A Material Approach to the Traditional Water Mass (Trans)Formation Framework

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Outline

- **Motivation**
- The **traditional** and **new** approach to the water mass framework
- **Why** do we need a new approach?
- Results from **comparison**
  1. Buoyancy forcings
  2. Formation
- **Future** work

Motivation

- The importance of **water masses**

1 **Water cycle**:

2 2-4 times more northward freshwater flux than anticipated (Sohail et al., 2022)

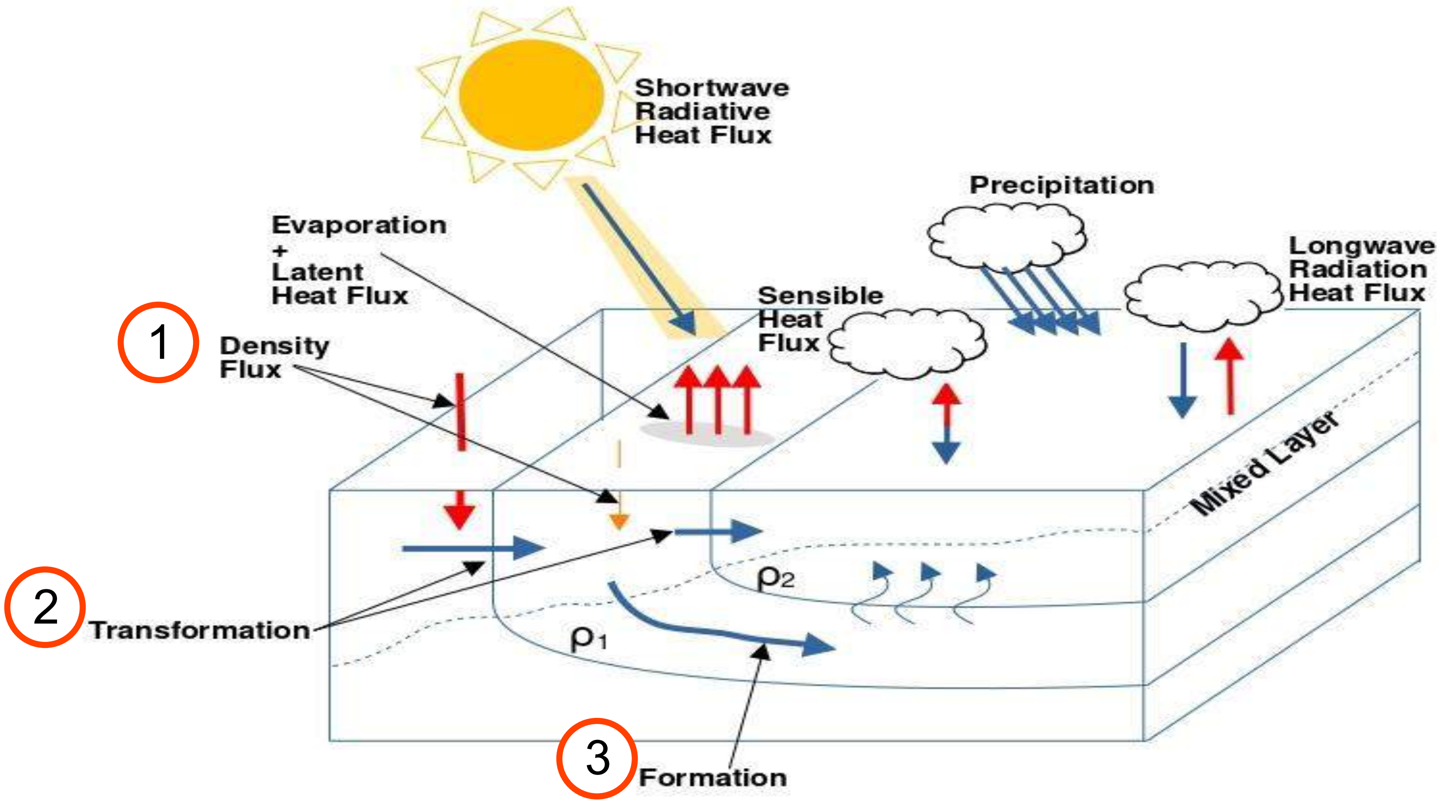
3 **Greenhouse gasses**:

4 86–93% loss in the past decade of North Atlantic water masses (Stevens et al., 2020)

5 **Biology**:

6 >0.3 increase in pH <1000m in northern North Atlantic from increased CO_2 (Puerta et al., 2020)

The Water Mass Framework



The traditional and new approach

- Material changes
  - all forcings driving scalar changes

1

$$\frac{D\tau}{Dt} = d_\tau + f_\tau$$

- Forcings on temperature and salinity
  - heat and freshwater fluxes

2

$$f_\theta = \frac{H}{C_p \rho}\delta(z=0)$$

$$f_S = QS\delta(z=0)$$

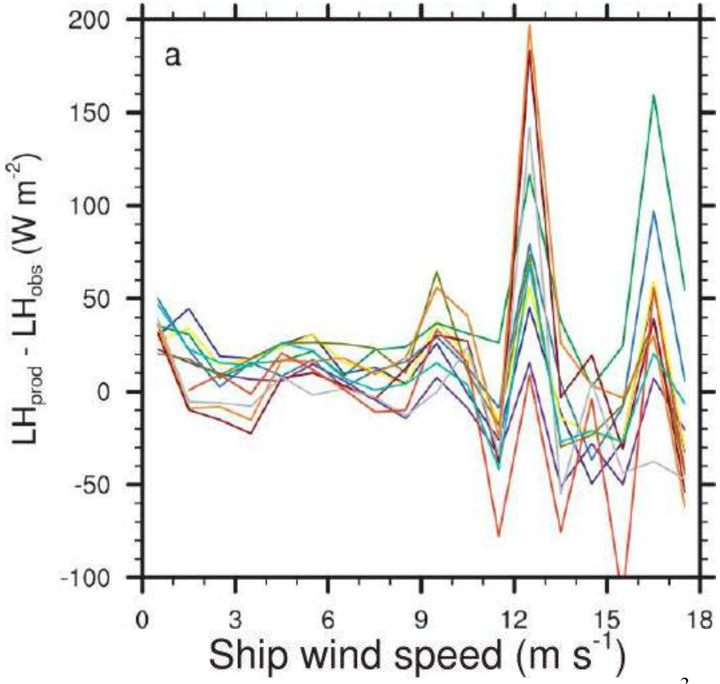
- Component SSS + SST → SSD
  - Arrive at equivalent relations of density flux

3

$$f = \rho[-\alpha\frac{D\theta}{dt} + \beta\frac{DS}{Dt}]$$

(Iudicone et al., 2007)

Why do we need a new approach?



(Brunke et al., 2011)

- Use of **air-sea fluxes**

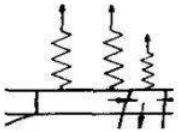
1. Bulk-Formula uncertainties
2. Biases
3. Positive biases of 22-62 Wm^{-2} in turbulent heat fluxes between numerical models, satellites and in-situ observations (Tomita et al. 2021; Zhou et al., 2020; Kubota et al., 2008)
4. **Linked to wind speed (especially in Western Boundary Currents)** (Brunke et al., 2011)
5. **Specific humidity** (Zhou et al., 2020)

traditional

Summary of approaches

New (NO FLUXES)

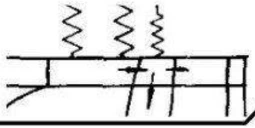
Density Flux



$$f = \frac{-\alpha H}{C_p} + \rho(0,T)\frac{\beta Q S}{1-S}$$

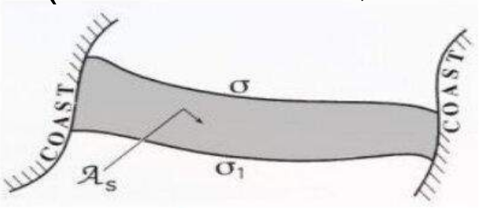
$$f = \rho[-\alpha\frac{D\theta}{dt} + \beta\frac{DS}{Dt}]$$

Transformation



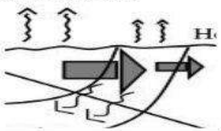
$$F(\rho) = \iint_{area} dA f \delta(\rho - \rho')$$

(Marshall et al., 1999)



$$S_{i,j,k}(\sigma'_\theta) = \frac{M_k(\sigma_{\theta'})}{R_k(\sigma'_\theta)}, \qquad \forall\, i,j$$

