An Observing System Simulation Study for an Optimal Moored Instrument Array in the Tropical Indian Ocean

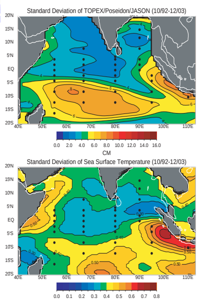
Eric Hackert, J. Ballabrera, R. Murtugudde and A.J. Busalacchi

ESSIC, University of Maryland, College Park, Maryland

INTRODUCTION

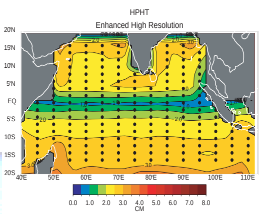
Under the auspices of CLIVAR, the Indian Ocean Panel has proposed an array of 35 moorings that is designed to observe the large-scale dynamical variability in the tropical Indian Ocean. These stations span the region 55°E to 95°E and vary in latitude between 12°S to 8°N. The goal of this research is twofold: first, we intend to validate the predetermined locations through the analysis of the error field of a reduced-space Kalman filter following the procedure used for the PIRATA moorings in the tropical Atlantic (Hackert et al., 1998). Second, we will investigate the simplification of the proposed array by identifying stations providing redundant information.

BACKGROUND

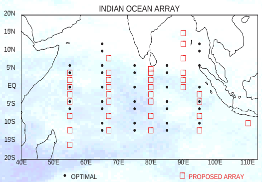


The observed variability of sea level (top) and SST (bottom) shows the key regions of interest to the oceanographic community. The current proposed mooring site locations are shown as black dots.

OPTIMIZATION PROCEDURE

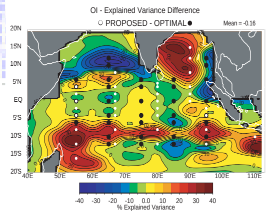


An experiment that assimilates TOPEX/Poseidon/Jason (TPJ) gridded product at synthetic mooring locations every 5° longitude and 2° latitude over the entire basin (above) is completed. In order to determine the 35 optimal mooring site locations in an objective fashion, the model forecast error analysis (**HPH^T**) is subsampled at the 178 mooring sites and a least squares regression approach is used to reconstruct the errors on this dense array of points from the data misfits at 35 selected points.



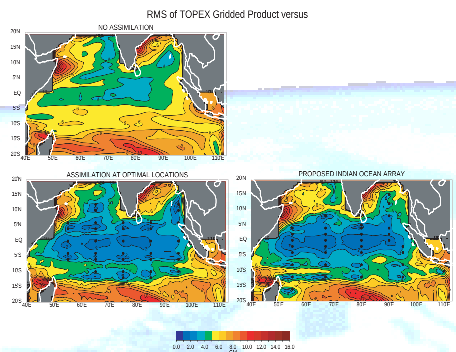
An array set-up with evenly divided mooring lines along the equator best reproduces the entire error field from this limited subset (OPTIMAL – black dots).

OPTIMIZATION RESULTS



Using the 35 mooring sites, the explained variance of the error field (**HPH^T**) at the remaining 143 locations (ie. 178-35) can be calculated for each array configuration – OPTIMAL and PROPOSED. The differences between the PROPOSED minus OPTIMAL show that the OPTIMAL configuration does better (blue) in the Arabian Sea while the PROPOSED has an overall higher explained variance (red) in the Bay of Bengal and along 10°S stretching across the basin. The average mean for the differences is negative (-0.16%) indicating that the OPTIMAL configuration has overall higher explained variance and presumably better represents the error field.

DATA ASSIMILATION RESULTS

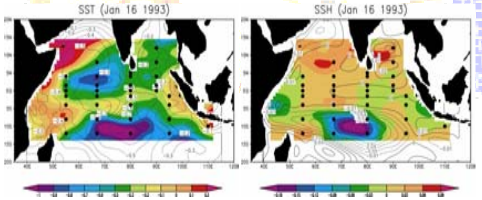


RMS differences between model results and observed sea level are presented for NOASSIM* (top left), OPTIMAL (bottom left), and PROPOSED (bottom right) mooring configuration data assimilation. OPTIMAL results show the good coverage of the simulated mooring sites and improvement over the NOASSIM case. However, note the relatively poor results from the assimilation case in the far eastern basin and Bay of Bengal regions highlighting the advantages of the PROPOSED mooring sites. * The NOASSIM case is the Cane and Patton linear model forced by anomaly ECMWF wind stress.

