High Resolution Assimilation Into Ocean Models Through a 4D re-analysis

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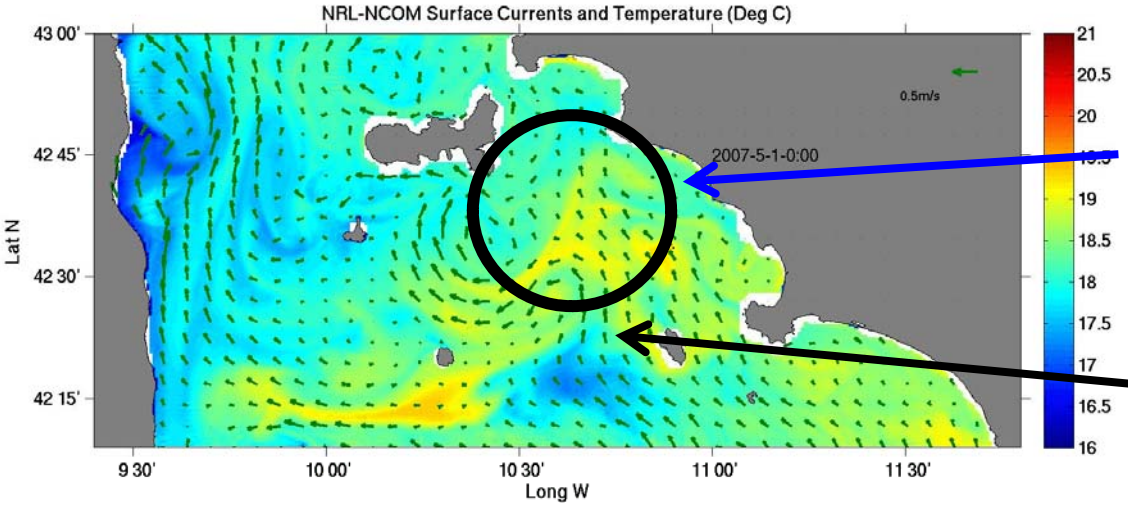
Outline:

- **Motivation**
- **Data Assimilation Problem**
- **Error Modeling Using Ensembles**
- **BP 07 Validation test**
- **Final Considerations**

MREA 2010, La Spezia-Italy, October 2010

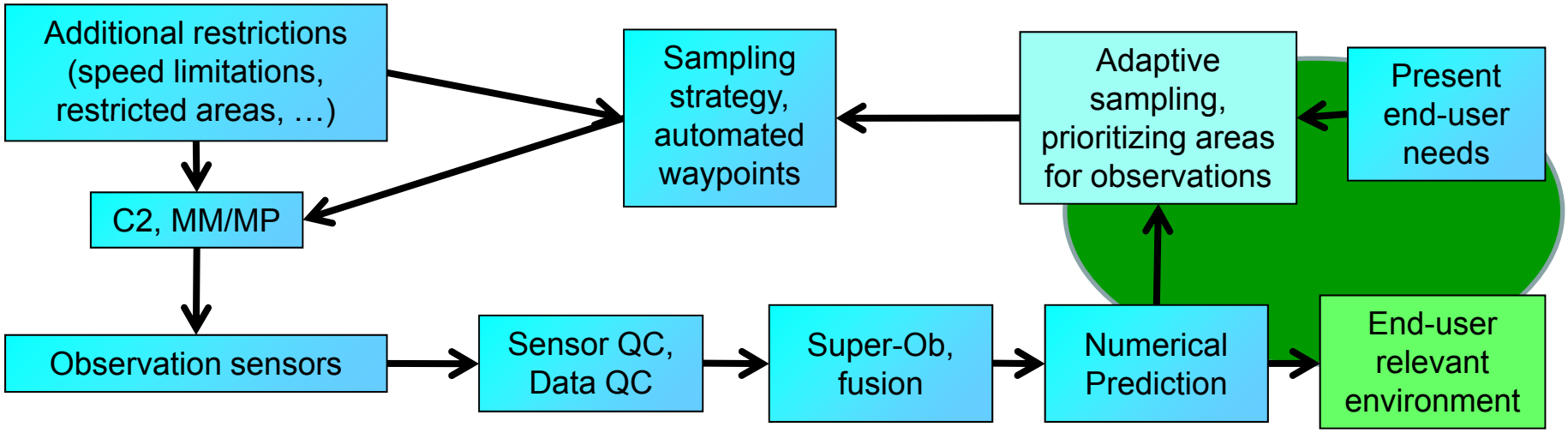
MOTIVATION

- Not just “know more”, but “know more of what you need to know”
- Higher frequency dynamics may not be accurate in high resolution numerical predictions
- **Need a tool to promptly adapt to continually changing needs**



