

Large case benchmark: NATL025 NEMO configuration

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- 3 Ensemble generation
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Model description

NATL025 configuration of the NEMO model:

- domain: 20°S - 80°N, 98°W - 23°E
- horizontal resolution: $\frac{1}{4}^{\circ}$
- vertical levels: 46 levels between \sim 3 m and 6000 m in depth
- time integration: a leap frog scheme with time step 2400 s
- ERAinterim atmospheric forcing
- Initial conditions: Levitus climatology for T and S, 0 for ssh, u, v, w
- spin up time: 16 years (January 1989 - January 2005)

Observation

Observation for assimilation

- Sea surface height: Jason-1 track, observation error 5 cm
- Sea surface temperature: composed AVHRR, error map (standard deviation of analysed sst)
- Temperature profile: ARGO, observation error 0.3°

Observation for validation

- Sea surface height: Envisat track
- Sea surface temperature: Mercator reanalysis
- Salinity profile: ARGO

Observation localization

- Observation weight function:

$$w = \exp\left(-\frac{r^2}{d^2}\right)$$

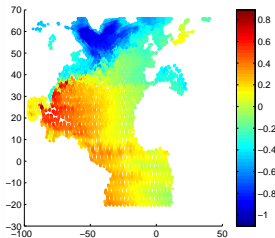
(d : correlation length, r : distance from the considered water column)

- autocorrelation length of model variables:
 - ssh: 200 km
 - sst: 400 km
- Localization length-scale: 300 km
- Maximum correlation length: 3000 km

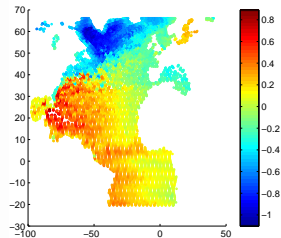
Ensemble generation

- 60 members
- perturbation in forcing variables: u , v , t , $radlw$, $radsw$ (related to sst)
- Fourier decomposition of the forcing variables vector (Barth et al. 2011)
- Monthly variability taken into account
- ensemble validation: ensemble spread / RMS misfit of the model prediction and observations at the end of the ensemble spin-up

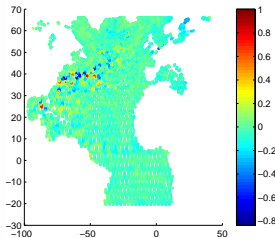
Ensemble validation: ssh



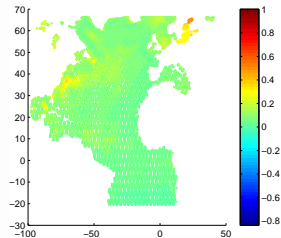
model



observation

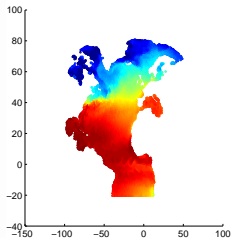


model - observation

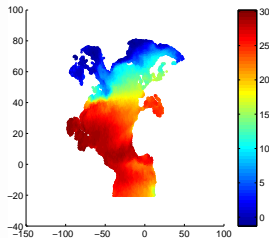


ensemble spread

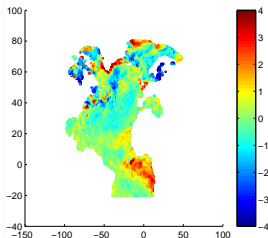
Ensemble validation: sst



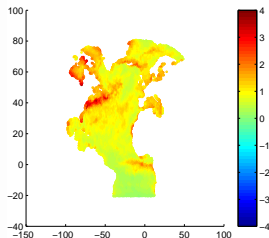
model



observation



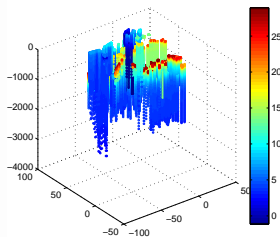
model - observations



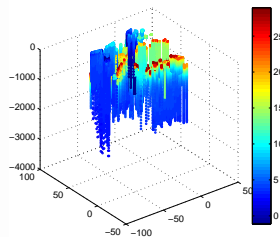
ensemble spread



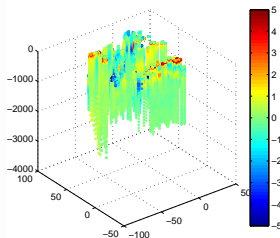
Ensemble validation: temperature profile



