Mechanisms of AMOC response to changes in surface buoyancy forcing under global warming in the IPSL-CM4 model

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Background

- IPCC 2001 : None of the GCM model includes melting of land-ice (Greenland, Antarctic and mountain glaciers)

- Fichefet et al. (2003), Swingedouw et al. (2006) melting of Greenland could be an important term for the AMOC response to global warming

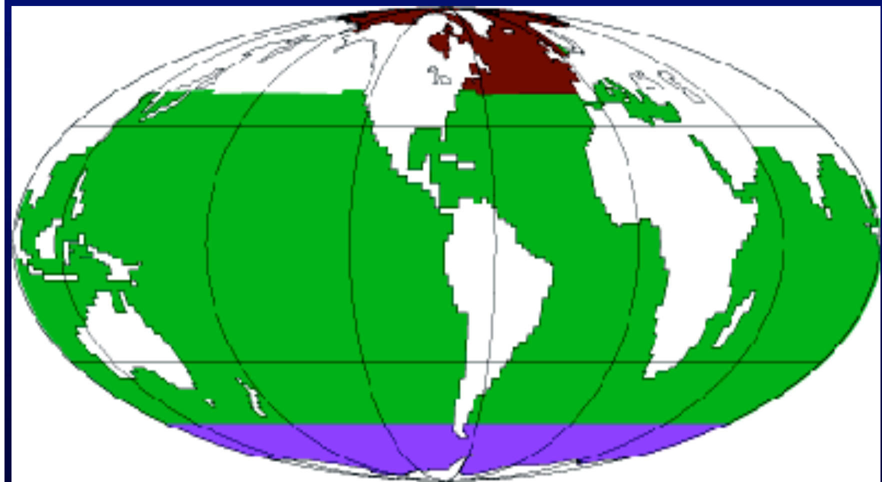
Aim of this work

- Estimate the impact of land ice melting on 500 years time scale
- Analyze the mechanisms of the response of the AMOC to global warming

Tool: IPSL-CM4 coupled GCM
Paris, France

IPSL-CM4:
- Ocean ORCA2: 2°*(0.5-2°) resolution
- Sea-ice LIM: dynamic-thermodynamic
- Atmosphere LMDz: 3.75° resolution
- Land model ORCHIDEE with a correct river routing scheme

Closure of the water budget



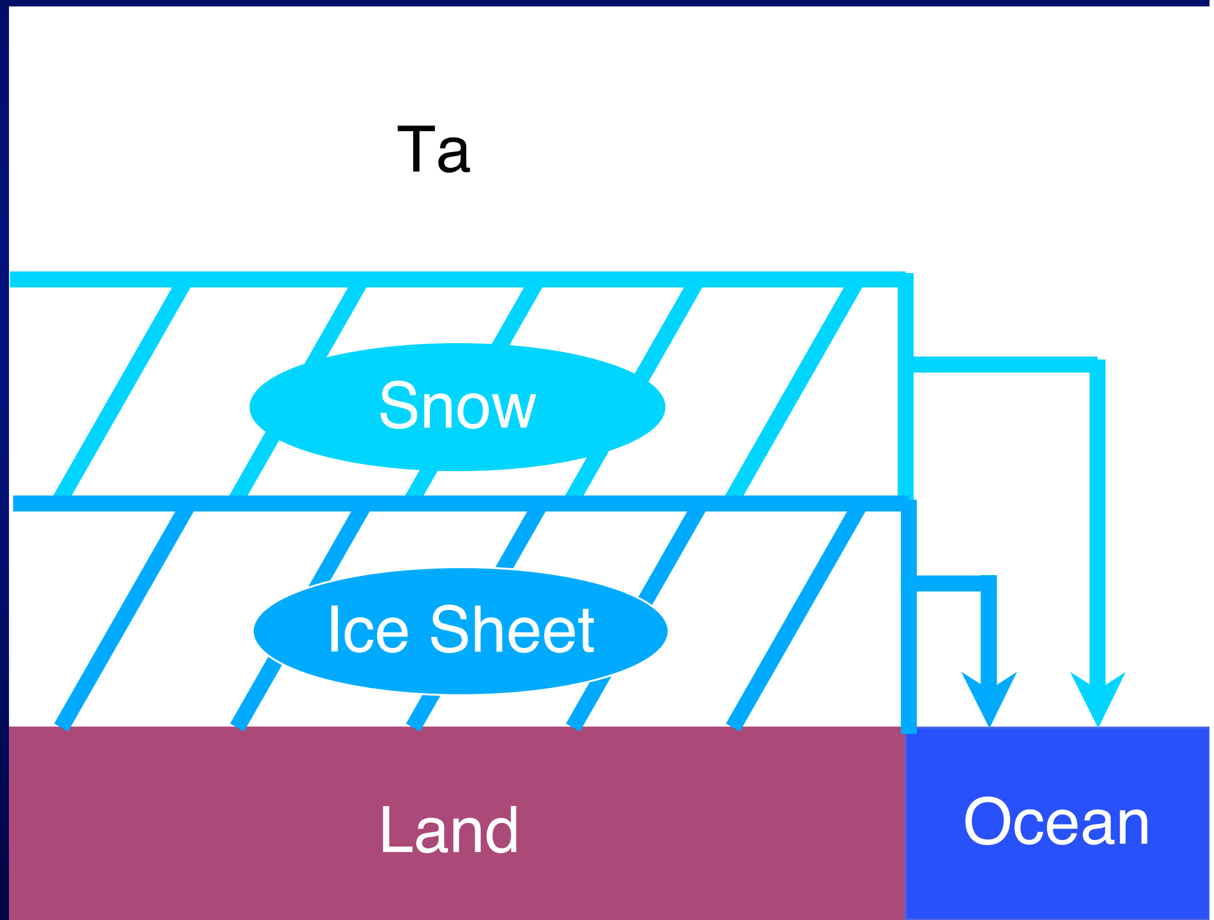
- The land-snow melted can go back to the ocean through runoff
- A crude parametrization of iceberg dynamics is implemented
- The land-ice could also melt in order to simulate glacier melting.

Different regions for the calving

Experimental design (1/2)

Two versions of the IPSL-CM4 model:

- With Glacier melting

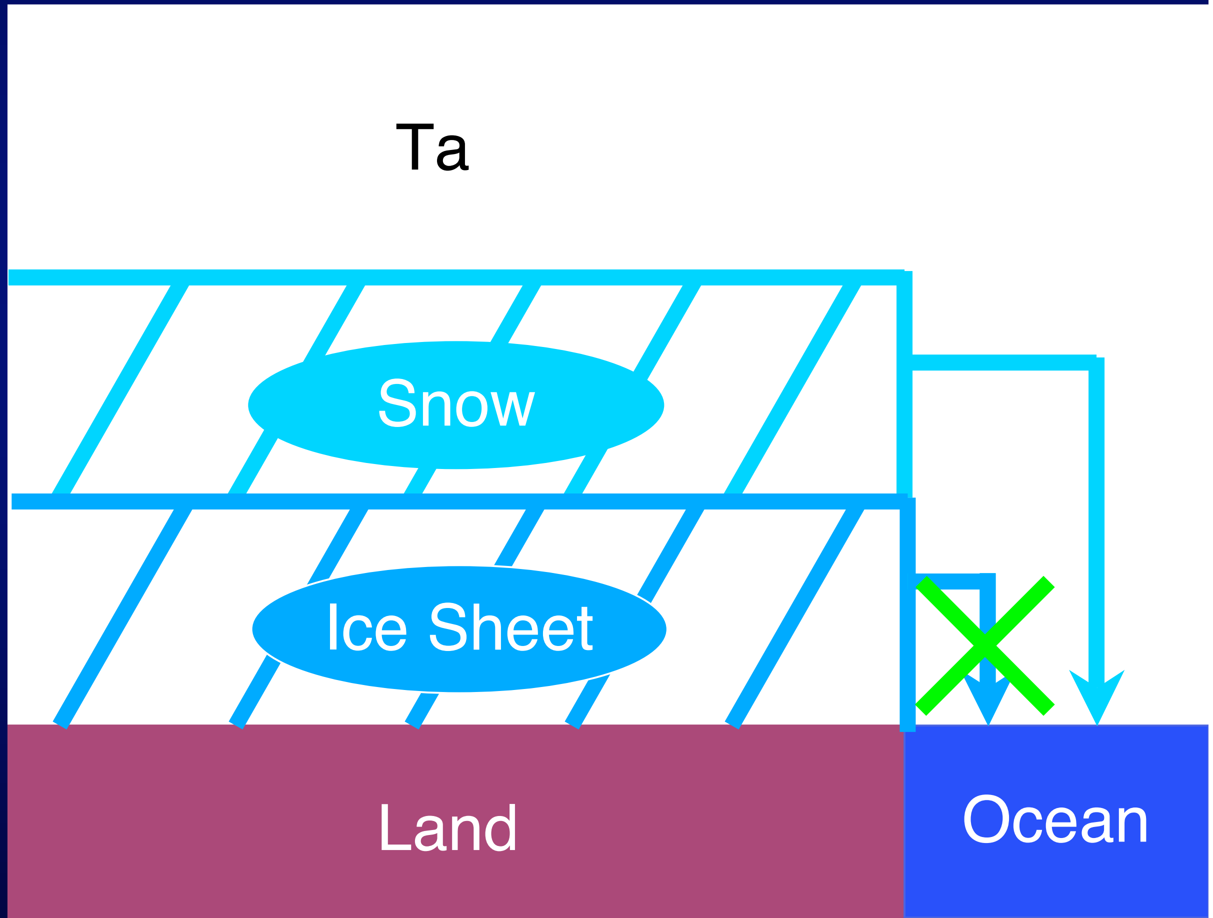


Experimental design (1/2)

