Correlating extremes in wind divergence with extremes in rain over the Tropical Atlantic

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Motivation

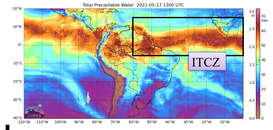
Due to **insufficient** numerical resolution and **inadequate** parameterizations, Mesoscale Convective Systems (**MCSs**) and other forms of organized convection are absent from global numerical weather prediction (**NWP**) and global climate models (**GCMs**).

Objective

Correlate (**quantitatively**) the ocean winds with precipitation in and near MCSs using ASCAT winds, and Meteosat Second Generation (MSG) Rain rates

Data

- ASCAT winds from tandem mission (12.5 km)
- MSG rain rates — samples every 15 mins at 3 km) resolution),
- Collocations : Short time series of rain rates with each ASCAT wind field. Study Area: ITCZ.

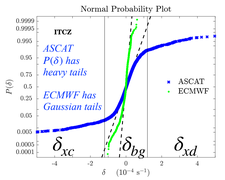


Methods

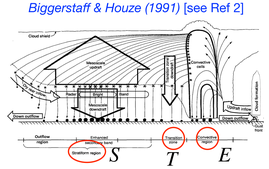
- Calculate **wind divergence**

$$\delta = -\partial w/\partial z = \partial u/\partial x + \partial v/\partial y$$

- **Rain is regridded** to the δ-grid using the **local maximum 3 km rain rate** (R^*).
- Build scattergrams (δ, R^*).
- Identify **thresholds** and partition δ into extremes of convergence (δ_{xc}), extremes of divergence (δ_{xd}) and background (δ_{bg}).
- Classify R^* as *stratiform* (**S**), *transition* (**T**) or *extreme* (**E**). Extreme rain > 10 mm/h and consists only of *convective rain* [2].
- Quantify correlation.



Biggerstaff & Houze (1991) [see Ref 2]

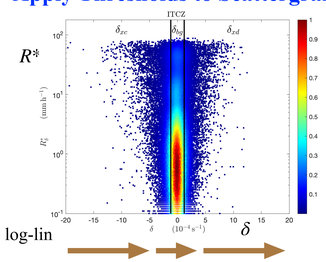


Results

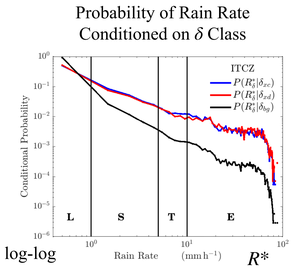
[see Ref 3]

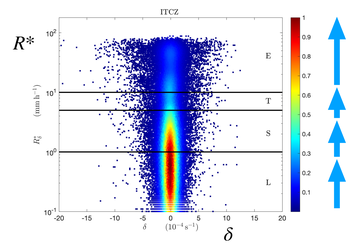
Correlation at lag $\tau = 0$
(At the time of the **ASCAT pass)**

Apply Thresholds to Scattergram

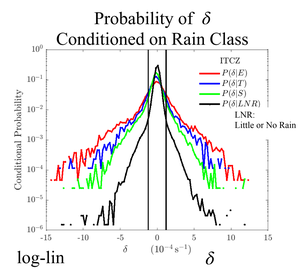


Vertical Slices

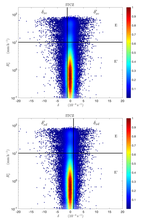




Horizontal Slices



Concentrate on the Extremes



2×2 **Contingency table**
present (=1) absent (=0).

		Y 1	Y 0	X sums
X	1	n_{11}	n_{10}	n_{1+}
	0	n_{01}	n_{00}	n_{0+}
Y sums		n_{+1}	n_{+0}	n_{++}

Correlation quantified by the Odds Ratio

$$OR(X,Y) = \frac{odds(X|Y)}{odds(X|Y')} = \frac{n_{11}n_{00}}{n_{10}n_{01}}$$

(X,Y)	$odds(X\|Y)$	$odds(X\|Y')$	$OR(X,Y)$
(E,δ_{xc})	0.311	0.025	12.55
(E,δ_{xd})	0.323	0.026	12.36

$OR > 1 \implies$ significant positive correlation

Odds Ratio vs time lag τ
Repeat calculation of 2x2 contingency tables using Rain Rates obtained 90 minutes before to 150 minutes after the ASCAT pass. The Odds Ratio calculated from these time-lagged contingency tables is plotted for both sets of extremes in the figure to the right.

The maxima in the red and black curves imply that most extreme rain occurs …
(1) **near the time of** extreme divergence, and
(2) about 30 minutes ***after*** extreme convergence

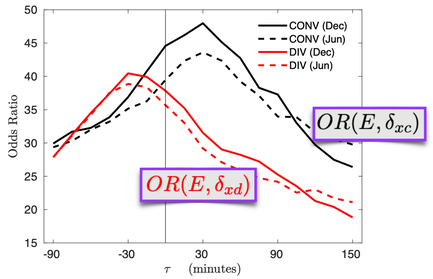
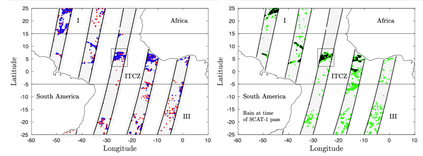


Figure 13. Odds ratios for convergence (black) and divergence (red) for a winter month and a summer month. Rain product lag is relative to SCAT-1 pass ($\tau = 0$).

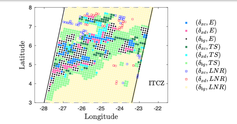
Spatial distribution of extremes

Extremes of convergence (blue) and divergence (red).

Extremes of rain (black); transition/stratiform rain (green).



The boxed area in the third swath is shown here segmented into subsets.



Conclusions

The scattergram showed that the correlation between rain and wind divergence was highly nonlinear. To untangle the scattergram and quantify the correlation we …

1. Centered our attention on the probability distributions.
2. Set thresholds based on the heavy tails of $P(\delta)$, and, for rain rates, from work on methods to classify and separate stratiform from convective rain in satellite reflectivity data from MCSs.
3. Found that the tails of the conditional probability distributions followed power-laws.
4. After reducing the joint probability distributions to contingency tables, correlations were quantified by calculating Odds Ratios.

References

1. G. Penide, A. Protat, V. V. Kumar, and P. T. May (2013); doi:10.1175/JTECH-D-13-00019.1
2. M. Biggerstaff and R. Houze (1991); doi:10.1175/1520-0493(1991)119<3034:KAPSOT>2.0.CO;2
3. G. P. King, M. Portabella, W. Lin, A. Stoffelen (2022); doi:10.3390/rs14051147

Further information