

Climatology of temperatures below -70°C near tropopause on Atlantic-tracks.

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Chapter 1

Introduction

On request of the Dutch Safety Board (Onderzoeksraad voor Veiligheid, OVV) the climatological occurrence of temperatures below -70°C on flight tracks on the Northern Atlantic routes has been assessed, to develop more knowledge concerning the risk of fuel icing. Besides this climatology, the Dutch Safety Board had special interest in the upper-air temperatures that occurred on December 28th, 2010 in an area NW of Schotland.

This research is done as part of the program Knowledge for Climate, Hotspot Schiphol, aiming at climatology of Flight Information Region Amsterdam, full details available at the website <http://www.knmi.nl/samenw/kbs>.

The required information is based on a reanalysis of the European Centre for Medium Range Weather Forecast (ECMWF), ERA-Interim. ERA-Interim is a reanalysis of the global atmosphere covering the data-rich period since 1989, and continuing in real time. This model improved existing reanalysis sets significantly, with the use of 4-dimensional variational analysis, a revised humidity analysis, the use of variational bias correction for satellite data, and other improvements in data handling.

In the next chapters the average temperatures (and standard deviation) near tropopause level are presented per wintermonth (December, January and February) and winterseason (three months). The levels are 250, 225 and 200 hPa, corresponding to the flightlevels FL340, FL360 and FL390 in ICAO-standard atmosphere.

As special interest is mentioned for temperatures near -70°C the 1%-percentile of the temperature distribution per flightlevel is presented and the returntime of -70°C as an indication of the climatological frequency of low temperatures near tropopause.

Chapter 2

Climatology of temperature at FL 340 or 250 hPa

Figures 1-3 present the recent twenty-year climatology of temperature at 250 hPa or flightlevel 340 on the Northern Atlantic (average temperature and standard deviation) for the months December, January and February. Figure 4 represents climatology of temperature in the winterseason DJF (covering the three months). Figure 5 presents the 1%-quantile of temperature at FL360. In the whole twenty year period 1989-2008 in 1% of all data temperatures were below the value displayed in this figure. This 1%-quantile corresponds to about 3 to 4 days average per year. Furthermore, figure 6 shows return times below $-70\text{ }^{\circ}\text{C}$ and indicates a variation in return time for this temperature from north to south on the Atlantic from less than 1.0 years (more than once per year) in the northern part of the chart to more than once per 6 years to the south. Because these analyses were based on (modelled) instantaneous temperatures at 6-hourly (4x daily) time steps, the cold extremes in reality, which have occurred in between these timesteps, may be somewhat colder than in these figures.

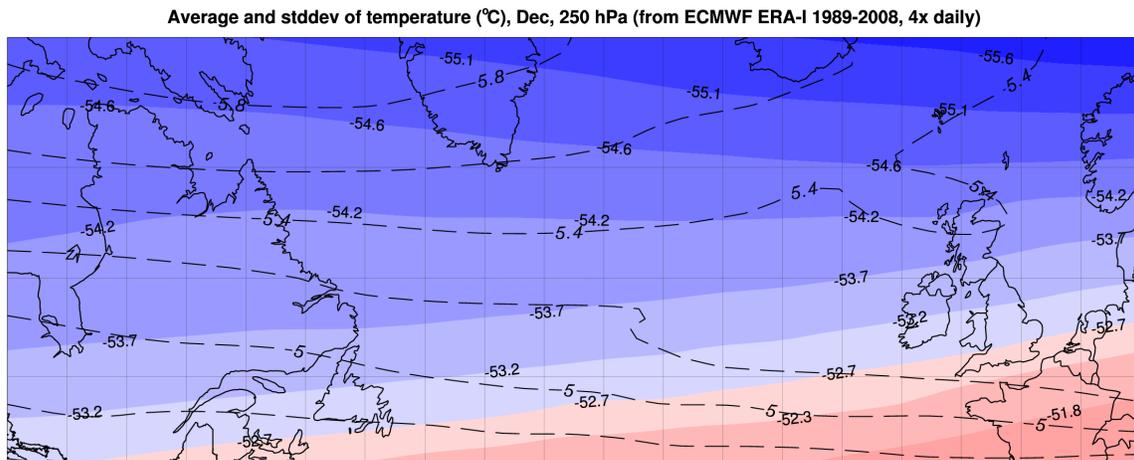


Figure 1

Average and stddev of temperature (°C), Jan, 250 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

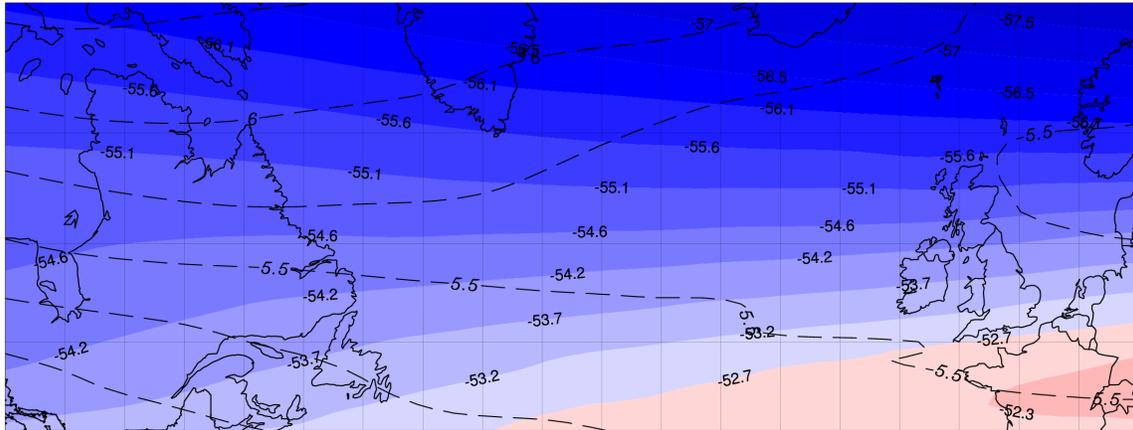


Figure 2

Average and stddev of temperature (°C), Feb, 250 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

