

# SMOWS

## Satellite M<sub>O</sub>de Waters Salinity, in synergy with Temperature and Sea Level

**Hasson Audrey**

LOCEAN/CNRS

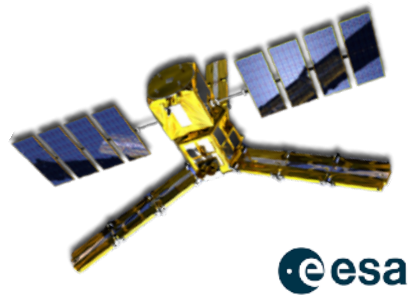
Currently at Mercator Ocean International

LIVING PLANET FELLOWSHIP

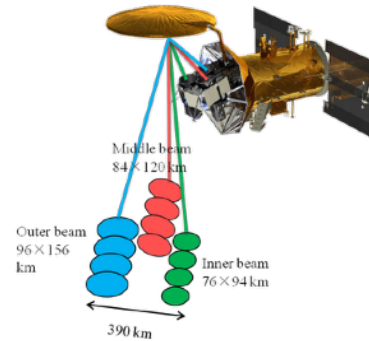
# HYDROSPHERE



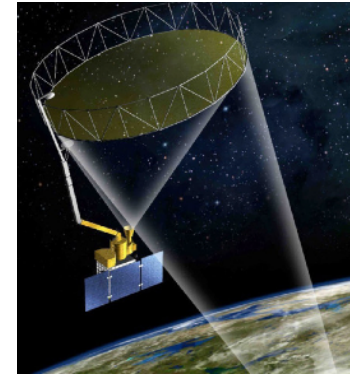
# Sea Surface Salinity : Colder, Smaller and at Depth ?



**SMOS (2010-now)**  
ESA Earth Observer (France and Spain)



**Aquarius (2011-2015)**  
Argentina-USA collaboration (CONAE/NASA)



**SMAP (2015-now)**  
Soil Moisture Active Passive  
NASA

**Colder** : the sensitivity of measurement decreases with temperature

**Smaller** : the resolution of SMOS and SMAP are about 40km

**At depth** : What can we infer at depth from Sea Surface Salinity ?



Improved calibrated  
global **Sea Surface  
Salinity** over  
2010-2019  
from **all available  
satellite L-band  
radiometer  
measurements**

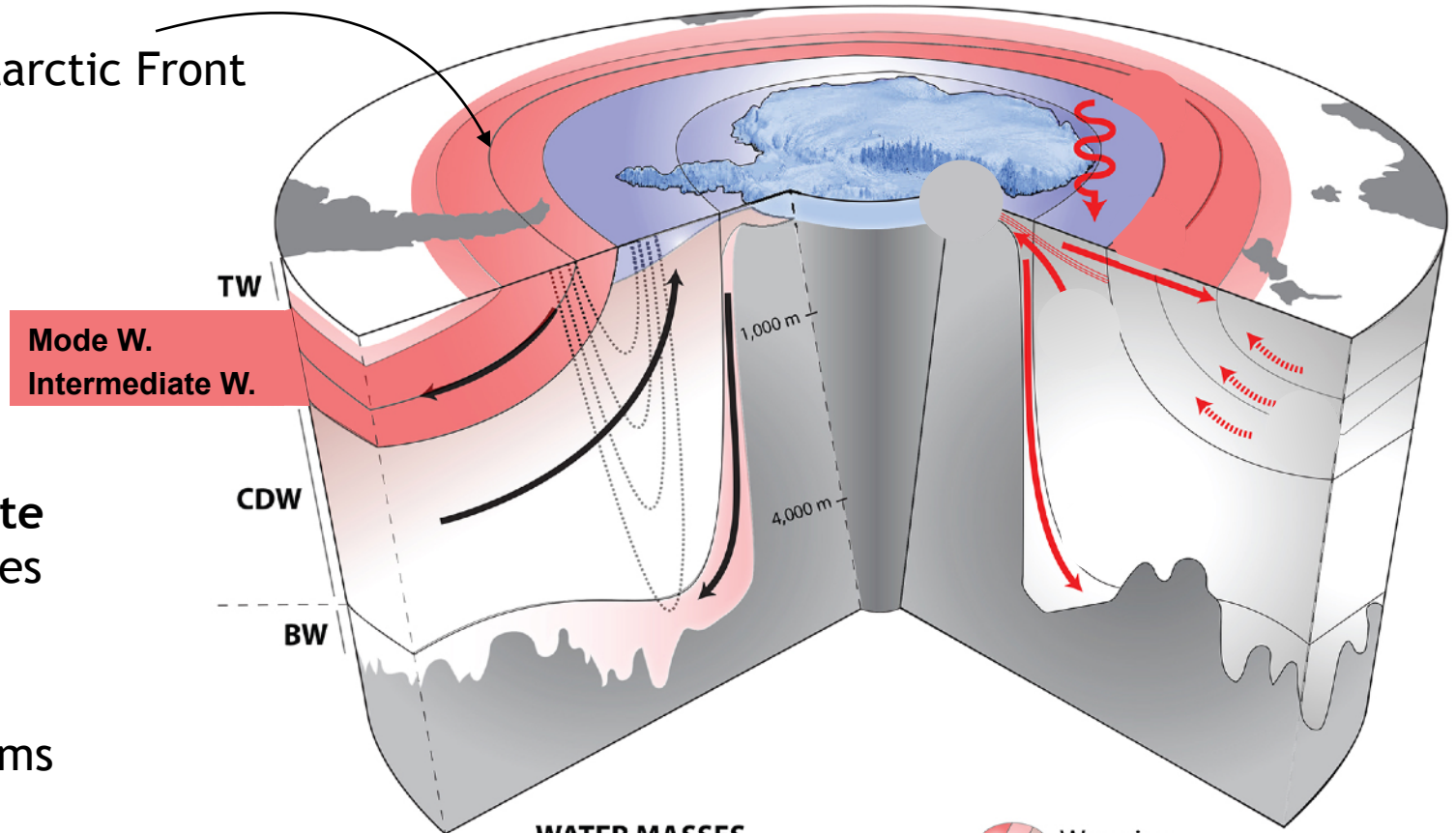


## Mode Waters and Intermediate Waters

- are identified by **large sub-surface volume** with horizontal and vertical homogeneous properties of temperature, salinity and oxygen content.
- play a **major role in the global Climate modulation** as they store large volumes of CO<sub>2</sub> and temperature at depth - isolated from the atmosphere
- signal erodes with time and mechanisms are still investigated



**What are the mechanisms of transformation after subduction and how can satellite observations help us ?**

Subantarctic Front



### WATER MASSES

TW: Subtropical Waters  
MW: Mode Waters  
IW: Intermediate Waters  
CDW: Circumpolar Deep Waters  
BW: Bottom Waters

 Warming  
 No warming or cooling

Adapted from Sallée 2018



# Southern Ocean and Mode Waters



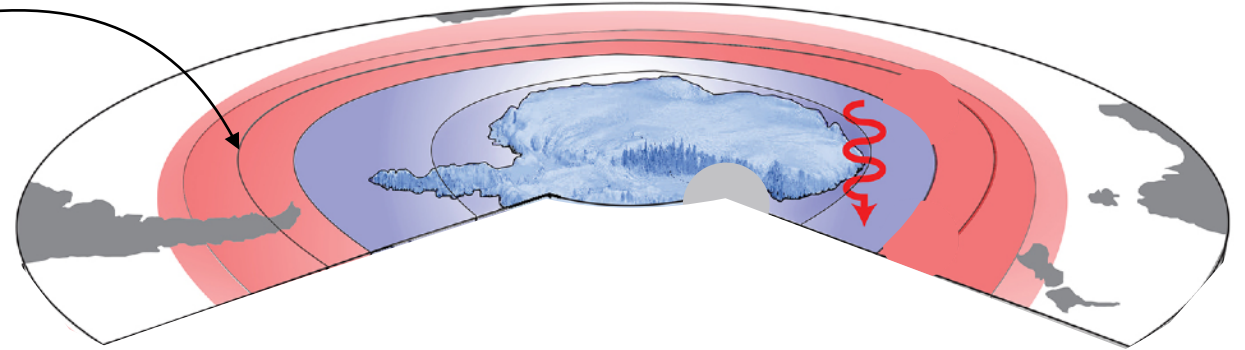
## Satellites enable the observation of the sea surface :

