Importance of wind variations and intersecting waveguides near Sri Lanka for the intraseasonal sea level variability along the west coast of India

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EGU General Assembly 2020

राष्ट्रीय समुद्र विज्ञान संस्थान

(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद)

National Institute of Oceanography

(Council of Scientific & Industrial Research)

Understanding the seas

Abstract

Remote wind forcing plays a strong role in the Northern Indian Ocean, where oceanic anomalies can travel long distances within the coastal waveguide. Previous studies for instance emphasized that remote equatorial forcing is the main driver of the sea level and currents intraseasonal variability along the west coast of India (WCI). Until now, the main pathway for this connection between the equatorial and coastal waveguides was thought to occur in the eastern equatorial Indian Ocean, through coastal Kelvin waves that propagate around the Bay of Bengal rim and then around Sri Lanka to the WCI (Fig. 1). Using a linear, continuously stratified ocean model, the present study demonstrates that two other mechanisms in fact dominate. First, the equatorial waveguide also intersects the coastal waveguide at the southern tip of India and Sri Lanka, creating a direct connection between the equator and WCI. Rossby waves reflected from the eastern equatorial Indian Ocean boundary indeed have a sufficiently wide meridional scale (Figs. 2 and 3) to induce a pressure signal at the Sri Lankan coast, which eventually propagates to the WCI as a coastal Kelvin wave. Second, local wind variations in the vicinity of Sri Lanka (Fig. 4) generate strong intraseasonal signals, which also propagate to the WCI along the same path. Sensitivity experiments (Fig. 5) indicate that these two new mechanisms (direct equatorial connection and local wind variations near Sri Lanka) dominate the WCI intraseasonal sea level variability, with the "classical" pathway around the Bay of Bengal only coming next (Fig. 6). Other contributions (Bay of Bengal forcing, local WCI forcing) are much weaker.

By providing an improved understanding of the mechanisms that control the WCI thermocline and oxycline variability, our results could have socio-economic implications for regional fisheries and ecosystems.

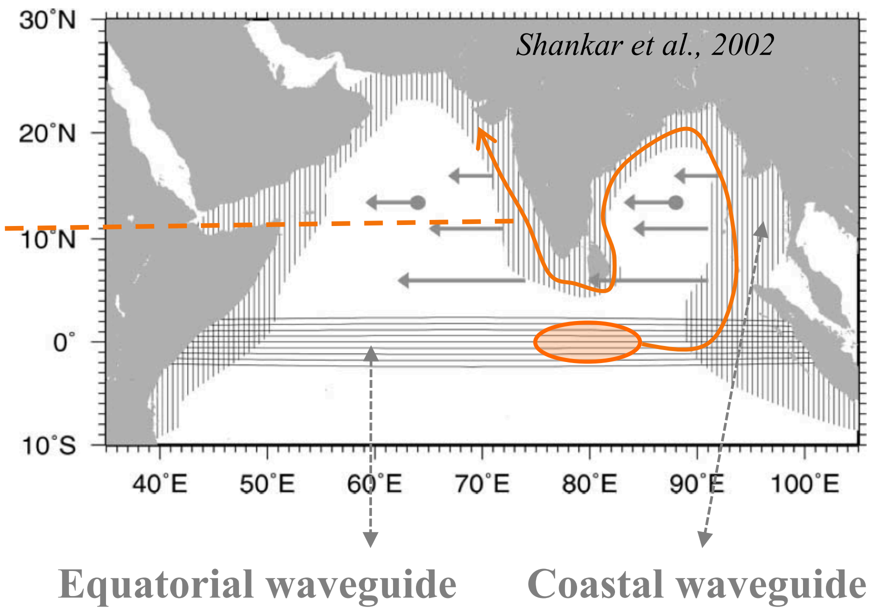
Background & Motivation: the North Indian Ocean (NIO) waveguide

Earlier studies – emphasized importance of remote forcing for seasonal sea level variability along the Indian coast & proposed "*leaky waveguide*" connecting remote regions of the NIO

Equatorial winds
- ⇒ equatorial Kelvin waves
- ⇒ coastal Kelvin waves in the Bay of Bengal (BoB)
- ⇒ signals turn around Sri Lanka
- ⇒ poleward along the west coast of India (WCI)

Refer to as "classical pathway" or EQB

Fig 1. Schematic showing NIO waveguide



Recent studies demonstrated that such a dynamical link between the equatorial and the coastal waveguides of the NIO exists even at intraseasonal timescale

