Simple OSE of Argo using space-time scales statistically derived from altimeter data

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1. Introduction

- Simple OSE is the method to evaluate an observing system for capturing phenomena by adopting a statistical OI instead of a dynamical ocean model.
- The number of Argo data in the e-folding domain is inspected as a proxy for the accuracy of OI analysis.

2. Space-time scales estimated from altimeter data

Space-time scale is evaluated by 3-dimensional Gaussian function:

$$\mu^t(x,y,t) = \exp(a_1x^2 + a_2y^2 + a_3t^2 + a_4xy + a_5xt + a_6yt)$$

where *x*, *y* and *t* are zonal, meridional and time distances from 2^0x 2^0 grids. Coefficients '*a*'s are determined as fitting the function to an actual distribution of correlation coefficients of SLAs.

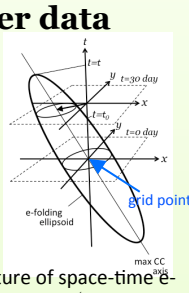


Fig.1 Feature of space-time e-folding scale as $\mu^t(x,y,t) = \exp(-1)$

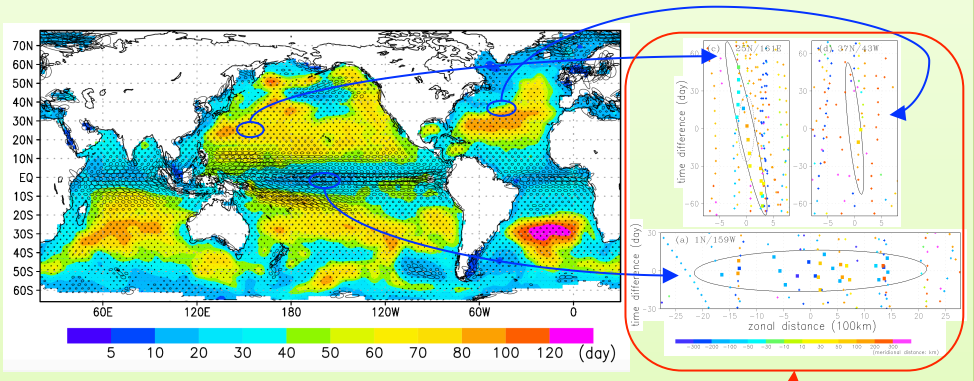
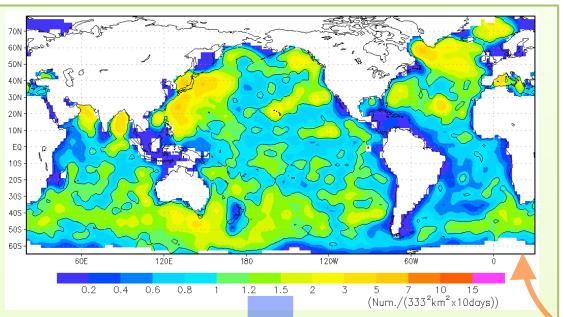


Fig.2 Space-time e-folding scales in the global ocean.
Ovals: e-folding horizontal scale of SLA variation at 2^0x 2^0 grids.
Color shade: persistent e-folding timescales.
Ovals in the right hand: examples of e-folding scales in *x*-*t* section. Argo data in the e-folding domain are shown with large square plots, whose colors show meridional distances.

3. Argo data density

Fig.3 Argo data density shown as the number of data in area of 333^2 km^2 for 10 days.
Area of 333^2 km^2 is equivalent to 3°x3° box area at the equator.
The mean numbers for 2010 - 2013 are shown. Total number of data is 469,395, which is equivalent to 3,215 data for every 10 days in the global ocean.



