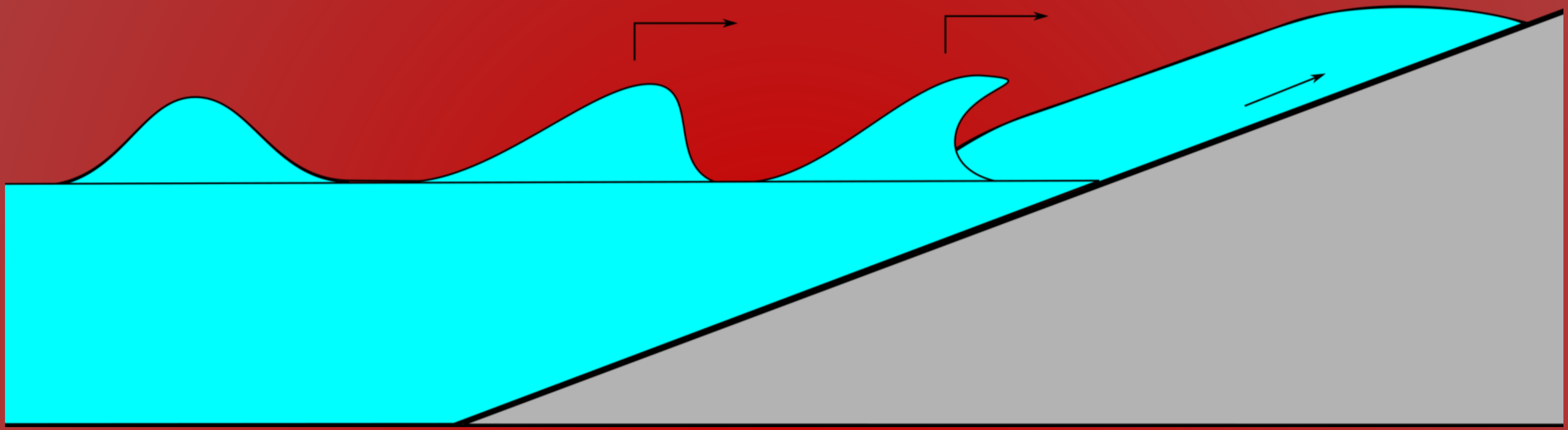
FLOW CHARACTERISTICS IN SWASH OF TRANSIENT LONG WAVES



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36th International Conference on Coastal Engineering

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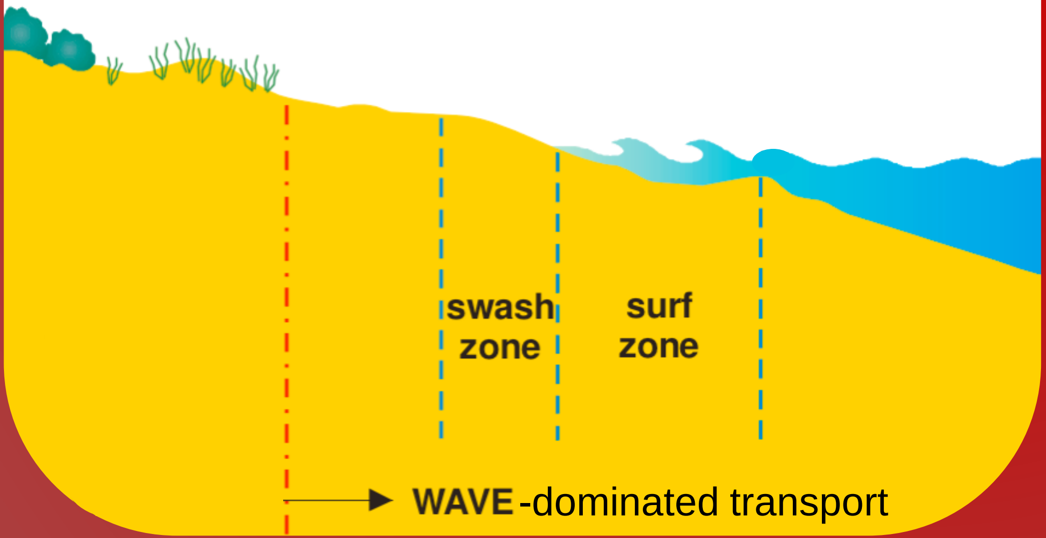
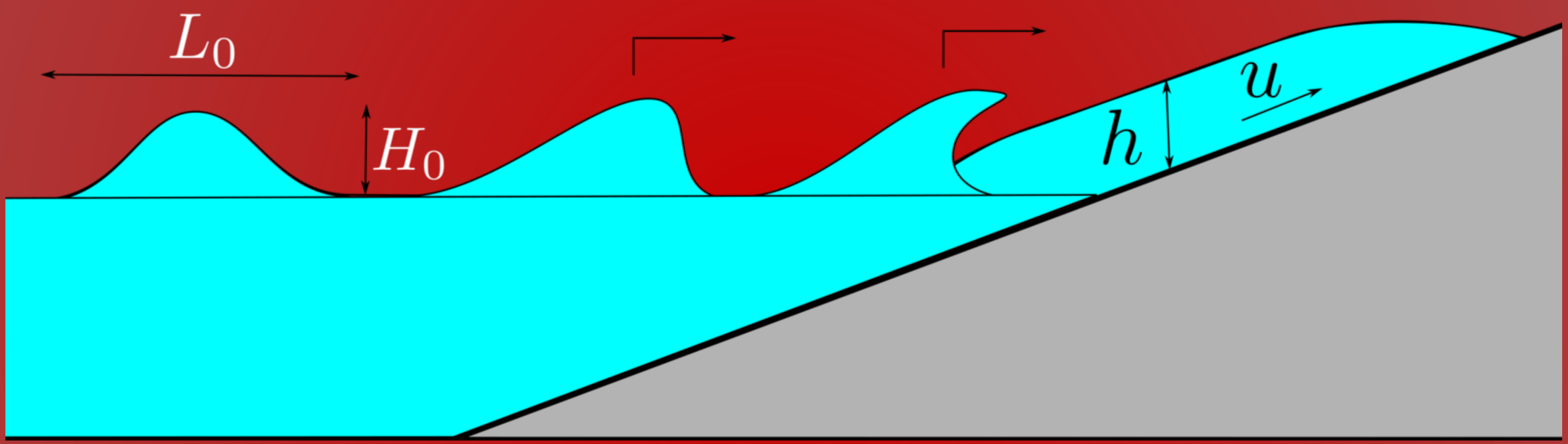
Waves are the dominant forcing on beaches

A typical beach system



Adapted from Short et al. (2012)

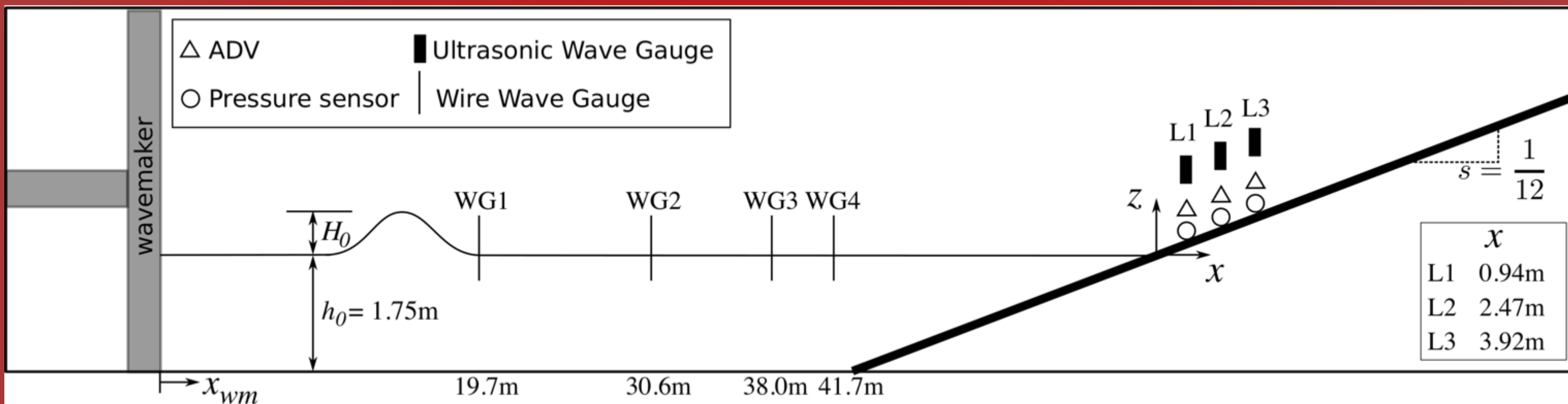
Schematic



Driving question:

