



Met Office

Meteorology Research and Development

**Preparations and experiments to assimilate satellite image data
into high resolution NWP.**



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Preparations and experiments to assimilate satellite image data into high resolution NWP.

(Key milestone of Research Activity RC01E Sep 2008)

Work on the use of SEVIRI radiances in the Met Office UK4 and NAE models.

Graeme Kelly

Abstract

The aim of the project is to assimilate in 3D-Var/4D-Var radiances from the SEVIRI instrument on board Meteosat. At present these data are only used in NWP indirectly using cloud and rainfall estimates from the aging Nimrod system. This study begins by developing the infrastructure to monitor and calculate SEVIRI radiance bias corrections. Then assimilation trials, using clearest SEVIRI data, were run using both the NAE and UK4. The success of these trials has led to clear SEVIRI radiances being included in PS20 and they will also be included in the next (1.5 km) version of the mesoscale system. More work is ongoing to improve the land cloud-clearing in order to make use of lower sensing SEVIRI channels. Finally, looking towards the future, simulations of cloudy SEVIRI radiances have been carried out using the model guess and comparisons with the SEVIRI radiances suggest it should be viable to assimilate cloudy SEVIRI radiances directly in 4D-Var.

Introduction

The first in the series of Meteosat Second Generation (MSG) spacecraft was declared operational and designated Meteosat 8 on 29th January, 2004. These spacecraft carry the Spinning Enhanced Visible and Infrared Imager (SEVIRI) as the successor to the Meteosat Visible and Infrared Imager (MVIRI) instrument carried by earlier Meteosat spacecraft. SEVIRI has 12 channels, 8 of which are in the infrared, compared with MVIRI's 3 channels (1 visible, 2 infrared). SEVIRI also has a higher spatial resolution and takes images more frequently. The instrument is described in Schmetz et al (2000). The current operational satellite is the second in this series, Meteosat 9. SEVIRI clear radiances are being used by other operational centres, which include Météo France (Montmerle, 2005a and b) and ECMWF (Szyndel, et al., 2004).

The aim of the current work is the assimilation initially of clear and eventually of cloudy SEVIRI radiances into the operational convective scale (1.5 km) NWP Model. The first trials assimilate clear SEVIRI radiances in the NAE and UK4 operational systems. Both the initial trials have been successful and the clear SEVIRI radiances have been included in the next operational cycle, PS20.

Outline of paper

This study begins by developing the infrastructure to monitor and calculate SEVIRI radiance bias corrections. A web site has been set up for this purpose similar to those for other instruments such as IASI.

Assimilation trials, using clearest SEVIRI data, were run using both the NAE and UK4. The success of these trials has led to SEVIRI clear radiances being included in PS20. SEVIRI clear data will then become part of the operational data stream and be included in the future 1.5 km mesoscale system which is being set up.

Work is ongoing to improve the land cloud-clearing in order to make use of lower sensing SEVIRI channels. Some work in this study suggests that the use of the High Resolution Visible (HRV) channel will help in the daytime cloud detection over land.

Finally, looking towards the future, simulations of cloudy SEVIRI radiances have been carried out using the model guess. Comparisons of these simulations with the observed SEVIRI radiances suggest it should be viable to assimilate cloudy SEVIRI radiances directly in 4D-Var.

Use of SEVIRI radiances

Pre-processing

SEVIRI radiances are received via EUMETCast and pre-processed through the Autosat system (Saunders et al. 2006, Francis et al. 2006). The data are then sent to the MetDB in BUFR format twice every hour:

- for slots ending at HH.45: data with satellite nadir angle less than 65 deg, within the NAE domain and thinned to one pixel in every four (figure 1);
- for slots ending at HH.15: data covering only the UK 4km domain, at full pixel resolution (figure 2).

Forward Modelling

The monitoring plots displayed on the SEVIRI [website](#) compare SEVIRI observations with simulated brightness temperatures calculated using the appropriate 6hr forecast fields produced by the NAE model and the RTTOV (Saunders et al., 1999) fast radiative transfer model. Observations within 180 minutes either side of the analysis time are processed, and the forecast fields are interpolated to the observation time and location. These calculations are carried out in a processing stage (which includes a 1D-Var step) in OPS.

Channel Selection

6 SEVIRI infrared channels are currently monitored (table 1). We do not currently monitor the 3.9 μm channel or the 9.7 μm ozone channel.

Table 1 SEVIRI channels monitored by OPS.

SEVIRI numbers	5	6	7	9	10	11
Wavelength (μm)	6.2	7.3	8.7	10.8	12.0	13.4

Cloud Detection

Cloud detection is first carried out in the pre-processing step on Autosat, using a series of visible and infrared tests. Only pixels classed as being cloud-free are used in the monitoring plots. Figures 3 and 5 show examples of the OPS monitoring for sea and land. There is a large increase in standard deviation (SD) for the low peaking channels over land. For example channel 9 increases by a factor of three from sea to land. This will be discussed later using two case studies to help understand this increase.

Bias Correction

All observations are bias corrected before being used in Var. The correction currently consists of a different constant offset for each channel plus a linear function of the 850-300 hPa thickness and 200-50 hPa thickness (Harris and Kelly, 2003), with different coefficients for each channel. The coefficients are static, but updated periodically as required depending on model or data assimilation changes and any drifts detected with the monitoring plots. Figures 4 and 6 show examples of the monitoring plots after bias correction.

Two cases studies examining Autosat cloud detection.

The magnitude of the clear uncorrected SEVIRI O-B differences found over land in comparison to sea (see monitoring plots in figures 3 and 5) for channels 7,9,10

and 11 are increased over land by a factor of two to three. The clear data locations were plotted on top of the HRV image which has a resolution of ~1.5km/pixel at these latitudes. In addition, histograms of O-B uncorrected departures of channel 9 are plotted for land and sea. Two different cases were chosen, one with large clear regions for land and sea and the other with many small clouds over the land. In the second case a large number of the clouds are smaller than the infrared pixel size (~ 5km) but can be seen in the HRV imagery with smaller pixels(~1.5 km).

Figure 7 shows HRV imagery for the first case, at 15 UTC on 14th of May 2008. There are some large clear regions over Ireland and the south of the UK. Towards the northeast and the southwest of the UK the cloudiness gradually increases. The small Channel 9 O-B departures with magnitudes up to 1 deg are plotted in yellow on HRV imagery (figure 8) and there is good agreement with the HRV clear regions. In contrast O-Bs with magnitudes greater than 1 deg are plotted on the same HRV image in figure 9. Red points (O-Bs less than -1 deg) suggest that the supposedly clear SEVIRI pixels are likely to be cloudy, as they are often points around cloudy regions on the HRV image. An additional source of error in the O-Bs may be errors in the UK4 surface temperature and also the assumption that land surface emissivity equals 1. The fewer blue points in figure 9 show the O-Bs greater than 1 deg and are generally in cloud free regions.

Figure 10 shows two histograms of clear O-B SEVIRI channel 9 departures for both land and sea points. Over sea the cloud detection and bias correction appear to be doing a good job. The data appear reasonably Gaussian and in agreement with the monitoring (figures 4 and 6). Over the land the variance is larger and the distribution is a little asymmetric suggesting that many Autosat flagged 'clear pixels' are in fact cloudy.

The second case, at 15UTC on the 19th July 2008, is shown in figure 11. This is a very difficult case for Autosat SEVIRI cloud detection over land. Over the central west of the UK there are some small regions of clear sky but further south there are many clouds likely to be smaller than the SEVIRI IR pixels.

Figure 12 shows the Autosat clear pixels with O-B magnitudes for channel 9 of less than 1 deg in yellow. These data points appear to be clear, based on the

HRV image. On the other hand if we now look at SEVIRI clear spots outside 1 deg for channel 9 O-Bs (figure 13) there are many spots marked 'clear' but which appear cloudy based on the HRV imagery. The red spots are cooler than the surface suggesting that the Autosat cloud detection has failed. Again there is a small number of blue spots where the difference may be due to errors in the model surface temperature. Figure 14 shows the same SEVIRI pixels, with departures plotted on top of the lower resolution SEVIRI VIS 0.8 μm channel. Here it is very difficult to see the small clouds.

Figure 15 again shows two histograms of clear O-B SEVIRI channel 9 departures for both land and sea points. Over sea the cloud detection and bias correction appear to be doing a good job. The data appear reasonably Gaussian and in agreement with the monitoring (figures 4 and 6). Over the land the variance is larger and the distribution is asymmetric, suggesting that many Autosat flagged 'clear pixels' are in fact cloudy.

Soon it is hoped to make use of HRV imagery in the Autosat's cloud processing to improved cloud detection. HRV has 9 visible pixels within each pixel of all the other SEVIRI channels.

Data assimilation and forecast impact.

The processing of SEVIRI radiances follows the general flow taken by other satellite instruments like AMSU-A, IASI or HIRS in OPS. The quality control for clear data is based firstly on the AutoSat cloud flag followed by the 1D-Var cost. Finally an extra window quality check is made using the O-B value for channel 9 to delete situations where the AutoSat fails to detect cloud. This test sometimes deletes some good measurements but it is important not to use cloud-affected spots as clear radiances in VAR. The observation errors are also set in OPS and based on the SEVIRI monitoring. The SEVIRI channel usage has been chosen carefully for these initial VAR trials until the AutoSat land cloud flag is improved. The channel usage is shown in Table 2.

Table 2 SEVIRI channel usage.

sea	SEVIRI channels 5,6,7,9,10
land	SEVIRI channels 5,6

Channel 11 (13.4 μm) was excluded due to the bias not being stable after periods of spacecraft decontamination. The data are finally thinned to a horizontal resolution of 40km to reduce the problems of correlated observations not entirely removed by the bias-correction process.

Results for the pre PS20 trials.

(a) NAE trials.

A PS19 control test suite was setup to test all likely changes to PS20 and an additional trial was run adding SEVIRI clear radiances. The data are used four times per hour during the six-hour 4D-Var assimilation cycle. The test suit was run during Summer 2008 for 40 days. After cloud clearing, quality control and thinning about 6500 clear SEVIRI spots remain over sea and about 4500 spots over land.

VAR O-B brightness temperature statistics for the first cycle of used clear SEVIRI data are shown in Table 3. The upper level water vapour channels 5 and 6 have the largest impact on the analysis. The RMS for these channels is reduced by over 40% after minimization, indicating that the analysis is drawing strongly to these channels at the first cycle. The other three channels reduce RMS by about 20% and have a smaller impact on the analysis. The biases for all the channels are generally small, reflecting the bias correction scheme doing a good job in accounting for both model and radiative transfer errors.

Table 3 VAR O-B stats for SEVIRI radiances in the first cycle.

	Ch 5	Ch 6	Ch 7	Ch 9	Ch 10
No of pixels	6608	6608	4667	4667	4667
RMS guess	1.73	1.36	.45	.60	.58
RMS anal	.86	.79	.38	.48	.39
Bias guess	.78	.51	.22	-.32	.08
Bias anal	.22	.17	.22	-.29	.12

Table 4 VAR O-B stats for SEVIRI radiances after 7 days of data assimilation.

