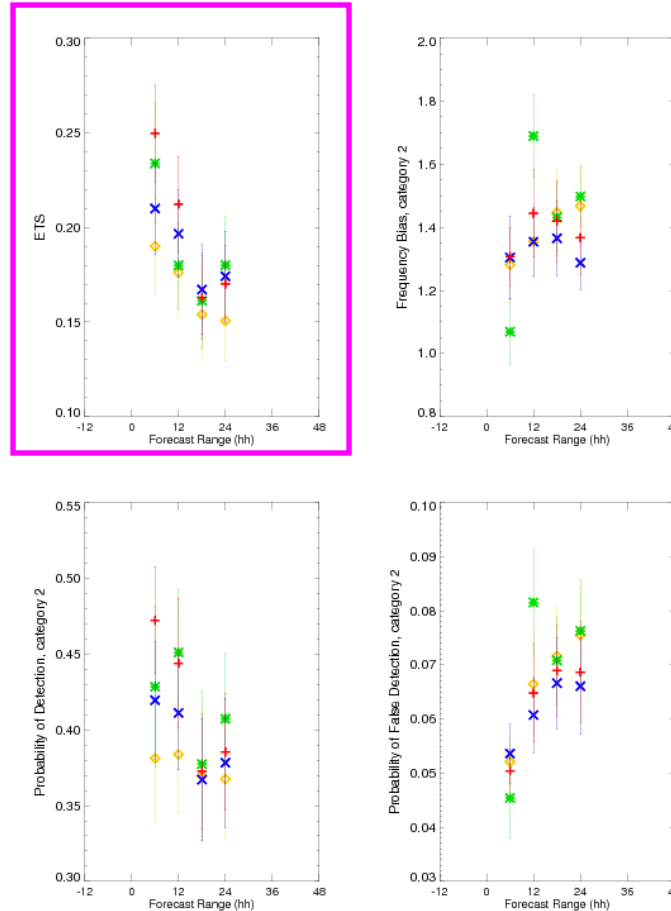
## 6-hour accumulations – July 2011

6hr Precip Accumulation (mm)(8.0): Surface Obs  
 WMO Block 03 station list  
 Equalized and Meaned from 1/7/2011 00Z to 10/8/2011 23Z

Cases: + UK4 PS28 DA x UK4 PS28 NHR DA \* UK4 PS28 DS o UK4 PS28 no LHN

0.5mm/6hr  
 1.0mm/6hr  
 4.0mm/6hr  
 8.0mm/6hr

ETS



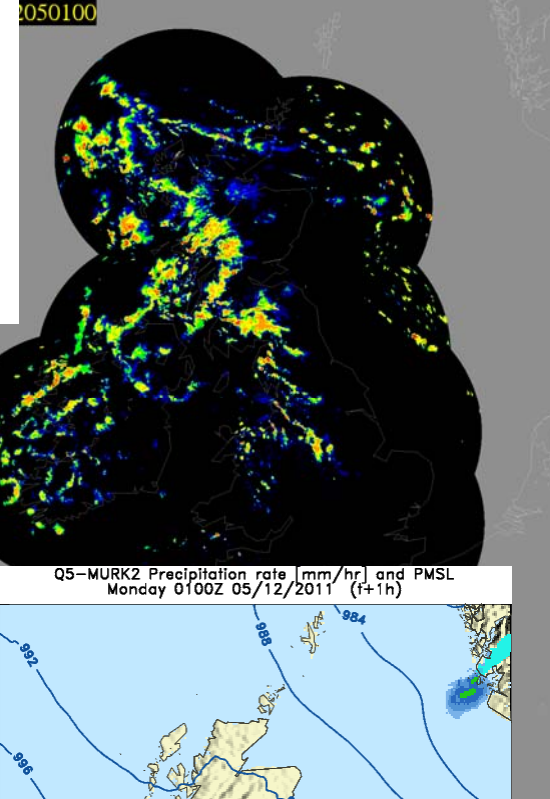
ETS	Frequency Bias
Detection Probability	False Detection Probability
Full DA DownScaler	Partial DA Full DA – LHN

68% error bars calculated using  $S/(n-1)^{1/2}$

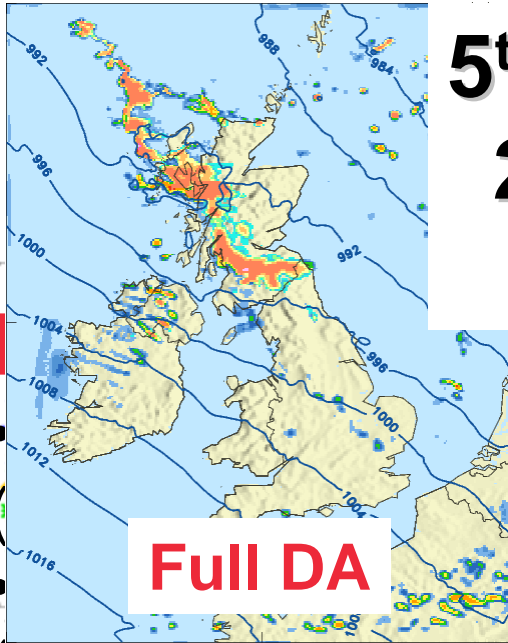


UK4-PS28\_DA Precipitation rate [mm/hr] and PMSL  
Monday 0100Z 05/12/2011 (t+1h)

5<sup>th</sup> Dec  
2011  
T+1

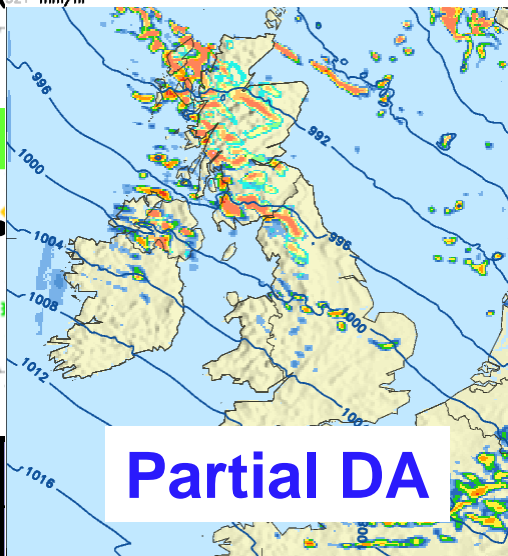
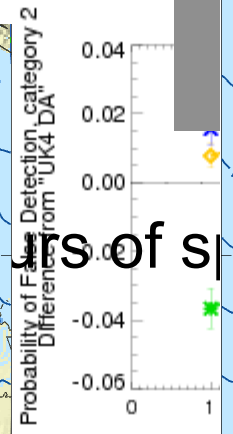


0.2mm/1hr  
0.5mm/1hr  
1.0mm/1hr



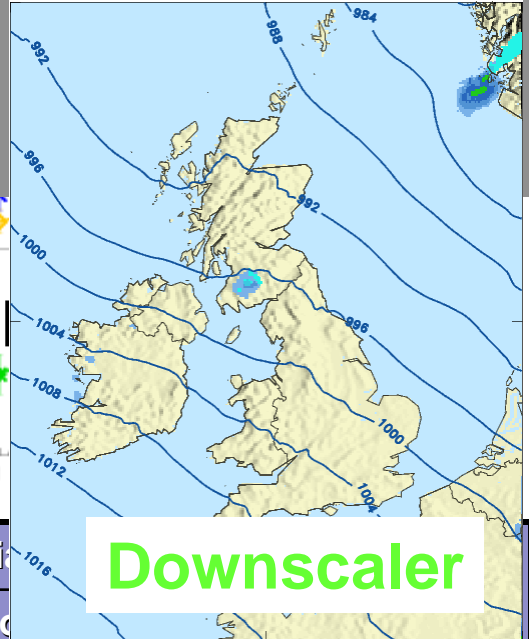
Full DA

Frequency Difference from "UK4 DA" using P



Partial DA

Q5-MURK2 Precipitation rate [mm/hr] and PMSL  
Monday 0100Z 05/12/2011 (t+1h)



