Respective roles of direct GHG radiative forcing and induced Arctic sea ice loss on the Northern Hemisphere atmospheric circulation

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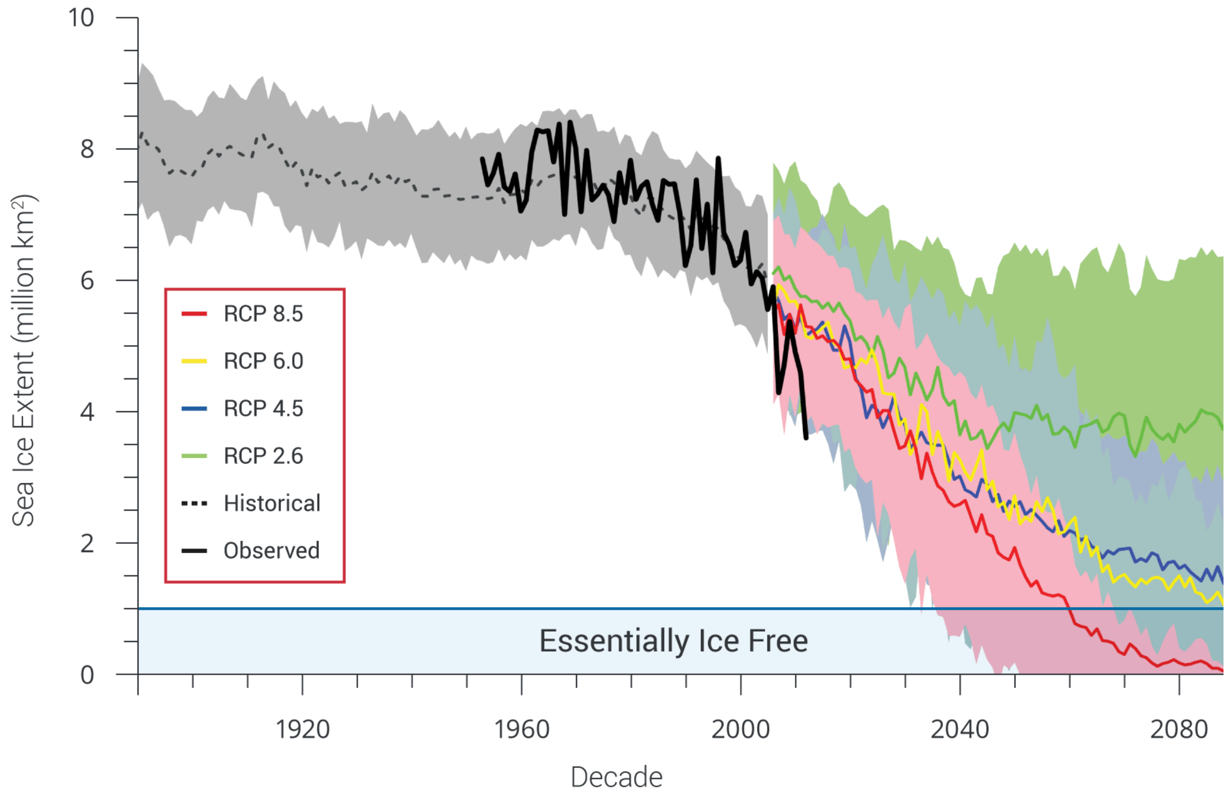
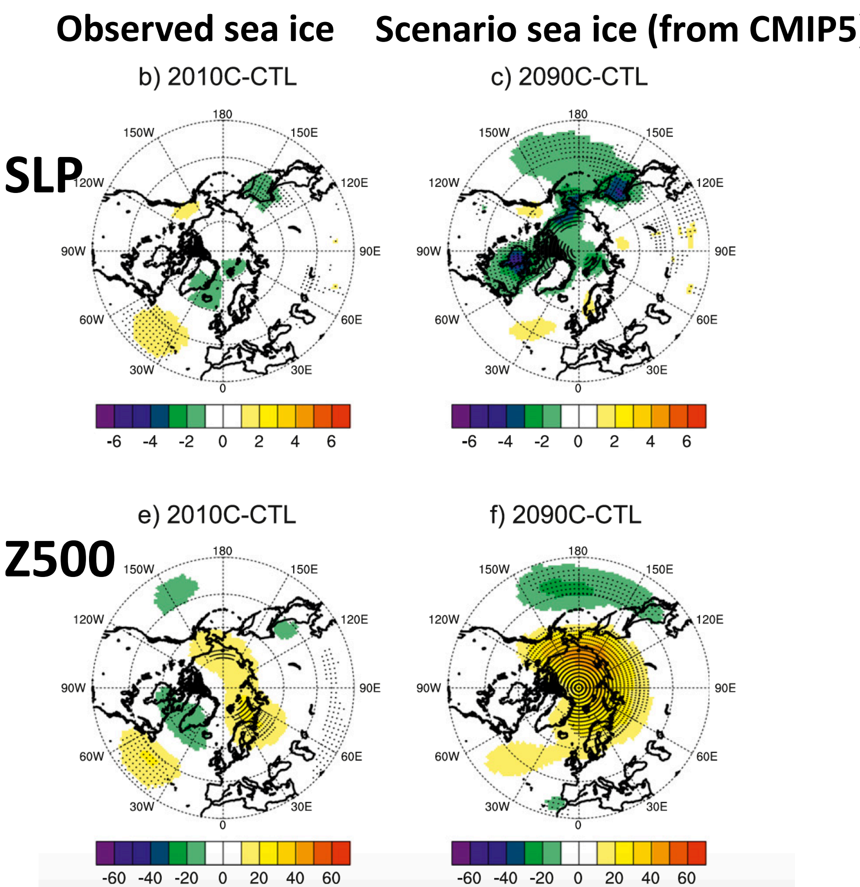
Introduction



Arctic sea ice is projected to disappear in summer by mid-to-late 21st century in response to anthropogenically driven increase in GHGs (*Stroeve et al. 2012; Stocker et al. 2013*)

Numerical approaches to characterised the forced response



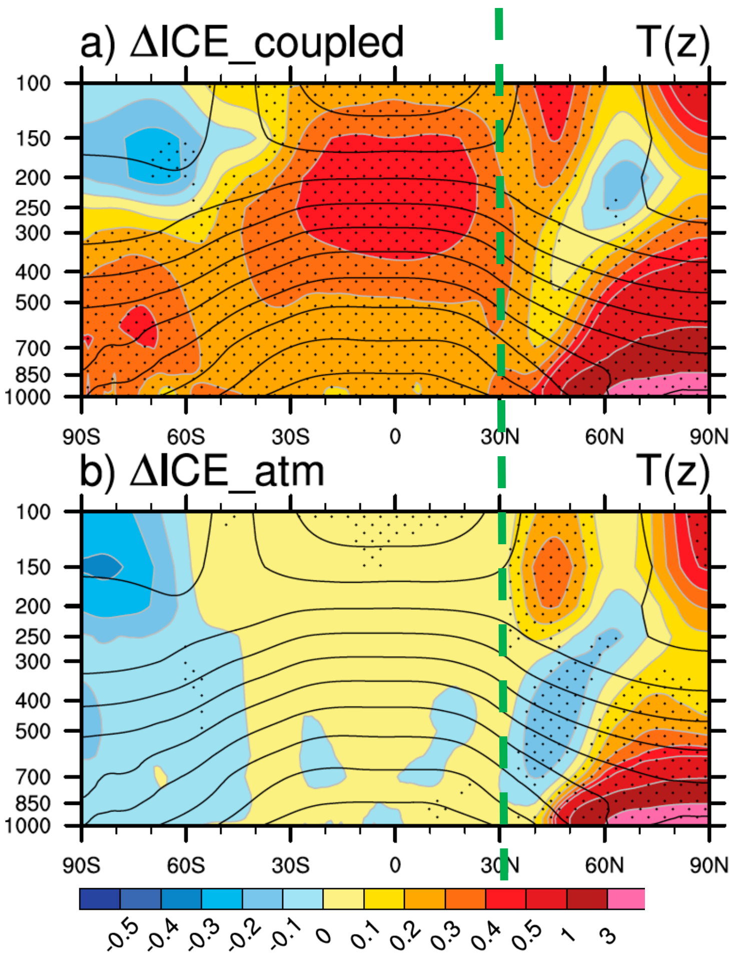
Peings and Magnusdottir 2014

Atmospheric forced by SST idealized patterns

- **No signal over the North Atlantic for future sea ice conditions**
- **Baroclinic response over the Arctic**

Numerical approaches to characterised the forced response

Future– Present condition



Deser et al 2015

Impact of Artic sea ice loss on zonal T(z) from an **idealized coupled versus atmospheric forced** experiment

In the absence of coupling, the atmospheric response is confined to north of 30ºN

Arctic sea ice impacts

Artic sea ice decrease is associated with:

- **Local impacts :** warming and moistening of polar latitudes, changes in ocean-atmosphere heat fluxes

- **Midlatitude atmospheric impacts:**

More or less robust: weakening of the zonal-mean westerlies at mid-latitudes (negative phase of the NAM/AO)

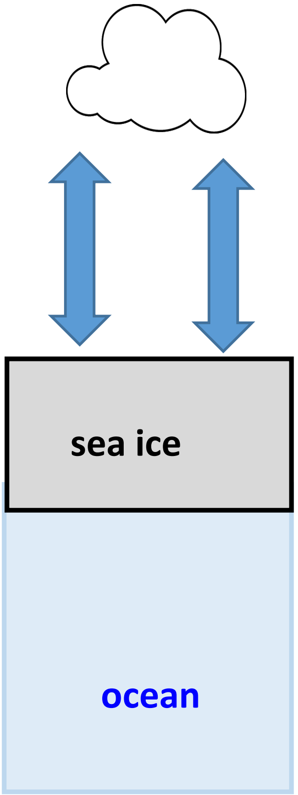
- **Less clear:** extreme events, blockings, jet stream changes, storm-tracks

- **Other remote impacts :**
  - Ocean circulation ? Tropics ?