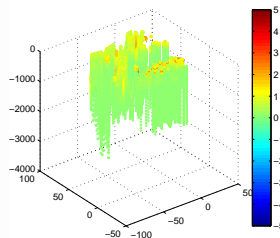
model



observation



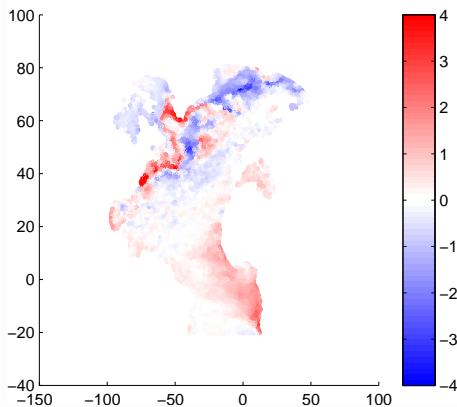
model - observation



ensemble spread

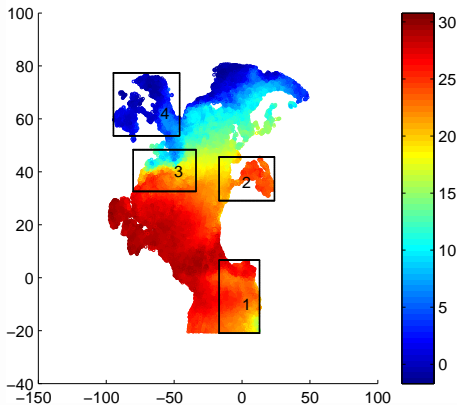
Model bias

SST difference between the model and the observation averaged over 6 months



Model bias

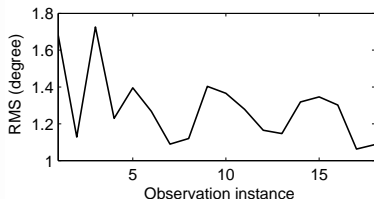
zone localisation:



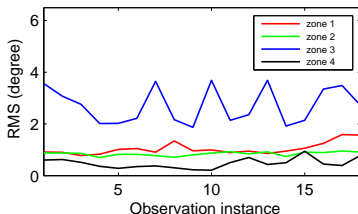
Model bias

Temporal evolution of the temperature RMS during the first 6 months of 2005:

the whole domain



each zone



zone 1: African coast, zone 2: East Atlantic,
zone 3: Gulf Stream region, zone 4: subpolar area.

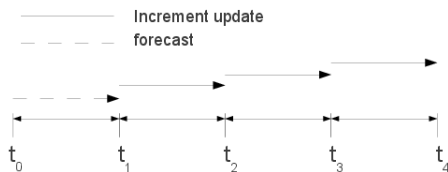
Model bias

Model bias areas:

- 1 subpolar area: no seasonal variation in the model prediction, but in the observation
- 2 Gulf Stream region: systematic error in the Gulf Stream pathway
- 3 African coast: weakness in the representation of the African upwelling off Senegal

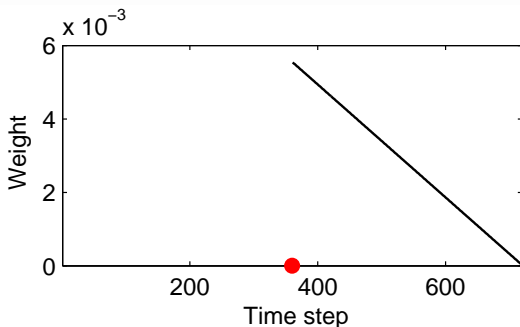
Assimilation setting

- Timing parameters:
 - analysis frequency: 10 days
 - duration: one year with ensemble spin-up of 6 months
- Assimilation tool: Ocean Assimilation Kit (OAK)
- Assimilation method: square root analysis scheme of EnKF
- Assimilation scheme: IAU 0 (Incremental Analysis Update)



Assimilation setting

Increment weighting in accord with observation decorrelation time scale: linearly decreasing function



red point: analysis time step

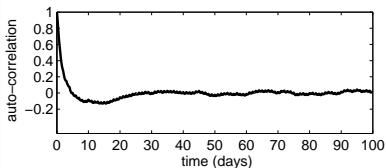
State vector

- Model state vector:
 - ssh
 - temperature
 - salinity
- Incremental Analysis Update:
 - temperature (ΔT)
 - salinity (ΔS)
- Forcing variables ???