No of pixels	6478	6478	4381	4381	4381
RMS guess	1.32	1.08	.45	.43	.53
RMS anal	.93	.78	.39	.40	.40
Bias guess	.31	.16	.29	-.10	.21
Bias anal	.25	.18	.23	-.19	.11

A measure of the value of a new data type in assimilation is the ability of the system to retain the information throughout the assimilation cycle process. This is demonstrated in Table 4. After a few days of SEVIRI assimilation the SEVIRI O-B stats become stable for each cycle and smaller than the first cycle, showing that SEVIRI channels 5 and 6 are retained by the system. The lower channels do not show a similar improvement, suggesting the observation errors for these channels are too large for these lower humidity channels.

The clear SEVIRI [impact](#) is neutral on most variables but there is some improvement on the 500 hPa wind and 300 hPa humidity. This is most likely to be due to the upper level SEVIRI humidity channels and has also been reported by ECMWF (Szyndel, et al., 2004). Figures 16 and 17 show the mean and RMS 48-hour forecast verification statistics compared with radiosondes for 38 days. Red is the control and Blue the control plus SEVIRI clear radiances. Parameters used in the NAE UK index are shown in figure 18 where most ETS scores are

positive except the wind, which is only slightly negative. The overall UK index (a weighted sum of ETS scores) shows an improvement of 0.16%

(b) UK4 trials with and without SEVIRI clear radiances.

A set of UK4 3D-Var PS19 controls similar to those for the NAE (described above) have been run to test various options for UK4 PS20. A series of 5 data assimilation cases have been run. Each case starts with the NAE background and uses NAE boundary conditions. Three 3-hourly data assimilation cycles are run followed by three assimilation cycles that include three 30-hour forecasts using the UK4 system. The weather types chosen are shown in Table 5.

Table 5. The weather types chosen.

Case	Weather
May 7th 2008 12UTC	Warm Anticyclonic
Jun 3rd 2008 12UTC	Cyclonic with Occlusion
Jul 28th 2008 12UTC	Vortex in SW
Aug 6th 2008 12UTC	Stalling Occlusion
Aug 31st 2008 12UTC	Cold front pushing east

An additional trial has been run adding the use of SEVIRI clear radiances to these five cases. These measurements are used four times per hour during the 3-hour 3D-Var assimilation cycle (the off-time observations are adjusted using FGET in OPS). After cloud clearing, quality control and thinning on average about 700 clear SEVIRI spots are used over sea and 500 over land, however these numbers are quite variable in this region, depending on cloud cover.

The O-B brightness temperature statistics for used SEVIRI data in for the guess and after minimization are shown in Table 6. The upper level water vapour channels 5 and 6 have the largest impact on the analysis. The RMS for these channels is reduced by over 40% after minimization showing that the analysis is drawing to these channels at the first cycle. The other three channels only reduce

RMS slightly and have little impact on the analysis. The biases for all the channels are generally small reflecting the bias correction scheme doing a good job in accounting for both model and radiative transfer errors.

Table 6

	Ch 5	Ch 6	Ch 7	Ch 9	Ch 10
No of pixels	696	696	659	659	659
RMS guess	1.7	1.2	.37	.38	.56
RMS anal	.94	.8	.36	.36	.51
Bias guess	-.78	-.53	-.15	-.15	-.24
Bias anal	-.03	-.12	-.10	-.13	-.16

During later assimilation cycles SEVIRI O-B RMS statistics do not reduce in contrast to the NAE trials. This could be due to the use of 3D-Var rather than 4D-Var in UK4. Another reason may be the use of the operational NAE for boundary forcing, which does not use SEVIRI clear radiances.

The forecast [impact](#) is small on most parameters except cloud cover. Figures 18, 19 and 20 show the improvement in cloud cover with respect to station measurements. Also figure 21 shows an improvement on the UK4 index of 3.5% based on 15 forecasts. In PS20, with the combined use of SEVIRI in both NAE and UK4, there may be some further improvement in UK4 forecasts.

Simulation of cloudy SEVIRI from NAE and UK4 models.

In the final part of this study some simulations of cloudy SEVIRI radiance have been made using ‘cloudy RTTOV’ in OPS using both NAE and UK4 forecasts. Comparisons of imagery and histogram plots of brightness temperature will be discussed.

NAE cloudy simulations for SEVIRI 10.8 μ m channel 9.

Before performing the model SEVIRI simulations a sanity check was made with the diagnostic software being used to display a reconstructed image from the

OPS in order to compare with the same image directly obtained from the EUMETSAT archive. For the NAE region this contains one in four pixels of the original SEVIRI image. Figure 23 is reconstructed from the OPS output and compared with the EUMETSAT archive in figure 22. The brightness temperature for each pixel is within .02 deg.

Figure 24 shows a 24km cloudy RTTOV simulation from a model first guess. It shows that most of the major cloud systems are present in the model but there are some details that could be adjusted by assimilating the cloudy radiances. The 24km NAE model used in this simulation shows details of the larger cloud features only. Further simulations will be run at the operational NAE resolution (12km).

UK4 cloudy simulations for SEVIRI 10.8 μm channel 9.

The current UK4 grid spacing is slightly smaller than the SEVIRI infrared pixel size over the UK. Figure 25 shows the simulated OPS imagery using 'cloudy RTTOV' from the UK4 guess. Figure 26 shows the SEVIRI channel 9 image which is reconstructed from the OPS output. The position of the main frontal band over central UK is in good agreement with cold brightness temperatures of similar magnitude (see later). The simulation in the cloudy band is a little lumpy showing the model's cloud is less organized. The convective band over Ireland in the simulated SEVIRI image is similar to that in the observed image but again less organized.

Histograms of the raw brightness values of channel 9 are plotted for both the simulated and observed SEVIRI pixels (figures 27 (sea) and 28 (land)). These types of plot show the cloud top temperatures are well distributed in the vertical even for the coldest clouds. Near the surface, clouds over the land appear colder than the SEVIRI values whereas the low clouds over the sea are in better agreement. Figure 29 shows the corresponding O-B histograms for figures 27 and 28. Over sea there is a more Gaussian distribution than over land, however, the width of the distribution is not greatly increased. These statistics are very encouraging and hopefully will be better with the 1.5km model.

Summary and Recommendations

The infrastructure to monitor and calculate SEVIRI radiance bias correction has been setup and is running routinely. This is an important first step in assimilation SEVIRI radiances. The next monitoring suite will be for cloudy SEVIRI radiances using both the UK4 and NAE operational first guesses.

Problems have been found with Autosat cloud clearing and work is required to improve the land cloud clearing. Use of the HRV channel during daylight hours could help. The CRM product from EUMETSAT may also be useful with a specification of land surface properties.

The success of the assimilation trials, using clearest SEVIRI data with both the NAE and UK4, has led to clear SEVIRI radiances being included in PS20. This is an important step towards the use of clear SEVIRI in 3D-Var for the new mesoscale system which will have horizontal grid resolution of 1.5km. However more work will be required in OPS and VAR to improve the use of superobbing and thinning to avoid problems with correlated error.

The simulations of cloudy SEVIRI radiances have been carried out using the NAE and UK4 models and are very encouraging. Simulations should be even more realistic using the 1.5km model. The cloudy radiance simulations from the forecast can now become part of the mesoscale forecast validation. These cloudy model simulations will help development of model cloud properties.

The next step, possibly the most important, is to assimilate cloudy SEVIRI radiances directly in 4D-VAR. Experiments will begin with 4D-Var using NAE assimilation followed with some 4D-Var mesoscale assimilation at 1.5km over a limited domain.

References

Francis, P.N., Capacci, D. and Saunders, R.W. 2006 Improving the Nimrod nowcasting system's satellite precipitation estimates by introducing the new SEVIRI channels. Proceedings of 2006 EUMETSAT Meteorological Satellite Conference, Helsinki, Finland 12-16 June 2006.

B.A.Harris and G.Kelly, 2001: A satellite radiance-bias correction scheme for data assimilation Q.J.Roy. Met. Society.,127,1453-1468

T. Montmerle, 2005a: Assimilation of satellite data in a regional mesoscale model Eumetsat Research fellowship,
Final report EUMETSAT Damstadt Germany

T. Montmerle, 2005b: Use of geostationary SEVIRI radiances in ALADIN 3D-Var ALADIN Newsletter 27

www.cnrm.meteo.fr/aladin/newsletters/news27

Saunders, R.W., M. Matricardi, and P. Brunel, 1999: An improved fast radiative model for assimilation of satellite radiance observation. Q. J. R. Meteo. Soc., 125, 1407-1425

R Saunders, R Francis, P Francis, J Crawford, A Smith, I Brown, R Taylor, M Forsythe, M Doutriaux-Boucher and S Millington, 2006. The exploitation of METOSAT SECOND GENERATION data in the MetOffice Proceedings of 2006 EUMETSAT Meteorological Satellite Conference, Helsinki, Finland 12-16 June 2006.

Schmetz, J., Pili, P. and Tjemkes, S. 2000: Meteosat Second Generation(MSG) Pp. 111-121 in proceedings of ECMWF seminar on exploitation of the new generation of satellite instruments for numerical weather prediction, 4-8 September 2000, ECMWF, Reading, UK

Szyndel, M., G. Kelly and J.-N. Thépaut, 2004: Evaluation and potential for assimilation of SEVIRI radiance data from Meteosat-8. EUMETSAT/ECMWF Fellowship programme, Research report No. 15

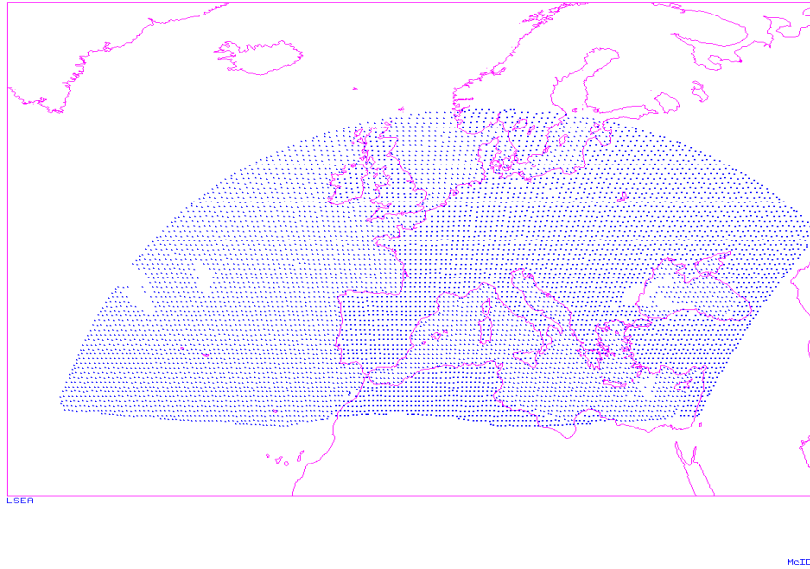


Figure 1. SEVIRI observations used within the NAE domain. SEVIRI spots with nadir angles greater than 65 degrees are excluded.

