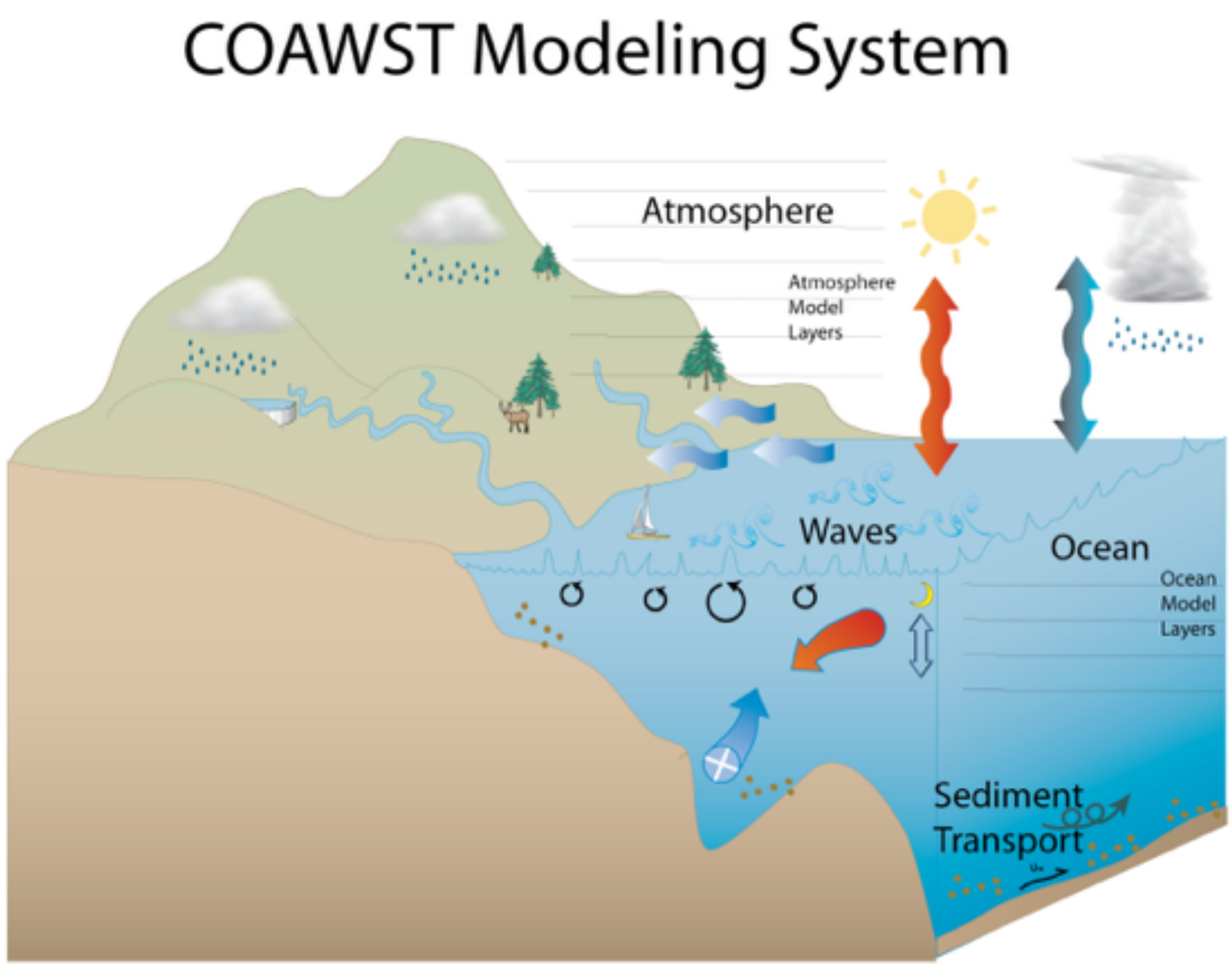
Wave-current Interaction (WEC) in the COAWST



Nirnimesh Kumar
with
JC Warner, G. Voulgaris & M. Olabarrieta

see Kumar et al., 2012:
Implementation of the vortex force formalism in the coupled ocean-atmosphere-wave-sediment transport (COAWST) modeling system for inner shelf and surf zone applications, Ocean Modelling, Volume 47, 2012, Pages 65-95, 10.1016/j.ocemod.2012.01.003.

Wave-Averaged Equations (*e.g.*, Eq 11)

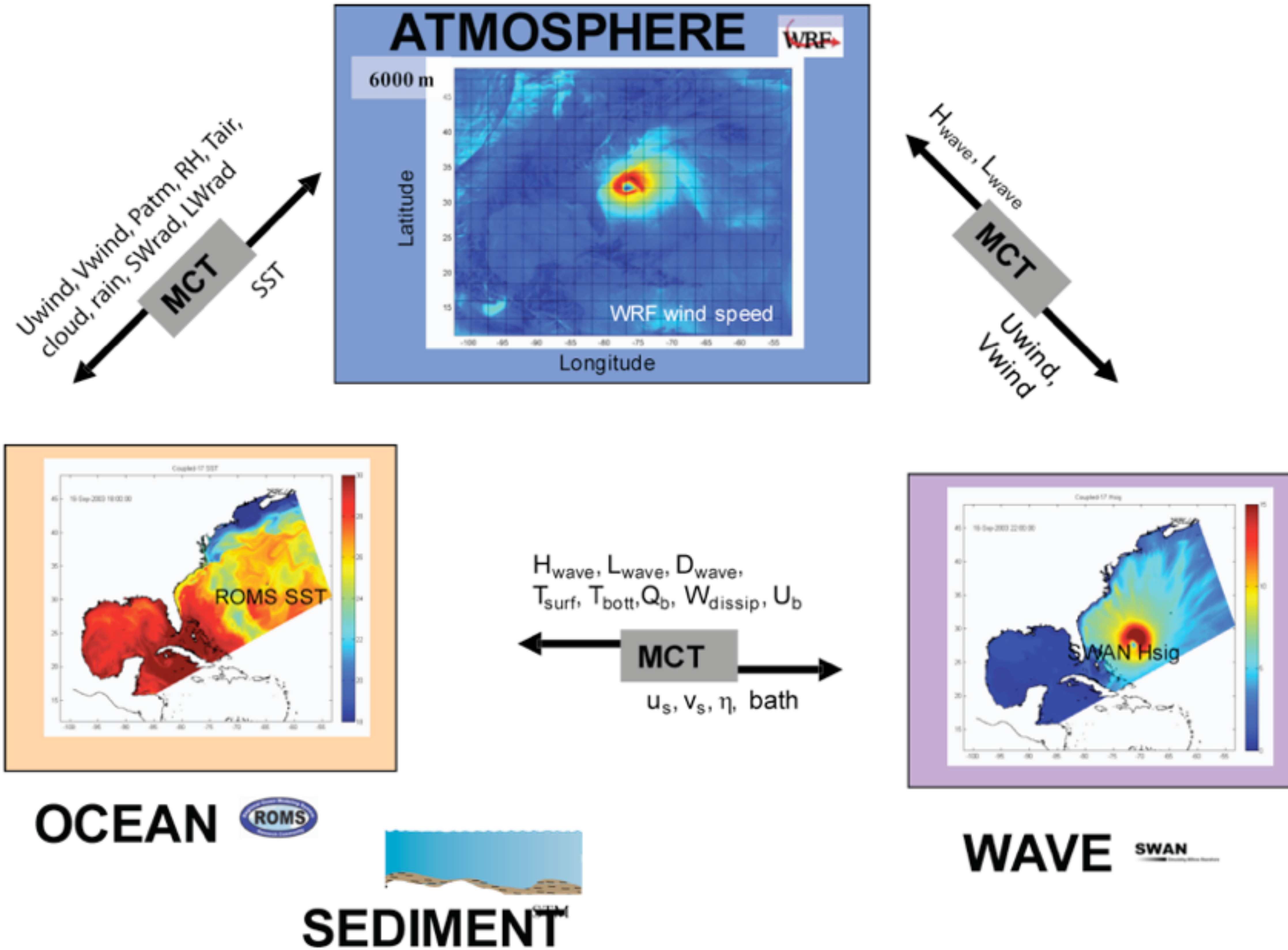
$$\underbrace{\frac{\partial}{\partial t}(H_z u)}_{ACC} + \underbrace{\frac{\partial}{\partial x}(H_z u \cdot u) + \frac{\partial}{\partial y}(H_z u \cdot v) + \boxed{u\frac{\partial}{\partial x}(H_z u^{St}) + u\frac{\partial}{\partial y}(H_z v^{St})}}_{HA}$$

