CD14B-0049: Adapting a Regional Scale Coupled Modeling System to Nearshore Applications

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1. ABSTRACT. The Coupled Ocean Atmospheric Modeling System (COAMPS) is a **modeling suite of atmospheric, ocean circulation, and wave models** that exchange information using the Earth System Modeling Framework (ESMF). In this system, the Navy Coastal Ocean Model **(NCOM) is the circulation model** and Simulating Waves Nearshore **(SWAN) is the wave model**. In nearshore applications of coupled circulation-wave models, one mechanism for transferring wave energy to the ocean circulation is via **radiation stress gradients**. Previous modeling studies with horizontal scales that resolve the surf zone show **a lag between dissipation of wave energy and the transfer of momentum to the water column**, resulting in an onshore shift in the location of the maximum wave forcing. Passive regions of circulating water carried onshore by breaking waves, referred to as **wave rollers, cause the lag and shift in location**. We consider the effects of the wave rollers by **computing the radiation stresses as a function of both wave and roller energies for an idealized plane beach study**.

3. APPROACH.

We employ an empirical form of roller energy, $\mathbf{E_r}$, and include it in the calculation of radiation stresses. For example, the $\mathbf{S_{xx}}$ radiation stress becomes

$$S_{xx} = E_w\left\{\left[\cos^2(\bar{\theta})+1\right]\frac{c_g}{c}-\frac{1}{2}\right\}+2E_r\left[\cos^2(\bar{\theta})\right],$$

as given by Apotsos et al. 2007.
The roller energy is given by (Reniers and Battjes, 1997)

$$E_r = \frac{\rho A c^2}{2L},$$

where ρ is water density, c is wave speed, L is wave length, and A is the roller area given by (Svendsen, 1984)

$$A = 0.9H_s^2,$$

where H_s is the significant wave height defined as

$$H_s = 4\sqrt{m_0}.$$

Therefore, the roller energy is given as

$$E_r = \frac{3.6\,\rho\, m_0\, c^2}{L},$$

and the $\mathbf{S_{xy}}$ and $\mathbf{S_{yy}}$ radiation stress tensors are given as

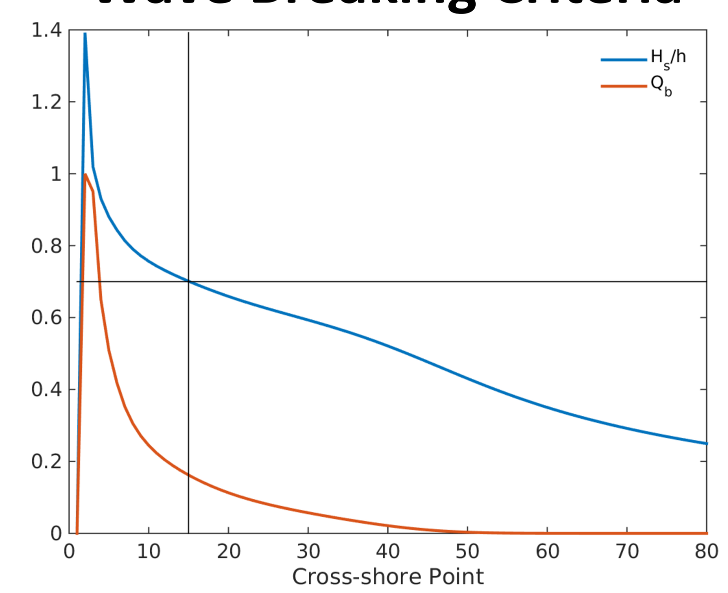
$$S_{xy} = E_w\left\{\frac{c_g}{c}\sin\bar{\theta}\,\cos\bar{\theta}\right\}+2E_r\left[\sin\bar{\theta}\,\cos\bar{\theta}\right]$$

$$S_{yy} = E_w\left\{\left[\sin^2(\bar{\theta})+1\right]\frac{c_g}{c}-\frac{1}{2}\right\}+2E_r\left[\sin^2(\bar{\theta})\right].$$

