Plate tectonic controls on atmospheric CO2 since the Triassic

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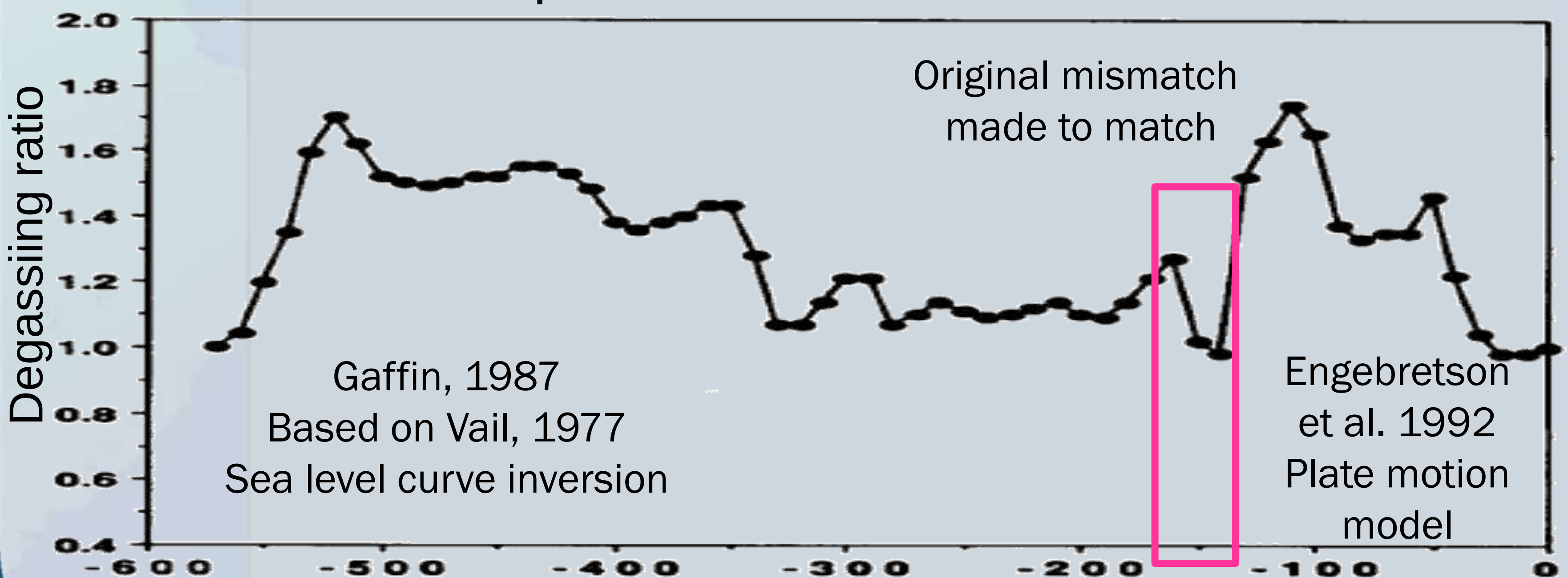
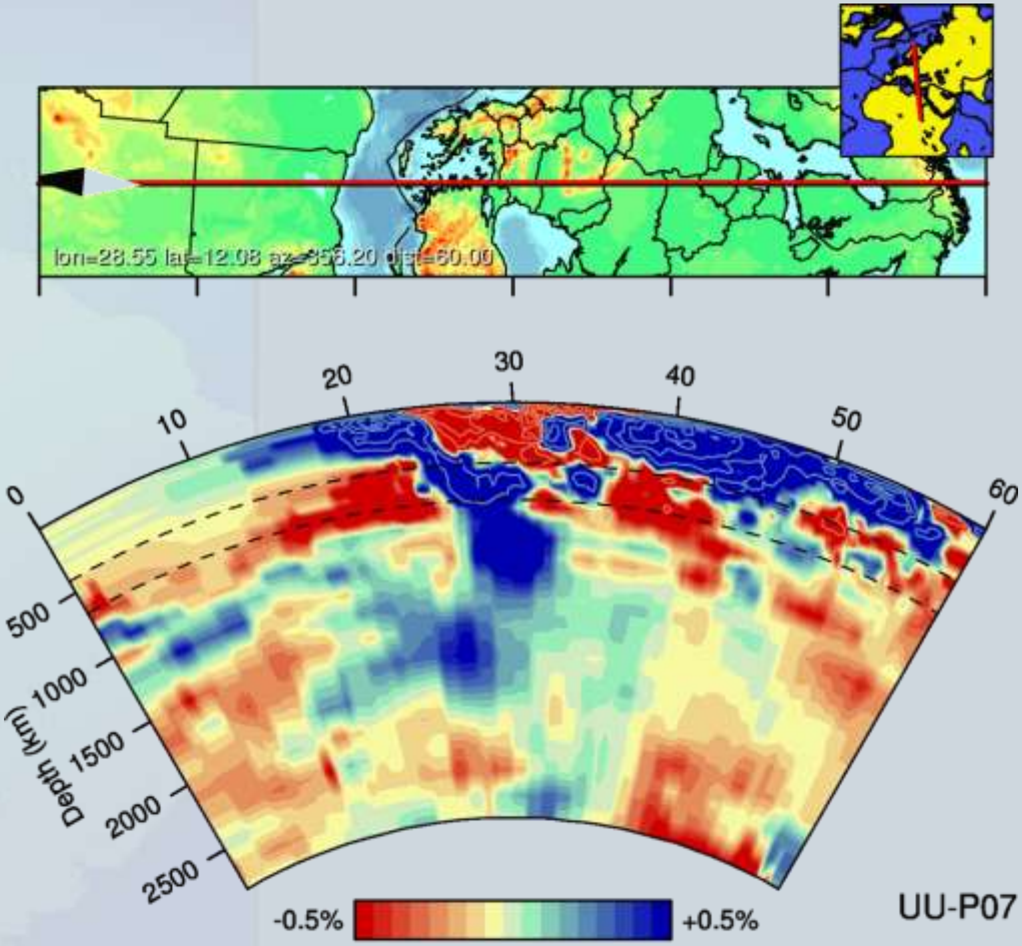
The Problem

- Plate tectonics assumed to drive long-term carbon cycle & atmospheric CO_2, but no direct proof



