OCEAN FRESHWATER TRANSPORT AND THE CARBON CYCLE

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Rainfall and evaporation require the ocean to transport mass from regions of net precipitation to regions of net evaporation. The magnitude of this freshwater transport in the ocean is of order 0.1-1 Sv. For properties with high mean concentrations relative to their dynamic range (salt, total carbon, alkalinity) transport carried by this freshwater redistribution is a crucial component of the total budget of any region.

A simple scaling argument can demonstrate this effect for nutrient and carbon transports. Suppose we imagine a simple hypothetical circulation for a bounded ocean region. The circulation consists of two components: an overturning transport of strength 20 Sv and a freshwater convergence of 1 Sv which is balanced by net evaporation. For the case of a nutrient, such as silica, the mean concentration in the ocean is about 100 μmol kg^{-1} and the dynamic range is about 200 μmol kg^{-1}. The overturning circulation will thus create a divergence of (200 μmol kg^{-1}) x (20 Sv) $\approx$ 4000 $kmols^{-1}$. In contrast, the freshwater transport component will only carry (100 μmol kg^{-1}) x (1 Sv) $\approx$ 100 $kmols^{-1}$. Thus for nutrient, transports, as with heat, the component of the net flux carried by the freshwater transport component is often safely neglected. This example can be compared with that for total carbon for which the mean oceanic value is about 2250 μmol kg^{-1} and the dynamic range is 200 μmol kg^{-1}. Since the mean value is so large, the freshwater transport component results in a convergence of 2250 $kmols^{-1}$ while the overturning component leads to a divergence of 4000 $kmols^{-1}$. Therefore, unlike nutrients, the freshwater transport component is not negligible in comparison with other components of the regional budget and must be properly accounted for when estimating the net carbon or alkalinity flux.

The magnitude and geographic distribution of the freshwater transport component of the carbon flux can be estimated by examining the net freshwater transport calculated by Wijffels et al., 1992. The subtropics are a region of convergence due to the high evaporation over the subtropical gyres. The tropics and high latitude are regions of divergence as the ocean carries away the net precipitation. The net mass transport through the Bering Strait, Indonesian archipelago, and the Drake Passage complicate the interpretation and comparison of carbon transport estimates carried by the freshwater flux. Much of this confusion can be avoided by focusing on, and reporting, the flux divergence of a region rather than the total meridional flux. Additionally, the crucial scientific questions, air/sea exchange and local accumulation, must be interpreted in terms of the flux divergence rather than the net flux.

Normalization of observed concentrations of total carbon and alkalinity by observed salinity is a common technique when examining property-property relations. This salt normalization factors out the changes of total carbon due to dilution and evaporation allowing the covariation with respect to oxygen and nutrients to be more readily perceived. Some studies (Broecker and Peng, 1992; Keeling and Peng, 1995) have proposed similar salinity normalizations to factor out the effects of the freshwater transport when calculating the total carbon transport. Careful examination of the effect of these normalizations, however, reveals that they fail to accurately account for freshwater flux (Robbins, 2001). An algebraicly correct normalization can be defined but in practice it yields no advantage over the standard technique of direct calculation of the freshwater flux from the salt balance. Firstly, in order for the salinity normalization to yield accurate carbon transport estimates, the circulation must be examined to insure it results in a reasonable salt budget. Secondly, although oceanic freshwater transport often have significant uncertainty, salinity normalizations fail to reduce the impact of these uncertainties on the carbon transport. Since the salinity observed on any individual transect is a synoptic snapshot and not a long term mean, the error incurred on the carbon transport is equivalent regardless of the technique used to account for the freshwater transport component.

References:

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