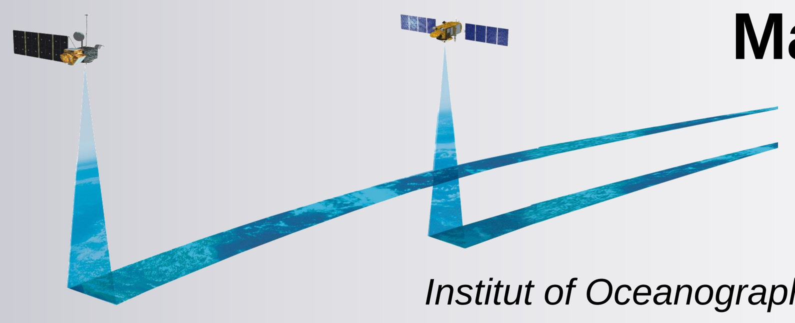
A Probabilistic Description of the Mesoscale Eddy Field in the Ocean

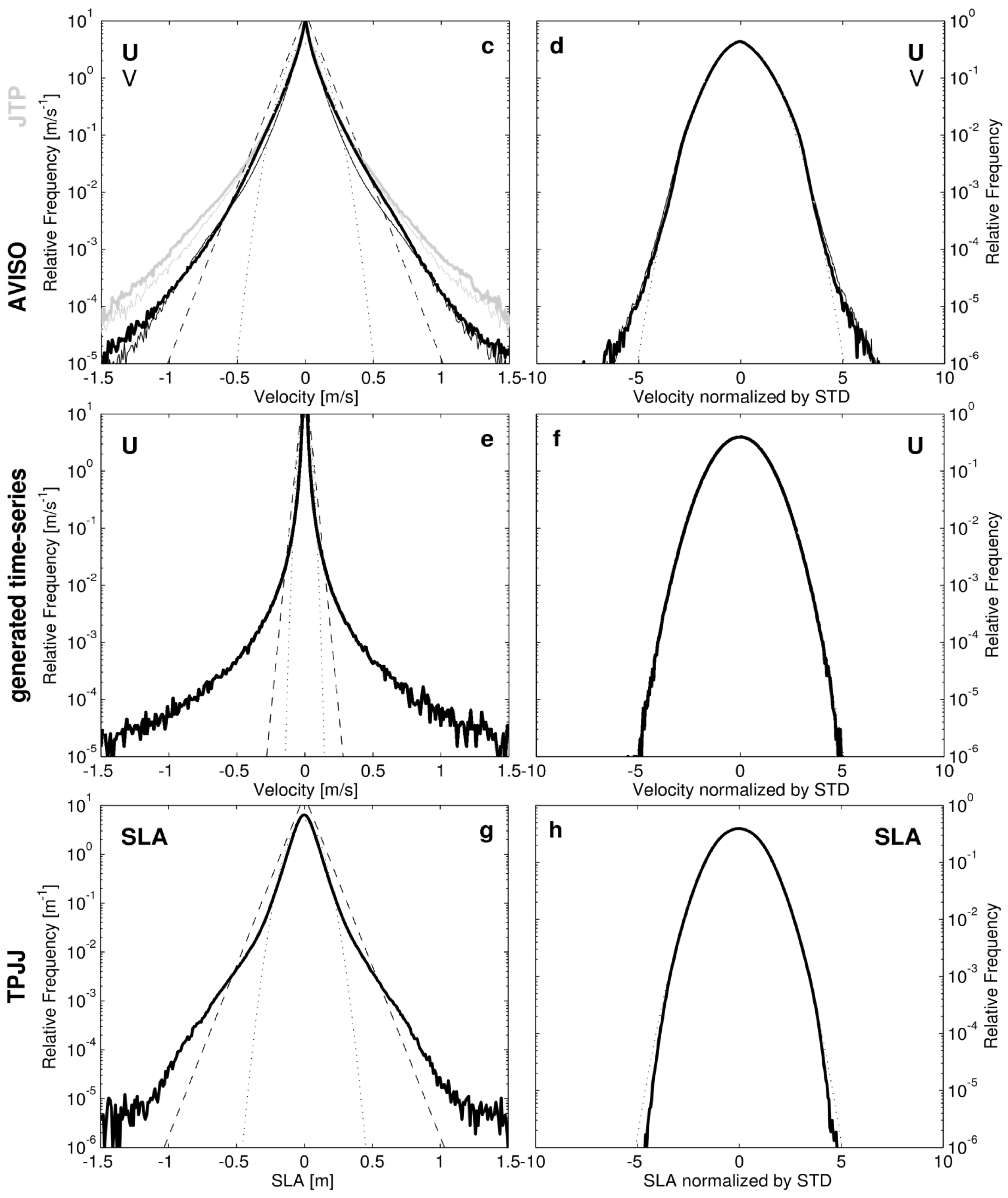


Martin G. Scharffenberg
Stavroula Biri
Detlef Stammer
Institut of Oceanography, CEN, University of Hamburg, Germany

Global and regional probability density functions (PDF) and higher statistical moments are analyzed for anomalies of the surface geostrophic velocity components inferred from the 3 year Jason-1 TOPEX/POSEIDON Tandem mission and for sea level anomalies (SLA) observed through the TOPEX/POSEIDON, Jason-1 and Jason-2 altimetric missions, together covering a 19 year period. Results are compared with those obtained from the AVISO 19 year, 1/3° gridded SLA space-time objective analysis, and associated geostrophic velocity anomalies. The study reveals that eddy variability appears to be Gaussian over most parts of the ocean, outside the influence of energetic current systems, and that specific flow regimes in the ocean can be identified through higher statistical moments of the flow field and SLA observations. However, the moment-ratio diagrams of skewness and kurtosis reveal