$$\underbrace{\frac{\partial}{\partial s}(w_s u) + \boxed{u\frac{\partial}{\partial s}(w_s^{St})}}_{VA} \underbrace{- H_z f v}_{COR} - \underbrace{\boxed{H_z f v_{St}}}_{StCOR} = \underbrace{\boxed{-H_z \frac{\partial \phi^c}{\partial x}}}_{PG} + \underbrace{\boxed{H_z v^{St}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) - \omega_s^{St}\frac{\partial u}{\partial s}}}_{HVF}$$

$$\underbrace{+H_z F^x}_{BF} + \underbrace{\boxed{H_z F^{wx}}}_{BA+RA+Str} \underbrace{+ H_z D^x}_{HM} - \underbrace{\frac{\partial}{\partial s}\left(\overline{u'v'} - \frac{\nu}{H_z}\frac{\partial u}{\partial s}\right)}_{VM}$$

Wave-current Interaction Terms	
StCOR	Stokes-Coriolis Force
PG	Pressure Gradient (includes Bernoulli head, quasi-static pressure etc.)
HVF	Horizontal Vortex Force
BA, RA	Breaking and Roller Accelerations
Str	Bottom and Surface Streaming

Data Field Exchange



Wave-Current Interaction

WEC_MELLOR

*see Kumar et al., 2011

WEC_VF (needs wave dissipation)

*see Kumar et al., 2012

cppdefs.h (COAWST/ROMS/Include)	
WEC_MELLOR	Activates Mellor (2011) method for WEC
WEC_VF	Activates McWilliams et al. (2004) for WEC

Additional Processes

- Roller Model
- Wave-induced Mixing
- Bottom Streaming
- Surface Streaming

Depth-limited Wave-Dissipation Options

- **WEC_VF** option requires depth-limited dissipation to estimate breaking acceleration (similar to radiation stress gradients).

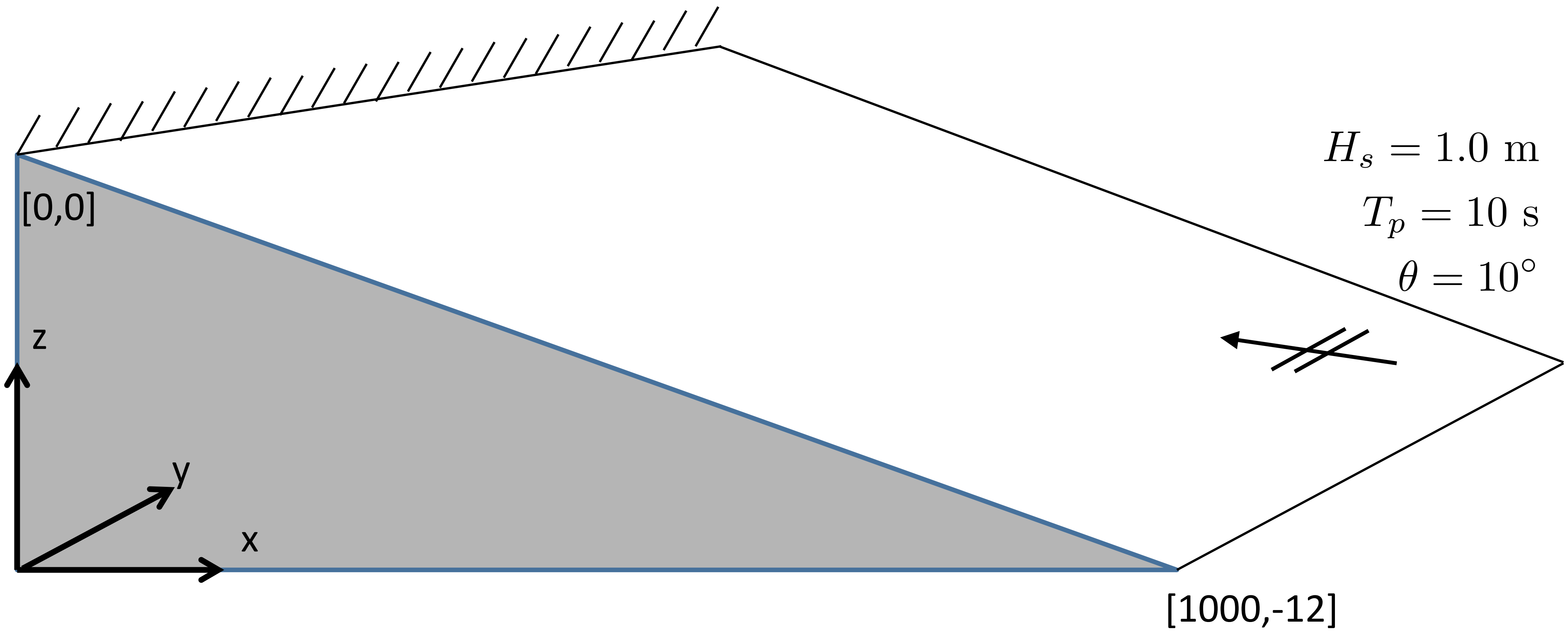
Dissipation Options	
WDISS_THORGUZA	Depth-limited wave dissipation from Thornton & Guza (1983), see Eq. 31.
WDISS_CHURTHOR	Depth-limited wave dissipation from Church & Thornton (1993), see Eq. 32
WDISS_WAVEMOD	Depth-limited wave dissipation from SWAN. Use INRHOG=1

