Diabatic Contributions to Warm Water Volume Variability during ENSO Events

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Motivation

- The equatorial Pacific Warm Water Volume (WWV, defined as the volume of water above the 20°C isotherm) leads the N34 index by 6-8 months and is an important inclusion in ENSO forecasts
- While the role of adiabatic volume fluxes during El Niño's WWV discharge and La Niña's WWV recharge is well understood, much about the diabatic fluxes remain unknown

Thus, we address the following research questions:

a) Which diabatic processes contribute to WWV changes over ENSO events?
b) What are the underlying physical mechanisms leading to these diabatic WWV changes?
c) Are there ocean-sourced non-linearities in the diabatic fluxes despite symmetric ENSO events?

The Warm Water Volume Balance

- **adiabatic fluxes** arise from horizontal transport across 5°N and 5°S ($\mathcal{T}_{5°N+5°S}$), the Indonesian Throughflow ($\mathcal{T}_{ITF}$) and the surface volume fluxes ($\mathcal{J}$) due to precipitation, evaporation and river runoff
- **diabatic fluxes** (Fig. 1) arise from
  - surface forcing ($\mathcal{G}_{\mathcal{F}}$): surface heat fluxes expand a water parcel's volume
  - vertical mixing ($\mathcal{G}_{\mathcal{M}}$): cools water masses above and heats water below leading to a volume flux between these regions
  - numerical mixing ($\mathcal{G}_{\mathcal{I}}$): emerges from truncation errors in the model's advection scheme

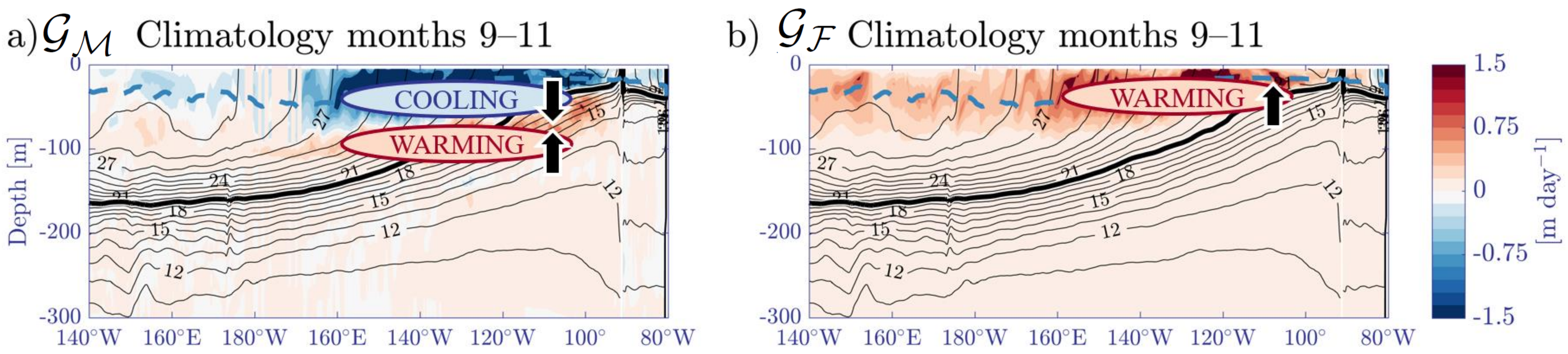

Fig. 1 Equatorial transects of the climatological water mass transformation velocities of (a) vertical mixing and (b) surface forcing in MOM025 with the 20°C isotherm in bold and the mixed-layer depth as a dashed line. The labels show where cooling and warming of water masses occurs which results in a subsequent volume flux across the 20°C isotherm.

WWV Balance Terms during ENSO

- WWV changes over two stages: the first stage is dominated by diabatic followed by adiabatic fluxes about six months later
- While adiabatic fluxes are reasonably symmetric, diabatic fluxes show strong asymmetries between El Niño and La Niña
- The strong asymmetries are caused by the upward shift of the 20°C isotherm during La Niña into the surface region (Fig. 2, 4b)

