Ocean Water Masses-T-S Diagrams and Upper Ocean Waters

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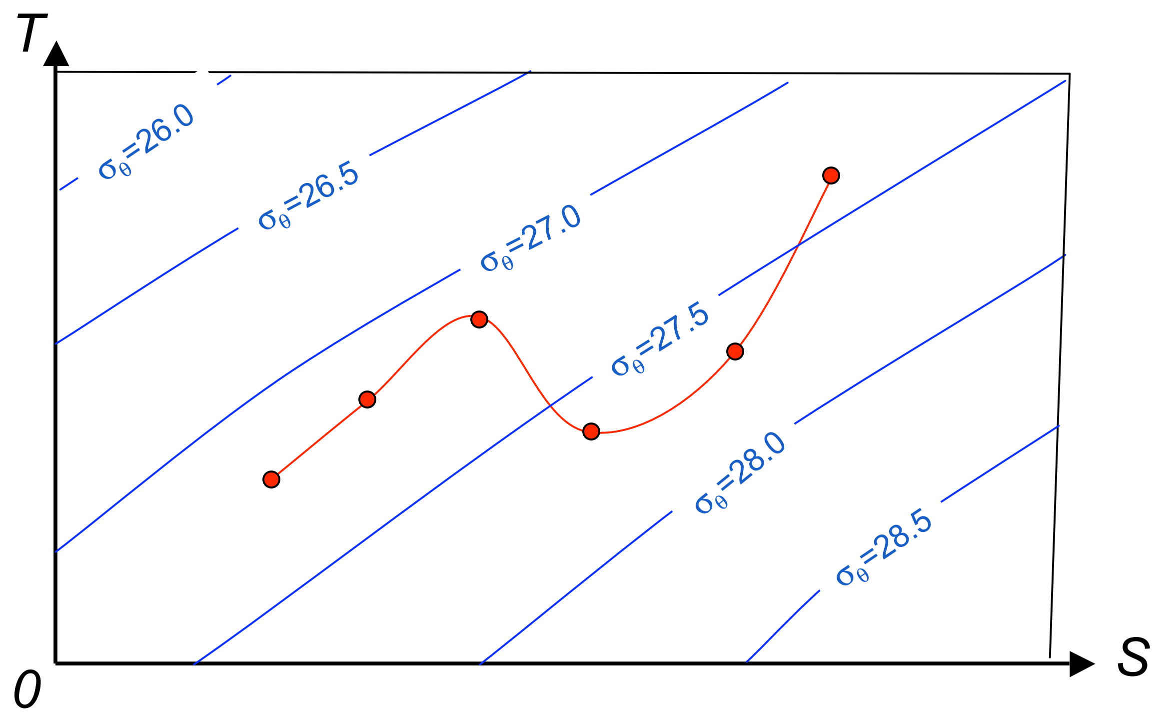
1. **Definition**: Water bodies with particular characteristics of temperature and salinity;

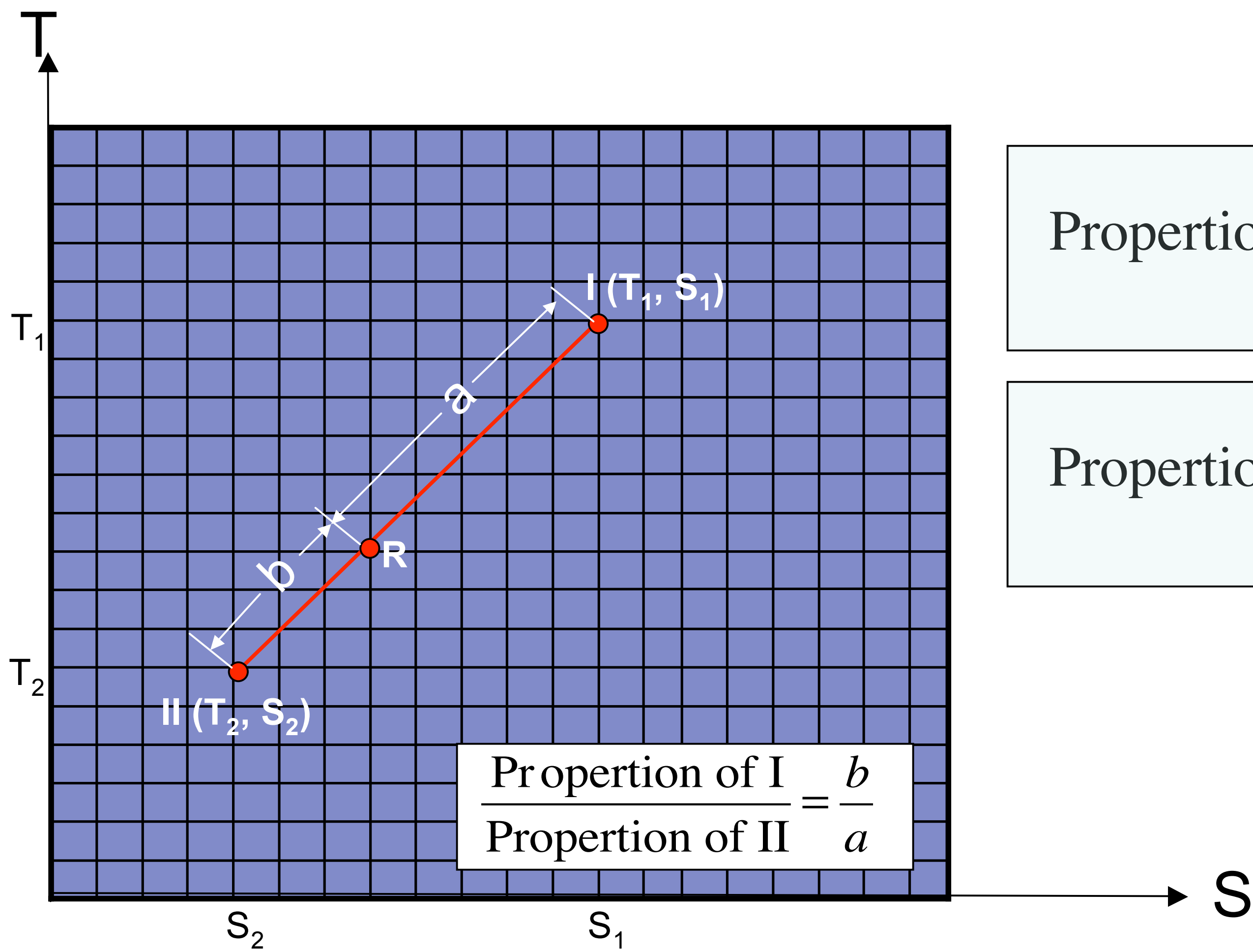
2. **Method**: The temperature (T)-salinity (S) diagram (relative conservative)

3. **Applications**: a) identify the water masses and its sources and b) water mixing



