INSTAAR Continuous Flow Ice Melter for Stable Isotopes

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West Antarctic Ice Sheet Divide Ice Core
Climate, Ice Sheet History, Cryobiology

ABSTRACT

The development of the integrated system for measuring high-resolution stable isotopes in WAIS divide ice has continued to evolve, and is now analyzing 10 to 12 meters of ice in a normal work day. The isotopic analyzer has been upgraded from the L1102 instrument to the L2130, which provides improves a 5 fold improvement in precision in δD and 2 fold improvement for $\delta^{18}O$. The dynamic range and stability have also improved. The faster (1 Hz) data stream provides significant oversampling of >2,400 data points per meter of ice. Sample carry-over and diffusion within the system have been characterized and most of it can be corrected for in the final data, but initial starts to each meter still require great care in post- analysis data reduction.

By the numbers

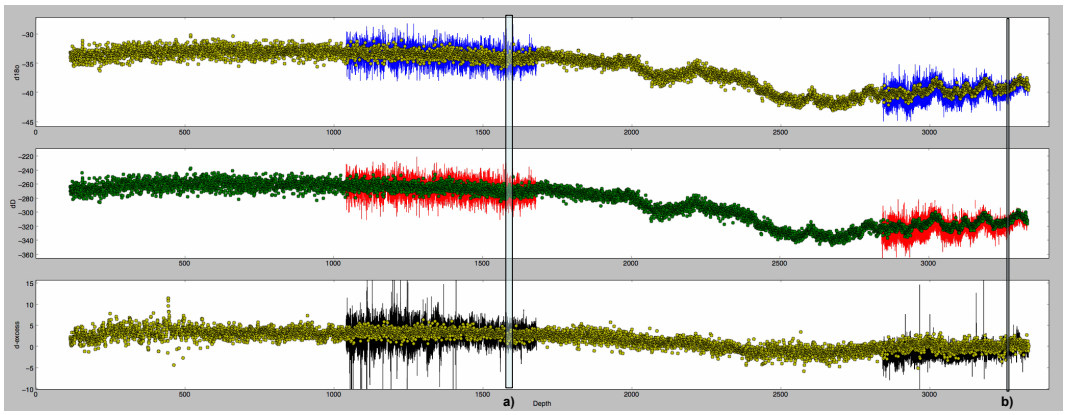
1,258
Meters of continuous ice melted an analyzed so far

1,569
Meters of ice left to analyze on the melter

6,582
½ meter average samples collected and analyzed (UW)

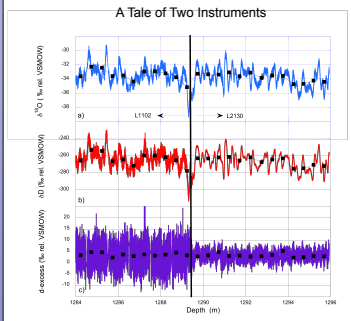
>1,600,000
Data points in continuous flow record so far

2,400
Individual isotope values per 1 meter of ice core ***before*** smoothing.



Plotted above are data for WAIS Divide WDC06A core which have been analyzed thus far by the INSTAAR continuous melter, and ½ meter discrete samples analyzed by the University of Washington. Green dots represent the discrete sample data in all three panels. The upper panel shows $\delta^{18}O$ in blue for the continuous melt record. The middle panel shows δD in red and the lower panel shows deuterium excess in black. Some noise persists as a result of start-stops in the melt record and our ability to properly filter the data. The continuous data is in shown for two sections of the core, analyzed as the ice became available. Initial analysis was done on the upper section of interglacial ice, and we then switched to the deep glacial ice when it became available. Zoomed in sections are shown below for 20 meters of ice at point **a)** and 7 meters at point **b).**

A Tale of Two Instruments



After analyzing ~ 323 meters of ice with the Picarro L1102, a new and improved laser analyzer became available, the L2130. The results above show the transition from the old instrument to the new one with striking improvement: a 5 fold improvement in precision in δD and 2 fold improvement for $\delta^{18}O$, with a dramatic affect on the deuterium excess signal.

First Generation
L1102

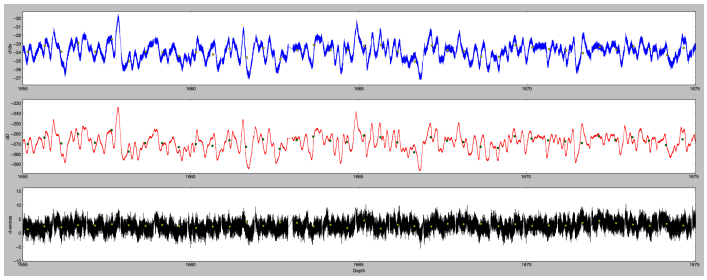
Third Generation
L2130

Guaranteed Performance Specifications

Isotope Ratio	Precision	Drift / 24 hrs (peak to peak)
$H_2{}^{16}O$ / $H_2{}^{16}O$, δ^2H_2O	<0.1 ‰ *	< +/- 0.3 ‰
$H_2{}^{18}O$ / $H_2{}^{16}O$, $\delta18O$	<0.3 ‰ *	< +/- 0.9 ‰
Self- Tolerance	Handles salt solutions to 6% **	

