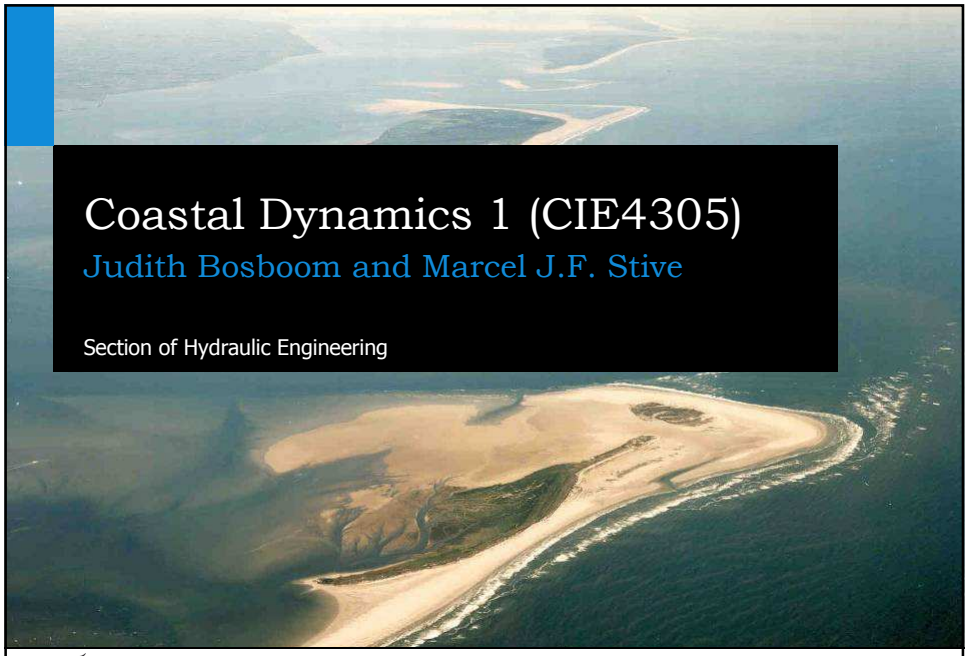


Coastal Dynamics 1 (CIE4305)

Judith Bosboom and Marcel J.F. Stive

Section of Hydraulic Engineering

4.

Global wave and tidal environments

Coastal Dynamics 1

Contents

1. Introduction
2. Large-scale coastal variation
3. Oceanic wind waves and tide
4. **Global wave and tidal environments (Chapter 4)**
5. Coastal hydrodynamics
6. Sediment transport
7. Cross-shore transport and profile development
8. Longshore transport and coastline changes
9. Coastal inlets and tidal basins
10. Coastal protection

4. Global wave and tidal environments

Do you know for your project site:

- What is the wind system at this latitude?
- What is the dominant wind direction?
- What wave heights and periods can be expected?
- Does the wave climate exhibit seasonality?
- How large is the tidal range?
- Is there a diurnal or semi-diurnal tide?

4. Global wave and tidal environments

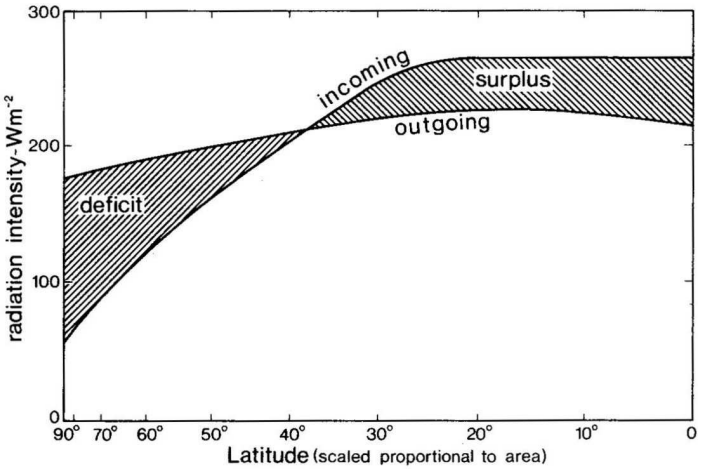
Chapter 4 of lecture notes

A. Zonal wind systems
B. Global wave environments
C. Global tidal environments
D. Coastal impact

4-A Zonal wind systems

The sun warms the equator more than the poles

Long-term average radiation intensity ($W\ m^{-2}$)

