South Pole ice core (SPICEcore)

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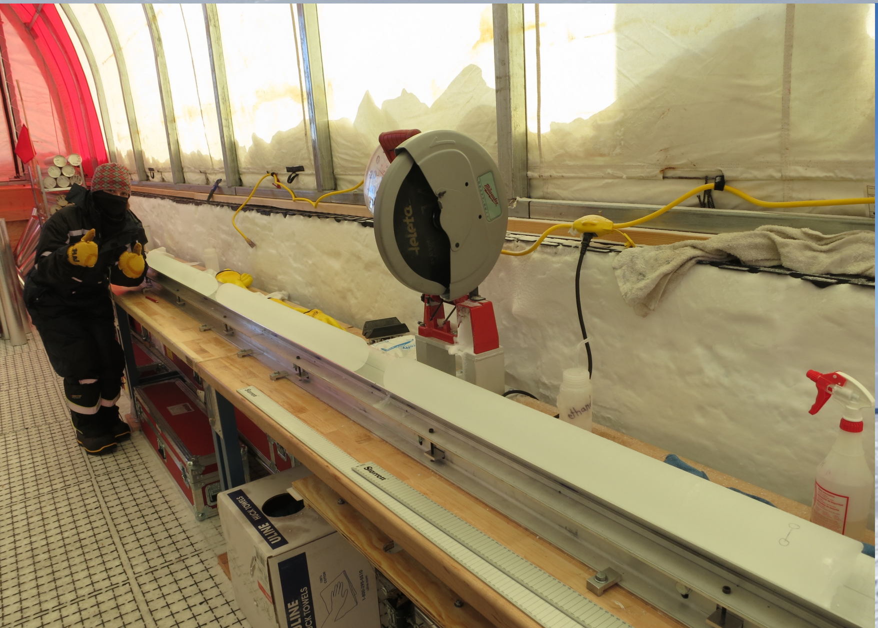
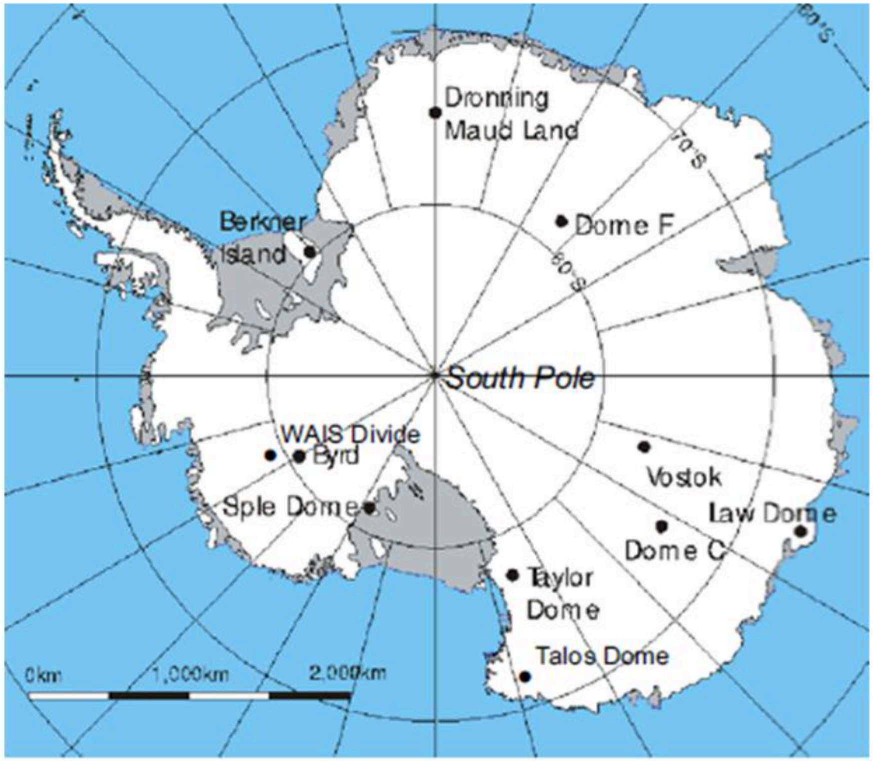


Supported by National Science Foundation Antarctic Glaciology Program

SPICEcore rationale

- High resolution East Antarctic ice core far from previously drilled ice cores
- Core/dust logging evidence of interpretable stratigraphy (Thanks IceCube)
- Interesting spot for a climate record
    - ✓ IndoPacific vs. Atlantic
    - ✓ Southern Ocean vs. low latitude
- Cold and clean ice (trace gas stability)
- Demonstrated ultra-trace gas record

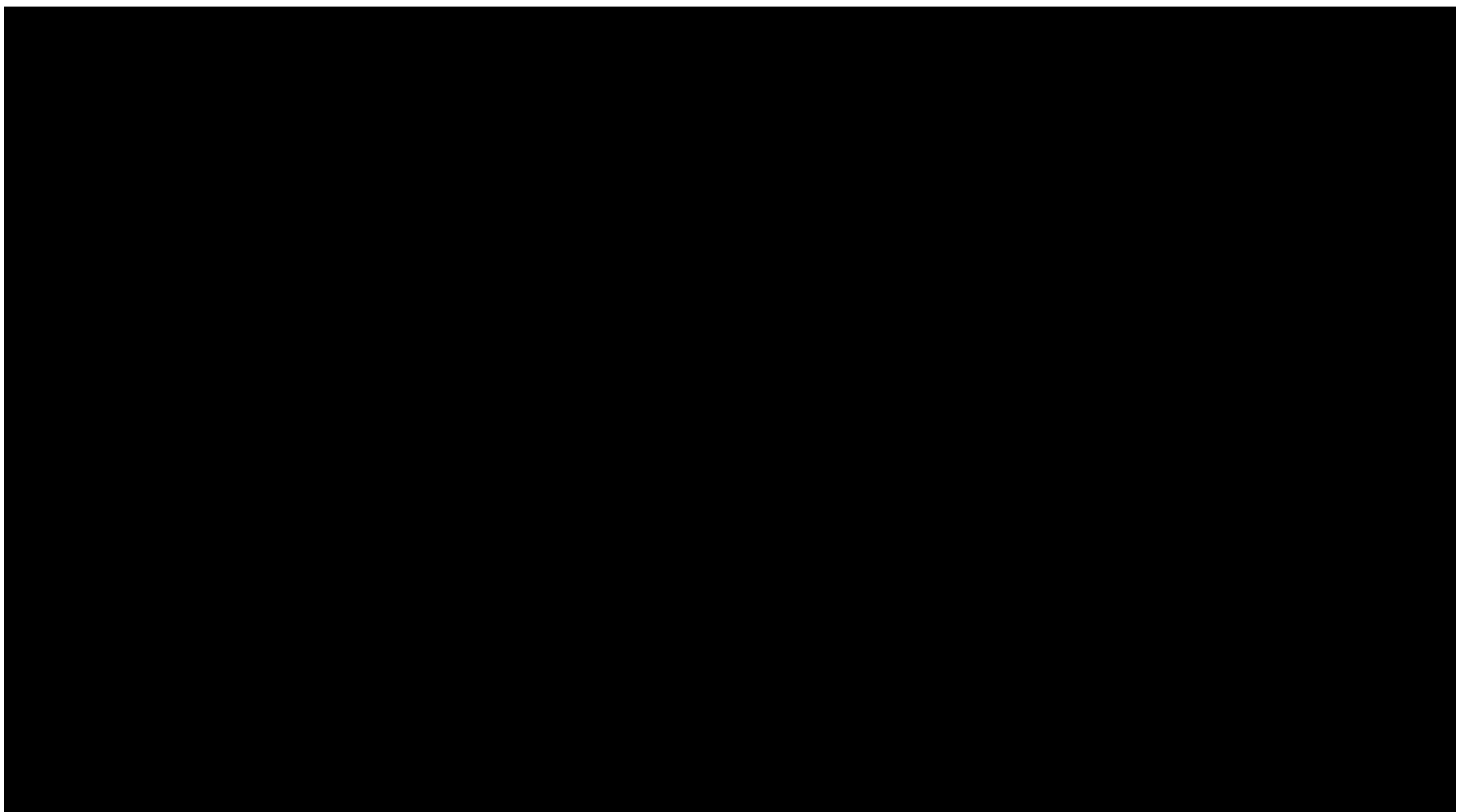


Why did we not drill to bedrock?

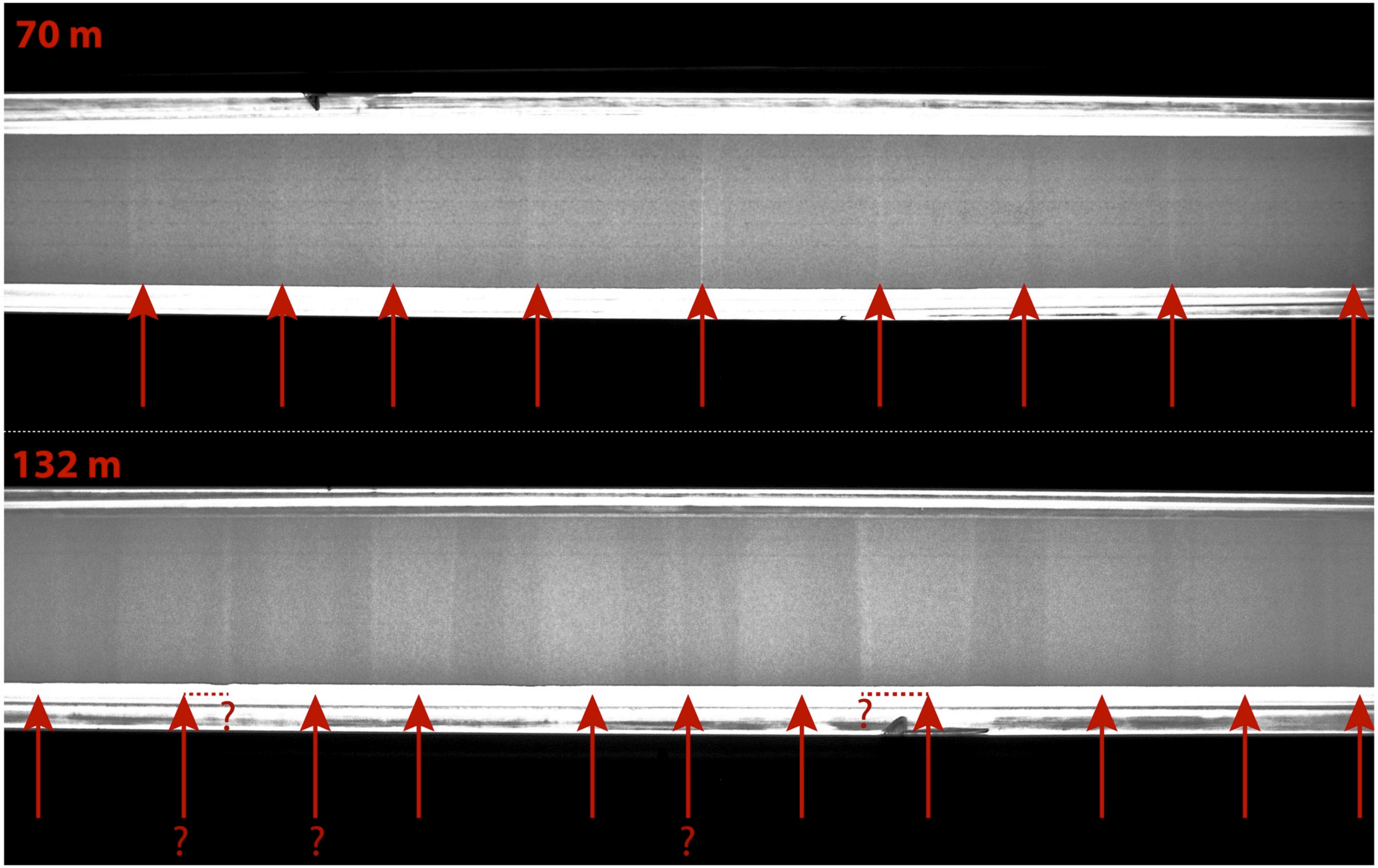
- South Pole is a flank site
- Ice comes from upstream
- The transport distance from origin increases with depth
- Interpretation of accumulation rate, stable isotope ratios, ice chemical/physical properties will be complicated
- Difficult to get it funded

SPICEcore drilling

- Field crew of 9-10 (5 drillers plus science)
- Camp set-up and drilling completed in 2 seasons
- Short 3rd season for core shipment and camp tear-down
- Final depth was 1751 m (original target was 1500 m)
- All ice in the US and processed, samples in labs, analysis continuing



