Improving the Climatology of Antarctic Sea Ice Thickness

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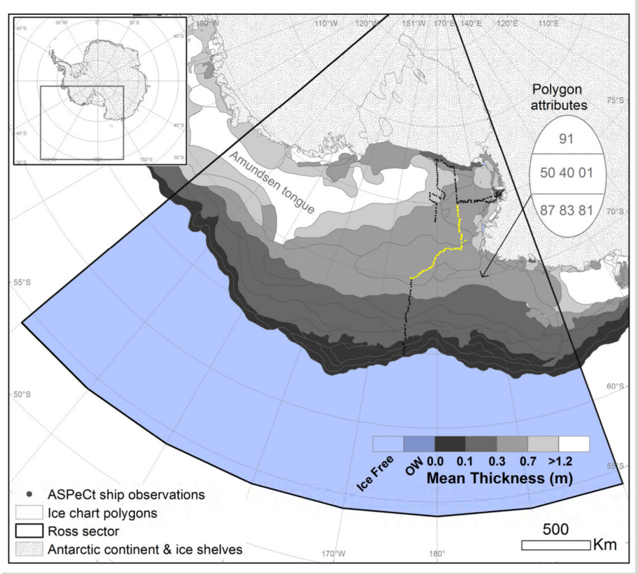
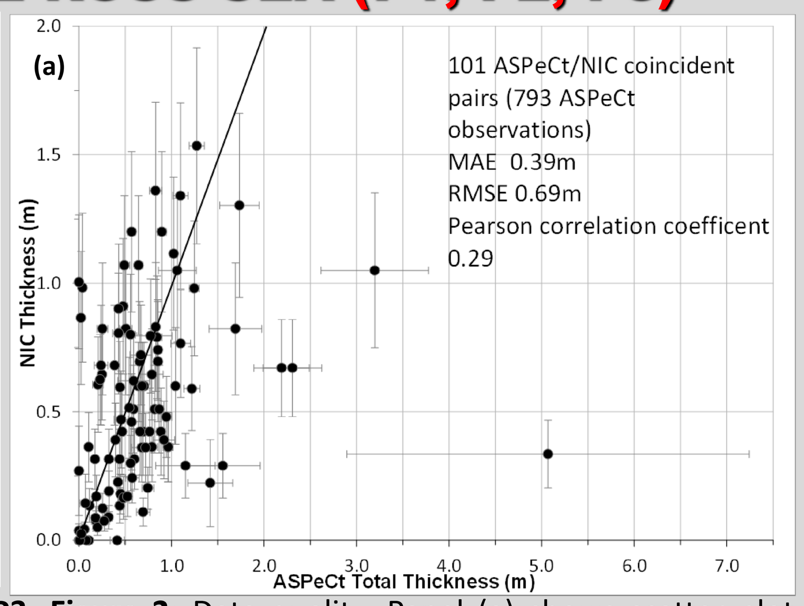
ABSTRACT

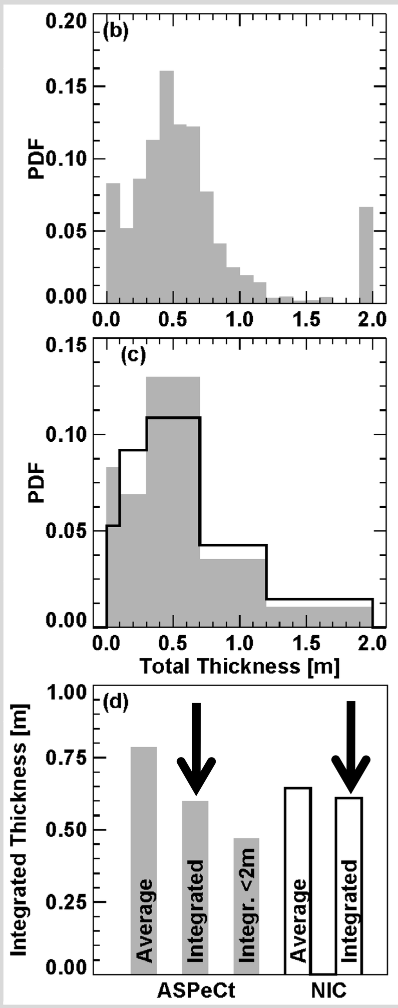
We demonstrate here recent advances to incorporate sea ice thickness estimates in operational products for integration with climate models and sea ice forecasting. Examples are from a collection of papers which characterize the quality of ship-based observations and ice chart products. Findings show these products provide a valuable resource for validating and improving climate models and regional ice forecast systems. Quantifying the uncertainties also provides users with decision making information when evaluating these products for their applications. These scientific efforts serve as a framework for guiding future improvements in operational ice chart products and developments.

