TEMPORAL AND SPATIAL VARIABILITY IN GLACIAL EROSION AND DEPOSITION BASED ON A STUDY OF PATAGONIAN AND ANTARCTIC PENINSULA TIDEWATER GLACIER SETTINGS

Rodrigo A. Fernandez and John B. Anderson. Rice University, Houston, Texas.

1. INTRODUCTION

Glaciers play a key role in the coupling between tectonics and climate through a number of processes and temporal/spatial scales, ranging from short-term glacial advances and retreats, millennial-scale glacial cycles, and million year-scale orogenies and global climate changes. In particular, glacier erosion and transport might be a first order control on mountain range exhumation and isostatic processes through the evacuation and removal of crustal material from orogens and its subsequent transport to continental margins (e.g. Molnar et al., 1990; Montgomery et al., 2001; Blisniuk et al., 2006).

Glacier sediment yields and erosion rates have been estimated for a number of glaciated basins based mainly on modern observations (last few decades) of sediment fluxes (Harbor, 1992, 1993; Harbor and Warburton, 1993; Hallet et al., 1996). However, recent studies have shown that modern sediment yields are not representative of long-term (centennial, millennial or million-year time scales) trends (Delmas et al., 2009; Koppes et al., 2009; Fernandez et al., 2010). Contemporary high sediment yields from tidewater glaciers and associated high erosion rates might be the result of high ice fluxes associated with the retreat of modern glaciers from their last Neoglacial positions (Koppes and Hallet, 2002, 2006).

We show time and spatial variations in glacier erosion rates at several timescales and from temperate to polar glaciers.

2. Methods

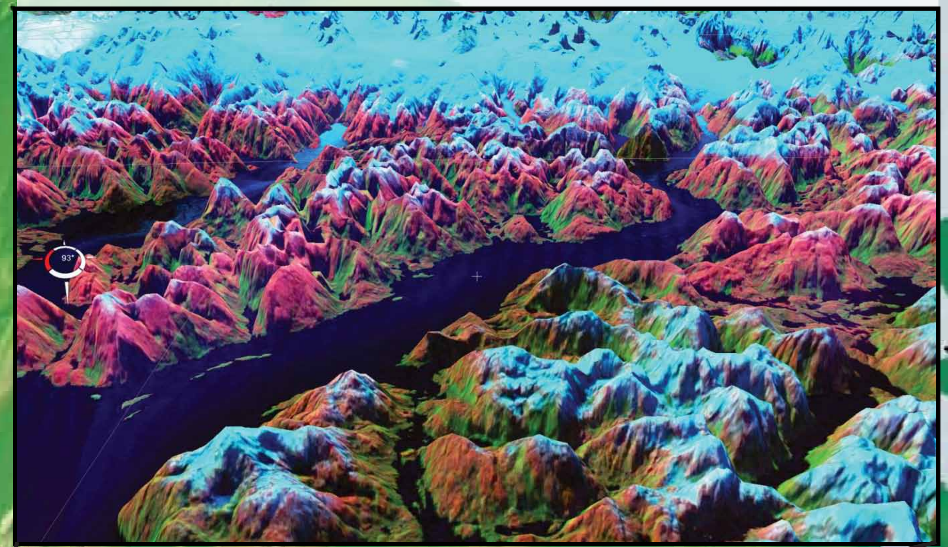
Glacier erosion rates were determined by estimating the volume of sediments deposited in fjords and bays. We used bathymetry data collected in several cruises, including NBP0505, NBP0703, NBP0502, along with gigh resolution seismic (chirp) data (3.5 khz) and water and air gun single channel seismic collected during the same cruises and in cruises PD91 and DF1986. Subsequently seismic units were mapped across the depositional basins to produce isopach maps. To constrain the age of the seismic units radiocarbon ages were obtained for a number of samples from cores collected during the mentioned cruises (shells of macro-fossils and foraminiferous). For Maxwell Bay (Marion Cove) and Lapeyrere Bay, Bernard Hallet provided decadal accumulation rates from 210 Pb determinations in cores from NBP0703.

