Horizontal coherent structures between channel and mudflat

van Prooijen Bram C.[1] and Qin Zhu[2]

[1] Department of Hydraulic Engineering, TU Delft, 2628 CN Delft, the Netherlands
E-mail: B.C.vanProoijen@TUDelft.nl

[2] State Key Laboratory of Estuarine and Coastal Research
East China Normal University, Shanghai 200062, P.R. China

Introduction

At various aerial pictures of estuaries, large scale eddies are visualized by a distinct difference in sediment concentration. Fig. 1 shows such a picture, where horizontal eddies or horizontal coherent structures are found at the interface between tidal flats and a channel. They are characterized by horizontal length scales that are an order of magnitude larger than the water depth. In general, these coherent structures are instabilities that grow due to an inflection point in the transverse profile of the streamwise velocity. As already shown in the areal picture, these coherent structures result in an exchange of sediment between the mudflat and the channel. It is however unknown what their contribution is to the net exchange.

In this study we explore the occurrence and development of coherent structures in tidal flow. Furthermore, we aim to determine the effect of these coherent structures on exchange of sediment between channel and tidal flat.

A field campaign was therefore set up to measure the horizontal coherent structures. High resolution flow measurements were carried out with velocimeters (ADV and ADCP), path lines were tracked by means of GPS-drifters and the footprint of the coherent structures was visualized with an Unmanned Automatic Vehicle (UAV or drone).

Study area and experimental setup

The field campaign was set up at the Kapellebank, a semi-enclosed flat bordering the outer bend of one of the channels of the Westerschelde (the Netherlands), see Fig. 1. At this location, the coherent structures were most clear on various areal pictures. Three methods have been used to determine the hydrodynamic processes at the interface between tidal flat and channel. First, *in-situ* measurements by flow instruments were installed. Upward looking ADCPs (Nortek Aquadopp) were buried in the bed and used in high frequency mode. A frame with an ADV (Nortek Vector) and a downward looking ADCP (Nortek Aquadopp) were employed. Second, path lines were tracked by means of GPS drifters. The drifters were employed for 3 hours during the ebb phase. Third, areal pictures were taken by a UAV. The coherent structures are visualized by the differences in sediment concentration. Dye release was tested, but turned out to be unsuccessful in the turbid water. Sediment concentrations were measured with 2 OBS's and a LISST (see also contributions of Zhu *et al.*, and of Guo *et al.*,).

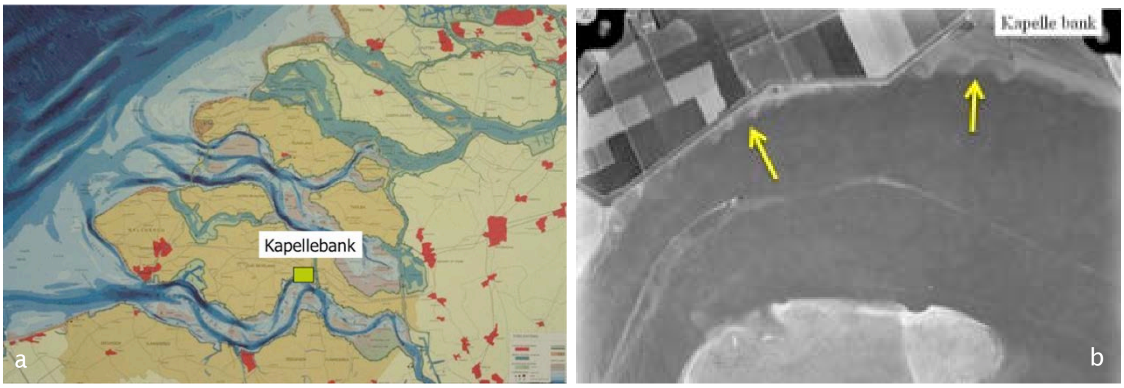

Fig. 1: (a) Map of the south-western part of the Netherlands with the Westerschelde (lower estuary) and the location of areal picture. (b) Areal picture with the Kapellebank at the upper right corner. The arrows indicate the horizontal coherent structures as visualized by the sharp sediment concentration gradients.