Basic Concepts

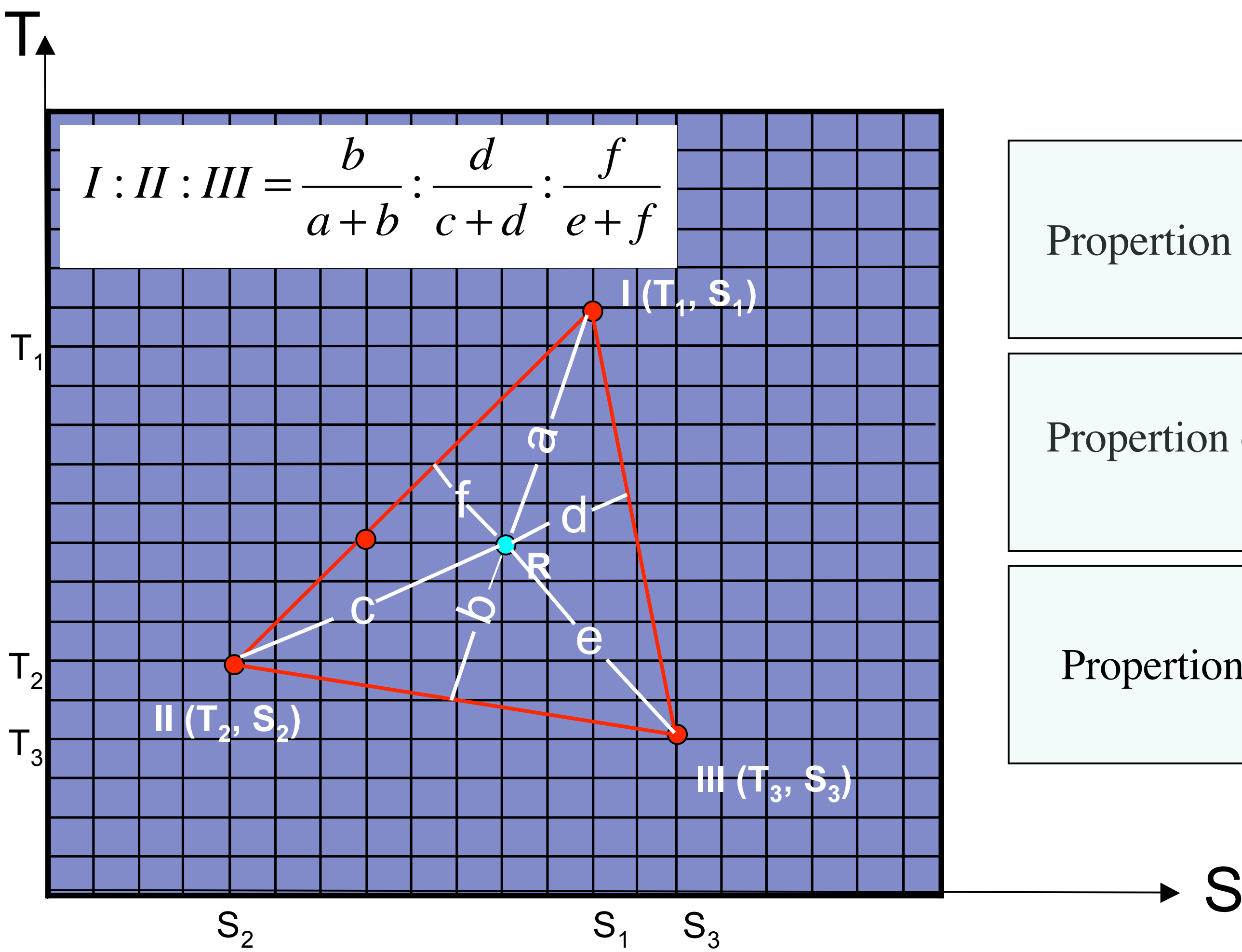
- Single point: A water type
- A smooth curve: a water mass