The following simple equations weer uesd to transform volumes to time-basin averrage erosion rates:

$$\langle Er\rangle = (1/T) * (1/A_{dr}) * Vol_{Rx} \quad \text{, where} \quad Vol_{Rx} = (\rho_{sed} / \rho_{source}) * V_p(sed) * P_A * \Sigma\, T_{ij}$$

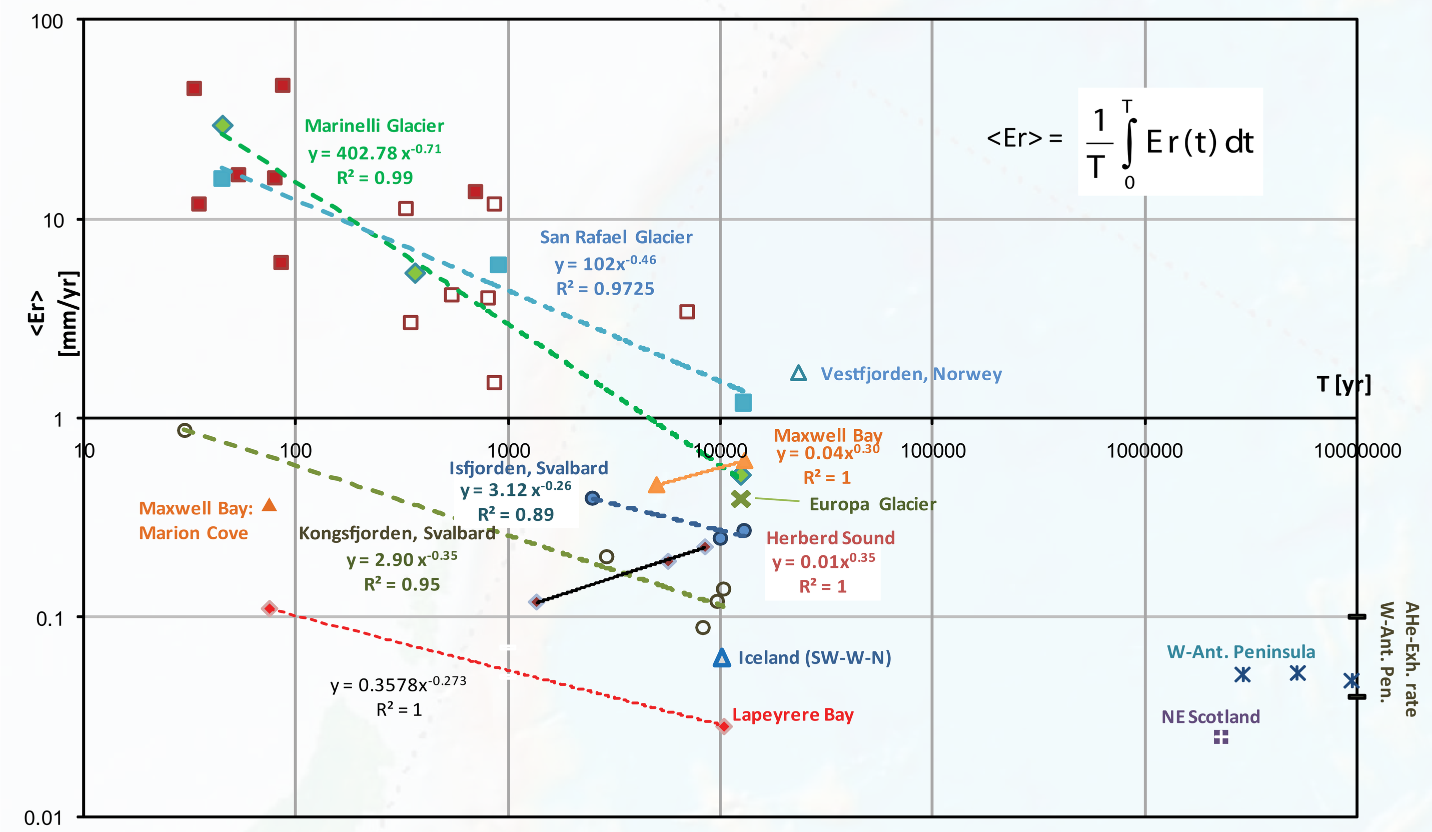
In this way, if Er=f(t), then $\frac{1}{T}\int_0^T Er(t)\,dt$ represents the average Er (<Er>) for the last T years. The plot of Figure 1 shows <Er> vs T for the glacier/fjords system studied in this work along with similar systems were erosion rates has been calculated at different timescales.

