West Antarctic Ice Sheet temporal and spatial accumulation variability from five new snowpits and firn cores

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Project Goals

- Extend accumulation record of the central West Antarctic Ice Sheet up to the present
- Add a new dataset to the existing ice core records from the area
- Describe the spatial and temporal patterns in accumulation
- Investigate the effect of ENSO on accumulation across the West Antarctic Ice Sheet

Outline

- Antarctic Accumulation Patterns
- Field Area
- Density Data
- Age/Depth Relationship
- Recent Accumulation

Antarctic Accumulation Patterns

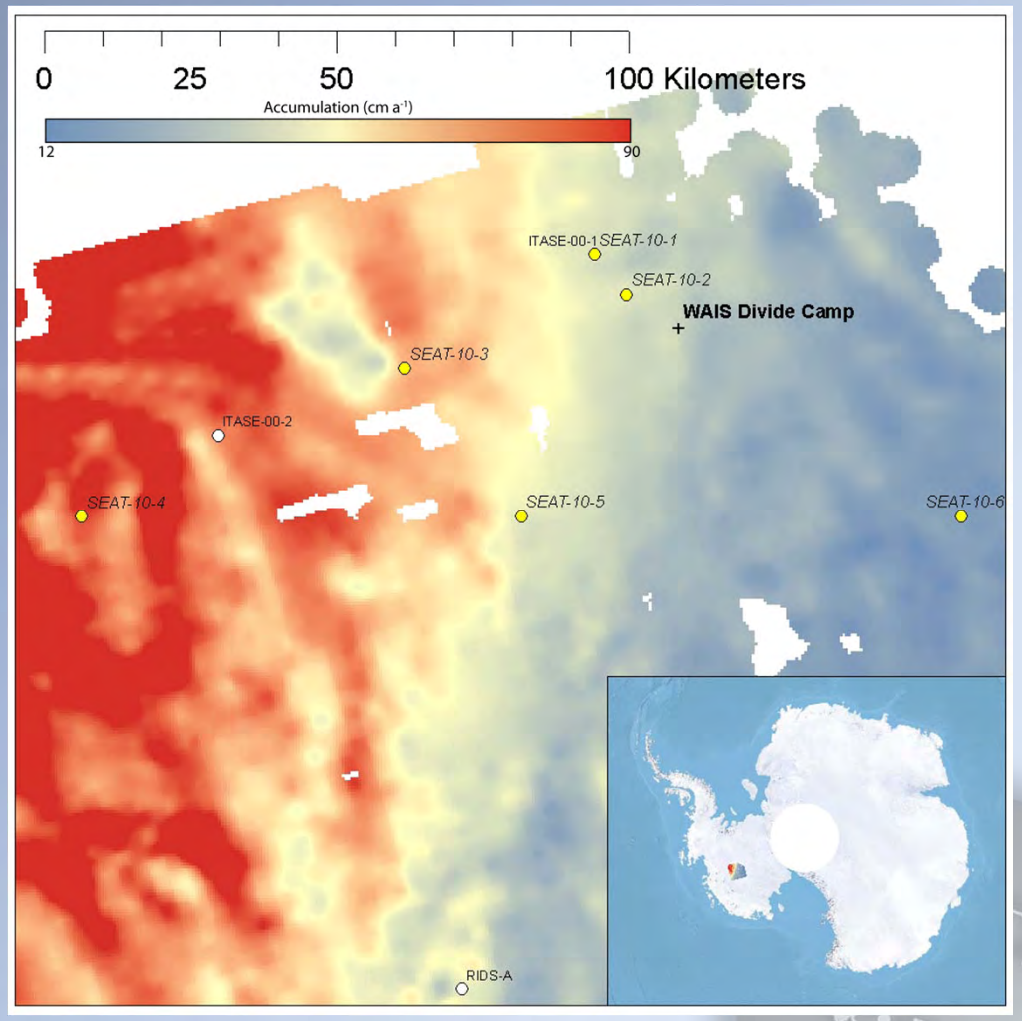
- High degree of small-scale spatial and temporal variability due to snow redistribution

- Factors affecting accumulation rates:
  - Large-scale topography
    - 100 km scale
    - Distance from moisture source (coast)
    - Elevation
  - Meso-scale topography
    - ~20 km
    - Large undulations
  - Small-scale topography
    - Sastrugi
  - Analytical uncertainty

