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On the Interannual Variability of Ice Conditions in the Vicinity of Cabot Strait

by

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ABSTRACT

The mean and interannual variability in the time of first ice, the time of last ice and ice duration at three locations in the vicinity of Cabot Strait are described. The sites are located in western Cabot Strait, off Scatari Island in eastern Cape Breton Island and off southern Newfoundland. Ice is normally present in this region during February to April with the ice lasting longest at the Cabot Strait site. In recent years, the ice has generally appeared earlier and left later than average at all three locations. Similar ice conditions to those in the 1990s had been seen in the early 1970s but contrast with the light ice years in the early 1980s. The relationship of air temperature and wind stress to ice conditions are also discussed.

RÉSUMÉ

L'étude décrit les variabilités moyenne et interannuelle de la date des premières glaces, de la date des dernières glaces et de la durée des glaces à trois emplacements au voisinage du détroit de Cabot. Les emplacements sont situés dans la partie ouest du détroit de Cabot, au large de l'île Scatarie à l'est de l'île du Cap-Breton et au large des côtes sud de Terre-Neuve. Les glaces sont normalement présentes dans ces régions de février à avril et leur durée est la plus longue à l'emplacement du détroit de Cabot. Au cours des dernières années, les glaces sont apparues plus tôt que la moyenne aux trois emplacements. Des conditions similaires à celles qui ont été observées dans les années 1990 avaient déjà été observées dans les années 1970, mais elles contrastent avec les glaces peu abondantes observées dans les années 1980. Une analyse de la relation entre la température de l'air et la tension du vent d'une part et l'état des glaces d'autre part est également présentée.

INTRODUCTION

One important environmental variable during the winter in the Laurentian Channel at Cabot Strait and on the eastern Scotian Shelf is the presence (or absence) of ice. Most of this ice is thought to originate in the Gulf of St. Lawrence or in the inshore areas of Sydney Bight and is advected southward towards the eastern Scotian Shelf. In certain years, such as 1992 and 1993, the ice on the Scotian Shelf is advected by the residual surface currents and pushed by the winds southwestward along the coast of Nova Scotia as far as Halifax and beyond. In these years of heavy ice concentrations and large areal extent, near surface waters in spring tend to be colder and fresher than normal.

Information on the location and concentration of sea ice is available from Ice Central in Ottawa in the form of daily ice charts. Within the last year these charts have been available in digitized format. One chart covers the Gulf of St. Lawrence and the Scotian Shelf. The time series of the position of the ice edge through the year have been described as part of the environmental overviews to FOS (Drinkwater 1993, 1994). Conditions are compared to the long-term (1962-87) median, maximum and minimum composite locations of the ice edge as presented by Coté (1989). In addition to publishing the charts, the Ice Climatology and Applications Division of Environment Canada undertakes an annual analysis of the ice conditions off the east coast of Canada from southern Labrador to the Scotian Shelf in the form of the time of onset, retreat, and duration of ice at 24 grid sites, three of which are in the vicinity of the Cabot Strait. In this paper we discuss the interannual ice conditions at these three grid points, investigate the role of air temperature and wind stresses in controlling ice conditions and then discuss some future ice climate studies.

DATA AND METHODS

Of the 24 grid points covering eastern Canada at which the first presence of sea ice, the last presence of sea ice and the duration of sea ice are available, 6 lay within the Gulf of St. Lawrence and 3 are located to the east of the Gulf (Fig. 1). Of these latter three, one is in Cabot Strait (G33), one is off southern Newfoundland (G35) and one is off Scatari Island near the eastern tip of Cape Breton Island (G87). The data begin in the 1971/72 ice season at G33, 1959/60 at G35 and 1970/71 at G87. The 1971/72 ice season refers to December of 1971 and the first three to five months of 1972. Note that the ice duration is not necessarily the difference between the times of first and last ice as it may disappear intermittently from a region.

Standard correlation analysis was performed between time series of ice conditions at the different grid points. Linear and multivariate regression analysis was performed between the ice records and the monthly mean air temperatures and wind stresses. Air temperature records were obtained from Sable Island on the Scotian Shelf and geostrophic wind stress data (up to 1991) from a grid point near Cabot Strait (Drinkwater and Pettipas, 1993). Tests for significance levels of correlation coefficients were adjusted for autocorrelation.

RESULTS

Ice has been present in western Cabot Strait in each of the 22 years when data have been collected, in all but one of the 23 years of data off Scatari (1983) but in only 18 of the 34 years off southern Newfoundland. In those years when ice was present, it typically lasted 10.7 weeks on the south side of Cabot Strait, 7.5 weeks off Scatari Island and 3.4 weeks off southern Newfoundland (Fig. 2). This compares to 11-12 weeks in most of the Gulf of St. Lawrence and 16 weeks in the Strait of Belle Isle. In the Strait of Belle Isle, ice from off the Labrador Shelf is advected into the Gulf which increases the duration

there. The standard deviations of the ice duration at the three sites near Cabot Strait are approximately 3 weeks.

