Coastal Dynamics I

Lectures notes CIE4305

Delft University of Technology

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Some of the information in Figures 2-3, 2-5, 2-7, 2-30, 2-31, 2-34, 4-2 and 4-6 is based on De Grote Bosatlas (53rd edition), Wolters-Noordhoff.

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Preface

This fourth draft version of these lecture notes serves to support and supplement the course COASTAL DYNAMICS I (CIE4305). This is a relatively recent (per the academic year 2009-2010) fourth-year course for MSc graduate students following the Hydraulic Engineering programme of the Faculty of Civil Engineering and Geosciences of Delft University of Technology. This course focuses on the interrelation between physical wave, flow and sediment transport phenomena and the resulting morphodynamics of a wide variety of coastal systems. The objective is to provide insights into the phenomenological and theoretical as well as applied aspects for civil engineering MSc students. It builds upon the BSc and MSc courses treating the dynamics of flow, wave and sediment transport, and forms the basis for the course on COASTAL DYNAMICS II (CIE4309) which focuses on coastal modelling.

Although several valuable course monographs and books exist on the topic of coastal dynamics and coastal engineering (see Section 1.7.2), we feel that no single standard teaching books exist for the purposes that we have in mind, given also the Hydraulic Engineering curriculum that the faculty of Civil Engineering and Geosciences has historically developed. It is our expectation that the present notes may develop towards that end. The present form and format of these notes is not final and far from perfect, both in language and contents. We feel that this is a matter of evolution, strongly steered by our continuous learning and the experience of both teaching and examination. It is our guess that it will take a few more academic years before we feel that these lecture notes have developed sufficiently to be published by an internationally renowned publisher. Until then anyone is welcome to order these lecture notes at the Delft Academic Press, a Delft University of Technology based, student-directed publishing house.

In the 1960's the topic of coastal engineering and coastal dynamics at our faculty was not really taught as a separate graduate course, it was rather an integral part of the hydraulic engineering chairs and courses of Professors Van Bendegom and Jansen. In 1972, Professor Bijker was appointed the first chair focusing on Coastal Engineering alone. He asked Associate Professor Massie to compose the first Coastal Engineering course notes which still form an input for our current notes. In 1988 Professor Bijker was succeeded by Professor D'Angremond, who invited both MSc van de Velden and Associate Professor Van de Graaff to develop two new courses and lecture notes, viz. Introduction to Coastal Engineering (CT4300) and Coastal Morphology and Protection (CT5309) respectively. In 1994, the topic of Coastal Inlets and Tidal Basins was added as a separate third course (CT5303) developed by Professor Stive, newly appointed in a part-time position. With assistance of MSc's Elias and Hibma, he composed lectures and lecture notes by integrating existing material of Professors De Vriend, Dronkers and Wang and Dr's Van der Spek and Van Dongeren.

Per the academic year 2009-2010, the courses CT4300, CT5309 and CT5303 have been replaced with two newly developed courses COASTAL DYNAMICS I (CIE4305) and COASTAL DYNAMICS II (CIE4309). The development of these two new courses was given in by our wish to update and streamline our Coastal Engeering curriculum and make room for morphodynamic modelling and new developments.

In developing the lecture notes of CIE4305 we have first revised, condensed and integrated the material of the three former courses. We wish to acknowledge the efforts of all our colleagues that developed these courses. Second, we developed new material that we found missing. In part, the new material is sometimes based on or at least inspired by some key references that we wish to acknowledge here. Chapter 2, especially Section 2.3, is heavily based on Davies (1994), whose well-illustrated textbook offers a good insight into larger scale coastal behaviour and classification. The energetics approach for cross-shore sediment transport in Chapters 6 and 7 is for a great part based on Bowen (1980), whose elegant work we still find important and very instructive. Chapter 11 on Integrated Coastal Zone Management has benefitted a lot from the book of Kamphuis (2000) and the World Coast Conference contribution (WCC, 1993). In a more general sense we have been inspired by a number of books we reference in Section 1.7, notably the books by Fredsøe and Deigaard (1992), Kamphuis (2000) and Masselink and Hughes (2003). We have tried to the most of our abilities to pay attention to cite where external material is used. If we have failed to do so, please inform us.
Further, we need to acknowledge some close Delft colleagues who have contributed to our knowledge by their work and comments or provided us with material. Hoping not to forget anyone, we mention Jurjen Battjes, Leo Holthuijsen, Jacobus van de Kreeke, Jan van Overeem, Roshanka Ranasinghe, Ad Reniers, Dano Roelvink, Ad van der Spek, Zheng Bing Wang and Han Winterwerp.
Special thanks go to Howard Southgate, who continues reading through our lecture notes in detail and making very relevant comments and suggestions. Many of the improvements is this new version and the previous version of the notes are due to him. Finally, we are grateful for the many suggestions we received from our students.
We are still investing in making the illustrations and graphs “our own”. For this we were assisted by Liang Li, Daire Stive, Marcio Boechat Albernaz and Janbert Aarnink, whose contributions we gladly acknowledge. It is thanks to Marcel Mol that the latest version now has a subject index.

As for now, the notes are available for your own personal use only. Please be aware that this is a work in progress. We would be very grateful to be informed of any inconsistencies that can be found in the present text.

Judith Bosboom and Marcel J.F. Stive

Delft, January 2015

Contents

1 Overview

1.1 Introduction

Humans have extensively used the coastal zone for amongst others fishing, tourism, transport of goods, water treatment and housing. Agriculture has benefited from the very fertile grounds due to marine and riverine deposits. Approximately three billion people - half the world's population - live and work within a couple of hundred kilometres of a coastline, notwithstanding the vulnerability of coastal areas to flooding. Due to the high population densities and extensive infrastructure and property development, disasters will have major consequences. Coastal engineers play an important role in both developing the coastal zone and protecting the coast and the hinterland.

