Machine learning-based long-term spatial reconstruction of surface total alkalinity for the northern Indian Ocean

Ministry of Earth Sciences
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Introduction

- Northern Indian Ocean (NIO) pH is decreasing at a rate of 0.015/dec from 1980-2019 (Chakraborty et al., 2024).
- DIC trends primarily drives an increasing ocean acidification trend in the NIO.
- El-Nino and pIOD events leads to an enhancement of the NIO acidification.
- The alkalinity buffers this increasing ocean acidification by 5% in the BoB.
- Are there pockets or region where surface alkalinity is increasing, which may act as a buffer to this increasing ocean acidification?
- To answer we require long term, gap free, and reasonably accurate surface alkalinity data (TA), which forms the basis of the current study.

Objective

- **An attempt has been made to improve the regional prediction of surface TA by developing high-resolution, gap free, observation-based surface TA and study the long-term changes.**
- **We develop a surface TA product (INCOIS_TA) for NIO region from 1993-2020 using a machine learning (ML) algorithm.**

Data and Methods

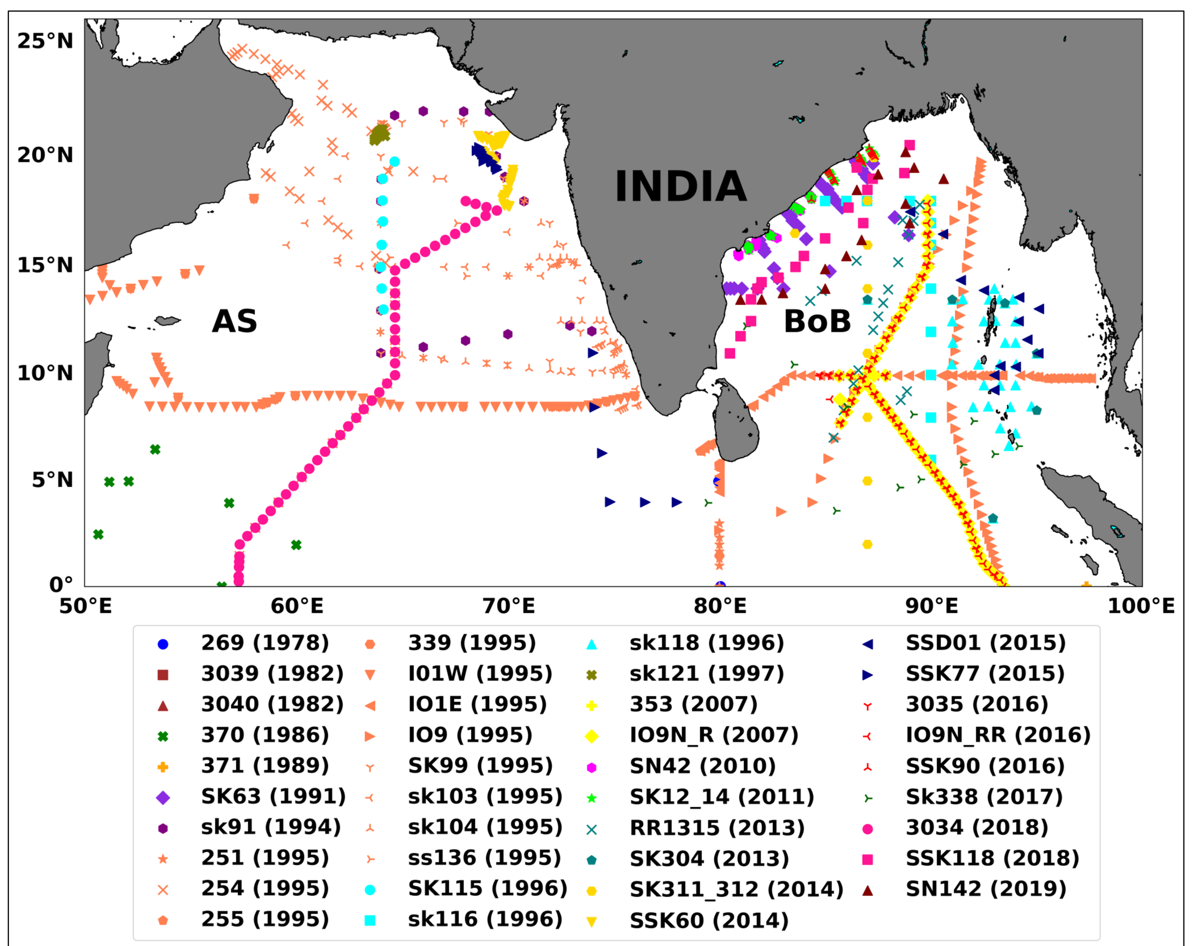

Figure 1: Study domain and spatial distribution of data

Assumption:

Surface TA = f(SST, SSS, and MLD)

These predictors serve as a proxy for temperature-induced biological effects, dilution effect (salinity), and mixing effect (mixed layer depth).

