Available online at www.sciencedirect.com
ScienceDirect
Continental Shelf Research 27 (2007) 1568–1583
CONTINENTAL SHELF RESEARCH
www.elsevier.com/locate/csr

An estimate of the suspended particulate matter (SPM) transport in the southern North Sea using SeaWiFS images, in situ measurements and numerical model results

Michael Fettweis*, Bouchra Nechad, Dries Van den Eynde

Management Unit of the North Sea Mathematical Models (MUMM), Royal Belgian Institute of Natural Sciences, Gulledelle 100, 1200 Brussels, Belgium

Received 10 March 2006; received in revised form 9 January 2007; accepted 17 January 2007
Available online 2 February 2007

Abstract

A study is presented where satellite images (SeaWiFS), in situ measurements (tidal cycle and snapshot) and a 2D hydrodynamic numerical model have been combined to calculate the long term SPM (Suspended Particulate Matter) transport through the Dover Strait and in the southern North Sea. The total amount of SPM supplied to the North Sea through the Dover Strait is estimated to be 31.74×10^6 t. The satellite images provide synoptic views of SPM concentration distribution but do not take away the uncertainty of SPM transport calculation. This is due to the fact that SPM concentration varies as a function of tide, wind, spring-neap tidal cycles and seasons. The short term variations (tidal, spring-neap tidal cycle) have not been found in the satellite images, however seasonal variations are clearly visible. Furthermore the SPM concentration in the satellite images is generally lower than in the in situ measurements. The representativness of SPM concentration maps derived from satellites for calculating long term transports has therefore been investigated by comparing the SPM concentration variability from the in situ measurements with those of the remote sensing data. The most important constraints of satellite images are related to the fact that satellite data is evidence of clear sky conditions, whereas in situ measurements from a vessel can be carried out also during rougher meteorological conditions and that due to the too low time resolution of the satellite images the SPM concentration peaks are often missed. It is underlined that SPM concentration measurements should be carried out during at least one tidal cycle in high turbidity areas to obtain representative values of SPM concentration.

Keywords: Cohesive sediments; Suspended particulate matter transport; Satellite imagery; SPM measurements; Hydrodynamic numerical model; Southern North Sea; Dover Strait

1. Introduction

The fine grained sediment dynamics in the southern North Sea have been the subject of many scientific and applied studies. There is clear evidence of long-term net inflow through the Dover Strait and thus also of net suspended particulate matter (SPM) transport into the North Sea (Prandle et al., 1993, 1996). Gerritsen et al. (2001) underline that this transport is the main source of recent fine-grained sediments in the North Sea. Extensive scientific literature on the residual SPM transport

*Corresponding author. Tel.: +32 2 7732132; fax: +32 2 7706972.
E-mail address: m.fettweis@mumm.ac.be (M. Fettweis).

0278-4343/$ - see front matter
doi:10.1016/j.csr.2007.01.017

through the Dover Strait exists; the values vary between $[2.5-57.8]\times 10^6$ t/yr (Eisma, 1981; van Alphen, 1990; Lafite et al., 1993; Velegrakis et al., 1997; McManus and Prandle, 1997). These big differences reflect partially the high temporal and spatial variability of the influx but have their origin also in the way the SPM measurements have been carried out, in the small number of SPM concentration measurements on which the calculations were based as well as the differences in the way the residual SPM transport was calculated. Accurate knowledge of the SPM flux through the Dover Strait is important in order to set up a sediment budget, to identify the sources and sinks of mud in the North Sea and to investigate the influence of anthropogenic activities, such as dredging and dumping on the local cohesive sediment transport.

The purpose of this paper is to present a study where satellite images (SeaWiFS), in situ measurements and a hydrodynamic numerical model have been combined to calculate the long term averaged SPM transport through the Dover Strait and in the southern North Sea. The use of optical remote sensing methods to produce SPM concentration maps benefits from the satellite's capabilities to view a wide area and to provide synoptic views of SPM concentration distribution. The disadvantages are mainly that the data are limited to the surface layer, that good data exist only during cloud-free daytime and that the time resolution is low. For the Belgian continental shelf about 60 (partially) cloud free images per year are available. In order to cope with the fact that only surface values are available, the method presented by Van den Eynde et al. (2006) has been applied in which in situ measurements of SPM concentrations during a tidal cycle and satellite images have been used to calculate the depth averaged SPM concentration distribution. The low time resolution prevents an accurate computation of the sediment flux when using:

$$T = \int_0^t \int_0^h u(z,t)c(z,t)\,\mathrm{d}z\,\mathrm{d}t, \tag{1}$$

where T is the sediment flux per unit width, h is the water depth, $u(z,t)$ is the current velocity normal to the section and $c(z,t)$ the SPM concentration. Prandle et al. (1996) wrote that the SPM dynamics in tidal waters are mainly determined by water depth h, eddy diffusivity K_z and settling velocity w and that the residual transport closely approximates

$$T \approx \int_0^t \int_0^h u(z,t)\,\mathrm{d}z\,\mathrm{d}t \int_0^t \int_0^h c(z,t)\,\mathrm{d}z\,\mathrm{d}t, \tag{2}$$

when $K_z > wh$. In coastal waters, such as the southern North Sea, with a water depth between 10–50 m and a K_z of 0.01 m^2/s the settling velocity must be <1 mm/s. This is a value in agreement with measured settling velocities of flocs and aggregates in estuaries and in the North Sea (van Leussen, 1994; Winterwerp, 1998; Mikkelsen and Pejrup, 2001). Both formulae have been used to calculate the SPM transport.

The paper is structured as follows. In Section 2 the study area is described with special emphasis on the Belgian coastal waters, followed by a presentation of the method used to obtain SPM concentration maps from satellite images and in situ measurements and of the hydrodynamic numerical model used to simulate the water flow in the area. In Section 3 the sediment transport results based on the hydrodynamic model and the satellite images using Eqs. (1) and (2) are presented. The question of the representativness of SPM concentration maps derived from satellites for calculating long term averaged transport is discussed in Section 4 by comparing the SPM concentration variability from in situ measurements with remote sensing data. Some general conclusions are offered in Section 5.

2. Methods

2.1. Study area

The study area is the southern North Sea and the Dover Strait (Fig. 1) and specifically the Belgian coastal zone. This area is especially of interest due to the occurrence of a high turbidity zone. It is characterised by depths between 5–35 m, a mean tidal range at Zeebrugge of 4.3 m (2.8 m) at spring (neap) tide and by maximum current velocities of more than 1 m/s. The winds are mainly from the southwest and the highest waves occur during north-westerly winds. The SPM concentration measurements indicate variation in the coastal zone between a minimum of 20–70 mg/l and a maximum of 100–1000 mg/l; low values (<10 mg/l) have been measured in the offshore area. Based on numerical results Fettweis and Van den Eynde (2003) conclude that the decreasing residual water transport vectors, the shallowness of the area and the difference in magnitude between neap and spring tidal currents