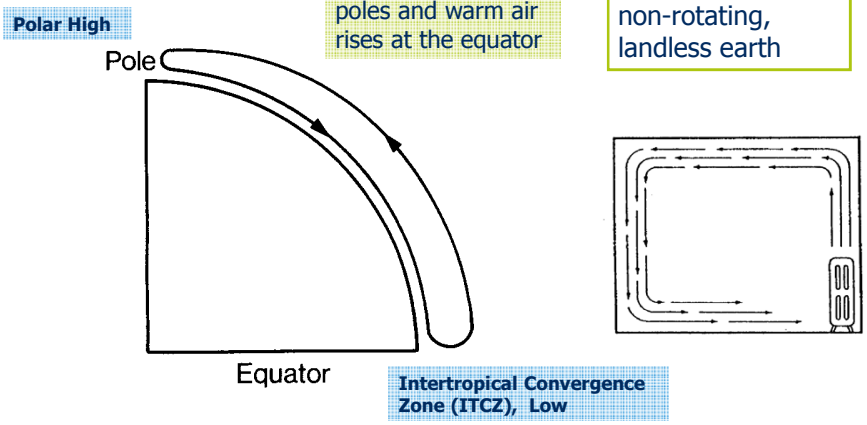


4-A Zonal wind systems

Uneven heating of the sun results in heat advection by ocean currents and winds

Cold air sinks at the poles and warm air rises at the equator

Convection cell for non-rotating, landless earth

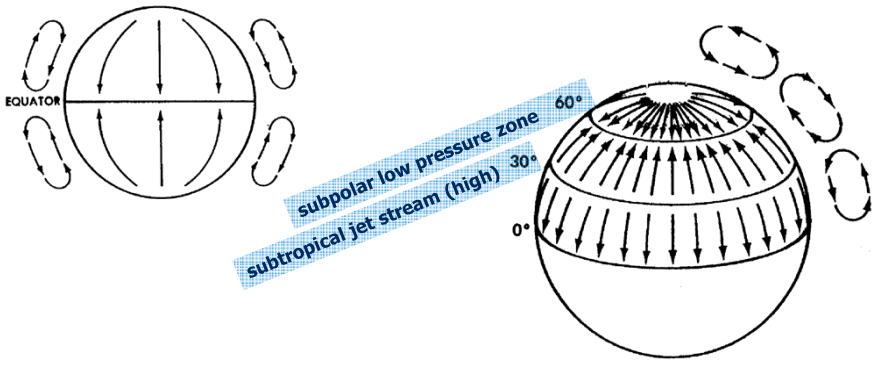


4-A Zonal wind systems

Effect Coriolis on convection cells for a landless earth

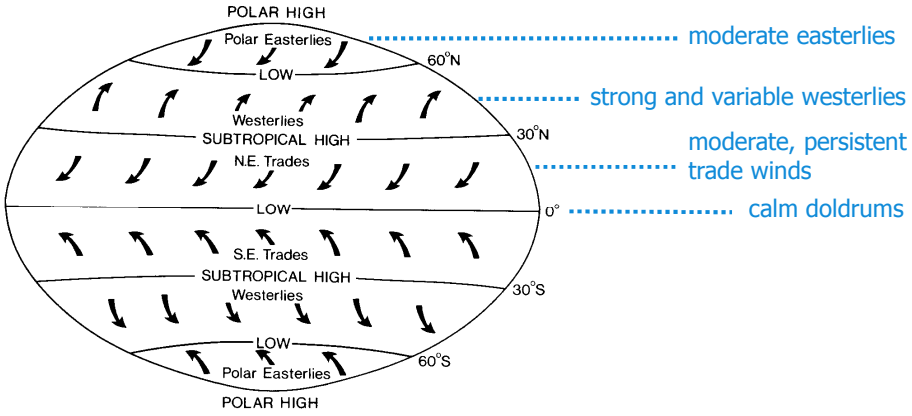
non-rotating

rotating



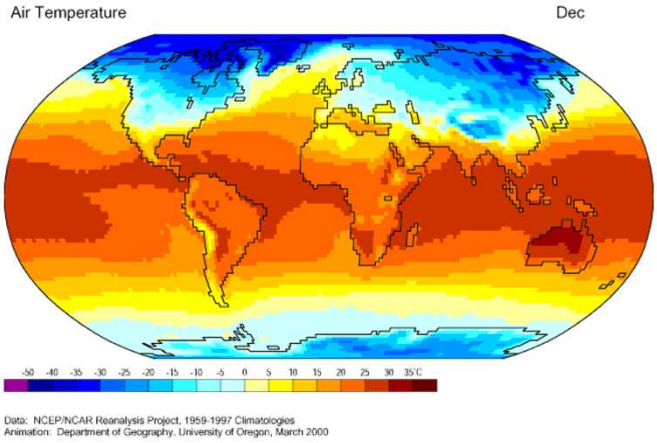
4-A Zonal wind systems

Pressure belts and wind systems at the surface of a rotating landless earth



