Global mode water detection and its representation in heat transport

Yanxu Chen and Sabrina Speich
Laboratoire de Météorologie Dynamique (LMD-IPSL)
Ecole Normale Supérieure (ENS-PSL), Paris

April 6th, 2022

Ocean heat uptake

- Ocean serves as a heat reservoir of the Earth system, accounting for over 90% of the total warming that has occurred since 1955.
- Mode water plays a major role in ventilating thermoclines and modulating SST signals.
- In our study, a new algorithm is developed to determine the mixed layer depth (MLD) and mode water (MW) thickness, which is applied to the Argo array.
- By co-locating mesoscale eddies derived from satellite altimetry maps (Laxenaire et al., 2019) and Argo profiles, we also assess the role of eddies in mode water transport and subduction.

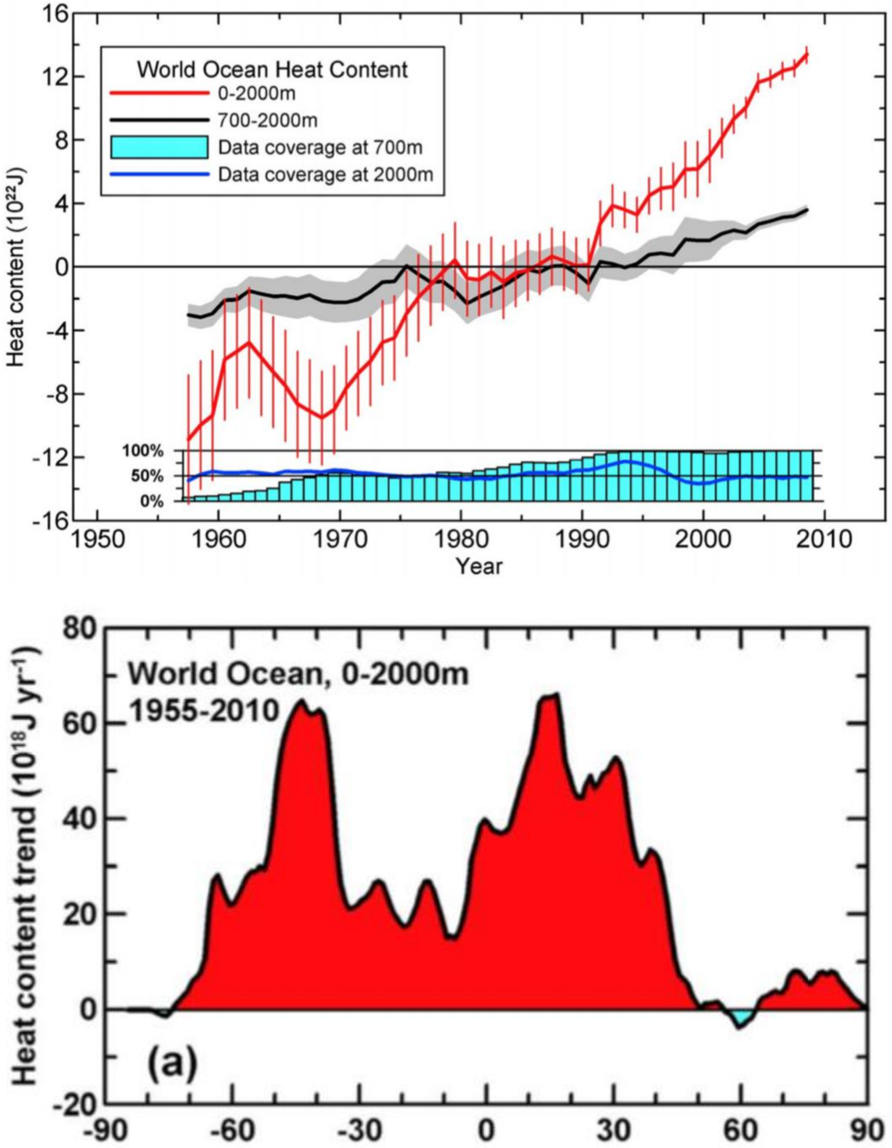
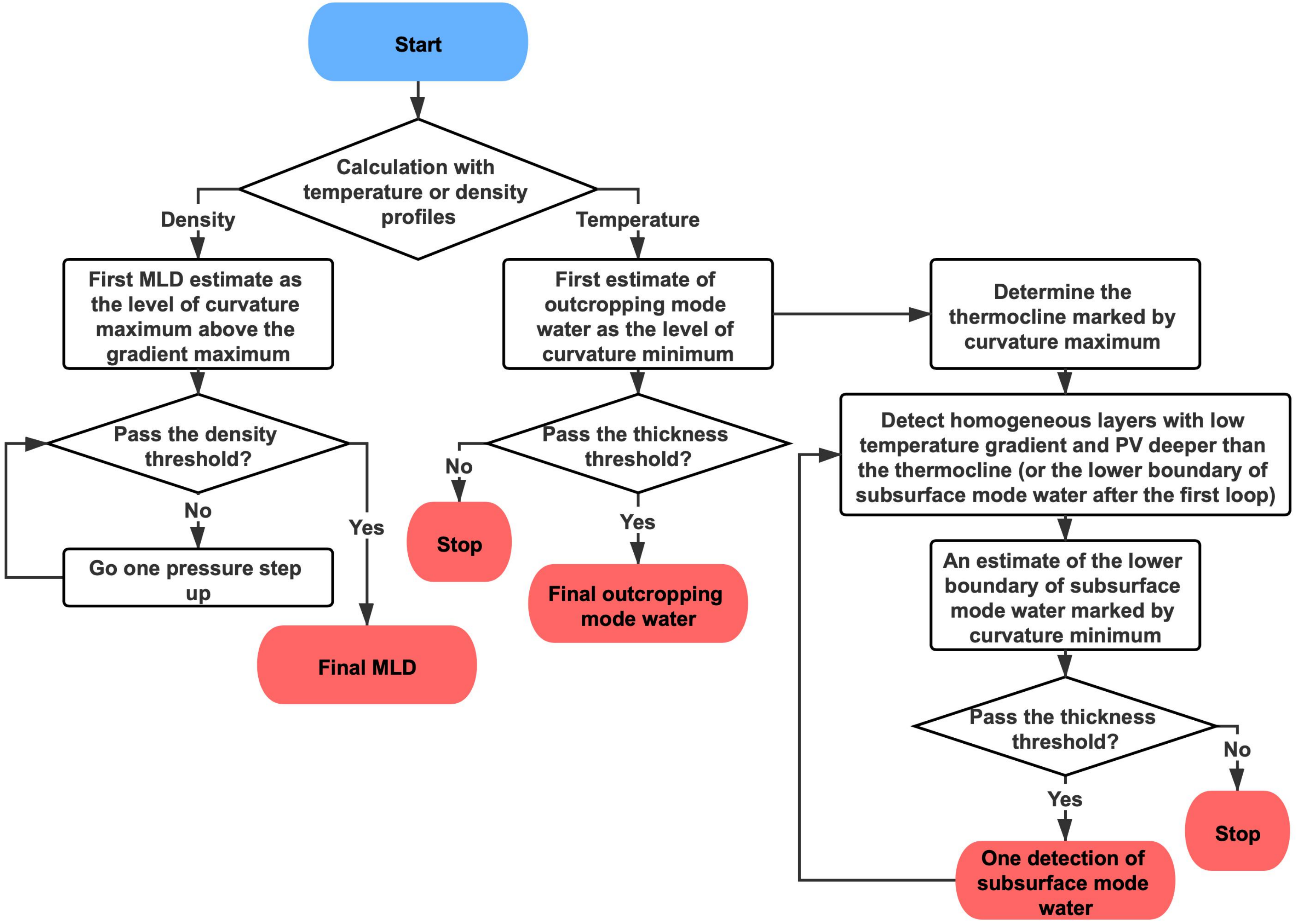


Figure: Ocean heat content. (Levitus et al., 2012)