**Sea Surface Salinity (SSS)** : ESA CCI weekly L4 7DAY 25km fv2.3

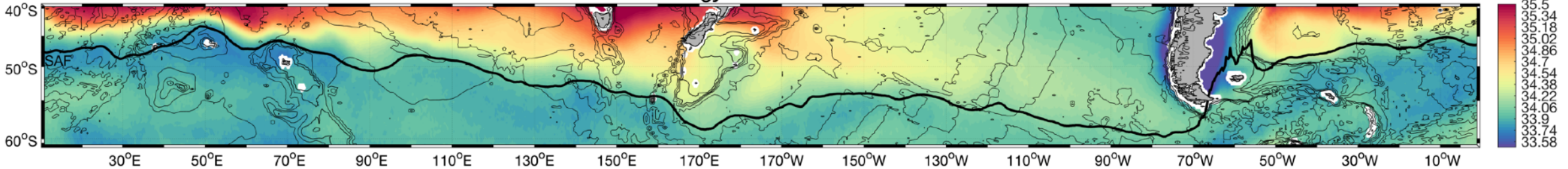
**Sea Surface Temperature (SST)** : Remss (Daily 1/12° v5)

**ACC fronts** : 2019 product allowing meanders developed at CTOH (LEGOS, R. Morrow et al.)

Subantarctic Front

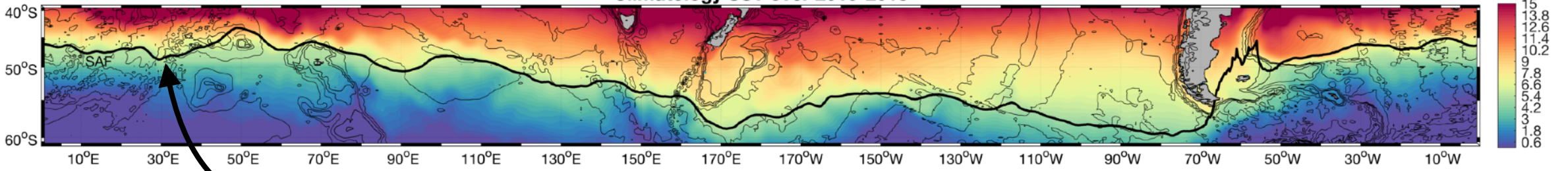


Climatology SSS over 2010-2018



Surface  
Salinity

Climatology SST over 2010-2018

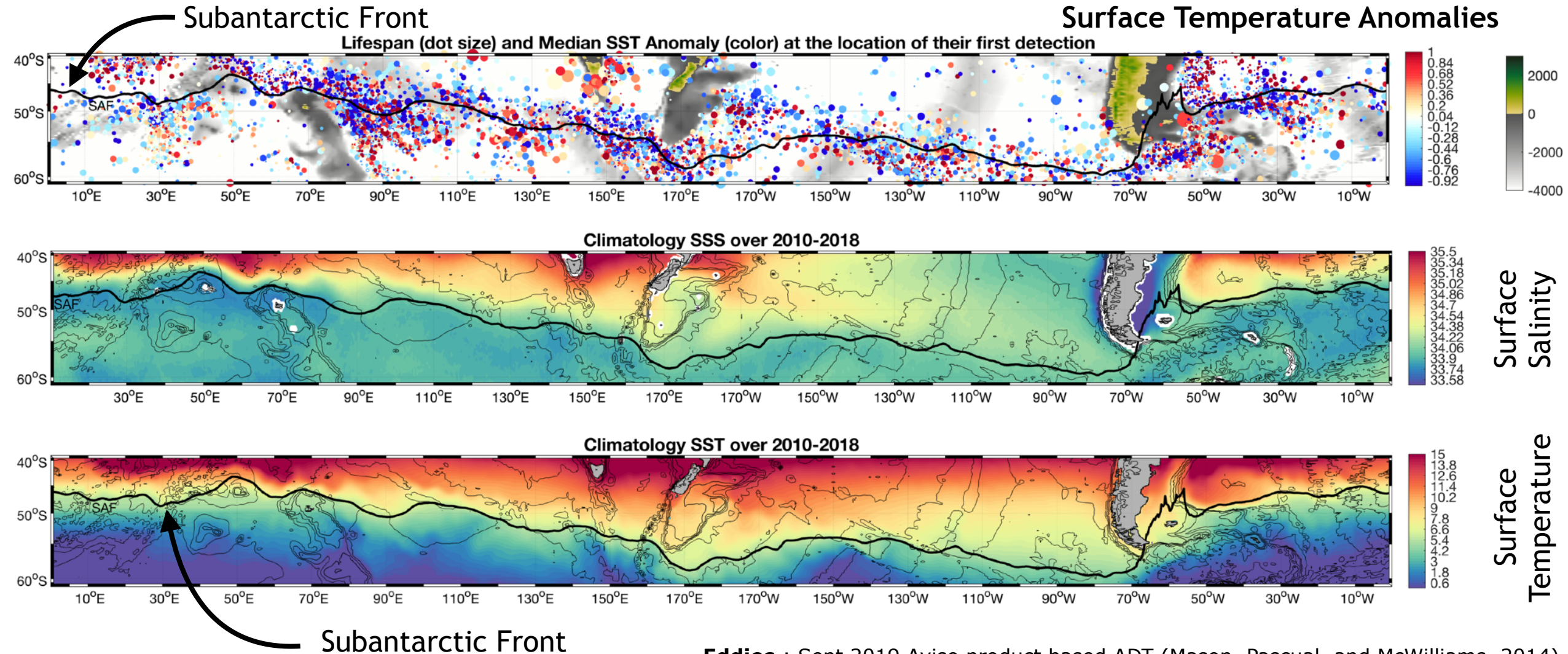


Surface  
Temperature

Subantarctic Front



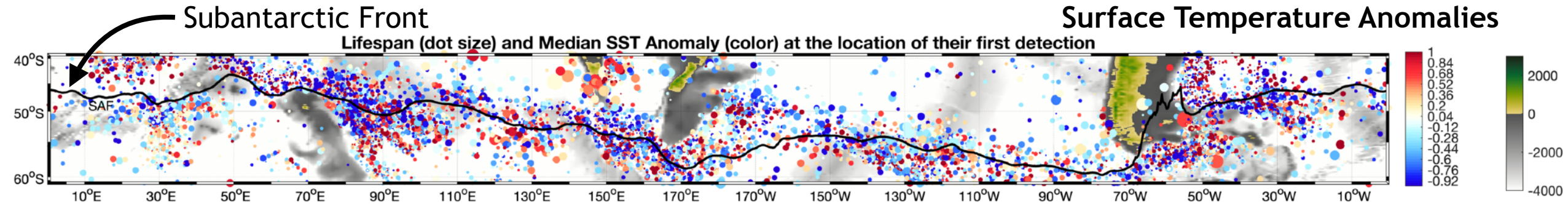
# Eddies of the Southern Ocean



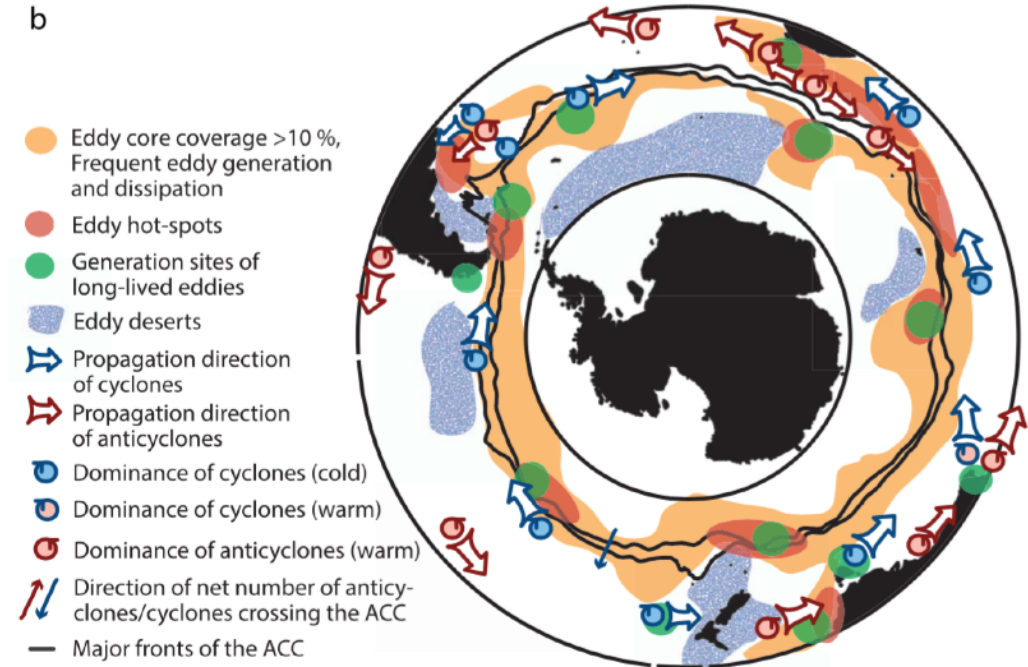