Europa Glacier <Er>=0.39 mm/yr [12500 yr]



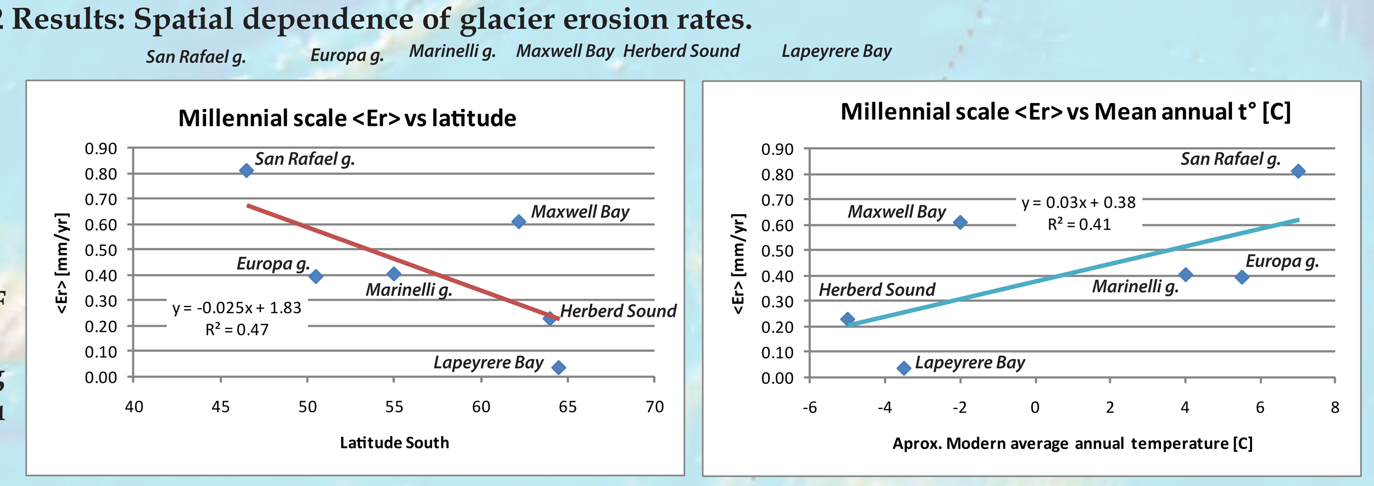
3.1 Results: Timescale dependence of glacier erosion rates.