Notes:

- If no wave-dissipation information available use WDISS_THORGUZA/ CHURTHOR

- If no wave-dissipation module is defined and WEC_VF is still activated, the model expects a forcing file with relevant wave quantities

Shoreface Test Case
(Obliquely Incident Waves on a Planar Beach)



- Wave-field computed using SWAN
- One-way coupling (WEC)
- Application Name: SHOREFACE
- Header: COAWST/ROMS/Include/shoreface.h
- Input: COAWST/ROMS/External/ocean_shoreface.in

Header File
(COAWST/ROMS/Include/shoreface.h)

```
/*
** svn $Id: shoreface.h 429 2009-12-20 17:30:26Z arango $
*******************************************************************************
** Copyright (c) 2002-2014 The ROMS/TOMS Group                              **
**   Licensed under a MIT/X style license                                   **
**   See License_ROMS.txt                                                   **
*******************************************************************************
**
** Options for Shore Face Planar Beach Test Case.
**
** Application flag:   SHOREFACE
** Input scripts:      ocean_shoreface.h
**                     sediment_shoreface.h
*/

#define ROMS_MODEL
#undef  WEC_MELLOR
#define WEC_VF
#define WDISS_CHURTHOR
#define BOTTOM_STREAMING
#define SURFACE_STREAMING
```

Do not use if not really studying streaming processes

Input File
(COAWST/ROMS/External/ocean_shoreface.h)

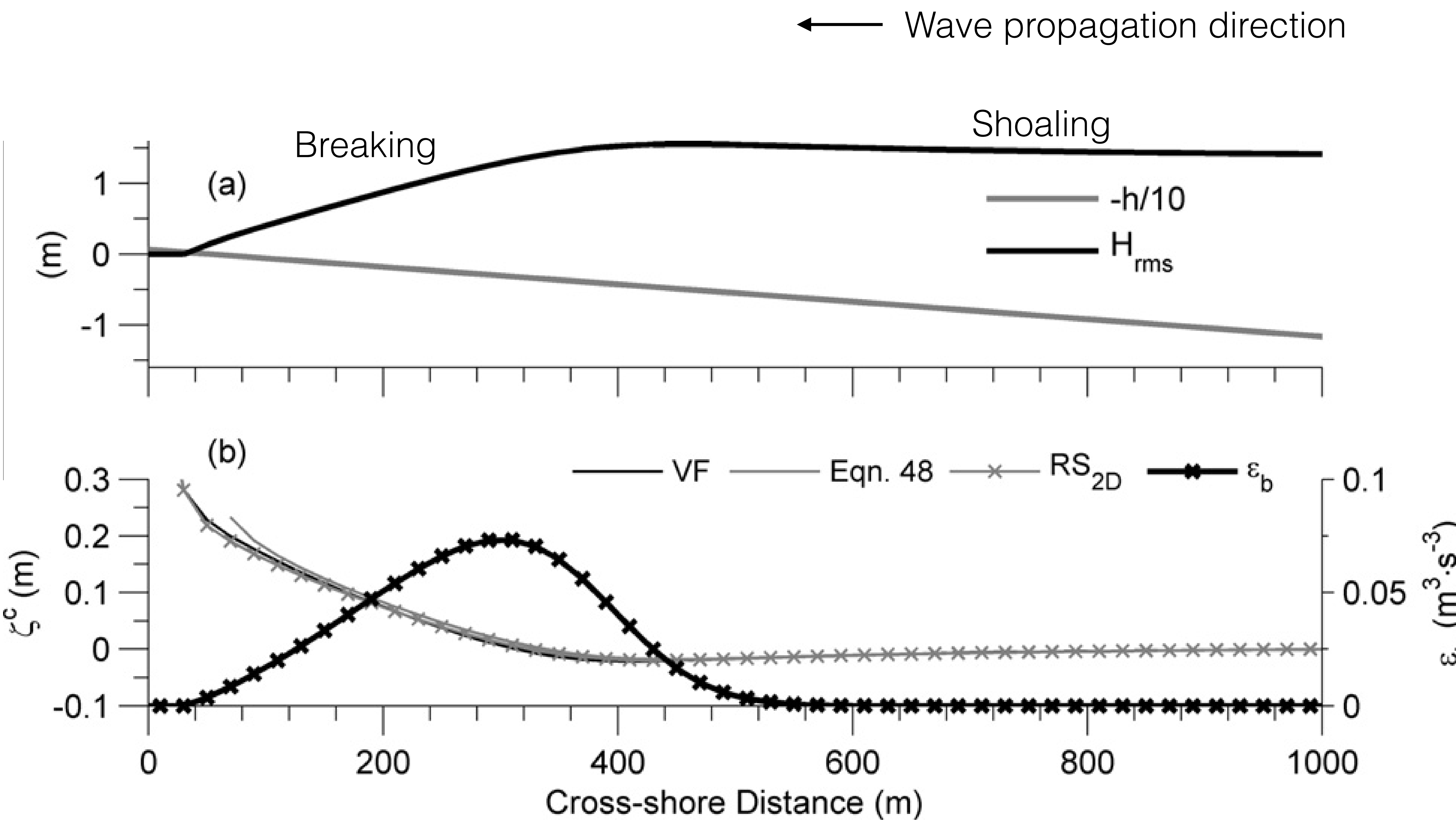
```
! Wec boundary conditions

  LBC(isU2Sd) ==   Gra      Clo      Gra      Gra           ! 2D U-stokes
  LBC(isV2Sd) ==   Gra      Clo      Gra      Gra           ! 2D V-stokes
  LBC(isU3Sd) ==   Gra      Clo      Gra      Gra           ! 3D U-stokes
  LBC(isV3Sd) ==   Gra      Clo      Gra      Gra           ! 3D V-stokes


! Constants used in surface turbulent kinetic energy flux computation.

  CHARNOK_ALPHA == 1400.0d0                   ! Charnok surface roughness
 ZOS_HSIG_ALPHA == 0.5d0                      ! roughness from wave amplitude
       SZ_ALPHA == 0.25d0                     ! roughness from wave dissipation
      CRGBAN_CW == 100.0d0                    ! Craig and Banner wave breaking
      WEC_ALPHA == 0.0d0                      ! 0: all wave dissip goes to break and none to roller.
                                              ! 1: all wave dissip goes to roller and none to breaking.
```

$$B^b = \frac{(1 - \boxed{\alpha^r})\boxed{\epsilon^b}}{\rho_0 \sigma}\mathbf{k} \cdot f^b(z)$$

