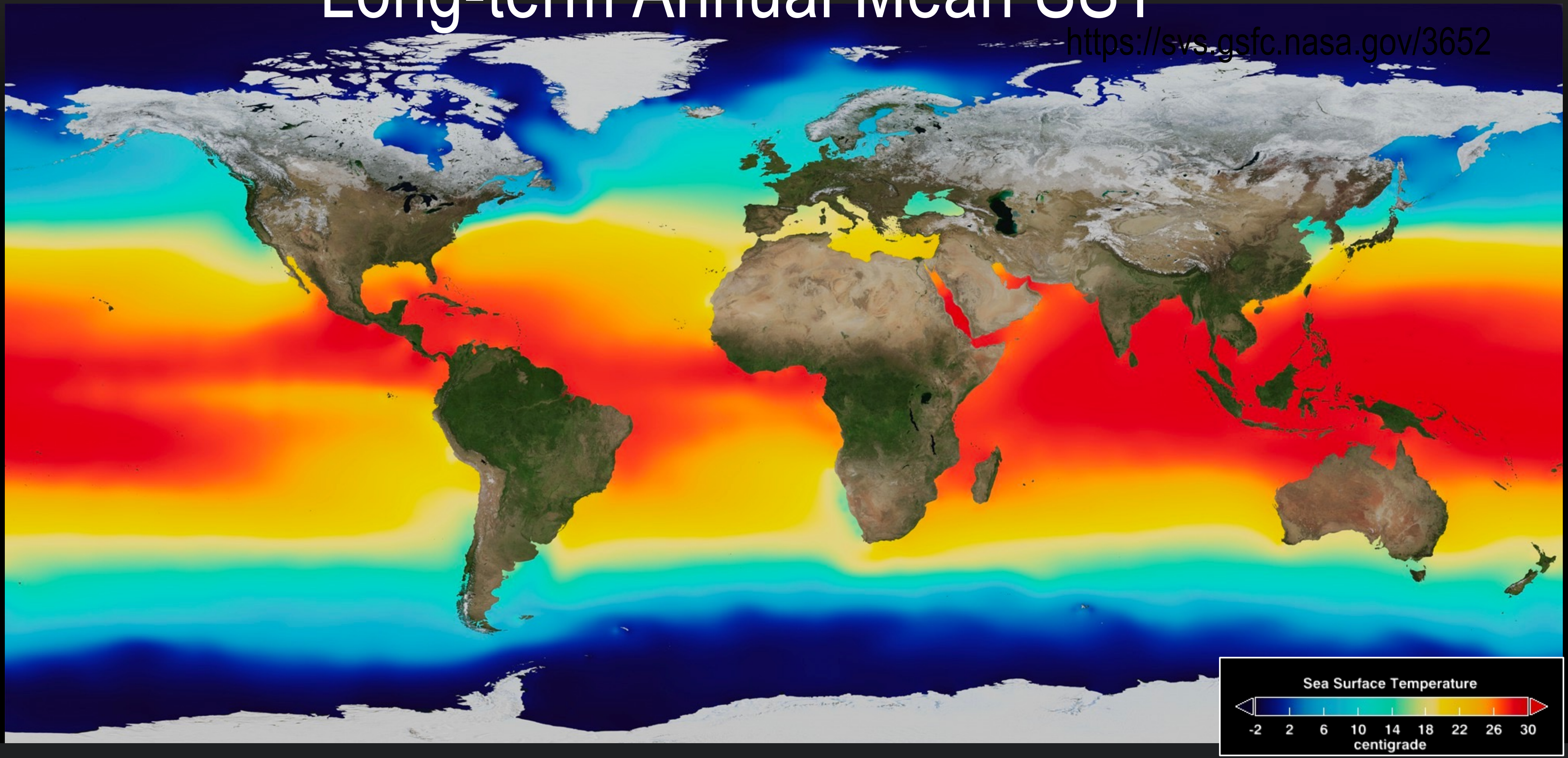
Mean State of the Ocean (temperature and salinity)

Why are oceans important for the global climate system?

