Scottish Windstorm 3 January 2012

by
Richard H. Grumm
National Weather Service State College PA 16803
Contributions from Albany Map Dialog 4-6 January 2012

Abstract:

.

A deep, fast moving cyclone produced a high wind event across portions of Northern Ireland and Scotland on 3 January 2012. The central pressure bottomed out around 952 hPa based on the United Kingdom Met Service surface analysis. The strongest wind occurred south of the cyclone in the relative cold air mass, north and west of the strong southerly flow in the warm air. Similar to other oceanic cyclone events, the strongest winds were associated with only light or showery precipitation.

The cyclone was relatively well predicted by numerical models and ensembles, however, the intense winds south of the cyclone in the cold air were not as well predicted. This mesoscale feature, associated with winds over about 80 mph was not so well predict. Forecasters, using pattern recognition identified this as a "*sting jet*" and correctly alerted the public for the potential for strong and damaging winds. Identifying and recognizing the pattern and probabilities is more important than names assigned to the phenomena. No debate on the name of the phenomena is offered here. Standardized anomalies were used to assess the strong winds and the overall intensity of the system.

The strong winds disrupted transportation, damaged homes, and interrupted power in northern Ireland, Scotland and portions of England. The higher and more damaging winds were farther to the north, closer to the passage of the deep oceanic cyclone.

1. INTRODUCTION

A deep cyclone affected Northern Ireland and Scotland with extremely high winds (Fig. 1). Winds in excess of 100 MPH were observed along the coast of Northern Ireland and northern Scotland. Strong winds affected most of the British Isle. New accounts (BBC 2012) suggest this storm damaged over 7000 homes in Scotland and 8500 homes in the East and West Midlands, and about 500 homes in south-east Wales. Strong winds downed trees disrupting rail and road traffic and downed power lines. Locally strong winds near Glasgow flipped lorries (trucks) closing roadways. The BBC (2012) cited Met Office reports of wind of 106MPH and 102MPH at Great Dun Fell and Edinburgh respectively.

The United Kingdom Met Office (UKMO) analyzed a 952 hPa cyclone (Fig. 2) at 0600 UTC 3 January 2012. The strongest winds were observed south of the cyclone center. Reports and observations suggest light or no precipitation was observed at most locations during the time of the strongest winds. At Glasgow, the winds peaked between 0600 and 1000 UTC (Table 1). During the period strongest winds the observations indicated showers in the vicinity or light showers. Interestingly, high wind observations associated with cyclones along the West Coast of the United States and Europe often show that the strongest winds are often associated with bent-back troughs or fronts and a large pressure gradient. These high wind events are often not associated with precipitation or associated with light or showery precipitation[1]. The high wind event of 8-9 December in Scotland (Grumm et al 2011) was not associated with rain or heavy rainfall during the period of strongest winds.

The NCEP GFS 00-hour forecasts (Fig. 3) showed a fast moving cyclone which passed north of Ireland at 0000 UTC 3 January and raced across northern Scotland between 0600 and 1200 UTC 3 January 2012. Pressure anomalies in the GFS were on the order of -3 to -4s below normal as the cyclone moved across the North Sea. The UKMO analysis (Fig. 1) suggested a significantly deeper mesoscale cyclone than indicated by the GFS analysis. Though difficult to see the UKMO analysis implied a strongly occluded system. The strongest winds were observed in the tight pressure gradient south of the cyclone center.

Deep oceanic cyclones often follow the Shaprio-Keyser cyclone model (Shapiro and Keyser 1990), rather than the more traditional Norwegian Cyclone model. Over the oceans, the cold front associated with the cyclone never meets the warm front developing a T-bone like structure. This leads to the development of a bent-back frontal structure (see Figs.2& 3 Neiman et al 1993). Rather than occluding, the system develops a warm seclusion with the warm air near the cyclone surrounded by colder air.

Mass and Dotson (2010) provided an historic review of major extratropical cyclones in the Northwest United States. Many of the historic wind events associated with these storms were associated with cyclones which often fit the Shapiro-Keyser cyclone model. The Shapiro-Keyser cyclone model produces a strong pressure gradient

---

[1] Observations of this event and collated comments from Albany MAP 4-6 January 2012. Comments contributed by many main points taken from Tim Hewson (UKMO) and Cliff Mass (University of Washington).

south of the cyclone center (see Fig. 2c& 2d lower panels Neiman et al. 1993). Mass and Dotson (2010:Fig. 12c) used MM5 simulations and showed the strong low-level high winds south of the cyclone center. Thus, they conclude that “the strongest winds generally occur when a deep northeastward-moving low center passes north of a location.” Other general characteristics include central pressures in the 955 to 980 hPa range and most of the cyclones were similar to those described by Shapiro and Keyser (1990). The decrease in stability behind the front and the enhance pressure gradient south of the cyclone may be an important mechanisms to produce strong winds and to bring these strong and damaging winds to the surface This region of strong winds south of the low, behind the cold or occluded fronts

This paper will document the pattern associated with the high wind event of 3 January 2012. The focus is on the pattern and the value of standardized anomalies as a tool to both analyze and predicted this and similar events.

2. Methods and Data

The NCEP GFS is used to re-produce the conditions associated with the storm to include the large scale pattern. The standardized anomalies are displayed in standard deviations from normal as in Hart and Grumm (2001) and are computed using the climatology from the NCEP/NCAR global reanalysis data (Kalnay et al. 1996). The focus is on the pattern and anomalies associated with the storm. The value of EFS and anomalies with EFS data are presented.

Ensemble data shown here are from the NCEP Global Ensemble forecast system which is run at 75km in horizontal resolution. The emphasis here is on product which may aid in predicting high wind events. This includes the probability strong winds at various levels to include 10m, 850 hPa, 700 hPa and 500 hPa. These data were also used to examine the pattern using the 27.5km NCEP GFS 00-hour forecasts. The pattern and standardized anomalies followed the methods outlined in Hart and Grumm (2001) and the GFS 00-hour forecasts were used to establish the pattern and standardized anomalies. *The term R-Climate is used in reference to analysis and forecast which use re-analysis climate data to diagnose or forecast the departures from normal.*

The wind reports were provided by the United Kingdom Meteorological Office (UKMO). The data were provided in a plotted format (Fig. 1) from the UKMO. The UKMO also provided surface analysis (Fig. 2).

For brevity times are presented as day and hour in the format 03/0000 UTC and 03/1200 UTC which would be 0000 and 1200 UTC 3 January 2012 respectively. Fully qualified dates are limited to comparative data from times outside of 01 and 5 January 2012.

3. The Storm system and impacts

i. The large scale pattern

The 500 hPa pattern (Fig. 4) shows the trough which moved over and deepened as it crossed the northern British Isles. The 500 hPa short-wave was moving over a relatively strong 500 hPa ridge over the Atlantic basin. This resulted in strong winds at 250 hPa (Fig. 5). The 250 hPa winds were 3-4σ above normal at 02/1800 UTC (Fig. 5a) and showed a coupled like jet in the wind anomalies over the British Isles at 03/0600 UTC (Fig. 5c).

The strong short-wave and the flow about the ridge pulled a tongue of high precipitable water (PW) air into the British Isles and into Scandinavia (Fig. 6).

ii. Regional pattern and key anomalies

The surface cyclone (Fig. 3) tracked across northern Scotland and into Scandinavia. The detailed analysis (Fig. 2) suggest the surface cyclone reached about 952 hPa, lower than indicate by the NCEP GFS analysis (Fig. 3). In addition to the tongue of deep moisture pulled into the region (Fig. 6), the storm pulled warm air across the British Isles in the warm sector (Fig. 7). The 850 hPa temperatures showed a brief surge of 2-5C air over the region which was about 1σ above normal. The crude 27 km GFS data implied an interesting frontal structure at 03/0600 UTC at both 850 hPa (Fig. 7) and 925 hPa (Fig. 8).

The 925 hPa temperatures (Fig. 8) indicated that the temperature anomalies were 2-3σ above normal in the warm air ahead of the cold front. These warm 850 and 925 hPa temperatures were associated with strong 850 hPa southwesterly winds (Fig. 9) which peaked at +3 to +4σ above normal as the swept across the British Isles (Fig. 9a-c). The relatively crude NCEP GFS at 27.5km was able to pick up the secondary low-level south of the 850 hPa low center (Fig. 8c) over northern Scotland. An isolated region of 3-4σ above normal 850 hPa winds were present in this region and in close proximity to Glasgow at this time (green dot which obscures some of the wind maximum).

iii. Forecasts

Several 12 and 3km WRF runs were attempted to analyze this event. At this time they offered little more than the GFS and are not shown. A GEFS forecast and 3 GFS forecasts of the high wind potential are presented. The GEFS forecasts from 02/0000 UTC valid at 03/0600 UTC (Fig. 10) show the deep cyclone and the accompanying strong 700, 850 and 10 m winds. Clearly the probability of +2σ 10m winds was low over land. Above the effects of friction in the models boundary layer, the 850 and 700 hPa winds showed the high potential for winds in excess of 2σ above normal. The GEFS ensemble mean did not produce a 40ms-1 850 hPa isotach but a broad region of winds over 30 ms-1 was present.

Three GFS forecasts of the 850 hPa winds are shown along with the standardized anomalies of these forecasts (Figs. 11-13). Relatively short range forecasts were provided here as the secondary wind maximum south of the low was a mesoscale feature. All three runs attempted to produce this feature but with varying degrees of success. The forecasts initialized at 02/1800 UTC hinted of the feature but did not clearly show the evolution of the secondary wind maximum in the cold air until 02/1800 UTC (Fig. 11e). There was a wind maximum north of the main low-level jet but it was not extremely well defined between 03/0300 and 03/0900 UTC (Figs. 11b-d).

The 03/0000 UTC GFS also had some difficulty showing the well-defined secondary wind maximum developing in the cold air (Fig. 12) removed from the strong broad anomalous southwesterly flow. A well-defined feature did evolve over the North Sea after 03/0900 UTC (Fig. 12d-f). Similar to the 02/1800 UTC forecast cycle, there were hints of stronger winds north of the broader southwesterly flow by 03/0300 UTC (Fig. 12b). But a more defined feature did not appear until the 03/0600 UTC (Fig. 13) cycle when the feature was initialized in Scotland (Fig. 13a) and moved over the North Sea. This feature was quite mesoscale in nature and clearly difficult to both analyze and forecast.

iv. WRF high resolution Forecasts

The workstation WRF-ARW core was used to simulate the cyclone evolution using the 03/0000 UTC NCEP GFS as both lateral and initial boundary conditions. The purpose was to see if the storm evolution, with the polar low cyclone could be simulated. Both the outer nest 12km and inner nest 4km simulations captured the bent-back frontal structure and the strong low-level jet south of the deep mesoscale cyclone which evolved. The results were similar to those presented by Mass and Dotson (2010).

The outer domain (Fig. 14) shows the 3-hourly pressure and 10m wind evolutions as the storm passed north of Ireland and moved across Scotland. The 4km simulations showed about a 958 hPa verse about a 959 hPa low in the 12km simulations.

