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The Scientific Committee on Antarctic Research (SCAR) Selected Science Highlights for 2012/13

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1. Background

This Background Paper highlights some recent key science papers published since the last Treaty meeting and should be read in conjunction with the Information Paper "*The Scientific Committee on Antarctic Research (SCAR) Annual Report for 2012/13*". Although not highlighted below, the new ACCE update (also a SCAR Background Paper) should also be consulted. It should also be noted that this is by no way a complete list (there have been many highly significant papers published over the last year) but represents a sample of key science papers highlighted by SCAR groups.

2. Selected Antarctic and Southern Ocean Science Highlights (2012/13)

Climate Change:

a) Mayeswski et al (2012) show that the location and intensity of the austral westerlies strongly influence southern hemisphere precipitation and heat transport with consequences for human society and ecosystems. With future warming, global climate models project increased aridity in southern mid-latitudes related to continued poleward contraction of the austral westerlies. This manuscript shows that recent poleward migration of the westerlies coincident with increased emission of greenhouse gases and the Antarctic ozone hole has led to unprecedented penetration, compared with >100,000 years ago, of air masses bringing warmth, extra-Antarctic source dust and anthropogenic pollutants into West Antarctica

Mayewski, P.A., Maasch, K.A., Dixon, D., Sneed, S.B., Oglesby, R., Korotkikh, E., Potocki, M., Grigholm, B., Kreutz, K., Kurbatov, A.V., Spaulding, N., Stager, J.C., Taylor, K. C, Steig, E.J., White, J., Bertler, N.A.N., Goodwin, I., Simoñes, J.C., Jaña, R., Kraus, S., Fastook, J. 2013. West Antarctica's sensitivity to natural and human-forced climate change over the Holocene. Journal of Quaternary Science, 28 (1), 40-48. DOI: 10.1002/jqs.2593

b) Sea ice extent in the Ross Sea region has increased since 1979 AD. Sinclair et al. (2012) discusses the results of a 125-yr seasonally resolved ice core record from northern Ross Sea Region. While reconstructed mean annual temperatures show no significant change between 1882 and 2006, a cooling of the autumn/winter seasons (April–September) temperatures of -1.56 ± 0.84C/decade is observed since 1979. This cooling trend is in contrast to a surface temperature record from Ross Island (Scott Base) where significant spring warming is observed. The authors argue that the observed cooling is forced through the strengthening of Westerly Winds (positive trend of the Southern Annular Mode), which causes stronger southerly winds and increased sea ice extent and duration in the western Ross Sea.

Sinclair, K.E., Bertler, N.A.N. and van Ommen, T.D. 2012. Twentieth century surface temperature trends in the western Ross Sea, Antarctica: Evidence from a high resolution ice core, Journal of Climate, 25 (10), 3629-3636, doi: 10.1175/JCLI-D-11-00496.1

c) Changes in atmospheric circulation over the past five decades have enhanced the wind-driven inflow of warm ocean water onto the Antarctic continental shelf, where it melts ice shelves from below. Atmospheric circulation changes have also caused rapid warming over the West Antarctic Ice Sheet, and contributed to declining sea-ice cover in the adjacent Amundsen–Bellingshausen seas. Steig et al. (2013) use water-isotope ($\delta^{18}O$) data from an array of ice-core records to place recent West Antarctic climate changes in the context of the past two millennia.

Steig E. J., Q. Ding, J. W. C. White, M. Küttel, S. B. Rupper, T. A. Neumann, P. D. Neff, A. J. E. Gallant, P. A. Mayewski, K. C. Taylor, G. Hoffmann, D. A. Dixon, S. W. Schoenemann, B. R. Markle, T. J. Fudge, D. P. Schneider, A. J. Schauer, R. P. Teel, B. H. Vaughn, L. Burgener, J. Williams, E. Korotkikh. Recent climate

and ice-sheet changes in West Antarctica compared with the past 2,000 years. 2013. Nature Geoscience. doi:10.1038/ngeo1778

Past Climate:

a) The paper by Pross et al. (2012) provides information on the early Eocene (~52 million years ago) climate from lowland settings along the Antarctic Wilkes Land coast of East Antarctica. Early Eocene climate supported near-tropical forests including palms and Bombacoideae (equivalent to today's Baobabs). Winters were extremely mild (warmer than 10°C) and frost-free, despite polar darkness. These new findings provide new constraints for the validation of climate models, for understanding the response of high-latitude terrestrial ecosystems to increased carbon dioxide forcing, and therefore provide insights into the response of Earth's climate and biosphere to the high atmospheric carbon dioxide levels that are expected in the future.