**Eddies** : Sept 2019 Aviso product based ADT (Mason, Pascual, and McWilliams, 2014)



# Eddies of the Southern Ocean



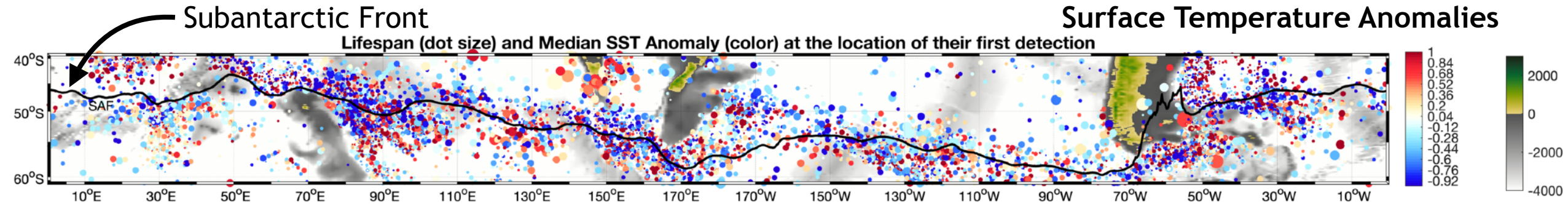
- Location of first detection consistent with literature i.e. coherent with bathymetry
- Distribution around the fronts (orange to the right)
- Direction of propagation : mostly eastward along the SAF
- No clear signal in Salinity or Temperature Anomalies



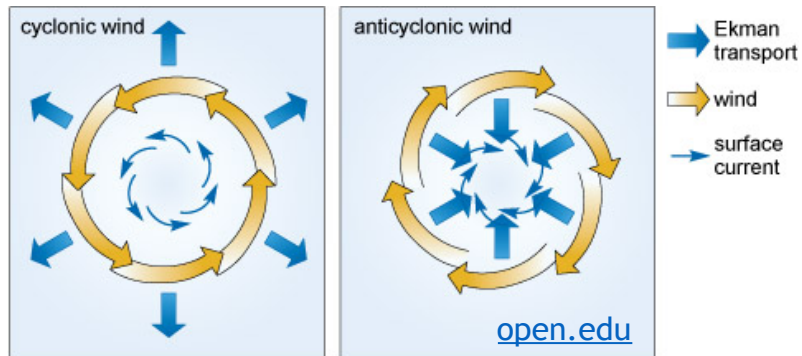
Frenger et al 2015



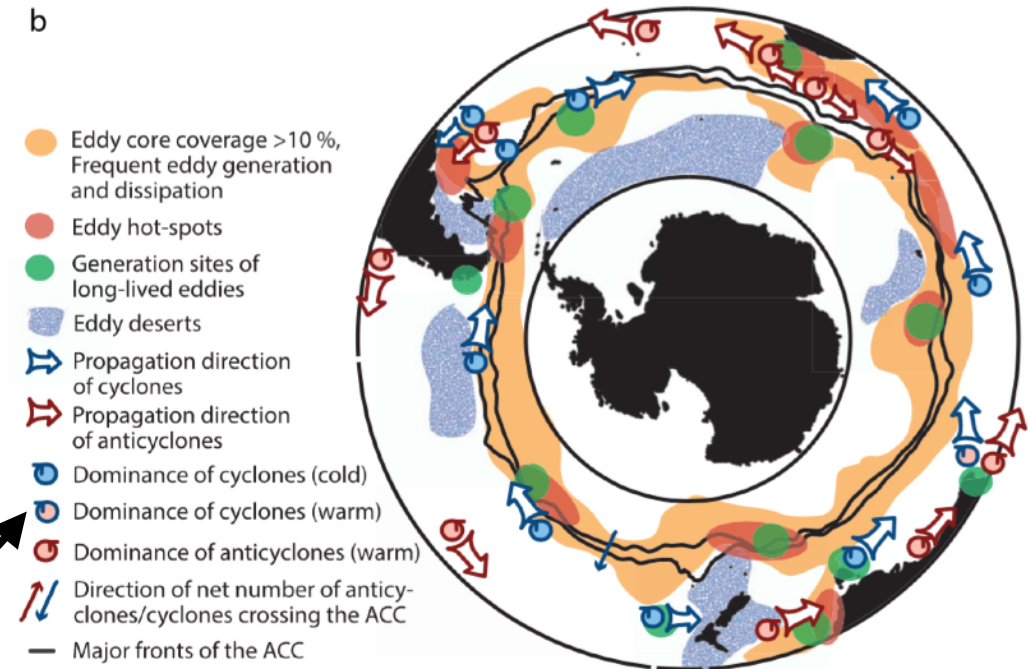
# Eddies of the Southern Ocean



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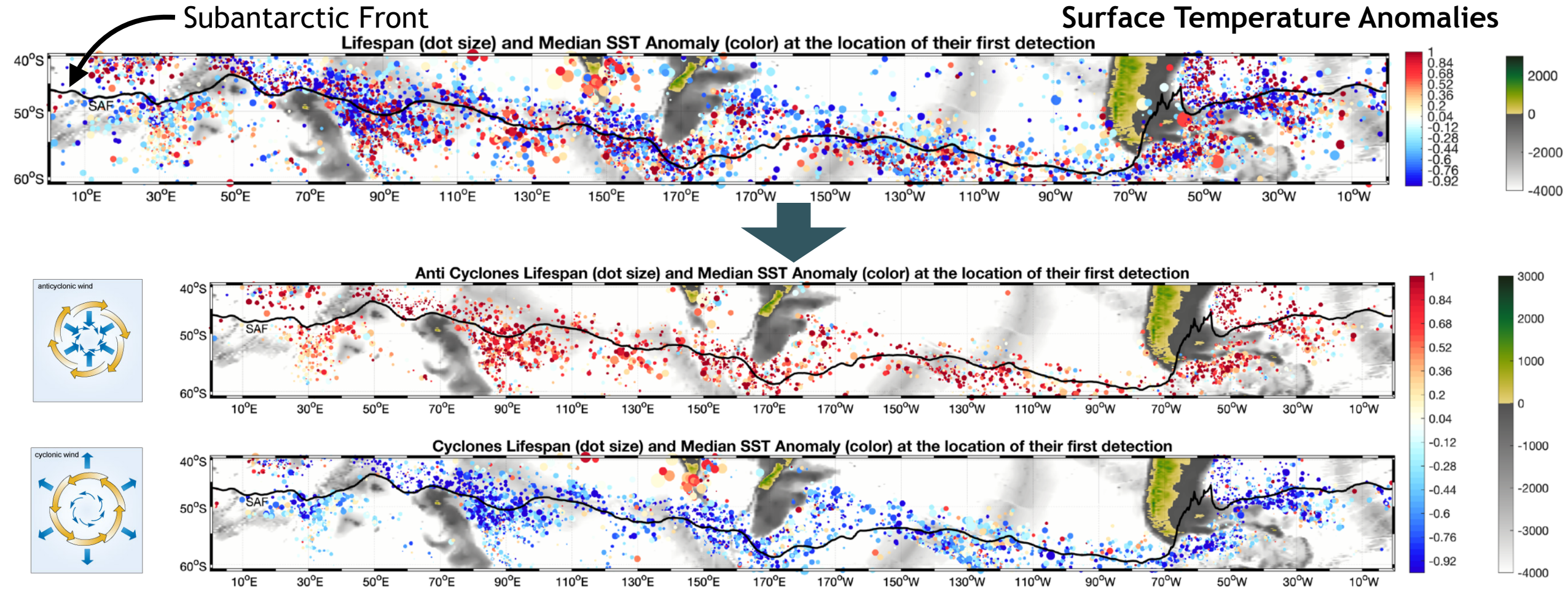
Previous studies show different SST signal depending on eddies rotation