In Cabot Strait, ice first appears near the end of January but has been seen as early as 4 January and as late as March 19 (day 78; Fig. 3). Off Scatari Island, the ice first appears on average one week later than in Cabot Strait. Only one year (1987) did the ice appear at Scatari before being spotted in Cabot Strait. This could have resulted from the advection of ice to site G87 from either Sydney Bight or the western side of Cabot Strait. Another possibility, albeit a more unlikely scenario, is that the ice at G87 in 1987 had formed locally. Ice off southern Newfoundland, in years when it is present, generally first appears around the end of February but has arrived as early as January 22 and as late as March 27 (day 86). The time of onset of ice occurs closer to the same date each year off Scatari than at the other sites as indicated by significantly smaller standard deviation (s.d. of 11 d for G87; 14.6 d for G33; and 18.5 d for G35).

Sea ice normally disappears first off southern Newfoundland (average March 30, day 89), then off Scatari (April 5, day 95) and finally from Cabot Strait (April 17, day 107)(Fig. 4). However, there are years when the date of the last appearance of sea ice at G87 occurred prior to G35 (1990) or after G33 (1978). At all three sites ice has on occasion survived until early (G87) to mid-May (G33, G35). There is greater variability in the date of the retreat of ice off Scatari than the other 2 sites (s.d. of 24.5 d for G87; 16.5 d for G33; and 21.9 d for G35).

Correlations show that the ice duration at each site is significantly related to the time of retreat. Duration is also related to the time of onset except at Scatari where the time of first ice was less variable (Table 1). There was no significant correlation between the times of first and last ice. Ice conditions off Scatari were highly correlated with those in Cabot Strait (Table 2). Neither of these sites were correlated with ice conditions at G35 off southern Newfoundland.

The trends in sea ice duration at G33 and G87 show a general decrease from the early 1970s to the early to mid-1980s followed by a general increase (Fig. 2). Similar trends are evident in the time of last ice (Fig. 4) and to a lesser degree in the time of first ice (Fig. 3). During the years since 1990, ice conditions have been near extreme with relatively early arrival, late departure and subsequently longer-than-normal duration at all three sites. Ice has been observed off southern Newfoundland for the past 4 years which is only the second time in 34 years that it has been seen in 4 consecutive years. Ice durations, similar to those observed recently, had been observed previously, noteably during the early to mid-1970s.

EFFECTS OF TEMPERATURE AND WINDS

The relationship of ice conditions to monthly means of air temperature and wind were explored using correlation and regression analysis. Sable Island air temperatures were used. Previous investigations had shown that the first mode of an EOF (empirical orthogonal function) analysis of long-term air temperatures (1950-1991) throughout the Atlantic provinces (including Sable Island) accounted for over 70% of the variance (unpublished data). Thus, the Sable Island measurements are considered reasonably representative of air temperatures over the region.

Temperatures in December of the previous year and in January were compared to the time of first ice together with winds during January. For the comparison with the time of last ice, temperatures and winds in March and April were used. For ice duration we averaged temperatures and wind stresses for the period December of the previous year to April. The results of the correlation analysis are listed in Table 3.

They suggest that ice conditions at the Cabot Strait site are strongly dependent upon air temperatures. Ice duration and time of first ice are also affected by the strength of the northwest wind component. The time of last ice is not affected by wind. Colder temperatures result in early onset of ice, late retreat of ice and longer duration. Strong winds from the northwest hasten the onset of ice and increase the duration

of ice. Temperature is also a factor in determining ice conditions at G87 but not as important as at G33. Winds generally cannot explain much of the ice variances at G87. Correlations of ice at G35 were not significant for either temperature or wind and do not appear in Table 3. This is not surprising given that monthly averages of the winds and air temperatures were used and that in 10 out of 18 years when ice was present at G35, the duration was of 2 weeks or less.

For G33, multiple regressions were run for time of first ice and ice duration with air temperatures and northwest wind stresses as the independent variables. The results are listed in Table 4 and plotted in Fig. 5. For the time of first ice over 73% of the variance is accounted for by the December-January averaged air temperature and the January northwest wind stresses. For ice duration, the air temperatures and northwest wind stresses averaged from December to April account for 57.5% of the variance. The regression of time of last ice as a function of air temperatures in March and April, which accounts for 40% of the observed variance, is also presented.

FUTURE STUDIES

Further studies on ice conditions in the Cabot Strait area and on the eastern Scotian Shelf are planned. The ice charts for the Gulf of St. Lawrence have been digitized at one per week beginning in 1962. The offshore boundary extended to just east of Cabot Strait. As part of the AFAP-funded climate studies at BIO we have issued a contract to digitize the ice for the areas seaward of Cabot Strait including the Scotian Shelf. The data includes location of the ice edge boundaries plus the concentration and ice type on a grid approximately every 50 km. This will allow better spatial resolution of ice conditions than presently available. We will continue to investigate the relationships between meteorological forcing and the distribution and amount of ice. In addition, the possible influence of ice on the temperature and salinity conditions in the Cabot Strait and eastern Scotian Shelf regions will be explored.

