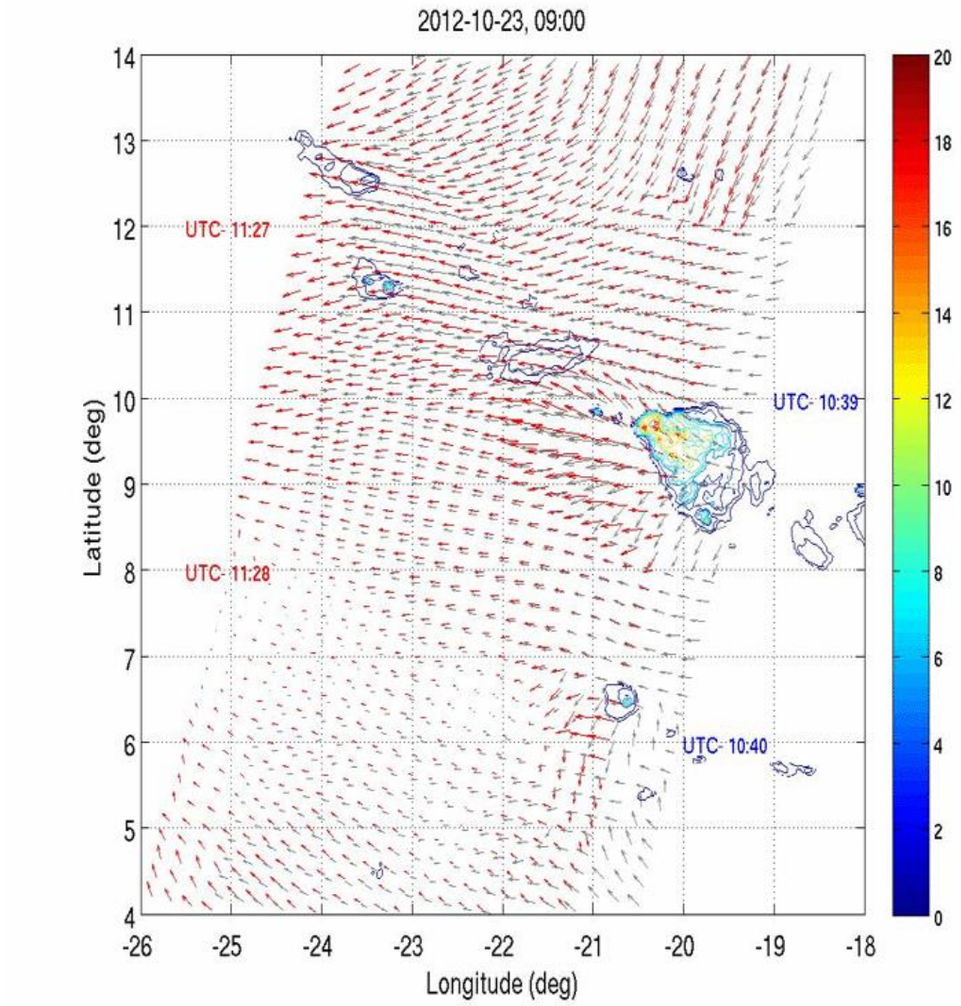
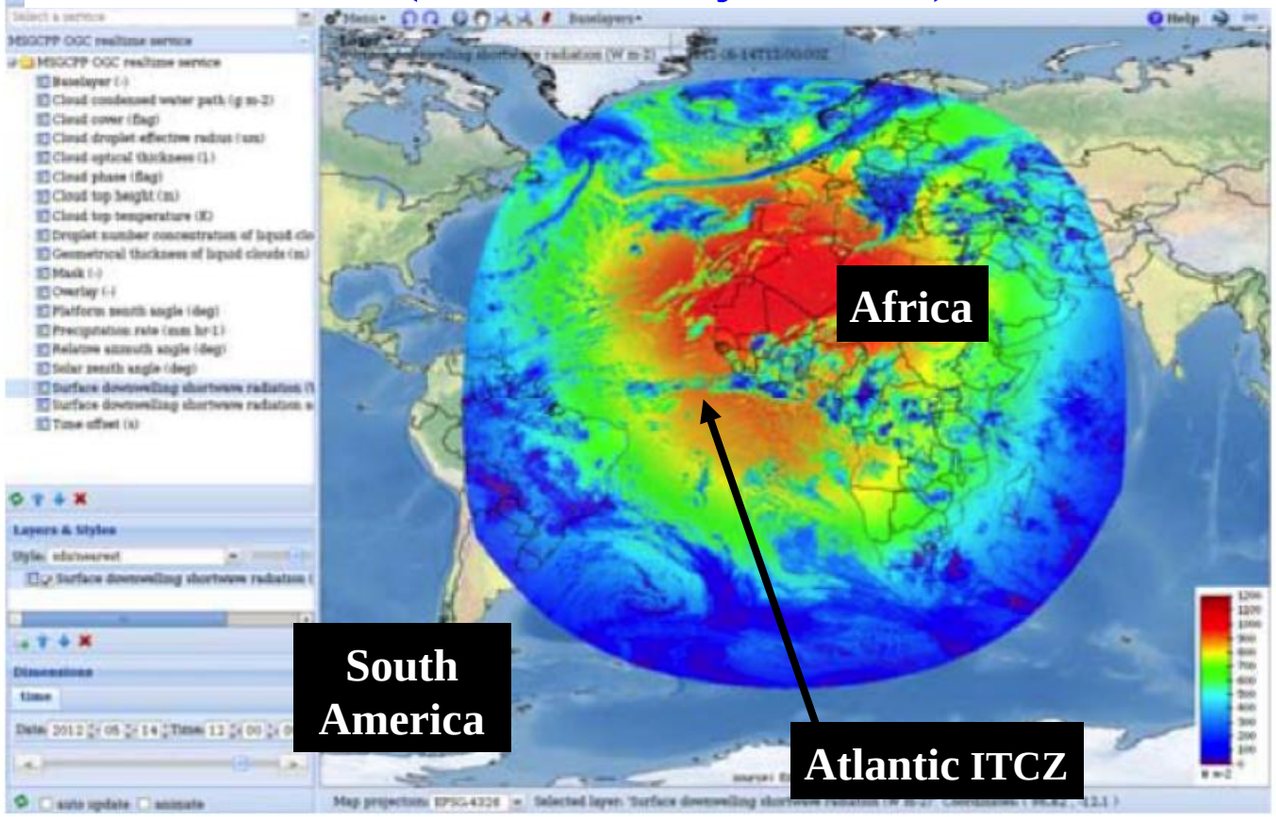
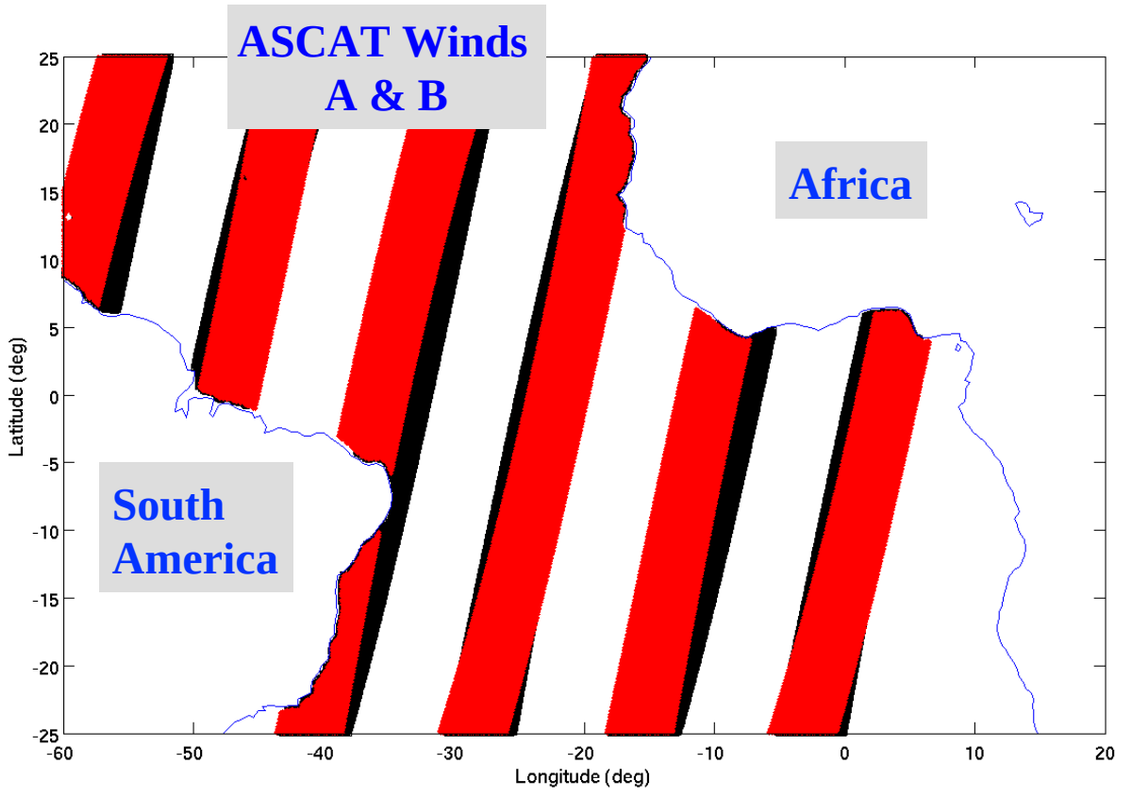
Correlating extremes in rain with extremes in wind & wind stress divergence