References: Banta et al., 2008; Kaspari et al., 2004

Field Area

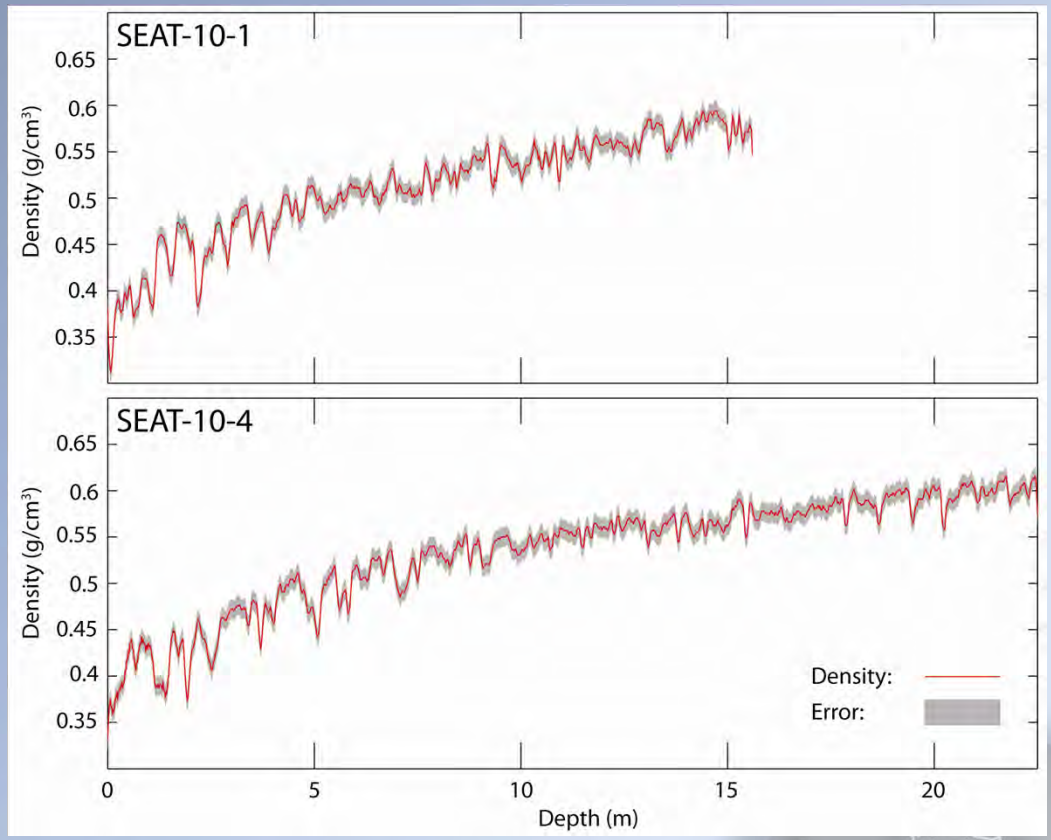
- 350 km traverse across WAIS divide
- 5 shallow firn cores
  - ~70 km apart
  - 1.5 - 3 m snowpits
  - Longest core = 22.5 m (*SEAT-10-3*)
  - Shortest core = 15.6 m (*SEAT-10-1*)
- SEAT-10-1 recovered from ITASE-00-1 site



(accumulation map from Morse et al., 2002)

