Equatorial deep jets and their influence on the mean equatorial circulation in an idealised ocean model forced by intraseasonal momentum flux convergence

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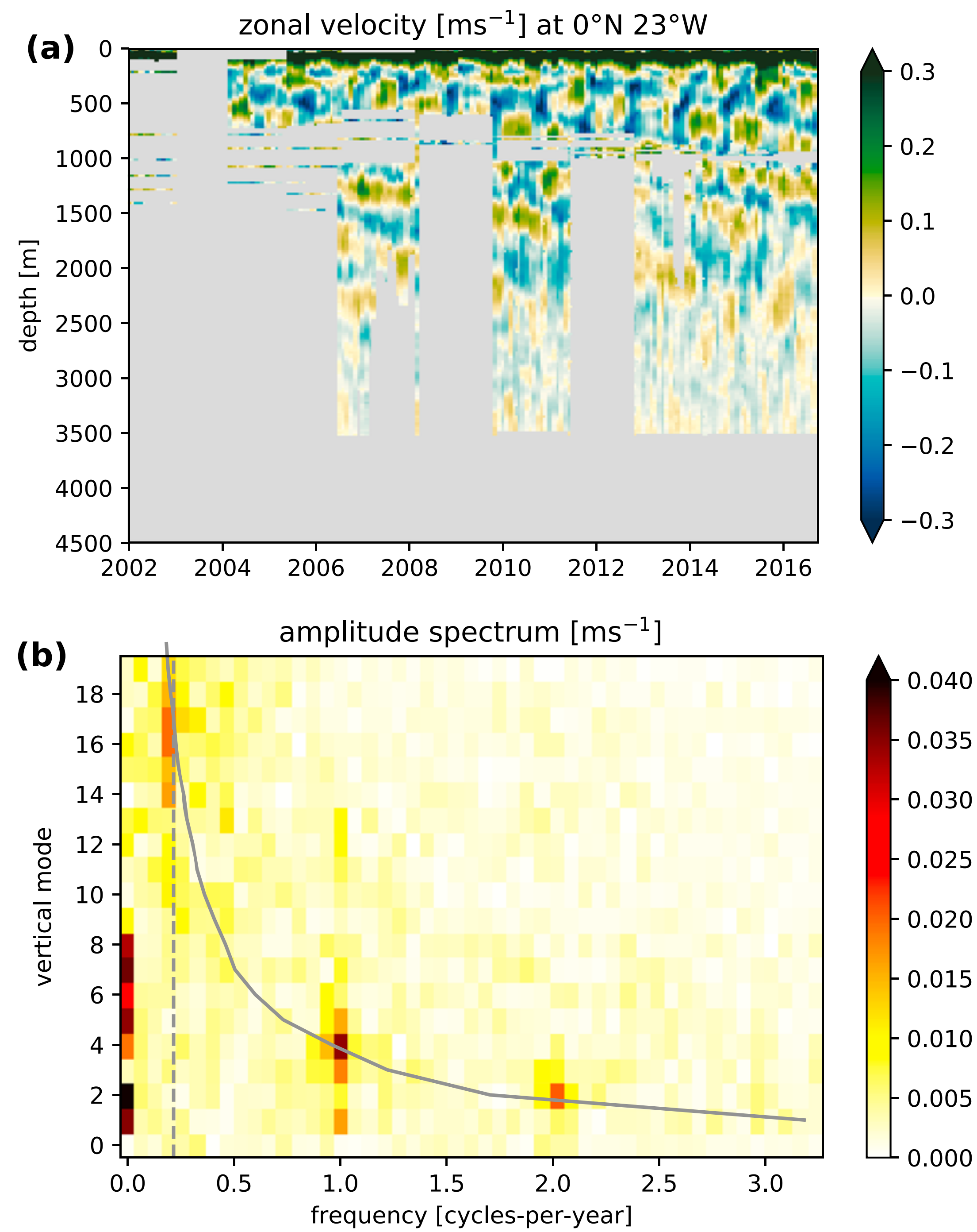
Introduction

Equatorial Deep Jets (EDJ)

- (figure on the right shows observed EDJ in the Atlantic Ocean)
- strong zonal currents on the equator, between 500 m and 2000 m depth
- alternating in direction with depth
- downward phase propagation, upward energy propagation
- frequency dependent on width of ocean basin, EDJ period in the Atlantic: ~4.5 years (as visible in Panel b on the right, they sit on the gravest basin mode resonance curve shown in solid grey)
- EDJ are dominant interannual variability in Atlantic

Why are the EDJ important?

