Atmospheric Iron Flux and Surface Chlorophyll in the North-Western Tropical Atlantic

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Resumen. Experimentos con modelos de transporte y datos de satélite son usados para explorar las escalas de espacio y tiempo de la relación entre flujo depositado de hierro (ΦFe) y concentración de clorofila [Chl] en la superficie del mar. El ΦFe fué estimado apartir dcl transporte atmosférico de polvo mineral del modelo GOCART, mientras que [Chl] proviene de observaciones por satélite de color del océano, NASA-Sea WIFS y OCTS de la agencia espacial japonesa NASDA. Promedios semanales y mensuales fucron obtenidos para estudiar la relación ΦFe/Chl. A escala global algunas áreas de coeficientes de correlación (CC) positiva fueron observados para las diferentes series de tiempo, coincidiendo particularmente en el Océano Atlántico Nor-tropical y Mar Caribe (NTA-CS). Aunque existen otras fuentes regionales de Fe (surgencia y descarga de ríos) que afectan anualmente la productividad primaria, la contribución atmosférica manifiestó en NTA-CS áreas de persistente correlación positiva con [Chl], lo que sugiere a ΦFe como factor en procesos biogeoquímicos regionales.

Abstract. A transport model and satellite data are used to explore the spatial and time scales in the relationship between iron deposition flux (ΦFe) and chlorophyll concentrations [Chl] at the sea surface. ΦFe was estimated from GOCART model outputs for the atmospheric transport of mineral dust, and [Chl] came from satellite observations of ocean color, NASA-SeaWIFS, and OCTS from NASDA Japanese Space Agency. We performed weekly and monthly averages on both fields to study the ΦFe/[Chl] relationship. At global scale several areas of positive correlation coefficients (CC) were observed for the different time series, particularly in the North tropical Atlantic Ocean, and the Caribbean Sea, (NTA-CS). Although there are other regional Fe sources (upwelling and river runoff) that affect the annual cycle of primary production, the atmospheric contribution in NTA-CS persistently showed areas of positive correlation with [Chl], suggesting ΦFe as a factor in regional biogeochemistry.

Palabras clave: coeficiente de correlation, procesos biogeoquimicos, respuesta en espacio y tiempo.

Key words: correlation coefficient, biogeochemical processes, time and spatial response.

Iron in atmospheric dust is important in climate research since it influences the efficiency of the biological pump of carbon in the ocean. Carbon exportation to depth depends on primary productivity and photosynthesis at the surface, and sea currents that influence atmospheric concentrations of CO_2. The ΦFe/[Chl] relationship has been subject of experiments like IRONEX II (Coale et al, 1996), where in situ iron fertilization of high-nutrients low-chlorophyll (NHLC) marine environments has showed that Fe availability limits the growth of phytoplankton (Fung et al, 2000; Archer and Johnson, 2000). According to Louanchi and Najjar (2000), NTA-CS is part of a region with comparable but lower nutrient concentrations to those considered in IRONEX II; however in the Caribbean coastal and oceanic biogeochemical processes affect the marine biological system as well. In NTA-CS, costal upwelling, advection of Amazon (AR), Orinoco (OR) and Magdelena (MR) rivers, and the zonal patterns of surface winds induce changes in the annual cycles of salinity, sea surface temperature, and nutrient concentration. These changes in atmospheric and oceanographic parameters control the higher primary production patches in the region (Müller-Karger et al, 1989). Our work focuses on the exploration of time and space scales that are germane to the response of [Chl] to ΦFe at the sea surface in NTA-CS. With this purpose, monthly and weekly averages have been used to evaluate correlation coefficient maps allowing us to localize the higher chlorophyll response sectors.

Iron deposition comes from the GOCART (Ginoux et al, 2001, in press; Chin et al, 2001, in press) transport model which simulates the global distribution of dust aerosol assuming topographic lows with bare ground as potential sources of mineral dust. The uplifting of particles (0.1 um – 6 um) in GOCART is a function of surface wind speed and wetness. Using assimilated data by *Goddard Earth Observing System Data Assimilation System* (GEOS DAS), the model reproduces seasonal changes in the African atmospheric plume over the Atlantic Ocean. Monitoring studies of mineral aerosols carried by trade winds at Barbados (59º 32' W, 13º 10' N) indicate that Fe constituted 3.4% of mineral dust in mass (Zhu et al., 1997). The chlorophyll field was obtained from ocean color satellite data. Two kinds of satellite data were considered, the ADEOS/OCTS from NASDA (National Space Development Agency of Japan) and SeaWIFS from NASA. Comparison between observations and SeaWIFS [Chl] estimates reveals disagreements (Vanderbloemen and Müller-Karger, 2001), however our study found mesoscale [Chl] patterns (>100km, >10^6s) in agreement with previous regional studies (Müller-Karger et al, 1989).

