Núcleo Milenio
Paleoclima

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DE CHILE

The dust cycle in South America-South Atlantic since the last deglaciation: Effects on atmospheric pCO_2

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My previous work: present-day dust monitoring

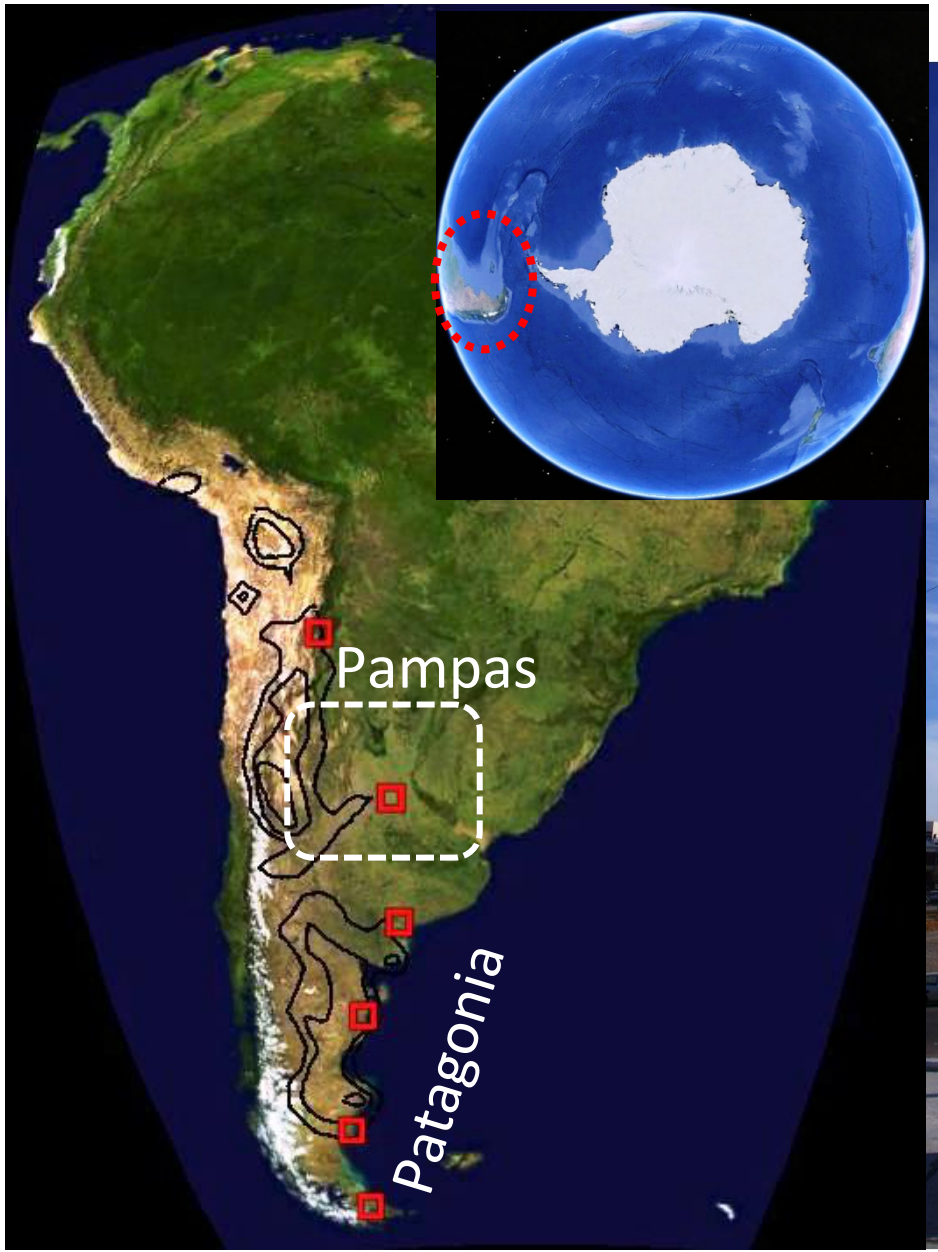
My work in 2018-2020 was on present-day dust monitoring in South America.

