'Effect of the sea state in the momentum flux across the ocean-atmosphere interface'

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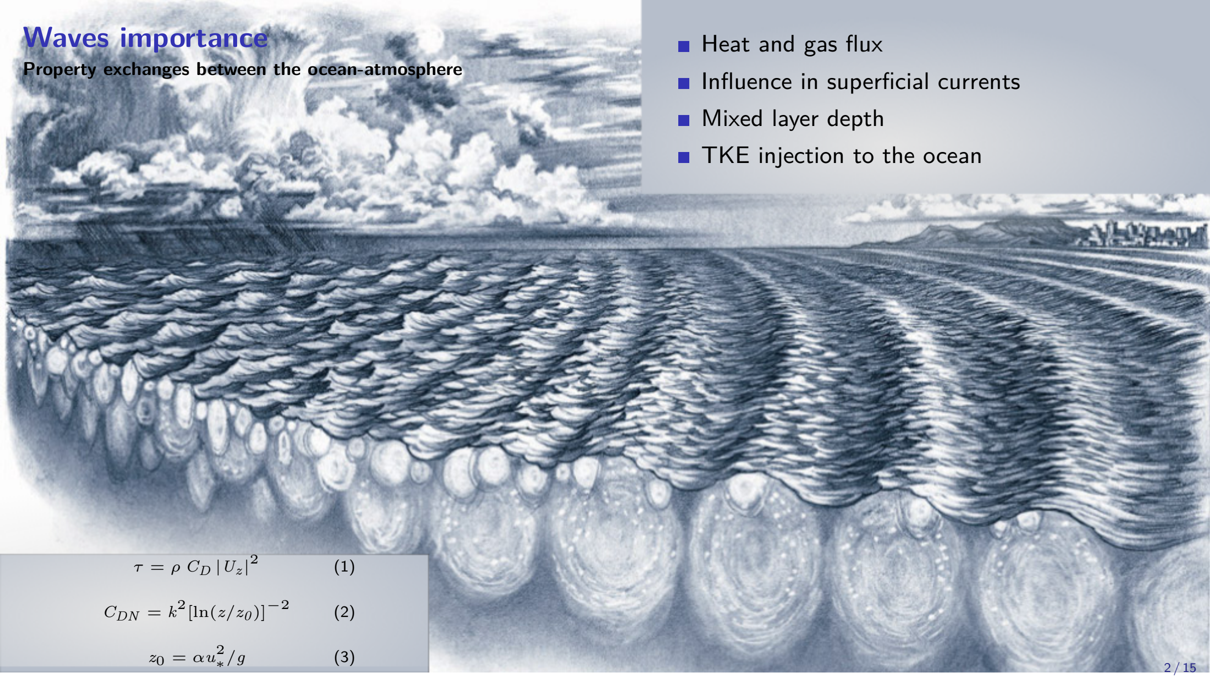
Waves importance

Property exchanges between the ocean-atmosphere



- Heat and gas flux
- Influence in superficial currents
- Mixed layer depth
- TKE injection to the ocean

$$\tau = \rho \, C_D \, |U_z|^2 \tag{1}$$

$$C_{DN} = k^2 [\ln(z/z_0)]^{-2} \tag{2}$$

$$z_0 = \alpha u_*^2 / g \tag{3}$$

Objectives

General objective:
Describe the importance of the waves on the momentum flux between the ocean and the atmosphere.

specific:

1. Evaluate the effect of different wave conditions (swell dominant and swell interacting with the locally generated waves) on the momentum transfer.
2. Determine the influence of the wind sea and swell over the wind stress.
3. Describe with parametric relations, the effect of different wave conditions on the momentum flux.

Data adquisition
Methods

Oceanographic and Marine Meteorology Buoy (BOMM).

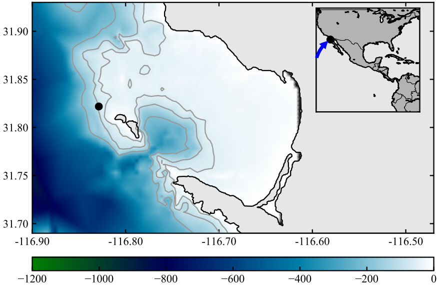


Table: List of sensors and some of their characteristics used onboard the BOMM1 buoy for the field campaign.