that in energetic boundary currents the ocean does not follow Gaussian statistics, but rather behaves like an exponential distribution. Higher statistical moments of SLA and velocity anomalies do vary seasonally and thereby provide valuable information about the seasonal changes of the oceans' flow field.

Estimates of PDF

global



Global histograms (◄ c) resemble an exponential PDF for along-track JTP velocities (grey) as well as for gridded AVISO products (black).

The shape of individual histograms averaged over 10°x10° regions (a ►) varies significantly over the ocean. The width is increased in regions of high STD (background color). Most histograms have a gaussian shape, except in high energetic regions where it is exponential.

This suggests that global histograms (◄ c) are impacted by inhomogeneous statistics. Normalizing individual time series (◄ d) with their local STD prior computation of statistics should then lead to a Gaussian mean distribution.

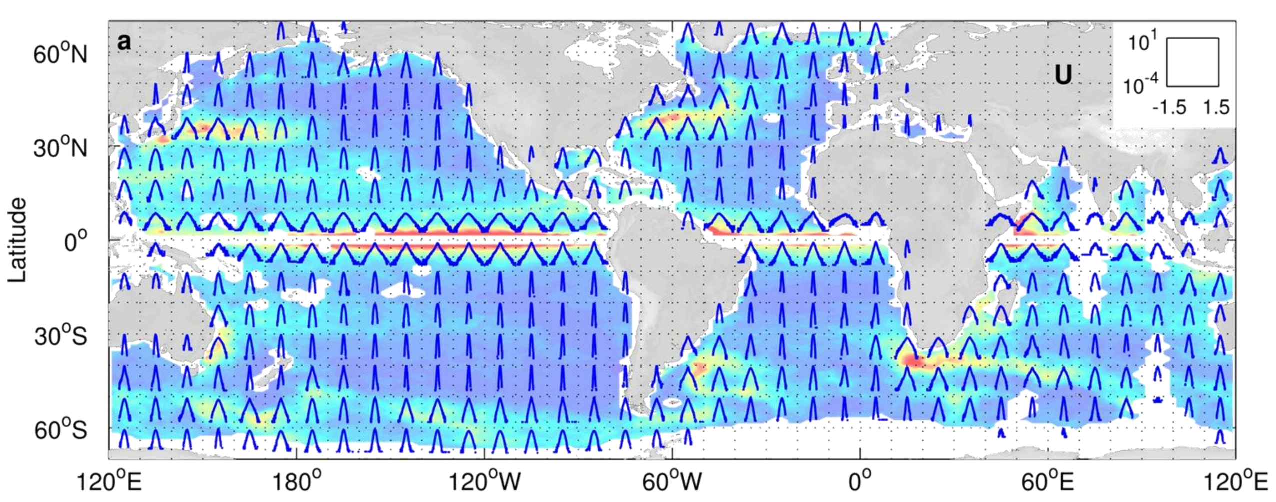
Using 10.000 Gauss distributed random time series with varying mean but invariable STD leads to a Gauss distributed histogram (◄ f).

