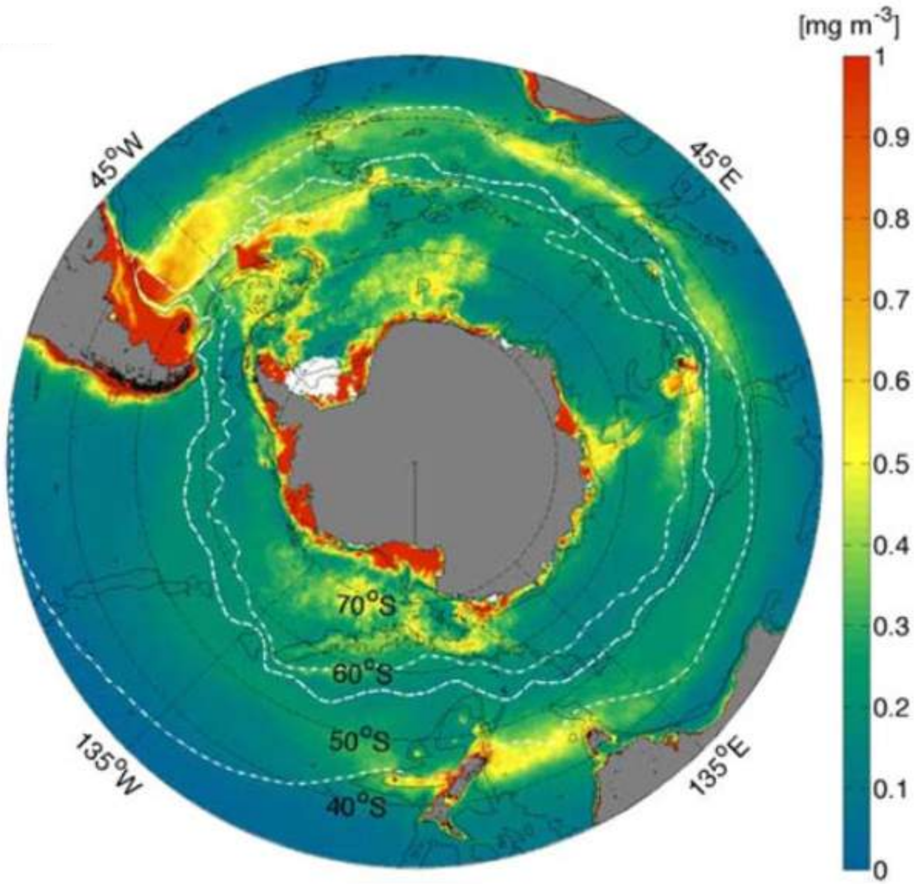
Variability of Nutrients and Carbon in the Antarctic Intermediate Water of the Atlantic sector of the Southern Ocean

Essowè Panassa, J. Magdalena Santana-Casiano, Melchor González-Dávila, Mario Hoppema, Steven M.A.C van Heuven, Christoph Völker, Dieter Wolf-Gladrow, Judith Hauck.

Southern Ocean (SO)



Mean summer chlorophyll

- **40% of the global ocean CO_2 uptake** (Khatiwala et al. 2009).
- **Climate change :** ozone hole & greenhouse gases
- **Dominant mode of climate variability :** Southern Annular Mode (SAM; Thompson et al.2011).
- Site of **water mass formation** (subduction/upwelling).