Acknowledgements

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Table 1. Correlation coefficients between the onset of ice, the retreat of ice and ice duration at the grid points G33 (western Cabot Strait), G87 (off Scatari Island) and G35 (off southern Newfoundland).

Grid Point	Onset Ice Duration	Retreat Ice Duration	Onset Retreat
G33	-0.827*	0.734*	-0.387
G87	-0.396	0.849*	-0.087
G35	-0.669*	0.688*	-0.032

*Statistically significant at ρ=0.05 level.

Table 2. Correlation coefficients of ice conditions between grid points G33, G87 and G35.

Ice Series	G33 G87	G33 G35	G87 G35
Duration	0.802*	-0.280	0.044
Onset	0.729*	0.149	0.461
Retreat	0.698*	-0.064	0.019

*Statistically significant at ρ=0.05 level.

Table 3. Correlation coefficients of ice time series with Sable Island air temperatures and geostrophic wind stresses at a site in Cabot Strait.

Ice Data	Month	Environmental Data	G33	G87
First Ice	Jan.	Temp.	0.772*	0.584*
		NE Wind Stress	-0.282	-0.226
		NW Wind Stress	0.613*	0.239
Last Ice	Mar-Apr	Temp.	-0.630*	-0.498
		NE Wind Stress	0.144	0.134
		NW Wind Stress	-0.269	-0.249
Duration	Dec-Apr	Temp.	-0.690*	-0.561*
		NE Wind Stress	0.162	-0.253
		NW Wind Stress	-0.685*	-0.442

*Statistical significances considered to be at the 0.05 level.

Table 4. The results from the multiple regressions and linear regression of air temperatures and wind stresses on ice conditions at site G33 in western Cabot Strait.

Day of First Ice = $25.403 + 11.989 \times T_{(Dec/Jan)} + 73.992 \times \tau_{NW(Jan)}$
Accounts for 73.6% of the variance in the time of first ice.
Day of Last Ice = $134.371 + 13.420 \times T_{(Mar/Apr)}$
Accounts for 39.7% of the variance in the time of last ice.
Duration (weeks) = $10.916 - 2.168 \times T_{(Dec\text{-}Apr)} - 29.455 \times \tau_{NW(Dec\text{-}Apr)}$
Accounts for 57.7% of the variance in the ice duration.

