A New Global Drifter Dataset at Hourly Resolution

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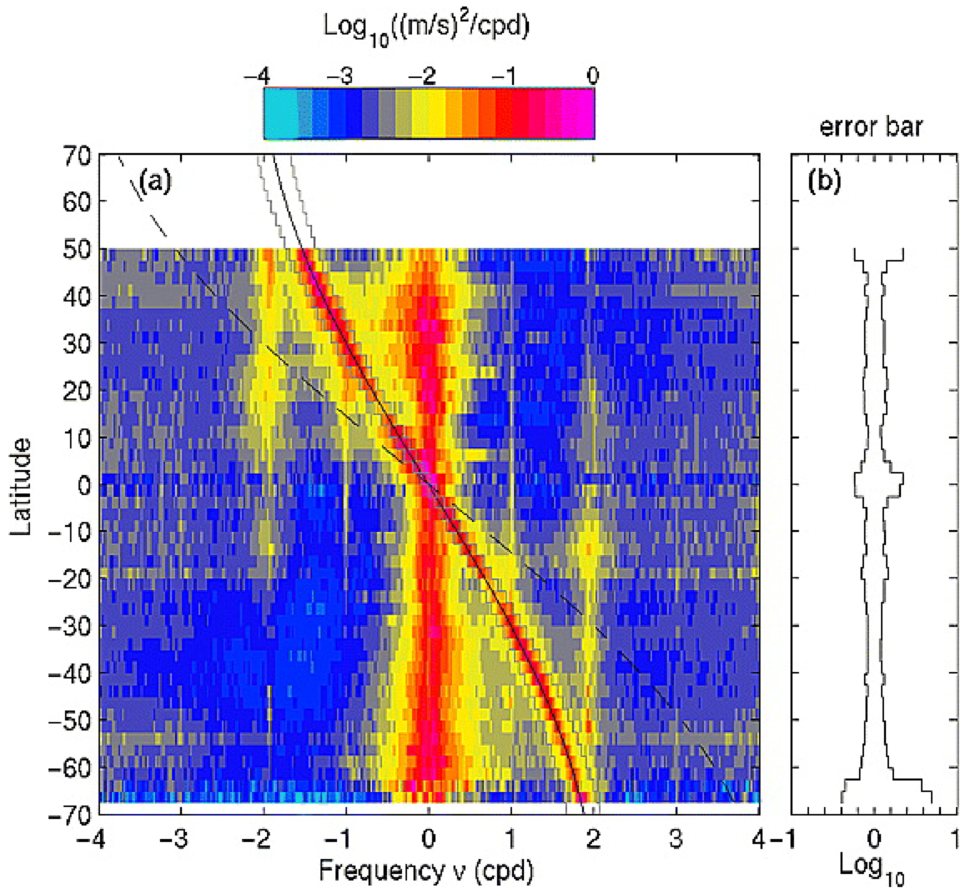
Post-2004 GDP Data

Since 2000, all drifters have been on continuous duty cycle (no more one day on, two days off).

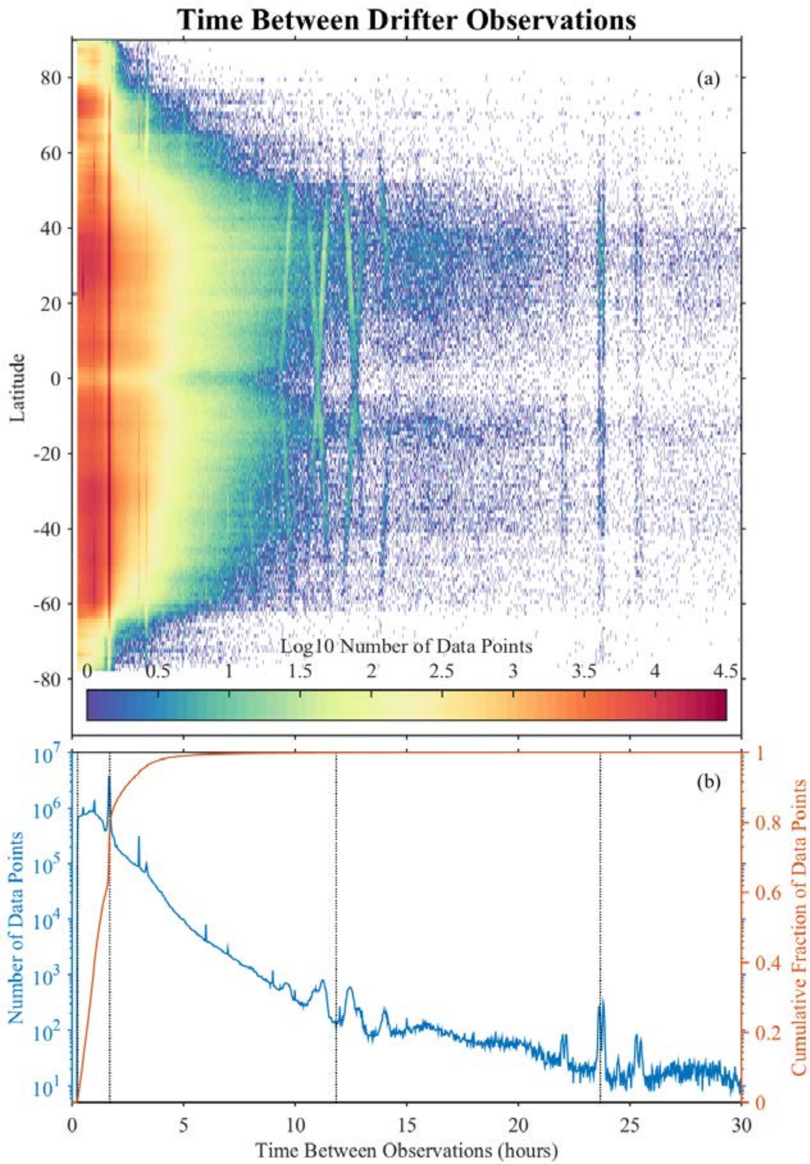
Starting in late 2004: Argos multisatellite processing (from two to 5+ satellites). median time between fixes decreased from ~4—6 hours to 1.2 hours.

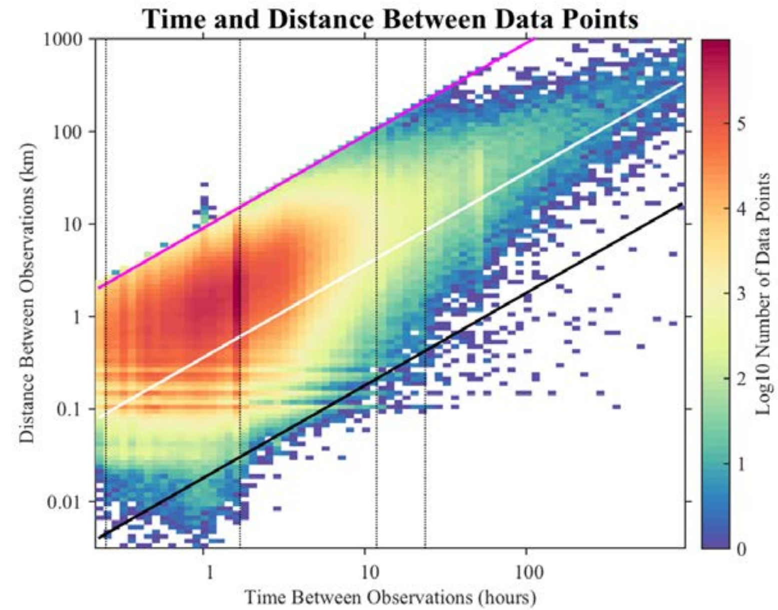


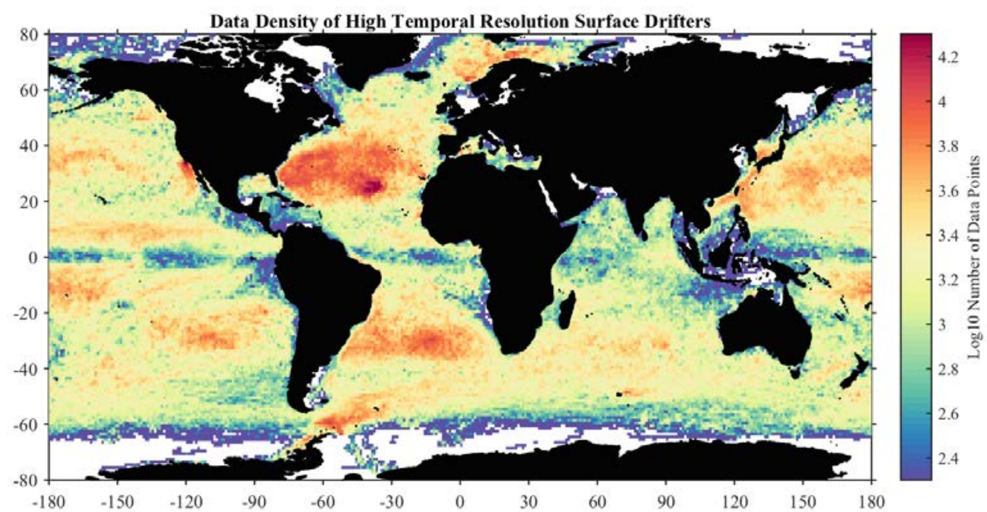
Left: spectral energy density of hourly drifter observations as a function of latitude, showing inertial, tidal (diurnal and semidiurnal) and subinertial (primarily geostrophic) variations (Elipot and Lumpkin, 2008)

Approach: simple linear interpolation, centered two-hour differences for velocity.