- an important source of water vapor
- large heat capacity
  - There is more heat energy in the top 3 m of the ocean than in the entire atmospheric column above it (due to its large density and large specific heat)
- long time scale
  - Response time ranges from years to decades and even to centuries and millenniums
  - A source of predictability for atmospheric variations

Long-term Annual Mean SST



- SSTs in the eastern sides of the Atlantic and Pacific Ocean basins are cooler than in the western basins in both hemispheres, similar to the structure seen in the low-level atmospheric temperature.
- Annual mean SST is more zonally uniform in the Indian Ocean, with slightly higher SST in the east Indian Ocean.
- SST gradients are especially strong off the east coasts of Asia and North America, north of about 30°N, consistent with the strong atmospheric geopotential height gradients and temperatures in this region.

Figure from https://svs.gsfc.nasa.gov/3652

Vertical cross sections of temperature

How does T vary with latitude and depth?

Where is the ocean least stable?

- The warmest waters are located at the surface in the tropics.
- Between 40°S and 40°N, the isotherms are aligned horizontally, denoting the stable layering of the oceans at these latitudes, with warmer (less dense) water floating on top of cold water.
- Isotherms at high latitudes (except in the North Pacific) are oriented vertically, indicating weak stratification. These regions play an important role in the large-scale circulation of the oceans.

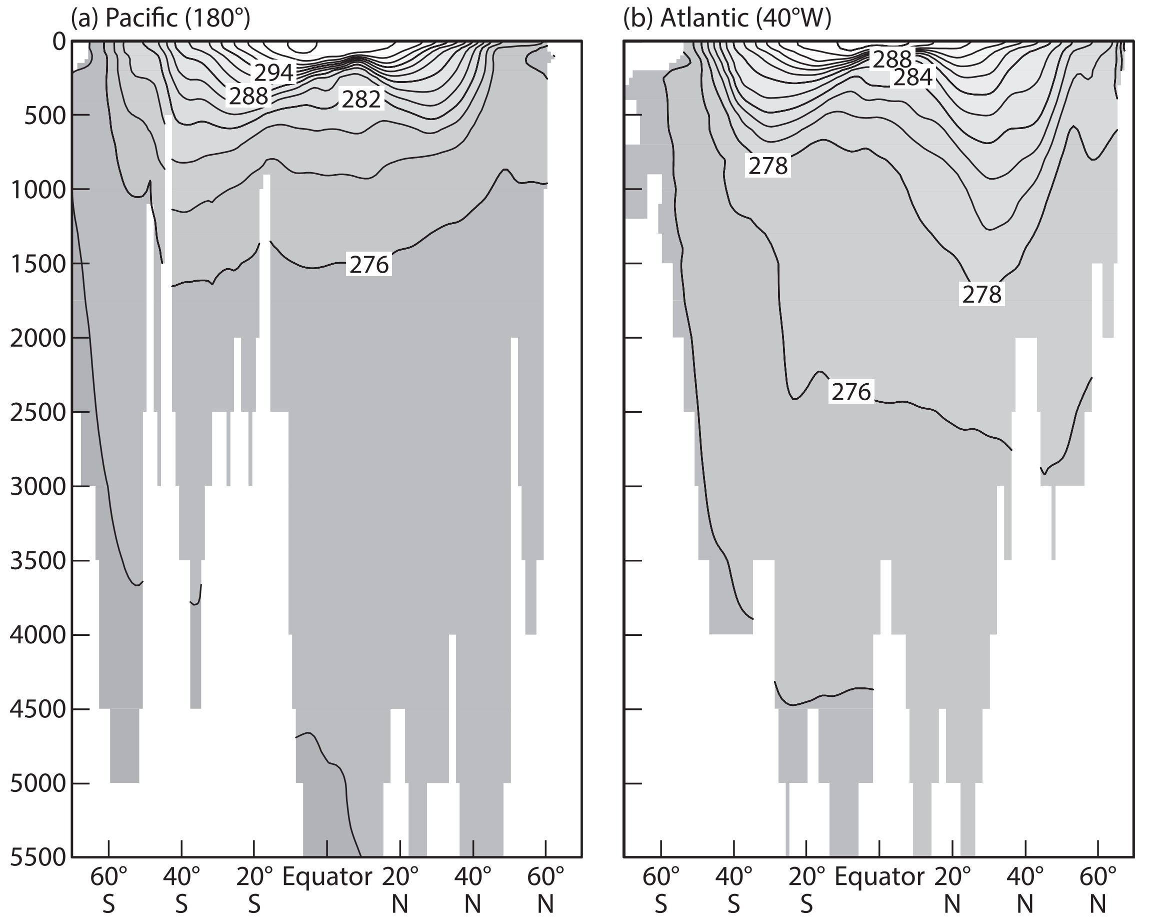


Figure 2.17 Vertical cross sections of temperature for (a) the Pacific Ocean along the International Date Line and (b) the Atlantic Ocean at 30°W. Contour interval is 2 K, and depth is in m.

