

10-5-2009

US ITASE Glaciochemistry Phase 2: East Antarctica

Paul Mayewski

Principal Investigator; University of Maine, Orono, paul.mayewski@maine.edu

Follow this and additional works at: https://digitalcommons.library.umaine.edu/orsp_reports



Part of the [Climate Commons](#), and the [Glaciology Commons](#)

Recommended Citation

Mayewski, Paul, "US ITASE Glaciochemistry Phase 2: East Antarctica" (2009). *University of Maine Office of Research and Sponsored Programs: Grant Reports*. 305.

https://digitalcommons.library.umaine.edu/orsp_reports/305

This Open-Access Report is brought to you for free and open access by DigitalCommons@UMaine. It has been accepted for inclusion in University of Maine Office of Research and Sponsored Programs: Grant Reports by an authorized administrator of DigitalCommons@UMaine. For more information, please contact um.library.technical.services@maine.edu.

Final Report for Period: 09/2008 - 08/2009

Submitted on: 10/05/2009

Principal Investigator: Mayewski, Paul A.

Award ID: 0439589

Organization: University of Maine

Submitted By:

Mayewski, Paul - Principal Investigator

Title:

US ITASE Glaciochemistry Phase 2: East Antarctica

Project Participants

Senior Personnel

Name: Mayewski, Paul

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Maasch, Kirk

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Kurbatov, Andrei

Worked for more than 160 Hours: Yes

Contribution to Project:

Software development, core processing techniques, field planning.

Post-doc

Graduate Student

Name: Dixon, Daniel

Worked for more than 160 Hours: Yes

Contribution to Project:

Ice core processing and analysis

Name: Korotkikh, Elena

Worked for more than 160 Hours: Yes

Contribution to Project:

Field assistant

Name: Spaulding, Nicole

Worked for more than 160 Hours: Yes

Contribution to Project:

Field assistant

Undergraduate Student

Technician, Programmer

Name: Sneed, Sharon

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinates and runs major ion and MS analyses

Name: Handley, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinates and runs trace element analyses

Other Participant

Research Experience for Undergraduates

Organizational Partners

University of Washington

Collaboration in field and sharing of data.

St. Olaf College

Collaboration in field and sharing of data.

CRREL

Collaboration in field and sharing of data.

British Antarctic Survey

We have had extensive collaboration with John Turner and others at the British Antarctic Survey. BAS has provided access to ERA40 climate reanalysis products and helpful discussions related to current Antarctic climate.

University of Nebraska Lincoln

Bob Oglesby, University of Nebraska Lincoln, has offered advice and computer software related to our Antarctic climate modeling efforts.

Victoria University of Wellington

Nancy Bertler, Victoria University, has shared ice core data collected by her program to use in compilations dedicated to understanding climate change over the Ross Sea embayment.

Other Collaborators or Contacts

21 national programs associated with ITASE for details see:
www.climatechange.umaine.edu/itase

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

We have considerably enhanced our ice core processing and ppq level detection analytical capabilities in order to address the lower level concentrations we will find in East Antarctica during US ITASE phase 2. This work has great benefits for our other ice core projects as well as teaching and student research.

Dan Dixon's and Sharon Sneed's PhD (expected 2009 and 2010/11, respectively) are based on US ITASE field and analytical research.

Outreach Activities:

Daniel Dixon (PhD student supported by this project) and Sharon Sneed (PhD student using data from this project) have given presentations of US ITASE results to our Institute, local audiences (K-12 and public), at scientific meetings including AGU, Beijing, and Florida, and at our Institute's yearly Climate Change Day.

Paul Andrew Mayewski (PI) has given numerous public presentations (eg., Audubon Society, local towns), invited lectures at professional venues (eg., SCAR, PAGES) and represented ITASE and US ITASE at SCAR AGCS meetings. He has also appeared regularly in the media (eg., CBS 60 Minutes, NOVA, Downeast and Metro Magazines).

