Modelling wave attenuation due to saltmarsh vegetation using a modified SWAN model

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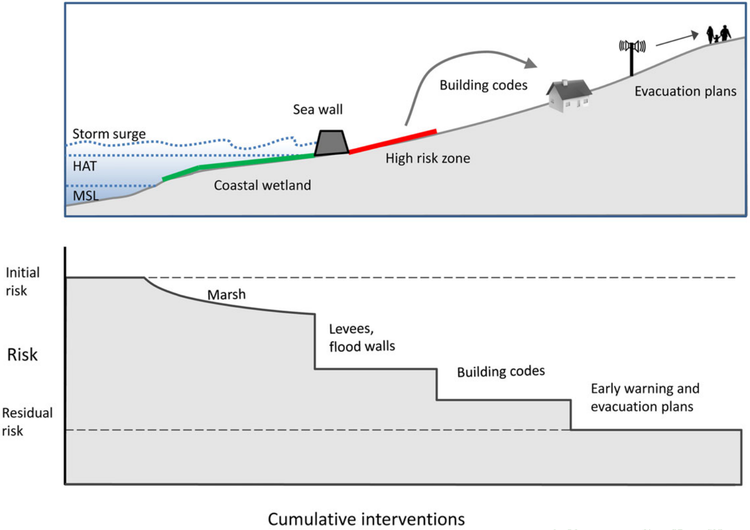
UNIVERSITY OF CAMBRIDGE RISC-KIT BLUE Coast Physical and biological dynamic coastal processes and their role in coastal recovery hydralabIV

Introduction

- Increased recognition of the role of coastal wetlands in coastal protection
- Coastal Protection is provided through a stable landform and hydrodynamic resistance by the vegetation
- Coastal vegetation (including saltmarsh) have been shown to dissipate waves

Wetlands as Coastal Defence



Spalding et al. 2014.

Wave energy dissipation due to vegetation

The vegetation wave dissipation formula is based on the Morison equation, which describes the force of a wave on a cylinder. The current SWAN vegetation uses a modified version of the Dalrymple et al. (1984) wave dissipation formula by Mendez and Losada (2004).

$$\langle \epsilon \rangle = \frac{1}{2\sqrt{\Pi}} \rho \tilde{C_D} D_v N_v \left(\frac{gk}{2\sigma} \right)^3 \frac{\sinh^3 kH_v + 3 \sinh kH_v}{3k \cosh^3 kh} H_{rms}^3$$

where ρ=water density, $\tilde{C_D}$=bulk drag coefficient, D_v=vegetation stem diameter, N_v=number of plants per m^2, k=mean wave number, σ=mean wave frequency, H_v=vegetation height, and h=water depth.

In SWAN, this formula has been extended to include the full spectrum by Suzuki et al. (2012) and incorporated as a sink term:

$$S_{ds,veg} = -\sqrt{\frac{2}{\Pi}} g^2 \tilde{C_D} D_v N_v \left(\frac{\tilde{k}}{\tilde{\sigma}} \right)^3 \frac{\sinh^3 \tilde{k} H_v + 3 \sinh \tilde{k} H_v}{3k \cosh^3 \tilde{k} h} \sqrt{E_{tot}} E(\sigma, \theta)$$

Wave energy dissipation due to vegetation in SWAN

Wave energy dissipation is a function the plant characteristics:

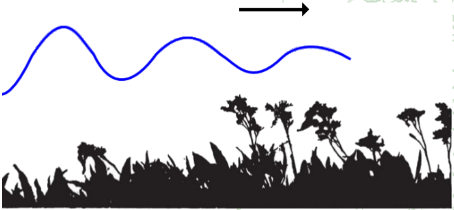
H_v : Vegetation Height

D_v : Vegetation diameter

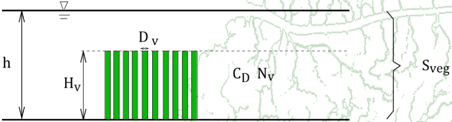
N_v : Number of plants per m^2

C_D : Bulk drag coefficient

Within SWAN-VEG D_v and N_v can vary spatially, and D_v, N_v and C_D can vary vertically. C_D is fixed over time, and H_v is fixed spatially



