Toward an Optimal Design of Profiling Float Network

Project Representative

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The importance of deep ocean observations has now been recognized in conjunction with the global changes as bottom-water warming. Within this background, schemes for optimizing deep-ocean observation programs are presently the subject of increased interest. Here we use an ocean data synthesis system on the basis of adjoint approach to identify key observation sites for deep-ocean monitoring. We demonstrate a more effective geographic deployment strategy for the deep profiling floats monitoring changes in the oceanic heat content focusing on the inter-annual to multi-decadal variations in particular. An adjoint sensitivity analysis identified two possible key regions in the Southern Ocean and North Atlantic.

Keywords: Ocean Observation System, Data assimilation, Argo float

1. Introduction

At the beginning of the 2000s, dramatic progress was made in ocean observations with the introduction of Argo profiling floats capable continuously monitoring ocean properties. The success of the monitoring network for upper oceans (*Argo Scientific Team, 2000* [1]) brings the deep-ocean monitoring into perspective since import role of deep ocean in global change is getting widely recognized in an aspect of the earth energy/mass budget.

Deep floats of a wide diversity of type has been developed for global ocean monitoring. Some of them are recently deployed in a limited region for a pilot projects. Witin this background, an effective design of a global deep profiling float network is required for climate research.

In this study, we have conducted an adjoint sensitivity analysis (*e.g., Masuda and Hosoda, 2014* [2]). The adjoint sensitivity analysis gives the temporal rate of change of a physical variable in a fixed time and space when model variables (e.g., water temperature) are arbitrarily changed in the 4-dimensional continuum of one temporal and three spatial coordinates. This is equivalent to specifying the "sensitivity" of a variable to small perturbations in the parameters governing the oceanic state. It is applied to identify the possible key regions involved in the deep ocean temperature changes.

2. Method

Global heat content change (water temperature warming) below 2000 m is our target. 20yr backward calculation is executed on the "Earth Simulator" (*e.g., Masuda et al., 2010* [3]). The background dynamical ocean state is Estimated STate of global Ocean for Climate research (ESTOC) derived from ocean data assimilation system (*e.g., Osafune et al., 2014* [4]), based on ocean general circulation model (OGCM); version 3 of the GFDL Modular Ocean Model (MOM) (*Pacanowski and Griffies, 1999* [5]) with major physical parameter values determined through a variational optimization procedure (*Menemenlis et al., 2005* [6]). The horizontal resolution is 1° in both latitude and longitude, and there are 46 vertical levels for the global ocean basin.

The adjoint sensitivity is derived from adjoint code of the OGCM. Here, we apply a set of warming trend signal to our sensitivity analysis as an artificial "cost" (Fig. 1). This can more clearly detect key sites for observation in conjunction with a bottom-water warming. Adjoint variable for T has been multiplied by the prior uncertainty estimate σ derived from the ESTOC and normalized by the cell volume.

backward

A warming signal at time t_2

Persistent warming signals influencing times t_1 & t_2

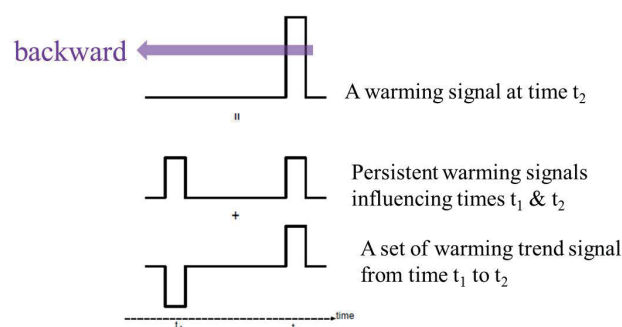A set of warming trend signal from time t_1 to t_2

Fig. 1 Schematic view of the artificial cost.

3. Result

Figure 2 shows the distribution of the adjoint sensitivity at 3000-m depth by 10-year backward calculation form 2010. The artificial cost is given below 2000-m depth at 2010 as a positive value and at 2005 as negative one (that is, t_1 in Fig. 1 is 2005, t_2 2010). An adjoint sensitivity analysis implies that changes in the water temperature in a local area around 130°E in the Southern Ocean can have subtle influence on the water warming in deep ocean for this pentadal time-scale.

Figure 3 shows decadal influences. The values in local areas around 120°E in the Southern Ocean and northern North Atlantic are prominent in this map. This result implies there can be two key regions for a decadal heat content increase in deep ocean from 2000 to 2010.
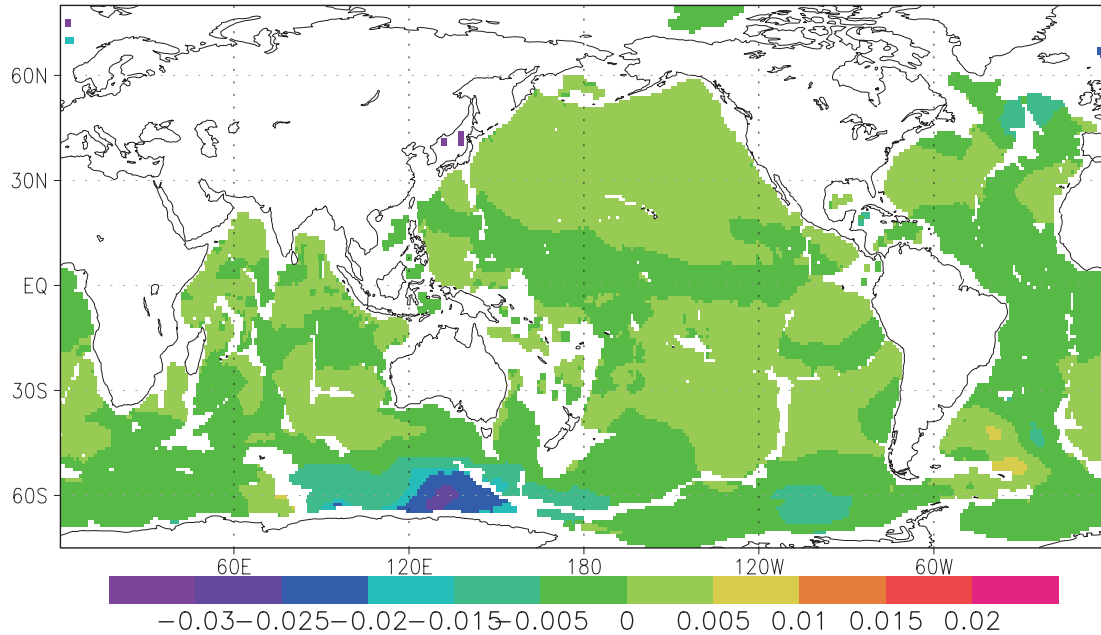
Adjoint T at 3000-m depth * std   (10 yr)