Frenger et al 2015



# Sea Surface Temperature and Eddies





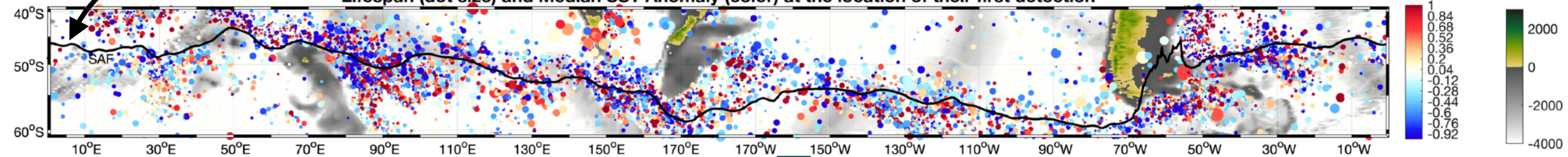
# Sea Surface Temperature and Eddies



Subantarctic Front

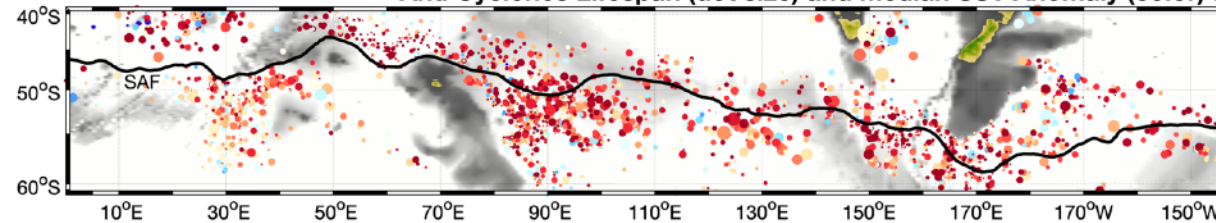
Surface Temperature Anomalies

Lifespan (dot size) and Median SST Anomaly (color) at the location of their first detection

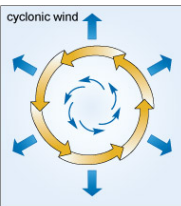
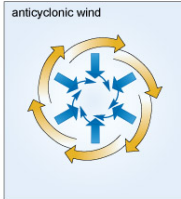
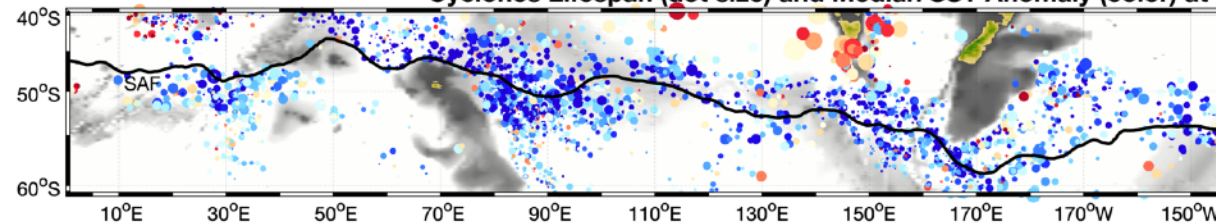


b

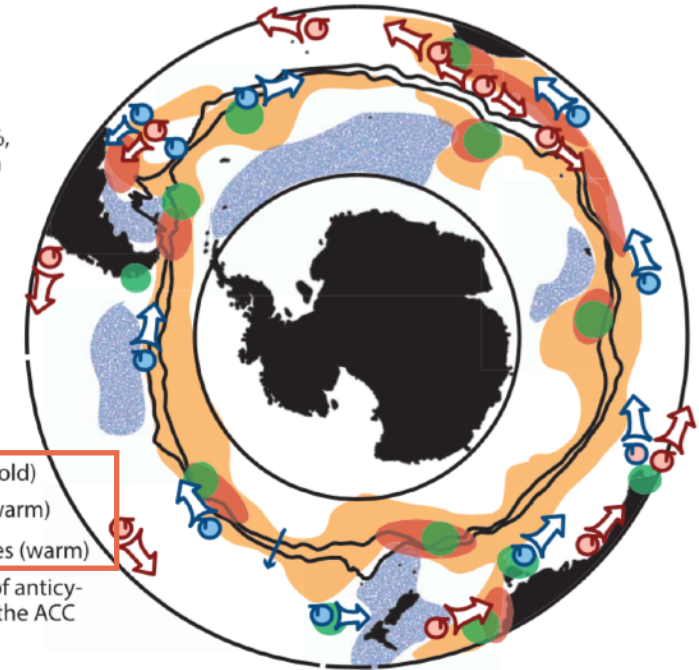
Anti Cyclones Lifespan (dot size) and Median SST Anomaly (color)



Cyclones Lifespan (dot size) and Median SST Anomaly (color) at



- Eddy core coverage >10 %, Frequent eddy generation and dissipation
- Eddy hot-spots
- Generation sites of long-lived eddies
- Eddy deserts
- ➡ Propagation direction of cyclones
- ➡ Propagation direction of anticyclones
- Dominance of cyclones (cold)
- Dominance of cyclones (warm)
- Dominance of anticyclones (warm)
- ➡ Direction of net number of anticyclones/cyclones crossing the ACC
- Major fronts of the ACC





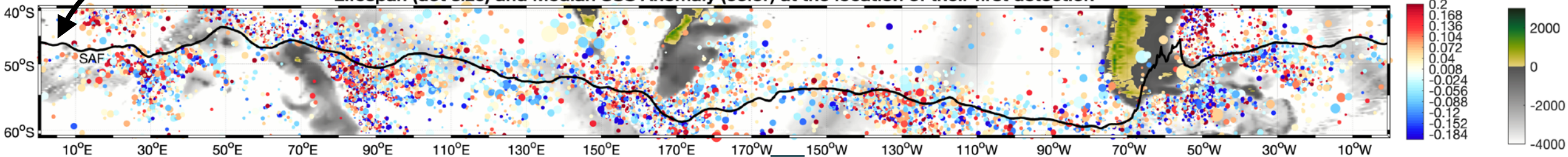
# Sea Surface Salinity and Eddies



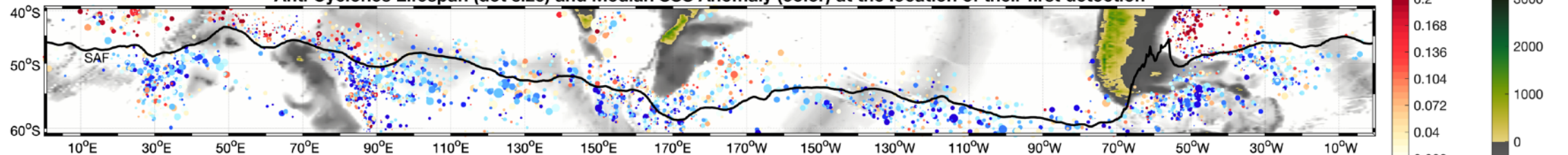
Subantarctic Front

Surface Salinity Anomalies

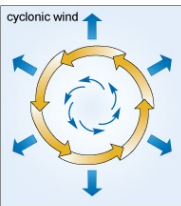
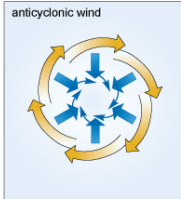
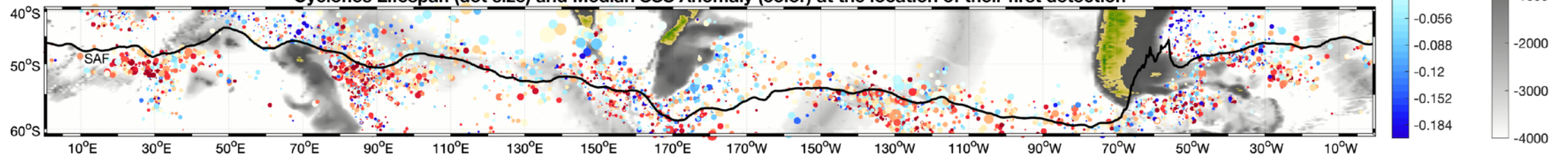
Lifespan (dot size) and Median SSS Anomaly (color) at the location of their first detection