4-A Zonal wind systems

Influence of seasons, latitude and differential warming of oceans and lands



4-A Zonal wind systems

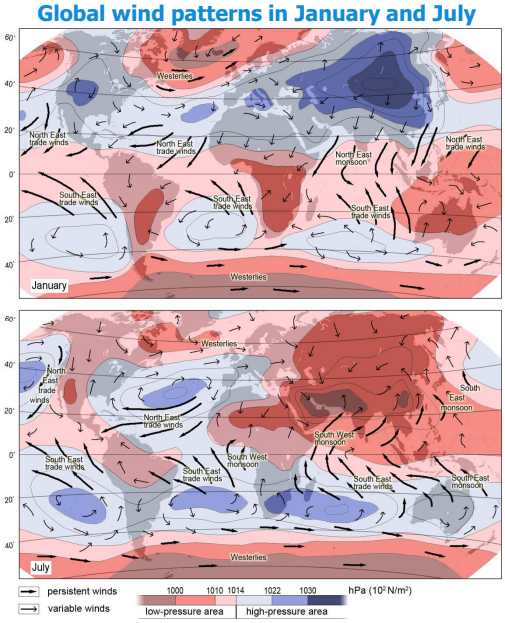
High and low pressure systems instead of belts

Seasonality of NH-westerlies

Regional and local effects

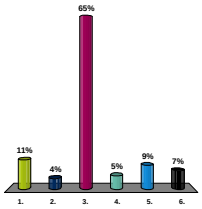
- Seasonally reversing monsoons
- Cyclones (tropical and east-coast cyclones)
- Land and sea breezes

Global wind patterns in January and July



4-A Zonal wind systems

Which of the statements is **wrong** in the below summary of zonal wind systems?



