

# Ocean

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ATM2016



**How the ocean is different from the atmosphere?**

# Difference #1: Type of the fluid

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- **Atmosphere = air : Compressible fluid**
- **Ocean = water : Nearly incompressible**
- Internal energy can go up or down in the compressible fluid (like air) by changing the volume.
- Internal energy can go up or down in the incompressible fluid (like water) by heating or cooling it.

## Difference #2: Latent heat

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- **The atmosphere has moisture.**
  - Moisture can be a source of latent heat.
- **The ocean does not have counterpart to atmospheric moisture.**
  - (Well, latent heat can be release when sea-ice forms.)

# **Polynyas :**

Opening of the ocean  
in the middle of sea ice

**Sea ice free**



**Sea ice**

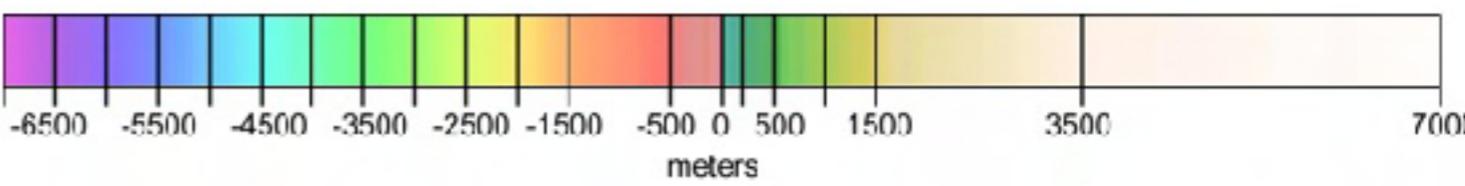
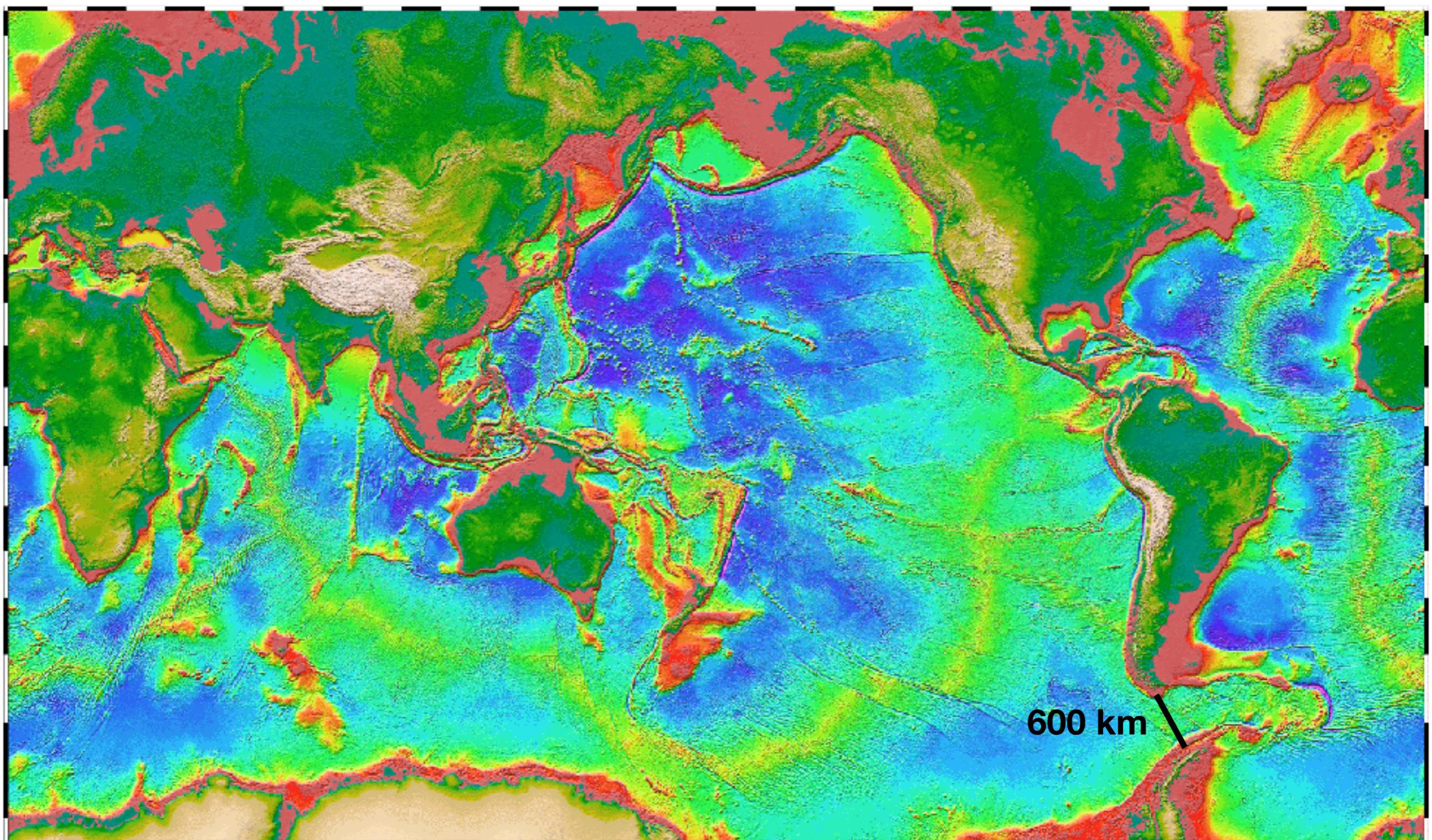
**Antarctica**

## Difference #3: Boundaries

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- **The atmosphere has no boundaries.**
  - The air can flow continuously without being blocked.
- **All oceans are bounded by continents.**
  - (Well, there is one exception: The Southern Ocean.)

# Bathymetry



## Difference #4: Heating

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- **The atmosphere is heated from below.**
  - Convection transport heat upward.
- **The solar radiation heats the ocean surface.**
  - Heating at the surface does not result in convection.
  - If the surface ocean becomes heavy, then convection can happen.

## Difference #5: Stress

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- **The atmosphere does not get a stress from the ocean.**
  - The air flows according to the state of the atmosphere.
- **The ocean can be driven by winds.**
  - Winds blowing over the ocean surface exert a stress.
  - The wind is a major driver of ocean circulation.

# **Physical characteristics of the ocean**

# 1. The ocean basins

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- The ocean covers 71% of the Earth's surface.
- Mean depth is 3.7 km
- The ocean's bottom topography is rougher than the land's surface.
- The ocean has huge heat capacity, approximately 1000 times that of the atmosphere.

## 2. The cryosphere

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- Originated from Greek, it means “cold” “globe”.
- About 2% of the water is frozen in different forms like
  - Ice sheets, sea ice, snow, glaciers, frozen ground.
- Antarctica has 89% of frozen water. (The average depth of the ice sheet is 2 km.)
- It plays an important role in climate system with high albedo (70%).



