

# Impact of Ocean Observations in the Indian Ocean: Insights from SYNOBS Experiments

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SynObs
UN Ocean Decade Project

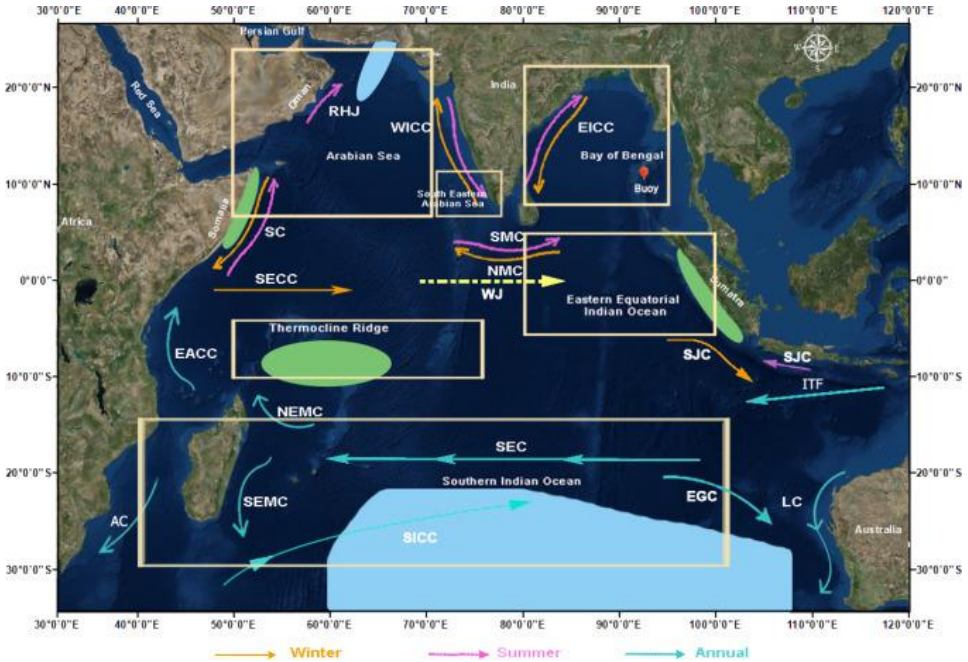
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

GOOS
Ocean Observing Co-Design
with The Global Ocean Observing System

INCOIS
Indian National Centre for Ocean Information Services

# *INDIAN OCEAN*

- Third-largest ocean basin
- Bounded on North (Asia) and West (Africa)
- Monsoon-driven circulation with strong seasonal reversal
- Historically undersampled compared with the Pacific and Atlantic




*Rahaman et al., 2020*

# *OBSERVING SYSTEM EXPERIMENT*

- Quantify the impact of observations on ocean analysis and prediction.
- Add or withhold observations and compare with a control.
- Observation impact depends on the model and assimilation system.
- Multi-system OSEs provide more robust estimates.
- Identify the most impactful observing systems.
- Support future observing-system design.

| | Name | Configuration of OSEs | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | CNTL | Ocean model | | SST | Argo 80% | Mooring | Other TS | Nadir altimeter |
| 2 | NoAlt | Ocean model | | SST | Argo 80% | Mooring | Other TS | |
| 3 | NoArgo | Ocean model | | SST | | Mooring | Other TS | Nadir altimeter |
| 4 | NoMoor | Ocean model | | SST | Argo 80% | | Other TS | Nadir altimeter |
| 5 | NoSST | Ocean model | | | Argo 80% | Mooring | Other TS | Nadir altimeter |
| 6 | NoInsitu | Ocean model | | SST | | | | Nadir altimeter |
| 7 | SSTonly | Ocean model | | SST | | | | |
| 8 | Free | Ocean model | | | | | | |
| 9 | HalfArgo | Ocean model | | SST | Argo 40% | Mooring | Other TS | Nadir altimeter |
| 10 | Oper | Ocean model | Operational setting | SST | Argo 80% | Mooring | Other TS | Nadir altimeter |

