SynObs & Ocean Observing Co-Design,
Joint International Workshop

Aug. 2026, Mutsu, Japan

Quantifying the Contribution of RAMA Observations to Seasonal Predictions of Tropical SSTA

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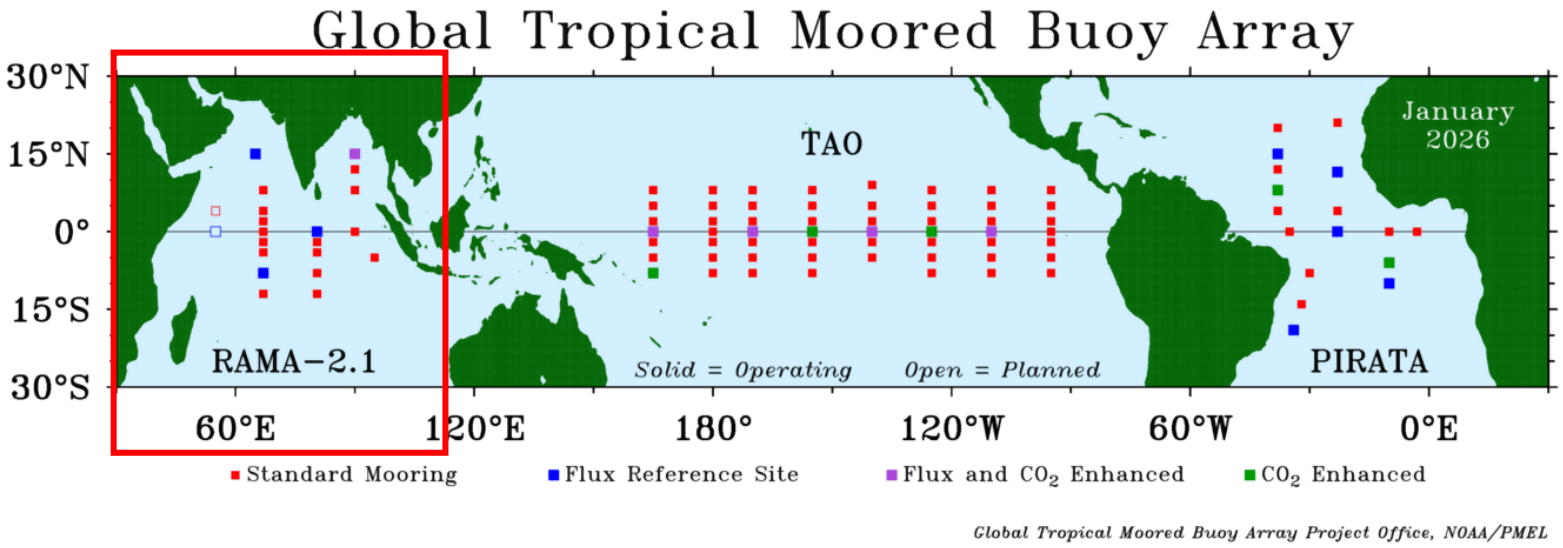
Aug. 26, 2026

Motivation

Overview of RAMA Observing Network

- **Core component of global ocean observation system**

  RAMA primarily provides high-frequency measurements of ocean and surface atmospheric conditions in the Indian Ocean region where data is historically scarce.

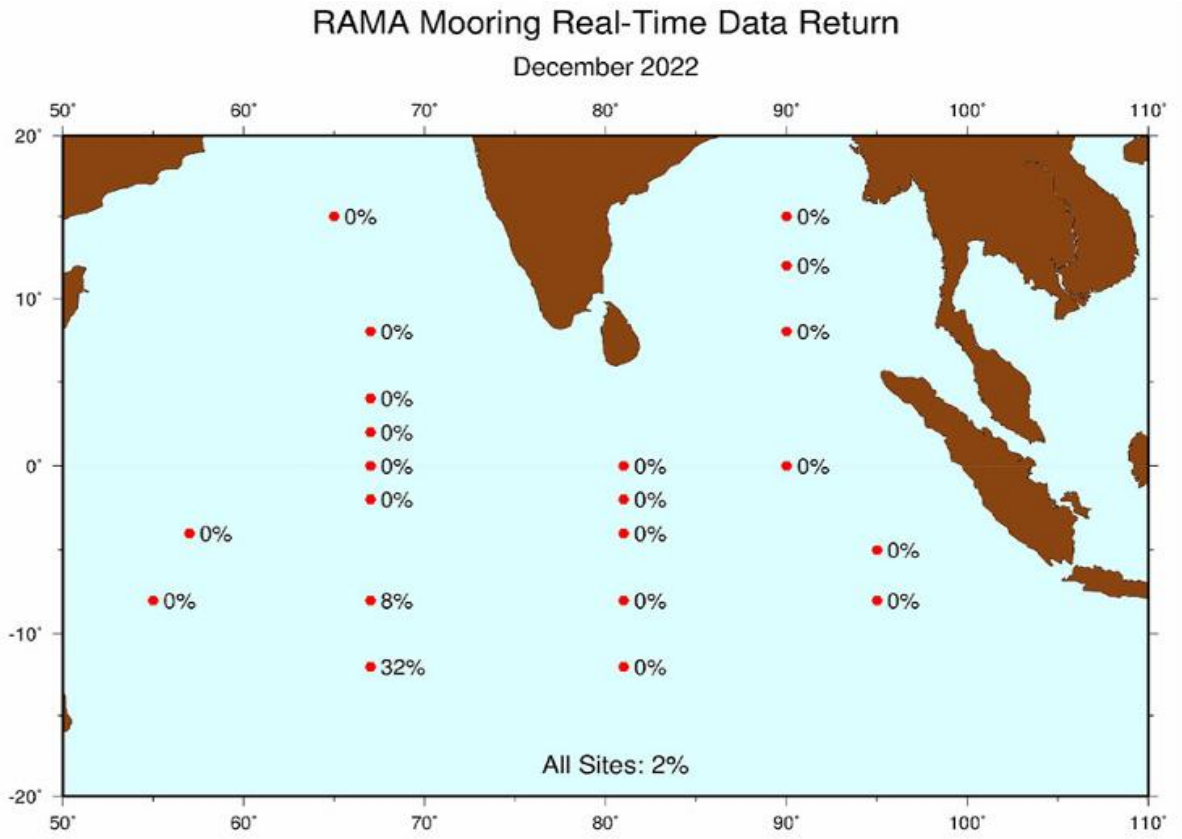


Motivation

Overview of RAMA Observing Network

- **Post-pandemic O&M Challenges**

We must **prioritize** the restoration of **the most critical observation sites**, which necessitates a **quantitative assessment** of each site's contribution