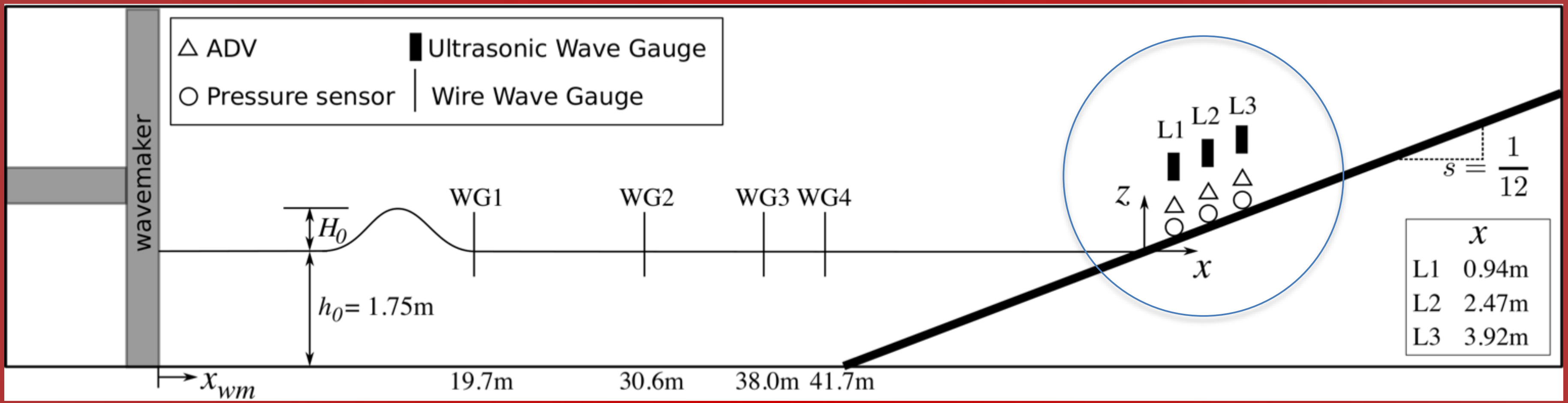
Can we predict flow on the beach (u , h) from incident wave properties (L_0 , H_0)?