Downscaler

Probability

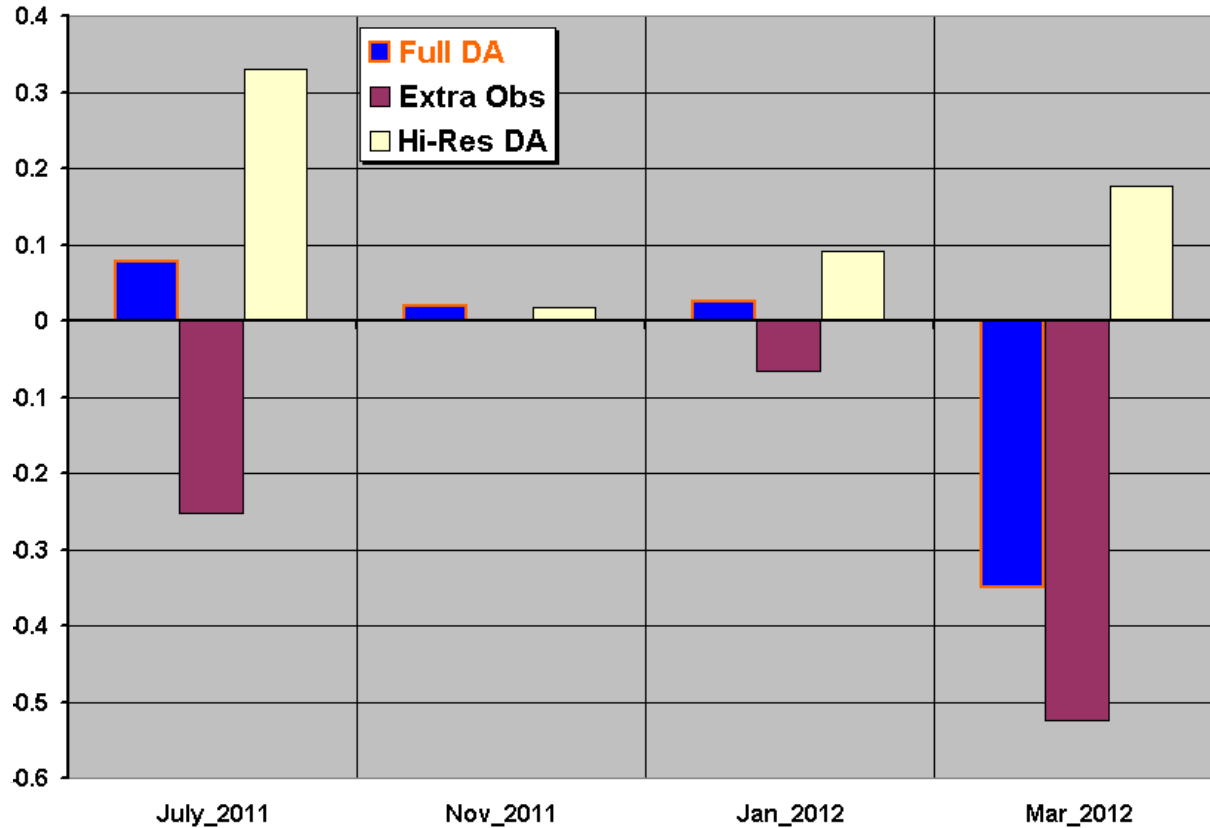


# Temperature

## November 2011

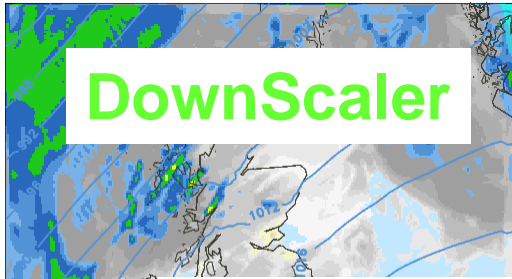
T <sub>2m</sub> Mean Error
T <sub>2m</sub> RMS Error
Full DA

Benefit from DA



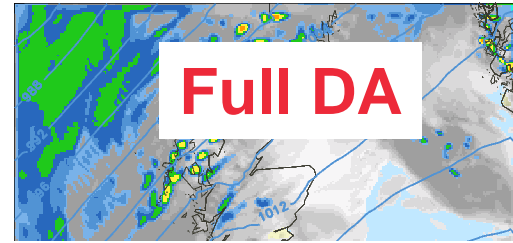
68% error bars calculated using  $S/(n-1)^2$

Q5-MURK2 Precipitation rate [mm/hr] and cloud  
Monday 0900Z 28/11/2011 (t+3h)

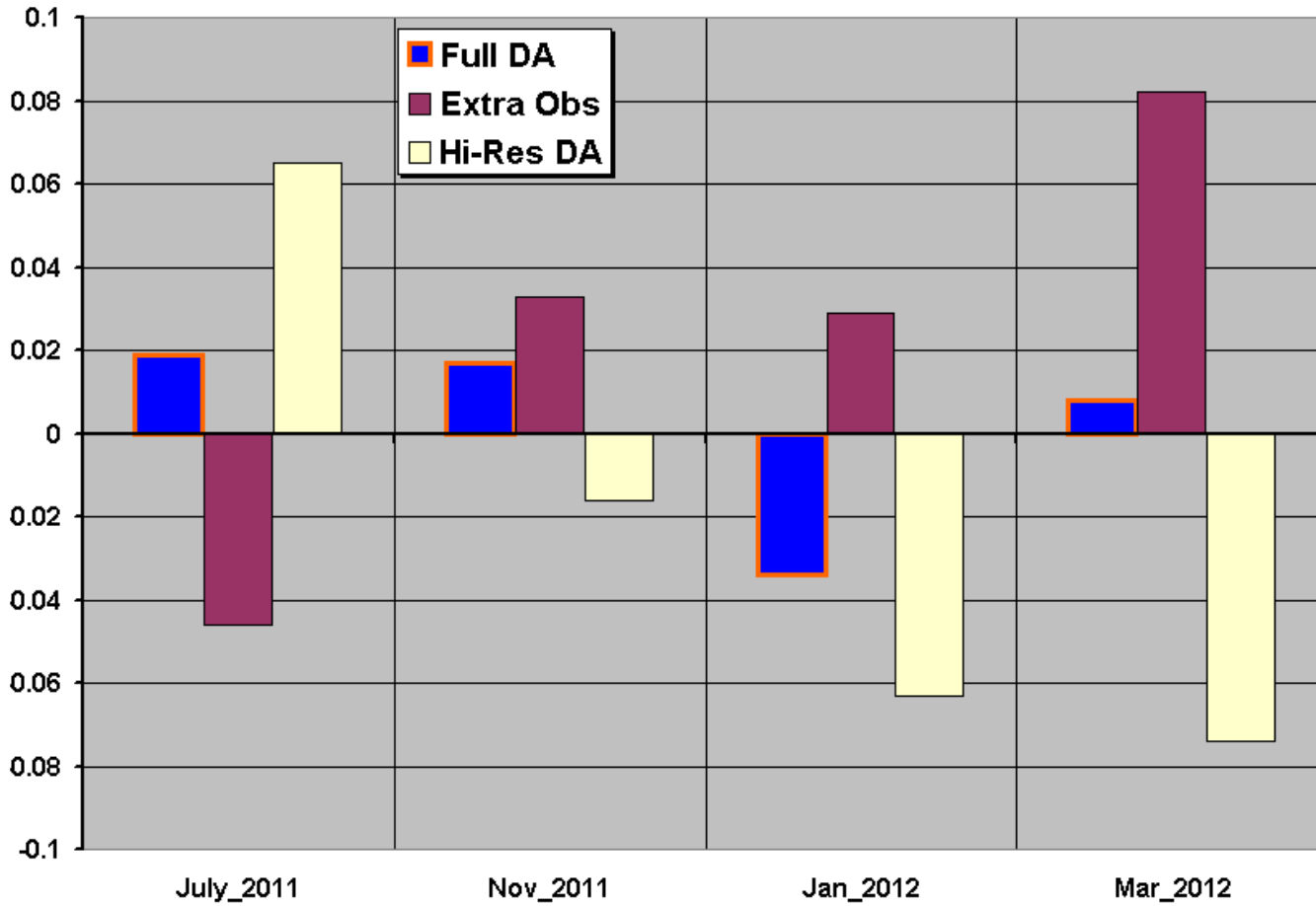


# Cloud Cover

UK4-PS28\_DA Precipitation rate [mm/hr] and cloud  
Monday 0900Z 28/11/2011 (t+3h)



