Ekman surface drift under the influence of waves and turbulence

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INTRODUCTION

An accurate model of local wind-driven currents is crucial for operational oceanography, for exemple to predict the drift of floating objects or marine pollution. Lagrangian drift velocities near surface are mostly controled by wind, waves and turbulent mixing.

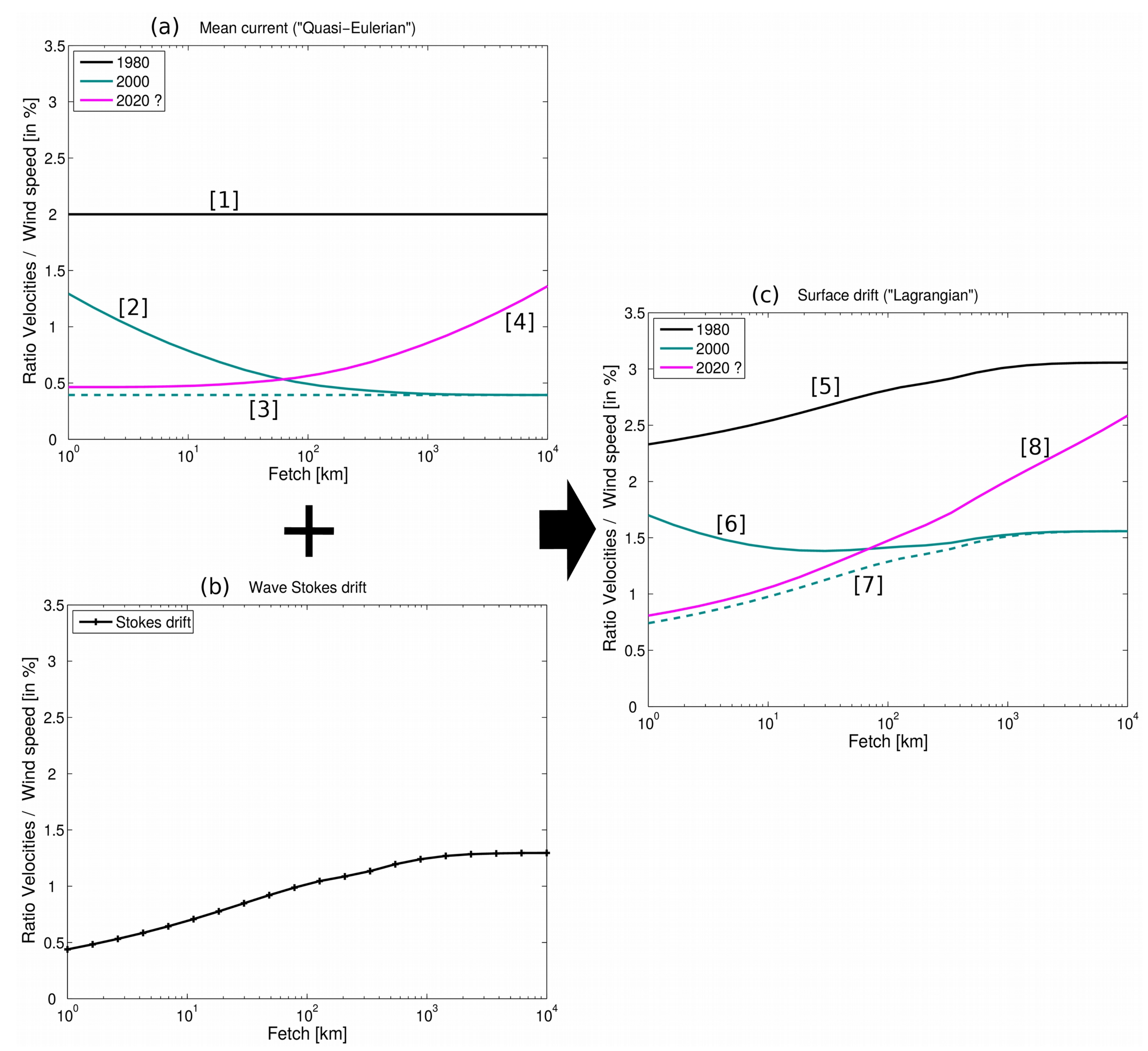
A Lagrangian mean drift is associated to waves (the Stokes drift). In the 1990's, measurements revealed enhanced near-surface turbulence in the presence of breaking waves.

In the recent years, wave-current models were developed. They separate the wind driven currents into the wave Stokes drift and a quasi-Eulerian mean currents: $U = U_{QE} + U_s$

In addition, waves induced vertical mixing applied to the quasi-Eulerian current has been added to the model. The implementation depends on the model and the vertical mixing scheme. Nevertheless how the near-surface turbulence evolves with waves is still a debated problem.