IPSL LMD ENS PSL

The MLD and MW algorithm



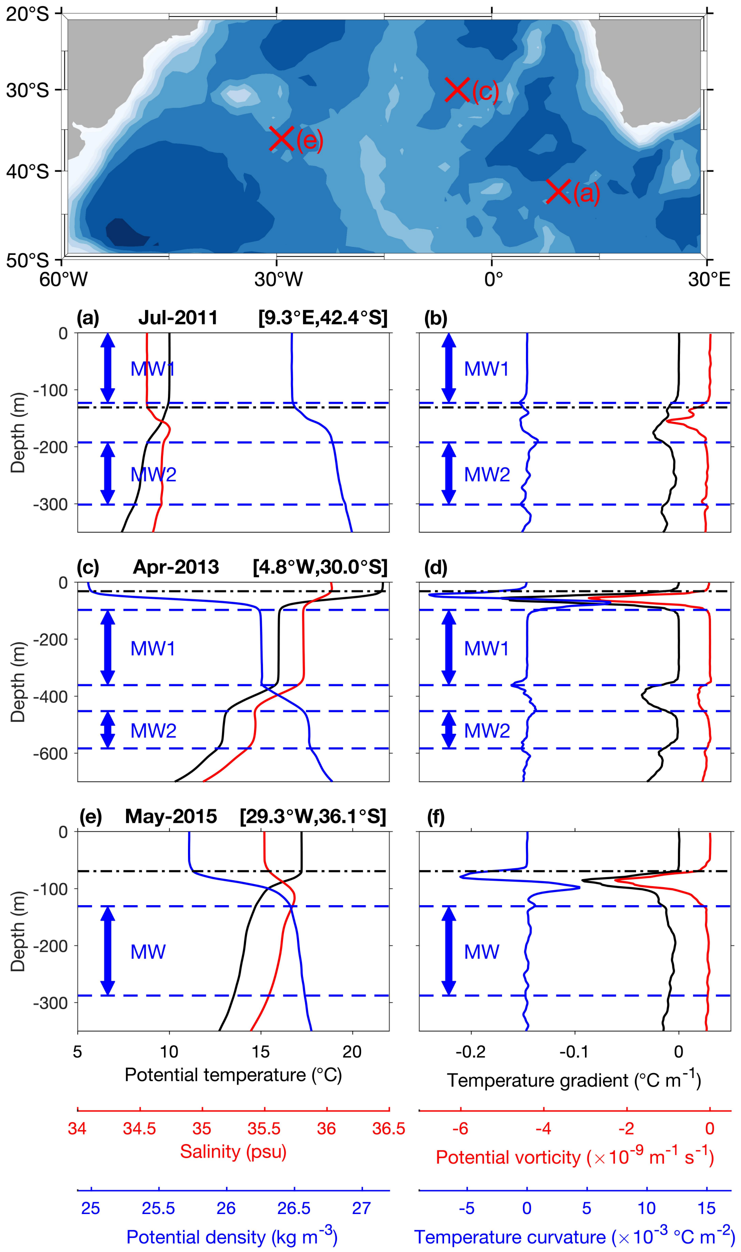


Figure: Three profile examples in the South Atlantic. (Chen et al., 2021)