1. At high latitudes (>70°) easterlies blow towards the west
2. In the subtropics (10-30°) extensive, but moderate trade winds are found mainly over the oceans
3. Monsoons are seasonally reversing (sub)tropical winds that for the large Asian land mass blow from land to the sea in summer (v.v. in winter)
4. The area of the doldrums is predominantly calm and can be found around the equator (10°N-10°S)
5. The westerlies at mid-latitudes (30-70°) are stronger in the S-Hemispere but exhibit a larger seasonality in the N-Hemisphere
6. Local effects are sea and land (blowing from land to sea) breezes

4. Global wave and tidal environments

Chapter 4 of lecture notes

A. Zonal wind systems
B. Global wave environments
C. Global tidal environments
D. Coastal impact

4-B Global wave environments

Wave environments

- Closely related to:
  - the wave generating systems i.e. the global and regional wind and cyclonic regimes
  - The shape and orientation of the oceans and coastlines

4-B Global wave environments

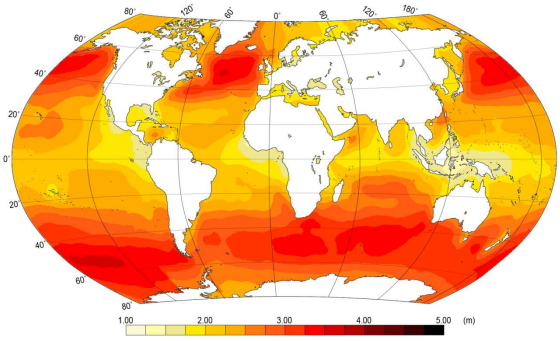
Annual mean values of significant wave heights

wave height classes

low wave energy:
H_s < 0.6 m

medium wave energy:
0.6 m < H_s < 1.5 m

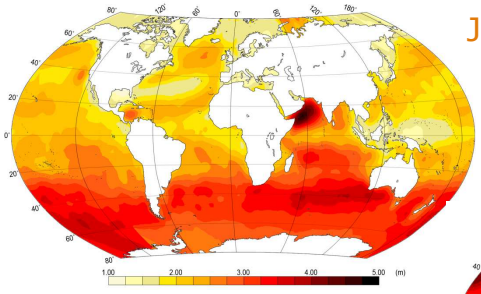
high wave energy:
H_s > 1.5 m



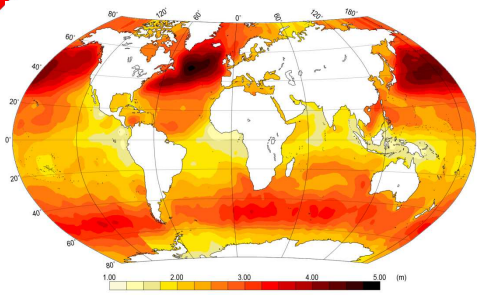
4-B Global wave environments

Monthly mean significant wave heights

July

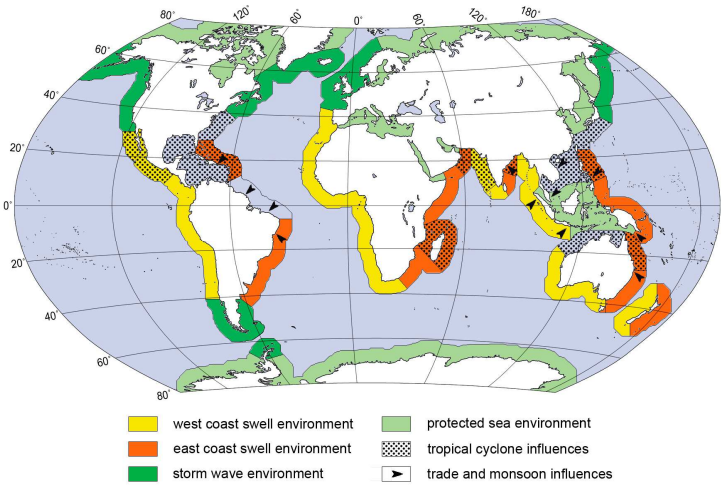


January



4-B Global wave environments

World-wide distribution of wave environments



4-B Global wave environments

Storm wave climate (1)

- most energetic wave environment
- located between 40° and 60° N and S
- year-round in SH
- in winter in NH
- locally generated by westerlies

4-B Global wave environments

Storm wave climate (2)

