The seasonal cycle of the Arctic Ocean in a summer ice-free climate : changes and driving processes

Camille Le Gloannec[1], Rym Msadek[1], Camille Lique[2]

[1]CECI, Université de Toulouse, CERFACS/CNRS/IRD, Toulouse, France

[2]Laboratoire d'Océanographie Physique et Spatiale (LOPS), Ifremer, Brest, France

legloannec@cerfacs.fr

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Annex : Mixed layer budget equation

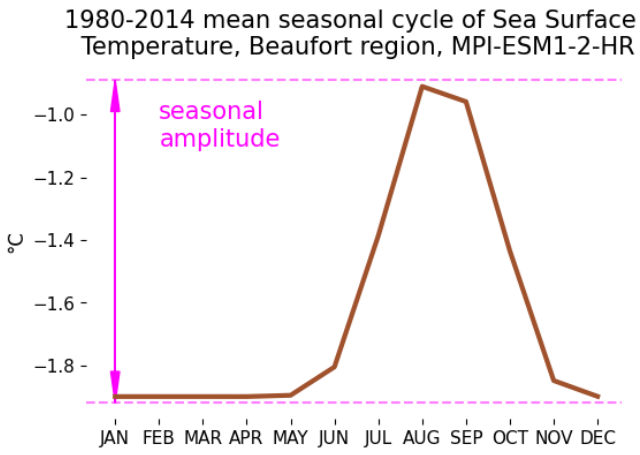
$$\underbrace{\frac{\partial \langle S \rangle_{\mathrm{ML}}}{\partial t}}_{\text{S tendency}} = \underbrace{-\frac{F_{\text{mass water}} \langle S \rangle_{\mathrm{ML}}}{\langle \rho \rangle_{\mathrm{ML}} h_{\mathrm{ML}}}}_{\text{surface forcing}} \underbrace{-\langle \mathbf{u} \rangle_{\mathrm{ML}} \nabla \langle S \rangle_{\mathrm{ML}}}_{\text{horizontal advection}} \underbrace{+\kappa_H \nabla^2 \langle S \rangle_{\mathrm{ML}}}_{\text{horizontal diffusion}} \underbrace{-\frac{\kappa_z}{h_{\mathrm{ML}}} \left. \frac{\partial S}{\partial z} \right|_{z=h_{\mathrm{ML}}}}_{\text{vertical diffusion}}$$

$$\underbrace{-\frac{\langle S \rangle_{\mathrm{ML}} - S_{z=h_{\mathrm{ML}}}}{h_{\mathrm{ML}}} \left(\underbrace{\frac{\partial h_{\mathrm{ML}}}{\partial t}}_{\text{ML tendency}} + \underbrace{\mathbf{u}_{z=h_{\mathrm{ML}}} \nabla h_{\mathrm{ML}}}_{\text{lateral induction}} + \underbrace{w_{z=h_{\mathrm{ML}}}}_{\text{vertical advection}} \right)}_{\text{entrainment in the ML}}$$

Annex : CMIP6 variables

sos	sea surface salinity	psu
so	sea water salinity	psu
mlotst	ocean mixed layer thickness defined by sigma-t	m
uo	sea water x velocity	$m.s^{-1}$
vo	sea water y velocity	$m.s^{-1}$
wfo	net flux of liquid water entering the liquid ocean	$kg.m^2.s^{-1}$
hfds	net surface downward heat flux at sea surface	$W.m^{-2}$

