US GEOTRACES North Atlantic Section: Measurement of Helium Isotopes and Tritium

Intellectual Merit: The biogeochemical cycling of trace elements and isotopes (TEIs) in the marine environment is an area of active research that has motivated the creation of GEOTRACES, a major new international program. Trace elements are known to play potentially important roles as nutrients in biological cycling, particularly in regard to enzymatic and catalytic processes in the open ocean. Isotopes are valuable tracers of these and related processes, and of the ocean's interaction with the atmosphere and the solid earth, which in turn play a role in shaping many trace element distributions within the ocean. Nevertheless, significant gaps exist in both our knowledge of the larger scale distributions of these TEIs in the ocean and in our understanding of the processes responsible for those distributions. This shortfall has implications for numerous scientific endeavors that are relevant to a broad range of intellectual and societal issues, including the carbon cycle and climate change, as well as the marine food web and anthropogenic impacts on the oceans. Recent advances in sampling and analytical techniques coupled with a better understanding of the roles of TEIs in ocean biogeochemical cycles present us with an opportunity to rectify this problem. Moreover, we are motivated by the prospect of ongoing global change and the need to understand the present and future workings of the ocean's biogeochemical cycles. The guiding mission of the GEOTRACES program is "*to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes in the ocean".* The key observational strategy for GEOTRACES is an internationally-coordinated global-scale ocean survey of key TEIs and the first U.S. section as part of that survey is in the North Atlantic. Knowing rates and fluxes is a vital step in the development of mechanistic and predictive models of ocean biogeochemical cycles of TEIs, particularly within the framework of global change (both past and future). Much of what we have learned about large scale oceanic rates and fluxes has been inferred from the observation and modeling of tracer distributions, both radioactive and transient. Measurement of appropriate transient tracers alongside of core TEIs would be an effective strategy for achieving GEOTRACES goals.

This is a proposal to make helium isotope and tritium measurements to provide useful biogeochemical rate information for the more centrally important TEI measurements made on the first U.S. GEOTRACES global survey section. The primary contributions that tritium and ^{3}He measurements can make to the program include:

- **Quantifying transit timescales and TEI dilution in the MOC:** ^{3}H and ^{3}He are useful tracers for determining deep western boundary current tracer transport rates and interior mixing dilution scales, an important issue for many TEIs.
- **As a shallow water chronometer:** using the tritium-^{3}He clock, we can determine the time elapsed since fluid parcels have been subducted on timescales ranging from 6 months to several decades. We can also combine ^{3}H-^{3}He ages and evolving ^{3}H and ^{3}He distributions with geostrophy, T,S, O_2, nutrient, and TEI distributions to estimate transformation rates.
- **A TEI thermocline reflux gauge:** ^{3}He is a unique "nutrient-like" transient tracer that can be used as a "flux gauge" to determine the rates at which thermocline-remineralized TEIs are returned to the upper ocean. This is important for biogeochemical models.
- **Gauging TEI hydrothermal dilution scales:** Volcanic ^{3}He injected during hydrothermal activity is a powerful conservative tracer of dilution in these plumes, allowing diagnosis of non-conservative behavior in some TEIs, and permitting flux estimates associated with hydrothermal activity on basin and global scale.

The P.I. will be responsible for the acquisition, measurement, interpretation and modeling of the tritium and ^{3}He to achieve the above objectives.

Broader Impacts: The proposed work is in support of the GEOTRACES program, as such contributes to the broader societal goals and intellectual objectives espoused by that program. The primary issues related to this are pertinent to understanding the carbon cycle and predicting/mitigating climate change, as well as the marine food web and anthropogenic impacts on the oceans.