Trends in the Southern Ocean Mixed Layer and Chlorophyll over the period 1990-2012 from Observations

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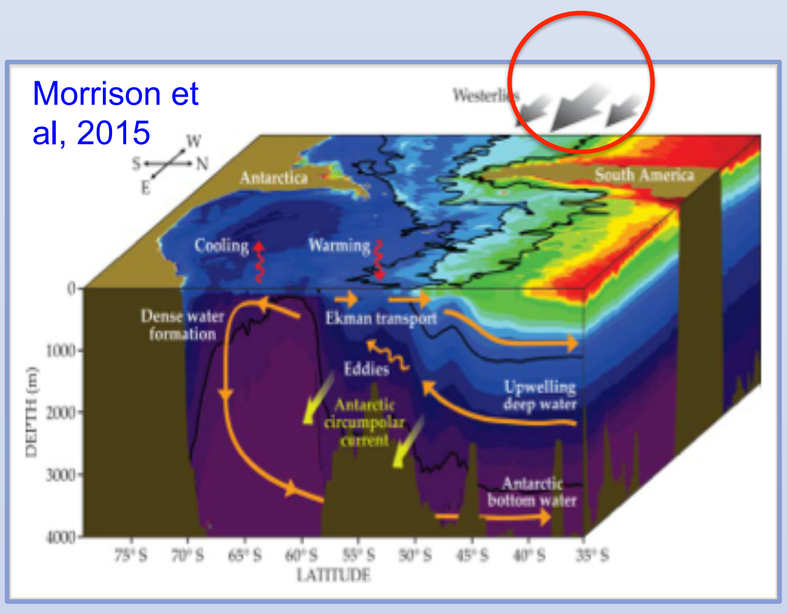
Motivation



- The positive trend in the Southern Annular Mode (SAM) pronounced during austral autumn and summer (e.g Thomson et al., 2000; Marshall, 2003; Abram et al., 2014) together with the global warming signal perturbs circulation, sea-air CO2 fluxes and biology in the Southern Ocean [Lovenduski and Gruber (2005); Dufour et al., 2013 ; Hauck et al., 2013; Morrison et al., 2015 ; Peter Landschützer et al., 2015]
- How will circulation changes in Southern Ocean alter the mixed layer depth (MLD) and chlorophyll on **multidecadal timescale** from observations is still missing

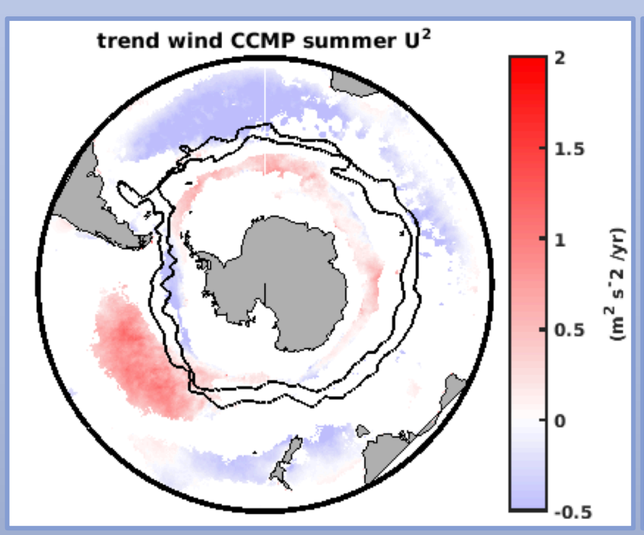
Data and Methods

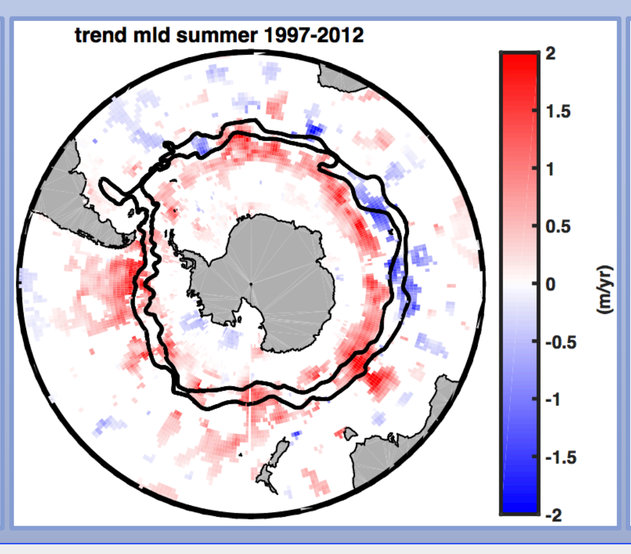
- Monthly SAM index (1957-2014) from Marshall et al.(2003)
- Surface monthly winds U10, V10 from **ERA-Interim** reanalysis (1979-2014) [Dee et al., 2011] and Cross Multiplatform (**CCMP**) (1990-2011) [Atlas et al., 2011]
- Gridded 3D in-situ monthly temperature and salinity fields (0.5°; 152 level; 1990-2012) mostly Argo data from **CORIOLIS** Cabanes et al, (2013)
- Monthly natural log of satellite chlorophyll from **ESA's OC-CCI** (Sept 1997 to July 2012)

