Improving the river outflow coupling in a global climate model

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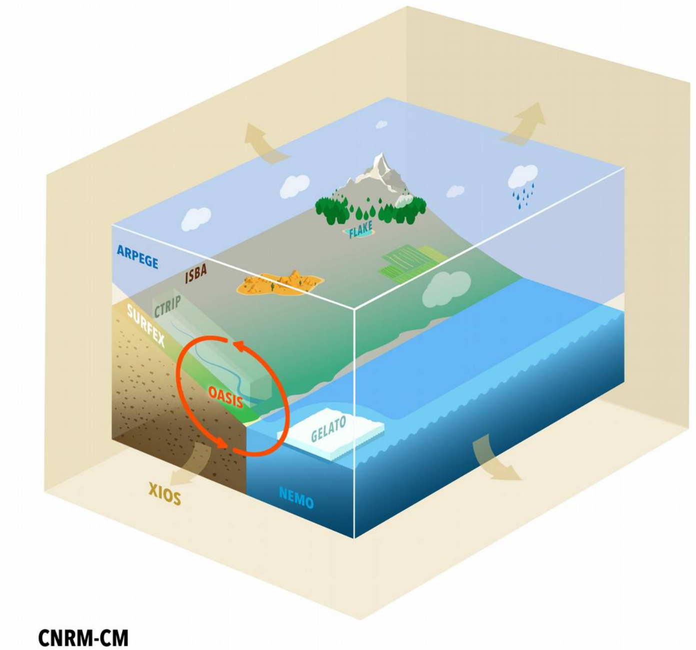
Background / Problematic



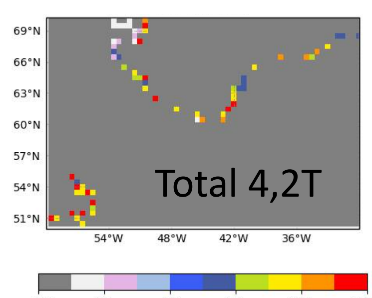
- CNRM-CM6-1 : the CMIP6 version of climate model developed by CNRM and Cerfacs (*Voldoire et al., JAMES, 2019*)
- Coupled components : Atmosphere-Land-River-Ocean-SeaIce

- The coupling is done through OASIS3-MCT (*Craig et al., GMD, 2017*).
  - Coupling interpolation between components has been designed to be the simplest as possible to ease any resolution change in model components (ie use existing OASIS interpolation types)
  - BUT: there was no appropriate interpolation method for river outflow to ocean coupling, we used what was available

