CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

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Drift dynamics in a coupled model initialized for decadal forecasts

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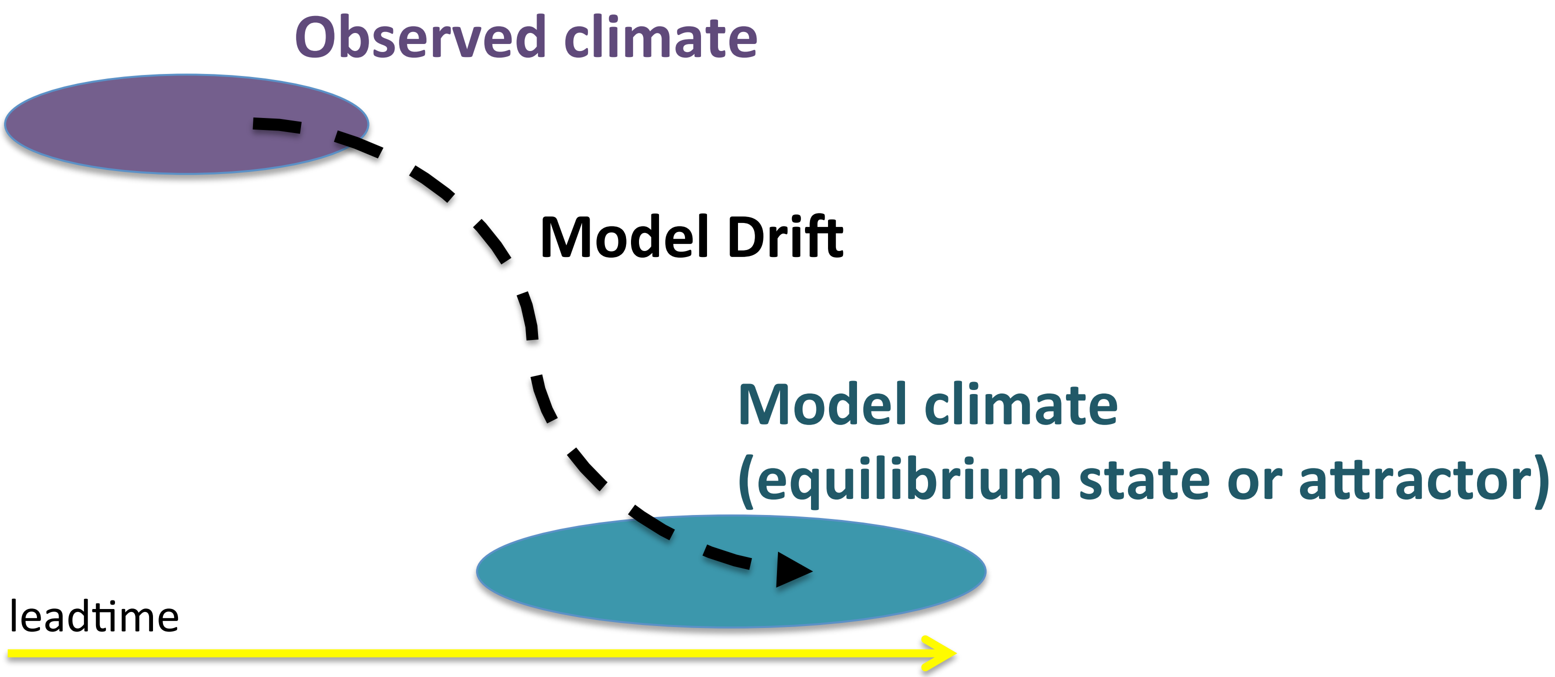
So I'm sorry that you've turned to driftwood
But you've been drifting for a long, long time …
(TRAVIS)

Context and motivation

Coupled models simulate an imperfect climate, hence **drifts are often present when models are initialized from observed conditions** to produce climate predictions.



The **model drift** *is the sequence of physical processes by which model adjust to its <u>equilibrium state or attractor.</u>*

Context and motivation

- Does the drift affect the signals we want to predict ? The challenge is to minimise it by **improving initialisation techniques**.

- Model drifts need to be removed from predictions for forecast verification

- They are rarely analysed …but the drift can provide useful information on the physical processes involved in the development of model systematic biases.

- This can be helpful to understand origins of model errors to **improve climate models**.

Objectives

- **To introduce a new protocol for ocean initialisation aimed at minimising the drift of a coupled model**
- **To investigate some of the physical processes involved in the model drift to understand the mechanisms leading to the model systematic errors**

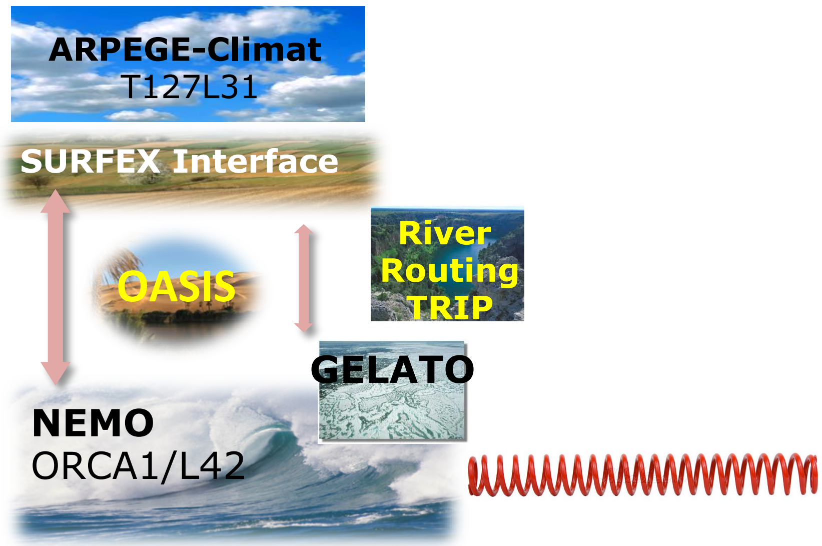
Two regions are considered:

- Tropical Pacific
- North Atlantic

Initialisation method

A **previous coupled simulation** is performed in which **the ocean component** of CNRM-CM5 **is nudged towards ocean reanalysis.**

CNRM-CM5 coupled model



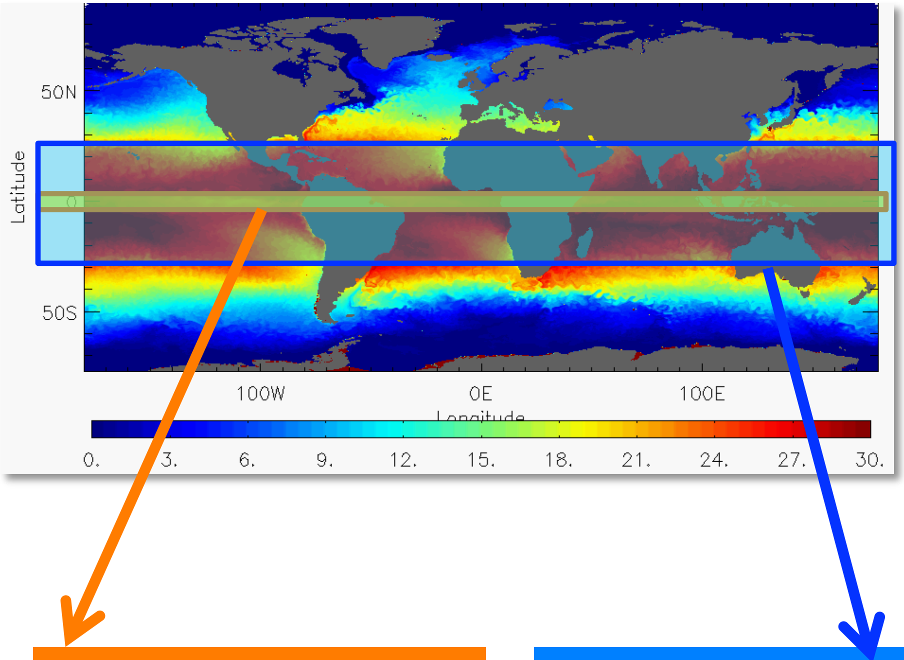
The goals:
- **Get closer to the model attractor** (Minimising the initial shock and the model drift)
- **To build initial conditions for land and sea-ice**

The NEMOVAR-COMBINE
ECMWF Ocean Reanalysis
Balmaseda et al. 2010

Nudging of NEMO = Sea surface restoring + 3D newtonian damping

Initial conditions

Two nudging experiments have been considered :
(sea surface restoring is applied everywhere in both cases)



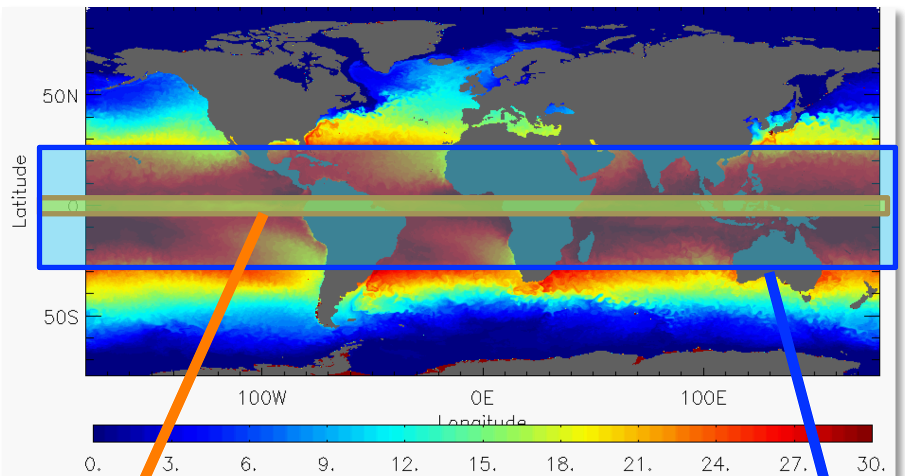
NOEQ _IC
No 3D nudging in 1°S–1°N

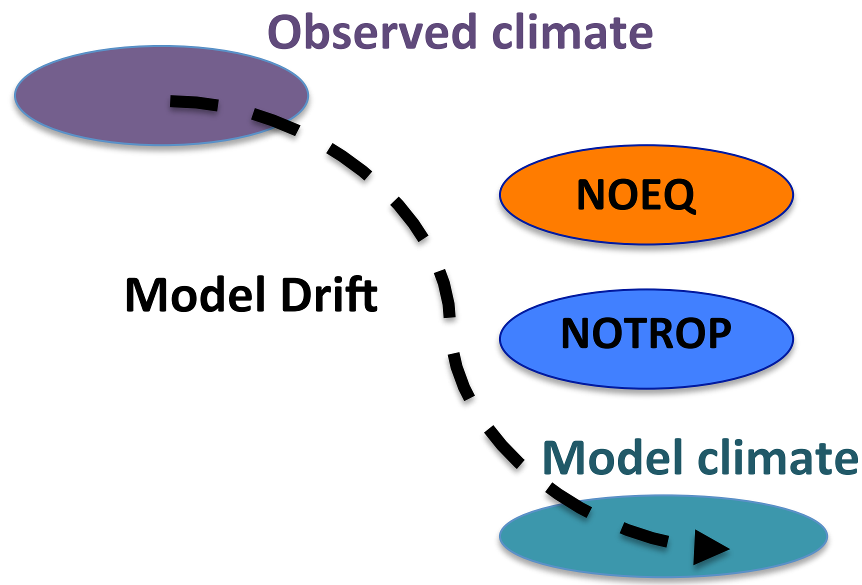
NOTROP IC→
No 3D nudging in 15°S–15°N

Initial conditions

Two nudging experiments have been considered :