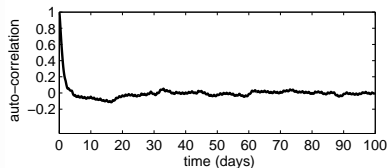
Forcing variables

Temporal correlation:

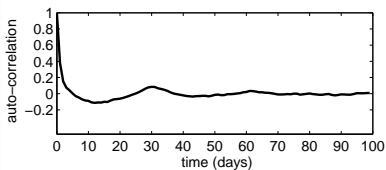
wind velocity: u



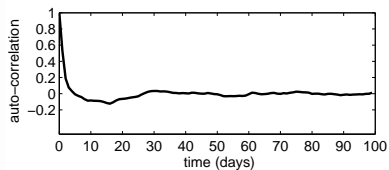
wind velocity: v



short wave radiation



long wave radiation



Forcing variables

Degradation of unobserved variables due to small ensemble size:

Variance of the covariance error, ϵ_c , between two random variables, x_1 and x_2 :

$$\text{var}(\epsilon_c) \simeq \frac{1}{N} (1 + \text{corr}(x_1, x_2)^2) \text{var}(x_1) \text{var}(x_2)$$

N : sample size.

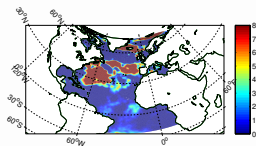
$$\text{relative error} = \frac{\text{covariance error}}{\text{absolute value of covariance}}$$

If the relative error > 1 , unobserved variables will be degraded by assimilation. (Hamill et al. 2001)

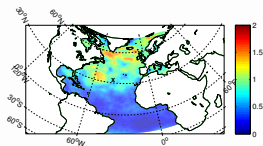
Forcing variables

sst at point (41.52° W, 33.44° N), wind velocities in 10 days:

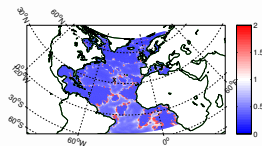
zonal velocity:



covariance

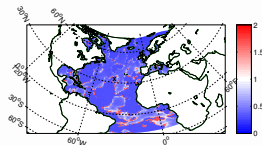
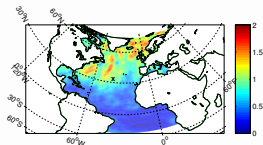
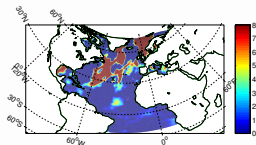


covariance error



relative error

meridional velocity:

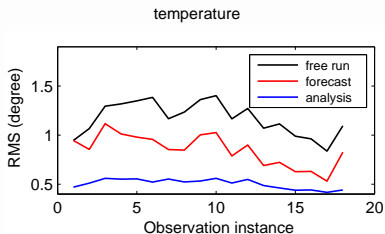
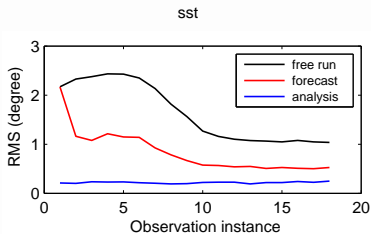
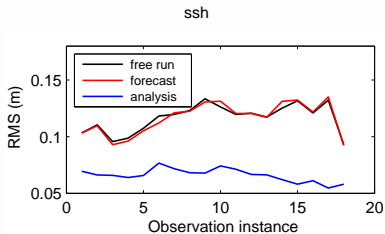


Metrics

- 1 RMS misfit between the analyses and the observations used in the assimilation experiments (ssh, sst, temperature).
- 2 RMS misfit between the analyses and independent observations (ssh, sst, salinity)
- 3 Assessment of unobserved quantities (velocities) according to our knowledge or other sources of information.