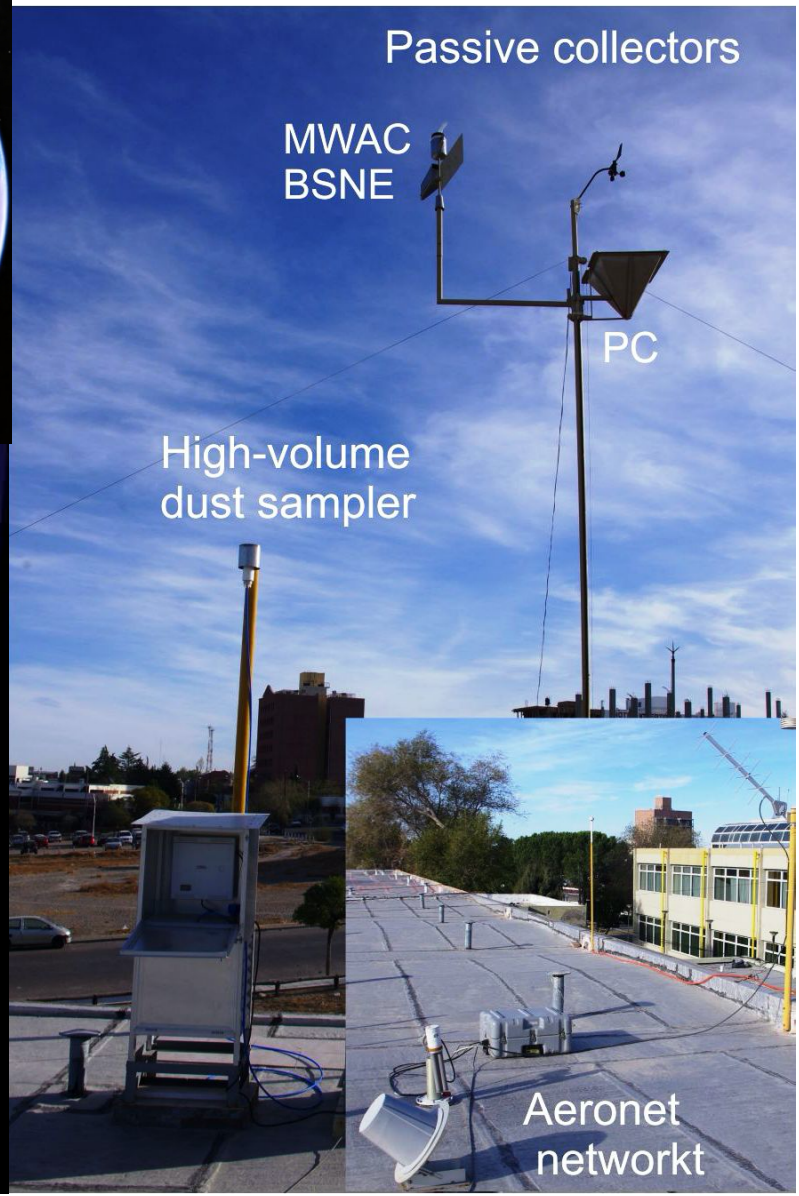
We obtained decadal mean surface dust fluxes in:

- the loessic Pampas region (Cosentino et al., 2020, *The Holocene*)

- southern eastern Patagonia (Cosentino et al., 2020, *Journal of Geophysical Research: Biogeosciences*)

- northern and central eastern Patagonia (Cosentino et al., under review, *Journal of Geophysical Research: Atmospheres*)