McCreary et al. 1993, 1996; Shankar and Shetye, 1997; Shankar et al. 2002; Shetye, 1998; Vialard et al., 2009; Suresh et al., 2013

The intersecting waveguides

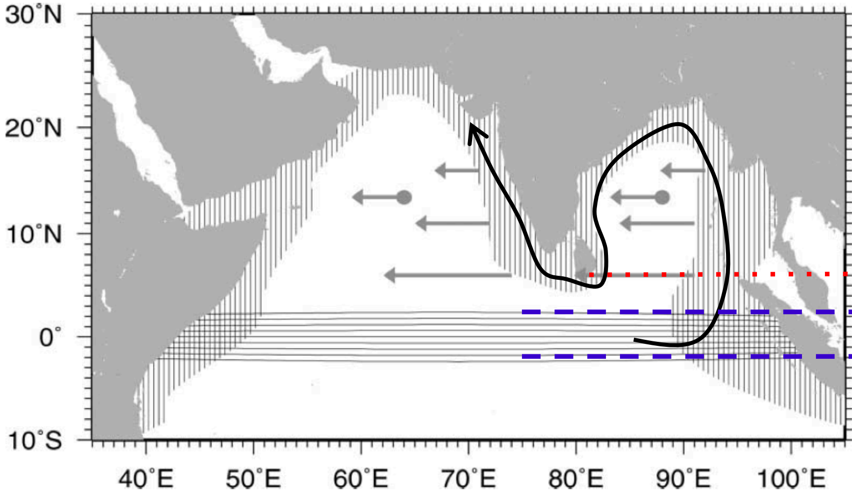
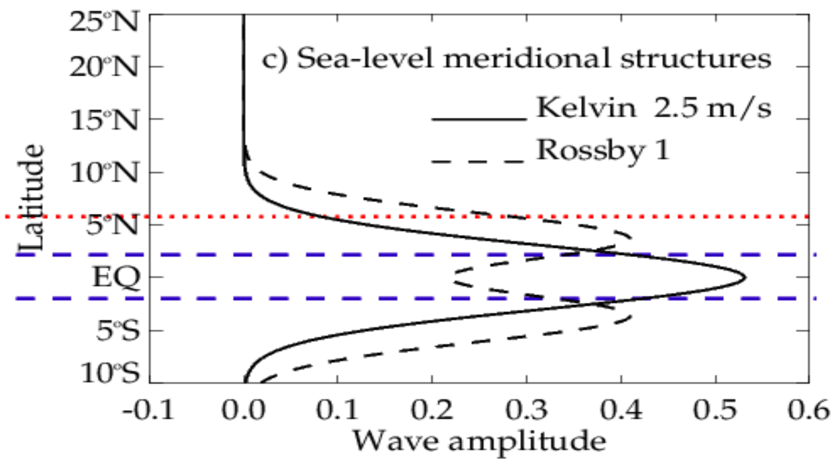


Fig 2. Theoretical meridional structures of Kelvin and first meridional mode Rossby waves

