Submesoscale sea surface temperature variability as a sink of eddy energy in a coupled regional model

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Introduction

Air-sea interaction impacts ocean energetics via modifications to the exchange of momentum and buoyancy. Prior work at the submesoscale has primarily focused on mechanisms related to the eddy kinetic energy (EKE), such as the current feedback on stress (CFB) [2], which generates negative wind work, or variations in sea surface temperature (SST) that modify the atmospheric boundary layer [3]. However, less is known about the influence of submesoscale SST variability on ocean energetics through its direct effect on the surface flux of eddy potential energy (EPE) [1].

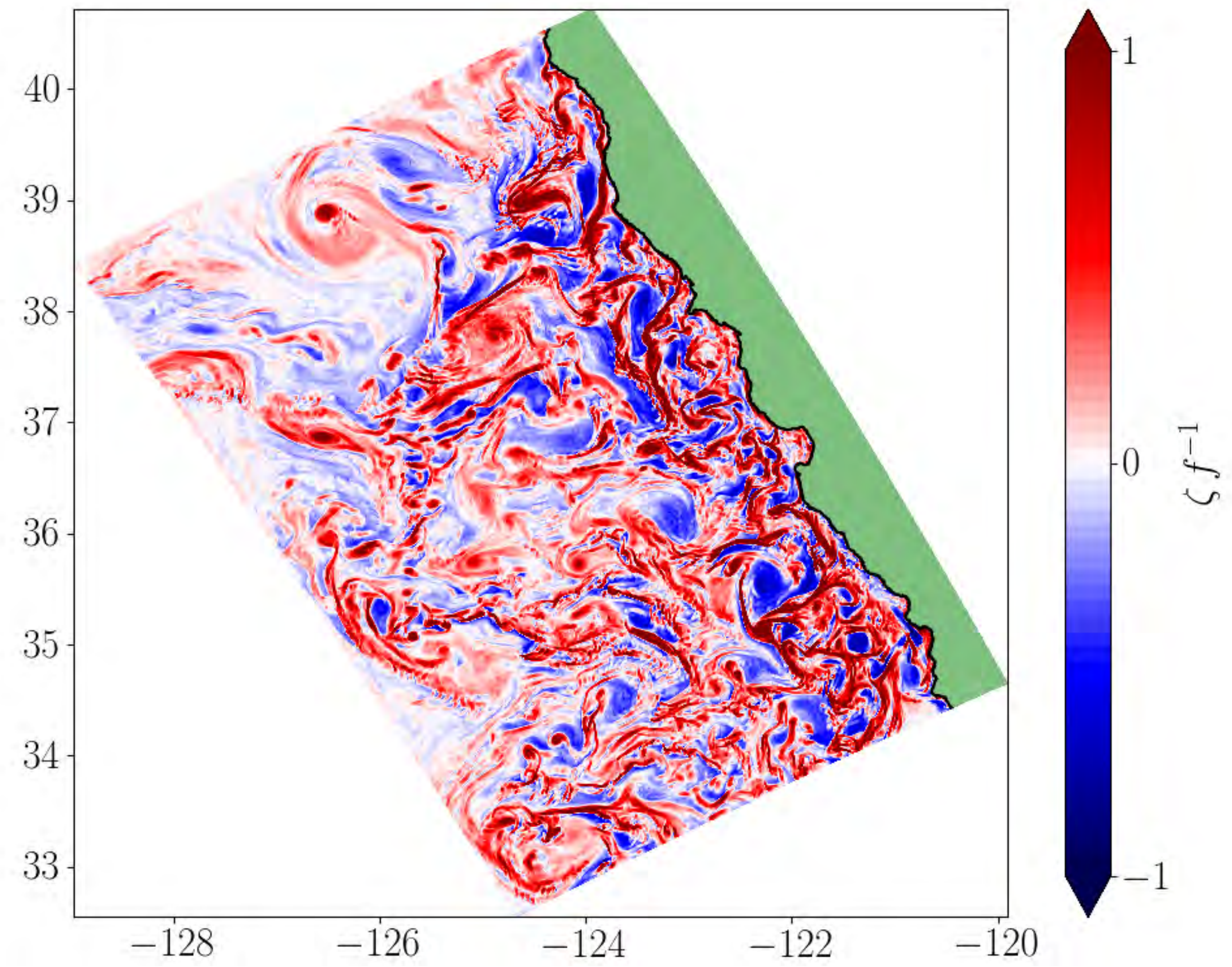

Fig. 1: Rossby number map from CROCO (Coastal and Regional Ocean Community Model) illustrating the model domain.

We estimate the loss or gain of EPE in the ocean to the atmosphere by computing the EPE flux parameter $F_{EPE} = \frac{\overline{b^{*\prime} B_o^\prime}}{N_r^2}$, where $b^{*\prime}$ is the surface buoyancy anomaly, $B_o^\prime$ is the buoyancy flux, and N_r^2 is a reference surface buoyancy frequency. SST variability increases the generation of air-sea fluxes of EPE via correlations between the thermal components of buoyancy and buoyancy flux (Fig. 2).

