X JORNADAS DE GEOMORFOLOGIA LITORAL
Castelldefels, 4 a 6 de septiembre de 2019

On the genesis of new ridges at prograding coasts

Susana Costas, Katerina Kombiadou, Dano Roelvink

CIMA
CENTRE FOR MARINE AND ENVIRONMENTAL RESEARCH

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United Nations Educational, Scientific and Cultural Organization

IHE DELFT
Institute for Water Education under the auspices of UNESCO

Deltares
Enabling Delta Life

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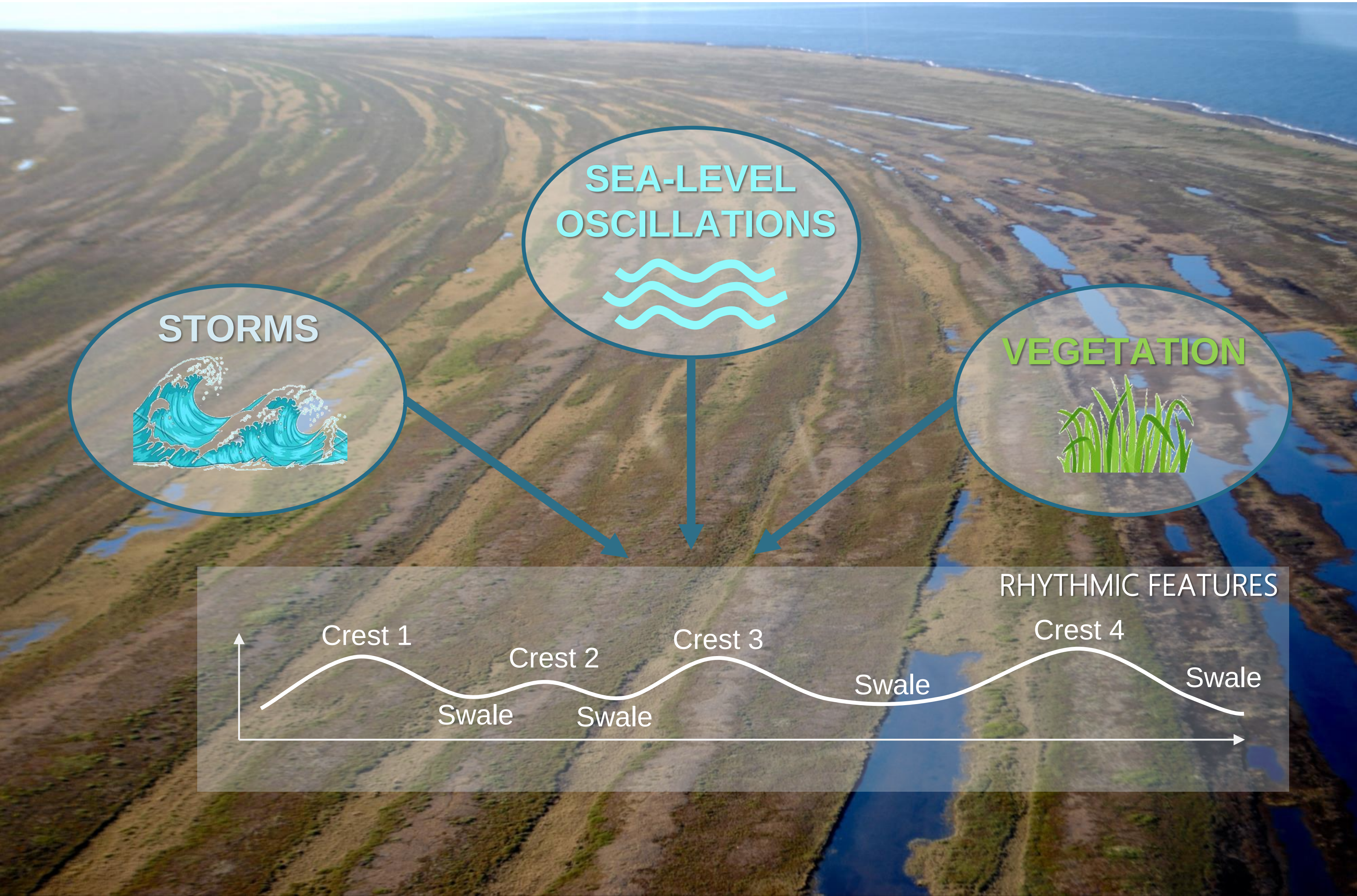
Introduction

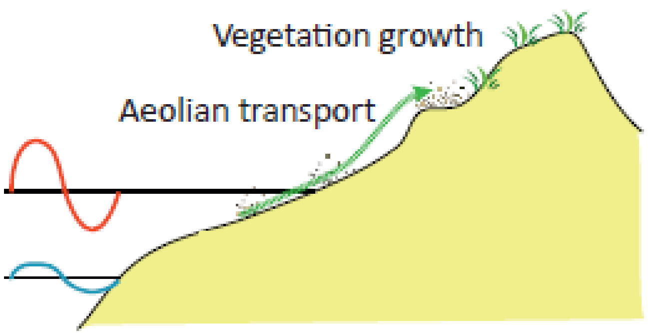
How do these rhythmic features form?



The approach

Modeling nearshore and aeolian processes

PROCESSES



PROCESS-BASED MODELS

Wind	[V_{10m} dir]	→	**1D Duna**
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Roelvink & Costas, 2019. Environmental Modelling & Software

The approach

Modeling nearshore and aeolian processes

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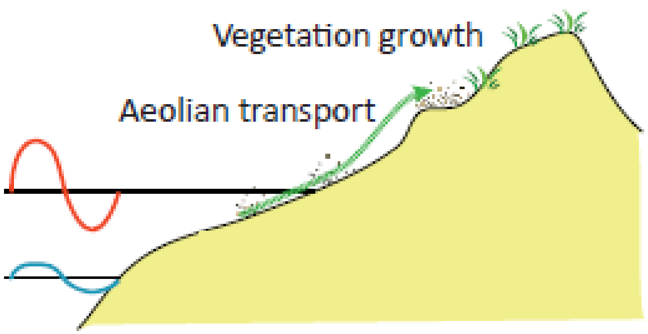

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XBEACH EXTRA FUNCTIONALITIES

- Longshore sediment transport gradients (lsgrad)
- Bermslope effect (upslope tansport solution for swash processes)

DUNA COMPONENTS

i. **Wind model** (Kroy et al. 2002)

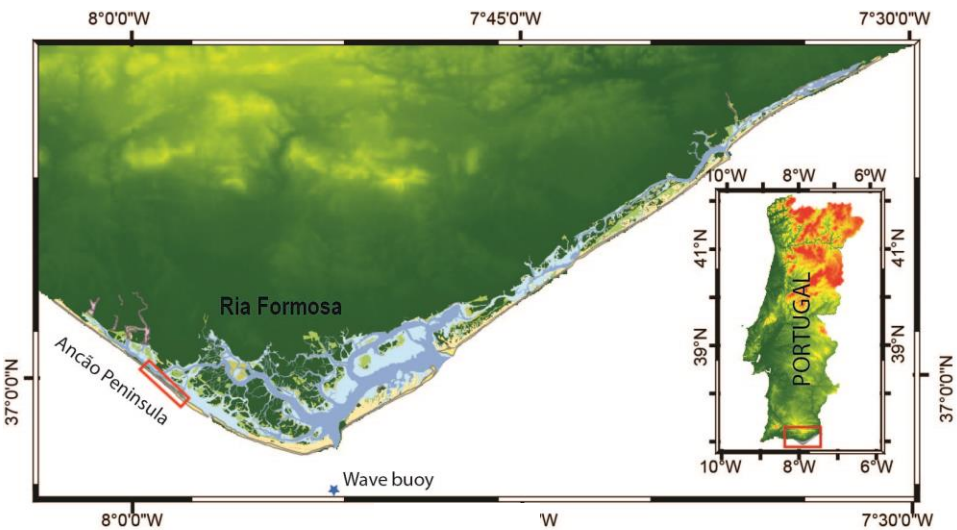
ii. **Sediment transport model** (Bagnold 1936, Sauermann et al. 2001)

