The impact of marine melting and sedimentation on glacier advance and retreat: Southern Patagonia Icefield, Chile

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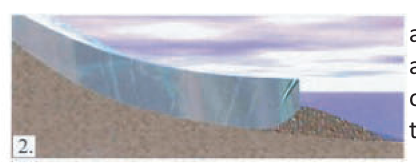
I. MOTIVATION

Glacial retreat around the world has been used as dramatic and visible evidence of climate change, and it has considerable practical importance because it directly contributes to global sea-level rise, a major threat of climate change. On a global scale, the complex behavior of outlet glaciers is a prime factor limiting confidence in predictions of sea-level rise. The controls, however, on the fluctuations of some of the largest glaciers on the planet, are only partly related to climate variability and they remain poorly understood.

A substantial set of investigations on fjord physical processes highlight the complexity of melting and sediment-delivery mechanisms occurring on and near the terminus. Melting is a strong function of water circulation, and it depends in part on the fjord geometry and the density structure of the water column, which are respectively affected by sediment accumulation and sediment concentration.

In addition to forming shoals that can physically and thermally buttress tidewater glaciers, sediments produced by these glaciers are of interest because they create sedimentary archives recording a wide-range of important continental-margin processes. Existing pioneering observations highlight the need for additional information based on more comprehensive, year-round measurements of temperature, circulation, and sediment-transport processes in fjords close to the ice front, as well as concurrent glaciological and meteorological observations.

Tidewater glaciers are thought to advance when their morainal shoal decreases exposure to ocean water (cases 1 and 2)

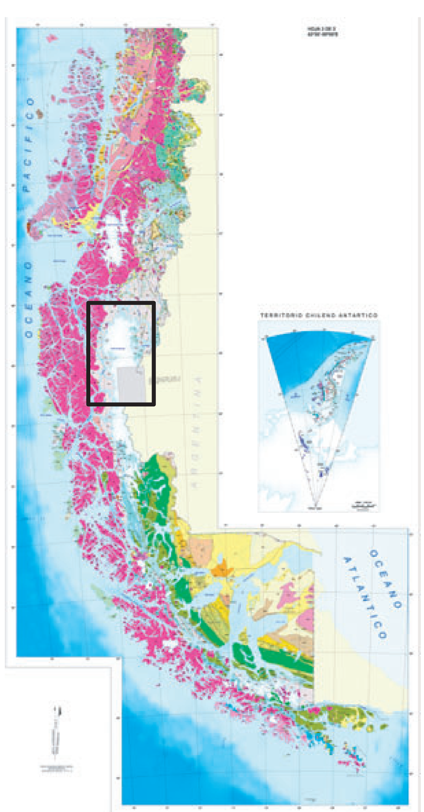


and retreat when moraines are detached and circulation of ocean water helps melt the glacier terminus (case 3).

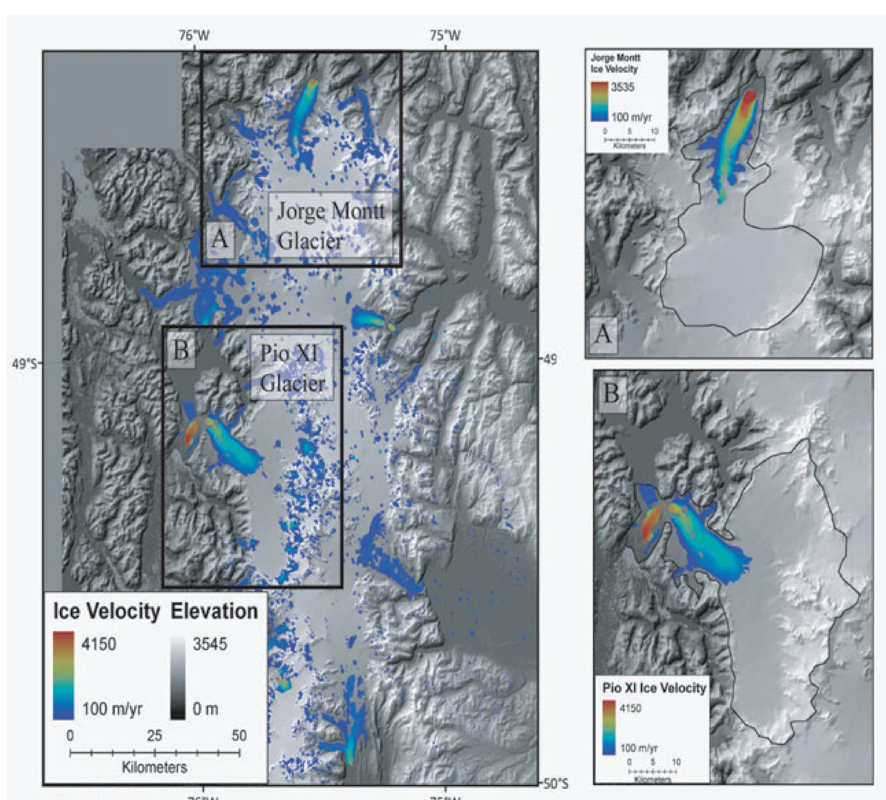
(from Collier, 2004)

