Modeling Dust and Dissolved Iron Depositions to the Southern Ocean Using GEOS-Chem: Application for Patagonia

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Abstract

Atmospheric transport of dust is considered to be a major source of iron (Fe) to the open oceans. Fe supply may play a key role in regulating ocean productivity, the atmospheric CO_2 and climate (Martin et al., 1990). Supply of micronutrient Fe is particularly important for high-nitrate low-chlorophyll (HNLC) waters of the Southern Ocean (Watson et al., 2000). Understanding the biogeochemical cycling of Fe in both present and past climate and the role of mineral dust in Fe-mediated carbon sequestration in the Southern Ocean is one of the most outstanding issues in climate science today. Patagonia is considered to be one of the most important suppliers of dust laden Fe to the surface waters of the Southern Ocean (Gaiero et al., 2003). However, only a small fraction of this mineral-Fe is available for oceanic biota (Wu et al., 2001). Therefore, in this study we address the following question:

Question: ***What is the magnitude and spatial variability of bioavailable Fe fluxes to the South Atlantic Ocean downwind from Patagonia?***

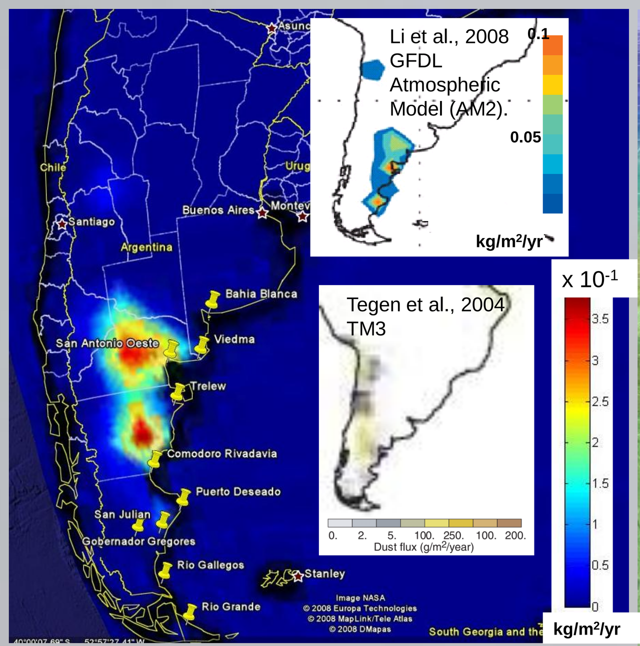
Method: Use GEOS-Chem with implemented iron dissolution scheme (Solmon et al., 2008) to calculate dust and dissolved Fe (DFe) deposition rates in Patagonian/Southern Ocean domain.

The Model

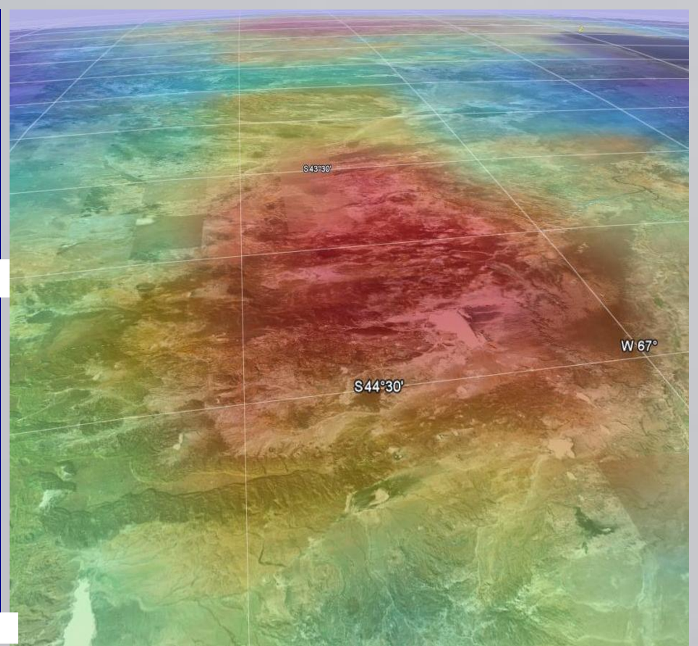
GEOS-Chem (version v8-01-01) is a global transport model driven by the newest GEOS-5 meteorological fields. Using the Dust Entrainment and Deposition (DEAD scheme) the model calculates dust emission, transport, and deposition (wet and dry) on a 2˚x2.5˚ grid resolution (Fairlie et al., 2006)This is the first time GEOS-Chem predicted dust mobilization and transport in Patagonia/South Atlantic domain is compared with the reported studies and local observations. Improvements made to the model prior to the simulations are:

- Implemented an iron dissolution scheme (Solmon et al., 2008) to the newest version of GEOS-Chem
- Altered dust mineralogy to represent Patagonian top soil

1. Source Location

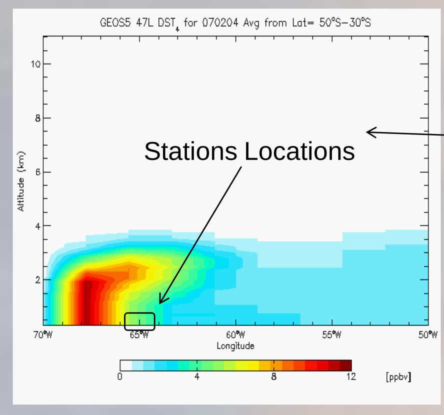


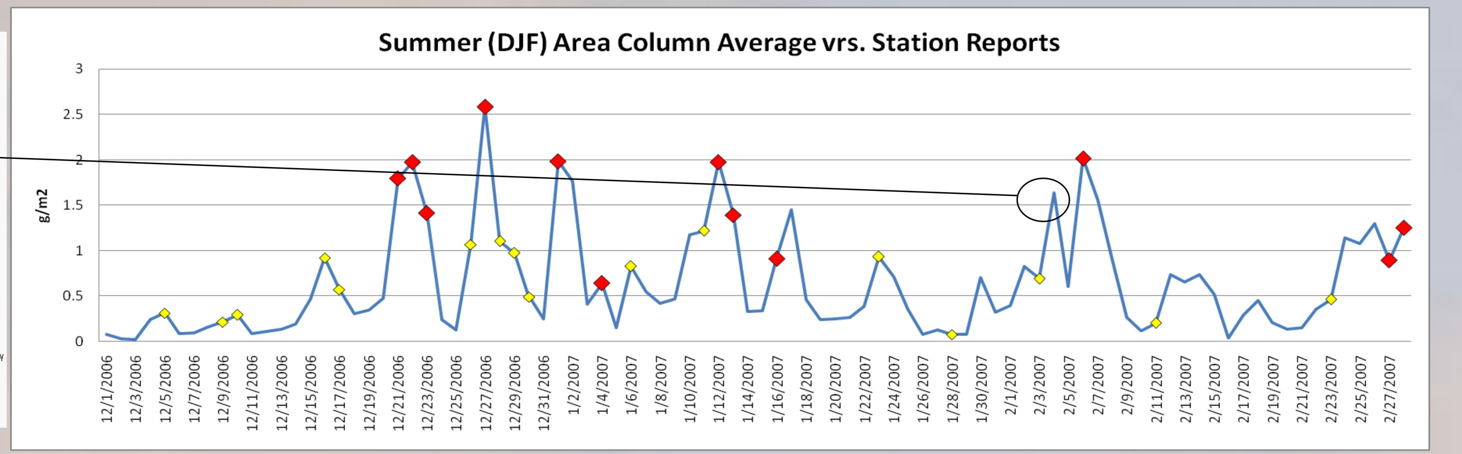
GEOS-Chem predicted dust source location averaged over the simulation period (October 2006 – September 2007)

