Update on High Resolution Data Assimilation with POP 1/10°

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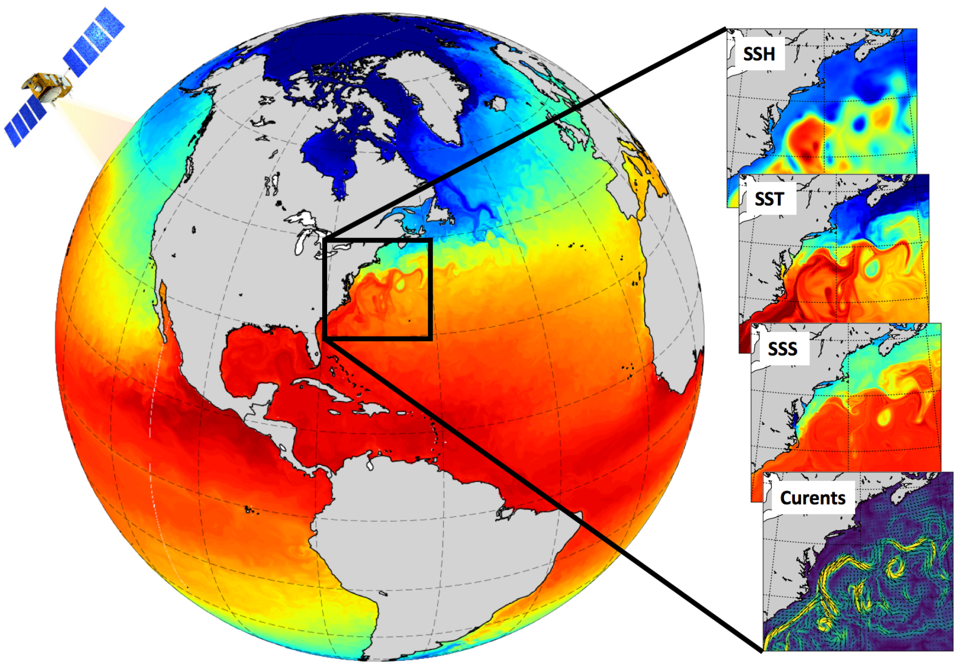
Motivations and background

- Growing demand for climate predictions that include a broader range of space and time scales and that include a more complete representation of weather and climate processes



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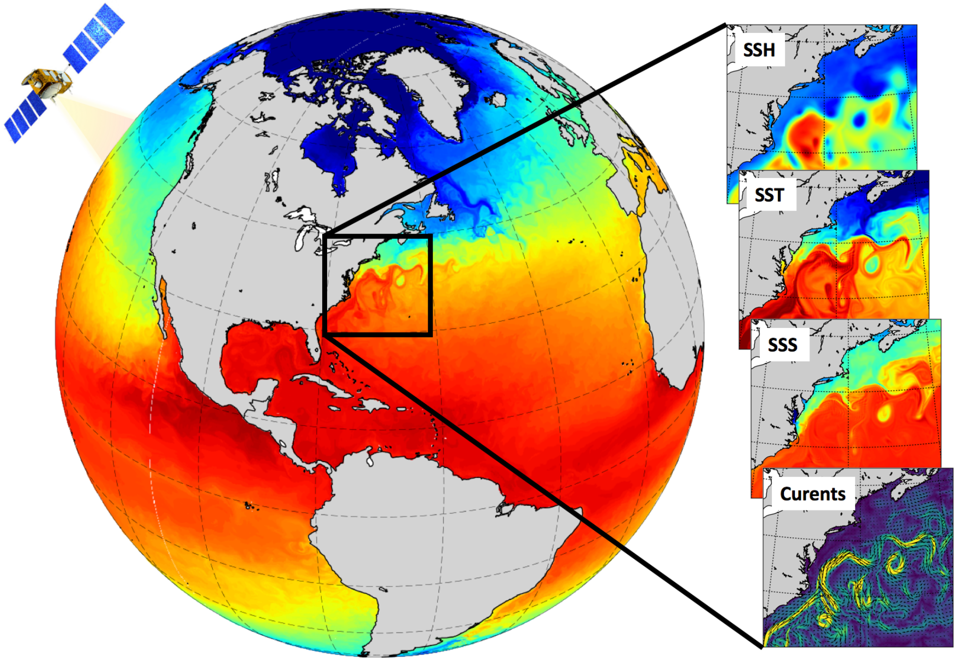
  ➢ inclusion of mesoscale ocean physics in both the forecasting and the data assimilation systems



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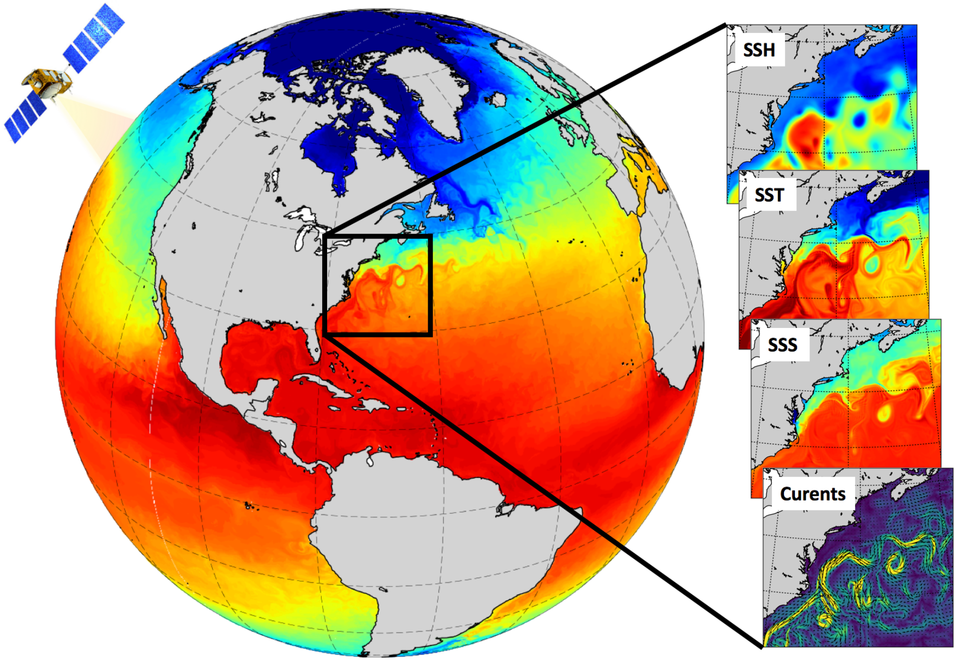