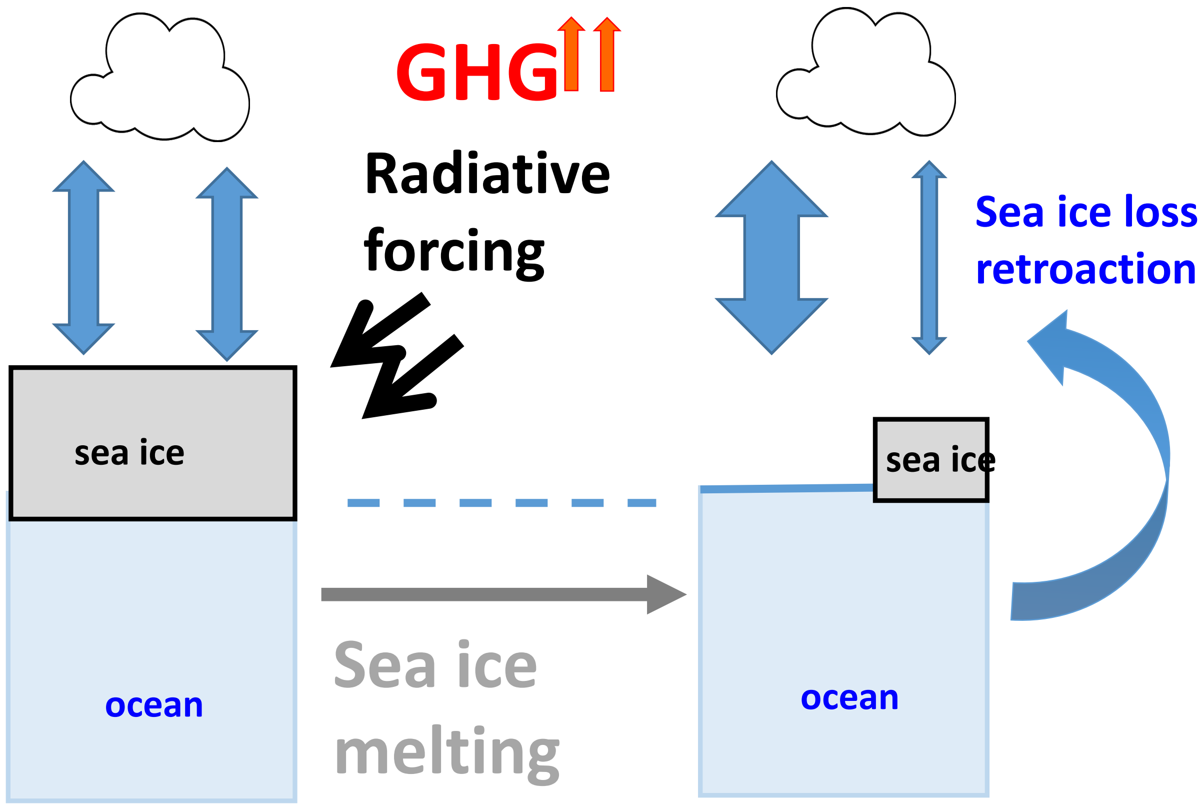
Objectives

- Study the atmospheric response to Arctic sea ice decline, isolating it from the effect of increasing GHG
- Coupled Model CNRM-CM5
- Idealized experimental protocol based on *Deser et al. 2015*

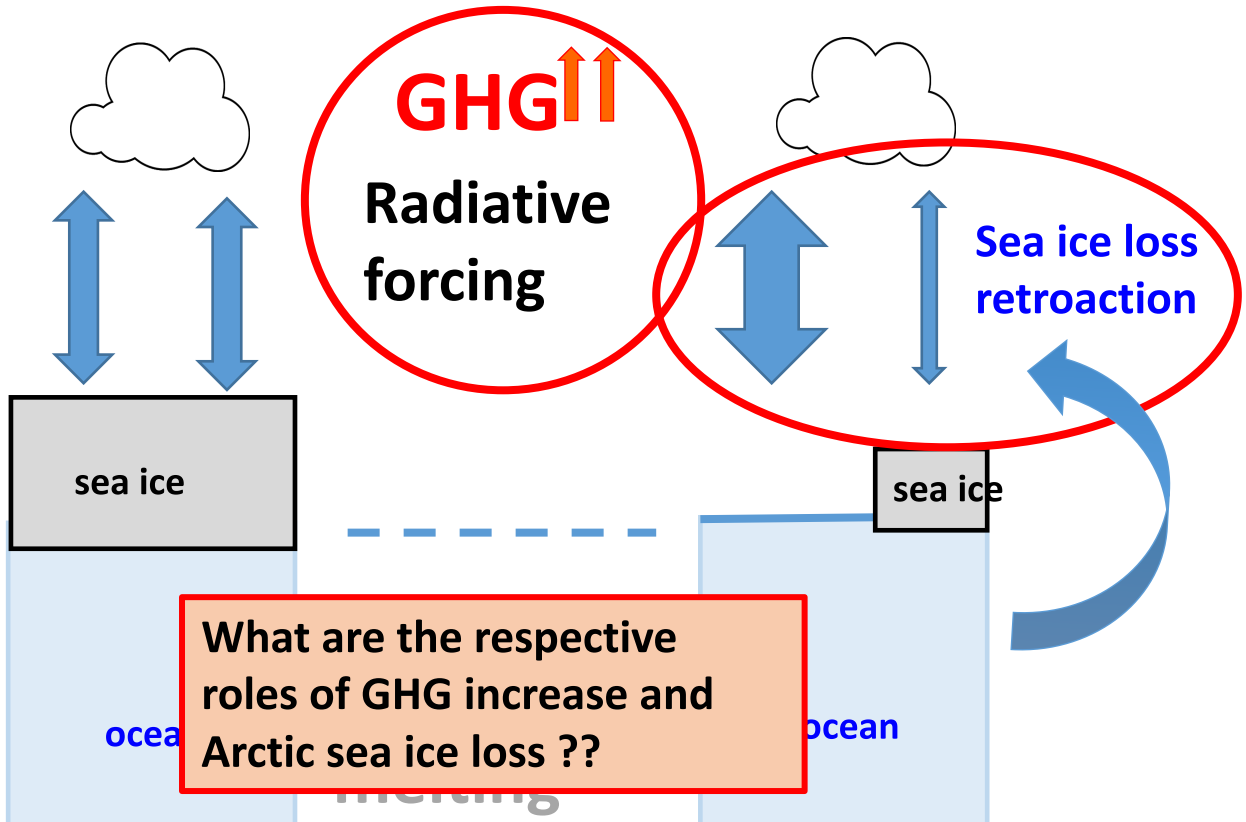
Arctic sea ice vs GHG ?



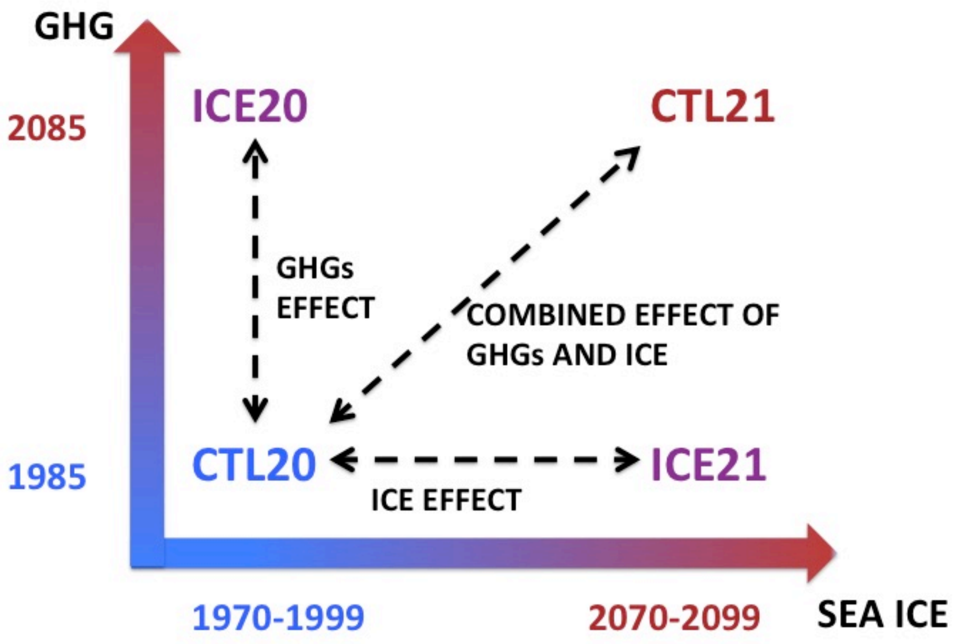
Arctic sea ice vs GHG ?



Arctic sea ice vs GHG ?



