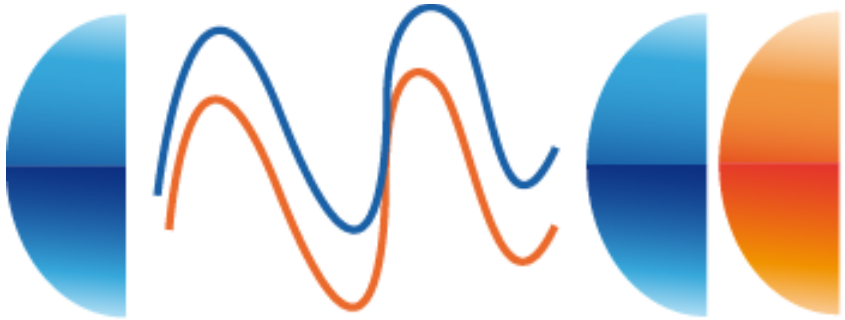


Centro Euro-Mediterraneo
per i Cambiamenti Climatici

The CMCC Global Ocean Reanalysis (1991-2010)

Andrea Storto, Simona Masina, Srdjan Dobricic, Ida Russo

4th International Conference On Reanalyses
Silver Spring, 7-11 May 2012

Outline

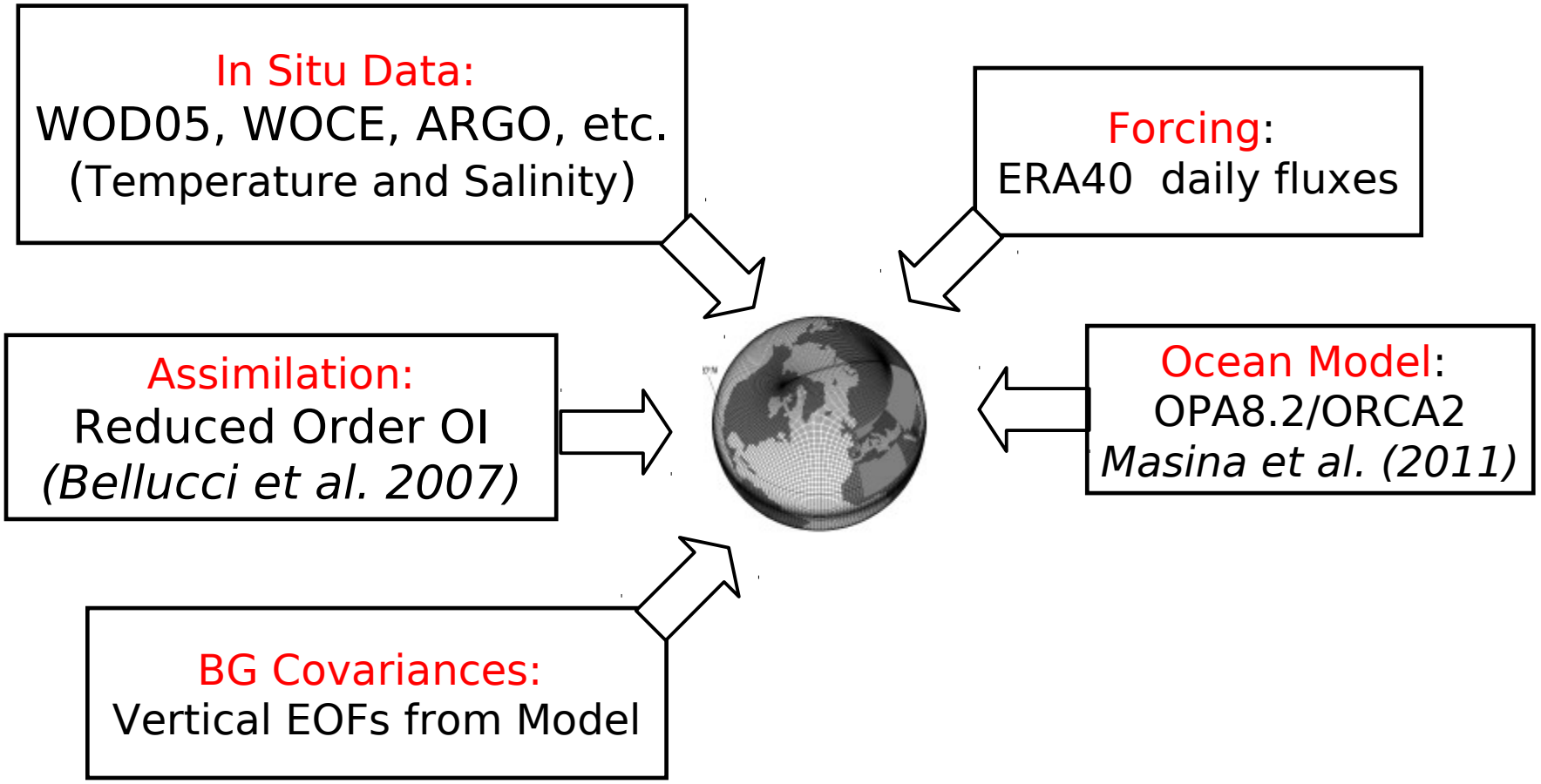
Overview of the CMCC global ocean reanalysis systems

Selected Results of recent and forthcoming developments

Plans and applications

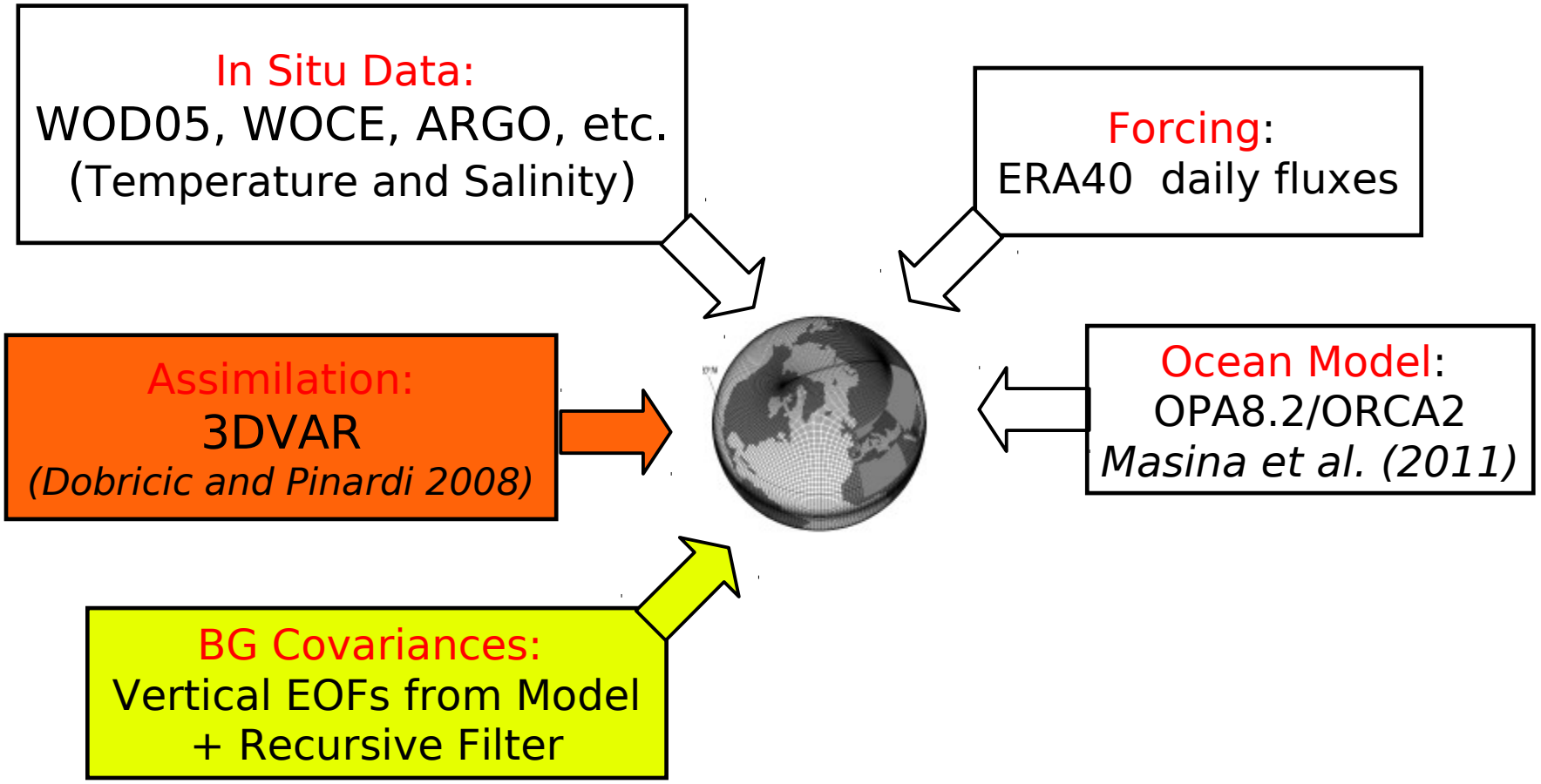
The CMCC Global Ocean (re-)analysis system

