

# **Ocean Circulation and Climate**

In addition to the atmospheric circulation heat is also transported to the poles by the ocean circulation. The ocean circulation is therefore an important part of the climate system. As in the atmosphere, ocean circulations are driven by buoyancy effects and the flow is influenced by Coriolis forces and drag at the interfaces.

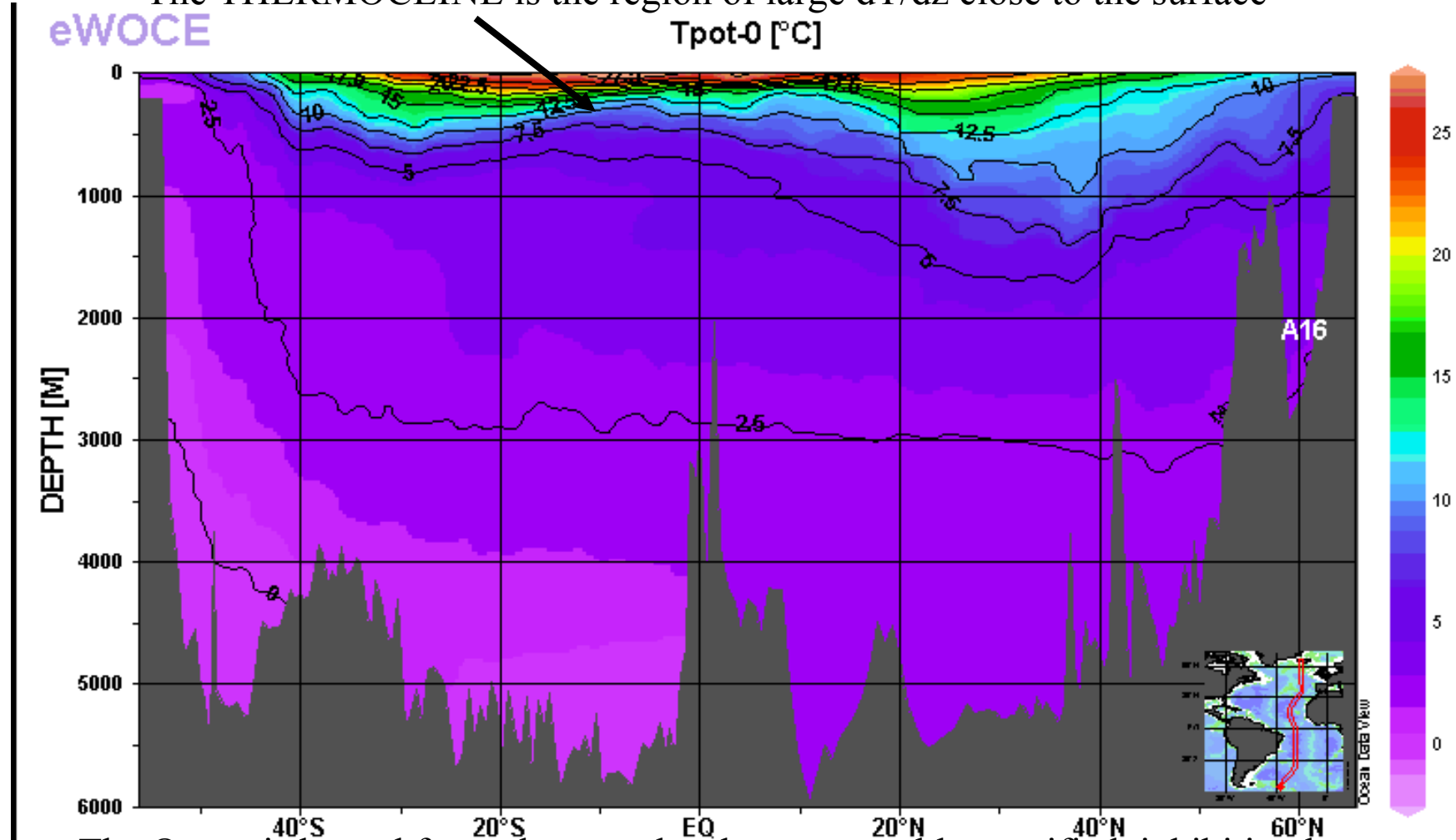
## **The Thermohaline Circulation**

The average depth of the ocean is 4 km but most of the life is confined to the surface layer around 100 m deep. The surface water is relatively warm but contains little nutrient or dissolved CO<sub>2</sub> because of the strong absorption by sunlight and sinking of decaying biomass.

The fact that over thousands of years the heat has not diffused downwards is a result of the THERMOHALINE CIRCULATION. This climatically very important as the solubility of CO<sub>2</sub> increase as temperature decreases. Any warming of the lower layers would cause dissolved CO<sub>2</sub> to escape from the ocean into the atmosphere.

