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Transient Attracting Profiles in the Great Pacific Garbage Patch

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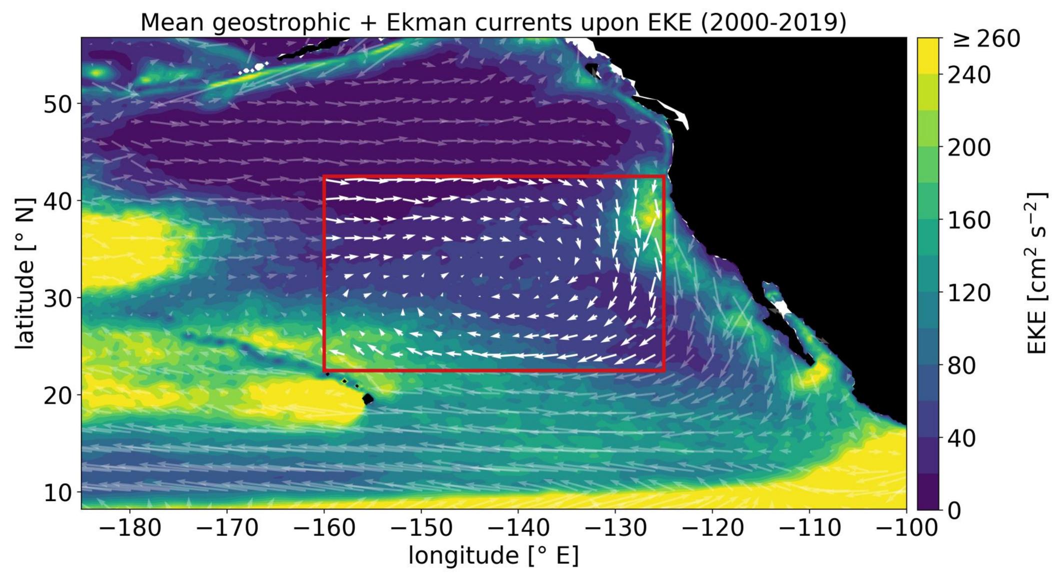
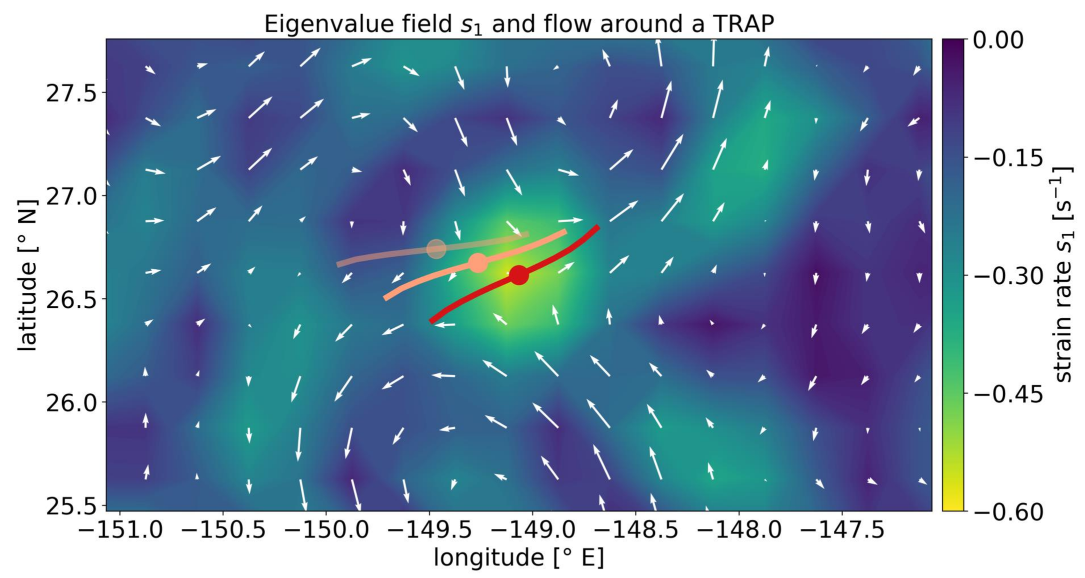
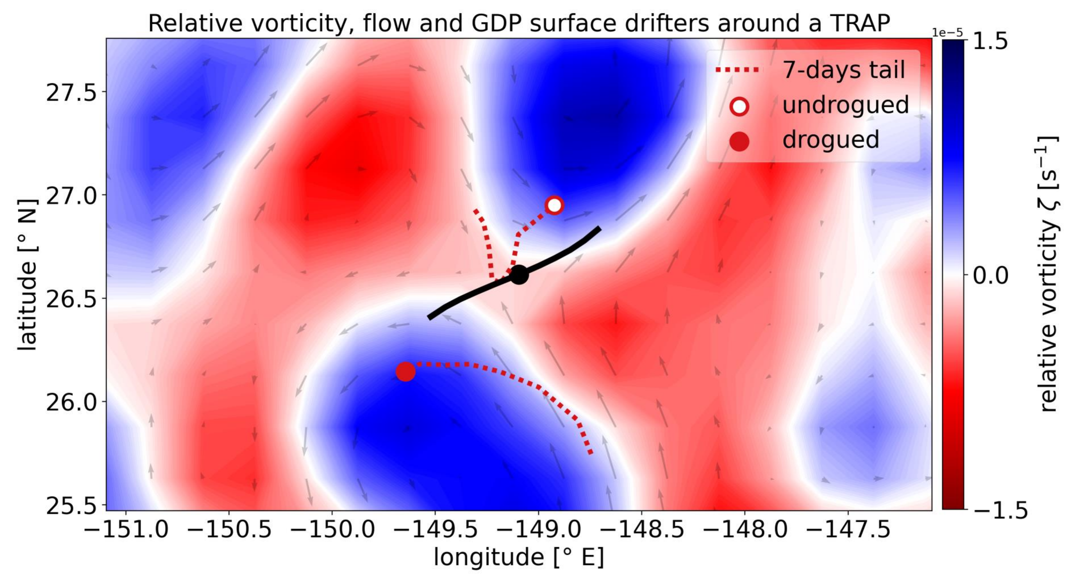
1 Motivation

