Sea Ice: Trends?

Rick Bradford, 31/12/19

1. Data Source

Data was taken from the US National Snow & Ice Data Center (NSIDC), which is within the US National Oceanic and Atmospheric Administration (NOAA). The correct citation is,

- Fetterer, F., K. Knowles, W. N. Meier, M. Savoie, and A. K. Windnagel. 2017, updated daily. *Sea Ice Index, Version 3*. [Subsets North and South]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5K072F8. [Date Accessed: 30/12/19]

I accessed the data from this link. These datasets provide monthly averaged surface areas of sea ice separately for the northern and southern regions (which I refer to synonymously as the Arctic and Antarctic regions, though they are actually more extensive, encompassing all sea ice between them). Only sea ice is included here, not land ice. The unit throughout is millions of km^2 (surface area).

2. Instrumentation

These sea ice time series from NSIDC are split into two sections: near-real-time sea ice (NRTSI) and the final approved data designated GSFC (Goddard Space Flight Center). Data starts in 1978 or 1979, depending on month, and extends to the present (end of December 2019). Data up to and including 2018 is designated GSFC, whilst the 2019 data is designated NRTSI (which means it may be subject to revision).

The GSFC and NRTSI data come from the Scanning Multi-channel Microwave Radiometer (SMMR) instrument on the Nimbus-7 platform and from a series of Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager/Sounder (SSMIS) instruments on the Defense Meteorological Satellite Program (DMSP) satellites. Over the time period in question some six different satellites/instruments contributed to the data collection.

3. Physical Basis of Ice Detection

The physical basis of the instrumentation used to identify ice, and to distinguish sea ice from water, is described in the technical specification thus,

"*Sea ice concentration can be estimated from brightness temperature data because sea ice and water have differing passive microwave brightness temperature signatures. For example, water has a highly polarized signature within a certain frequency band, that is, its brightness temperature in the vertical channel is higher than that in the horizontal, while sea ice does not. Most algorithms use some form of a polarization difference or ratio and a linear mixing formula with brightness temperature tie points to estimate the concentration of sea ice within the field of view of the sensor. The Sea Ice Index is based on the NASA Team algorithm (Cavalieri et al. 1997)*"

4. Temporal and Spatial Resolution

The temporal resolution of the NSIDC Sea Ice Index is daily, but only monthly data are archived. As each month concludes, NSIDC runs a processing script which calculates and retains monthly averaged data. Data relates to grid cells which are nominally 625 km^2 (25 km by 25 km), but in the polar stereographic projection employed the area actually varies with latitude. Grid cell areas range from 382 km^2 to 664 km^2 for the Northern Hemisphere grid domain and from 443 km^2 to 664 km^2 for the Southern Hemisphere grid domain.

The raw signal from the instrumentation is processed to provide a figure for the ice concentration within each grid cell, which is an estimate of the proportion of the cell's area covered with ice (from 0% to 100%).

5. Extent Versus Area

The datasets which can be downloaded via ftp from here include two distinct measures, referred to as ice "Extent" and ice "Area". Both these measures ignore all cells with less than 15% ice concentration. The "Extent" measure is defined by simply adding the areas of all cells which have more than 15% ice concentration. This will tend to be an over-estimate of the actual ice area since many cells will have substantially less than 100% ice cover. The "Area" measure is a best attempt to estimate the actual ice surface area. This is defined by multiplying the ice concentration in every cell by the area of that cell (thus estimating the actual area of ice in that cell) and summing this over all cells with at least 15% concentration. (This description is my rendition of the explanation given here). These definitions mean that Extent is always greater than Area (and substantially so).

I now offer my own opinion: it seems clear to me that the Area measure is the better measure of "how much ice there really is". The Extent measure is almost certainly an over-estimate (assuming that ignoring cells with less than 15% ice cover does not outweigh the implicit approximation of 100% cover elsewhere, which seems unlikely). On the other hand, the Area measure almost certainly under-estimates the total amount of ice, both because the cells with less than 15% ice concentration are ignored, and also because of limitations in the ability to detect ice. The FAQ linked previously advises,

"*Scientists at NSIDC report Extent because they are cautious about summertime values of ice concentration and area taken from satellite sensors. To the sensor, surface melt appears to be open water rather than water on top of sea ice. So, while reliable for measuring area most of the year, the microwave sensor is prone to underestimating the actual ice concentration and area when the surface is melting. To account for that potential inaccuracy, NSIDC scientists rely primarily on Extent when analyzing melt-season conditions and reporting them to the public*."

Hence, when ice Area is at its minimum, it probably underestimates the absolute area of sea ice. It is worth bearing that in mind, though I maintain that Area is a better measure than Extent which is a rather crude work-around and definitely over-estimates the total area. However, I am less interested in absolute ice area than upon trends.

6. Area Trends

Figure 1a plots the average sea ice Area, in millions of km^2, in January for each year from 1978 to 2019, showing northern and southern sea ice, and their total, separately. Figure 1b is the same for February, Figure 1c for March, etc., through all twelve months.

The Arctic sea ice achieves its minimum in September (Figure 1j), whilst the Antarctic has its minimum in March (Figure 1c).

Figure 2 is the yearly average sea ice Area plotted from 1979 to 2019.

For comparison, Figure 3 plots the yearly average sea ice Extent between 1979 and 2019.

Figure 4 shows the monthly variation in sea ice Area over the year 2019.

Figure 1j (September), Figure 1c (March) and Figure 2 include best estimate trend lines. However, a best estimate trend is not necessarily statistically significant. Regression permits evaluation of the lower and upper trend slopes at 95% confidence levels. The range of slopes between these 95%CL limits defines the 90% confidence interval. If this encompasses zero then the trend is not statistically significant (at the 90% confidence level). Table 1 gives these 90% confidence intervals.