sensor	model	freq.[Hz]	height [msnm]
Sonic Anemometer	Gill R3-100	100	6
Meteorologic station	Gill Maximet GMX	1	4.5
Capacitance wires	Wave Staff OSS	0	1.5
Movement sensor	SBG Systems Ekinox2-M	100	-7.8
CTD+ pH $+O_2$	RBR-Concerto	0.001	-7.8

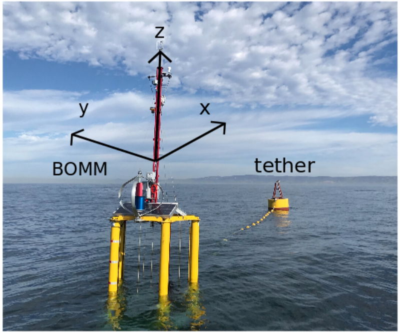
Data correction for the motion of the buoy

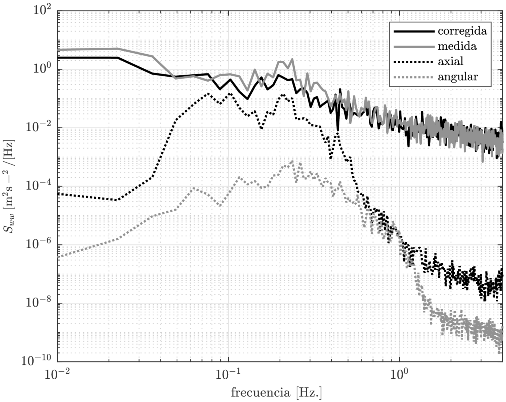
Methods

Velocity vectors $\mathbf{U} = [u, v, w]$ and position $\mathbf{X} = [x, y, \eta]$ (Anctil et al., 1994):

$$\mathbf{U} = \mathbf{T}\mathbf{U}_{\text{obs}} + \mathbf{T}\int \mathbf{a}\,\mathrm{d}t + \boldsymbol{\Omega} \times \mathbf{T}\mathbf{L}$$

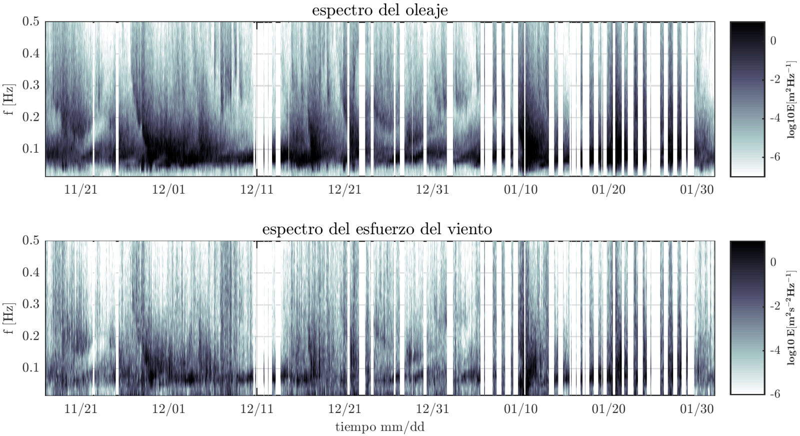
$$\mathbf{X} = \mathbf{T}\mathbf{X}_{\text{obs}} + \mathbf{T}\iint \mathbf{a}\,\mathrm{d}t\,\mathrm{d}t + \int \boldsymbol{\Omega} \times \mathbf{T}\mathbf{L}\,\mathrm{d}t$$





Evolution of the wave specta and the wind stress spectra

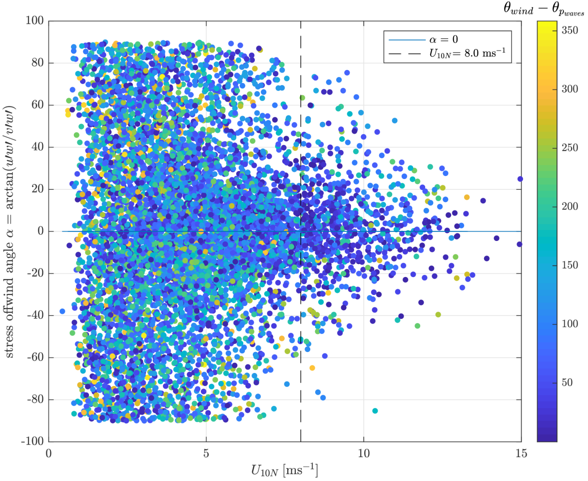
Results



$$\tau = \tau_\nu + \tau_{\mathrm{turb}} + \tau_{\mathrm{w}}$$

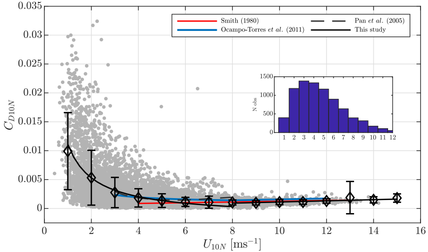
Stress offwind angle as function of wind speed