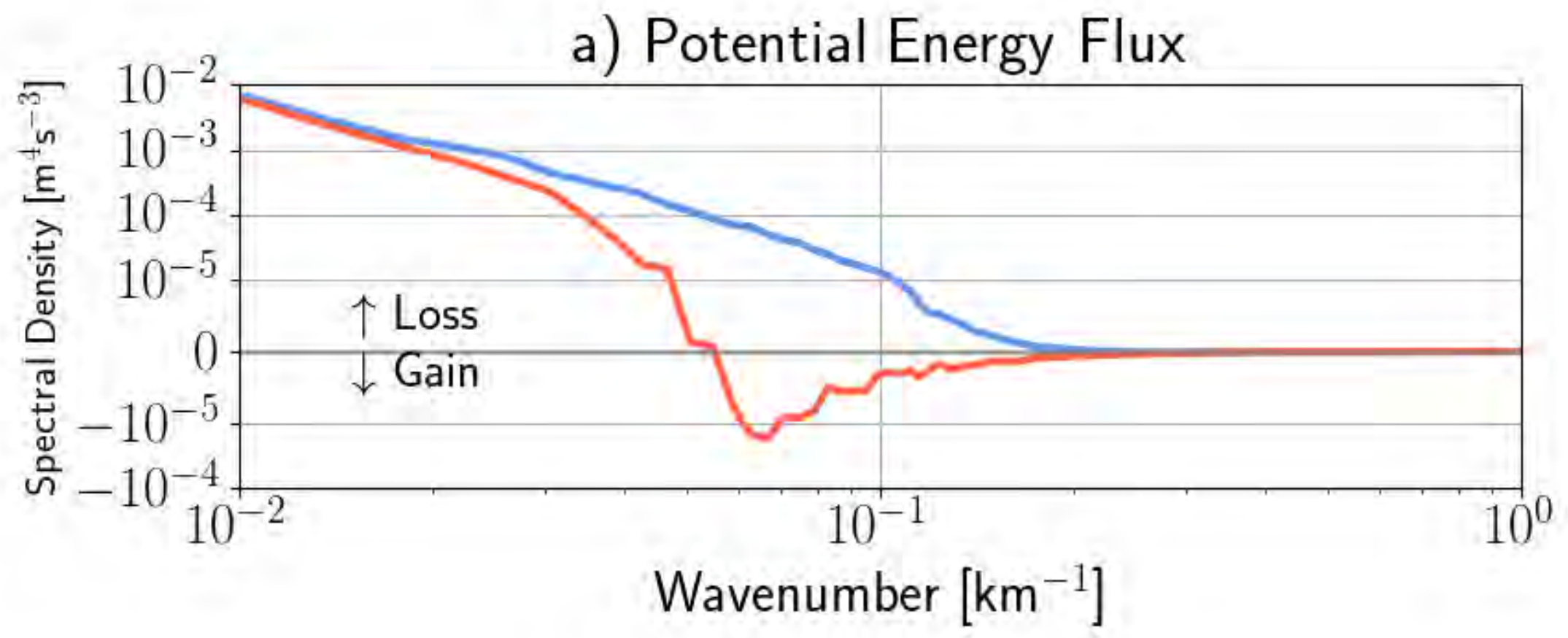

Fig. 2: Submesoscale SST variability accounts for a significant loss of EPE to the atmosphere. Two-dimensional spectra of potential energy flux for **FULL** and **SMTH** simulations.

Coupling Setting

The role of thermal feedbacks on submesoscale ocean energetics is investigated using a fully-coupled model of the California Current region (Fig 1), including a numerical experiment that suppresses submesoscale air-sea heat fluxes (FULL and SMTH simulations). For the coupling of FULL simulation, WRF provides fields of freshwater, heat, and momentum fluxes, and CROCO provides the current and SST fields. For the SMTH simulation, the same methods of parameter exchange are applied, but with smoothing of SST fields in the coupling computation. The schematics of both simulations are illustrated in Fig. 3.

Table 1: Model specifications of horizontal resolution.