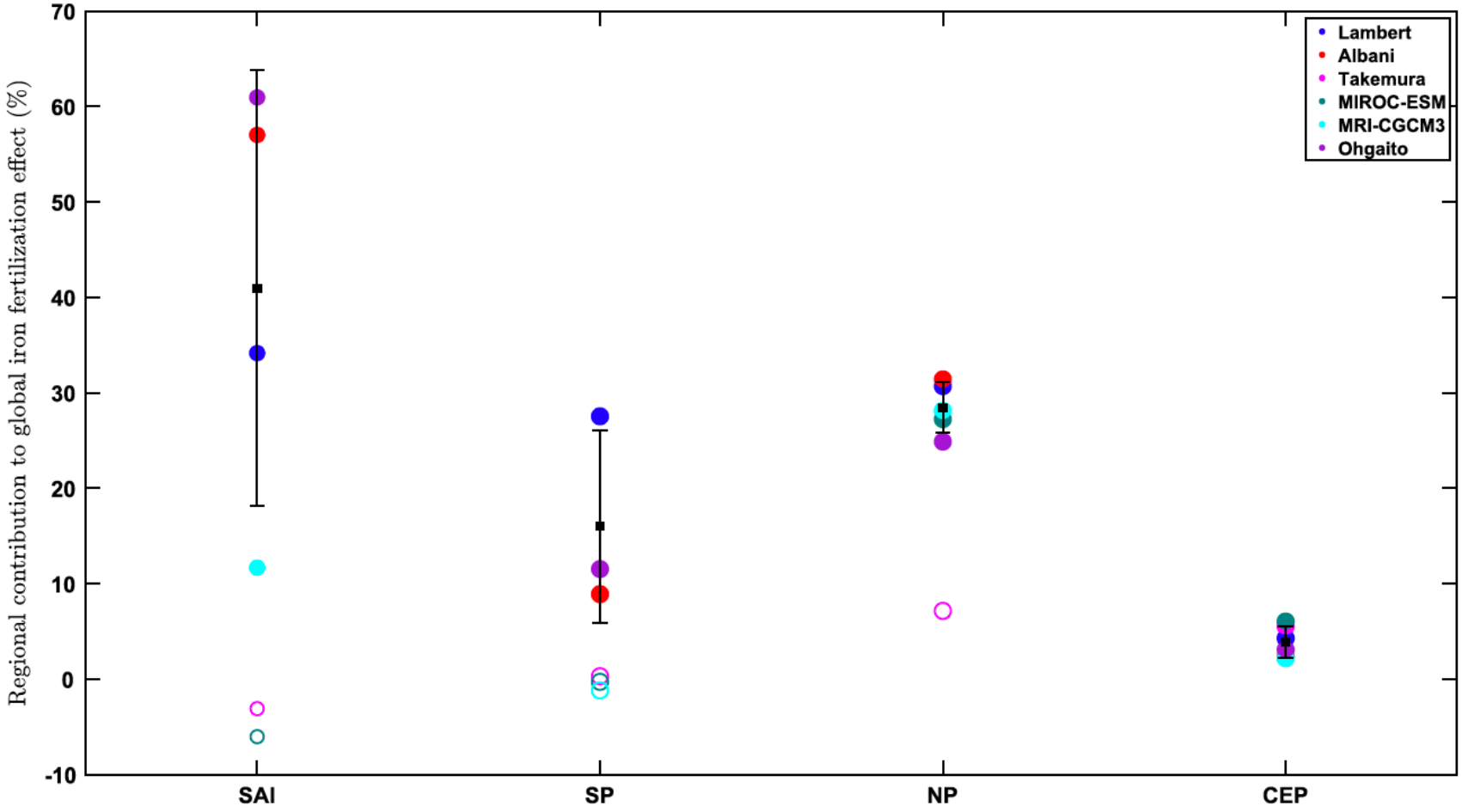


Previous work by Fabrice and Natalia: modeling paleo-dust fertilization effect

Relative contribution of each HNLC region to ΔpCO_2 (atm.) through the last termination due to dust-Fe fertilization (using EMICs).

Southern Ocean accounts for 41 ± 23% (Atlantic and Indian) and 16 ± 10% (Pacific). North Pacific: 28 ± 3%.

Inclusion of glaciogenic sources is crucial to correctly simulate LGM dust.



Lambert, Opazo et al., 2021, Earth and Planetary Science Letters

Questions that guide our current work

How did the emission rates of southern South American dust sources change since the LGM? Current knowledge: 1) Sparse distribution of measured dust flux time series close to the sources (i.e., terrestrial proxies). 2) High variability in simulated South American dust emission and deposition during the LGM.

How can we use recently measured dust flux time series from the South American continent to constrain CESM South American dust emissions? For example, use relative changes in deposition to guide emission variability.

What is the variability of dust deposition since the LGM globally and in South America/South Atlantic? Transient termination simulation too expensive, but stable simulations every 2000 years possible. Are there any accepted forcings and boundary conditions for simulations between LGM and Mid-Holocene?

How did atmospheric pCO_2 respond to South American dust deposition (millenial scale)? Compare EMIC results with CESM biogeochemistry module. Constrain iron solubility using EMIC simulations.