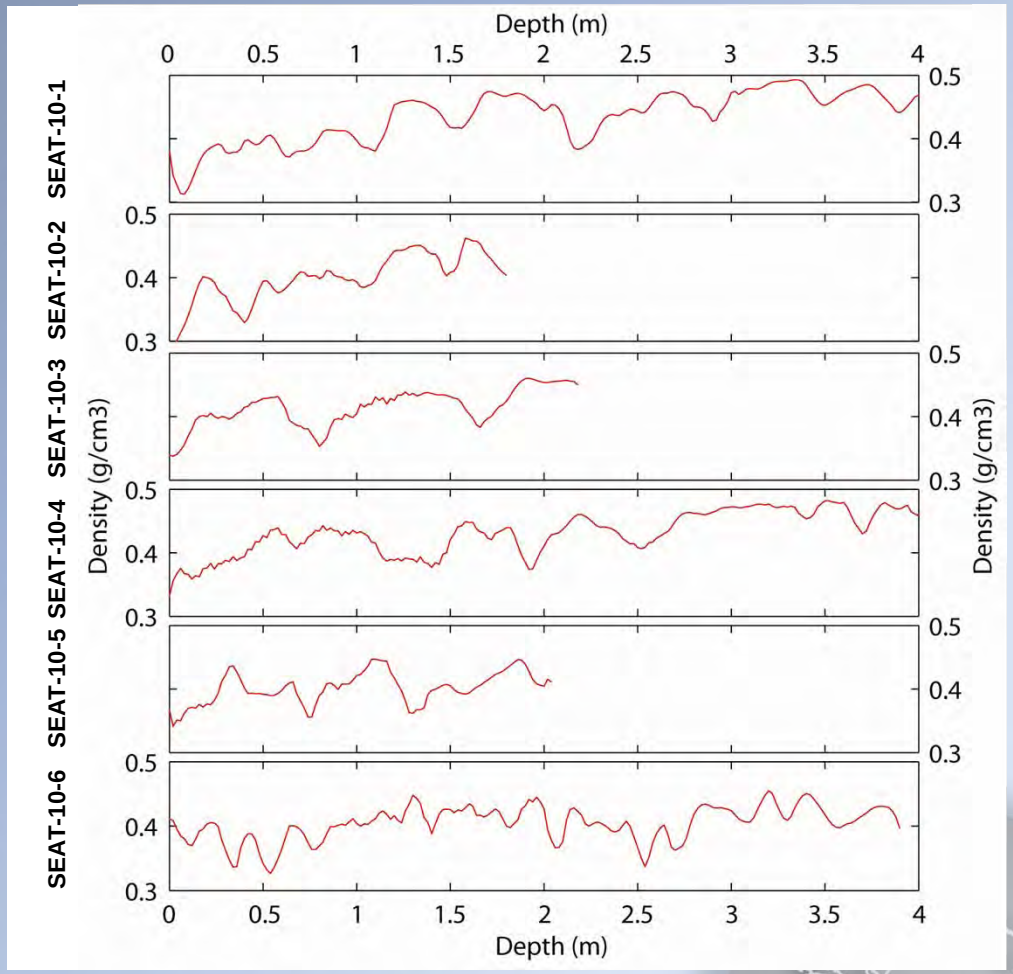
Density

- Density estimate error: 0.01 g/cm^3
- Increasing density with depth largely due to compaction
- ECM record dependent on both density and concentration of solutes in firn