IPSL | LMD | ENS | PSL

Global MLD distribution

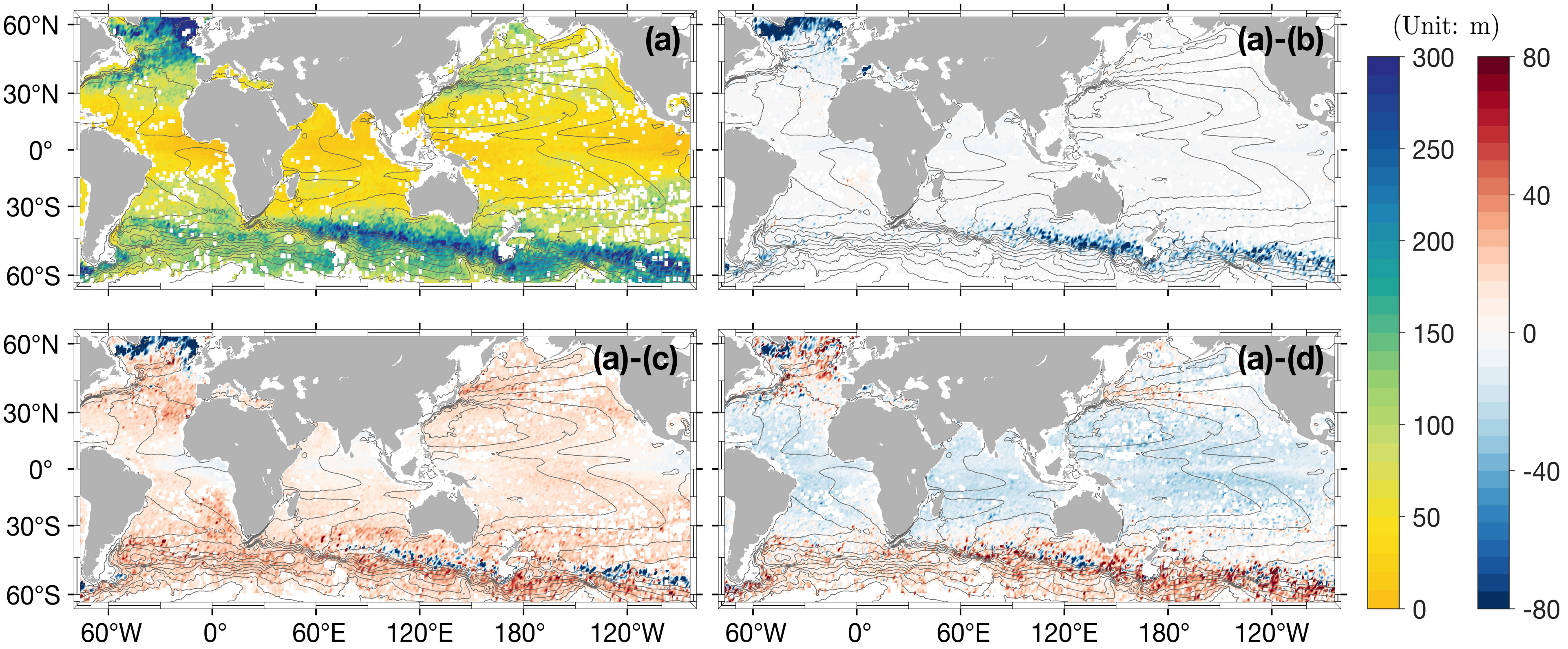


Figure: Winter-mean MLD.

Four methods of MLD detection are:

(a) The new algorithm

(b) Density threshold (0.03 kg m^{-3})

(c) Density gradient (0.0005 kg m^{-4})

(d) Hybrid method (Holte and Talley, 2009)