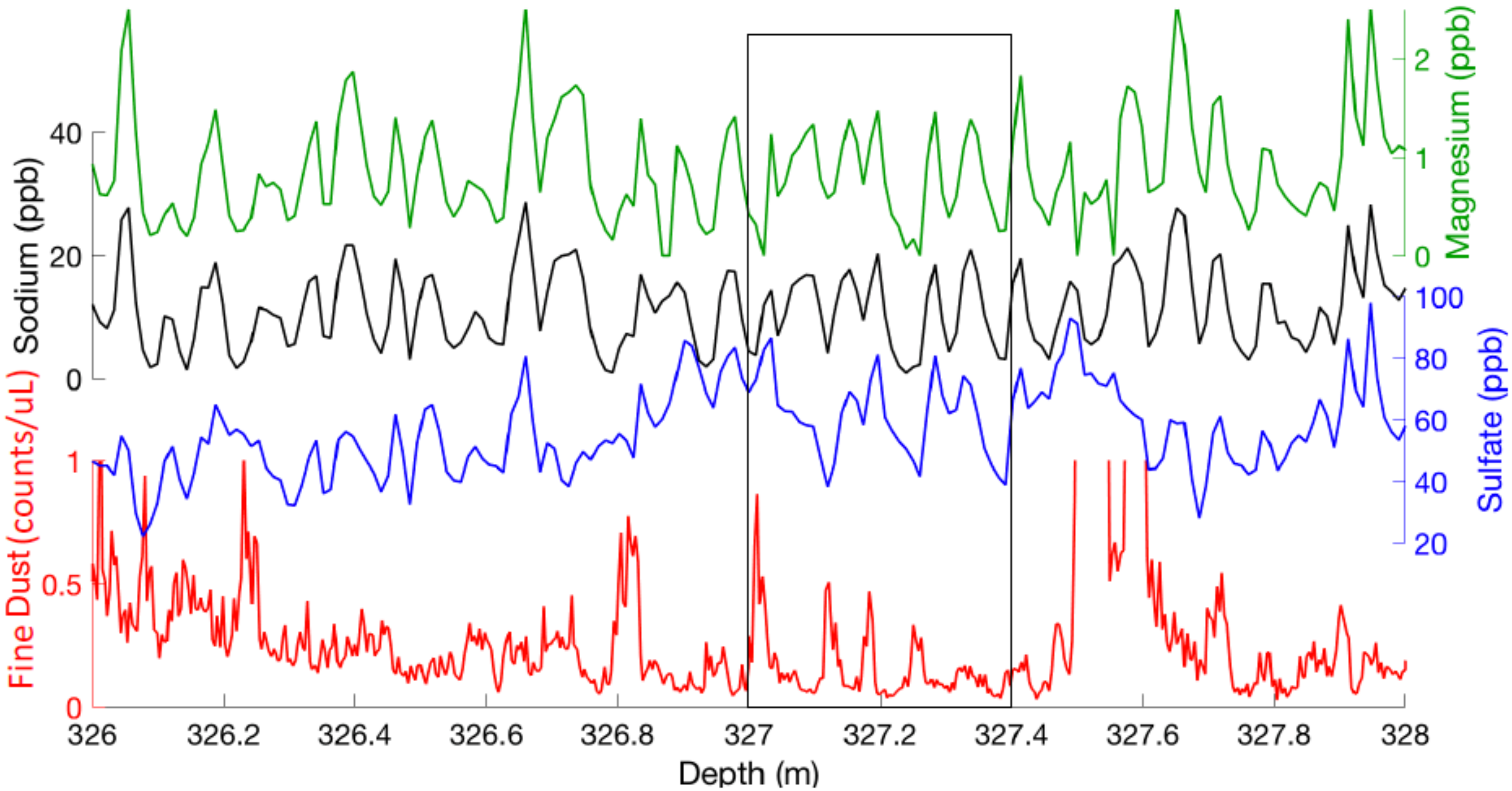
Visual strat. and physprops (J. Fegyveresi, D. Voigt et al.– Penn State)



Data show no signs of disturbance of the ice stratigraphy in SPC14 by folding, boudinage, or other processes acting at a large enough scale to affect the paleoclimate records.

Dartmouth CFA Conductivity vs. UW ECM

Annual Signals in Chemistry



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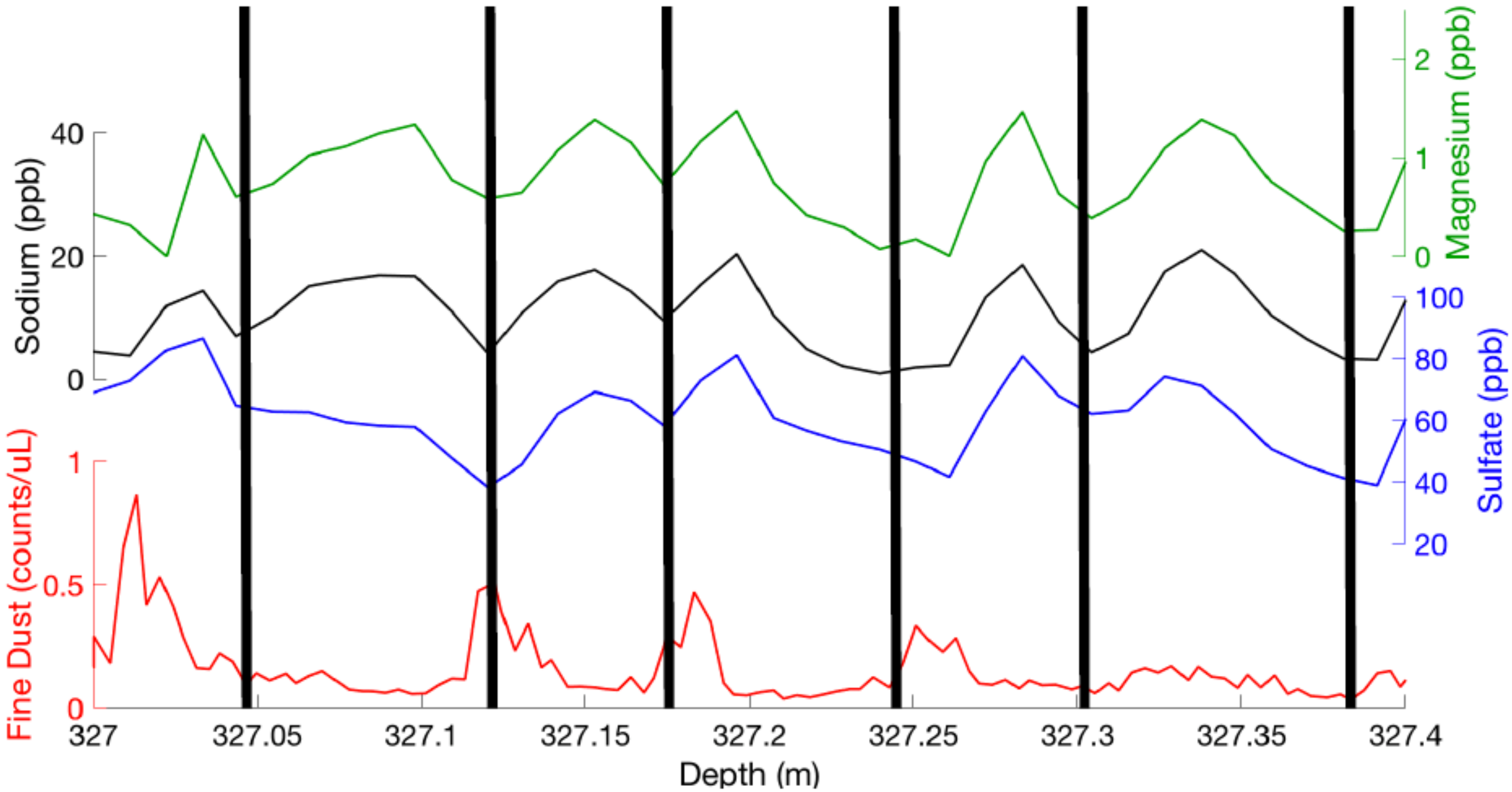
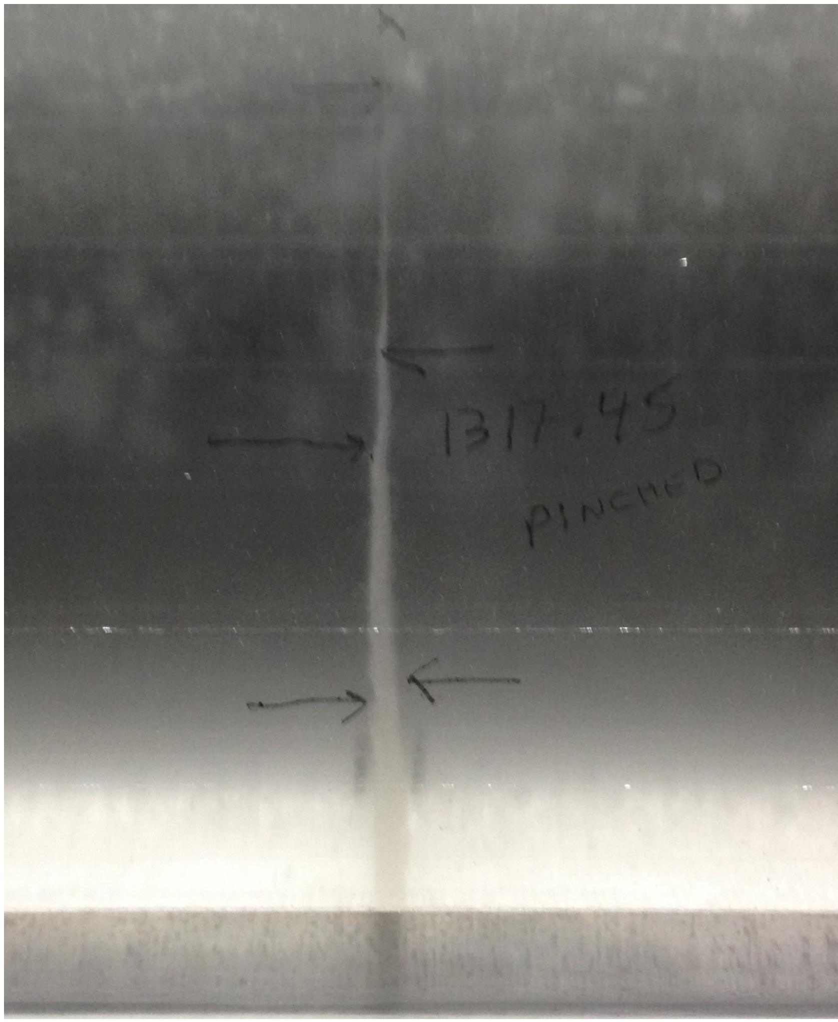
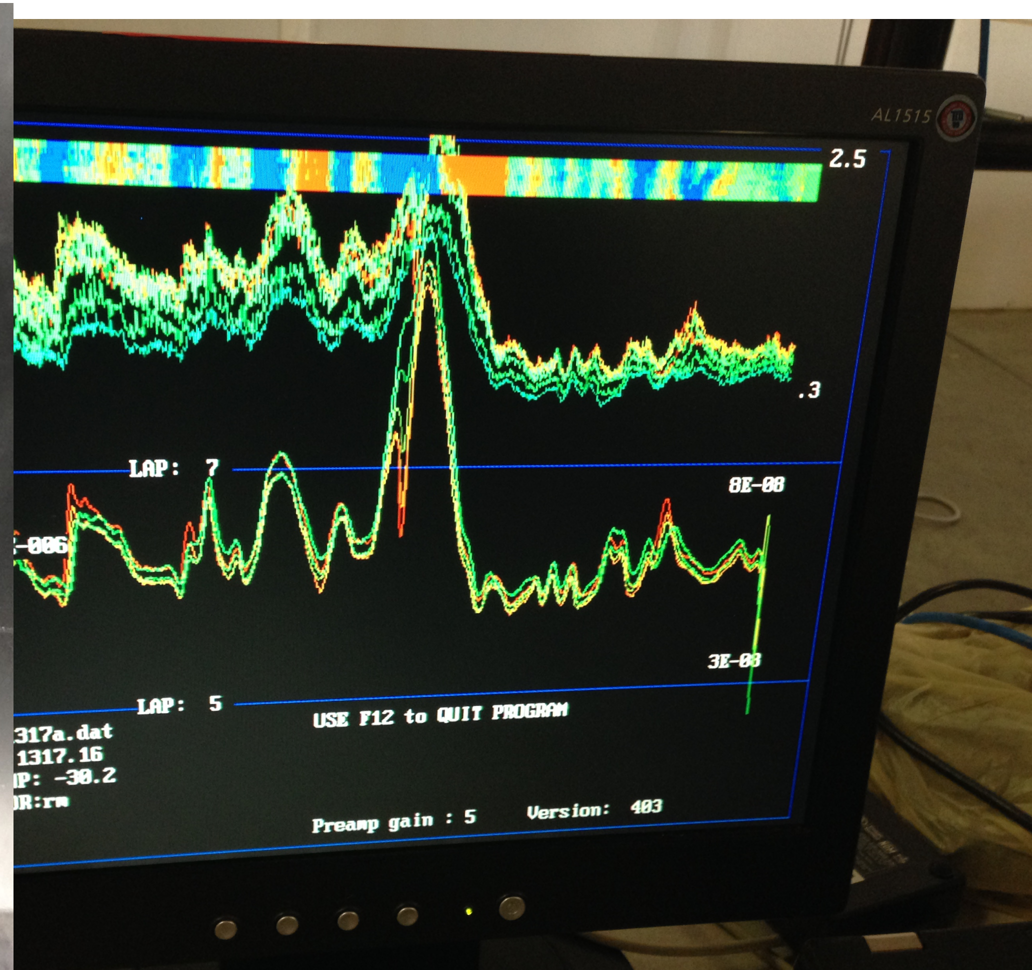