Results and conclusions

Fig. 2a shows a typical picture made by the UAV, one hour before low water. It shows sharp gradients in sediment concentration, visualizing the coherent structures. Low concentrations are found in the channel. Relatively small waves stir up the sediment at the shallow water part along the waterline, resulting in high concentrations. The coherent structures result in sediment transport from the tidal flat into the channel. The typical size of the coherent structures is 100m-300m. Such dimensions are also found from the path lines of the GPS drifters, Fig. 2b. These path lines show typical turn over time scales of 20 minutes. From the drifter measurements, almost no translation of the coherent structure was found. For over one hour, the coherent structures stayed in place. The along shore flow at the water line was even opposite of the along shore ebb flow in the channel. This was also observed in the ADV and ADCP data. Fig. 2c shows the velocity (ADV) and water level variation for 4 typical tidal periods at the interface between channel and flat. Where a consistent flow pattern is found for the flood phase, significant differences in velocities are found in the ebb phase, just before falling dry. Especially in the third cycle, a significant along shore flow is found in eastern direction. This implies that the flow is opposite of the ebb flow in the channel.

It is concluded that horizontal coherent structures could be detected by various instruments at the interface between channel and tidal flat. The results from the UAV, velocimeters and GPS-drifters show a consistent pattern. The coherent structures were found during the ebb period, just before falling dry. In this period, the conditions seem to be most favourable with shallow water and sufficient lateral shear. From the GPS-drifter data followed that the coherent structures rotate slowly, taking about 20 minutes to make a full rotation. The drifter data also show that the coherent structures only show weak translations. Further analysis will be carried out on the effect of the coherent structures on net sediment transport between channel and tidal flat.

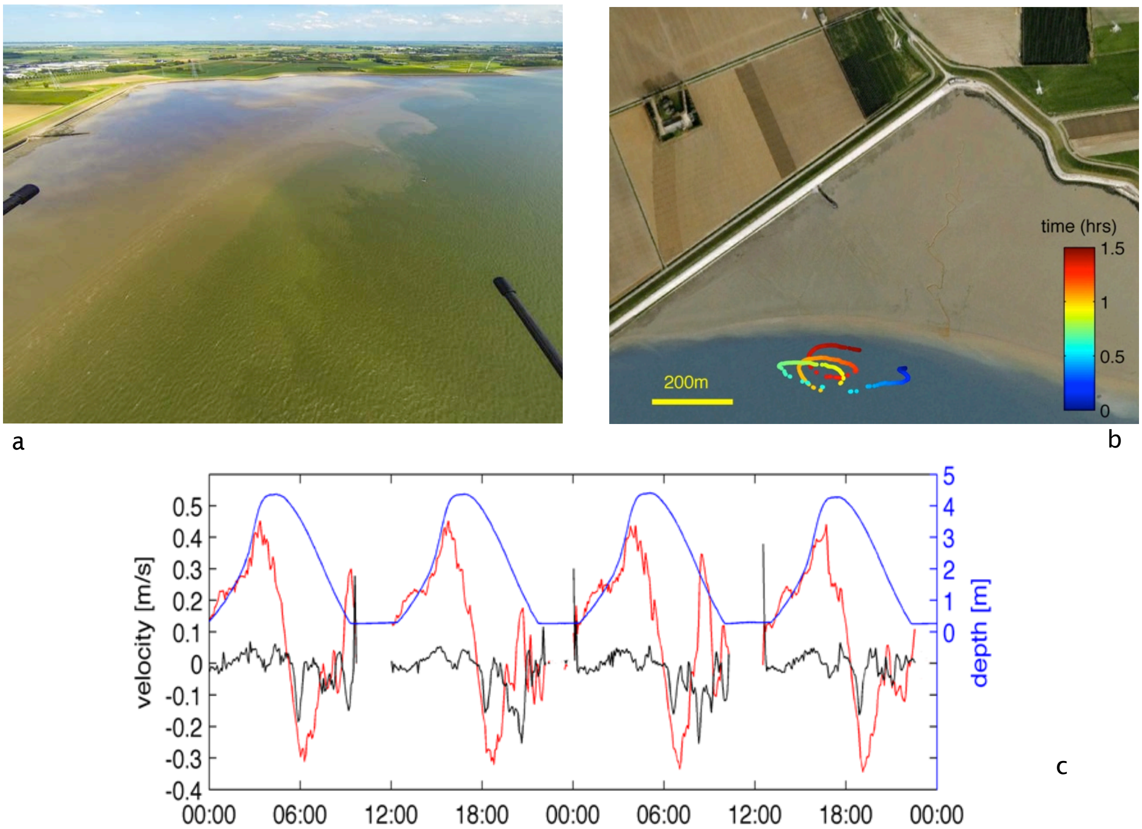

Fig. 2. (a) Areal picture of the Kapellebank, made with the UAV. (b) Path line of GPS-drifter. The colours indicate the time in hours. (c) Time series of the water depth (blue), along shore velocity (red) and cross shore velocity (black). Positive along shore velocities indicate flow to the East (landward), and positive cross shore velocities indicate flow to the North (onto the flat). Velocities are measured at 15cm above the bed.