Last interglacial sea level along the Patagonian coast

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Last Interglacial Sea Level in Patagonia

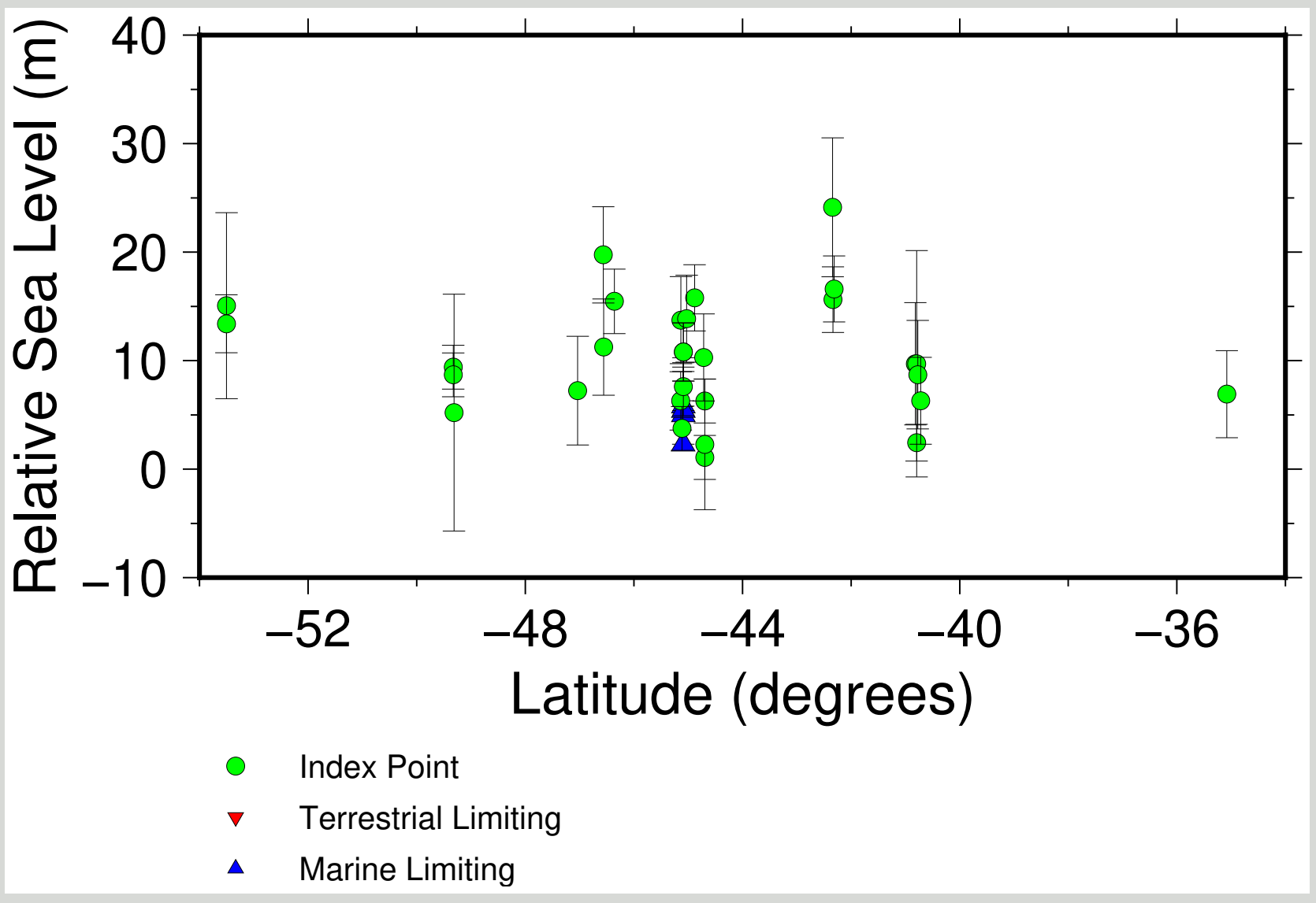
Since the initial reports by Charles Darwin during the Beagle Voyages (Darwin, 1846), the remarkably continuous staircase-like platforms of past sea level highstands along the coast of Argentina have been the subject of numerous investigations. There two hypotheses regarding these age of the landforms:

- The platforms represent late Pleistocene sea level highstands, and the coast of Patagonia is undergoing tectonic uplift (*i.e.* Pedoja *et al.* 2012)
- The coast of Argentina is tectonically stable and the platforms older than the Holocene and Last Interglacial are older than the Quaternary. Departures from eustatic sea level are a result of glacial-isostatic adjustment. (*i.e.* Schellmann and Radtke, 2003)

Last interglacial shorelines at Caleta Valdès (Google Earth)

The Patagonian coastline is located in the area presumed to be in the intermediate field of the West Antarctic Ice Sheet. If the later hypothesis is correct, then it may be possible to use variability in elevation the Last Interglacial (MIS 5e) sea level indicators to infer the size of the last interglacial ice sheet. A complicating factor is that glacial isostatic adjustment from the Patagonian Ice Sheet will likely also impact sea level.