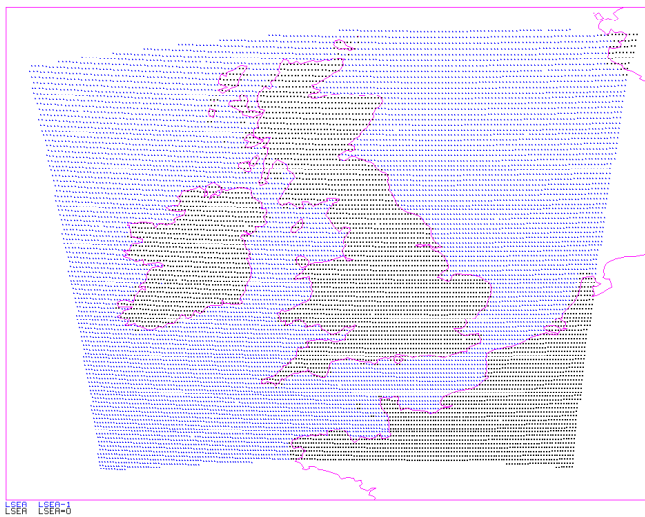


Figure 2. SEVIRI observations used within the UK4 domain

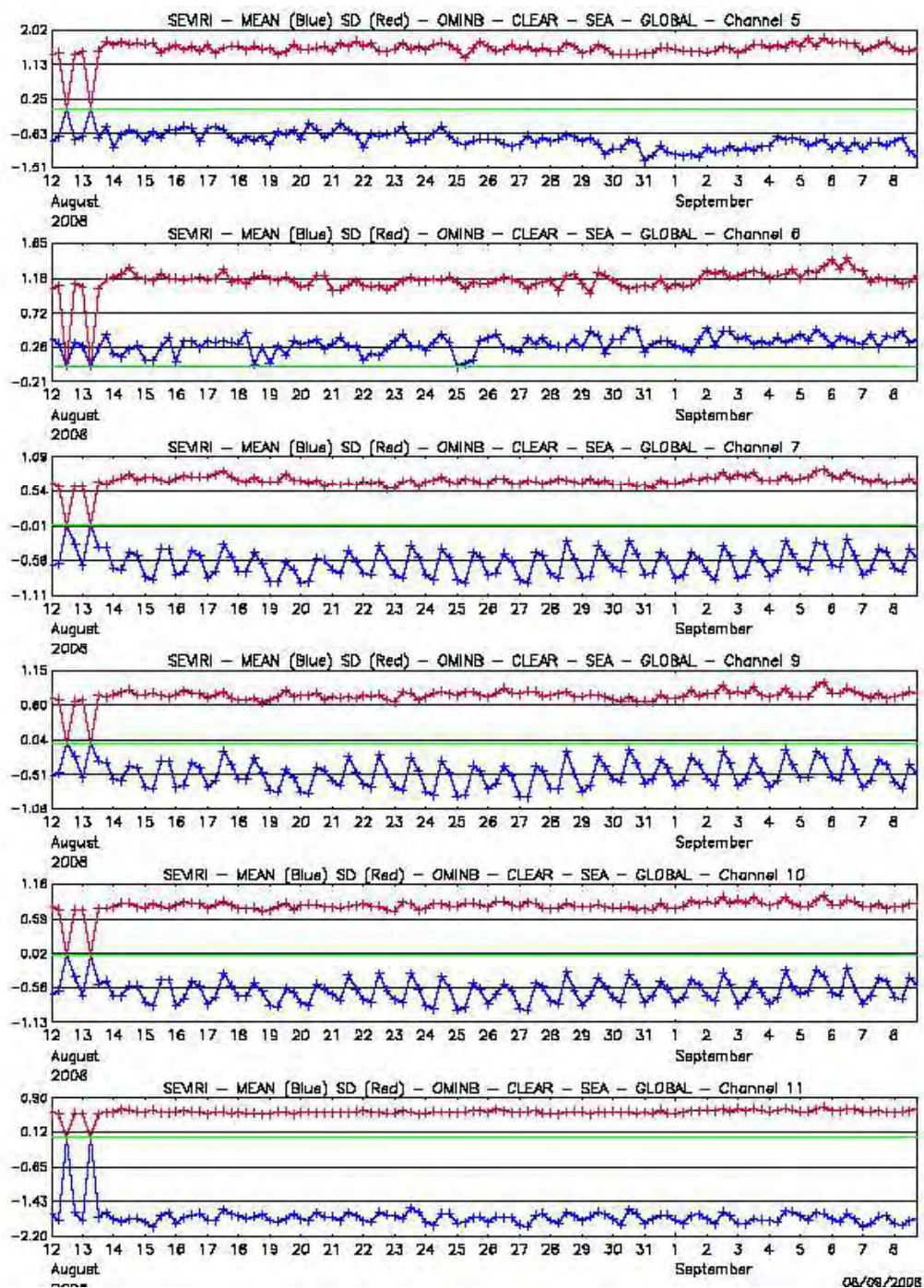


Figure 3. SEVIRI monitoring plots (sea) uncorrected

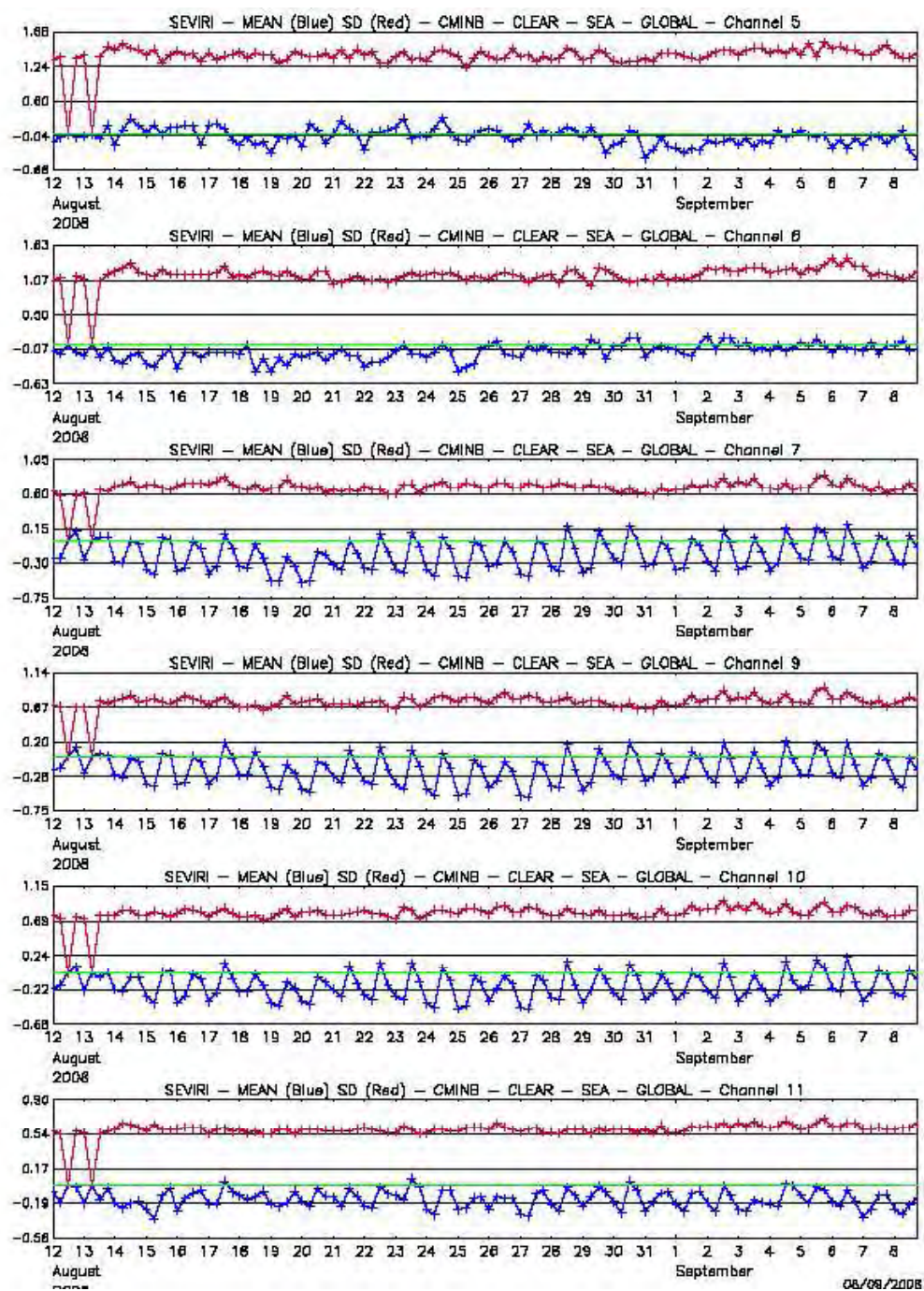
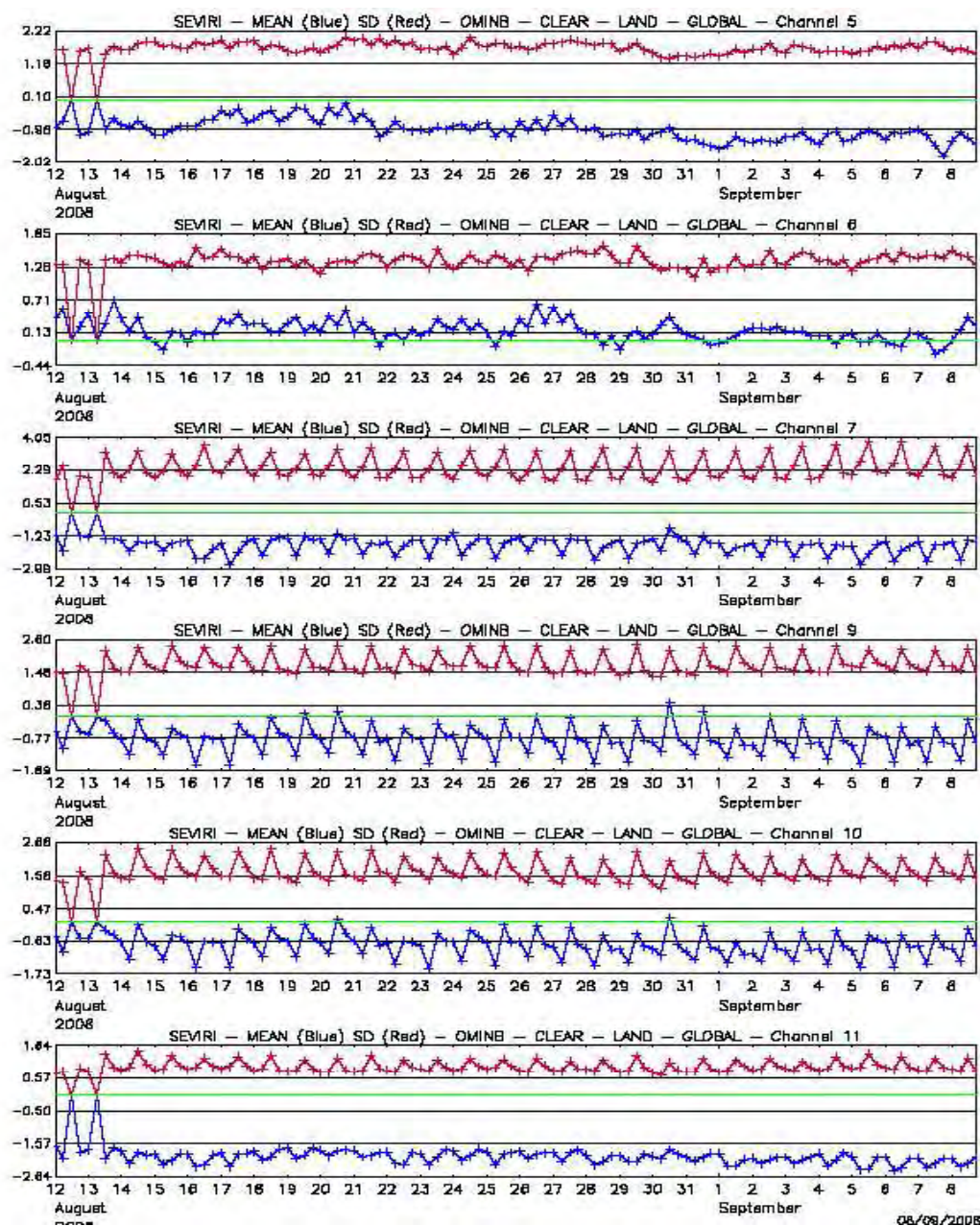