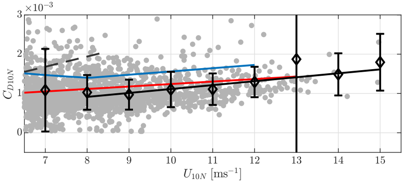
Results



Observed Drag Coefficient

Results

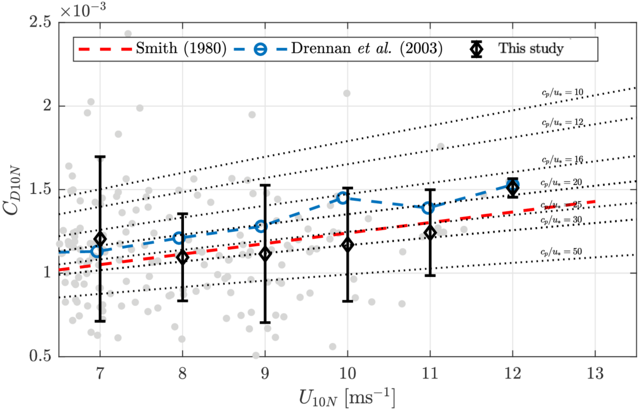




$$C_{D10N} = 1 \times 10^{-3} \begin{Bmatrix} -1.5 + 14.4\ U_{10N}^{-1} - 1.91\ U_{10N}^{-2} & U_{10N} < 8\text{ms}^{-1} \\ 0.11 + 0.10\ U_{10N} & U_{10N} \geq 8\text{ms}^{-1} \end{Bmatrix} \quad (4)$$

Analysis of the observed Drag Coefficient

moderate winds



$$z_0 g/u_*^2 = 1.7(u_*/c_p)^{1.7} \tag{5}$$

$$z_0 g/u_*^2 = \alpha \tag{6}$$

$$z_0 = \alpha u_*^2/g \tag{7}$$

$$C_{DN} = k^2[\ln(z/z_0)]^{-2} \tag{8}$$

Dependece of the wind stress as function of the sea state

Results

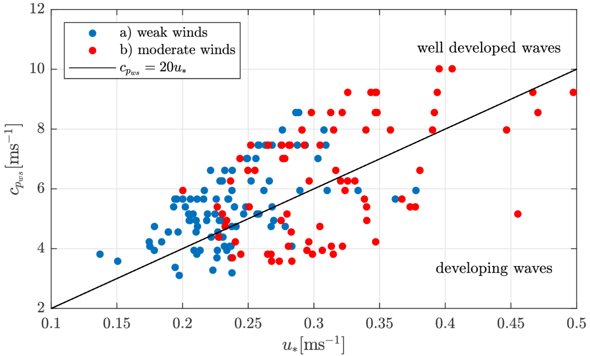


Table: Ratio of the measured variables in this study and Drennan *et al.* (2003)

Reference	N	U_{10N} [ms^{-1}]	u_* [ms^{-1}]	$c_{p_{ws}}$	$c_{p_{ws}}/u_*$
Drennan *et al.* (2003)	110	4.9 - 18.9	0.21 - 0.82	5.0 - 10.9	10 - 33
a) weak winds	98	6.5 - 8.0	0.13 - 0.37	3.1 - 8.50	13 - 29
b) moderate winds	78	8.0 - 12.0	0.20 - 0.49	3.5 - 10.0	11 - 30

