Formation of Antarctic Bottom Water
Part III : Results

Culture Sciences
de l'Ingénieur

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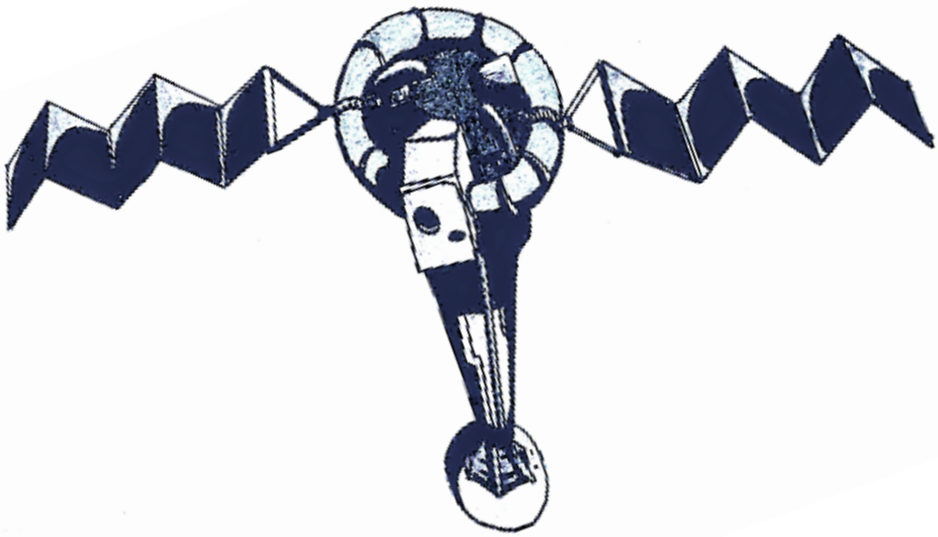


This document comes from a one-year internship at Southampton University (UK), with Mr. Alberto NAVEIRA-GARABATO and Mr. Alessandro SILVANO. Noémie SCHIFANO is a final year student at Ecole Normale Supérieure Paris-Saclay. After a first-year master degree in civil engineering, she had pursued a second-year master degree in physical oceanography at Ecole Polytechnique.

Introduction

Oceans are the thermal regulators of the Earth : solar radiations warm up the ocean, whose heat storage capacity is much higher than that of the atmosphere and the land. Due to the spherical shape of the Earth, equatorial region accumulates more solar radiations than the poles. As the region close to the Equator receives the most solar radiations, a natural oceanic circulation, from the Equator to the poles, is set up. This circulation is the Meridional Overturning Circulation (MOC). The MOC is an important phenomenon for the biodiversity because it regulates the Earth thermal heating, but also because it transports nutrients, oxygen and carbon dioxide.

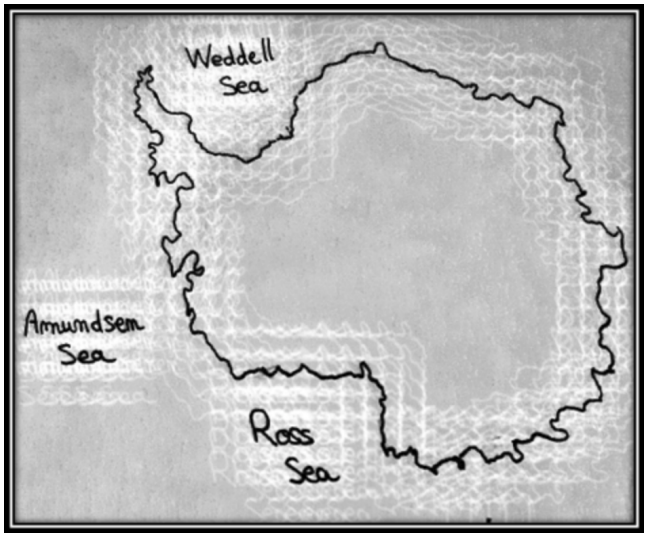
MOC is mostly composed by a surface circulation from the Equator to the Poles, and an abyssal circulation. When waters transported by the MOC reach the Poles, one part is transformed into the denser water due to surface cooling and brine rejection by sea ice formation. In those area, there is a huge density gradient, where denser water are at the surface of the Ocean. Therefore, heavy surface waters sink into the abyss : this is called "bottom water formation". Bottom water are the waters which transport oxygen, carbon dioxide and nutrients from the surface of the ocean and the atmosphere to the deep ocean.