Table 1: Trends and Statistical Significance in Sea Ice Area. *(Positive slopes imply increasing ice; negative slopes imply decreasing ice. 90% confidence is the range between the lower and upper 95%CL bounds. If this encompasses zero, the trend is not statistically significant).*

Location	Month	Slope ($10^6 km^2$/year)			Statistically Significant Trend?
		Best Estimate Trend	95%CL Lower Bound	95%CL Upper Bound	
North	March(1)	-0.004	-0.014	0.006	No
South		0.007	-0.004	0.019	No
Total		0.003	-0.015	0.022	No
North	September(2)	-0.048	-0.062	-0.034	Yes
South		0.006	-0.005	0.017	No
Total		-0.042	-0.058	-0.026	No
North	Whole Year	-0.023	-0.032	-0.013	Yes
South		0.008	-0.002	0.017	No
Total		-0.015	-0.030	0	Borderline

(1)Antarctic minimum; (2)Arctic minimum.

7. Conclusions

[1] The northern sea ice minimum (in September) has a statistically significant downward trend. The northern sea ice also has a statistically significant downward trend over the year as a whole.

[2] The southern sea ice has a best estimate trend upward at all times, but these are not statistically significant. This lack of significance may be a temporary state of affairs caused by the relatively smaller Antarctic sea ice cover in the last 4 years if this subsequently picks up again (i.e., the trend in Antarctic sea ice was statistically significantly upward up until 2015).

[3] The total sea ice cover averaged over the year has a slight downward trend but this is of borderline statistical significance. (Until 2015 this would have been a small upward trend, but also not statistically significant).

[4] Extrapolation of the trend in Figure 1j indicates that summer sea ice in the Arctic may become challenged in ~65 years (with potential impact on local fauna). Whether this extrapolation has any real significance is difficult to judge without making assumptions about its underlying physical driver (and whether this will persist).

[5] If the physical driver were global average temperature, the yearly average sea ice would expect to be affected, yet Figure 2 displays only slight trends, even if nominally statistically significant in the north. Figure 2 hardly seems to merit the term “climate emergency”.

