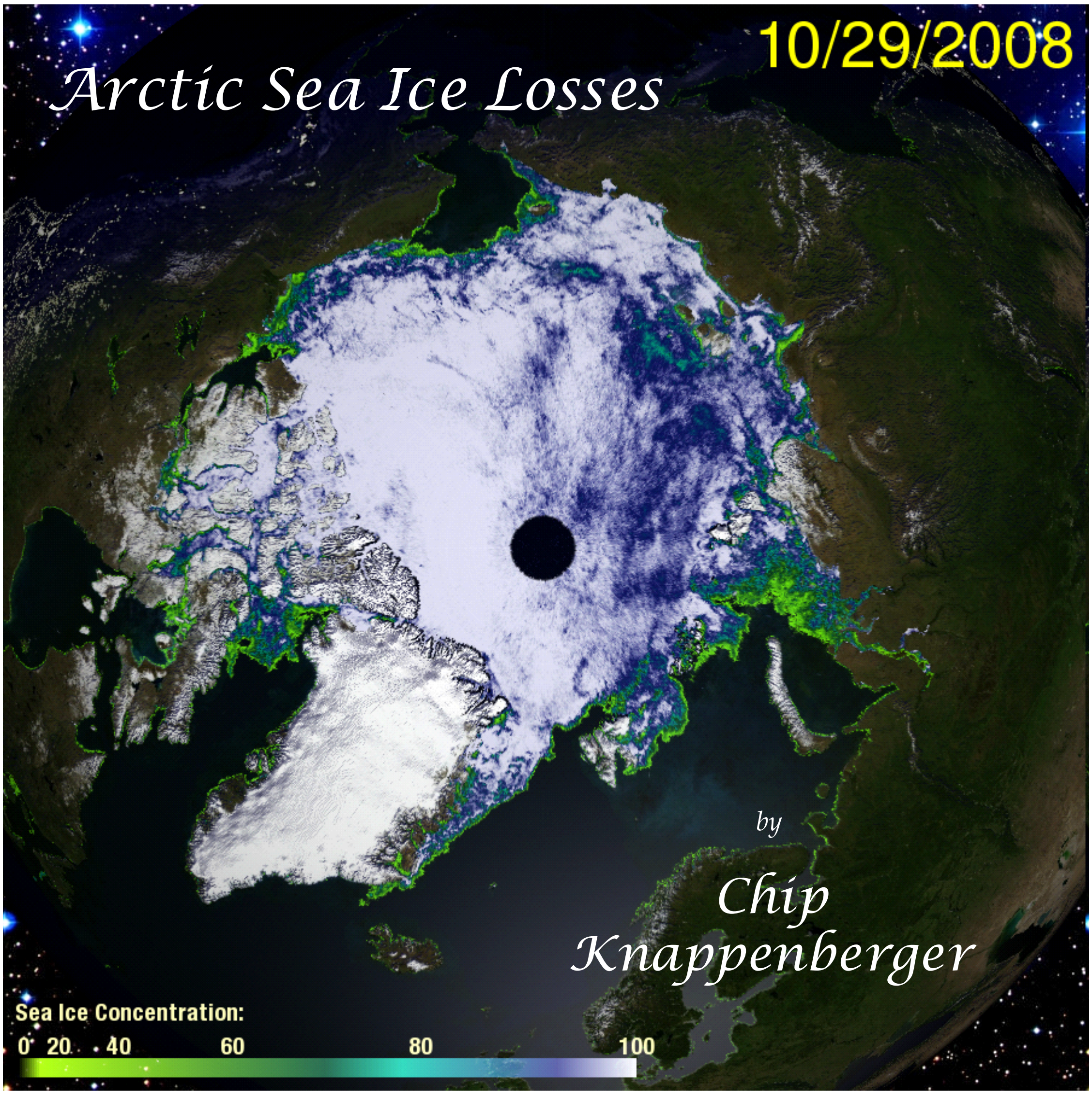


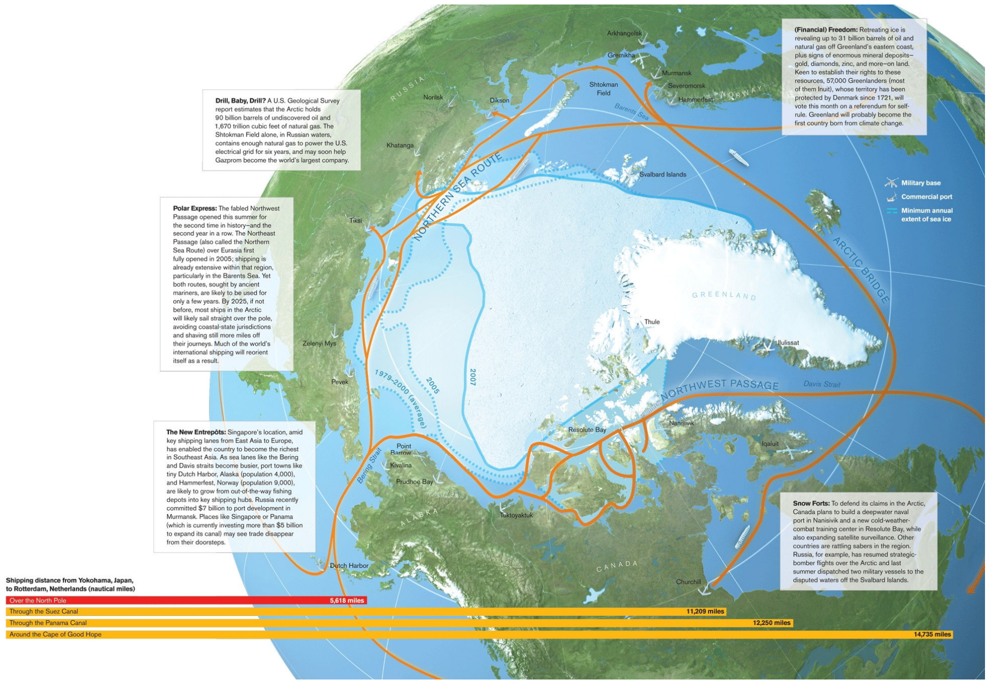
SPPI
Science & Public Policy Institute
"science based policy for a better world."

www.scienceandpublicpolicy.org
[202] 288-5699

Arctic Sea Ice Losses

Already various countries are setting into motion plans to take advantage of the potential opening of important shipping lanes through the Arctic waters. In the November 2008 issue of *The Atlantic* magazine, the potential opening of reliable shipping routes through the Arctic is