The 850 hPa temperatures and winds (Fig. 15) and 925 hPa temperatures and winds (Fig. 16) show the evolution of the wind and thermal fields. Both thermal fields show the evolution of a bent-back frontal system with strong winds ahead of the developing frontal system, south of the primary cyclone. The low-level jet with this feature (highlighted in Fig.16 bottom panel) peaked in intensity offshore. The peak winds over Scotland were on the order of 35 to 40 ms-1 with this feature at 850 hPa at 03/1000 UTC (Fig. 15 bottom panel). This strong jet or "sting jet" was in close proximity to where some of the strong surface winds were observed.

The prevailing observations suggest these strong jets south of the maritime or polar lows are not associated with heavy rainfall. The simulations herein showed that the heavy rain was with the broader frontal boundary and only showery weather accompanied the bend back front and strong winds. The simulated radar shows this concept (Fig. 17) with weak echoes over Scotland near the time of the stronger winds with stronger echoes over the North Sea.

4. Conclusions

A strong cyclone produced a high wind event over the British Isles on 3 January 2012. The strongest winds were observed along the coast of Northern Ireland and in northern Scotland (Fig. 1). The UKMO analysis suggested an extremely deep cyclone passed north of Ireland with a central pressure of 925 hPa. The strongest winds with this, and many past Shapiro-Keyser (Shapiro and Keyser 1990) cyclones were observed south of the surface cyclone center (Mass and Dotson 2010). Overall the event was relatively well predicted.

Like many meteorological phenomena, this area of strong winds south of deep oceanic cyclones is occasionally referred to as the "sting jet". The "sting-jet" concept is a term applied to the region of strong winds south of the cyclone (Browning 2004; Clark et al. 2005). This term was applied during discussions about this storm. This concept suggests strong winds in major cyclones associated with descent and evaporative cooling. The cyclone of 3 January 2012 likely followed the Shapiro-Keyser model (Shapiro and

Keyser 1990) and the strongest and most damaging winds were likely in the tight pressure gradient and subsidence region south of the deep cyclone. No attempt to prove the mechanism for or meaning of the “sting-jet’ is presented herein. It is sufficient to show that in this case, strong winds occurred behind the cold front away from the intial surge of high winds in the warm sector. The former likely did not translate into strong winds at the surface due to static stability issues.

The NCEP analysis clearly picked up the secondary wind maximum at 850 hPa at 03/0600 UTC which was in close proximity to the time of the strongest winds in Scotland. The NCEP analysis had difficulty with the analysis and forecasts of the depth of the mesoscale oceanic cyclone which the UKMO analyzed to 925 hPa relative to a 956 to 960 hPa cyclone in the GFS.

The GFS was able to predict strong winds in the cold air. But the true character of this feature was difficult to place and predict with much lead time. The GEFS was able to predict a broad scale area to be affected by strong winds at 850 and 700 hPa. However, the 10m winds showed the stronger winds confined mainly to oceanic regions.

WRF simulations at 12 km with a nested 4km run were able to simulation a slightly stronger cyclone than the 27.5km GFS. These simulations were also able to simulate the bent-back front which appeared in the GFS 00-hour analysis at 03/0600 UTC. The strong jet and bent-back frontal structure peaked in GFS and WRF simulations over the North Sea. There clearly were some timing issues and location issues with this strong low-level jet. The 10m winds were relatively too low though based on observed winds and the frontal structure the 40ms-1 winds at 850 and 925 hPa would have contributed to gusts in the 80kt range, lower than observations as a few locations. A successful forecast of strong and damaging winds but under representative of the maximum observed winds.

5. **Acknowledgements**

Thanks to COMET and the NWS training office for access to the workstation WRF to run test on this and other cases. Special thanks to Tim Hewson and the UKMO for information on the event to include a wide range of observations and images and of course the Albany map for near real-time diagnosis and discussions on cases to include lots of potential references.

6. **References**

British Broadcasting Corporation 2011: Strong winds cause disruption around UK(and similar stories 4-5 January 2012).

Browning, K. A., 2004: The sting at the end of the tail: Damaging winds associated with extratropical cyclones. Quart. J. Roy. Meteor. Soc., 130, 375–399.

Clark, P.,K.Browning, andC.Wang, 2005: The sting at the end of the tail: model diagnostics of fine-scale three-dimensional structure of the cloud head. Quart. J. Roy. Meteor. Soc., 131, 2263–2292.

Graham, Randall A., and Richard H. Grumm, 2010: Utilizing Normalized Anomalies to Assess Synoptic-Scale Weather Events in the Western United States. Wea. Forecasting, 25, 428-445.

Grumm, R.H 2011: The Central European and Russian Heat Event of July-August 2010.**BAMS,** 92, 1285-1296.

Grumm, R.H. and R. Hart. 2001: **Standardized** Anomalies Applied to Significant Cold Season Weather Events: Preliminary Findings. *Wea. and Fore.***, 16,736**–754.

Hart, R. E., and R. H. Grumm, 2001: Using normalized climatological anomalies to rank synoptic scale events objectively. *Mon. Wea. Rev*., **129,** 2426–2442.

Junker, N.W, M.J.Brennan, F. Pereira,M.J.Bodner,and R.H. Grumm, 2009:Assessing the Potential for Rare Precipitation Events with Standardized Anomalies and Ensemble Guidance at the Hydrometeorological Prediction Center. Bulletin of the American Meteorological Society,4 Article: pp. 445–453.

Junker, N. W., R. H. Grumm, R. Hart, L. F. Bosart, K. M. Bell, and F. J. Pereira, 2008: Use of standardized anomaly fields to anticipate extreme rainfall in the mountains of northern California. *Wea. Forecasting*,**23,** 336–356.

Lalaurette, F. 2003: Early Detection of abnormal weather conditions using a probabilistic extreme forecast index. QJRMS,129,3037-3057.

Mass, Clifford, Brigid Dotson, 2010: Major Extratropical Cyclones of the Northwest United States: Historical Review, Climatology, and Synoptic Environment. *Mon. Wea. Rev.*, **138**, 2499–2527.

Neiman, Paul J., M. A. Shapiro, L. S. Fedor, 1993: The Life Cycle of an Extratropical Marine Cyclone. Part II: Mesoscale Structure and Diagnostics. *Mon. Wea. Rev.*, **121**, 2177–2199.

Root, B., P. Knight, G.S. Young, S. Greybush, **R.H. Grumm, R. Holmes**, and J. Ross, 2007: A fingerprinting technique for major weather events. Journal of Applied Meteorology and Climatology, 46, 1053–1066.

Shapiro, M. A. and D. Keyser, 1990: Fronts, jet streams, and the tropopause, Extratropical Cyclones, The Eric Palmen Memorial Volume, C.W. Newton and E. Holopainen, Eds., Amer. Meteor. Soc., 167-191.

Stuart N. A., and R. H. Grumm, 2006: Using wind anomalies to forecast east coast winter storms. *Wea. and Forecasting*, **21**, 952-968.

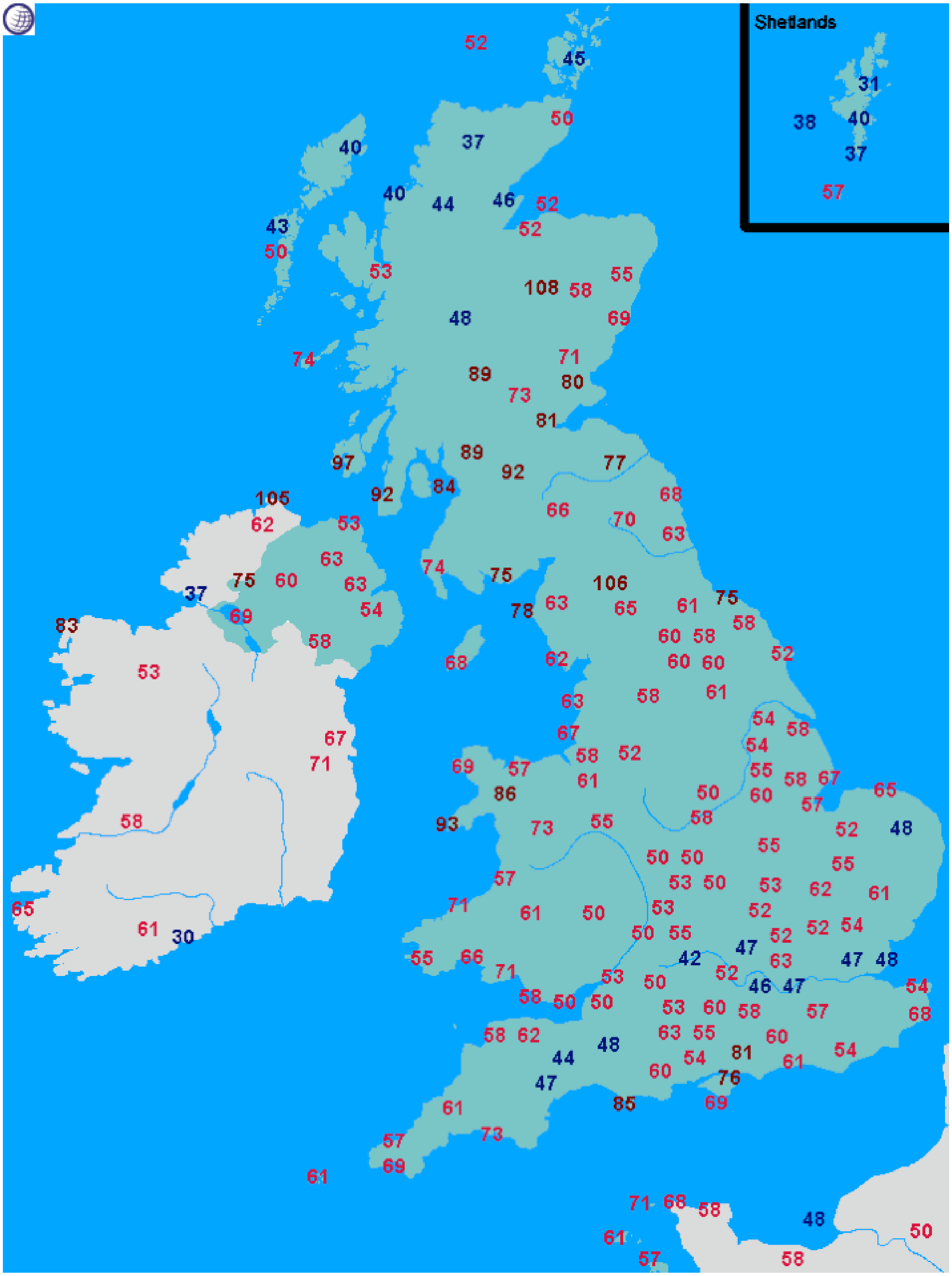

Figure 1. Maximum reported wind speed (mph) for 3 January 2012. Date provided by United Kingdom Met Office. Return to text.