Pross, J., Contreras, L., Bijl, P.K., Greenwood, D.R., Bohaty, S.M., Schouten, S., Bendle, J.A., Röhl, U.,Tauxe, L., Raine, J.I., Huck, C.E., van de Flierdt, T., Jamieson, S.S.R., Stickley, C.E., van de Schootbrugge, B., Escutia, C., Brinkhuis, H., and IODP Expedition 318 Scientists. Persistent near-tropical warmth on the Antarctic continent during the early Eocene epoch. Nature Vol 488, No. 7409: 73-77, doi:10.1038/nature11300.

b) Over the past 50 years, warming of the Antarctic Peninsula has been accompanied by accelerating glacier mass loss and the retreat and collapse of ice shelves. A key driver of ice loss is summer melting; however, it is not usually possible to specifically reconstruct the summer conditions that are critical for determining ice melt in Antarctic. Abram et al. (2013) reconstruct changes in ice-melt intensity and mean temperature on the northern Antarctic Peninsula since AD 1000 based on the identification of visible melt layers in the James Ross Island ice core and local mean annual temperature estimates from the deuterium content of the ice. They conclude that ice on the Antarctic Peninsula is now particularly susceptible to rapid increases in melting and loss in response to relatively small increases in mean temperature.

Abram N. J., Robert Mulvaney, Eric W. Wolff, Jack Triest, Sepp Kipfstuhl, Luke D. Trusel, Françoise Vimeux, Louise Fleet & Carol Arrowsmith. 2013. Acceleration of snow melt in an Antarctic Peninsula ice core during the twentieth century. Nature Geoscience. doi:10.1038/ngeo1787

Ice Sheet Mass Balance:

The recent study of Shepherd et al. (2012) reconciled the various satellite-derived estimates of changes in the mass of the Antarctic ice sheet and also estimated the contribution to sea level rise. They found that over the period 1992–2011 the Antarctic Peninsula, West Antarctica and East Antarctica have respectively contributed +0.05±0.04, +0.18±0.07 and -0.04±0.12 mm per year to global sea level rise. Combined this gives a contribution from the whole Antarctic ice sheet of +0.20±0.15 mm per year, which compares to +0.39±0.14 mm per year from the Greenland ice sheet.

Shepherd, A., Ivins, E. R., Geruo, A., Barletta, V. R., Bentley, M. J., Bettadpur, S., Briggs, K. H., Bromwich, D. H., Forsberg, R., Galin, N., Horwath, M., Jacobs, S., Joughin, I., King, M. A., Lenaerts, J. T. M., Li, J. L., Ligtenberg, S. R. M., Luckman, A., Luthcke, S. B., McMillan, M., Meister, R., Milne, G., Mouginot, J., Muir, A., Nicolas, J. P., Paden, J., Payne, A. J., Pritchard, H., Rignot, E., Rott, H., Sorensen, L. S., Scambos, T. A., Scheuchl, B., Schrama, E. J. O., Smith, B., Sundal, A. V., van Angelen, J. H., van de Berg, W. J., Van den Broeke, M. R., Vaughan, D. G., Velicogna, I., Wahr, J., Whitehouse, P. L., Wingham, D. J., Yi, D. H., Young, D., and Zwally, H. J. A Reconciled Estimate of Ice-Sheet Mass Balance. Science 338(6111), 1183-1189. 30-11-2012.

Mapping of the Antarctic Bedrock:

The recently published Bedmap2 paper (Fretwell et al., 2013) represents a significant contribution to Antarctic Science mainly because using a higher resolution and multiple data set this work reports a nearly 5% increase in ice-volume from previous estimates. Similarly, there is a significant revision in the bed-rock level leading to an increased volume of ice below sea-level.

P. Fretwell, H. D. Pritchard, D. G. Vaughan, J. L. Bamber, N. E. Barrand, R. Bell, C. Bianchi, R. G. Bingham, D. D. Blankenship, G. Casassa, G. Catania, D. Callens, H. Conway, A. J. Cook, H. F. J. Corr, D. Damaske, V. Damm, F. Ferraccioli, R. Forsberg, S. Fujita, Y. Gim, P. Gogineni, J. A. Griggs, R. C. A. Hindmarsh, P. Holmlund, J. W. Holt, R. W. Jacobel, A. Jenkins, W. Jokat, T. Jordan, E. C. King, J. Kohler, W. Krabill, M. Riger-Kusk, K. A. Langley, G. Leitchenkov, C. Leuschen, B. P. Luyendy, K. Matsuoka, J. Mouginot, F. O. Nitsche, Y. Nogi, O. A. Nost, S. V. Popov, E. Rignot, D. M. Rippin, A. Rivera, J. Roberts, N. Ross, M. J. Siegert, A. M. Smith, D. Steinhage, M. Studinger, B. Sun, B. K.Tinto, B. C. Welch, D. Wilson, D. A. Young, C. Xiangbin, and A. Zirizzotti. 2013. Bedmap2: improved ice bed, surface and thickness datasets for Antarctica. The Cryosphere, 7, 375–393, 2013 www.the-cryosphere.net/7/375/2013/, doi:10.5194/tc-7-375-2013

