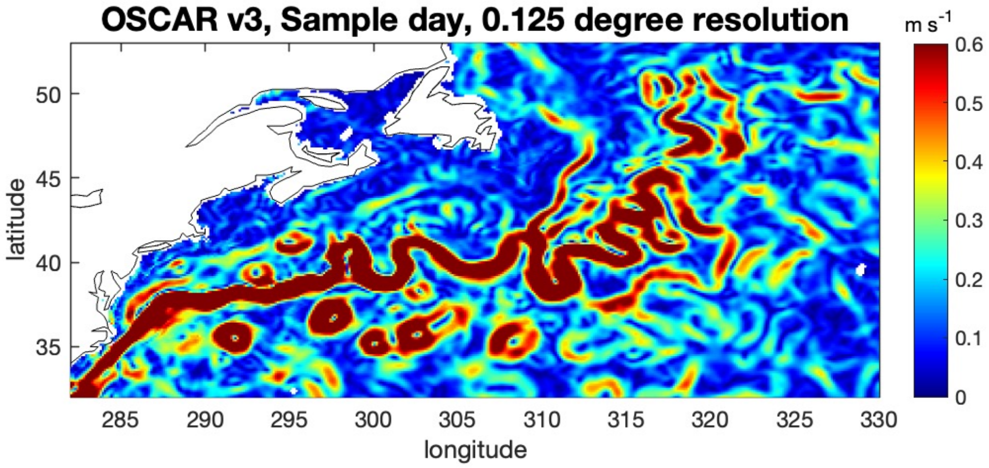
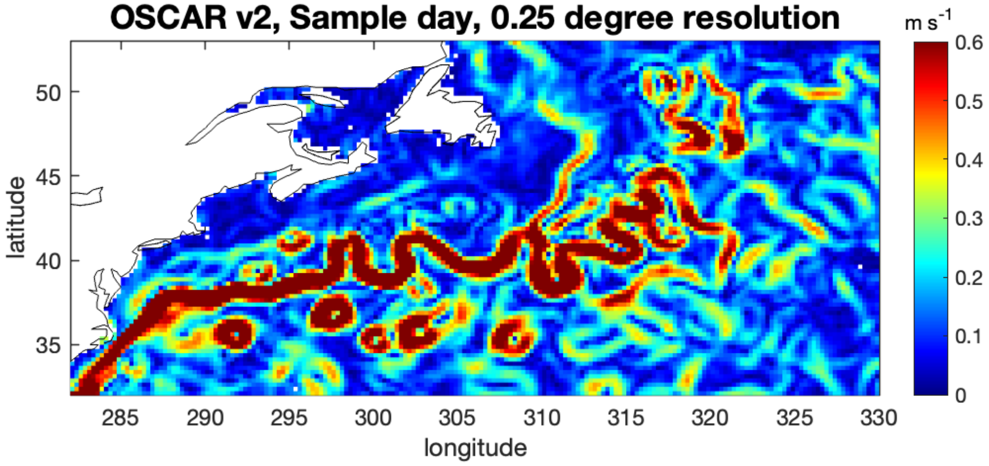
OSCAR Developments, Long Term Trends, and Surface Wave Effects

Kathleen Dohan, Earth and Space Research, Seattle, WA

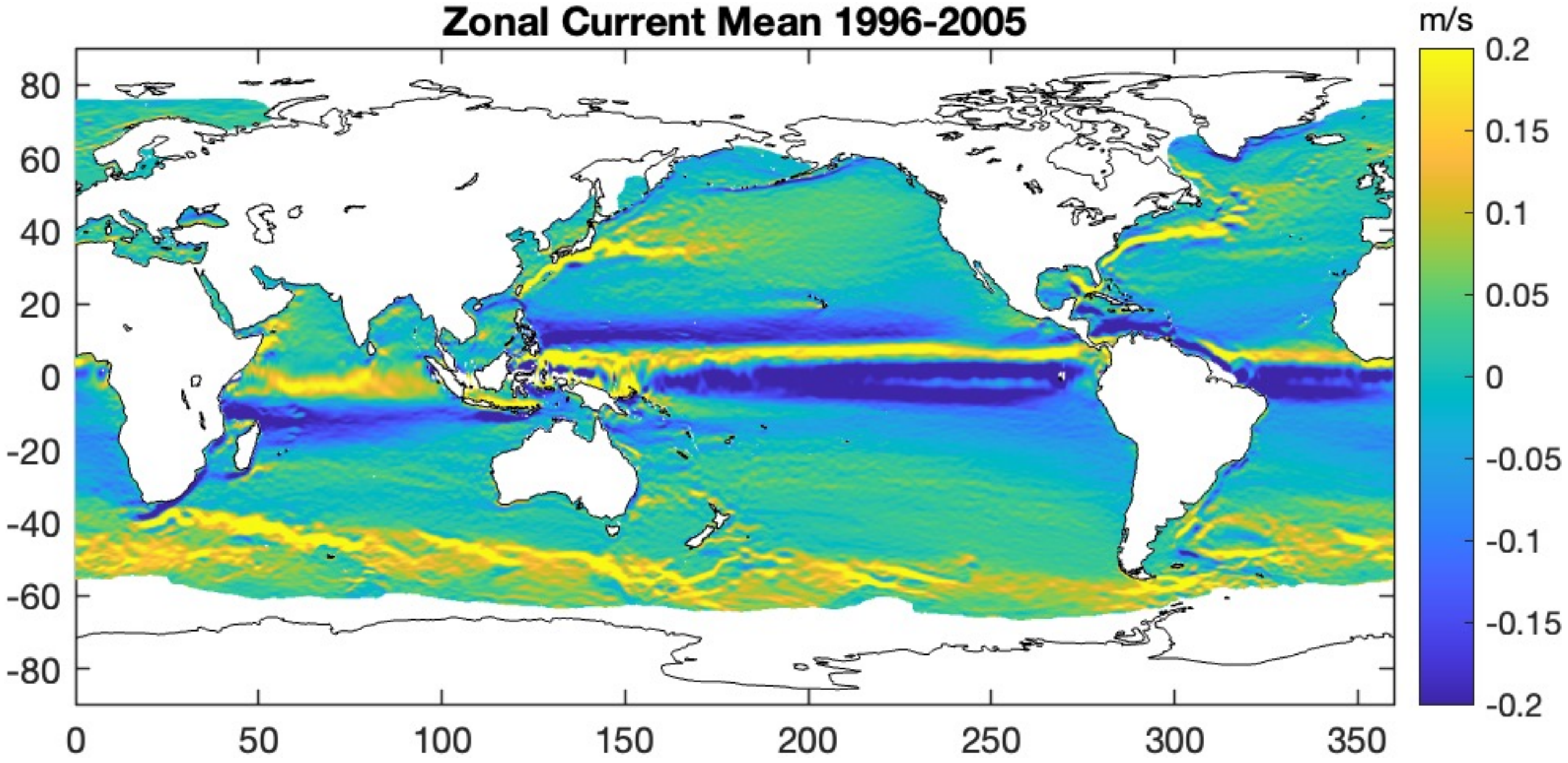
- OSCAR v3
  - 0.125 degree, daily
  - Geostrophic, Ekman, and total currents (which include a thermal wind component)
  - Improvements in time averaging and interpolation methods
  - Final, Interim, (NRT)
  - ERA5 winds
  - CMEMS SSH
  - CMC SST