Benefit from DA



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

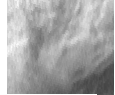
1



# Visibility

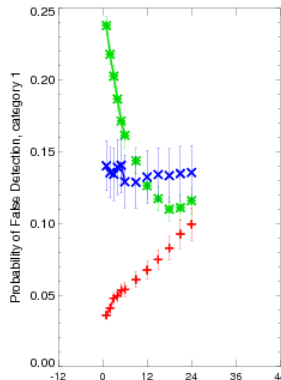
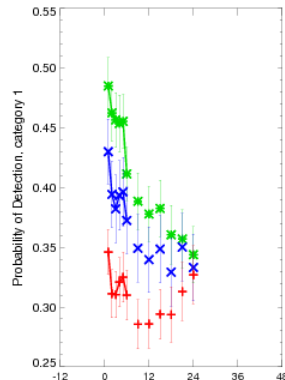
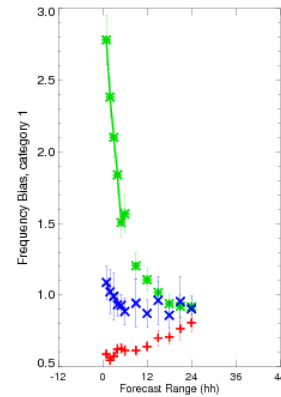
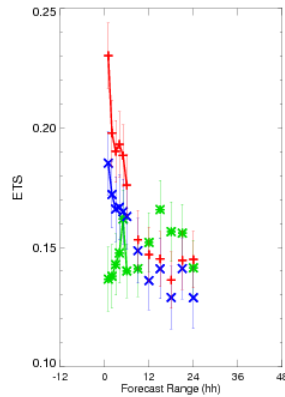
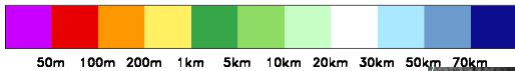
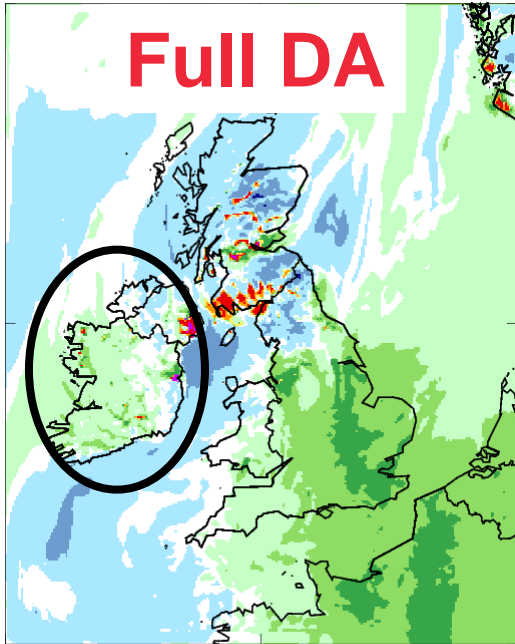
## 5000m

EVUK71 MSG



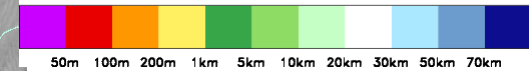
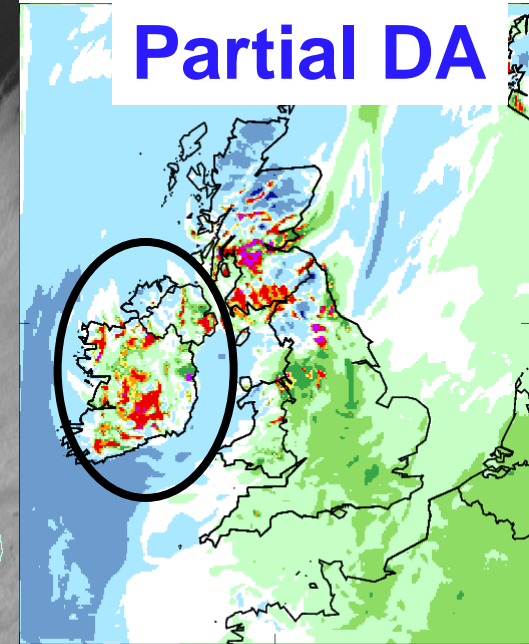
UK4-PS28\_DA Visibility [km]  
Monday 0900Z 07/11/2011 (+3h)

**Full DA**



UK4-PS28\_DA\_NHR Visibility [km]  
Monday 0900Z 07/11/2011 (+3h)

**Partial DA**

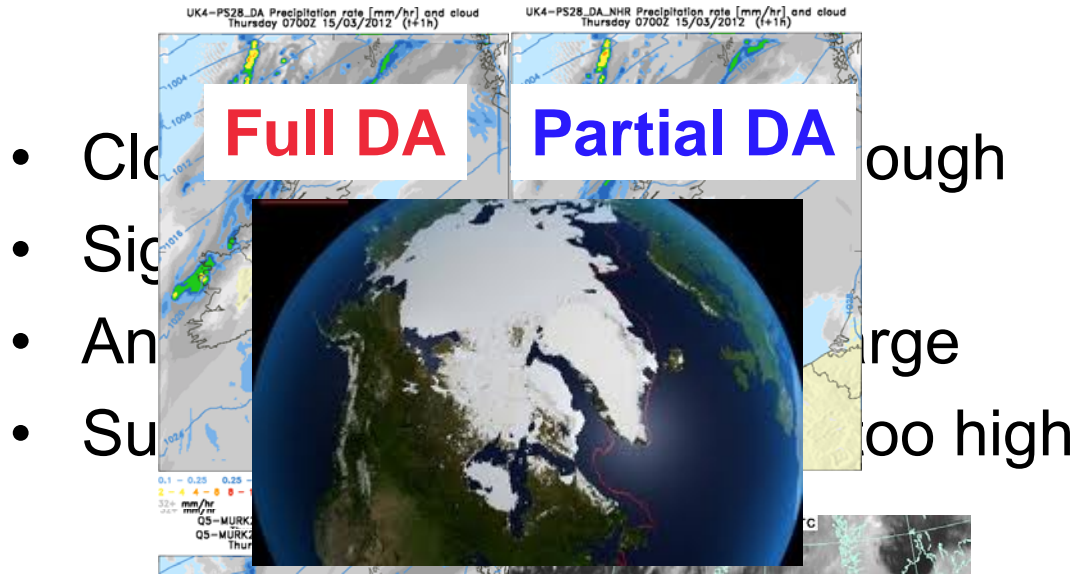


1/11/2011 to 15/12/2011

ETS	Frequency Bias	<b>Full DA</b>
Detection Probability	False Detection Probability	<b>Partial DA</b>
		<b>DownScaler</b>

