Augmenting the BSH operational forecasting system by *in situ* data assimilation

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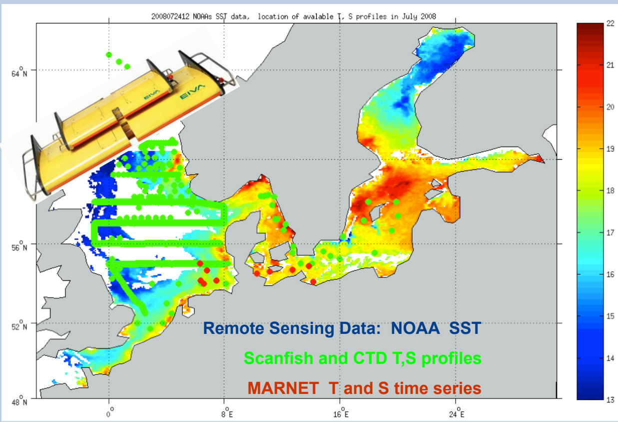
Abstract

Quality of the forecast provided by the German Maritime and Hydrographic Agency (BSH) for the North and Baltic Seas had been previously improved by assimilating satellite sea surface temperature SST *(project DeMarine, Losa et al., 2012)*. We investigate possible further improvements using *in situ* observational temperature and salinity data: Marnet time series and CTD and ScanFish measurements. To assimilate the data, we implement the Singular Evolutive Interpolated Kalman (SEIK) filter *(Pham et al., 1998).* The SIEK analysis is performed locally *(Nerger et al. 2006)* accounting for/assimilating the data within a certain radius. In order to determine suitable localisation conditions for Marnet data assimilation, the BSHcmod error statistics have been analysed based on LSEIK filtering every 12 hours over a one year period (September 2007 – October 2008) given a 12-hourly composites of NOAA's SST and under the experiment conditions corresponding the maximum entropy. The principle of Maximum Entropy is also used as an additional criterion of plausibility of the augmented system performance.

Assimilated Data



Acknowledgement: *The authors are grateful to* ***Simon Jandt[2]*** *for setting up the observational data.*

The data archive is based on measurements collected by BSH, Sweden's Meteorological and Hydrological Institute (SMHI) and the Institute of Marine Research (IMR, Norway)

Principle of Maximum Entropy

general formulation, Kivman et al., 2001

$$He(\rho) = -\int_X \rho(x \mid y)\ln\frac{\rho(x \mid y)}{\mu(x)}\prod dx$$

$\rho(x|y)$ is the probability density function (PDF) of model trajectories realisations x given the y or the conditional PDF also called the analysis PDF, which expresses the state of our know-knowledge about the model state when data are observed. $\mu(x)$ is the lowest information about x. The maximum probable x or mean with respect to $\rho(x/y)$ is

$$x_i = M_m x_m + M_d x_d$$

$$M_m = L_* L, \qquad M_d = H_* H$$

L_*, H_* reflect our assumptions on the model and data error covariances. Operators M_m and M_d are nonnegative, self-adjoint and $M_m + M_d = I$. M is an operator-valued measure. Given λ_i of M_m or M_d matrixes, one can calculate the entropy

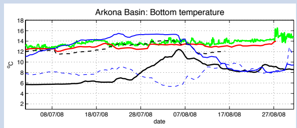
$$He(M) = -trace(M_d \ln M_d + M_m \ln M_m) = -\sum_{i=1}^{N}[\lambda_i \ln \lambda_i + (1-\lambda_i)\ln(1-\lambda_i)]$$

In Kalman type Filtering

The maximum probable x or state vector analysis x^a is $x(t_n)^a = x(t_n)^{f,m} + K_n(d_n - Hx(t_n)^{f,m})$, where $x(t_n)^a$ and $x(t_n)^f$ denote analysis and forecast of the model state at certain time t_n. y_n is observations available at t_n. K is the Kalman gain

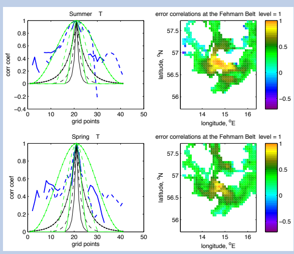
$$K_n = P_n^f H(HP_n^f H^T + R)^{-1}$$

Here, following Pham (1998), P_n^f is the forecast error covariance matrix, H is the observation operator and R is the observational error covariance matrix. To calculate the entropy $He(\rho)$, we just need to know λ_i of the Kalman gain matrix (using SVD decomposition). Such a matrix could be constructed by collecting and considering K_n, for instance, globally over a certain period of time or locally. The last variant is valuable for validation of localisation conditions.

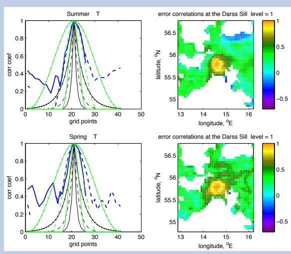


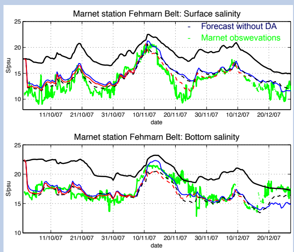
Temporal evolution the bottom temperature forecast at the MARNET station "Arkona Basin" produced with BSHcmod without DA (black); with LSEIK analysis of the model and NOAA's SST DA under statistical conditions corresponding the He= 4.86 for the period 25 June – 8 August 2008 (blue solid); based on NOAA's SST LSEIK analysis under error statistics with He=2.71 for the same period (blue dashed); assimilating satellite SST and in situ T, S data including MARNET(black dashed); assimilating only in situ data (red). The green curve depicts MARNET observations.

MARNET data

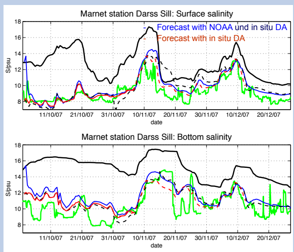


Model error correlations based on the experiments with Maximum Entropy





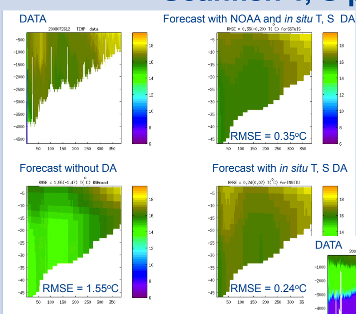
Time series at Marnet stations



The model error correlations obtained with an increment analysis based on the experiments corresponding the Maximum Entropy. The blue curves are the correlations along the latitudes and longitudes. The green and black curves are possible approximations of the correlation functions.

The surface and bottom salinity forecast at the MARNET stations against observations for the period October – December 2007.

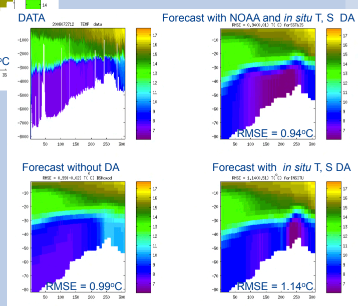
Scanfish T, S profiles



Temperature profiles plotted in the longitude order on 26 July 2008 (to the left) and on 27 July 2008 (to the bottom).

Despite of good agreement between LSEIK analysis and observations both for T and S, the forecast quality is crucially depends on the plausibility of the localisation conditions.

In some locations, the best forecast is possible only with combined satellite and in situ data assimilation.



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