CASE STUDY: THE ROSS SEA (P1, P2, P3)

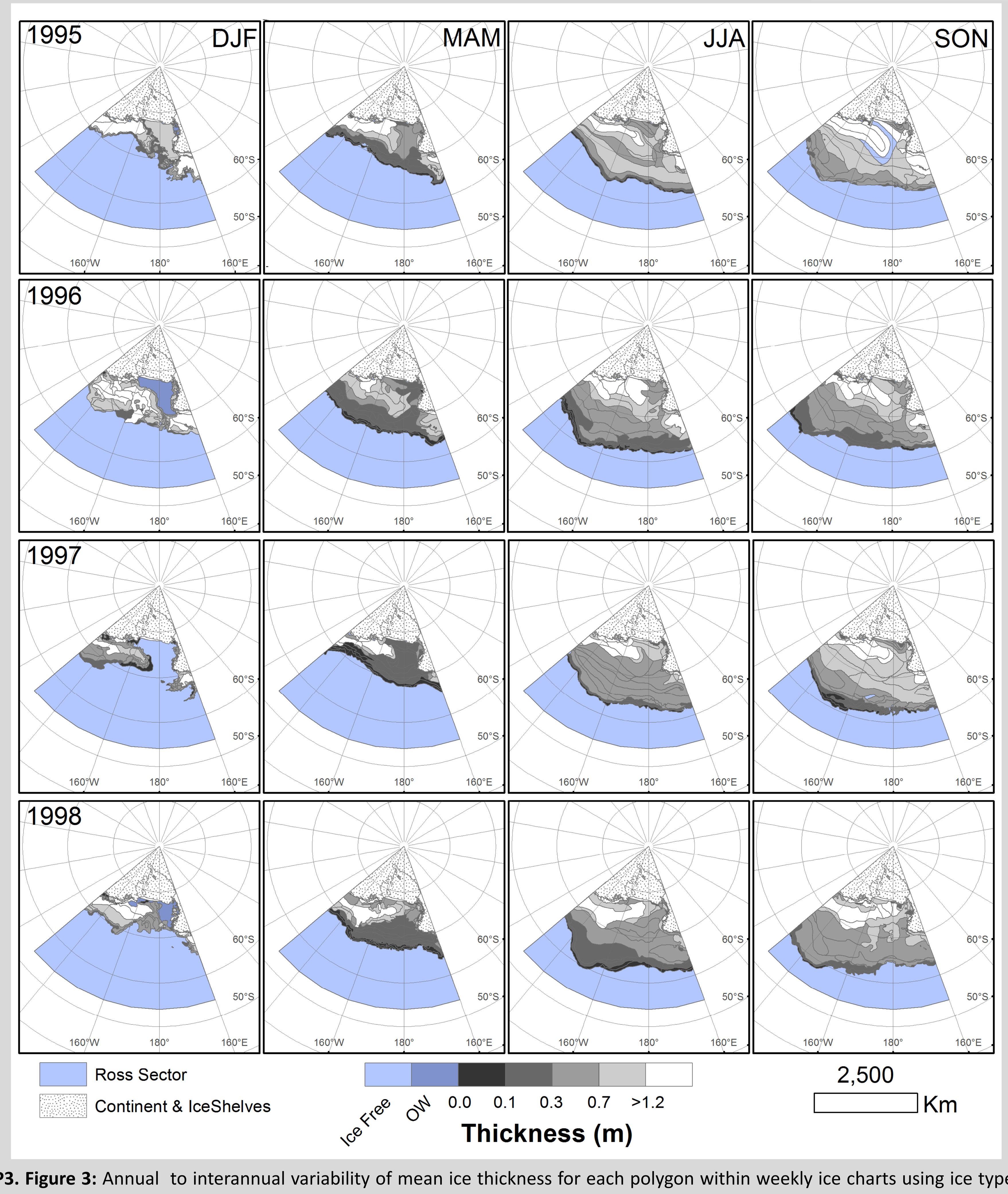


P3. Figure 1: Example from both data archives. May-June 1998 cruise over laid on an ice chart for the week of 1 June 1998. The segment of ship track coincident with ice chart dates is emphasized. Sample egg code shows properties within a sample polygon.

