Polar Stratospheric Clouds over Western Europe

C. Hinz[1], P. Krämer[2] and G. P. Können[3]

[1]Brannenburg, Germany
[2]Bochum, Germany
[3]Soest, The Netherlands

Introduction

Polar stratospheric clouds (PSCs) are sometimes present in the stratosphere at altitudes between 20 and 30 km. Their formation requires temperatures below –78 °C, which limits their appearance to the winter months. Over the Antarctic they may form at a large scale, but in the Northern Hemisphere (NH) their occurrence is normally restricted to Scandinavia, Iceland, Scotland, and Alaska. PSCs are classified in three different types: at temperatures lower than –78 °C, so-called NAT-clouds (Type Ia) can form by condensation of particles of nitric acid trihydrate, and also the formation of so-called STS-clouds (Type Ib) from a supersaturated mixture of sulphuric and nitric acid and water is possible. Clouds of pure water ice (Type II), also known as mother-of-pearl clouds, require stratospheric temperatures below –86 °C. As the size of the crystals in these clouds is comparable to the wavelength of visible light, they may exhibit the splendid iridescence from which they owe their name (Figure 1).

Figure1. Strongly iridescent mother-of-pearl clouds (Type II PSCs) in the lee waves of mountains, photographed on 2 February 2005, over Breiðdalsvik, Iceland. (© H. Hansson.)

As the temperature in the NH stratosphere is typically 10 degC above the – 78 °C threshold for PSC formation (Climate Prediction Center, 2008), the formation of boreal PSCs requires atmospheric circumstances in which excessive cooling takes place. The most common mechanism of formation is adiabatic cooling due to uplifting of air masses by mountains. These results in geographical-specific PSCs, occurring in mountain lee waves in the areas mentioned above. A second possibility for boreal PSC formation occurs over tropospheric high pressure systems, in which the convergence at the tropopause level forces vertical air motions in the stratosphere and hence adiabatic cooling. This mechanism may occasionally allow PSC formation in NH regions other than near mountains. Such a situation occurred in the second half of February 2008 over the North Sea, where a stratospheric area with temperatures down to –91 °C (182 K, Figure 2) developed over a strong tropospheric high pressure system. In this cold air a large field of PSCs formed, which had never before been reported at such low latitudes.

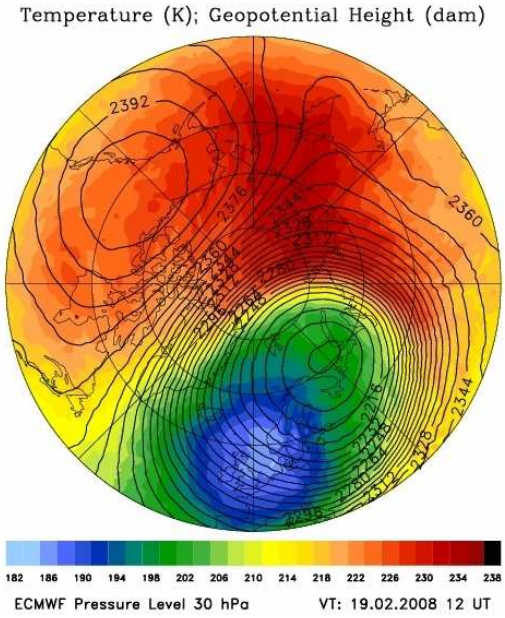
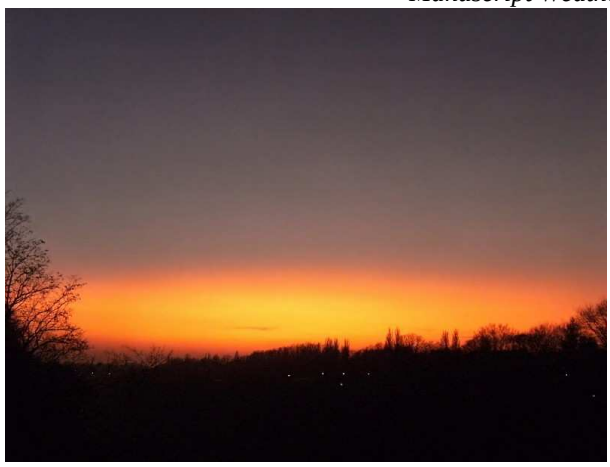


Figure 2. Temperatures and geopotential heights at 30 hPa, 19 February 2008, 1200 UTC. The cold area has its centre over the North Sea. (Source: ECMWF.)