### 3. Salinity

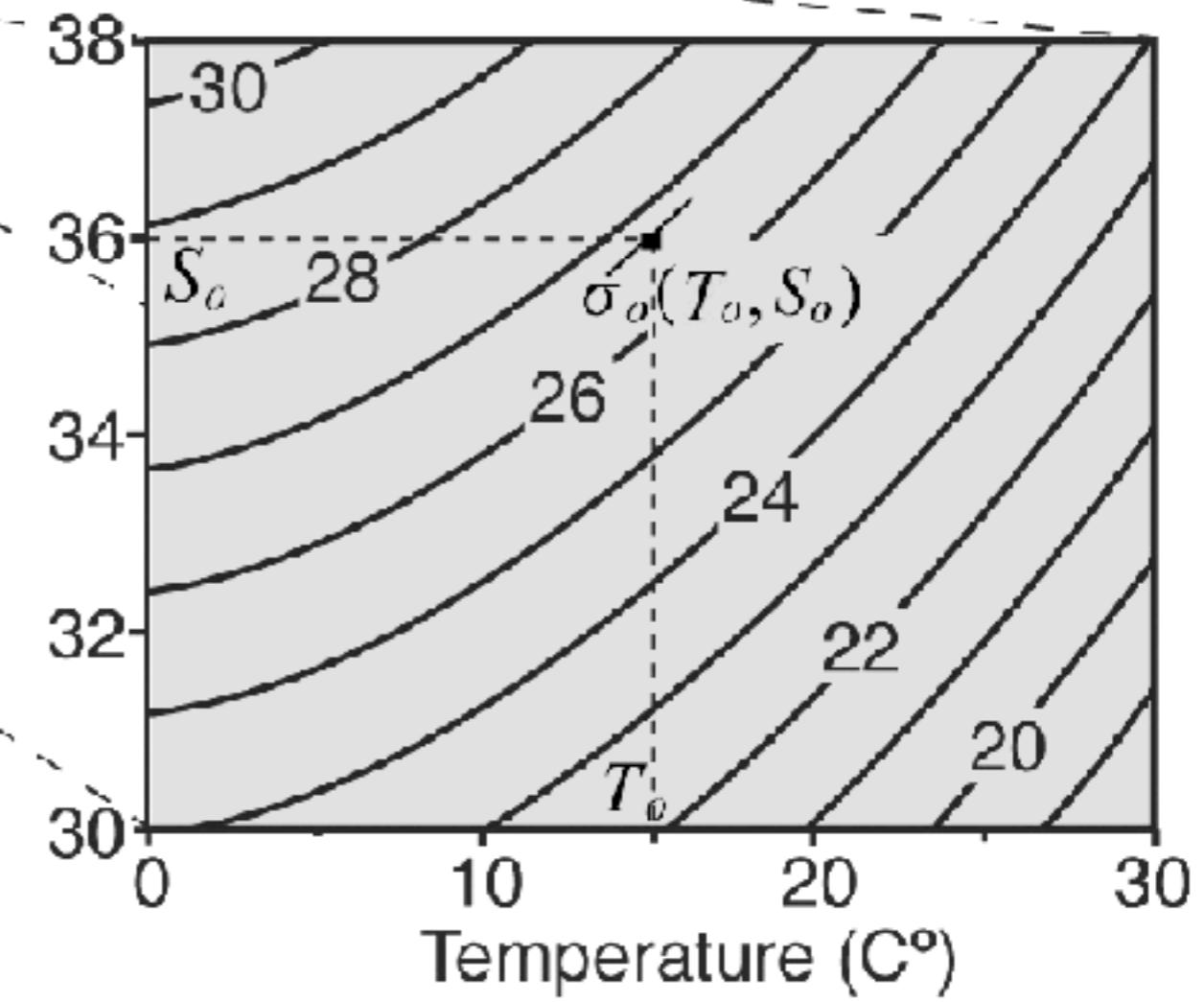
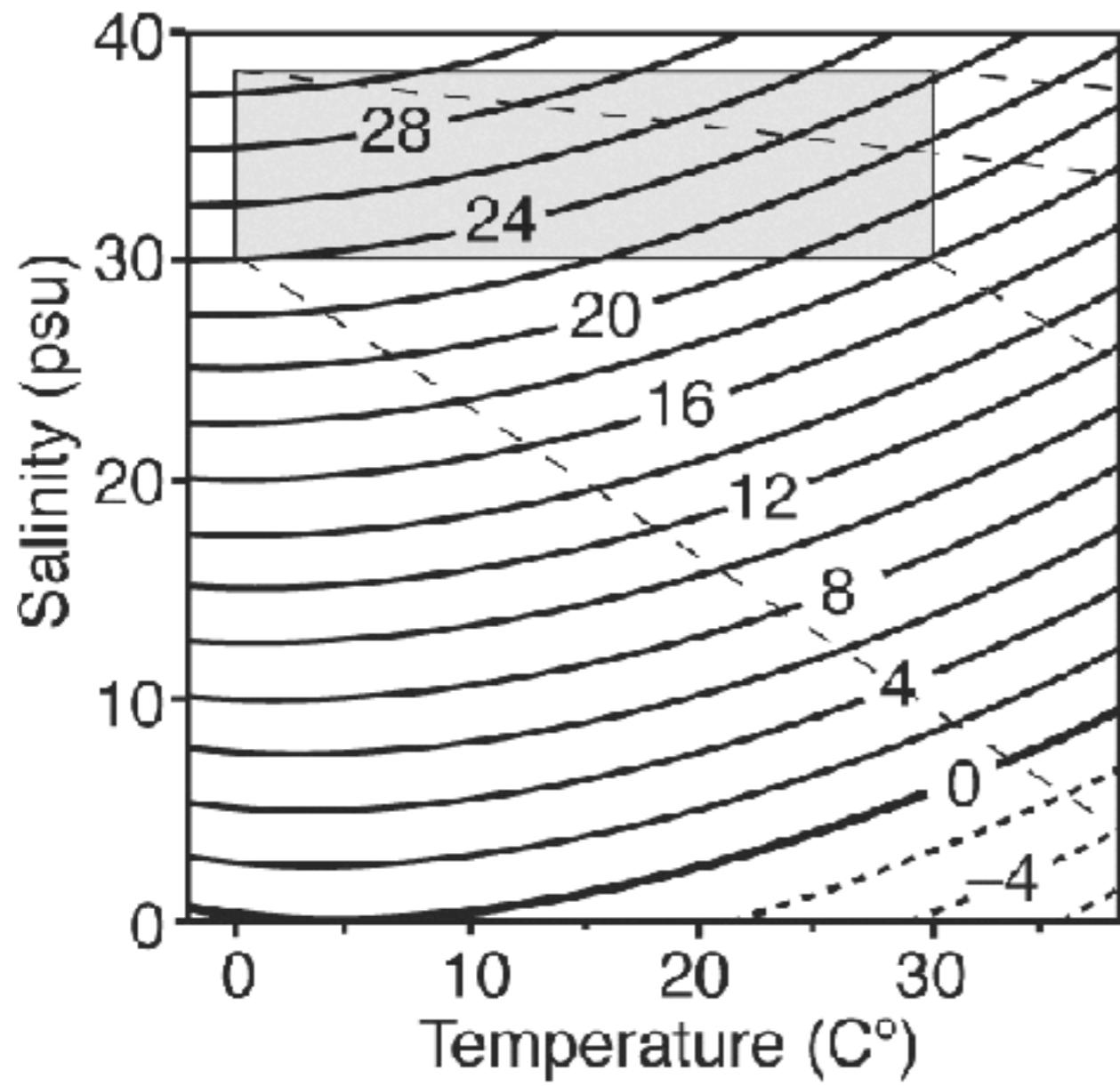
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- A measure of amount of salt dissolved in the ocean
- The unit of salinity is about the ratio of salt in the water:
  - psu, g/kg, ‰
- The typical salinity is 34.5 psu = 34.5g of salt in 1kg of water.

