Examining Drifter Velocity Measurements for Use in Constraining Climate Models

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I. Scientific Questions and Approach

- How good are surface circulations simulated in climate models?
- Can climate models be improved by incorporating surface drifter velocity measurements?
- Use surface circulation in latest state estimate from ECCO (*Estimating the Circulation and Climate of the Ocean*) as an example.
- Estimate data errors, including both instrumental errors and representation errors (signals in the data that cannot be represented by model physics and resolution)
- to weight the model-data misfits on timescales of daily, monthly and climatology.

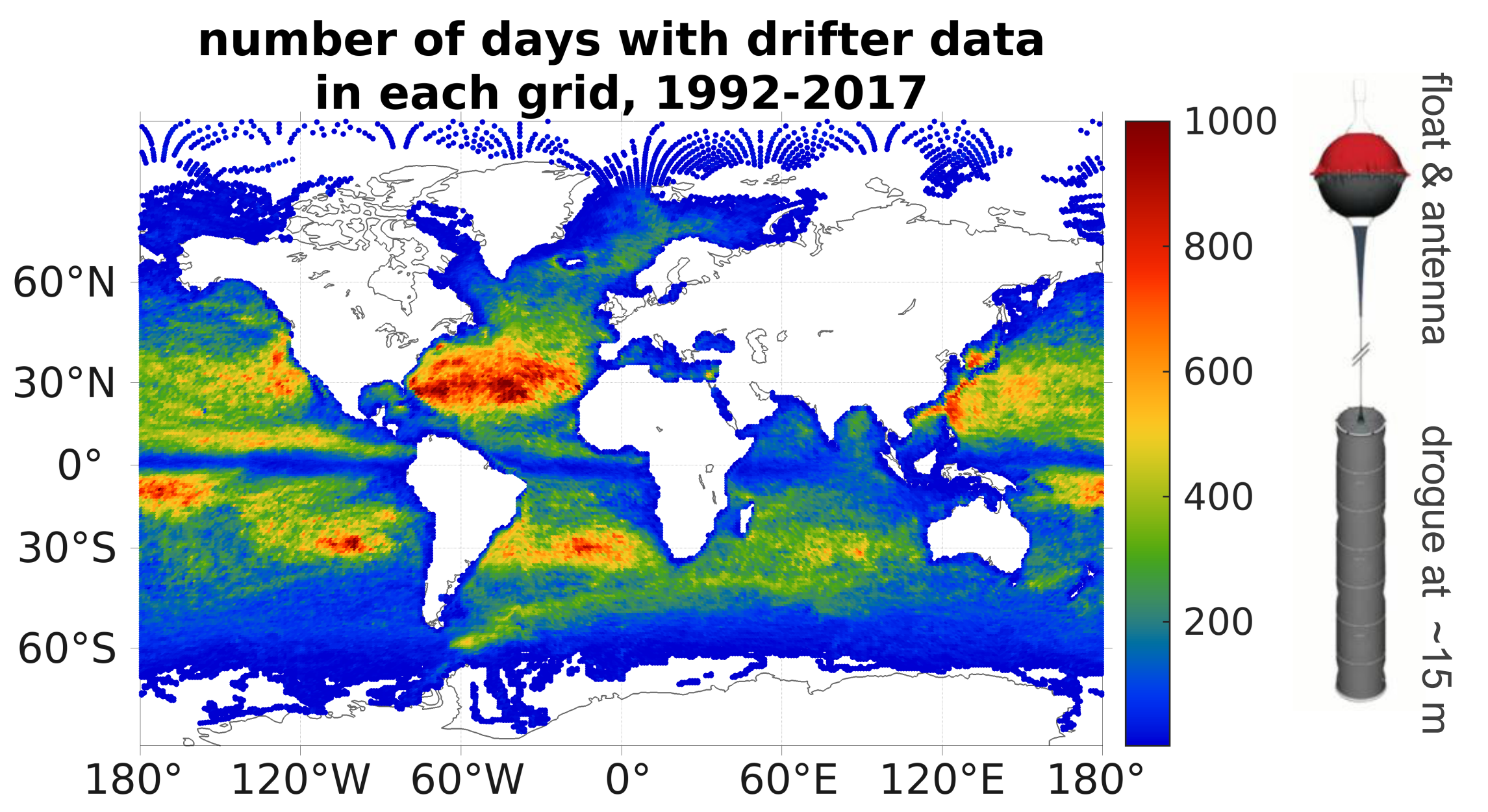
II. Data

Global Drifter Program (GDP)