Patterns of [Chl] show pronounced seasonal cycle as observed by Melo et al (2000) in the Gulf of Mexico, similar to the dust carried by trade winds from Northern Africa (Figure 1). The maxima [Chl] (>1.0 microg/1) and greatest iron depositions (>250 pKg m^{-2} s^{-1}) occur from July to September in the eastern Caribbean and Ocean Atlantic, when simultaneously both fields display the largest patterns. The higher [Chl] take place at coastal scale influenced by upwelling (Corredor, 1979) driven by surface wind parallel to shoreline, or nutrient transport from rivers due to regional system of currents. The wind is mostly westward in NTA-CS along the year, but in Venezuela and Columbia coastal regions (11ºN to 13ºN) wind is parallel to the coast and presents an intensification in summertime (Hernandez, 2000), inducing the upwelling that can reduce ~1º the sea surface temperature with respect to oceanic waters.

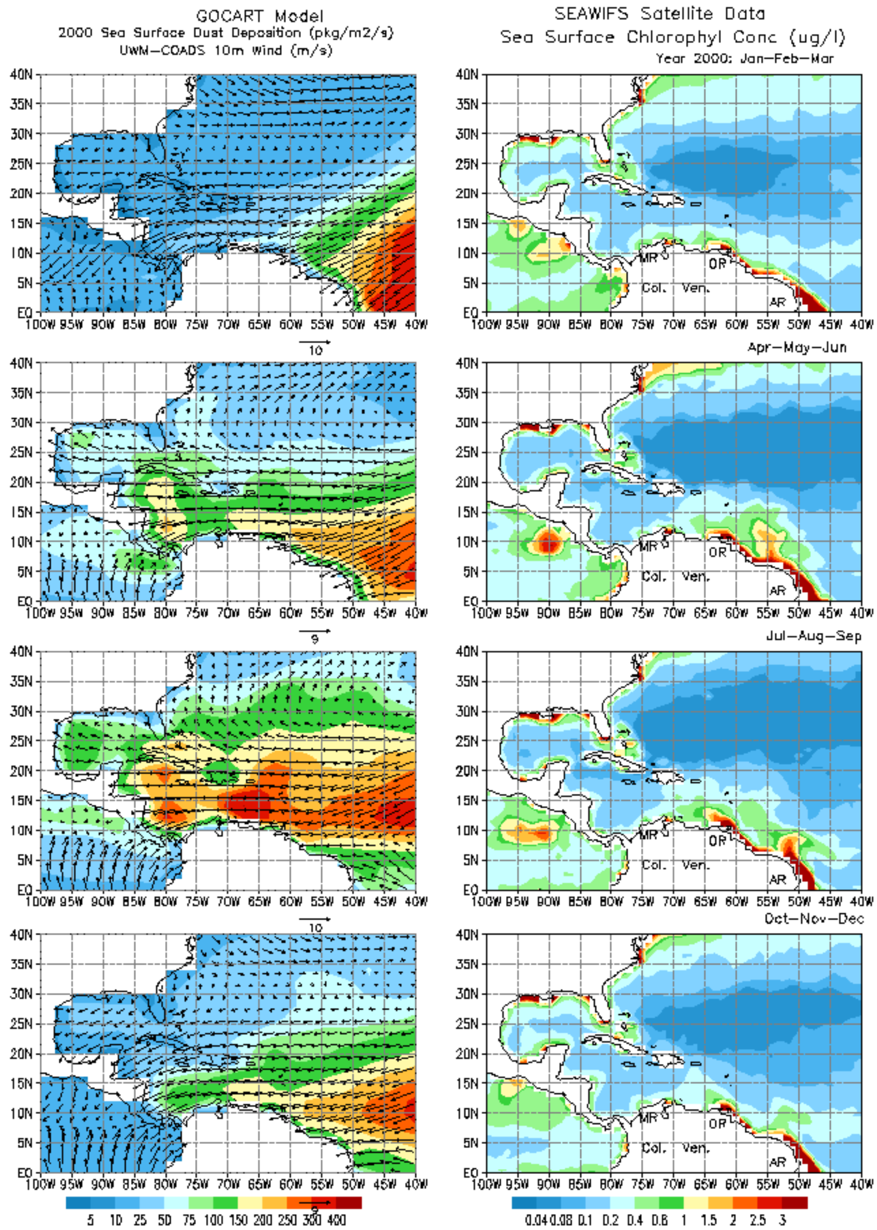

Figure 1. Seasonal cycles

Weekly and monthly [Chl] and ΦFe time series coincide in postive CC at some areas in NTA-CS. Although marine and atmospheric forcing act together in the region, the most oceanic influenced areas (15ºN-22ºN, 55ºW-65ºW, less affected by biogeochemical coastal processes), have high CC (>.8 in the year 2000), revealing a clear response to ΦFe (Figure 2) in the annual cycle. The whole region shows a seasonal cycle in ΦFe and [Chl], however studies considering a combination of higher resolution distributions, longer time series and observations are suggested to analyze in detail the impact from different biogeochemical components on [Chl] and phytoplankton. The parameterization of these relationships at different time and space scales represents important improvements in the description of the atmosphere-land-ocean interactions by transport or general circulation models, and global or regional climate studies.

