CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

Influence of greenhouse gas concentration and Arctic sea-ice change on the West African Monsoon

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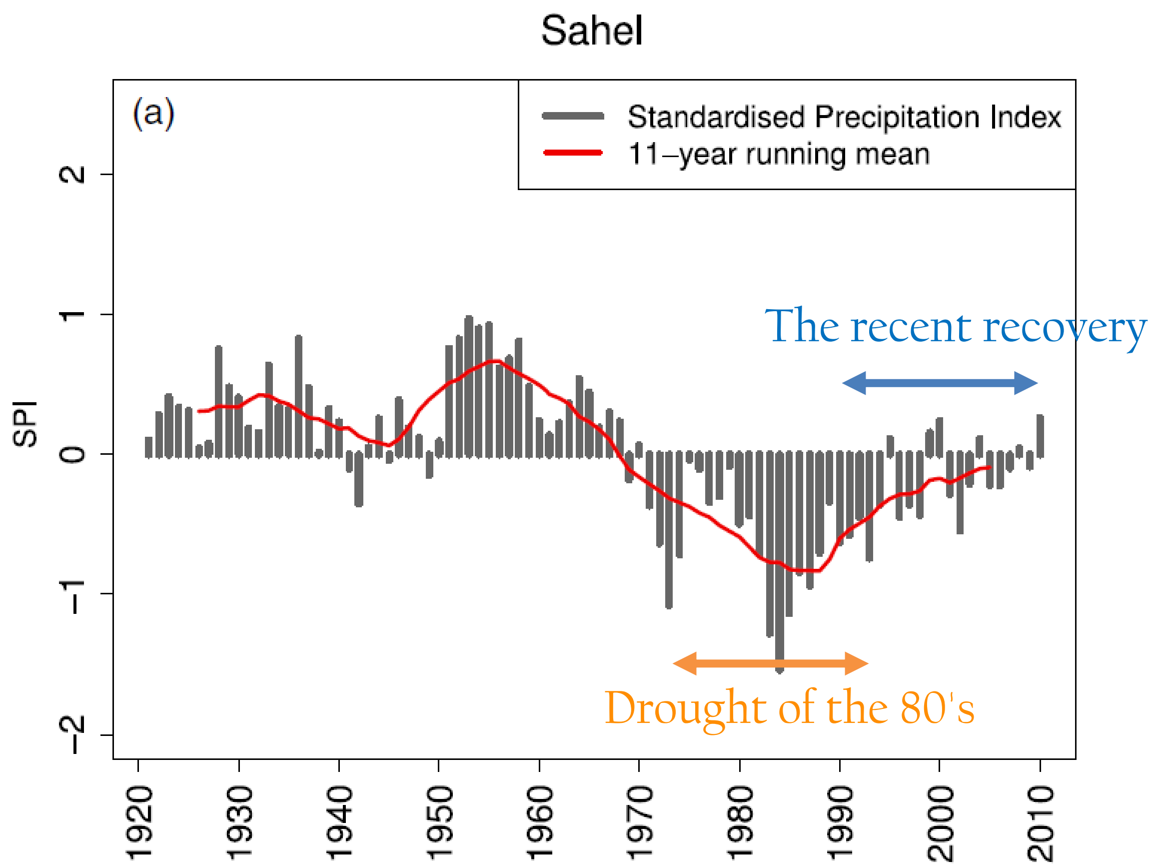
dépasser les frontières

The recent rainfall recovery in West Africa



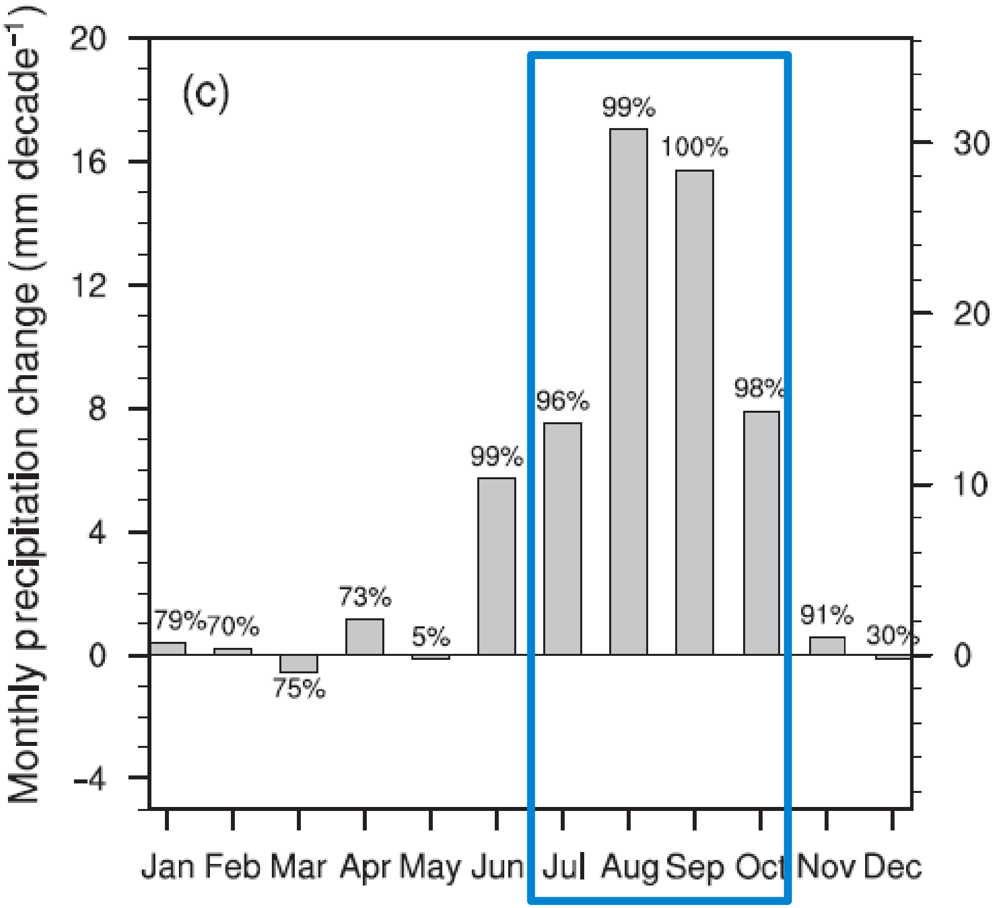
The Standardised Precipitation Index (SPI) and its 11-year running mean, between 1921 and 2010.

