# Dynamics of an Antarctic coastal polynya

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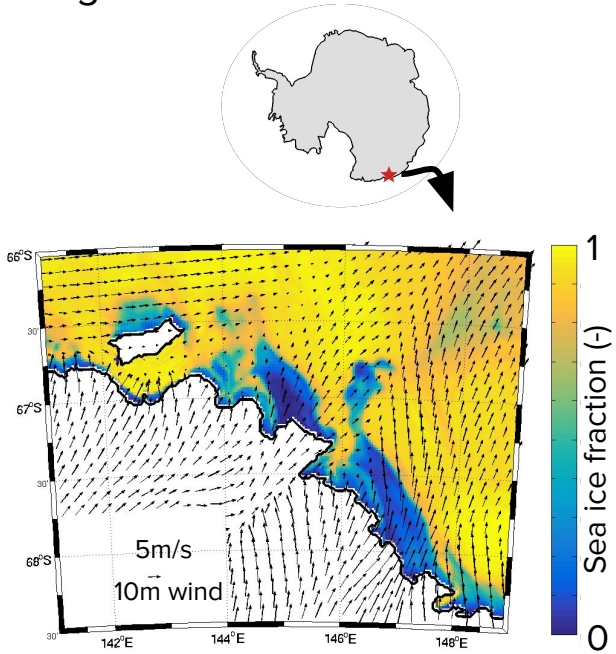
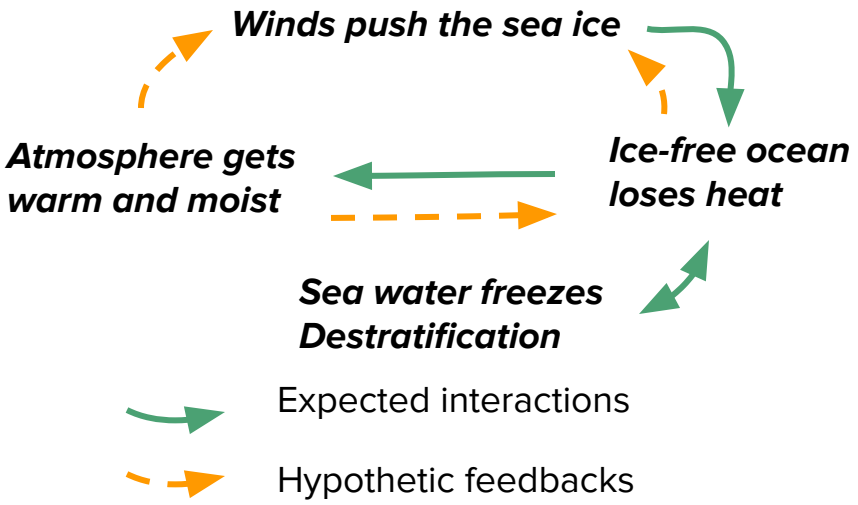
# Overview

With the help of a Regional Climate Model, we simulate the Mertz Glacier Polynya and investigate its interaction with the atmosphere.




*Polynya forced by offshore winds*

Air-sea-ice interactions in a polynya




- How is the atmosphere responding to the polynya activity ?
- How does it affect the polyna in return ?

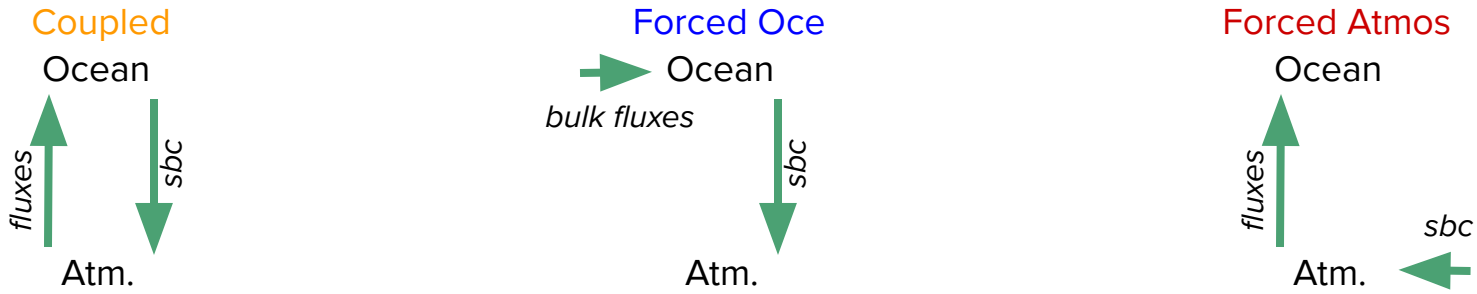
# About the Regional Climate Model*

## Added value of air-sea-ice coupling vs. forcing

Coupling between NEMO-LIM (Ocean) and MAR (Atmosphere)
- Knowledge of the atmosphere state for flux computation
- High frequency (10mn) and high resolution boundary conditions (1/24° Ocean - 10 km Atm.)
- Feedbacks !