Journal Publications

Schneider, D. P., E. J. Steig, T. D. van Ommen, D. A. Dixon, P. A. Mayewski, J. M. Jones, and C. M. Bitz, "Antarctic temperatures over the past two centuries from ice cores", *Geophys. Res. Lett.*, p. L16707, vol. 33, (2006). Published,

Bertler, N.A.M, Naish, T. R., Mayewski, P.A., and Barrett, P.J., "Opposing oceanic and atmospheric ENSO influences on the Ross Sea Region, Antarctica", *Advances in Geoscience*, p. 83, vol. 6, (2006). Published,

Gao, C., A. Robock, S. Self, J. B. Witter, J. P. Steffenson, H. B. Clausen, M. Siggaard-Andersen, S. Johnsen, P. A. Mayewski, and C. Ammann, "The 1452 or 1453 A.D. Kuwae eruption signal derived from multiple ice core records: Greatest volcanic sulfate event of the past 700 years", *J. Geophys. Res.*, p. 6710, vol. 111, (2006). Published,

Mayewski, P.A. and Maasch, K., "Recent warming inconsistent with natural association between temperature and atmospheric circulation over the last 2000 years", *Climate of the Past (Discussions)*, on line: <http://www.copernicus.org/EGU/cp/cpd/2/327/cpd-2-327.htm>, p. 327, vol. 2, (2006). Published,

Monaghan, A. J., D. H. Bromwich, R. L. Fogt, S.-H. Wang, P. A. Mayewski, D. A. Dixon, A. A. Ekaykin, M. Frezzotti, I. D. Goodwin, E. Isaksson, S. D. Kaspari, V. I. Morgan, H. Oerter, T. D. van Ommen, C. J. van der Veen, and J. Wen, "Insignificant change in Antarctic snowfall since the International Geophysical Year", *Science*, p. 827, vol. 313, (2006). Published,

AGCS (P.A. Mayewski, M. Meredith, C. Summerhayes, J. Turner, S. Aoki, Barrett, P. N.A.N. Bertler, T. Bracegirdle, D. Bromwich, H. Campbell, G. Casassa, A. N. Garabato, W.B. Lyons, K.A. Maasch, A. Worby, C. Xiao), "State of the Antarctic and Southern Ocean Climate System (SASOCS)", *Reviews of Geophysics*, p. , vol. 47, (2009). Published, 10.1029/2007RG000231

Witherow, R.A., Lyons, W.B., Bertler, N.A.N., Welch, K.A., Mayewski, P.A., Sneed, S. B., Nylén, T., Handley, M.J. and Fountain, A., "The Aeolian flux of calcium, chloride, and nitrate to the McMurdo Dry Valleys landscape: evidence from snow pit analyses", *Antarctic Science*, p. 497, vol. 18, (2006). Published,

P. A. Mayewski, "Venturing to the Ends of the Earth - Exploring our planet's polar regions' chroniclers of the past and portents of the future", *Explores Club Journal*, p. 22, vol. 3, (2007). Published,

Williamson, B.R., Kreutz, K.J., Mayewski, P.A., Bertler, N.A.N., Sneed, S., Handley, M., and Introne, D., "A coastal transect of the McMurdo Dry Valleys (Antarctica) snow and firn: marine and terrestrial influences on glaciochemistry", *Journal of Glaciology*, p. 681, vol. 53, (2007). Published,

editors J.T. Turner, P. Convey, G. di Prisco, P.A. Mayewski, D. Hodgson, E. Fahrbach, R. Bindshadler, C. Summerhayes, "ACCE (Antarctic Climate Change and the Environment)", SCAR Publication, p. , vol. , (2009). Accepted,

Hodgson DA, Abram N, Anderson J, Bargelloni L, Barrett P, Bentley MJ, Bertler NAN, Chown S, Clarke A, Convey P, Crame A, Crosta X, Curran M, di Prisco G, Francis, J.E., Goodwin I, Gutt J, Masson-Delmotte V, Mayewski PA, Mulvaney R, Peck L., "Antarctic climate and environmental history in the pre-instrumental period. In: Turner J, Convey P, di Prisco G, Mayewski PA, Hodgson DA, Fahrbach E, Bindshadler R (eds) *Antarctic Climate Change and the Environment*", SCAR Publication, p. , vol. , (2009). Accepted,