Last Interglacial sea level indicators

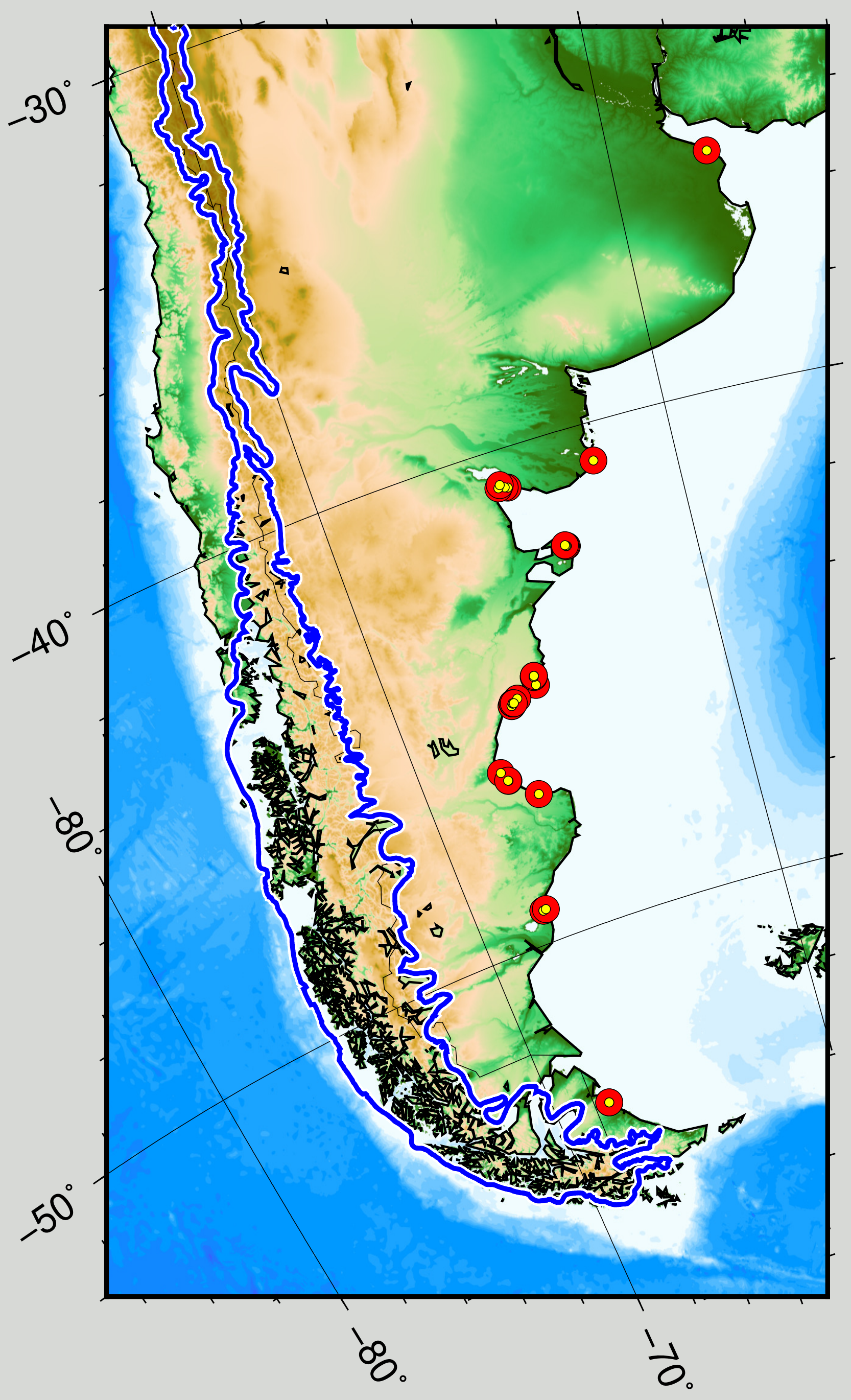


Sea level indicator elevations

As part of the World Atlas of Last Interglacial Shorelines (WALIS), we have compiled MIS 5e sea level indicators for the coast of Argentina. For acceptance into the database, the following criteria were used:

- Location can be determined.
- Measured elevation, including datum and measurement technique, are provided
- The age of the feature was determined using an appropriate technique (*i.e.* U/TH, AAR, ESR, see below)
- The geological context of the indicator was reported

Reported indicators are at a variety of elevations, ranging between about 2 and 25 m above present day sea level.



Location of reported MIS 5e sea level indicators (red circles). The blue outline shows the extent of the Patagonian Ice Sheet at the Last Glacial Maximum (Ehlers *et al.*, 2011)

Dating techniques

Several dating techniques have been used to distinguish raised shoreline platforms in Argentina, these are summarized below:

Technique	Description	Notes
Amino Acid Racemization	Measures ratio of the "D" and "L" configuration of amino acid molecules, the lower the ratio, the older the sample.	Applied to mollusc and sea snail fossils. The thermal history of Patagonian samples are not known, so this is technique can only be applied to differentiate Holocene and older shoreline levels. In addition, different species have different decay rates for the amino acids. It is assumed that the lowest platform above the Holocene highstand is MIS 5e in age.
Electron Spin Resonance	Measures the amount of unpaired electrons in a crystal structure, caused by natural radioactivity after formation.	Applied to mollusc shells. The accuracy of the dates is dependent on the assumption that the mollusc shells are a close system to radioactive elements like uranium, which may not be true, as the pre-Holocene shells are generally covered in secondary carbonate. This could bias the ages.
U/Th	Measures the ratio of uranium and thorium, under the assumption that the organism does not initially contain any thorium.	Applied to mollusc shells. Like ESR dating, it is dependent on the assumption that the shells are a closed system to uranium, which is likely not true, potentially biasing the age.

Conclusions

- MIS 5e indicators are not at a uniform elevation along the Argentina coastline - possibly due to east-west gradients in GIA signals (from the Patagonian ice sheet and flooding of the continental shelf), or mis-assignment of older benchmarks to MIS 5e due to dating errors.
- Patagonia is strongly affected by the ice sheet history of the Patagonian Ice Sheet.
- Patagonia is not particularly sensitive to changes in the West Antarctic Ice Sheet and any signal is likely obscured by GIA from the Patagonia Ice Sheet and continental shelf flooding.
- Modelled sea level along the coast will also be affected by choice of Earth model.
- The Argentinian coast could be regarded as tectonically stable, high relative sea level can be explained by GIA signals alone.

References

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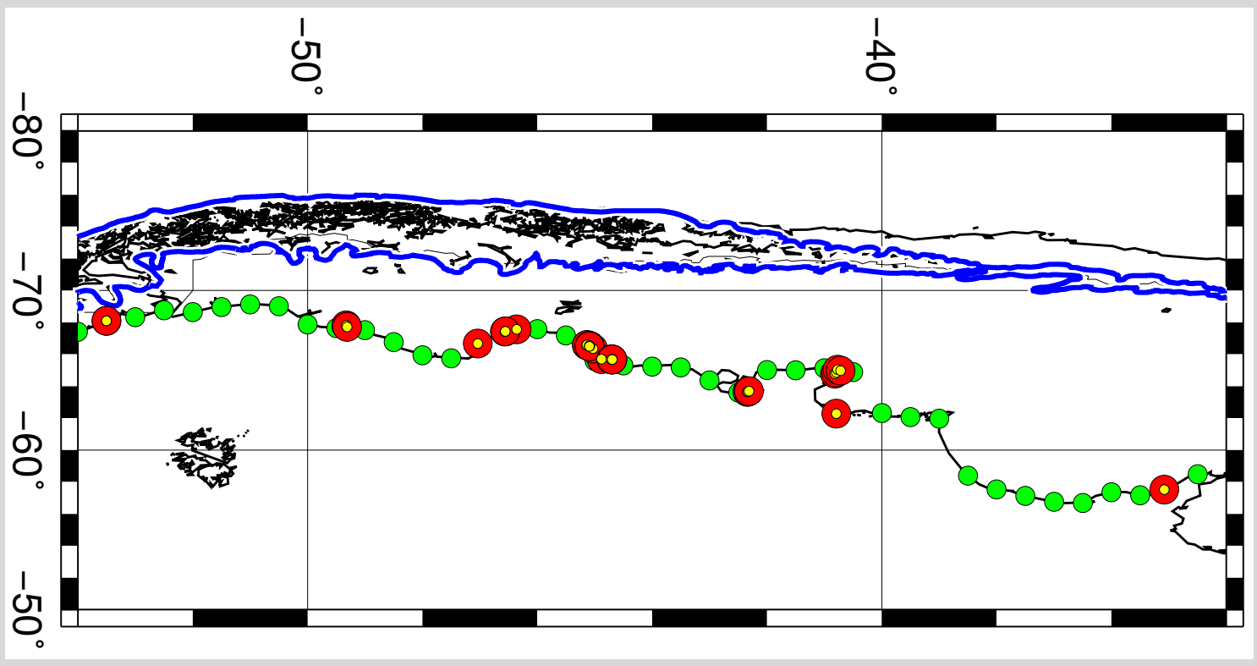
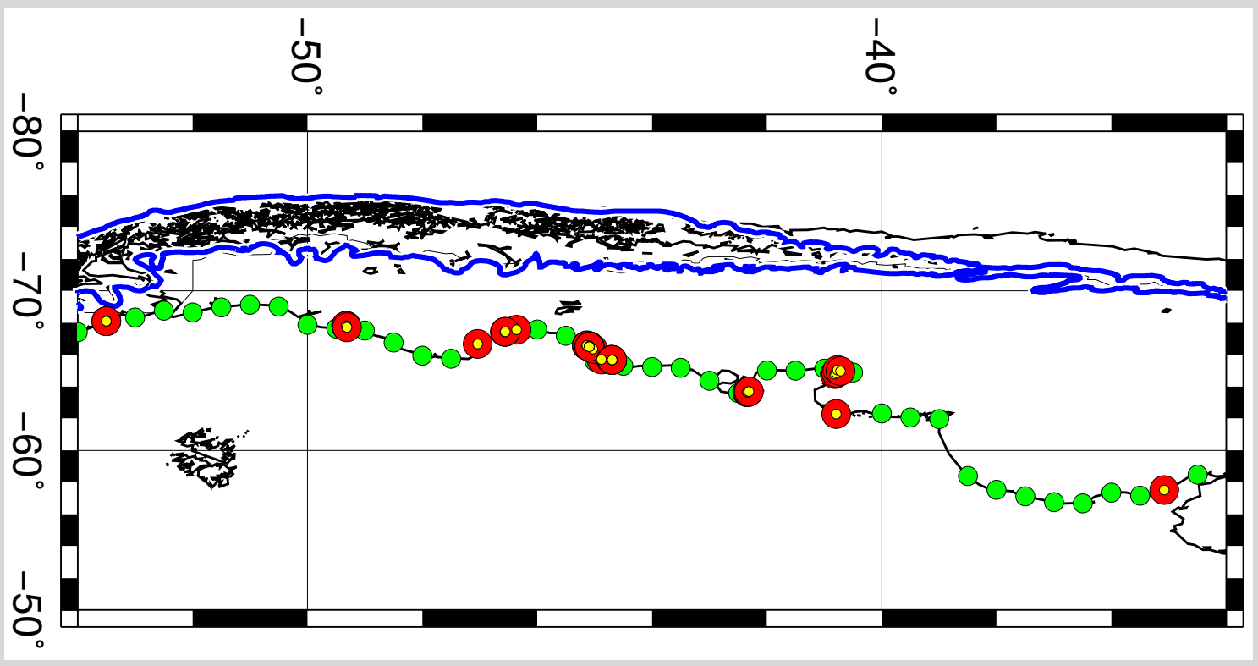
- Pedoja *et al.* 2012. Uplift of quaternary shorelines in eastern Patagonia: Darwin revisited. Geomorphology, 127, 121–142.
- Schellmann and Radtke, 2003. Coastal terraces and Holocene sea-level changes along the Patagonian Atlantic coast. Journal of Coastal Research, 983–996.
- Spada and Stocchi 2007. SELEN: A Fortran 90 program for solving the "sea-level equation". Computers & Geosciences, 33, 538–562.