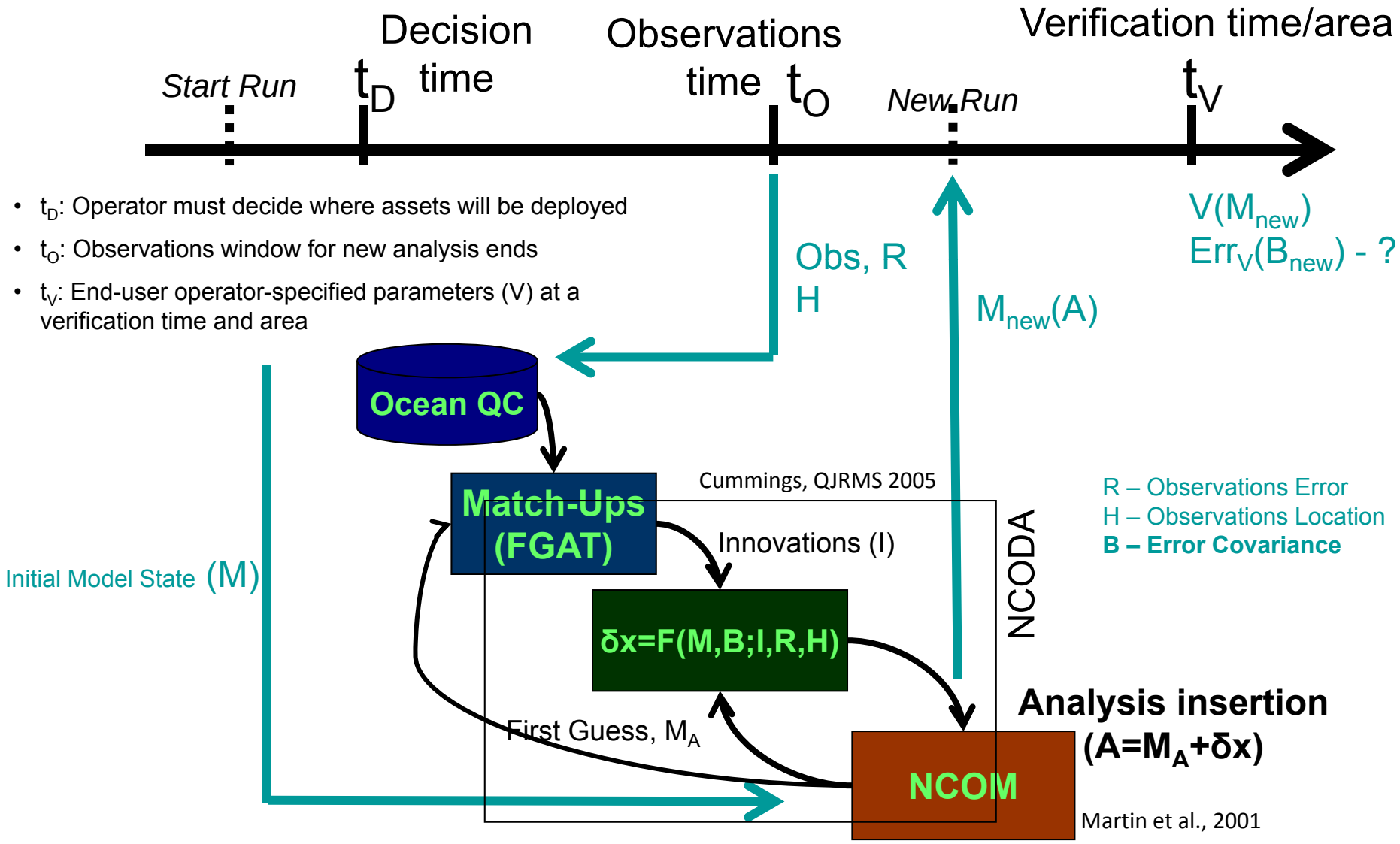
Where should this asset be deployed and how can be used to minimize Sound Speed uncertainty in this area 48 hours from today?

?



GOAL – select locations (H) and use observations (Obs) that will minimize the error (Err_V) of operator-specified parameters (V) at their usage time/area

Times involved in the decision-making process



- t_D: Operator must decide where assets will be deployed
- t_O: Observations window for new analysis ends
- t_V: End-user operator-specified parameters (V) at a verification time and area