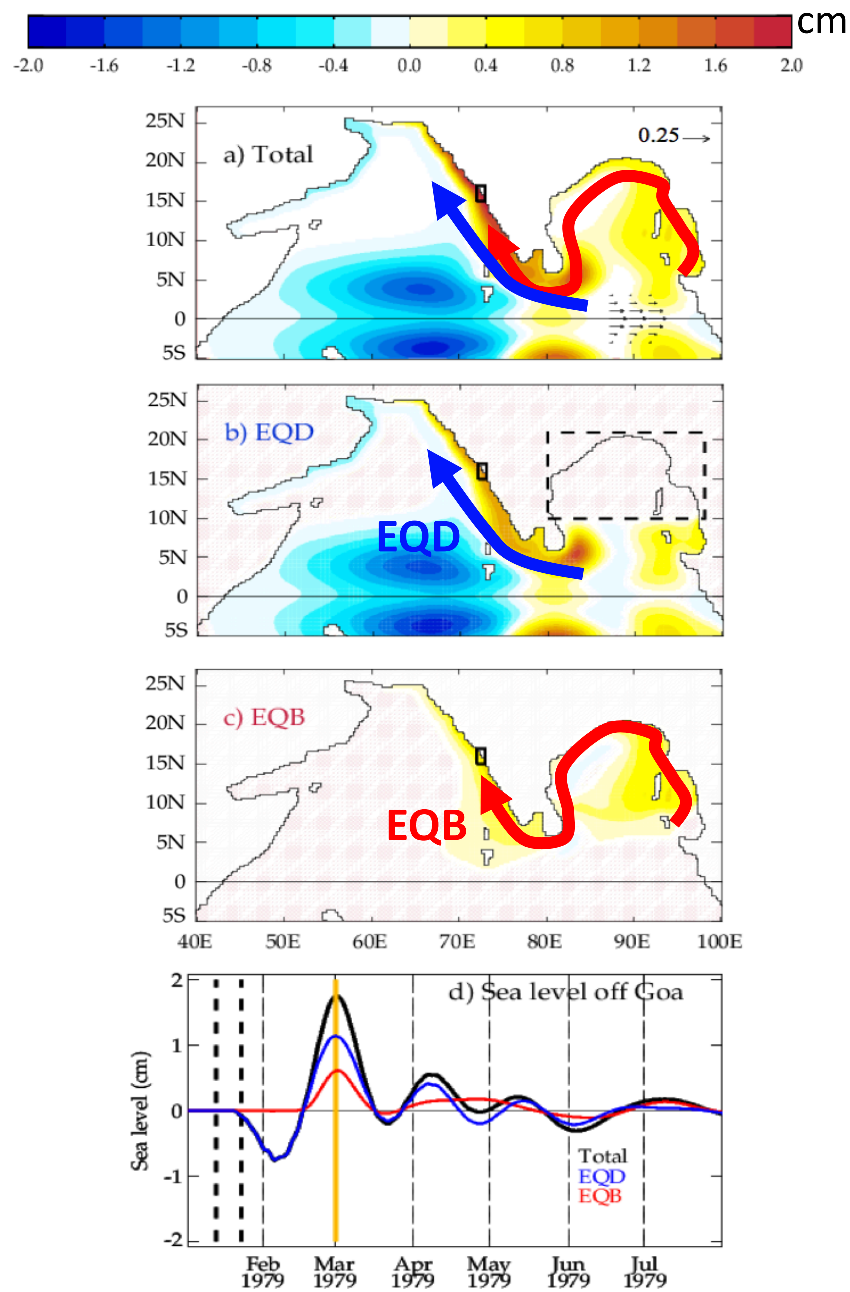


- Amplitude of first baroclinic, first meridional mode Rossby wave at the southern tip of Sri Lanka is 70% of its maximum at 4°N => equatorial and NIO coastal waveguides intersect at the Sri Lankan coast
- Equatorial Rossby waves can potentially trigger Kelvin wave signals at the Sri Lankan coast
- Suggestive of a new "direct" connection between the equatorial and the NIO coastal waveguides, which we refer to as EQD

Demonstration of the new direct connection (EQD)

Fig 3. Idealized experiment with a linear, continuously stratified (LCS) model

Response to equatorial westerly wind burst



Suggests that there is indeed a direct connection at the southern tip of India (EQD) associated with equatorial Rossby waves

Role of this EQD process for WCI sea level variability has so far not been explored in the literature!

Respective EQD & EQB contributions?