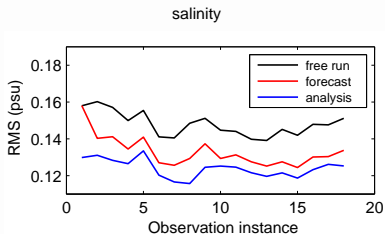
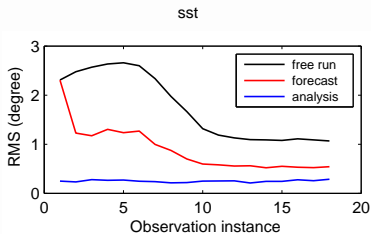
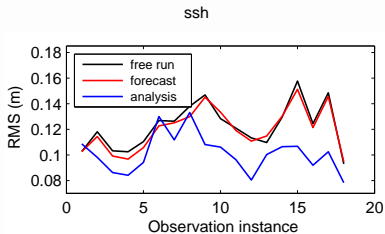
RMS misfit: analysis, forecast, free run / observation

RMS misfit between the forecasts|analyses and observations for assimilation:

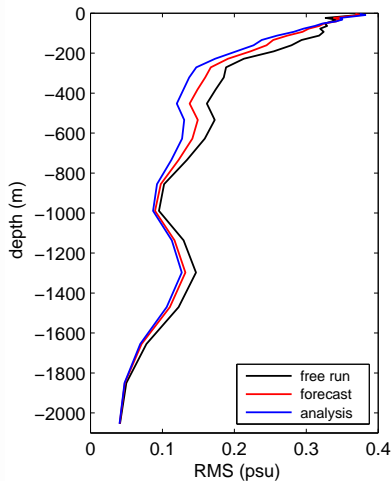
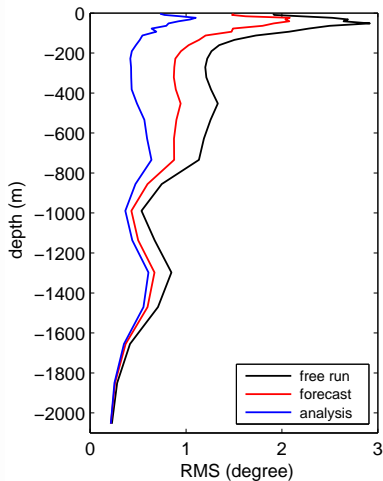


RMS misfit: analysis, forecast, free run / observation

RMS misfit between the forecasts|analyses and independent observations:

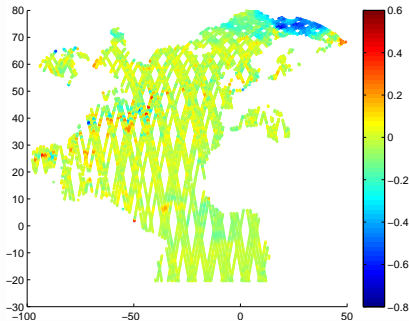


RMS misfit of T & S in depth

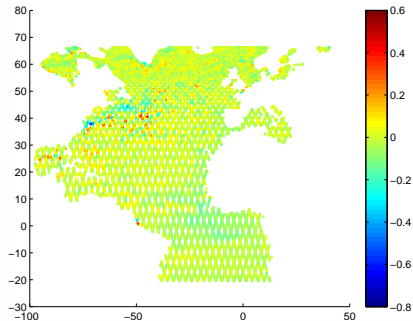


averaged over 6 months.

Example of residual: SSH



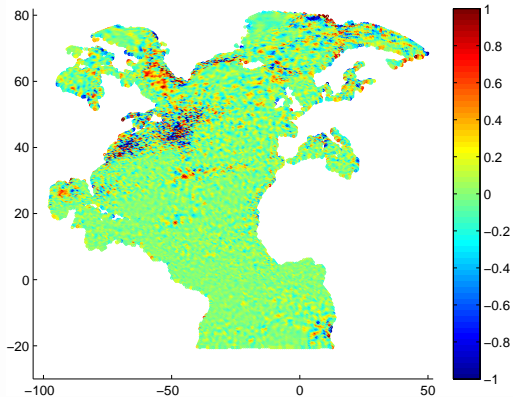
Envisat



Jason-1

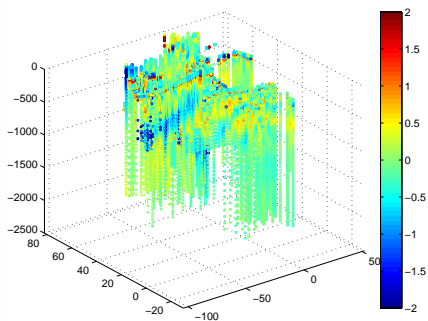
analysis - observation

Example of residual: SST

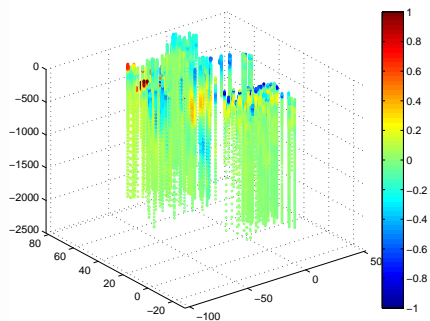


analysis - observation (Mercator reanalysis)