    → the river outflow was conserved globally but not regionally

Example over the Labrador Sea / south Greenland region

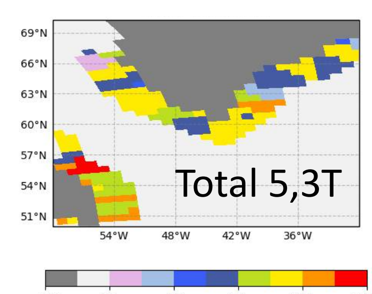
River model outflow



Interpolation

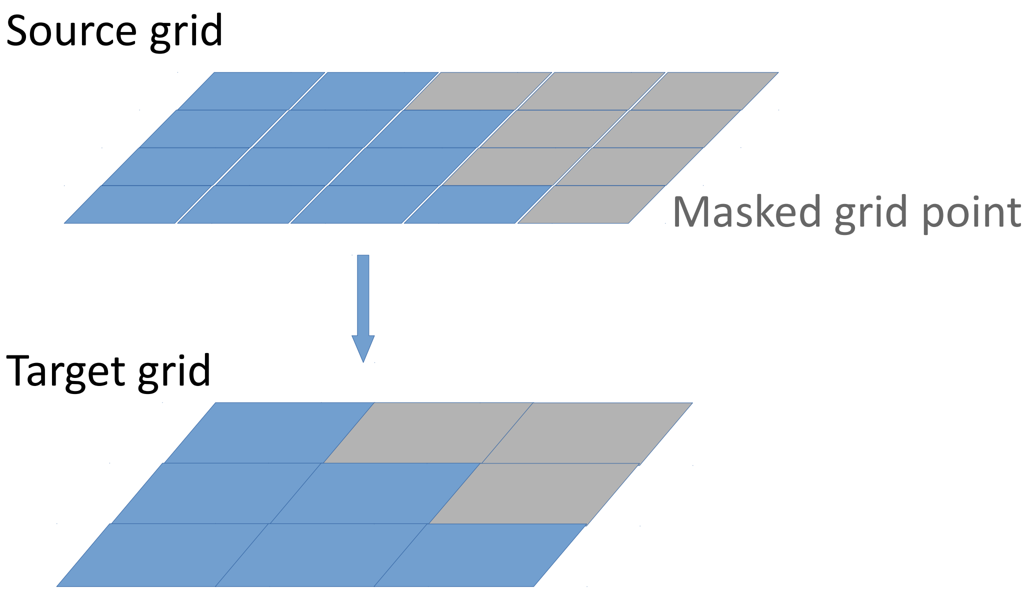
Distance weighted
+
Global conservation

Ocean model river runoff



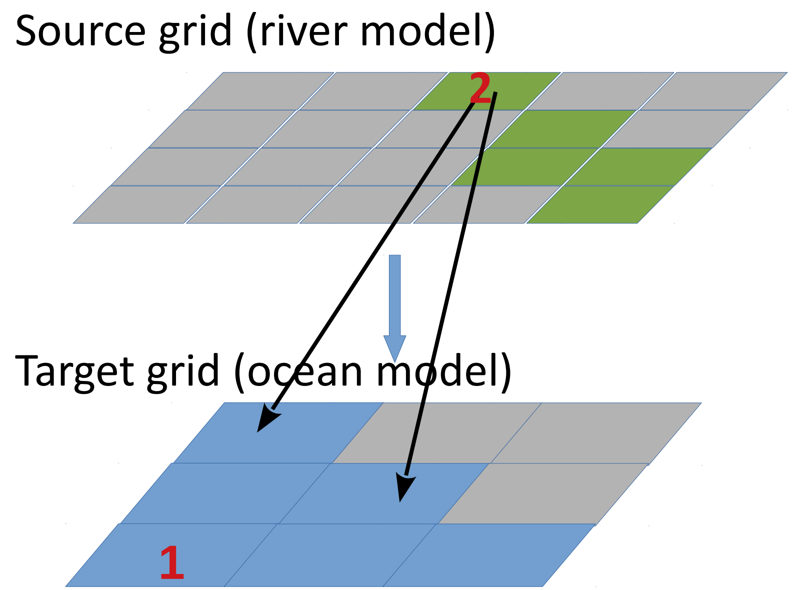
Why existing interpolation methods in OASIS are not appropriate for river outflow interpolation to ocean?

General case



In general, the objective of the interpolation is to get a value on each unmasked target grid point
This is the general point of view in OASIS

River outflow to ocean case



In the river outflow case,

- unmasked target grid points may not receive any flow (case grid point **1**)
- the source grid points are not geographically "over" the target grid points (case grid point **2**)

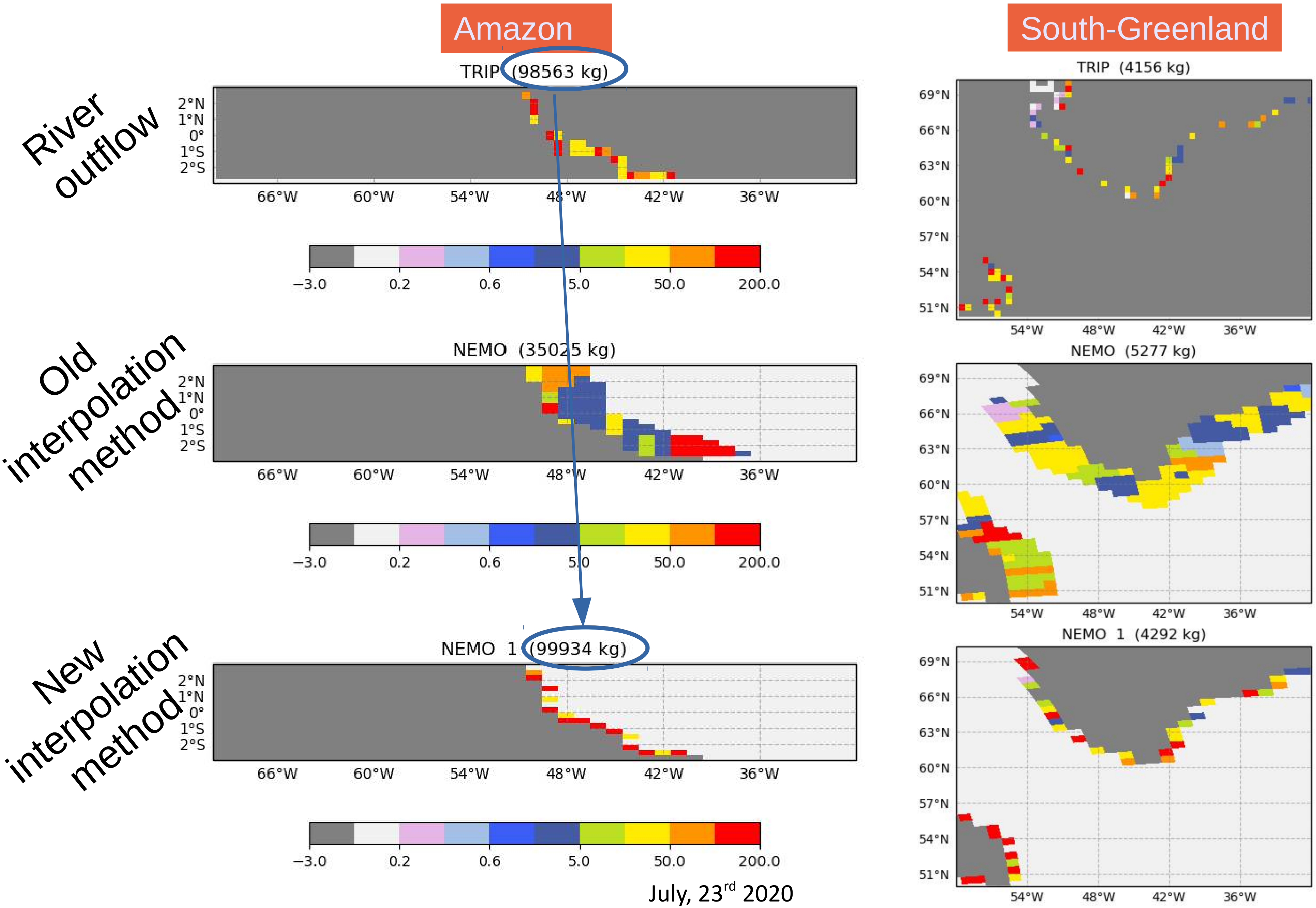
New interpolation method

- For each source grid point, look for the closest target grid point
  - = the oasis nearest neighbour interpolation from the target grid to the source grid
  - = take the reverse interpolation links
    - ✗ take the weights file for an Ocean → River nearest neighbour interpolation
    - ✗ calculate new weights to conserve flux locally, for a given ocean grid point :

