MEAN AND EDDY KINETIC ENERGY OF THE GULF STREAM FROM MULTIYEAR UNDERWATER GLIDER SURVEYS

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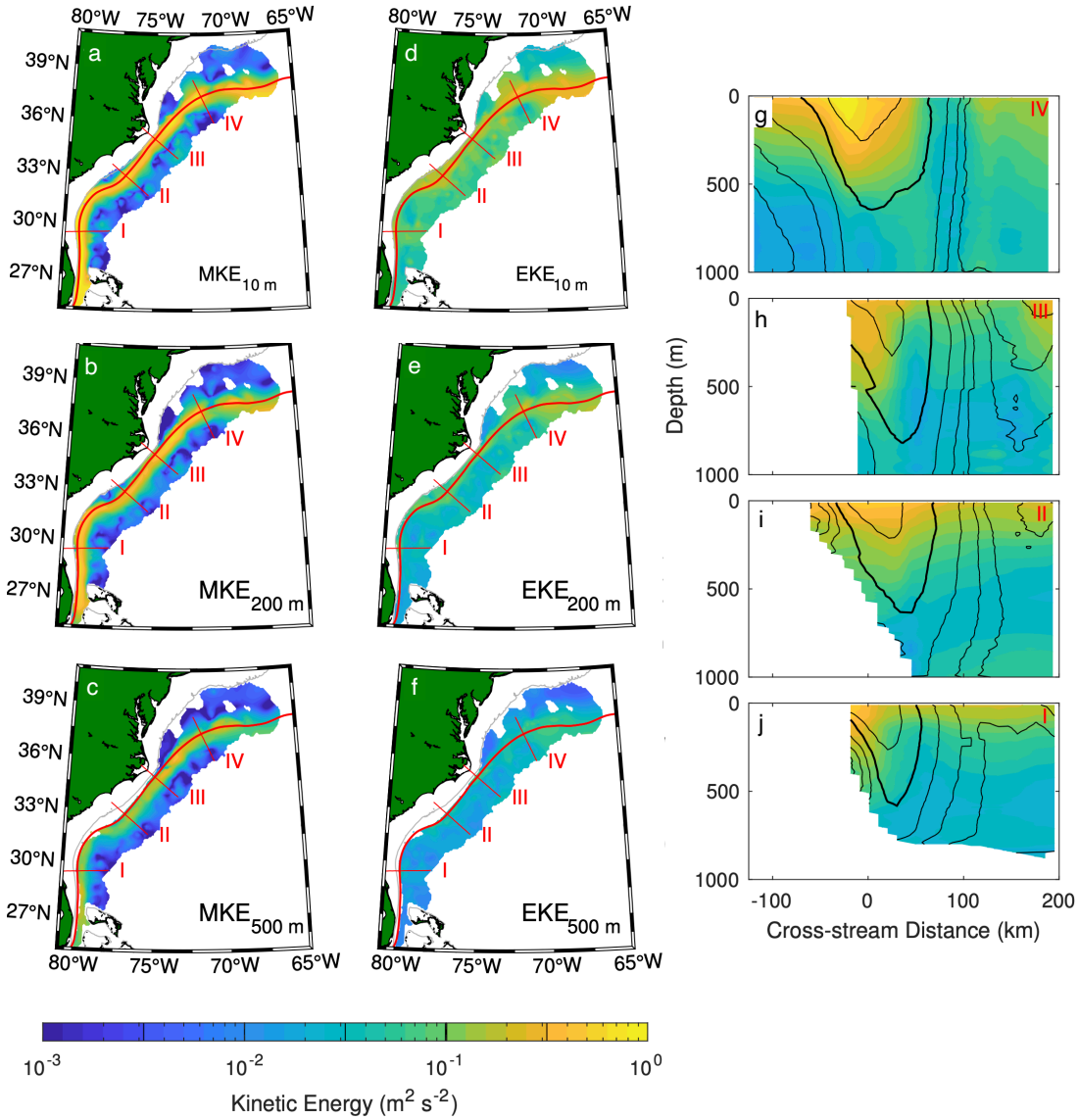
Three-dimensional Kinetic Energy Estimates in the Gulf Stream

- Subsurface estimates of ocean energy are limited, but needed to validate ocean models.
- Over 20,000 velocity profiles distributed in and near the Gulf Stream over the past 5 years allow estimation of mean and eddy kinetic energy in a western boundary current.