Post-2004 GDP data







GOAL OF THIS WORK

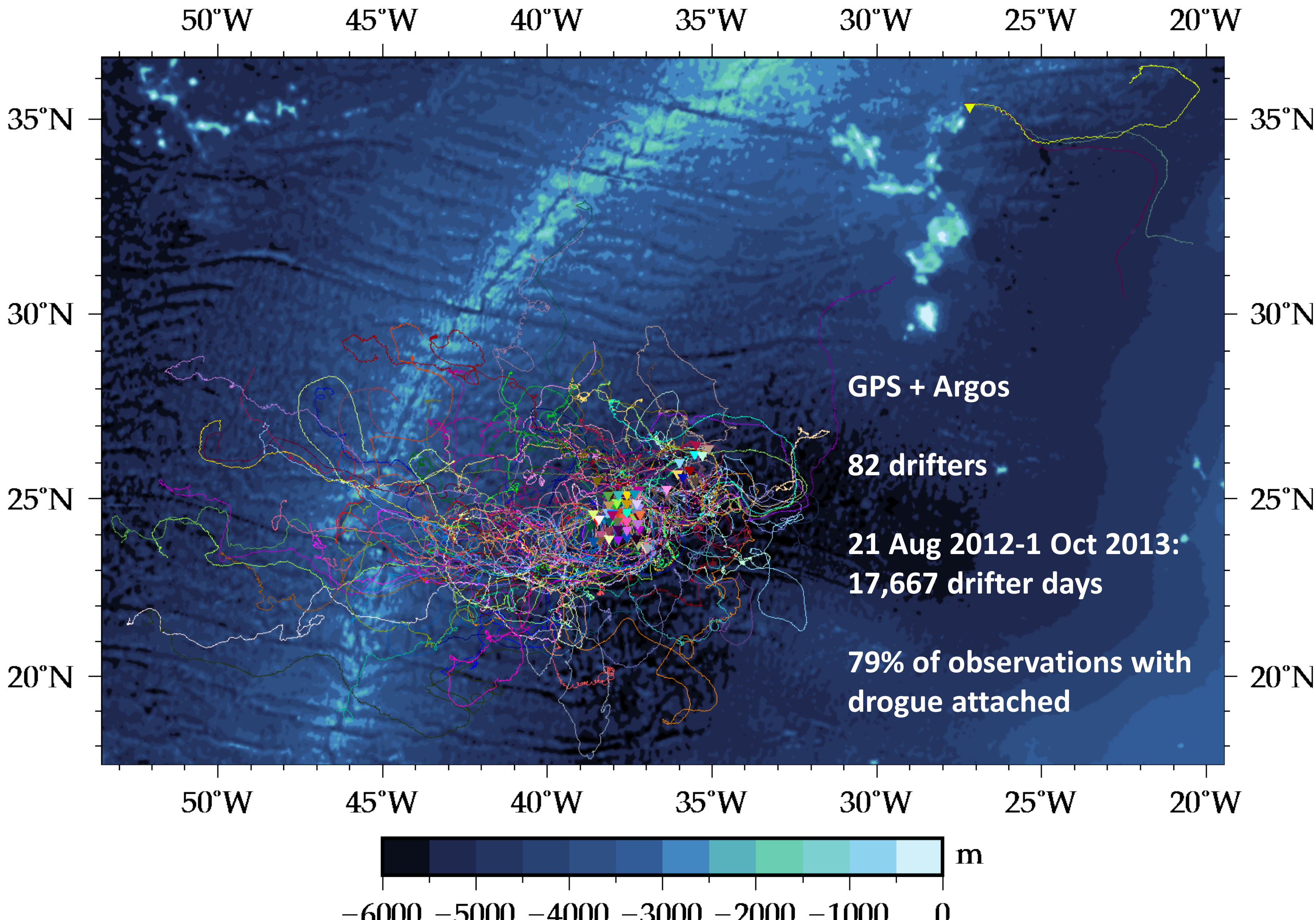
Create a high-quality, hourly data set of drifter location and velocity from post-2004 irregular location fixes.

Incorporate error information (e.g., Argos Location Class) in interpolation. Generate formal error bars on hourly interpolated values.

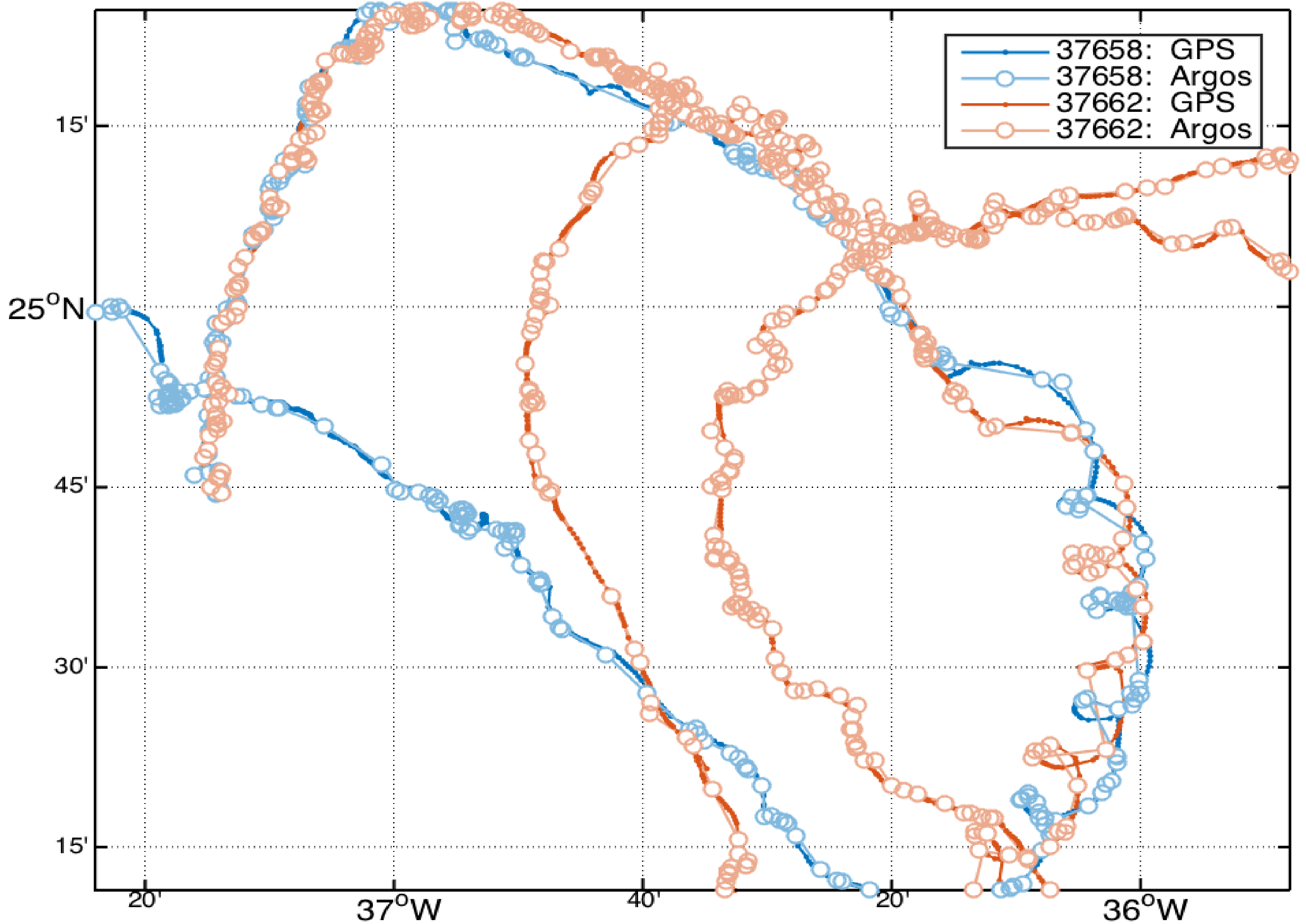
Use GPS data to evaluate various approaches – choose best method based on quantitative evaluation.

Publish results in *J. Oceanic and Atmos. Technology*; distribute data set for studies of tides, inertial oscillations, submesoscale ocean features, etc.

SPURS data set



SPURS data set



Quality controlling GPS data

GPS data includes outliers, including gross outliers.

Location quality index not useful to identify outliers.

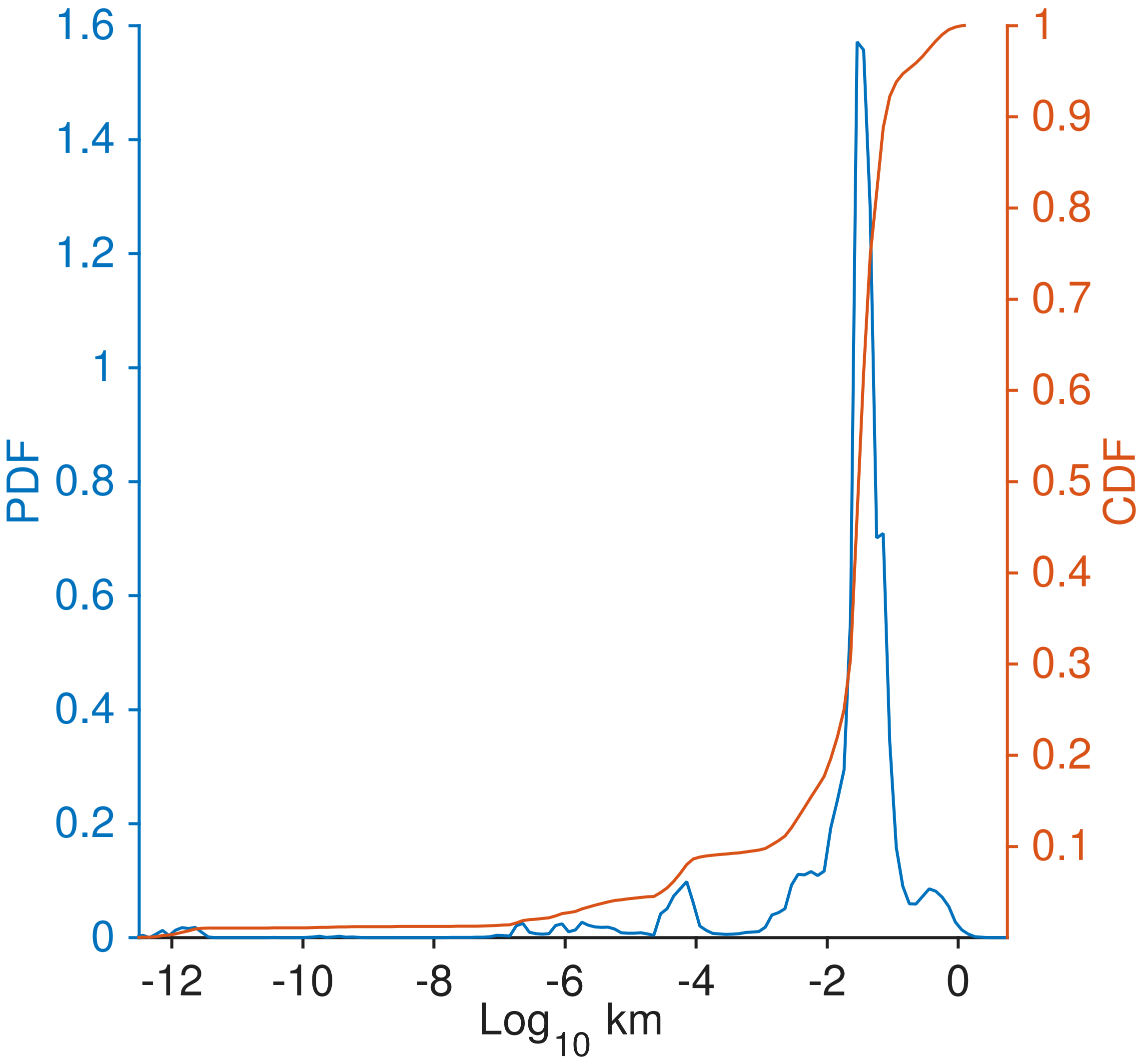
Two-step quality control algorithm developed for ***all GPS data*** from drifters:

1. If Argos positions also exist, find closest in time Class 2 or 3 fixes to each GPS fix. If speed > 3 m/s, flag GPS fix as bad.

2. Apply 1D, 5 point median filter to GPS longitudes and latitudes (mirror boundary conditions at ends). Flag fix as bad if it deviates by >5 standard deviations from median. Repeat this step five times.

Additional processing for SPURS GPS data: values within 10 minutes that produce speeds > 2 m/s removed. Locally-weighted scatter plot smoother (LOWESS) applied to remove remaining noise (position errors, unresolved ocean physics).

QC'd vs smoothed GPS

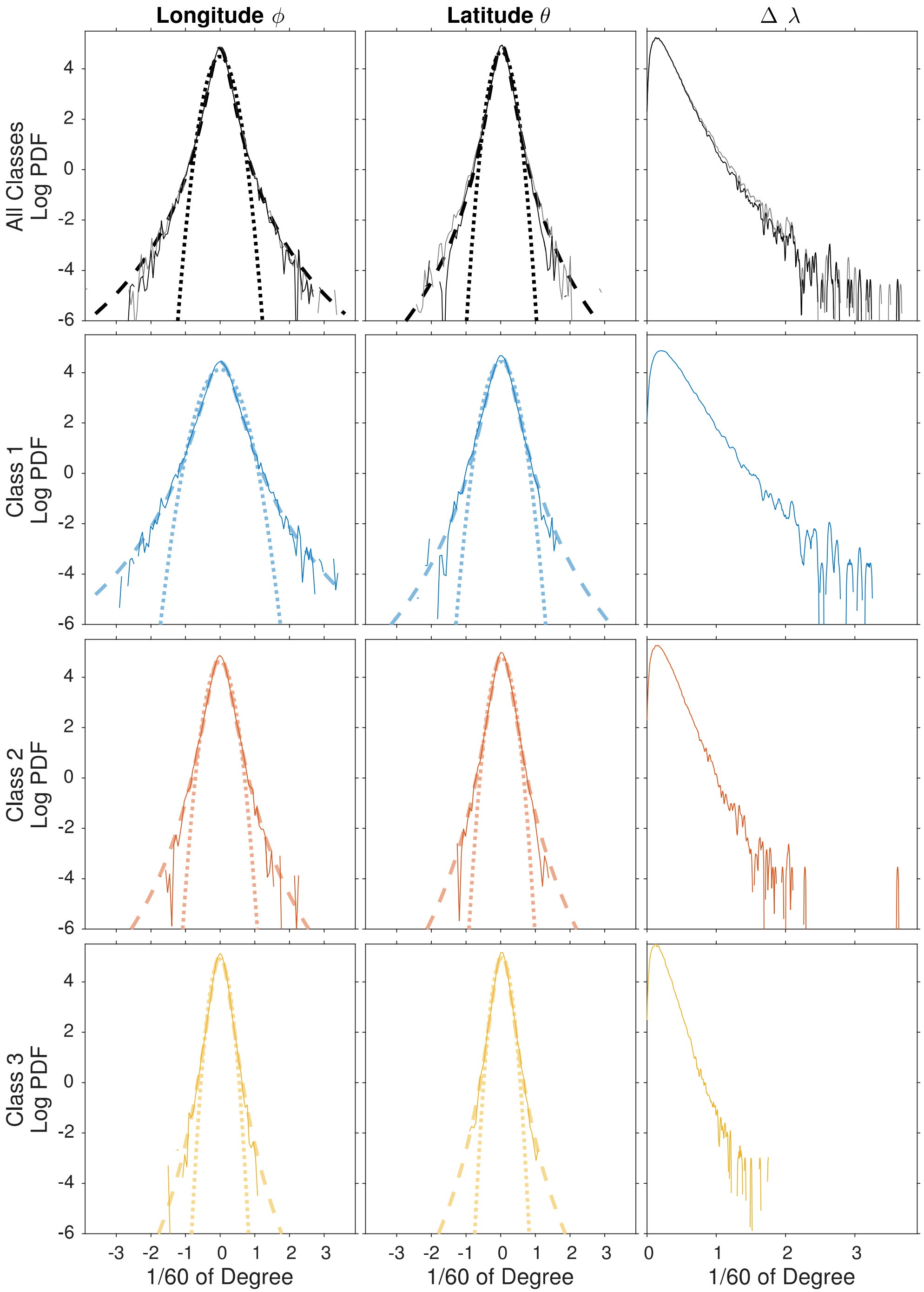


Largest change due to smoothing: 6.8 km.

50% of positions are changed <30 m.

90% are changed <77 m.

Assessing Argos position fix errors as a function of location class



Interpolate GPS fixes (“truth”) to Argos fixes, if there are GPS fixes before and after within 1 hour.

Examine differences as function of location class. Fit histogram of differences by Gaussian and Student’s T-dist.

Assessing Argos position fix errors as a function of location class

To our knowledge, this is the most rigorous evaluation of Argos errors for deployed drifting buoys. Results of evaluation:

- The errors decrease from class 1 to class 3: Argos location class is indeed a qualitative and relative indication of the location error. The most probable error (mode of the distribution) for the best location class (Class 3) is 234 m and for the worst location (Class 1) is 378 m.

- Errors are not exactly isotropic: longitude errors are 35% larger for Class 1, 12% larger for Class 2, and 5% larger for Class 3.

- Errors are not Gaussian: outliers are more likely. A Student T-distribution is a much better fit. The interpolation methodology must address this, or outliers will be given too much weight.

Method 1: kriging

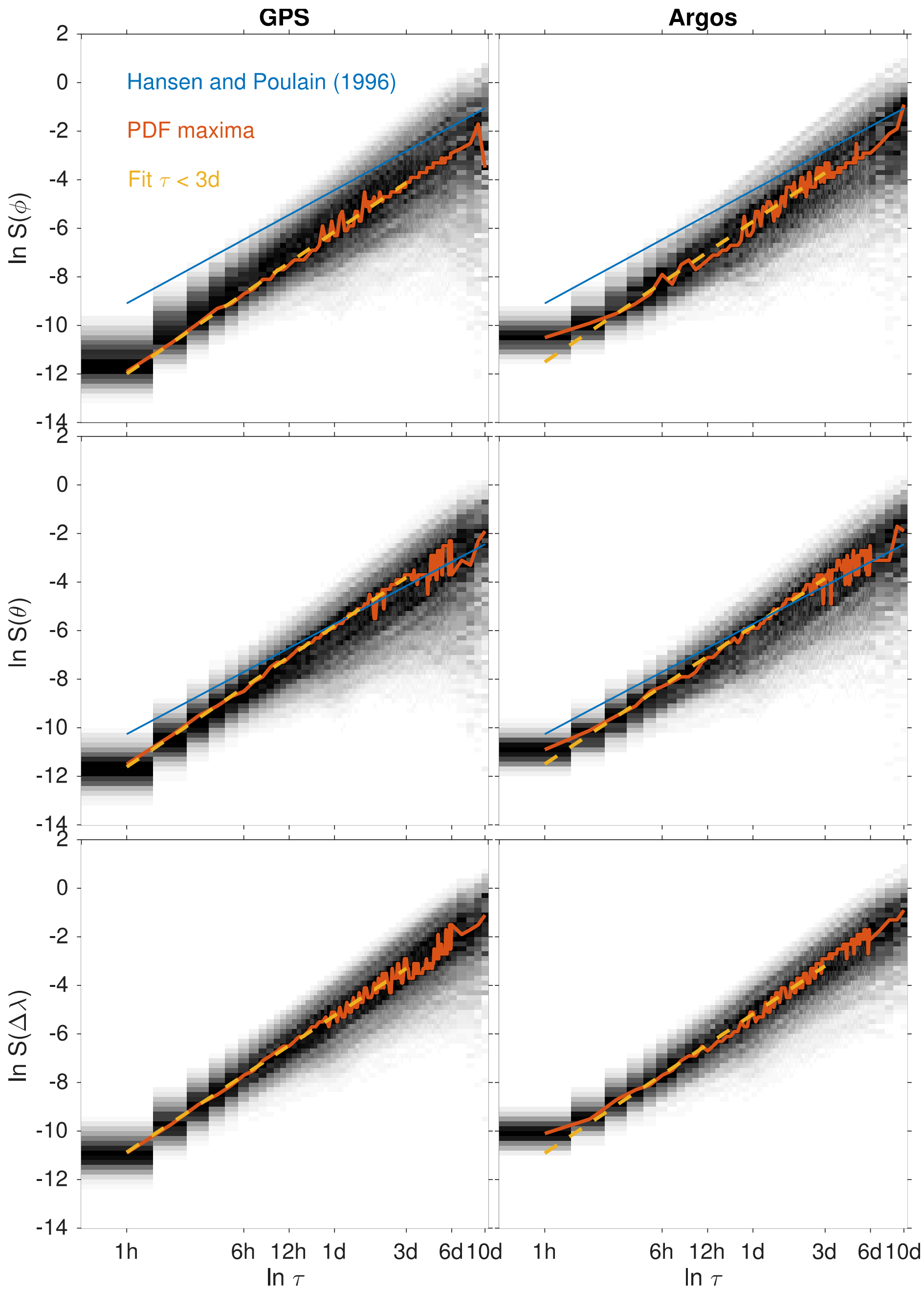
For details, see Hansen and Poulain (1996).