Our knowledge about Antarctic Bottom Water (AABW) is limited, principally because of the difficulty to measure Antarctic water properties. Indeed, sea ice limits fieldwork. Campaigns are possible only in Summer, in specific area.

The purpose of this internship, topic of these publications, is to measure AABW formation using satellite data. The results are then compared with in−situ data (Argo floats and one mooring). A first document which presents state of the art knowledge of Antarctic physical oceanography and the issue of AABW formation, "Formation of Antarctic Bottom Water : General knowledge", has been published. A second one, explaining the method to compute AABW formation using satellite data, has also been published. **In this document, the main results of this study are presented.** The comparison between argo floats and satellite results were very good, both in Wedell gyre, Ross shelf and Ross gyre. These comparisons are not presented here, to focus on the interpretation of the time-evolution of AABW formation.

Writer's Note

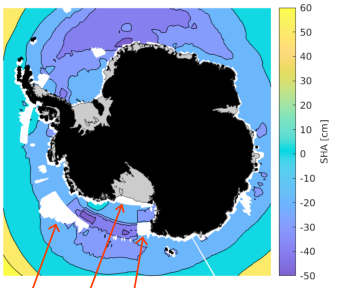
In this document, many hand-written drawings and schematics are used. The purpose, by linking art and science, is to offer students another way of visualisation and, hopefully, a good understanding of physical processes.



AABW formation is studied in Weddell and Ross seas. For each sea, AABW is mostly formed on the shelf !

The Ross shelf is large compared to most of the shelf regions around Antarctica. However, it is not large enough to use satellite data. Quantify AABW formation is then not always feasible in Ross sea -with these satellite databases!-.

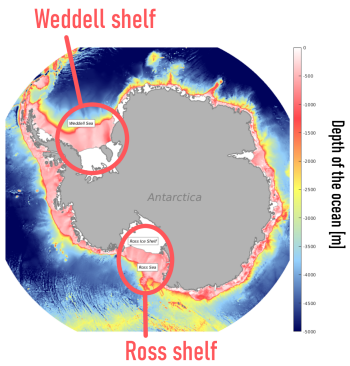
Steric Height Anomaly (SHA**) on August 2017



White blocs = Missing satellite data

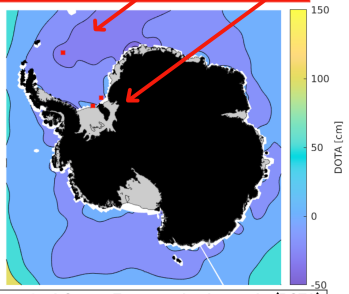
** SHA represents AABW formation

In Weddell Sea, the shelf is bigger than in Ross Sea, and satellite data are available !



