

Seasonal effects of Indian Ocean freshwater forcing
in a regional coupled model
-Barrier Layers and Indian Monsoon-

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Outline

- *Background*

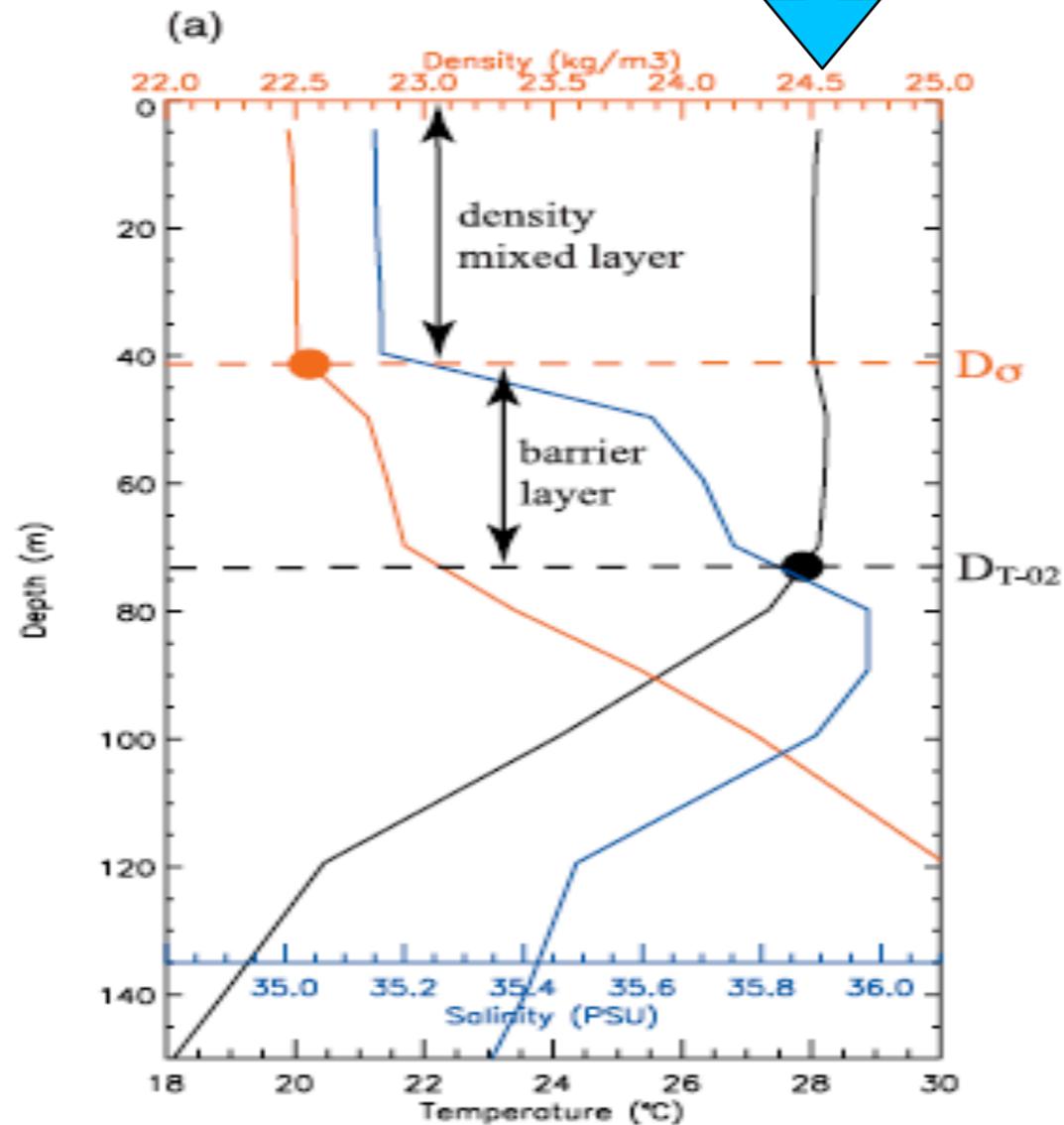
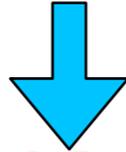
River discharge ➔ Freshwater flux ➔ Barrier layers (BLs) ➔ Heat flux and SST ➔ Air-sea interactions ➔ Monsoon precipitation

- *Tool*

Regional ocean-atmosphere coupled model

Introduction: BLs and temperature inversion

Summer weak heat flux

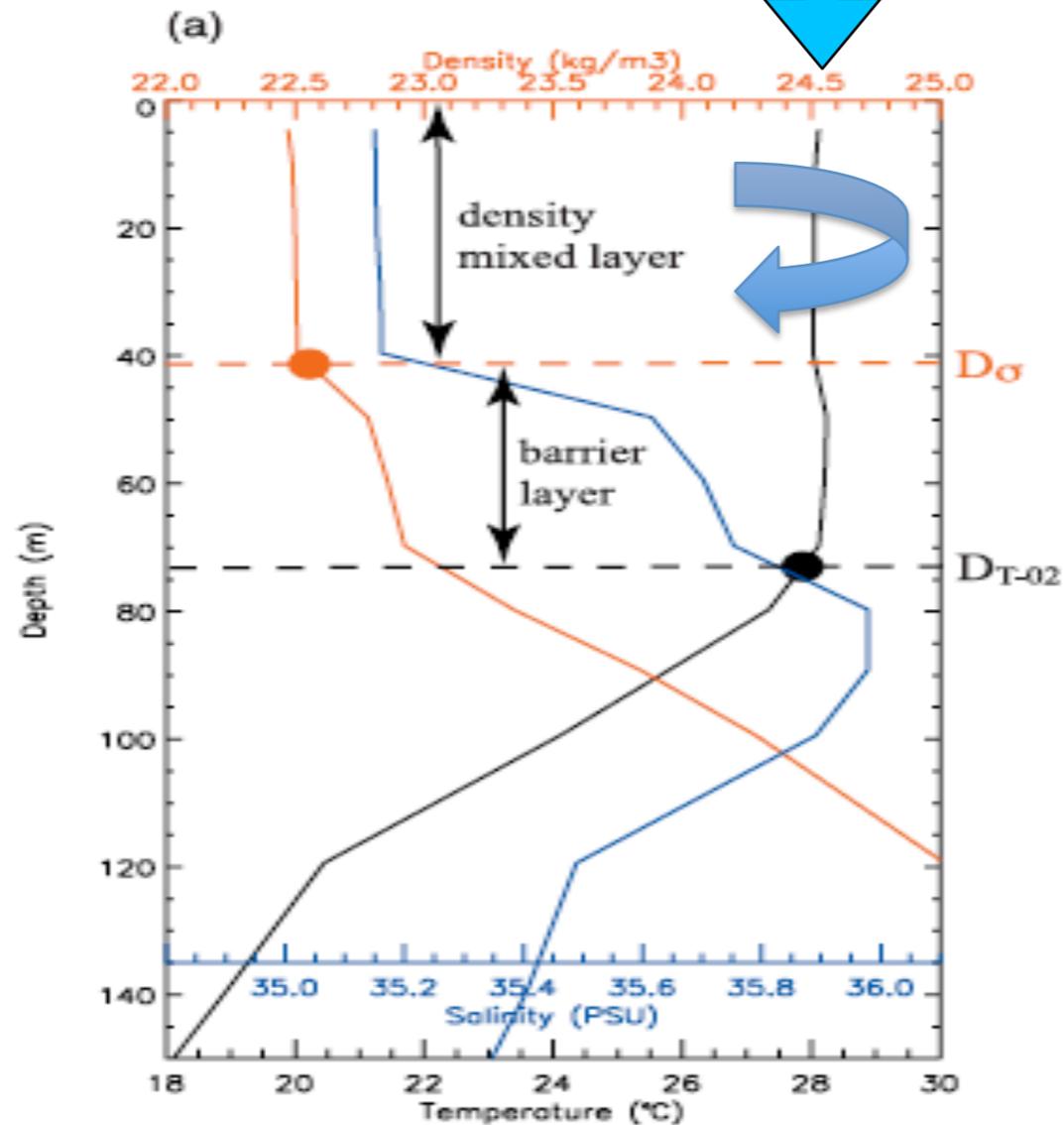
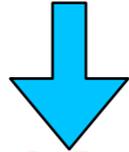


de Boyer Montegut et al. 2007

BLs *decouple* dynamics and thermodynamics of the ocean by acting as a barrier to sub-thermocline water to mixed layer.