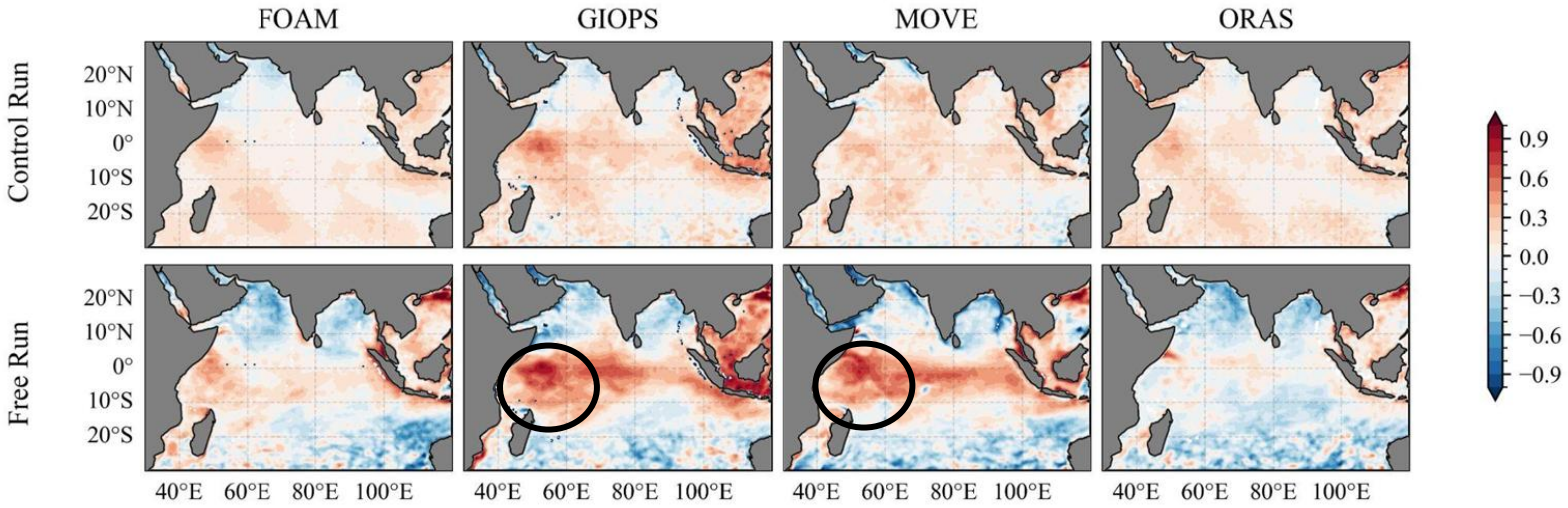
*Fujii et al 2024*

# *DATA*

- Variables : SST, SSS, SSU
- Time: 01-jan- 2020 to 31-Dec-2020
- Domain: Indian Ocean Region
- Reference observation data: OISST, Multi Observation Global Ocean Sea Surface Salinity , GlobCurrent

| SYSTEM/ EXPERIMENT | CNTL | FREE | HALF ARGO | NO ALTIMETER | NO ARGO | NO INSITU | NO MOOR |
|---|---|---|---|---|---|---|---|
| FOAM | Y | Y | Y | Y | Y | N | N |
| GIOPS | Y | Y | Y | Y | Y | Y | Y |
| MOVE | Y | Y | Y | Y | Y | Y | Y |
| ORAS | Y | Y | N | Y | Y | Y | Y |

