A. Intra-wave velocity time-series

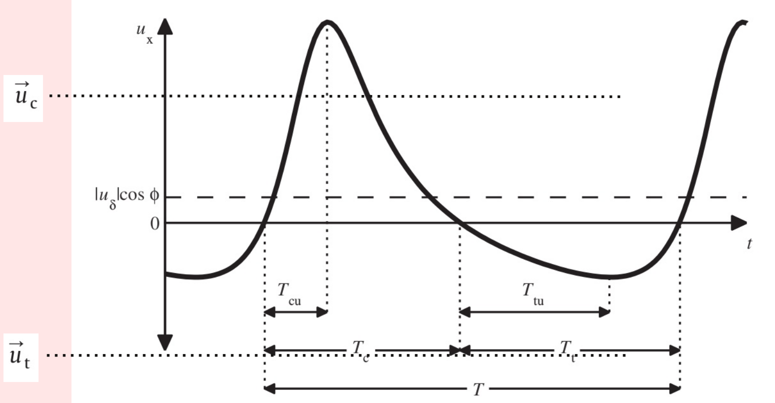

Fig. 1. Definition sketch of near-bed velocity time-series in wave direction. The parameters T_c and T_c are the positive (crest) and negative (trough) flow durations. Similarly, T_{cu} and T_{tu} are the durations of flow acceleration in positive and negative x-directions.

$$\hat{u} = \sqrt{\frac{2}{T}\int_0^T u_w^2(t)\mathrm{d}t} \qquad (8)$$

$$\hat{a} = \frac{\hat{u}T}{2\pi}. \qquad (9)$$

$$\tilde{u}_{c,r} = \frac{1}{2}\sqrt{2}\hat{u}_c \qquad (10)$$

$$\tilde{u}_{t,r} = \frac{1}{2}\sqrt{2}\hat{u}_t. \qquad (11)$$

$$u_x(t) = u_w(t) + |u_\delta|\cos\varphi \qquad (4)$$

$$u_y = |u_\delta|\sin\varphi \qquad (5)$$

$$\vec{u}_{c,r} = \left\{u_{c,rx}\ ,\ u_{c,ry}\right\} = \left\{\tilde{u}_{c,r} + |u_\delta|\cos\varphi,\ |u_\delta|\sin\varphi\right\} \qquad (12)$$

$$\vec{u}_{t,r} = \left\{u_{t,rx}\ ,\ u_{t,ry}\right\} = \left\{-\tilde{u}_{t,r} + |u_\delta|\cos\varphi,\ |u_\delta|\sin\varphi\right\}. \qquad (13)$$

B. Entrained sand load

$$\Omega_i = \begin{cases} 0 & \text{if } |\theta_i| \le \theta_{cr} \\ m(|\theta_i| - \theta_{cr})^n & \text{if } |\theta_i| > \theta_{cr} \end{cases} \qquad (2)$$

C1. Wave friction factor

$$f_{wi} = 0.00251\exp\left[5.21\left(\frac{\left(\frac{2T_{iu}}{T_i}\right)^{c_1}\hat{a}}{k_{sw}}\right)^{-0.19}\right] \quad \text{for} \quad \frac{\hat{a}}{k_{sw}} > 1.587$$
$$f_{wi} = 0.3 \quad \text{for} \quad \frac{\hat{a}}{k_{sw}} \le 1.587 \qquad (21)$$

$$f_w = 0.00251\exp\left[5.21\left(\frac{\hat{a}}{k_{sw}}\right)^{-0.19}\right] \quad \text{for} \quad \frac{\hat{a}}{k_{sw}} > 1.587$$
$$f_w = 0.3 \quad \text{for} \quad \frac{\hat{a}}{k_{sw}} \le 1.587. \qquad (A.4)$$

$$\langle|\theta|\rangle = \frac{\frac{1}{2}f_\delta|u_\delta|^2}{(s-1)gd_{50}} + \frac{\frac{1}{4}f_w\hat{u}^2}{(s-1)gd_{50}} \qquad (A.3)$$

C2. Current friction factor

$$f_\delta = 2\left[\frac{0.4}{\ln(30\delta/k_{s\delta})}\right]^2 \qquad (20)$$

$$\alpha = \frac{|u_\delta|}{|u_\delta| + \hat{u}}. \qquad (19)$$

$$f_{w\delta i} = \alpha f_\delta + (1-\alpha)f_{wi} \qquad (18)$$

$$|\theta_i| = \frac{\frac{1}{2}f_{w\delta i}|u_{i,r}|^2}{(s-1)gd_{50}} \qquad (17)$$

$$\tau_{wRe} = \rho\frac{f_{w\delta}}{2c_w}\alpha_w\hat{u}^3 \qquad (22)$$

$$\theta_{ix} = |\theta_i|\frac{u_{i,rx}}{|u_{i,r}|} + \frac{\tau_{wRe}}{(s-1)gd_{50}} \qquad (15)$$