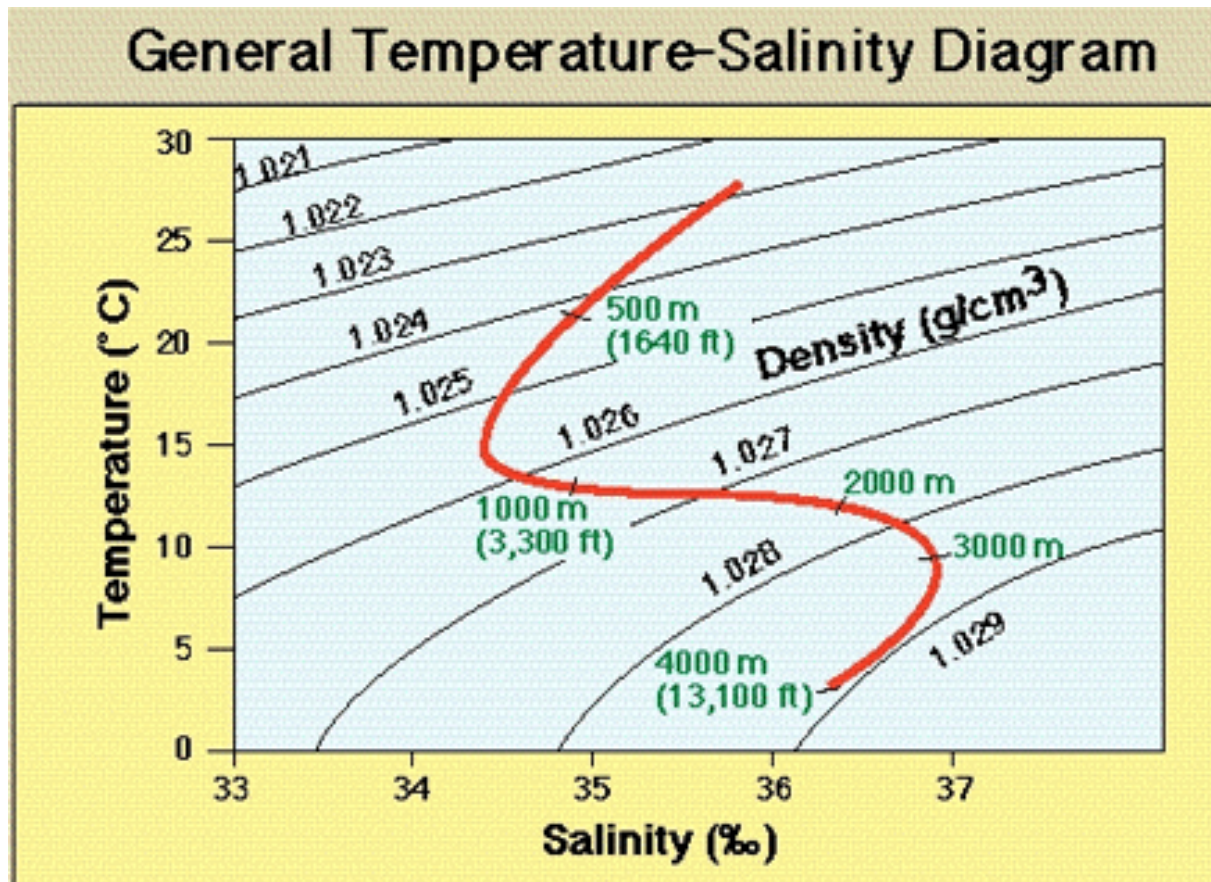
# A Vertical meridional section of potential Temperature in the Atlantic Ocean

The THERMOCLINE is the region of large  $dT/dz$  close to the surface

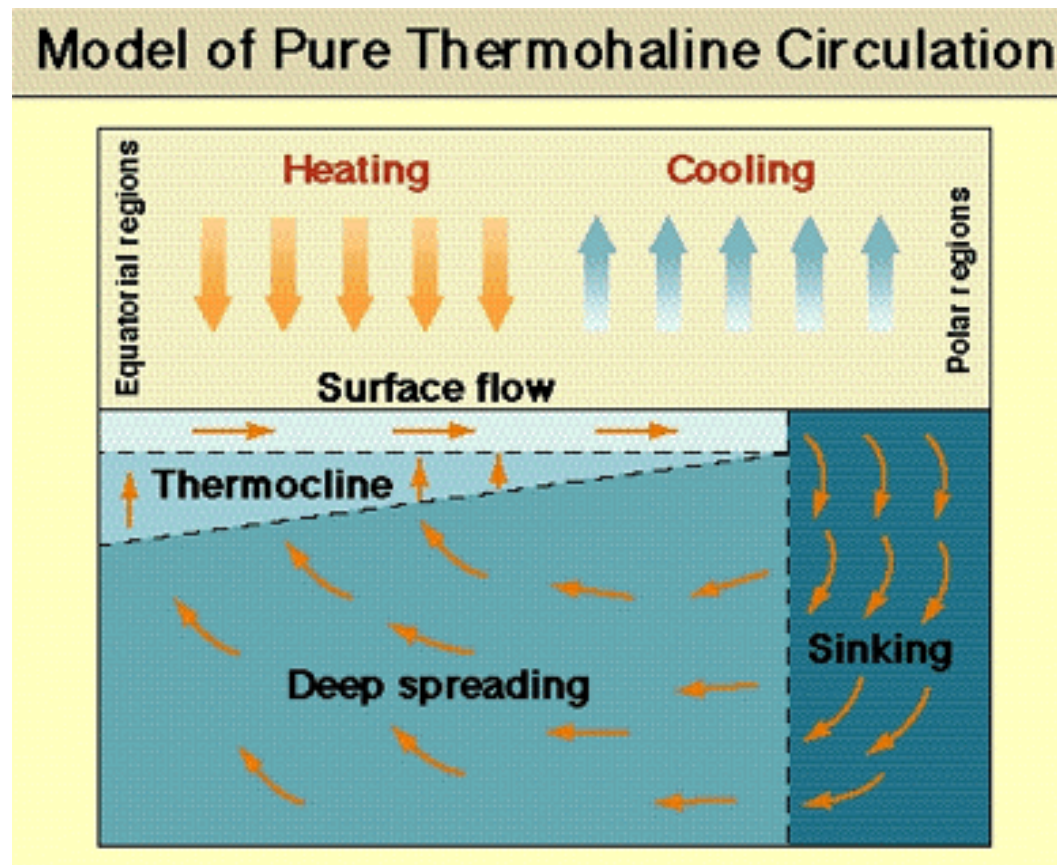


The Ocean is heated from above and so becomes stably stratified, inhibiting heat transfer to lower levels