described in the following way (http://www.theatlantic.com/doc/200811/map-arctic):

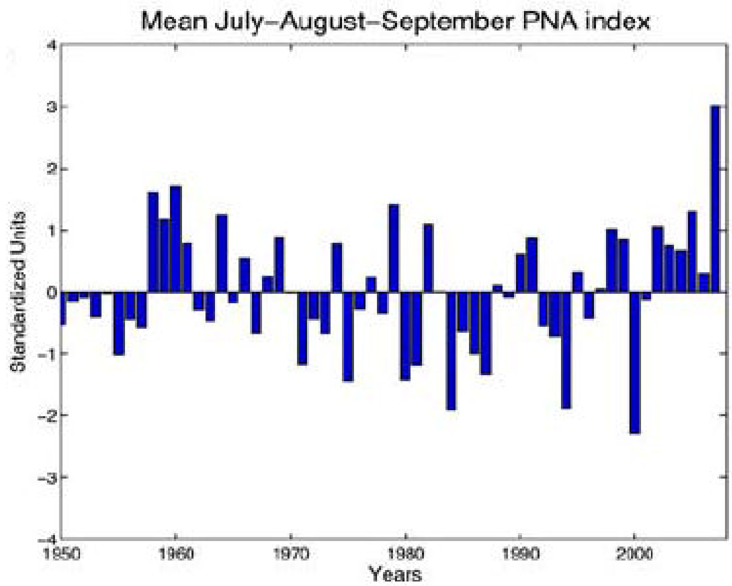
> The opening of a new waterway between the Atlantic and Pacific oceans is akin in historic significance to the opening of the Suez Canal, in 1869, or is Panamanian cousin, in 1914. With this sea change will come the rise and fall of international seaports, newfound access to nearly a quarter of the world's remaining undiscovered oil and gas reserves, and a recalibration of geo-strategic power.