# Stratocumulus Period


## Mar 10 -15 2012



T+7

T+1

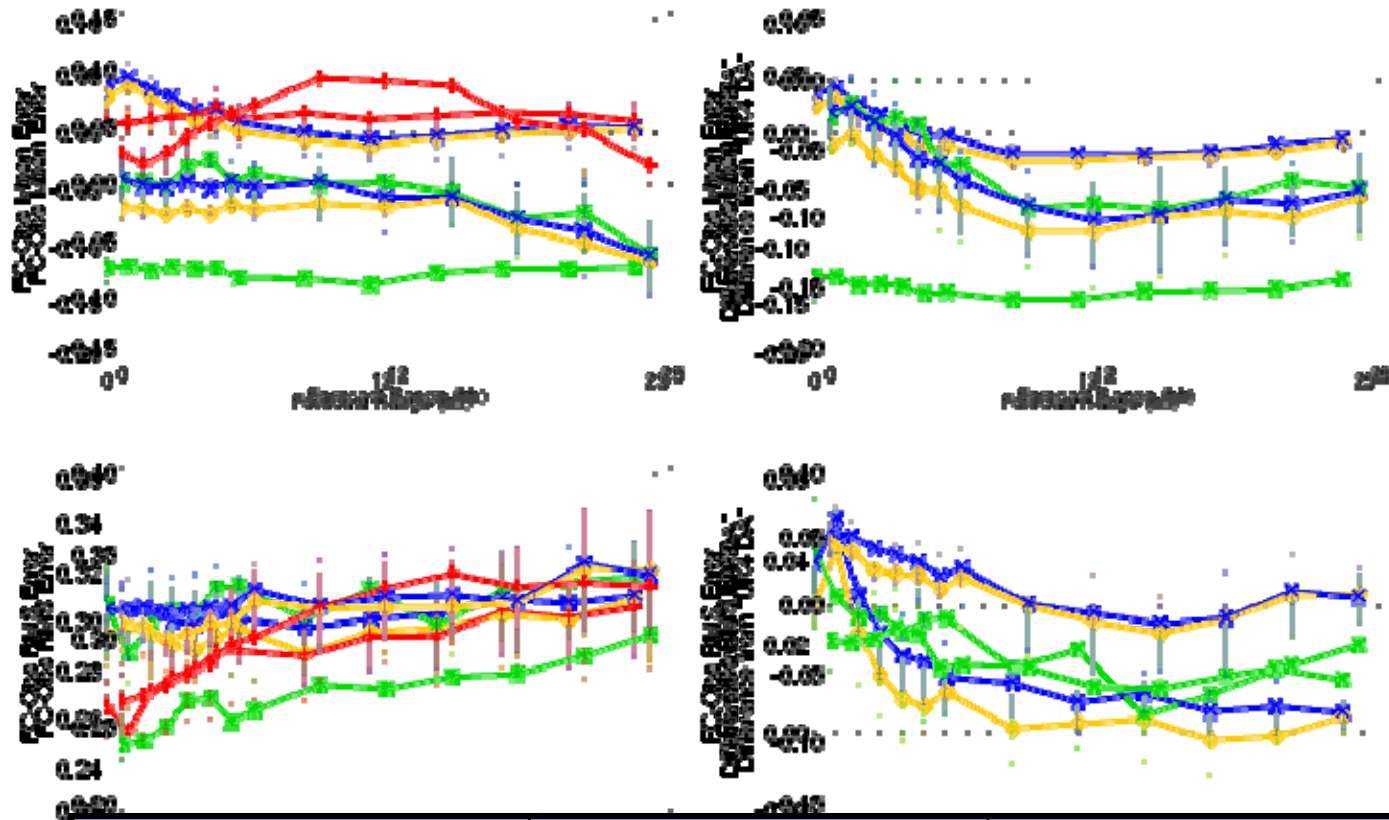
Arctic Ice Syndrome

..... the  **thickness** also matters





# Cloud Cover March 2012 10-15<sup>th</sup> (SCu)



Mean Error	Mean Difference from 'Full DA' trial	Full DA Partial DA DownScaler Full DA - MOPS Cloud
RMS Error	RMS Difference from 'Full DA' trial	



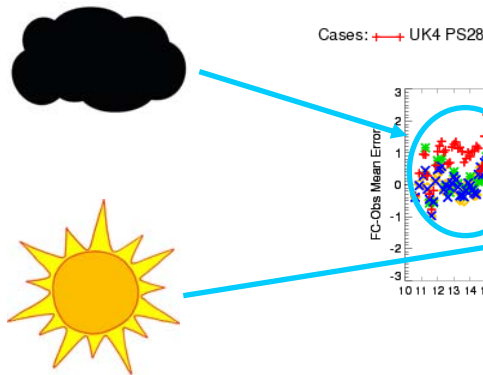


# T<sub>2m</sub> impact from SCu errors

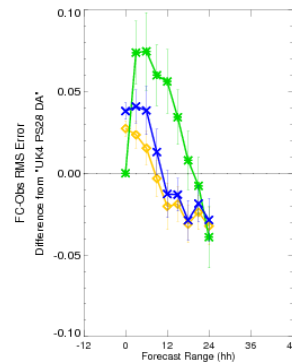
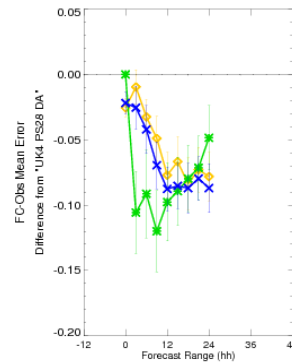
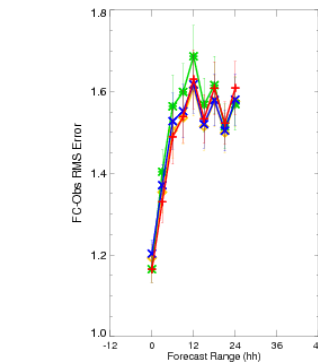
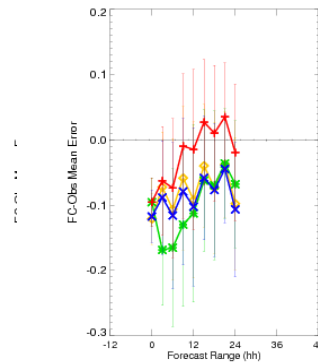
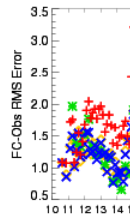
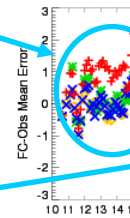
Mean Error	Mean Difference from 'Full DA' trial	Full DA Partial DA DownScaler Full DA – MOPS Cloud
RMS Error	RMS Difference from 'Full DA' trial	

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 16/3/2012 00Z to 31/3/2012 23Z

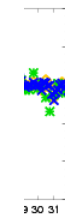
Cases Cases: UK4 PS28 DA UK4 PS28 NHR DA UK4 PS28 DS  
UK4 PS28 No MOPS cloud