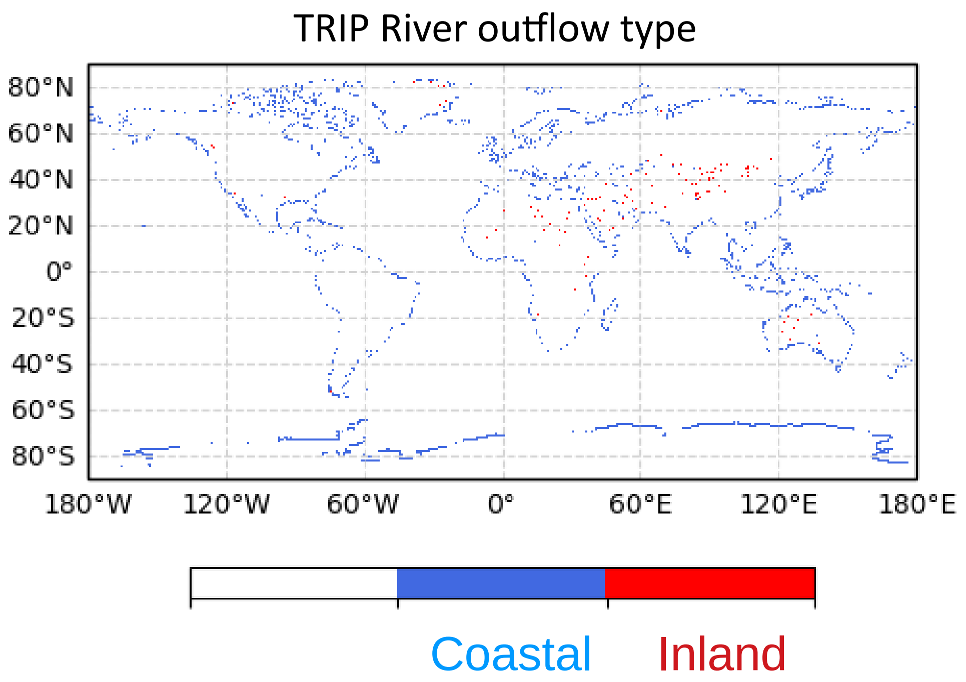
$$F_{ocean} = \sum_i ww_i F_{river}(i) \quad \text{where} \quad ww_i = \frac{area_{river}(i)}{area_{ocean}}$$

- NB:
  - ✗ This can be extended to an interpolation with n-nearest neighbours.
  - ✗ Easy to implement, links are already calculated in OASIS

New interpolation method



Second improvement



- Not all TRIP river outflow are at the coast
- For **coastal** grid points, the nearest ocean point is close

  → ok

- For **inland outflow,** the nearest ocean grid point is far

  → not physical to spread water on one distant ocean grid point

  → must take these river outflow into accound otherwise the water mass budget is not closed in the model

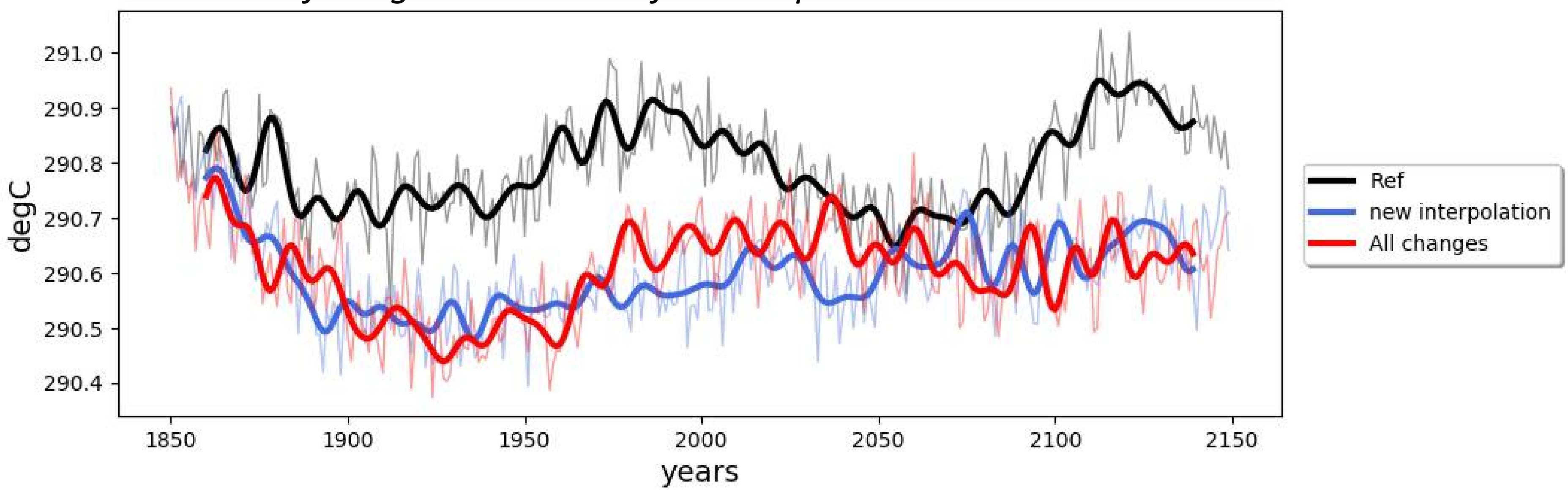
- <u>Solution proposed</u> : spread the runoff from inland outflow over the whole ocean surface = small uniform quantity

Sensitivity experiments performed

- **Ref** : reference experiment is the CMIP6 piControl simulation (forcings fixed to their preindustrial values)
- **New interpolation** : new interpolation method using **1** neighbour
- **All changes,** all recent developments gathered :
  - New interpolation method using **1** neighbour
  - Separate treatment for inland outflow
  - Land-sea mask of ocean and atmospheric model in better agreement