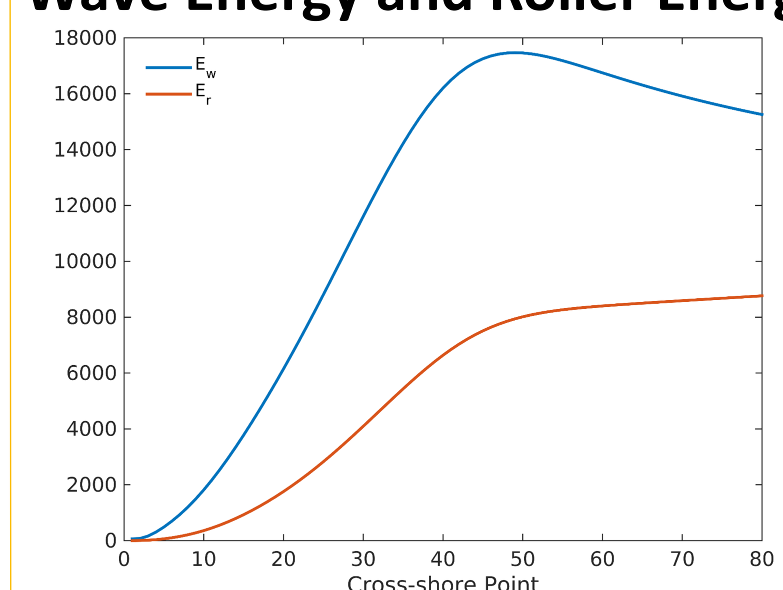
4. ROLLER CONTRIBUTION

- We consider waves to be breaking when
$$\frac{H_s}{h} \geq 0.7$$
and include the roller contribution only when this criterion is met.
- The percent wave breaking, $\mathbf{Q_b}$, was considered as a criterion and factor.