YEAR 2008



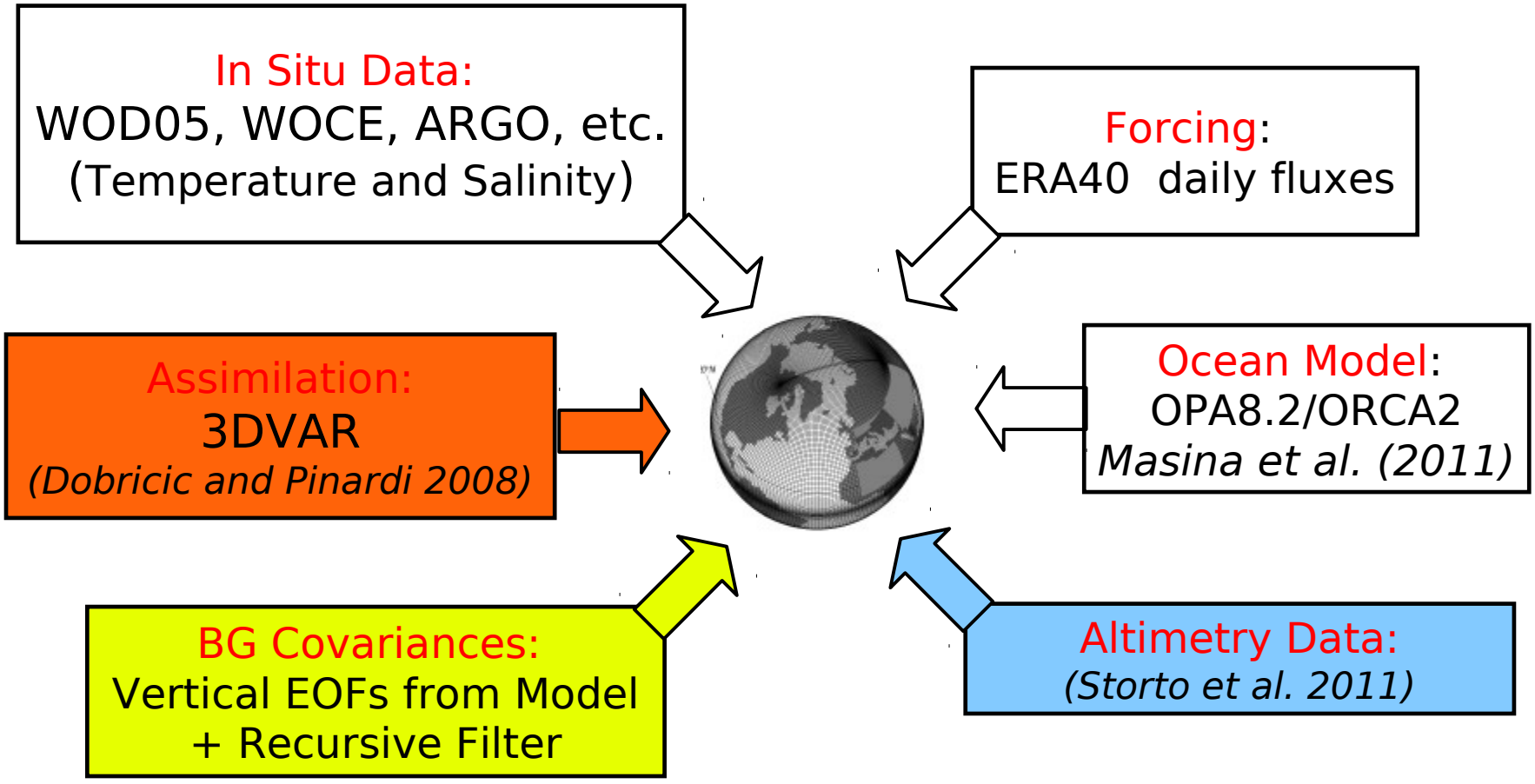
The CMCC Global Ocean (re-)analysis system

YEAR 2009



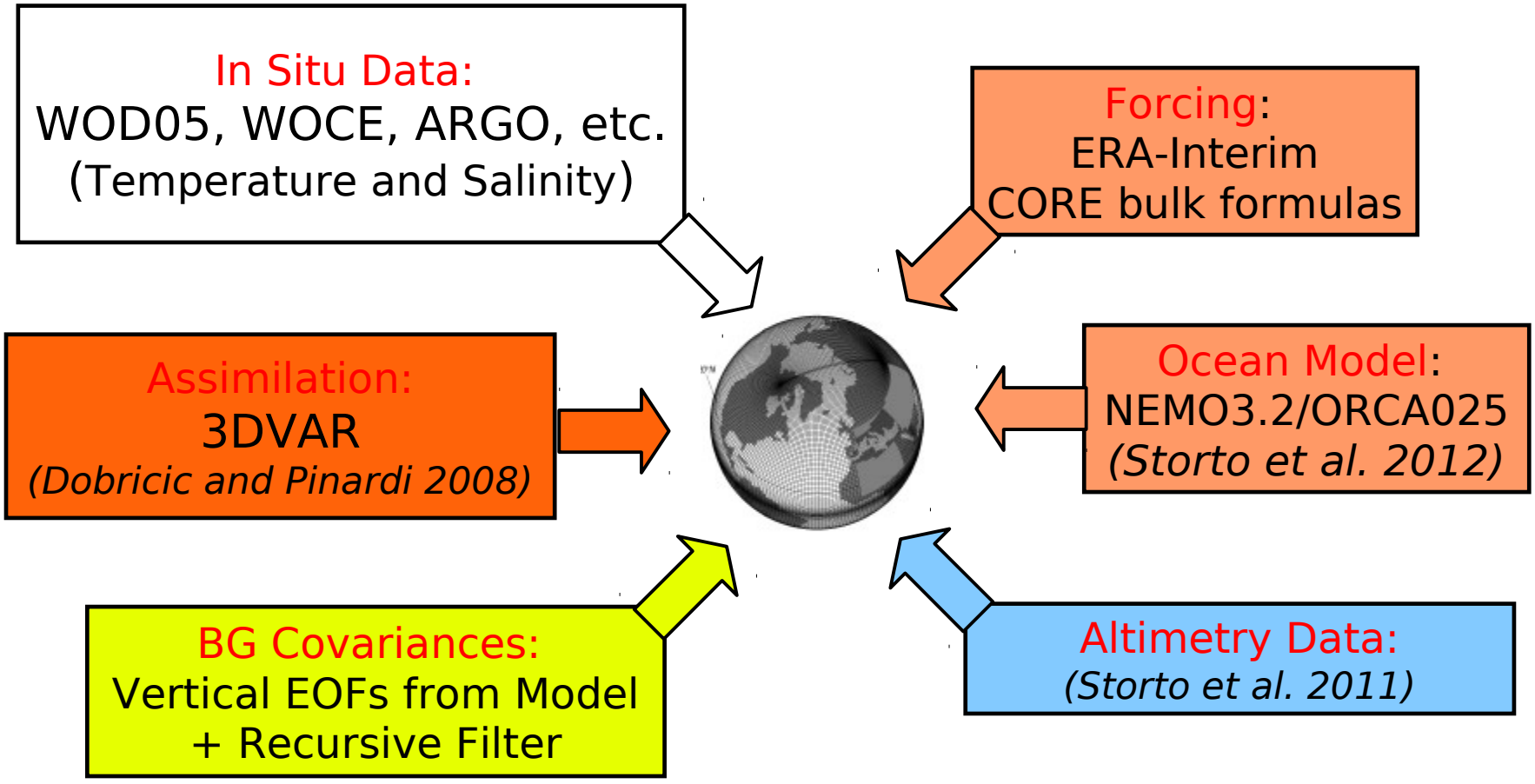
The CMCC Global Ocean (re-)analysis system