Layout of the project

Field sampling

PATAGONIAN dust continental records - lake bed and peat bog coring

PAMPEAN dust continental records - loess coring

Coding in MATLAB

Interpolation TOOLBOX for global kriging

Data search and systematization

NEW DUST deposition interpolation FIELDS: better resolved time slices since LGM

Num. modeling

The global dust cycle with CESM with emphasis on South America/ Southern Ocean

Num. modeling

Use EMICs (DCESS, cGENIE) and CESM with active ocean biogeochemistry to simulate atmospheric pCO_2 changes due to dust fertilization of oceans

TIME PROGRESSION

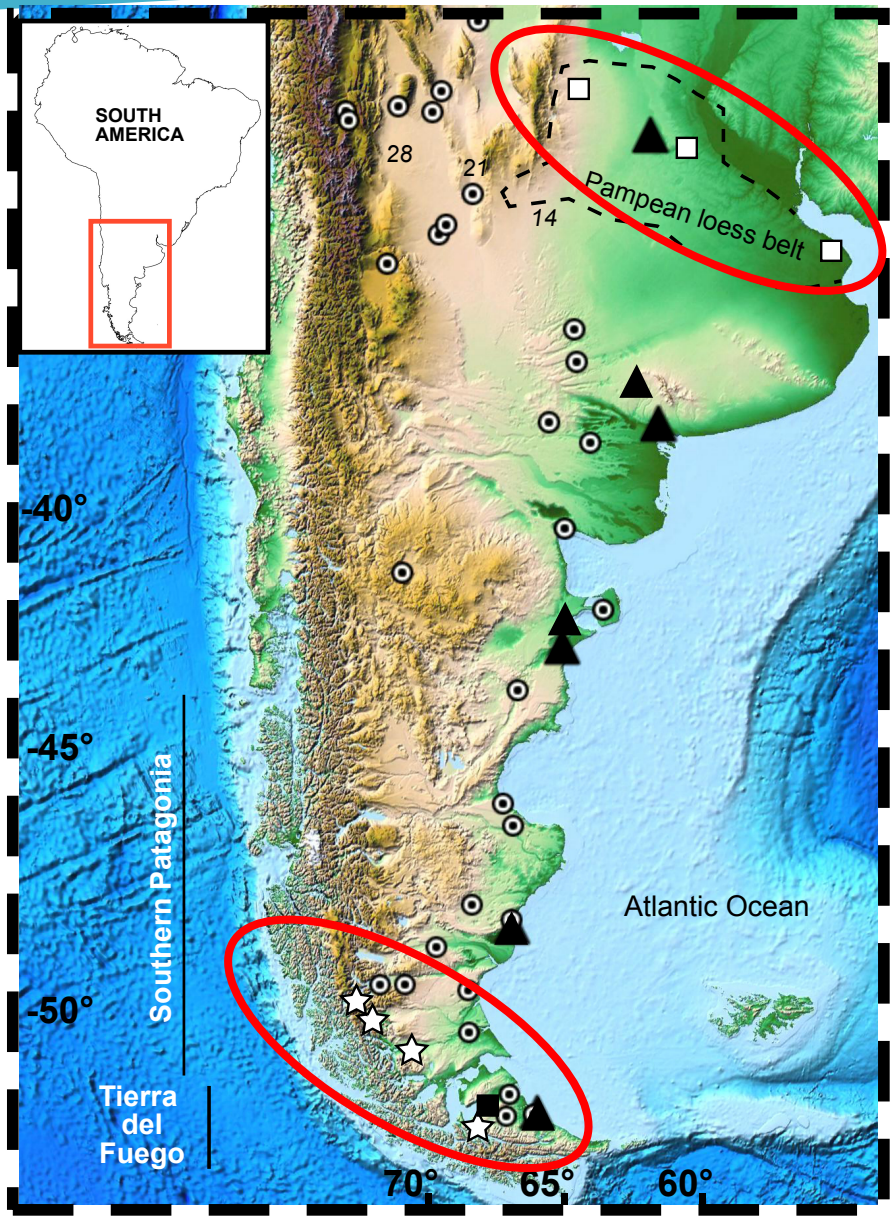
South American dust continental records: Patagonia and the Pampas

Pampean loess (white squares)

- Dust MARs for three sites at the core of the loess belt, between 20-47 kyr BP at 1.75 kyr resolution and between 9-20 kyr BP at 6 kyr resolution (Torre et al., 2019).
- Soon to be expanded to 54-8 kyr BP (Coppo et al., in prep.).
- Projected: approx. 4-70 kyr BP.