Introduction: BLs and temperature inversion

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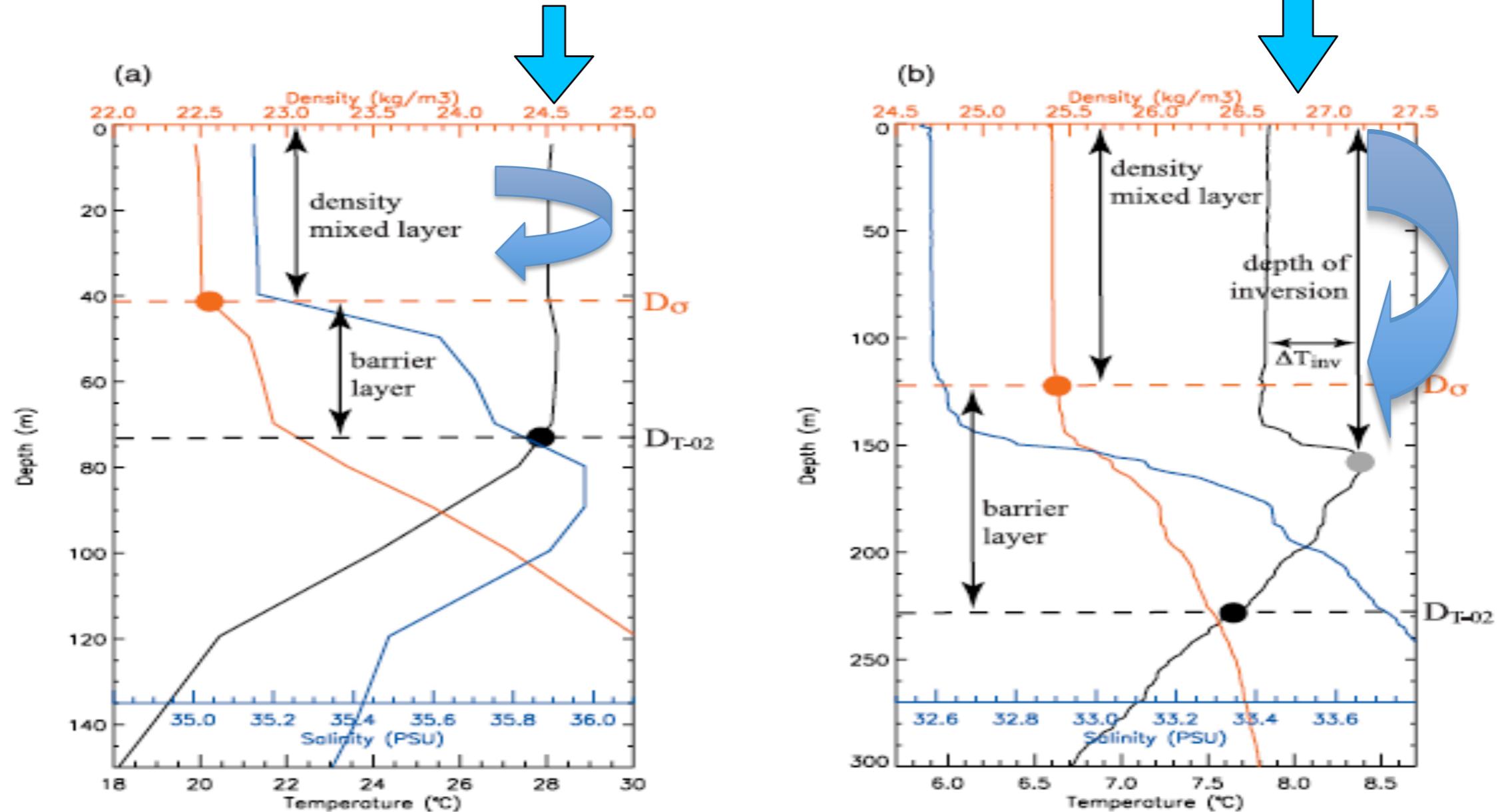
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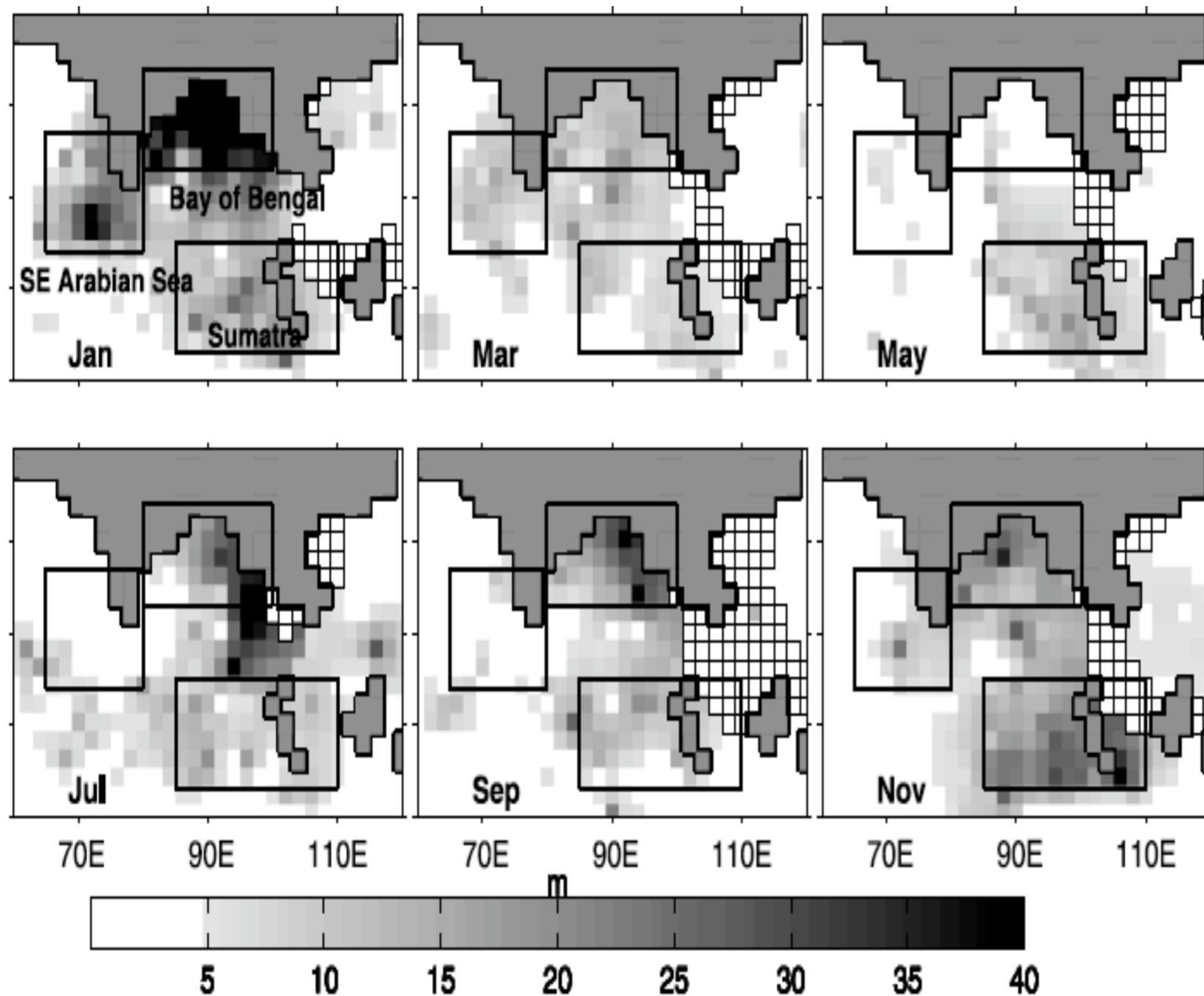
Winter heat flux cooling