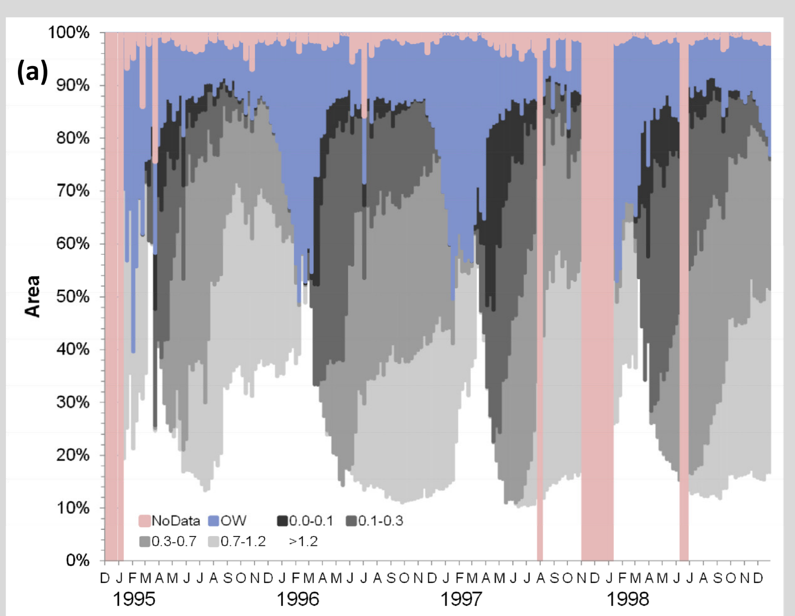


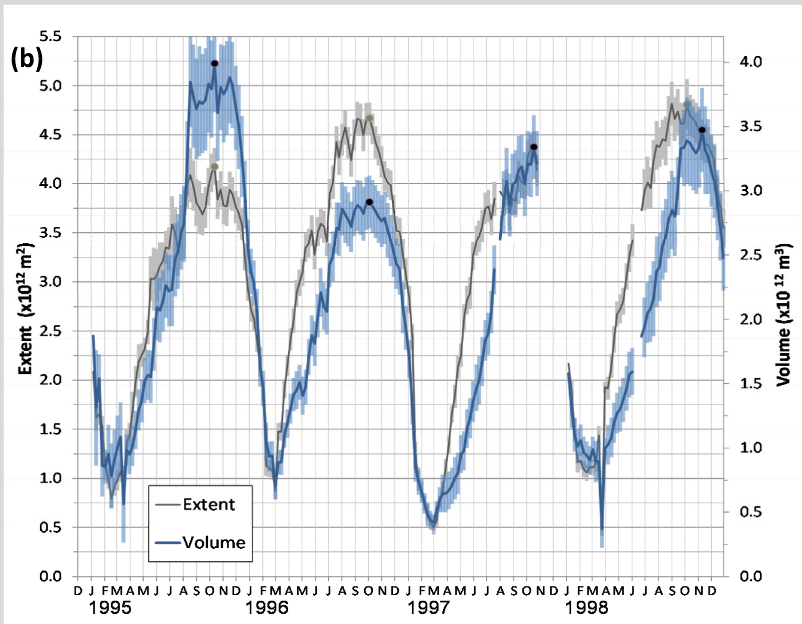


P3. Figure 2: Data quality. Panel (a) shows scatter plot comparing ship- and ice chart -derived ice thickness. Uncertainties developed in P1: Geiger (2006) and P2: Worby et al (2008). Panel (b) shows ship observations distributed in 0.10-m bins with panel (c) illustrating the same records re-binned into ice chart thickness ranges (solid black line). Panel (c) shows average and integrated thickness computed from distributions. Integrated method most effective as found in P6 and P7.



P3. Figure 3: Annual to interannual variability of mean ice thickness for each polygon within weekly ice charts using ice type as a proxy record. Each panel is a sample weekly ice chart in the middle of each season.





P3. Figure 4: Seasonal and interannual variability of sea ice thickness, extent, and volume for the Ross Sea from 1995-1998. Panel (a) shows four-year time series of weekly varying ice thickness distribution as a percentage of ice area. Panel (b) shows seasonal to interannual variability of sea ice extent and volume. By isolating the maximum volume and extent each year and computing their averages, both are aligned proportionally. Propagated uncertainties are shaded in their respective colors following methods developed in P1: Geiger (2006). The maximum extent and volume of each year marked with circle symbol to estimate phase lags between thickness and extent cycles.

SOUTHERN OCEAN CLIMATOLOGY (P6, P7)