(sea surface restoring is applied everywhere in both cases)



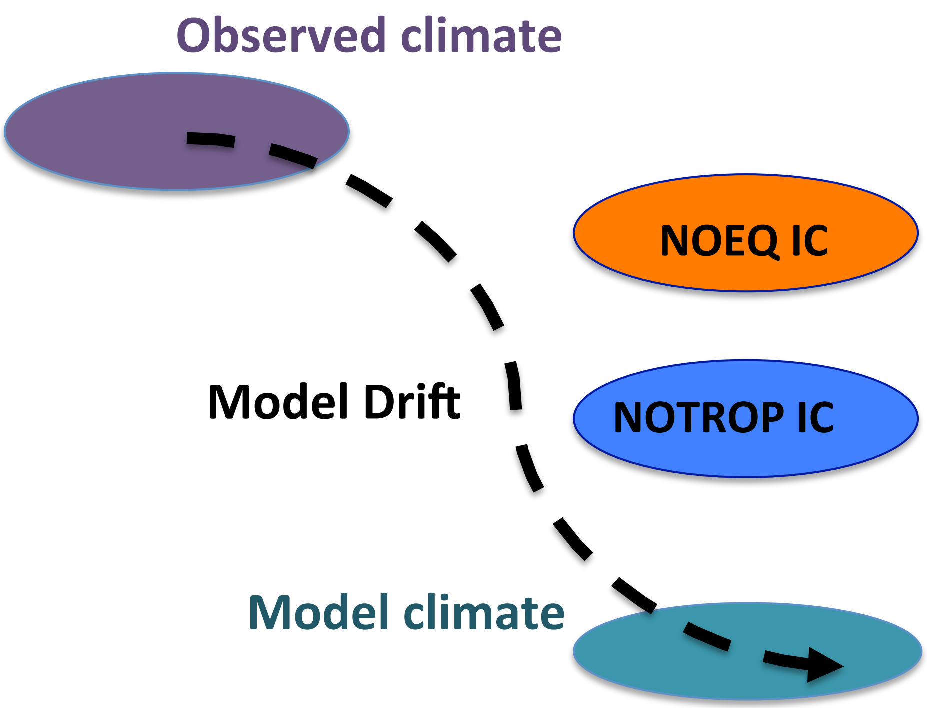


NOEQ _IC
No 3D nudging in
1°S–1°N

NOTROP IC→
No 3D nudging in
15°S–15°N

NOTROP ICs are expected to be closer to the model mean state

Numerical experiments



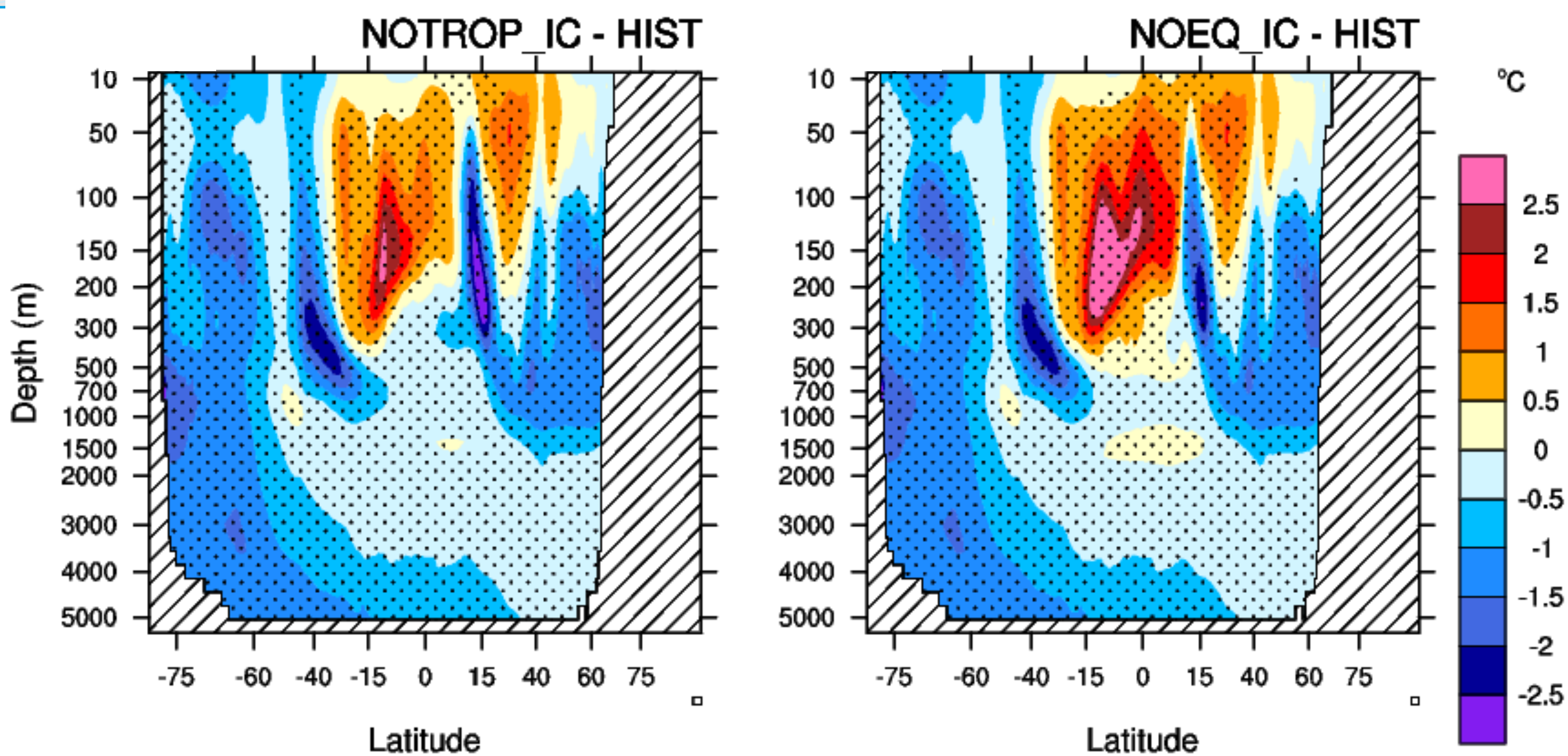
→ **DEC_NOEQ :**
initialised every 5 years within 1960-2000 (10 years, 10 members)

→ **DEC :**
initialised every 5 years within 1960-2000 (10 years, 10 members)

→ **HIST :**
Non initialized, 1960-2005, 10 members

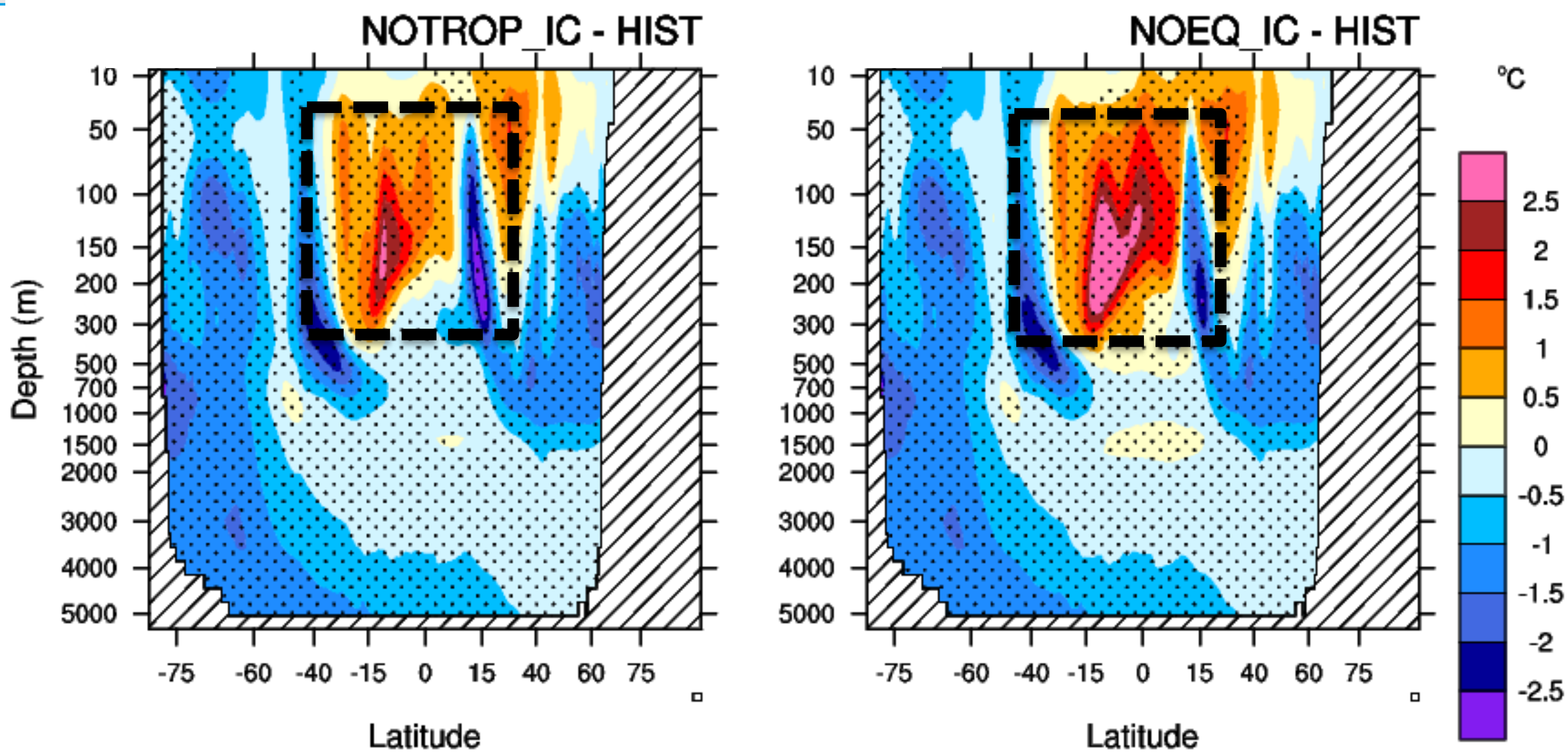
The model drift is estimated as DEC – HIST (averaged over all the start dates all the members)

