Surface Salinity Trends

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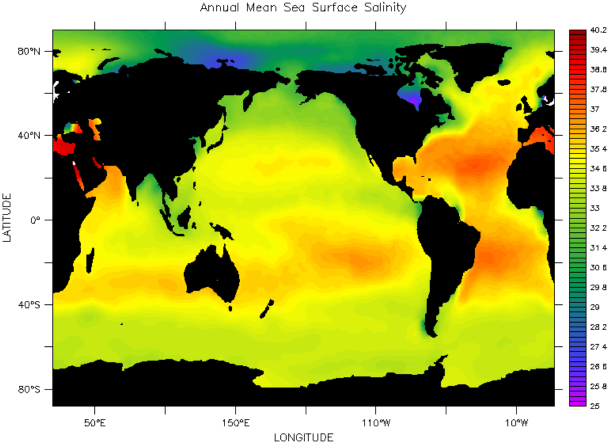
The salinity of the oceans



Q: Why the seawater of Atlantic is saltier than Pacific ocean?

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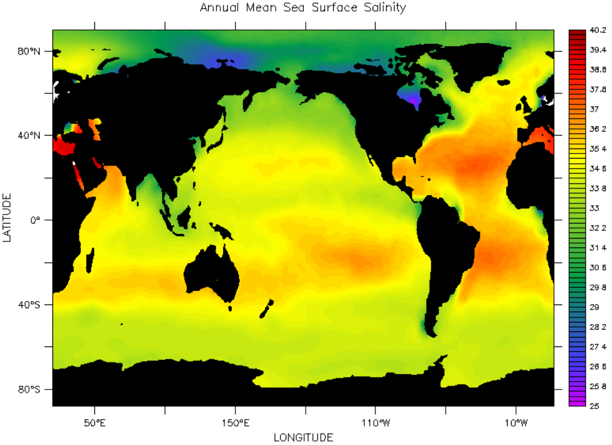

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Why is the Atlantic So Salty

- Evaporation - precipitation is larger, because much water vapour is transported to land, and doesn't precipitate in the ocean.
- Much water vapour is carried to the Pacific ocean by the trade wind.
- There are more runoff in the Atlantic, so that rivers can bring much salt or other minerals into the ocean. (??)
- The seawater of Mediterranean Sea is saltier, which can come into the Atlantic ocean.
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What will influence salinity and its distribution

1. The land will influence the salinity.
    - River discharge or runoff
    - Glacier ⇒ Melting icecaps

   Because the land introduces many complications, so we just ignore the existence of land.

2. Salinity is driven by changes in the net fresh water input at the surface, P-E (Precipitation - Evaporation).
   We cares not P or E individually, but only the redistribution of P-E.

3. The oceanic flow redistributes salinity through a mix of advection by steady circulations and transport by coherent eddies, chaotic advection, and turbulent diffusion.

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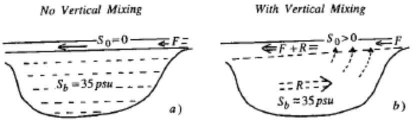
River runoff driven circulation



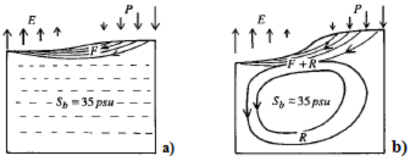
Schematic models of plain water-driven circulation. **(a)** and **(b)** River runoff (F)-driven circulation in a salty estuary.

- River runoff F is small ⇒ If there is no mixing, the only motion be confined to a thin layer on the top (a).
- If there is mixing induced by tide, waves, or wind stress, so salt is entrained into the upper layer (b).

$$(F+R)S_0 = RS_b \Rightarrow R = \frac{S_0}{S_b - S_0}F$$

(R is return flow.)

P-E driven circulation



Schematic models of plain water-driven circulation. **(a)** and **(b)** evaporation minus precipitation - driven circulation in a closed basin. The vertical scales are exaggerated, especially the free surface elevations.

If there is no river runoff, only P and E:

- If no mixing, precipitation at high latitudes builds up the free surface ⇒ water flow toward low latitudes ⇒ evaporation can affect only the fresh water on the surface ⇒ the only motion will be the equatorward flow of fresh water on top of stagnant deep, salty water (a).
- If there is vertical mixing, there will be a very strong return flow induced by vertical mixing:

$$R = \frac{S_0}{\Delta S} F \gg F, F = P - E.$$

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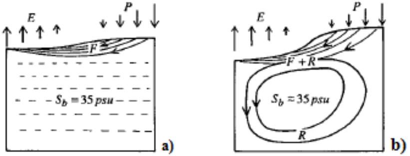

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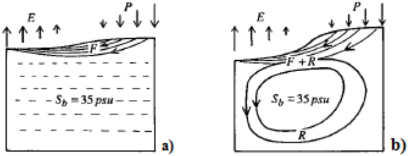

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Active or passive tracer

- What is the difference between active and passive tracer?
- Salinity is an active scalar which affects the density of seawater and, through the equation of motion, changes the flow.
  ⇒ This is important in subpolar regions, where salinity is the primarily factor controlling density in the relatively cold subpolar oceans.
- If we ignore this, salinity would becomes a passive tracer, that is the value of the salinity does not affect the density nor the flow field of the ocean and its dynamics is linear, driven only by the surface flux of freshwater P-E.

