

# Prévisibilité décennale

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## Plan:

- Introduction
- Etude en modèle parfait
- Initialisation: l'approche IPSL
- Premières simulations CMIP5
- Prochaines étapes



*Pôle de modélisation IPSL*  
*29 Juin 2010*



# Questions scientifiques



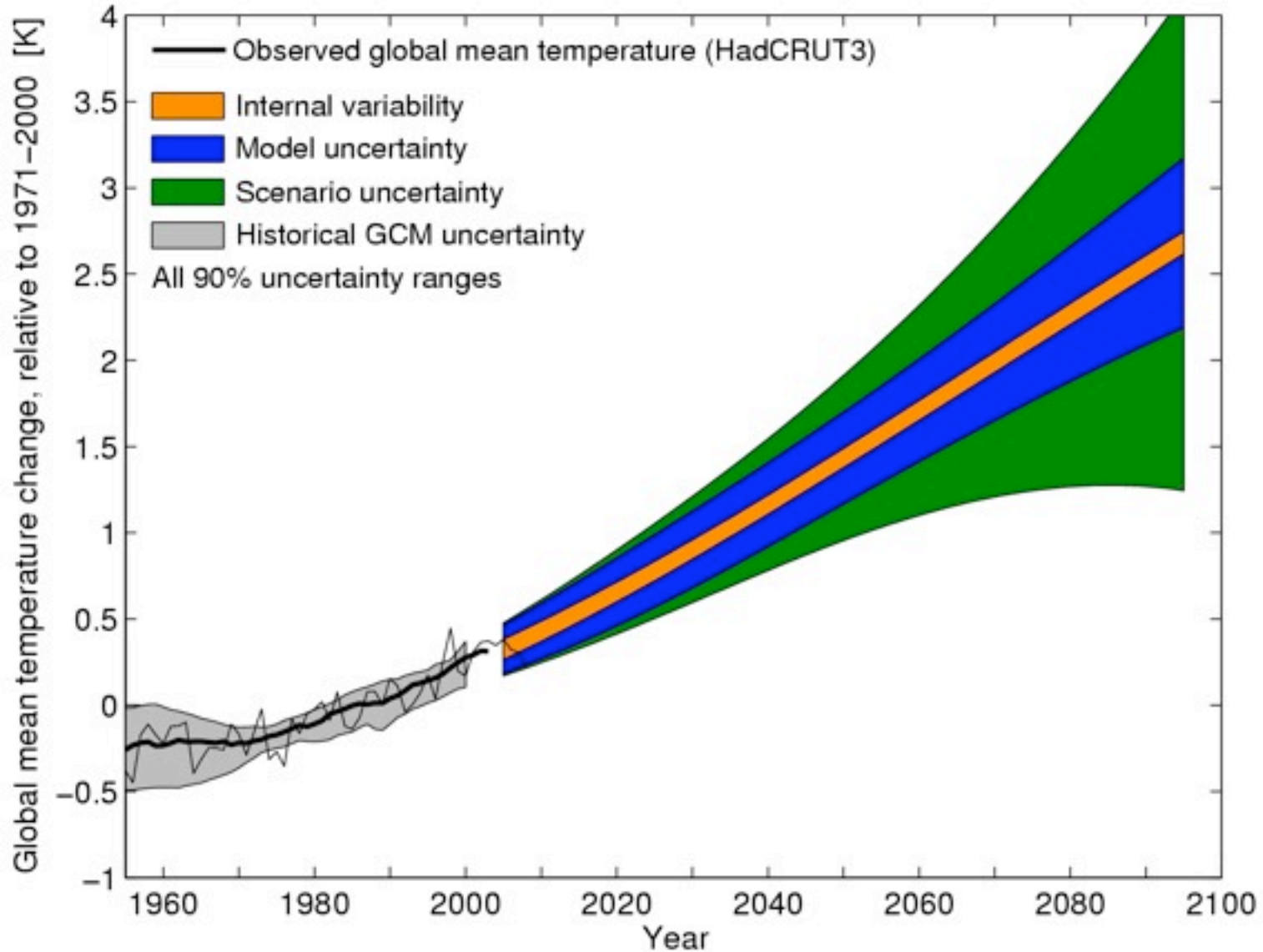
- Quelle prévisibilité décennale ?
- Mécanismes associés
- Focus Atlantique Nord (Tropiques et austral à suivre)

Mais aussi:

- Comment initialiser le système couplé O/A (+SI/LS) ?
- Prévisibilité potentielle et études en modèle parfait
- Comprendre l'ajustement initial du modèle

# Projections 21ème siècle

Sources d'incertitude pour les projections décennales de température moyennes



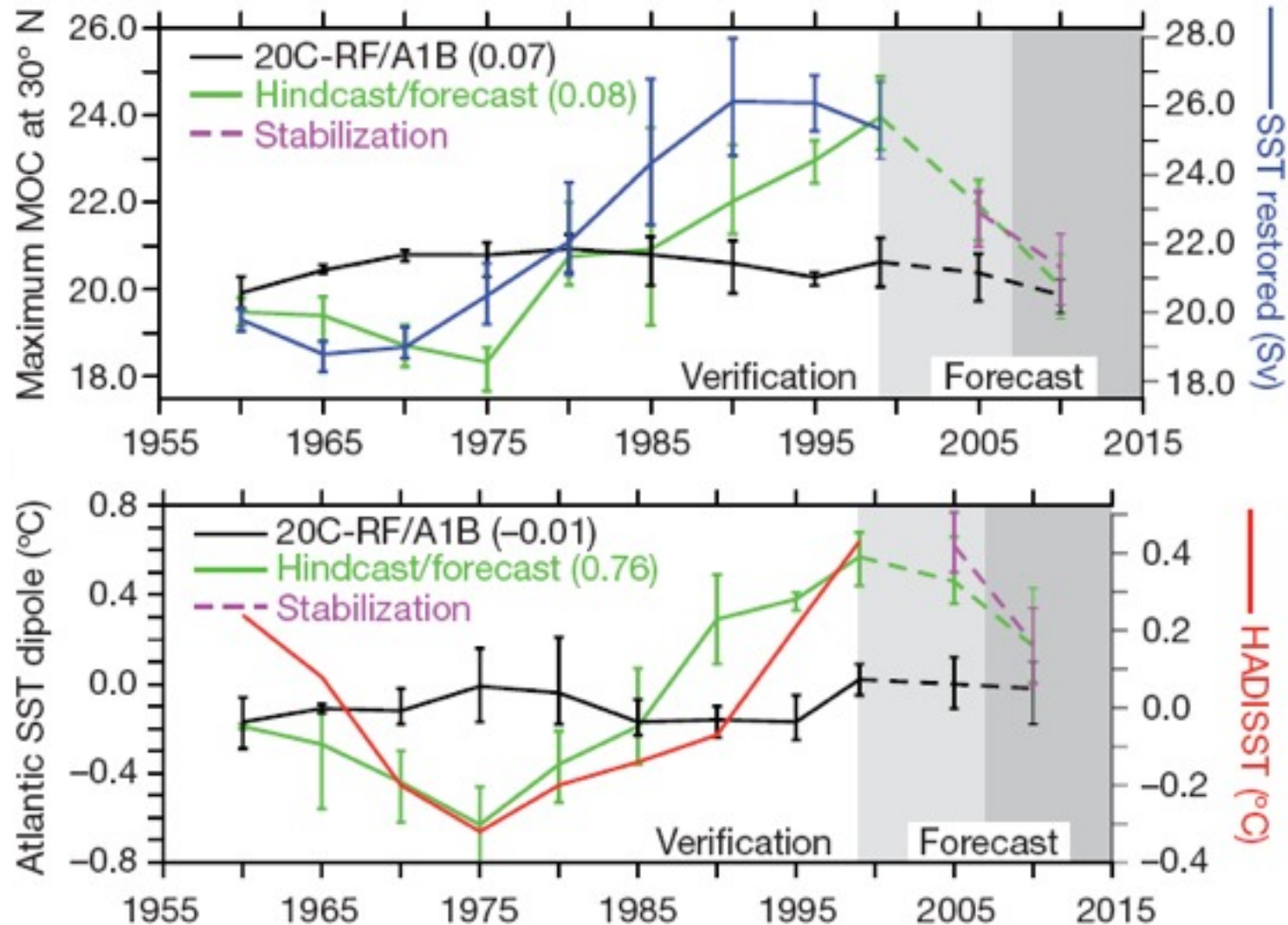
# Un exemple d'exercice de prévision décennale

ECHAM5/MPI-OM

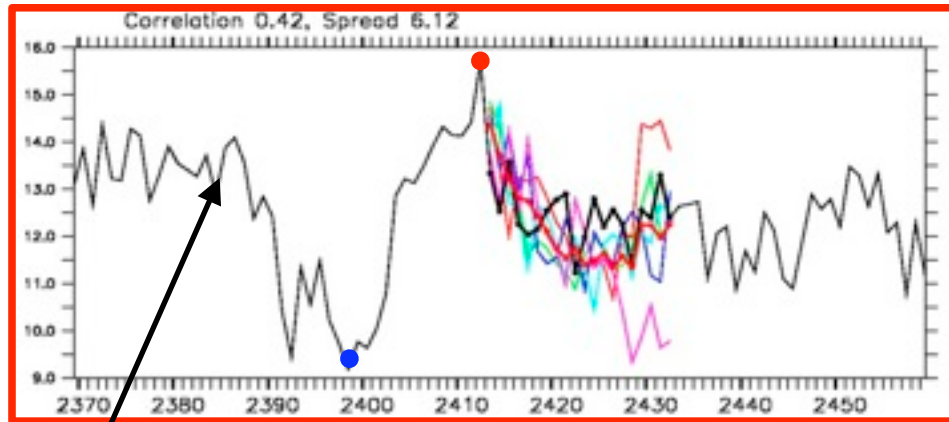
*Keenlyside et al. 2008*



Les variations basse fréquence de la circulation océanique et la structure de SST associée sont mieux représentées dans une simulation initialisée

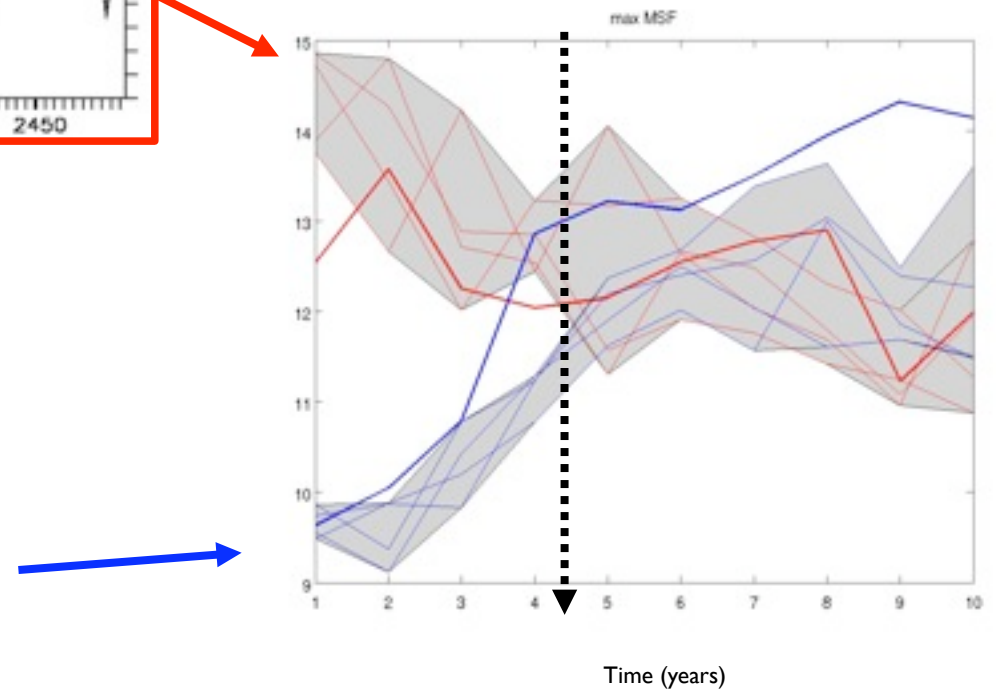
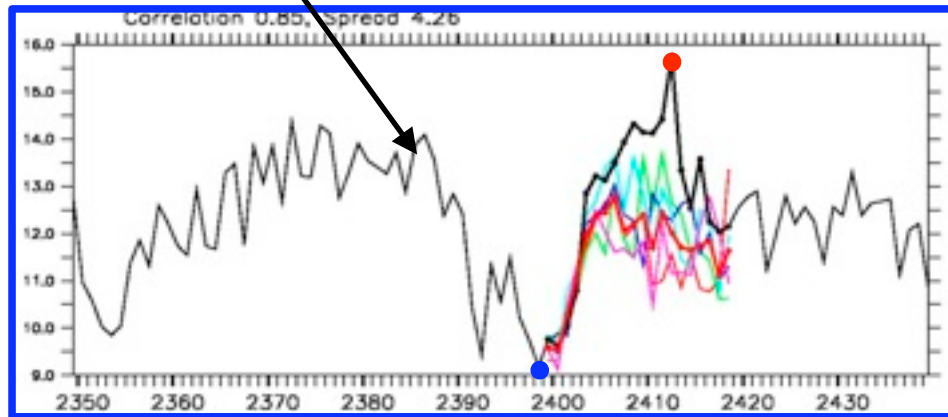


# Prévisibilité de IPSL-CM5 en modèle parfait



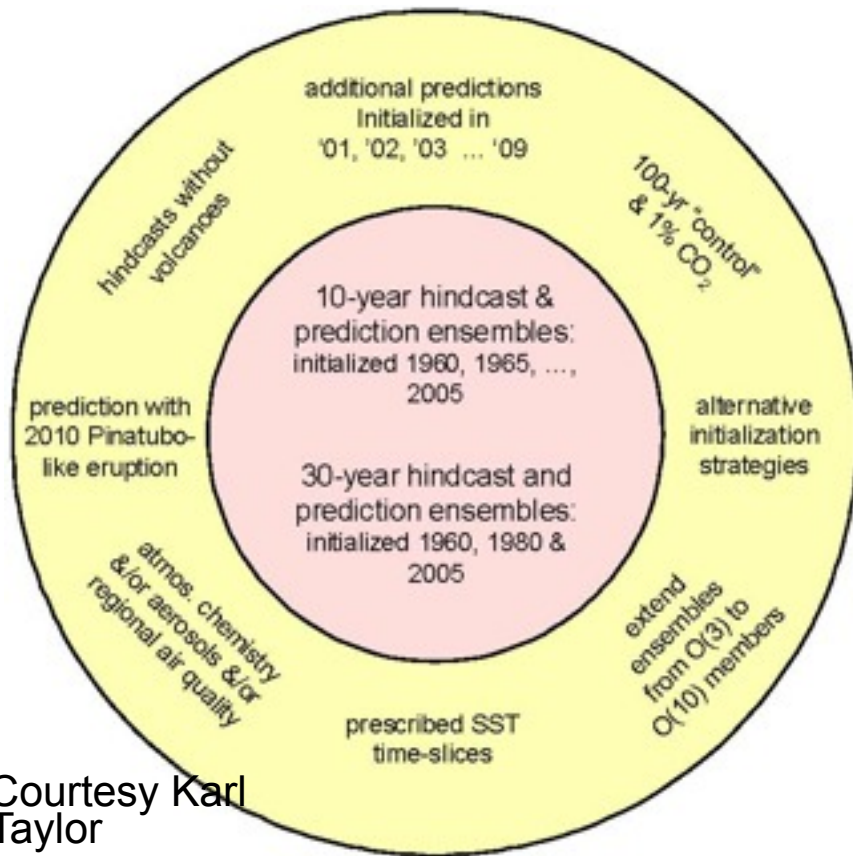
Diagnostic: max MOC Atlantique

CTL= ST11R

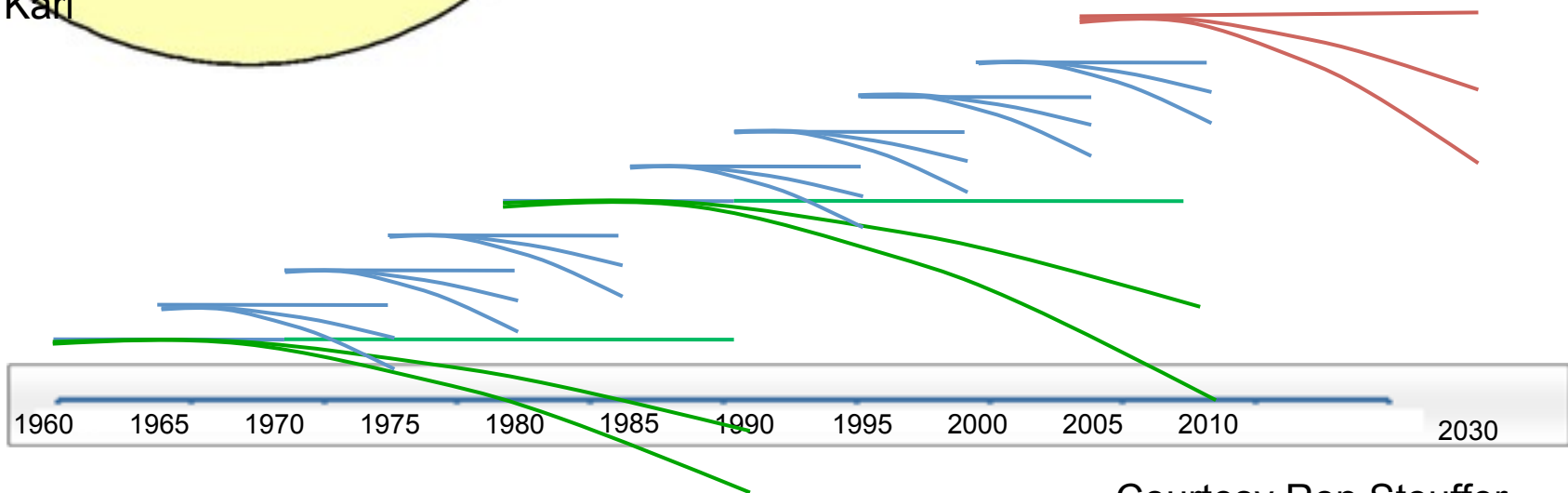


Prévisibilité de 4-5 ans

# Expériences CMIP5 de prévisibilité décennale du climat



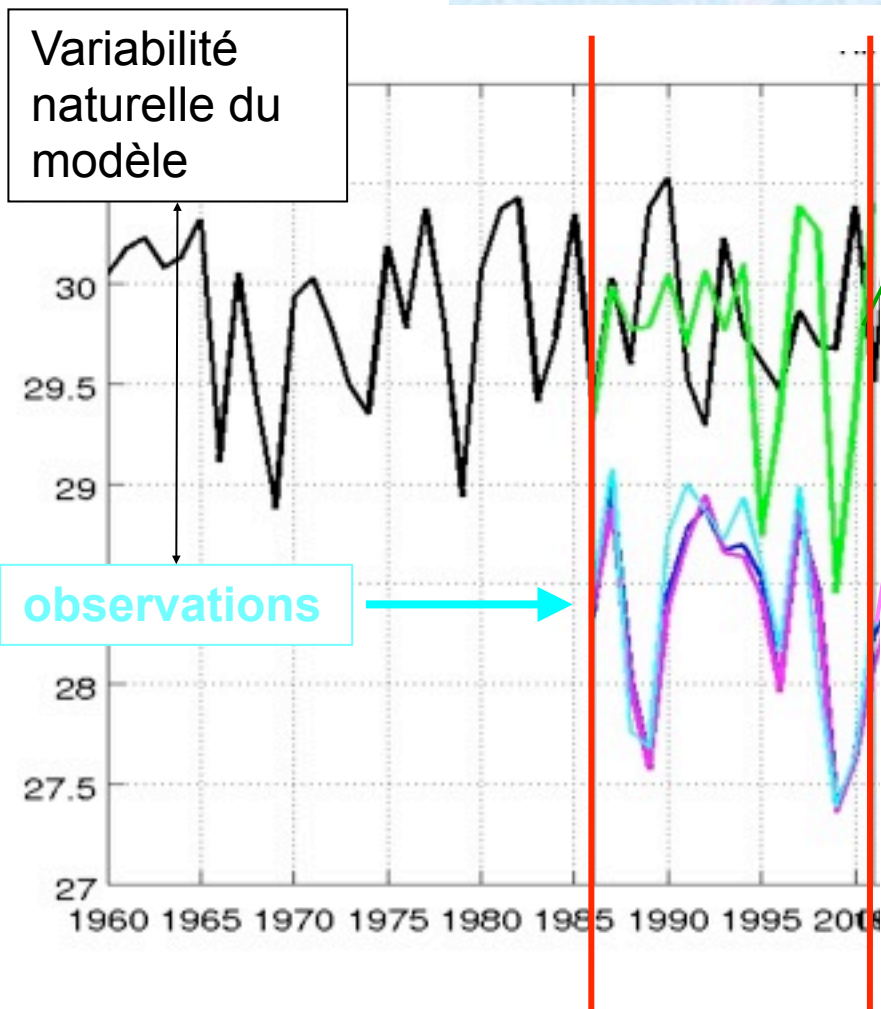
~12 groupes vont contribuer



Courtesy Ron Stouffer

Courtesy Karl Taylor

# Le problème de l'initialisation



## Q1: FULL vs. ANOM ?

Initialisation ANOM:

Pas de dérive mais état moyen non-conforme aux obs.