IPSL LMD ENS | PSL

Mode Water T-S relation

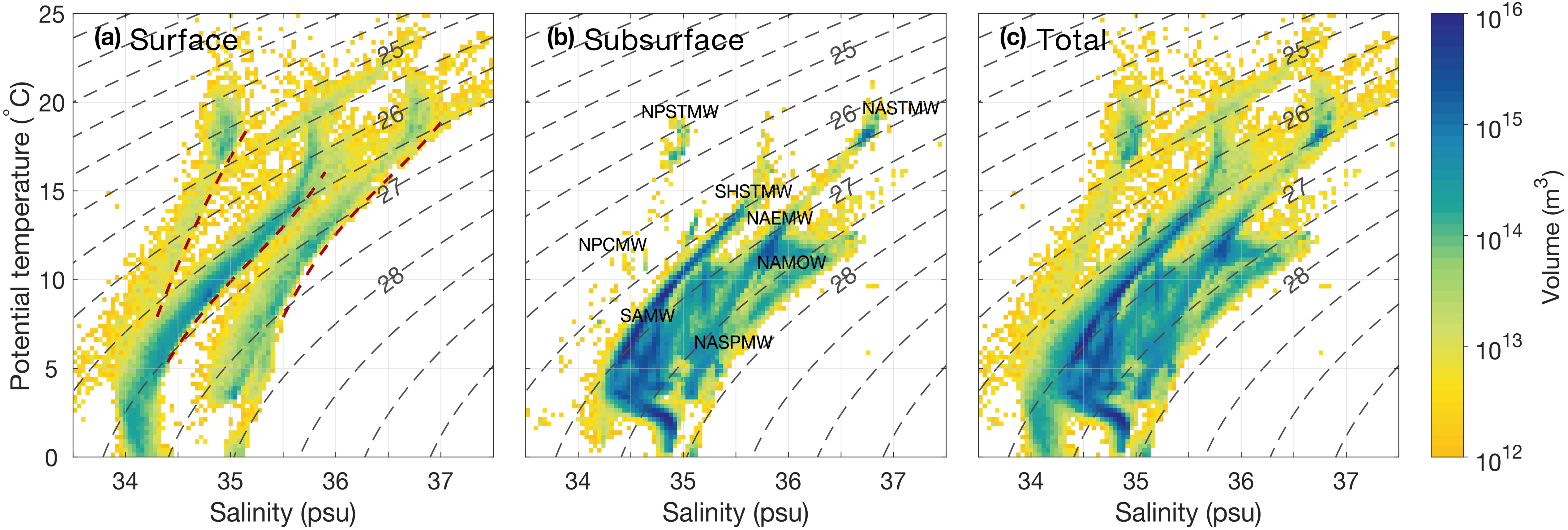
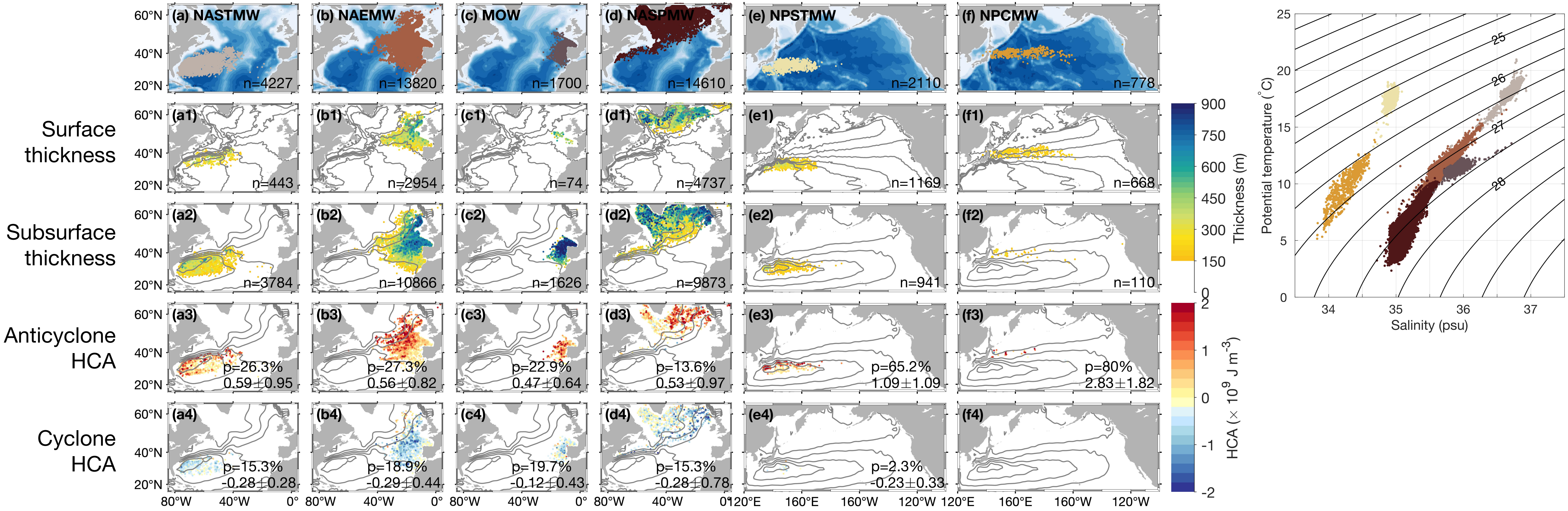


Figure: T-S diagram of surface and subsurface mode waters detected by the new algorithm.

