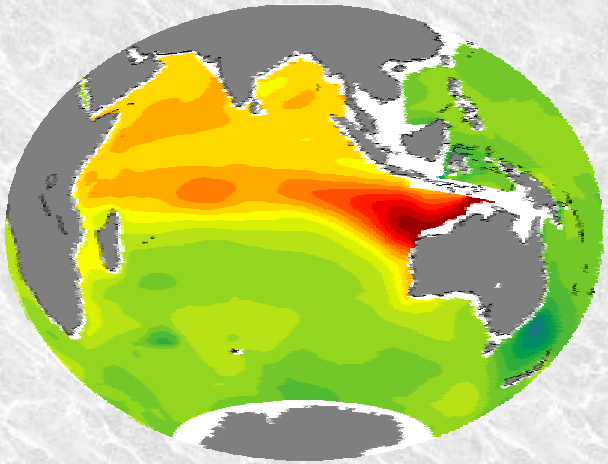
Pathways and Effects of Indonesian Throughflow water in the Indian Ocean using “Trajectory” and “Tracer” experiments in an OGCM



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OBJECTIVES

1. The 3-Dimensional pathways of the Indonesian Throughflow (ITF) in the Indian Ocean.

2. Effects of ITF in the Temperature and Salinity in the Indian Ocean.

METHODS

1. 3-D Pathways of ITF in the Indian Ocean are found using,
   a. "Lagrangian trajectories" -of the "particles" representing the ITF- derived from an OGCM.
   b. Pathways -of "Tracers" initialized at the ITF entrance region- in an OGCM.

2. Effects of ITF in the Temperature and Salinity are identified by contrasting a reference case with a "closed ITF" case and categorize the regions of effects; "whether they are induced by the actual track or not ?"

OGCM & EXPERIMENTS

- **Australian Community Ocean Model (ACOM2.0) [a modified version of MOM.2]**
- **The model domain include both the Indian and Pacific Ocean with a constant resolution of 1^0 x 0.5^0 in longitude and latitude respectively.**
- **Lagrangian type "particle trajectories" are traced from the ITF entrance region. "Particle Trajectories" *does not include* horizontal and vertical diffusion and convection.**
- **"Inert Tracers" are released at the ITF entrance region. Tracers are set to no surface forcing and independent of modeling restorations. Tracers *include* the horizontal and vertical diffusion and convection.**

Lagrangian Trajectories shows that,

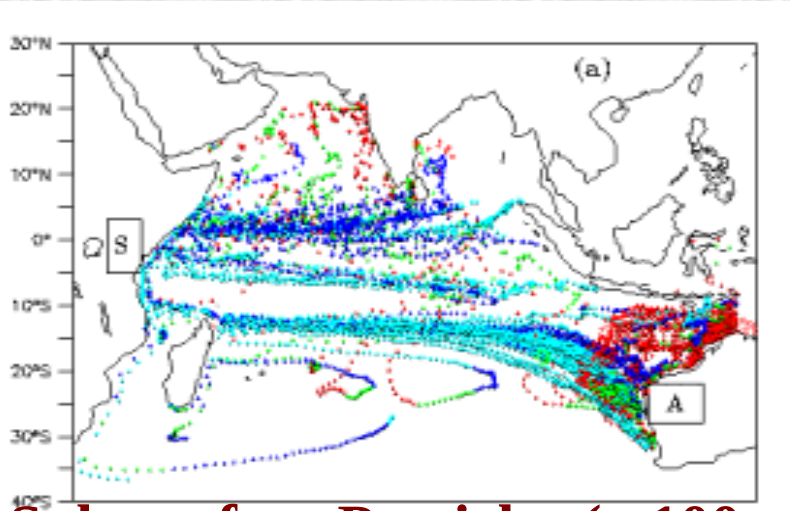
1. At the Entrance region the Surface ITF (< 70m) flows to the south and sinks at the north-west coast of Australia and subduct and takes a deeper pathway across the Indian Ocean.