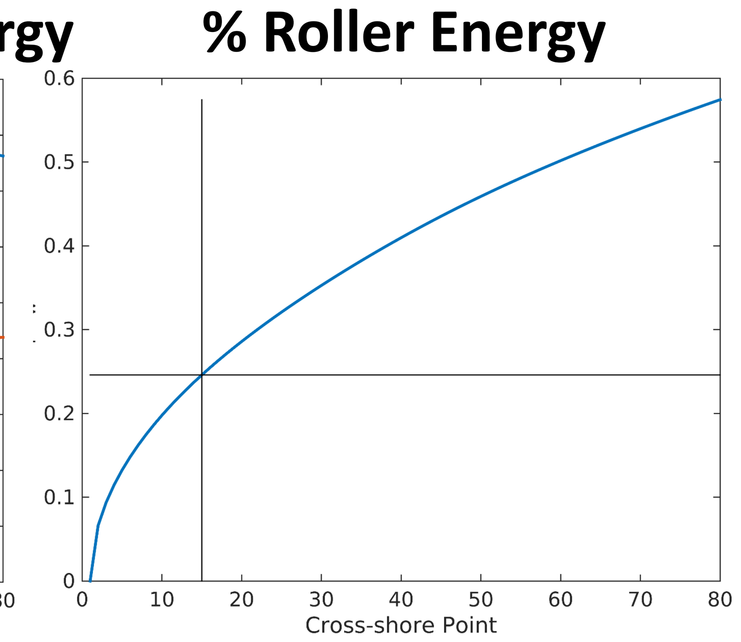
Wave Breaking Criteria



Wave Energy and Roller Energy



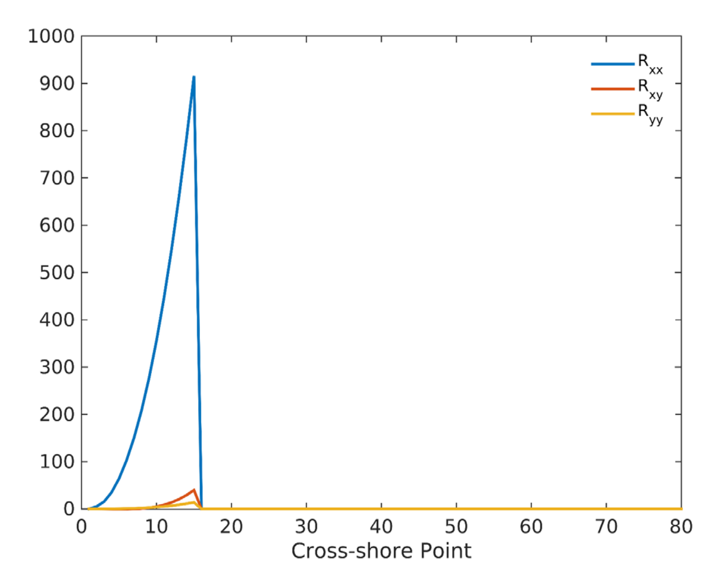
% Roller Energy



At the cross-shore location of initial "breaking" the wave roller energy is approximately 25% of the wave energy.

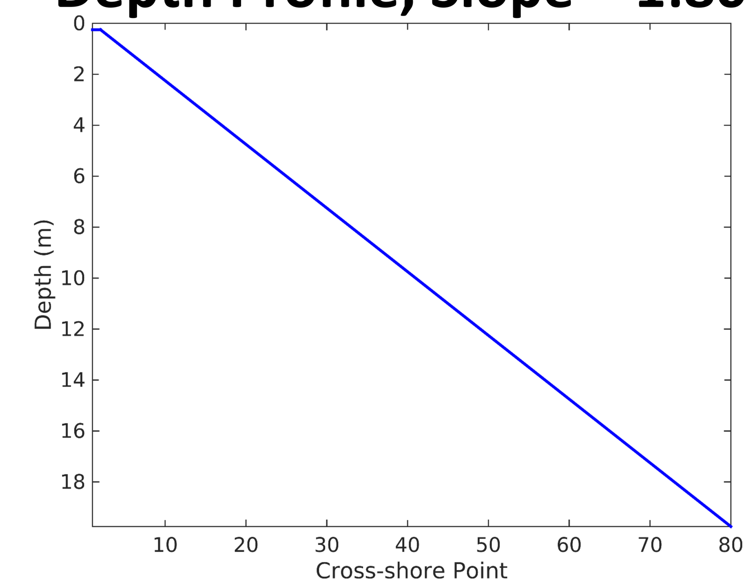
- The roller contributions are ZERO until the breaking criterion is met.
- The roller contributions are greatest for the xx-stress.