Reanalysis Data :

SST, SSS, and MLD taken from GLORYS12V1 having spatial resolution of 1/12º and available from 1993 to 2021. NO3 taken from GOBH having 1/4º spatial resolution and is available from 1993 to 2021.

ML Algorithm :

We chose XGB algorithm as it has proven to work. excellently for less data sets.

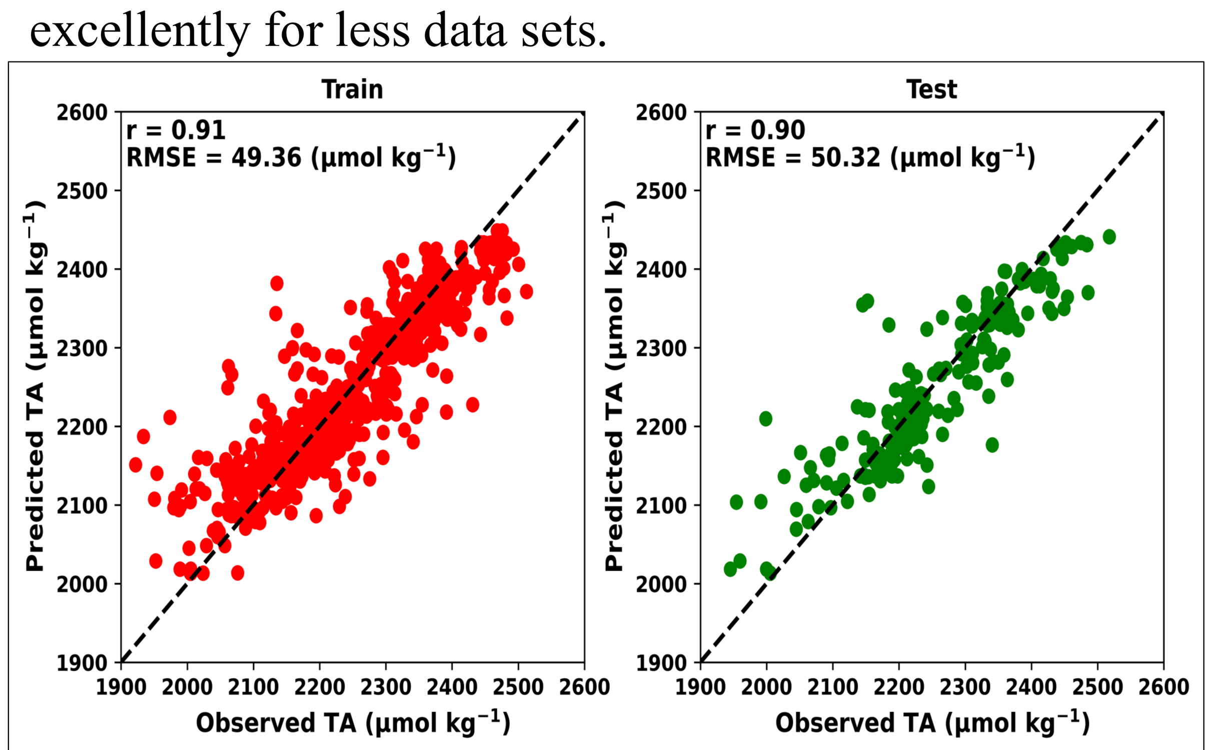

Figure 2: Train and Test performance

Ensemble & Uncertainty

We first create 150 train-test pairs (80:20 split). Then, using the tuned hyper-parameters of the XGB algorithm, we produced 150 models. We progressively add the predictions of a common test set using each of these 150 models. We check the ensemble size after which the cost function (RMSE) becomes stable.