Projected on e-folding scales

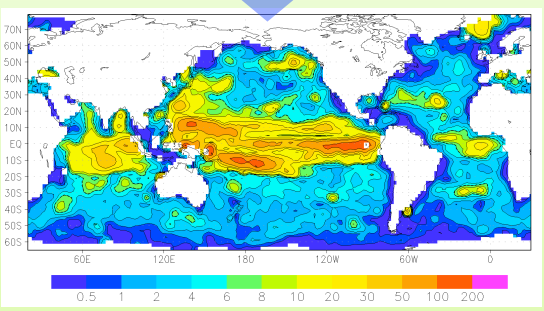
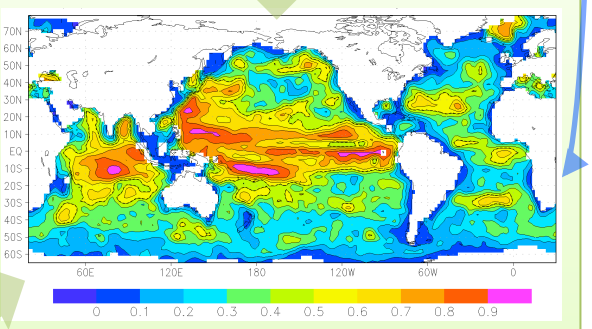
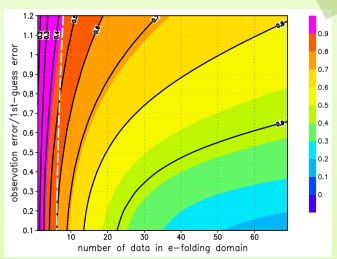


Fig.4 The number of Argo data in the space-time e-folding domain.

4. Expected accuracy of OI in relation to data density

Fig. 5 Expected correlation coefficient of the space-time OI analysis of Argo data with the true value.
The correlation coefficient is inferred from the data density with the result of the OI test as below.





Test of space-time OI
The space-time OI is tested for homogeneously distributed data with different data density and observation error.
The data number in the e-folding domain (lateral axis) and ratio of observation error relative to the first-guess error (vertical axis) provide 'correlation coefficient of the analysis value with the ideal true (solid contours)' as well as analysis error (colors), according to.

$$CorrelCoef = \sqrt{1 - AnalError^2 / 1stGuessError^2}.$$

More than six data are required for the reliable analysis in which correlation with the true value is 99% confidence level (white dash line) and is above 0.5.