## Methodology

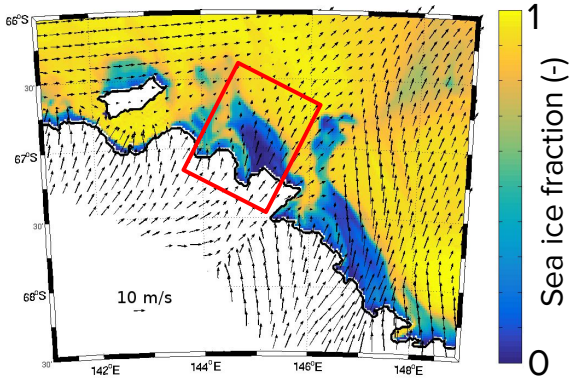
Test the sensitivity of air, sea and ice to changes in surface boundary condition and to the interactions between ocean and atmosphere:

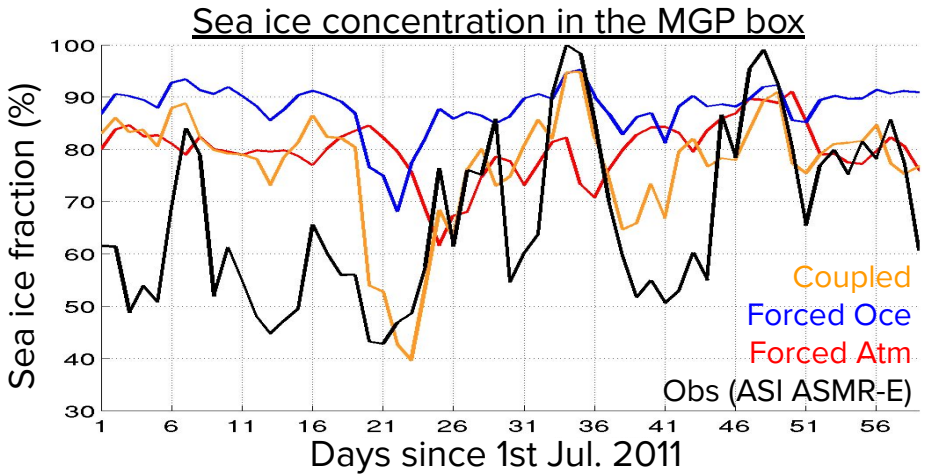



* see slide 11 for technical details

# How is the coupling affecting the polynya ?

Simulations of the MGP in winter 2011 (post-calving condition) in coupled and forced mode (both ocean and atmosphere).




Forced vs. coupled:
- different method for fluxes
- change in mean state
- feedbacks

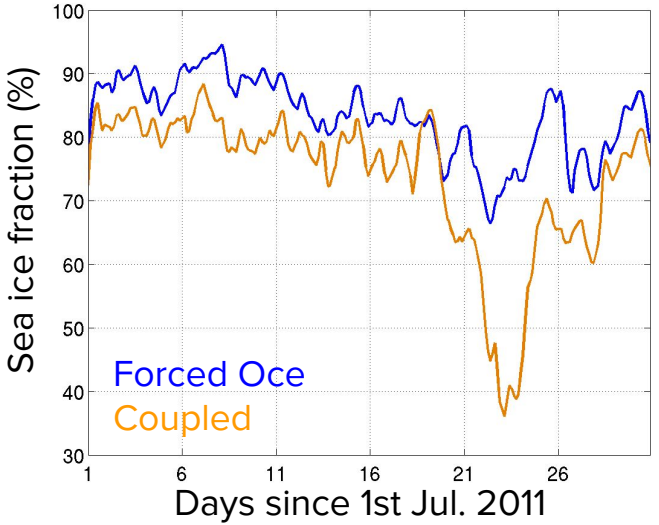
MGP activity underestimated in forced mode
- forced ocean does not open polynya
- MGP absent from ERAint reanalysis

Coupled model offers better agreement with obs. !