Output	Resolution
CROCO	0.2 km
WRF	1.5 km
Filter Scale (SMTH)	50 km

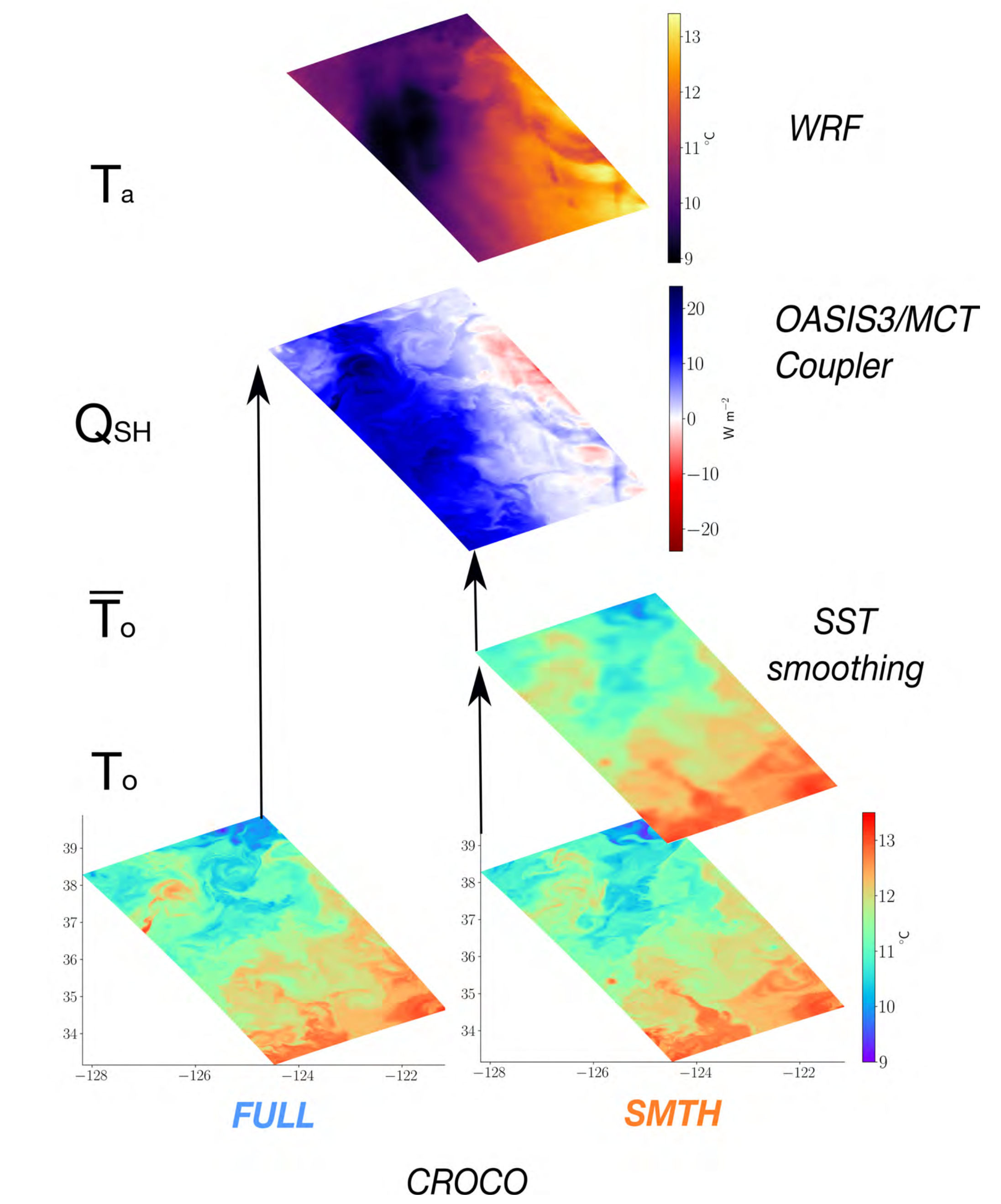

Fig. 3: Schematics of the different coupling computations using WRF (The Weather Research and Forecast Model) and CROCO (Coastal and Regional Ocean Community Model). The suppression of sea surface temperature submesoscale variability on the coupling computation is illustrated in the SMTH simulation.

Results and Discussions

As indicated in Fig.2, the differences between the potential energy fluxes indicate that air-sea buoyancy exchange driven by submesoscale SST variability alters the pathways and reservoirs of eddy energy in the ocean. In the SMTH simulation (Fig. 2), potential energy injection into the atmosphere (loss of EPE) is depleted and even of opposite sign (gain of EPE) in comparison with the FULL simulation.

Submesoscale SST variability increases the air-sea potential energy flux to the atmosphere hence reducing EPE in the ocean by ≈ -10%. Consequently, the rate of conversion of EPE to EKE is depleted (≈ -25%), slowing the growth of EKE by ≈ -10%. Since the loss of momentum from ocean to atmosphere is proportional to the EKE at submesoscale ('eddy killing' effect of CFB), wind work also decreases (≈ -25%, see Fig 4) [2].