Two versions of the IPSL-CM4 model:

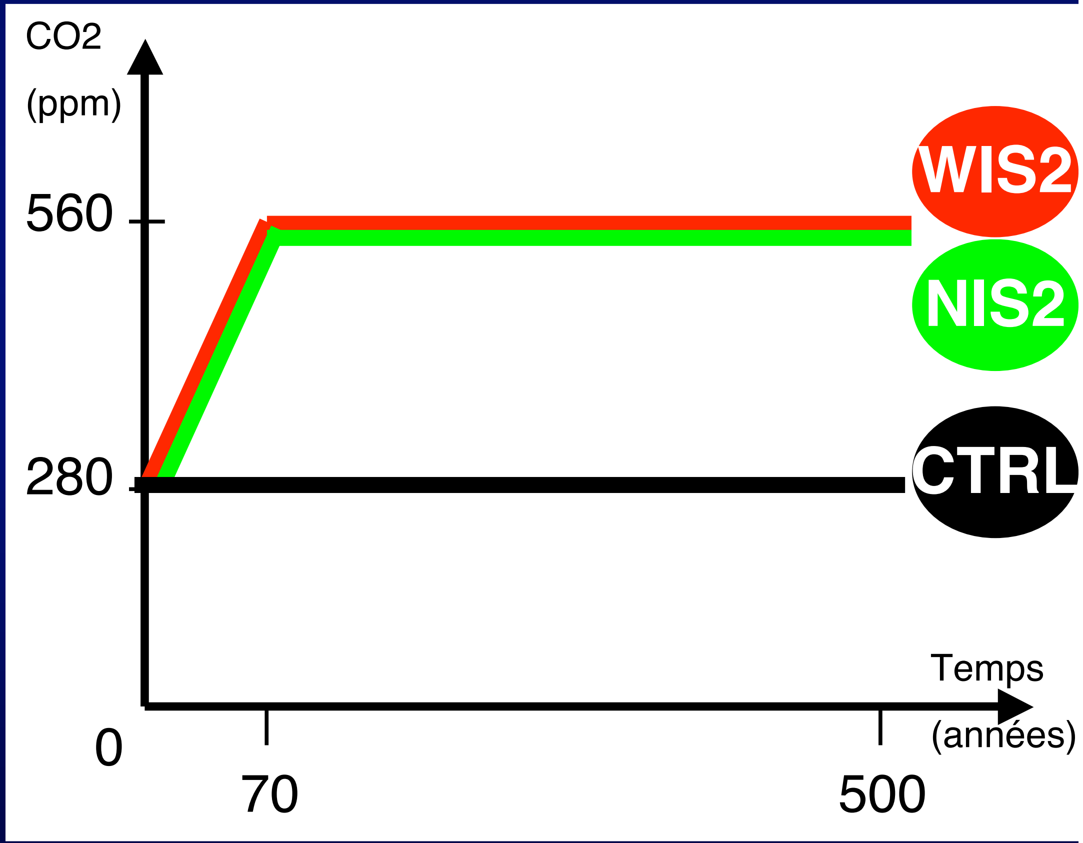
1) With Glacier melting

2) Without Glacier melting



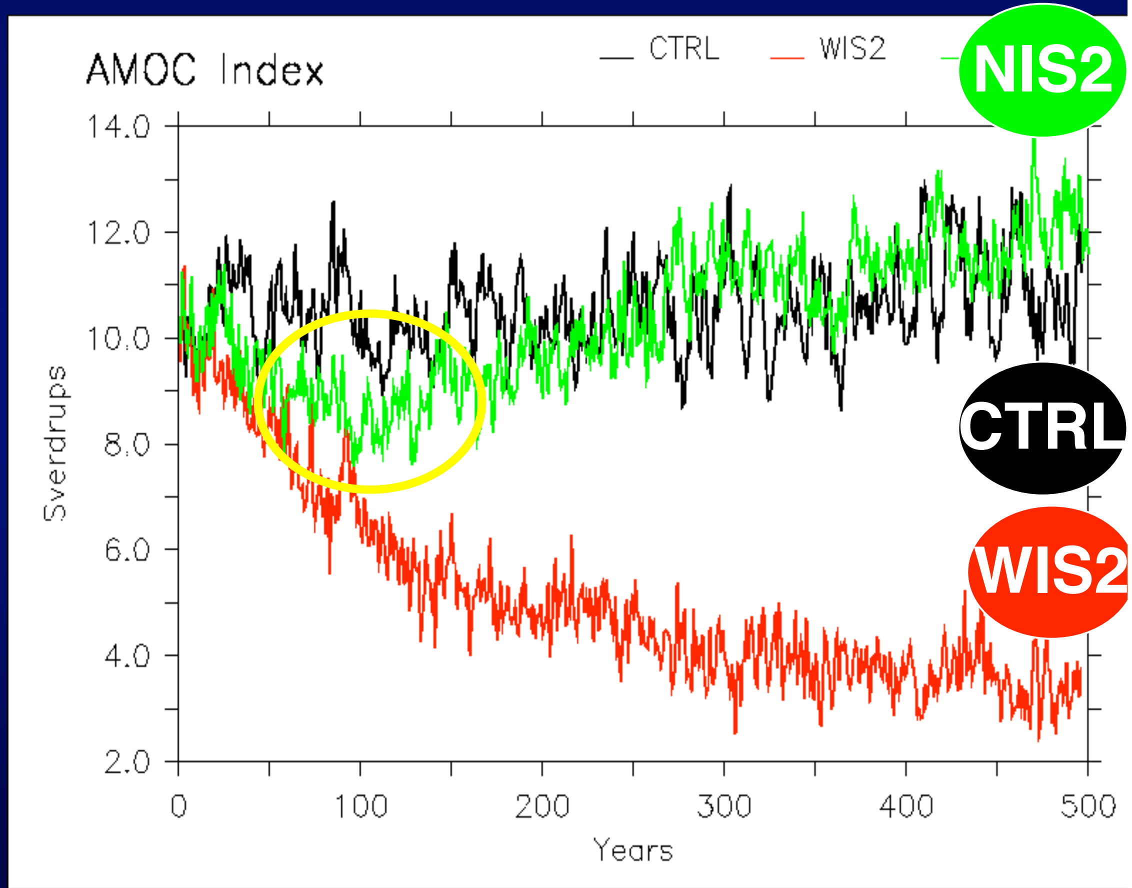
Protocole experimental (2/2)

- CMIP Scenarios: atmospheric CO2 concentration is increased by 1%/yr until doubling CO2 in 70 years
- It is stabilised at 2xCO2 for 430 years