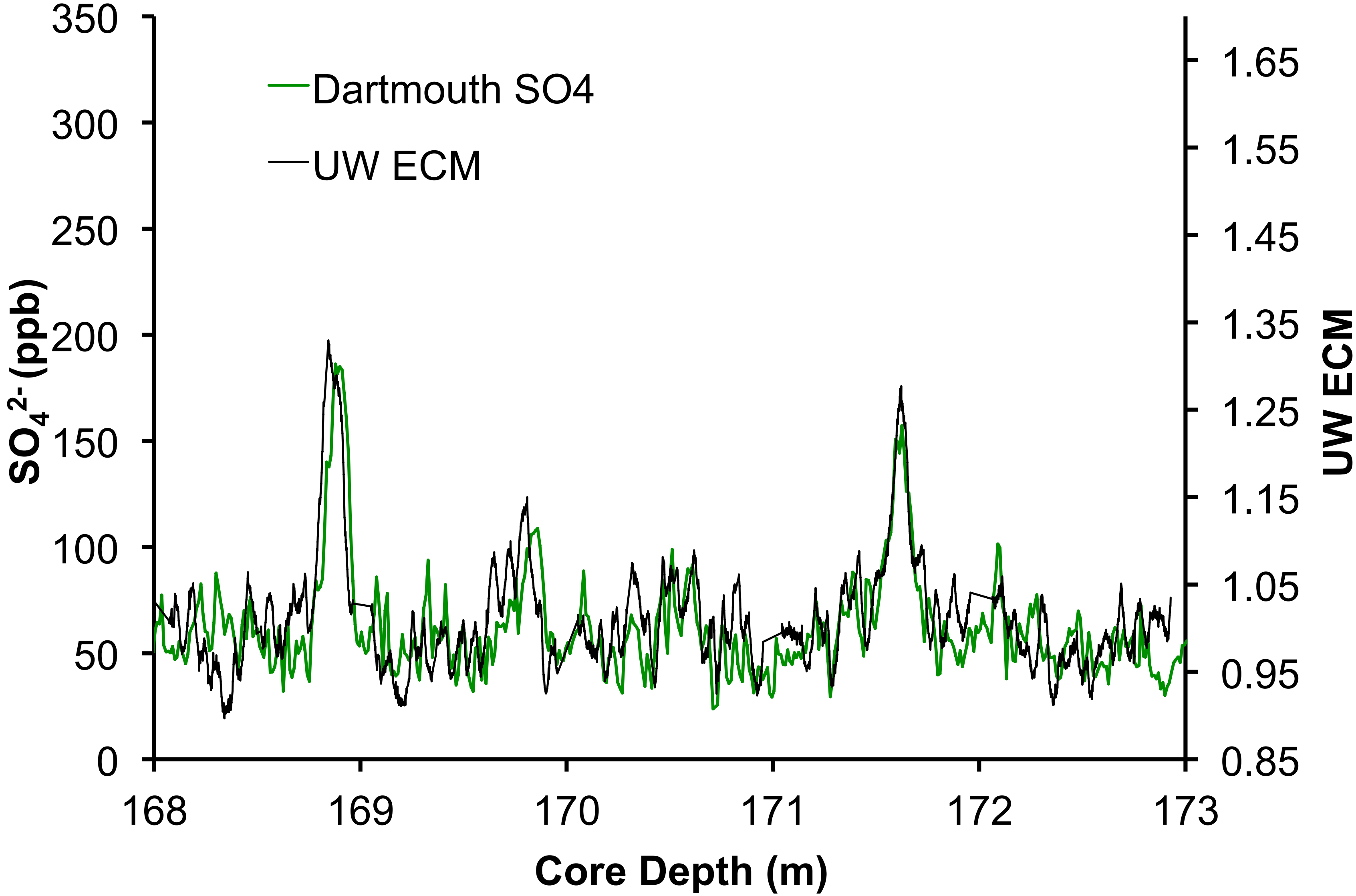
What we learned – Electrical conductivity (TJ Fudge – UW)

Electrical conductivity measurements (ECM) display annual layers and provide volcanic matches to other ice cores