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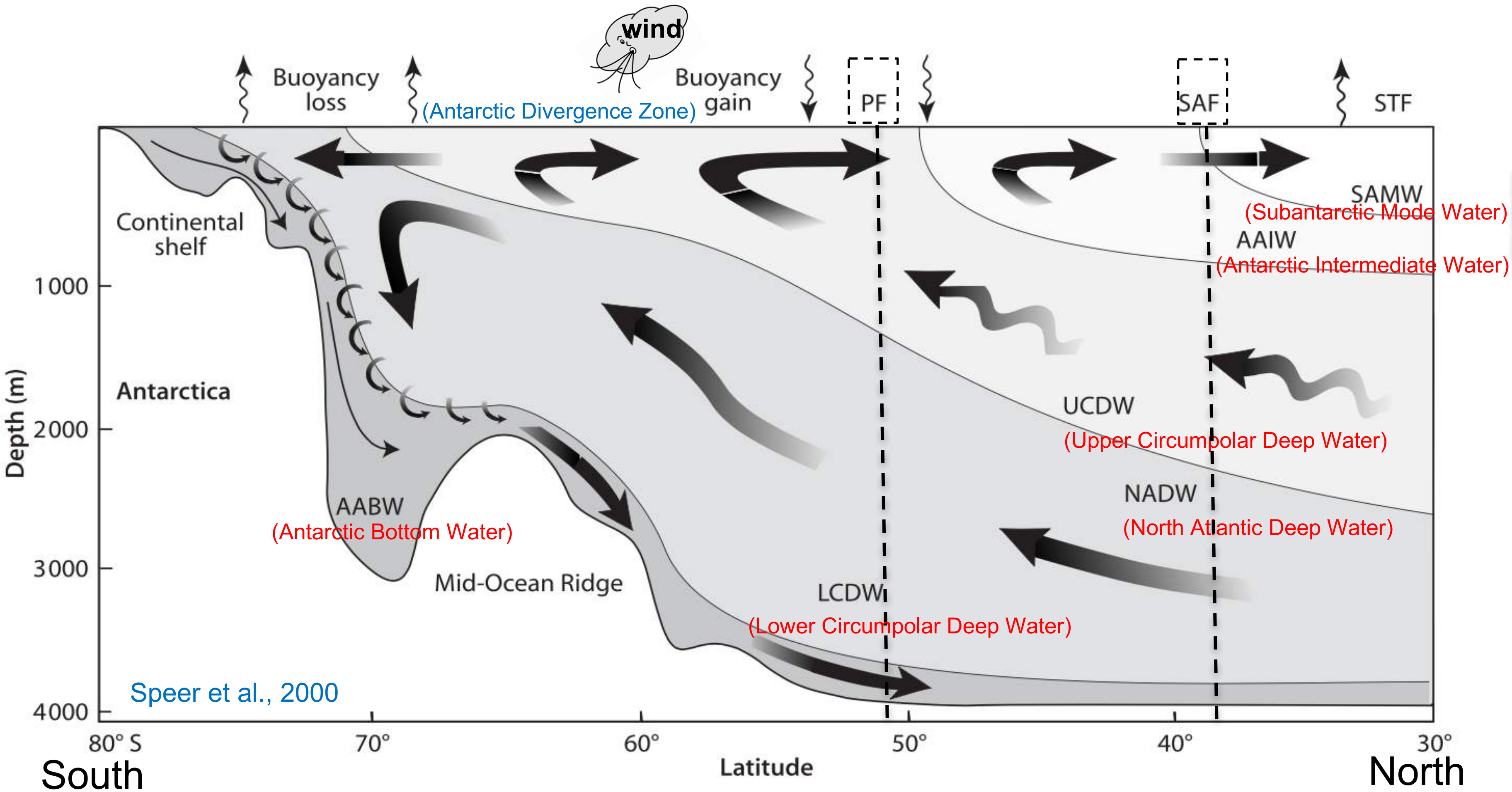
Mean Circulation



Schematic two-cell meridional overturning circulation in the Southern Ocean.