Figure 4. SEVIRI monitoring plots (sea) bias corrected



**Figure 5. SEVIRI monitoring plots (land)
uncorrected**

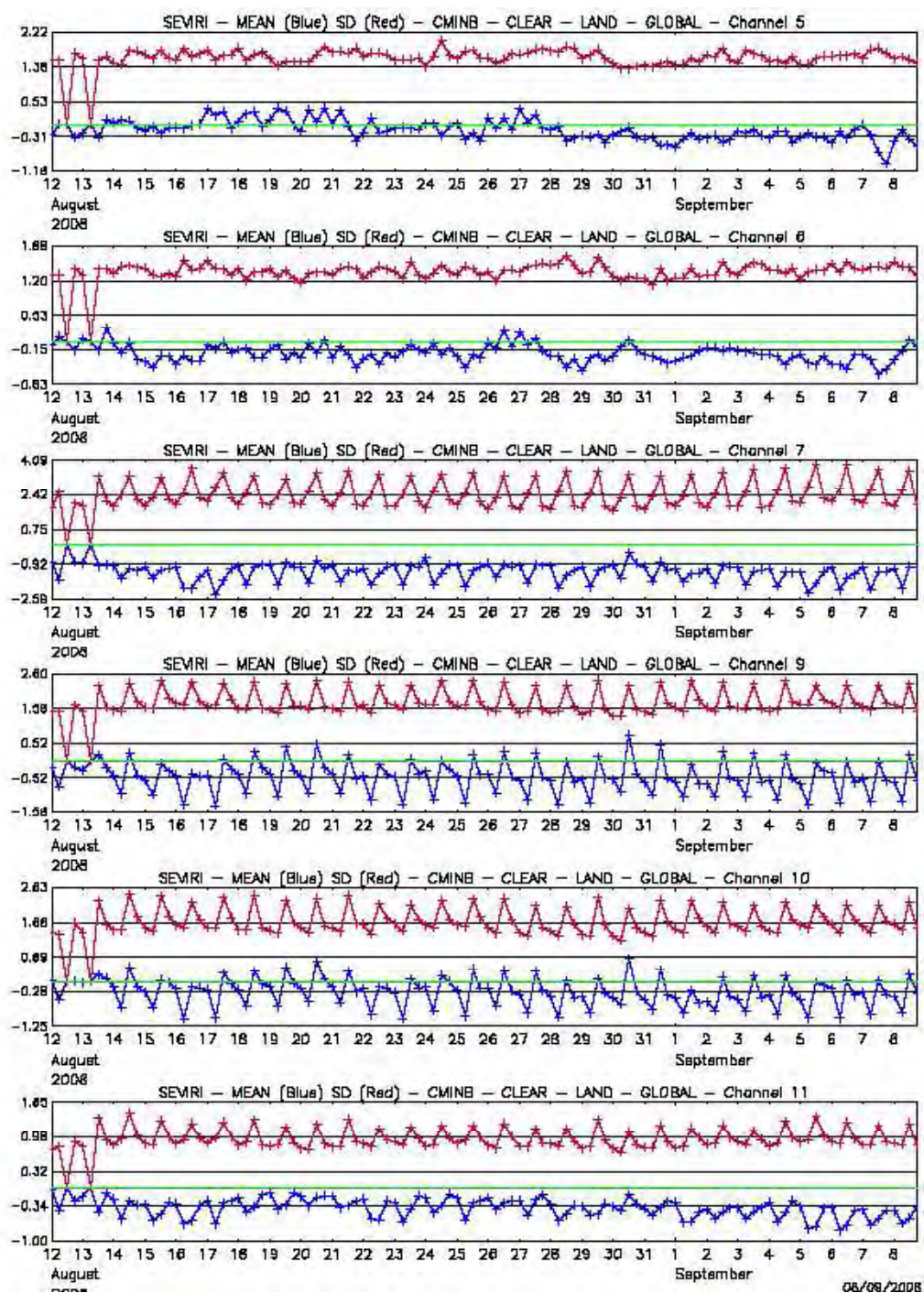


Figure 6. SEVIRI monitoring plots (land)
bias corrected

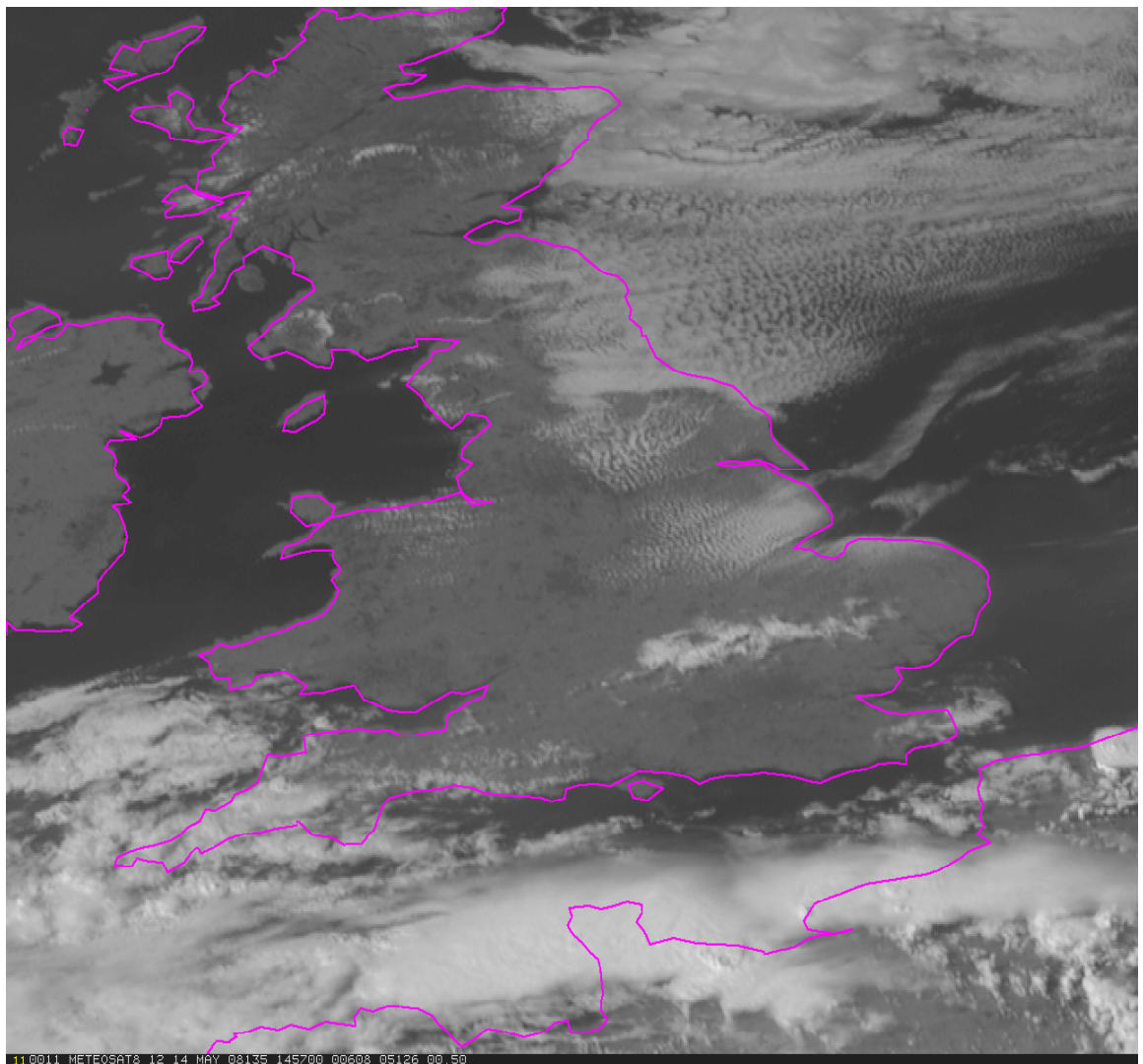


Figure 7 HRV SEVIRI 15UTC 14 May 2008

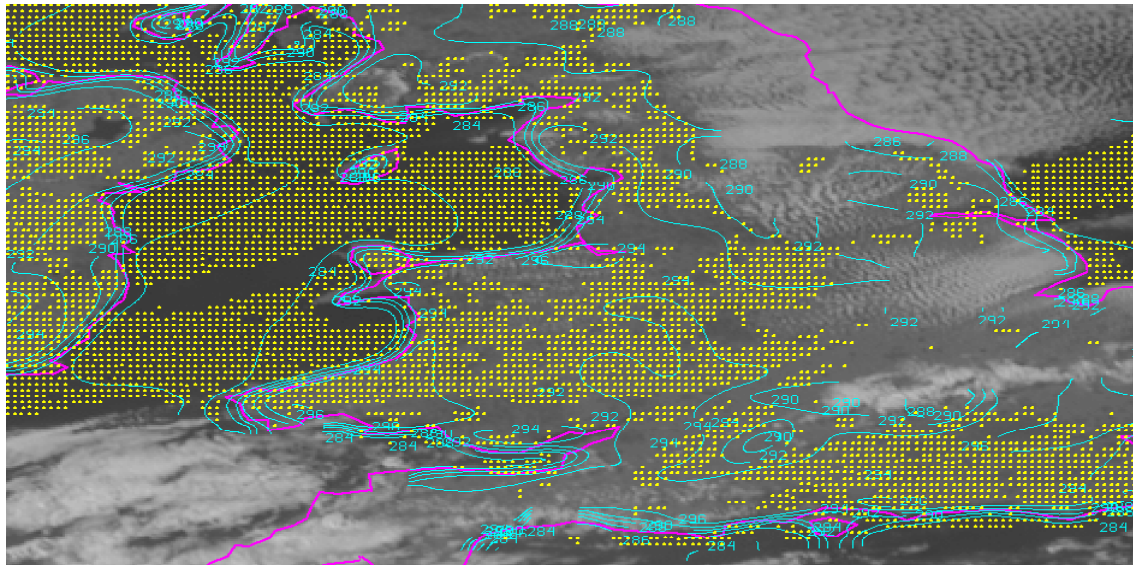


Figure 8. HRV SEVIRI 15z 14 May 2008 , overlaid with uncorrected channel 9 clear IR spots of O-B brightness temperatures within one deg of UK4 analysis in yellow. Blue contours are UK4 analysis.