Gregory King (ICM-CSIC)
Marcos Portabella (ICM-CSIC)
Wenming Lin (NUIST)
Ad Stoffelen (KNMI)



Meteosat Second Generation (MSG) Rain Rates (Produced by KNMI)





Data

***MSG* Rain Rate:**

3 km pixels,

snapshot every 15 minutes (daylight only)

ASCAT-A&B

12.5 km WVCs

Overlapping A&B swaths (Atlantic ITCZ)

Collocations

ASCAT winds

at time t_0

at time t_0 + 50 minutes

MSG snapshots

start: t_0 - 2 hrs

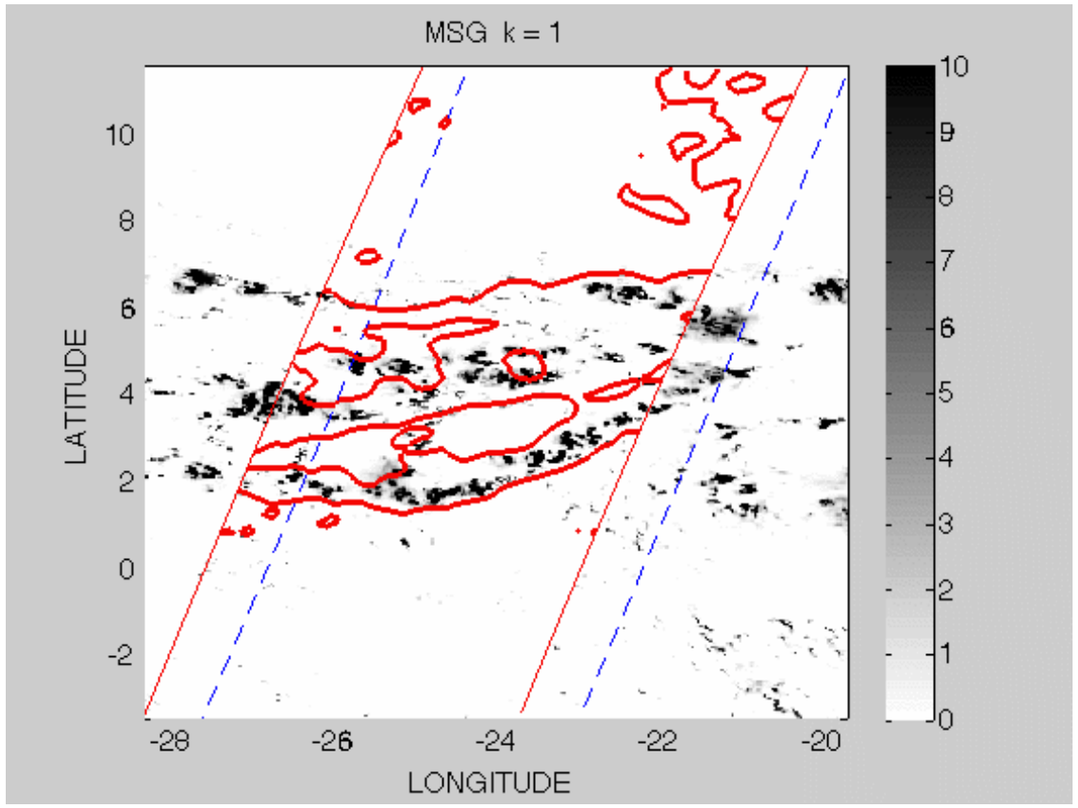
end: t_0 + 2 hrs

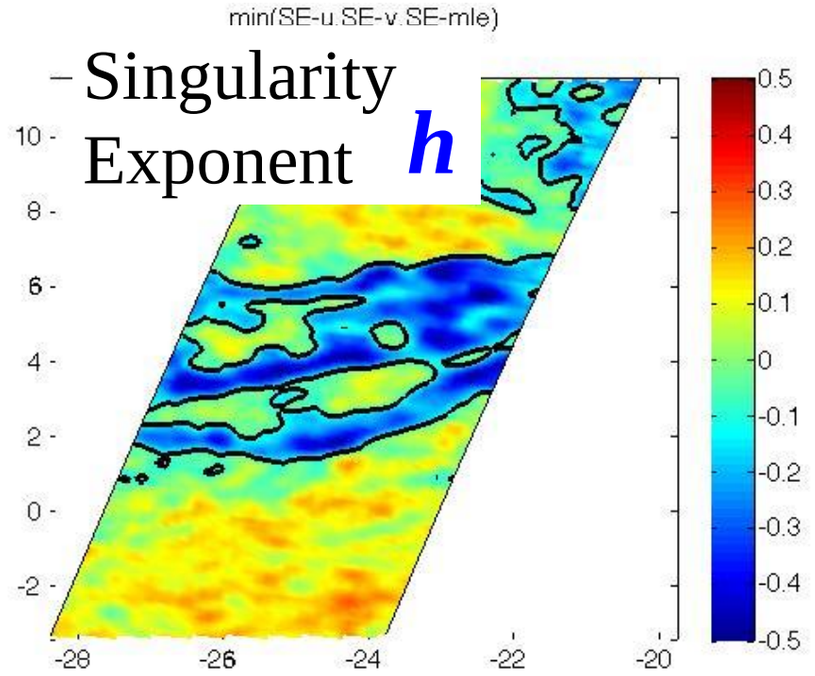
sampling interval: 15 minutes