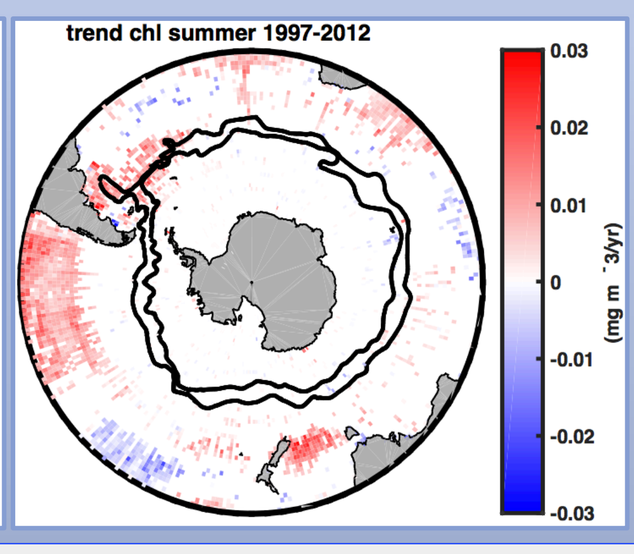
- **MLD** : is defined using a density threshold criterion (threshold **of 0.03 kg m^{-3}**, of de Boyer Montegut et al. [2004])
- **DINEOF** approach (Taylor et al, 2013 ; Beckers and Rixon, 2003) to fill gaps in satellite data due to clouds, sun glint, and sea ice coverage

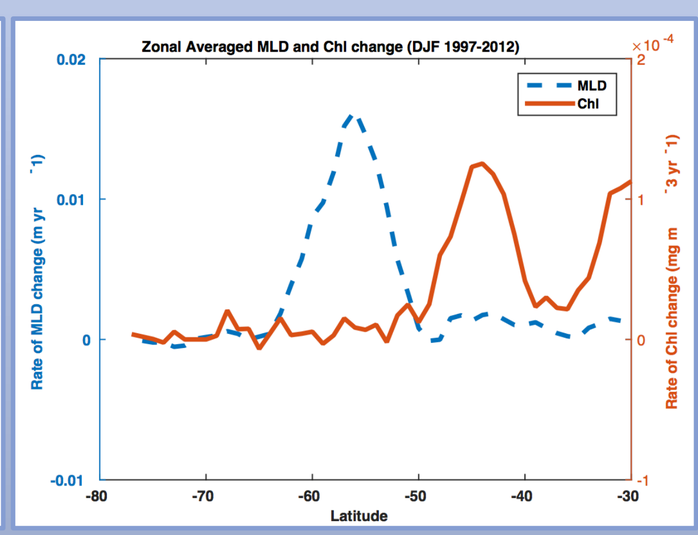
Results

◆Summer trend in MLD, chlorophyll (1997-2012) and winds (1990-2011)