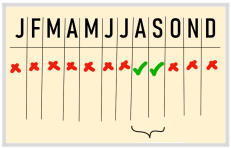
So we have selected 3 grid points,

1 grid point in the gyre and 2 on the shelf

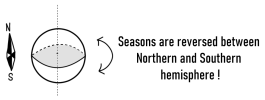


Dynamical Ocean Topography Anomaly (DOTA) on August 2017

have considered only winter values,

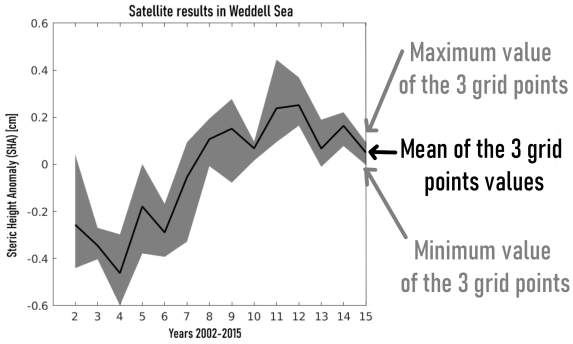


For each year, August and September values are averaged for each grid point

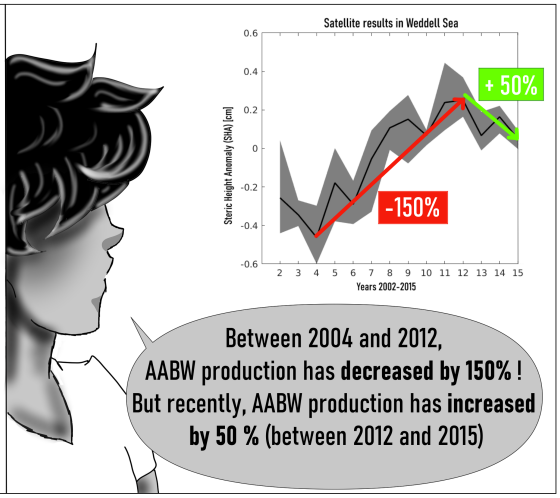


Seasons are reversed between Northern and Southern hemisphere !

and here is the result ** !

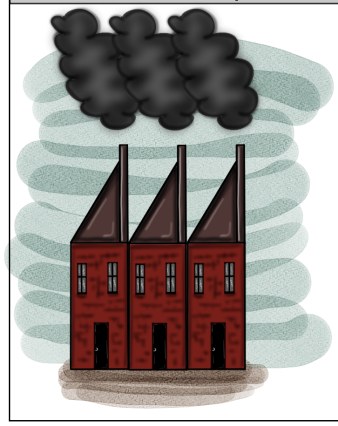


** Remember that if SHA get more positive, AABW production decreases !



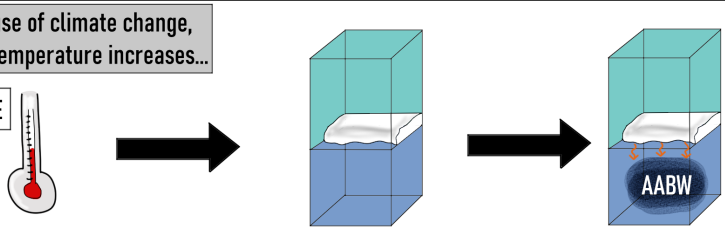
Between 2004 and 2012, AABW production has **decreased by 150%** ! But recently, AABW production has **increased by 50 %** (between 2012 and 2015)

The decrease of AABW production is due to human impact.



Because of climate change, Earth temperature increases...

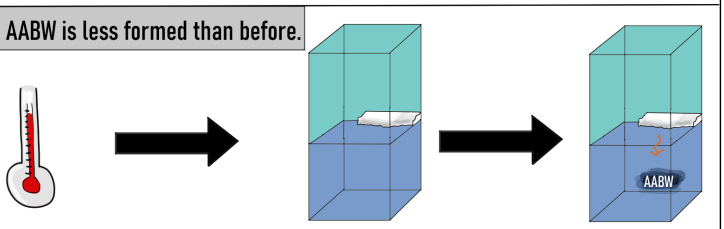
BEFORE



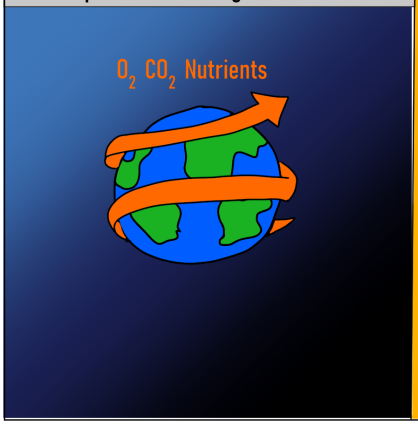
... and then AABW is less formed than before.

NOW

T ↗



This implies that the worldwide transport of oxygen, carbon and nutrients have also experimented a huge decreases.



So why does AABW formation have increased since 2012 ?

Other researchers have also observed an increase of AABW production in rencent years...

Silvano et al., 2020

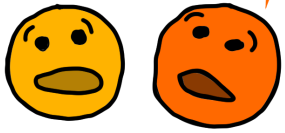
Hatterman et al., 2021

...and they have found an answer !

Climate change implies that extreme climatic events are more and more frequent.

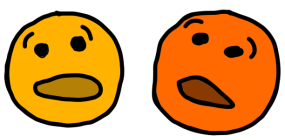
Some extreme climatic events modify the wind intensity around Antarctica.