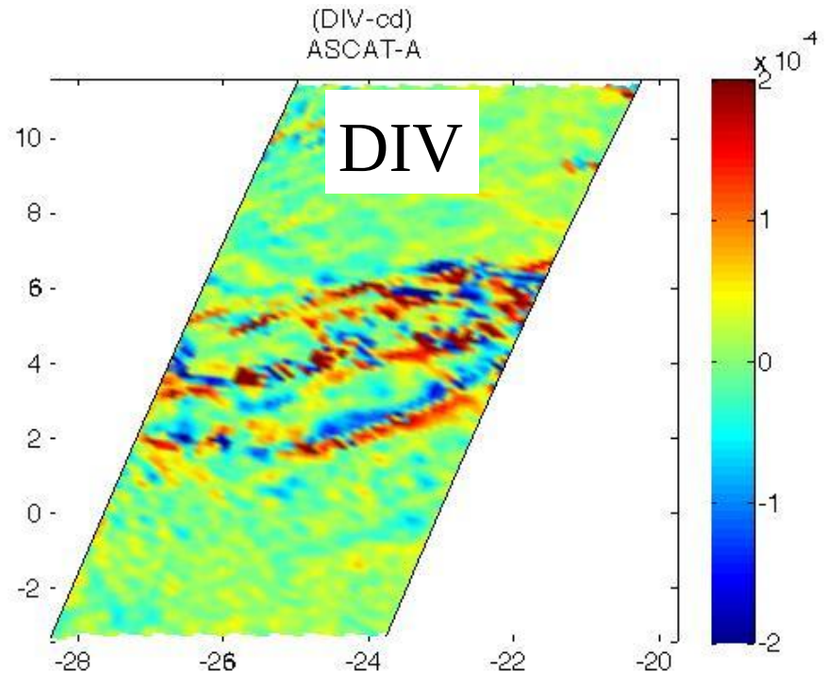
Animation

MSG Rain (black pixels)

Singularity Exponent (***h*** = -0.1) contour (red)







$$||\nabla s(\mathbf{x})|| \sim r^{h(\mathbf{x})}$$

$$||\nabla s(\mathbf{x})|| = \max\left(||\partial u_i/\partial x_j||\right)$$

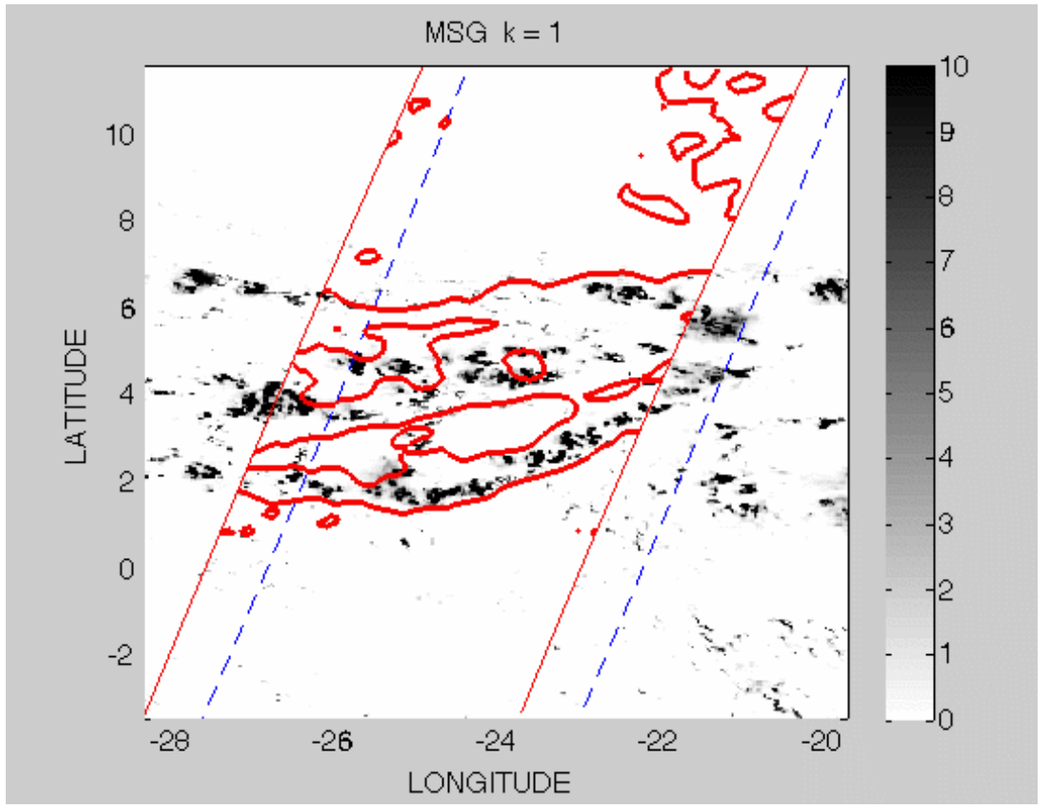
$$\max\left(||\partial u_i/\partial x_j||\right) \sim r^{h(\mathbf{x})}$$

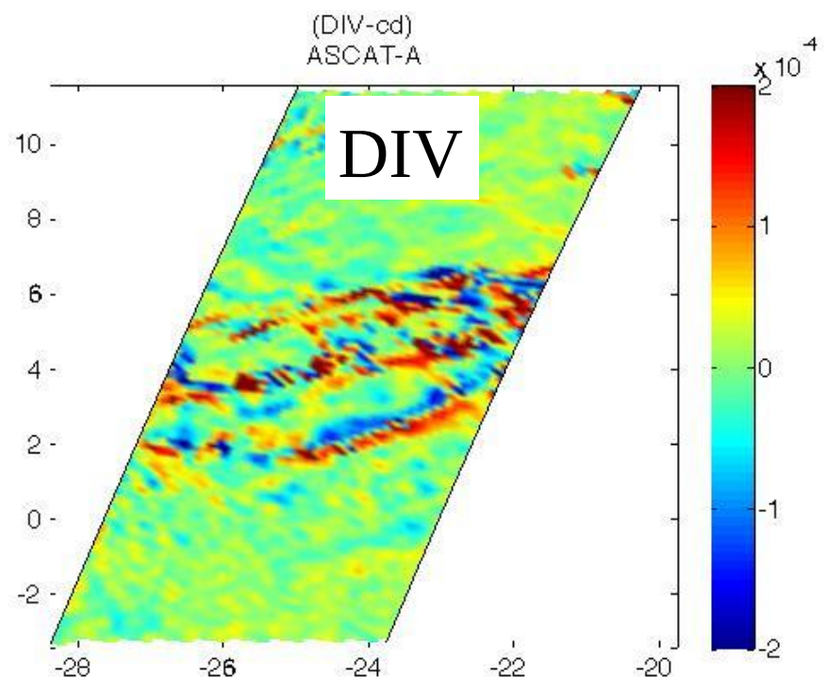
h **< -0.1** → **Locations where velocity gradients are steep**

Animation

MSG Rain (black pixels)

Singularity Exponent (***h*** = -0.1) contour (red)