Model drift in the Tropical Pacific



NOTROP_IC and NOEQ_IC differences from HIST for zonal temperature annual means

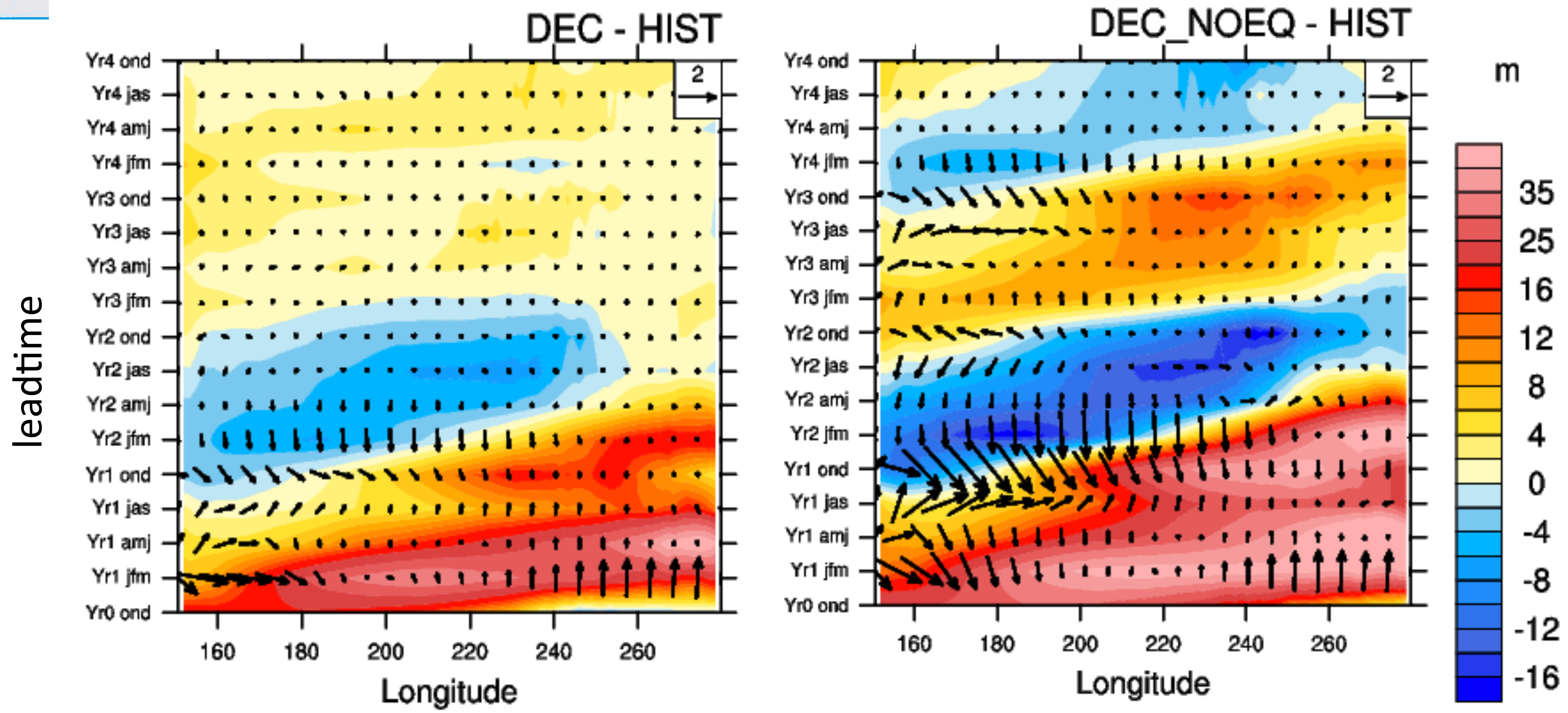
Model drift in the Tropical Pacific



NOTROP_IC and NOEQ_IC differences from HIST for zonal temperature annual means

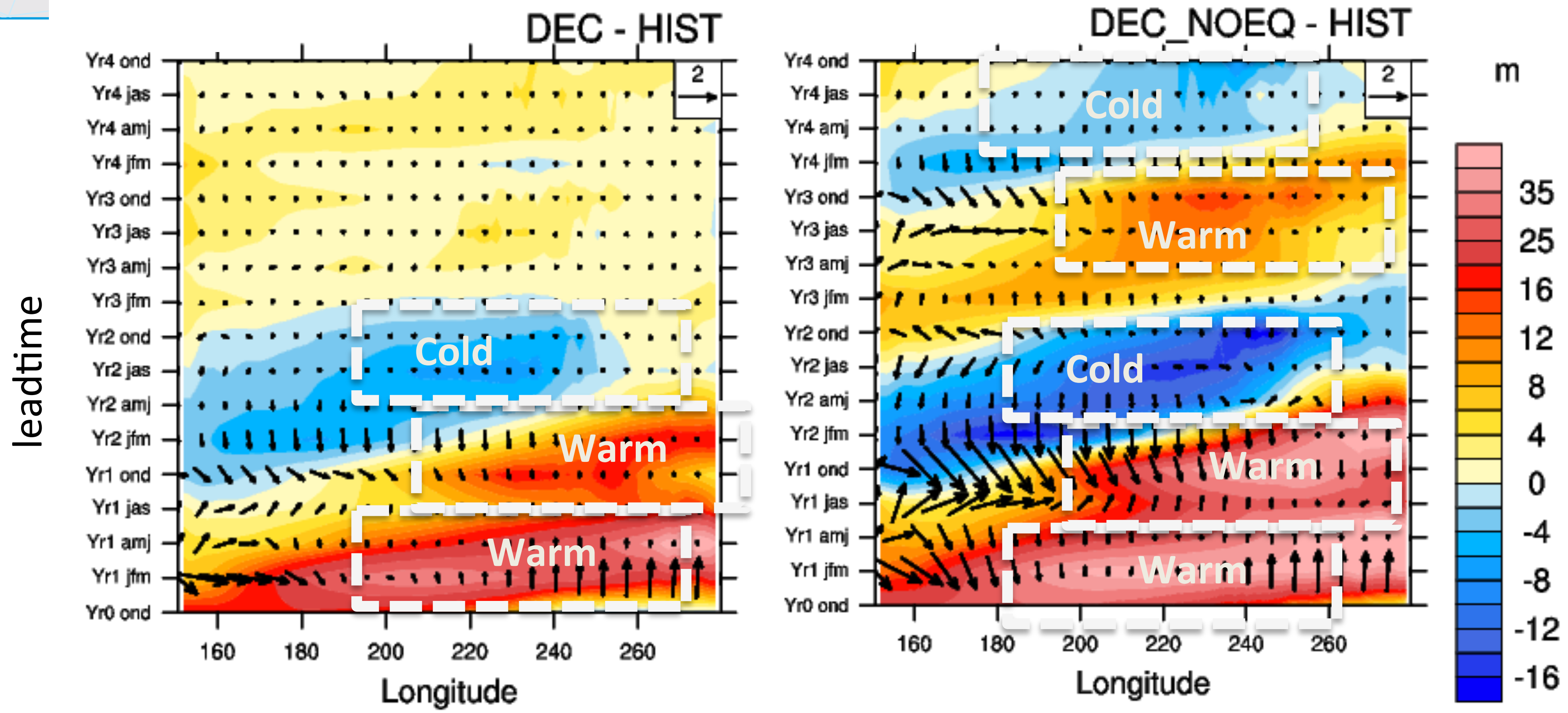
Largest temperature differences on the equatorial Pacific subsurface.
NOEQ_ICs are more different from the model climate (HIST).