Fig. 2 Adjoint variable for a pentadal heat content increase from 2005 to 2010 below 2000-m depth. The distribution is for 2000 at the depth of 3000-m.

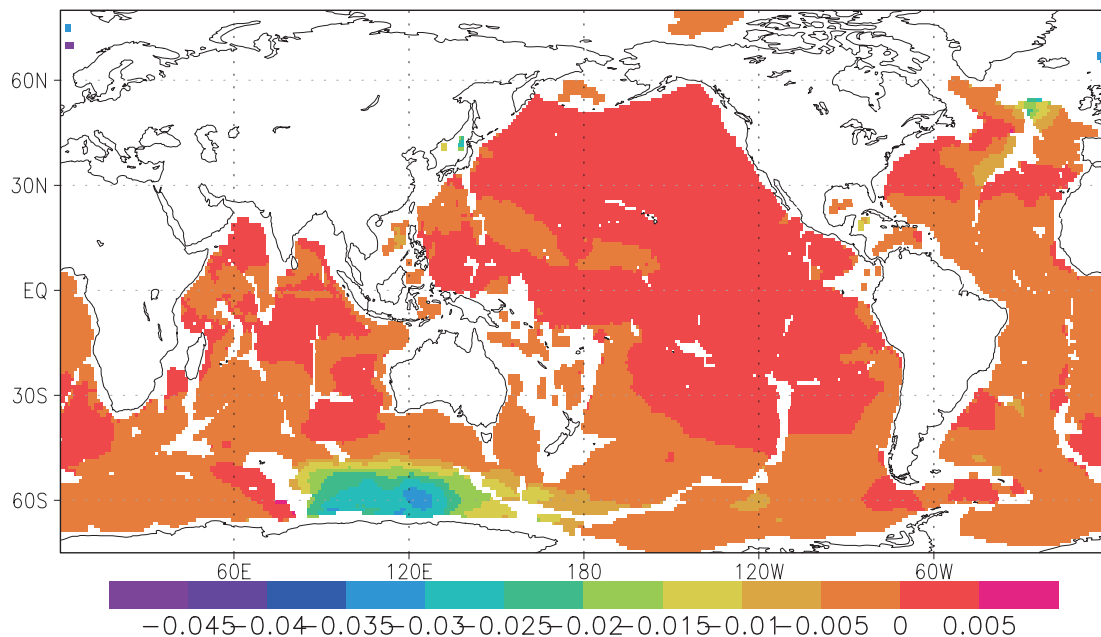Adjoint T at 3000-m depth * std   (20 yr)

Fig. 3 Adjoint variable for a decadal heat content increase from 2000 to 2010 below 2000-m depth. The distribution is for 1990 at the depth of 3000-m.

4. Discussions

We are deploying 11 Deep profiling floats in the key sites in the Southern Ocean detected by the sensitivity exercise to make an improved state estimation and to uncover the mechanism of the changes in deep oceans.

Toward an Optimal Design of Deep Profiling Float Network, observing system simulation experiment is planned by using two global data synthesis systems in JAMSTEC which are constructed for a long-term state estimation. One is the system used for sensitivity analysis (based on MOM3 base) and the other is a 4D-VAR system with finer resolution (based on tri-polar OGCM). Since sensitivity may depend on the system, such a multi system analysis shall be fair and preferable.

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大深度フロートの最適観測ネットワーク構築に向けた実験

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　近年、数年から数十年の時間スケールを持つ気候変動現象や地球温暖化等に関わる海洋環境変動に 2000m より深い海洋中深層が重要な役割を果たしていることが示唆されている。その包括的な理解を深めるためには深海の状態を正確に把握することが重要であり、自動昇降型フロートを用いた全球モニタリング計画が国際的に進められつつある。本研究では大深度フロートの最適観測ネットワーク構築に向けたアジョイント感度解析実験を実施し、2000m 以深の貯熱量の 5 − 10 年規模の変化に対してどの海域の海洋変動がどの程度の影響力を持ちうるかを定量的に示した。10 年スケールの貯熱量変化には南大洋と北大西洋の限定された海域に大きな感度がみられ、それらの海域での長期モニタリングの重要性を示唆している。

キーワード：海洋観測システム，データ同化，アルゴフロート

大深度フロートの最適観測ネットワーク構築に向けた実験