Berner, 1994, GEOCARBII

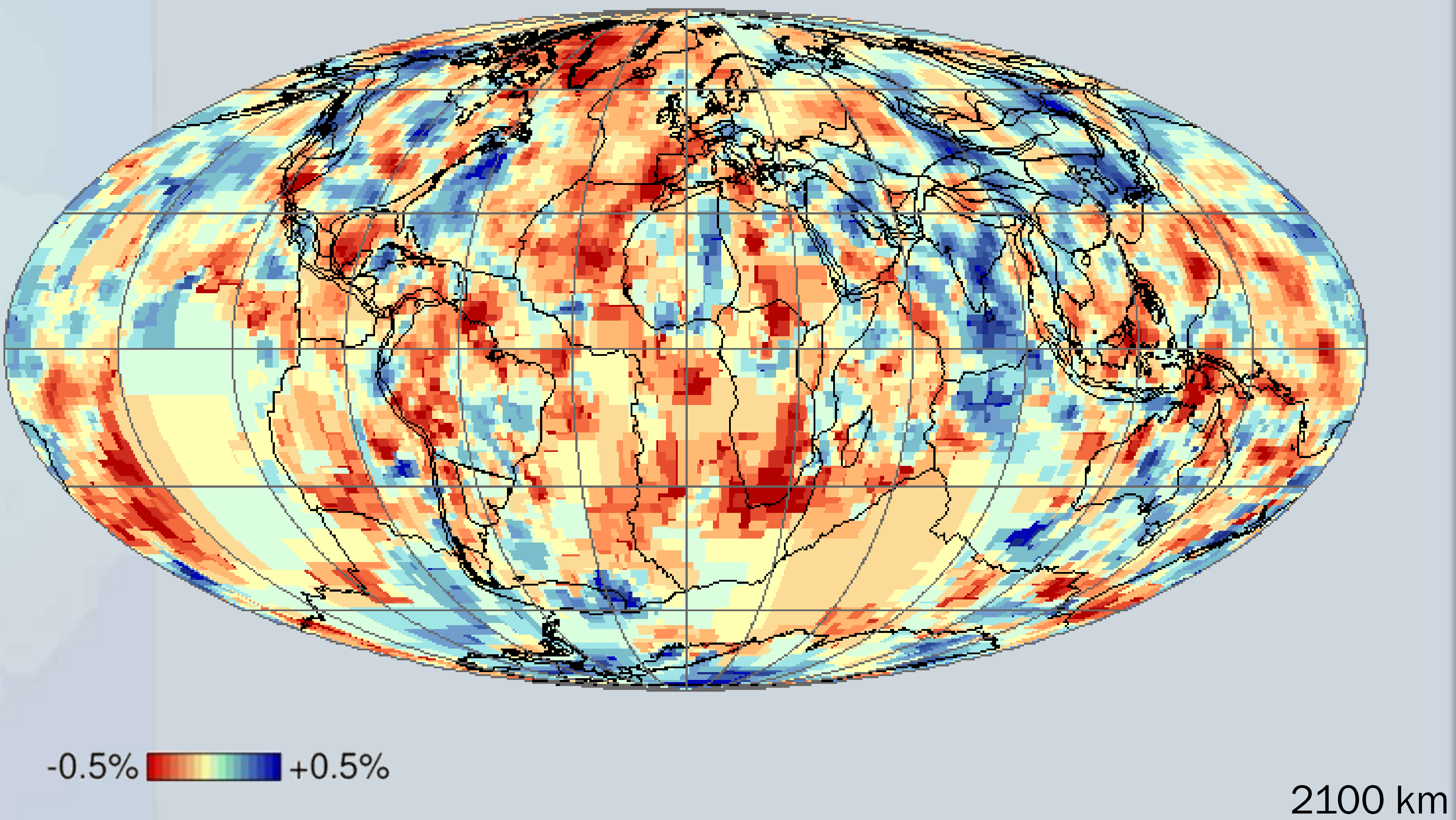
Mantle tomography show subduction record



- Slabs up to 250 Myr old identified
- Subduction and spreading interdependent
  - Dominant over hotpot volcanism >10 Myr timeframe
- Most carbon CO2 recycled to atmosphere within few Myr
- Can we estimate volcanic degassing through time?

UU-P07 tomographic model: Amaru (2007)
Image from Van der Meer et al. (2010)

Mapping paleo subduction from tomography



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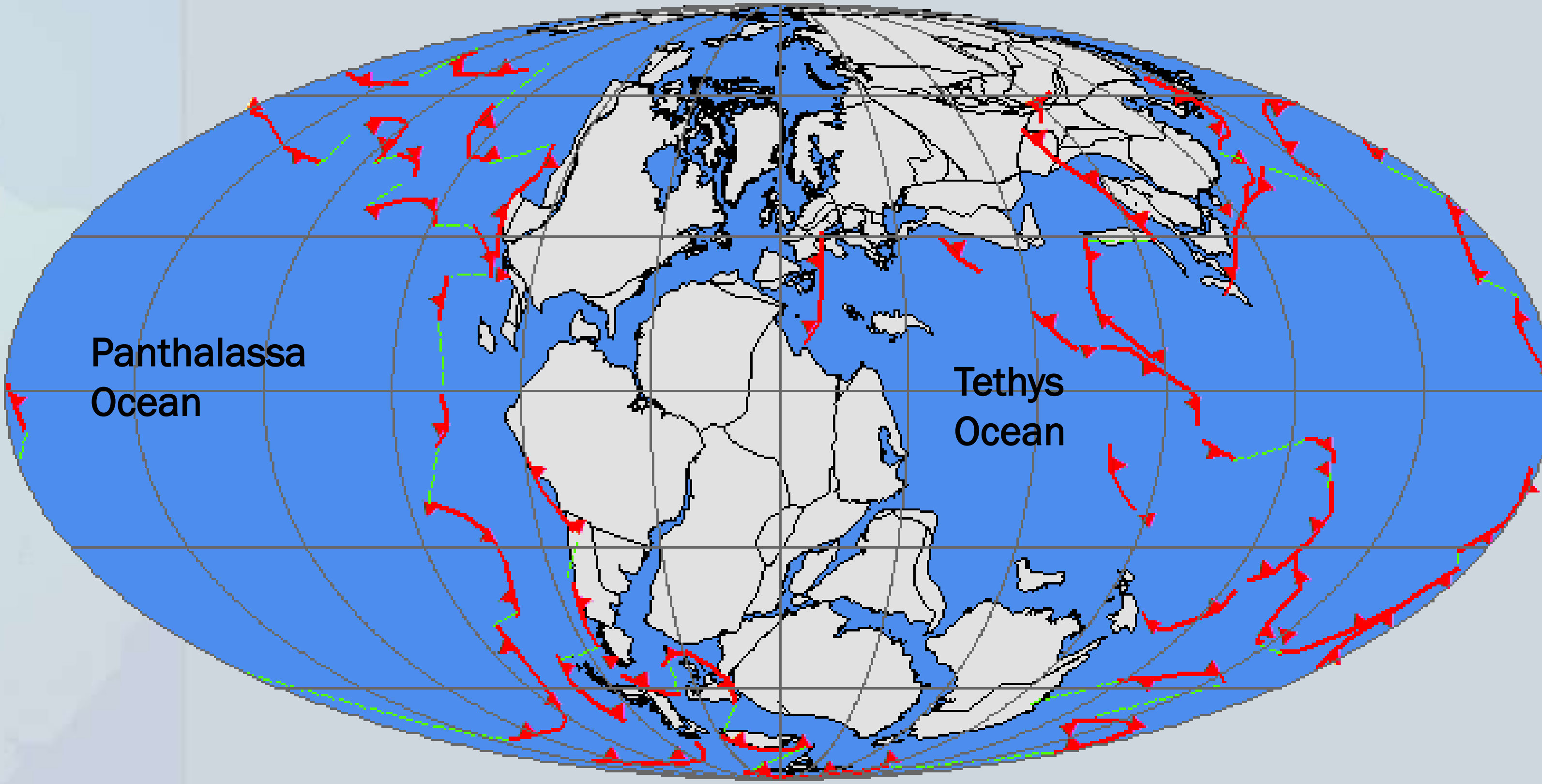