II. STUDY SITES

CHILEAN PATAGONIA FJORDS



Chilean national service of geology and mining



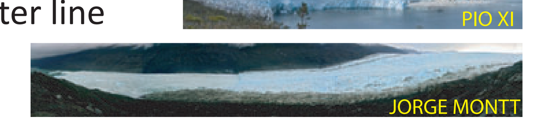
Two neighboring glaciers in Patagonia display opposite terminus behavior: one has retreated dramatically while the other has advanced, and yet they share essentially the same source area. (Surface velocities courtesy Eric Rignot, 2003)

Pio XI Glacier:
- -longest temperate glacier in South America
- -only advancing glacier in South Patagonia Icefield
- -terminus has thickened, advanced through mature forest
- -surface speeds: 1964 ~2 m/day
  1984-1986: 3.3 m/day
  1995: 50 m/day (avg. 19 m/day for 5 days)

Jorge Montt Glacier:
- -18 m/yr thinning
- -retreated 7.8 km betweem 1990 and 2000
- -surface velocities in 1980's ~ 0.7 m/day
- -1995 SAR pixel tracking suggests 5.6 m/day
- -11 km-long fjord with ~40 m of sediment

III. OBJECTIVES

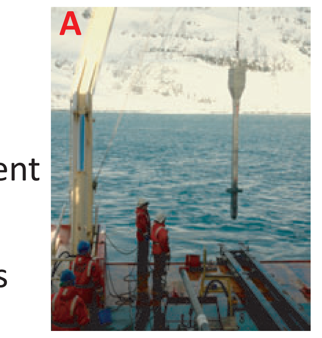
For both study glaciers we plan to document:
1) The principal submarine sediment transport and depositional processes that control sediment accumulation and shoaling, and the rates at which they operate
2) Characteristics of fjord circulation that determine the rate of melting below the water line



In order to answer the questions:
1) How do sediments and seawater impact the stability of glaciers by respectively controlling how much of the ice terminus is exposed to marine waters and how fast it is melting?
2) How exactly do glacial-marine sediments impact and record the detailed history of glacier advance and retreat?

IV. METHODS

- -Bathymetry
- -Sediment cores for record of glacial activity
- -Radiochemical analyses (^{234}Th, ^{210}Pb)
- -Seismic profiling for sediment thickness and extent
- -Water-column measurements (currents, salinity, temperature, suspended sediment) for melt rates and sediment-transport processes