This is the method used for the standard GDP 6h product.

Requires structure function: $S(\tau) = \frac{1}{2}E\{[x(t) - x(t+\tau)]^2\}$

where E is the expectation operator.

Structure function calculated from data at discrete lags: hourly, from 1 hr to 6 days, then daily from 6—10 days.



Structure function estimates

$$S(\tau) = \alpha\tau^{\beta}.$$

	$10^4\alpha$	β
Longitude		
Hansen and Poulain (1996)	119, 99	1.47
GPS	22	1.84
Argos	33	1.82
Latitude		
Hansen and Poulain (1996)	33, 32	1.43
GPS	30	1.83
Argos	30	1.79
Angular separation		
GPS	53	1.77
Argos	56	1.80

Method 2: linear interpolation on a sphere

Very simple 1d linear interpolation fails to create interpolated path along great circle between points, or fails to yield constant speed along interpolated path.

Shoemake (1985): interpolate using hypercompex numbers ("quaternions").

Compared to simple linear interpolation: biggest difference is 74 m; 96% of locations are <1m different.

Method 3: weighted maximum likelihood estimator

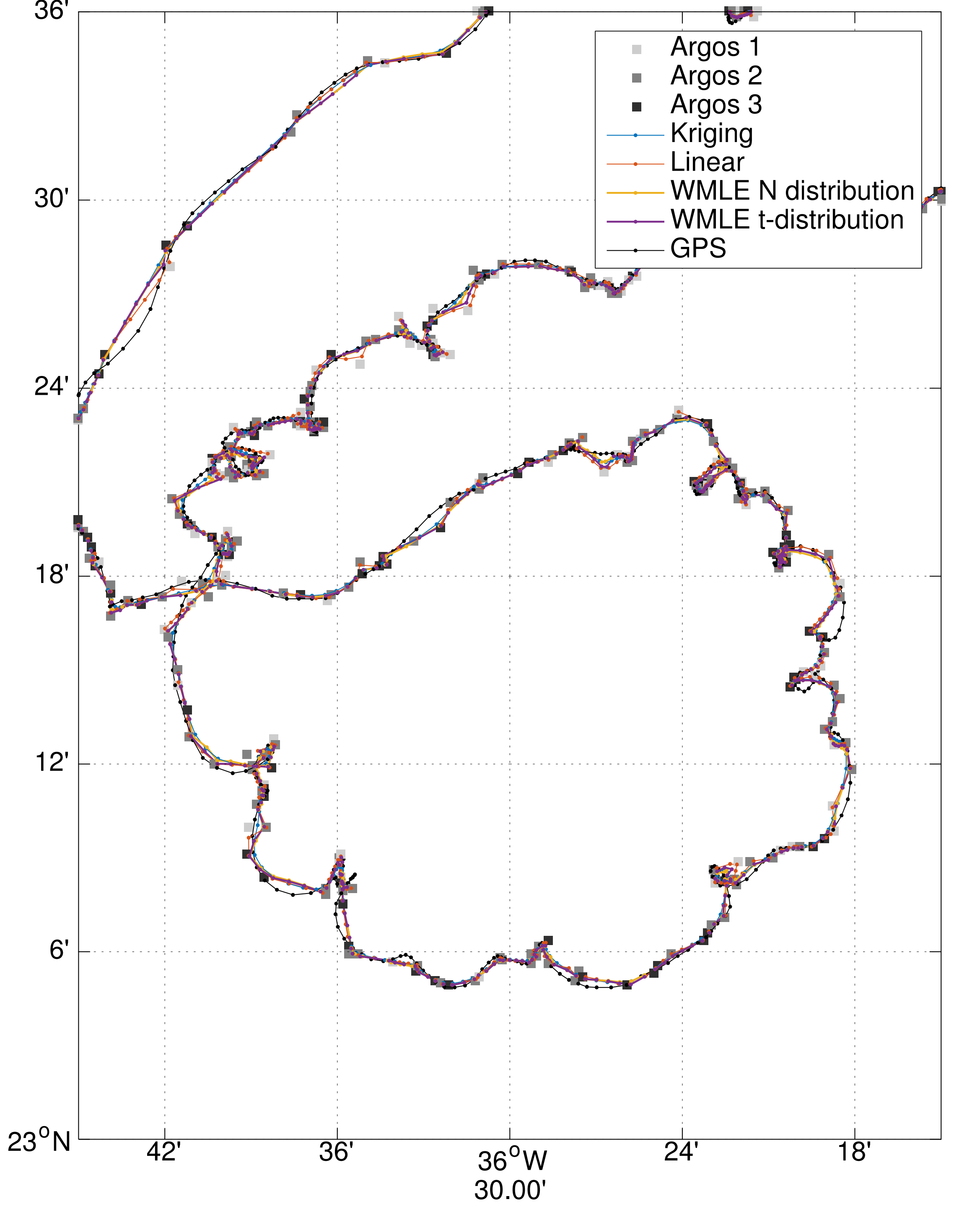
Polynomial model with prescribed error distribution (Gaussian or Student T-distribution fit as function of location class).

Weighted Maximum Likelihood Estimate (WMLE) found numerically.

Two points before and two after hourly value used for interpolation.

Method produces both interpolated positions and velocities with formal error estimates.

Example trajectory with even hourly positions

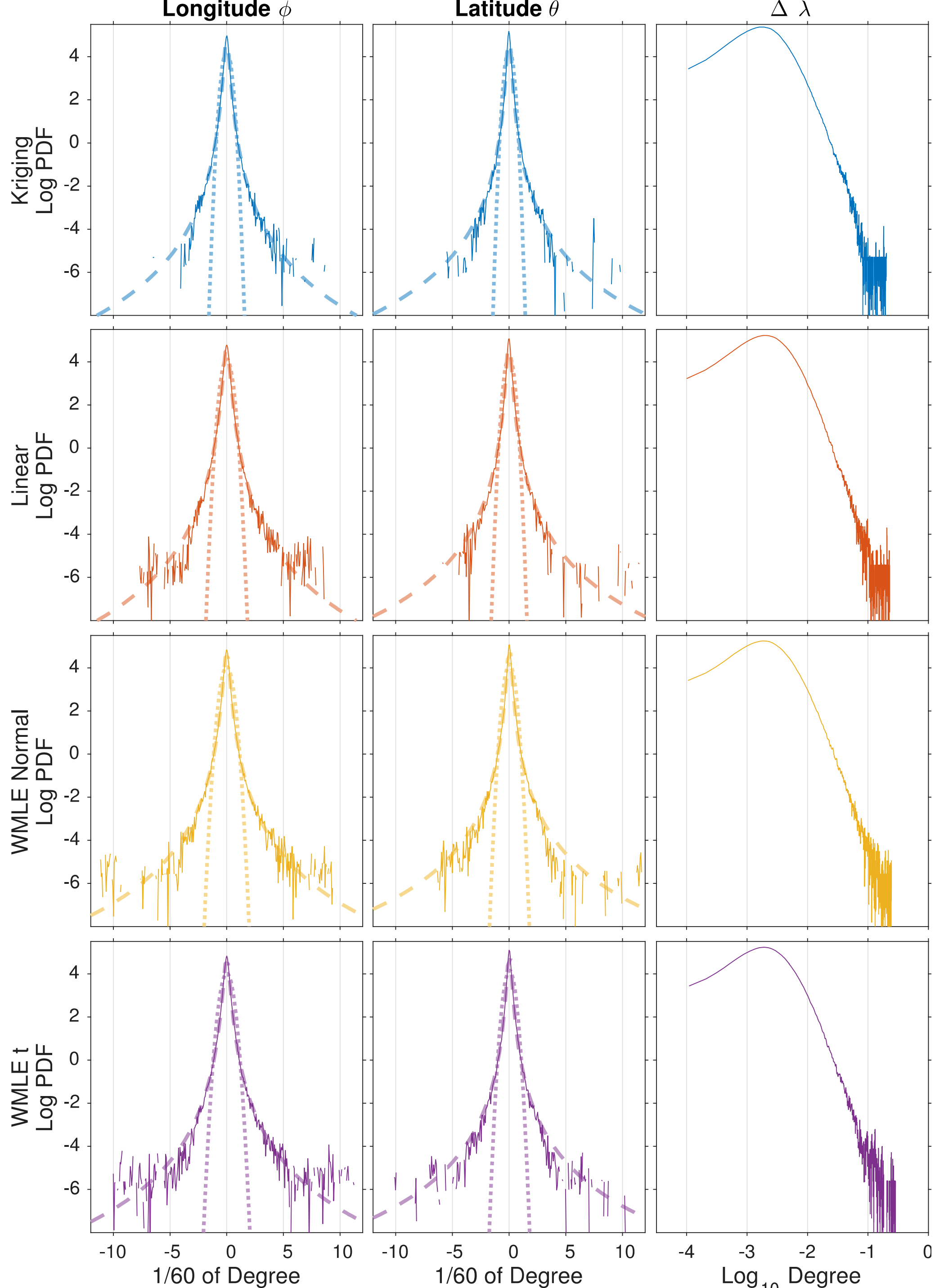


Evaluating positions

Interpolate GPS fixes ("truth") to hourly values, if there are GPS fixes before and after within 1 hour. Compare to results from each method.

All methods have a mode error smaller than the best location class of Argos fixes.