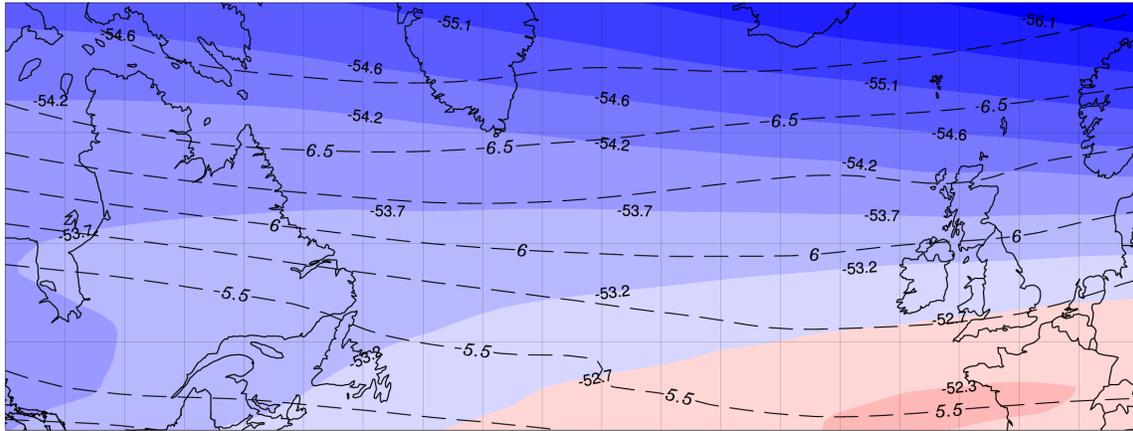


Figure 3

Average and stddev of temperature (°C), DJF, 250 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