IPSL LMD ENS | PSL

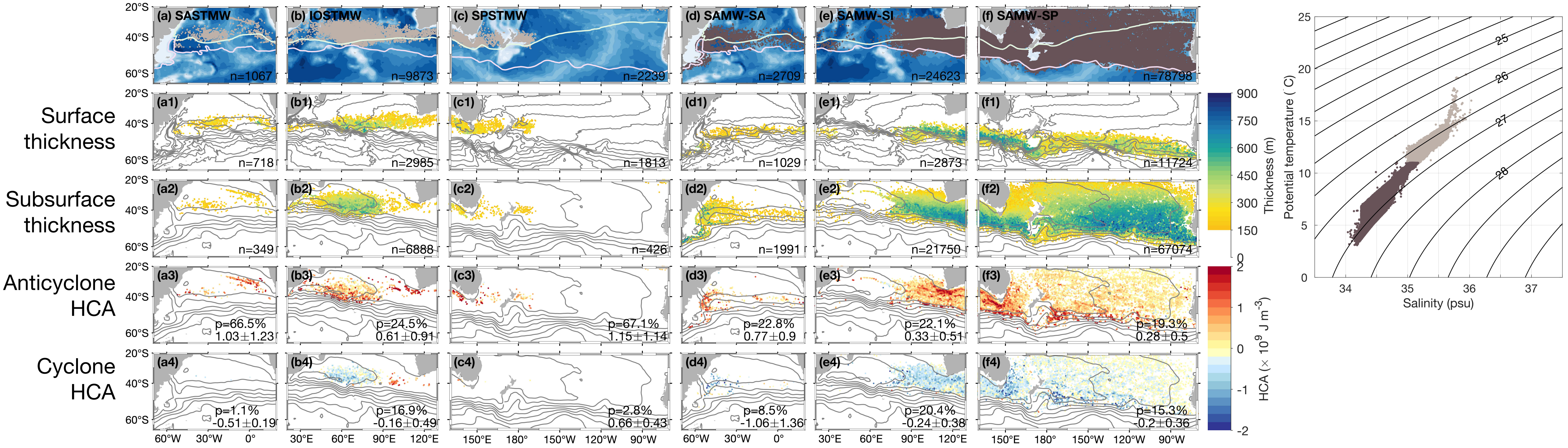
Mode Water in the Northern Hemisphere



- 4 MW types in the North Atlantic, and 2 types in the North Pacific.
- Surface MWs for each group are retrieved from the entire pool with the same properties as subsurface MWs.
- The positive HCA inside MWs is related to co-location with anticyclones.

IPSL LMD ENS | PSL

Mode Water in the Southern Hemisphere



➢ Cluster analysis is applied to divide all subsurface MWs into 2 types.

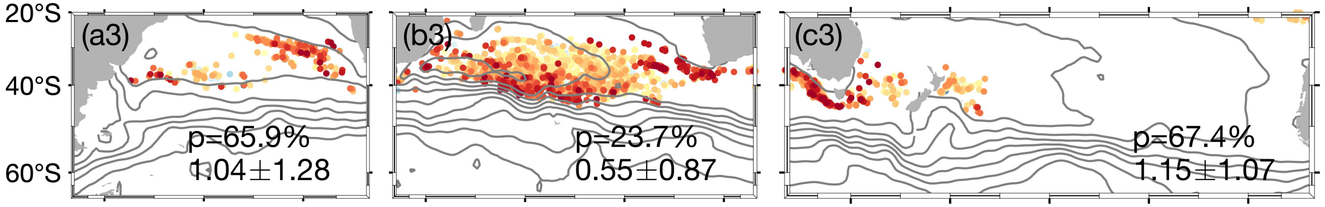
➢ STMWs originate at the northern periphery of STF, and SAMWs are formed insize the SAZ.

➢ Interbasin heat transport is associated with anticyclonic eddies.

IPSL LMD ENS | PSL

Prospectives

- Evidence shows 60%-90% of excess heat is absorbed by the Southern Ocean, which draws attention to the ability of SAMWs in taking up heat.
- The detection of subsurface eddies (that are not detectable from satellite) needs to improve.
- By comparing the trajectories of anticyclonic eddies and the depths of these mode waters, we can assess the ventilation process associated with eddies.