Initialisation FULL:

Dérive mais état moyen observé au départ

*Se caler sur la variabilité observée, mais sans s'éloigner trop du monde du modèle pour pouvoir envisager une prévision*

**Q2: Guidage en surface vs. 3D océanique ?**

# Initialisation strategy at IPSL for decadal hindcasts



- Surface nudging only
  - explore different strategies of surface nudging
- Less “intrusive” for ocean dynamics
- Benefit from Drakkar / NEMO forced OGCM experience

The coupled model: IPSL-CM5

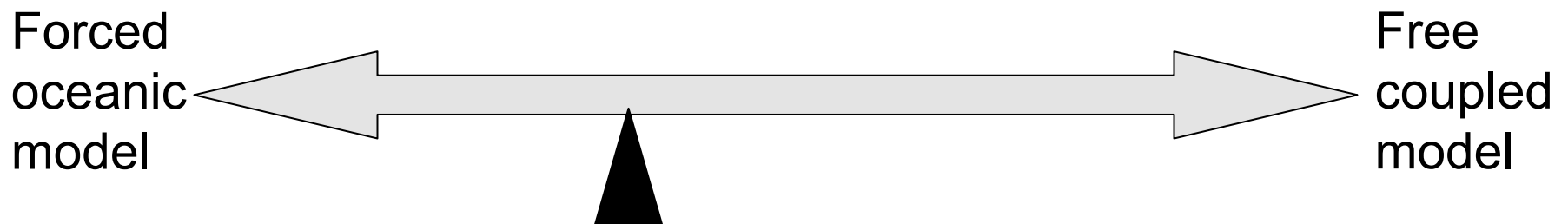
- Current tests: 96x95 L39 + ORCA2
- Other target: 144x142 L39 + ORCA2



# Constraints and time scales

<i>Region</i>	<i>Variables</i>	<i>Timescales</i>
Tropics	SST, wind key in initial shock	Quick adjustment (5y)
Mid-latitudes	SST, mean wind for circulation, thermohaline processes (3D T,S ?)	Slow adjustment (decades)
Sea-ice regions	Coherence of nudging fields, S	Quick adjustment, slow impacts

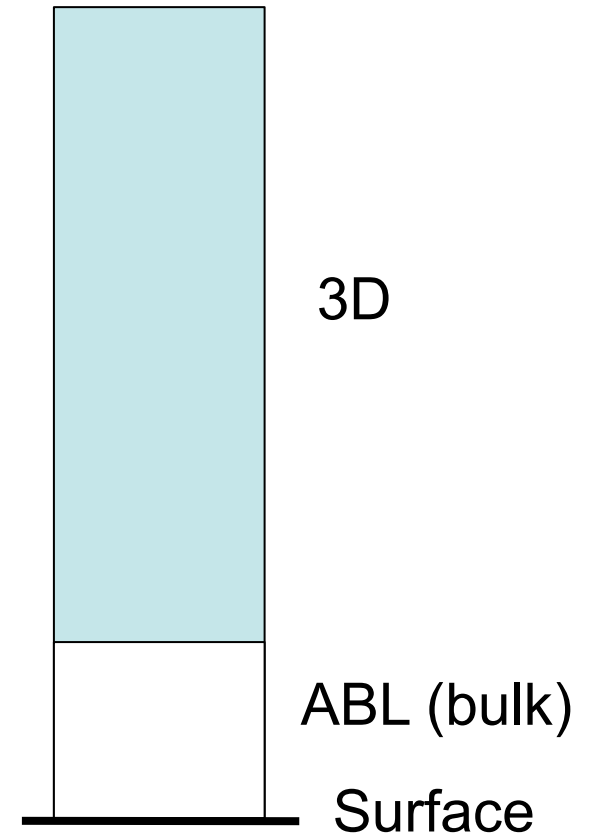
## The hard question:



Where should the cursor be placed?

# Surface nudging

- Heat
  - method:  $\gamma(T-T^*)$  or bulk
  - full field or anomaly
  - $\gamma$ : value, constant in space or not
- Momentum
  - method: apply  $\tau_x / \tau_y$  obs or bulk or 3D?
  - full field or anomaly
  - where ? (avoid tropical shock)
- Fresh water
  - method:  $\gamma(S-S^*)$ , P obs, E bulk,...
  - full field or anomaly



Nudging “height”

# Développements nécessaires

## (INCAS LOCEAN, Sonia)



### modIPSL:

- Gestion simulations d'ensembles
- Génération d'états initiaux (bruit blanc)
- Execution au CCRT:
  - SX9 (simulations guidées pour états initiaux)
  - titane pour ensembles (3 membres x 10 dates CMIP5 = 1 semaine)
- Gestion suivi et relance (runs et postpro pour 30+ simulations par qsub !)

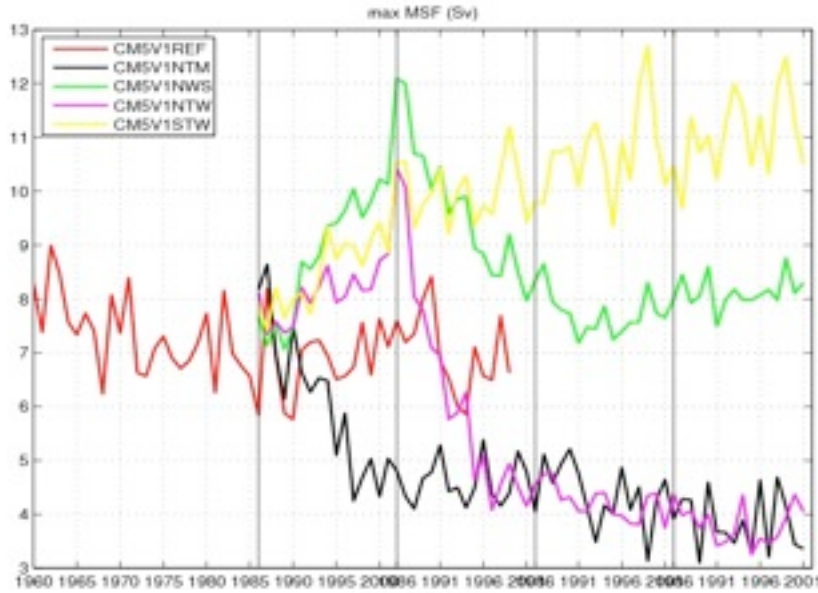
### NEMO:

- système de guidage (SST, vent, SSS)
- option  $\text{Flux}_{\text{nudged}} = (1 - \alpha) \text{Flux}_{\text{bulk}} + \alpha \text{Flux}_{\text{AGCM}}$

# Quelques tests sur la méthode d'initialisation

Diagnostic: max MOC Atlantique

Full



$$\gamma(T-T_{obs}) + \text{vent} + \gamma_s (S-S_{obsclim})$$

$$\text{vent}$$

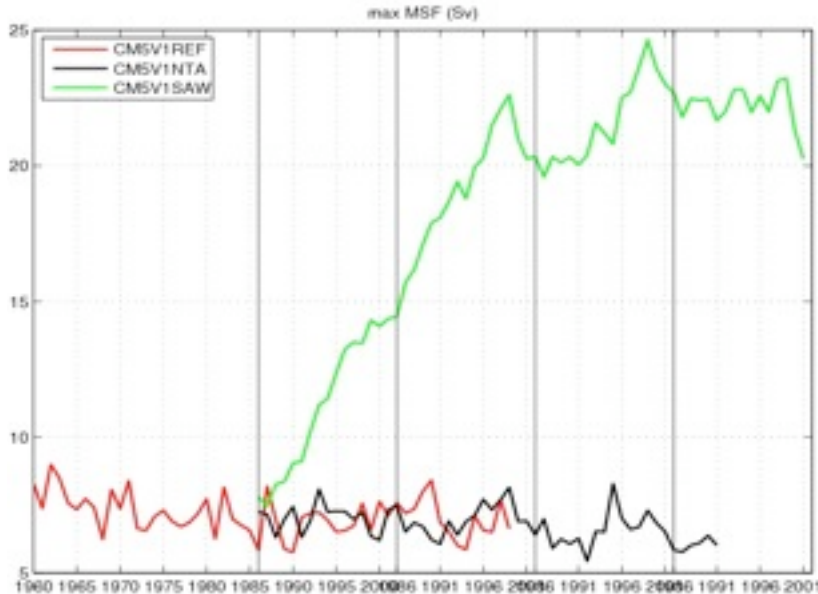
$$\gamma(T-T_{obs}) + \text{vent}$$

$$\gamma(T-T_{obs})$$

$\gamma = 40 \text{ Wm}^{-2}/\text{K}$

REF

Anom



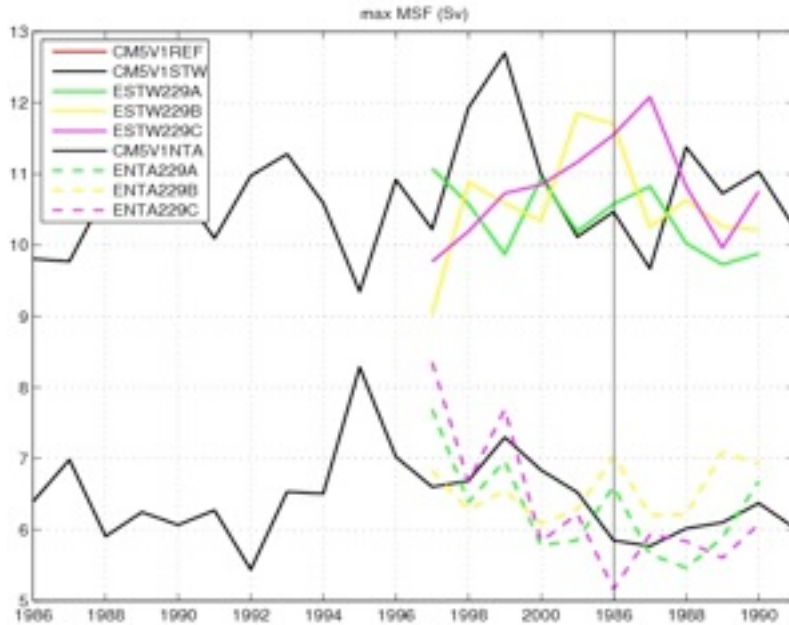
$$\gamma(T'-T'_{obs}) + \text{vent} + \gamma_s (S-S_{obsclim})$$

$$\gamma (T'-T'_{obs})$$

REF

# Quelques tests de « lâchers » (3 membres sur 10 ans)

## Diagnostic: max MOC Atlantique

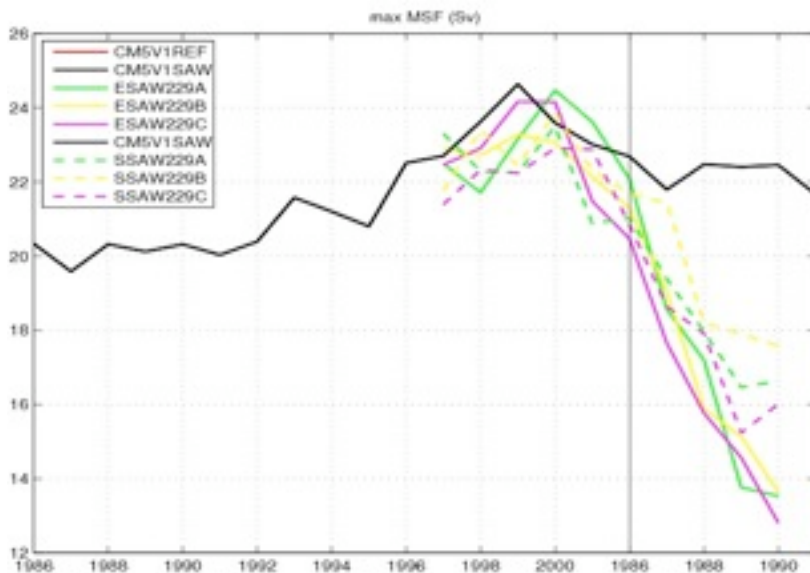


$$\gamma (T-T_{\text{obs}}) + \text{vent} + \gamma_s (S-S_{\text{obsclim}})$$

**Full**

$$\gamma (T'-T'_{\text{obs}})$$

**Anom SST**



$$\gamma (T'-T'_{\text{obs}}) + \text{vent} + \gamma_s (S-S_{\text{obsclim}})$$

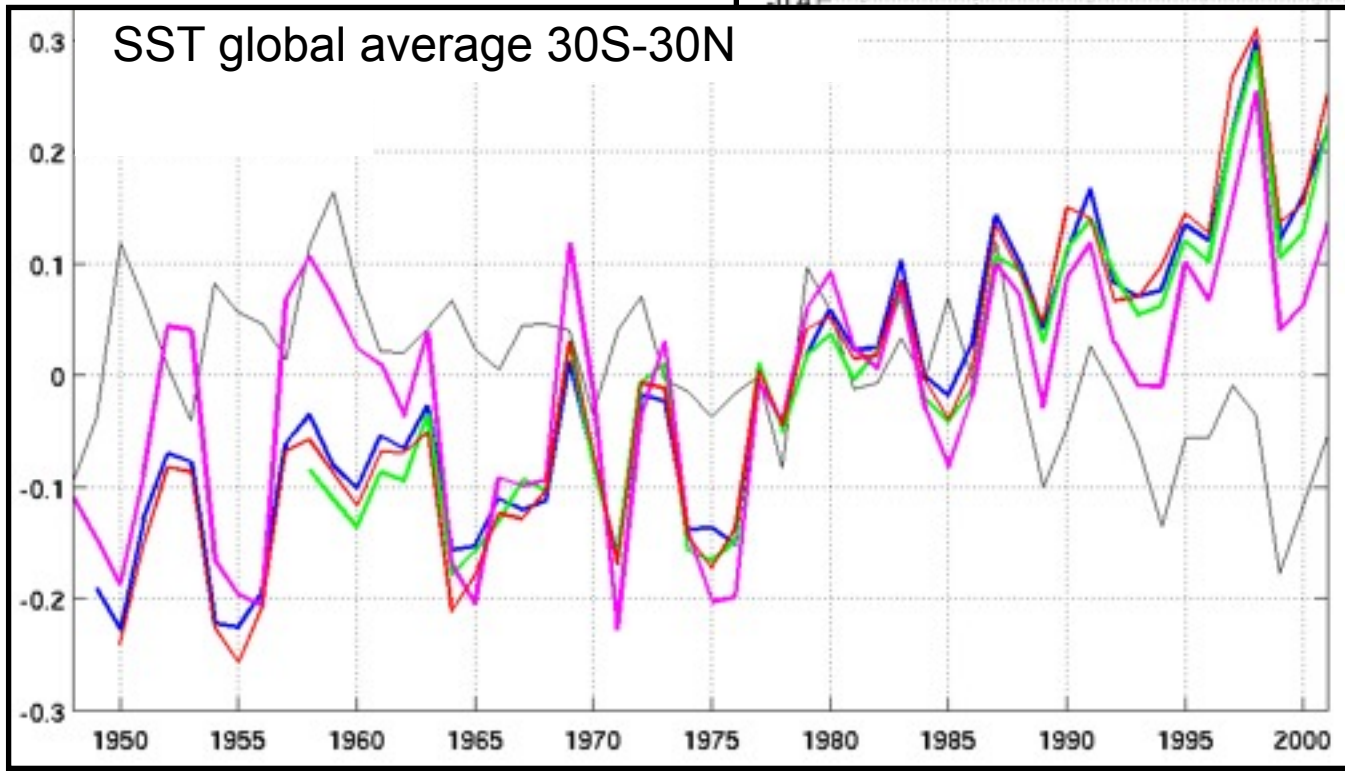
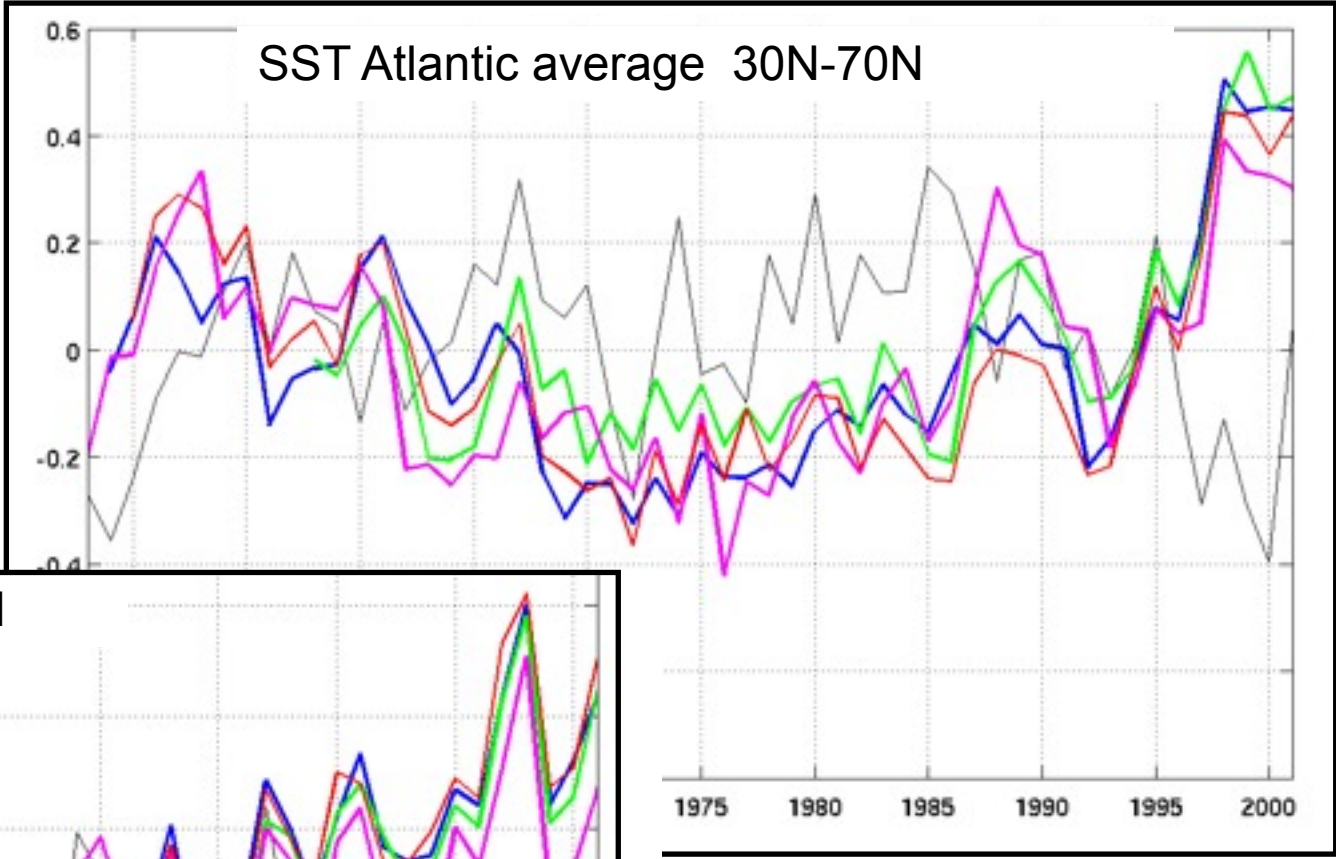
**Anom SST + vent + SSS**

# Initialisation par les anomalies de SST 1958-2004

Daily Reynolds SKT anomalies up to lat(60)

Monthly Reynolds SST anomalies

Monthly Reynolds SST anomalies + wind stress forcing



Control simulation  
Reynolds SST

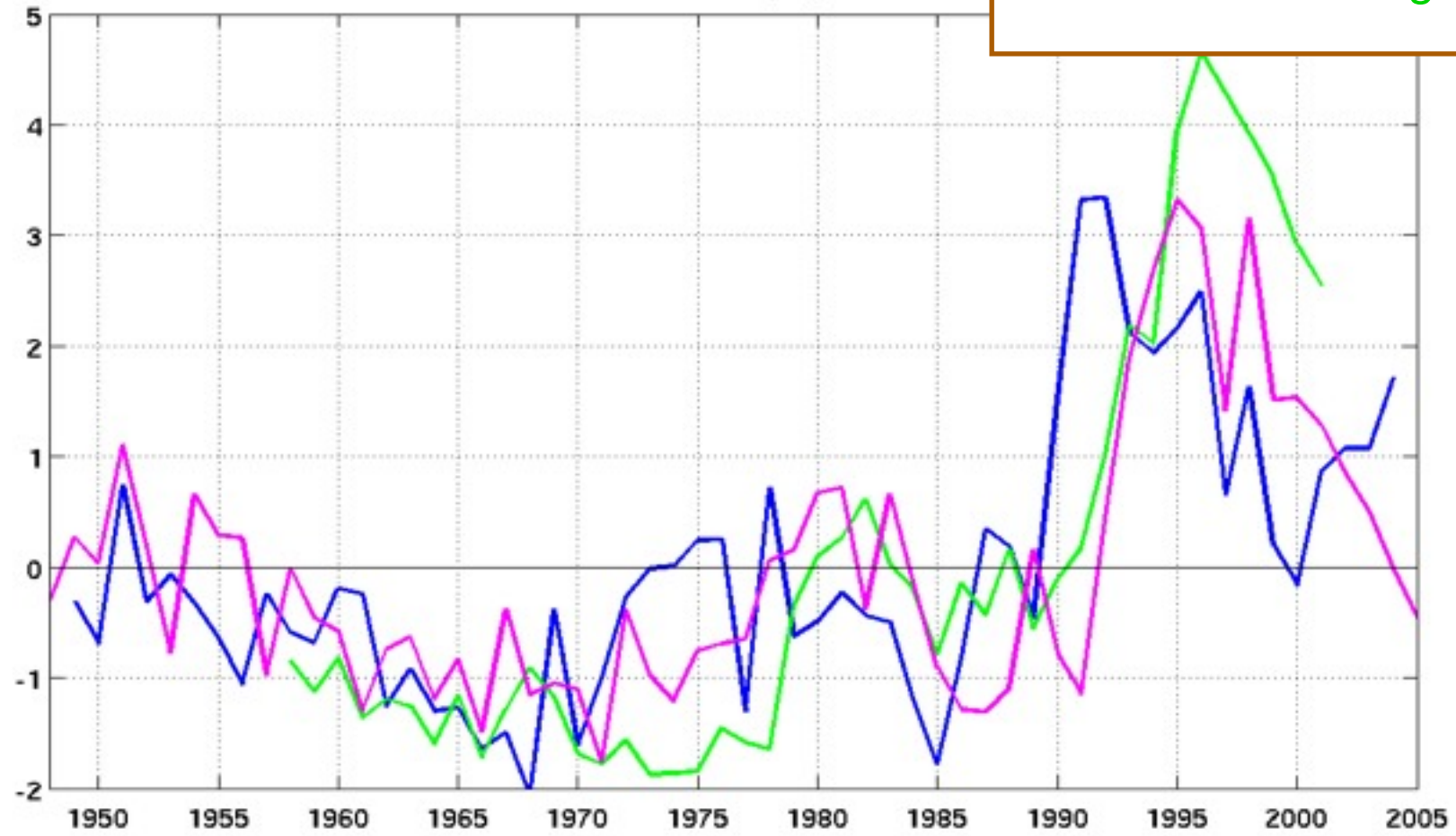
# Initialisation par les anomalies de SST 1958-2004