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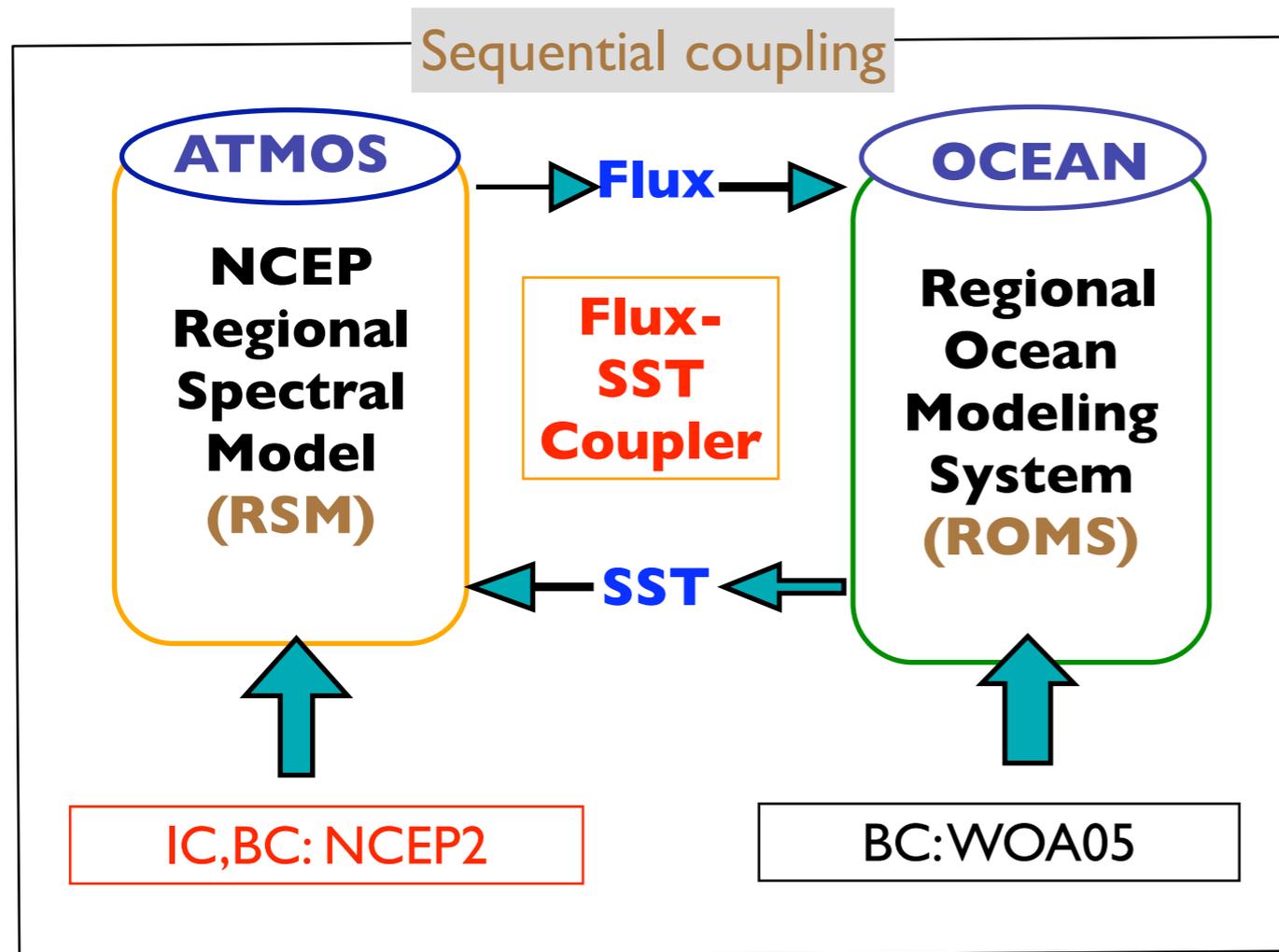
Seasonal cycle of BLT



- Permanent feature persisting throughout the year (>10 months)
- BLs form during summer monsoon due to river discharge and rainfall
- Maximum in boreal winter.
- **Expect more impacts of BLs during the winter time!**

Regional coupled model

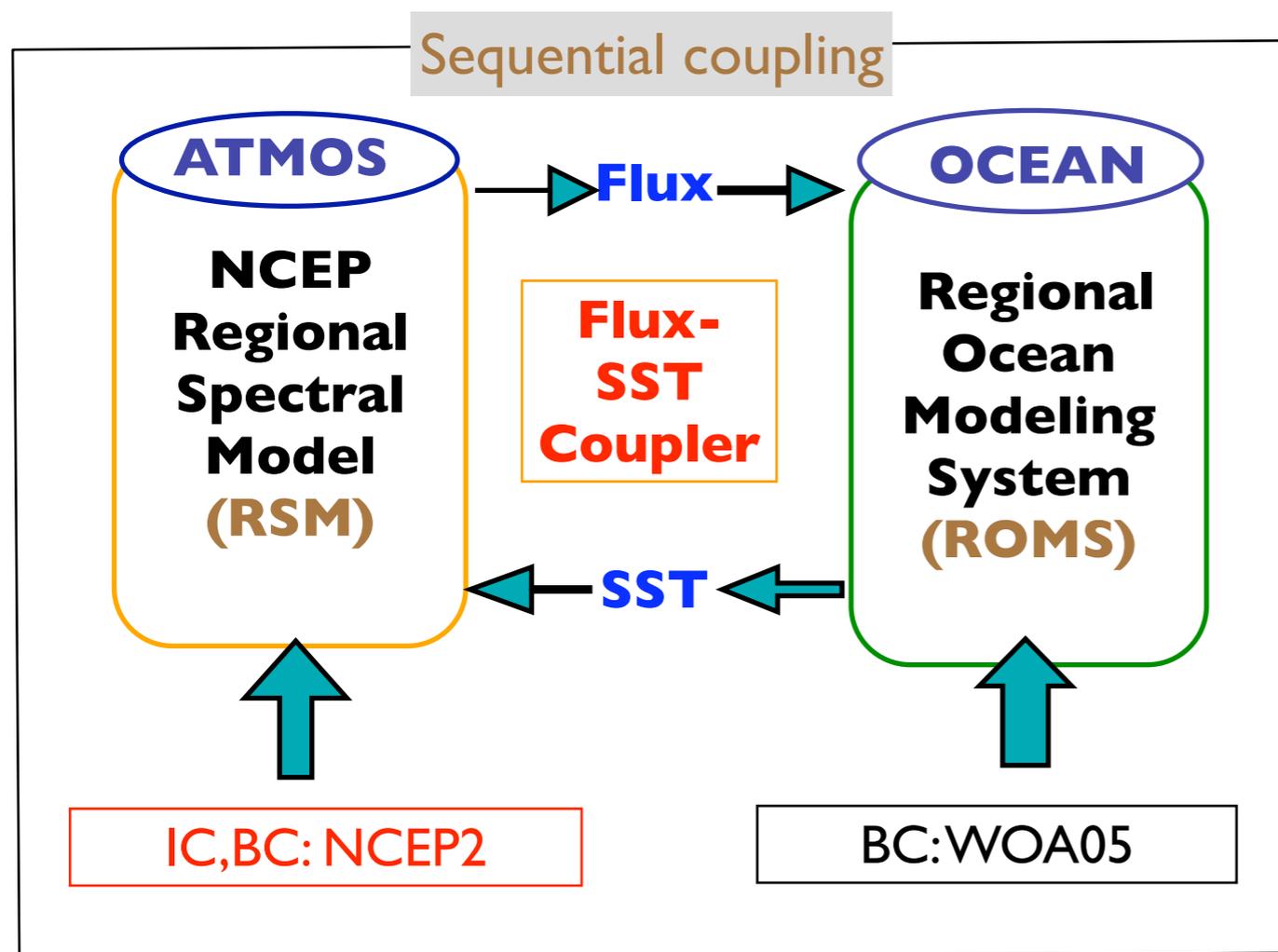
Model and Experiment: Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model