Separating GHG and ICE effects



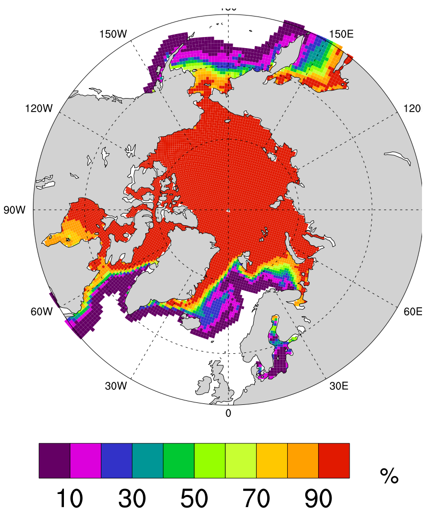
- **CTL21 – CTL20 = ΔRCP**
- **ICE20 – CTL20 = GHG effect**
- **ICE21 – CTL20 = ICE effect**

Oudar et al. 2017

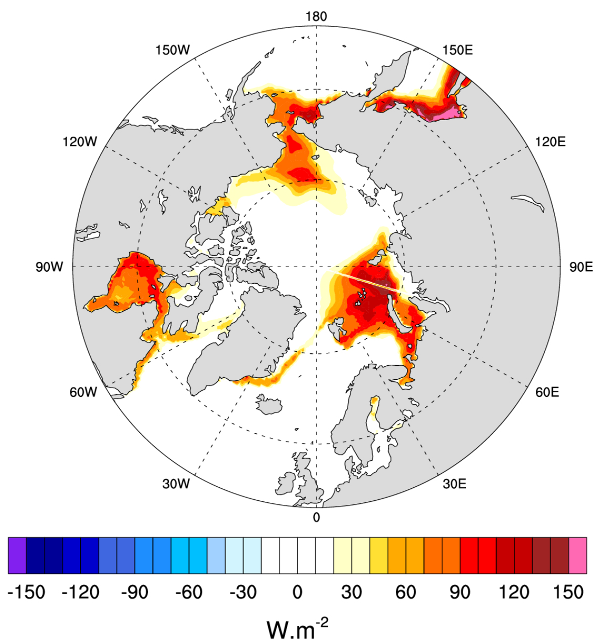
- **200 years** for each experiment
- Spin-up=**100 years**
- **ICE20** and **ICE21** are created using a flux correction technique to either melt or reform sea ice with fixed GHG concentration

Experiment ICE21: Positive flux correction to melt sea ice

END XXth



Artificial warming of the Arctic



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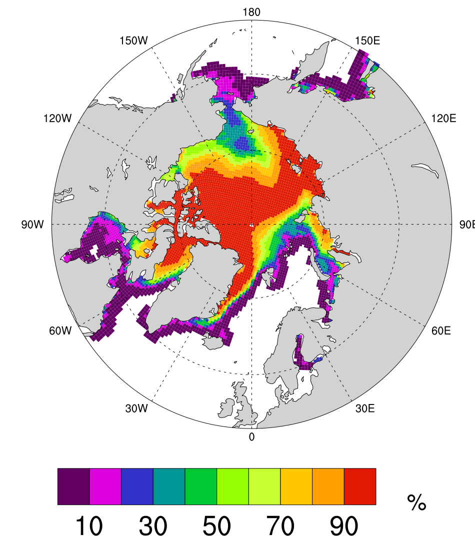
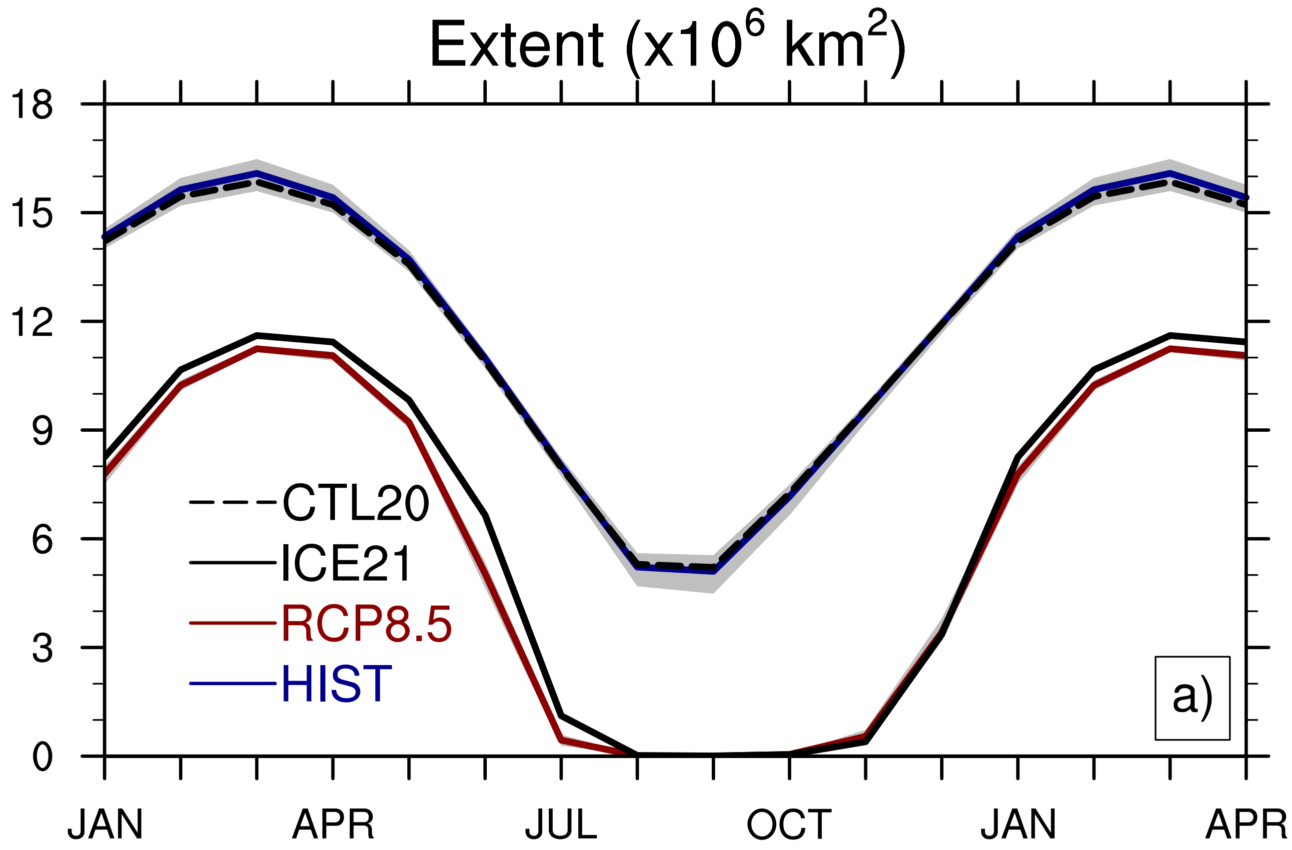


