Impacts of Environmental Variability & Change on Firn Memory in West Antarctica

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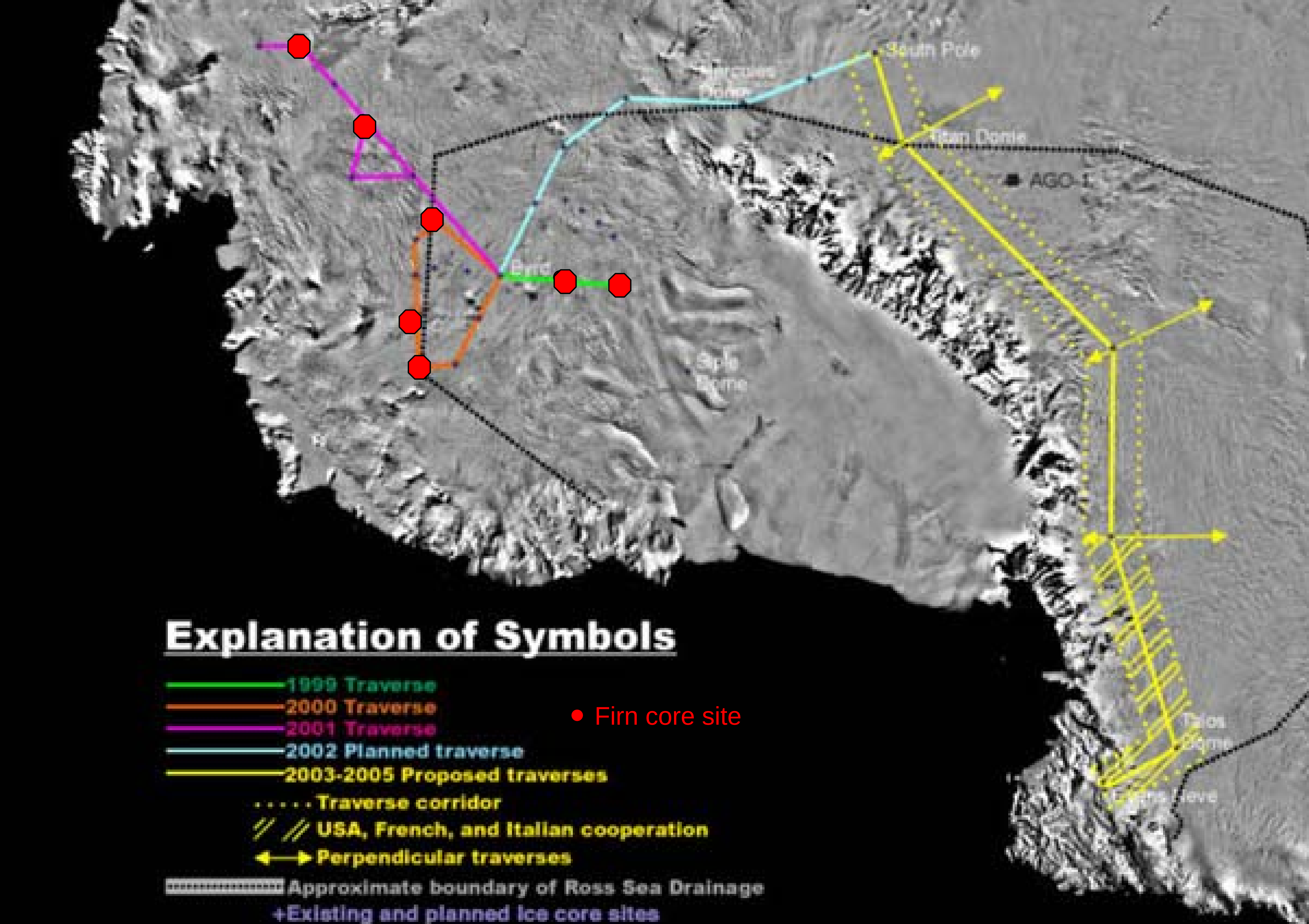
Overview

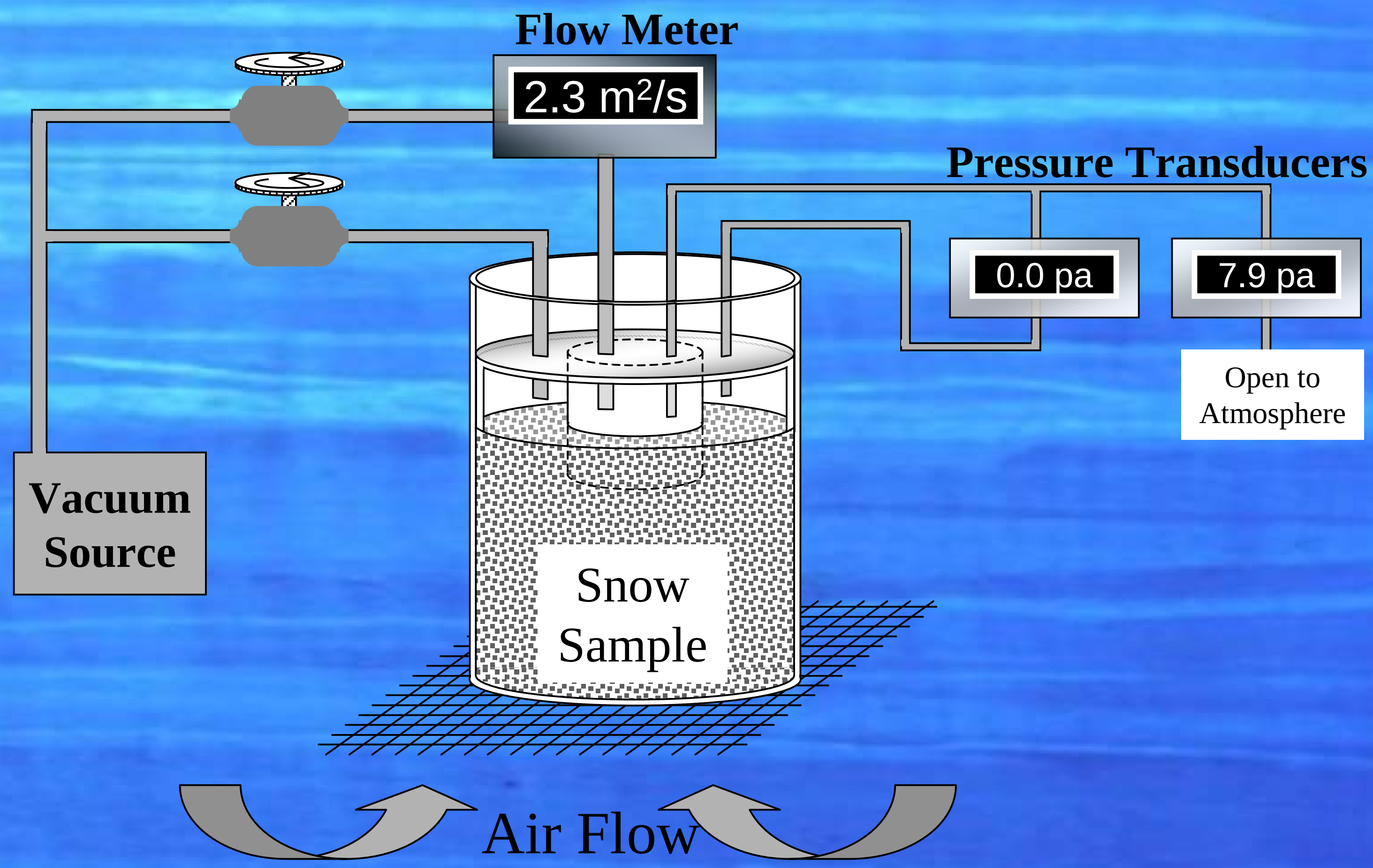
Processes affecting the ability of firn to remember climate.