From Climate Dynamics by K. H. Cook 2013

Long-term Annual Mean Sea Surface Salinity (SSS)

- Salinity is the mass of dissolved salts in a kilogram of seawater.
- Unit: g/kg, or practical salinity unit (PSU), or ‰ (part per thousand; per mil)
- The average salinity of the world ocean is 34.7‰.
- *What physical processes affect salinity?*
    - evaporation
    - precipitation
    - inflow of river water
    - sea-ice formation and melting.
- *How do you explain the spatial variations of S in low latitudes?*

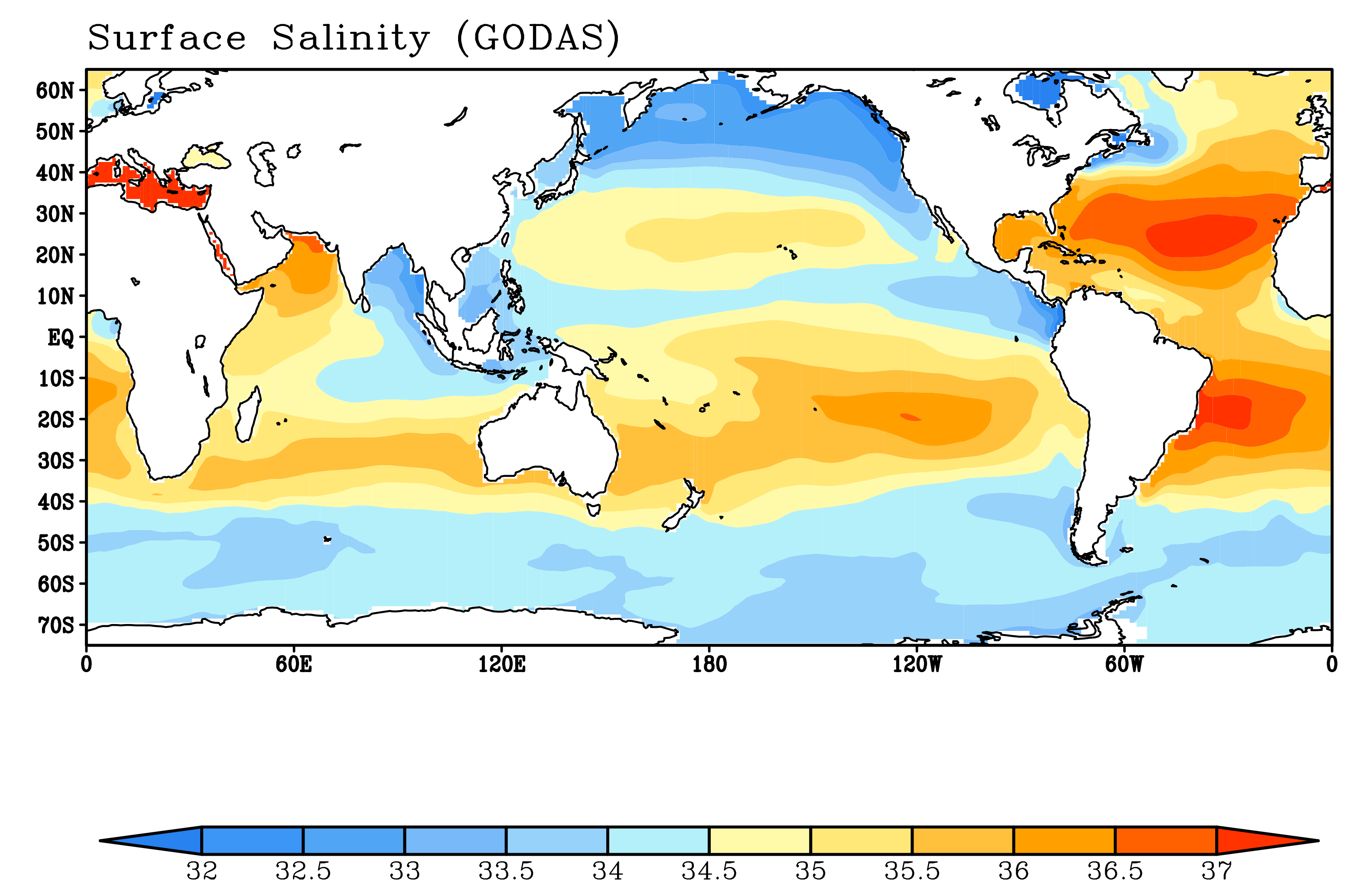


Figure produced using GODAS data

Surface salinity distribution is closely tied to the distribution of “evaporation minus precipitation (E-P)”

