8.2 USING HIGH TEMPORAL RESOLUTION WIND DATA TO EXPLAIN INTERANNUAL VARIATIONS IN WINTER ICE EXTENT WEST OF THE ANTARCTIC PENINSULA

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1. INTRODUCTION

There is increasing evidence that winter ice extent (IE) west of the Antarctic Peninsula (see Fig. 1 in paper J3.1) can be greatly altered by meridional (north-south) winds over periods lasting up to a few weeks (Ackley and Keliher, 1976; Stammerjohn et al., 2003; Turner et al., 2003). Harangozo (2004) demonstrated short-lived ice retreats are as important as advances in explaining the winter maximum IE in most Antarctic regions. In contrast, systematic studies of atmospheric circulation impacts on interannual variations in winter IE (Enomoto and Ohmura, 1990; Godfred-Spenning and Simmonds, 1996) have given mixed results.

This paper reports results of a statistical analysis of the relationship of late winter (August) IE (around the time of the maximum) to meridional winds near the west Antarctic Peninsula coast (70 °W) where IE strongly modulates winter (JJA) temperatures (Harangozo, 2000). It also uses a seasonal ice motion dataset to look at how winds influence ice motion on seasonal timescales.

2. METHOD

The ice edge position (30% ice concentration) at 70 °W on each day in the austral winter (May-September) during 1979-2001 has been extracted from satellite passive microwave data and is used as a proxy for Antarctic IE. Following Harangozo (2000), these data are used to calculate a late winter 'baseline' IE. This is the low pass filtered monthly average ice edge position for August obtained using a 1-2-1 binomial filter. The baseline IE for each winter is correlated with winter (May-August) daily averaged 10 m meridional (*V*) wind component at the ice edge taken from the European Centre for Medium Range Forecasting (ECMWF) 40 year reanalyses.

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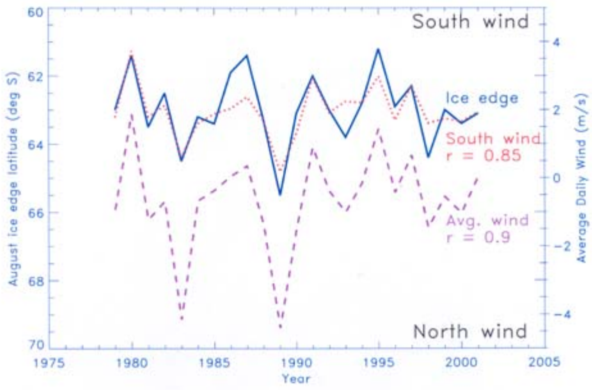

Figure 1. Time series of August ice edge position (solid line) at 70° W, the winter daily average 10 m meridional wind (dash) at the ice edge and the average southerly wind on days with such winds.

The winter daily average 10 m meridional wind component at the ice edge has been obtained for each winter during 1979-2001. Similarly, averages of southerly and northerly winds across all days with such winds have also been calculated. Renwick (2004) noted the daily sea level pressure fields from ERA-40 closely agree with those of the National Center for Environmental Prediction (NCEP). Weekly ice edge advance and retreat data (Harangozo, 2004) have also been used in a composite analysis to determine how the atmospheric circulation is associated with sub-monthly ice extent changes.

3. MERIDIONAL WIND IMPACT ON LATE WINTER ICE EXTENT

The late winter baseline IE at 70° W (and other nearby locations) is very strongly correlated (r = 0.9) with the winter daily average meridional wind at the ice edge (Fig. 1). The correlation for the daily average southerly wind (over all days with south winds) is only slightly weaker (r=0.85). These results indicate winter IE is primarily controlled by the atmospheric circulation. This is consistent with a previous study (Harangozo, 2004) that showed IE at the start of winter has little or no influence on the maximum extent.

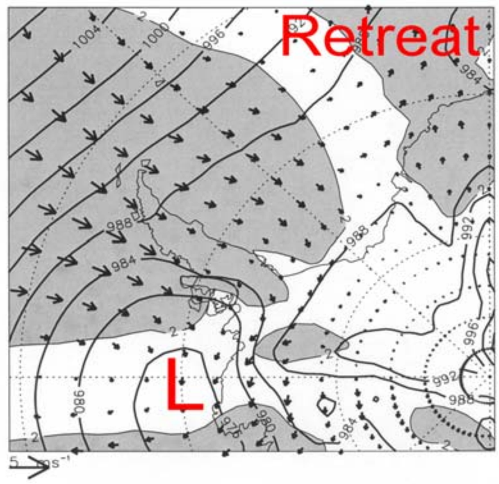

Figure 2. Composite mean SLP and anomalous 10 m winds during weeks of ice retreat at 70° W. Shading indicates meridional wind is statistically different from the mean at less than the 5% level.

