The wind storm of 18th January 2018

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During a 24 hour period starting on the 17th January 2018, a deepening low moved rapidly from the Atlantic across the UK and into northern Germany. Damaging winds developed on its southern flank, with the following gusts (knots) reported early on the 18th over Wales, and during the morning further east: Wattisham 60, Weyborne 61, Cranwell 62, Valley and Pembray Sands 63, Wittering, Aberporth and Liscombe 64, Lake Vyrnwy 66, Aberavon 68 and Capel Curig, 81. Here in Wokingham, which lay to the south of the strongest flow and is in an urban environment, 53 kn was recorded near 0400 hours. Damaging winds were also experienced over Holland and northern Germany.

The surface low was analysed near 53N 22W, 997 hpa, at 17/1200, near the Isle of Man 981 hpa at 18/0000, and near Bremen 978 hpa at 18/1200. The speed of movement of the centre was approximately 28 m/s. Falls of pressure at locations in its path exceeded 10 hpa in 3 hours as a result of this rapid movement. Using the 12 hourly upper air analysis charts, available from the University of Wyoming, a thickness change budget over the surface low centre could be drawn up, and this is shown in Table 1.

Layer	17/12 to 18/00	18/00 to 18/12
Above 100 hpa	+10 gpdam	+6 gpdam
100 to 300 hpa	+6	+14
300 to 500 hpa	-1	-7
500 to 1000 hpa	-2	-11
Net change	+13	+2
Surface p change hpa	-16 hpa	-3 hpa

Table 1. Thickness change budget over the centre of the low, 17th January 2018 1200 to 18th January 2018 1200. Increasing thickness above a level indicates falling pressure (or geopotential) at that level, and vice-versa.

The thickness above 300 hpa over the surface low increased by 36 gpdam in the 24 hours to 18/1200, (see Table 1), while the tropospheric thickness between 300 and 1000 hpa decreased by 21 gpdam, a net change of +15 gpdam. This resulted in the 1000 hpa geopotential falling from -30 m at 17/1200 to -180 m at 18/1200, the equivalent surface pressure falling from 997 hpa to 978 hpa. In table1 it can be seen that thermal changes in the 100 to 300 hpa layer between 17/1200 and 18/0000 were modest, and were predominently associated with the tropospheric thermal wave advecting northwards under the existing stratospheric thermal structure, higher thickness values being to the north. Over the following 12 hours there is a marked increase in the thermal change in this layer, and this can be linked to the dynamic effects associated with the start of amplification of the upper trough.

The system consisted initially of a well developed quite large amplitude tropospheric baroclinic wave embedded in a strong westerly flow over the Atlantic, (Fig1). The driving trough at jet-stream level was of very low amplitude, and showed no sign of development during the initial 12 hours. The jet exit lay well to the east of the tropospheric baroclinic wave and associated surface low. At 17/1200 the surface low lay about 350 km south of the jet axis.

From 17/1200 to 18/0000 the track of the baroclinic wave and surface low had a component towards the jet axis, and at 18/000 the surface low was almost under the core. This northward component continued over the following 12 hours, so that by 18/1200 the low was located about 250 km to the north of the jet axis.

This 24 hour track of the tropospheric thermal warm pulse (baroclinic wave) took it towards lower contours in the stratosphere, and for the atmosphere above 100 hpa table1 shows that this resulted in a 16 gpdam increase the thickness over the surface low, nearly the same as the actual net increase in total thickness of 15 gpdam and associated fall in 1000 hpa geopotential, and a drop in surface pressure at the low centre from 997 hpa to 978 hpa.

As noted earlier, the driving upper trough was initially weak, and dynamic changes nearly absent before 18/0000, but after that time some modest development commenced. The troposphere over the surface low initially cooled a little, by 3 gpdam in total, but after 18/0000 cooling increased markedly as cold air began to circulate the low centre. Above 300 hpa, and particularly in the 100 to 300 hpa layer, there was an increase in the rate of warming, at least in part due to dynamic descent as the upper trough amplified. In many cases this would have lead to further deepening of the low, but in this case tropospheric cooling amounting to an 18 gpdam fall in thickness caused the low to almost cease deepening.