Sprintall et al., 2024

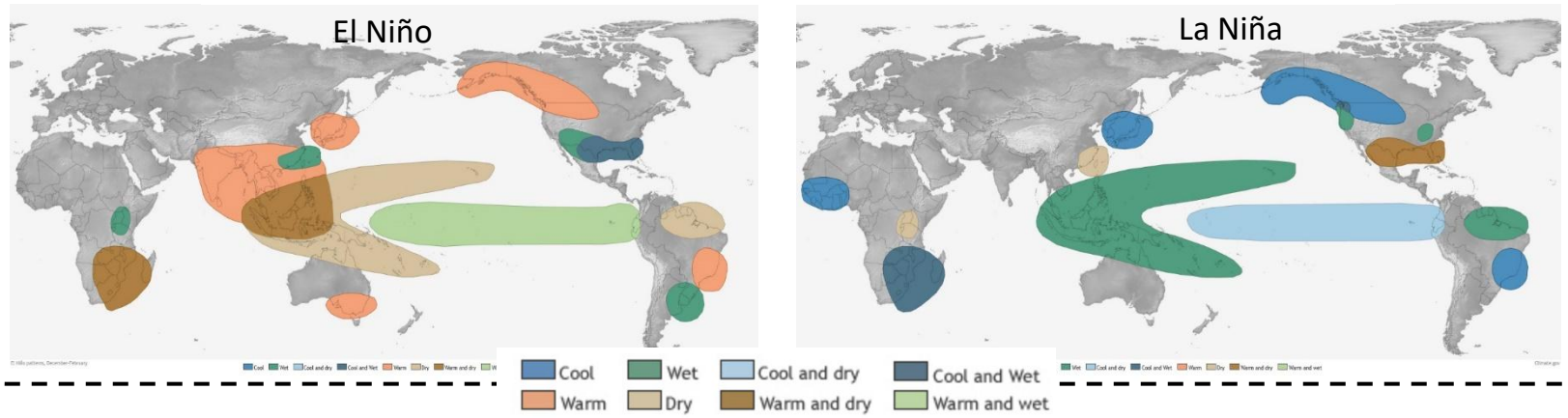
Motivation

Target: TSST prediction

- **Key driver of global climate dynamics**

  Tropical Sea Surface Temperature (TSST) anomalies drive interannual variations in ocean-atmosphere circulation, triggering global extreme climate events. For example:

El Niño and La Niña have extensive impacts on **global precipitation**



Accurate TSST seasonal prediction is crucial for reducing risks from extreme events, and enhancing socio-economic resilience.

Objectives

Targeted (adaptive) observation: seeking the optimal observing sites/areas that can decrease the initial uncertainties mostly and thus improve predictions.

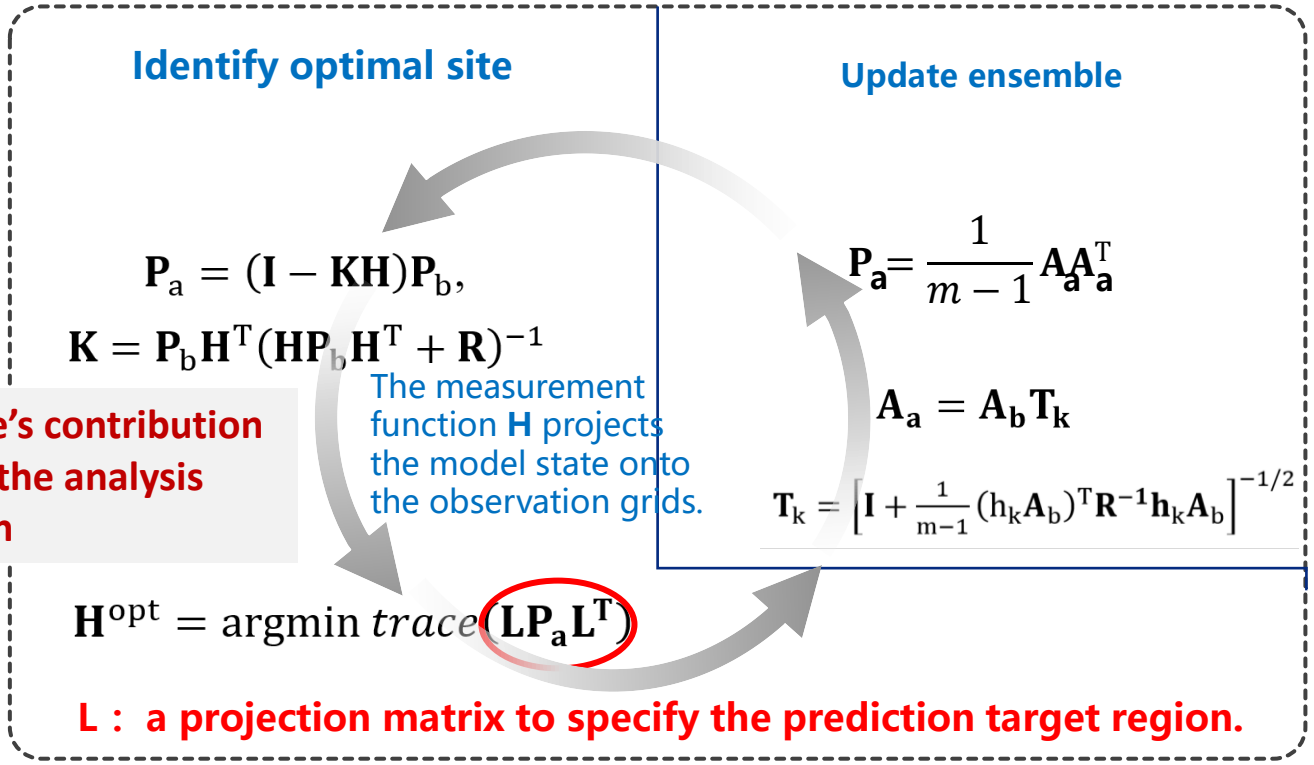
- **Quantify** RAMA's contribution to TSST analysis in the Indian Ocean, and also extend our assessment to the Pacific and Atlantic given growing interest in inter-basin interactions.
- **Identify** optimal observing network for restoration under limited resources.
- use OSSEs in a coupled climate model to **validate** the benefits of our optimal array.

