Improvement of wind forecasts through limited area modelling

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Contents

This presentation covers the following areas

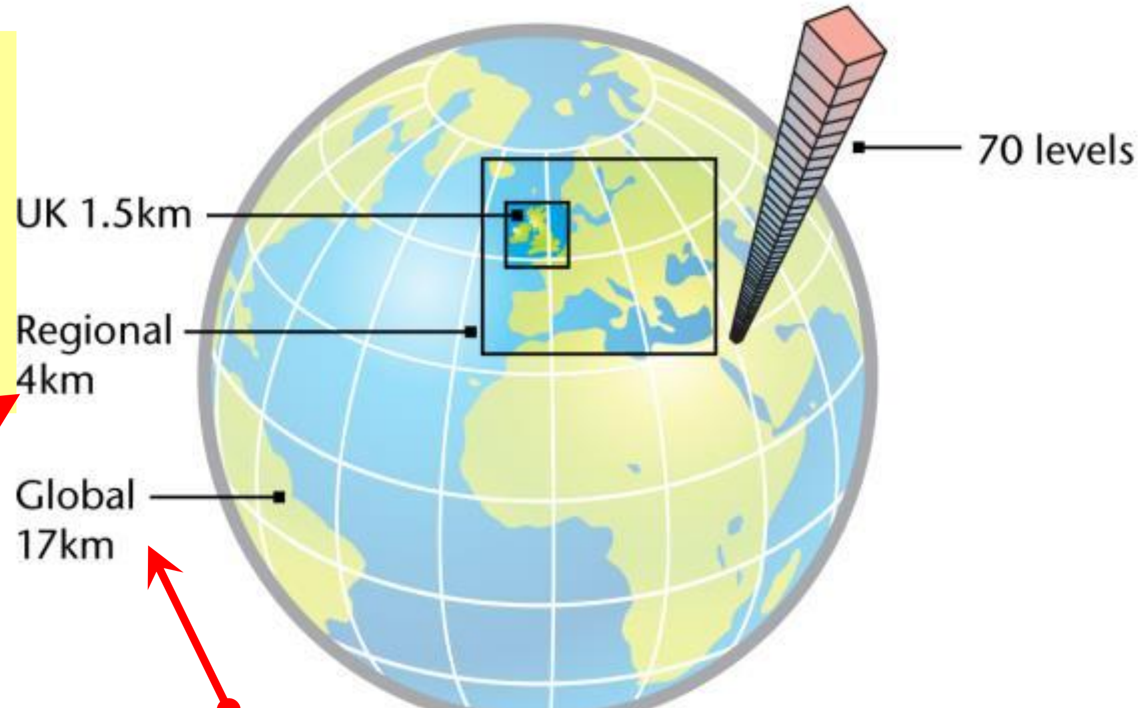
- Numerical weather prediction
- Benefits of limited area (mesoscale) modelling
  - Wind resources – cf global & reanalyses
  - forecasts
- Finer-scale models (~100m)
- Prospective improved finer-scale reanalyses
- Wind Power forecasts

2013 NWP Models Seamless Suite

Met Office

UKV and MOGREPS-UK

- 1.5km 70L (40km model top)
- 3DVAR
- 36hr forecast
- 8 times per day
- 12-member EPS - 2.2km 4x/day 36h



Euro4

- 4km 70L (40km model top)
- Global downscaler
- 66hr forecast twice/day
- 144hr forecast twice/day

Global and MOGREPS-G

- 25km 70L (80km model top) (17km from PS34)
- Hybrid 4DVAR – 60km
- 66hr forecast twice/day
- 144hr forecast twice/day
- 12-member EPS - 33km 4x/day 72hr
- 24-member EPS - 60km 2x/day 15d

EPS=ensemble prediction system

Model levels – focusing on the near surface

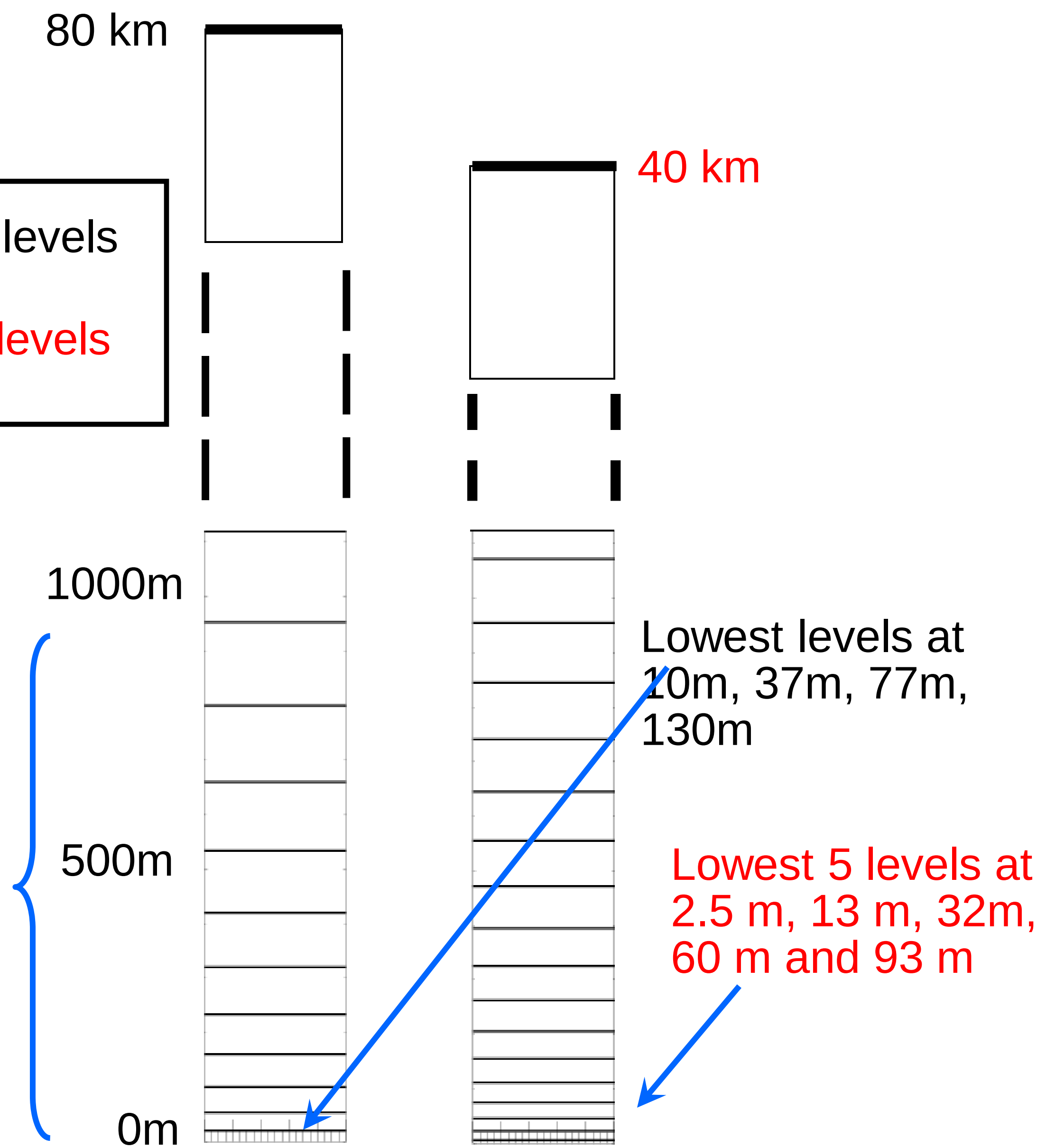
LEFT:- Global and 12 km model levels

RIGHT:- 4 km and 1.5 km model levels

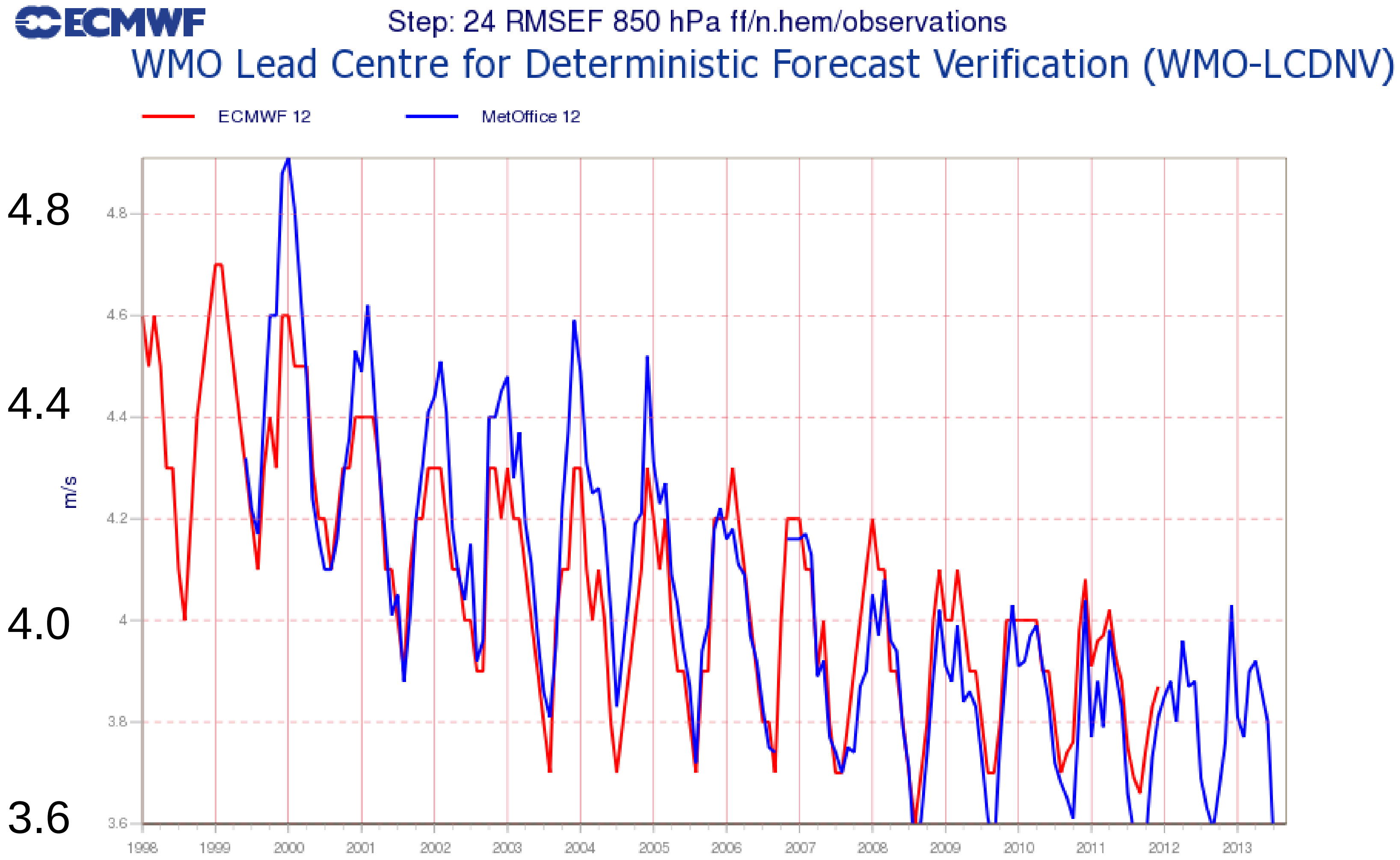
Lowest 1000m

Global +12km L70: 11 levels

4km + 1.5km L70: 16 levels



Global Model forecasts
wind accuracy – 850hPa (~1.5km)