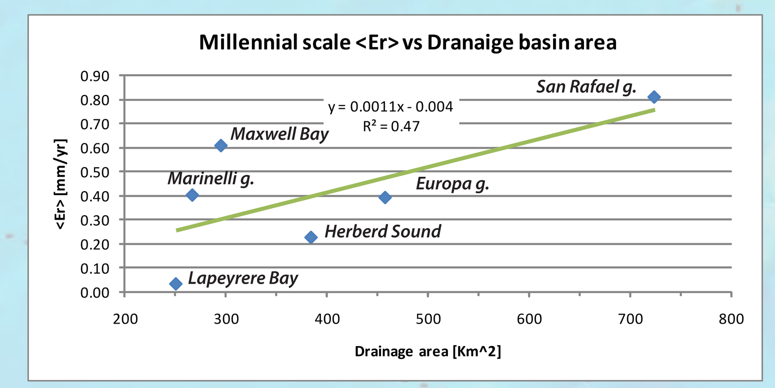
Figure 1



3.2 Results: Spatial dependence of glacier erosion rates.

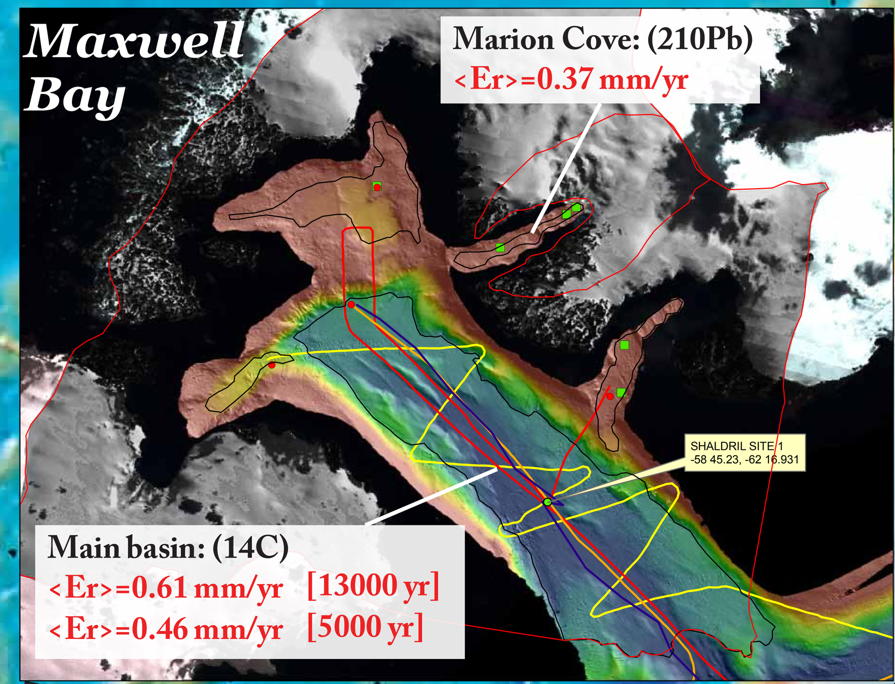
Figure 2





Glacier/Fjord/Bay	Time Interval [yr]	<Er> [mm/yr]	Reference
Marinelli	45	29.31	Koppes et al. 2009
Marinelli	364	5.34	This study
Marinelli	12500	0.52	This study
San Rafael	45	16.00	Koppes et al. 2009
San Rafael	900	5.90	This study
San Rafael	12800	1.20	This study
Maxwell	5000	0.46	This study
Maxwell	13000	0.61	This study
Maxwell Bay, Marion Cove	75	0.37	This study
Herberd Sound	1372	0.12	This study
Herberd Sound	5704	0.19	This study
Herberd Sound	8511	0.23	This study
Lapeyrere Bay	10500	0.03	This study
Lapeyrere Bay	75	0.11	This study
W-Ant. Pen.	2900000	0.052	Smith et al. 2010
W-Ant. Pen.	5260000	0.052	Smith et al. 2011
W-Ant. Pen.	9450000	0.048	Smith et al. 2012