YEAR 2010



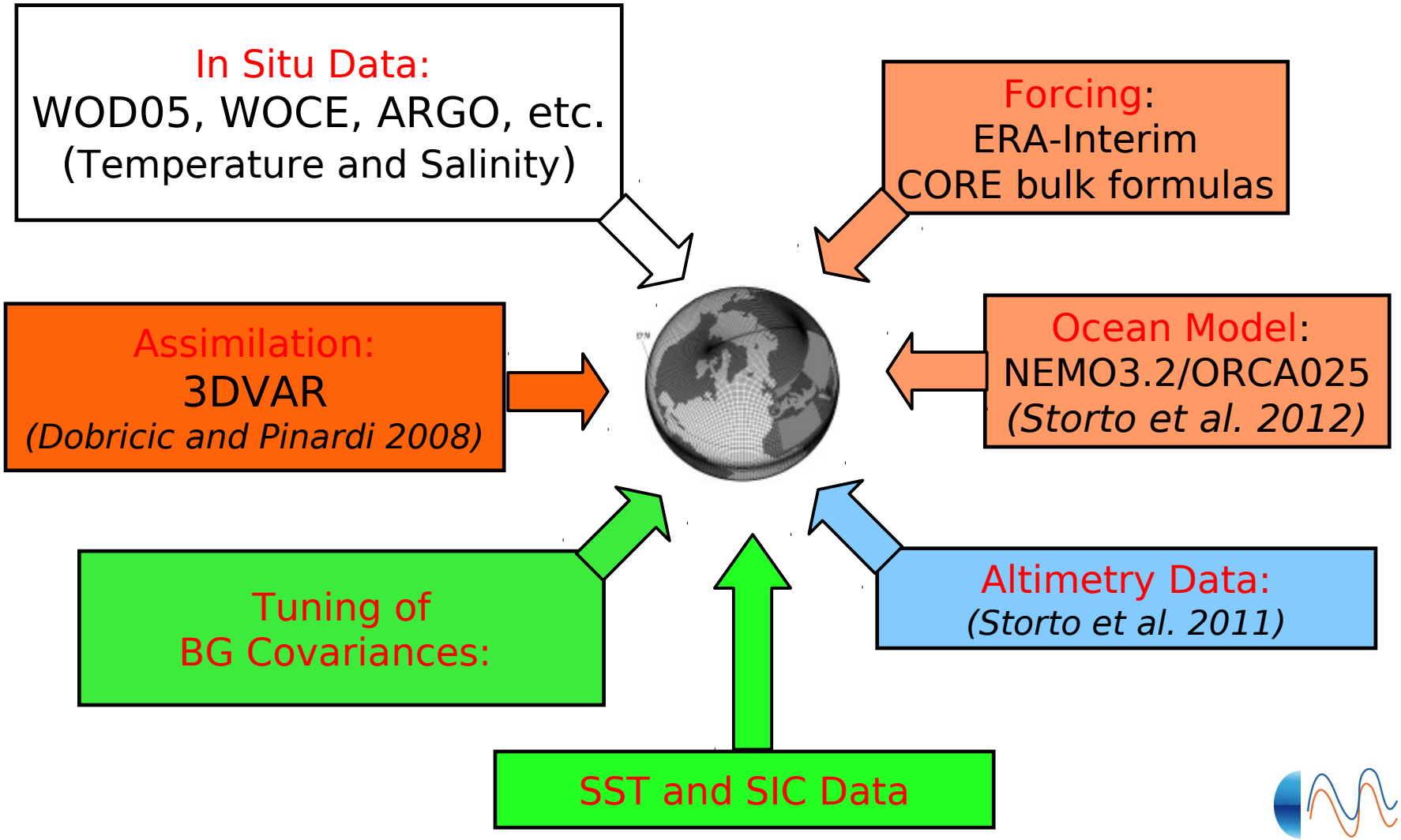
The CMCC Global Ocean (re-)analysis system

YEAR 2011



The CMCC Global Ocean (re-)analysis system

YEAR 2012



The 3DVAR formulation

Usual 3DVAR/FGAT formulation with BG term preconditioning (Dobricic and Pinardi, 2008, Ocean Mod.)

$$B = VV^T \qquad v = V^{-1}\left(X - X^B\right) \qquad d = Y - M\left(X^B\right)$$

$$J = \frac{1}{2} v^T v + \frac{1}{2}\left(d - H\left(Vv\right)\right)^T R^{-1}\left(d - H\left(Vv\right)\right)$$

$$V = V^H V^V$$

HORIZONTAL CORRELATIONS

Modeled by means of a first-order recursive filter (with 4 forward and back iterations):

$$V^H = W_y G_y W_x G_x$$

G are recursive filter operator;
W are normalization coefficients in order to have correlations with unitary amplitude.
Filter coefficients depend on resolution and correlation scale.

VERTICAL COVARIANCES

Modeled by means of seasonal vertical bivariate EOFS (at either full or coarse model resolution) derived from the eigendecomposition of a properly defined error dataset:

$$V^V = S\Lambda^{1/2}$$

which contains info on vertical variances and auto- and cross-correlations.

Assimilation of SLA

Within the 3DVAR iterations, the observation operator is given by the "dynamic height" approximation.

Analysis increments profiles are driven by the vertical structure of background-error covariances through the adjoint of the Eta operator.

Impact of choice of MDT
(Storto et al., 2011, MWR)

NO SLA ASSIMILATION

MDT FROM MODEL MSSH

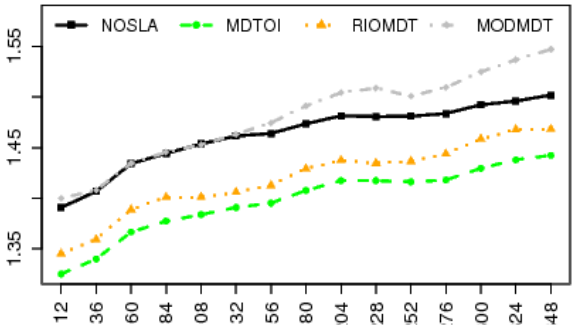
MDT FROM OI OF SLA ASSIMILATION MISFITS

RIO MDT (grav.+altim.+ins)

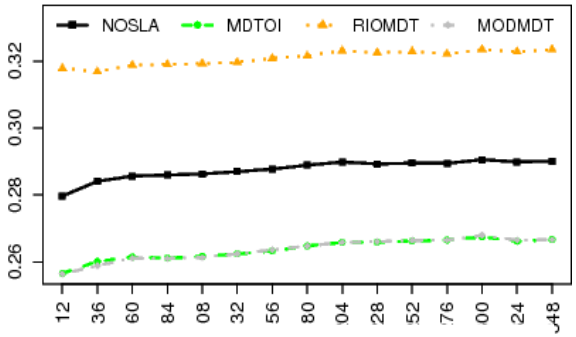
MDTOI always outperforms other MDTs

RMSE against TAO (PACIFIC)

TEMPERATURE

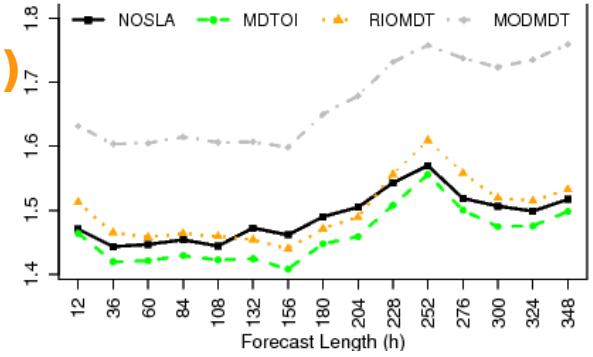


SALINITY

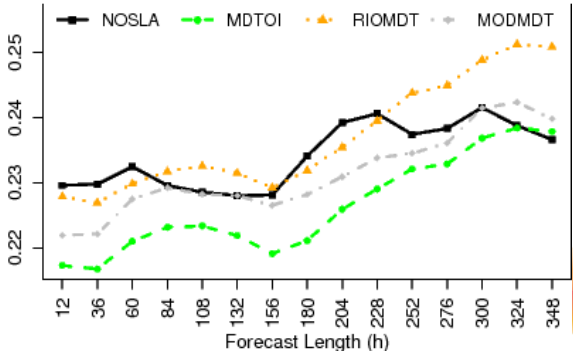


RMSE against RAMA (INDIAN)

