MONITORING THE SAHARAN DUST DISPERSION IN THE MEDITERRANEAN SEA WITH A NUMERICAL MODEL (2001-2002)

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Abstract

A modeling system has been developed to monitor the Saharan dust cycle in the Mediterranean Sea. It is based on the Princeton Ocean Model, modified to include the physics of dust dispersion and deposition onto the ocean floor. It is shown that the atmospheric deposition has a highly episodic character, which affects gravely the patterns of oceanic distribution as well as the bottom deposition of dust. The oceanic circulation plays an important role in the dust distribution and deposition onto the sea bed.

Key-words: Saharan dust, Mediterranean Sea, Modelling

Introduction

Suspended particulate matter in the ocean plays a significant role in different biogeochemical processes and is a crucial parameter in determining the water quality (1). The case of the Mediterranean Sea is of particular interest since it borders the Saharan desert, the world's largest source of aeolian soil dust (2), and its northern coasts are located in the industrialized and semi-industrialized regions of Southern Europe, which are important sources of anthropogenic aerosols. Since direct observations of dust deposition and transport into the ocean are very difficult and costly to obtain, modelling studies become a very important monitoring tool.

Methods

The distribution and deposition of Saharan dust onto the sea bed in the Mediterranean Sea has been simulated using the Princeton Ocean Model. The horizontal resolution of the model is 1°/8x1°/8 degrees, with 25 sigma levels in the vertical. The oceanographic model was coupled with the SKIRON/Eta atmospheric model (3).

To simulate the transport and diffusion of Saharan dust in the ocean an additional advection-diffusion equation has to be solved by the model, introducing also a settling velocity of the dust in the sea water (due to its density difference from the sea water). The dust that reaches the lowest level of the model evacuates the water column and is deposited onto the seabed. During the first phase of the experiments, the atmospheric input of Saharan dust includes only one class of particles with diameter of $2\mu m$. More realistic experiments, with four classes of particles, are also being performed.

Results and Discussion

The model has been integrated with atmospheric dust deposition for the period April 2000 to December 2002, and the results of the last two years are presented here. Although the Saharan dust cycle does not reach a steady state, basic characteristics of the cycle are already evident.

The daily atmospheric deposition of Saharan dust on the surface of the Mediterranean Sea is plotted in Figure 1a. The annual deposition over the Mediterranean for 2001 is 1.22 $g\ m^{-2}$ and 2.13 $g\ m^{-2}$ for 2002. The dust deposition on the sea surface of the Eastern Mediterranean is much larger than the dust deposition on the sea surface of the western Mediterranean, in agreement with previous observational and modeling studies (1). Another important conclusion is the highly episodic character of the atmospheric deposition. A few episodes account for the biggest part of Saharan dust deposited on the sea surface. It is characteristic that two episodes during spring 2002 account for 44% of the total deposition on the sea for this year. It is interesting to note that this episodic character can create patches of water very rich in dust with considerable effects on the area's biology and water quality.

The effects of oceanic circulation on the dust distribution and deposition onto the sea bed were found to be very important. The dust concentration is mainly defined by advection and diffusion, while the particles' settling velocity, being very small, contributes very little in the dispersion of dust into the water column. The general eastward surface flow along the African coast is currying large amounts of dust uptaken in areas of high atmospheric deposition (close to the source), thus further increasing the contrast between the western and eastern sub-basins. Other oceanic features tend to trap the Saharan dust atmospheric input creating large patches of high concentration. Figure 1b shows the mean Saharan Dust concentration for the eastern, western and the whole Mediterranean basin.

Figure 1c presents the bottom deposition for the eastern, western Mediterranean and the whole basin. The bottom deposition rate for the Mediterranean Sea is 115.8 $mgr\ m^{-2}$ and 198.6 $mgr\ m^{-2}$ per year for 2001 and 2002, respectively. The difference between the eastern and the western Mediterranean is again apparent. The deposition rate presents its highest values during winter. The highest values of Saharan dust deposition are encountered in the continental shelf of the African coast, the coasts of the southern Adriatic Sea, the Cyclades Plateau in the Aegean Sea, the Gulf of Lions and the northeastern coast of Spain. Some areas of intense local bottom deposition are associated with strong events taking place in coastal and generally shallow locations.

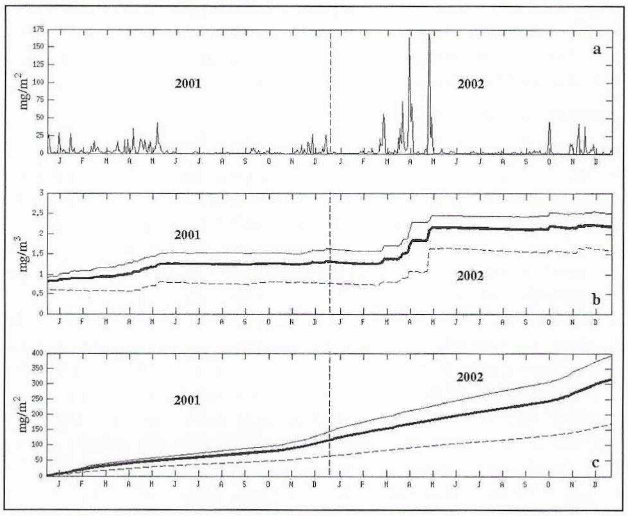

Fig. 1. (a) Atmospheric deposition of Saharan dust, (b) Saharan dust concentration in the Eastern Mediterranean (thin line), Western Mediterranean (dashed line) and whole basin (thick line), and (c) cumulative bottom deposition in the Eastern Mediterranean (thin line), Western Mediterranean (dashed line) and whole basin (thick line).

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