Cases: UK4 PS28



R



T+1

10-14<sup>th</sup>

16-31<sup>st</sup>





# Ad-hoc Studies

- Doppler Radial Winds**
- OpenRoad**



# Doppler radial winds

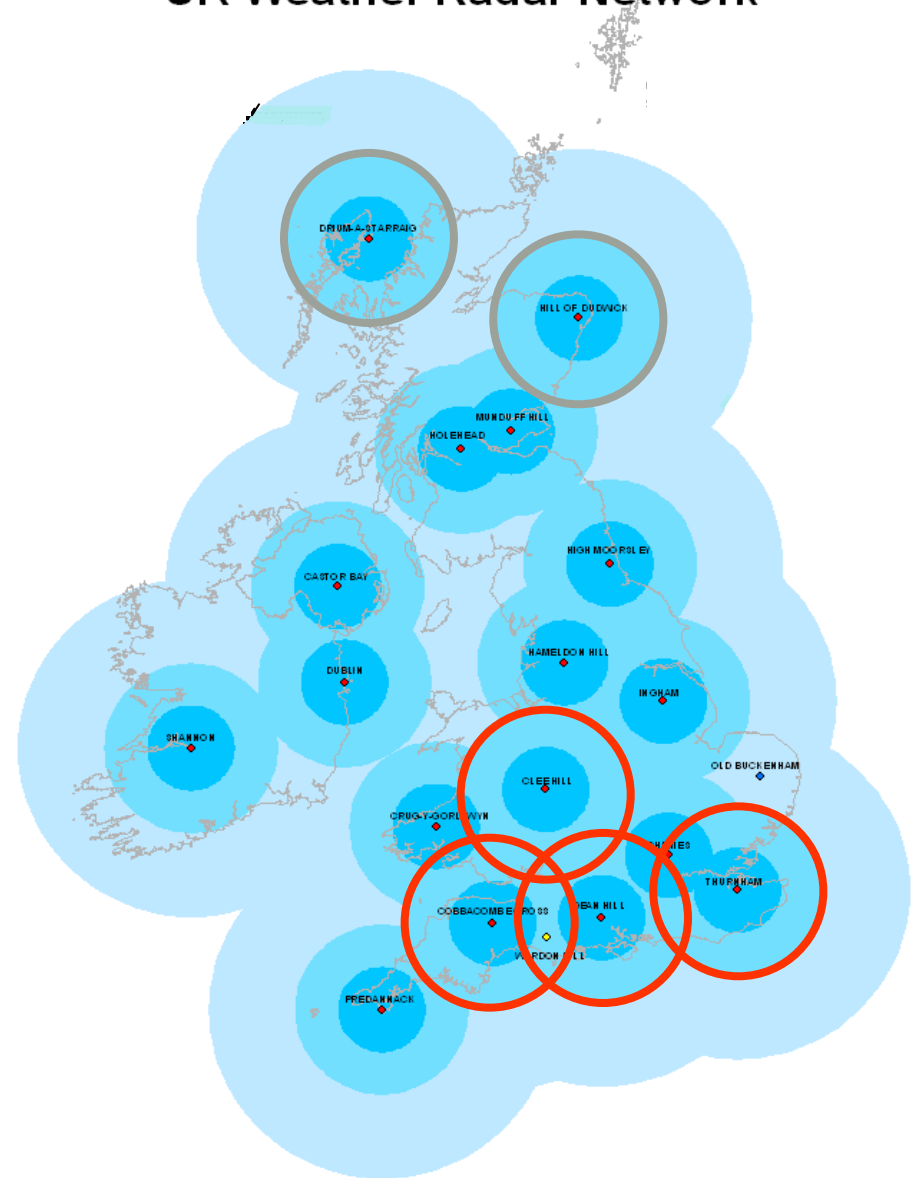
6 radars currently providing radial winds

(plans to upgrade whole network by 2015)

**4 currently assimilated operationally**

obs within 100 km radius  
elevations between 1° and 9°  
1° azimuthal, 600 m radial  
available every 5 minutes  
assimilated every 3 hours

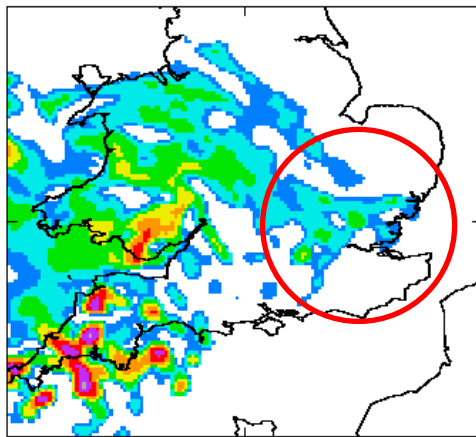
UK Weather Radar Network



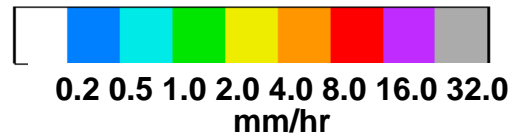
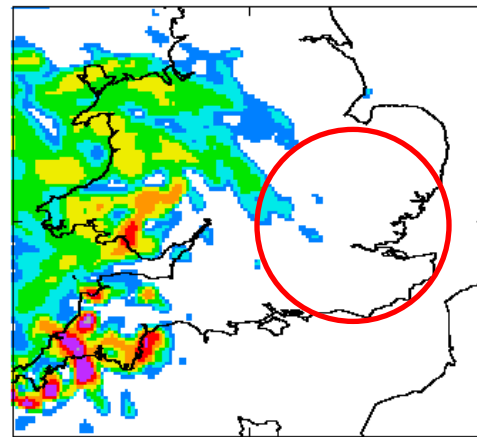


Individual case where rainfall location is seen to be improved

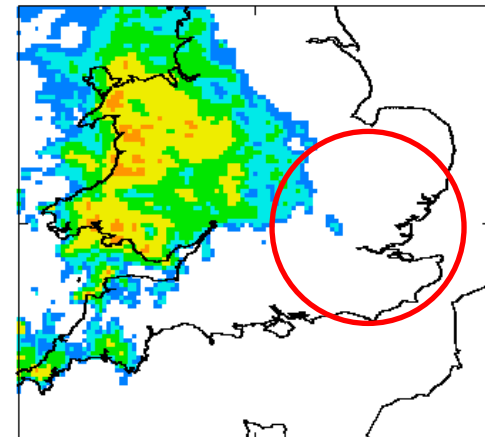
CNTL



CNTL +  
radial winds



Radar



T+4

Helen Buttery



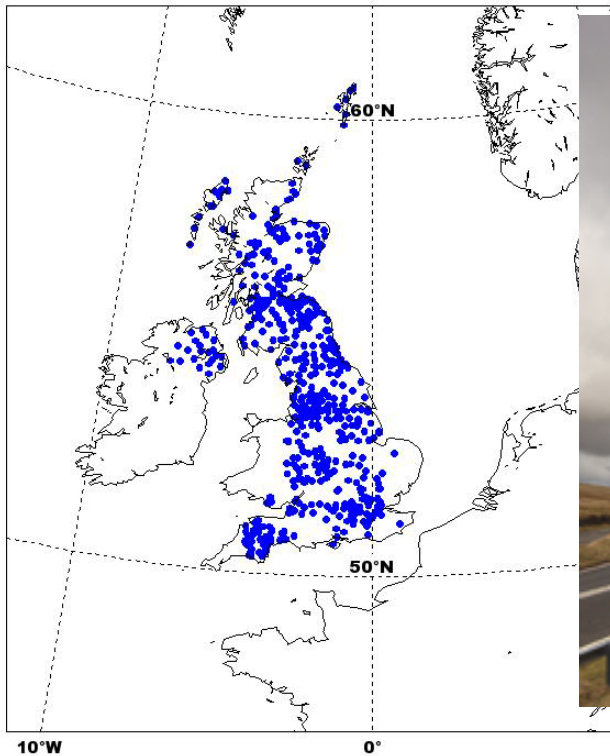
# Roadside sensor network

**OpenRoad – full network**

**SYNOP**

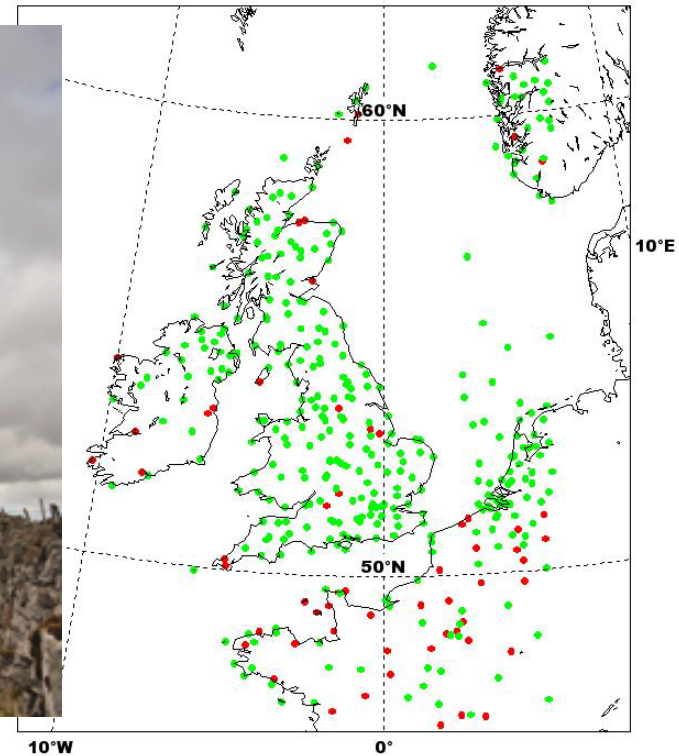
**Data Coverage: Surface (20/2/2010, 6 UTC)**  
**Total number of observations assimilated: 1507**