TEMPERATURE



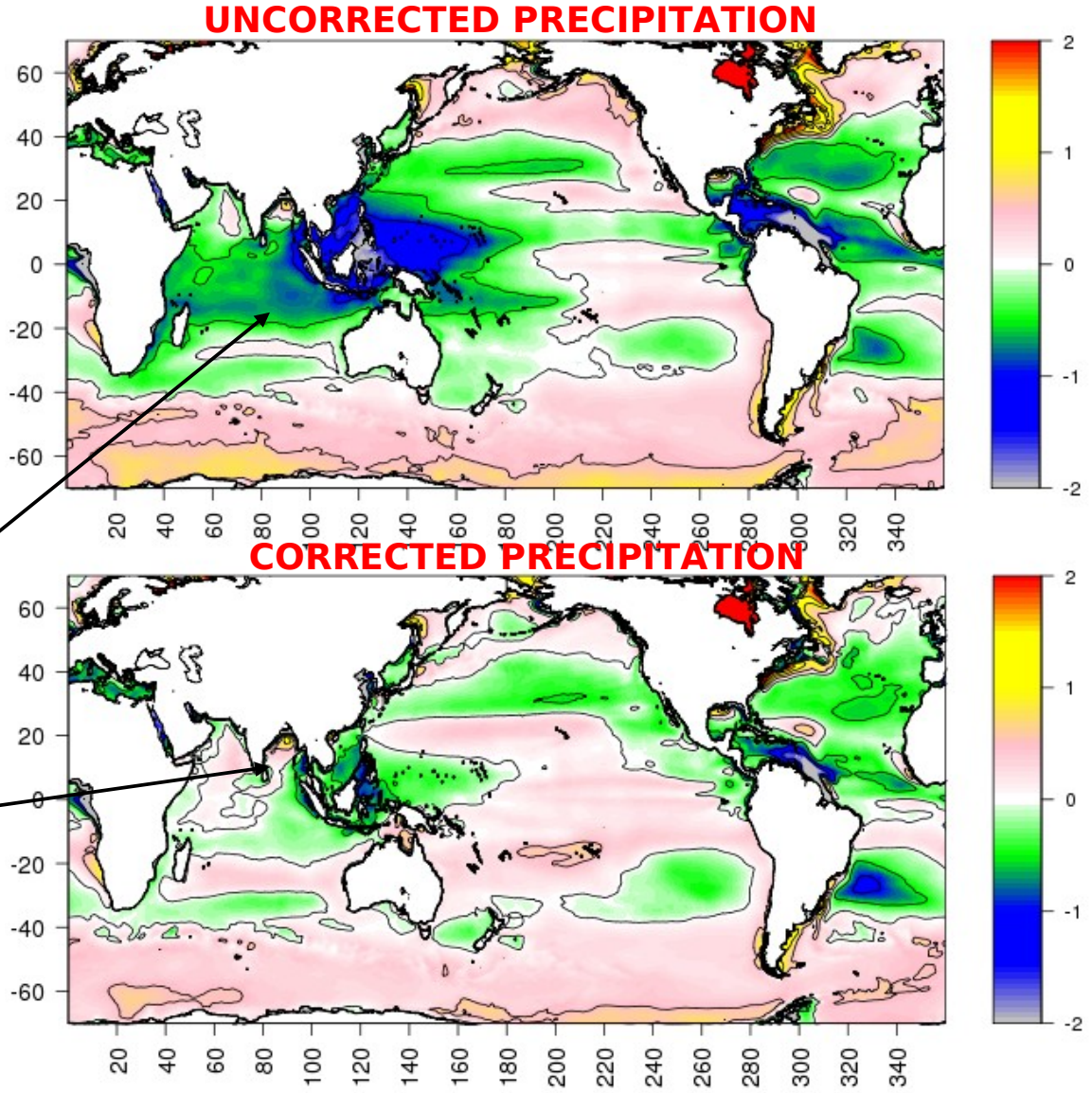
SALINITY



Correction of freshwater fluxes

1989-2009 SSS BIAS (psu, MODEL-WOA2009)

Precipitation fluxes are corrected with a climatological coefficient deduced from the comparison between ERA-Interim and REMSS/PMWC microwave satellite data (*Storto et al. 2012, OSD*)



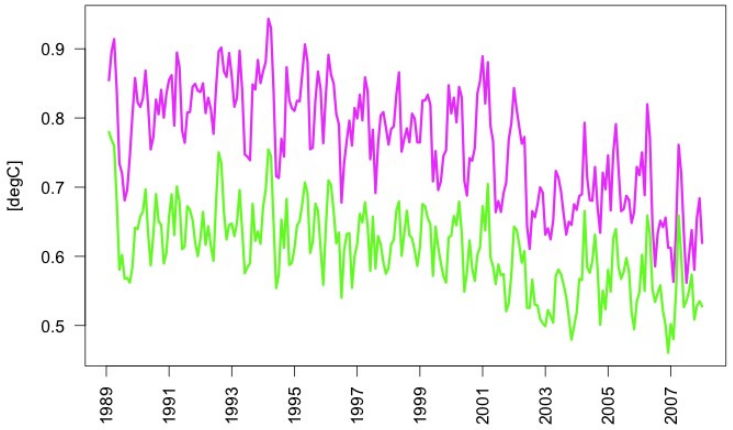
Fresh Bias Reduction in the Tropics (especially ITF)

Correction of radiative fluxes

Radiative fluxes from ERA-Interim are corrected with a climatological coefficient deduced from the comparison between ERA-Interim and GEWEX/SRB radiation data (G. Garric, Mercator-Ocean)

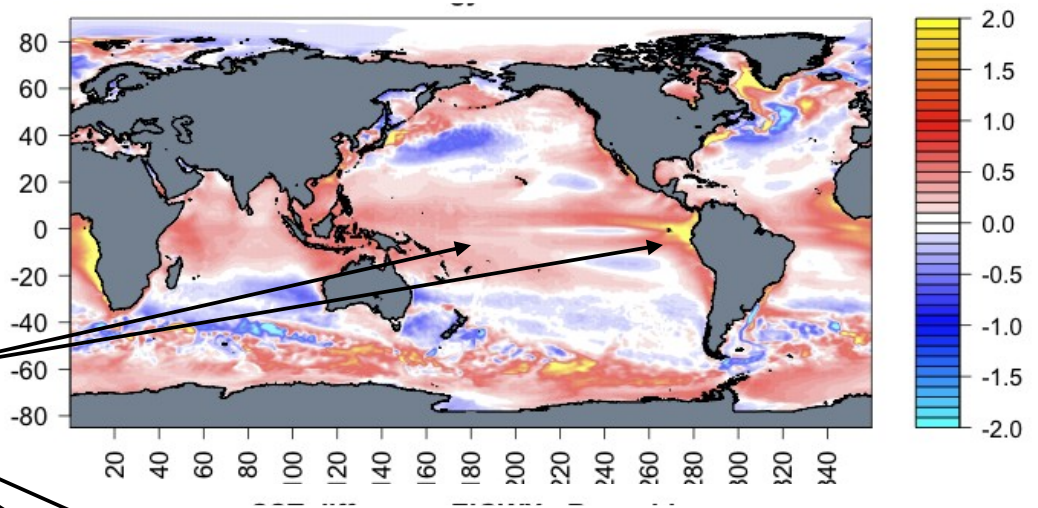
Warm Bias Reduction in the Tropics (especially eastern upwelling areas)

TROPICAL SST RMSE
UNCORRECTED vs CORRECTED

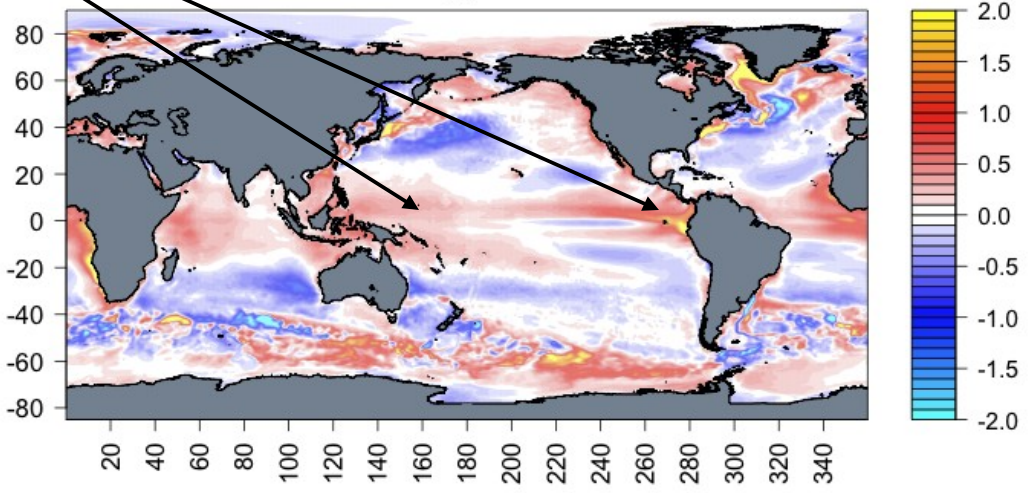


1989-2007 SST BIAS (degC, MODEL-REYNOLDS)