The forcing hotspots

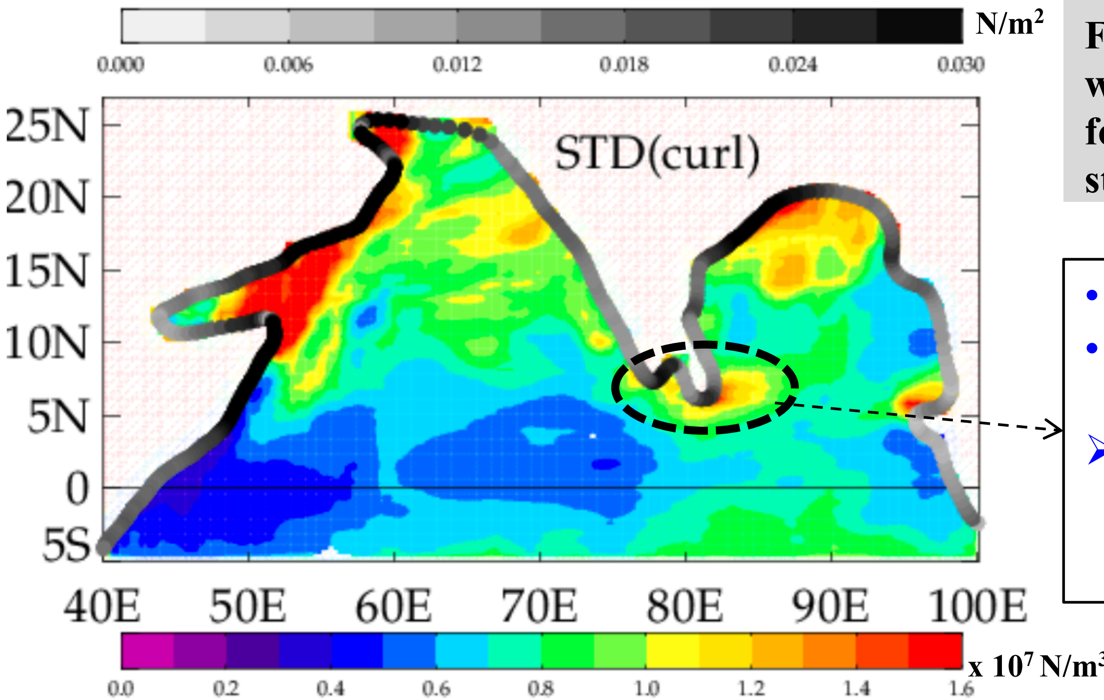


Fig 4. Amplitude of intraseasonal wind variations: alongshore forcing (grey scale) and wind-stress curl forcing (color scale)

- **Strong alongshore forcing**
- **Strong wind-stress curl forcing**

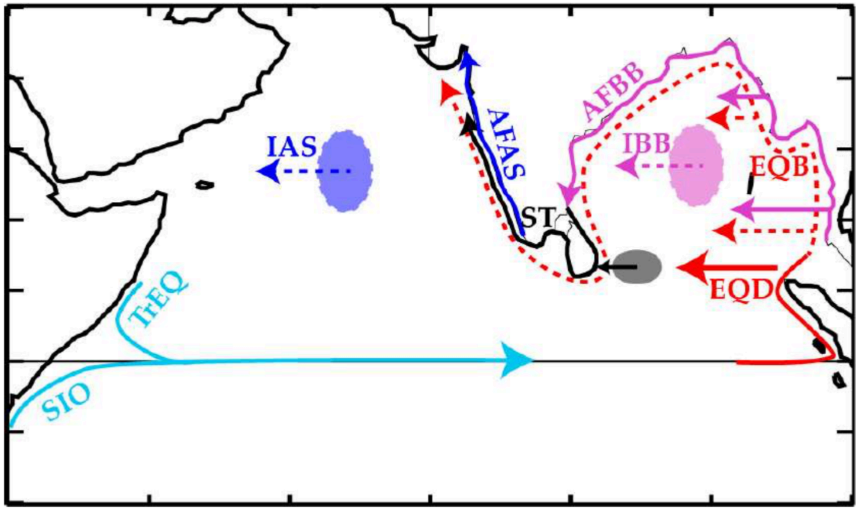
➢ **Both processes will collectively be referred to as ST process**

Suresh et al. (2016) demonstrated that seasonal wind variations near Sri Lanka, i.e. ST process drives most of the seasonal sea level variability along the WCI

What is the role of wind stress forcing near Sri Lanka (ST process) for intraseasonal sea level variability along WCI?

The model and experiments

Fig. 5. Schematic pathways & process decomposition



A linear continuously stratified (LCS) ocean model

- **LCS model: solves linearized shallow water equations individually for each baroclinic mode**
- **Modified version of McCreary et al. (1996)**
- **Configured for Indian Ocean domain**

- **Forced with Tropflux wind stress anomalies (1979-2013) => CTL simulation**
- **Processes are isolated using sensitivity experiments**
- **Linearity allows isolating the processes: Equatorial (EQB and EQD), Bay of Bengal (BB), southern tip of India (ST) and Arabian Sea (AS) wind forcing**

