Integration of a 3D numerical model, field data and remote sensing to study fine suspended sediment transport in the lagoon of New-Caledonia

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INTRODUCTION

In New Caledonia, where open-cast mining plays a significant economic role, the coral reef lagoon ecosystem is strongly dependent on the sediment distribution and dynamics. A study on the influence of anthropogenic and terrigenous inputs has been conducted by the Institut de Recherche pour le Développement (IRD) since 1996 and this paper presents results on the integrated study of sediment dynamics in the south-west lagoon of New Caledonia, involving in situ measurements, numerical modelling and remote sensing. New Caledonia, located at 1500 km east of Australia, is surrounded by coral reef lagoons covering a total area of approximately 24 000 km^2. The study area extended over an area of 2 100 km^2 where available depth data were sufficiently dense to allow for the definition of a 500 m grid size in the numerical models.

FIELD DATA

Several kinds of data have been regularly recorded within the south-west lagoon of New Caledonia from 1997 so as to support the analysis of hydrodynamics and sediment transport, the calibration and validation of the models, and the satellite data inversion: wind, wave parameters, current profiles, CTD and turbidity profiles, water and sediment sampling, hyperspectral reflectance. In complement to these measurements, geochemical studies were devoted to quantify the change in riverine sediment supply during the last century associated to the mining activities and to analyze the fate of terrigenous particles within the lagoon (Fernandez *et al.* submitted).

Temperature and salinity distributions within the lagoon and their seasonal and interannual variability were analyzed against their regional variations (Ouillon *et al.* in press). Turbidity distribution and its variability were also analyzed from data collected during 20 field campaigns (1997-2001) under non-storm conditions. Its strong and rapid variations along short distances were analyzed against river discharges, wind stress and wind direction. It was shown that interannual variability in turbidity applies both to the mean turbidity level and to its vertical distribution. Sediment inputs by rivers are likely expected during La Niña or neutral periods. Resuspension, that is the main origin of turbidity during non-storm conditions and that induces the facies organization, is enhanced by stronger winds during El Niño events. An increase in stratification in turbidity was also observed in the lagoon waters during a La Niña event.

Additional measurements of grain size distribution in the water column have been recently performed by use of a LISST-100X. The first analysis of the spatial distribution within the lagoon in grain size of particles (range 1.25-250 µm) is presented at the INTERCOH conference.

INTEGRATION OF A NUMERICAL MODEL, FIELD DATA AND REMOTE SENSING

The numerical models include a 3D hydrodynamic model that was validated from currentmeter moorings, the wave model Wavewatch III from NOAA and a classical 3D numerical model for cohesive sediment transport (Douillet *et al.* 2001). The fine suspended sediment transport is modelled by use of several equations of transport, one per grain-size class. It involves the formulations of Krone and Partheniades for the exchange rates of particles through deposition and erosion, respectively. Parameters involved in the model (settling velocity, critical shear stress, erosion rate, Schmidt number) are described.

In spite of their very original geomorphology and environmental conditions, few numerical models have been applied to coral reef lagoons. As the bathymetry and sedimentology are very variable throughout the lagoon, and due to the lagoon size, it was not suitable to calibrate the model of sediment transport through local time-series of measurements. Despite the present abandonment of effort to author global or universal algorithms to quantify suspended particulate matter (SPM) concentrations from remotely sensed data, considerable success in SPM estimation has been demonstrated regionally from a great variety of sensors (Acker *et al.* 2005). In our study, a first calibration of the model for the finest particles (7 µm diameter) was established from sedimentological characteristics, from quasi-instantaneous maps of turbidity measured using OBS measurements, and from instantaneous maps of turbidity obtained from Landsat7 ETM+ data (Ouillon *et al.* 2004).

APPLICATION TO THE SOUTHWEST LAGOON OF NEW CALEDONIA

Simultaneous measurements of turbidity depth-profile and above-water spectral reflectance integrated according Landsat 7 ETM+ band 2 spectral sensitivity provided a linear regression relationship for the southwest lagoon of New Caledonia (r^2=0.95, n=40). This relationship was applied to an empirically atmospherically-corrected Landsat ETM+ image of the lagoon acquired on October 23, 2002. A comparison between Landsat-estimates of turbidity and concurrent measurements at 14 stations indicated that the mean standard error in the satellite-estimated turbidity was 17.5 %. The numerical model introduced in Douillet *et al.* (2001) was used to simulate the transport of the finest class of suspended particles in the lagoon in October 2002. A calibration of the erosion rate coefficient required by the model was proposed using *in situ* turbidity profiles and the remotely sensed turbidity field. *In situ* data were used to tune locally the erosion rate coefficient, while satellite data were used to determine its spatial zonation (Ouillon *et al.* 2004).

The model was applied to both theoretical forcing (typical tidal and wind conditions) and real meteorological data. Numerical results were compared to turbidity profiles, to the existing sediment distribution in the lagoon, and to the turbidity maps obtained using satellite data. After validation which is under process, the next step is to analyze the erosion rate coefficient distribution that was optimized using the combination model-image against the sedimentological parameters and habitat indicators. First results are presented during the INTERCOH conference.

This work provides an attempt to model the transport of fine suspended sediments in a lagoon. In particular, we show the potential of remotely sensed data to map turbidity in a coral reef lagoon and thus to provide helpful data for the calibration of a numerical model of fine suspended sediment transport. We discuss necessary improvements in such an integrated study relative in particular to the relationships between turbidity and sediment concentration, the correction of bottom reflection in satellite data processing over shallow waters, and the necessary process studies concerning, for example, the transport of mixed biogenic and terrigenous particles or of mixed cohesive and non cohesive fractions that are necessary to improve the modeling strategy and the model formulation.

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