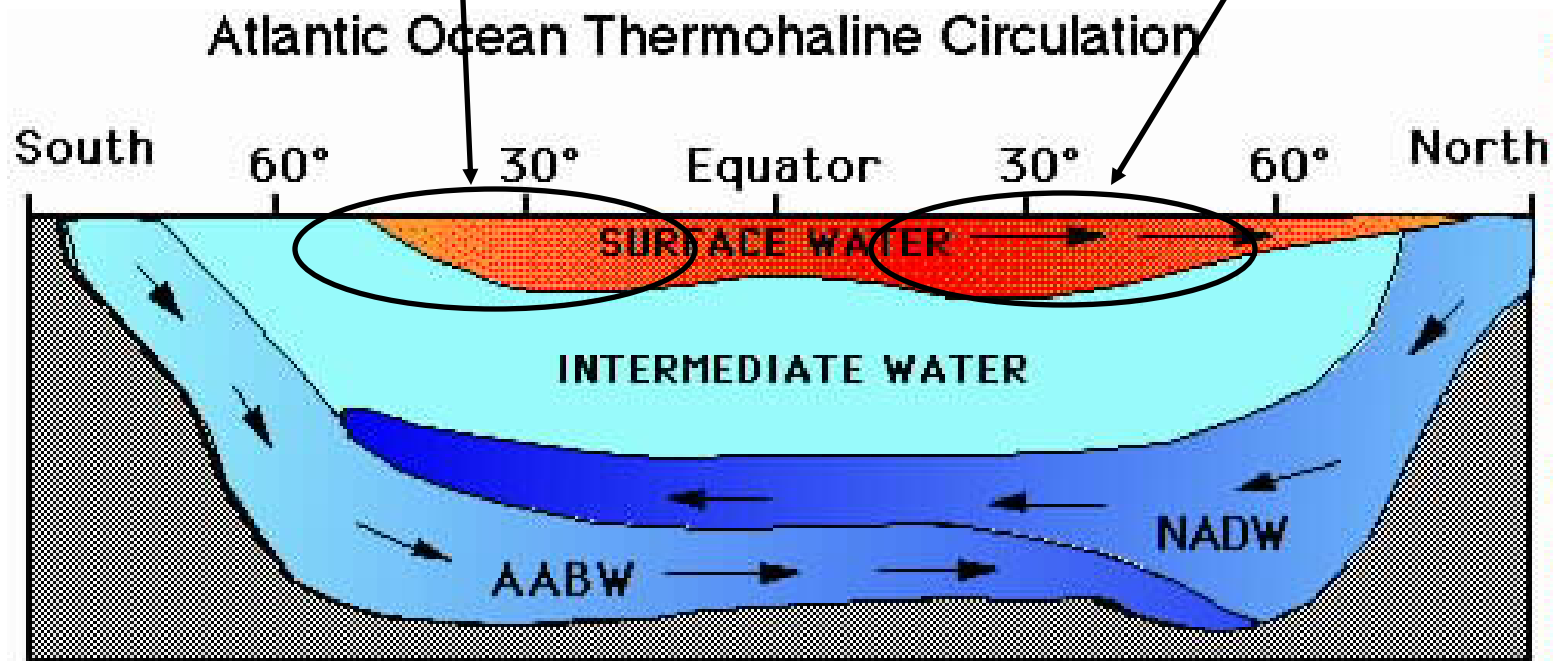
Thermohaline circulation arises because the density of seawater is dependent on temperature and salinity



To counter the downward diffusion of heat, the lower water must rise slowly. This must be compensated by descent in limited regions. However, the surface water is warm, so it can only sink as a result of its salinity



1. At high latitudes temperature changes with depth are smaller than at low latitudes and hence in these regions salinity induced changes in density are likely to have the largest effect



Increased nutrients & dissolved CO<sub>2</sub> 

Warm, low nutrients, & oxygenated 

## Salinity induced density changes

Cold dry air from continental regions creates large amounts of evaporation, while also warming the air.

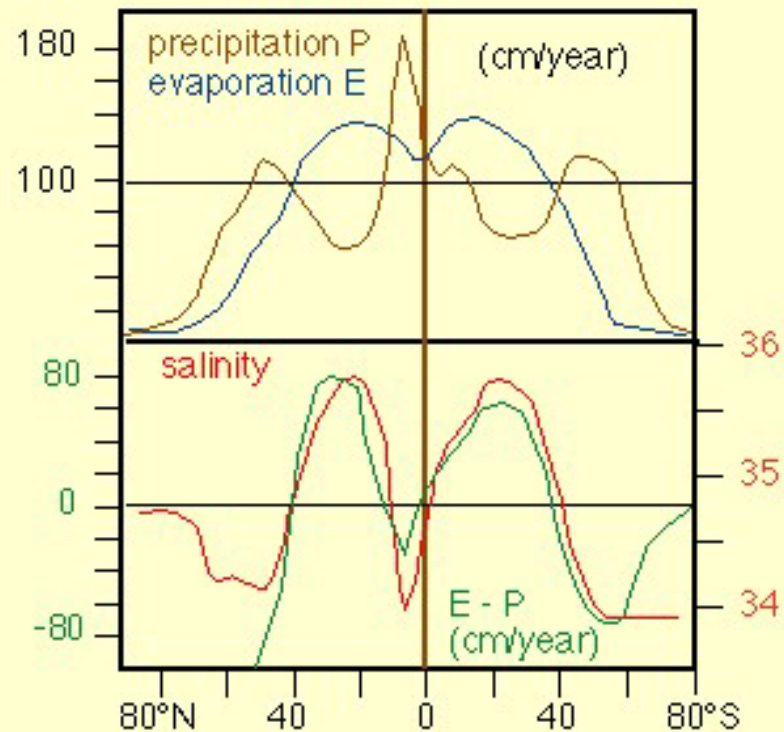
Heat exchange may locally reach  $1000 \text{ W m}^{-2}$