Observations

Between the evening of 17 February and the morning of 20 February 2008, observers in Central and Western Europe reported an extraordinary intense purple twilight (Figures 3–6). The phenomenon started as a bright yellow glow of light, which appeared a few minutes after sunset, bathing the landscape in a strange and unearthly light. This light originated from an extremely bright yellow or brownish-yellow glow in the western sky. After about 10 minutes this glow became surrounded by an intense purple light. While the twilight progressed, the yellow glow sank towards the horizon but kept its brightness. Only its shrinking caused the strange shining of the landscape to fade away. About half an hour after sunset, the yellow glow turned to orange and later to red, resembling red clouds after sunset. Above this red light, a second purple light developed. The strange and unusual twilight persisted for up to one hour after sunset. In the morning the phenomena appeared in the reverse order. In one instance, the strange yellow light could even be perceived through a layer of stratus clouds (personal communication, N. Bläsner, Dresden).

Figure 3. Intense purple light with crepuscular rays, photographed in the evening of 19 February 2008, in Barsinghausen, Germany. (© R. Nitze).

)

Figure 4. (left) Intense purple light, photographed in the evening of 18 February 2008, in Bochum, Germany. (© C. Krause.)

Figure 5. (right) Low yellow glow, photographed in the evening of 19 February 2008, in Bochum, Germany. (© P. Krämer.)

The reports where anomalous twilights were observed extended from southern Norway over almost all parts of Germany and the Netherlands up to southern England down to the Spanish Pyrenees (R. Baylina, E-Sort). In the centre of this region, there were also observations of clouds with faint greenish and pink iridescence (Figure 7). In England, these clouds showed up more than one hour before sunrise (K. Boyle, UKNewchapel, R. Winter, D-Eschenbergen). Observers in southern Norway and the Netherlands reported bright, cirrus-like clouds persisting throughout the entire nautical twilight (F. Nieuwenhuys, NL-Den Haag, E. Knudsen, N-Baerum). The Norwegian observers noticed a strong iridescence in these clouds.


Figure 6. (left): Opposite purple light at the Eastern horizon, photographed in the evening of 18 February 2008, in Heidelberg, Germany. (© C. Gerber.)

Figure.7 (right): Tenuous iridescent cloud structures, photographed in Newchapel, Stoke-on-Trent, UK, during the evening of 19 February 2008. (© Kevin Boyle.)

PSC-related twilights

The long visibility of the phenomena after sunset and before sunrise indicates that the cause of the glow stems from the stratosphere. Only at these altitudes is the Sun still or already shining when it is 13 degrees below the horizon. The twilight reports closely resemble those occurring after big volcanic eruptions (Meinel and Meinel, 1983). On such occasions, volcanic ashes and dust are deposited in the stratosphere, where they may stay for years. But there had been no major volcanic eruption for several years, and the ashes of the most recent significant eruptions, the Shiveluch in Kamtschatka (December 2007), the Llaima in Chile (January 2008), and the Tungurahua in Ecuador (December 2007), had not been ejected high enough into the atmosphere

to spread that far (Volcano World Eruptions, 2008). So the observed phenomena had not been volcanic twilights.