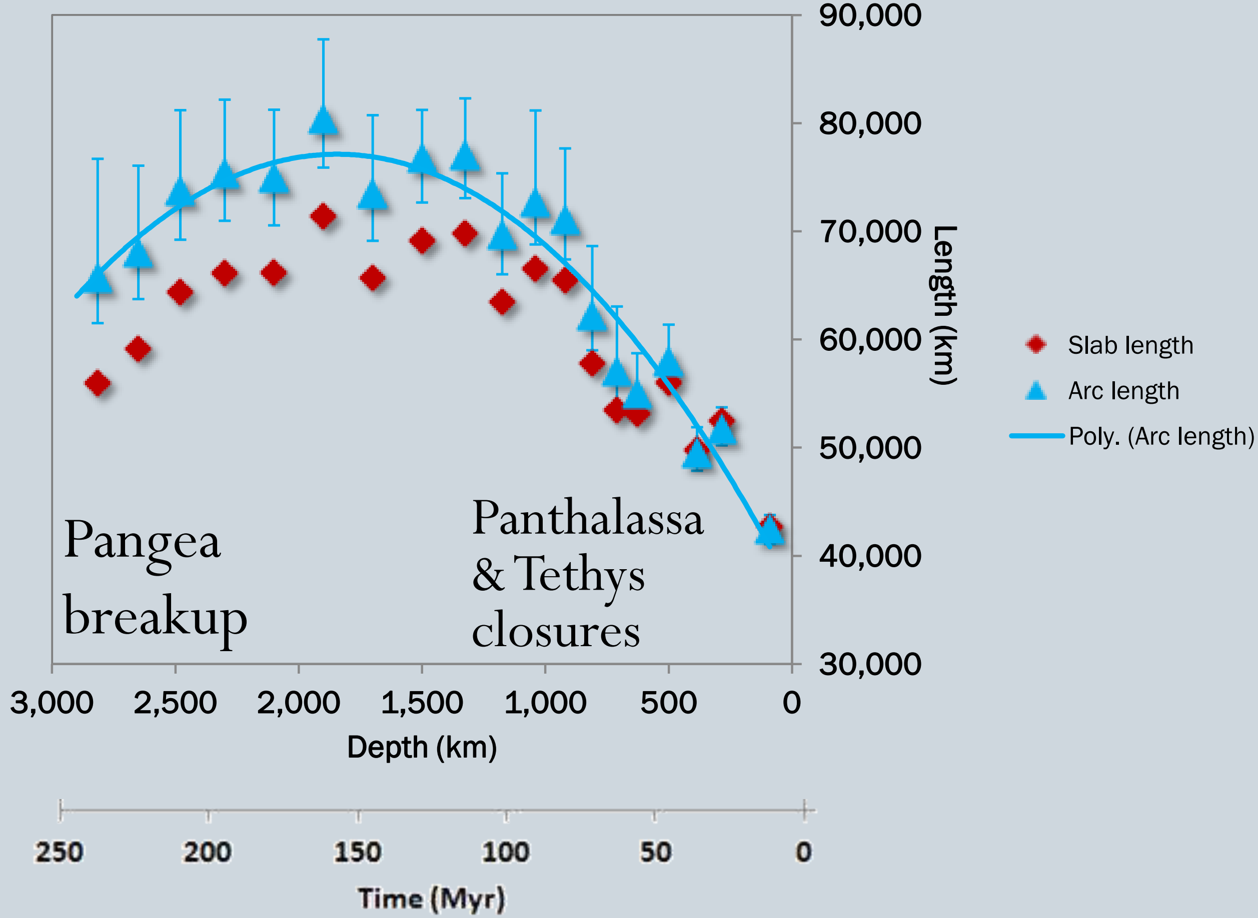
~170 Myr
Length=74941 km

Plate tectonic reconstruction: Torsvik et al. (2008), TPW corrected by Steinberger et al. (2008), Slab-frame corrected by Van der Meer et al. (2010), Subduction interpretation (Van der Meer et al. 2010, 2012)

Subduction zone length through time

Ak135 density Model

Avg sinking velocity 1.2 cm/yr



Ak 135 model: Kennett et al. (1995)
Sinking velocity: Van der Meer et al. (2010)

Uncertainties/assumptions

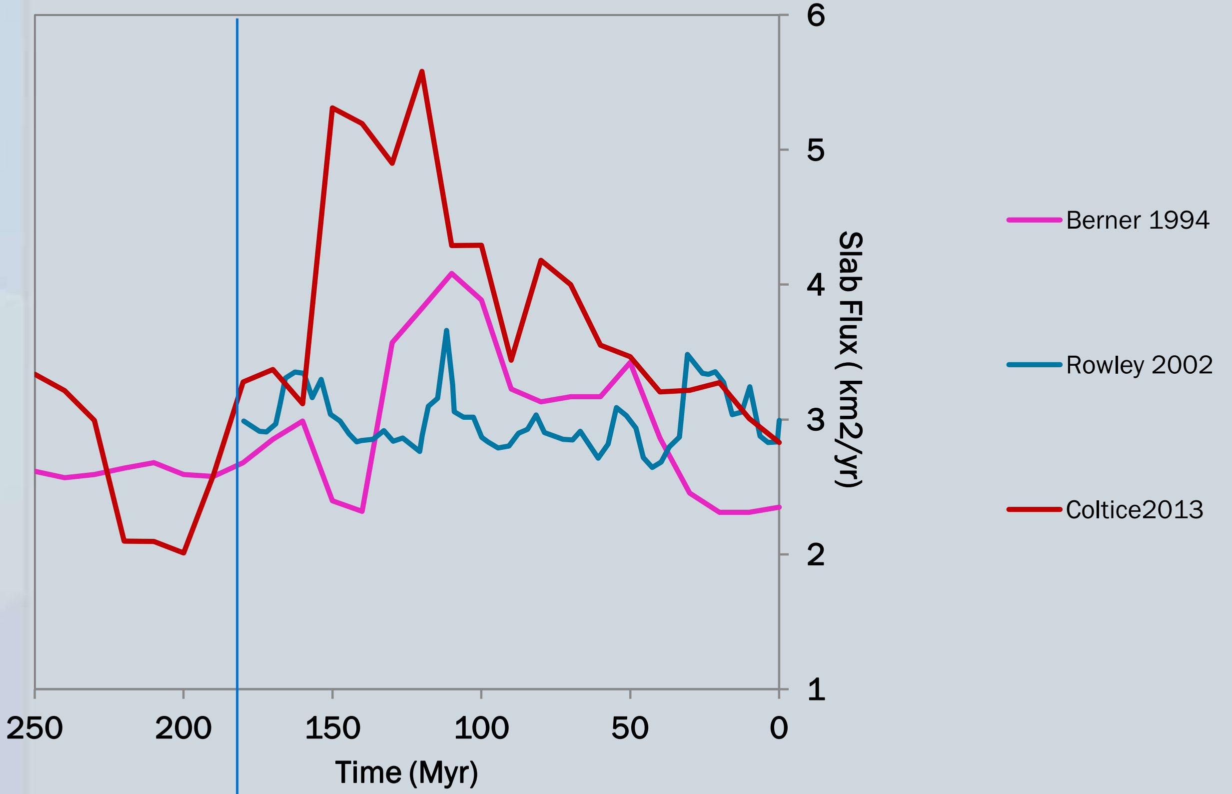
- In our error analyses:
  - Tomographic spatial resolution
  - No/poor imaged zones
- Assumptions/limitations:
  - One tomographic model (Amaru, 2007)
  - Compression correction ak135 (Kennett et al, 1995)
  - Linear time-depth function (van der Meer et al. 2010)
    - Smoothing of individual slabs contributions
  - Constant CO_2 contributions per arc-km, time and spatially constant
  - No difference between continental versus oceanic arcs