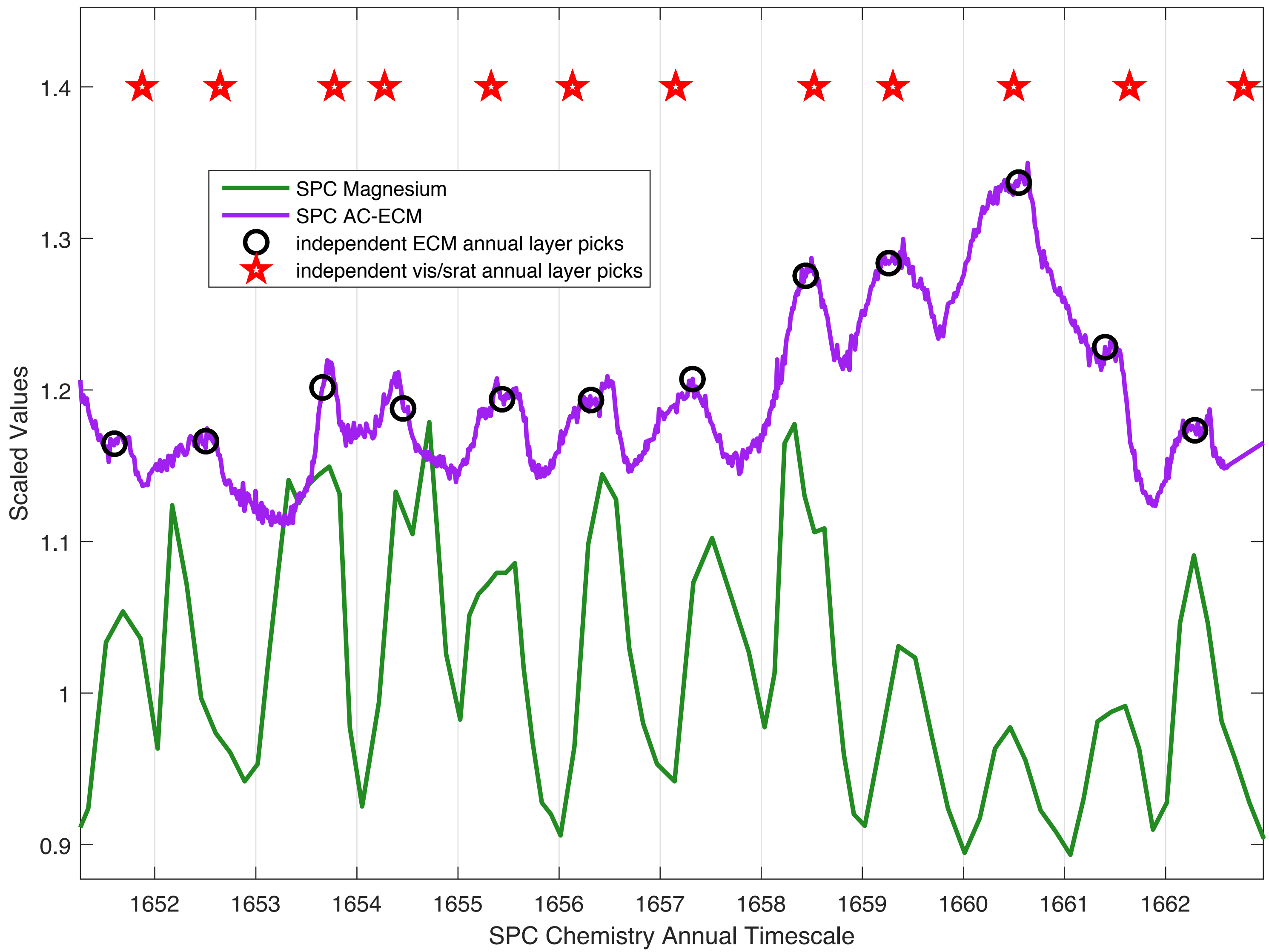




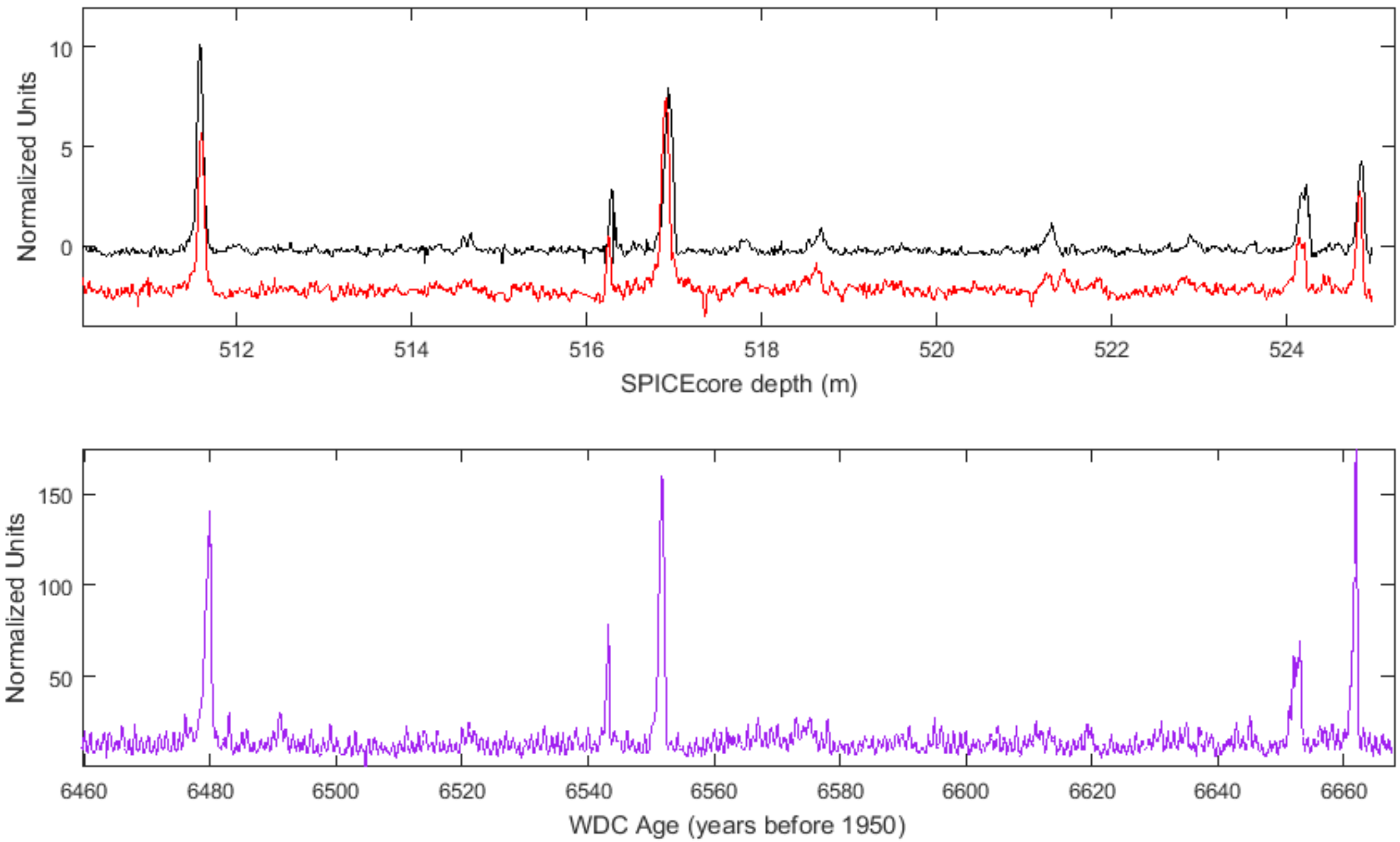
Dartmouth Sulfate vs. UW ECM



SPICE Annual Layers in Chemistry, ECM & Vis-Strat

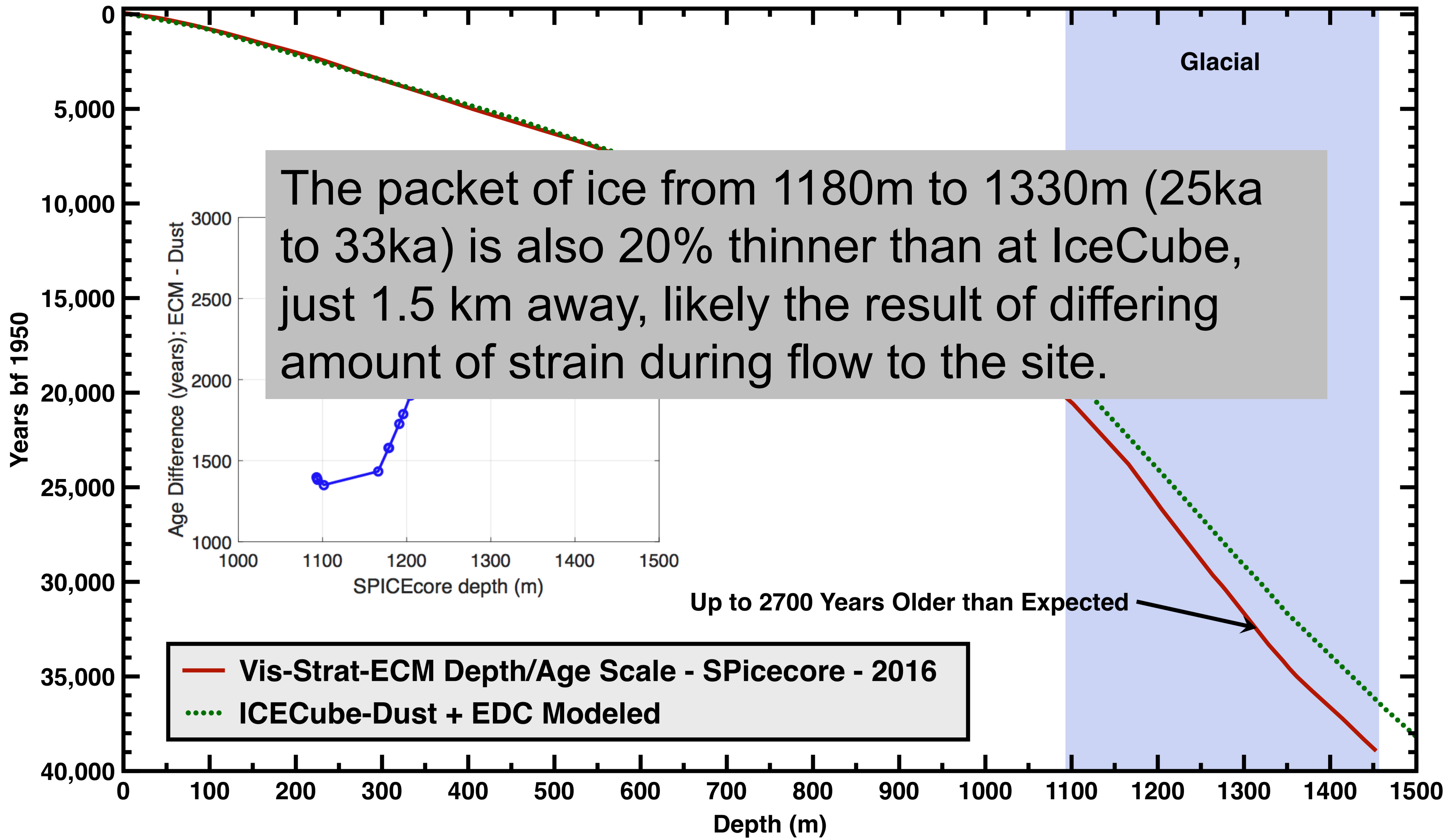


Volcanic Matching to assess the annual layer interpretation



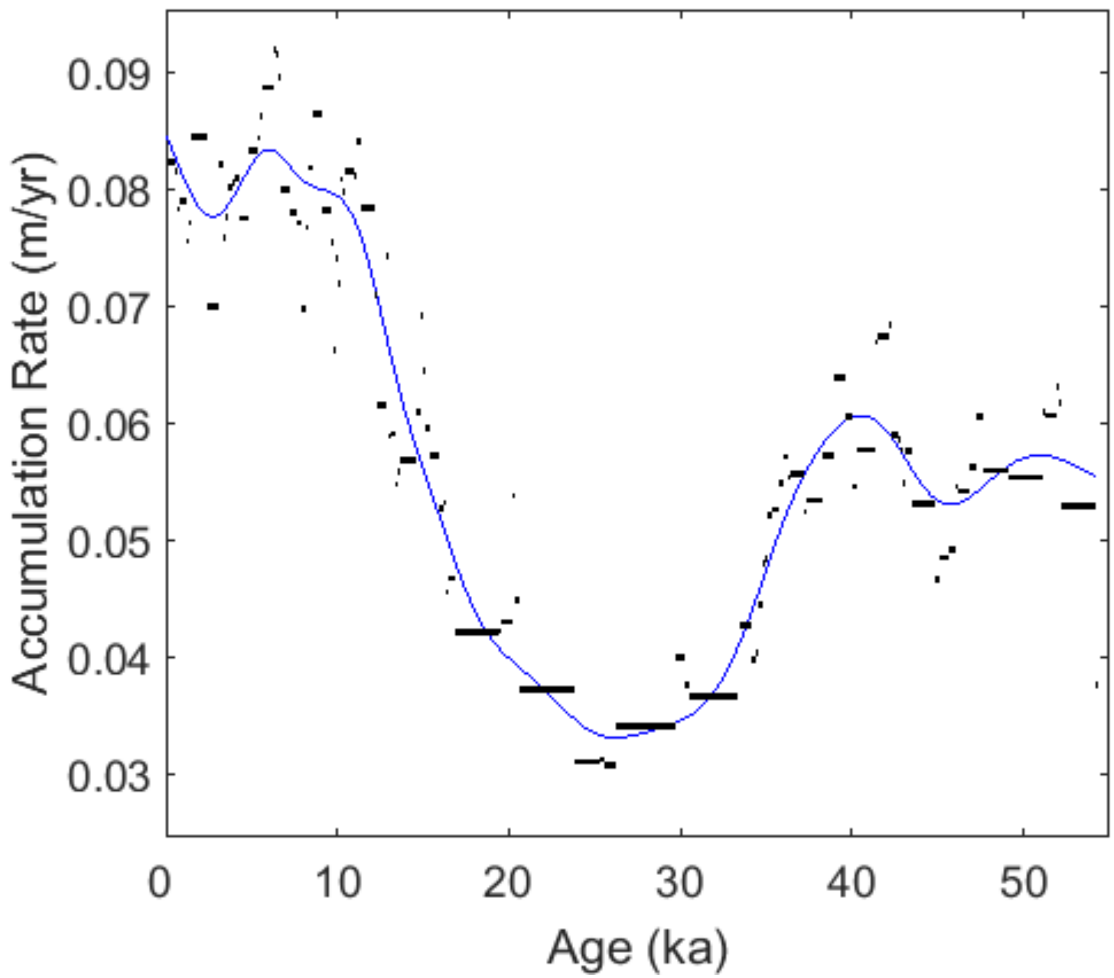
Distinct volcanic sequences allow the precise cross-dating to the WD2014 chronology from the WAIS Divide ice core

Comparing with ICECube/EDC Scale



The packet of ice from 1180m to 1330m (25ka to 33ka) is also 20% thinner than at IceCube, just 1.5 km away, likely the result of differing amount of strain during flow to the site.

SPICEcore Inferred Accumulation Rate
T.J. Fudge – Univ. of Washington



Accumulation rate is well constrained and shows no discontinuities for the full length of the SPICEcore record

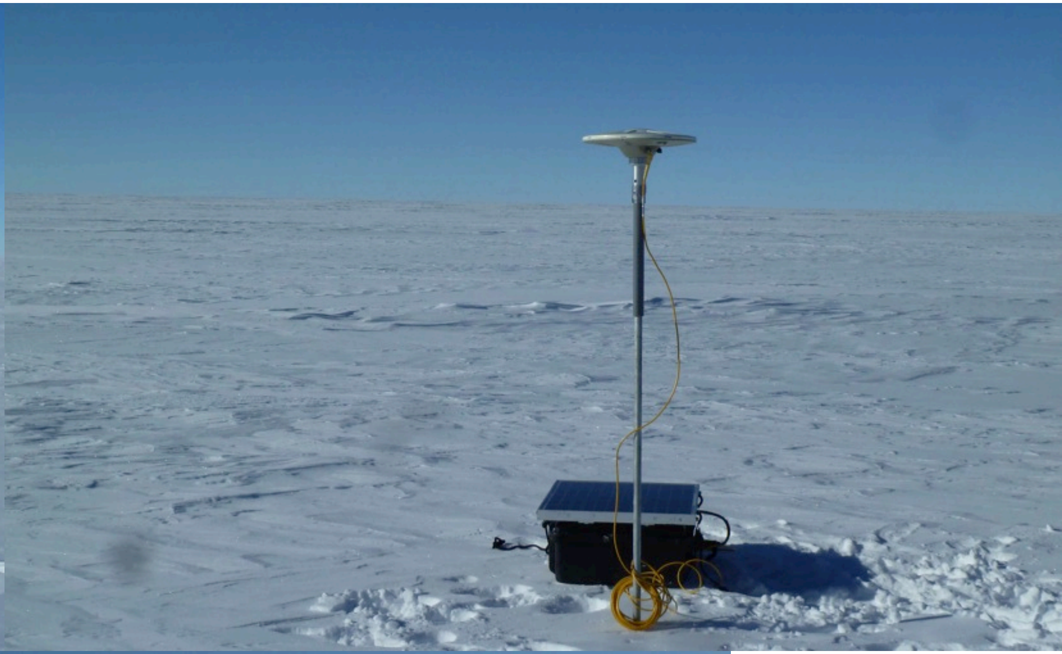
SPICEcore sister project

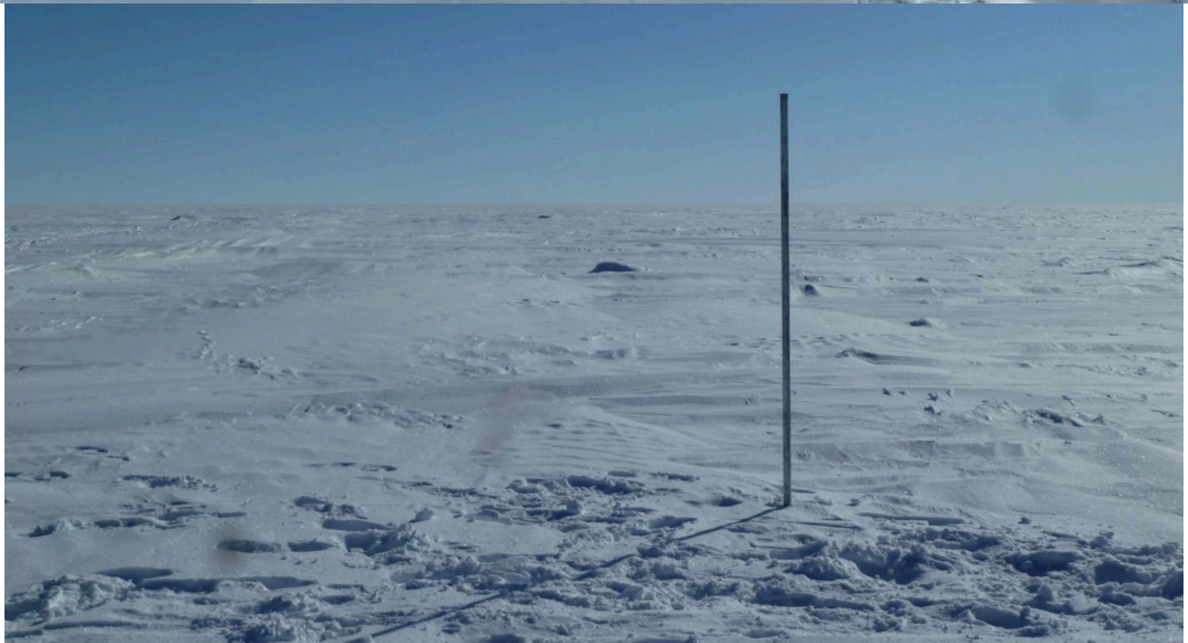
Characterization of upstream ice and firn dynamics affecting SPICEcore

Univ. of Washington: **Michelle Koutnik, Howard Conway, Ed Waddington, T.J. Fudge, Max Stevens, David Lilien**

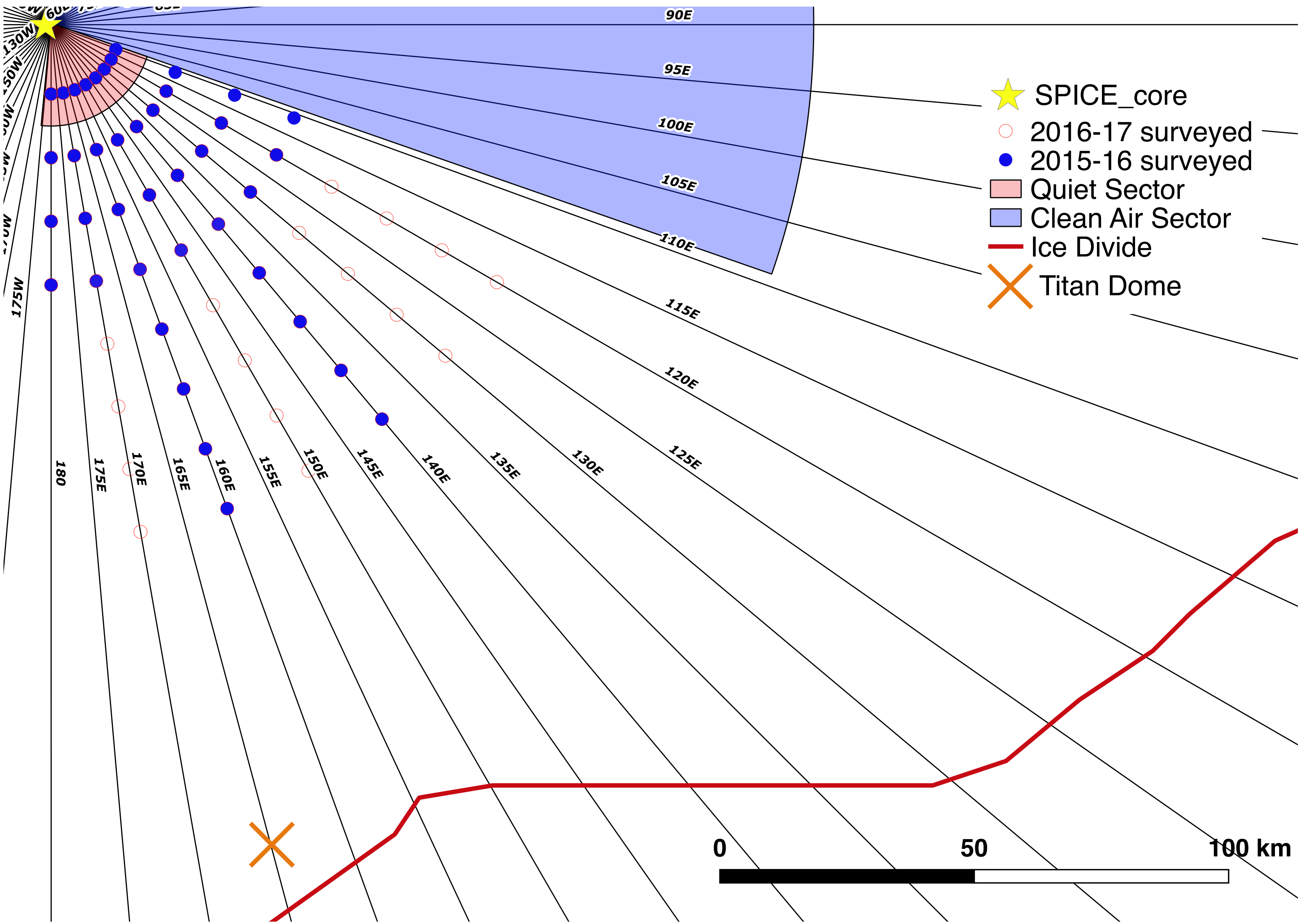
Dartmouth College: **Bob Hawley, Erich Osterberg, David Clemens-Sewall, David Ferris, Mary Albert**

