Incorporating Random Wave Effects into a Nearshore Circulation Model

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Introduction

- NOPP Nearshore Community Model Project (lead PI: JT Kirby)
- Central circulation model – SHORECIRC (Van Dongeren and Svendsen 2001)
  - ➔Quasi–3D
  - ➔Forced by radiation stress gradients, short–wave volume flux, etc.
  - ➔Standard version of SHORECIRC: wavedriver subroutine is monochromatic wave model (REF/DIF1)
- Application to random waves desired (NCEX motivation) – use spectral model REF/DIF–S
- NOPP modular structure: all wave information to be calculated in wave model

Random Wave Considerations

Need random wave formulation for

1) Short wave volume flux Q
2) Roller effect on radiation stress
3) Wave height decay and energy dissipation

Need input condition modifications

1) Longshorevarying initia l conditions
2) Nestable inside largerscal e model

Random Wave Formulations

Short–wave Volume Flux (outside surf):

$$Q_w = \Sigma \frac{(g|A_n|^2)}{(2\omega_n)}(\cos\Theta_n, \sin\Theta_n)$$

Short–wave Volume Flux (inside surf):

$$Q_{wr} = \frac{A'}{\bar{T}}(\cos\bar{\Theta}, \sin\bar{\Theta})$$

Expressions for roller area *A'* require assumptions about roller characteristics

Random Wave Formulations

1) Lippmann et al. 1996 (using Englund 1981)

$$A' = \frac{\left(B\langle H_b \rangle\right)^3}{\left(4h \tan\sigma\right)} \qquad \langle H_b \rangle^3 = \left(3\frac{\sqrt{\pi}}{4}\right)\left(\frac{1}{(\gamma h)^2}\right) H_{rms}^5 \, F(\gamma, h, H_{rms})$$

$$E_r = \frac{(\rho A' C^2)}{(2L)}$$

"Local Roller"

2) Stive and deVriend (1994) (using Deigaard 1994):

$$(2E_r C \cos\bar{\Theta})_x = S - (2g E_r \sin\beta) \qquad A' = \frac{(2LE_r)}{(\rho C^2)}$$

"Evolving Roller"

Roller Effect on Radiation Stress

Roller Radiation Stress: (Svendsen 1984; Deigaard 1993)

$$S_{xxr} = 2E_r \cos^2 \bar{\Theta} \qquad S_{xyr} = 2E_r \cos \bar{\Theta} \sin \bar{\Theta} \qquad S_{yyr} = 2E_r \sin^2 \bar{\Theta}$$

Radiation Stress of Organized Wave Motion

$$S_{xx[yy]o} = \frac{1}{2} \rho g \Sigma |A_n|^2 \left(\frac{C_{gn}}{C_n} (1 + \cos^2[\sin^2] \Theta_n) - \frac{1}{2} \right)$$

$$S_{xyo} = \frac{1}{4} \rho g \Sigma |A_n|^2 \frac{C_{gn}}{C_n} \sin 2\Theta_n$$

Wave Decay and Energy Dissipation

$$(EC_g)_x = \quad \text{General statement of energy balance}$$

$$= \frac{(3\sqrt{\ })}{16}\frac{(\ gB^3 f)}{(\ ^4 h^5)} H_{rms}^7 \qquad \text{Thornton and Guza (1983)}$$

$$= \frac{(\ g)}{(4\ T)}\ ' Q_b H_{max}^2 \qquad \text{Battjes and Janssen (1978)}$$

$$\frac{(1\ \ Q_b)}{(\ln Q_b)} = \left(\frac{H_{rms}}{H_{max}}\right)^2 \qquad H_{max} = \frac{0.88}{k}\tanh\left(\frac{(\ \ ' kh)}{0.88}\right)$$