NCOM ERROR PROGNOSTICS (B, *Err*) USING MONTE-CARLO SIMULATIONS

NCODA analysis error

NCOM analysis, $M_{new}(A)$

Bishop and Toth, 1999
Coelho et al., JMS 2008

M_{new} forcing

ET

Space-time deformation

Perturbed forcing

Ensemble forecast perturbations

X_f

$B(X_f)$

X_a

Perturbed IC

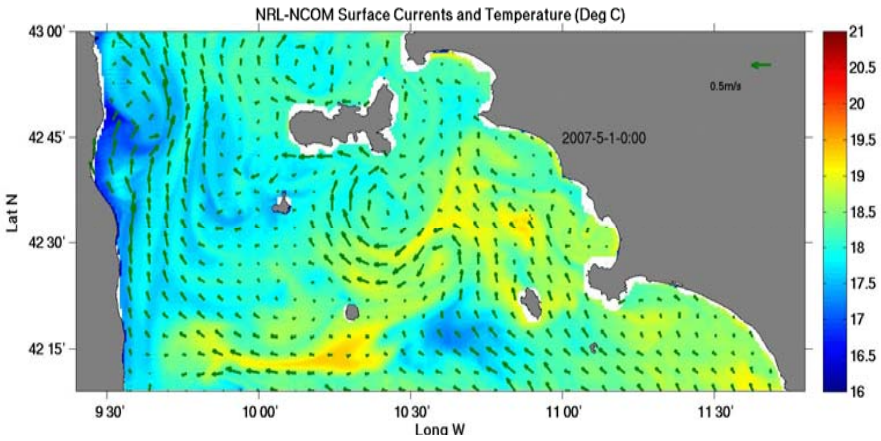
$X_{f,new}$

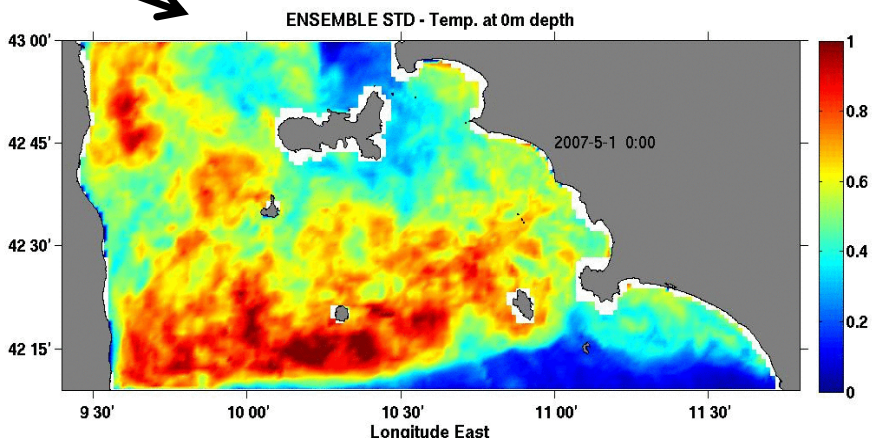
$B_{new}(X_{f,new})$

New Ensemble forecast

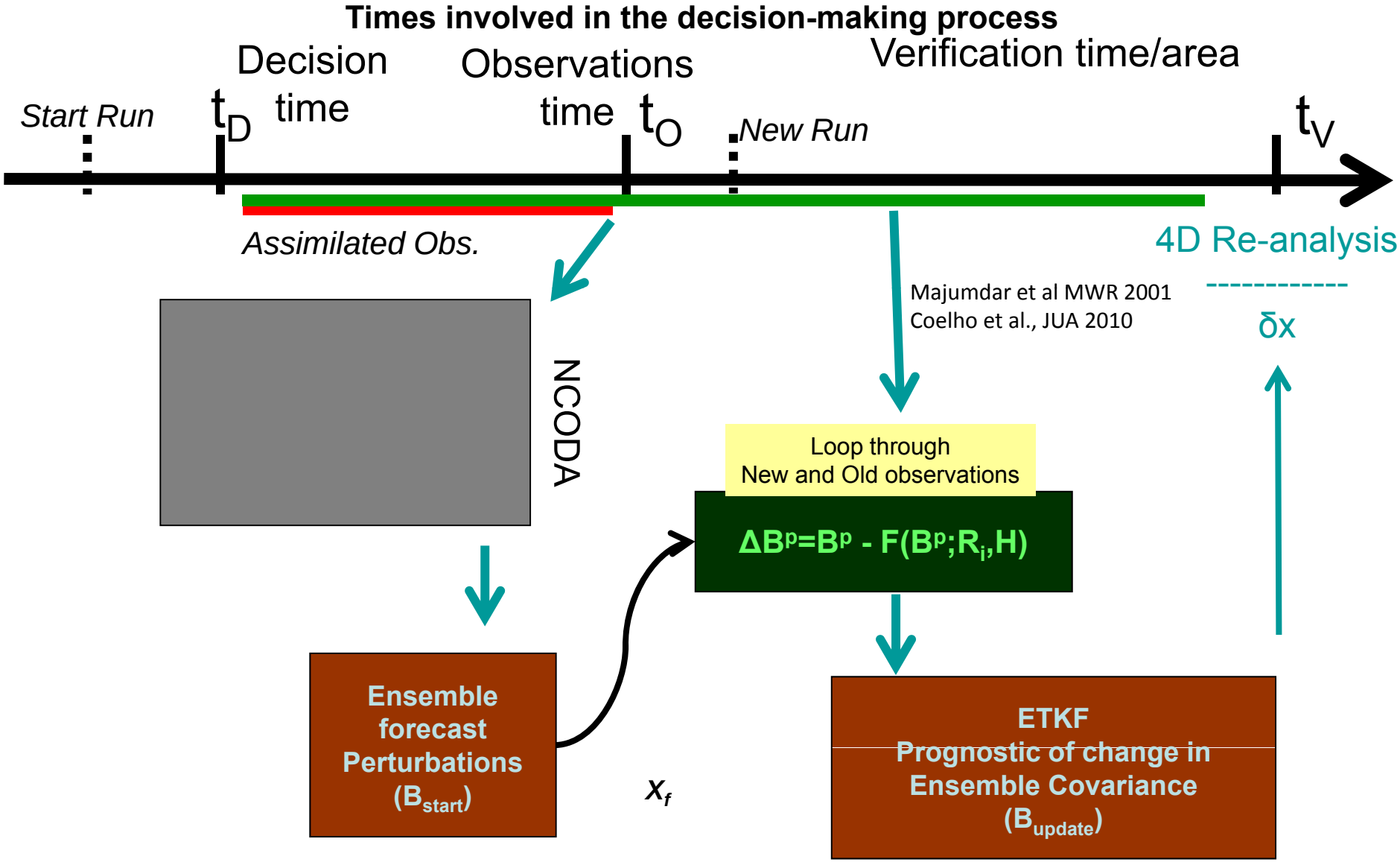
NCOM ERROR VARIANCE (*Err*)