Experimental Setup



Large Wave Flume (104 m x 4 m x 5 m)
Oregon State University

Experimental Setup

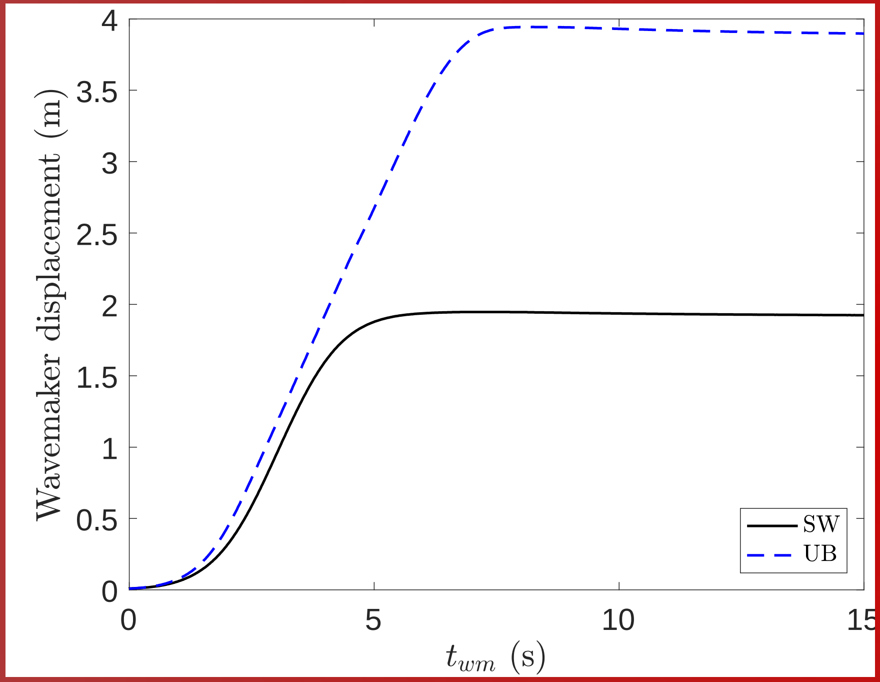


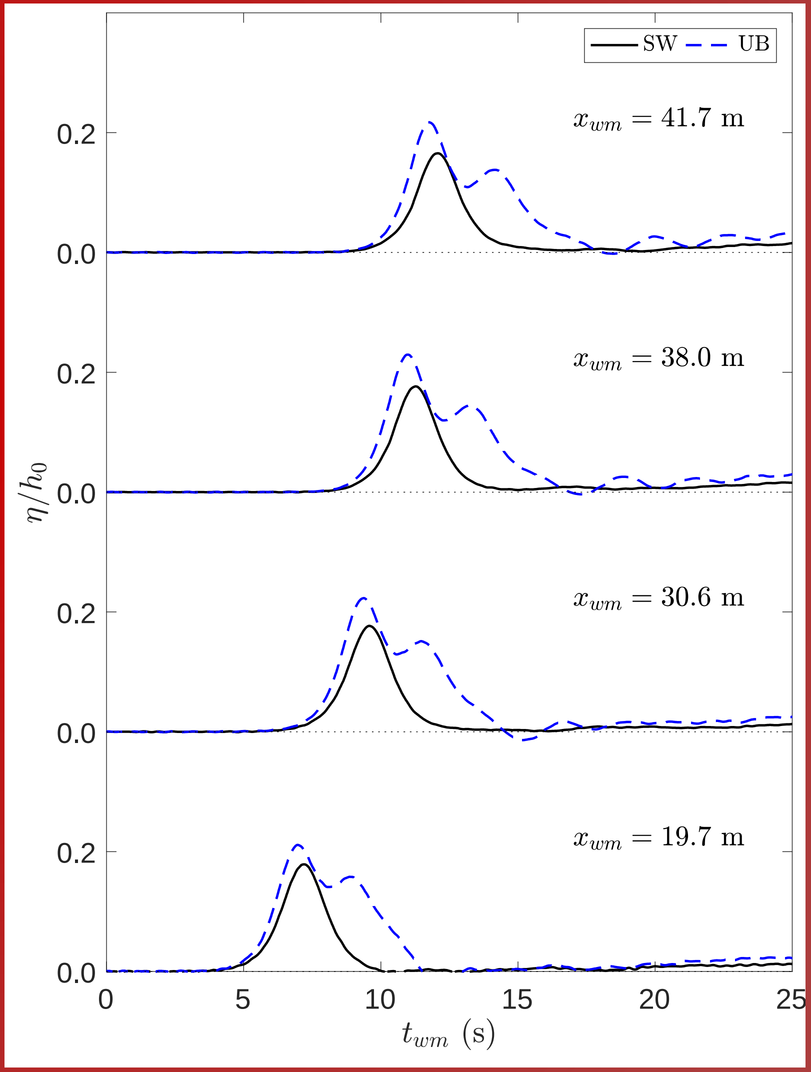
Swash measurement locations

Large Wave Flume (104 m x 4 m x 5 m)
Oregon State University

Experimental Setup

Incident waves are transient long waves of different forms



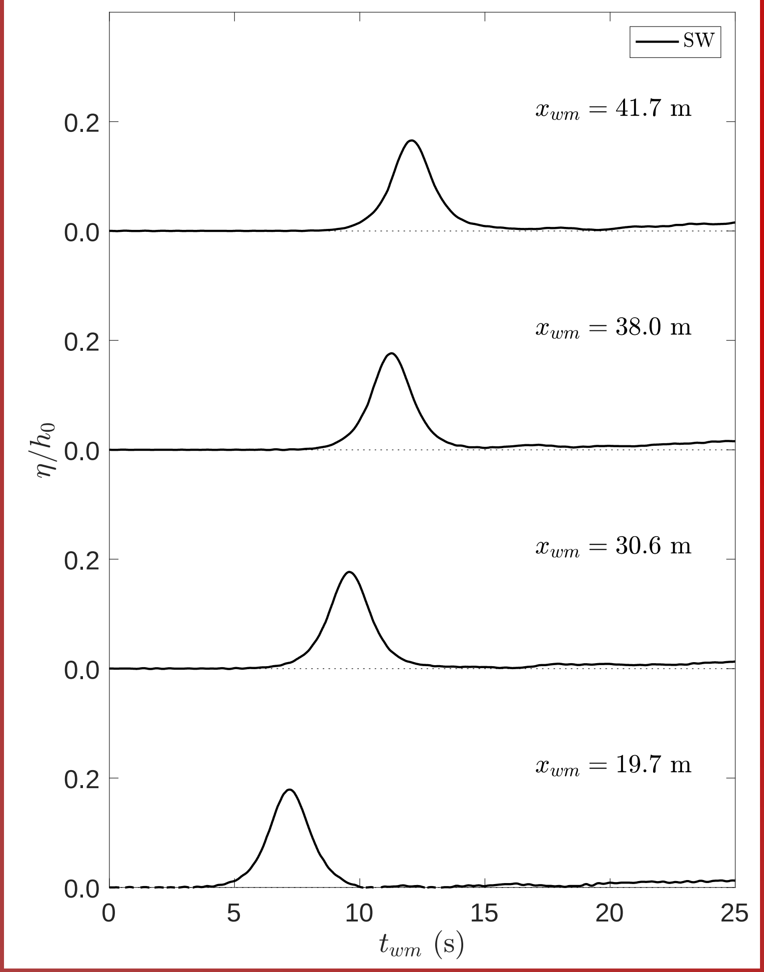


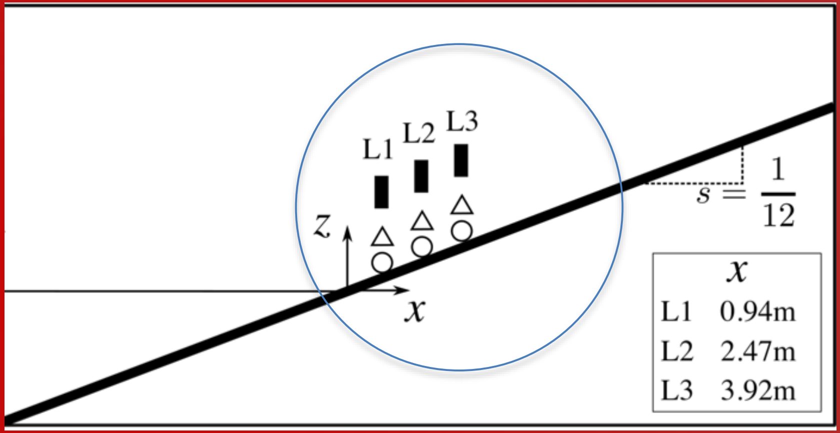
Solitary wave (SW) travels without change of form

Undular bore (UB) evolves due to non-linear and dispersive effects

Solitary wave $H_0/h_0 \approx 0.2$

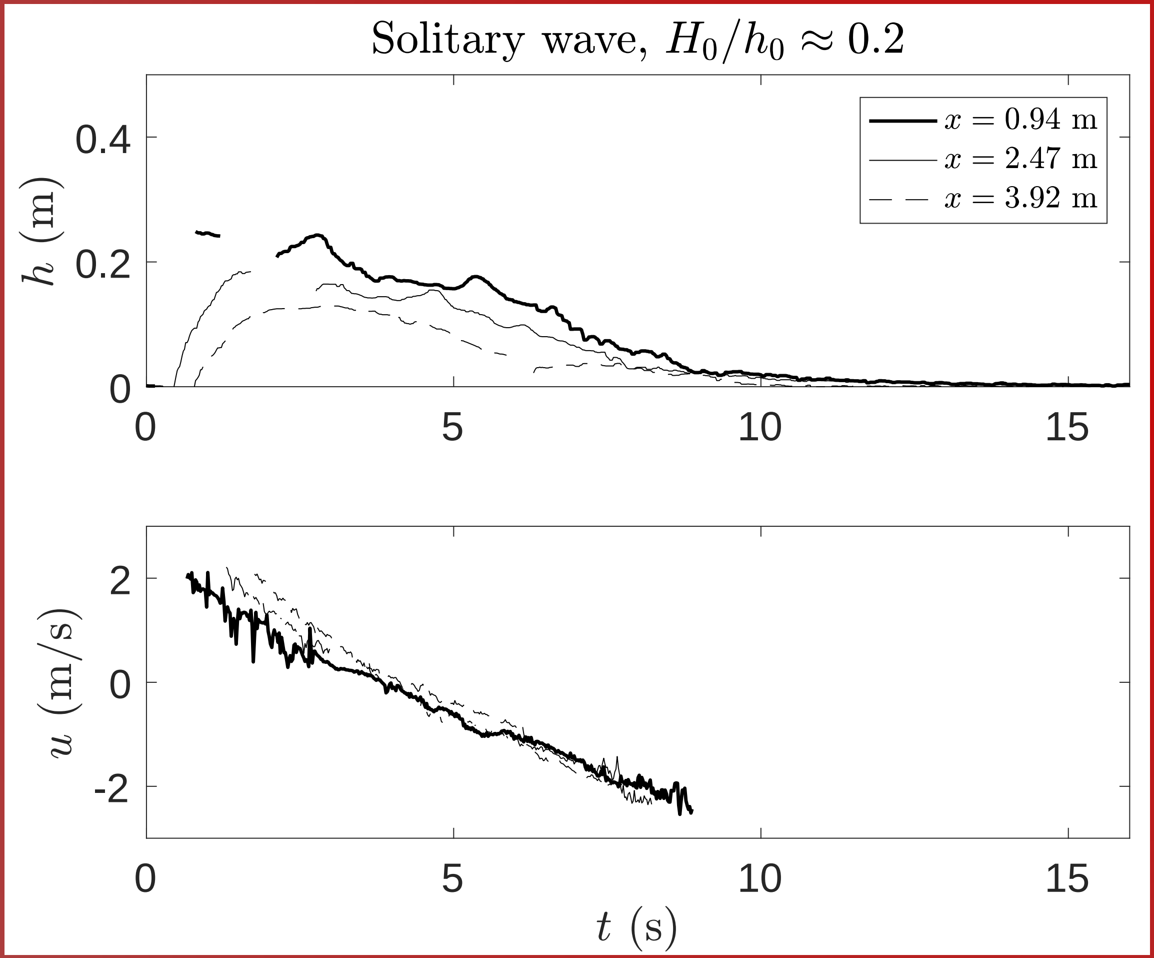
Examine flow data on the beach for incident solitary wave with $H_0/h_0 \approx 0.2$