John Turner, Rob Arthern, David Bromwich, Gareth Marshall, Tony Worby, James Bockheim, Guido di Prisco, Cinzia Verde, Pete Convey, Howard Roscoe, Anna Jones, David Vaughan, Philip Woodworth, Ted Scambos, Alison Cook, Andrew Lenton, Josifino Comiso, "The instrumental period, In: Turner J, Convey P, di Prisco G, Mayewski PA, Hodgson DA, Fahrbach E, Bindshadler R (eds) *Antarctic Climate Change and the Environment*", SCAR Publication, p. , vol. , (2009). Accepted,

John Turner, Jonathan Shanklin, Mike Sparrow, Rob Arthern, Andrew Fleming, David Bromwich, Gareth Marshall, Tony Worby, James Bockheim, Guido di Prisco, Cinzia Verde, Pete Convey, Zhaomin Wang, Howard Roscoe, Anna Jones, David Vaughan, Philip Woodwo, "Observations, data accuracy and tools, In: Turner J, Convey P, di Prisco G, Mayewski PA, Hodgson DA, Fahrbach E, Bindschadler R (eds) Antarctic Climate Change and the Environment", SCAR Publication, p. , vol. , (2009). Accepted,

Dixon, D. A., Mayewski, P.A., Freeman, R., Goodwin, I., Maasch, K.A., Sneed, S.B., "Long term behavior of the Southern Hemisphere westerlies", Journal of Glaciology, p. , vol. , (2009). Submitted,

Spaulding, N., Meese, D., Baker, I., Mayewski, P.A. and Hamilton, G., "A new technique for firn grain size measurements", Journal of Glaciology, p. , vol. , (2009). Submitted,

Convey, P. Turner, J., DiPrisco, G., Mayewski, P.A., Hodgson, D.A., Fahrbach, E., Bindschadler, R., Gutt, J. and Summerhayes, C., "Antarctic climate change and the environment", Antarctic Science, p. , vol. , (2009). Accepted,

Books or Other One-time Publications

Web/Internet Site

URL(s):

<http://www2.umaine.edu/USITASE>
<http://www.icereader.org/icereader/>
<http://nsidc.org/data/nsidc-0273.html>

Description:

Description:

<http://www2.umaine.edu/USITASE>

The US ITASE site is maintained by the Climate Change Institute, University of Maine, as the official science web site. Science and Implementation Plans, links to researchers, abstracts of projects, field reports, and draft proposals are all available here. Daily logs and photos from the team for the 6 years they were in the field are archived here for use by schools and the general public. An extensive Teacher's Resource section including activities and lesson plans is here as well.

<http://www.icereader.org/icereader/IceREADER> contains metadata and data thus far available from ITASE and other Antarctic ice cores.

IceREADER was established by the Climate Change Institute, University of Maine, at the request of SCAR.

<http://nsidc.org/data/nsidc-0273.html> contains US International Trans-Antarctic Scientific Expedition (US ITASE) Glaciochemical Data.

All data are listed here:

ftp://sidacs.colorado.edu/pub/DATASETS/AGDC/dixon_nsidc_0273/

Other Specific Products

Contributions

Contributions within Discipline:

We pioneered new techniques for the processing of ice cores that allow detection of uncontaminated samples at ppq levels.

We pioneered ice core dating software designed to create a depth-age scale from ice core glaciochemical records. It reads data from comma separated files that contain depth vs. concentration of elements information. The user selects the elements to plot, and then dynamically performs the dating process. The User generates a report at the end of the process that contains depth-age information. For details see:

<http://www.climatechange.umaine.edu/Research/software/index.html>

Contributions to Other Disciplines:

US ITASE provides a climate framework for several other disciplines interested in Antarctic climate change (eg., biology, glaciology, oceanography).

US ITASE research contributed significantly to the SCAR AGCS document: 'State of the Antarctic and Southern Ocean Climate System (SASOCS)' and to the forthcoming SCAR document: 'Antarctic Climate Change and the Environment (ACCE)'.