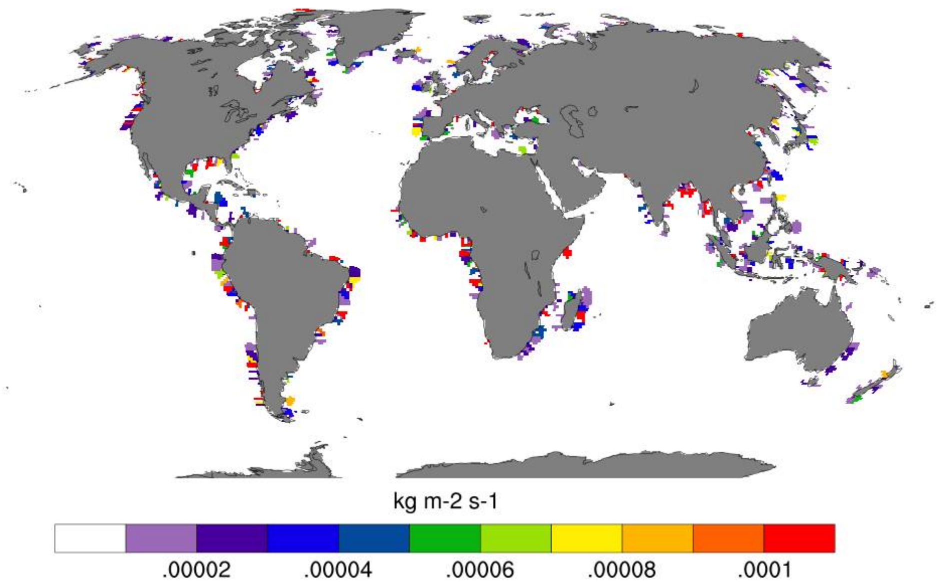
250 years of integration

Evolution of the global mean surface temperature

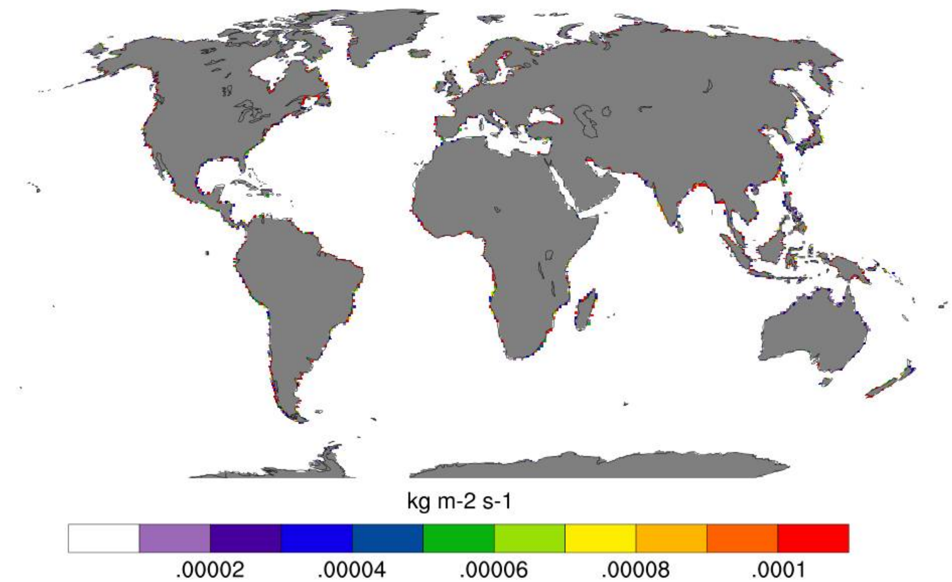


Runoffs in the ocean (moy 1900-1949)