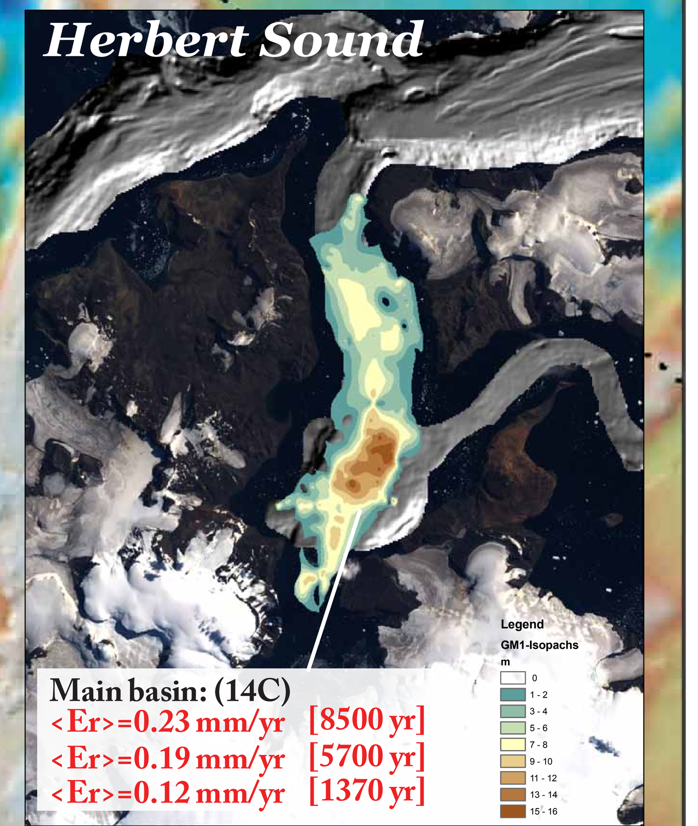
Maxwell Bay



Marion Cove: (210Pb)
<Er>=0.37 mm/yr

Main basin: (14C)
<Er>=0.61 mm/yr [13000 yr]
<Er>=0.46 mm/yr [5000 yr]

Herbert Sound

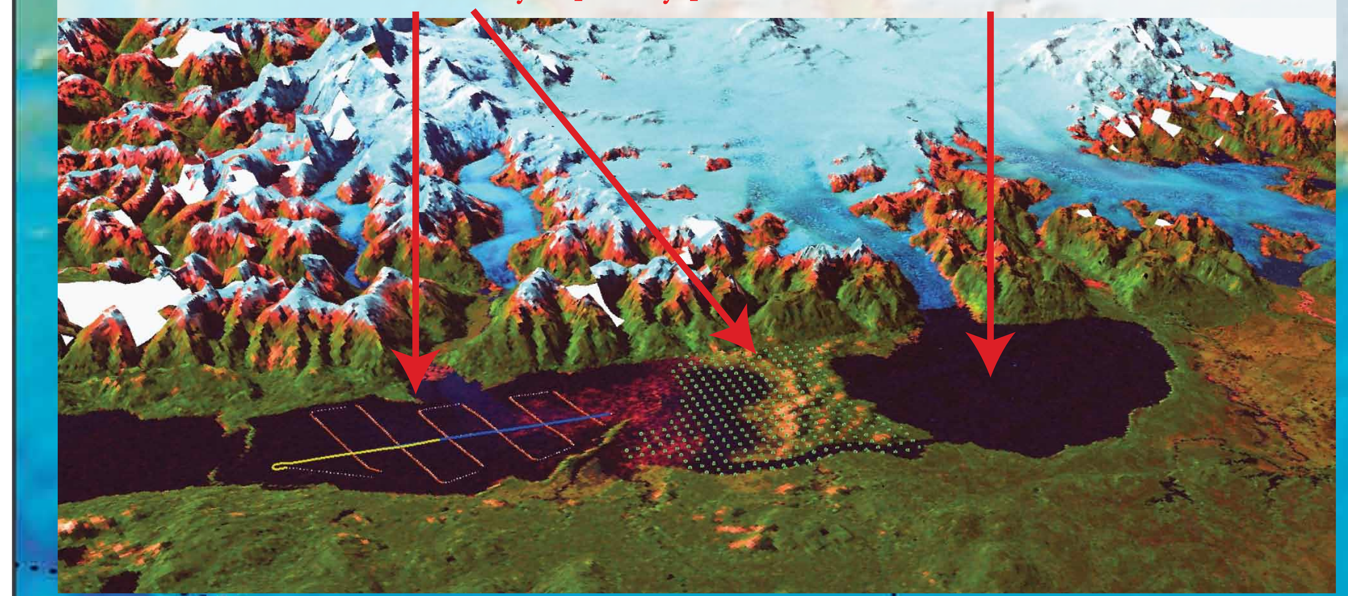


Main basin: (14C)
<Er>=0.23 mm/yr [8500 yr]
<Er>=0.19 mm/yr [5700 yr]
<Er>=0.12 mm/yr [1370 yr]

San Rafael Glacier

+Medial basins:
<Er>=1.2 mm/yr [12800yr]