- steep, short-crested, irregular and multi-directional waves (sea)
- westerly to south-westerly directions
- deep water wave heights:
  - 2-3 m 90% of the time
  - 5-6 m 10% of the time
- periods for instance 5 s, longer during storms

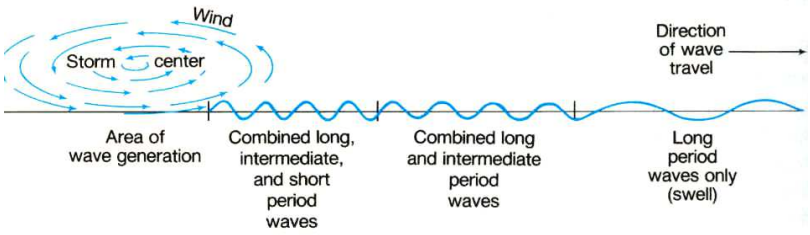
4-B Global wave environments

West coast swell climate (1)

- located between 0-40° (N and S)
- originate from NH and SH storm wave belts
- reaches west coasts of Americas, Africa, Australia and New Zealand
- year-round in SH
- in winter in Northern hemisphere
- in tropics swell can also stem from trade winds

3-C Linear propagation

Transformation of sea waves into longer, faster and lower swell waves outside area of wave generation



- Waves of different lengths will disperse (spread out) because they propagate at different speeds
- Dissipation processes favour shorter waves and hence filter them out
- Propagation in various directions

Exam question 2010:

Why are swell waves lower and longer than storm waves?

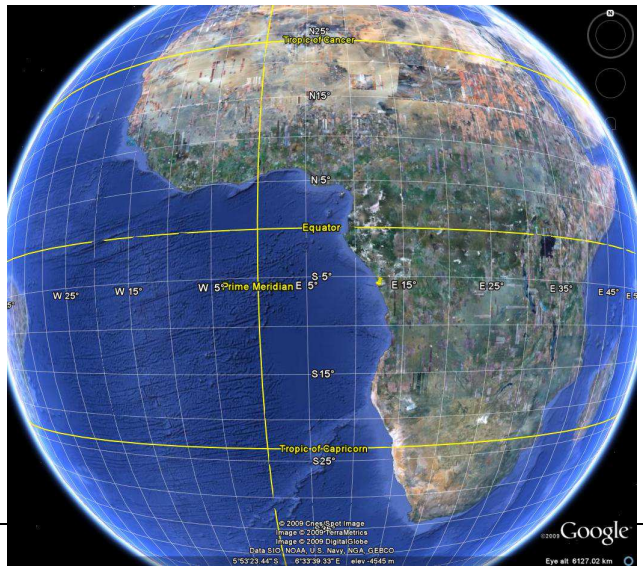
4-B Global wave environments

West coast swell climate (2)

- persistent and long waves (typical period 10 s)
- uniform in direction, shape and size
- typical wave heights 1-2 m
- not much variation in wave heights around the mean (only as result of tropical storms)
- arriving from northwest in the NH and from southwest in the SH
- higher in the higher latitudes and slowly decreasing toward the equator