After Möller et al. 1999



After SWAN User Manual

Empirically calculated Drag Coefficient

$$K_C = \frac{U_m T}{D_v}$$

U_m : max bottom orbital velocity

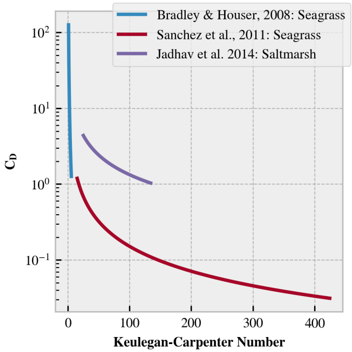
T : wave period

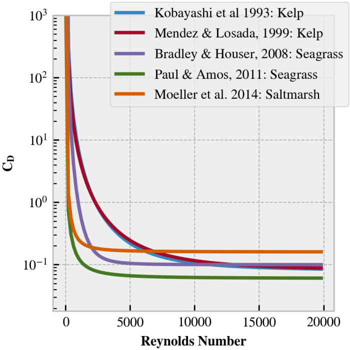
$$Re_v = U_m \left(\frac{D}{\nu}\right)$$

D : vegetation diameter

ν : kinematic viscosity

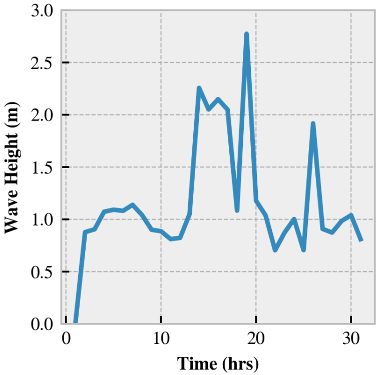
$(\nu = 1 \times 10^{-6} m^2 s^{-1})$





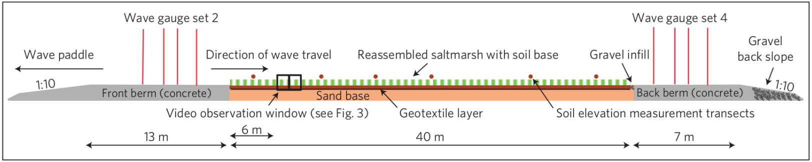
Objectives

- Introduce a time-varying C_D into SWAN-VEG.
- Introduce and spatial varying H_V.



C_D Empirical Data: Möller et al. (2014)

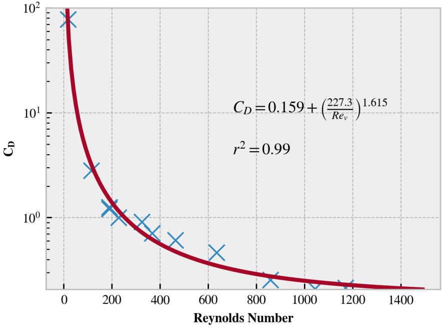
Hydralab large wave flume, GWK Hannover, wave attenuation over saltmarsh under storm conditions by Möller et al. (2014)



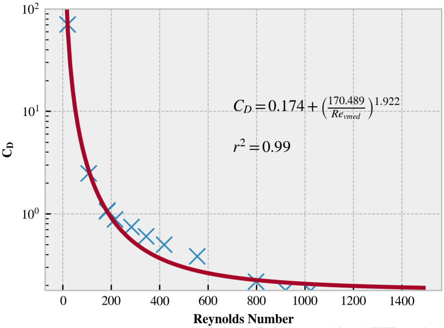
- Flume dimensions: 310m long, 5m wide, 7m deep
- Approx 40m long Test section of excavated saltmarsh blocks
- Using data for irregular waves in 2m water depth (H_s 0.111-0.909, T_p=1.44-6.26)

