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

\[
\text{Propportion of type I} = \frac{b}{a + b}
\]

\[
\text{Propportion of type II} = \frac{a}{a + b}
\]
Three Water Types

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

Propertion of type I = \( \frac{b}{a+b} \times 100\% \)

Propertion of type II = \( \frac{d}{c+d} \times 100\% \)

Propertion of type III = \( \frac{f}{e+f} \times 100\% \)
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 90 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 compare two water parcels with different pressures?

$T(P_o) = \theta$: 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 ($\sigma_t$) and Potential Density ($\sigma_\theta$)

The water density:

$$\rho = \rho(T,S,P)$$

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

The sigma-t ($\sigma_t$) is defined as

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

Replacing $T$ by the potential density, we can define the potential density ($\sigma_\theta$) as

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

In some applications, you can find

$$\sigma_{\theta_o}, \sigma_{\theta_1}, \sigma_{\theta_2}, \ldots$$

defined using the different reference pressure levels.
CIW—California Intermediate Water: low salinity

MIW—Mediterranean Intermediate Water: high salinity
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.
<table>
<thead>
<tr>
<th>Atlantic Ocean</th>
<th>Pacific Ocean</th>
<th>Indian Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>West North Atlantic Central Water (WNACW)</td>
<td>West North Pacific Central Water (WNPCW)</td>
<td>South Indian Central Water (SICW)</td>
</tr>
<tr>
<td>T: 7.0-20.0°C</td>
<td>T: 10.0-22.0°C</td>
<td>T: 8.0-25.0°C</td>
</tr>
<tr>
<td>S: 35.0-36.7 PSU</td>
<td>S: 34.2-35.2 PSU</td>
<td>S: 34.6-35.8 PSU</td>
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<tr>
<td>East North Atlantic Central Water (ENACW)</td>
<td>East North Pacific Central Water (ENPCW)</td>
<td></td>
</tr>
<tr>
<td>T: 8.0-18.0°C</td>
<td>T: 12.0-20.0°C</td>
<td></td>
</tr>
<tr>
<td>S: 35.2-36.7 PSU</td>
<td>S: 34.2-35.2 PSU</td>
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</tr>
<tr>
<td>South Atlantic Central Water (SACW):</td>
<td>West South Pacific Central Water (WSPCW)</td>
<td></td>
</tr>
<tr>
<td>T: 5.0-18.0°C</td>
<td>T: 6.0-22.0°C</td>
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<tr>
<td>S: 34.3-35.8 PSU</td>
<td>S: 34.5-35.8 PSU</td>
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<tr>
<td></td>
<td>East South Pacific Central Water (ESPCW)</td>
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<tr>
<td></td>
<td>T: 8.0-24.0°C</td>
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</tr>
<tr>
<td></td>
<td>S: 34.4-36.4 PSU</td>
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</tbody>
</table>
$18^\circ$ 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)