Testing the subduction curve

1. Crustal consumption should equal crustal production

2. Strontium Isotopes: weathering versus volcanism

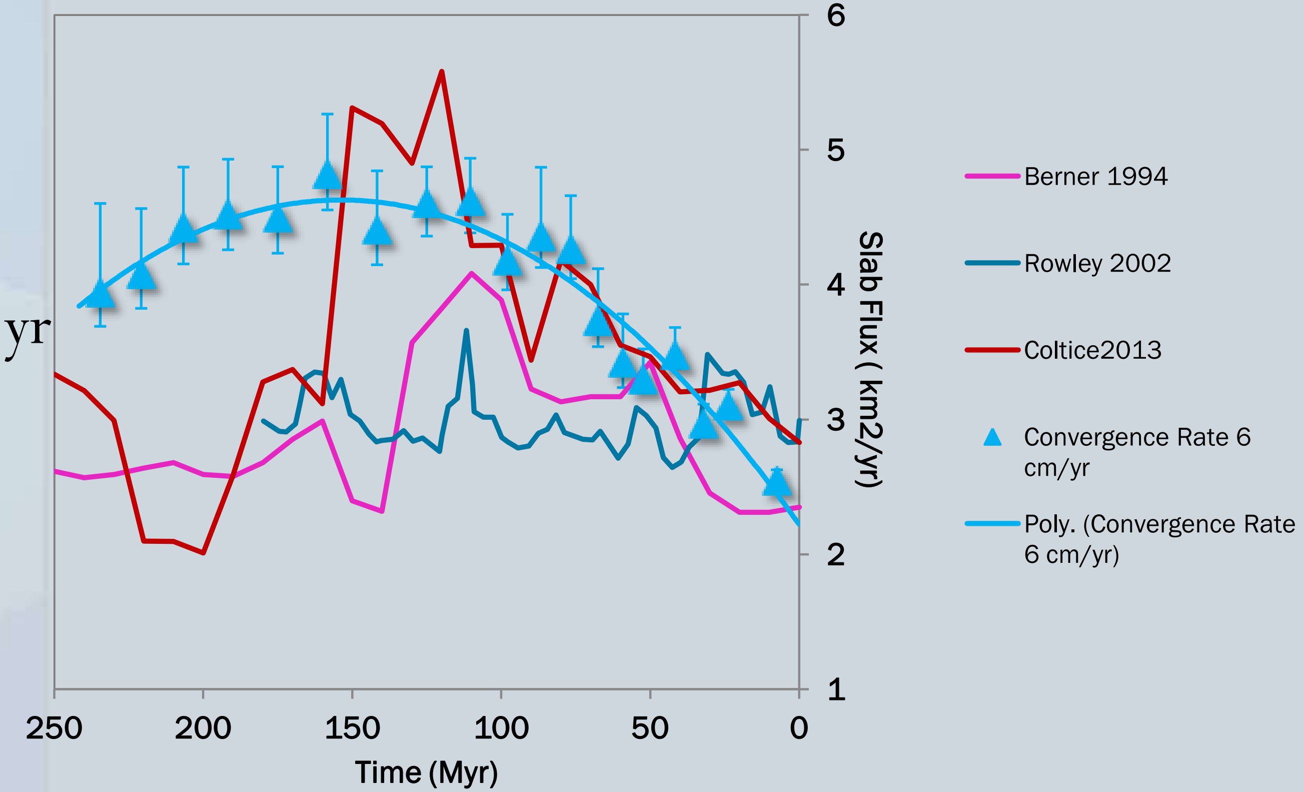
Test 1: Consumption should equal production