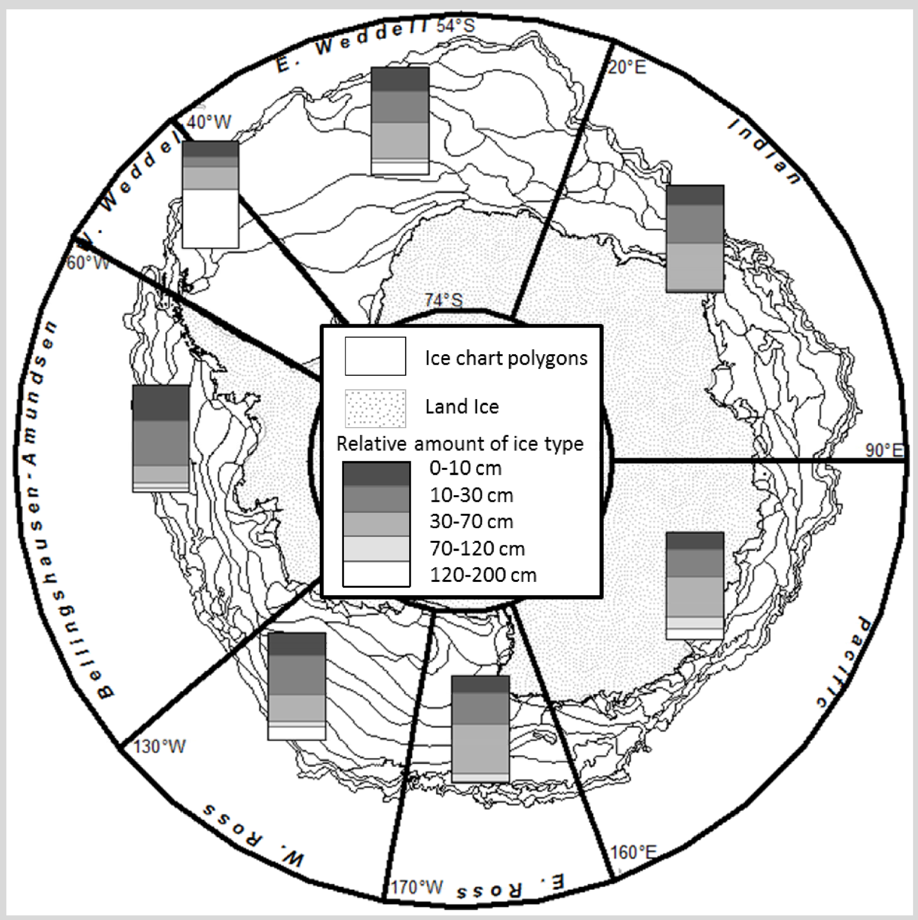


Figure 6: Example of ice thickness proxies from ice charts. Ice chart polygons contain sea ice stage-of-development information. Regions contain the relative amount of each range of sea ice thicknesses from a sample weekly ice chart by integrating relative ice thickness fractions from individual polygons to regional totals.

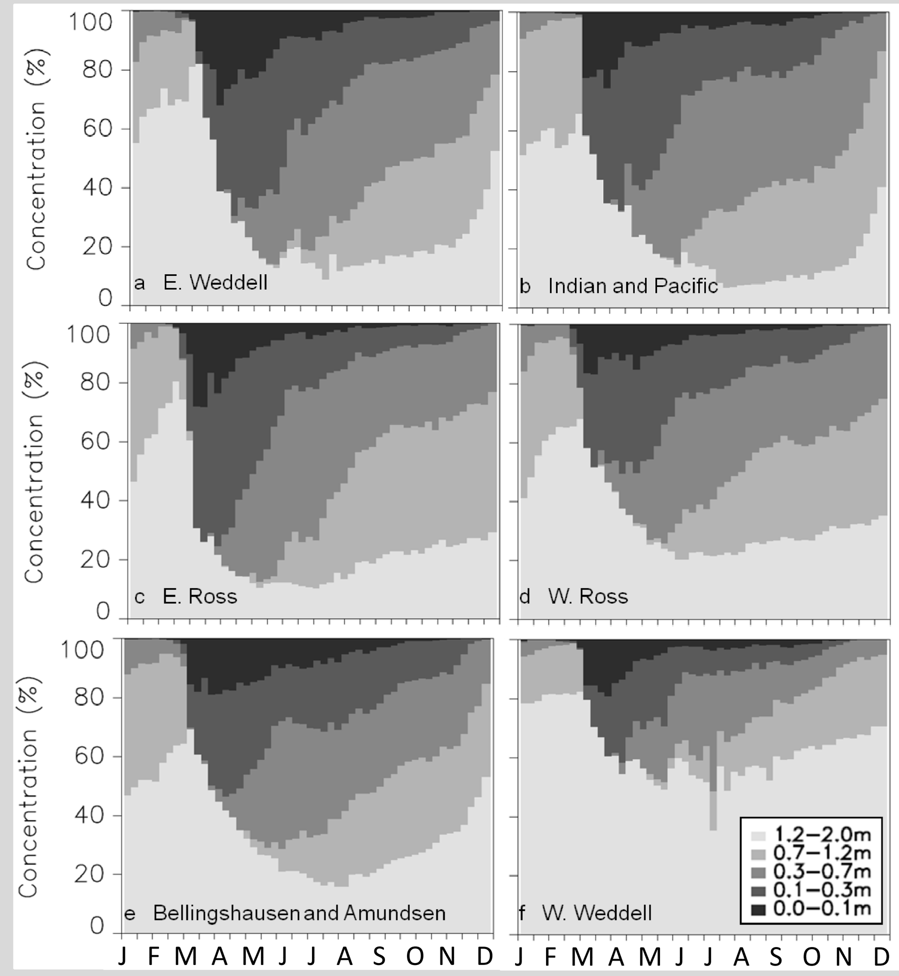


Figure 7: The climatology of thickness distribution by region. Plots of weekly thickness distribution to resolve the seasonal cycle of sea ice in regions of the Southern Ocean.