$$\text{Propertion of type I} = \frac{b}{a+b}$$

$$\text{Propertion of type II} = \frac{a}{a+b}$$

Three Water Types

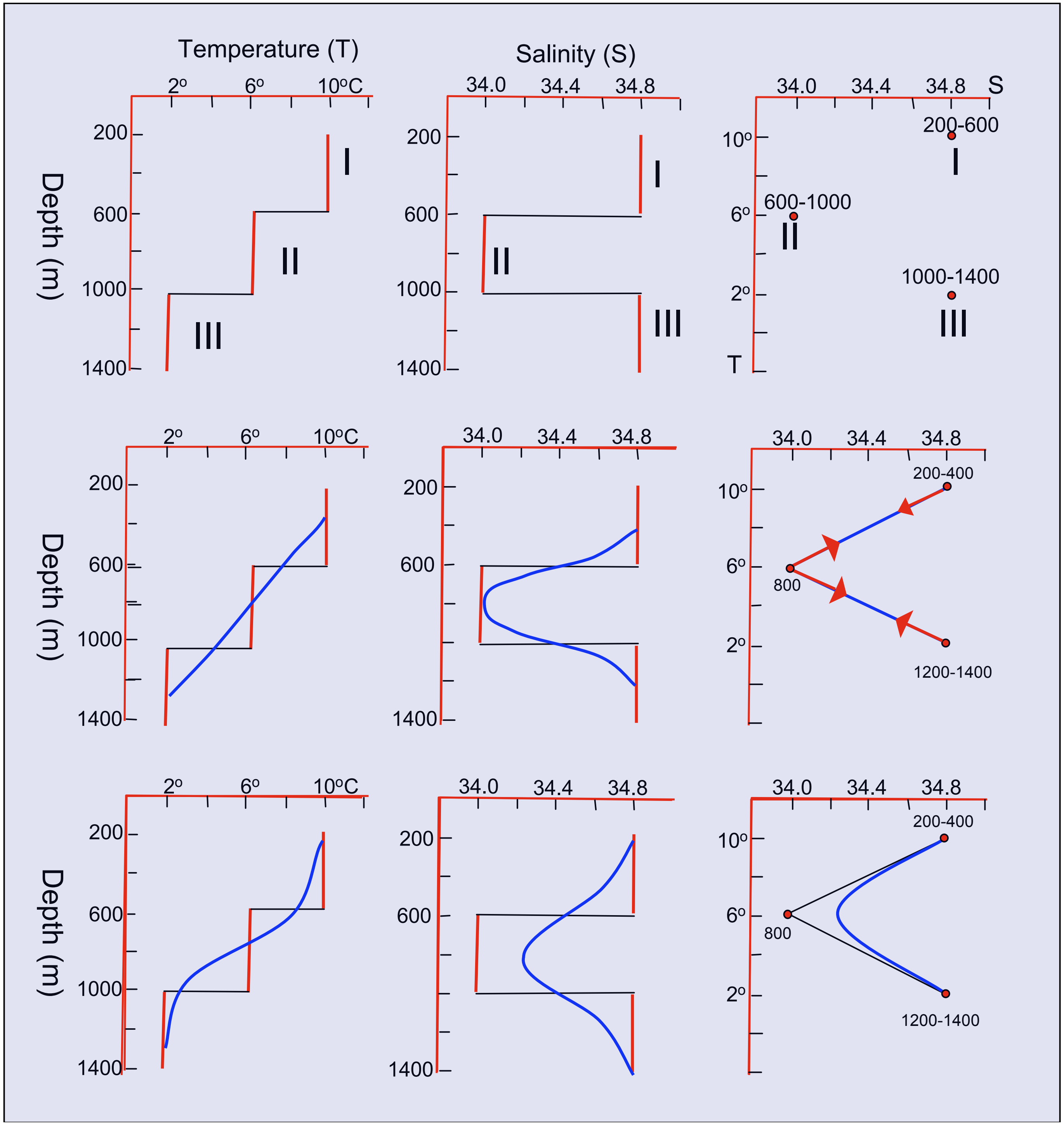


$$I : II : III = \frac{b}{a+b} : \frac{d}{c+d} : \frac{f}{e+f}$$

$$\text{Propertion of type I } = \frac{b}{a+b} \times 100\%$$

$$\text{Propertion of type II } = \frac{d}{c+d} \times 100\%$$

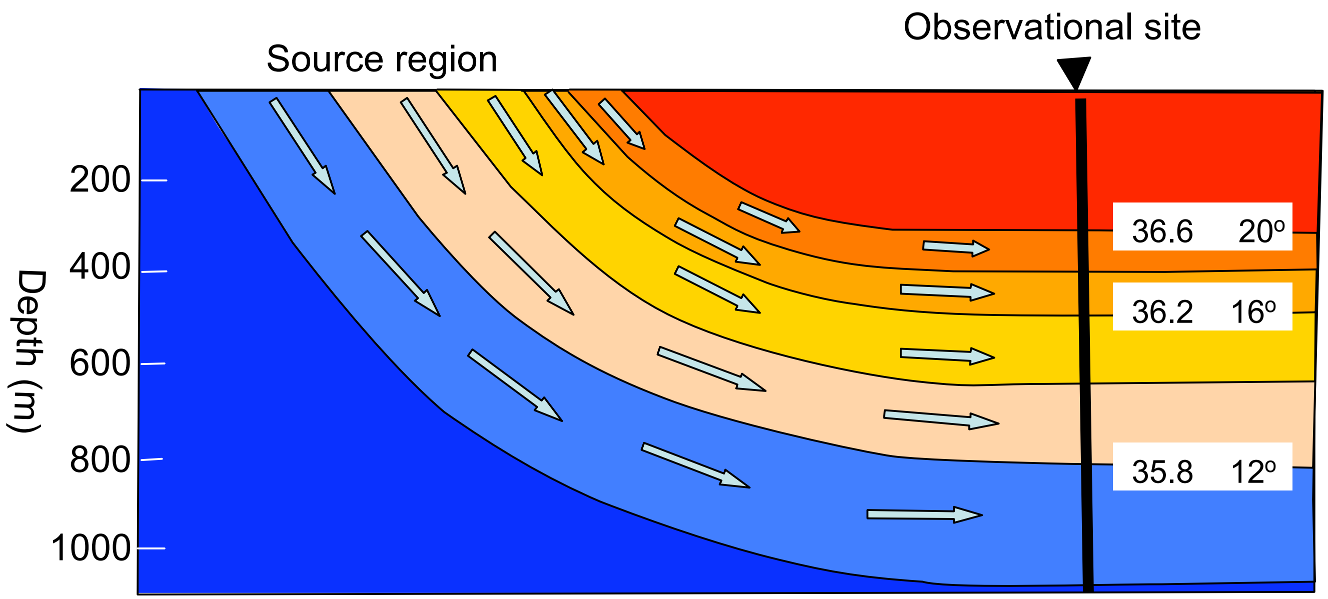
$$\text{Propertion of type III } = \frac{f}{e+f} \times 100\%$$



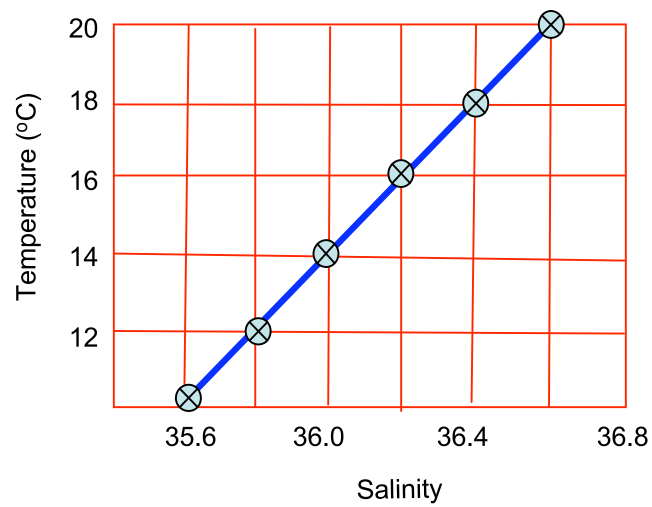
Temperature (T)
Salinity (S)
Depth (m)
2º
6º
10ºC
34.0
34.4
34.8
S
T
200
600
1000
1400
I
II
III
200-600
600-1000
1000-1400
10º
6º
2º
200-400
800
1200-1400

In general, mixing of two water mass shows a straight line on a T-S diagram, but it is not always true.

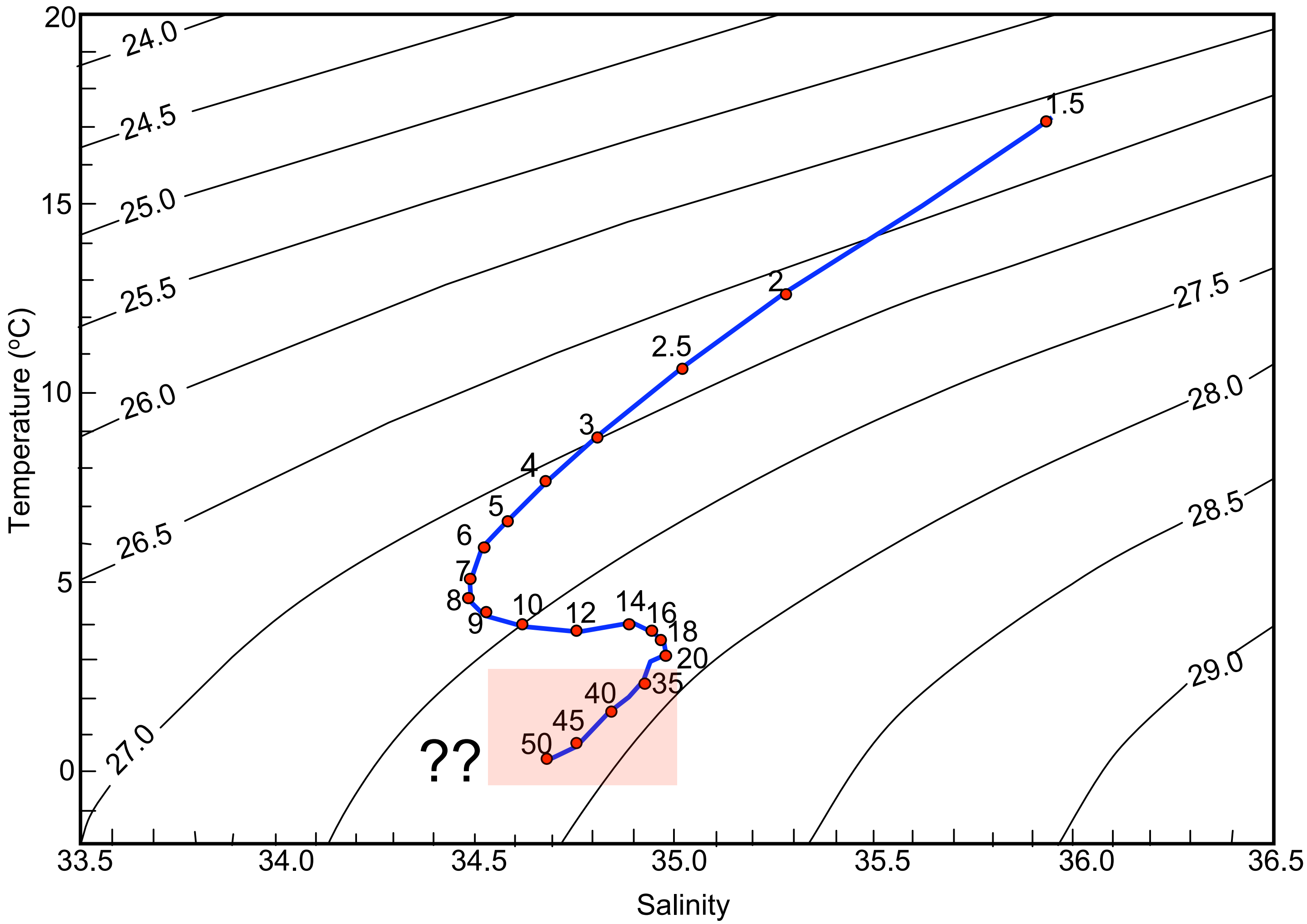
Example: The North Atlantic Central Water in the Subtropic Gyre