- Higher model resolution in the ocean and atmosphere.
- Dynamical consistency with the NCEP Reanalysis forcing
- More complete and flexible coupling strategy
- Parallel architecture
- State-of-the-art physics implemented in RSM and ROMS
- **Greater portability**

Seo, Miller and Roads, 2007

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EXPs	
SR	SSS is restored to WOA05
NoSR	No SSS restoring

- Resolution: 25 km ocean and atmosphere
- Integration: 1993-2004
- Coupling: Daily

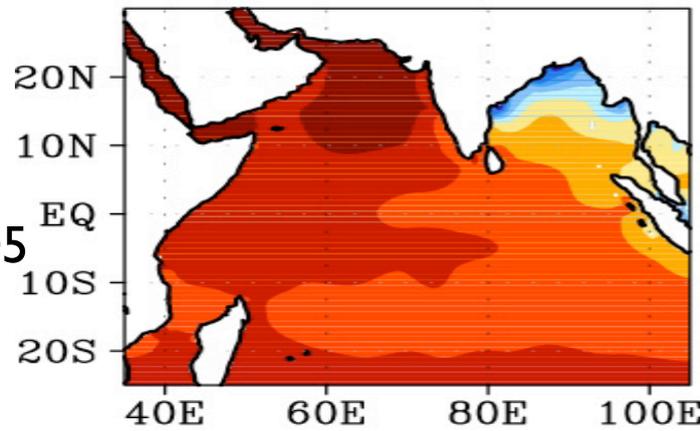
JJA SSS

DJF SSS

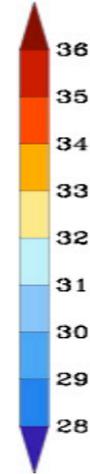
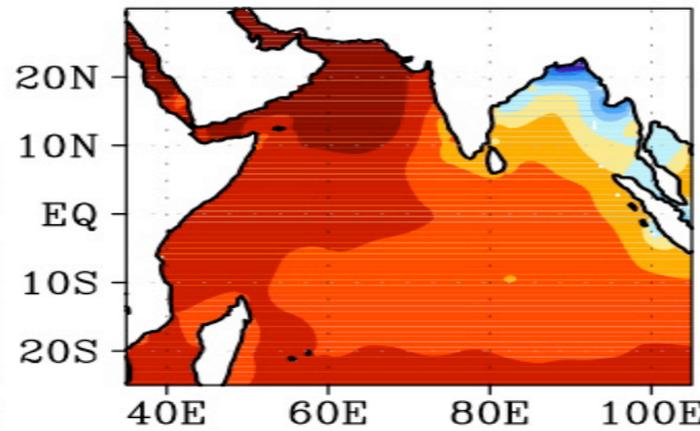
Simulated Salinity Fields

- In WOA05, the freshest water is found in BoB in both seasons.
- Too high salinity in NoSR
- SSS restoring removes error.
- So, we are adding a strong perturbations (>4 psu) in salinity fields.

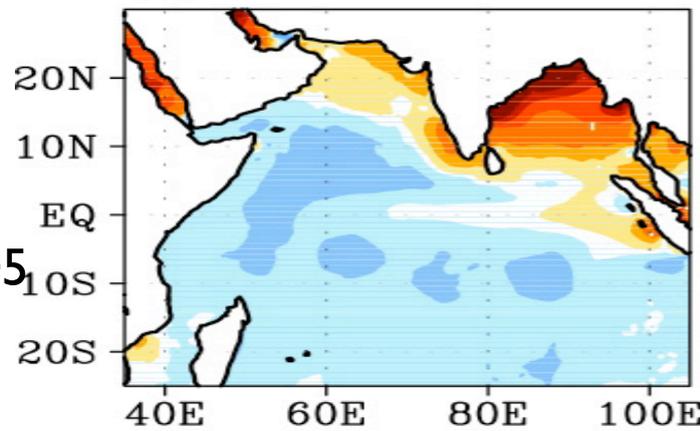
(a) JJA WOA05 SSS



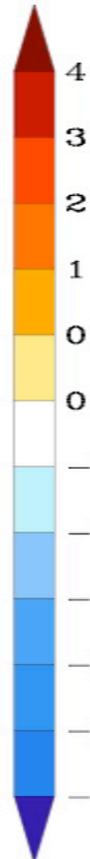
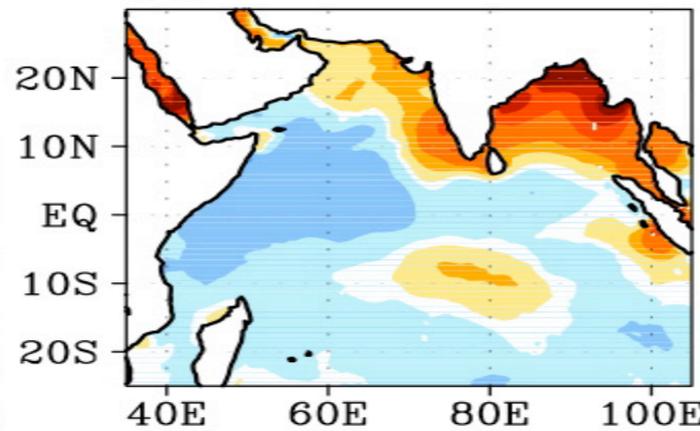
(b) DJF WOA05 SSS