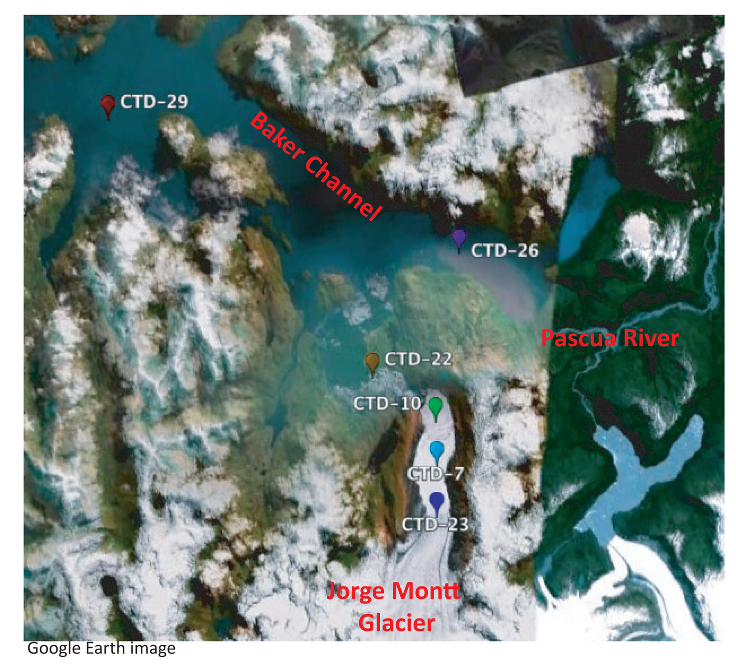


coring photos courtesy B. Kimball

KASTEN CORE:
(A) collection
(B) processing
(C) photo with dropstone

(D) CTD profiler

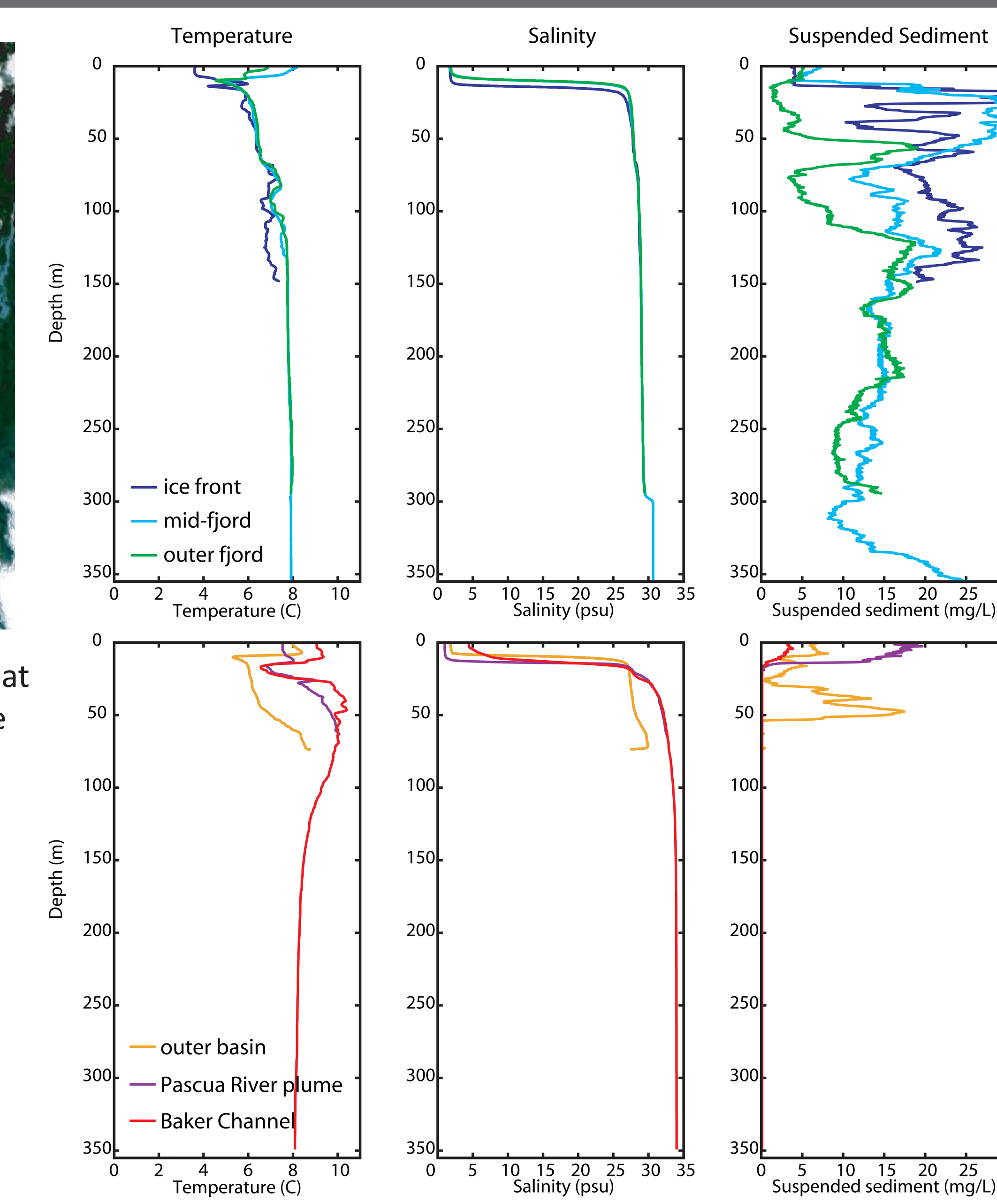
V. FJORD PROPERTIES



Above: Location map for CTD profiles shown at right. Location colors indicate the color of the corresponding CTD profile.

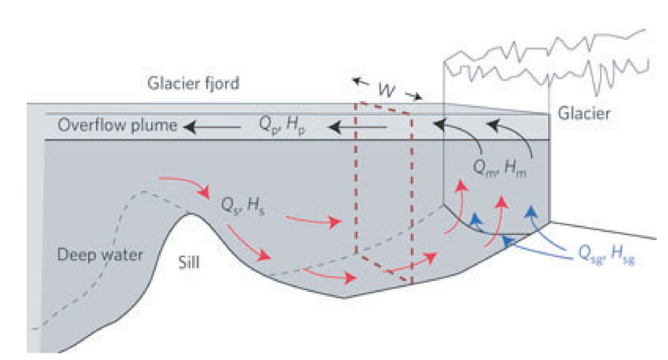
Right: Temperature, salinity, and suspended-sediment profiles from within the inner fjord (upper panel), and from various sites outside the inner fjord (bottom panel).

High concentrations of suspended-sediment near the fjord seabed likely reflect sediment transport in intermediate melt layers and the bottom boundary layer.



VI. FJORD PROCESSES

ICE-FRONT MELTING

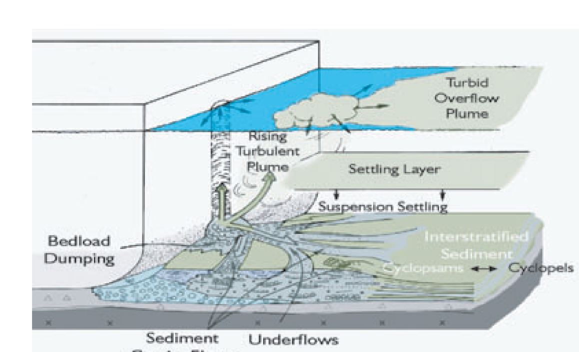