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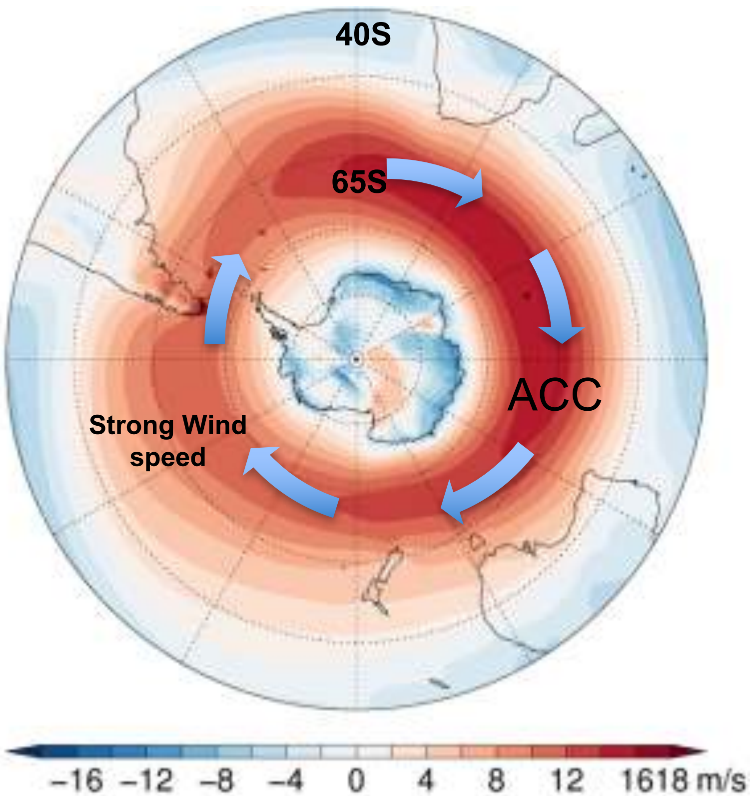
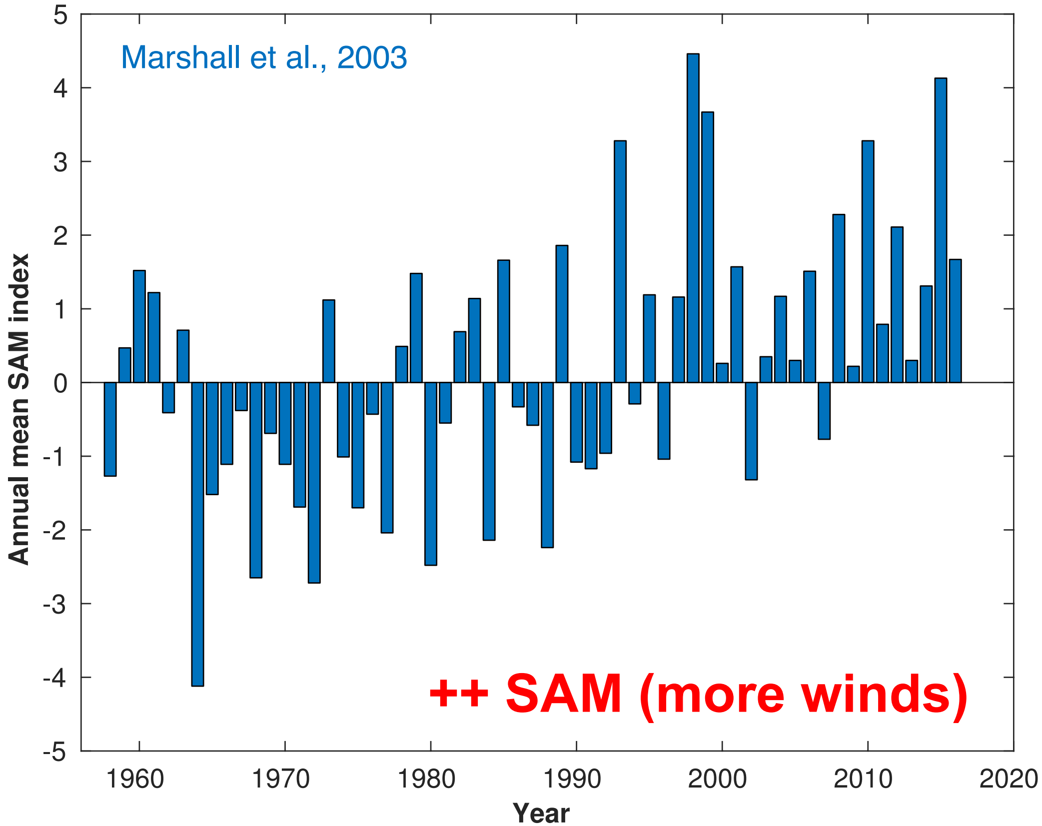
Variability and Change : atmosphere

Southern Annular Mode (SAM)

SAM Index: pressure or sea surface height anomalies of opposite sign in mid (40ºS)- and high-latitudes (65ºS).



Wind speed



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Variability and Change : ocean

- **Freshening** (Durack and Wijffels, 2010) and **subsurface warming** (Gille, 2002, 2008)
- **Regional cooling** (wind stress) / strong signal in Pacific (England et al., 2014)
- **Substantial variability** in **carbon and nutrient** (Pacific, Australian, Indian sectors, Ayers and Strutton, 2013; Pardo et al., 2017; Weddell Gyre, Hoppema et al., 2015)

Variability of nutrients and carbon in AAIW & SAMW of the Atlantic sector?

