

WP4: T4.1. Impacts on the Gulf of Finland (MSI).

Objective: To provide a detailed assessment of the Gulf of Finland water quality for the coastal zone and open sea during the time periods of marine regime shifts in changing climate conditions.

Deliverables:

1. High spatial resolution coupled physical-biogeochemical model simulations of present time slice 1997-2006 and two 10-year future climate time slices (**month 30, June 2011**).
2. Uncertainty estimates of the Gulf of Finland model output fields (**month 33, September 2011**).
3. Distribution maps of water quality indicators in the coastal zone and open Gulf of Finland (**month 33**).
4. Recommendations for future country-wise actions on achieving and preserving good water quality of the Gulf of Finland management its marine resources (**month 33**).



*Marine Systems Institute
at Tallinn University of Technology*



Physical model: General Estuarine Transport Model (GETM)

General Estuarine Transport Model

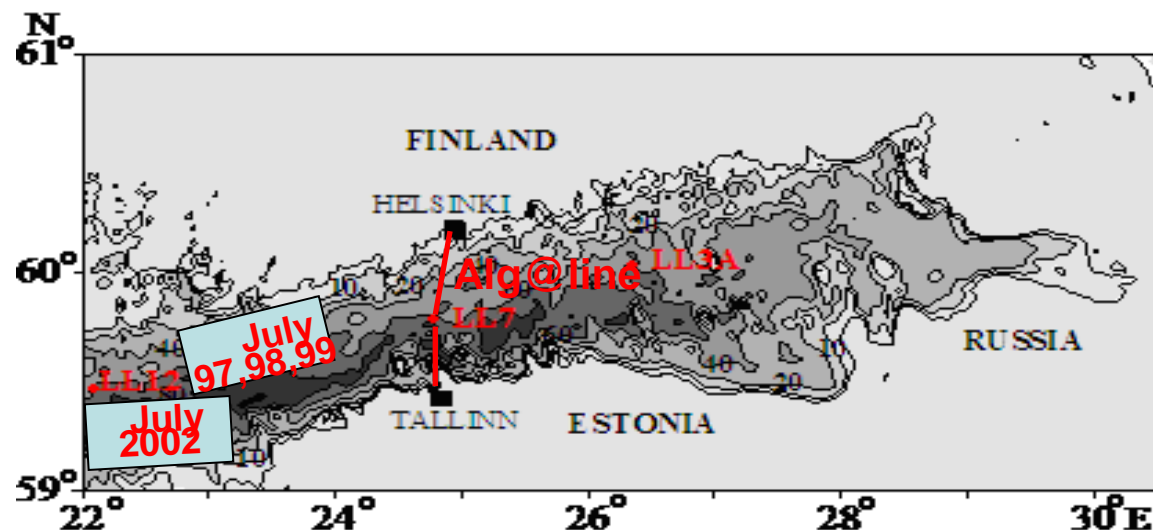


Setup for present time slice (1997-2006):

1. Bathymetry: Seifert et al. (2001), interpolated on 0.5 nm grid.
2. 25 σ -layers in the vertical.
3. Open boundary of the Gulf: nested-grid approach, elevations and vertical slices of temperature and salinity from larger scale (2 nm) Baltic Sea simulation.
4. Atmosphere forcing (wind stress and heat flux components):
RCA3.0 (Rossby Center Atmosphere model) model (3h time step, ERA-40).
5. Initial temperature and salinity fields: MOM (Modular Ocean Model), mean 3D fields for December 1996.
6. Rivers: ICZM-ODER project (from MOM setup).
7. Output: 6h mean values