UNCORRECTED RAD FLUXES



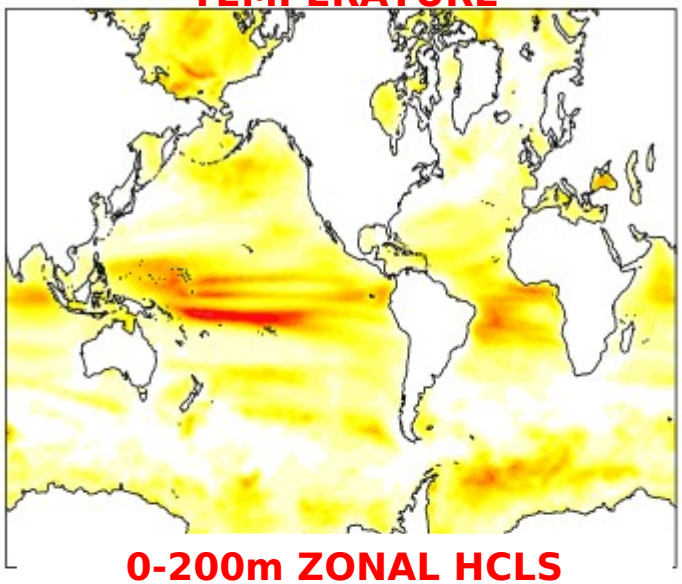
CORRECTED RAD FLUXES



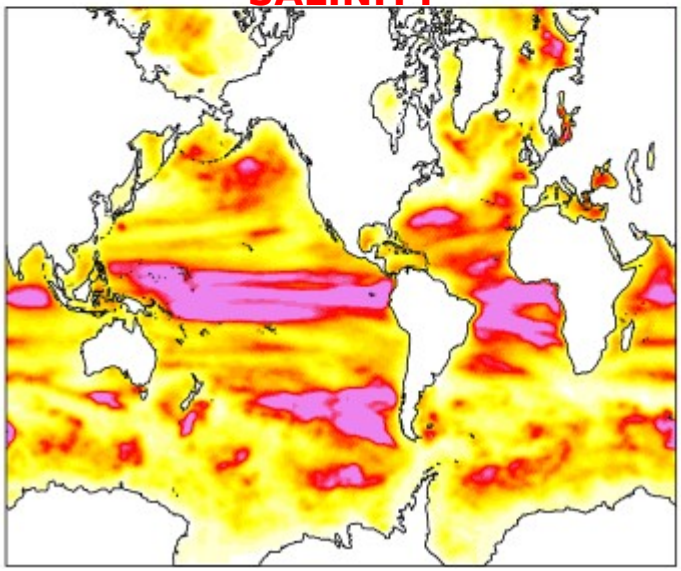
Locally-varying horizontal correlation length-scales

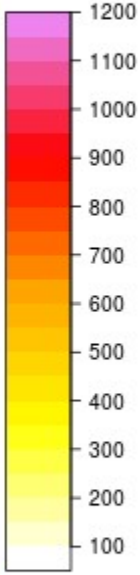
Recent extension in the global ¼ degree configuration allows for non-uniform horizontal correlation length-scales (HCLSs), i.e. recursive filter has anisotropic coefficients function of 3D HCLSs