Temperature at 0m





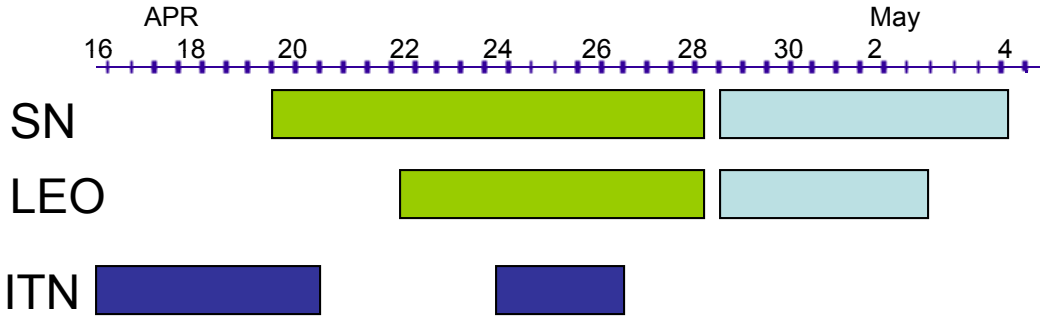
Use all observations (Obs) in minimizing the error (Err_V) of operator-specified parameters (V) at their usage time/area



MREA07 (BP07) Trial
April 16 – May 4, 2007

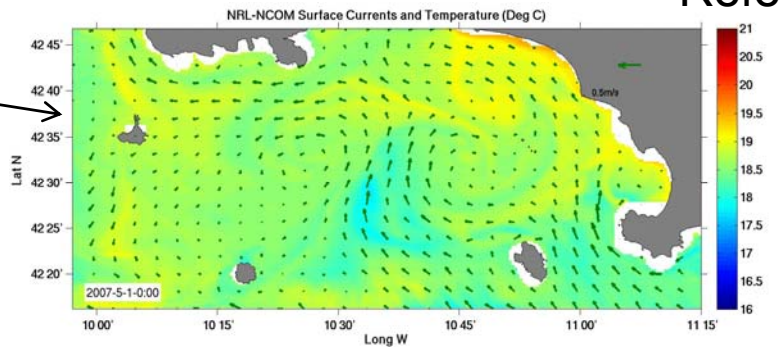
- Lead by the NATO Undersea Research Center and with the participants:
  - NURC, ITN and TNO for the Ocean observations
  - RNINC, ULB, UAlg, TUDelft for ocean Acoustics
  - NRL/US and MIT/US for Ocean modeling and ensembles

Three ships, VLA's, moorings and 1 AUV



- - CTD's/SSP with some constraints
- - CTD's only
- - CTD's/SSP with strong constraints

Reference area



NCOM Observed Simulation Errors

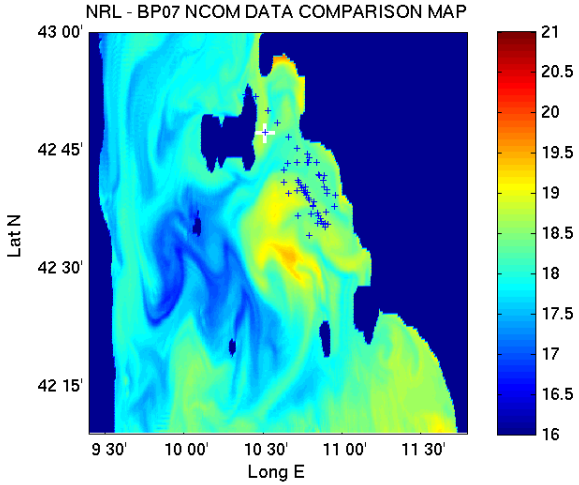
NCOM vs. CTD RMS during period 2007-05-01 00:00 to 48:00

