



Recent trends and regional patterns of Ocean Dissolved Oxygen change

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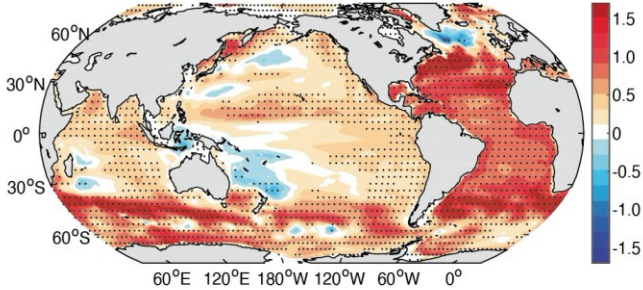
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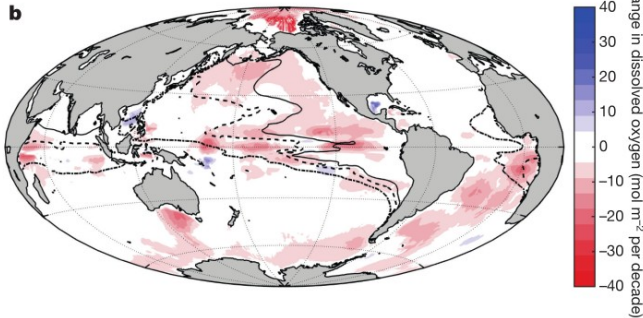
Argo 2030 Meeting, 26 September 2023, Brest, France

Ocean is warming and deoxygenating

D Ocean heat content 0-2000m trend (W m^{-2}) (1955-2019)



(Cheng et al., *J. Clim.*, 2017)

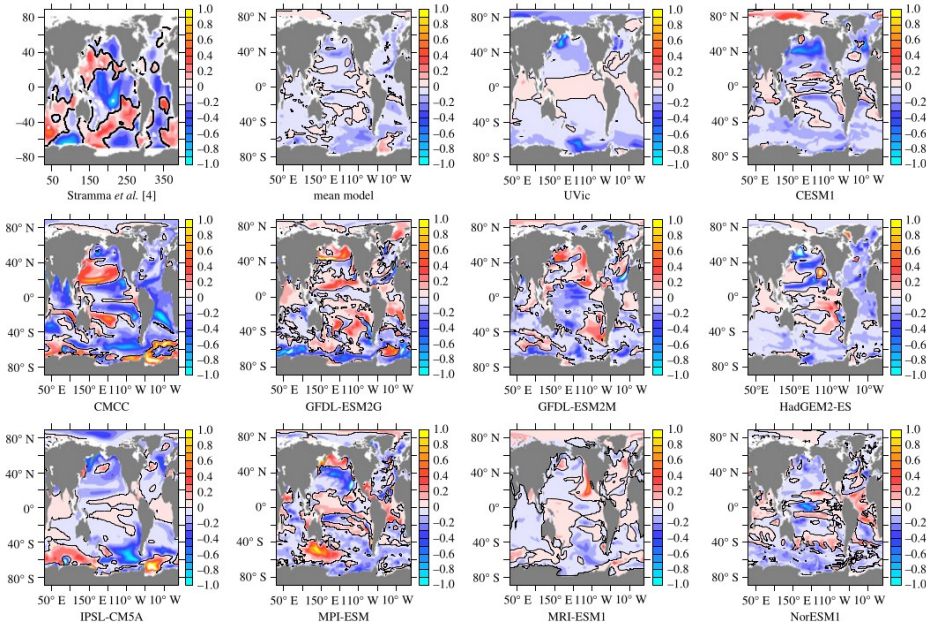


1955-2015 DO inventory change (Schmidtke et al., *Nat.* 2017)

- Ocean Warming \rightarrow less O_2 solubility
- Stratification and circulation change \rightarrow less ventilation
- Loss of solubility quantified in the surface layer
- But deep O_2 change related to AOU (circulation and biology)