Contributions to Human Resource Development:

US ITASE field experiences, resulting analytical and cyberinfrastructure experiences, and scientific interpretations have contributed significantly to the career development of several graduate students who represent the next generation of scientists.

Contributions to Resources for Research and Education:

The Climate Change Institute at the University of Maine is the home institution for this project and for SCAR Ice READER - a web based ice core meta data base.

Contributions Beyond Science and Engineering:

Understanding Antarctica's role in global climate change is essential to climate prediction. As a scientific community we now realize that Antarctica is responding to both long term natural forcing and more recent tropospheric and stratospheric based greenhouse gas forcing. The rate of change appears to be increasing with serious implications for attendant changes in hemispheric to global scale atmosphere and ocean circulation. Some of the most immediate responses to changes in Antarctic climate include recent drought in Australia, changes in glacier mass balance and sea level, and changes in ocean chemistry and temperature.

Conference Proceedings**Categories for which nothing is reported:**

Any Book
Any Product
Any Conference

Recent Major Findings:

Synthesis of the US ITASE spatial array of ice cores is providing new insights concerning recent (last 200-1000 years) of climate change. The most recent investigations provide perspective with respect to changes in: (1) characteristics of westerly (zonal) flow around the continent and (2) sea ice extent as follows:

(1) Despite Antarctica's remote location the impact of human activity is becoming increasingly evident. Greenhouse gas induced warming and ozone depletion are both changing the dynamics of high-latitude Southern Hemisphere climate, notably the strength of the Southern Hemisphere circumpolar westerly wind (SHW). Correlation between NCEP reanalysis data and nssCa in US ITASE ice cores demonstrates that nssCa is positively correlated with changes in the 850 mb pressure field surrounding Antarctica. Examination of the spatial distribution of nssCa for US ITASE ice core records covering East and West Antarctica reveals change in the intensity of the westerly wind field as early as the mid-19th century with greatest intensification in recent decades (fig. 1).