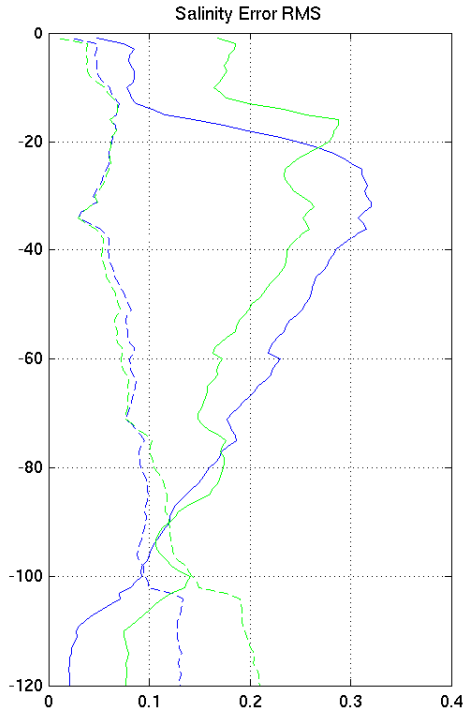
CTD DATA FROM RV LEONARDO

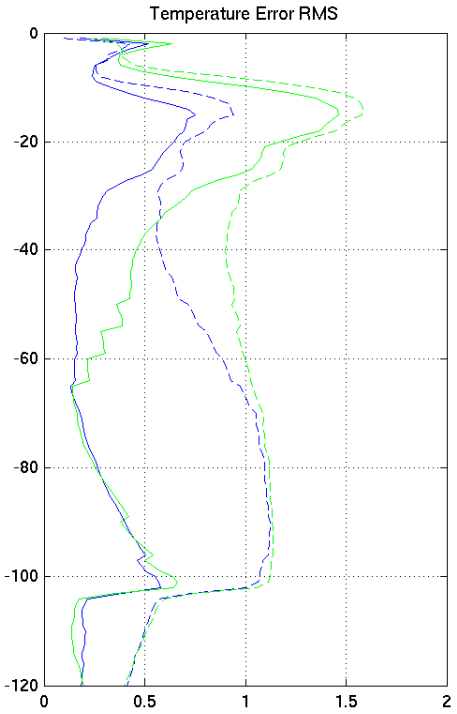
CTD AND SVP DATA FROM HNLMS SNELLIUS

BLUE DASHED: nest 1(FR); BLUE SOLID: nest 1 (ASSIM)

GREEN DASHED: nest 2 (FR); GREEN SOLID: nest 2 (ASSIM)

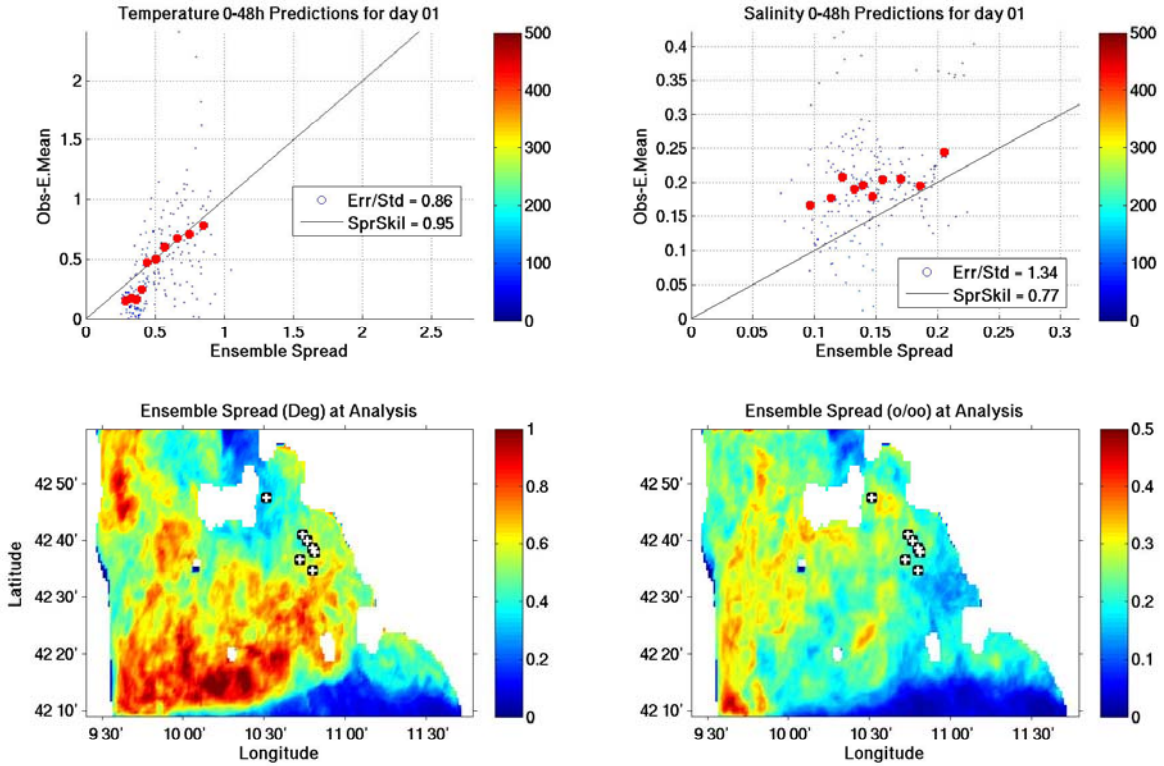






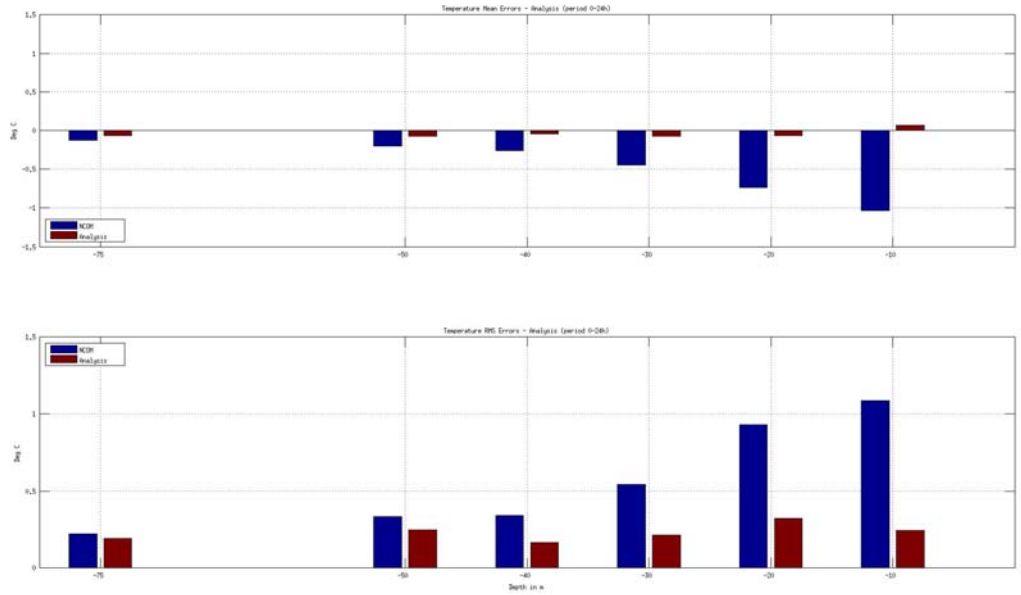
- **Increased resolution in the model does not increases efficiency of assimilation**