Hence the sea ice transport around Antarctica, due to wind, is modified too.

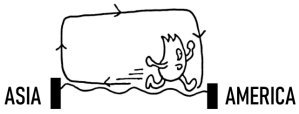


In some case, it allows more sea ice to form on the Antarctica shelf.

And then more AABW will be formed !!

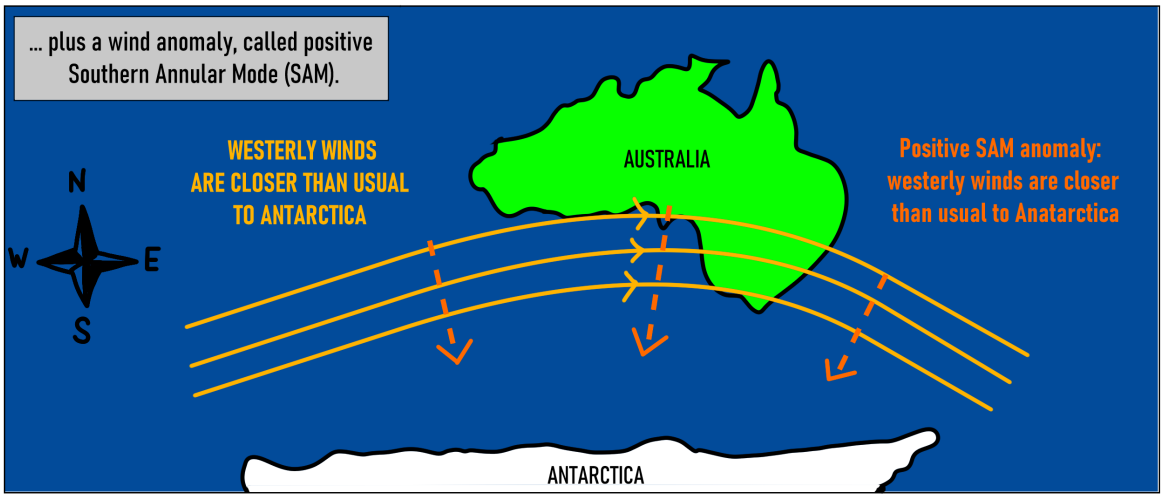


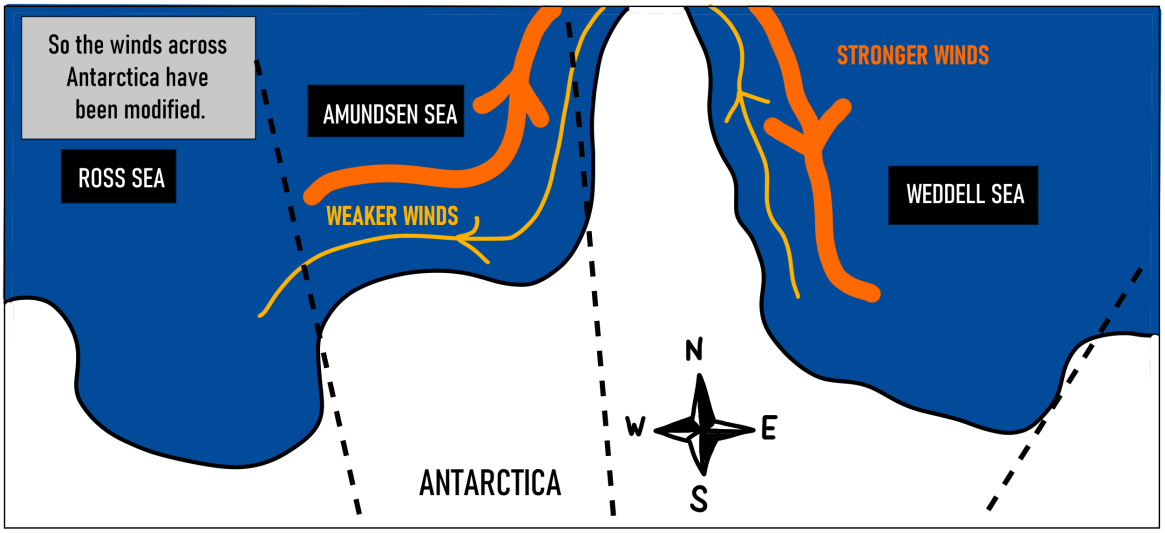
For example, in 2015, there was a violent El Nino event ....