DATA CONSISTENCY & QUALITY (P4 – P7)

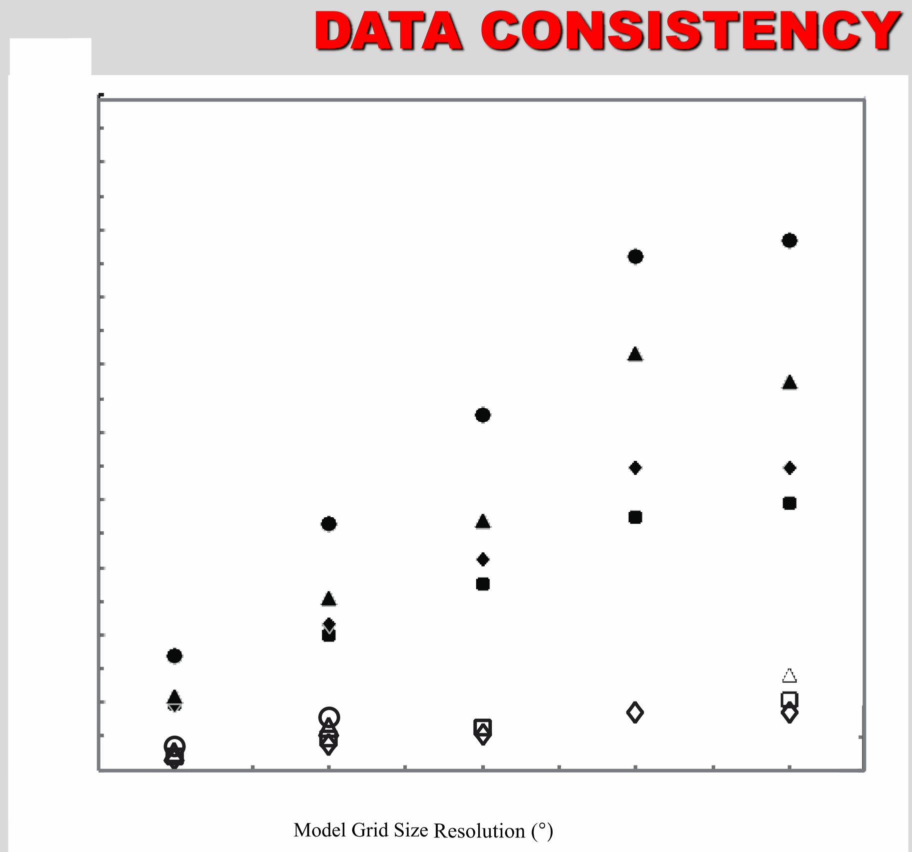


Figure 8: Testing data set quality for model grid resolutions. The comparison examines resolution errors between ship observations and ice charts as a function of seasons for summer (DJF), fall (MAM), winter (JJA), spring (SON).