- Pseudo-Eulerian horizontal velocities at ~15 m derived from drifter locations
- Wind induced non-oceanic velocity and high frequency signals (e.g., tides and inertial motions) removed

Estimating the Circulation and Climate of the Ocean (ECCO)

- ECCO describes the ocean state by fitting a general circulation model (MITgcm) to observations in a weighted least square sense.


number of days with drifter data in each grid, 1992-2017

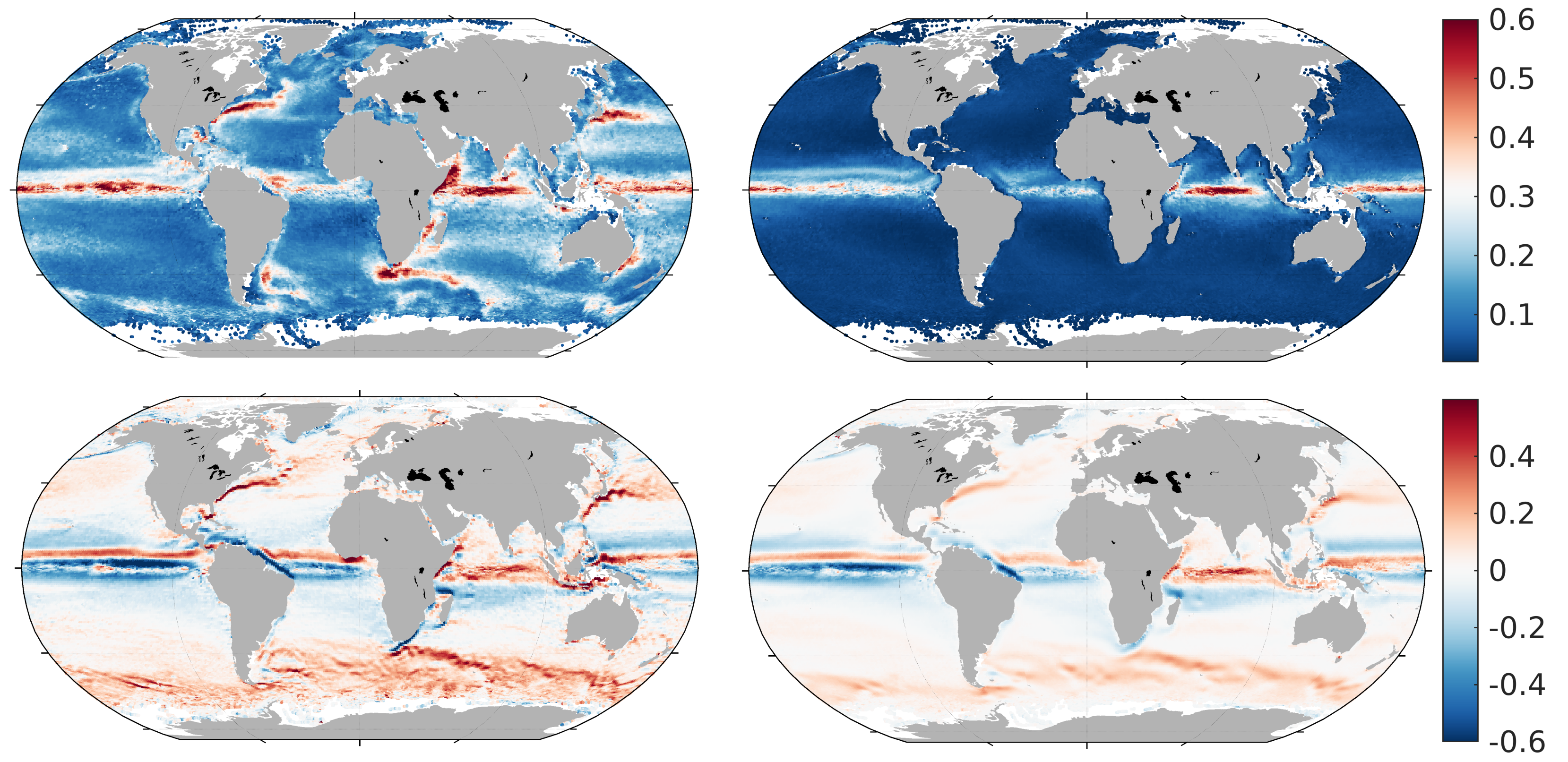
Ocean Surface Current Analysis Real-time (OSCAR)