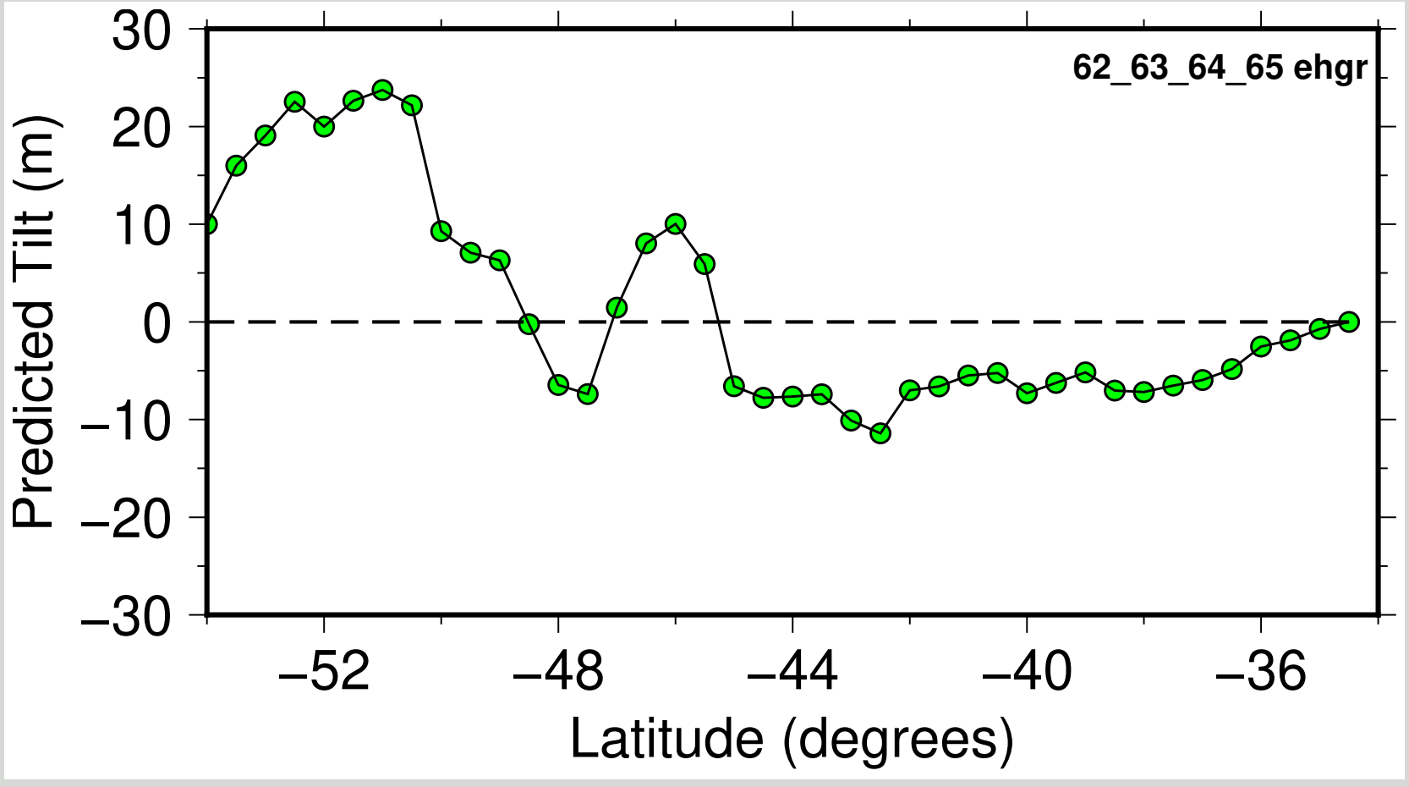
Impacts of Patagonian Ice Sheet

To assess how much the Patagonian Ice Sheet impacts sea level along the Argentinian coast, we plot the difference between the calculated sea level at points along the Argentinian coast relative to the northernmost point. We use an ice sheet reconstruction that goes from 80 000 yr BP to present at 2500 year intervals (see presentation by E.J. Gowan at INQUA - Friday, 17:30), spanning MIS 4 to present. We ran the calculation using SELEN (Spada and Stocchi, 2007), both with and without the Patagonian ice sheet (which reaches present date extent at 12 500 yr BP in the reconstruction).

