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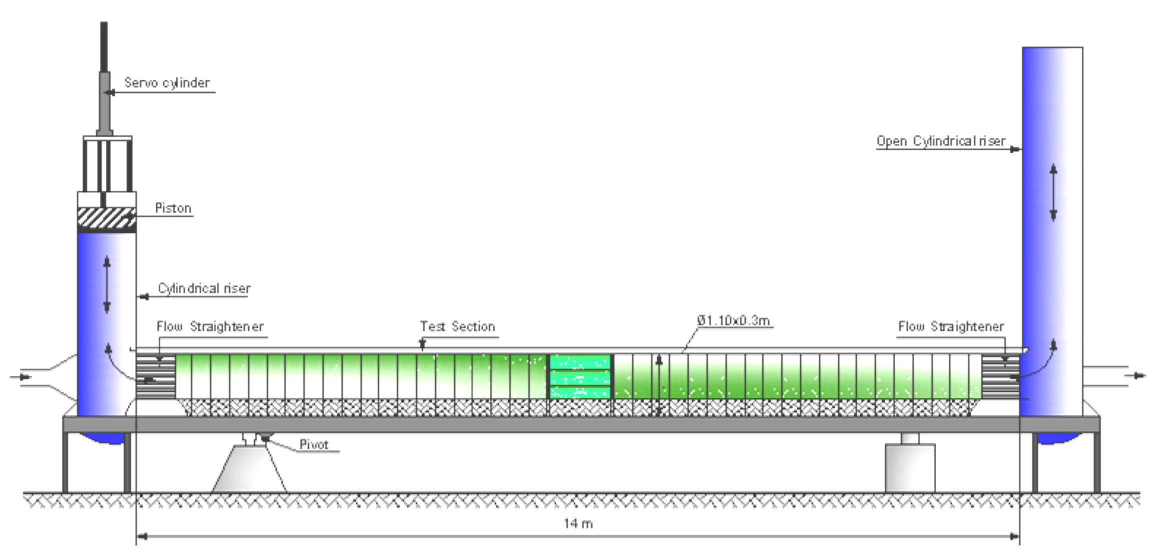
Velocity defect law in the wave bottom boundary layer

Objective

This work presents a simple method based on the defect law (Nielsen,1992) to reproduce the velocity vertical profile within the wave bottom boundary layer.

TRANSKEW experiment

- New series of experiments to evaluate the net transport rates in **sheet flow regime**, (well-sorted sand bed, d50≈0.20 mm), under accelerated skewed waves, (Silva *et al.*, 2010).
- Different hydraulic conditions
  - **Series A:** regular oscillatory flows with different degrees of acceleration skewness, β;
  - **Series B:** acceleration-skewed oscillatory flows with a collinear net current, opposing the wave direction;
  - **Series C:** velocity- and acceleration- skewed oscillatory flows.
- An Acoustic Doppler Velocity Profiler (ADVP) measured simultaneously both horizontal and vertical velocities every 3mm over a 14cm layer immediately above the bed.



Condition	β^a	R^b	T^c [s]	U_0^d [m/s]
A1	0.65	0.5	7	0
A2	0.65	0.5	10	0
A3	0.75	0.5	7	0
A4	0.75	0.5	10	0
B1	0.65	0.5	7	−0.2
B2	0.65	0.5	7	−0.4
B3	0.75	0.5	7	−0.2
B4	0.75	0.5	7	−0.4
C1	0.65	0.6	7	0
C2	0.65	0.6	10	0
C3	0.50	0.6	7	0

[a] β is acceleration skewness, $a_{max}/(a_{max}-a_{min})$, where a is acceleration
[b] R is velocity skewness, $u_{max}/(u_{max}-u_{min})$, where u is velocity
[c] T is wave period
[d] U_0 is net current

Analysis Procedure

DEFECT LAW

- the velocities $u(z,t)$ inside the wave bottom boundary layer can be written in terms of the free stream velocity, $u_\infty(t)$, and a dimensionless velocity defect function $D_1(z)$:

$$u(z,t)=\left[1-D_1(z)\right]u_\infty(t) \quad (1)$$

- Nielsen (1992) suggested that, for turbulent flows, $D_1(z)$ requires the knowledge of a vertical scale, z_1, and a power p that fits the data :

$$-\ln\left|D_1(z)\right|=\left(\frac{z}{z_1}\right)^p \quad (2)$$

- An analysis of the primary harmonic of the velocity records from ADVP pointed $z_1 \approx 8mm$ and $p \approx 0.75$ for all the experiments.