Visually, r**ain rates / storm tracks appear well-correlated with DIV.**

In fact…

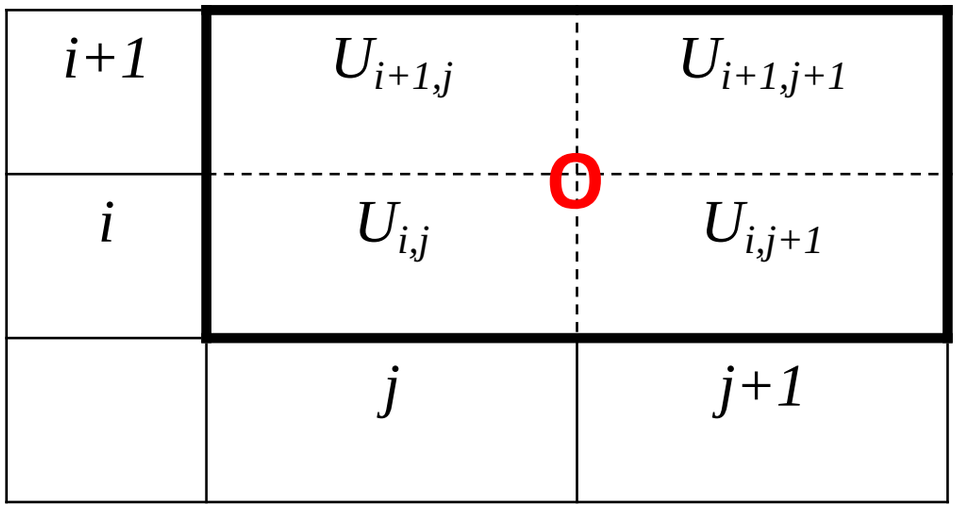
Key Point: Very large rain rates correlate with very large DIV.

The TASK: make the correlation quantitative.

Preparing data for correlation

Computational Cell

25km-by-25km area spanned by 12.5km WVCs …



At each grid point **(*i*+1/2, *j*+1/2)…**

(1) DIV — calculate using difference-then-average method.

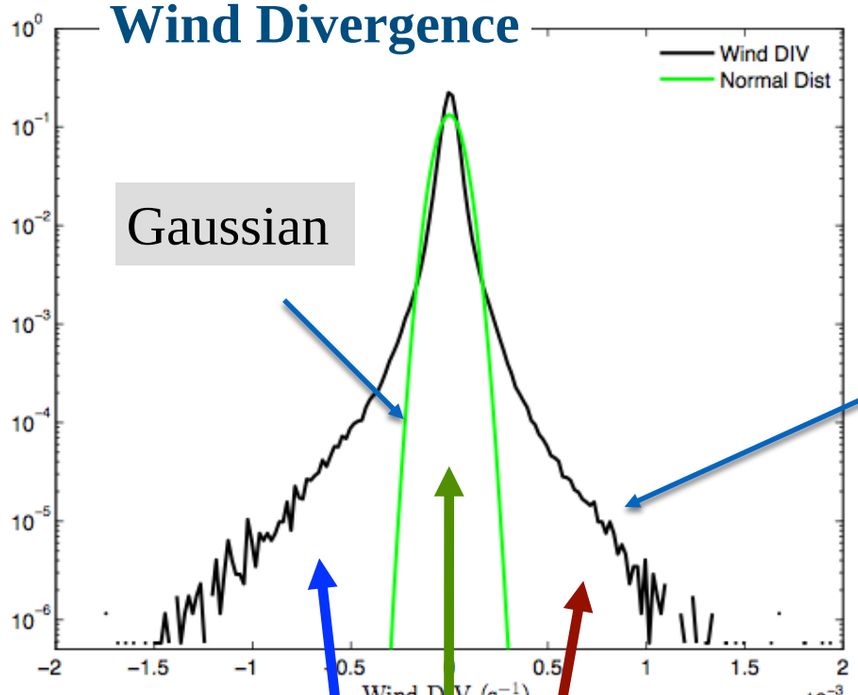
(2) RR*max* — the max rain rate in the area spanned by the computational cell**.**

Rationale: RR*max* is the **most influential rain rate** affecting the calculation of DIV

Statistical Approach

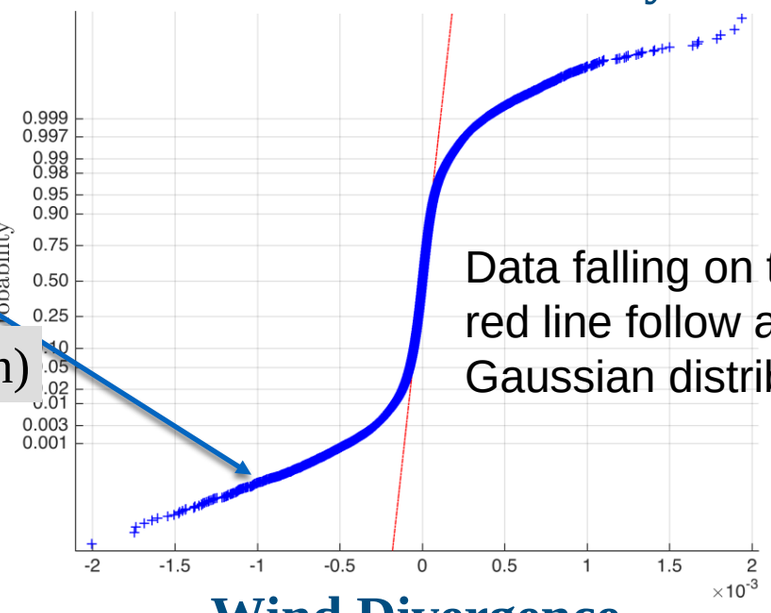
P(DIV)