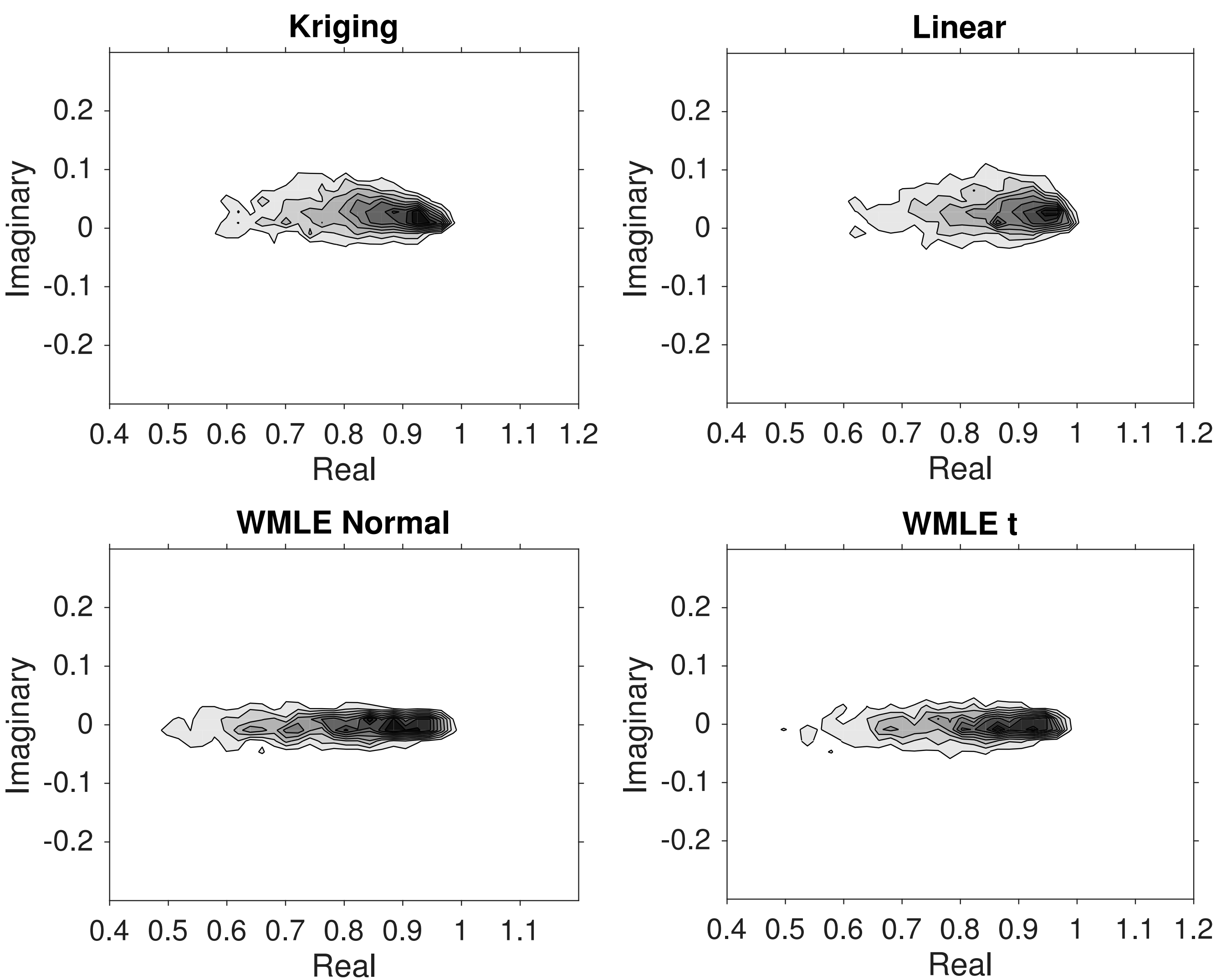
Kriging, WMLE-t: 201m mode.
WMLE-normal: 212 m.
Spherical linear: 222m.



Evaluating velocities - complex linear regression:

$$u^m(t) = \frac{R_{vu}(0)}{R_{vv}(0)} v(t) = \frac{|R_{vu}(0)|}{R_{vv}(0)} e^{i\mathrm{Arg}[R_{vu}(0)]} v(t),$$

Perfection: real=1, imaginary=0.



Kriging, linear: more spread in imaginary axis indicates Argos-derived velocities aren’t well aligned with GPS velocities.

WMLE methods: less spread in imaginary, but velocity amplitudes slightly underestimated (more spread on real axis).

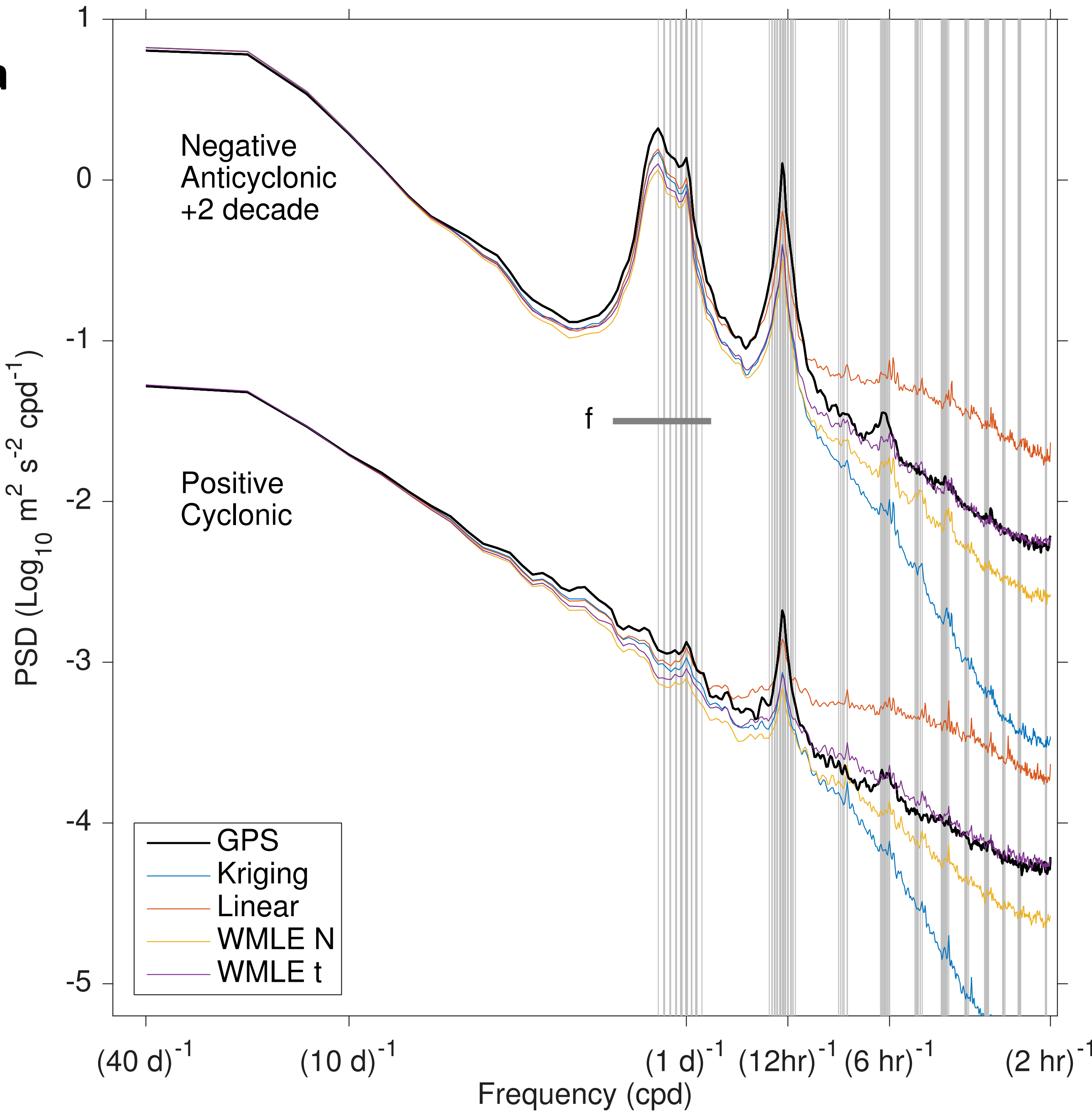
Evaluating spectra

All methods do equally well at very low frequencies.

Kriging underestimates energy at high frequencies (oversmoothing).

Spherical linear interp has too much energy at high frequencies (noise added).

WMLE methods are best, especially WMLE with Student T-dist (nearly identical spectra to GPS)