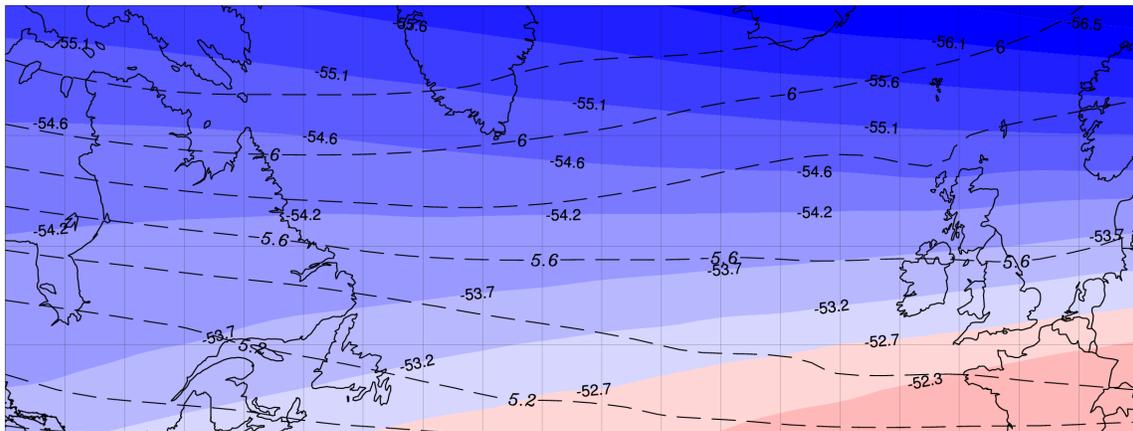


Figure 4

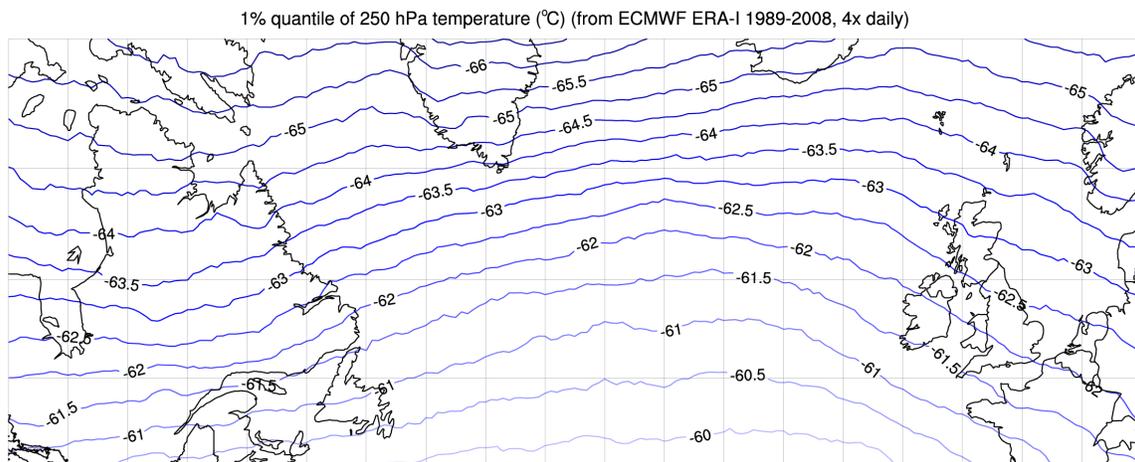


Figure 5

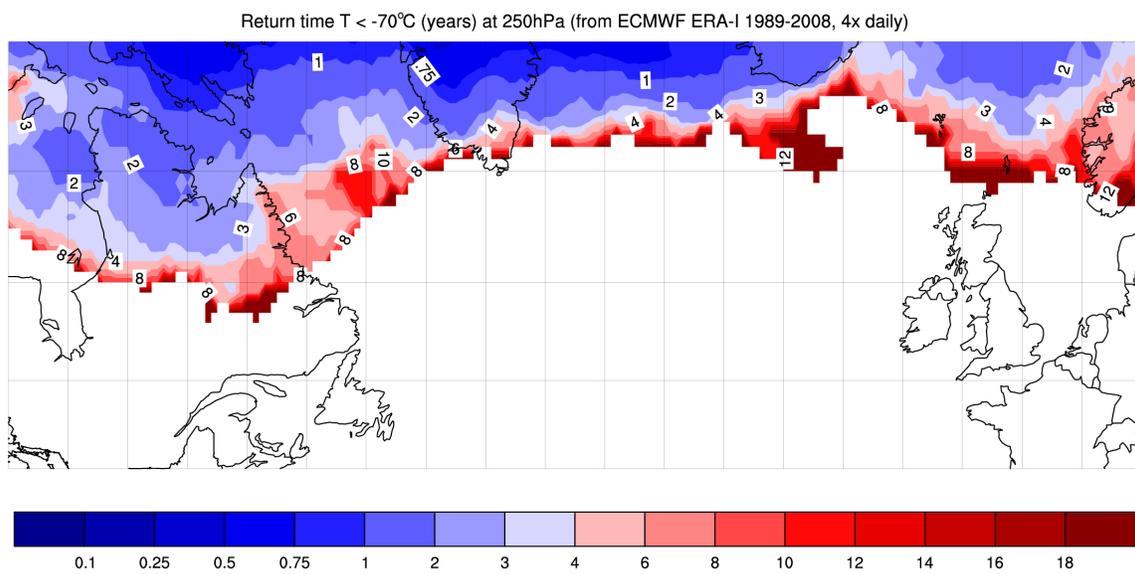


Figure 6

Chapter 3

Climatology of temperature at FL 360 or 225 hPa

Figures 7-9 present the recent twenty-year climatology of temperature at 225 hPa or flightlevel 360 on the Northern Atlantic (average temperature and standard deviation) for the months December, January and February. Figure 10 represents climatology of temperature in the winterseason DJF (covering the three months).

Figure 11 presents the 1%-quantile of temperature at FL360. In the whole twenty year period 1989-2008 in 1% of all data temperatures were below the value displayed in this figure. This 1%-quantile corresponds to about 3 to 4 days average per year. Furthermore, figure 12 shows return times below -70°C and indicates a variation in return time for this temperature from north to south on the Atlantic from less than 0.25 years (more than four times per year) in the northern part of the chart to more than once per 10 years to the south. Because these analyses were based on (modelled) instantaneous temperatures at 6-hourly (4x daily) time steps, the cold extremes in reality, which have occurred in between these timesteps, may be somewhat colder than in these figures.

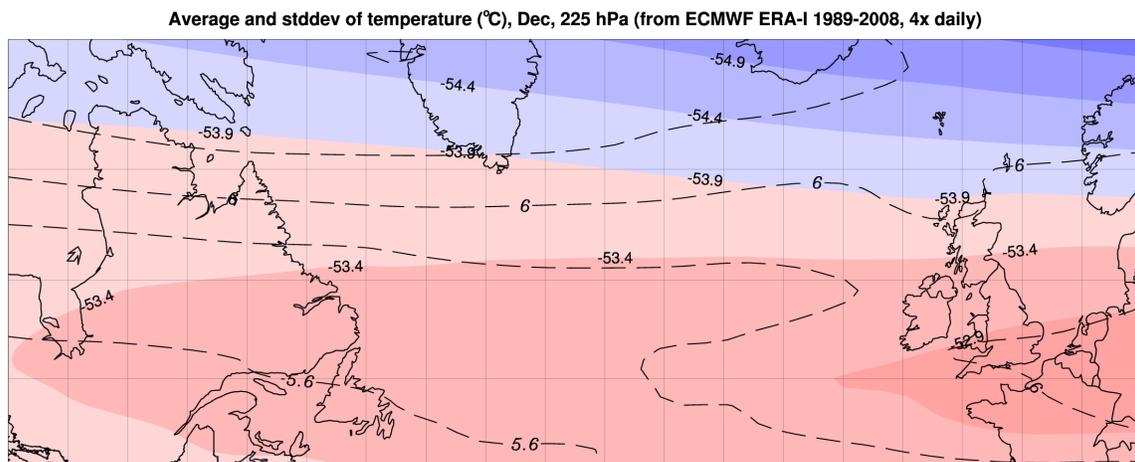


Figure 7

Average and stddev of temperature (°C), Jan, 225 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