Method

Targeted observation method based on sequential data assimilation

Core idea: optimize the observational operator H to minimize the analysis error covariance after one assimilation

flow path



Assess one site's contribution by calculating the analysis error reduction

This targeted observational method for **grid-by-grid** format is particularly suitable for the design of **moored buoy ocean observing networks**

Li et al. 2023

Method

monthly ocean temperature data from the **EN4** analyses;

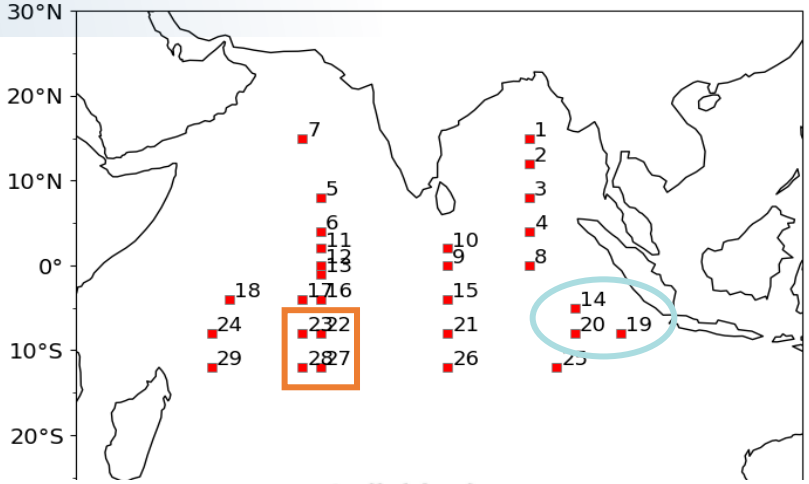
1°×1°; 2000-2023 Initial $\mathbf{P}_b$

Target region: tropical regions of the **Indian Ocean** (30°S–30°N, 40°E–110°E), the **Pacific Ocean** (30°S–30°N, 130°E–80°W), and the **Atlantic Ocean** (30°S–30°N, 60°W–10°E).

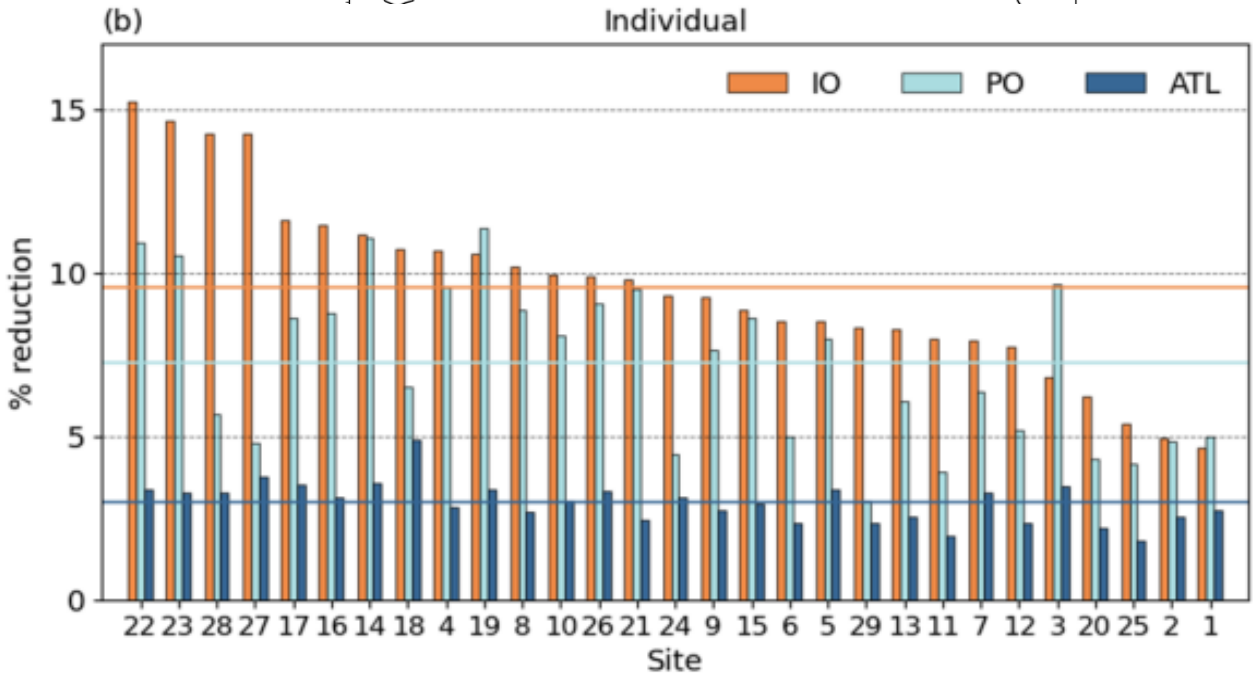
Temperature observing depths: 5m, 100m, and 150m