## 4. The density

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- The density of pure water at 4°C  $\approx 1000 \text{ kg m}^{-3}$
- The density of the ocean  $\approx 1035 \text{ kg m}^{-3}$
- The density depends on temperature (T), salinity (S) and pressure (P).
- $\rho = \rho(T, S, P) \rightarrow$  determined from lab measurements.
- The widely used property is density anomaly
  - $\sigma = \rho - \rho_{\text{ref}} = \rho - 1000 \text{ kg m}^{-3}$



Contours of seawater density anomalies ( $\sigma$ )

## 4. The density

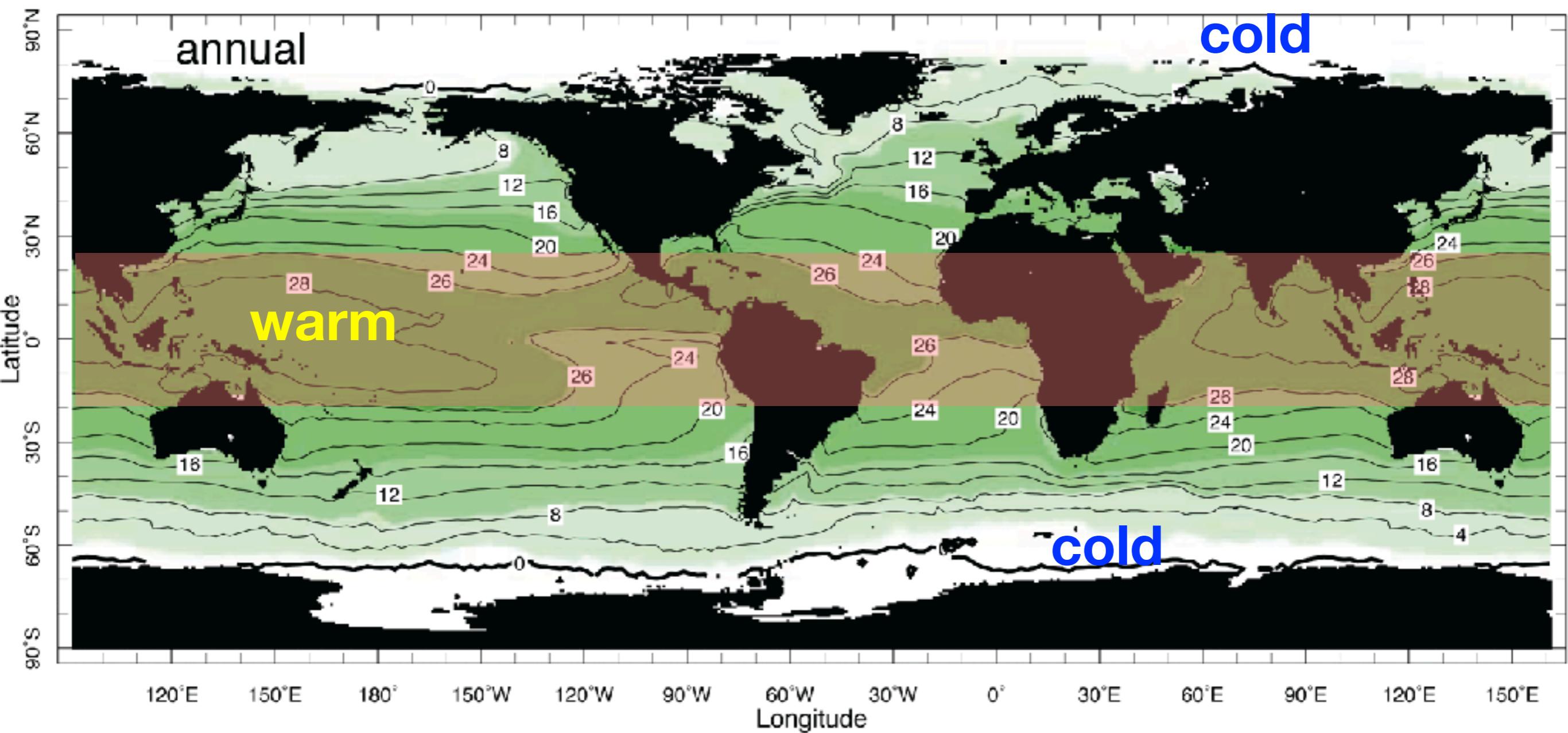
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- Salty water is more dense than fresh water.
- Warm water is less dense than cold water.
- Fresh water has the maximum density at 4°C.
  - This is why ice forms on the top of freshwater lakes.
  - Typically, temperature has greater impact on the density because it varies over the wide range (0 - 30°C)

## 5. Temperature structure

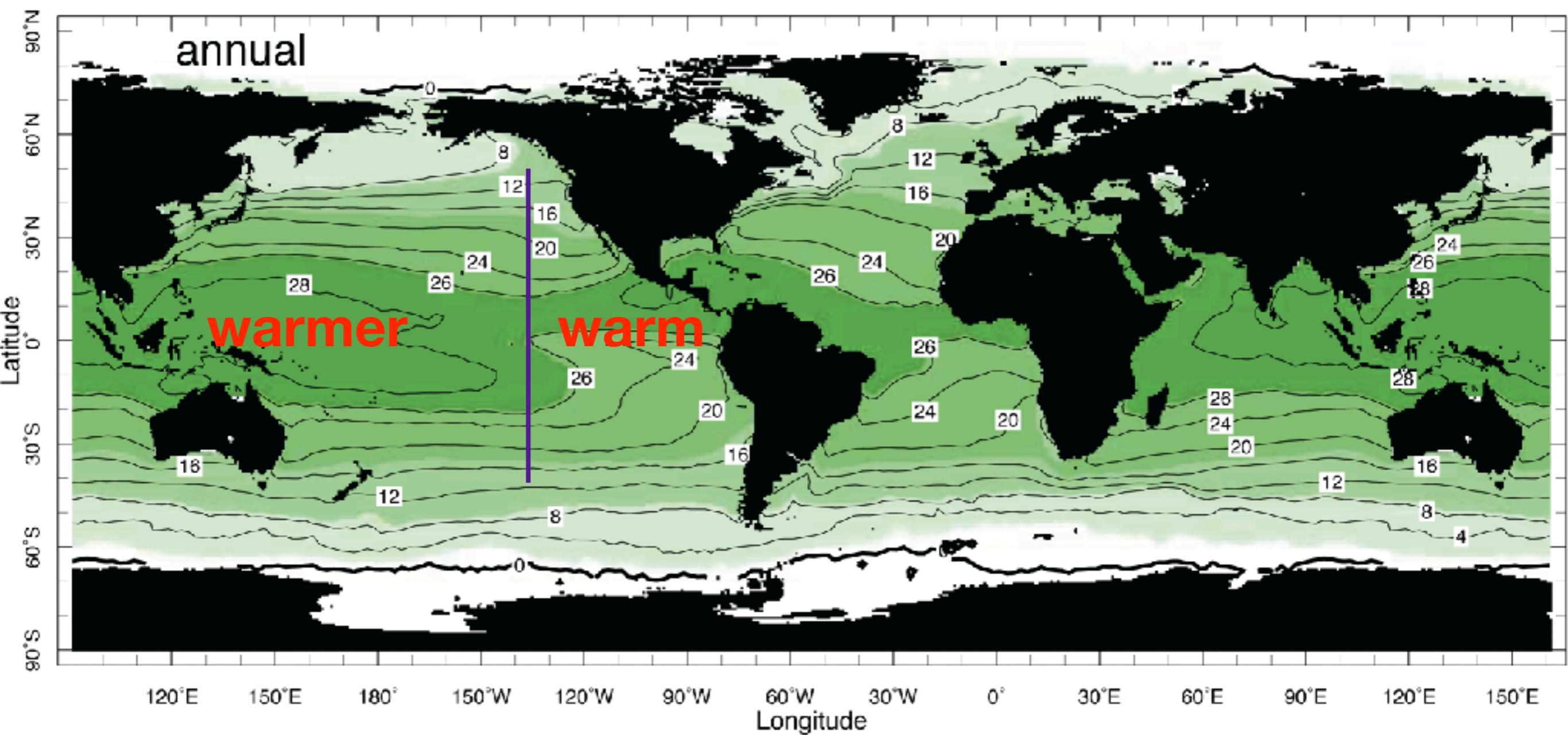
Low albedo → heating at the surface

Sea Surface Temperature ( $^{\circ}\text{C}$ )