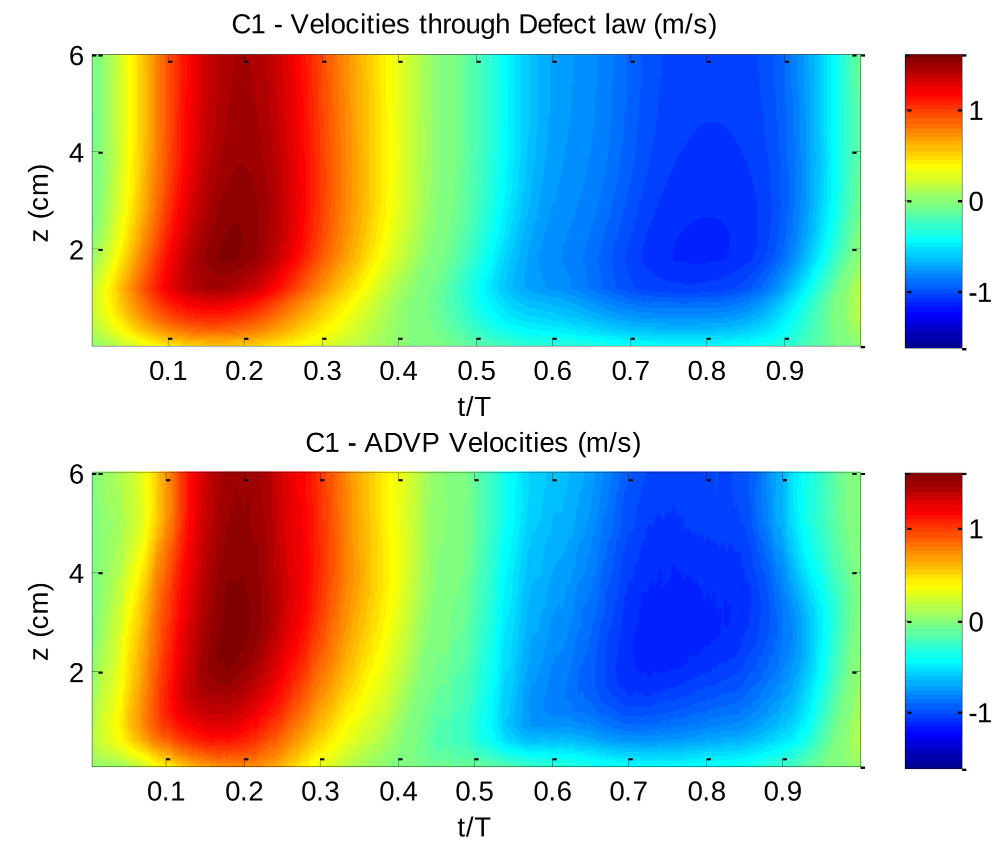
ADVProfiler

- Abreu et al. (2010) showed that an arbitrary nonlinear free stream velocity, $u_\infty(t)$, can be represented according to 4 parameters (Uw, T, r, ϕ):

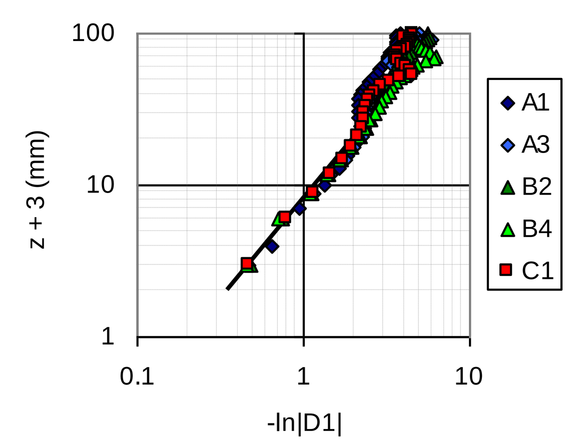
$$u_\infty(t)=U_w\sqrt{1-r^2}\,\frac{\left[\sin(\omega t)+\dfrac{r\sin\phi}{1+\sqrt{1-r^2}}\right]}{\left[1-r\cos(\omega t+\phi)\right]} \quad (3)$$

- Eq. (2) was combined with Eq. (3) to reproduce $u(z,t)$ inside the wave bottom boundary layer.