- High salinity occurs in the subtropics, where evaporation exceeds precipitation
- Low salinity occurs along the ITCZ and monsoon regions, where precipitation exceeds evaporation.

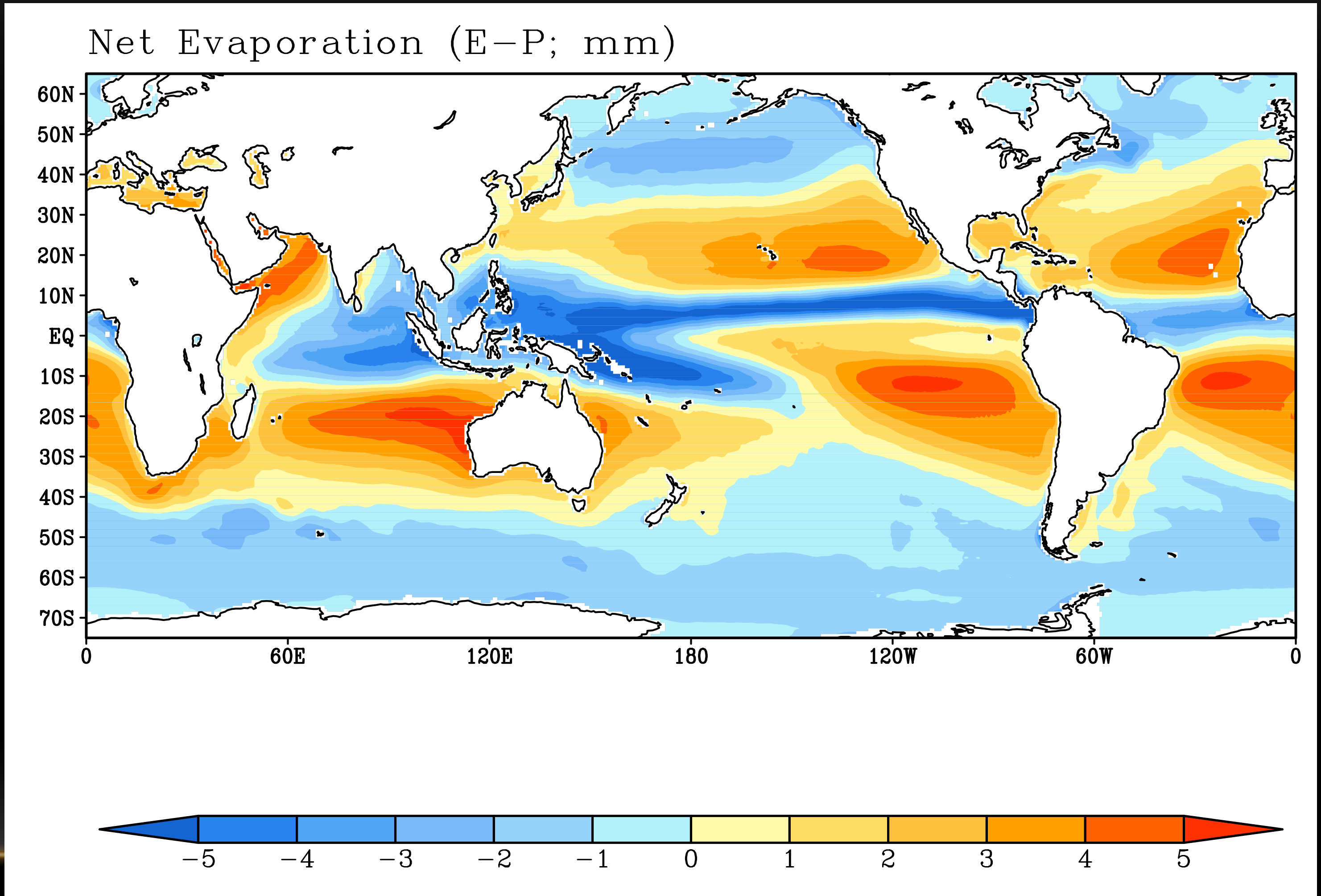


Figure produced using ERAI reanalysis