0-200m ZONAL HCLS TEMPERATURE

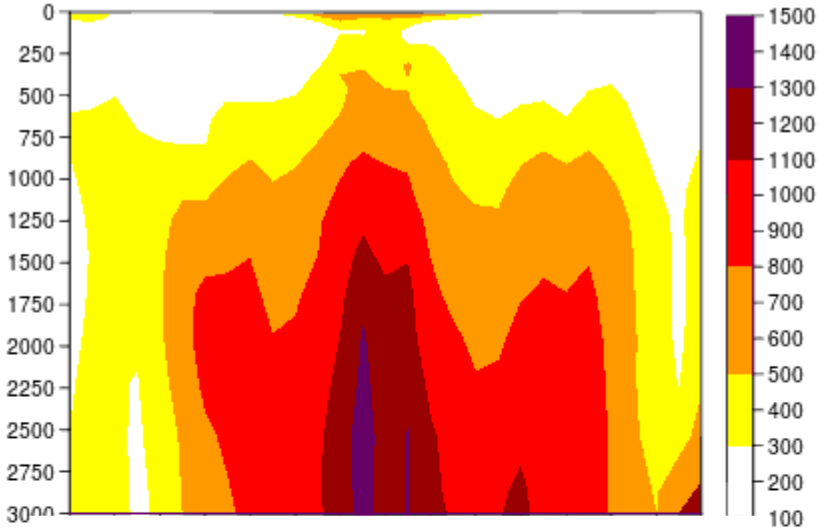


0-200m ZONAL HCLS SALINITY

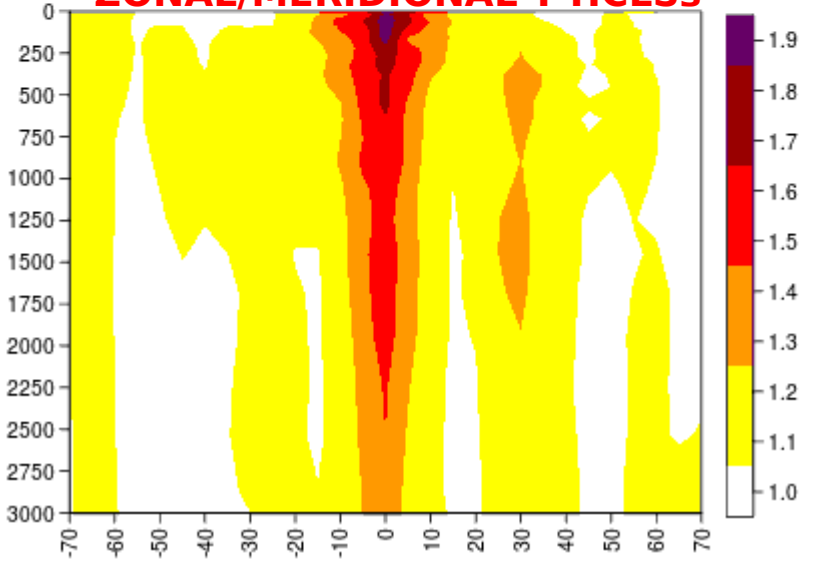




ZONALLY AVERAGED ZONAL T HCLSs vs DEPTH

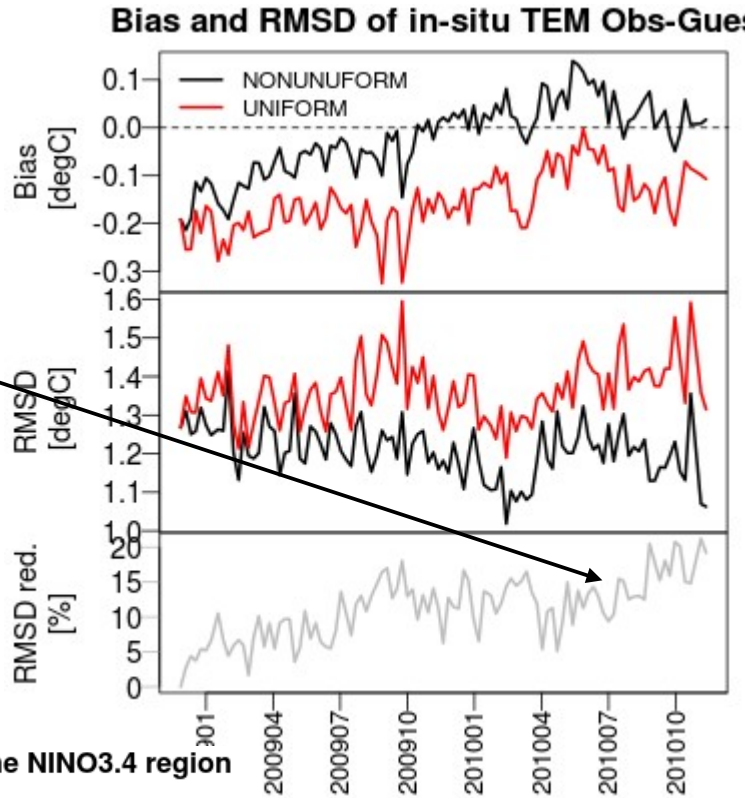


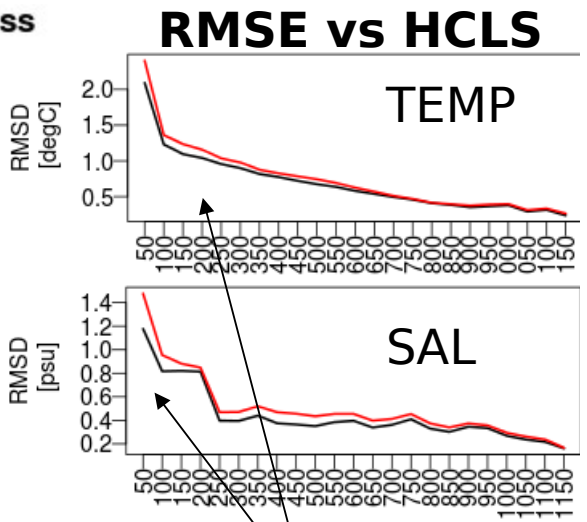
ZONALLY AVERAGED RATIO ZONAL/MERIDIONAL T HCLSs



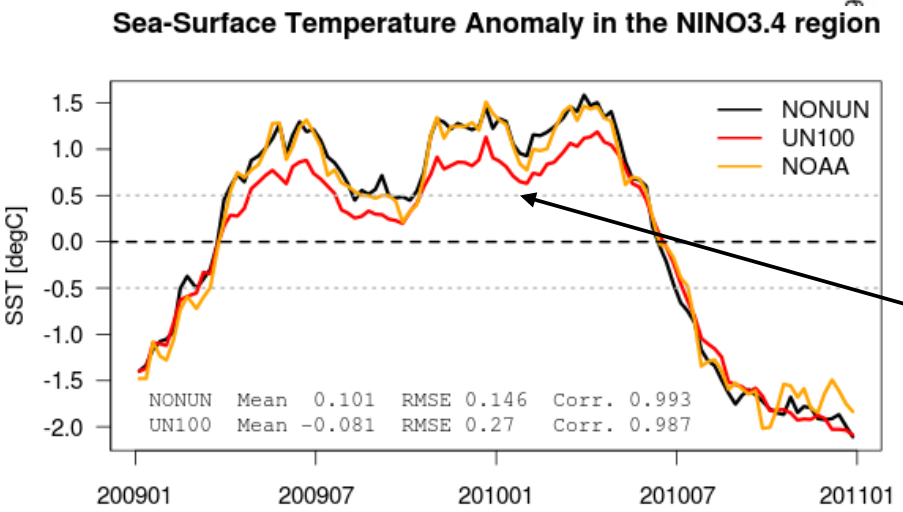
Locally-varying horizontal correlation length-scales

Increasing T obs minus guess RMSD





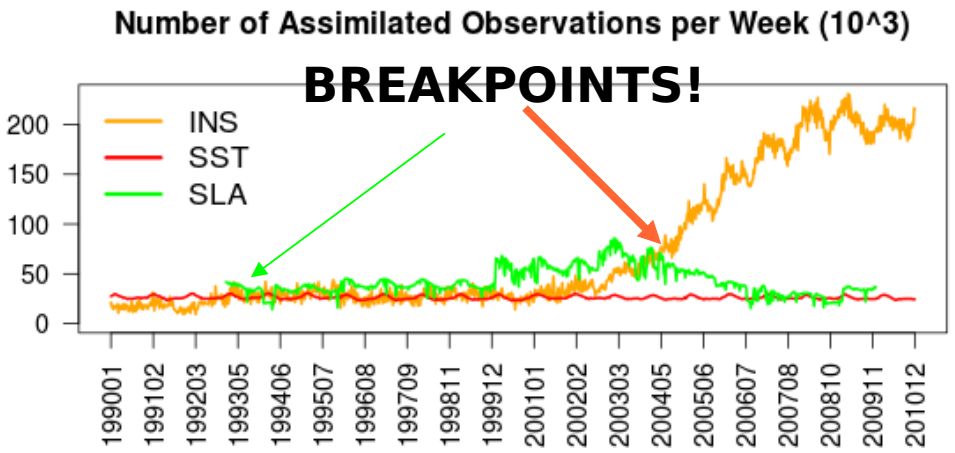
Impact on Mesoscale areas

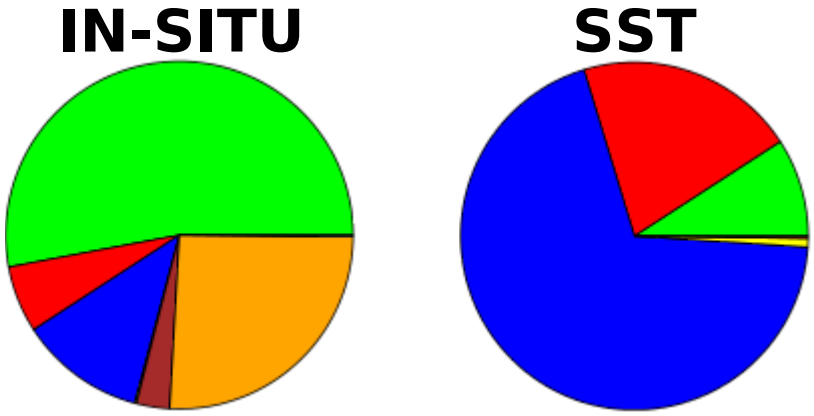


Impact on Tropical Pacific SSTA During El Nino 2009

Observing network

	DATASET	PREPROCESSING
IN SITU PROFILES	**UKMO HADLEY EN3 DATASET [quality-checked XBT (fall-rate corrected), CTD, Argo, Moorings]**	**Climatology check** **Background quality check** **Horizontal Thinning** **Vertical Thinning** **Ice rejection** **Vertical Consistency check**
SLA	**CLS/AVISO Delayed time along-track products**	**Background quality check** **Horizontal Thinning** **Ice, coastal and Equator rejection** **Applicability LNM**
SST	**NOAA ¼ daily archived analyses (AVHRR+AMSR-E)**	**Climatology check** **Background quality check** **Horizontal Thinning** **Ice and coastal rejection**



