Upper Ocean Salinity Balance and Imprints of Salinity in Carbon Cycle

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1. Ocean surface salinity budget

The equation for upper ocean salinity balance is

$$E-P=\frac{h_0}{S_0}\left(\frac{\partial S}{\partial t}+V\cdot\nabla S\right) \quad (1)$$

where V is current, S is salinity in the surface mixed layer with average depth h_0 and average salinity S_0. V is provided by the OSCAR program. The salinity data are measured by Aquarius and Argo. E is derived from AMSR-E (Liu and Xie 2013), and P is measured by TRMM.

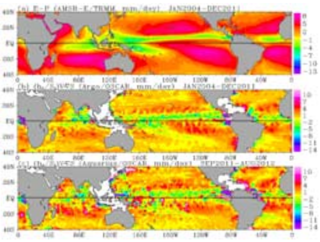

Fig. 1 (a) E-P, (b) salinity advection derived from Argo, averaged from 2004 to 2011, and (c) advection derived from Aquarius data, averaged from September 2011 to August 2012. ∂S/∂t is negligible in the long term averages. There should be a balance between E-P and advection.

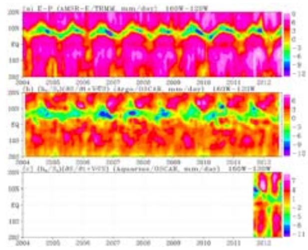

Fig. 2 Time-latitude cross sections of (a) E-P, (b) advection derived from Argo, and (c) advection derived from Aquarius, averaged between 160ºW-120ºW in the Pacific ITCZ. The change of salinity follows the fresh water flux closely.

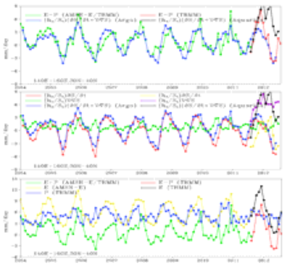

Fig. 3 Time series of each term in Equ. (1) over the Kuroshio Extension (KE, 140ºE-160ºE, 30ºN-40ºN). The last 12 months of Aquarius data are also displayed. The local change of salinity dominates over the advection. Evaporation plays a major role in the seasonal change of salinity.

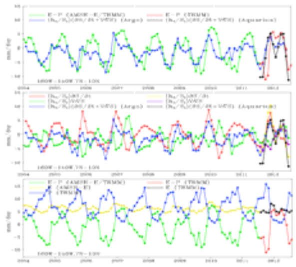

Fig. 4 Same as Fig. 3, except over the Pacific ITCZ. Different from KE, E-P over the ITCZ is dominated by precipitation and the advection is as important as the local change term. The location of salinity minimum is shifted from the maximum rainfall (not shown).

The advection calculated from Aquarius data is higher than that from Argo in the Kuroshio Extension, but there is an agreement over the ITCZ.

2. Role of salinity in carbon dioxide partial pressure

The air-sea exchange in CO2 (F) is

$$F=k\alpha(\Delta pCO2) \quad (2)$$

where k is CO2 gas transfer (piston) velocity, α is solubility of CO2 in seawater, and $\Delta pCO2=pCO2_{sea}-pCO2_{air}$. A statistical model was developed using support vector regression (Xie et al. 2008) to derive the daily $pCO2_{sea}$ from SST, Chl-a, and salinity.

(1) Kuroshio Extension

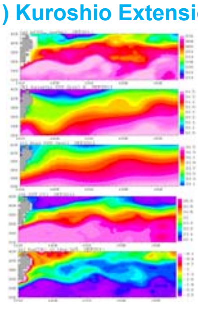

Fig. 5 (a) Derived $pCO2_{sea}$, (b) salinity from Aquarius, (c) salinity from Argo, (d) SST, and (e) log(Chl-a) for September 2011 over the Kuroshio Extension. The spatial variations of $pCO2_{sea}$ is consistent with SST and Chl-a, but not with salinity. Salinity measured by Aquarius and Argo shows different spatial patterns, with much larger spatial gradient in the Aquarius data.

(2) Tropical Instability Wave

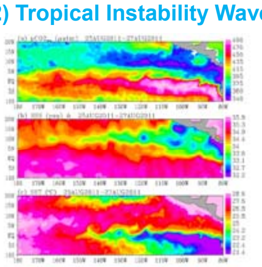

Fig. 6 3-day average of (a) $pCO2_{sea}$, (b) Aquarius salinity, and (c) SST from AMSR-E over the tropical Eastern Pacific. The high and low values of $pCO2_{sea}$ are colocated with those of salinity, whereas the cold tongue of SST is located to the south.

(3) Tropical Atlantic

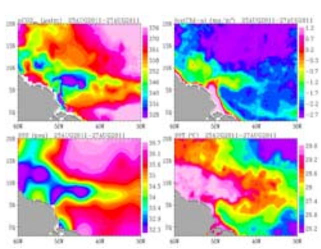

Fig. 7 3-day averages (August 25-27, 2011) of $pCO2_{sea}$, salinity, log(Chl-a), and SST in the tropical Atlantic. $pCO2_{sea}$ is in phase with salinity, and out of phase with Chl-a and SST, which suggests that salinity along with Chl-a are the determining factors for $pCO2_{sea}$.

3. Summary

- The salinity advection bears similar large scale patterns with the fresh water flux and captures the seasonal migration of ITCZ. However, large discrepancies are clearly shown, especially in the subtropics.
- The salinity budget in the Kuroshio Extension shows that the local change of salinity dominates over the advection, and the seasonal change of salinity is mainly attributed to evaporation. It is in contrast to the ITCZ, where precipitation is the major cause of the salinity change and the advection term is as important as the local change of salinity.
- Salinity is the dominating driving force of $pCO2_{sea}$ in the equatorial Eastern Pacific. In the tropical Atlantic north of the Amazon river mouth, $pCO2_{sea}$ changes are attributed to both salinity and productivity. The relation of salinity and $pCO2_{sea}$ is less clear in the midlatitude ocean fronts, where salinity data from Aquarius and Argo show clear differences.

4. References

Xie X., W.T. Liu, and B. Tang, 2008: Spacebased estimation of moisture transport in marine atmosphere using support vector machine, Rem. Sens. Environment, doi:10.1016/j.rse.2007.09.003.

Liu, W.T., and X. Xie, 2013: Ocean-atmosphere water flux and evaporation, Encyclopedia of Remote Sens. P. Minnett and E. Njoku (eds.), Springer-Verlag Berlin Heidelberg. DOI: 10.1007/SpringerReference_327186.