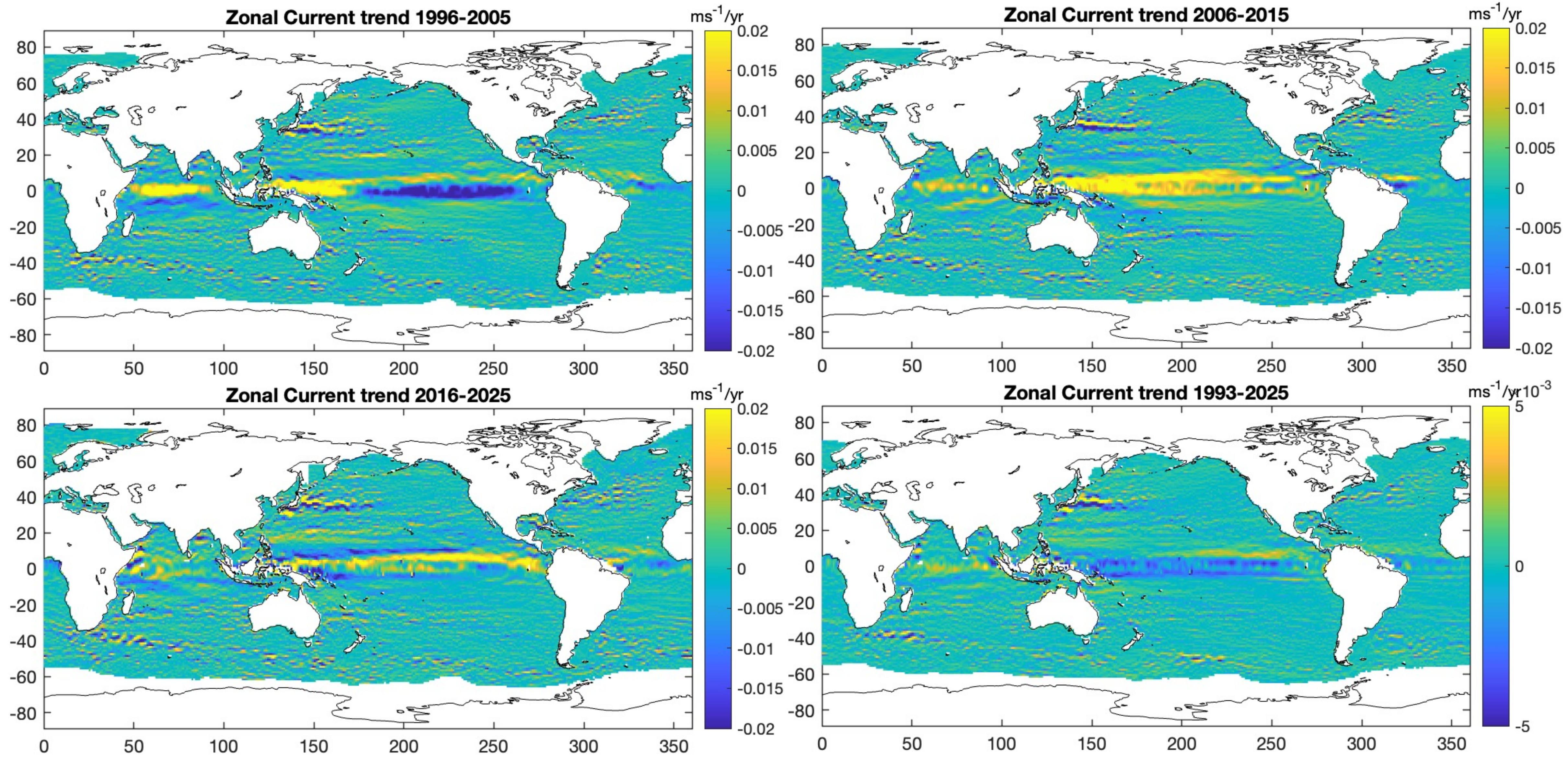


Over 3 Decades of Surface Currents

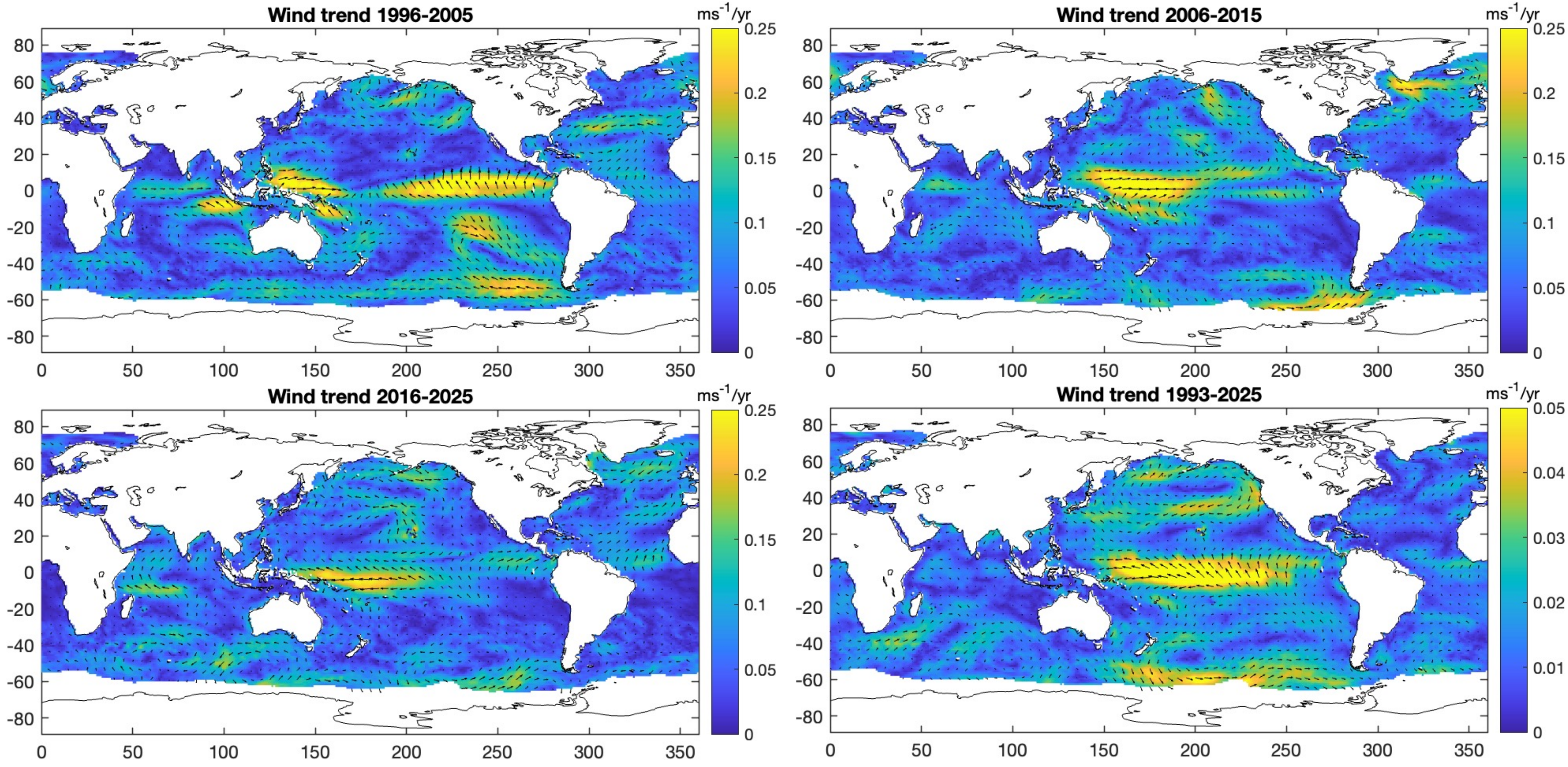
- We now have over 30 years of currents, starting from 1993.
- Brief look at general trends in currents