No oceanic crust | Increasing uncertainty

Test 1: Consumption should equal production

* 6 cm/yr

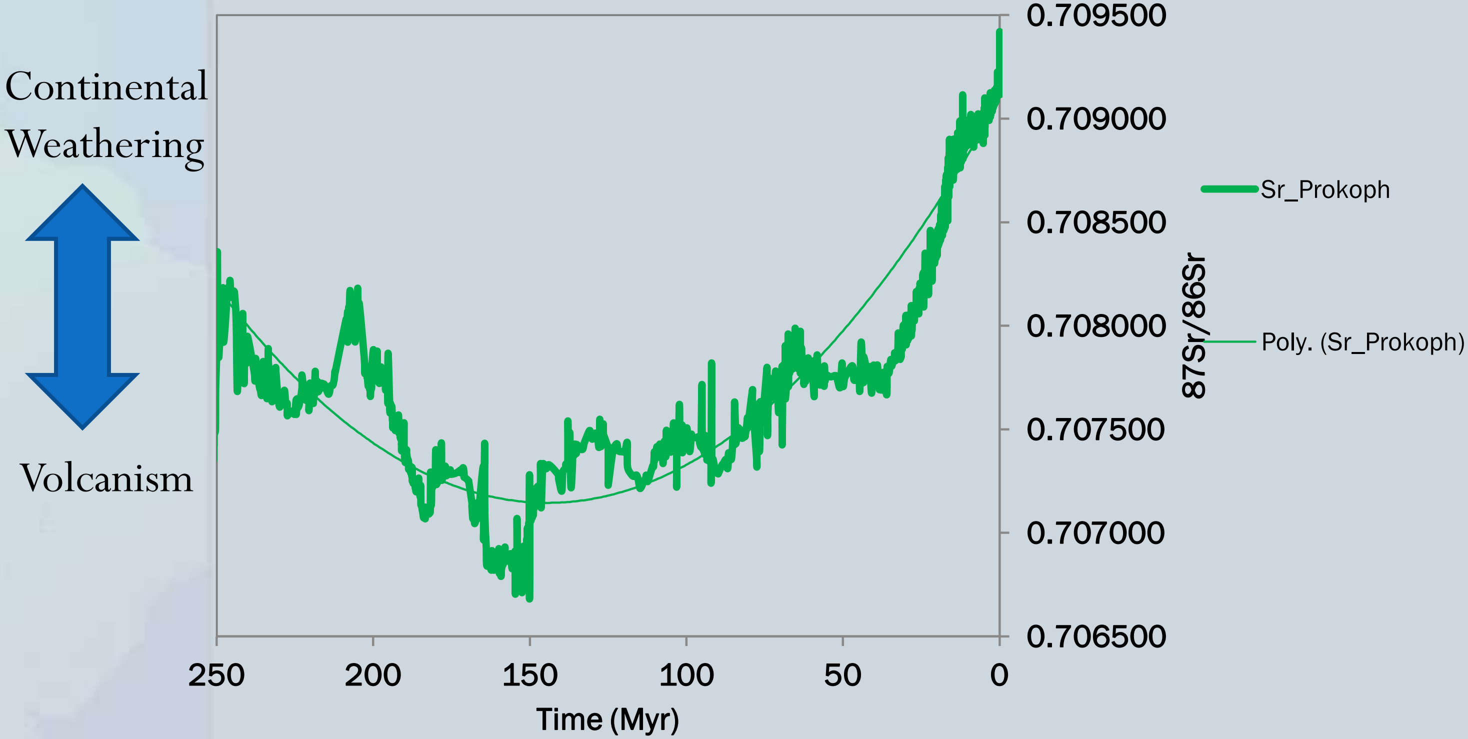


- With constant 6cm/yr convergence, subduction curve in agreement with most recent plate motion model where constrained by isochrons