* Does West Antarctica have significant spatial variability in firn properties?
* If so, are ventilation rates and isotopic concentrations affected?
* At a single site, is temporal environmental variability detectable in the physical nature of the firn?



by Gordon Hamilton and Blue Spikes, University of Maine

Permeability - measured from pit and firn core samples



Density of each sample = measured mass/vol

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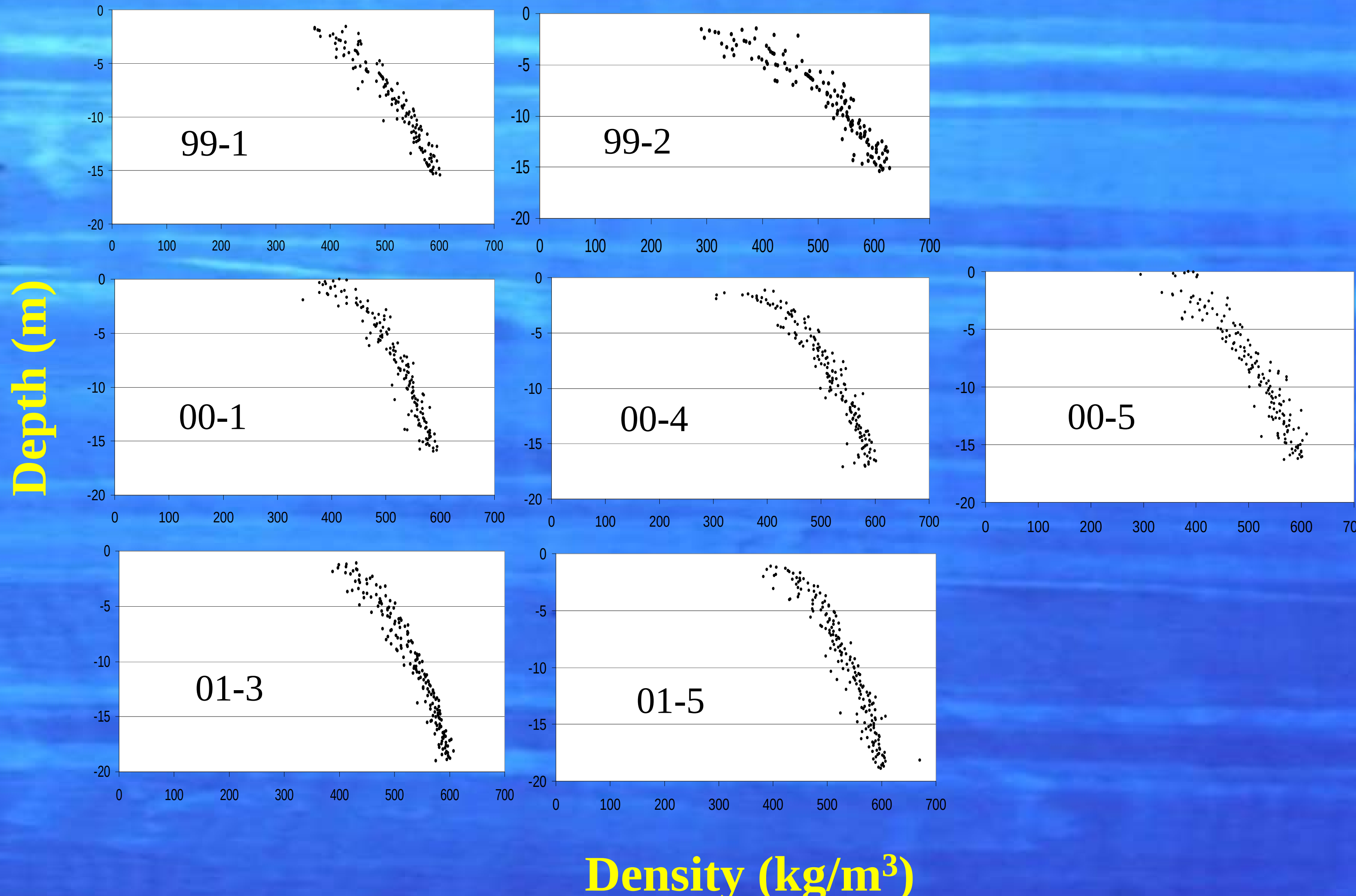
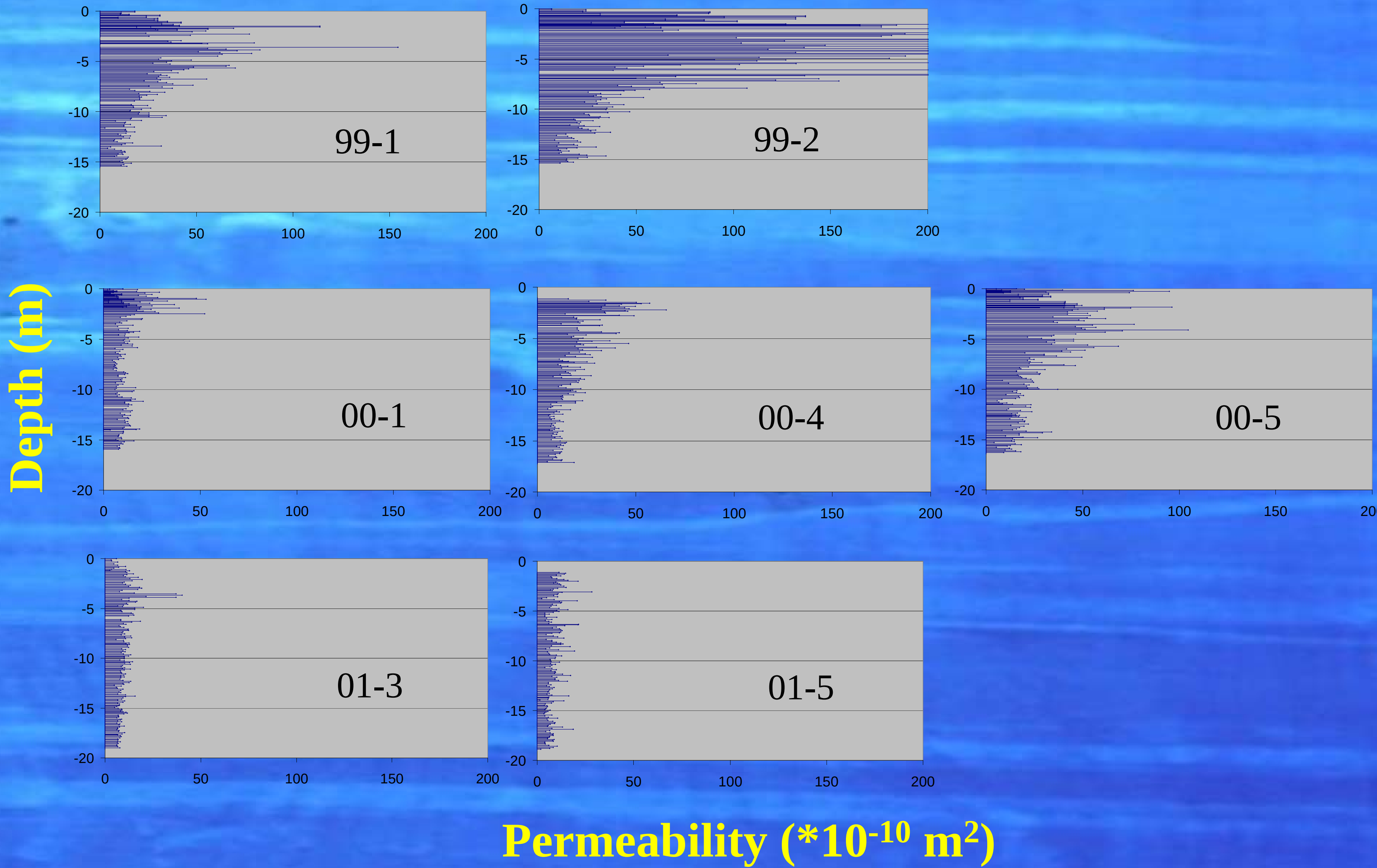
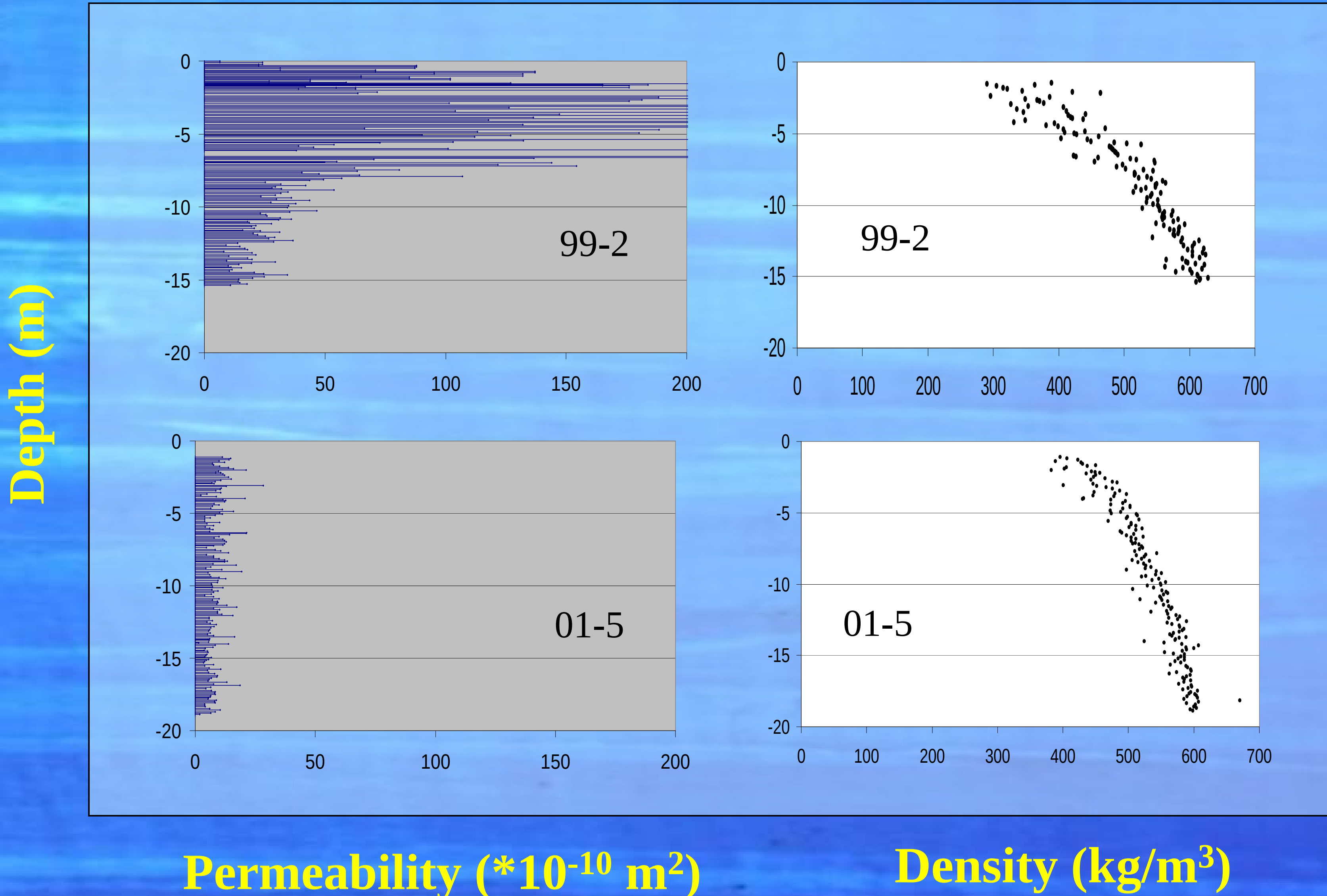
Firn density profiles show varying amounts of scatter, but follow a similar overall profile.



