Surface Gravity Wave Effect in Turbulent Kinetic Energy Flux across the Air-sea Interface

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Motivation for this Study

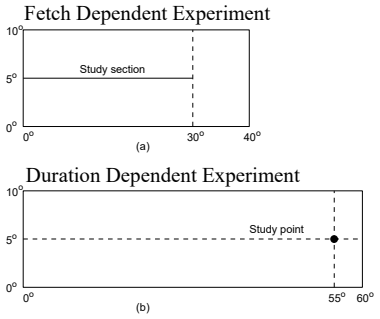
The kinetic energy (KE) fluxes into subsurface currents (EF_c) is important boundary condition for ocean circulation models. Traditionally, numerical models assume the KE flux from air (EF_{air}) is identical to the KE flux into subsurface currents, that is, no net KE is gained (or lost) by surface waves. This assumption, however, is invalid when the surface wave field is not fully developed. When the surface wave field grows (decays) in space or time, it acquires (gives up) kinetic energy, hence, reduces (increases) the KE fluxes into subsurface currents compared to the fluxes from wind. In this study, numerical experiments are performed to investigate the KE flux budget across the air-sea interface under both uniform and idealized tropical cyclone winds.

The Model

WAVEWATCH III® (WWIII) version 4.18:

- 24 directions
- 40 frequencies (0.0285 ~ 1.1726 Hz)
- 1/12° resolution in both directions
- 100 seconds global time step
- ST4 source package (Ardhuin et al 2010)
- ST6 source package (Babanin 2011)

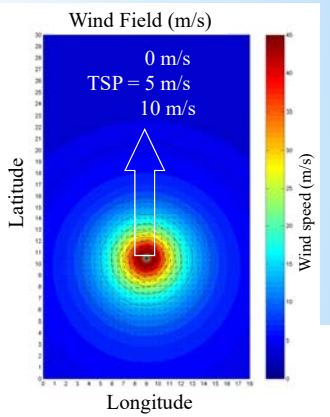
Uniform Experiment



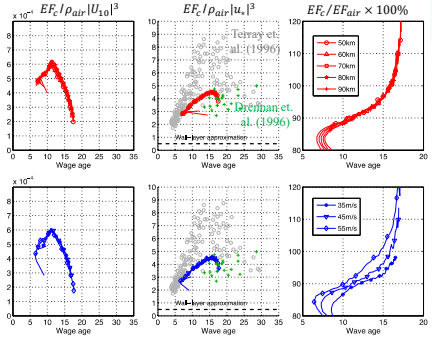
TC Type	TSP (ms^{-1})	MWS (ms^{-1})	RMW (km)
stationary	0	45	50, 60, 70, 80, 90
stationary	0	35, 45, 55	70
moving	5, 10	45	70

TC – tropical cyclone, MWS – maximum wind speed
TSP – translation speed, RMW – radius of maximum wind

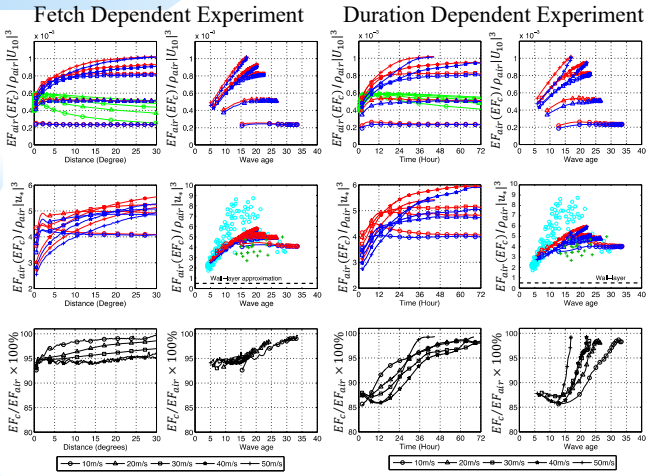
Tropical Cyclone Experiments



Stationary



ST4 Source Function



Kinetic energy flux in the fetch /duration dependent experiments with steady homogenous winds of 10, 20, 30, 40, and 50 ms^{-1} represented by different symbols in the legend.

Red line with symbols – normalized energy flux from air, EF_{air}

Blue line with symbols – normalized energy flux into currents, EF_c

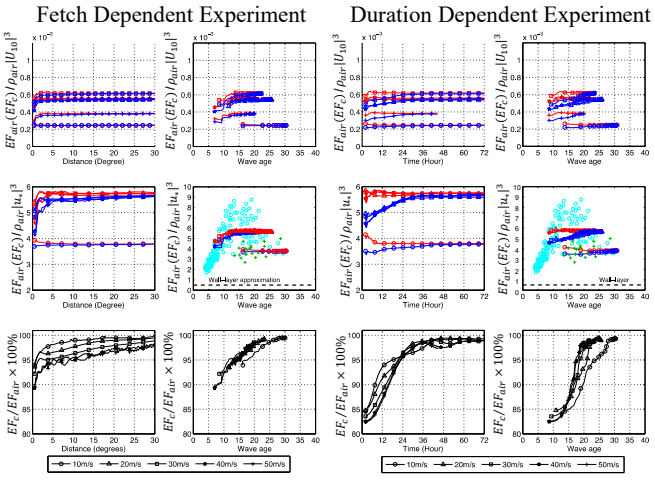
Green line with symbols – analytical expressions of the normalized EF_{air} by Hwang and Sletten (2008)

Black line with symbols – ratio of EF_c/EF_{air}

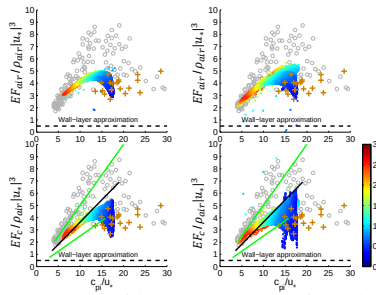
Green cross – normalized EF_{air} data from Drennan et al. (1996)

Cyan circles – normalized EF_{air} data from Figure 8 in Terray et al. (1996)

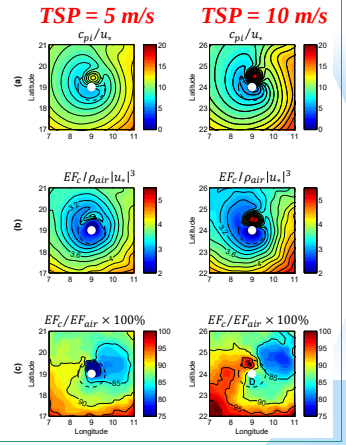
ST6 Source Function



TSP = 5 m/s and TSP = 10 m/s



o Terray et al (1996) + Drennan et al (1996)
– and – : Hwang and Walsh (2006)



Conclusion

The modeled EF_c is significantly reduced relative to EF_{air} under growing seas for both the uniform and TC experiments. The reduction can be as large as 20%, and the variation of this ratio is highly dependent on the choice of source function for the wave model. Normalized EF_c are found to be consistent with analytical expressions by Hwang and Sletten (2008) and Hwang and Walsh (2016) and field observations by Terray et al. (1996) and Drennan et al (1996), while the scatters are more widely in the TC cases due to the complexity of the associated wave field. The waves may even give up KE to subsurface currents in the left rear quadrant of fast moving storms. Our results also suggest that the normalized KE fluxes may depend on both wave age and friction velocity (u_*).

References

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