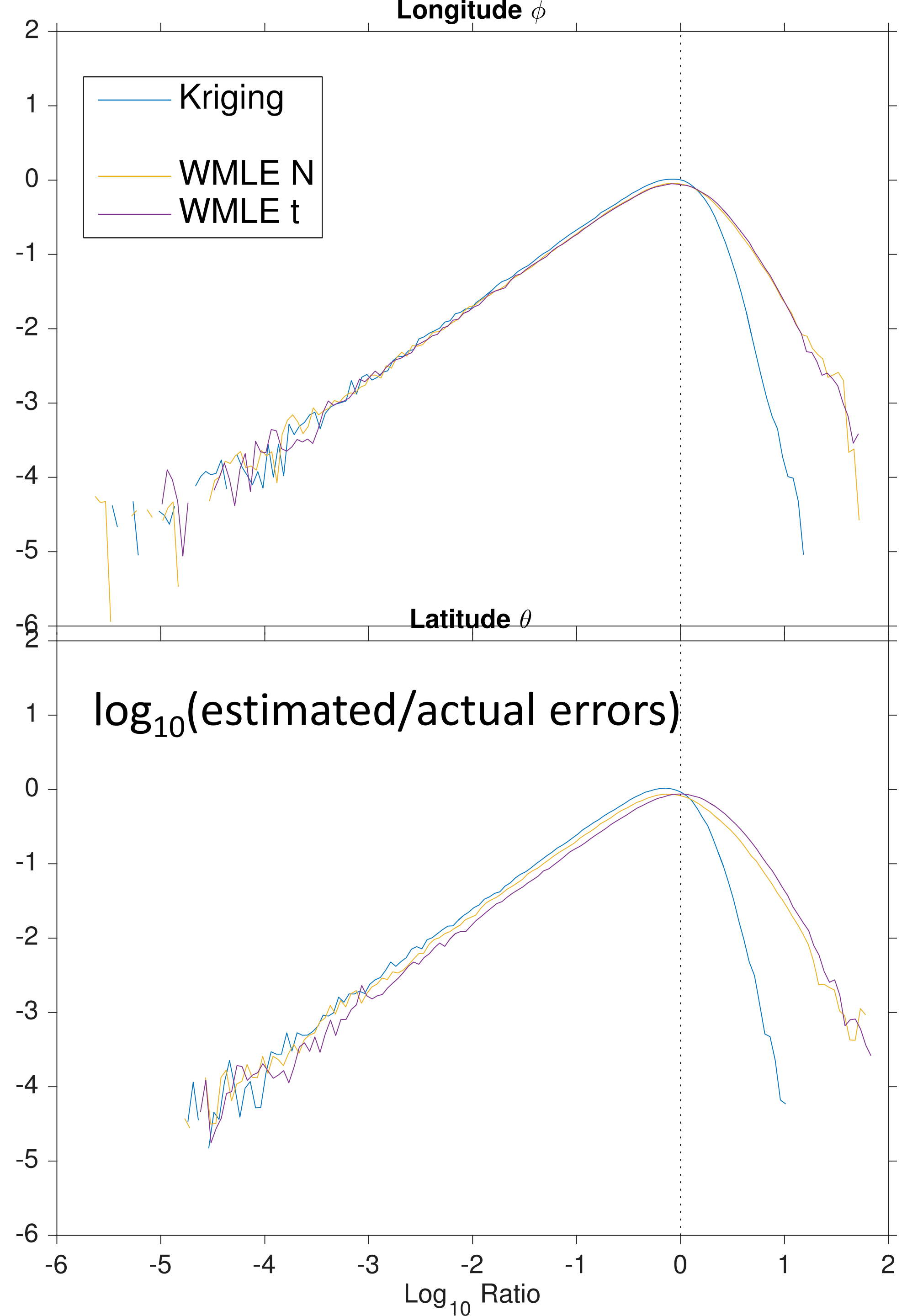
Evaluating formal error estimates

Kriging and WMLE methods provide formal error estimates on the positions (WMLE also provides velocity error estimates).

We can compare these estimates to the actual errors, using the GPS positions.

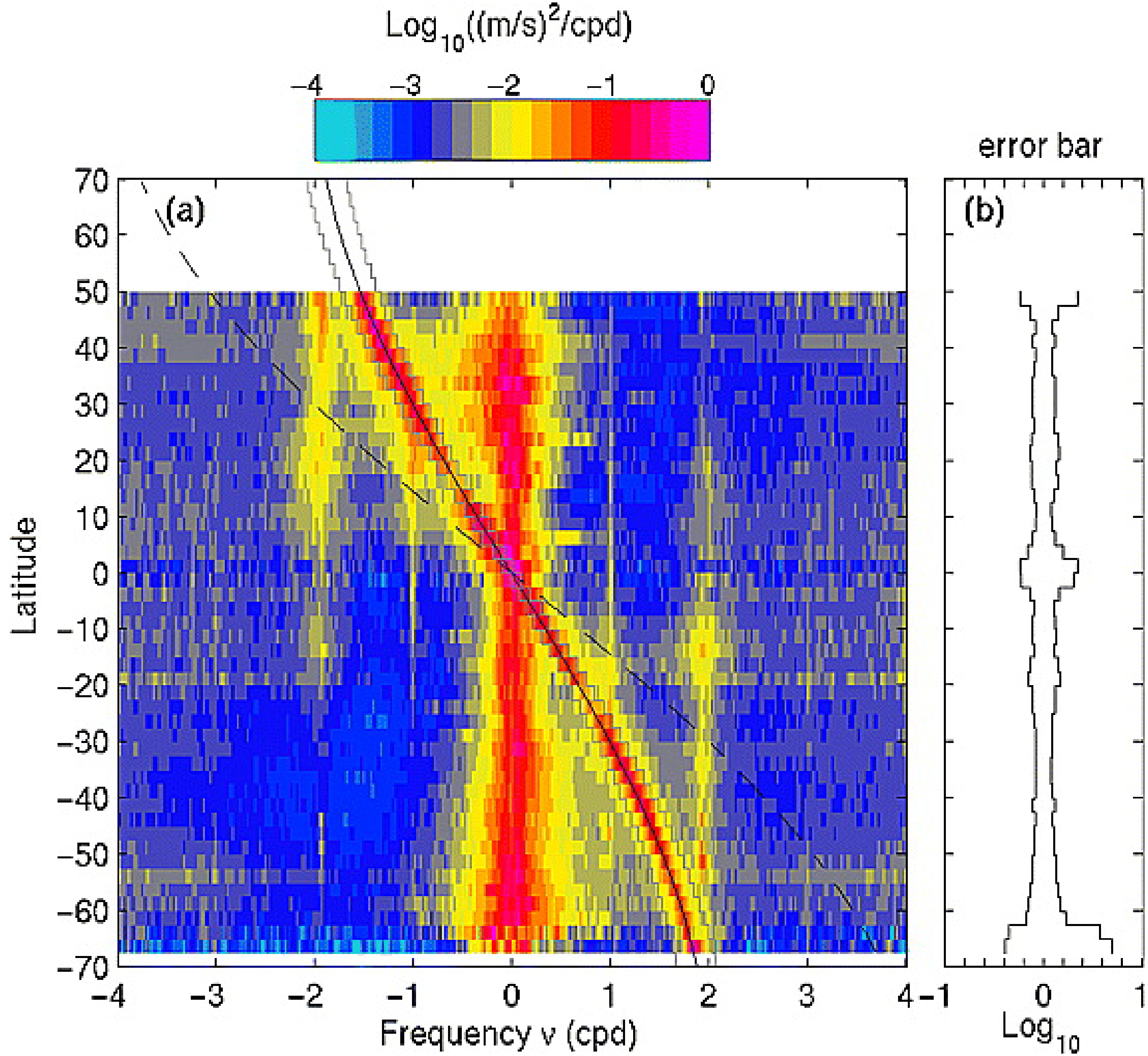
Results:

Mode of (estimated/actual errors) is very similar for the three methods, but the mean is ~1 only for WMLE. Kriging tends to underestimate errors, especially for large outliers.

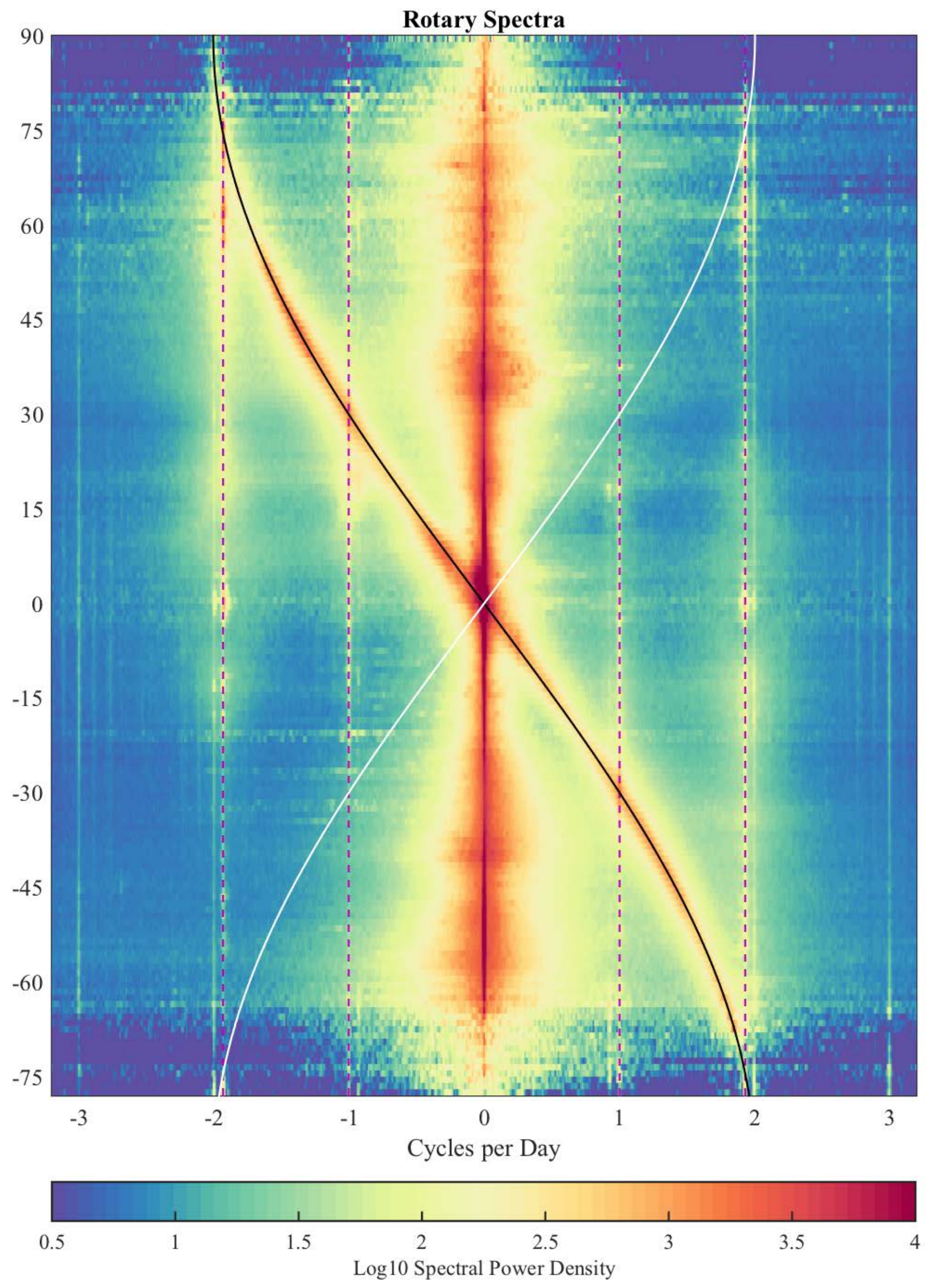


Conclusions

- Weighted Maximum Likelihood Estimator with a Student T-distribution to fit Location Class errors is the overall best approach.
- Results documented in manuscript, in preparation for submission to *JAOT*.
- Data set will be released upon acceptance (to make sure no major changes are necessary).