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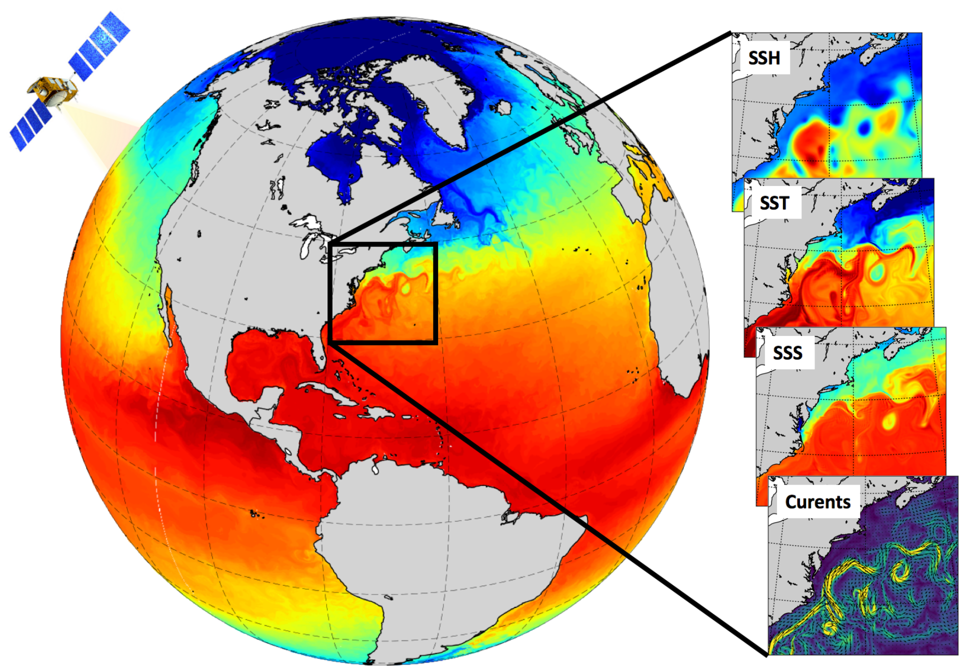
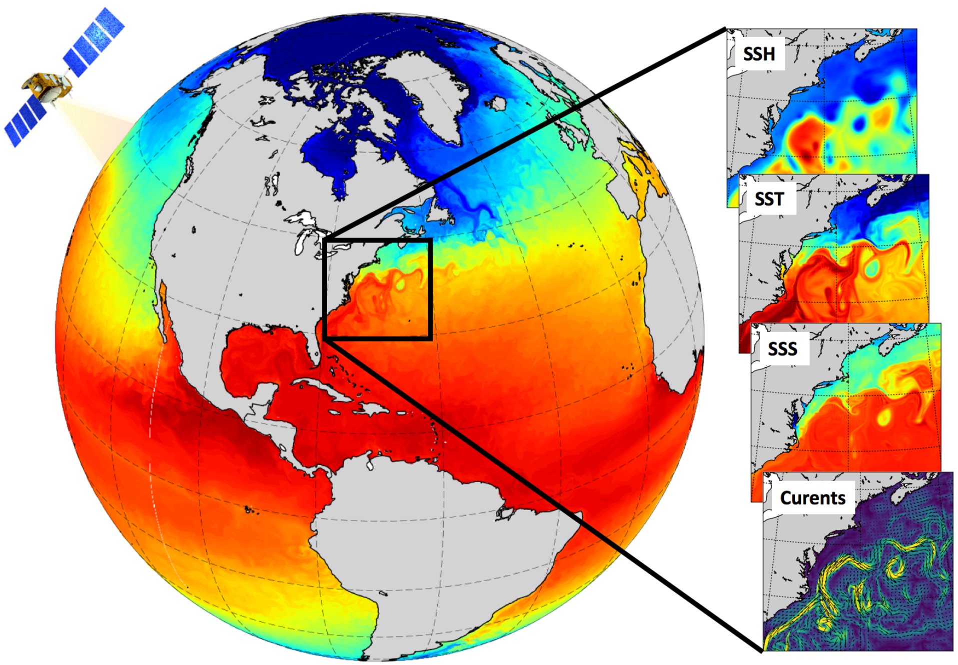
- But recent results indicate that when air-sea interactions associated with oceanic fronts and eddies are adequately resolved, more realistic variability enhances skill in near-term climate predictions (e.g., Siqueira and Kirtman 2016, GRL).