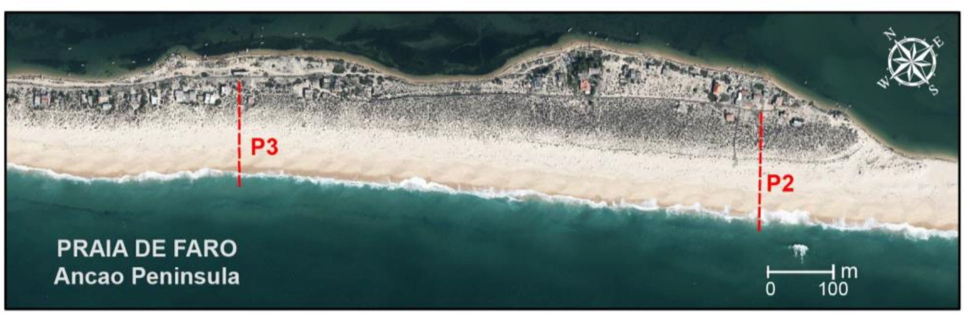
iii. **Vegetation growth model** (loosely based on Durán & Herrmann 2006)

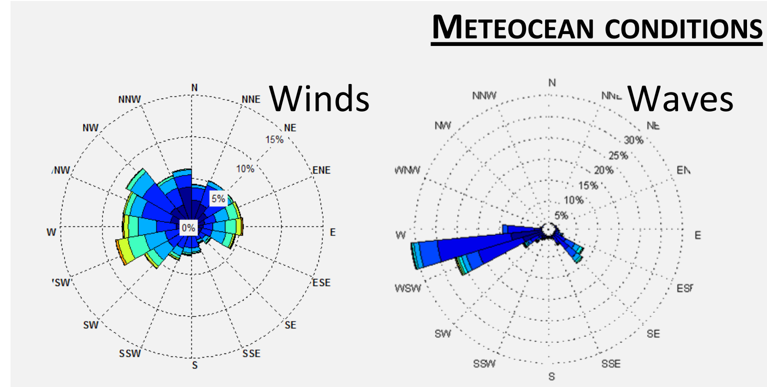
The approach

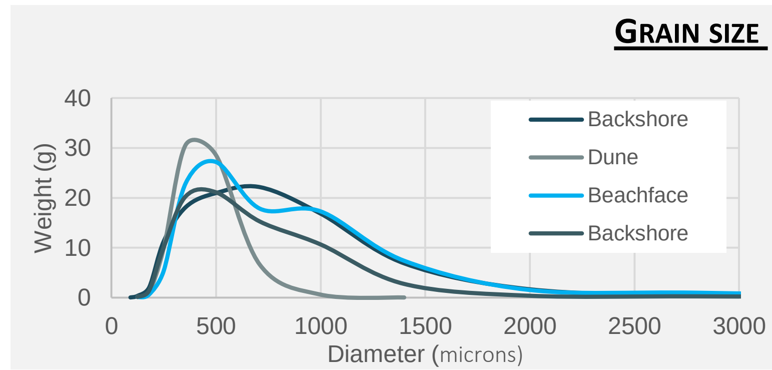
Boundary and forcing conditions

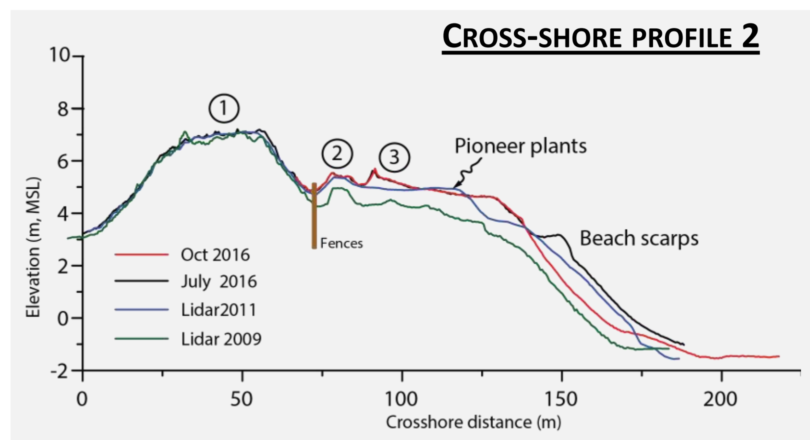
Test site: Praia de Faro











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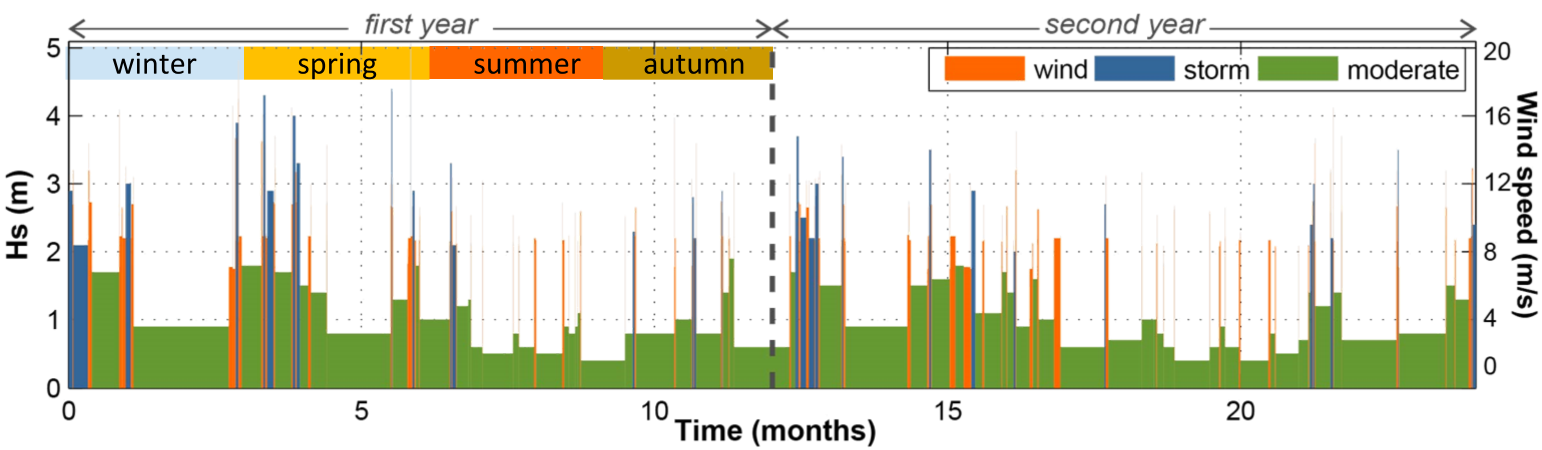
The approach

Boundary and forcing conditions

Esquematized wave and wind conditions for the period 2009-2011



- Intra- and Interannual varibility;
- First year stormier than the second year
- Storm H0 > 2 m
- Morfac; moderate (25) and storms (5)
- Winds above critical velocity relatively rare

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Simulations

- Testing variable sediment supply and wind strength over 20 yrs

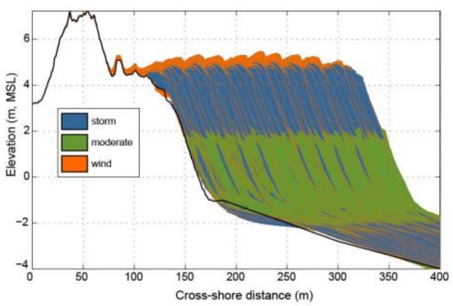
DUNA & XBEACH	longshore gradient (LS in 10^{-4} m^{-1}) (longshore sediment transport rate m/yr))				
$V_{wind} \cdot 1$	2 (5 m/yr)	3.5 (7.5 m/yr)	5 (11 m/yr)	6.5 (15 m/yr)	8 (18 m/yr)
$V_{wind} \cdot 1.2$	2 (5 m/yr)	3.5 (7.5 m/yr)	5 (11 m/yr)	6.5 (15 m/yr)	8 (18 m/yr)