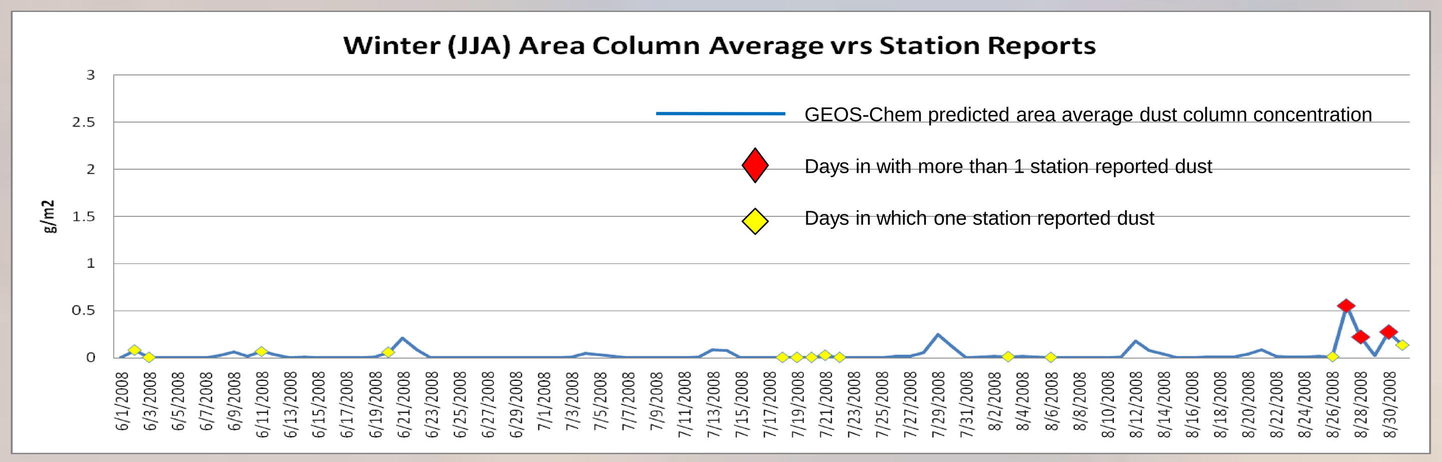


GEOS-Chem dust emission sources overlaid on Google Earth demonstrating topography of major dust emission locations.

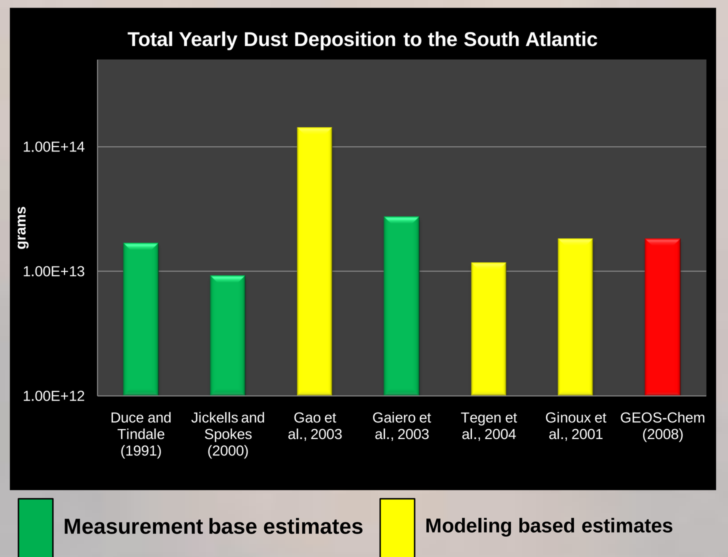
2. Model Simulations and Local Dust Reports