January

Constant GHGs **1985** **(Present GHG conditions)**

Oudar et al. 2017

Validation of the experimental protocol

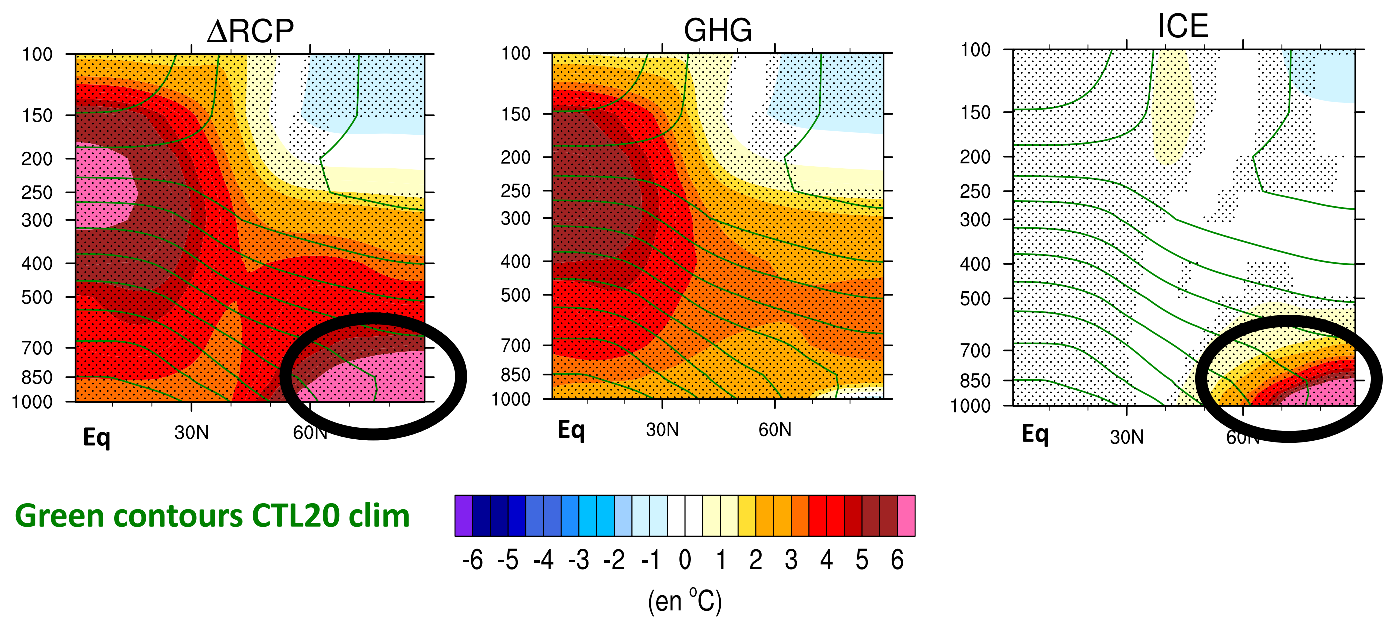


CTL20→ target HIST

ICE21 → target RCP85

Oudar et al. 2017

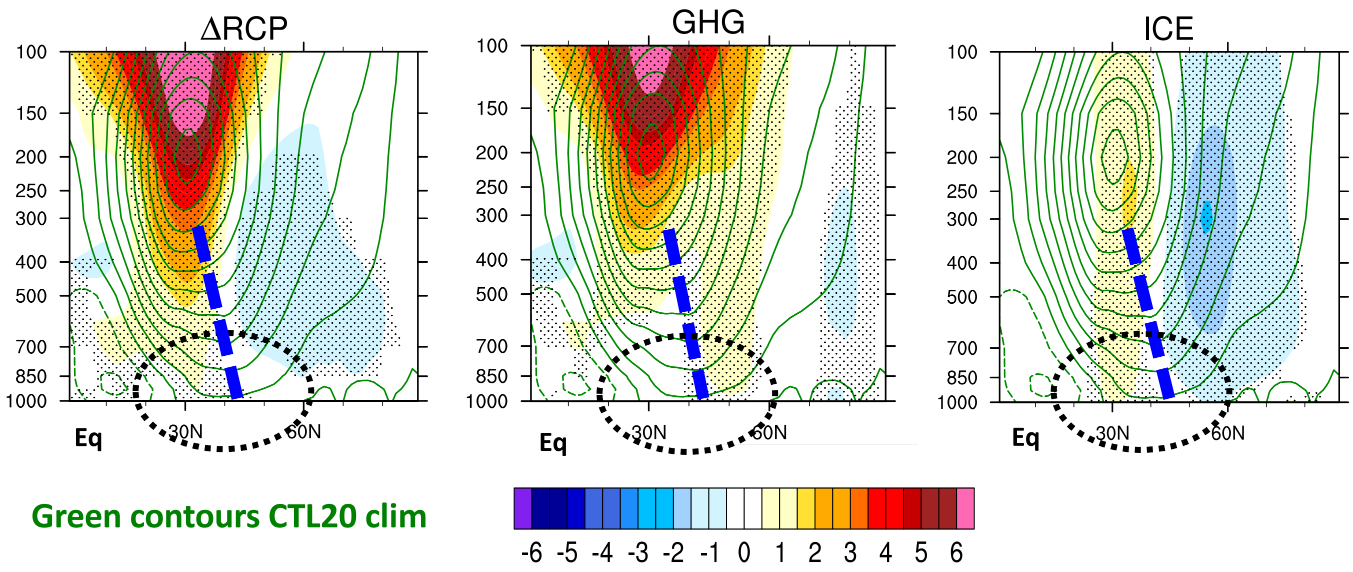
Vertical structure of the NH zonal mean temperature



- **GHG: strong effect of upper level tropical areas**
- **ICE: strong surface warming north of 60°N (AA)**
- **ICE effect some signal in lower latitudes**

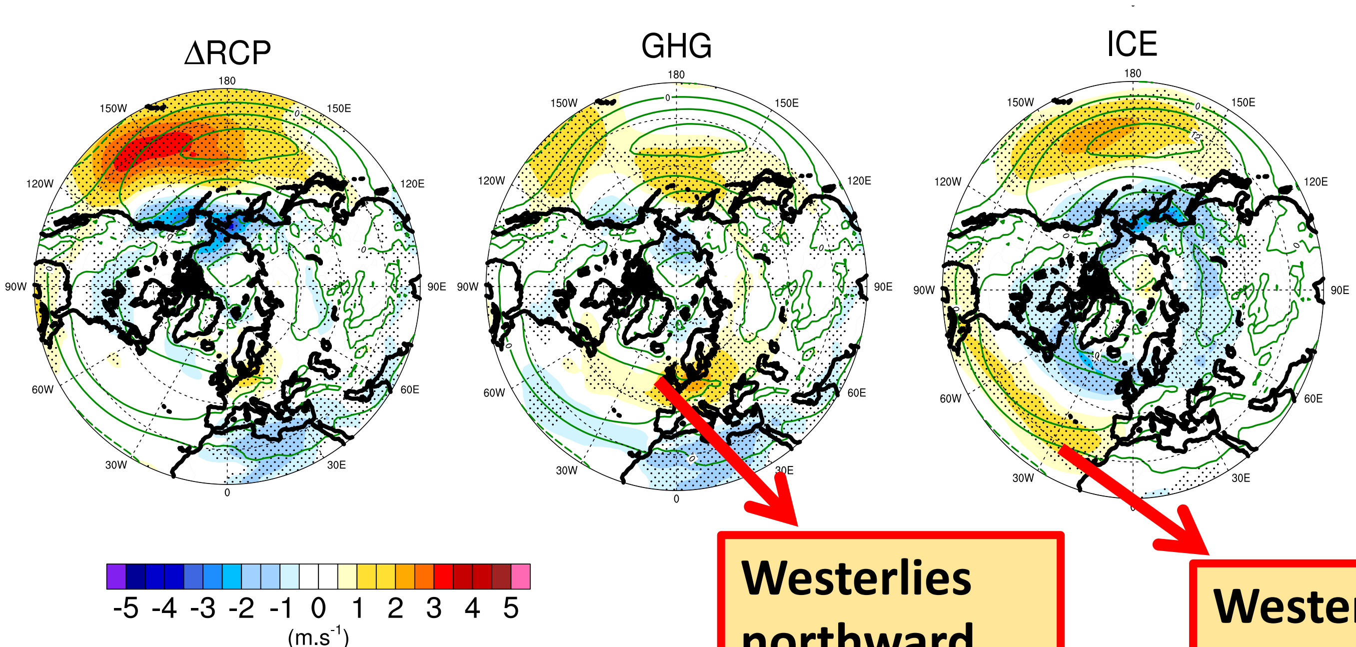
Oudar et al. 2017

Vertical structure of the zonal mean zonal wind response



- **GHG: strengthening of the upper level jet**
- **GHG: strengthening of low level westerly winds and shift northwards**
- **ICE: southward shift of the westerly winds**