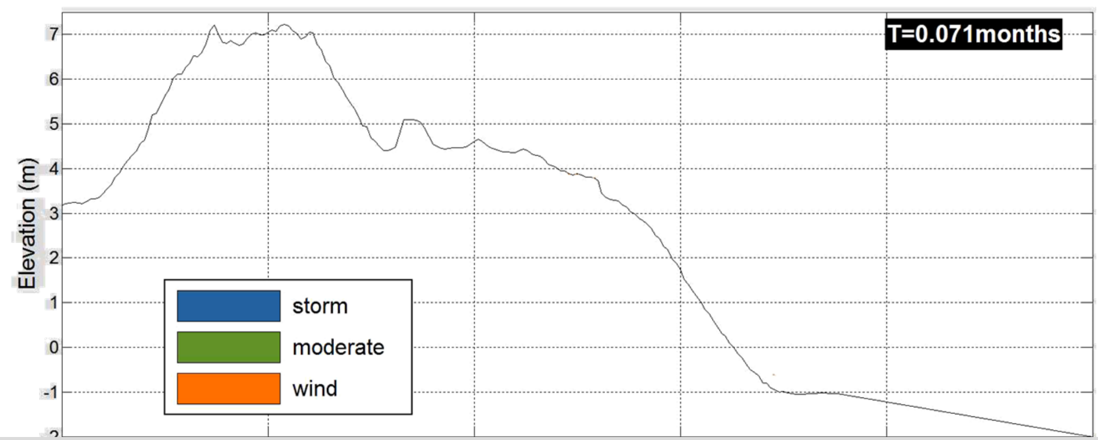
- Runs excluding marine conditions

DUNA	longshore sediment transport rate (m/yr)		
$V_{wind} \cdot 1$	47 m/yr	72 m/yr	97 m/yr

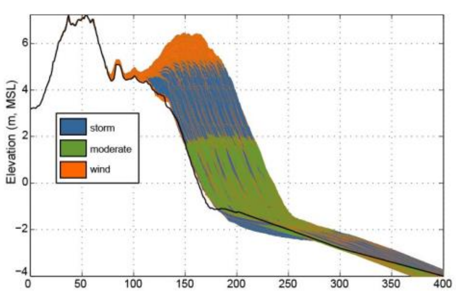
Results

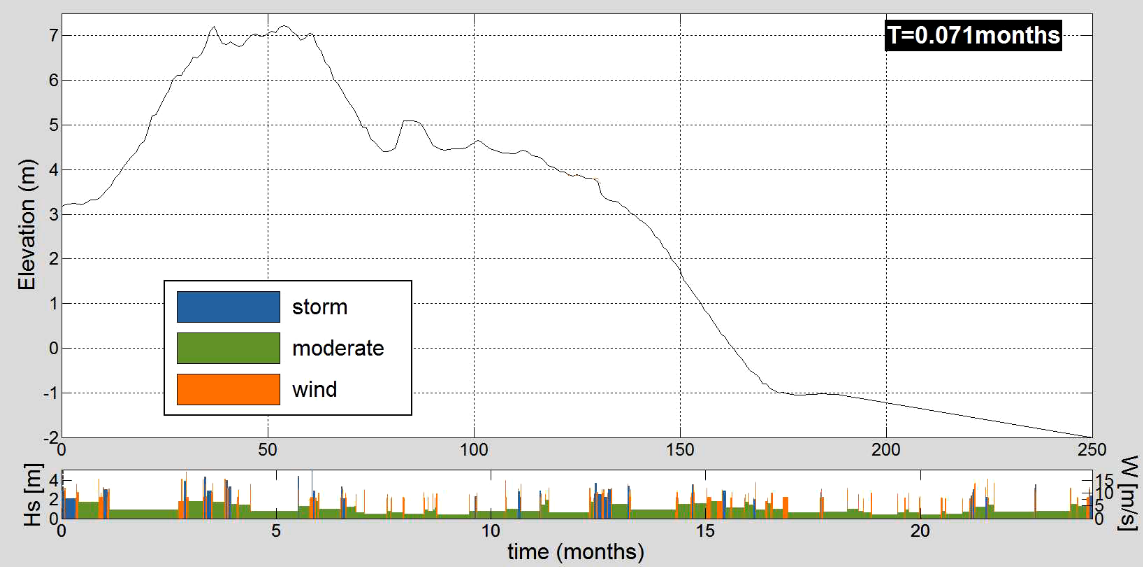
Progradation
11m/s





Progradation
5m/s

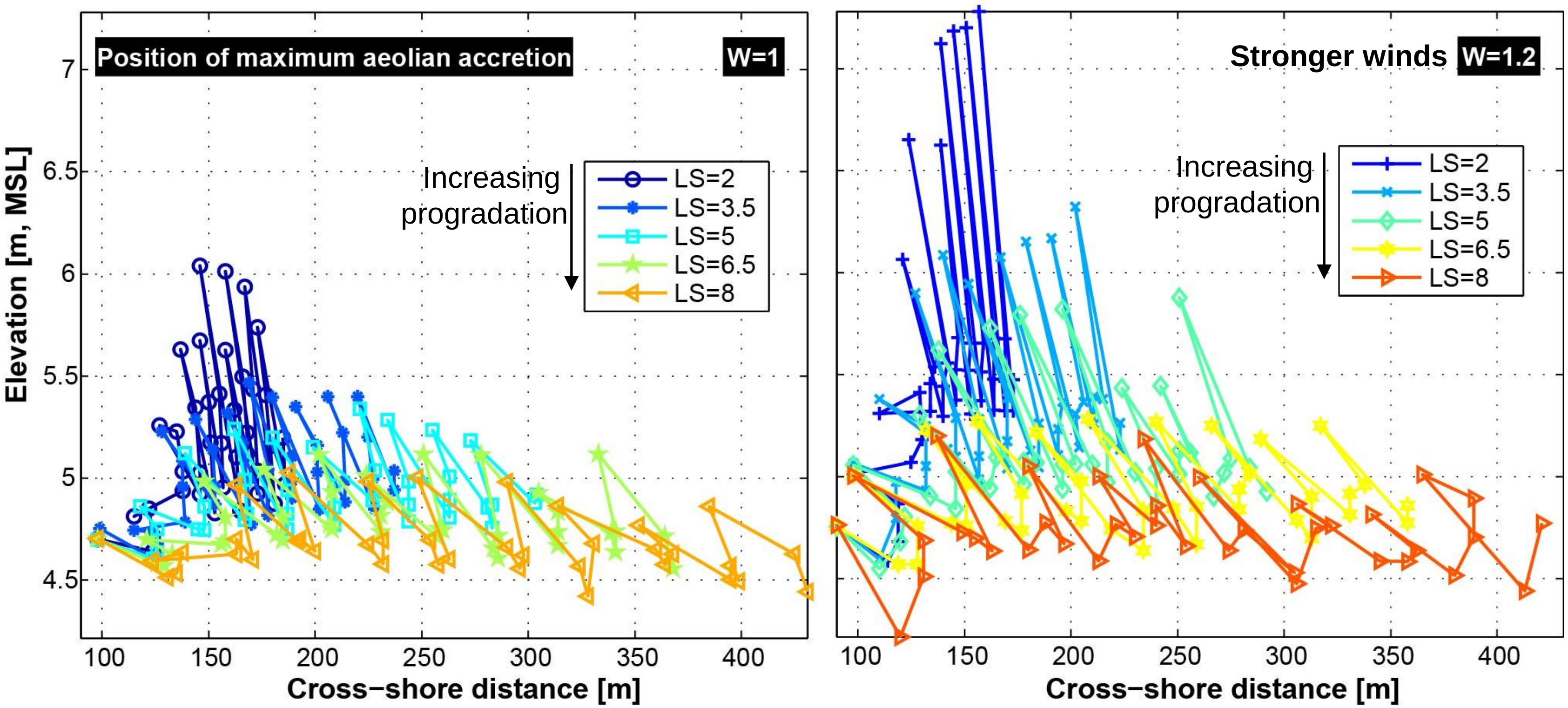




Results

Spatial distribution of the maximum aeolian accumulation

1. foredunes grow vertically during winter, when onshore winds are stronger,
2. stronger winds generate higher dunes,
3. higher progradation rates → backshore collonization during summer → vegetation barriers for sediment trapping seaward; contribute to the process of ridge isolation,
4. lower progradation rates → aeolian deposits coalescence; limited crosshore expansion.