Sanogo et al., (2015)

The recent rainfall recovery in West Africa

The **August-October** period exhibits the largest rainfall recovery in the Sahel.

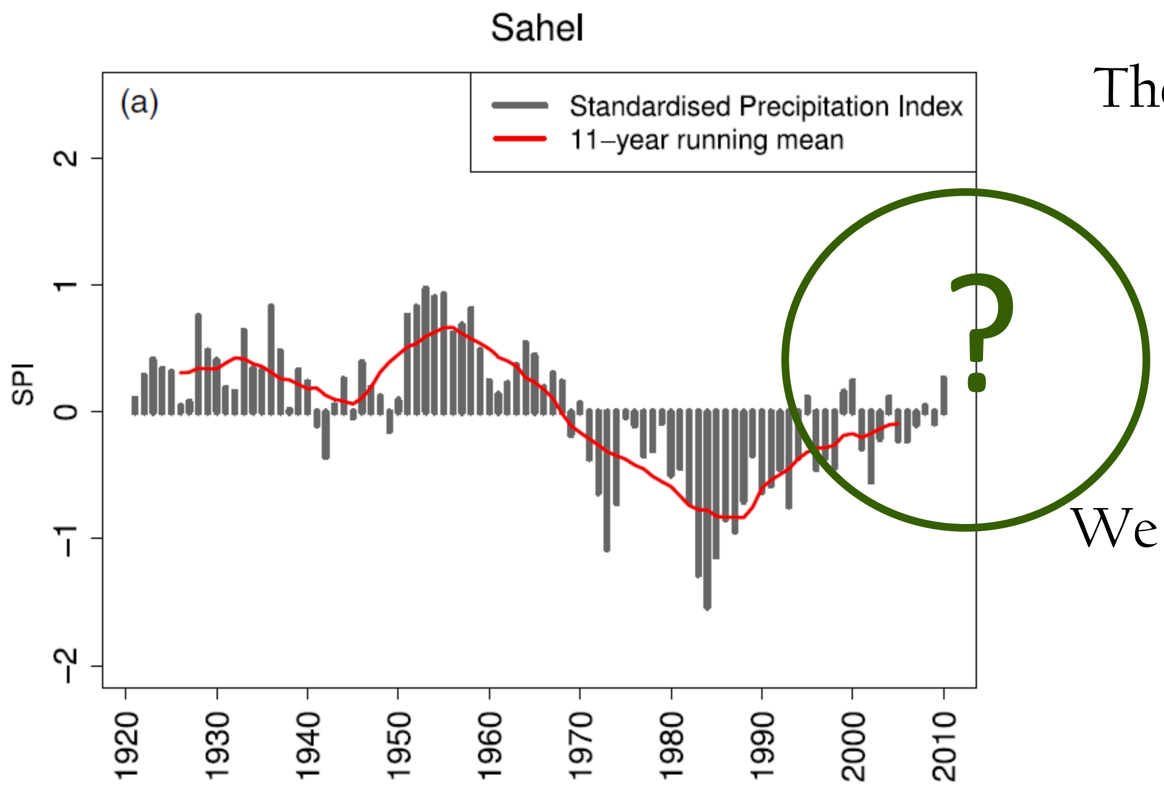
The date of the retreat of the rainy season significantly moved later.



The monthly rainfall trends (in mm decade-1; left axis) and their percentage contribution to the annual trends (in%, right axis). 1980-2010.

Sanogo et al., (2015)

In the future ?

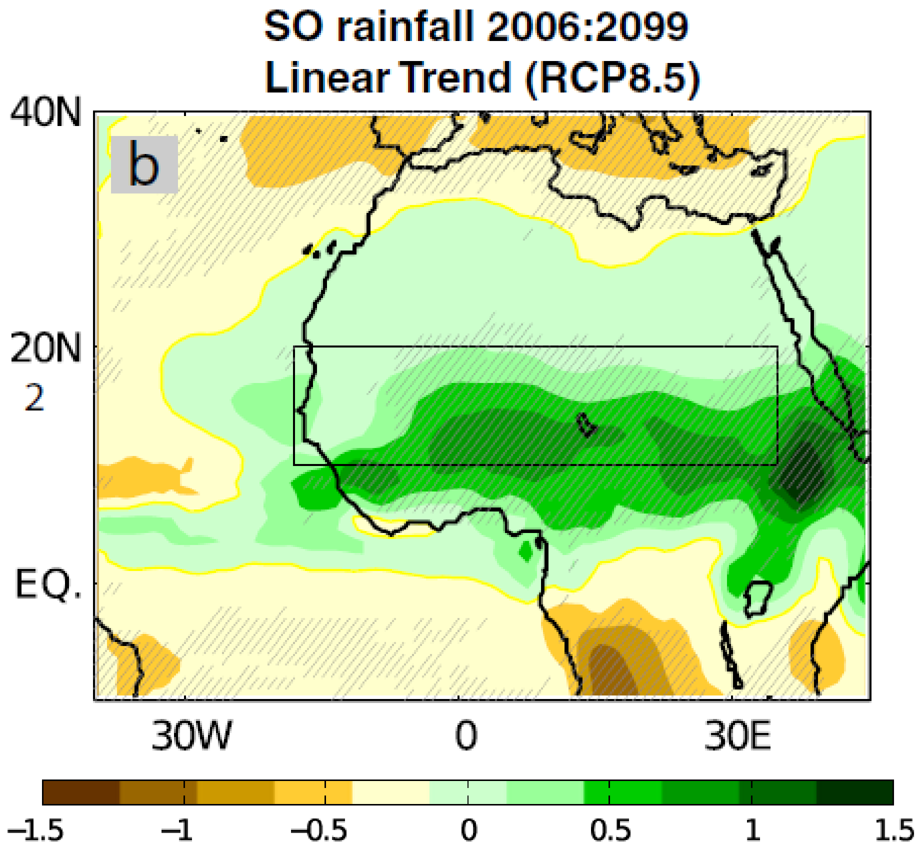


Sanogo et al., (2015)

The recovery is associated with the increase in GHGs (*Dong and Sutton, 2015*).