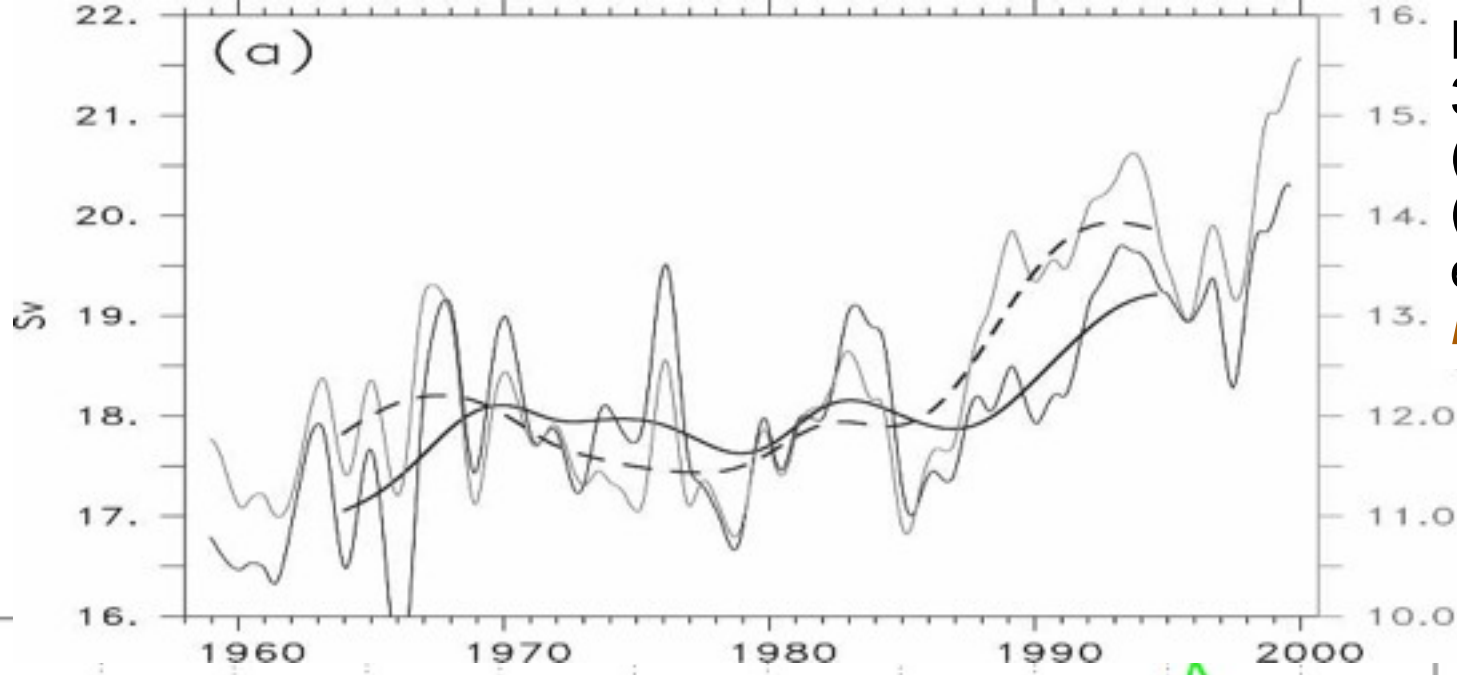
Daily Reynolds SKT anomalies up to lat(60)

Monthly Reynolds SST anomalies

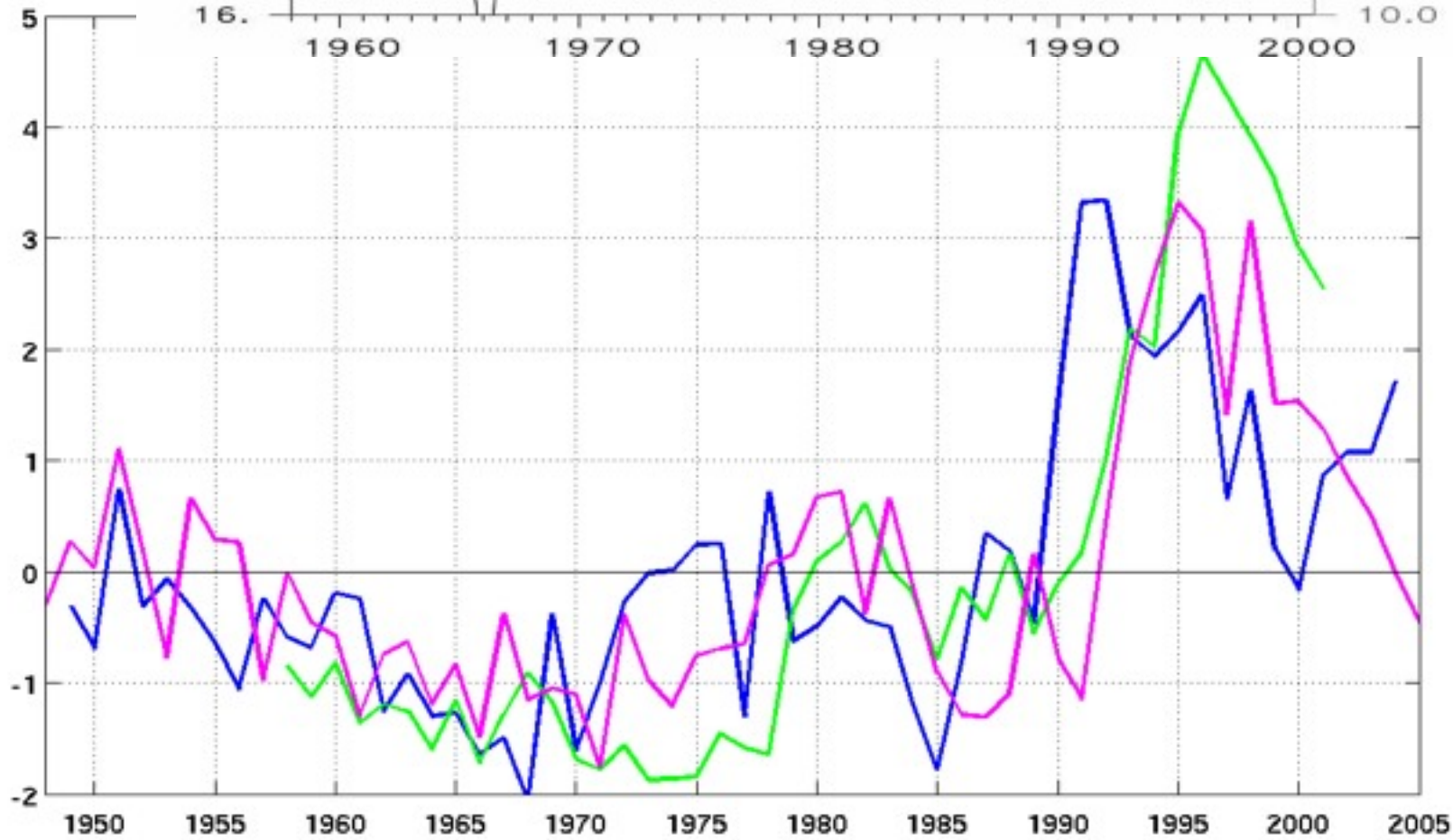
Monthly Reynolds SST anomalies + wind stress forcing

Anomalous max (Atlantic MOC) (Sv)





MOC strength at  
36°N in FLAME  
(black) and ORCA  
(gray) reference  
experiments  
*Bjastoch et al. 2008*

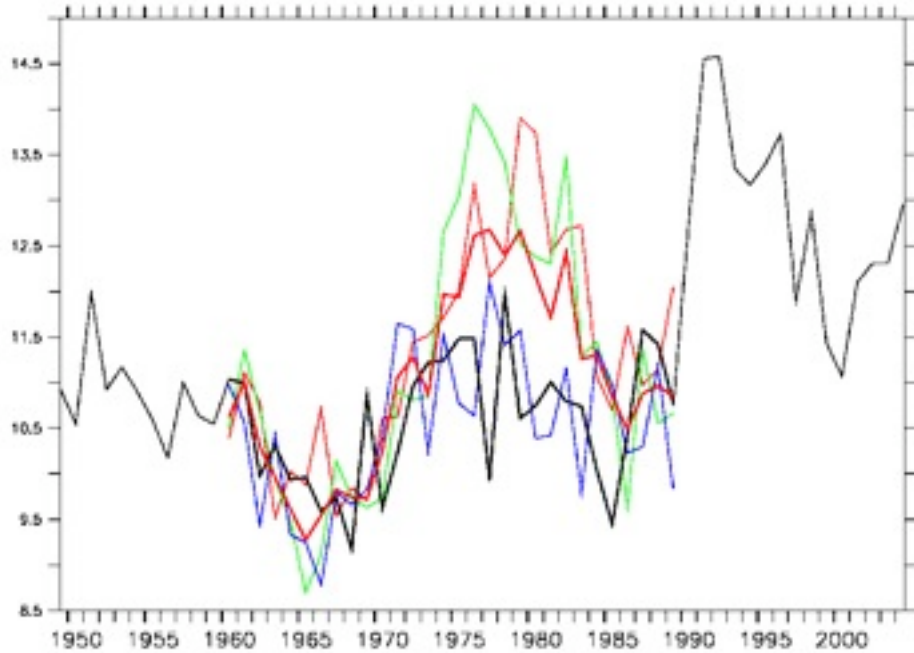




# Premiers tests de prévisibilité

## Hindcast 1960 (+30 yrs)

corr : 0.46, spread 0.77

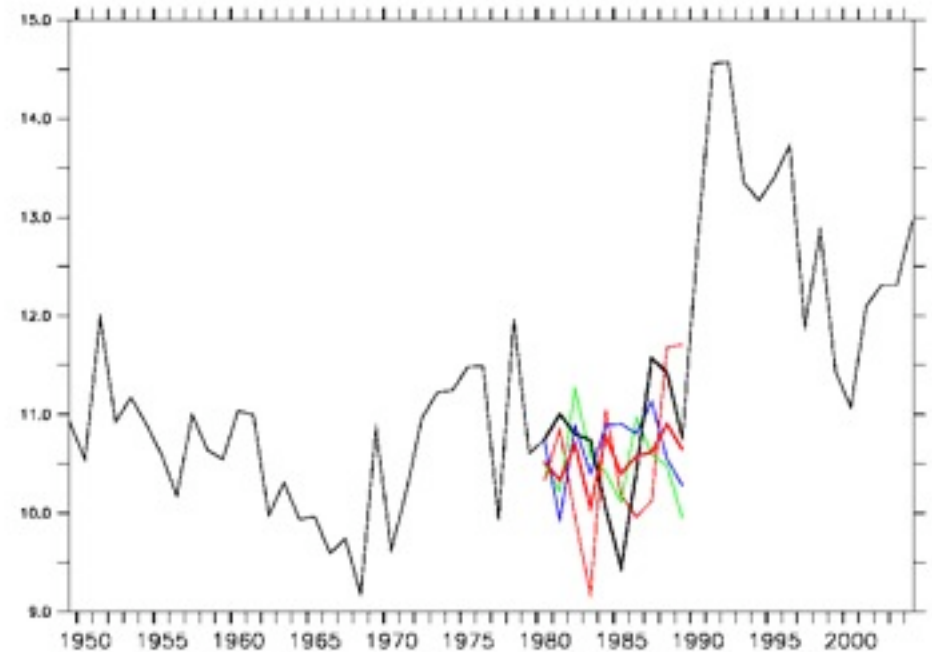


## Monthly Reynolds SST anomalies

### Max (Atlantic MOC) (Sv)

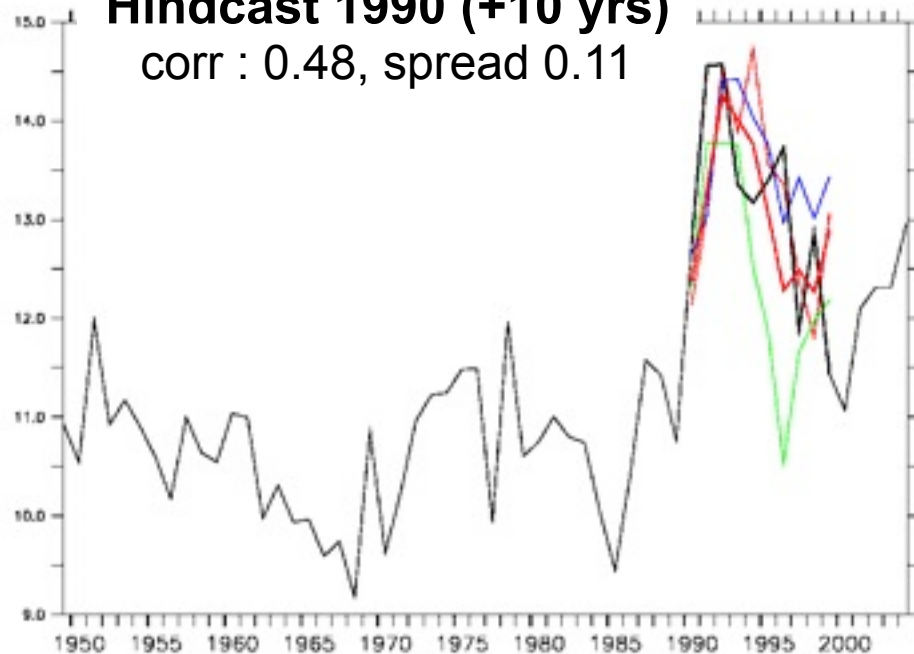
## Hindcast 1980 (+10 yrs)

corr : 0.06, spread 0.18



## Hindcast 1990 (+10 yrs)

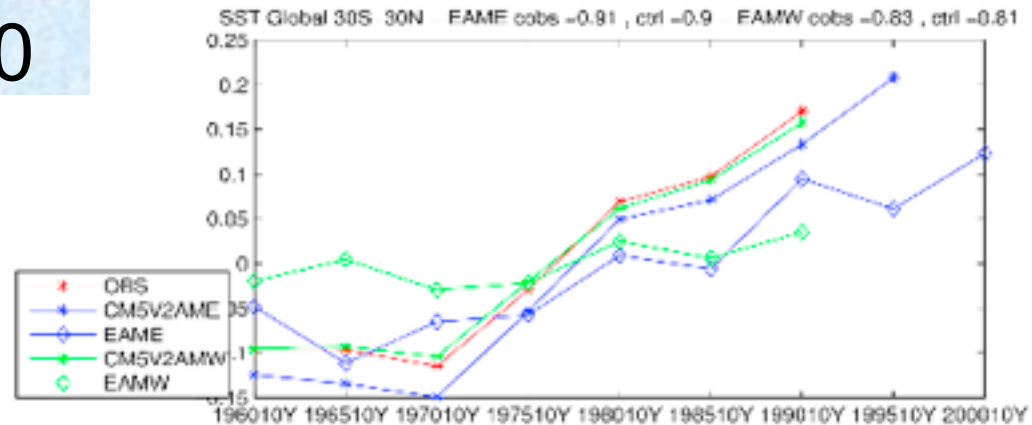
corr : 0.48, spread 0.11



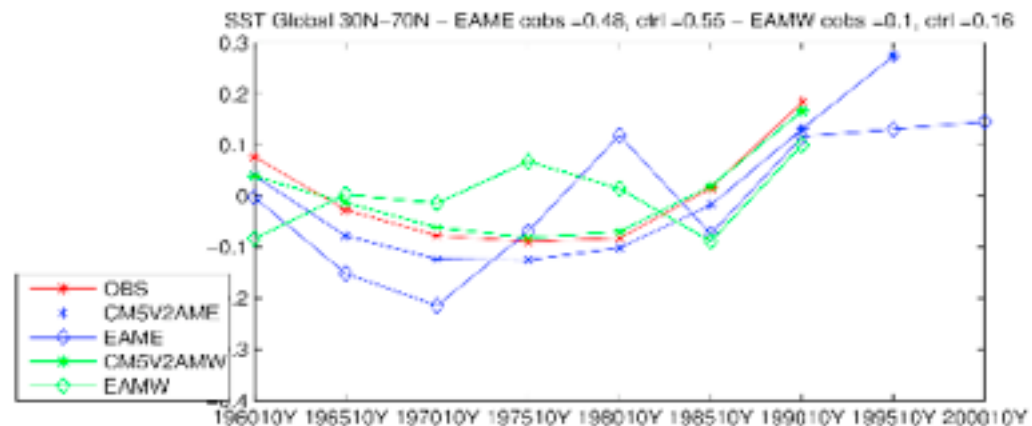
# Scores de prévisibilité décennale 1960-2000

## Exercice complet CMIP5

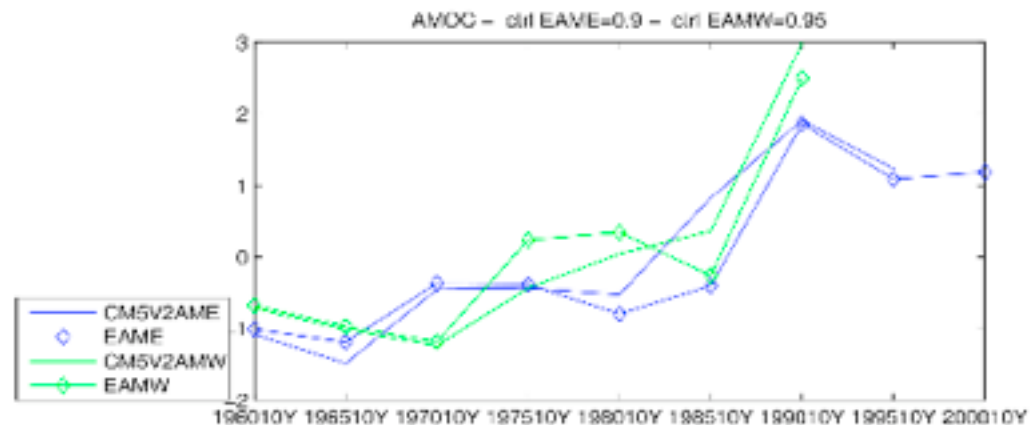
**SST 30S/30N**  
corr=**0.91** (SSTA)  
corr=**0.83** (SSTA+vent)



**SST 30N/70N**  
corr=**0.48** (SSTA)  
corr=0.1 (SSTA+vent)



**THC index**  
corr=**0.9** (SSTA)  
corr=**0.95** (SSTA+vent)



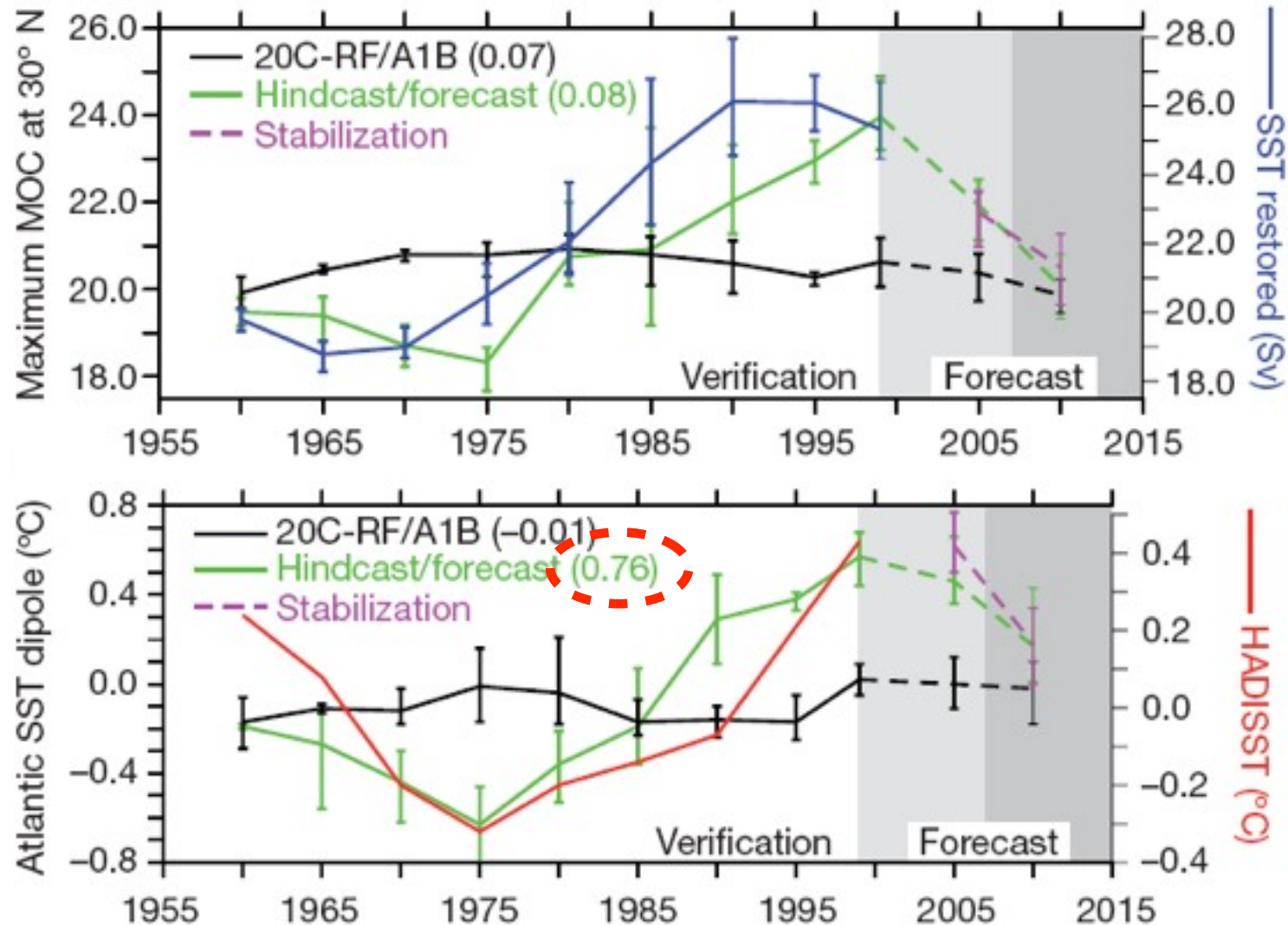
# Un exemple d'exercice de prévision décennale