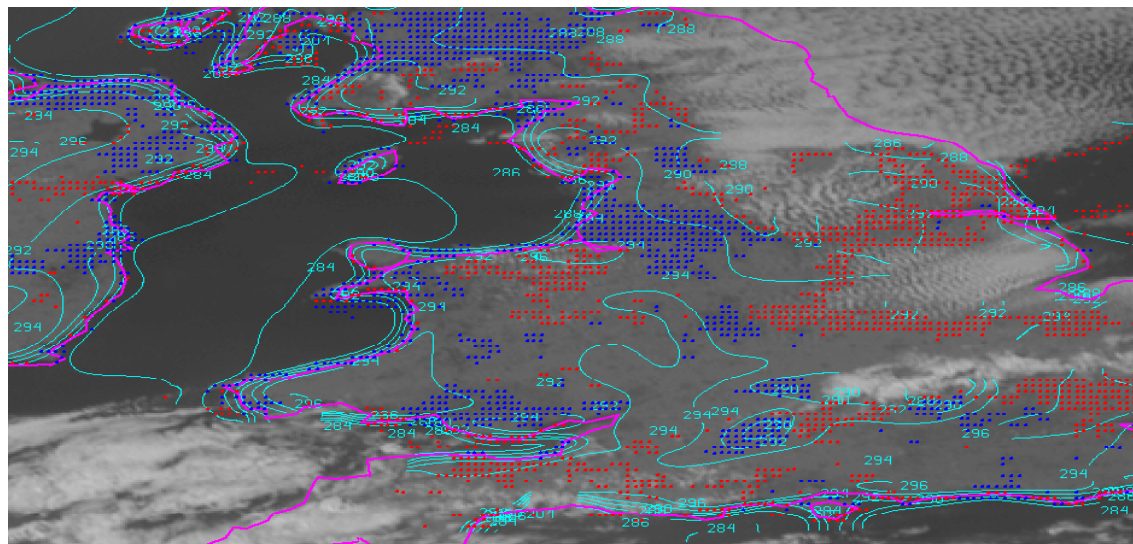
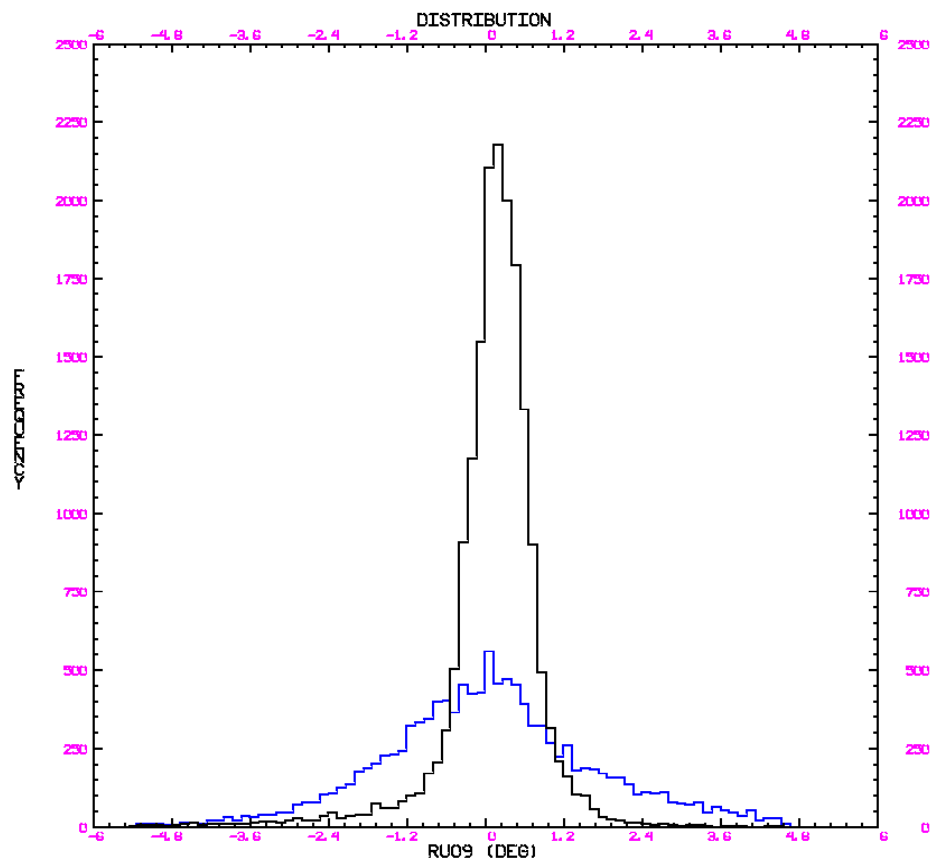


Figure 9. HRV SEVIRI 15z 14 May 2008 , overlaid with uncorrected channel 9 clear IR spots outside one deg of UK4 analysis (red = colder; blue = warmer). Blue contours are of UK4 surface temperature



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Figure 10. Case of 15UTC 14 May 2008; O-B histograms of uncorrected channel 9 brightness temperatures (black = sea; blue = land).

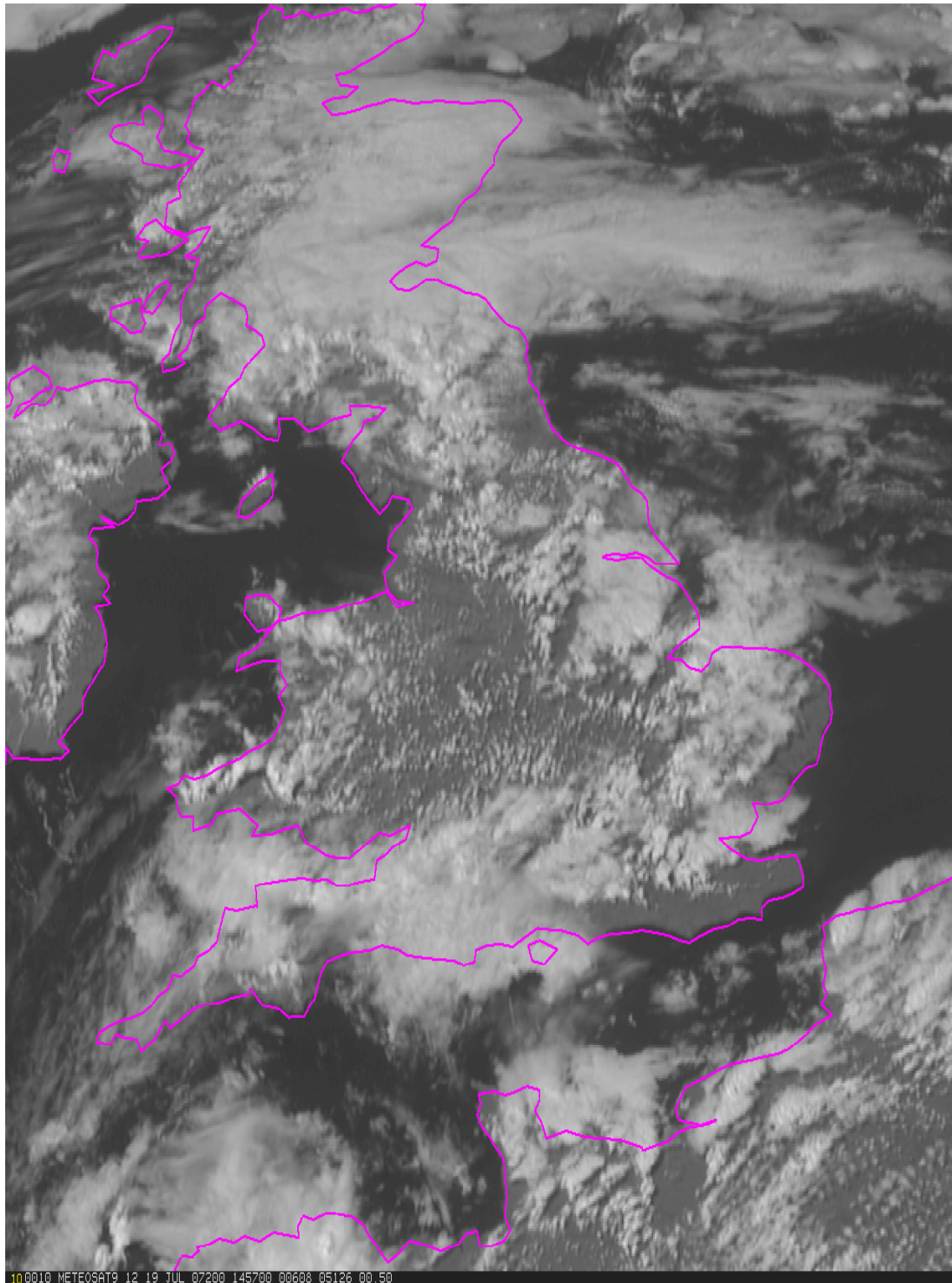


Figure 11. HRV SEVIRI 15UTC 19 July 2008

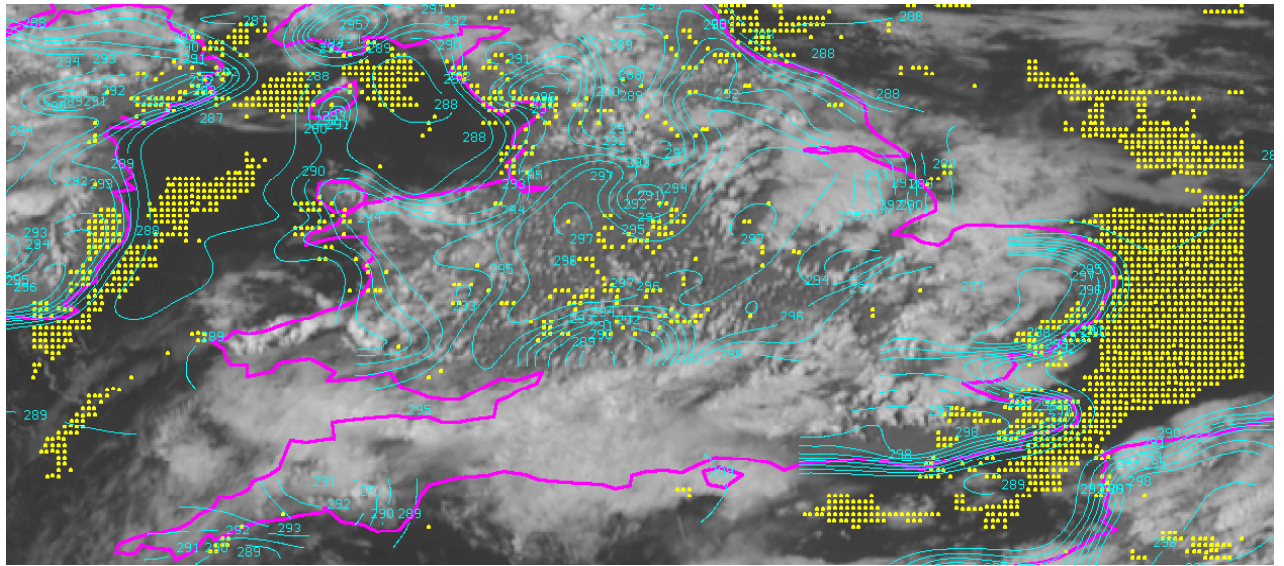


Figure 12. HRV SEVIRI 15UTC 19 July 2008, overlaid in yellow with uncorrected channel 9 clear IR spots of O-B brightness temperatures within one deg of UK4 analysis. Blue contours are UK4 analysis.

