Upper Ocean Velocity Distributions: Comparing Topex with Jason and Interpreting Altimetry with Winds

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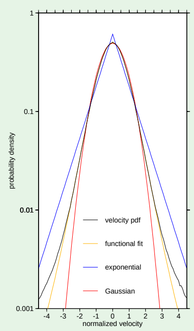
Background: Probability Density Functions

Probability density functions (PDFs) measure the likelihood that a particular data value will be observed. Most physical quantities are expected to have Gaussian distributions, but surprisingly, this expectation is not always met.

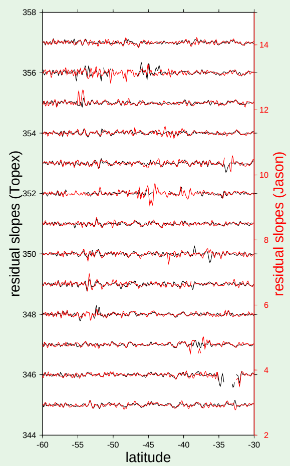
Here PDFs are computed from altimeter-derived geostrophic velocities. PDFs are used to address two issues:

- **Cal/Val: Assessing whether velocity distributions of Jason data match distributions from TOPEX data. Do the instruments observe extreme velocities with the same frequency?**
- **Ocean response to wind: Why are oceanic PDFs more Gaussian than wind PDFs, and what does this tell us about the ocean's dissipation of wind energy?**



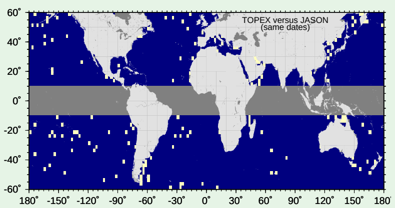
Globally-averaged velocity PDFs are Gaussian near zero, but indicate non-Gaussian tails. This PDF is computed from TOPEX sea surface slope data. In this case, data have ben normalized by the local variance.

Quality Controlling Jason, Topex, and Poseidon

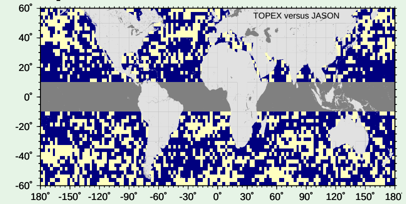


Time series for track 'a003' in the Southern Ocean show that TOPEX and JASON measurements are roughly in agreement although both instruments show signs of anomalous events. Data processing methodology adapted from Yale et al. [1995].

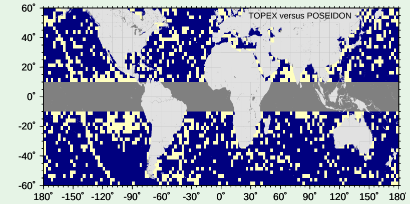
Kolmogorov-Smirnov statistics are a formal mechanism to diagnose whether two randomly sampled data sets are drawn from the same PDF. Here, they are used to assess whether PDFs of preliminary Jason IGDR data match PDFs of older, well-calibrated TOPEX data.



Global map based on Kolmogorov-Smirnov statistics shows that Jason and TOPEX observations are statistically indistinguishable (blue) over most of the ocean when only data from the overlap time period are considered. Roughly 4% of the data boxes have PDFs that differ (yellow). In these boxes there is a greater than 95% probability that we should reject the null hypothesis, which assumes equivalent PDFs.

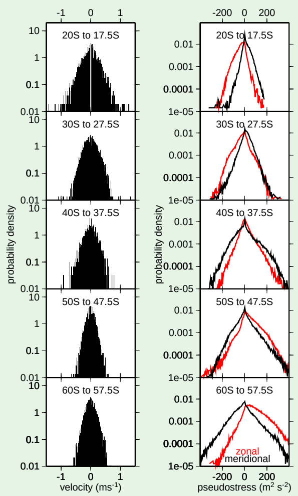


Temporal variability is substantial, and PDFs are not stationary in time. When all available data are used, PDFs from Jason differ from TOPEX PDFs in 40% of the available boxes.



POSEIDON data from the TOPEX/POSEIDON satellite differ from TOPEX data in 25% of sampled boxes. This can be partially attributed to temporal variability, but may also be due to altimeter noise.

Using PDFs to Understand How the Ocean Responds to Wind Forcing



Wind PDFs are shaped differently than ocean velocity PDFs. These sample PDFs come from altimeter and scatterometer observations along the dateline.

To understand differences between wind and ocean PDFs, consider the system:

$$\frac{\partial u}{\partial t} = -bu + \tau^x.$$

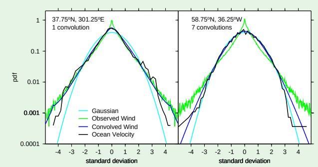
In this system, ocean velocities (u) are accelerated and decelerated by the wind (τ^x). Linear drag dissipates wind energy with a time scale T, where $b = 1/T$.

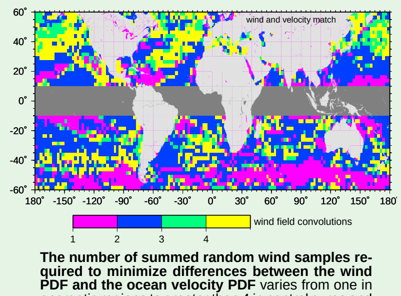
If b is small, then the ocean has a very long memory, and ocean velocities will represent a summation of many independent wind forcings. Since we sum many independent samples, the central limit theorem says that u should have a Gaussian distribution.

If b is large, then the ocean has very little memory, and ocean velocities will directly reflect wind velocities. In this case we expect that u should have the same PDF as τ^x.

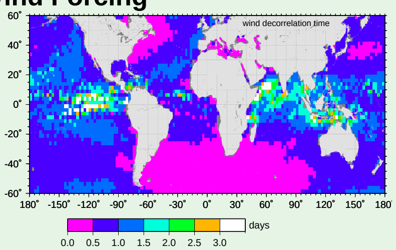
The real ocean must lie somewhere in between these extremes. Can we use the differences between the PDFs of u and τ^x to infer the effective dissipation time scale b for the ocean?

An ocean velocity PDF resembles a wind PDF that has been convolved with itself. (Left) In the Gulf Stream the ocean "remembers" roughly two random kicks from the wind. (Right) Elsewhere, ocean velocities resemble a summation of many random forcings.

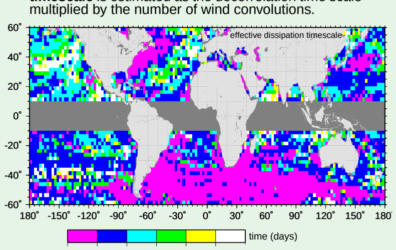




The number of summed random wind samples required to minimize differences between the wind PDF and the ocean velocity PDF varies from one in energetic regions to greater than 4 in central gyres and high latitude regions.



(above) **The decorrelation time scale** for oceanic velocities varies spatially. (below) **Effective dissipation timescale** is estimated as the decorrelation time scale multiplied by the number of wind convolutions.



Summary

- Jason data do not appear statistically different from recent TOPEX data, on the basis of Kolmogorov-Smirnov tests. Temporal variability in the ocean makes comparisons between Jason and the full TOPEX record difficult.
- Ocean velocity PDFs resemble wind PDFs that have been convolved with themselves. The number of convolutions varies depending on the geographic region, and appears large in quiescent regions with low eddy energy.

For further information and preprints see: http://www-mae.ucsd.edu/~sgille/