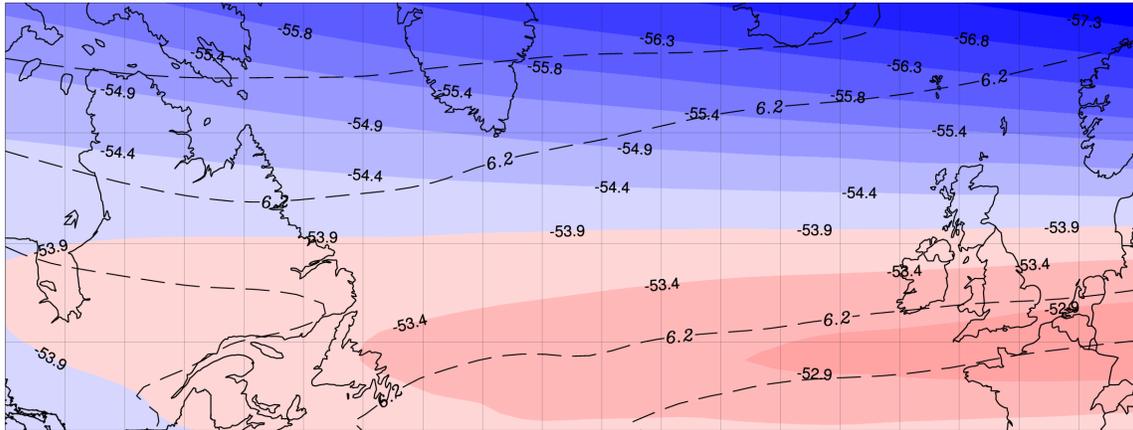


Figure 8

Average and stddev of temperature (°C), Feb, 225 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

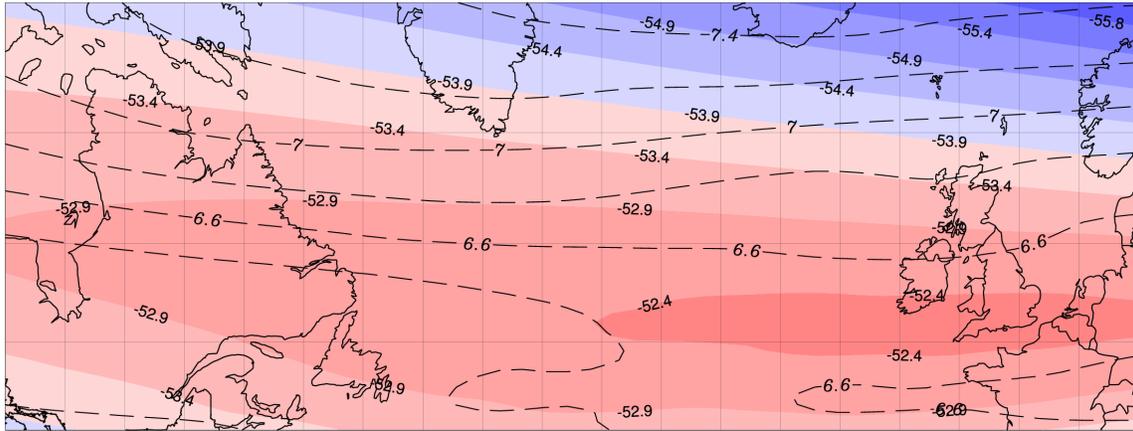


Figure 9

Average and stddev of temperature (°C), DJF, 225 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