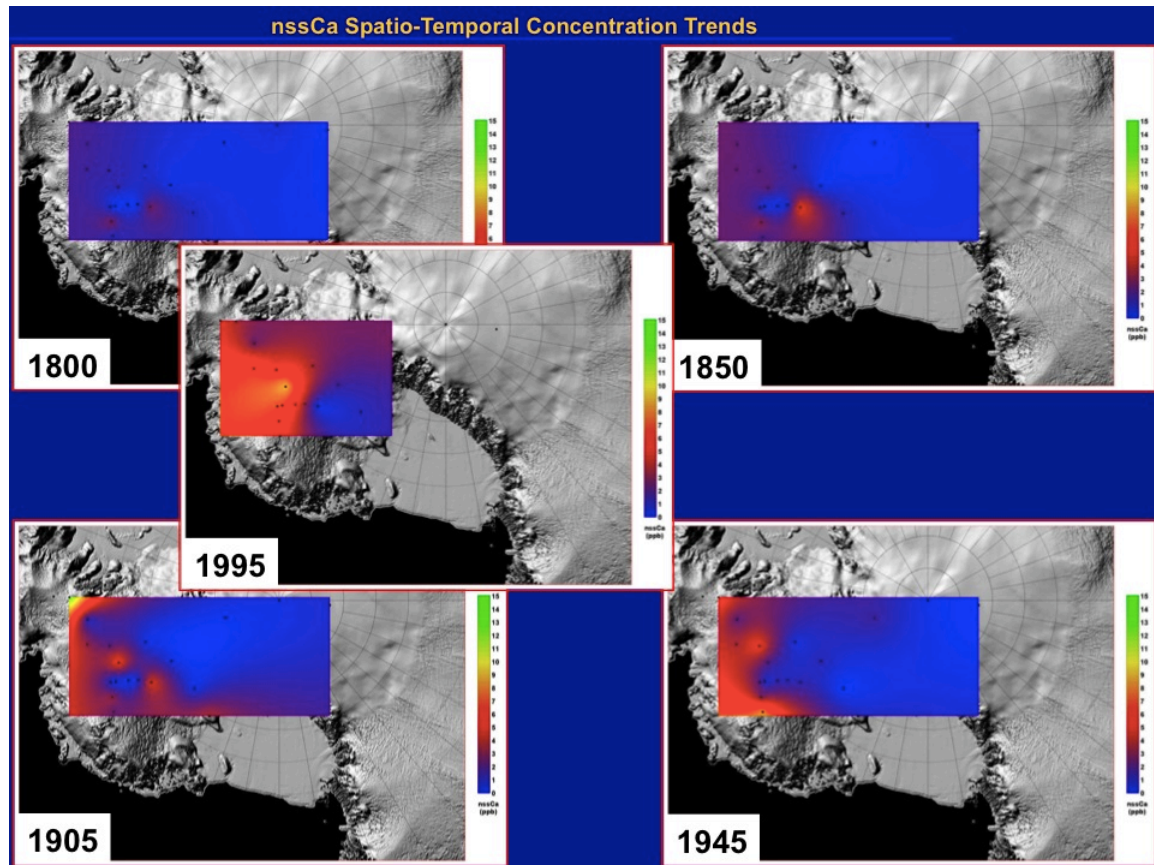
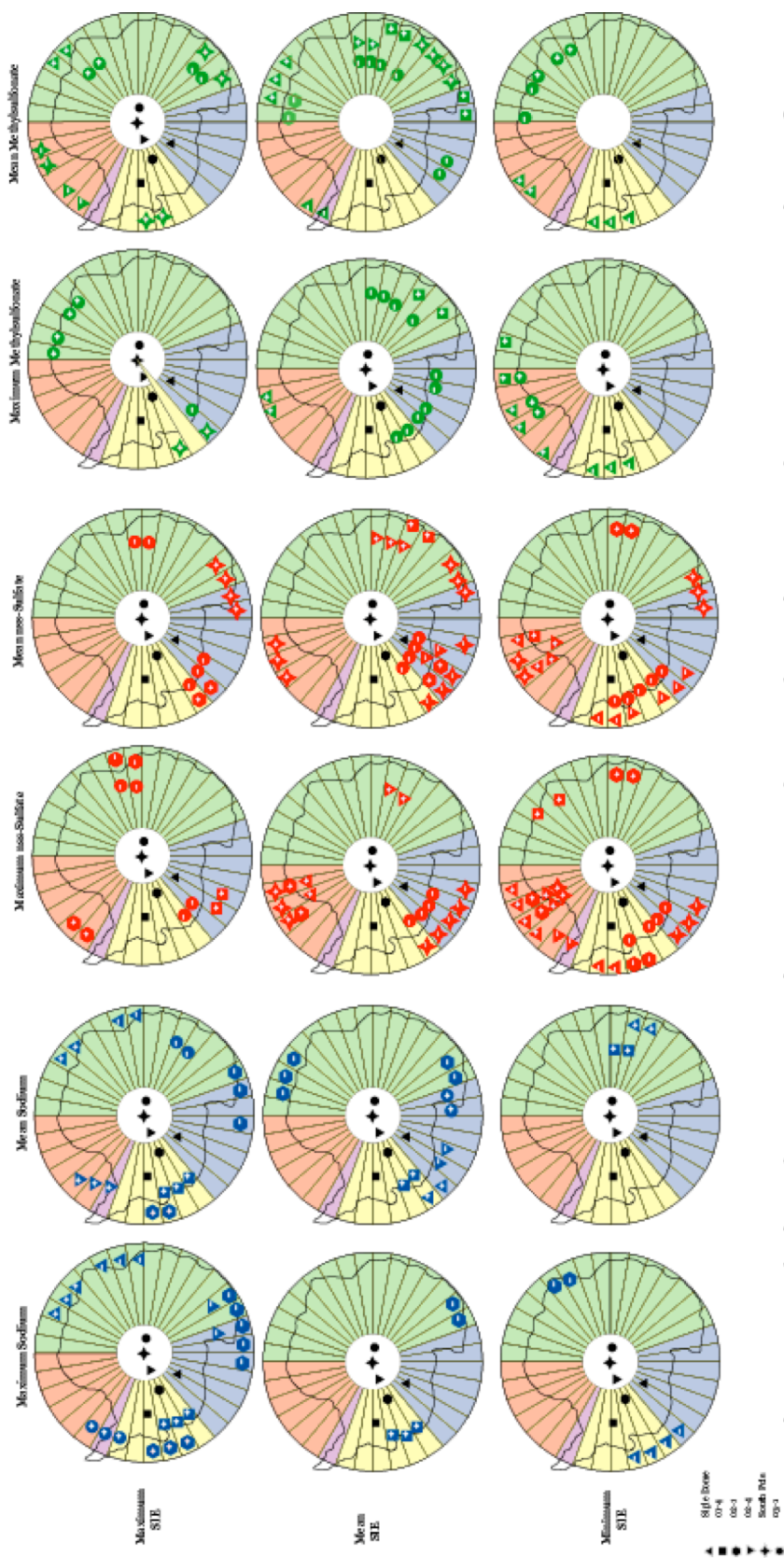