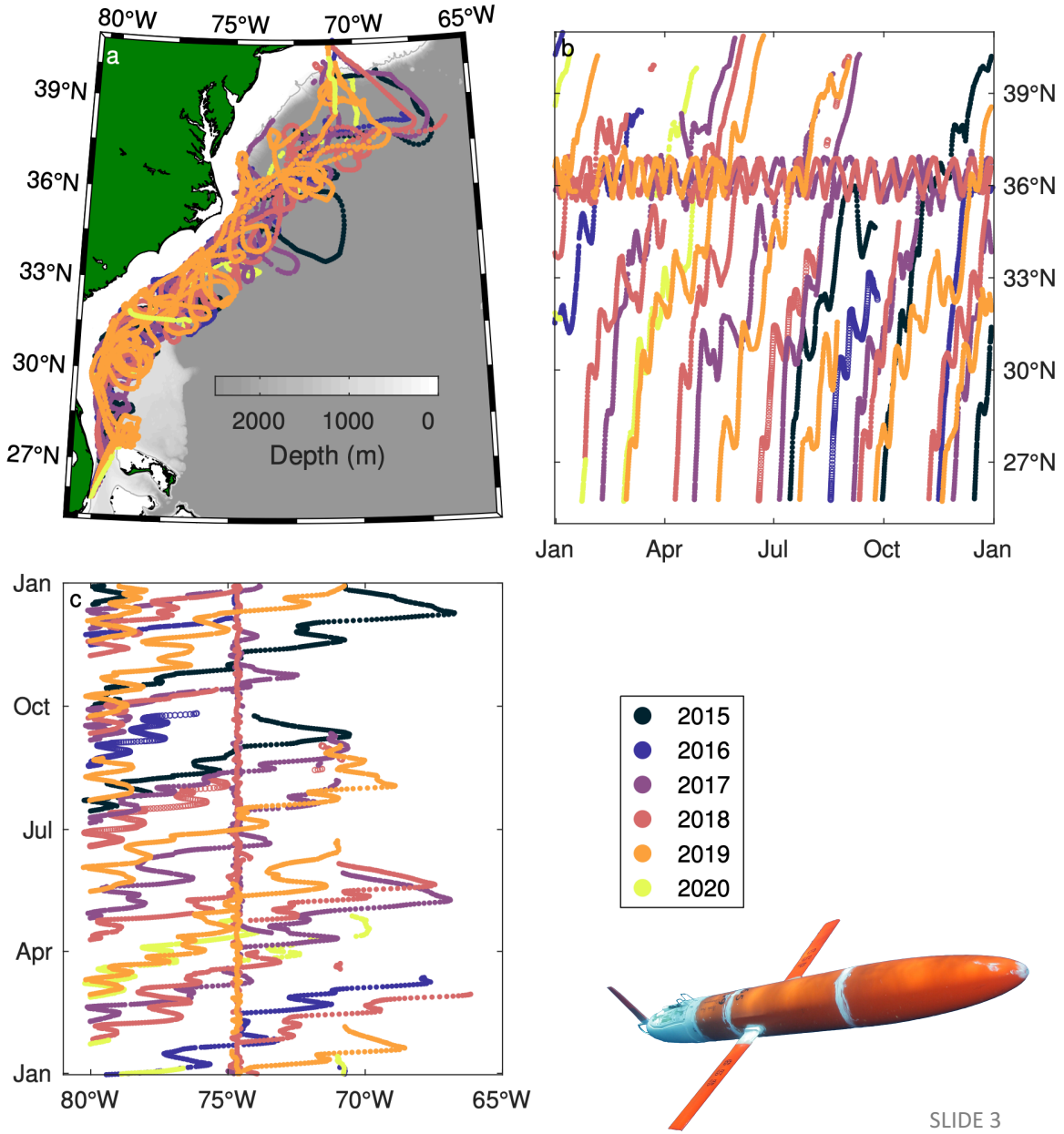
$$\mathrm{MKE} = \frac{1}{2}\left(\langle u\rangle^2 + \langle v\rangle^2\right)$$
$$\mathrm{EKE} = \frac{1}{2}\left\langle u'^2 + v'^2\right\rangle$$