Anti Cyclones Lifespan (dot size) and Median SSS Anomaly (color) at the location of their first detection



Cyclones Lifespan (dot size) and Median SSS Anomaly (color) at the location of their first detection



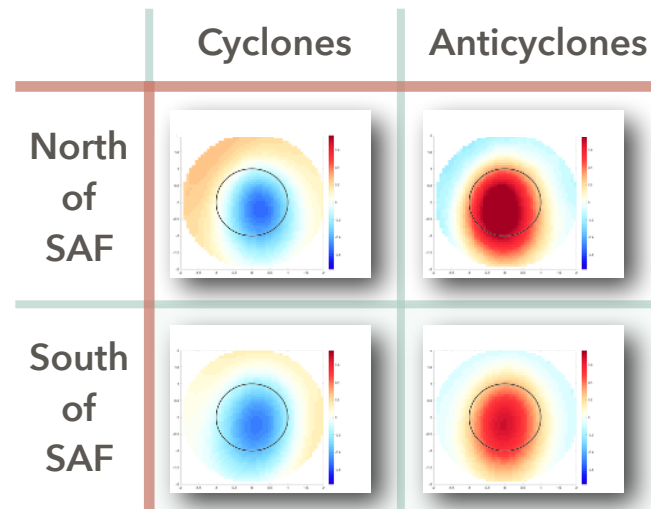


# Salinity and Temperature Composites

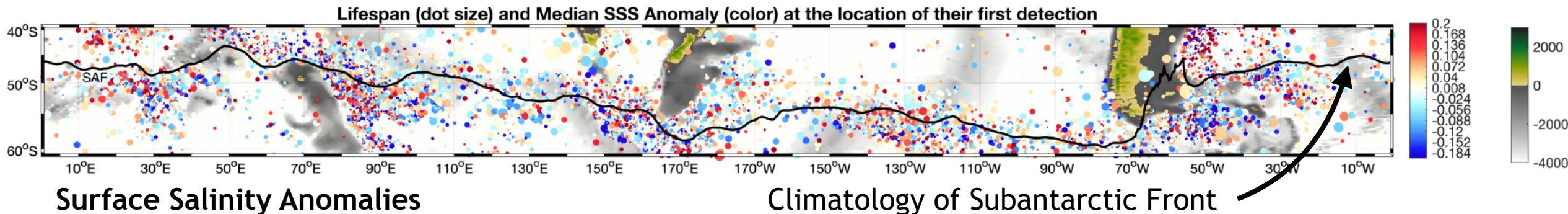
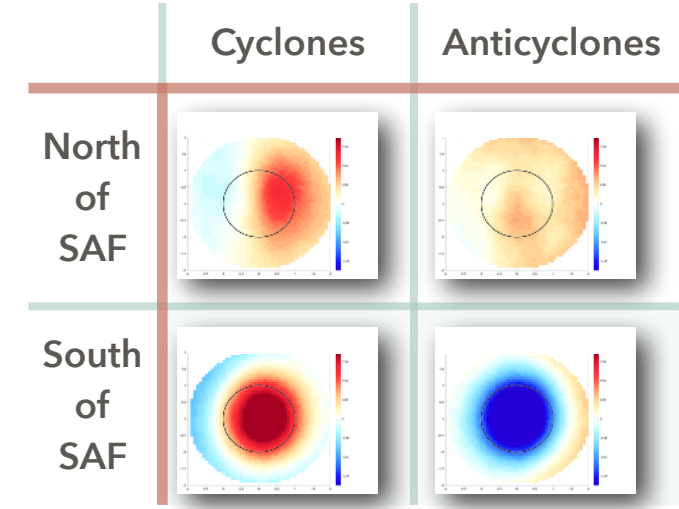


- **Position and radius of eddies** from novel Aviso product
- **Weekly position of the Subantarctic Front** allowing meanders (CTOH)
- **Rotation** with respect to large scale gradient
- **Removed Eddies** from composites:
  - Eddies crossing the SAF
  - First + last 15 days
  - Lifespan between 30 and 1000d

## Temperature (REMSS v5)



## Salinity (CCI)

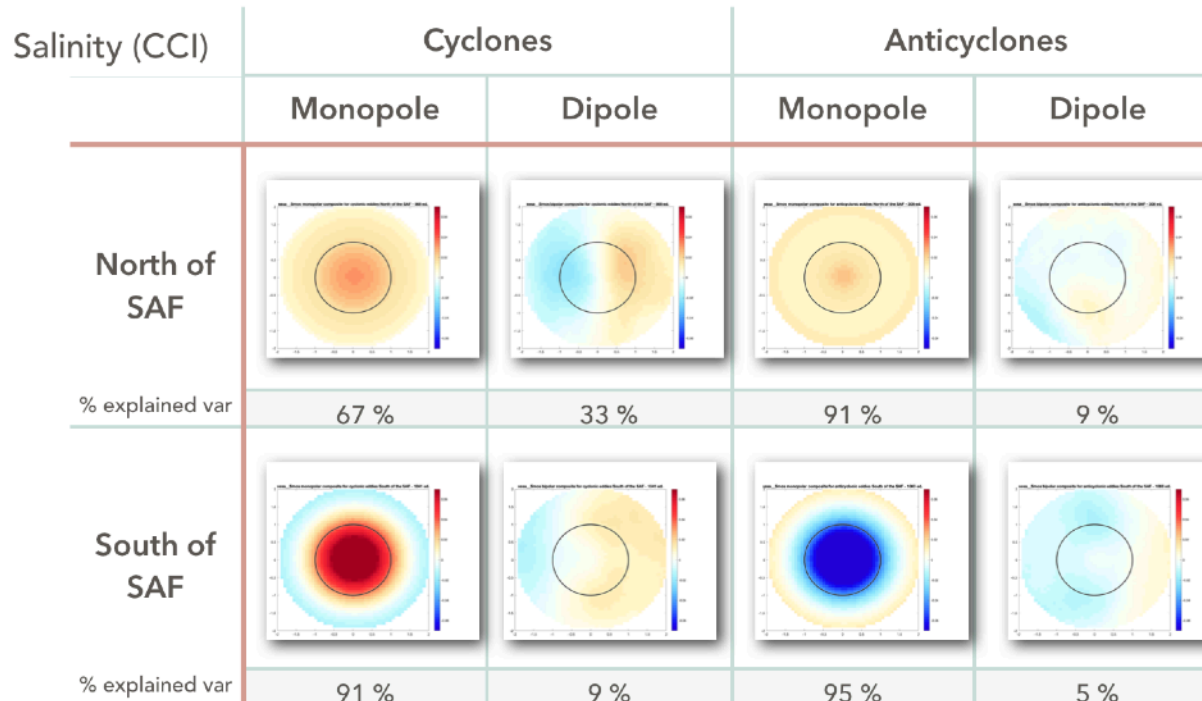
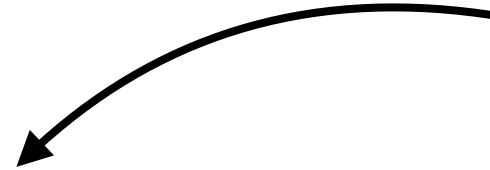