Conceptual model for measuring ice- front melt rates (from Rignot et al., 2010)

Few studies provide ice-front melt rates, which highlights the necessity for more in-depth studies:

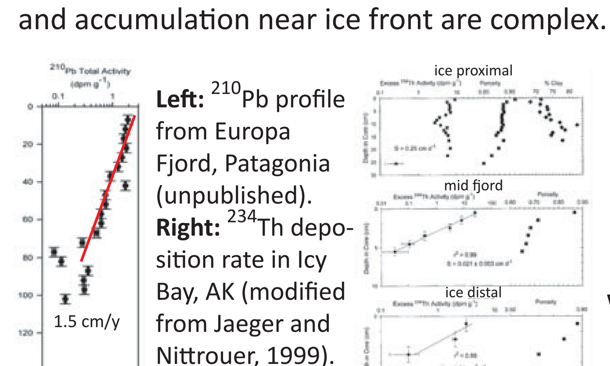
Motyka et al. (2003):	Temperate Alaskan fjord 12 m/day 7.8 deg C at ice front
Rignot et al. (2010):	West Greenland fjords 0.7-3.9 m/day, ~1.2 deg C at ice front
Straneo et al. (2010):	East Greenland fjord max ~4 deg C at ice front

SEDIMENT TRANSPORT PROCESSES



(After Powell and Molnia 1989)

Patterns of circulation, sediment transport and accumulation near ice front are complex.



Left: ^{210}Pb profile from Europa Fjord, Patagonia (unpublished). **Right:** ^{234}Th deposition rate in Icy Bay, AK (modified from Jaeger and Nittrouer, 1999).