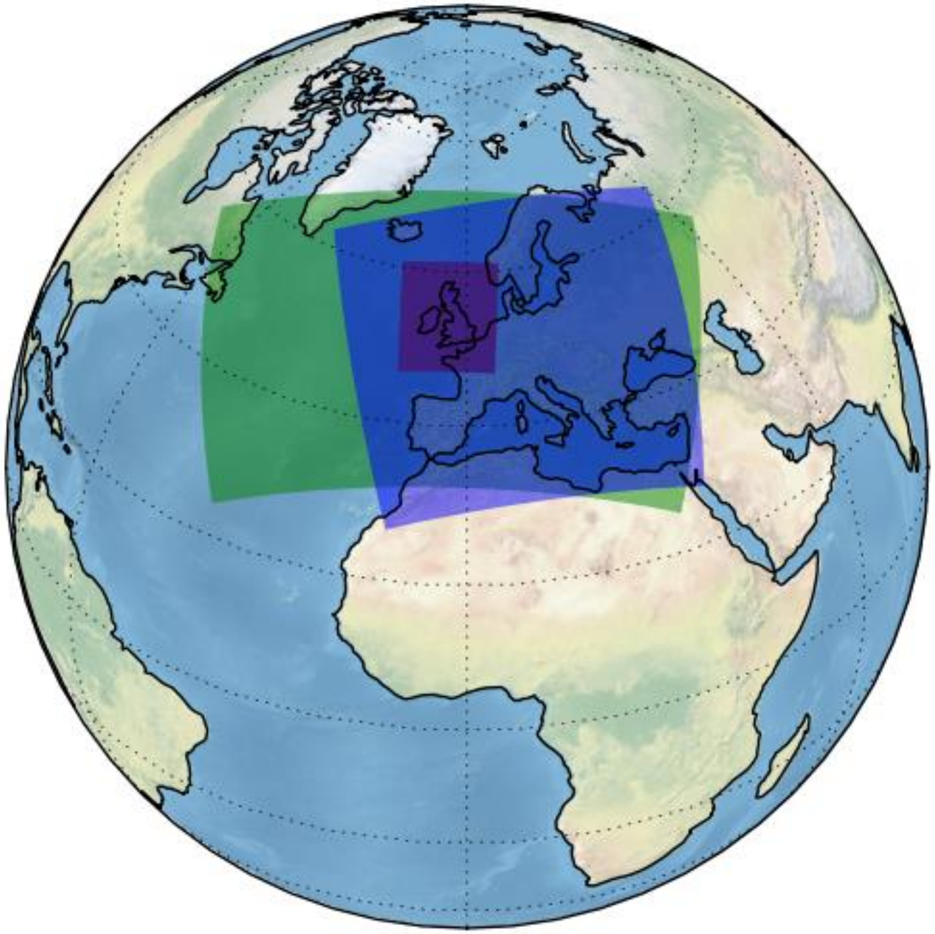


Operational Limited area models

NAE – 12km

Euro4 -4km

UKV – 1.5km

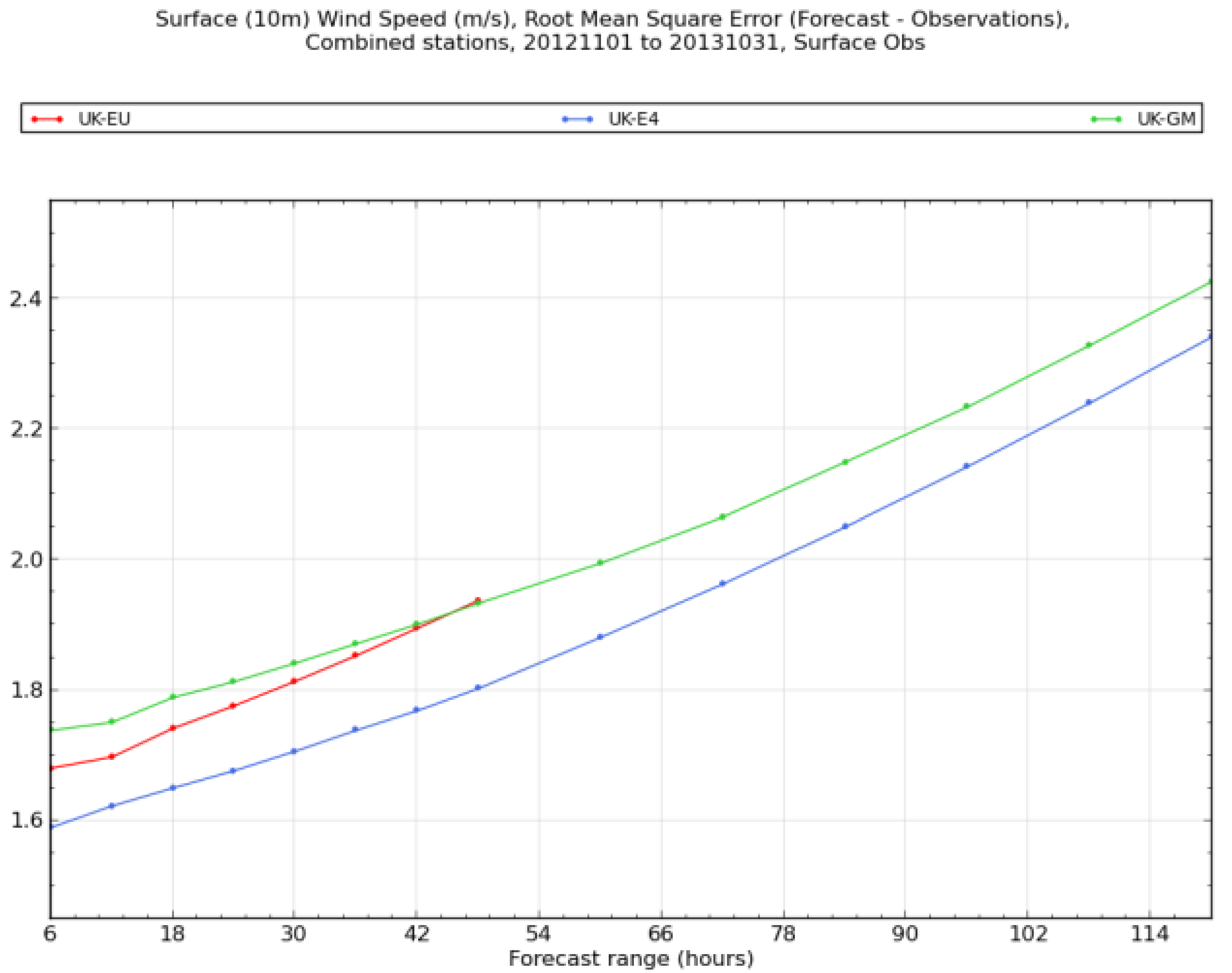


Added benefit LAMs over global – 1 year verification 10m winds

Global -25km

NAE - 12km

Euro4 -4km

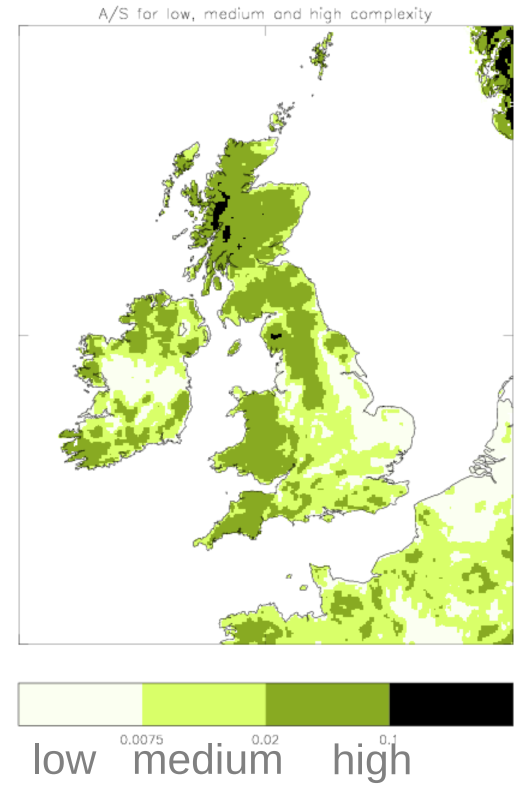


Met Office

Reanalyses + global data

Data	**Resolution**	**Resolution & Levels used**	**nominal heights / m**	**Temporal frequency**
ERA-Interim	TL255 (~80km)x 60 levels	0.5^o x 0.5^o Lowest 6 hybrid	10,30,60,100 ,160,240	3 hourly
MERRA	$2/3^o$ x $½^o$ x 72 levels	$2/3^o$ x $½^o$ Lowest 2 sigma	60,180	6 hourly
MERRA 10_50	$2/3^o$ x $½^o$ x 72 levels	$2/3^o$ x $½^o$ 10,50m diagnostic	10,50	hourly
NCEPNCAR (R1)	T62 x 28 levels	2.5^o x 2.5^o Lowest 3 sigma	40,150,300	6 hourly
CFSR	T382x 64 levels	0.5^o x 0.5^o 10m, level1, sigma=0.995, p=975,950 hPa	10,20,40,200,400	hourly
EC operational deterministic	TL511 (55km)x 60 levels T799 /91 levels	0.5^o x 0.5^o As ERA Interim to 01/02/2006 then lowest 7 of 91 levels	10,30,60,90, 140,200,260m	3 hourly
EURO4M – Met Office	***12km x 70 levels***	***12km, lowest 5 levels***	***10,35,75,130,200***	***6 hourly***

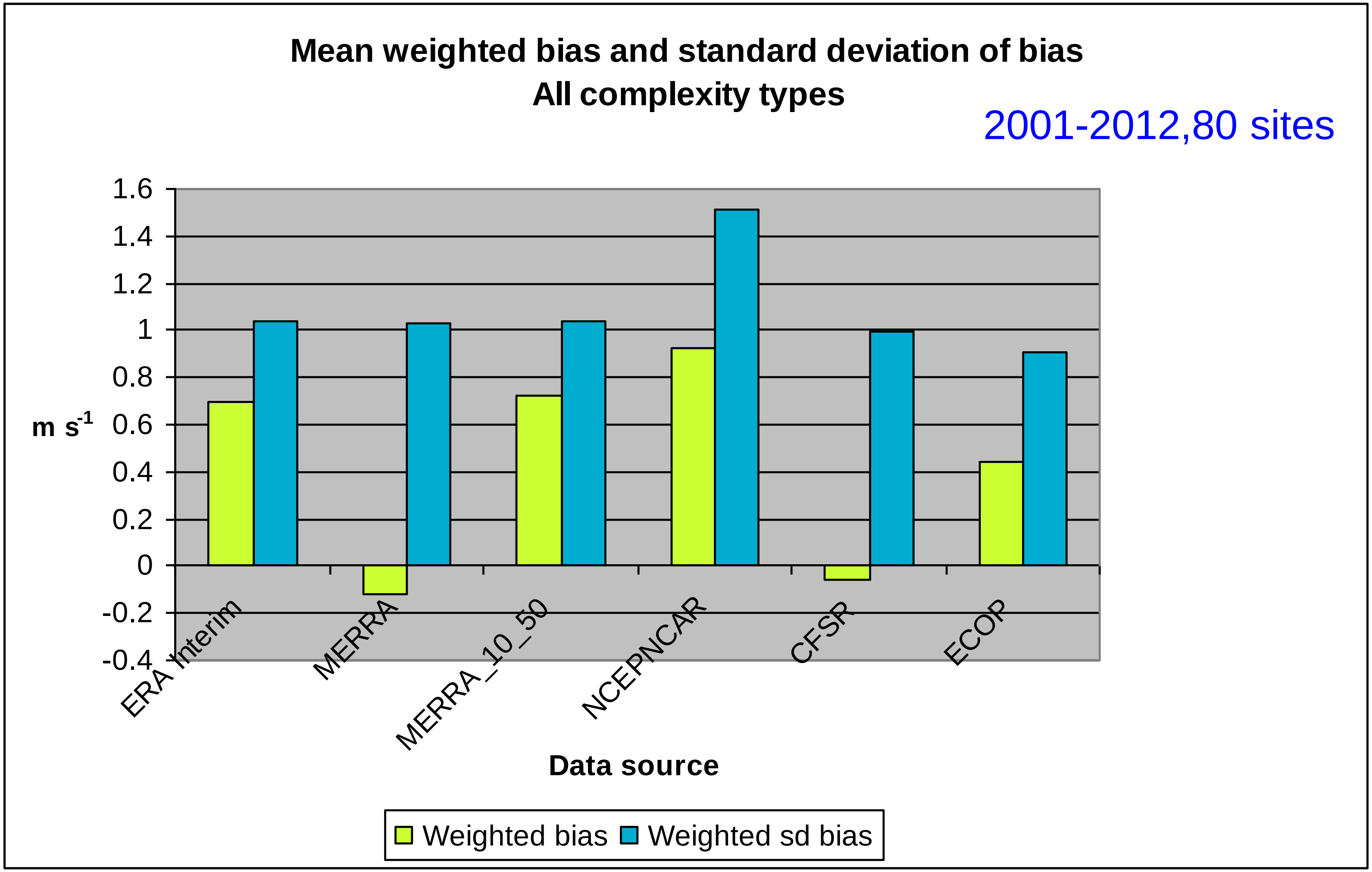
Direct use of reanalyses



- Interpolate to observed wind locations
  - Bi-linear horizontal
  - Vertical - logarithmic in height
- Verify with meteorological mast data
  - all at elevated heights >20m
- 185 sets of observations at 80 sites
  - 2001 to 2012

Complexity	Offshore	Near-shore	Orographic		
			Low	Medium	High
# sites	11	5	16	24	24
# sites x levels	21	10	38	68	47

Quality of direct use of reanalyses
Speed bias -mean and standard deviation



Added benefit of mesoscale models + "Virtual Met Mast"

Virtual Met Mast

Use archived and rerun Met Office mesoscale *weather forecast* models

- Downscaled reanalyses – ERA Interim

Local downscaling adjustments around site

Extension to long term climatology (32y 1979-2012)

Local wind maps

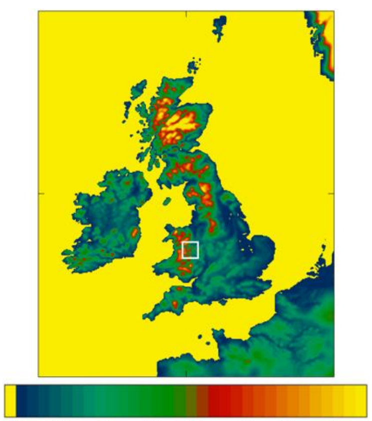
Verification and uncertainty estimates

High resolution modelling to improve adjustment

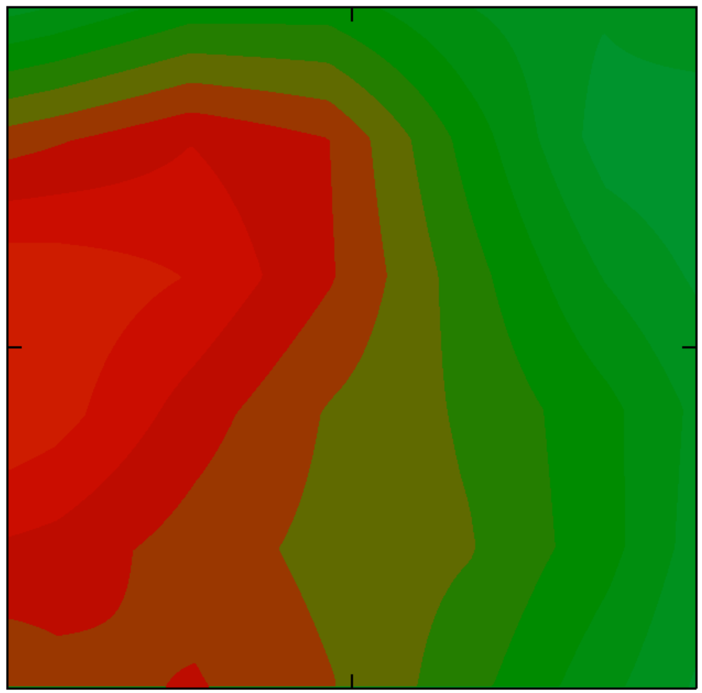
Incorporation of on-site mast observations (VMM **Plus**)

Parametrisation of effects of unresolved orography: eg over the COLPEX (Cold Air Pooling Experiment) region

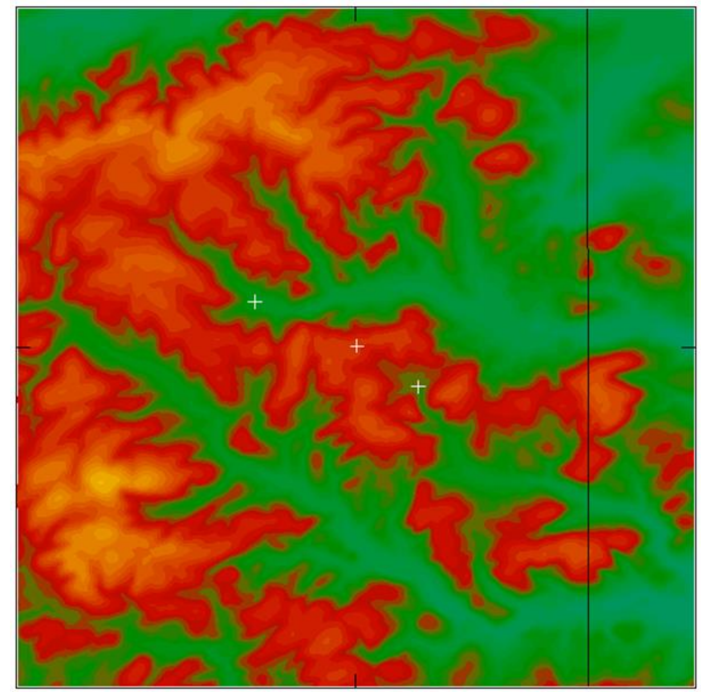
- Orographic Roughness scheme in NWP models accounts for drag due to unresolved terrain.
- Local wind predictions need to correct for this