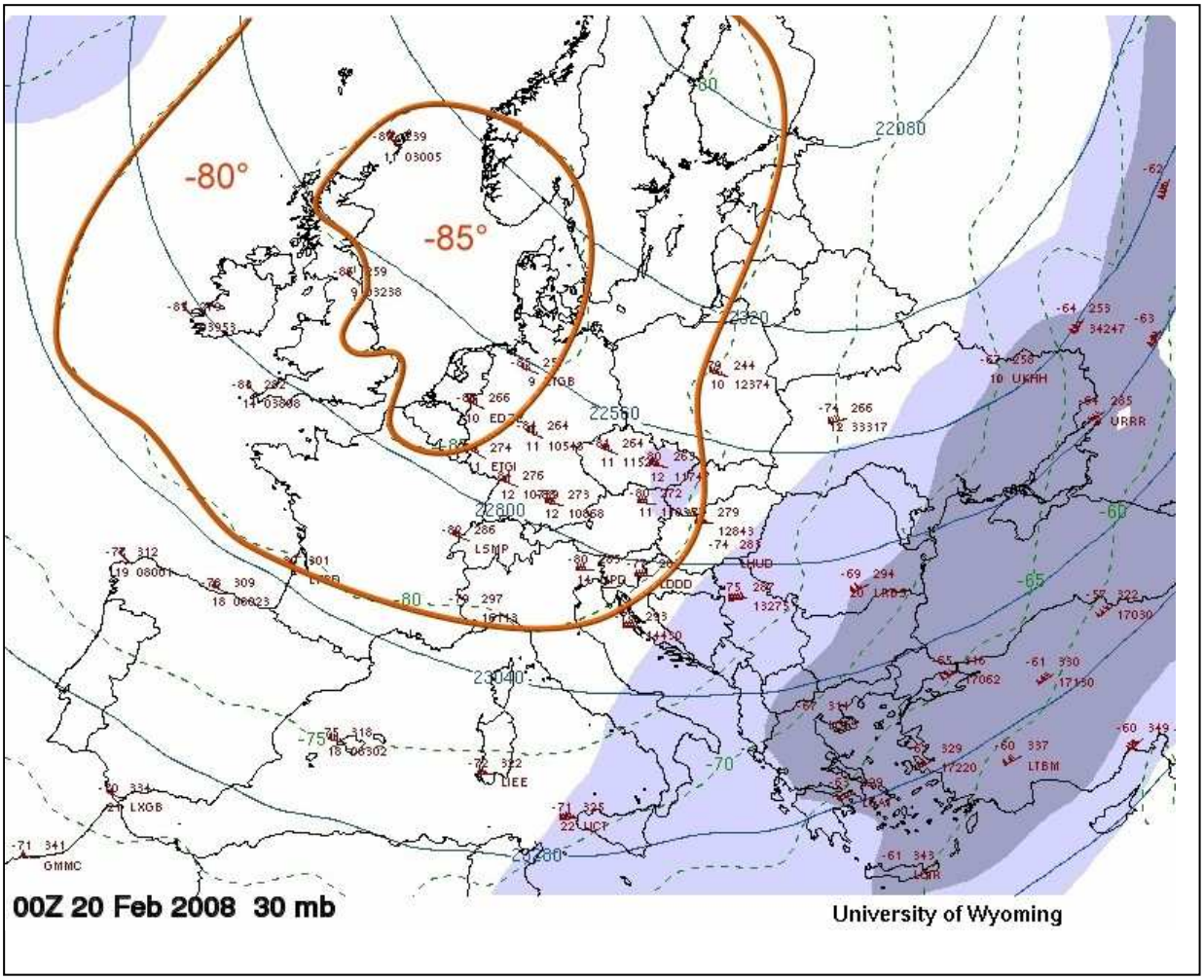
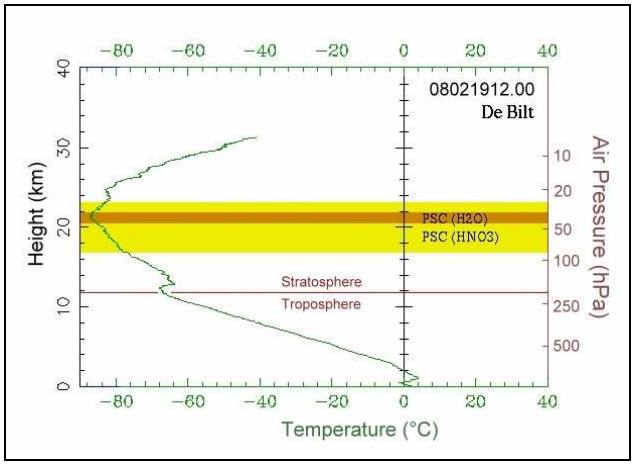


Figure 8. Stratospheric temperatures at the 30 hPa level and surface air pressure at 20 February 2008, 0000 UTC. (Source: University of Wyoming.)

