Progress in data assimilation: the future

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WP 7.3

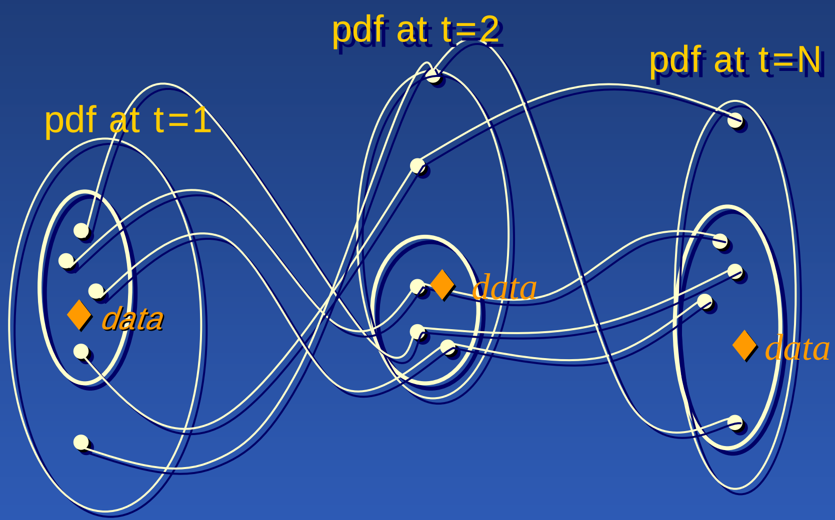
Task 7.3: Data assimilation (DA)

- Task 7.3.1 Development of advanced sequential ensemble based filters

Ensemble Kalman filter (EnKF, NERSC, TOPAZ)
sea ice parameters assimilation
Sequential Importance Resampling (SIR) non-linear filter (IMAU, AWI)
sea ice and biological parameters/ properties optimization
Reduce order Kalman filter, SEEK filter (CNRS)
simultaneous state (UML properties) & parameter (air-sea fluxes) estimation

- Task 7.3.2 Global OPA data assimilation

Statistical DA methods



The idea – approximating the continuous probability density function (pdf) with an ensemble of δ-functions – particles,- which evolves according to a stochastic dynamical model (t is analysis step).

EnKF progress in MERSEA

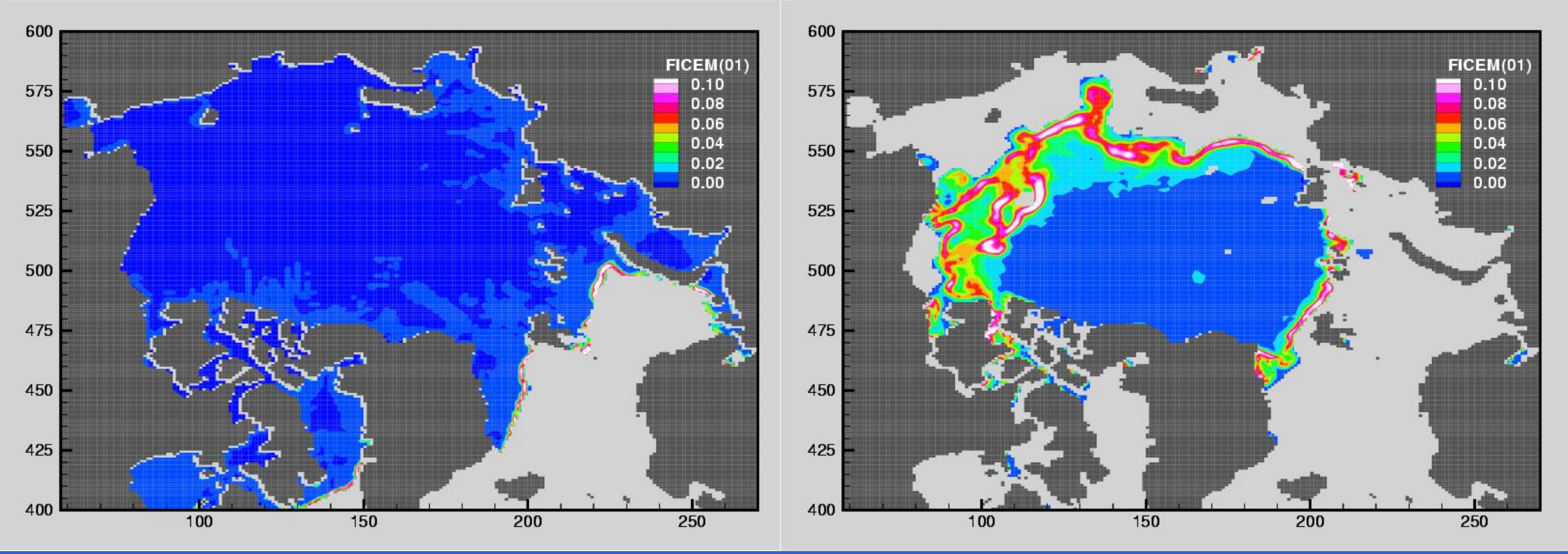
(NERSC)

- Demonstration of flow-dependent covariances
- More variables assimilated in TOPAZ
  - V0: SLA, SST, ice concentrations
  - V2: Ice drift from CERSAT, Ifremer
  - Demonstrates 4D Lagrangian assimilation
  - V3: Coriolis profiles
- Algorithmic improvements
  - Square root schemes AND localization to be pursued
- Technical improvements
  - MPI parallelization
    - memory requirements reduced
    - from 25Gb to 1Gb in TOPAZ
    - Fits on clusters
- Distribution
  - EnKF code served on web
    - open source (F90)
    - updates documented
  - Linked from MERSEA web page

Ensemble Variances

Temporal evolution TOPAZ2
(variance of ice concentrations)