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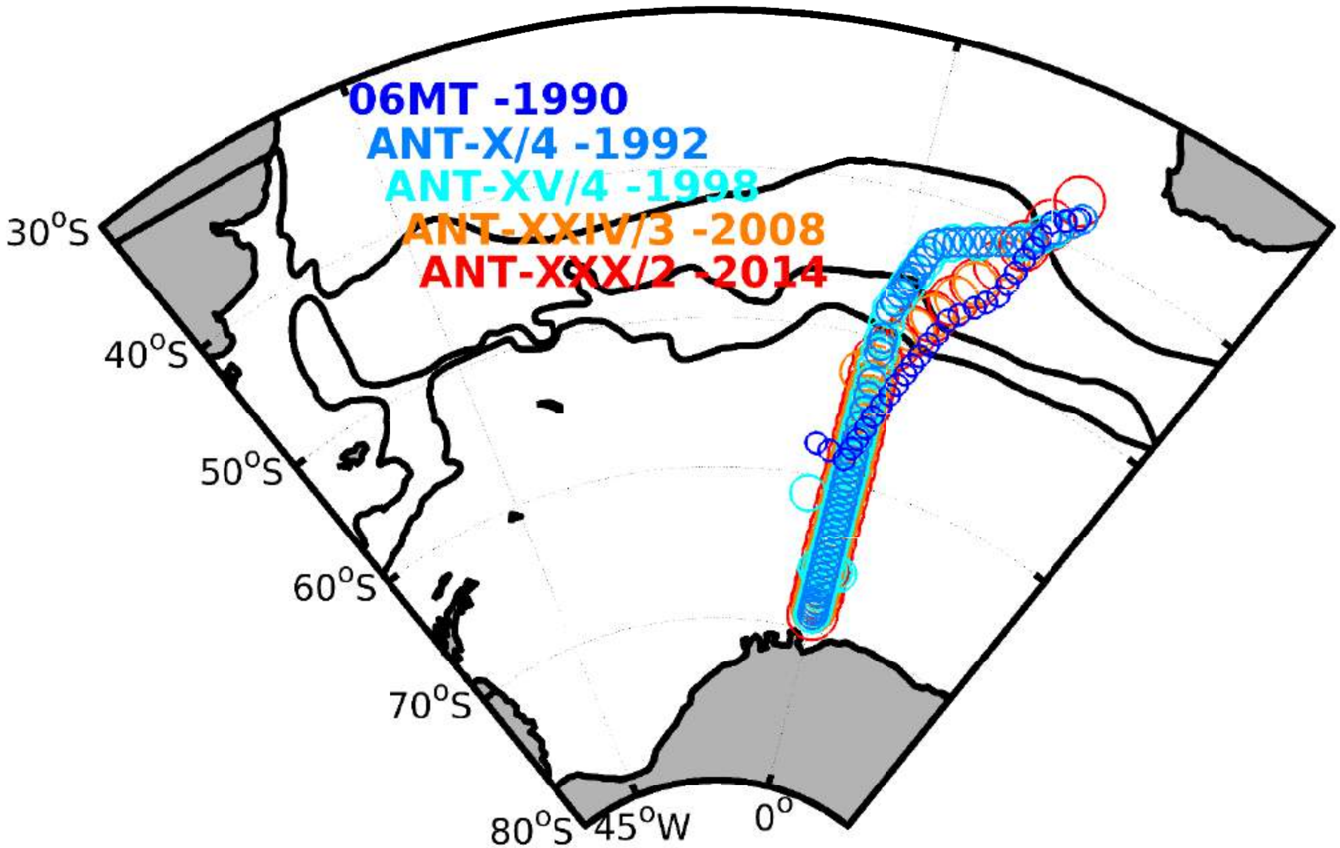
Data



DIC, nutrients (N, P and Si), T and S

- Global Ocean Data Analysis Project, **GLODAPv2 data.**
- Polarstern cruise: **ANT XXX/2-2014**.

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Quality control (QC)

Data

DIC, nutrients, T, S and AOU (T,S,O_2, Weiss cstes, 1970) from 11 cruises (10 GLODAPv2 and <u>cruise 2014</u>)
i) sufficient spatial resolution (north APF).
ii) WOCE flag=2
iii) Sample 57-66S

QC

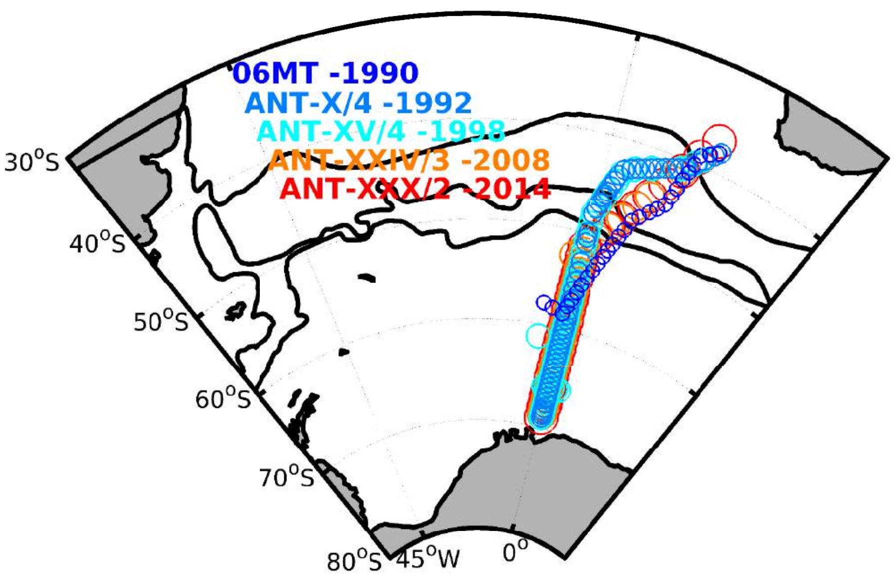
1st QC: histogram
2nd QC: consistency in IWDW/uWSDW (57-66S; 800-2200m).