GPS survey with stakes

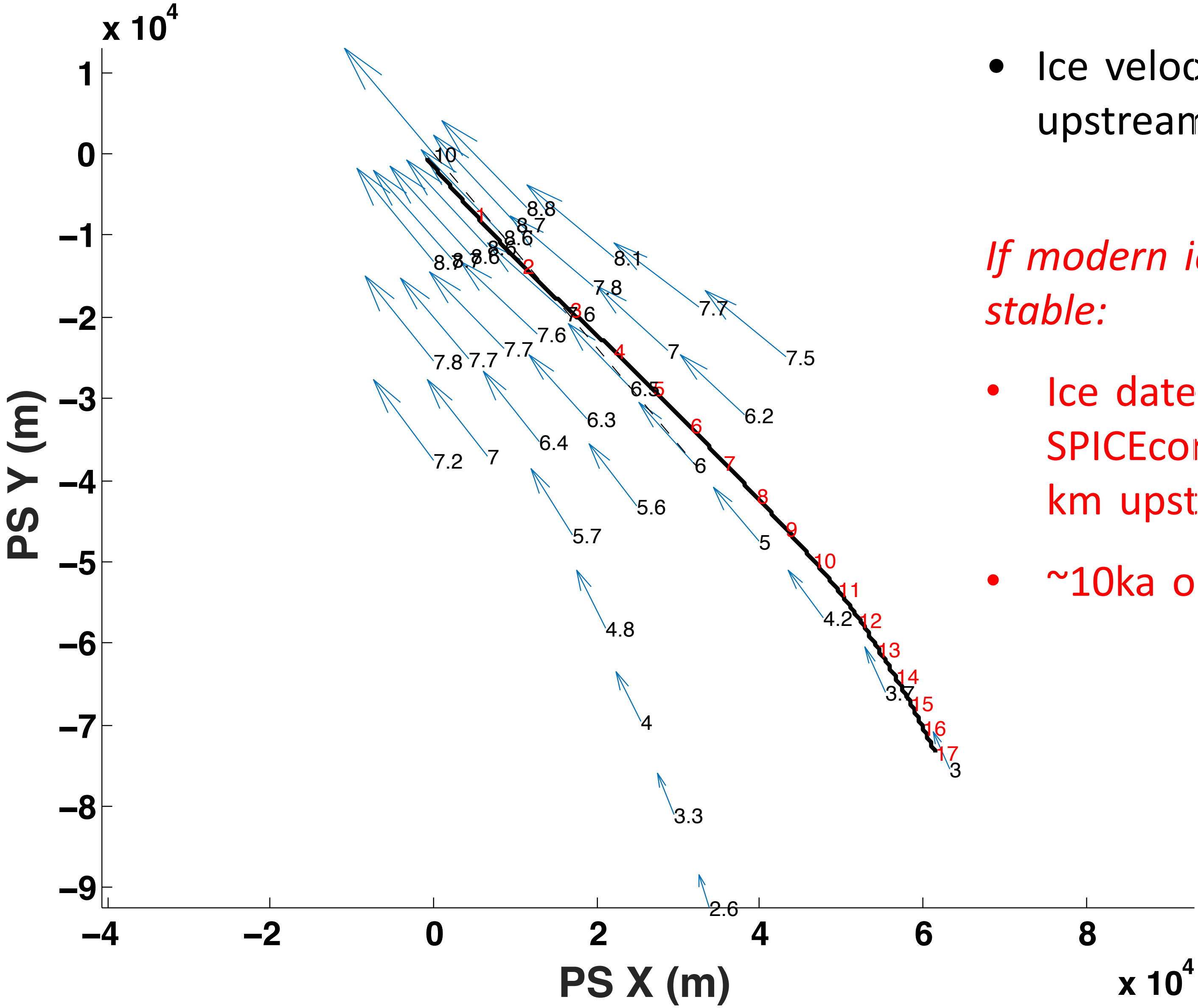




GPS survey of stake locations



GPS survey of stake locations: Flowline

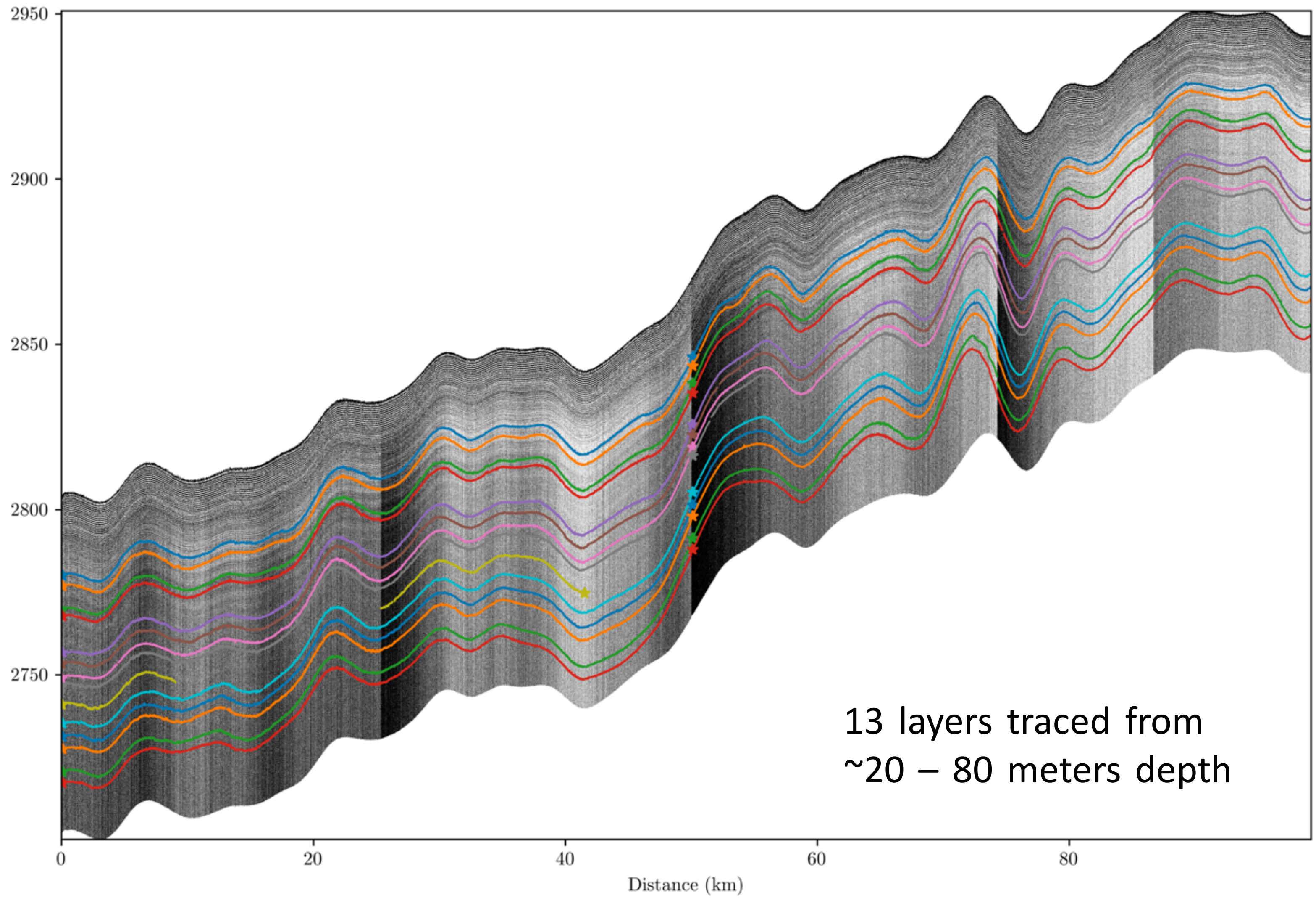


- Flowline is along 140 E
- Ice velocity decreases upstream

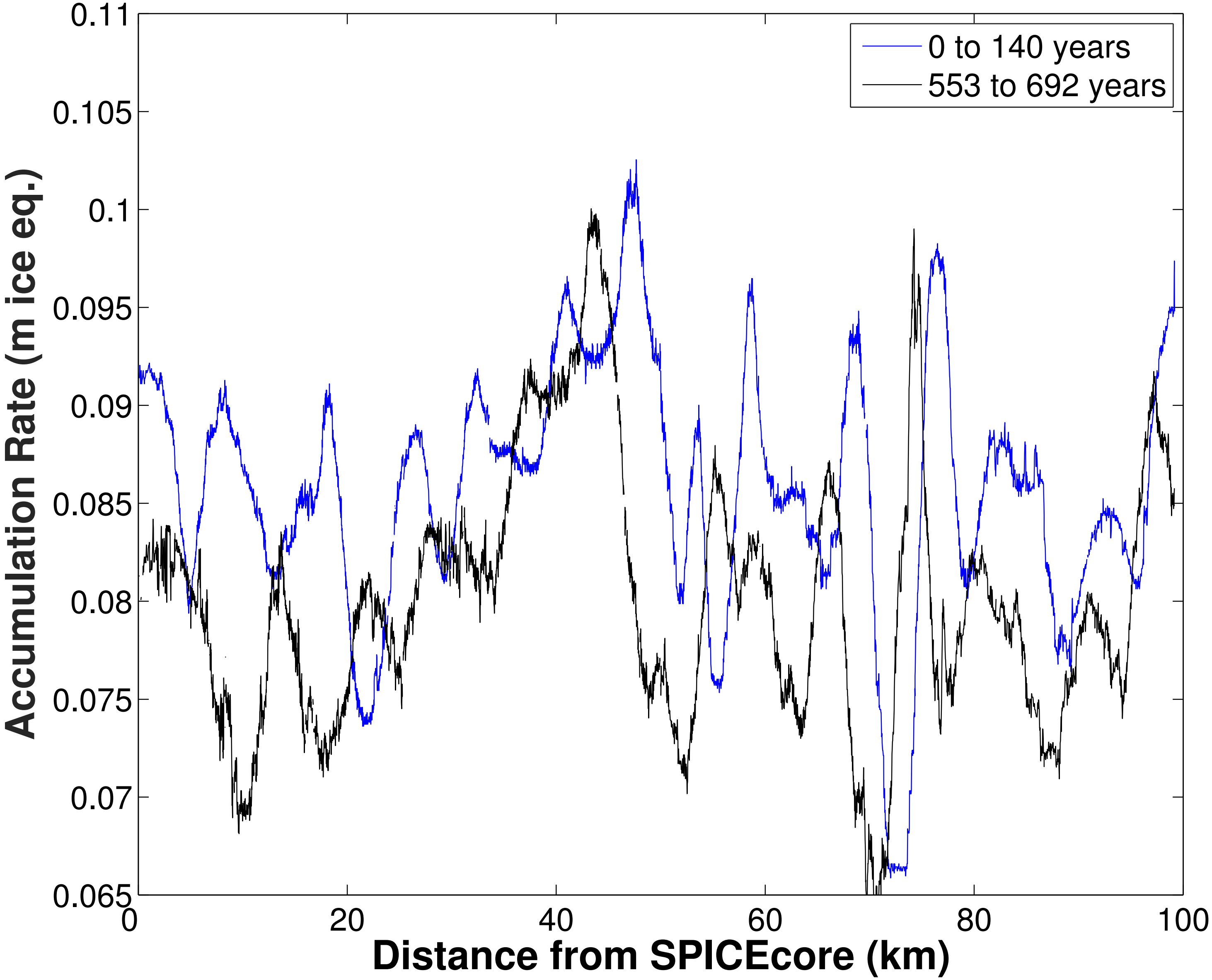
If modern ice-flow velocity is stable:

- Ice dated to 17ka in SPICEcore originated ~100 km upstream
- ~10ka originated at ~65 km

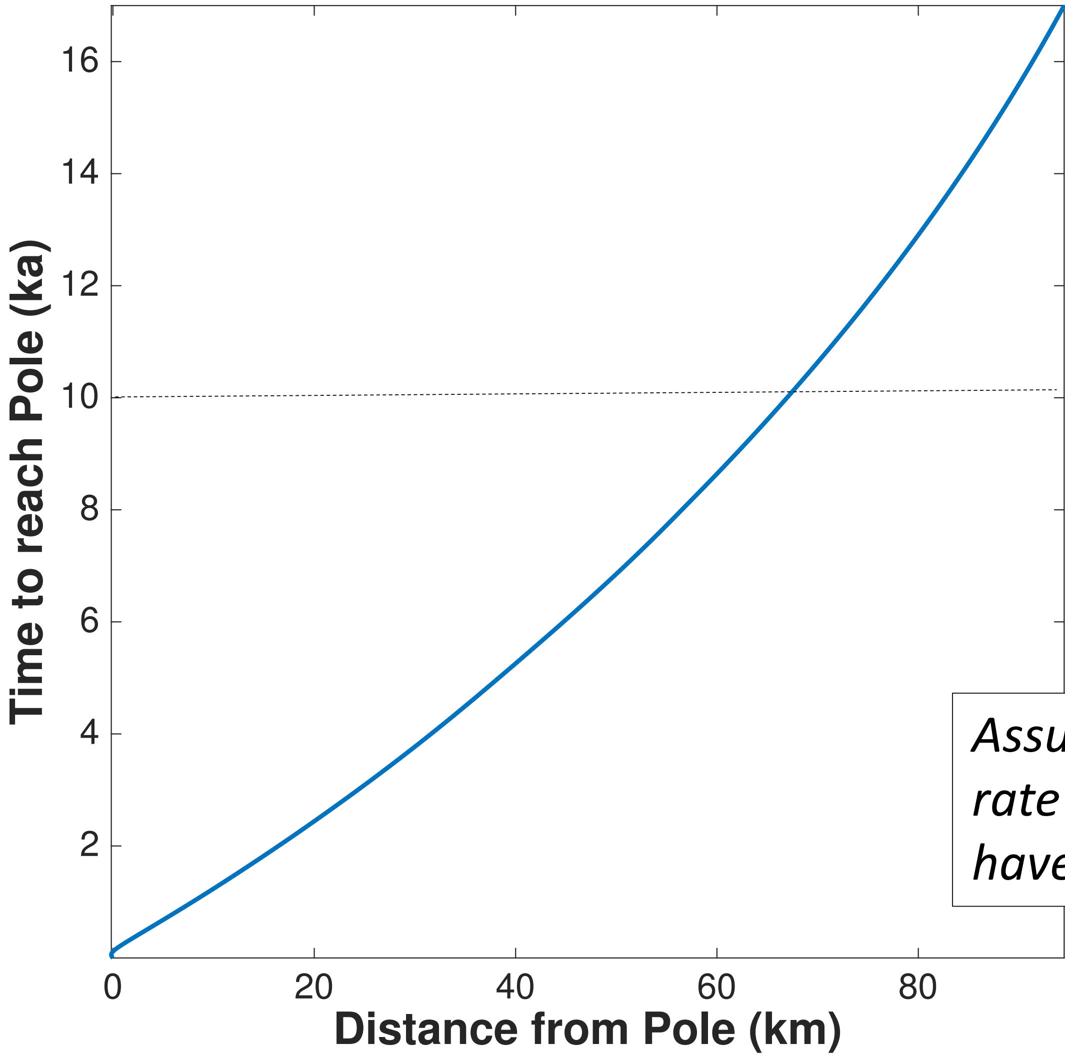
Ice penetrating radar: 200 MHz shallow radar