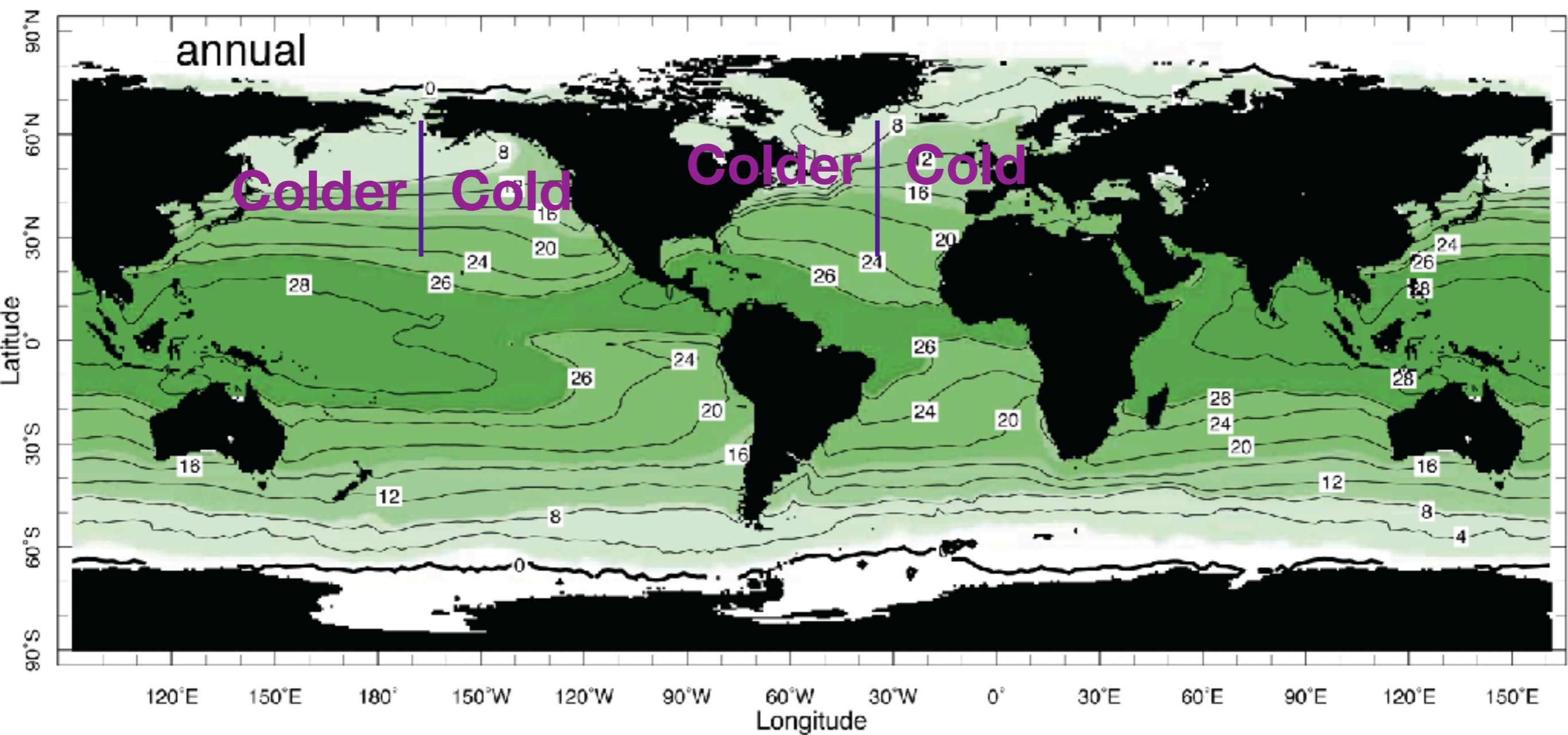
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Sea Surface Temperature ( $^{\circ}\text{C}$ )



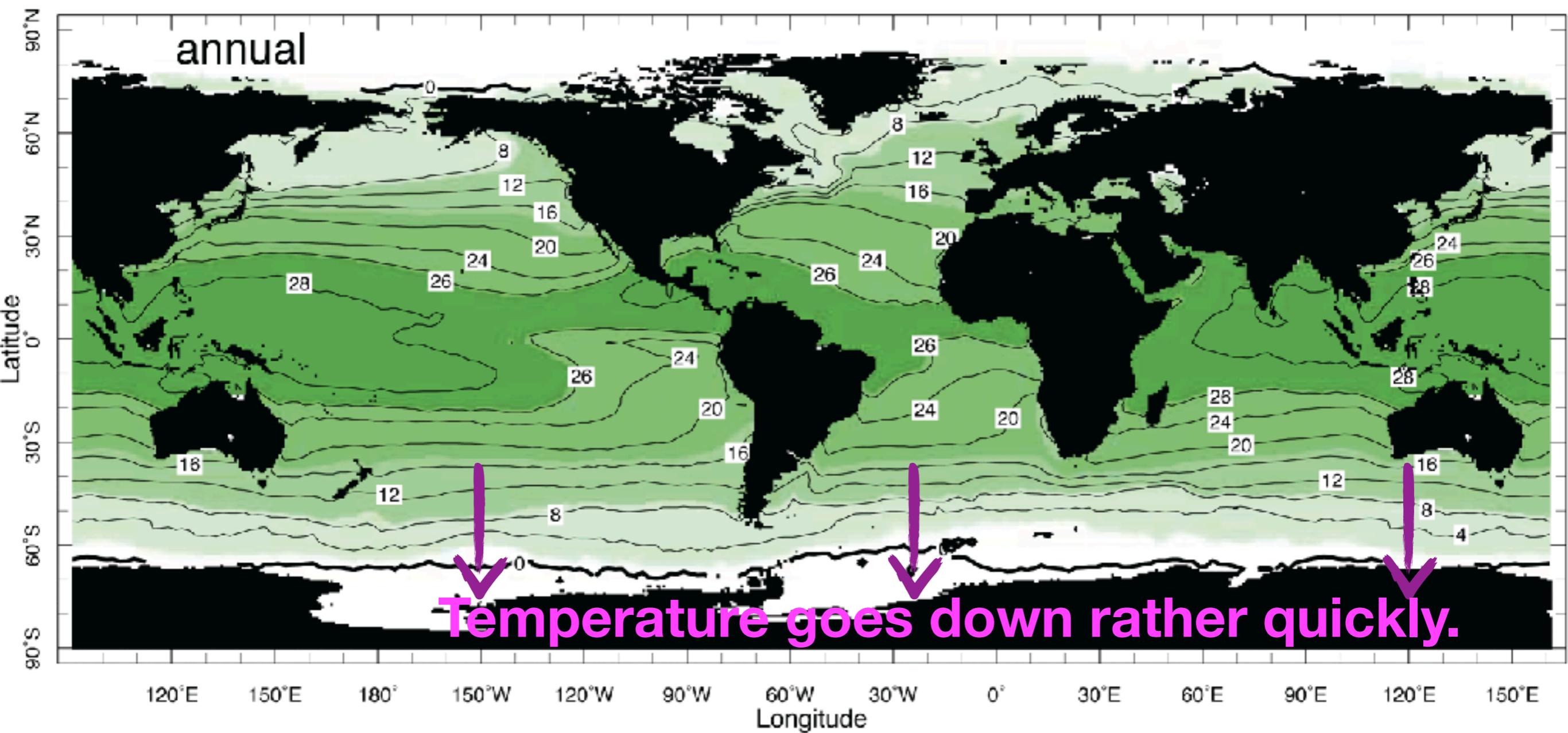
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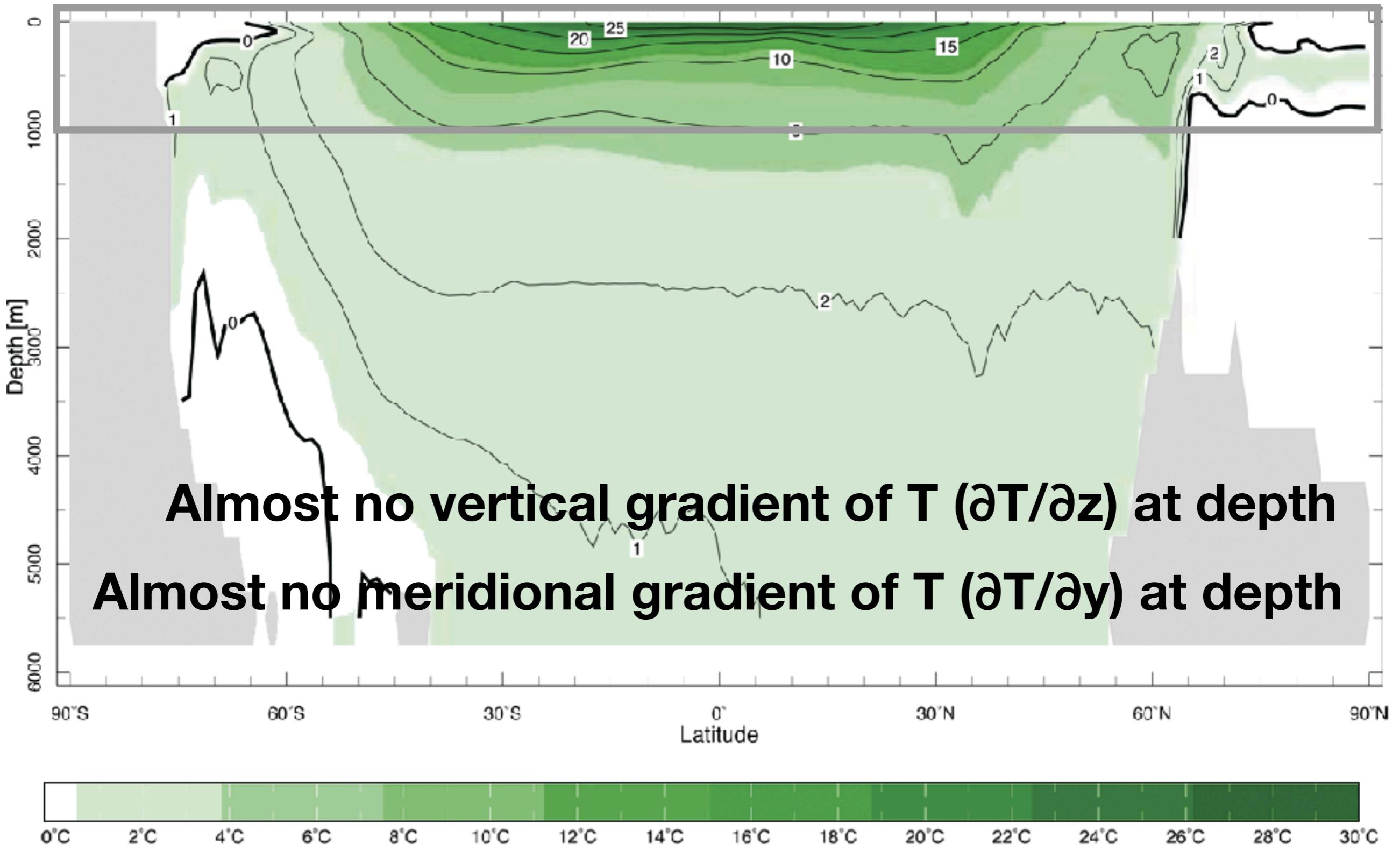