Formation of the water mass by the sinking of surface water along isopycnic surfaces. This type of the water mass shows a straight line on the T-S diagram with no relevance to mixing of two water masses.

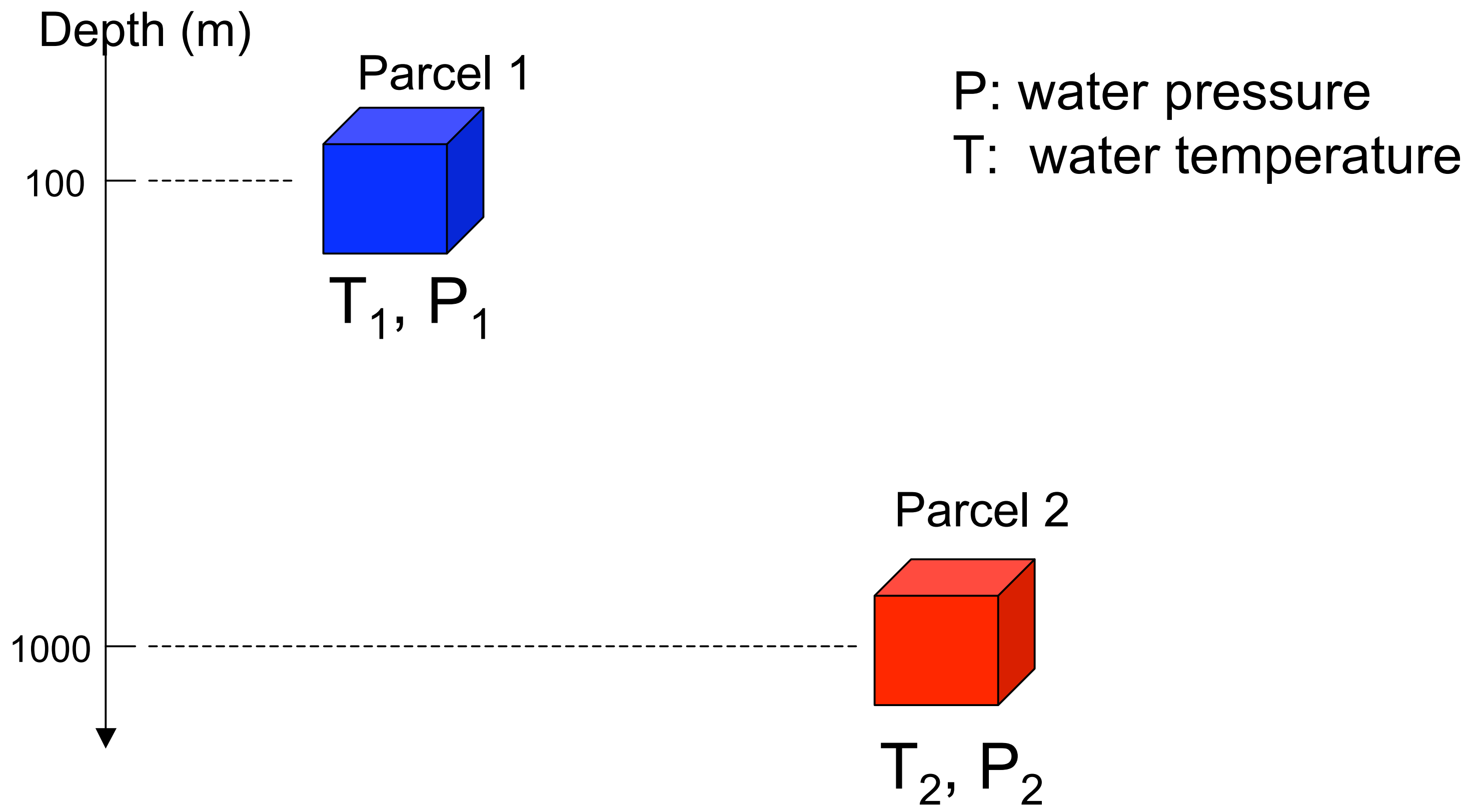


QS. Could we use the in-situ water temperature and salinity to draw a T-S diagram and compare the different water masses?



The T-S curve for Meteor station 200 at 9o S in the Atlantic Ocean.

Potential Temperature and Potential Density



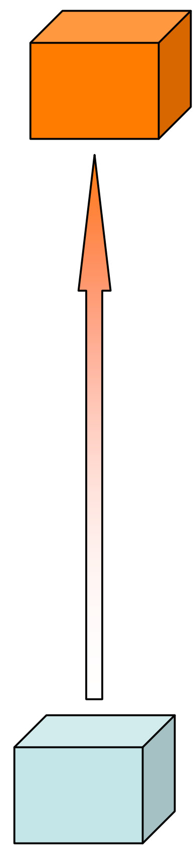
If $T_2 > T_1$, does it means that the water parcel 2 is warmer ?

Answer: NO! The water is slightly compressible and these two water parcels have different pressures

How could we compared two water parcels with different pressures?

Reference pressure level

$T(P_o) = \theta$: potential temperature



Adiabatically (no thermal contact with the surrounding water)

$T(P)$: in-situ water temperature

Then,

the waters can compare each other based on their potential temperature.

In-situ Water Density (σ_t) and Potential Density (σ_θ)

The water density:

$$\boxed{\rho = \rho(T, S, P)}$$

where T and S are the in-situ water temperature and salinity.