Roller Contributions



2. PLANE BEACH TEST CASE

Depth Profile, Slope = 1:80



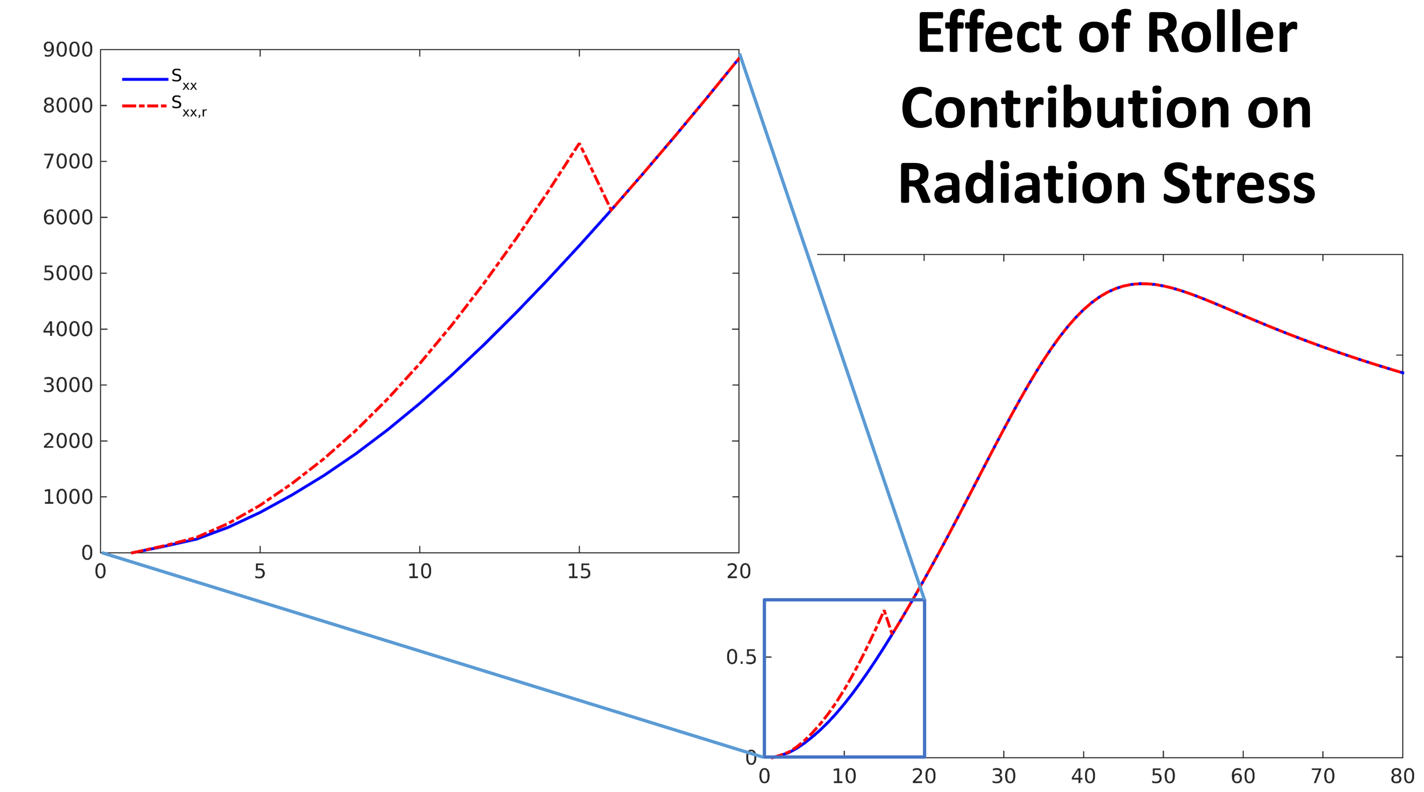
Grid Properties:
dx = dy = 25.0 m
m = 80
n = 120

Boundary Conditions:
H_s = 5.0 m
T_p = 20.0 s
θ_p = 80º

5. RESULTS

The roller contribution in the x-direction pushes increased stress closer to the shore.

Effect of Roller Contribution on Radiation Stress



WHAT'S NEXT?

- Couple SWAN with NCOM.
- Evaluate how the roller contribution changes the wave force and the wave-driven circulation.
- Repeat the Plane Beach Test Case for a barred bathymetry.
- Evaluate the roller contribution and its effects on the circulation model for a field site (DUCK, NC).

6. REFERENCES.

Apotsos, A., B. Raubenheimer, S. Elgar, R. T. Guza, and J. A. Smith (2007), Effects of wave rollers and bottom stress on wave setup. J. Geophys. Res., 112, C02003, doi:10.1029/2006JC003549.

Reniers, A. J. H. M. and J. A. Battjes (1997), A laboratory study of longshore currents over barred and non-barred beaches. Coastal Eng., 30, 1-22.

Svendsen, I. A. (1984), Wave heights and set-up in a surfzone. Coastal Eng., 8, 303-329.