Formation



$$M(\rho) = -[F(\rho + \Delta\rho) - F(\rho)]$$

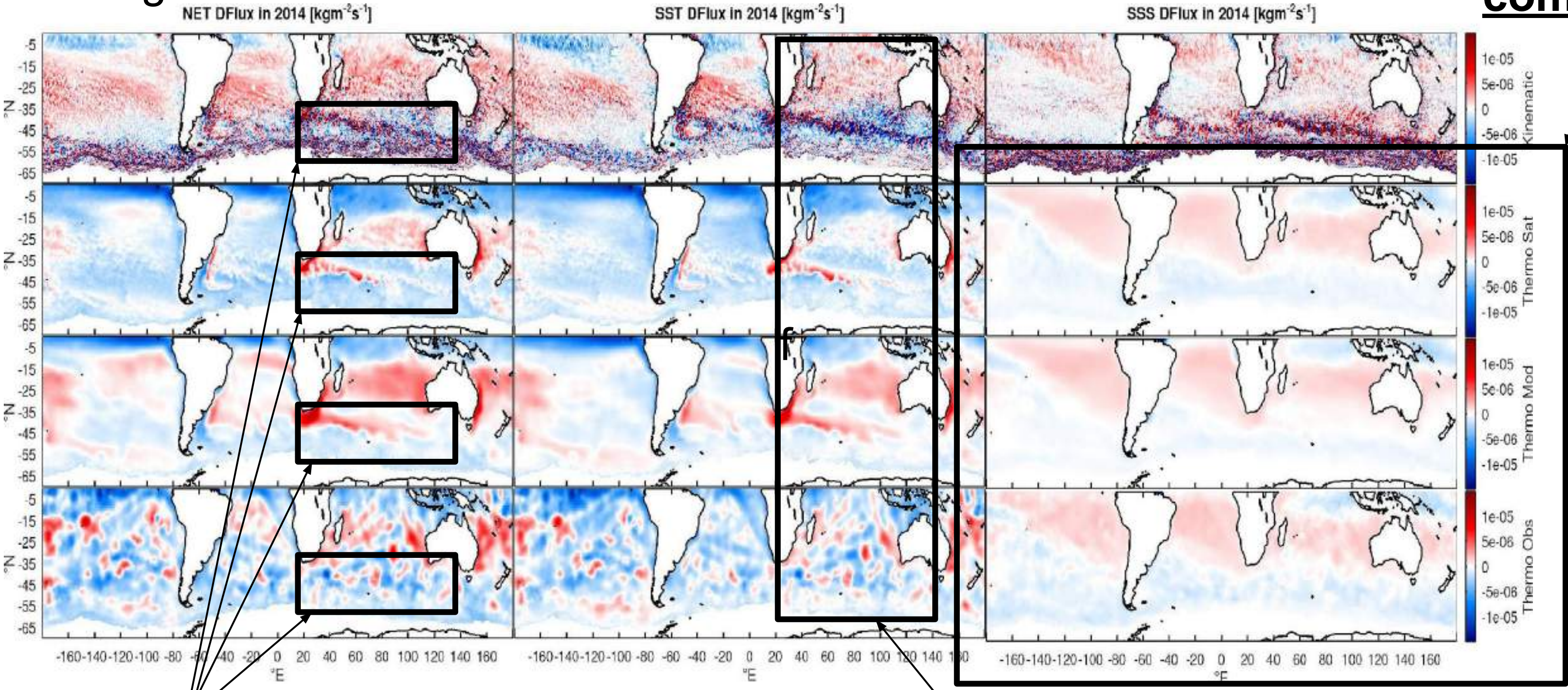
(Brambilla et al., 2008)

Results I

2014 – 0.25/Mon.
Buoyancy Forcings

NET | THERM | HALINE

MAT. | SAT. | MOD. | OBS.