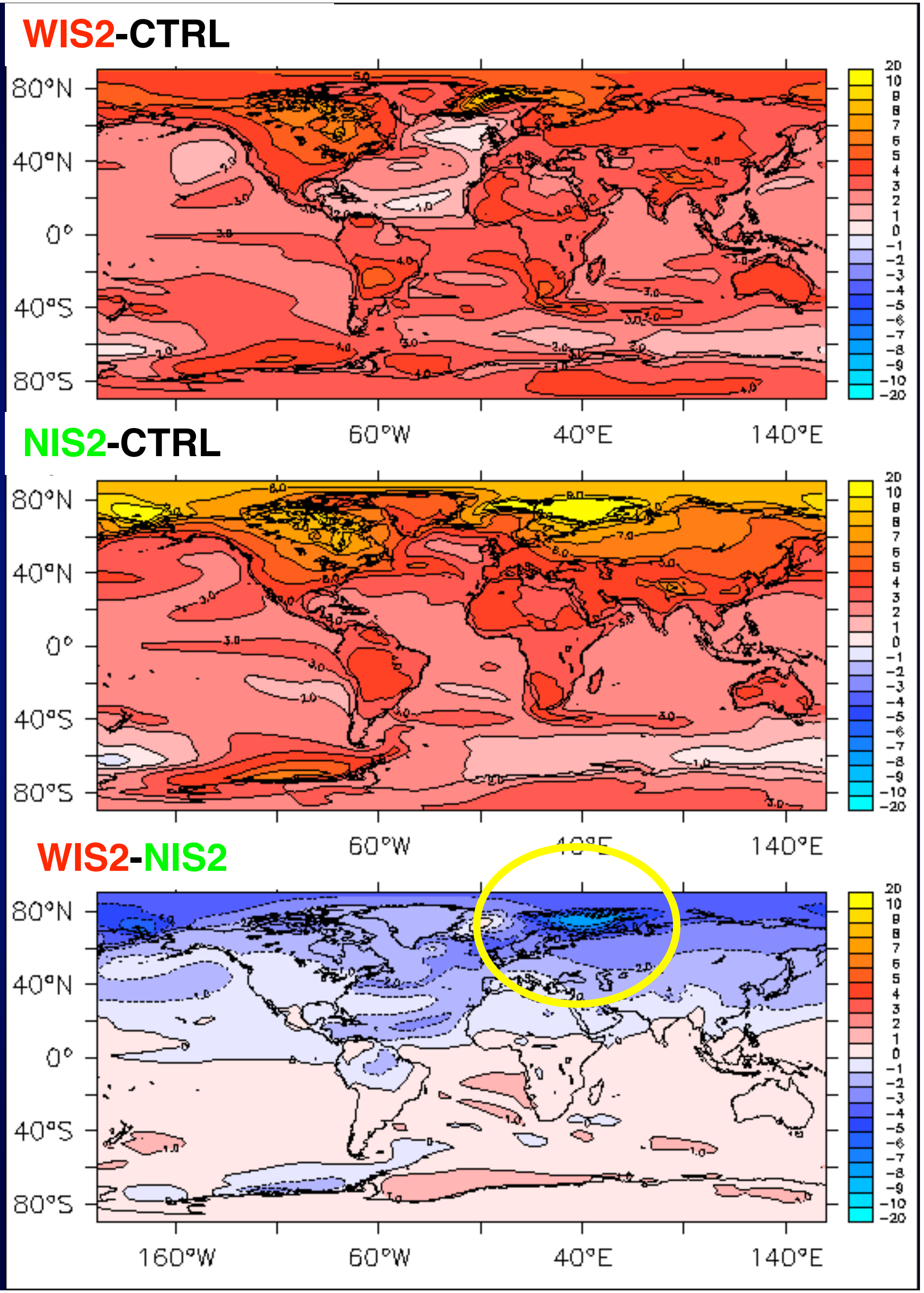
AMOC response

- Important effect of greenland melting on the AMOC
- About 0.15 Sv difference in freshwater forcing in the North Atlantic



Surface temperature response

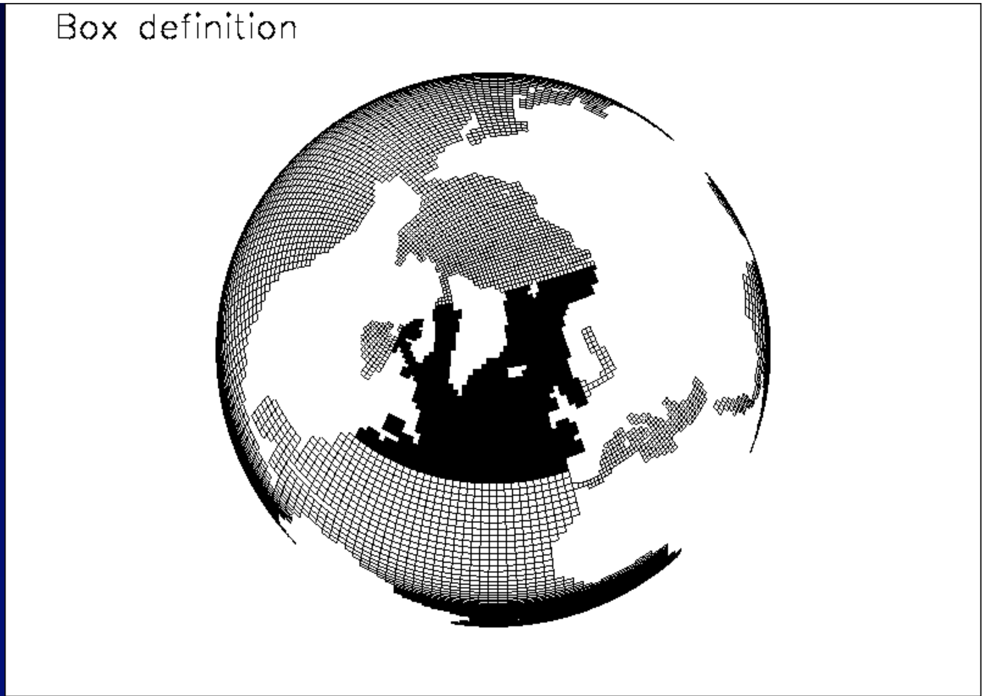
- Most warming in high latitude
- AMOC impact = sea-ice melting => Temperature difference

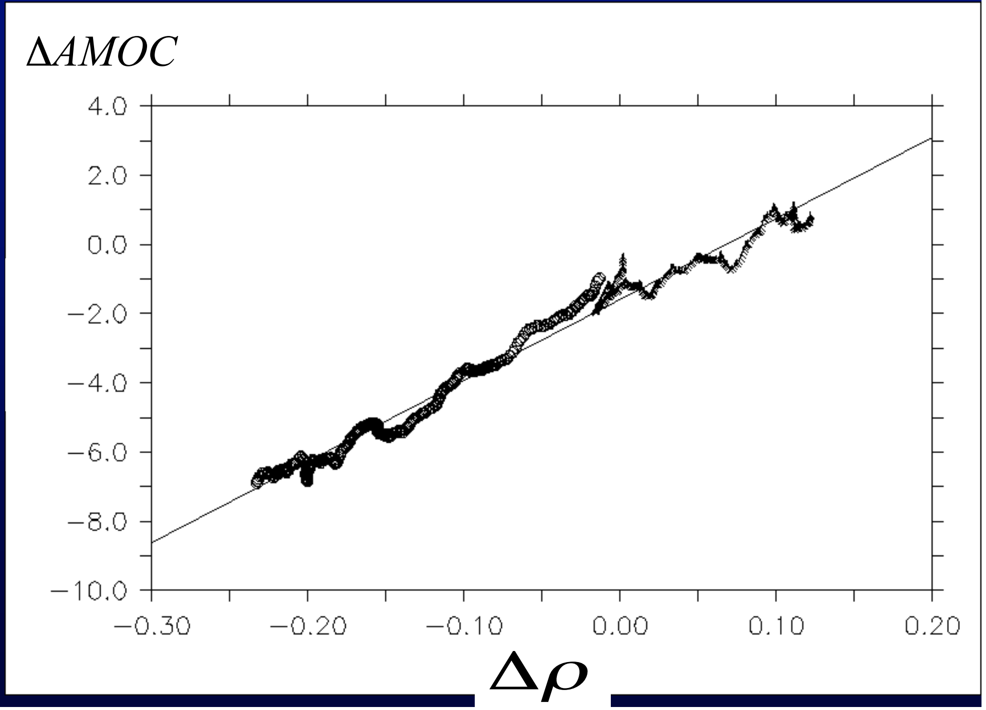


AMOC et sites de convection

Correlation of 0.98 between density anomaly in the convection sites and AMOC anomaly :