Zonal current trends, broken into decades



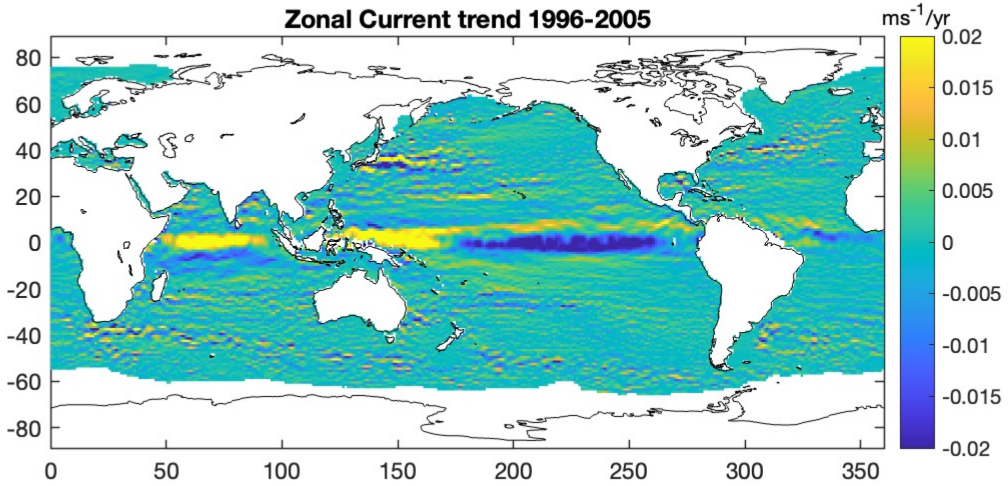
Wind Trends

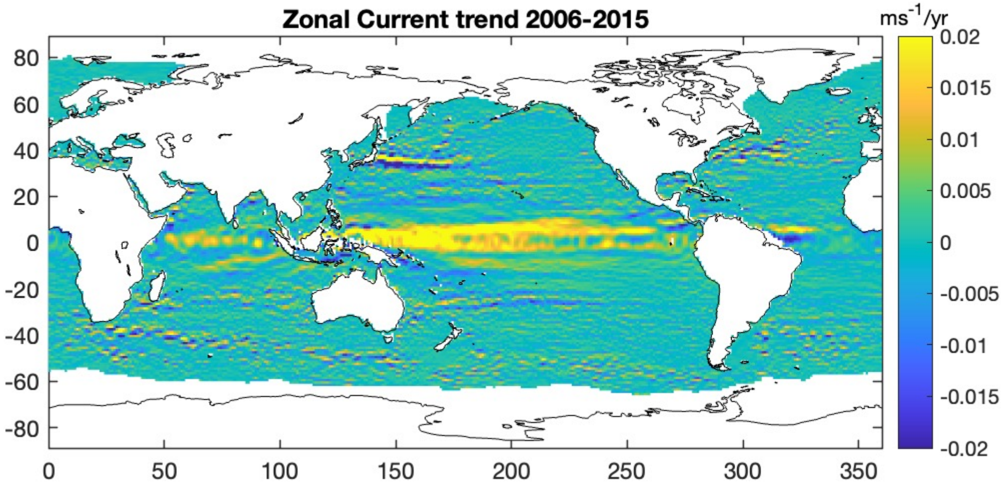


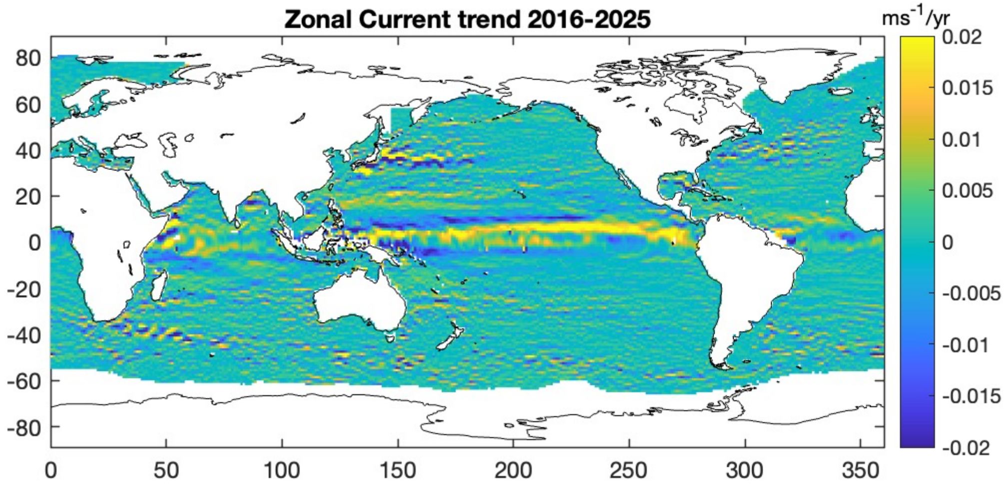
Wind trend 1996-2005
Wind trend 2006-2015
Wind trend 2016-2025
Wind trend 1993-2025
ms-1/yr
0.25
0.2
0.15
0.1
0.05
0
0.05
0.04
0.03
0.02
0.01
80
60
40
20
-20
-40
-60
-80
50
100
150
200
250
300
350

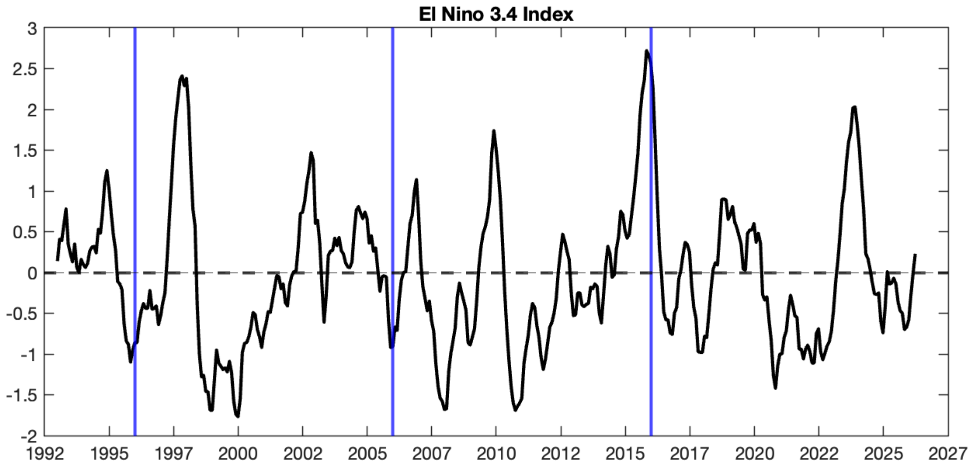
Zonal current trends, broken into decades

- ENSO events will significantly affect the trend.