Gridding

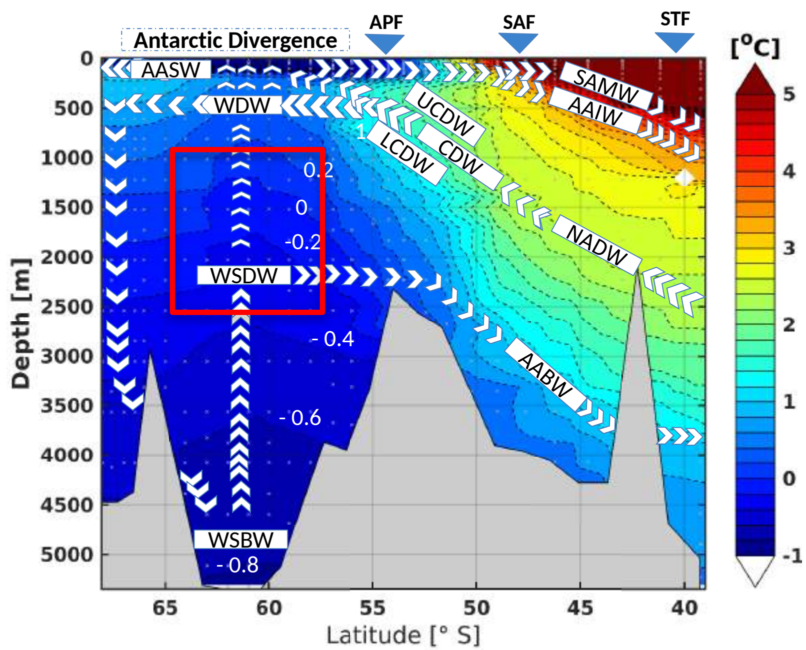
-0.5 (lat, depth, 46 layers).
-Simple objective mapping interp

Variability

-Filter data in AAIW (27<density<27.4)
-Average and STD
-Time trend of mean value
-IAR



Potential temperature (cruise 2014)



QC: Adjustments applied

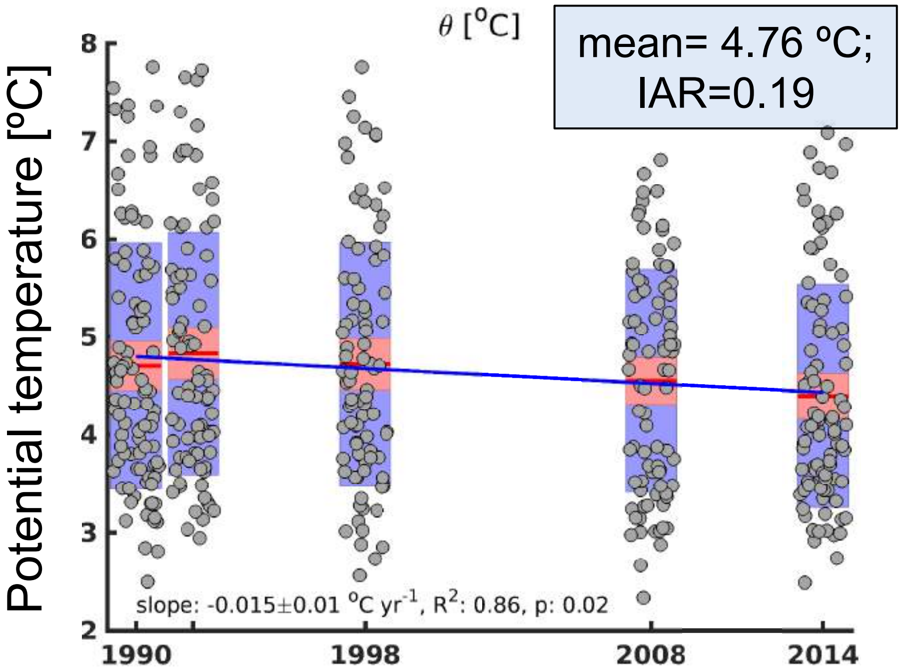
Table 1 Relevant details of the five cruises used in this study: expocode, cruise, research vessel, and adjustments applied to the data and use of Certified Reference Material (CRM, Dickson 2010)