ECHAM5/MPI-OM

Keenlyside et al. 2008



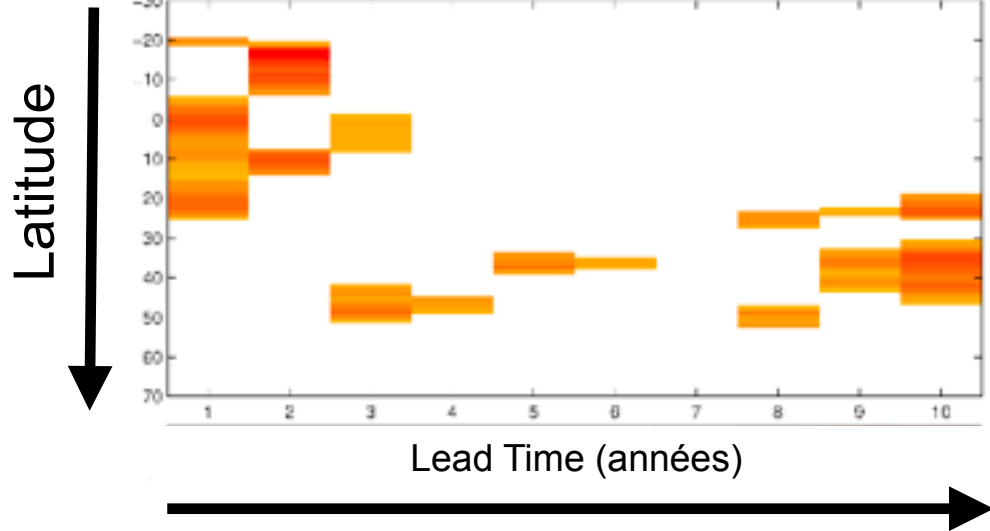
Les variations basse fréquence de la circulation océanique et la structure de SST associée sont mieux représentées dans une simulation initialisée



# Score SST en fonction de la latitude et du lead time

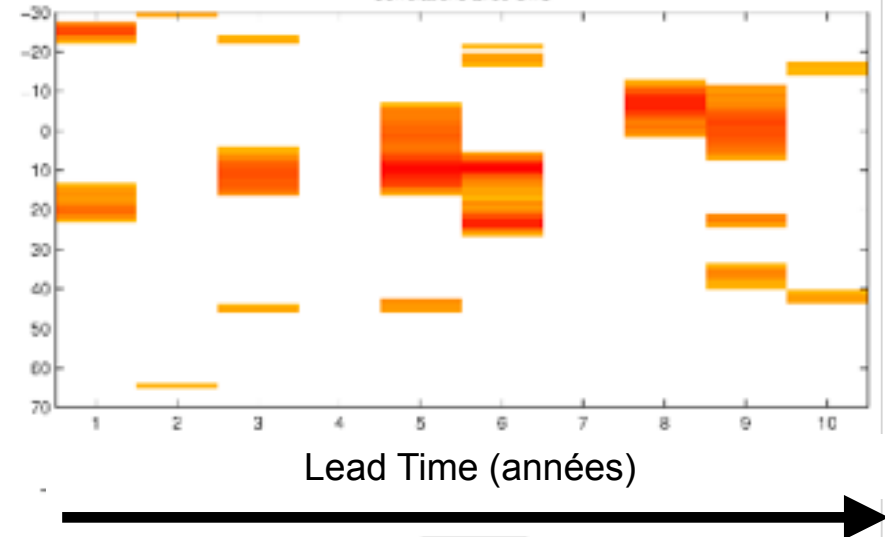
Init SSTA

Correlation Obs

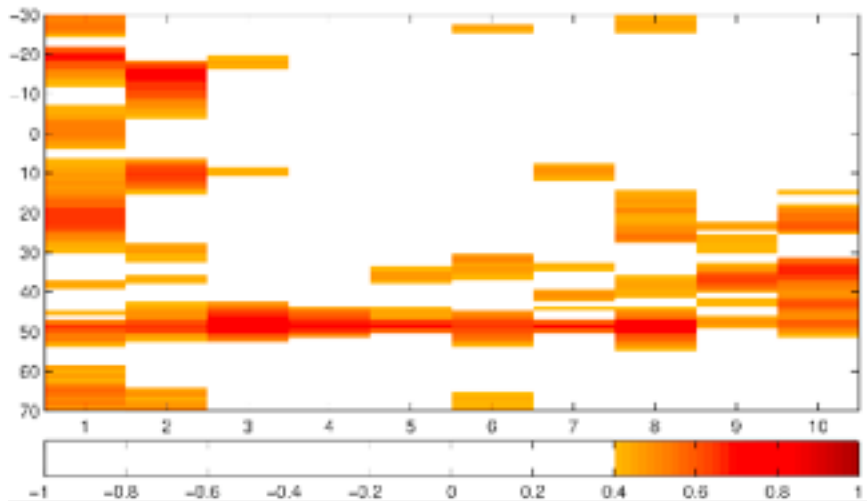


Init SSTA+vent

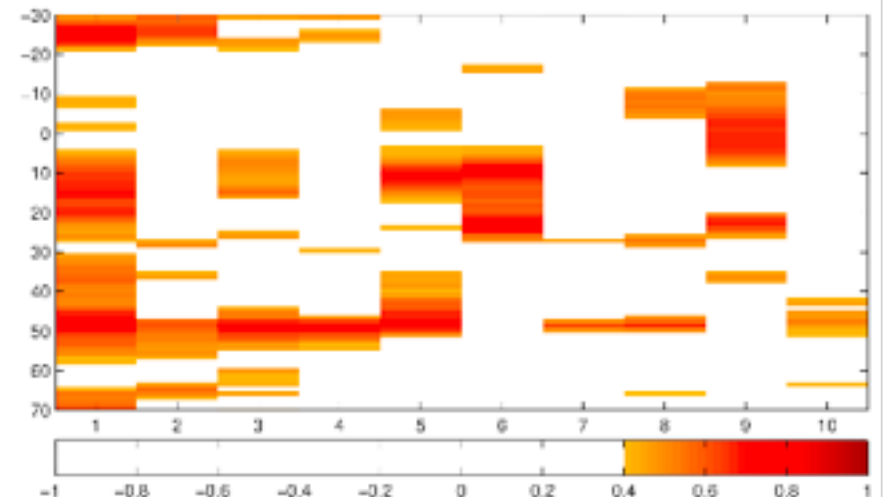
Correlation Obs



Correlation CTL



Correlation CTL



# Résumé

- **Initialisation:**
  - Nombreux tests en nudgé de surface (SST, vent, SSS, anomalies vs. full)
  - Meilleurs scores: nudgé en anomalies de SST
  - Encore des choses à comprendre
- **Hindcasts (“lâchers”):**
  - Premiers tests encourageants (même si en piControl)
  - Le modèle IPSL-CM5 a de la prévisibilité décennale (THC ++, SST -)
- **Equipe qui s'étoffe:**
  - 4 permanents
  - un projet GICC: EPIDOM (+ Cerfacs/MF, cadre MISSTERRE et **2 ans de postdoc**)
  - contributions EU FP7 Combine + CMIP5
  - thèse à venir

**PUB !**

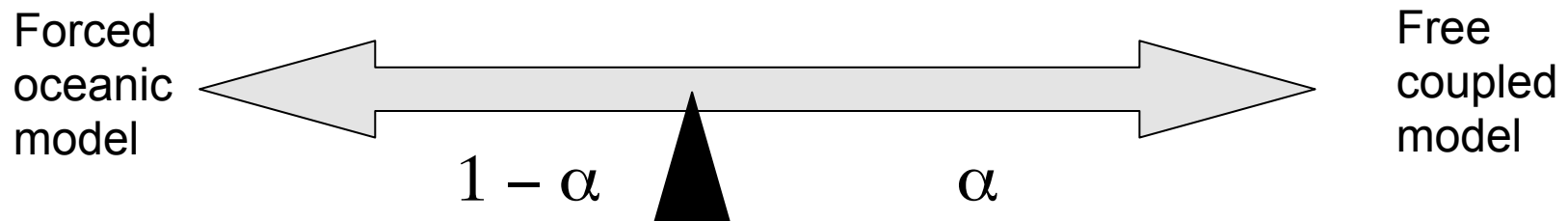
# Prochaines étapes

- Initialisation:
  - Utilisation des bulks (tests en cours)  $\text{Flux}_{\text{nudged}} = (1 - \alpha) \text{Flux}_{\text{bulk}} + \alpha \text{Flux}_{\text{AGCM}}$
  - Comparaison avec autres méthodes (3D, ...)
- Hindcasts (“lâchers”):
  - Simulations avec forçages 20<sup>ème</sup>
  - Génération d’ensemble (bruit blanc -> perturbations optimales)
  - set CMIP5 (+ haute resolution ?)
- Mécanismes physiques de la prévisibilité
  - Modèle parfait, rôle initialisation, forçage externe vs. variabilité interne,...
  - Post doc EPIDOM (automne 2010) **PUB !**

# Nudging via CORE-type bulk formulae

$$\text{Flux}_{\text{bulk}} = F(T_s, \theta_a, q_{\text{air}}, \Delta U_{10})$$

$T_s$  vs. large scale atmospheric variables



$$\text{Flux}_{\text{nudged}} = (1 - \alpha) \text{Flux}_{\text{bulk}} + \alpha \text{Flux}_{\text{AGCM}}$$

$$\text{Flux}_{\text{nudged}} = F[(1 - \alpha) T_s^{\text{obs}} + \alpha T_s^{\text{AGCM}}, (1 - \alpha) \theta_a^{\text{obs}} + \alpha \theta_a^{\text{AGCM}}, \dots]$$

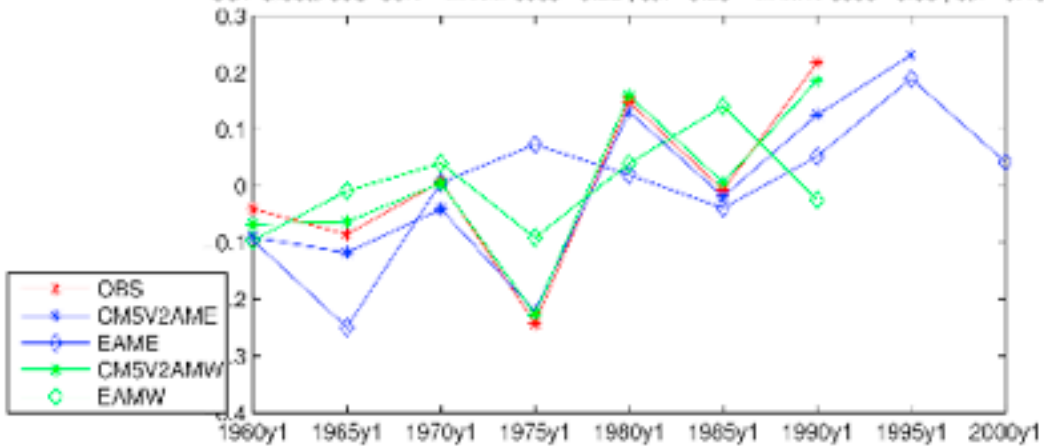
$$\text{Flux}_{\text{nudged}} = F[(1 - \alpha) T_s^{\text{obs}} + \alpha T_s^{\text{AGCM}}, \theta_a^{\text{AGCM}}, q_{\text{air}}^{\text{AGCM}}, \Delta U_{10}^{\text{AGCM}}]$$

## Questions:

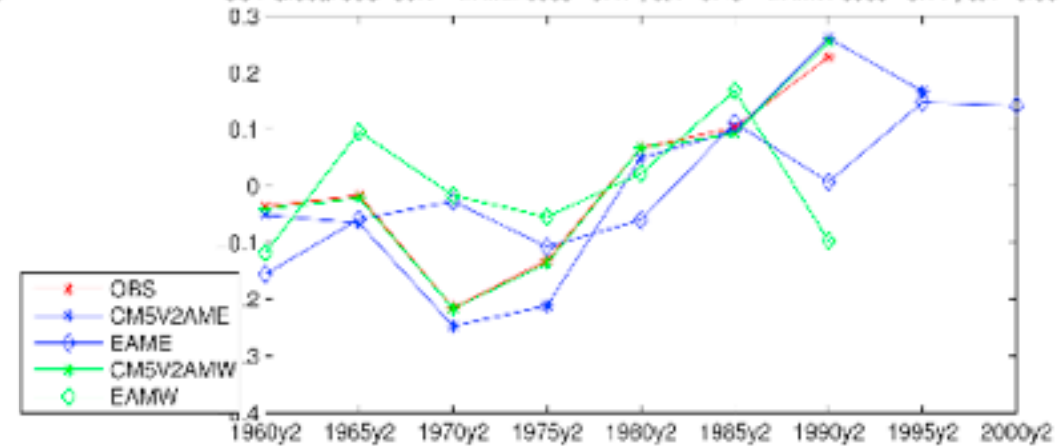
- Which method ?
- How to define  $\alpha$  ?
- Sea-ice regions ?

*"Choice depends on objective"* (best prediction or science)

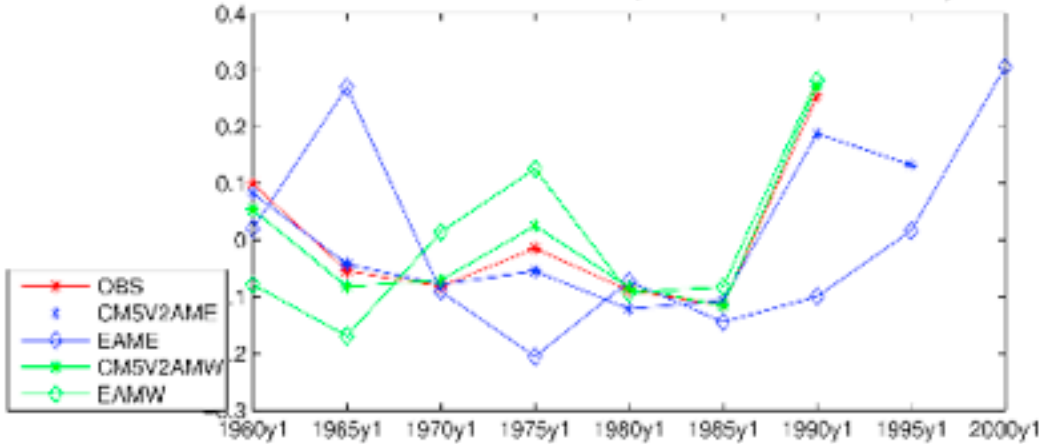
SST Global 30S 30N - FAVF cobs -0.22 , ctrl -0.28 - FAMW cobs -0.35 , ctrl -0.43



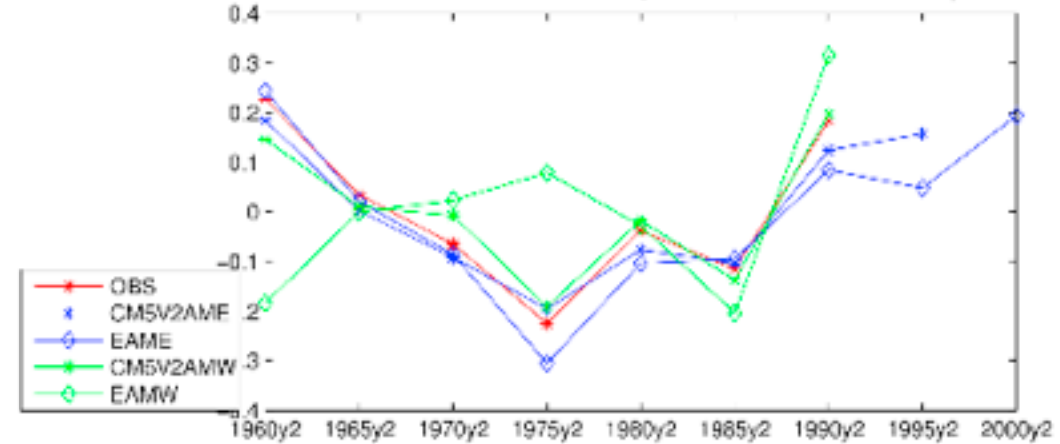
SST Global 30S 30N - FAME cobs -0.47 , ctrl -0.48 - FAMW cobs -0.11 , ctrl -0.06



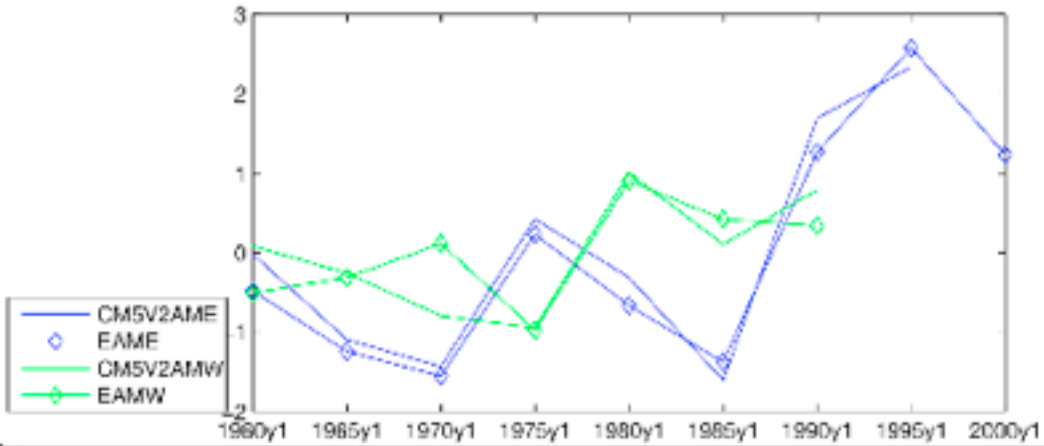
SST Global 30N-70N - EAME cobs -0.04 , ctrl -0.07 - EAMW cobs -0.71 , ctrl -0.84



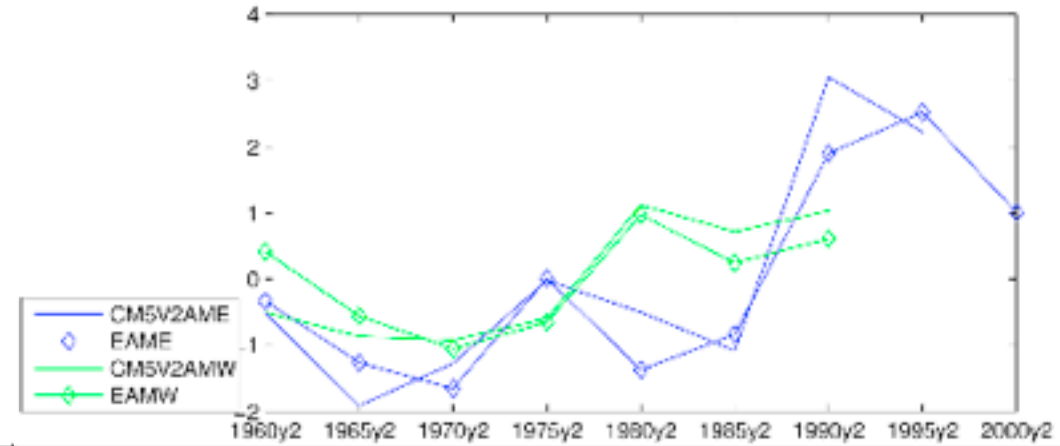
SST Global 30N-70N - EAME cobs -0.96 , ctrl -0.97 - EAMW cobs -0.13 , ctrl -0.33