Figure 1 – Snapshots in time of change in nssCa (ppb) summarized from an array of annually resolved ice cores (black dots). Blue (no change) and red (increase).

Since the source of nssCa is dust, primarily from extra-Antarctic regions such as South America and Australia), and nssCa is a proxy for westerly flow (as noted by our previous work reported in Yan et al., 2006) the increase in nssCa represents intensification of

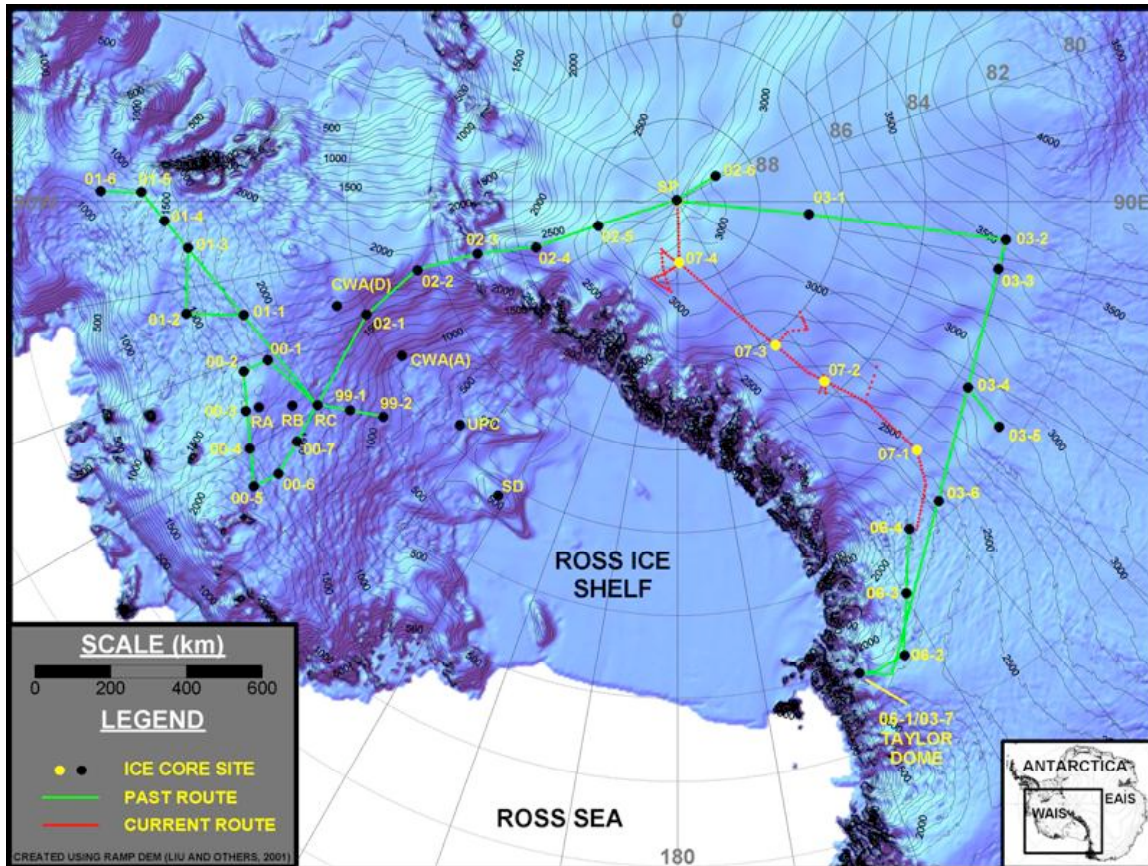
westerly flow surrounding Antarctica and possibly migration of the region of westerly flow southward (contraction of the polar vortex). Our interpretation (Dixon et. al., in review) supports the finding that the westerlies are speeding up and moving closer to Antarctica as suggested by D. Thompson and S. Solomon (2002) consistent with changes in the thermal gradient induced by lower stratospheric ozone depletion. Our findings demonstrate, however, that the westerly flow regime change started earlier than would have due solely to CFC impacted ozone depletion and is therefore also consistent with changes in circulation reported by Mayewski et al. (2005) related to change in solar variability and the initial phases of greenhouse gas rise. Our finding that nssCa (westerly proxy) levels increase most markedly in recent decades suggests that the most recent and intense change in the westerlies is consistent with the importance of the impact of ozone depletion. The nssCa example presented here demonstrates that both natural and anthropogenically forced change in climate must be considered in examining current change over Antarctica. In addition our SHW proxy shows that intensification since ~1980 is unprecedented for at least the last 5400 years by extrapolation into the Siple Dome deep ice core record. Also demonstrated is the potential for SH atmospheric circulation to shift abruptly from an enhanced state as exists today to a relatively weak state. Such weakening of the SHW could hasten Antarctic warming and have significant impacts on future SH climate and sea level. Modelling activities to be conducted in the near future will address this potential.