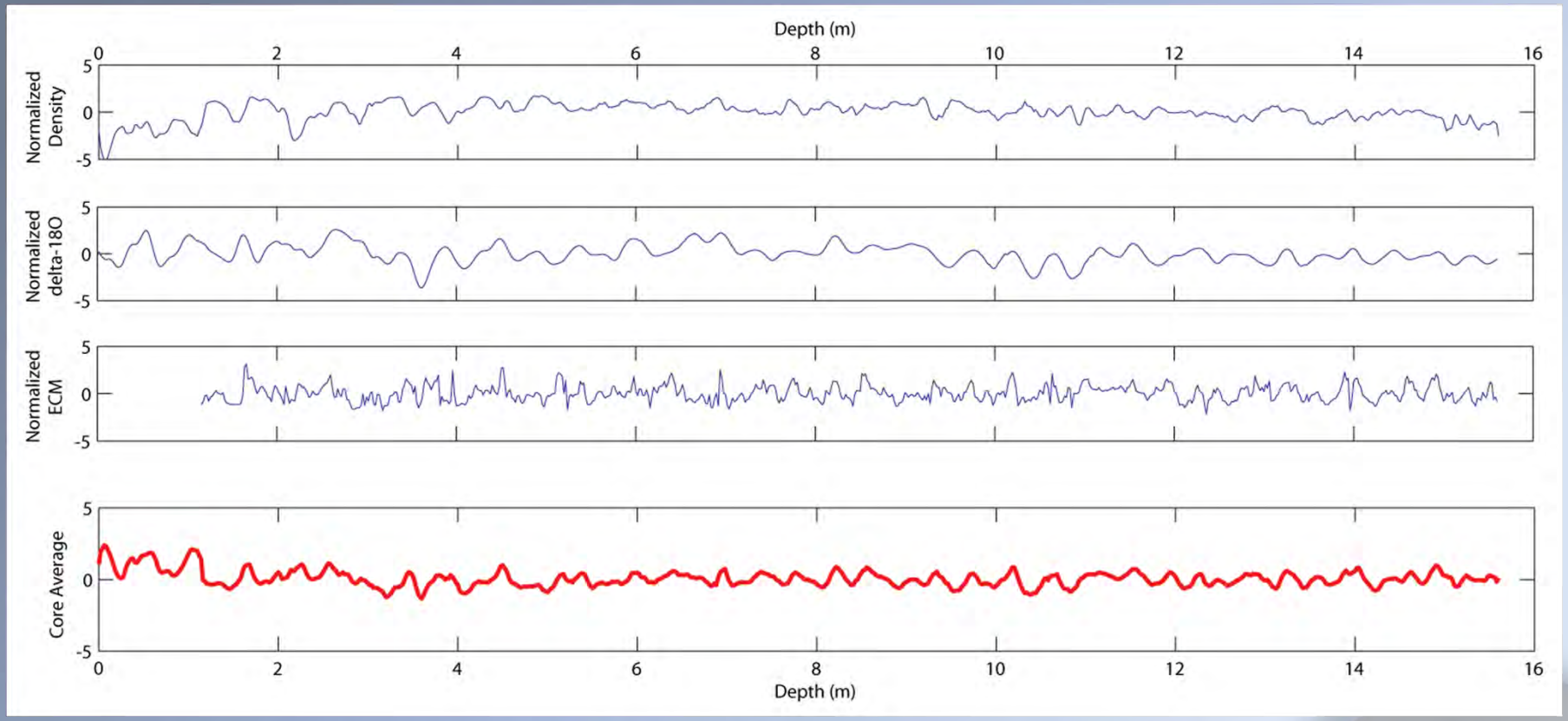


Density

- High variability in firn layer
- Multiple factors influence density:
  - Temperature
  - Accumulation rate
  - Particulate content
  - Compaction
- What is driving rapid variations?

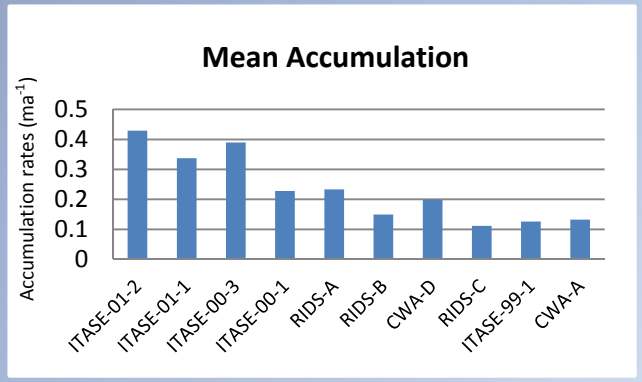


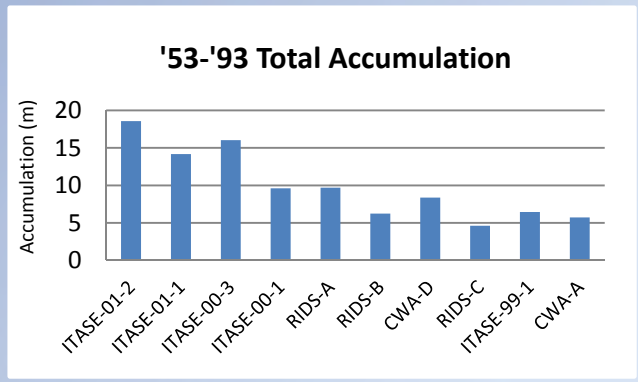
Age/Depth Relationship

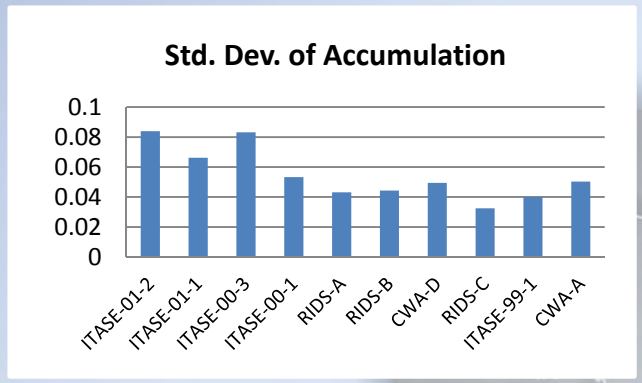


Recent Accumulation Rates

- Accumulation rates between individual US-ITASE cores is highly variable
- Low correlation between individual cores
- Coastal regions:
  - Higher accumulation rates
  - Higher inter-annual variability
- Do accumulation rate trends from the past decade follow these patterns?