Motivations and background

- NSF award “EaSM-3: The Role of Ocean Eddies in Decadal Prediction”

  Goal: develop and implement proper high-resolution ocean initialization practices and data assimilation infrastructures at NCAR to support seasonal-to-decadal prediction with the high-resolution versions of the CESM



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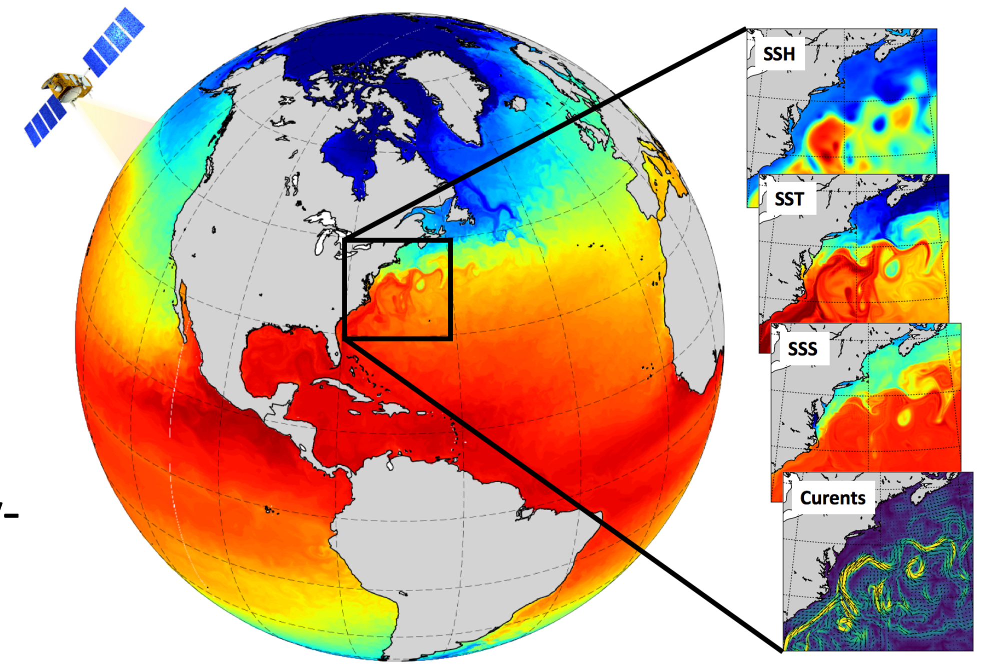
Question: Do we need to initialize the small scales?

➣ Profound implications in the design of decadal prediction systems and the associated data assimilation systems.

➣ Require the development of data assimilation strategies and tools for initializing eddy-resolving models.



DART

- POP2 1^{o} model currently has ensemble data assimilation capabilities through the Data Assimilation Research Testbed (DART) software system.

- Assimilation state is typically small (e.g., SSH,T,S,U,V only) but still needed to fit into the memory of a single MPI task to compute forward operators.

- Highres model runs exceed available memory (increase in the size of ocean model state by two orders of magnitude)

  $\Rightarrow$ DA updates to the POP2 1/10^{o} ocean are not possible in the standard version of DART on Cheyenne

  $\Rightarrow$ A new Remote Memory Access (RMA) version of DART has been developed to work with large state-space models

DART RMA

More efficient use of parallel computing through:

- **Distributed State Vector**
  No longer need to have all variables on a single processor to compute forward operators.
- **One Sided MPI Communication**
  Allows all processes to access (read/write) state information without synchronizing with the target process.
- **Direct NetCDF Read/Write**
  Elimination of a conversion step that translates between POP restart files and DART format.

- **Many internal code improvements**

Official release: DART Manhattan on March 15th 2017

Design challenges for global high resolution ensemble data assimilation

Time and computing resources remain a big challenge:

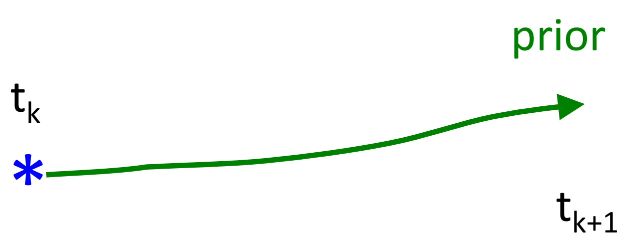
- DA update step takes ~20 minutes on ~3K cores
- However, the limiting factor is not the DA step…

  The DA step is only 5% of the cost of the assimilation with a 50-member ensemble. The vast majority of the cost is running ensembles of the $1/10^o$ model.
- We need an alternative strategy

  $\Rightarrow$ Ensemble Optimal Interpolation (EnOI)

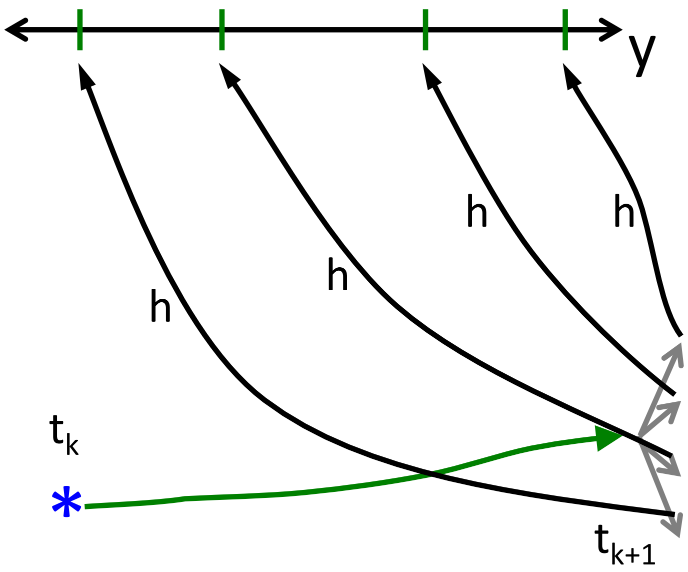
EnOI

Advance the model
in time



Adapted from Anderson et al. 2009 (BAMS)