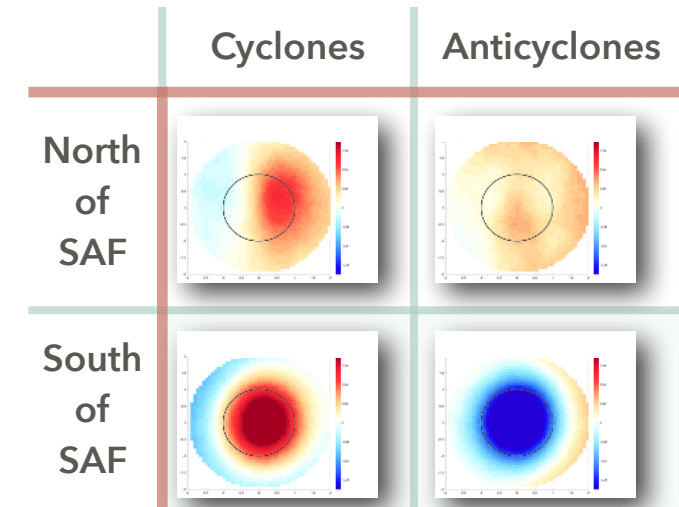
# Decomposing the Composites

In order to understand the mechanism of these anomalies we decompose the composites into

- **Monopoles** (radial means)
- **Dipoles** (the remainder)



## Salinity (CCI)



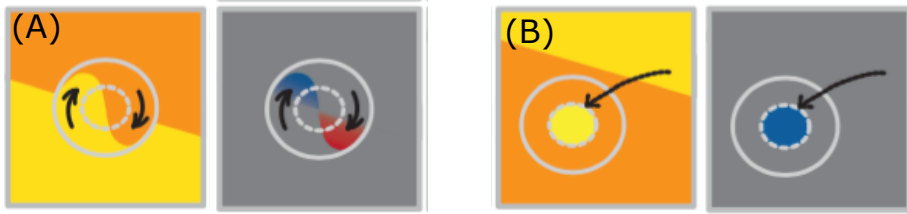
Dipoles are weak probably because we are staying away from fronts ...



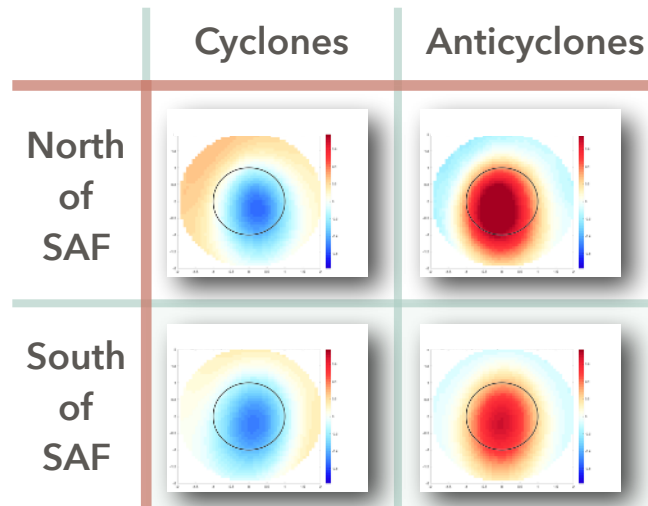
# Mechanisms for Anomalies

4 mechanisms :

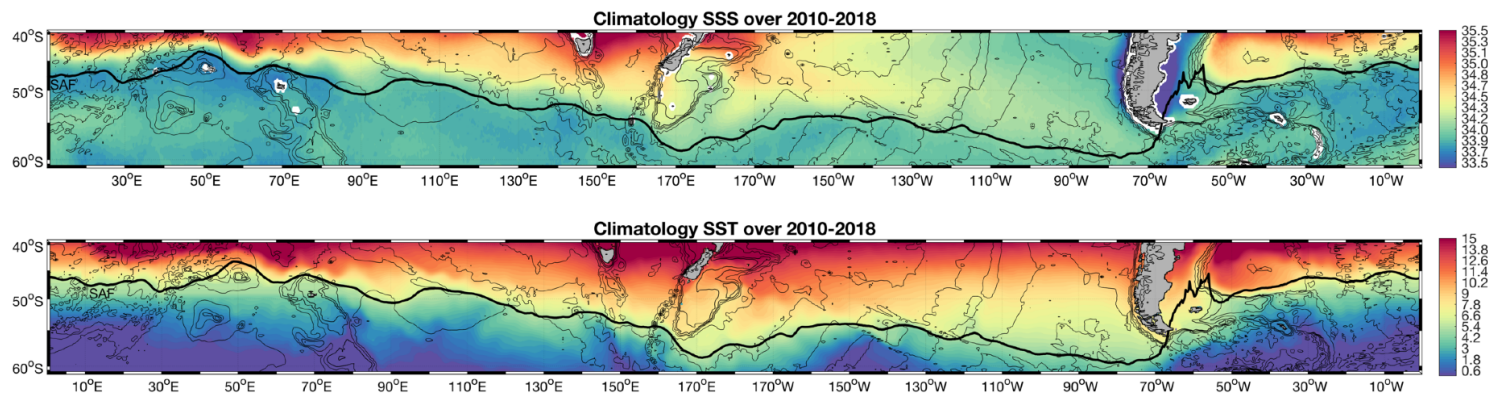
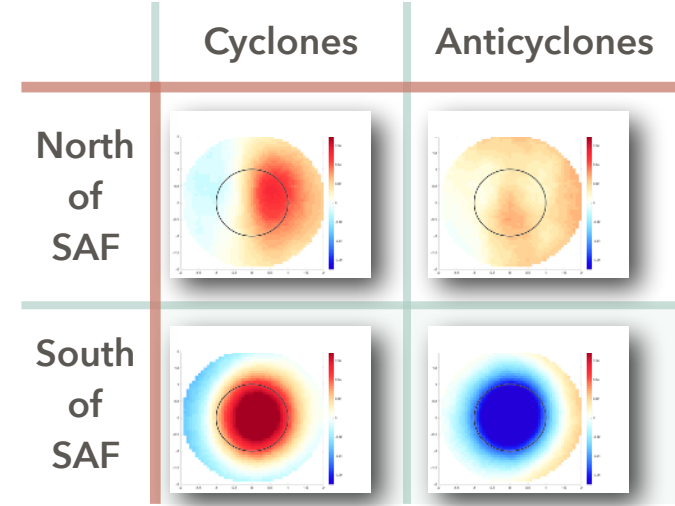
- (A) Bi-pole by stirring**
- (B) Monopole by trapping**
- (C) Monopole by vertical mixing
- (D) Bi-pole by accumulation**



Temperature (REMSS v5)



Salinity (CCI)



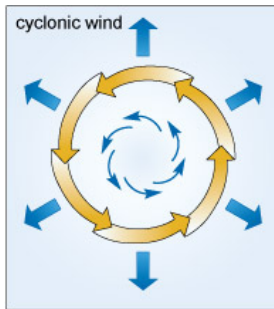


# Mechanisms for Anomalies

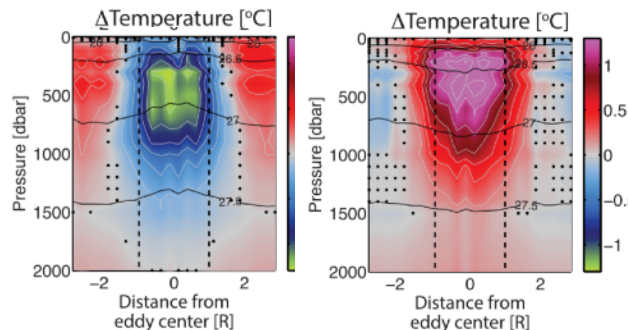
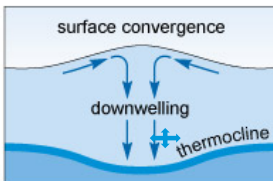
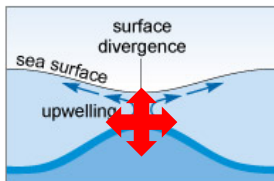
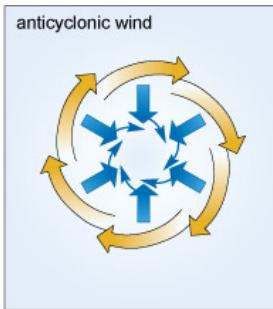
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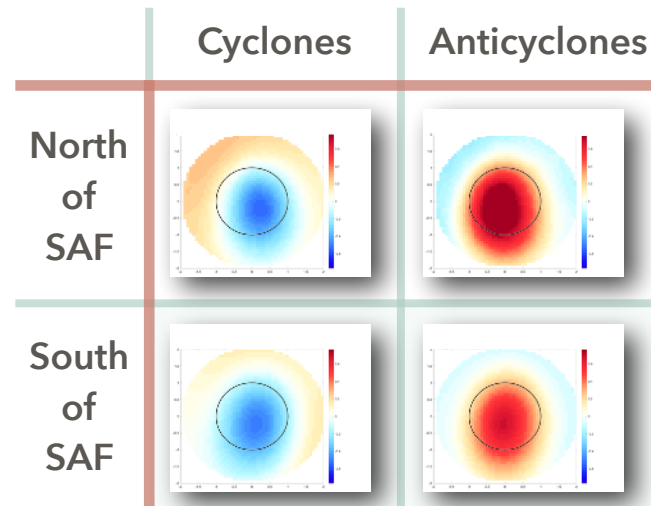
(C) Cyclones