Log Probability

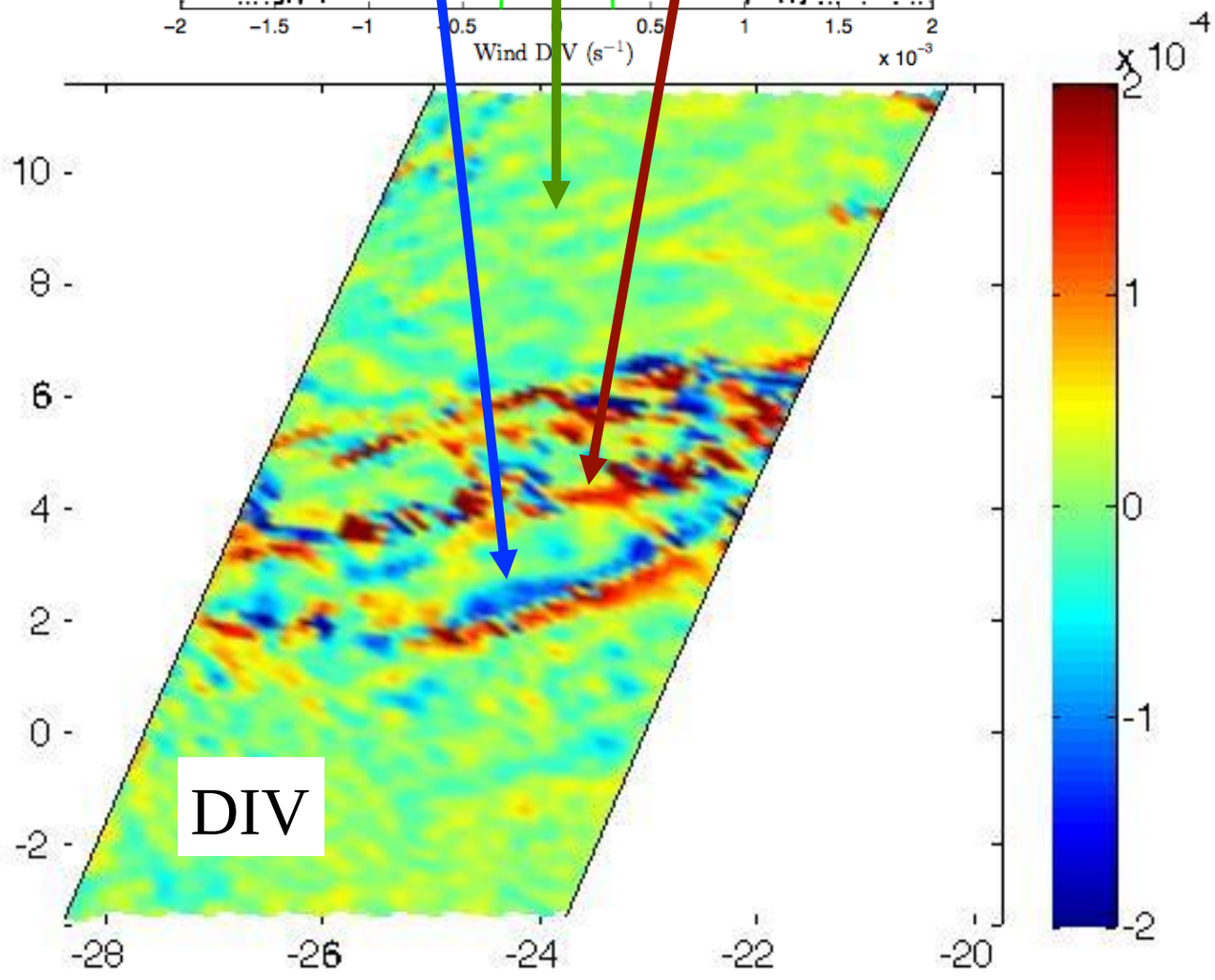


Fat Tails

(Non-Gaussian)



Data falling on the red line follow a Gaussian distribution

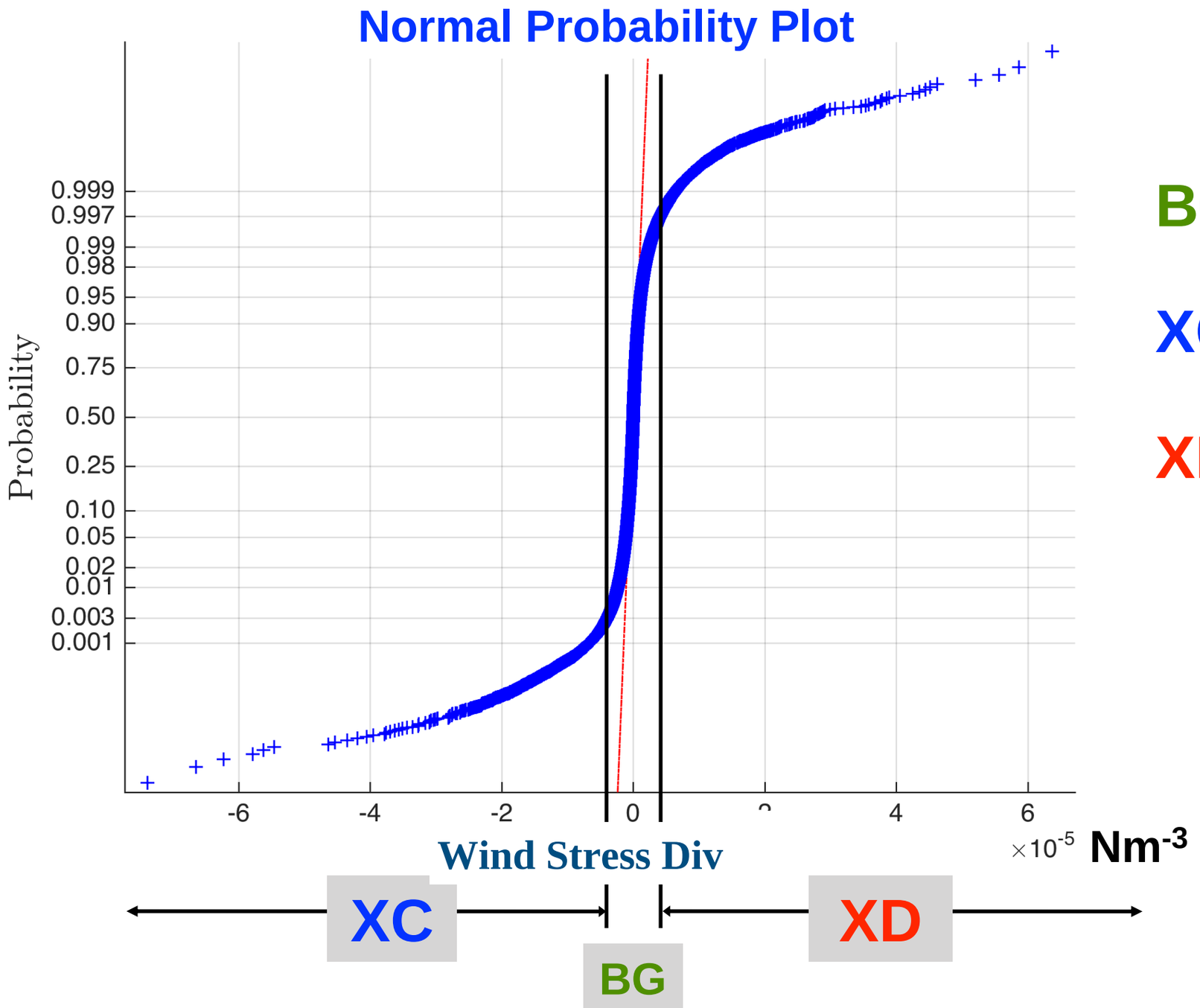


Top Left fig: P(DIV)
Top Right fig: quantiles of P(DIV) vs quantiles of Gaussian.
*The Fat Tails are due to large **Extreme Events***

Top Left & Bot Left fig show
Splitting of P(DIV) into three subsets.

To split the data — **Must define a threshold**. Probability Plot aids in selecting a threshold value.

Using statistics to define a threshold and partition the data into subsets



BG - **B**ack**G**round (Gaussian)