AMOC - ctrl EAME=0.99 - ctrl EAMW=0.74



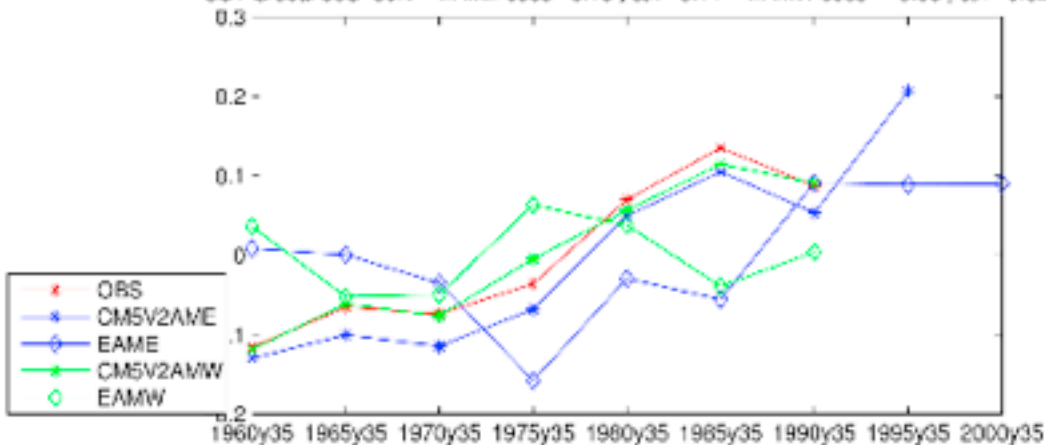
AMOC - ctrl EAME=0.93 - ctrl EAMW=0.85



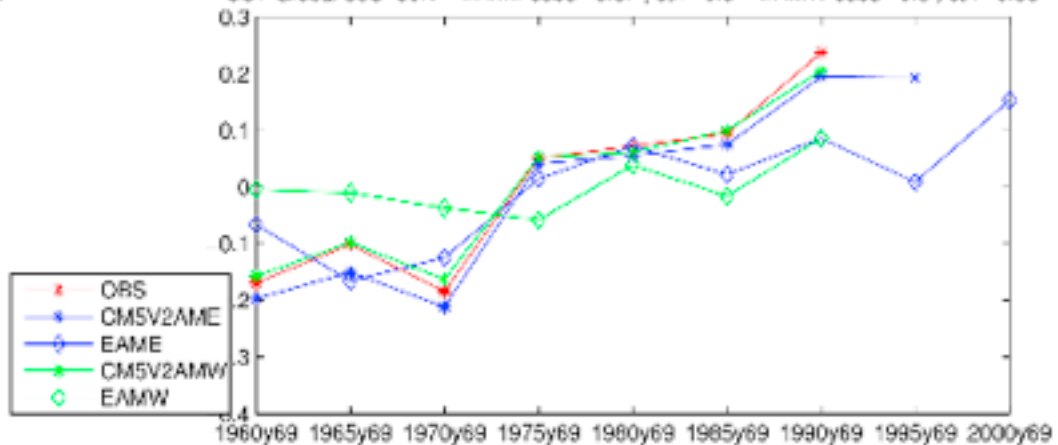




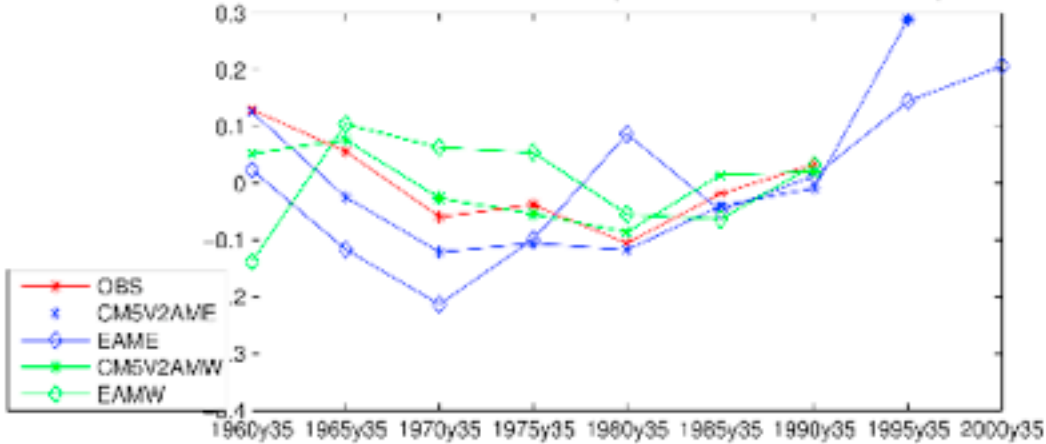
SST Global 30S 30N - FAME cobs -0.13 , ctrl -0.14 - FAMW cobs - 0.06 , ctrl -0.02



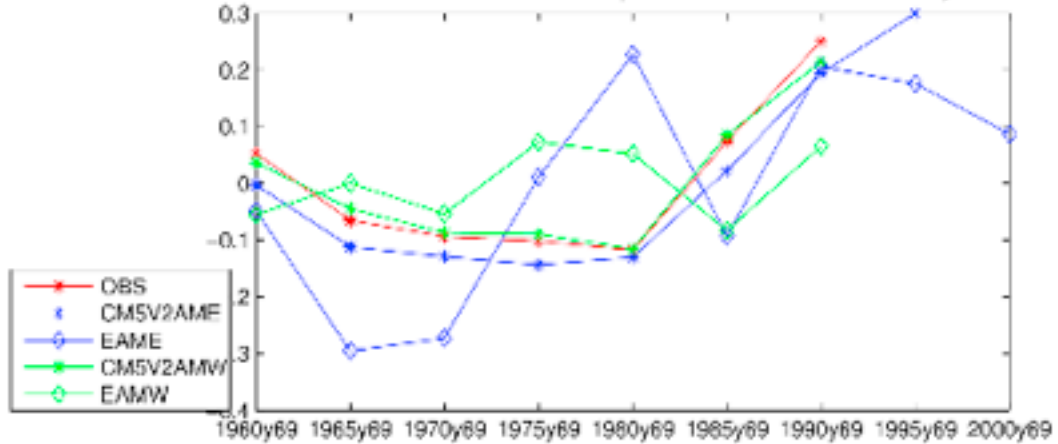
SST Global 30S 30N - FAME cobs -0.87 , ctrl -0.9 - FAMW cobs -0.6 , ctrl -0.56



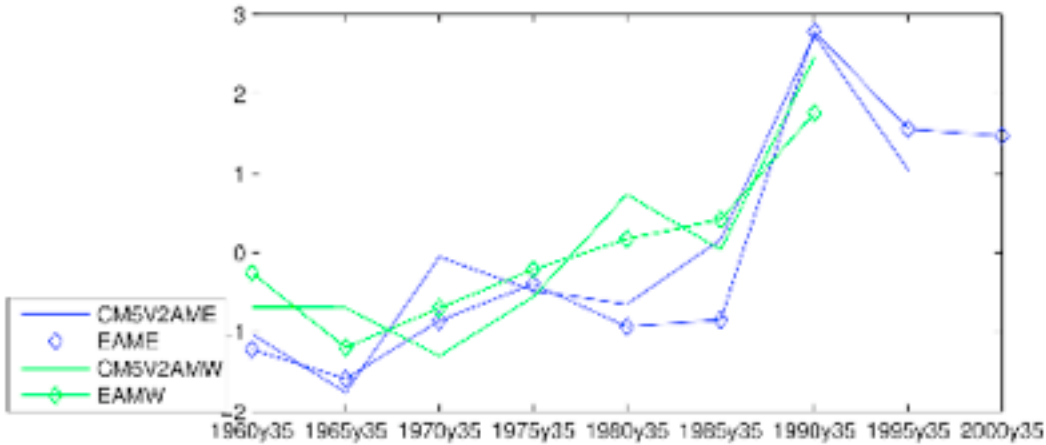
SST Global 30N-70N - EAME cobs -0.1 , ctrl -0.36 - EAMW cobs -0.24 , ctrl -0.02



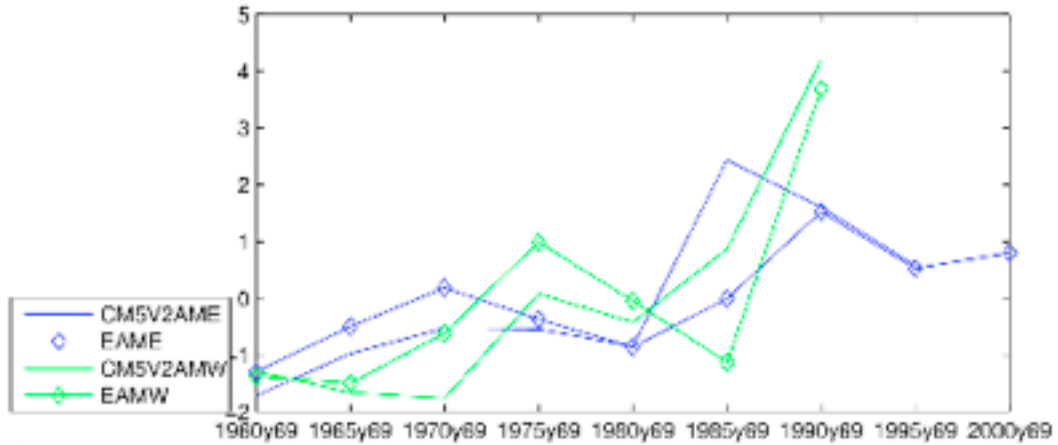
SST Global 30N-70N - EAME cobs -0.35 , ctrl -0.42 - EAMW cobs -0.02 , ctrl -0.06



AMOC - ctrl EAME=0.95 - ctrl EAMW=0.91

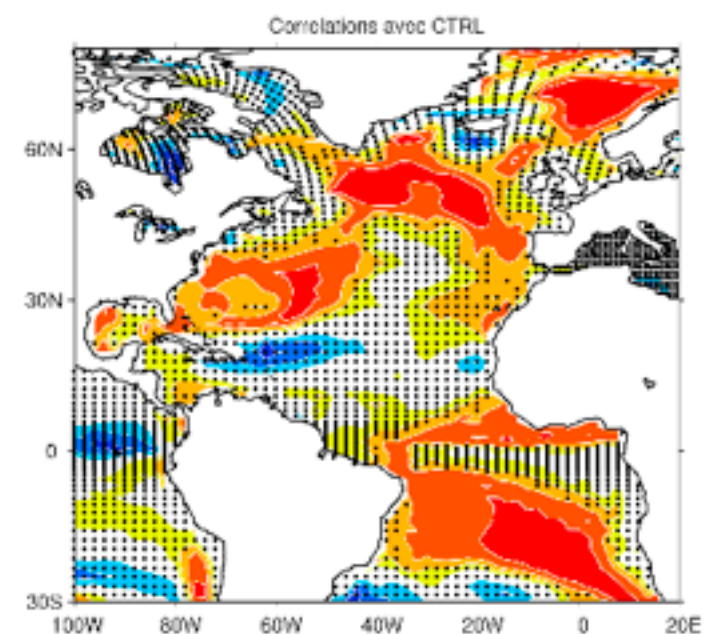
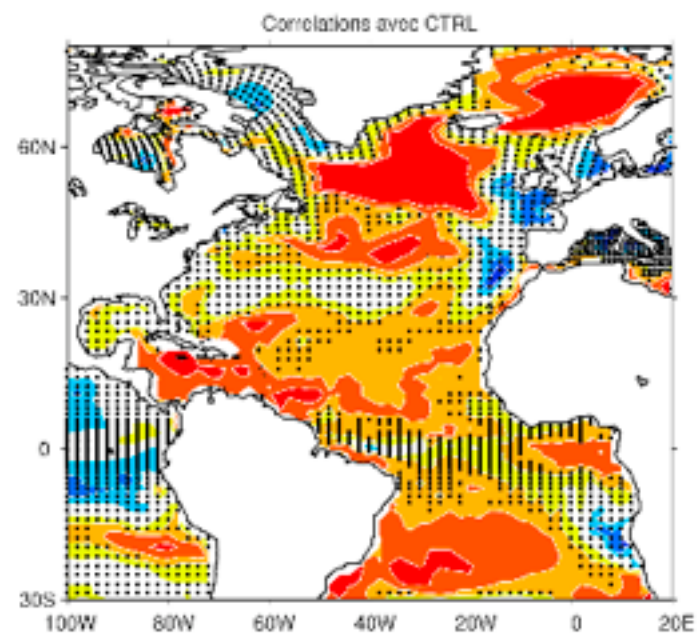
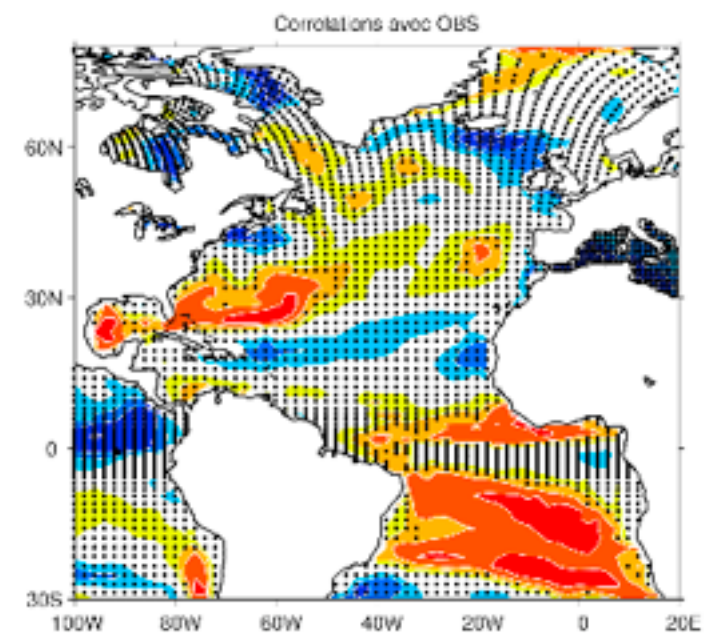
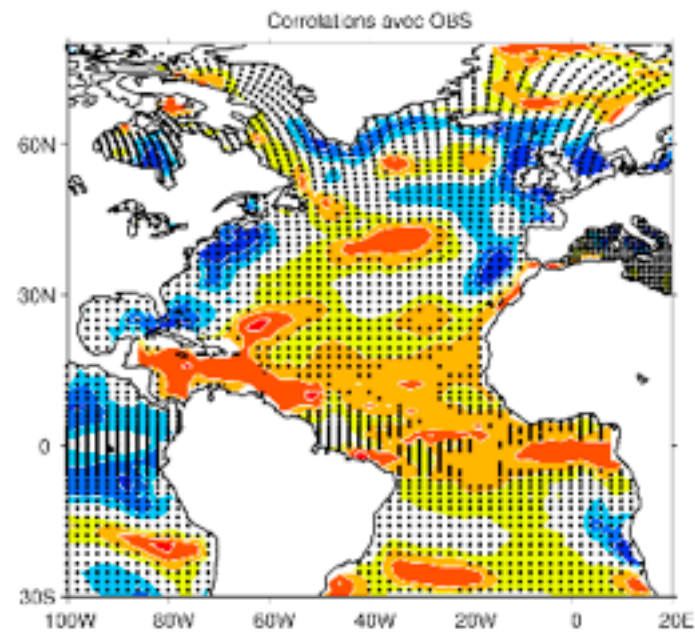


AMOC - ctrl EAME=0.72 - ctrl EAMW=0.87



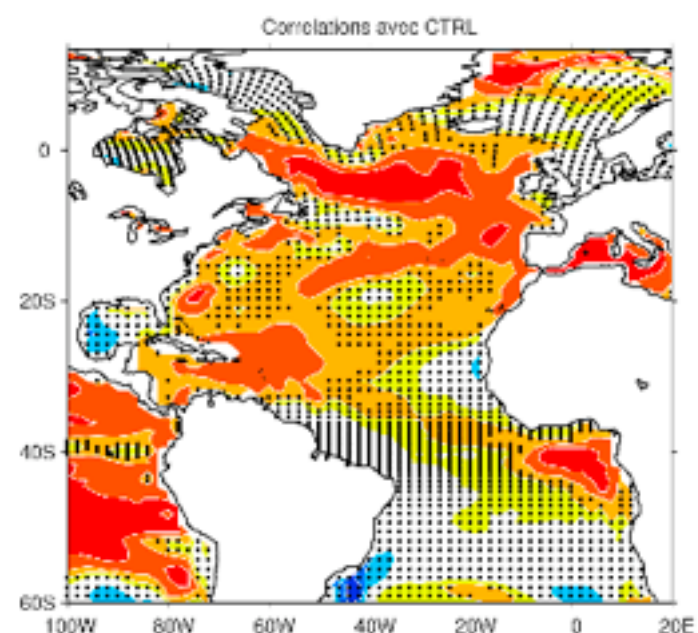
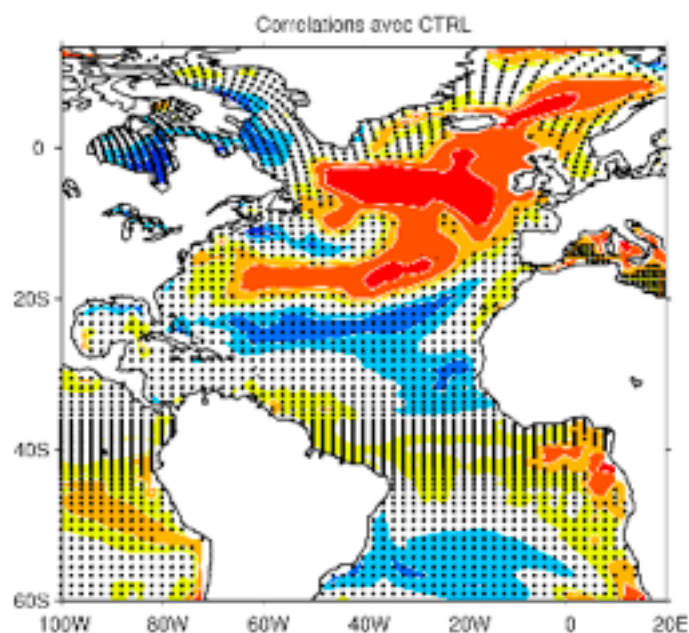
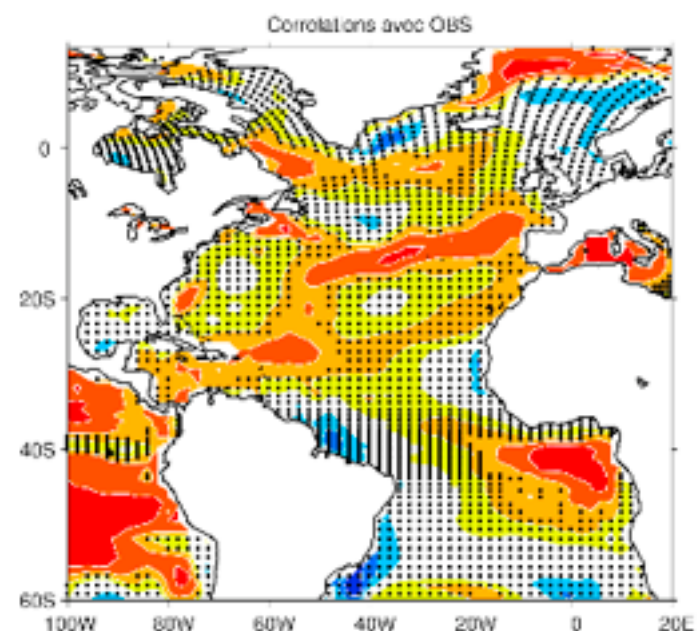
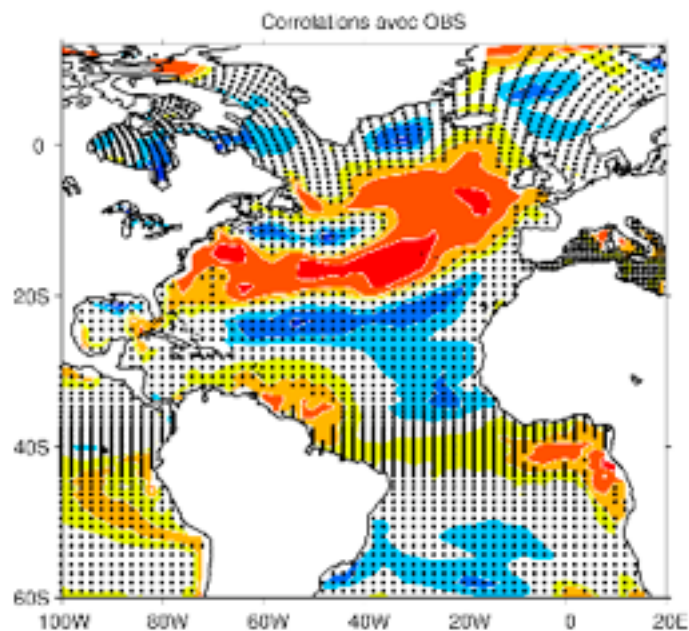
EAME - yr1

EAME - yr2



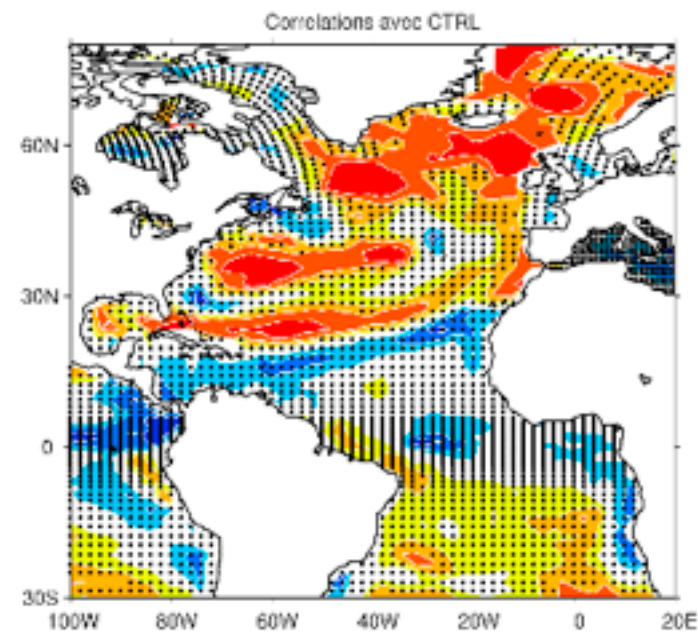
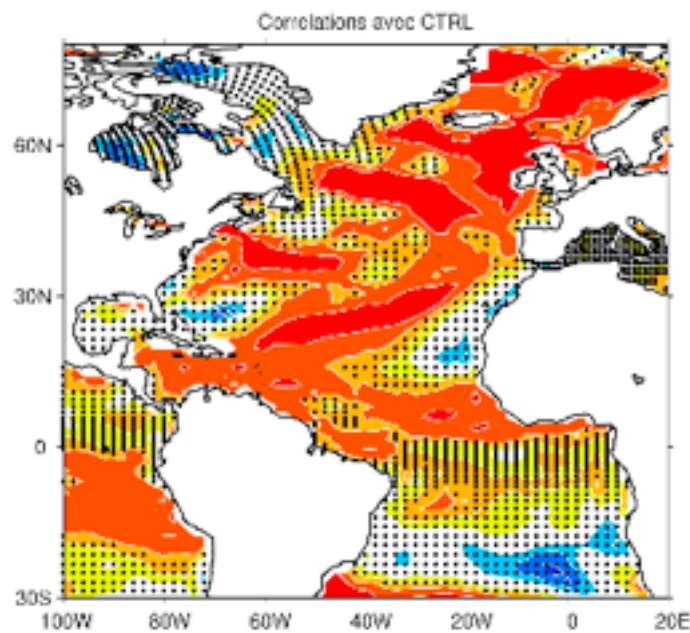
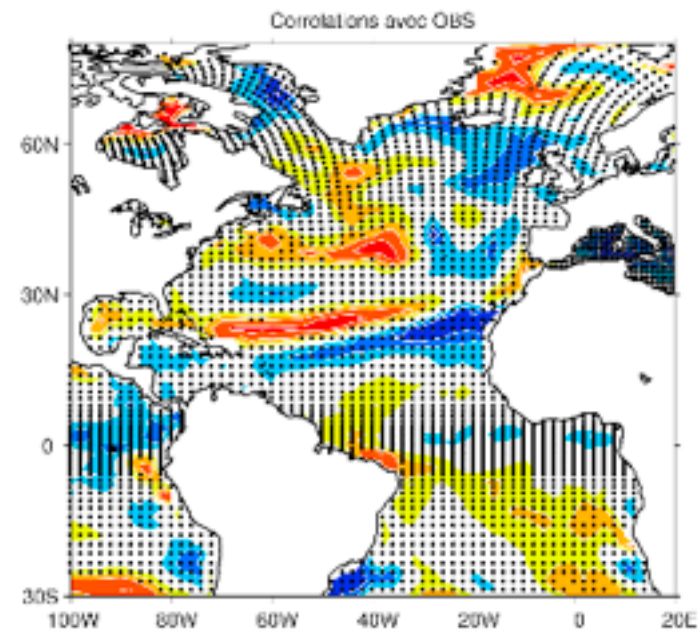
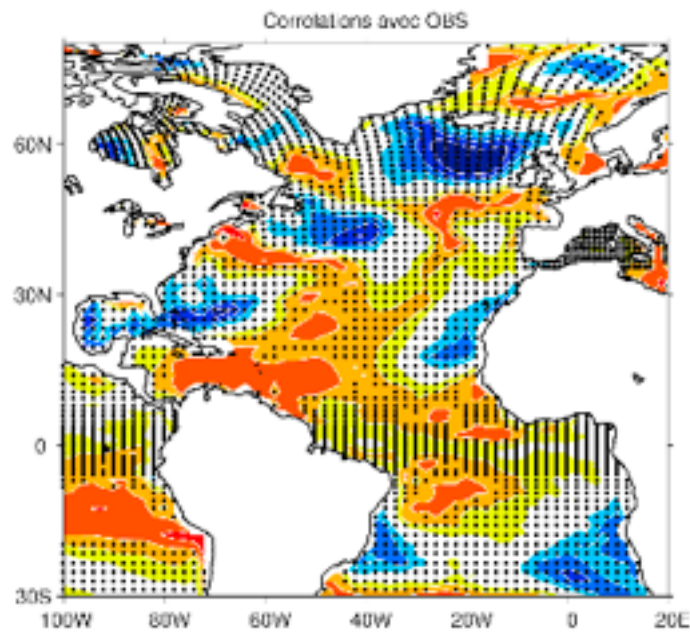
EAME - yr35