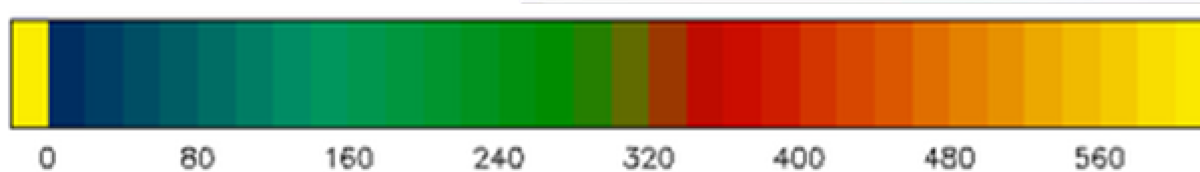


4 km model orography



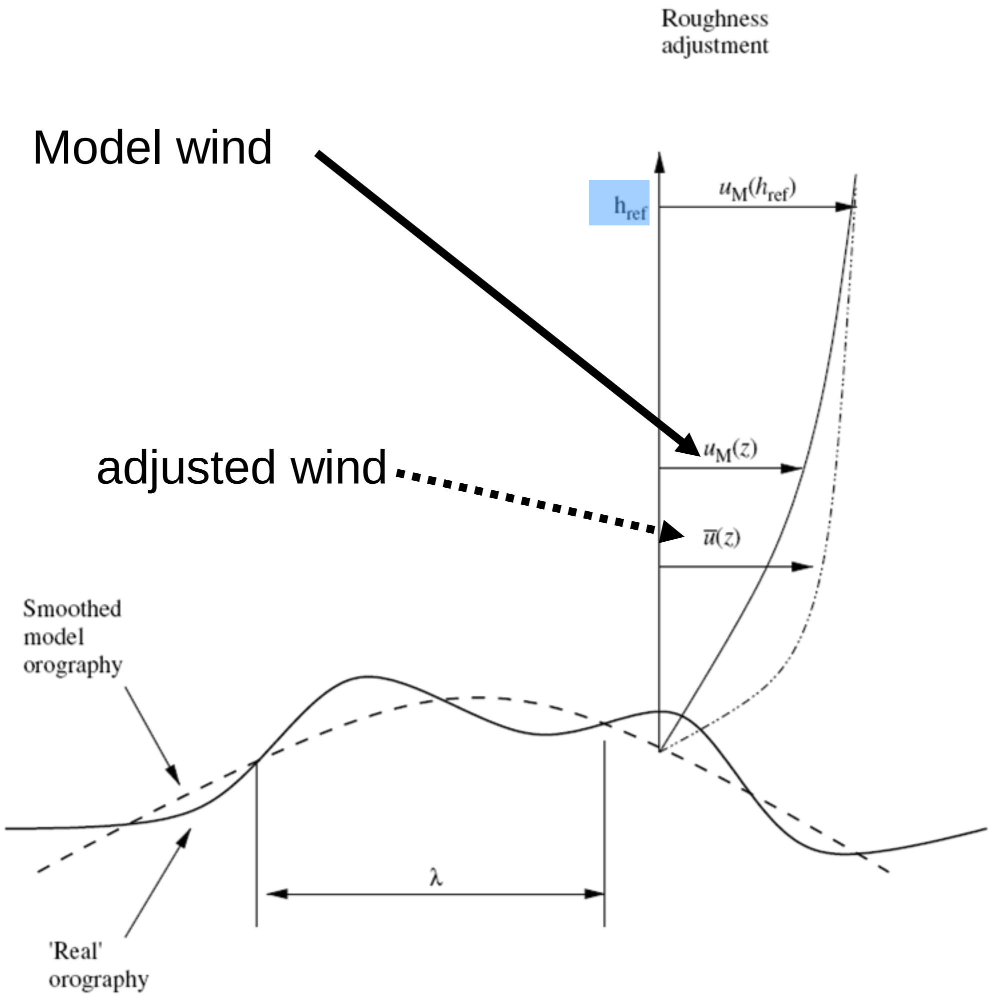
Terrain at 100 m resolution



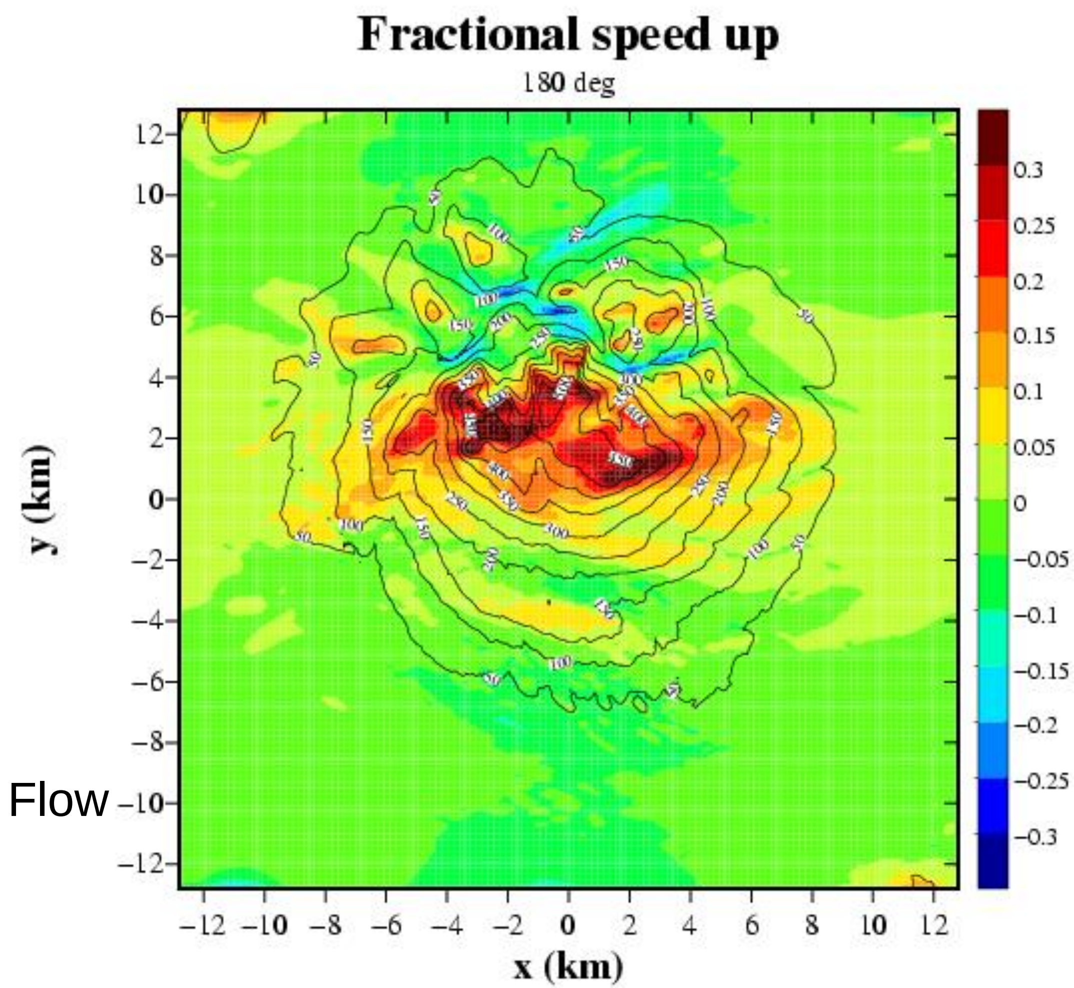


Height in Metres

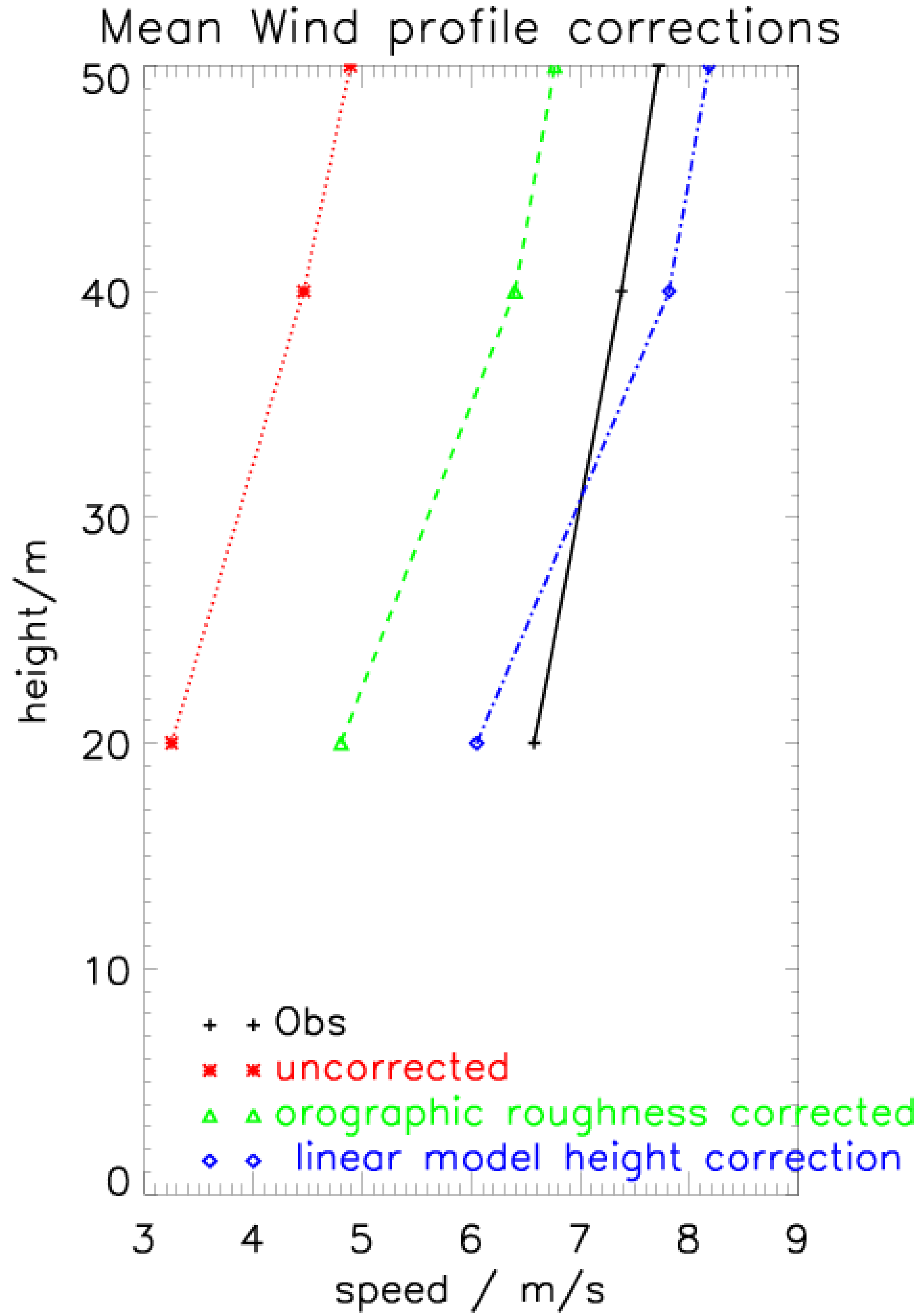
Land adjustments, Howard and Clark(2007) - roughness correction



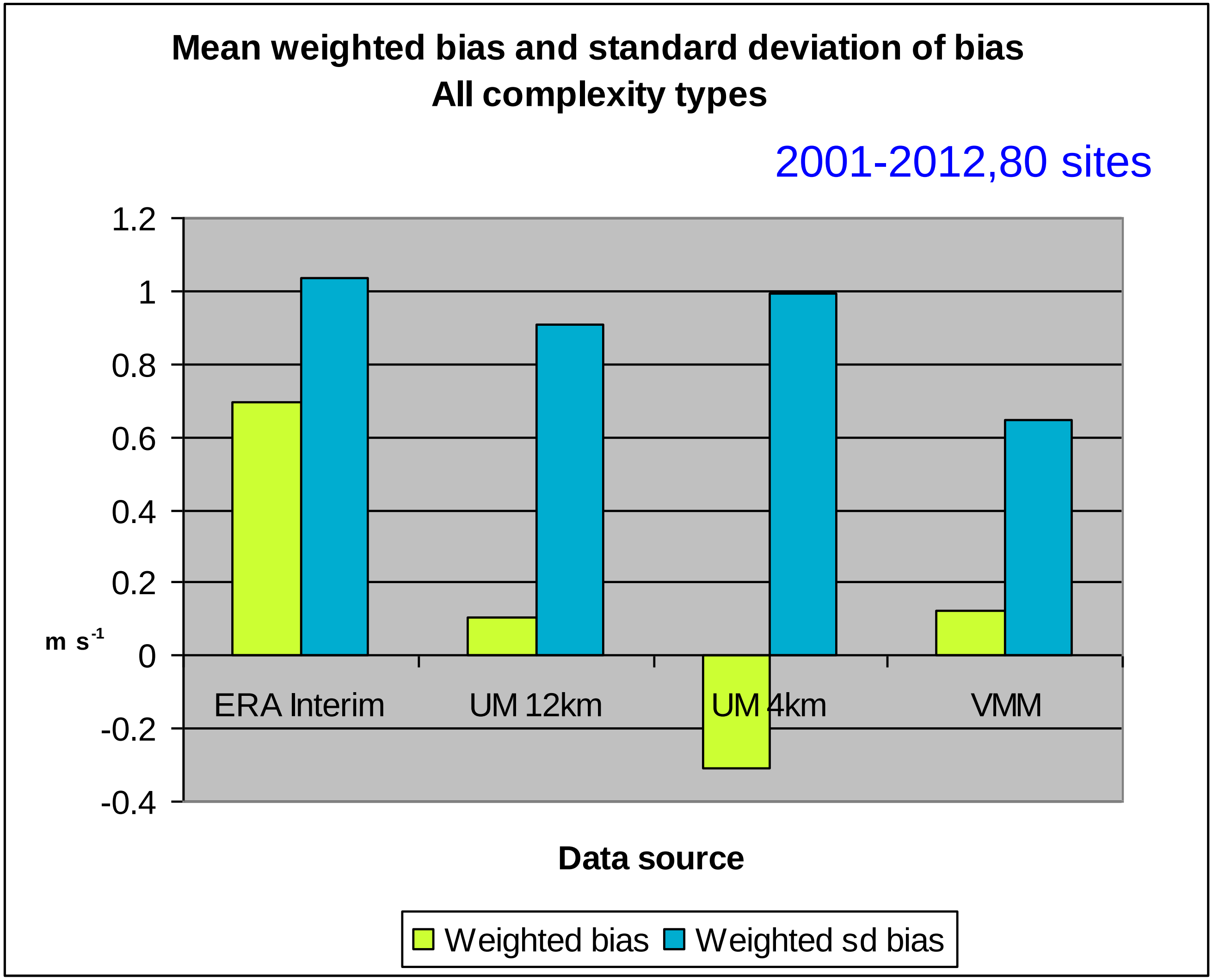
Height adjustment for local orography -Linear model

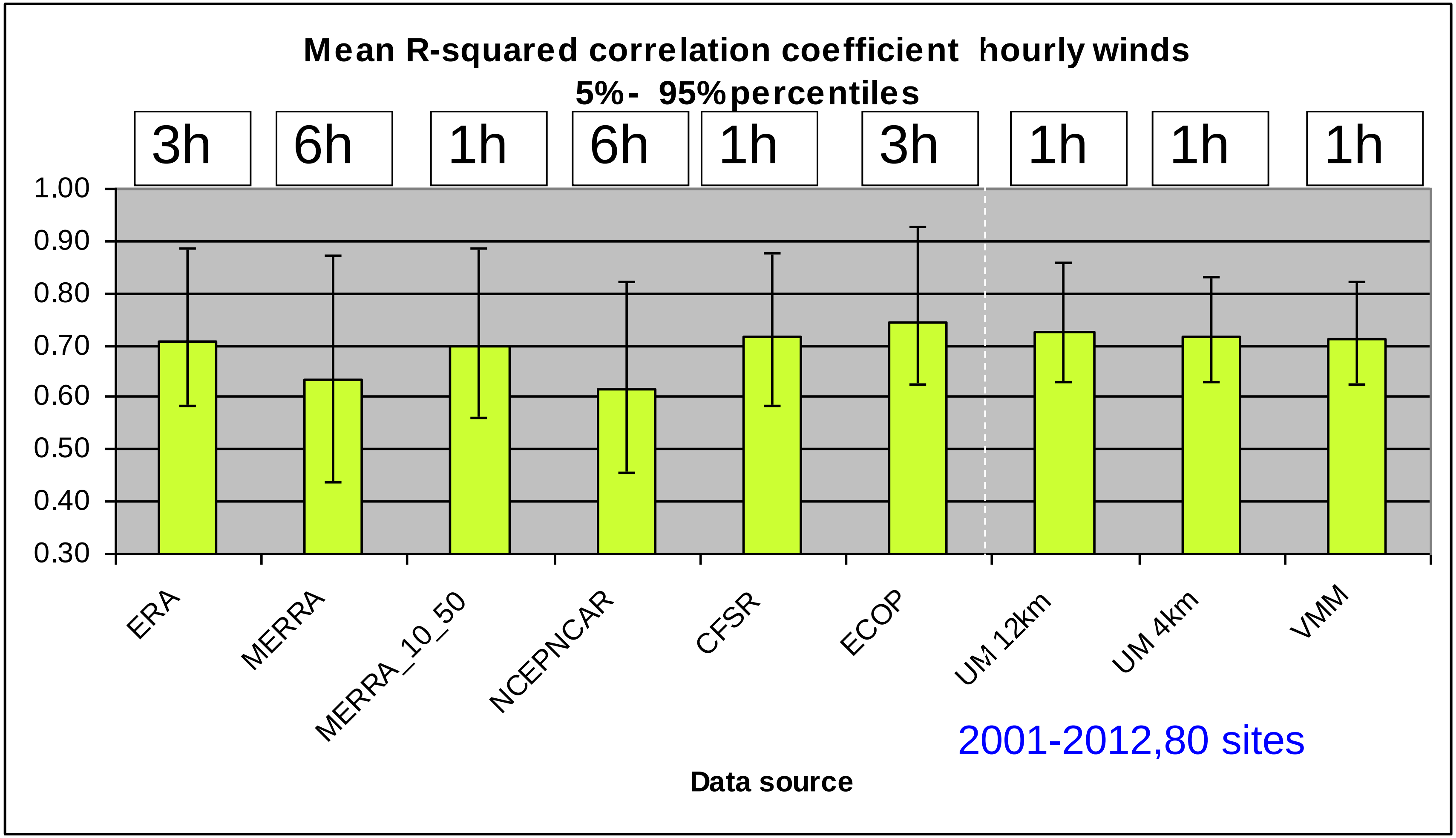


- Mason & King ‘model D’
- 100 m orography
- Tapered at edges of domain (25x25 km^2)
- Filtered to remove larger scales represented in mesoscale model
- Run for every wind direction with 5^o resolution