XC - e**X**treme **C**onvergence

XD - e**X**treme **D**ivergence

Thresholds at
+/- 0.18 x 10^{-5} Nm^{-3}

Define Rain Rate partitions

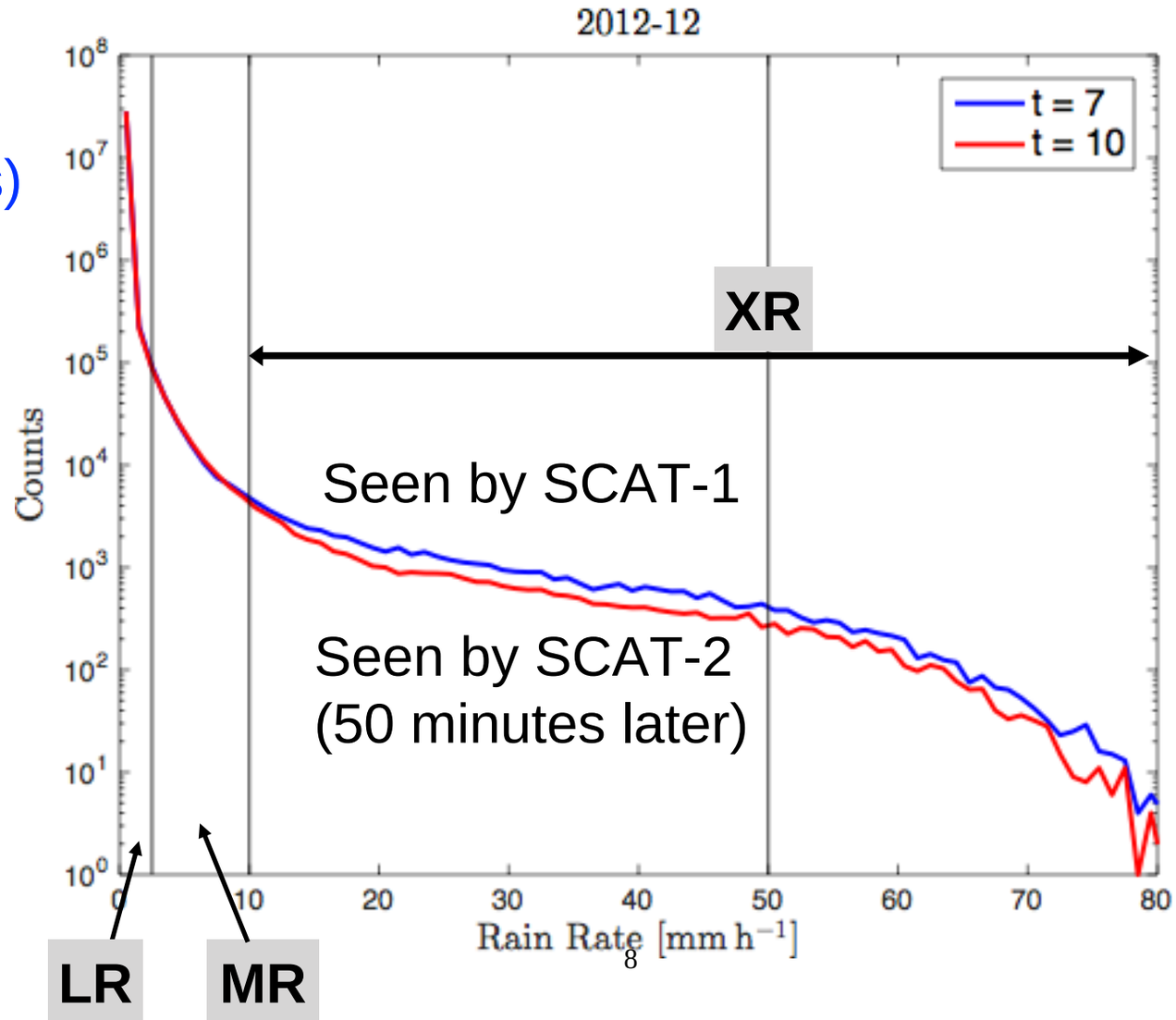
Rain rates follow a different kind of distribution.

Must apply a different strategy.

We use the
UK Met Office (**UKMO**) classification…

Rain Rate [mm h^{-1}]	UKMO	Present work	
< 2.5	Light	LR	BGR
2.5 - 10	Moderate	MR	
10 - 50	Heavy	XR	XR
> 50	Torrential		

Rain rate distribution
(one month of collocations)



LR - **L**ight **R**ain

MR - **M**oderate **R**ain

XR - e**X**treme **R**ain

Results

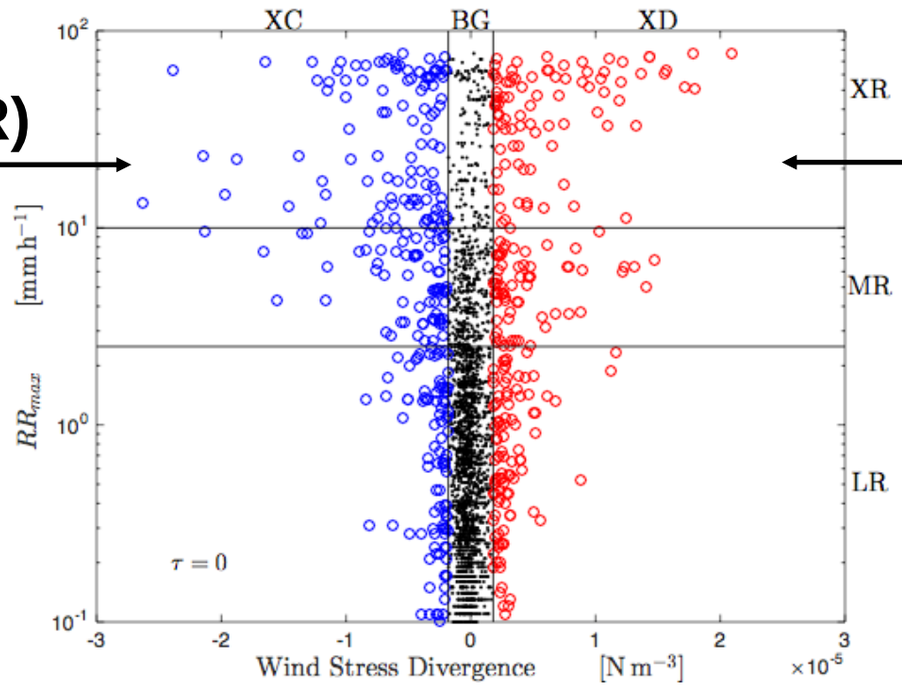
Wind Stress Divergence

Scattergram of DIV vs RR_{max}

- Data from one collocation and using one MSG snapshot.
- DIV and Rain categories are indicated along top and side

(XC, XR)

(XD, XR)

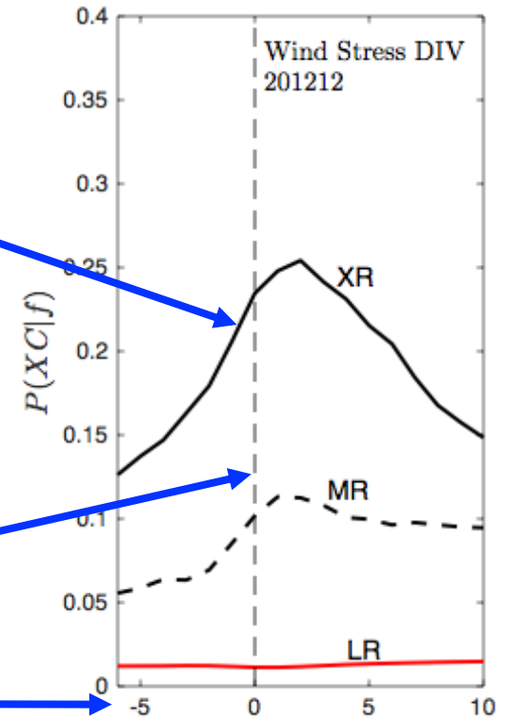


The most extreme DIVs fall mainly in the XR bins — i.e., bins (**XC**,**XR**) and (**XD**,**XR**).