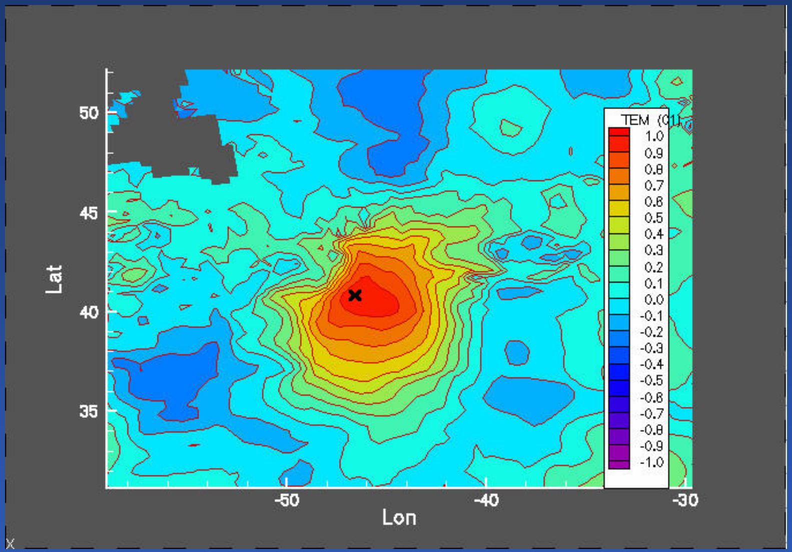
1st March 2006 — 13th Sept 2006

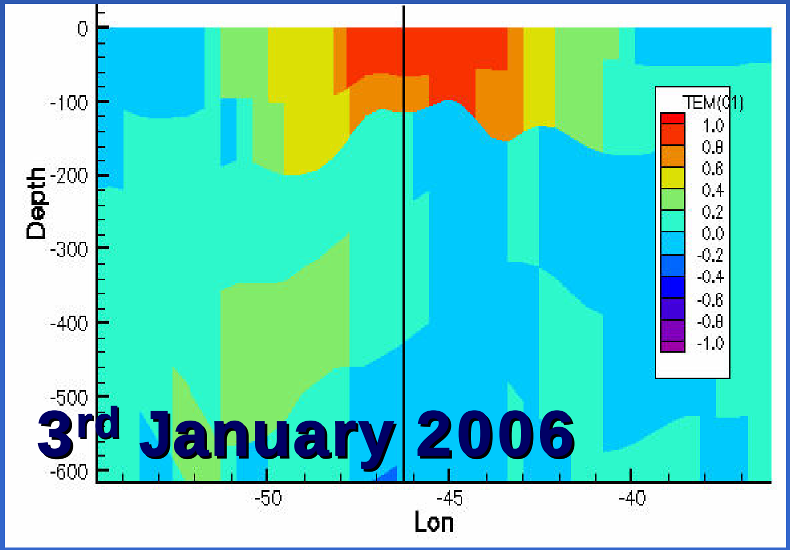


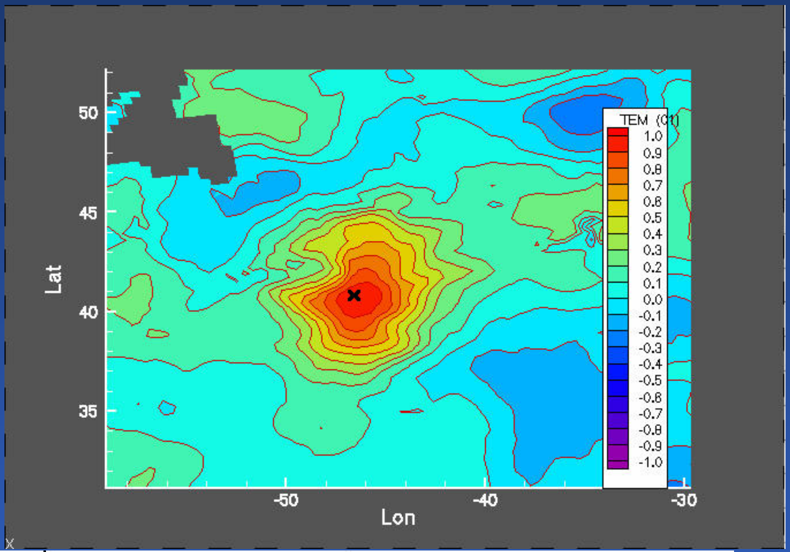
http://topaz.nersc.no

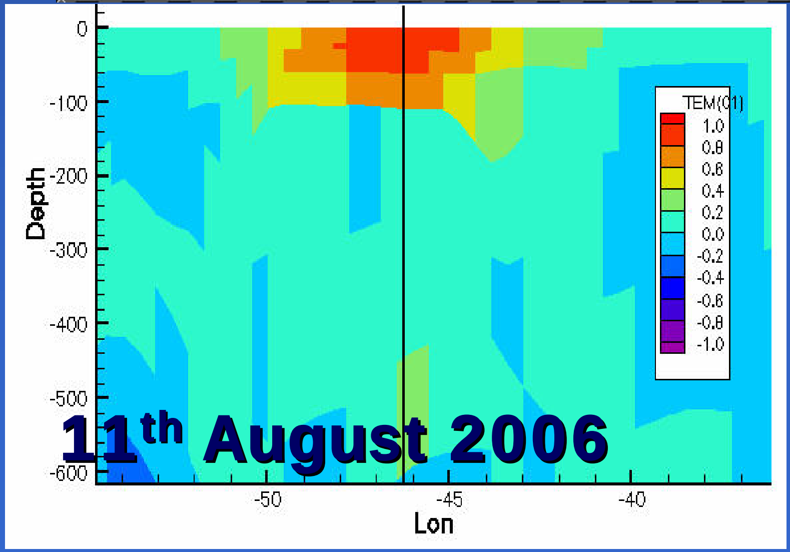
Ensemble Correlations

Temporal evolution – horizontal and vertical









Assimilation of sea-ice drift
example of a 4D Lagrangian dataset

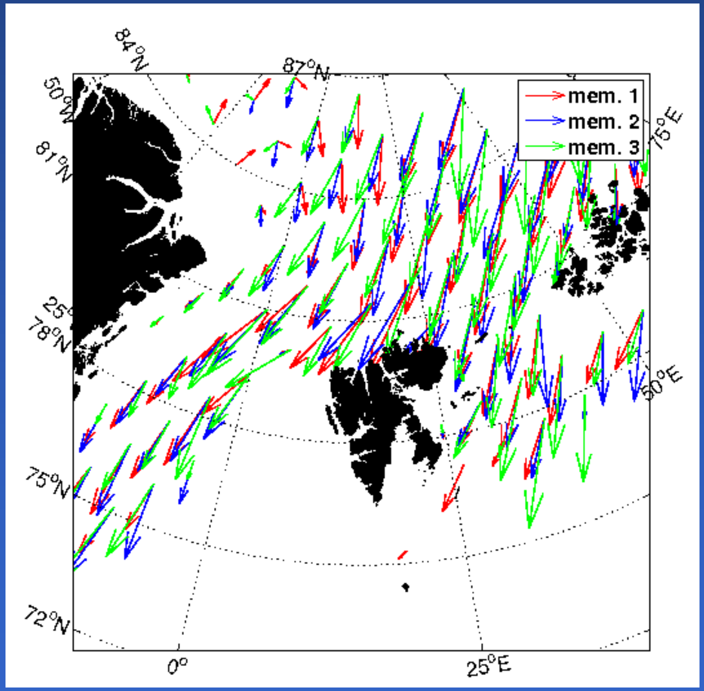
CERSAT data
- 3-days products
- Pattern recognition

