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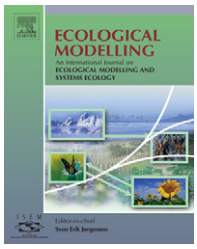

Harmonic analysis of suspended particulate matter in the Menai Strait (UK)

V. Krivtsov, J. Gascoigne, S.E. Jones*

School of Ocean Sciences, University of Wales Bangor, Marine Science Laboratories, Menai Bridge, Anglesey LL59 5AB, UK

ARTICLE INFO

Keywords:
Suspended particulate matter
Marine ecosystem
Advection gradient
Resuspension
LISST
Tidal analysis

ABSTRACT

An application of harmonic analysis is presented to estimate M2 and M4 tidal constituents of various suspended particulate matter (SPM) fractions in a marine ecosystem. The data were collected on two cruises in August and September 2004. In both sets of data there appeared to be clearly identifiable advection (i.e. semidiurnal increases in concentrations), resuspension (i.e. quarterdiurnal increases in concentrations), and flocculation (e.g. increases in median diameter at slack waters) signals. In most cases, the simulations on M2 and M4 components (estimated using harmonic analysis) explained a considerable proportion of variance (typical r^2 is 0.4–0.65). However, some of the variables examined (e.g. median diameter in deeper layers) could not be modelled satisfactorily using the method chosen. In August, the amplitude of the M4 component was invariably lower than of the M2 component, thus indicating that advection signal dominated the overall dynamics observed. In September, however, this pattern was reversed for small and medium-sized particle diameters, thus indicating that resuspension for this fractions was prevalent. Another remarkable difference between the two data sets is the considerable difference between the estimated advection phases, which were, in general (and variable depending on the specific fraction), approximately 8 and 5 h after LW in August and September, respectively. These differences might have been partly related to the differences in the exact sampling locations, seasonal changes between the two cruises, local processes in the Menai Strait, and/or preceding meteorological conditions. The results are discussed in terms of their importance for the Menai Strait biota.

1. Introduction

The Menai Strait (Wales, UK) is situated between the Island of Anglesey and the mainland Britain. The Strait has a diverse and well-studied biological community, and for many years has been a subject of intensive research by scientists from UWB and other institutions (see, e.g., Buchan et al., 1972; Bowers and Brubaker, 2004, and references therein). In respect of the environmental and scientific value of the area, there is a proposal for a Special Area of Conservation (Young, 1994).

Previous research in the Menai Strait revealed that concentrations of suspended particulate matter (SPM) are greater in winter than in summer, and also greater during the spring than the neap tide (Buchan et al., 1967). Although a considerable proportion of SPM is organic, the majority of suspended sediments is inorganic (Kratzer et al., 2000), and surface inorganic loads appear to correlate with tidal range, wind direction, and, negatively with temperature (Buchan et al., 1967). There has been a slight increase in SPM loads throughout the second half of the last century, which is a cause of

* *Corresponding author*. Present address: CECS, The Crew Building, King's Buildings, University of Edinburgh, West Mains Road, Edinburgh EH9 3JN, Scotland, UK.
E-mail address: e96kri69@netscape.net (V. Krivtsov).
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doi:10.1016/j.ecolmodel.2007.10.039

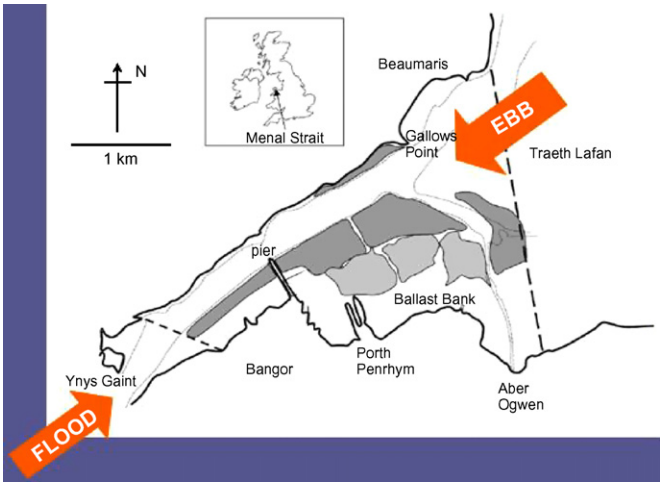

Fig. 1 – Study area. Please refer to the journal's website for the colour version of this figure.

concern because of its potential effects on local ecology, in particular algae and juvenile fish (see Kratzer et al., 2003, and references therein).