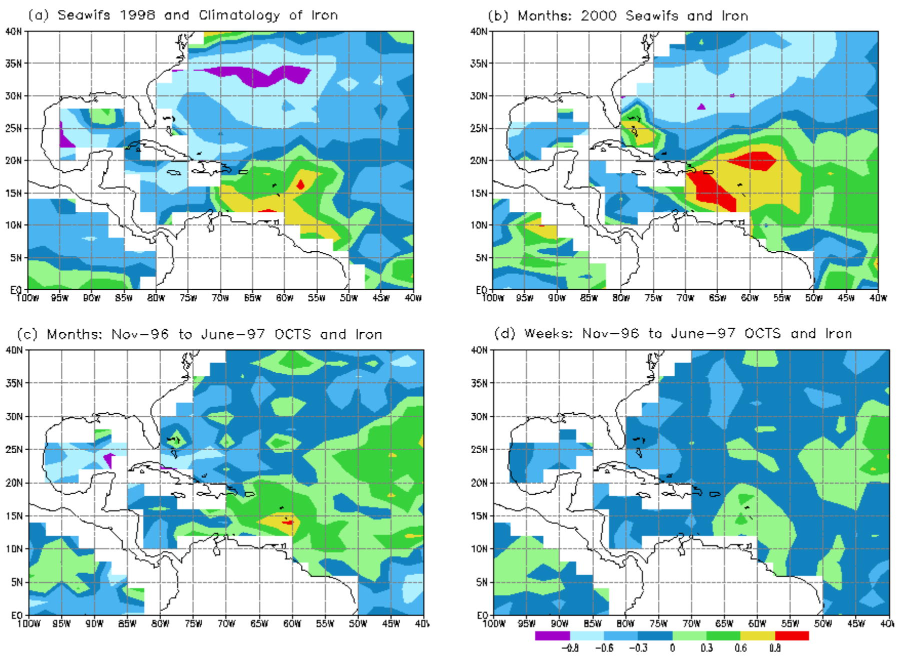

Figure 2. Correlation coefficients

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References:

Archer, D. E. and K. Johnson, A model of the iron cycle in the ocean, Global Biogeochem. Cycles, 14 (1): 269-279, 2000.

Coale et al, A massive phytoplankton bloom induced by an ecosystem-scale iron fertilization experiment in the equatorial Pacific Ocean, Nature, 383, 495-501, 1996.

Chin, M., P. et al, Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and sunphotometer measurements, J. Atmos. Sci., special issue of Global Aerosol Climatology, accepted, 2001.

Corredor, J. E., Phytoplankton response to low level nutrient enrichment through upwelling in the Columbian Caribbean Basin, Deep-Sea Res., 26:731-741, 1979.

Fung, I. Y., S. K. Meyn, I. Tegen, S. C. Doney, J. G. John, and J. K. Bishop, Iron supply and demand in the upper ocean, Global Biogeochem. Cycles, 14(1): 281-295, 2000.

Ginoux, P., et al, Source and Distribution of dust aerosols simulated with the GOCART Model, J. Geophys. Res., (in press), 2001.

Hernández, J. L., Atmosphere-ocean energy and N2O exchange and mixed layer dynamics in the Caribbean Sea and neighboring Atlantic Ocean, Ph.D. Dissertation, University of Puerto Rico-Mayaguez, 2000.

Louanchi, F. and R. G. Najjar, A Global monthly Climatology of Phosphate, Nitrate, and silicate in the upper Ocean: Spring-summer export production and shallow remineralization, Global Biogeochem. Cycles, v.14, n.3, 957-977, 2000.

Melo, N, et al. Near-surface phytoplankton distribution in the western Intra-Americas Sea: The Influence of El Nino and weather events. J. Geophys. Res. 105, C6:14029-14043, 2000.

Müller-Karger, F. E., C. R. McClain, T. R. Fisher, W. E. Esaias, and R. Varela, Pigment distribution in the Caribbean Sea: Observations from space, Prog. Oceanog. 23:23-64, 1989.

Vanderbloemen, L. and F. E. Müller-Karger, Chlorophyll concentrations along West Florida shelf, Earth System Monitor, 11 (3), 2001.

Zhu, X. R., J. M. Prospero, and F. J. Millero, Diel variability of soluble Fe(II) and soluble total Fe in North African dust in the trade winds at Barbados, J. Geophys. Res., 102:21297-21305, 1997.