$$\Delta AMOC = \gamma \Delta\rho$$





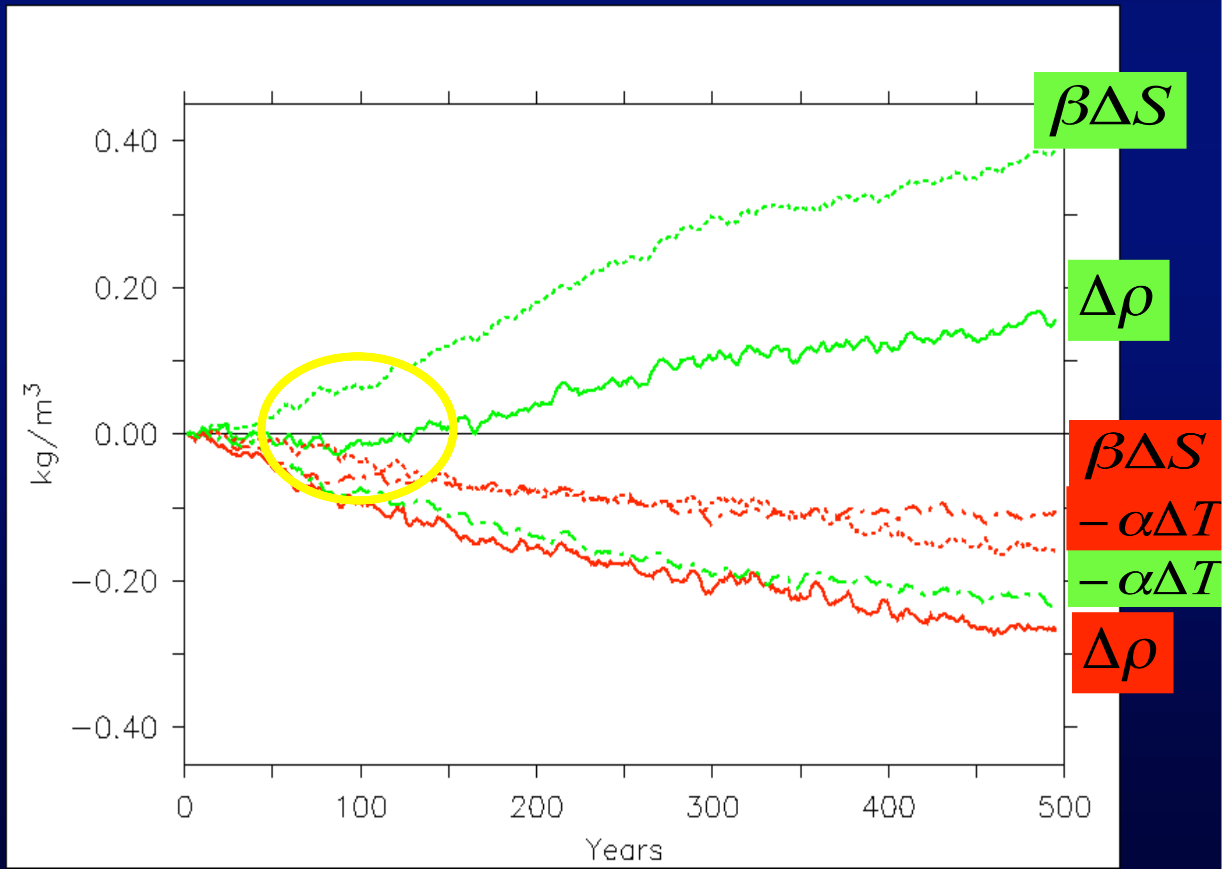
Thermal and haline influence

$$\Delta\rho \approx \beta\Delta S - \alpha\Delta T$$

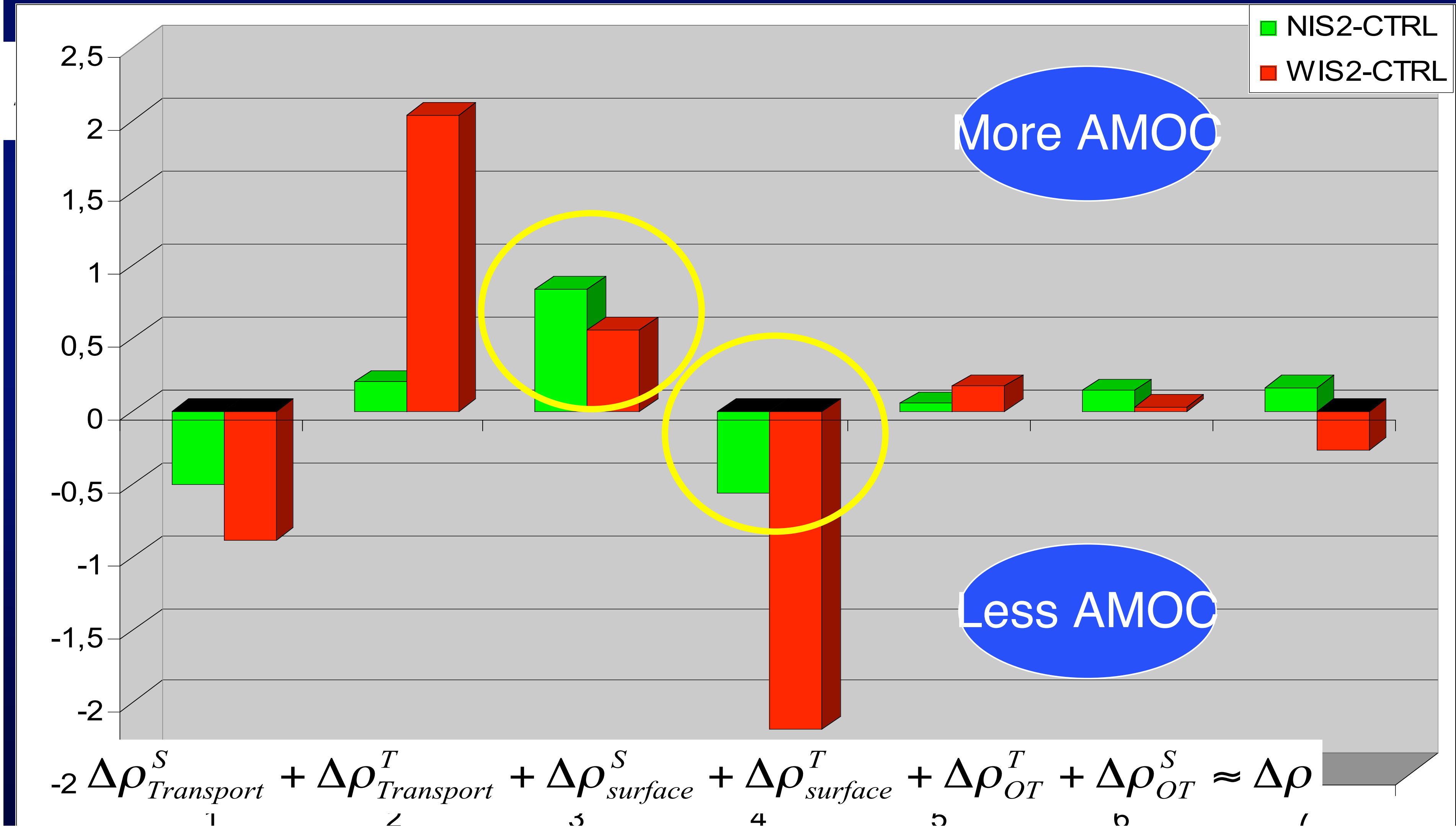
Thermal and haline influence

- NIS2 : temperature (T) diminishes the AMOC, salinity (S) increases it
- WIS2 : T et S increase the AMOC