Zonal Average of SSS and E-P

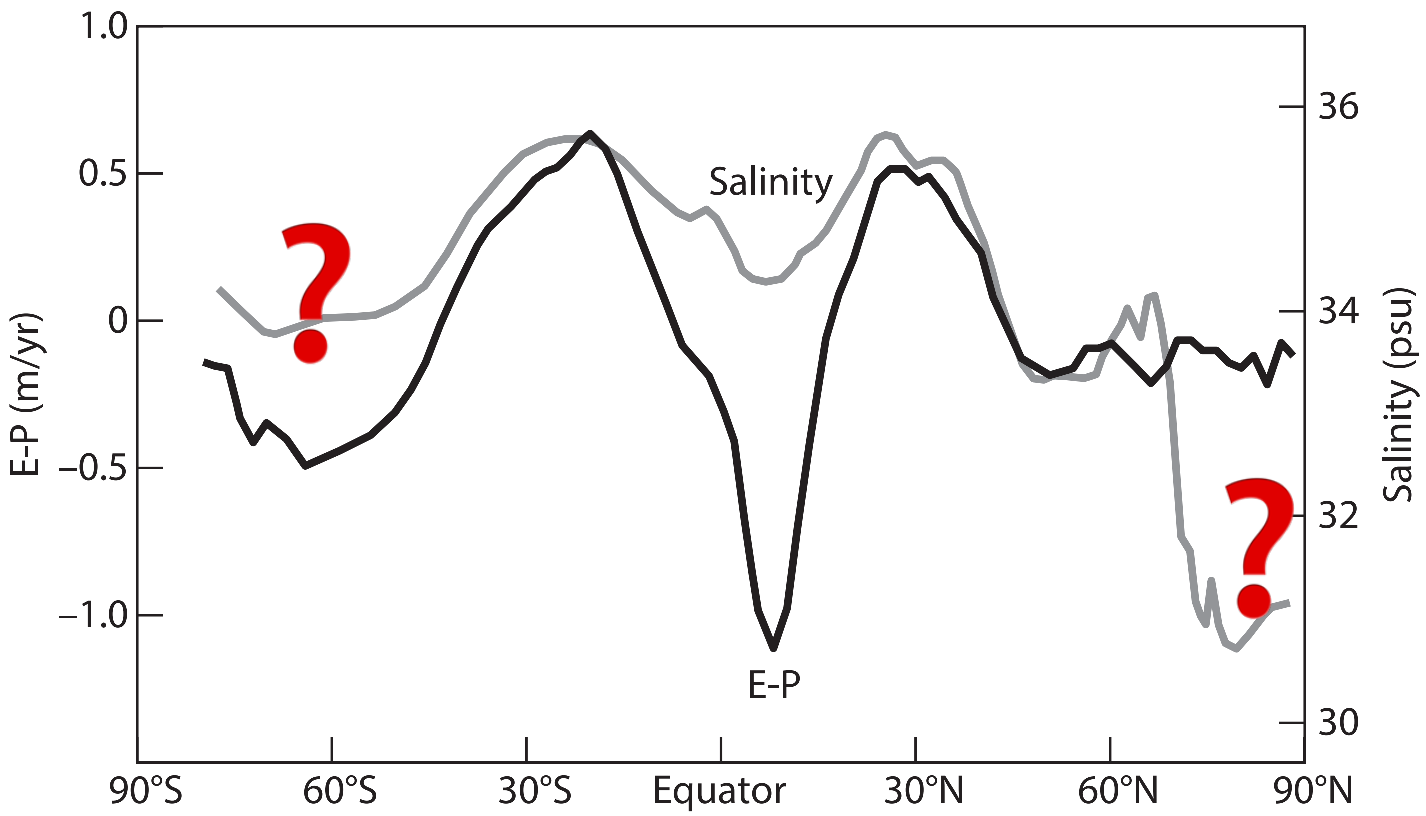


Figure 2.20 Zonally averaged sea surface salinity (gray line) calculated for all oceans and the difference between evaporation and precipitation (E – P; black line).

