Atmospheric iron delivery and surface ocean biological activity in the Southern Ocean and Patagonian region

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[1] Iron is a limiting nutrient for biologic activity in much of the world ocean. We present a method to quantitatively address the response of surface ocean biology to inputs of atmospheric Fe associated with atmospheric dust. We merge two enabling technologies, global models of Earth system processes and satellite derived chlorophyll concentrations to assess the importance of Fe in oceanic biogeochemistry. We present an objective correlation analysis to elucidate the spatial response of chlorophyll to iron flux considering the ocean surface meridional center of mass in areas with high correlation. Several regions between 40°S and 60°S show correlations from 0.6 to 0.95, significant at the 0.05 level, particularly the Patagonian region. Surface chlorophyll and iron flux follow similar patterns, however chlorophyll may be displaced to different latitudes than where Fe input occurs due to meridional ocean transport. *INDEX TERMS:* 1615 Global Change: Biogeochemical processes (4805); 1640 Global Change: Remote sensing; 0305 Atmospheric Composition and Structure: Aerosols and particles (0345, 4801); 0312 Atmospheric Composition and Structure: Air/sea constituent fluxes (3339, 4504); 0330 Atmospheric Composition and Structure: Geochemical cycles. **Citation:** Erickson, D. J., III, J. L. Hernandez, P. Ginoux, W. W. Gregg, C. McClain, and J. Christian, Atmospheric iron delivery and surface ocean biological activity in the Southern Ocean and Patagonian region, *Geophys. Res. Lett.*, *30*(12), 1609, doi:10.1029/2003GL017241, 2003.

1. Introduction

[2] The role of iron in oceanic biogeochemical cycles has been a topic of increasing research interest for several years [*Martin and Fitzwater*, 1988; *Martin et al.*, 1994; *Arimoto et al.*, 1990; *Duce*, 1995; *Behrenfeld et al.*, 1996; *Witter et al.*, 2000]. Since much of the global ocean is far removed from significant oceanic sources of iron, such as rivers, upwelling and shallow water sediments, the flux of dust iron transported by the atmosphere may play a significant role in biological activity. We perform an empirical analysis between ocean surface monthly averages of simulated atmospheric dust-iron deposition (Φfe) and remotely sensed chlorophyll (*Chl*). The premise that we are testing involves the idea that atmospheric iron deposition could be correlated with surface ocean remotely sensed chlorophyll. The correlations are expected to be the highest where iron is an important limiting nutrient [*Martin*, 1991; *Fung et al.*, 2000; *Banse*, 1995], however we focus on regions where high correlations in the Southern hemisphere are observed. The first part of our analysis is to identify, with 2.0° × 2.5° latitude-longitude spatial resolution, regions of the world ocean where *Chl* is correlated in time with Φfe. We study the correlation of the monthly anomalies, computed by subtracting the mean of the time series from each monthly value, to assess the response of *Chl* departures to those of Φfe. It is important to note that high correlations do not imply a tight coupling between Φfe and *Chl*. We carry out an objective analysis by computing their meridional band 'Center of Mass' in the regions where we find high correlations. This allows us to estimate the loci of higher *Chl* and Φfe every month and to determine if there is a relationship when the two fields are collocated. Finally, we augment this computation with an interpretation of the time mean surface ocean transport to elucidate the latitude deviations between *Chl* and Φfe center of masses. These results may be useful in understanding the biogeochemical cycles in these regions and highlight specific regions of the ocean where observational studies could be focused to assess the importance of atmospheric Fe deposition on ocean biology.

2. Data and Methods

[3] This analysis uses two state-of-the-art geophysical data sets. One is an indicator of ocean biological activity, as reflected in ocean surface chlorophyll derived from remotely sensed platforms. The 2000–2001 monthly averages of SeaWiFs *Chl* is used here as a metric for oceanic

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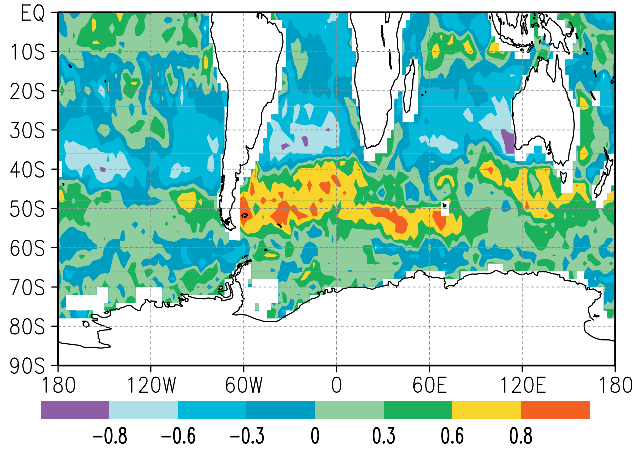

Figure 1. Atmospheric dust Fe flux and SeaWiFS chlorophyll (*Chl*) anomaly correlation maps for the Southern Hemisphere. Large regions east of Patagonia show a strong correlation between *Chl* and atmospheric supply of dust-Fe. These data are from 2000–2001 monthly averages of Fe deposition and SeaWiFS *Chl*.

biological activity. The iron (Fe) data set was derived from a detailed atmospheric dust generation, transport and deposition model [*Ginoux et al.*, 2001]. The model is driven by assimilated meteorological fields from the Goddard Earth Observatory Data Assimilation System (GEOS DAS). The Fe deposition data sets have been simulated since 1981 and we have sub-sampled the global Fe deposition field for the Southern hemisphere and the years 2000–2001.