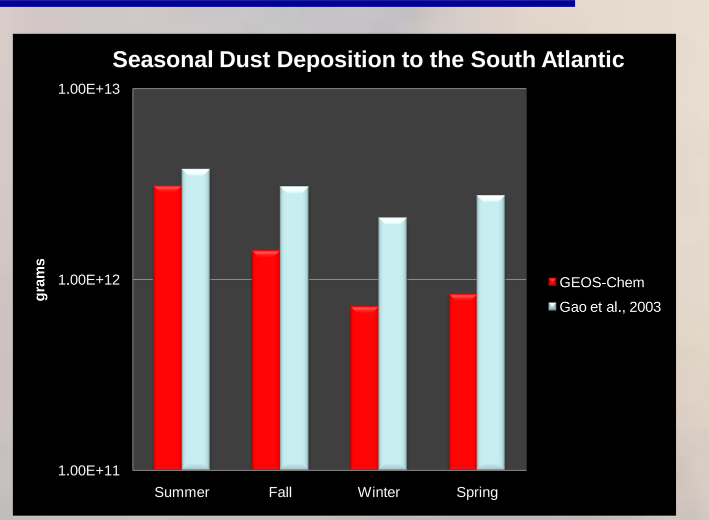




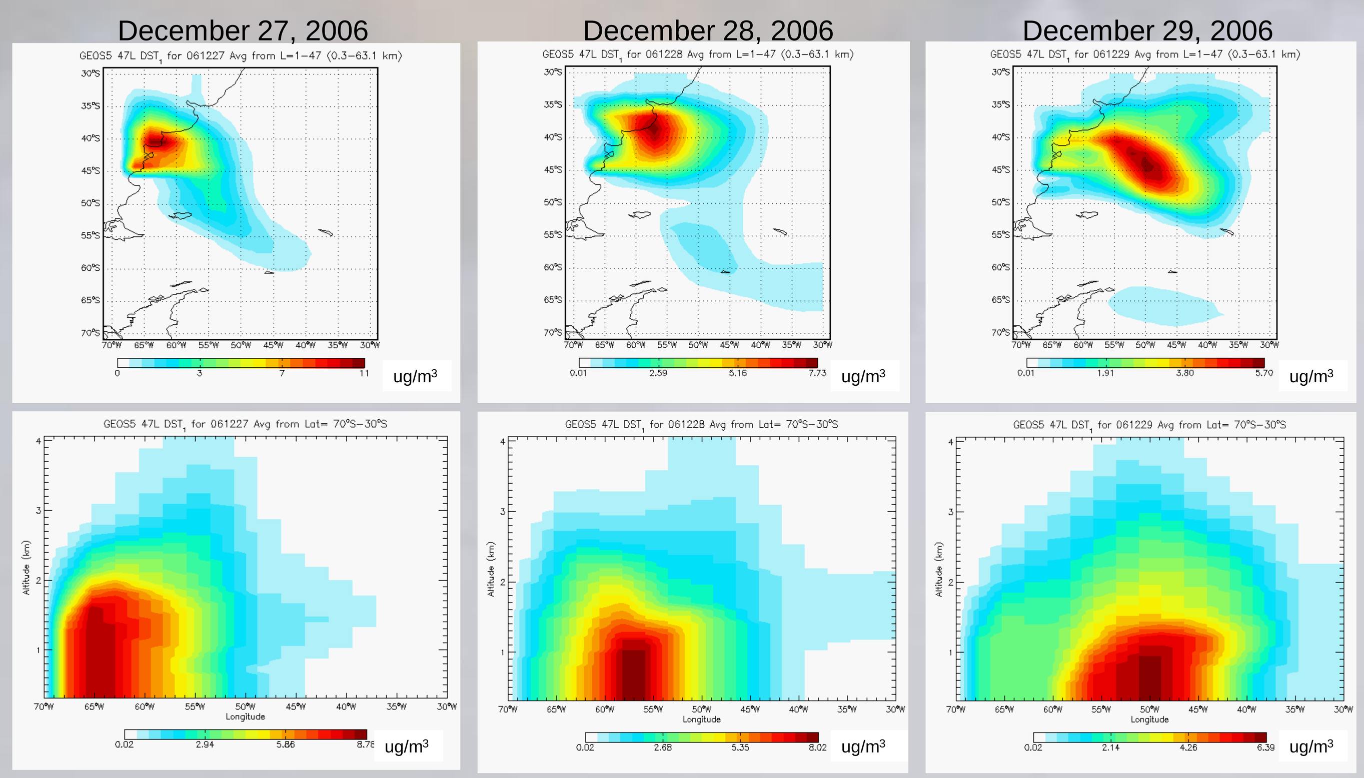


3. Dust Comparison with Available Results



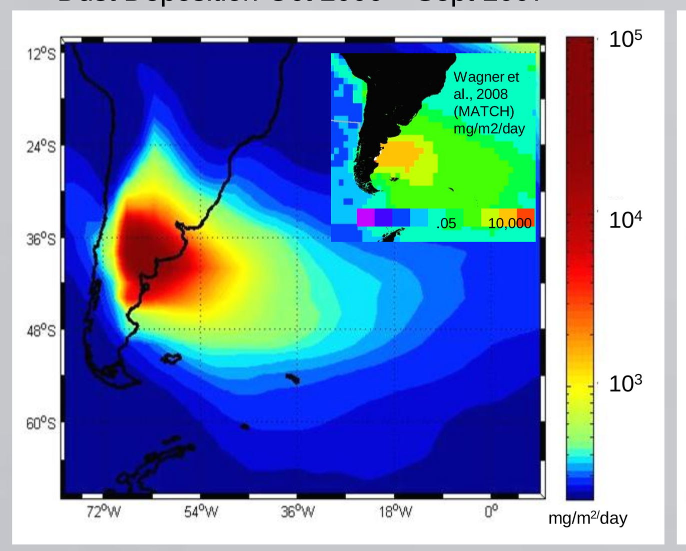


4. Dust Transport Path

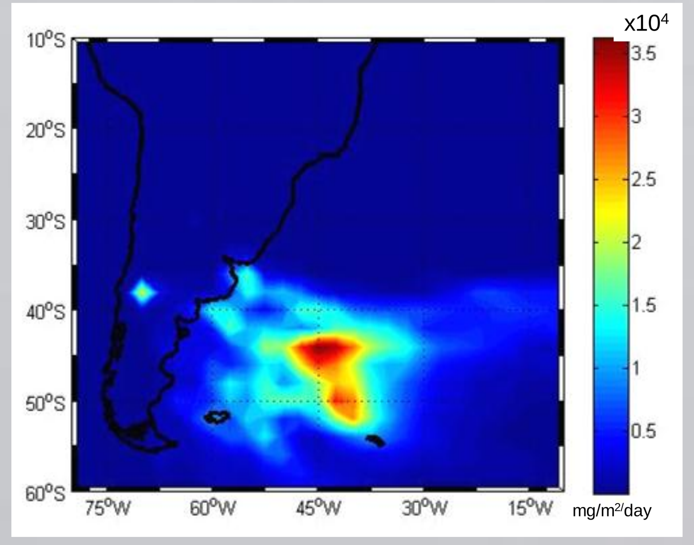


5. Dust Deposition

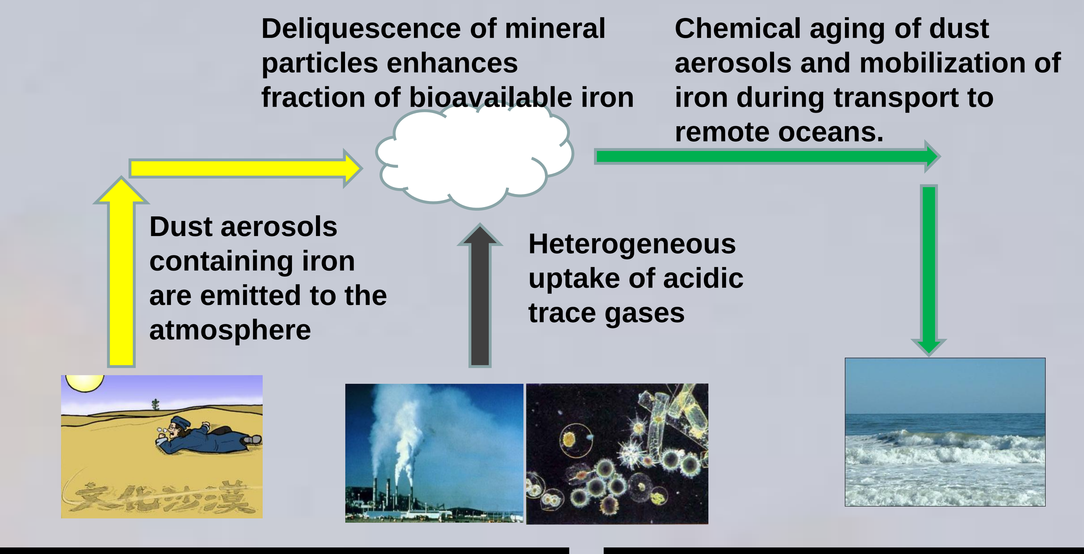
Dust Deposition Oct 2006 – Sept 2007

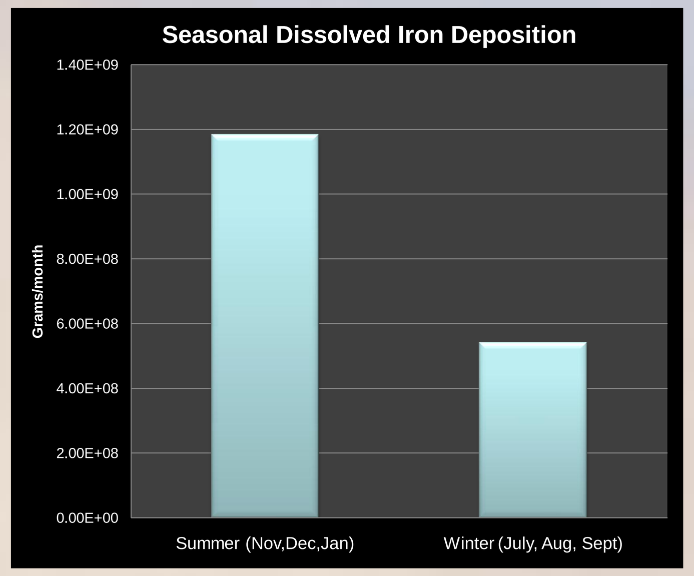


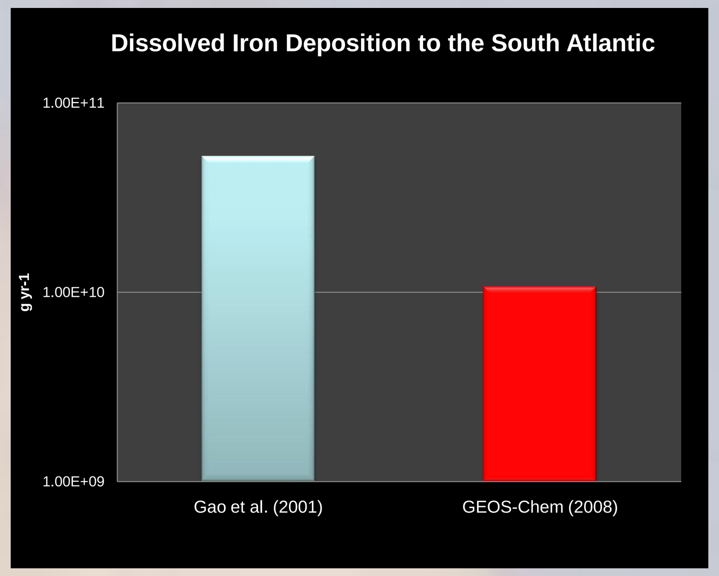
Wet Deposition, December 2006

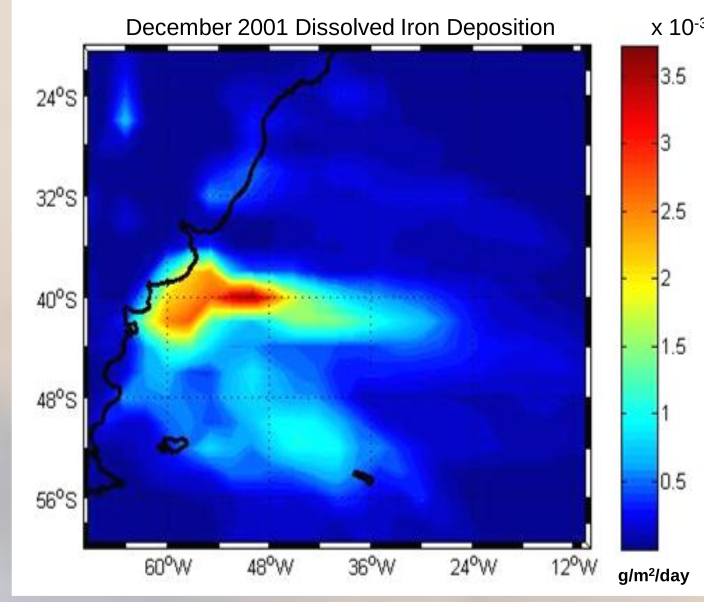


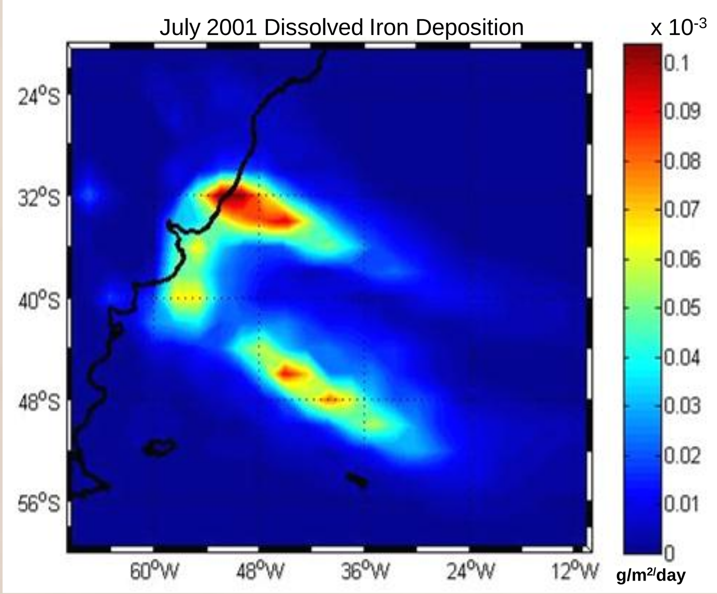
6. Dissolved Iron Deposition