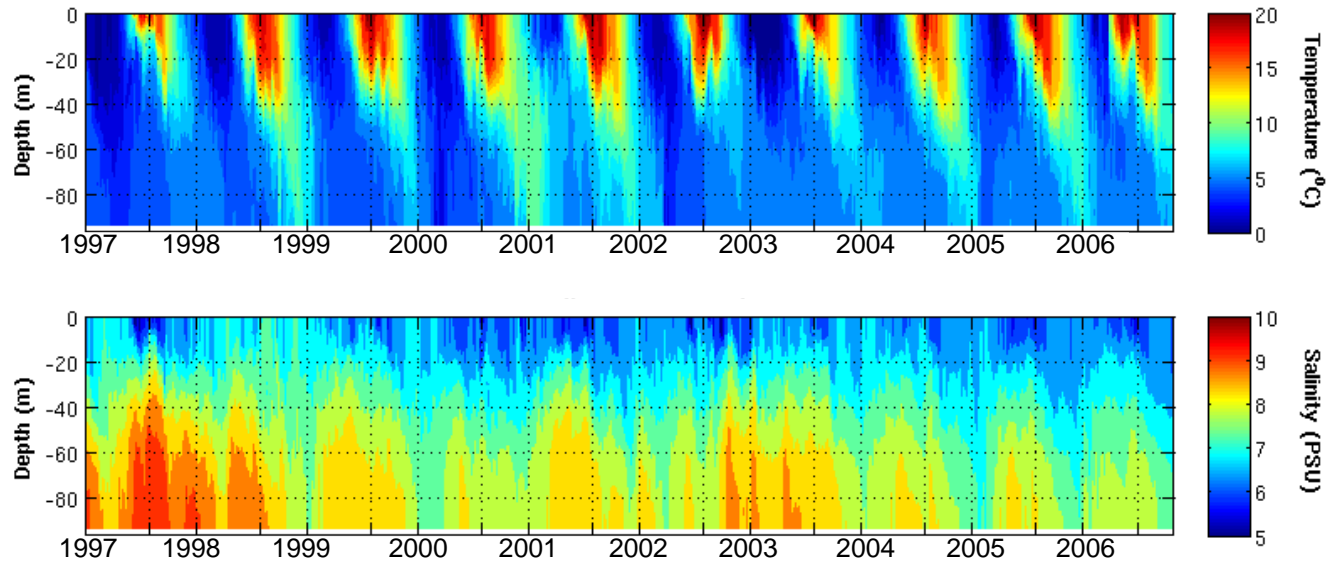
Validation data

- a) time series of temperature, salinity, phosphate, nitrate, silicate, oxygen and chlorophyll *a* in the surface and bottom layer at HELCOM monitoring stations **LL12** (60 samples), **LL7** (100 samples) and **LL3A** (40 samples) in 1997-2006.
- b) case studies in **July 1997, 1998, 1999 and 2002** (temperature, salinity, phosphate, nitrate, phytoplankton and chlorophyll *a*). Data cover the coldest (1998) and warmest (2002) summer within selected time slice.
- c) Alg@line data (Estonian Marine Institute, phytoplankton on group level) for spring bloom and late summer cyanobacterial bloom validation in **1997-2005**. Weekly data from 4 m depth, horizontal resolution about 5 km.



GETM: simulation results 1997-2006

Temporal course of vertical distribution of temperature and salinity near the location LL7.