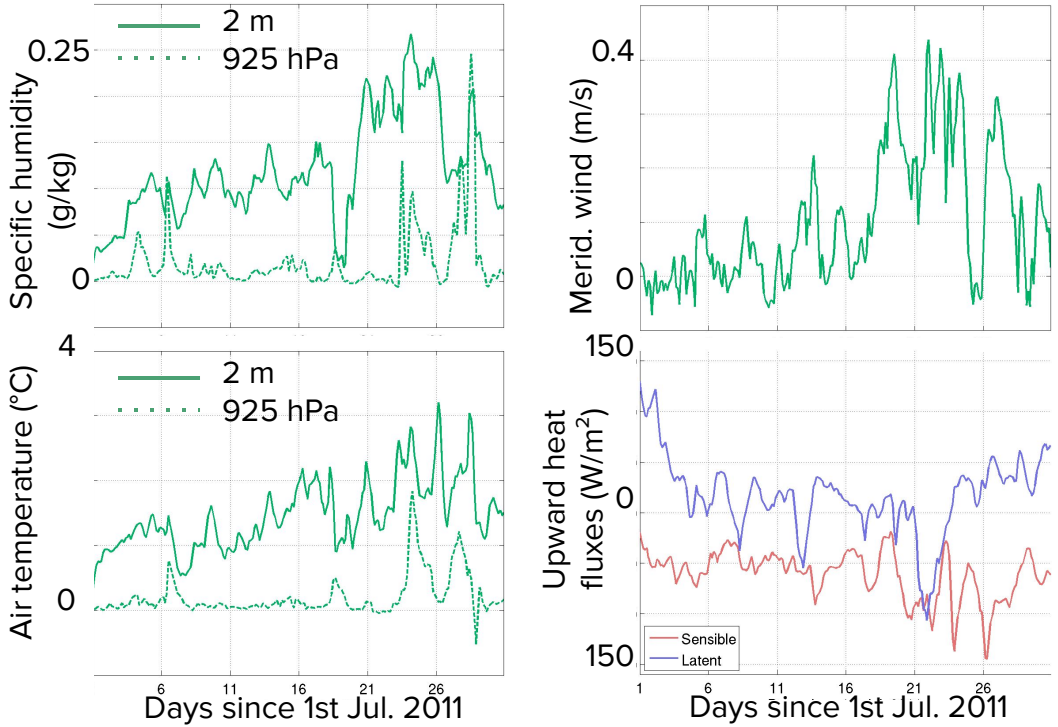
# Sensitivity of the atmosphere to the polynya

The atmosphere ‘sees’ a polynya in coupled, but not in forced oce.

Sea ice state in Coupled and Forced




Atmosphere state above the MGP: Coupled - Forced Oce




=> During the polynya +5% wind - +2 °C - +30% spec. humidity

# Looking for feedbacks

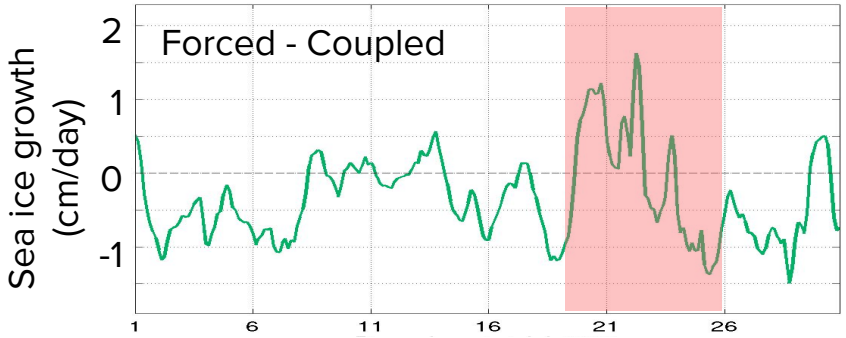
How to detect feedbacks (1) ?

The atmosphere ‘sees’ a polynya in coupled, but not in forced atm.

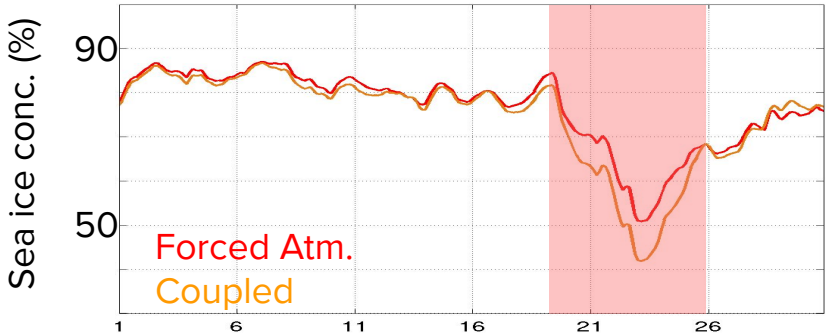
Ocean-ice response:
the polynya is larger in coupled, but the total sea ice production is similar to forced.