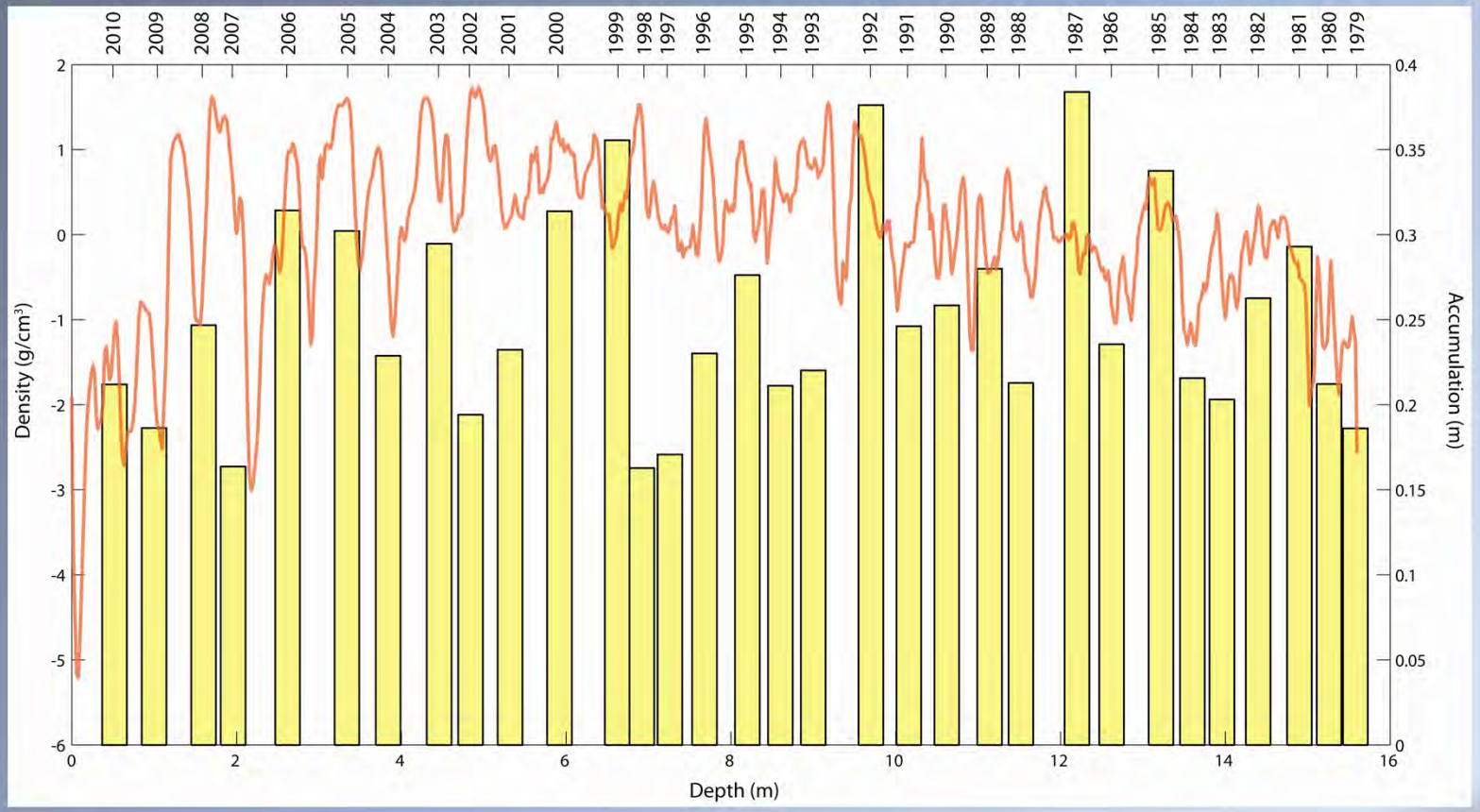






References: US-ITASE group, Kaspari et al., 2004

Recent Accumulation Rates

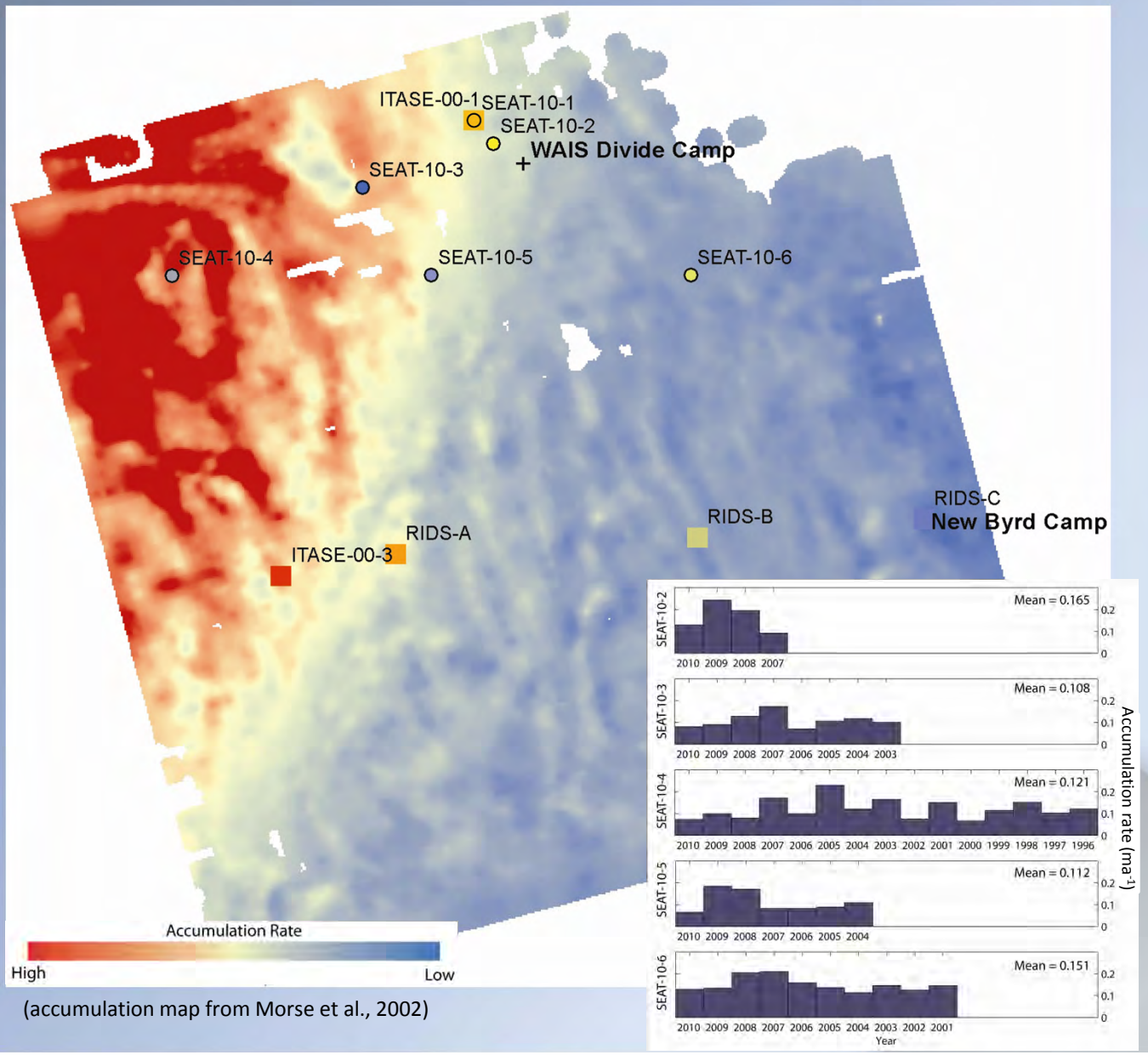


Period	Mean Accumulation rate (m)
2006-2010	0.22
2001-2005	0.25
1996-2000	0.25
1991-1995	0.27
1986-1990	0.27
1981-1985	0.26

- SEAT-10-1
  - Mean: 0.26 m
  - Std. Dev: 0.06
- ITASE-00-1:
  - Mean: 0.25
  - Std. Dev: 0.06
- Slight decrease in accumulation rates during the most recent decade?