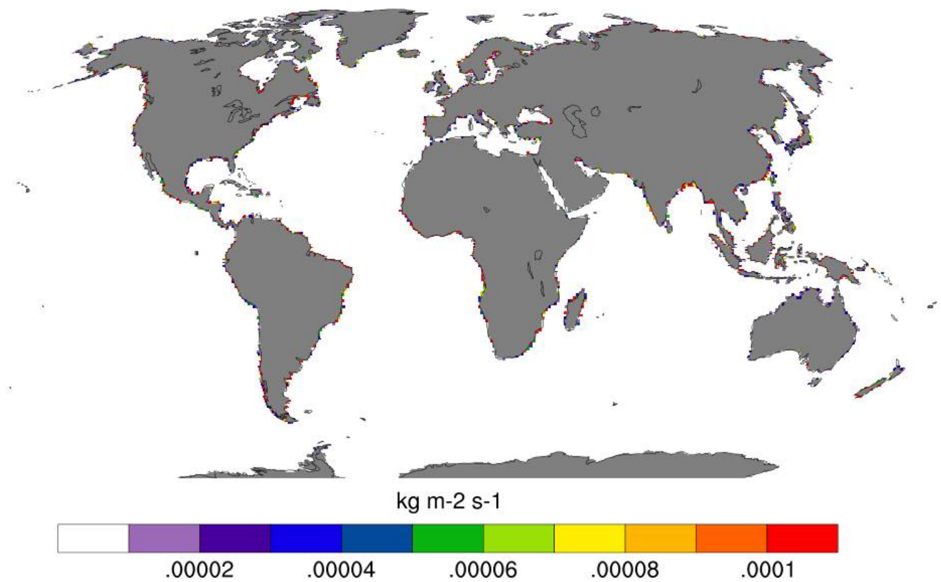
Ref



New interpolation

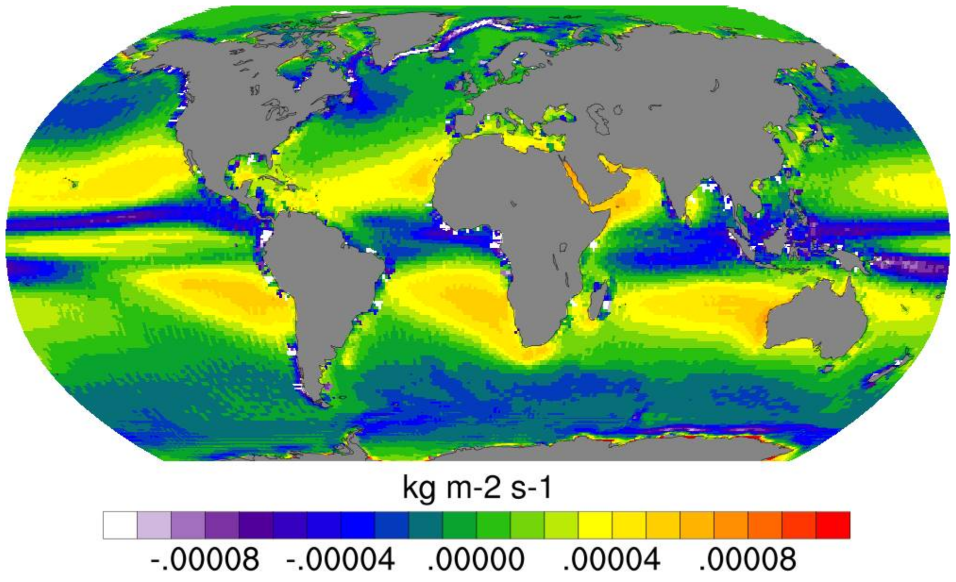


All changes

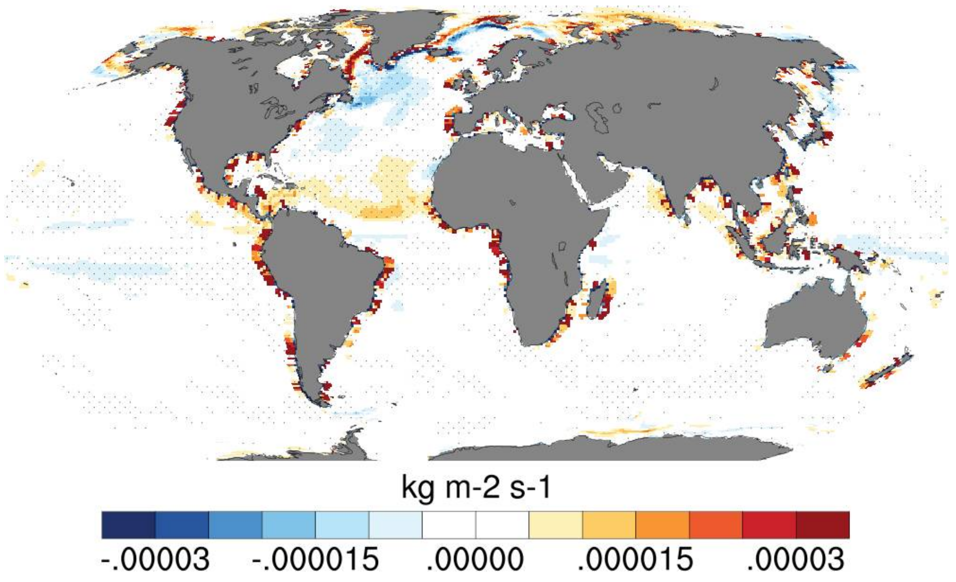


Net water flux from the ocean (moy 1900-1949)