Potential future shipping routes through the Arctic waters (for a larger, more detailed image see: http://www.theatlantic.com/images/issues/200811/map.jpg)

Recent scientific studies point to the cause of the dramatically reduced summer ice in extent in the Arctic Ocean in recent years as a combination of natural variability superimposed on a slow but persistent anthropogenic global warming. Positive feedback mechanisms are especially efficient in this region as the loss of a highly reflective ice exposes the dark water surface beneath, which absorbs sunlight and warms up, leading to more ice loss. Once things get rolling along, it becomes hard to slow the process—requiring the loss of sunlight (seasonally, in the fall) to cool the temperatures and stop the ice melt—until the coming spring. A lessening of the time between the end of melting in the fall and the beginning of melting in the spring jump starts the next melt season. Throw in some unusual atmospheric circulation patterns which have recently been acting to drive ice out of the Arctic waters and drive in warmer ocean waters and higher air temperatures, and a decline summer cloud cover (more sunshine) and you have a situation where rapid summer ice loss has been occurring. A relaxation of the unusual (natural) atmospheric circulation patterns may act to slow the rate of loss, but there is some speculation that the loss of ice may have been so large in recent years that without a long-term temperature decline, the Arctic may be headed for ice free summers in the not too distant future.

Several recently published studies identify the unusual atmospheric circulation patterns acting on the Arctic in recent years. L'Heureux et al. (2008) report that the atmospheric pattern known as the Pacific-North America Pattern (or, PNA) attained a state last summer (2007) that was unprecedented since 1950—a value that was 3 standard deviation above normal (a 1 in 333-year chance of occurrence in a stationary climate). The PNA is a natural occurring atmospheric pattern of circulation in which, in its positive phase (like in 2007), brings a strong southerly atmospheric flow across the western Arctic.



Summertime PNA index, 1950-2007. The PNA was the highest on record in the summer of 2007. (Source: L'Heureux et al., 2008).

L'Heureux et al. (2008) report that the atmospheric circulation which accompanied the unusually positive PNA led a multi-pronged attack on the 2007 sea ice extent:

> Never before has the summertime PNA been implicated in the decline of sea ice over the Arctic, but it is also clear that, since 1950, the summertime circulation anomalies have never projected so strongly onto the PNA. The corresponding atmospheric circulation anomalies contributed to: (a) the tremendous loss of sea ice through increased solar radiation, (b) the enhanced transport of warm air poleward, and (c) the increased sea ice drift away from the western Arctic. The confluence of these impacts helped to create a precipitous decrease in Arctic sea ice from 2006 to 2007 that was 41% larger than the previous largest year-to-year decline.

The authors further conclude that natural variation still plays a large role in the variability of Arctic sea ice: "Even though three standard deviation PNA patterns are rare, the 2007 event indicates that naturally occurring atmospheric circulation patterns, superimposed on decreasing sea ice trends, must be monitored more closely due to their capability to dramatically change sea ice amounts."

The L'Heareux et al. (2008) work on atmospheric circulation patterns nicely ties together other individual findings that have appeared in the recent literature on the subject of Arctic ice loss.

For instance, Kay et al. (2008) reported that an abundance of clear skies and sunshine during the summer of 2007 enhanced the sea ice melt that year and contributed to the record low ice extent. Kay et al. (2008) contributed the excess sunshine to atmospheric circulation patterns conducive to stable air masses and cloud-free skies. While Kay et al. (2008) determined that there were a few other years since 1950 when conditions were as sunny or sunnier, that, in 2007, the exceptional sunshine shone upon an already weakened ice field (thinner and less older ice) which hastened the melt. They concluded that, similar to L'Heureux et al. (2008) that:

> Thus, our results suggest that when sea ice is vulnerably thin, natural year-to-year variations in the summertime atmospheric circulation and associated changes in clouds and shortwave radiation can play an increasingly large role in modulating sea ice extent.