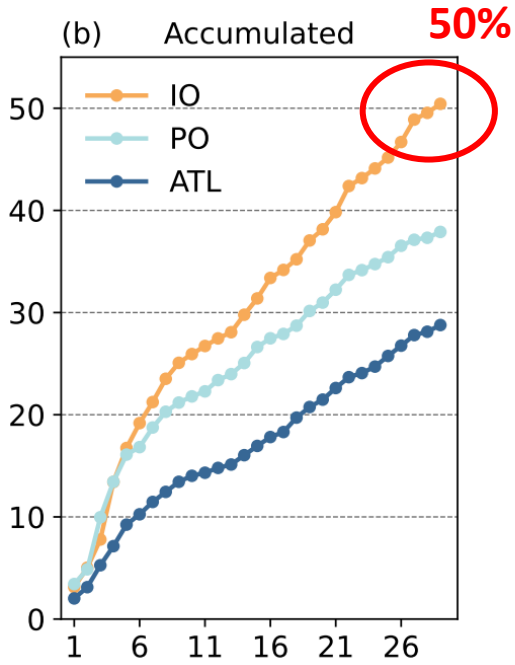
Results

Individual site quantification



29 RAMA observing sites

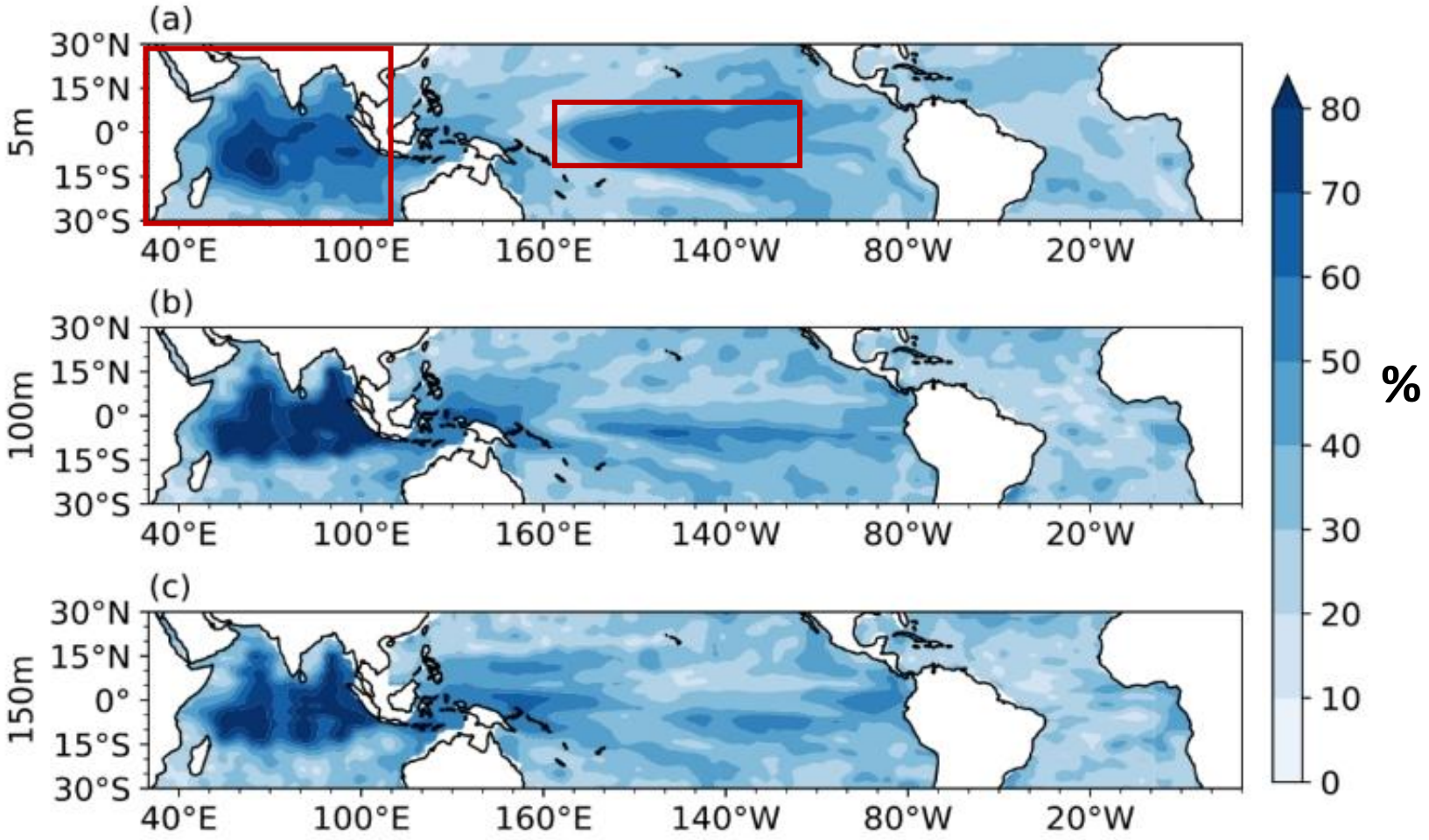




Individual percentages of error reductions in the initial covariance for TSST

Results

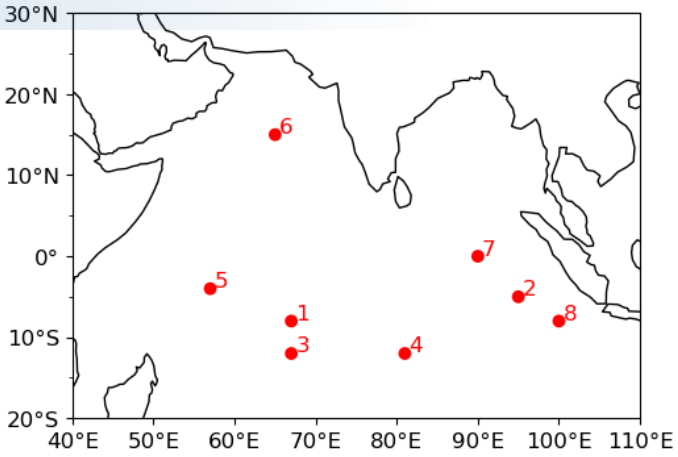
Spatial distribution of error reduction



Percentages of error reduction in the tropical sea temperatures over three oceans at the layers of 5m (a), 100m (b), and 150m(c)