4-B Global wave environments

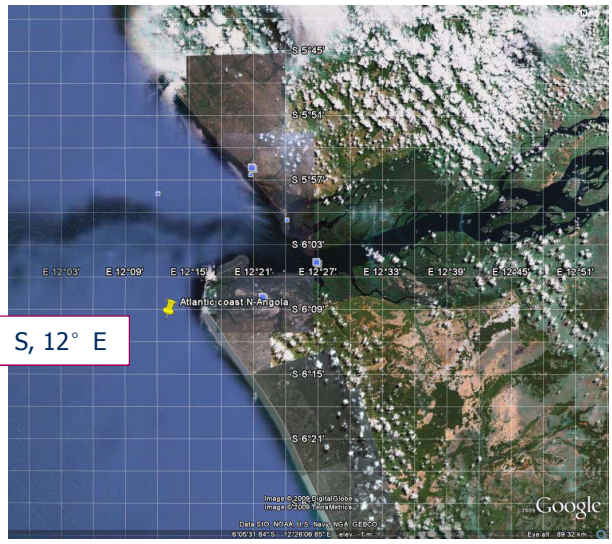
Atlantic coast N-Angola



TU Delft

4-B Global wave environments

Project location



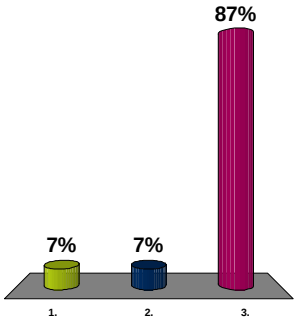
6° S, 12° E

TU Delft

4-B Global wave environments

What are the expected offshore wave conditions?

1. Hardly any waves most of the time because of location in ITCZ (calm doldrums)
2. As 1, but with high storm waves around July (Southern-Hemisphere winter)
3. ✓ Year-round low swell waves from predominantly SW directions



4-B Global wave environments

Long-crested swell waves from two distinct directions (main swell from SW and secondary swell from NW)

Atlantic coast, Angola

4-B Global wave environments

Conditions at project site?

4. Global wave and tidal environments

Chapter 4 of lecture notes

A. Zonal wind systems
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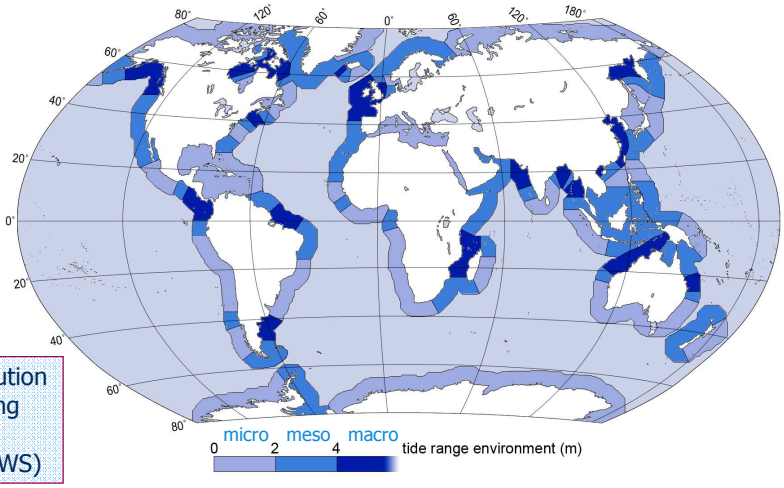
C. Global tidal environments
D. Coastal impact

4-C Global tidal environments

Global variations in tidal range controlled by large-scale coastal configuration

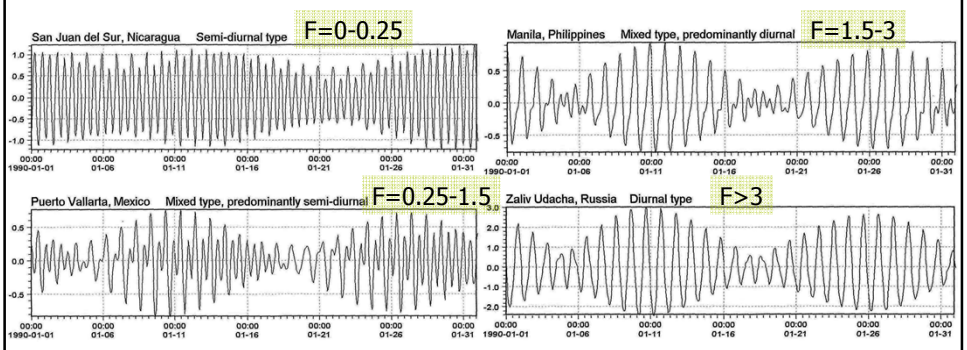


World distribution of mean spring tidal range (MHWS – MLWS)