This leads to increased salinity as only water is evaporated.

As a result of the increased salinity the water becomes more dense.

At high latitudes freezing of sea water leads to the segregation of salt from the ice also increasing the density of the surrounding water.

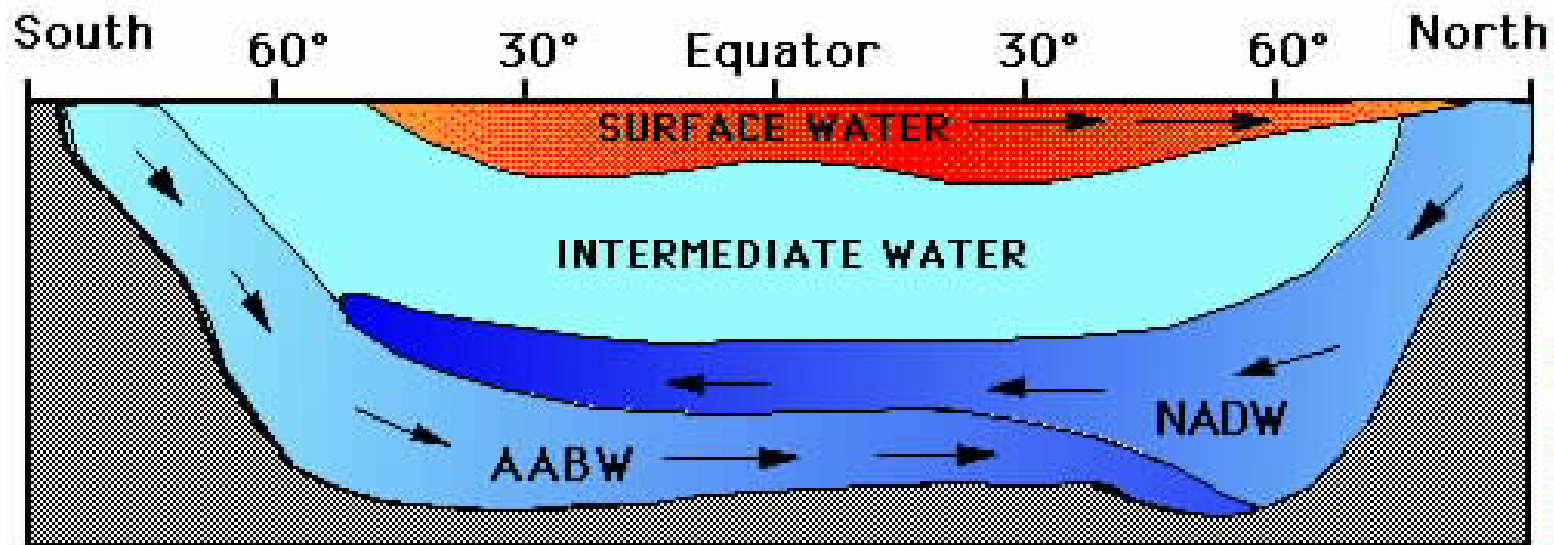
As the temperature of the water falls at high latitudes the surface water sinks.



**The Thermohaline Circulation:** Sinking of cold water at high latitudes gives a poleward flow in the surface layers and equatorward flow in the deep oceans with slow rising motion outside the polar regions. The resulting circulation maintains the contrasts between the upper and lower regions of the ocean.

In the oceans of the Earth, this simple description is modified due to irregular distribution of the continents.