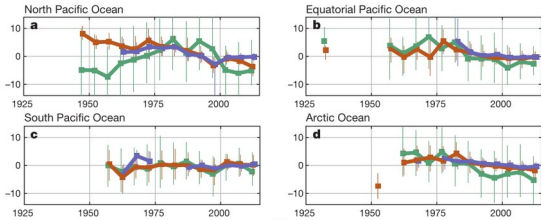
Modelling ocean DO

- Climate model shows DO decline in future projection (Bopp et al., 2013; Oshlies et al., 2018)
- But, models have difficult to represents pattern and variability of O₂ (Oshlies et al., 2017)
- Both physical and biological drivers needs to be better understood

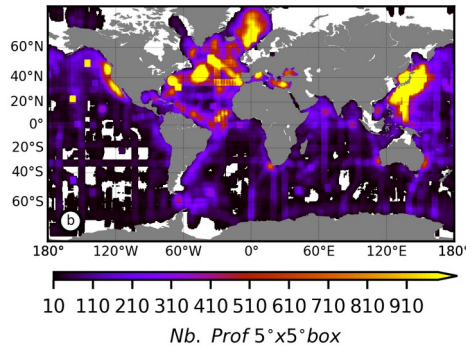


300 m depth DO in climate models
(from Oshlies et al., *Phys. Trans.*, 2017)

Uncertainties



1955-2015 DO change (Schmidtke et al., *Nat.*, 2017)



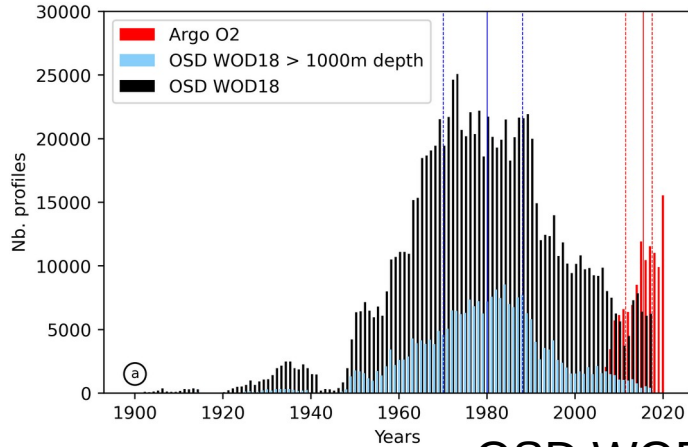
Number of historical bottle sample (1000 m depth) from WOD18

- Observation remain sparse in some region such as Southern Ocean
- Large uncertainties are remaining on the regional DO change.
- Hidden by large seasonal to interannual variability
- Quantitative and mechanistic understanding of deoxygenation driver is till lacking
- BGC Argo provides new consistent DO dataset

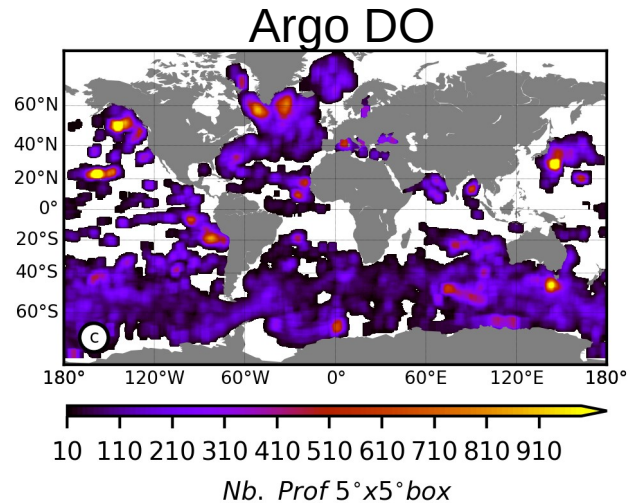
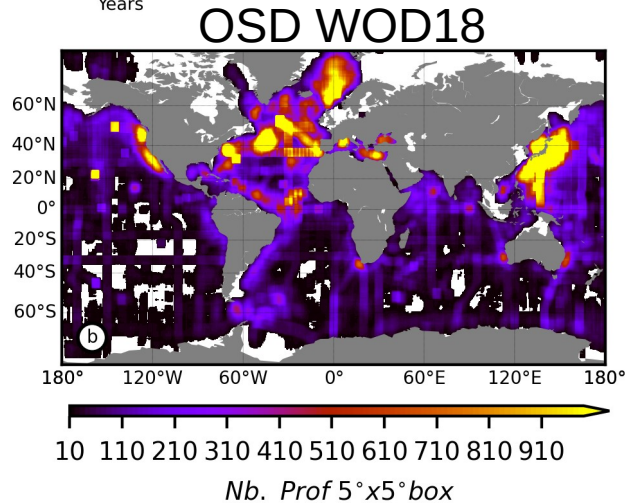
Questions