Observations Glasgow Scotland
EGPF 031620Z 25017KT 9999 SCT037 05/01 Q0987
EGPF 031550Z 28010KT 9999 SCT020 BKN027 04/01 Q0986
EGPF 031520Z 27017KT 6000 -RA FEW021 SCT027 BKN039 05/01 Q0985
EGPF 031450Z 28021G35KT 9000 -RA FEW005 SCT014 BKN018 04/02 Q0984
EGPF 031420Z 26018G33KT 5000 -RA FEW016 SCT022 BKN027 04/02 Q0983
EGPF 031350Z 28016G27KT 9000 -RA SCT017 BKN023 05/03 Q0982
EGPF 031320Z 28018G32KT 9000 -RA SCT013 BKN018 OVC049 04/02 Q0981
EGPF 031250Z 26020KT 7000 -RA FEW015 SCT021 BKN026 04/02 Q0981
EGPF 031220Z 26023G33KT 6000 RA SCT019 BKN025 BKN031 04/02 Q0980
EGPF 031150Z 26022KT 9999 -RA FEW008 SCT026 BKN032 06/02 Q0979
EGPF 031120Z 28020G31KT 9999 FEW023 SCT034 06/02 Q0978
EGPF 031050Z 28022G35KT 9999 FEW023 BKN030 07/02 Q0976
EGPF 031020Z 27026G40KT 9999 SCT027 BKN032 07/02 Q0975
EGPF 030950Z 27033G50KT 9999 FEW022 SCT028 BKN035 07/02 Q0973
EGPF 030920Z 26041G58KT 9999 -RA SCT022 BKN025 06/02 Q0970
EGPF 030850Z 26044G62KT 9000 -RA FEW019 SCT024 BKN031 06/03 Q0967
EGPF 030820Z **25051G78KT** 3500 -RA BKN020 BKN033 05/04 Q0964
EGPF 030750Z 24040G57KT 9000 FEW020 SCT027 BKN032 07/03 Q0964
EGPF 030720Z 22043G56KT 7000 RA BKN022 BKN027 07/04 Q0965
EGPF 030650Z 23044G59KT 9000 SCT027 BKN032 09/03 Q0967
EGPF 030620Z 22033G48KT 9999 VCSH BKN021 BKN033 11/08 Q0967
EGPF 030550Z 21029G44KT 9999 VCSH SCT013 BKN020 11/09 Q0968
EGPF 030520Z 20021G32KT 8000 -RA FEW007 BKN010 10/09 Q0970

Table 1. Observations from Glasgow, Scotland from 0520-16520 UTC 03 January 2012. Observations collected and provided by Lance Bosart. Return to text.

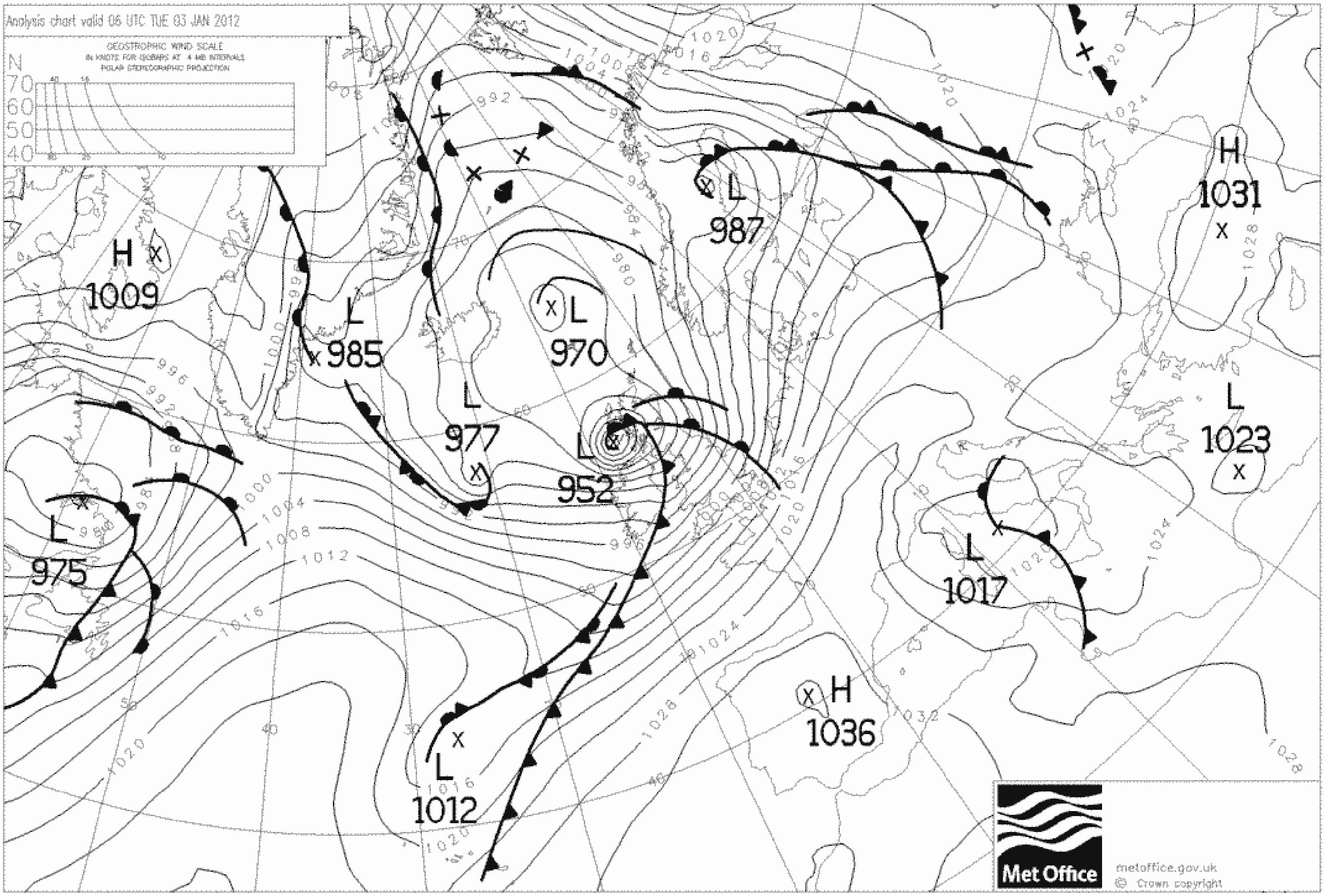

Figure 2. UKMO analysis of mean sea-level pressure and fronts valid at 0600 UTC 3 January 2012. Map provided by the UKMO. Return to text.

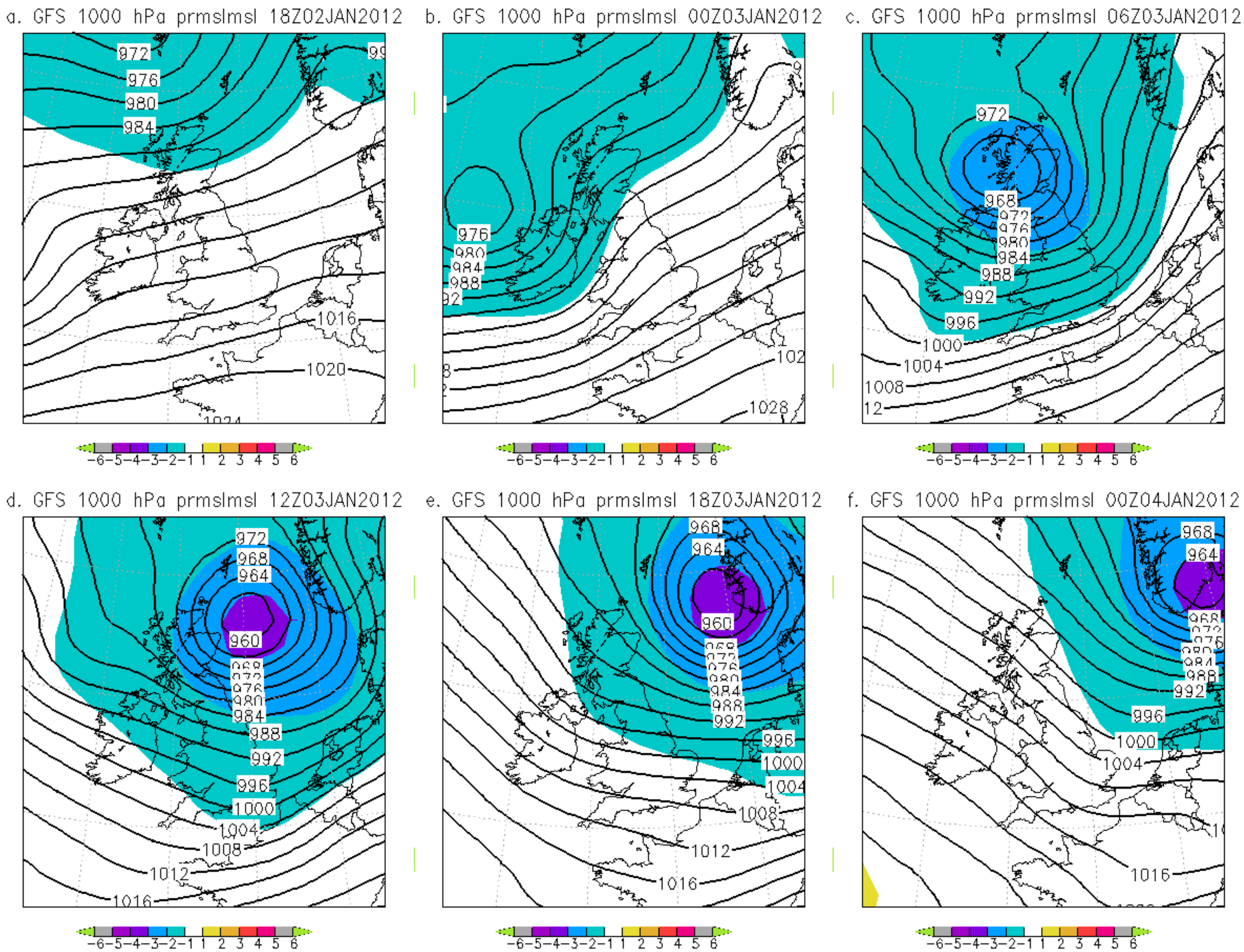

Figure 3. NCEP GFS 00-hour forecasts of mean sea level pressure (hPa) and pressure standardized anomalies (shaded) from GFS initialized in 6-hour increments from a) 1800 UTC 02 January through f) 0000 UTC 4 January 2012. Isobars every 4 hPa. [Return to text.](#)