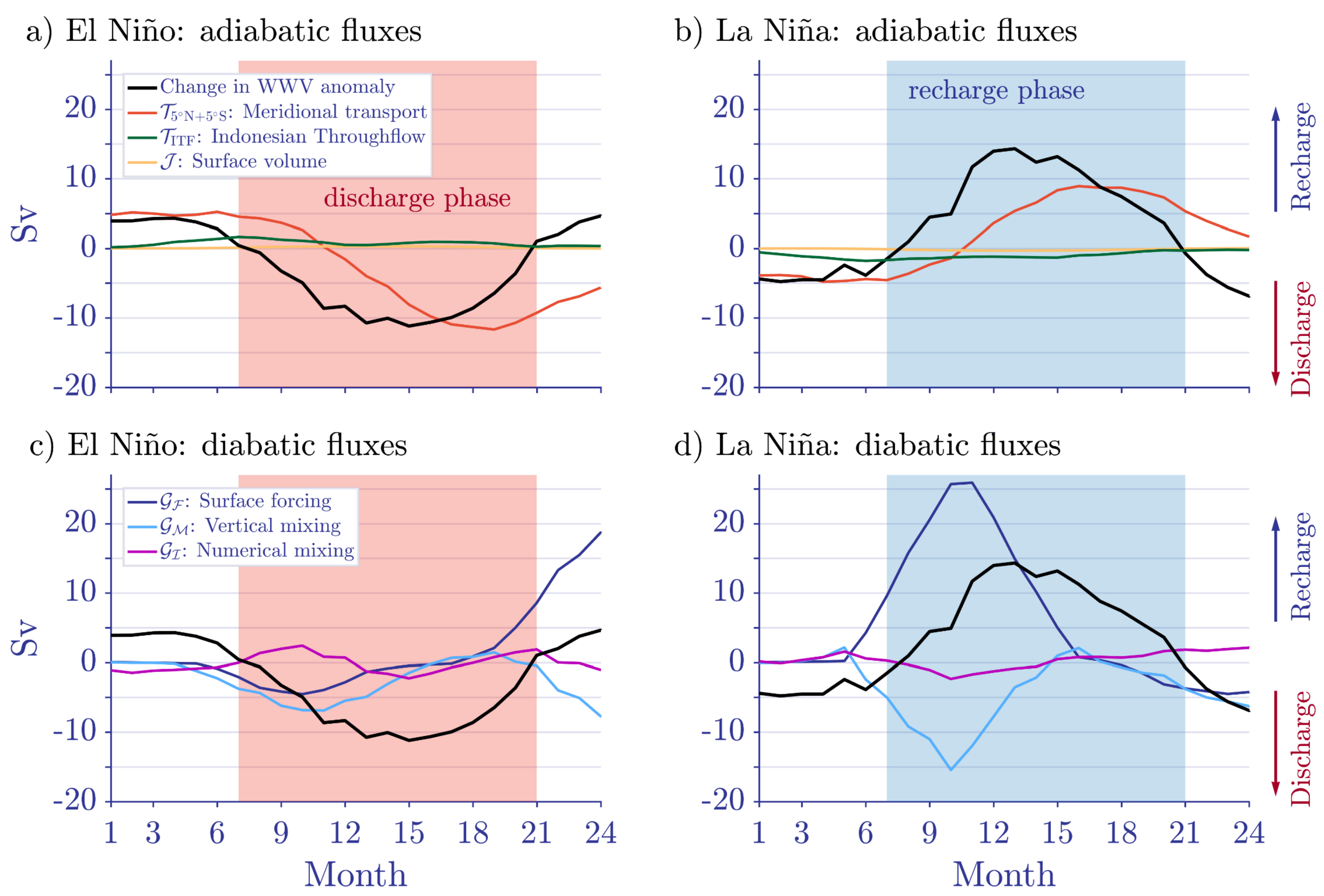

Fig. 2 Anomalous WWV balance terms [Sv] throughout the idealised symmetric El Niño and La Niña simulations with a five-month running mean as in Meinen and McPhaden (2000). The discharge phase (red region in (a)) is defined when the change in WWV is negative – for a symmetric analysis, the recharge phase during La Niña covers the same time period. Positive values indicate volume transport into the WWV region, with negative values representing transport out.

Model, Data and Methods

Model: MOM025 (global ocean sea-ice model, ¼° resolution, 50 vertical levels, KPP vertical mixing & precise temperature-space diagnostics)
Input Data: GFDL's climatological CNYF with anomalies from ERA-Interim to calculate wind stress, surface heat and freshwater fluxes

- Following & extending from McGregor et al. (2014), we use an EOF approach of equatorial wind stress anomalies (Fig. 3) to create idealized symmetric ENSO events by
  1) regressing the time series (Fig. 3c) onto each anomaly field to create spatial maps
  2) constructing idealised symmetric time series composites based on strong El Niño's (red areas, Fig. 3c)
  3) scaling the spatial maps with the idealised time series to obtain atmospheric anomalies