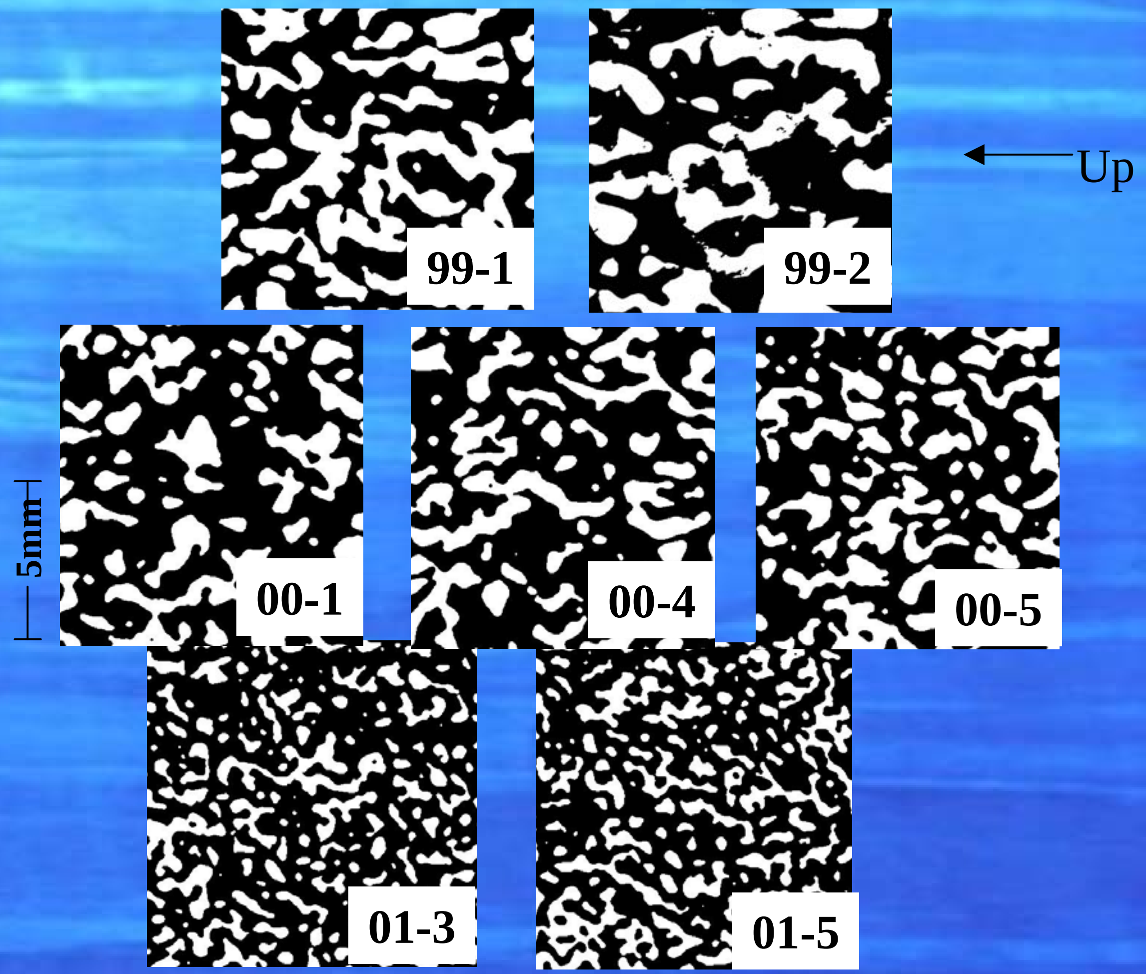
Permeability profiles show very large site-to-site variation.