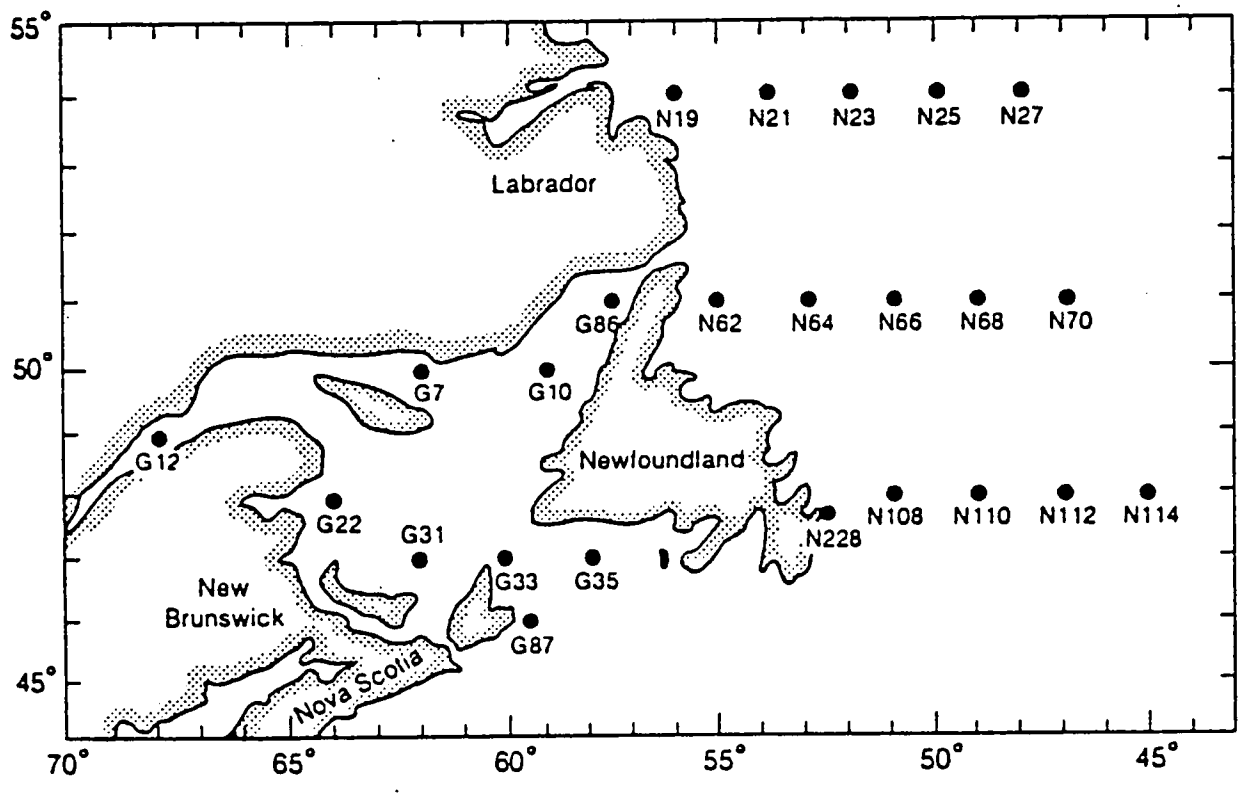

Fig. 1. The location of the 24 grid points at which ice statistics have been tabulated.

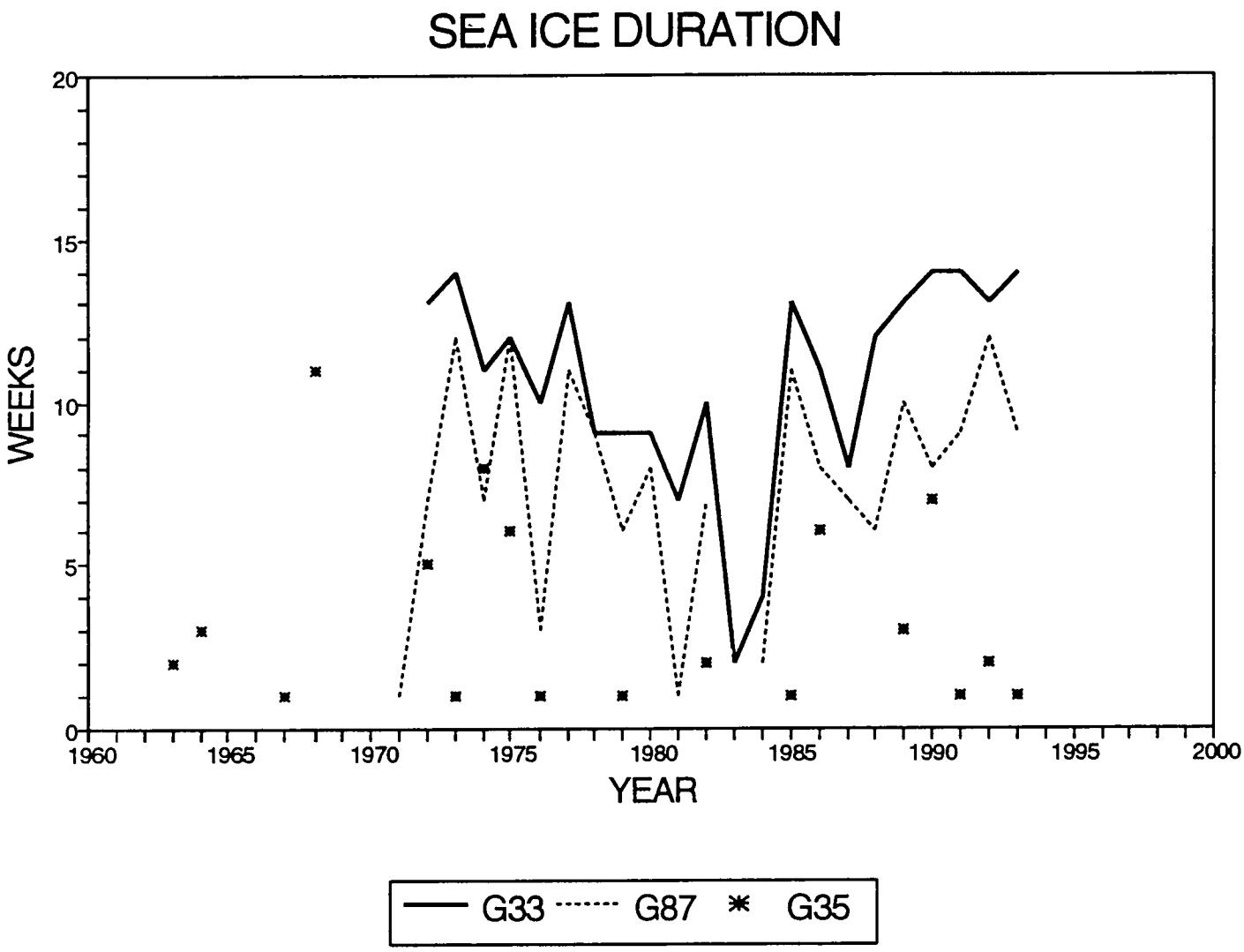

Fig. 2. The duration of ice measured in weeks.