EAME - yr69



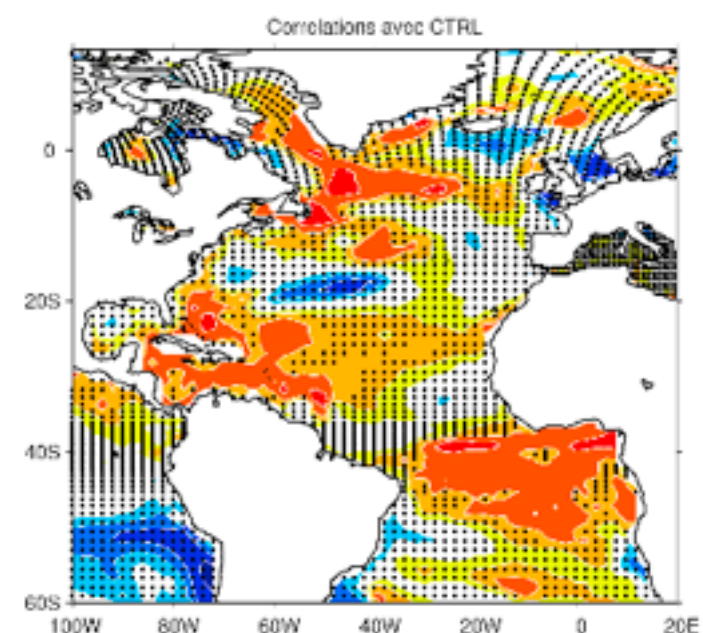
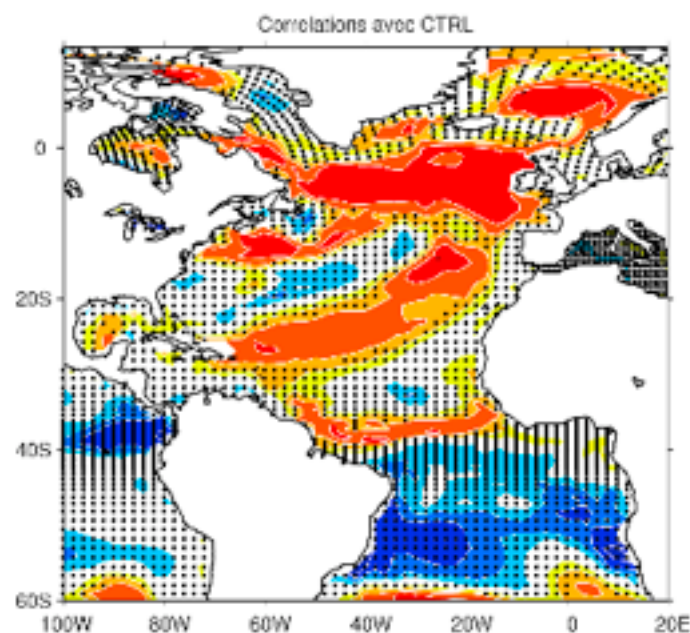
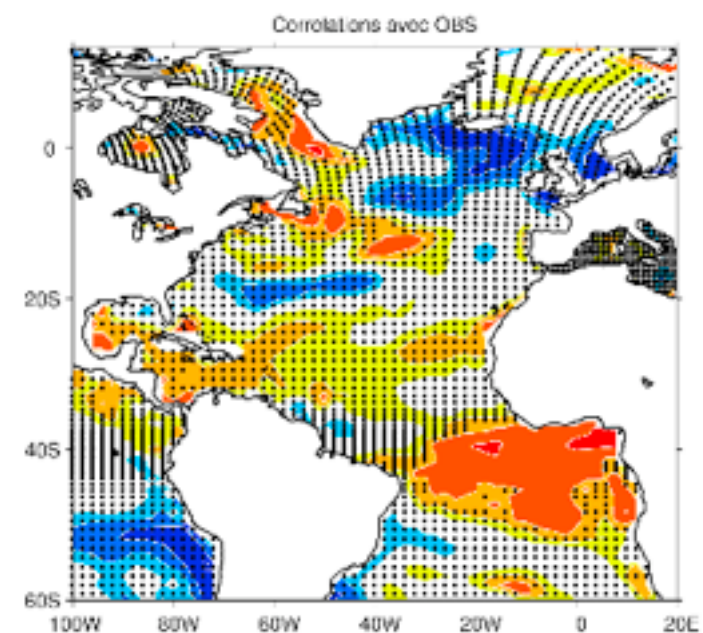
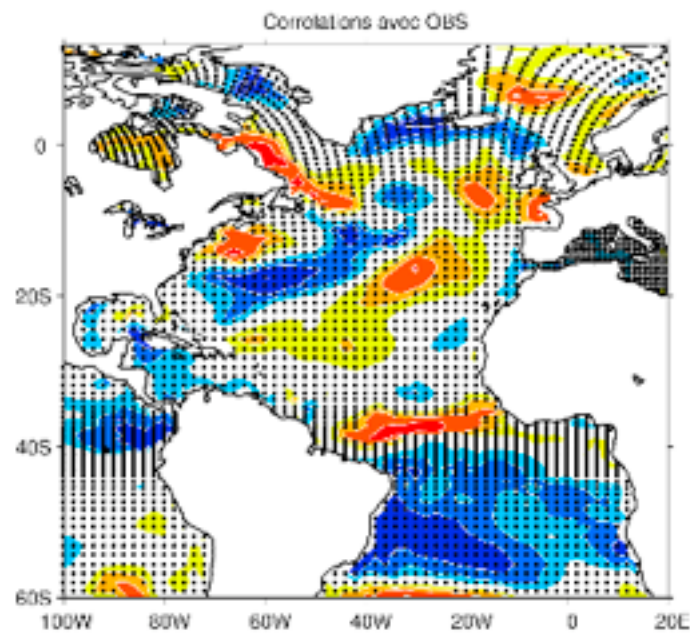
EAMW - yr1

EAMW - yr2



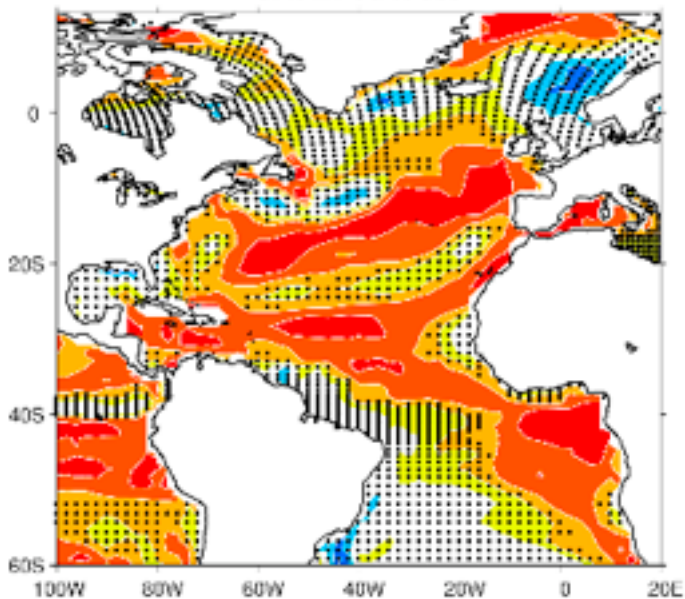
EAMW - yr35

EAMW - yr69



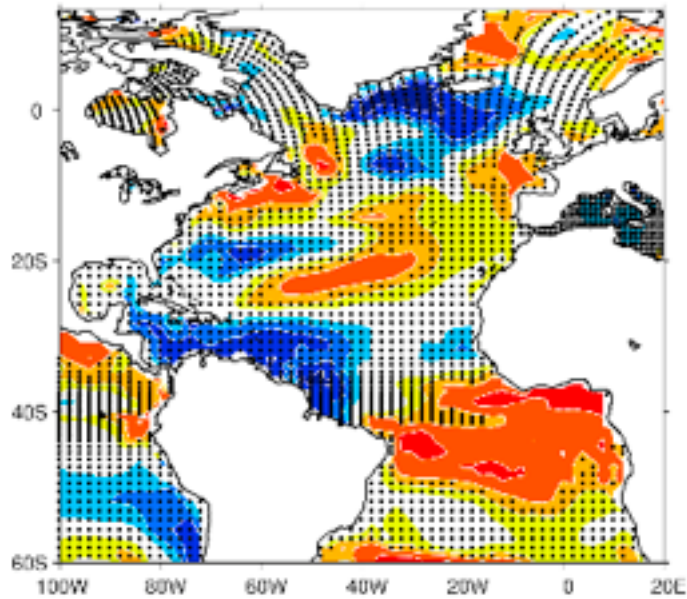
EAME - 10YR

Correlations avec OBS

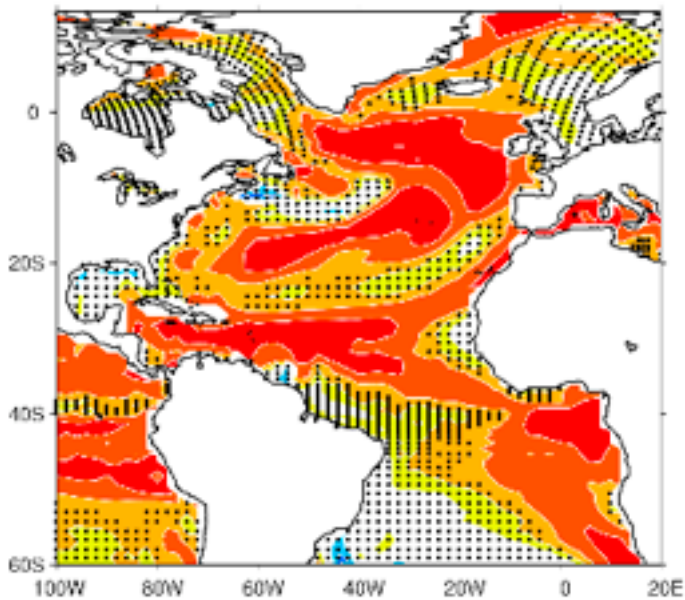


EAMW - 10YR

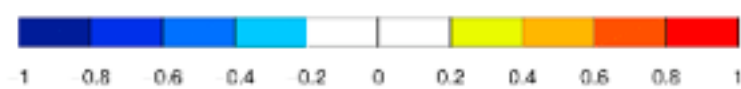
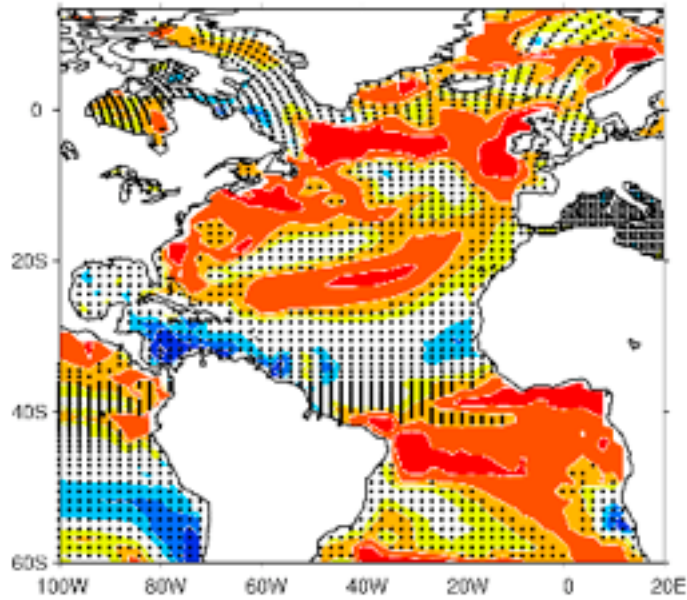
Correlations avec OBS



Correlations avec CTRL



Correlations avec CTRL



# Forecasting with surface nudging only?

ECHAM5/MPI-OM

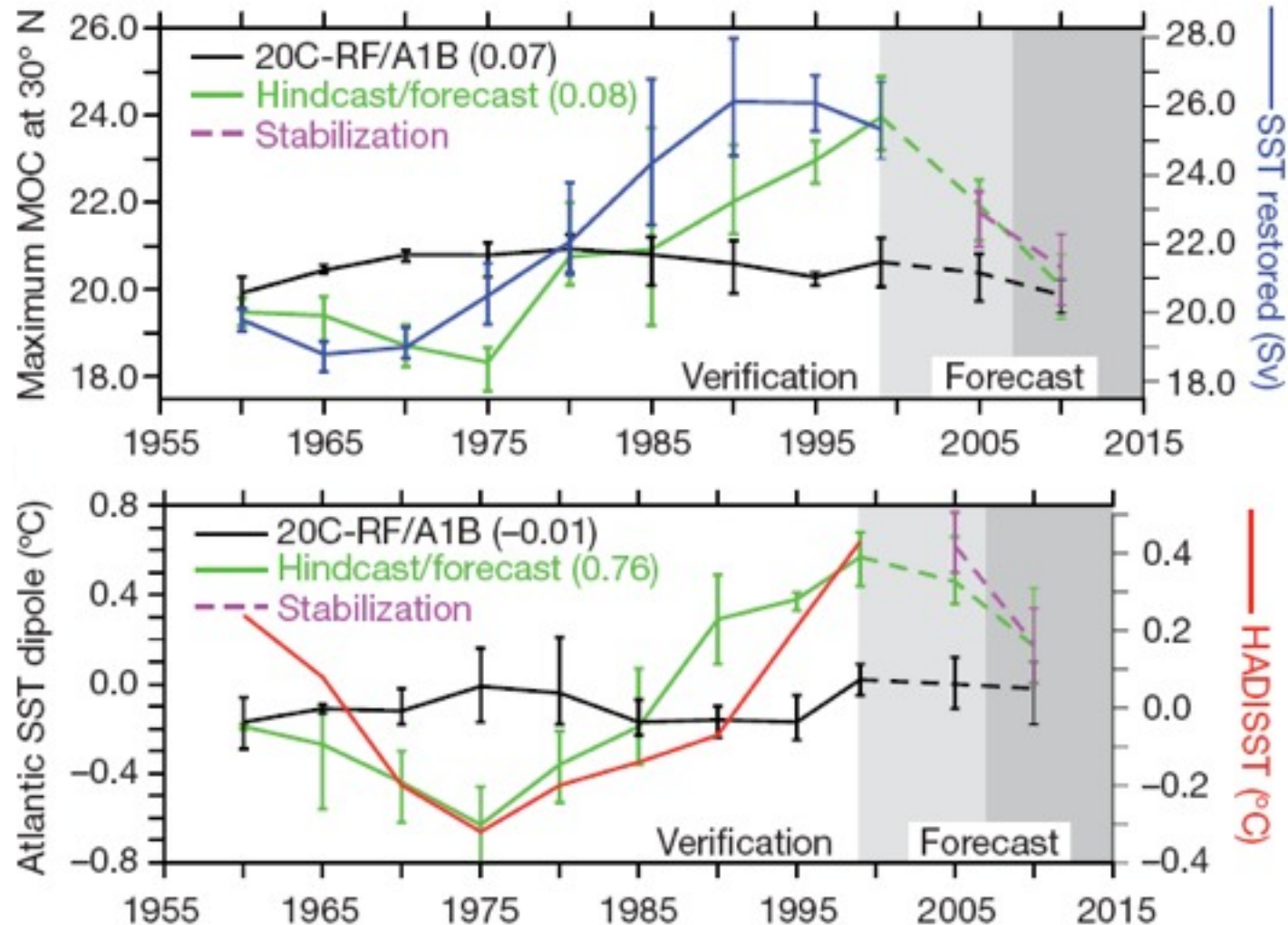
SST nudging equatorward  
of lat( $60^\circ$ )

*Keenlyside et al. 2008*



Low frequency  
variations of the  
oceanic circulation  
and the associated  
SST pattern are  
better reproduced  
than in «simple»  
scenario run.