$$\Delta\rho \approx \beta\Delta S - \alpha\Delta T$$



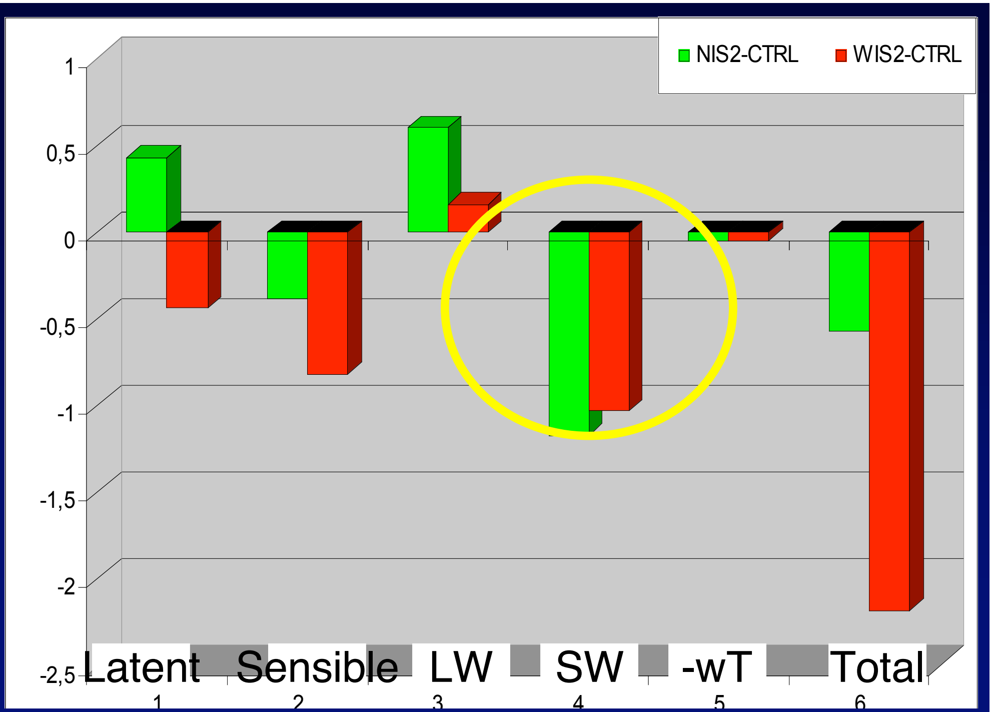
Balance of density forcing



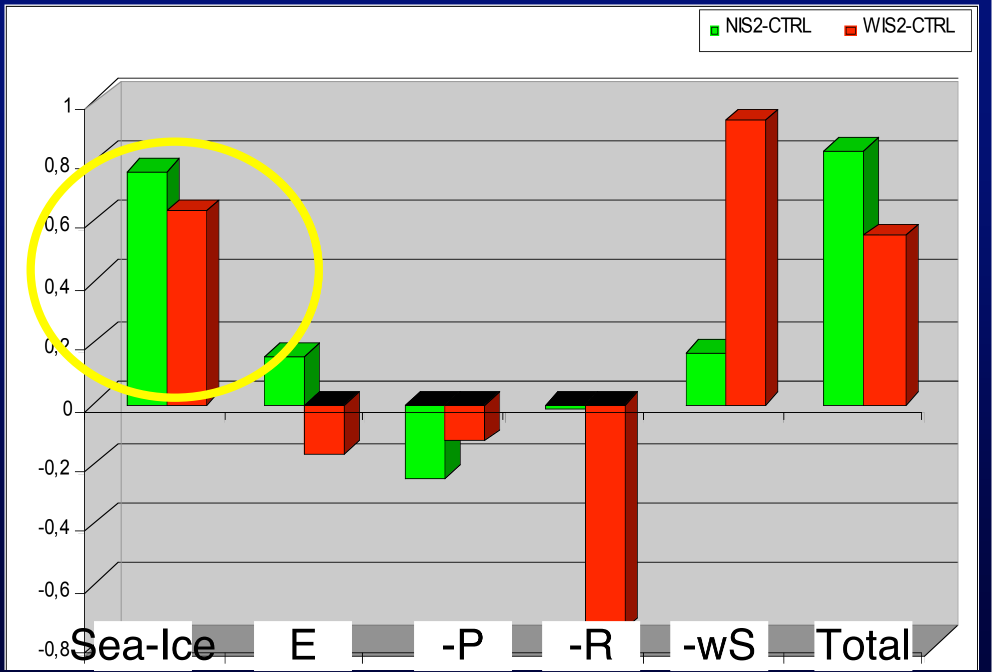
$$\Delta\rho^{S}_{Transport} + \Delta\rho^{T}_{Transport} + \Delta\rho^{S}_{surface} + \Delta\rho^{T}_{surface} + \Delta\rho^{T}_{OT} + \Delta\rho^{S}_{OT} \approx \Delta\rho$$