Examples of the three-dimensional structure of kinetic energy in and near the Gulf Stream. (a-c) Maps of MKE at depths of (a) 10 m, (b) 200 m, and (c) 500 m. (d-f) As in (a-c), but for EKE. (g-j) Cross-Gulf Stream transects of EKE (colors) and MKE (black contours) along transects I-IV (arranged bottom-to-top). In (a-f), the bold red line is the mean location of the 40-cm sea surface height contour from 2015 through 2019, which serves as the origin of the cross-stream coordinate system; thin red lines are cross-stream transects examined herein.

Sampling the Gulf Stream with Spray Gliders

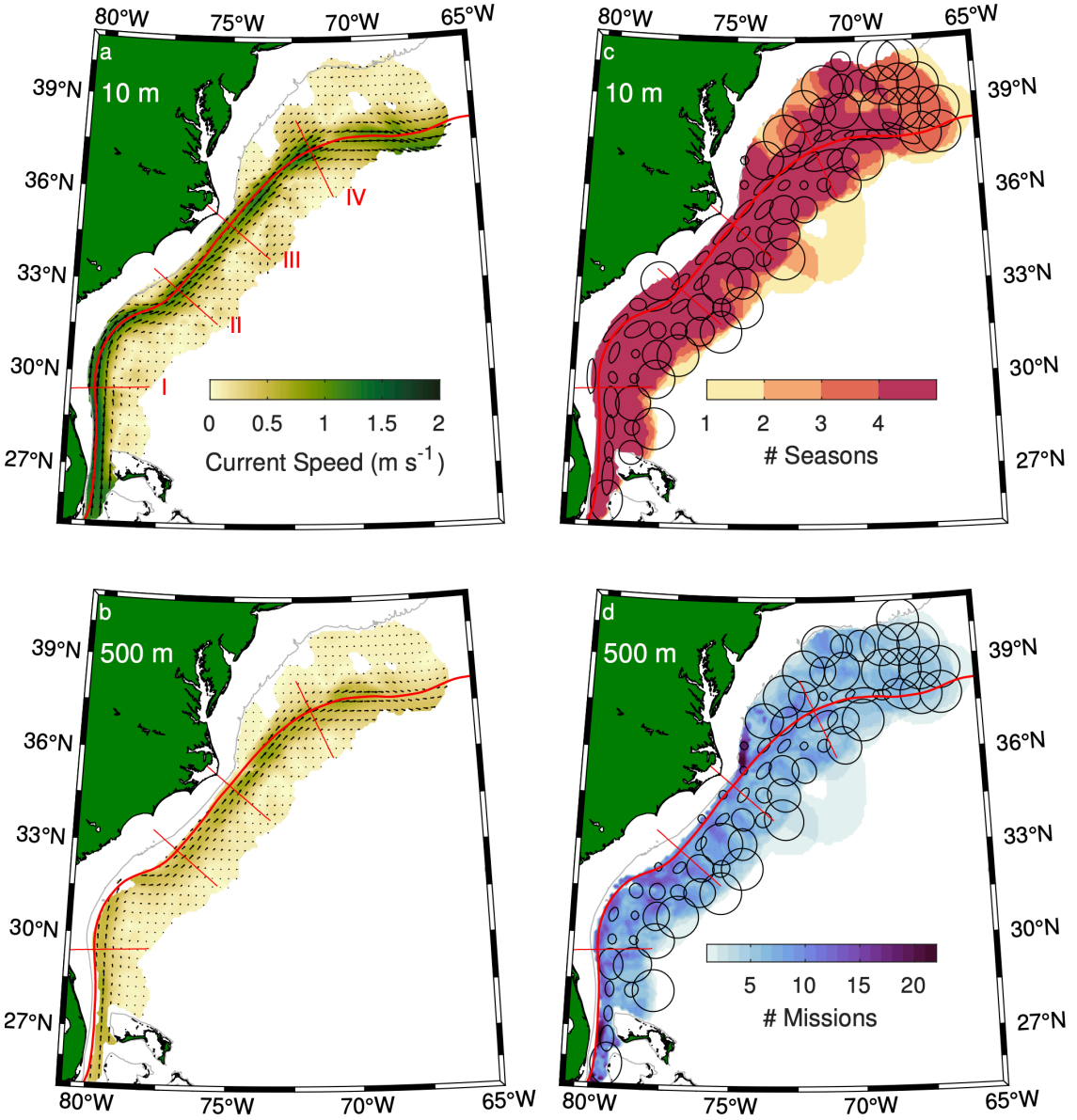
- Since 2015, Spray gliders have routinely sampled the Gulf Stream along the US East Coast (Todd 2017; Heiderich and Todd, in rev.).
- Profiles in the upper 1000 m of:
  - Temperature
  - Salinity
  - Horizontal currents (Todd et al. 2017)
  - Chlorophyll fluorescence