## 5. Temperature structure

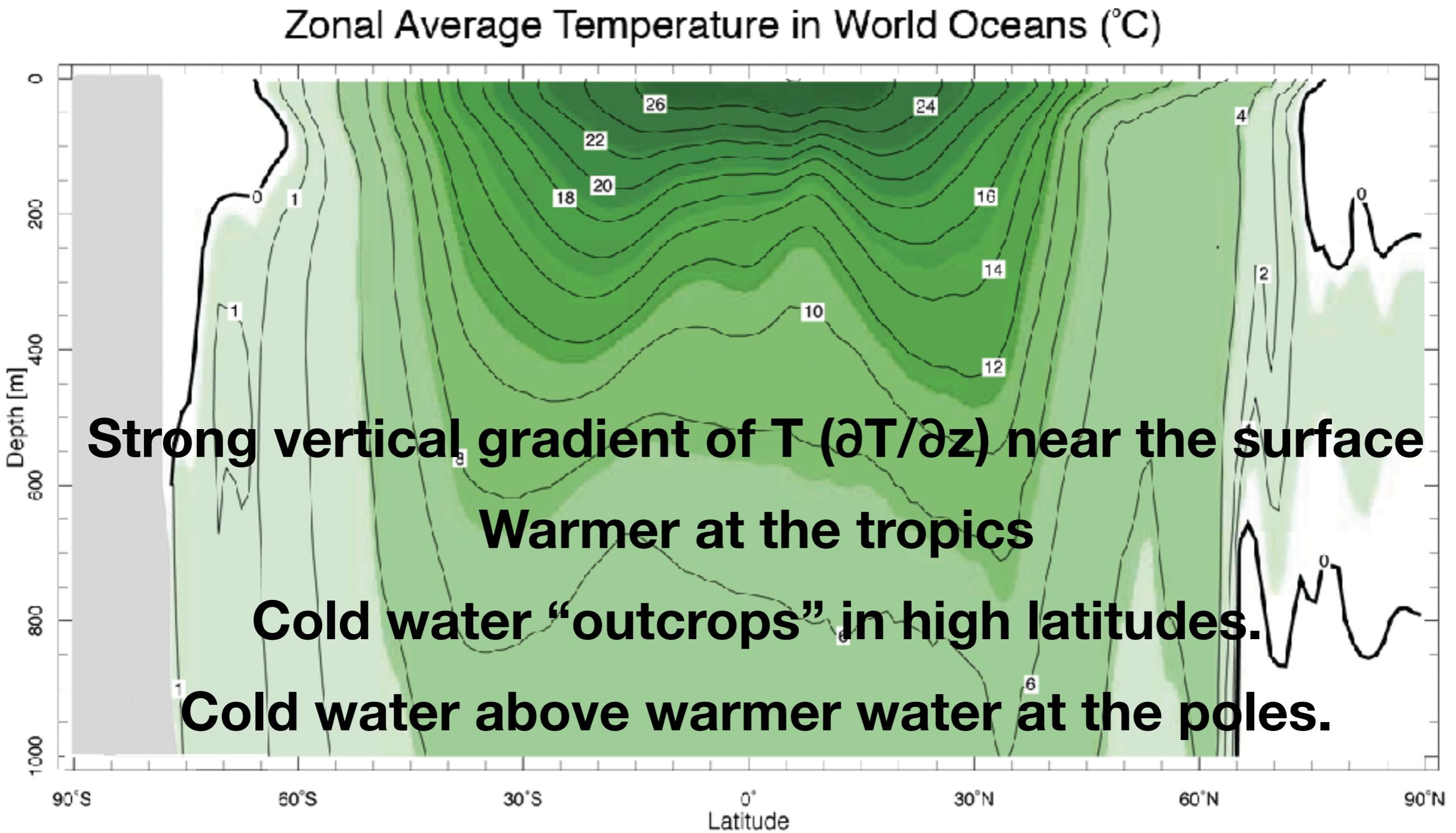
Sea Surface Temperature ( $^{\circ}\text{C}$ )