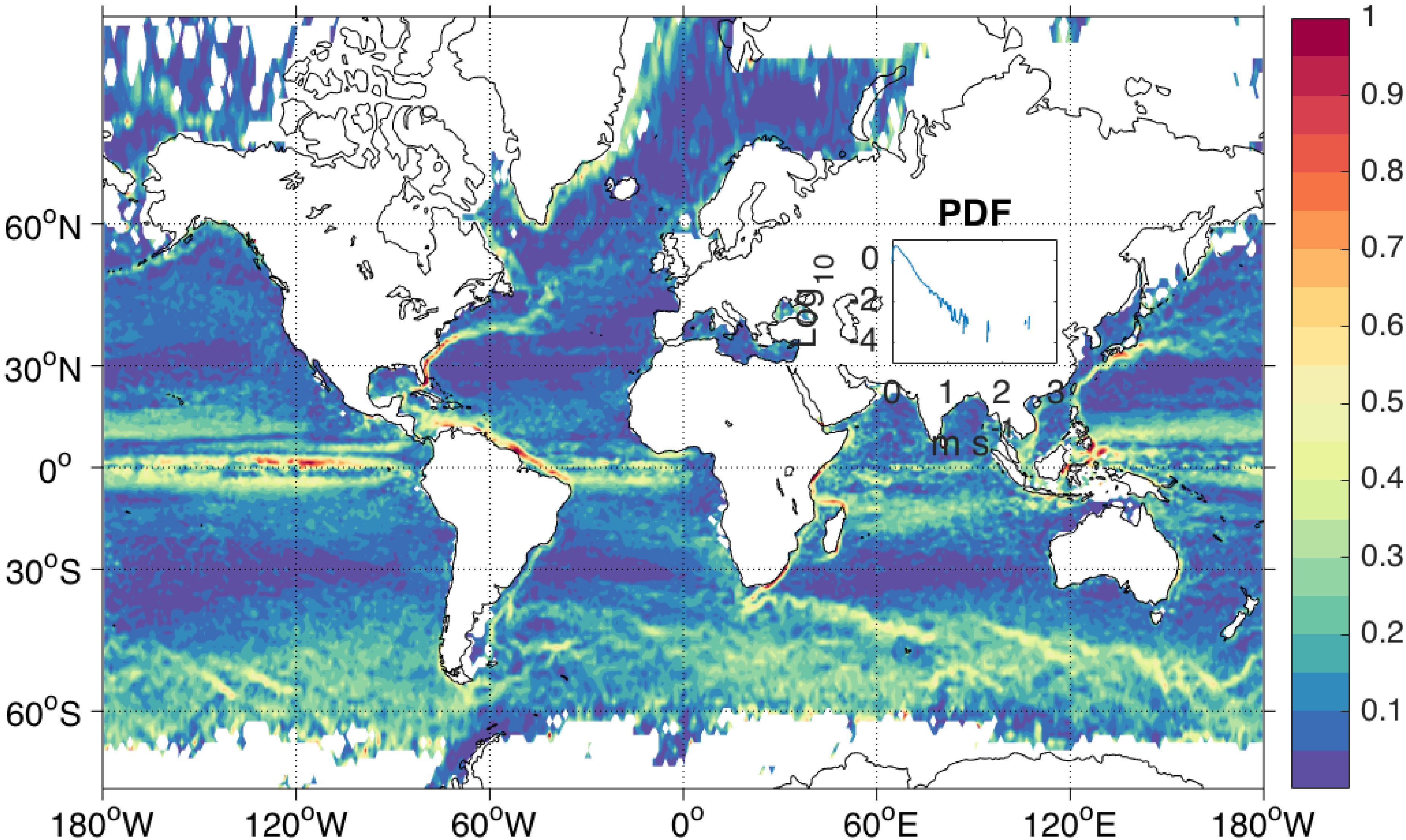


Log10((m/s)2/cpd)
−4
−3
−2
−1
0
error bar
(a)
(b)
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
Latitude
−4
−3
−2
−1
0
1
2
3
4
Frequency ν (cpd)
−1
0
1
Log10



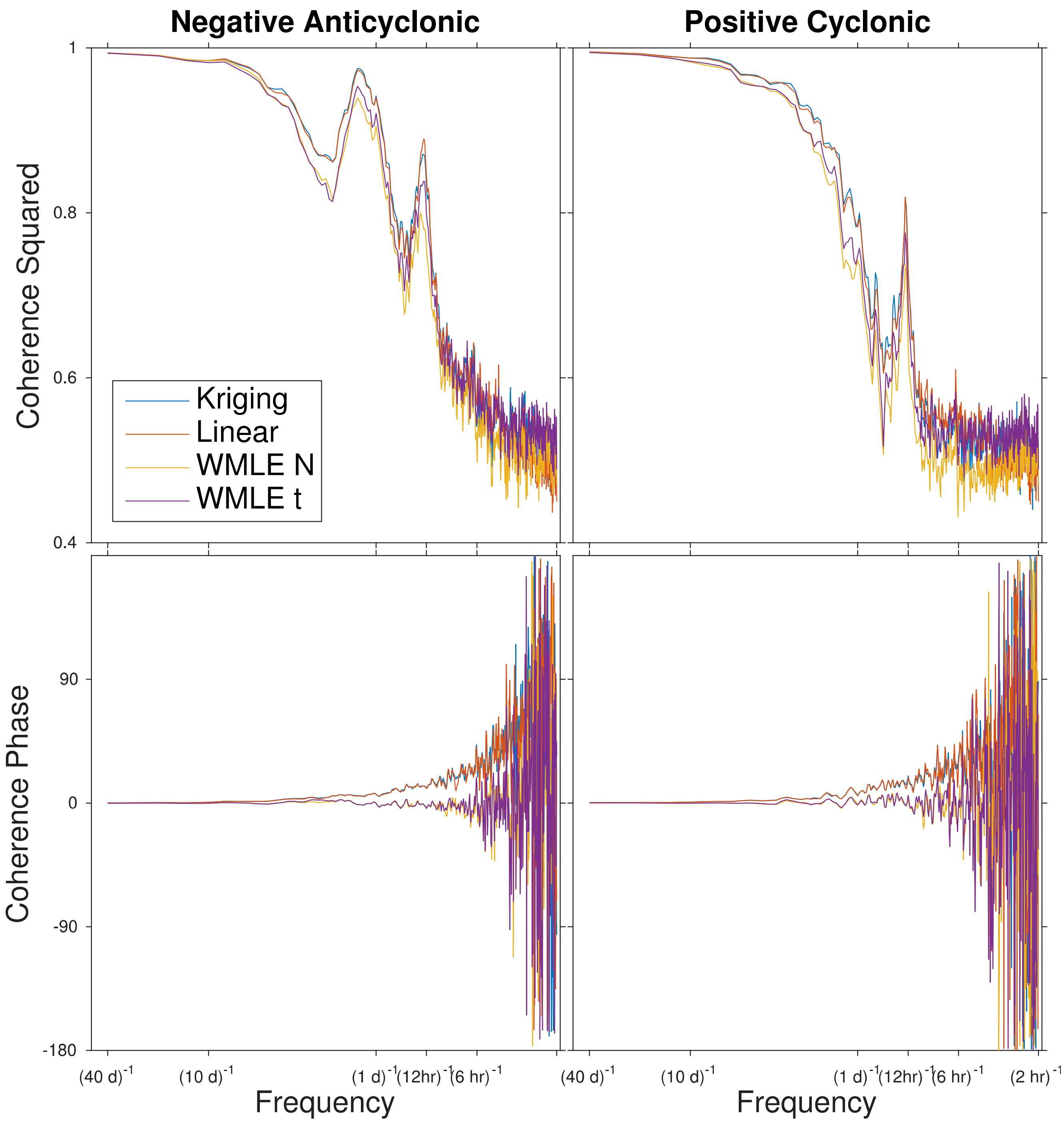
Rotary Spectra
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
-3
-2
-1
0
1
2
3
Cycles per Day
0.5
1
1.5
2
2.5
3
3.5
4
Log10 Spectral Power Density