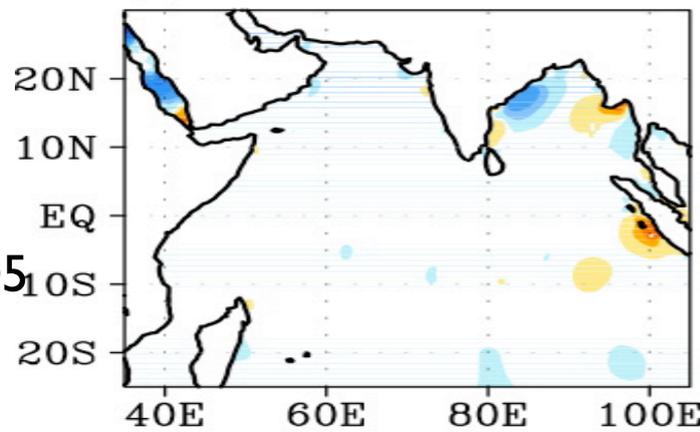
(c) JJA NoSR - WOA05



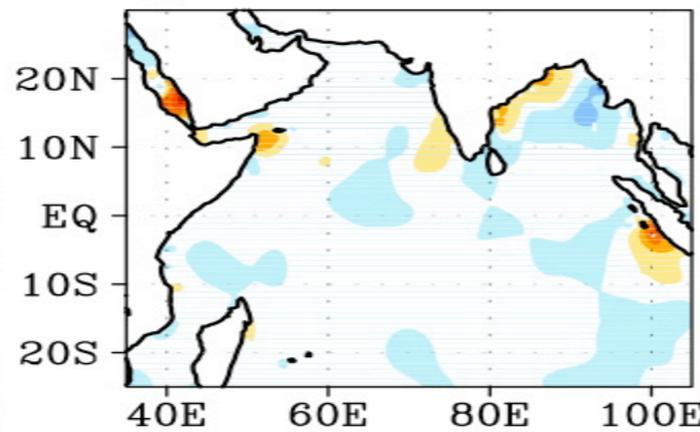
(d) DJF NoSR - WOA05



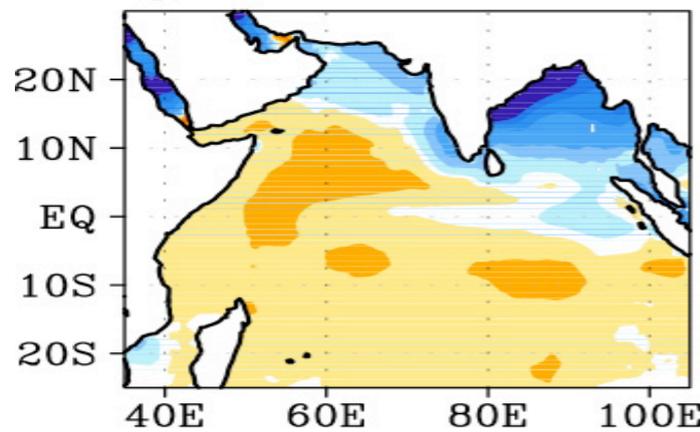
(e) JJA SR - WOA05



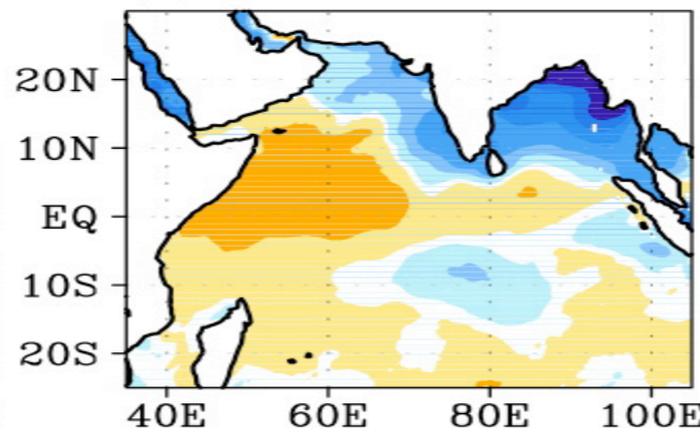
(f) DJF SR - WOA05



(g) JJA SR - NoSR



(h) DJF SR - NoSR



WOA05

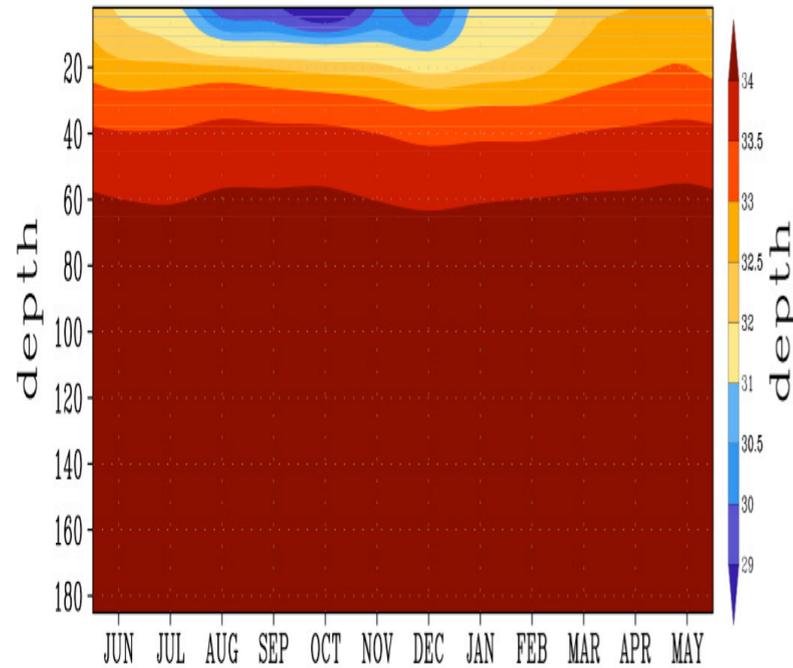
NoSR-
WOA05

SR-
WOA05

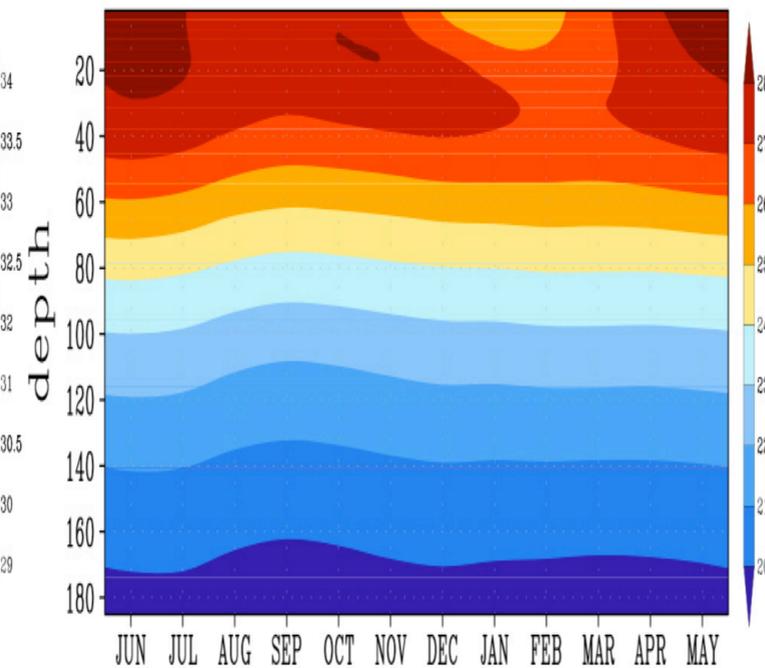
SR-
NoSR

Seasonal cycle of BoB Salinity and Temperature

