



HAL
open science

Impact of 3D non-hydrostatic dynamics on tracer transport in the nearshore region

Simon Treillou, Patrick Marchesiello

► **To cite this version:**

Simon Treillou, Patrick Marchesiello. Impact of 3D non-hydrostatic dynamics on tracer transport in the nearshore region. EGU, Apr 2023, Vienna, Austria. 2023, 10.5194/egusphere-egu23-7843 . ird-04511509

HAL Id: ird-04511509

<https://ird.hal.science/ird-04511509>

Submitted on 19 Mar 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

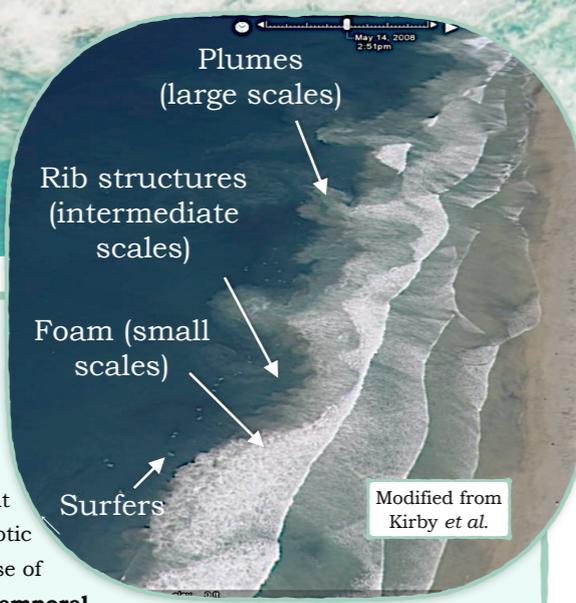
L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Impact of 3D non-hydrostatic dynamics on tracer transport in the nearshore region



Simon Treillou¹, Patrick Marchesiello¹
 1. Université de Toulouse, LEGOS (IRD/CNES/CNRS/UPS), Toulouse, France.

Contact: simon.treillou@ird.fr



1 Context

* The nearshore region, consisting of the inner shelf (up to 20m depth) and the surfzone (from breaking point to shoreline), is a highly chaotic area difficult to study because of **very different spatial and temporal scales** coexisting and interacting with each other. Understanding transport and mixing in this area is of very importance to **predict the fate of tracers, such as pollutants, sediments, bacteria, or larvae**.

* Up to now, most of the models used for nearshore simulations are 2DH Boussinesq, resulting in a **poor understanding of 3D processes** in this area. In addition, 2DH models still have difficulties in accurately representing observations. In particular, they tend to **overestimate the offshore directed tracer propagation** while **underestimating surfzone mixing**, as shown for the IB09 experiment presented below (Hally-Rosendahl & Feddersen, 2016).

* New 3D wave-resolving models are now available to analyze full 3D dynamics while evaluating 2D model realism.

2 Dye release experiment

* IB09 is an experiment conducted in 2009 over one month to better understand the tracer transport in the Southern Californian Bight (Hally-Rosendahl & Feddersen, 2016)

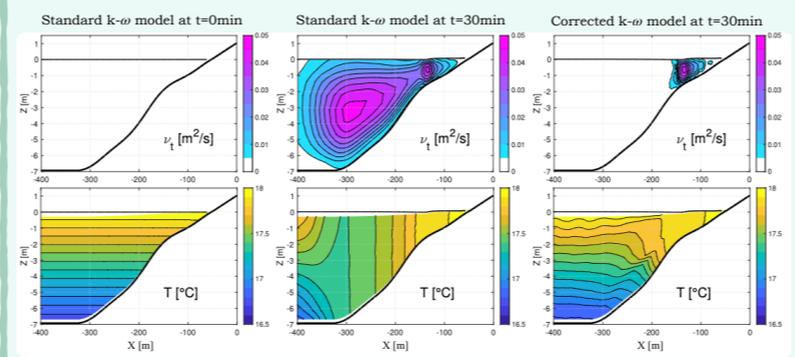
- * Data used: 6 hours **IB09 large-scale dye release**
- * Alongshore-uniform bathymetry: **ideal for process study**
- * Data already compared with the 2D wave-resolving *funwaveC* model (Hally-Rosendahl & Feddersen, 2016): **ideal for 3D processes identification**
- * Domain of 400 m by 1000 m with 1 m resolution forced with southerly alongshore wind stress and JONSWAP wave spectrum with directional spreading ($H_s=0.74$ m, $T_p=13$ s, $\theta=17^\circ$, $\sigma=30^\circ$, $\gamma=20$)
- * Inner shelf stratification representative of summer conditions in Southern California



3 CROCO: a 3D non-hydrostatic wave-resolving model

- * Free-surface **wave-resolving** model (like NHWAVES, SWASH) but with a **compressible** approach in the **non-hydrostatic** solver.
- * Validated in hydrodynamics (Marchesiello *et al.*, 2021) and morphodynamics (Marchesiello *et al.*, 2022) studies.
- * CROCO has recently been improved for nearshore studies by correcting several key issues (see below).