Why large differences in permeability but not density?

The amount of firn mass is important, but the *arrangement* of that mass governs interstitial processes.



Images from winter layers at approx 2.5 m depth corresponding to sites in previous plots

Density reflects mass per unit of volume, while permeability reflects the nature of the interconnected pore space.

Using permeability profiles may allow improved interpretation of ice core records affected by pore space processes, compared with interpretation based on simple densitiy/porosity.

Even a perfect description of the density profile is not likely to tell the whole story of a gas or reactive chemistry record.

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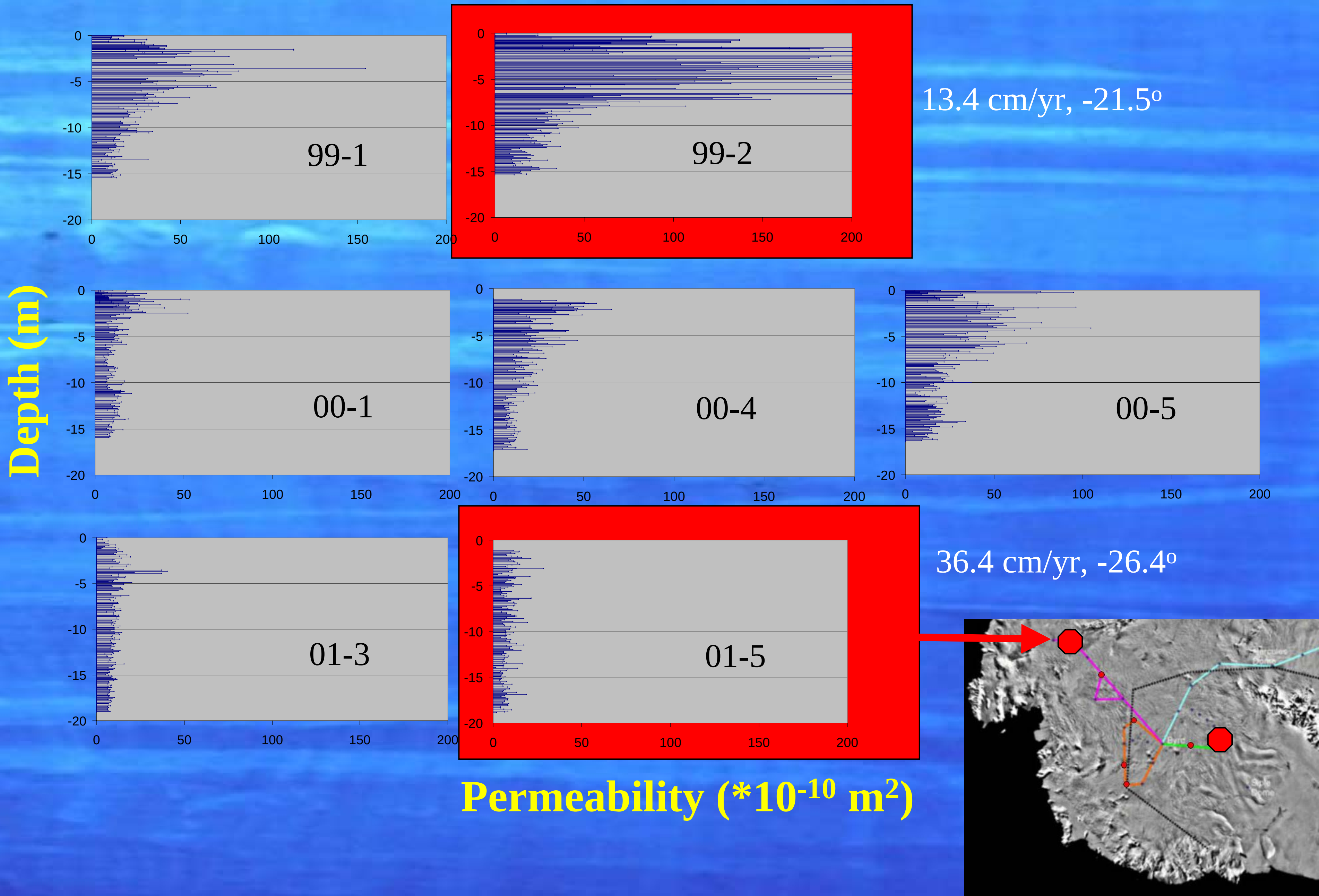
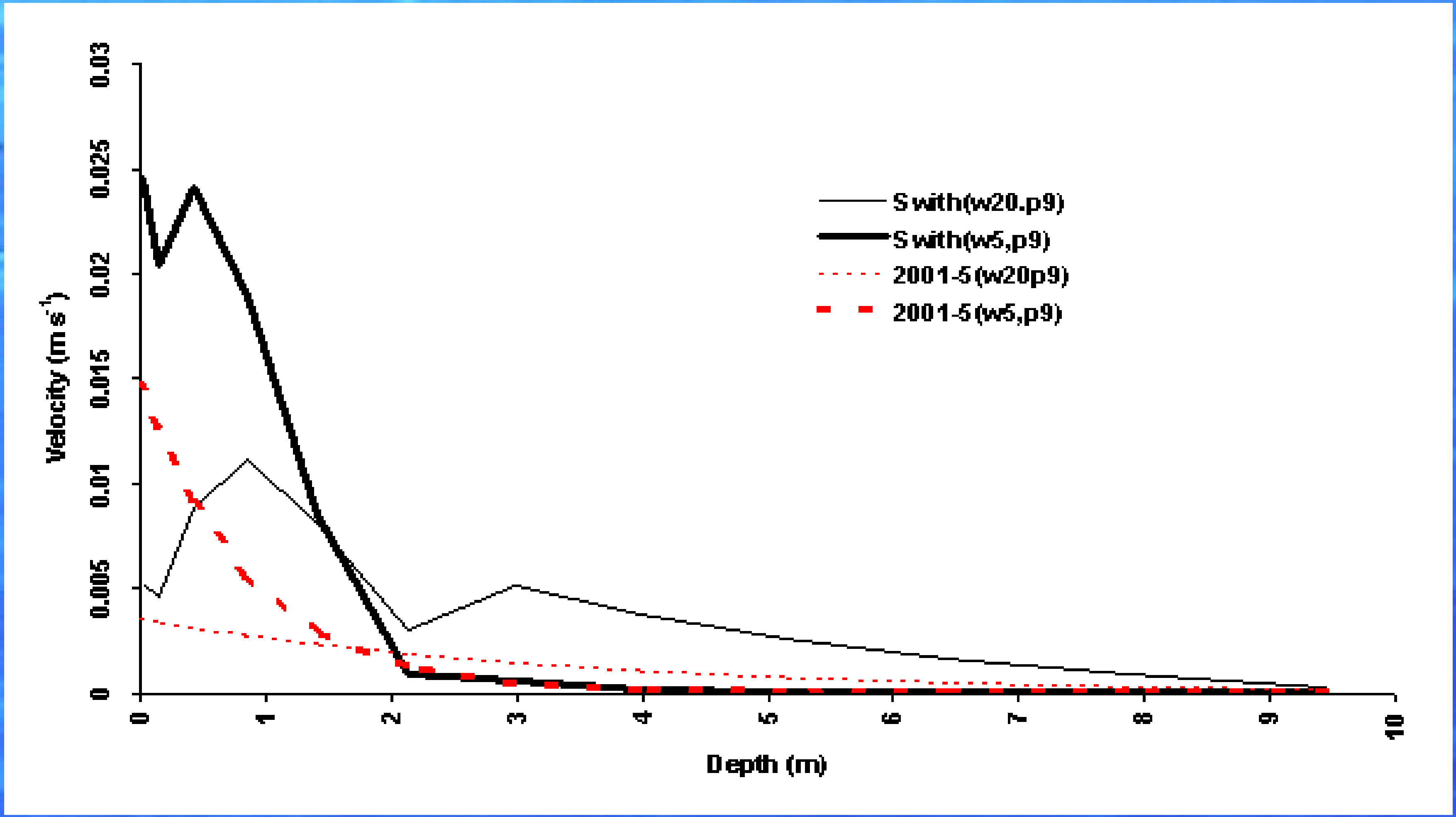
A brief look at ventilation at two different sites