Wave Decay and Energy Dissipation

Generic Form of REF/DIFS:

$$C_{gn} A_{n,x} - QA_n - RA_{n,yy} - SA_{n,xy} - TA_{n,yyx} - A_n = 0$$

$$= \frac{(3\sqrt{\ })}{4} \frac{(fB^3)}{(4h^5)} H_{rms}^5$$

Chawla et al. (1998) standard formulation in REF/DIF S

$$= \frac{(\ ')}{2} fQ_b \left(\frac{H_{max}}{H_{rms}} \right)^2$$

Eldeberky and Battjes (1996)

Test Cases

SHORECIRC Quasi3D Model Forced by REF/DIF S

Dispersive 3D mixing engaged in SHORECIRC

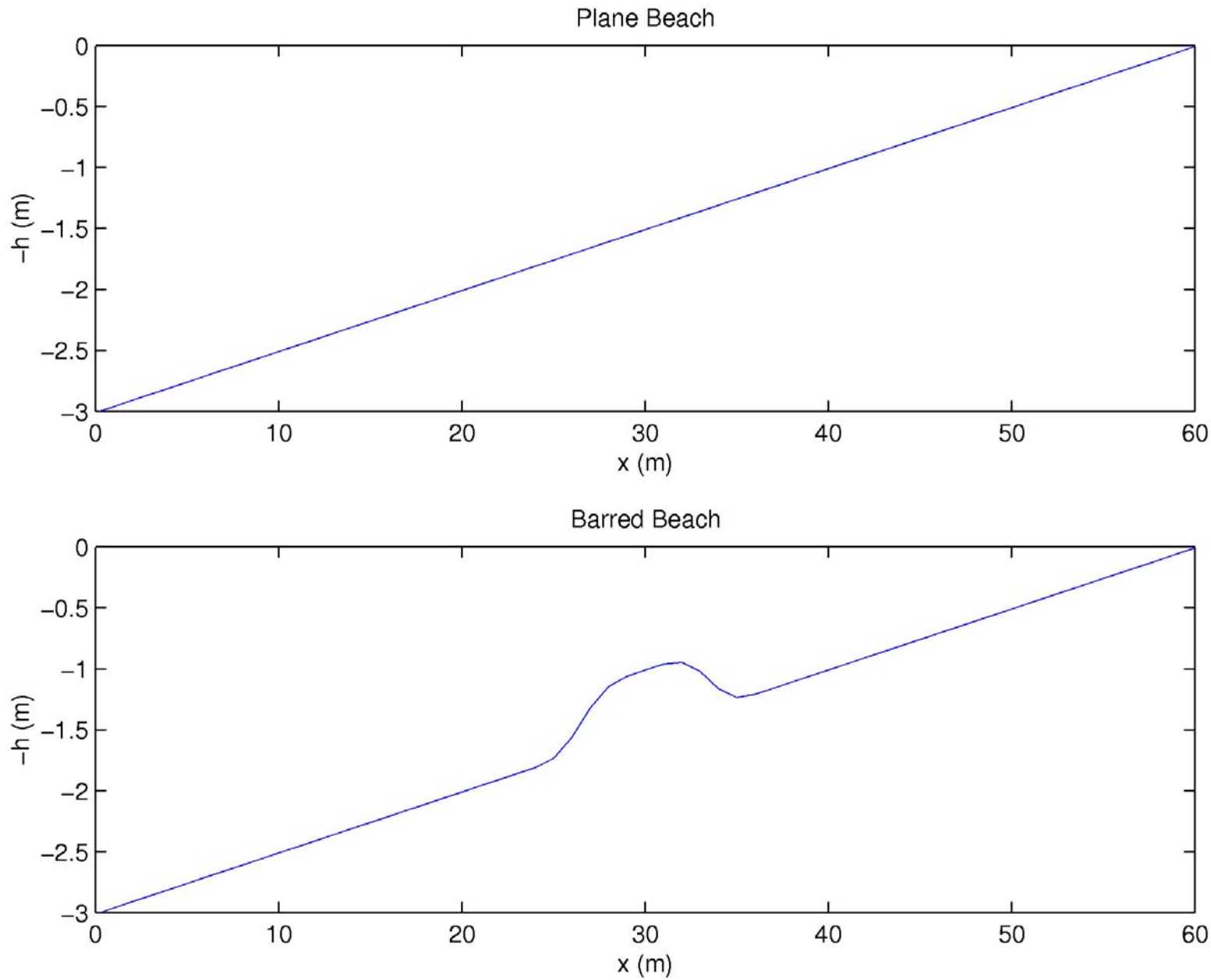
Free parameters for SHORECIRC fc=0.02, CK=0.2, M=0.1