# *RESULTS: SST*

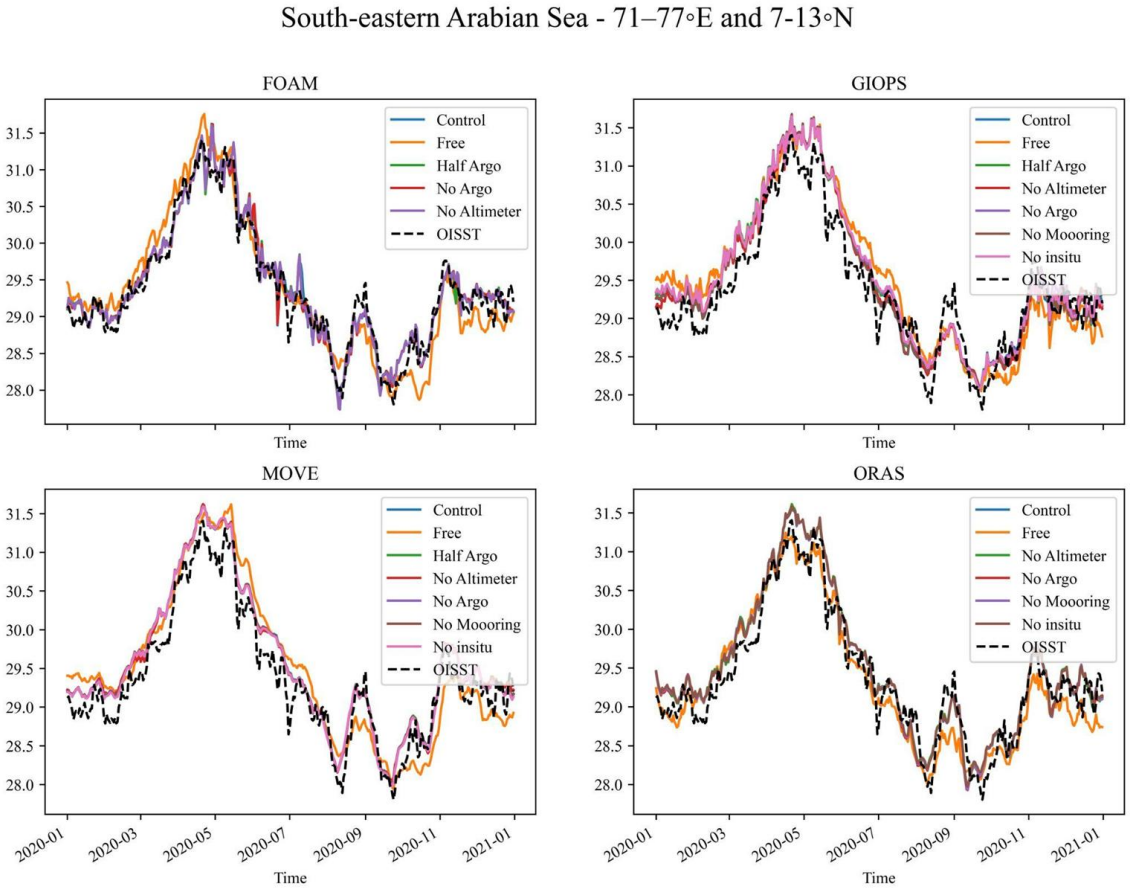



*Bias of SST with OISST (Annual mean 2020)*

- Strong positive bias in the equatorial Indian Ocean with a pronounced bias in the west for Free run

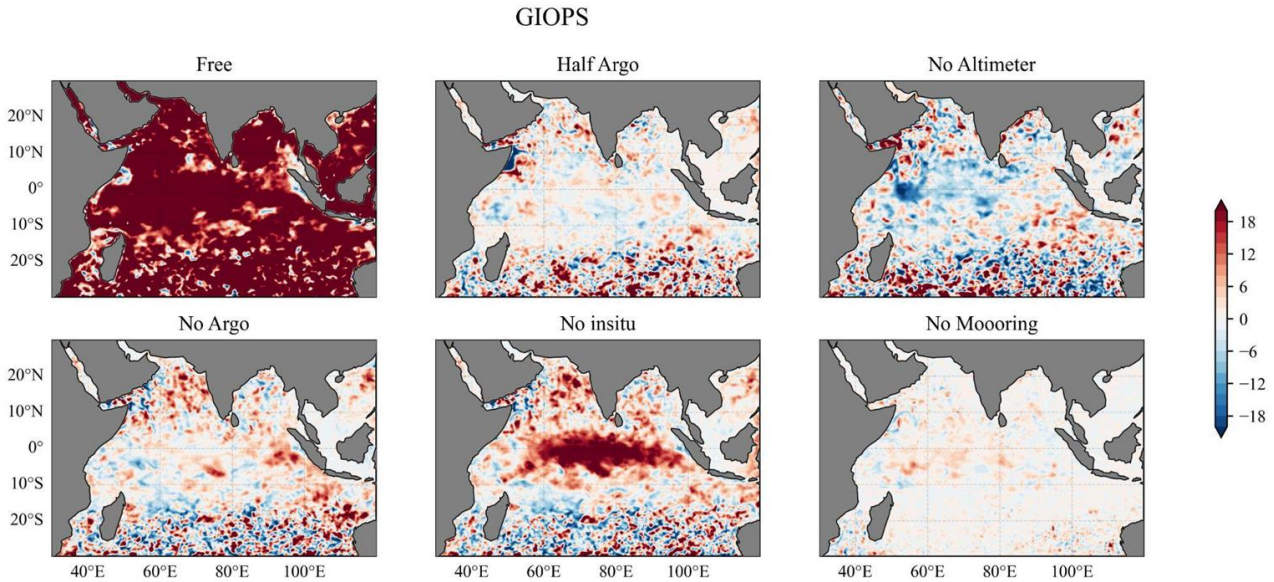
- Basin wide weaker positive (warmer) bias for Control run