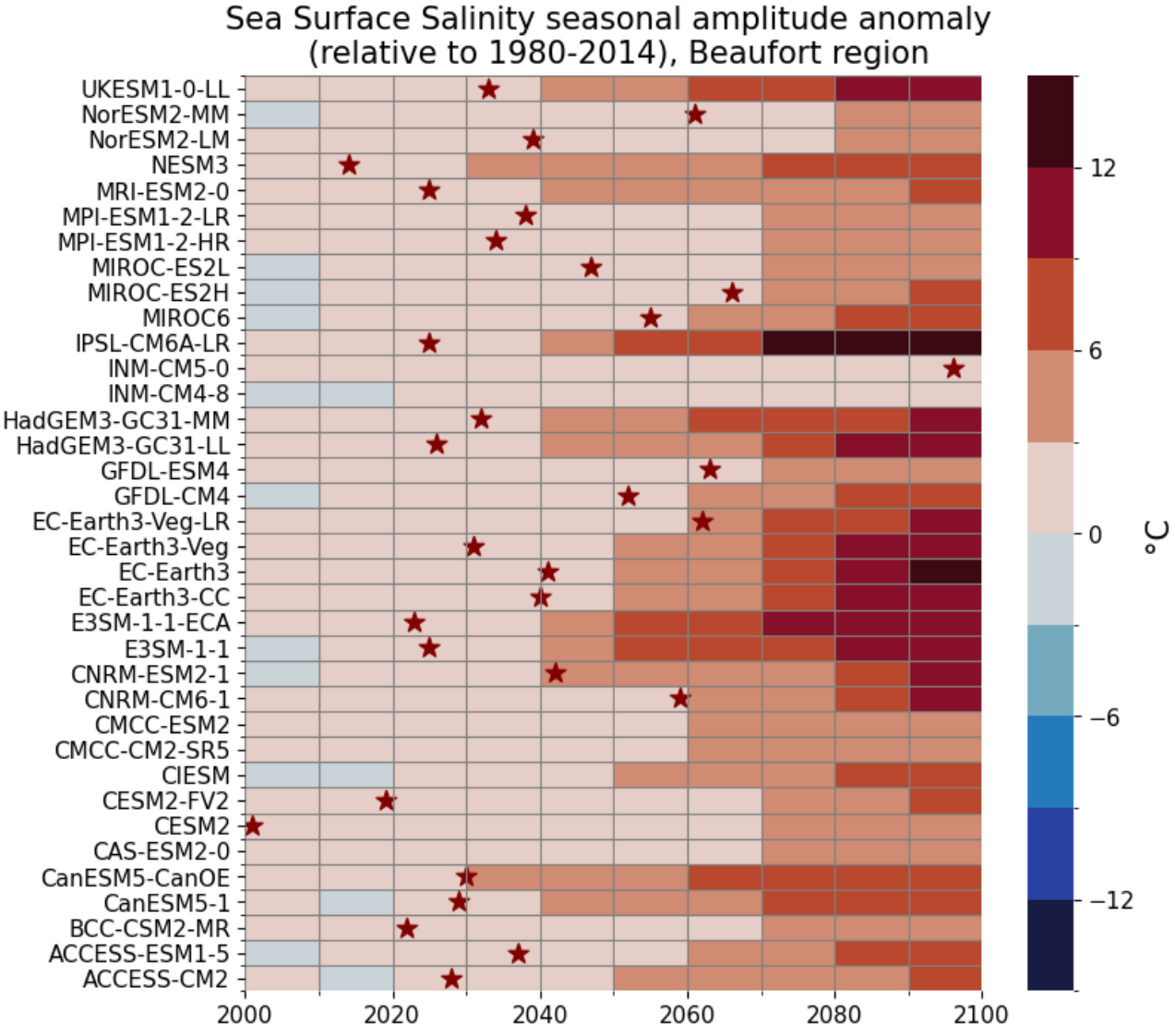
Annex : how does the sea surface temperature seasonal cycle change in the Beaufort region ?



CMIP6 models project :