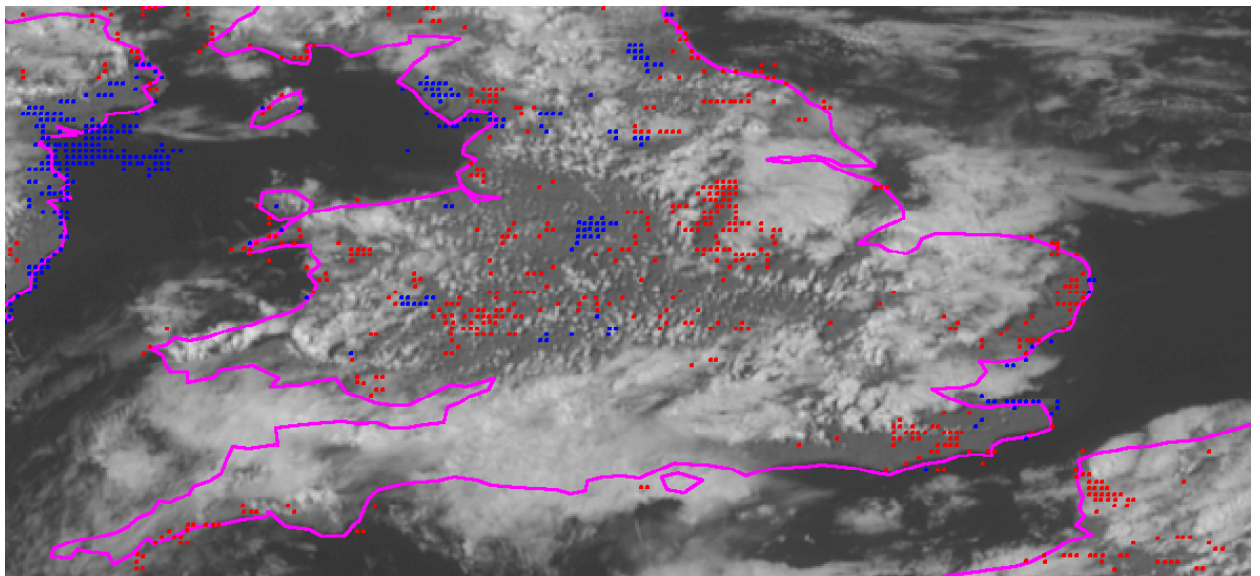


Figure 13. HRV SEVIRI 15UTC 19 July 2008, overlaid with uncorrected channel 9 clear IR spots outside one deg of UK4 analysis (red = colder; blue = warmer).

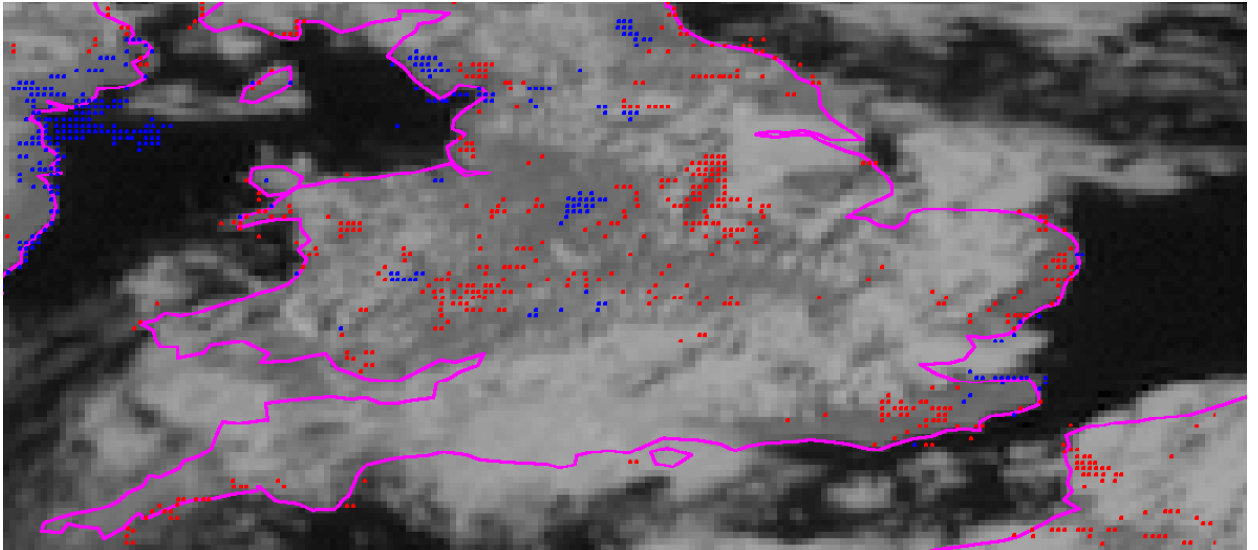
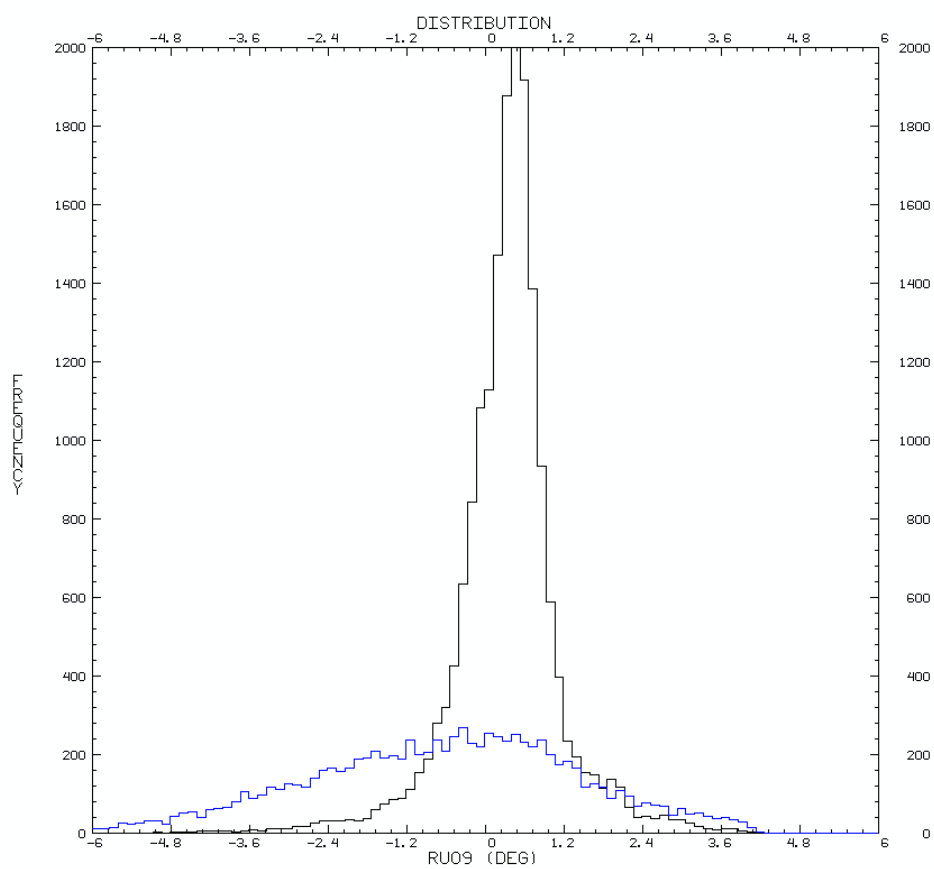


Figure 14. SEVIRI 0.8 μm VIS 15UTC 19 July 2008, overlaid with uncorrected channel 9 IR clear spots outside one deg in blue and red (blue = warmer; red = colder).



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Figure 15. Case of 15UTC 19 July 2008; O-B histograms of uncorrected channel 9 brightness temperatures (black = sea; blue = land).

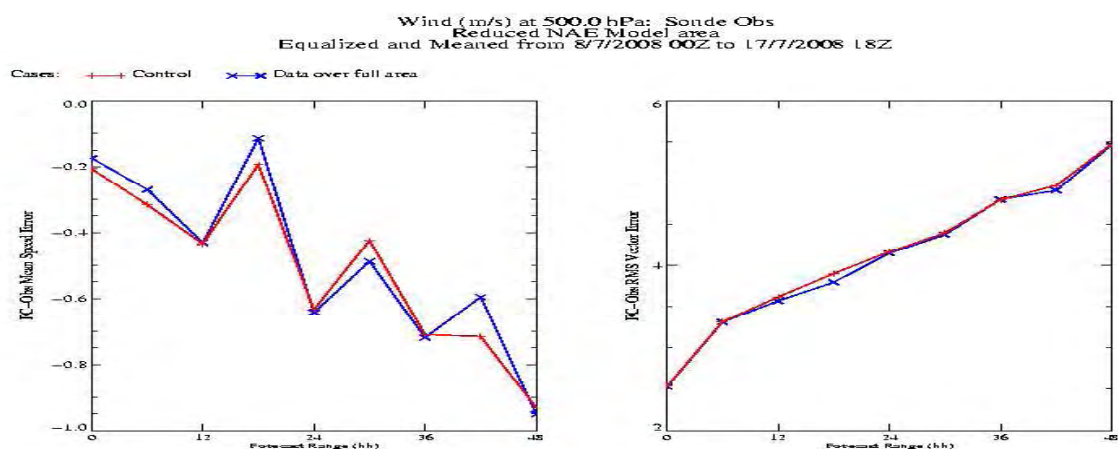


Figure 16. NAE 0-48 hr forecast impact (38 cases): upper level vector wind for Bias and RMS error. Blue SEVIRI and Red control.