Figure 1a: January

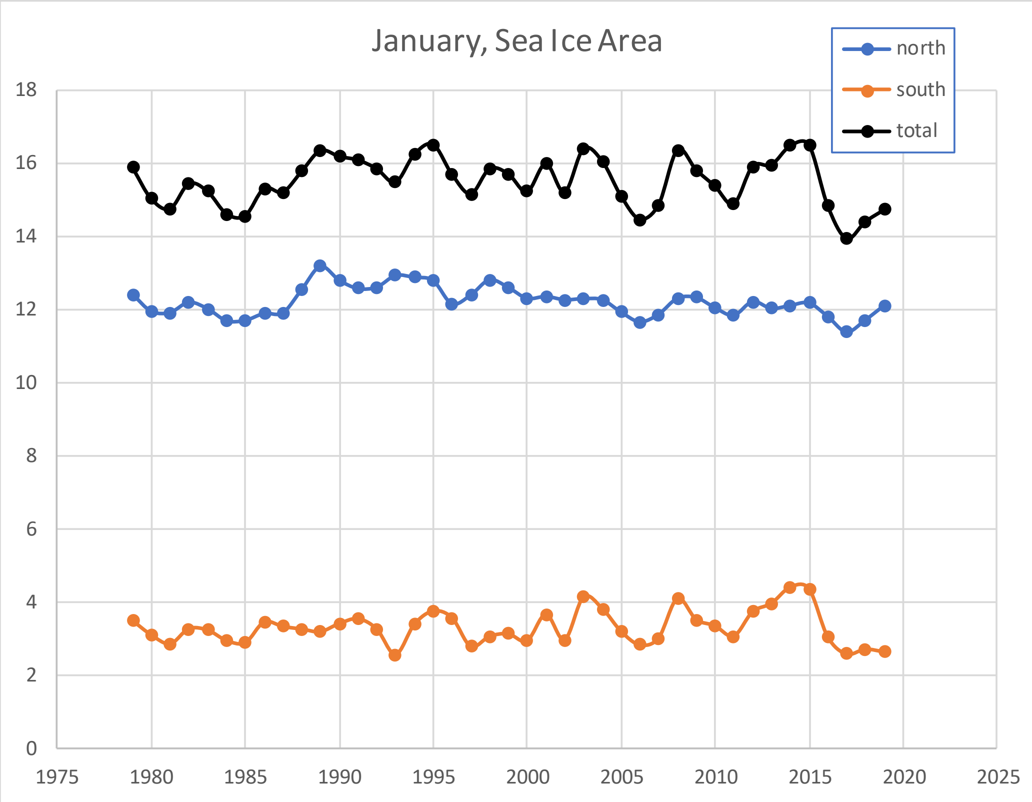

Figure 1b: February

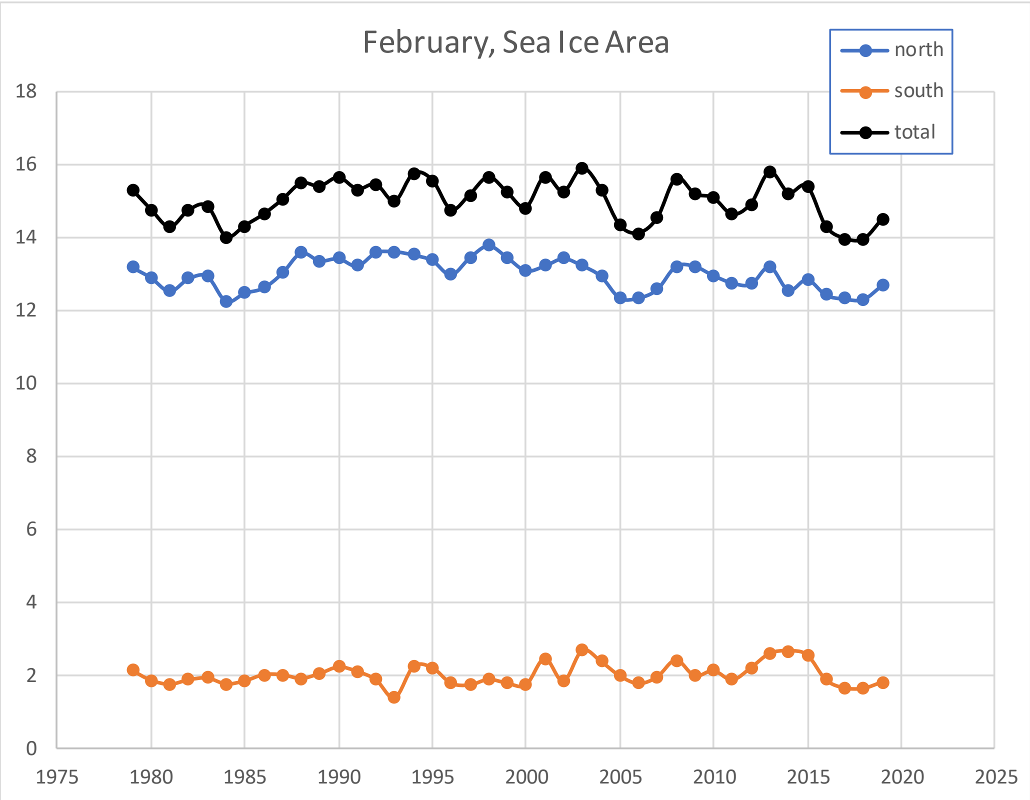

Figure 1c: March