SALT SR

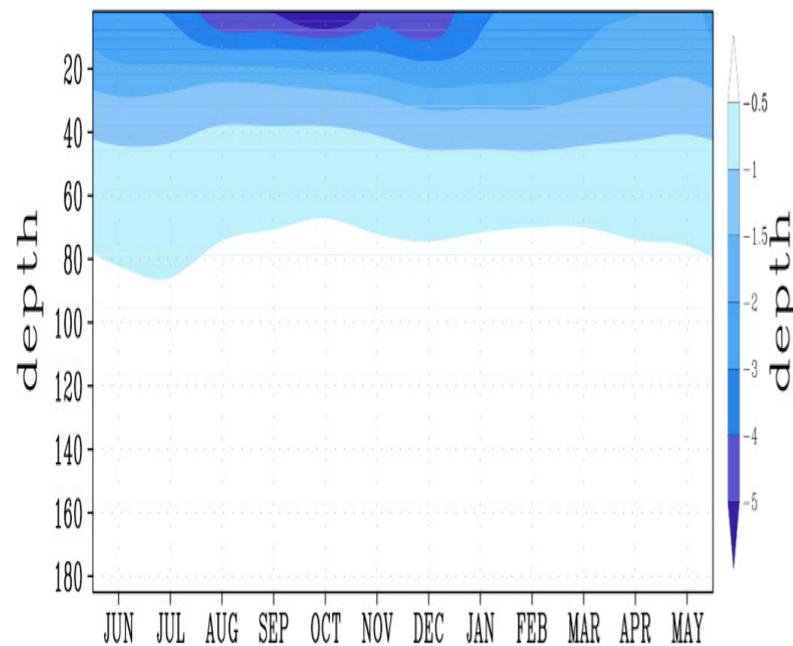


TEMP SR

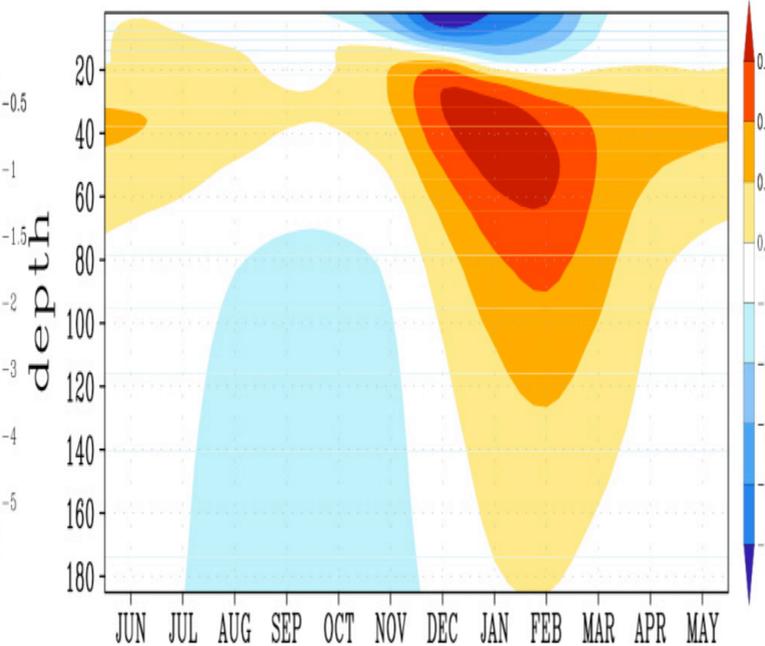


- Largest salinity signal found in July-October.
- Temperature only marginally increases in summer

SALT SR-NoSR

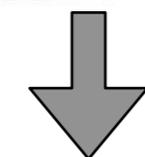
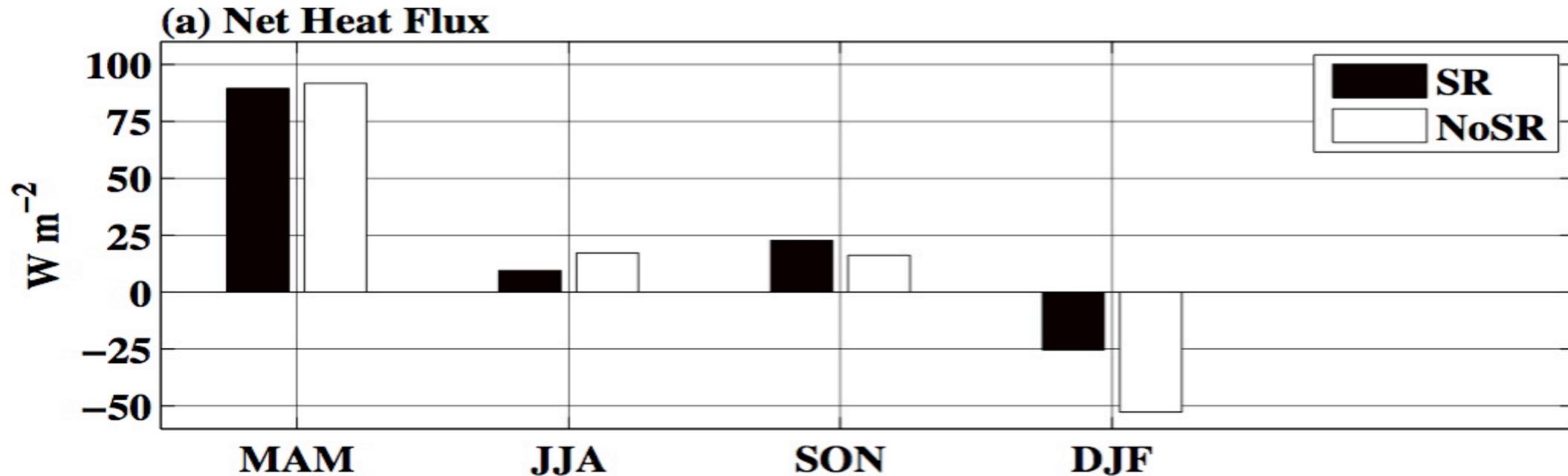


TEMP SR-NoSR

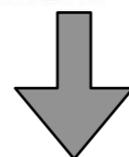


- In winter, surface layer cools but the subsurface warms
➔ temperature inversion