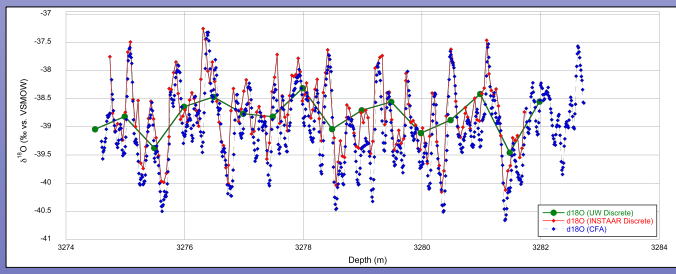
Vapor Specifications*

Measurement range	1,000 to 50,000 ppm
Guaranteed Precision (1σ) 2,000 ppm	0.250 / 0.080 ‰ for δ^2H for 10 / 100 sec
	1.600 / 0.500 ‰ for δD for 10 / 100 sec
Guaranteed Precision (1σ) 12,500 ppm	0.120 / 0.040 ‰ for δ^2H for 10 / 100 sec
	0.500 / 0.160 ‰ for δD for 10 / 100 sec
Typical Precision (1σ) 12,500 ppm	0.120 / 0.016 ‰ for δ^2H for 10 / 100 sec
	0.150 / 0.050 ‰ for δD for 10 / 100 sec
Measurement Rate	1 Hz



a)

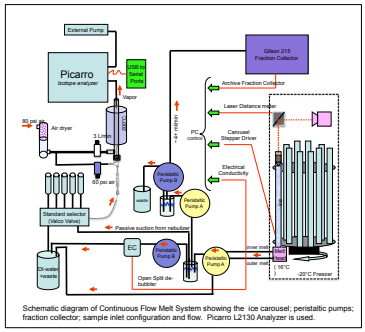
Zoomed in section from 1655 to 1675 meters depth showing $\delta^{18}O$ (blue), δD (red) and D-Excess (black). Discrete samples analyzed at the University of Washington on different ½ meter sticks of ice are shown as dots in each plot. Excellent agreement can be seen between the two data sets. The ultimate resolution visible at this depth is governed by a) mixing within the analytical system, and b) diffusion within the ice core itself, originating mostly in the firn.



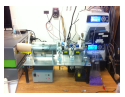
b)

Comparison of discrete samples with continuous flow data over a ~7 meter section. UW samples (green) are from analysis of ½ meter samples; INSTAAR discrete samples (red) are archive samples collected from melt stream approximately every 4 cm; and CFA data (blue) are averaged to 1cm intervals. Major trends are captured by all three methods. CFA data naturally capture the higher amplitude signals more so than the lower resolution discrete samples. Small offsets in the phase between CFA and discrete data are likely due to approximation errors in depth assignments to fraction collector vials.

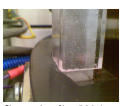
The Continuous Flow Ice Melter System Details



Schematic diagram of Continuous Flow Melt System showing the ice carousel; peristaltic pumps; fraction collector; sample inlet configuration and flow. Picarro L2130 Analyzer is used.

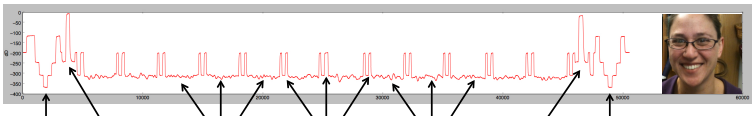


Over all system that is outside th freezer, showing pumps, standards, open split, nebulize, furnace, and Picarro instrument. The small box is the display for the infrared water detector.



Close up view of ice stick being delivered to the melted by the square acrylic tube held by the carousel.

A day in the life of the Melter



Each melt-day includes the analysis 2 sets standard waters, at the beginning and end of the day. In addition, sets of test ice sequences are analyzed twice per day that consist of a short stack of 10 cm sticks of isotopically differing waters arranged in an order of Low- High-Low (so called 'Neapolitans') , to help characterize the mixing and diffusion of the entire system. The ice carousel can hold up to 16 tube positions for ice core or Neapolitans. Typically we analyze approximately 10-12 ice cores and 2 Neapolitans in one day. Each ice core takes approximately 45 minutes, with melt rates of approximately 2 cm/min. Melt days are normally 12-14 hours long, and require several shifts of operators, all of which are gracefully orchestrated by Valerie Morris, shown here.

Acknowledgements

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