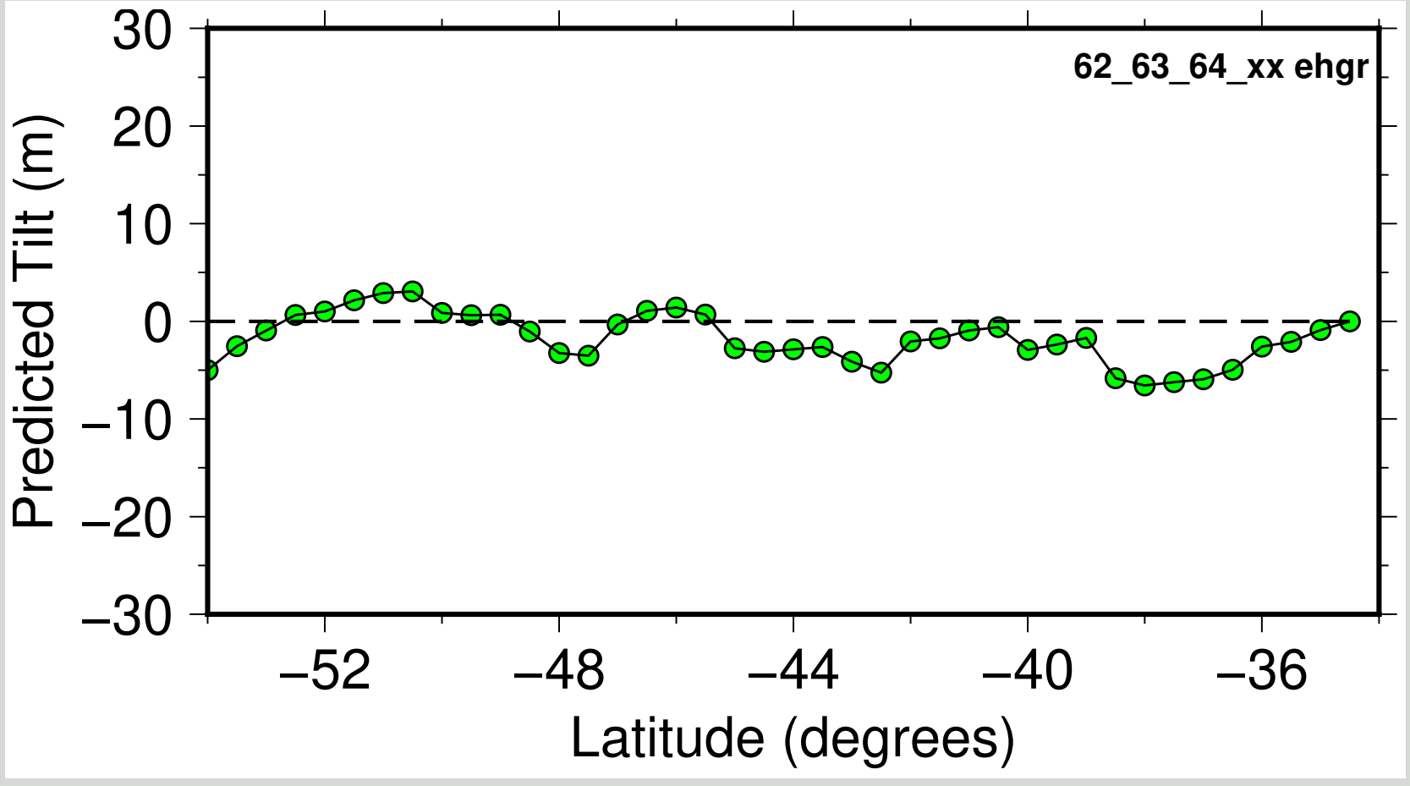




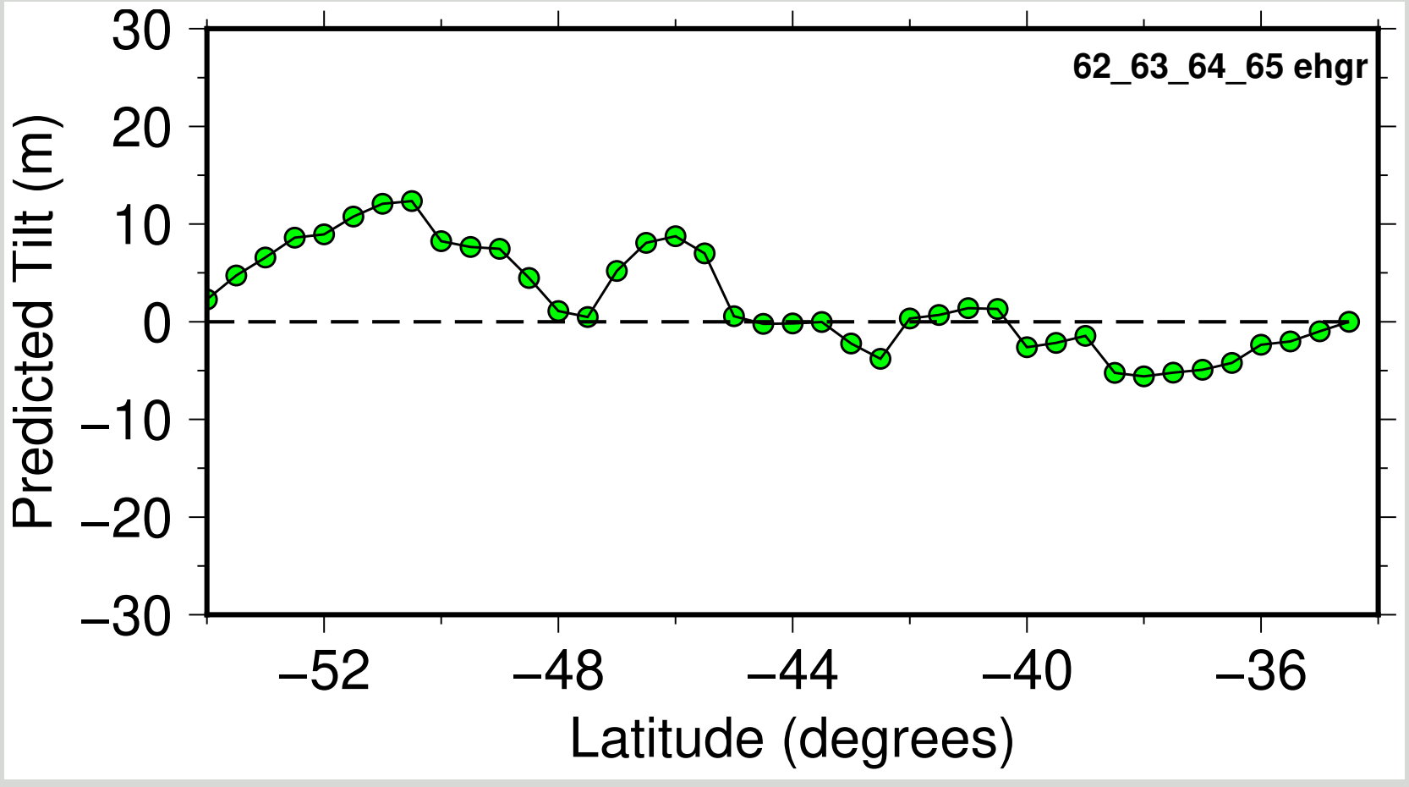
20 000 yr BP with Patagonian ice sheet



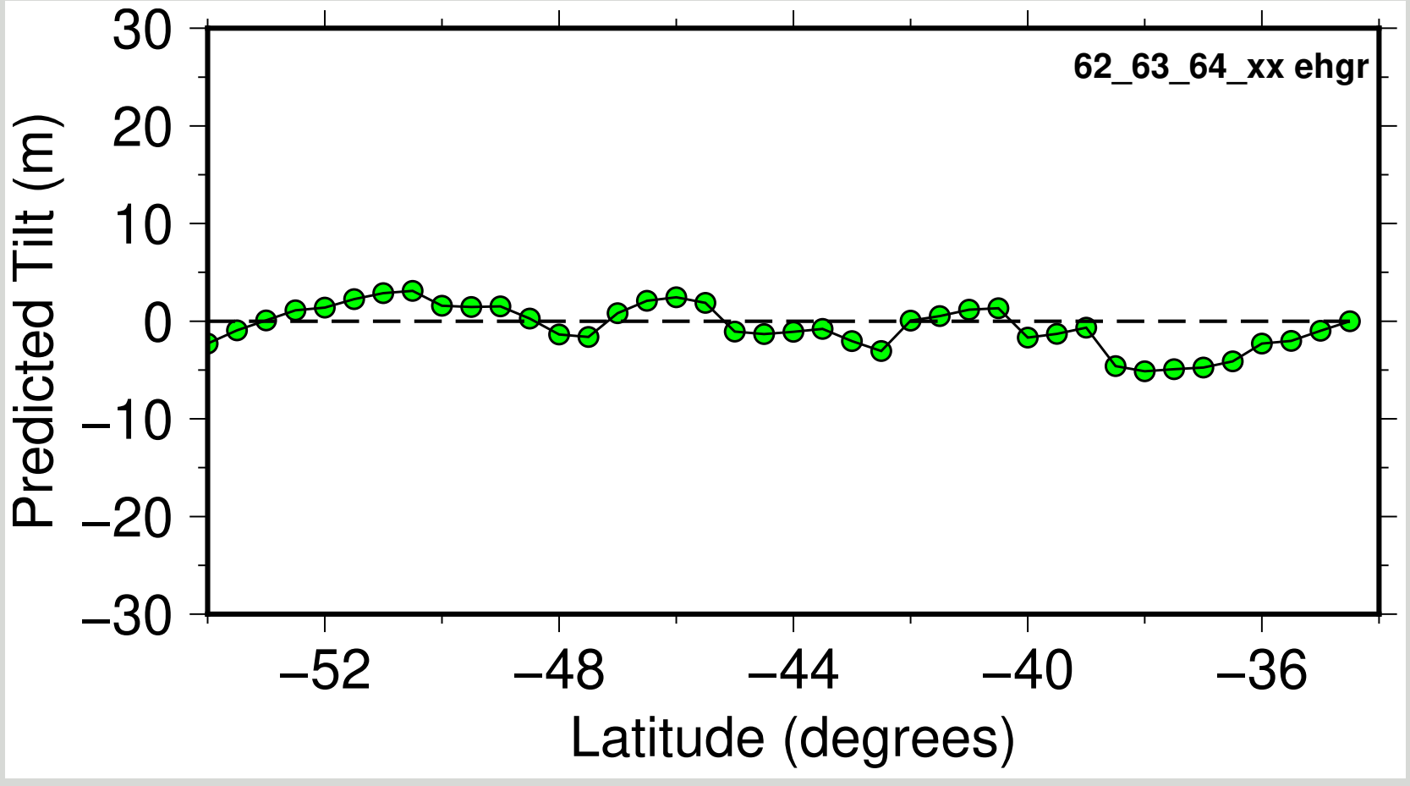
20 000 yr BP without Patagonian ice sheet