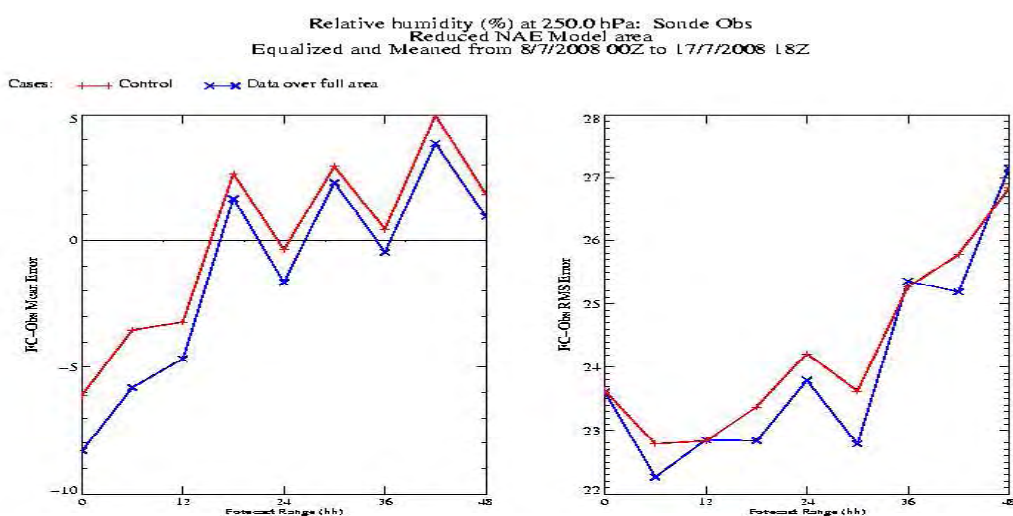


Figure 17. NAE 0-48hr forecast impact (38 cases) of upper level relative humidity for Bias and RMS error. Blue SEVIRI and Red control.

Parameter	Control Data	Test Data	Test - Control
	Mean ETS	Mean ETS	Wted ETS Diff
Surface Visibility	0.069	0.072	0.057
6 hr Precip Accum	0.277	0.278	0.009
Total Cloud Amount	0.354	0.355	0.002
Cloud Based Height (3/8 Cover)	0.182	0.183	0.007
	Mean Skill	Mean Skill	Wted Skill Diff
Surface Temp	0.631	0.631	0.000
Surface Wind	0.672	0.671	-0.015

Total Weighted Score (%)
Control Case = 38.357
Test Case = 38.417
Test - Control = 0.060 (0.16 % change)

Figure 18. NAE forecast impact (38 cases): UK Index - reduced NAE model area.

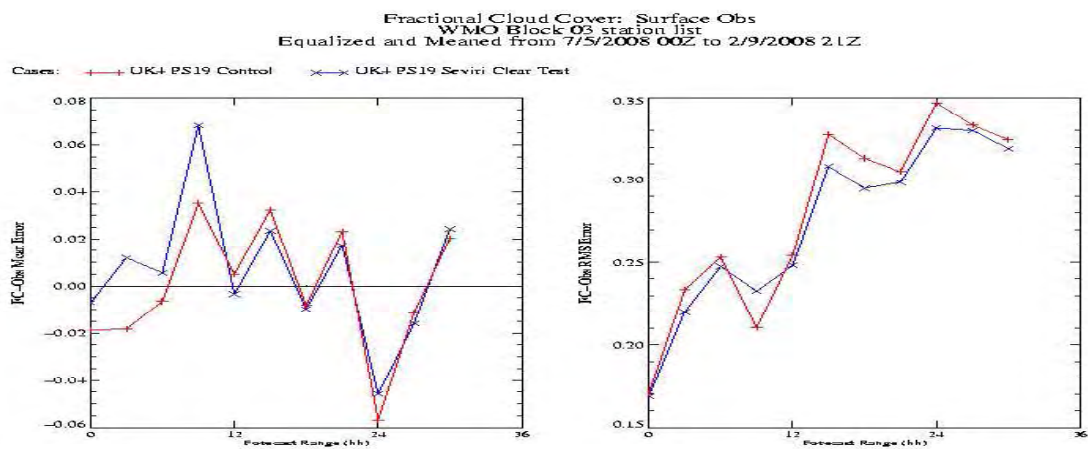


Figure 19. Forecast 0-36 hr impact of 5 recent UK4 cases between 03 06 2008 - 31 08 2008, for Bias and RMS error. Blue SEVIRI and Red control.

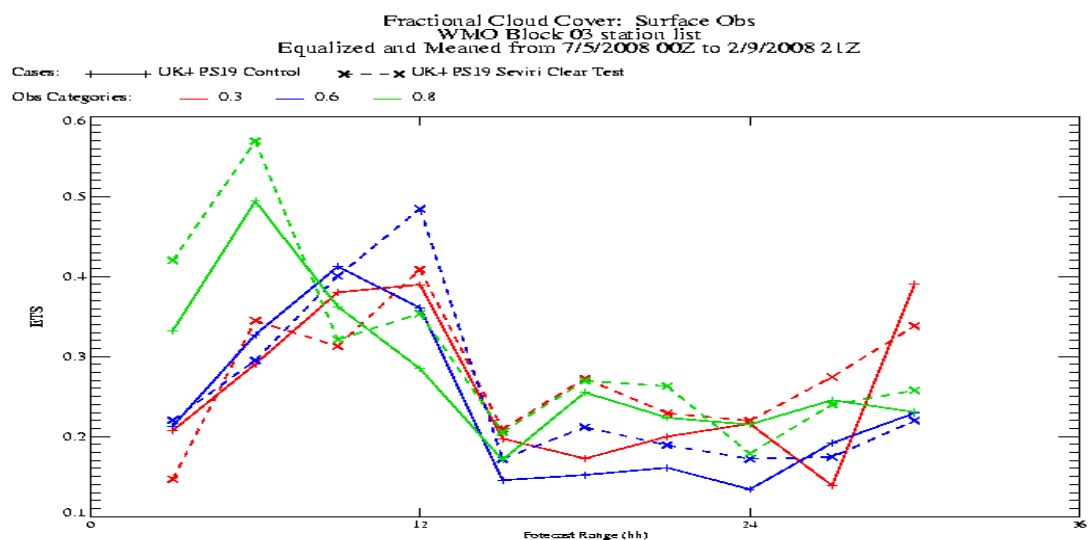


Figure 20. Forecast 0-36 hr impact of 3 ETS categories of 5 recent UK4 cases between 03 06 2008 - 31 08 2008, ETS. Dashed SEVIRI and Solid control. Larger ETS indicates improved forecast.

Parameter	Control Data	Test Data	Test - Control
	Mean ETS	Mean ETS	Wted ETS Diff
Surface Visibility	0.054	0.057	0.072
6 hr Precip Accum	0.000	0.000	0.000
Total Cloud Amount	0.210	0.225	0.157
Cloud Based Height (3/8 Cover)	0.190	0.185	-0.051

Total Weighted Score (%)

Control Case = 5.071

Test Case = 5.249

Test - Control = 0.179 (3.52 % change)

Figure 21. Forecast impact of UK index for 5 recent UK4 cases between 03 06 2008 and 31 08 2008.

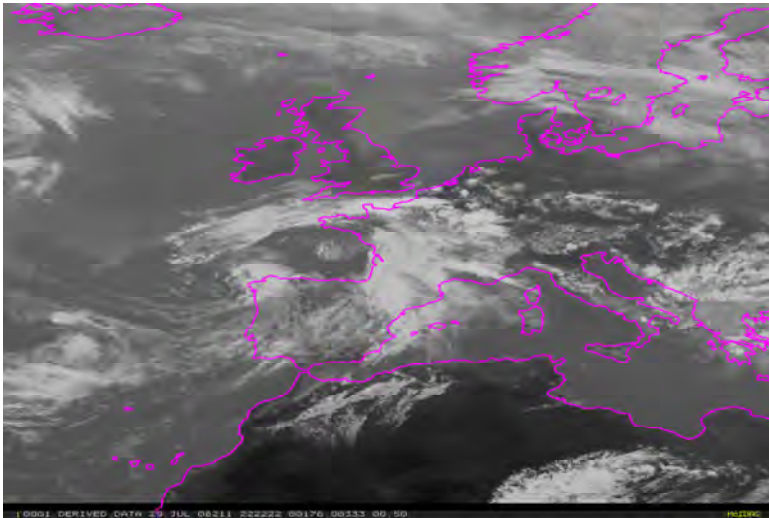


Figure 22. 10.8 μm SEVIRI channel 9 EUMETSAT archive image at 1457 UTC 14 May 2008.

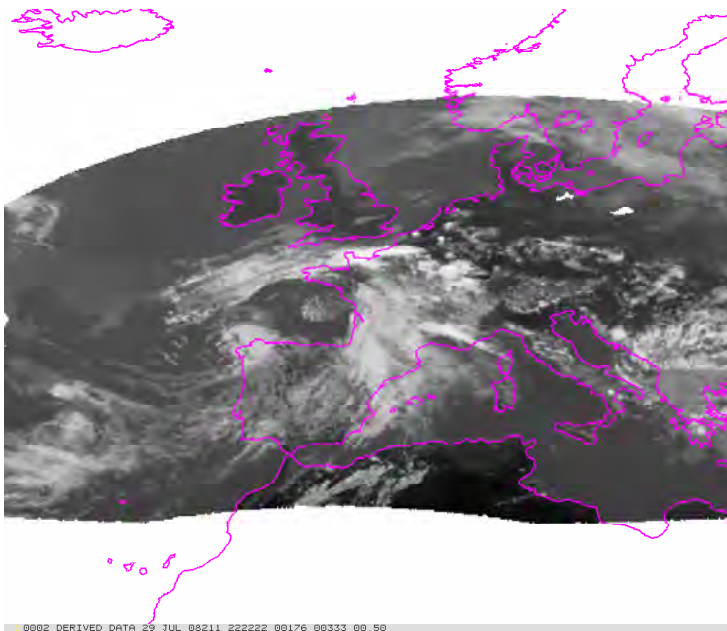


Figure 23. SEVIRI 10.8 μm channel 9 spots extracted from OPS (1 in 4 pixels)

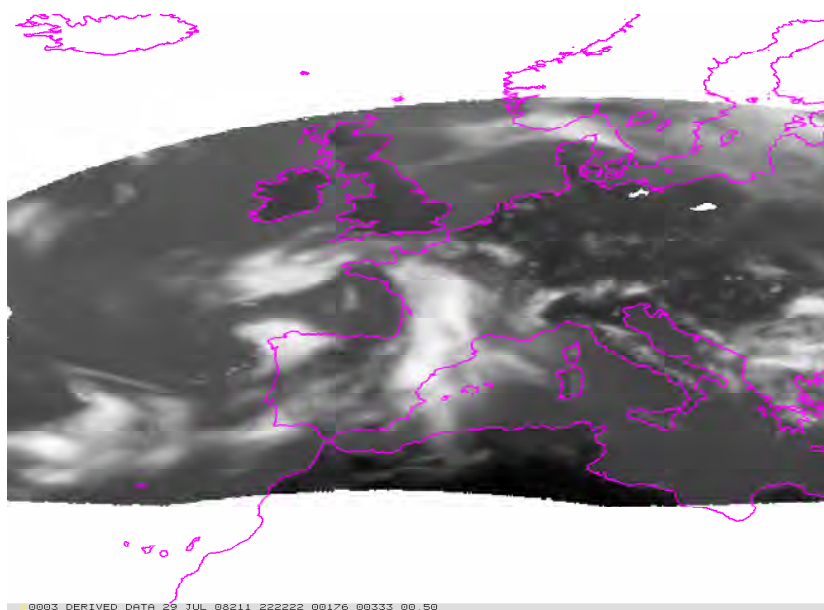


Figure 24. NAE (24 km) 10.8 μm SEVIRI channel 9 simulated image.