The sigma-t (σ_t) is defined as

$$\boxed{\sigma_t = \rho(T, S, P) - 1000}$$

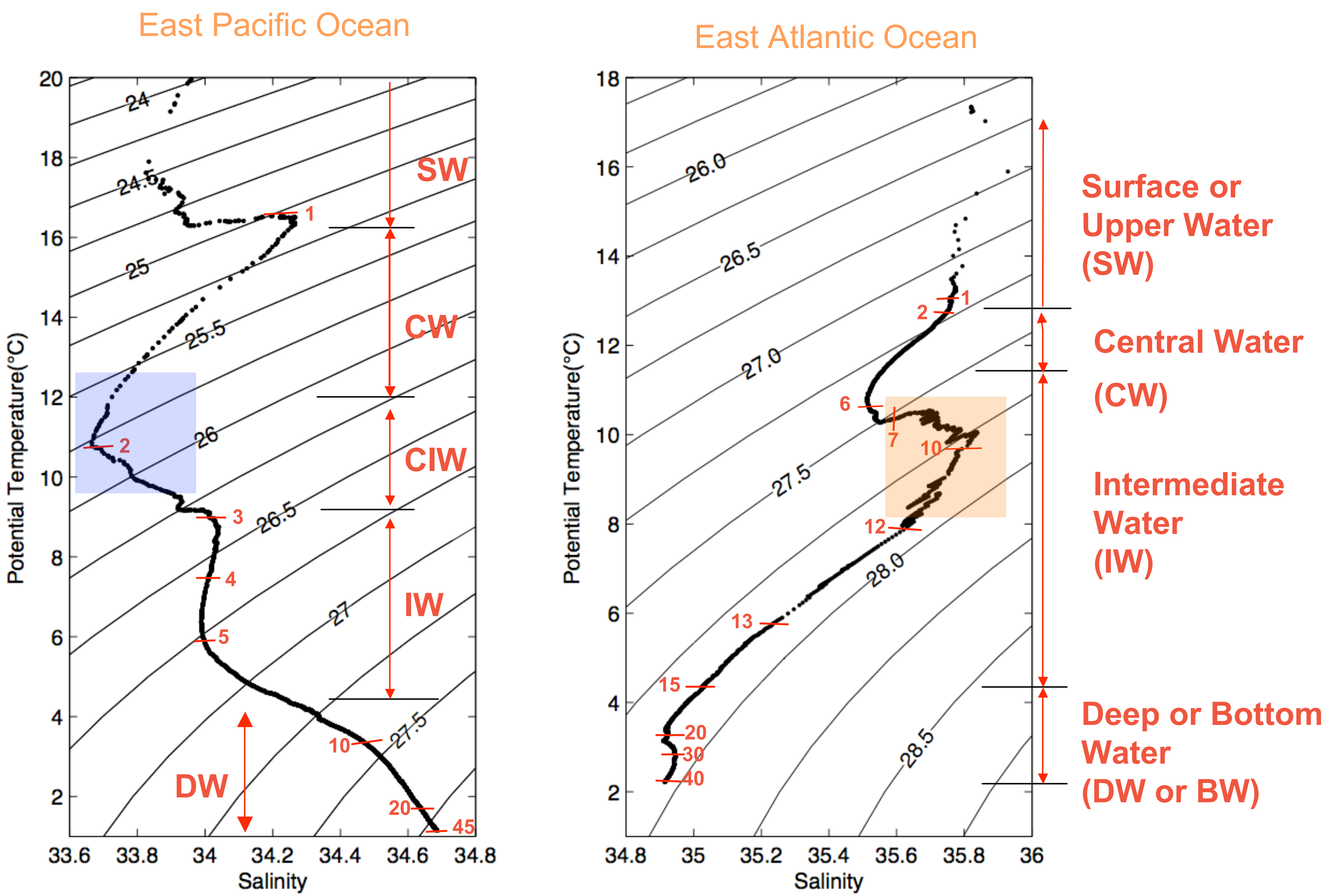
Replacing T by the potential density, we can define the potential density (sigma-θ) as

$$\boxed{\sigma_\theta = \rho(\theta, S, P_o) - 1000}$$

In some applications, you can find

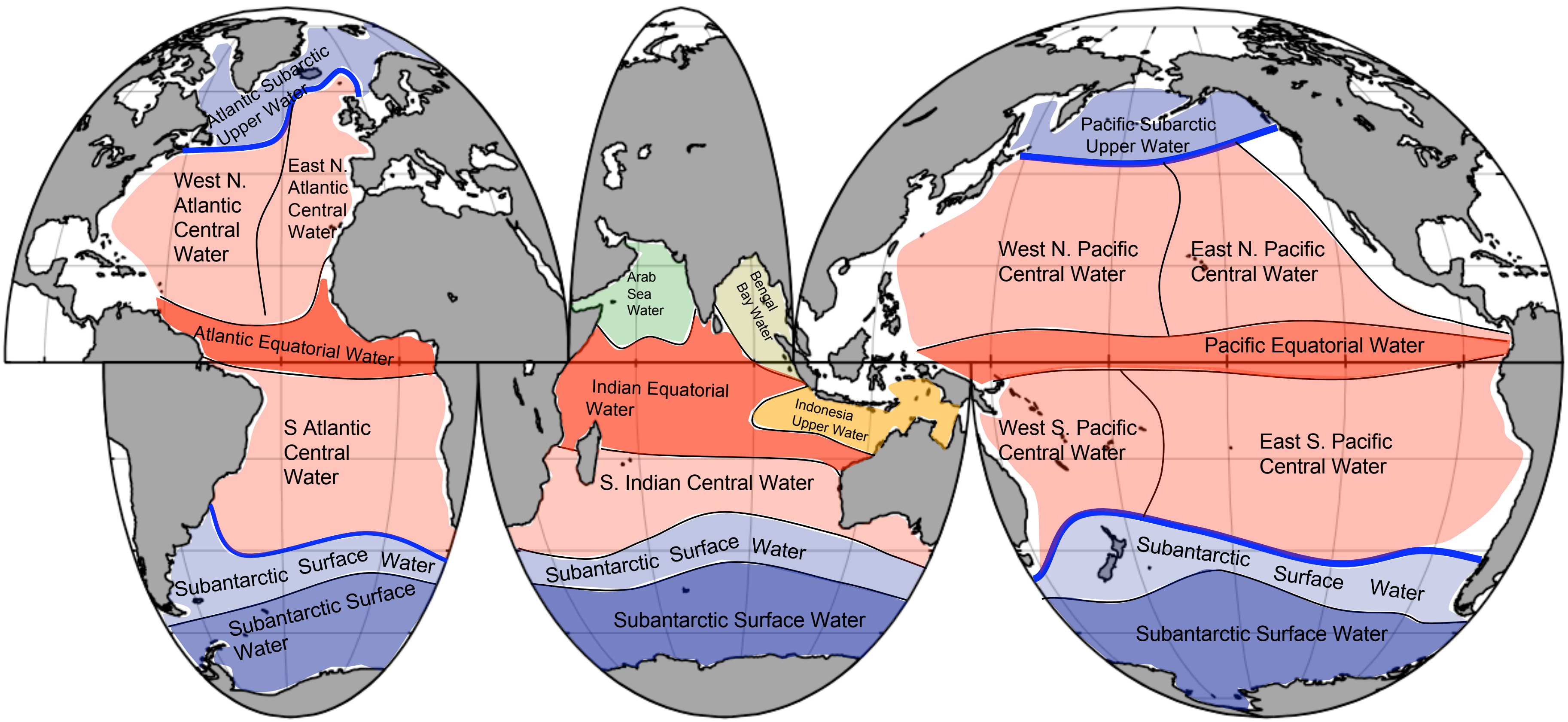
$$\sigma_{\theta_o}; \quad \sigma_{\theta_1}; \quad \sigma_{\theta_2} \cdots$$

defined using the different reference pressure levels.