- In the global average, subtropical surface salinity is about 1.5 psu greater than that close to the equator.
- Subtropical waters are relatively salty because E > P in this region
- The relationship breaks down at high latitudes. In the Arctic, surface waters are freshened by outflow from numerous rivers and by sea ice melting. The high salinity of the Antarctic circumpolar region is a result of sea ice formation, which leaves salt behind in the ocean.

From Climate Dynamics by K. H. Cook 2013

Vertical Structure of Salinity

- The high salinity of the subtropical Atlantic Ocean, especially in the Northern Hemisphere, is displayed clearly in the figure.
- The salinity of polar surface waters is relatively low.
- Salinity does not change much in deep ocean.

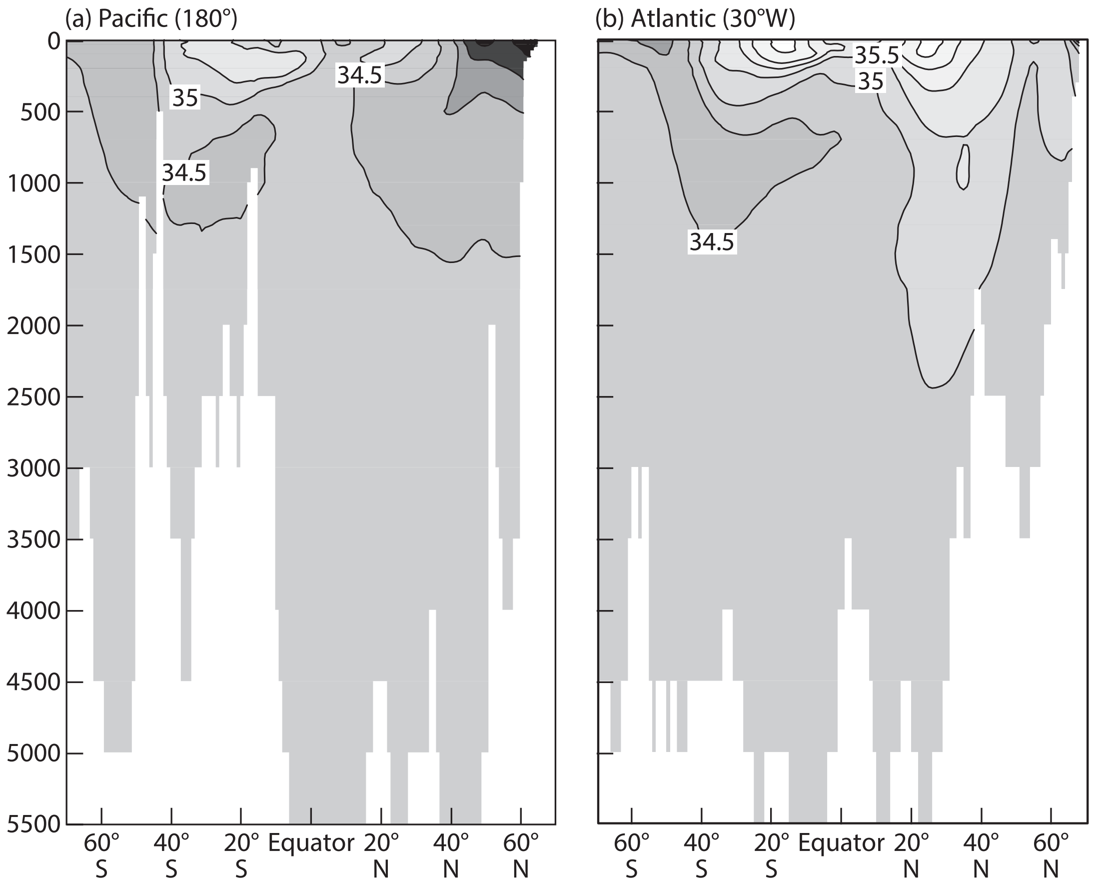


Figure 2.21 Annual mean salinity cross sections for the Pacific and Atlantic Oceans taken (a) along the International Date Line (180°) and (b) at 30°W. The contour interval is 0.5 psu. From *World Ocean Atlas*, Conkright et al. (1998).