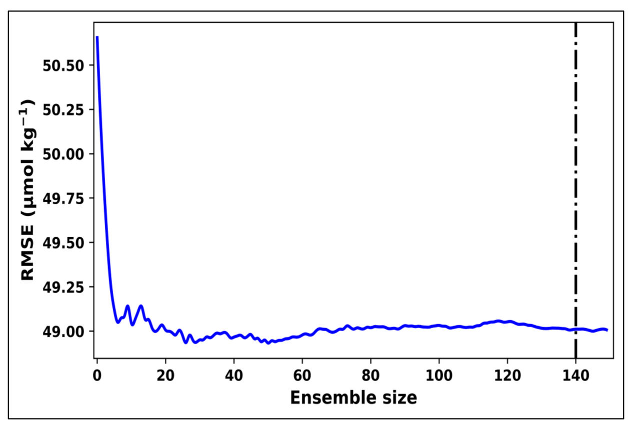

Figure 3: Increase in ensemble size stabilizes the RMSE. The vertical line denotes the ensemble size 140, chosen for this study.

Uncertainties:

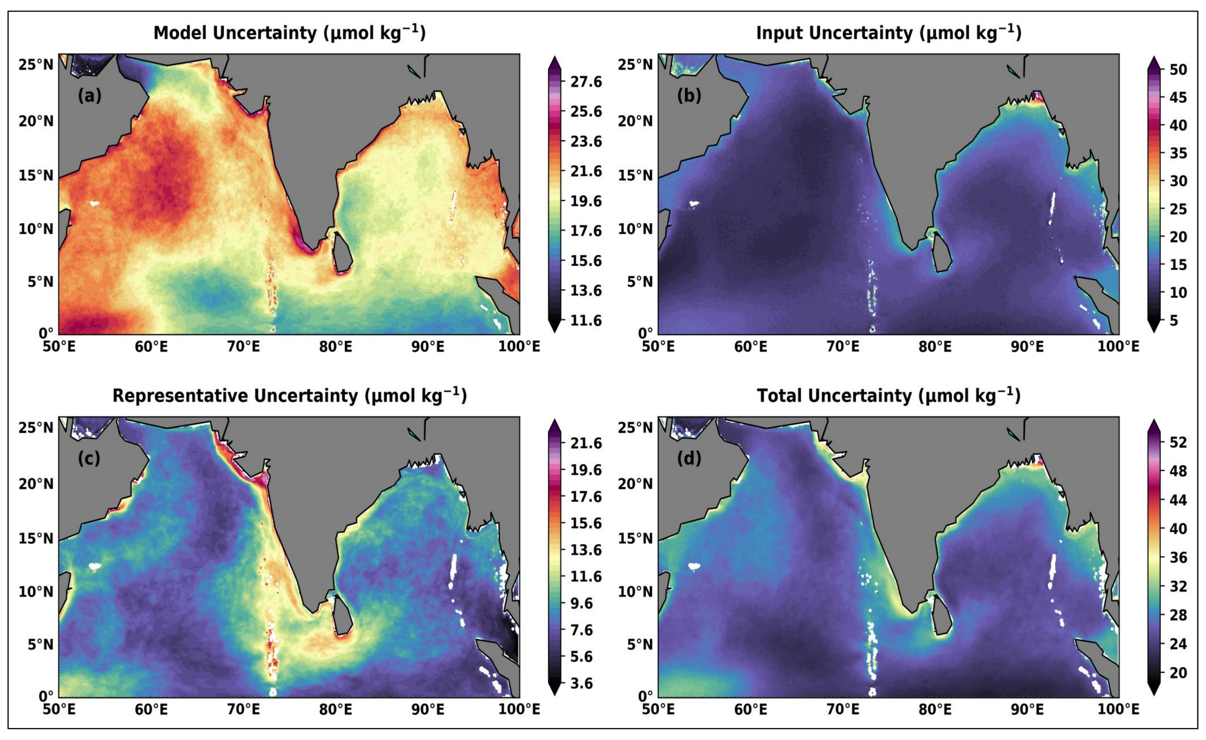