Spatial pattern of accumulation rate over past ~700 years

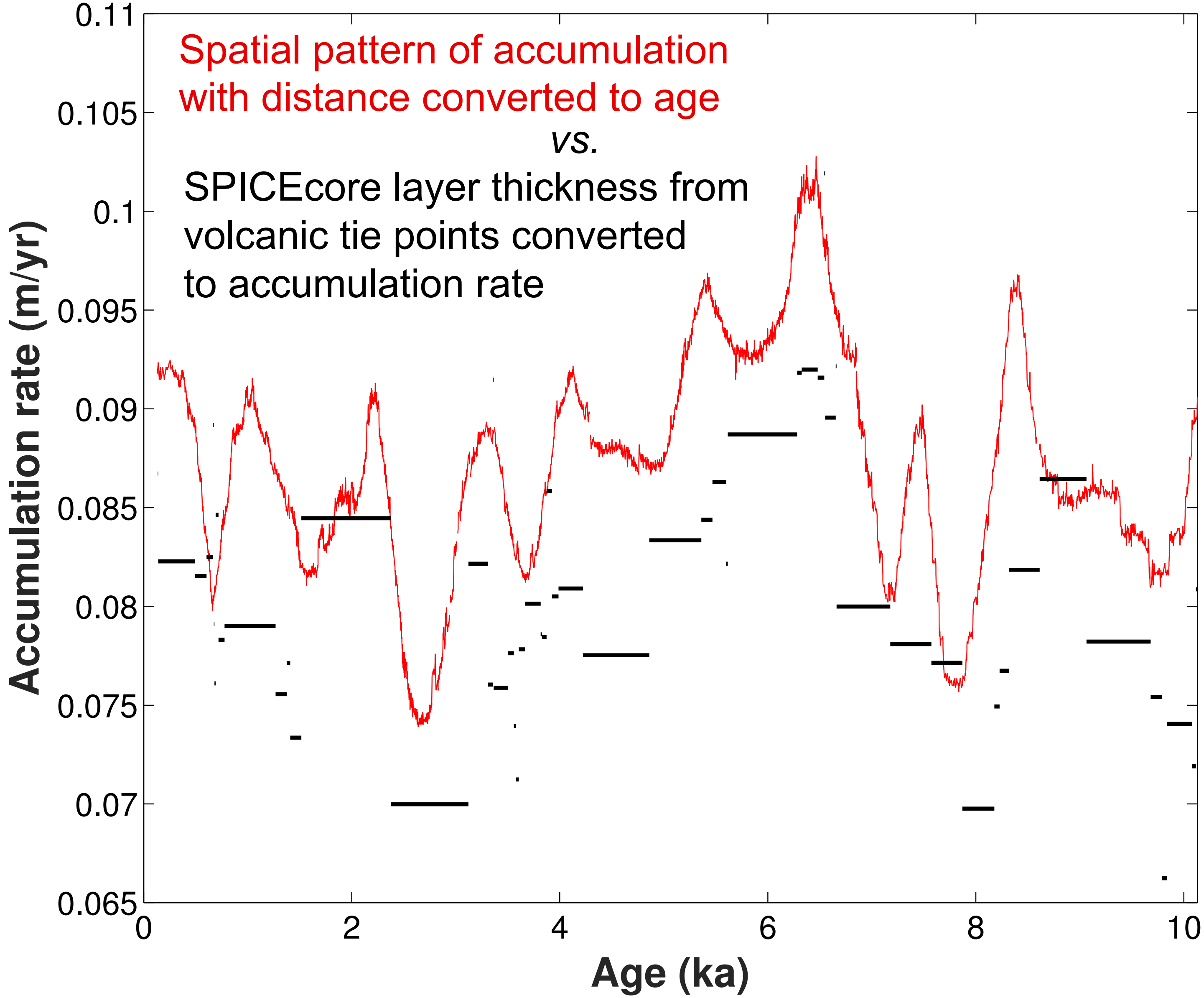


Ice-flow velocities give distance upstream *vs.* time

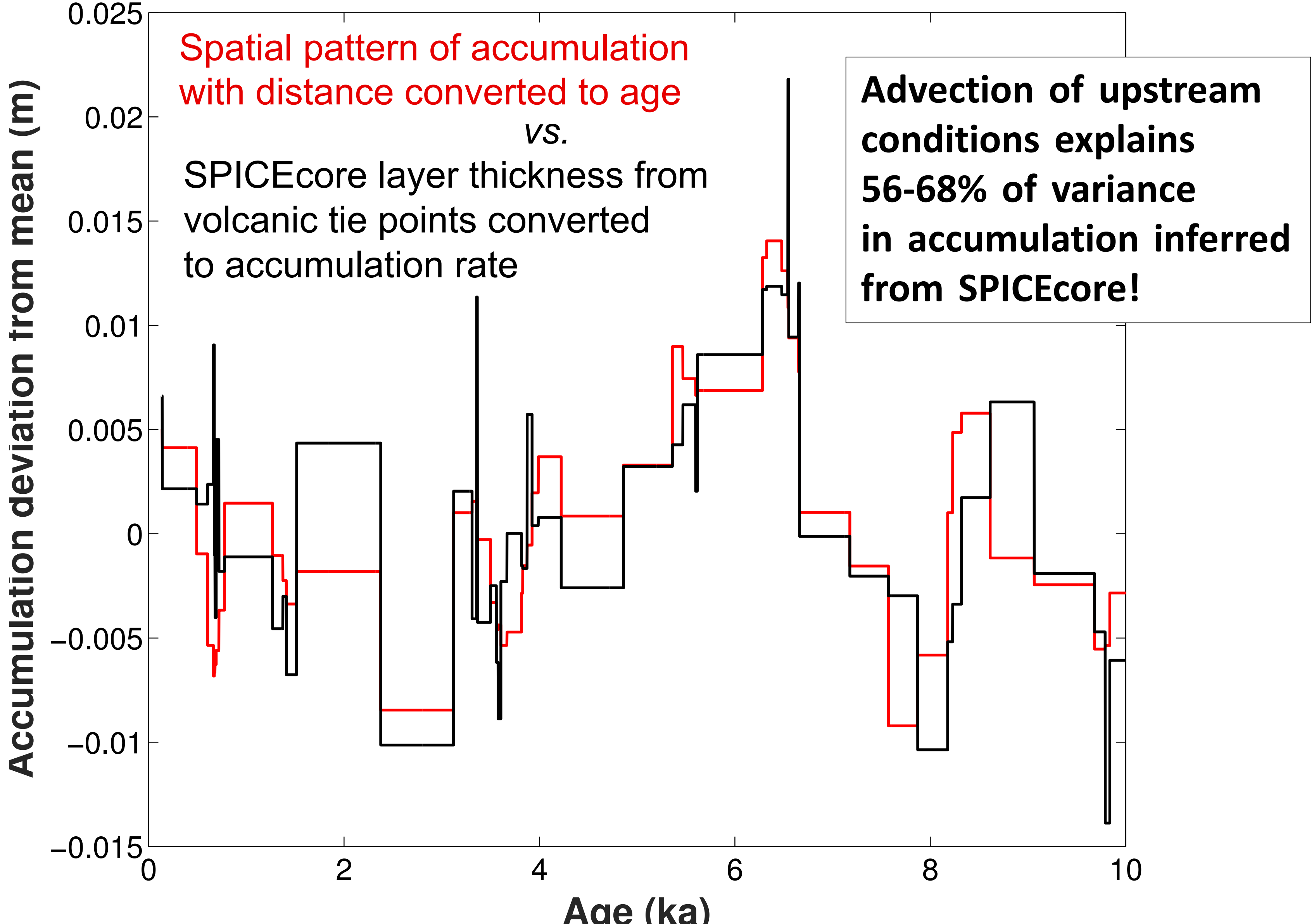


Assume that modern ice-flow rate and accumulation rate have been stable over the past 10 ka

Temporal variation in accumulation over the past 10 ka



Temporal variation in accumulation over the past 10 ka



Takeaway points

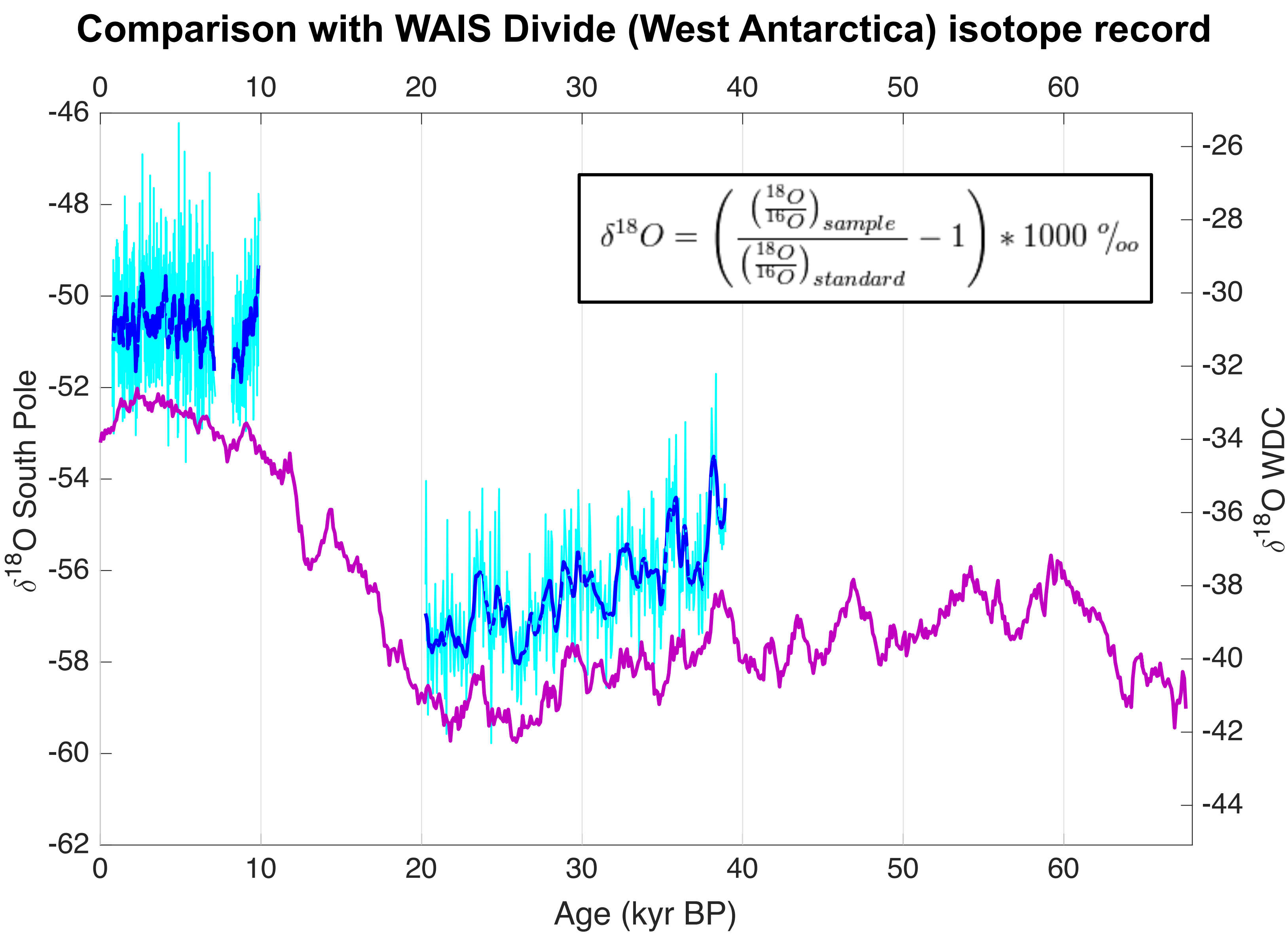
- Flowline is along 140 E and ice velocity decreases upstream from ~10 m/yr at South Pole to ~3 m/yr at 100 km upstream
- Titan Dome is likely source
- Temporal variation in SPICEcore accumulation rates during the Holocene largely driven by advection of upstream conditions, not by climate!
- Accumulation pattern and flow likely remained stable over past 10 ka

SPICEcore record can be used to evaluate Holocene ice dynamics

Ice Core Climate Records (isotope measurements)
(Eric Steig, Univ. of Washington)

- *Stable isotopes of ice core water (^{18}O and ^{2}H of H_2O)*
- *Directly correlated with local climate but also provides information on global climate*
- *Caution: Water isotopes are not a perfect temperature proxy*

SPICEcore Isotope Measurements (UW and CU, Eric Steig and Jim White)