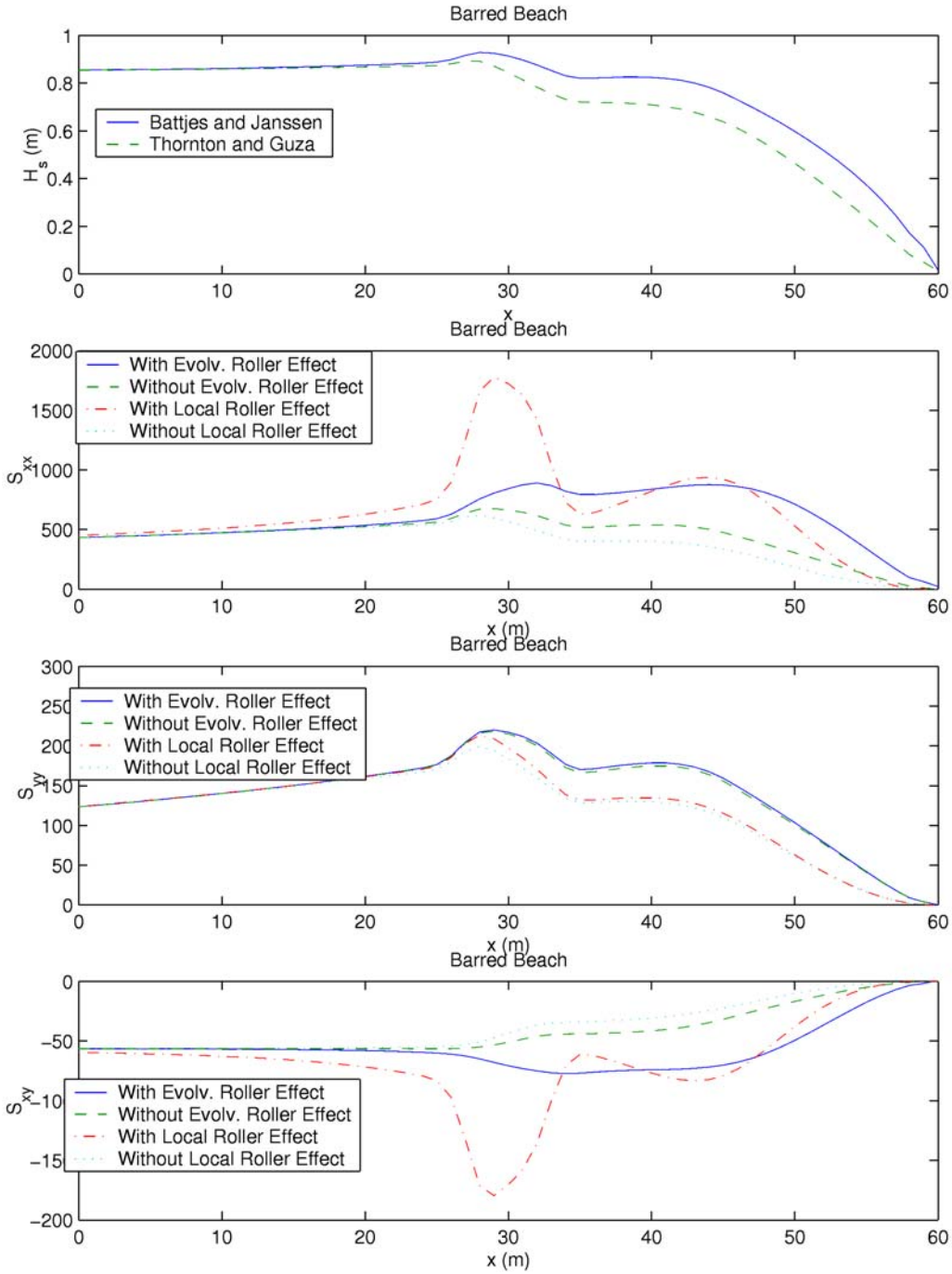
dx=dy=1 m