EnOI

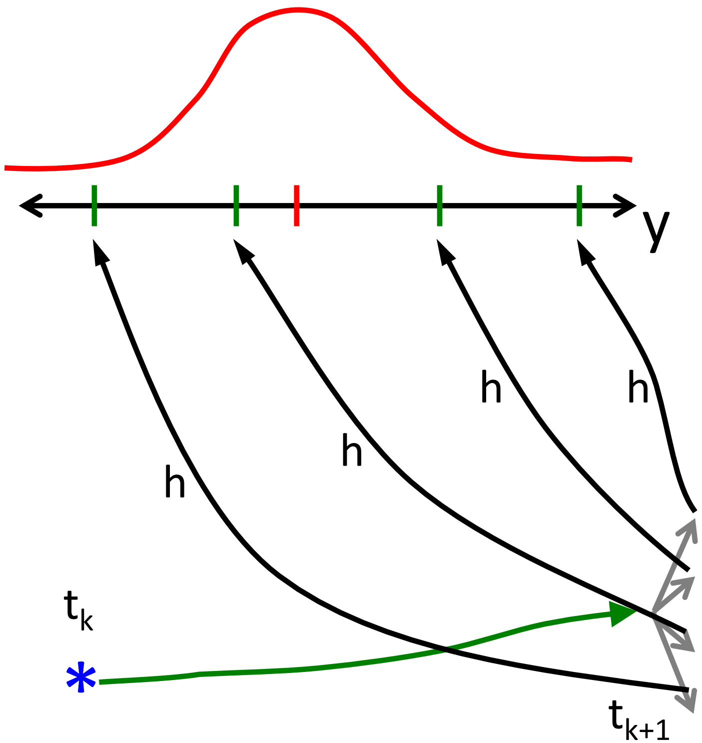


Add background perturbations
and
convert each ensemble to an expected observation

$$y = h(x)$$

Adapted from Anderson et al. 2009 (BAMS)

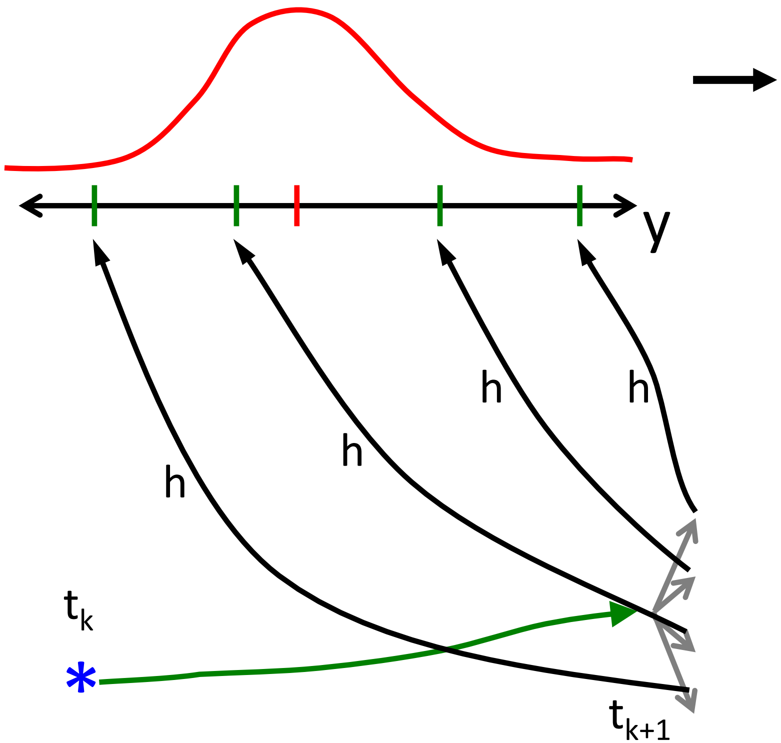
EnOI

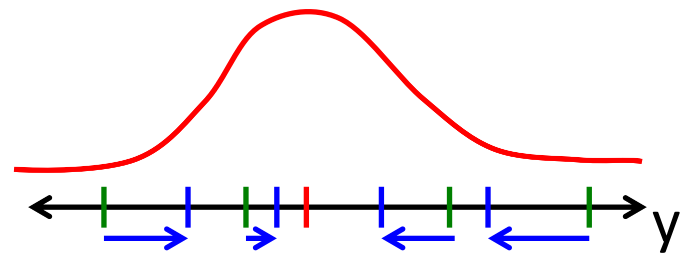


Compare with observation and observational error distribution

Adapted from Anderson et al. 2009 (BAMS)