## 5. Temperature structure: zonal-average mean



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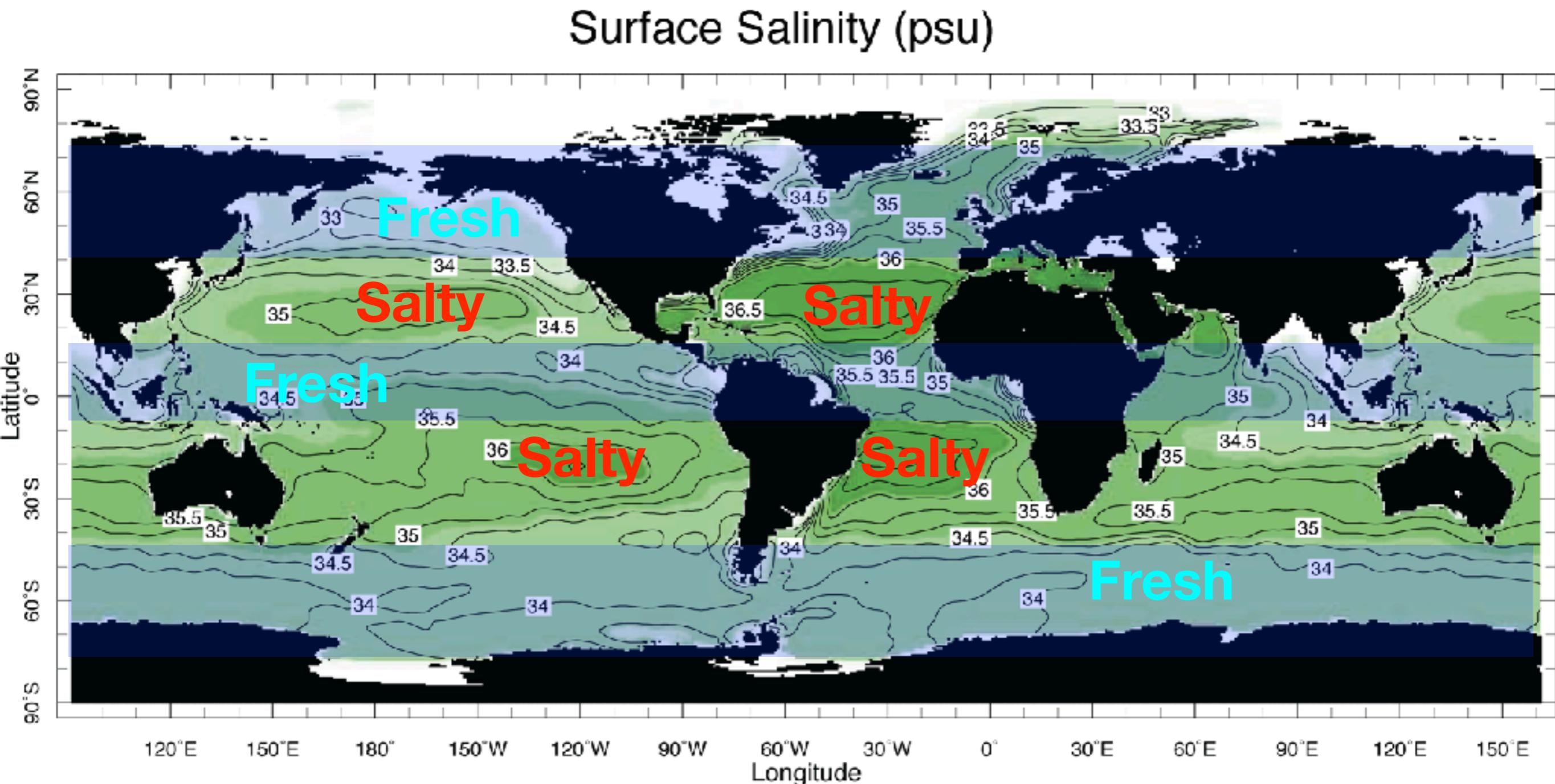
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polynya →