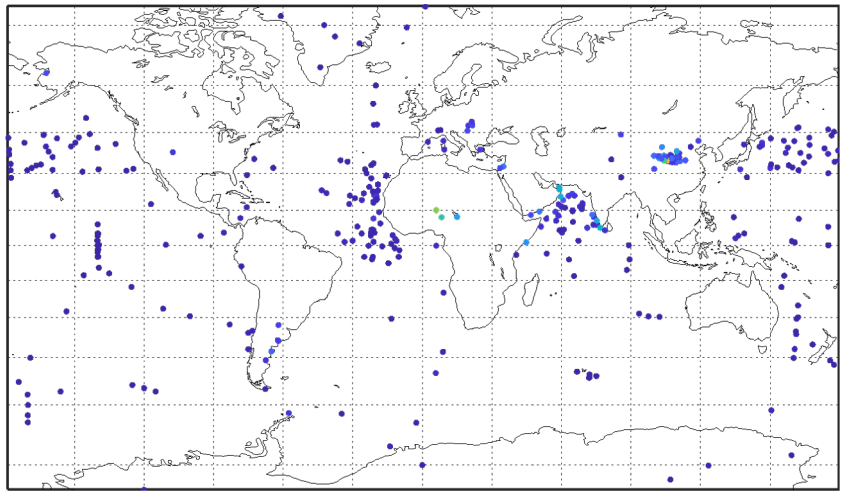
Patagonian dust sources (white stars)

- Three lake cores are already sampled, with bottoms aged 19-12 kyr BP (Sagredo et al., 2011; P. I. Moreno, pers. comm.).
- An extra lake will be cored, projected to date back to 21 kyr BP.
- Two peat bogs will be sampled, covering the Holocene.

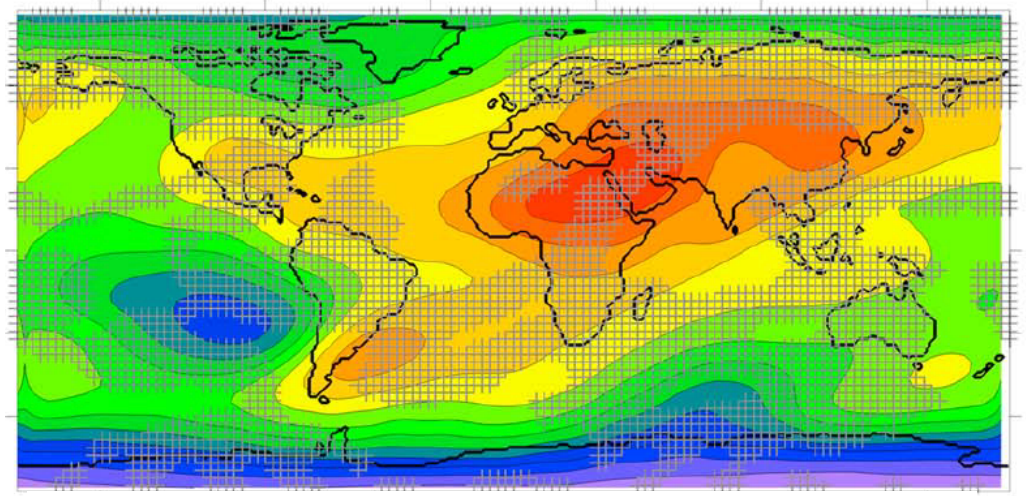


New MATLAB interpolation toolbox + LGM-to-present global dust deposition interpolated fields

Mean HOL dust deposition obs.



Mean HOL dust dep. interpolation



Lambert et al., 2015
Geophysical Research Letters

- Enough dust deposition measurements available now to obtain narrower time slices since LGM (e.g., Albani et al., 2015).

- Design a MATLAB code and interface for anisotropic kriging on a sphere, with explicit calculation of uncertainty due to interpolation + individual measurement error

CESM2 in NLHPC-Leftraru (Chilean supercomputer)

Leftraru Chile is administered by the
National Laboratory of High-Performance Computing (NLHPC)

Total capacity of:
- 5236 cores
- 266 TFLOPS

CESM 2.1.3 installation was completed in September 2020.