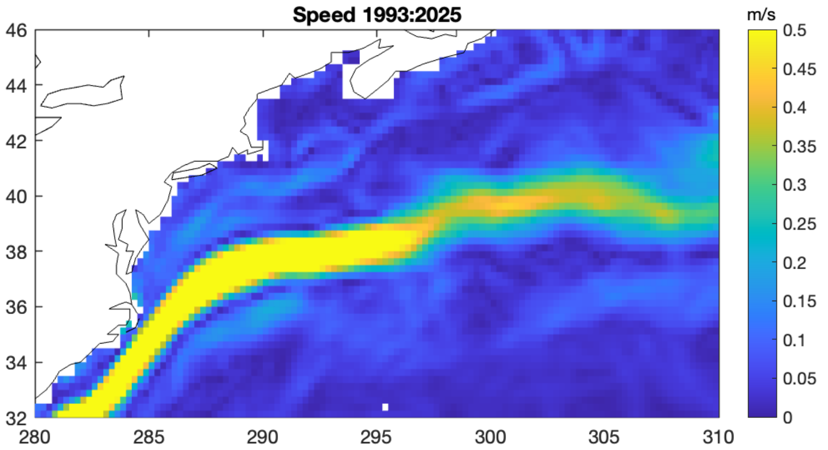


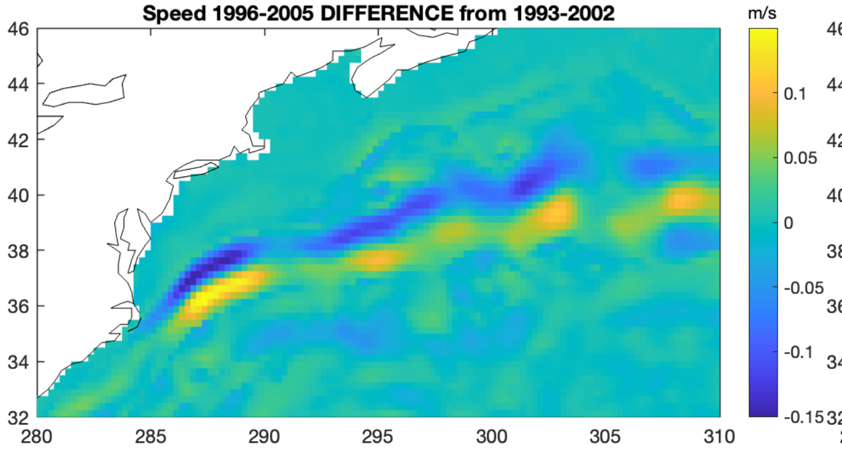


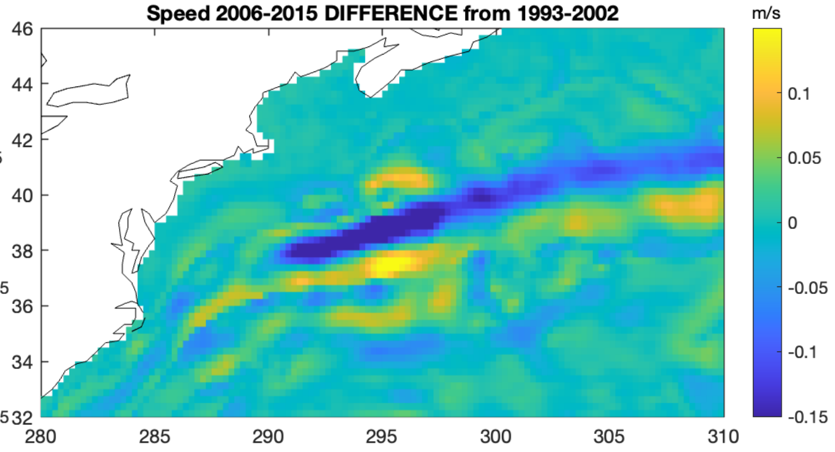
Gulf Stream

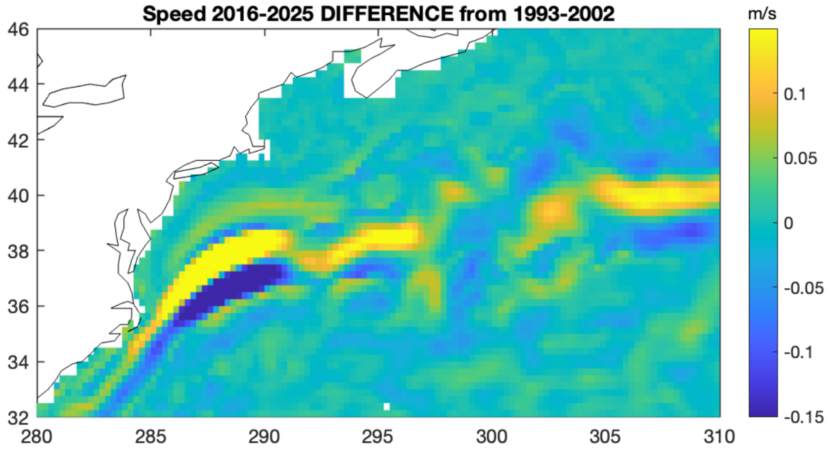
- Shown: shifts from the first decade of data.
- The Gulf Stream does shift from year to year generally,