Ensemble estimate (Err^p) is a consistent estimate of observed NCOM errors (Err_{obs})

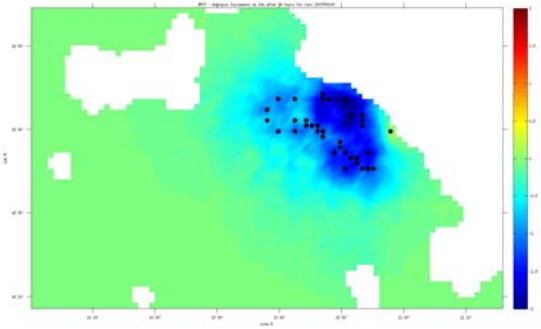


- Mean Ensemble Spread of T gets smaller and S increases along the fronts as data becomes available
- Very good spread-skill relation (red bins along positive slope lines) ~ 1
- Observed mean error variances were slightly over-predicted by the ensemble spread for TEMPERATURE and under-predicted for SALINITY

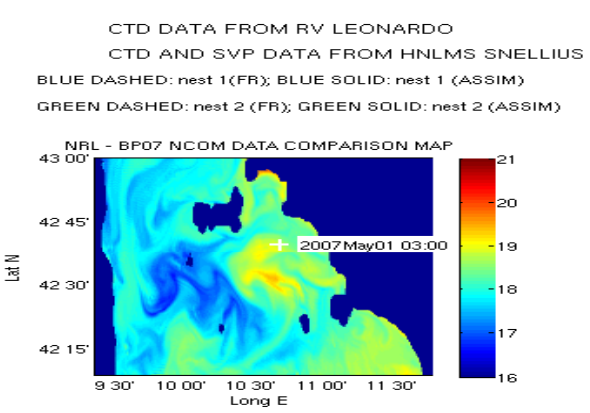
Impact of Observations in T Predictions (residual analysis error)

