Forecaster empirical techniques

Presented by Mike Bush

Eddy Carroll, Jim Galvin, Phillip McGarry, Andy Page, Nick Silkstone, Tony Sullens, Chris Tubbs

For 34th EWGLAM and 19th SRNWP Annual Meeting 2012

08th – 11th October 2012 Helsinki, Finland

Contents

Met Office

- Minimum temperatures
- Maximum temperatures

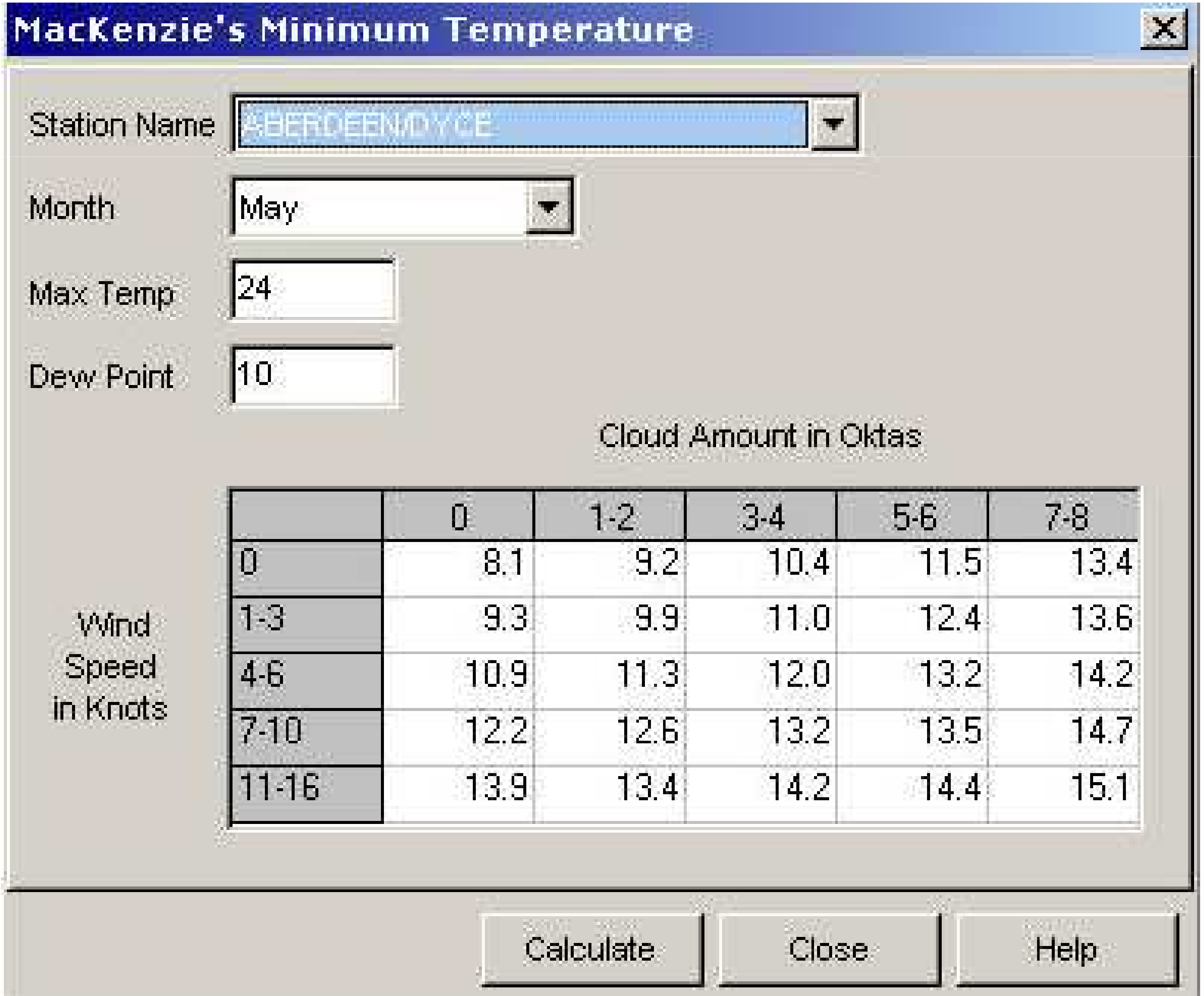
(usually only used when extremes are expected)

- Orographic enhancement of rainfall
- CAT
- Wind gust
- Mountain waves (vertical velocities)

Forecasting minimum temperatures

- A number of techniques have been developed, based on empirical methods, to estimate the night minimum temperature during a clear night.
- These depend on solving an equation of the form:
- Tmin = aT + bTd + C
- T is an afternoon temperature, Td is the dew point at a particular time or a mean dew point over a cooling period and C is a quantity depending only on wind speed and cloud amount. a and b are constants.
- The methods are applicable only when the ground is not snow covered

MacKenzie's Forecast Minimum Temperatures (1944)



MacKenzie's Minimum Temperature

Station Name: ABERDEEN/DYCE

Month: May

Max Temp: 24

Dew Point: 10

Cloud Amount in Oktas

Wind Speed in Knots	0	1-2	3-4	5-6	7-8
0	8.1	9.2	10.4	11.5	13.4
1-3	9.3	9.9	11.0	12.4	13.6
4-6	10.9	11.3	12.0	13.2	14.2
7-10	12.2	12.6	13.2	13.5	14.7
11-16	13.9	13.4	14.2	14.4	15.1

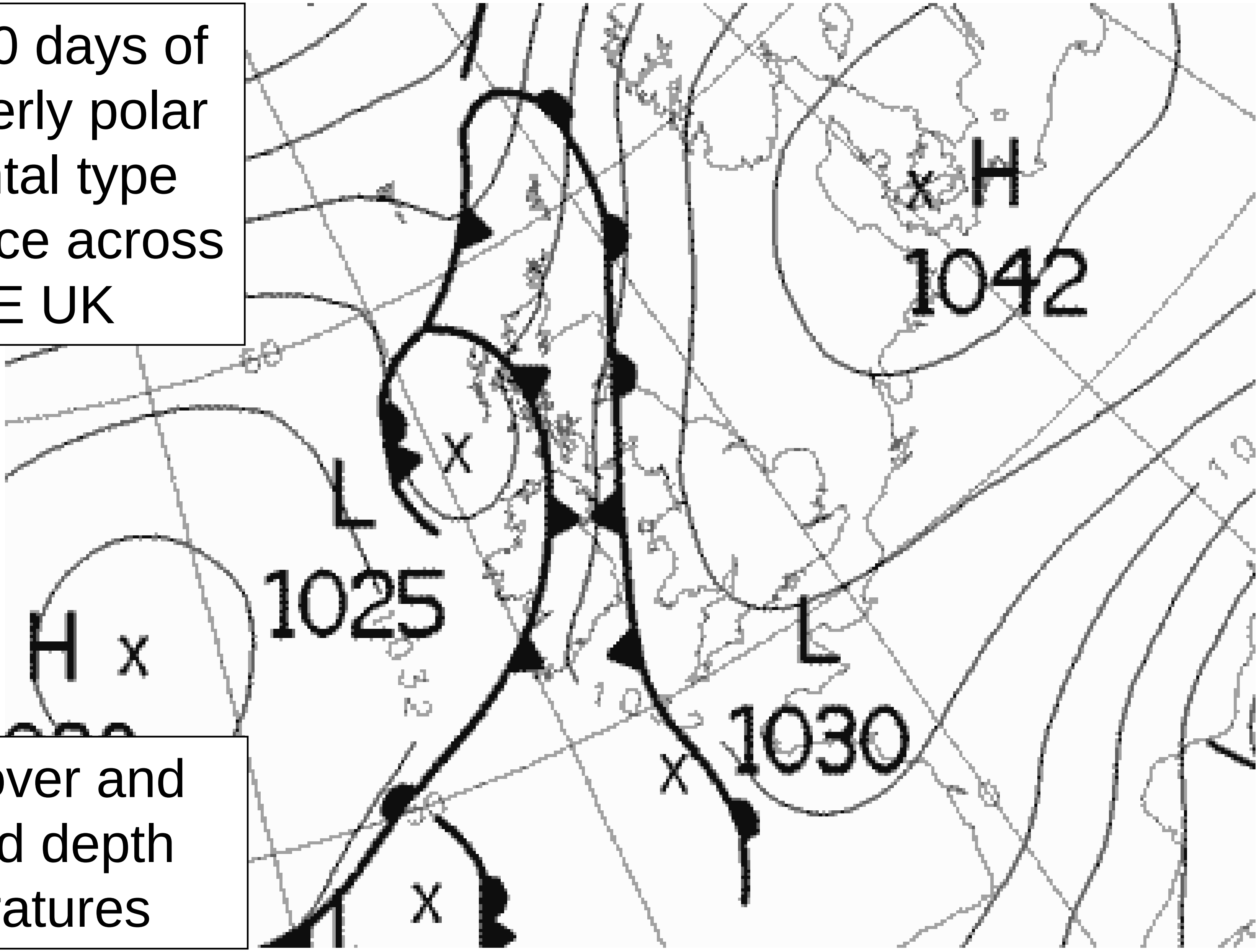
Calculate | Close | Help

MacKenzie's Forecast Minimum Temperatures (1944)

