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Stochastic transport in an idealized ocean-atmosphere coupled system

Long Li¹

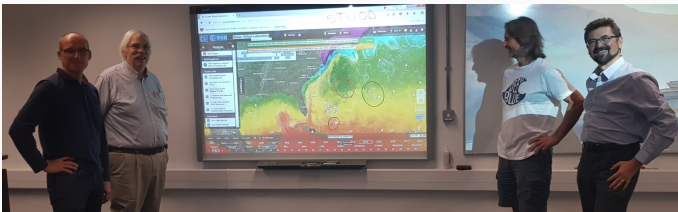
May 23, 2022

Joint work with Etienne Mémin¹, Bertrand Chapron² and Noé Lahaye¹

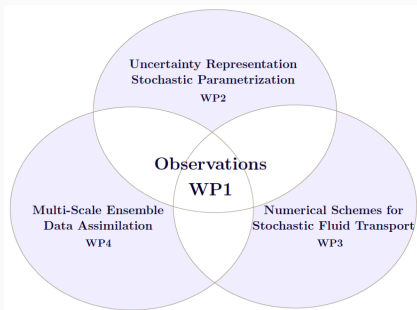
¹ ODYSSEY - Inria Rennes France

² LOPS - Ifremer Brest France

Stochastic Transport in Upper Ocean Dynamics (STUOD)



<https://www.imperial.ac.uk/ocean-dynamics-synergy/>



“Our approach accounts for transport on scales that are currently unresolvable in computer simulations, yet are observable by satellites, drifters and floats.”

Methods: SALT [Holm, 2015] or LU [Mémin, 2014]

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- Flow under location uncertainty (LU)

$$d\mathbf{X}_t = \underbrace{\mathbf{u}(\mathbf{X}_t, t) dt}_{\text{resolved}} + \underbrace{\sum_m \xi_m(\mathbf{X}_t, t) dB_t^m}_{\text{unresolved}}$$

References: [Bauer et al., 2020a, Li, 2021]

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- Stochastic transport of tracer

$$\mathbb{D}_t \Theta := d_t \Theta + \underbrace{\left(\mathbf{u}^* dt + \sum_m \xi_m dB_t^m \right) \cdot \nabla \Theta}_{\text{backscattering}} - \underbrace{\frac{1}{2} \nabla \cdot \left(\sum_m \xi_m \xi_m^T \nabla \Theta \right)}_{\text{eddy diffusion}} dt = 0$$

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- Pathwise conservation of moments

$$\mathbb{D}_t \Theta^p = 0, \quad d_t \int_{\Omega} \Theta^p dx = 0$$

References: [Bauer et al., 2020a, Li, 2021]

Application to Q-GCM [Hogg et al., 2003]

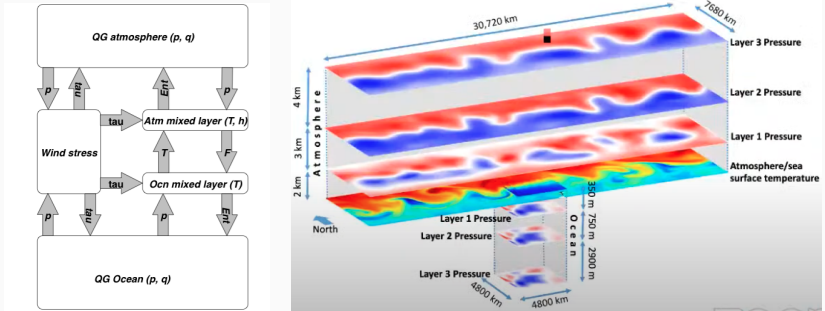


Figure 1: Model illustration from <http://www.q-gcm.org>

- Idealized midlatitude coupled model emphasizing ocean dynamics

Application to Q-GCM [Hogg et al., 2003]