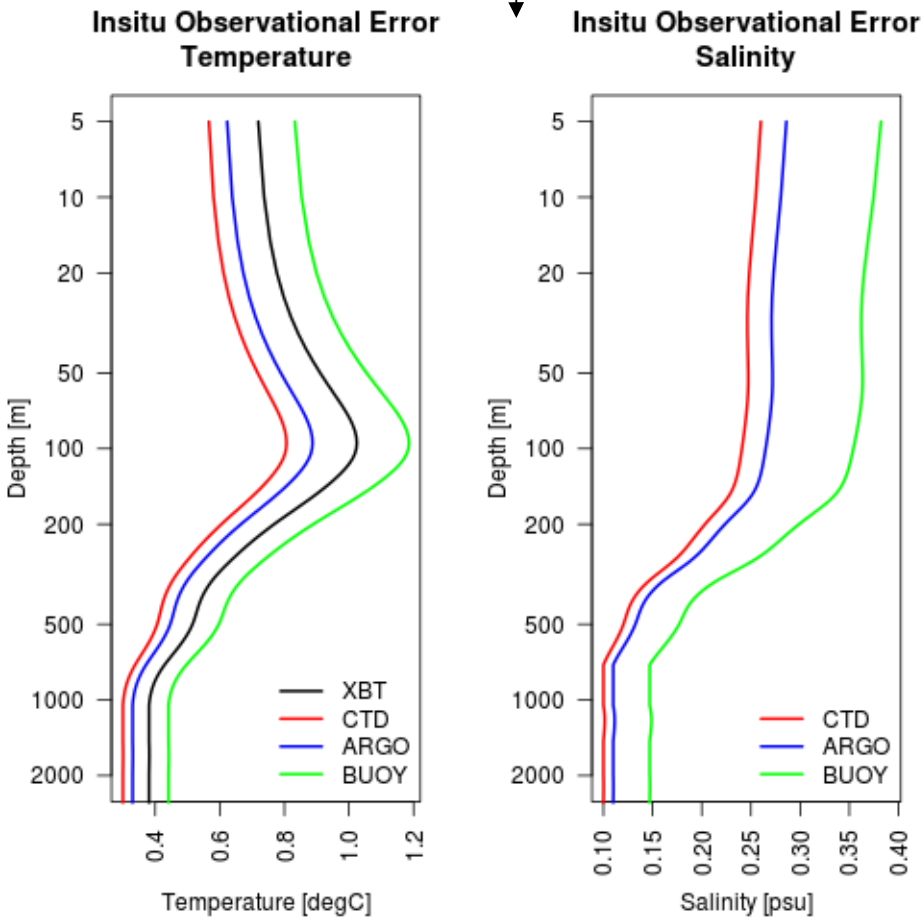


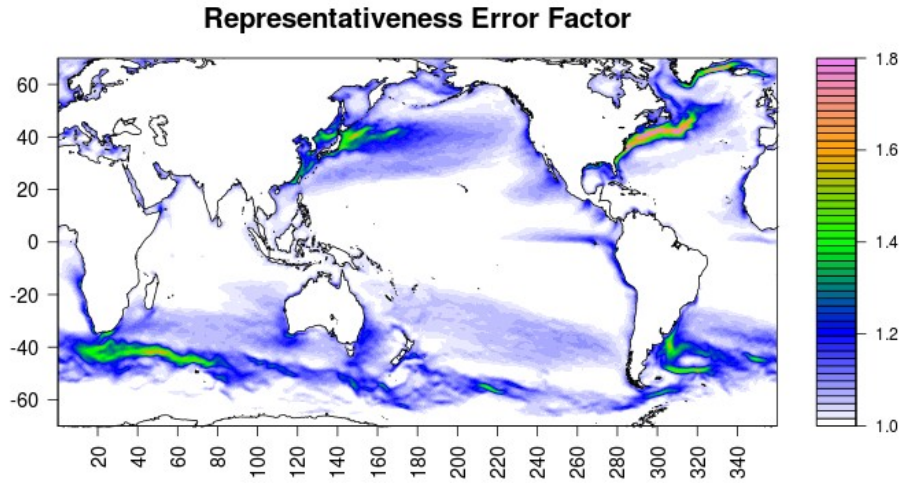
Retained observations

Observational errors

Observational errors were tuned starting from Ingleby and Huddleston (2007) with by means of the Desroziers' method (a posteriori diagnostics from assim)

Obs type dependence for Insitu





Geographical dependence for Insitu

SLA error defined as sum of MDT, obs. oper., instr. and representation error variances

Status and plans

PRODUCTION (¼ degree resolution)

• 2 Releases have been produced for MyOcean (CGLORSV1 and CGLORSV2) for the period 1991-2010 (1993-2009 officially released)

> Bernard Barnier's presentation tomorrow

• 1 Release that fixes some problems in CGLORSV2 (sea-ice and SLA assimilation) is under production

MAIN CONCERNS

• T/S Vertical covariances may produce significant model drifts

• Optimal Initialization/Spinup for the reanalysis still needs to be addressed

PLANS

• Use of ensemble-derived sets of vertical covariances;

• Vertical localization operator to avoid spurious vertical correlations;

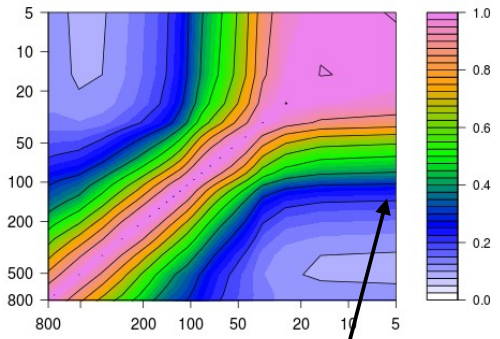
The main concern: model drifts

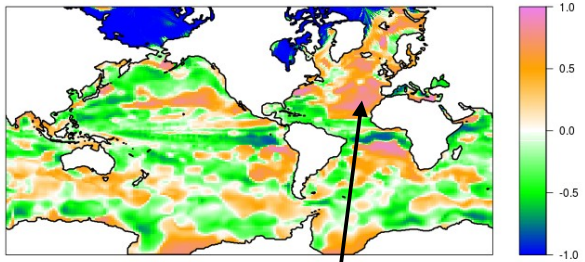
Global T Vertical Correlations

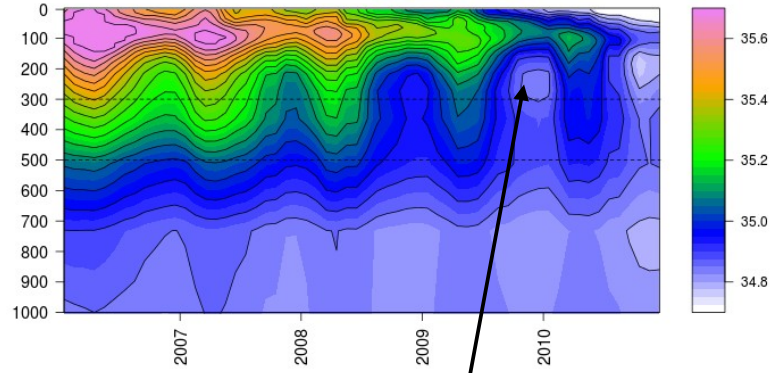
SST/SSS Cross-correlation

ATLANTIC SALINITY (60S-60N)

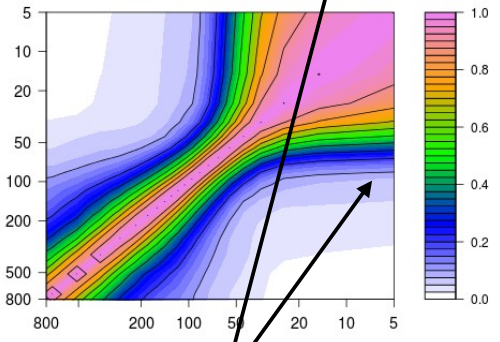
CLIMATOLOGICAL ANOMALY DERIVED EOFS

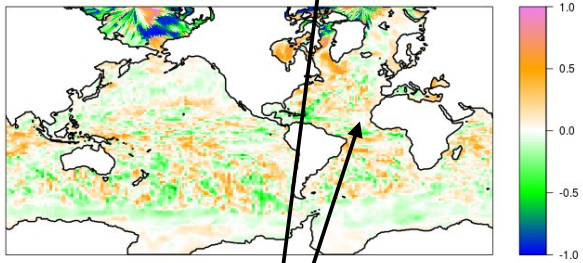


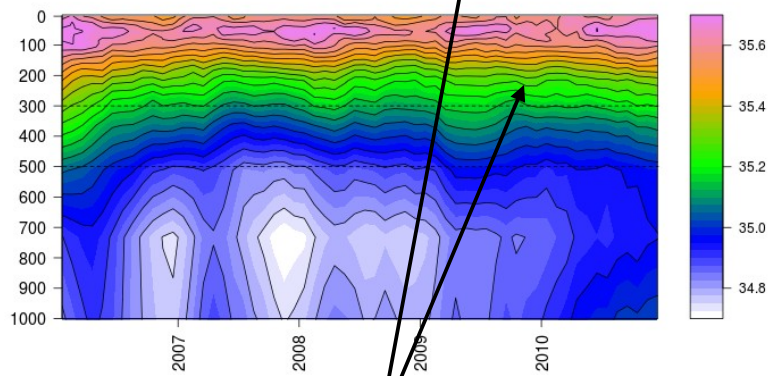




ENSEMBLE DERIVED EOFS FROM COUPLED MODEL (COLLABOR. JAMSTEC/RIGC)







