FINAL REPORT PROGRAM LEFE

Program LEFE/ MANU	Project Title	Years 2019
	FASIL: Fluctuating Air-Sea-Interaction in Local models	

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Context

Air-sea interaction is a key process in the dynamics of the atmosphere, the ocean and the climate system. At the air-sea interface there is an exchange of heat, inertia and chemical substances, as carbon-dioxide and other gases. Many aspects of it are today not well understood.

Objectives / scientific questions

To further our understanding of air-sea interaction using the modern formalism of non-equilibrium thermodynamic. To this end we adapt the formalism developed for molecular motion, subject to thermal fluctuations to air-sea interaction subject to turbulent fluctuations.

Main results

We show using a hierarchy of local models of air-sea interaction (Fig. 1) that the most prominent of the work theorems, the Jarzynski equality and the Crooks relation (Fig. 2) can be applied to air-sea interaction. In the more idealized models, with and without a Coriolis force, the variability is provided from a Gaussian white noise which modifies the shear between the atmosphere and the ocean. The dynamics is Gaussian and the Jarzynski equality and Crooks relation can be obtained analytically solving stochastic differential equations. The more involved model consists of interacting atmospheric and oceanic boundary-layers, where only the dependence on the vertical direction is resolved, the turbulence is modelled through standard turbulent models and the stochasticity comes from a randomized drag coefficient. It is integrated numerically and can give rise to a non-Gaussian dynamics. Also in this case the Jarzynski equality allows for calculating a dynamic-beta β_D of the turbulent fluctuations (the equivalent of the thermodynamic-beta $\beta = (k_B T)^{-1}$ in thermal fluctuations). The Crooks relation gives the β_D as a function of the magnitude of the work fluctuations (Fig. 2). It is well defined (constant) in the Gaussian models and can show a slight variation in the more involved models. This demonstrates that recent concepts of stochastic thermodynamics used to study micro-systems subject to thermal fluctuations can further the understanding of geophysical fluid dynamics with turbulent fluctuations.

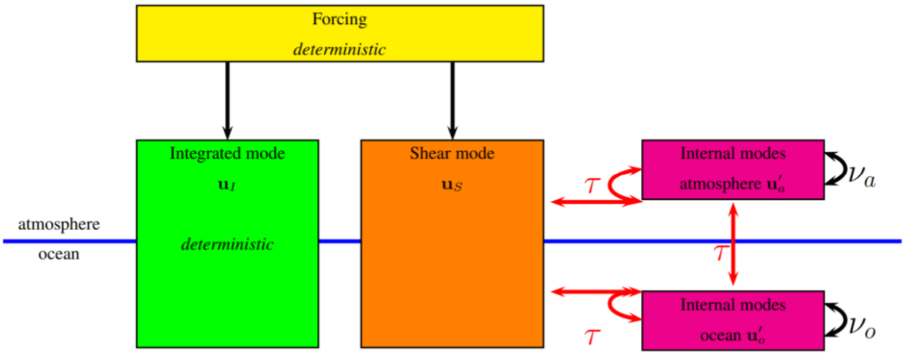
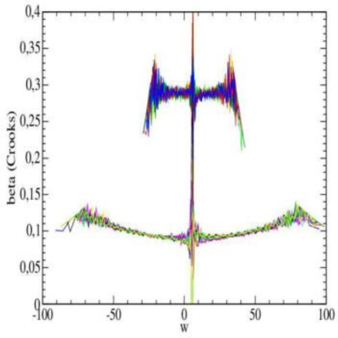
Figure 1	Figure 2
	

Figure 1: Schematic of the models considered: The integrated mode and the shear mode are forced. The integrated mode is decoupled from the rest of the dynamics. The shear mode is coupled to the internal modes of the atmosphere and the ocean by the surface stress. The internal modes in the atmosphere and the ocean depend on the eddy viscosity in each layer and the surface stress. the randomness arises thorough the surface friction τ (red colour). In the 1D model the internal dynamics in the atmospheric and oceanic layer are explicitly resolved and a random noise is added to the surface friction coefficient. In the 0D model their influence on the shear mode is parameterized by a random noise.

Fig. 2, gives the dynamic β as a function of the work w calculated with the Crooks relation for exp.1 (upper graph) and exp.2 (lower graph). For each experiment ten statistically independent realizations are superposed.

Future of the project:

We are asking for funding to extent the project to observations from the Gulf of Trieste (Italie). This work will be a collaboration with OGS (Trieste, Italie).

Nombre de publications, de communications et de thèses

Wirth, A. and Lemarié, F.: Jarzynski equality and Crooks relation for local models of air-sea interaction, Earth Syst. Dynam., 12, 689-708, https://doi.org/10.5194/esd-12-689-2021, 2021.