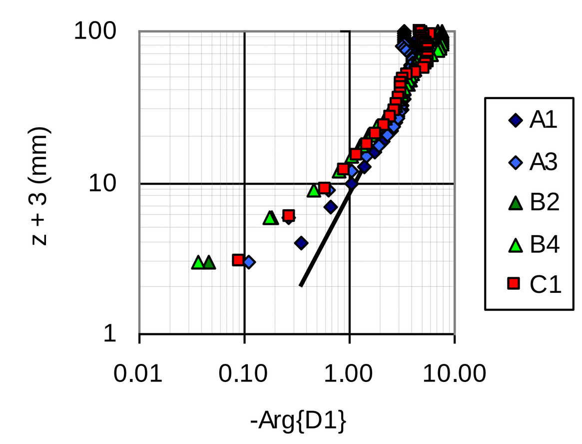
Results



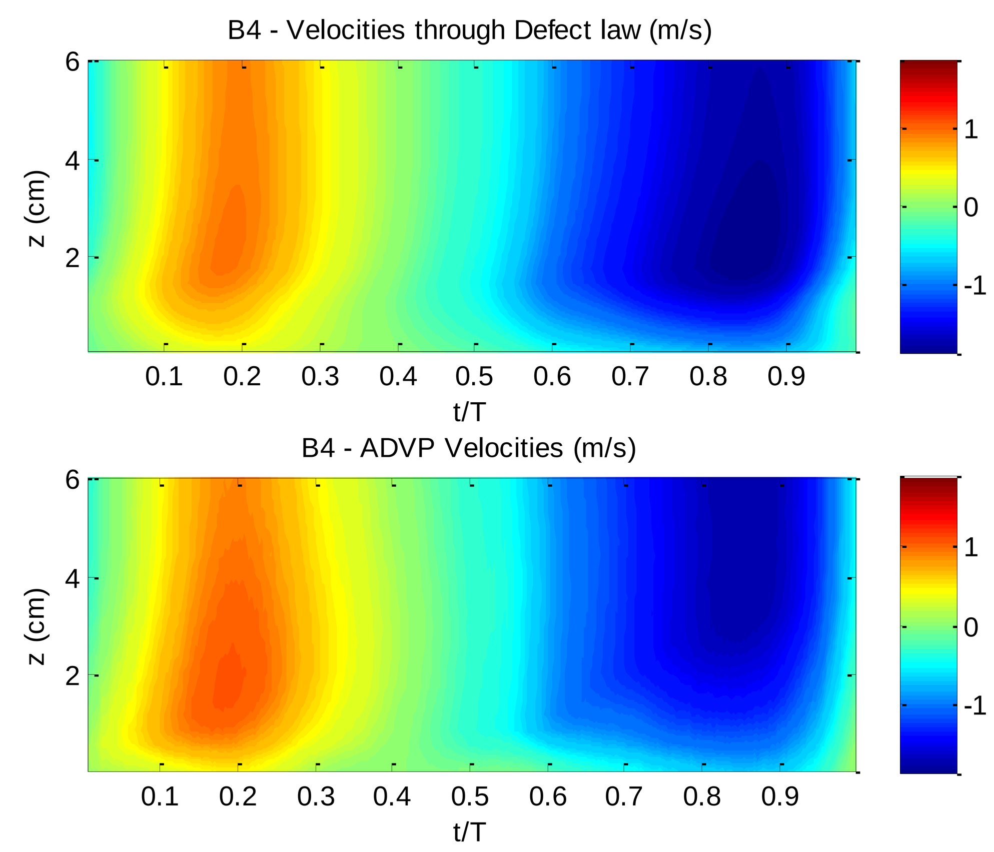
C1 - computed velocities



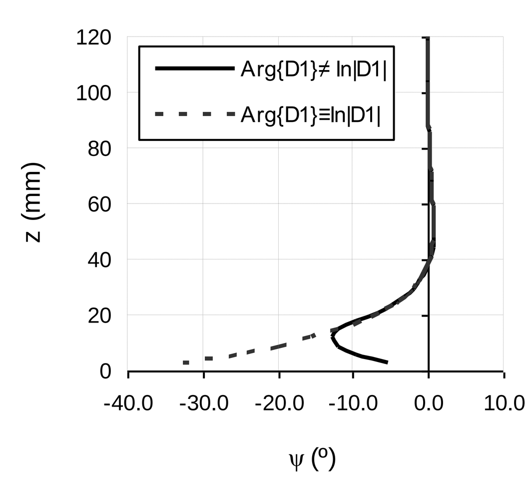
Evolution of $-ln(D_1(z))$



Evolution of $-Arg\{D_1(z)\}$



B4 - computed velocities



Velocity phase-lags closer to the bed assuming $ln(D1(z))=Arg\{D1(z)\}$ or $ln(D1(z)) \neq Arg\{D1(z)\}$

Main Conclusions

- The model results agree fairly well with the ADVP measurements and show that the defect law reproduces typical features of the oscillatory boundary layer: the velocity magnitude first increases with distance from the bed, with an overshoot at approximately 3 cm above the bed.
- There is a phase shift in the velocity that is maximum at about 1cm above the bed.
- Processing of the bed shear stress as well as velocities estimates within the sheet flow layer is under progress. (e.g. Ruessink *et al.*, submitted)

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