Mean over all years

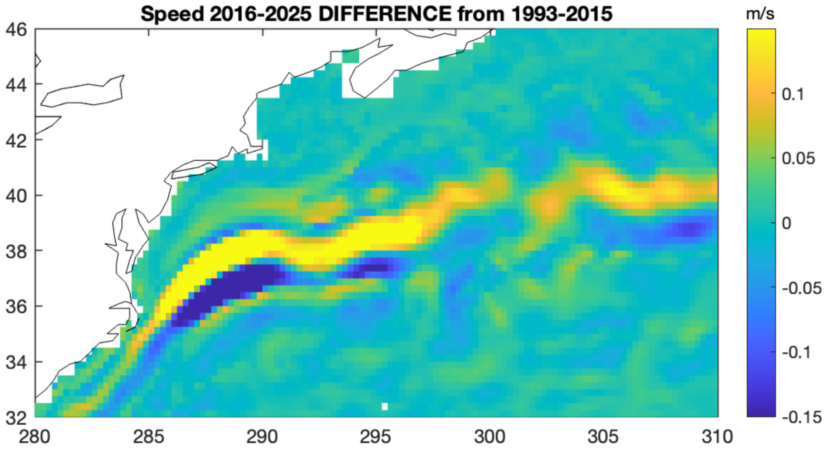






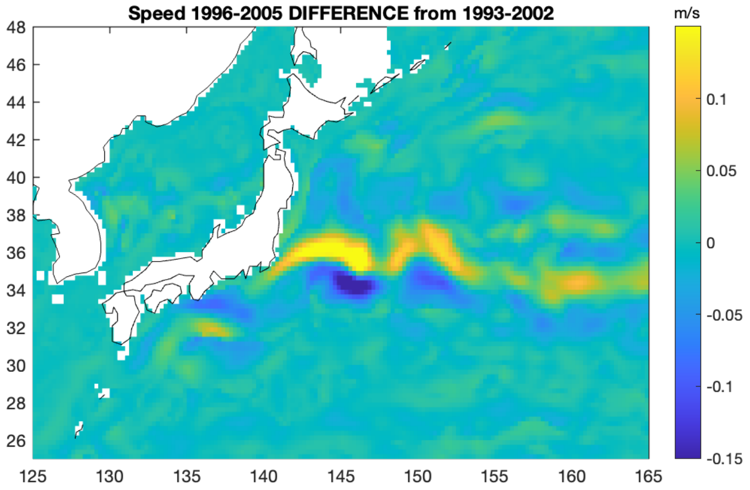


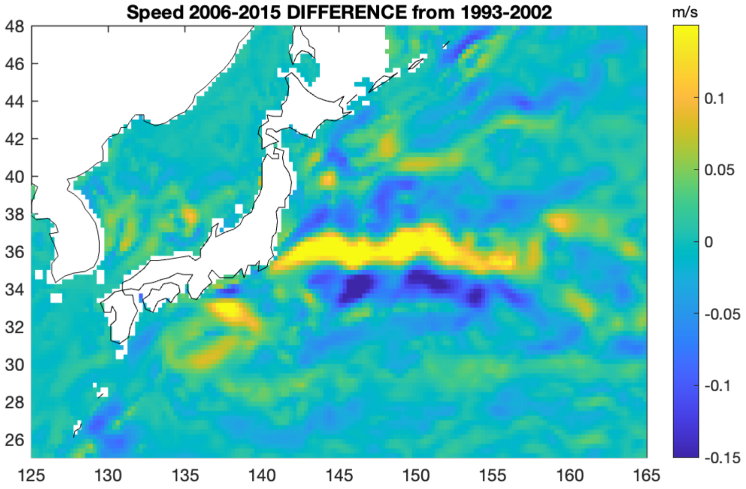
Last decade - first 2 decades

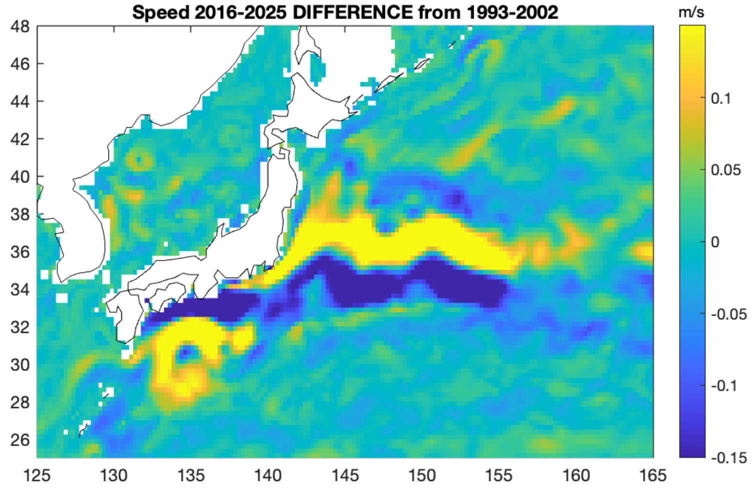


Kuroshio

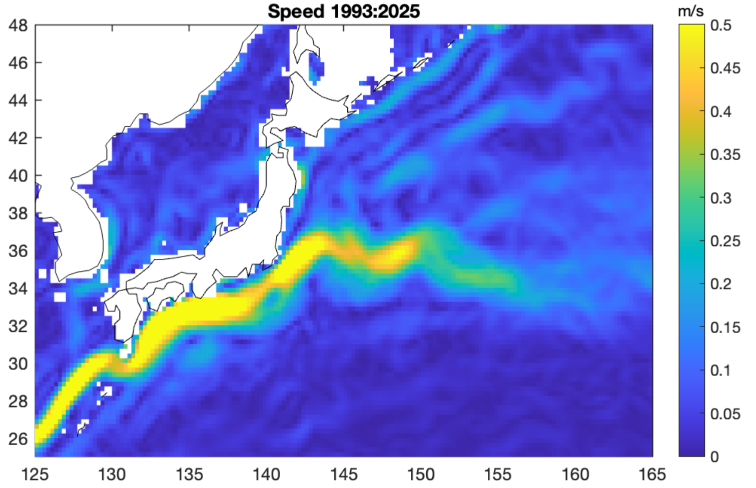
- The eddy at the south point does appear regularly over the years, but looks to be more permanent now
- Like the Gulf Stream, permanent shift north, closer to the coast



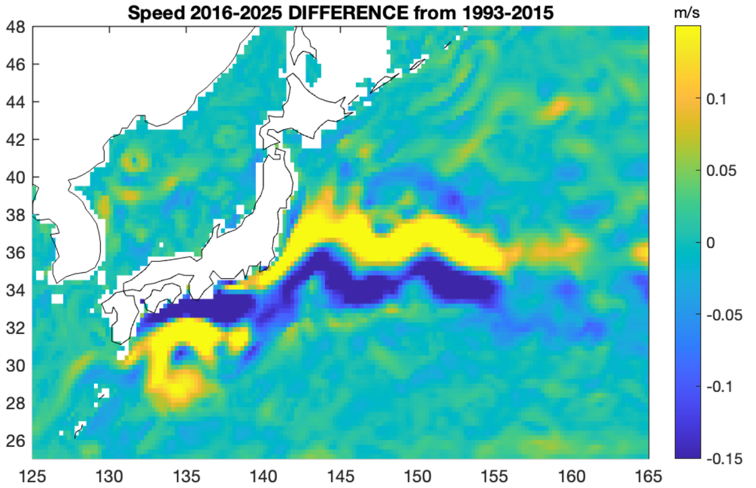




Mean over all years

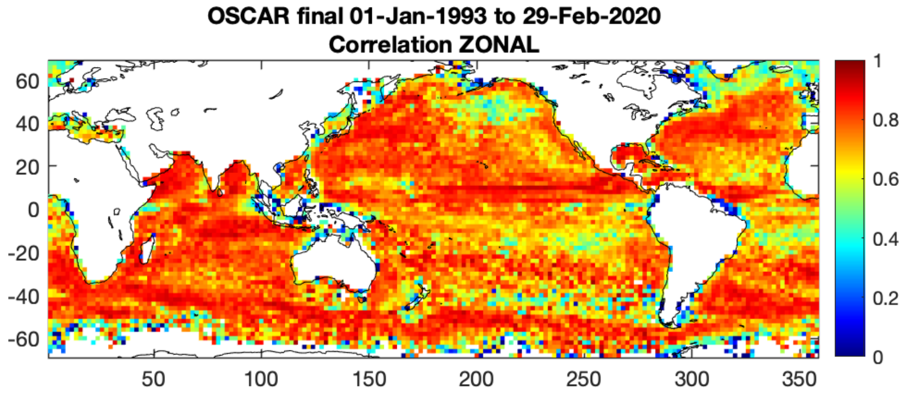


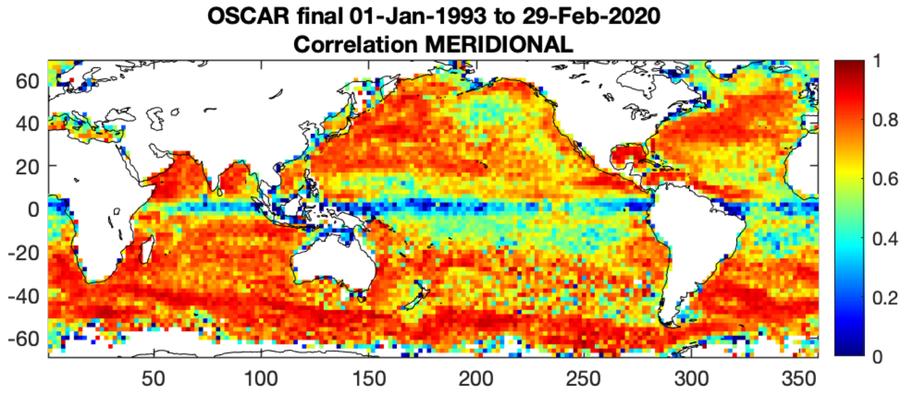
Last decade - first 2 decades



Stokes drift and vertical variation in OSCAR, Motivation

- Continual motivation to improve the performance of the wind-driven component
- OSCAR model solves for the classic Ekman balance and averages over the top 30m.