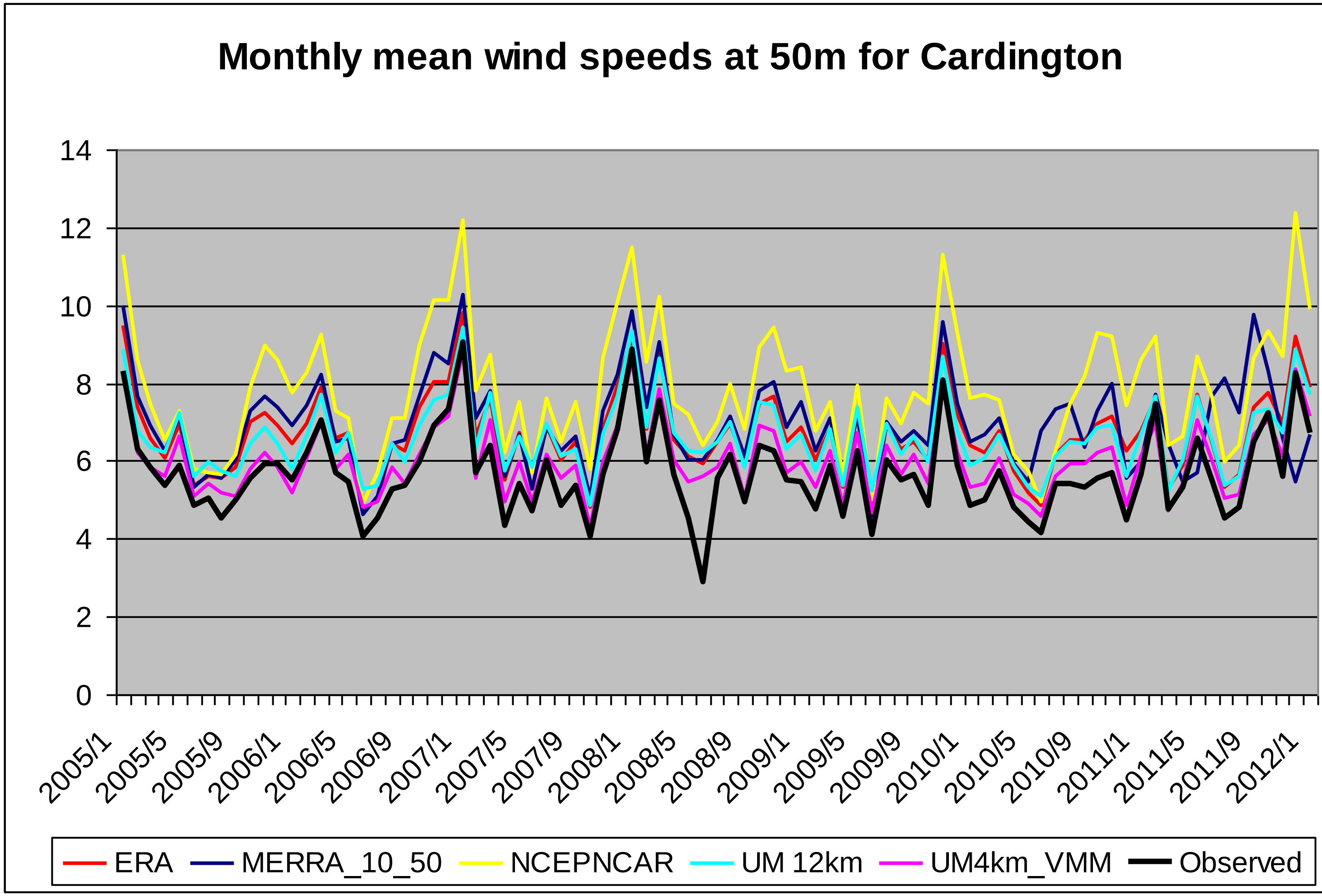


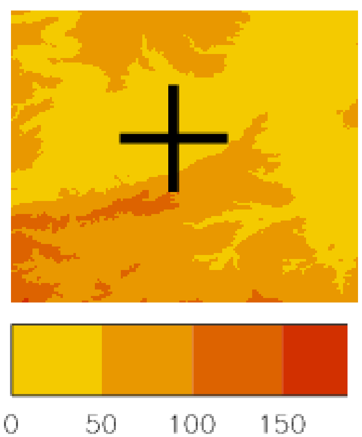
Mean Wind profile corrections
height/m
speed / m/s
50
40
30
20
10
0
3
4
5
6
7
8
9
Obs
uncorrected
orographic roughness corrected
linear model height correction


Mean weighted bias and standard deviation of bias
All complexity types
2001-2012,80 sites
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
m s-1
ERA Interim
UM 12km
UM 4km
VMM
Data source
Weighted bias
Weighted sd bias

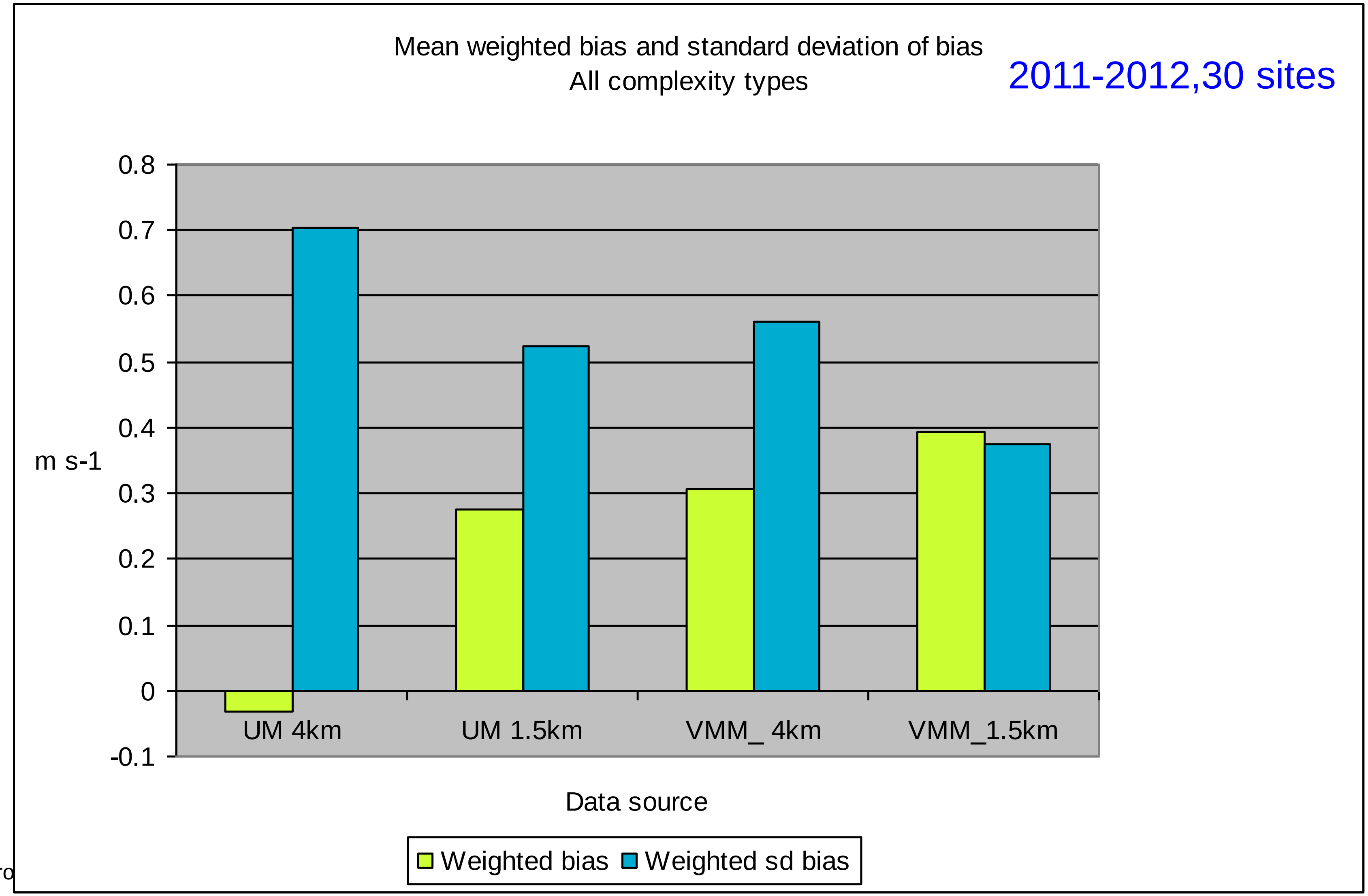


Mean R-squared correlation coefficient hourly winds
5% - 95% percentiles
3h
6h
1h
6h
1h
3h
1h
1h
1h
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
ERA
MERRA
MERRA_10_50
NCEPNCAR
CFSR
ECOP
UM 12km
UM 4km
VMM
2001-2012,80 sites
Data source

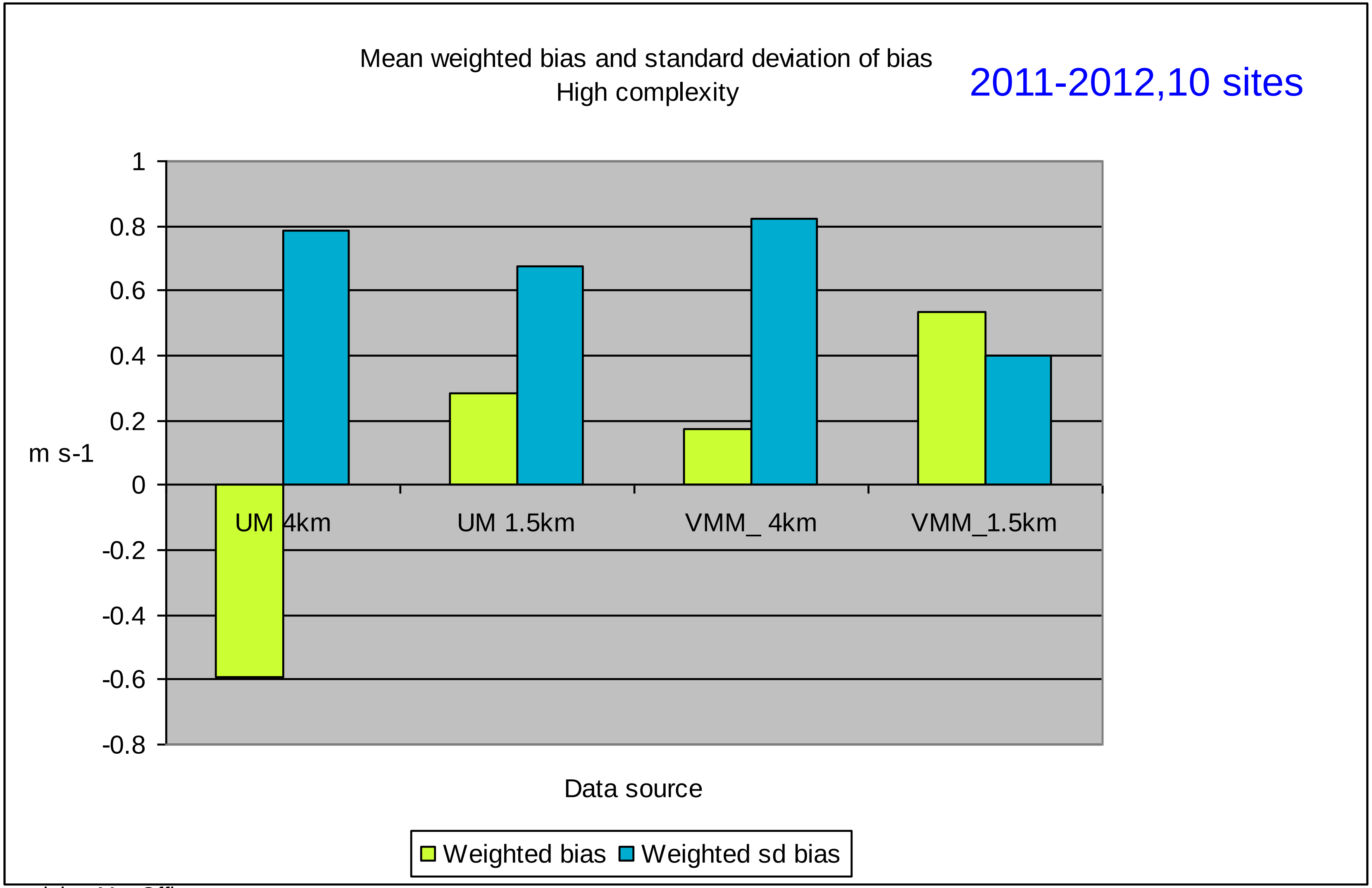

Monthly mean wind speeds at 50m for Cardington
14
12
10
8
6
4
2
0
2005/1
2005/5
2005/9
2006/1
2006/5
2006/9
2007/1
2007/5
2007/9
2008/1
2008/5
2008/9
2009/1
2009/5
2009/9
2010/1
2010/5
2010/9
2011/1
2011/5
2011/9
2012/1
ERA
MERRA_10_50
NCEPNCAR
UM 12km
UM4km_VMM
Observed