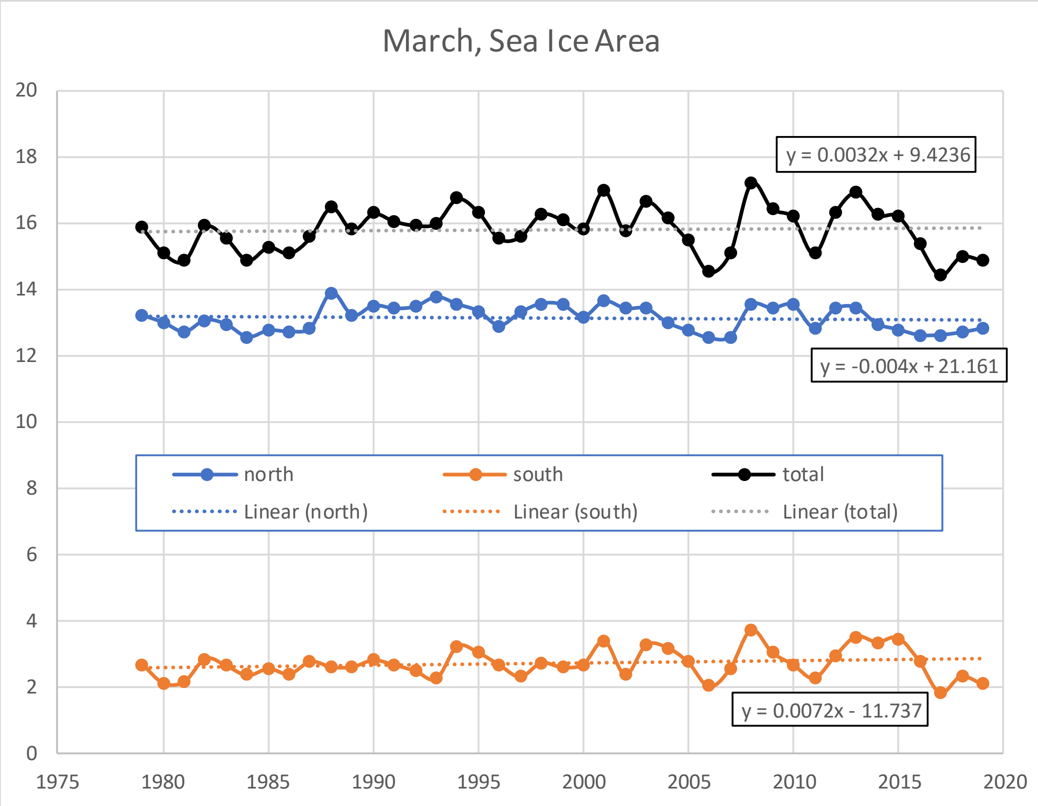

Figure 1d: April

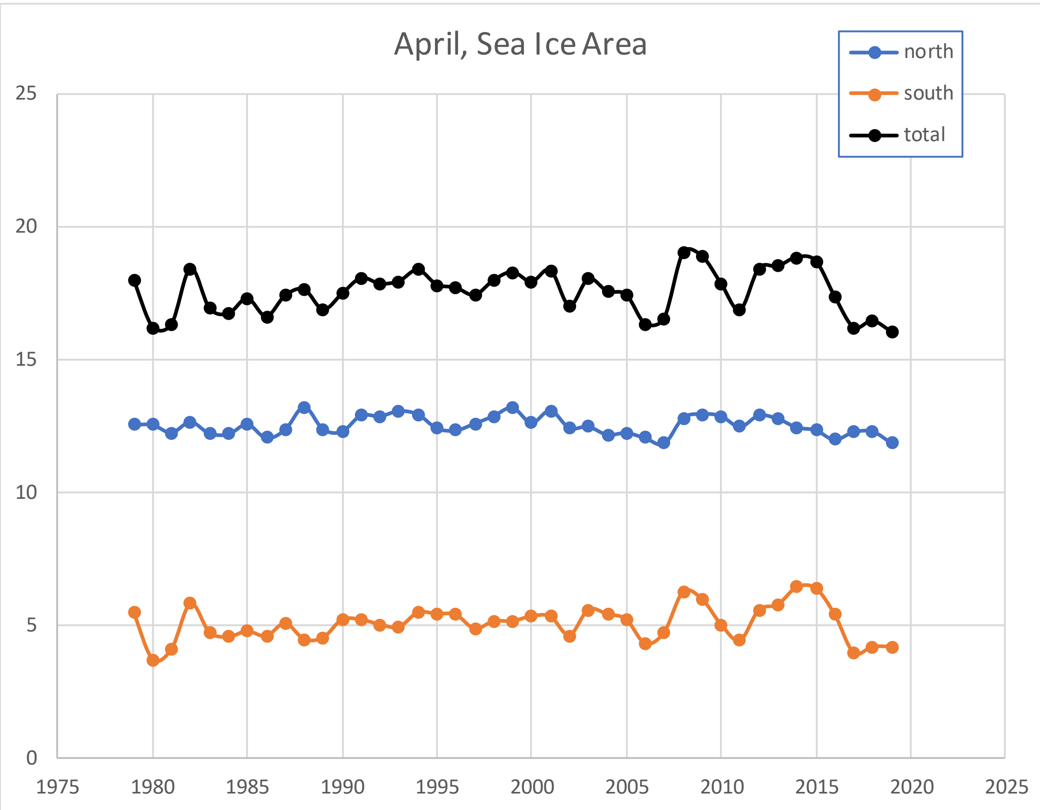

Figure 1e: May

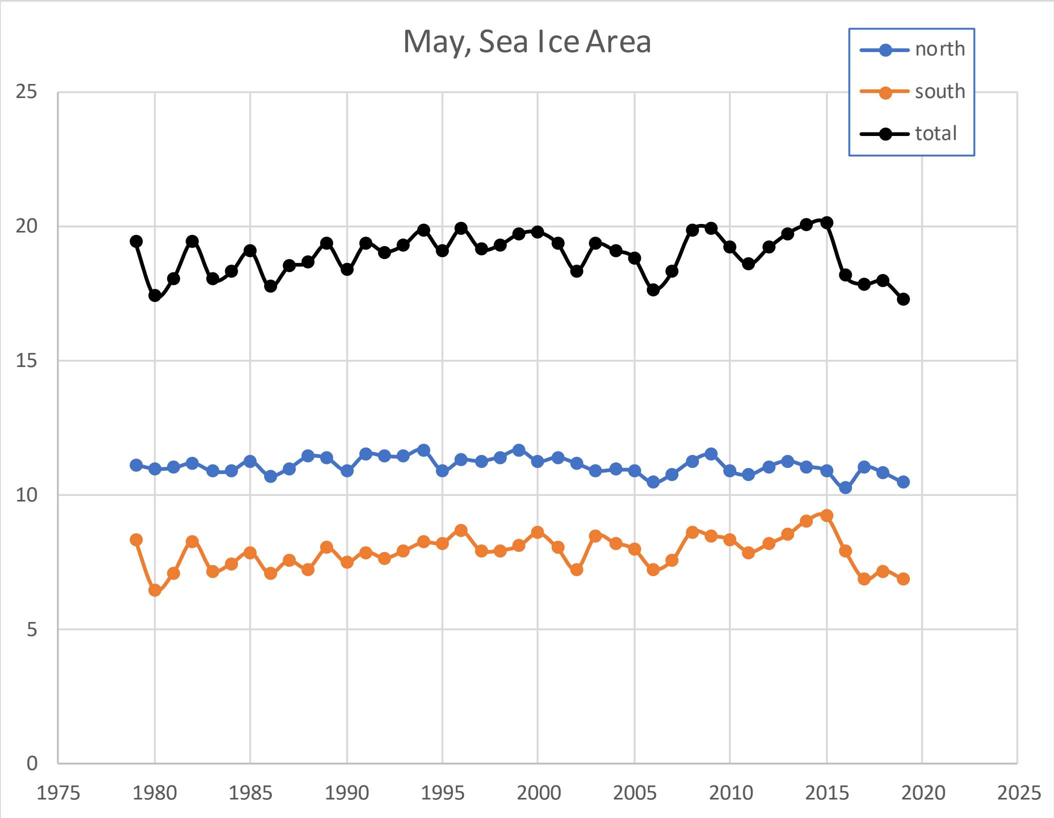