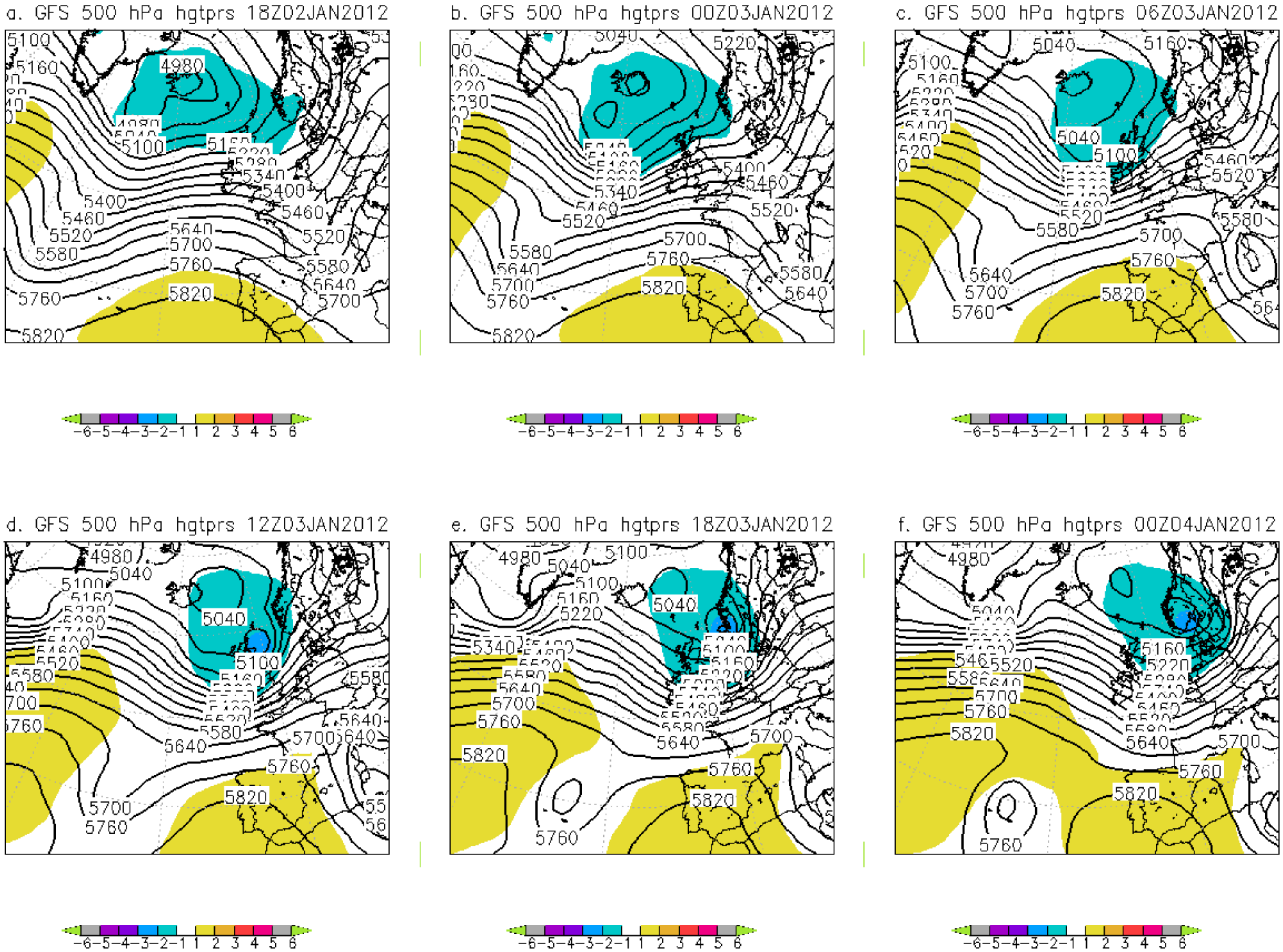

Figure 4. As in Figure 3 except for showing 500 hPa heights (m) and 500 hPa height anomalies. Heights every 60m. **Return to text.**

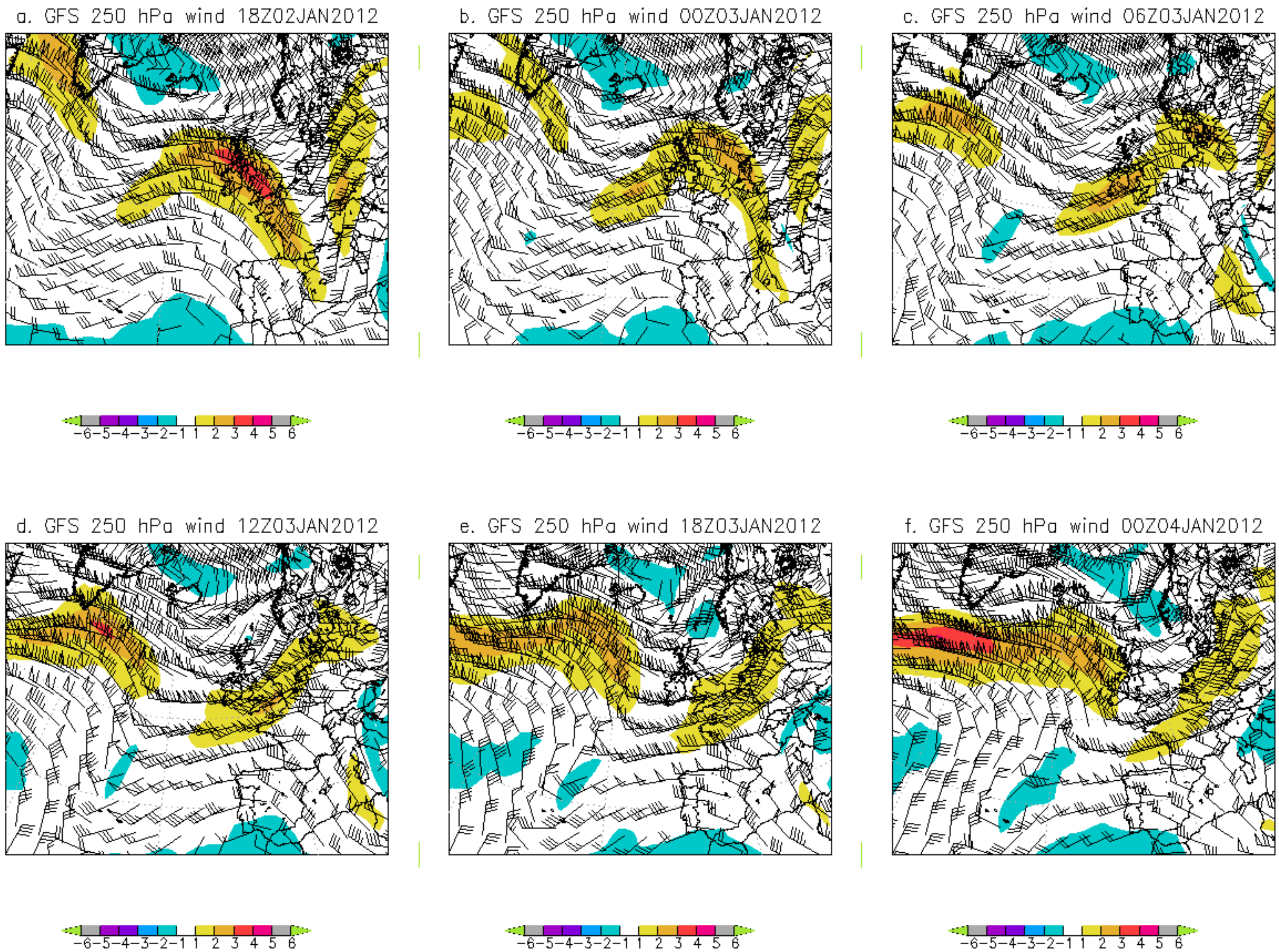

Figure 5. As in Figure 3 except for 250 hPa winds (ms-1) and total wind anomalies. [**Return to text.**]

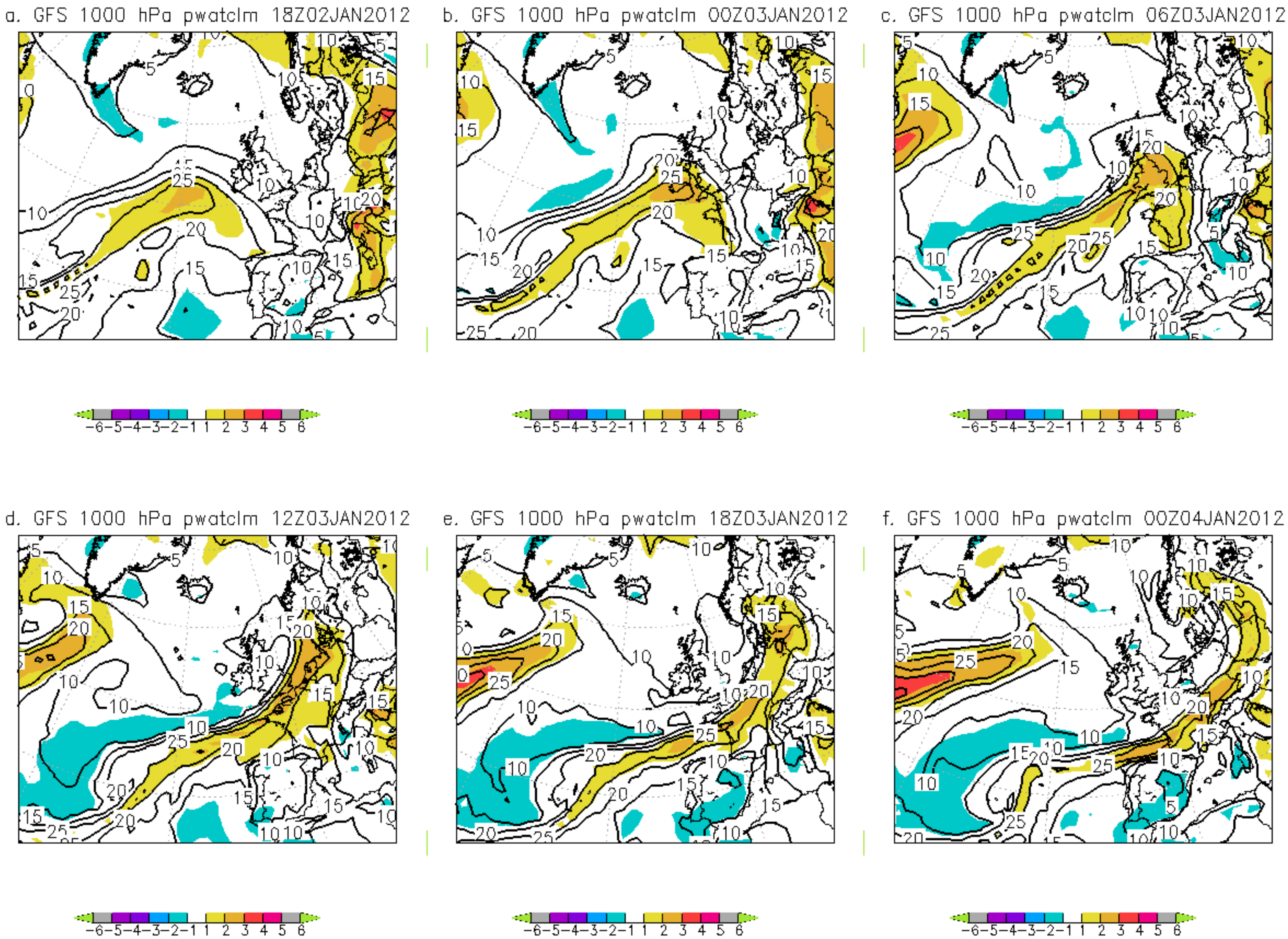

Figure 6. As in Figure 3 except for precipitable water (mm) and precipitable water anomalies. Precipitable water contours every 5mm. Ret[urn to text.](#)