CIW-California Intermediate Water: **low salinity** **MIW-**Mediterranean Intermediate Water: **high salinity**

Upper Ocean Water Masses

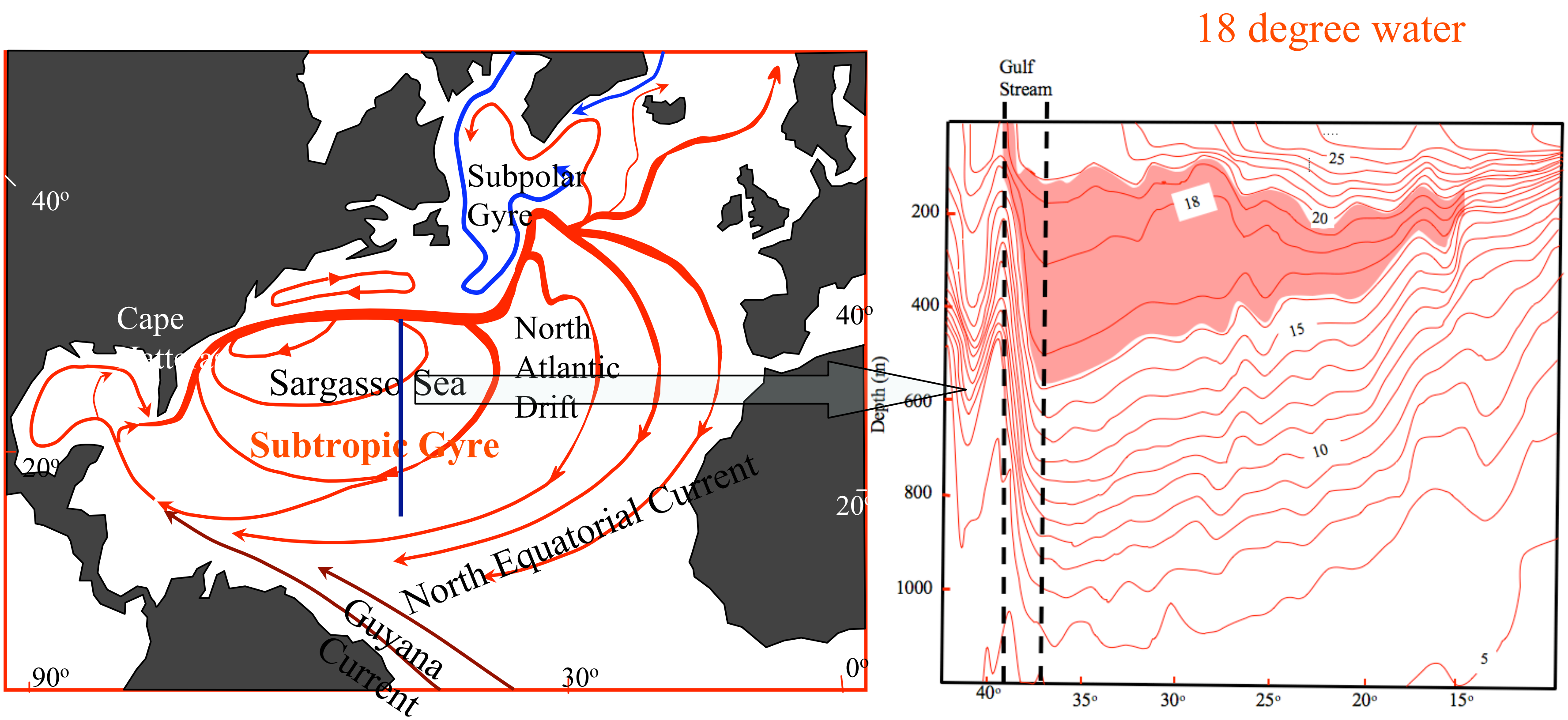


Strongly influenced by the pattern of surface currents in the mixed layer and the upper part of the permanent thermoclines

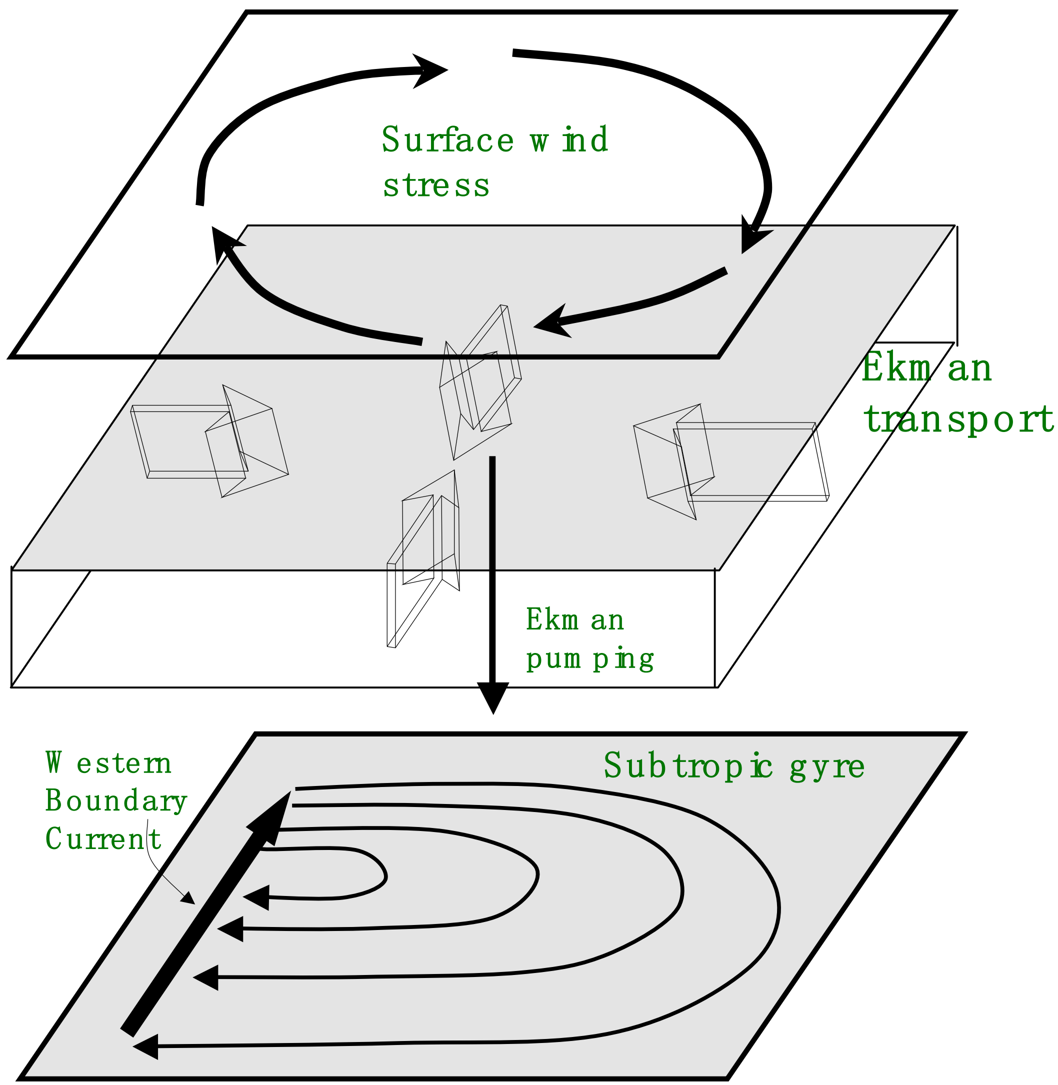
Central Waters are characteristics of subtropic gyres.