Allowing the STD to vary leads to an exponential histogram (◄ e).

As for the velocities above, the global mean histogram of along-track SLA has an exponential distribution (◄ g).

Again, when the time series are normalized prior the computation of the statistics, the histogram (◄ h) has an almost perfect Gaussian distribution.

regional

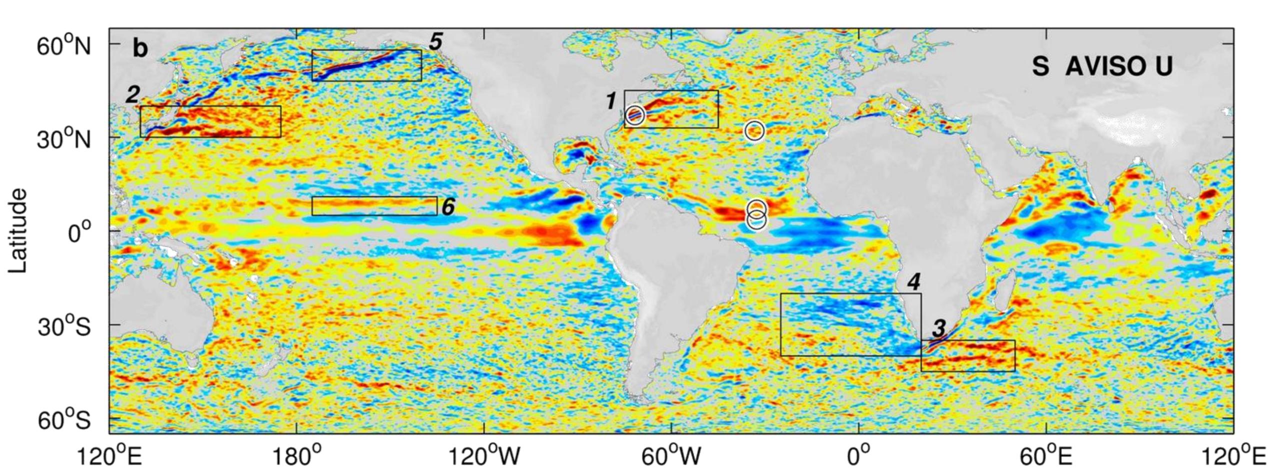


Skewness

marks the location of major current systems, as the triple pole structure[+ - +] in vicinity of meandering jets (Box1, 2).

Negative S e.g. in Agulhas ring corridor (Box4) or Alaskan Stream (Box5).