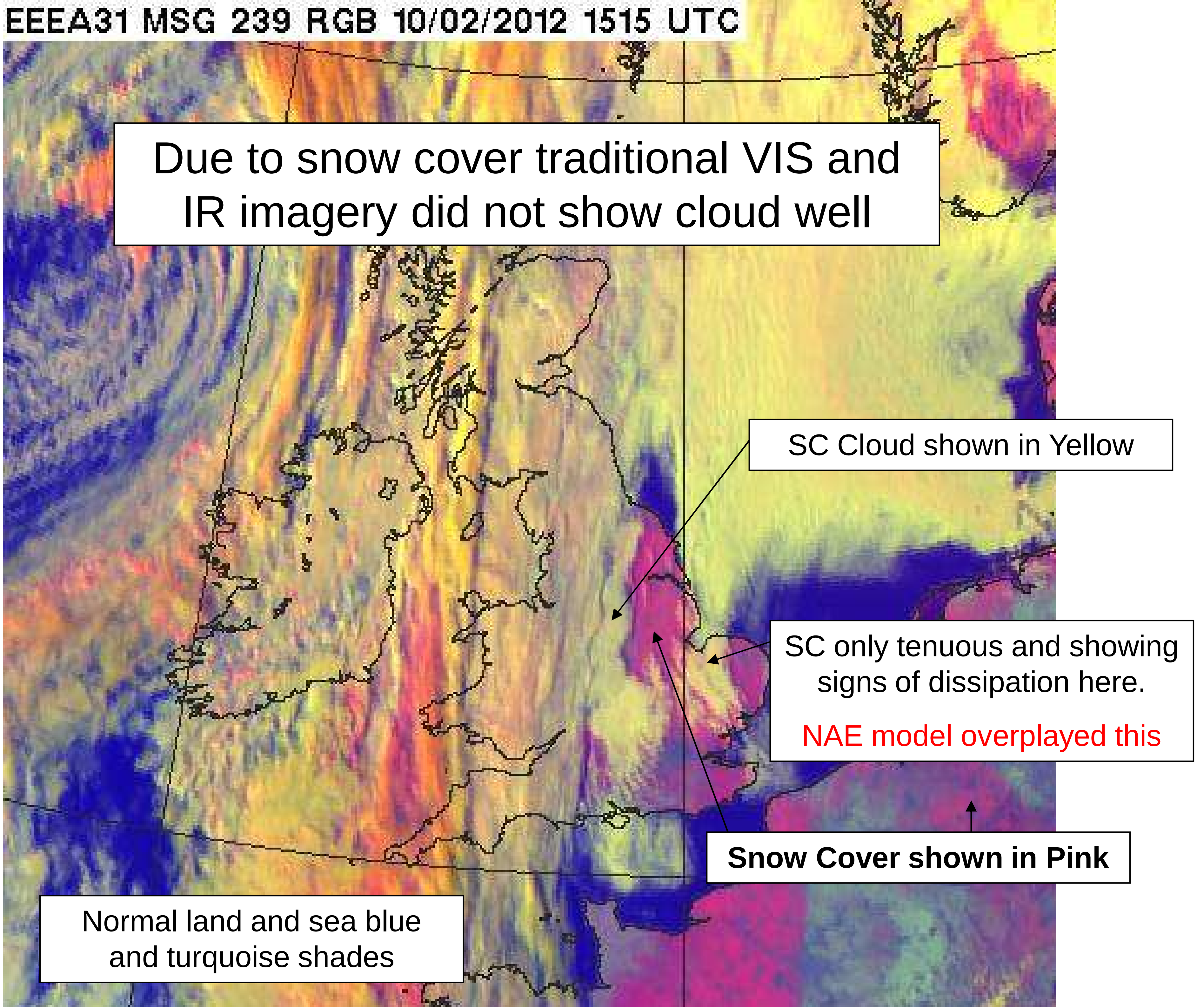
- $T_{min} = 0.5(T_{max} + T_d) - K$
- The Mackenzie's Minimum Temperature dialog enables you to produce a grid of forecast night minimum air temperatures for a range of various wind speeds and low cloud amounts.
- Select the nearest location to you from the list of stations
- Select the current month of the year
- Enter either the actual or the forecast maximum temperature for the day.
- Enter the dew point at the time of the maximum temperature.
- As the algorithm depends on constants that have been calculated for a wide range of locations in the UK (Kensett (1983), it should only be used outside the UK with caution.

Example case: 10th-11th February 2012

Around 10 days of cold easterly polar continental type flow in place across the SE UK

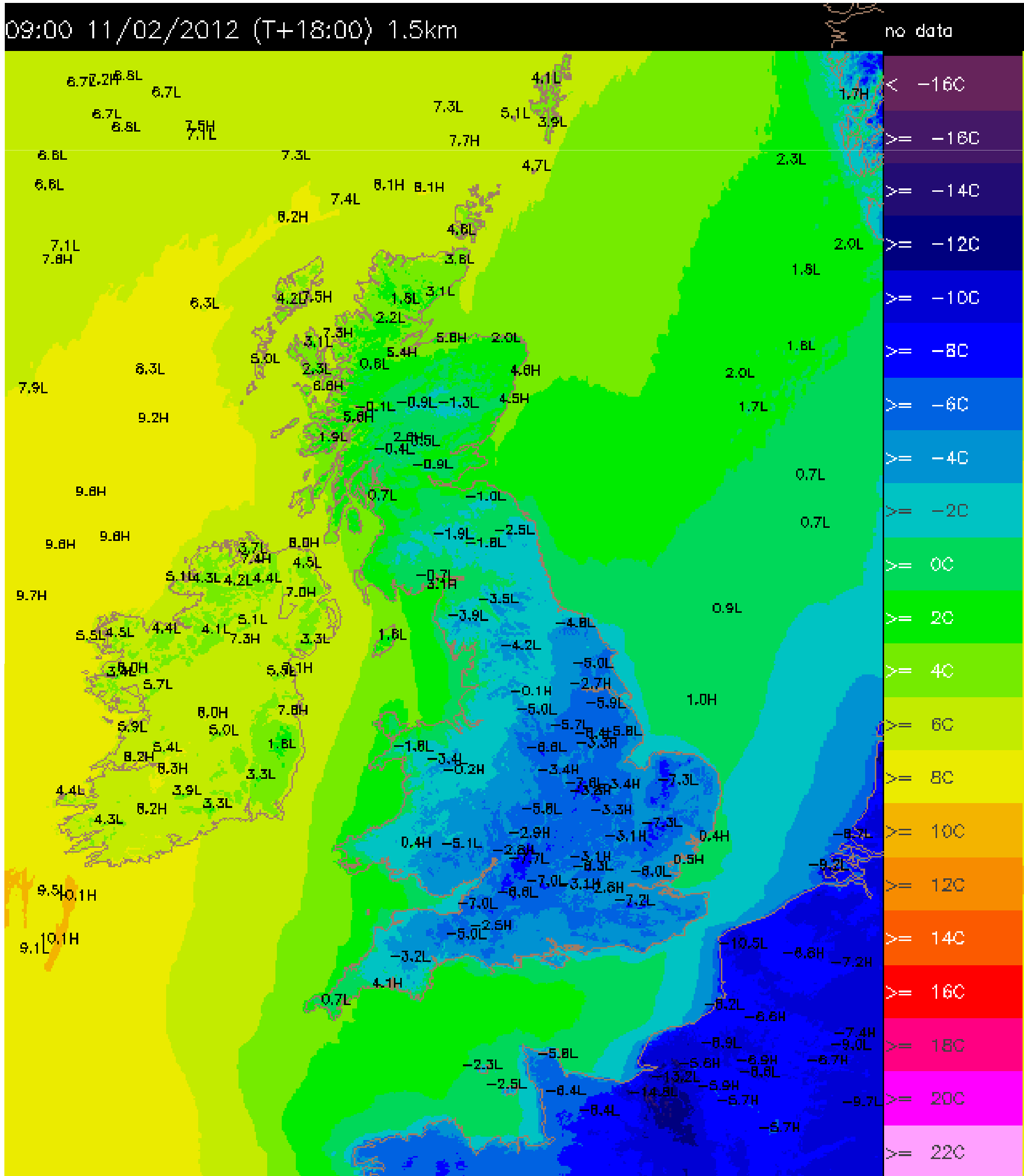


Snow cover and very cold depth temperatures

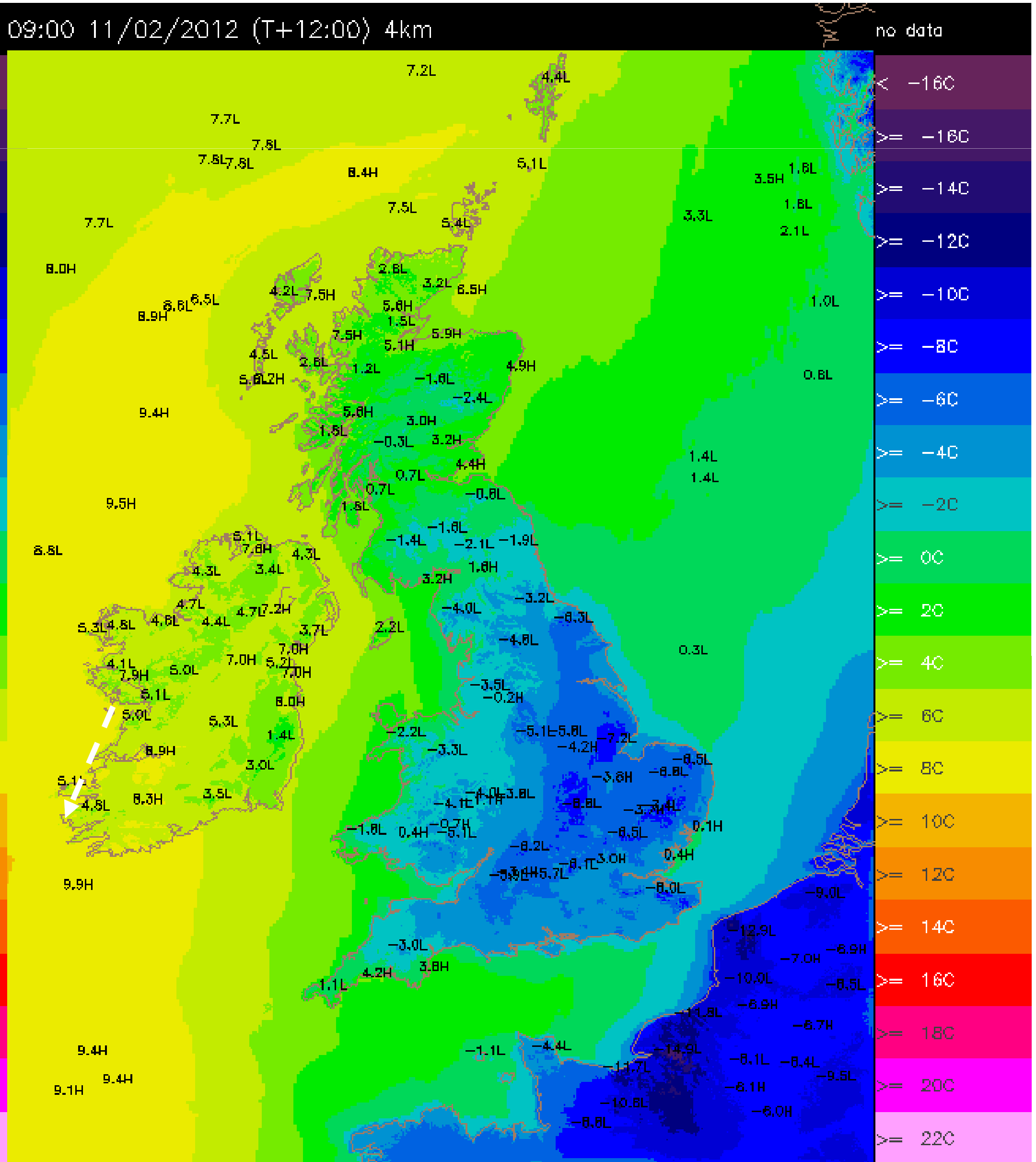

EEEA31 MSG 239 RGB 10/02/2012 1515 UTC
Due to snow cover traditional VIS and IR imagery did not show cloud well
SC Cloud shown in Yellow
SC only tenuous and showing signs of dissipation here.
NAE model overplayed this
Snow Cover shown in Pink
Normal land and sea blue and turquoise shades