During the last 6 months we performed a complete suite of tests to validate the installation:

1) Verification of machine installation: *scripts_regression_tests.py*, 361 tests 95% PASSED

2) Internal consistency of CESM in Leftraru
Prealpha tests (create_test), 70 tests 75% PASSED… we keep working on remaining tests

3) Comparison of Leftraru output against Cheyenne output
Ensemble Consistency Tests: UF-CAM-ECT (CAM-CLM, 9 time steps) and POP-ECT (POP-CICE, 12 months) tests BOTH PASSED

CESM simulations of the dust cycle

Tuning South American dust emissions

- Dust emissions in CESM are based on the saltation-sandblasting process that depends on modeled wind friction velocity, soil moisture and vegetation and snow cover (Zender et al., 2003). Embedded in CLM.

- Emissions are scaled by a spatially varying soil erodibility parameter that is proportional to the susceptibility to erosion at each grid cell (Zender et al., 2003).

- Following Otto-Bliesner et al. (2020), scale the soil erodibility map at a continental level to fit global fields of observation-based interpolated dust fluxes for each time slice.

- Third step: scale once again the erodibility map within South America based on dust deposition fluxes in South America/Southern Ocean.

CESM simulations of the dust cycle

- Equilibrium simulations due to high computational cost of transient simulations and available resources at Leftraru-NLHPC.

- Interested in modeling the last glacial termination (aprox. 6-21 kyr BP).

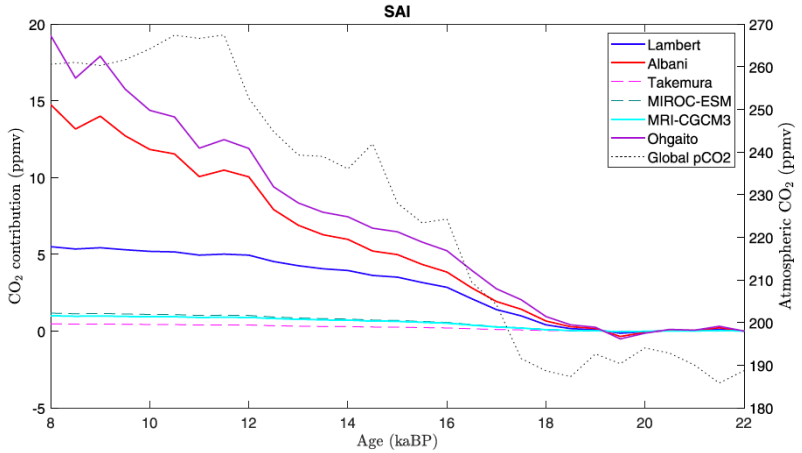
- Based on expected resolution of proxy data collections, we aim at performing simulations at four extra times between *midHolocene* and *LGM*: 9, 12, 15, 18 kyr BP.

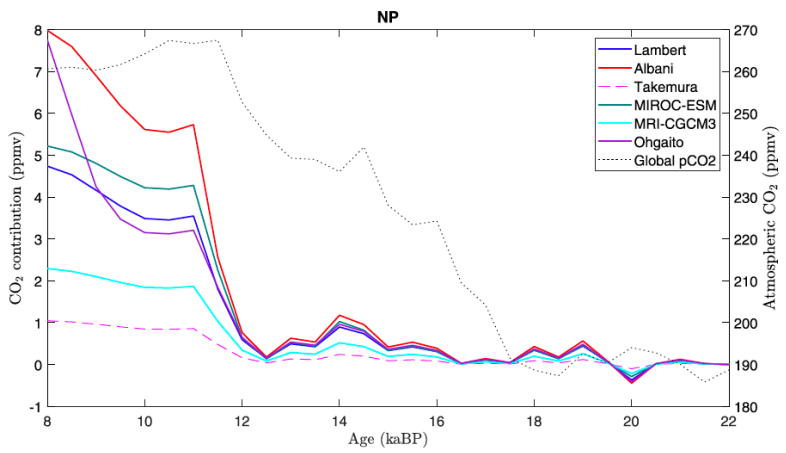
- Is this feasible based on availability of accepted forcings/boundary conditions between midHolocene and LGM?

Simulating the dust-Fe fertilization effect

- Use observational global dust deposition fields every 3 kyr between 6-21 kyr BP to feed EMICs (cGENIE, DCESS) that model ocean biogeochemistry dynamics.

- Improve on time histories of CO_2 drawdown due to dust fertilization during the last glacial termination (Lambert, Opazo et al., 2021). Is the SH vs. NH difference in timing real?