2. Sub-surface pathways are from east to west as a narrow jet across the Indian Ocean.

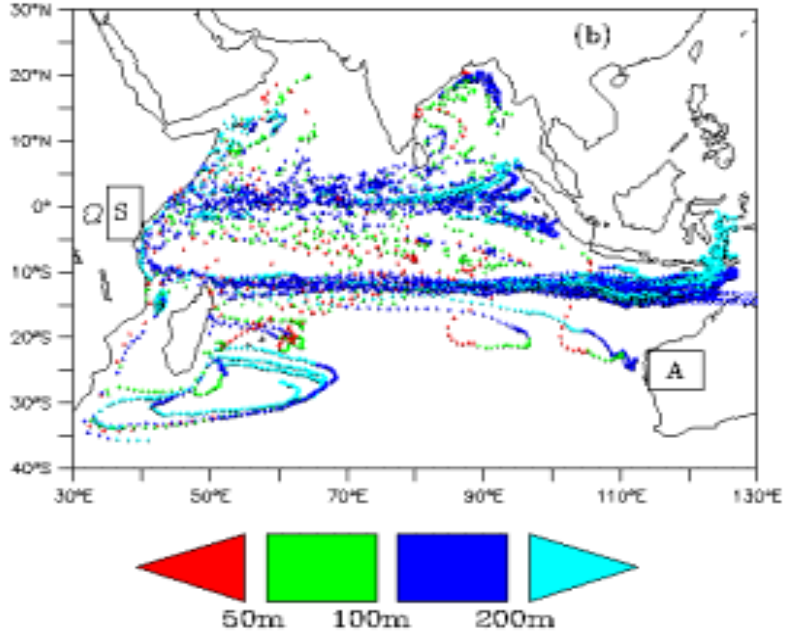
3. At the western Indian Ocean the majority of Particle trajectories turns to the north along the Somalia Coast. (as in Song et al. 2004)

Trajectory in 20 years

Surface Particles (< 60m)



Sub-surface Particles (~100m)

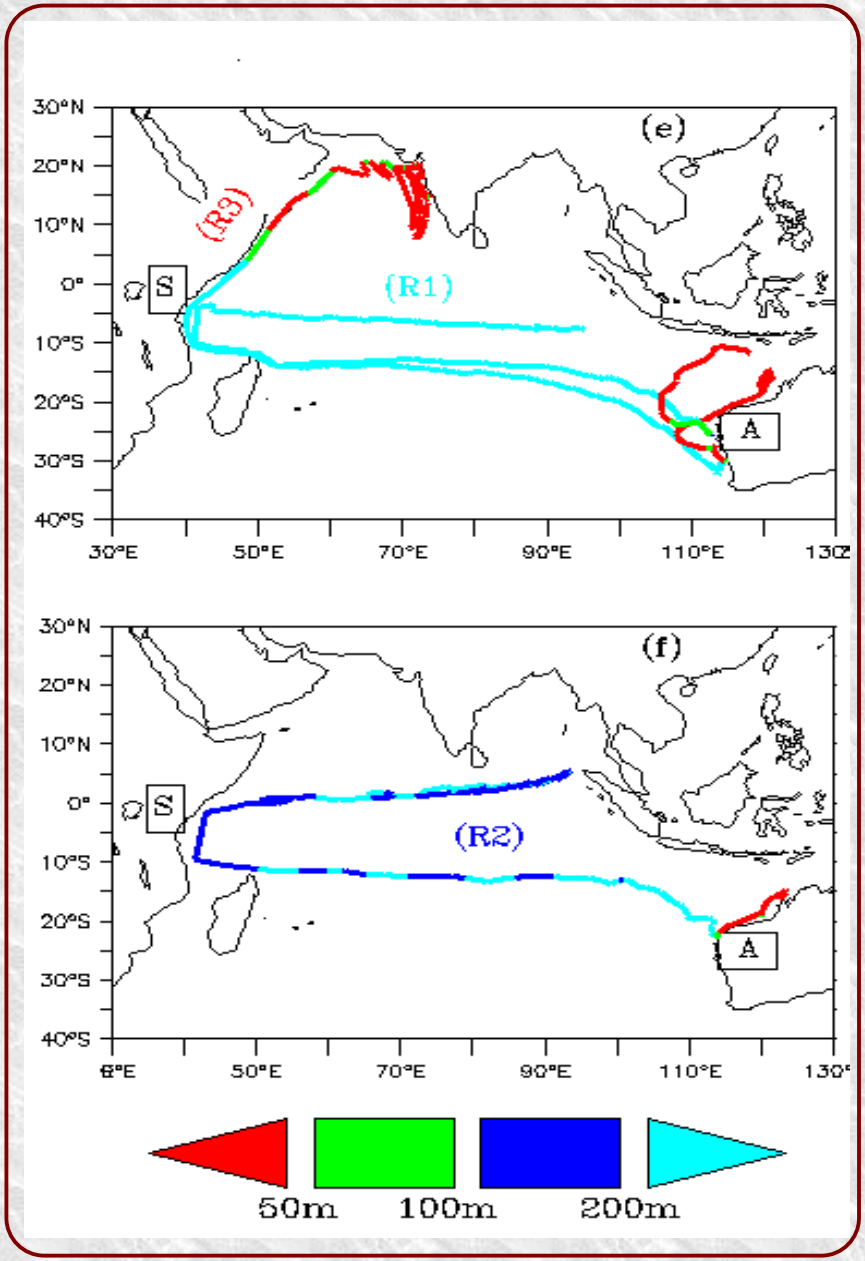


At the Somalia Coast the particles are re-routed into 3 distinct depth ranges.