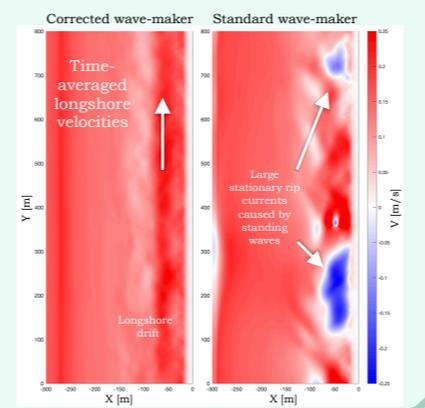
4 Correction of turbulent closure for stratified nearshore studies



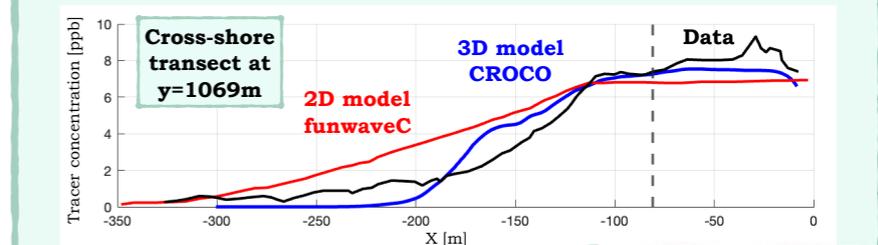
- * Instability of two-equation turbulence closures (e.g. $k-\omega$, $k-\epsilon$) leads to **overmixing in near-potential (irrotational) flows** under non-breaking waves and results in destruction of the inner shelf stratification.
- * This problem is corrected in CROCO (Marchesiello & Treillou, *in revision*), allowing 3D studies with stratification.

5 Correction of the standing wave problem

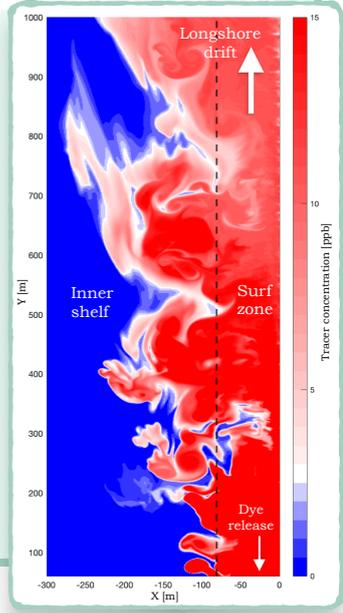
* Simulating realistic random sea state with a deterministic wave-maker can lead to **phase-locking** (interference between two waves of the same frequency but different directions) and to **spurious standing waves**. This problem is addressed and corrected in CROCO by adding random frequencies.



6 RESULT: Attenuated surf-shelf exchanges



- * In our 3D non-hydrostatic framework, new processes are taken into account. Vertical shear affects the whole spectrum of dynamics: 1) it creates rib structures at **intermediate scales** of about 5 meters from 3D Kelvin-Helmholtz instabilities **increasing surfzone mixing**; 2) it weakens large-scale flash rips in the surfzone, **significantly attenuating cross-shore exchange with the shelf**.
- * The 3D processes drastically change the kinetic energy cascade. While 2D simulations only exhibit a strong inverse cascade typical of 2D turbulence, 3D simulations have **both inverse and direct cascades** typical of 3D turbulence (but the inverse cascade is weaker).



7 Conclusions and perspectives

- * Our results so far demonstrate the importance of 3D processes on tracer transport. Shear-driven processes that weaken the inverse cascade appear to play an important role in the observed intensity of surf-shelf exchange. Their absence in 2D models may explain why they **overestimate tracer mass in the inner shelf**. On the other hand, 3D instabilities at intermediate scale increase surfzone mixing and their absence in 2D models would explain why they **underestimate mixing in the surf zone**.
- * Future work will focus on a more detailed analysis of surfzone mixing diagnostics and diffusivity estimation. More attention will also be given to parameter sensitivity analysis (*i.e.*, the effect of bathymetry or wave spectrum on currents and mixing). The **effect of stratification** and Earth rotation will also be studied in this configuration.

KEY MESSAGE: 3D non-hydrostatic processes can significantly reduce cross-shore exchange between surf zone and inner shelf