Almost a diagnostic variable
- Direct insertion has no effect
- Need to be correlated to state variables

4D Lagrangian assimilation
- Compute the 3-days drift at the time of the actual drift
- Ensemble correlations with a posterior state vector

Implemented in Arctic V2 system since November 07

Impacts mostly
- Ice thickness
- Ocean currents



How it works

Run HYCOM

– Dump ice velocities from each member

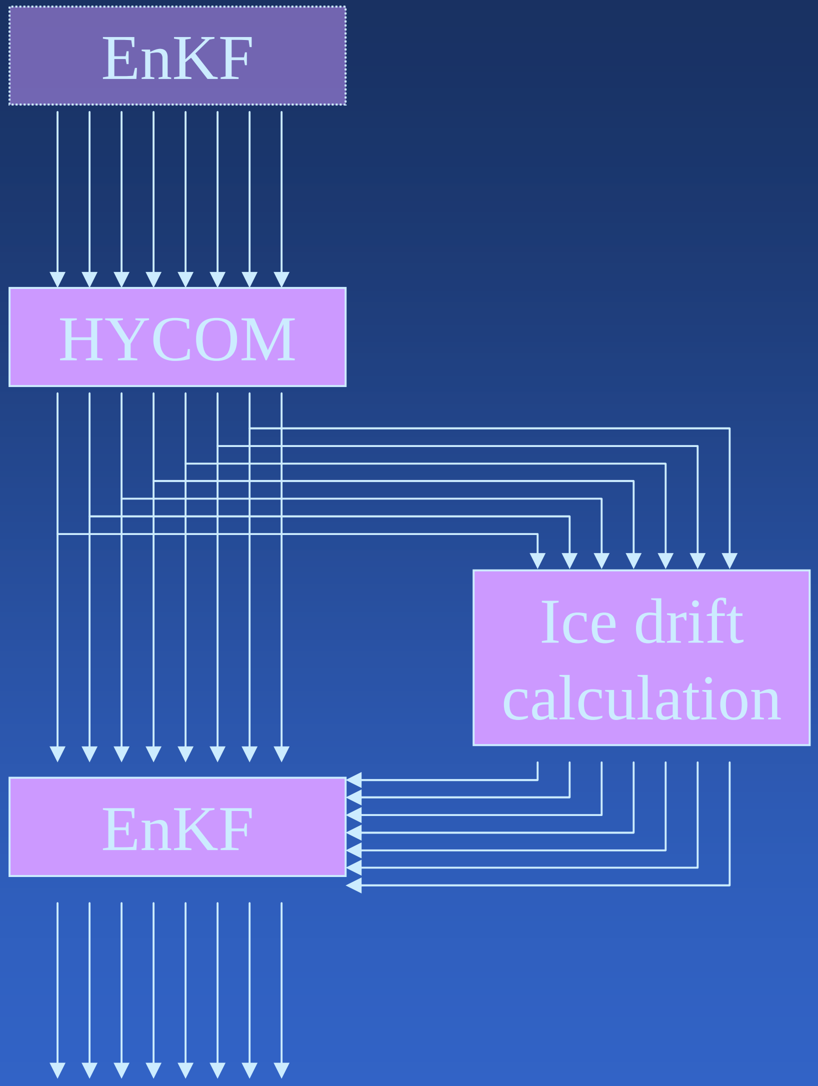
Compute ensemble ice drift (tracer advection)

– Takes a few minutes

Calculate innovations and assimilate in EnKF

Run HYCOM

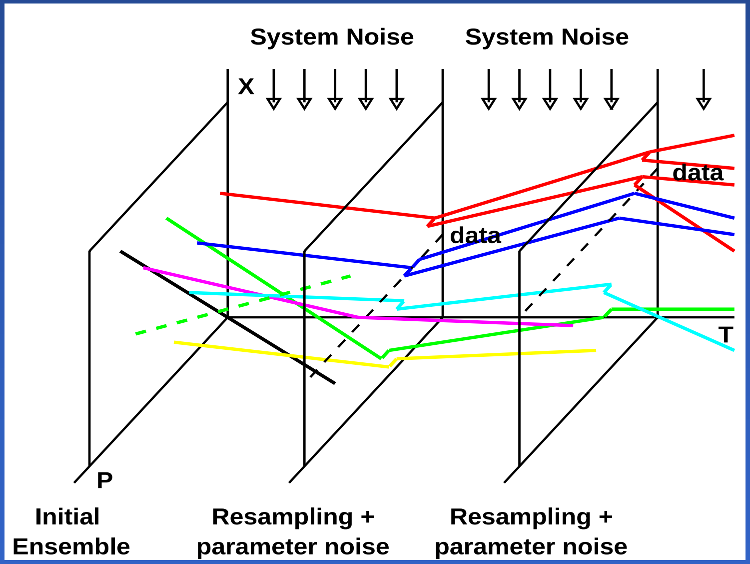
…



SIRF progress in MERSEA
(IMAU/AWI)

Non-linear filter to handle non-Gaussian error statistics.

One updates probability of the particles according to their agreement with the observed data. The full forecast and data errors statistics is used.



Algorithmic developments

- Simultaneous state and parameter estimation
- Smoothing schemes and localization
- Different sampling strategies

Technical/algorithmic improvement

- Decreasing ensemble size

Implementation

- Sea ice modelling
- Biogeochemical state/parameter/model noise variance optimization

Distribution

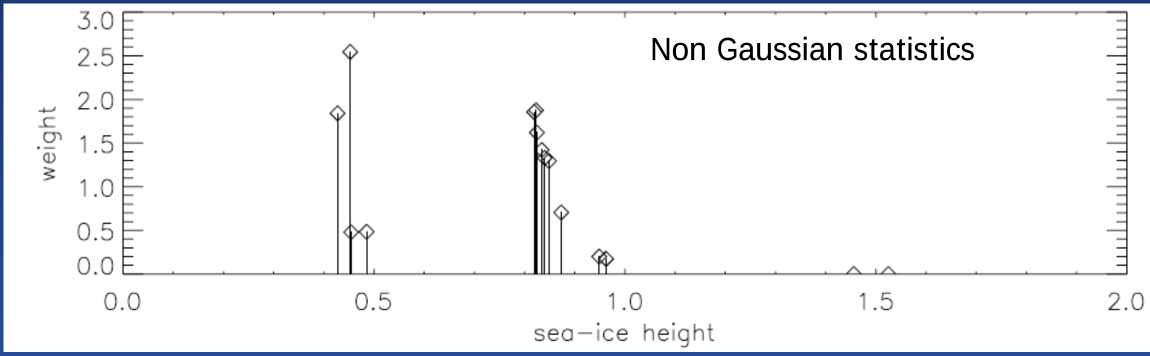
- Deliverable 7.3.4
- Linked from MERSEA web page

Improving sea-ice dynamics using a local SIR filter

Model:
Finite element ocean and sea-ice model (FESOM) developed at the AWI; 27840 grid points, $\Delta x \sim 15$ km, with local refinement close to coasts.