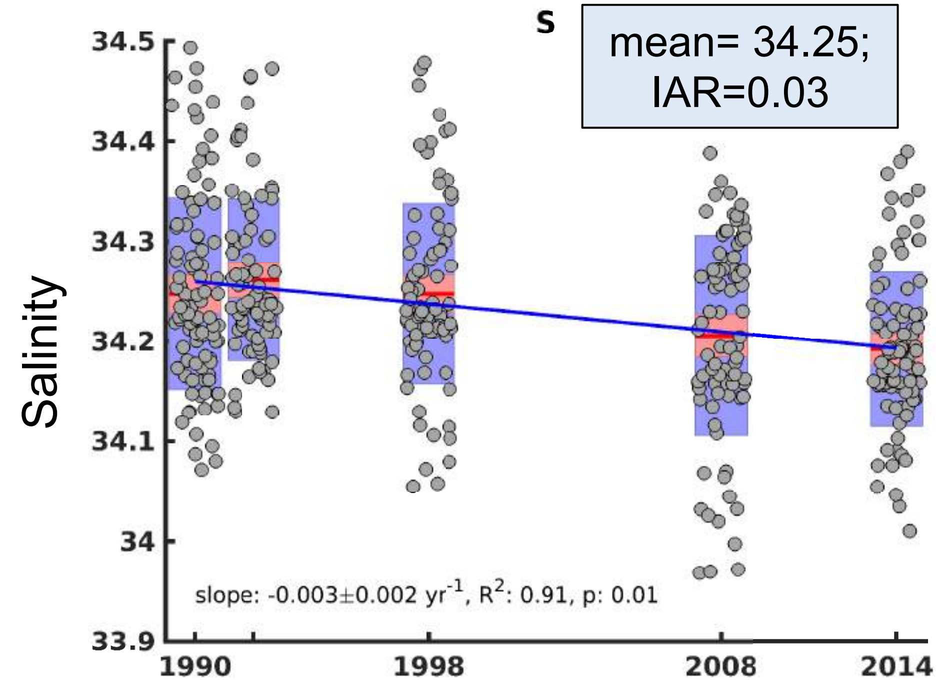
Expocode	Cruise	Vessel	SAL	DIC	A_T	NO_3^-	PO_4^{3-}	H_4SiO_4	O_2	Reference	CRMs
06MT19900123	06MT	Meteor	−0.0004 (0.0)	+1.01 (0.0)	NA	×1.00 (×0.98)	×1.00 (×0.98)	×1.02 (×0.96)	×1.00 (×0.99)	Chipman et al. (1994)	No
06AQ19920521	ANT-X/4	Polarstern	+0.001 (0.0)	−0.68(0.0)	NA	×1.01 (×0.98)	×1.00 (×0.98)	×1.00 (×0.98)	×1.00 (×1.00)	Hoppema et al. (1995)	No
06AQ19980328	ANT-XV/4	Polarstern	+0.0007 (0.0)	0.17 (−3)	NA	×0.99 (×1.0)	0.99 (×1.0)	0.99 (×1.0)	×0.99 (×1.00)	Hoppema (2004a)	Yes
06AQ20080210	ANT-XXIV/3	Polarstern	−0.0002 (0.0)	−0.92 (0.0)	+0.29 (−4)	×1.00 (×1.0)	×1.00 (×1.0)	×1.00 (×1.0)	×1.00 (×1.01)	van Heuven et al. (2011)	Yes
06AQ20141202	ANT-XXX/2	Polarstern	+0.004	−1.36	−1.00	×0.98	×0.98	NA	×0.99	This work	Yes

The data of all cruises were extracted from the GLODAPv2 product, except the 2014 cruise data (ANT-XXX/2). The table shows the adjustments that we applied in this study to obtain consistency on a regional level and the adjustments already applied in the GLODAPv2 dataset in brackets before we checked the local consistency. Both corrections were taken into account as we used the adjusted GLODAPv2 dataset and applied our own adjustments on top. Adjustments applied to the data are additive for S, DIC, and A_T, and multiplicative for the other parameters. NA=not available and x1.00=means no adjustments were applied to the data

- Adjustments without brackets are those applied in the current study, required to obtain consistency in the lWDW/uWSDW

Variability of nutrients and carbon in AAIW





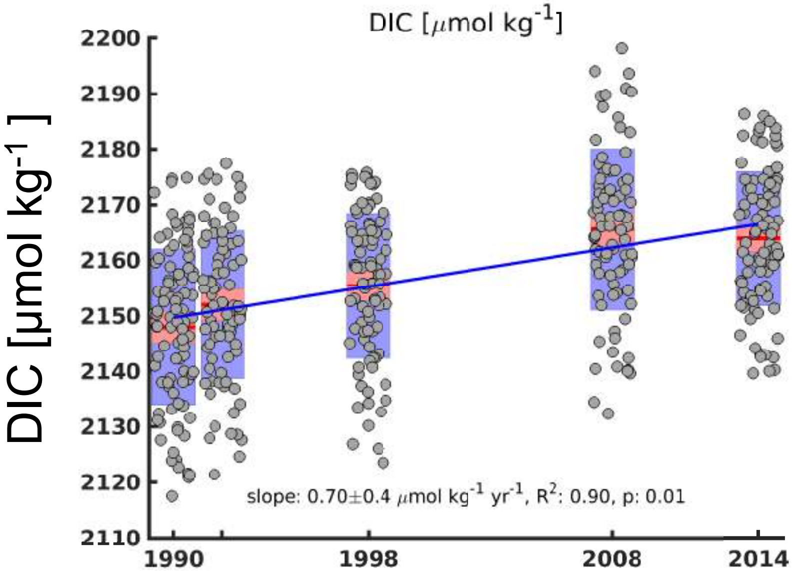
Gray circ.=raw data
Blue=1std. Dev
Red hz.Line= mean
Light Red=95-confidence
Interval around mean.