1. **Route-1, across the Indian Ocean along the south of the equator is the 'deepest' route (200-300m or more).**

2. **Route-2, across the Indian Ocean along the north of the equator is the 'intermediate' depth range (100m – 200 m).**

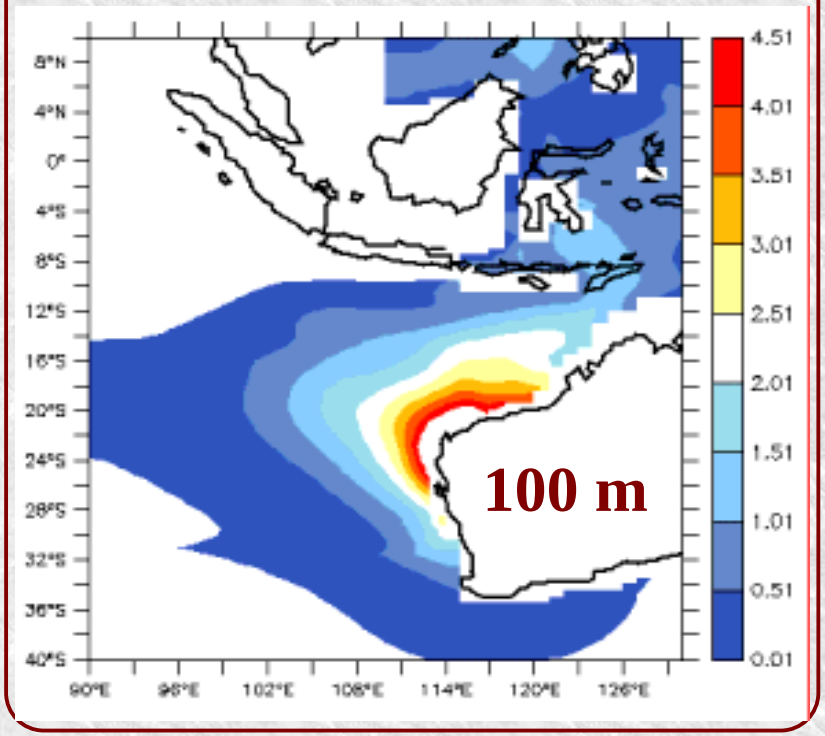
3. **Route-3, up-wells at the Somali coast and intrude into the Arabian sea as well as spread all over the central Indian Ocean (< 100m).**



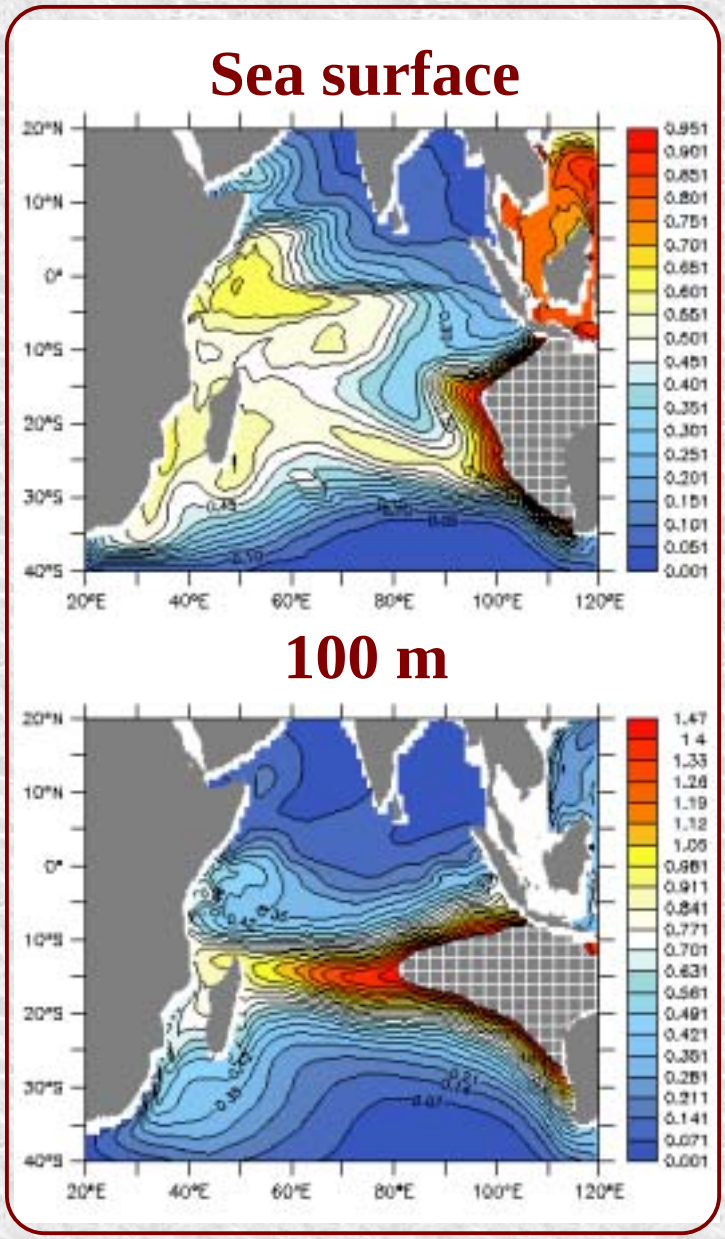
Tracer Pathways show that at the entrance region,