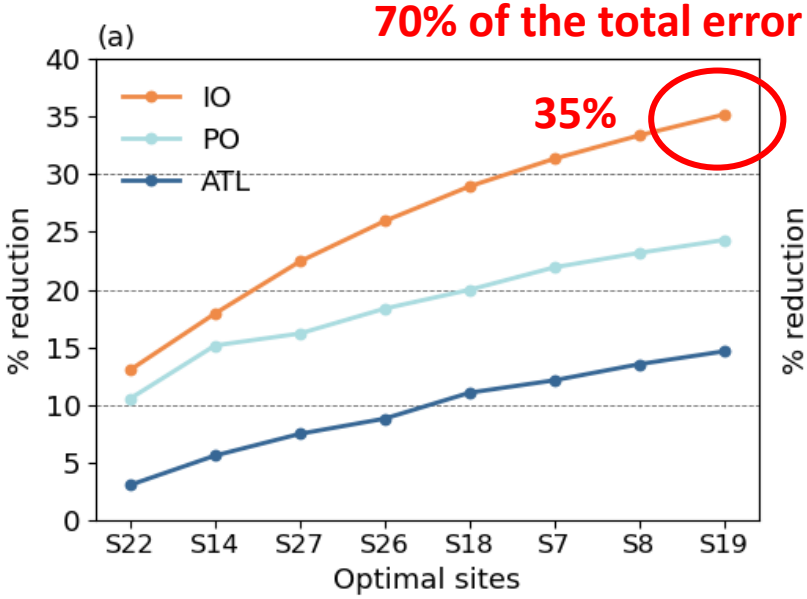
Results

Optimize observing network

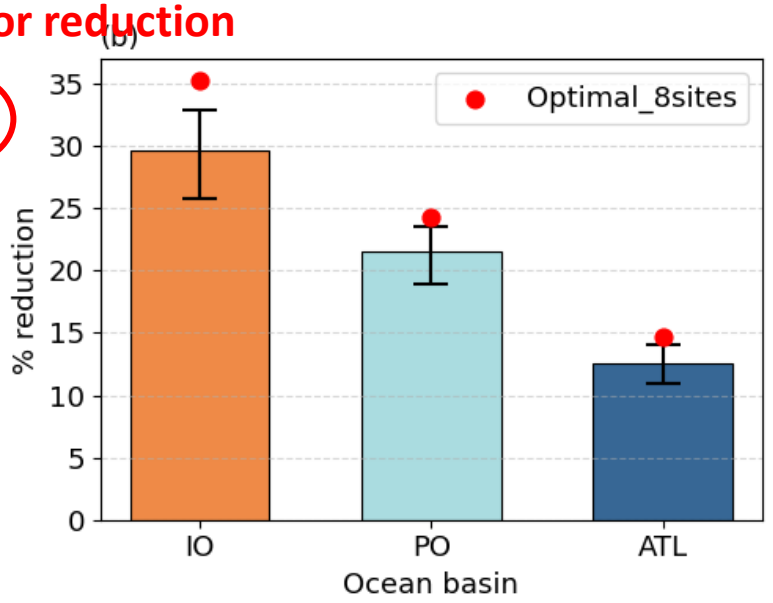


First 8 optimal observation sites (numbers indicate optimal ranking)

70% of the total error reduction



Accumulated percentages of error reductions in the initial covariance for TSST



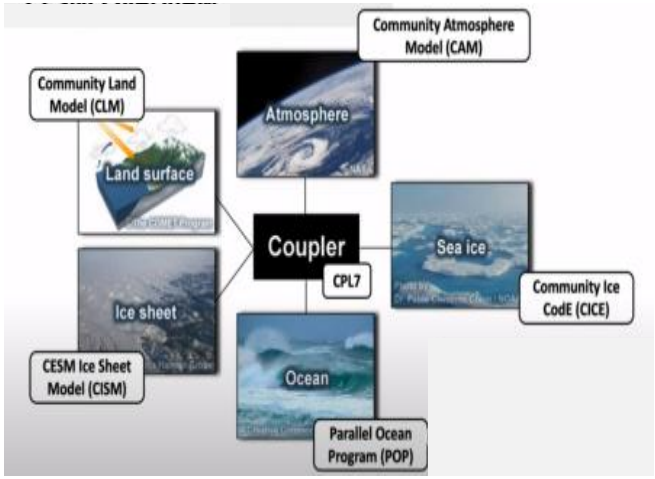
Percentage reduction in error after 100 rounds of analysis using 8 randomly selected sites

OSSE – Observing System Simulation Experiment

An OSSE is a modeling experiment used to evaluate the impact of new observing systems on forecasts when **actual observational data is not available**.

- **The truth run** generates the "true" state of the system, and provides the pseudo observations used during the assimilation run.
- **The control run** is obtained by integrating the model after adding small errors to the "true" initial condition.
- **The assimilation run** assimilates the pseudo-observations into the integration on the control run.

OSSE setups



Community Earth System Model (CESM) v.1.2

Atmospheric component: Community Atmosphere Model (CAM)

Oceanic component: Parallel Ocean Program v.2 (POP2)

CAM: ~ 0.9°×1.25° horizontally; 26 vertical levels;

POP2: ~ 1°×1°, with a refined meridional resolution of 0.5° over the equatorial region; 60 vertical levels