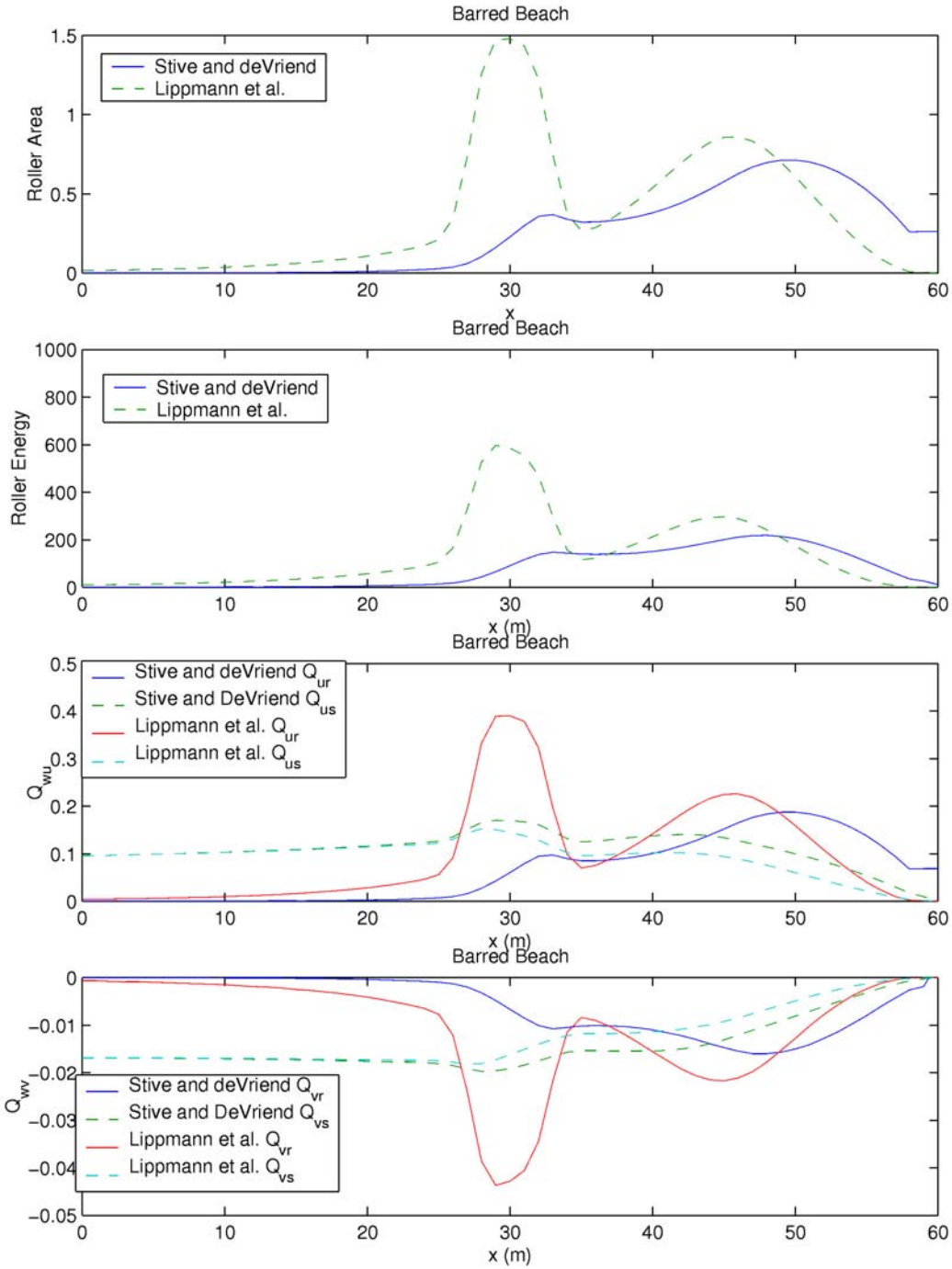
Grid = 60 $m$crossshore, 40 $m$longshore