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How P-E affect salinity distribution

- Suppose that we are given the statistically steady salinity distribution of a control climate and then assume that P-E is perturbed.
  Consider the simplest possible case:
- P-E is simply multiplied by a global constant, as the crudest possible representation of increased atmospheric water transport accompanyin -g warming.
- The total salt in the ocean is unchanged, so what this means is that all spatial salinity gradients are multiplied by a constant once the system settles into a new steady state.

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P-E can change the salinity distribution pattern

- The advection-diffusion operator can make this relationship non-local.
- If the Atlantic is much saltier than the Pacific, then scaling P-E up, in this passive limit, will create an even larger gradient between the Atlantic and the Pacific, whatever combination of P-E distribution and circulation asymmetry can be thought of as generating this salinity gradient in the mean climatology.

The salinity of the oceans

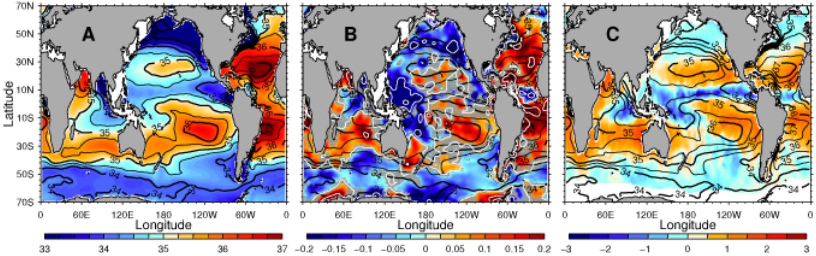

Fig. **A)** Climatological surface salinity (0.5 pss contour), averaged over 1950-2000; **B)** the linear trend over these 50 years (pss/50 years) ; and **C)** the NOCS Southampton estimate of net climatological freshwater flux from ocean to atmosphere (m/yr).

- There is a correspondence in all major features between panel A and B, the upshot being that surface salinity gradients are increasing throughout the world ocean.
- In particular, the average salinity difference between the saltier Atlantic and the fresher Pacific is increasing, as one would expect from the quasi-steady advective-diffusive response to a scaled up P-E pattern, with little change in ocean circulation.
- The correlation between panel A, B and C.

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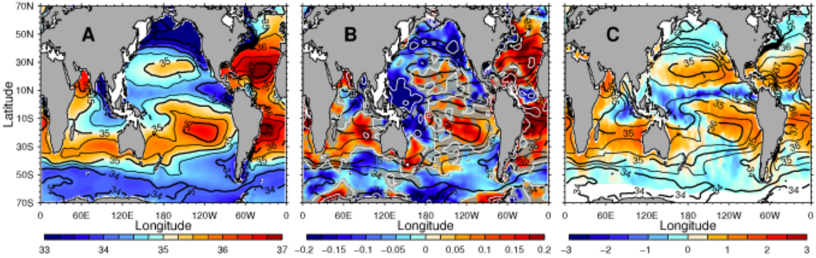

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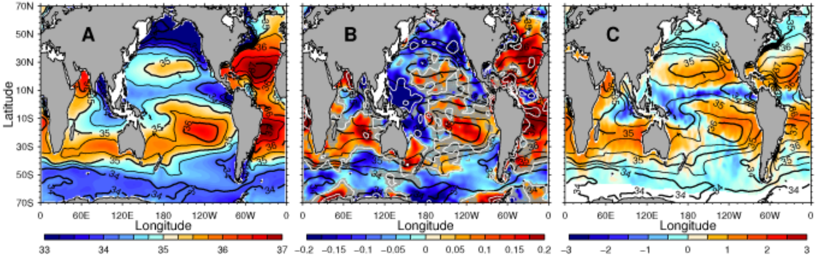

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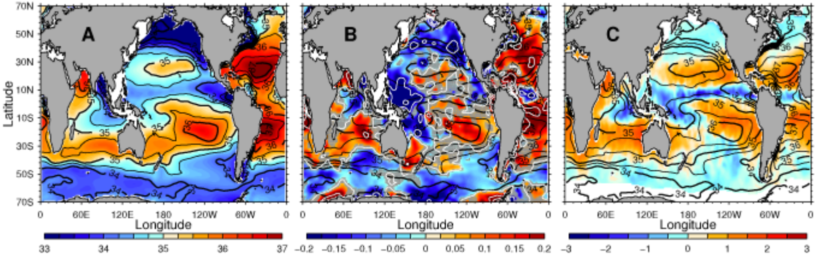

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Take home message

1. Land, glacier, P-E and ocean motion can influence the distribution of salinity.
2. We can see P-E as a passive tracer, and its dynamics is linear, so that only P-E can also affect the distribution and shape of salinity.
3. This salinity trend analysis is deserving of close scrutiny given its potential to serve as a centerpiece for discussions of changes in the hydrological cycle associated with warming.

Discussion

1. Can we use the change of salinity to show the change of hydrological cycle?
2. Does the pattern of salinity trend in which saltier ocean become saltier due to global warming ?

The End

Thank you!