EnOI

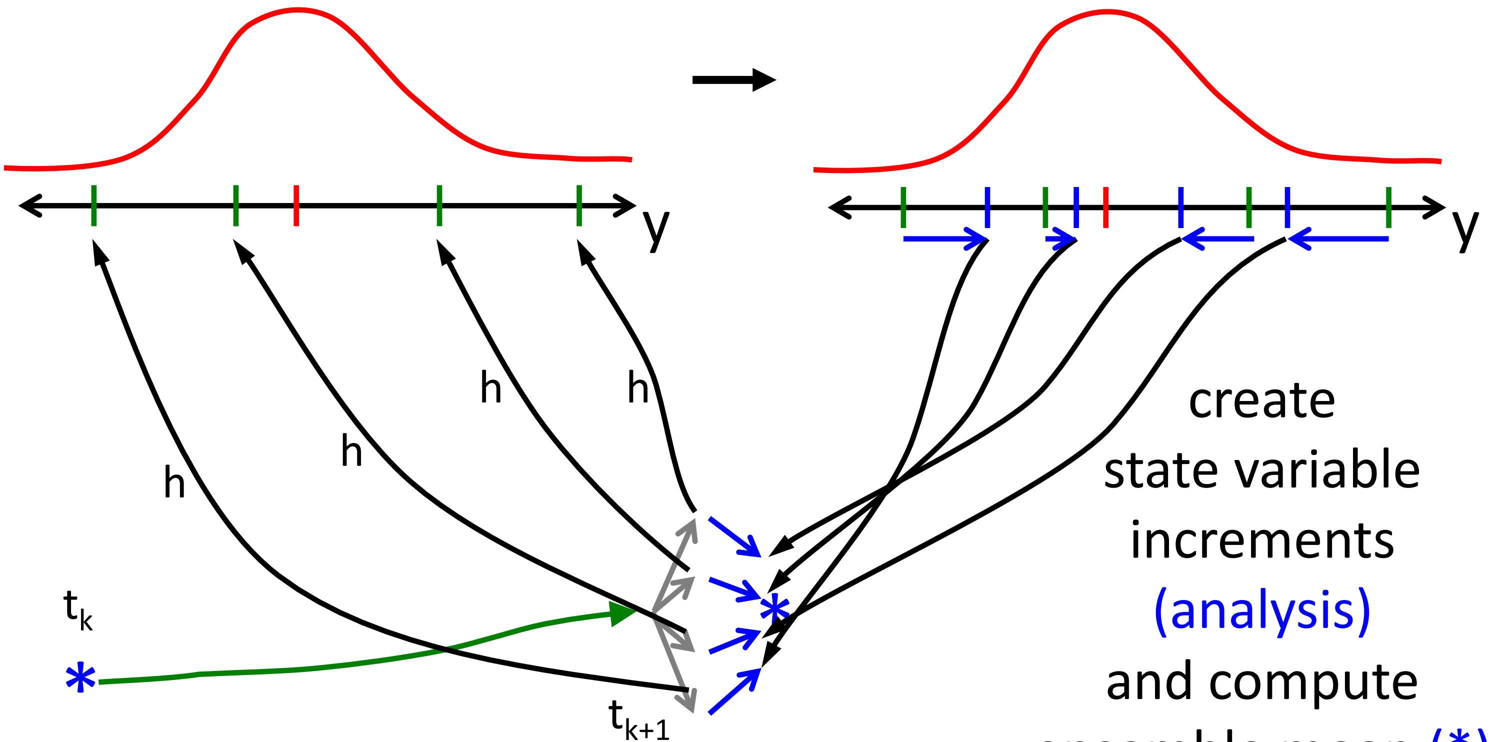




Find the increments

Adapted from Anderson et al. 2009 (BAMS)

EnOI

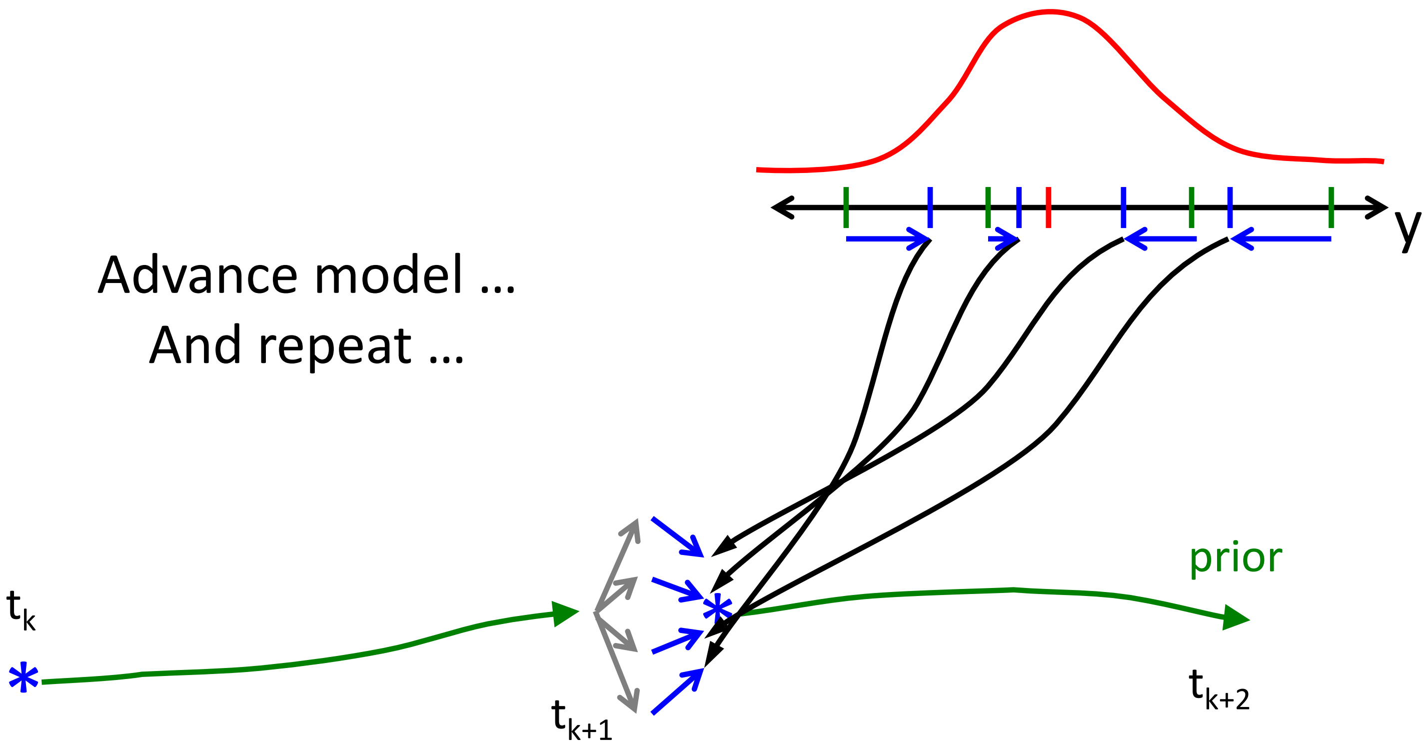


create
state variable
increments
(analysis)
and compute
ensemble mean (*)

Adapted from Anderson et al. 2009 (BAMS)

EnOI

Advance model ...
And repeat ...