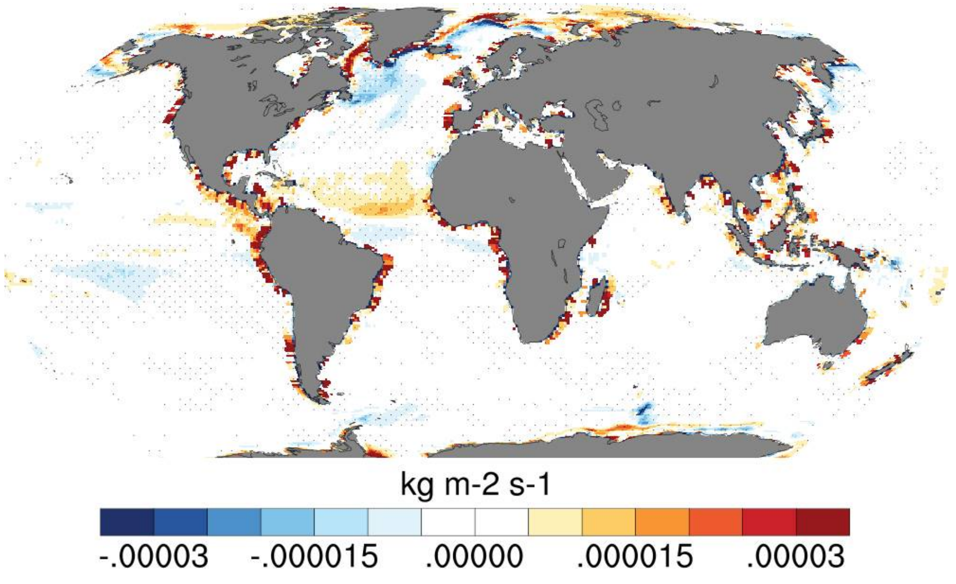
Ref



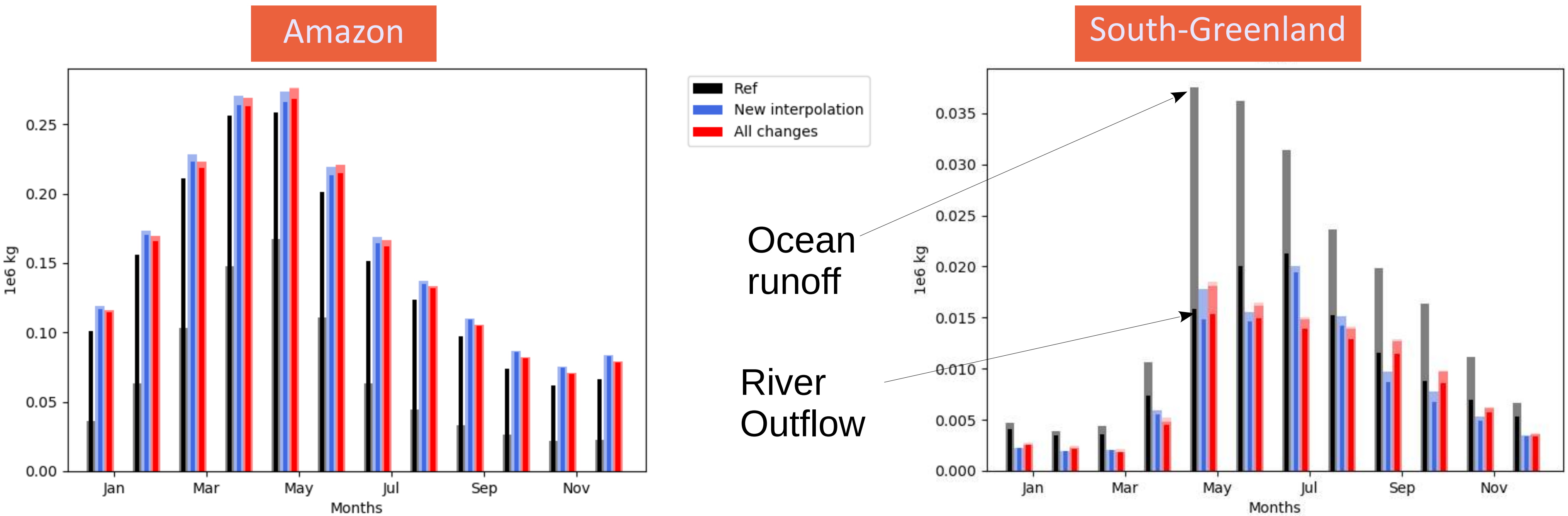
New interpolation - Ref



All changes - Ref



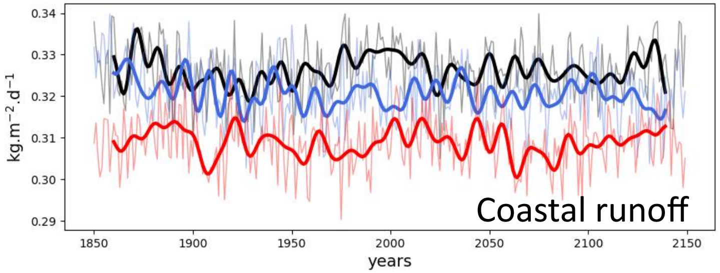
Outflow regional budget

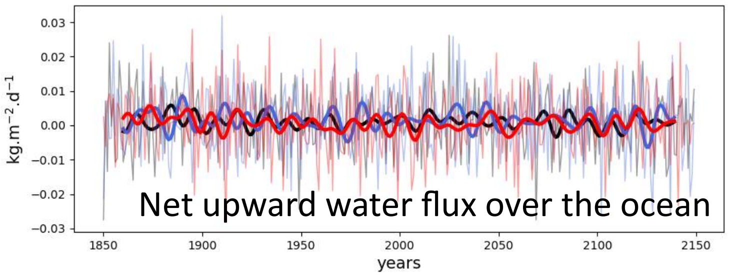


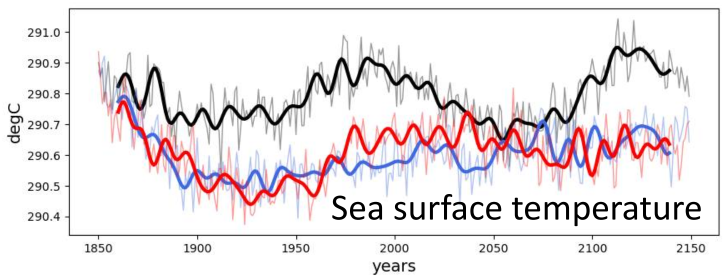
Mean annual cycle of river runoffs averaged over years 1900-1949 for each simulation and for 2 regions. For each simulation, the dark color bar indicate the river outflow and is superposed on the light color bar which represents the runoff received over the ocean.

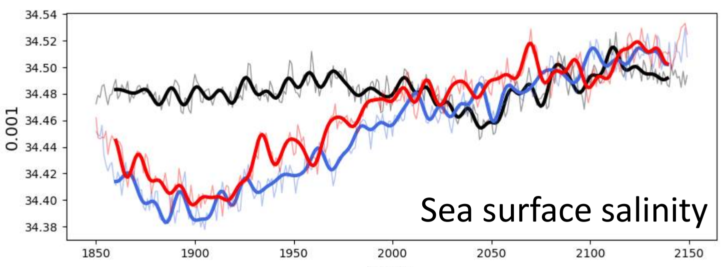
- Confirm the regional conservation whatever domain is considered