### Atlantic Ocean Thermohaline Circulation



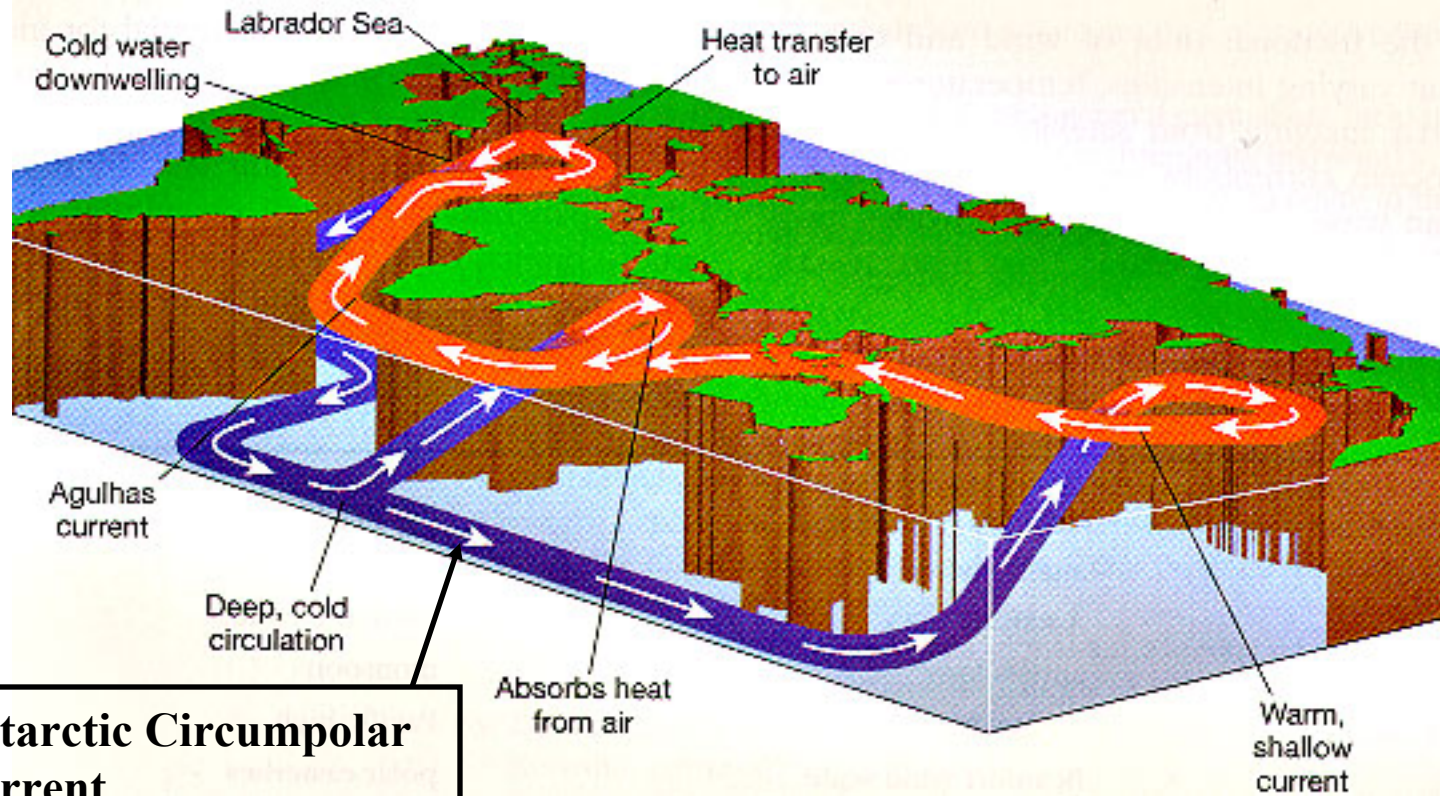
Increased nutrients & dissolved CO<sub>2</sub> 

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The deep ocean circulations are connected by the Antarctic Circumpolar Current.

The North Pacific and North Indian Oceans are not cold or saline enough for sinking to occur. As a result **ONLY THE NORTH ATLANTIC MAINTAINS THE THERMOHALINE CIRCULATION.**

It is estimated that it takes around 1000 years for a water parcel to leave the surface of the north Atlantic and find its way to the deep north Pacific Ocean.