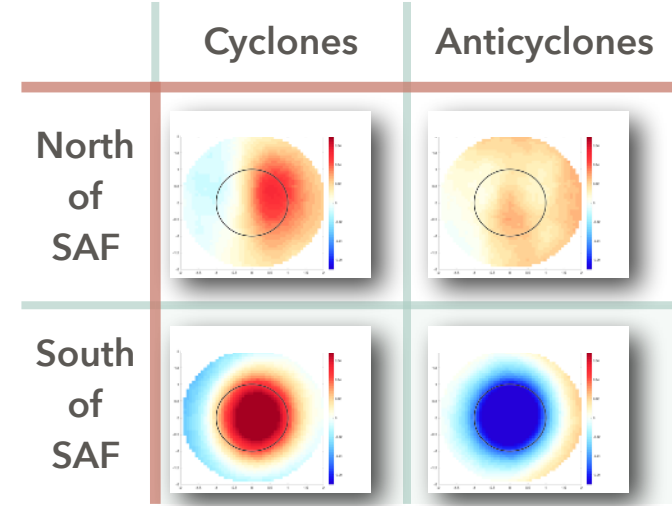
(C) Anti-Cyclones



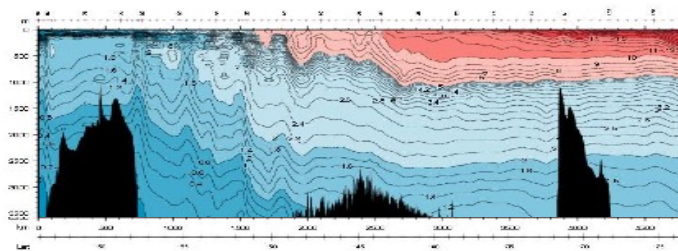
Temperature (REMSS v5)



Salinity (CCI)



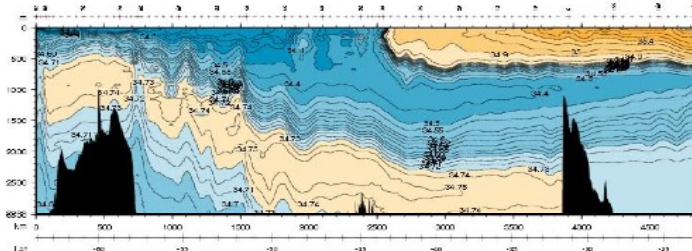
Temperature with depth



south

north

Salinity with depth



south

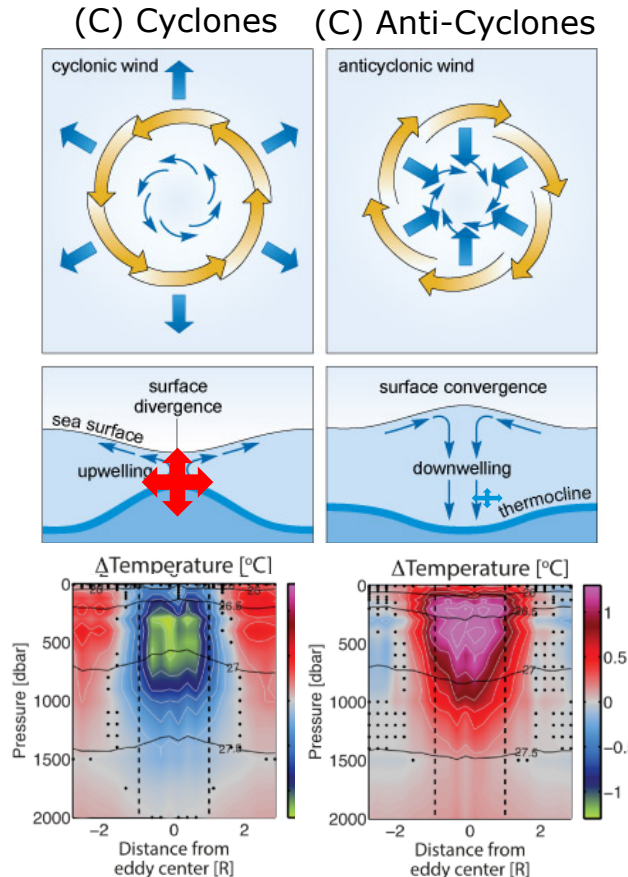
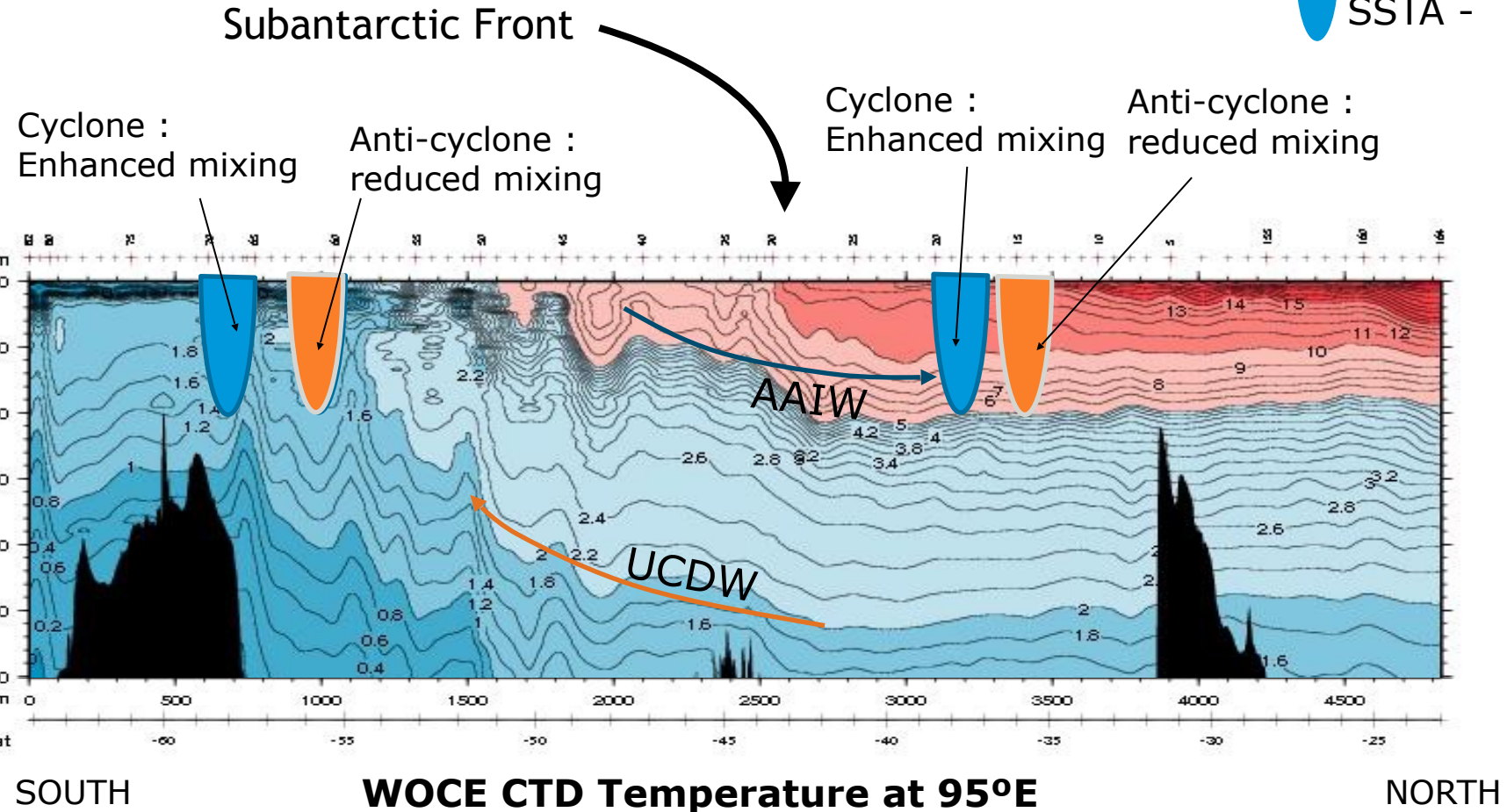
north