A study by Perovich et al. (2008) also found that absorption of solar radiation in the upper layers of the Arctic ocean led to enhanced melting to the bottom surface of the Arctic sea ice and thus was a major contributor to the record 2007 summer ice loss.

Similar conclusions regarding the combination of natural variability acting on top of on-going warming to enhance Arctic ice loss were reached by scientists studying wind patterns and ice drift in the Arctic. For example Maslanik et al

(2007), Ogi and Wallace (2007), Ngheim (2007) and Zhang et al. (2008) all conclude that a combination of warming temperatures and wind patterns have led to enhanced ice flow out of the Arcitic and hence to the downward trends in Arctic sea ice. Zhang et al. (2008) summed things up as follows:

> During summer 2007 the atmospheric changes considerably strengthened the ice motion and transpolar drift, causing more ice to move out of the Pacific sector and the central Arctic Ocean, to exit Fram Strait, and to pile up in part of the Canada Basin and along the coast of northern Greenland. The unusual ice advection is responsible for a large area of thin ice and open water in the Pacific sector as well as the central Arctic Ocean where surface albedo is lowered considerably, leading to intensified surface solar heating and enhanced ice melting....About 70% of the loss is due directly to the enhanced melting, while 30% the unusual ice advection. The amplified ice melting shows the dominant effects of the positive ice-albedo feedback that is significantly enhanced by the changes in the ice circulation. So if the changes in the atmospheric circulation are considered a trigger of the unprecedented ice retreat in summer 2007, then the ice-albedo feedback accelerated the retreat. The large loss of ice mass and ice extent may suggest that arctic sea ice has entered a state of being particularly vulnerable to anomalous atmospheric forcing.

Just how much of the Arctic ice loss is related to warming temperatures and how much is related to natural atmospheric circulation variability is unclear, but both clearly play a role. The most recent calculations are from Smedsrud et al. (2008), who used a coupled air-sea-ice model to examine potential strengths of the various causes. They lead in to their experiment as follows:

> The interest in the Arctic sea ice seems inversely proportional to the area covered, and has exploded after the record minimum September 2007. The Arctic ice has in many ways become the "canary in the coal mine" of global warming. At the same time global models show a large spread in future predictions of the Arctic energy budget.
>
> The Arctic ice loss over the last few years has been well documented, but the causes of this major change have yet to be established. Furthermore, the idea that the Arctic may transfer into a seasonal ice cover within a limited number of years has gained large public interest. Here we use a physical process-based 1-D coupled air–sea–ice model to compare some key drivers of Arctic sea ice changes with updated trends, and find a fairly robust ice cover.

They go on to describe their findings:

> Oceanic heat advection contributes to the ongoing reduction of the Arctic ice cover, but the increased ice-area export contributes more. Recent ocean profiles indicate no intensification in upward mixing of heat from the Atlantic layer. Advection of atmospheric heat has also decreased slightly during the last 20 years, and thus cannot account for the present ongoing dramatic changes.

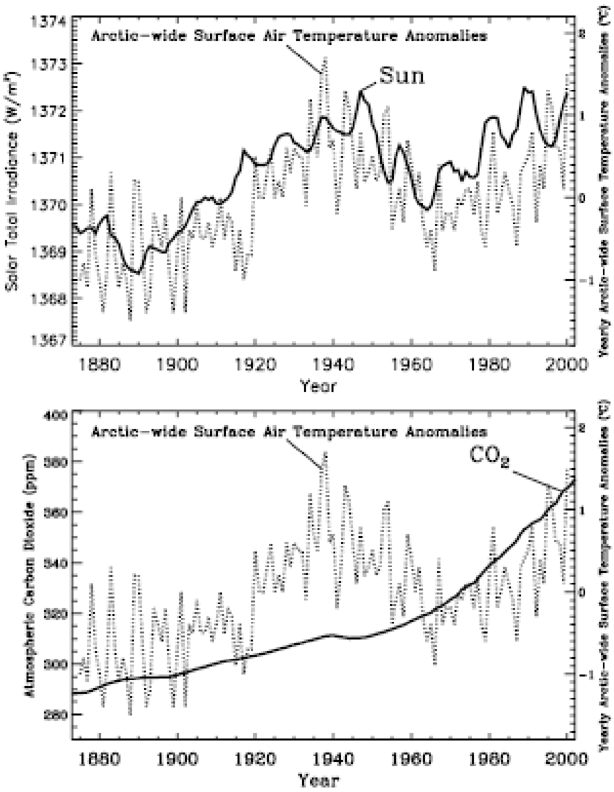
And they conclude, similar to other researchers, that natural variability and anthropogenic warming will slowly erode away the summertime sea ice, although at a slower rate than other estimates:

> Our model results show that the 2007 minimum could be maintained by high Fram Strait ice export and oceanic heat advection, but a further increase in forcing, like a 2*CO2 state, is needed to drive the Arctic into a seasonal ice free cover permanently. As the globe slowly warms, the Arctic ice cover will slowly diminish too, but there are limits as to how fast this can take place. This depends on Arctic cloud cover as much as it does on greenhouse gas forcing. The increased Fram Strait ice export reported here forecasts a reduced ice cover also in 2008, but if the present high export is not maintained it is likely that we will see a partly recovery in the next few years.

While all researchers find that warming temperature are to some degree responsible for the recent declines in Arctic sea ice (*e.g.*, Overland et al., 2008; Stroeve et al., 2008), not everyone is convinced that anthropogenic emissions of greenhouse gases are primarily responsible for the temperature rise. For instance, Soon (2006) finds that solar variability apparently plays a larger role that it is often credited with. Soon concluded the following:

> Two main results highlight the need for further research towards the proper quantitative evaluation of the hypothesis that multi-decadal- and longer-term variations of solar irradiance may provide significant forcing of Arctic-wide SATs [surface air temperature] through modulations on the operation regimes of the large-scale atmospheric circulation, ocean and sea ice over the Arctic. These results are the following:
>
> (1) Solar forcing explains well over 75% of the variance for the decadally-smoothed Arctic annual-mean or spring SATs, and
>
> (2) Time-frequency characteristics for the annual mean or seasonally-averaged Arctic SATs are consistent with similar wavelet structures derived for the TSI [total solar irradiance] forcing.

In contrast, a CO2-dominated forcing of Arctic SATs is inconsistent with both the large multidecadal warming and cooling signals and the similar amplitude of warming trends between cold (winter) and relatively warmer (spring and autumn) seasons found in the Arctic-wide SAT records



Annual-mean Arctic-wide air temperature anomaly time series (dotted lines) correlated with the estimated total solar irradiance (top panel; solid lines) and with the atmospheric carbon dioxide, CO2, mixing ratio (bottom panel; solid lines) from 1875 to 2000 (source: Soon, 2006).

Overall, the general consensus is that Arctic sea ice is on the decline as a result of a gradually warming Arctic, and that this decline is leading to Arctic sea ice conditions that are more vulnerable to natural variability, such that fluctuations in the amount of sunshine, the direction of the winds, etc. can hasten the seasonal melt and lead to record-setting conditions, such as those in the summer of 2007. As to when the Arctic will become ice-free in the summer, the estimates vary, from one to several decades—depending largely on whether or not natural variability reverses its recent positive influence on ice loss, and whether or not the ice can recover from its currently vulnerable state as a result of the major losses in 2007 and 2008. Currently, the rate of Arctic ice loss exceeds that projected by climate models, primarily because of the amplification provided by natural cycles.