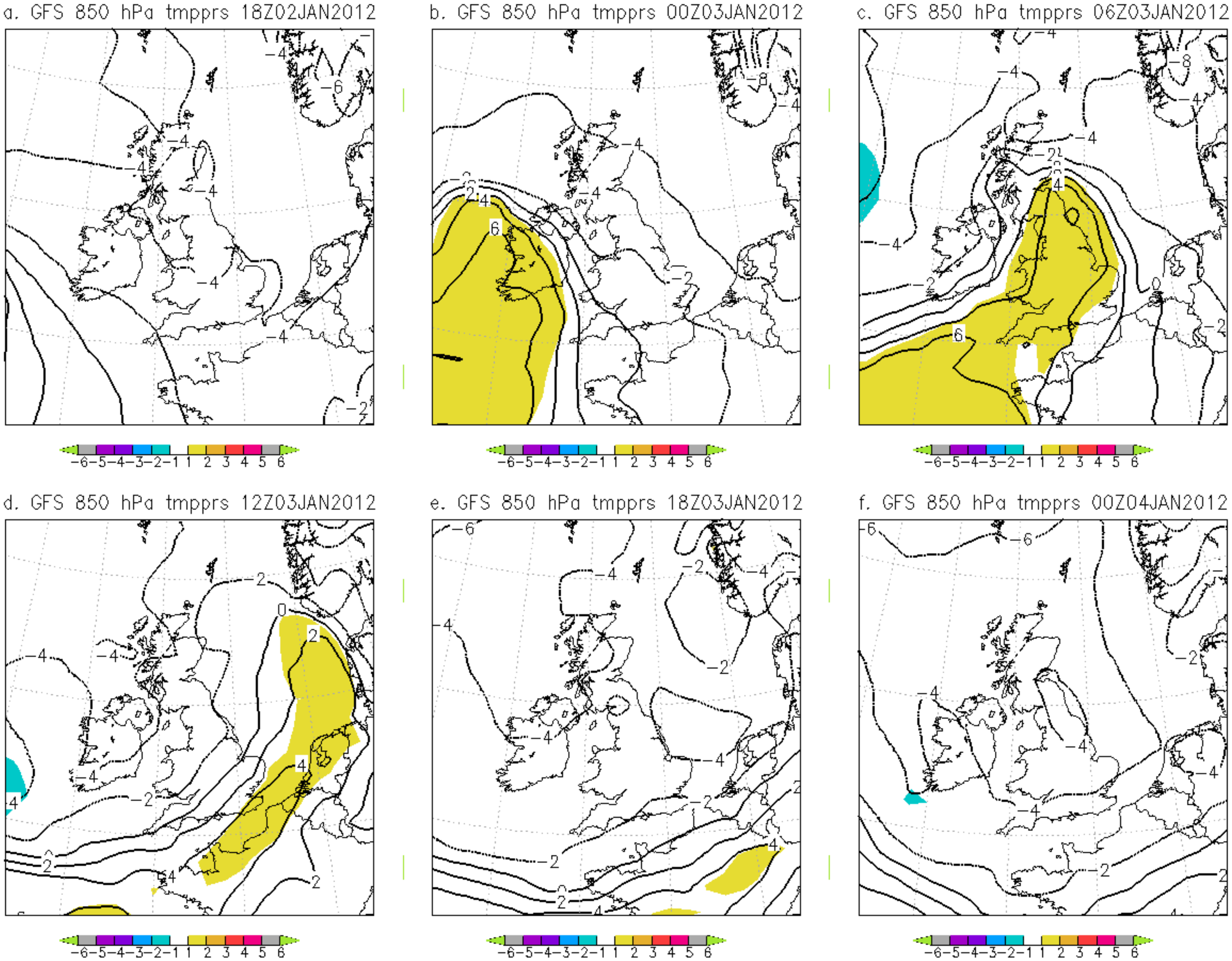

Figure 7. As in Figure 3 except for 850 hPa temperatures and temperature anomalies. Isotherms every 2C. [Return to text.](#)

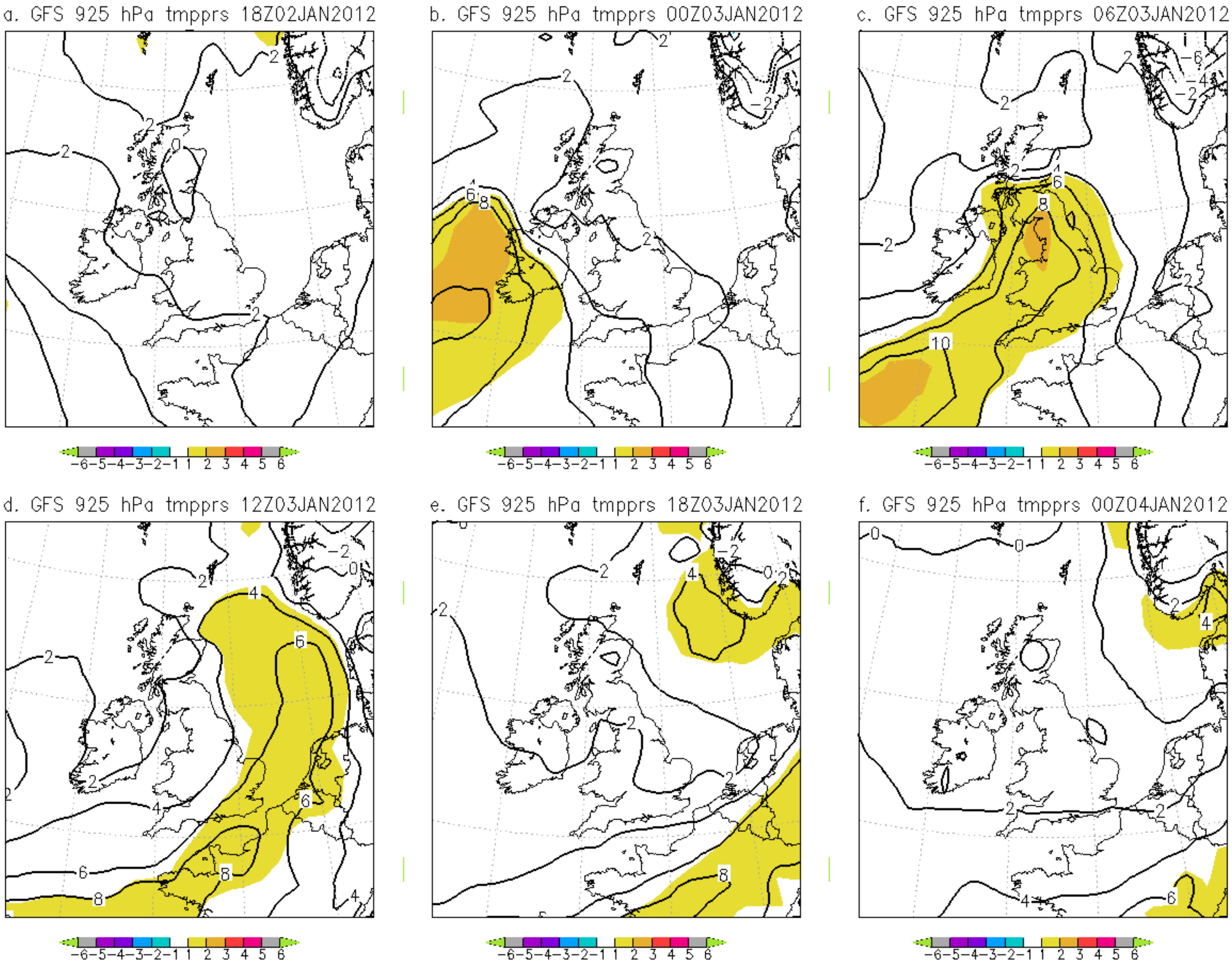

Figure 8. As in Figure 3 except for 925 hPa temperatures and temperature anomalies. Isotherms every 2C. [Return to text.]

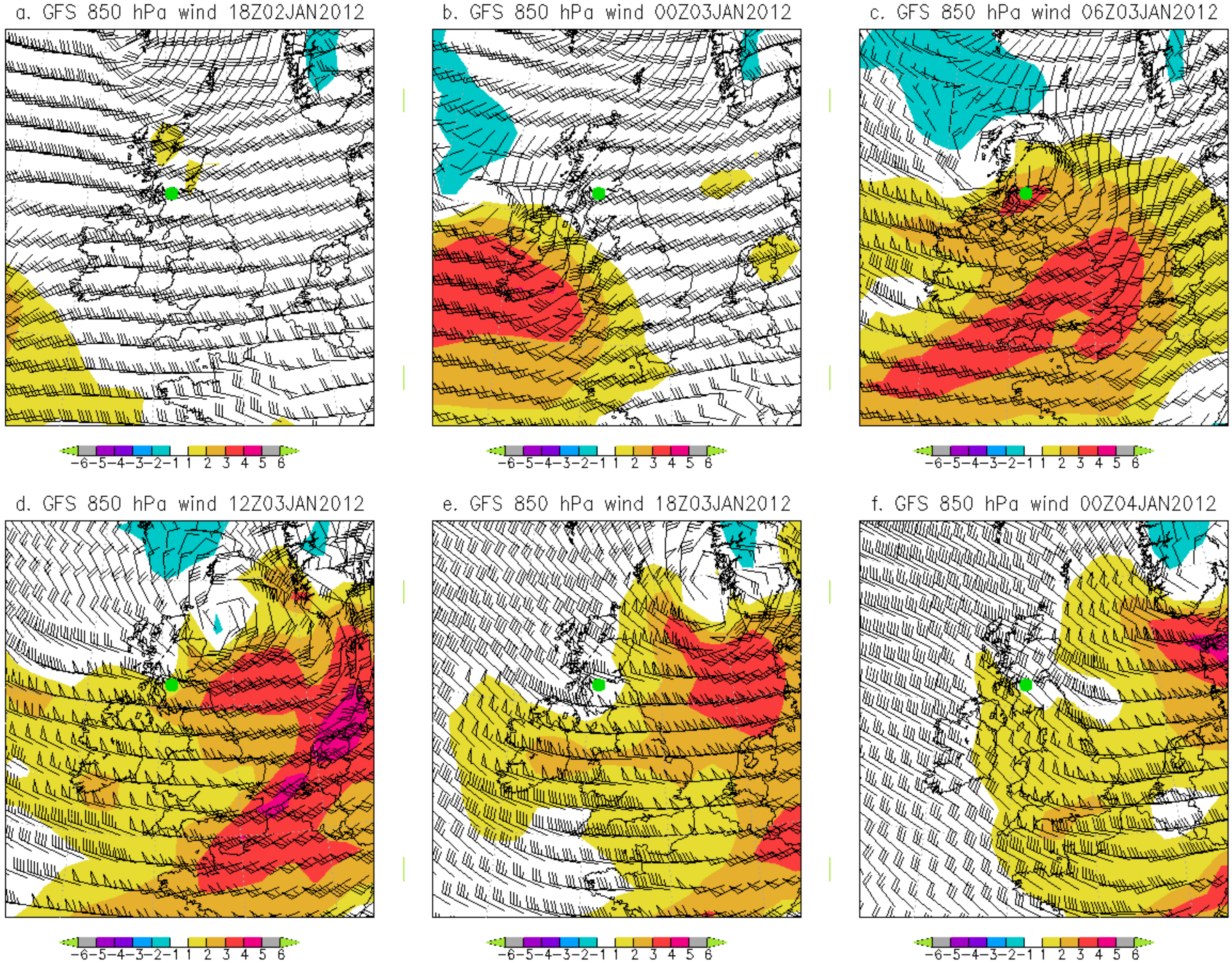

Figure 9. As in Figure 4 except for 850 hPa winds and wind anomalies. The green dot is the location of Glasgow. [Return to text.]()

