FORUM

Computing and Representing Sea Ice Trends: Toward a Community Consensus

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Estimates of the recent decline in Arctic Ocean summer sea ice extent can vary due to differences in sea ice data sources, in the number of years used to compute the trend, and in the start and end years used in the trend computation. Compounding such differences, estimates of the relative decline in sea ice cover (given in percent change per decade) can further vary due to the choice of reference value (the initial point of the trend line, a climatological baseline, etc.). Further adding to the confusion, very often when relative trends are reported in research papers, the reference values used are not specified or made clear. This can lead to confusion when trend studies are cited in the press and public reports.

To help reduce misunderstandings, we propose that research papers should always report absolute trends (in units of square kilometers per year or square kilometers per decade, except in the case of sea ice concentration, where the data themselves are area fractions and thus have units of percent and not square kilometers). In addition, we suggest that articles and websites aimed at the wider public, if using relative trends to put the observed temporal changes in sea ice extent into perspective, should explicitly state the reference value used. We recommend reporting trends relative to the initial point on the trendline (in units of percent change per decade). We further recommend that the absolute trend numbers be included.

Absolute and Relative Trends

For sea ice extent, the absolute trend or slope of the trend line usually has units of square kilometers per year or square kilometers per decade [e.g., *Parkinson and Cavalieri,* 2008; *Tivy et al.,* 2011]. Scientific studies involving the intercomparison of trends should restrict themselves to the use of absolute trends to avoid ambiguity. However, this metric (square kilometers per year) has no intuitive meaning to the wider public and is difficult to visualize. It also makes comparisons to changes in other geophysical parameters, such as changes in snow cover, difficult. For these reasons, observed temporal changes in sea ice extent are often converted to relative trends, which are computed by dividing the slope of the trend line by some reference value. Relative trends are generally presented in units of percent change per decade [e.g., *Parkinson and Cavalieri,* 2008; *Tivy et al.,* 2011].

Two commonly used reference values are the mean ice cover of a defined baseline or climatological period [e.g., *Meier et al.,* 2007, 2012; *Fetterer et al.,* 2002] and the computed ice cover for the initial point on the trend line (i.e., the value of the trend line at the first year in the time series, which is not always the same as the intercept value [e.g., *Parkinson and Cavalieri,* 2008; *Tivy et al.,* 2011; *Wang et al.,* 2012]). In either case, the resultant relative trends are equally sensitive to the variability in the extent time series and are also equally sensitive to the start and end years used to calculate the trend.

The magnitude of the relative trend depends on the reference value used. For example, the slope of the trend line through the 1979–2012 National Snow and Ice Data Center pan-Arctic September average sea ice extent data (Sea Ice Index [*Fetterer et al.,* 2002]) is -0.09161×10^6 square kilometers per year (see Figure 1). Dividing this slope by the initial value of the trend line produces a smaller relative trend, −11.53% change per decade, than if the slope is divided by the mean extent for 1979–2012, which yields −14.24% change per decade. The difference between the two methods in this example is nearly 3% per decade. Because the results can differ significantly, an argument can be made for the adoption of a single standard method of relative trend computation by the sea ice community.

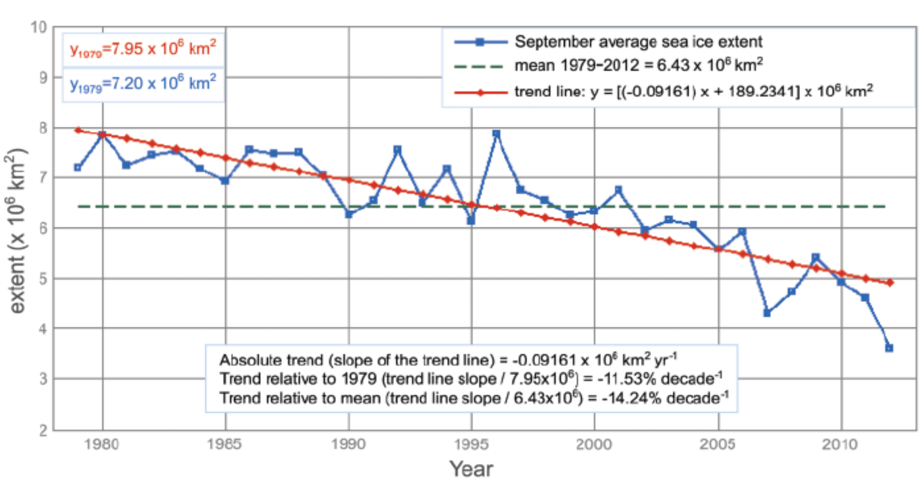

Fig. 1. The 1979–2012 National Snow and Ice Data Center (NSIDC) pan-Arctic September average sea ice extent data. Is there a relative change of −11.53% or −14.24% per decade? It depends on whether the trend is computed relative to the first year on the trend line or relative to the mean. Source data: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/Sep/N_09_area.txt.

A Community Consensus for Relative Trends

Climatological means are widely used in metrics that quantify sea ice changes that have taken place over the period of the record (e.g., extent anomalies). However, one distinct advantage of using the initial value of the trend line as the reference value is that the resultant relative trend then represents the overall magnitude of the change in ice extent between the start and end dates. For this reason, we propose that this method of relative trend computation be uniformly adopted in all public reports, articles, and websites.

For example, by this method, a relative trend of −11.5% per decade relative to 1979 (see Figure 1) can be interpreted as follows: if the change in sea ice extent is approximated using a linear trend and sea ice extent has declined by 11.5% per decade since 1979, then in 1999 the ice extent was 23% less than it was in 1979. The questions "Is sea ice extent really decreasing?" and "By how much?" are thus clearly answered for the general public. An agreement by the scientific community to consistently use this method of computing relative trends would allow for clearer communication.

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