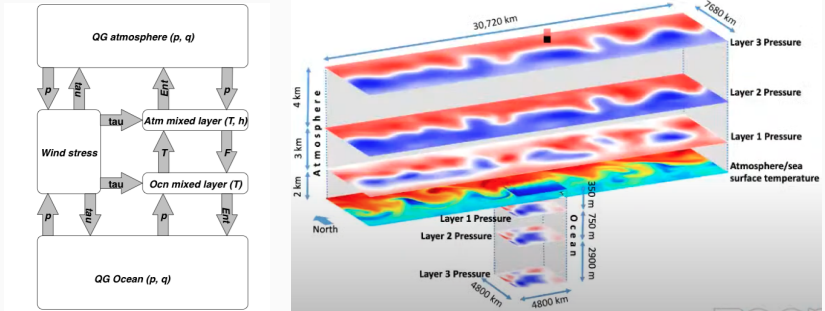


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- Classical Ekman model with wind-current-dependent stresses

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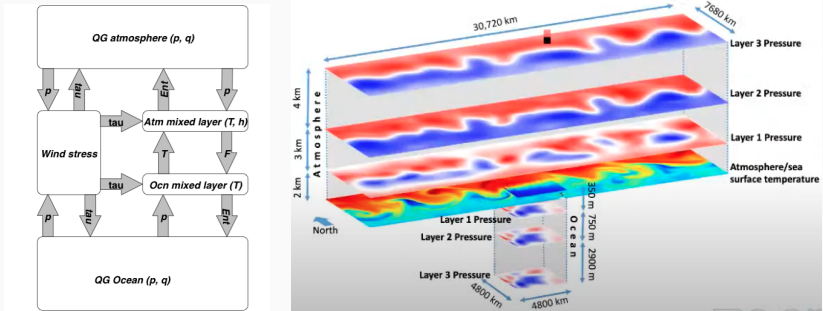


Figure 1: Model illustration from <http://www.q-gcm.org>

- Idealized midlatitude coupled model emphasizing ocean dynamics
- Classical Ekman model with wind-current-dependent stresses
- Our applications: stochastic transport of PV and SST for both ocean and atmosphere

- Our objectives: designing adequate unresolved flow structure (ξ_m) for coarse-resolution models to reproduce statistical properties of eddy-resolving simulation

Data-driven calibration of unresolved flow

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- Code available on:
https://github.com/matlong/qgcm_lu
https://github.com/louity/qgm_pytorch

Numerical results

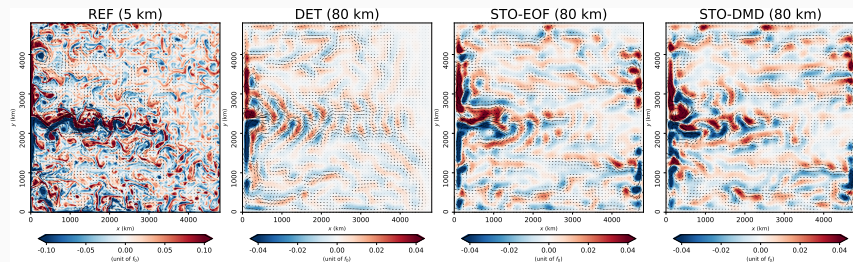


Figure 2: Snapshots of ocean upper layer relative vorticity.

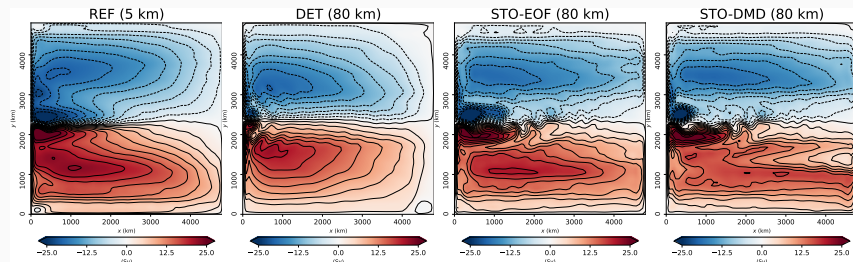


Figure 3: 40-years averages of ocean upper layer streamfunction.

- Energy-budget-based parameterization
[Bachman, 2019, Jansen et al., 2019]

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- More realistic configurations: surface buoyancy conditions [Lapeyre and Klein, 2006], North Atlantic circulation (from FFT to multigrid)
- Ensemble forecasting and data assimilation

Thank you very much!

Questions?



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