The identification of the phenomena in terms of PSCs is supported by the fact that extremely low stratospheric temperatures and high surface pressures were measured over the areas from where the reports came from (Figures 2 and 8). The vertical sounding in the Netherlands of 19 February 2008 shows that the temperature in the lower stratosphere, instead of being isothermal, decreased with height with a lapse rate of no less than 3 °C/km. This decrease in temperature starts just above the tropopause, which is in accordance with the cooling mechanism outlined above. The sounding yields a 36-hPa (21.6 km) temperature of -87.2 °C (Figure 9), which is the lowest stratospheric temperature on record since the start of De Bilt observations in 1945 (KNMI Nieuws, 2008) (Figure 10). This low temperature allows even for the formation of Type-II PSCs, hence PSCs consisting of pure water. Figure 11 shows that the area of extremely low stratospheric temperatures coincides with the area from where the twilight phenomena and the high-level iridescent clouds were observed. We conclude that the extraordinary twilights over Central and Western Europe of February 2008 have been caused by the formation of an exceptionally large field of NH PSCs at an unusual place.



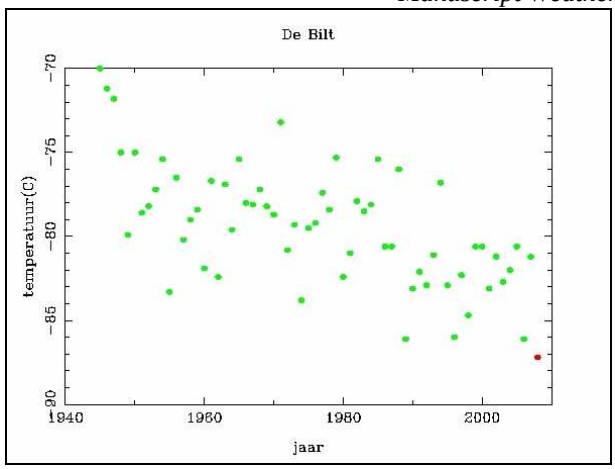


Figure 9 (left). Vertical temperature sounding of 19 February 2008, 1200 UTC from De Bilt, the Netherlands. The regions of possible PSC formation have been added. (Courtesy of M. Allaart, KNMI De Bilt.)
Figure 10 (right). Annual lowest temperatures in the stratosphere over De Bilt, the Netherlands. The red dot is the temperature of 19 February 2008. (Source: KNMI De Bilt.)