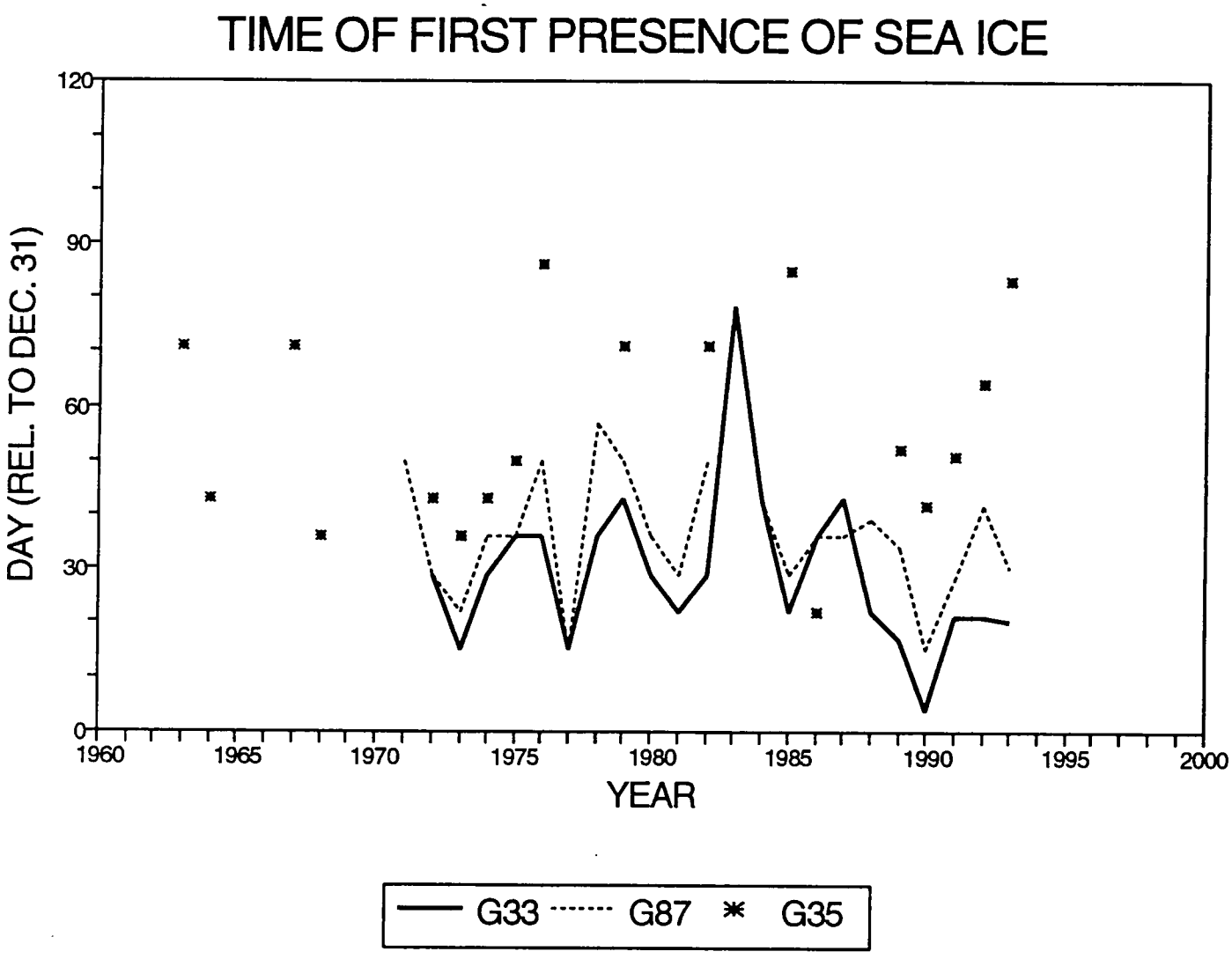

Fig. 3. The time of first presence of ice measured relative to Dec. 31.