Example of residual: T & S



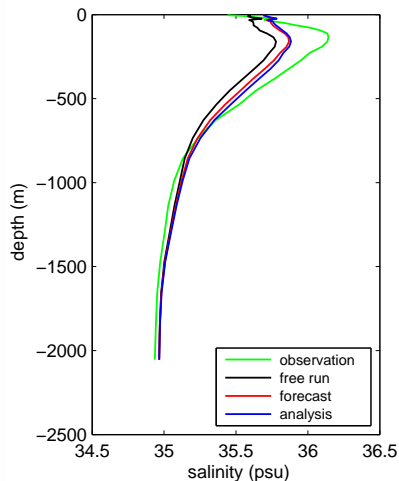
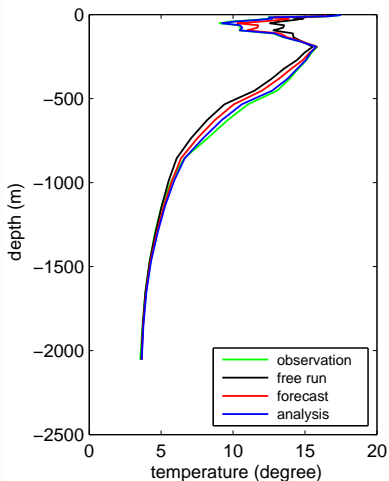
temperature



salinity

analysis - observation

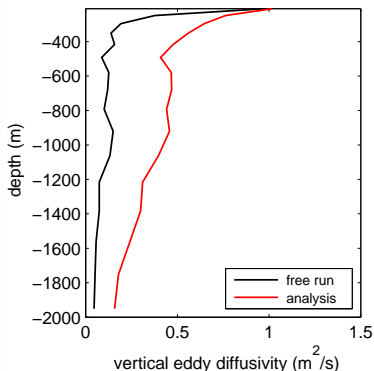
Example of T & S profile



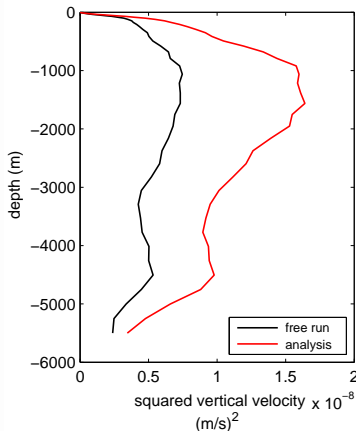
averaged over the Gulf Stream region over 6 months.

Vertical eddy diffusivity & vertical velocity

vertical eddy diffusivity

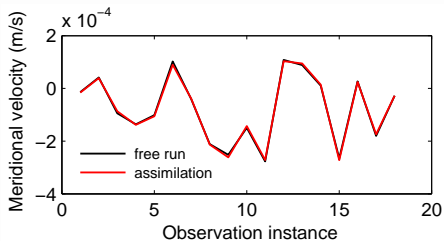
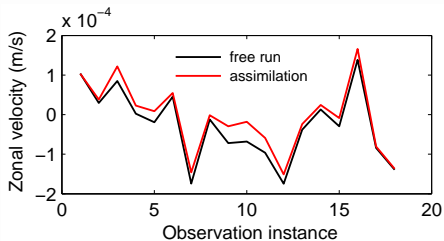


squared vertical velocity



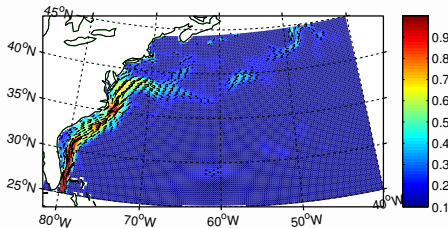
averaged over the Gulf Stream region over 6 months.