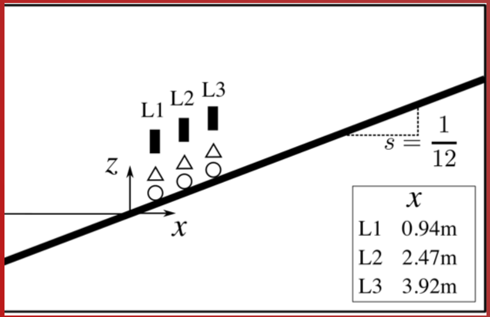




Flow velocity and water depth on the beach

Typical flow evolution in swash zone





Water depth measured with ultrasonic sensor

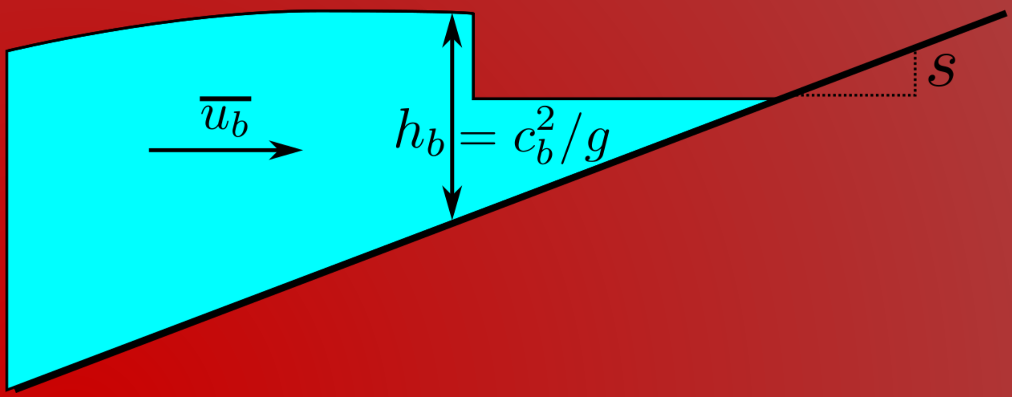
Flow velocity measured with acoustic Doppler velocimeter

Theoretical description of wave breaking

Non-linear shallow water equations

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left[(h+\eta)\,\overline{u}\right] = 0$$

$$\frac{\partial \overline{u}}{\partial t} + \overline{u}\frac{\partial \overline{u}}{\partial x} + g\frac{\partial \eta}{\partial x} = 0$$



In characteristic form

$$\left[\frac{\partial}{\partial t} + (\overline{u}+c)\,\frac{\partial}{\partial x}\right]\alpha = 0$$

$$\left[\frac{\partial}{\partial t} + (\overline{u}-c)\,\frac{\partial}{\partial x}\right]\beta = 0$$

$$\alpha = \overline{u} + 2c + gst = \text{const. on } dx/dt = \overline{u} + c$$

$$\beta = \overline{u} - 2c + gst = \text{const. on } dx/dt = \overline{u} + c$$

Theoretical description of wave breaking

Non-linear shallow water equations

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left[(h+\eta)\,\overline{u}\right] = 0$$

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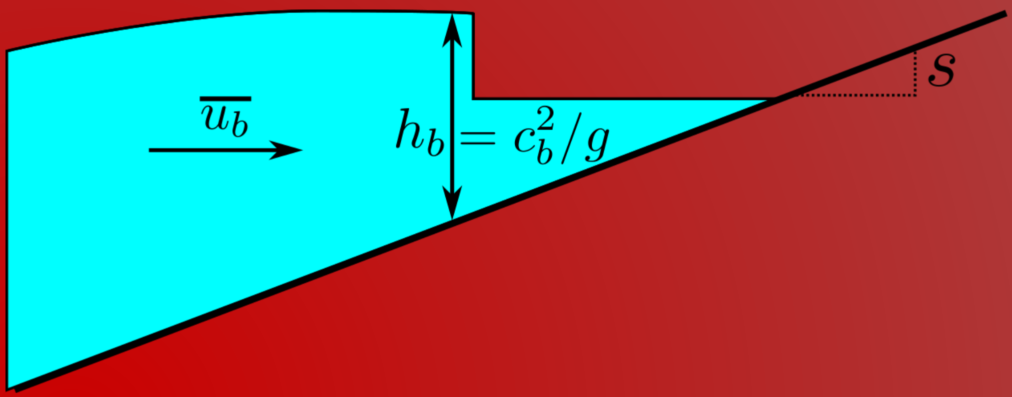


Whitham's characteristic rule for breakers:

$$\alpha = \bar{u_b} + 2c_b + gst = \text{const.}$$

At the shoreline, the breaker *collapses* and
α = constant behind the breaker

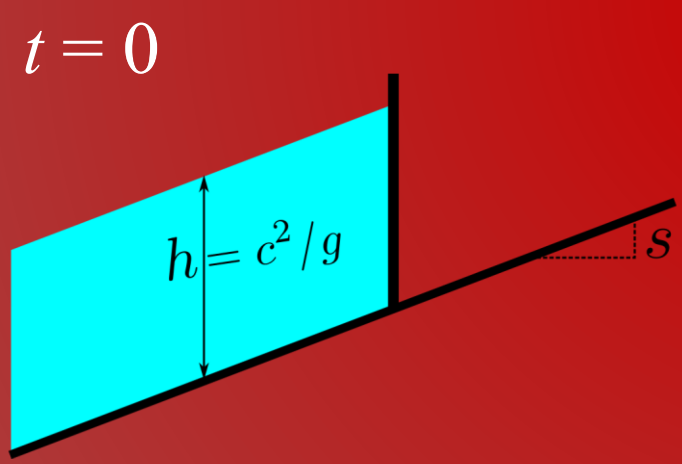
Whitham (1958), Meyer et al. (1972)

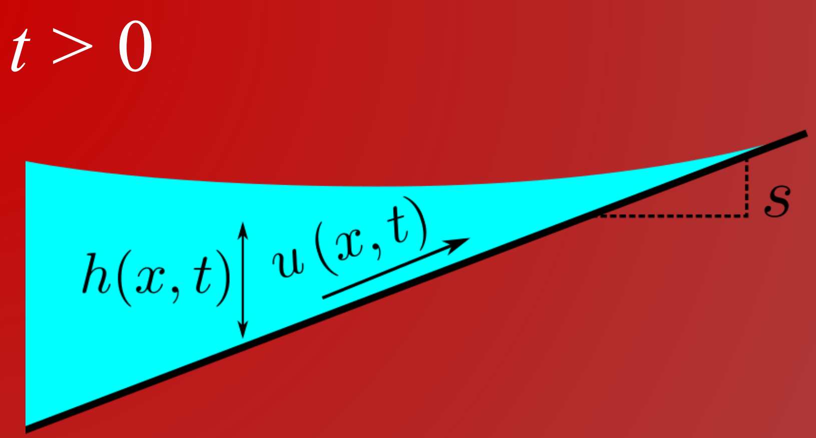
Theoretical description of wave breaking

A dam-break on a slope creates a flow with similar properties

Dam-break on a slope:

$$\alpha = \bar{u} + 2c + gst = \text{const.}$$





Any initial condition where α = const. leads to a dam-break flow

Peregrine & Williams (2001)

Theoretical description of wave breaking

A dam-break on a slope creates a flow with similar properties

Dam-break on a slope:

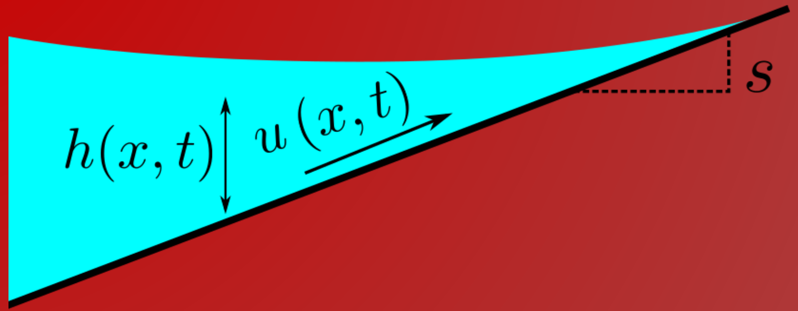
$$\alpha = \bar{u} + 2c + gst = \text{const.}$$