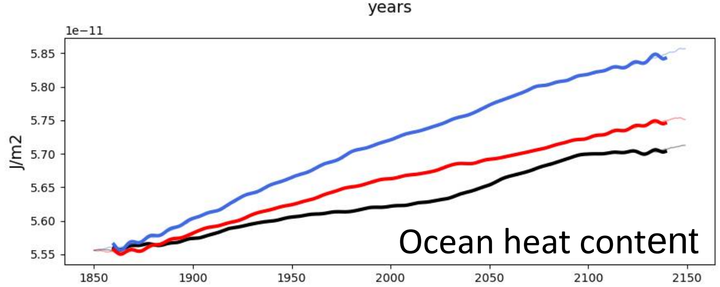
Global impacts



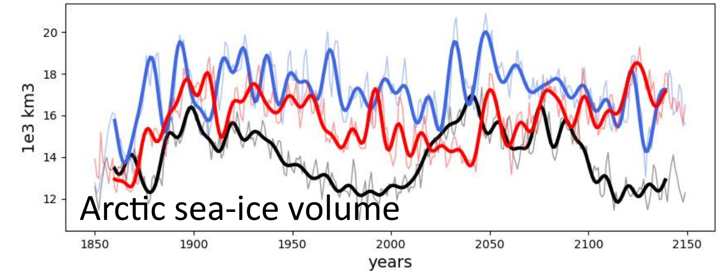


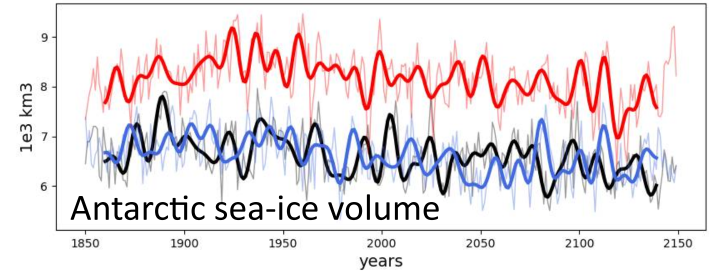


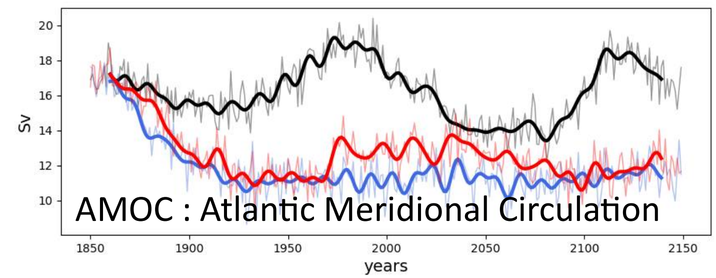


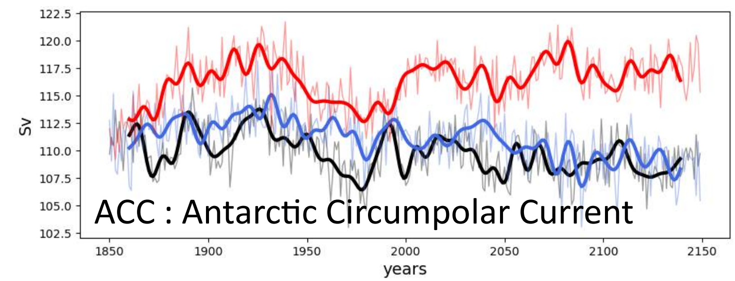


Global annual mean (thin lines) and high-pass filtered time-series (thick lines)







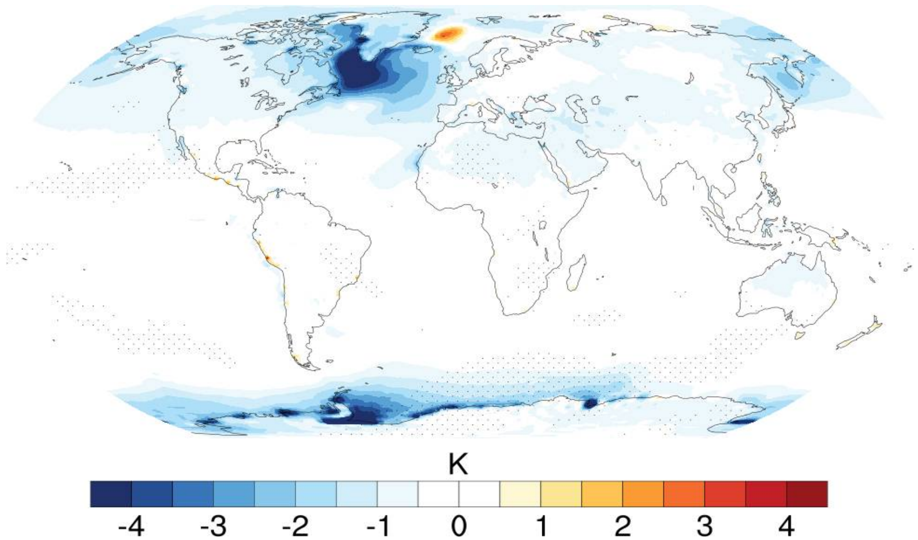


- ✗ Strong perturbation of the mean climate
- ✗ Takes 150 years for surface salinity to stabilize
- ✗ Increase in Arctic sea-ice for both experiments
- ✗ Increase in Antarctic sea-ice for the « All changes » experiment.
- ✗ Change in sea-ice impacts the large-scale ocean circulation, ie reduction in AMOC and increase in ACC