OBSERVING SYSTEM SIMPLIFICATION

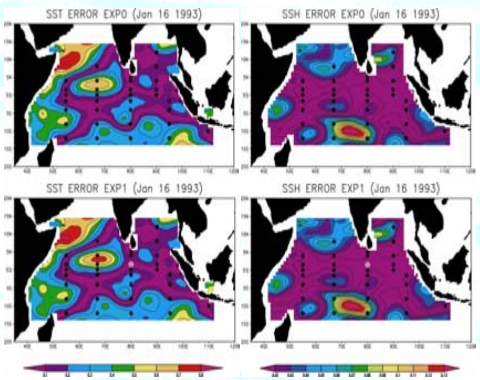
Another use of data assimilation techniques is to investigate whether some stations provide redundant information. While operational systems always require some degree of redundancy in case of failure of one of the instruments, knowledge about the amount of redundant information might be used to simplify the observing system.

This part of the study uses the outputs of a primitive equation, reduced gravity model (Gent and Cane, 1989). The Multivariate EOFs of the model will account for the statistical relationship between the physical parameters of interest (temperature, salinity, currents, and sea level). Fitting the MEOF of the model to the SSH and SST observations at the PROPOSED locations provides a reference solution:

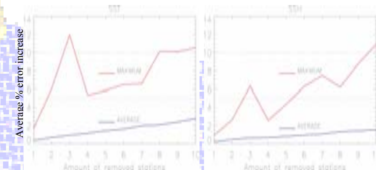


Observations (color shades) corresponding to January 1, 1993 are compared with the result of the EOF fitting (contours). Dots indicate the locations of the PROPOSED array.

Thirty-three experiments are done by removing one station at each time. The change of the error with respect to the reference experiment (all 33 stations) is calculated. The station which has the lowest error increase is the station providing the largest amount of redundant information. We repeat the analysis for January 1993 through December 2003. The station with the lowest error increase is 80E,1.5N (white circle below). The average (120 months) error increase is 0.36% (SST) and 0.20% (SSH). The maximum error increase is 1.71% and 0.92%.



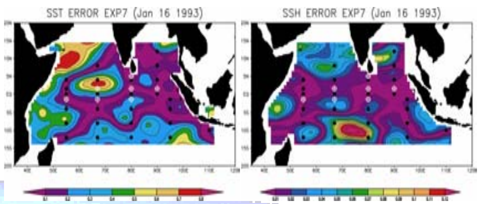
After removing station 80E,1.5N, we perform 32 experiments. A second station is removed each time. Again, we compare the error with respect to the reference experiment (all 33 stations). The station providing the next lowest average error increase is 90E,1.5N. The process is repeated until the maximum error increase is consistently larger than 10% for both SST and SSH:



Stat.	Location
1	80.0E 1.5N
2	90.0E 1.5N
3	67.0E 1.5N
4	80.0E 5.0N
5	55.0E 1.5S
6	67.0E 1.5S
7	80.0E 1.5S
8	90.0E 8.0N
9	80.0E 0.0N
10	55.0E 1.5N

The results suggest that, in order to reconstruct the monthly variability of observed sea level and sea surface temperature, the stations at each side of the equator (1.5S and 1.5N) provide redundant information. Also, the station at 80E,5N is not required to reconstruct those variables.

On average (120 months), the removal of these 10 stations provide a degradation of the error smaller than 5%. However, the smaller grids have a tendency to provide episodically larger errors. If 7 stations are removed (array 21% smaller, below), the largest error is about 6% larger. If 10 stations are removed (array 30% smaller) the largest error increase is about 11% larger.



CONCLUSIONS

- An objective methodology is presented to pick the optimal locations for a mooring array in the tropical Indian Ocean
- The PROPOSED mooring locations do a better job of recreating the observed signal in the Bay of Bengal and along 10°S whereas the OPTIMAL sites better reproduce the error in the Arabian Sea.
- The simplification study shows that sea level variability displays lower degrees of freedom than sea surface temperature: the impact on the reconstructed SST is larger than on SSH.
- Both methodologies indicate that reconstruction of SSH (and SST) does not require the near equatorial PROPOSED mooring site locations (ie. 1.5°N and 1.5°S) in the context of these two fields: With the same amount of stations, a larger latitudinal region might be sampled instead of resolving latitudinal gradients at the equator.
- Finally, removing any ten or more stations from the PROPOSED array will increase the maximum error in reconstructed SST and SSH by more than 10%.

Contact: Eric Hackert (ehackert@essic.umd.edu) or http://essic.umd.edu/~ehackert

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