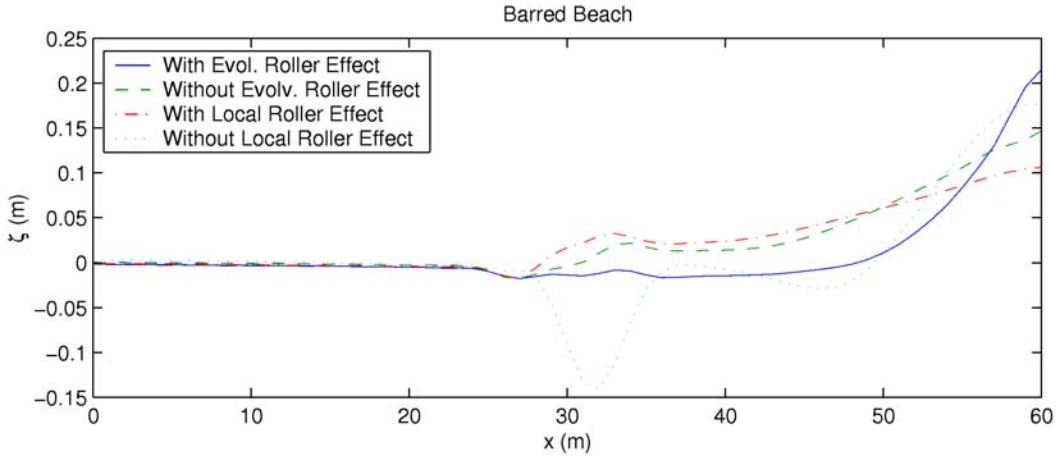
Periodic lateral boundary conditions

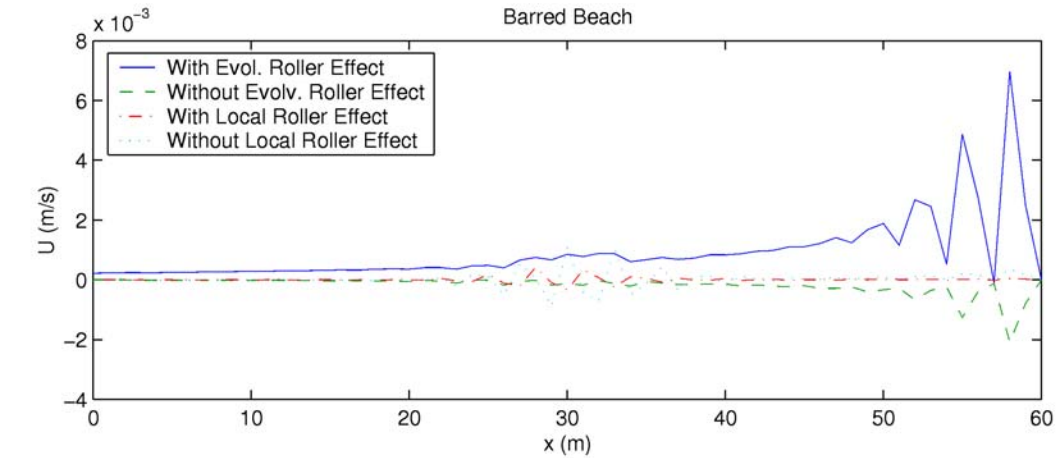
Input wave condition: TMA spectrum (narrowness coefficient = 20) with 5 degree directional spread, 10 degree m ean approach angle, peak period = 4 s, Hs = 0.86 m