The Southern Ocean:

(a) Bednaršek et al. (2012) represents a key paper on the effects of Ocean acidification in the Southern Ocean. As deep-water upwelling and CO_2 absorption by surface waters is likely to increase as a result of human activities, they concluded that upper ocean regions where aragonite-shelled organisms are affected by dissolution are likely to expand.

Bednaršek, N., Tarling, G. A., Bakker, D. C. E., Fielding, S., Jones, E. M., Venables, H. J., Ward, P., Kuzirian, A., Lézé, B., Feely, R. A., Murphy, E.J. 2012 Extensive dissolution of live pteropods in the Southern Ocean. Nature Geoscience, 5 (12). 881-885. 10.1038/NGEO1635

(b) Costa et al. (2012) review the advances made in our ability to study highly pelagic large marine vertebrates. While the review is global it highlights work being carried out in the Antarctic, especially the thriving field of using animals as ocean sensors. Studies enabled by new technologies now allow us to follow the movements of marine vertebrates over great distances and long time periods in great detail. Providing detailed characteristics of the habitats they use and clues to their navigation abilities. Together these tools are providing critical insights into the ecology of highly pelagic marine vertebrates that are key for their conservation and management.

Costa, D.P., G. A. Breed, P. W. Robinson. 2012. Annual Review of Ecology, Evolution and Systematics. 43:7 3–96.

(c) The paper by Murphy et al. (2012) considers the main ecological and modelling challenges in predicting the responses of Southern Ocean ecosystems to change, and proposes three interlinked focus areas that will advance the development of integrated models for Southern Ocean ecosystems.

E.J. Murphy, R.D. Cavanagh, E.E. Hofmann, S.L. Hill, A.J. Constable, D.P. Costa, M.H. Pinkerton, N.M. Johnston, P.N. Trathan, J.M. Klinck, D.A. Wolf-Gladrow, K.L. Daly, O. Maury, S.C. Doney. 2012. Developing integrated models of Southern Ocean food webs: Including ecological complexity, accounting for uncertainty and the importance of scale. Progress in Oceanography, 2012, 102 (SI), p. 74-92.

Terrestrial Ecosystems:

The polar regions are experiencing rapid climate change with implications for terrestrial ecosystems. This paper makes some important early predictions on soil invertebrate community responses to predicted twenty-first century climate change. It suggests that climate amelioration is likely to allow a greater influx of non-

native species into both the Arctic and Antarctic promoting landscape scale biodiversity change.

U. N. Nielsen and D. H.Wall. 2012. The future of soil invertebrate communities in polar regions: different climate change responses in the Arctic and Antarctic? Ecology Letters, 16: 409–419 doi: 10.1111/ele.12058

Conservation in the Antarctic:

A major highlight in the Antarctic conservation literature has been the Conservation and governance horizon scanning exercise reported in the Chown et al. (2012) Science paper. The is an authoritative attempt to identify future challenges to the Antarctic Treaty System and continental governance in advance of them actually happening:

Chown, S. L., J. E. Lee, K. A. Hughes, J. Barnes, P. J. Barrett, D. M. Bergstrom, P. Convey, D. A. Cowan, K. Crosbie, G. Dyer, Y. Frenot, S. M. Grant, D. Herr, M. C. Kennicutt, II, M. Lamers, A. Murray, H. P. Possingham, K. Reid, M. J. Riddle, P. G. Ryan, L. Sanson, J. D. Shaw, M. D. Sparrow, C. Summerhayes, A. Terauds, D. H. Wall, Challenges to the Future Conservation of the Antarctic, Science, Vol 337, 13 July 2012

Astronomy and Astrophysics:

The origin of ultra high energy cosmic rays is one of the great unsolved mysteries of modern astrophysics. Gamma-Ray Burst (GRB) sources currently offer the leading explanation; if they are indeed responsible then significant numbers of TeV neutrinos should also be produced. However, analyses of two years of data from the IceCube detector at South Pole Station have produced no evidence of this neutrino flux - further deepening the mystery.

IceCube Collaboration (R. Abbasi et al.). 2012.An absence of neutrinos associated with cosmic-ray acceleration in γ-ray bursts, Apr 2012. 6 pp. Nature 484. 351-353 DOI: 10.1038/nature11068. e-Print: arXiv:1204.4219