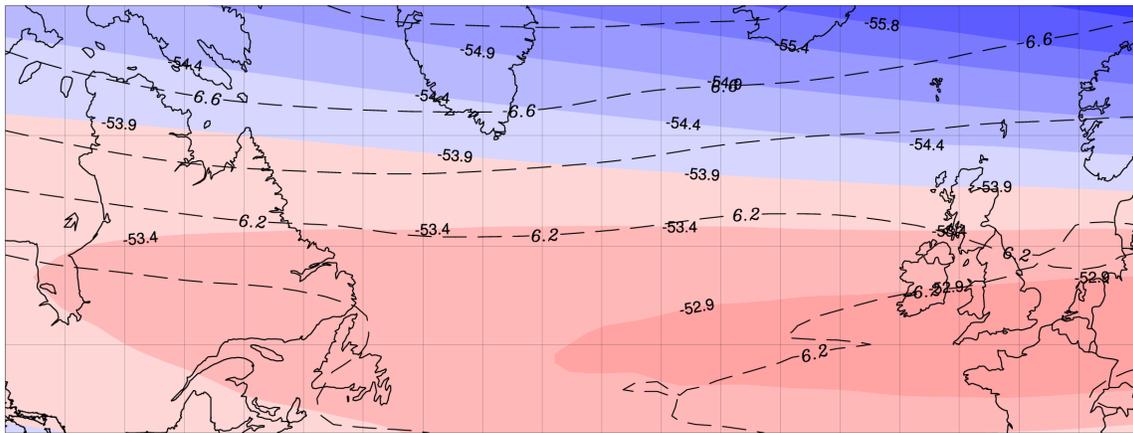


Figure 10

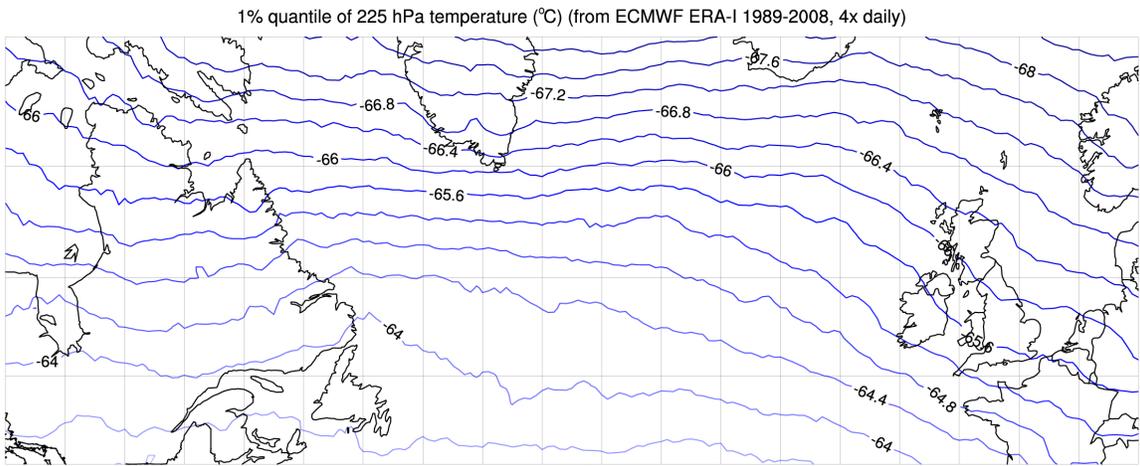


Figure 11

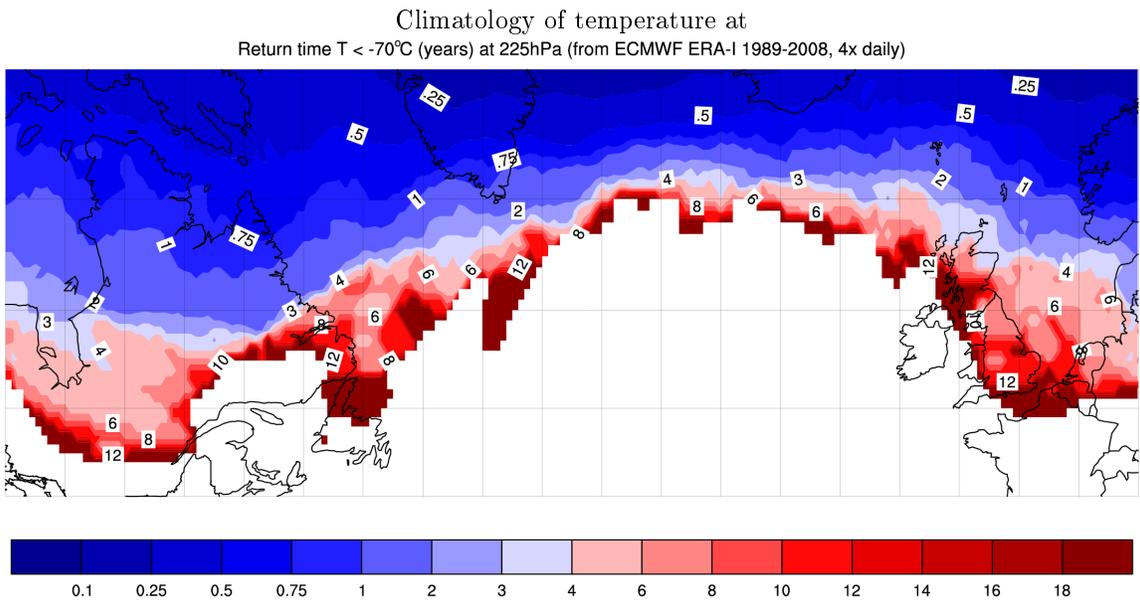


Figure 12

Chapter 4

Climatology of temperature at FL 390 or 200 hPa

Figures 13-15 present the recent twenty-year climatology of temperature at 200 hPa or flightlevel 390 on the Northern Atlantic (average temperature and standard deviation) for the months December, January and February. Figure 16 represents climatology of temperature in the winterseason DJF (covering the three months).

Figure 17 presents the 1%-quantile of temperature at FL390. In the whole twenty year period 1989-2008 in 1% of all data temperatures were below the value displayed in this figure. This 1%-quantile corresponds to about 3 to 4 days average per year. Furthermore, figure 18 shows return times below $-70\text{ }^{\circ}\text{C}$ and indicates a variation in return time for this temperature from north to south on the Atlantic from less than 0,1 years (more than 10 times per year) in the northern part of the chart to more than once per 4 years to the south. Because these analyses were based on (modelled) instantaneous temperatures at 6-hourly (4x daily) time steps, the cold extremes in reality, which have occurred in between these timesteps, may be somewhat colder than in these figures.