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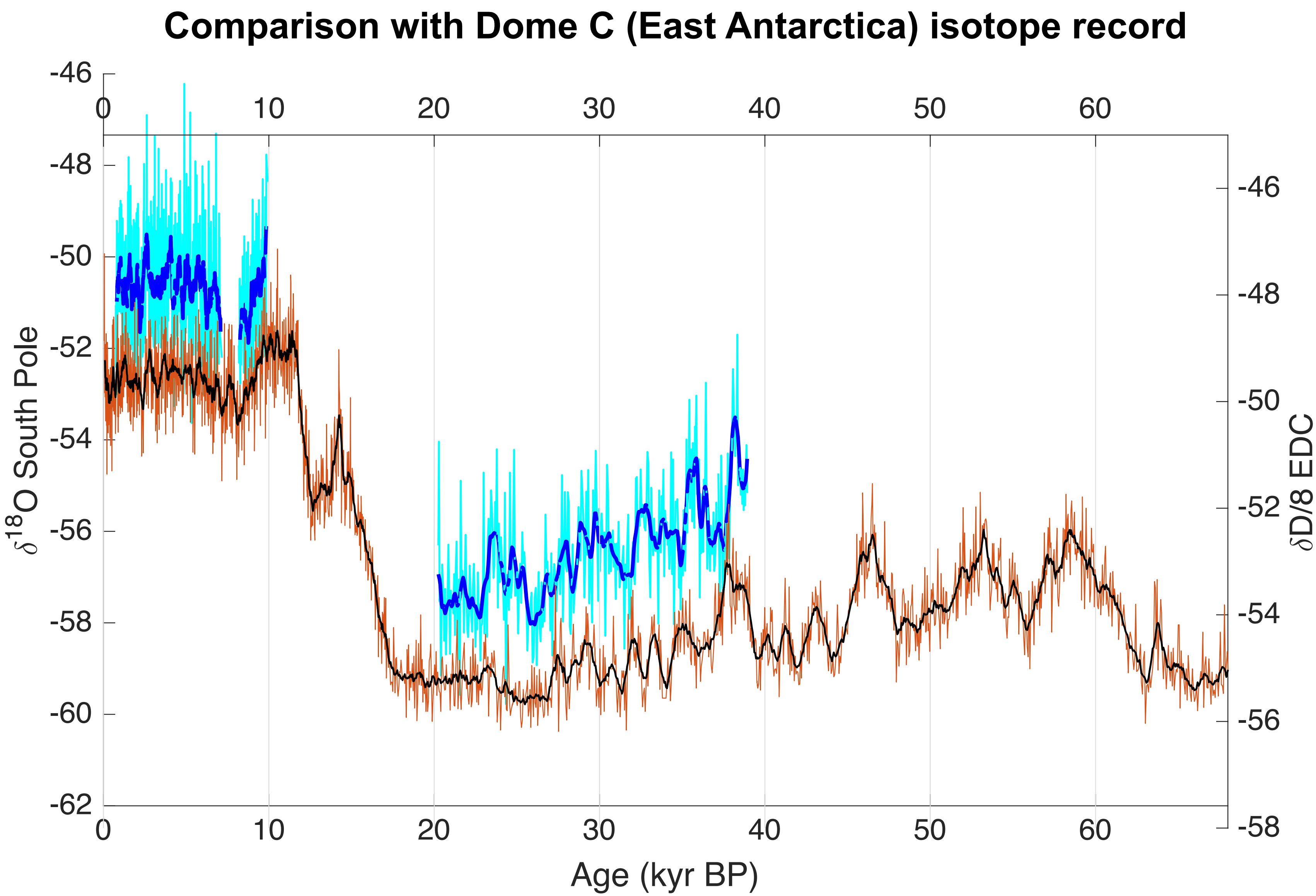
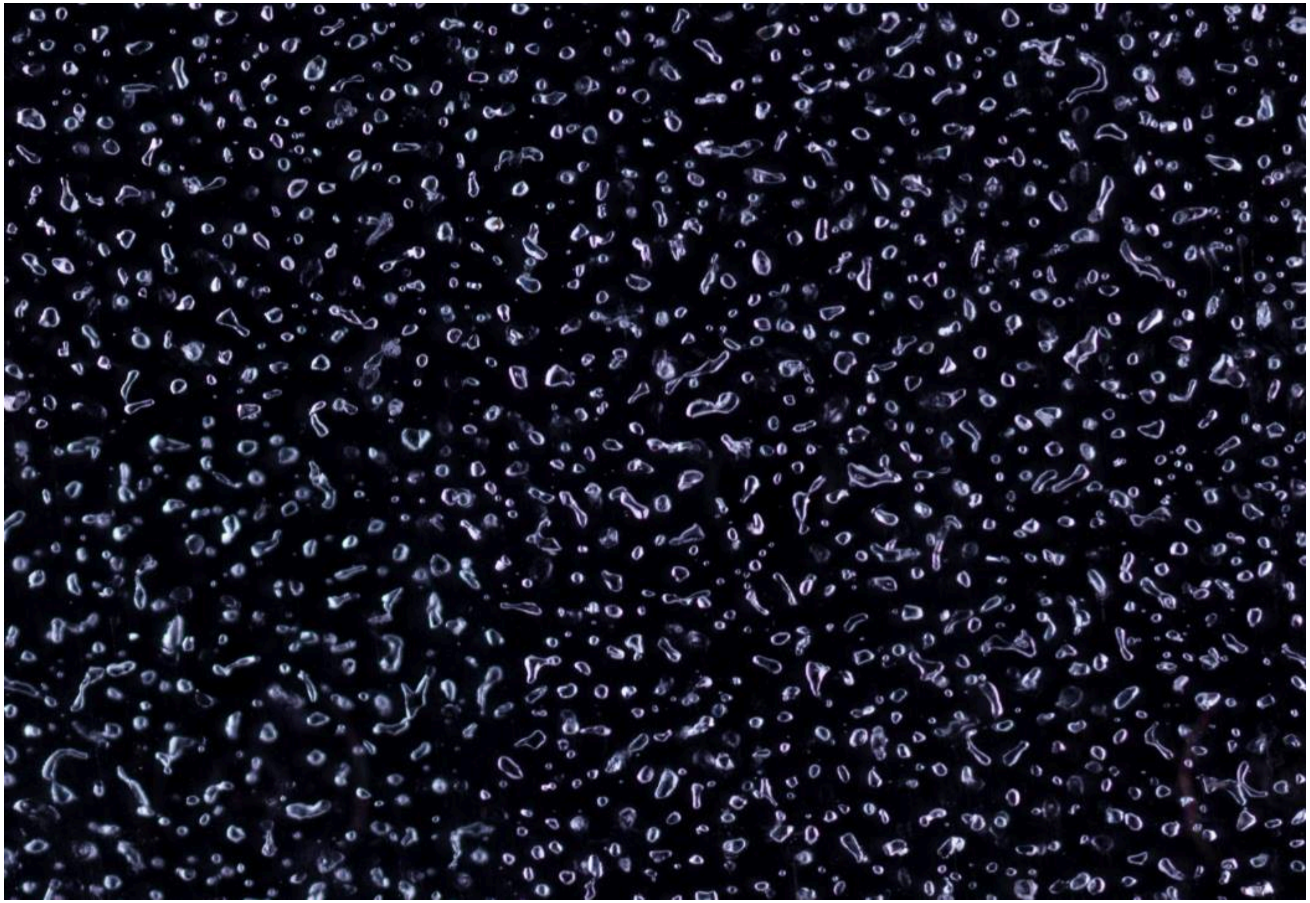


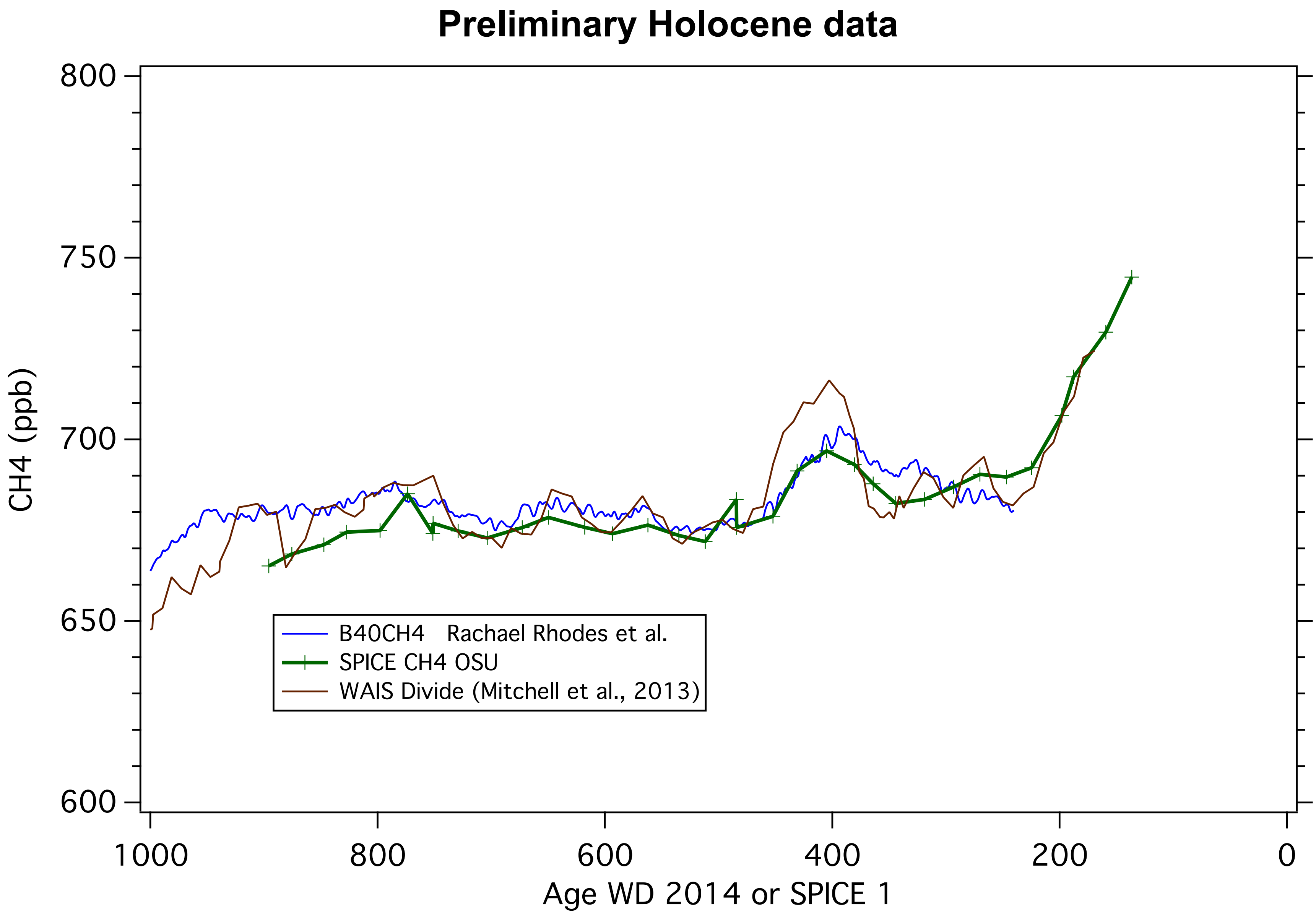
SPICEcore gas measurements

- Ice cores contain an archive of ancient air
- Trace gas measurements reflect a global atmospheric signal



Air bubbles in SPICEcore at 160 m (~1500 yrs BP)

SPICEcore Methane Measurements (OSU, Ed Brook)



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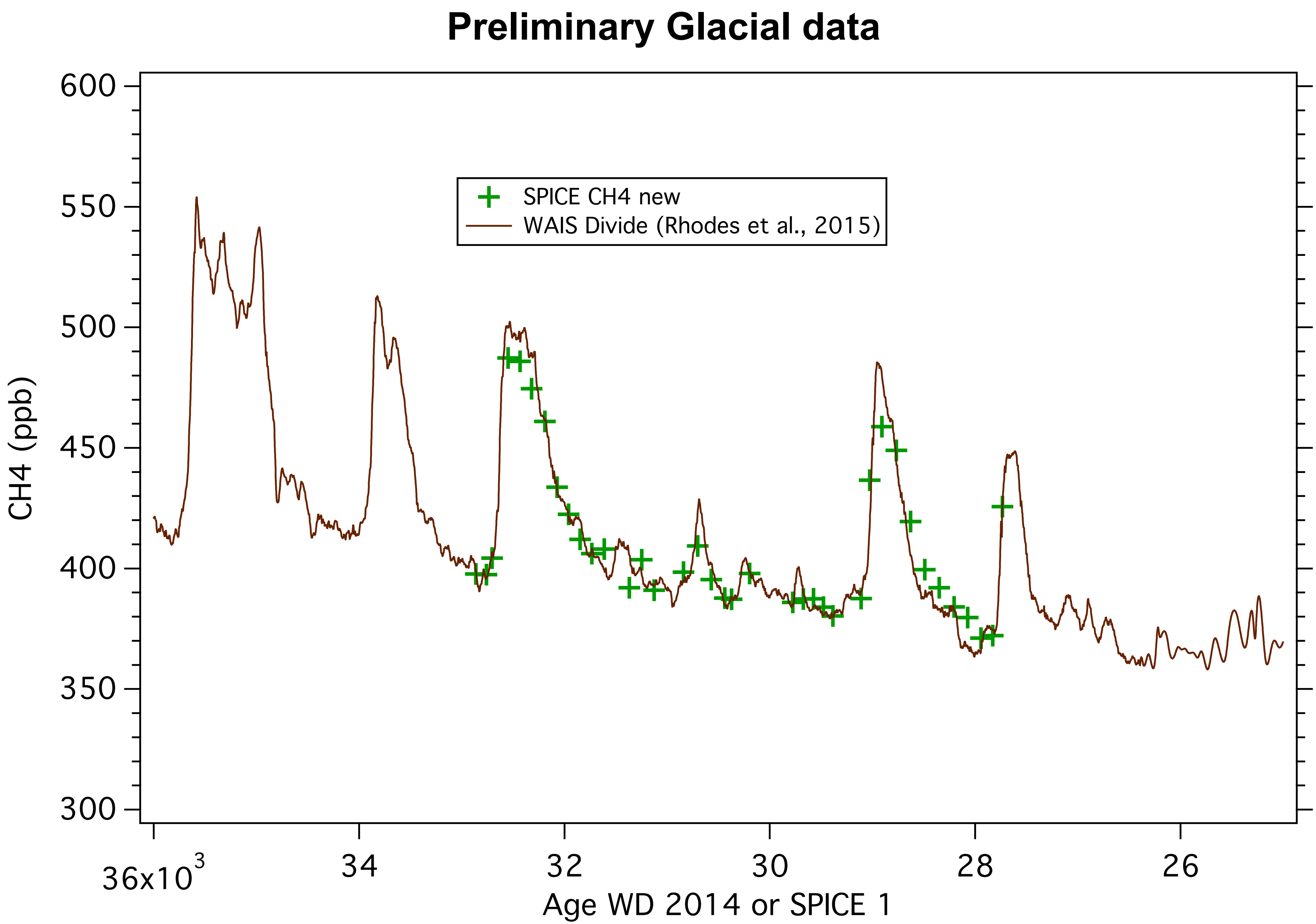