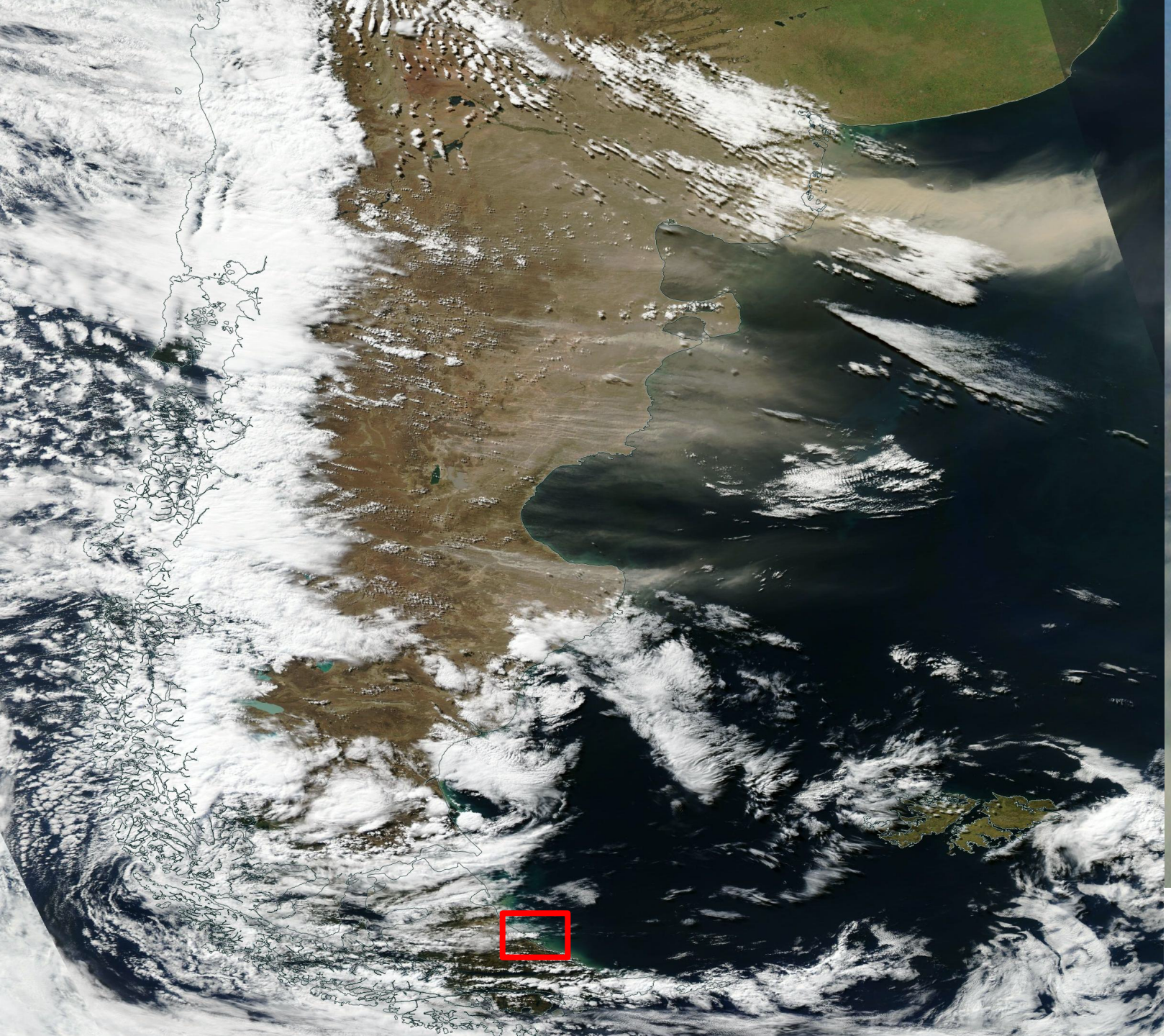




Lambert, Opazo et al., 2021
Earth and Planetary Science Letters

- Perform sensitivity analyses of CO_2 drawdown to dust-Fe solubility using EMICs.

- In the stand-alone active ocean with the biogeochemistry module turned on… is atmospheric pCO_2 allowed to evolve or is it prescribed to force the model? If the latter, then explore cost of fully-coupled CESM + ocean biogeochemistry simulations.



Thanks!

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