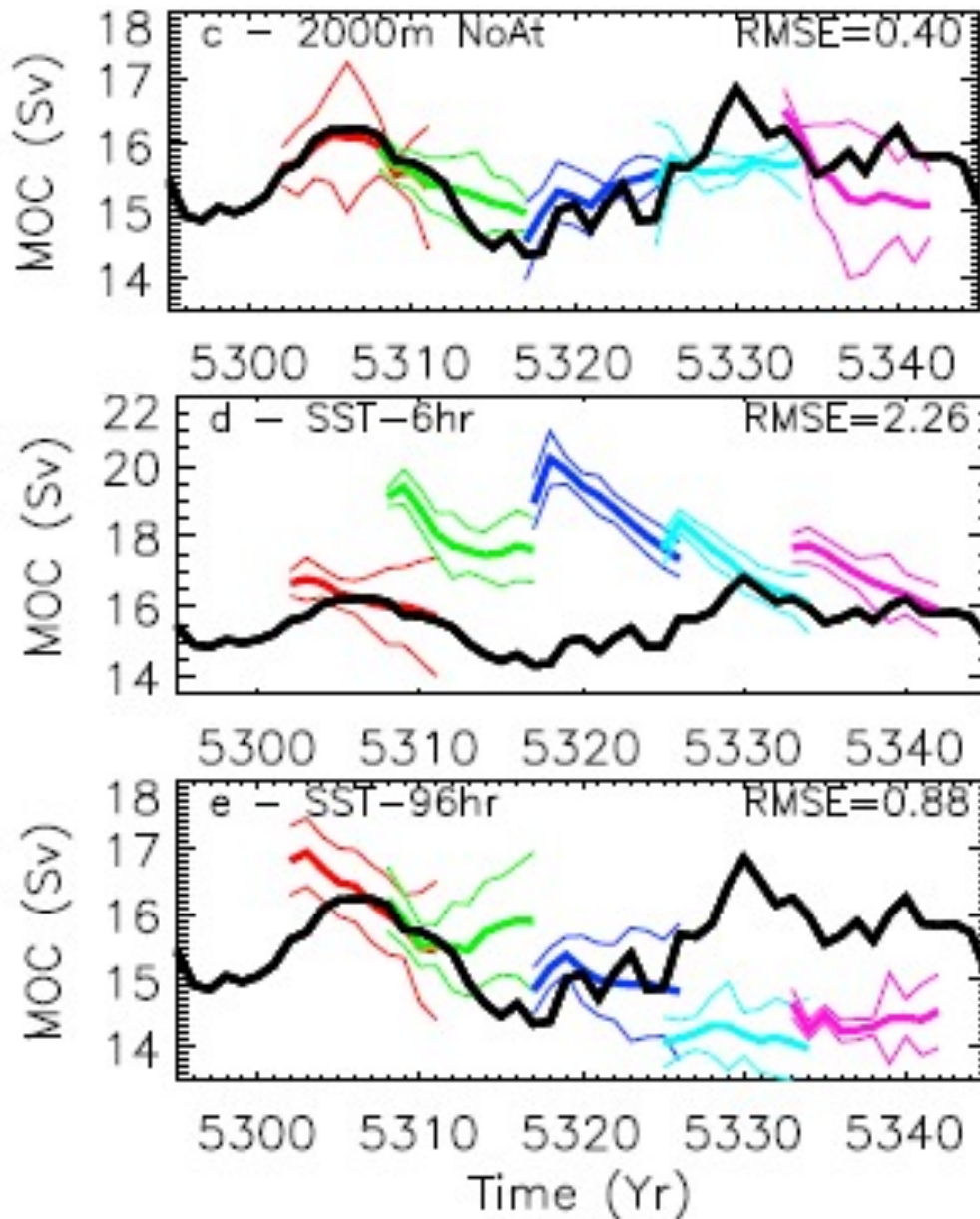
Decadal timescales





# Forecasting with surface nudging only?

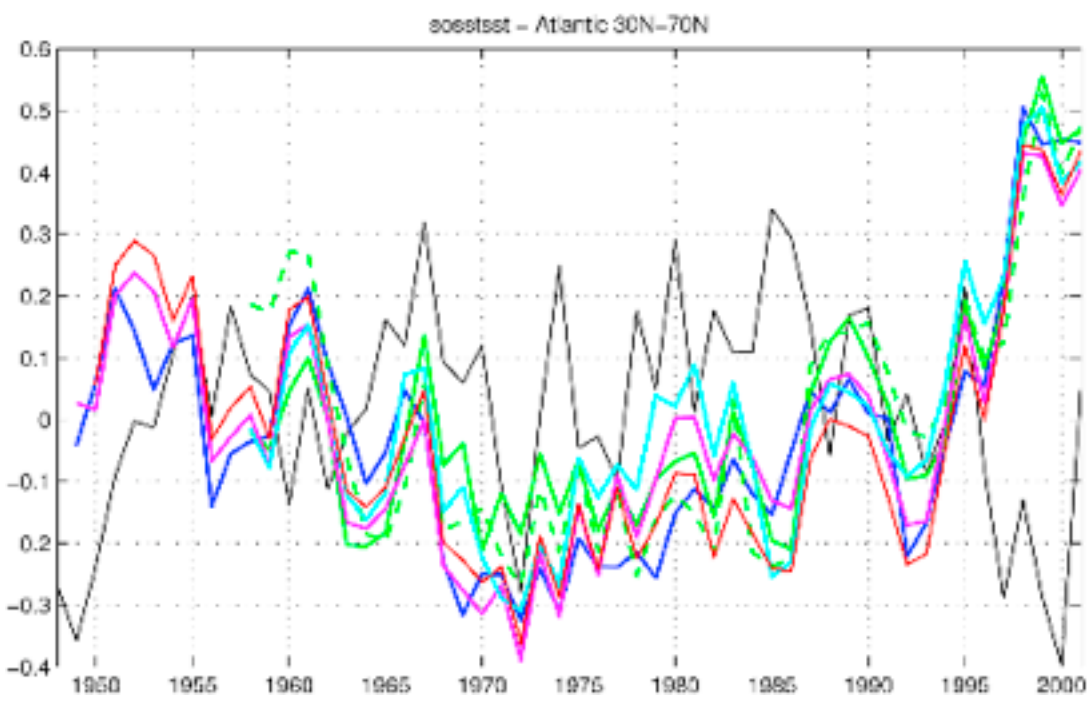
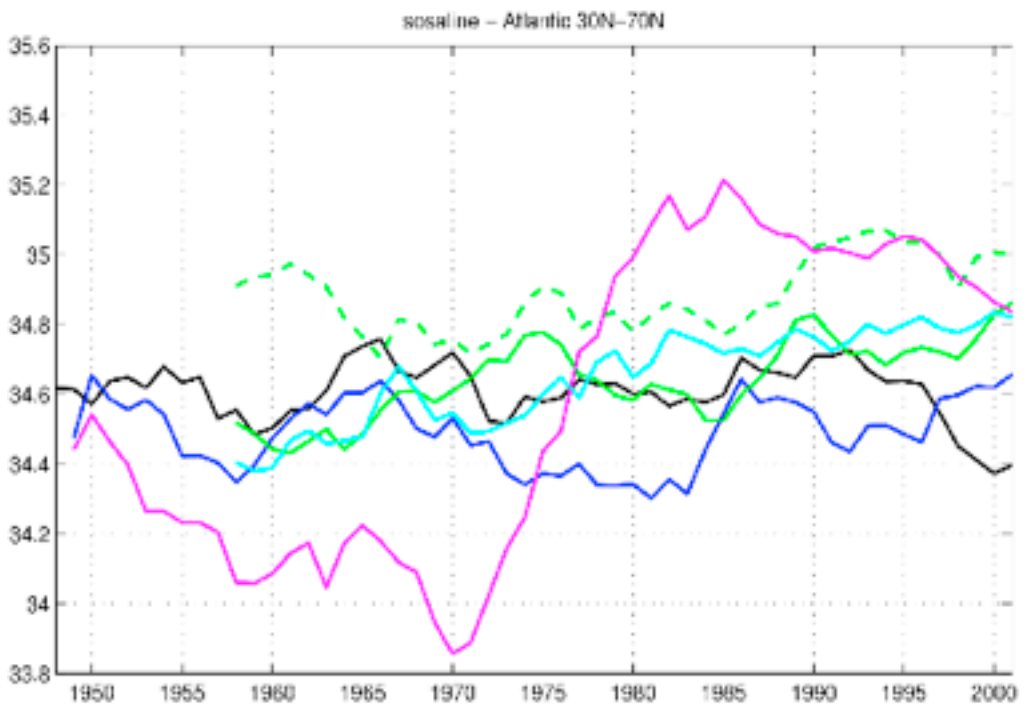
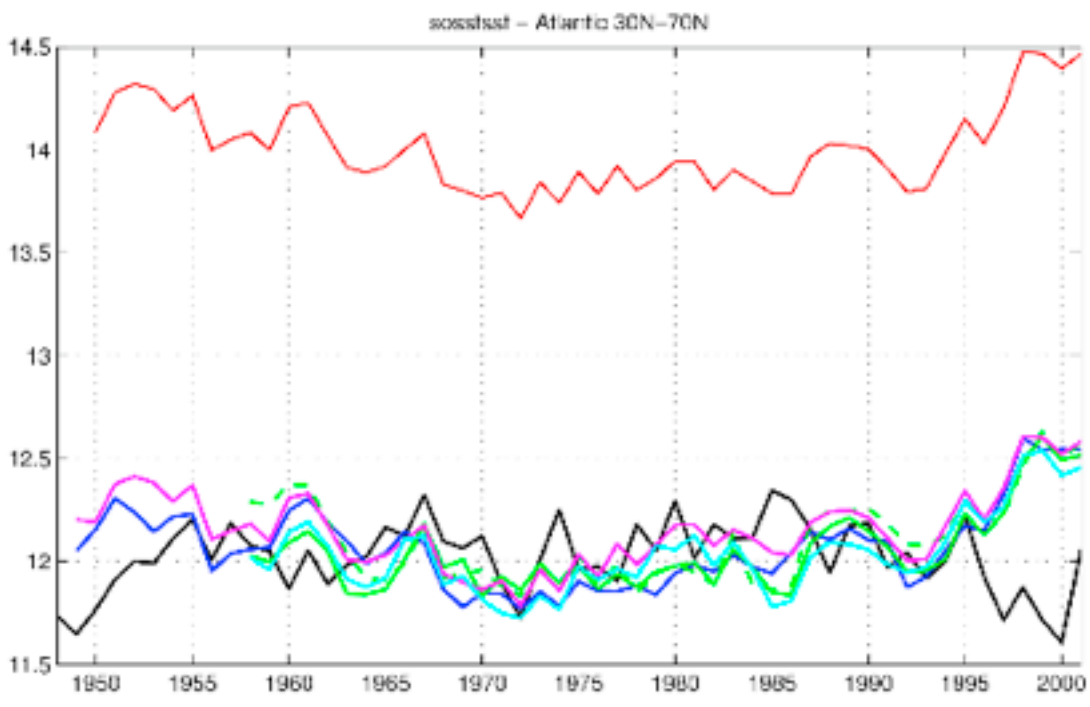
Decadal timescales



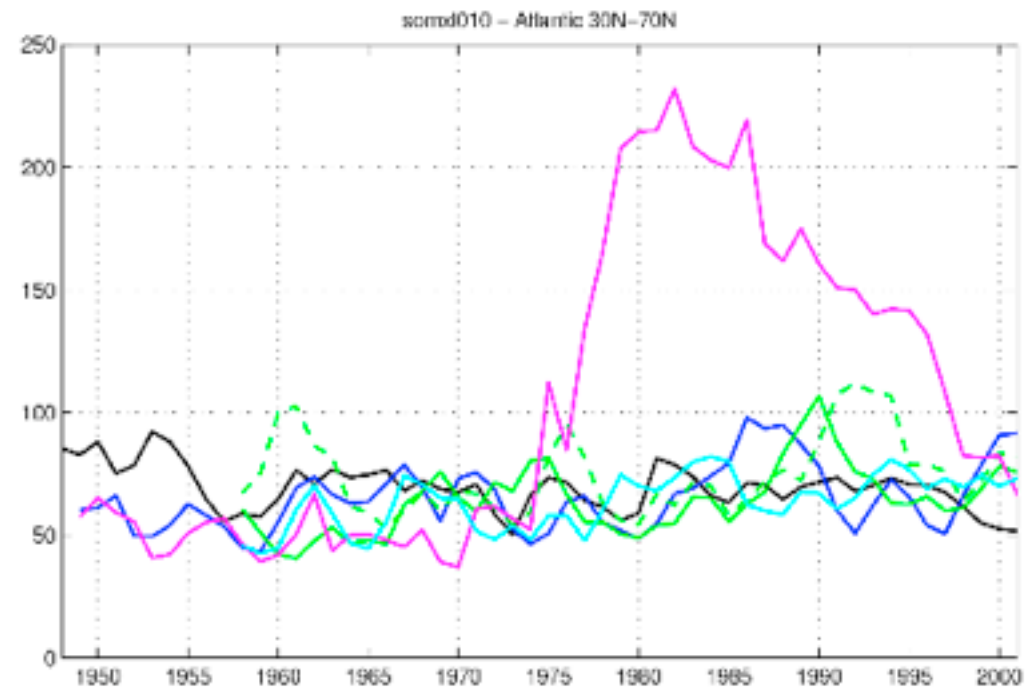
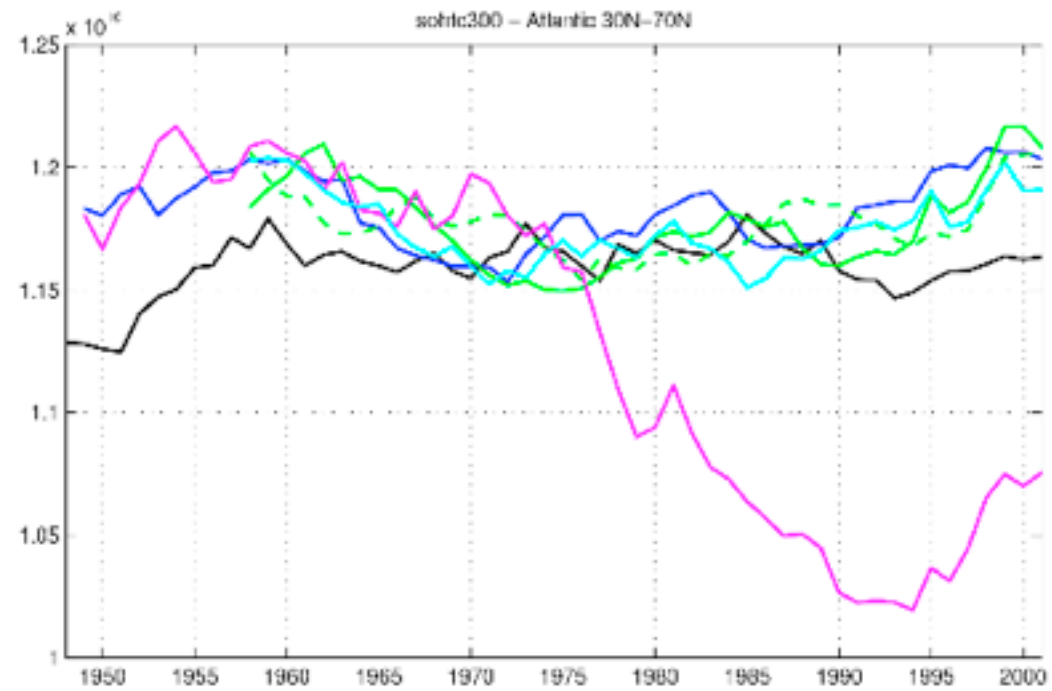
HadCM3 idealised experiments

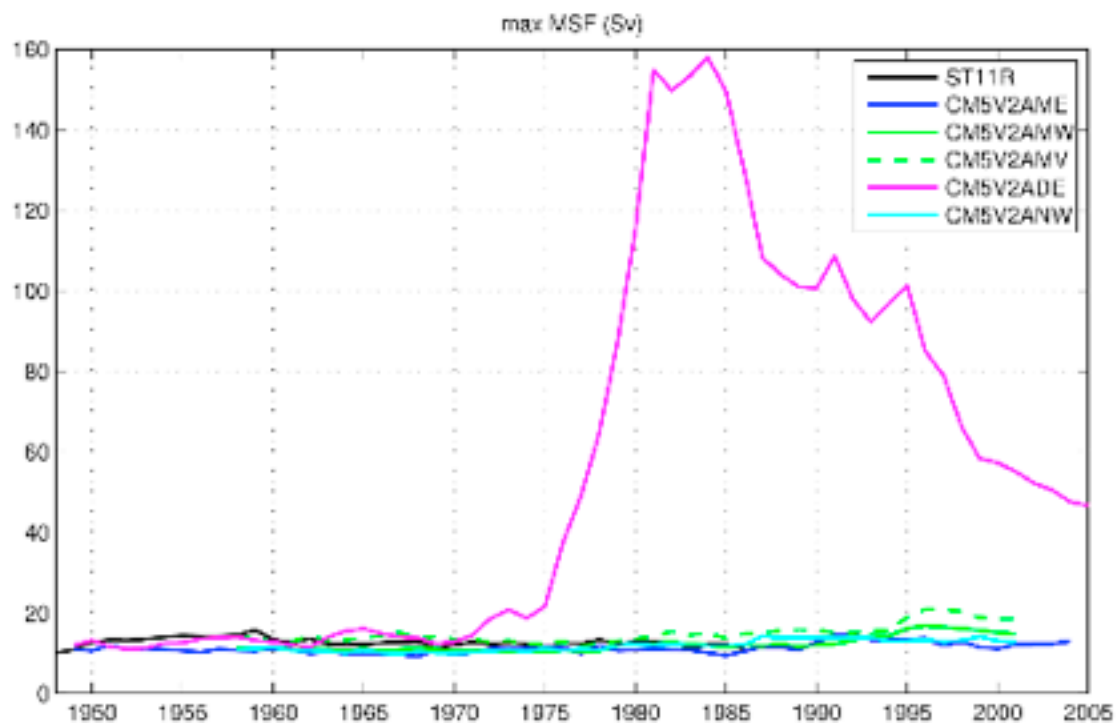
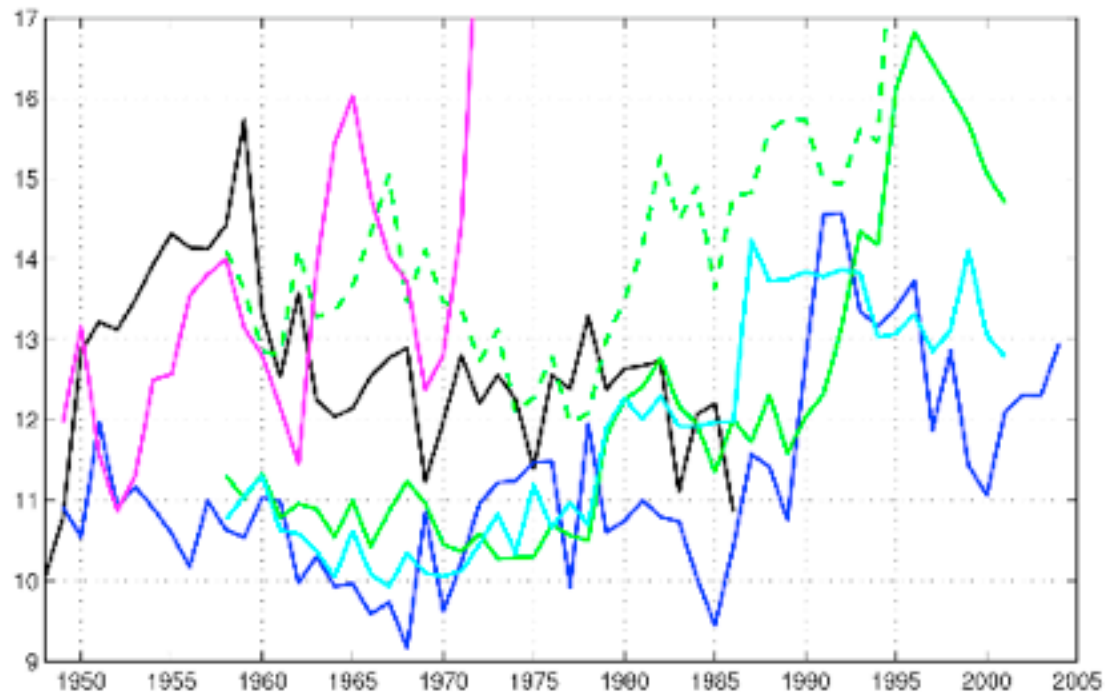
impact of assimilating different amounts of ocean data on decadal climate prediction skill.

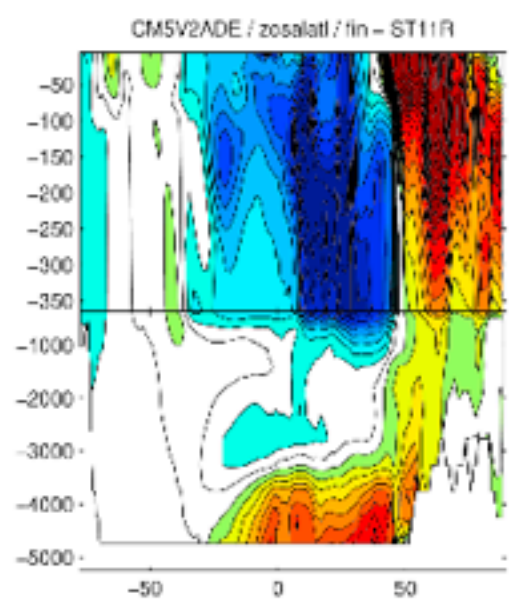
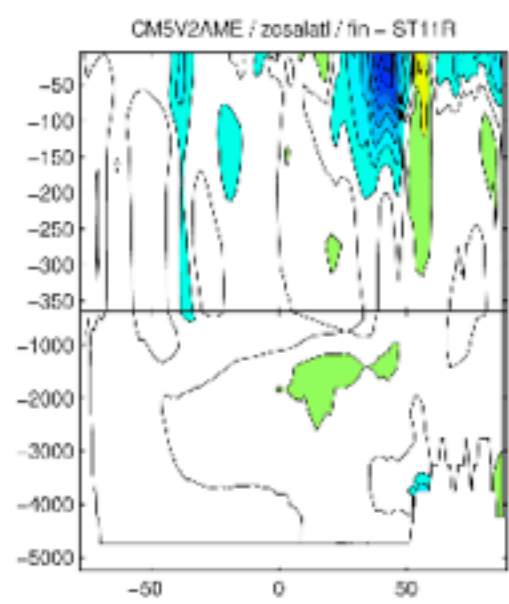
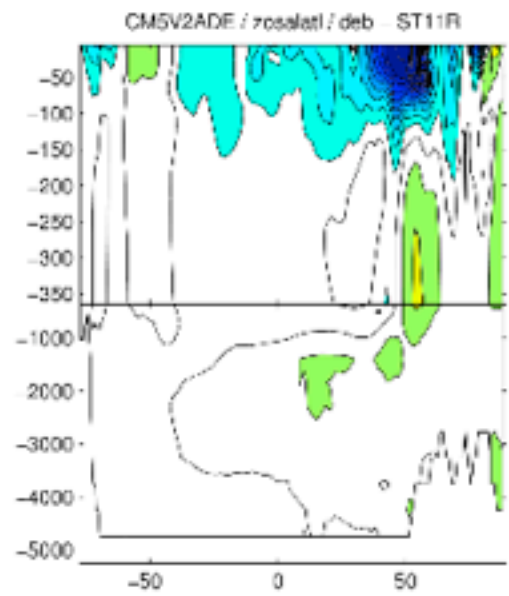
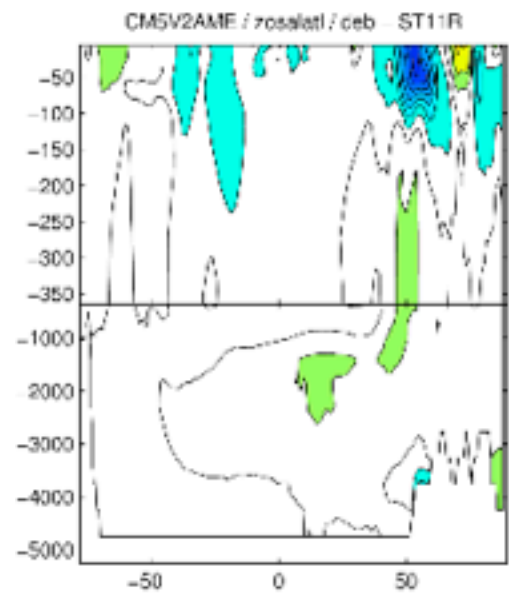
*Dunstone and Smith 2010*



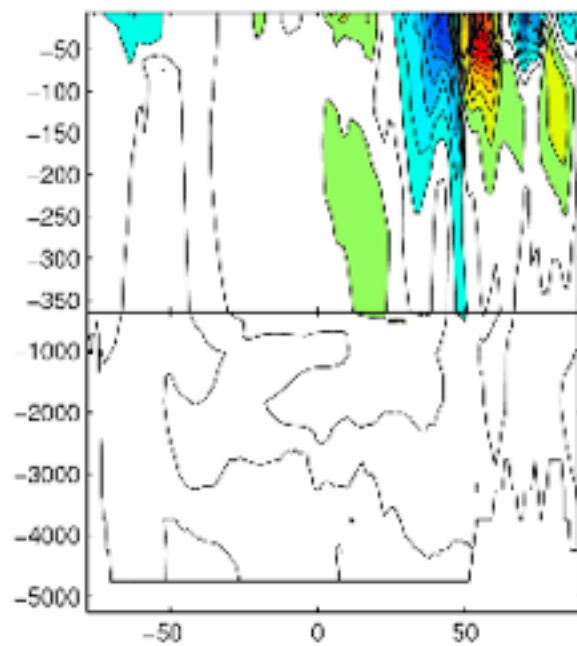
- Obs
- CM5V2AME – SST Reynolds 40W/m2
- CM5V2ADE – SST Reynolds 1200W/m2
- CM5V2AMW – SST Reynolds 40W/m2 + wind stress (x2)
- CM5V2ANW – SST Reynolds 40W/m2 + wind stress x 2
- départ AME