TRansient Attracting Profiles[1,2] (TRAPs) indicate the most attractive regions of the flow and have the potential to facilitate offshore cleanups in the Great Pacific Garbage Patch (GPGP). We study the characteristics of TRAPs and the prospects for predicting debris transport from a mesoscale permitting dataset. Can TRAPs help to identify hotspots of marine debris?



2 Methods



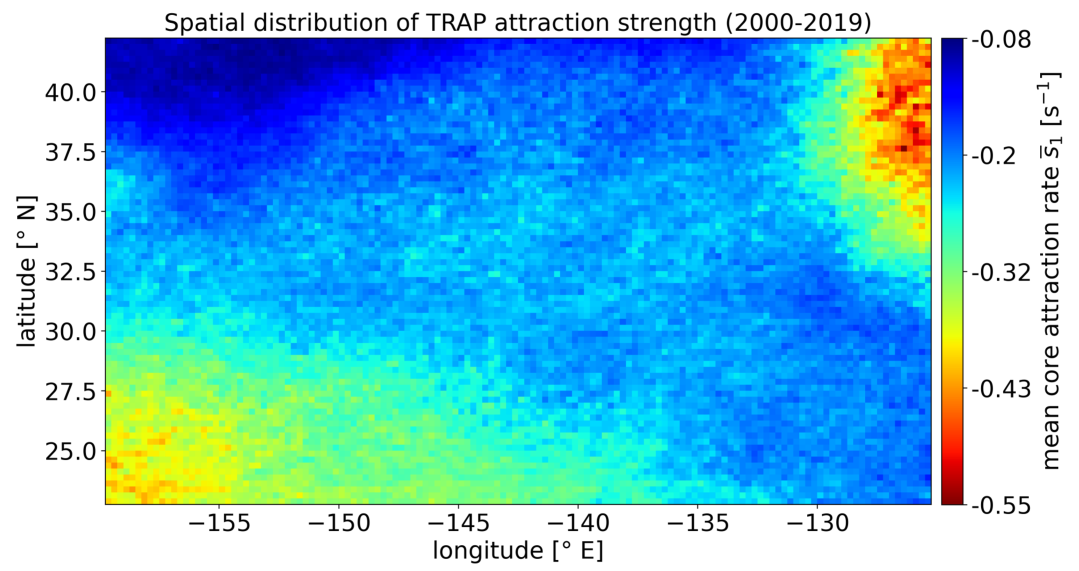


- computable from eigenvalues s_i and eigenvectors $\mathbf{e}_i$ of the two-dimensional rate of strain tensor $\mathbf{S}(\mathbf{x},t)$
- cores at negative local minima of the smaller eigenvalue field s_1
- branches extend along $\mathbf{e}_2$-lines until s_1 stops monotonic increase
- cores indicate local maxima of fluid compression,
- branches indicate the direction of maximal fluid stretching