Surface Wave Effects

- **Stokes drift**: The Stokes drift is the average velocity in a Lagrangian setting. The classic Stokes profile for a monochromatic deep water wave, amplitude a, wave number k, and sea surface wave frequency σ is:

$$\mathbf{U}_s = U_s e^{2kz}\hat{\mathbf{k}}, \quad U_s = a^2\sigma k$$

- Can estimate U_s globally using significant wave height H_s and mean wave period T from wave model data (here, WaveWatch III)

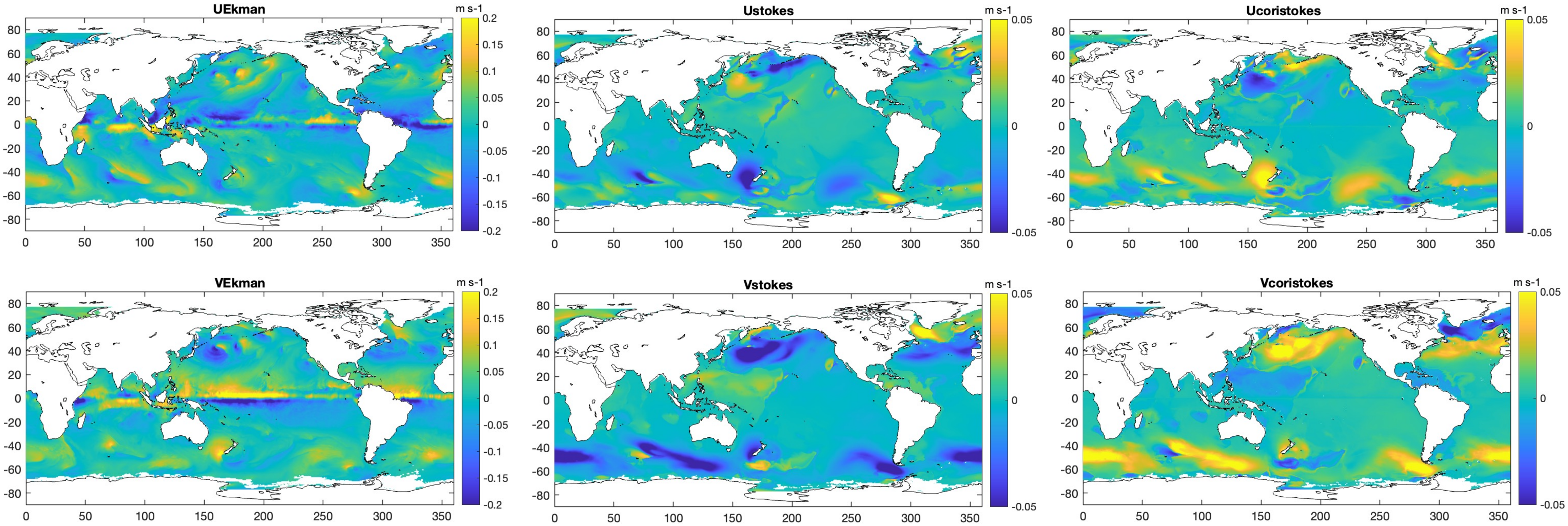
$$U_S = \frac{2\pi^3}{g}\frac{H_S^2}{T^3}$$

- **Coriolis-Stokes force:** We're also exploring the significance of Coriolis-Stokes forcing on Ekman currents – the interaction between the Stokes drift and the Coriolis force, similar in concept to Langmuir circulations, where the plane of the orbital velocity is tilted in the along wave crest direction by the Coriolis acceleration

$$\rho f \hat{\mathbf{z}} \times (\mathbf{u} + \mathbf{u}_s) = \frac{\partial \boldsymbol{\tau}}{\partial z}$$

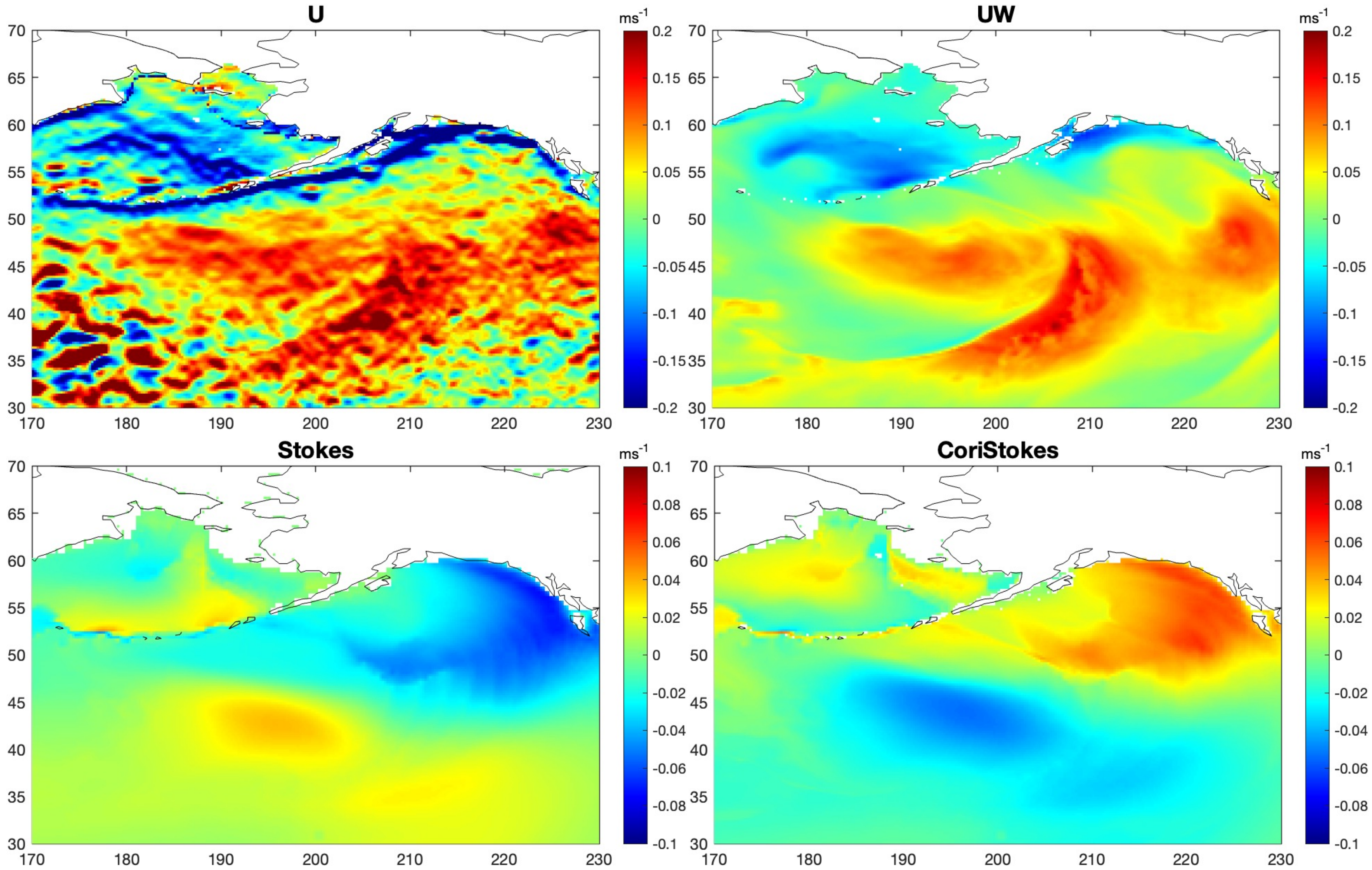
Surface Wave Effects

- Sample plots for one day for the OSCAR Ekman component, the Stokes drift term and the Coriolis-Stokes term. The latter two terms are calculated at 15m depth, the depth at which drifters are drogued.