0
50
100
150

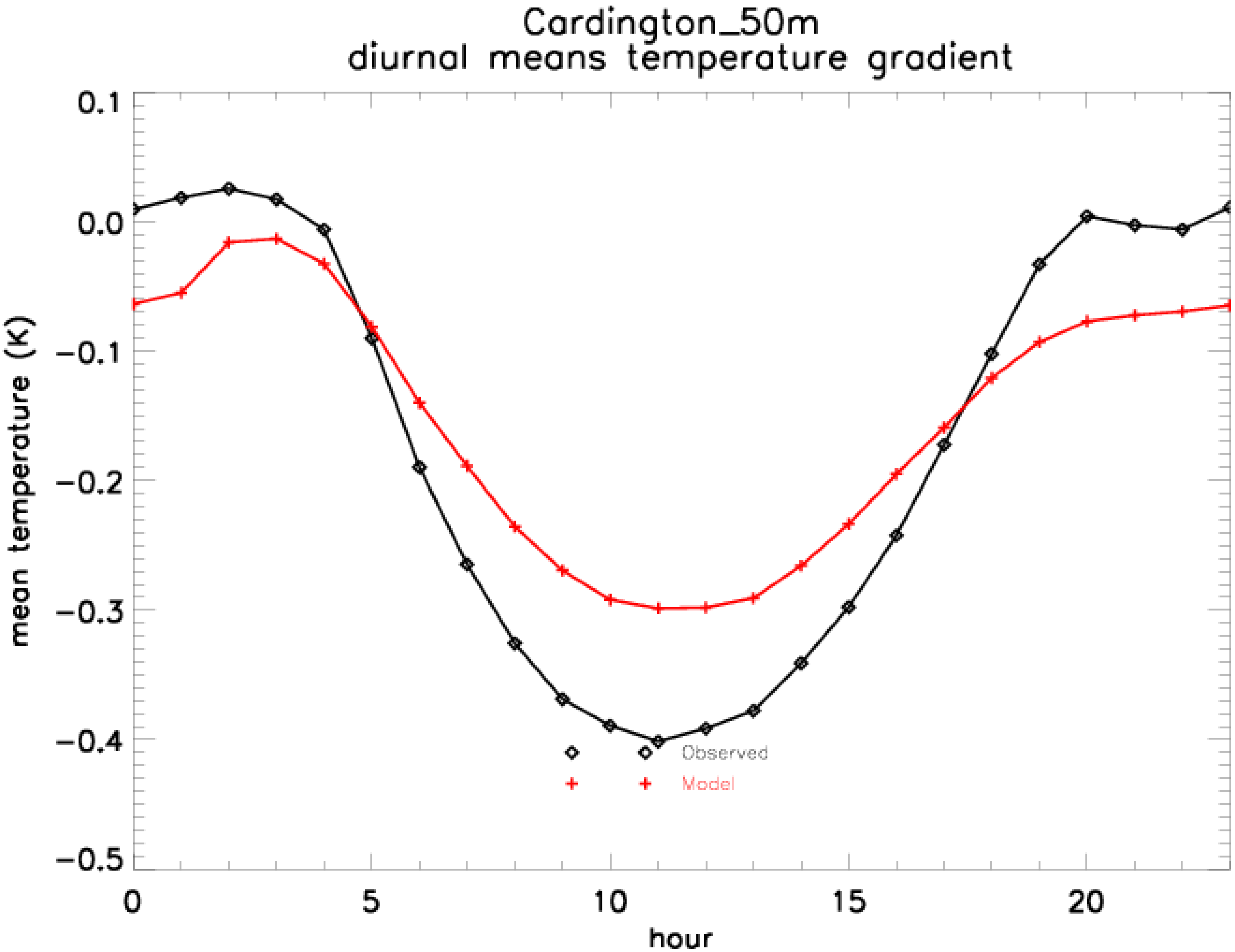
1.5km model improvement



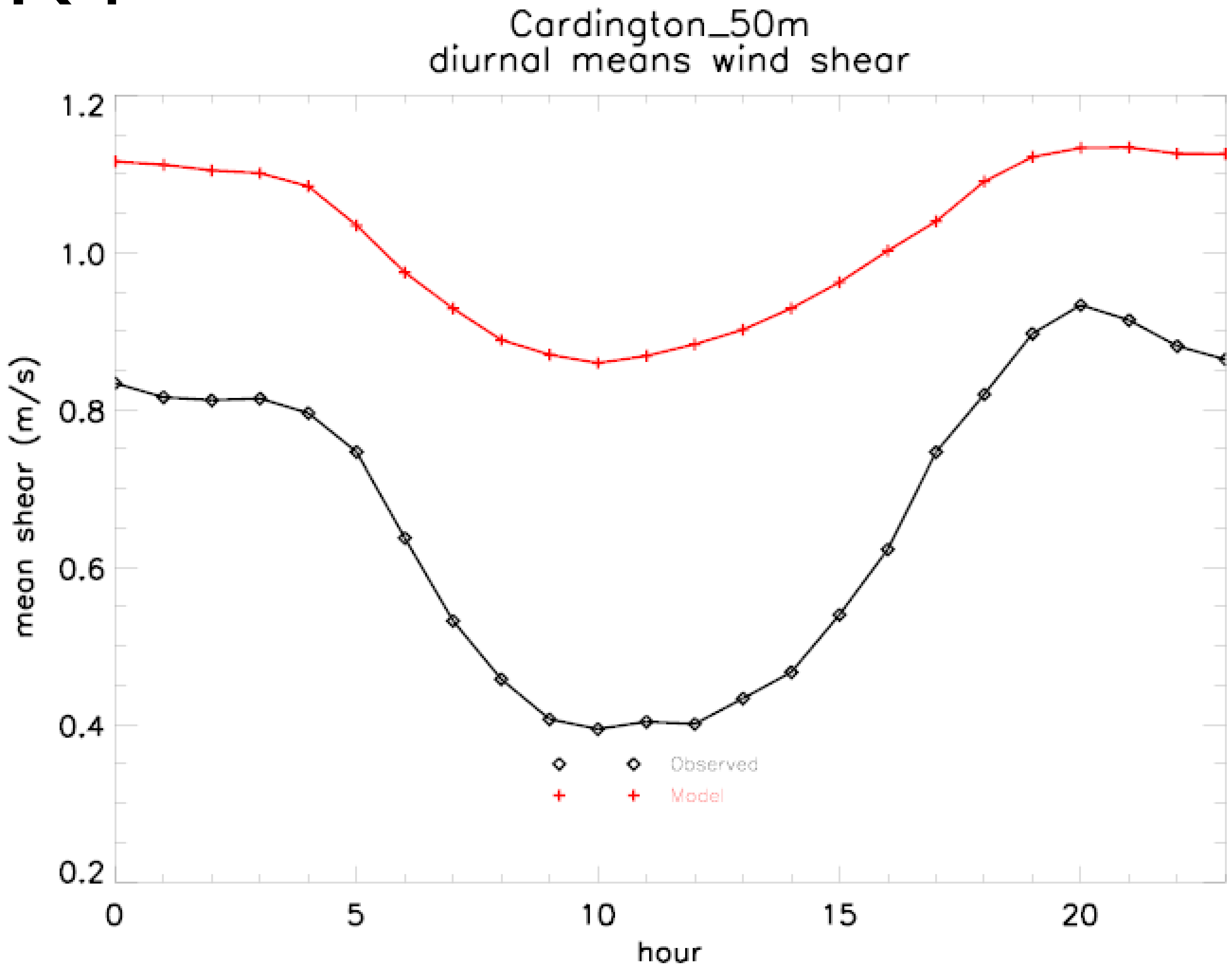
1.5km model improvement



Mean stability 50-25m – UK4



Mean speed shear 50-25m UK4



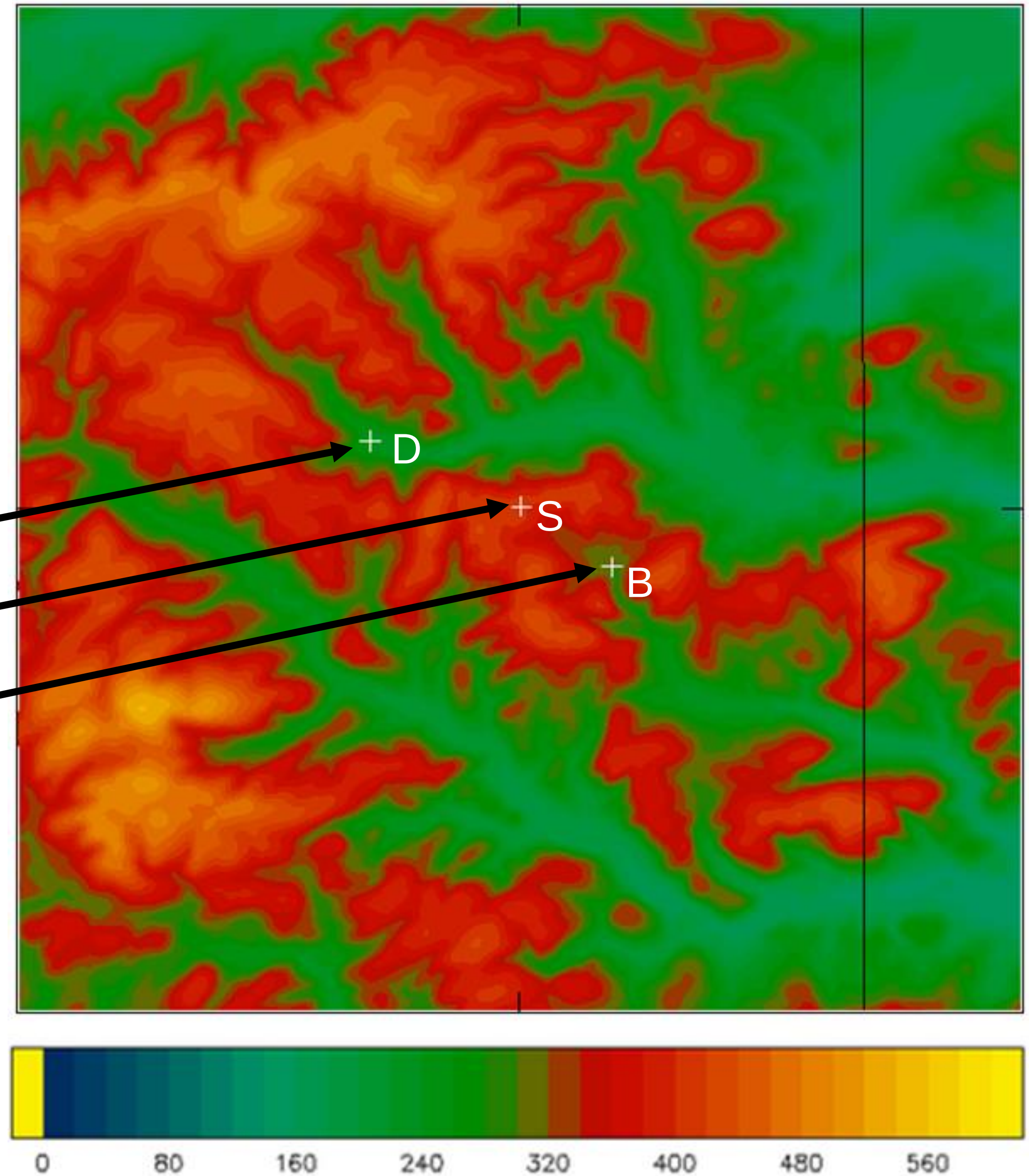
High Resolution modelling

Outline method

- Use nested suite
- Global(60km) →12km→4km→1km→330m→100m grids
- Short period 1-2 months of re-initialised daily cycles
- Derive statistical relationship between 4km and 1km,330 and 100m simulated winds
- Apply same parameters to rescale VMM downscaled winds

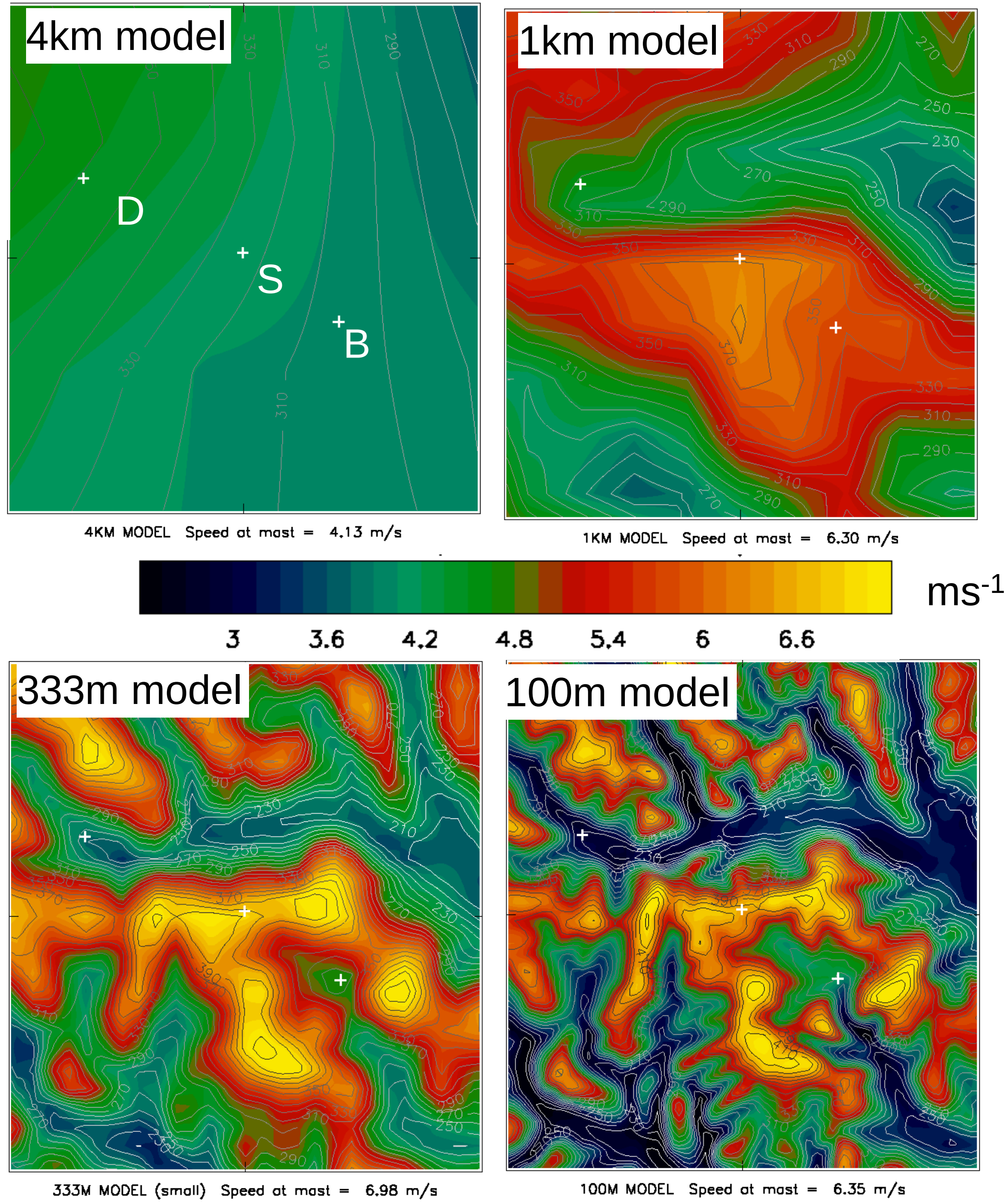
100 m model domain and orography

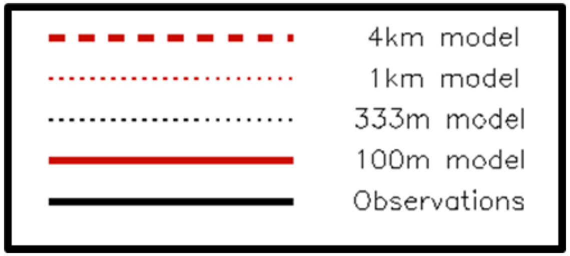
- Area = 20km x 20km centred on Springhill
- Masts at:-
  - **D**uffryn (main valley)
    - 50m
  - **S**pringhill (valley rim)
    - 30m
  - **B**urfield (adjacent valley)
    - 30m



Time averaged wind speed at 30m above ground level

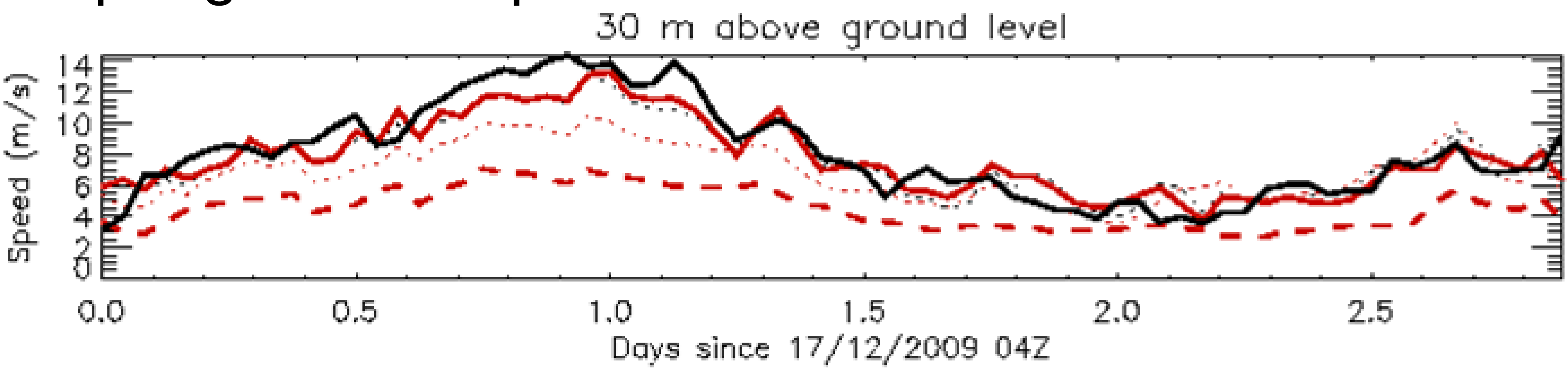
- Area = 10km x 10km centred on **S**pringhill
- Orography contours from 200m (white lines) to 600m (black lines).
- Increased detail and larger range of winds in finer resolution simulations.
- Not surprisingly, windier over the hill tops (including **S**pringhill) and calmer in the valleys (including **D**uffryn).