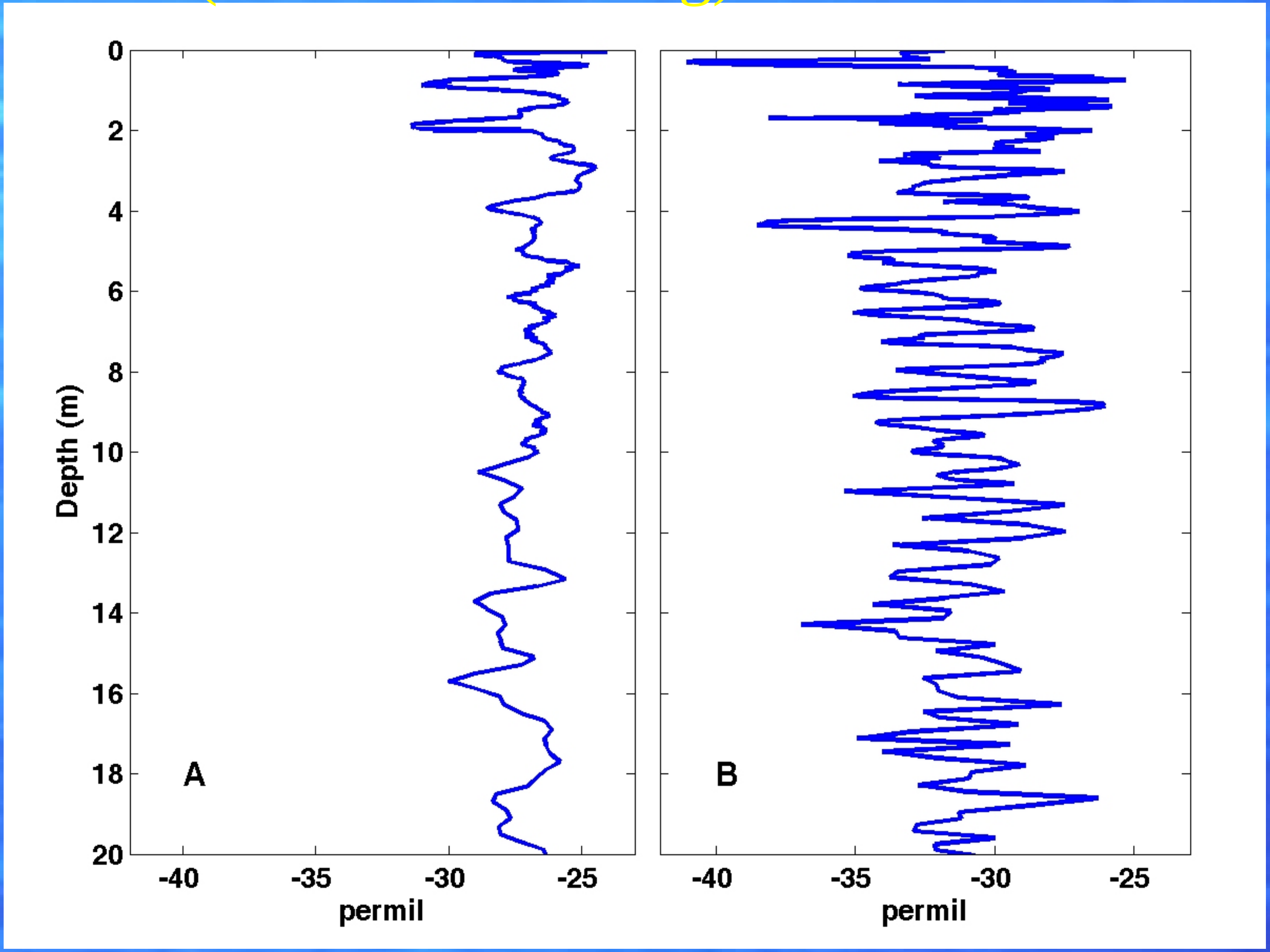
Calculated ventilation velocity magnitude for short and long surface roughness wavelengths at the two sites.

Differences in permeability leads to a factor of two difference in interstitial flow rates.



Will this affect the isotope ratios?

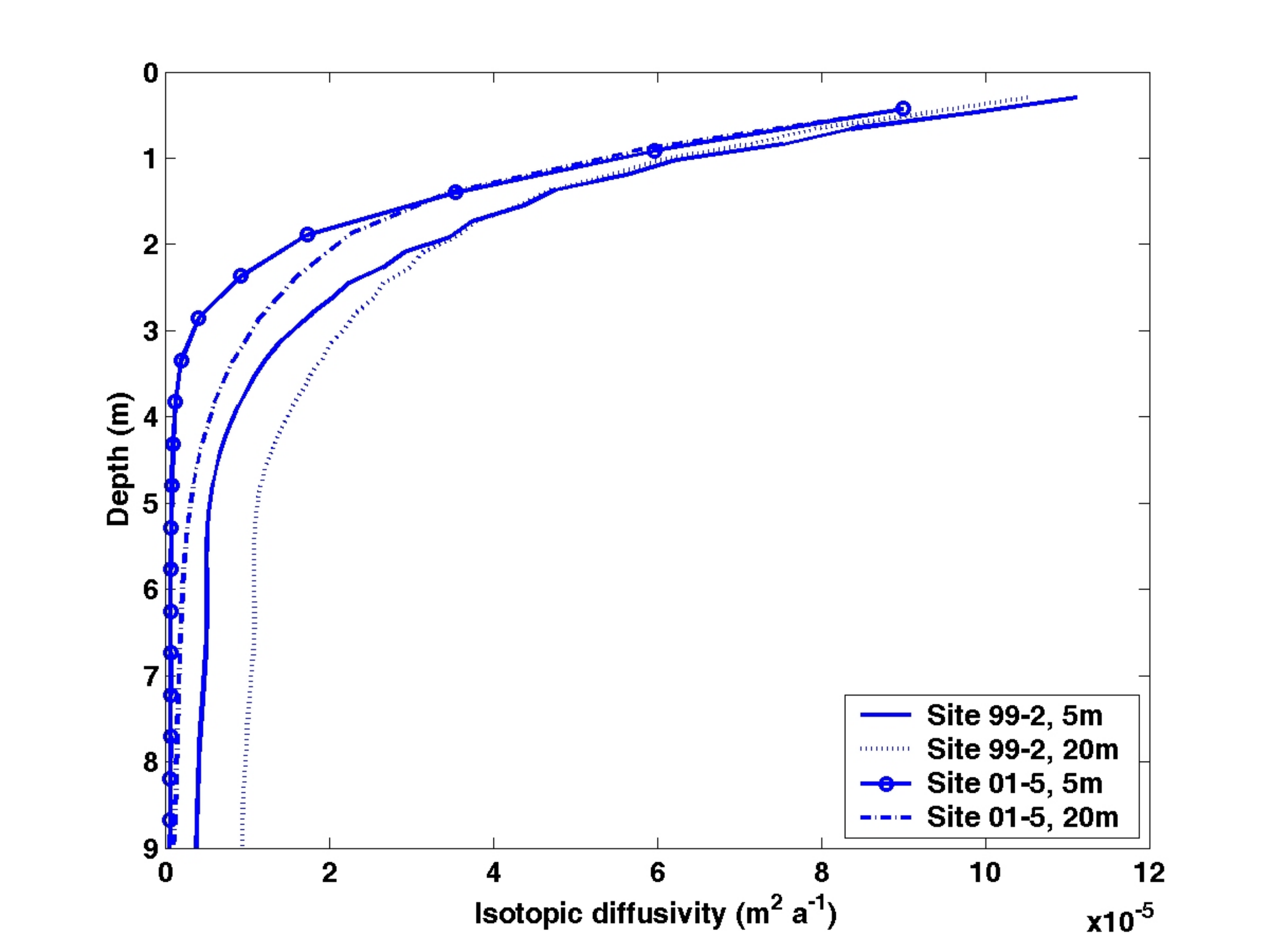
Stable oxygen isotope ratios
(data from E. Steig)



Site 99-2
13.4 cm/yr, -21.5°
High permeability

Site 01-5
36.4 cm/yr, -26.4°
Low permeability

While mean temperature dominates isotopic ratios, ventilation does increase the effective isotopic diffusivity. (Neumann-Waddington isotope model)



Large spatial variability exists in the physical nature of the firn in West Antarctica.