Min to 09Z on 11th from the UKV and UK4 21Z runs

UKV pp: -7.7 deg



UK 4 pp: -8.8 deg



Empirical Techniques:

Mackenzie Min Temps: From Tmx and Td at Tmax

Lincs and Norfolk: *Suggestion of Min Temps: -10 deg to -12 deg*

McKenzie Minimum Temperature

Station Name: Scampton
Month: February ☐ Default
Max Temp: -0.9
Dew Point: -6.8

Total cloud in oktas

Wind speed in knots	0 oktas	1-2 oktas	3-4 oktas	5-6 oktas	7-8 oktas
Calm	*****	*****	*****	*****	*****
1-3 kts	-9.9	-8.3	-8.5	-8.5	-5.9
4-6 kts	-9.5	-9.1	-8.1	-7.4	-6.0
7-10 kts	-9.0	-8.1	-7.7	-6.8	-5.5
11-16 kts	-6.3	-6.2	-5.8	-5.2	-5.1

Print Help

McKenzie Minimum Temperature

Station Name: Cranwell
Month: February ☐ Default
Max Temp: -0.9
Dew Point: -6.8

Total cloud in oktas

Wind speed in knots	0 oktas	1-2 oktas	3-4 oktas	5-6 oktas	7-8 oktas
Calm	-11.1	-11.7	-8.7	-8.8	-6.8
1-3 kts	-10.4	-8.7	-9.1	-8.2	-6.4
4-6 kts	-10.1	-9.0	-8.0	-8.0	-6.3
7-10 kts	-8.9	-8.6	-7.6	-6.9	-6.1
11-16 kts	-7.4	-6.8	-6.8	-5.9	-5.8

Print Help

McKenzie Minimum Temperature

Station Name: Marham
Month: February ☐ Default
Max Temp: -0.9
Dew Point: -6.8

Total cloud in oktas

Wind speed in knots	0 oktas	1-2 oktas	3-4 oktas	5-6 oktas	7-8 oktas
Calm	*****	*****	*****	*****	-8.9
1-3 kts	-11.5	-10.3	-9.9	-8.4	-6.3
4-6 kts	-11.0	-10.1	-8.7	-7.8	-6.2
7-10 kts	-9.6	-8.9	-8.1	-7.6	-6.1
11-16 kts	-7.3	-7.3	-6.5	-5.8	-5.5

Print Help

Oxfordshire and greater London: *Suggestion Min Temps: - 09 deg*

McKenzie Minimum Temperature

Station Name: Benson
Month: February ☐ Default
Max Temp: 0.5
Dew Point: -5.5

Total cloud in oktas

Wind speed in knots	0 oktas	1-2 oktas	3-4 oktas	5-6 oktas	7-8 oktas
Calm	-9.4	-8.8	-7.5	-6.4	-4.3
1-3 kts	-9.3	-8.2	-7.5	-6.0	-4.6
4-6 kts	-8.7	-8.0	-6.9	-6.1	-4.3
7-10 kts	-7.0	-6.5	-5.7	-5.3	-4.2
11-16 kts	-5.1	-5.0	-4.1	-4.2	-3.6

Print Help

McKenzie Minimum Temperature

Station Name: Northolt
Month: February ☐ Default
Max Temp: 1.3
Dew Point: -5.0

Total cloud in oktas

Wind speed in knots	0 oktas	1-2 oktas	3-4 oktas	5-6 oktas	7-8 oktas
Calm	-8.6	-8.6	-8.5	-6.9	-5.2
1-3 kts	-8.5	-7.3	-6.9	-5.7	-4.0
4-6 kts	-6.7	-6.3	-5.7	-4.7	-4.2
7-10 kts	-5.7	-5.5	-5.1	-4.3	-3.5
11-16 kts	-3.1	-4.1	-3.1	-4.1	-3.1

Print Help

Other Min Temp techniques suggested MS 10 through this area

Actual minima (degrees)

- Holbeach (Lincolnshire): -15.6
- Wainfleet (Lincolnshire): -14.4
- Marham (Norfolk): -14.3
- Scampton (Lincolnshire): -13.4
- Coningsby (Lincolnshire): -13.2
- Church Fenton (North Yorkshire): -12.9
- Leconfield (East Yorkshire): -12.7
- Benson (Oxfordshire): -12.5
- Wittering (Cambridgeshire): -12.5
- Bedford (Bedfordshire): -12.3
- Northolt (Greater London): -9.6

Model challenges for this case

Met Office

- Snow cover
- Current snow scheme is a zero-layer scheme
- The warm bias is associated with excessive ground heat fluxes.
- The greater insulating effect of the new multilayer snow scheme (currently under test) can give significant reductions in temperature in this case
- Stratocumulus
- Stable boundary layer issues (see tomorrow’s physics talk)

Craddock and Pritchard's Forecast Minimum Temperatures (1951)

- The following regression equation was obtained from a "statistical investigation of 16 stations in eastern England not close to the sea"
- It is considered valid for a wide area of eastern England:
- $T_{min} = 0.316\ T12 + 0.548\ Td12 - 1.24 + K$
- T12 = screen temperature at 1200 UTC
- Td12 = dew-point temperature at 1200 UTC

Forecasting maximum temperatures: Callen and Prescott (1982)

- This is an empirical method based on the maximum temperatures observed at Gatwick and the 1000–850 hPa thickness values at midday at Crawley.
- There are three steps:
- (i) Classify the cloud cover or presence of fog between dawn and 1200 UTC on a scale from 0 to 3 as follows:

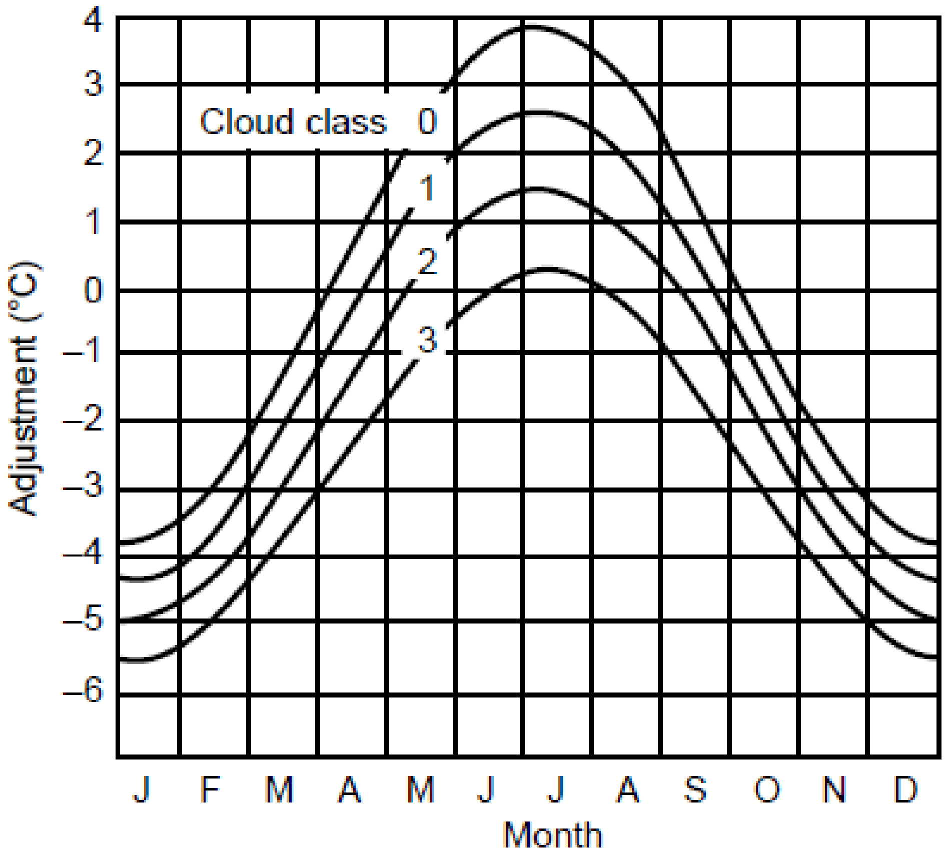
Table 2.4.

Class 0	$C_L + C_M \leqslant 3/8$, $C_H \leqslant 5/8$; or any fog confined to dawn period.
Class 1	$C_L + C_M + C_H = 4/8–6/8$; or any fog clearing slowly during morning.
Class 2	$C_L + C_M \geqslant 6/8$; or any fog clearing before noon.
Class 3	Predominantly overcast with precipitation (not including very slight drizzle) or persistent fog.

- (ii) Obtain the temperature adjustment for the month for the appropriate cloud class using the graph on the next slide.
- (iii) Apply this adjustment to the values given in **Table 2.5** to find the predicted maximum temperature.