# *RESULTS - SST*




- All models capture the **observed seasonal SST cycle** well.
- Assimilation experiments remain **closely clustered around the control**.
- **Free runs show the largest deviations** from OISST.
- Individual observing systems analysed have a **relatively small impact on SST**.

# RESULTS - SST

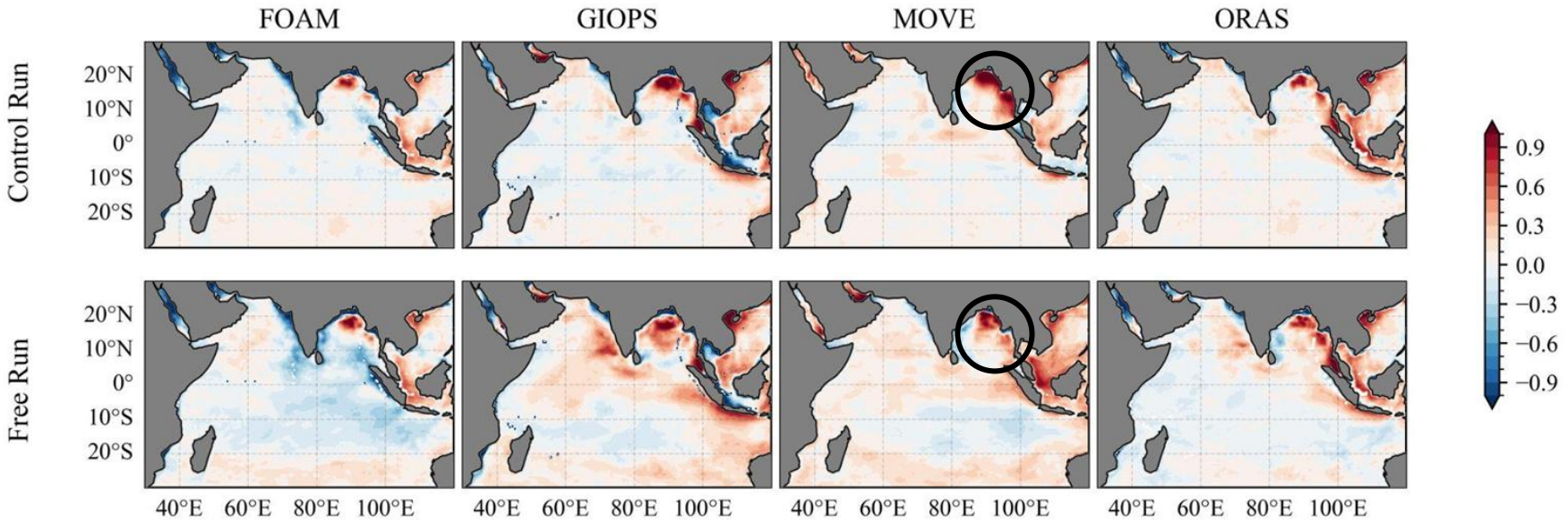



*% change in RMSE with respect to Control*

- **No in-situ** assimilation strongly increases RMSE in the tropical Indian Ocean.
- **Density of Argo** effects is more in EEIO and AS.
- **Mooring** removal has minimal impact, with RMSE remaining close to the control.