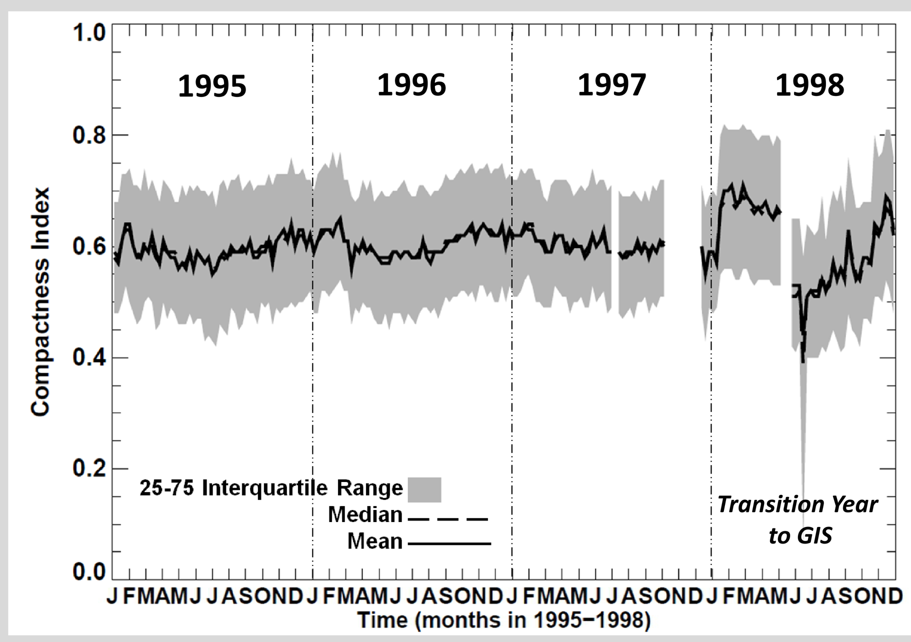


Figure 10: Consistency of ice charting. We use the measure of relative polygon shape as a metric to gauge ice chart consistency. Prior to the 1998 transition into electronic ice charts, there is a consistent mapping techniques in hand-drawn ice charts. The 1998 transition year clearly shows how changes in procedures alter this consistency. Analysis of new electronic chart practices are underway to evaluate consistency of charts from 1999-present and compare these to hand-drawn practices. These evaluations are critical to establishing the climatological value of ice charts for modeling applications.