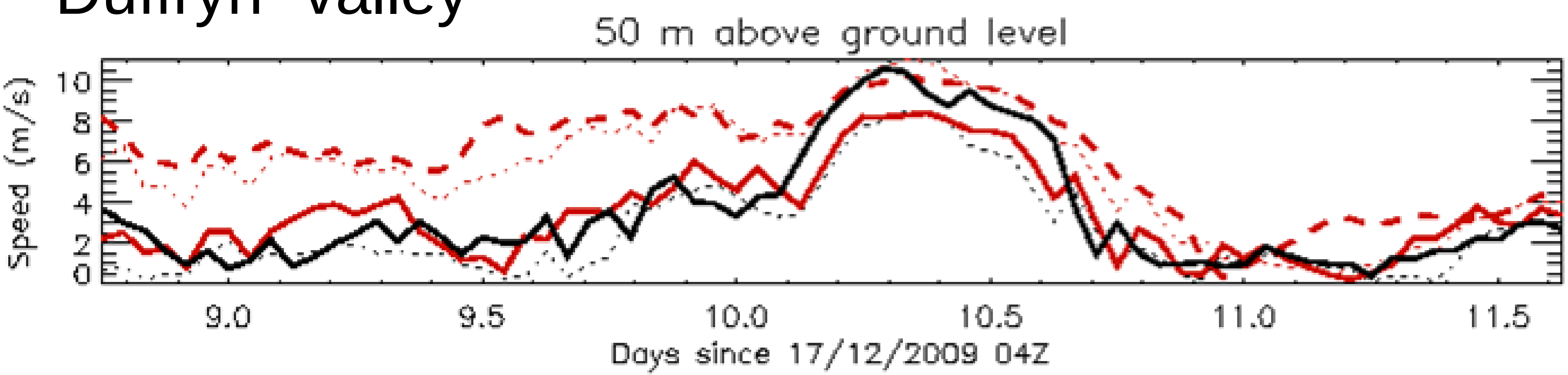


- 4 & 1km too slow/fast hilltop/valley
- 330m sufficient at both
- Mean err< 0.2 m/s (333, 100m)

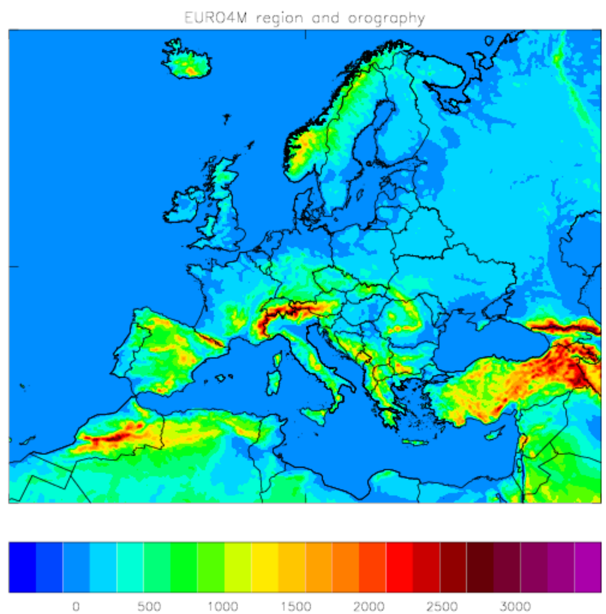
Springhill -hill top



Duffryn -valley

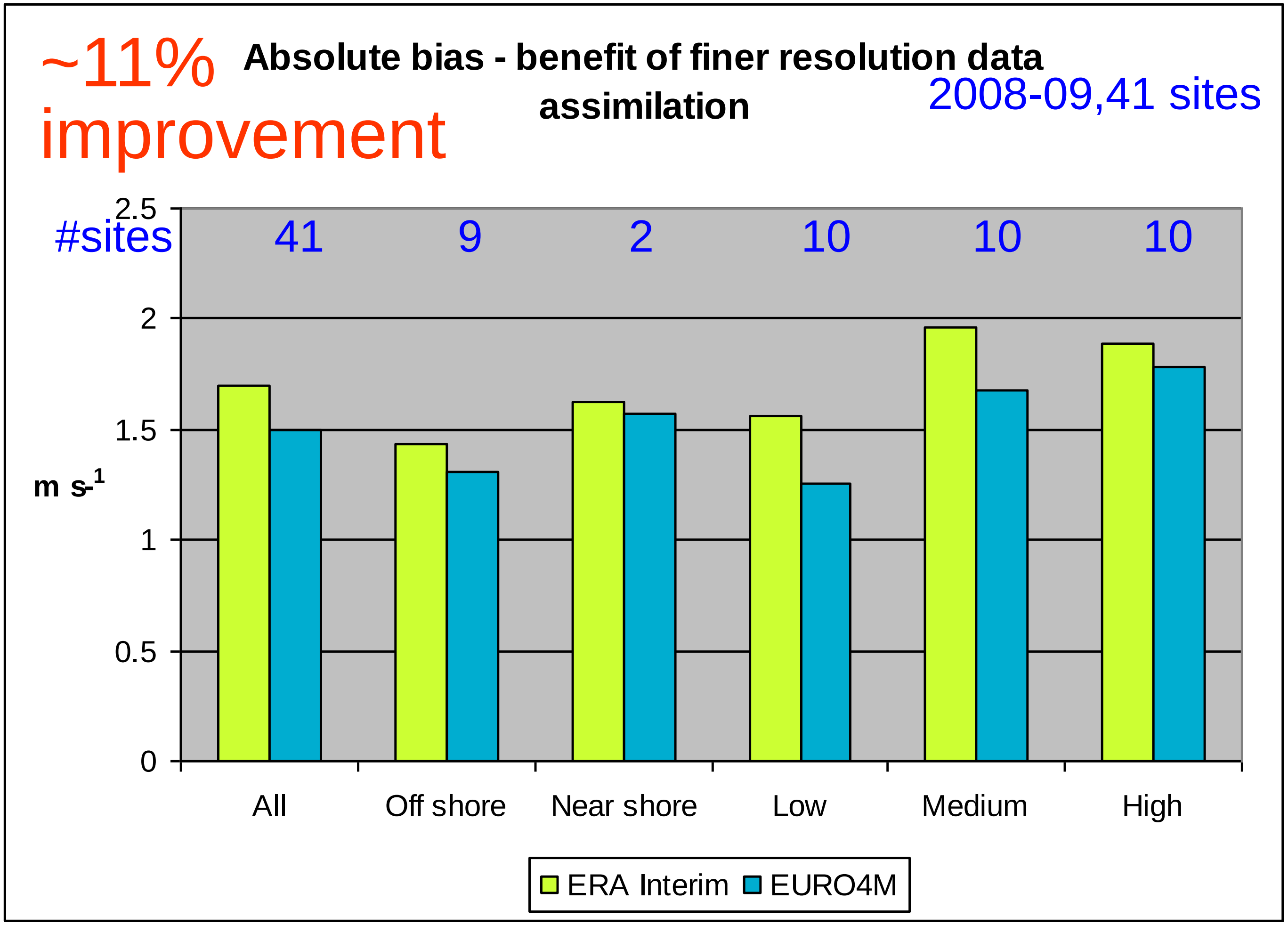


Prospects of improved finer scale reanalyses

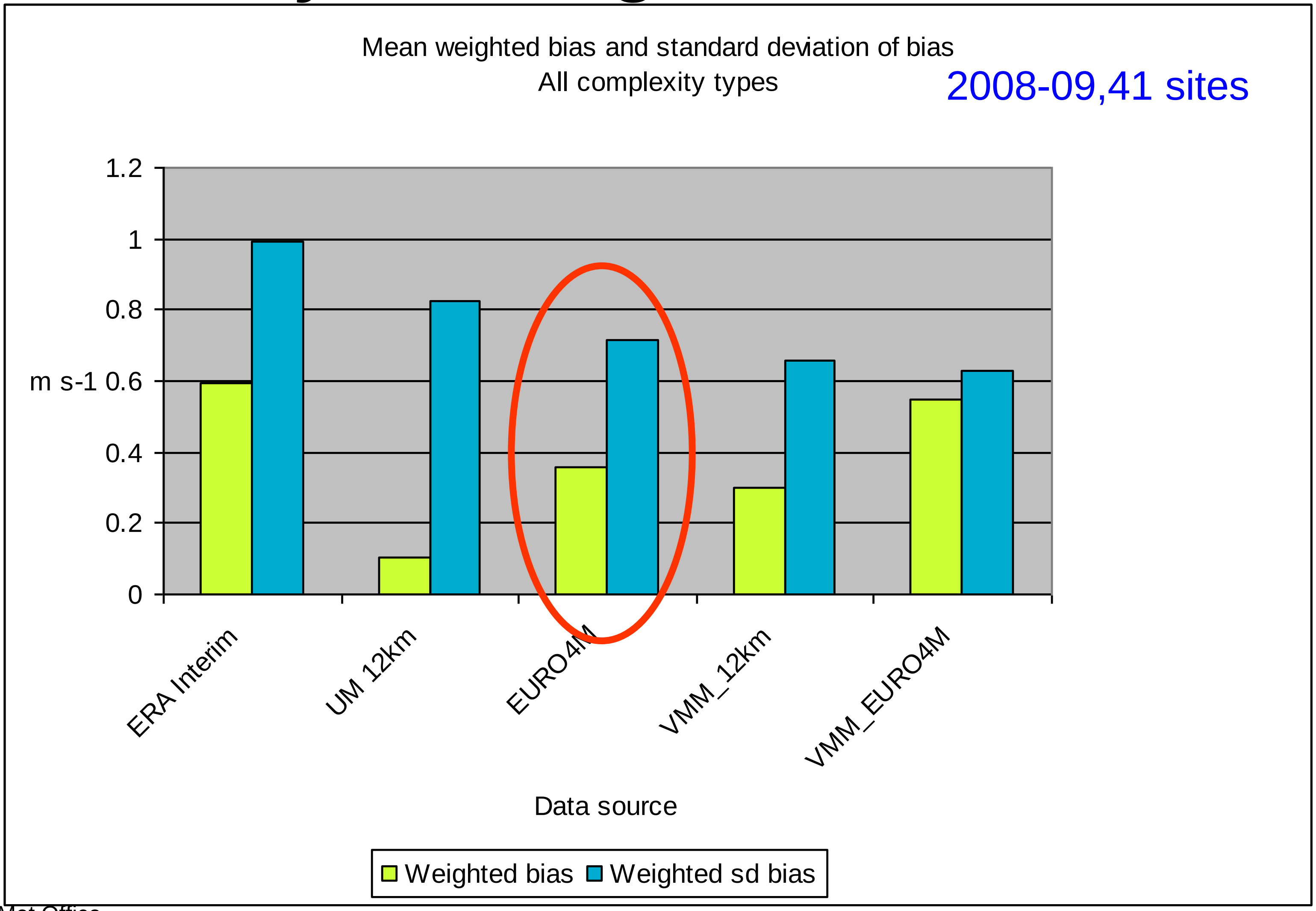


- Euro4M project
  - FP7 pilot
  - Regional reanalyses ~12km
- UERRA – (2014-2018) will build **probabilistic** reanalysis capability and **provide 30-40yr multivariate dataset of essential climate variables (ECVs).**
- New EUROPEAN wind atlas
  - Maybe ~ 4km

EURO4M preliminary reanalysis –regional 12km compared to ERA



EURO4M preliminary reanalysis –regional 12km



Operational Wind Production Forecast

Parameters:

- Wind speed at hub height
- Kalman filtered wind speed at hub height *(where observations are available)*
- Gust/Maximum wind speed at hub height
- Minimum wind speed at hub height
- Wind direction at hub height
- Pressure at hub height
- Temperature at hub height
- Relative humidity at hub height
- Air density at hub height
- Sensible heat flux
- Lightning risk

Met Office

Wind Production Forecast (WPF)

Deterministic

- Hourly to T+168h, 6 hourly to T+14 days
- updated 24 times daily
- Observations (WPF+)
  - Kalman filter
  - Basic nowcasts

Models used:

- UKV
- Euro4
- Global
- MOGREPS-UK
- MOGREPS-G
- MOGREPS-15

Methods:

VMM, site specific,blending, lagging, Kalman

Probabilistic

- Hourly to T+120h, 6 hourly to T+14 days
- Updated 4 times daily

Ensembles used:

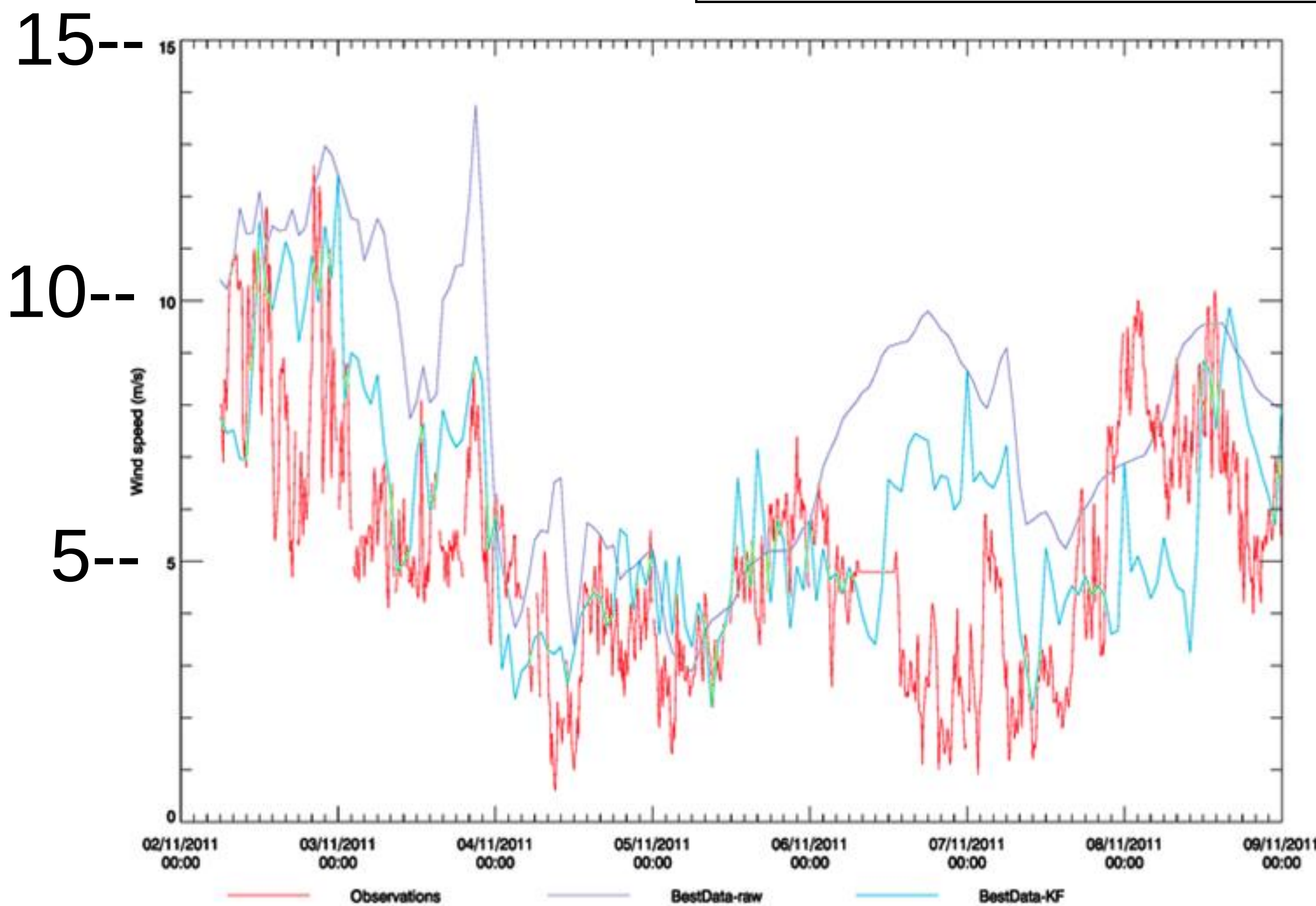
- MOGREPS-UK
- MOGREPS-G
- MOGREPS-15

Deterministic forecasts

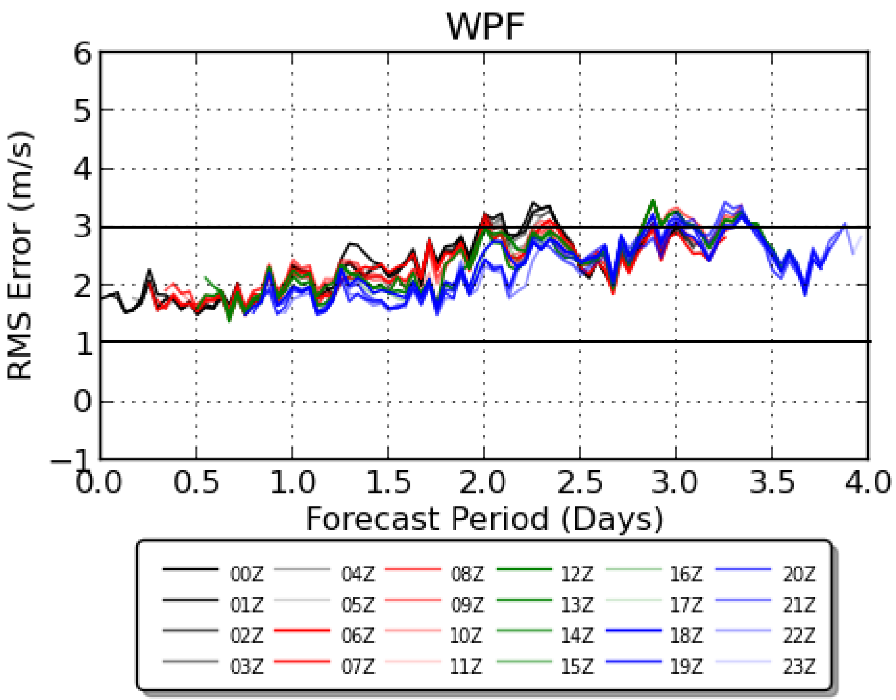
__obs

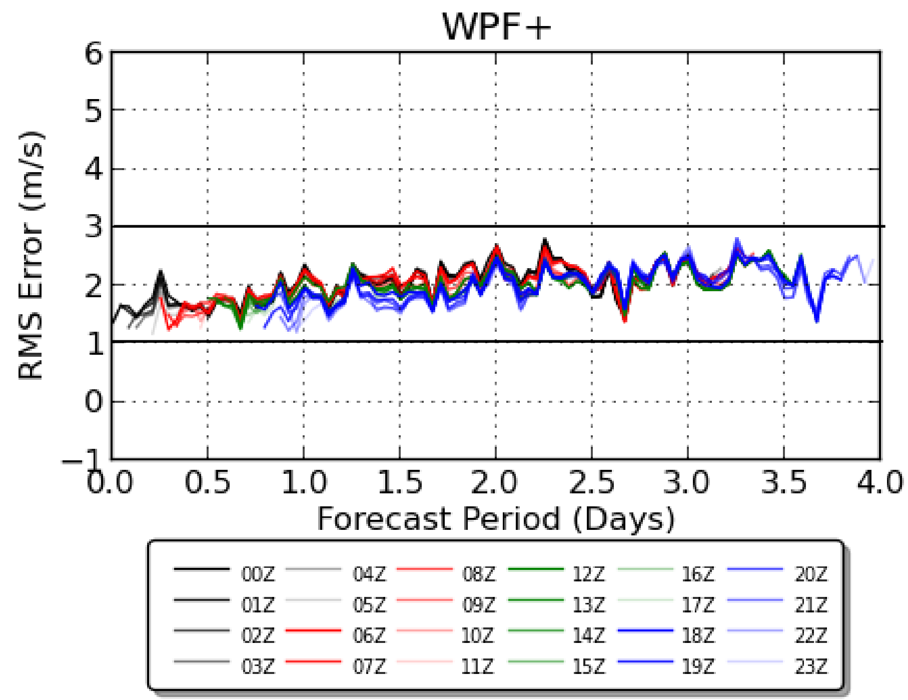
__Best data(= site + blend + lag)

__Best data + Kalman filter

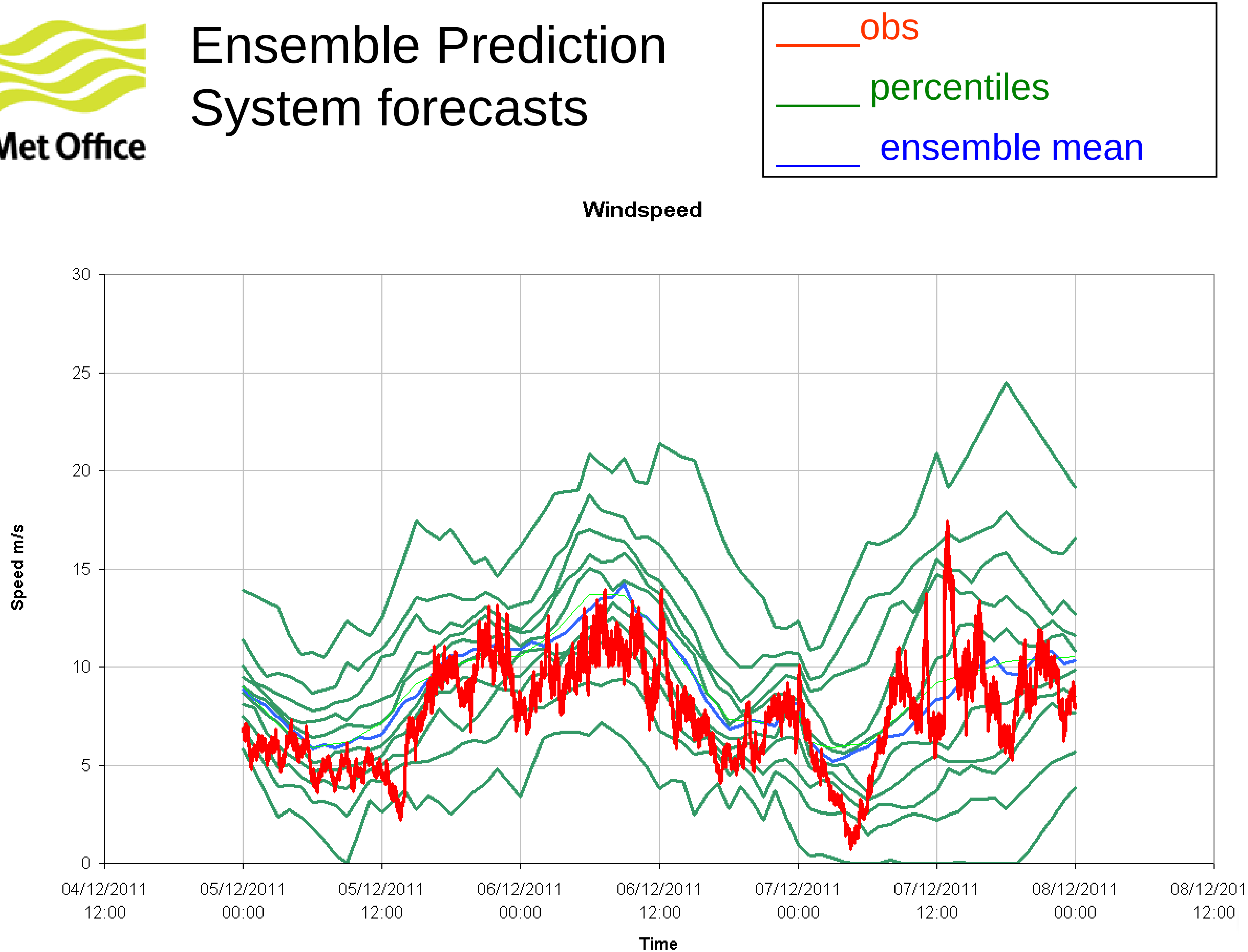


Deterministic forecasts MAE – March 2013 single location

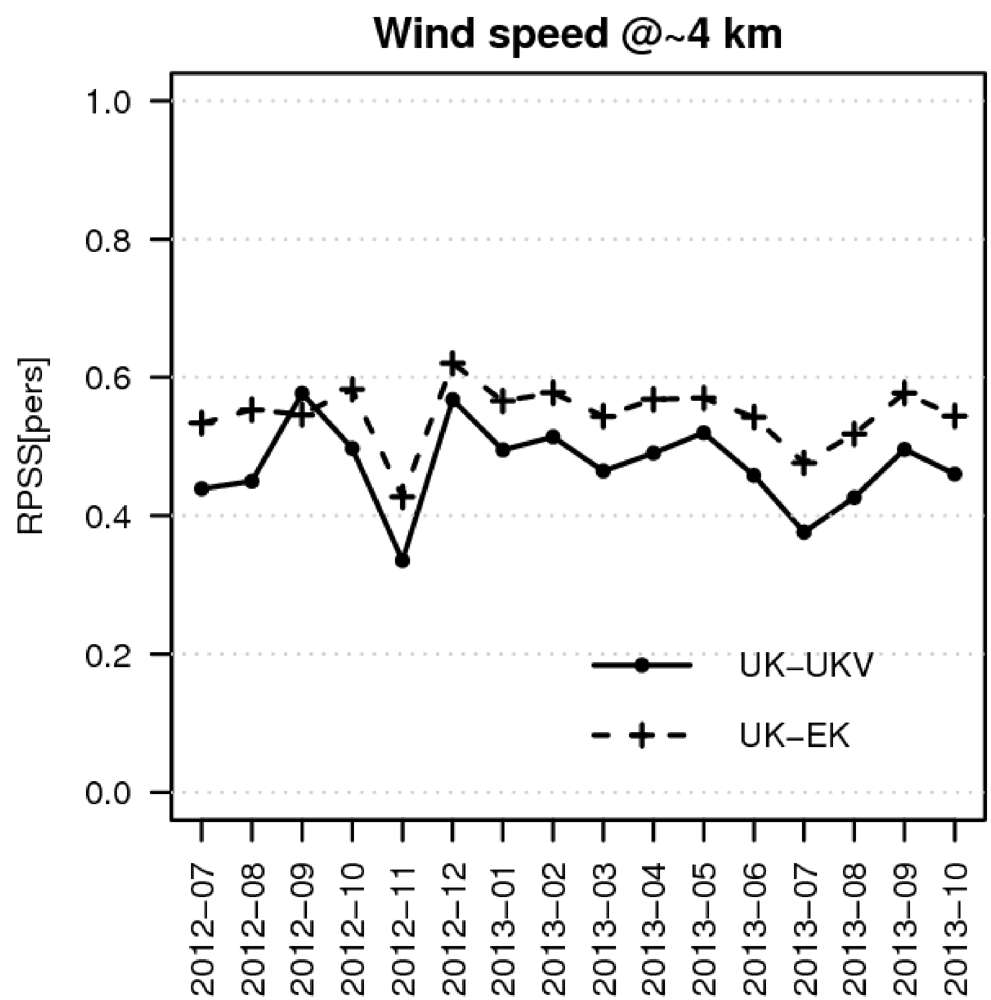




Ensemble Prediction System forecasts



UK (2km) ensemble improved skill relative to UK 1.5km -10m winds



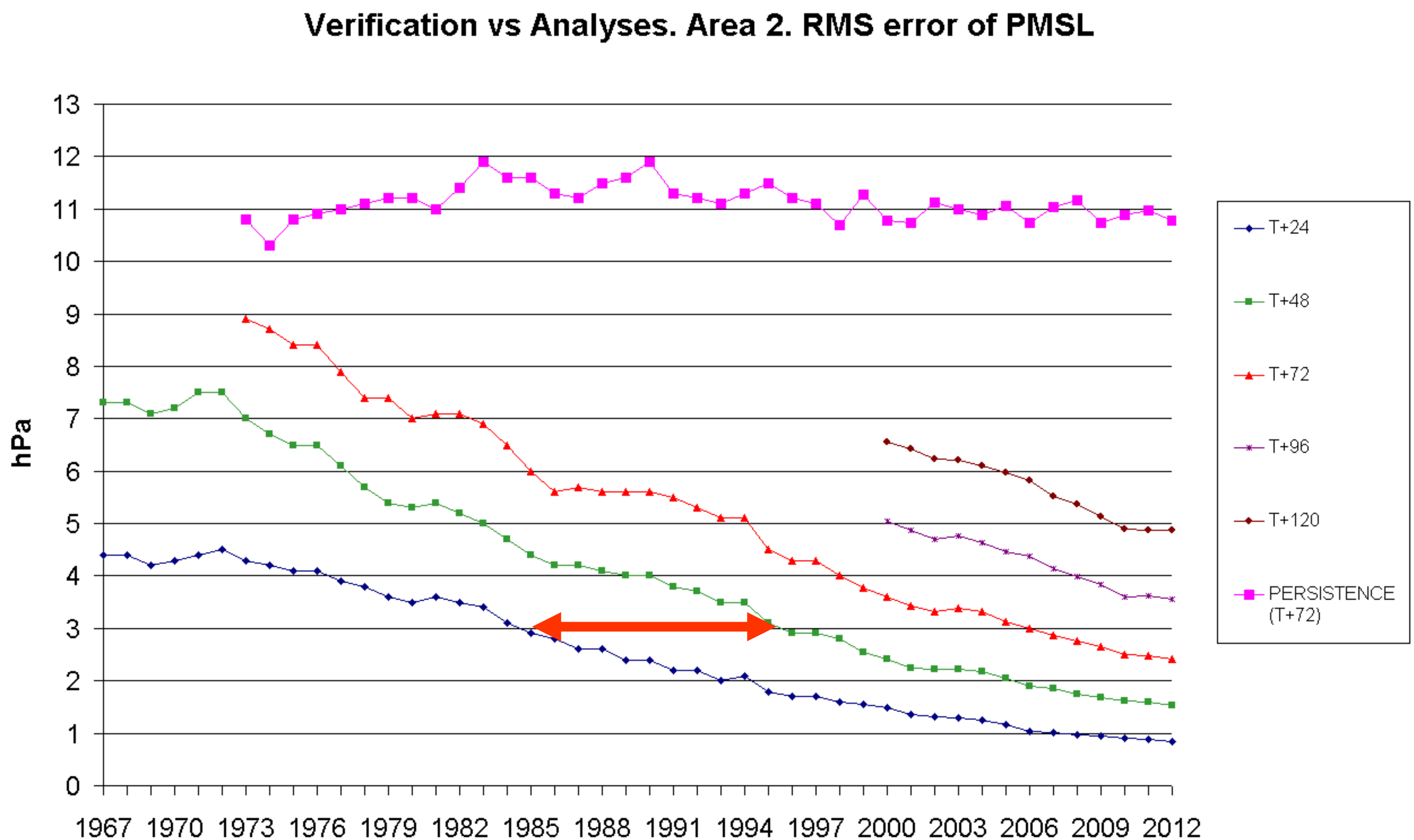
better

Conclusions

- Modern reanalyses better than older
  - better resolution, temporal resolution
  - Finer Regional reanalyses ~10% improvement
- Mesoscale added accuracy
  - Closer representation of orography/locality
  - Diurnal better
- Higher resolution to refine mesoscale (correlation/correct)
- Operational forecasts
  - Site +blend+lag+ensembles +Kalman+nowcasts

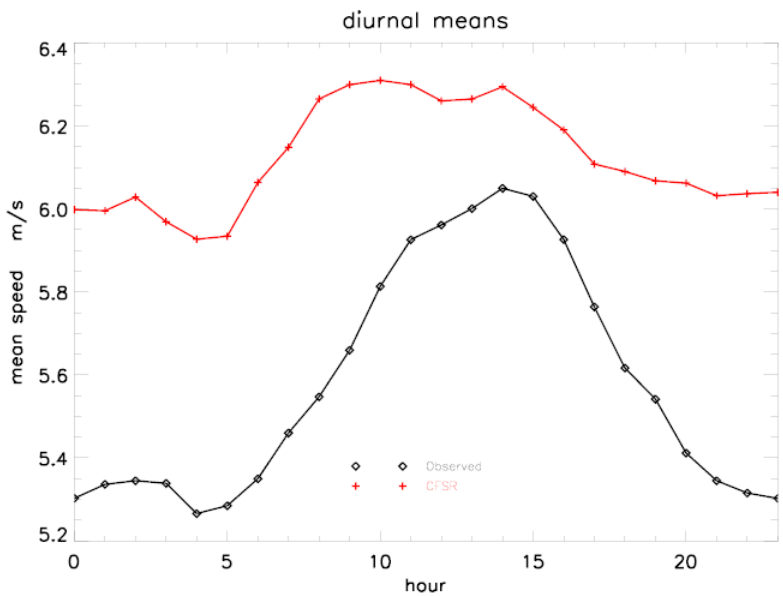
Questions ?