- OSCAR represents altimetry-derived geostrophic and wind-stress-estimated Ekman components.

product	depth	temporal scales	spatial scales
GDP	~15 m	6 h	a few km
ECCO	~15 m	1 day	~20 km to ~100 km
OSCAR	upper 30 m	5 day	1/3 degree

III. Surface Currents in ECCO and GDP

- Daily GDP and ECCO velocities: processed to same temporal and spatial coverage.
- Monthly velocities and climatology (1992-2017): averaged available daily velocities.



↑ Standard deviation of daily zonal velocities [m/s] from GDP and ECCO over 1992-2017 (top) and climatology over the same period (bottom).

IV. GDP Instrumental and Representation Errors

Daily and Monthly Timescales:

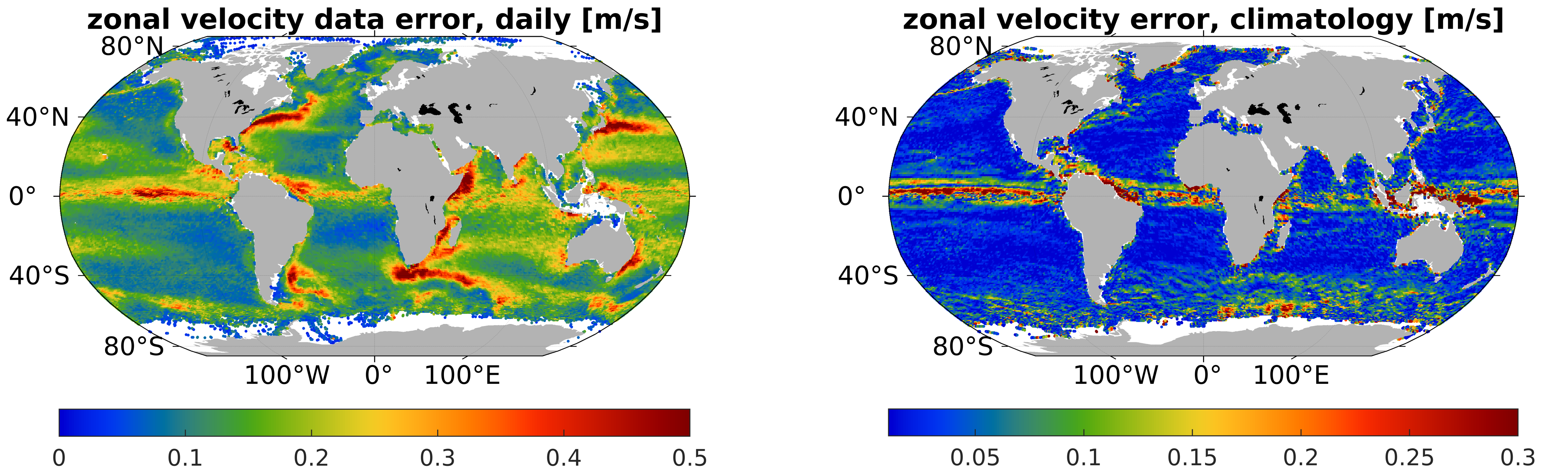
Measured velocity D and modeled velocity M consists of true value s and errors ε_D and ε_M: $D = s + \varepsilon_D$ and $M = s + \varepsilon_M$. Data error variances $\mathrm{var}(\varepsilon_D)$ can be derived as

$$\mathbf{var}(\boldsymbol{\varepsilon_D}) = \mathbf{var}(\boldsymbol{D}) - \mathbf{cov}(\boldsymbol{D}, \boldsymbol{M}) \qquad (1)$$

where var and cov are variances and covariances. Equation (1) holds if $\mathrm{cov}(s, \varepsilon_D)$, $\mathrm{cov}(s, \varepsilon_M)$ and $\mathrm{cov}(\varepsilon_D, \varepsilon_M)$ can be neglected. To avoid unphysically large estimates of $\mathrm{var}(\varepsilon_D)$ from (1), we arbitrarily cap $\mathrm{var}(\varepsilon_D) \leq 90\%\ \mathrm{var}(D - M)$.