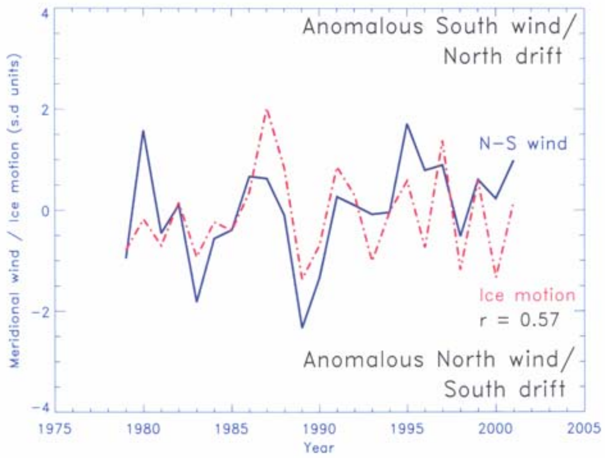

Figure 3. Time series of anomalous winter daily average 10 m meridional wind (solid) and ice motion (both in standard deviations) in the main pack at 67° S, 70° W.

Southerly winds would support IE increases both through in-situ formation at the ice edge and northward ice drift. But the fact that IE most strongly correlates with daily average winds across all days rather than just southerlies indicates northerly winds must also impinge on ice extent.

Strong winter IE - meridional wind correlations have been reported for a sub-Arctic region, again using daily winds (Kimura and Wakatsuchi, 1999). The results are also consistent with case studies of submonthly ice advance and retreats west of the Antarctic Peninsula (Ackley and Keliher, 1976; Allison, 1989; Stammerjohn et al., 2003; Turner et al., 2003; Massom, pers comm). Harangozo (1997) also showed average southerly winds in a winter of above-normal IE reversed to northerlies in a case of below-normal IE. Other less conclusive Antarctic studies have used different diagnostics. Godfred-Spenning and Simmonds (1996), for example, used cyclone densities that do not take into account geostrophic wind strength.

4. WINTER ICE RETREAT AND ADVANCE

Harangozo (1997, 2004) found ice retreat in winter is as important as advance in determining late winter IE in the Antarctic. He showed extensive winter ice fails to occur in most of the Antarctic when winter retreat is above-average. During winter weekly retreats at 70 °W a cyclonic circulation occurs on average west of the Antarctic Peninsula (Fig. 2). Northerly winds occur in 92% of cases. Warm air advection may contribute to melting but ice dynamics could also be important in retreats that give rise to low winter IE in some years (Harangozo, 1997).

During weekly advances (not shown) an average anticyclonic circulation dominates the study area. Anticyclonic 10 m wind anomalies also occur. Therefore no simple relationship exists between cyclonic activity and IE changes. Stammerjohn et al. (2003) found similar circulation patterns in advances and retreats west of the Antarctic Peninsula in one winter.

5. ICE DYNAMICS

Several case studies (Stammerjohn et al. 2003; Turner et al. 2003; King, pers comm. Massom, pers comm) have suggested wind-induced ice drift contributes greatly to winter ice advances and retreats in the study area. If this is generally the case the strong IE-wind correlations noted above suggest winters of low IE should have very weak net northward ice drift or southward drift and vice-versa when ice is more extensive.

Seasonal average ice motion fields (from National Snow and Ice Data Center) derived by tracking 'features' in the 85GHz channel of daily satellite passive microwave data (Fowler, 2003) confirm the ice pack drifted south at 67° S, 70° W in winters of low IE (Fig. 3) when northerly winds are strong (Fig. 1). Examples are 1983 and 1989. Examples of anomalous (and actual) northward drift occurring on average over winter include 1987 and 1997, winters when ice became extensive. Ice dynamics are thus crucial to explaining interannual variations in winter IE.

6. CONCLUSIONS

Evidence has been found that interannual variations in winter ice extent around the west Antarctic Peninsula are strongly controlled by the atmospheric circulation. The main findings are:

- High temporal resolution wind data show winter ice extent very strongly correlates with meridional winds, the correlations being the strongest ever reported in both the Antarctic and Arctic
- Northerly winds dominate retreats and extensive ice fails to occur when winter retreat is above-average
- The strong correlations appear to be partly due to the alignment of the Antarctic Peninsula that constrains ice motion to a north-south direction, correlations being weaker in other Antarctic regions
- Wind-induced ice drift contributes greatly to winter ice extent

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