WEC Related OUTPUT
(COAWST/ROMS/External/ocean_shoreface.h)

```
Hout(idU2Sd) == T         ! ubar_stokes         2D U-Stokes velocity
Hout(idV2Sd) == T         ! vbar_stokes         2D V-Stokes velocity
Hout(idU3Sd) == T         ! u_stokes            3D U-Stokes velocity
Hout(idV3Sd) == T         ! v_stokes            3D V-Stokes velocity
Hout(idW3Sd) == T         ! omega_stokes        3D Omega-Stokes velocity
Hout(idW3St) == T         ! w_stokes            3D W-Stokes velocity
Hout(idWamp) == T         ! Hwave               wave height
Hout(idWlen) == T         ! Lwave               wave length-mean
Hout(idWlep) == T         ! Lwavep              wave length-peak
Hout(idWdir) == T         ! Dwave               wave direction
Hout(idWptp) == T         ! Pwave_top           wave surface period
Hout(idWpbt) == T         ! Pwave_bot           wave bottom period
Hout(idWorb) == T         ! Uwave_rms           wave bottom orbital velocity
Hout(idWbrk) == T         ! Wave_break          wave breaking (percent)
Hout(idUwav) == T         ! uWave               wave-depth avgeraged U-velocity
Hout(idVwav) == T         ! vWave               wave-depth avgeraged V-velocity
Hout(idWdif) == T         ! Dissip_fric         wave dissipation due to bottom friction
Hout(idWdib) == T         ! Dissip_break        wave dissipation due to breaking
Hout(idWdiw) == T         ! Dissip_wcap         wave dissipation due to white capping
Hout(idWdis) == T         ! Dissip_roller       wave roller dissipation
Hout(idWrol) == T         ! rollA               wave roller action density
```