High permeability sites can double the ventilation rates under the same wind forcing, increasing the effective diffusivity both for isotopes and for inert gases in the convective zone.

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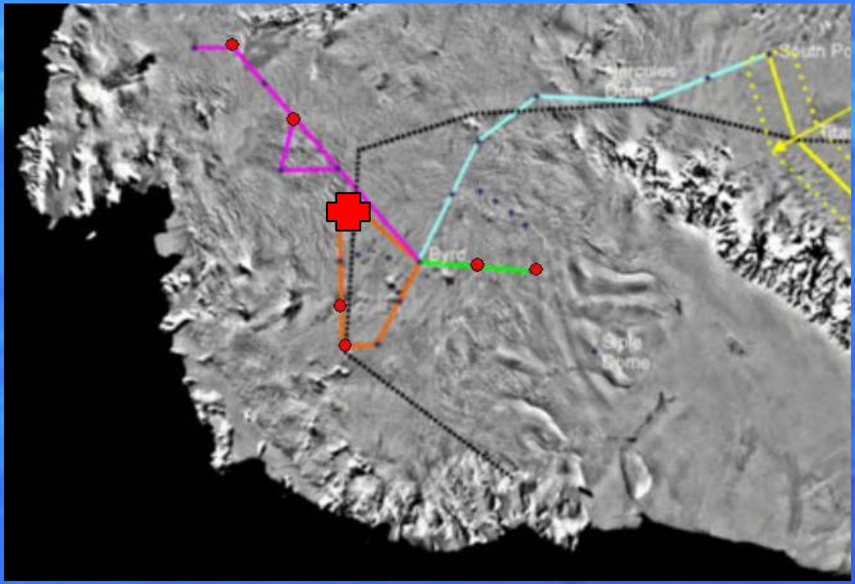
Is there evidence that temporal variability at a fixed site is detectable in the physical nature of the firn?

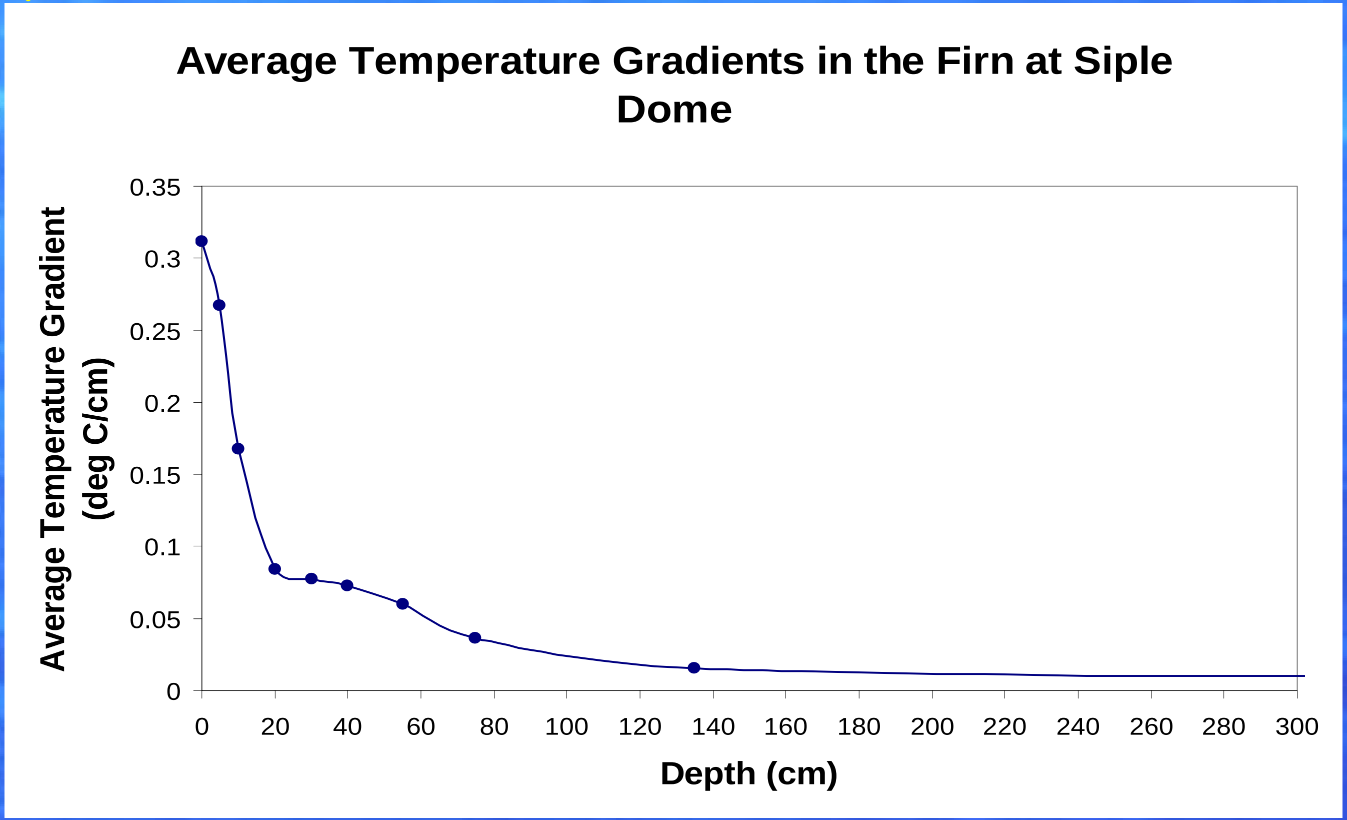
Example site ITASE 00-1: 79º23'S, 111º14'E