Forecasting maximum temperatures: Callen and Prescott (1982)

Tu = -192.65 +0.156h
Tu = unadjusted temperature
h = 1000-850hPa thickness



Forecasting maximum temperatures: Callen and Prescott

Table 2.5. Unadjusted maximum temperature (°C) in terms of 1000–850 hPa thickness

Thickness (gpm)	0	1	2	3	4	5	6	7	8	9
	Maximum temperature									
1230	−0.8	−0.6	−0.5	−0.3	−0.1	0.0	0.2	0.3	0.5	0.6
1240	0.8	0.9	1.1	1.3	1.4	1.6	1.7	1.9	2.0	2.2
1250	2.3	2.5	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.8
1260	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.2	5.3
1270	5.5	5.6	5.8	5.9	6.1	6.2	6.4	6.6	6.7	6.9
1280	7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.1	8.3	8.4
1290	8.6	8.7	8.9	9.1	9.2	9.4	9.5	9.7	9.8	10.0
1300	10.1	10.3	10.5	10.6	10.8	10.9	11.1	11.2	11.4	11.6
1310	11.7	11.9	12.0	12.2	12.3	12.5	12.6	12.8	13.0	13.1
1320	13.3	13.4	13.6	13.7	13.9	14.0	14.2	14.4	14.5	14.7
1330	14.8	15.0	15.1	15.3	15.5	15.6	15.8	15.9	16.1	16.2
1340	16.4	16.5	16.7	16.9	17.0	17.2	17.3	17.5	17.6	17.8
1350	17.9	18.1	18.3	18.4	18.6	18.7	18.9	19.0	19.2	19.4
1360	19.5	19.7	19.8	20.0	20.1	20.3	20.4	20.6	20.8	20.9
1370	21.1	21.2	21.4	21.5	21.7	21.8	22.0	22.2	22.3	22.5
1380	22.6	22.8	22.9	23.1	23.3	23.4	23.6	23.7	23.9	24.0
1390	24.2	24.3	24.5	24.7	24.8	25.0	25.1	25.3	25.4	25.6
1400	25.7	25.9	26.1	26.2	26.4	26.5	26.7	26.8	27.0	27.2
1410	27.3	27.5	27.6	27.8	27.9	28.1	28.2	28.4	28.6	28.7
1420	28.9	29.0	29.2	29.3	29.5	29.6	29.8	30.0	30.1	30.3
1430	30.4	30.6	30.7	30.9	31.1	31.2	31.4	31.5	31.7	31.8
1440	32.0	32.1	32.3	32.5	32.6	32.8	32.9	33.1	33.2	33.4

Callen et al. (1982)

Forecasting maximum temperatures: Using 850 theta-w (wet bulb potential temperature)

The maximum temperature derived from the 850 WBPT is presented in **Table 2.6**, with corrections for wet and sunny conditions (based on London Weather Centre data for southern England).

Table 2.6. Maximum temperatures derived from 850 hPa wet-bulb potential temperatures

850 hPa θ_w	Equivalent thickness (m) 1000–850 hPa	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Correction	
														Wet	Sunny
18	1390	19	20	21	23	25	26	26	25	24	22	20	19	−5	+3
16	1380	17	19	19	21	23	25	25	23	23	21	19	17	−5	+2
14	1370	16	17	18	20	22	23	23	22	21	19	17	16	−4	+2
12	1360	15	15	17	19	21	21	21	21	19	17	15	17	−4	+2
10	1350	13	14	15	17	19	20	20	19	18	16	14	13	−4	+2
8	1340	11	13	13	15	17	19	19	17	17	15	13	11	−3	+2
6	1325	9	10	11	13	15	16	16	15	14	12	10	9	−3	+1
4	1320	8	9	10	12	14	15	15	14	13	11	9	8	−3	+1
2	1305	6	7	8	10	12	13	13	12	11	9	7	6	−3	+1
0	1295	4	5	6	8	10	11	11	10	9	7	5	4	−2	+1
−2	1285	3	4	5	7	9	10	10	9	8	6	4	3	−2	+1
−4	1270	−1	1	1	4	6	7	7	6	5	3	1	1	−2	+1

Maximum temperatures

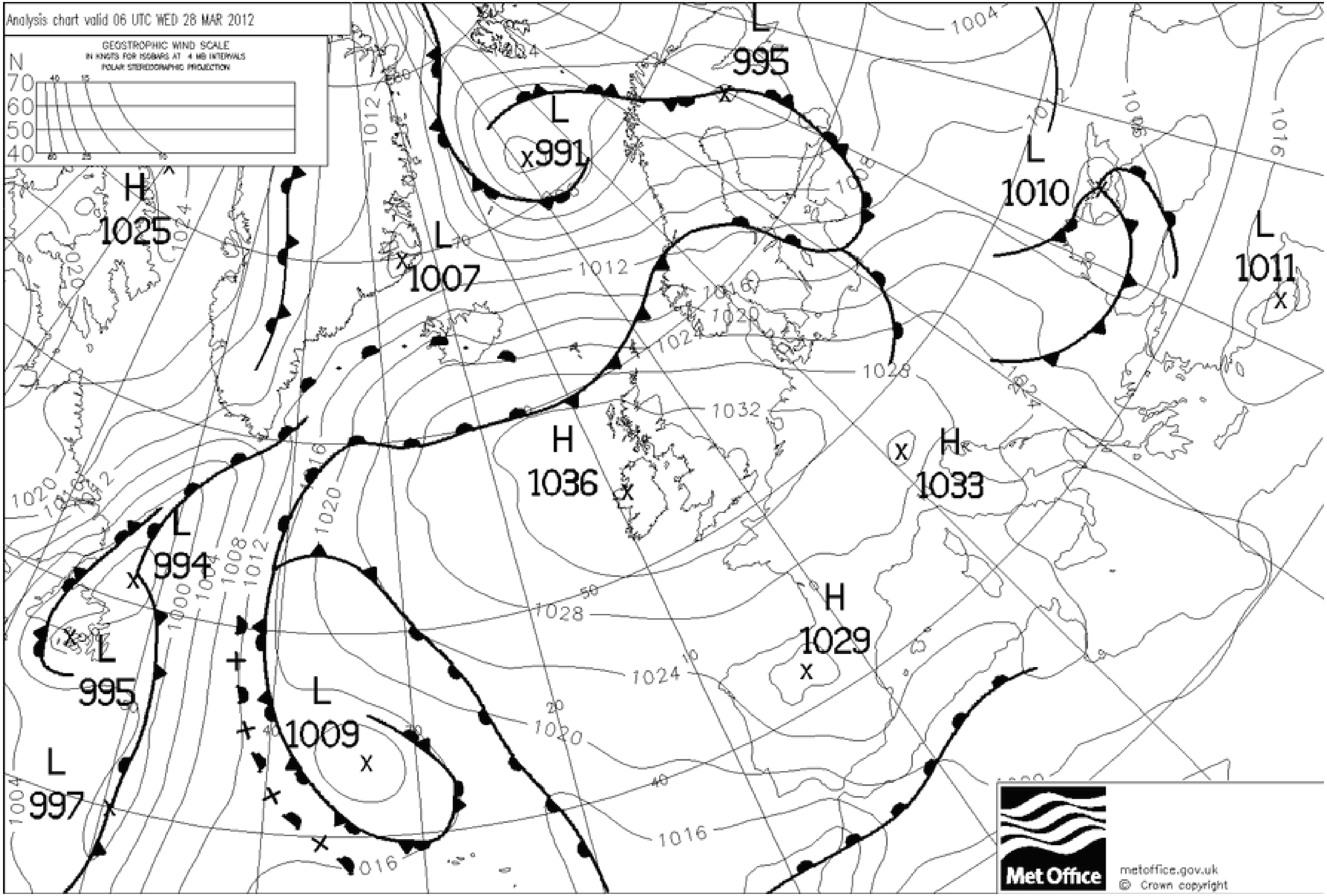
- Forecasters tend to use 1000hPa - 850hPa thickness and recent model performance rather than following Callen and Prescott too closely

- Callen and Prescott is derived for one location in southern England so it may not work so well for other locations .

- Forecasters look to see whether the 1000hPa - 850hPa thickness is higher or lower than the previous day.

- They look at the model Tmax error over previous days and then predict the likely errors in model Tmax for today

Example case: 28th March 2012



Maximum temperatures: 28/03/12

Met Office

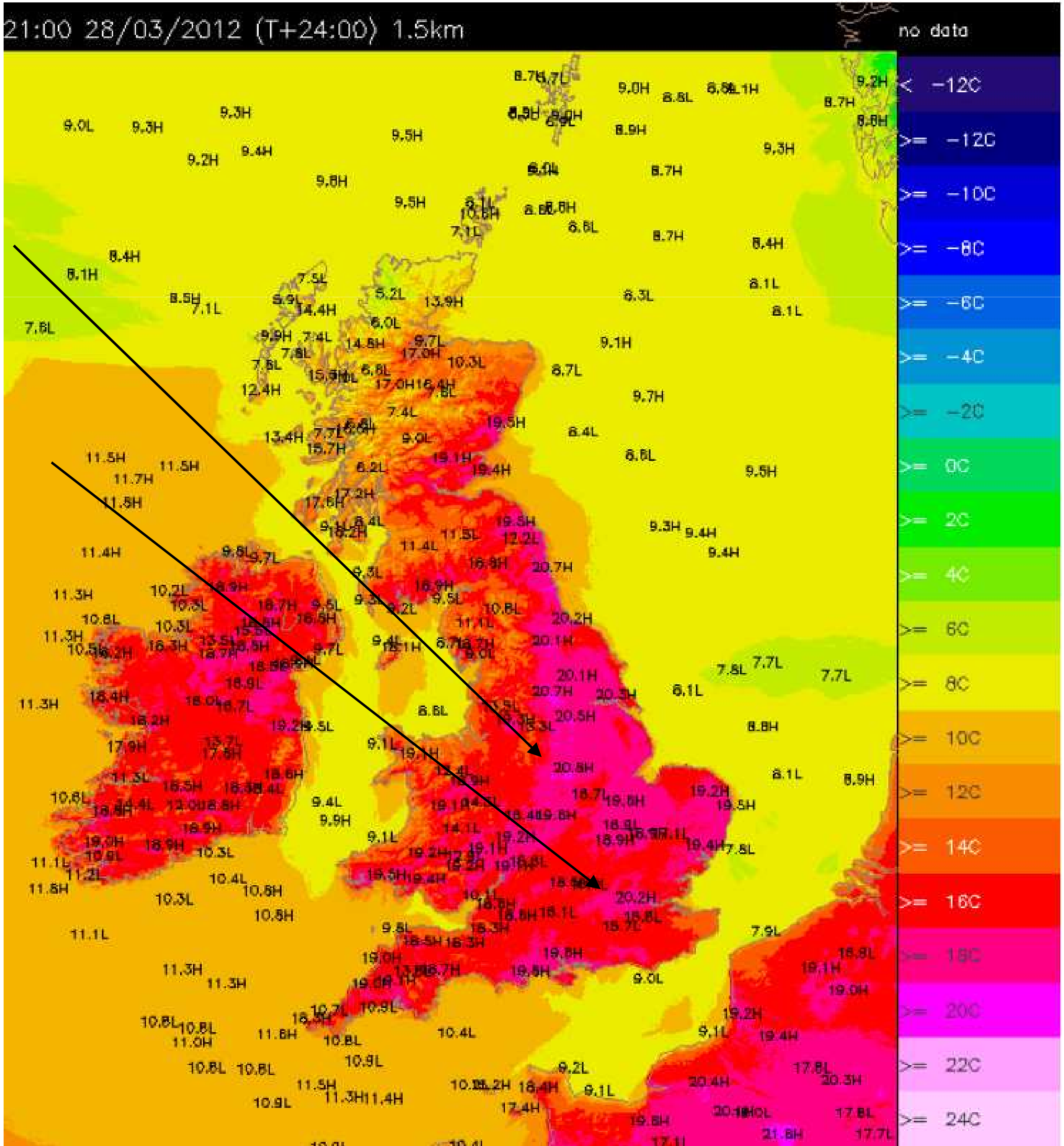
- The following comes from the Chief Forecaster Model Assessment and Emphasis:
- In order to judge the UKV model maximum temperature bias we need to compare similar runs e.g 21Z runs on consecutive days.
- Looking at the maxima yesterday compared to model expectation, the UKV was 1-2 degrees too low in some, but not all areas, notably in urban areas in the south and also to lee of high ground
- 18Z NAE analysis shows the expected 1360-1365 M over E Scotland and we expect an increase to 1360 M across many central and S parts of the UK for Wednesday.