**OPENROAD (1507)**



**Data Coverage: Surface (20/2/2010, 6 UTC)**  
**Total number of observations assimilated: 1150**

**SYNOP (201) SYNOP AUTO (949) SYNOP MIXED (0)**





# Roadside sensor network impact

## Mean $T_{2m}$ error

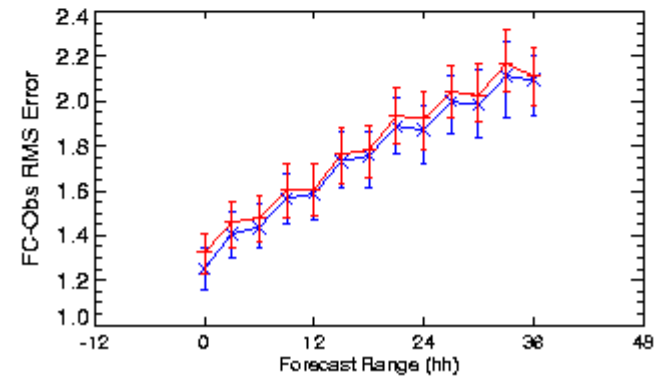
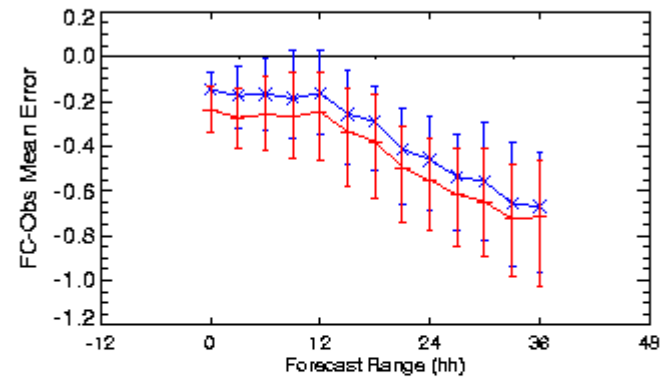
— control  
— test

## RMS $T_{2m}$ error

*(2<sup>nd</sup> half of Dec 2010)*

Temperature (Kelvin) at Station Height  
Reduced UK  
Equalized and Meaned from 1.

Cases: —+ UK4 PS25 Control    —x UK4 PS25 with All OpenF



# Summary

- ❑ Consistent Benefit for all elements from **full higher-resolution analysis** (except perhaps for wind) relative to downscaled analysis
- ❑ Mixed performance from the **extra observations**
  - Sometimes detrimental to the UK Index scores
  - Consistent summer precipitation benefit up to T+6 from Radar RainRate (**LHN**) and for some thresholds to T+12
  - **MOPS cloud** shows overall benefit for cloud cover, but not so good for SCu
  - Visibility – higher thresholds benefit from vis assimilation, lower thresholds sensitive to RH bias
- ❑ Shower spin-up is a significant weakness in the downscaler
- ❑ DA impacts don't necessarily appear at T+1 !



# Further Work

- Do additional trial configurations to decipher signals from individual obs types
- Assess benefit from staggered Data Times
- Look at sensitivity of DA signal to synoptic conditions
- Adjoint-based impact studies in the UK Model (see Richard Marriott's talk tomorrow)



# Questions ?

With thanks to: Bruce Macpherson, Mark Weeks, Dale Barker, Jorge Bornemann, Richard Renshaw, Helen Tubbs, David Simonin

And others...

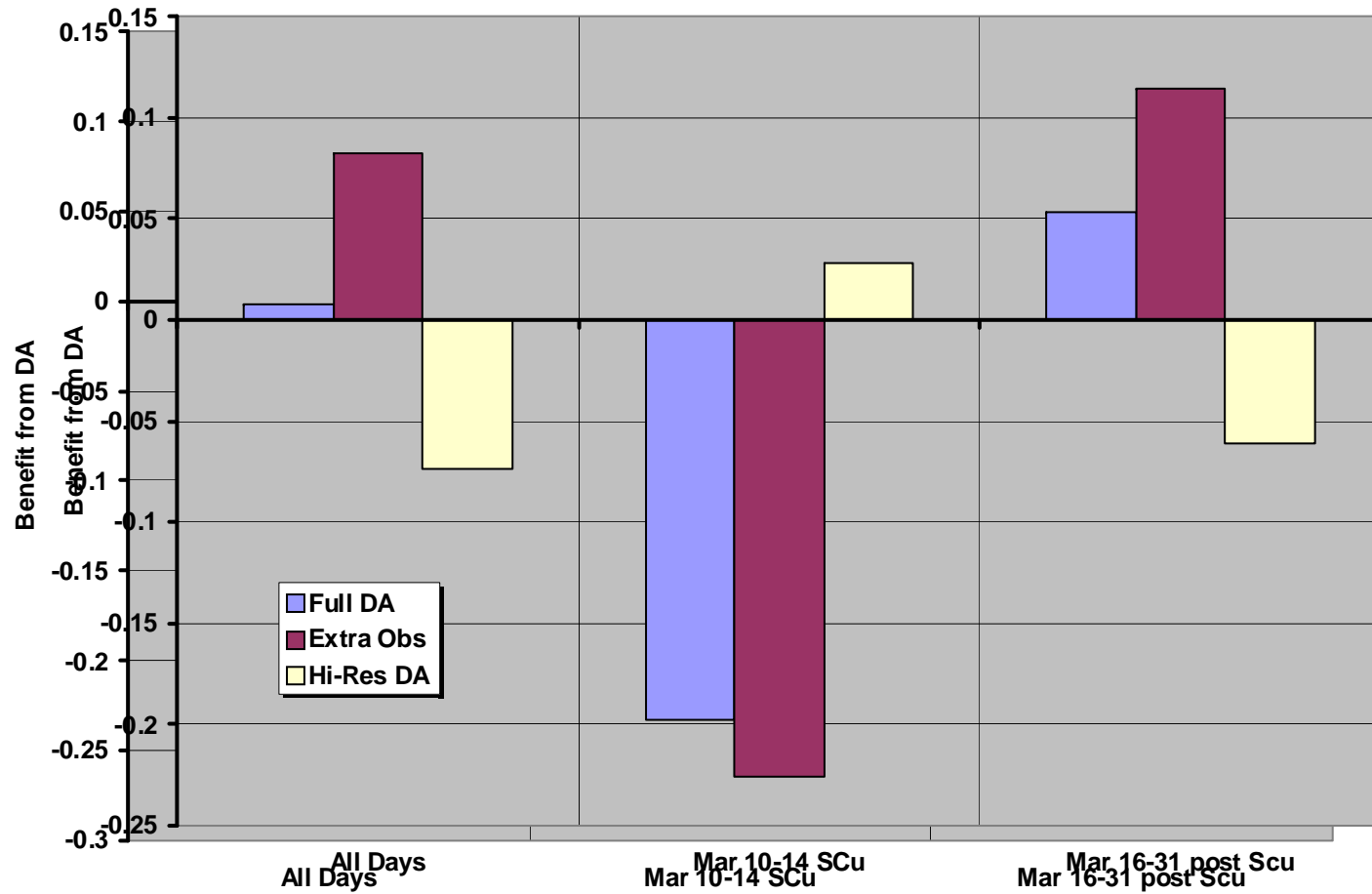




# Extra slides...



# March SCu DA Problems





Met Office

# Operational NWP Models: July 2012

## Global

- 25km 70L
- Hybrid 4DVAR – 60km inner loop
- 60h forecast twice/day
- 144h forecast twice/day