10 000 yr BP with Patagonian ice sheet



10 000 yr BP without Patagonian ice sheet



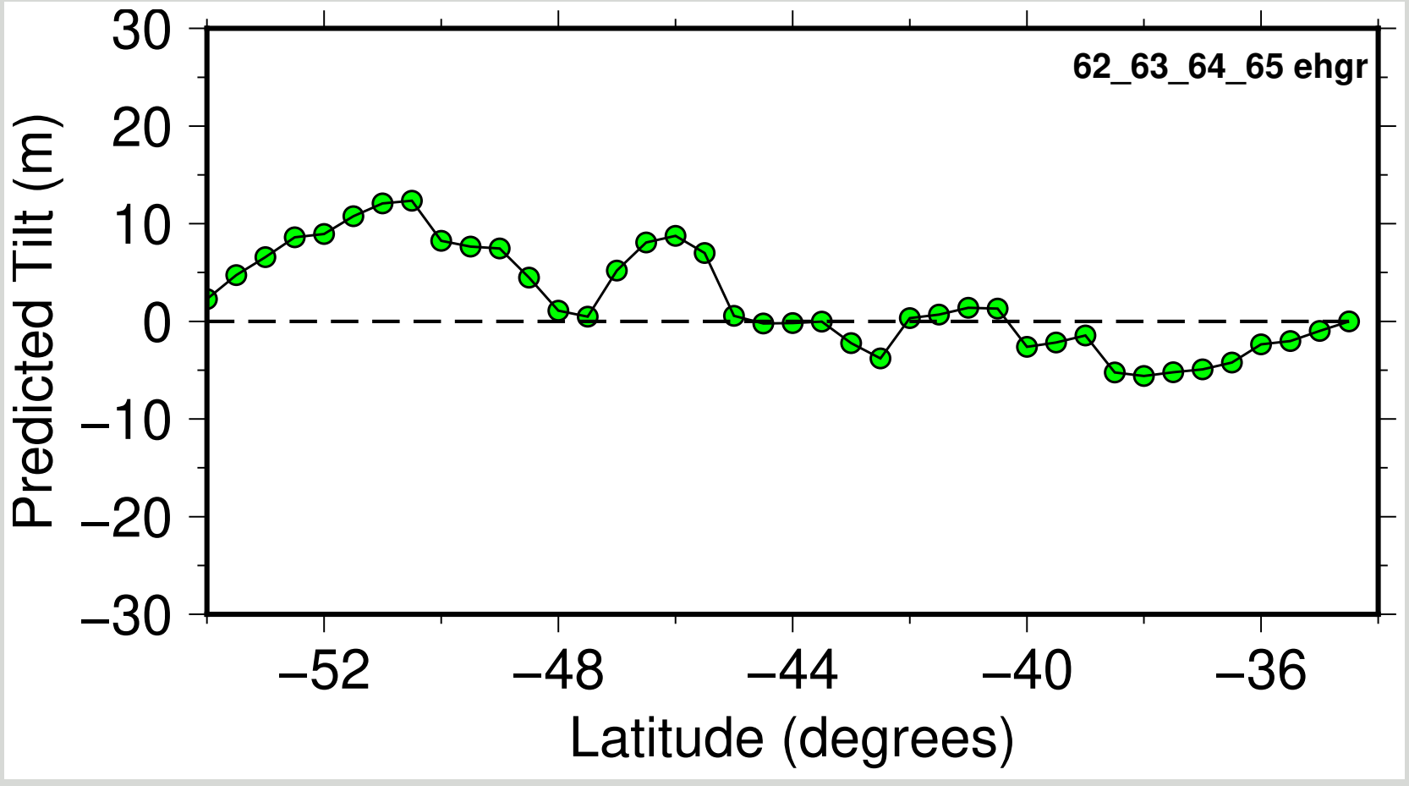
Impacts of Earth Model

The impact of GIA on the Argentinian coast will be dependent on whether or not the underlying mantle rheology is more similar to a continental area, or more like a region with active tectonics. The left figures show a continental rheology model. The right figures show a rheology model more typical of a region with active tectonics. At 70 000 yr BP, the Patagonian ice sheet extent is similar to present, so this might be the analogous of the magnitude of variability along the coast for a past interglacial.

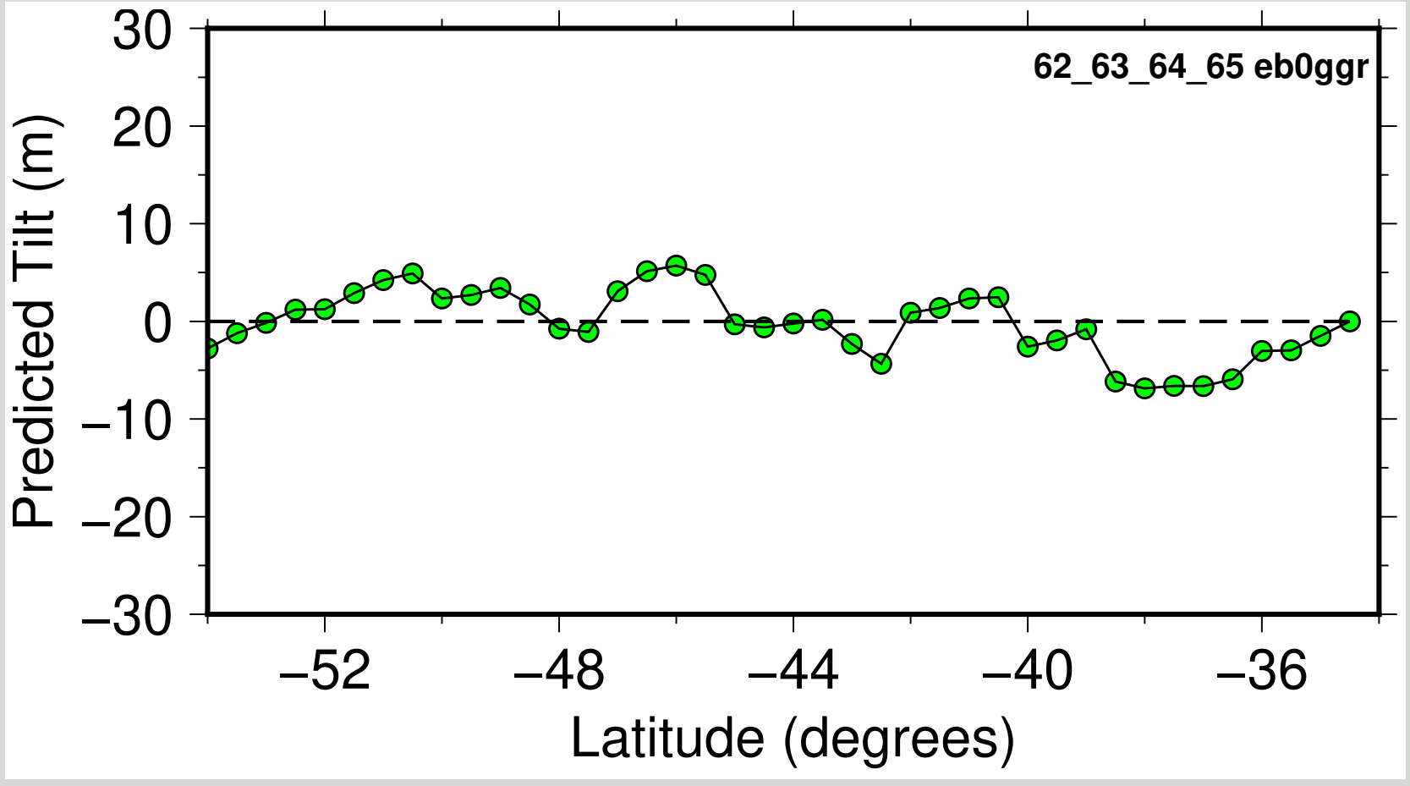
Continental model (120 km thick lithosphere, $\mathbf{4\times10^{20}}$ Pa s upper mantle, $\mathbf{4\times10^{22}}$ Pa s lower mantle)