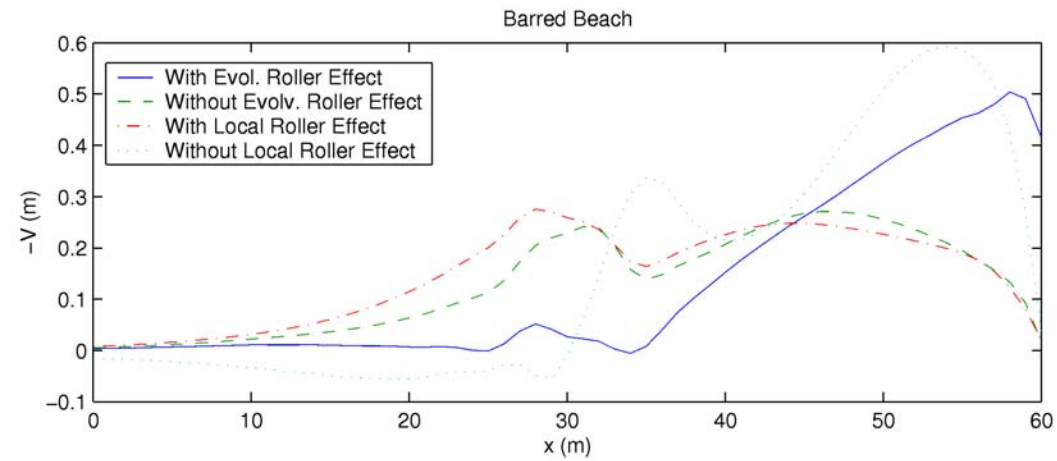

Plane Beach
0
−0.5
−1
−1.5
−2
−2.5
−3
−h (m)
0
10
20
30
40
50
60
x (m)
Barred Beach
0
−0.5
−1
−1.5
−2
−2.5
−3
−h (m)
0
10
20
30
40
50
60
x (m)