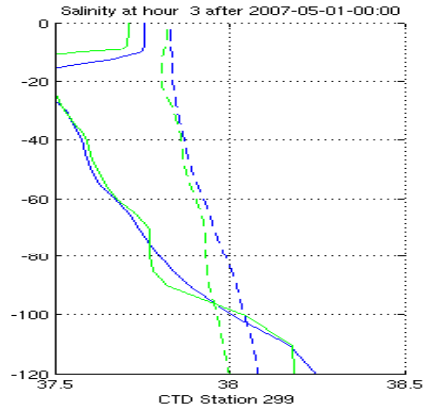


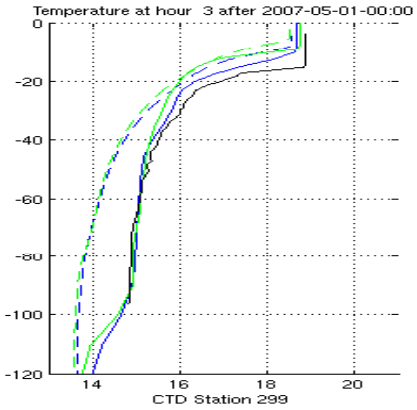
Innovations map



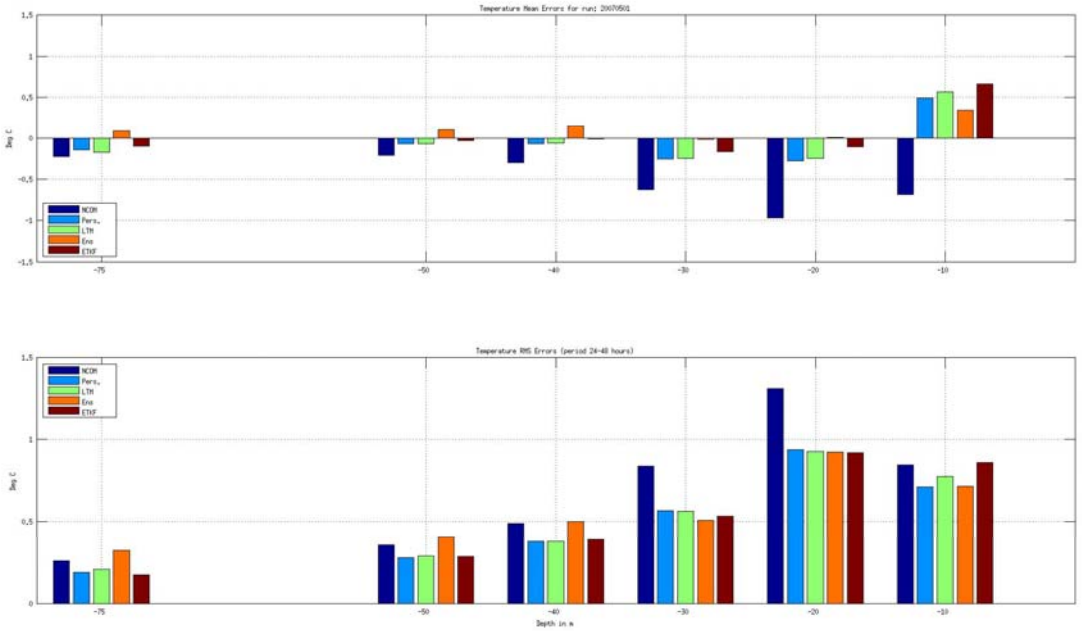
Black dots are observation locations



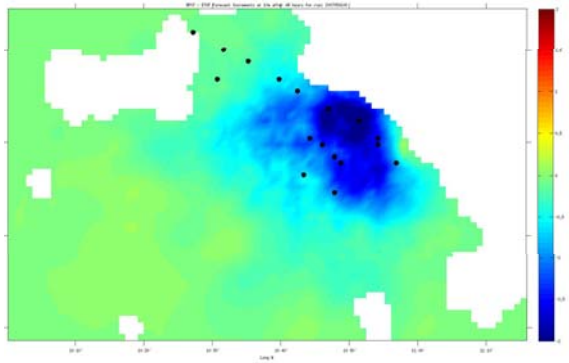




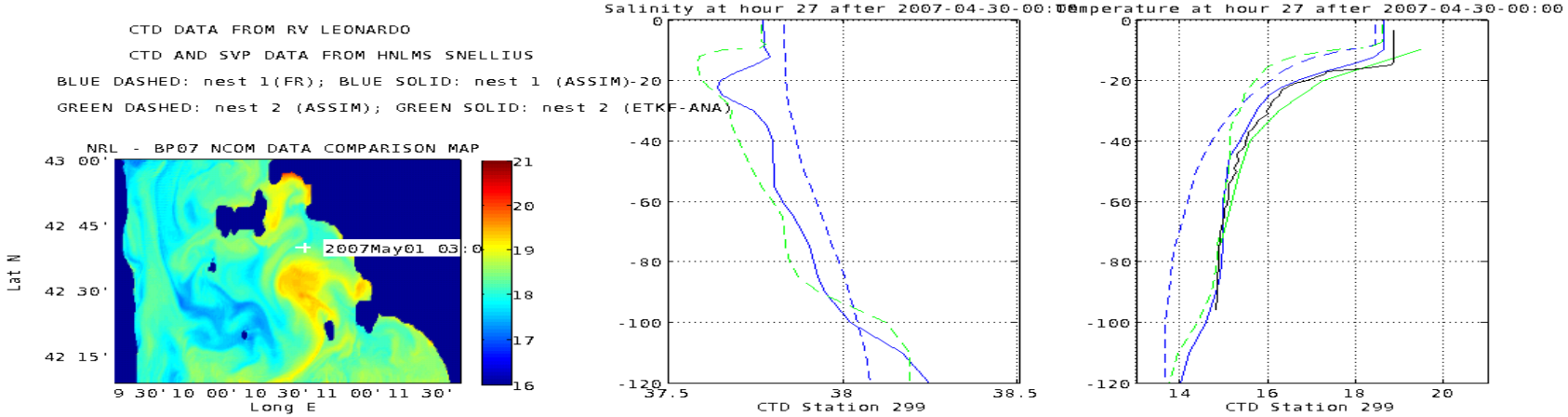
Measured Impact of Observations in 4D re-analysis predictions at observations time