Patchy structure > eddies of differing strenght and rotation

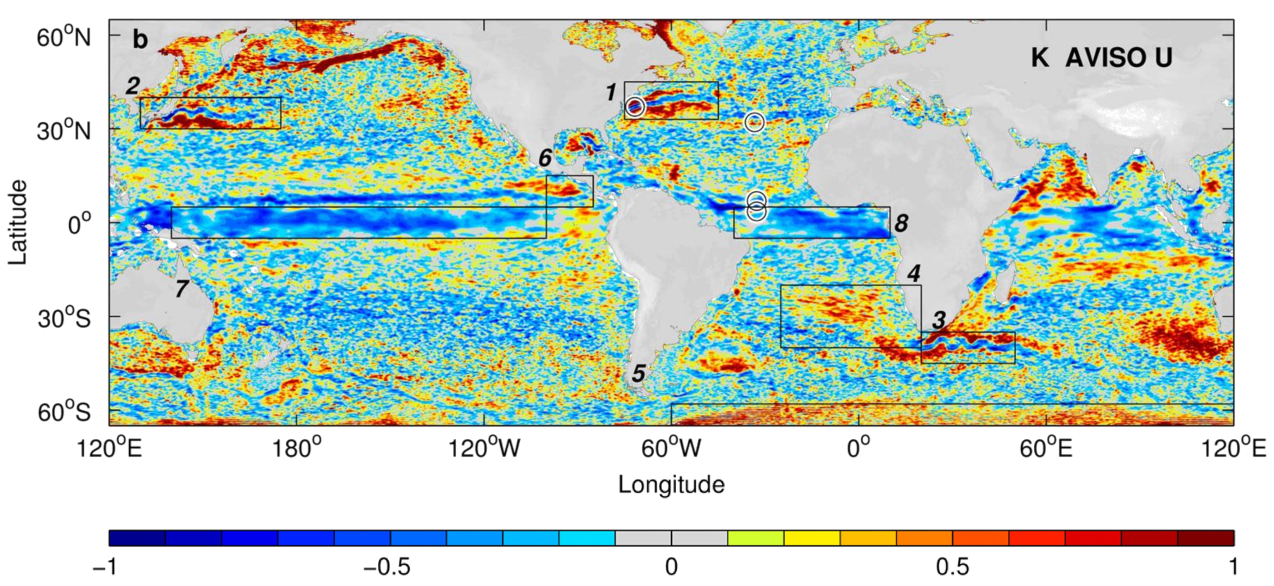


Kurtosis

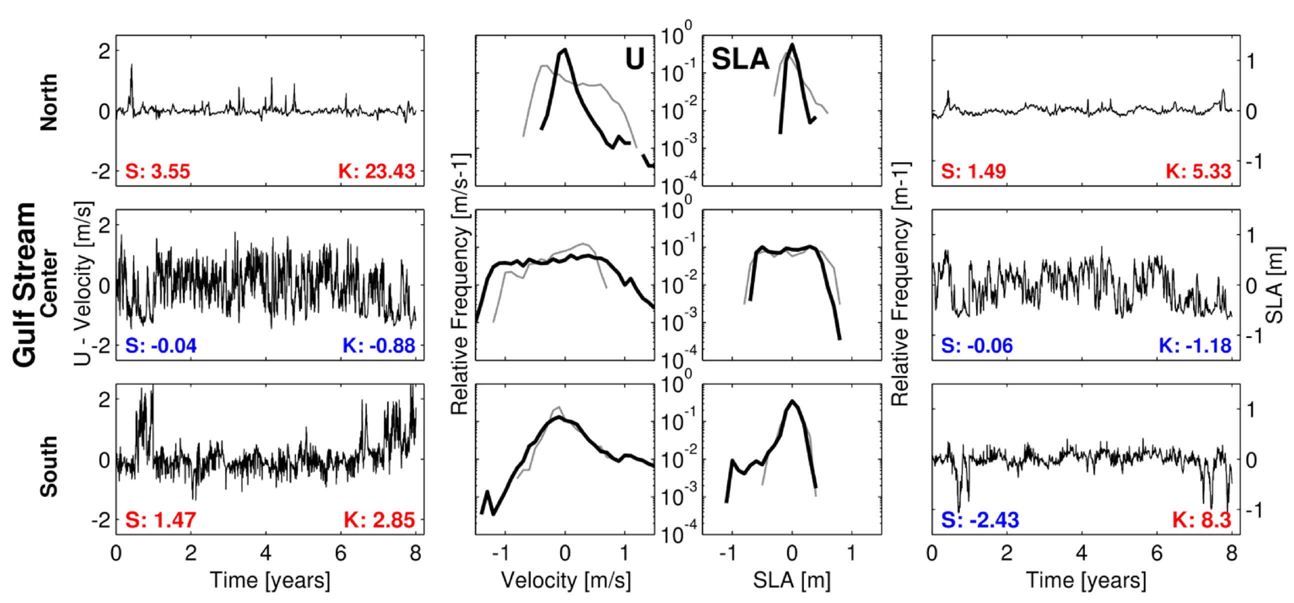
Positive K (peaked PDF) in regions populated by infrequent intense eddies (Boxes1 to 6).

Negative K dominates the equatorial regions.

Boundary currents exhibit triple pole structure [+ - +]. [-] mean axis of a jet has rather steady flow. [+] north and south of the mean axis due to infrequent eddies.