Horizontal velocities

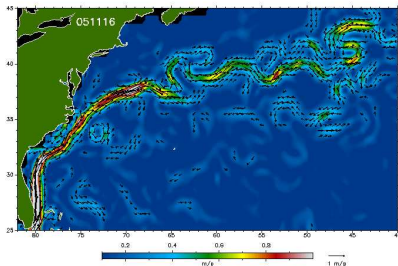
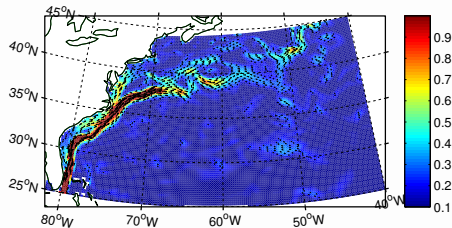


Horizontal velocity at surface:

Free run



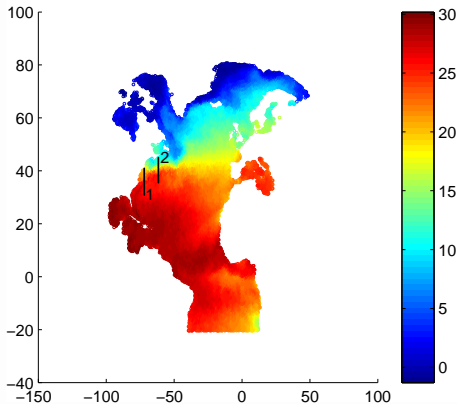
Assimilation



Gulf Stream velocity field
generated from 4 altimetric
satellite data (DEOS)

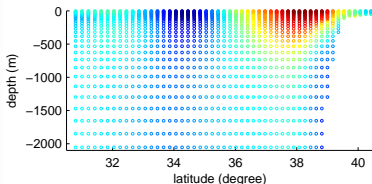
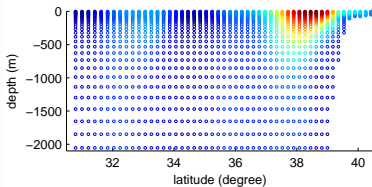
Meridional section in the Gulf Stream:

Localisation of the meridional sections:

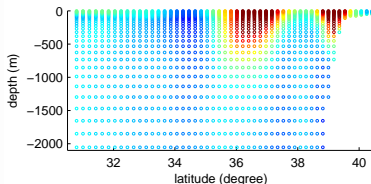
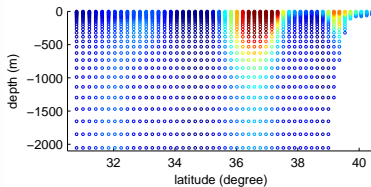


Meridional section in the Gulf Stream region (72° W):

Free run



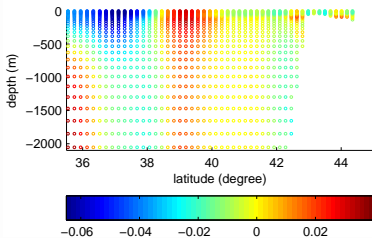
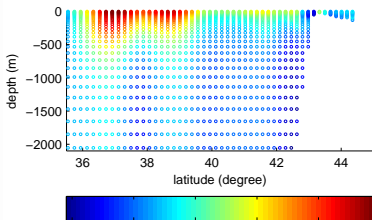
Assimilation



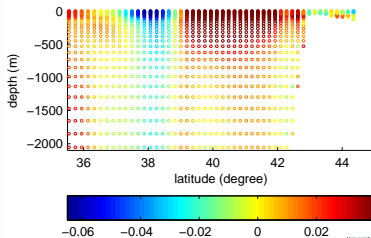
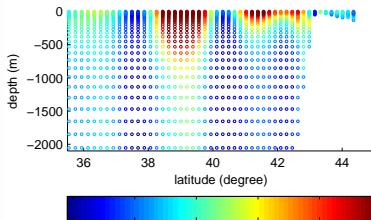
top: zonal velocity. bottom: meridional velocity.

Meridional section in the Gulf Stream region (61.5° W):

Free run



Assimilation



top: zonal velocity. bottom: meridional velocity.

Conclusion

Questions:

- assimilate Envisat SSH instead of Jason-1
- add SSH increment
- how to improve the analysis in depth? (assimilate S-profile, reduce T-profile error)
- more information for velocity validation

Acknowledgments

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