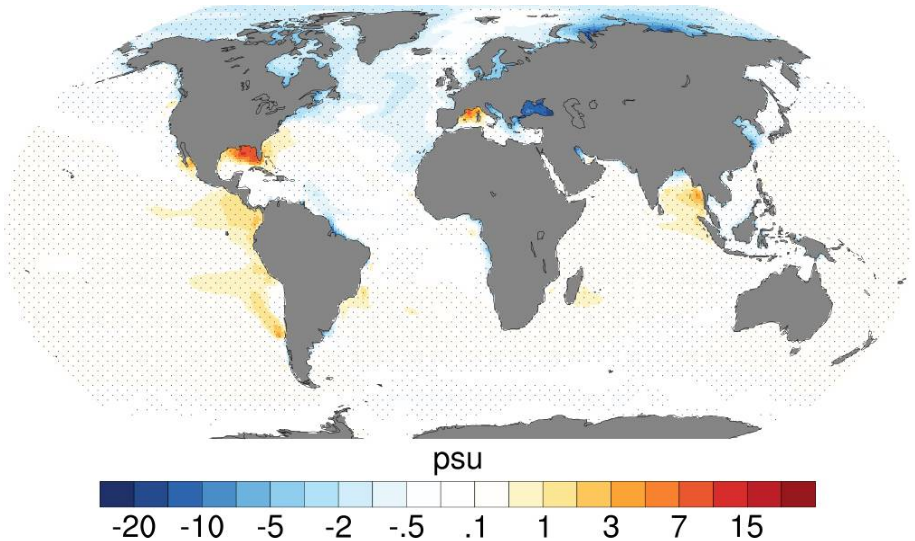
Regional impacts

Mean difference ***All Changes*** *–* ***Ref***
averaged over the last 50 years

Near surface temperature



Ocean surface salinity



- Strong impacts on surface salinity that spread far from the coast
- Strong reduction in surface temperature over high latitudes → Reveals strong sea-ice changes

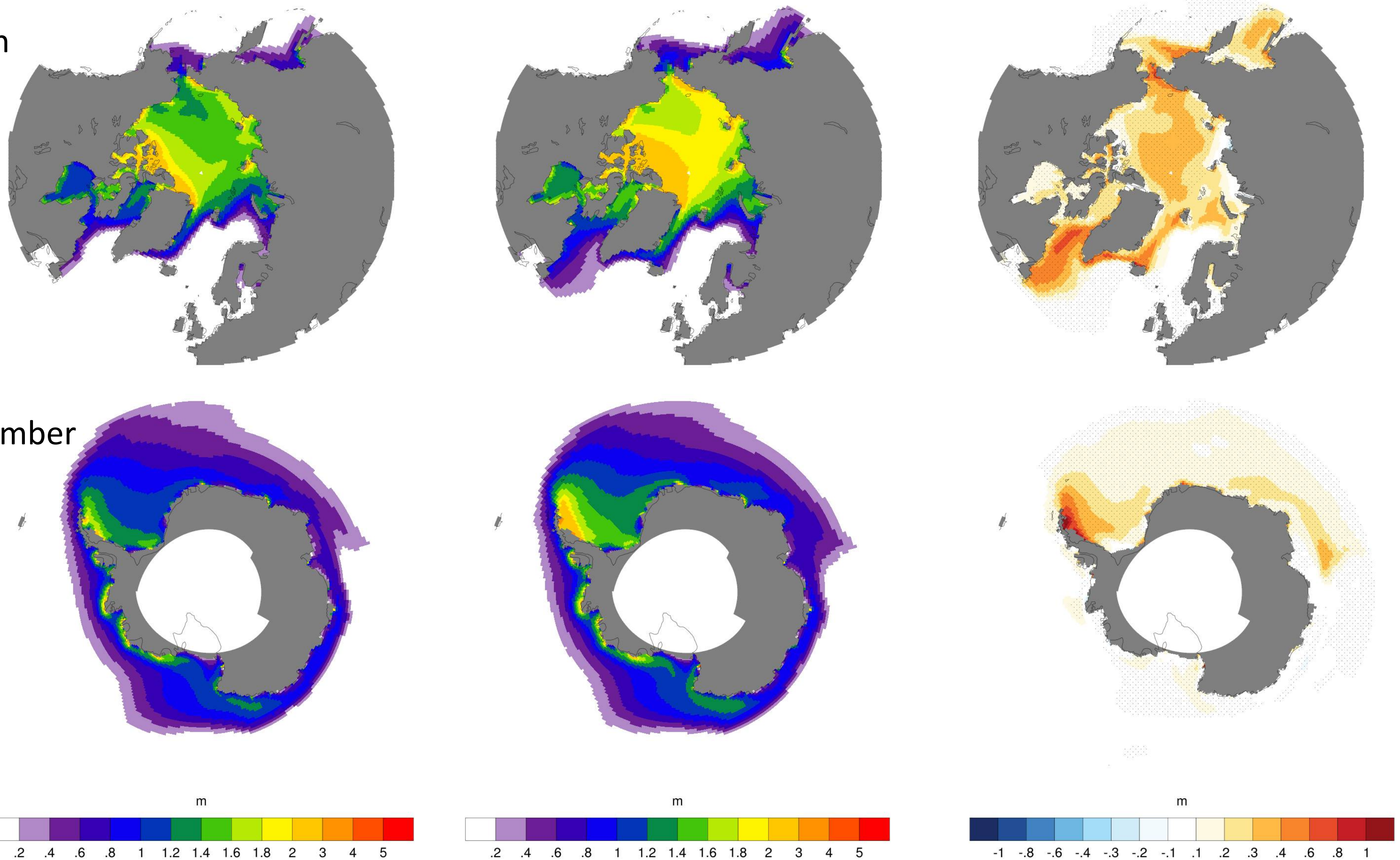
Sea-ice impacts - volume

Averaged over the last 50 years

Ref | **All changes** | **All changes - Ref**

March

September



Conclusions

- Propose a generic method to interpolate river outflow to ocean

  → based on OASIS nearest neighbours from the reverse interpolation
  → just need to re-calculate weights

  This new method **ensure water conservation locally**

- The impact on the model mean climate is important on

  → salinity over high latitudes and closed sea
  → sea-ice cover and volume

  Such changes impact mean ocean mass transport and circulation (AMOC, ACC)

- The new method will be directly available in OASIS in future versions.