Dynamical Interpretaion

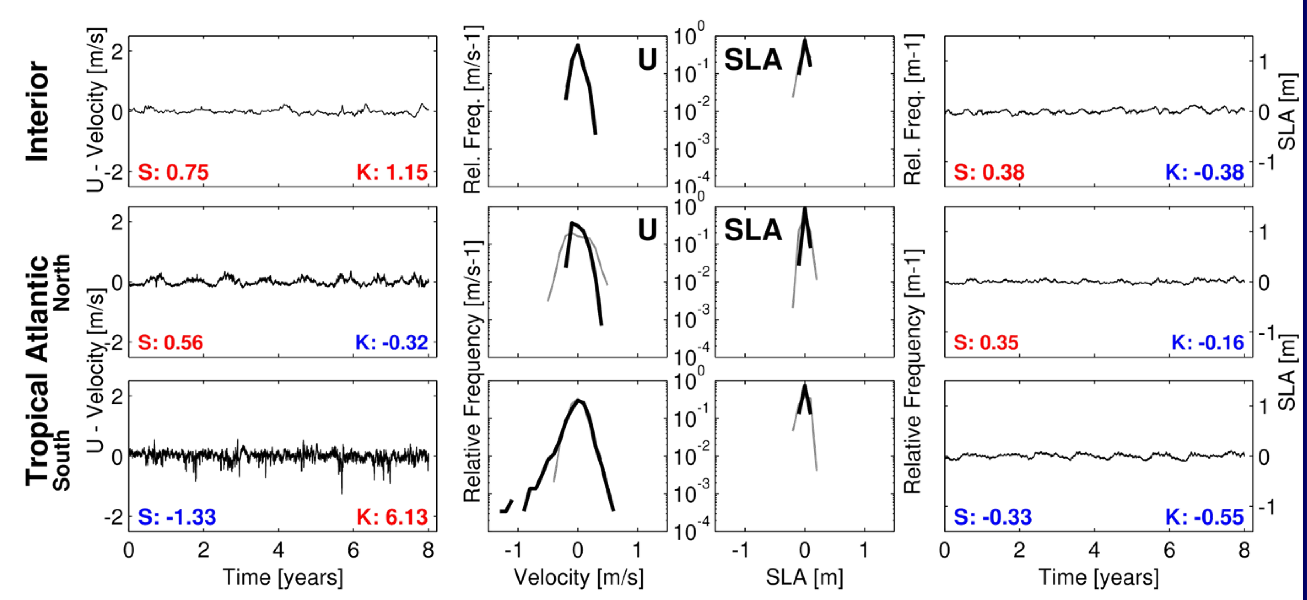


Time series and corresponding histograms of U and SLA from an eddy resolving circulation model with 4 km resolution. Black circles in S and K (▲ b).

► Interior: histograms of U and SLA are normally distributed.