Atlantic Ocean	**Pacific Ocean**	**Indian Ocean**
West North Atlantic Central Water (**WNACW**) **T: 7.0-20.0ºC** **S: 35.0-36.7 PSU** East North Atlantic Central Water (**ENACW**) **T: 8.0-18.0ºC** **S: 35.2-36.7 PSU** South Atlantic Central Water (**SACW**): **T: 5.0-18.0ºC** **S: 34.3-35.8 PSU**	West North Pacific Central Water (**WNPCW**) **T: 10.0-22.0ºC** **S: 34.2-35.2 PSU** East North Pacific Central Water (**ENPCW**) **T: 12.0-20.0ºC** **S: 34.2-35.2 PSU** West South Pacific Central Water (**WSPCW**) **T: 6.0-22.0ºC** **S: 34.5-35.8 PSU** East South Pacific Central Water (**ESPCW**) **T: 8.0-24.0ºC** **S: 34.4-36.4 PSU**	South Indian Central Water (SICW) **T: 8.0-25.0ºC** **S: 34.6-35.8 PSU**

18° degree water is central water. It is also called “mode water”. It is characterized by the minimum vertical density gradient.



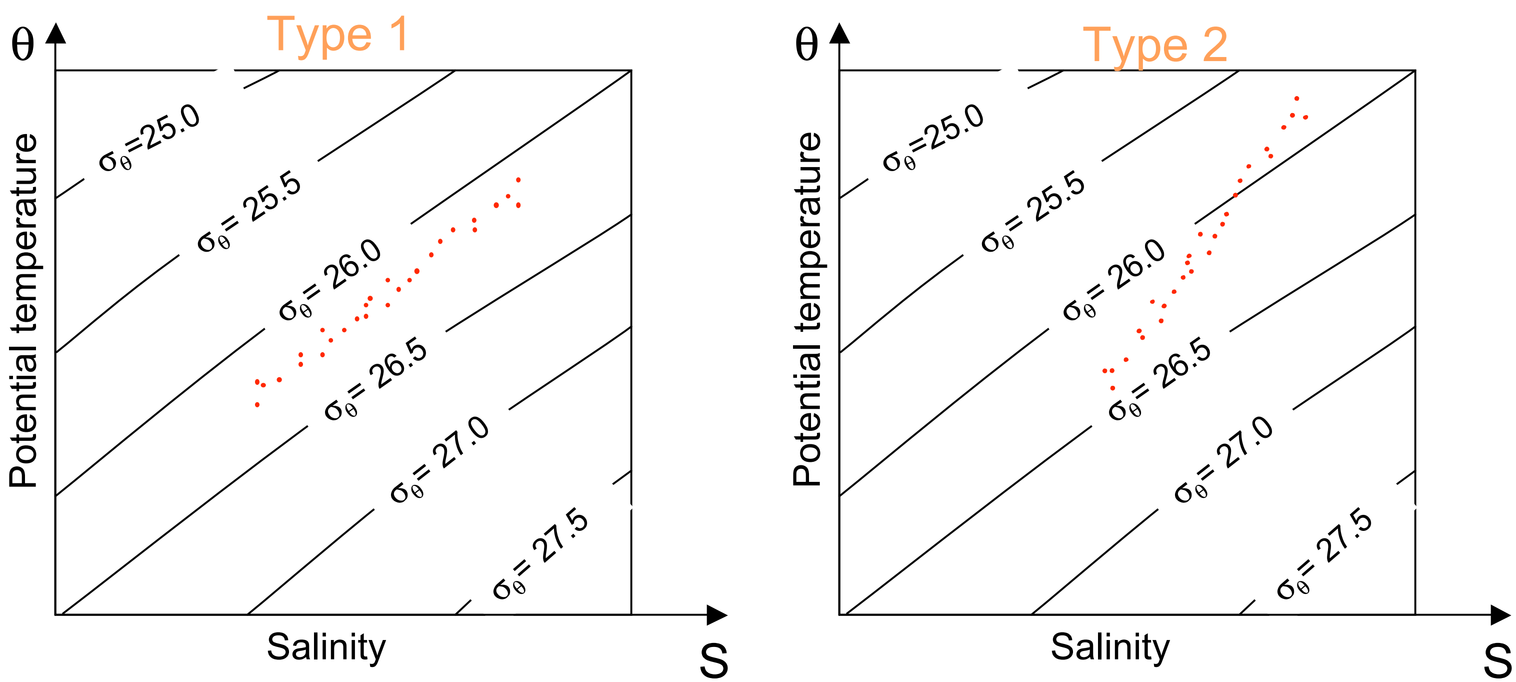
Formation of the Central Water: the convergence and subduction of the subtropic gyre and also vertical convection caused by the wintertime cooling