So why the damaging winds? At 18/0000, the low centre near the Isle of Man is almost under the jet axis at 300 hpa, and at 500 hpa there is a very strong westerly flow of about 55 m/s. As the flow in the centre of the surface low is calm, there must have been a correspondingly strong westerly thermal in the 500 to 1000 hpa layer over that point, also of 55 m/s. (The geostrophic flow at a lower level is determined by the flow at some upper level minus the intervening thermal wind). A little further south, over north Wales, the 500 hpa flow is westerly at 50 m/s, but the thermal gradient is much weaker, westerly 20 m/s approximately, resulting in a 1000 hpa geostrophic flow of about 30 m/s.

In the next 12 hours, surface winds increased somewhat, to the south and southwest of the low, associated with changes in the in the tropospheric warm pulse as the wave cooled and distorted and cold advection increased, the overall effect being to decrease the strength of the thermal wind, (Fig1). There were also slight changes taking place in the shape of the flow at 500 hpa associated with the upper tropospheric/lower stratospheric development.

By 18/1200, when the surface low is over northwest Germany, the low is now under the northern edge of the jet stream. The changes in the shape of the flow at 500 hpa are leading to the development of a broad trough at that level, such that the flow over the low centre has now weakened to westerly 10 m/s. Once again, as the surface flow at the centre of the low is calm, the strength of the tropospheric thermal flow must also have weakened to westerly 10 m/s. As noted earlier, the tropospheric warm pulse has by now cooled, and the thermal pattern has opened markedly, (Fig1). Gone is the 50 m/s thermal flow seen 12 hours earlier over Wales, instead, about 250 km south of the low centre, where the 500 hpa flow is westerly 55 m/s, the thermal here is west-southwest 15 m/s, resulting in a 1000 hpa geostrophic flow of westerly 40 m/s. Meanwhile, about 180 km to the south-southwest of the low centre. with cold advection taking place, the 500 to 100 hpa thermal has backed to south-southwest 20 m/s, under a 500 hpa flow of west-northwest 45 m/s, the resulting 1000 hpa geostrophic flow being northwest 45 m/s. Slightly further to the northwest, about 180 km southwest of the low centre, where the tightest surface isobar spacing is to be found, the thermal flow is southerly 20 m/s, while the 500 hpa flow is west-northwest at 35 m/s, giving a geostrophic flow at 1000 hpa of north-northwest 50 m/s.

All the values above are approximate, derived from measuring contour spacing on the available charts. As such they are strictly geostrophic, that is, a straight flow with no accelerations. In certain situations, actual winds can depart significantly from the geostrophic value. One of those situations is in regions where the flow is curved, and in such conditions, anticyclonic curvature results in the actual flow being higher that the geostrophic, but in cyclonic cases, the actual flow will be less that the geostrophic. For the present case, the radius of curvature at 180 km from the centre of the surface low will lead to about a 50 % reduction in strength from the geostrophic, and further out at 250 km the reduction will be less, as it will where the flow straightens, effectively increasing the radius of curvature and bringing the actual flow closer to the geostrophic.

Conclusions.

The wind storm over parts of the UK and northern Europe on the 18th January 2018 was the result of a fairly extreme example of a fast moving baroclinic wave, (Fig1). The upper troposphere contained a strong westerly jet stream, and the flow at mid tropospheric levels was also very strong. The pressure/contour pattern at any level in the atmosphere is a result of the pattern at some higher level minus the intervening thermal pattern. When a strong distortion in the thermal field occurs, in this case in the shape of a baroclinic wave, the pressure pattern and flow at a lower level will match that at the upper level more closely where the intervening thermal field is weak and less so where it is strong. In this case, there was a very strong thermal gradient in the 500/1000 hpa layer, and which was concentrated near the baroclinic wave crest, at least initially, (Fig1), and which was enough to prevent the strength in the upper flow from appearing at the surface. A surface low appeared there as a result of it being the location where the net thickness in the atmosphere above was at a maximum.

The surface low deepened during the 24 hour period primarily as a result of the northward extension of the tropospheric baroclinic wave under the tight west-east contours in the upper troposphere and stratosphere, with the associated thermal gradient, warm to the north and cold to the south in the lower stratosphere. The thickness change over the surface low in the atmosphere above 300 hpa was +36 gpdam, and if no cooling had taken place in the troposphere in the final 12 hour period, this would have been reflected in a fall in 1000 hpa geopotential of 36 gpdam, and a surface low of 955 hpa, instead of the actual 978 hpa.