- We compute[3,4] TRAPs from daily snapshots of near-surface geostrophic + Ekman currents[5] in the GPGP for 2000-2019. We determine:
  - ➢ trajectory and lifetime Λ of TRAPs
  - ➢ evolution of attraction strength s_1 over the life cycle of long-living TRAPs (Λ > 30 days)
  - ➢ translation speeds of TRAPs and mesoscale eddies[7]
  - ➢ evolution of vorticity patterns around long-living TRAPs
  - ➢ motion patterns of surface drifters[8] around TRAPs
  - ➢ retention time φ of drifters around TRAPs

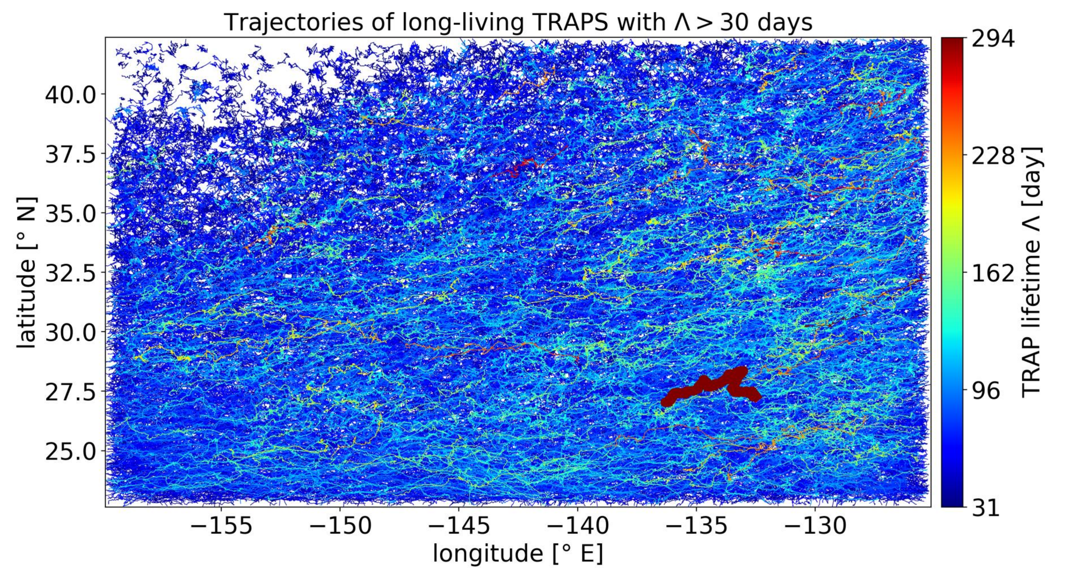
3 Spatial distribution

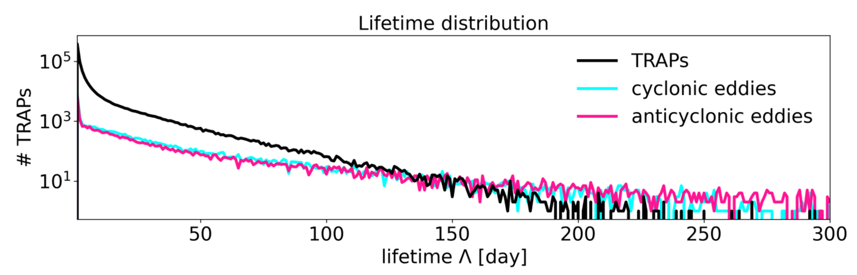
- 4,076,065 instances, 720,391 trajectories
- abundant, weak, ephemeral around eddy desert
- less abundant, stronger and more persistent towards California Upwelling System and North Hawaiian Ridge Current
- mean attraction s_1 correlates with EKE (r = -0.93)