UKV Tmax for 28/03/12 from 21Z run

Met Office

20.8 degrees

20.2 degrees



Example case: 28th March 2012

- Sample of actual maxima for Wednesday 28 March 2012
- **England**
- Heathrow and London St.James's Park 22.8
- Watnall 21.9
- Durham 21.8
- **Wales**: Usk 21.9
- **Scotland**: Strathallan 20.9
- **Northern Ireland**: Derrylin, Cornahoule 20.6

Model challenges

- Urban areas – MORUSES scheme under test
- Bowen ratio – LH Flux too large, sensible heat flux too small
- Soil - atmosphere coupling (too greater heat flux into the soil during the day).
- Radiation sees a (global) climatological aerosol. Values too high for the U.K - leads to damped diurnal cycle

Orographic enhancement of rainfall (Manchester weather Centre)

- The following rates of rainfall are what have been observed regularly, they persist for many hours over the named hilly areas (see next slide) when the following conditions are met:
- 1) Model output shows dynamically induced rainfall, at any rate
- 2) Warm advection persists during the period
- 3) A frontal system is near or will cross the area during the period
- The process of amplification of rainfall rate (compared to the model forecast rates) is probably due to enforced uplift (hence wind speed dependent), absolute water content (hence theta-w dependent) and warm advection (which maintains saturation of the airmass depth).
- Seeder-feeder effect. The effect is particularly marked when a conveyor belt is identifiable (a nose of high theta w is pointing towards the area)

Orographic enhancement of rainfall (Manchester weather Centre)

Met Office

Table A: NE Region - rates for the wettest gauges in West Pennines and Cheviot

Gradient wind speed with direction 190-260 degrees	30-35 knots	40-45 knots	55 knots	60-70 knots
850mb theta w 7,8,9 degrees C	1.0mm/hr	2.0mm/hr	3.0mm/hr	3.5mm/hr
850mb theta w 10,11,12 degrees C	1.0mm/hr	3.0mm/hr	3.5mm/hr	4.5mm/hr
850mb theta w 13,14,15 degrees C	1.5mm/hr	4.5mm/hr	5.0mm/hr	5.5mm/hr

South, Central and Northern Pennines, typically have 0.5-0.6 of these rates.

Table B: NW Region - rates for Honister

Gradient wind speed with direction 200-260 degrees	30-35 knots	40-45 knots	55 knots	60-70 knots
850mb theta w 7,8,9 degrees C	2.0mm/hr	4.0mm/hr	6.0mm/hr	9.5mm/hr
850mb theta w 10,11,12 degrees C	3.5mm/hr	6.5mm/hr	8.0mm/hr	10.0mm/hr
850mb theta w 13,14,15 degrees C	7.0mm/hr	10.0mm/hr	11.0mm/hr	12.0mm/hr

Other gauges e.g. Cornhow, Brotherswater, Thirlmere, Kentmere, typically have 0.5-0.6 of these rates.

Orographic enhancement of rainfall (Manchester weather Centre)

Table C: Snowdonia - rates for wettest gauges in Snowdonia

Gradient wind speed with direction 210-300 degrees	35-40 knots	40-50 knots	55 knots	60-70 knots
850mb theta w 7,8,9 degrees C	3.5mm/hr	5.0mm/hr	6.0mm/hr	7.0mm/hr
850mb theta w 10,11,12 degrees C	4.0mm/hr	5.5mm/hr	7.0mm/hr	9.0mm/hr
850mb theta w 13,14,15 degrees C	4.5mm/hr	7.0mm/hr	8.0mm/hr	10.0mm/hr

Clear Air turbulence (CAT)

- CAT is generated by the following processes

  1) wind shear

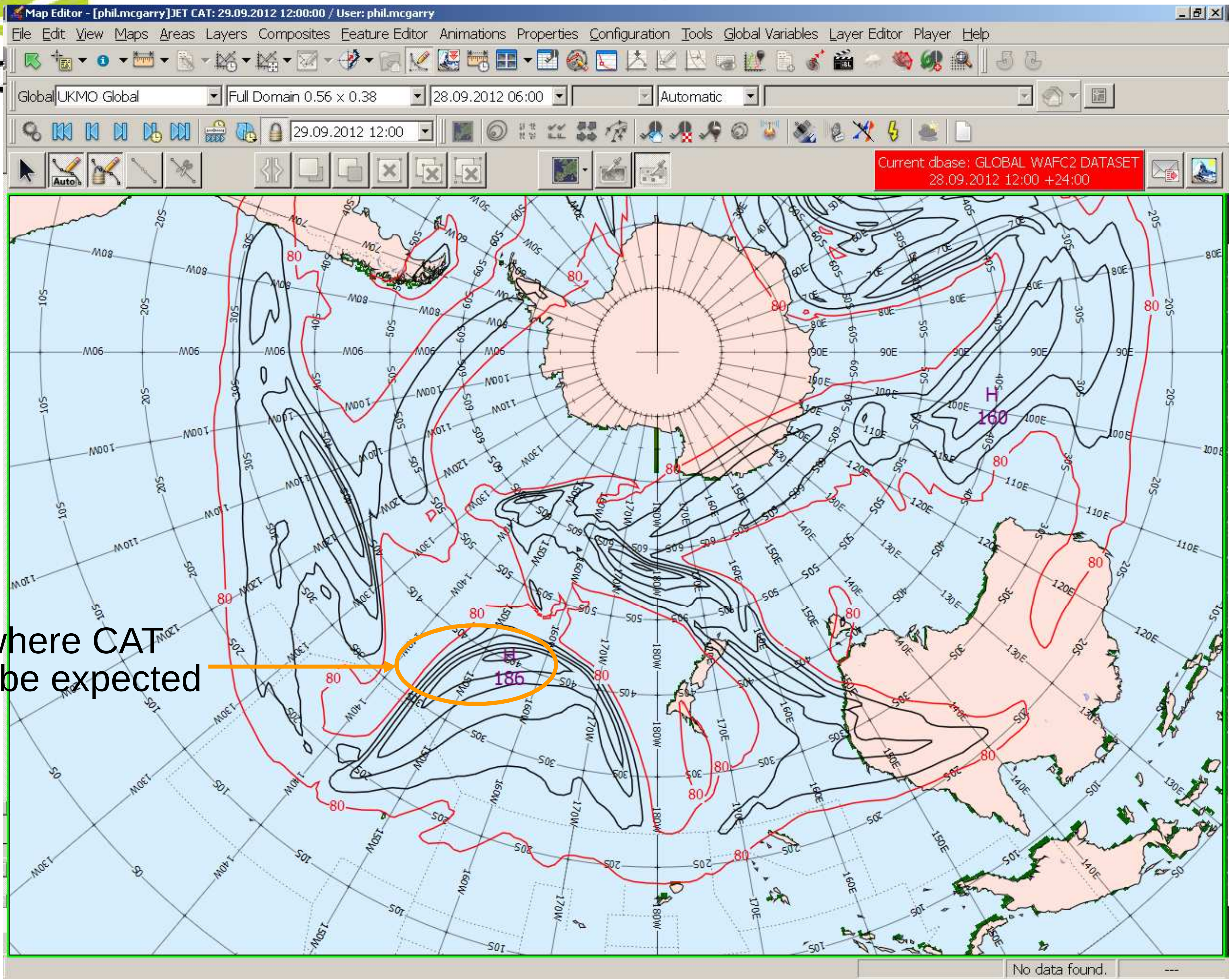
  2) Convection

  3) Mountain waves
- Two of the main methods used are Dutton (1980) and Ellrod (1990)
- Dutton gives a probability of CAT whilst Ellrod gives a potential
- Work in hand to combine these methods
- The NWP product has to serve two main users:

  1) Flight planning

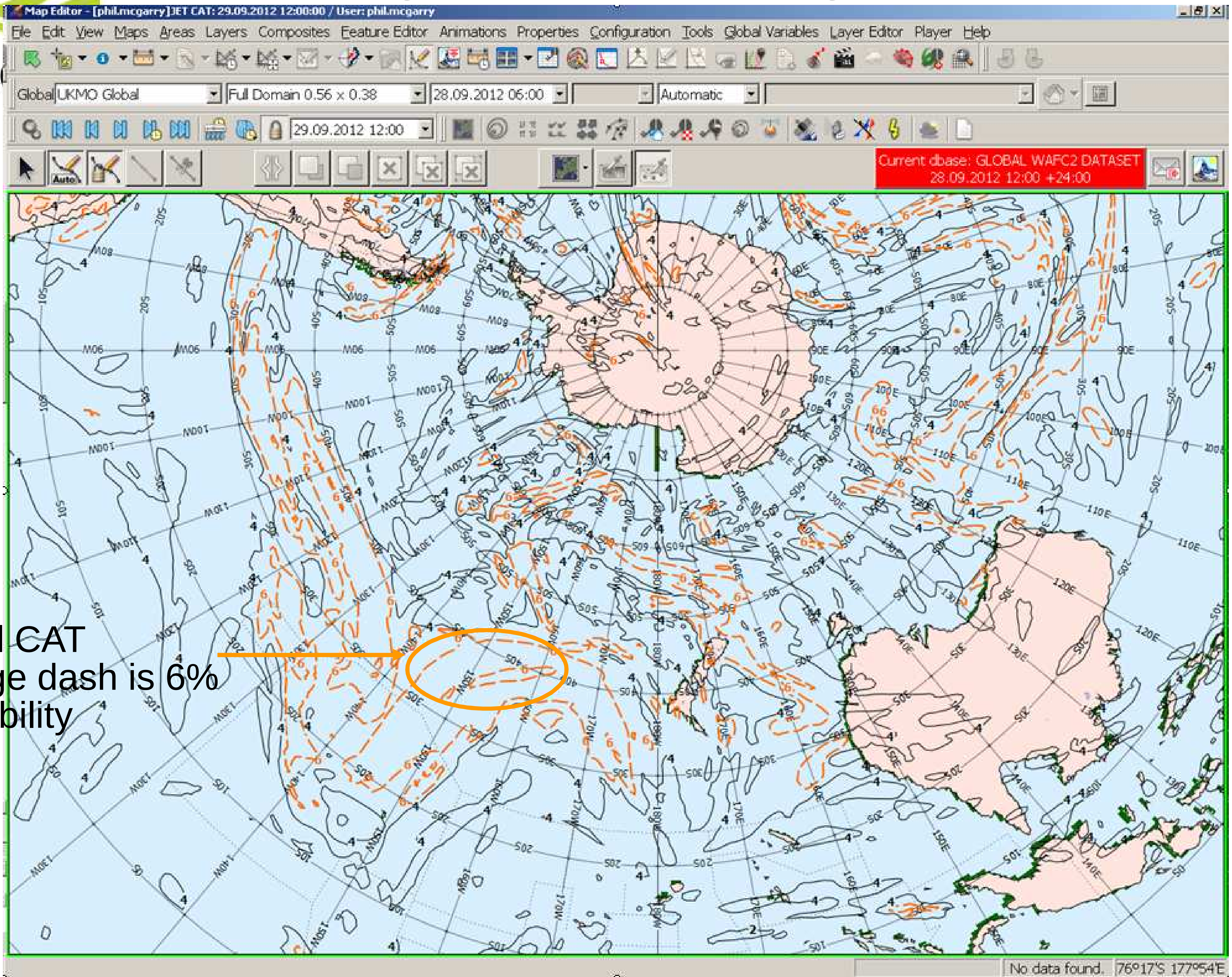
  2) Briefings for pilots
- The first of these can be quite a detailed field, whilst the second one has to be quite a smooth field