Model drift in the Tropical Pacific



Equatorial 20°C isotherm depth (colors) and 10m winds (arrows) averaged over 2°S–2°N

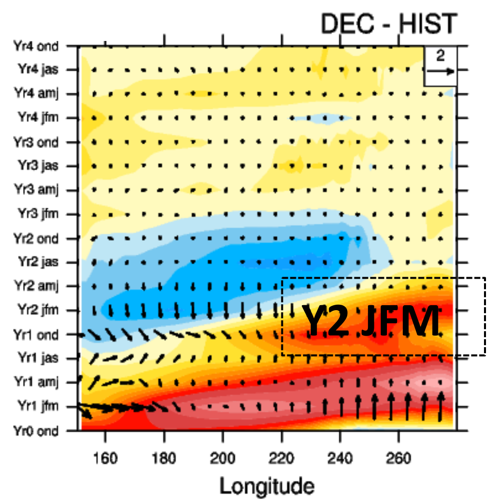
Model drift in the Tropical Pacific

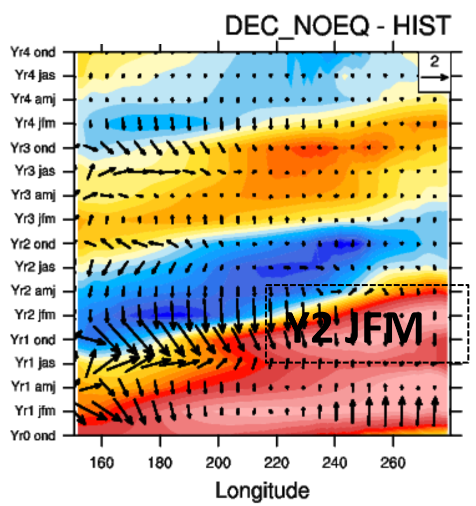


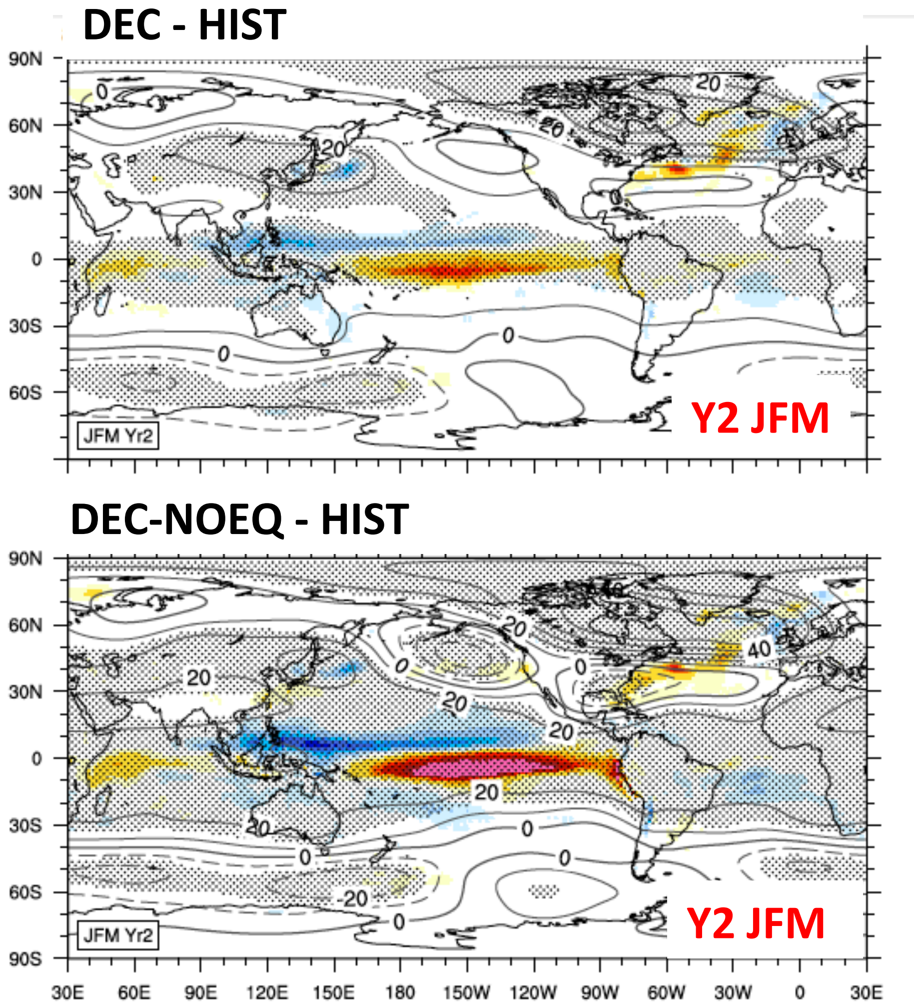
Equatorial 20°C isotherm depth (colors) and 10m winds (arrows) averaged over 2°S–2°N

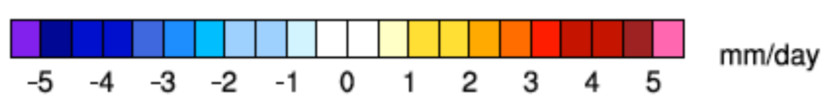
- **Excitation of El Niño event at Y1.** La Niña event occurs at Y2. The spurious oscillatory behavior is progressively damped until Y4.
- **This mechanism is much more pronounced in DEC_NOEQ**

Model drift in the Tropical Pacific



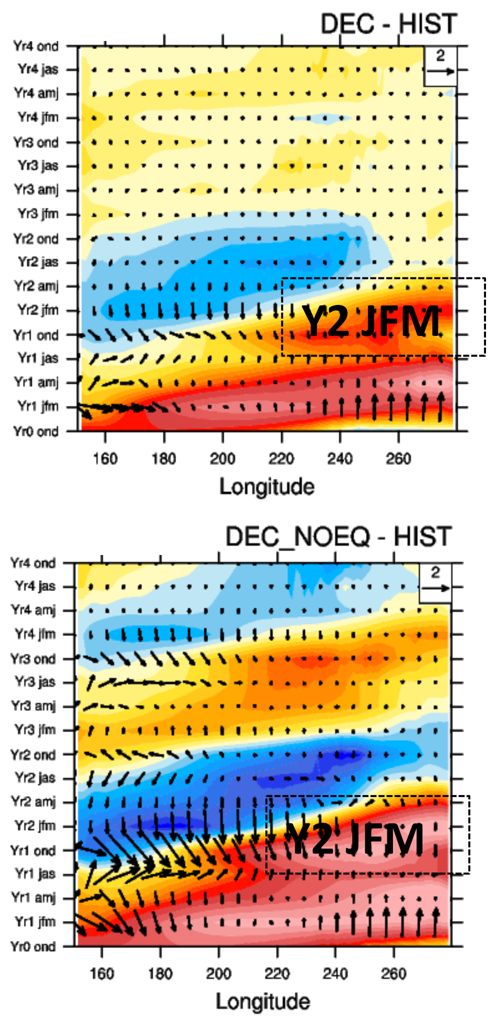


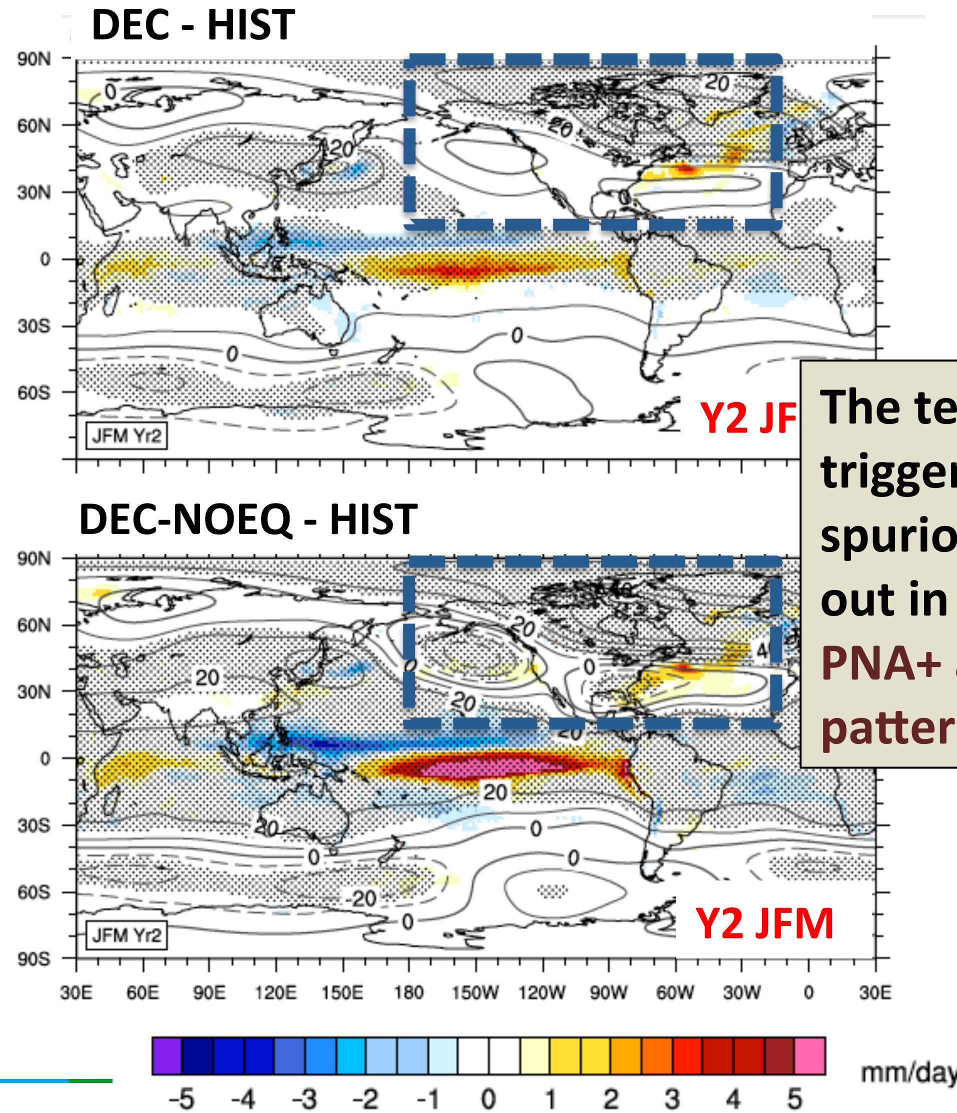




Contours: Z500, shading: precipitation

Model drift in the Tropical Pacific



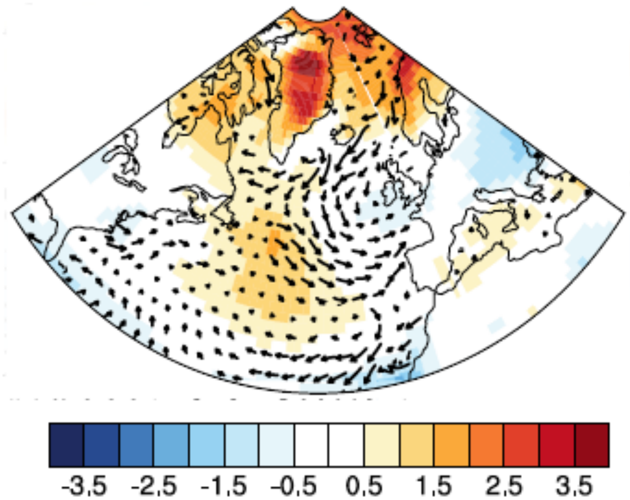


The teleconnection triggered by the spurious ENSO spread out in midlatitudes: PNA+ and NAO- patterns

Contours: Z500, shading: precipitation

Model drift in the North Atlantic

NOTROP_IC- NCEP

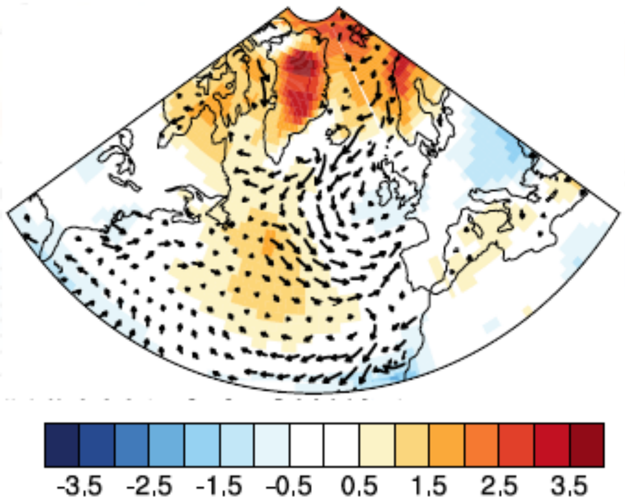


SLP (hPa)

The stand-alone atmospheric component bias projects onto the **negative phase of the NAO**.