(2) The seasonal to decadal scale and longer growth and retreat of Antarctic sea ice imparts significant changes in deep ocean water formation and ventilation, albedo and subsequent feedback loops, and both primary production and phytoplankton blooms. Variability in sea ice is assessed by determining extent from the continent, duration, areal extent, and amount of adjacent open water. In all cases measurements are significantly more accurate and extensive since the implementation of satellite observations. Antarctic ice cores provide a valuable proxy record of past climate. The primary proxies used for sea ice reconstruction are sodium, non-sea salt sulfate, and methanesulfonic acid. These are routinely measured using ion chromatography at the ppb level. Sodium is representative of sea salt inputs and is preserved and measured in ice cores as Na^+ . Sources of non-sea salt sulfate (nssSO_4^{2-}) include atmospheric inputs (natural and anthropogenic), biogenic contributions, and volcanic emissions. Breakdown of phytoplankton cells and subsequent oxidation reactions is the only source of methanesulfonic acid in Antarctica and it is preserved and measured in ice cores as methylsulfonate (MS^-). To better understand these associations we are examining the maximum and mean concentrations of Na^+ , nssSO_4^{2-} , and MS^- in US ITASE ice cores and correlating them to the maximum, mean, and minimum sea ice extents for 36-10° sectors around Antarctica. Initial correlations (fig. 2 below) are highly promising. While previous sea ice extent ice core proxies (including our own) have primarily focused on the use of a single chemical species our new approach could demonstrate that multiple proxies afford complimentary but expanded interpretations. These interpretations may allow finer differentiation of sea ice extent seasonal timing and geographic location.