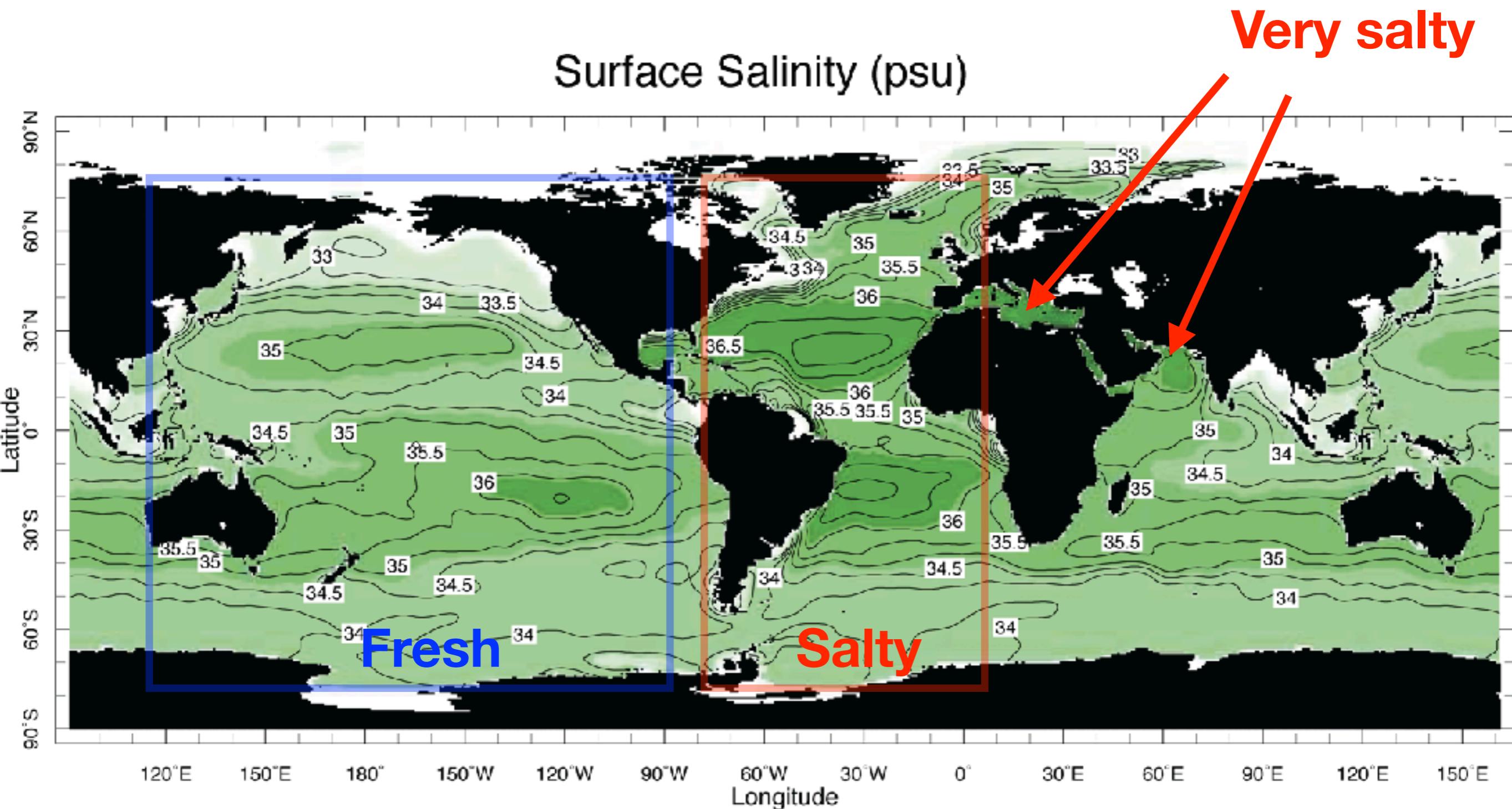


Antarctica

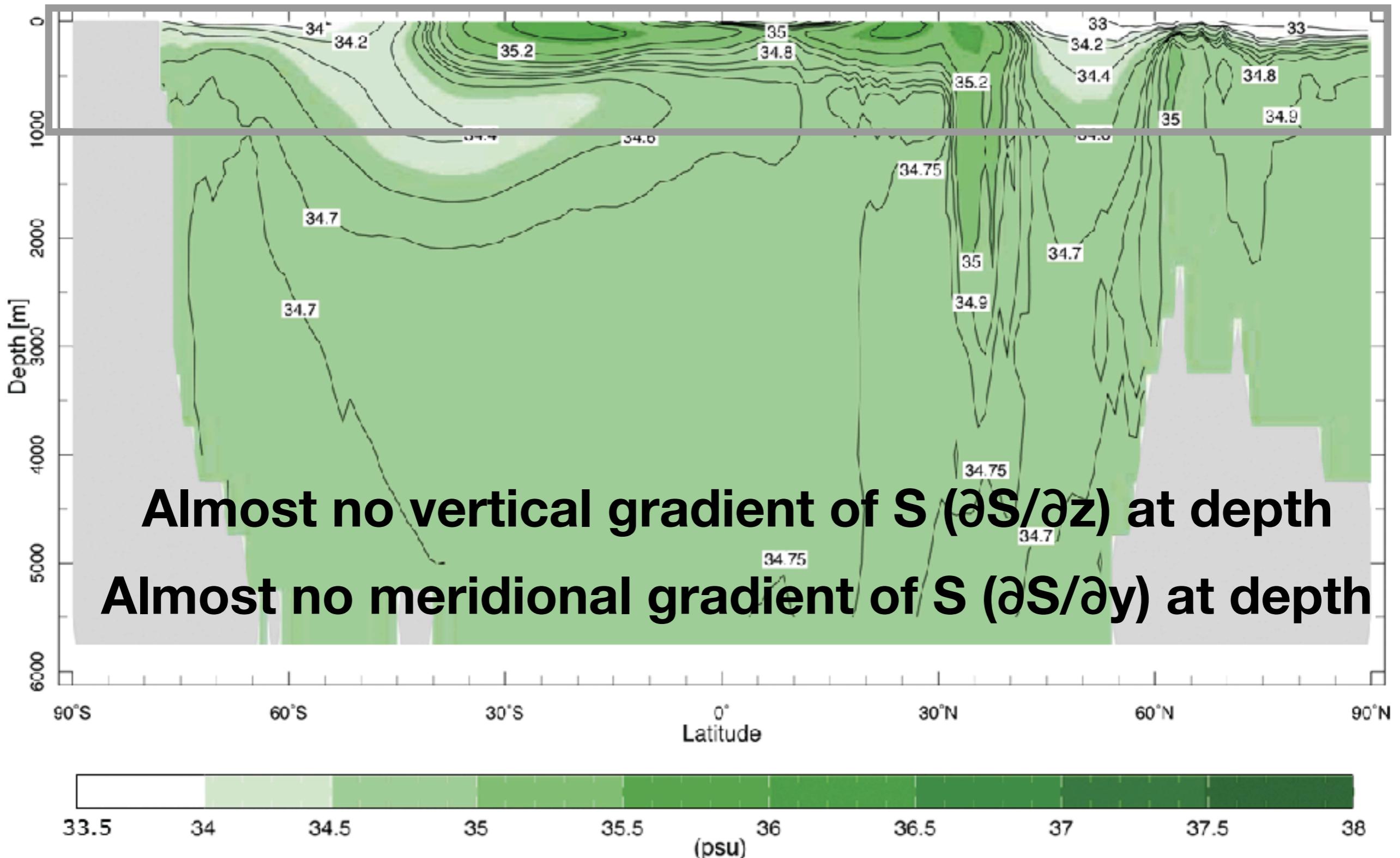
## 5. Salinity structure



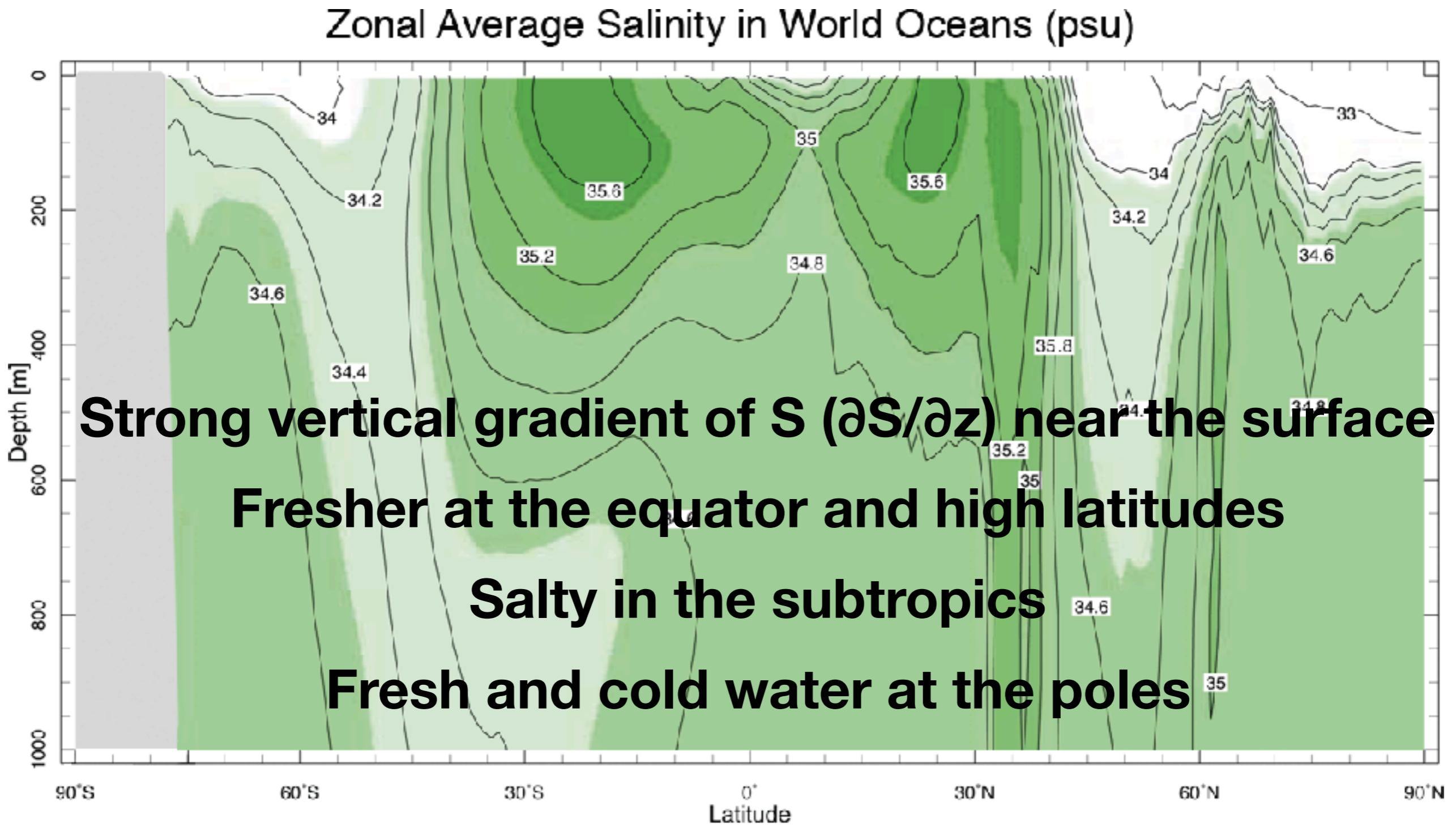
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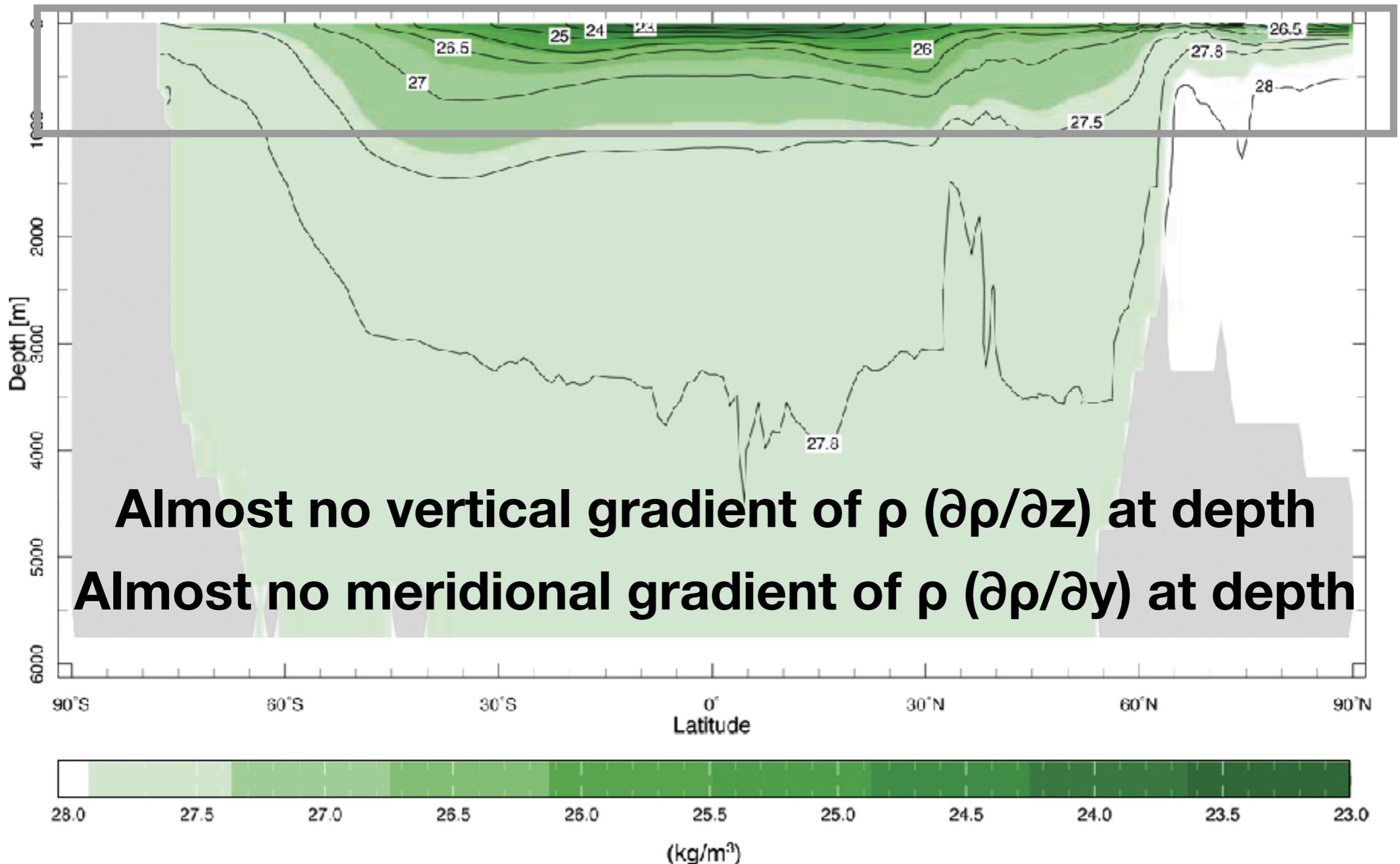
## 5. Salinity structure : zonal-average mean