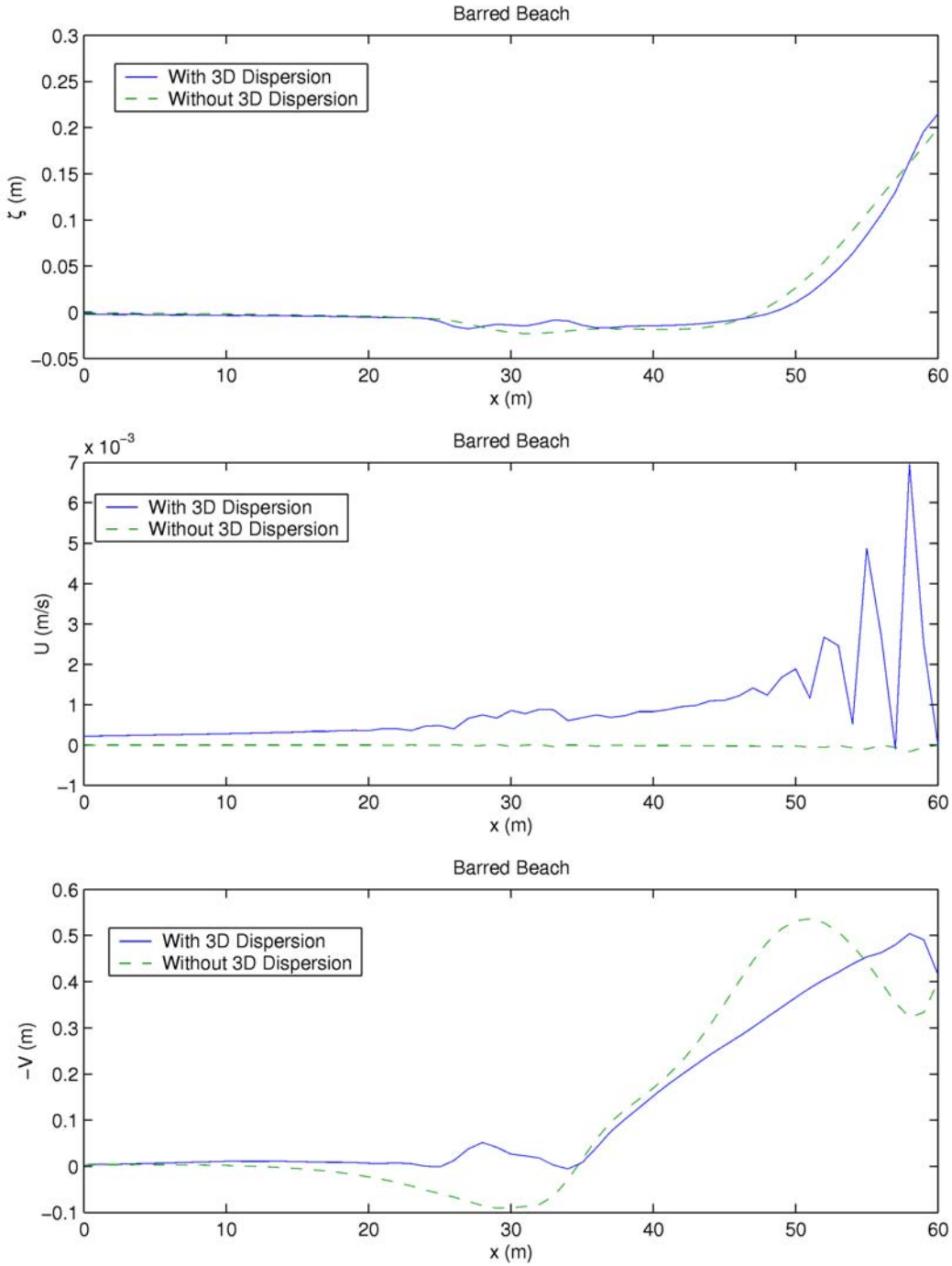

Barred Beach
Battjes and Janssen
Thornton and Guza
H_s (m)
x
Barred Beach
With Evolv. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
S_{xx}
x (m)
Barred Beach
With Evolv. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
S_{xy}
x (m)
Barred Beach
With Evolv. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
S_{xy}
x (m)


Barred Beach
Roller Area
Stive and deVriend
Lippmann et al.
x
Barred Beach
Roller Energy
Stive and deVriend
Lippmann et al.
x (m)
Barred Beach
Q_{wu}
Stive and deVriend Q_{ur}
Stive and DeVriend Q_{us}
Lippmann et al. Q_{ur}
Lippmann et al. Q_{us}
x (m)
Barred Beach
Q_{wv}
Stive and deVriend Q_{vr}
Stive and DeVriend Q_{vs}
Lippmann et al. Q_{vr}
Lippmann et al. Q_{vs}
x (m)


Barred Beach
With Evol. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
ζ (m)
x (m)


Barred Beach
x 10^-3
With Evol. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
U (m/s)
x (m)


Barred Beach
With Evol. Roller Effect
Without Evolv. Roller Effect
With Local Roller Effect
Without Local Roller Effect
-V (m)
x (m)


Barred Beach
With 3D Dispersion
Without 3D Dispersion
ζ (m)
x (m)
Barred Beach
x 10^-3
With 3D Dispersion
Without 3D Dispersion
U (m/s)
x (m)
Barred Beach
With 3D Dispersion
Without 3D Dispersion
-V (m)
x (m)

Summary

- The random wave model REF/DIF–S has been incorporated into the quasi–3D model SHORECIRC
- Random formulations for short wave volume flux, roller effects on radiation stress, etc. were developed
- Roller mechanisms ("local roller" and "evolving roller") were incorporated.
- Dissipation mechanism of Battjes and Janssen incorporated to compliment Thornton and Guza
- Simple tests reveal that evolving roller may not interact well with 3D dispersion mechanism in SHORECIRC