Structure of the Airflow above Surface Waves

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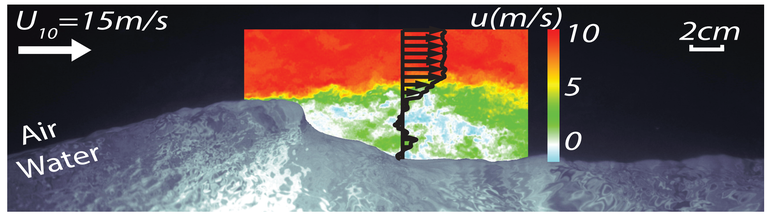

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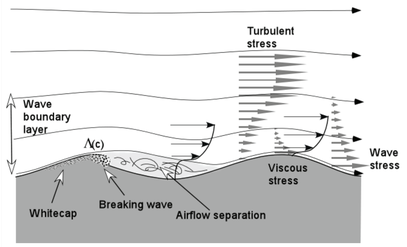
EGU2016-18323

1. Background

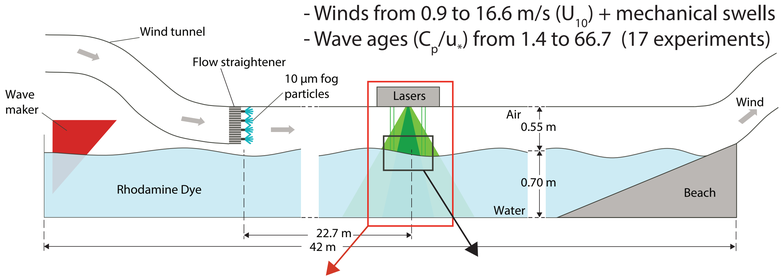


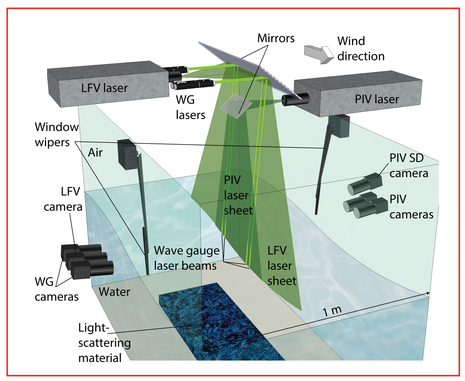
- Momentum and energy fluxes are important boundary conditions for weather, climate and oceanic models.
- Small-scale processes at the air-sea interface control these fluxes.
- We present high resolution laboratory measurements of the structure of the airflow above waves.

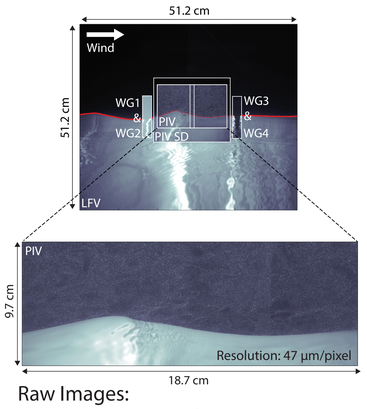
2. Methods

University of Delaware's large Wind-Wave-Current Tank

- Winds from 0.9 to 16.6 m/s (U_{10}) + mechanical swells
- Wave ages (C_p/u_*) from 1.4 to 66.7 (17 experiments)







Imaging system:
- airflow velocities by PIV (Particle Image Velocimetry)
- wave field properties by LIF (Laser-Induced Fluorescence)

Raw Images:
- PIV + 2D LIF at 7.2 frames/sec
- 4 single point LIF wave gauges at 93.6 Hz

4. Summary

- Wave age influences the structure of the airflow.
- Young, strongly wind-forced waves cause important sheltering downwind of crests: Airflow separation occurs frequently over wind waves with U_{10} = 5 m/s, and causes intense phase-locked turbulence and viscous stress drop downwind of wave crests.
- Older swells cause a reversed upwind sheltering effect.
- The wave-coherent airflow above wind waves with C_p/u_* = 6.5 is qualitatively consistent with Miles' (1957) critical layer theory.

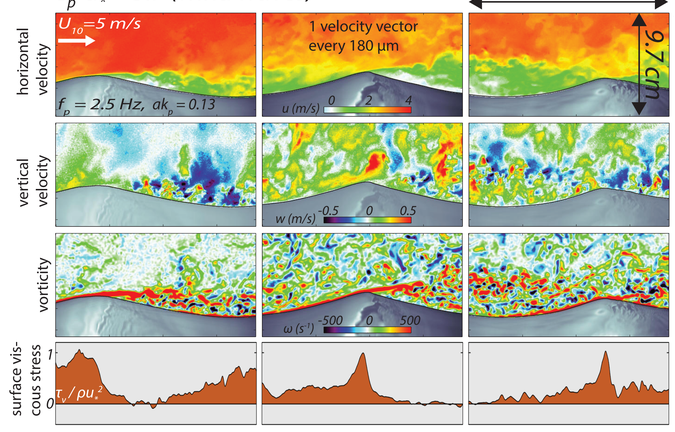
5. Reference

Buckley, M. P. and Veron, F. (2016). Structure of the airflow above surface waves. J. Phys. Oceanogr.