# Vertical Mixing and Temperature Gradient

Vertical gradient of Temperature is the same North and South of the Subantarctic Front

## Vertical Distribution of Temperature

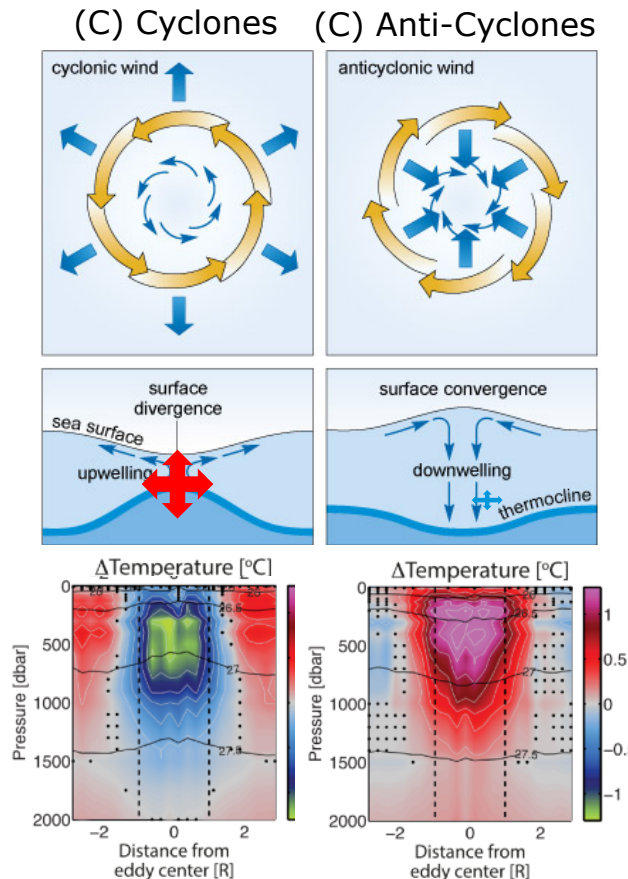
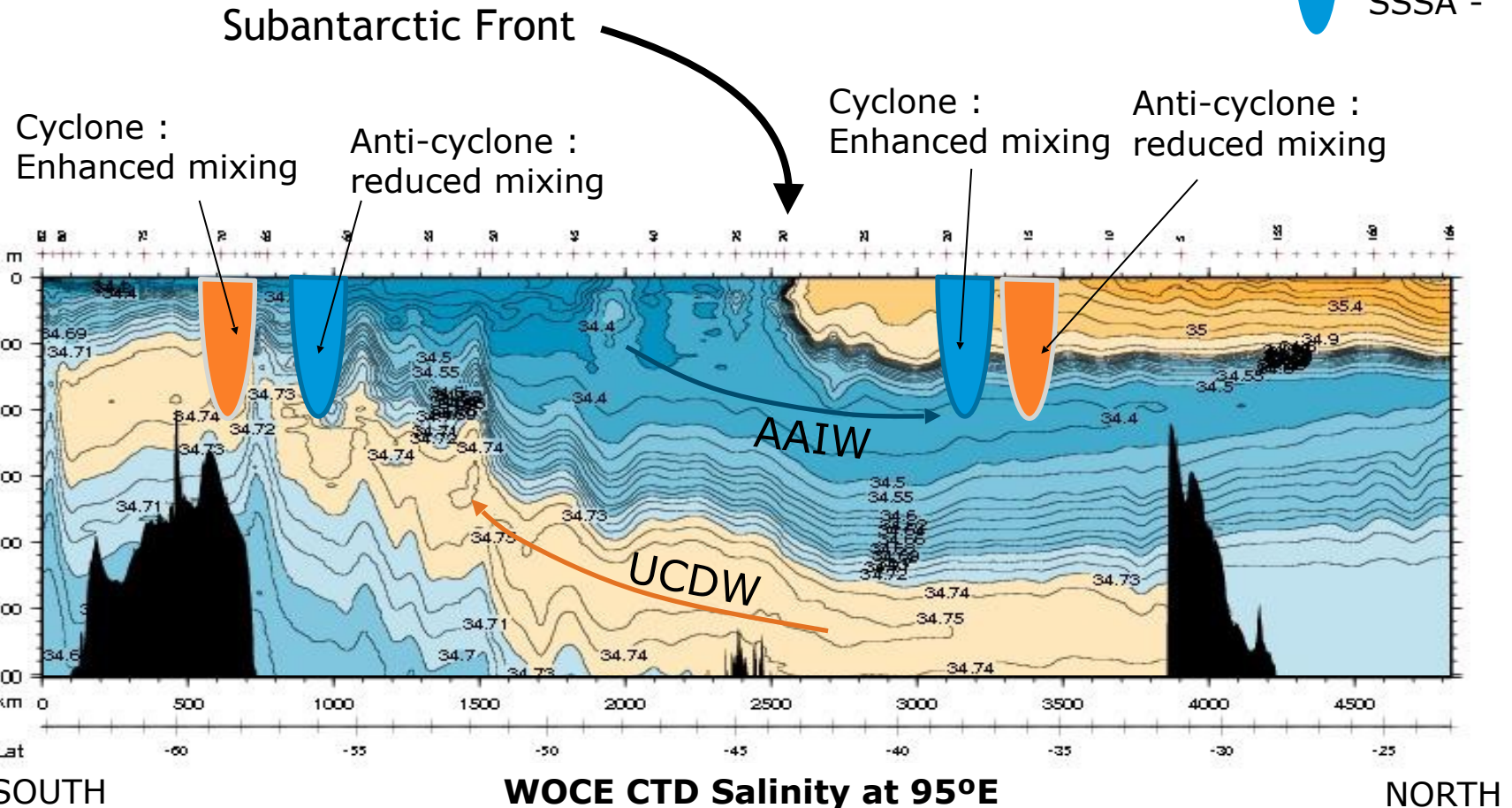




# Vertical Mixing and Salinity Gradient

Vertical gradient of Salinity is different North and South of the Subantarctic Front

## Vertical Distribution of Salinity





# Sea Surface Salinity : Colder, Smaller and at Depth ?

-- YES !!! --

**New Sea Surface Salinity processing enable the unprecedented observation and study of Southern Ocean (colder) Meso-scale Eddies (smaller) interactions with Mode Waters (at depth)**

Since 2010, space missions dedicated to **Sea Surface Salinity (SSS)** have been providing observations with a **resolution of about 45 km every 3 days**. The European Space Agency (ESA) SMOS mission was the first orbiting radiometer to collect regular SSS observations from space.

Most SSS satellite-based studies have left out the Southern Ocean because of its **lower sensitivity in rough and cold waters**. **New processing** now allows a **better SSS estimate** at high latitudes.

Sea Surface Salinity anomalies associated with moving eddies were **first studied** in the Southern Ocean with these datasets

The analysis of surface salinity reveals the **erosion of subsurface waters**, such as mode waters, induced by changes in **vertical mixing** caused by the deep reaching eddies in the Southern Ocean.



# Southern Ocean and Mode Waters