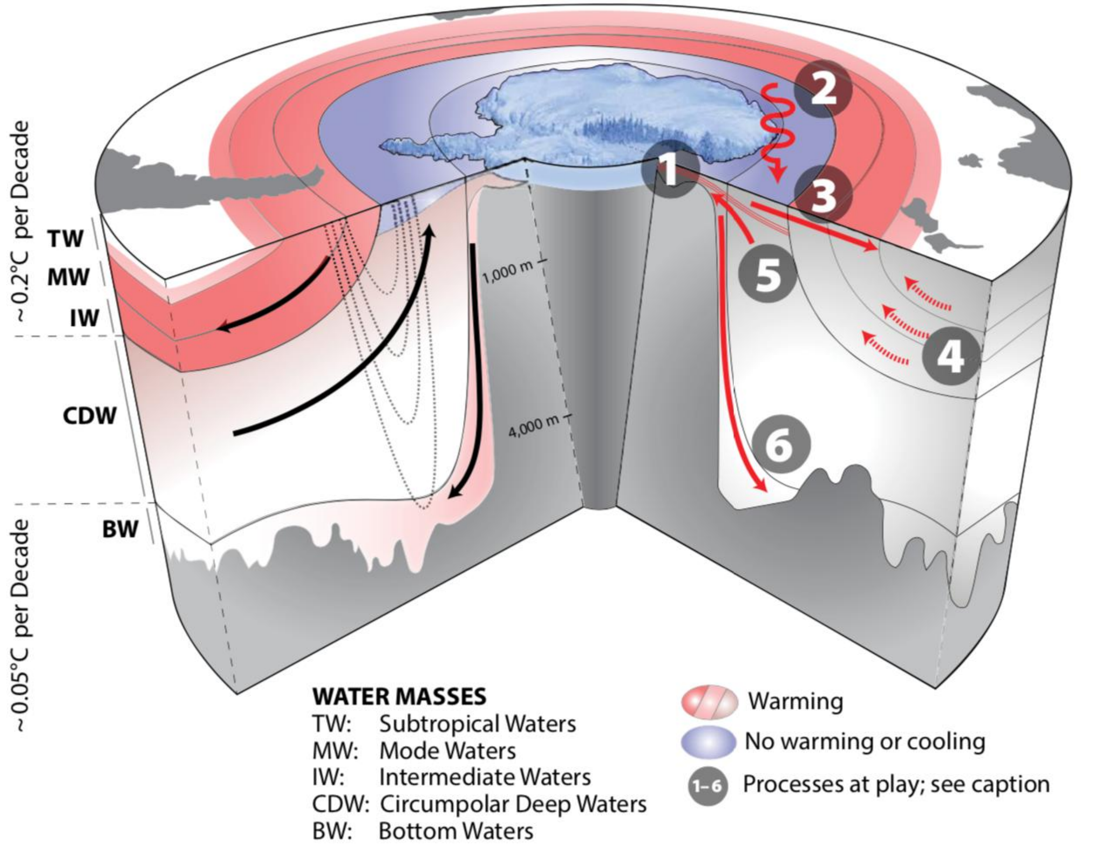


Figure: Temperature trends in different layers of the Southern Ocean. (Sallée, 2018)

IPSL LMD ENS | PSL

Subduction rate

$$\overline{S_{ml}}(t) = \frac{\partial H}{\partial t} + \nabla\cdot\left(\int_0^H \boldsymbol{u}\,dz\right), \qquad (1)$$

$$S_{ml}(t) = \frac{\partial H}{\partial t} + \nabla\cdot\left(\int_0^{H(t)} \boldsymbol{u}\,dz\right) + \nabla\cdot\left(\int_{H(t)}^{H_{max}} \boldsymbol{u}\,dz\right). \qquad (2)$$

$$S_{ml}(t) = \frac{\partial H}{\partial t} + \nabla\cdot(\boldsymbol{U}_{ek}) + \nabla\cdot[\boldsymbol{u}_{ml}(t)H(t)] + \nabla\cdot[\boldsymbol{u}_{sth}(t)(H_{max}-H(t))]. \qquad (3)$$

$$\overline{S_{ml}} = \nabla\cdot(\overline{\boldsymbol{U}_{ek}}) + \nabla\cdot(\overline{\boldsymbol{u}_{ml}}\,\overline{H}) + \nabla\cdot[\overline{\boldsymbol{u}_{sth}}(\overline{H_{max}-H})] + \nabla\cdot(\overline{\boldsymbol{u}^*_{ml}H}) + \nabla\cdot[\overline{\boldsymbol{u}^*_{sth}(H_{max}-H)}]. \qquad (4)$$

$$\overline{S_{ml}} = \overline{S_{ek}} + \overline{S_{geo}} + \overline{S_{eddy}}, \qquad (5)$$

$$\overline{S_{ek}} = \overline{w_{ek}},$$
$$\overline{S_{geo}} = \overline{\boldsymbol{u}_{ml}}\cdot\nabla\overline{H} + \overline{\boldsymbol{u}_{sth}}\cdot\nabla(\overline{H_{max}-H}) + \beta \text{ correction},$$
$$\overline{S_{eddy}} = \nabla\cdot(\overline{\boldsymbol{u}^*_{ml}H}) + \nabla\cdot[\overline{\boldsymbol{u}^*_{sth}(H_{max}-H)}]. \qquad (6)$$

$$\overline{S_{eddy}} = \nabla\cdot(\kappa\overline{\boldsymbol{s}})_{z=H_{max}}. \qquad (8)$$