Figure 1f: June

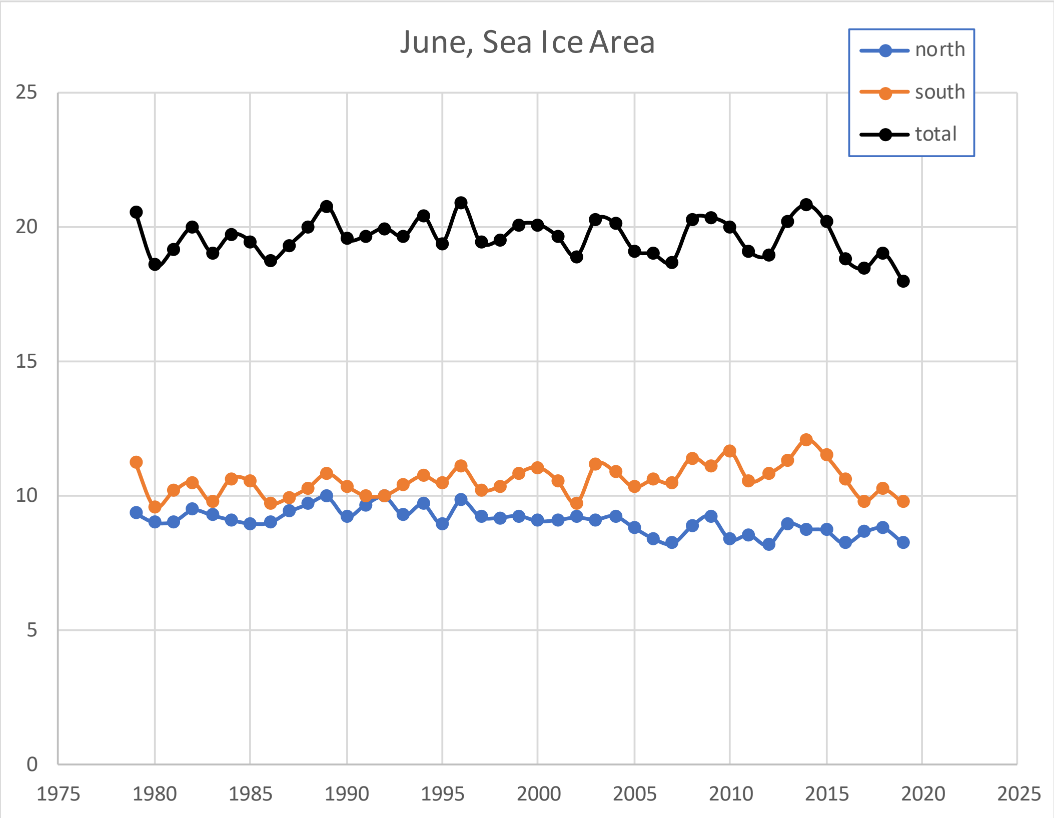

Figure 1g: July

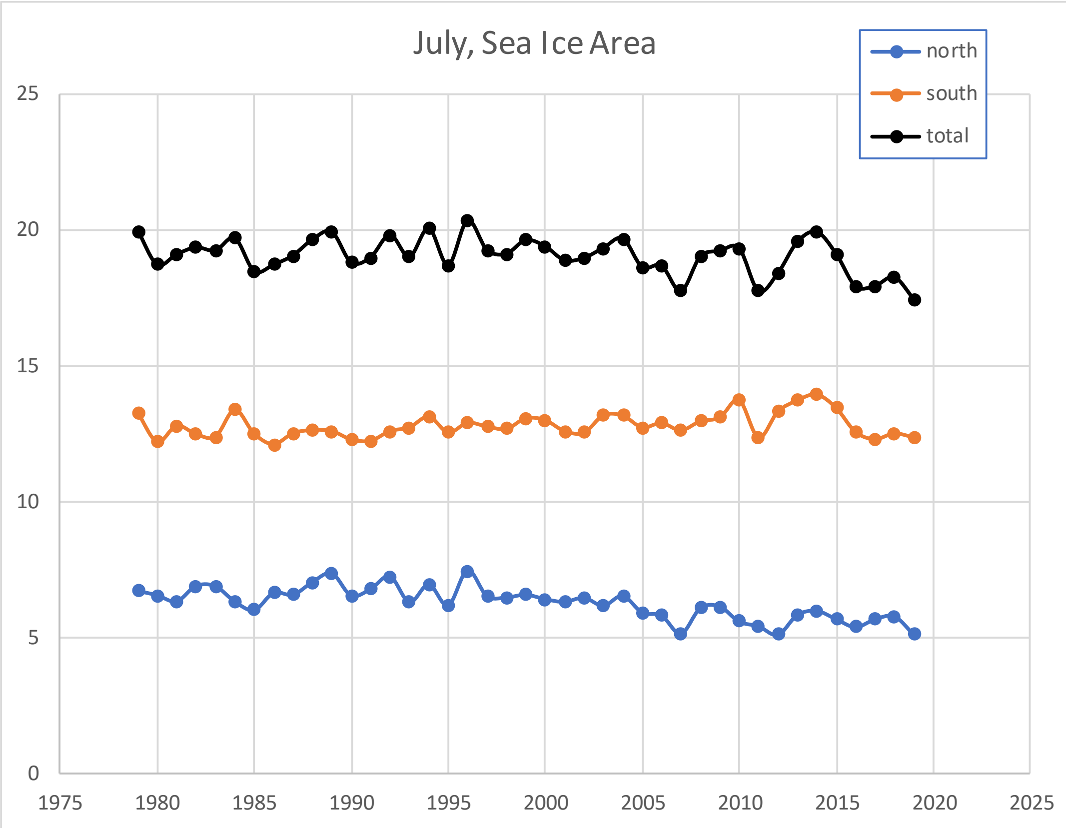

Figure 1h: August