CTL sea level can be decomposed into that due to each process

$$SL_{CTL} = SL_{EQD} + SL_{EQB} + SL_{ST} + All\ other\ processes$$

Dominant mechanisms of WCI intraseasonal sea level variability

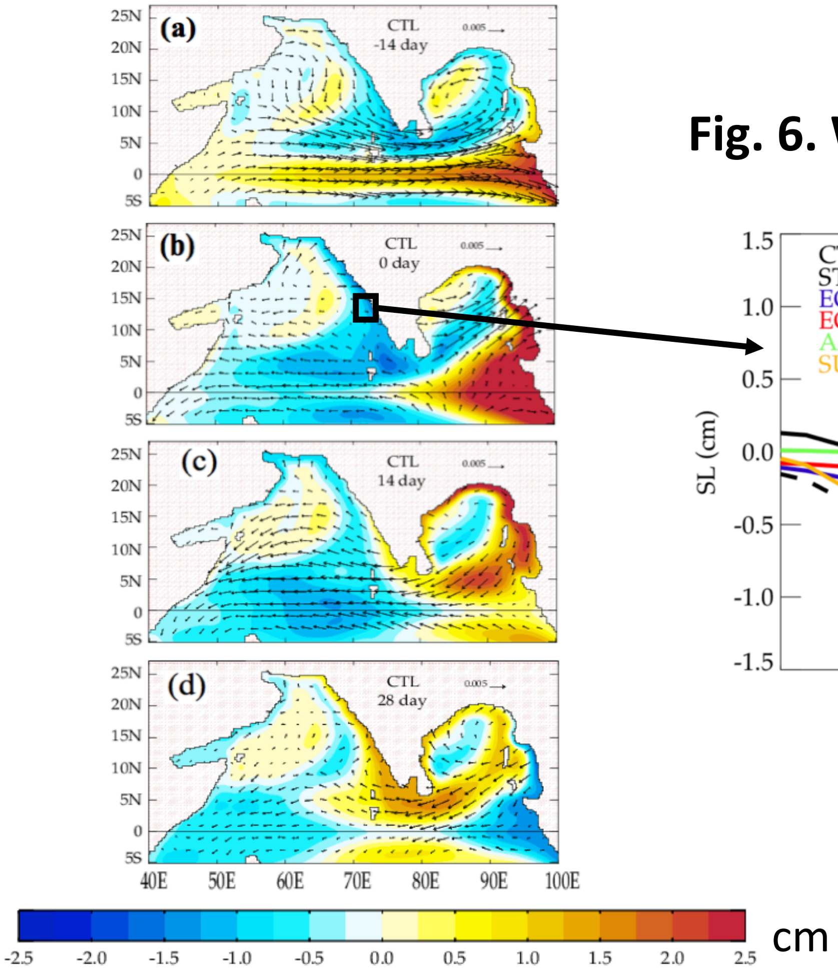
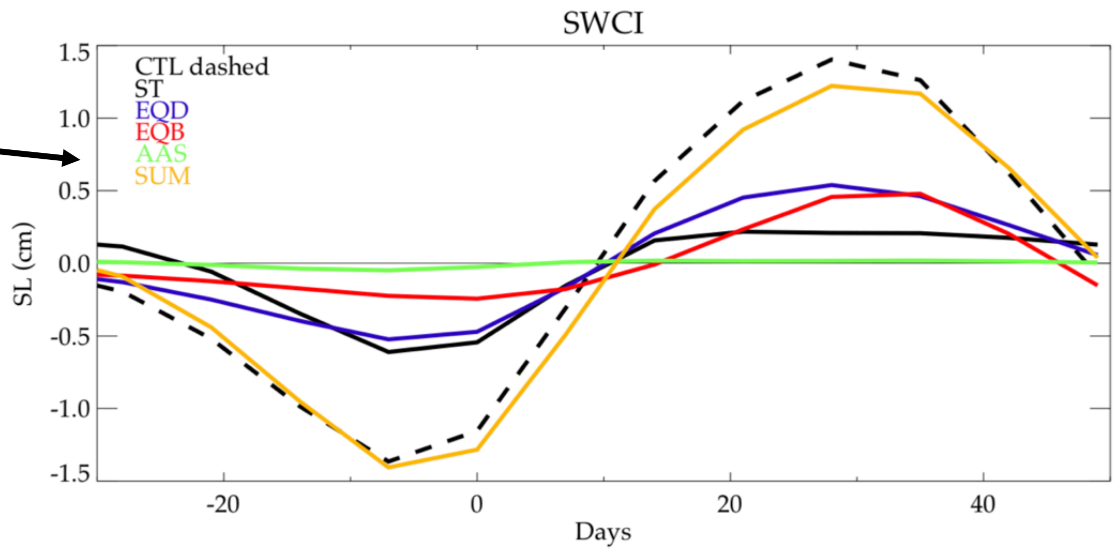


Fig. 6. West coast of India process decomposition



- **EQD and ST are the main contributing processes to the WCI intraseasonal sea level variability, followed by EQB**

Summary

- Using idealized experiments with a linear, continuously stratified model, we demonstrate for the first time, a new direct connection between equatorial waveguide and the west coast of India

- Equatorial signals through the above link, i.e. the EQD process, is the dominant mechanism of WCI intraseasonal sea level variability, followed by wind forcing near Sri Lanka (ST) and, finally, the ”classical” equatorial connection through the Bay of Bengal (EQB)

- While EQD is also important at interannual timescale, it does not operate at seasonal timescale (not shown)

Suresh et al., Importance of wind variations and intersecting waveguides near Sri Lanka for the intraseasonal sea level variability along the west coast of India, in preparation

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