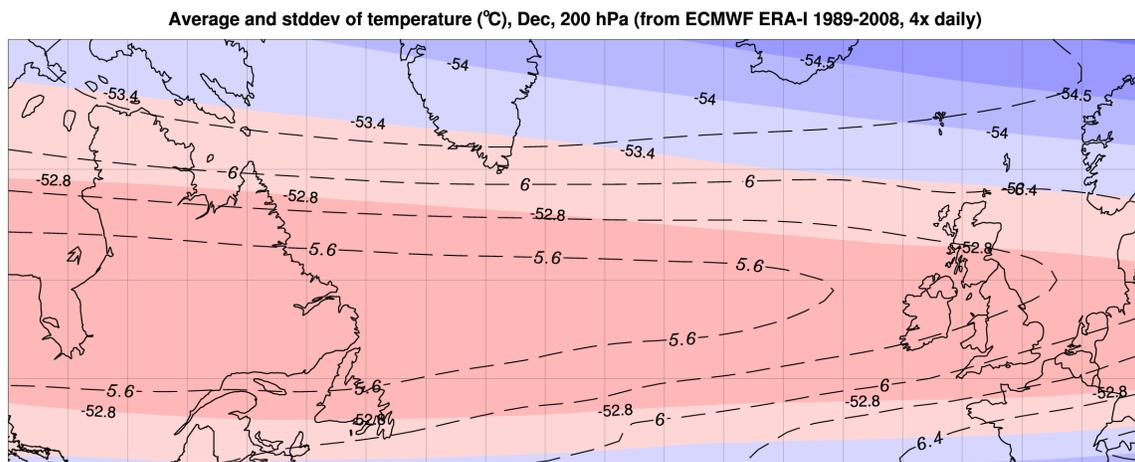


Figure 13

Average and stddev of temperature (°C), Jan, 200 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

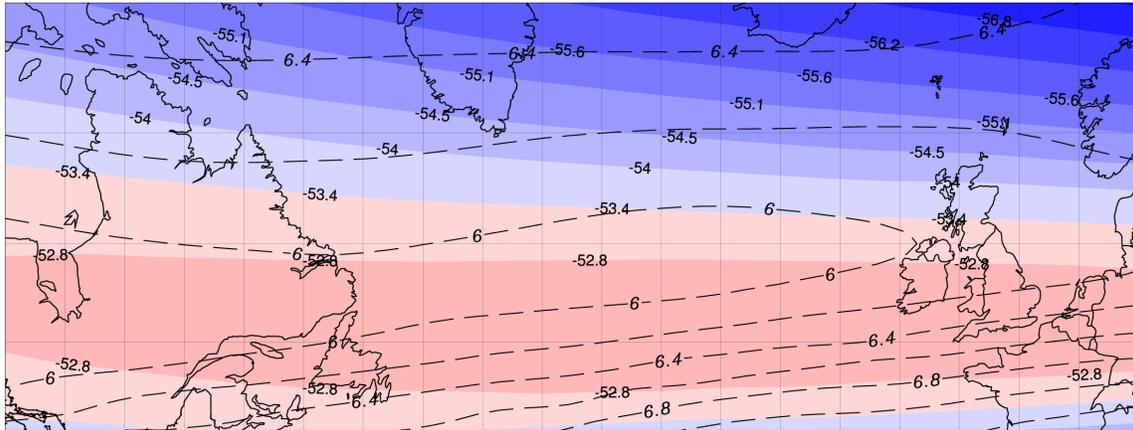


Figure 14

Average and stddev of temperature (°C), Feb, 200 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

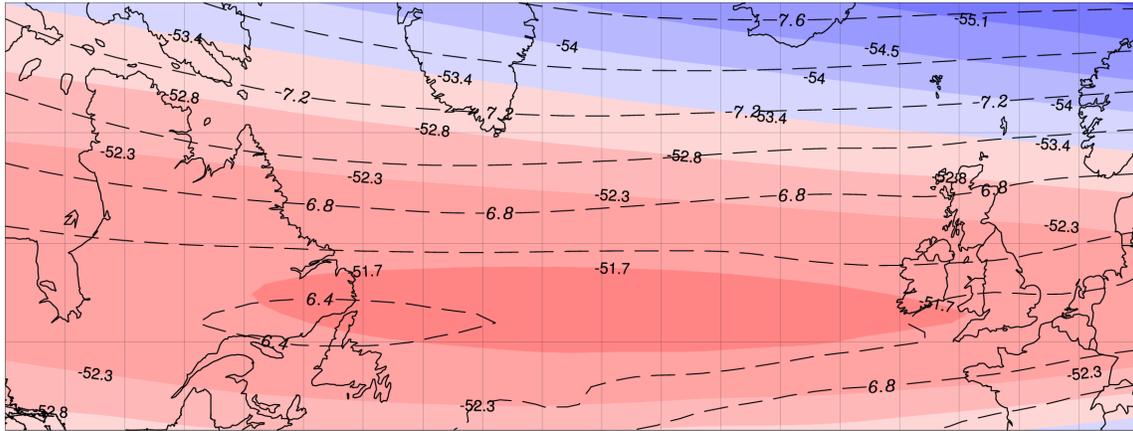


Figure 15

Average and stddev of temperature (°C), DJF, 200 hPa (from ECMWF ERA-I 1989-2008, 4x daily)