In Section 1.2, the course contents and the position in the curriculum are explained. Section 1.3 lists the study goals. Section 1.4 gives some examples of the problems coastal engineers may be faced with. In doing so coastal engineers need a thorough knowledge of the natural dynamics of the coastal system. An introduction on that topic is given in Section 1.5. Important players in the (Dutch) coastal engineering sector are summarized in Section 1.6. The chapter concludes with a list of handbooks, journals, conference proceedings and internet sources for further reading (Section 1.7).

1.2 Coastal dynamics for coastal engineers

1.2.1 What is coastal engineering?

Coastal Engineering is the branch of civil engineering concerned with the planning, design, construction and maintenance of works in the coastal zone. Coastal engineering usually involves either 1) the transport and stabilization of sand and other coastal sediments or 2) the construction of structures.

Measures in the first category are called 's*oft' measures* since they make use of natural (soft) coastal material. Examples are beach nourishments, maintenance dredging and land reclamation.

3 Ocean waves

3.1 Introduction

This chapter deals with ocean waves. By ocean waves we mean all oscillations of the water surface generated in the ocean (see Section 3.2). The most important in shaping the coastal zone are the short waves generated by wind and the longer tidal motion generated by the attractive forces of the sun and the moon on the water masses of the earth. In Section 3.3 we look at how waves can be measured. Statistical and spectral representations of wind waves are treated in Section 3.4. Both wind wave generation and the propagation away from the area of wave generation are treated in Section 3.5. We see how ocean waves become longer and smaller when propagating away further from their source due to the phenomenon of wave frequency dispersion and due to frequency dependent dissipation. Long term statistics are briefly discussed in Section 3.6. The generation of the tide is explained and the origin of the different harmonic constituents is treated in Section 3.7. We look into the propagation of the tide in the world's oceans and in doing so talk about propagation velocity, Coriolis forces and amphidromic systems (Section 3.8). Tidal analysis and prediction are the topics of Section 3.9.

After having taken the courses Ocean Waves (CIE4325), Hydraulic Engineering (CTB2410, in Dutch) and Open Channel flow (CTB3350/CIE3310-09) the larger part of this Chapter on Ocean Waves should be familiar to you. This particularly holds for the Sections 3.2 through 3.6 on wind or short waves. You will find that Sections 3.7 through 3.9 treat the tidal generation and propagation more extensively than CTB2410 does. In CTB3350/CIE3310-09 you will have encountered some aspects of tidal propagation as well.
For those of you without any prior knowledge of wind waves or tides in oceanic waters, this Chapter deals with the main aspects that are required in order to successfully follow Coastal Dynamics I.

3.2 Oscillations of the ocean water surface

We can broadly define ocean waves as all sea-surface variations on the timescale of seconds to months as generated in the oceans. Mean Sea Level (MSL) is the sea level

4 Global wave and tidal environments

4.1 Introduction

In this chapter we look into the global variation in the main processes that shape the coast: wind, waves and tides. Based on large scale observations such as the latitude and the continent, a general idea of the wave, wind and tidal conditions at a project site can be obtained. Questions that can be answered are for instance:

- What is the wind system we are dealing with at this latitude and what is the dominant direction?
- Are locally generated waves important or are we mainly dealing with swell waves?
- What wave heights can we expect?
- Does the wave climate exhibit seasonality?
- Can we expect a large tidal range in this part of the world?
- Is there a diurnal or a semi-diurnal tide?

This chapter starts with a treatment of the zonal wind systems (Section 4.2). Knowledge of these global wind patterns is helpful in identifying the prevailing wind conditions for a project site as well as the wave climate. In Section 4.3, the global wave climate is discussed and some generalizations are made about the coastal impact of different wave conditions. Subsequently, global tidal environments and coastal characteristics are discussed in Section 4.4. Here also it is emphasised that it is the *relative* effect of waves and tides rather than the absolute tidal ranges and wave heights that determines the coastal character.

Please bear in mind that wind, waves and tides vary regionally and locally as well. An example of variation due to regional geographic variation is the sheltering of the Southern part of the Florida coastline from waves due to the presence of the Bahamas. On a local scale, the project location of a land reclamation may be chosen such that persistent swell cannot arrive at the site. These smaller scale variations are considered from Chapter 5 onwards.

5 Coastal hydrodynamics

5.1 Introduction

This chapter deals with the near-shore hydrodynamics that are important for sediment transport. It treats mean and oscillatory water levels and currents induced by waves, wind and tides. Relatively a lot of attention is paid to waves and wave-induced currents because of their effectiveness in transporting sediment in the surf zone.

The following aspects of waves are described:

- Linear wave propagation effects in shoaling waves (until wave breaking): increasing wave heights, decreasing wavelengths and refraction towards normal incidence (Section 5.2);
- Non-linear transformation of the wave shapes from initially symmetric, sinusoidal profiles, to asymmetric, pitched forward profiles characteristic of near-breaking waves (Section 5.3);
- Wave dissipation in the wave boundary layer and its effect on wave-orbital velocities, bed shear stress and net wave-induced flow (called Longuet-Higgins streaming) close to the bed (Section 5.4);
- Wave-induced water level changes in breaking waves such as the set-up (raising of the water level) at the coast, and wave-induced flow in breaking waves: a circulation current in the cross-shore direction (within the lower part of the water column an offshore directed undertow) as well as a longshore current along the coast (Section 5.5).

Subsequently Section 5.6 describes wind-generated set-up and currents. Section 5.7 is dedicated to tidal propagation in coastal waters. Last, Section 5.8 discusses some other long wave phenomena in coastal waters, viz. seiches and surf beat.