4-C Global tidal environments

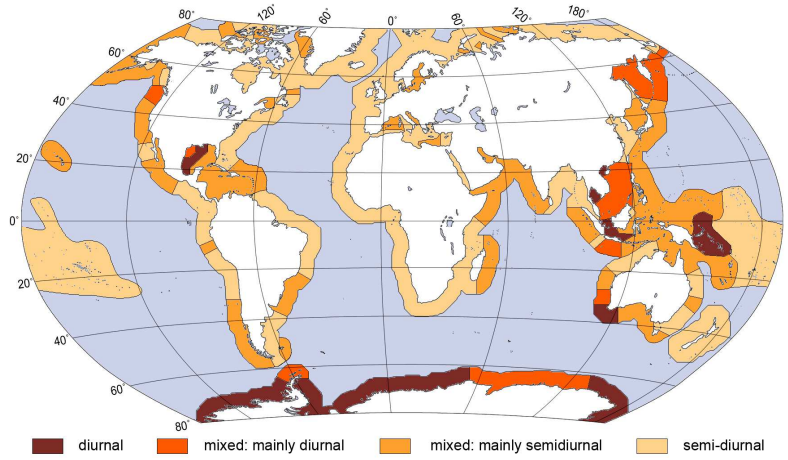
Character of the tide is determined by importance of diurnal versus semi-diurnal components

Form factor F expresses tidal character:
$F = (K1 + O1)/(M2 + S2)$



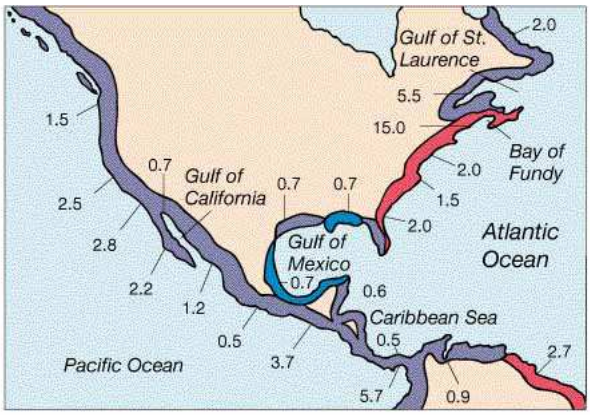
4-C Global tidal environments

Tidal environments: semi-diurnal, mixed, diurnal



4-C Global tidal environments

Local tide depends on size, shape and depth of basin



Exam question june 2010

Diurnal
Semidiurnal
Mixed
2.7 Spring tide range (meters)

Exam question june 2010

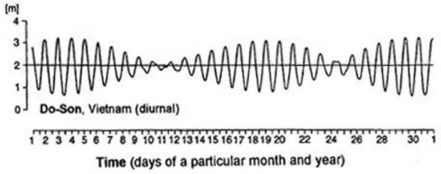
2. Tidal generation and propagation [8 points – 19 minutes]

8(75)

Consider a landless earth.

a. **[3]** Would you rather expect diurnal tides closer to the equator or closer to the poles? Support your explanation with a sketch of the earth and its tidal bulges.

Consider the following tidal curve from Do-Son, Vietnam.



b. **[3]** Elaborate on a possible reason that a diurnal tidal curve is found for this location.

The tidal character is often described by the so-called form factor F given by:

$$F = (K1 + O1)/(M2 + S2) \quad (2)$$

In this expression K1, O1, M2 and S2 represent the amplitudes of the respective tidal elevation components.

c. **[2]** Is it likely that the form factor for Do-Son is $F = 0.25$? Why (not?)