- Updated global picture of ocean DO change from Argo data ?
- More insight in regional pattern at interannual time scale to long term trends ?
- More insight in (physical) drivers of DO change ?

Argo DO DATA



- BGC Argo DO (2005-2019)
- WOA18 → bottles samples from WOD18 (~1900-2018)



Method

- **ISAS Optimal Interpolation** (Gaillard et al., 2016)

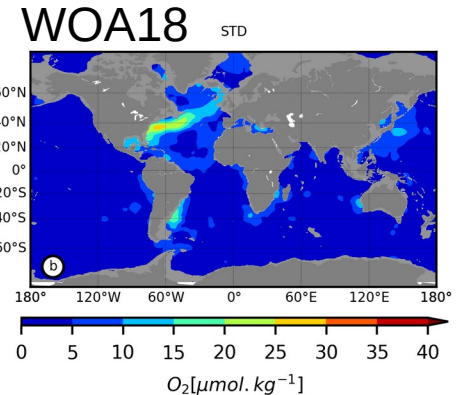
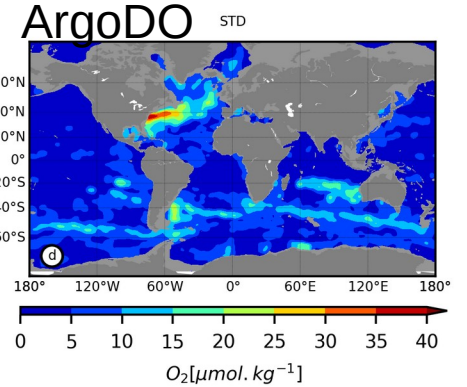
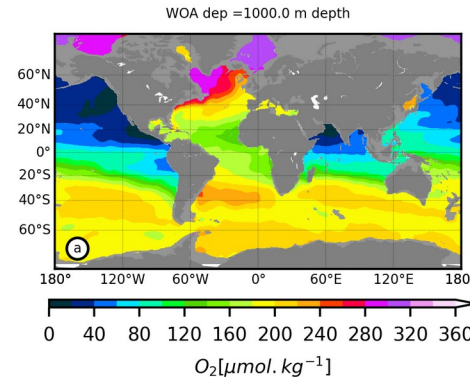
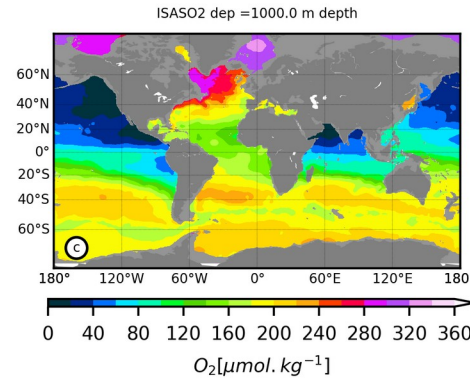
- Global DO climatology
- 0-2000 m
- 2005-2019