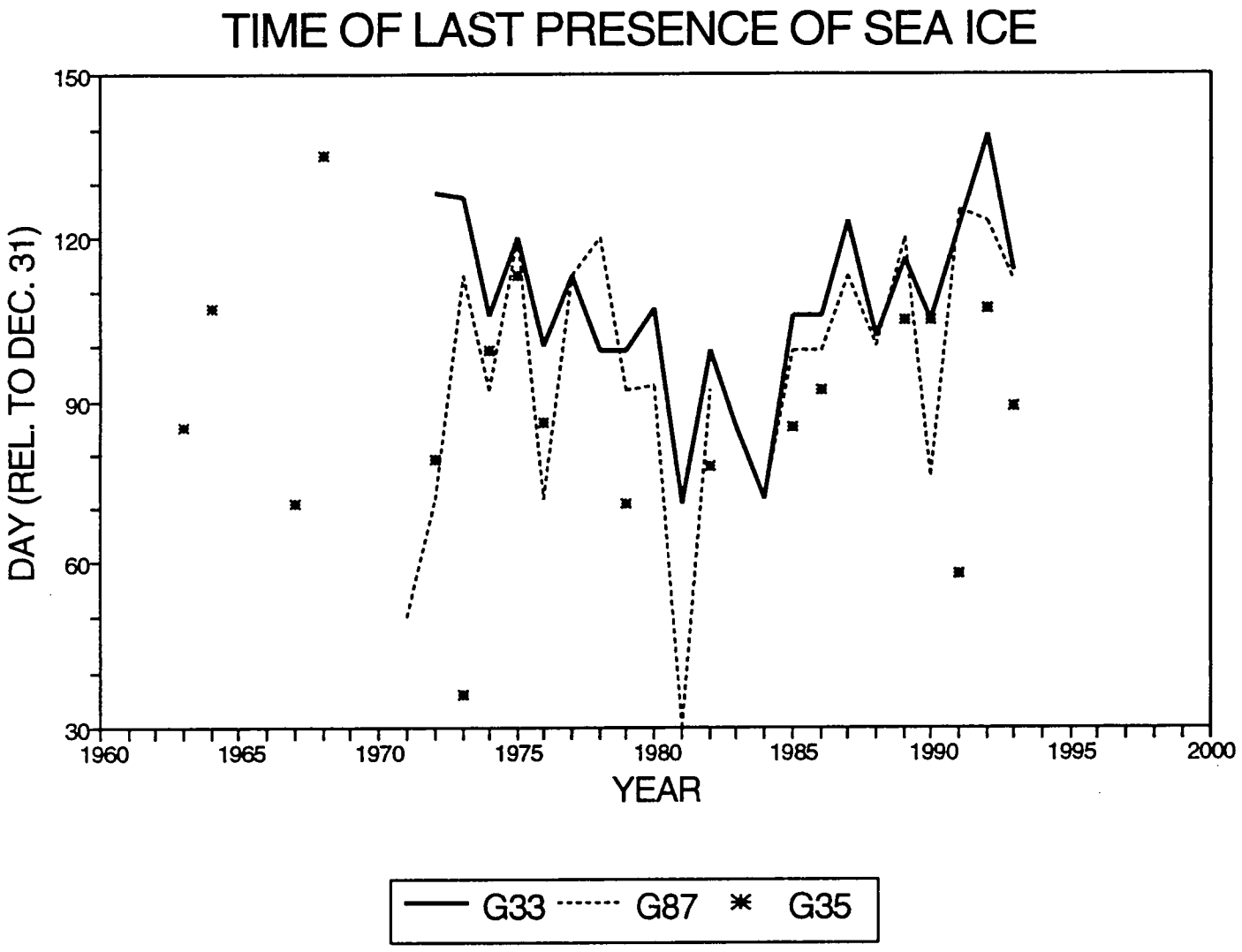

Fig. 4. The time of last presence of ice.