Model drift in the North Atlantic

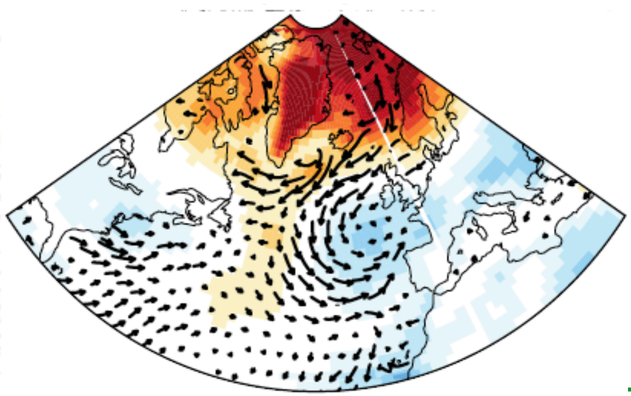
NOTROP_IC- NCEP



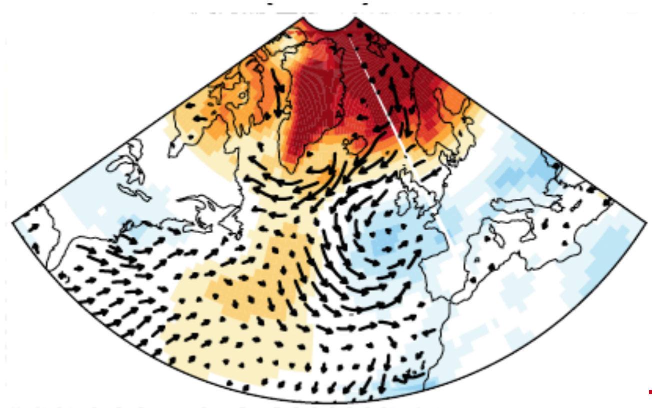
SLP (hPa)

The stand-alone atmospheric component bias projects onto the **negative phase of the NAO**.

DEC – NCEP (Year1-Year4)



DEC – NCEP (Year5-Year10)

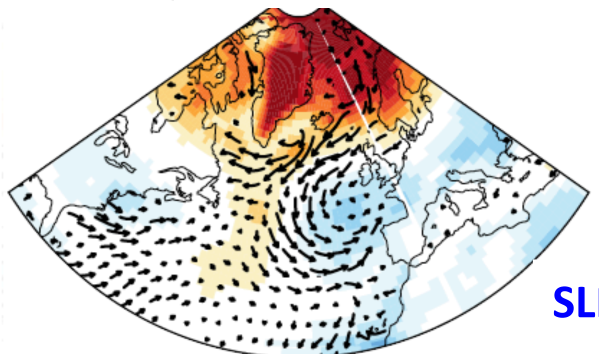


Model drift in the North Atlantic

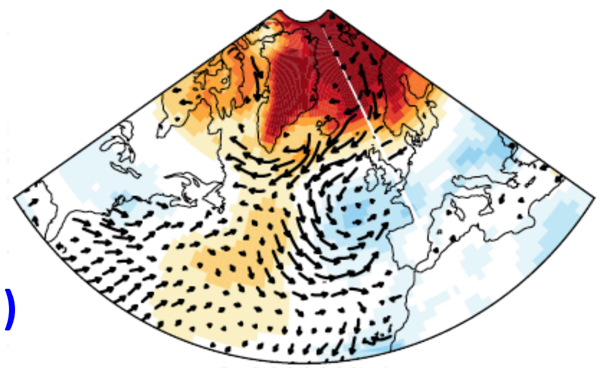
Year1 – Year4

Year5 – Year10

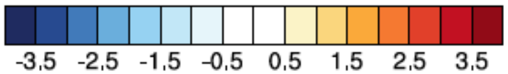
DEC – NCEP



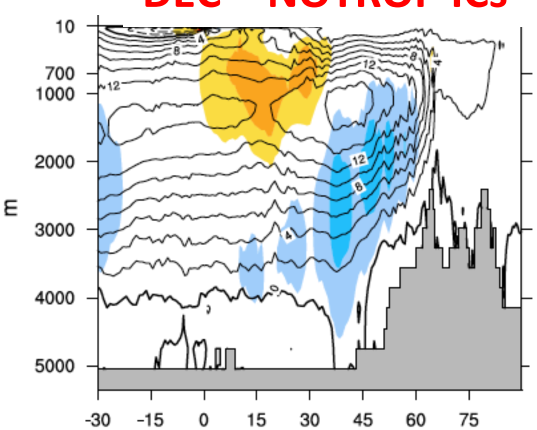
DEC – NCEP



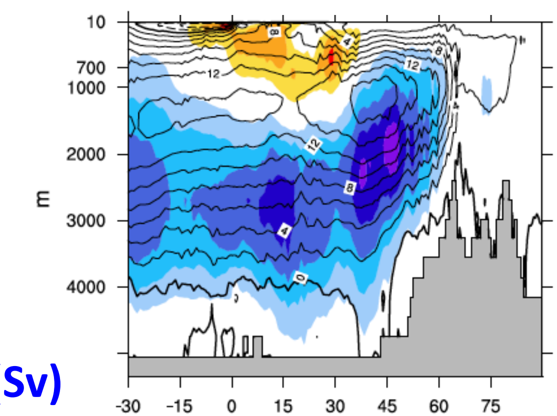
SLP (hPa)



DEC – NOTROP ICs



DEC –NOTROP ICs



AMOC (Sv)

AMOC decrease as response to intrinsic atmospheric biases (NAO- pattern)

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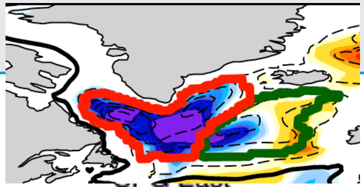
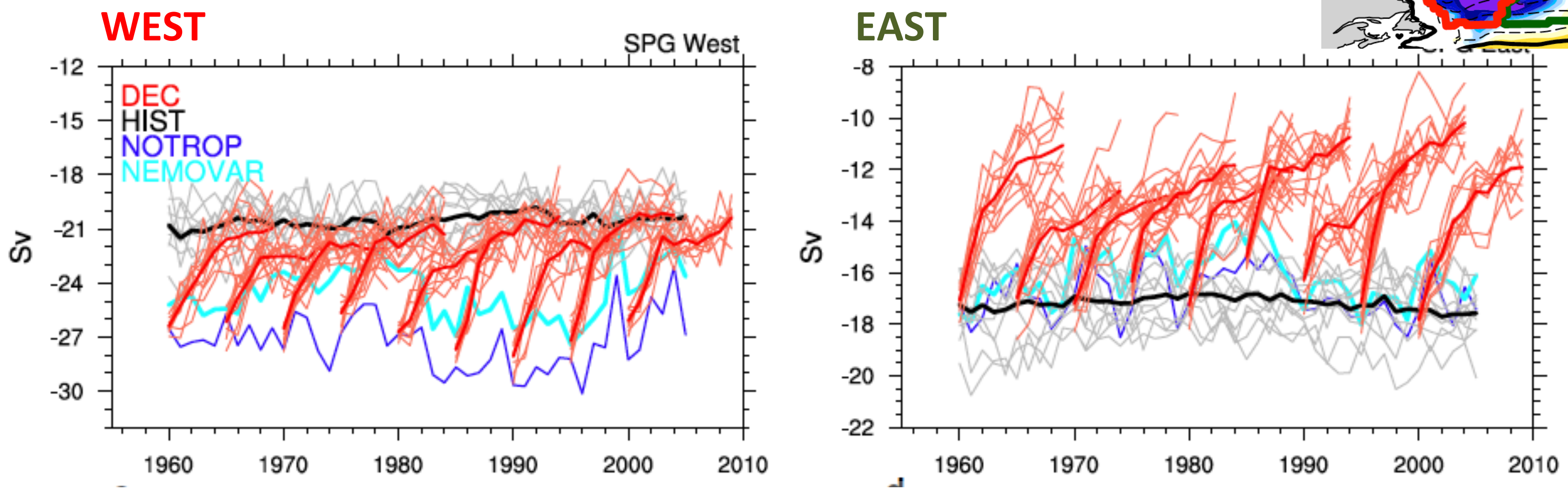
Model drift in the North Atlantic