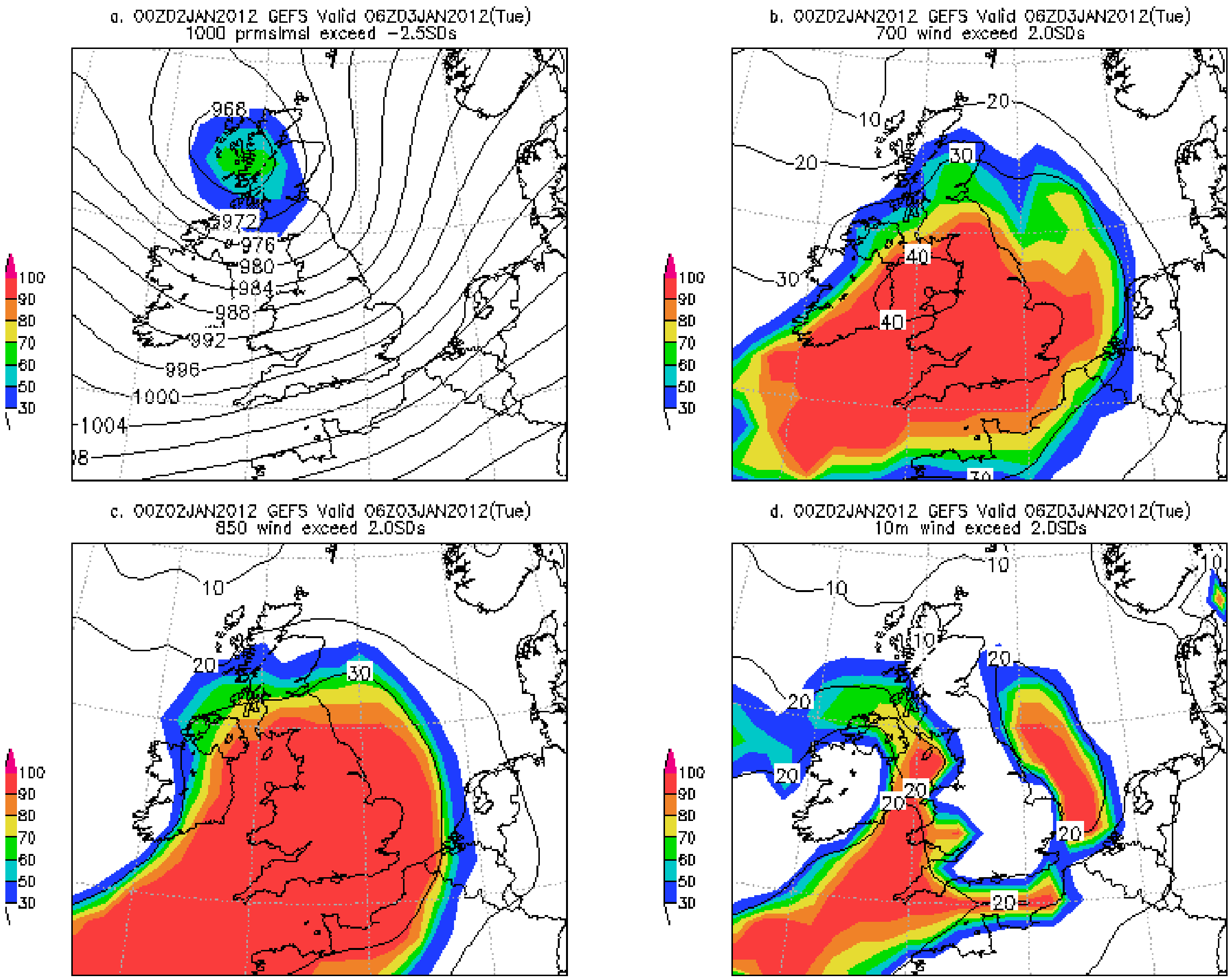

Figure 10. NCEP 21-member GEFS initialized at 0000 UTC 02 January 2012 showing conditions forecast at 0600 UTC 03 January 2012 including a) mean sea level pressure and the probability of pressure anomalies of -2.5σ or lower, b) the mean 700 hPa winds and the probability of winds in excess of 2σ above normal, c) the mean 850 hPa winds and the probability of winds in excess of 2σ above normal, and d) the mean 10m winds and the probability of winds in excess of 2σ above normal. **Return to text.**

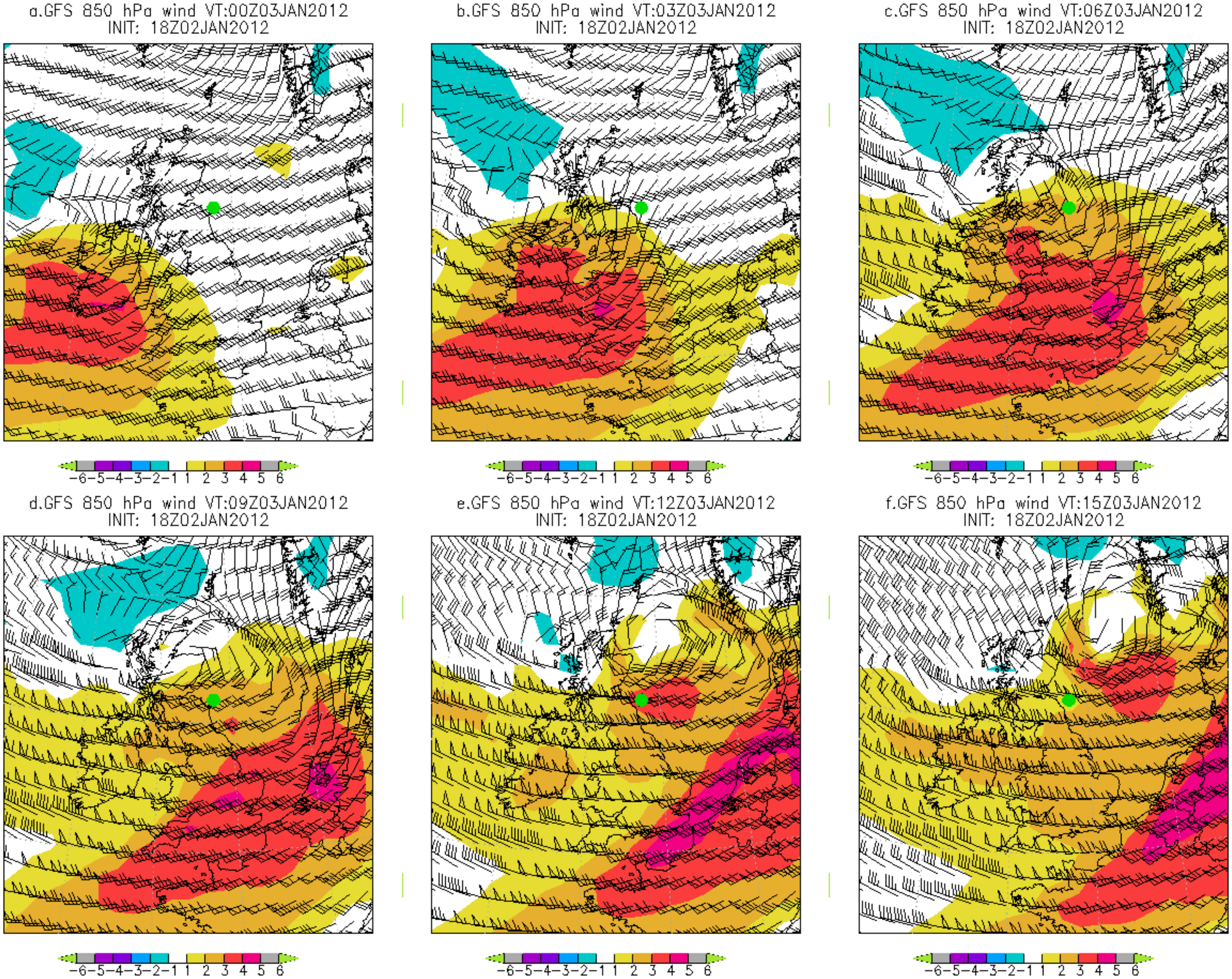

Figure 11. NCEP GFS forecasts of 850 hPa winds and wind anomalies from forecasts initialized at 1800 UTC 2 January 2012 valid in 3-hour increments from a) 0000 UTC 3 January through f) 1500 UTC 3 January 2012. **Return to text.**