Max wind from global model



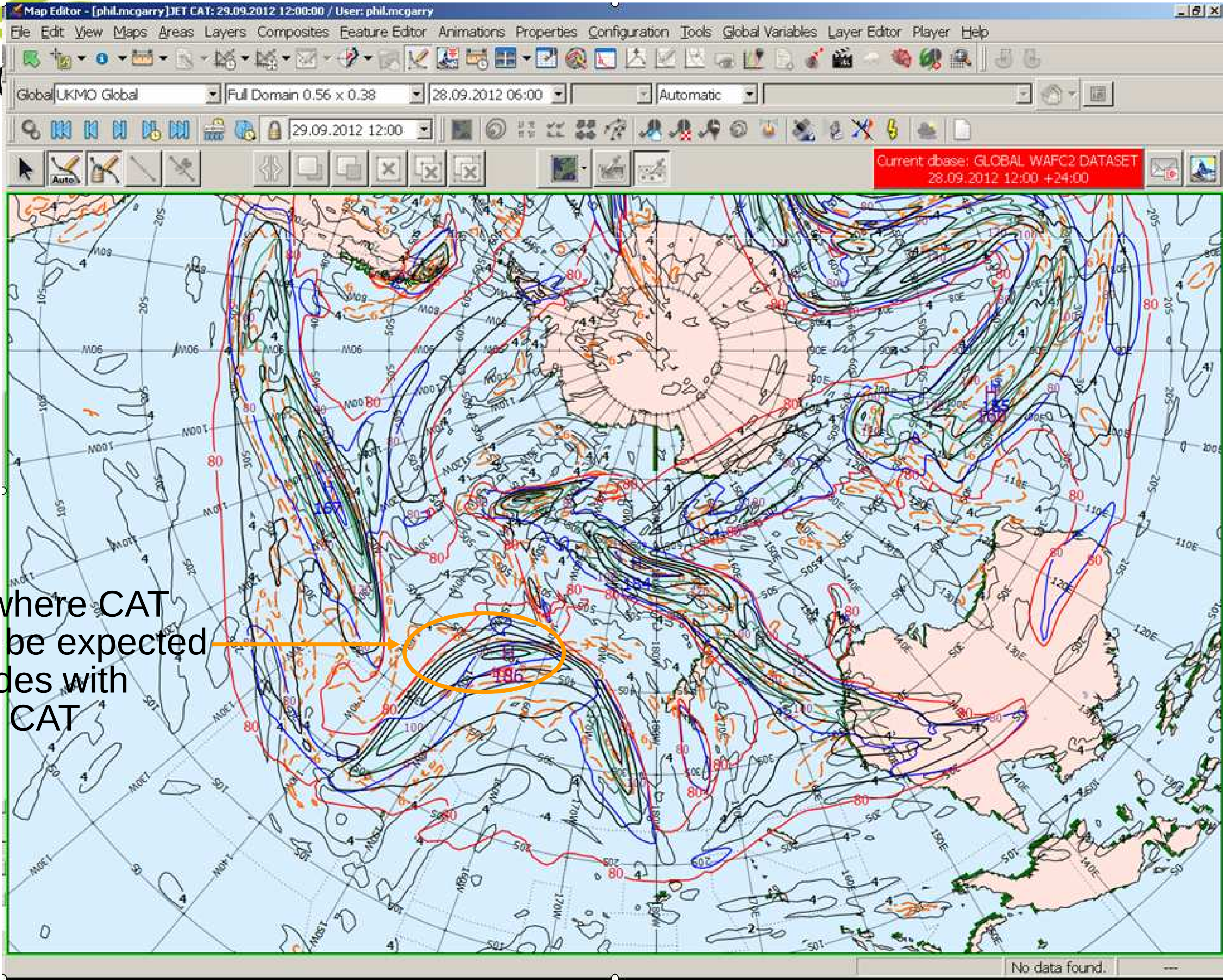
Area where CAT would be expected

CAT diagnostic from global model



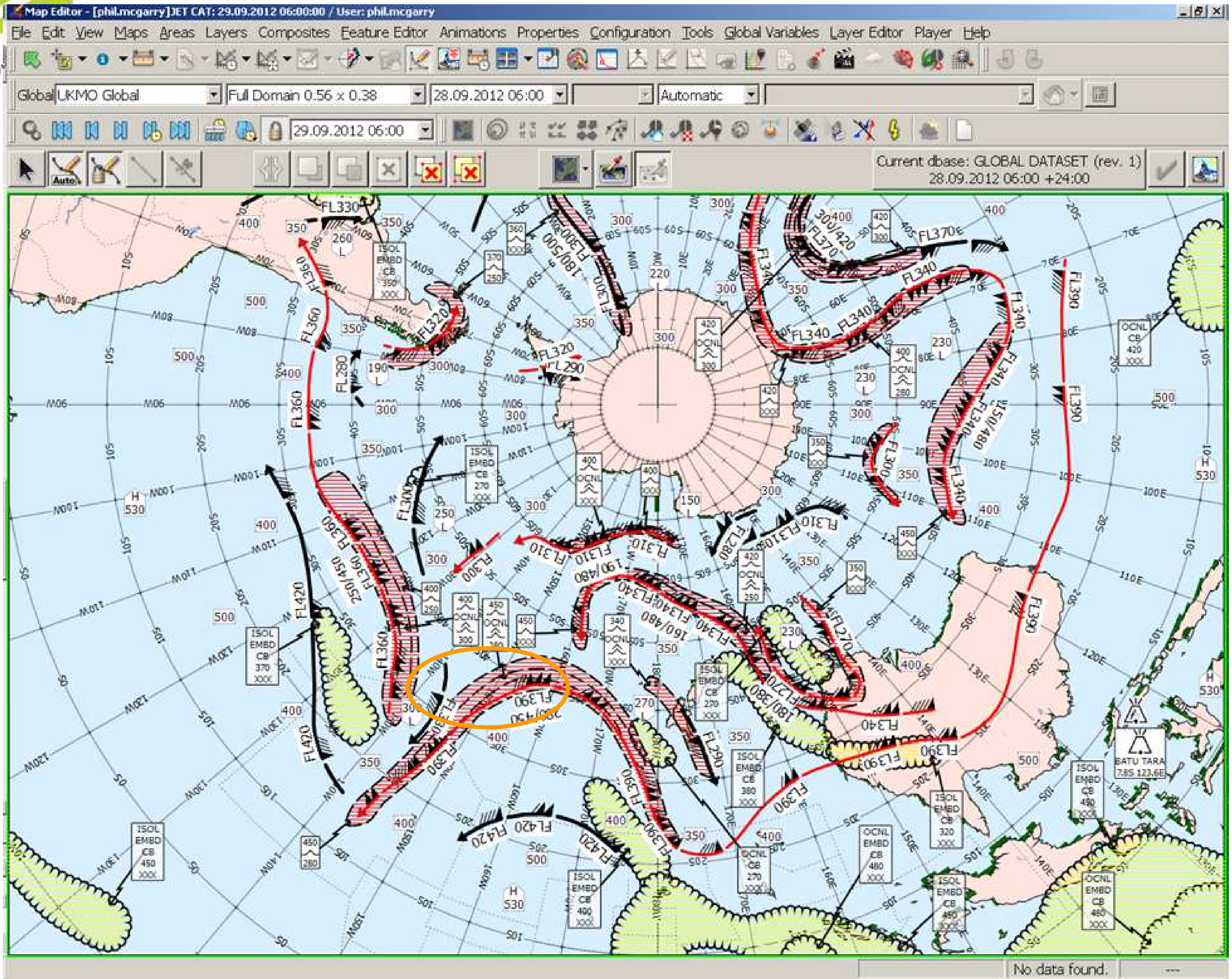
Model CAT
Orange dash is 6% probability

Model max wind and CAT overlaid

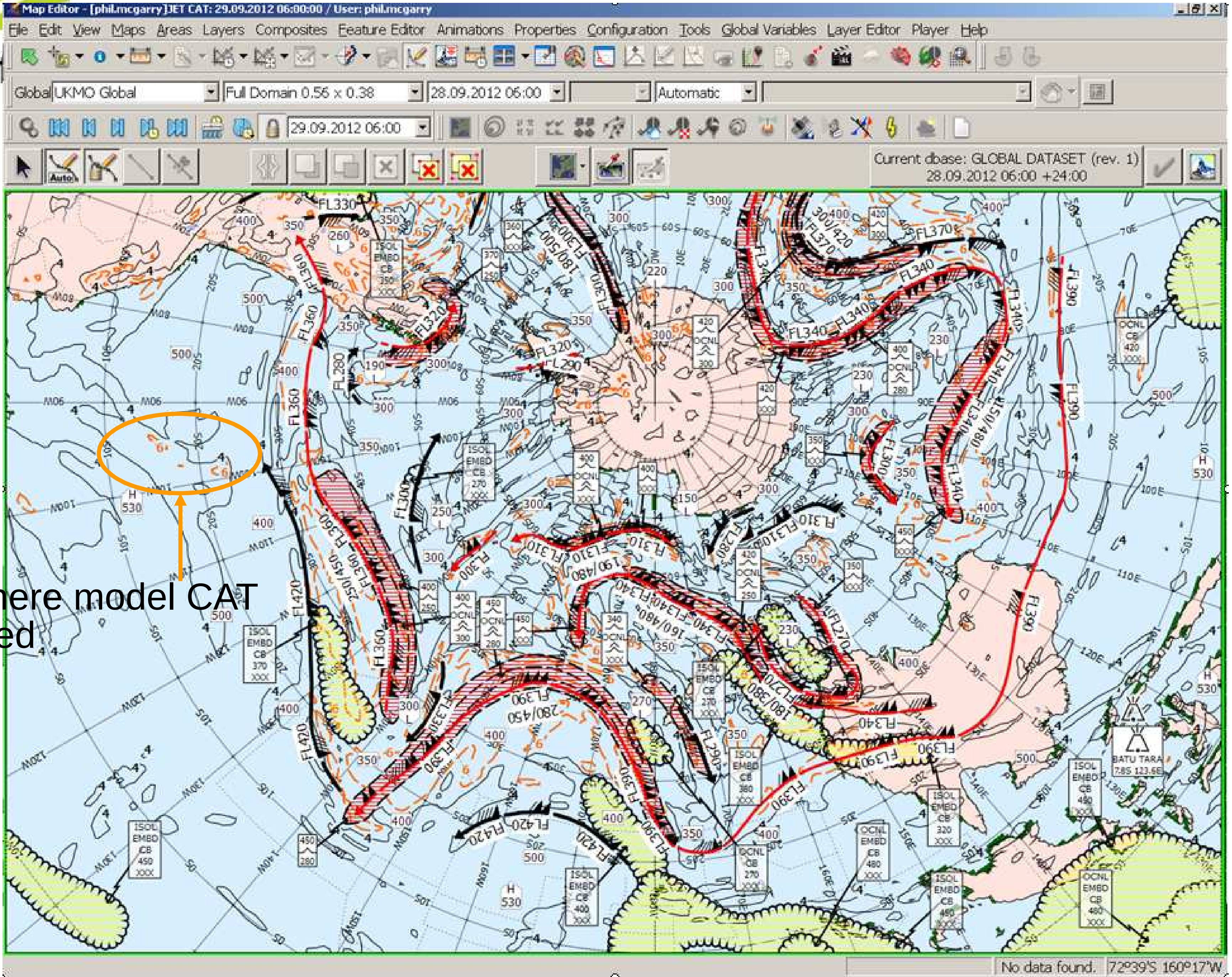


Area where CAT would be expected coincides with model CAT

WAFC CAT – much smoother



WAFC CAT



Area where model CAT
Is ignored

Clear Air turbulence (CAT) & WAFC

Met Office

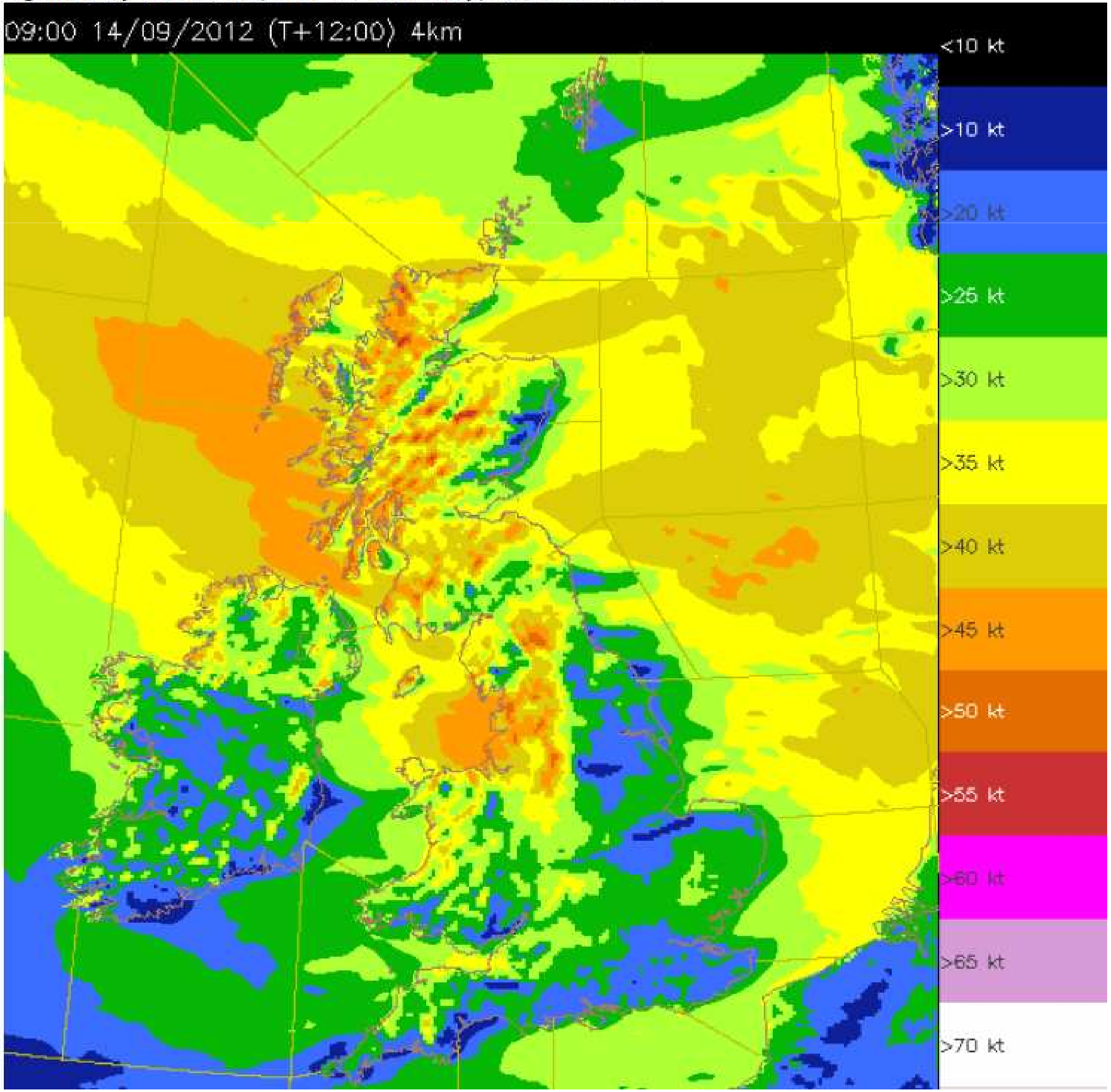
- The World Area Forecast Centre (WAFC) bench have to produce CAT maps
- Forecasters visualise the maximum wind field and the 300mb wind field and will mentally pick out areas of CAT based on the tightness of the wind contours around jets.
- They overlay the model CAT probability field (Dutton) and then hand draw charts of CAT to produce a smoothed field.
- The Significant Weather Automation Project aims to produce an NWP product (smoothed objects) that forecasters can use directly without having to hand draw charts

Wind gust diagnostic

- The parametrisation is essentially the same as the one used by ECWMF
- Gust=wind_10m + C* sigma
- C=4.0 and sigma estimated from Ustar in surface boundary layer parametrisation.
- There hasn't really been a tuning to obs ,and the same constant C is used for all resolutions.
- We do not add a contribution from convective downdrafts.

Wind gust: 14/09/12

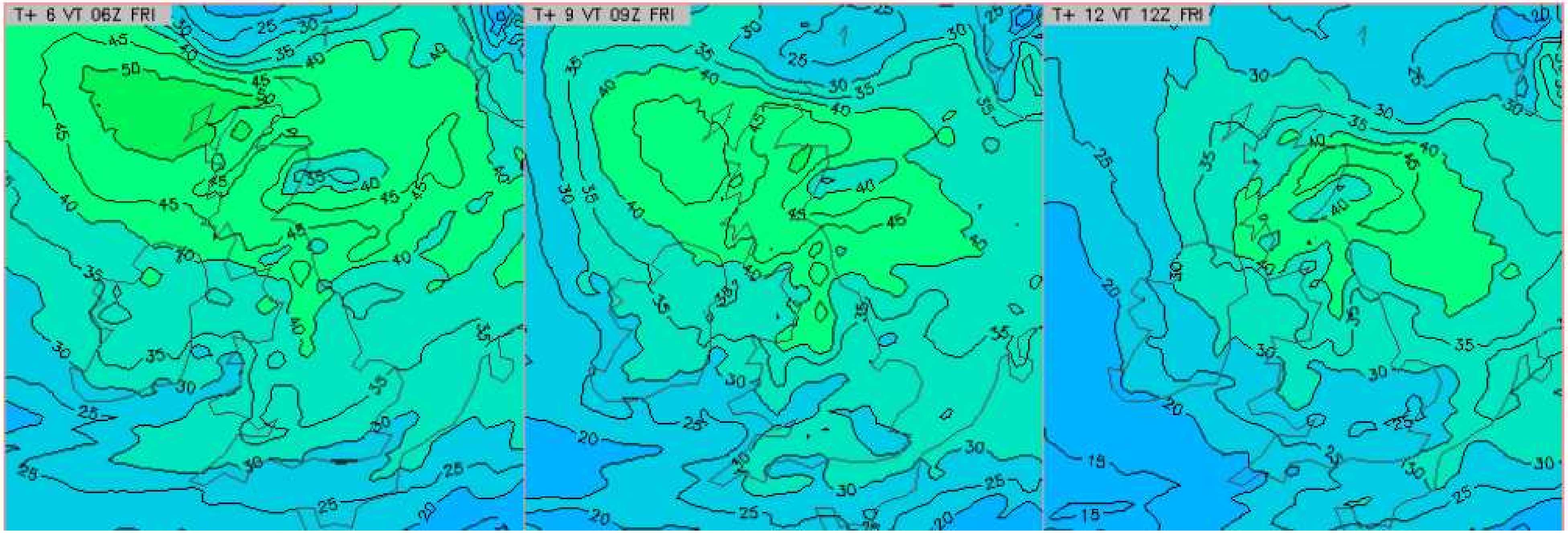
UK4 gusts 09Z today – suggests close to 50kn top of Pennines. Gusts lee of Pennines likely to be significantly underdone, with 40-45kn likely, and isol 50kn+.