Surface forcing

- Temperature

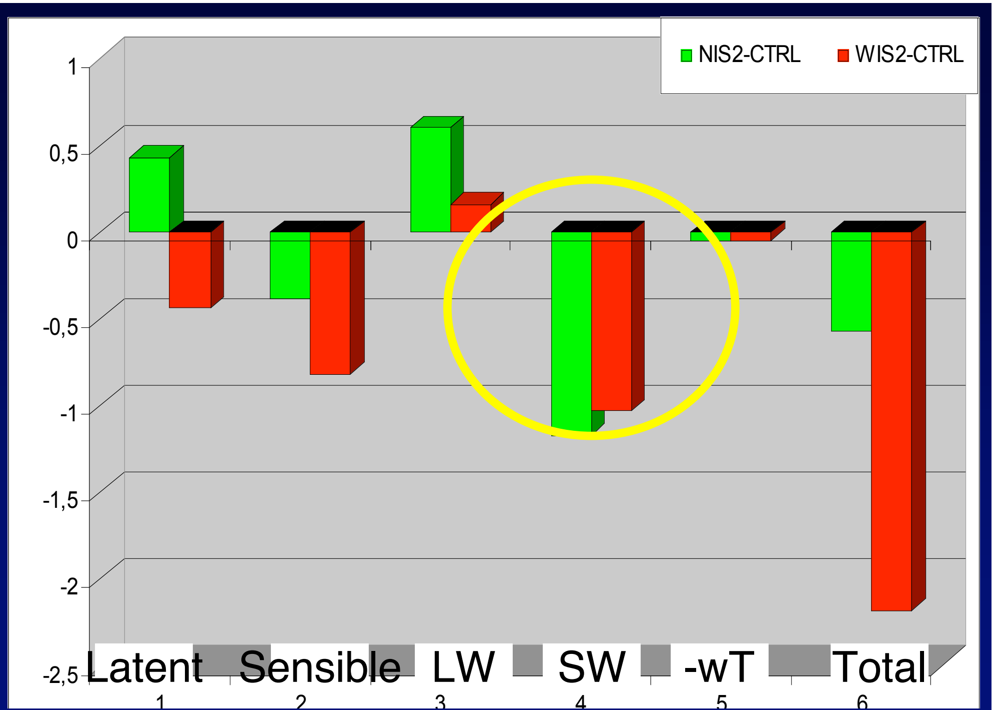


- Salinity

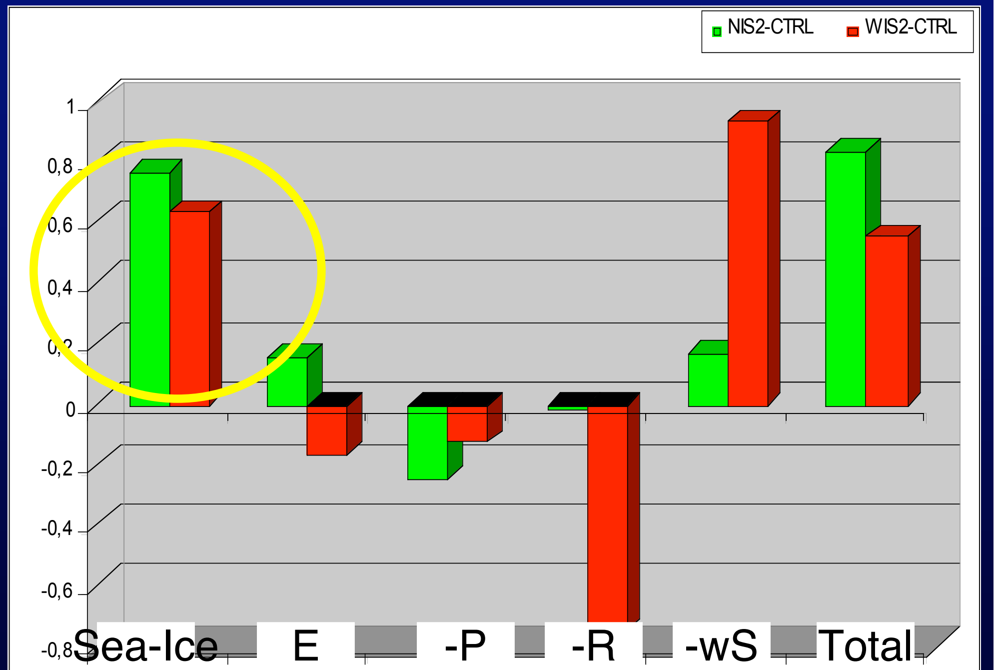


Surface forcing

- Temperature : SW and sensible flux ; principal negative effect

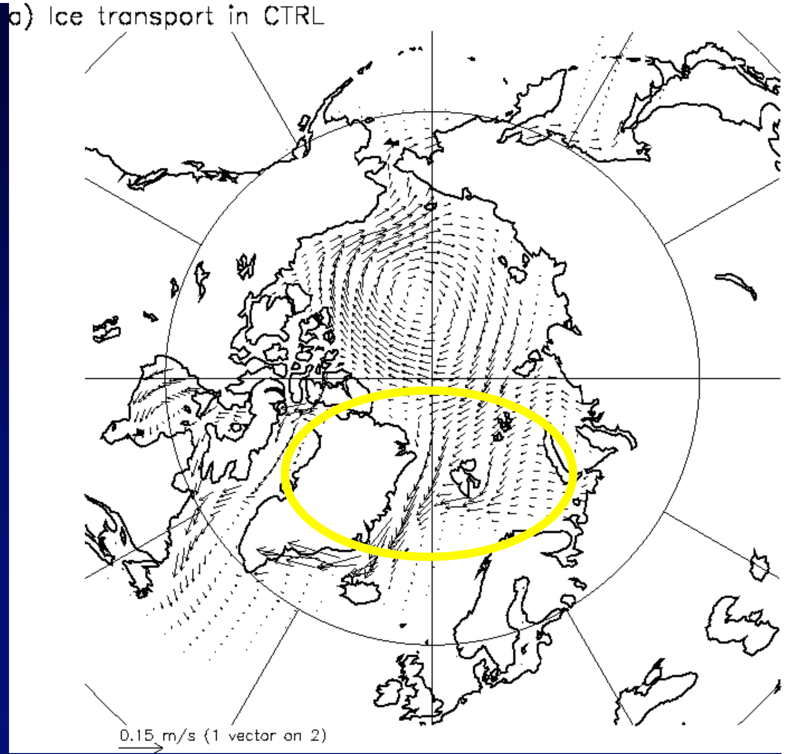


- Salinity : sea-ice freshwater flux, principal positive effect



Change in sea-ice

- Sea-ice transport through Fram Strait



Change in sea-ice

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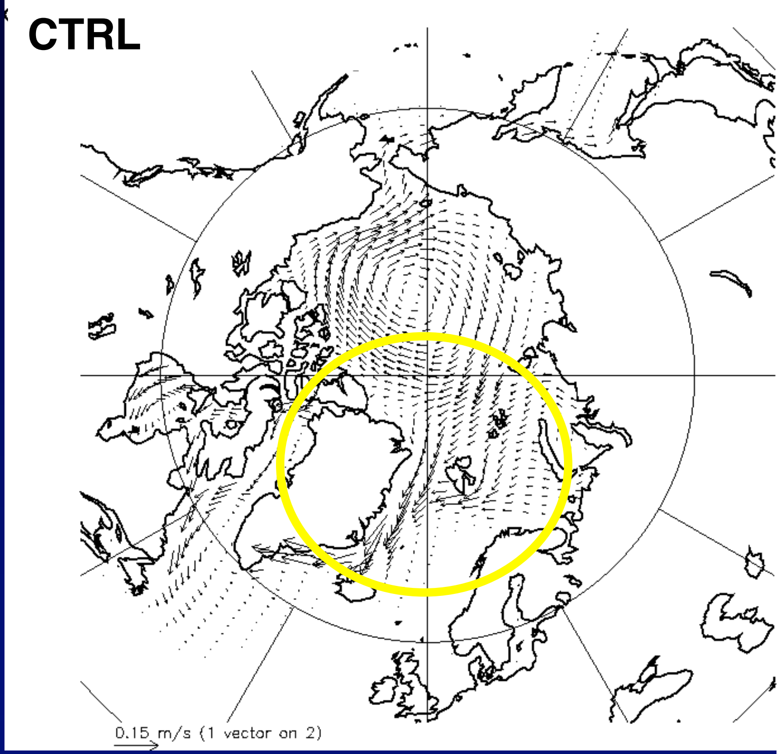
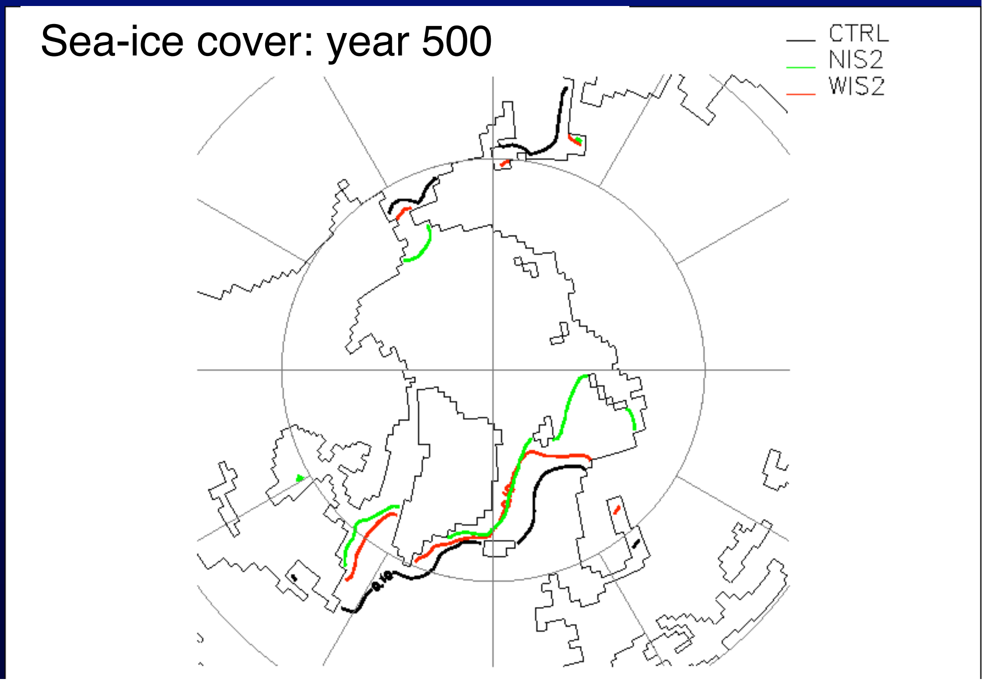