**Antarctic Circumpolar Current.**

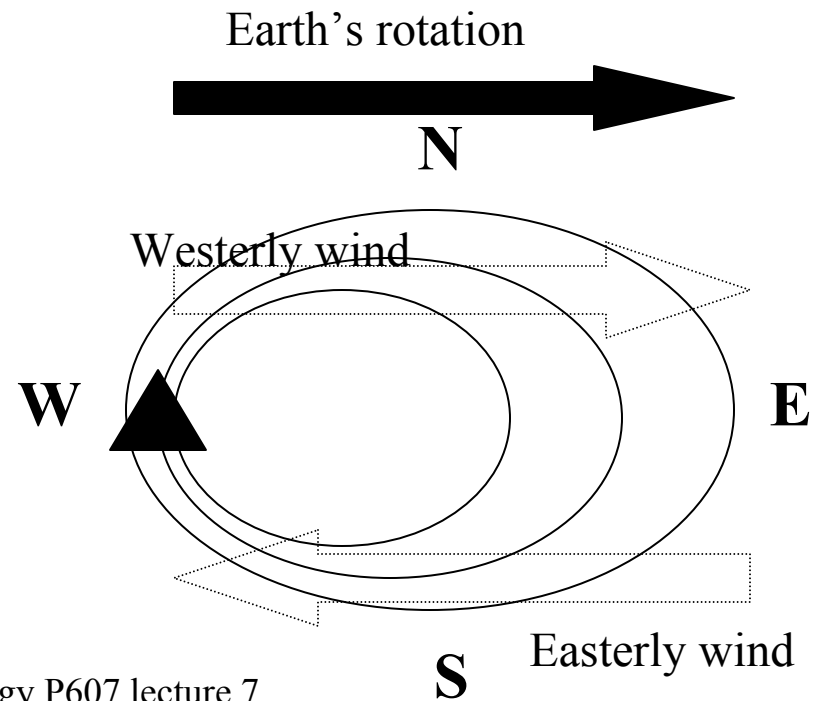


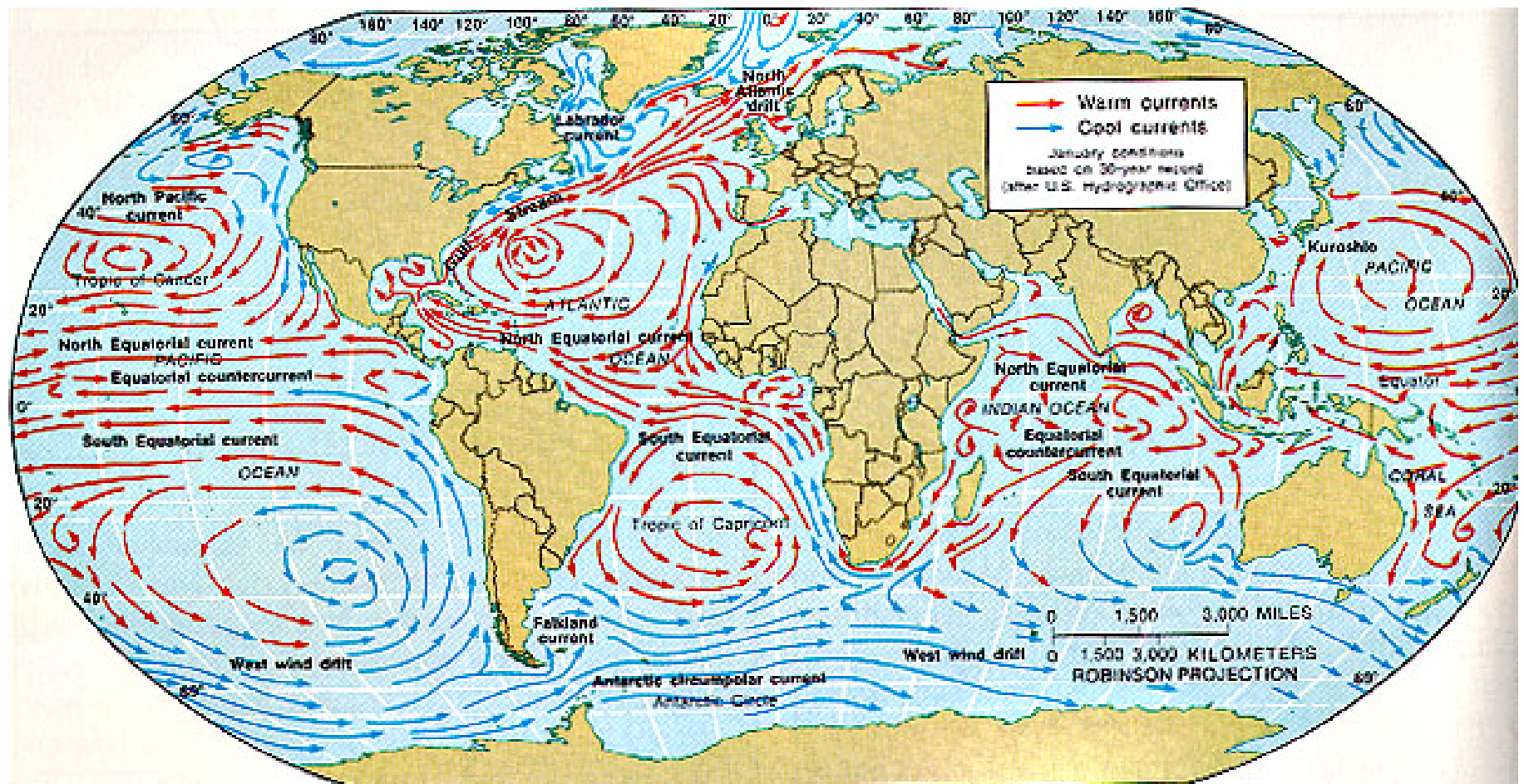
## Wind Driven Circulations:

The thermohaline circulation is not the only one leading to descent of sea water into the deep ocean. In these regions the water is not forced down vertically but along constant density surfaces. Thus the vertical thermal structure depends on latitudinal surface temperature variations.

The Antarctic Circumpolar Current exists because wind forcing at the surface can penetrate to great depths due to weak stratification and because of the long fetch.

In other ocean basins the wind exerts a torque on the surface water which results in westerly winds at high latitudes and easterlies at low latitudes. The resulting **ocean gyres** are not symmetrical as a result of the rotation of the Earth and its sphericity which results in a variation of the Coriolis effect with latitude. The flow gives a strong poleward western boundary current with a weaker equatorward flow.

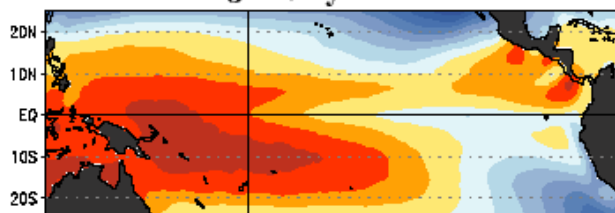




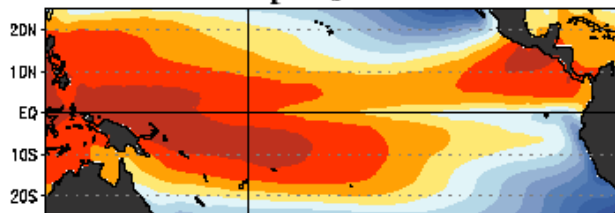
Climate and Energy P607 lecture 7

# Pacific Ocean Circulation

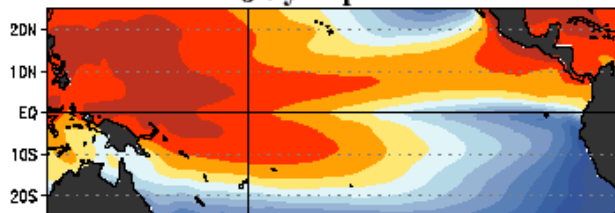
Average Ocean Temperatures (°C)  
January-March