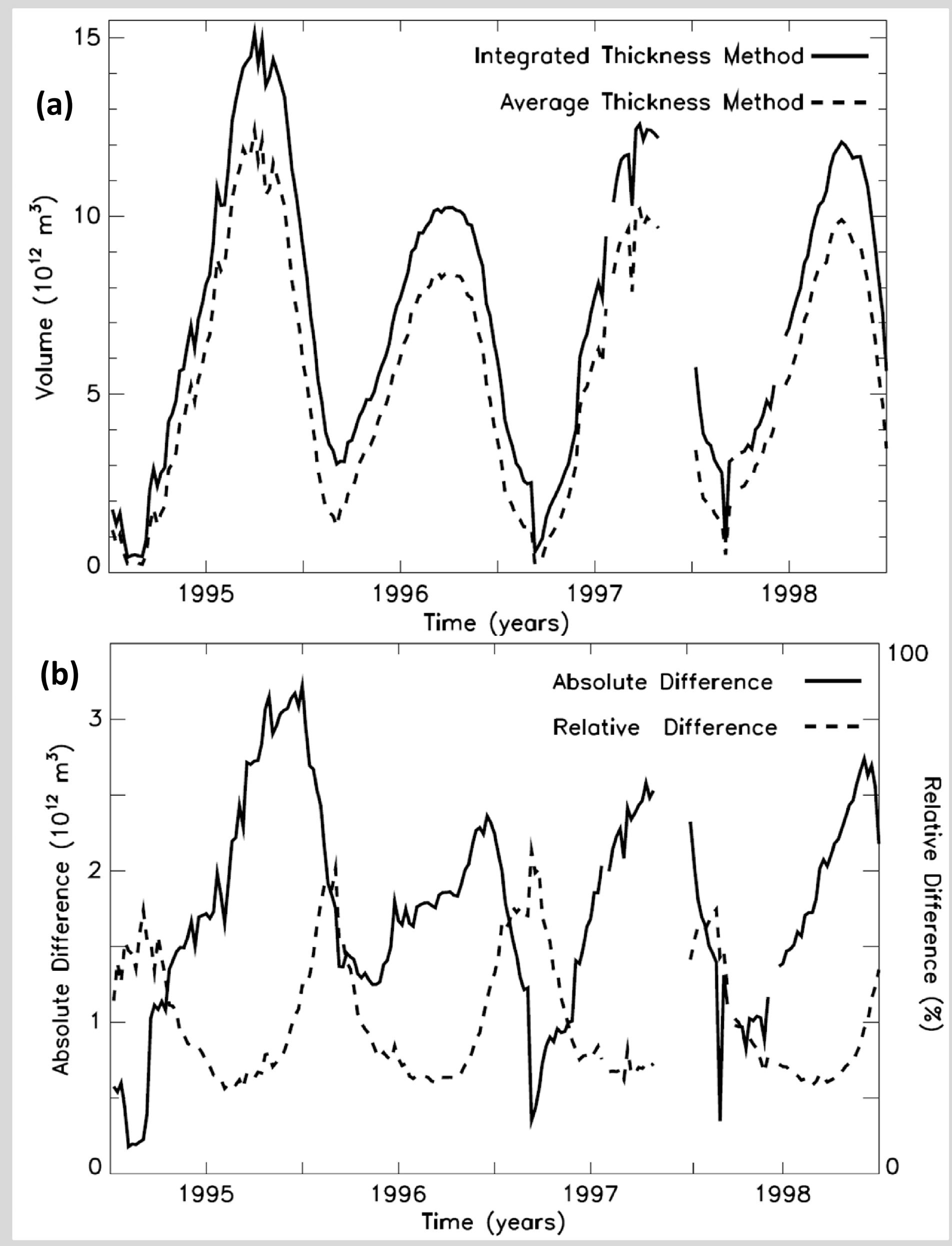


Figure 9: Impact on volume calculation when averaging thickness distribution versus retaining thickness distribution when upscaling. Because sea ice thickness is not normally distributed, the process of averaging decreases the total sea ice volume estimate with roughly a 25% relative underestimate in winter and over 50% relative underestimate at summer minimum growth.

SUMMARY

Through these studies, we continue to develop systematic methods to test and evaluate the efficacy of ice charts and ship observations as resources for climate studies. To date, there remains no routine global-coverage measurements of sea ice thickness from spaceborne or airborne instruments. These studies provide surrogate measurements which, when carefully bounded with documented uncertainities, provide both validation and evaluation of past and current conditions of sea ice which can one day be integrated with systematic global-coverage measurements.

Cited Publications

P1. Geiger, C. A. (2006), Propagation of Uncertainties in Sea Ice Thickness Calculations from Basin-Scale Operational Observations, ERDC/CRREL Technical Report TR-06-16, September 2006, 39 pp.