Locations and dates of absolute velocity profiles from Spray gliders sampling in or near the Gulf Stream through April 2020. (a) Locations of profiles. (b) Distribution of profiles as a function of time-of-year and latitude. (c) Distribution of profiles as a function of longitude and time-of-year. Each dot represents an individual profile and is color-coded by year according to the legend in the lower right.

Averaging Glider Observations

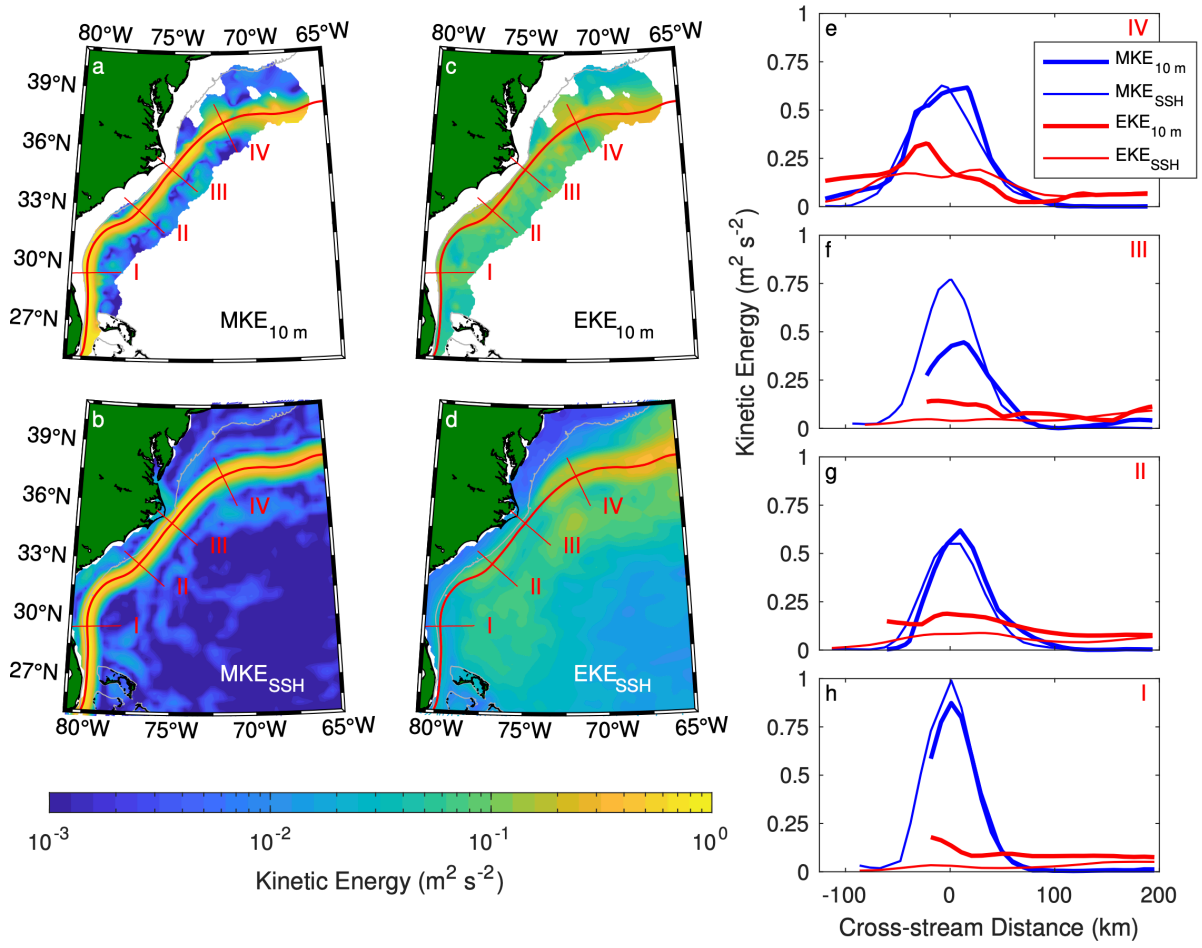
- The choice of averaging function defines the `eddy' component.
- We use a spatial average with anisotropic and inhomogeneous Gaussian weights that depend upon:
  - Mean currents (stretched in direction of flow)
  - Observation density (larger scales for sparse data)