Linear correlations between sea ice extent and annual maximum and mean concentrations of sulfur hexafluoride (blue), nss-sulfate (red), and methylsulfonate (green) for 6 Antarctic cores: Siple Dome (▲), 01-4 (■), 02-1 (●), 02-4 (▼), South Pole (◆), and 03-1 (○). Correlations were calculated for each of the 36-10° sectors around Antarctica. All plotted values are greater than the 90% confidence interval and for all but 10-12 sectors correlations at least one confidence interval are at the 95% confidence interval. Highlighted regions are: East Antarctica (0° to 160°, green), Ross Sea (160° to 230°, blue), Amundsen-Bellinghousen Seas (230° to 290°, yellow), Antarctic Peninsula (290° to 360°, lilac), and the Weddell Sea (300° to 360°, red).

Since 1999, US ITASE traversed >8000 km throughout West and East Antarctica (Fig. 1) and collected a total of 3945m of ice cores. Together with six shallow cores collected in conjunction with the Long Ground Traverse, US ITASE conducted scientific investigations (ice coring, surface glaciology, radar) at 45 sites and radar (crevasse, shallow, and deep) along almost the entire >8000 km of the US ITASE routes. US ITASE has therefore sampled the ice climate record surrounding the Ross Ice Shelf and hundreds of km inland. In addition US ITASE completed six field seasons setting a new benchmark for Antarctic climate multi-disciplinary research. This program has been extremely successful; resulting in more cores than can reasonably be processed and



analyzed within the scope of the originally proposed funding cycle. While there are still more US ITASE cores to be processed and analyzed, a sufficient number have been completed to provide significant advances to our understanding of Antarctic climate change.

ITASE findings are published in >100 peer-reviewed publications (see summaries in Mayewski (2003, 2006, 2009) and Mayewski et al. (2006)). Scientific accomplishments include:

- Identification of seasonal timing, source contributions, controls on spatial distribution, and covariance association with moisture flux for all major ions.
- Precise annual layer counting of ice cores resulting in estimates of past mass balance, identification of moisture source regions, and environmental interpretations.

- Direct linkage between ice core glaciochemical markers and shallow and deep radar reflectors, demonstrating that the latter are isochrones.
- Highly resolved temporal and spatial volcanic event records, and identification of stratospheric versus tropospheric source volcanic emission input pathways to Antarctica and utilization of stratospheric source events as evidence of emission plume history over the ice sheet.
- Differentiation of the relative influence of sea salt spray and salt flowers on sodium loading over Antarctica.
- Instrumental record-calibrated proxies using ice chemistry and isotope tracers from multiple ice cores for: Amundsen Sea Low, East Antarctic High, ENSO, ice surface wind drainage, Antarctic Oscillation, and the southern hemisphere westerlies.
- Integration of ITASE spatial records with deep ice core records to significantly refine paleoclimate reconstructions and global scale abrupt climate change correlations.
- Proxies for sea ice extent, a critical component in the climate system, and ENSO-sea ice connections through calibrations between sea ice extent observational series and ice chemistry (eg., sodium, MSA, non sea salt sulfate).
- The “Solar Polar” hypothesis for the initiation of annual to decadal scale climate variability over Antarctica and the Southern Ocean and potentially for global scale abrupt climate change events.
- Definition and understanding of the current state of the Antarctic climate system relative to the last few hundred years demonstrating that Antarctic climate change is still within the range of natural variability except for the strength of the southern hemisphere westerlies which are currently more intensified than any time in the last 5100 years.
- Implications of the current ozone hole on the current and future strength of the westerlies.
- Large-scale calibrations between satellite observations, surface snow properties, and ITASE ice core proxies for temperature.
- Partitioning of the sources of sulfate using sulfur isotopes as an aid to further refining air mass trajectory fingerprinting and the sulfur cycle over Antarctica.
- Site selection for new deep drilling projects (eg., inland WAIS and potentially Hecules Dome).
- Documentation of the impact of solar forcing (via UV induced changes in stratospheric ozone concentration) on zonal westerlies at the edge of the polar vortex.
- Distribution of snow precipitation over the Antarctic continent on varying spatial and temporal scales and dependence on wind and surface slope.
- Production of a global array of high resolution, multi-proxy records of Holocene climate.
- Compilation of an Antarctic wide array of glaciochemical and isotopic data.
- Comparison between ITASE climate proxies and climate model results.
- Refined estimates of Antarctic surface mass balance.