It has been shown recently (Tweddle et al., 2005) that there is a gradient in chlorophyll-a concentration along the strait, resulting from a combination of a substantial residual SW flow (350–800 $m^3\ s^{-1}$) and intensive filtration over mussel beds. As filtration by mussels and some other suspension feeders is predominantly non-selective (Gosling, 2003), and also considering that the conditions within the Strait are generally calmer than outside the Strait due to a relatively sheltered environment, it may, therefore, be expected that there should be a gradient in suspended particulate matter. Here we use harmonic analysis to estimate amplitudes and phases of semi- and quarter diurnal constituents (M2 and M4, respectively), and to interpret the results obtained in terms of the relative importance of advection and resuspension processes for the Menai Strait biota.

2. Methods

2.1. *Site description*

The measurements were conducted in the Menai Strait, North Wales, UK. It is a narrow channel (Fig. 1), which in places is only 400 m wide. The site has strong tidal currents (up to 60 cm s^{-1}) and a relatively short slack tide period of 20–60 min (Gascoigne et al., 2005). The tidal pattern is characterised by a considerable time lag between the slack current and an extreme of elevation (Young, 1994), which is due to the fact that the tidal wave travelling directly through the Menai Strait meets with the one propagating around Anglesey.

The site is adjacent to the area which is usually used by the commercial mussel industry for ongrowing mussels prior to moving them to subtidal fattening areas. At the north–east of the Menai Strait there is an area of extensive sand and mud flats (the Lavan Sands). Further details about the study area and the specifics of the Menai Strait biota can be found in references reviewed by Young (1994).

2.2. *Observations*

The selections of data presented below were collected on two separate research cruises in August and September 2004. On each cruise the observations reported here were conducted at an anchor station, which was positioned at 53°14.680′N 4°7.257′W (closer to the pier, south side of the channel) and 53°15.025′N 4°6.575′W (closer to the Gallows point, north side of the channel) in August and September, respectively. Principally, the observational evidence comes from applying two techniques: a bottom-mounted RDI Workhorse ADCP (Acoustic Doppler Current Profiler), and a LISST_100 (Laser In-Situ Scattering and Transmissometry, Sequoia Ltd.). The latter technique (model C) provides estimates of volumetric concentrations (in microlitters per litter) for 32 size classes corresponding (on a log scale) to particle median diameters between 2.5 and 500 μm. The primary data were pre-processed using Sequoia software and a suite of custom-made Matlab programs for data quality analysis and despiking, and calculations of values for wider-ranged size fractions and basic statistics.

2.3. *Harmonic analysis*

There are a number of mathematical techniques commonly used for analysis of time series exhibiting cyclic patterns, including Fourier analysis and harmonic analysis. The former involves computations of harmonic amplitudes at equally spaced frequency intervals (Emery and Thomson, 2001). In the oceanographic research, however, the cycle frequencies are often known *a priori* due to their relation to the astronomical tidal forces. In the case of an over-determined problem (i.e. when there are many more data points than

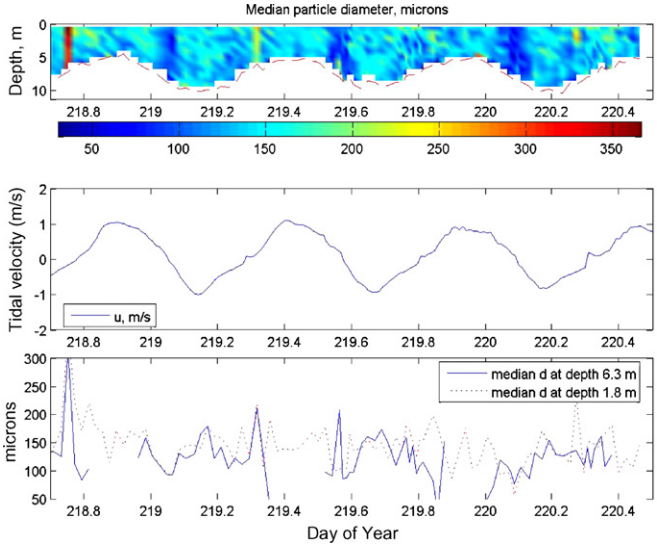

Fig. 2 – Median particle *d* (μm)—results for August 2004. The upper panel shows temporal changes in the profile, whilst the lower panel shows changes at two particular depths. Temporal changes in the along channel tidal velocity are given in the middle panel for reference. Please refer to the journal's website for the colour version of this figure.