Modelling period:
01.07.2004 – 01.07.2005

Observations:
SSM/I (concentration)
Quickscat (drift)

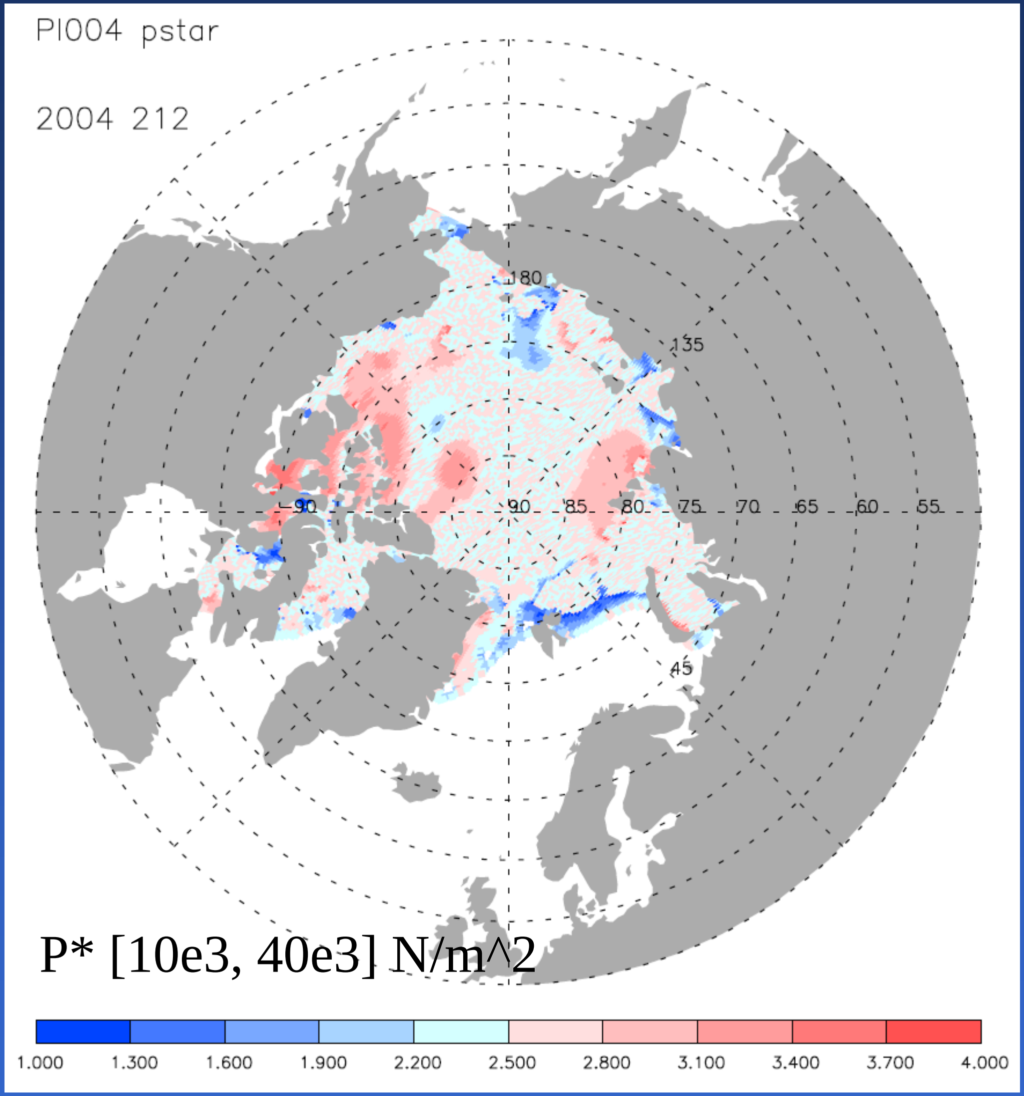


Estimation problem (highly nonlinear!) :
solved for the model state and one of the parameters P* in ice strength parameterization;
Local SIR successful with 16 members(!);
P* appeared to have large spatial (80%) and temporal (30%) variations.

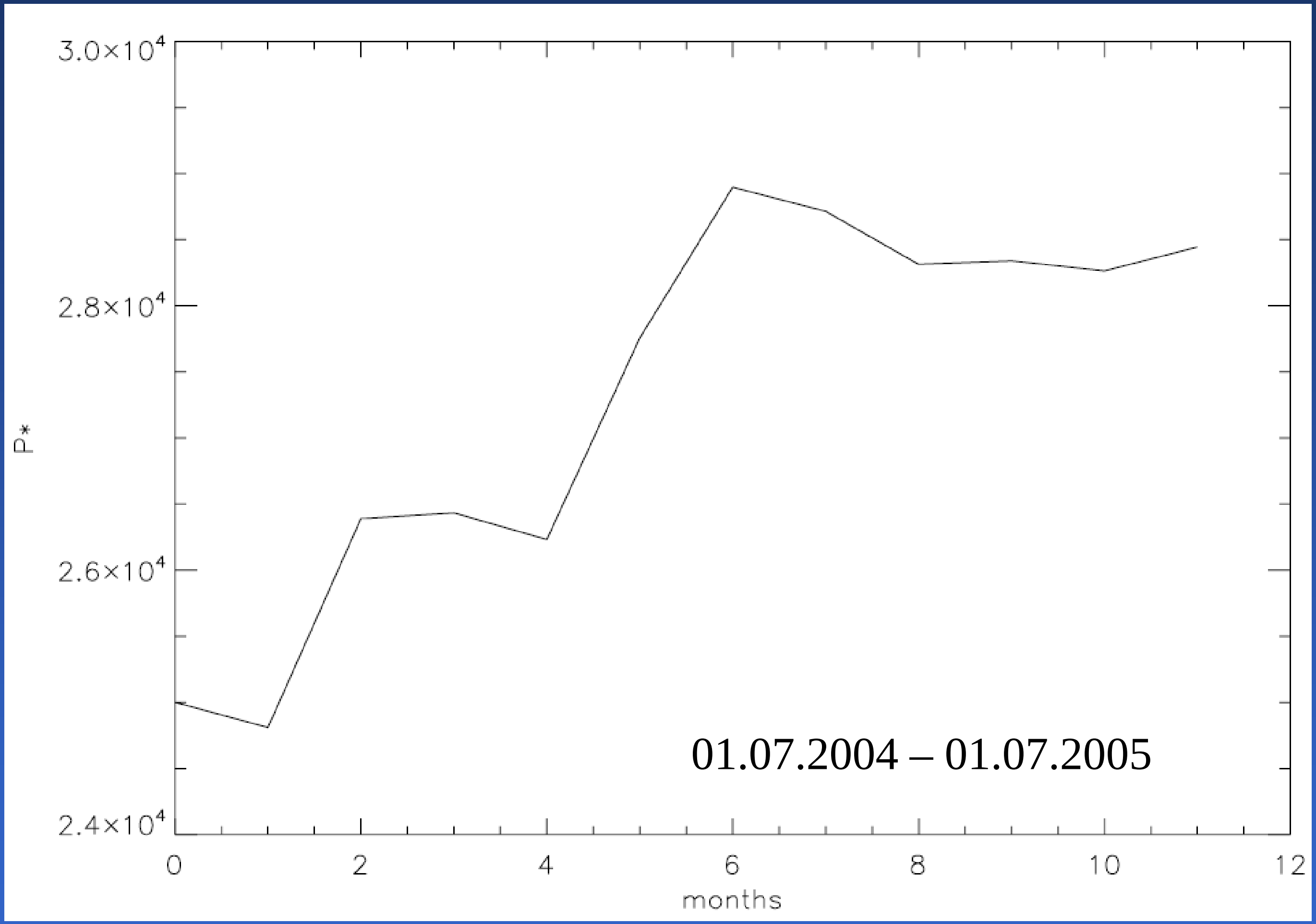
In cooperation with
IMAU: Arjen Terwisscha
AWI: Sergey Danilov, Ralph Timmermann, Sven Harig