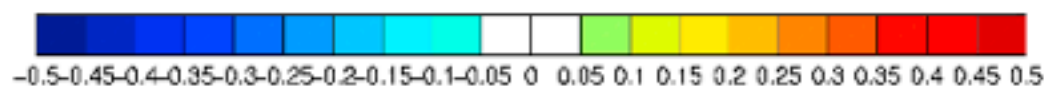
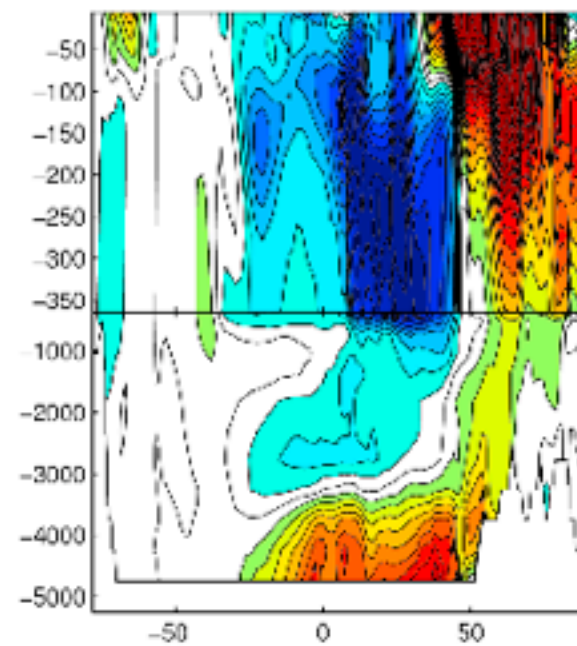




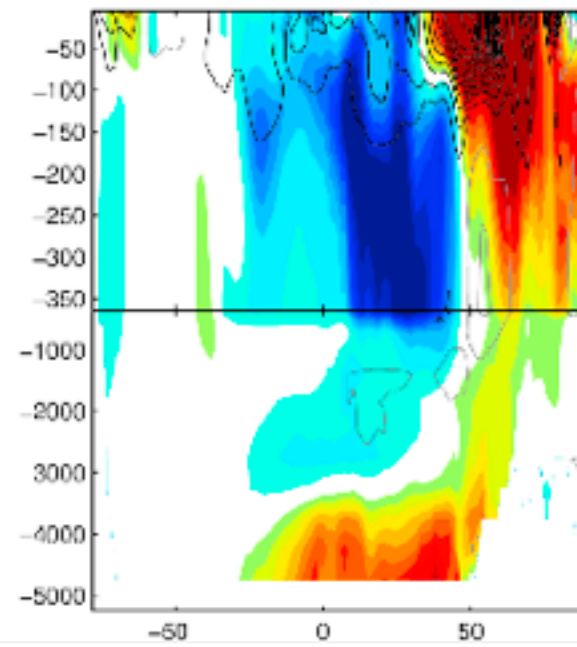
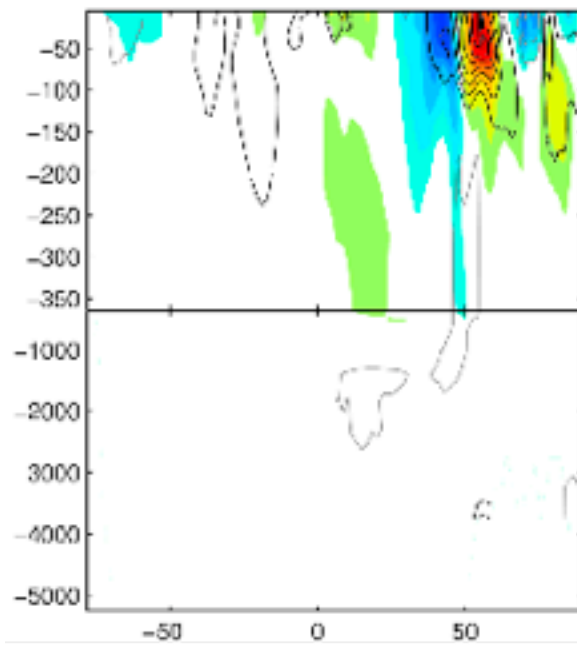
CM5V2A0E / zosalatl / fin - deb

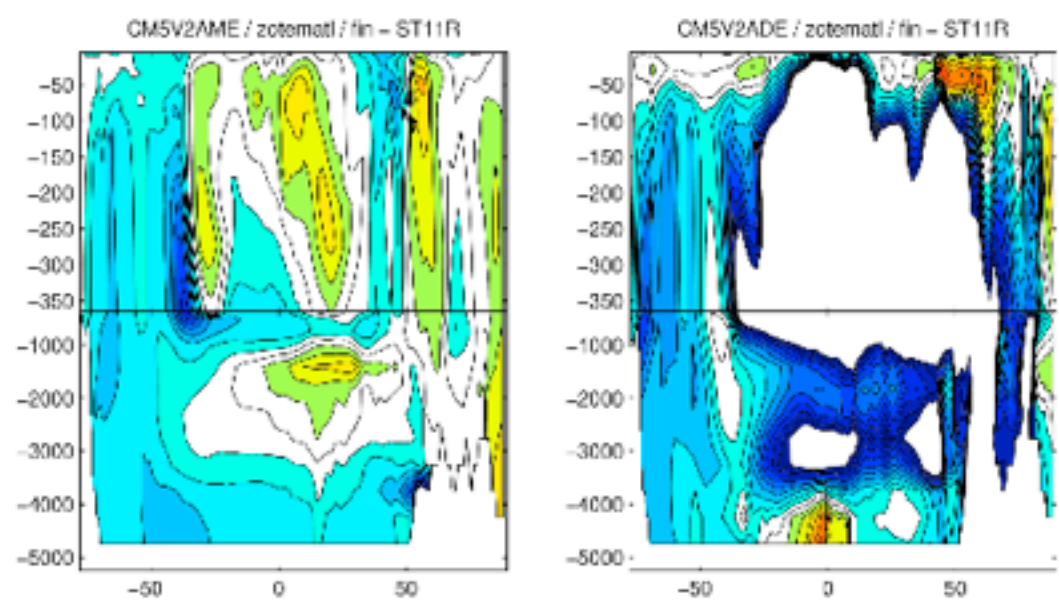
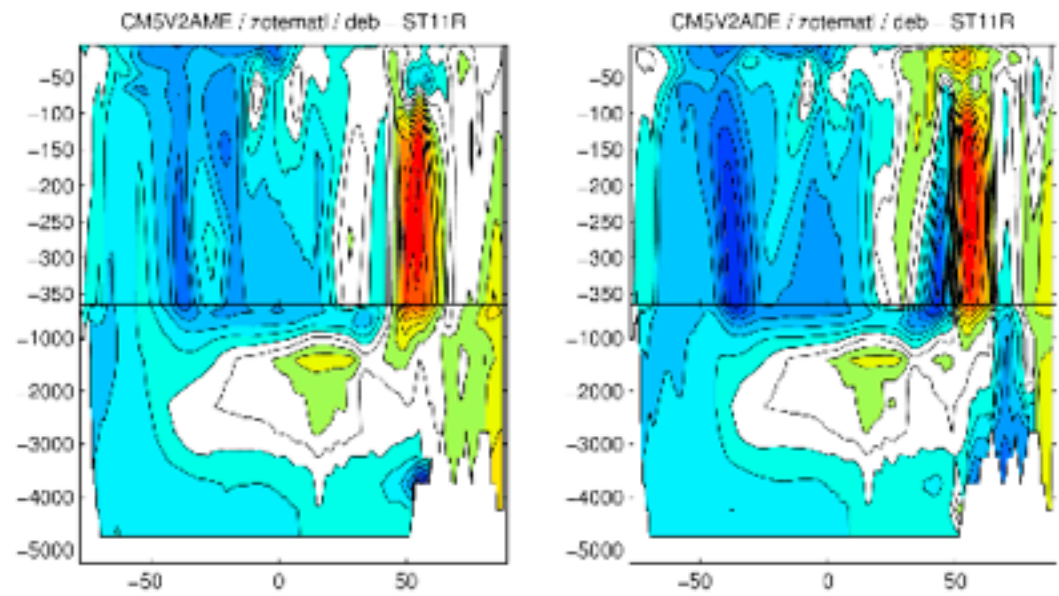


CM5V2A0E / zosalatl / fin - deb

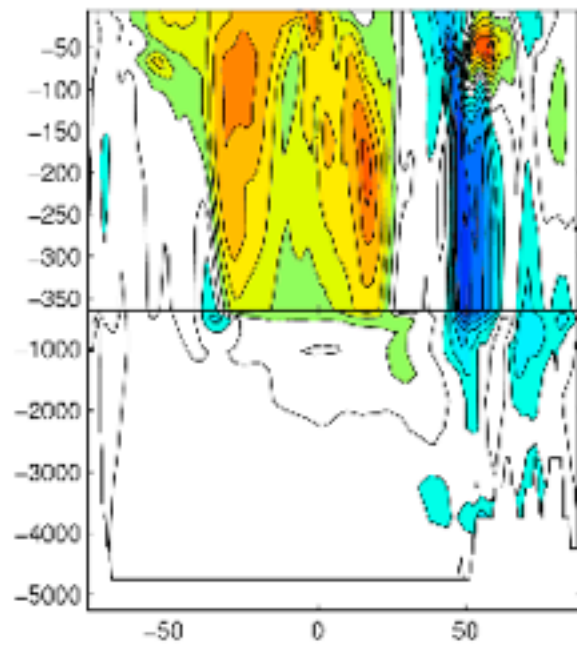


CM5V2A0E / zosalatl / contour:deb - ST11R, colors: fin-deb CM5V2A0E / zosalatl / contour:deb - ST11R, colors: fin-deb

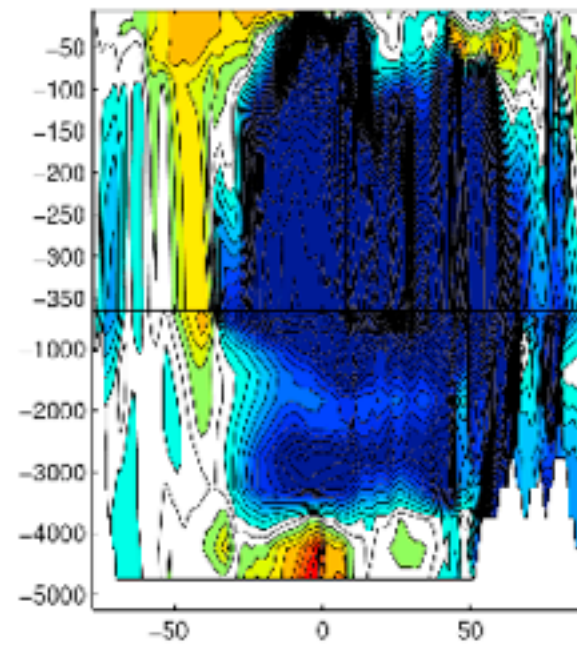




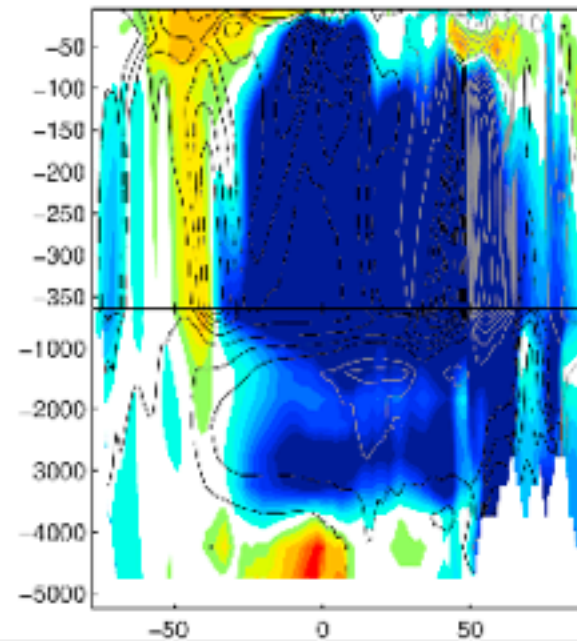
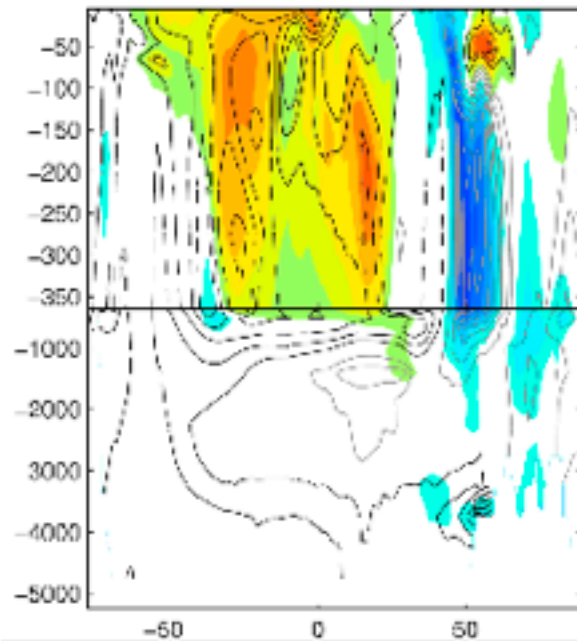
CM5V2AME / zotematl / fin - deb



CM5V2ADE / zotematl / fin - deb

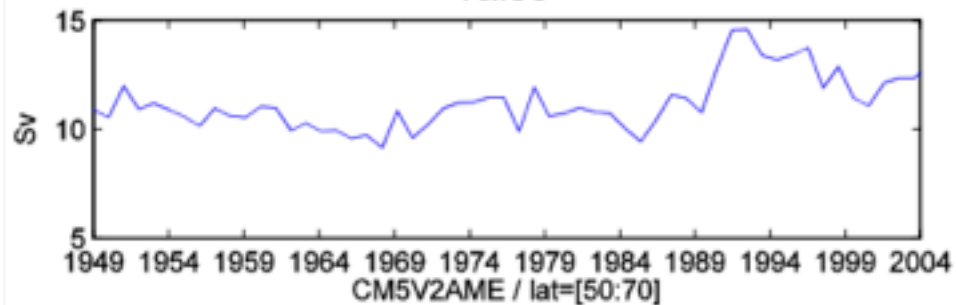


CM5V2AME / zotematl / contour:deb - ST11R, colors: fin-deb CM5V2ADE / zotematl / contour:deb - ST11R, colors: fin-deb

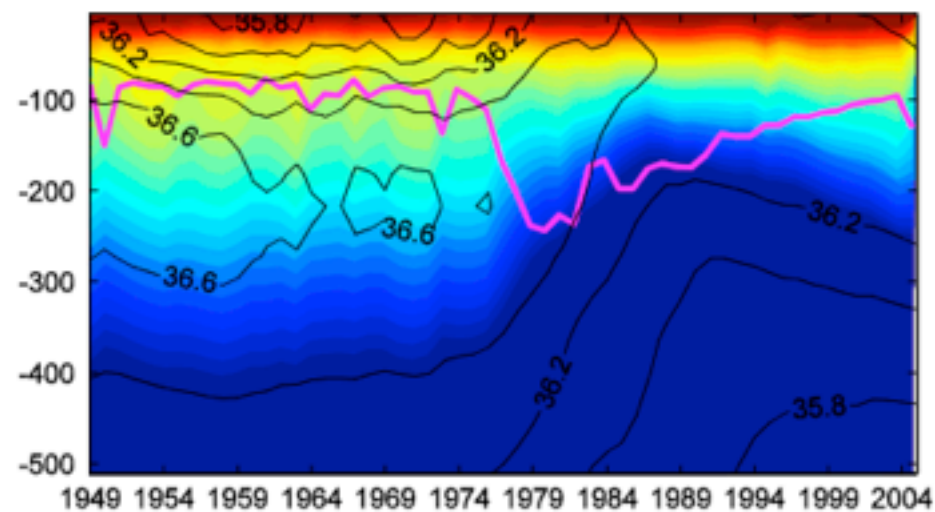
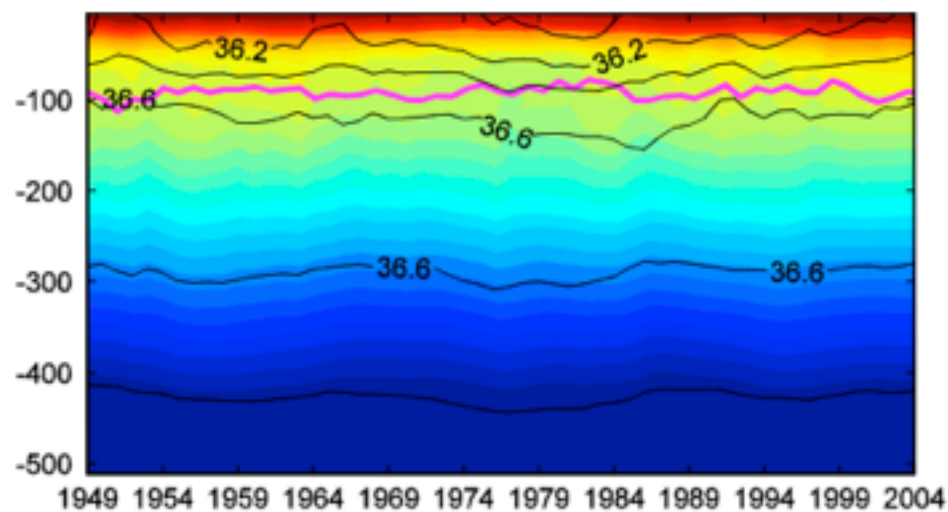
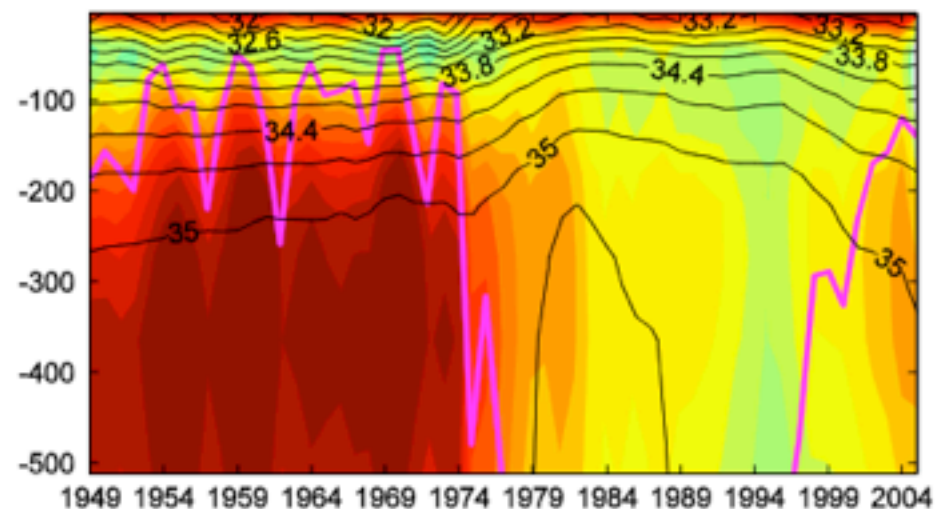
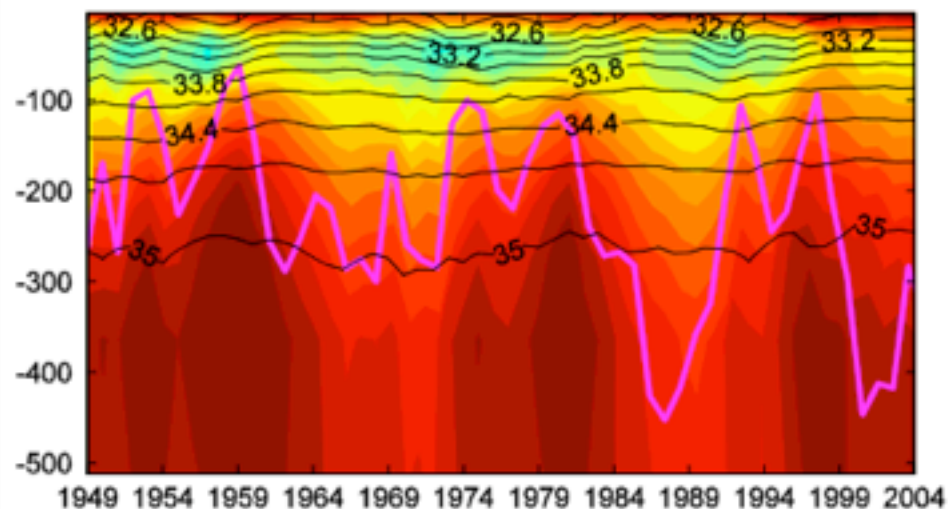
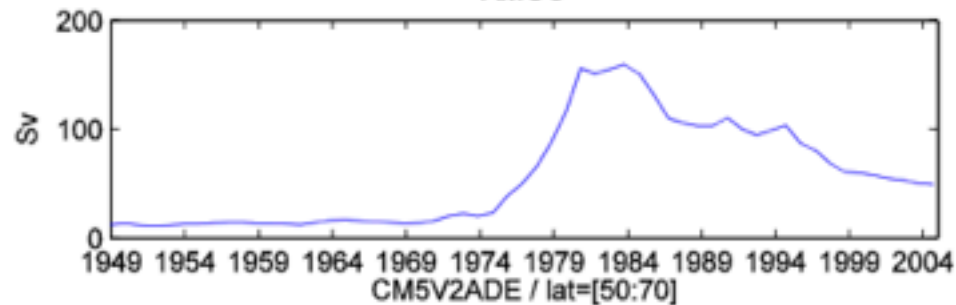




AMOC



AMOC



12 13 14 15 16 17 18

12 13 14 15 16 17 18