- **The ITF turns south-ward and subduct -> consistent with "particle trajectories".**
- **Sub-surface tracer mixes with the surface tracer, also up-wells at Sumatra-Java coast.**
- **ITF undergoes large scale mixing at the Entrance Region; is a challenge to identify it further using TS-analysis.**

Surface Tracer (initialized above 60m) reached at 100 m depth due to the vertical mixing and subduction.



Tracer pathways across the Indian Ocean after 4 years of initialization.



Major upwelling zones are,

1. Somali region and coastal Arabia,
2. Equatorial region,
3. Mozambique channel.

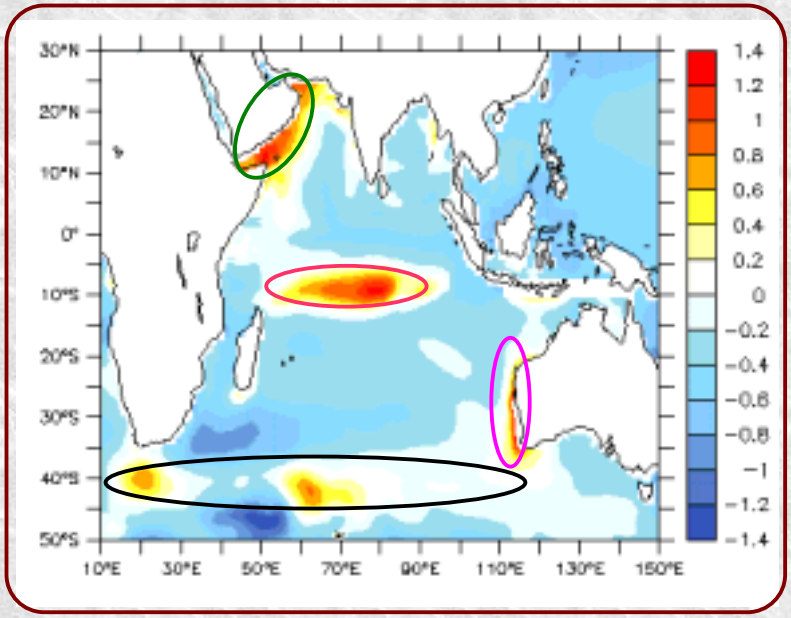
- At the western Indian Ocean in the sub-surface level majority of Tracers turns to the “south” and escape the Indian Ocean.

- The horizontal diffusion makes tracer distribution spread around the particle trajectories.

- Tracer pathways suggest a possible escape of ITF into the southern Indian Ocean at the western boundary in sub-surface level.

Effects of ITF in the SST as found in (ITF – noITF) case

SST (ITF - noITF)



The SST prints of ITF are at

1. The entrance region
2. Somali upwelling region
3. Equatorial region
4. South of 40^0S

consistent with Hirst and Godfrey (1993), Schneider (1998) Wajsowicz (2002).