Thanks to
TUDelft: Julie Pietrzak,
DMI: Nicolai Kliem,
U. Calgary: Alex Braun

Spatial distribution of P*



P* temporal variations



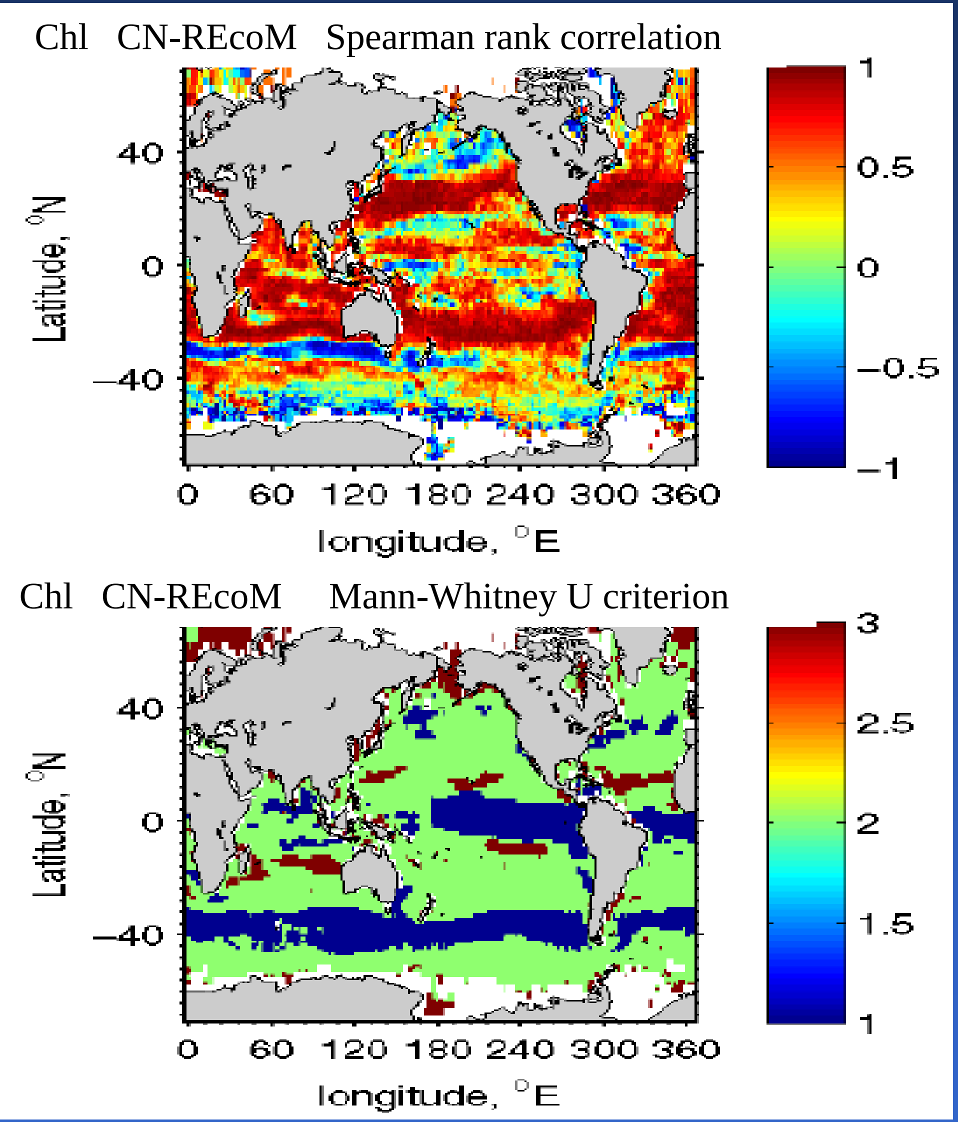
Assessing CN-REcoM

Monthly mean chlorophyll concentrations against SeaWiFs colour data, obtained with a version of REcoM coupled to MIT general circulation model (2^ox2^o resolution).

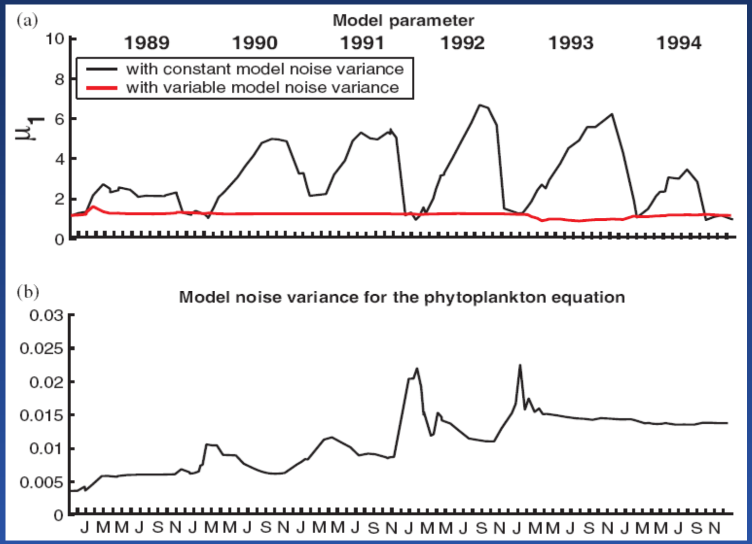
In collaboration with
M. Losch, C. Völker and S. Hohn (AWI)

