An Ensemble Estimation of the Variability of Upper-ocean Heat Content over the Tropical Atlantic Ocean with Multi-Ocean Reanalysis Products

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Current ocean reanalysis systems contain considerable uncertainty in estimating the subsurface oceanic state, especially in the tropical Atlantic Ocean. Given this level of uncertainty, it is important to develop useful strategies to identify realistic low-frequency signals optimally from these analyses. In this paper, we present an "ensemble" method to estimate the variability of upper- ocean heat content (HC) in the tropical Atlantic based on multiple-ocean reanalysis products. Six state-of-the-art global ocean reanalaysis products, all of which are widely used in the climate research community, are examined in terms of their HC variability from 1979 to 2007. The conventional empirical orthogonal function (EOF) analysis of the HC anomalies from each individual analysis indicates that their leading modes show significant qualitative differences among analyses, especially for the first modes, although some common characteristics are discernable. Then, the simple arithmetic average (or ensemble mean) is applied to produce an ensemble dataset, i.e., the EM analysis. The leading EOF modes of the EM analysis show quantitatively consistent spatial-temporal patterns with those derived from an alternative EOF technique that maximizes signal-to-noise ratio of the six analyses, which suggests that the ensemble mean generates HC fields with the noise reduced to an acceptable level. The quality of the EM analysis is further validated against AVISO altimetry sea level anomaly (SLA) data and PIRATA mooring station data. A regression analysis with the AVISO SLA data proved that the leading modes in the EM analysis are realistic. It also demonstrated that some reanalysis products might contain higher level of intrinsic noise than others. A quantitative correlation analysis indicates that the HC fields are more realistic in the EM analysis than in individual products, especially over the equatorial regions, with signals contributed from all ensemble members. A direct comparison with the HC anomalies derived from in situ temperature measurements showed that the EM analysis generally gets realistic HC variability at the five chosen PIRATA mooring stations. Overall, these results demonstrate that the EM analysis is a promising alternative for studying physical processes and possibly for initializing climate predictions.

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