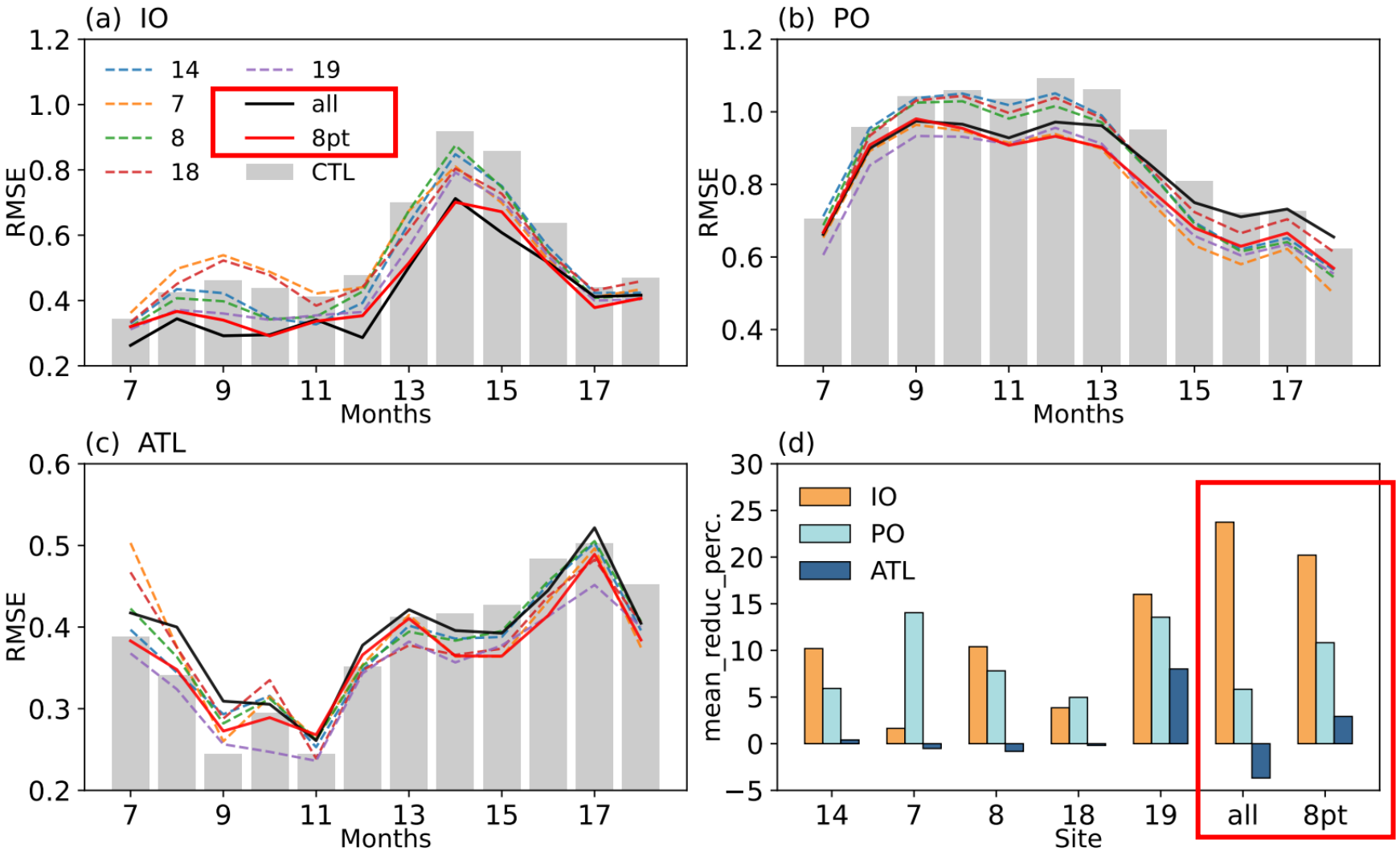
Ensemble Adjustment Kalman Filter (EAKF) **DART**

Exp. Name	Ensemble Size	Assimilation	Assim. Data
TRUTH	1	NO	—
CTL	20	NO	—
ALL	20	YES	All 29 sites
8OPT	20	YES	8 Optimal sites

Assimilation: every **10 days**

Run for **two years**

OSSE results



Conclusions

Targeted observation analysis & OSSE

Quantify

- SST analysis errors are reduced not only in the **Indian Ocean**, but also in the **Pacific** and **Atlantic. Site contributions vary greatly.**

Optimize

- 27.6% of the array (**8 sites**) account for **70%** of the total error reduction

The RAMA sites in the **thermocline ridge, Sumatra-Java upwelling** region, and **Arabian Sea** are prioritized for restoration.

Li et al. 2026, to be submitted

Application-1

Targeted observation analysis in the IO for the **IOD SST prediction**

JGR Oceans

RESEARCH ARTICLE

10.1029/2023JC019781

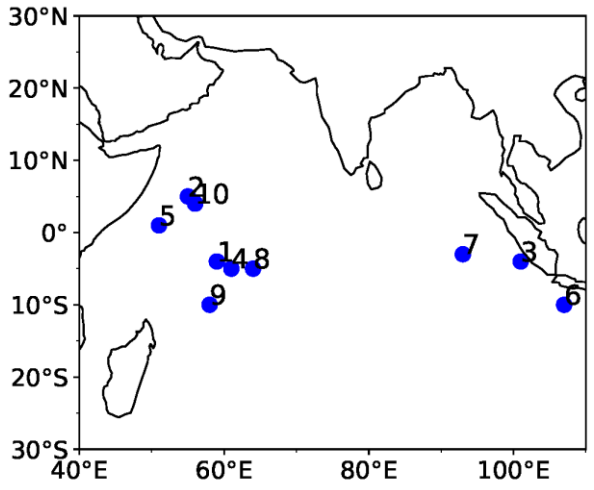
Key Points:

- A region-optional targeted observation method was proposed by introducing a project vector
- The optimal observation sites for the sea surface temperature (SST) prediction associated with Indian Ocean Dipole were identified
- The observation simulation system experiments supported the efficacy of

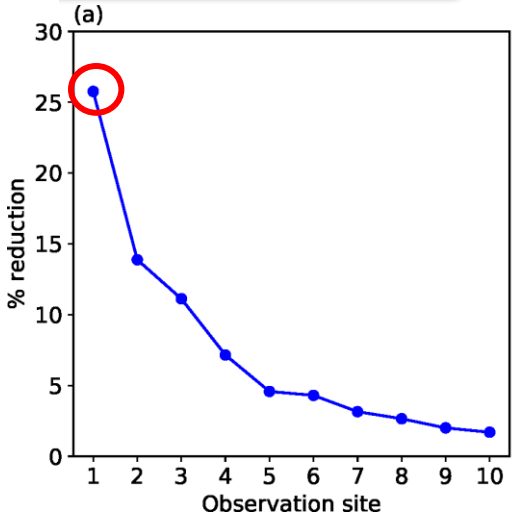
A Region-Optional Targeted Observation Method and Its Application in the Sea Surface Temperature Prediction Associated With the Indian Ocean Dipole