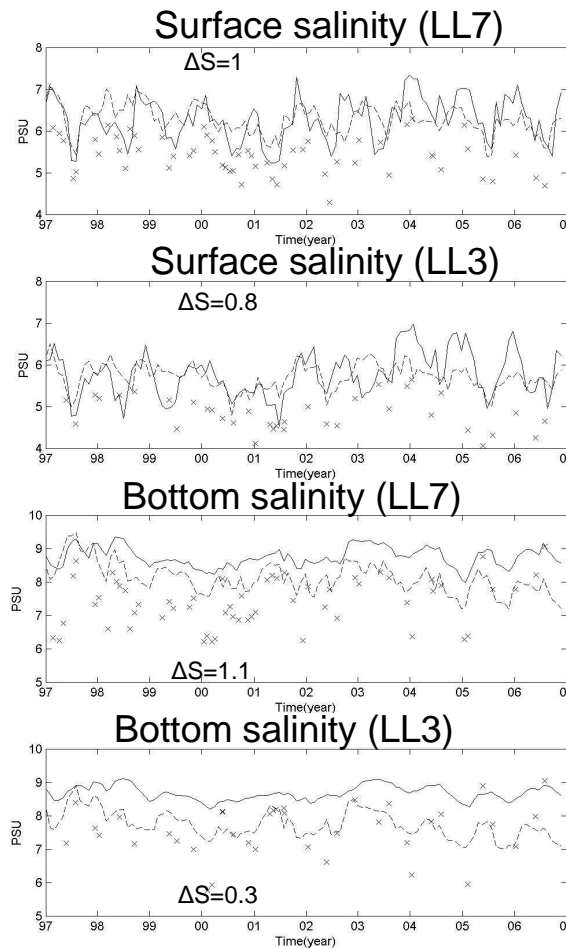
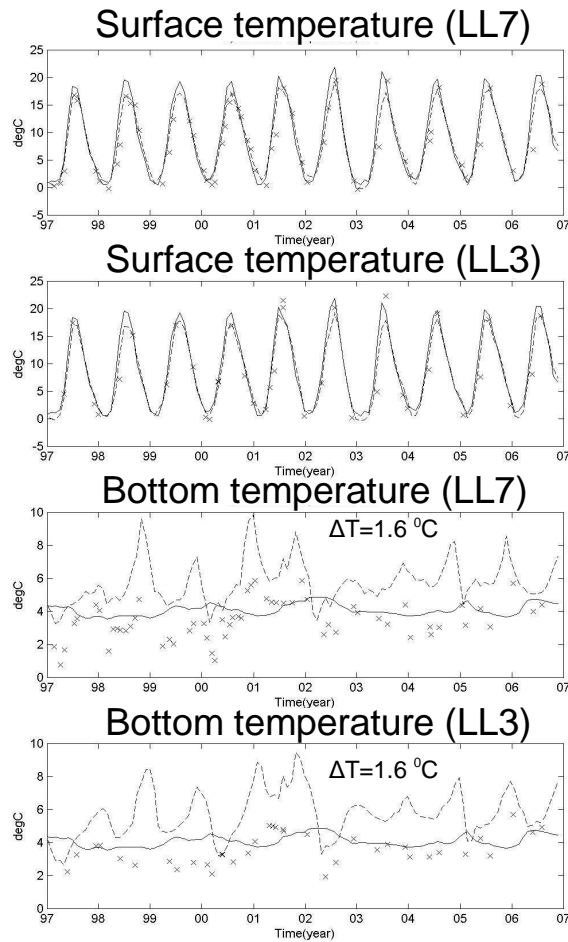


Annual upper layer temperature cycle is reproduced by the model:

- 1) Seasonal thermocline started to develop in the end of April-beginning of May
- 2) Depth of thermocline varied between 10-20 m
- 3) The strongest thermal stratification occurred in July-August
- 4) Seasonal thermocline started to erode in the September
- 5) Surface layer reached the freezing point except warm winters 2000/2001 and 2001/2002

Temporal course of vertical distribution of the salinity showed high seasonal and interannual variations both in the bottom and surface layer.

GETM: comparison of simulated and measured temperature and salinity (1997-2006)



Observed (x) and **simulated GETM** (dashed line) and **MOM** (solid line) surface and bottom temperature (**left panel**) and salinity (**right panel**) at HELCOM monitoring stations LL7, LL3A.

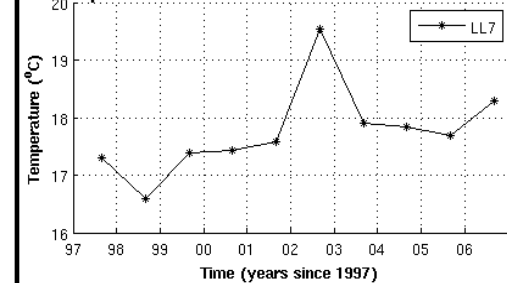
$$\Delta T = \overline{T}_{\text{GETM}} - \overline{T}_{\text{Obs}}$$