- Polynya extent =/= polynya production ?
- What is limiting the freezing ?
  Lower air-sea fluxes vs. ocean heat flux

Effect of atmosphere warming above the polynya
Coupled (polynya) vs. Forced Atm. (no polynya)




Beginning of polynya, Forced has higher sea ice growth rate. In response: smaller polynya area ?



# Looking for feedbacks

How to detect feedbacks (2) ?

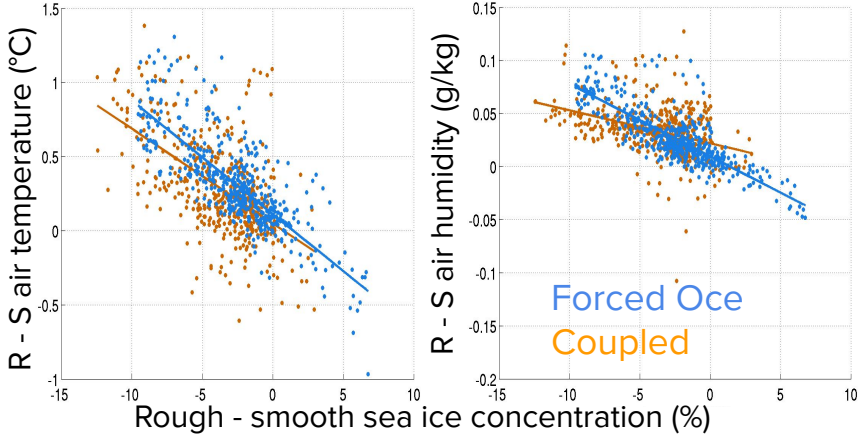
Apply the same perturbation to the coupled and forced oce simulations
Increase sea ice roughness* (‘R’ exp) vs classic (‘S’ exp) to stimulate the polynya activity.

* Coupled: $z0_S$ = 0.02, $z0_R$ = 0.2 cm
  Forced: $Cd10_S = 1.4\ 10^{-3}$, $Cd10_R = 2.4\ 10^{-3}$

Increasing sea ice roughness in the atmospheric model also reduce near surface winds …

⇨ Weaker atmospheric response in coupled

Distinct response of the atmosphere to increase in polynya activity if feedbacks are present:



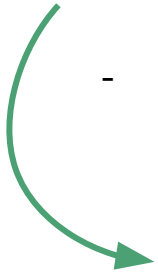

The warming and moistening effect of the polynya on the atmosphere appears to be dampened in coupled.

# Conclusions

We have developed a regional climate model to study air-sea-ice interactions in East Antarctica. We use it to simulate the dynamics of the Mertz Glacier Polynya.

Standalone forced ocean and atmosphere underestimate the polynya activity, the coupled model has a lower bias.

- Air temperature rise by 2-3°C and humidity by 30% above the polynya. This effect can be felt at 925 hPA above the polynya. Winds are almost not affected above the polynya.
- In absence of atmospheric response to the polynya, sea ice growth rate is higher and polynya extent larger.
- Artificially increasing the polynya activity leads to distinct response of the atmosphere in coupled and forced ocean mode.



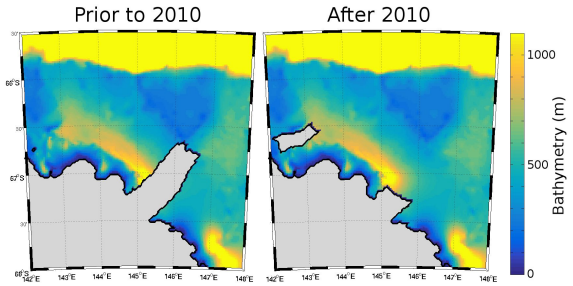
Negative feedback ?
Implications for the interpretation of 1) forced simulations 2) satellite products 3) ...

# Future work

## Effect of the Mertz calving

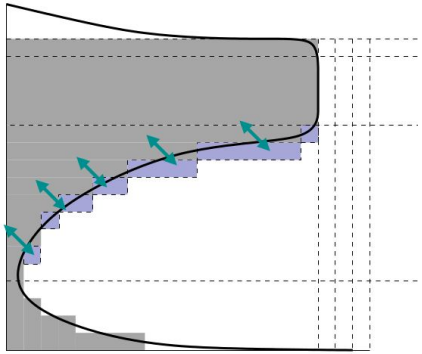
How does the atmosphere responds to a bigger polynya ?