3. Conclusions

[9] We present evidence of a strong temporal correlation between Φfe from a global erosion and transport model and

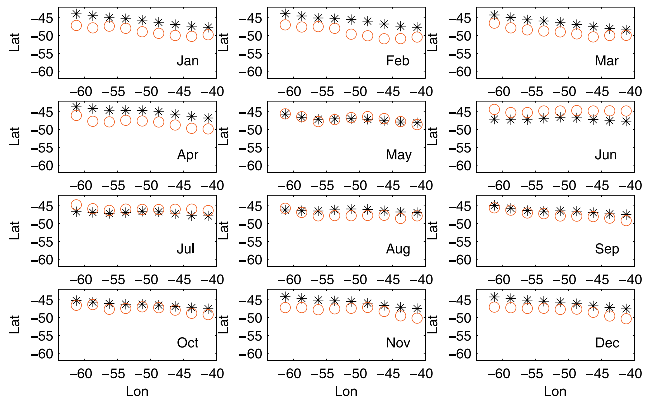

Figure 3. The 'Center of Mass calculation' for SeaWiFS ocean color and Fe deposition for the region 40°S–65°S, 40°W–70°W. The circles indicate chlorophyll and the stars indicate dust (Fe) flux. The main point is that the Center of Mass (CM) of the Fe flux and the chlorophyll are for the most part co-located for most of the analyses in the region of high anomaly correlation. Surface currents may advect the *Chl* signal away from the region of highest Fe input.

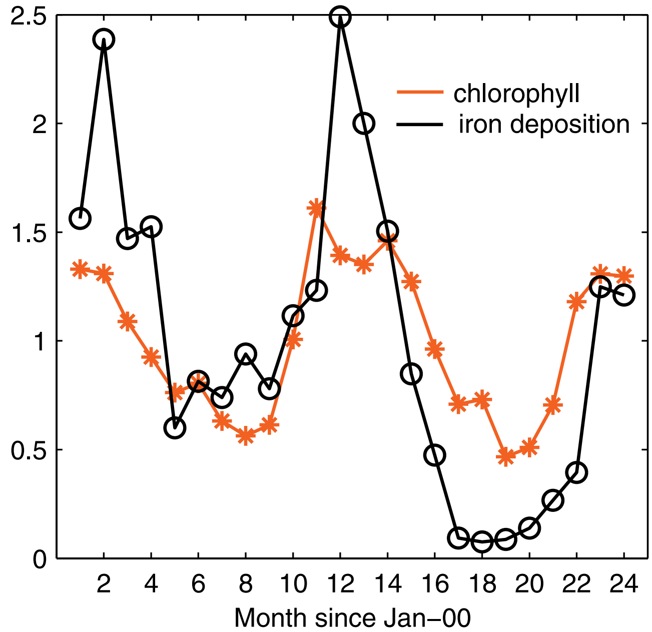

Figure 4. The standarized time series of the SeaWiFS chlorophyll and dust-Fe deposition for the 24 month period for the region 62.5W-42W, 40S-60S. This simple representation of the data averaged over the study region indicates correlation between Fe deposition and *Chl* that is more quantitatively represented in Figure 1.

Chl as observed by satellite ocean color sensors. These correlations are strongest in a coherent region of the subantarctic south Atlantic that substantially overlaps the region where enhanced dust deposition and biogenic sedimentation are inferred to have occurred during the last glacial maximum [*Anderson et al.*, 2001; *Kumar et al.*, 1995; *Anderson et al.*, 2002].

[10] Using the CM calculation and a basic understanding of the ocean transport in the study region, we can attempt to explain deviations of several trends in the studied parameters. Basically, dust deposition of Fe may occur in one region and then ocean circulation moves the fertilized water mass away from the area of highest Fe flux. This results in a non-co-location of high *Chl* and high dust flux even though the causative influence of Fe on Chl and biota may still be strongly linked.

[11] Analyses such as these provide tests of various conceptual biogeochemical models and are the result of two emerging technologies, large computational models evaluated on supercomputers [*Mahowald et al.*, 1999; *Tegen et al.*, 1996] and space based remotely sensed satellite data. Such calculations may provide guidance and input for the planning of field experiments and will become increasingly more valuable as more satellite data becomes available and numerical simulations of global biogeochemical cycles are included explicitly in Earth system models.