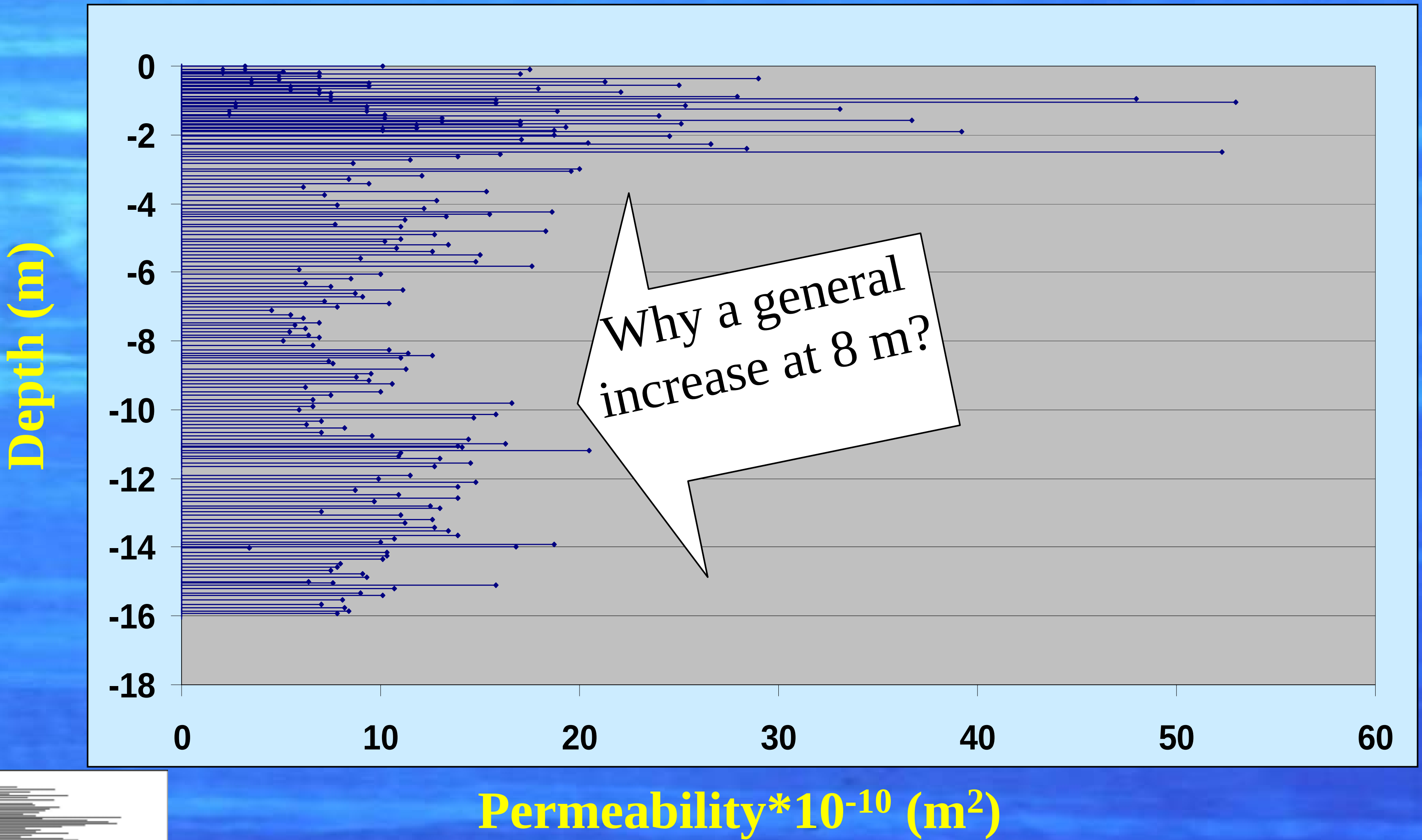
Kaspari et al (in press) determined that accumulation at this site was climate-driven rather than feature-driven.

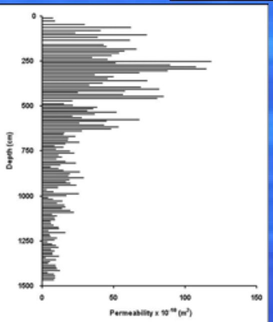
Background info:

Grains grow fastest in the large temperature gradients near the surface, but do continue to grow at slower rates deeper in the firn. So if the climate stays the same, the mean grain size of a winter layer will generally increase with depth/time.