SPICEcore COS measurements (UC Irvine)

Only about 500 parts per trillion of COS in the atmosphere today

Interested in ice core COS measurements because

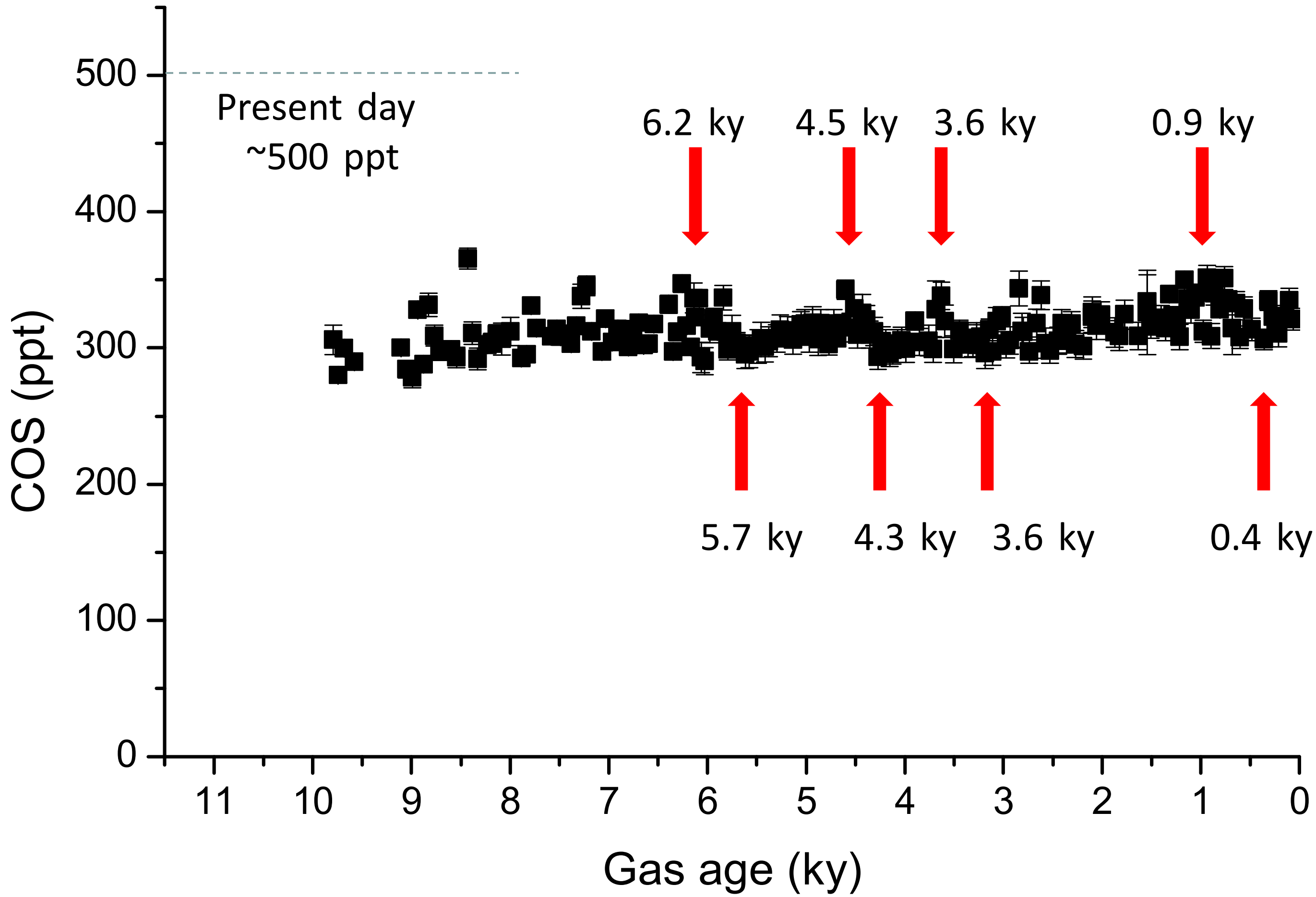
- Uptake by terrestrial plants during photosynthesis accounts for 60-70% of COS removal from the atmosphere

COS uptake by plants is linked to gross primary productivity (GPP) via the ratio of atmospheric COS to CO_2 levels and leaf relative uptake (LRU)

$$\text{Uptake} = \text{GPP} \times X_{COS}/X_{CO2} \times \text{LRU}$$

We are producing the first continuous long-term records of ppt level

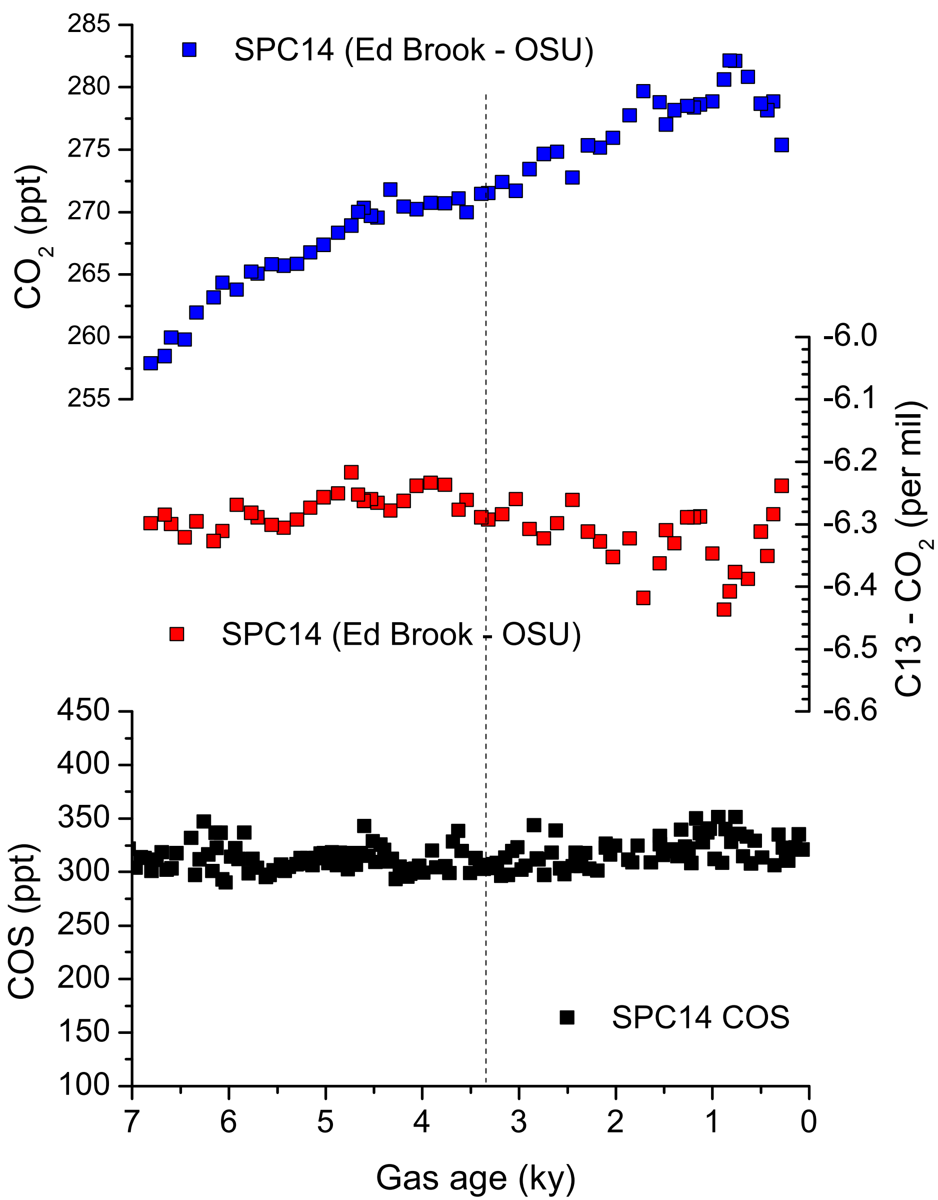
SPICEcore – Holocene COS



- Multiple maxima and minima
- Increasing trends from ~9 to ~7.5 ky, from 5.7 to 4.5 ky, and 4.2 to 1 ky

GPP inferences from CO_2-COS relationship

(New CO_2 and 13C data from Ed Brook, Oregon State)



At steady-state (sources=sinks) plus constant sources and LRU:

$$\frac{GPP_a}{GPP_b} = \frac{COS_b}{COS_a} \times \frac{CO_2^a}{CO_2^b}$$

From 3.5 ky to 1 ky

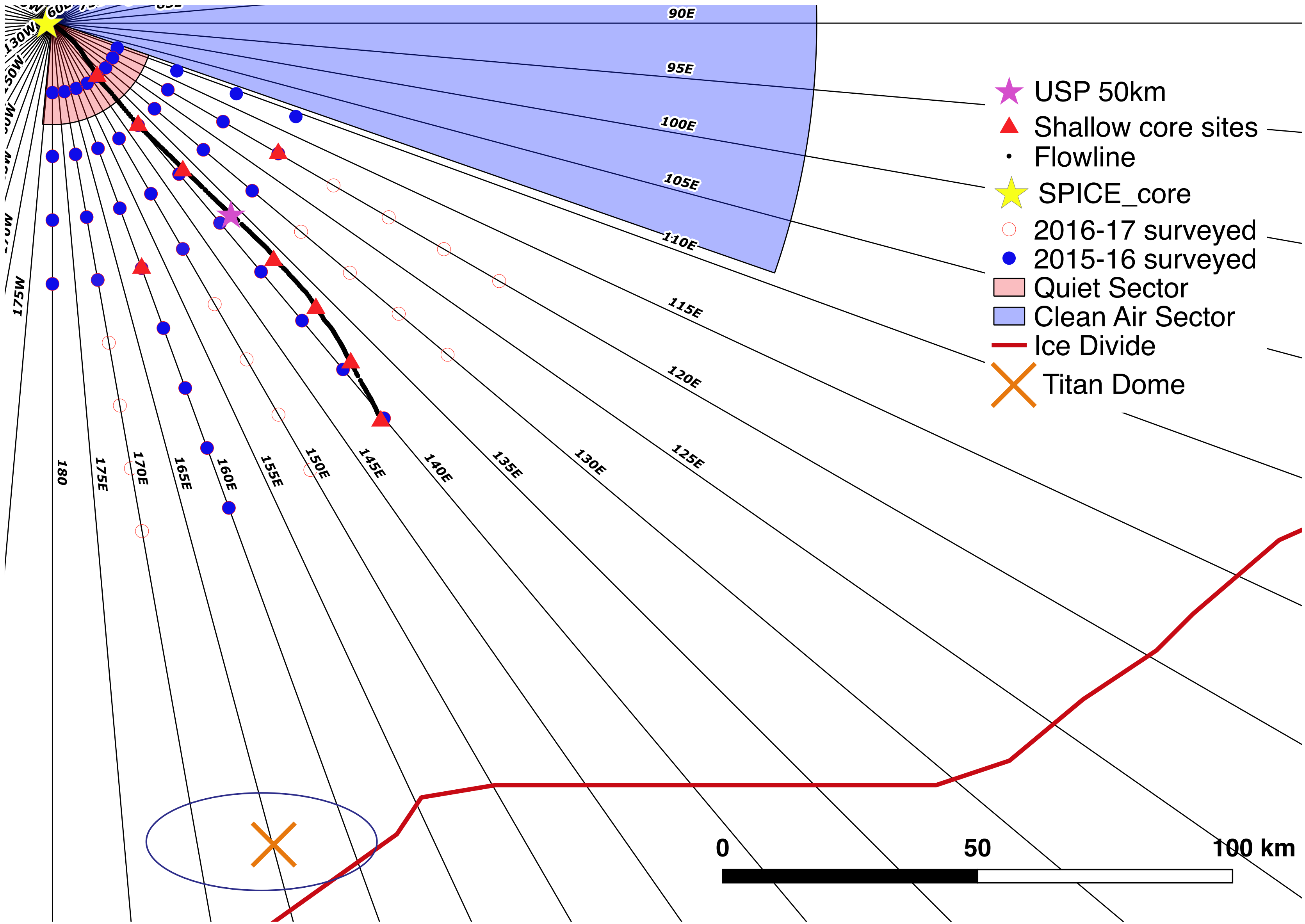
- CO_2 increases by ~3%
- COS increases by 10%+

Implies GPP decline of 6-7%

- 13C-CO_2 getting lighter suggests land carbon release in agreement with COS analysis

Thanks!

10-meter cores for isotope gradients



3. Eight ~10-meter deep cores for isotope gradients