- In scenario, decrease of sea-ice cover



Change in sea-ice freshwater flux

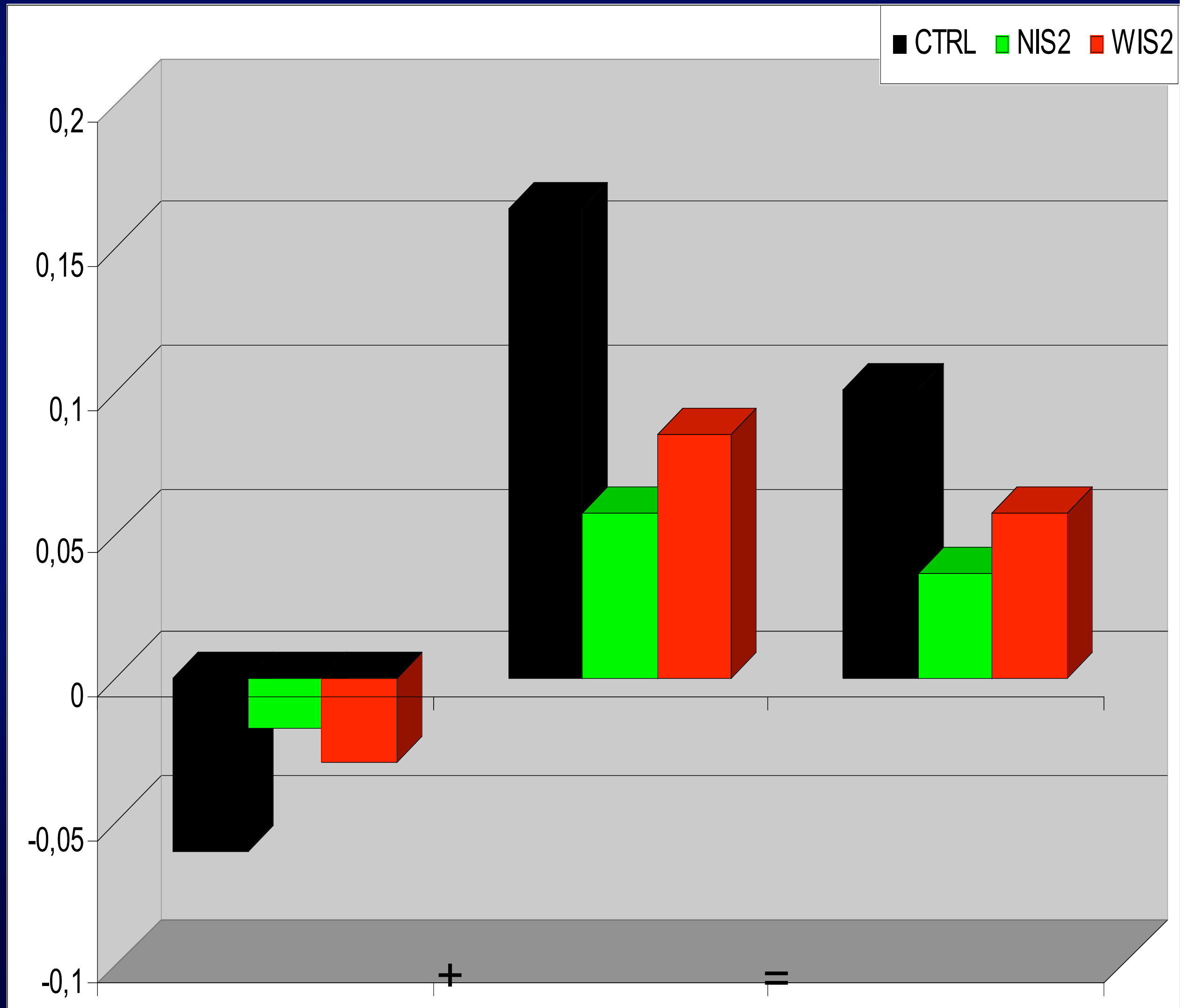
More local melting =

Negative effect

Less sea-ice transport =

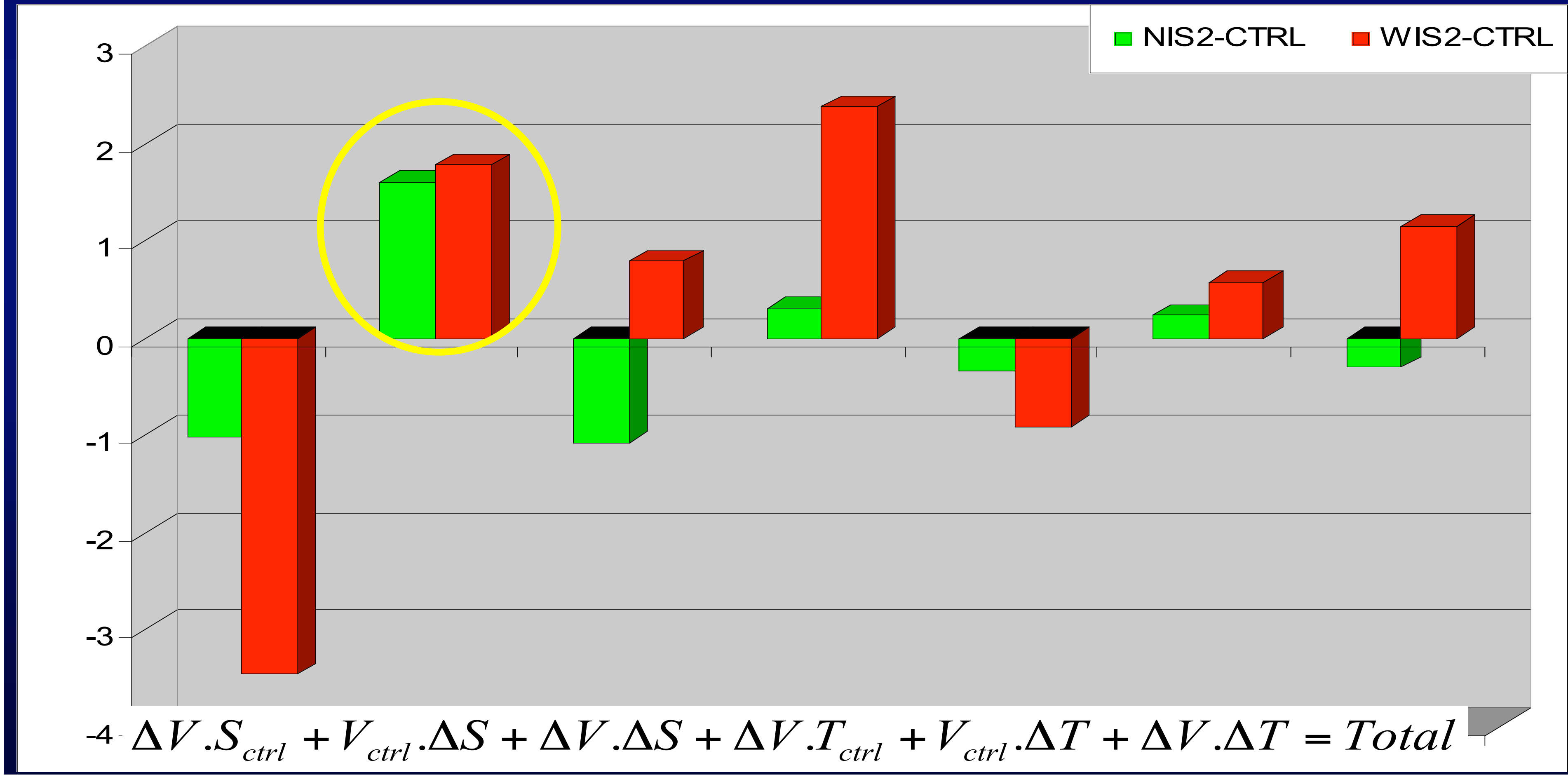
Negative effect

Total : transport change dominates : less melting in the convection sites



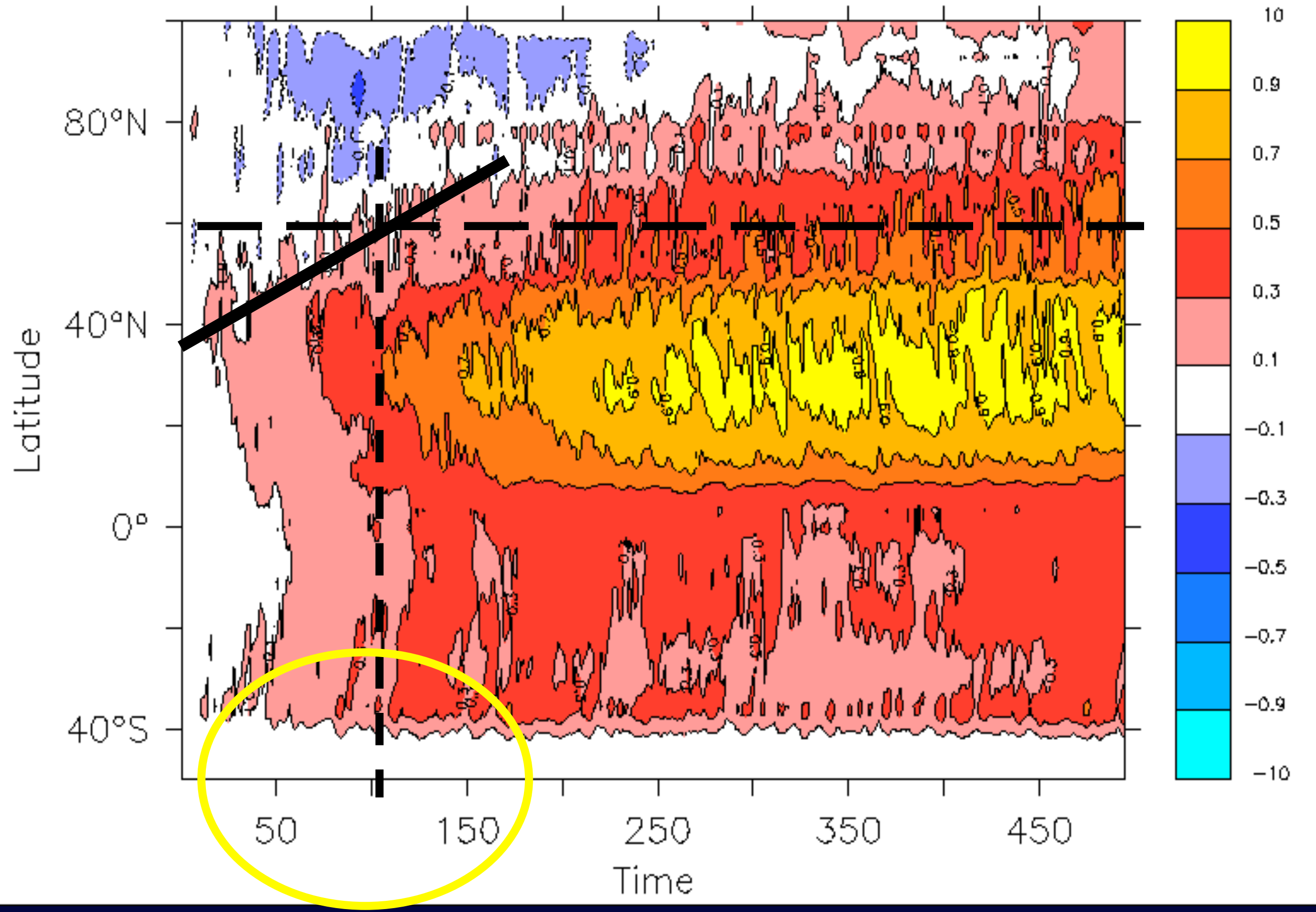
Different component for the transport

$$\Delta(V.\Theta) = V_{ctrl}.\Delta\Theta + \Delta V.\Theta_{ctrl} + \Delta V \Delta\Theta$$