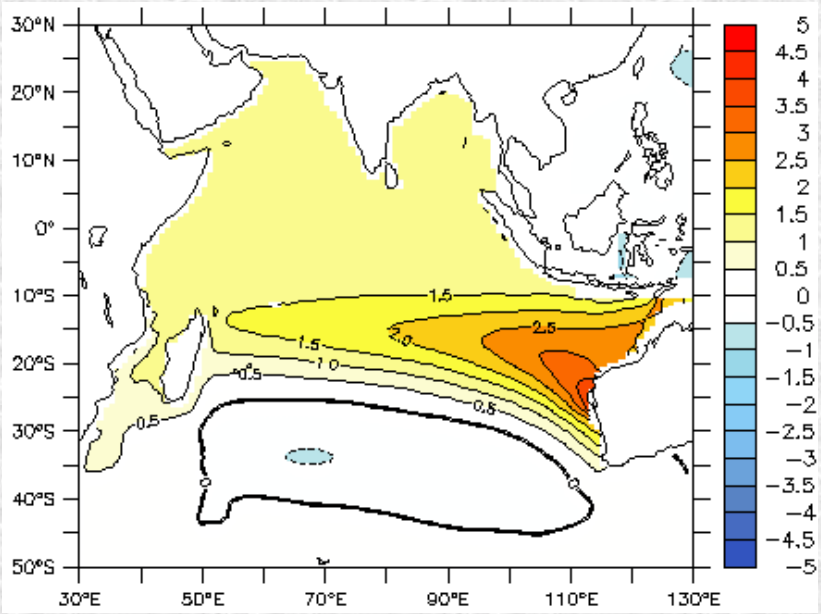
- The region 1,2 and 3 are shown as the major pathways of ITF and hence the direct effect of ITF advection in the Indian Ocean SST.

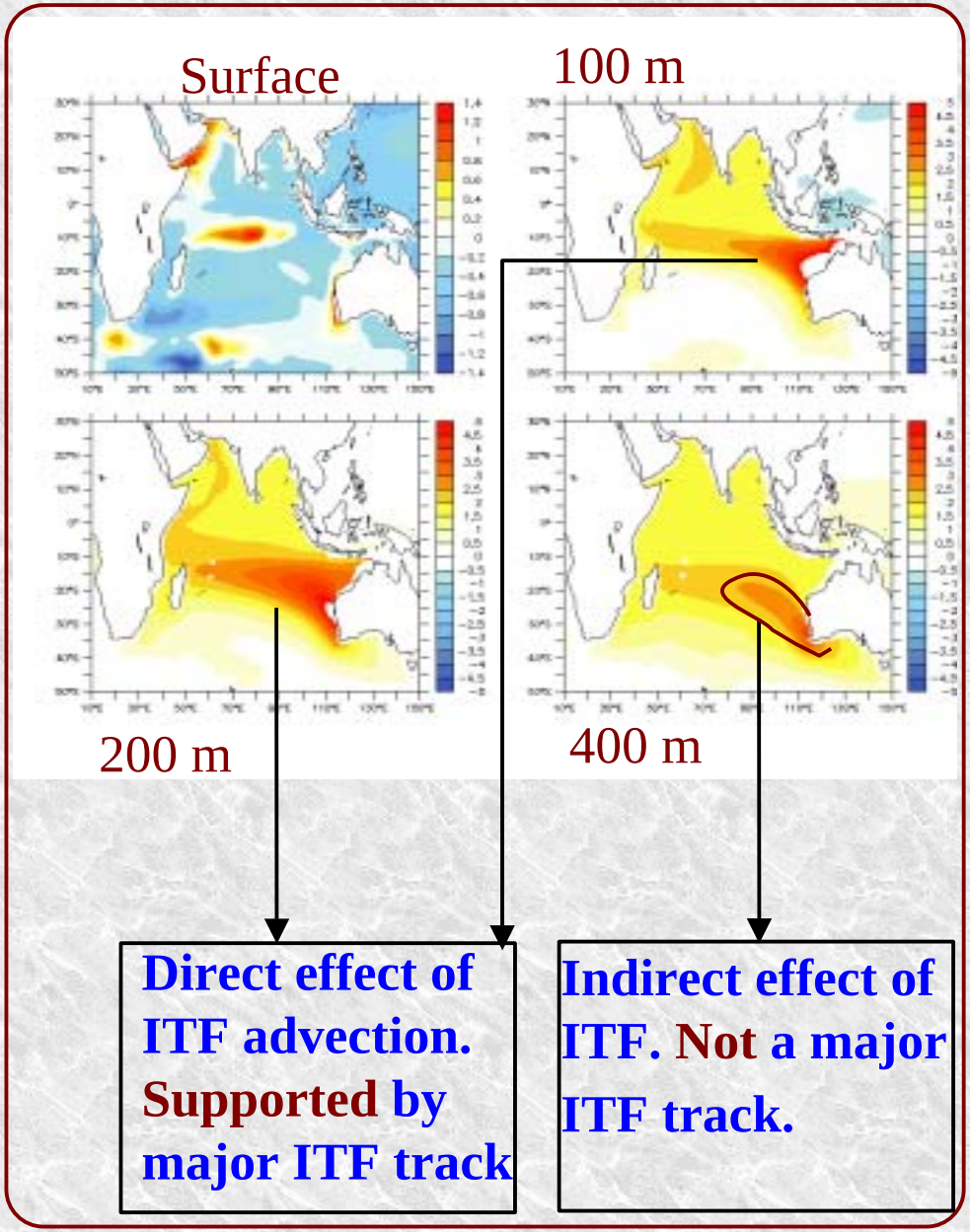
- The region 4 is “indirect effect” of ITF in the SST, where the ITF travels a deeper route and appears in the surface by enhancing the convective overturning and winter time mixing.