Figure 4: Spatial uncertainties at each grid cell

Results

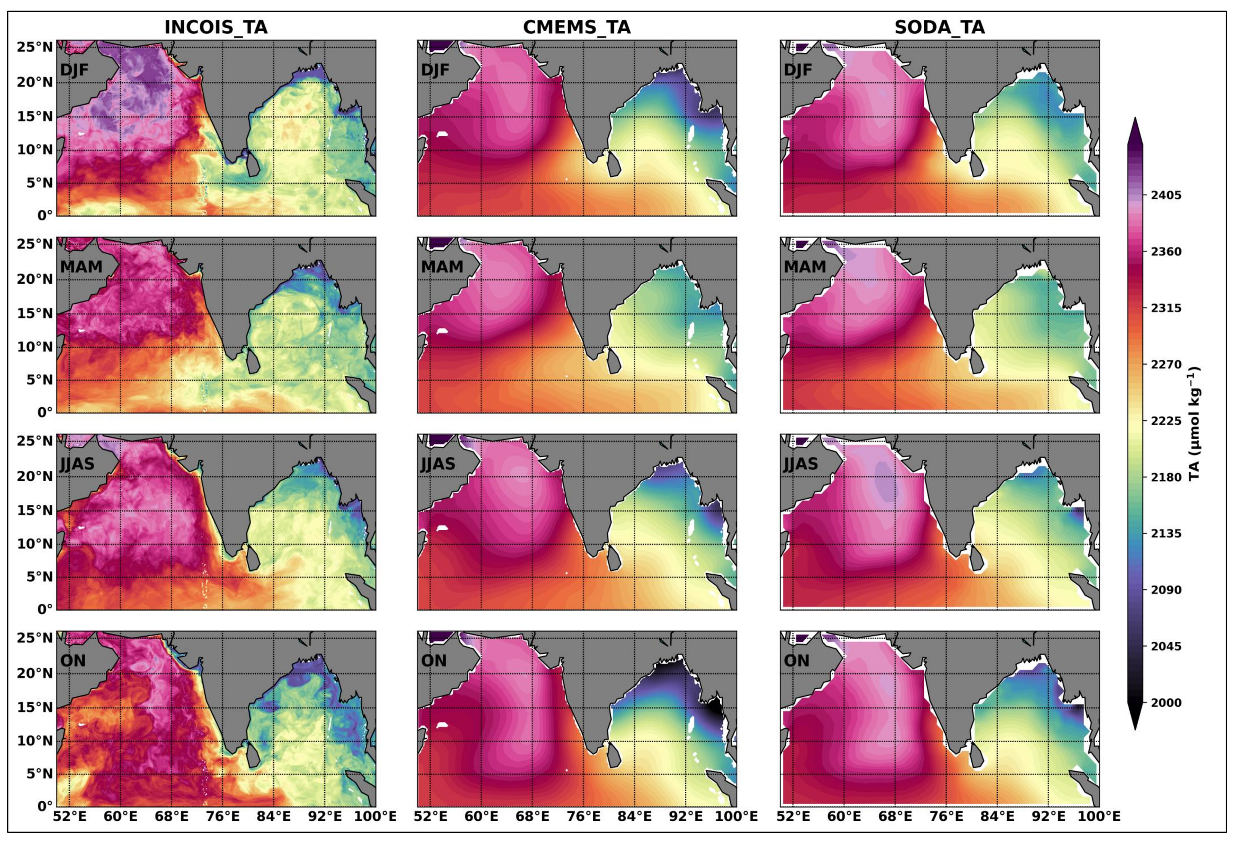

Figure 5: Comparison of the seasonal composite of surface TA from INCOIS TA, CMEMS TA, and SODA TA for the period 1993-2020.