- **A priori statistics, covariance scale, weight**

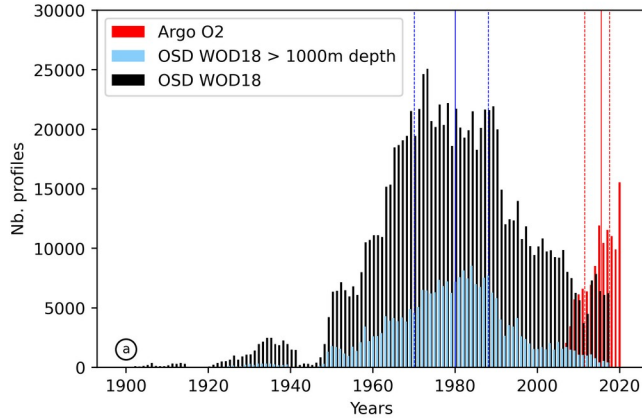
$$C(dx, dy, dt) = \sum_{i=1}^2 \sigma_{Li}^2 \exp\left(\frac{dx^2}{2L_{xi}^2} + \frac{dy^2}{2L_{yi}^2} + \frac{dt^2}{2L_{ti}^2}\right) \quad (4)$$

- **3 configurations:**

- **First guess WOA18**
- ISASO2_MEAN: 2013, T= 5 years (2009-2018=10y)
- ISASO2_M11 : 2011, T=2.5 years (2009-2013=5y)
- ISASO2_M16 : 2016, T=2.5 years (2014-2018=5y)



Time scales for WOA18



- Equivalent trend pattern :

$$DO_{eqtrend} = \frac{DO_{ISAS} - DO_{WOA}}{T_{scale}}$$

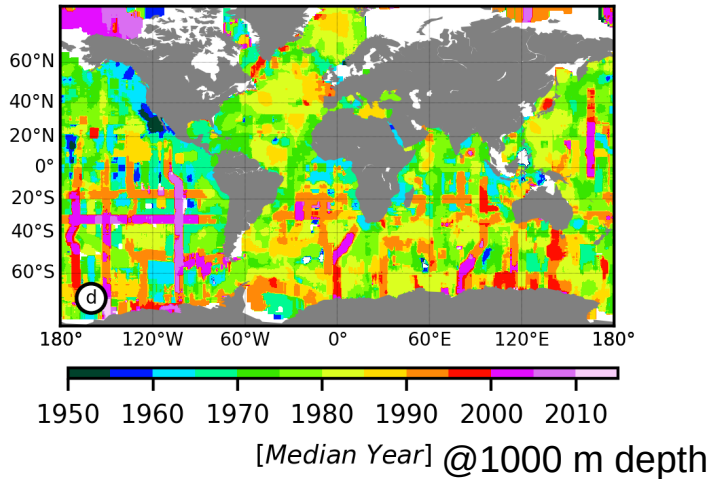
- Error propagated using updated ISAS STD

→ T_{scale} ?

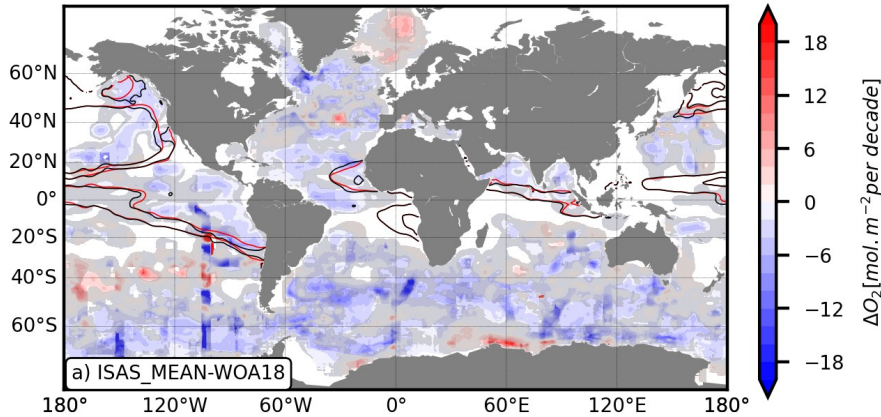
- WOA18 → OI WOD 18 (Barnes et al., 1964)

- OSD sample distribution centered around 1980 (@ 1000 m depth)

