Ocean-Atmosphere Interaction Improvement of wind stress for coastal physical modelling

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Challenge and objectives

Wind stress is a **key parameter** for ocean-atmosphere mechanical exchanges. As such, its realistic parameterization in atmospheric models or for forcing oceanic models is of special interest. In particular, it may significantly influence **modelling of oceanic processes** such as surface/coastal circulation, upwellings, waves, surges and modelling of **atmospheric processes**. This research work aims at better representing the wind stress in numerical models, leading to an improved parameterization of turbulent fluxes, namely momentum flux, sensible and latent heat fluxes.

The objective is to define an **optimal wind stress parameterization**, based on a more physical approach, taking into account:

(1) **the wave influence,** especially dependence of the drag on the wave age, by moderate to strong winds,

(2) **the spray influence** by very high winds.

State of the art

The wind stress in numerical models is parameterized using a drag coefficient, which may or not depend on the waves through a variable Charnock parameter (e.g. directly derived from a wave model).

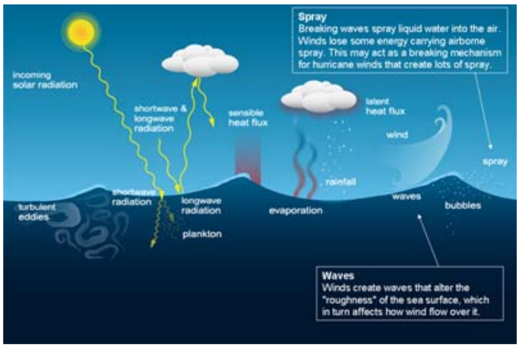
The influence of the wave age on this drag coefficient has been demonstrated by several studies using in situ wind stress obervations (Smith et al., 1992; Drennan et al., 2003). At very strog wind (>30 m/s), in situ or basin observations have shown a saturation, then decrease of the drag coefficient with increasing wind (Powell et al., 2003; Donelan et al., 2004; Jarosz et al., 2007; Holthuijsen et al., 2012).

(1) **Numerous formulations** of drag coefficients are currently available for use in numerical models (Charnock, 1955; Smith and Banke, 1975; Large and Pond, 1981; Wu, 1982; Janssen, 1991; Makin, 2005; Moon et al., 2007…), some of them taking into account the wave effect (Fairall et al. 2003).

(2) Despite over 20 years of research on this topic, and even if the effect of the waves on the drag coefficient has been shown by several studies using in situ observations, there is still **no clear consensus** on the precise **influence of waves**. This is partly related to the lack of observations by high winds (typically > 20 m/s) and various sea conditions.

(3) As a consequence, there is still **large uncertainties** on the drag parameterization, which can easily reach 50% by strong wind, and up to 200% in cyclonic conditions.

(4) Previous studies have shown that using a **parameterization including the effects of the waves** (from WWIII) improves to some extent the ocean response to storm surges with respect to sea level observations (Pineau-Guillou et al., 2014; Muller et al. 2014). In particular, taking into account the impact of the wave age leads to simulation results closer to obervations in modelling the Xynthia storm (France, 28 Feb. 2010; Bertin et al. 2012).

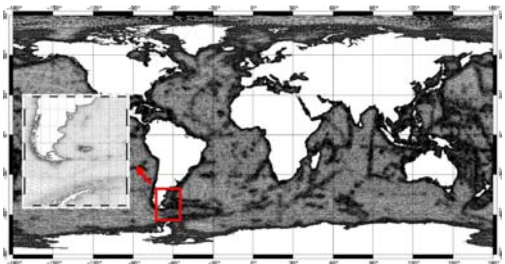


Air-Sea interactions *(source Woods Hole Oceanographic Institution)*

Research program : improvement and optimization of drag coefficient

Ocean response

Impact of different wind stress parameterizations will be tested on coastal ocean dynamics (storm surges). The modelling study will use the **global and finite element model TUGO** (Lyard et al., 2006) developed by LEGOS, with a statistical approach (global hindcasts of surges) including a wide range of wind and wave conditions. We will take advantage of the finite grid of TUGO to use a finer resolution in the coastal environment. Validation will be done using the sea level observations of the GLOSS (Global Sea Level Observing System) tide gauge stations.

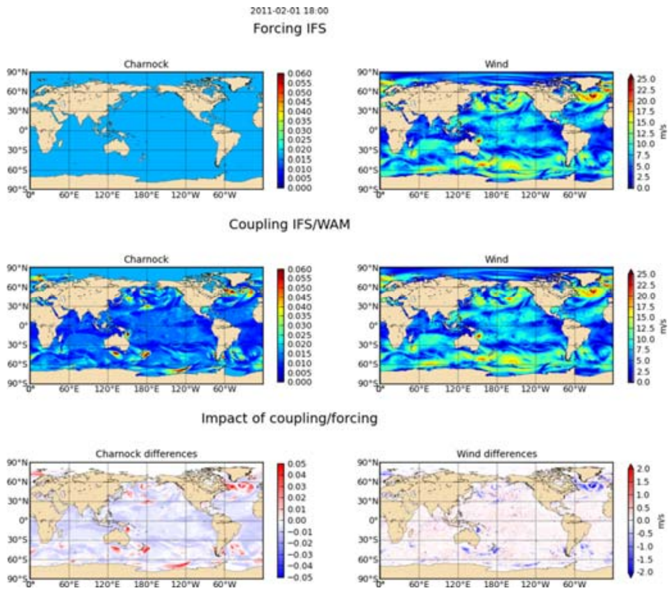


FES2004 Finite Elements Grid (Lyard et al. 2006)

GLOSS (Global Sea Level Observing System) Core Nerwork

Atmosphere response

A similar effort (impact of different wind stress parameterizations, definition of the optimal parameterization) will be performed using a **coupled wave-atmosphere model**, namely **WAM/IFS** model at global scale. Different wave-dependant drag formulations will be tested, and the best parameterization selected based on comparisons between forecasts (typically beyond the 4 day horizon) and analyses, or on comparison with **satellite data**.



Comparison of Charnock coefficient (left colum) and wind (right colum) without coupling IFS (first line) and coupling IFS/WAM (second line), 2011 February 11th. The third line represents differences between coupling and forcing (differences between second and first line).

Applications

Selecting or developing improved parameterizations of the air-sea momentum flux can find applications in several domain, including:

• fine-scale **high-resolution oceanic processes** modelling,
• dense water formation, upwelling,
• **coastal risk** assessment: storm surge forecasting, prevention for coastal flooding,
•,**atmospheric processes** modelling, e.g. mid-latitude storms, tropical cyclones, heavy precipitation events,
• **climate** studies.

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