LBC

## NAE

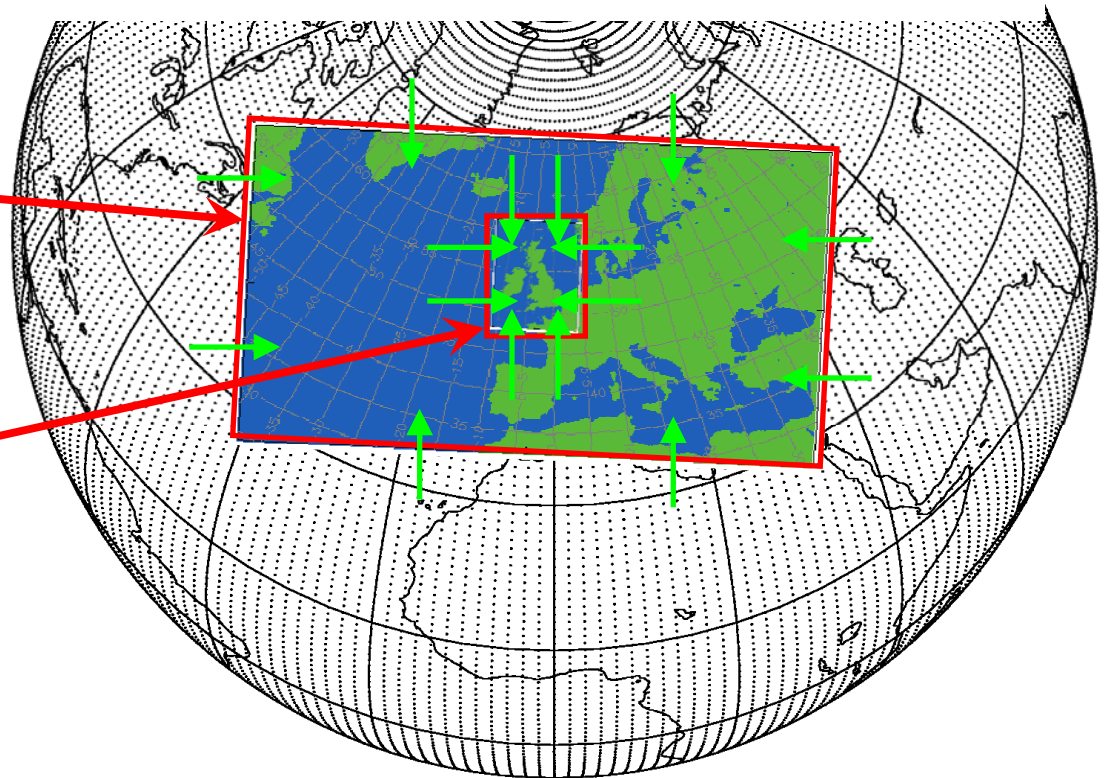
- 12km 70L
- 4DVAR – 24km
- 60h forecast
- 4 times per day

LBC

## UK4 (& UKV)

- 4km/1.5km UK 70L
- 3DVAR (3 hourly)
- 36h forecast
- 4 times per day

# Better large-scale Analysis from Global cf NAE

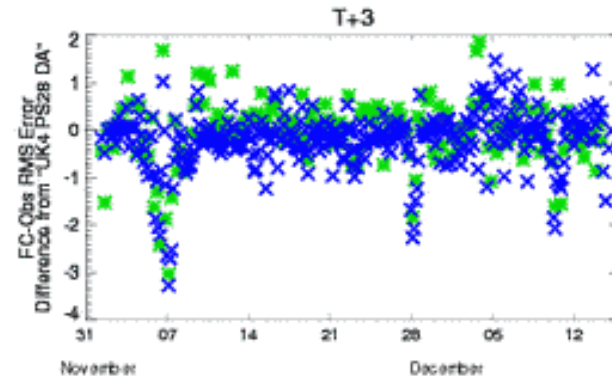
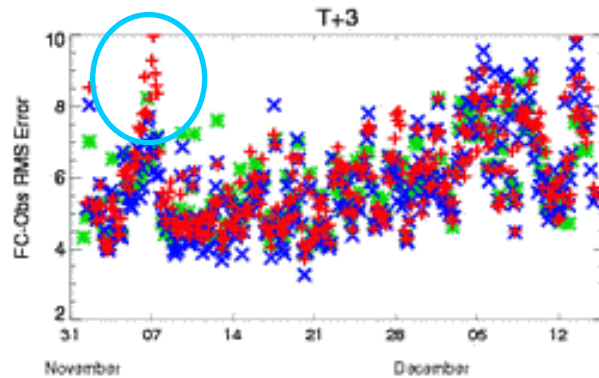
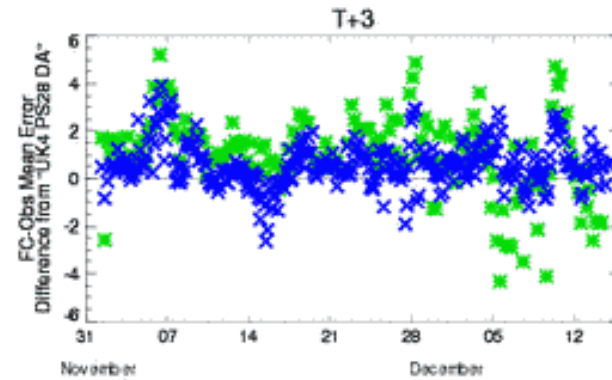
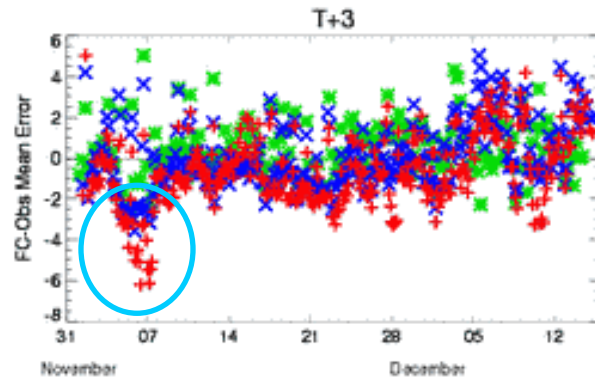




# RH<sub>2m</sub> DA Dry Bias

Relative humidity (%) at Station Height: Surface Obs  
WMO Block 03 station list

Cases: + UK4 PS28 DA x UK4 PS28 NHR DA x UK4 PS28 DS



Mean Error	Mean Difference from 'Full DA' trial	Full DA
RMS Error	RMS Difference from 'Full DA' trial	Partial DA
		DownScaler
		Partial DA + Visibility

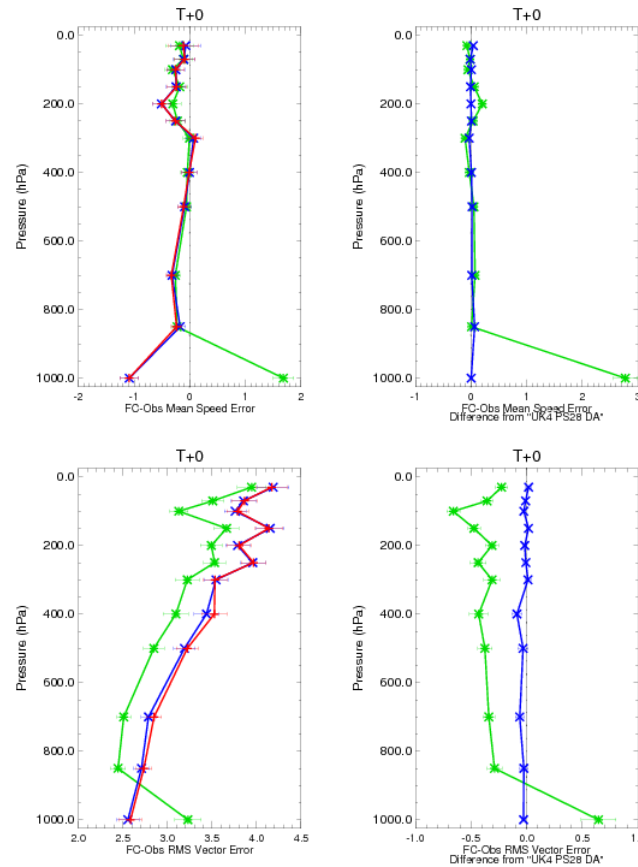


# Verification vs Radiosonde

T+0  
 Temperature  
 Relative Humidity  
 Wind Vector

Wind (m/s): Sonde Obs  
 WMO Block 03 station list  
 Equalized and Meaned from 1/11/2011 00Z to 15/12/2011 23Z