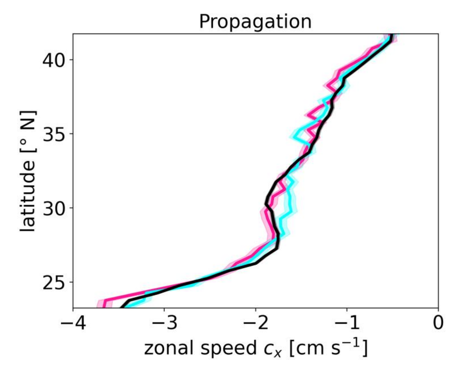


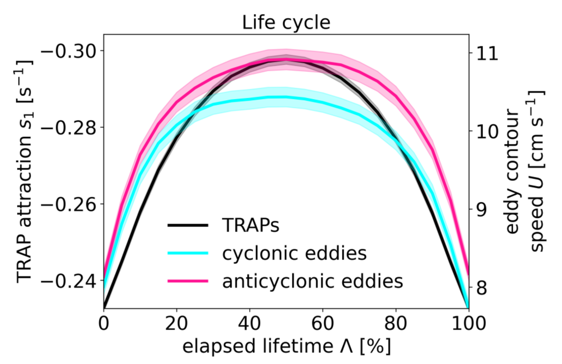
4 Life cycle and propagation

- range from days to seasons
- average lifetime of Λ ≈ (6 ± 12) days
- 41% detections relate to lifetimes Λ > 30 days
- distinct evolution of s_1 for long-living TRAPs
- intensify during the first, weaken during the second half of their cycle
- attraction s_1 scales with eddy contour speed U
- propagate with mesoscale eddies