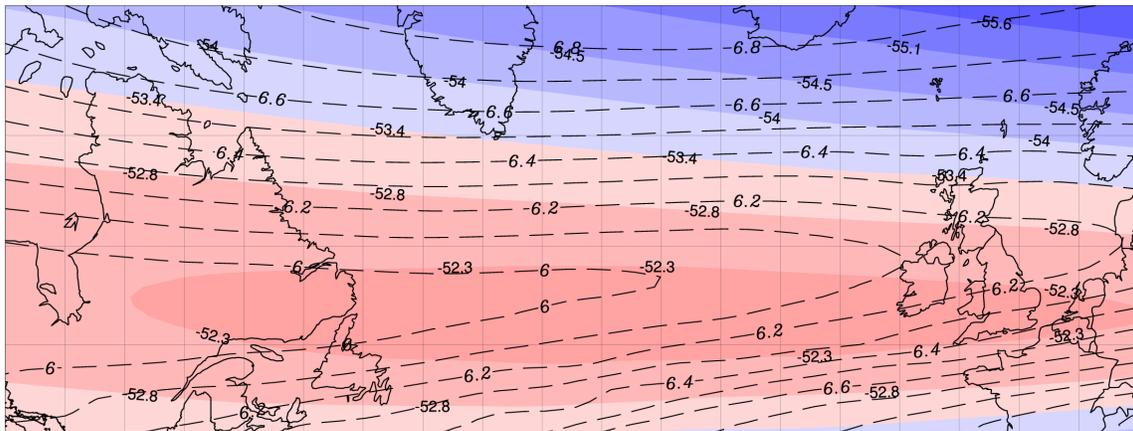


Figure 16

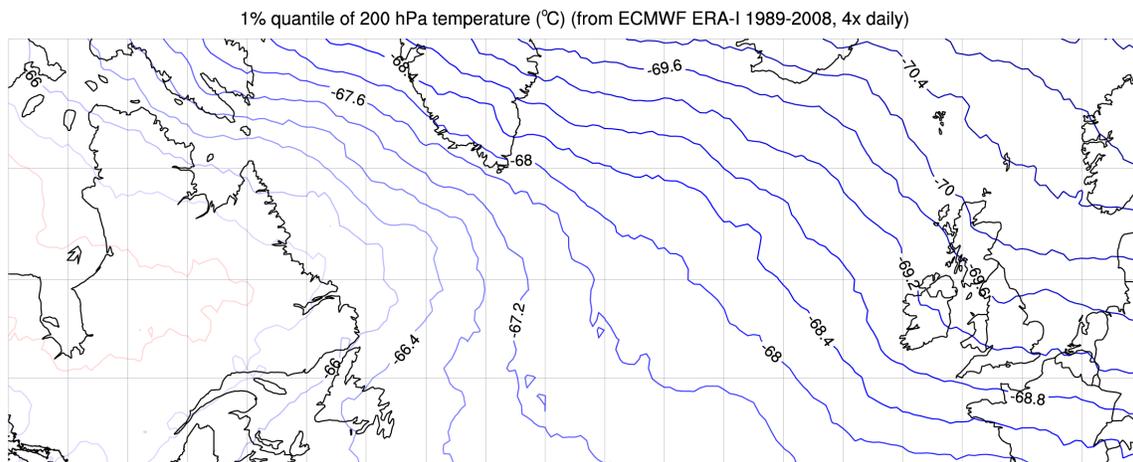


Figure 17

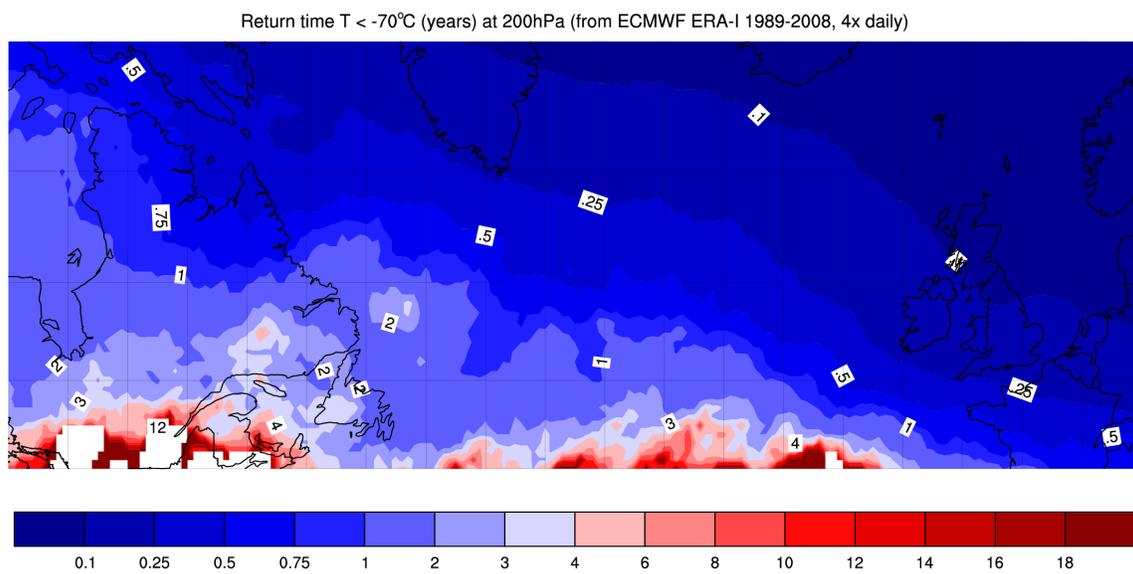


Figure 18

Chapter 5

Special case on December 28th 2010

Figures 19 and 20 present the temperatures on the special date December 28th, 2010, as in the NCEP/NCAR reanalysis (a reanalysis similar to ERA-Interim, on a coarser spatial resolution). South of Iceland, a box indicates the estimated area of interest for the case of December 28, 2010. Temperatures at 200 and 250hPa (FL 340 resp. FL 390) are shown.