We may thus expect an increase in rainfall in the future.

In the future ?



Biasutti, 2013

The increase in the late rainy season is very robust among models and scenarios

Biasutti 2013; Kitoh et al., 2013; Seth et al., 2013; Monerie et al., 2016a, 2016b

Precipitation increase in late rainy season

- Local recycling (evaporation)

  Monerie et al., 2016a

- Change in the land-cover (vegetation) ?

  Wang and Alo, 2005

- Seasonal cycle of the SSTs

  Biasutti and Sobel, 2009; Dwyer et al., 2012, 2014

Precipitation increase in late rainy season

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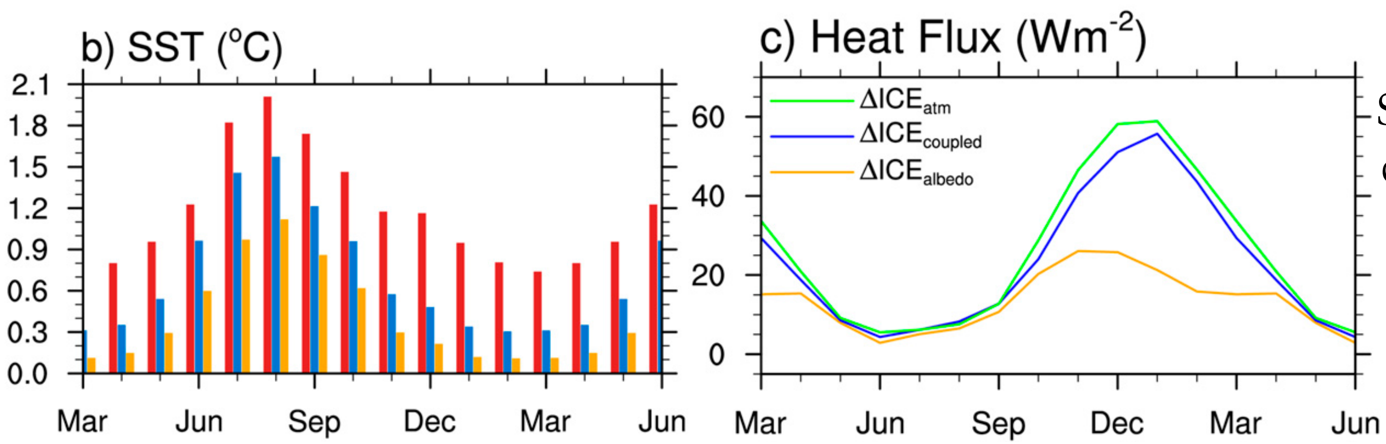


Sea-ice melting leads to a change in the Arctic SST seasonal-cycle

(b) As in (a), but for SST (8 C) averaged over all grid boxes in which the sea ice concentration is reduced in the late twenty-first century relative to the late twentieth century. (c) Net surface heat flux response (sum of the turbulent and longwave radiative flux components;Wm22) to Arctic sea ice loss in DICE_coupled (blue), DICE_atm (green), and DICE_coupled_albedo (orange)

Deser et al., 2015

Motivation

- *Deser et al., (2015)* have shown an impact of the Arctic sea-ice melting on global tropical precipitation

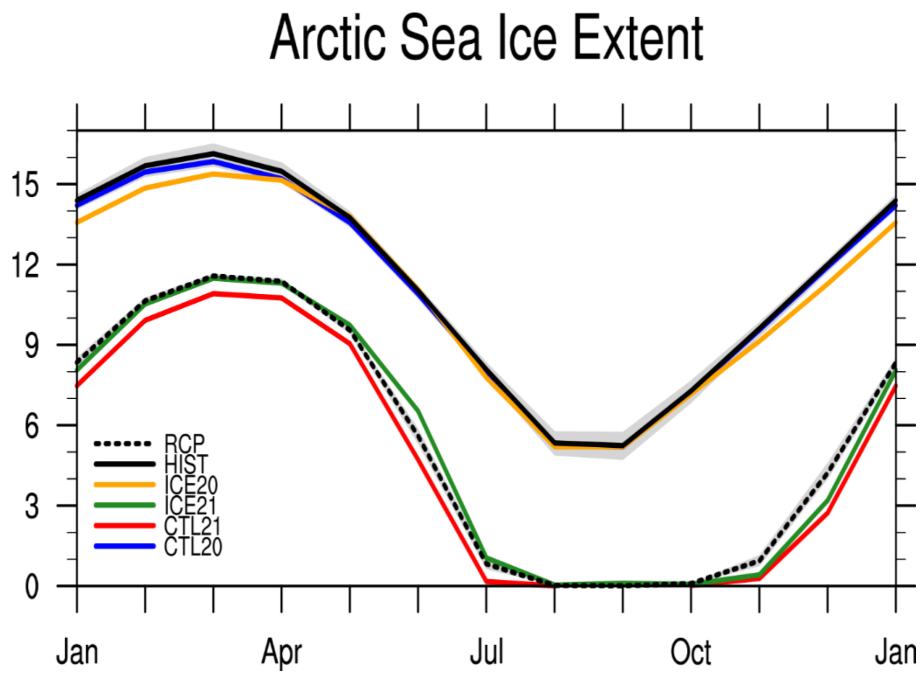
↓

What is the impact of the Arctic sea-ice melting on the West African Monsoon ?
Mean state and seasonality

Results

Simulation with CNRM-CM5, heat fluxes are modified over the Arctic to keep the sea ice extent constant/melt the sea ice