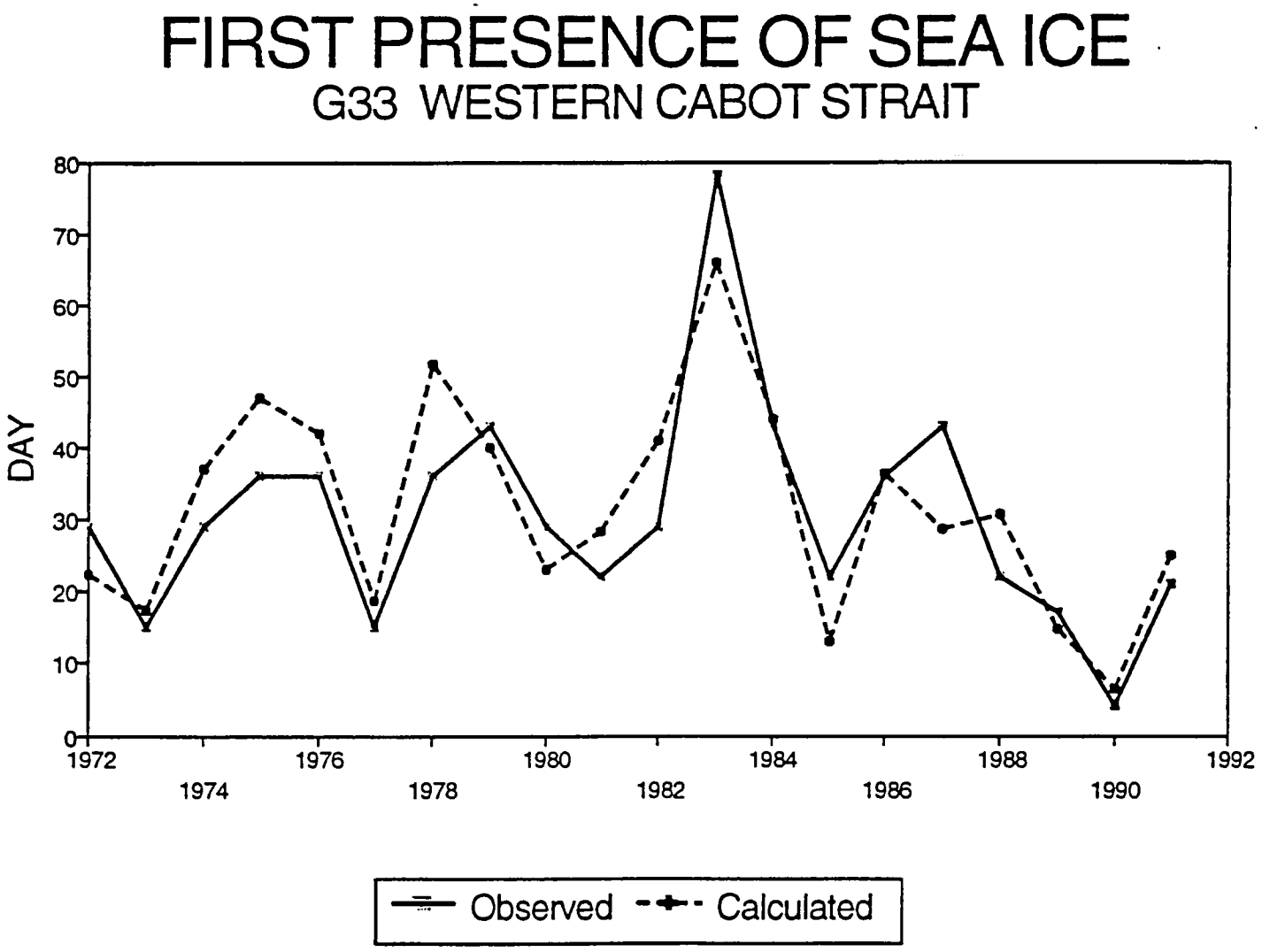

Fig. 5a. The observed and estimated first presence of ice at site G33 in western Cabot Strait based upon regressions with air temperatures and wind stresses (see Table 4).