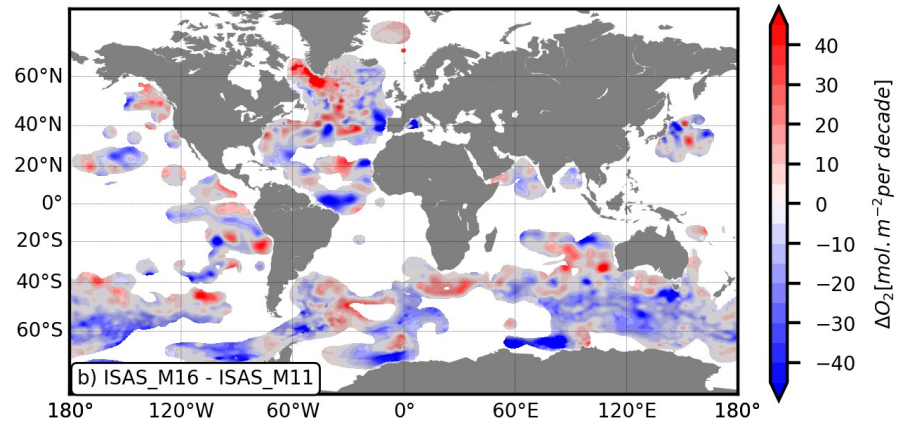
- Spatial variability median time of the OSD