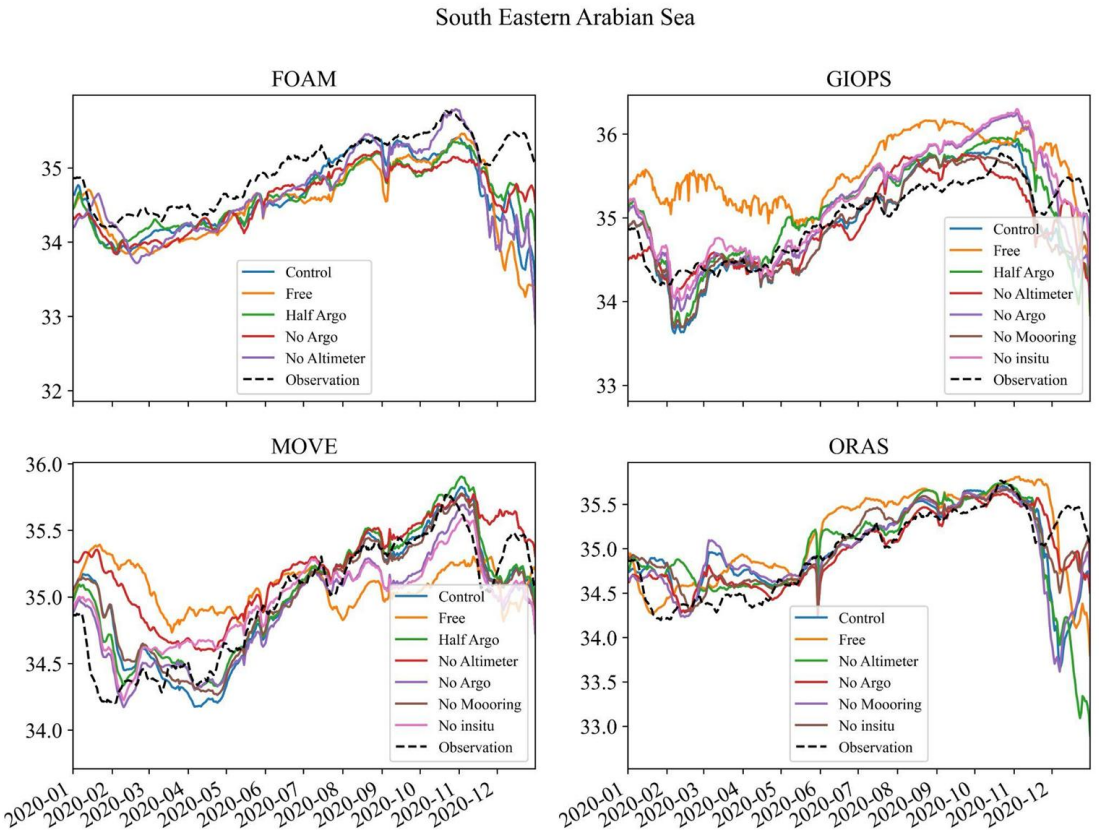
| | | | |
|---|---|---|---|
| **Positive** | Error increased → degradation | **Negative** | Error decreased → improvement |