Long term forecast accuracy improvement
surface pressure~1day/decade

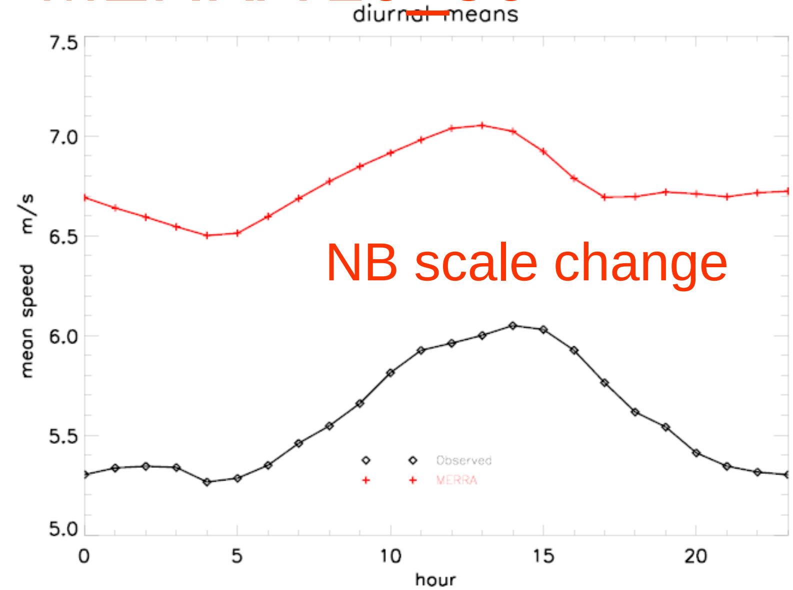


Met Office

CFSR

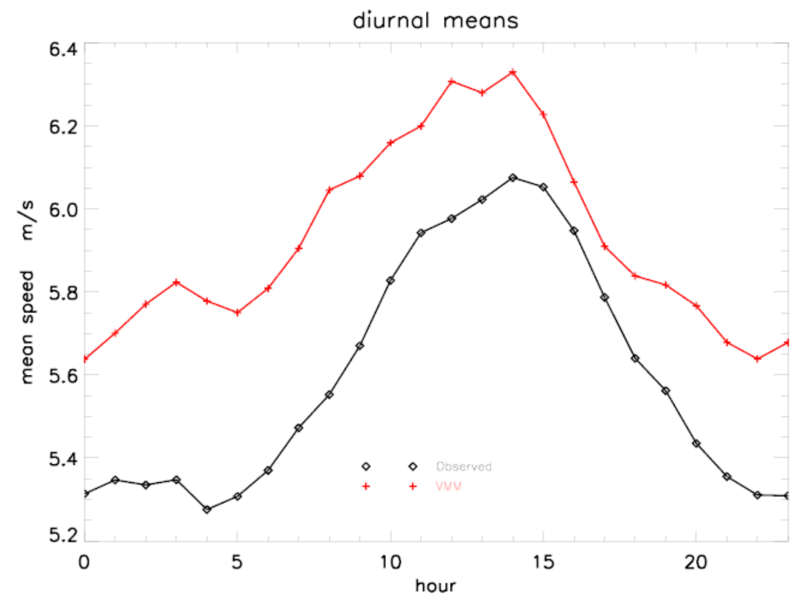


MERRA 10_50

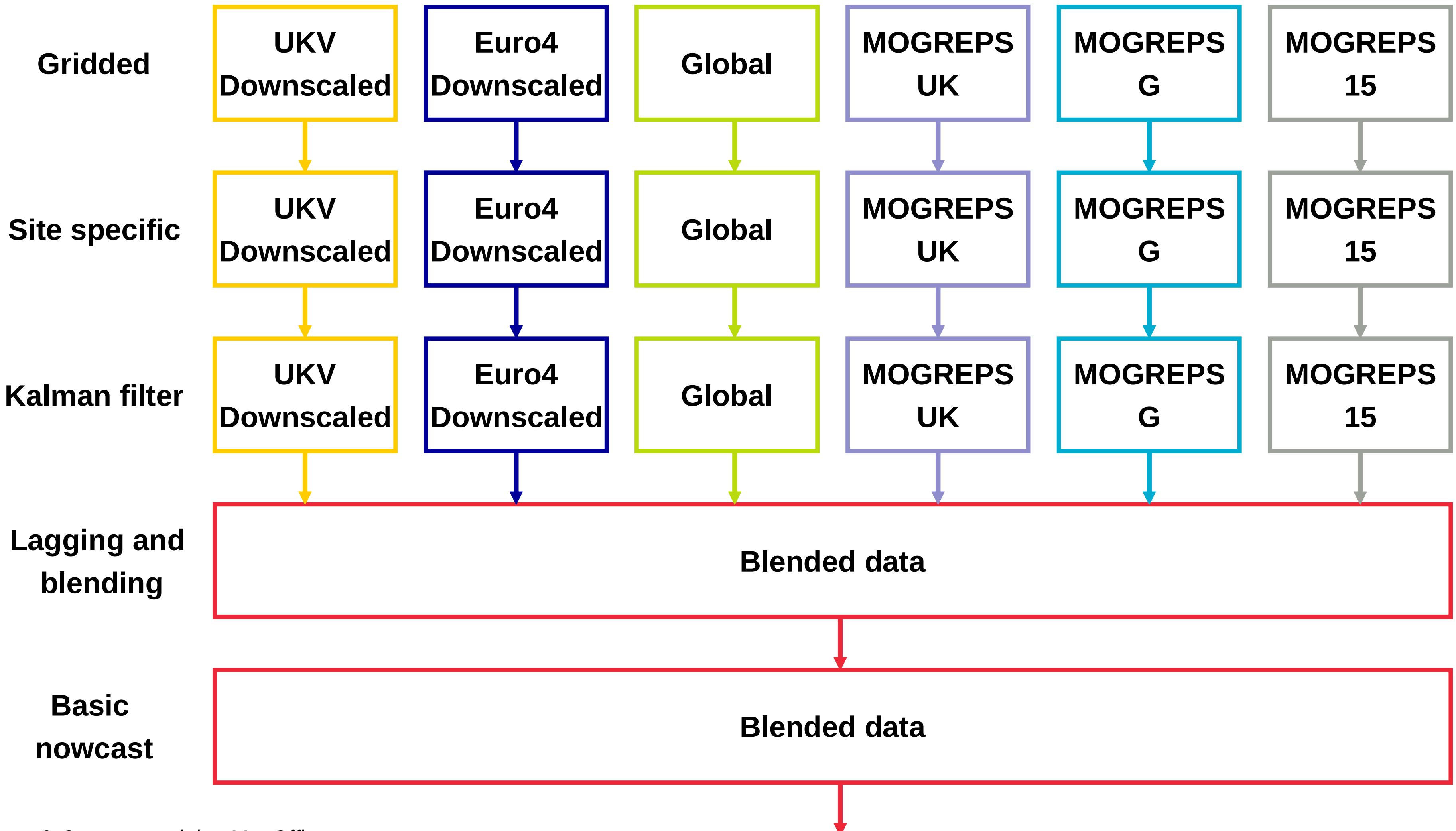


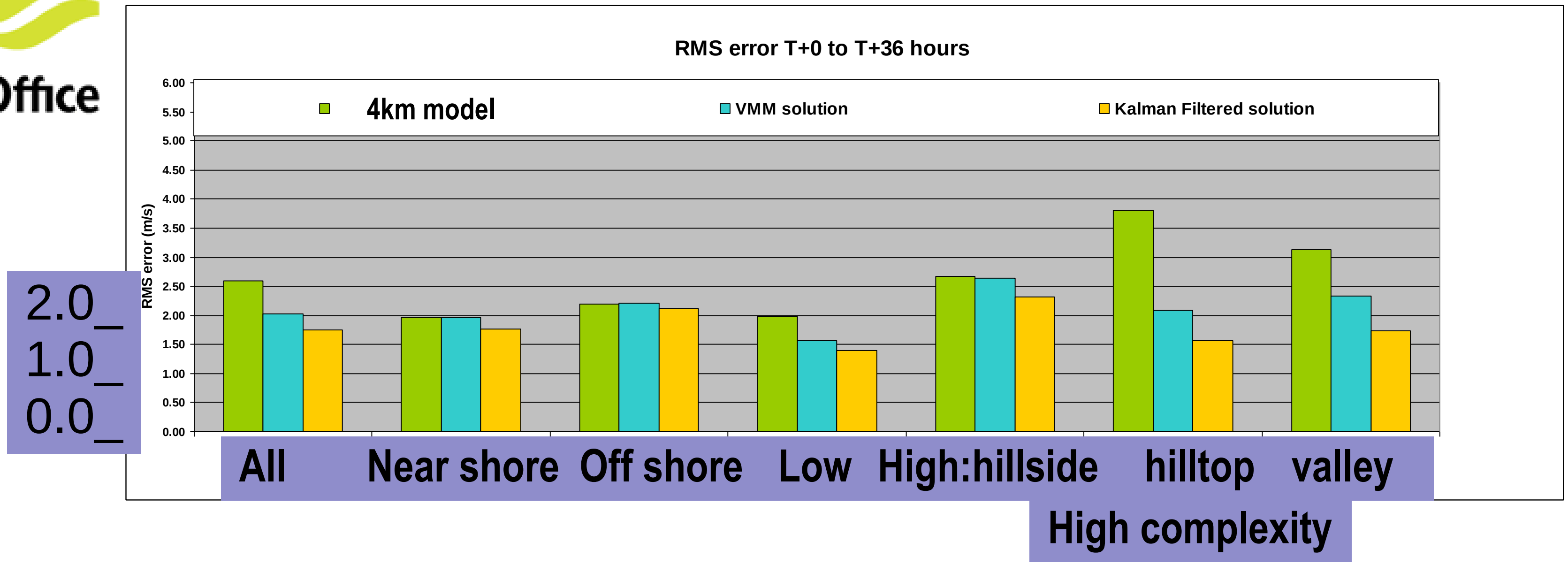
NB scale change

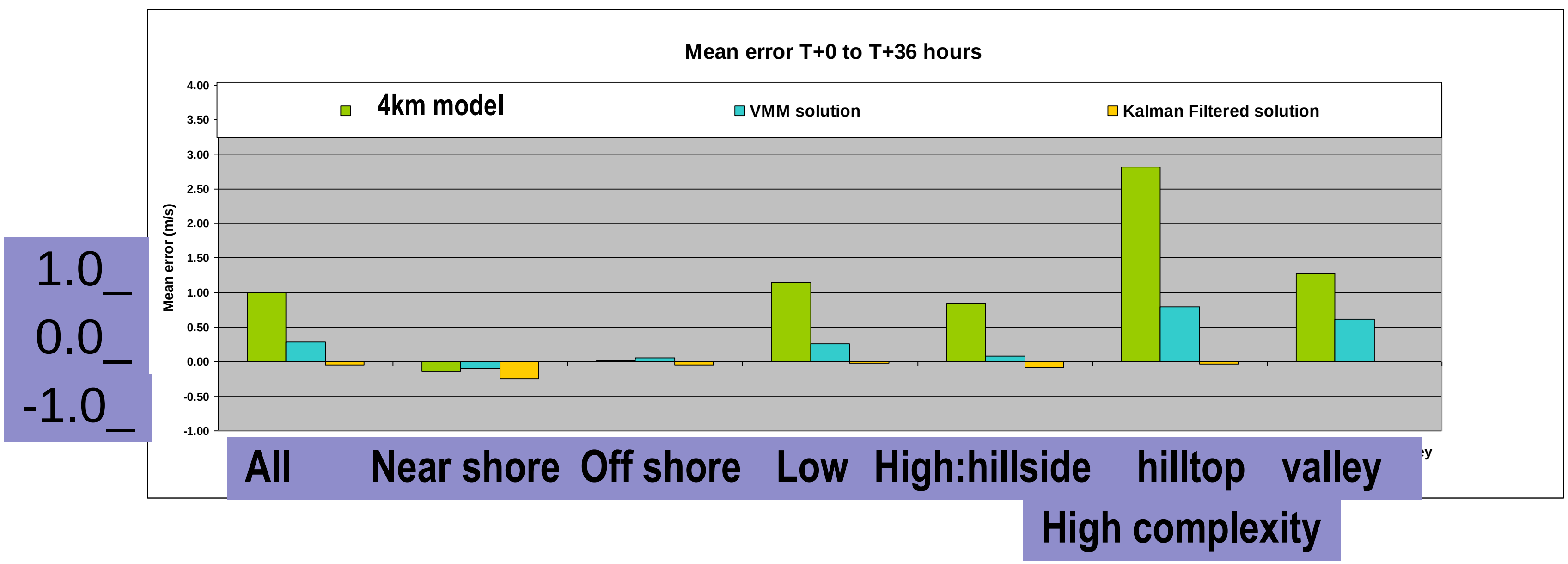
VMM



VMM best amplitude


Gridded
Site specific
Kalman filter
Lagging and blending
Basic nowcast
UKV Downscaled
Euro4 Downscaled
Global
MOGREPS UK
MOGREPS G
MOGREPS 15
Blended data
Blended data


RMS error T+0 to T+36 hours
4km model
VMM solution
Kalman Filtered solution
RMS error (m/s)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2.0_
1.0_
0.0_
All
Near shore
Off shore
Low
High:hillside
hilltop
valley
High complexity


Mean error T+0 to T+36 hours
4km model
VMM solution
Kalman Filtered solution
Mean error (m/s)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
1.0_
0.0_
-1.0_
All
Near shore
Off shore
Low
High:hillside
hilltop
valley
High complexity