Oudar et al., Under Review in Climate Dynamics



Monerie et al., to be submitted

CTL20; $GHG_{historical}$ and $SeaIce_{historical}$

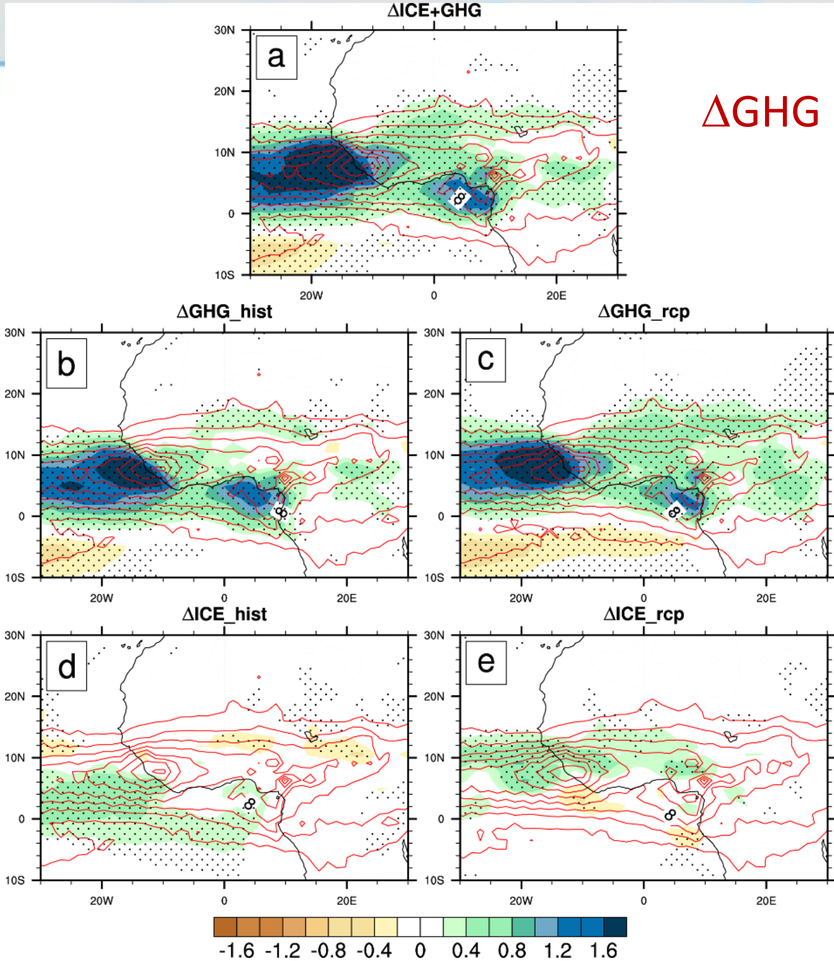
CTL21; $GHG_{rcp8.5}$ and $SeaIcer_{cp8.5}$

ICE20; $GHG_{rcp8.5}$ and $SeaIce_{historical}$

ICE21; $GHG_{historical}$ and $SeaIce_{rcp8.5}$

Simulations last for 200 years and a spin-up of 50 years was applied

Results



ΔGHG Δsea-ice

ΔGHG

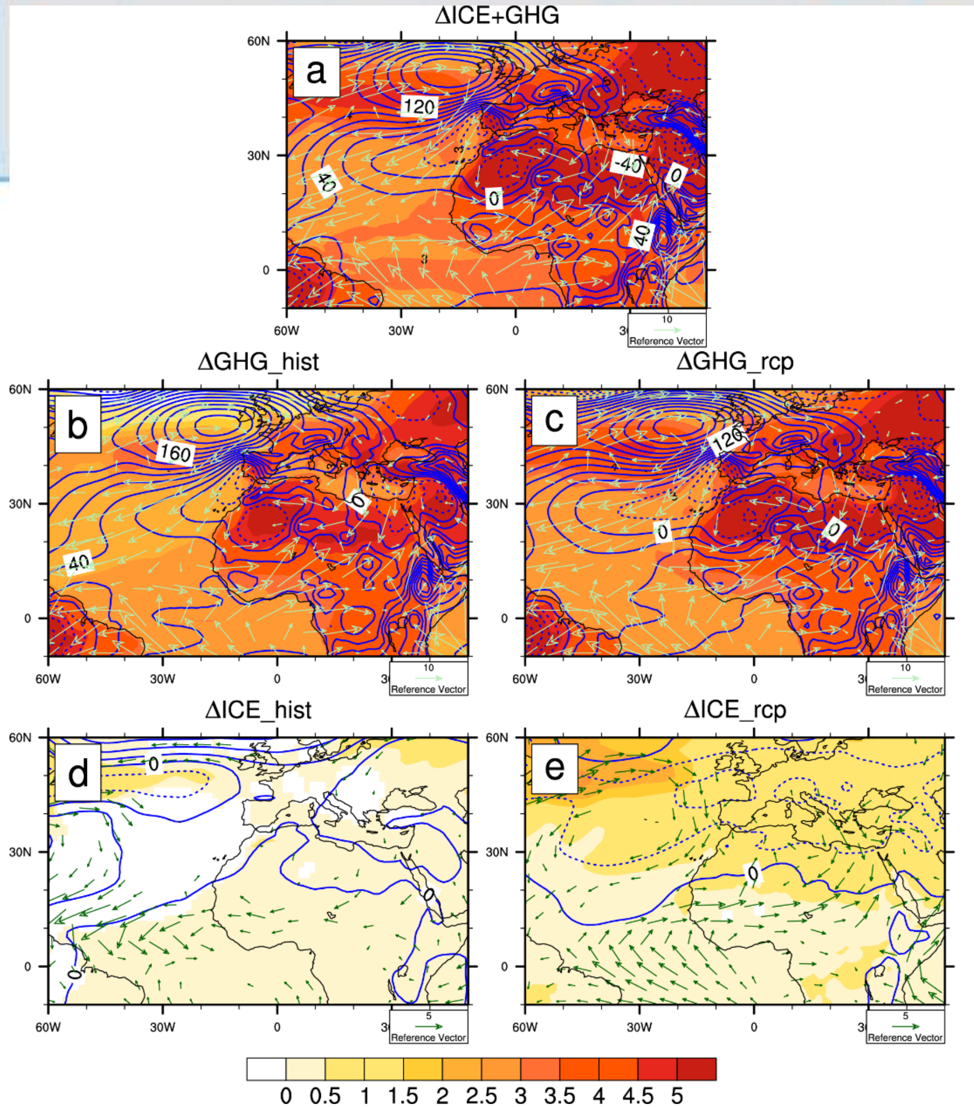
- The increase in the GHG concentration leads to more precipitation over West Africa. ΔGHG largely dominates Δsea-ice.