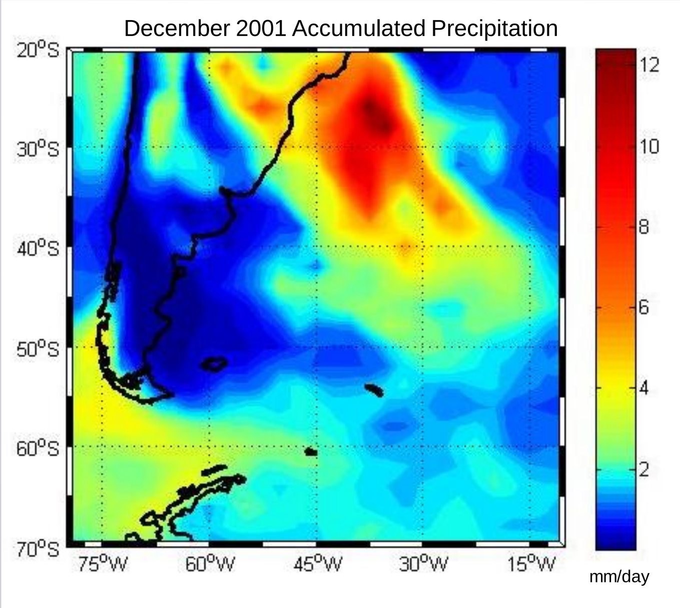


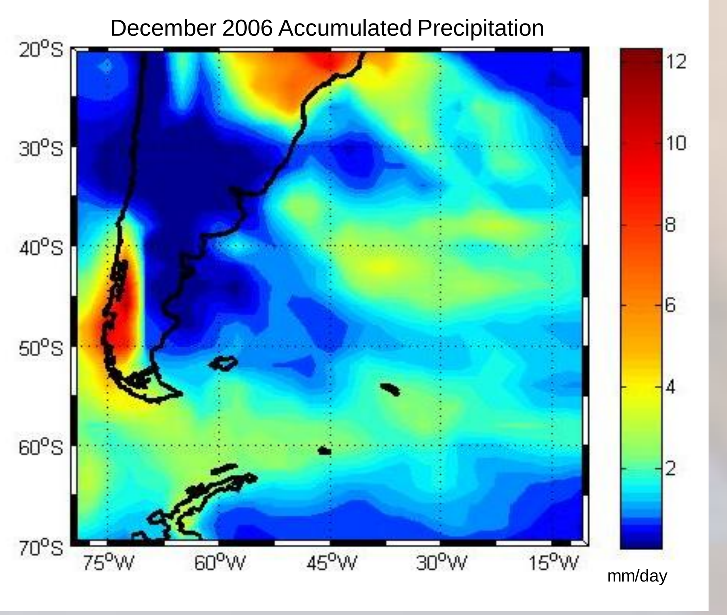






December 2001/2006 Precipitation





Patagonian Mineralogy

Minerals	In Soil, % wt[a] In Silt	In Soil, % wt[a] In Clay
Anhydrite	6[+]	0
$CaSO_4$		
Calcite	4	0[+]
$CaCO_3$		
Plagioclase	28	8
Albite – $NaAlSi_3O_8$		
Microcline – $KalSi_3O_8$		
Illite	18[+]	13
$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$		
Smectite/Montmorillonite	7[+]	62
$Na_{0.6}Al_{1.4}Mg_{0.6}Si_4O_{10}(OH)_2 \cdot 4H_2O$		
Hematite	5	3
Fe_2O_3		
Quartz	27	7
SiO_2		
Kaolinite	5[+]	7
$Al_2Si_2O_5(OH)_4$		
Total	100	100