Results

Overall…

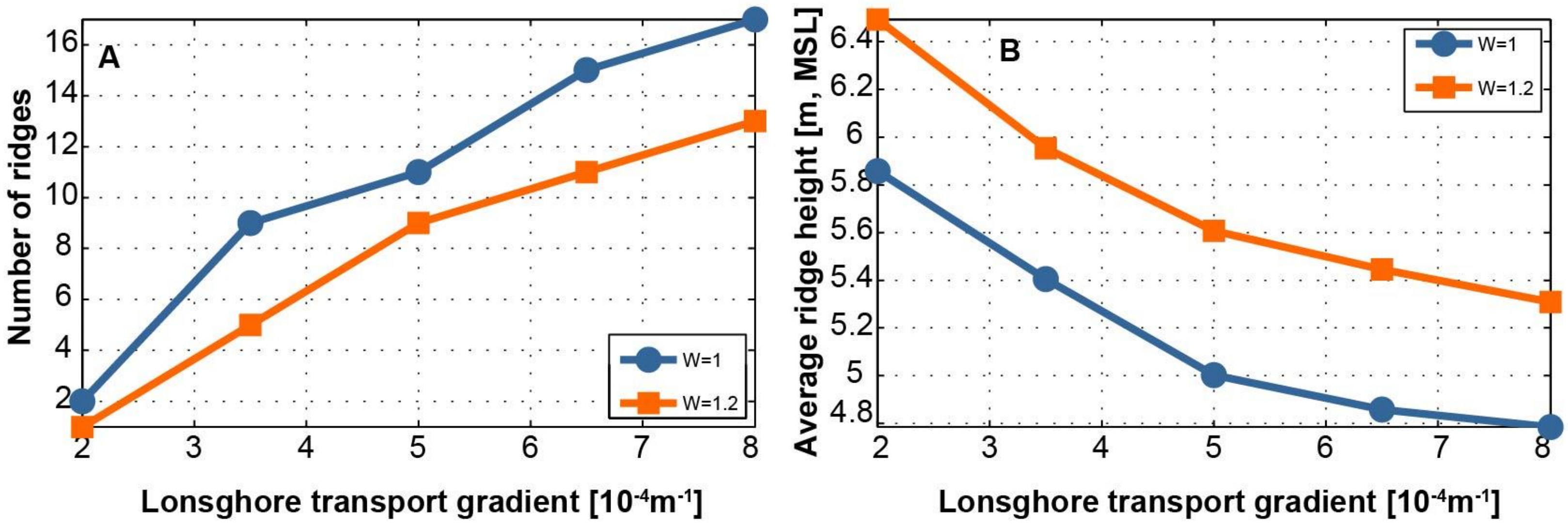
1. as progradation rates increase, the accumulation of aeolian sand is distributed across the barrier,

   higher progradation → greater number of new ridges,

   higher progradation → lower ridges,

2. foredune elevation also depends on the capacity of the wind,

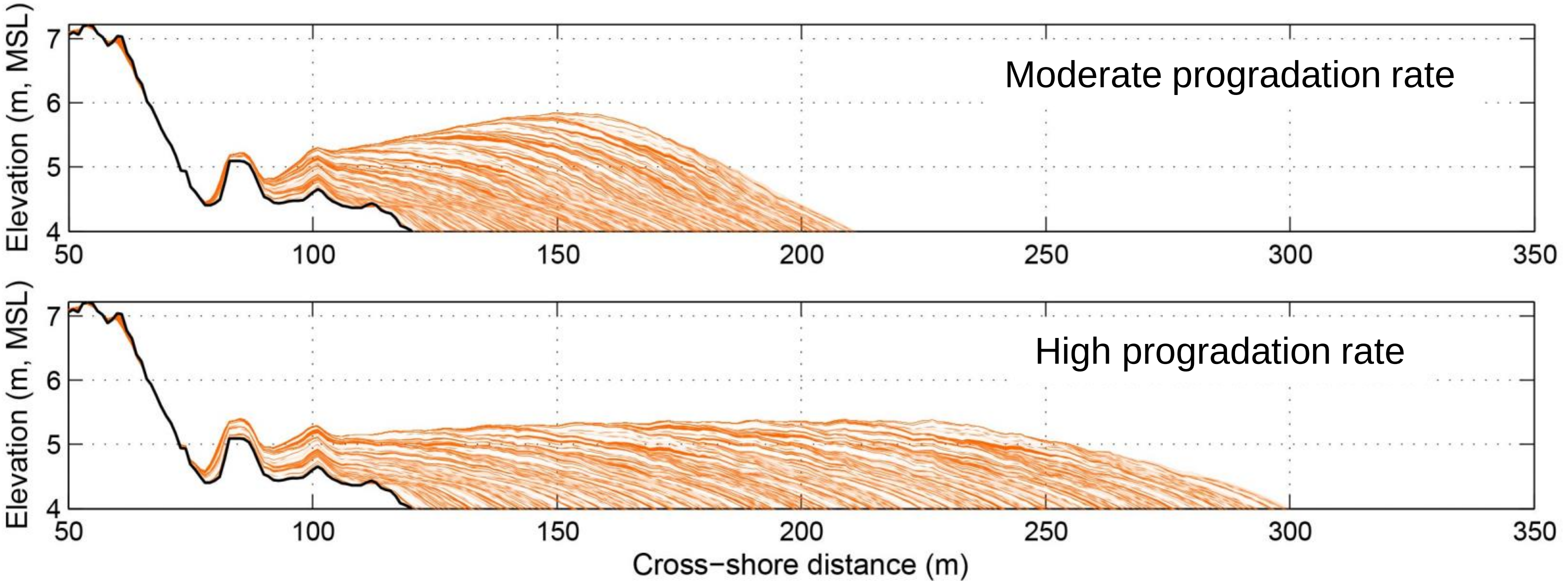
   stronger winds → higher dunes.



Results

Can we grow ridges excluding marine conditions ?

The isolated effect of aeolian sediment transport and progradation does not generate new ridges as topographical roughness is prevented



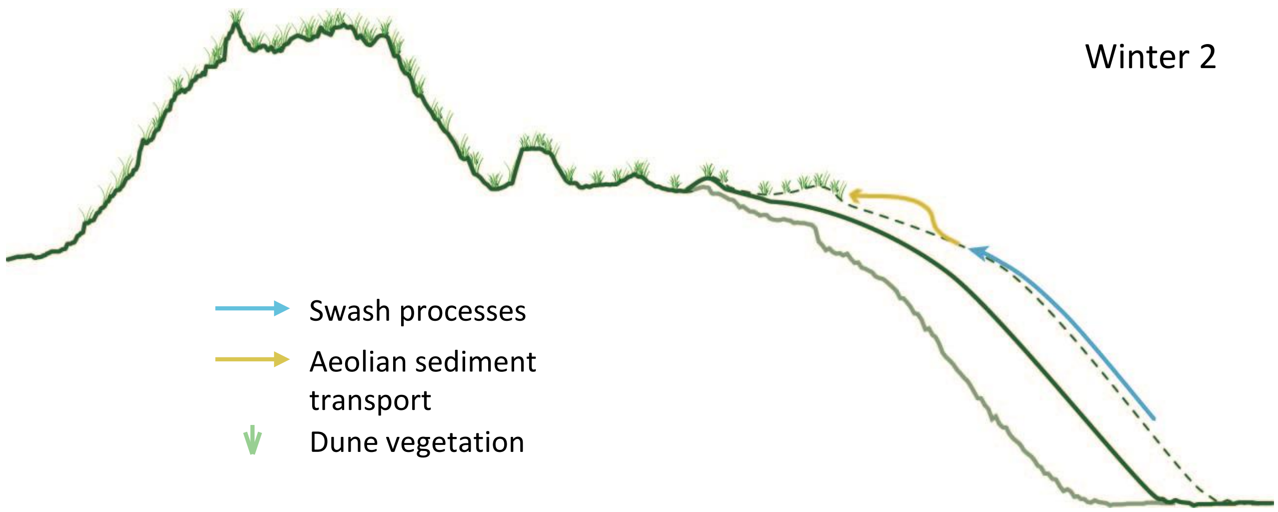
Insights...

i. The morphodynamic solution XBeach-Duna successfully generates new ridges

ii. The approach is sensitive to changes in progradation rate and wind strenght

iii. Ridges are generated after calm conditions (i.e. summer or less stormy winter)

iv. Intra- and interannual variability in marine conditions allow the seaward migration of the vegetation edge, shifting the point of aeolian accumulation and allowing the isolation or genesis of new ridges



Muchas gracias ..