A cold pool is visible at these levels, close to the marked area of interest. At FL340 temperatures were close to $-62\text{ }^{\circ}\text{C}$, at FL390 close to $-67\text{ }^{\circ}\text{C}$. At localized places, temperatures may have been somewhat lower (estimation from high resolution model Hirlam about $3\text{ }^{\circ}\text{C}$) since on this horizontal resolution, the model may have smoothed gradients and dampened extremes somewhat, actual temperatures might be 2 to 3 degrees lower.

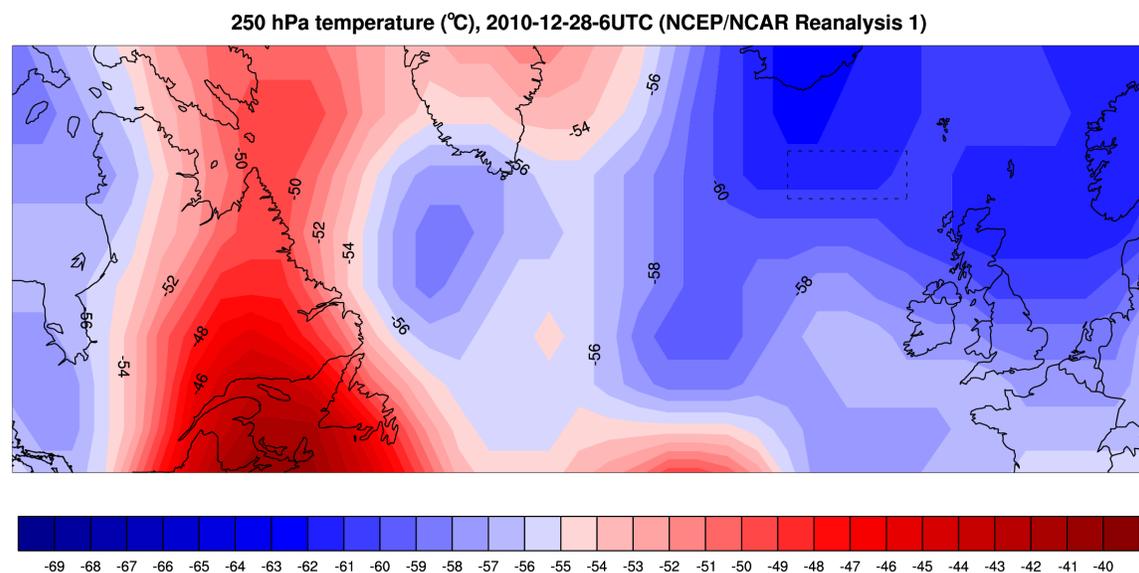


Figure 19

200 hPa temperature (°C), 2010-12-28-6UTC (NCEP/NCAR Reanalysis 1)

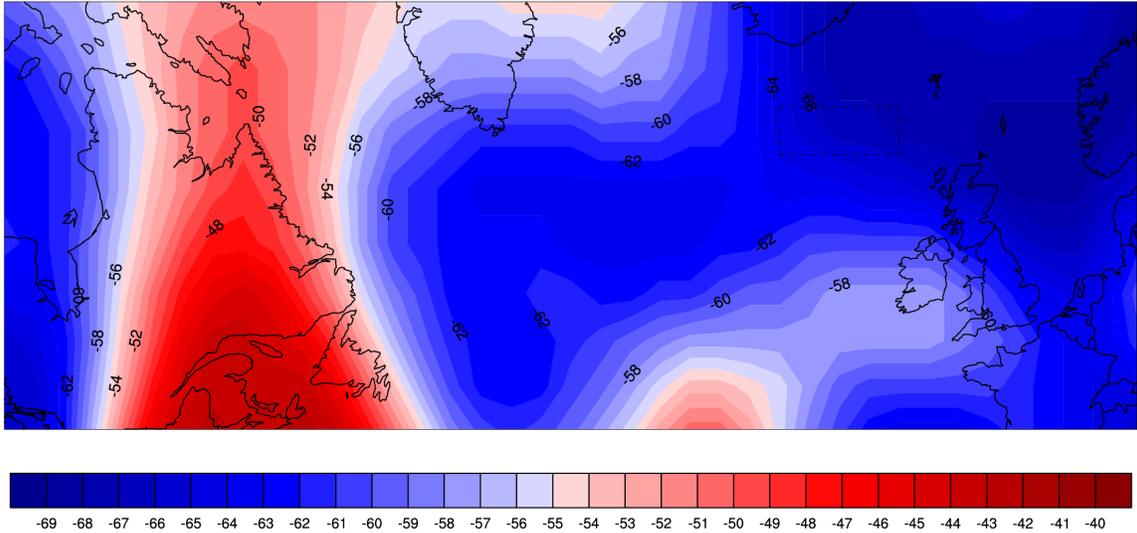


Figure 20