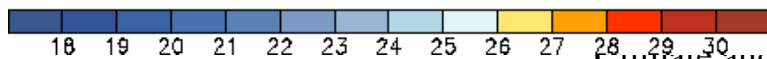
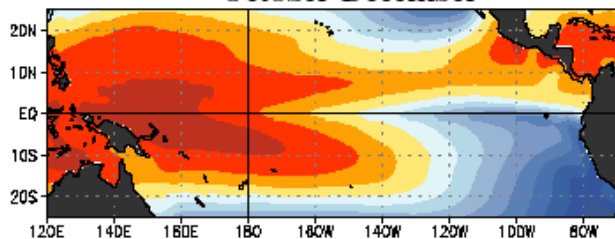
April-June



July-September



October-December



The mean state of the tropical Pacific ocean is identified by both its surface and subsurface characteristics, each of which exhibit considerable evolution across the eastern half of the tropical Pacific during the course of the year. Throughout the year the ocean surface is warmest in the west and coldest in the east.

The warmer water expands and the sea level in the W Pacific is higher than that the E Pacific.

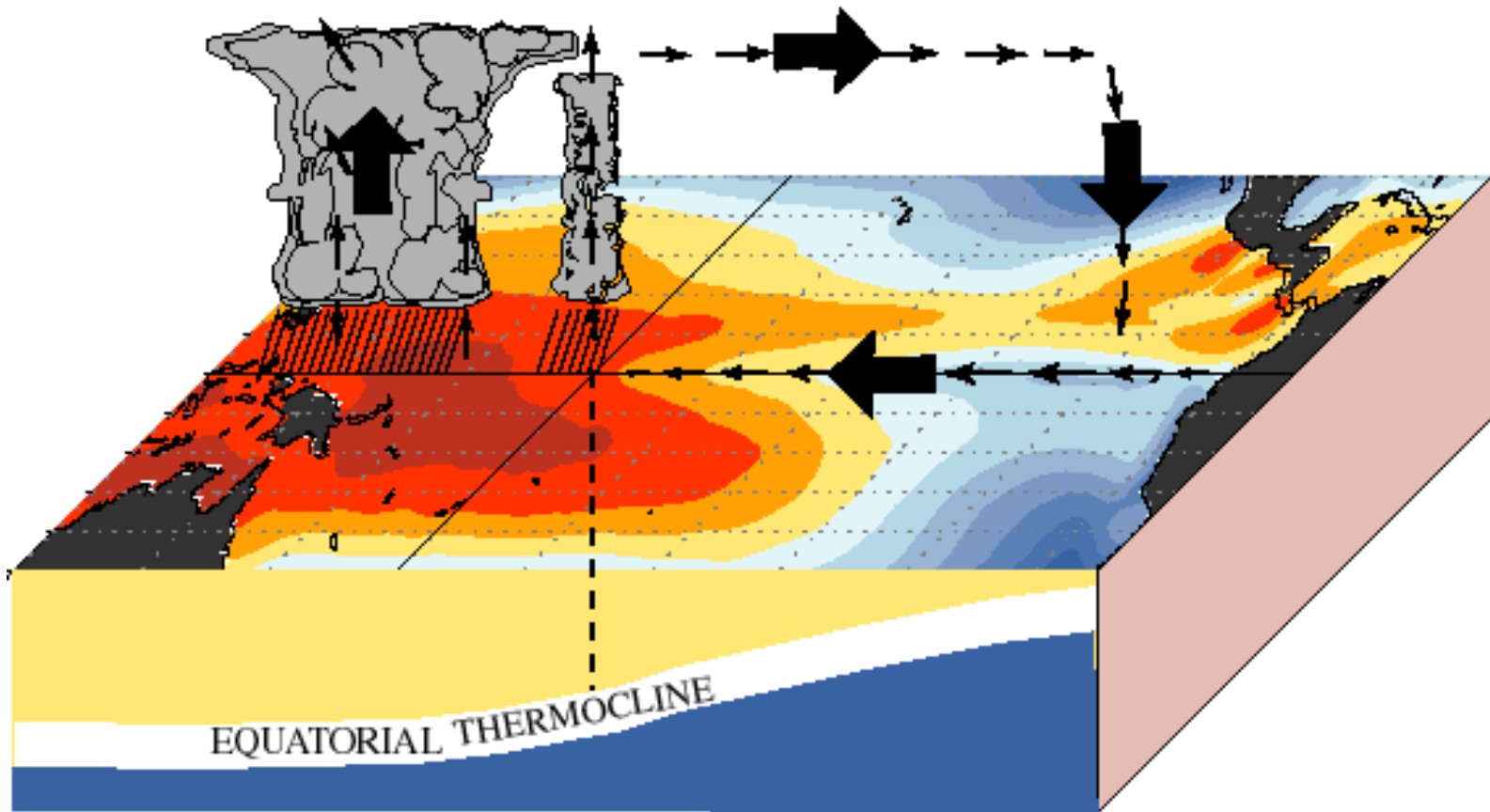
This height variation drives a flow to the east at lower levels in opposition to the surface wind driven flow.

This reverse flow occurs at around 100 m depth.

The resulting ascent occurs close to the Peruvian coast where it results in the ascent of nutrient rich water from lower levels with a consequent benefit to fishermen.