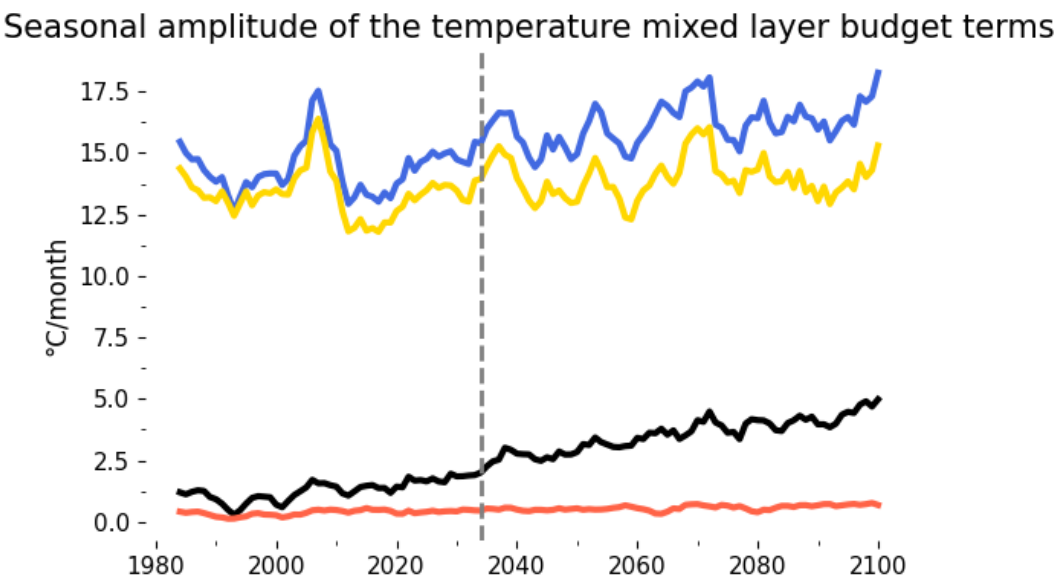
- A summer ice-free Beaufort region in the next decades.
- An intensification of the SSS seasonal cycle, after the loss of summer sea ice.

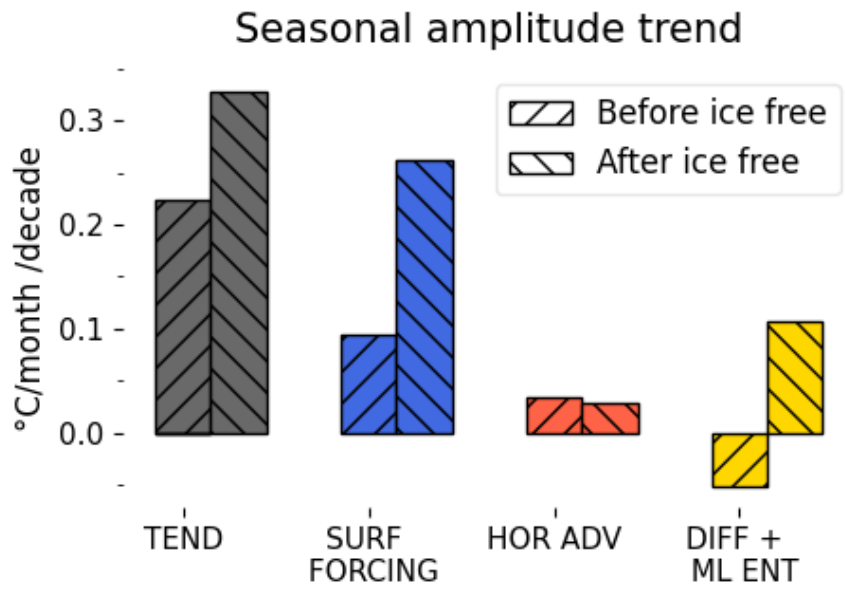
★ = first year of september ice free conditions



