An ensemble-based forecasting system for the North and Baltic Seas using the BSH circulation model and PDAF

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Outline

- Assimilation system with BSHcmod and PDAF
- Assimilation of satellite SST and in situ data
- Assimilation software

Related projects:

**DeMarine**
Development of the assimilation system (German GMES project)

**SANGOMA**
Unification of assimilation tools and new algorithms (EU FP7)
Operational BSH Model (BSHcmod), Version 4

Grid nesting:
- 10 km grid
- 5 km grid
- 900 m grid

Data assimilation:
5 km grid

BSSC 2007, F. Janssen, S. Dick, E. Kleine

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Assimilated Data - Satellite

- Surface temperature (from NOAA satellites)
- 12-hour composites
- Strong variation of data coverage (clouds)

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Assimilation Methodology

- Ensemble Kalman filter (local SEIK)
- 12-hour forecast/analysis cycles
- Ensemble size 8 (sufficient for good results)
- Assumed data errors (SST):
  - uncorrelated, 0.8°C (gave best results)
- Localization:
  - Weight on data errors
  - Exponential, e-folding at 100 km (tuned)
- Implementation:
  - Single program with PDAF (more later)
Deviation from NOAA Satellite Data

**No assimilation**
- RMSE of SST forecast (without DA)
  - RMS = 1.0577
- Bias of SST forecast (without DA)
  - RMS = 0.52981

**Assimilation**
- ensemble forecast (with LSEIK)
  - mean = 0.81149
- over 01.10.2007 - 30.09.2008
Improvement of long forecasts

RMS error over time

black: free model run

Blue/red: 12h assimilation/analysis cycles

green: 5 day forecast

→ Very stable 5-day forecasts

Figure 7: RMS error temporal evolution over the period 16 October 2007 – 21 October 2007 for simulated SST without DA (black curve); LSEIK analysis (red); mean of ensemble forecast based on 12-hourly analysis (blue) and 5 days forecast (green curve) initialized with the analysis state obtained on 16 October 2007.
Validation with independent data (only SST assim.)

MARNET station data

- Reduction of
  - Bias
  - RMS error

1 year mean over 6 stations:

<table>
<thead>
<tr>
<th></th>
<th>RMSe</th>
<th>bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>free</td>
<td>0.87</td>
<td>0.3</td>
</tr>
<tr>
<td>data</td>
<td>0.59</td>
<td>0.11</td>
</tr>
<tr>
<td>assim.</td>
<td>0.55</td>
<td>0.08</td>
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</table>

Red: Assimilation 12h forecasts

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Independent salinity data

No salinity data assimilated

Success depends on localization method

Difficulties at the bottom (model resolution only 5 km)

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**Assimilation of MARNET data**

- **Salinity:** Significant improvement at surface and bottom
- **Success depends on localization parameters**

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Assimilation of MARNET data

Marnet station Darss Sill: Surface salinity

Marnet station Darss Sill: Bottom salinity

For details see Poster by Losa et al. (Board 26)

Also CTD and Scanfish data

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PDAF: A tool for data assimilation

PDAF - Parallel Data Assimilation Framework
- a software to provide assimilation methods
- an environment for ensemble assimilation
- for testing algorithms and real applications
- useable with virtually any numerical model
- also:
  - apply identical methods to different models
  - test influence of different observations
- makes good use of supercomputers
  (Fortran and MPI; tested on up to 4800 processors)

More information and source code available at
http://pdaf.awi.de
Logical separation of assimilation system

**Model**
- initialization
- time integration
- post processing

**Filter**
- Initialization
- analysis
- re-initialization

**Core of PDAF**

**Observations**
- obs. vector
- obs. operator
- obs. error

**For online implementation:**

- Explicit interface
- Indirect exchange (Fortran: module/common)

External Do-loop can be avoided – lower flexibility!
Building an assimilation system with PDAF

Don’t adapt the model to the assimilation system

→ Attach DA functionality to model

Very small changes to model code:

➢ Model time stepper not required to be subroutine
➢ Low abstraction level for optimal performance
➢ Elementary user-supplied routines
  (interfacing with model, observation handling)
➢ Model-sided configuration of assimilation system

→ Run assimilation system like model with additional parameters

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SANGOMA: Development of assimilation tools

- Tools are addition to assimilation frameworks
  (PDAF, OpenDA, OAK, SESAM, …)

- Past PDAF development focused on core part
  (framework & filter algorithms)

- In SANGOMA:
  - New filters for nonlinear assimilation
  - Addition of tools (collaborative development)

Diagnostics
Assess assimilation performance

Perturbations
Ensemble generation

Transformations
e.g. for Gaussianity

Utilities
e.g. for particular observations

More information
http://www.data-assimilation.net
and next talk by Jean-Marie Beckers

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Ongoing and future work

- Switch to HBM (HIROMB-BOOS model)
- Switch to ESTKF filter (Nerger et al., MWR, 2012)
- Include coastal mesh (900m resolution)
- Include Ecosystem model ERGOM
- Assimilation of ecosystem data


Posters:
- Losa et al. – board 26 – on in situ data assimilation
- S. Siiriä et al. – board 27 – Baltic Sea operational data assimilation
- Ehlert et al. – board 47 – Marine GMES Products for German Users

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Summary

- Assimilation system of BSHcmod and PDAF for operational use
- Successful assimilation of satellite SST & in situ data
- Flexible assimilation framework PDAF
- New tools and assimilation methods expected in SANGOMA

Thank you!

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