The strong surface winds on the southern flank of the low were located where the tropospheric thermal gradient was relative weak, (Fig1), and the upper flow was strong. In the final 12 hours, an equivalent effect was the distortion of the tropospheric thermal pattern as cold air wrapped around the low on its western flank (tropospheric thickness change, table 1). As the thermal field became more aligned south to north, the upper pattern at 500 hpa was also distorting, these two factors together leading to a zone of intense geostrophic gradient which fortunately was mitigated to some degree by the strong cyclonic curvature of the surface flow.

What perhaps was non typical in this case was that the upper trough driving the system was relatively weak, and neutral as regards dynamic development in the initial stages. Some dynamic effect was seen in the final 12 hours, and is reflected in the increase in 12 hour thickness change above the surface low in the 100 to 300 hpa stratospheric layer, (table 1.). Intense mid-latitude surface lows are most often the result of a strong dynamic development in the upper troposphere/lower stratosphere, and usually combined with a tropospheric baroclinic feature in the initial stages.

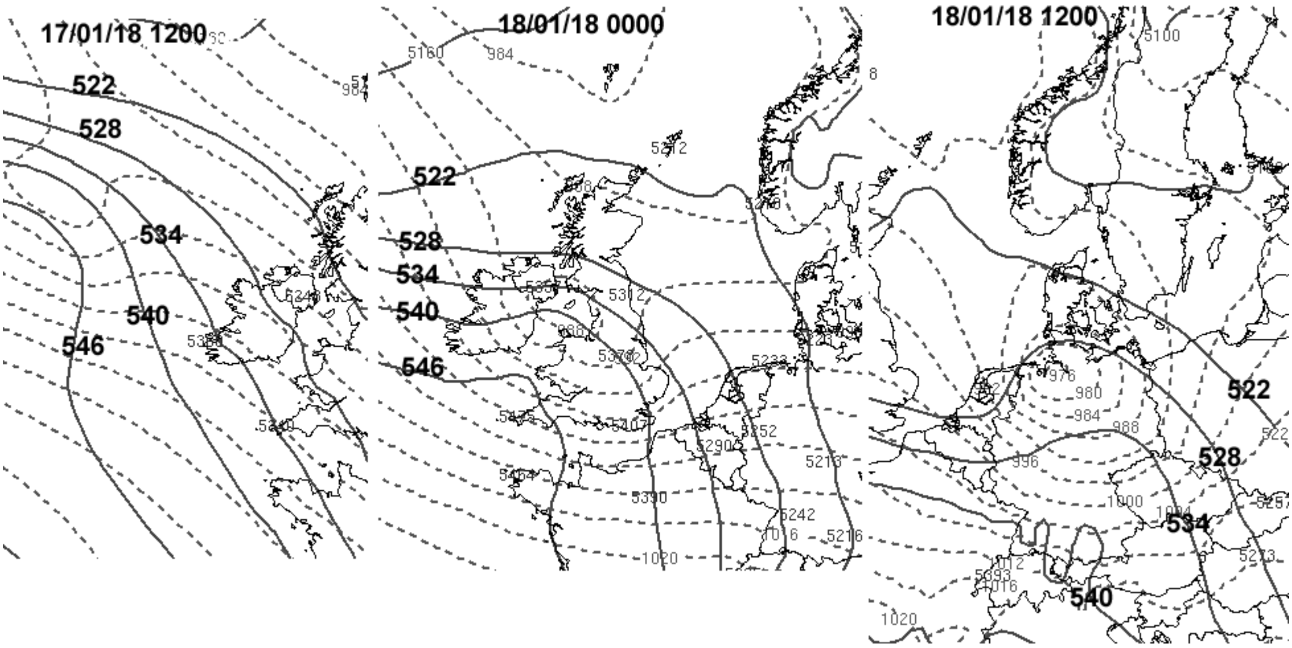

Figure 1. 500 to 1000 hpa thickness charts for 17 January 2018 1200, 18 January 2018 0000, and 18 January 2018 1200. Thickness values (solid) are shown in gpdam. MSL pressure (dashed) are labled in hpa. Note the reduction in thermal gradient after 18th 0000. Charts courtesy of University of Wyoming.