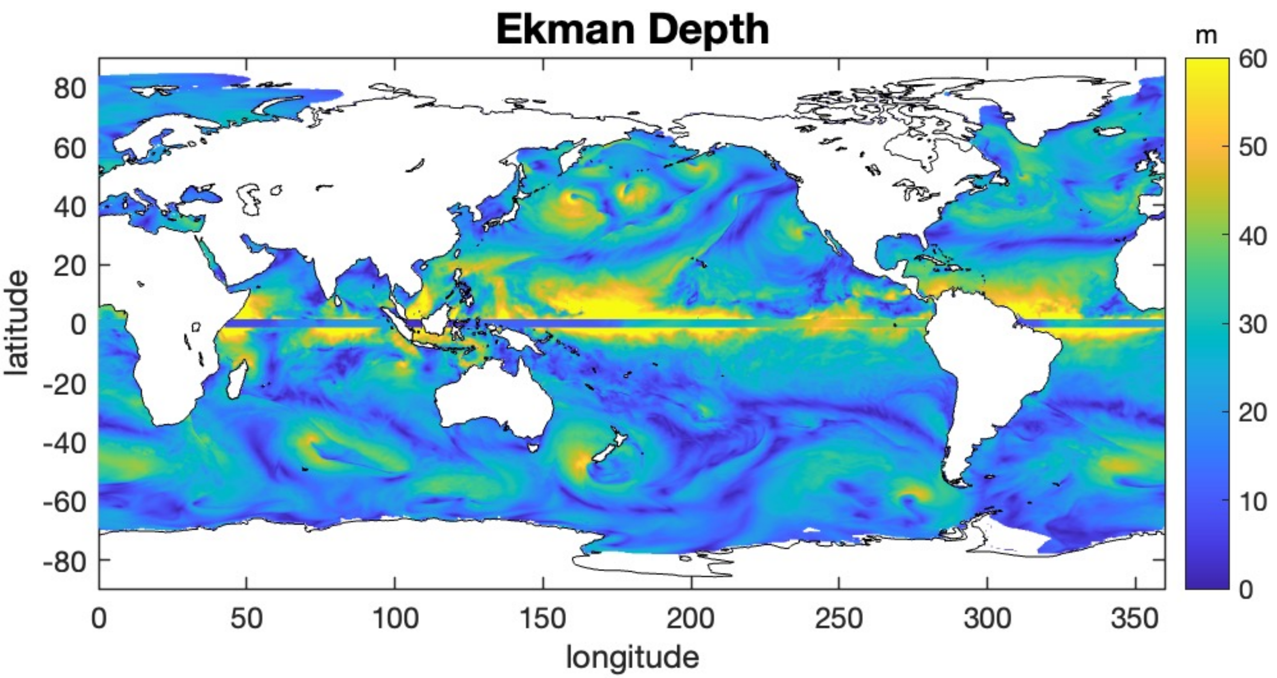
- double the amplitude colorscale

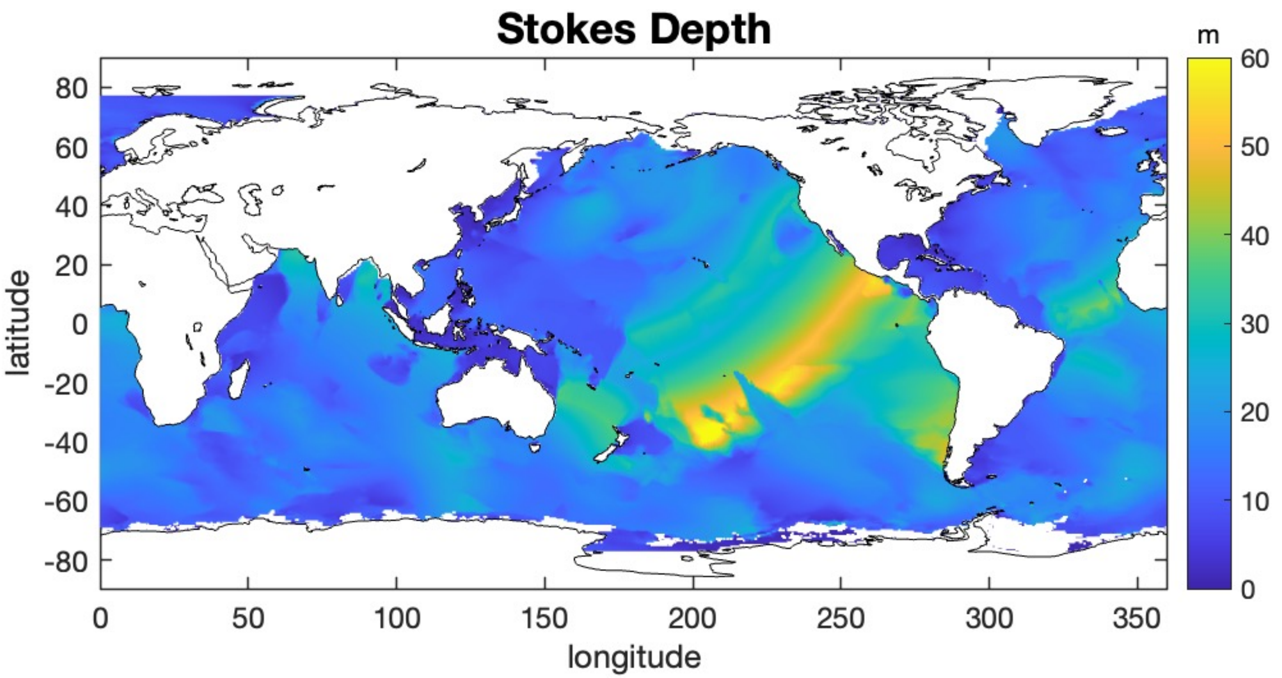
Relative strengths of each term in the North Pacific



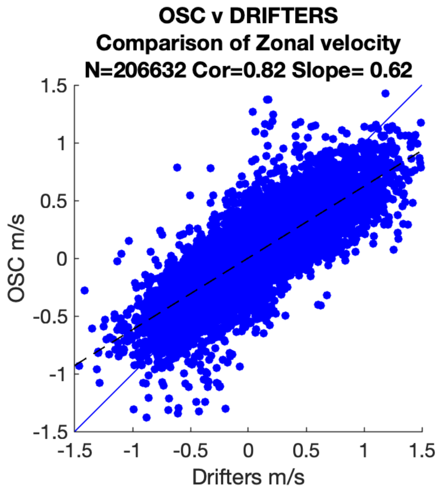
Vertical Variation

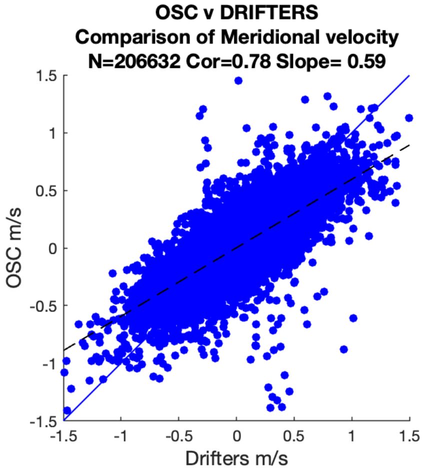
- Ekman depths and Stokes drift depths for a sample day. While the Ekman depth is generally deeper, both vary significantly and the Stokes depth reaches past 15m in many locations.