surface dimensionless roughness as function of wave age

swell slope

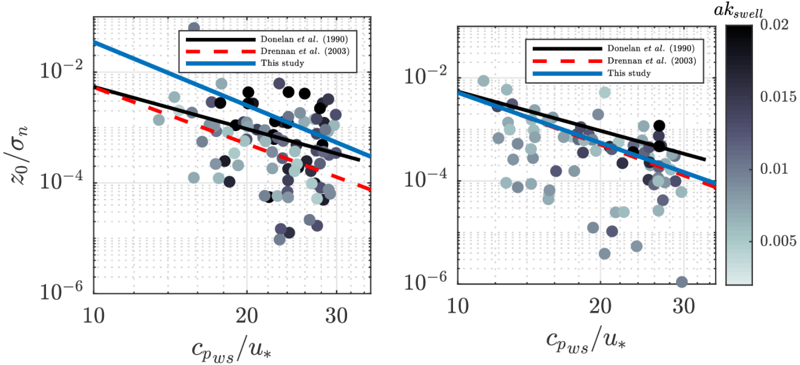
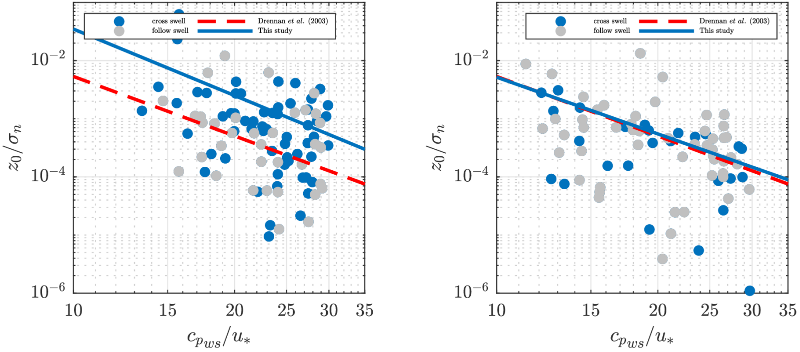


Table: Referenced parameterizations $z_0/\sigma = a(u_*/c_p)^b$.

Reference	Parametrization
Donelan (1990)	$z_0/\sigma = 1.84\ (u_*/c_p)^{2.53}$
Drennan *et al.* (2003)	$z_0/\sigma = 13.4\ (u_*/c_p)^{3.4}$
Tsai *et al.* (2018)	$z_0/\sigma = 146\ (u_*/c_p)^{4.0}$
a) weak winds	$z_0/\sigma = 220\ (u_*/c_p)^{3.8}$
b) moderate winds	$z_0/\sigma = 9.0\ (u_*/c_p)^{3.24}$

Sea surface dimensionless roughness as function of wave age

swell angle relative to mean wind direction



follow swell = 315° <= θ< 45°

cross swell = -135°<= θ< -45° and 45° <= θ< 135°

Histogram and PDF associated to the slope of the wind sea and swell

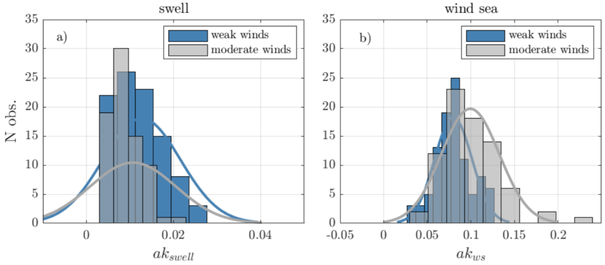


Table: Slope (ak) of swell and wind sea during a) weak winds and b) moderate winds.

	ak	
	swell	wind sea
a) weak winds	0.0118 $\pm$ 0.0044	0.0801 $\pm$ 0.0107
b) moderate winds	0.0091 $\pm$ 0.0049	0.0970 $\pm$ 0.0166

Recapitulación

- During weak wind conditions ($U_{10N} \leq 8$ ms^{-1}) the swell dominated conditions caused deviations of the stress angle up to 150°.

- During weak wind conditions ($U_{10N} \leq 8$ ms^{-1}), the presence of swell increases the wind stress compared with pure wind sea conditions and the parametric relations proposed by other authors.

- The data suggest that this increased wind stress under the previous conditions may me due to the effect of both the misaligment of the wind direction and the swell direction and the slope (greater) of the swell and its interaction with the airflow.

- Under moderate wind conditions ($U_{10N} \geq 8$ ms^{-1}) (swell interacting with the locally generated waves), the dimensionless roughness decreases and the swell slope decreases respect weak wind conditions, and the presence of swell modifies the roughness related to the wind sea part of the spectrum .

- The data suggest that during moderate wind conditions the combination of the slope of the wind sea and swell and its interaction with the airflow, has the net result that the present wave field behaves as expected in pure wind sea conditions (Drennan *et al.* (2003), as if there was no swell effect.

- Given this influence of swell over C_{D10N}, a corresponding parameterization is required that includes the swell effects previously described.

Thnaks!
Questions and comments