Met Office

Wind gust: 14/09/12

Adjusted 600m winds as guide to gusts – probably good guide to lee gusts in prone spots although will underplay strengths on high ground.



Model challenges

- Vale of York lee gustiness associated with downslope winds and mountain waves.
- The new ENDGAME dynamical core will treat gravity waves better than New dynamics and I is hoped that lee waves will be better represented.
- Model resolution is also important.

Mountain waves

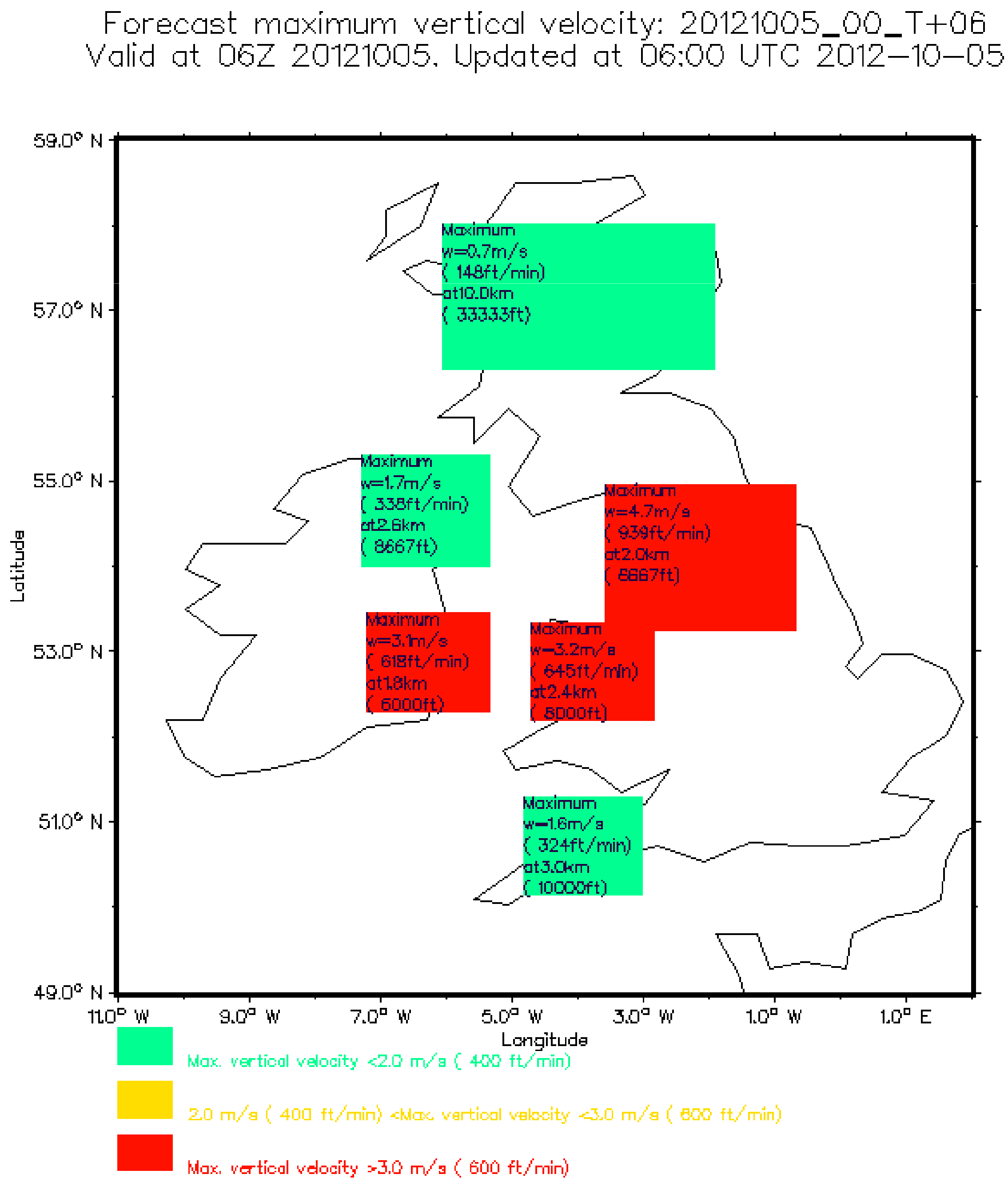
- Casswell (1966)
- Shutts (1993)
- Forecasters typically use Casswell to give them an idea of the spatial extent of mountain wave activity
- They then explore forecast tephis in the region of interest and get values of w from Shutts
- They look at 3DVOM output
- Then combining all of this with satellite imagery they come up with a best guess forecast

3DVOM

Met Office

- 3DVOM (3-D Velocities over Mountains) is a finite-difference numerical model designed for high-resolution simulations of lee waves generated by flow over complex terrain.
- The model is based on a set of simplified equations of motion, the linearised shallow Boussinesq equations of motion for a dry atmosphere
- Because the equations of motion are greatly simplified (relative to those in a full NWP forecast model) solutions can be generated relatively quickly.
- The 3DVOM code is used to generate high-resolution detailed forecasts of lee-wave fields and associated near-surface winds.

3DVOM output

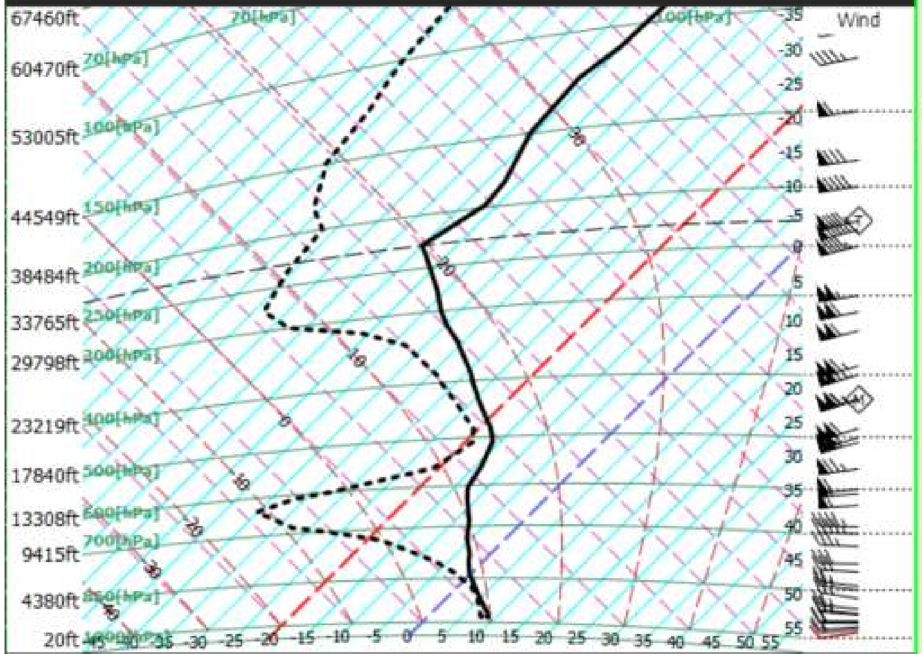


Forecast tephi and lee waves (Shutts)

Global UKMO Global | Full Domain 0.56 x 0.38 | 05.10.2012 06:00 | 00.0 | 000.0

Ascent Navigator

Model: UKMO Global/Full Domain 0.56 x 0.38*
Run: 05.10.2012 06:00*
Validity: 05.10.2012 06:00 (+0:00)



TABULATED LEE WAVES

Height (ft)	Maximum vertical velocity (ft/min)
16404	580.85

Height ft	1st wave ft/min	2nd wave ft/min	3rd wave ft/min	4th wave ft/min
1640	174.06	177.82	***	***
3281	306.81	308.35	***	***
4921	397.24	388.88	***	***
6562	461.88	441.23	***	***
8202	511.57	479.33	***	***
9843	531.65	485.35	***	***
11483	527.32	464.77	***	***
13123	534.80	452.74	***	***
14764	558.02	448.57	***	***
16404	**580.85**	437.73	***	***
18045	573.47	407.07	***	***
19685	542.66	367.13	***	***
21325	508.77	329.55	***	***
22966	476.11	295.60	***	***
24606	446.56	265.98	***	***
26247	425.21	244.58	***	***

Lee Wave

Model challenges

Met Office

- Verification of 3DVOM has been carried out against satellite and aircraft observations.
- S. B. Vosper, H. Wells, J. A. Sinclair and P. F. Sheridan: **A climatology of lee waves over the UK derived from model forecasts** *Meteorol. Appl. (2012)*
- However forecasters “feel” that 3DVOM tends to overpredict mountain waves.
- Work is in hand to improve 3DVOM output for forecasters e.g. outputting 95^{th} percentile winds rather than the maximum.

General comments (1)

- Forecasters use these methods to give themselves an independent way of checking whether the model output looks sensible or not.

- Do the predictions from these methods tally with the model?

- If not then look more closely…

- The precipitation example gives you an idea of the potential accumulations.

- Particularly useful at long lead times (e.g. 5 day forecast) to give a "heads up warning". You may not have high resolution model output and positioning errors may be quite large.

- Ensembles do not always sample all the eventualities, having a tendency to cluster too strongly around the deterministic solution.

General comments (2)

- Despite the considerable advances in NWP skill, there remain serious challenges for our models
- Data assimilation: soil moisture/temperature initialisation. DA for convective scale models…
- Parametrizations: correctly representing parameters such as snow, cloud etc.
- Resolution: the horizontal and vertical resolution of our models is only just enough to resolve mountain lee waves for example. Parameters such as fog and screen temperature can vary greatly on very local scales.
- So these empirical methods may hang on for a little while longer…