Time-mean speed (m/s) from global hourly data set

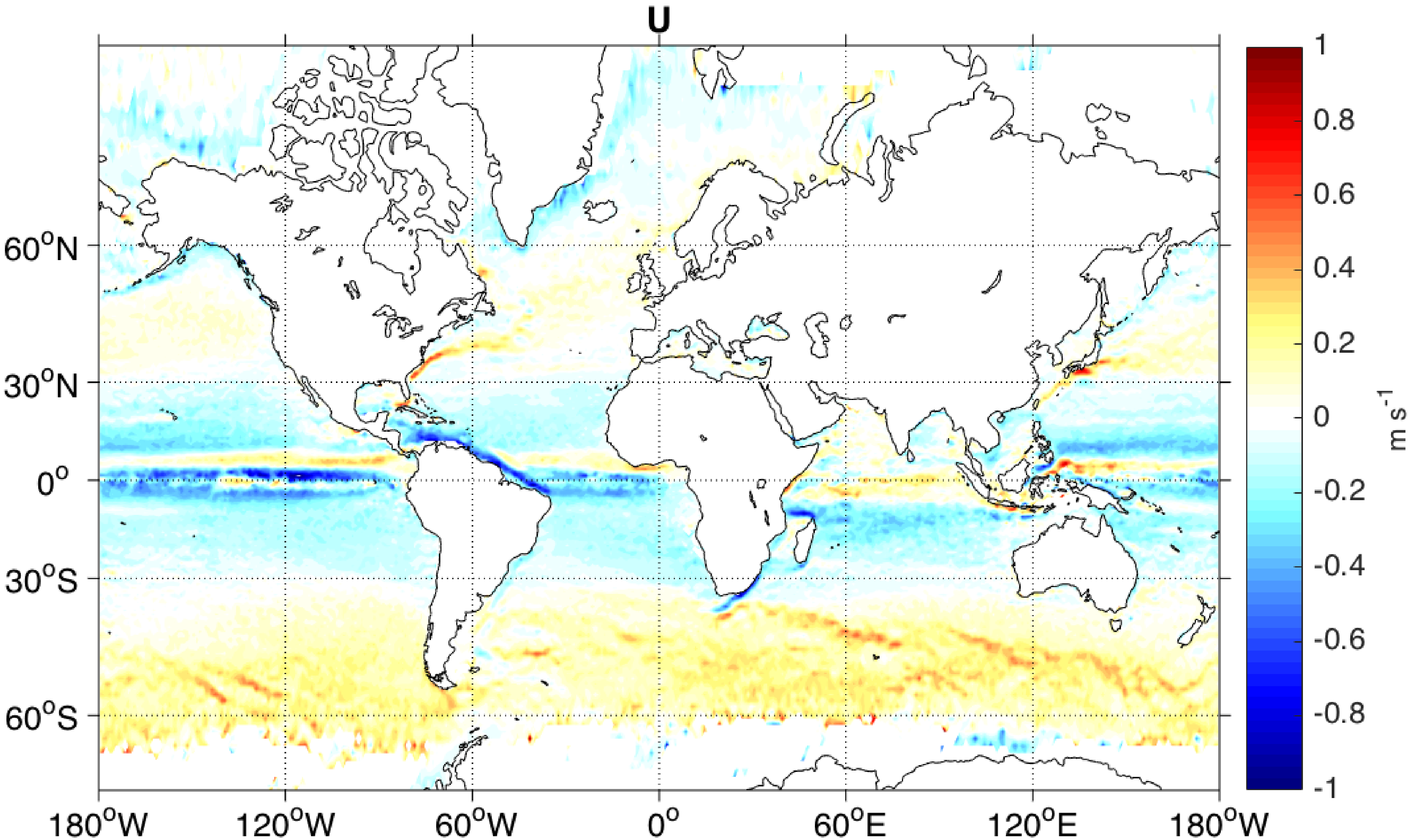


All methods do well at very low frequencies, but kriging and linear slightly outperform others.

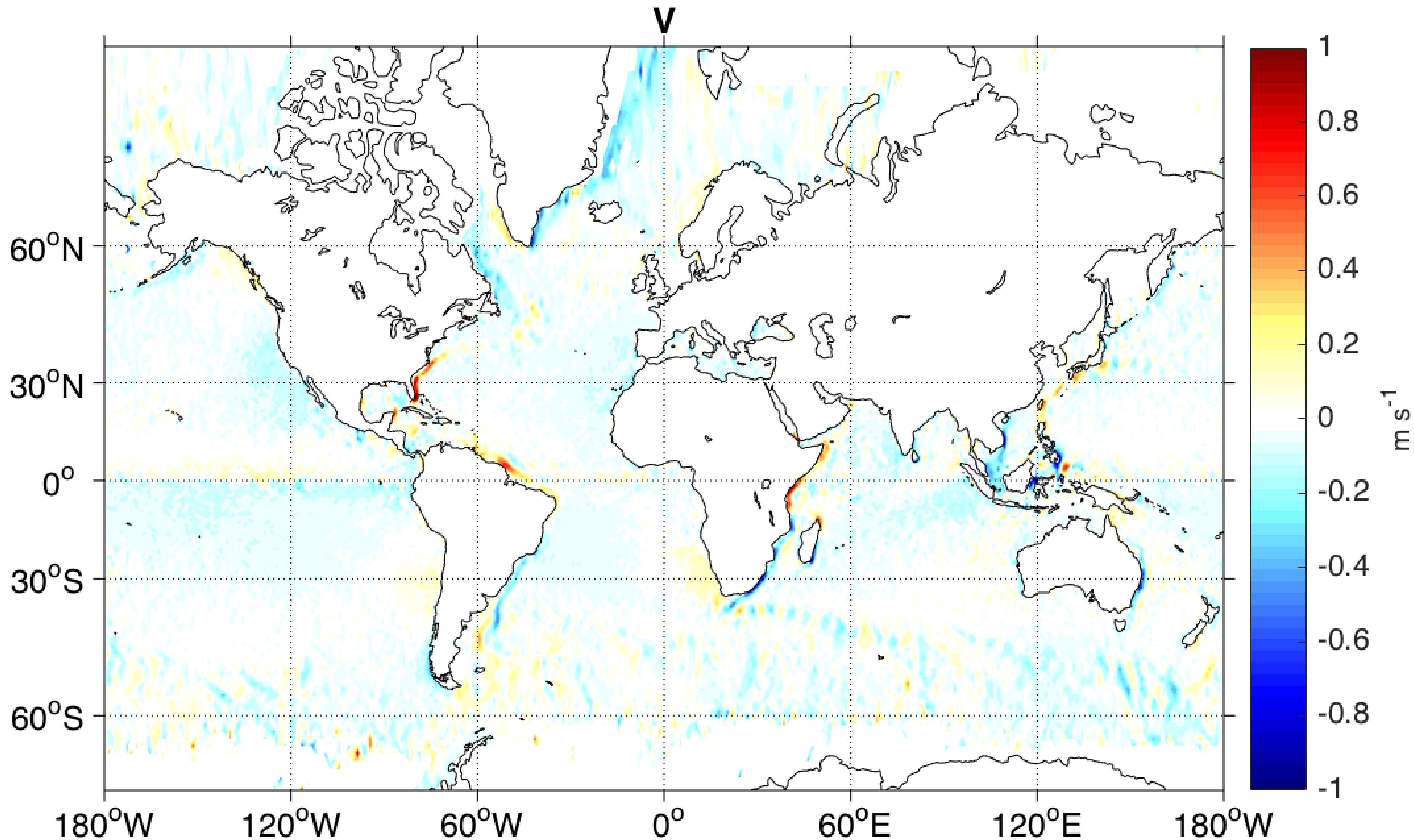
Kriging and linear introduce phase bias at higher frequencies that implies a constant lag with respect to GPS velocities.

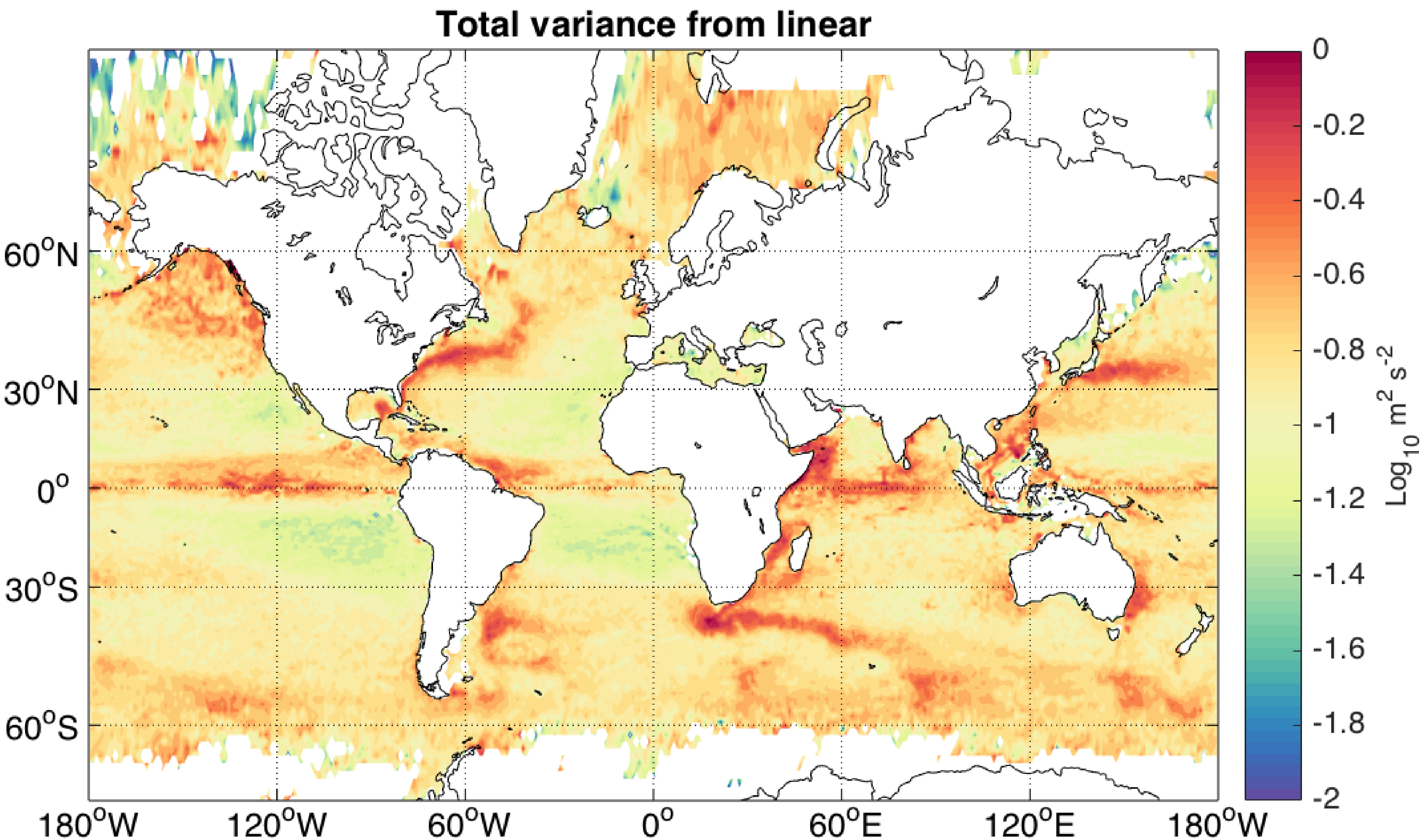


Zonal velocity from spherical linear interpolation



Meridional velocity from spherical linear interpolation




Total variance from linear
60°N
30°N
0°
30°S
60°S
180°W
120°W
60°W
0°
60°E
120°E
180°W
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
Log$_{10}$ m^2 s^{-2}