Proximal basin:
<Er>=16 mm/yr
[45yr]

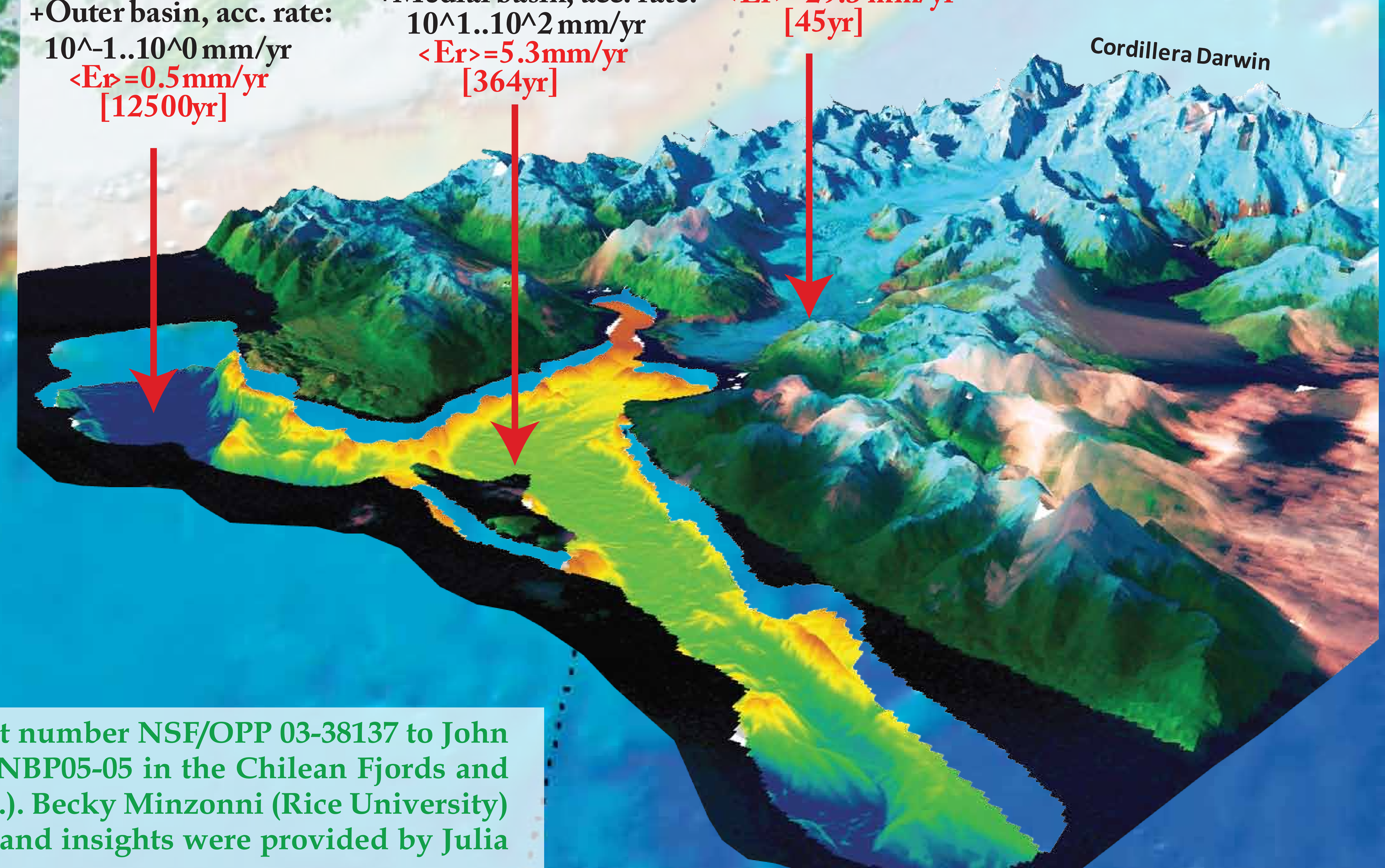


Marinelli Glacier

+Outer basin, acc. rate:
10^-1..10^0 mm/yr
<Er>=0.5mm/yr
[12500yr]