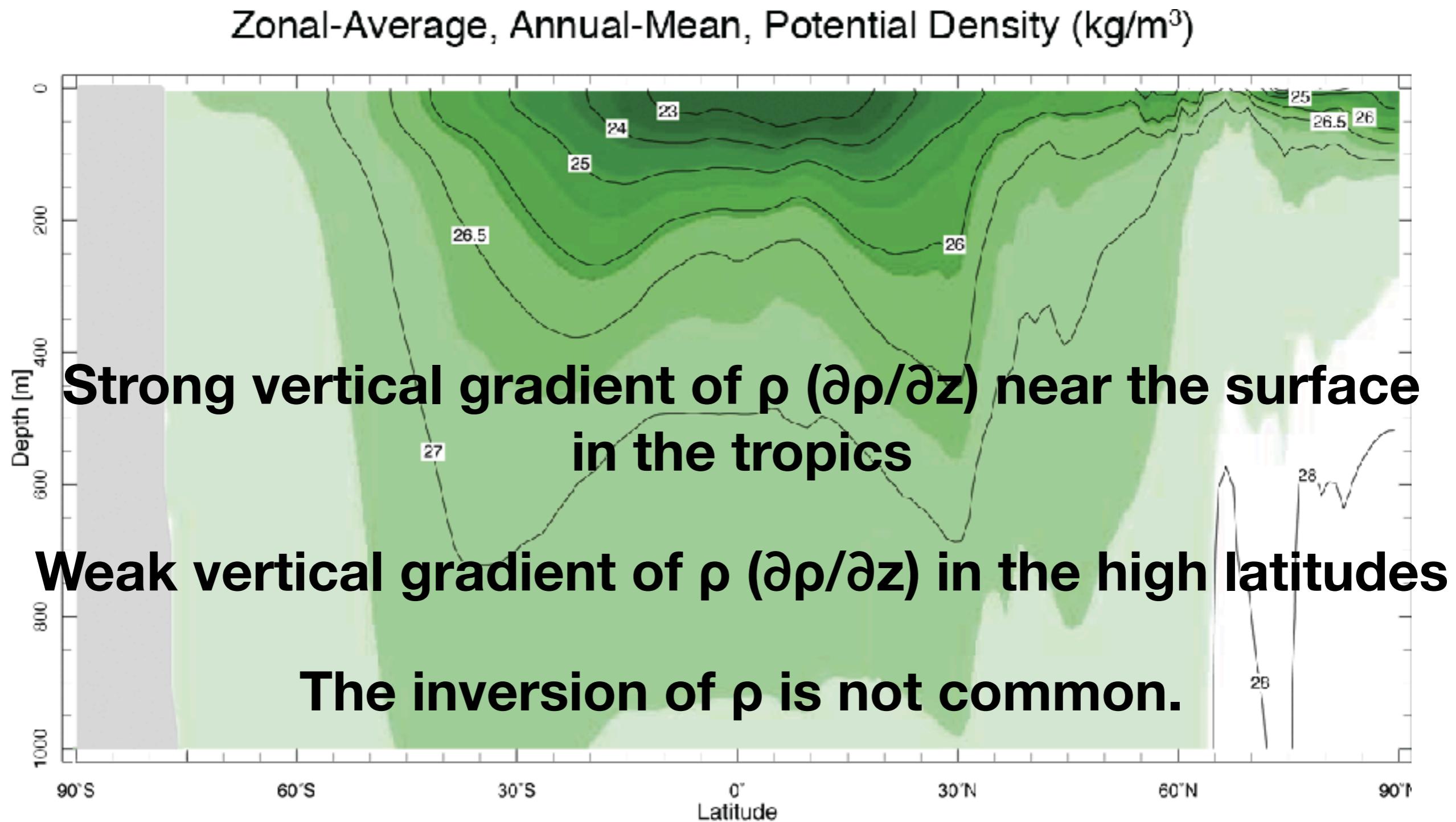
## 5. Salinity structure : zonal-average mean



## 6. Density structure : zonal-average mean



## 6. Density structure : zonal-average mean



## 6. The depth of 26.5 density surface