SUSPENDED SEDIMENT IN FJORDS

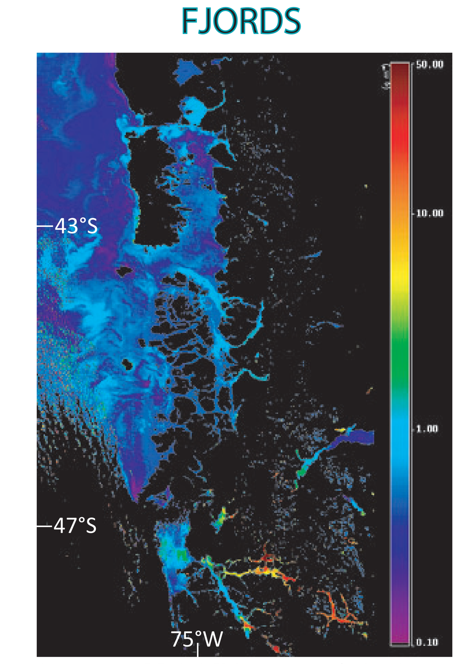
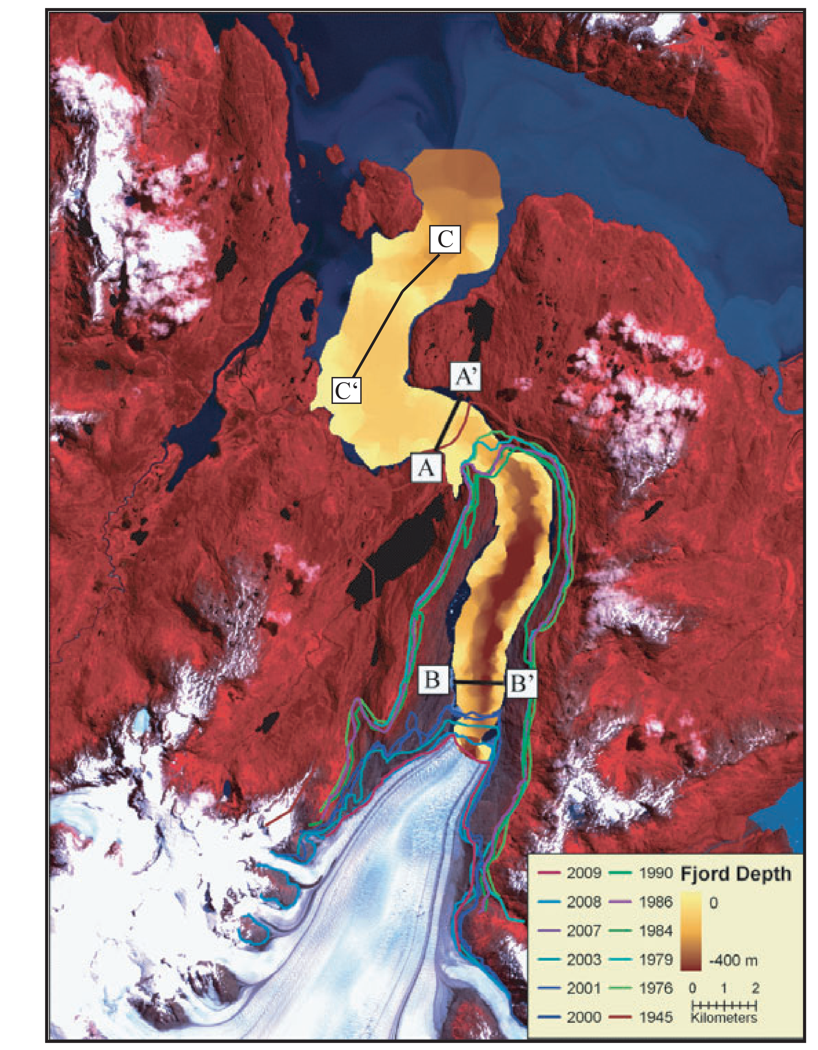


Image courtesy F. Tapia. MERIS sensor output (on board ENVISAT) for 25 Feb 2010.