The swash solution:

$$\alpha = \bar{u} + 2c + gst = U_s$$

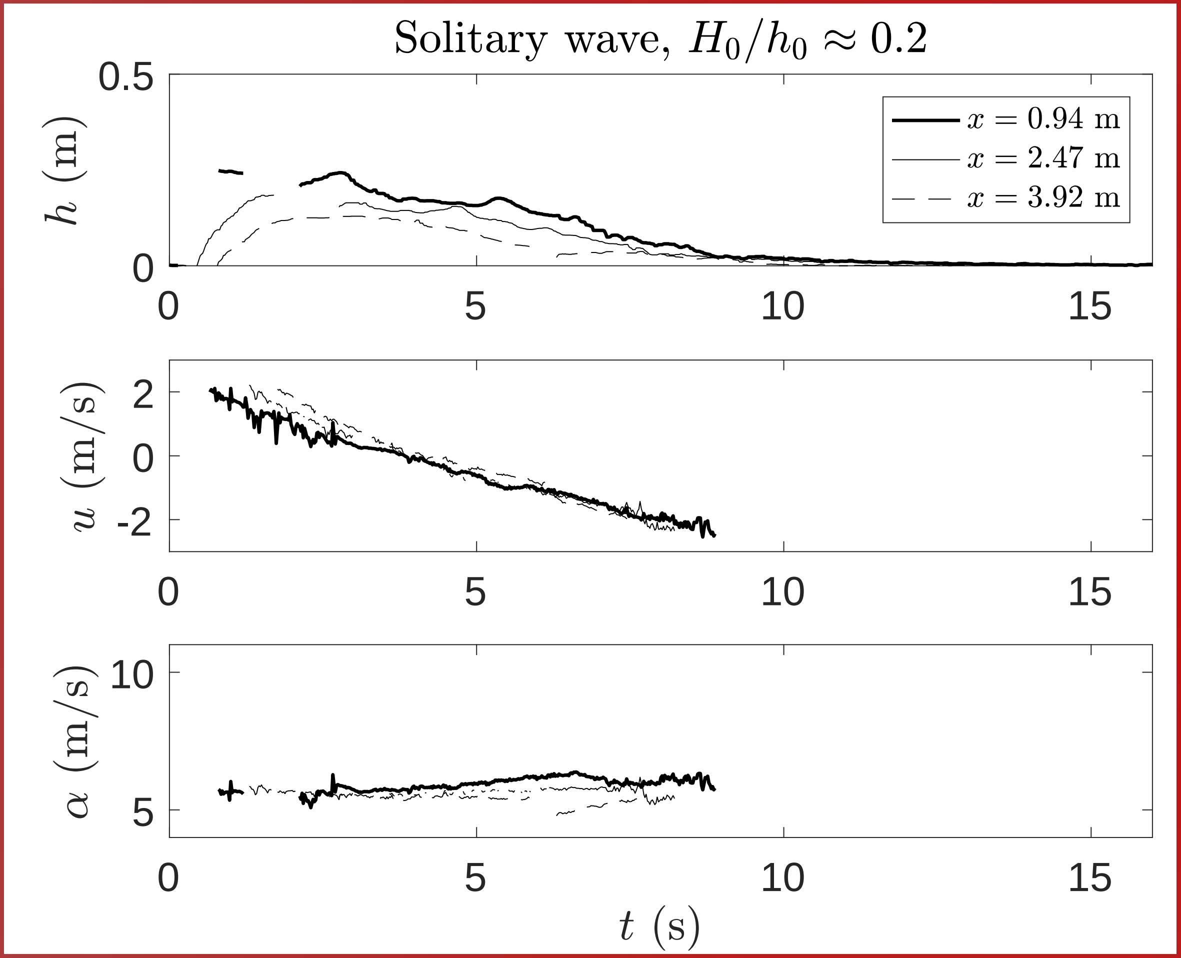
$$h\left(x,t\right) = \frac{1}{9g}\left(U_s - \frac{1}{2}gst - \frac{x}{t}\right)^2$$

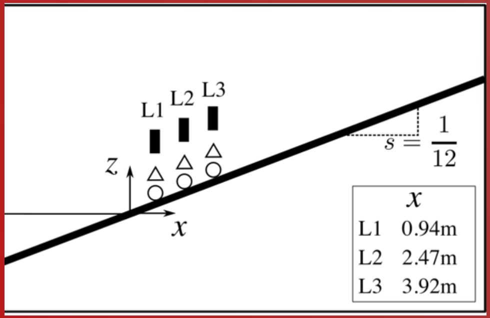
$$u\left(x,t\right) = \frac{1}{3}\left(U_s - 2gst + 2\frac{x}{t}\right)$$



Peregrine & Williams (2001)

Flow velocity and water depth on the beach



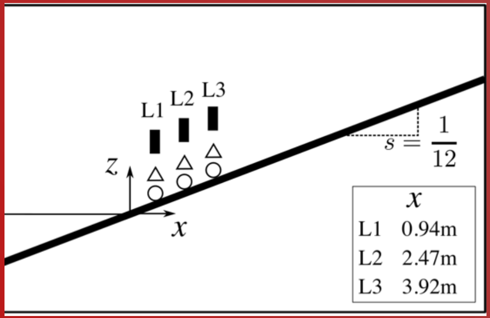


α is constant throughout the swash of solitary waves

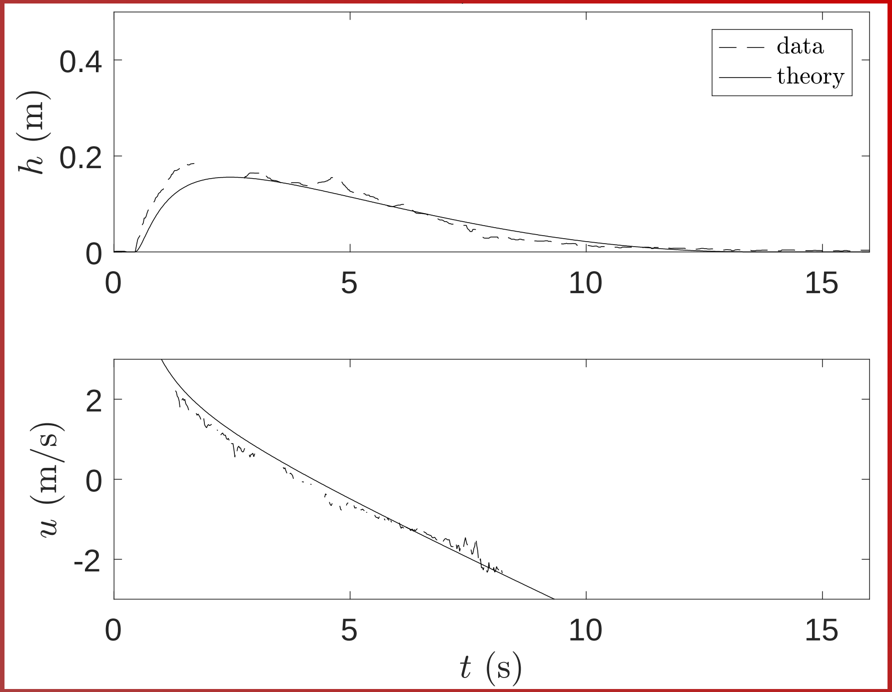
Pujara, Liu & Yeh (2015)

Flow velocity and water depth on the beach

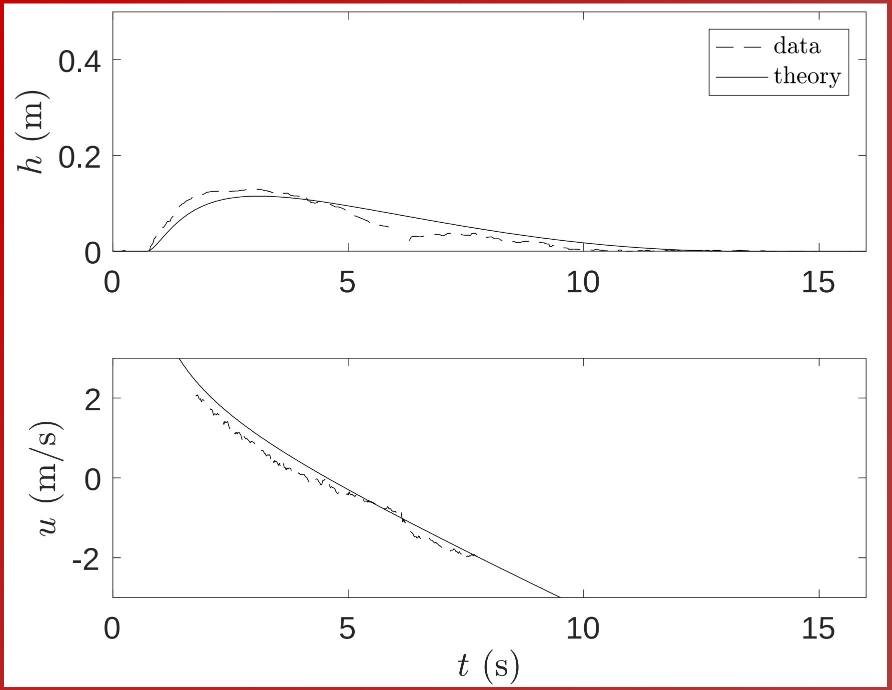
Flow evolution on the beach can be predicted