4. Global wave and tidal environments

Chapter 4 of lecture notes

A. Zonal wind systems
B. Global wave environments
C. Global tidal environments
D. Coastal impact

4-D Coastal impact

Storm wave climate: high and short waves and highly variable

dimensionless fall velocity :

$$\Omega = \frac{H_b}{w_s T}$$

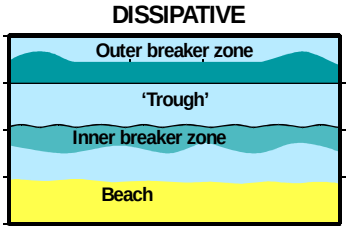
with : H_b is the wave height at breaking

w_s is the sediment fall velocity

- Higher and shorter waves give **wide and flat** sandy coastal zone with **multiple bars**, dunes and a wide beach:
  - High waves break at large water depths
  - High waves tend to move sediment offshore
  - "Spilling" breakers
- Variability in wave heights results in:
  - **highly dynamic** coastal profile

4-D Coastal impact

At end of spectrum: Dissipative beach (Ω>6)



Muriwai, NZ

Aracaju, NE Brazil

4-D Coastal impact

Swell (and monsoon) wave climate: low, long waves (relatively constant in time)

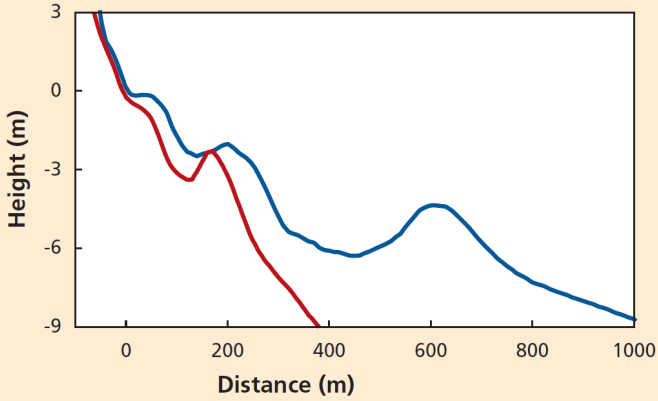
- Low and long waves break close to the shore and tend to move sediment onshore
  - Narrow sandy profile
  - Steep
  - Berms
- Less dynamic

Jibbon (Sydney)

At end of spectrum: reflective beach $\Omega<1$

4-D Coastal impact

Egmond (blue) vs Surfers Paradise (red)



4-D Coastal impact

Wave and tide influence

Wave dominated features

- dynamic sandy coastal profile with bars and dunes
- beach slope dependent of wave characteristics

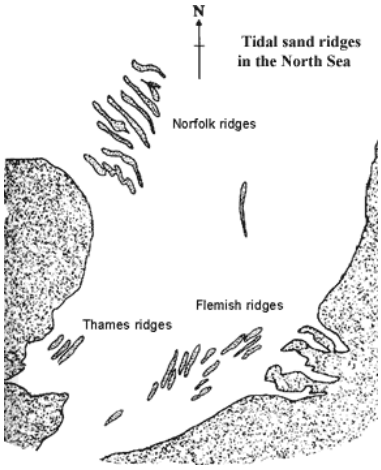
Tide dominated features

- tides smear beach morphology
- wide, low-gradient and muddy tidal flats
- salt marshes, mangroves
- tidal ridges

4-D Coastal impact

Wave and tidal influence

Dorset, UK



Exam question april 2010

9(90)

1. Wave environment and coastal impact [9]

Consider a deep water wave climate at a certain location on earth that is classified as *west coast swell environment*. These swell waves reach a nearby coastal stretch consisting of long sandy beaches.

a. **[3]** Where are swell waves predominantly generated? In your explanation do not forget to specify latitude(s) and hemisphere(s). (50 words).

b. **[3]** In swell wave environments wave heights are lower and wave periods longer than in storm wave environments. Can you explain this? (70 words).

c. **[3]** Describe qualitatively in what way the width and slope of the active profile differ between this coast and a coast dominated by storm waves. (40 words).