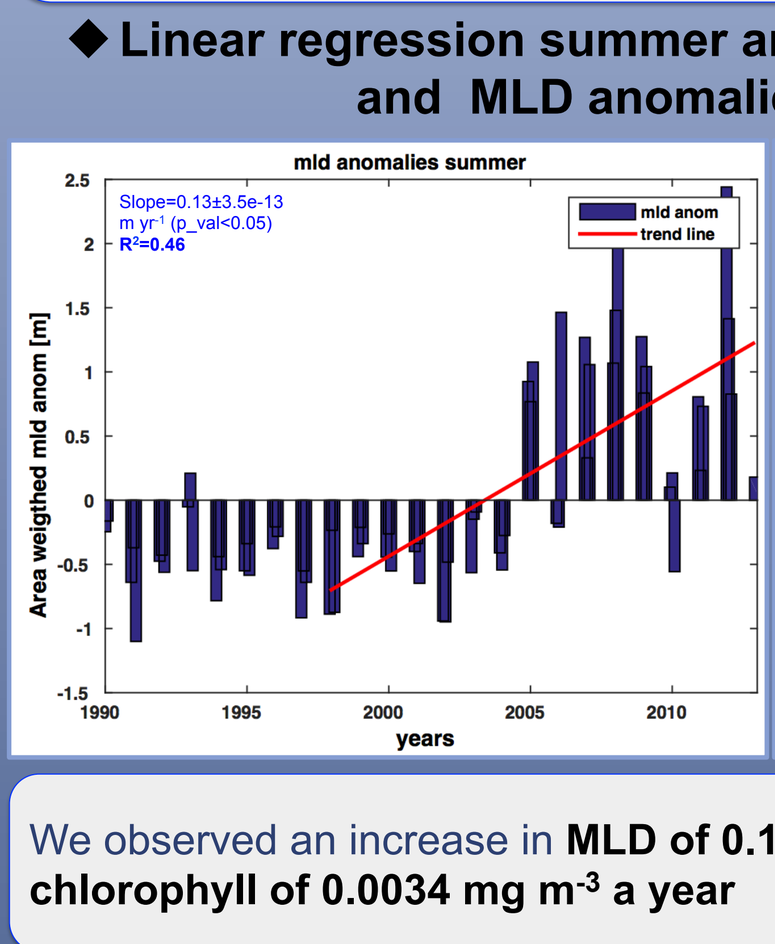


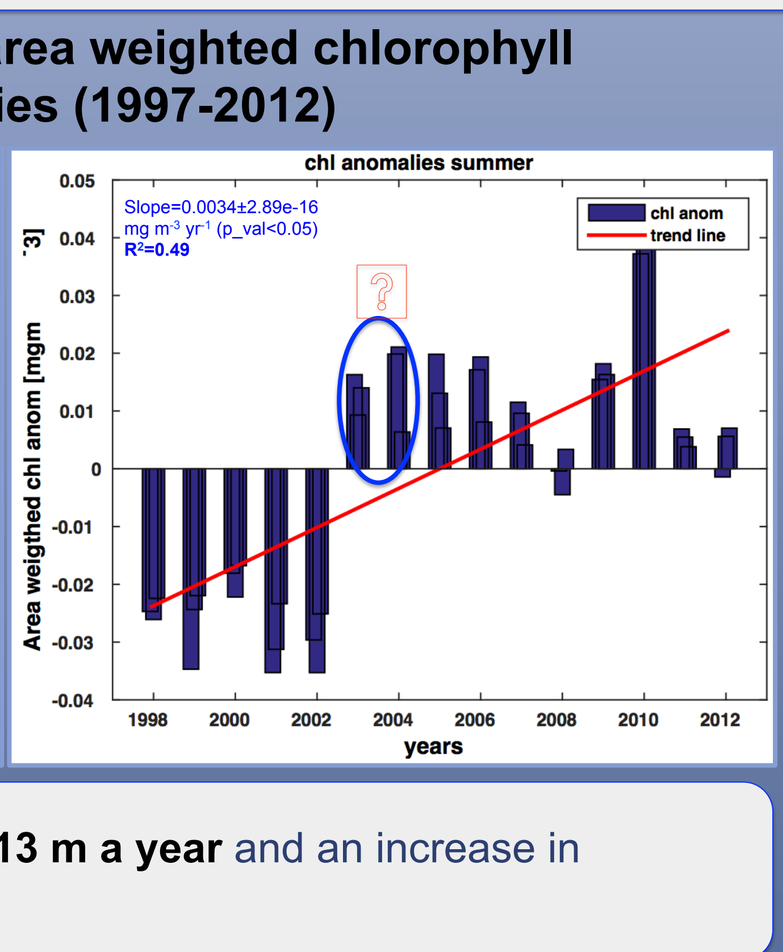




- **Largest changes** in **chlorophyll** and **MLD** occur in **Pacific Ocean** where the changes in Winds are large (Wanninkhof et al 2013).
- **Deepening in MLD** occurs in [**60°S-50°S]** (strong winds) whereas **increase in chlorophyll** is within [**50°S-40°S]**
- **Frontal regions** (mode water regions **at about 50°S**/low nutrient) act as a **boundary** for high/low chlorophyll zones

◆ Linear regression summer area weighted chlorophyll and MLD anomalies (1997-2012)





We observed an increase in **MLD of 0.13 m a year** and an increase in **chlorophyll of 0.0034 mg m^{-3} a year**

Conclusions

- **Integration of summer chlorophyll change over the change observed in summer MLD in the entire southern ocean (south of 30°S) from 1997-2012 is not that high like expected. An increase/ decrease [-8% to 8%] a year to the global summer chlorophyll mean ~0.48mg m^{-3}.**
- **Large changes in chlorophyll observed in Pacific sector is due to further intensification of winds (more cyclonic) associate with strong northward Ekman transport of rich upwelled waters (Peter Landschützer et al., 2015) .**

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