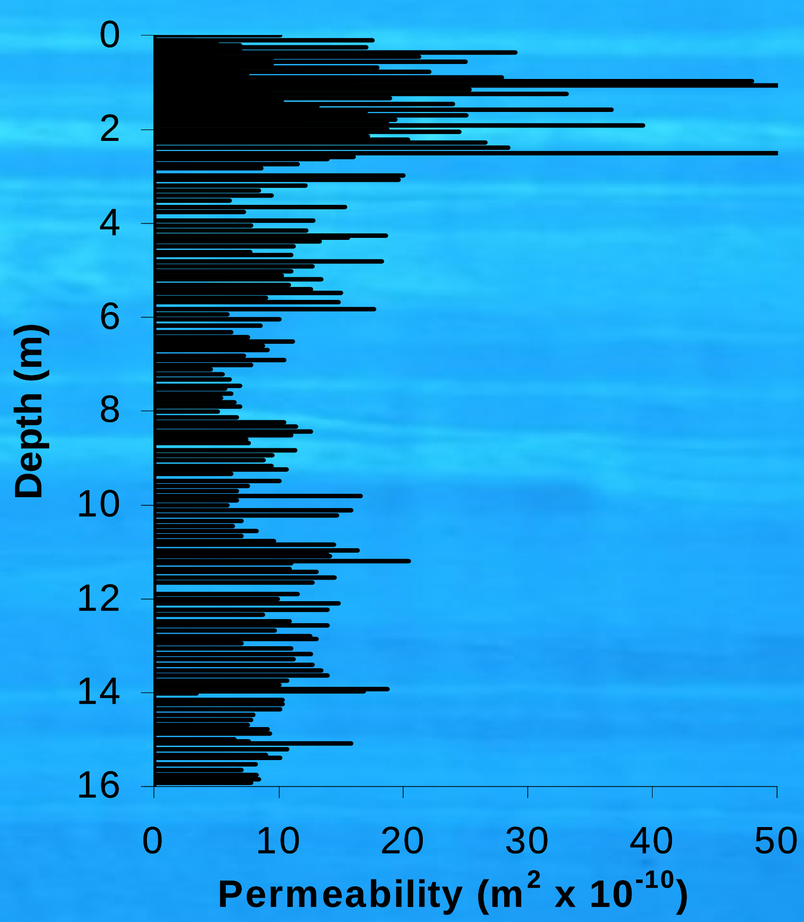
Site 00-1 Permeability profile

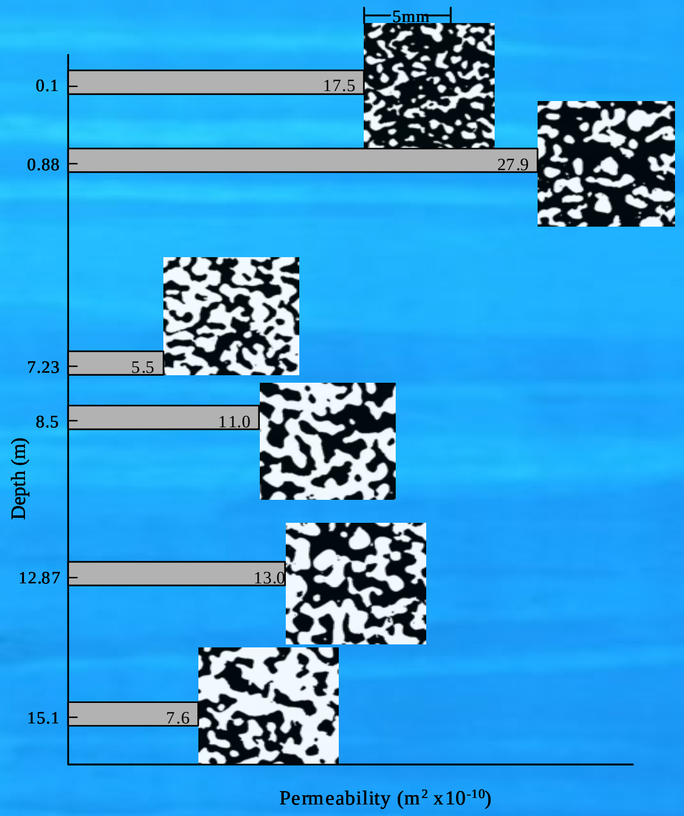




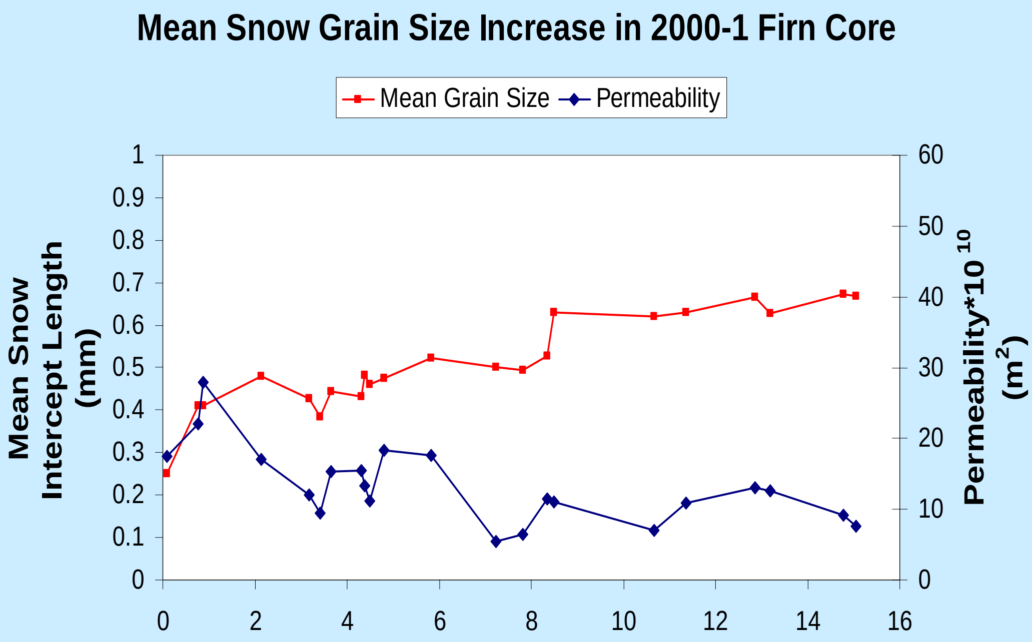
(…at Siple Dome, the overall permeability profile generally decreased with depth.)

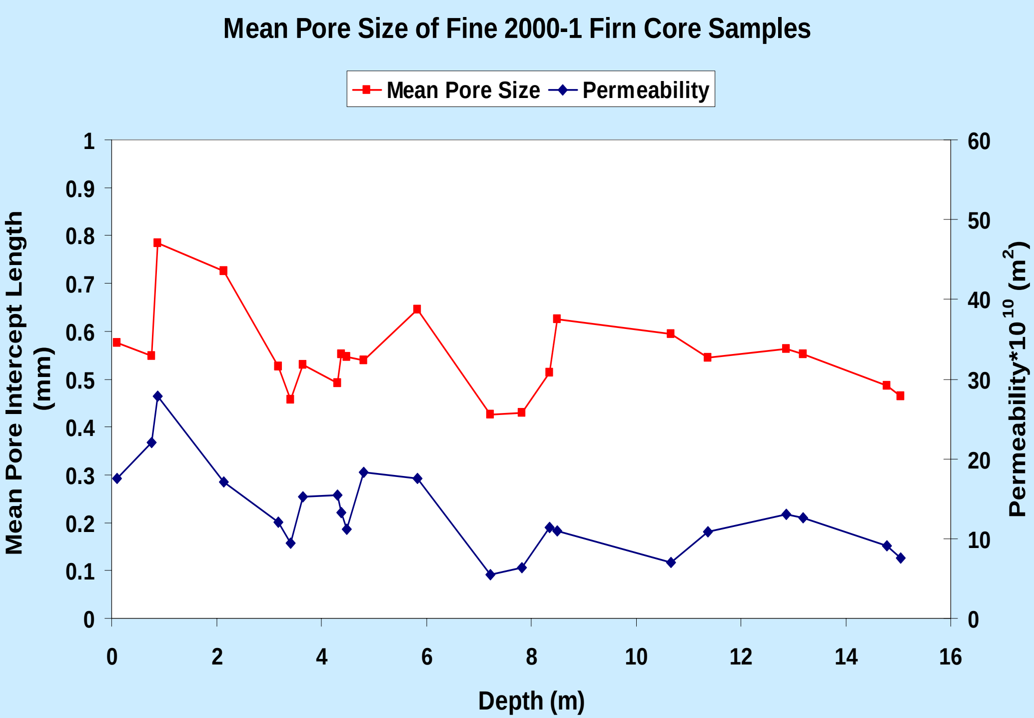
Permeability & winter layer microstructure at 00-1 site





A period of increased accumulation the early 1990s left a low-permeability physical record in the firn. This is consistent with 1992-94 El Nino period of above-mean accumulation for this area seen in the U Maine records (Kaspari et al. in press).





Post-depositional impact on winter layers:

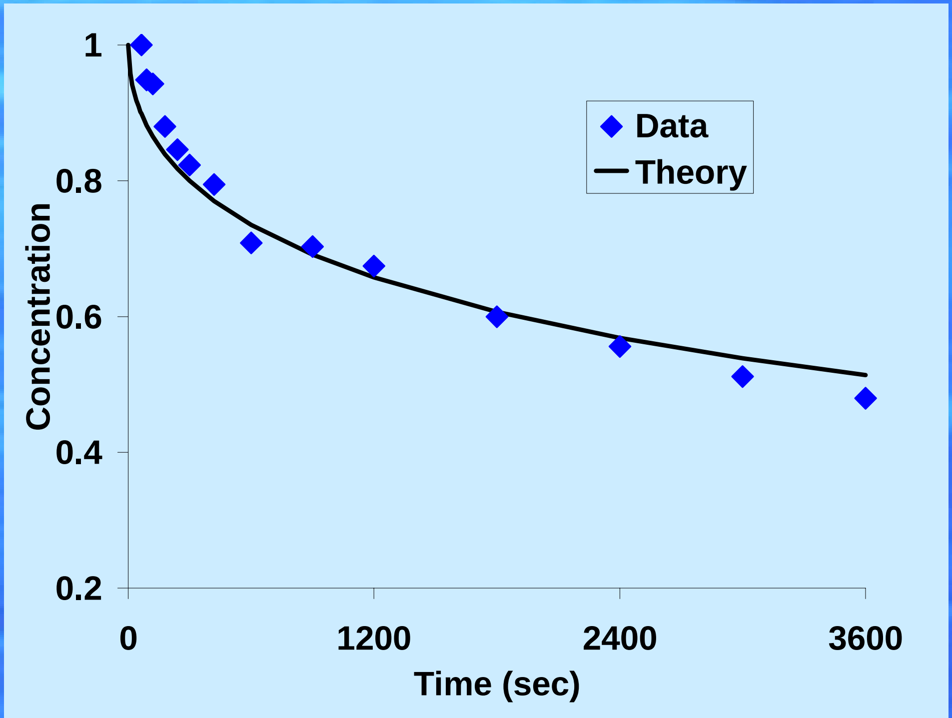
- Changing environment alters near-surface residence time and gradients. Higher accumulation rate and lower mean annual temperature lead to lower mean grain size and lower permeability.

- Accumulation rate has larger impact on post-depositional changes in grain size and permeability than does mean annual temperature.

- Temporal environmental variability may trap a high permeability layer between low permeability layers, affecting interstitial gas movement.

(Rick & Albert, in press)

Diffusion is ubiquitous throughout the firn, and varies according to microstructure



Come hear the Courville & Albert talk at AGU: permeability-diffusivity-microstructure for the top 30m at a very interesting Antarctic site.

Conclusions

* West Antarctica has significant *spatial* variability in firn properties that affect ventilation rates and effective isotopic diffusivities.
* Local climate in the years immediately following deposition creates permeability and grain size variations that persist and affect interstitial transport. *Temporal* variability is evident in the physical characteristics of the firn.
* Variations in the permeability profile due to changing environmental conditions affect interstitial transport and likely impact gas diffusion throughout the diffusive zone.

References

Albert, M.R., 2002. Effect of Snow and Firn Ventilation on Sublimation Rates. Annals of Glaciology 35, p. 510-515.

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