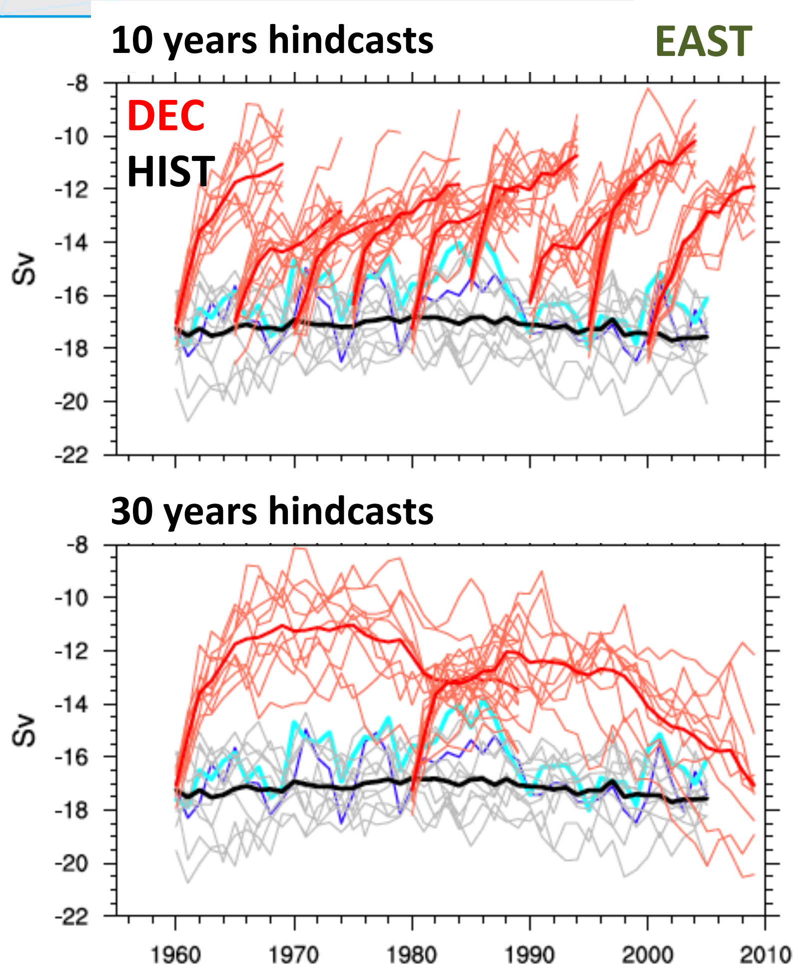


Drift in the barotropic stream function averaged over the western and eastern Subpolar gyre

Coherent with the NAO- forcing, there is an slackening of the SPG circulation:

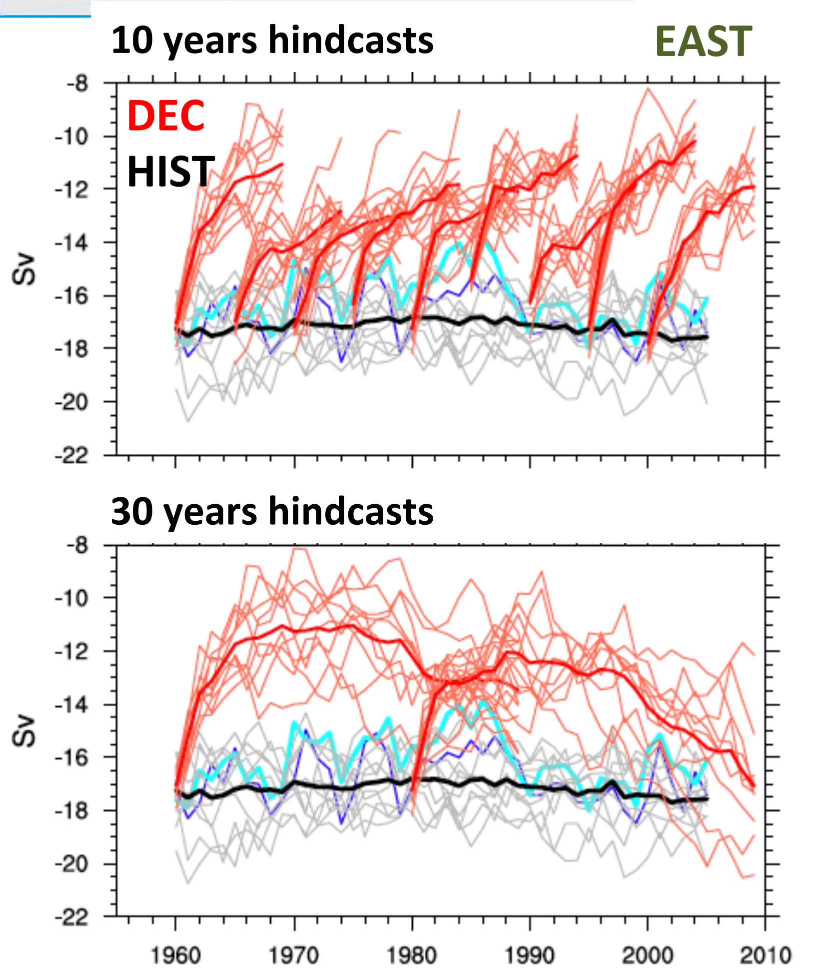
- **The west SPG in DEC rapidly weakens to reach HIST after around 4–5 years.**
- **The East SPG weakens and unexpectedly drifts away from HIST until Y10**

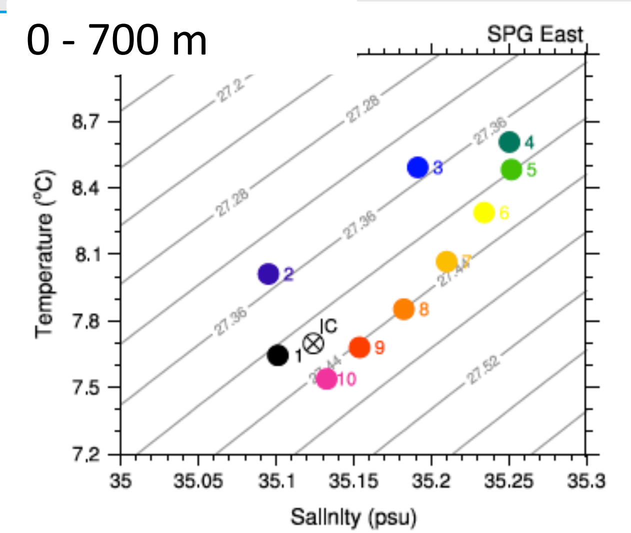
Model drift in the North Atlantic

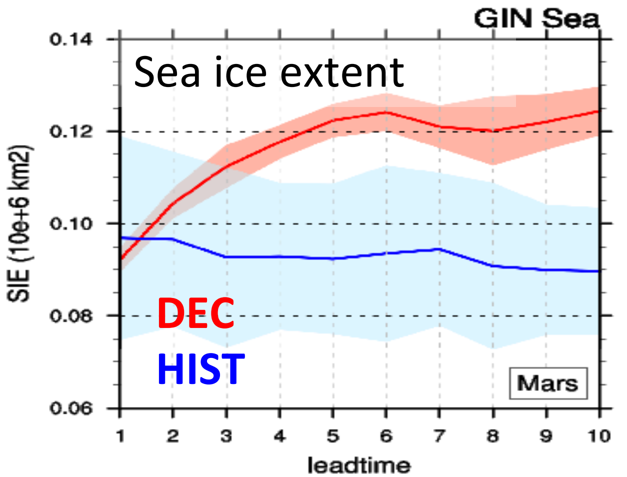


- The East SPG strengthens from Yr11-12 to reach barely the attractor after 30 years.

Model drift in the North Atlantic







- The East SPG strengthens from Yr11-12 to reach barely the attractor after 30 years.
- After Yr5, cooling of eastern area consistent with NAO- like forcing, and associated spurious sea ice formation in GIN sea

Summary and conclusions

- **Drift analysis allows to understand the physical origin of model errors, which is useful to identify mechanisms to be improved in coupled models.**

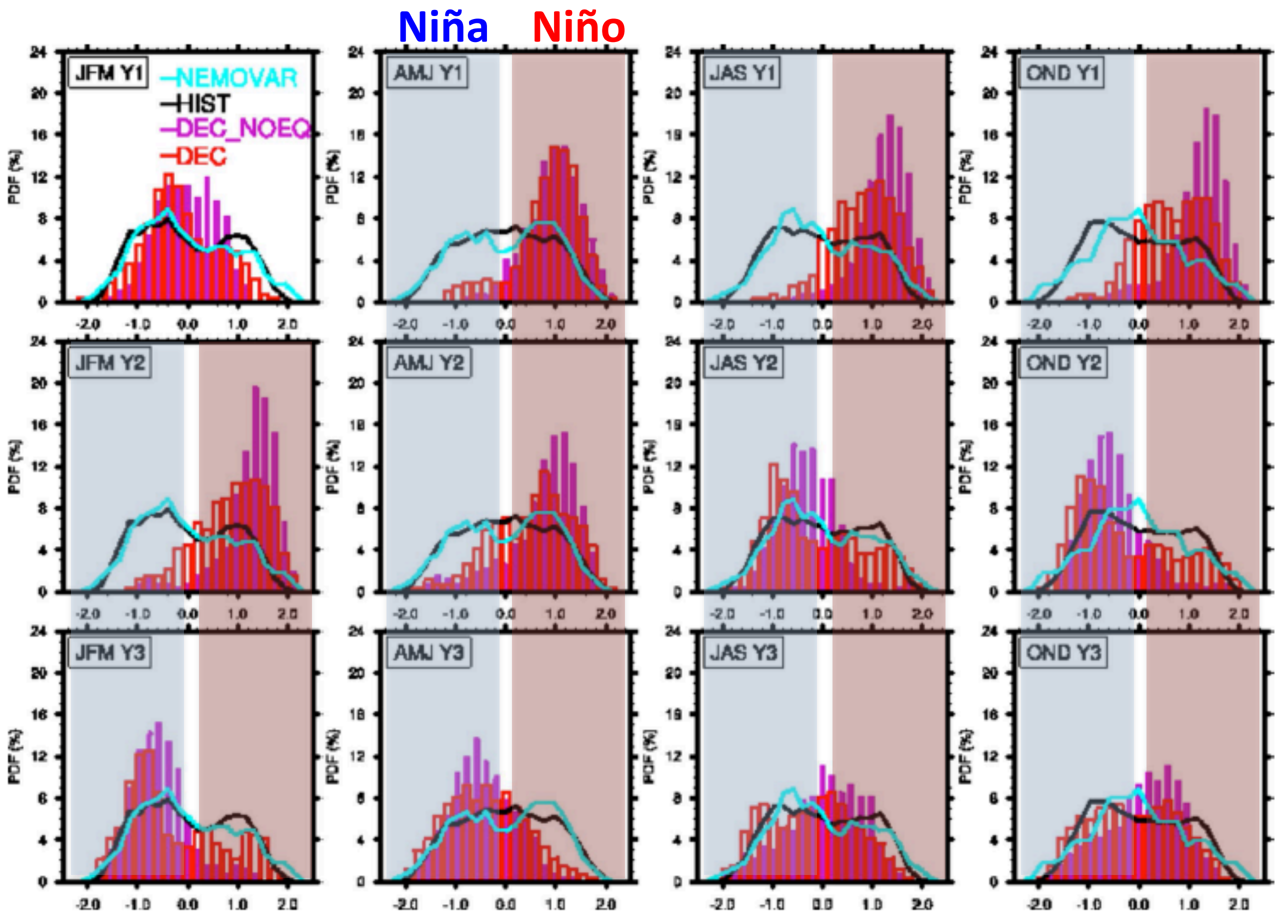
  (Vanniere et al. 2013, Tonniazzo and Woolnough, 2013, Voldoire et al. 2014, Huang et al. 2015, Sanchez-Gomez et al. 2015)