Response of the atmospheric circulation: 850 hpa wind



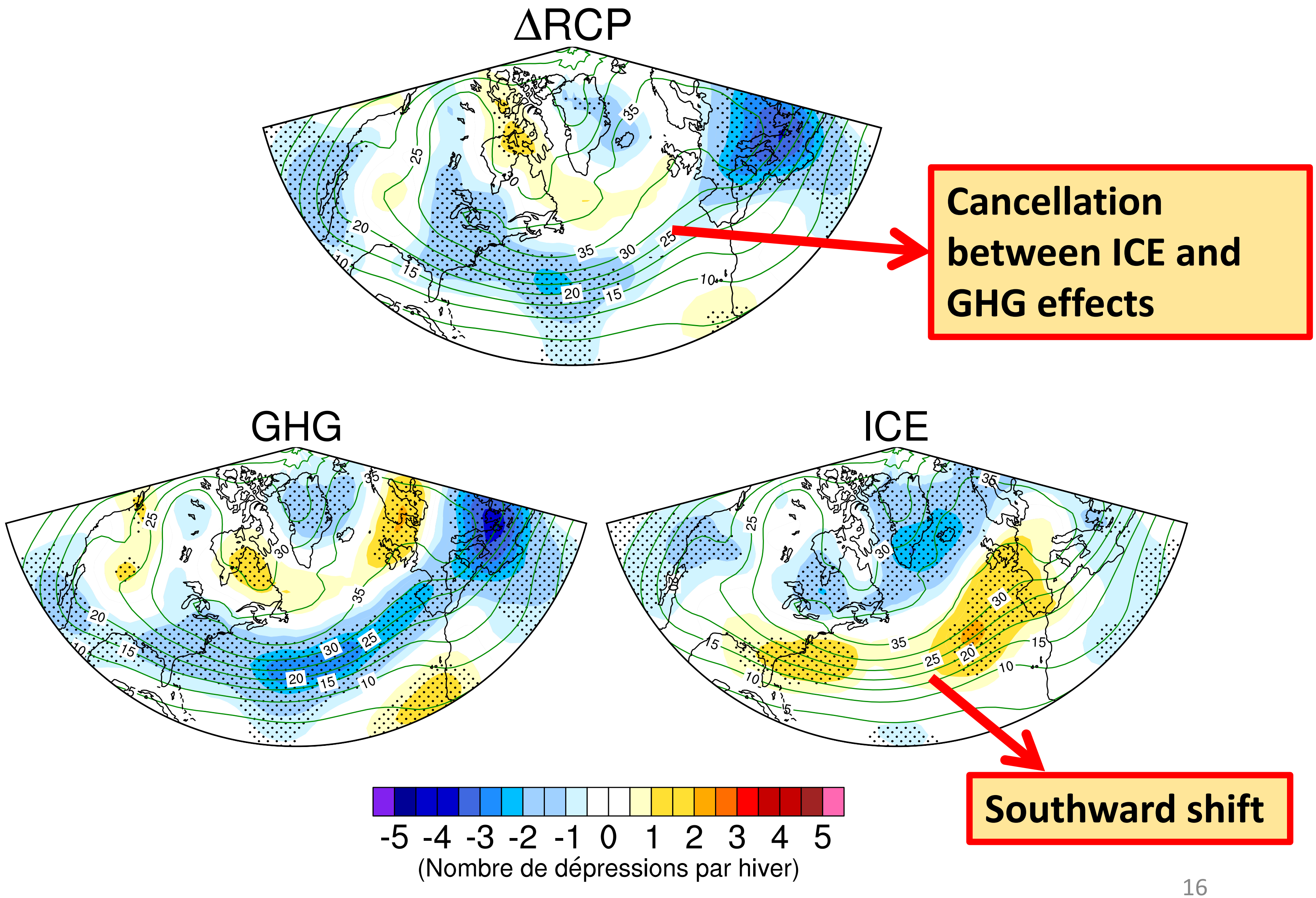
Green contours CTL20 clim

Westerlies northward

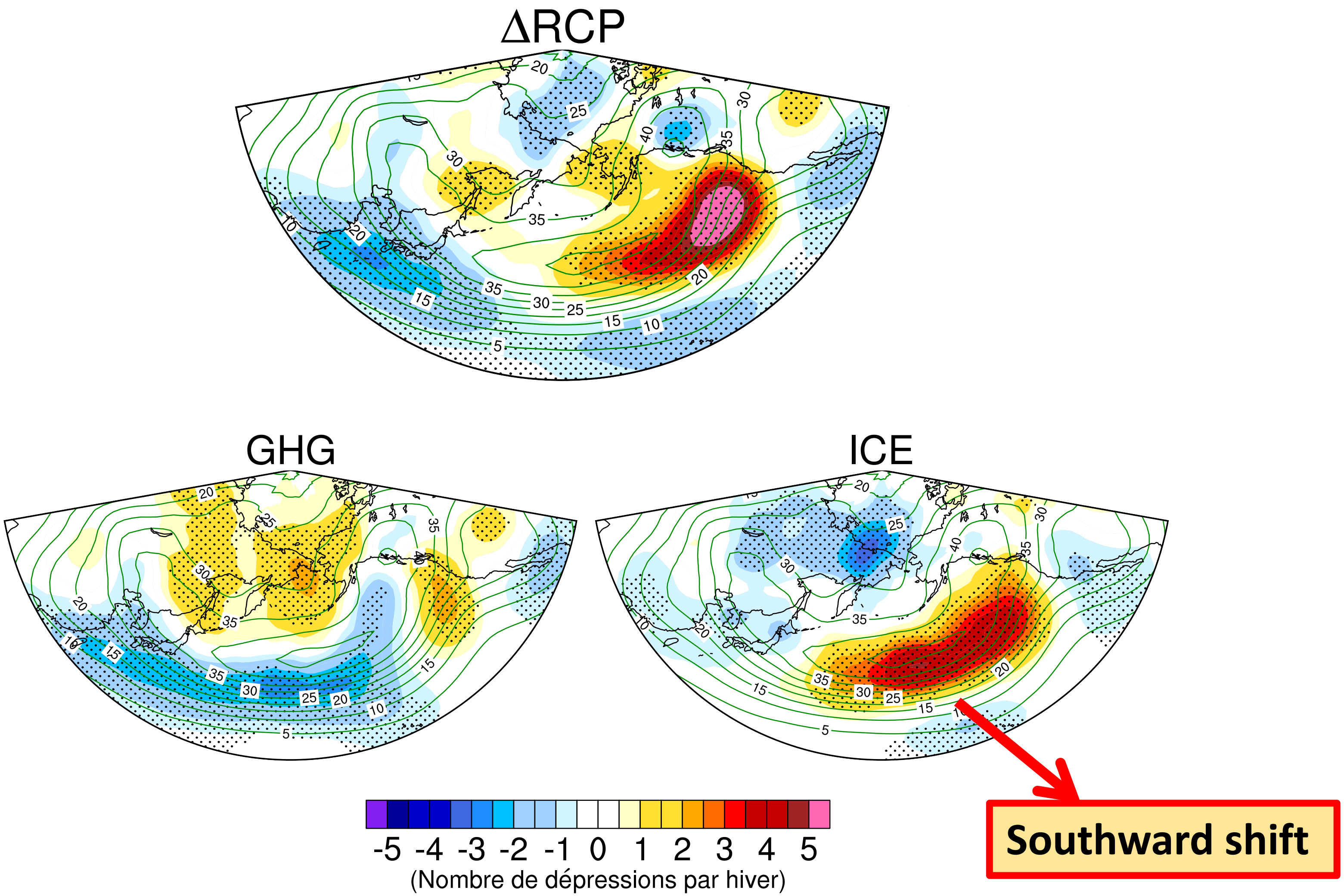
Westerlies southward

- **Opposite response in GHGs and ICE in the North Atlantic**
- **ICE effect: negative NAM response**

North Atlantic storm-track



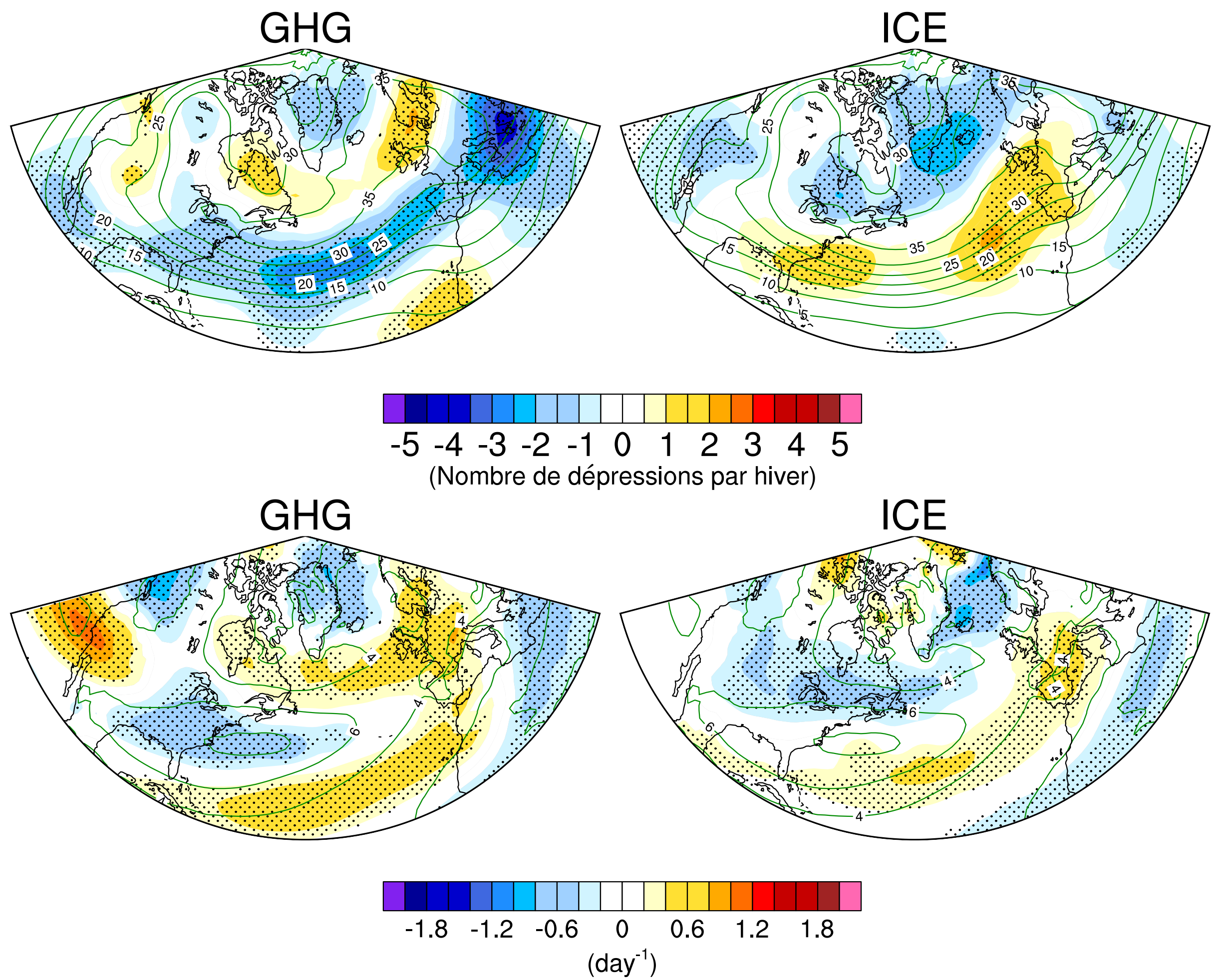
North Pacific storm-track



Eady Growth Rate response

Storm-tracks

EGR
Integrated
between 850
et 400 hPa



Conclusions

- **Negative phase of the NAM (Northern Annular Mode)** in response to Arctic sea ice loss (according to previous studies)
- **Coupled approach**: **the Arctic sea ice loss effect** seem to spread out in to the **tropical regions**
- **The GHG and ICE show opposite effects** in the North Atlantic region:

  GHG -> NAO+

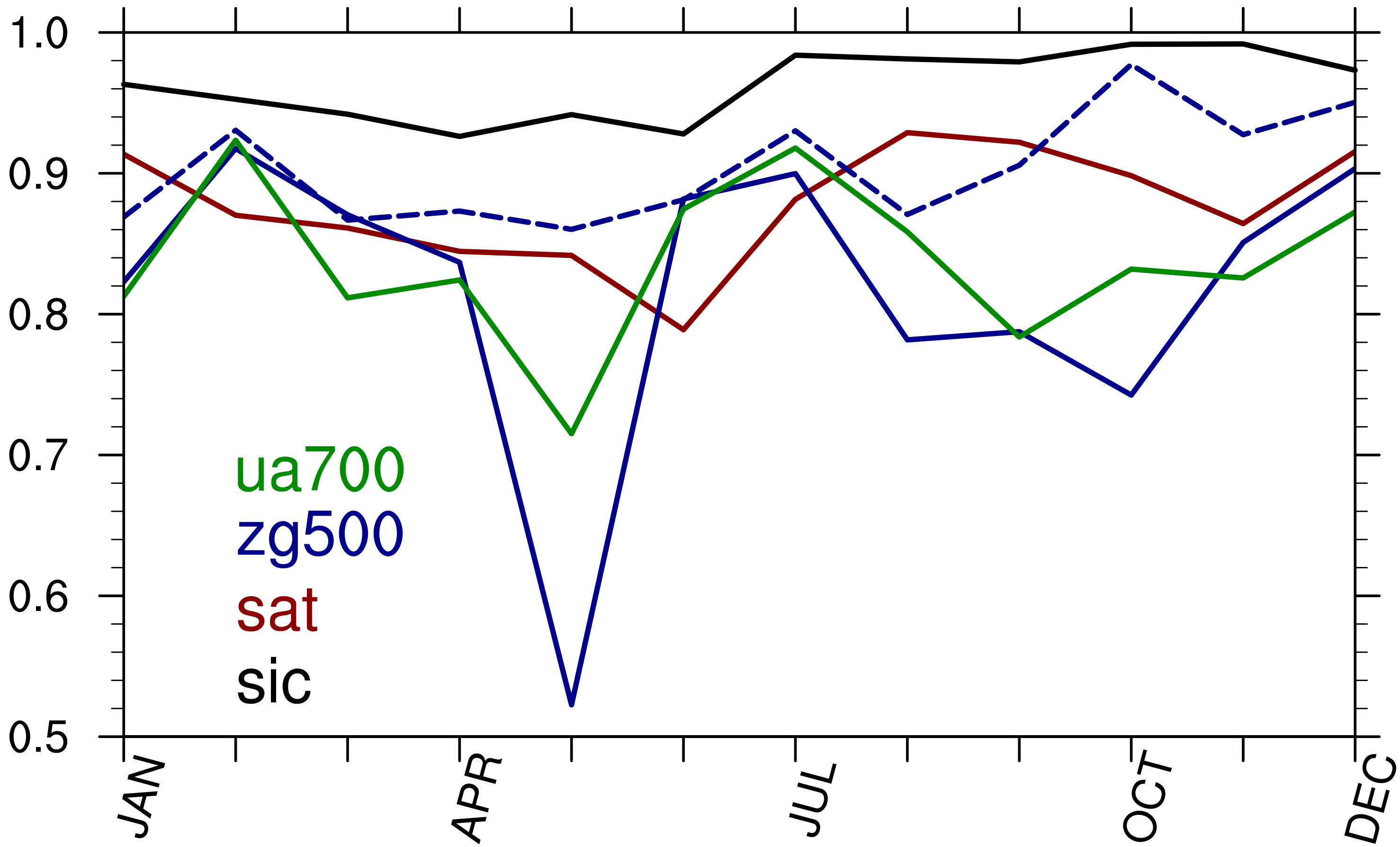
  ICE -> NAO-

this could explain the lack of signal in CMIP5 models

Perspectives

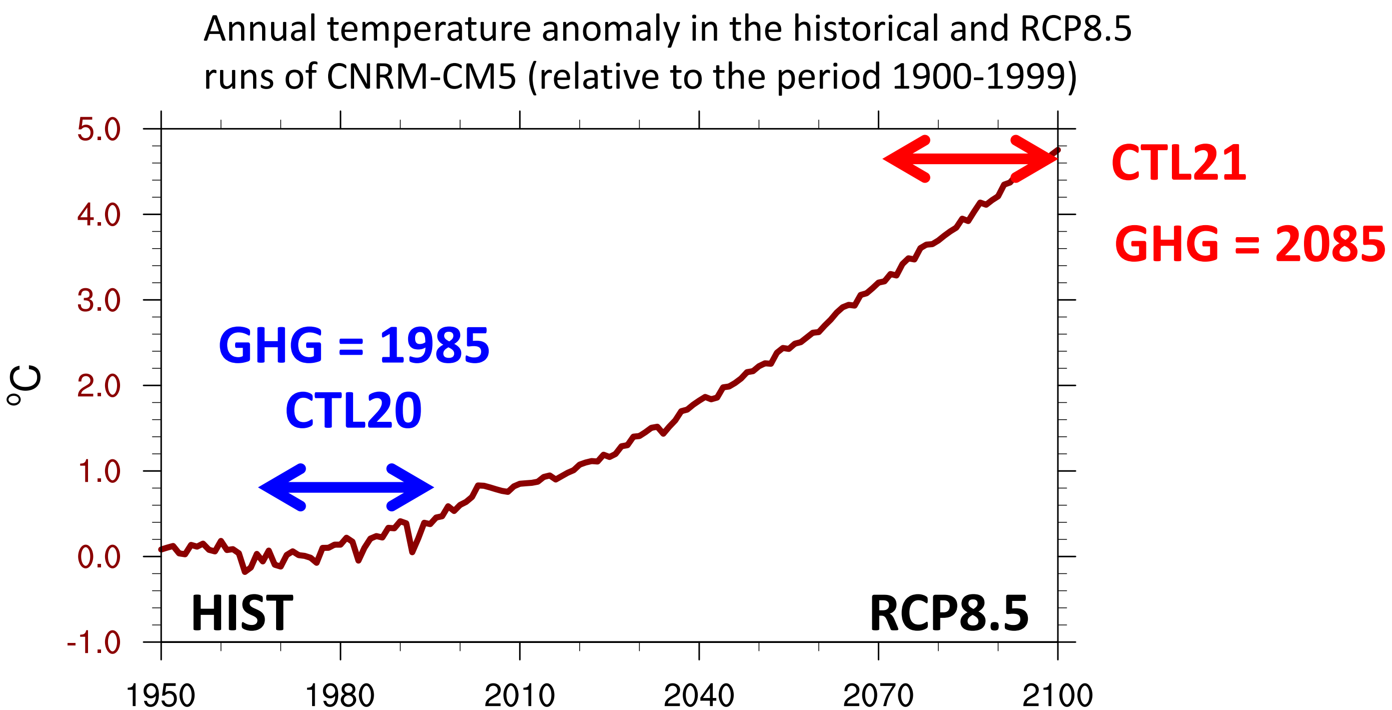
- **Multi-model approach** (APPLICATE Project)
- Study the response of **intense storm-tracks**
- Investigate the **oceanic response** to Arctic sea ice loss
- Test the **additivity** of the ICE and GHG effects

Linearity of the GHG and ICE effects



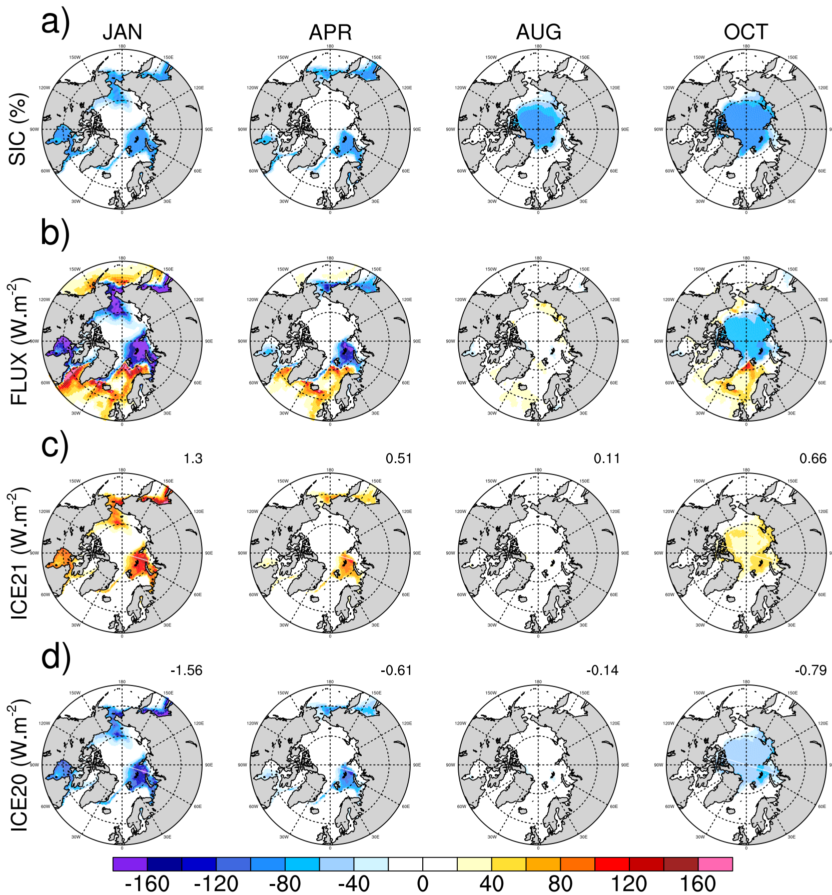
Minimum correlation in May. Consistent with *McCusker et al. (2017)*