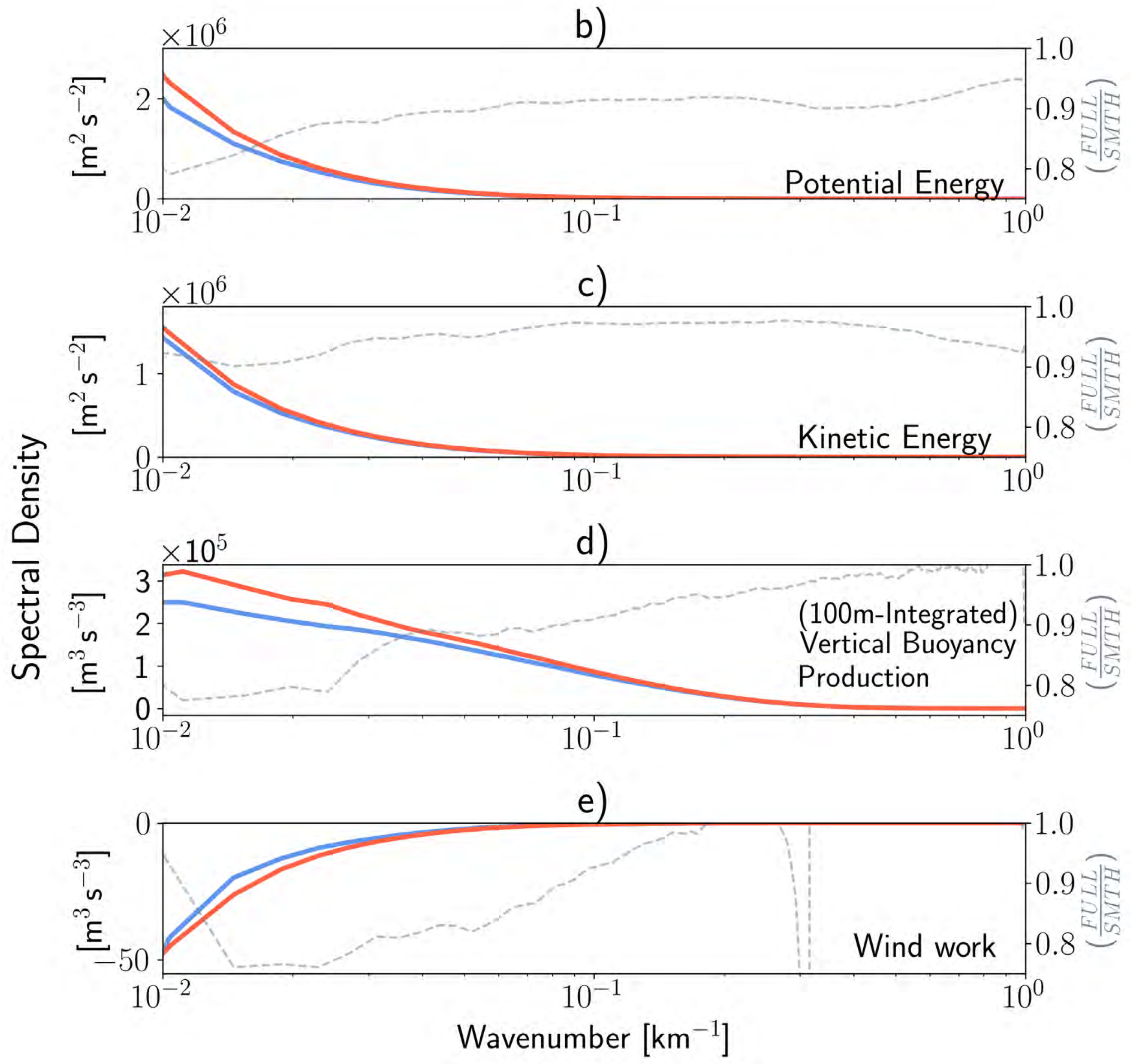

Fig. 4: Cumulative spectra show the effects of EPE flux at submesoscale for **FULL** and **SMTH** simulations. Ogive graphs of (b) Surface Potential Energy , (c) Surface Kinetic Energy, (d) 100 m integrated vertical buoyancy production, and (e) wind work. Grey dashed lines indicate the ratio of simulations.