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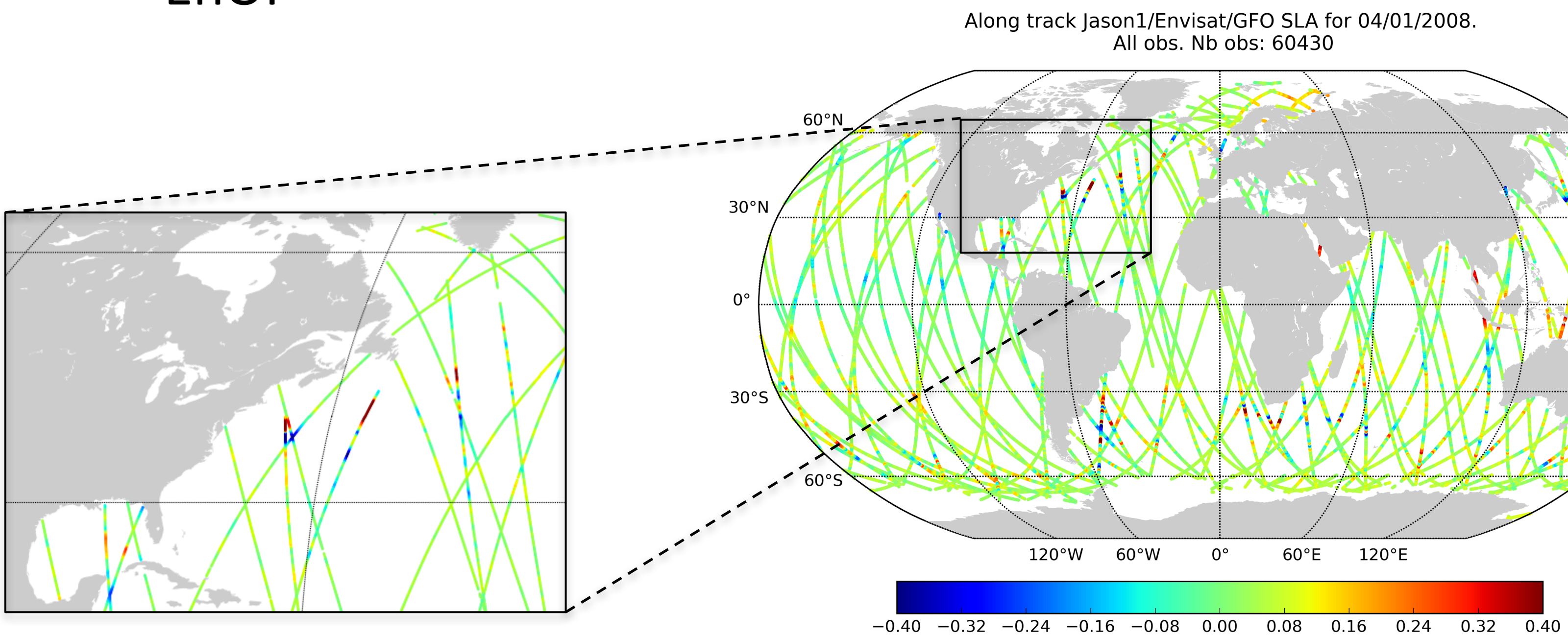
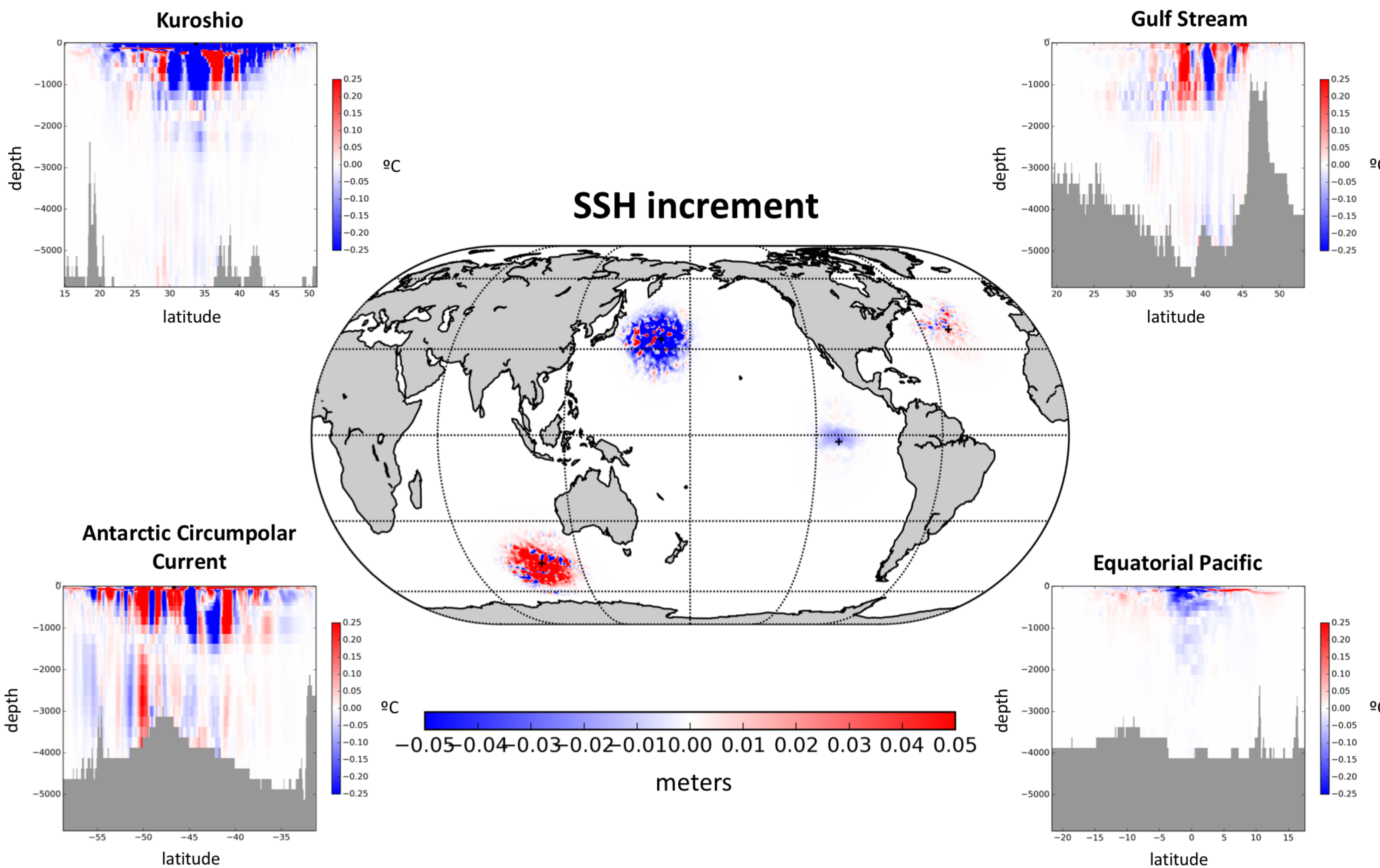
Assimilation of along-track altimetry