- they influence atmospheric and oceanic variables at the ocean surface (Brandt et al., 2011)
- they influence deep oceanic oxygen and tracer distribution (Brandt et al., 2012; 2015)
- nevertheless, they are not present in most ocean models today



(Greatbatch et al., 2018)

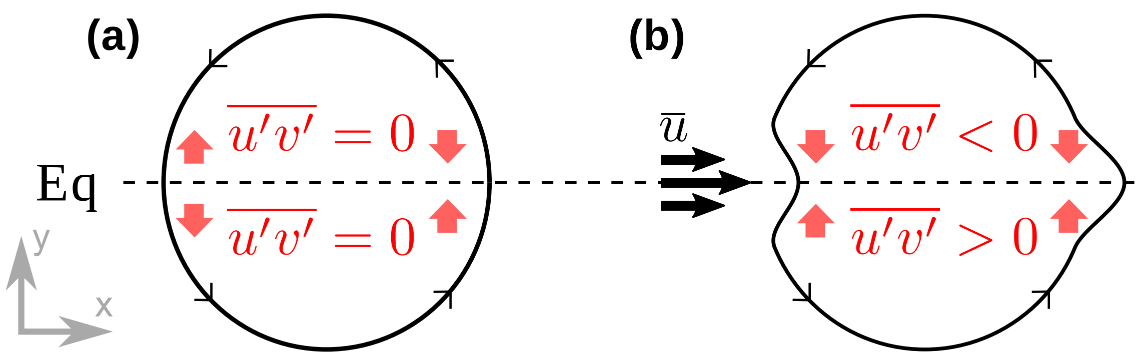
Introduction

How are the EDJ generated?

- originate from number of mechanisms, involving:
  - instabilities in western boundary currents and upper ocean currents
  - resonant triad interaction of intraseasonal waves
  - basin mode resonance

How are they maintained against dissipation?

- EDJ must have maintenance mechanism in their depth range, or they could not propagate vertically as far as they do (Claus et al., 2016)
- Greatbatch et al. (2018) suggested that this mechanism could be the convergence of the meridional flux of intraseasonal zonal momentum (IMFC), originating from the deformation of intraseasonal waves by the EDJ, and fluxing momentum into the EDJ (see figure on the right)



(Greatbatch et al., 2018)

Intraseasonal Momentum Flux Convergence (**IMFC**): $-\dfrac{\partial\overline{(u'v')}}{\partial y}$

Prime: time scales < 70 days
Overbar: time scales > 70 days

Aim of this study (Bastin et al., 2020, in press):

- What happens if we introduce IMFC associated with EDJ into an ocean model as the only forcing term?
  - Can we reproduce EDJ with realistic amplitude?
  - Is there nonlinear generation of time mean flow when the EDJ are the only variability present?

Model & experiment setup

Model setup:

- NEMO version 3.6 (Madec et al., 2017)
- rectangular ocean basin with flat bottom, 5000 m deep
- 55° wide (chosen to mimick equatorial Atlantic)
- 1/4° horizontal resolution, 200 vertical levels
- initialised with basin-averaged vertical profiles of temperature and salinity from World Ocean Atlas 2018 (Locarnini et al., 2019; Zweng et al., 2019)