Xiaojing Li[1], Youmin Tang[2,3], Zheqi Shen[3,4], Feng Zhou[1], Xunshu Song[1,4], Yanling Wu[3,4], and Yi Li[3,4]

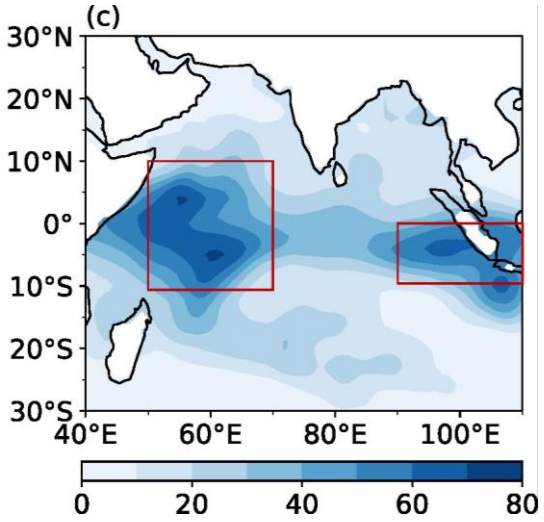
[1]State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China, [2]Department of Geography, Earth and Environmental Sciences, University of Northern British Columbia, US, Canada, [3]College of Oceanography, Hohai University, Nanjing, China, [4]Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, China



Optimal observation sites



Error reduction Percentage



Spatial distribution of error reduction percentages using the 10 optimal sites

Li et al. 2023 JGR: Oceans

Application-2

Targeted observation analysis for the **TPOS**

RESEARCH ARTICLE

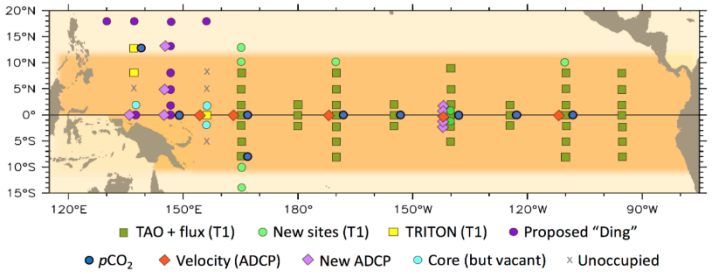
National Science Review
10: nwad231, 2023
https://doi.org/10.1093/nsr/nwad231
Advance access publication 2 September 2023

EARTH SCIENCES

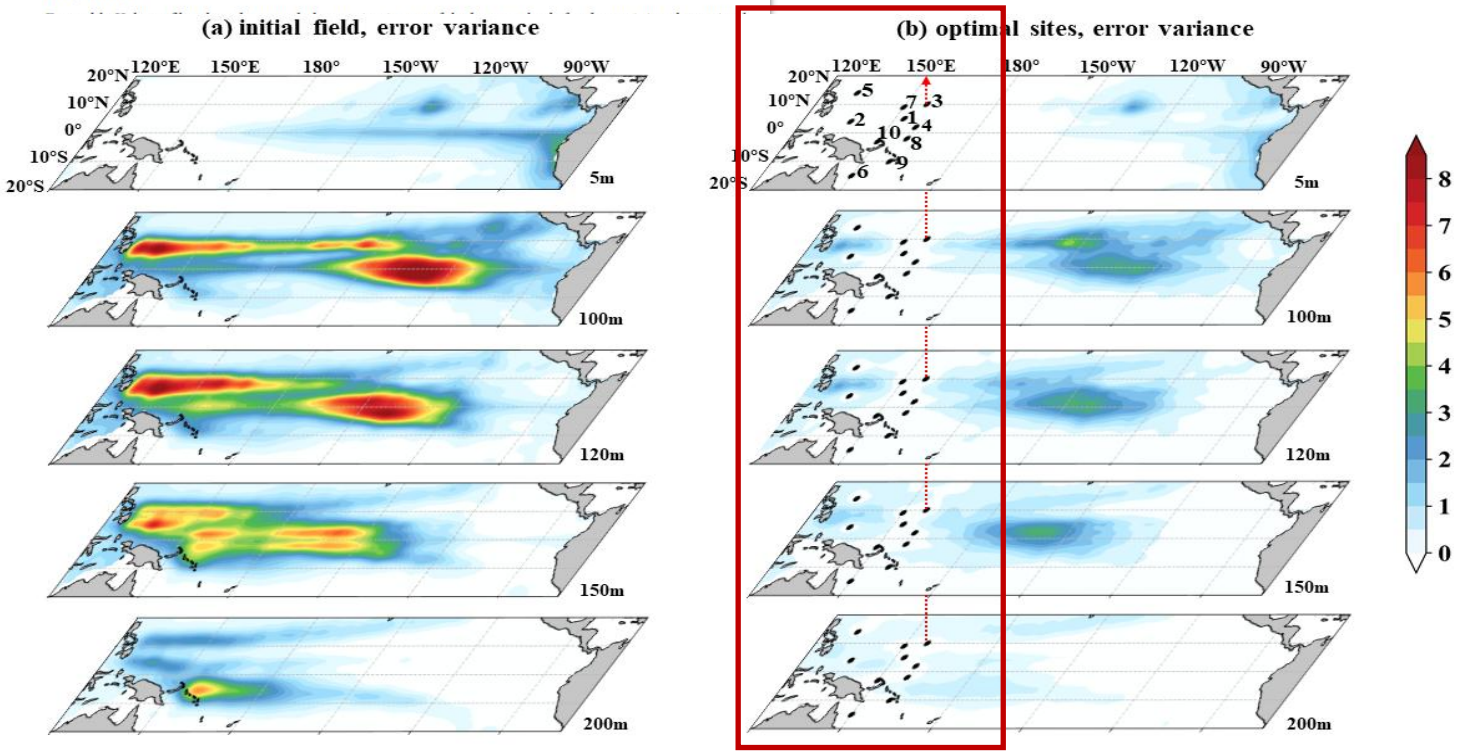
A new ensemble-based targeted observational method and its application in the TPOS 2020