However, reduced ice, or even ice-free conditions in the Arctic summer are likely not historically unprecedented in the era since the termination of the last ice age. Recent evidence to this occurrence was presented by England et al. (2008) who examined driftwood assemblages along the northern shores of Canada's Ellesmere Island. During times when a significant ice shelf existed there, driftwood was prevented from reaching to shoreline, however, in the absence of a blocking ice shelf, driftwood accumulated along the coast. By dating samples of driftwood collected upon the island, the researchers could gain an idea of times when an ice shelf extended from the Ellesmere Island and times when one was largely absent. They found virtually no driftwood on the northern shores that was less than 5,500 years old, indicating that multiyear landfast sea ice has been present for the past 5 millennia, and that current ice loss there—initiated at the end of the Little Ice age in the late 1800s—may result in conditions there unprecedented during the past 5,500 years. However, prior to 5,500 years ago, drift wood assemblages were found which dated rather sporadically from the end of the last ice age until about 7,000 years ago, and then rather continuously for a period spanning about 1,500 years from ~7,000 to ~5,500 years ago. This indicates that the ice shelves on the northwest coast of Ellesmere Island were not well-established during that period, probably because conditions were too warm. And the authors speculate that ice shelf conditions along northwest Ellesmere Island may reflect the sea ice condition in the Arctic at large. This would imply that total Arctic sea ice was less than present for many thousands of years since the end of the last ice age—and native species (including humans) survived through those conditions.

References:

England, J.H., et al., 2008. A millennial-scale record of Arctic Ocean sea ice variability and the demise of the Ellesmere Island ice shelves. *Geophysical Research Letters*, **35**, L19502, doi:10.1029/2008GL034470.

Kay, J. E., et al., 2008. The contribution of cloud and radiation anomalies to the 2007 Arctic sea ice extent minimum, *Geophysical Research Letters*, **35**, L08503, doi:10.1029/2008GL033451.

L'Heureux, M. L., et al., 2008. Role of the Pacific-North American (PNA) pattern in the 2007 Arctic sea ice decline. *Geophysical Research Letters*, **35**, L20701, doi:10.1029/2008GL035205.

Maslanik, J., et al., 2007. On the Arctic climate paradox and the continuing role of atmospheric circulation in affecting sea ice conditions, *Geophysical Research Letters*, **34**, L03711, doi:10.1029/2006GL028269.

Ogi, M., and J. M. Wallace, 2007. Summer minimum Arctic sea ice extent and the associated summer atmospheric circulation, *Geophysical Research Letters*, **34**, L12705, doi:10.1029/2007GL029897.

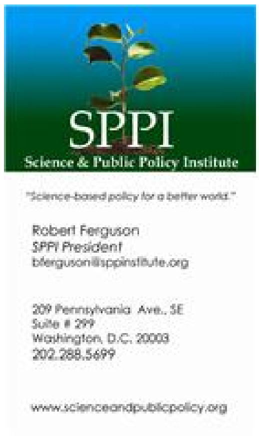
Overland, J. E., et al. 2008. The recent Arctic warm period, *Tellus*, Ser. A, 60, 589 – 597, doi:10.1111/j.1600-0870.2008. 00327.

Perovich, D. K., et al., 2008. Sunlight, water, and ice: Extreme Arctic sea ice melt during the summer of 2007, *Geophysical Research Letters*, **35**, L11501, doi:10.1029/2008GL034007.

Soon, W., 2006. Variable solar irradiance as a plausible agent for multidecadal variations in the Arctic-wide surface air temperature record of the past 130 years, *Geophysical Research Letters* , **32**, L16712, doi:10.1029/2005GL023429.

Stroeve, J. M., et al., 2008. Arctic sea ice plummets in 2007, *Eos Transactions of the AGU*, **89**, 13– 20.

Bio:



Mr. Knappenberger holds an M.S. degree in Environmental Sciences (1990) from the University of Virginia as well as a B.A. degree in Environmental Sciences (1986) from the same institution. His over 20 years of experience as a climate researcher have included 10 years with the Virginia State Climatology Office and 13 years with New Hope Environmental Services, Inc. During his career, he has studied such diverse topics as patterns of global warming, causes of global warming, hurricanes, behavior of U.S. temperature and precipitation change, weather/mortality relationships in the United States, Greenland ice melt, diurnal temperature change, weather and agriculture, circulation changes in the eastern United States, snowfall/temperature relationships in Canada, wintertime coastal storm tracks in the eastern United States, and winter weather forecasting techniques. From this research, he has authored or co-authored over 20 papers appearing in the peer-reviewed scientific literature, and numerous others appearing in scientific conference proceedings, professional journals, and the popular press.

Cover: http://arctic.atmos.uiuc.edu/cryosphere/