Green colour means:

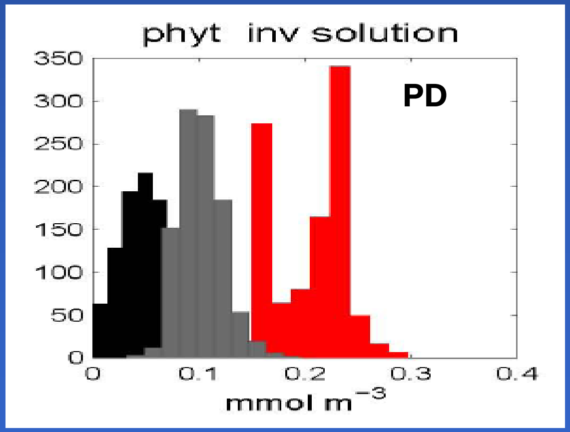
All modes of model and data distributions are similar and sampled equally well



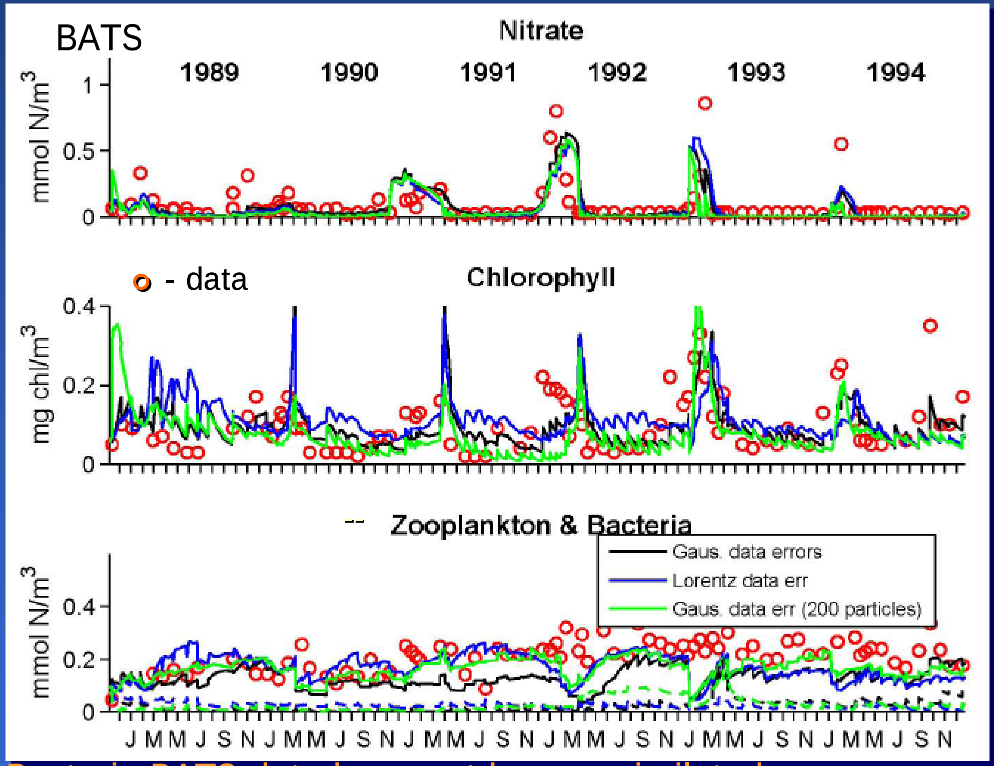
SIRF in ecosystem modelling



Ensemble size may be de-creased if new ini particles generated from the posterior estimated pdf



Model noise variance estimation The more correct the model errors are accounted for, the better biological model parameters estimates and therefore the model state forecast are (Brasseur et al., 2005).



Bacteria BATS data have not been assimilated

SEEK progress in MERSEA

(CNRS/LEGI)

SSH
TEM
SAL
U
V

x_k^a Ocean state vector

CE (**latent heat, Coef.**)

CH (**sensible H. Coef.**)

CLOUD(**cloud coverage**)

PRECP (**precipitation**)

TA (**air temperature**)

EA (**air humidity**)

P_k^a: Forcing parameters: assumed Source of errors

« Augmented » state vector

A procedure of air-sea turbulent fluxes estimation by assimilating SST and SSS data has been developed (Skachko et al., 2007; Skandrani et al., 2008).

Several selected flux parameters are included in the control space.

Apply the correction in the augmented ocean space $\mathbf{x_k^a}$ and $\mathbf{p_k^a}$.

1) correction of the ocean state $\mathbf{x_k^a}$ in the current cycle.

2) Use of the corrected forcing parameters $\mathbf{p_k^a}$ for the next cycle of forecast.

Validation of the scheme using twin experiments

MODEL: OPA/NEMO OGCM
Grid: (2°x2°)
PERIOD: year 1992
with original forcing
ERS/TAO winds, NCEP data

CONTROLLED PARAMETERS:
Latent heat flux exchange Coefficient (CE)
Sensible heat flux exchange coefficient (CH)
Cloud coverage (CLOUD)
Precipitations (PRECP)
Air température de l'air (TA)
Air Humidity (EA)

TRUE OCEAN :
OPA simulation with original bulk formulations

FALSE OCEAN:
OPA simulation (free run)
with perturbation of the selected parameters (CE, CH,CLOUD,….EA) (sampled in the assumed Gaussian error pdf)