Shorter T Vert. Corrs

Weaker T/S coupling

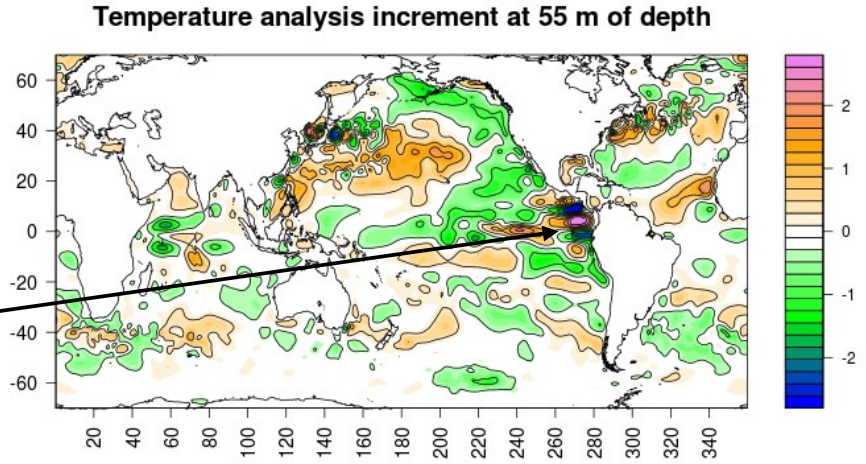
No salinity drift

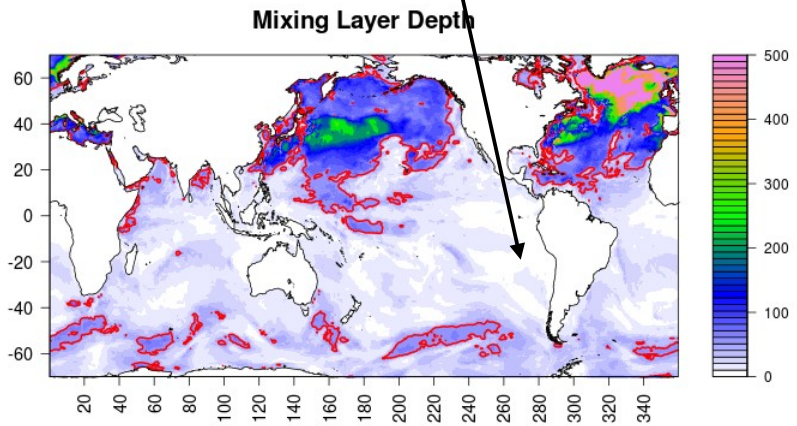
Flow-dependent aspects: Vertical Localization of Corrs

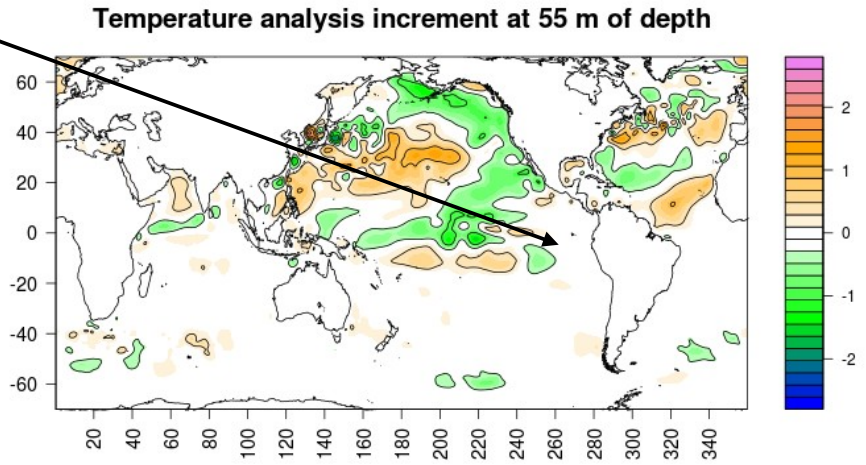
Use of adaptive density criterion to form a vertical localization operator for avoiding spurious long vertical correlations below MLD in the EOFs

The localization zeroes the influence of surface observations below MLD

Example of winter-time application of flow-dependent localization: twin experiment with SST only







Further developments we're working on

- Detailed EOFS comparison and implement simple large-scale bias-correction schemes for model drift mitigations;

- A balance operator ("barotropic operator") that will allow to correct u,v further to T,S. It will be possible to test the assimilation of drifter trajectories;

- Variational correction of the Mean Dynamic Topography to improve SLA assimilation;

- Multilinear bias correction of space-borne observations and reformulation of background quality check to account for actual observation misfit distributions;

- Sea-ice assimilation brought into 3DVAR (now nudging);

Main Usage of CMCC ocean reanalyses

Estimate the interannual-to-decadal upper ocean variability *(Masina el al. 2011)*;

- **Provide ocean initial condition for seasonal *(Alessandri et al, 2010)* and decadal forecating activities *(Bellucci et al, under review)*;**
- **Give a contribution to the GSOP/GODAE Ocean View initiative on global ocean analyses intercomparison;**
- **Provide a set of oceanic variables for the validation and comparison with the CMCC Earth System Model *(Vichi et al, 2011)***

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Thank you!

General configuration of C-GLORS

OCEAN GENERAL CIRCULATION MODEL

- NEMO (3.2.1) 0.25 L50 + LIM2 Sea-Ice Model
- CORE bulk formulas with 3-hourly ERA-Interim turbulent fluxes and daily freshwater and radiative fluxes (solar diurnal cycle analytically imposed)
- Correction of radiative fluxes with GEWEX/SRB
- Correction of precipitation fluxes with REMSS/PMWC
- Nudging to NOAA sea-ice concentration data (15-day relaxation scale)

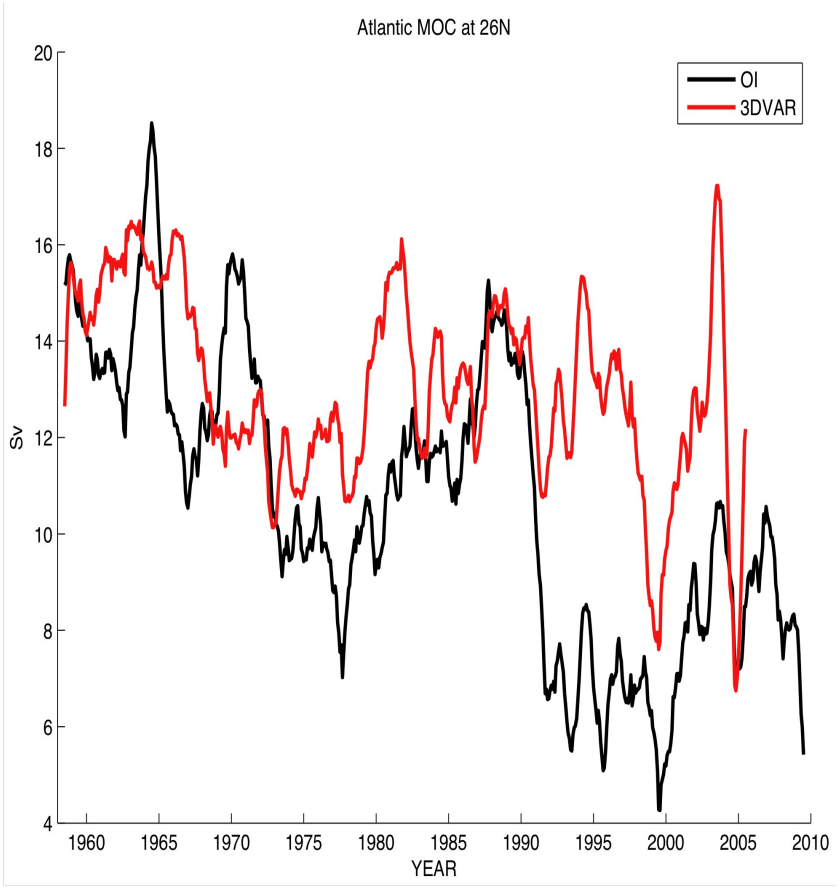
DATA ASSIMILATION

- 3DVAR/FGAT formulation with weekly correction of (T,S)
- “Direct initialization”
- Horizontal correlations via first-order recursive filter
- Vertical covariances via seasonal bivariate EOFs of T, S
- Assimilation of SLA through the adjoint of the “dynamic height” formula

INITIALIZATION

- Free run initialized from 1979 (ERA-Interim) from ocean at rest and WOA climatology
- Assimilation switched on in 1989

Decadal climate predictions with the CMCC coupled model



Courtesy by A. Bellucci

Time series of the maximum Atlantic MOC (AMOC, Sv; 1 Sv=106 m3s-1) at 26oN from CMCC ocean analyses (used to initialize decadal predictions) using OI and 3DVAR data assimilation schemes.

Assimilating altimetry data determines a stronger AMOC. This results in large perturbations on the initial state of the MOC for different ensemble members.

Hindcasts initialized on 1995 with OI (black) and 3DVAR (red).