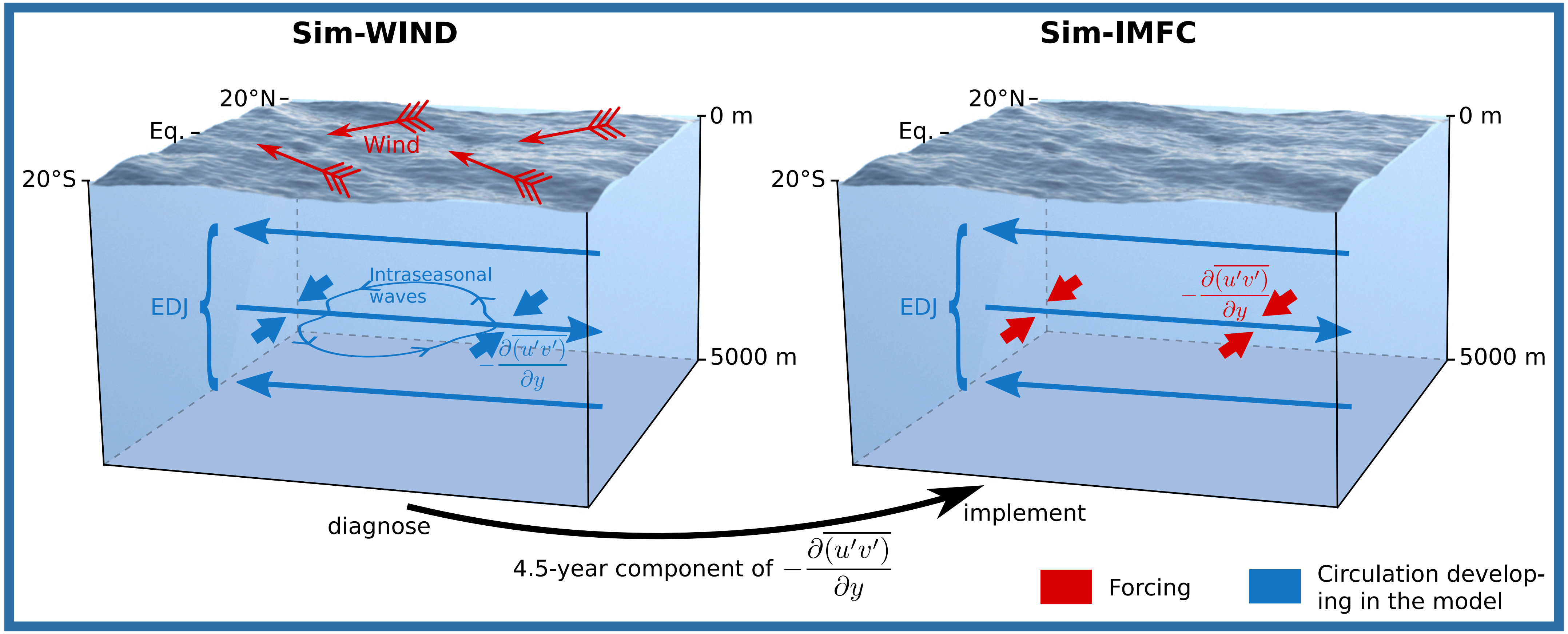
Two model runs (see figure below):

Sim-WIND

- forced with steady, zonally averaged winds from NCEP/NCAR reanalysis (Kalnay et al., 1996; Kistler et al., 2001)

Sim-IMFC

- forced at every point in the basin with the 4.5-year component of IMFC diagnosed from Sim-WIND



(Bastin et al., 2020)