Funding:

INVESTIGADOR FCT

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

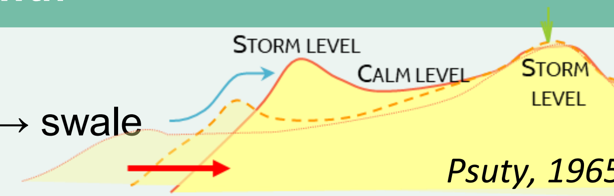
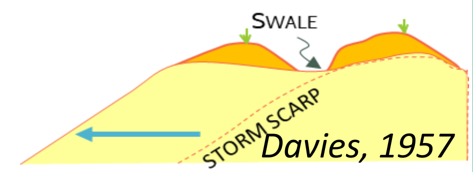
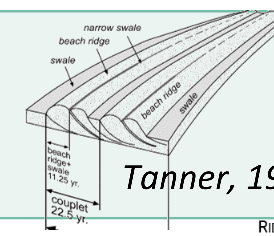
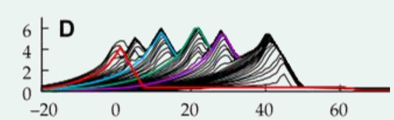
ENLACE

Exploring New approaches to simuLAte long-term Coastal Evolution FCT 28949

https://www.cima.ualg.pt/ENLACE/

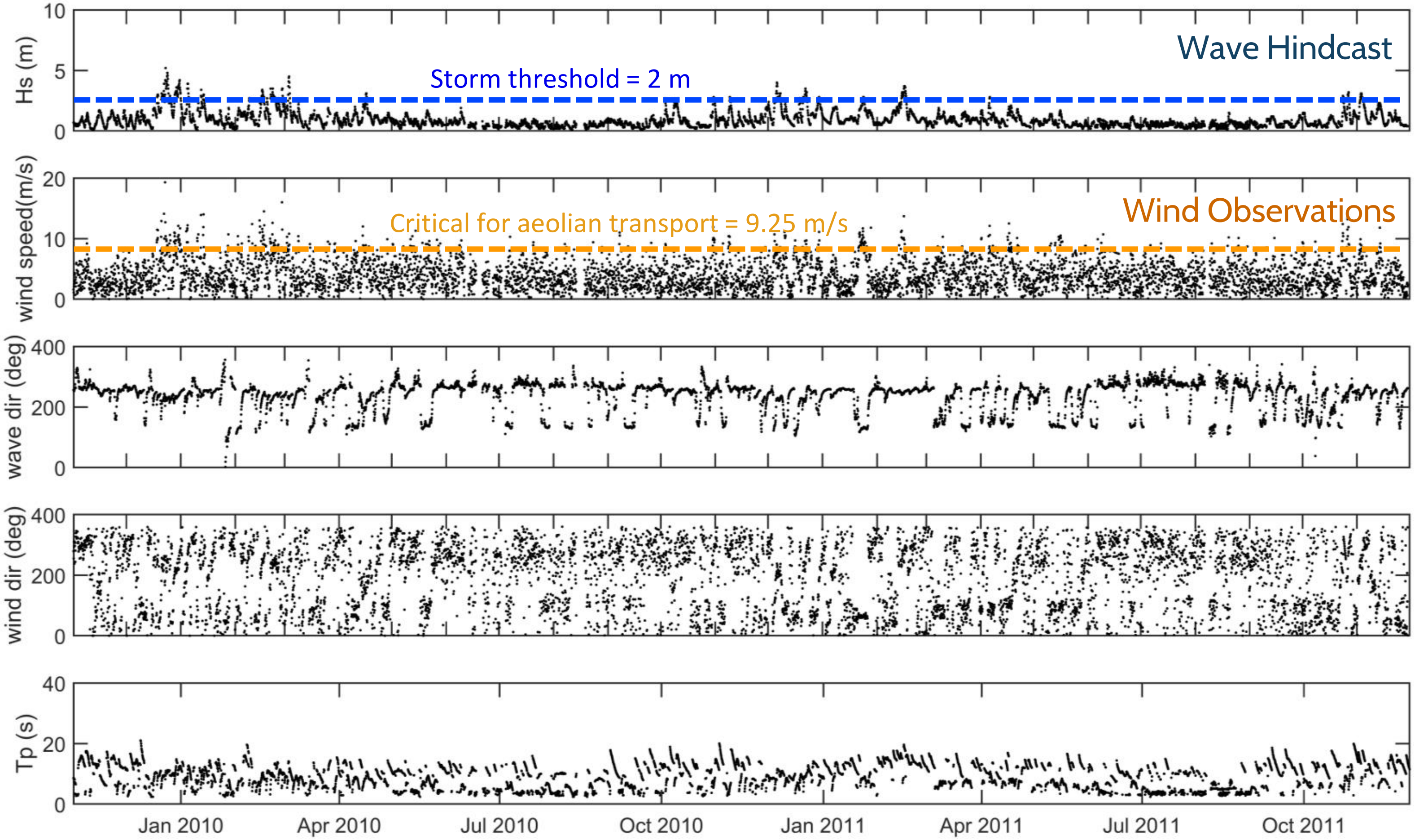
Introduction

Modes of ridge isolation and growth

Driver		Ridge-swale growth	
STORMS	(1) Storm Swash builds high berms	Calm conditions → swale	 *Psuty, 1965*
	(2) Fair-weather waves build high berms	Storm cuts → swale	 *Davies, 1957*
SEA-LEVEL OSCILLATIONS	(3) Higher water levels build higher berms	Lower water level → swale	 *Tanner, 1995*
VEGETATION	(4) Backshore vegetation within the swash limit traps sediment	Minimum deposition → swale	 *Hesp, 1984*
	(5) Autocyclic growth induced by geometric relationships	Lows formed because of progradation	 *Moore et al. 2016*

The approach

Boundary and forcing conditions

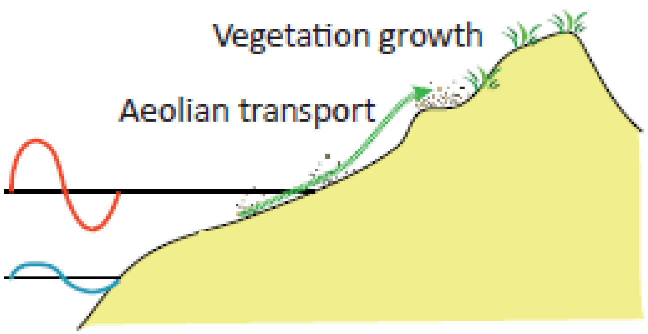


November 2009 to November 2011

The approach

Modeling nearshore and aeolian processes

PROCESSES



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Roelvink & Costas, 2019

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I. WIND MODEL

V_{wind} updated by local roughness, wind direction, lee slope

$$V_{wind} = f\ (z, vegett, lee\ slope, dir)$$

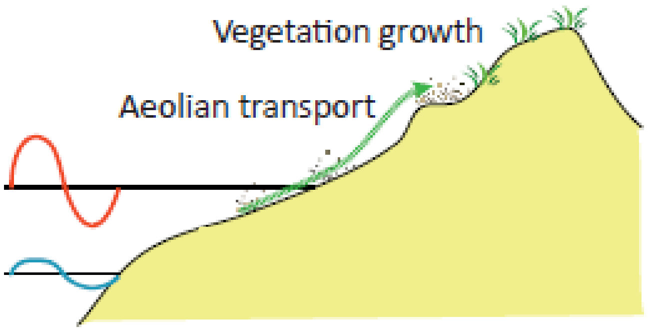
$V_{critical}$ updated by grain size, profile slope, moisture

$$V_{critical} = f\ (d, \Theta, M)$$

The approach

Modeling nearshore and aeolian processes

PROCESSES



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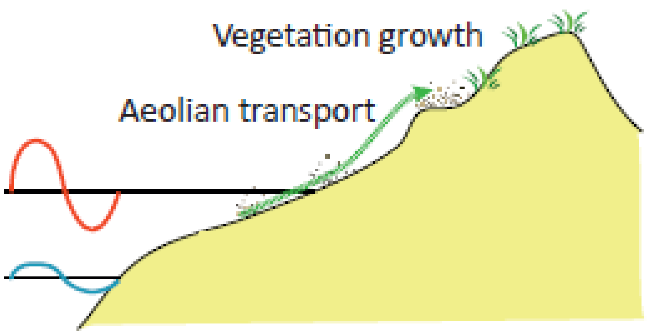
II. AEOLIAN SEDIMENT TRANSPORT

- Transport potential (Q)
- Equilibrium sediment concentration (C_u, function of V_{wind} and Q)
- Actual sediment concentration (including supply limiting factors)