Initial phases of testing the infrastructure, optimizing the system performance and preparing the necessary observational data streams for eddy-resolving data assimilation are complete.

- Data streams and forward operators
- Workflow and scripting for DART RMA-CESM2 EnOI
- A long hindcast simulation (2000-2016) to parameterize the EnOI

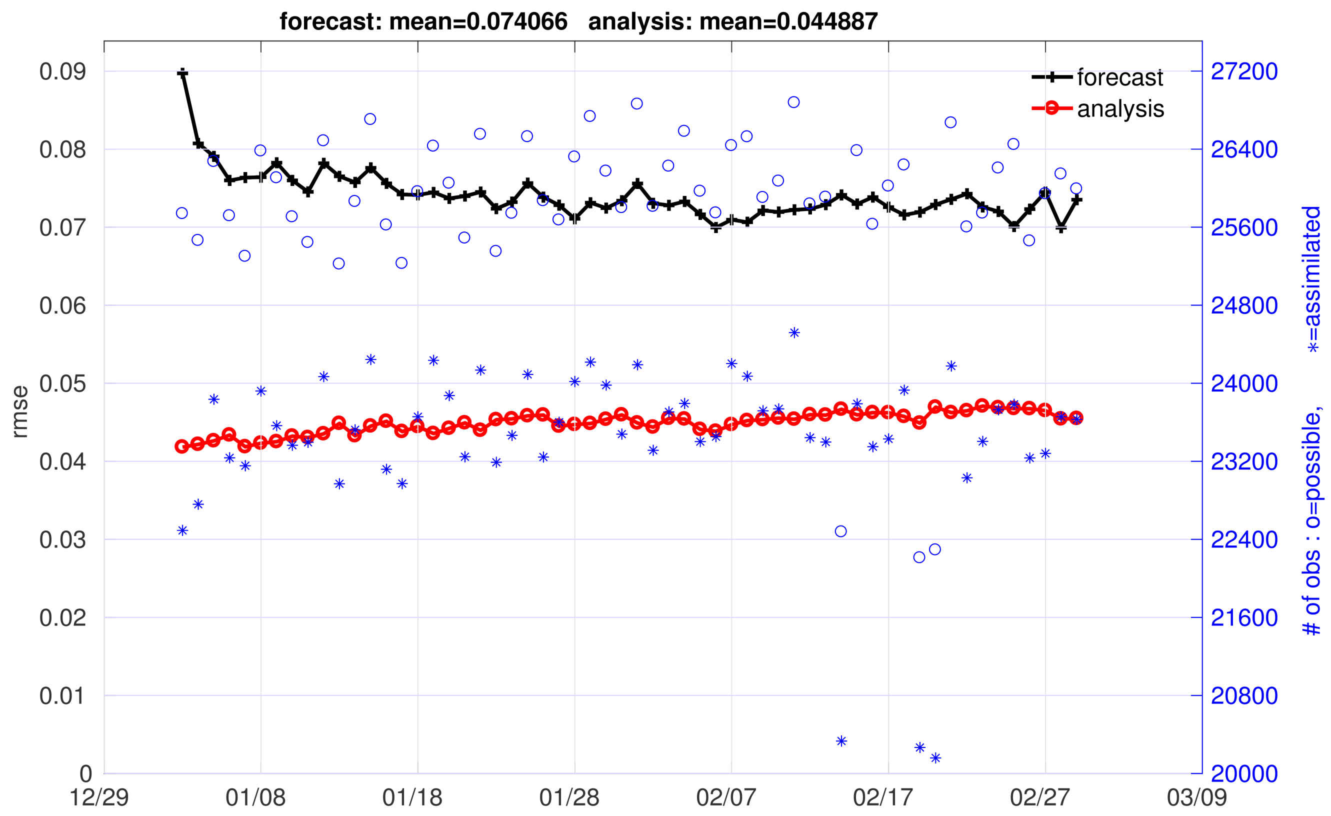


Assimilation of along-track altimetry



- SSH increments resulting from a single along-track SLA observation
- The increments are physically consistent with expected patterns of influence