C_D ~ Re_v Relationship

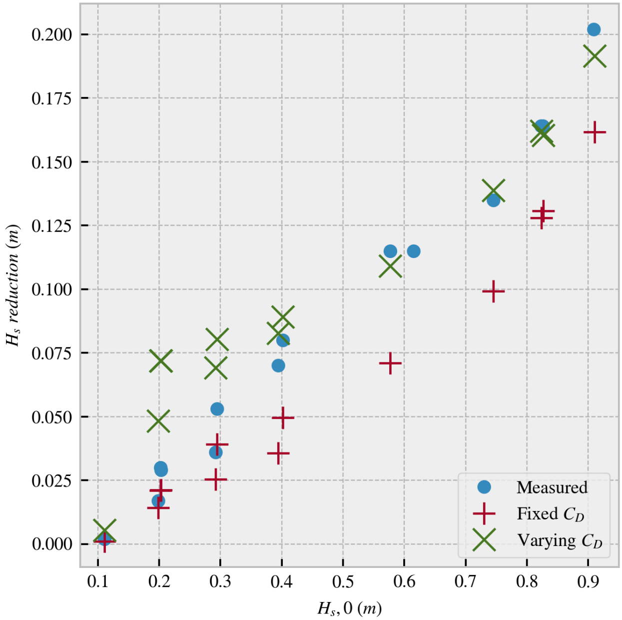
From Möller et al. (2014)



New relationship based on median Re_v



Large wave flume results with SWAN

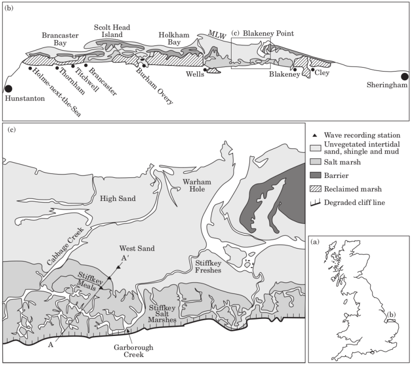


Fixed C_D *RMSE* $=$ $0.027m$

Varying C_D *RMSE* $=$ $0.022m$

Wave setup and wave breaking ($\alpha = 1, \gamma = 0.73$) included

Saltmarsh transect: Möller et al. (1999)

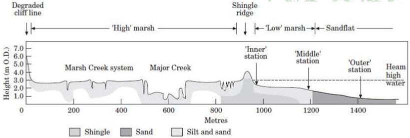


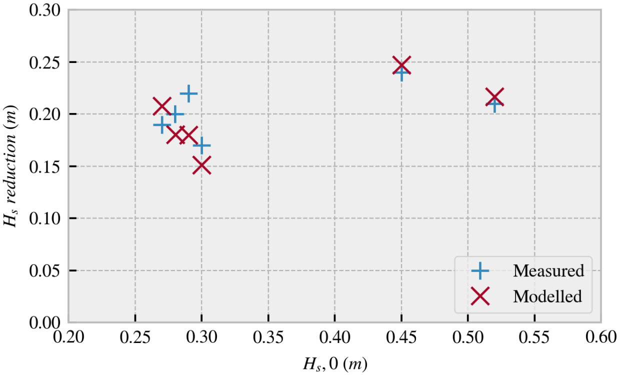
Validated against the wave dissipation measurements of Möller et al. (1999).
197m saltmarsh transect at Stiffkey, North Norfolk, UK.