# *RESULTS: SSS*



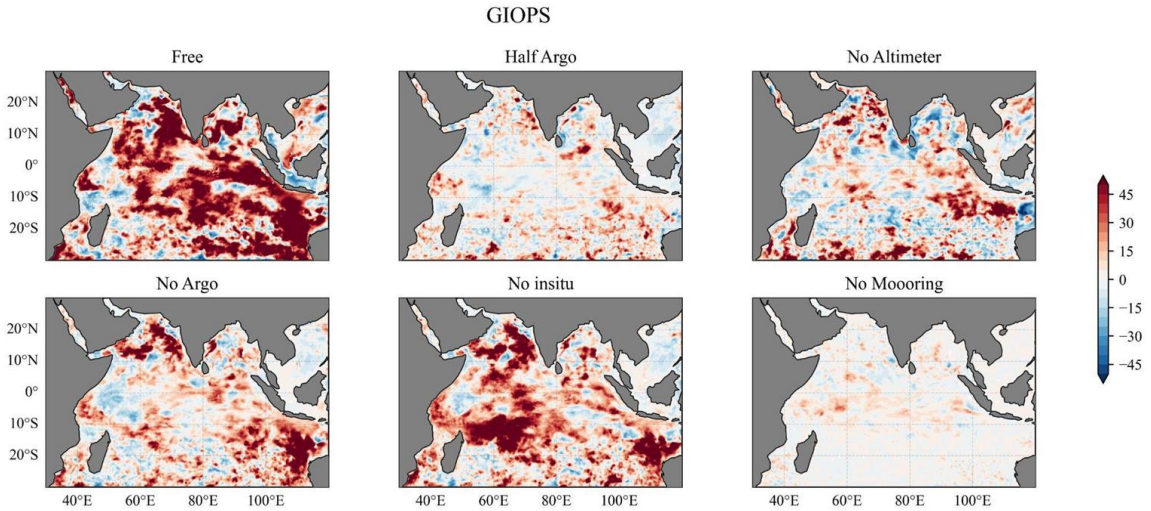

- Largest SSS biases occur in the **Bay of Bengal**
- Free run for FOAM has a fresher bias.
- Salinity bias increases in Control run for MOVE in the north eastern BoB compared to observation.
- Biases in GIOPS decreases more with assimilation

# RESULTS:SSS




- All models capture the **broad seasonal SSS evolution**.
- Assimilation generally **improves agreement with observations**.
- **Free runs show the largest deviations**, particularly in GIOPS and MOVE.
- Differences among observing-system experiments are **generally modest**, with larger divergence toward year-end.

# RESULTS:SSS

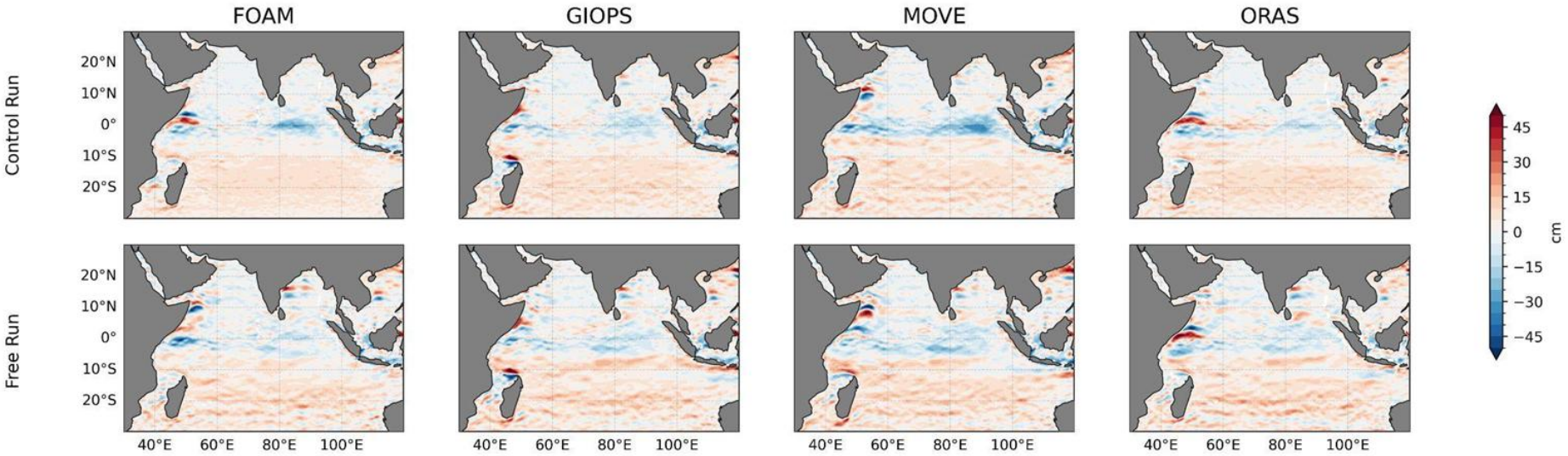



*% change in RMSE with respect to Control*

- **Free run shows the largest normalized SSS RMSE** across most of the Indian Ocean.
- **Argo and altimeter removal substantially increase errors**, especially in the northern and southern Indian Ocean.
- **No in-situ experiment shows strong regional degradation**, particularly south of ~10°S.
- **Mooring removal has the smallest impact**, remaining closest to the control.