Δsea-ice

- Δsea-ice depends on the "background" level of GHG (mean state of the climate)

Difference in precipitation (mm.day[-1]) in JAS for a) ΔICE+GHG, b) ΔGHG_hist, c) ΔGHG_rcp, d) ΔICE_hist and e) ΔICE_rcp. Stippling indicates that the differences are statistically significant at the 90% confidence level according to a Student t test. The red line indicates the climatology, defined as the JAS mean period for a), b) and d) CTL20 average, c) the ICE21 average and e) the ICE20.

Results



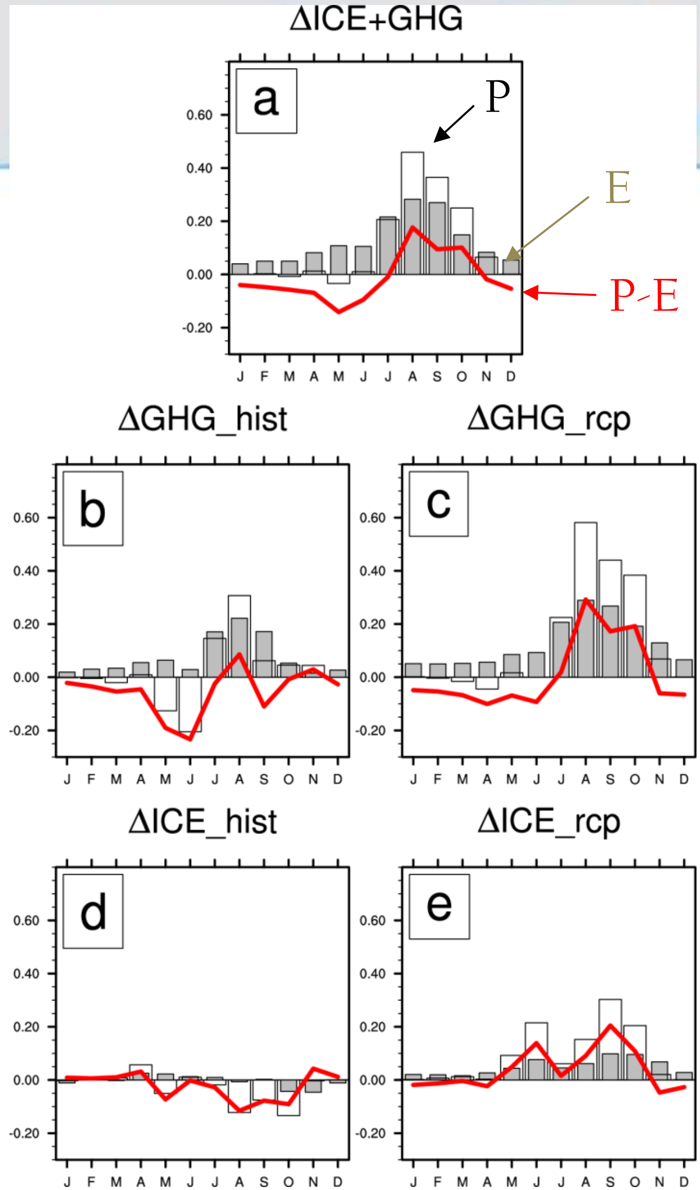
Difference in 925 hPa moisture flux (g.kg^{-1} * m.s^{-1}; green arrow), surface air temperature (°C; shading) and sea level pressure (Pa; blue lines) for a) ΔICE+GHG, b) ΔGHG_hist, c) ΔGHG_rcp, d) ΔICE_hist and e) ΔICE_rcp. Only statistically significant differences in temperature and moisture fluxes are represented, according to a Student *t* test at the 95% confidence level.

- The increase in the GHG concentration is associated with a **stronger warming over the continent than over the ocean**, i.e. with a strengthening of the **temperature gradient** between the Sahara and the gulf of Guinea.

- Sea-ice melting leads to an increase in the air-surface temperature. The temperature gradient change are however different According to the level of GHG.

ΔSea-ice is associated with a decrease in the northward heat transport (due to a strong warming over the Arctic)

Results



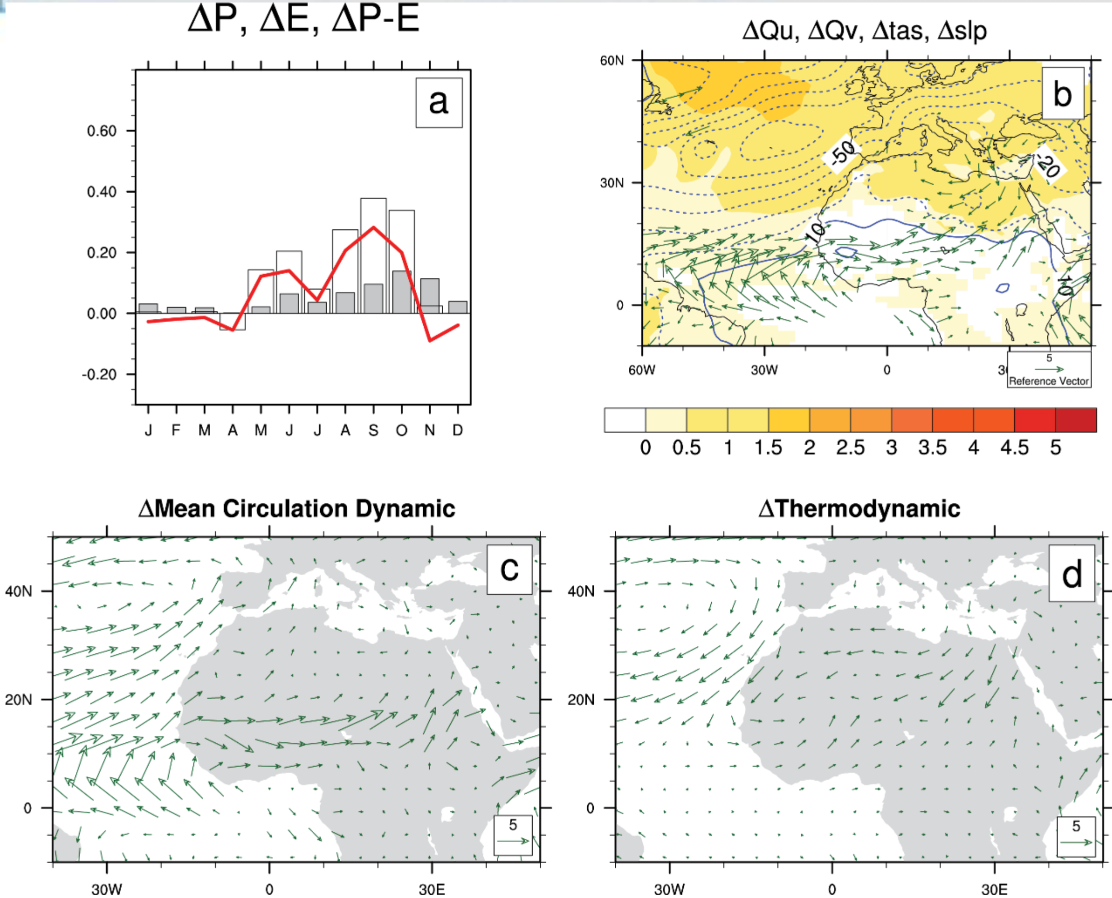
Difference in precipitation (ΔP in mm.day-1; white bar), evaporation (ΔE in mm.day-1; gray bar) and moisture flux convergence (ΔP-E in mm.day-1; red line) for a) ΔICE+GHG, b) ΔGHG_hist, c) ΔGHG_rcp, d) ΔICE_hist and e) ΔICE_rcp.