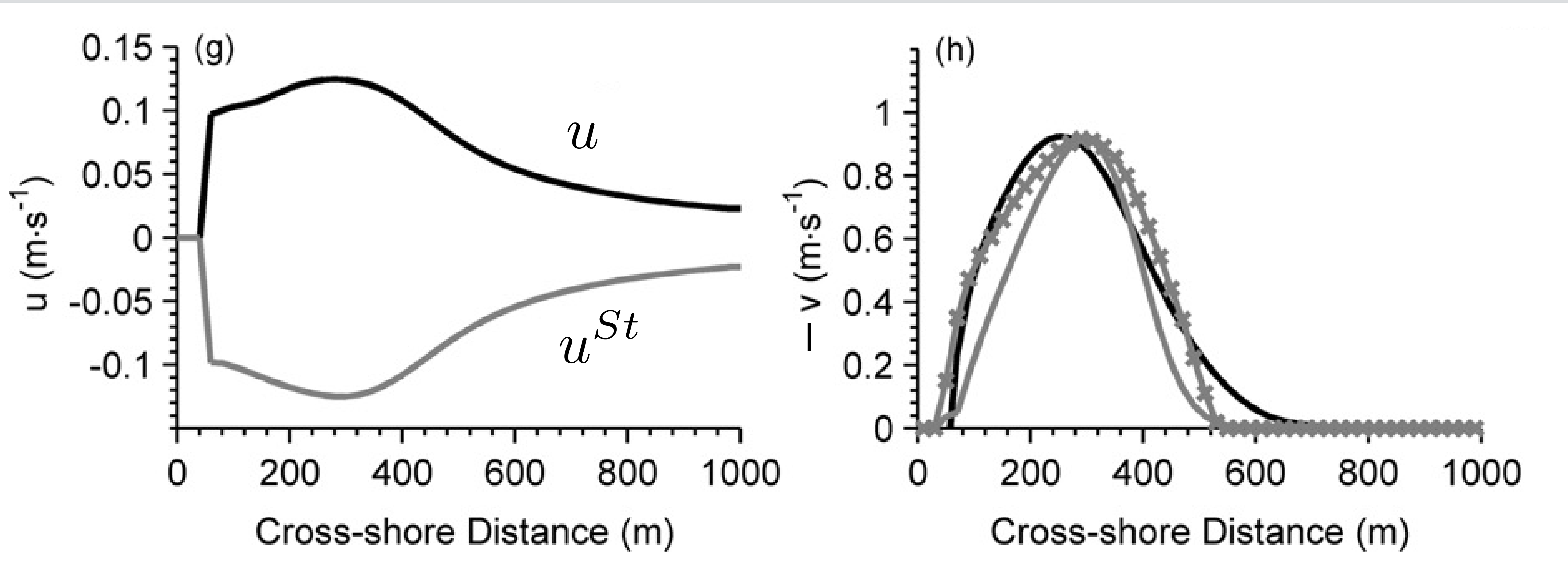
Shoreface Test Results



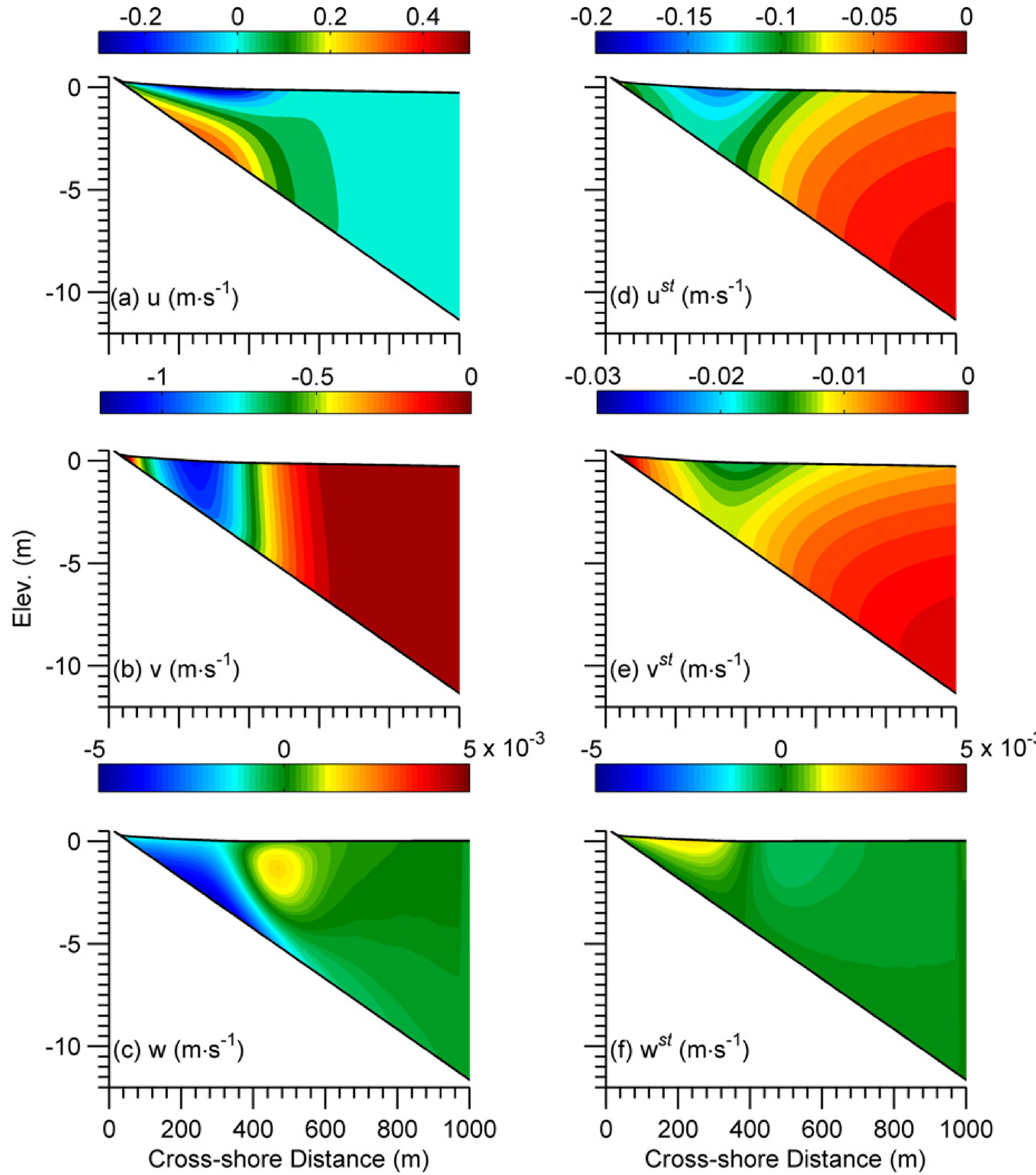
Shoreface Test Results

Cross-shore Velocity

Alongshore Velocity



Shoreface Test Results



Roller Model Options

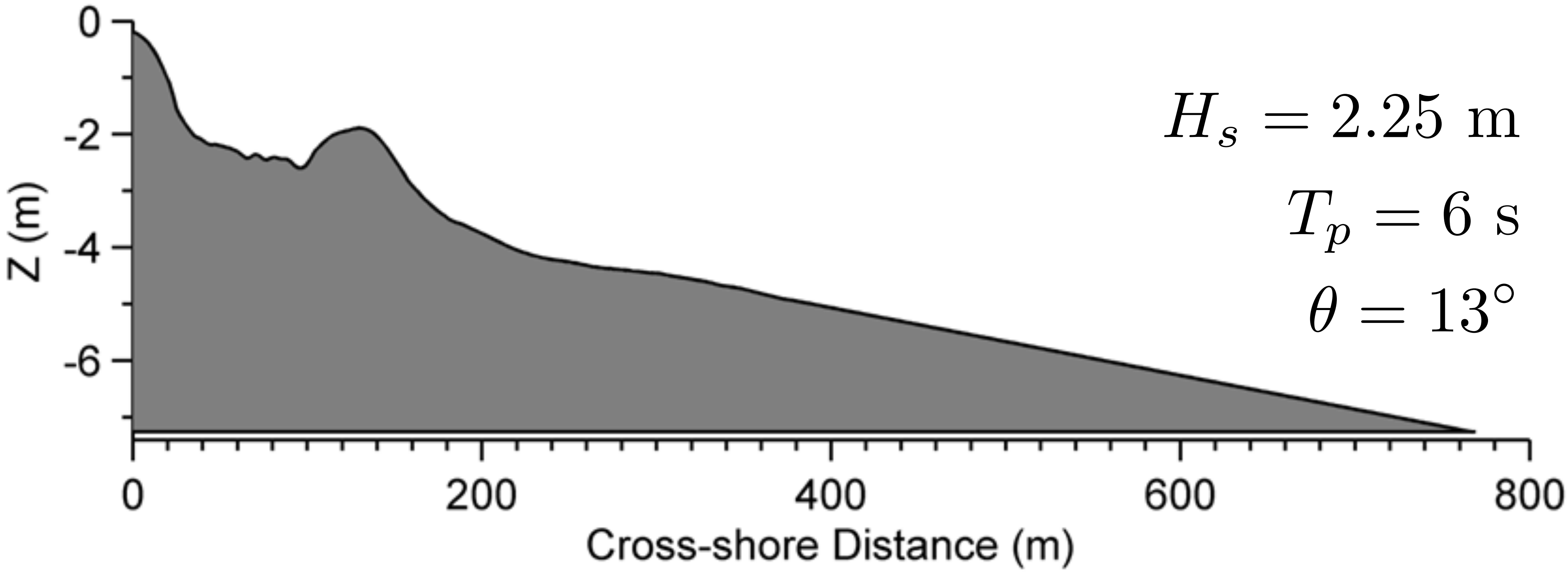
Roller Options	
ROLLER_SVENDSEN	Activates wave rollers based on Svendsen, 1984. See Warner et al. (2008), Eqns. 7 and 10.
ROLLER_MONO	Activates wave roller for monochromatic waves from REF/DIF. See Haas and Warner, 2009.
ROLLER_RENIERS	Activates wave rollers following Reniers et al. (2004). See equations 34-39.

Notes:

- If ROLLER_RENIERS is activated then the parameter wec_alpha in the INPUT file must be changed. For wec_alpha=0 no wave-dissipation goes into creating rollers, while for wec_alpha=1 all wave dissipation creates rollers

```
WEC_ALPHA == 0.0d0                    ! 0: all wave dissip goes to break and none to roller.
                                      ! 1: all wave dissip goes to roller and none to breaking.
```

DUCK'94 Test Case
(Obliquely Incident Waves on a Barred Beach)