Surface heat fluxes

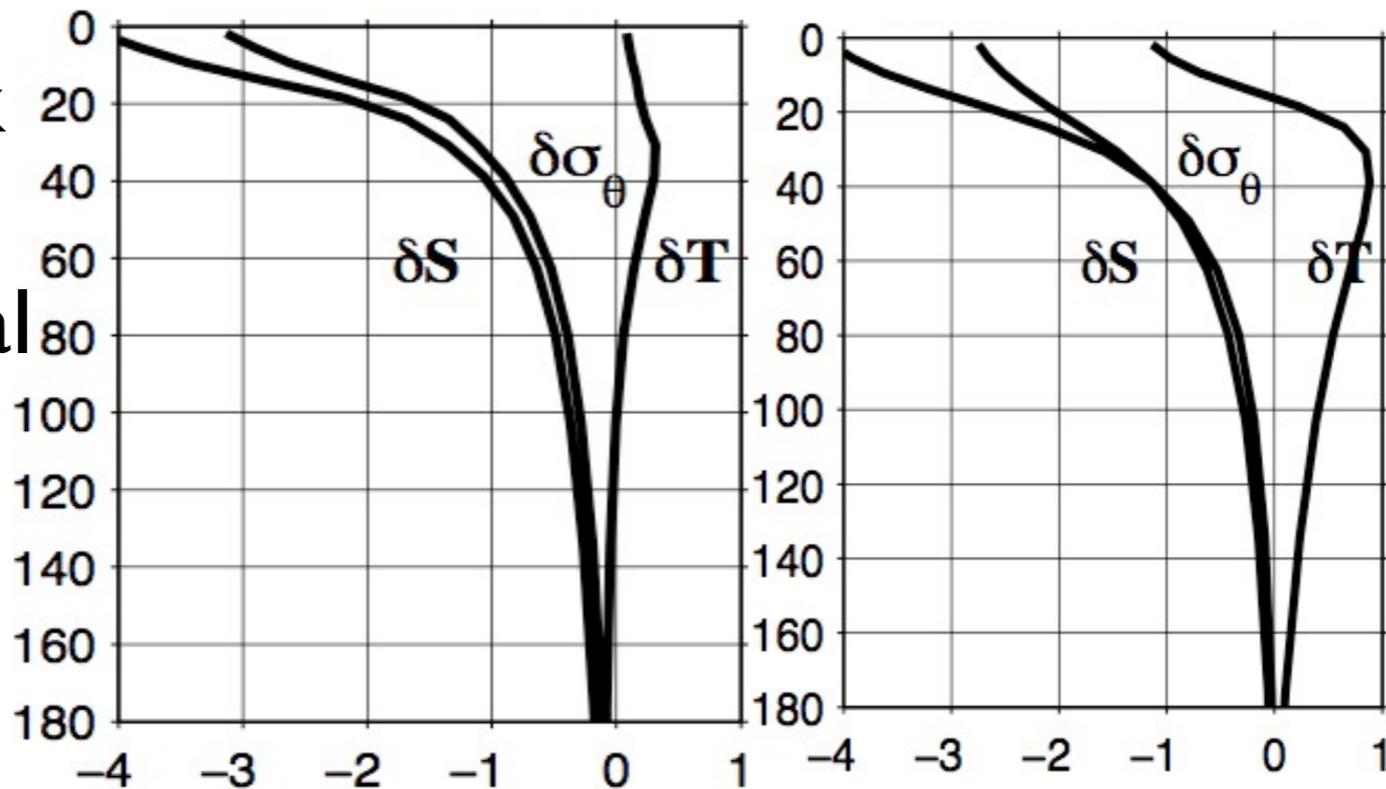


JJA SR-NoSR



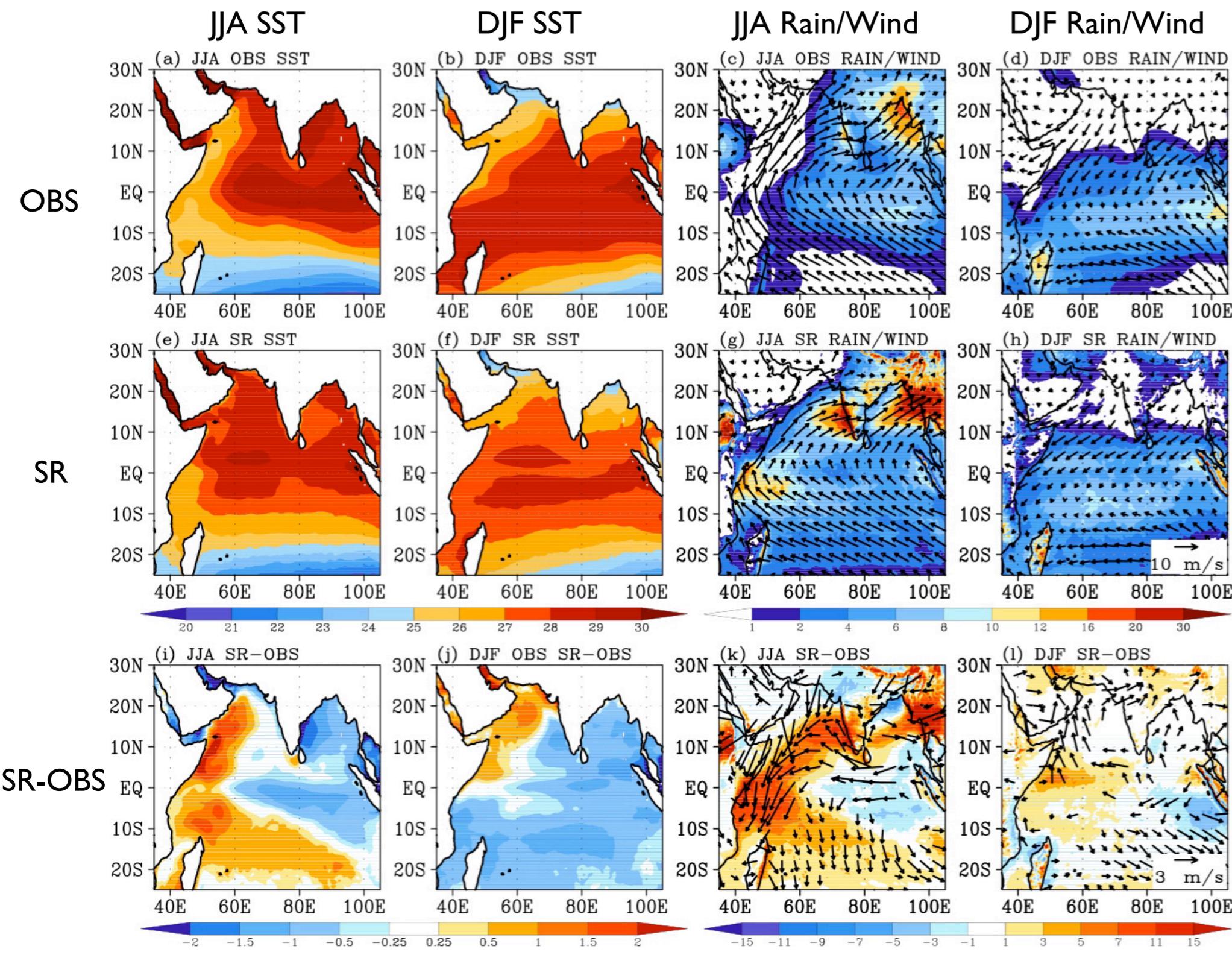
DJF SR-NoSR

Summer: Weak heat flux → near-isothermal structure



Winter: surface heat flux cooling → temperature inversion

Model Validation



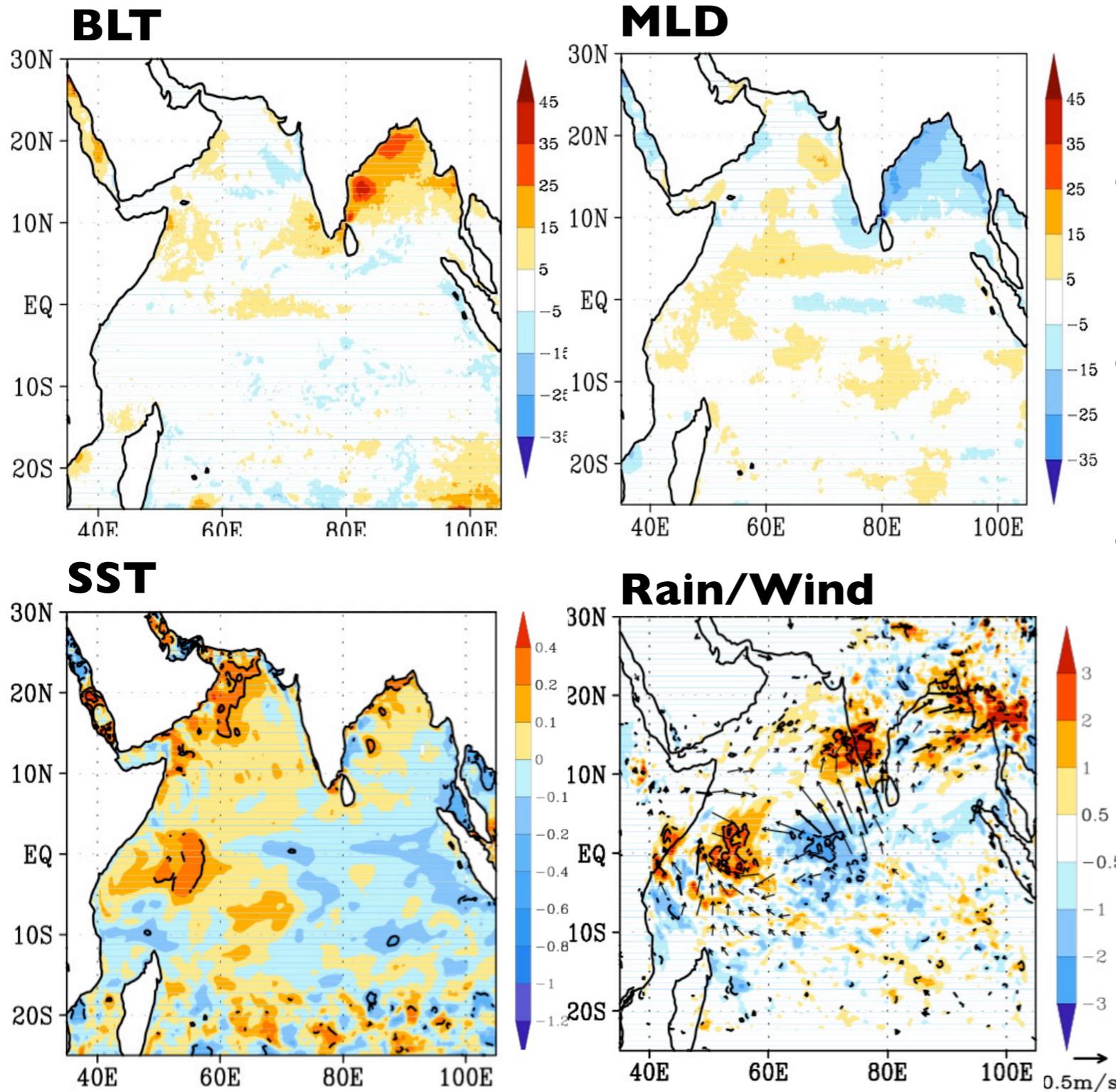
- Summer: Warm east/cold west. Weak upwelling in the Arabian Sea and cold bias in BoB.

- Monsoon rainfall is excessive in the western and northern IO.

- Winter: SST is lower over the whole basin, but the rainfall bias is less than in summer.

Seasonal sensitivity of ocean and atmosphere to freshwater forcing

Summer response: SR-NoSR



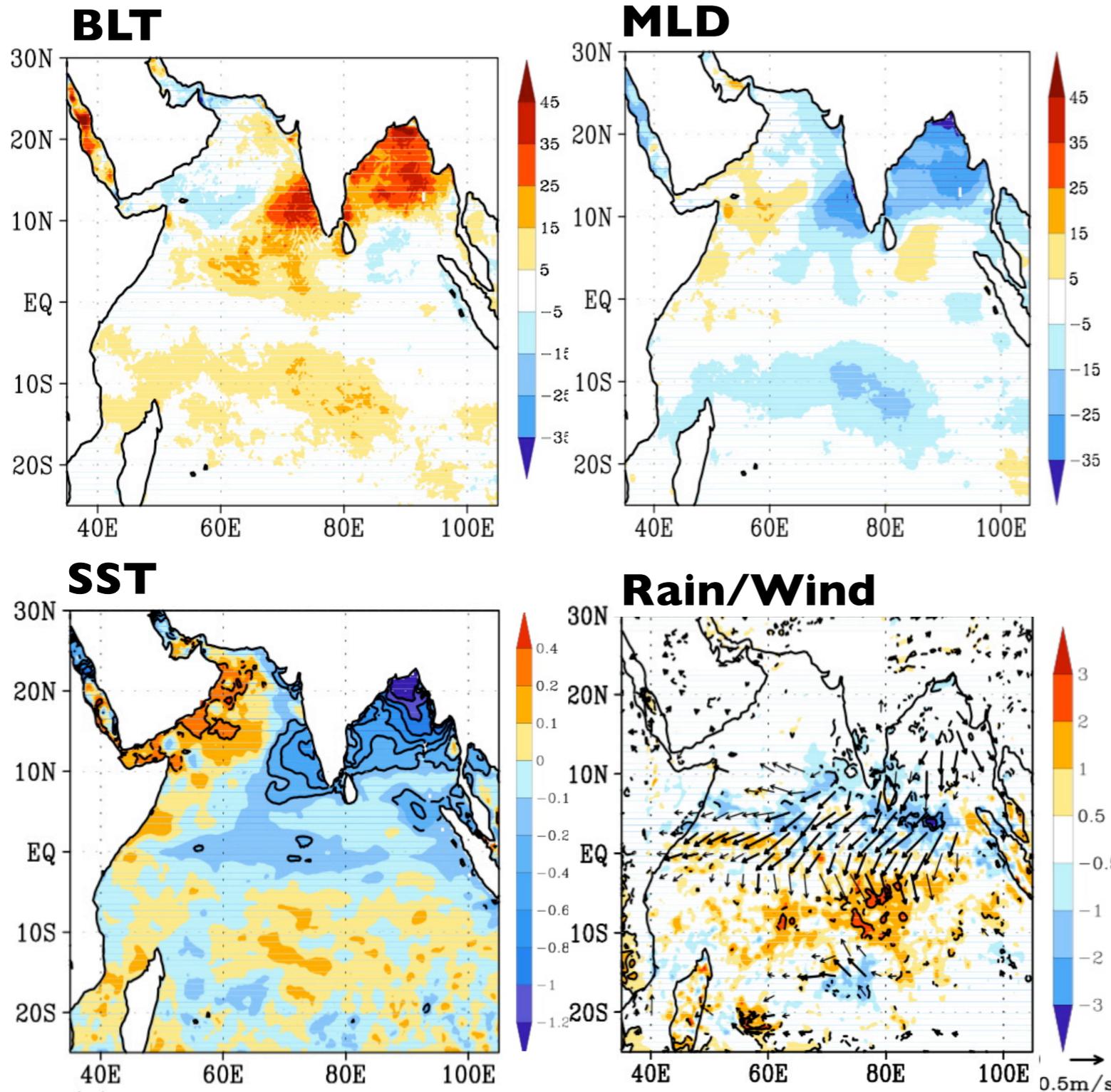
- BLT increases ➔ MLD decreases

- BoB SST increases by 0.1-0.2°C.

- Amplitudes are not large
1) Isothermal structure,
2) Weak heat flux

- Equatorial changes in SSS/
SST cause increases in rainfall
➔ This is not directly related
to river flux forcing

Winter response: SR-NoSR



- BLT thickens substantially ➔ MLD shoals more than 25m (MLD in SR is ~5-25m)

- The entire northern Indian Ocean cools with significant change of SST by 1°C.

1) Max. BL and Min. ML
2) Heat flux cooling

- Divergence atmospheric flows ➔ enhances precip. in the ITCZ.

Conclusion and Future Work

- A fully coupled high-resolution regional climate model is used to find that **it is in the boreal winter that freshwater flux from river discharge is most influential** to the atmosphere
 - 1) Max. BLT and Min. of MLD
 - 2) Wintertime heat flux cooling and the temperature inversion
- **Summer precipitation is not sensitive to river discharge in BoB,**
(*n.b.:* But, it is sensitive to equatorial changes in SSS/SST)
 - 1) Isothermal structure of the ocean
 - 2) Weak total heat flux
- *Future work*
 - 1) Treat the river discharge as a local forcing
 - 2) Better tuning of model parameter to reduce mean model bias
 - 3) Survey of BLs from coupled GCMs to detect robust sensitivity of monsoon

Thanks!