- What are the consequences of the stokes drift and vertical mixing for the surface drift ?
- Different current models and wave-current coupled models are used. How do they compare?
- How important are the differences between those models for applications?

IDEALIZED NUMERICAL SIMULATION



Currents are calculating using a 1D vertical models, following Ekman 1905, with no horizontal variations, no stratification and steady state.

1] 1980's, Model without waves

[2] 2000's, Larger mixing, function of the wave age

[3] For fully developed waves, the mixing can be calculate directly from the wind.

[4] Sullivan et al. (2007), shallower turbulence when the waves growth

[5] Current coupled to Stokes drift but uncoupled to wave mixing

[6] Current coupled to Stokes drift and mixing depend on the wave age

[7] Current coupled to Stokes drift but mixing depend on winds

[8] Current coupled to Stokes drift and vertical mixing shallower when the waves growth

Magnitude (expressed as a percentage of the wind speed) of (a) the Quasi-Eulerian mean current, (b) the wave Stokes drift, and (c) the Lagrangian drift, as a function of the fetch, a proxy of the wave age. Calculations are made for a fixed wind speed of 10 m s−1 and different parameterizations of the roughness length.

REALISTIC NUMERICAL SIMULATION

CROCO → Surface elevations and currents → **WW3**

20minutes

WW3 → Hs, T0M1, dir, Uss, TUs → **CROCO**

1st vertical layer: 5cm (Souza,2015)
Spatial resolution: 1/20 degree
Forcing: CFSR
3rd-order upstream biased advection scheme for the current velocity

Wind-wave interactions
Nonlinear wave-wave interactions
Wave-bottom interactions
Depth-induced breaking
Dissipation & reflection offtheshoreline

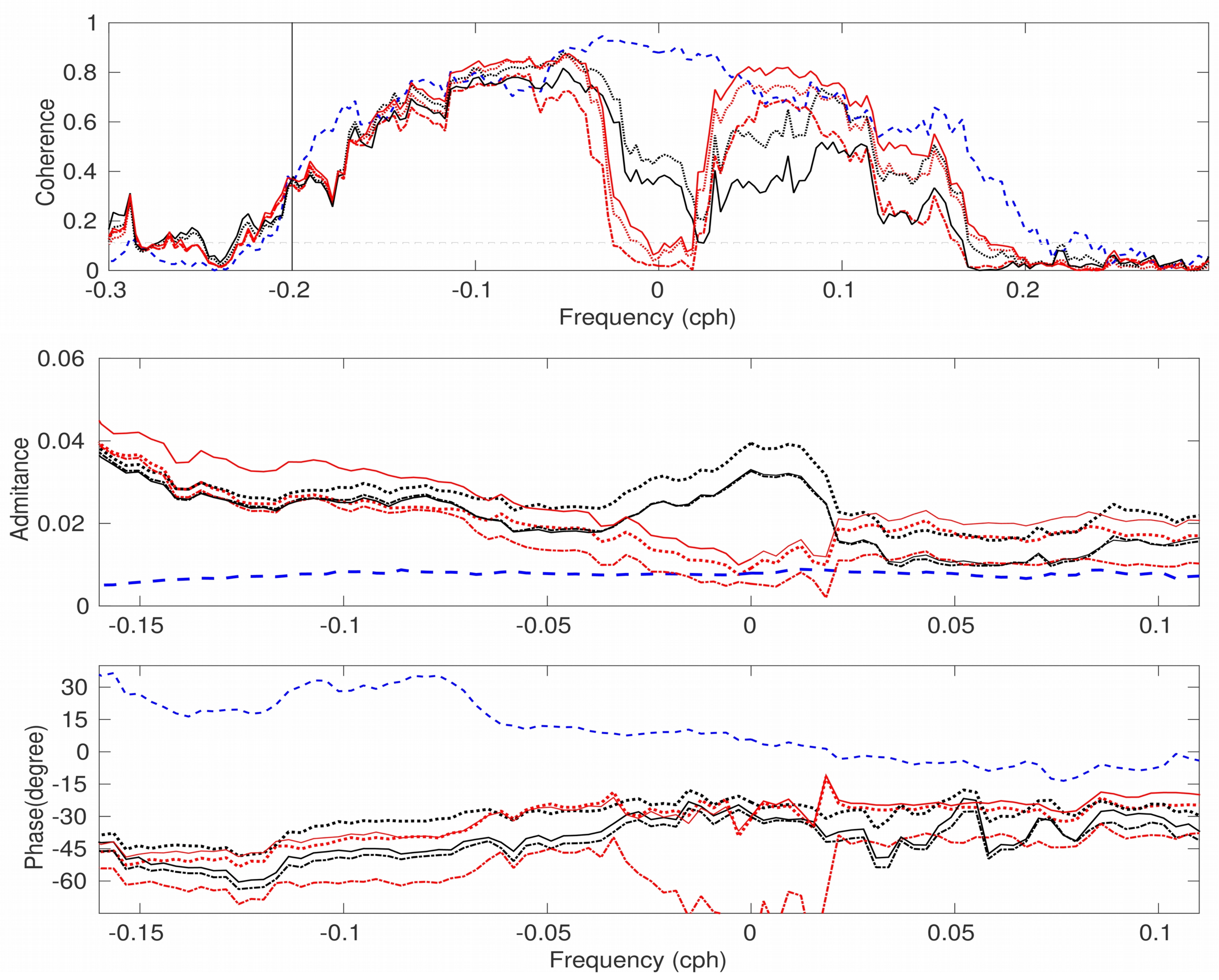
The coupled model used the vortex force formalism (Uchiyama,2010) and take into account the Stokes-Coriolis force.