L1 (x=0.94 m)



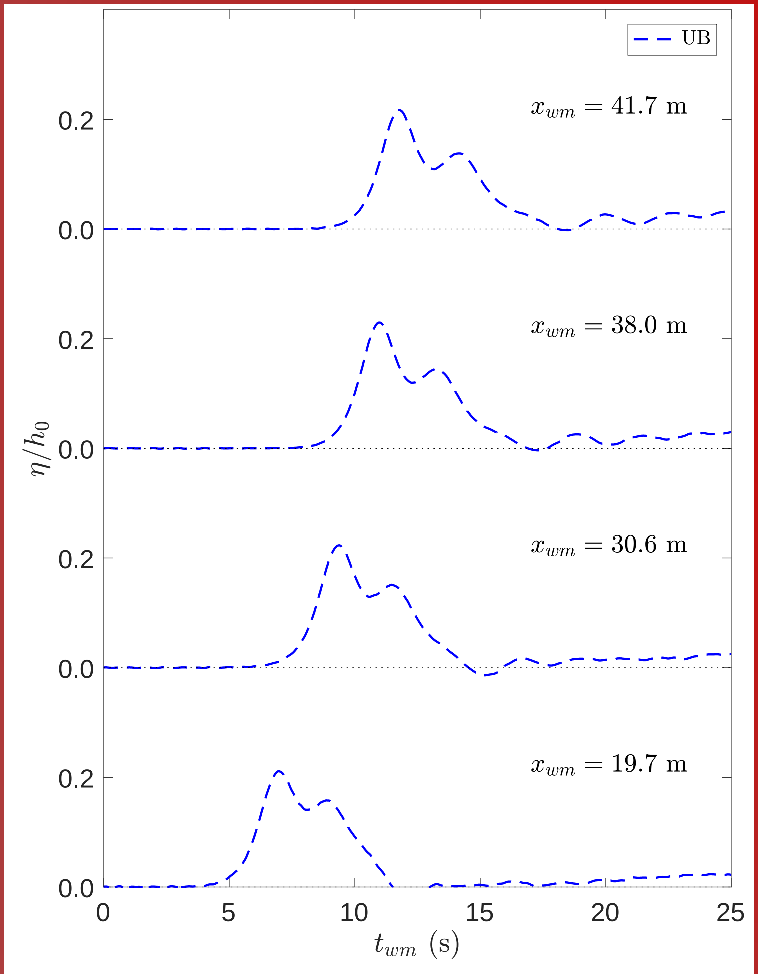
L2 (x=2.47 m)

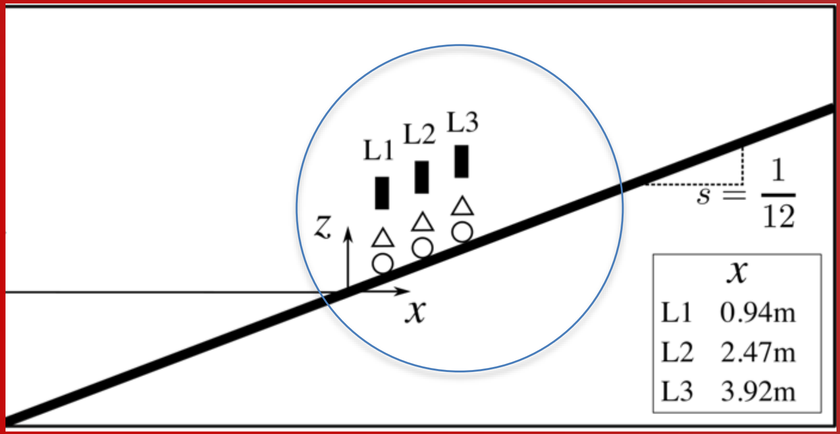


Pujara, Liu & Yeh (2015), Peregrine & Williams (2001)

Undular bore $H_0/h_0 \approx 0.2$

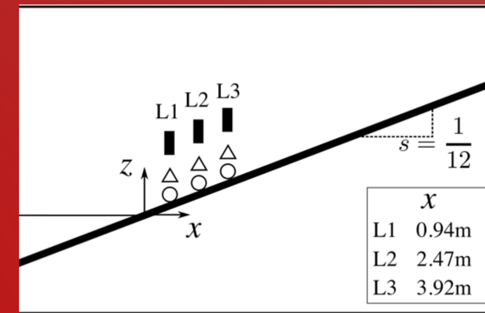
Examine flow data on the beach for incident undular bore with $H_0/h_0 \approx 0.2$





Flow velocity and water depth on the beach

A comparison between solitary wave and undular bore



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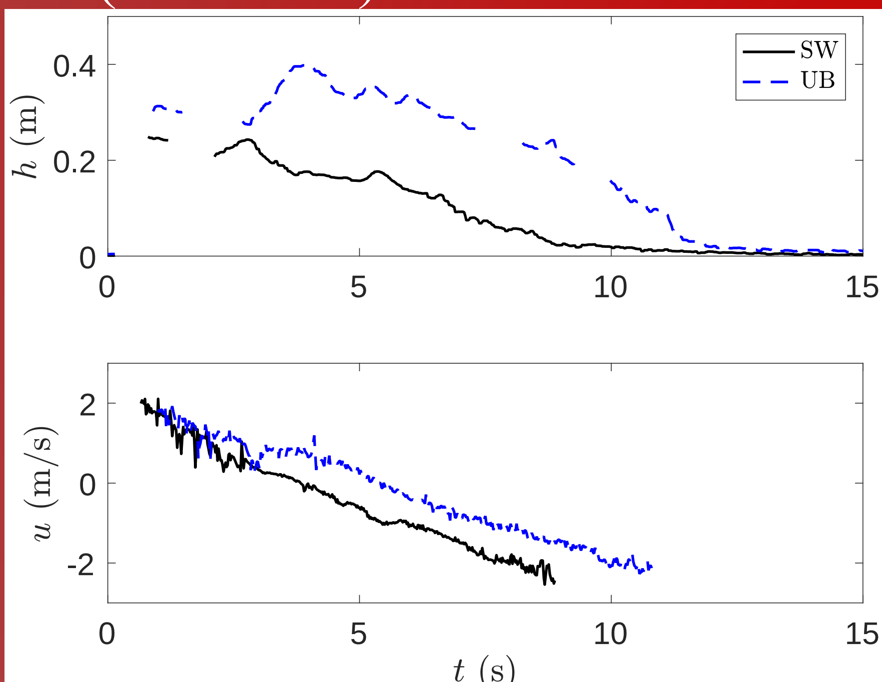