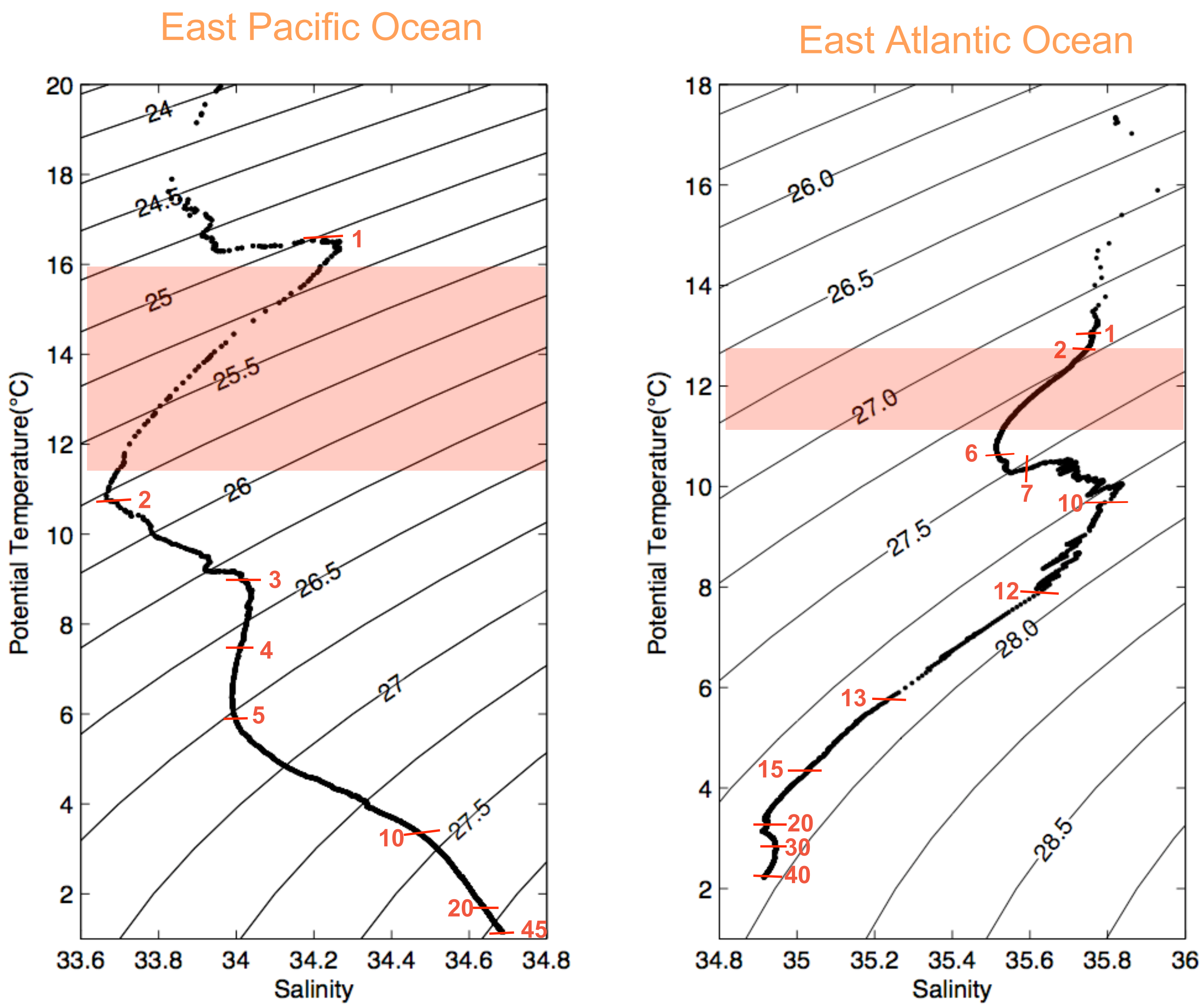
A T-S diagram also can help us determine the characteristics of water mixing in the water column

Type 1: Isopycnal mixing ⇒ mixing along the density surface

Type 2: Diapycnal mixing ⇒ mixing across the density surface

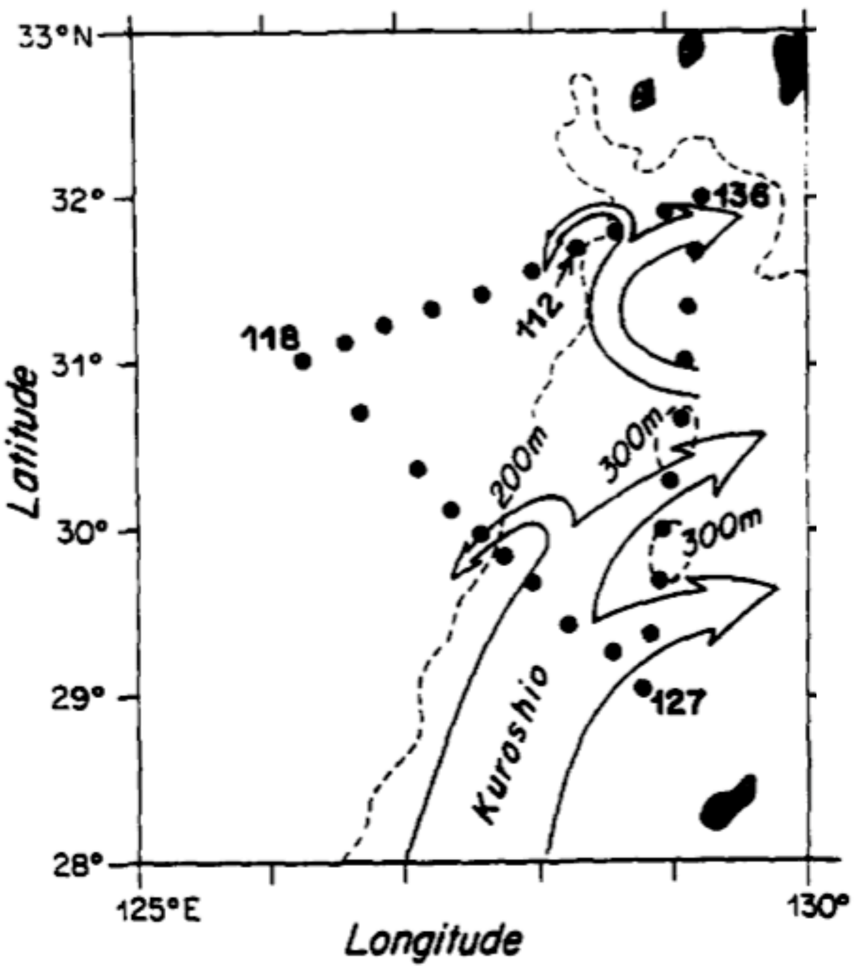


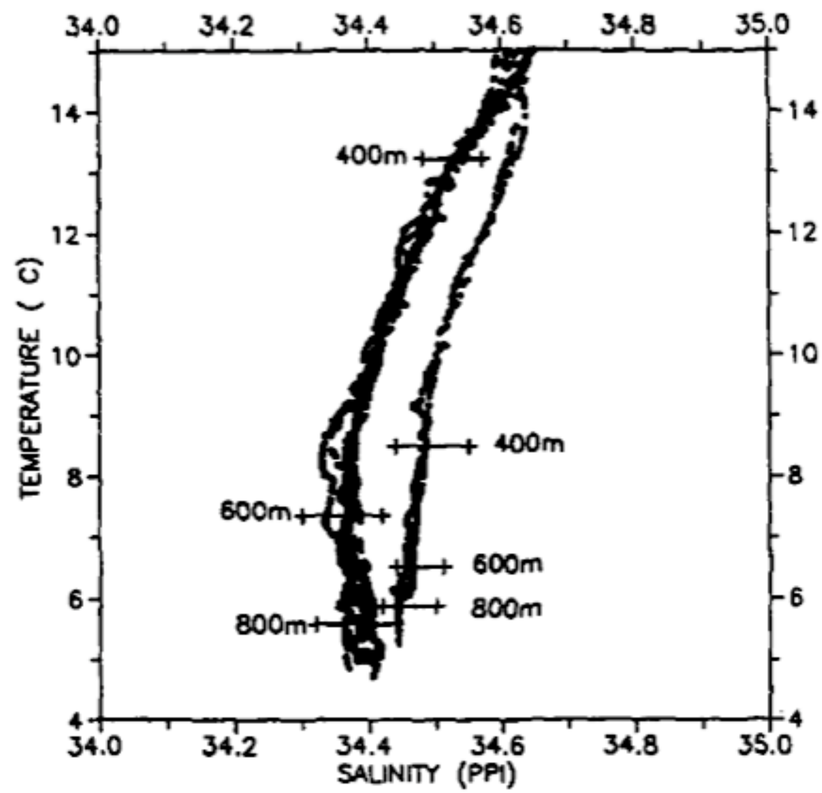
Central Waters show the diapycnal mixing, so it does not form only by the along-density surface subduction



T-S diagram also can be used to track the mixed water back to their upstream source.

An example in Kuroshio southwest of Japan





From Chen et al. (1994)