2 control runs

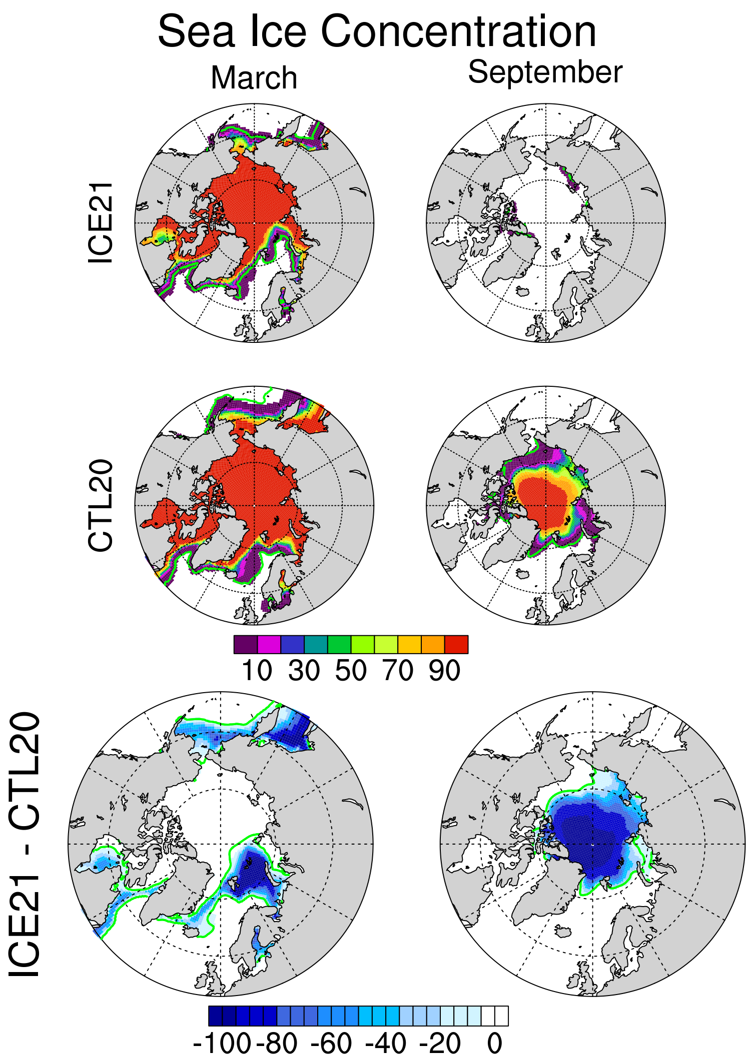


HIST et RCP8.5 : Transient climate

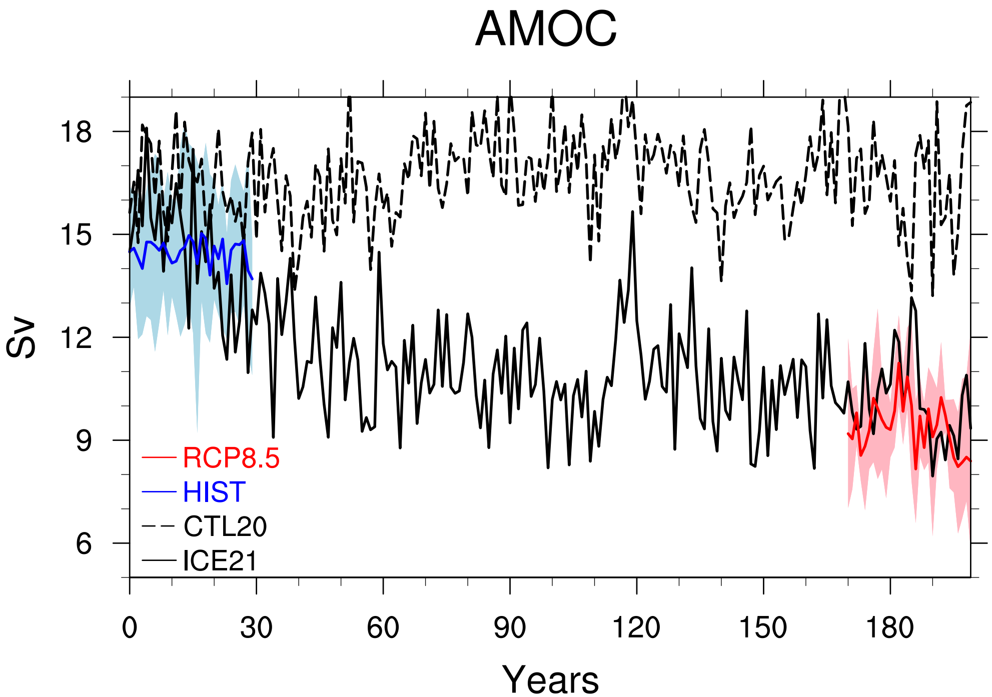
CTL20 et CTL21 : Stabilized climate



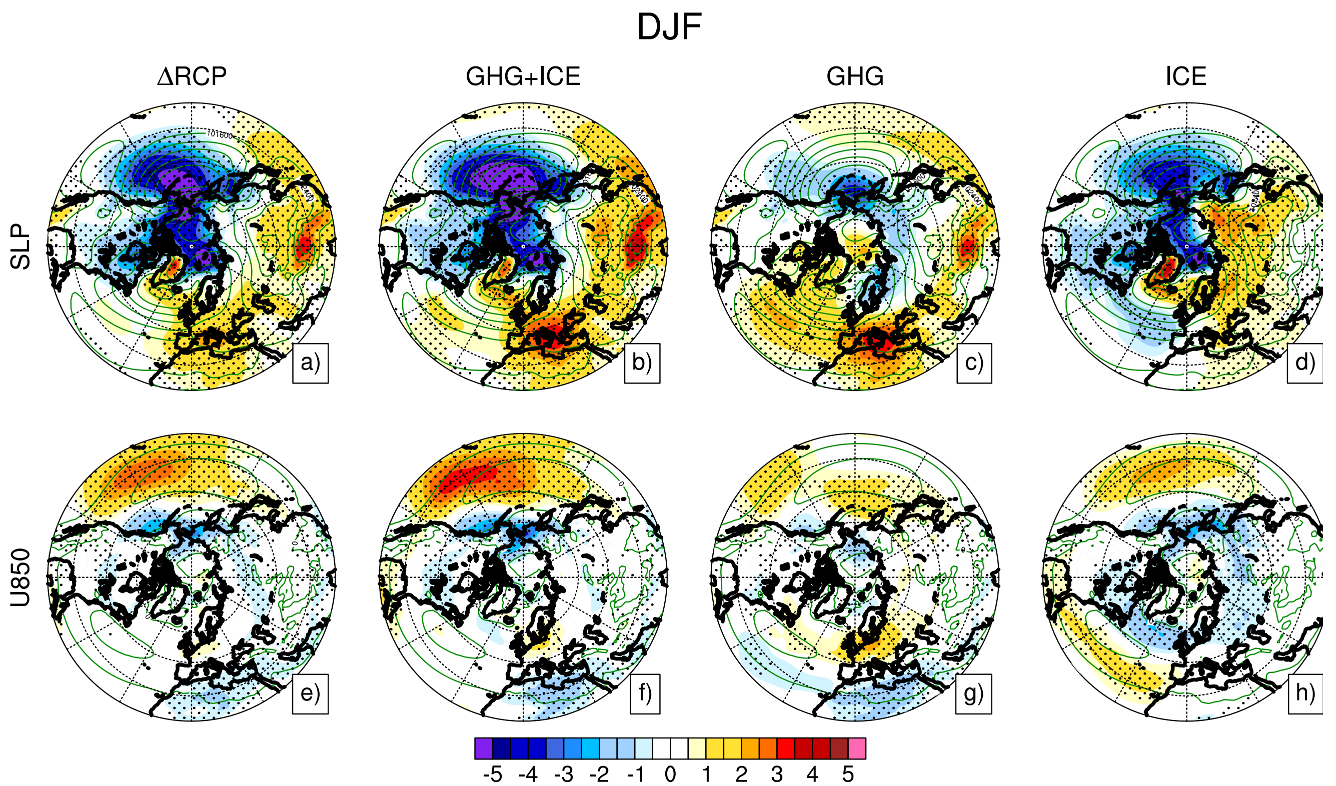
a)
JAN
APR
AUG
OCT
SIC (%)
b)
FLUX (W.m-2)
c)
1.3
0.51
0.11
0.66
ICE21 (W.m-2)
d)
-1.56
-0.61
-0.14
-0.79
ICE20 (W.m-2)
-160
-120
-80
-40
0
40
80
120
160



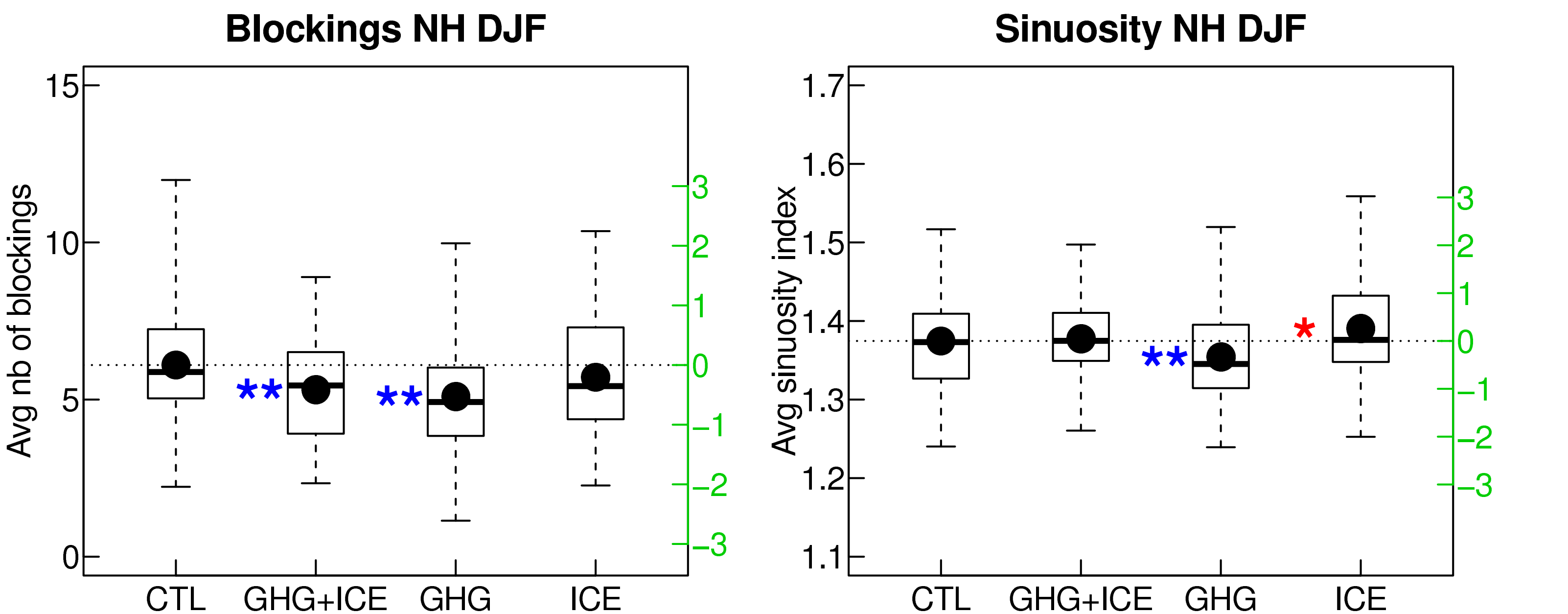
Sea Ice Concentration
March
September
ICE21
CTL20
10 30 50 70 90
ICE21 - CTL20
-100 -80 -60 -40 -20 0