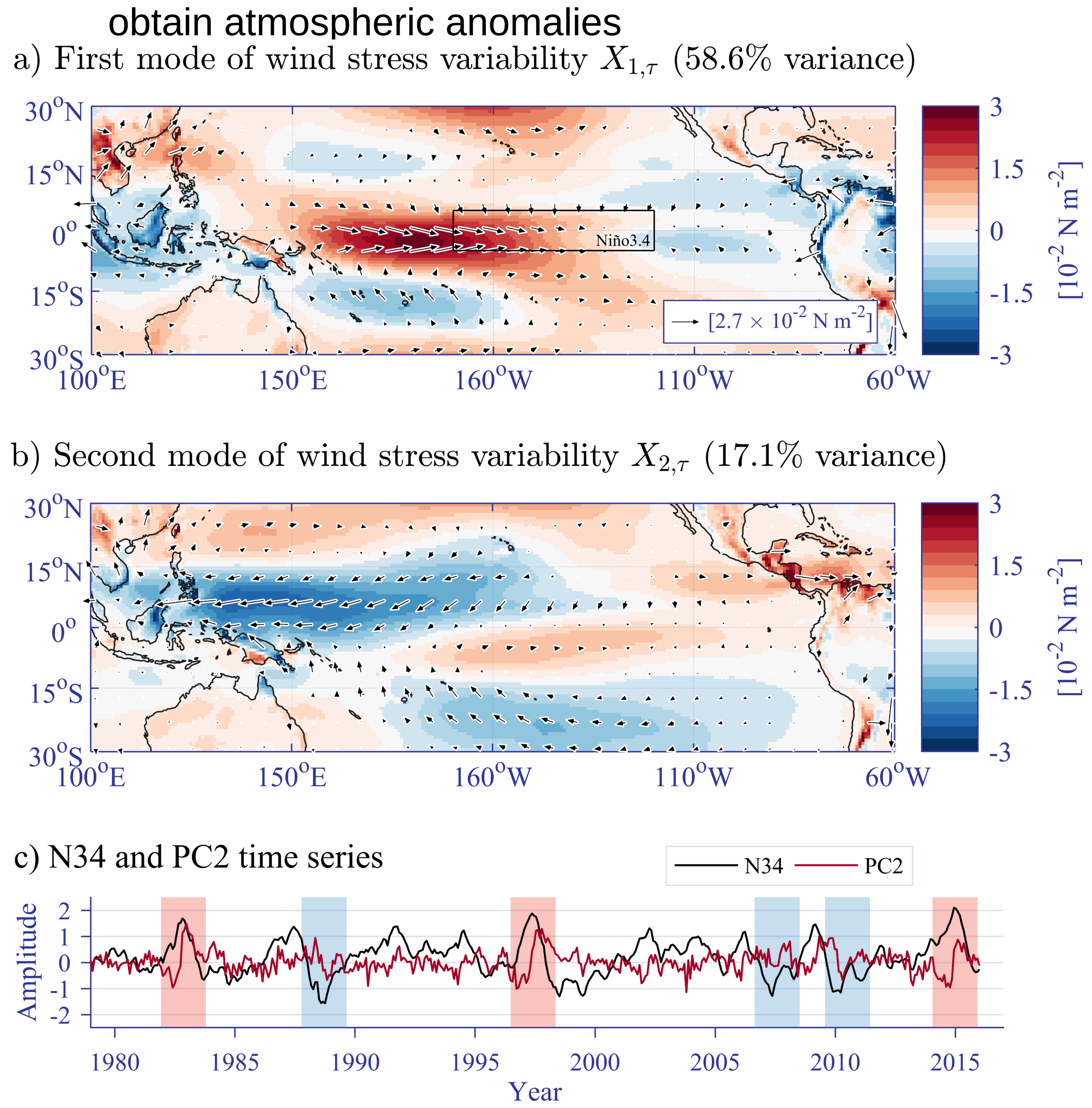

Fig. 3 The (a) first and (b) second mode of wind stress variability related to ENSO [10^{-2} N m^{-2}]. The zonal component is shaded. The Niño3.4 area (170°W–120°W and 5°N–5°S) is indicated as the framed area in (a). In (c) the associated time series with the observed N34 (Reynolds et al. 2007) in black and PC2 in red. Both patterns and time series are scaled with their standard deviation as in McGregor et al. (2014). Shaded periods in (c) are the strongest ENSO events.