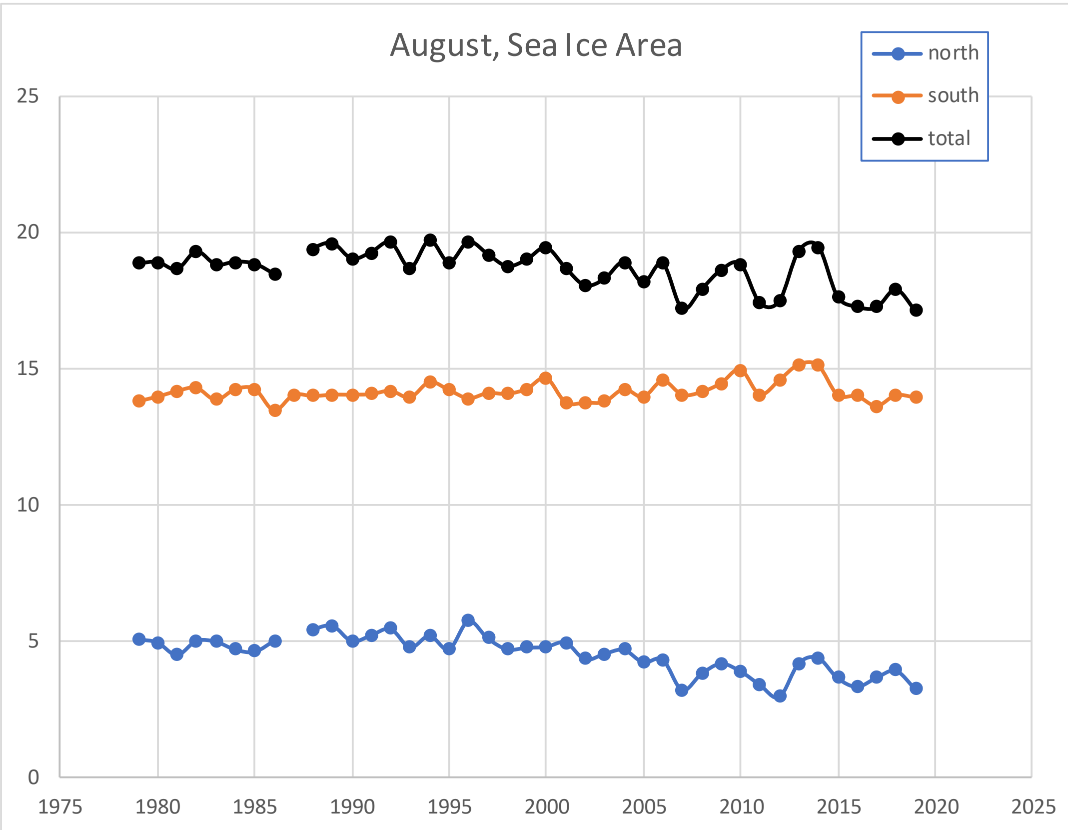

Figure 1j: September

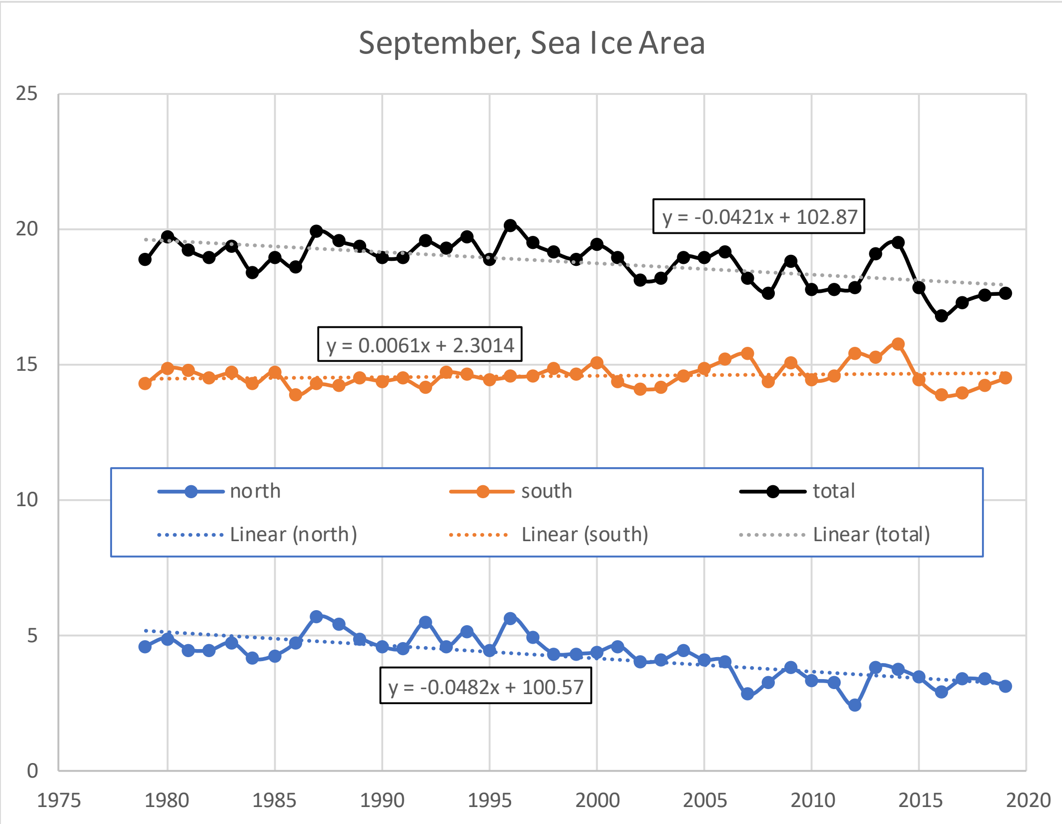

Figure 1k: October

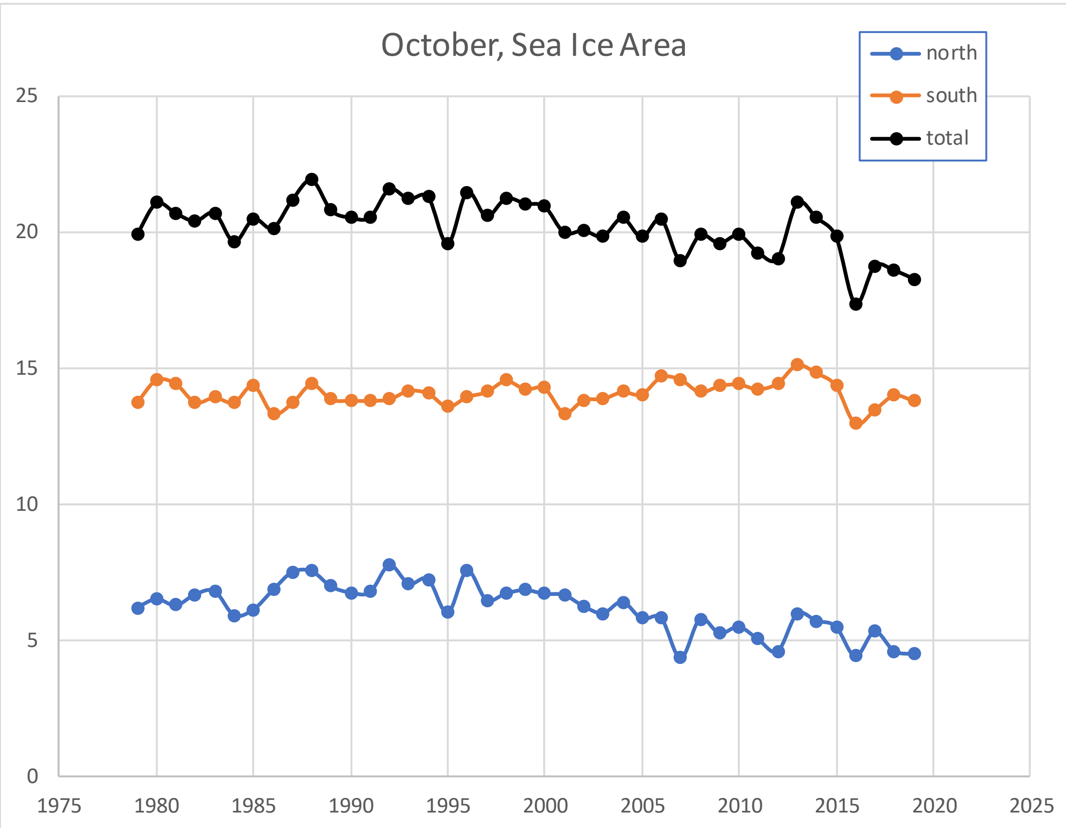