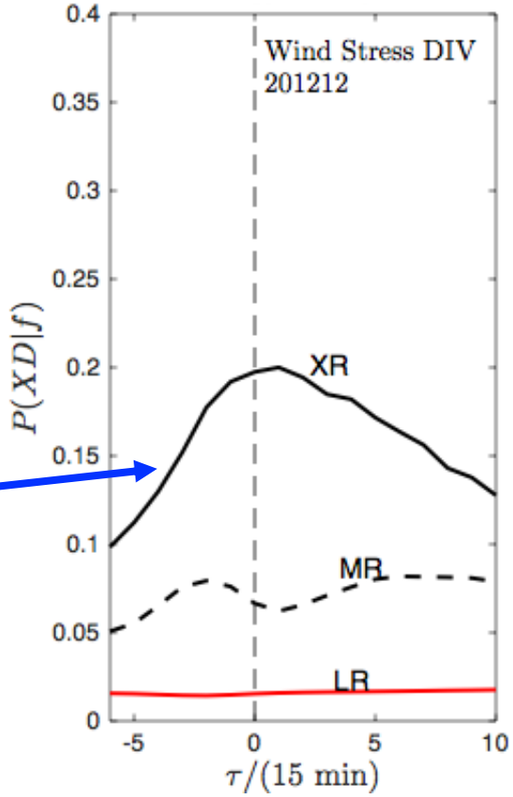
Probability of **XC** given **XR**

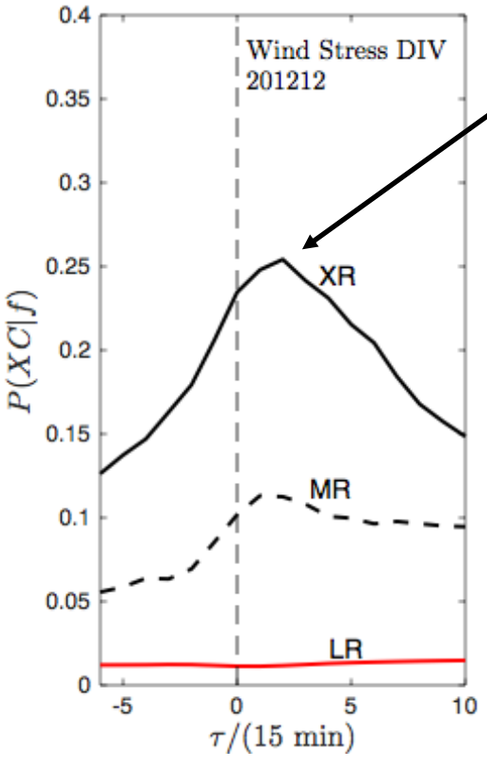
SCAT-1

MSG snapshot index

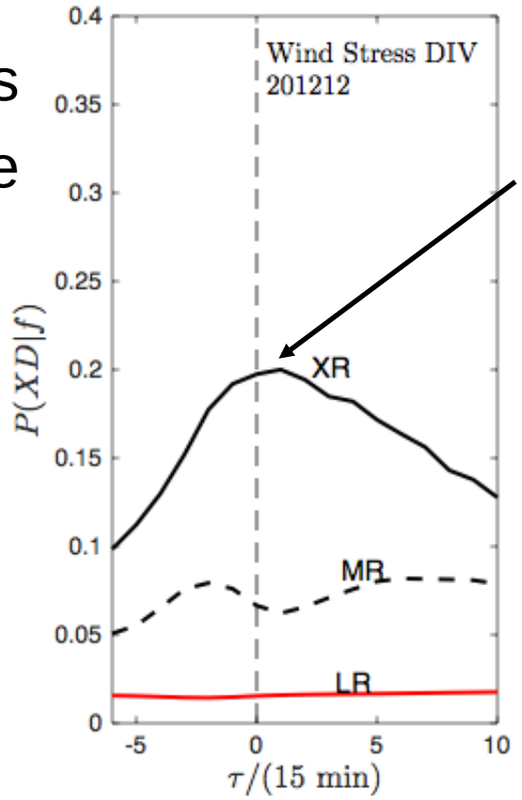


Probability of **XD** given **XR**





Most extreme rain occurs 30 minutes ***after*** extreme convergence



Most extreme rain occurs **at the time of** extreme divergence

Extreme rain falls fast, resulting in a rapid impact on the wind field (downdrafts),

These results show that …

- Extreme rain generally appears 30 minutes after extreme convergence.
- Temporal scale of Moist Convection is determined by the slower updraft process.

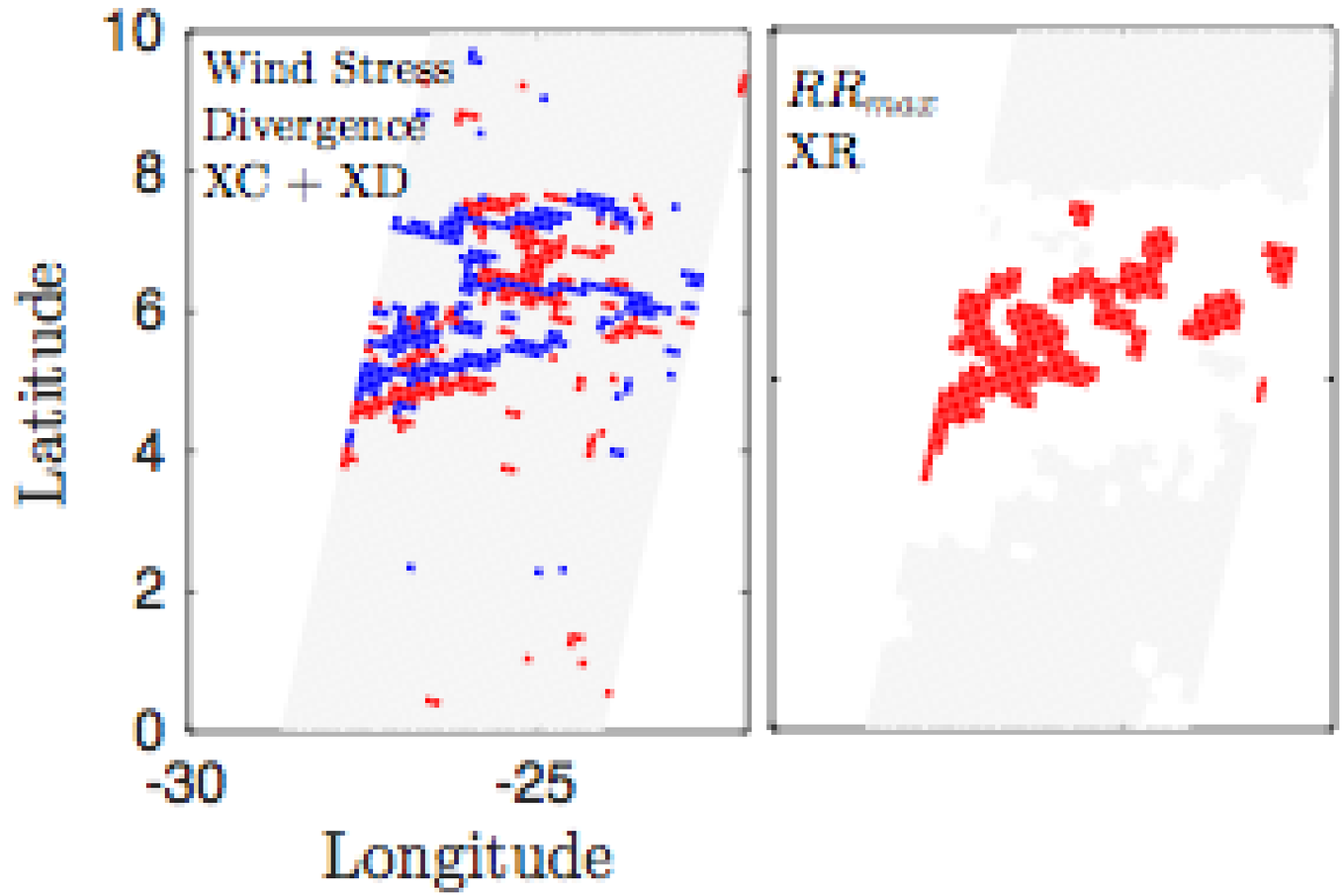
Extremes fall into coherent spatial clusters Different sizes and shapes