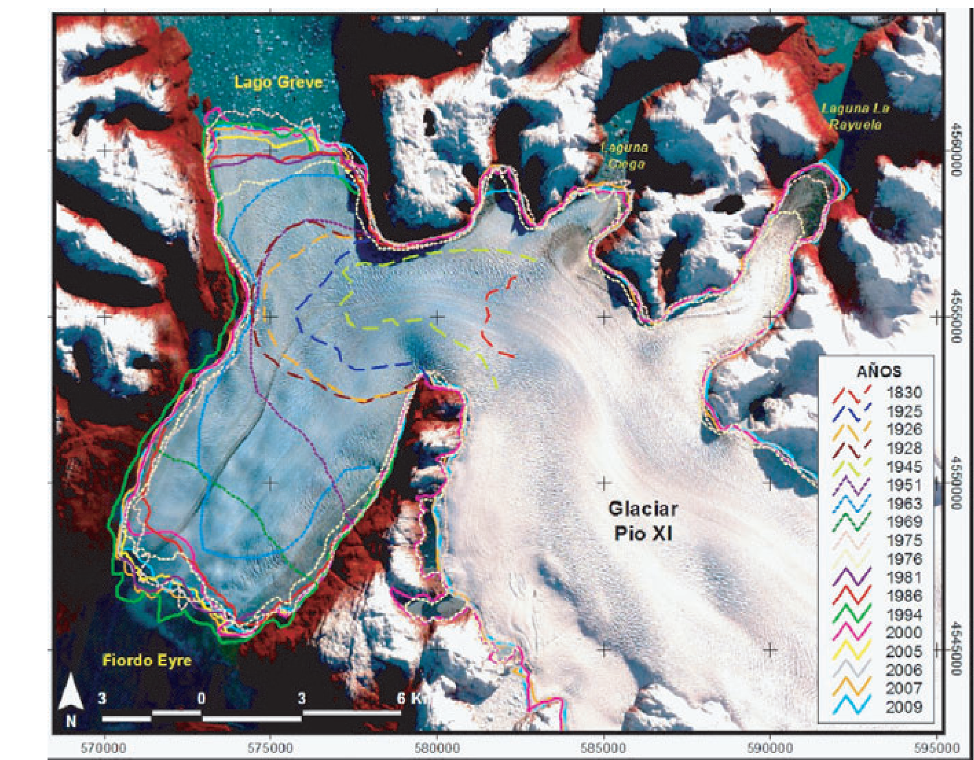
What are the details of the mechanisms delivering and transporting sediment?