Recent Accumulation Rates

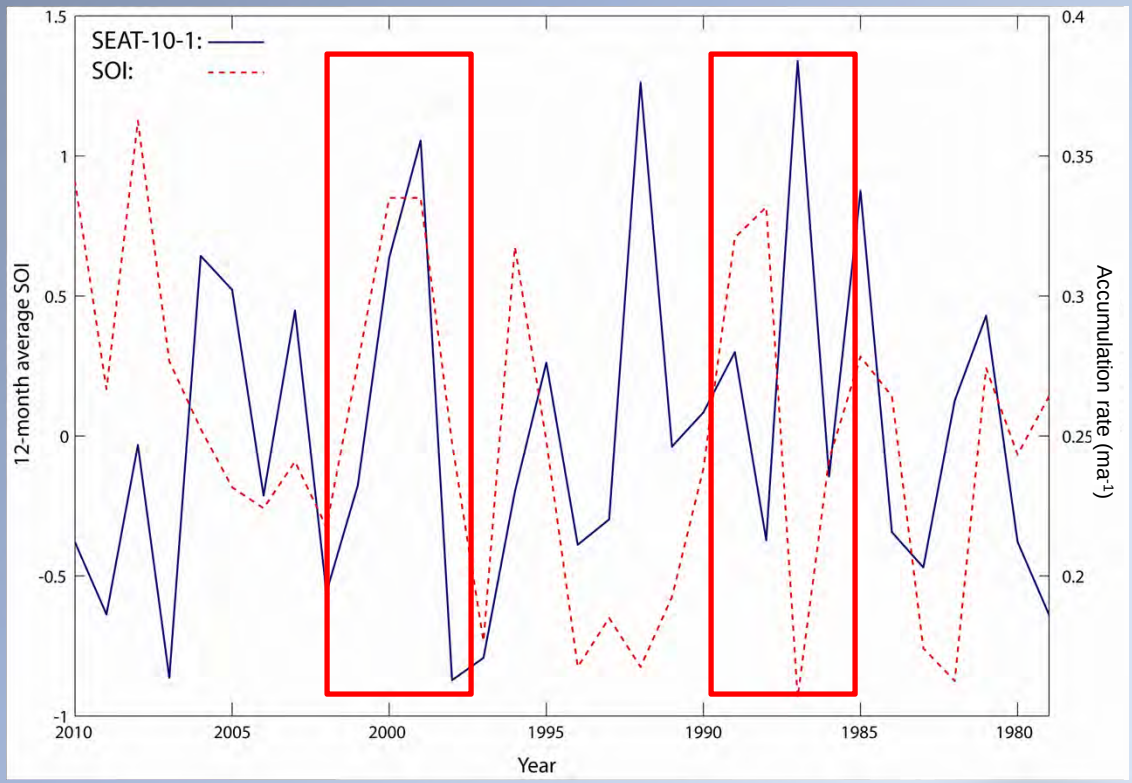
- Previous WAIS core averages from 1952-1993 show a general decrease in accumulation rates across the divide
- SEAT-10 cores do not show trend (short record)



(accumulation map from Morse et al., 2002)

Recent Accumulation Rates

- What is the role of the Southern Oscillation in driving variations in accumulation?
- SEAT-10-1 averages:
  - Total: 0.25 m
  - During positive anomalies: 0.26 m
  - During negative anomalies: 0.26 m
- Suggests that on an annual resolution, SO is not the main driver of accumulation variability



Conclusions

- Overlap of USITASE-00-1 and SEAT-10-1 allows for validation of new results, giving confidence in derivation methods
- ITASE-00-1 and preliminary SEAT-10-1 accumulation rates during period of overlap are virtually identical
- Average accumulation rates of upper 4 m of SEAT-10 cores do not reflect general acc. trends across WAIS divide (likely due to short records and uncertainties in age-depth relationship)
- SEAT-10-1 shows little or no correlation with the Southern Oscillation at an annual resolution, suggesting that at this temporal resolution the SO is not the dominant driver of accumulation rate variability at that location

References

Banta, J.R., McConnell, J.R., Frey, M.M., Bales, R.C., and Taylor, K., 2008, Spatial and temporal variability in snow accumulation at the West Antarctic Ice Sheet Divide over recent centuries: Journal of Geophysical Research, v. 113, p. 1-8.