Stokes drift is calcuated with the Breivik implementation (Breivik,2016).

	WW3	Stokes drift	Wave enhanced mixing parametrization		
			Increased viscosity	Depend on u*	Depend on Hs
KPP			X		
KPP_CO (u)	X		X		
KPP_CO (u+us)	X	X	X		
GLS				X	
GLS_CO (u)	X				X
GLS_CO (u+us)	X	X			X

RESULTS OBTAINED FOR THE GULF OF MEXICO

Cospectra analysis between wind and 1st layer currents:

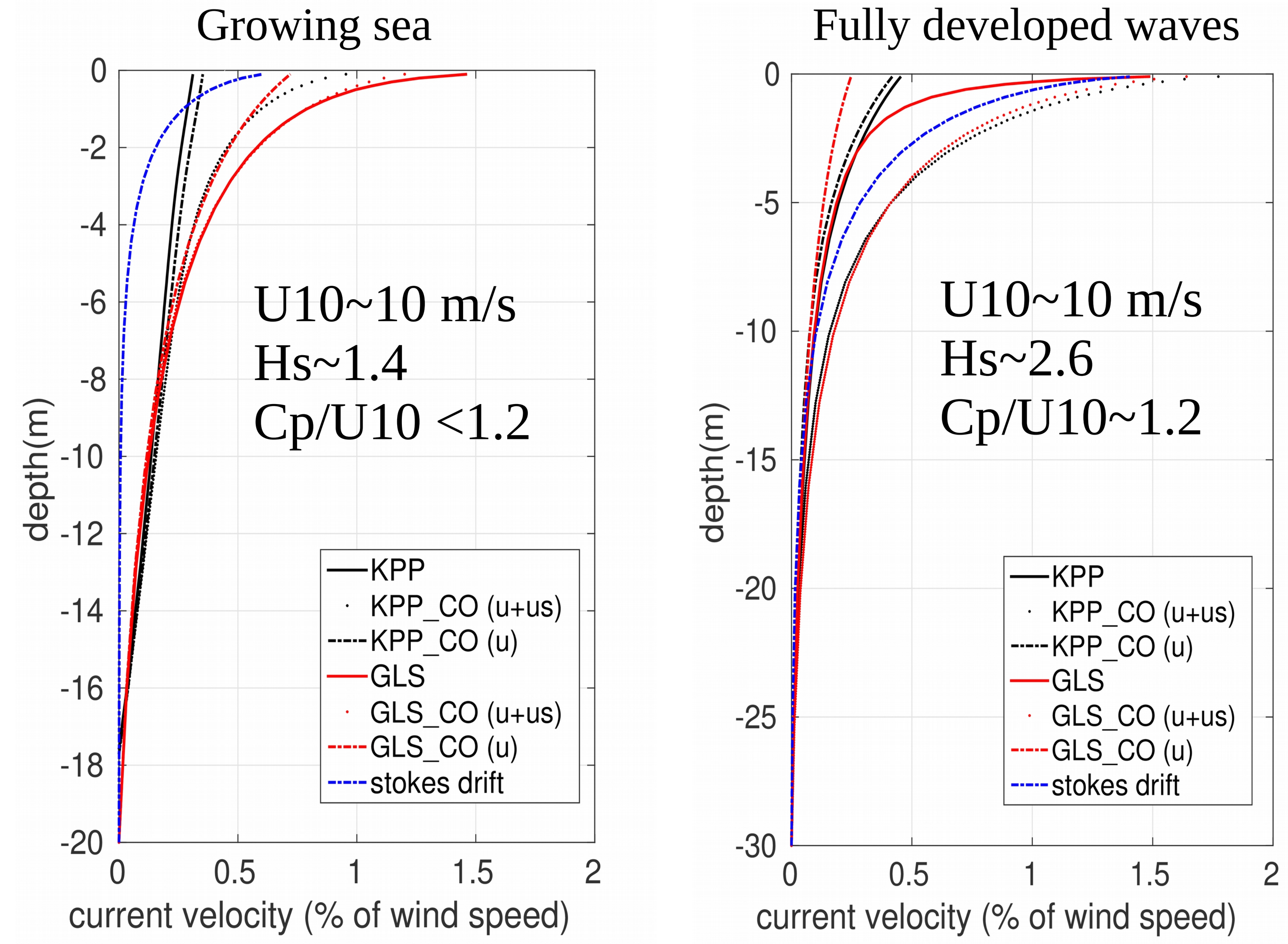


Average over all frequencies where the cross spectrum coherence is significant