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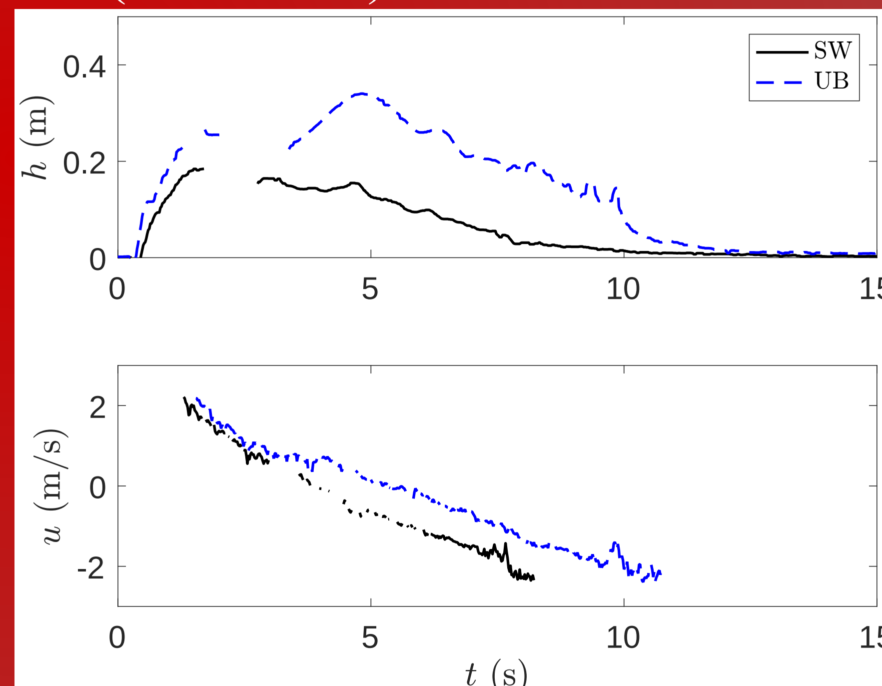
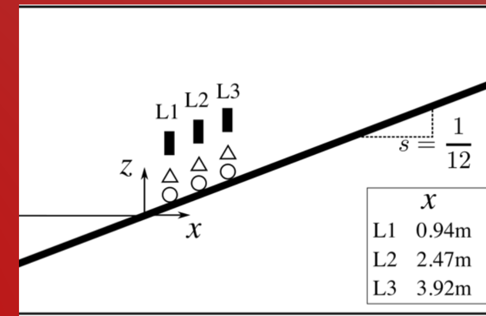


Undular bores generate deeper and more sustained flows

Baldock et al. (2005), Guard & Baldock (2007), Pritchard et al. (2009)

Flow velocity and water depth on the beach

A comparison between solitary wave and undular bore



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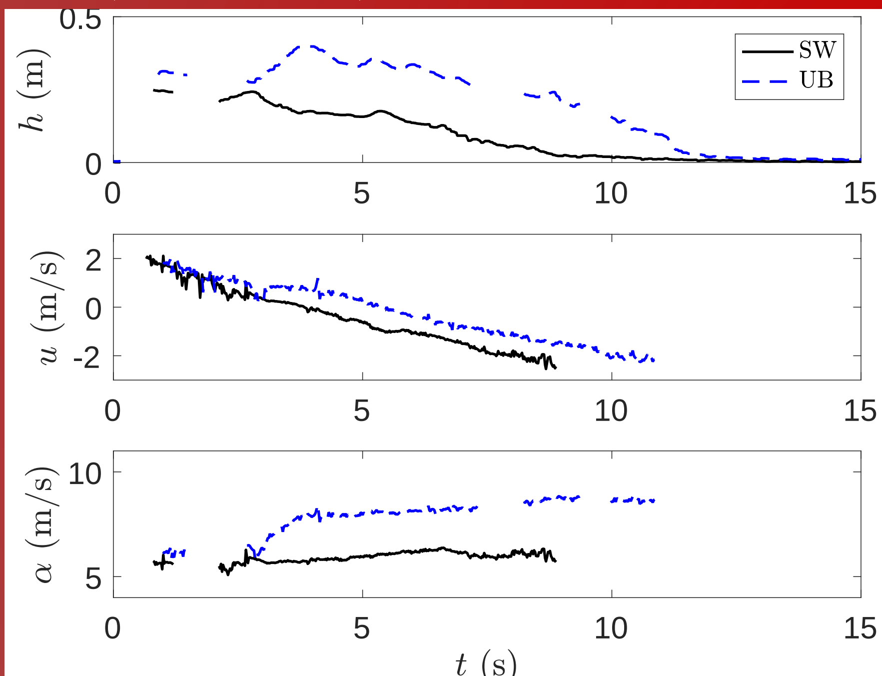

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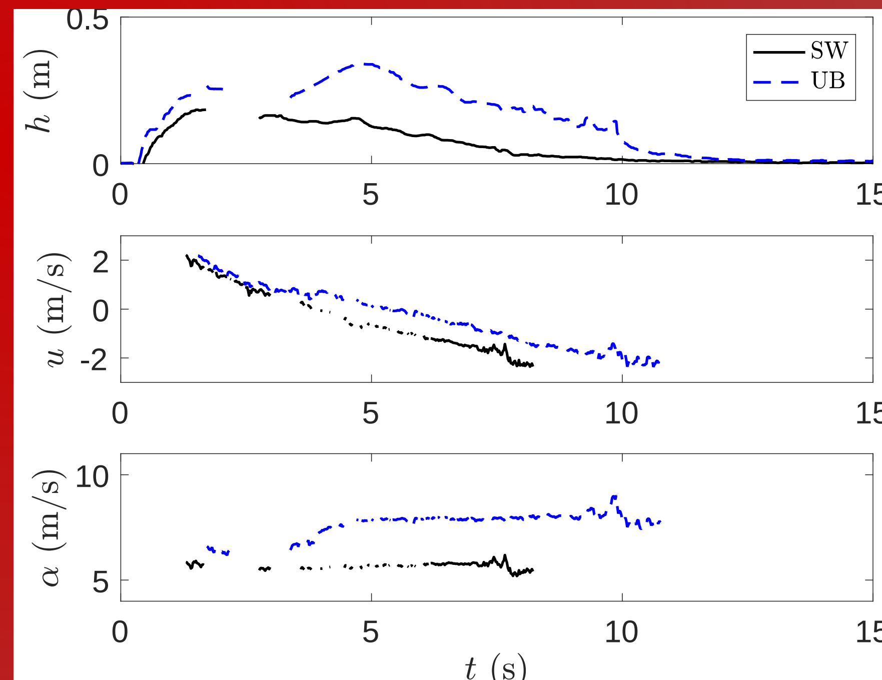
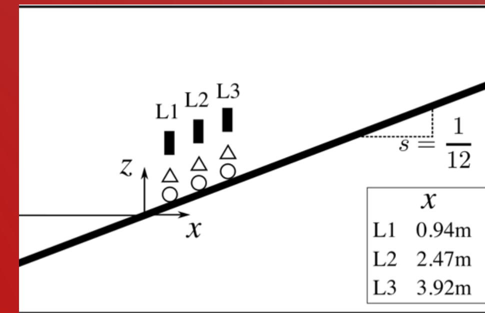


α varies, but transitions from one constant to another

Flow velocity and water depth on the beach

A comparison between solitary wave and undular bore



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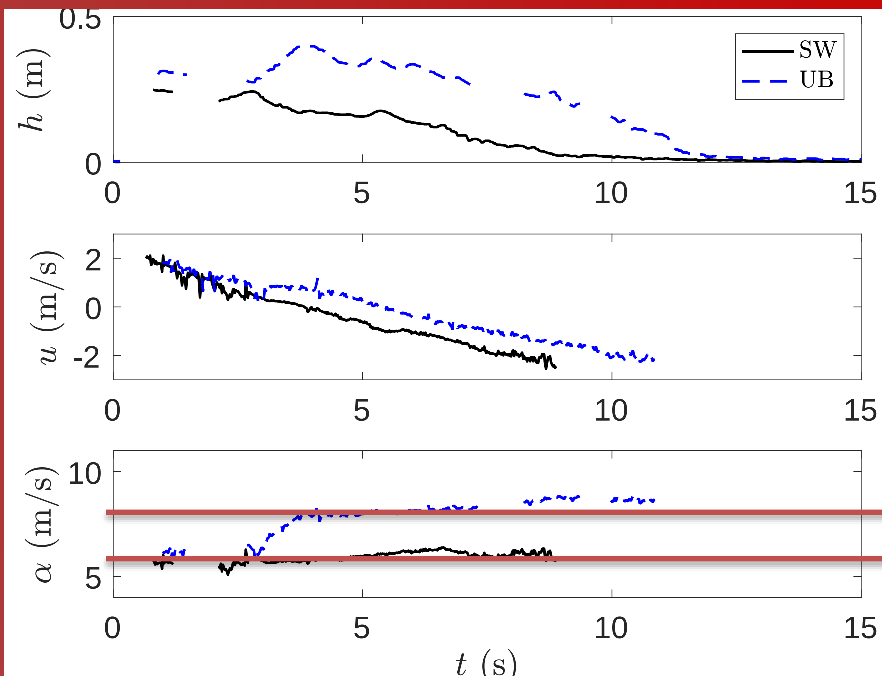