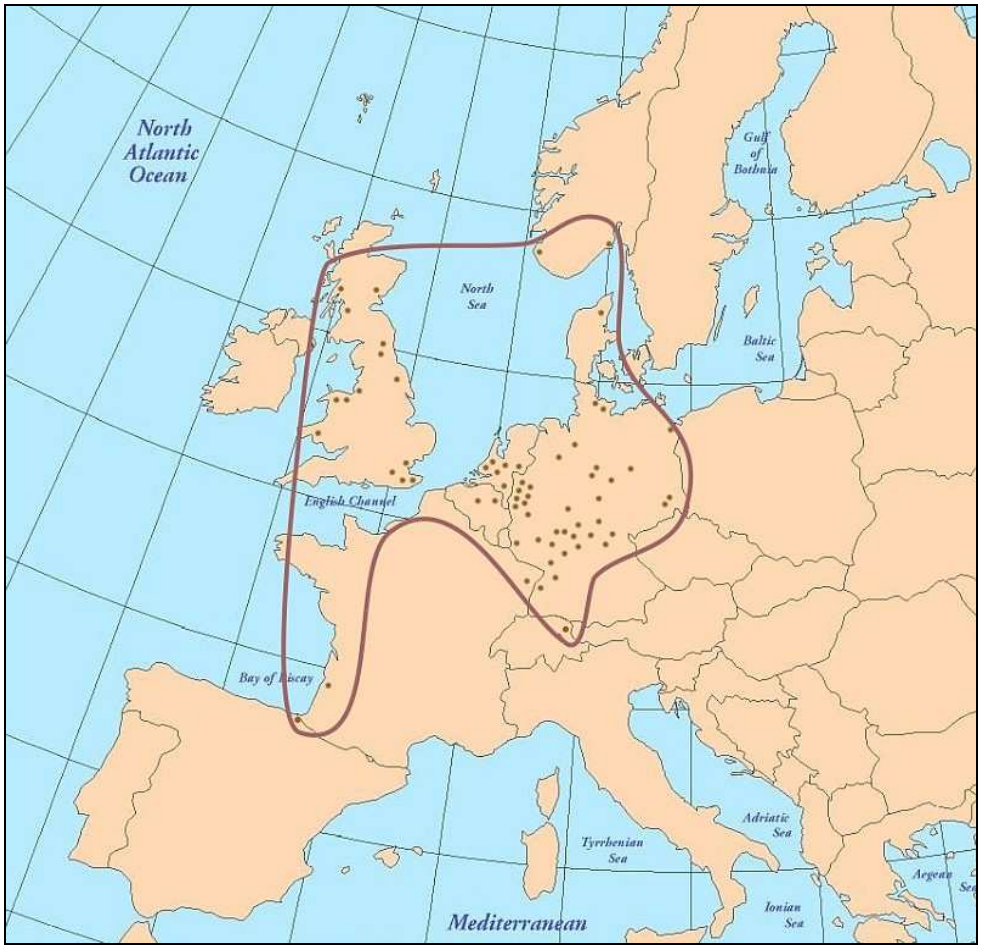


Figure 11. Shape of the PSC field as inferred from the location of the observers and the area from where twilight phenomena have been reported.

Acknowledgements

We thank the Meteorological Observatory Hohenpeissenberg, Germany and Alfred- Wegener-Institute for Polar and Oceanic Re search Potsdam, Germany for providing atmospheric measurements as well as Peter Siegmund, Toon Moene and Marc Allaart (all from KNMI) and Sirko Molau for general help.

References

53 observations were collected from the following web forums and sites:
Forums of the Arbeitskreis Meteore e.V.: http://www.meteoros.de/forum.htm
(Germany: P. Krämer, Bochum, R. Nitze , Barsinghausen, C. Gerber, Heidelberg, R. Manig, Neuhaus/Thüringen, H. Schremmer, Niederkrüchten, P. Kuklok, Frankfurt/Main, J. Vollmer, Hannover; UK: S. Boyle, Newchapel; The Netherlands: F. Nieuwenhuys, Den Haag)
Wetterzentrale forum: http://www.wzforum.de/forum2/
Meteored.com Forum: http://foro.meteored.com
Spaceweather.com: http://spaceweather.com
Atmospheric Optics, Today's feature: Incredible Twilights http://www.atoptics.co.uk

Climate Prediction Center (2008)
http://www.cpc.ncep.noaa.gov/products/stratosphere/temperature/

Hinz C. and Bardenhagen H. (2000) Perlmutterwolken in Deutschland beobachtet? *Meteoros*, **3**, pp 35-36

KNMI Nieuws (2008) "Kouderecord op grote hoogten boven DeBilt"
http://www.knmi.nl/VinkCMS/news_detail.jsp?id=40635

Meinel, A. and Meinel, M. (1983) *Sunsets, twilights, and evening skies*, Cambridge University Press, ISBN 0 521 25220 2

Volcano World Eruptions (2008)**:** http://volcanoworld.wordpress.com
Public outreach project of the North Dakota and Oregon Space Grant Consortia administered by the Department of Geosciences at Oregon State University