$$\Delta S = \overline{S}_{\text{GETM}} - \overline{S}_{\text{Obs}}$$

Overbar means the time averaging over the whole simulation period

GETM overestimates:
1. bottom temperature
2. surface and bottom salinity

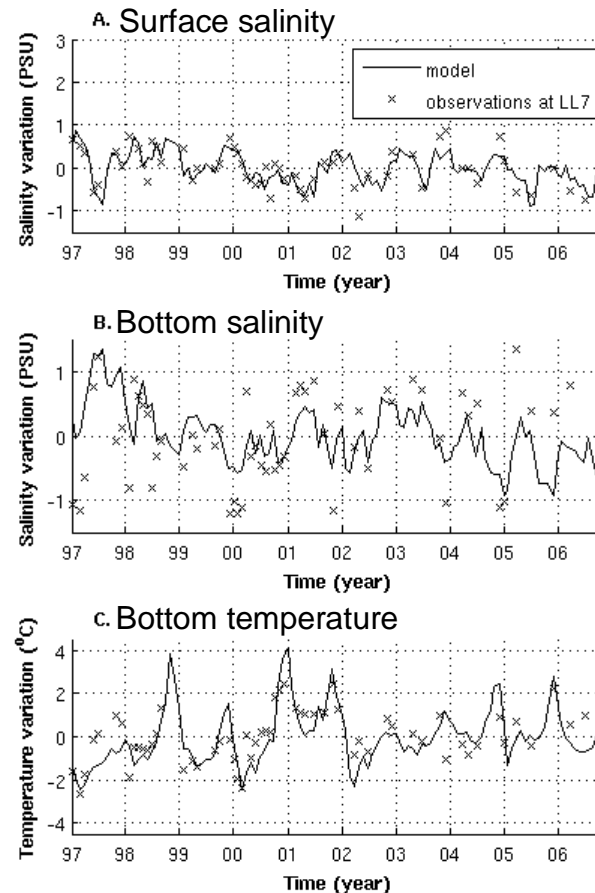
Simulated mean August surface temperature at station LL7.



Interannual variability agrees with satellite SST (Siegel et al. 2006). GETM underestimates surface temperature 1-1.5 °C. The coolest (1998) and warmest (2002) summers are resolved.

GETM: comparison of simulated and observed variability of temperature and salinity at LL7 (1997-2006)

Simulated salinity and temperature are monthly averaged and mean values over the whole period were subtracted from corresponding datasets.



Natural variability of salinity in the near bottom layer is high, not resolved by model

Bottom layer temperature variability is resolved by model

Simulated (solid line) and **observed** (crosses) variability of monthly mean surface (a) and bottom (b) salinity and bottom temperature (c) at the location LL7.

Measurements were averaged if there exist more than one observation in the month.

GETM: comparison of simulated and measured temperature and salinity (1997-2006)

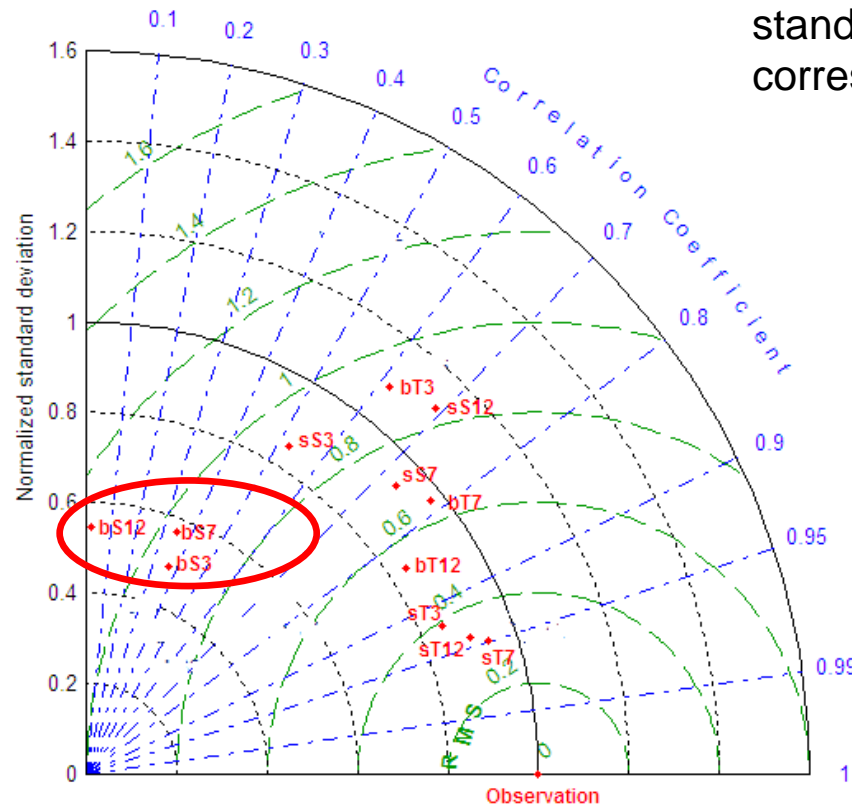
Normalized standard deviation:

standard deviation of the simulated data divided by corresponding standard deviation of the observations.