Innovations map after 24 hours

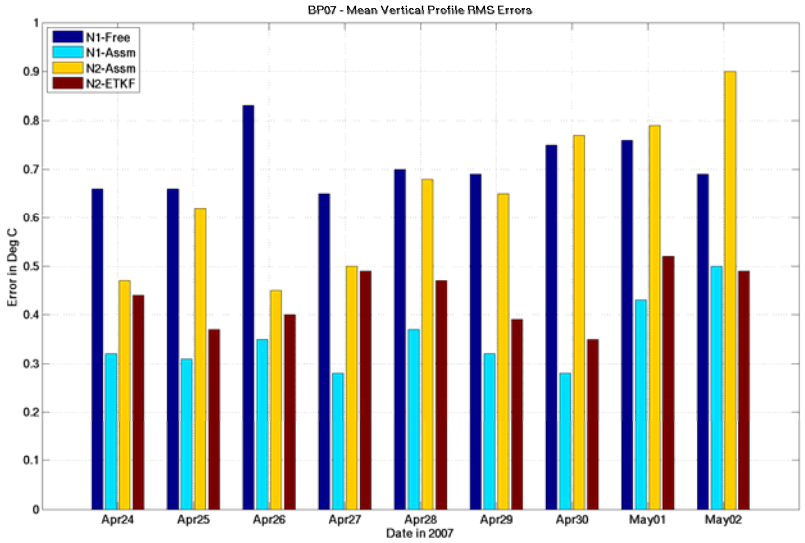


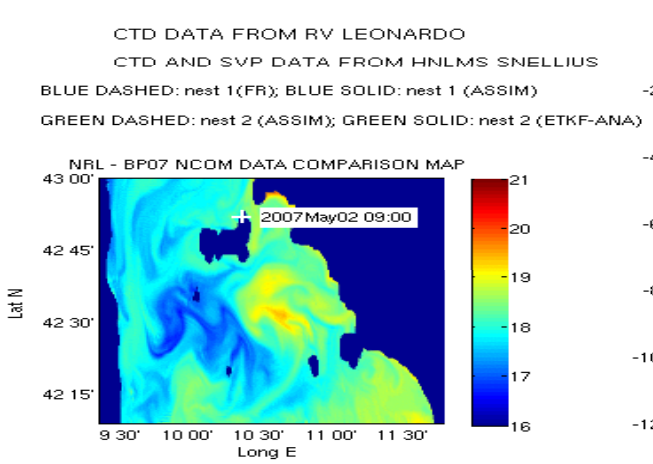
Black dots are Validation obs. locations

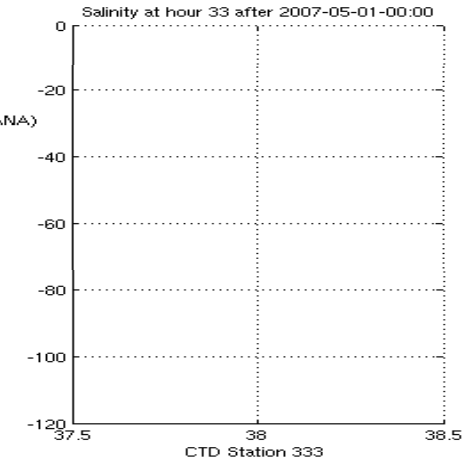


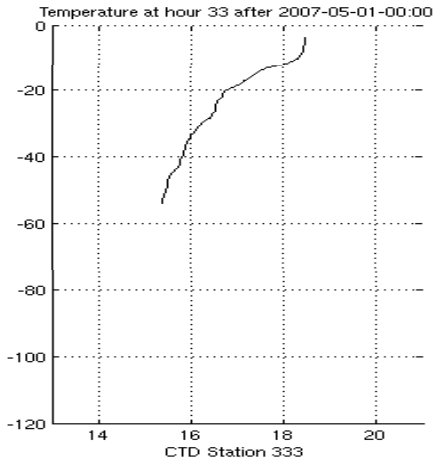
Trial Summary

Re-analysis improved high resolution run (N2) on-scene allowing to keep higher frequency dynamics with statistics comparable to the smoother outer nest assimilating local data (and up to 24h earlier).

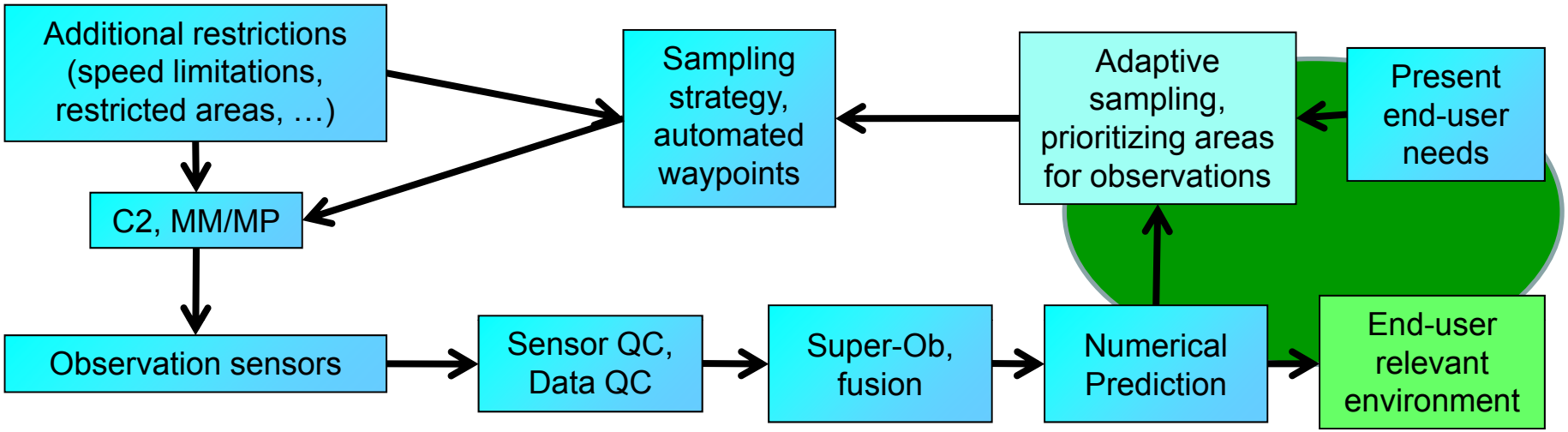








FINAL CONSIDERATIONS



- Adapting forecast systems to end-user applications require solving two problems:
    1. Select and adapt observations network
    2. Assimilate observations to improve forecast errors of relevant parameters
- **Ensemble based solutions seem to provide** robust solutions for both the adaptation of sampling networks (e.g. Coelho et.al. 2010 –Oceans 2010 IEEE/MTS) and high resolution analysis problems (this work)