Examples of key parameters associated with the averaging algorithm. (a-b) Mean currents at depths of (a) 10 m and (b) 500 m with speed colored and vectors plotted at every third grid point for clarity. (c) Number of seasons with data at 10 m that have weights exceeding exp(-1); ellipses denote the area over which the weight function exceeds exp(-1) at every eighth grid point. (d) As in (c), but for number of missions with data at 500 m that have weights exceeding exp(-1). Velocity fields (a-b) are masked where either the number of seasons or the number of missions is less than 3.

Comparison to Satellite-based Estimates

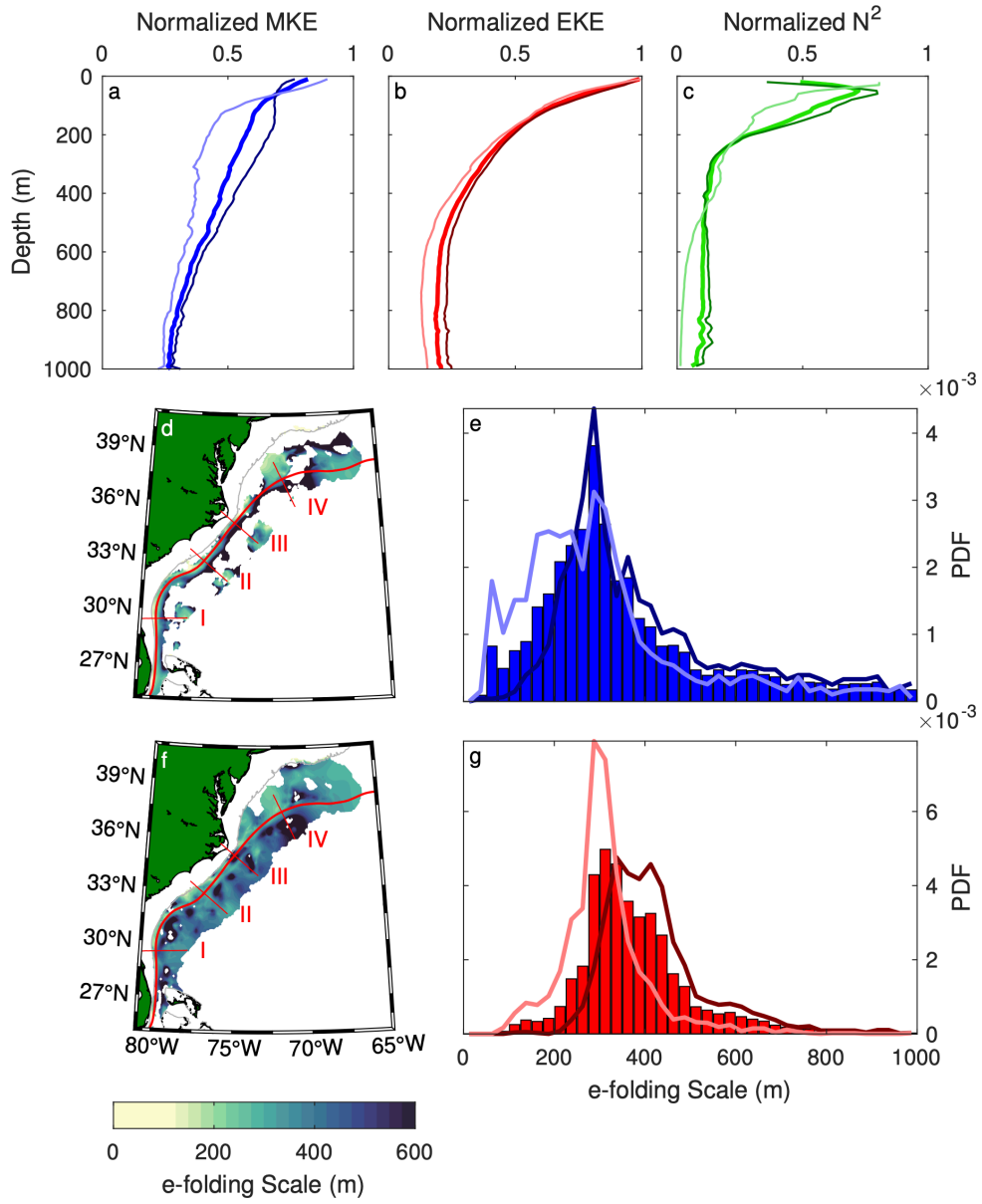
- Surface MKE and EKE may be estimated using geostrophic velocities from satellite altimetry (SSH).
- Glider-based estimates of MKE at 10 m compare well to SSH-derived MKE.
- Glider-based EKE estimates are typically larger, perhaps because of higher spatial resolution and/or ageostrophic effects.



