

Response to comments on: Atmosphere-interactions in the Greenland Sea during Solar Cycles 23-24, 2002-2011 – P E Binns

Point 1: Fig. 3 and Section 3.3, which describe mean Sea Surface Temperatures (SST), do not form part of the argument of an association with solar activity. As the section heading makes clear, this is background information only.

Point 2a: The physical significance of the day-to day variability of the SST field is explained, (Section 6 Attribution).

Point 2b: Association with the solar low (Figs. 5a & b). The argument for an association between variability and solar activity is not based on these figures. They are intended only to give an overview of the data and show that further investigation is merited:-

Figure 5a: Indeed, the size of the difference is important. However, it does not seem unreasonably small when set against the seasonal differences (right column); winter values are 14-30% higher than summer values. These seasonal values have a clear physical basis in the increased number of weather systems (Section 6). The annual mean variability during the three years of the solar low (bottom line) are 10-22% lower than other years; the three years with the lowest variability coincide perfectly with the solar low (Section 6).

Figure 5b: There is a seasonal ‘overprint’ in variability and indeed, at first sight, the difference appears subtle. However, as pointed out in the caption, there is a very distinct decreasing variability trend in the winter and summer extremes. This is particularly interesting as it parallels the solar trend down into the solar low. A plot of 11-point running mean variability is attached. Overall the two variables do not correlate. However, there is a distinct variability “trough”, which coincides almost perfectly with the extreme solar low (see also Point 3a (ii)).

These observations suggest further investigation is merited. The referee states that “*these changes have not been shown to depart from chance*”. This is not true; the significance of the changes have been investigated in detail (Point 3 below).

Point 3a (i) Running mean: See comment on Fig. 5b above.

Point 3a (ii) Significance testing: As the basic data unit is day-to-day variability with >3000 data points, the best way to test for statistical significance is: (a) to use this parameter and (b) to test for a difference between two populations, rather than to use a correlation. A correlation will give a false negative if there is a genuine difference, which is introduced suddenly by some “trigger mechanism”.

If, as the referee asserts, the difference found is due to chance, then the main test runs should return a result similar to the ten control runs. However, both T-test and the Kolmogorov-Smirnov test return significance at the 95% level. The difference in the means is indeed 10% lower but, again, the size of the effect is not small in the context of the seasonal variations (see above).

Point 3b: Practical/physical significance: This result, taken together with the link with weather systems (Section 6) has considerable “*practical significance*”; it implies a degree of predictability of use to anyone with a long term operation in the area.

Point 3c (i): The reviewer states that the forms of the SST fields over the solar low are “*somewhat different*”. They are radically different ($\sim 2^\circ$ C) and the difference is in the key area of intersection of Polar and Atlantic waters.

Point 3c (ii): The close association of cluster symmetry with the solar low (Fig. 8) would be a considerable coincidence. The clustering would change if the Cut-off Distance was changed, for example, light blue and green would combine but symmetry would be maintained. Of course, there will always be some “Cut-off Distance” at which symmetry will be lost, but once symmetry is found the point is made.

Point 3c (iii): I do not agree that an “*association based on a single cycle would not be very persuasive*”. This may be true (as in the past) if the solar minimum is short and more active, and if there is only monthly or annual data; in that case, indeed, there will not be enough data to assess significance. In this unusual

situation of a long solar low, with >3000 daily data points, there is more than enough data to test significance between the solar low and the other periods.

Significance - to summarise: Three independent and convincing features in the data each indicate an association between the day-to-day variability of the SST field and the solar low. Taken together they make a very strong case. It would be a considerable coincidence if all three were “*chance*” or “*natural variability*”.

Final Paragraph: The paper does provide a plausible mechanism for the association. There is a substantial amount of data in the paper relating SST variability to weather systems (Section 6.2) and the association is consistent with work associating Greenland Sea climate with the NAO (Section 6.1). Section 7 summarises substantial recent work describing evidence for the influence of solar activity on surface climate. The link to solar is credible.