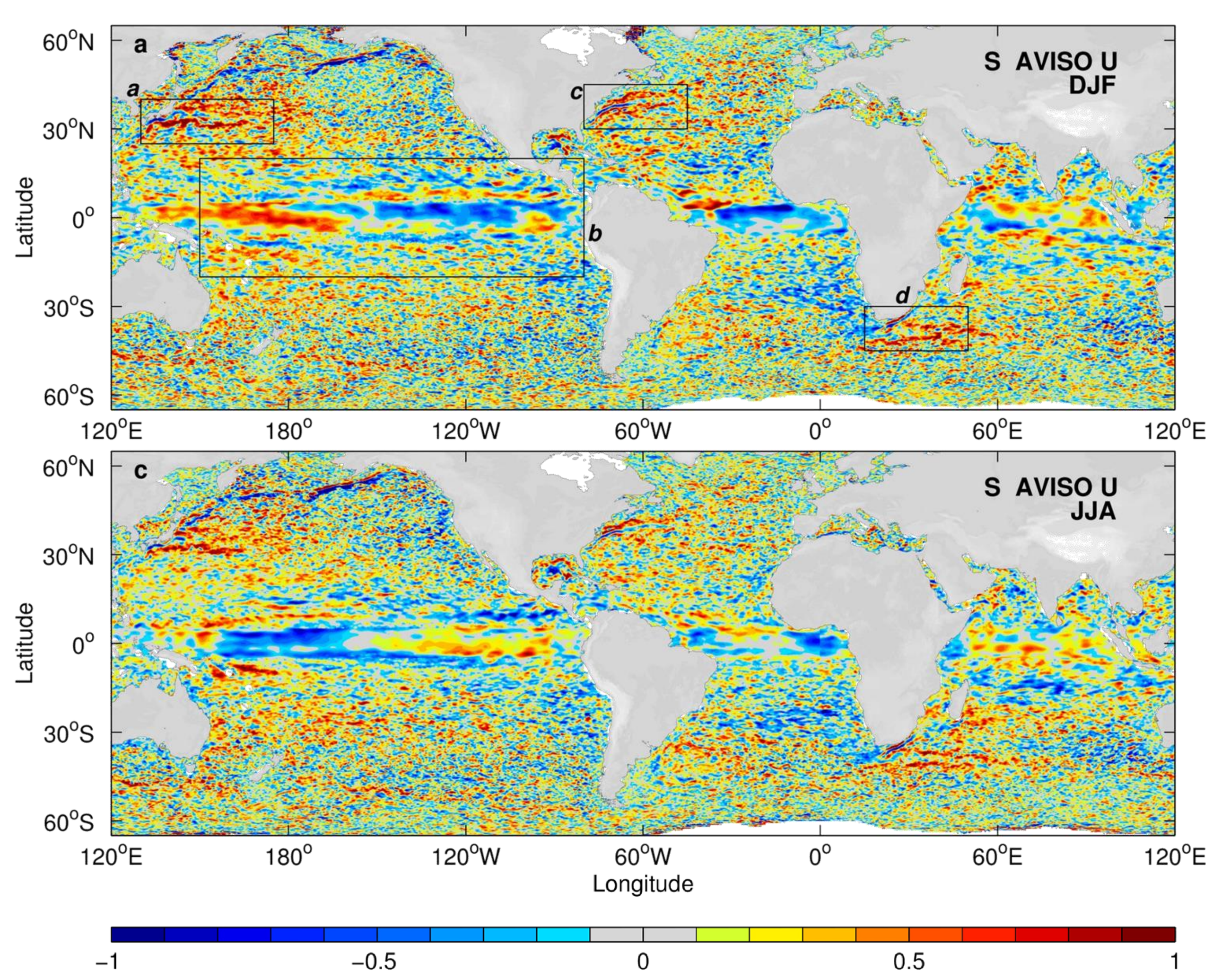
◄ Gulf Stream: jet axis is uniformly distributed (flat histograms [-] K) resulting from meandering [+] and [-] anomalies. North and south of current axis rare but strong U-anomalies lead to [+] K and S. Warm/cold core rings north/south have [+] / [-] SLA, lead to [+] / [-] S north/south of the axis. Rare and strong occurence of cold and warm core rings lead to [+] K north and south.

► Tropical Atlantic: two opposing currents (NECC and NEC) are cause for dipole structure in S and K (U) and S (SLA).



Seasonal Variations

Skewness of U



Annual and semiannual harmonics were subtracted before computing the Skewness and Kurtosis for the 19 year long AVISO SLA time series, to emphasize the seasonal changes that are on top of the annual and semiannual signals. Shown are months December, January, February (DJF) and June, July, August (JJA) only.