Vegetation Parameters:
$H_v = 0.11m$, $D_v = 0.00125m$, $N_v = 1061$

SWAN run as 1D transect over 6 wave bursts with large waves, the test conditions are:
$h = 0.74 - 1.19m$,
$H_s = 0.27 - 0.52m$,
$T_p = 1.86 - 6.83s$

Saltmarsh transect: Results

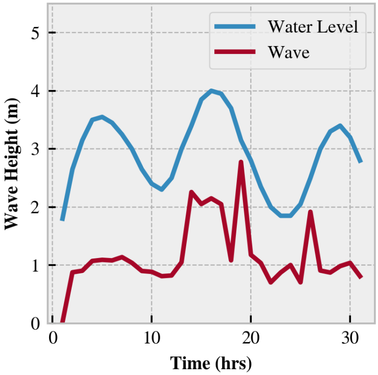


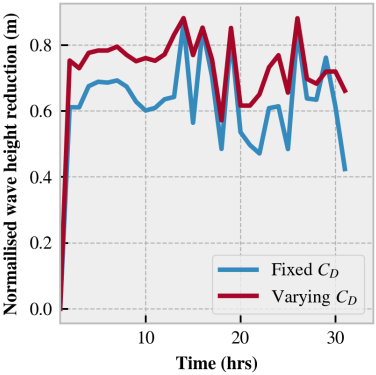


$RMSE = 0.0274m$

Sensitivity Testing: Storm Timeseries

200m Transect: $H_v = 0.4m$, $D_v = 0.00125m$, $N_v = 1061$. Wave setup and breaking included

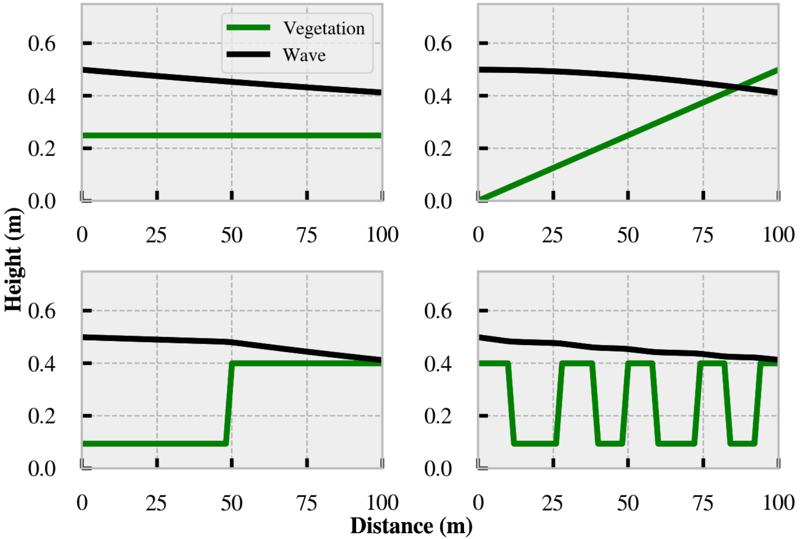




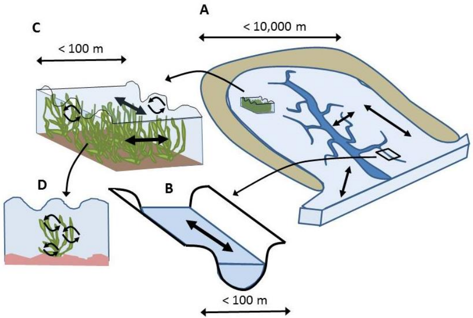
Sensitivity Testing: Spatial Varying Vegetation

Includes wave breaking and setup $H_s = 0.5$, $T_p = 4s$

Vegetation: Mean $H_v = 0.25m$, $D_v = 0.0045m$, $N_v = 1061$



Discussion



Future work: Currently setting up a 2D case at Tillingham, UK, using a diamond shaped pressure sensor transect to calibrate.

Conclusions

- Introduced Varying C_D and spatial varying vegetation height in the SWAN-VEG module.
- Varying C_D allows prediction of the wave dissipation over a timeseries.
- Spatial varying vegetation height is useful for 2D modelling and cases where vegetation is varied or patchy.

Thank you!
Any Questions?