# The Walker Circulation:

## December - February Normal Conditions



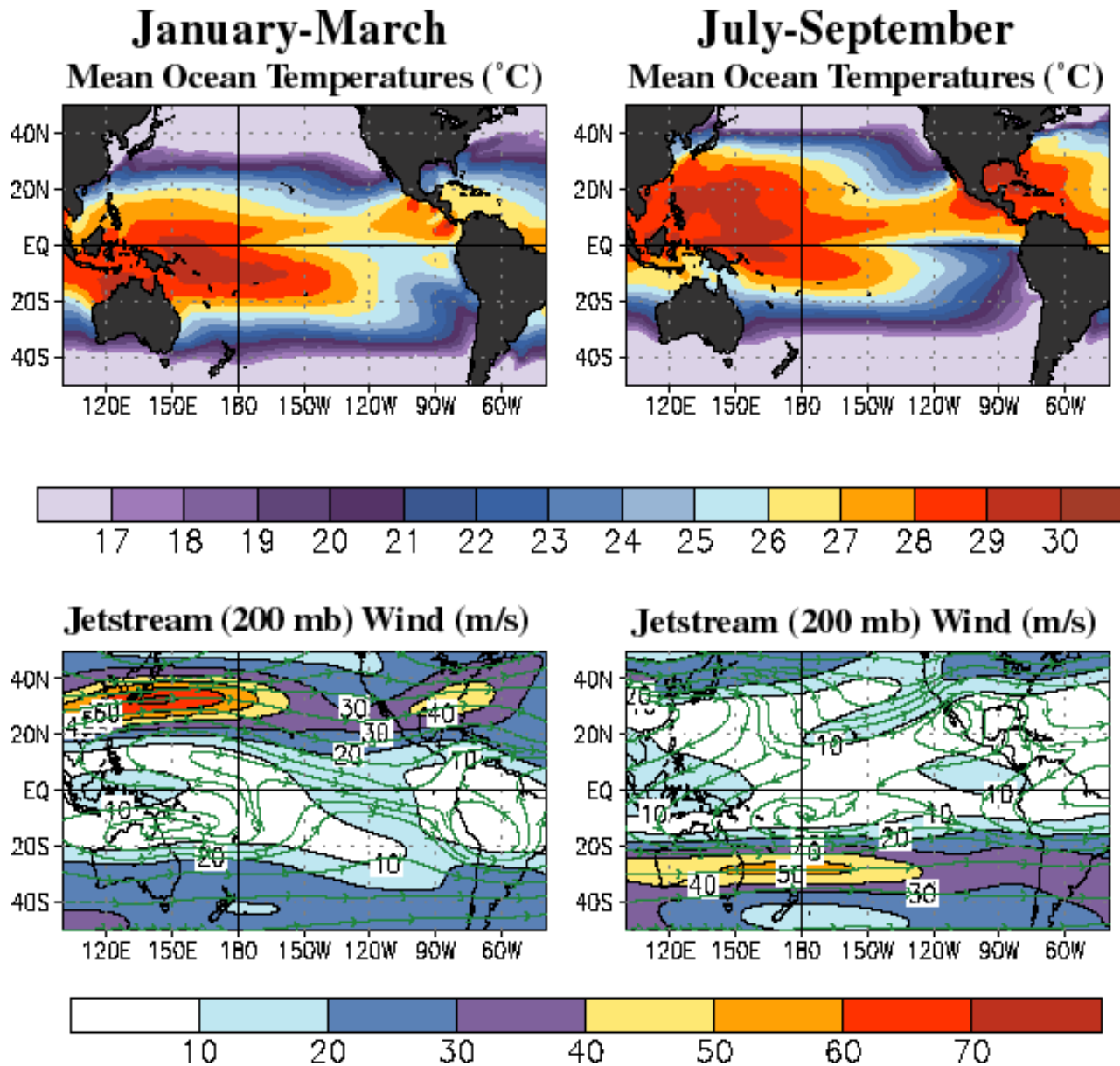
## **The Walker Circulation:**

Ocean surface temperatures across the tropical Pacific contribute significantly to the observed patterns of tropical rainfall and tropical thunderstorm activity. The heaviest rainfall is typically observed across Indonesia and the western tropical Pacific, and least rainfall is normally found across the eastern equatorial Pacific.

The mean patterns of sea surface temperature and equatorial rainfall are accompanied by low level easterly winds (east- to- west flow) and upper level westerly winds across the tropical Pacific. Over the western tropical Pacific and Indonesia this wind pattern is associated with low air pressure and ascending motion, while over the eastern Pacific it is accompanied by high pressure and descending motion. Collectively, these conditions reflect the equatorial Walker Circulation, which is a primary large-scale circulation feature across the Pacific.

The subsurface ocean structure is characterized by a deep layer of warm water in the western tropical Pacific, and by a comparatively shallow layer of warm water in the eastern Pacific. This warm water is separated from the cold, deep ocean waters by the oceanic thermocline, which is normally deepest in the west and slopes upward toward the surface farther east. The resulting east-west variations in mean upper-ocean temperatures result in east-west variations in sea level height, which is higher in the west than in the east.

# Equatorial Heating and the subtropical jetstreams



# Equatorial Heating and the subtropical jetstreams

Pacific ocean temperatures, tropical rainfall and vertical motion patterns greatly affect the distribution of atmospheric heating across the tropical and subtropical Pacific.

Normally, the strongest heating and warmest air temperatures coincide with the warmest ocean waters and heaviest rainfall. This atmospheric heating helps determine the overall north-south temperature differences in both hemispheres, which significantly affects the strength and location of the jet streams over both the North and South Pacific.

This influence on the jet streams tends to be most pronounced during the respective hemisphere's winter season, when both the location and eastward extent of the jets (to just east of the date line) exhibit a strong relationship to the pattern of tropical heating.

These jet streams are then a major factor controlling the winter weather patterns and storm tracks in the middle latitudes over both North and South America.