+Medial basin, acc. rate:
10^1..10^2 mm/yr
<Er>=5.3mm/yr
[364yr]

Proximal basin, acc. rate:
10^3..10^4 mm/yr
<Er>=29.3 mm/yr
[45yr]



4. Discussion/Preliminary Conclusions:

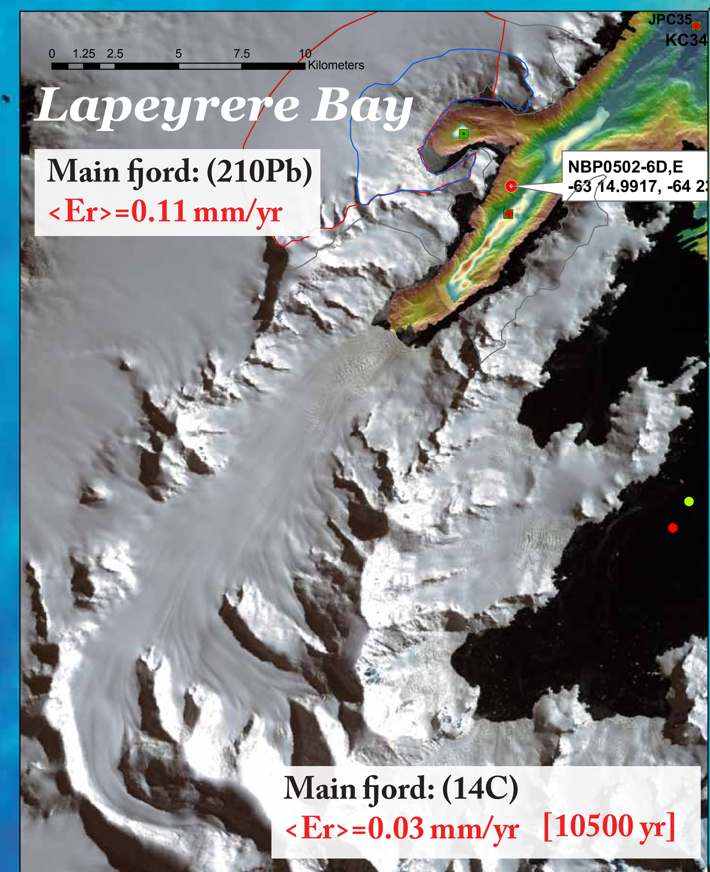
The negative power law dependence of <Er> with T (decadal to millennial) migth reflects the increased frequency of enhanced erosion rates periods (retreat) and sediment delivery events to the depositional basins (e.g. reworking of seds. during advances).

The positive power law observed for subpolar glaciers from Svalvard and Antarctica, might reflect a power law decrease in sediment production during the late Pleistocene - Holcene transition, and low sediment production for long periods during the Holocene.

As expected, erosion rates decrease at higher latitudes (lower temperatures) reaching values comparables with exhumation rates (10^6-7 yrs timescales).

At centennial and millennial timescales sources and sinks of seds. are relatively easy to identify, however, at decadal timescales, much uncertainty exists to this respect.

Lapeyrere Bay



Main fjord: (210Pb)
<Er>=0.11 mm/yr

Main fjord: (14C)
<Er>=0.03 mm/yr [10500 yr]

Acknowdelgments: This research was funded by the National Science Foundation, Office of Polar Programs grant number NSF/OPP 03-38137 to John Anderson. Special thanks to officers, crew and scientists who sailed on the RV/IB Nathaniel B. Palmer during NBP05-05 in the Chilean Fjords and during NBP0703 in the Antarctic Peninsula. 210Pb to estimate decadal <Er> were provided by Bernard Hallet (U.W.). Becky Minzonni (Rice University) provided valuables insights and produced 14C ages from foraminiferous for Herber Sound. Much help, support and insights were provided by Julia Wellner (U.H.).

Poster presented at:
AGU Chapman Conference on Source to Sink Systems Around the World and Through Time
Oxnard, California, USA
24–27 January 2011