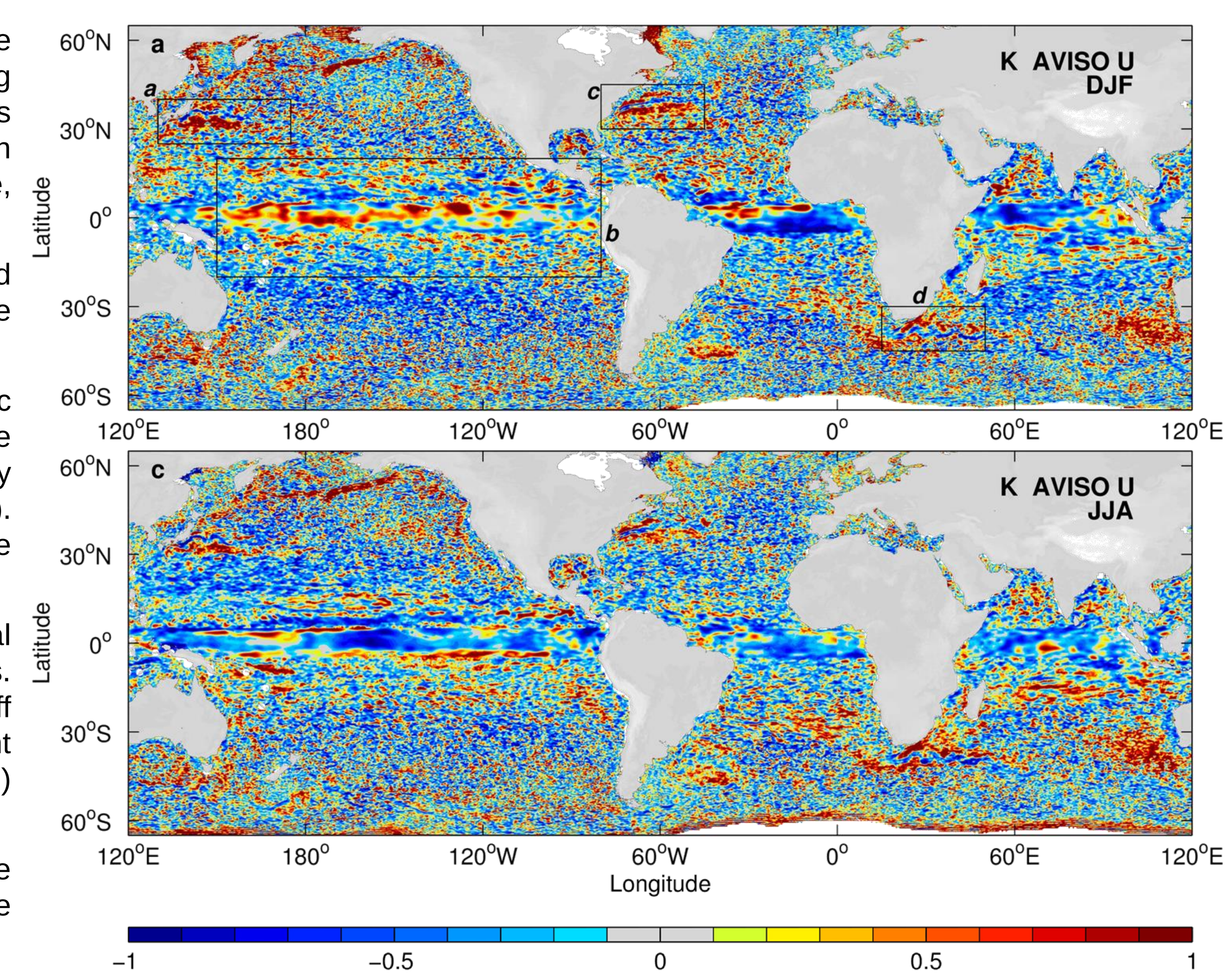
Most prominent seasonal changes of Skewness (◄) and Kurtosis (►) can be seen in the equatorial regions of the Pacific, Atlantic and Indian Ocean.

E.g. the enhanced seasonal changes in the eastern Pacific upwelling region of the Equatorial Undercurrent (EUC) are seen at 5°S with negative Skewness from December to May (◄ a) and positive Skewness from June to November (◄ c). Kurtosis is positive in this region for DJF (► a) and positive the rest of the season.

Indian Ocean surface circulation has large seasonal variations due to the reversal of the monsoon winds. Consistent with the reversal of the surface Somali Current off the African coast and the changes of the Monsoon Current south of Sri Lanka, the Skewness (◄) and Kurtosis fields (►) change.

Further, the North Equatorial Current (NEC) and the Equatorial Counter Current (ECC) can be seen as triple pole structure slightly south of the equator.

Kurtosis of U



References

Biri, S., M. G. Scharffenberg and D. Stammer, 2015: A Probabilistic Description of the Mesoscale Eddy Field in the Ocean, *JGR*, 120(7), 4778-4802, doi:**10.1002/2014JC010681**.

martin.scharffenberg@uni-hamburg.de | mgs-research.jimdo.com