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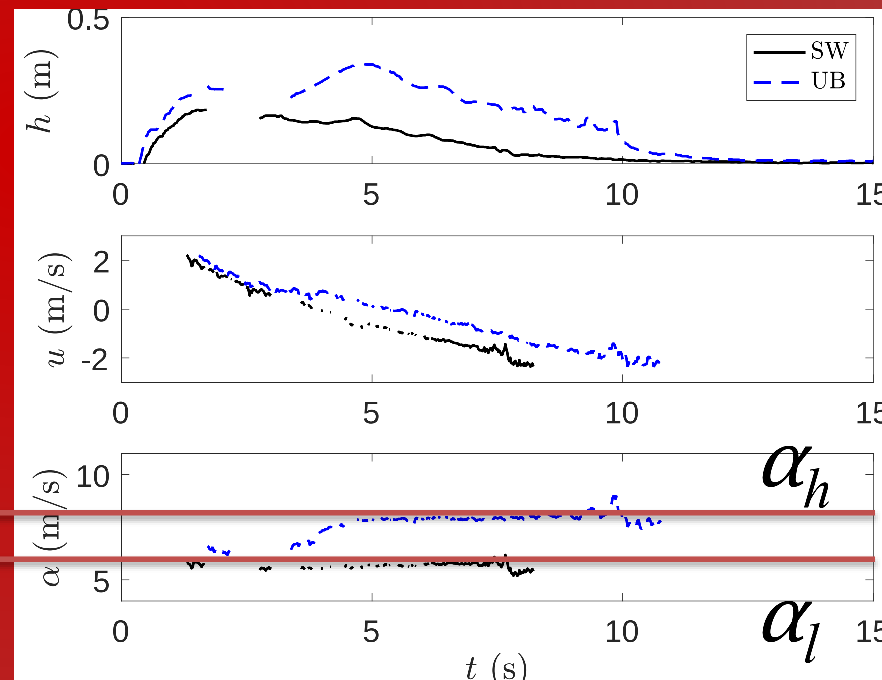
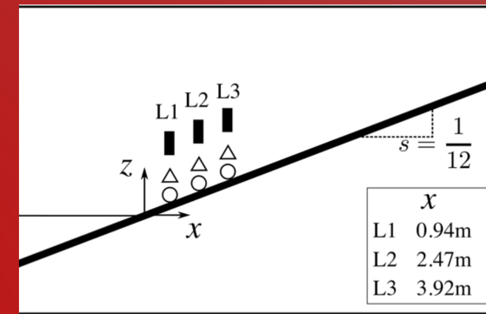


α is the same as the solitary wave case initially, but then transitions to a new value

Flow velocity and water depth on the beach

Undular bore flow evolution is defined by two α values



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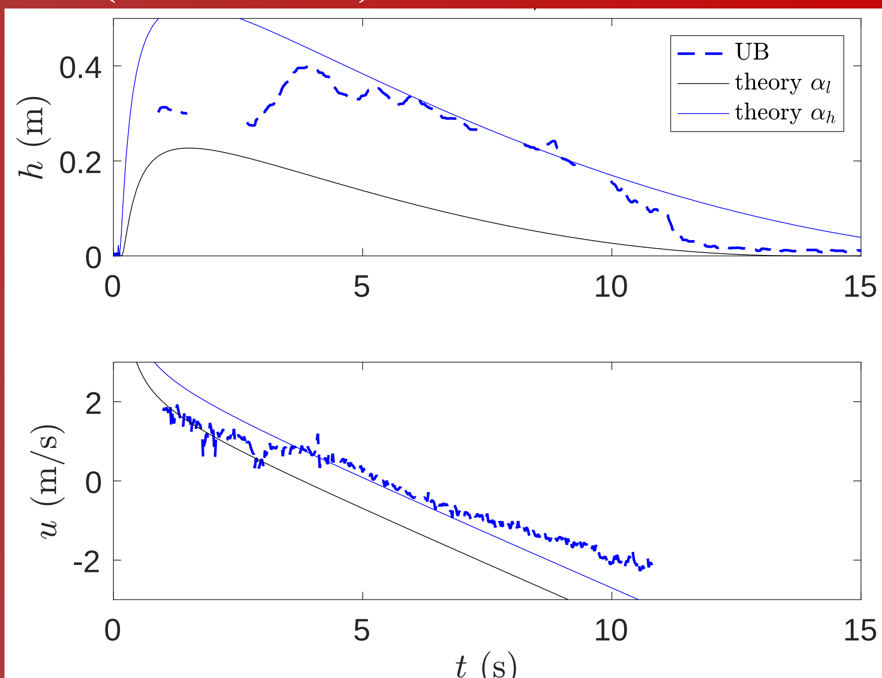

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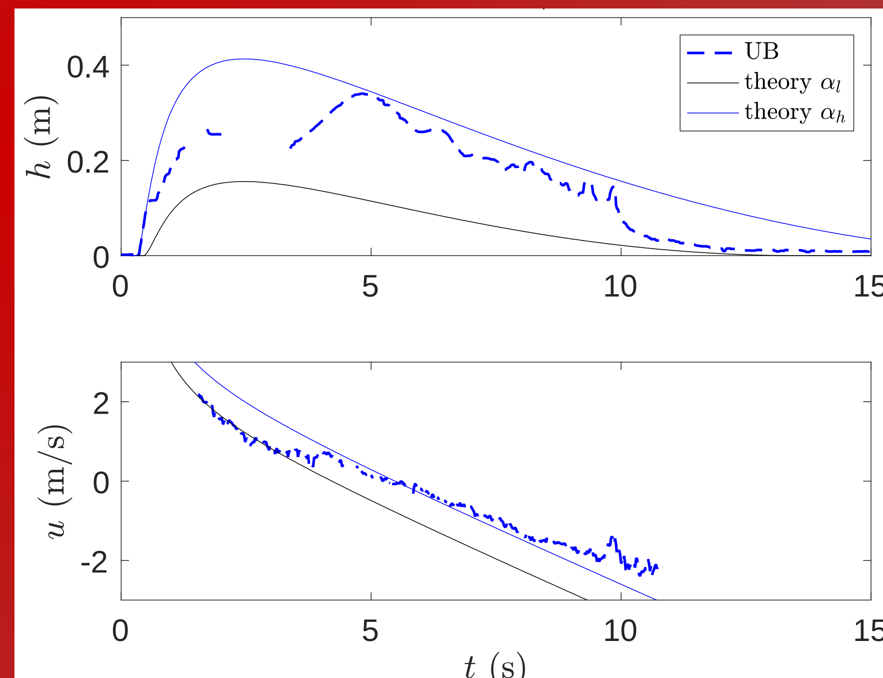

Water depth seems to follow the α_h throughout, whereas the velocity shows signatures of both α's

Conclusions and future work

1. The value of the forward characteristic variable is an important quantity for the flow evolution on a beach
2. With the constant value of the characteristic variable known, flow evolution for solitary wave can be predicted
3. Flow evolution for the bore is initially very similar to that of the solitary wave
4. At some point during the swash of the undular bore, the flow transitions to a flow driven by a higher energy constant
5. Understanding the flow evolution in more detail requires further research

Acknowledgements

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NEES

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