Effects of ITF in the Sub-Surface Temperature.

- At 100 and 200 the Indian Ocean warms up due to the direct advection of ITF. It is supported by the track of ITF.

Dynamic depth difference (ITF - noITF) related to 230 m

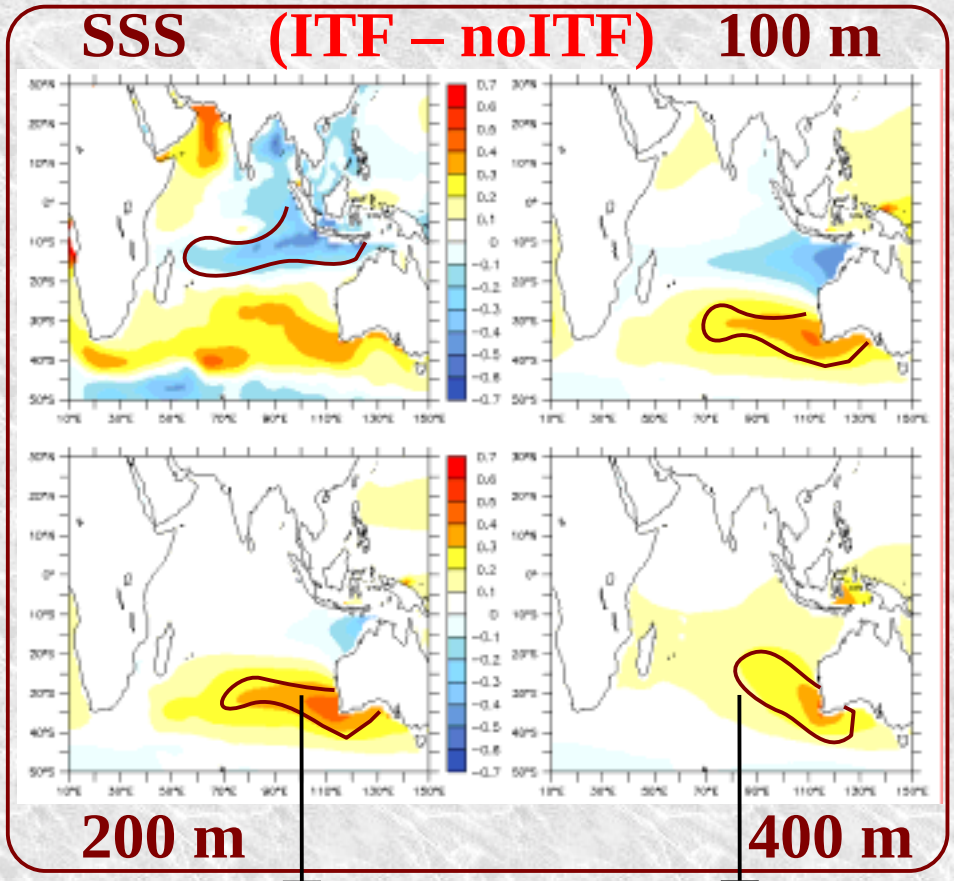




- Surface Salinity prints shows the “fresh” ITF water at the entrance region and the sumatran-upwelling zone.

- In the sub-surface ITF flows as a fresh water jet across the Indian Ocean.

- The Sub-surface saline anomalies are due to the coastal subduction associated with the enhanced on-shore geo-strophic current.