Cases: — UK4 PS28 DA — UK4 PS28 NHR DA — UK4 PS28 DS



Bias

RMS

68% error bars calculated using  $S/(n-1)^2$

Full DA —

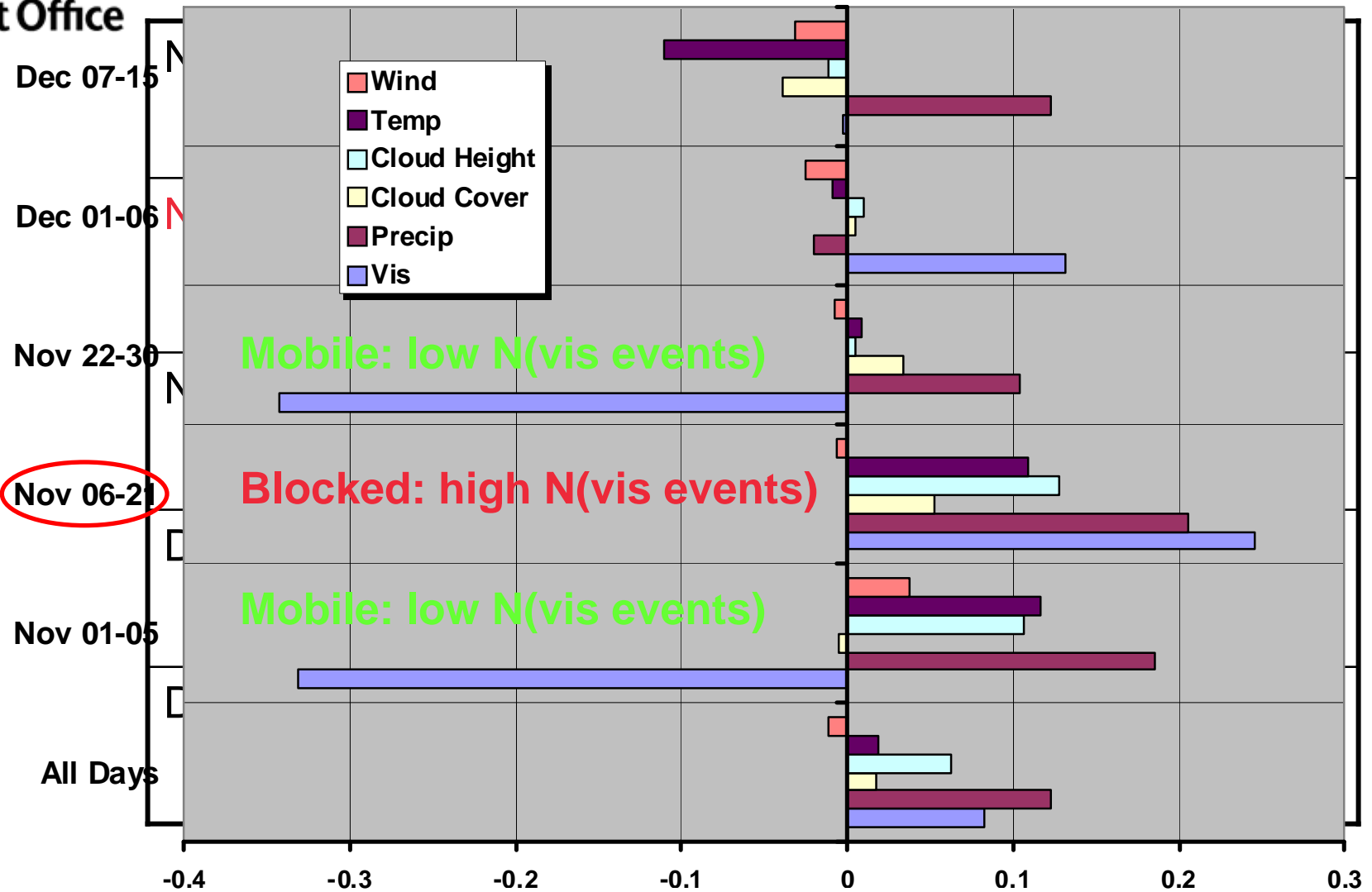
Partial DA —

DownScaler —



# Nov 2011 Verification by Synopsis

Met Office



## Benefit from Full DA



# UK4 Downscaler Configuration & Analysis

## As UK4 except

- Runs **4x daily**
- 2stage 4D-Var assimilation at 120km/60km resolutions, **resulting 25km Global Analysis then reconfigured to 4km/UK4 70 levels**
- Prognostic 'murk aerosol' value for visibility (constant value in operational)
- Global Obs Cut Off ~ hh+160 mins



# Obs in both Global & UK4

Observation type	Notes	Global	UK
<b>SYNOPs and METARS</b>	<b>Surface Pressure U,V Temperature and RH</b>	✓ ✓ ✓	✓ ✓ ✓
<b>Drifting buoys</b>		✓	✓
<b>Aircraft</b>	<b>AIREPS, AMDARS</b>	✓	✓
<b>Sondes</b>	<b>TEMP, PILOT, Dropsondes</b>	✓	✓
<b>Wind profilers</b>	<b>European radars (excluding those giving radial winds)</b>	✓	✓
<b>Satellite atmospheric motion winds</b>	<b>Meteosat-9 (IR,WV, VIS)</b>	✓	✓
<b>GPS - ZTD</b>	<b>METOP-A ASCAT and Coriolis Windsat</b>	✓	✓
<b>AIRS, IASI</b>	<b>Clear sky radiances</b>	✓	✓
<b>GOES</b>	<b>Mostly EU and US wind profilers</b>	✓	✓





# Obs only in the Global

Observation type	Notes	Global	UK
Satellite atmospheric motion winds	Meteosat-7 (IR,WV, VIS)	✓	-
	GOES-11 (IR,WV)	✓	-
	GOES-12 (IR,WV)	✓	-
	MTSAT-1R (IR,WV, VIS)	✓	-
	AQUA, TERRA - MODIS (IR,WV)	✓	-
	AVHRR polar (IR)	✓	-
GPS - RO	COSMIC1-6, GRAS, CHAMP & GRACE-A	✓	-
ATOVS	Radiances (NOAA15,17,18,19 METOP-A)	✓	-
SSMIS	AMSU-A radiances DMSP F16	✓	-
AIRS, IASI	A radiance subset from AQUA and METOP-A	✓	-
GOES	Clear sky radiances	✓	-



# Obs only in the UK4

Observation type	Notes	Global	UK
<b>SYNOPS and METARS</b>	<b>Visibility</b>	-	✓
<b>OpenRoad</b>	<b>Temperature and RH from Highways Agency sites</b>	-	✓
<b>GPS - ZTD</b>	<b>Zenith total delay (giving total column water vapour) using ground-based GPS receivers</b>	-	✓
<b>Doppler radial winds</b>	<b>4 radars in southern UK</b>	-	✓
<b>MOPS cloud</b>	<b>Satellite &amp; surface derived 3-d cloud fraction</b>	-	✓
<b>Radar rain rate</b>	<b>5km European composite</b>	-	✓