Test 2: weathering vs mantle input

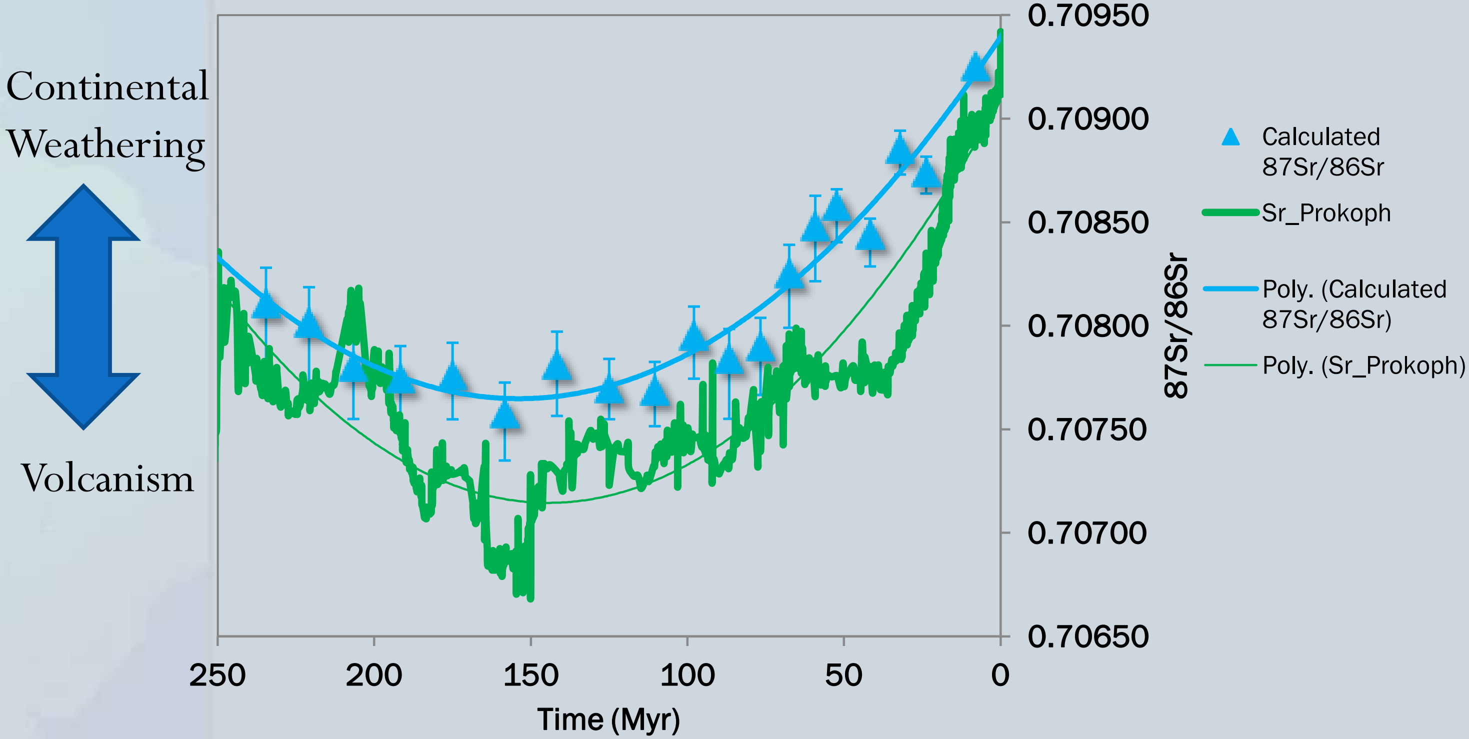
Continental Weathering

Volcanism



Sr isotope data: Prokoph et al. 2008

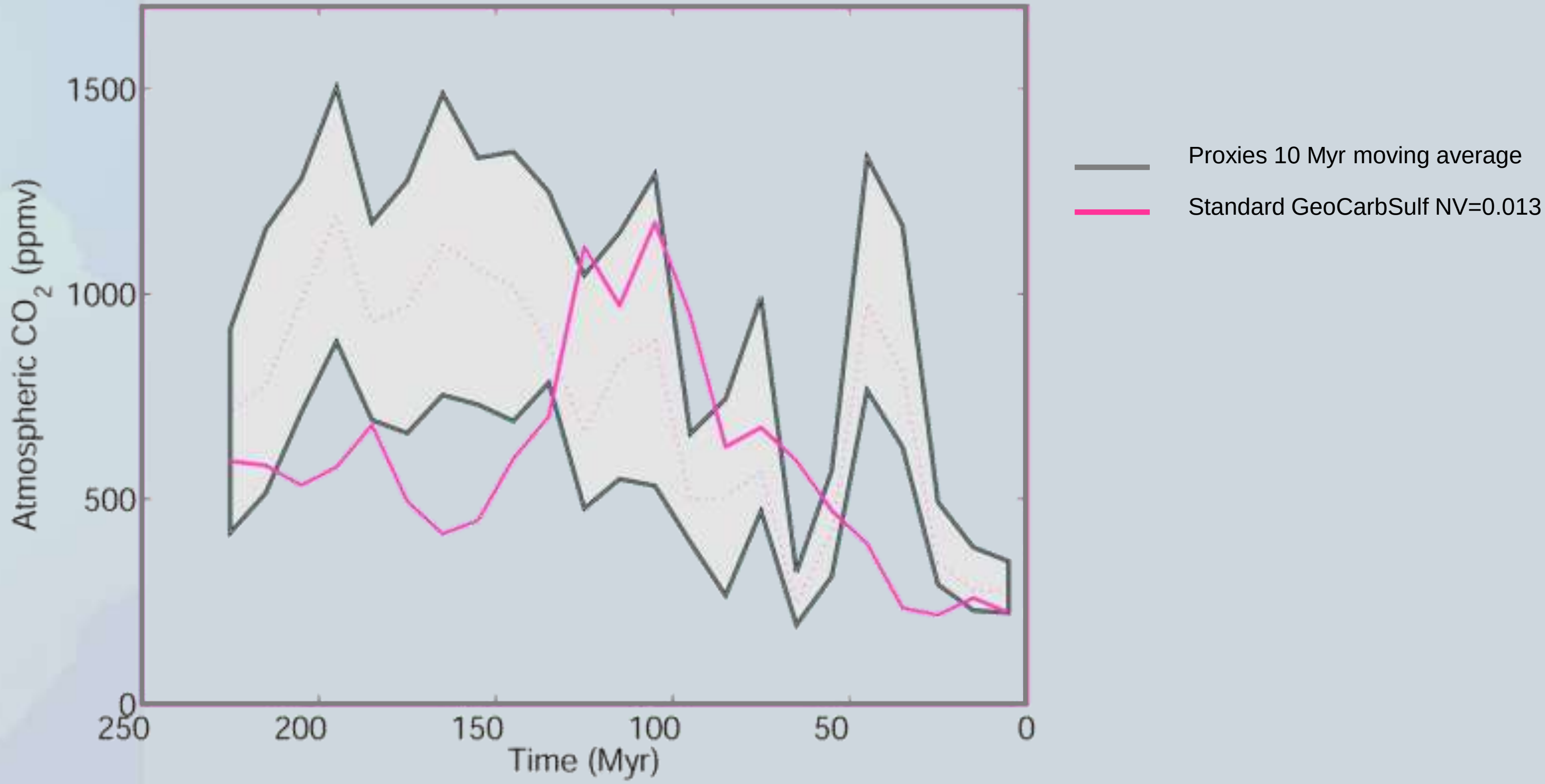
Sr isotopes: weathering vs mantle input



- By using a recent mixing model (Allegre et al. 2010), subduction length ratio correlates with 87/86Sr curve at first order