IAR: inter-annual range

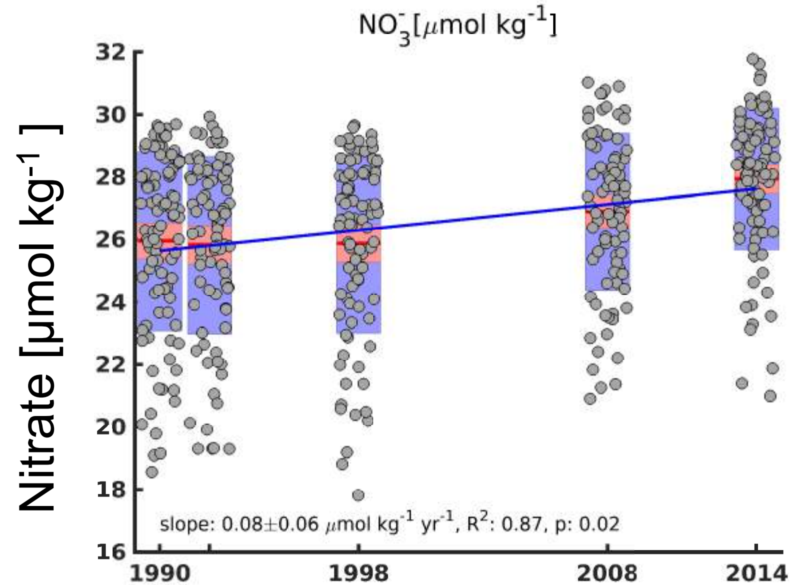
Variability about mean measure by: $\mathrm{IAR} = \max(|\overline{\overline{\mathrm{X}}} - \overline{\mathrm{X}}_k|)$

Panassa et al. (2018), Ocean Dynamics

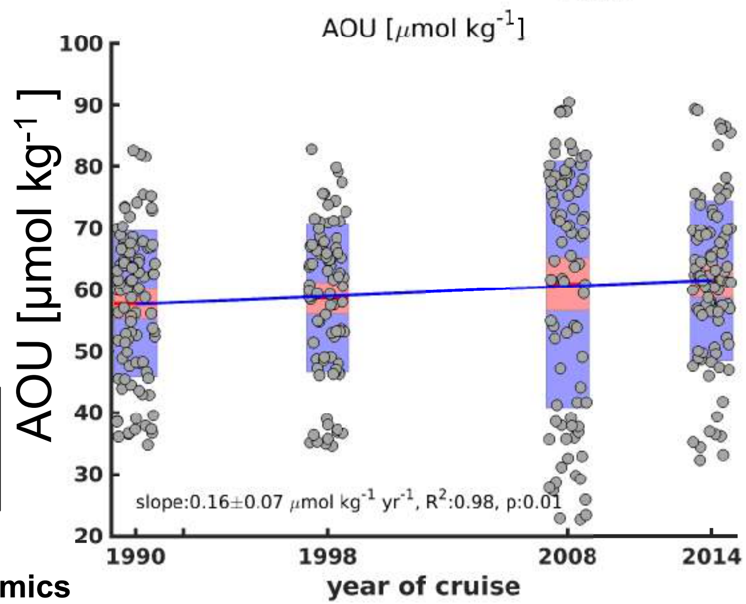
Variability of nutrients and carbon in AAIW



mean= 2157.1 μmol kg^{-1};
IAR=10.4



IAR/mean = %
1.6/26.5 = 6%



mean= 59.7 μmol kg^{-1};
IAR=1.7

AOU:C (1:4.4=0.23)
smaller than 1:1.5=0.7
(Anderson and Sarmiento, 1994)

Panassa et al. (2018), Ocean Dynamics

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Variability of nutrients and carbon in AAIW

Observations

DIC changes in core AAIW: **ΔDIC_{obs} = 17.5 ± 10 μmol kg^{-1}** in 25 yrs.

Surface source water (50 – 53°S): **(1) theoretical calculation based on increase atmospheric CO_2 → ΔDIC_{ant} = 19 μmol kg^{-1}** in 25 yrs.

(2) $\Delta DIC_{2014-1990}$ = 22 μmol kg^{-1} in 25 yrs.

Separate C_{ant} from other effects:

ΔNO_3 and **C:N:P=106:14:1** (de Baar et al.1997)