Annex : salinity mixed layer budget in the Beaufort region for the MPI model

TEMPERATURE TENDENCY = SURFACE FORCING (dominated by SW flux) + HORIZONTAL ADVECTION + DIFFUSION + ML ENTRAINMENT



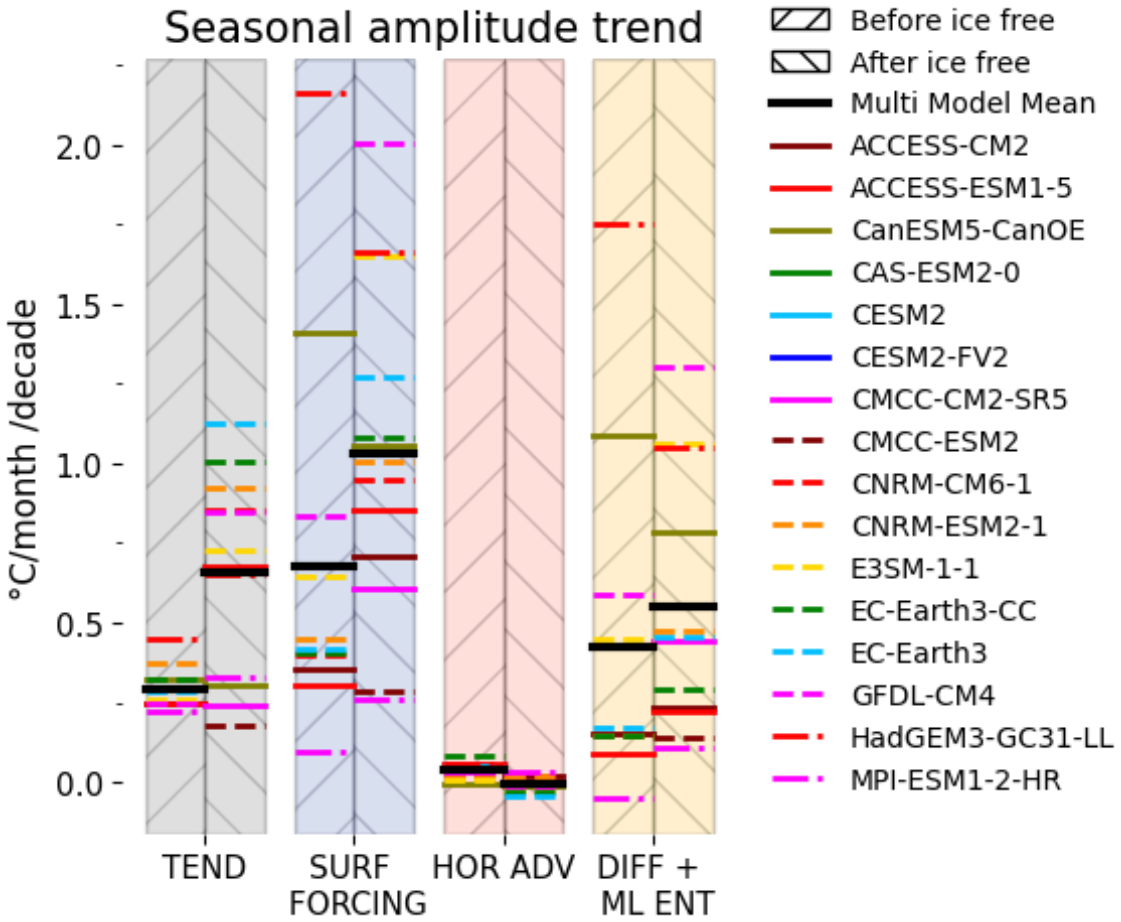


The increase in SST seasonality is due to :

- An increase in **surface forcing** and **diffusion + mixed layer entrainment** seasonality...
- ...amplified once the region is **september ice-free**.

Annex : temperature mixed layer budget trends in the Beaufort region in CMIP6 models