VII. SEDIMENTS RECORD GLACIER HISTORY

JORGE MONTT

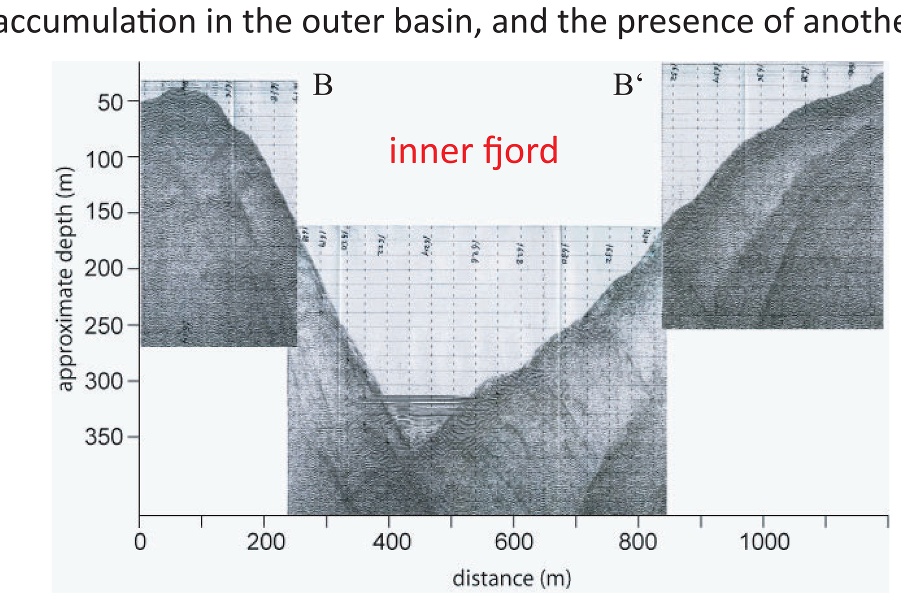


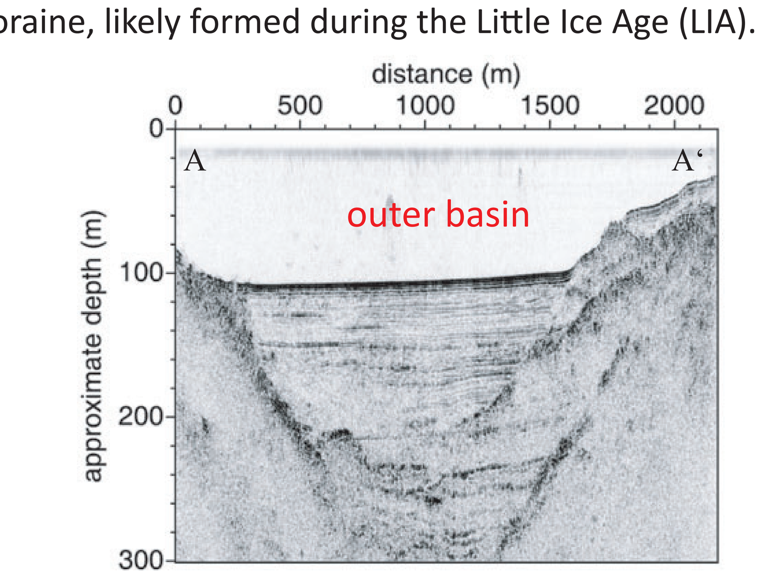
PIO XI

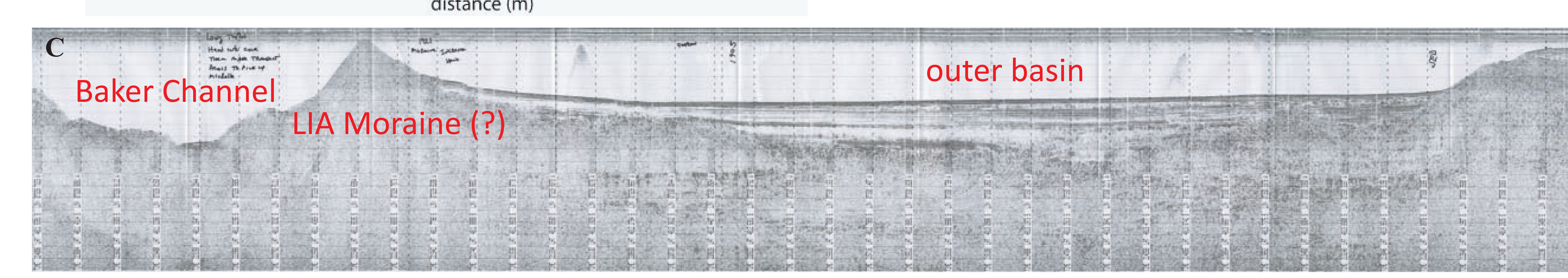


Left: Bathymetry and glacier extent of Jorge Montt Glacier since 1945, with locations of seismic lines shown below. Bathymetry and seismic profiles were collected during the 2010 survey.
Above: Terminus positions during advance for Pio XI.

Below: Sample seismic data from the Jorge Montt inner fjord (top left, B-B') and beyond the recent moraine (top right, A-A'). Note the steep-sided fjord walls and ~40 m of sedimentary sequence in the seismic line from the inner fjord. Beyond the moraine, ~ 100 m of sediment has accumulated. An along-channel transect (bottom, C-C') shows sediment accumulation in the outer basin, and the presence of another moraine, likely formed during the Little Ice Age (LIA).

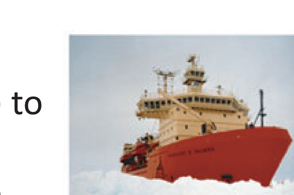






VIII. FUTURE WORK

March 2011: Bathymetric and hydrographic surveys, moored-instrument deployments, and sediment-core collection. Also install meteorological stations and time-lapse cameras.
Future: Early and late melt season ice-proximal measurements (coring and water-column profiles) to relate changes in subglacial hydrology to concurrent fjord processes. Also monitor ablation with a pressure transducer in a bore hole, and install GPS units. We would return the subsequent year to mirror the sampling plan, utilizing both locally available vessels and a large ice breaker.



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IX. ACKNOWLEDGMENTS

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