Results (1): Equatorial deep jets

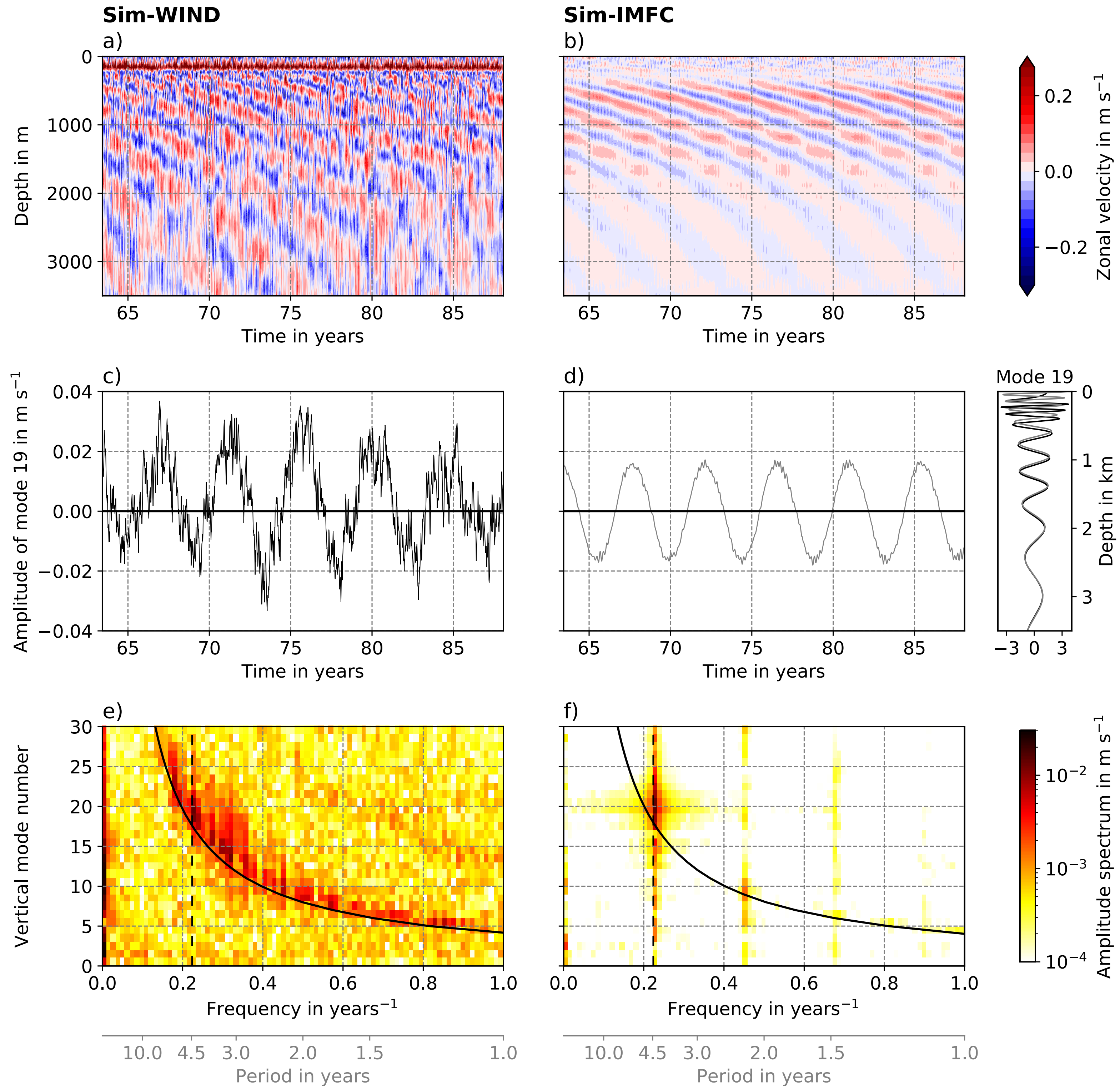
EDJ in Sim-WIND:

- some differences to observed EDJ, but reasonably realistic
- period of simulated EDJ very close to observations (~4.5 years)

EDJ in Sim-IMFC:

- characteristics compare well with EDJ from Sim-WIND
- main differences: lack of near-surface circulation and lack of variability on other frequencies (both due to experiment design)
- in particular, EDJ amplitude in Sim-IMFC is similar to Sim-WIND

➡**strongly corroborates theory by Greatbatch et al. (2018): IMFC likely is the key process maintaining the EDJ at depth**



(Bastin et al., 2020)