[a] Mineralogical composition were largely based on Gaiero et al. (2003), Smith et al. (2003), and Ramsperger et al. (1998).
[+] Assumed generic dust composition due to insufficient data.

Comparison Results

- Modeled dust source locations match up well with the local topography (dry river/lake beds)
- GEOS-Chem capable of capturing large dust events
- When compared to local dust reports, model captured ~75% of large dust outbreaks
- In several cases simulated dust plumes were advected above the boundary layer and may have been missed by the stations
- GEOS-Chem can capture annual and season variability of dust and DFe deposition to the South Atlantic and Southern Oceans
- Though modeling and in-situ data are very limited for the simulated domain, GEOS-Chem predicted fluxes of dissolved Fe are comparable to the available data.
- Dissolved iron deposition is in phase with dust seasonality

Future Plans

We plan to run our new model of GEOS-Chem implemented with the iron dissolution scheme for the same base simulation time explain previously. We will run sensitivity studies such as (listed below) that will allow for further evaluation of the model and implications of future scenarios.

1. Sensitivity studies
   - SO_2 emission doubling
   - Change in dust emissions rates
   - Variability in dust mineralogy by increasing or decreasing calcite percentages in initial dust composition
2. Use in-situ measurements from stations in Patagonian to validate modeled dust concentrations and fluxes
3. Additional improvements to the iron dissolution scheme
   - Combustion (industrial and biomass) sources of iron
   - Photo-reductive dissolution of iron containing minerals
   - Photochemical cycling of Fe(II)-Fe(III).

Acknowledgments

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