D. Ripple model

$$\mu = \begin{cases} 6 & \text{if } d_{50} \le 0.15\text{mm} \\ 6 - \frac{5(d_{50} - 0.15)}{(0.20 - 0.15)} & \text{if } 0.15\text{mm} < d_{50} < 0.20\text{mm} \\ 1 & \text{if } d_{50} \ge 0.20\text{mm} \end{cases} \qquad (A.2)$$

$$k_{s\delta} = \max\{3d_{90}, d_{50}[\mu + 6(\langle|\theta|\rangle - 1)]\} + 0.4\eta^2/\lambda \qquad (A.1)$$

$$k_{sw} = \max\{d_{50}, d_{50}[\mu + 6(\langle|\theta|\rangle - 1)]\} + 0.4\eta^2/\lambda. \qquad (A.5)$$

E. Phase lag

$$w_{sc} = w_s - w_{\min}(r_c) \qquad (29)$$

$$w_{st} = \max(w_s - w_{\max}(r_t), 0) \qquad (30)$$

$$\Omega_{cc} = \begin{cases} \Omega_c & \text{if } P_c \le 1 \\ \frac{1}{P_c}\Omega_c & \text{if } P_c > 1 \end{cases} \qquad (23)$$

$$\Omega_{ct} = \begin{cases} 0 & \text{if } P_c \le 1 \\ \left(1 - \frac{1}{P_c}\right)\Omega_c & \text{if } P_c > 1 \end{cases} \qquad (24)$$

$$\Omega_{tt} = \begin{cases} \Omega_t & \text{if } P_t \le 1 \\ \frac{1}{P_t}\Omega_t & \text{if } P_t > 1 \end{cases} \qquad (25)$$

$$\Omega_{tc}\begin{cases} 0 & \text{if } P_t \le 1 \\ \left(1 - \frac{1}{P_t}\right)\Omega_t & \text{if } P_t > 1 \end{cases}. \qquad (26)$$

$$P_c = \begin{cases} \alpha\left(\frac{1 - \xi\hat{u}_c}{c_w}\right)\frac{\eta}{2(T_c - T_{cu})w_{sc}} & \text{if } \eta > 0 \text{ (ripple regime)} \\ \alpha\left(\frac{1 - \xi\hat{u}_c}{c_w}\right)\frac{\delta_{sc}}{2(T_c - T_{cu})w_{sc}} & \text{if } \eta = 0 \text{ (sheet flow regime)} \end{cases} \qquad (27)$$

$$P_t = \begin{cases} \alpha\left(\frac{1 + \xi\hat{u}_t}{c_w}\right)\frac{\eta}{2(T_t - T_{tu})w_{st}} & \text{if } \eta > 0 \text{ (ripple regime)} \\ \alpha\left(\frac{1 + \xi\hat{u}_t}{c_w}\right)\frac{\delta_{st}}{2(T_t - T_{tu})w_{st}} & \text{if } \eta = 0 \text{ (sheet flow regime)} \end{cases} \qquad (28)$$

F. Sheet flow thickness

$$\hat{\theta}_i = \frac{\frac{1}{2}f_{w\delta i}\hat{u}_i^{\,2}}{(s-1)gd_{50}} \qquad (C.2)$$

$$\frac{\delta_{si}}{d_{50}} = \begin{cases} 25\hat{\theta}_i & \text{if } d_{50} \le 0.15 \text{ mm} \\ \left[25 - \frac{12(d_{50} - 0.15)}{(0.20 - 0.15)}\right] & \text{if } 0.15 \text{ mm} < d_{50} < 0.20 \text{ mm} \\ 13\hat{\theta}_i & \text{if } d_{50} \ge 0.20 \text{ mm} \end{cases} \qquad (C.1)$$

G. Main function

$$\vec{\Phi} = \frac{\vec{q}_s}{\sqrt{(s-1)gd_{50}^3}} = \frac{\sqrt{|\theta_c|}T_c\left(\Omega_{cc} + \frac{T_c}{2T_{cu}}\Omega_{tc}\right)\frac{\vec{\theta}_c}{|\theta_c|} + \sqrt{|\theta_t|}T_t\left(\Omega_{tt} + \frac{T_t}{2T_{tu}}\Omega_{ct}\right)\frac{\vec{\theta}_t}{|\theta_t|}}{T} \qquad (1)$$