‘Missing’ polar lows enhance deep-water formation in the Nordic Seas

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The atmosphere plays a key role in forcing the large-scale ocean circulation by moderating the formation of deep water in the sub-polar North Atlantic. Every year thousands of intense storms – polar lows and polar mesoscale cyclones - cross this climatically sensitive region of ocean that are either too small, or short-lived, to be captured in meteorological reanalyses or numerical models. Here we show that by parameterizing ‘missing’ polar lows we are able to reproduce the high wind speeds and heat fluxes associated with individual storms, as well as their integrated effects on the ocean, in remarkable agreement with observations. In a high resolution ocean circulation model our realistic atmospheric forcing increases the depth, frequency and area of deep convection in the Greenland, Norwegian, Iceland and Irminger Seas, and results in an unexpectedly large increase in the volume of deep water overflowing Denmark Strait (by up to 0.5 Sv). We conclude that polar lows play an important role in driving the large-scale ocean circulation and so must be accounted for in models in order to accurately predict near-future climate. Recent studies predict a decrease in the number of polar lows over the Northeast Atlantic in the 21st Century which, based on our work, implies a reduction in deep convection and a potential weakening of the Atlantic Meridional Overturning Circulation.

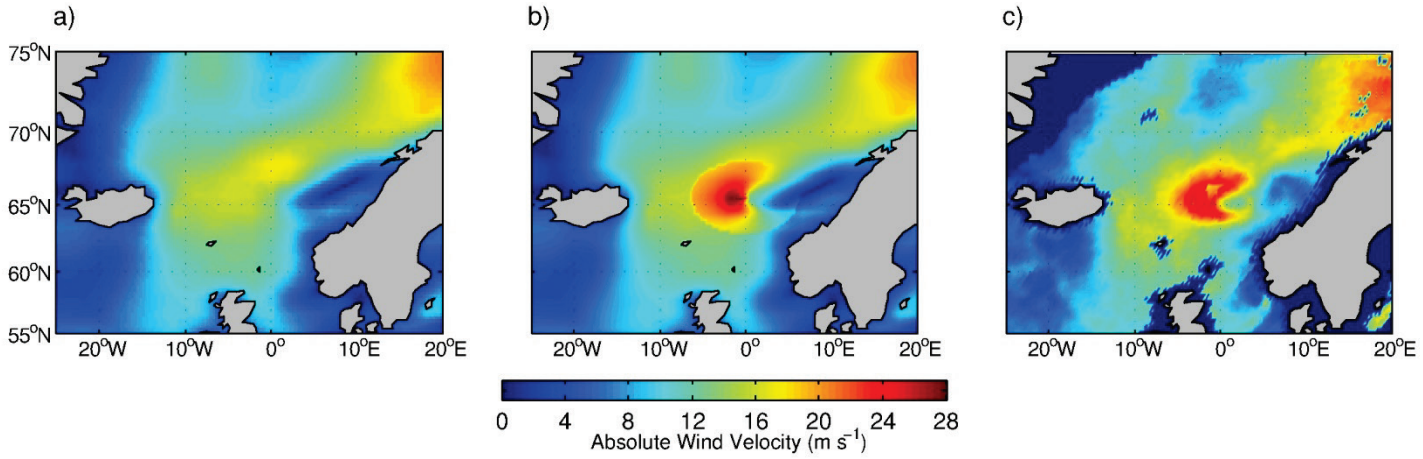

Fig. 1 An illustration of the polar low parameterization. Panels show the wind speed at 06:00 UTC 15 October 1993 for: **a)** Standard ERA-40 data; **b)** ERA-40 with a polar low parameterized; and **c)** satellite data (morning pass) from Special Sensor Microwave/Imager (SSM/I) satellite data, NASA Pathfinder Mission (www.remss.com). The satellite data reveal a polar low over the Norwegian Sea with a diameter of ~400 km. The standard ERA-40 reanalysis do not capture the structure or magnitude of the wind field of this vortex. Parameterizing the vortex produces a considerably more accurate wind field.

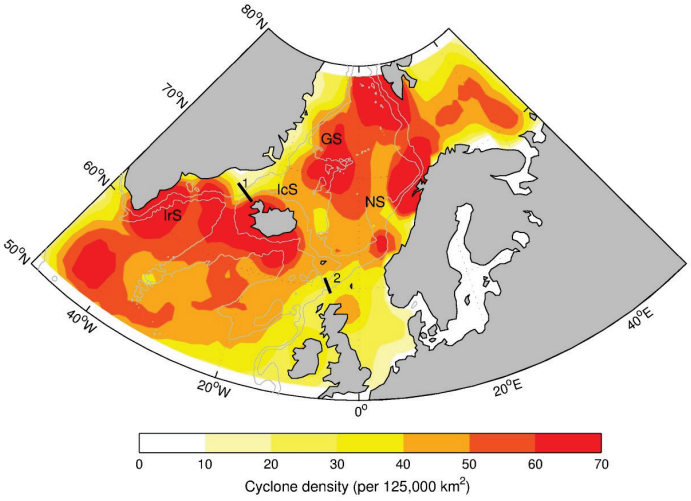

Fig. 2 The annual mean density of polar lows. Annual mean cyclone density from 1978 to 1998 over the North East Atlantic Ocean (per 125,000 km^2; colour shading). The pattern is in good agreement with a satellite-determined dataset ($r = 0.75$, $p<0.1$) and existing polar low distributions using different identification techniques[4-6,16], showing quantitatively similar features within the Irminger Sea, the lee of Greenland, south of Iceland, and in the central Norwegian and Greenland Seas. Bathymetry is drawn at 500 m and 2000 m depths (grey contour lines). The location of the Greenland (GS), Norwegian (NS), Iceland (IcS) and Irminger (IrS) Seas are marked. The sections used to calculate the volume of deep water overflowing the Greenland-Iceland-Scotland ridge are marked: (1) Denmark Strait Overflow Water (DSOW) and (2) Faroe-Shetland Channel (FSC).