P2. Worby, A. P., C. A. Geiger, M. J. Paget, M. L. Van Woert, S. F. Ackley, and T. L. DeLiberty (2008), The thickness distribution of Antarctic sea ice, J. Geophys. Res. VOL. 113, C05S92, doi:10.1029/2007JC004254, 2008.

P3. Deliberty, T. D., C. A. Geiger, S. F. Ackley, A. P. Worby, M. VanWoert (2011), Estimating the annual cycle of sea ice thickness and volume in the Ross Sea, Deep Sea Research II: Topical Studies in Oceanography, Antarctic Sea Ice Research during the International Polar Year 2007-2009, vol 58, Issue 9-10, May 2011, Pages 1250-1260, doi:10.1016/j.dsr2.2010.12.005.

P4. Stampone, M. D. (2009), The sensitivity of CSIM5 sea-ice simulations to atmospheric state variables, Ph.D. Thesis in Geography/Climatology, University of Delaware, pp 155.

P5. Stampone, M. D., C. A. Geiger, E. R. Bernstein, T. L. DeLiberty (*upcoming submission*), Data-derived spatial-resolution errors of Antarctic sea-ice thickness, to *Polar Geography.*

P6. Bernstein, E. R. (2010), Sea ice thickness and the distribution contributing to the mass balance of the southern ocean, Master Thesis in Geography, University of Delaware, pp. 127.

P7. Bernstein, E. R., C. A. Geiger, T. DeLiberty, and M. D. Stampone (in preparation), Impact of retaining thickness distribution when computing sea ice volume estimates, to *Polar Geography*