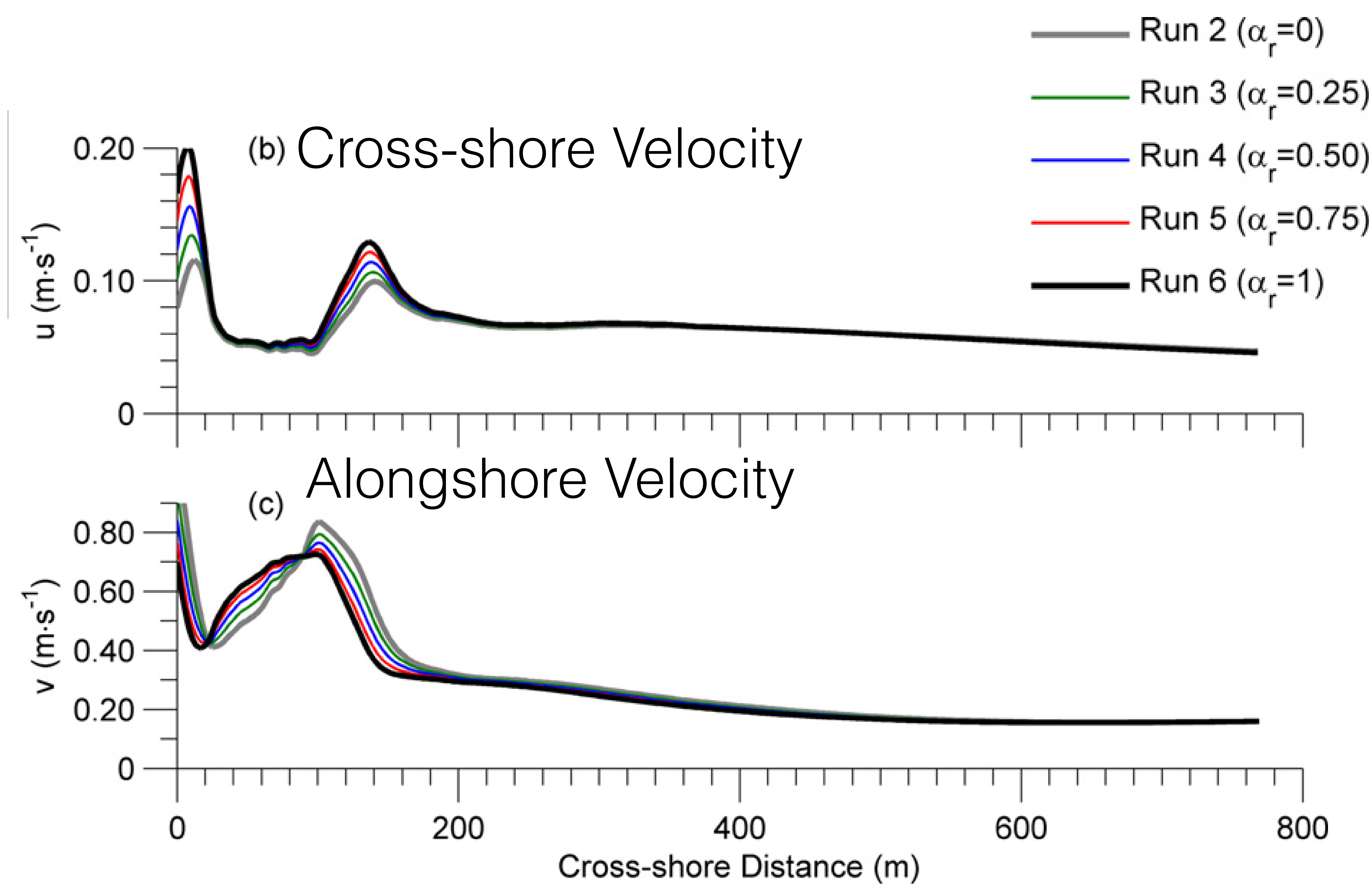


$$H_s = 2.25 \text{ m}$$

$$T_p = 6 \text{ s}$$

$$\theta = 13^\circ$$

Roller Reniers Example (DUCK'94)



Wave-induced Mixing

Mixing Options	
TKE_WAVEDISS ZOS_HSIG	Inputs part of wave-energy dissipation as near surface TKE. See equations 44-47.
	The option ZOS_HSIG indicates that (a) the thickness of near-surface layer where TKE is provided is determined through percent of wave height (see equation 46); (b) the amount of energy as TKE is provided as percent of wave dissipation (see equation 47).

```
ZOS_HSIG_ALPHA == 0.5d0                              ! roughness from wave amplitude
      SZ_ALPHA == 0.25d0                             ! roughness from wave dissipation
```

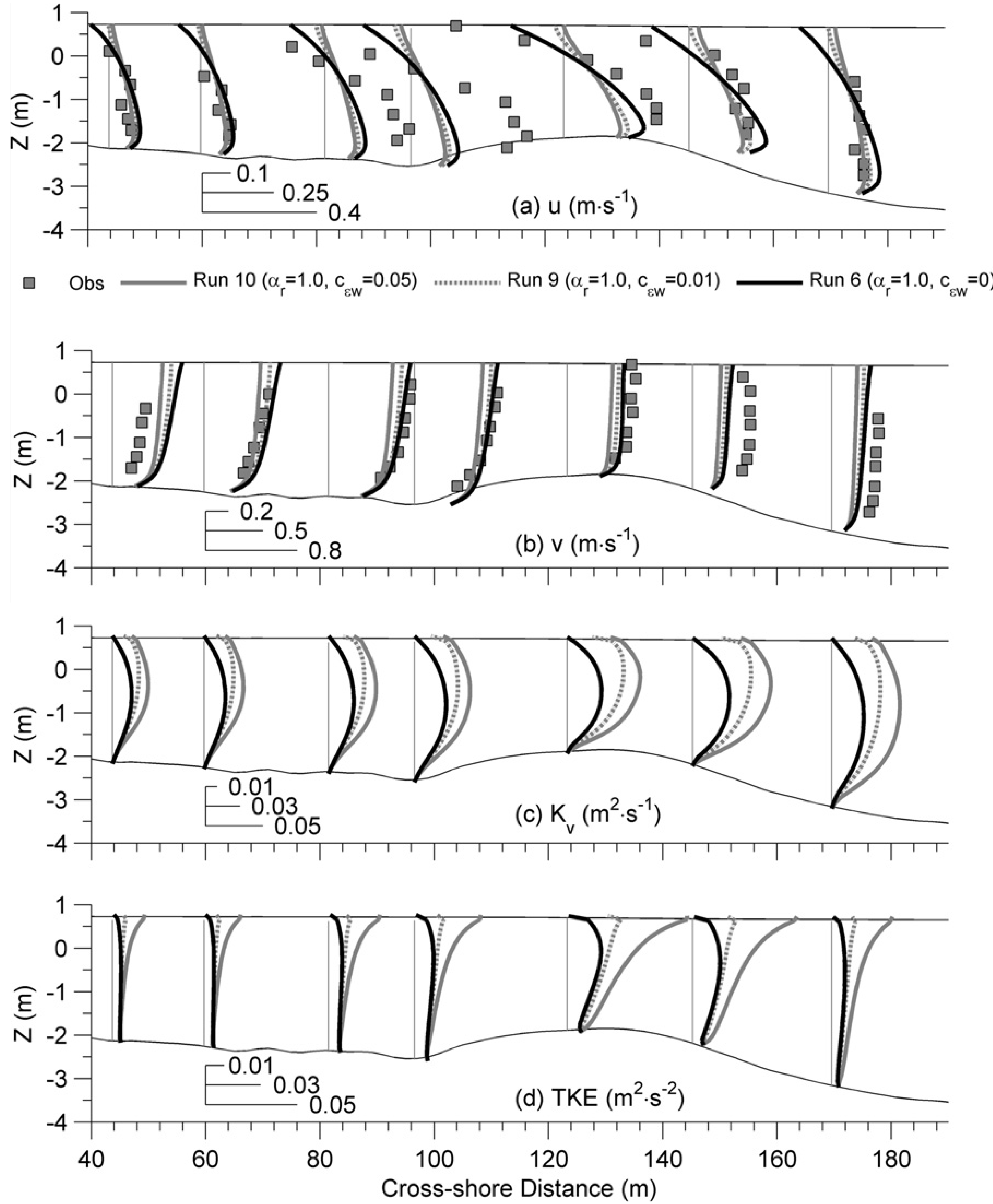
Wave-induced Mixing Example (DUCK' 94)