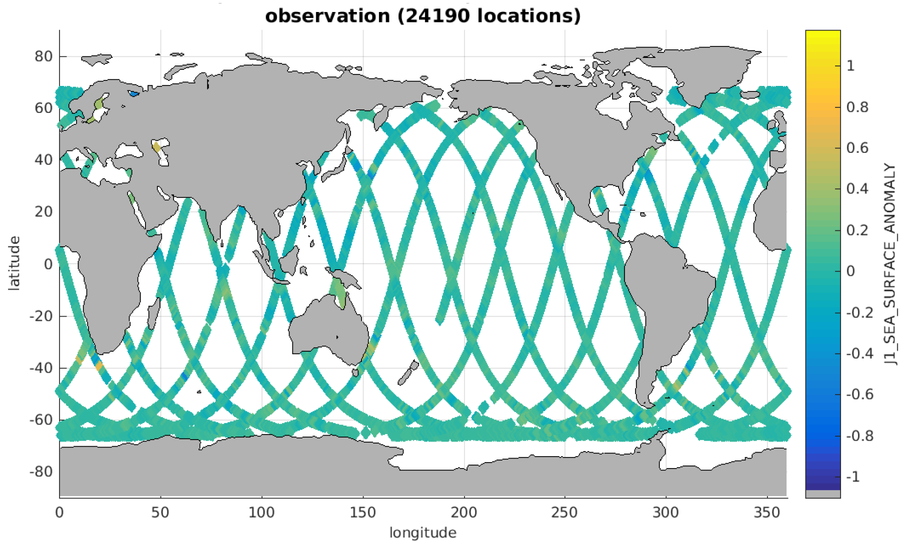
Assimilation of along-track altimetry



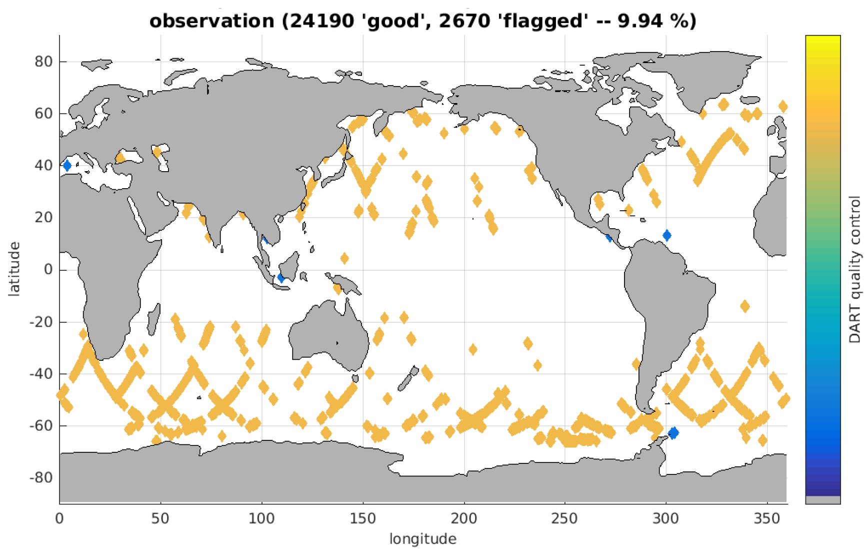
- First realistic EnOI experiment using 84 "static" but monthly varying ensemble
- RMSE of the forecast initially go down
- Ratio between number of observation assimilated and number of observation available is low

Assimilation of along-track altimetry

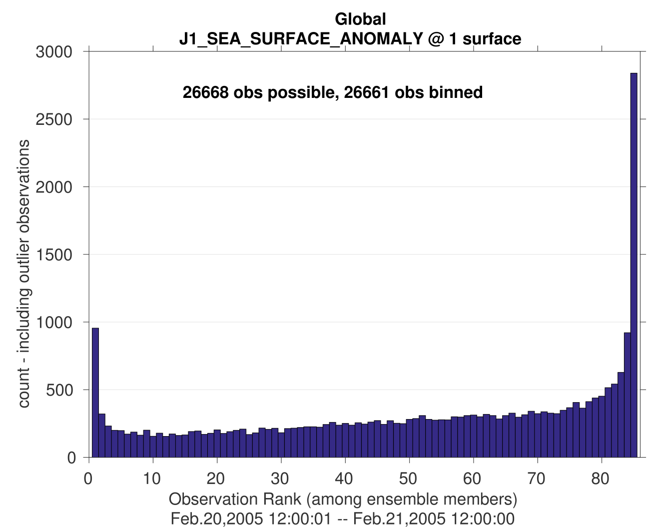
02/01/2005



- Almost all the non-assimilated observations are rejected as outlier
- Suggest that the spread of the static ensemble is too narrow



→ Outlier rejected



Conclusion & Future works

Conclusion

- We have implemented an EnOI based on DART to run assimilation experiments with the 1/10^{o} POP ocean model
  $\Rightarrow$ Cost of integration is down to ~500K from ~10M per year of simulation with the EnKF
- A highres hindcast forced with JRA (2000–2016) has been run
- Short 2-month EnOI experiments have been run
- The initial results are encouraging

Future work

- Tuning of the DA
- Perform a highres reanalysis with DA (2005–2016)
- Perform highres experimental prediction experiment (NMME-type seasonal hindcast experiment) initialized using the highres reanalysis with DA .

Thank you

Questions?