- In the Pacific, the **year1 is characterized by a quasi-systematic excitation of El Niño**, affecting the atmospheric circulation in midlatitudes. The model comes into a discharge-recharge mechanism until year4. **This spurious effect is minimised with the initialisation method.**

- **In the North Atlantic, the coupled model biases can be attributed to the biases of stand-alone atmospheric component which projects onto a negative NAO.** This NAO- forcing leads to a weakening of westerlies, a warming in the SPG and a reduction of deep-water formation yielding to a slackening of the AMOC.

Sanchez-Gomez et al., Clim.Dyn. 2015

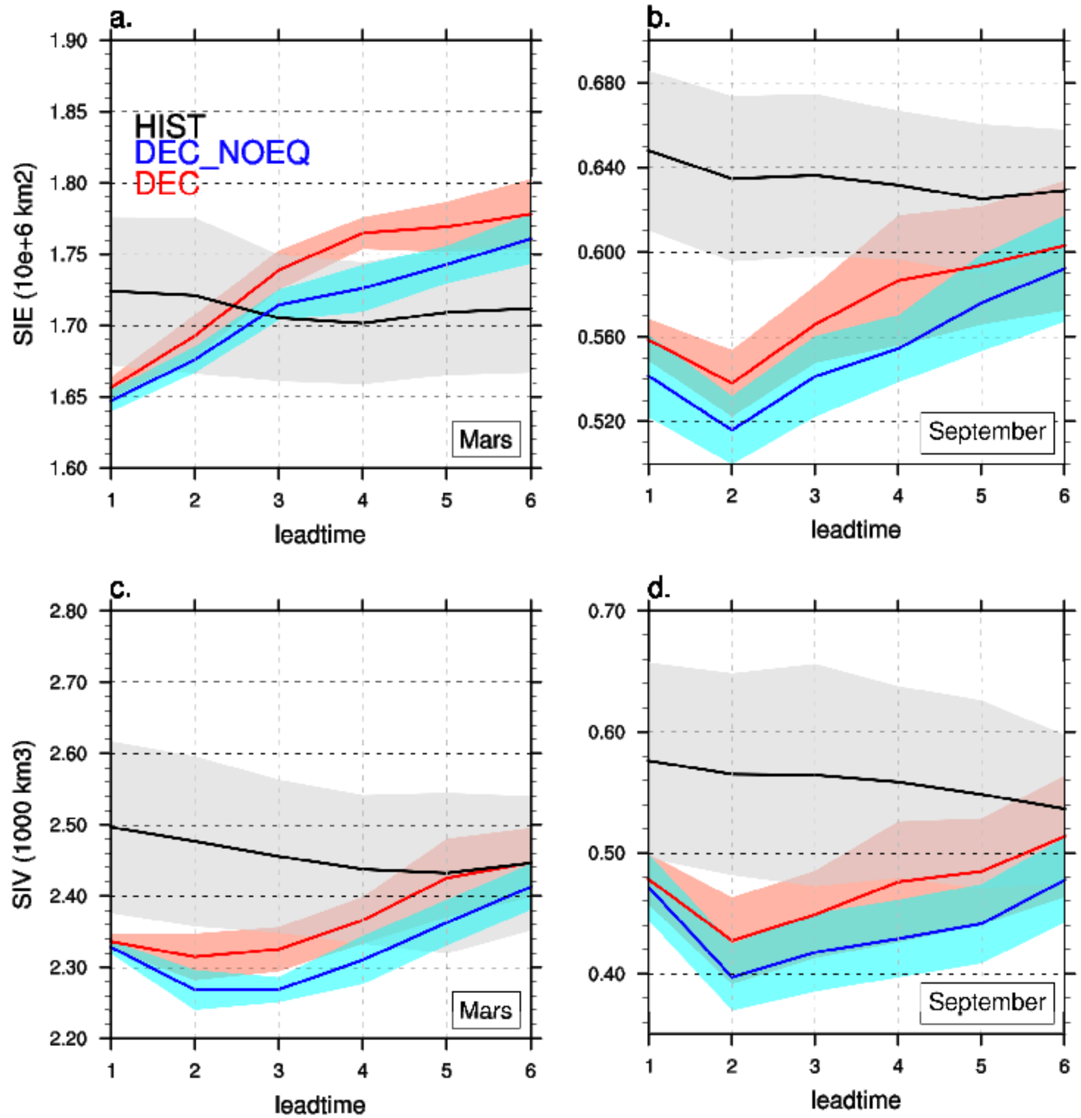
Model drift in the Tropical Pacific



- **Quasi excitation of El Niño events at Y1.** La Niña event occurs at Y2. The spurious oscillatory behavior is progressively damped until Y4.
- **This mechanism is much more pronounced in DEC_NOEQ**

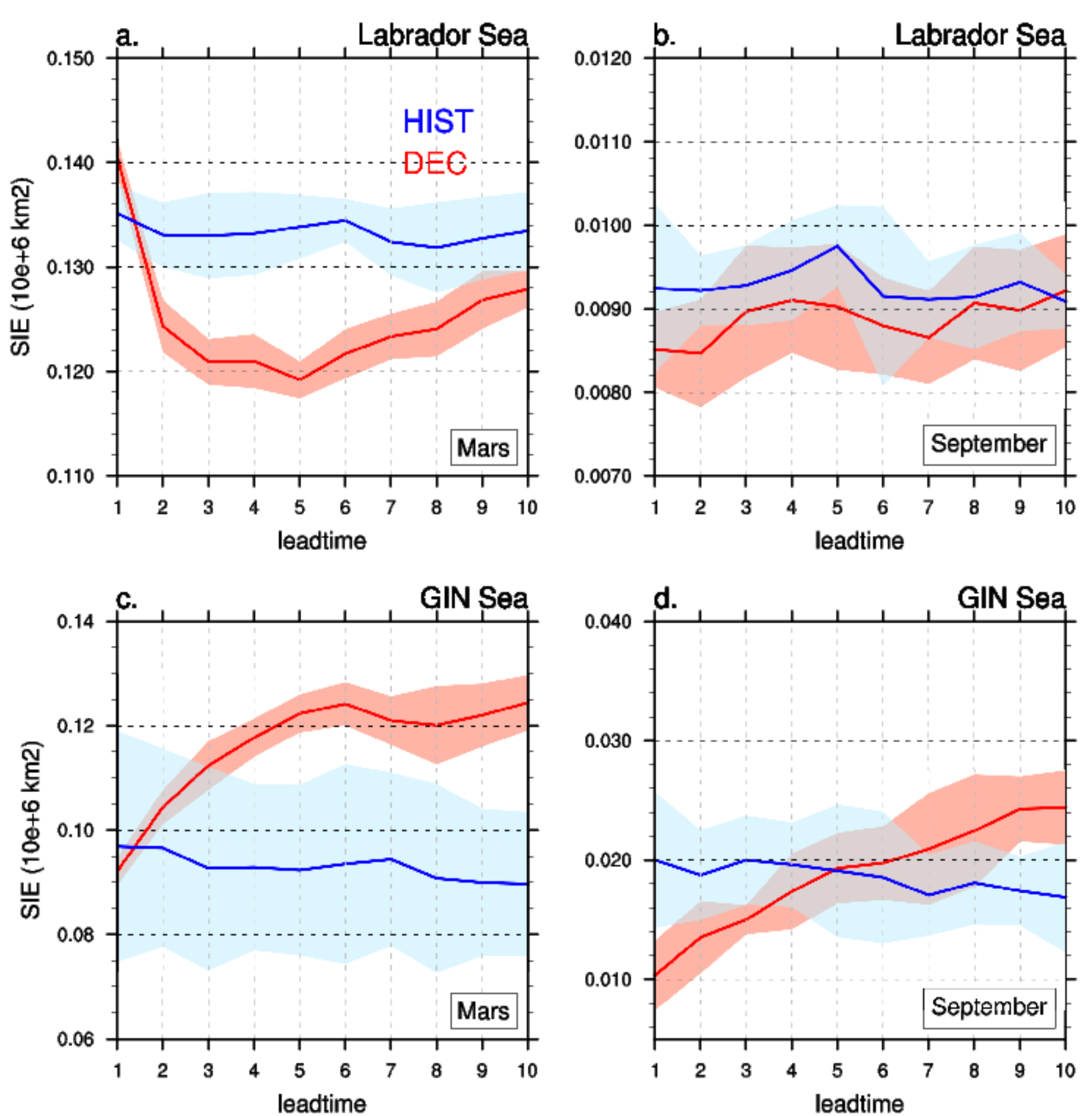
Model drift in Arctic Sea Ice

Drift averaged over the whole Arctic domain: Comparison between DEC and DEC_NOEQ



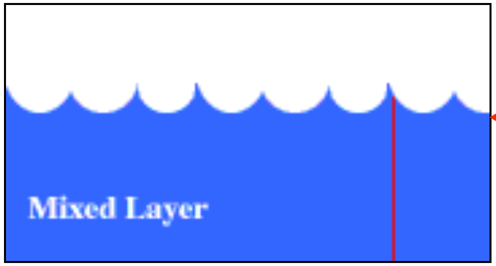
Model drift in Arctic Sea Ice

Drift averaged over the Labrador Sea area (top) and GIN seas area (botton). Only for DEC and for th Sea ice extent.