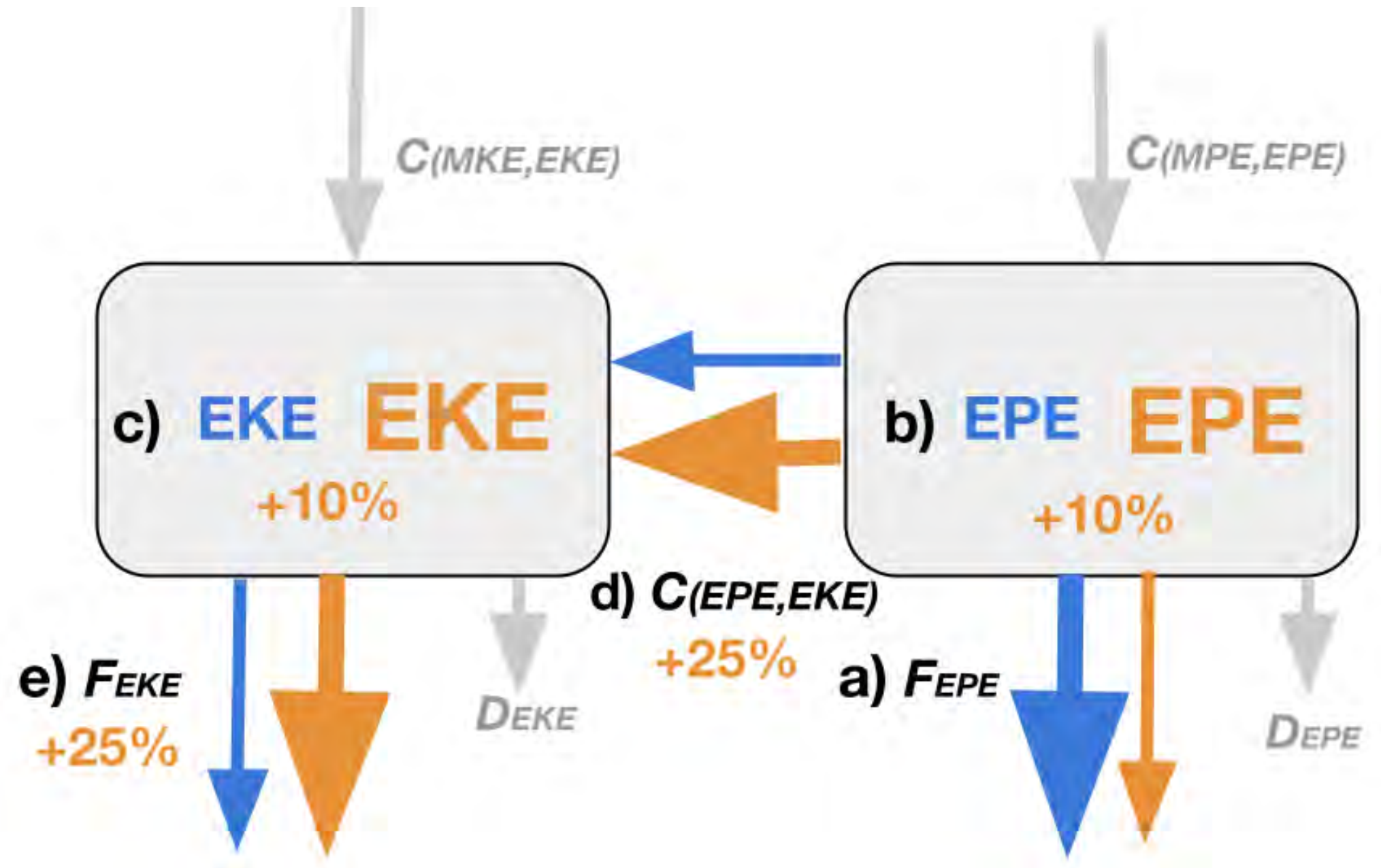

Fig. 5: Representation of the Lorenz energy cycle for **FULL** and **SMTH** simulations. The thickness of the arrows represent the relative increase or decrease of reservoirs and pathways of energy. MKE, EKE, MPE, EPE acronyms indicate the mean and eddy kinetic energy and mean and eddy potential energy, respectively. The F,C, and D letters indicate flux, conversion, and dissipation, respectively.

Takeaway Messages

- **Submesoscale SST variability drives buoyancy fluxes and, hence, EPE flux from ocean to the atmosphere, reducing eddy energy of the ocean.**
- **Changes in submesoscale energy dissipation/conversion due to eddy potential energy fluxes are on the same order of magnitude as the 'eddy killing' effect of the CFB.**
- **Parameterizing the effect of SST submesoscale variability in coupling computations such as heat flux may be important for correctly computing the energy budget in the ocean.**

References

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