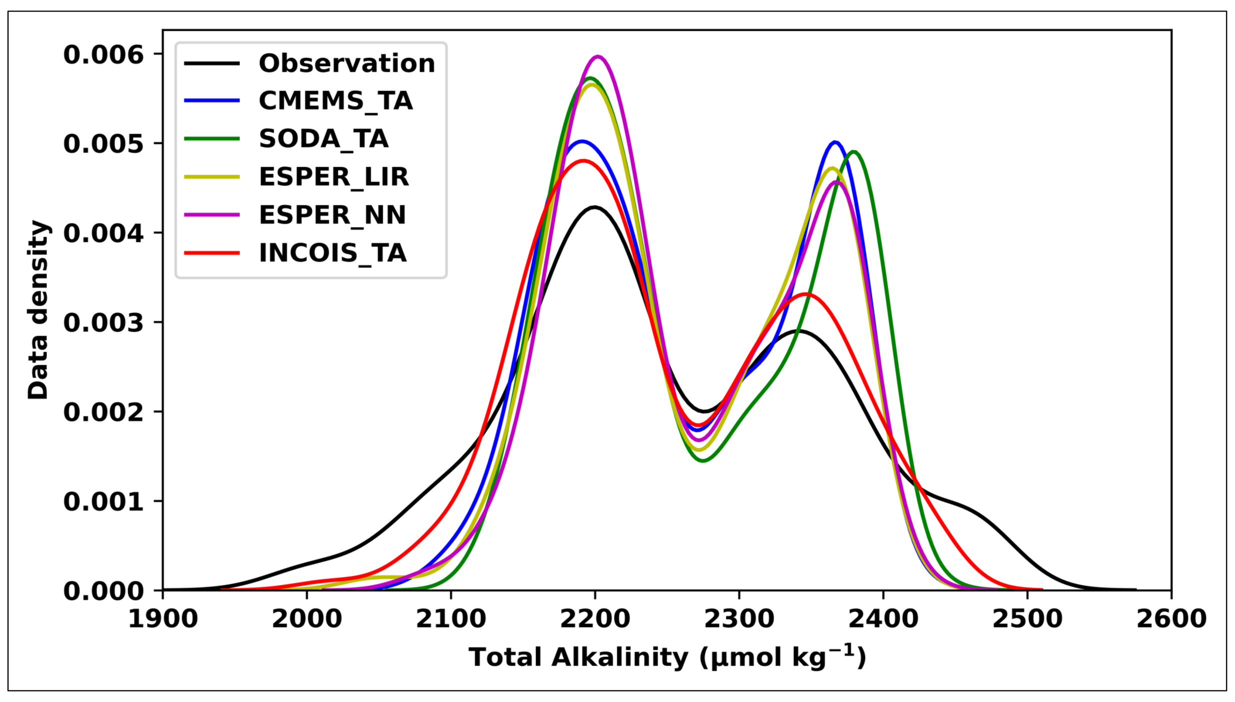

Figure 6: Data density distribution of predicted TA from various data products at the locations where TA observations are available

	RMSE (μmol kg^{-1})	r ($p < 0.01$)	PSS
INCOIS_TA	48.5	0.89	0.78
CMEMS_TA	69.7	0.77	0.70
SODA_TA	71.0	0.78	0.65
ESPER_LIR	69.6	0.77	0.71
ESPER_NN	70.1	0.77	0.72

Table 1: Statistical comparison of the surface TA between INCOIS TA (CMEMS TA,SODA TA, ESPER LIR, ESPER NN) and ship-based observations.