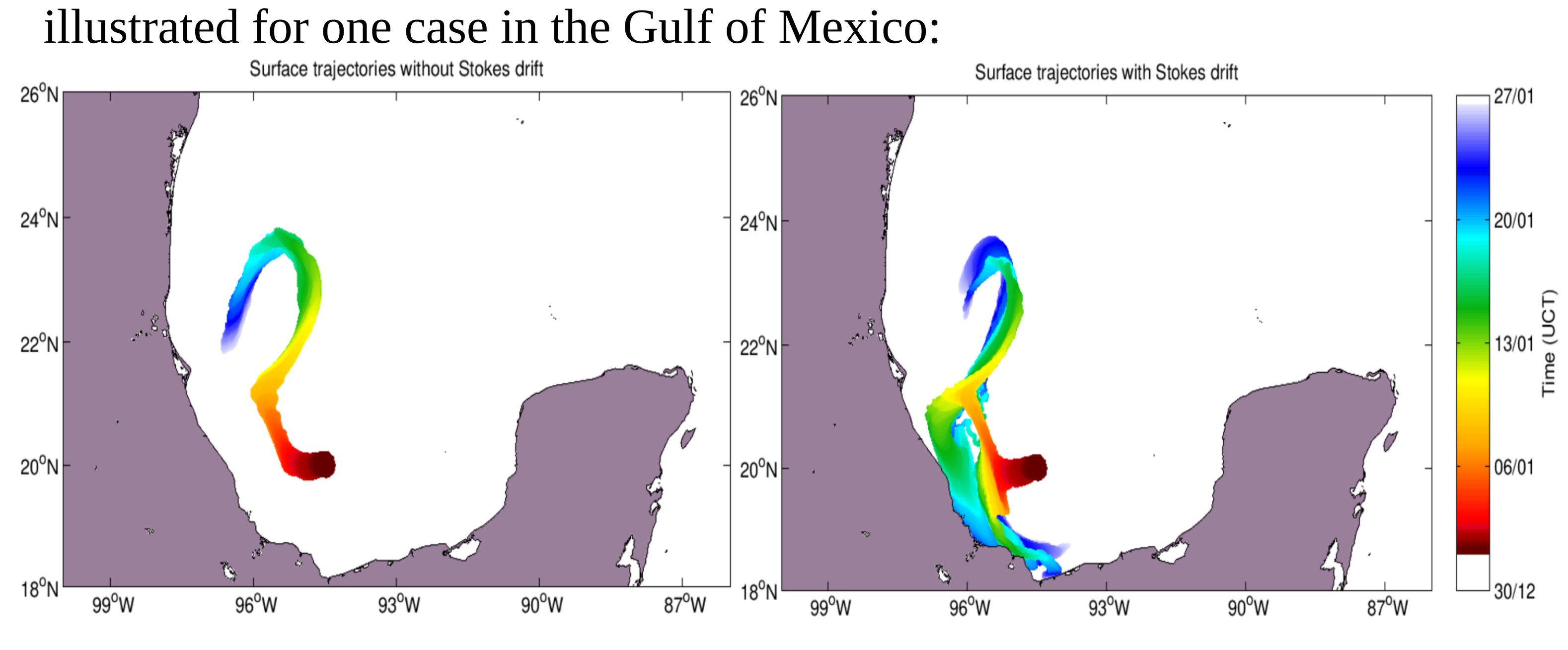
	KPP	KPP_CO (u)	KPP_CO (u+us)	GLS	GLS_CO (u)	GLS_CO (u+us)	Stokes drift
Admitance (% 10m wind speed)	1.5	1.5	2.2	2.5	1.3	2.1	0.85
Phase (degree)	-44	-48	-32	-30	-54	-34	6

Current vertical profile for:

Growing sea | Fully developed waves



Large consequences are predicted in terms of surface drift trajectories, as illustrated for one case in the Gulf of Mexico:



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