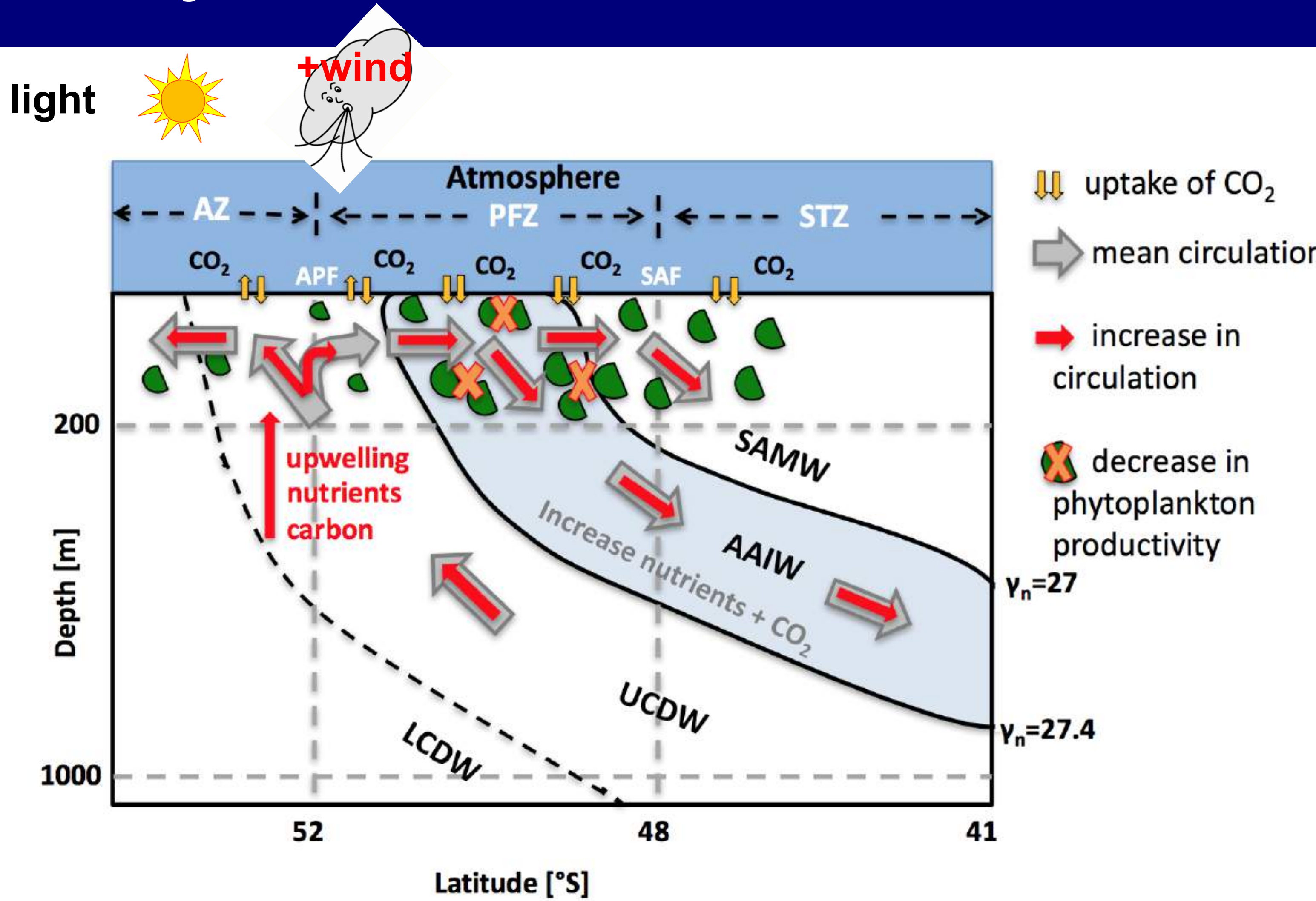
$\Delta DIC_{Redfield}$ = 15.3 ± 11.3 μmol kg^{-1} in 25 yrs

Optimal value: **ΔDIC_{obs}** - **$\Delta DIC_{Redfield}$** = **17.5** - **15.3** = 2.2; [85% circulation or PP; 15% C_{ant} uptake]

✓ **Lower value**: **ΔDIC_{obs}** - **$\Delta DIC_{Redfield}$** = **17.5** – **4** = 13.5; [25% circulation or PP; 75% C_{ant} uptake]

 Panassa et al. (2018), Ocean Dynamics

Summary



- **<u>DIC changes</u>: 75% (uptake C_{ant}) and 25% (change in circulation).**

Panassa et al. (2018), Ocean Dynamics

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Take home message

Variability of nutrients and carbon in AAIW of the Atlantic sector (1990-2014)

- Positive trend in DIC, NO_3 and AOU & negative trend in T and S.
- Support a scenario of an increase in upwelling.
- Smaller contribution of Remineralization and decrease in net primary Productivity (PP).
- DIC changes: 75%~C_{ant} uptake & 25%~circulation/PP.
- This finding will leads to changes in low latitudes PP.

BSc. Marine Science at University of Kara

Training program (2020 - 2023): Modules

- Basic courses: Phys. Math. Chemistry
- Oceanography & coast meteorology
- Data analyses & applied Statistics
- Policy & management of coast/ marine pollution
- Maritime & Portuary administation
- Ocean Observing
- Mod. halieutic resources and fishing & marine Aquaculture

- **Start:** January 2021
- **Number of Students** : 21 (13 women and 08 men)
- **Who can apply?** ECOWAS & International students
- **Lecturers?** National & International

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Pedagogic visit of maritime & meteorological services
April 2021, 26, 28, 29 and 30

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Thanks for your attention!