Weixun Rao[1], Youmin Tang[1,2,*], Yanling Wu[1,3,4,*], Zheqi Shen[1,3,4], Xiangzhou Song[1,3], Xiaojing Li[4,5], Tao Lian[4,5], Dake Chen[4,5] and Feng Zhou[5]

[1]College of Oceanography, Hohai University, Nanjing 210024, China; [2]Faculty of Environment, University of Northe British Columbia, Prince George, Britis Columbia V2N 4Z9, Canada; [3]Key Laboratory of Marin Hazards Forecasting Ministry of Natural Resources, Hohai University, Nanjing 210024, China; [4]Innovation Group o



TPOS schematic



Initial covariance errors

Analysis covariance errors

Rao et al. 2023 NSR

Application-3

Targeted observation analysis in the IO for the **Nino4 SST prediction**

IOP Publishing Environ. Res. Lett. 20 (2025) 074023 https://doi.org/10.1088/1748-9326/addbf3

ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Quantifying the role of tropical Indian Ocean observations to central Pacific El Niño prediction

Xiaojing Li[1], Youmin Tang[2,3,*], Michael J McPhaden[4], Lei Zhou[5], Yi Li[1], Xunshu Song[1], Tao Lian[1] and Dake Chen[1]

[1] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natu Hangzhou, People's Republic of China
[2] Department of Geography, Earth and Environmental Sciences, University of Northern British Columbia, Prince George,
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[4] NOAA/PMEL, Seattle, WA, United States of America
[5] School of Oceanography, Shanghai Jiao Tong University, Shanghai, People's Republic of China
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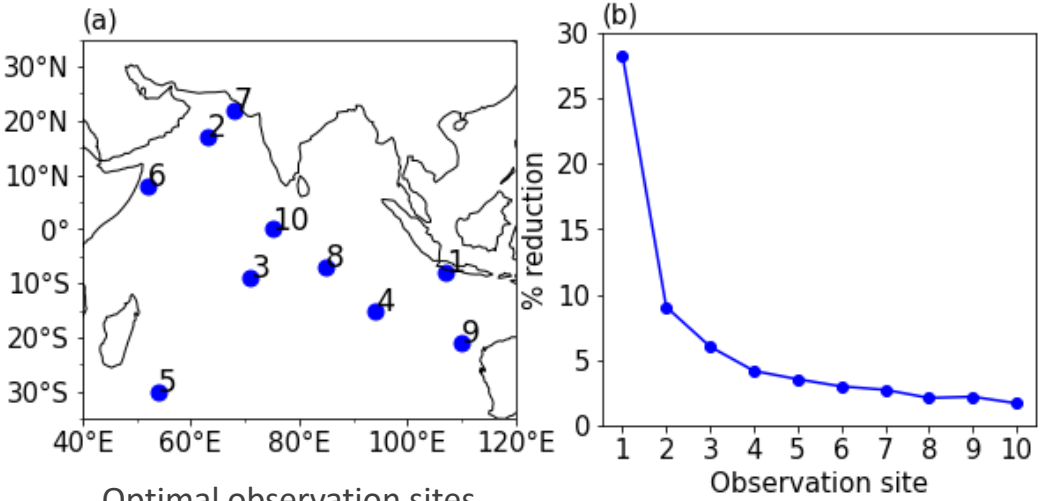
Keywords: targeted/adaptive observation, predictability, OSSE, Indian Ocean, El Niño–Southern Oscillation

Supplementary material for this article is available online

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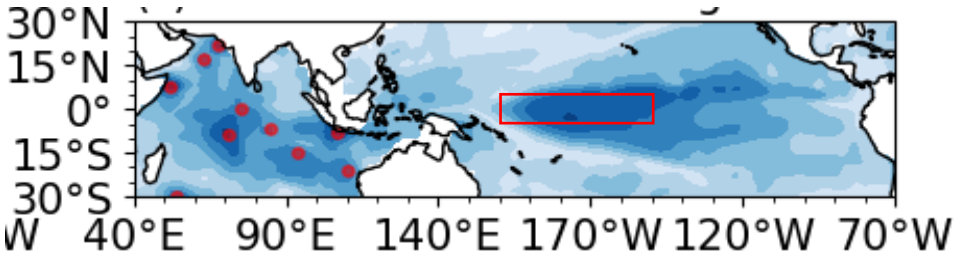
RECEIVED 25 February 2025
REVISED 5 May 2025
ACCEPTED FOR PUBLICATION 22 May 2025
PUBLISHED 6 June 2025

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Optimal observation sites

Error reduction Percentage



Spatial distribution of error reduction percentages using the 10 optimal sites

Li et al. 2025 ERL

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Thanks for your attentions!

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Aug. 26, 2026

Method

Targeted observation

- Assimilating **observation** can produce **good initial conditions** and improve prediction skill
- However, it is costly and difficult to add observational sites as many as possible, especially in oceans.

Observations in some sites ⇨ more useful for prediction

Targeted observation: seeking the optimal observing sites that can largest decrease the initial uncertainties and thus improve predictions.

Ideas by Riehl etc (1956) ➡ Methods developed in 1990s (Burpee et al., 1996; Aberson, 2003)

Method

Targeted observation

Two categories of methods：

The first category concerns the **growth of the initial error**, namely identifying the location where the error grows most rapidly (e.g., singular vectors, CNOPs)

The second category involves **sequential data assimilation** techniques. It quantify the contribution of each individual observation point through separate assimilation analyses (e.g., EnKF, EAKF).