Climatology 1992-2017:

Data errors are estimated to be the absolute value of difference between GDP and OSCAR climatologies.


zonal velocity data error, daily [m/s]

zonal velocity error, climatology [m/s]

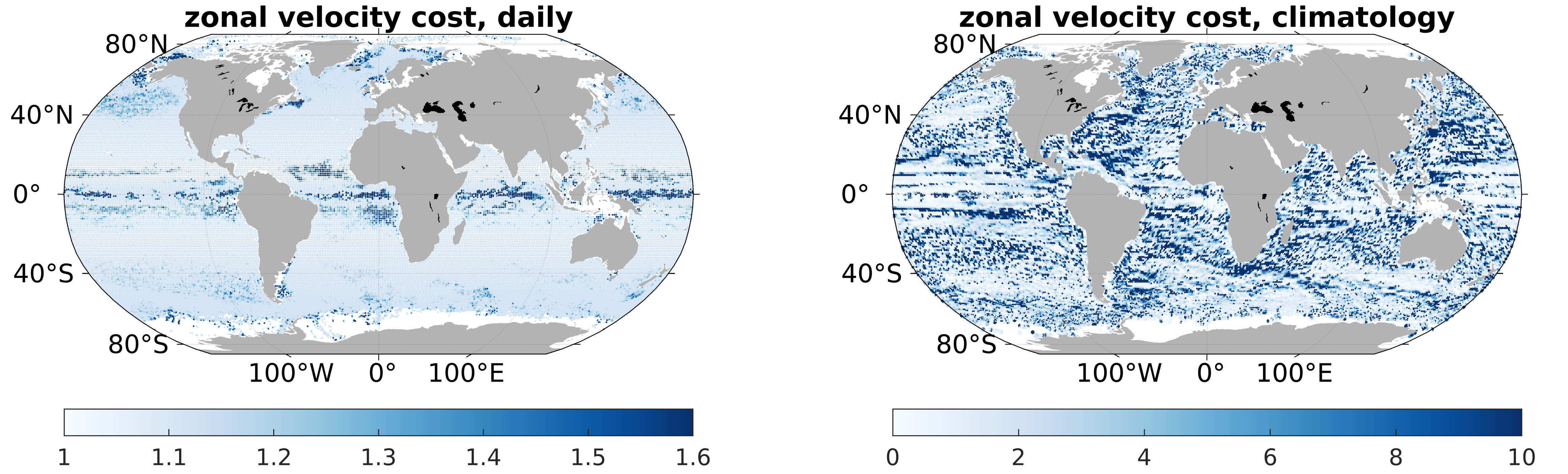
↑ GDP instrumental and representation errors ε_D [m/s] on daily timescale (left) and climatology 1992-2017 (right).

V. Constraining ECCO Velocity Field

The model-data misfits against estimated data errors (i.e., cost) are used to examine whether constraining ECCO velocity using drifter data could be important. Cost is calculated as:

$$\boldsymbol{cost} = \mathbf{var}(\boldsymbol{D} - \boldsymbol{M})\ /\mathbf{var}(\boldsymbol{\varepsilon_D}) \qquad (2)$$

Regions with cost values >1 are where ECCO velocities deviate from the measurements by more than expected from considering instrumental and representation errors.


zonal velocity cost, daily

zonal velocity cost, climatology

↑ Cost for daily zonal velocity field (left) and climatology (right).

VI. Summary

- ECCO surface currents tend to be weaker and less variable than GDP measurements.
- Constraining ECCO solutions to GDP data may have an impact on mean surface velocity estimates, but not so much on daily and monthly values, except mostly in equatorial regions.