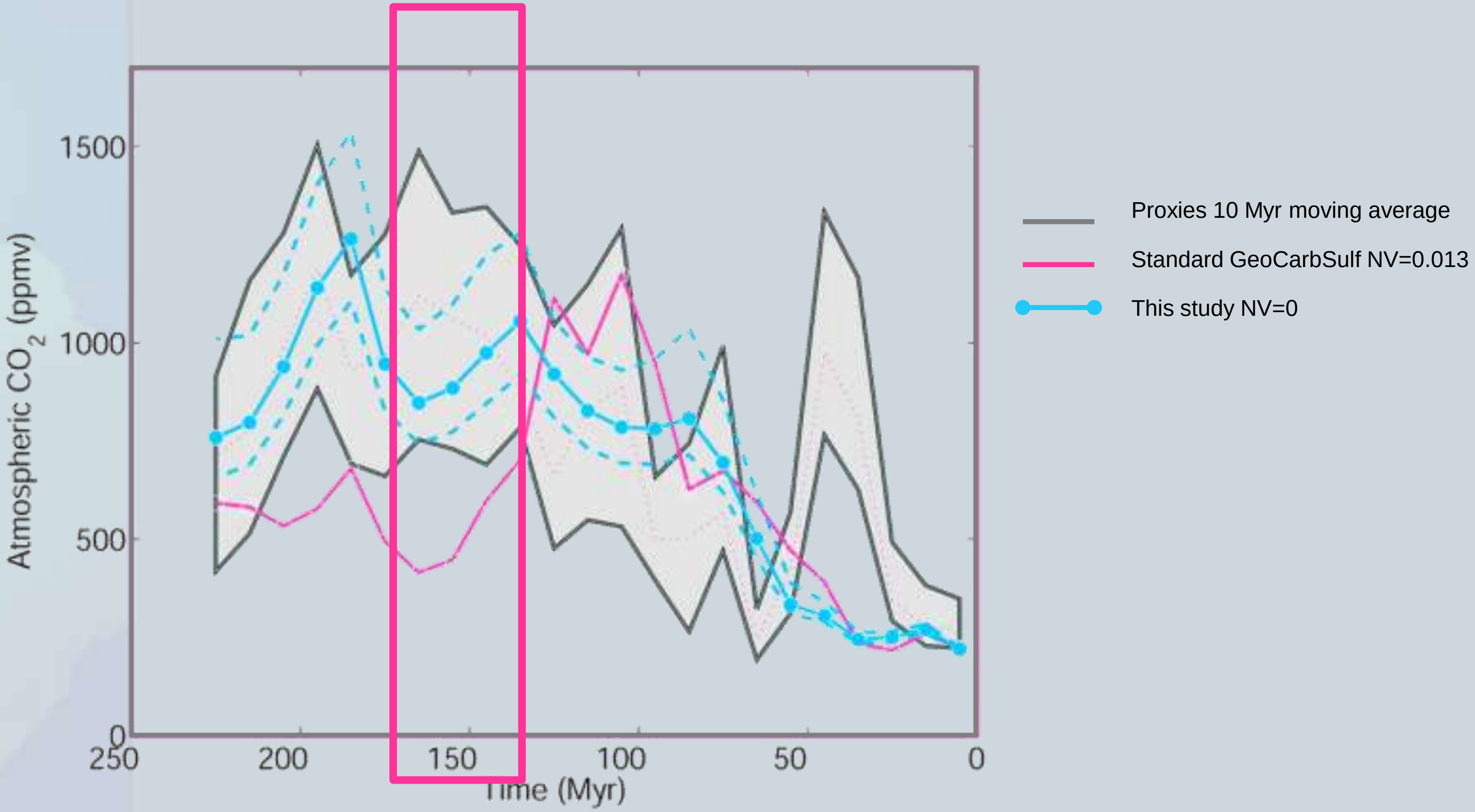
Sr isotope data: Prokoph et al. 2008

Effect on atmosphere



CO2 proxy data: Park & Royer (2011)
Geocarbsulf: Berner, 2006

Effect on atmosphere

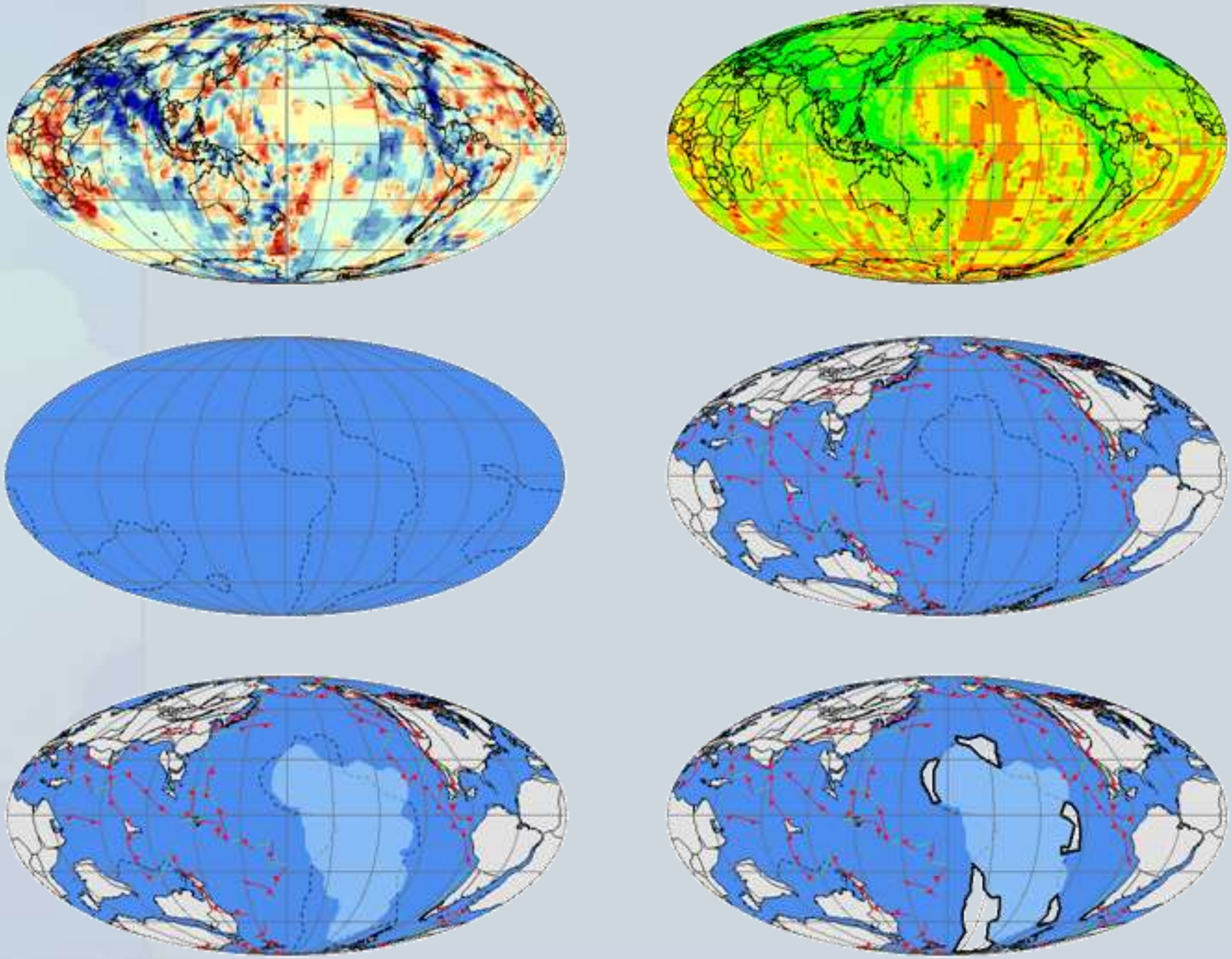


- Better match with proxy data in Mesozoic

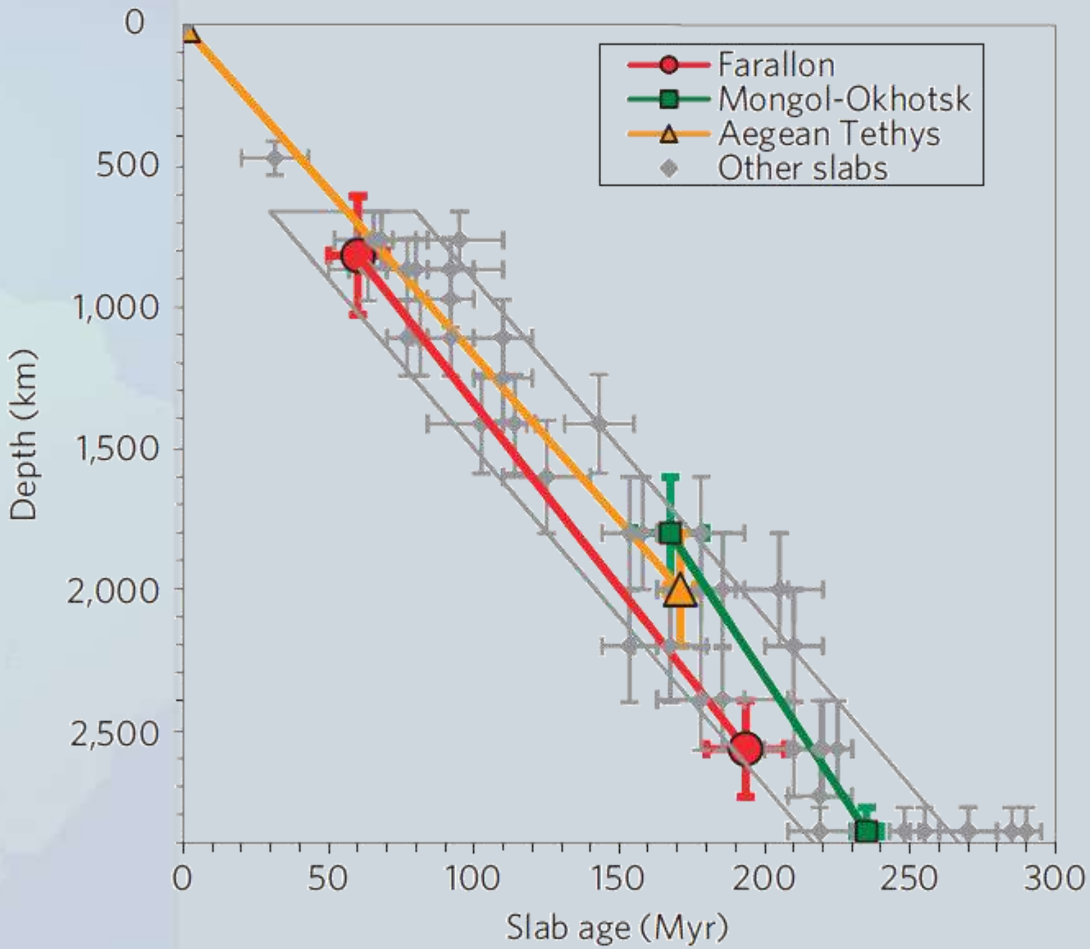
Conclusions

- Subduction length for the past 250 Myr
- Verified by crustal production & Sr isotopes
- Improved match with atmospheric CO2 proxies
- Proof that carbon cycle is controlled by plate tectonics at first order

Questions?