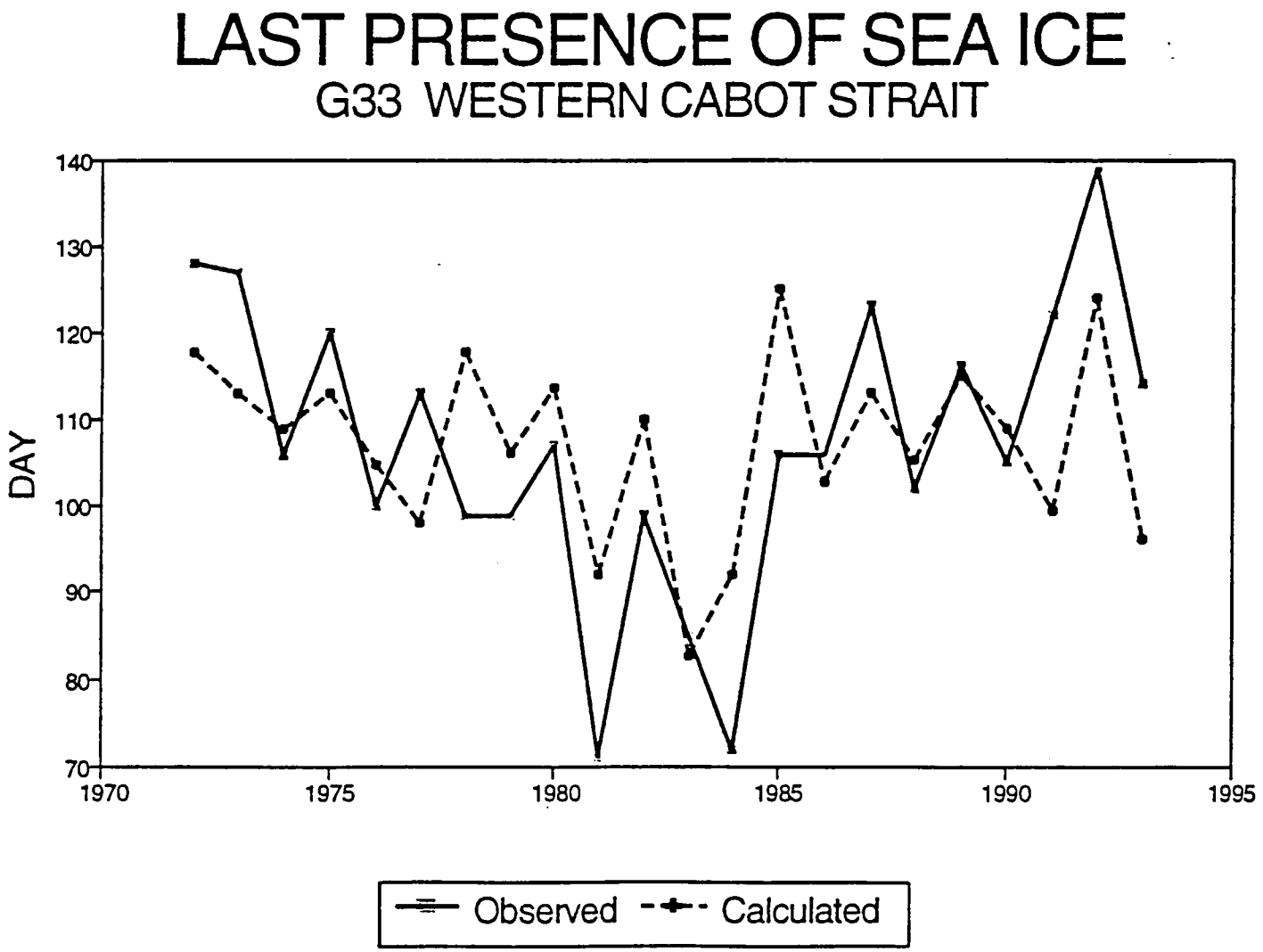

Fig. 5b. The observed and estimated last presence of ice at site G33 in western Cabot Strait based upon a regression with air temperatures (see Table 4).

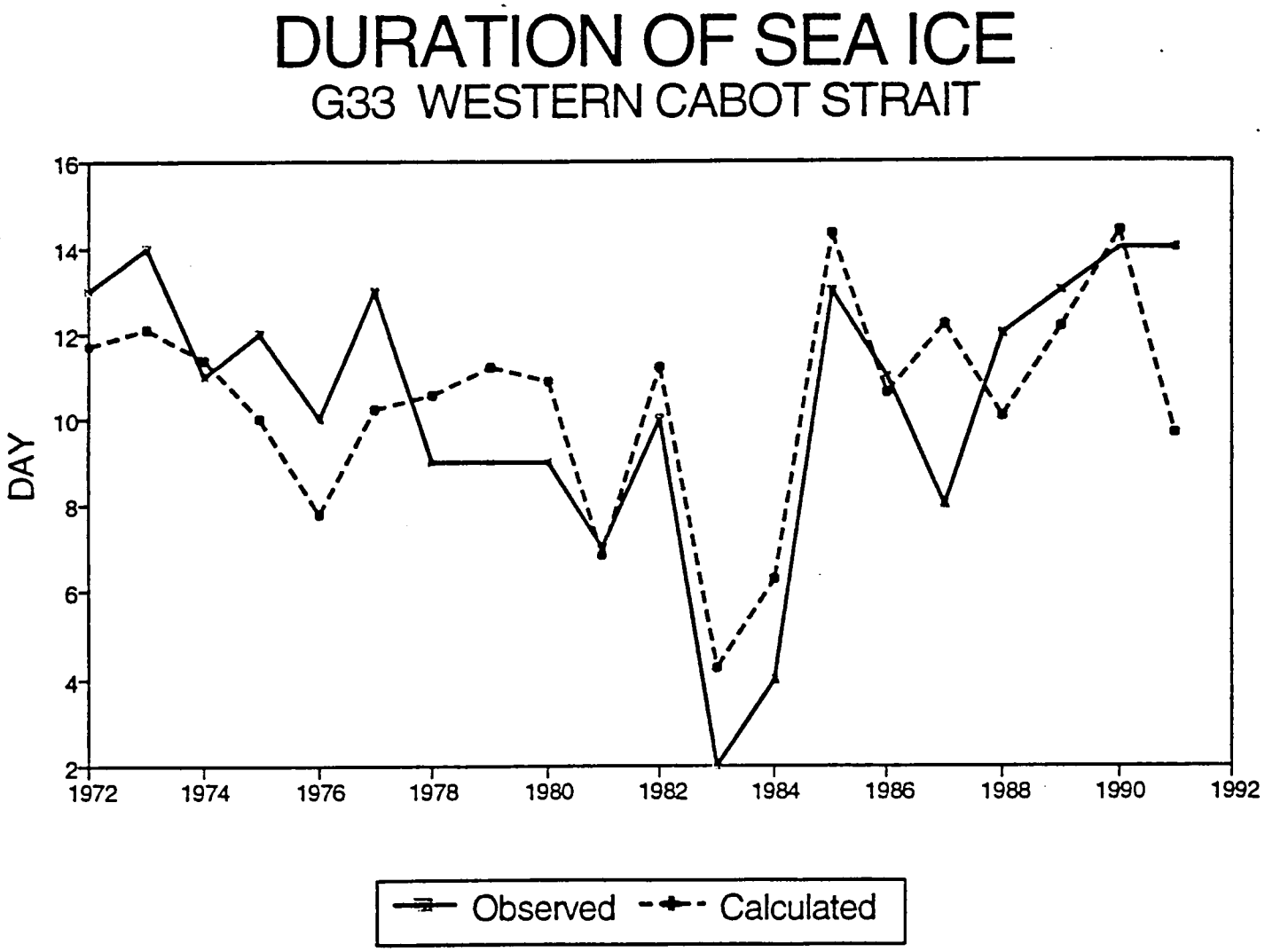

Fig. 5c. The observed and estimated duration of ice at site G33 in western Cabot Strait based upon regressions with air temperatures and wind stresses (see Table 4).