Results

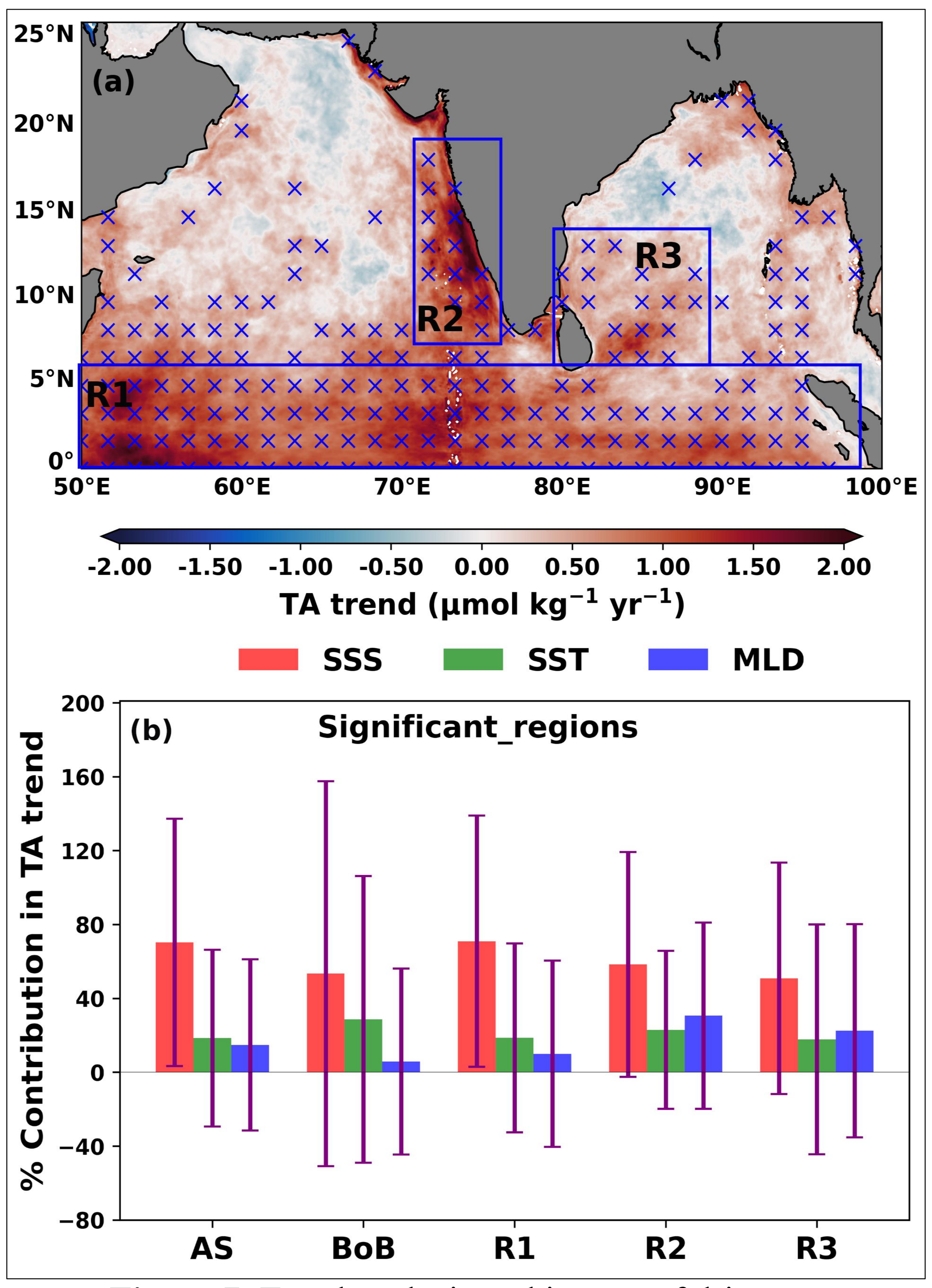

Figure 7: Trend analysis and impact of drivers

$$Alk^{*}_{tij} = nTA_{tij} - \frac{\sum_{t,i,j} nTA_{tij} \times A_{ij}}{T \times \sum_{ij} A_{ij}}$$

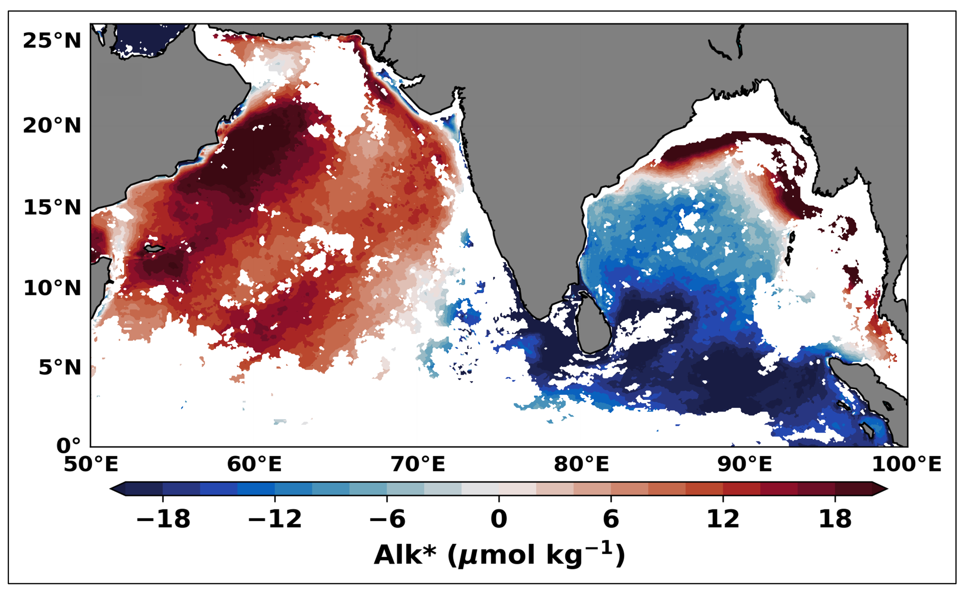

Figure 8: Annual mean values of Alk*

Summary and Conclusions

- Three regions showing significant increasing trend in TA are south of 7º N, southwest coast of India, and the southwestern region of the BoB.
- These significant trend in TA across all the three regions are primarily driven by surface salinity.
- The lack of significant trend in the north of the NIO are observed to be associated with significant are observed to be associated with significant trend in anthropogenic AOD.
- This suggests that the anthropogenic dust deposition may neutralize the TA trends in the north of the NIO region.
- The spatial pattern of the annual mean excess alkalinity (Alk*) suggests AS could be more favourable for calcification than BoB.

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