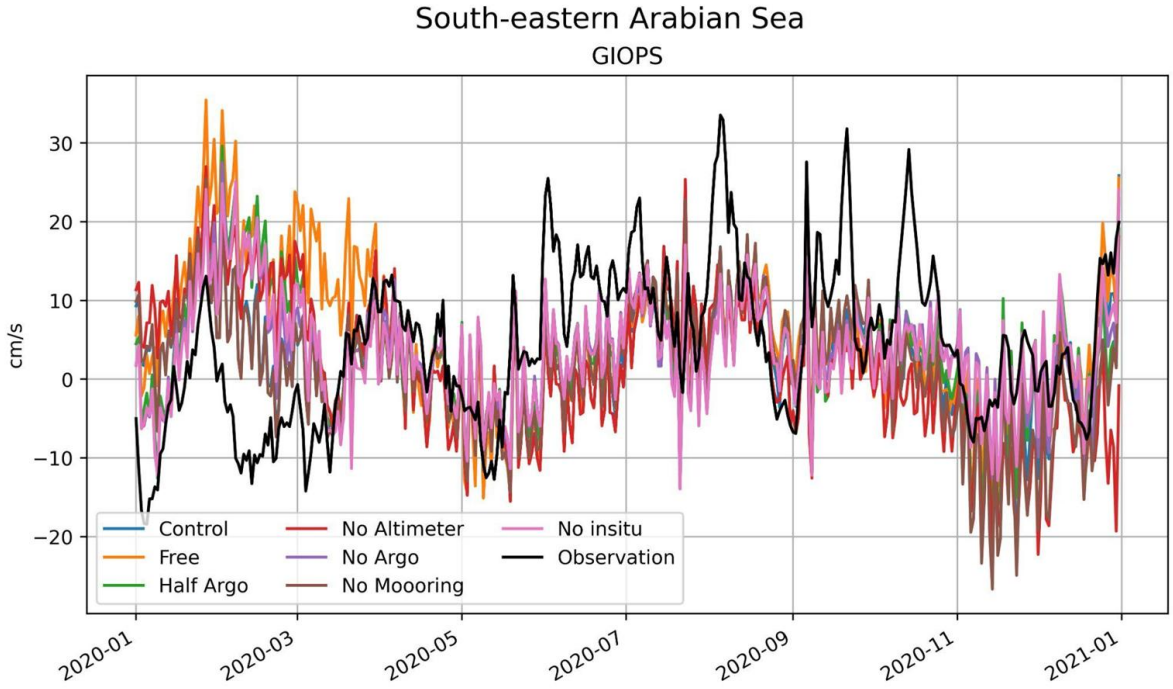
**Positive** Error increased → degradation **Negative** Error decreased → improvement

# RESULTS: SSU



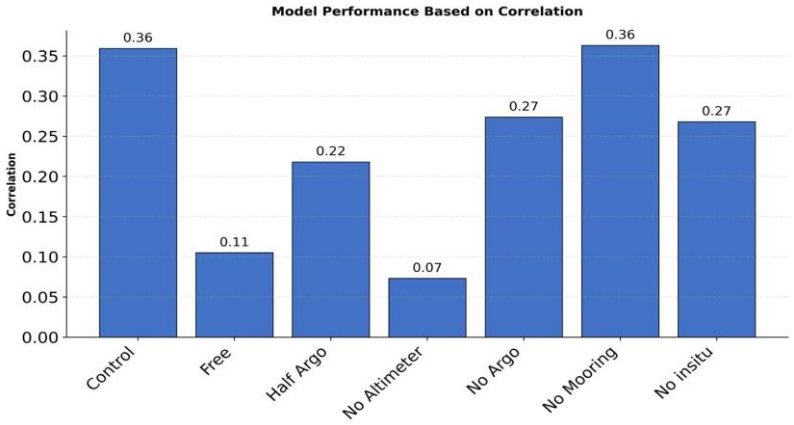

- All four models reproduce similar large-scale current bias patterns.
- Free runs show slightly stronger deviations than the control across the basin.
- Largest differences occur in the western Indian Ocean and equatorial region.
- Assimilation substantially reduces current errors, with relatively modest inter-model differences.