RMSD:

$$E'^2 = \frac{1}{N} \sum_{n=1}^N [(f_n - \bar{f}) - (r_n - \bar{r})]^2$$

Where: E' - centered RMS difference,
(f) - observation and (r) - model data



Simulated salinity variability in the bottom layer is underestimated.

Comparison of simulated data by GETM to observed data from HELCOM monitoring stations LL12, LL7 and LL3a. The parameters are temperature (T) and salinity (S). Small letters *s* and *b* indicate surface and bottom values, respectively.

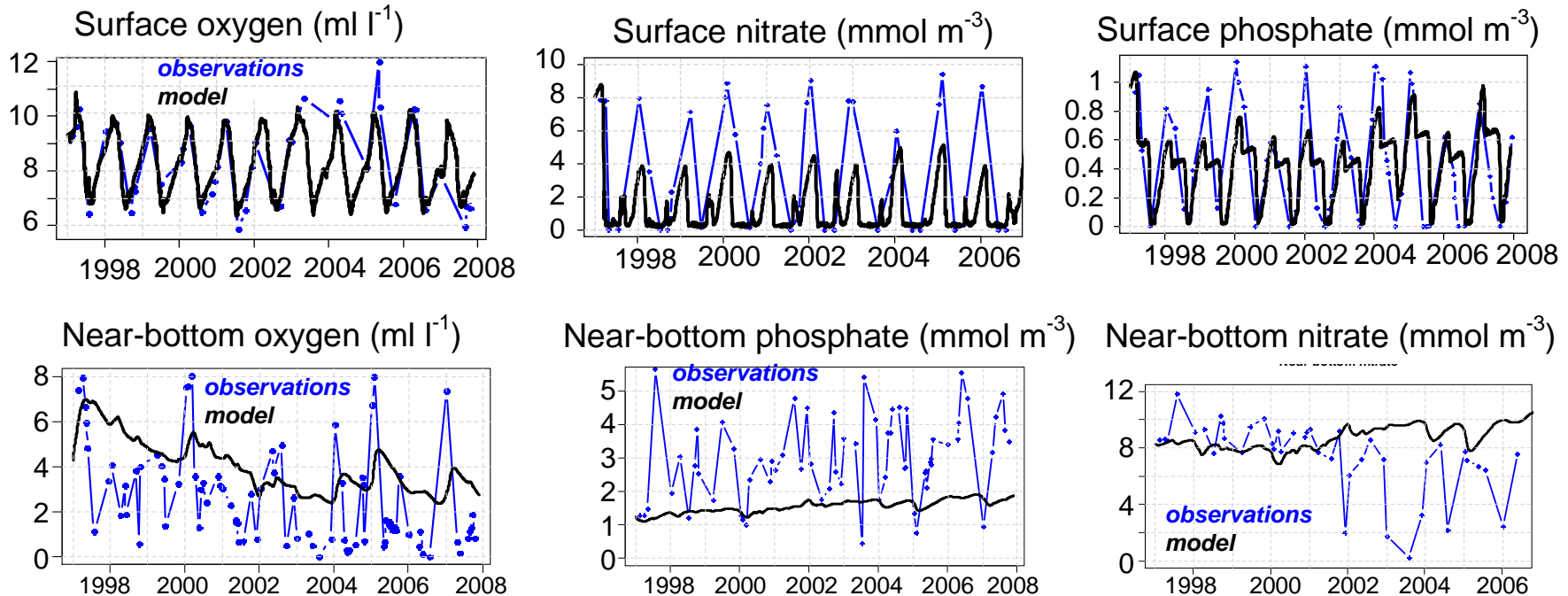
Problems in GETM:

1. Something is wrong with mixing during cooling period.
2. Conflict between boundary conditions from 2 nm whole Baltic Sea model and 0.5 nm model.

Model improvement:

1. Refinement of 2 nm grid in the Baltic Sea to 0.5 nm grid in the Gulf of Finland at the entrance.
2. Adaptive vertical coordinate system (GETM community)

1D chemical-biological model ERGOM coupled with GOTM:



1. Near-bottom oxygen overestimation, no anoxia.
2. Underestimated phosphate release from sediments
3. Changes connected to lateral transport of material not resolved

Gulf of Riga test-case: 3D ERGOM coupled with GETM