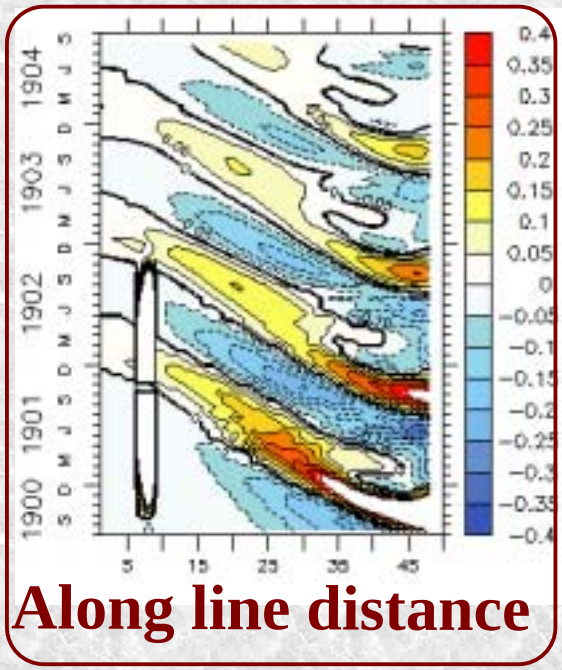
Indirect effect of ITF. Not a major ITF track.

- In the northern Indian Ocean ITF has east (fresh)-west (saline) basin-wide structure above 100m.

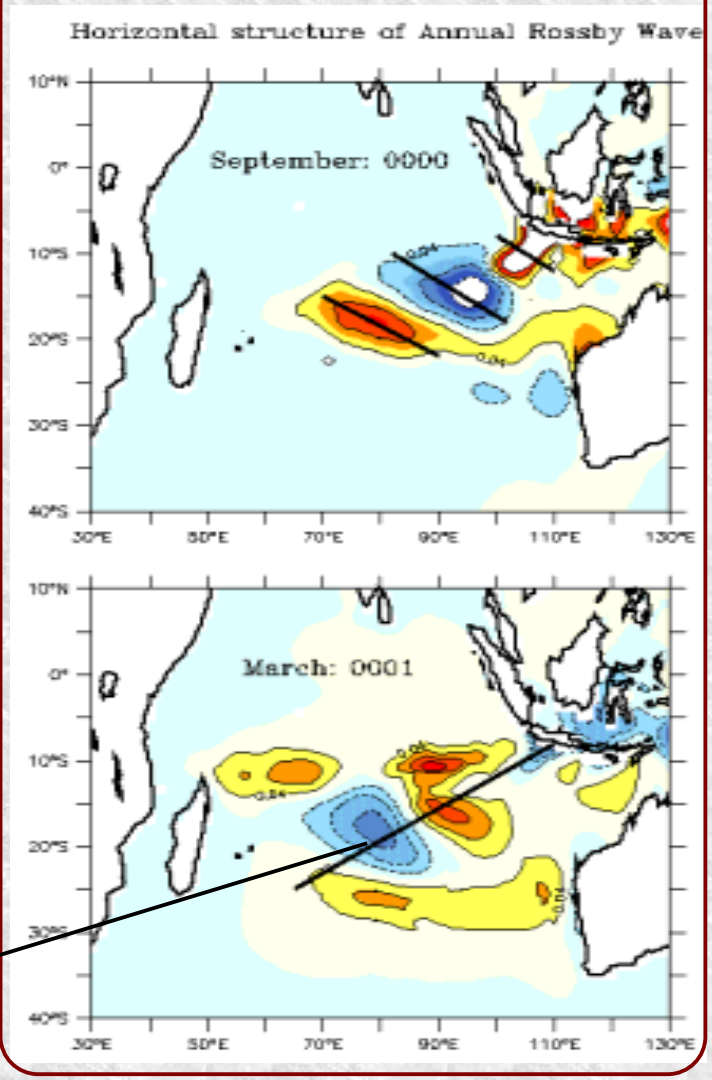
Effects of Planetary Waves in the pathways of ITF in the Indian Ocean

- **Annual Rossby waves triggers from the South Java-Sumatran upwelling region (Periguad and Delecluse, 1992)**

- **The associated currents are significant in spreading the ITF pathways in the Southern Indian Ocean.**