Comparison of near-surface kinetic energy estimates from satellite altimetry and gliders. (a-b) MKE (a) at a depth of 10 m from glider measurements and (b) at the surface from satellites. (c-d) EKE (c) at 10 m from glider measurements and (d) at the surface from satellites. (e-h) MKE (blue) and EKE (red) along transects I-IV (arranged bottom-to-top) with glider based estimates shown by thick lines and satellite-based estimates shown thin. SSH estimates are for the full years 2015-2019 to avoid seasonal bias.

Vertical Structure

- Typical profiles of EKE decay exponentially with an *e*-folding scale of greater than 300 m.
  - Decay scales are typically smaller on the shoreward side of the Gulf Stream, where the thermocline is shallower.
- MKE profiles are less well modeled as exponential.
- Stratification has a much shorter scale.



(a-c) Mean normalized profiles of (a) MKE, (b) EKE, and (c) N^2. Spatial averages over the entire domain are bold, averages seaward of the 40-cm time-mean ADT contour are dark colors, and averages shoreward of the 40-cm ADT contour are lighter colors. (d) Map of *e*-folding scale for MKE where the least-squares fit explained at least 50% of the variance in the profile above 600 m. (e) Probability density functions (PDFs) of *e*-folding scales for MKE with the PDF for all estimates shown with bars and PDFs for estimates seaward (shoreward) of the 40-cm ADT contour shown by dark (light) lines. (f-g) As in (d-e), but for EKE.

References and Acknowledgements

Fields of MKE and EKE will be made publicly available alongside a forthcoming publication describing the estimates. Stay tuned…

Related References:

- Todd, R.E., D.L. Rudnick, J.T. Sherman, W.B. Owens, L. George (2017), Absolute velocity estimates from autonomous underwater gliders equipped with Doppler current profilers, *J. Atmos. Oceanic Technol.*, 34(2), 309-333, doi: 10.1175/JTECH-D-16-0156.1.
- Todd, R.E. (2017), High-frequency internal waves and thick bottom mixed layers observed by gliders in the Gulf Stream, *Geophys. Res. Lett.*, 44(12), 6316-6325, doi: 10.1002/2017GL072580.
- Heiderich, J., R.E. Todd, Along-stream evolution of Gulf Stream transport, in revision for *J. Phys. Oceanogr.*
  - See Joleen Heiderich's presentation (#9280)
- Todd, R.E. and W.B. Owens (2016), Gliders in the Gulf Stream. Publicly available dataset, https://doi.org/10.21238/S8SPRAY2675.

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