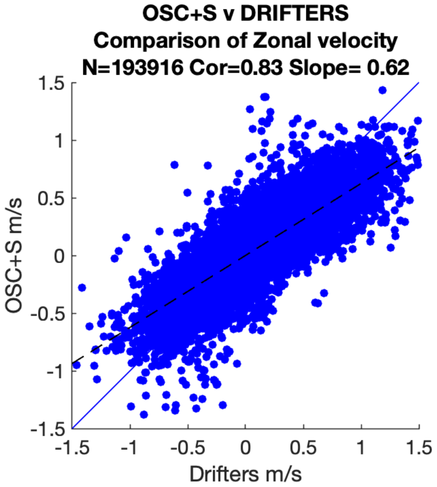


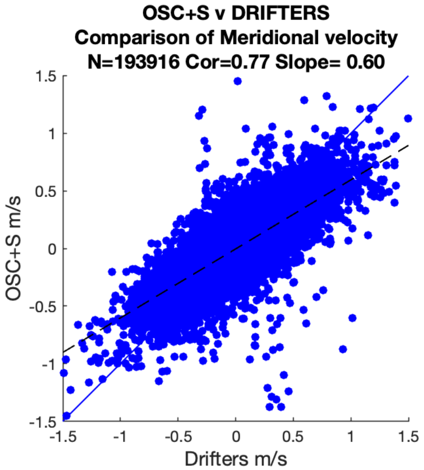


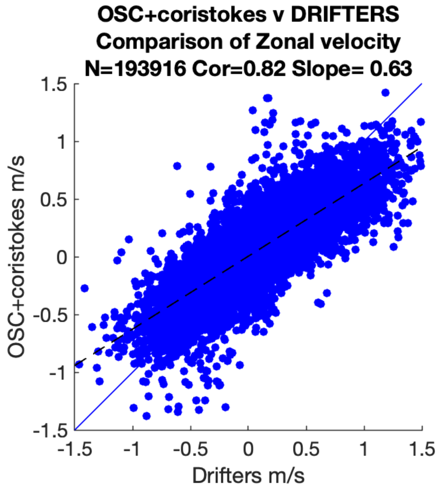
Comparison with Drifters, 1 year global

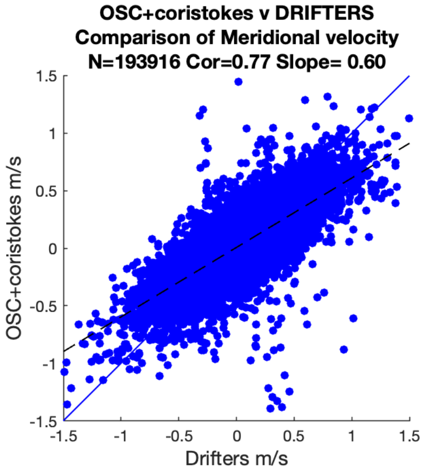


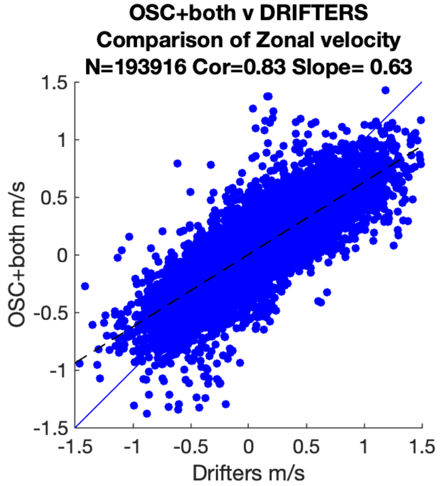


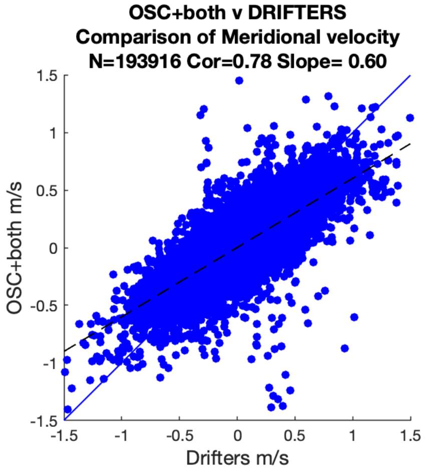






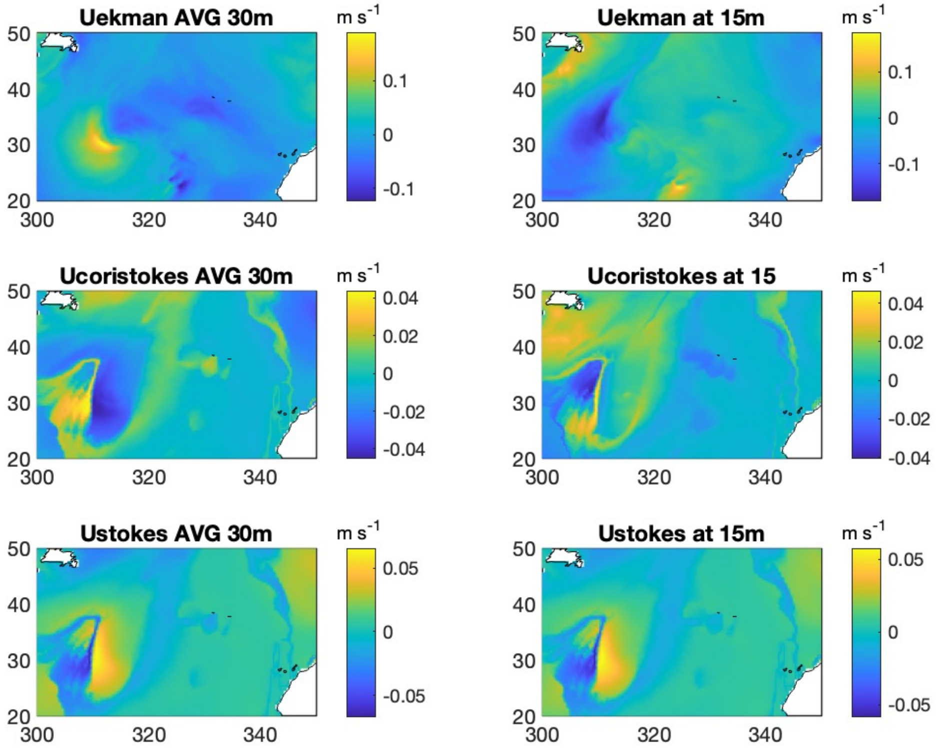




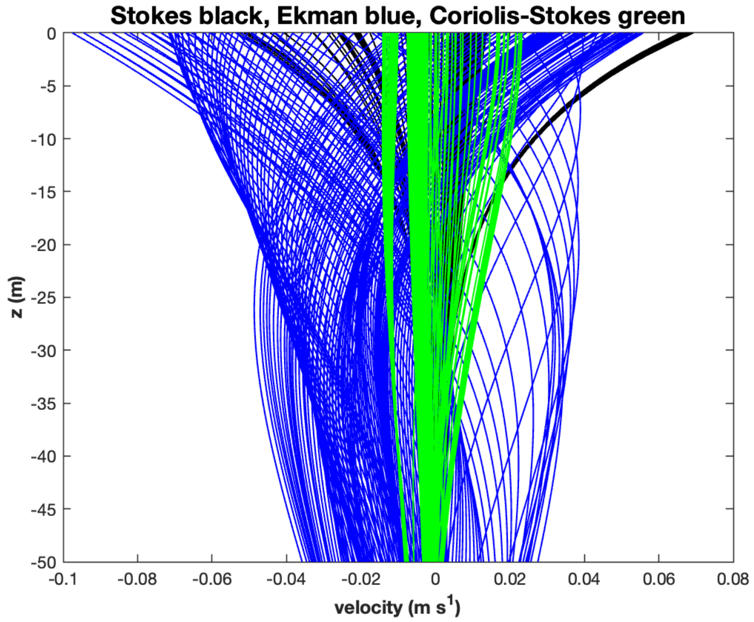


Vertical Variation

- Differences between values when averaged over the top 30m versus calculated at 15m, for a sample patch of ocean. This is for theoretical profiles and does not account for mixed layer turbulence.



- Vertical variation of Ekman, Coriolis-Stokes, and Stokes drift for a sample day in the same ocean



Next Steps

- Results so far:
  - Marginally different statistics when compared to drifters
  - Sort drifters comparisons by specific criteria for cleanest evaluation
- Revisit the basic model, explicitly calculated in the vertical, at the S-MODE location
- Extend to surface level and compare with areas where possible
- Have to consider alternate contributions, like tides and ageostrophic submesoscale processes
- Re-evaluate/re-tune the turbulence parameters
- Validation
  - Challenges: geostrophic signal is strong but it's also where most of the drifters are
    - Cannot completely uncouple geostrophic signal
    - Focus on areas with most favorable conditions for evaluation
  - Top surface currents: HF radar and field programs for validation, undrogued drifters