How does air-sea-ice interactions change the response of the MGP to the calving ?




## Response of the ocean

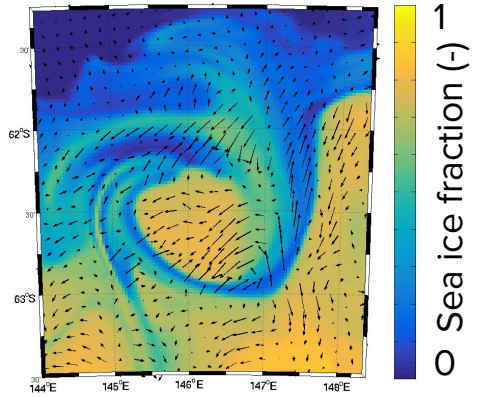
How is the Mertz glacier impacted by the polynya activity ?
What is the impact of Ice Shelf Melt Water (cold and fresh) or Circumpolar Deep Water (warm and saline) on the polynya activity ?



*Scheme of the ocean-ice shelf interactions, adapted from NEMO book 3.6*

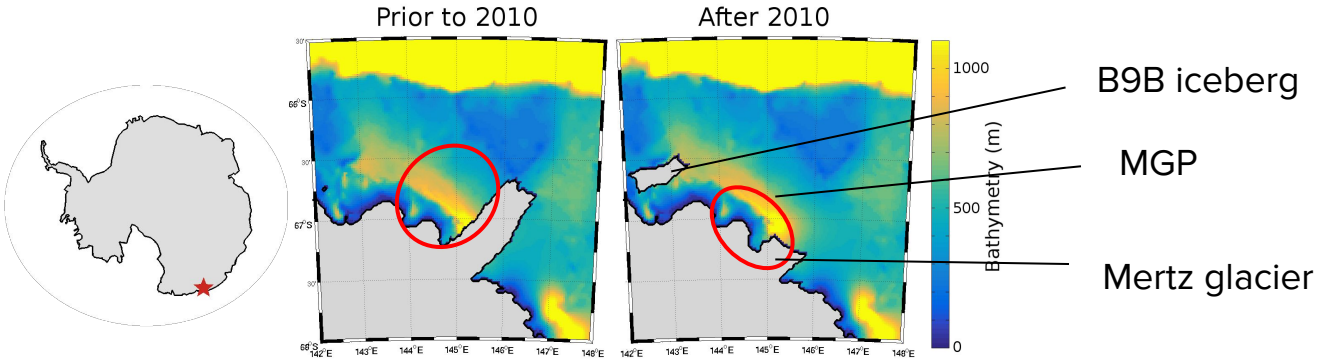
## Air-sea-ice interactions at the mesoscale

How does the atmosphere ‘feels’ eddies in polar regions ?
Is there an ‘Eddy killing effect’ in presence of sea ice ?




*High-pass filtered wind above swirls of sea ice*

# SM1: About the Mertz Glacier Polynya




*The situation of the Mertz Glacier Polynya, in Adélie land, and the change of ice scape which took place in 2010.*

The Mertz Glacier Polynya (MGP) was a hotspot for Dense Shelf Water (DSW) formation. After the calving of the Mertz Ice Tongue, the activity of the MGP undergone a significant diminution.

Due to the scarcity of in-situ observations, the understanding of the calving event's aftermath partly rely on models. These models uses atmospheric reanalysis, that might have a too coarse resolution to see the changes in ice cover.

# SM2: the numerical model

The Regional Climate Model is composed of NEMO-LIM 3.6 (ocean and sea ice) and MAR 3.10 (atmosphere). The coupling is managed by the Oasis3-MCT coupler.

Lateral (or surface) boundary conditions for the atmosphere: ERAint
‘’ ‘’ ‘’ ‘’ ‘’ ‘’ ocean : PSY4V3R1 reanalysis and MAR10km outputs
Coupling fields Ocean: SST, SSU, SSV, Sea ice conc., Thick, Snow thick., Sea ice temperature
Coupling fields Atm: Radiative and turbulent heat fluxes + Momentum flux over Ocean and Ice, Evaporation, Precipitation, Non solar fluxes sensitivity
Coupling frequency: 600s (4 ocean time step, 10 atmospheric time step)

Runs start in 2011, after a spin up of 4 years in forced mode (forced by MAR 10 outputs).

Additional details for NEMO-LIM:
1/24° grid
Interactive ice shelf basal melt (open under ice shelf cavities)
6 tidal constituents applied at the domain boundaries
5 sea ice categories