The approach

Modeling nearshore and aeolian processes

PROCESSES



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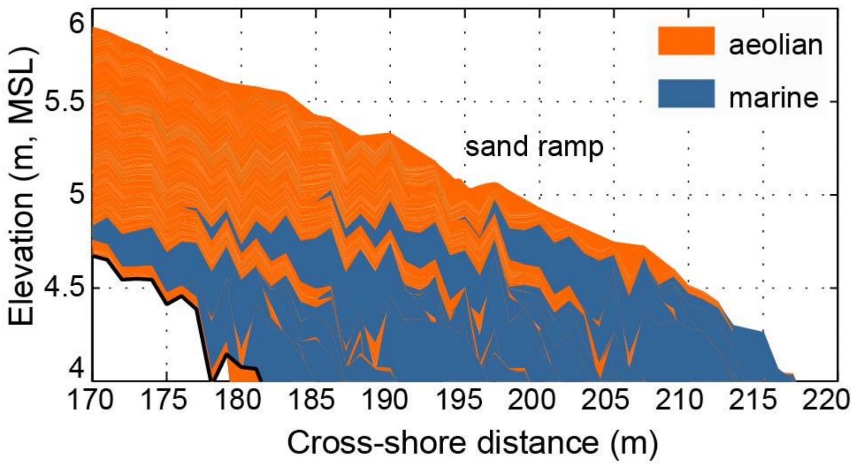
III. VEGETATION GROWTH MODEL

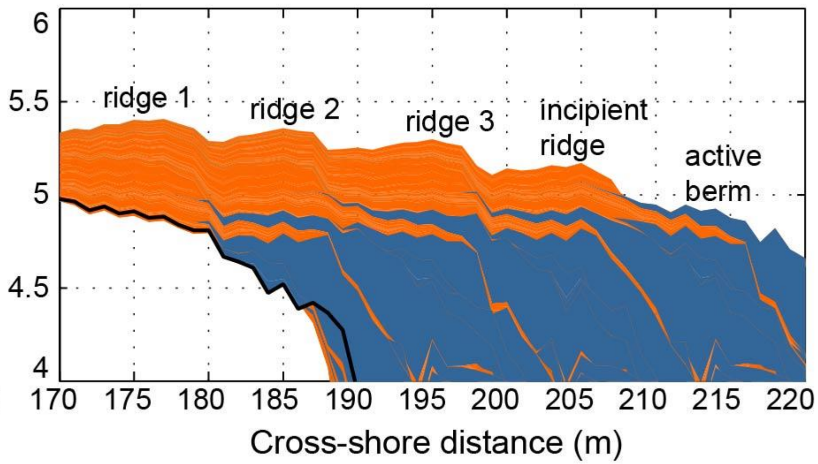
- Coverage and height crosshore zonation
- Sensible to sand burial and inundation

$$C_{veg}, H_{veg} = f\ (T_{growth}, z)$$

Results

- Ridge isolation only if backshore is stable; rarely affected by wave runup and erosion, plants eventually grow, available accommodation space
- Interannual variability might play a role
- Topographical irregularities, associated with the growth of new berms, may play a key part in the individualization of new ridges



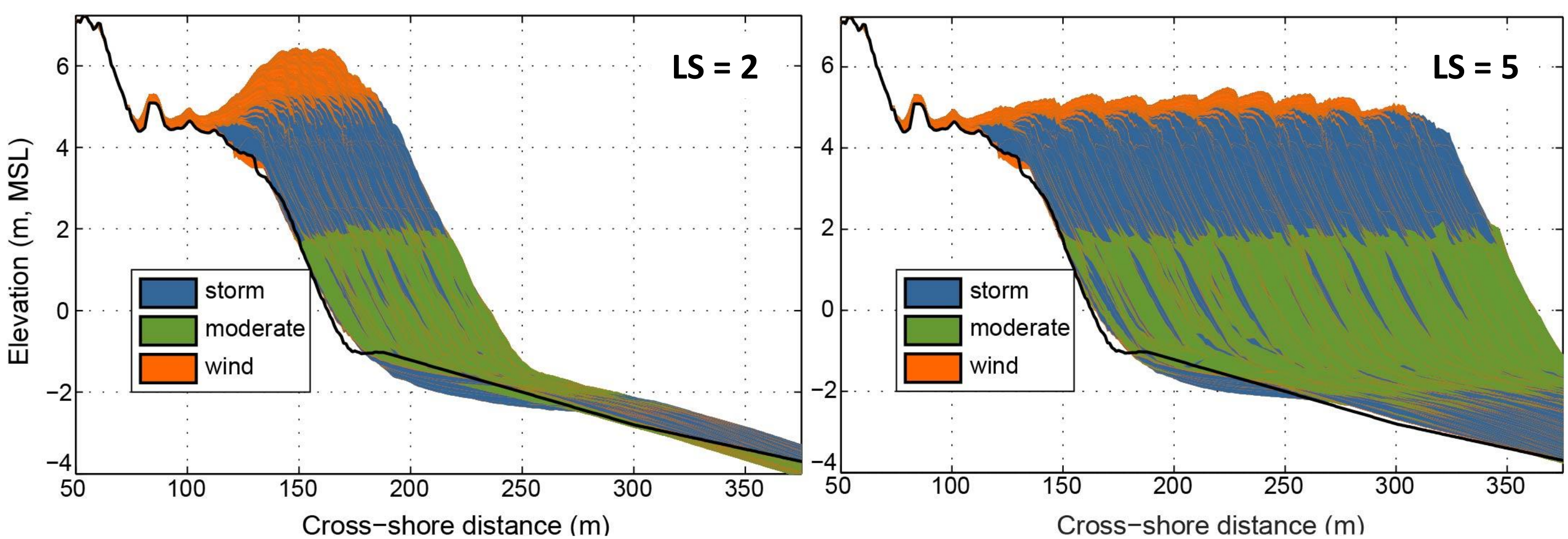


Intrannual varibility (seasonal)
Stormier winter
High runup prevents new ridges

Intrannual varibility (seasonal)
Less stormy winter
Calmer conditions allow new ridges