Figure 1m: November

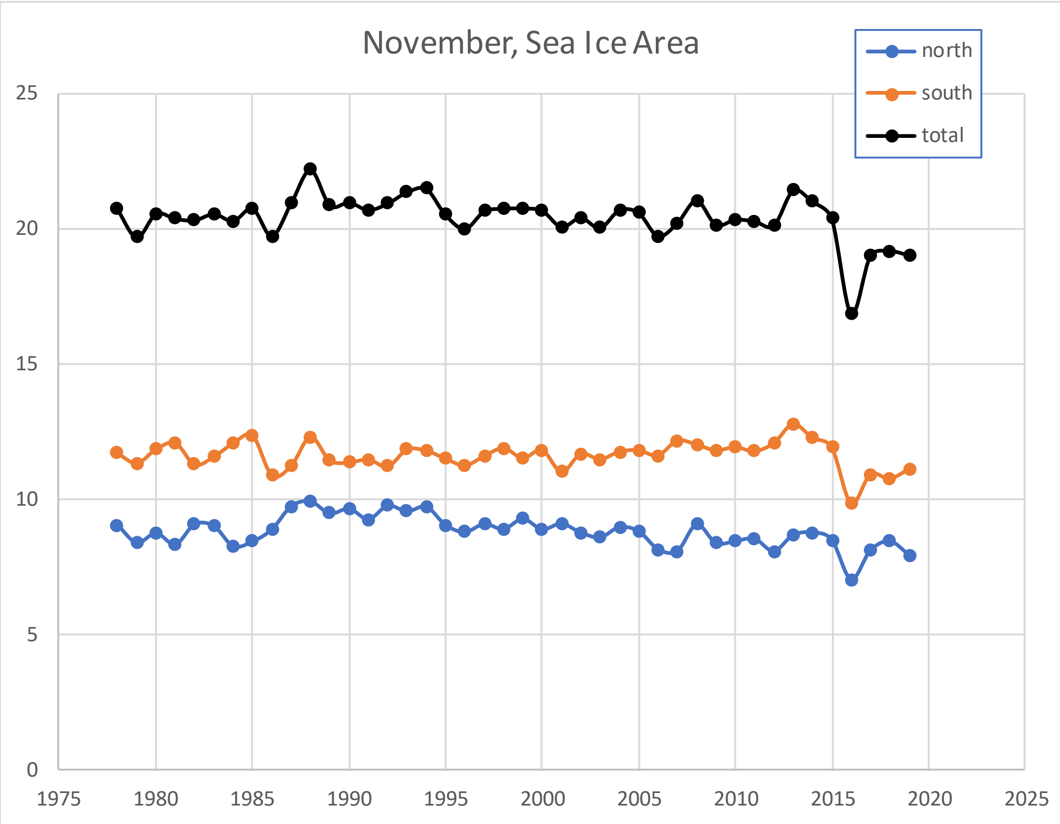

Figure 1n: December

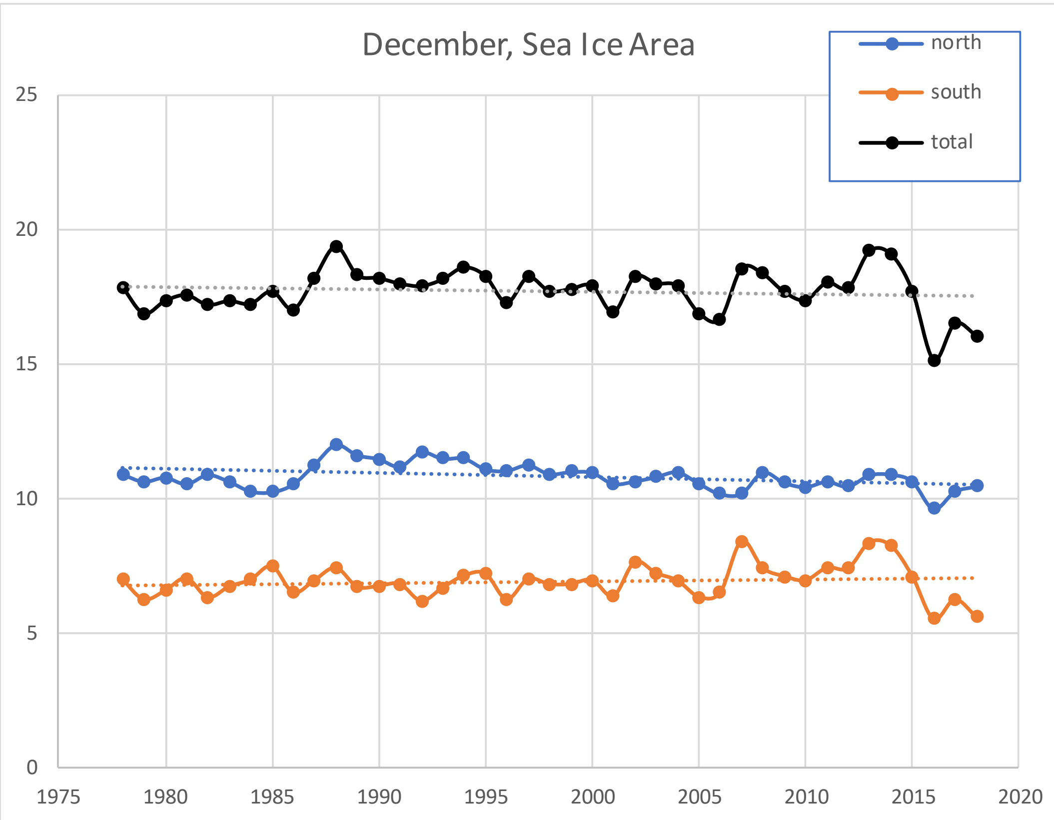

Figure 2: Yearly Average (Area)