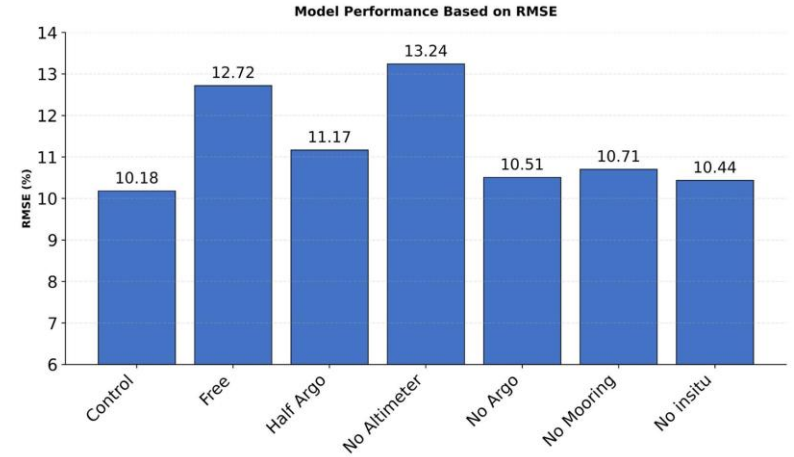
# *RESULTS*




- **Large mismatch with observed current variability** throughout the year.
- Model experiments are **tightly clustered**, despite changes in assimilated observations.
- **Free run differs most strongly** during the early-year period (till March).
- Assimilation has **limited impact on reproducing observed current variability** in this region.

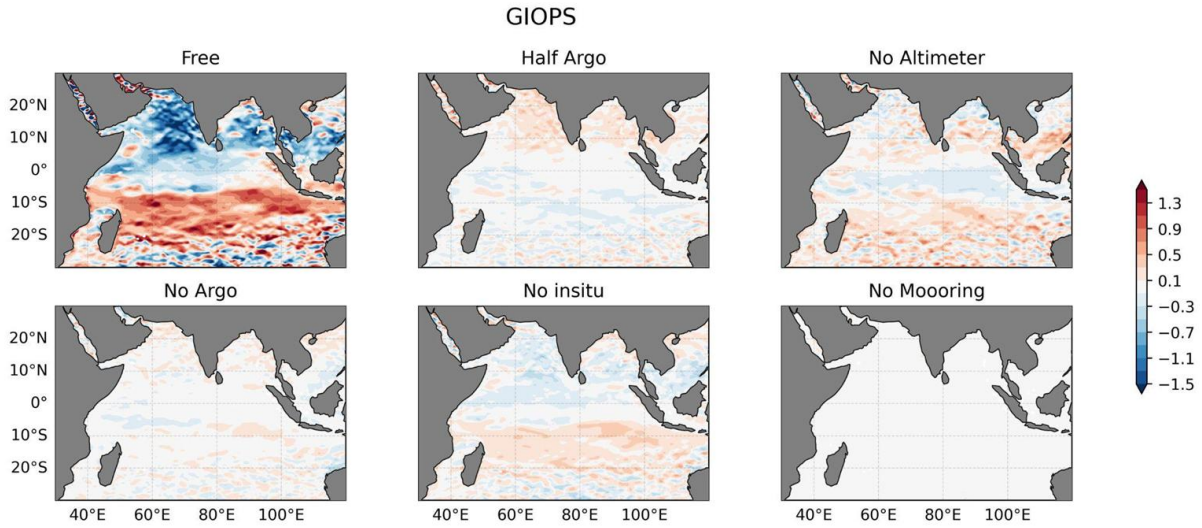
# *RESULTS:SSU*




- **Control and No Mooring show the highest correlations** (r = 0.36).
- **Control has the lowest RMSE** (10.18), indicating the best overall performance.
- **No Altimeter performs poorest**, with the highest RMSE (13.24) and lowest correlation (0.07).
- **No Argo and No in-situ show relatively low RMSE**, but weaker correlations than Control.

# RESULTS




*% change in RMSE with respect to Control*

- Free run shows the largest RMSE changes, with strong spatial contrasts across the basin.
- Half Argo, No Argo, and No Altimeter show relatively modest impacts compared with the control.
- No in-situ produces a noticeable RMSE increase south of ~10°S.
- No Mooring has a negligible impact, with RMSE almost identical to the control.

**Positive** Error increased → degradation

**Negative** Error decreased → improvement

# *SUMMARY*

- For SST analysis, mooring has least impact
- The density of argo affects moderately (with SST assimilation)

- SSS is highly impacted by assimilation system.
- In-situ data has the highest impact with mooring having least impact
- Density of Argo has a prominent effect

- SSU is least affected by assimilation
- Assimilation of all data has a contrasting effect in the north and south of Indian Ocean basin compared to free run
- Impact of mooring is negligible

# Thank you!