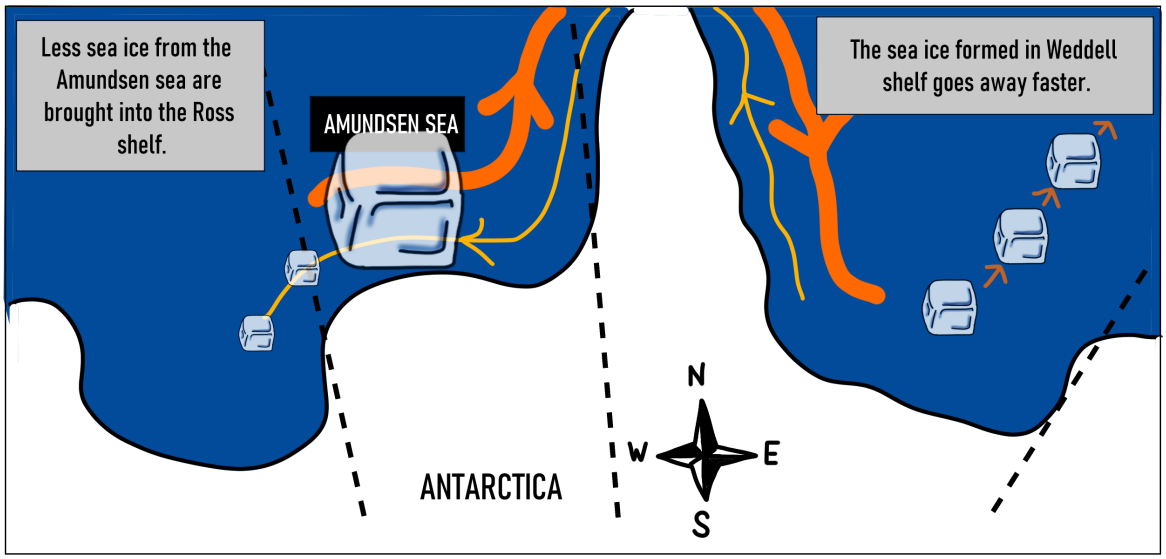


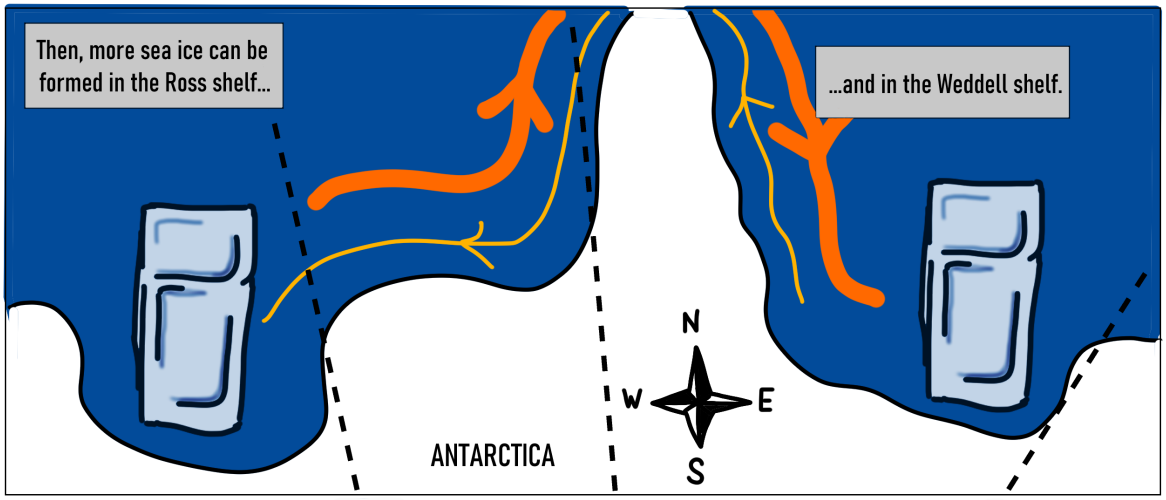
Sea surface is warmer than usual in the south-eastern Pacific. Clouds are then formed, which modifiy all the winds. El Nino is known for decreasing fish population in Mexico.**