•Time-depth curve

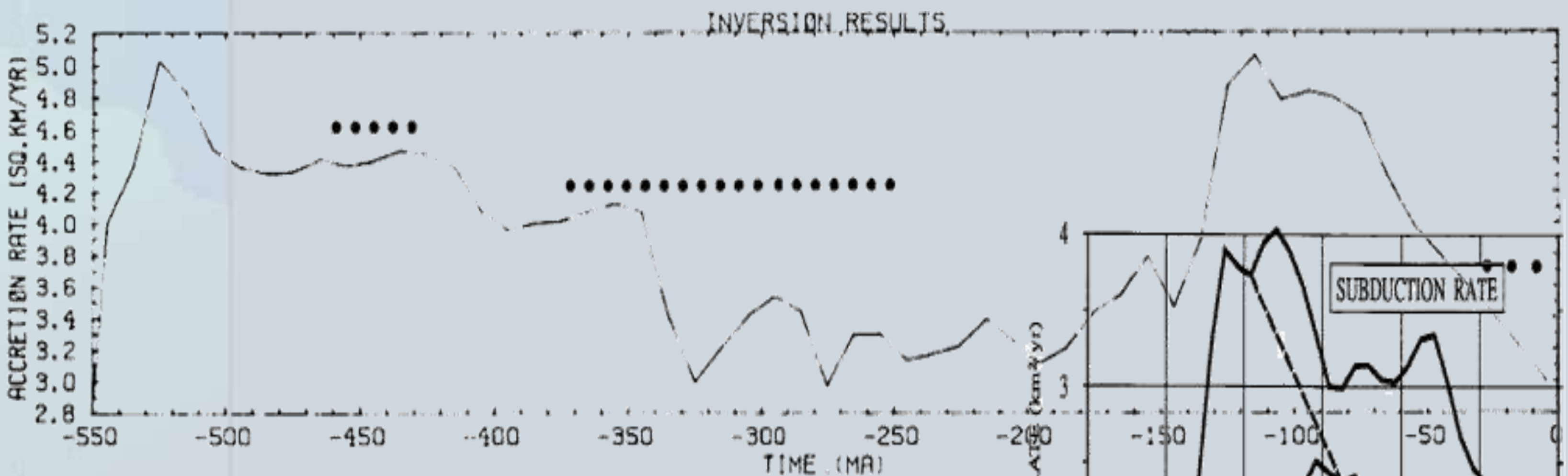


- Tomographic anomalies correlated with geological record
- 28 slabs dated

van der Meer et al., 2010

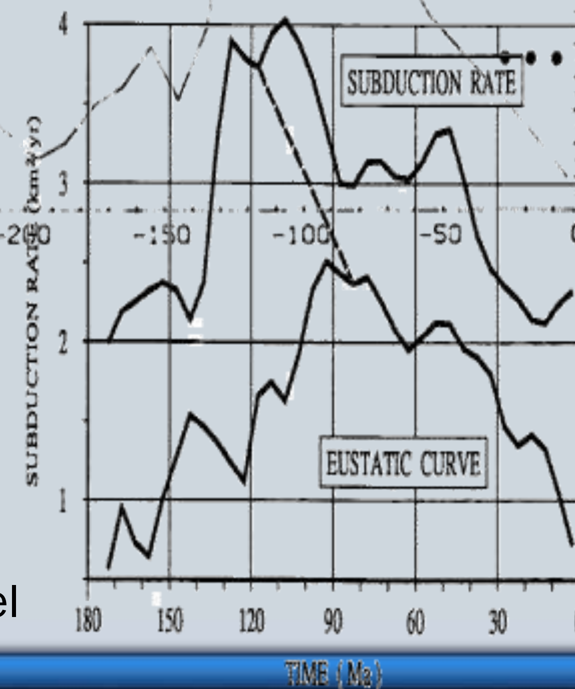
•The problem; plate tectonics assumed to be driving atmospheric CO2; outdated views

- outdated curves in paleo-climate modelling



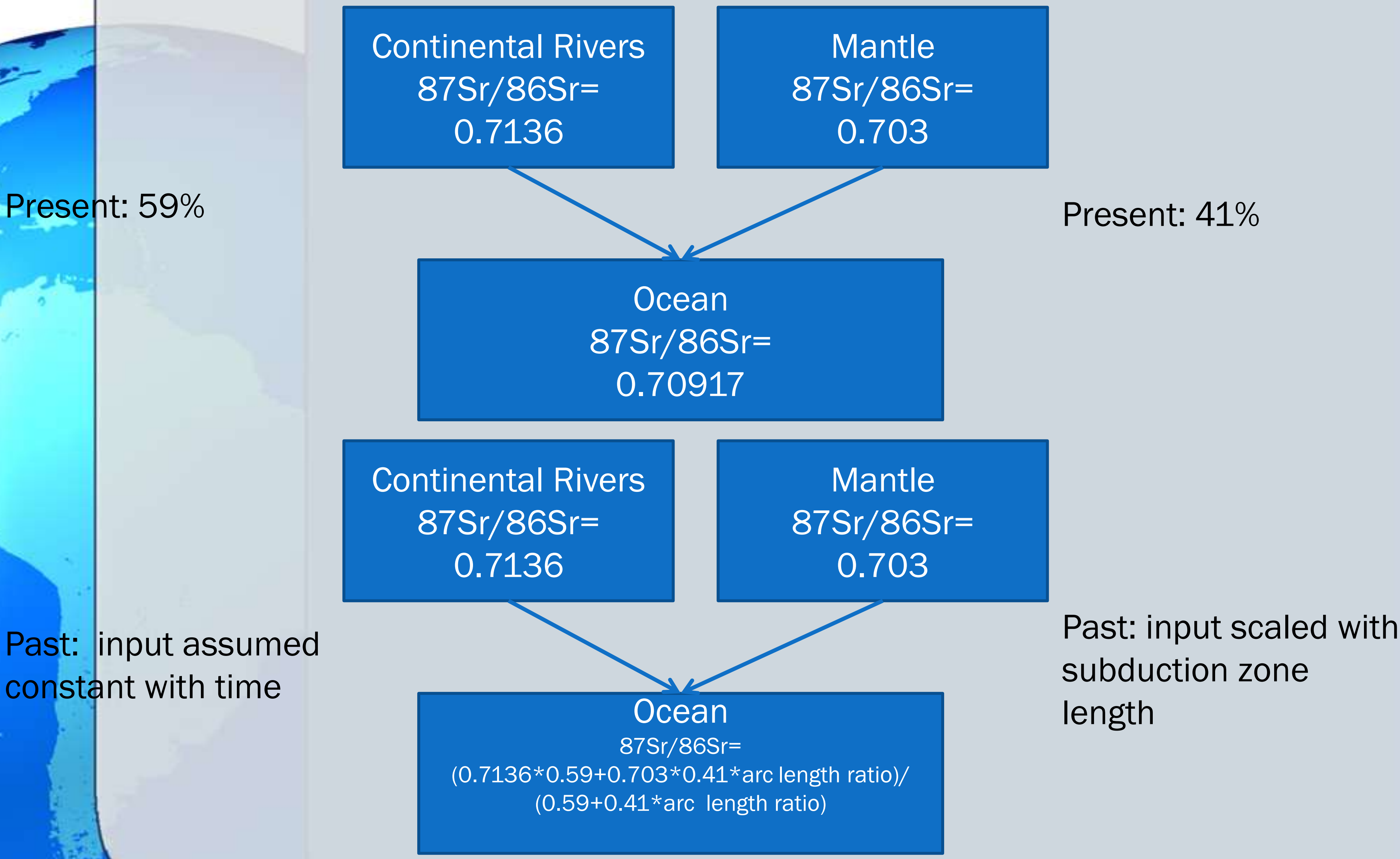
Gaffin, 1987

Based on sea-level curve of Vail et al. 1977



Engebretson et al. 1992

Derived from plate motion model



Radiogenic Strontium mixing model . Adopted from Allegre et al, 2010. Palaeo ocean 86Sr/87Sr ratios are calculated by scaling the mantle component with our derived subduction zone length.