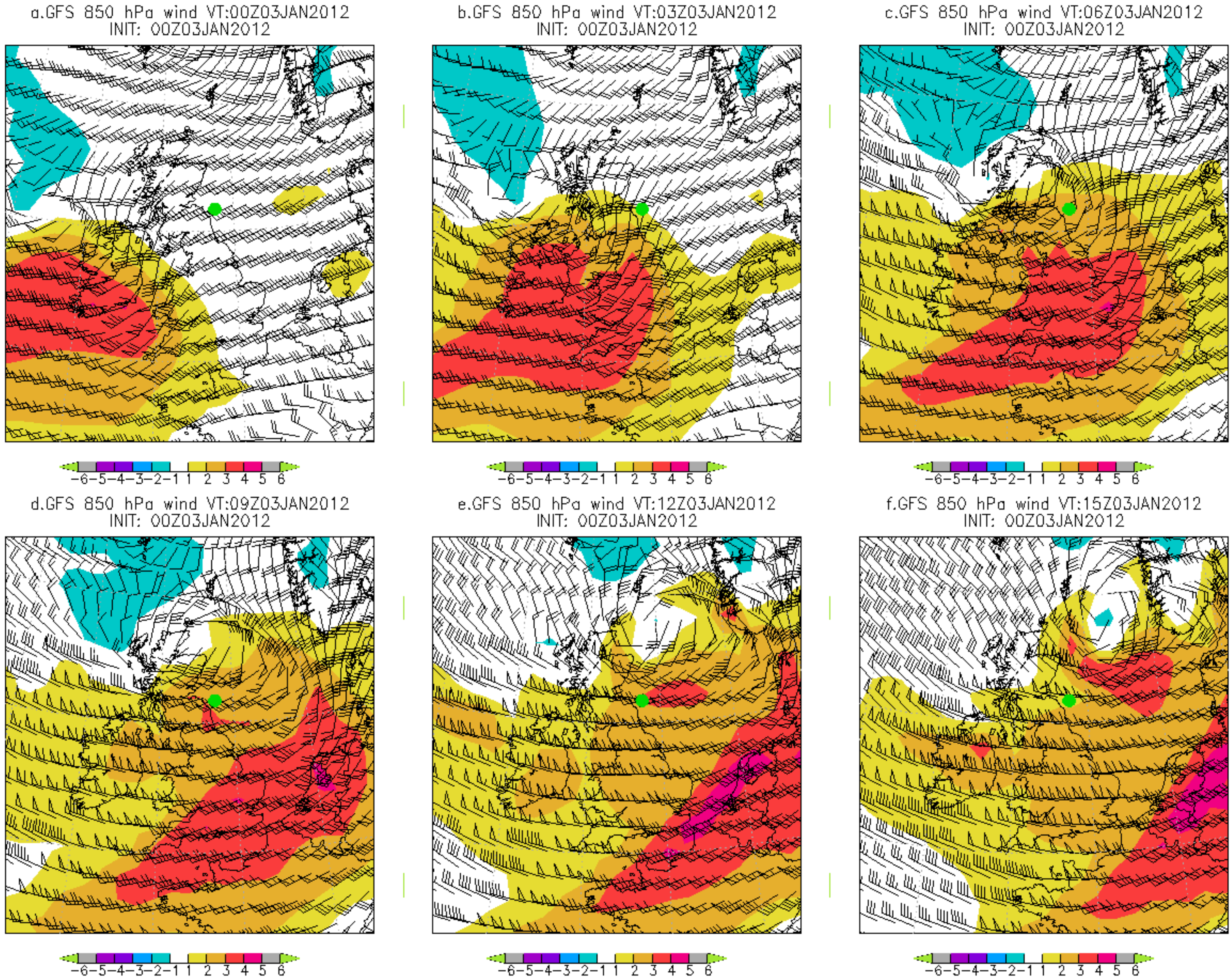

Figure 12. As in Figure 11 except initialized at 0000 UTC 03 January 2012. Return to text.

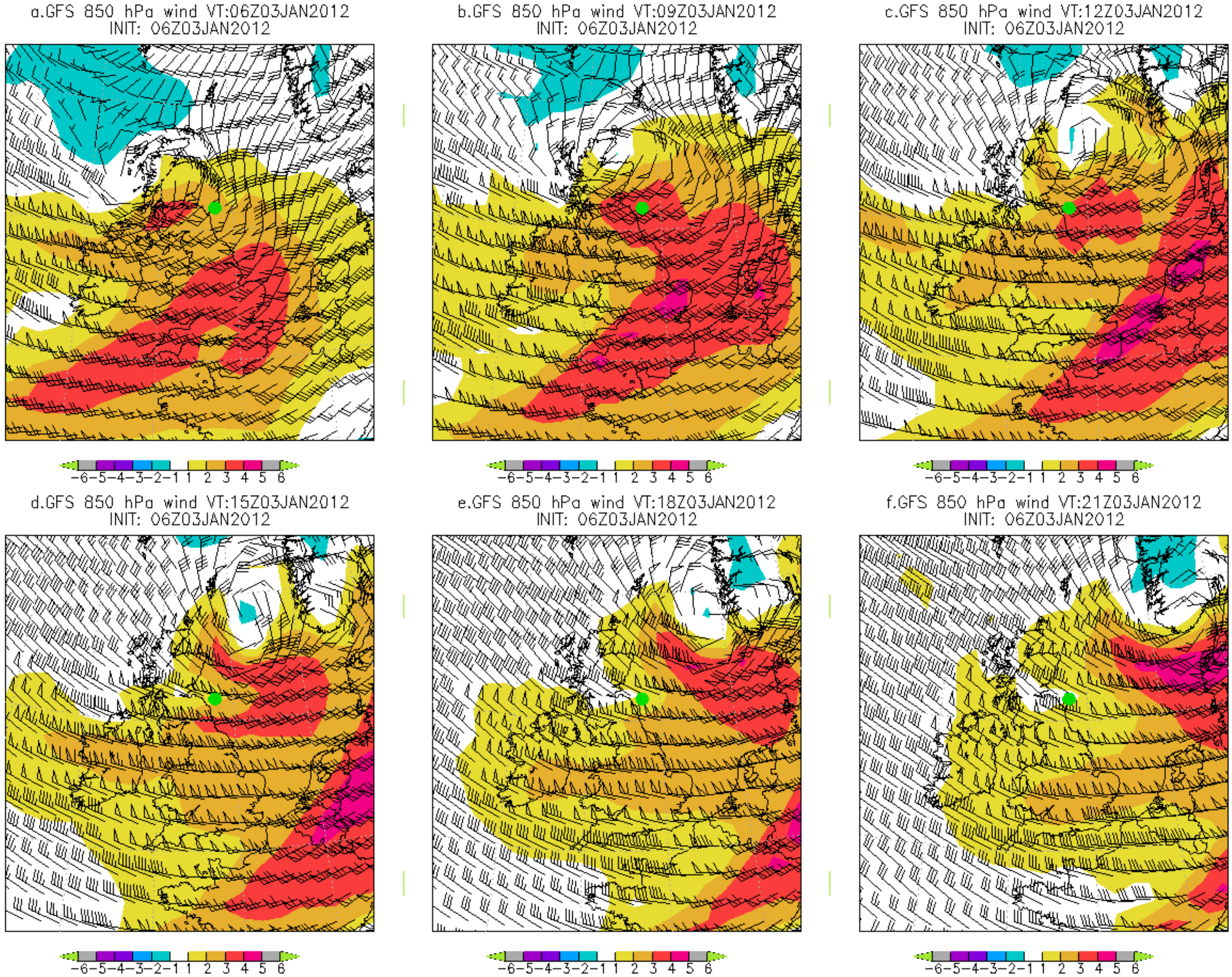

Figure 13. As in Figure 11 except initialized at 0600 UTC 03 January 2012 and for the period a) 0600 UTC 3 January through f)2100 UTC 3 January 2012. [Return to text.](#)

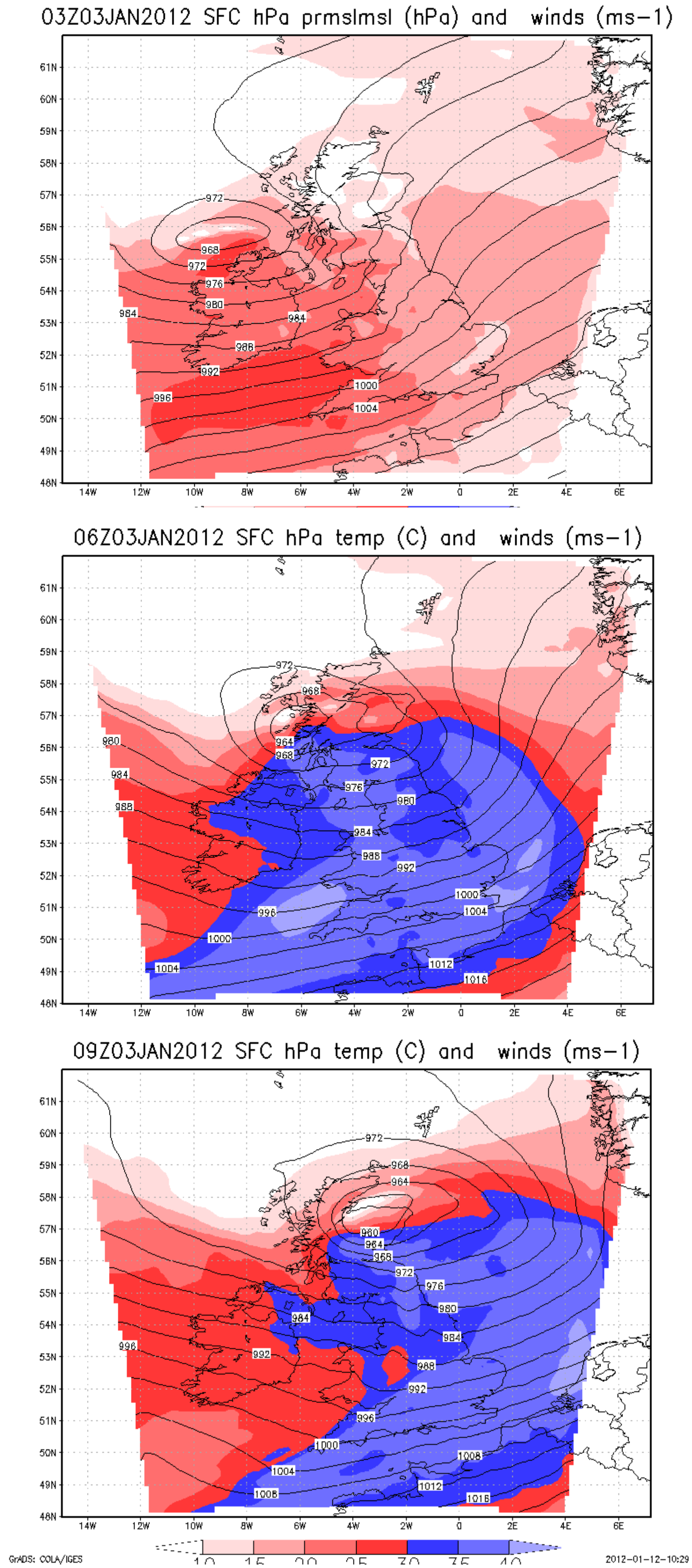

Figure 14. 12km WRF initialized at 0000 UTC 3 January 2012 showing mean sea-level pressure (hPa) and 10m winds (ms-1) in three hourly increments from from 0300 UTC through 0900 UTC. **[Return to text.]()**