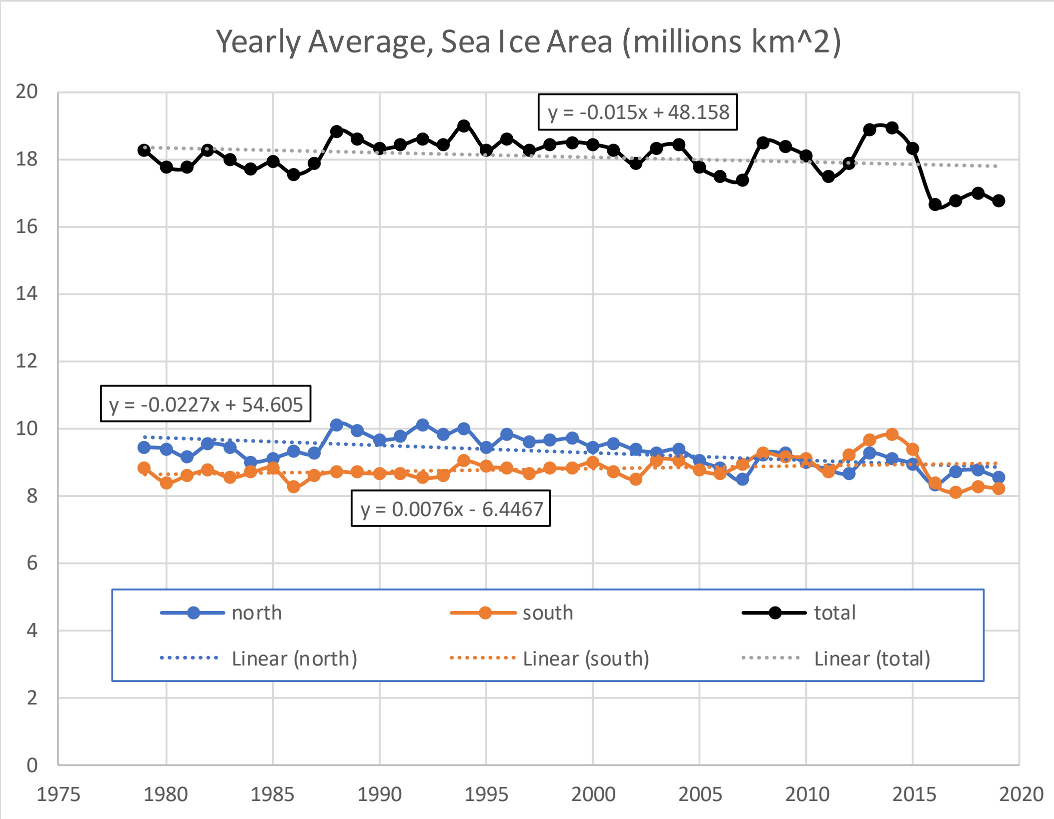

Figure 3: Yearly Average (Extent)

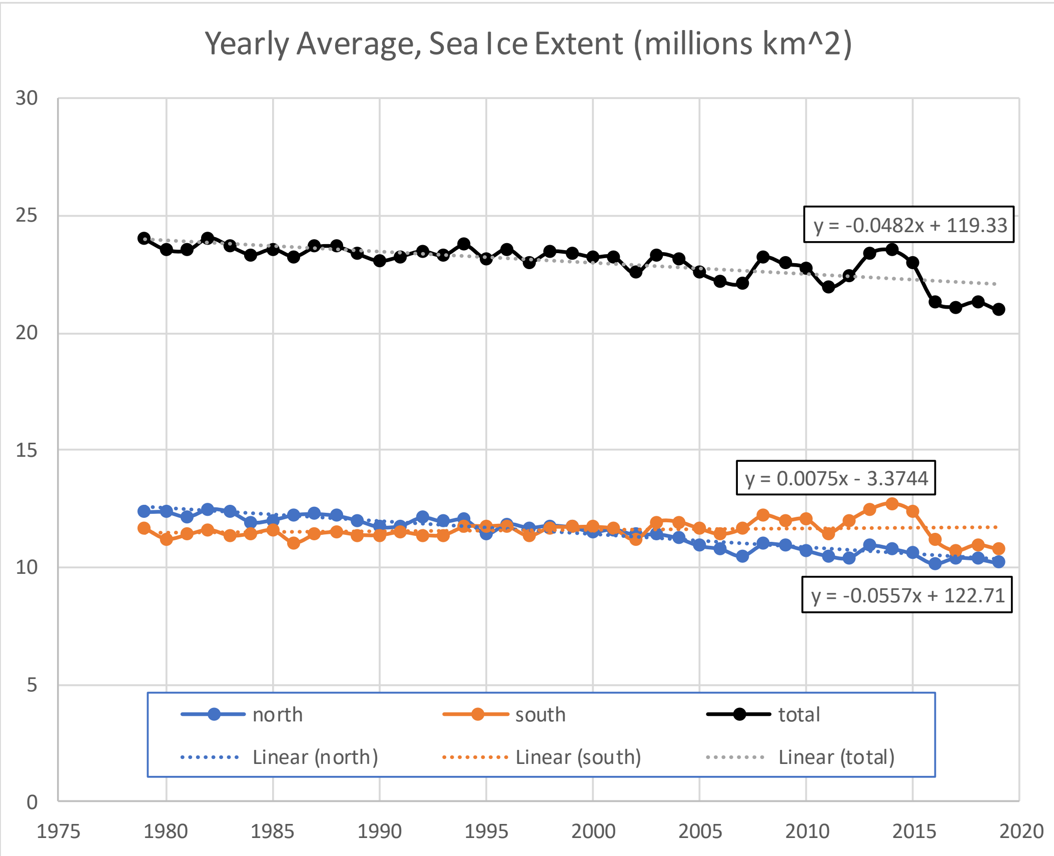

Figure 4: Variation During 2019