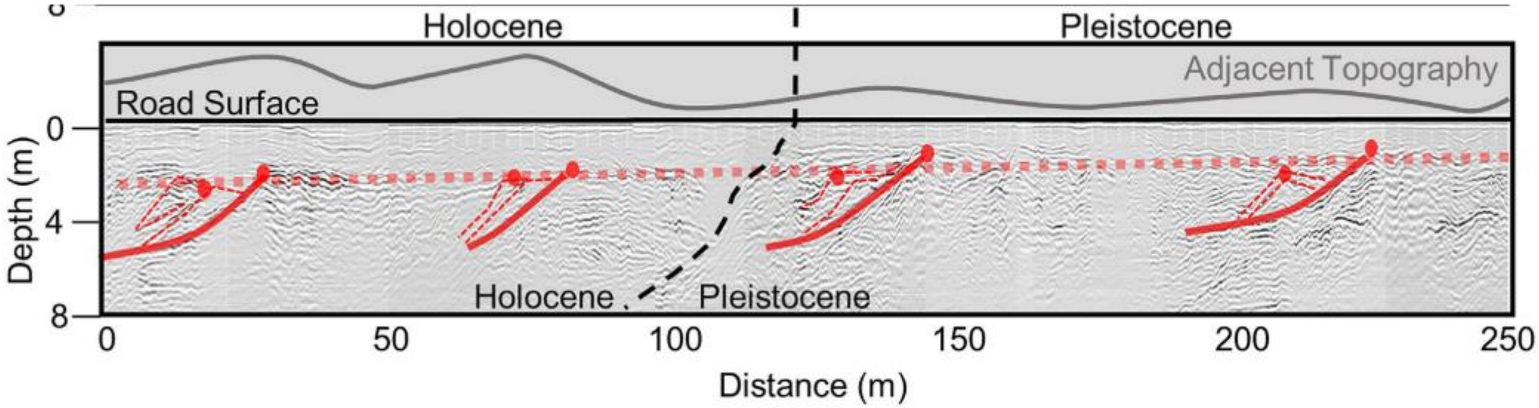
Results

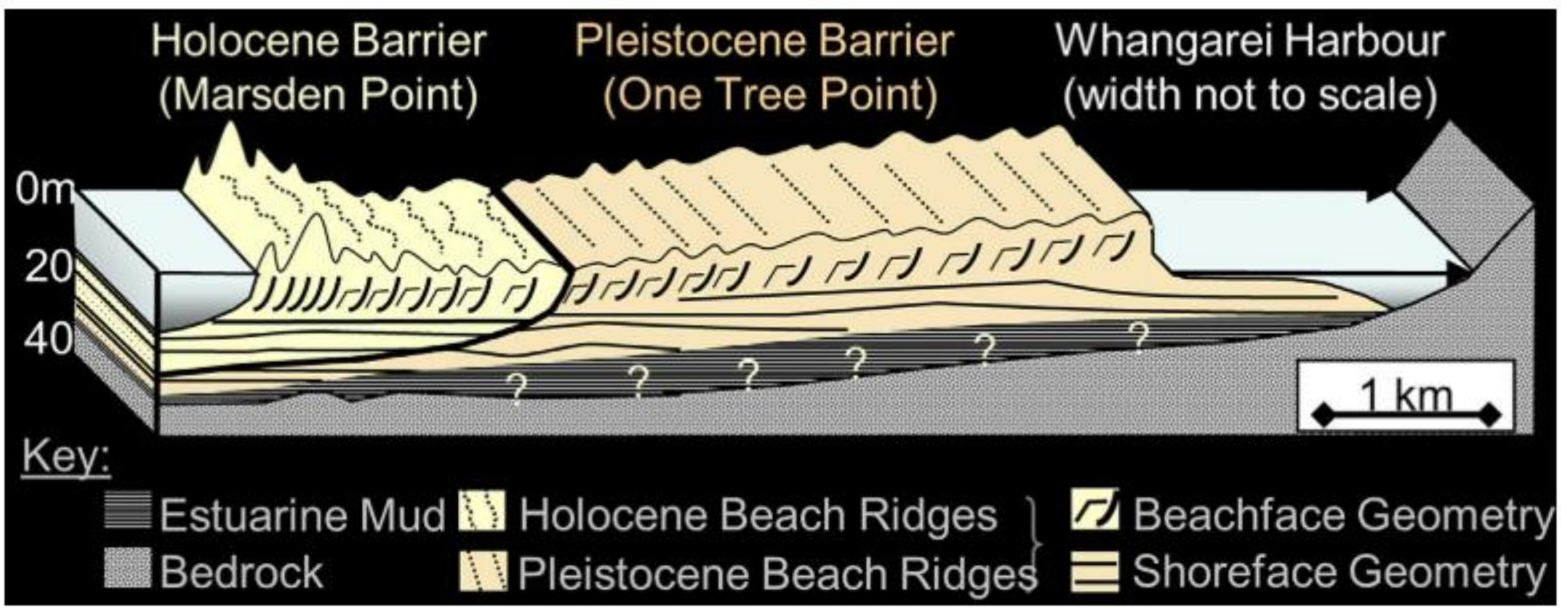
- ✓ Profile mostly shaped by **marine processes**
- ✓ **Storm conditions** dominate the upper profile by **building beach berms upwards**
- ✓ **Moderate conditions** dominate the **lower foreshore and inner nearshore**.
- ✓ **Seaward growth** of the beach occurs **during winter and spring**,
- ✓ The width of the emerged beach decreases with the advance of the dune vegetation cover in summer.
- ✓ Most of aeolian transport occurs during winter
- ✓ The beach-dune transition with alternating marine and aeolian processes



Introduction

Palaeoenvironmental reconstruction





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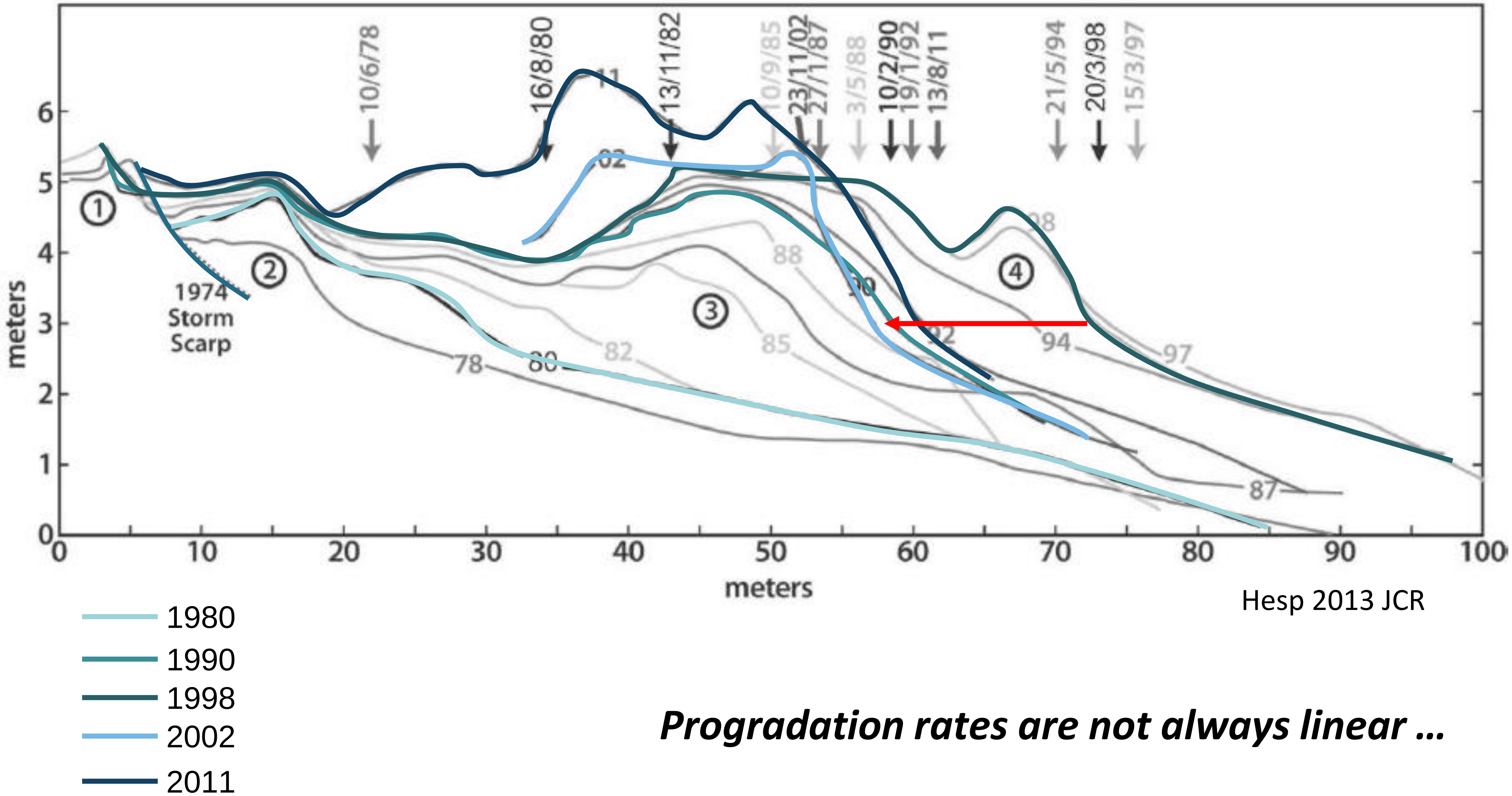
Introduction

Modes of ridge isolation and growth



Hesp 2013 JCR

Progradation rates are not always linear …

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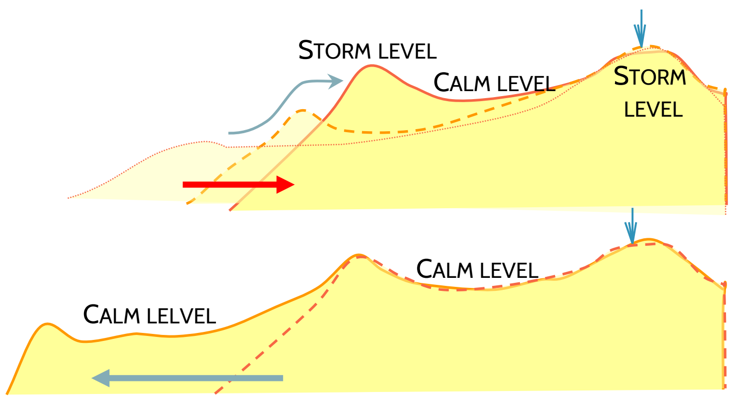
Introduction

Modes of ridge isolation and growth

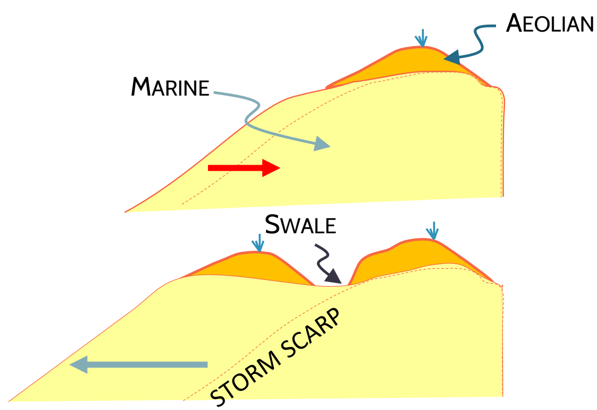
STORM WAVES – STORM SWASH RIDGE



- Alternate storm-calm conditions
- Storm waves erode the foreshore
- Swash builds a high berm during storms
- Calmer conditions allow progradation and ridge isolation