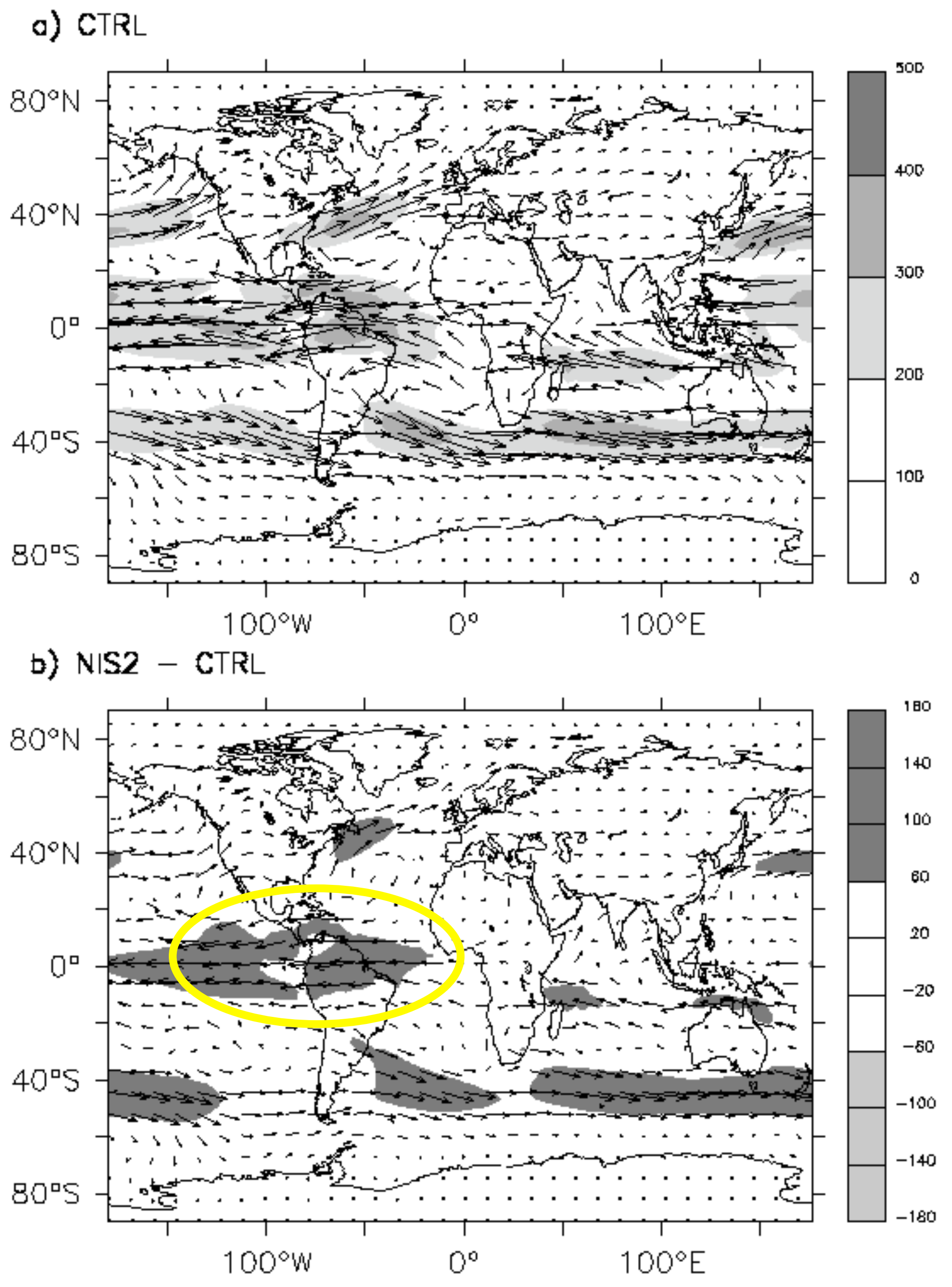
Origin of salinity anomalies

Surface salinity anomalies: NIS2-CTRL



Atlantic freshwater forcing

- Changes in moisture export between Atlantic and Pacific
- Freshwater balance in the Atlantic
  - NIS2 : 0.39 Sv
  - WIS2 = CTRL =0.26 Sv



Conclusions

- Land ice melting influence the long term future of the AMOC in the IPSL-CM4

- In global warming condition, the main decreasing term for the AMOC is the changes in heat flux in the convection sites

- Main processes that help the AMOC to recover:
  - Decrease of sea-ice melting in the convection site;
  - transport of salinity anomalies from the tropics

Thank you

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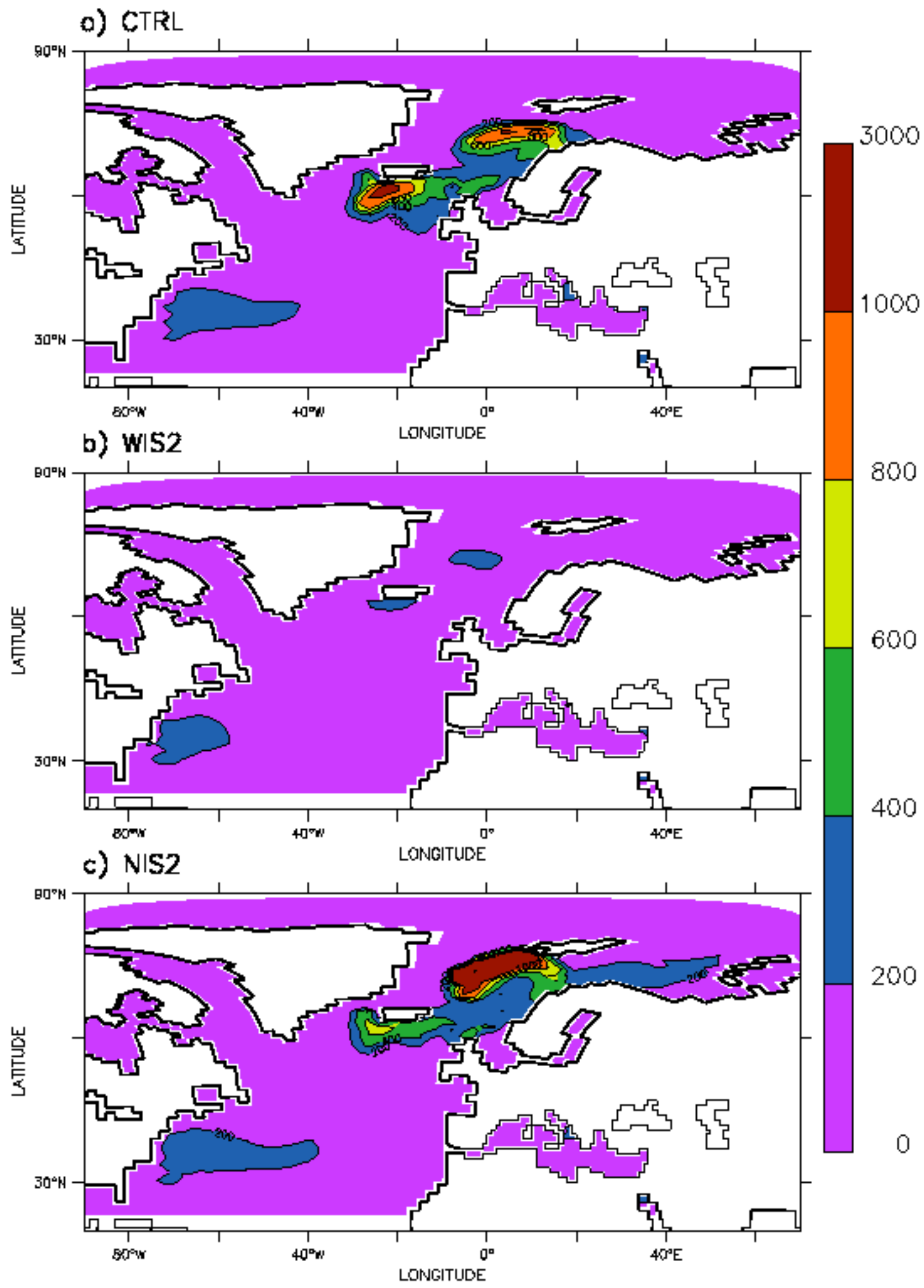
Climato rrapide (Labrador…)

- Land-ice melting leads to important AMOC weakening in the IPSL-CM4, and thus needs to be taken into account in coupled model

Réponse des sites de convection

- Pas de convection en labrador dans CTRL
- Arret convection dans WIS2
- Renforcement convection dans GIN, affaiblissement dans Irminger pour NIS2



Rétroaction (?)

- Equations

- Résultats : amortissement par flux de surface = feedback + très fort !!!