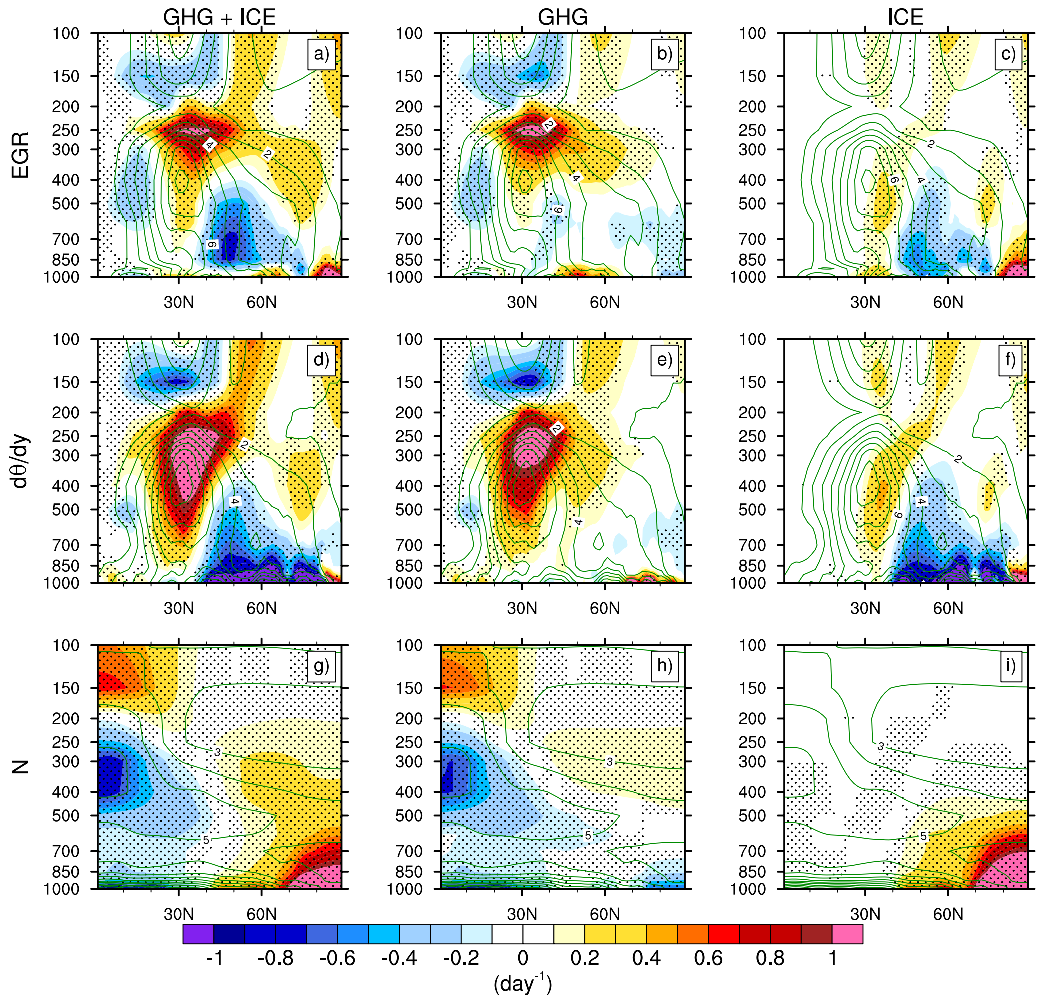
AMOC
Sv
18
15
12
9
6
0
30
60
90
120
150
180
Years
RCP8.5
HIST
CTL20
ICE21



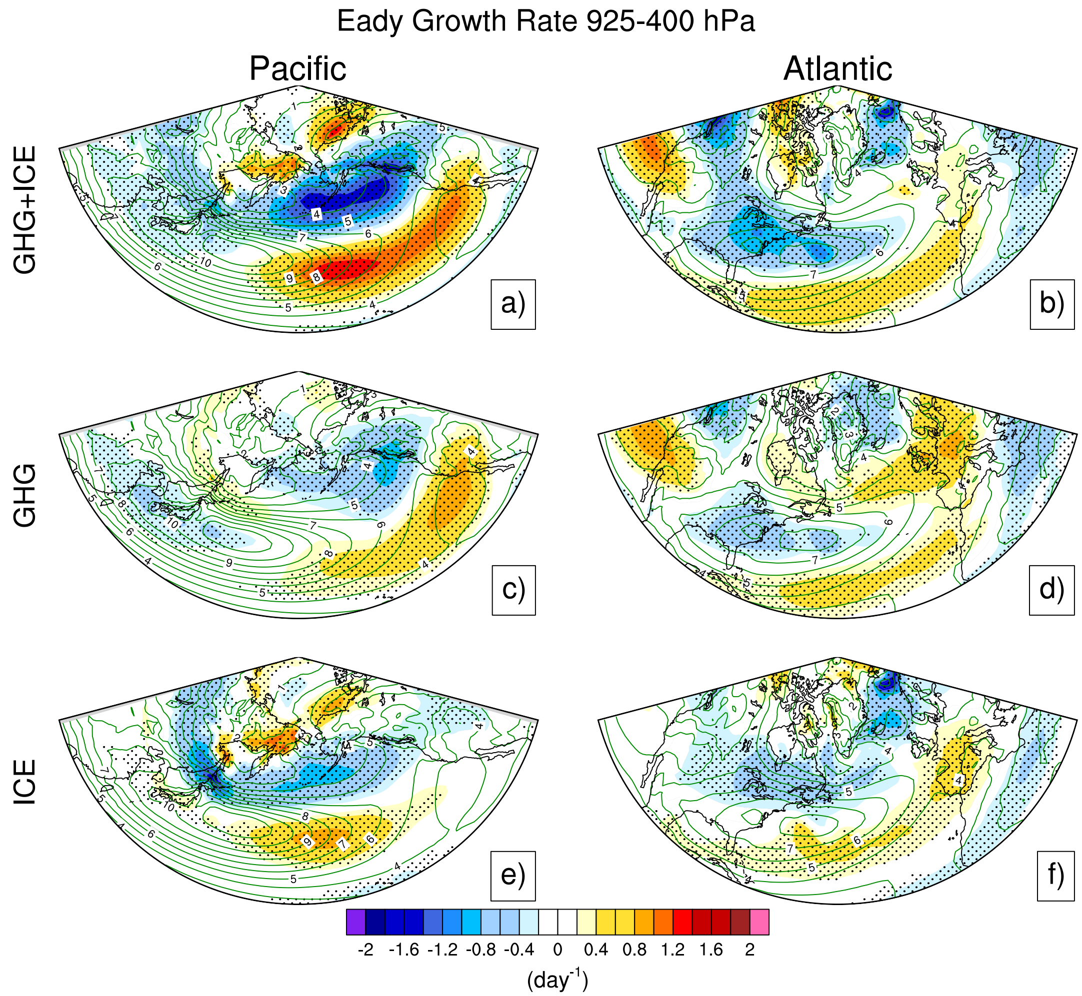
DJF
ΔRCP
GHG+ICE
GHG
ICE
SLP
U850
a)
b)
c)
d)
e)
f)
g)
h)
-5
-4
-3
-2
-1
0
1
2
3
4
5



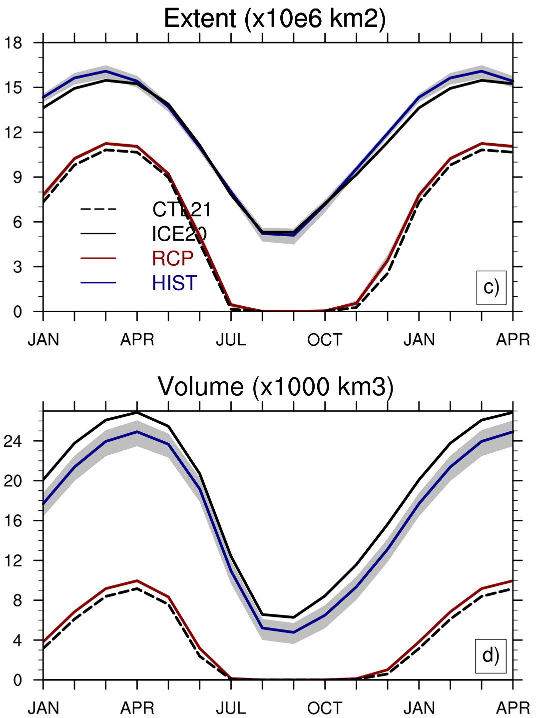
Blockings NH DJF
Avg nb of blockings
15
10
5
0
3
2
1
0
−1
−2
−3
CTL
GHG+ICE
GHG
ICE
**
**
Sinuosity NH DJF
Avg sinuosity index
1.7
1.6
1.5
1.4
1.3
1.2
1.1
3
2
1
0
−1
−2
−3
CTL
GHG+ICE
GHG
ICE
**
*



GHG + ICE
GHG
ICE
EGR
dθ/dy
N
a)
b)
c)
d)
e)
f)
g)
h)
i)
100
150
200
250
300
400
500
700
850
1000
30N
60N
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
(day^{-1})



Eady Growth Rate 925-400 hPa
Pacific
Atlantic
GHG+ICE
GHG
ICE
a)
b)
c)
d)
e)
f)
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
(day^{-1})



Extent (x10e6 km2)
CTL21
ICE20
RCP
HIST
c)
Volume (x1000 km3)
d)
JAN
APR
JUL
OCT
JAN
APR