Cross-shore Velocity

Alongshore Velocity

Vertical eddy viscosity

Turbulent Kinetic Energy



Bottom and Surface Streaming

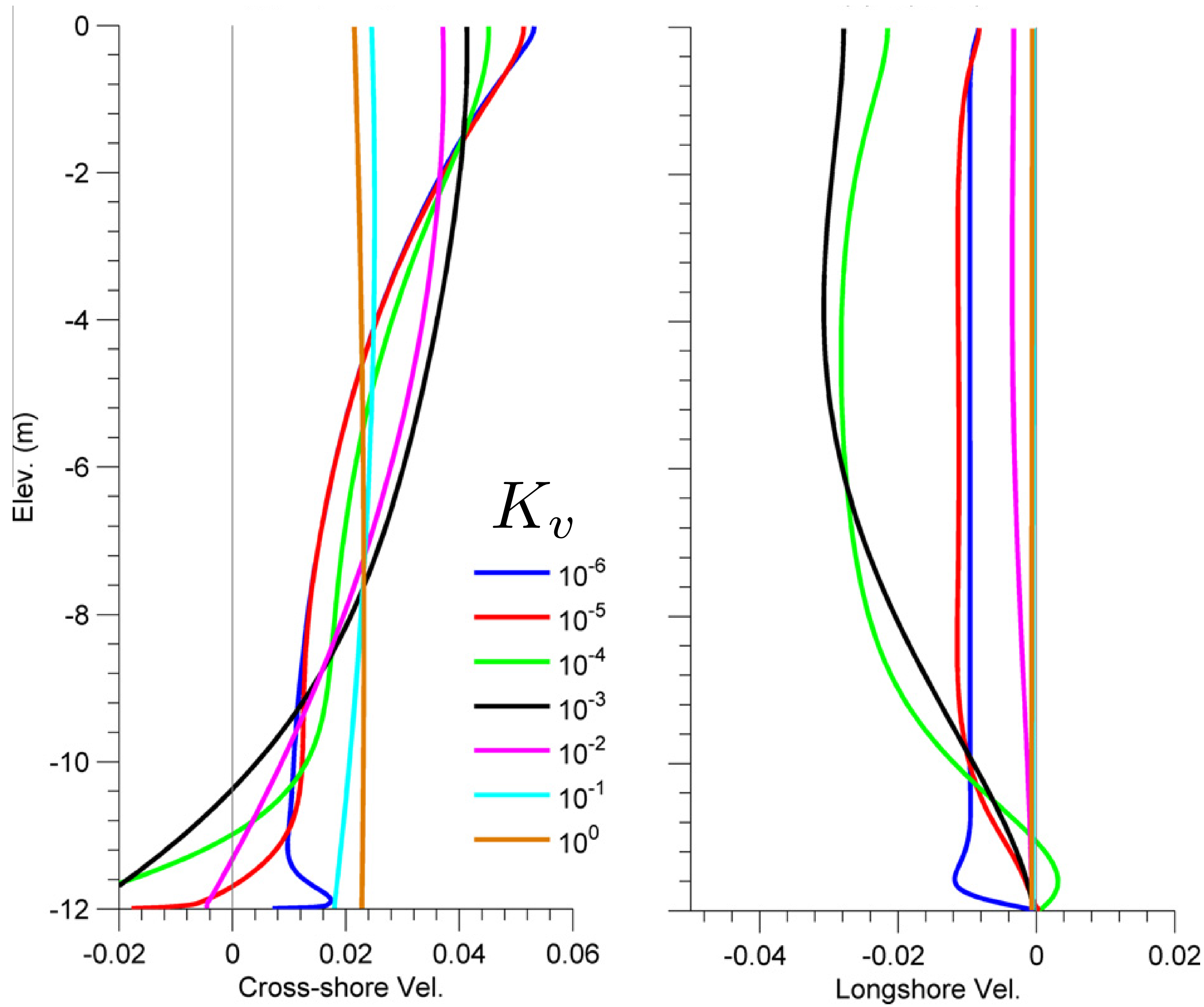
Streaming Options	
BOTTOM_STREAMING	Wave-induced bottom streaming based on Reniers et al. (2004). Requires bottom friction induced wave-dissipation
BOTTOM_STREAMING_ XU_BOWEN	Estimates bottom streaming based on Xu & Bowen (1994)
SURFACE_STREAMING	Estimates surface streaming based on Xu & Bowen (1994)

Notes:

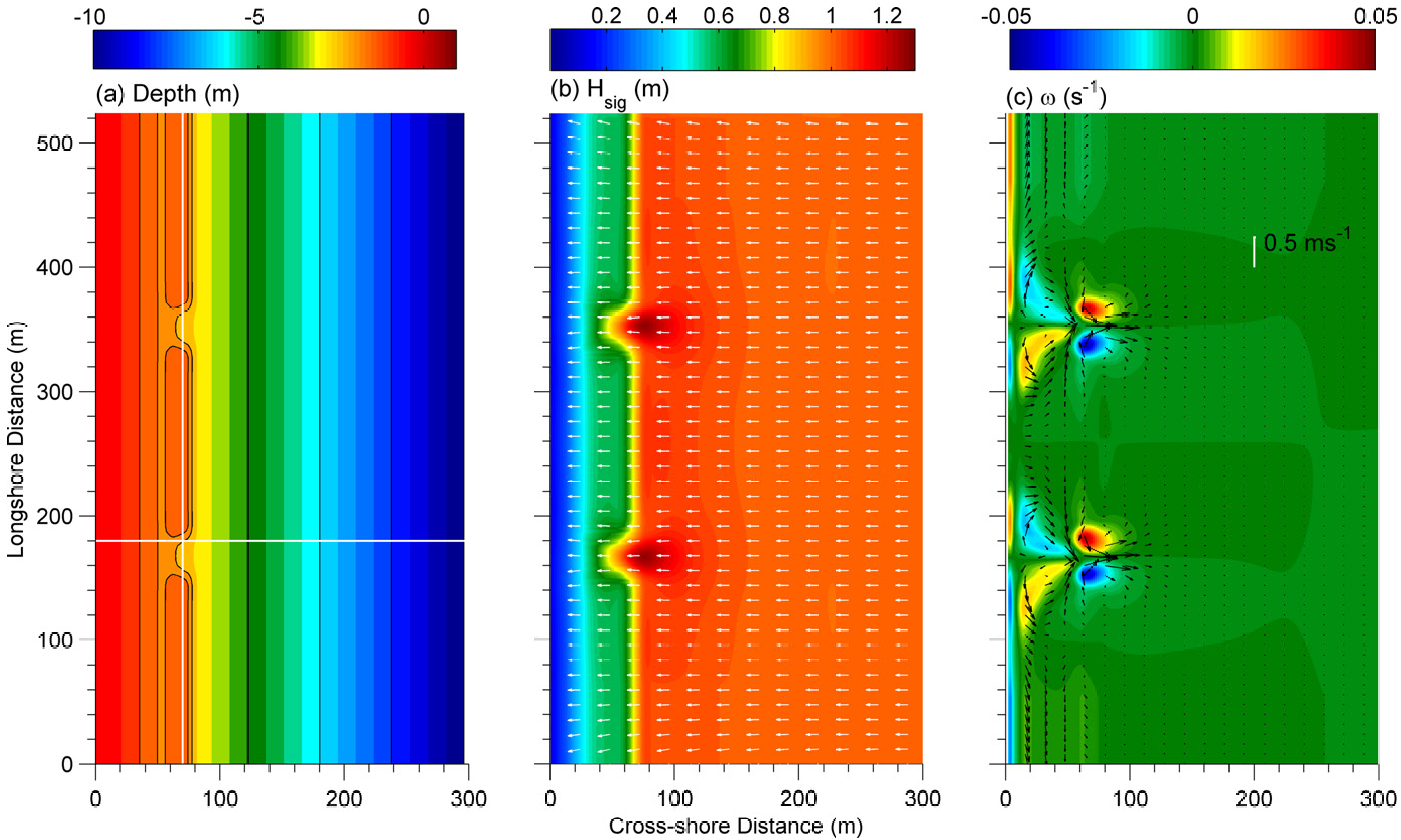
- If BOTTOM_STREAMING_XU_BOWEN is activated, the wave-bottom boundary layer needs to be resolved, which requires very high near-bottom resolution. Suggested **VTRANSFORM=2** and **VSTRETCHING=3**