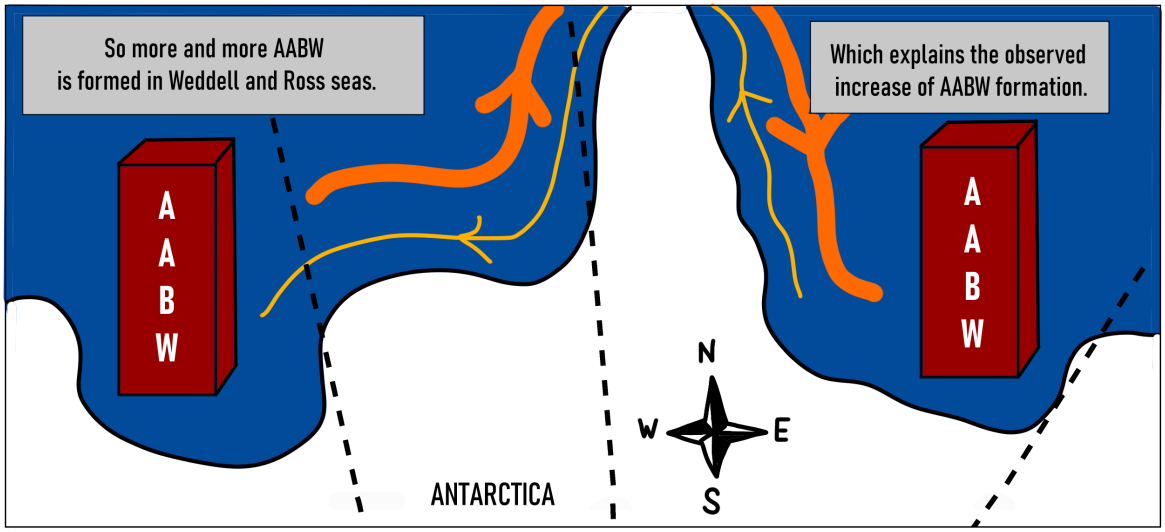
** See Formation of Antarctic Bottom Water Part I


... plus a wind anomaly, called positive Southern Annular Mode (SAM).
WESTERLY WINDS ARE CLOSER THAN USUAL TO ANTARCTICA
AUSTRALIA
Positive SAM anomaly: westerly winds are closer than usual to Anatarctica
N
W
E
S
ANTARCTICA


So the winds across Antarctica have been modified.
AMUNDSEN SEA
ROSS SEA
WEAKER WINDS
STRONGER WINDS
WEDDELL SEA
N
W
E
S
ANTARCTICA


Less sea ice from the Amundsen sea are brought into the Ross shelf.
AMUNDSEN SEA
The sea ice formed in Weddell shelf goes away faster.
N
W
E
S
ANTARCTICA





In 2015, AABW formation had been enhanced by El Nino and positive SAM.

But for how long will extreme climatic event...

...counterbalance temperature increase impact on AABW formation ?

A lot of aspects about AABW still need to be understood...

How does the changing properties (temperature and salinity) of AABW impact worldwide biology ?

How does it impact the meridional overturning circulation?

Will AABW return to decrease?

...and the satellite method designed here provides an usefull tool for it !

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References

[1] Hatterman et al., 2021
Hattermann, T., Nicholls, K.W., Hellmer, H.H. et al. (2021). Observed interannual changes beneath Filchner-Ronne Ice Shelf linked to large-scale atmospheric circulation. Nature Communications 12, 2961. https://doi.org/10.1038/s41467-021-23131-x

[2] Silvano et al., 2020
Silvano, Alessandro and Foppert, Annie and Rintoul, Stephen R and Holland, Paul R and Tamura, Takeshi and Kimura, Noriaki and Castagno, Pasquale and Falco, Pierpaolo and Budillon, Giorgio and Haumann, F Alexander and others (2020). Recent recovery of Antarctic Bottom Water formation in the Ross Sea driven by climate anomalies. Nature Geoscience, 13 (12), 780-786 https://doi.org/10.1038/s41561-020-00655-3

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