- Precipitation increases during the late rainy season.

- Δpr is mostly due to ΔE in ΔGHG_hist, but is associated with changes in both ΔE and ΔP-E in ΔGHG_rcp. The dynamic is different.

- Precipitation decreases in ΔICE_hist but increases in ΔICE_rcp;
- There is no clear change in the seasonal cycle of the precipitations

Results



ΔICE_rcp - ΔICE_hist difference in a) precipitation (ΔP in mm.day^{-1}; white bar), evaporation (ΔE in mm.day^{-1}; gray bar) and moisture flux convergence (ΔP-E in mm.day^{-1}; red line) and in b) 925 hPa moisture flux (g.kg^{-1} * m.s^{-1}; green arrow), surface air temperature (°C; shading) and sea level pressure (Pa; blue lines). The moisture fluxes are broken into its c) mean circulation dynamic and d) thermodynamic component (g.kg^{-1} * m.s^{-1}).

ΔICE is different according to the state of the climate; the impact is not linear.

In ASO the difference in Precipitation is associated with an increase in precipitation, due to a strengthened circulation (westerlies), and a change in the pressure gradient between the northern and southern subtropical Atlantic Ocean

Conclusion

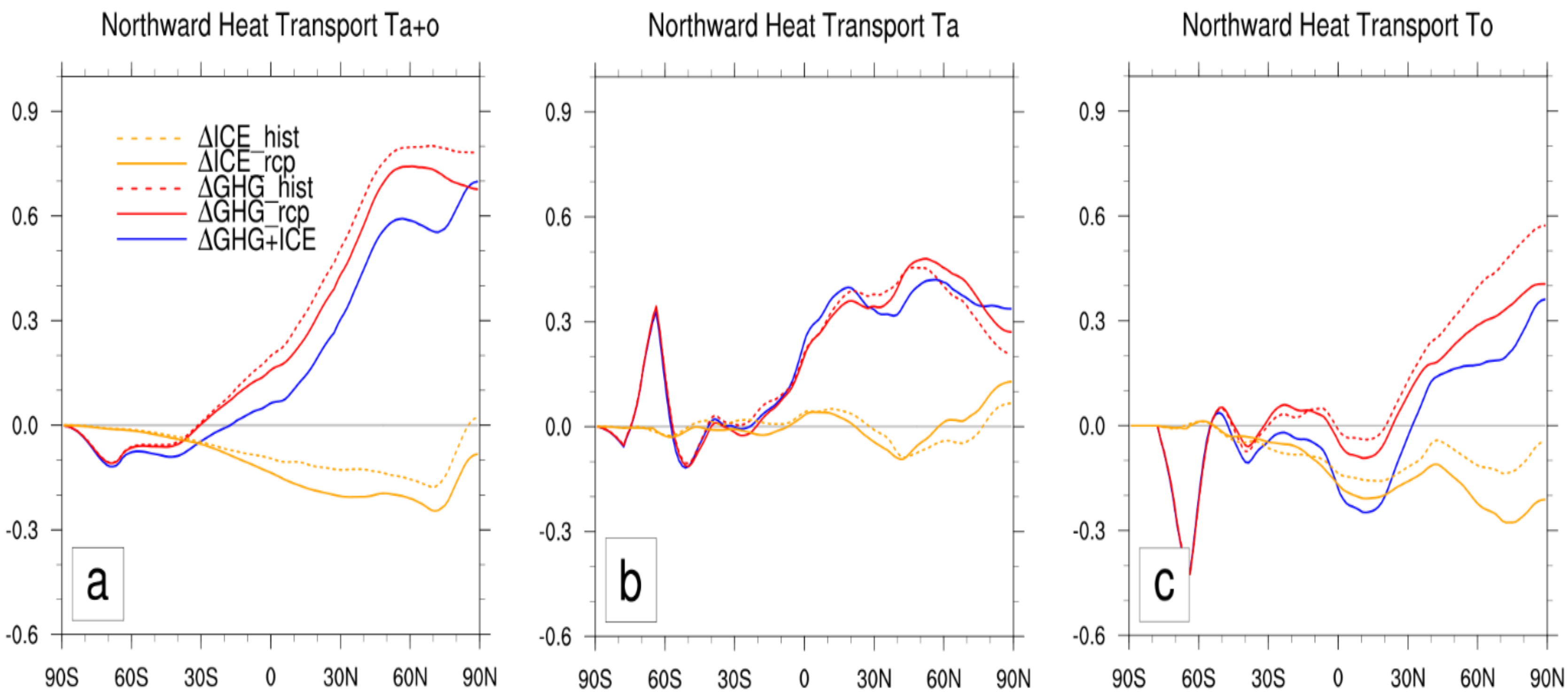
We can split the responses of the external forcing into the ΔGHG and ΔICE contributions:

- ΔGHG impact is prominent:
  - strengthened land-sea temperature gradients
  - northward shift of the monsoon-cell
  - Sahel precipitation increases

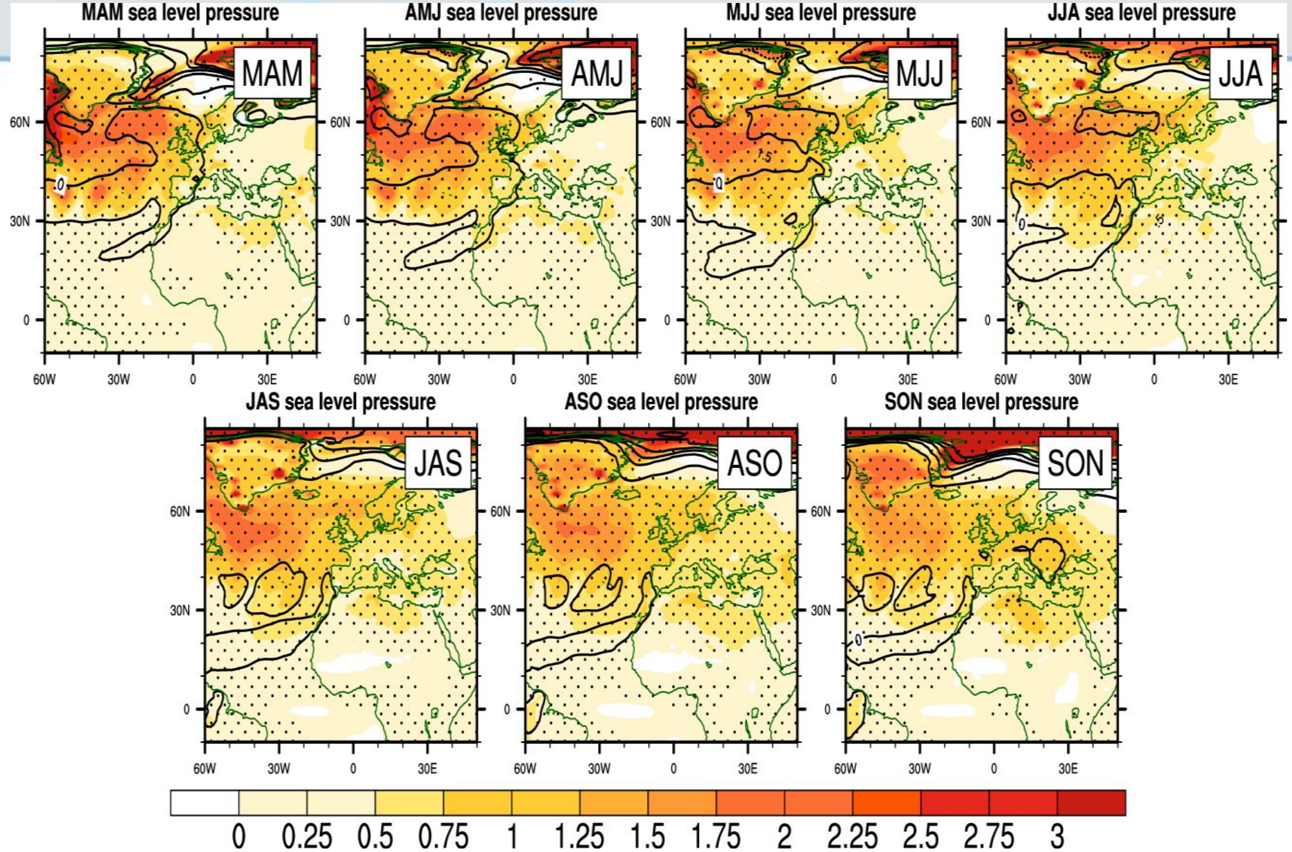
- ΔICE depends on the climate mean state:
  - With the current level in GHG:
    weak impact, decrease in Sahel precipitations
  - Under a future level in GHG:
    the sea-ice impact is stronger, and is associated with more Sahel precipitations

- ΔICE is thus not linear, depending on the concentration in GHG, the impact of a vanishing Arctic sea-ice may strengthens while a continuous warming is projected