Bottom Streaming Example (Lentz et al., 2008)

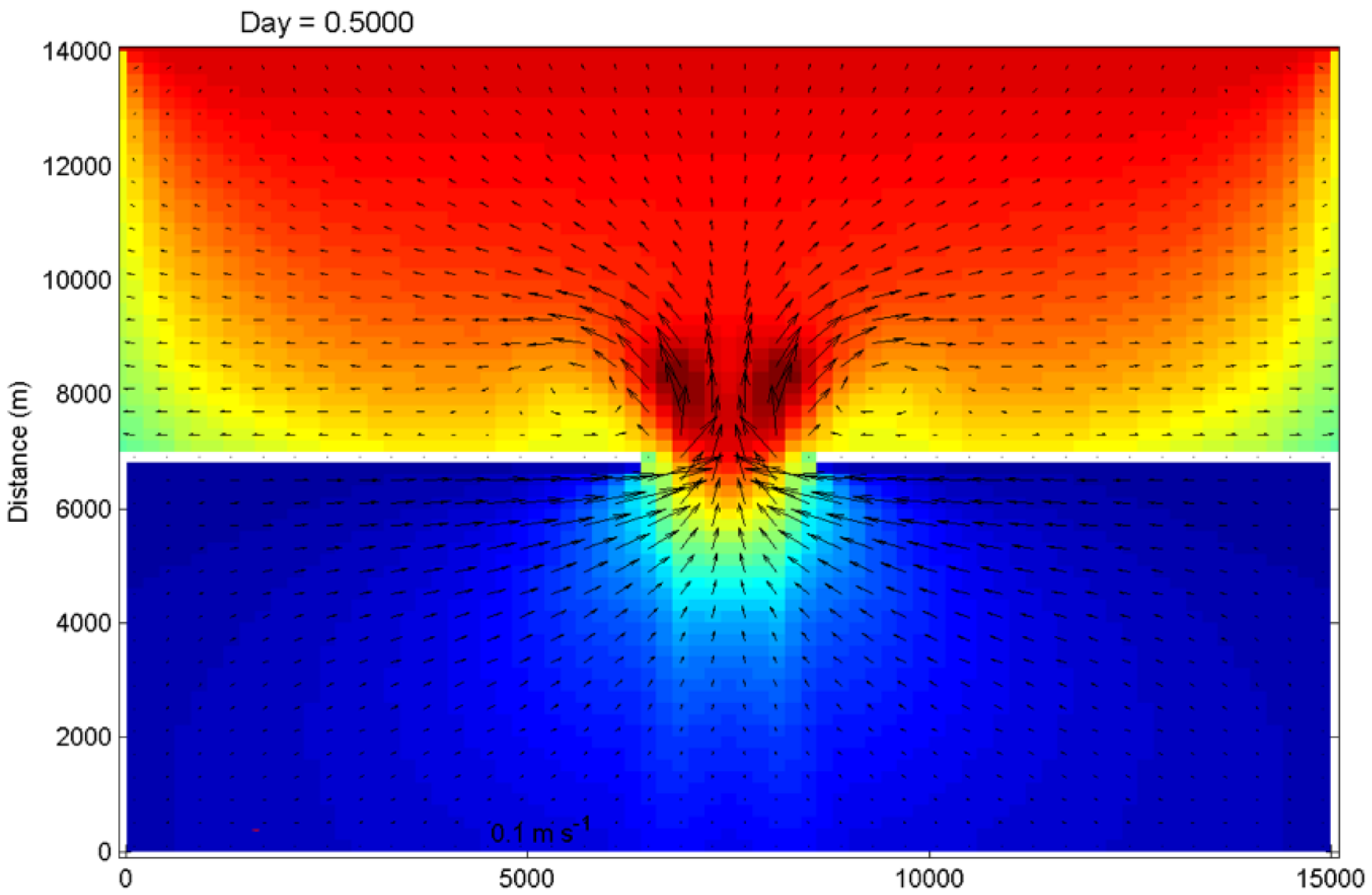
Cross-shore Velocity Alongshore Velocity



Rip-Current Dynamics



Inlet Dynamics



References (& other relevant papers)

Mid-shelf to Surfzone Coupled ROMS-SWAN Model Data Comparison of Waves, Currents, and Temperature: Diagnosis of Subtidal Forcings and Response. Nirnimesh Kumar, Falk Feddersen, Yusuke Uchiyama, James McWilliams, and William O'Reilly, Journal of Physical Oceanography, DOI: /10.1175/JPO-D-14-0151.1, 2015, Link.

The role of morphology and wave–current interaction at tidal inlets: An idealized modeling analysis. Olabarrieta, Maitane, W. Rockwell Geyer, and Nirnimesh Kumar, Journal of Geophysical Research: Oceans, 119(12), 8818-8837, 2014, DOI: 10.1002/2014JC010191, Link.

Implementation of the vortex force formalism in the coupled ocean-atmosphere-wave-sediment transport (COAWST) modeling system for inner shelf and surf zone applications. Nirnimesh Kumar, George Voulgaris, John C. Warner, Maitane Olabarrieta, Ocean Modelling, 47: 65-95, DOI: 10.1016/j.ocemod.2012.01.003, 2012, Link.

Implementation and modification of a three-dimensional radiation stress formulation for surf zone and rip-current applications.Nirnimesh, Kumar, George Voulgaris, and John C. Warner, Coastal Engineering 58, no. 12 (2011): 1097-1117, DOI: 10.1016/j.coastaleng.2011.06.009, 2011, Link.

Wave–current interaction in Willapa Bay. Maitane, Olabarrieta, John C. Warner, and Nirnimesh Kumar, Journal of Geophysical Research: Oceans (1978–2012) 116, no. C12 (2011), DOI: 10.1029/2011JC007387, Link.