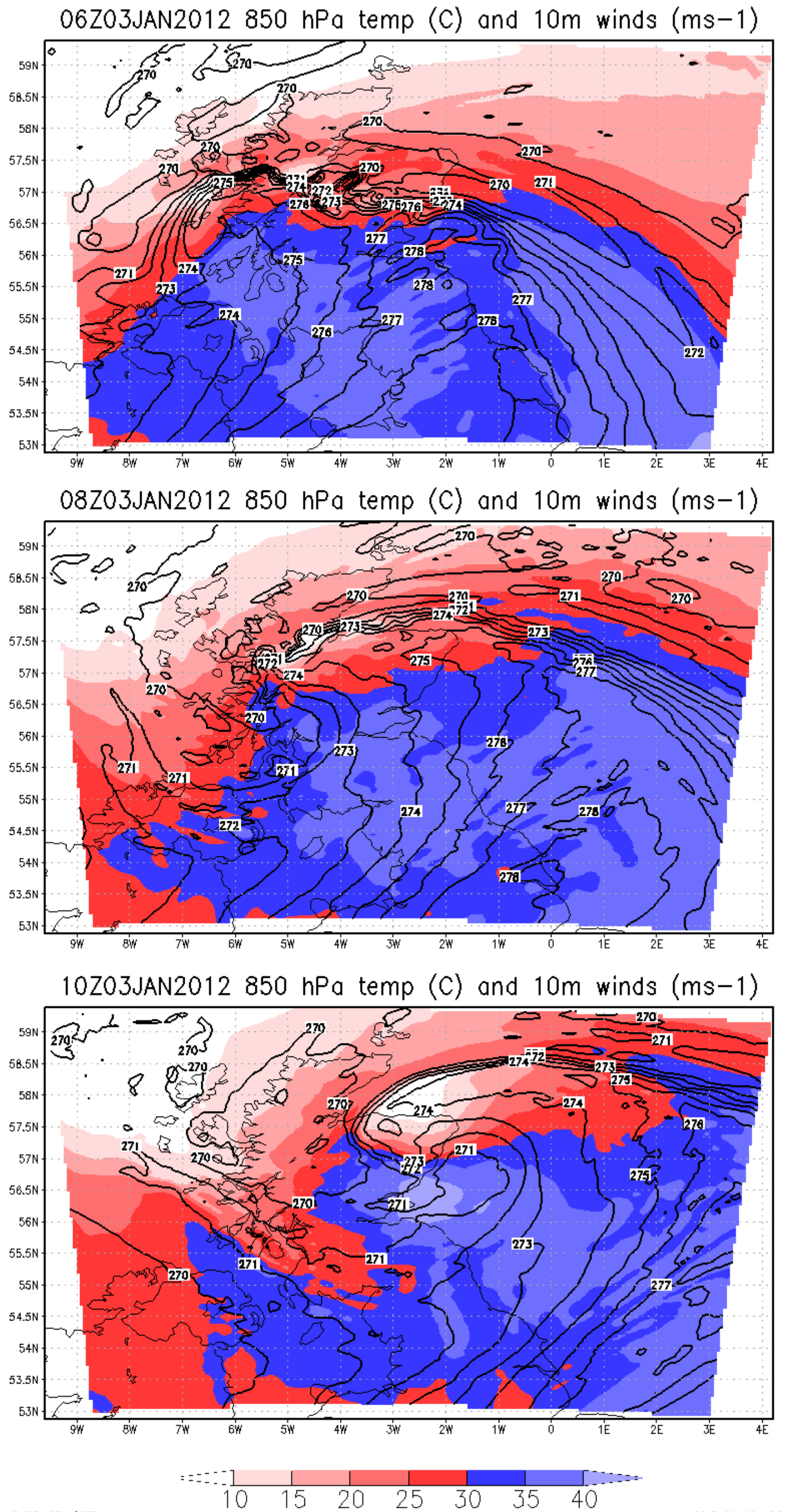

Figure 145. 4km WRF-ARW initialized at 03/0000 UTC showing 850 hPa temperatures (C) and winds (ms-1) in 2-hour increments from top to bottom at 0600, 0800 and 1000 UTC. [Return to text.]

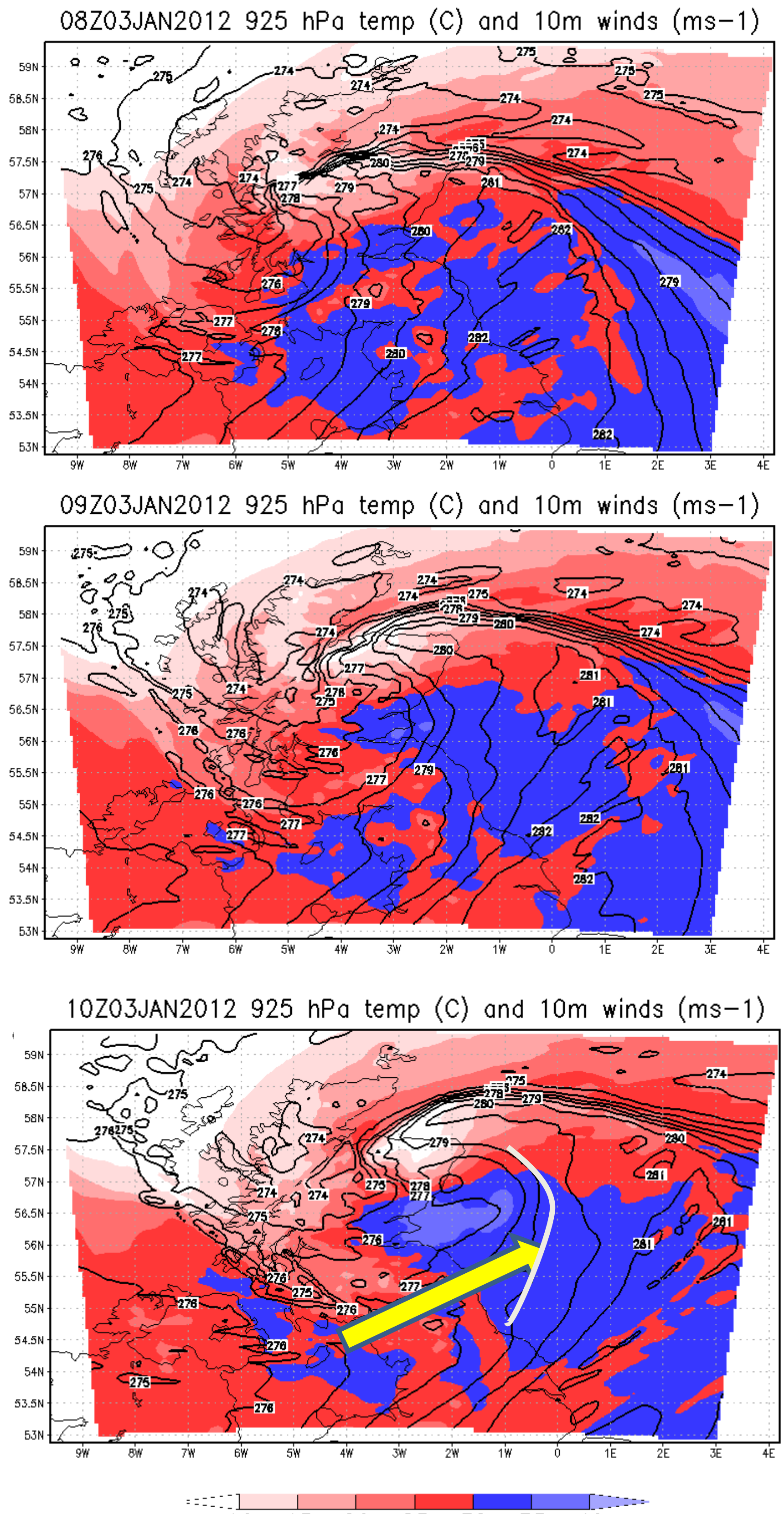

Figure 16. As in Figure X except for 925 hPa temperatures and winds in hourly increments from 0800 through 10000 UTC 3 January 2011. The yellow arrow shows the strong jet and is drawn below it as not to obscure it. The white line shows the advancing bent-back frontal system. **Return to text.**

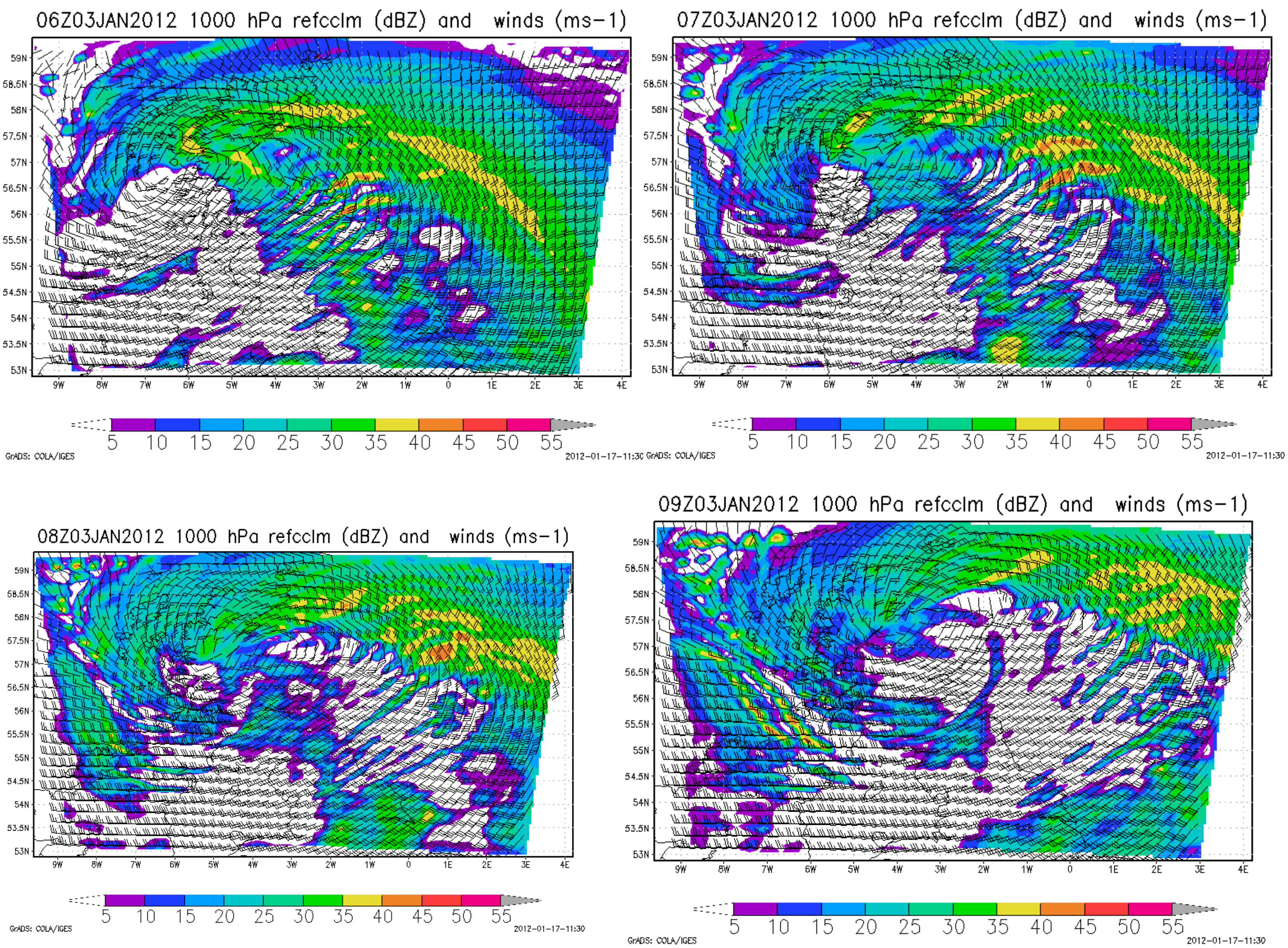

Figure 7. 4km WRF simulated radar (reflectivity dBZ) in hourly increments from 0600 UTC through 0900 UTC 3 January 2012.