Initialisation method

Sea surface restoring



Sea Surface restoring

Heat flux:

$$Q_{ns} = Q_{ns}^{o} + \frac{dQ}{dT}(T_{k=1} - SST_{NEMOVAR})$$

Heat flux at the surface

feedback term

$\frac{dQ}{dT}$ *Feedback coefficient = -40W/m2/K*

Fresh water flux:

$$EMP = EMP_o + \gamma^{-1} e_{3t} \frac{(S_{k=1} - SSS_{NEMOVAR})}{S_{k=1}}$$

Fresh water budget at the surface

feedback term

γ_s *Feedback parameter = -167 mm/day*

Initialisation method

3D Newtonian damping

β = f(depth, space)

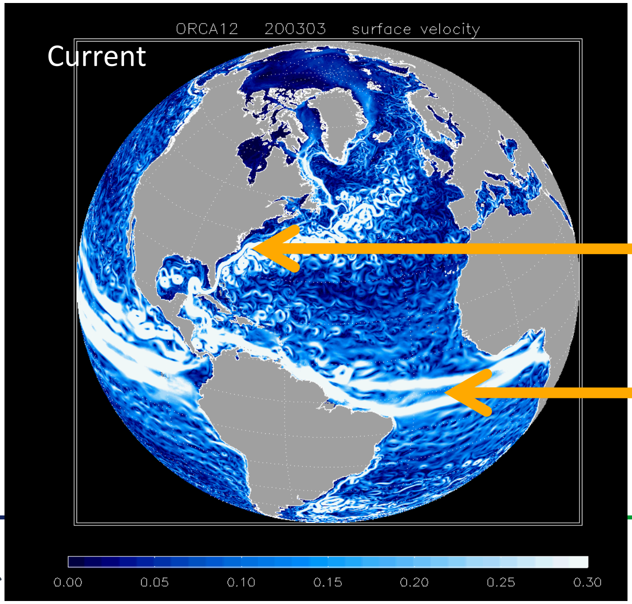
$$\frac{\partial T}{\partial t} = \cdots - \frac{1}{\beta}(T - T_{NEMOVAR})$$
$$\frac{\partial S}{\partial t} = \cdots - \frac{1}{\beta}(S - S_{NEMOVAR})$$

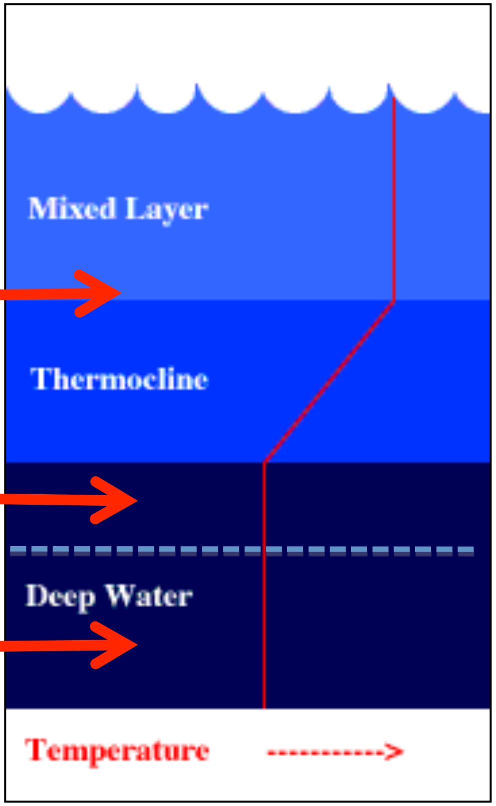
In the thermocline
(1/ β) =0

Below thermocline
β = 10 days

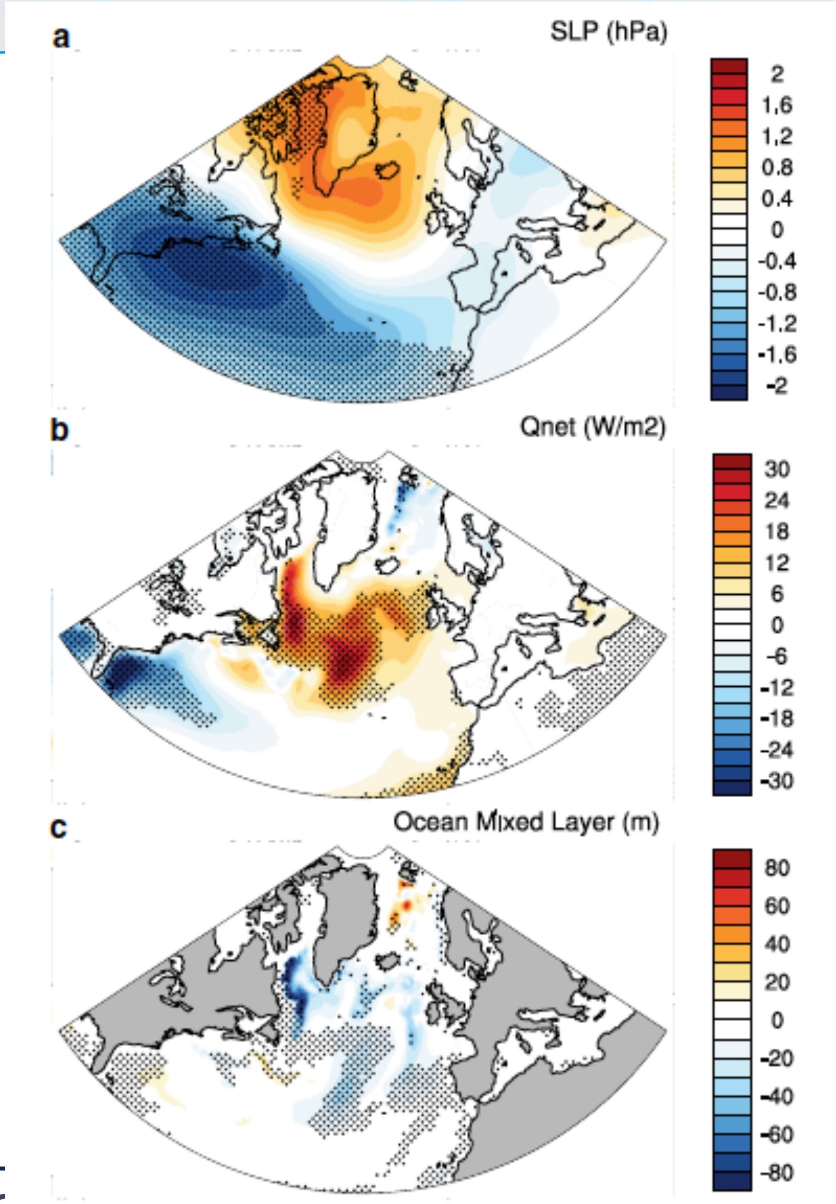
Deep Ocean
β = 360 days

No nudging within the Equatorial band (1°N-1°S) and Near the coast (300km)
(1/ β) =0

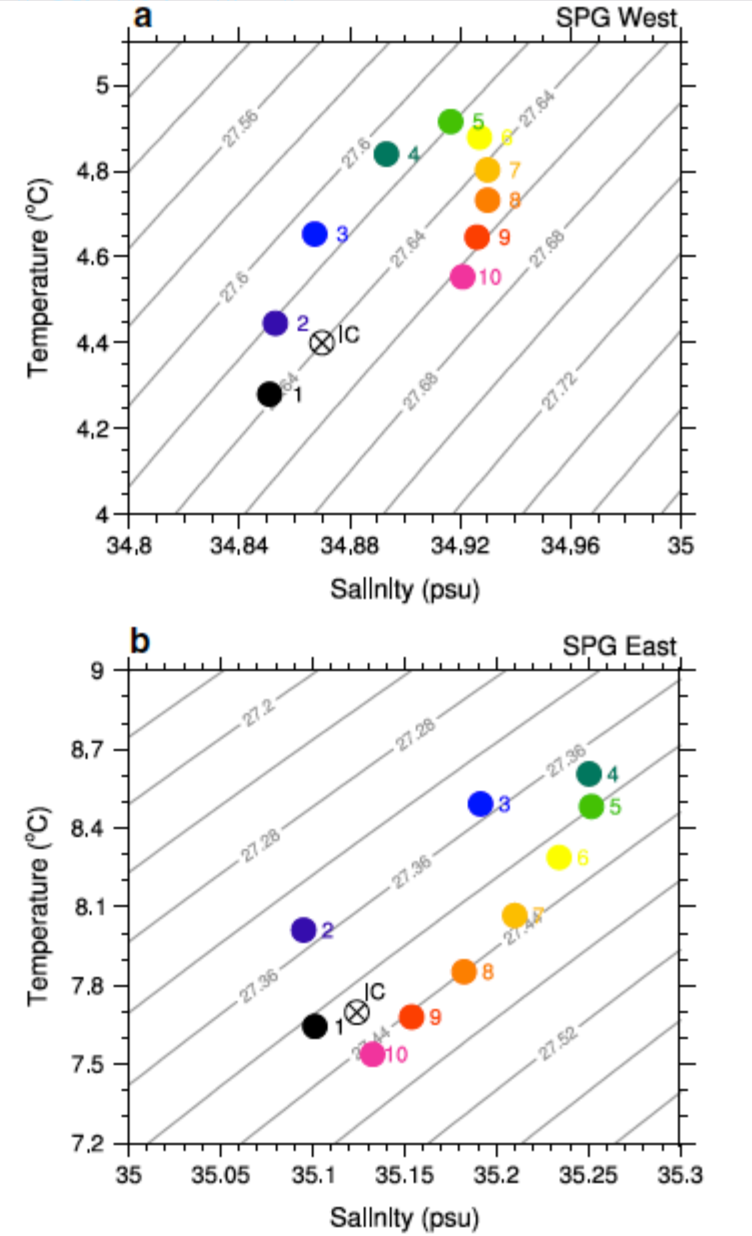




North Atlantic Y2 JFM



Model drift in the North Atlantic



TS diagrams for the first 700 meters