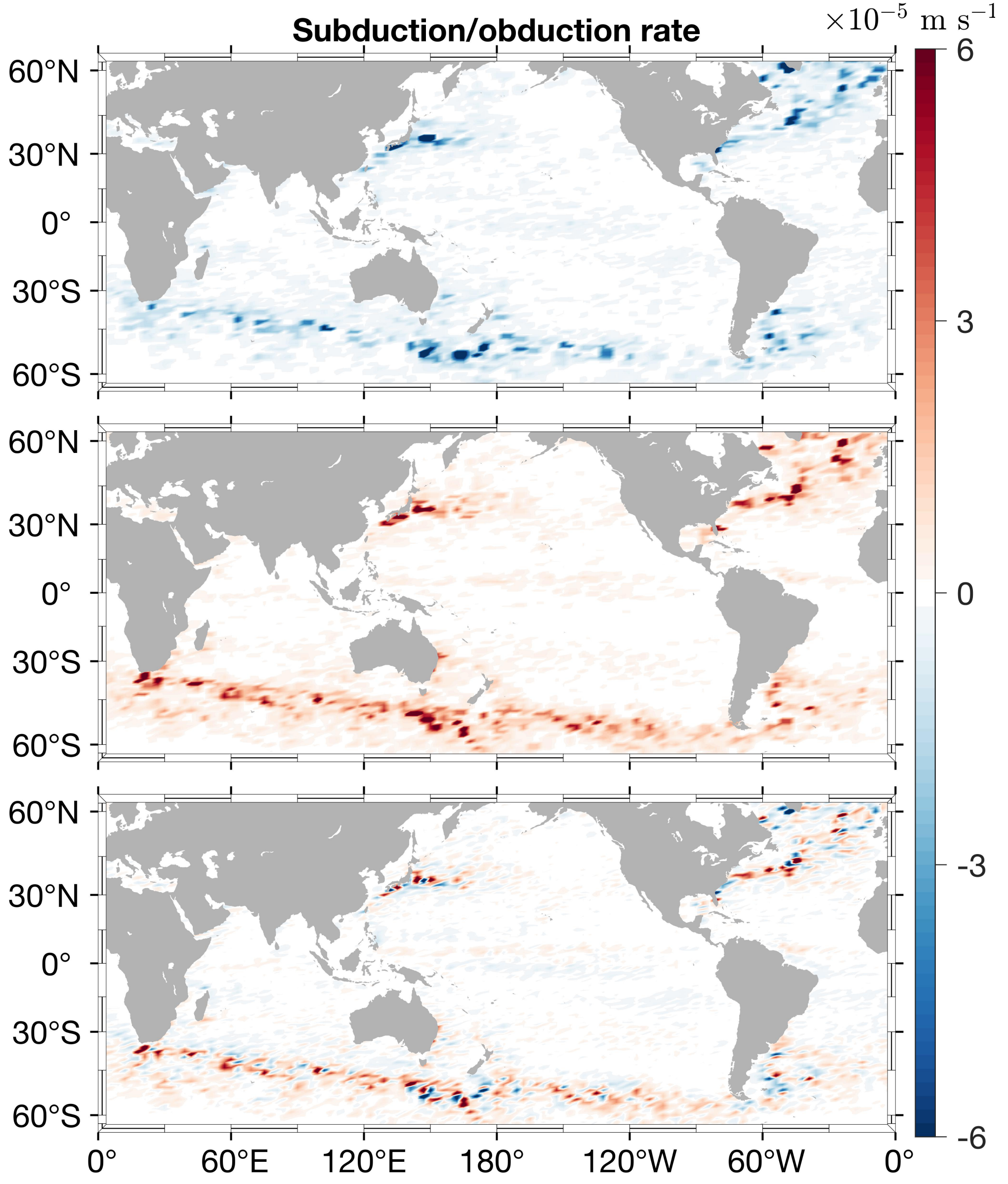


Figure: The geostrophic component of subduction and obduction rates based on the new MLDs.

IPSL LMD ENS | PSL

Thanks for your attention.

Contact: yanxu.chen@lmd.ens.fr