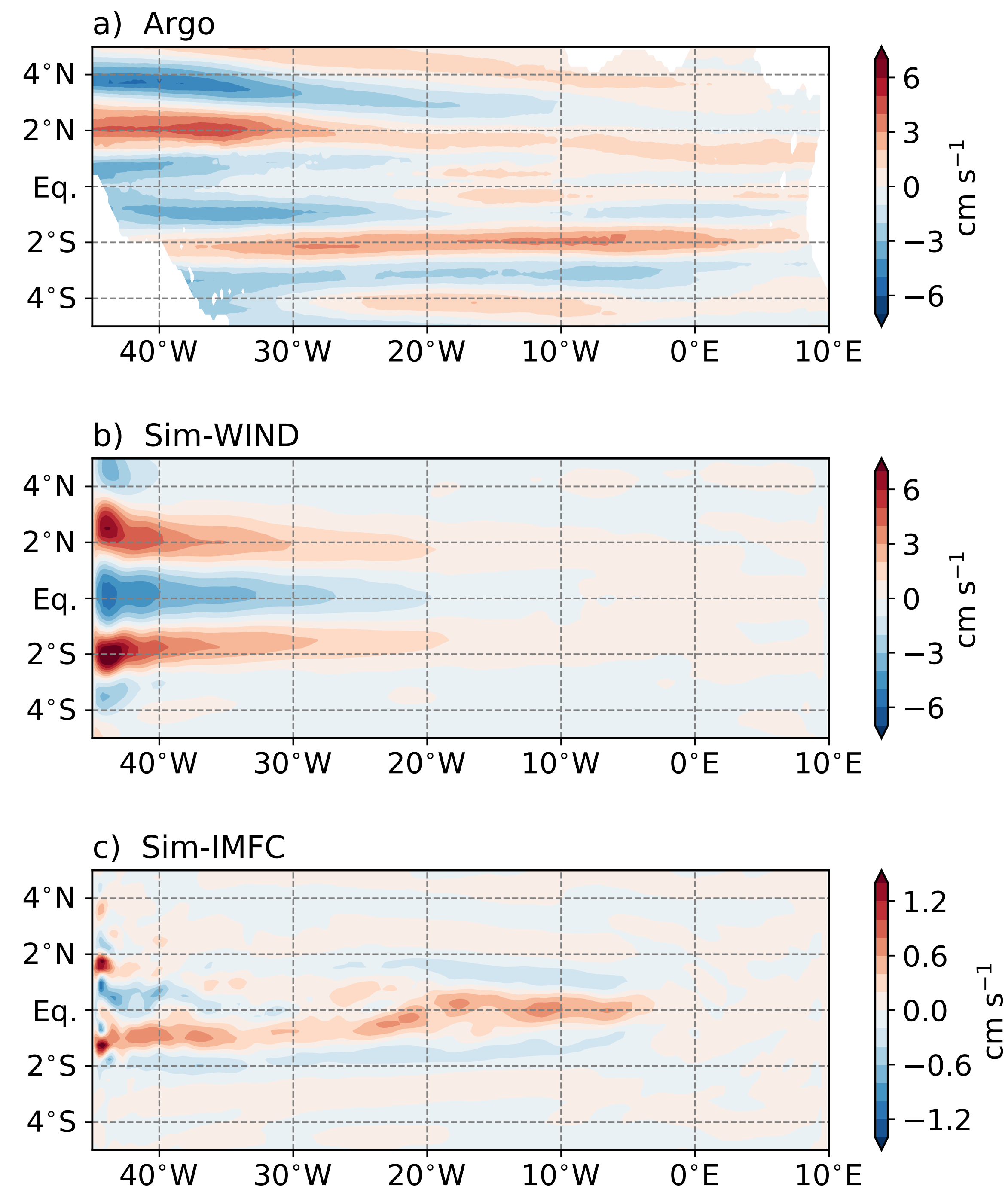
Results (2): Influence on mean circulation

Mean zonal circulation at 1000 m depth:

Sim-IMFC:

- although there is forcing only at the EDJ period, there is nonlinear generation of variability on other frequencies
- in particular, time mean flow is generated in EDJ depth range
- transfer of energy from EDJ to mean flow happens through zonal self-advection of EDJ (not shown here, see Bastin et al., 2020)
- generated near-equatorial mean circulation is westward on equator with flanking eastward currents, but changes sign around 25°W, becoming eastward on equator and westward to north and south
- this mid-basin change of sign is also visible in Argo data

➡**Atlantic EDJ play a role in determining the mean current direction along equator at intermediate depths: important e.g. for ventilation of deep eastern oxygen minimum zones**



(Bastin et al., 2020)

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