Summary Figure

WWV discharge during El Niño: 60% adiabatic, 40% diabatic
WWV recharge during La Niña: 40% adiabatic, 60% diabatic

- The surface forcing flux during La Niña exceeds total change in WWV compensated for by strong vertical mixing

All units: [$\times 10^{14}$ m^3]

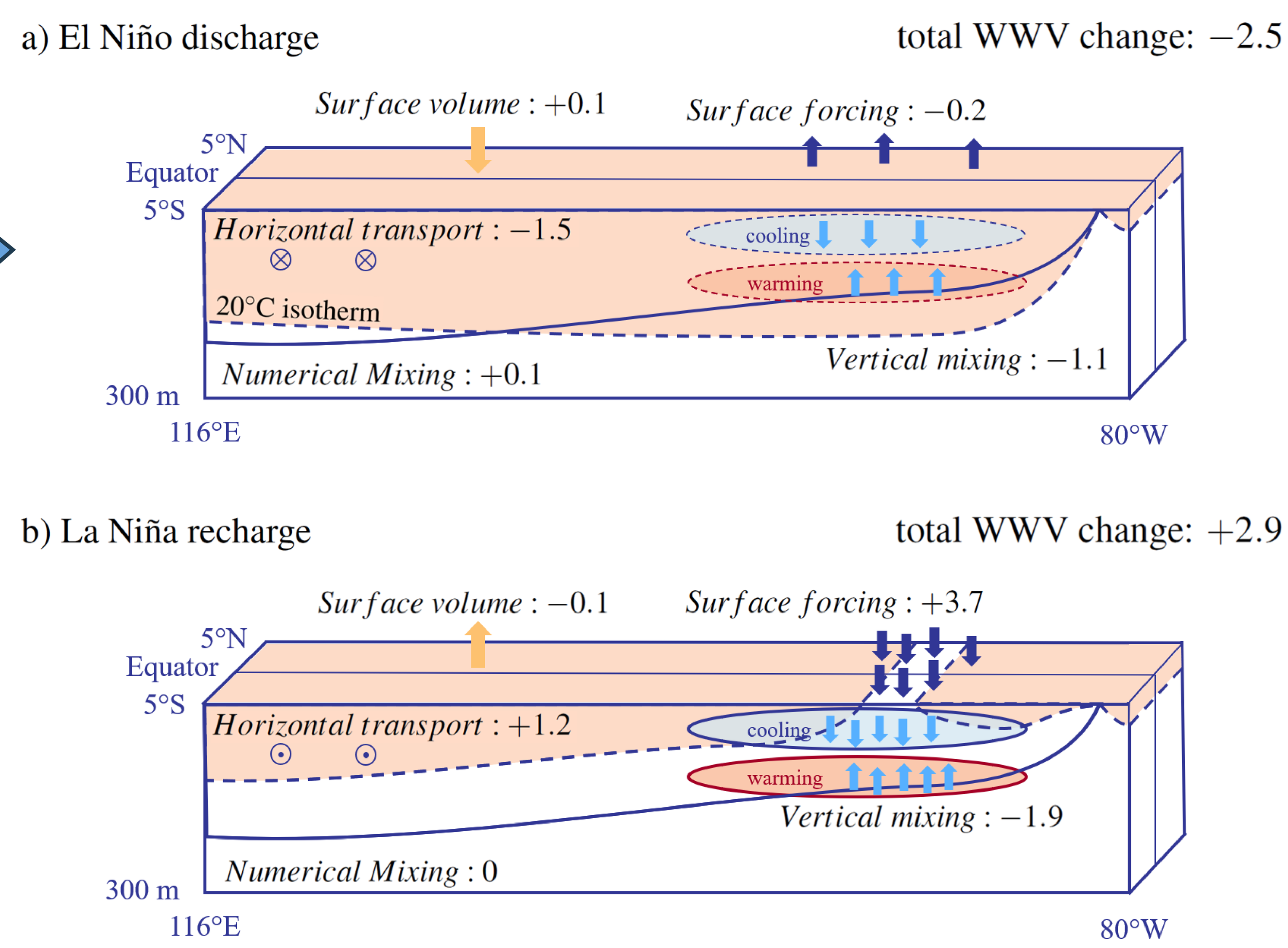

Fig. 4 Schematics representing the discharge and recharge phases of WWV. The solid line between 116°E–80°W displays the climatological 20°C isotherm depth & the dashed line its anomalous position. The shaded volume above indicates the WWV during the peak of the event. The values show the contribution of each volume flux in units of [10^{14} m^3] to the total WWV change for the idealised and symmetric ENSO phases.

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