Final Preport for Project **1003** Project title: **SMART-CHAOS** Principal investigator: **Maik Thomas** Report period: **July 1, 2016 - June 30, 2019**

The combination of scientific sensors and subsea telecommunication cables would benefit a wide range of scientific areas. The so-called SMART cables (Scientific Monitoring And Reliable Telecommunications) could supplement or replace existing observing systems and provide long-term, high-resolution in situ measurements for ground-truthing satellites, improving tsunami early warning systems and supporting ocean and climate research (Howe et al. (2015)).

In the project "SMART Cables Heuristically Assimilated into Ocean Simulations" (SMART-CHAOS) an observing system simulation experiment (OSSE) is set up in order to determine the improvement of medium-term ocean dynamics by assimilating synthetic SMART cable observations into an ocean model. By means of the Singular Evolutive Interpolated Kalman (SEIK, Pham et al. (1998), Nerger et al. (2005)) filter, synthetic observations from the Regional Ocean Model Systems (ROMS) along possible SMART cable transects are assimilated into the Max-Planck Institute Ocean Model (MPIOM).

Data assimilation of the synthetic observations demonstrates the ability of data assimilation (DA) to improve processes on the regional scale. Thereby the global root mean square error is reduced by 13 Pa and the global mean correlation is increased by 0.14. Furthermore, the OBP error of major dynamic systems, such as the Gulf Stream and the Kuroshio, is reduced in the DA experiments (cf., Fig. 1). The correlation of observed and simulated OBP is increased particularly on time scales shorter than two weeks.



Fig. 1 (a) OBP temporal mean error between the control run with MPIOM (CTRL) and the reference run with ROMS (TRUTH). (b) Temporal OBP correlation between CTRL and TRUTH. (c) Reduction of the temporal mean error by DA of synthetic observations from SMART cables. (d) Increase in correlation due to DA.

We compared the improvement by DA of synthetic SMART cable measurements of OBP to simulations with DA of synthetic OBP observations from moorings and the GRACE satellites. The DA of SMART cable observations improves the global mean OBP twice as much as the DA of measurements by moorings (cf., Fig. 2). However, several areas of high variability in OBP, such as the Arctic and Southern Oceans, are not observed by SMART cables. In these regions, the simulations with DA of synthetic observations from moorings represent OBP by 20% than simulations with assimilated SMART cable observations. This highlights the importance of measuring highly dynamic regions, especially when they are remote and under sampled.



Fig. 2 Global mean of OBP filtered in time by a 30 day running mean for the observation systems SMART cables, moorings, GRACE satellites and a combination of all three experiments. Left: improvement of RMSE due to DA. Right: improvement of correlation due to DA. Crosses mark monthly values.

DA of GRACE solutions of OBP lead to a larger improvement in the simulation of OBP than the assimilation of SMART cable observations. This is due to the dense observations compared to SMART cables and albeit the lower observations frequency and accuracy of GRACE solutions. While GRACE reduces the error mainly in high latitudes, SMART cables improve OBP particularly in the tropics. Hence, the two observing systems complement each other (cf., Fig. 3).

The additive combination of the three simulations with individual DA of SMART cables, moorings and GRACE solutions leads to an almost global improvement of the representation of OBP with respect to RMSE and correlation. Local errors introduced by the assimilation of measurements from an individual observation system cancel each other out. Thereby an error reduction of more than 40% is obtained in the Indian and Arctic Ocean. The Southern Oceans, Atlantic, and Pacific Ocean are improved by more than 15%.



Fig. 3 Reduction of the temporal mean error by DA of synthetic observations from (a) GRACE observations and (c) moorings. Increase in correlation due to DA of synthetic observations from (b) GRACE observations and (d) moorings.

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