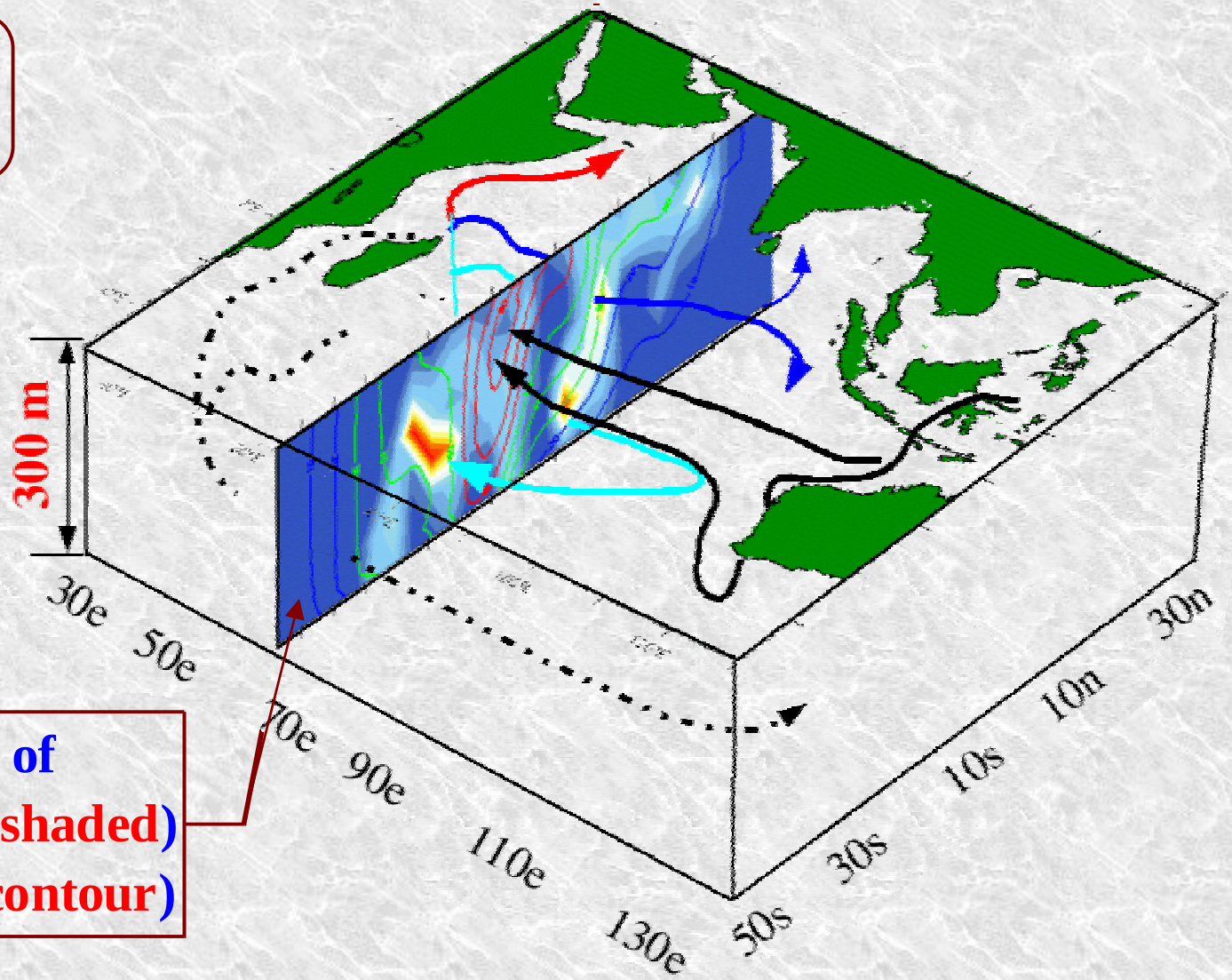


Horizontal structure of Annual Rossby wave revealed from the tracer.



Schematic 3-D view of the ITF revealed from the Trajectory and Tracer pathways.

Route-1 (200 m)
Route-2 (100 m)
Route-3 (50 m)



Meridional Section of
Particle pathways (shaded)
Tracer Pathways (contour)

Summary

1. At the entrance region the surface ITF moves southward along the Australian Coast, subduct and travels across the Indian Ocean while the sub-surface (~100 m) ITF takes a narrow jet like path.

2. Off Somali coast, ITF mostly upwells and takes three distinct routes
   (1) 200-300 m depth along South of the Equator.
   (2) 100-200 m depth along North of the Equator.
   (3) < 100 m into the Arabian Sea and Spreads over Indian Ocean.

3. Tracer distribution is consistent with particles trajectories, but is mixed vertically and spreads horizontally.

4. Foot prints of ITF in the Temperature and Salinity are consistent with its major pathways, otherwise justifiable by indirect effects.

5. Annual Rossby waves visible in the tracer distribution is an implication of spreading the ITF pathways in the STIO.

Thank you!

Acknowledgment

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