Active tectonics model (60 km lithosphere, $\mathbf{1\times10^{19}}$ Pa s, 90 km asthenosphere, $\mathbf{4\times10^{20}}$ Pa s upper mantle, $\mathbf{4\times10^{22}}$ Pa s lower mantle)

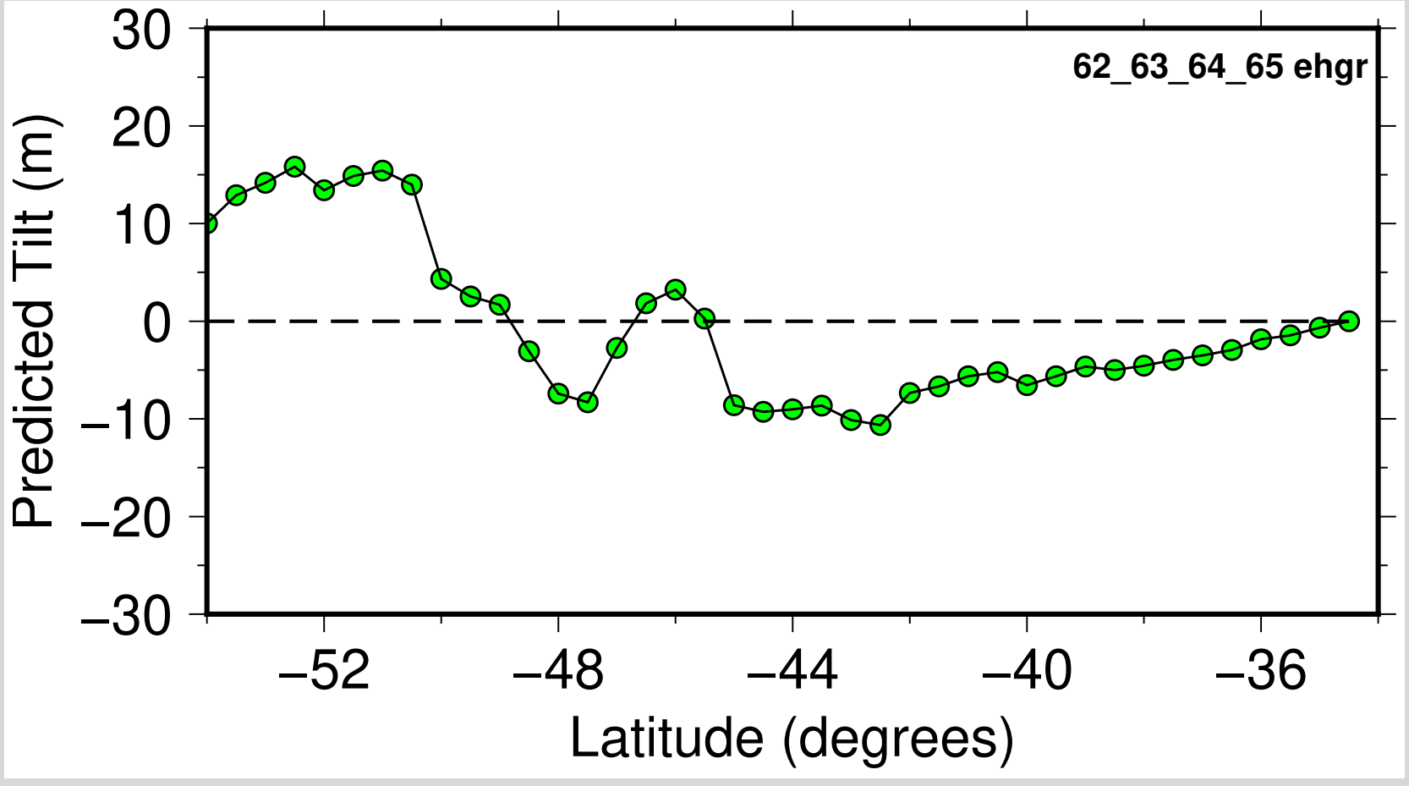
70 000 yr BP



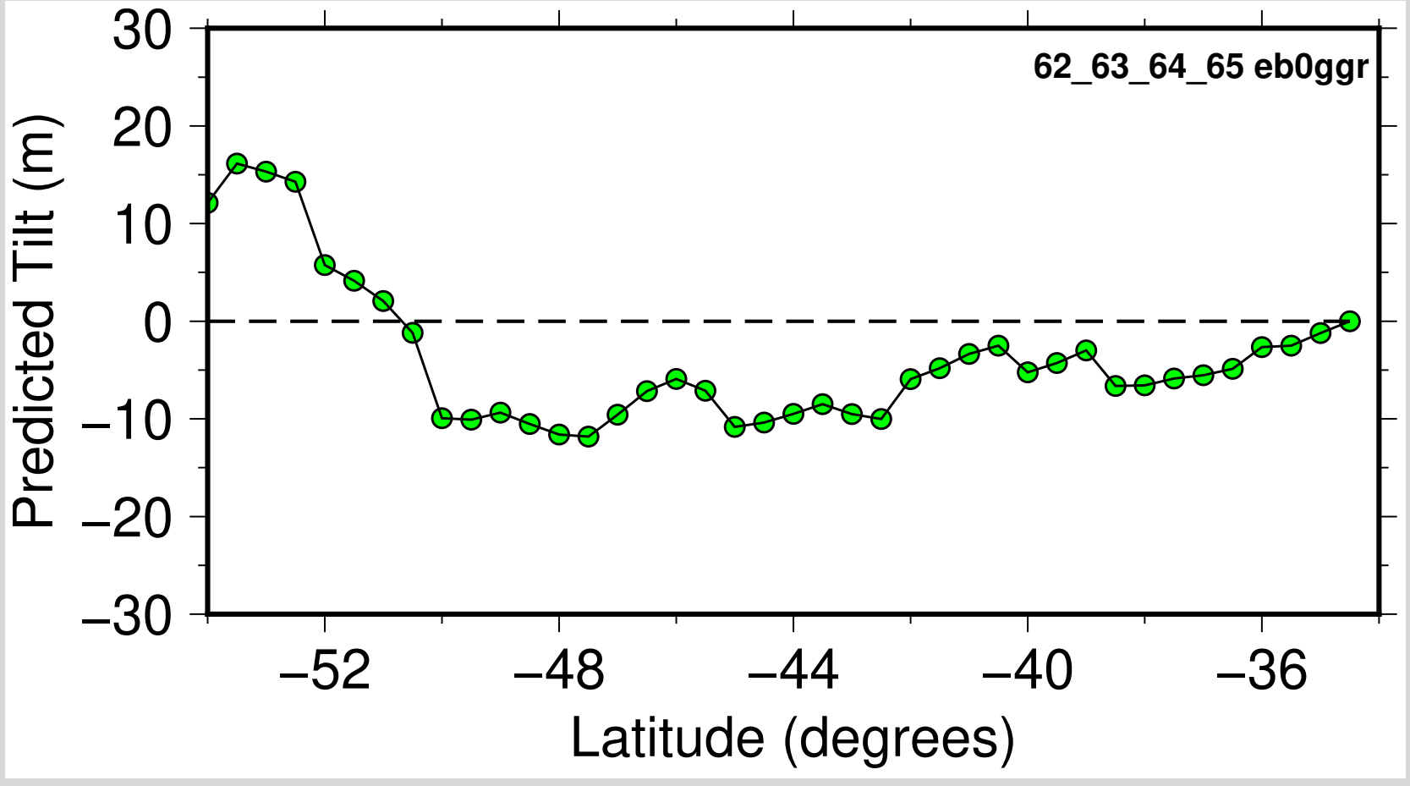
70 000 yr BP



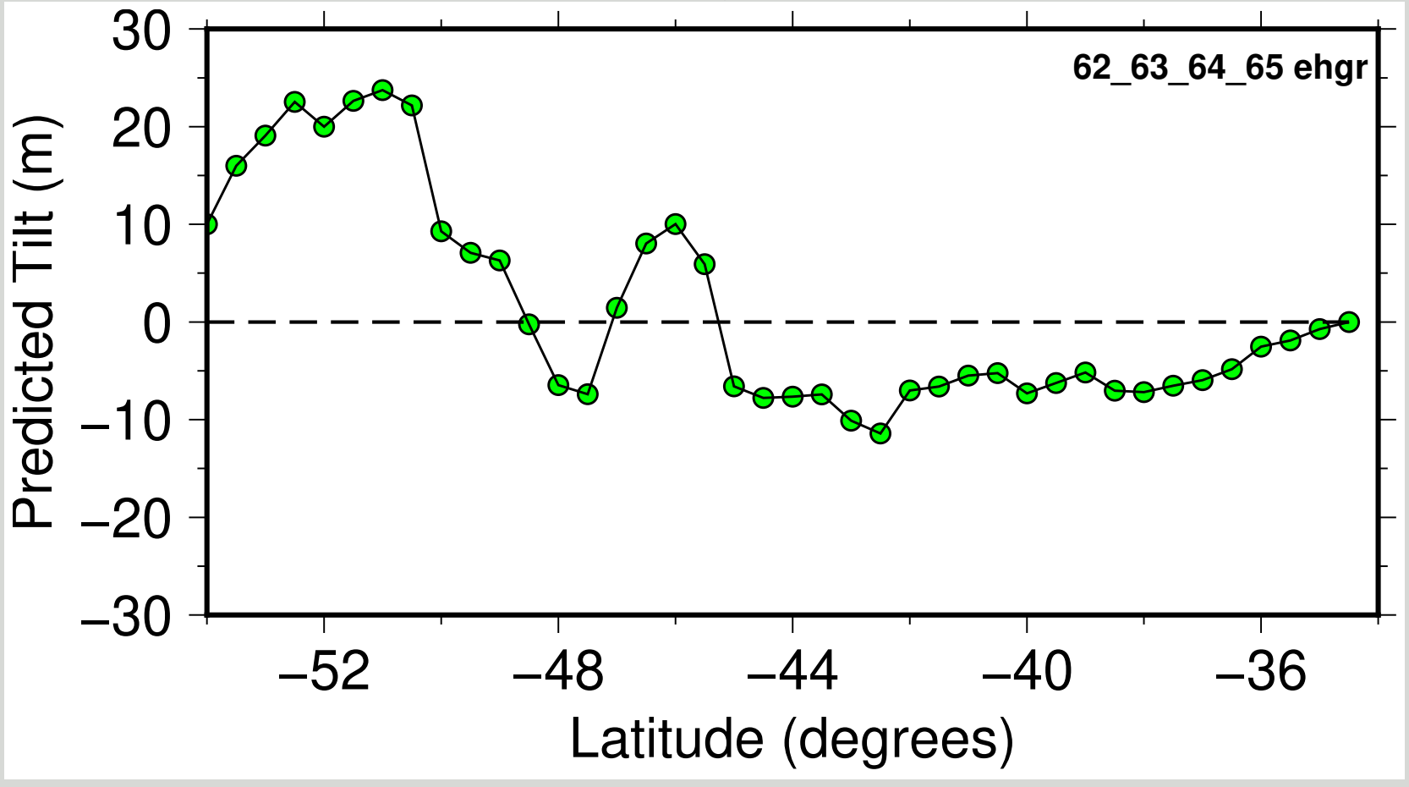
40 000 yr BP



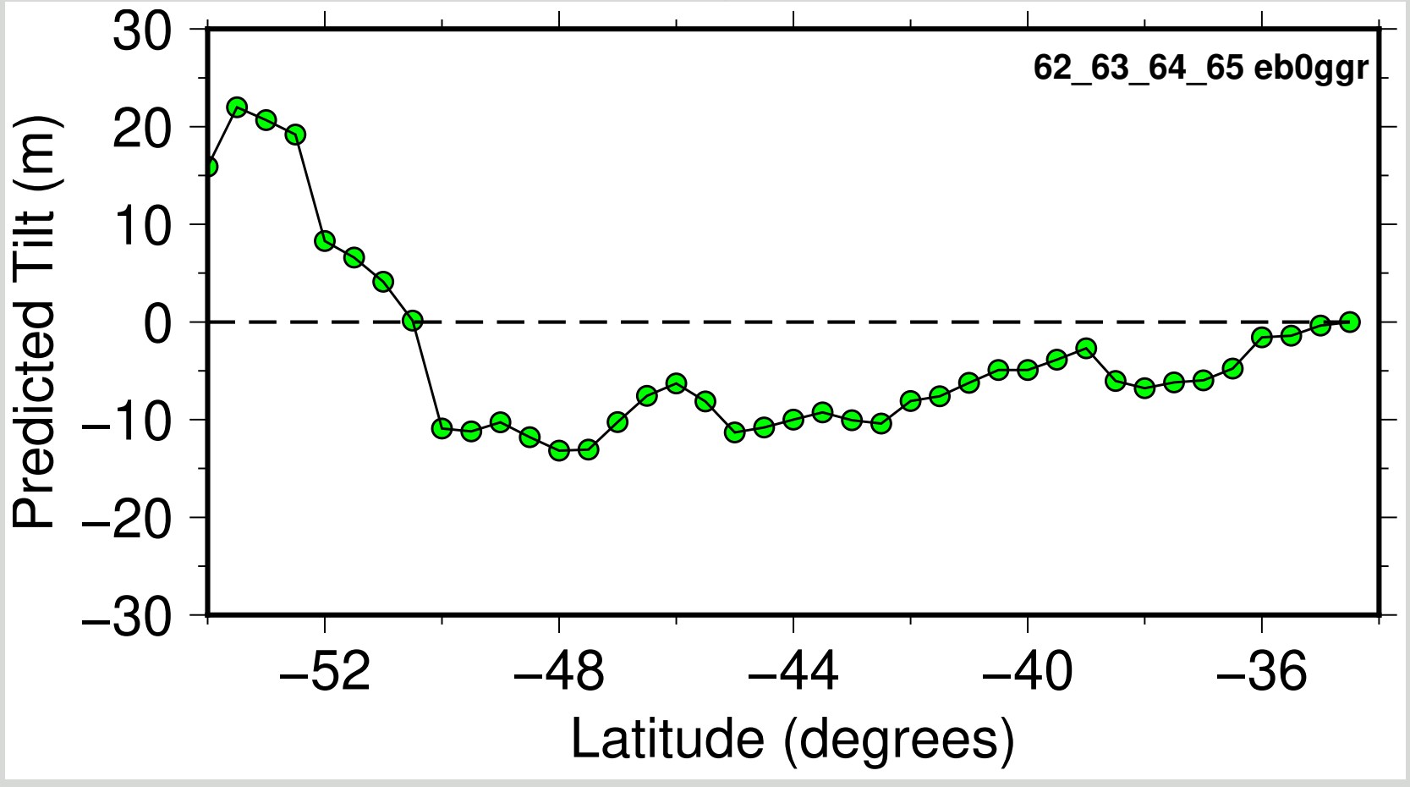
40 000 yr BP