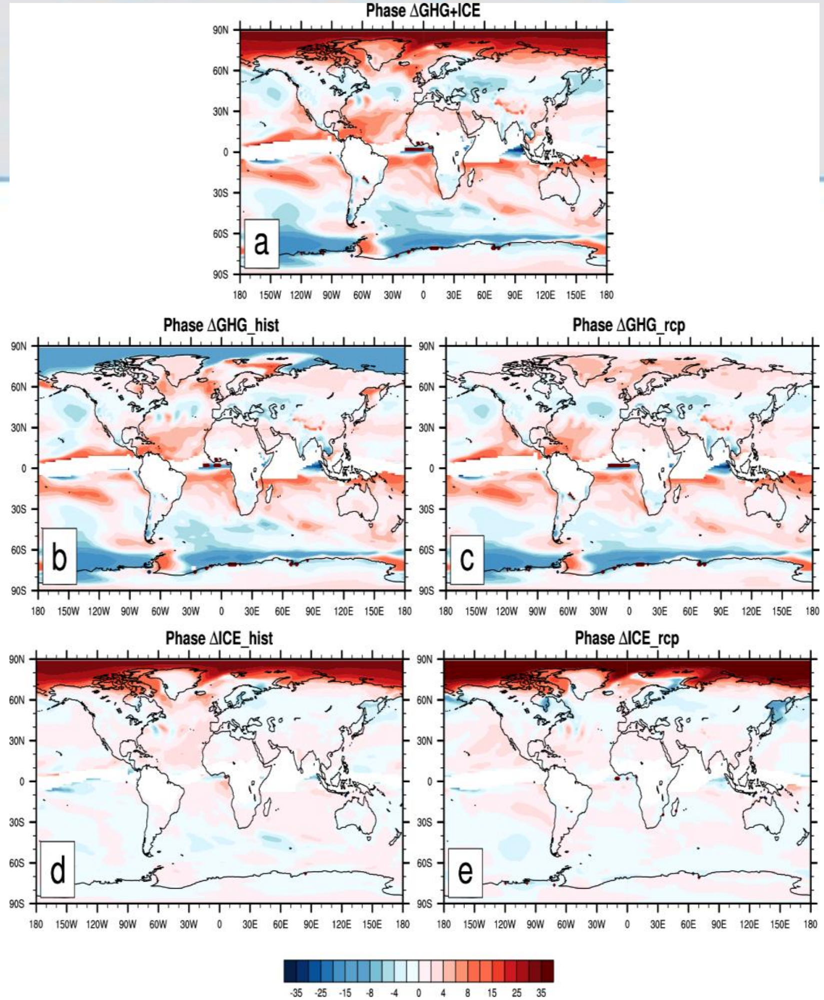
Thank you for your attention



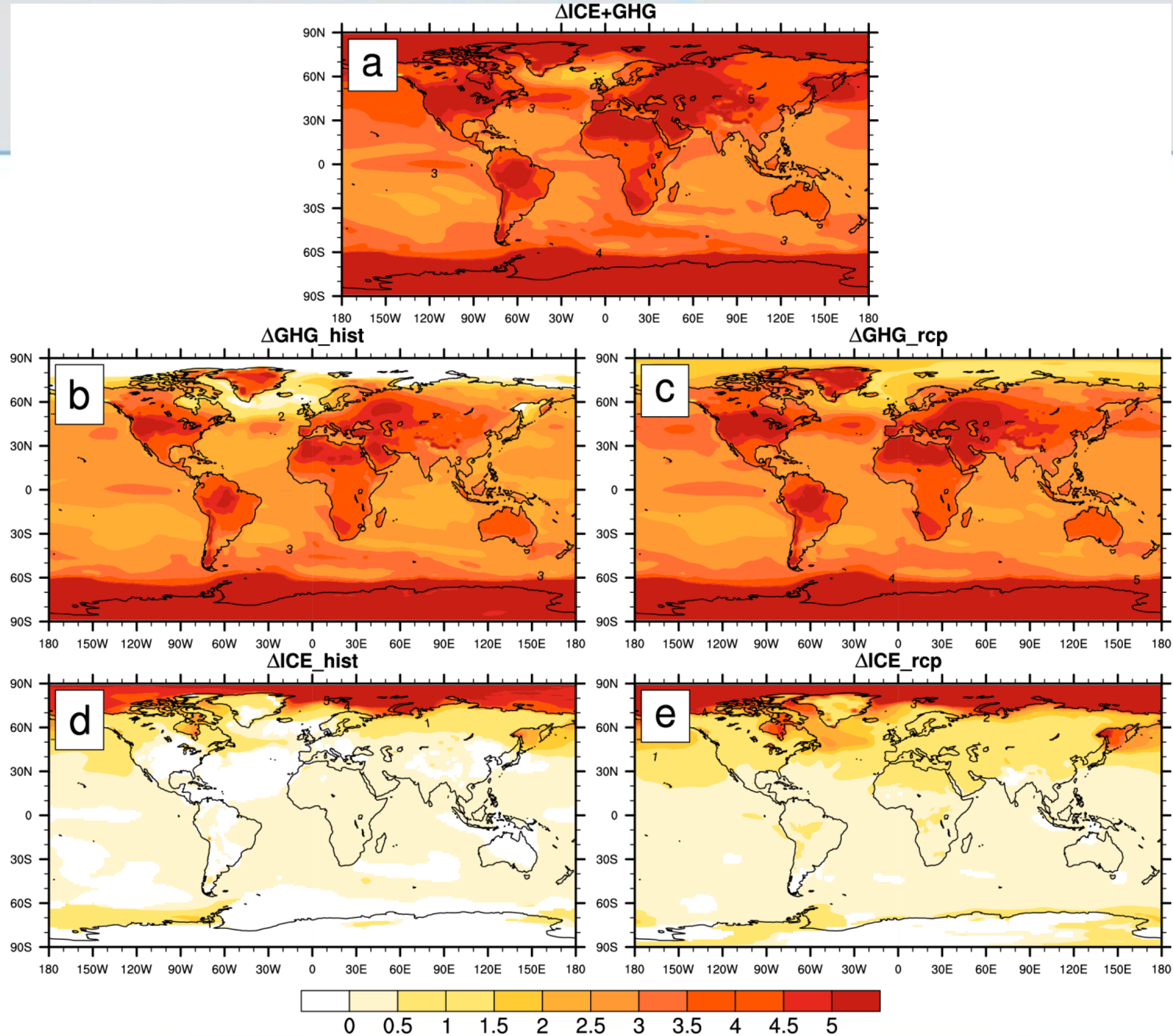
Global meridional heat transport (PW) for ΔICE+GHG (blue line), ΔGHG_hist (discontinuous red line), ΔGHG_rcp (continuous red line), ΔICE_hist (discontinuous yellow line), ΔICE_rcp (continuous yellow line) and for a) the atmosphere and the ocean, b) the atmosphere and c) the ocean.



Air surface temperature difference (color; in °C) for ΔICE_rcp – ΔICE_hist for 3-months period (from March-April-May to September-October-November). The black line indicates the climatology, defined as the ΔICE_hist mean. Continuous (discontinuous) lines indicate positive (negative) value of sea level pressure. Stippling indicates statistically significant value in regard to a Student *t* test at a 95% confidence level.



Annual Air surface temperature phase change for a) ΔICE+GHG, b) ΔGHG_hist, c) ΔGHG_rcp, d) ΔICE_hist and e) ΔICE_rcp. We used Fourier transformation of the data and obtained the annual harmonic of air-surface temperature. We only represent the location where the annual component explains at least 80% of the total variance of the temperature cycle. The temperature phase is computed relative to the local insolation phase (from the incoming surface shortwave flux) to ensure that the phase anomaly is


ΔICE+GHG
a
ΔGHG_hist
b
ΔGHG_rcp
c
ΔICE_hist
d
ΔICE_rcp
e
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

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