SYNTHETIC OBSERVATIONS :
SST and SSS

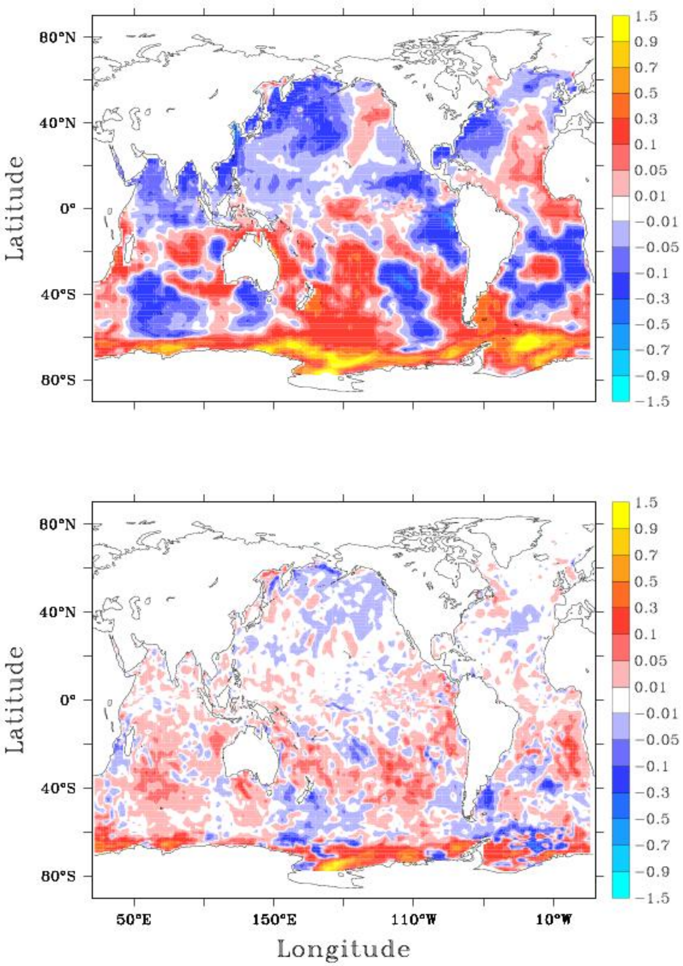
ASSIMILATION

Quality of Temperature correction and forecast

TEM on the 16th of January 1992

Without correction

With correction

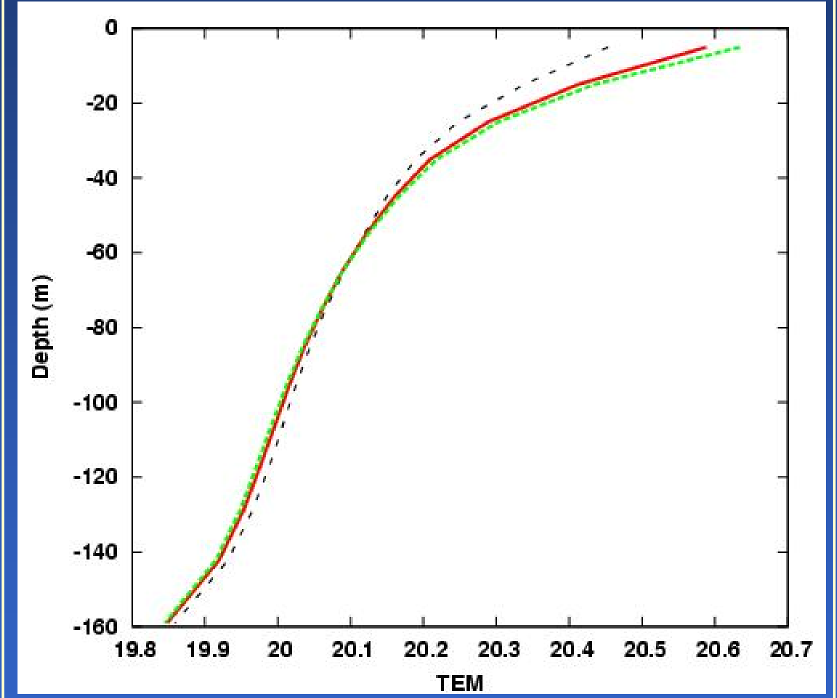


1992/03/21

------- Without correction

——— With correction

——— Reference

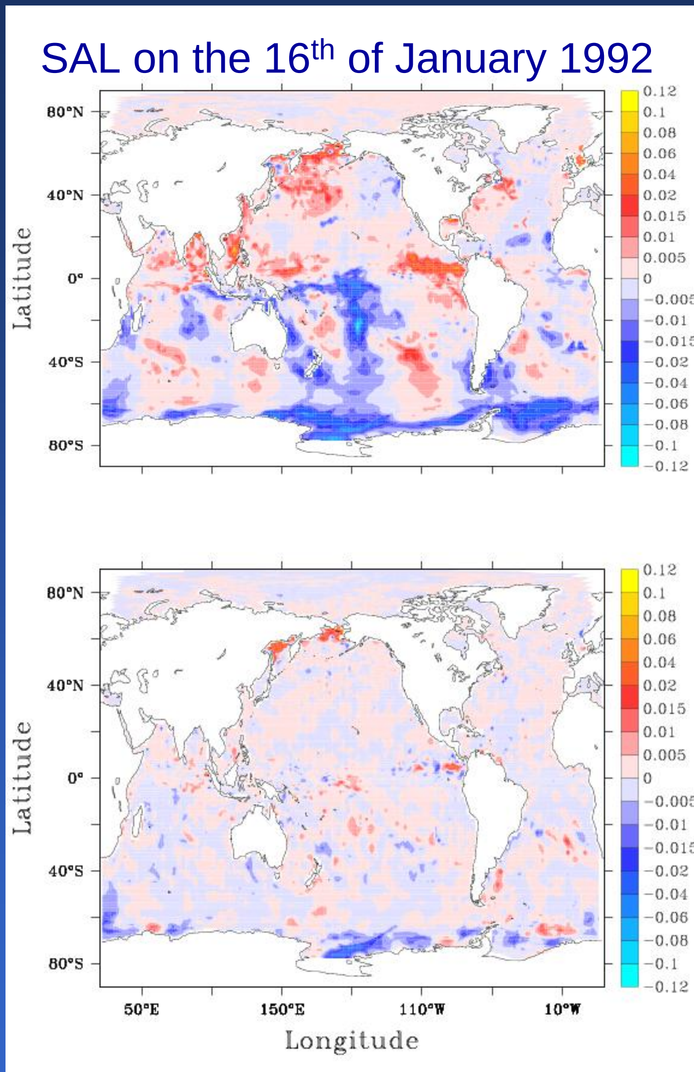


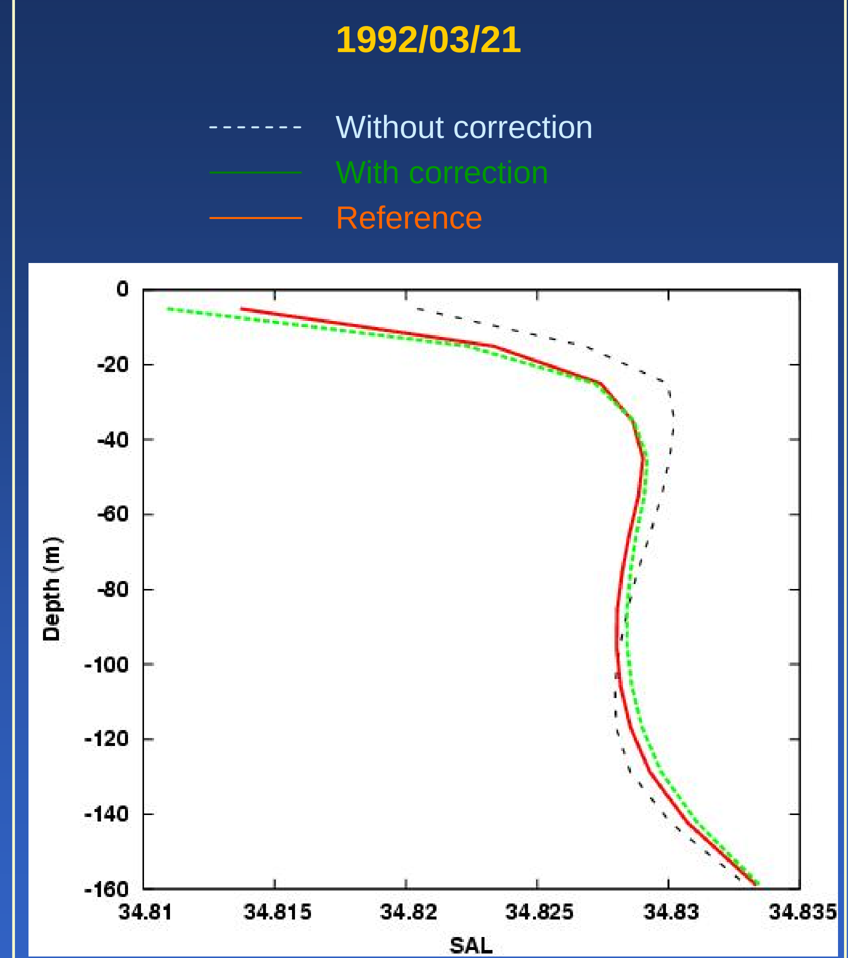
Improvement of TEM profile forecast

Quality of Salinity correction and forecast

Without correction

With correction





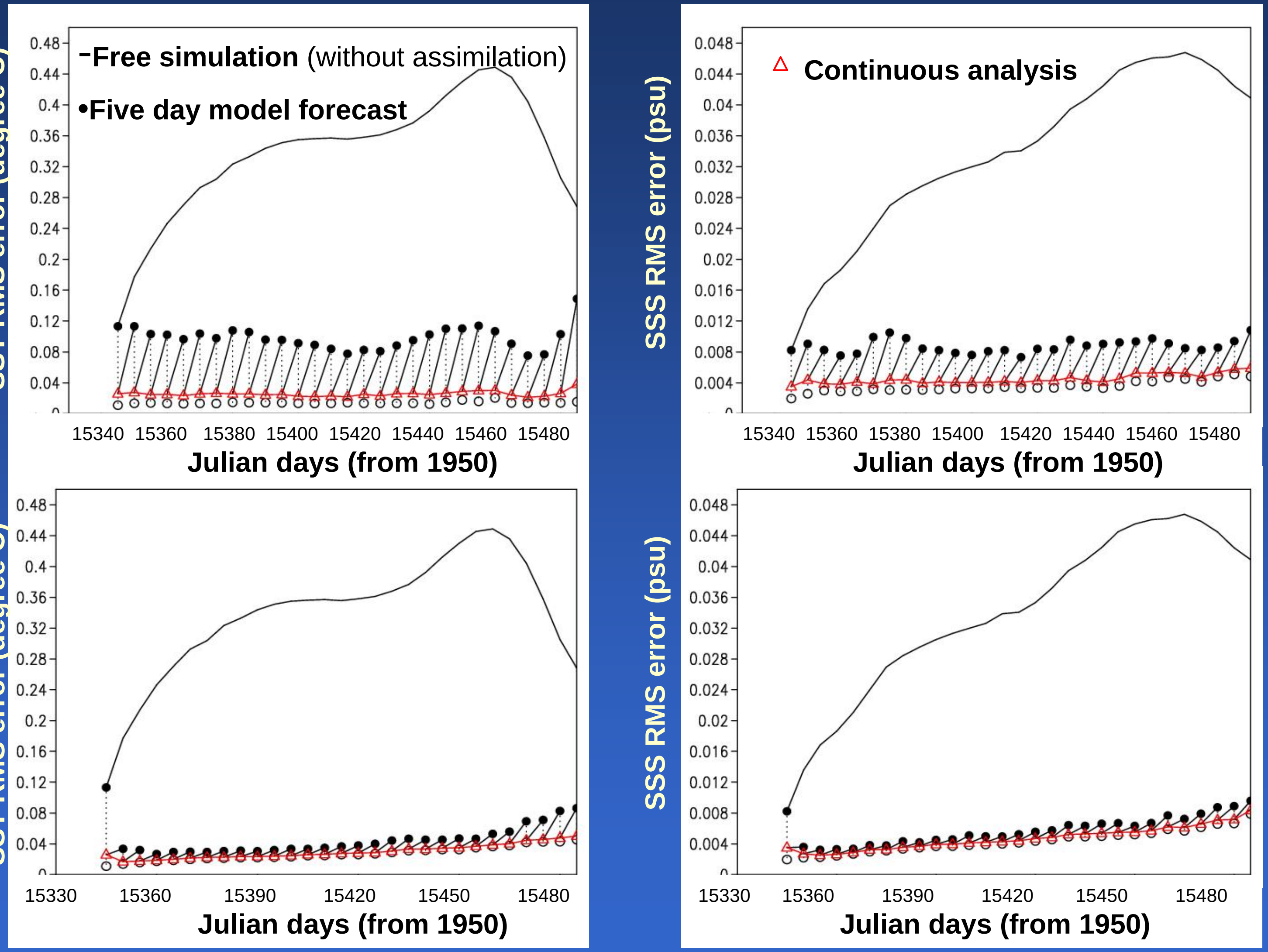
Improvement of SAL profile forecast

Skandrani et al, 2008

5 months RMS error evolution with respect to SST and SSS for the world ocean (except the Northern polar zone)

Without forcing correction

With forcing correction



Assimilation of simulated data in global OPA 2°x2°

➢Improvement of the SST/SSS forecast around 80% of error reduction

Perspectives

The new SEEK scheme will be applied on a realistic assimilation experiment by using a French operational (MERCATOR) re-analysis data as observations to check if the forecast can be improved by correcting the fluxes.

SIRF tests with ocean general circulation models OGCMs

Physical constraints?

Computational costs

- Is it possible to use less members? (EnKF, SIRF)
- Examine square root schemes with localization (for EnKF, NERSC)

Perspectives

Ice modelling

– The work on the sea-ice parameters estimation should be continued (IMAU, AWI in cooperation with Uni Alberta, and TUDelft)

Ecosystem models

– Non-Gaussian variables!
– Assimilate ocean colour with Gaussian anamorphosis (NERSC, TOPAZ, MyOcean)
– Local SIRF (state&parameter estimation)
– SEEK – MERCATOR VERT, MyOcean

Strong non-linearities (ice and ecosystem modelling)

– More hybrid methods (EnKF – SIRF, variational – ensemble based methods)