DIV

XC and XD Clusters

Rain

XR clusters



Pooled statistics …

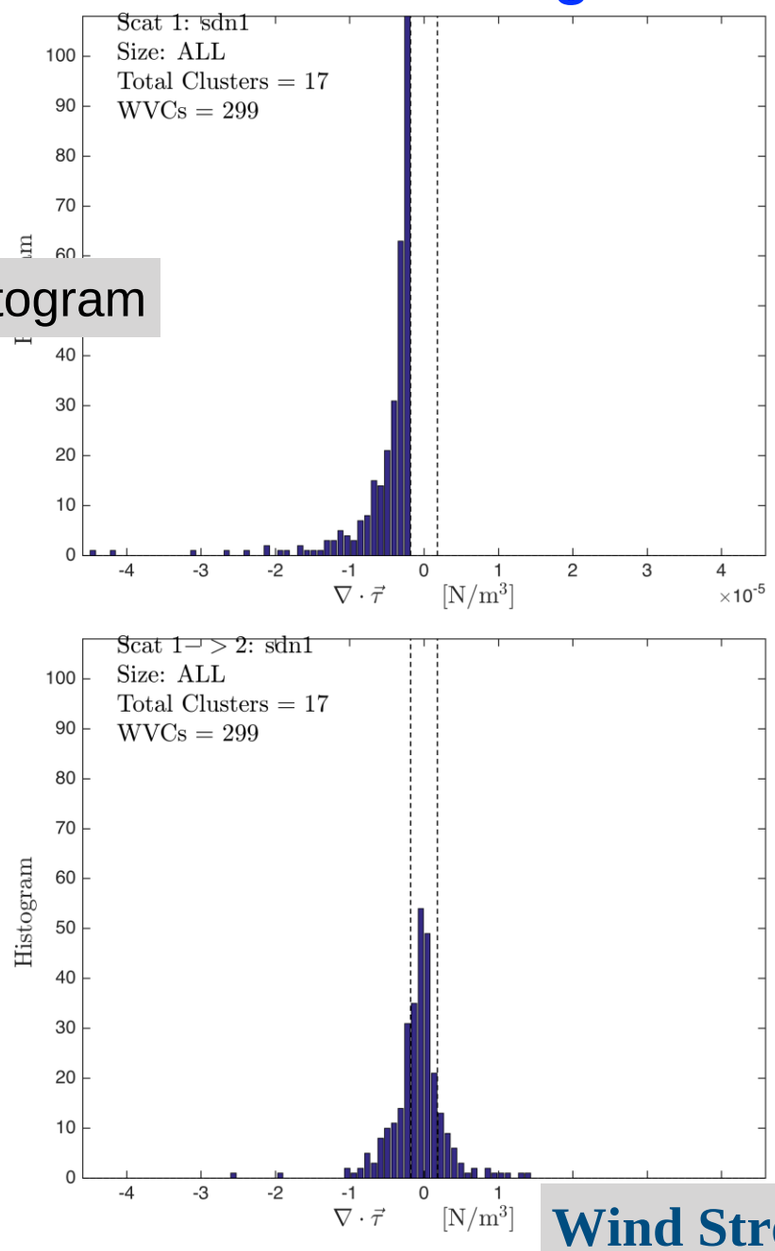
One month of collocations

Statistics of SCAT-1 WVCs labelled as Extreme DIV

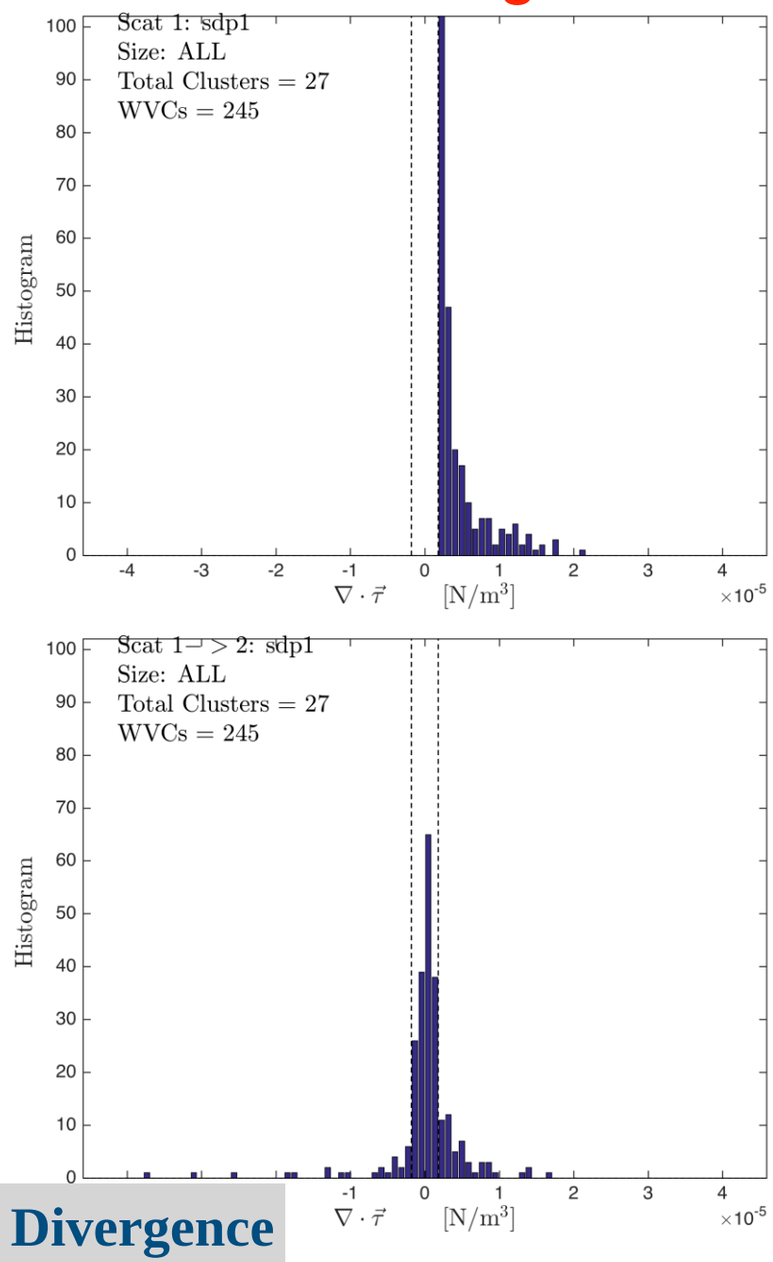
DIV statistics 50 minutes later for those same WVC areas…

(SCAT-2 WVCs)

Extreme Convergence



Extreme Divergence



Histogram

Wind Stress Divergence

A dramatic change in the distribution after only 50 minutes!

Summary

- **Extremes correlate with Extremes**: Extreme DIV with Extreme Rain
- A methodology was developed that made **correlation quantitative**.
- Extreme values found in **spatially coherent clusters** — indicating dynamical structures.
- **Key time scales** associated with wind field / Mesoscale Convective System interaction were identified.

Further Work

- More investigation of SCAT-1/SCAT-2 differences.
- Apply methodology to investigate Wind Curl / Wind Stress Curl and correlation with extreme rain.
- Investigate correlation between extremes in other collocated datasets.