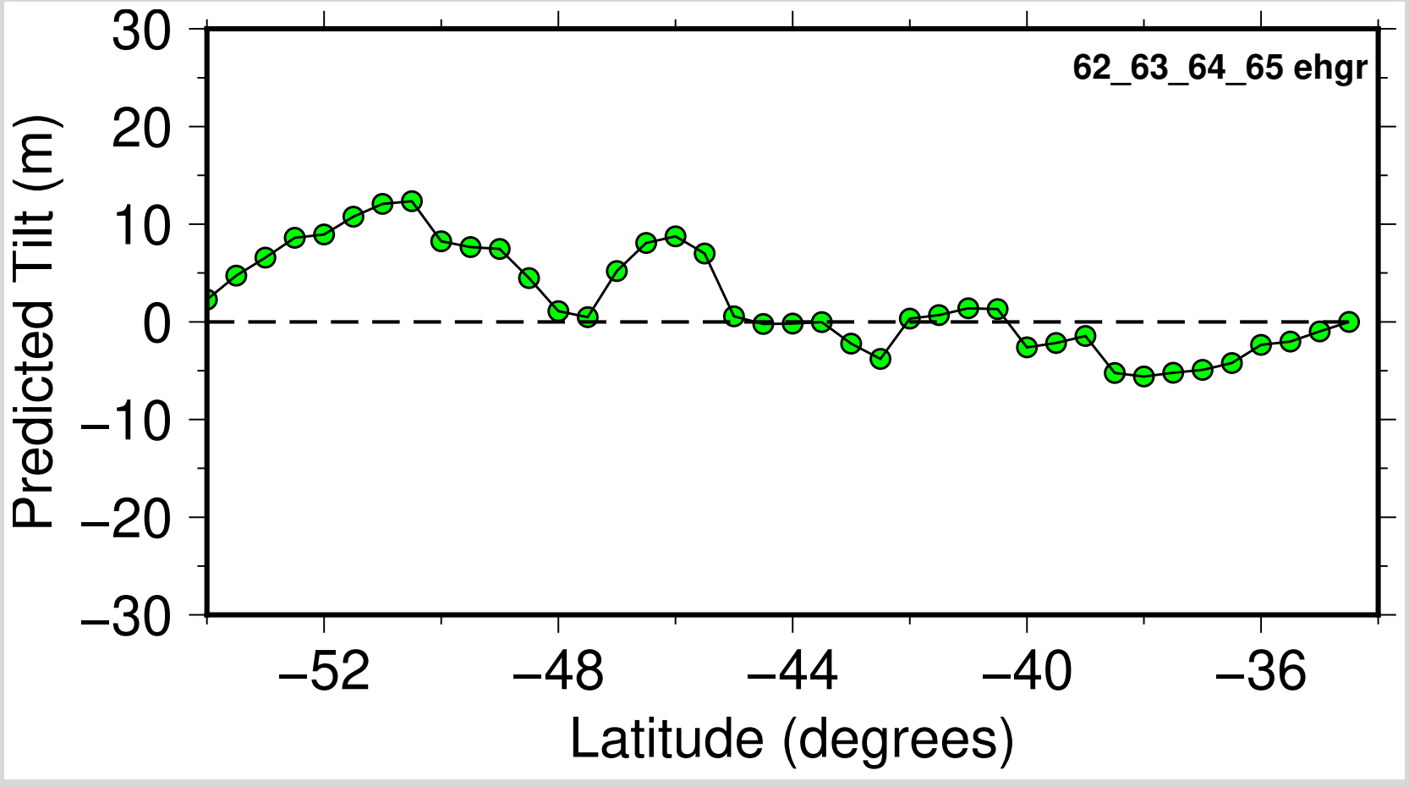
20 000 yr BP



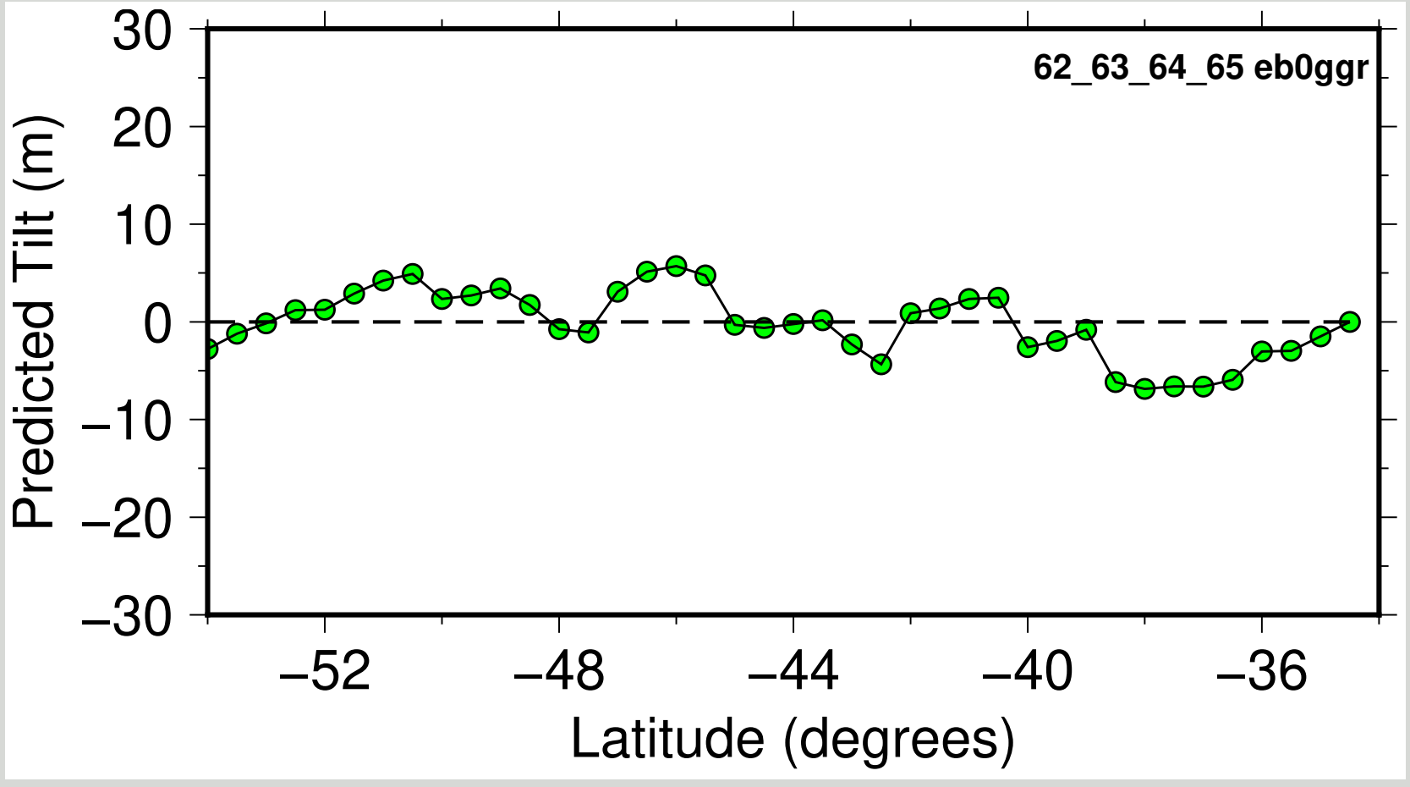
20 000 yr BP



10 000 yr BP



10 000 yr BP



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