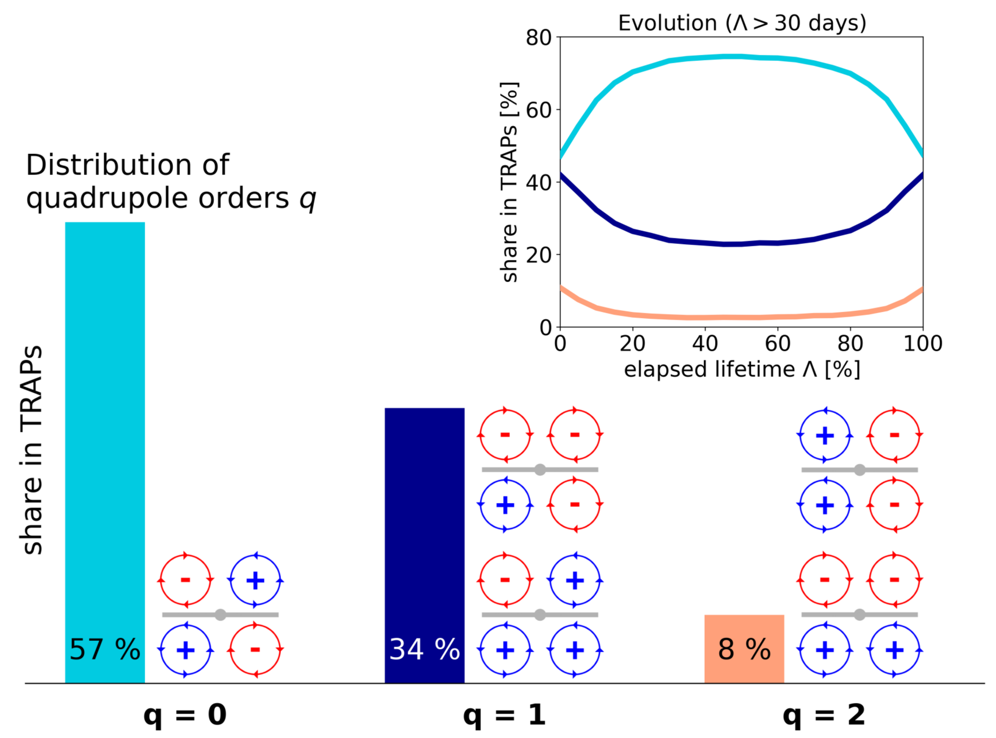


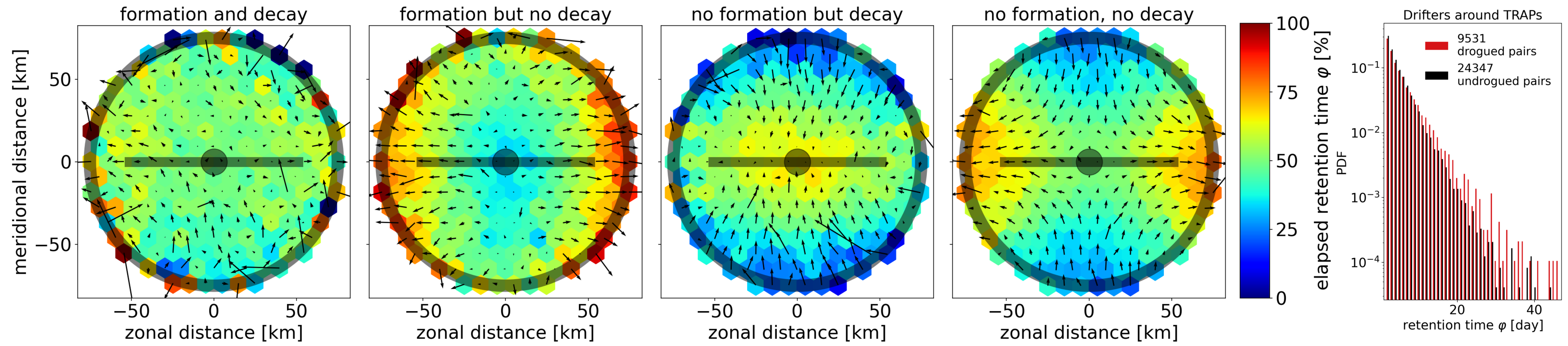




5 Vorticity patterns

- on average surrounded by four vortices of alternating polarity (reference quadrupole)
- variations of this pattern exist
- quadrupole order q indicates number of polarities different to the reference pattern
- q decreases from formation to mature phase
- q increases towards decay phase





Average drifter motion around TRAPs depends on TRAP evolution stage

6 Impact on drifters

- hyperbolic transport primarily throughout the mature phase of a long-living TRAP
  - ➢ surrounding flow is particularly organized
  - ➢ quadrupole generates high strain
- hyperbolic transport takes on average φ ≈ (5.3 ± 3.8) days
- some drifters retained for multiple weeks
  - ➢ material clustering at the submesoscale?

7 Conclusion

Cleanup operators should search for long-living TRAPs that are at an advanced stage of their life cycle. These TRAPs streamline floating objects into hyperbolic pathways. Such a streamlined bypass involves a short but strong attraction which could be exploited to filter the flow around a TRAP. But we also find TRAPs that retain material over multiple weeks. Investigating these long retentions with high-resolution observations from the current SWOT mission[9] could further improve the prospects of a cleanup operation.

References: [1] Serra et al., Nature Communications, https://doi.org/10.1038/s41467-020-16281-x, 2020. [2] Serra, M. and Haller, G., Chaos, https://doi.org/10.1063/1.4951720, 2016. [3] Serra, M., Github, https://github.com/MattiaSerra/TRAPs, 2020. [4] Kunz, L., Github, https://github.com/kunzluca/trapsgpgp, 2024. [5] CMEMS, https://doi.org/10.48670/moi-00050, 2022. [6] CMEMS, https://doi.org/10.48670/moi-00148, 2022. [7] AVISO+, https://doi.org/10.24400/527896/a01-2022.005.220209, 2023. [8] Lumpkin and Centurioni, NOAA, https://doi.org/10.25921/7ntx-z961, 2022. [9] International Altimetry Team, Advances in Space Research, https://doi.org/10.1016/j.asr.2021.01.022, 2021.