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Reconsideration of biogeochemical impacts of the Kuroshio based on a recent intensive observation and historical data

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The Kuroshio, the western boundary current in the North Pacific, plays major roles in transporting heat and organic/inorganic materials from the subtropical region to the subarctic one. The Kuroshio undoubtedly must impact on the ecosystem in its neighboring and downstream regions as well as on climate changes via air-sea interactions, however it is generally recognized as a mere boundary between the oligotrophic Subtropical waters to the south and the more productive Slope waters to the north. Surprisingly neither quantitative nor qualitative researches have advanced to clarify the actual distribution of nutrients in the Kuroshio region with focus on the impacts of the jet, the core of the current maximum. On the other hand, as long as in the frontal region, an accumulation of studies has clarified the productive enhancement due to sub-mesoscale processes, but the transport of nutrient and its impacts on the ecosystem have been still unknown because of lack of simultaneous measurement of both horizontal and vertical fluxes of nutrients around the jet.

We conducted an intensive observation in Apr. 2009 and analyzed historical hydrographic data, in order to clarify the 3D distribution of the water properties in the Kuroshio region and to estimate horizontal and vertical fluxes of nutrients and their impacts on the productivity in the surrounding and downstream regions. The observation was carried out by the R/V Tansei-maru in the cruise KT-09-3 at intervals of 10 miles along the 5 lines crossing the Kuroshio in 137-141^{o}E south of Japan. It obtained the 3D distribution of the water properties by CTD with multi- profilers and bottle-samplings, the horizontal velocity by the shipboard and lowered ADCP, and the vertical turbulent diffusivity by the microstructure profiler. As a result we detected that maxima of nitrate, silicate, phosphate and AOU were located along the jet on the isopycnal surface of 24.5-26.0sigma-theta. It is the first detection of the nutrient/AOU maximum along the Kuroshio jet, and the structure is analogous to the characteristic one well-known as Nutrient Stream found in the Gulf Stream region. Moreover, the nutrient/AOU maximum along the Kuroshio jet was also detected on the 24.5-25.5sigma-theta surface in spring at both the upstream side in the East China Sea and the downstream one in the Kuroshio Extension, by analyzing the historical data of JODC.

It should be emphasized that the nutrient concentration on the isopycnal surface of 24.5-25.5sigma-theta gradually decreases along the jet toward the downstream region. It implies that the high nutrient water is originated from the upstream and its adjacent regions and transported downstream epipycnally along the Kuroshio as is the case with the Nutrient Stream in the Gulf Stream. Our observation estimated the maximum of the epipycnal nitrate flux at 10mmolNm^{-2}s^{-1} around the 26.0sigma-theta surface just beneath the current maximum of the Kuroshio jet. A part of the flux is served out to both the northern and southern sides of the jet due to eddy diffusivity, and especially on the northern side the nutrient transport is important for the new production. The depth of the isopycnal surface is much shallower on the northern side because of the strong baroclinicity, where the nutrient is utilized more actively for the primary production under sufficient irradiance.

Moreover our observation clarified quantitatively that nutrient is supplied upward more intensively on the jet and its inshore side than the offshore side due to higher diapycnal mixing observed by direct measurement of microstructure. The diapycnal flux of nitrate amounts to 3.0x10^{-6} mmolNm^{-2}s^{-1} at the 25.0-25.5sigma-theta just above the core of the epipycnal flux, indicating that the high nutrient transported epipycnally along the jet is supplied efficiently upward by the strong diapycnal mixing and that it contributes significantly to the spring new production around the Kuroshio.

Keywords: Kuroshio, Nutrient Stream, jet, epipycnal flux, diapycnal flux