Bertler, N., Mayewski, P.A., Alberto Aristarain, P.Barrett, S.Becagli, Ronaldo Torma Bernardo, Xiao Cunde, M.Curran, Qin Dahe, D.Dixon, Francisco Adolfo Ferron, H. Fischer, Markus Frey, M.Frezzotti, F. Fundel, Christophe Genthon, R.Gragani, G.Hamilton, M.Handley, Sungmin Hong, E.Isaksson, Ren Jiawen, Kokichi Kamiyama, Satoru Kanamori, Eija Karkas, L.Karlöf, S.Kaspari, K.Kreutz, A.Kurbatov, E.Meyerson, Hideaki Motoyama, R. Mulvaney, Zhang Mingjun, H.Oerter, E.Osterberg, M.Proposito, A.Pyne, U.Ruth, Jefferson Cardia Simoes, B.Smith, S.Sneed, Kimmo Teinila, F. Traufetter, R.Udisti, Aki Virkkula, Okitsugu Watanabe, B.Williamson, E. Wolff, Li Zhongqin, 2006, Snow chemistry across Antarctica, Annals of Glaciology 41, 167-179.

Bromwich, D., Monaghan, A., and Guo, Z., 2004, Modeling the ENSO Modulation of Antarctic Climate in the Late 1990s with the Polar MM5: American Meteorological Society, v. 17, p. 109-132.

Cullather, R.I., Bromwich, D.H., Van Woert, M.L., 1996, Interannual variations in Antarctic precipitation related to El Niño-Southern Oscillation: Journal of Geophysical Research, v. 101, p.19109-19118.

Dixon, D., Mayewski, P.A., Kaspari, S., Sneed, S., and Handley, M., 2004, A 200 year sub annual record of the primary sources of sulfate in West Antarctica, Annals of Glaciology 39, 545-556.

Dixon, D., Mayewski, P.A., Kaspari, S., Sneed, S. and Handley, M., 2005, Connections between West Antarctic ice core sulfate and climate over the last 200+ years, Annals of Glaciology 41, 155-156.

Kaspari, S., Mayewski, P.A., Dixon, D., Spikes, V.B., Sneed, S.B., Handley, M.J., and Hamilton, 2004, Climate variability in West Antarctica derived from annual accumulation rate records from ITASE firn/ice cores, Annals of Glaciology 39, 585-594.

Kaspari, S., Mayewski, P.A., Dixon, D., Sneed, S.B., and Handley, M.J., 2005, Sources and transport pathways for marine aerosol species into West Antarctica, Annals of Glaciology 42, 1-9.

Mayewski, P.A., K. A. Maasch, J.W.C. White, E. Meyerson, I. Goodwin, V.I. Morgan., T. van Ommen, M.A.J. Curran, J. Souney, and K. Kreutz, 2005, A 700 year record of Southern Hemisphere extra-tropical climate variability, Annals of Glaciology 39, 127-132.

Mayewski, P.A., Frezzotti, M., Bertler, N., van Ommen, T., Hamilton, G.H., Jacka, J., Welch, B., Frey, M., Dahe, Q., Ren, J., Simoes, J., Fily, M., Oerter, H., Nishio, F., Iasaksson, E., Mulvaney, R., Holmund, P., Lipenkov, V. and Goodwin, I., 2006, The International Trans-Antarctic Scientific Expedition (ITASE) – An Overview, Annals of Glaciology 41, 180-185.

Mayewski, P.A., Maasch, K., Yan, Y., Kang, S., Meyerson, E., Sneed, S., Kaspari, S., Dixon, D., Morgan, V., van Ommen, T., and Curran, M., 2006, Solar forcing of the polar atmosphere, Annals of Glaciology 41, 147-154.

Mayewski, P.A. and Maasch, K., 2006, 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.

Morse, D.L., Blankenship, D.D., Waddington, E.D., and Neumann, T.A., 2002, A site for deep ice coring in West Antarctica: results from aerogeophysical surveys and thermo-kinematic modeling: Annals of Glaciology, v. 35, p. 36-44.

Steig, E.J., P.A. Mayewski, D. Dixon, S. Kaspari, M. Frey, D.P. Schneider, S.A. Arcone, G. Hamilton, B. Spikes, M.R. Albert, D.A. Meese, A. Gow, C.A. Shuman, J. White, S. Sneed, J. Flaherty, M. Wumkes and US ITASE Project Members, 2006, High-resolution ice cores from US ITASE (West Antarctica): development and validation of chronologies and determination of precision and accuracy, Annals of Glaciology 41, 77-84.

Yan, Y., Mayewski, P.A., Kang, S., and Meyerson, E., 2005, An ice core proxy for Antarctic circumpolar wind intensity, Annals of Glaciology 41, 121-130.