TEMPERATURE TENDENCY = SURFACE FORCING (dominated by SW flux) + HORIZONTAL ADVECTION + DIFFUSION + ML ENTRAINMENT

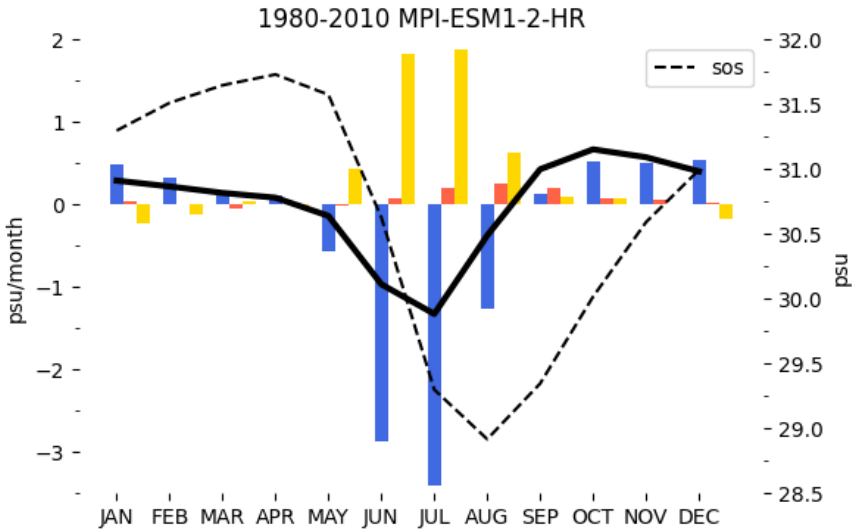


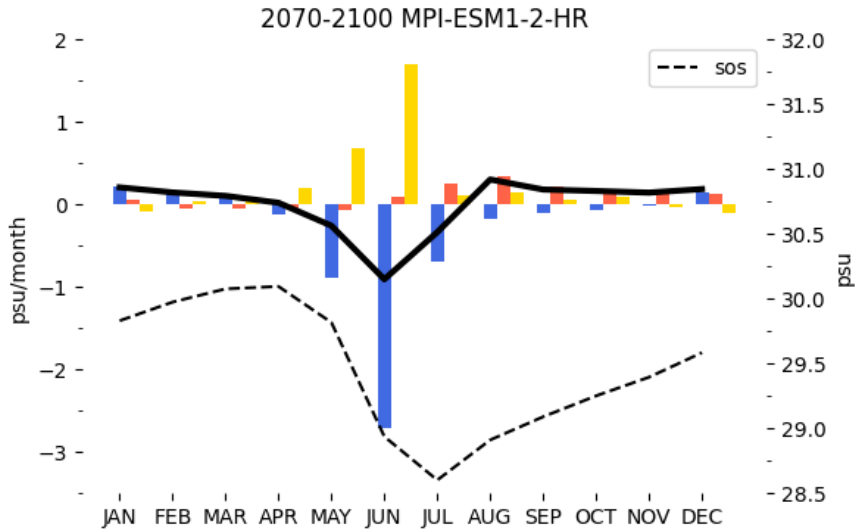
Coherent picture across CMIP6 models :

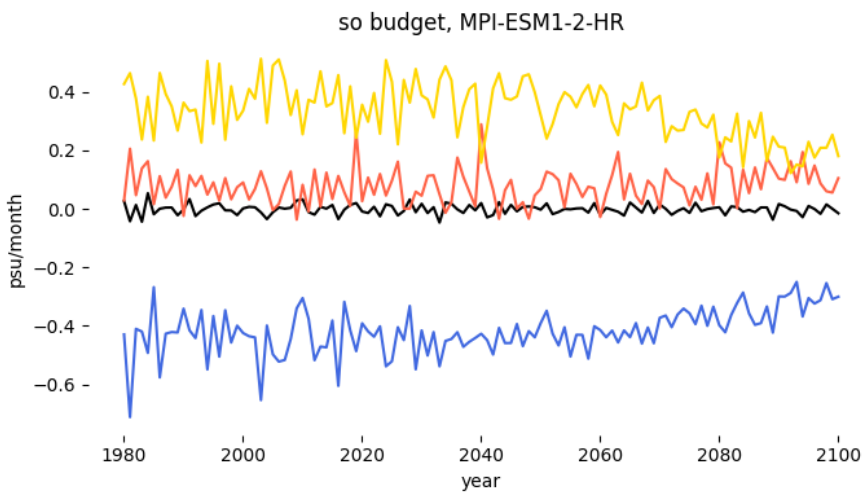
- **Robust increase** of the surface forcing and diffusion + mixed layer entrainment seasonality.
- Weak changes of the horizontal advection seasonality.

Annex : salinity mixed layer budget seasonal cycle and annual mean for the MPI model

SALINITY TENDENCY = SURFACE FORCING (dominated by SEA ICE + HORIZONTAL ADVECTION + DIFFUSION + ML ENTRAINMENT







Annex : temperature mixed layer budget seasonal cycle and annual mean for the MPI model

TEMPERATURE TENDENCY = SURFACE FORCING (dominated by SW flux + HORIZONTAL ADVECTION + DIFFUSION + ML ENTRAINMENT