5. Comparison of OI analyses using Argo and Altimeter

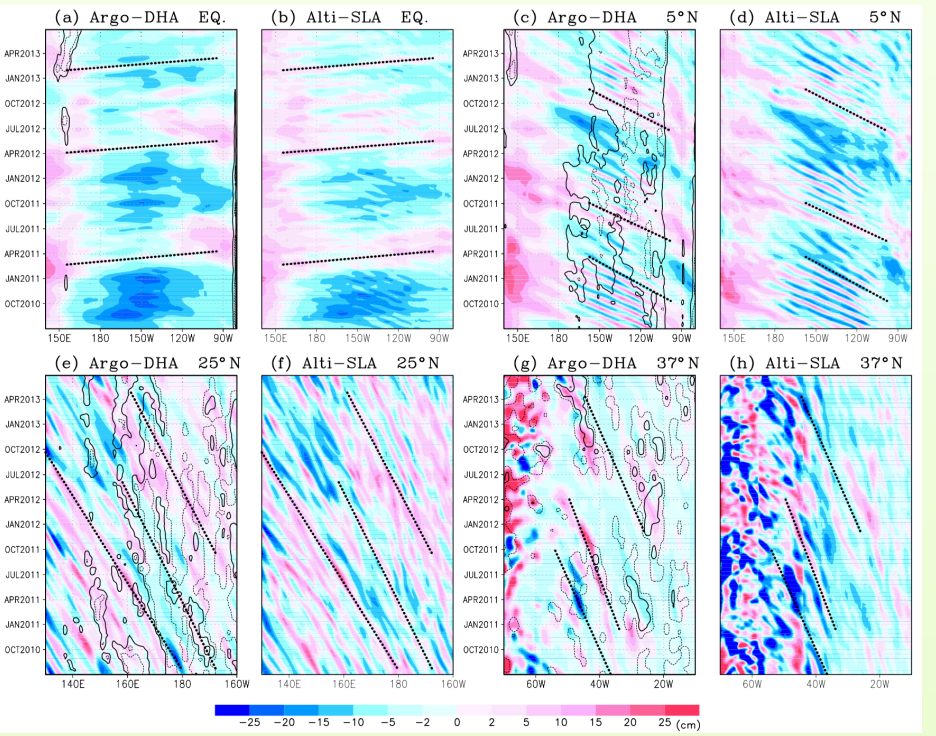


Fig.6 *x*-*t* diagrams of analyzed Argo DHA and altimeter SLA along four sections.
DHA is SSDH (0-1200 dbar) anomaly from the monthly mean SSDH obtained from WOA2009.
Refer Fig.7 for location of the sections.
The space-time OI is separately applied to both Argo DHA and altimeter SLA using the space-time scales as in Fig.2. GPVs are obtained every 5 day from July 2, 2010 to June 27, 2013.
Solid (dotted) contour shows the number of Argo data in the e-folding domain is 6 (2). Bold dotted lines indicate propagating positive/negative signals detected by SLA analysis, and projected to the same time/location in the DHA analysis.

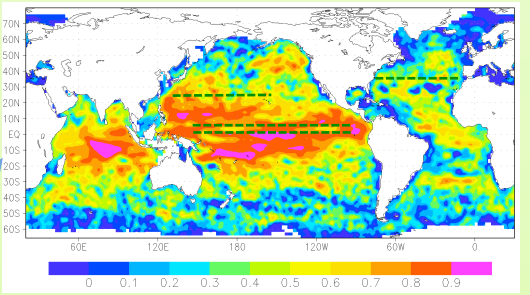


Fig. 7 Correlation coefficient between the DHA and SLA analyses.

High correlations are found in lower latitudes, especially in the Pacific, and lower in higher latitudes. High correlations are also found in the subtropical western North Pacific and in the Gulf of Alaska. The distribution is similar to that inferred from the number of ARGO in the e-folding domain (Fig. 5).

6. Required data density for eddy-scale analysis

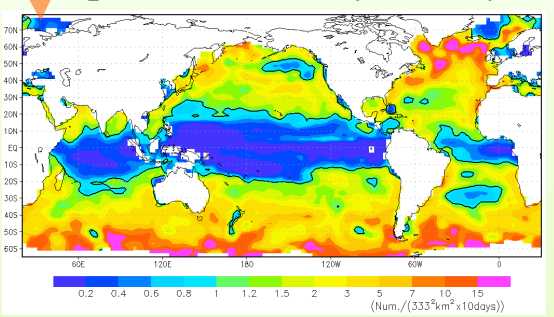


Fig. 8 The required number of data in 333^2 km^2 area for 10 days.
The number is inferred from the e-folding domain volume (km^2 x day), as that the number of six data in the e-folding domain are expected.
Total data number required is 11,000.

In order to accomplish the reliable OI analysis in which the correlation with true value is 99% confidence level,

- more than 10 data in the area of 333^2 km^2 are required in high latitudes, and
- total 11,000 data are requited in the global ocean, but
- the current data density is enough high for the equatorial wave.

However, the last point should be discussed more as below.

7. Discussion

The confidence level mentioned above provides only 15% reduction of the analysis error from the first-guess error. If 50% reduction is required, at least 30 data are needed in the e-folding domain. The low latitudes are important for monitoring climate variability and the heat content should be estimated far more precisely than the significant level shown above. So, **the current Argo data density should be at least sustained at the low latitudes in the Pacific and Indian oceans**.

This study is based on Kuragano et al. (2015), Evaluation of Argo network using statistical space-time scales from satellite altimetry data, JGR Oceans, 120, 4534-4551, doi: 10.1002/2015JC010730.