Psuty, 1965

STORM WAVES – STORM CUT-SWALE



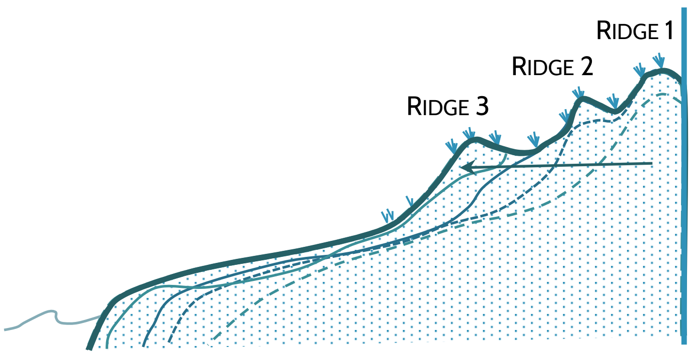
- Cut and fill
- Storms erode and create the swale or inter-ridge
- Storm waves erode the foreshore
- Wave-wind ridge formation

Davies, 1957; Bird, 1960

Introduction

Modes of ridge isolation and growth

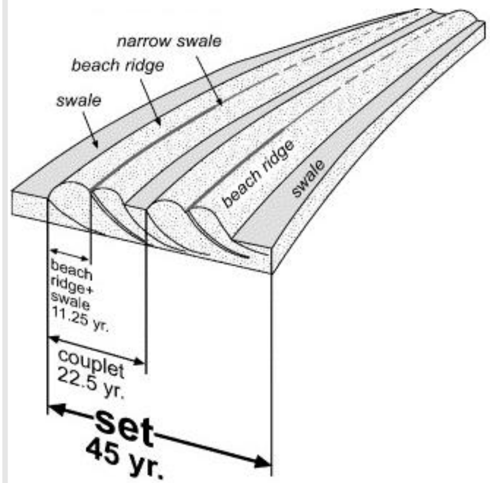
BACKSHORE SEEDLINGS



- Seeds germinate on backshore after being deposited
- Accumulation within the new vegetation cover
- New ridge after a new line of seedlings at the backshore

Hesp, 1984

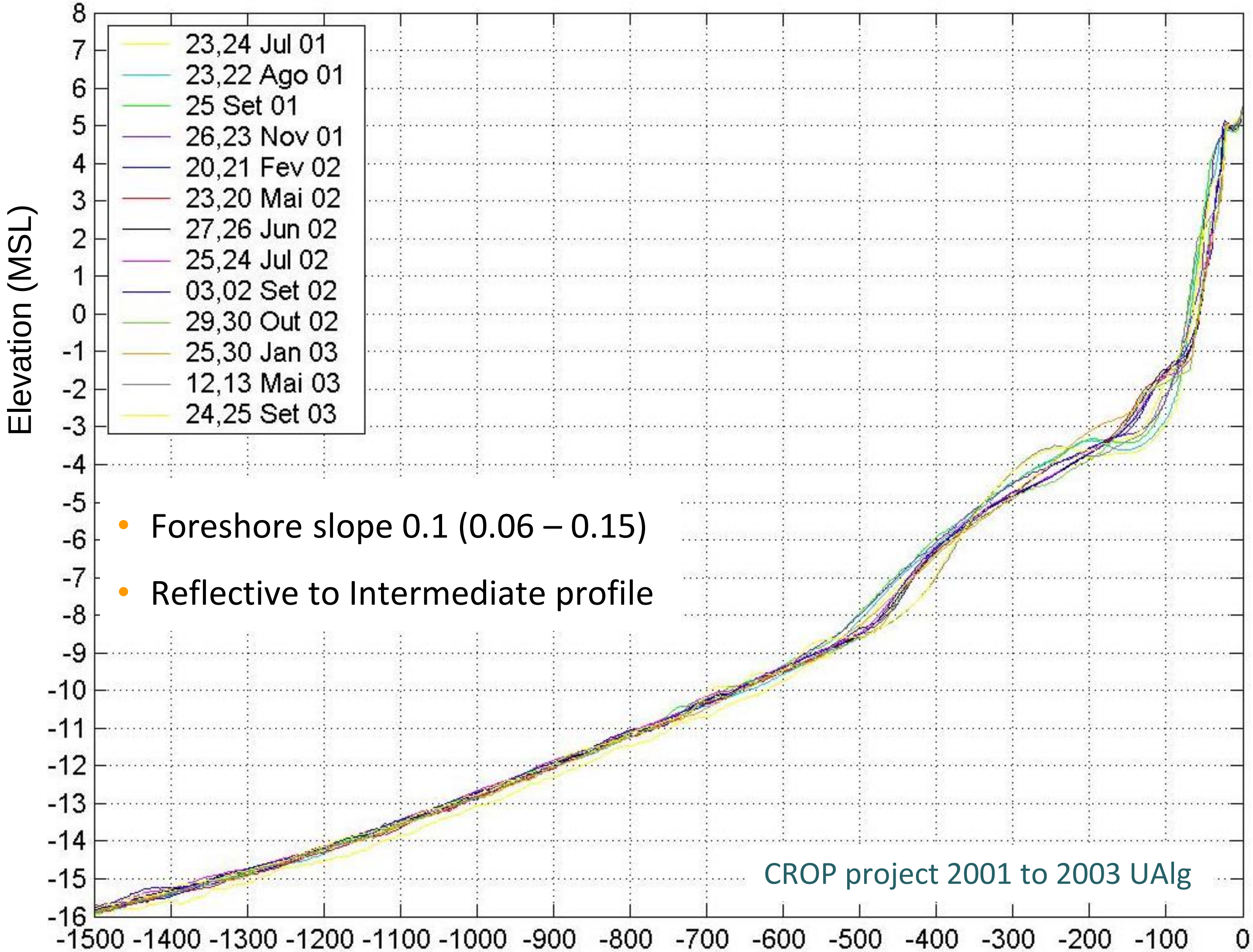
SEA LEVEL OSCILLATIONS



- Shifts in wave energy or water level oscillations
- Ridges built by fair-weather waver

Tanner, 1995; Goy et al. 2003

The approach



- Foreshore slope 0.1 (0.06 – 0.15)
- Reflective to Intermediate profile

CROP project 2001 to 2003 UAlg

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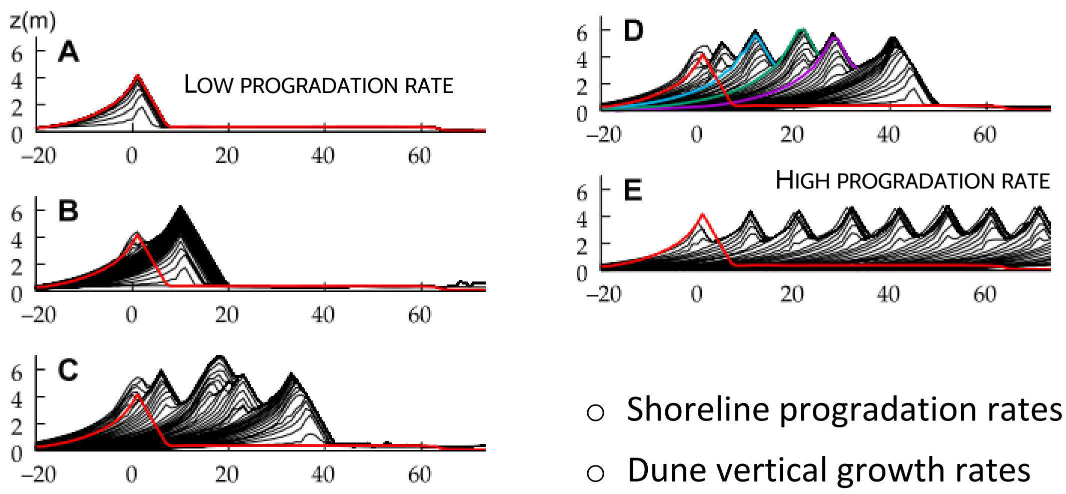
Introduction

Modes of ridge isolation and growth

INTERNAL FEEDBACKS



- Shoreline progradation rates
- Dune vertical growth rates
- New ridges develop without being affected by marine conditions

Moore et al. 2016

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Incresing wind strenght

Number of ridges

Incresing progradation rate