Regional pattern of DO inventory



Long term

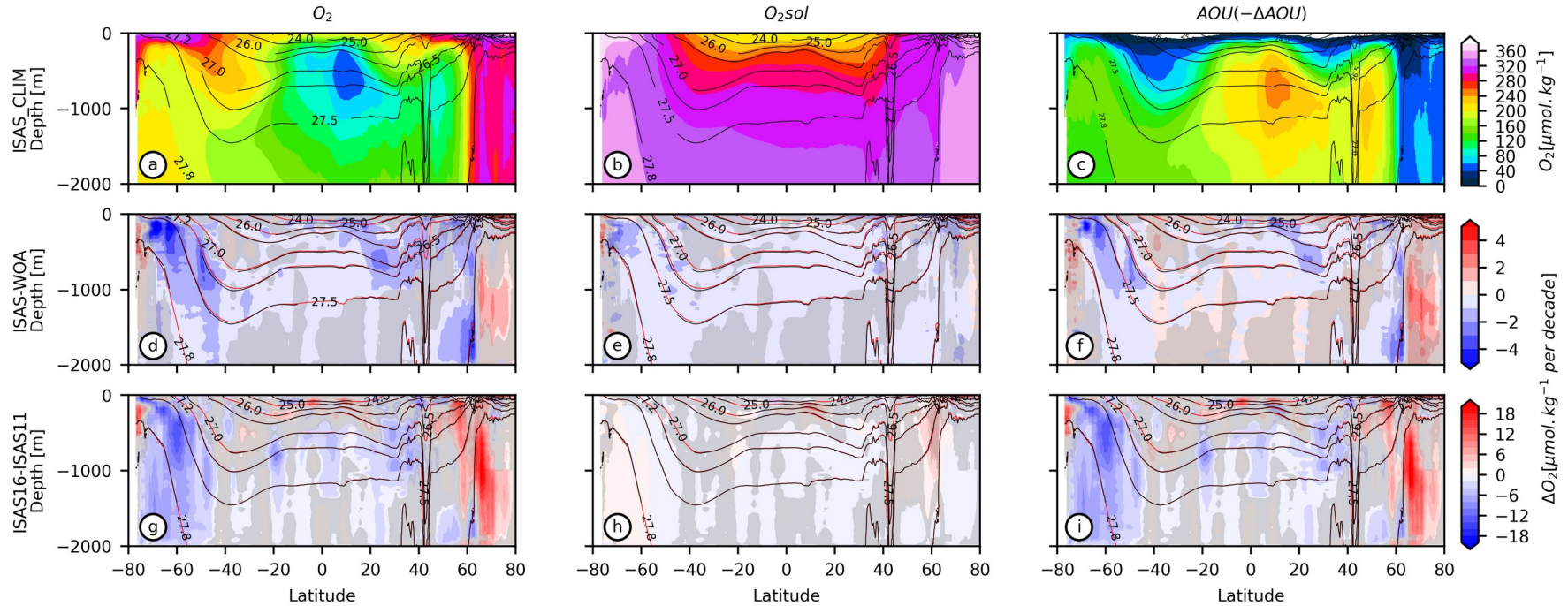


Argo period

- Argo – pre-Argo → -451 ± 243 Tmol per decade since ~1980
Argo → -1211 ± 218 Tmol per decade over the Argo period
- Hot spots : Southern Ocean, North Atlantic, North Pacific, OMZ extension
- But oxygenation along Antarctic, poleward subtropical gyre (mode waters?)
- Argo period : North Atlantic oxygenation (Feucher et al., 2022), poleward subtropical gyre (mode waters) ?

Global section

Isopycnals :
— ISAS_CLIM~2013
— WOA18~1980

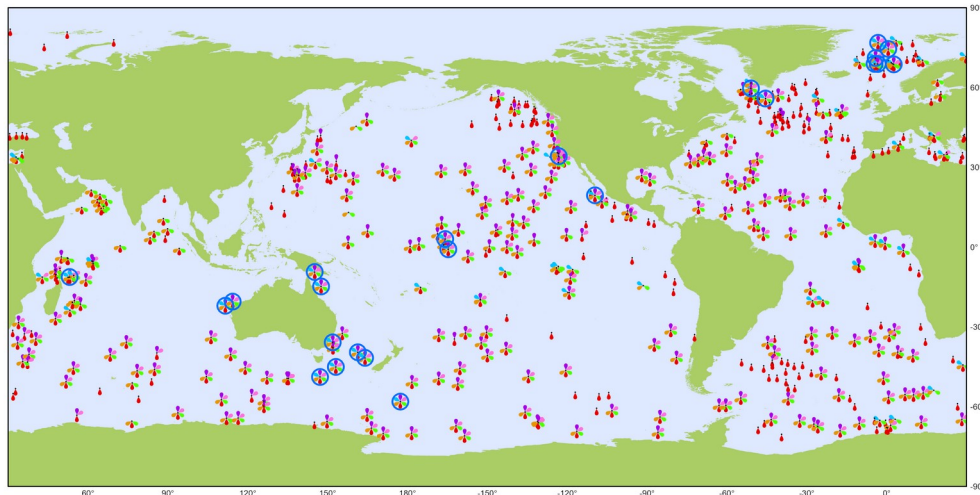


- Long term trend : Doxygenation everywhere except in the Nordic Seas
- 2009-2018 : Oxygenation north 40°N

Conclusion

- Argo ISASO₂ climatology allows to better estimate regional interannual to long-term change of the ocean Dissolved Oxygen.
- In the long term (Argo-PreArgo), oxygen has declined in key ventilation regions e.g. the Southern Ocean
- Over the Argo period (2005-2019), the AOU change explains the complex regional pattern (and more intense) linked to interannual to decadal mode of variability (e.g. North Atlantic,...).
- Still difficult to disentangle the natural vs anthropogenic variability of ocean DO

Discussion



Biogeochemical Argo

Sensor Types

December 2022

Latest location of operational floats (data distributed within the last 30 days)

- Operational Floats (493)
- Suspended particles (276)
- Downwelling irradiance (66)
- pH (234)
- Nitrate (206)
- Chlorophyll a (276)
- Oxygen (484)
- Full BGC Floats (23)



Argo DO → red flag

Generated by ocean-ops.org, 2023-01-01
Projection: Plate Carree (-150,0000)

- Remaining gap in the Argo DO data
- Argo data are adjusted using reference profiles and database
- but bias up to 3 $\mu\text{mol/kg}$ due can be observed due to ad hoc correction and/or time response correction (Maurer et al., *Front. Mar. Res.*, 2021)
- Still difficult to quantify the biology contribution (→ OneArgo BGC)

Thanks !

- Questions ?