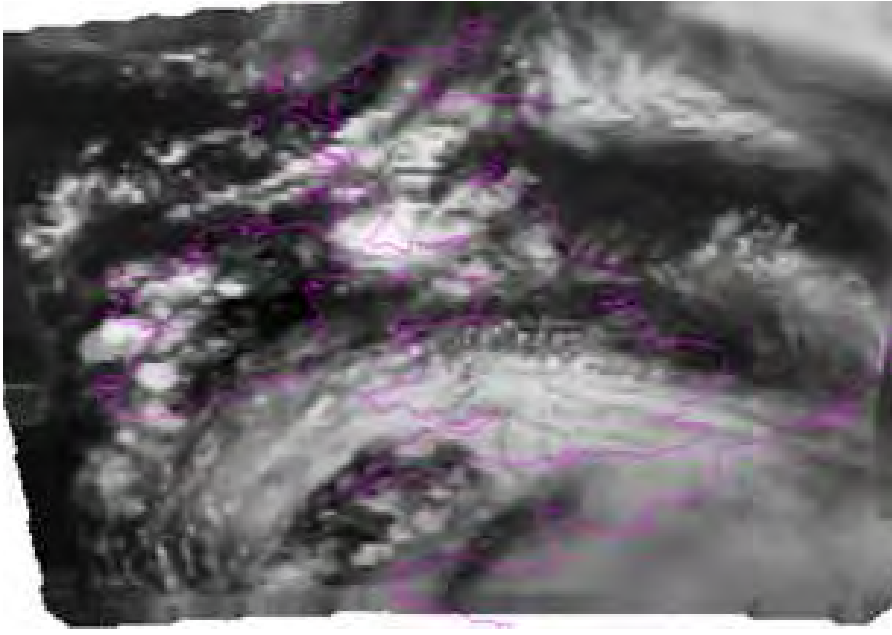


Figure 25. UK4 10.8 μm SEVIRI channel 9 simulated image

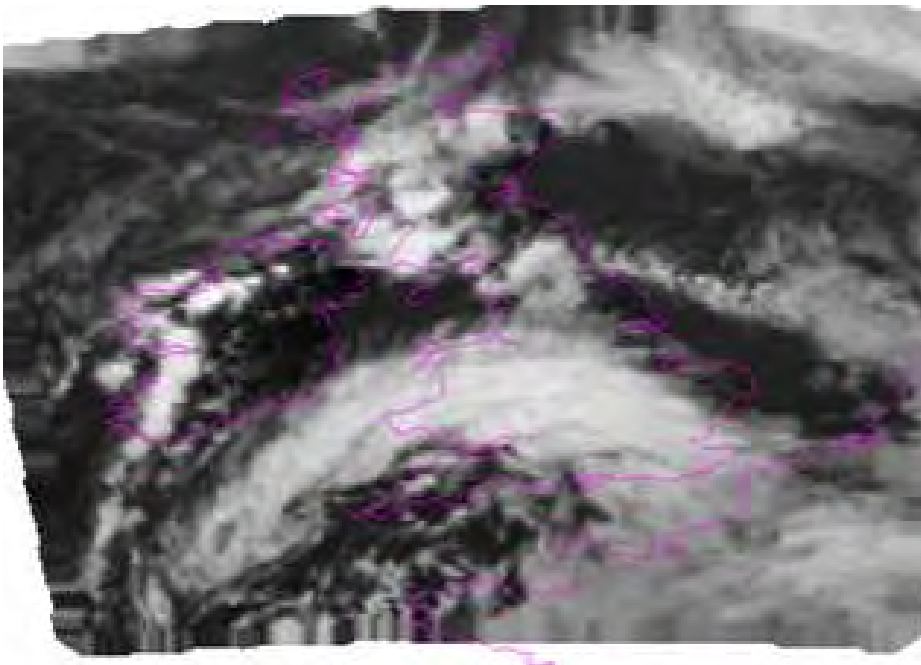
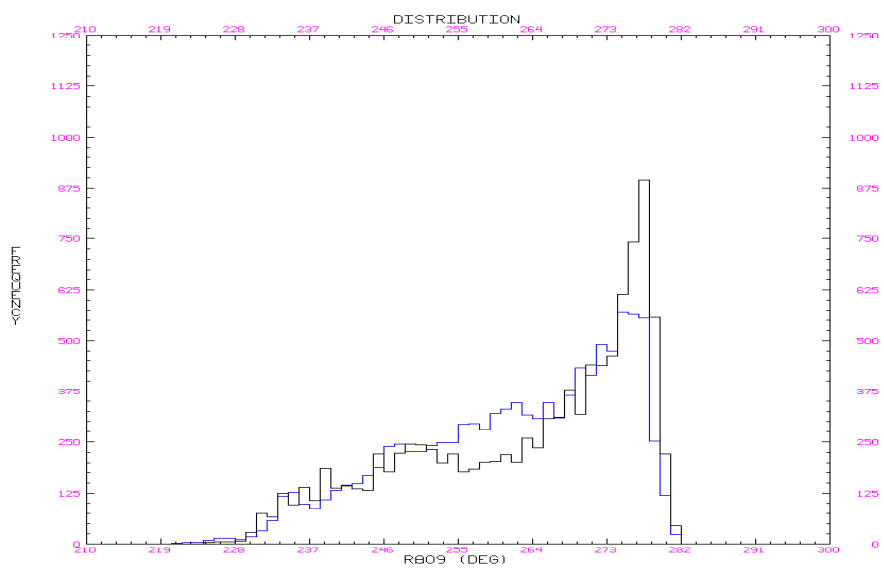
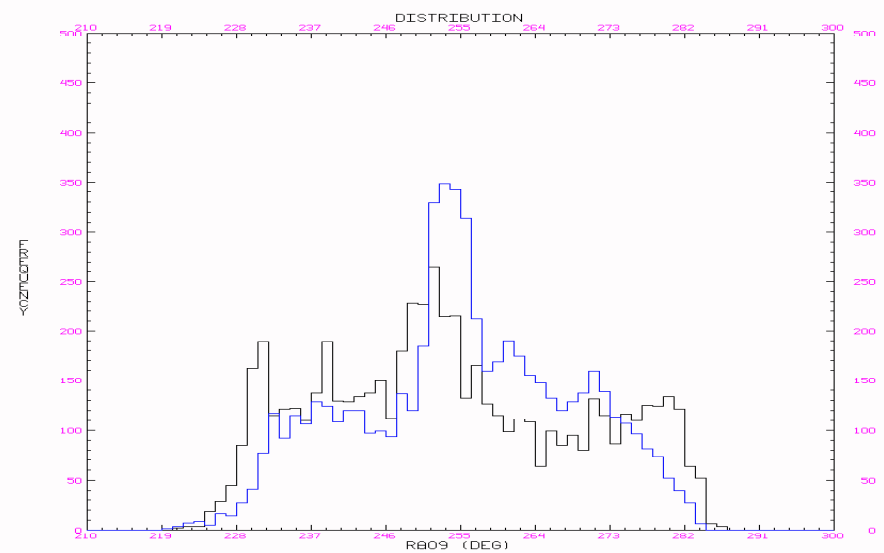


Figure 26. UK4 10.8 μm SEVIRI channel 9 image



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Figure 27. UK4 SEVIRI 10.8 μ m brightness temperatures over sea (blue = first guess; black = uncorrected obs)



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Figure 28. UK4 SEVIRI 10.8 μ m brightness temperatures over land (blue = first guess; black = uncorrected obs)

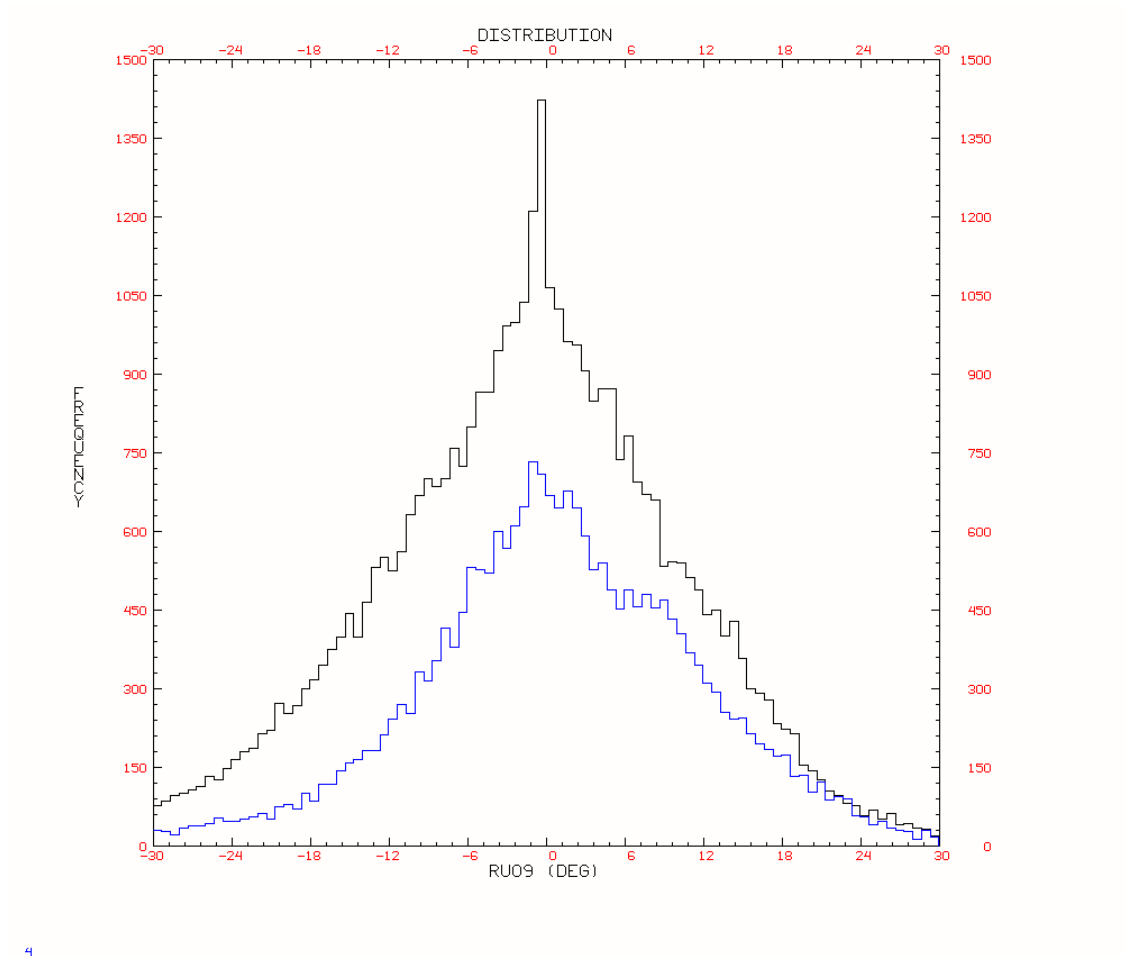


Figure 29. UK4 O-B SEVIRI 10.8 μm uncorrected brightness temperatures (black sea; blue = land)