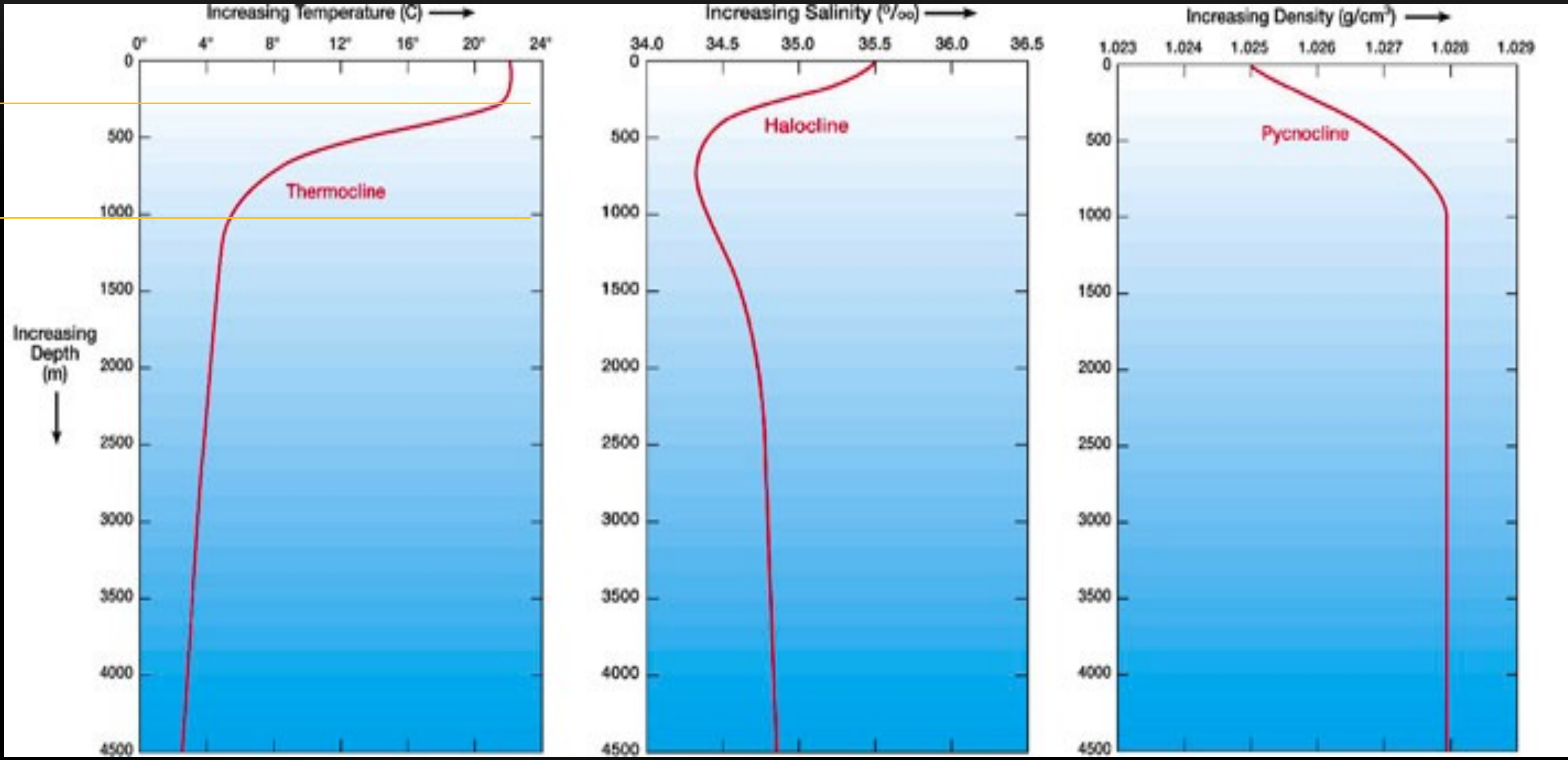
From Climate Dynamics by K. H. Cook 2013

Typical Vertical Structure of the Ocean

the mixed layer where T and S well mixed by wind, waves and currents

pycnocline: density increases rapidly with depth due to large vertical gradient of T or S

Deep Ocean: T and S do not vary much with depth



Plots of typical water properties in the open ocean. Figure credit: UCAR – Windows to the Universe.

- T and S both play an important role in modulating density and stratification. The thermocline is where the temperature changes rapidly, the halocline is where the salinity changes rapidly and the pycnocline is where the density changes rapidly.
- In the tropics and midlatitudes T is often the controlling factor for density.

References

- Cook, K. H., 2013: section 2.2
- NOAA Currents Tutorial: https://oceanservice.noaa.gov/education/tutorial_currents/welcome.html