1 Air-Sea fluxes **underestimate** **<u>haline</u>** **<u>component</u>**

2 Underestimation – IO Monsoon???
2014 record low summer rainfall (Gadgill and Francis 2016)
Summer ↓ rainfall = Winter ↓ buoyancy (Thopil et al., 2022)

3 Underestimation – ACC
<u>Noise</u> form derivatives
<u>Signal</u> of frontal dynamics → High Res
Future work

Results II

2014 – 0.25/Mon.
Geo. Formation

NET | THERM | HALINE

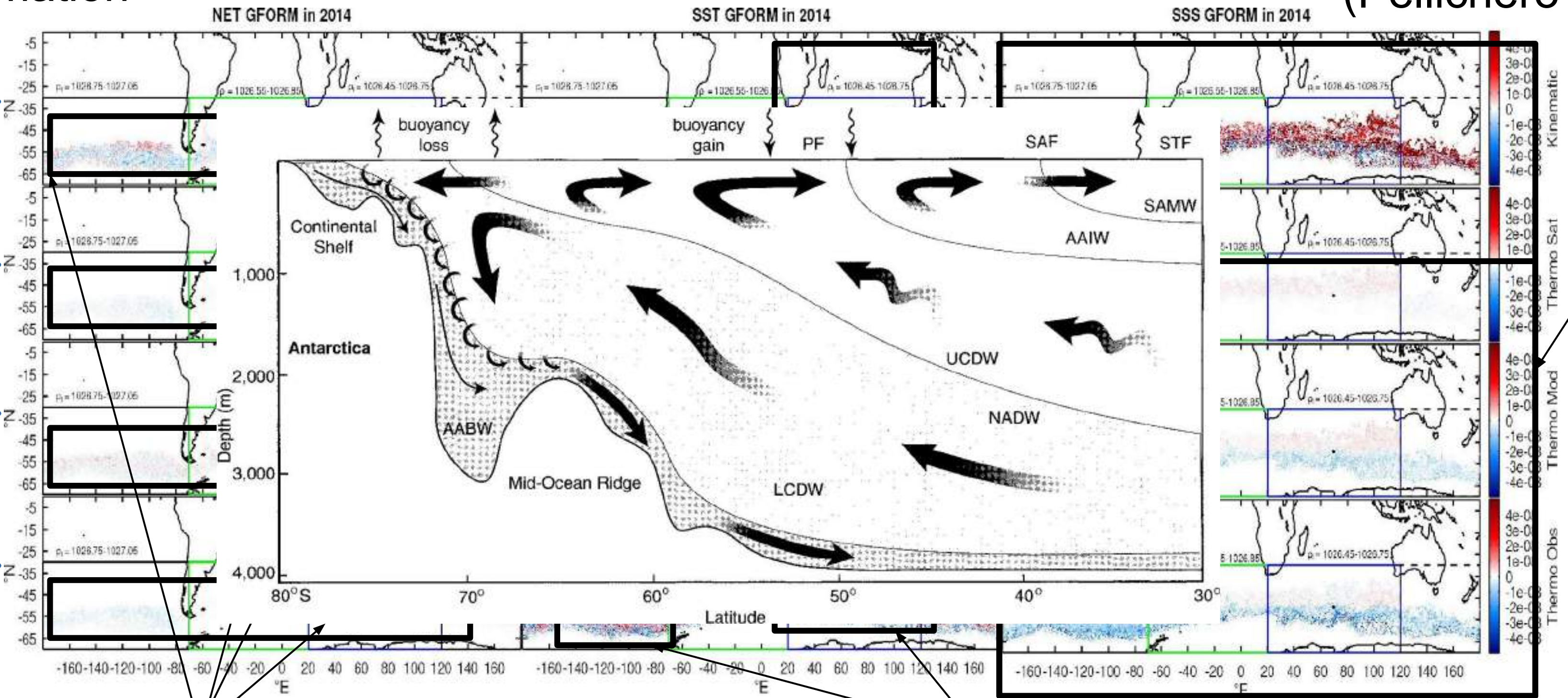
Sea-Ice dynamics
Dominate formation
1 South. Ocean
(Pellichero et al., 2018)

MAT.

SAT.

MOD.

OBS.



Weakly resolved air-sea fluxes

3 **Bipolar** pattern of **Sub./Upwel.**
Not seen in **air-sea fluxes**
Signal of Deacon Cell
(Doos and Webb, 1993)

2 **"Hot spots"** of formation in SO
Eastern South Pacific/Eastern Indian Ocean
(Li et al., 2021)

Future Work

- Paper in preperation → Front. Mar. Sci.

- Seperate Signal/Noise Material water mass framework →Gaussian Approach

- Apply new approach →Cold-Blob
  - Record breaking cold anomaly linked to AMOC
    - (Josey et al., 2019)

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