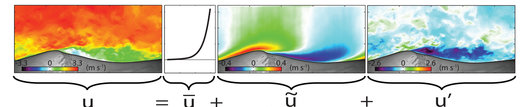
3. Results

Instantaneous snapshots

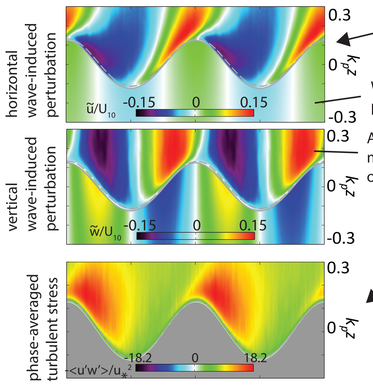
C_p/u_* = 3.7 (wind waves)



Triple decomposition



Phase averages



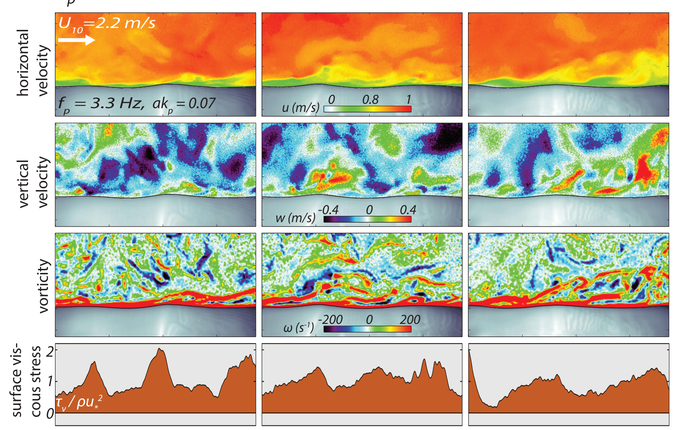
Water-side: computed orbitals

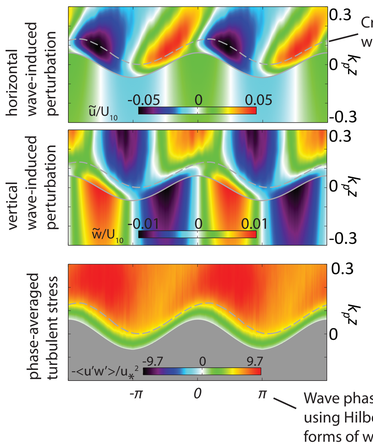
Air-side: averaged measurements over >1000 waves

3 experiments are considered, with wave ages Cp/u_* = 3.7, 6.5, and 31.7.

- When C_p/u_* = 3.7, waves are strongly wind-forced, and airflow separation often occurs downwind of wave crests (see vorticity fields), causing a drop in viscous stress, and intense phase-locked turbulent stress.

C_p/u_* = 6.5 (wind waves)



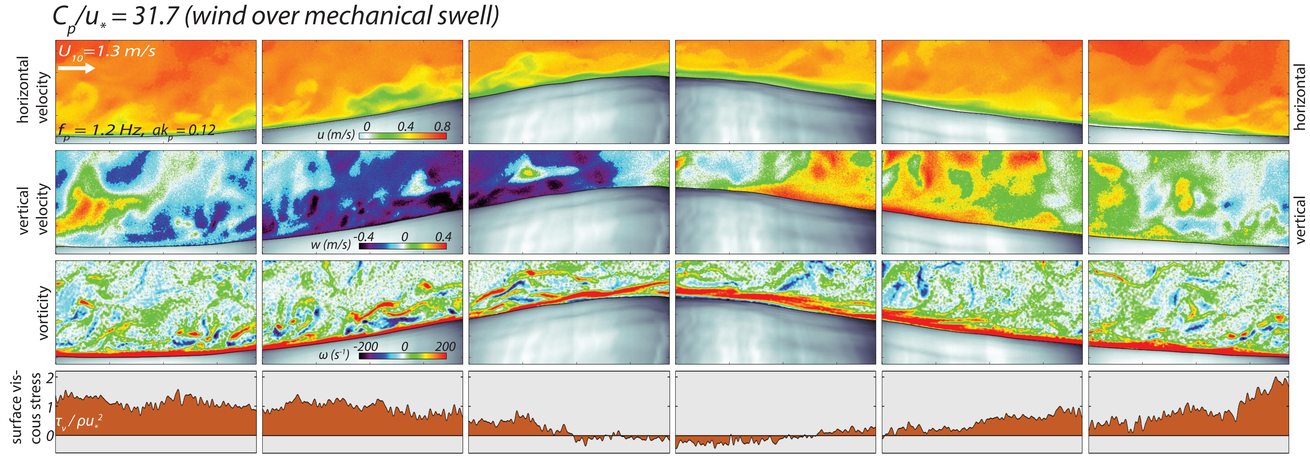


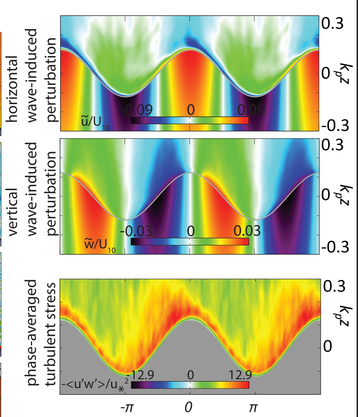
Critical height z_c with $u(z_c) = C_p$

Wave phases, detected using Hilbert transforms of water surface

- For C_p/u_* = 6.5, non-separated sheltering is the norm downwind of wave crests: High vorticity layers detach from the surface, but the airflow remains attached. Wave-induced perturbations show a phase shift at the critical height z_c, below which the airflow is coupled with underwater orbitals. Above z_c, sheltering effects dominate.

C_p/u_* = 31.7 (wind over mechanical swell)





- Over older and faster waves (C_p/u_* = 31.7) the airflow is strongly coupled with the wave orbital motions (see instantaneous and phase-averaged vertical air velocities), and the turbulent stress intensifies on average upwind of the crests (wake effect). The wave crest, traveling faster than the near surface wind, exerts upward viscous stress on the airflow.