3rd Split Workshop in Atmospheric Physics and Oceanography

Friday, May 27th, 2011 – Brač Island, Croatia

Saturation Fraction and Gross Moist Stability in the Mediterranean environment

Raymond et al., 2009: The mechanics of Gross Moist Stability

Molini et al., 2010: Classifying severe rainfall events over Italy by hydrometeorological and dynamical criteria

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1. Background theory
2. Proposed hypothesis
3. Methodology
4. Results
5. Conclusions

1. BACKGROUND THEORY – SF

- Saturation Fraction indicates how much saturated a column of tropospheric air is in respect to water vapor

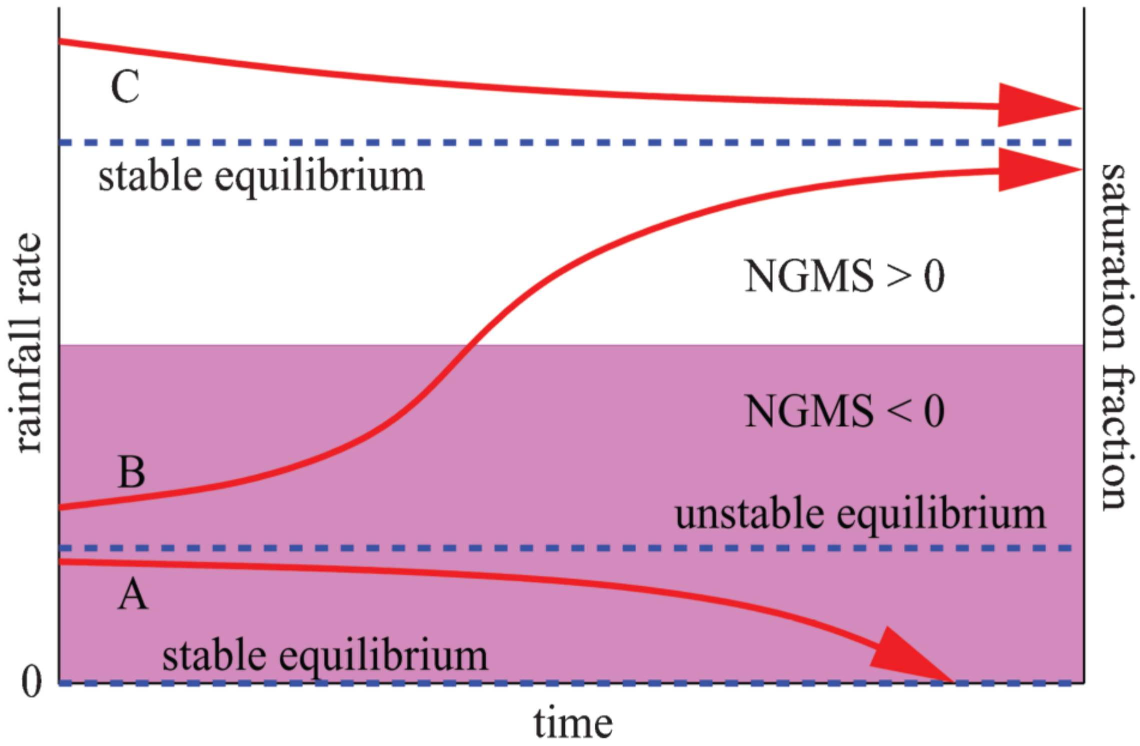
$$SF = \frac{Precipitable\ water}{Saturated\ precipitable\ water}$$

- So far basically employed for tropical convection studies
- Rain rate is a strong, nonlinear function of saturation fraction
- High SF associated to stratiform systems; lower SF to convective environments (Raymond et al., 2009)

1. BACKGROUND THEORY – SF

- Precipitation over warm tropical oceans → Column RH or SF (Raymond, 2000)

- SF and rain rate related by NGMS values! NGMS in multiple equilibria conditions:



1. BACKGROUND THEORY – NGMS

- **GMS: some kind of estimation of the 'convective behavior' in convectively-coupled systems** (in other words: the relationship between convective forcing and convection response)

$$NGMS = \frac{\int_s^t \nabla_H \, Moist\ entropy}{\int_s^t Moisture\ convergence}$$

- Numerator: also moist static energy*, or equivalent Θ (variables conserved in slow moist adiabatic processes)
- Denominator: also convective mass flux or divergence of Θ flux (a variable representative of the moist convection per unit area)

1. BACKGROUND THEORY – NGMS

Entropy forcing

Steady state: $$P - E = \frac{T_R[F_s - R]}{L\Gamma_R}$$

Precipitation forcing

NGMS: $$\Gamma_R = \Gamma_H + \Gamma_V = -\frac{T_R[v \cdot \nabla s]}{L[\nabla \cdot (rv)]} - \frac{T_R\left[\omega \cdot \frac{\partial s}{\partial p}\right]}{L[\nabla \cdot (rv)]}$$

NGMS over a region (averaged in space):

$$\overline{[\nabla \cdot (sv)]} = \frac{1}{A}\left[\int \nabla \cdot (sv) \cdot dA\right] = \frac{1}{A}\left[\oint sv \cdot n\, dl\right]$$

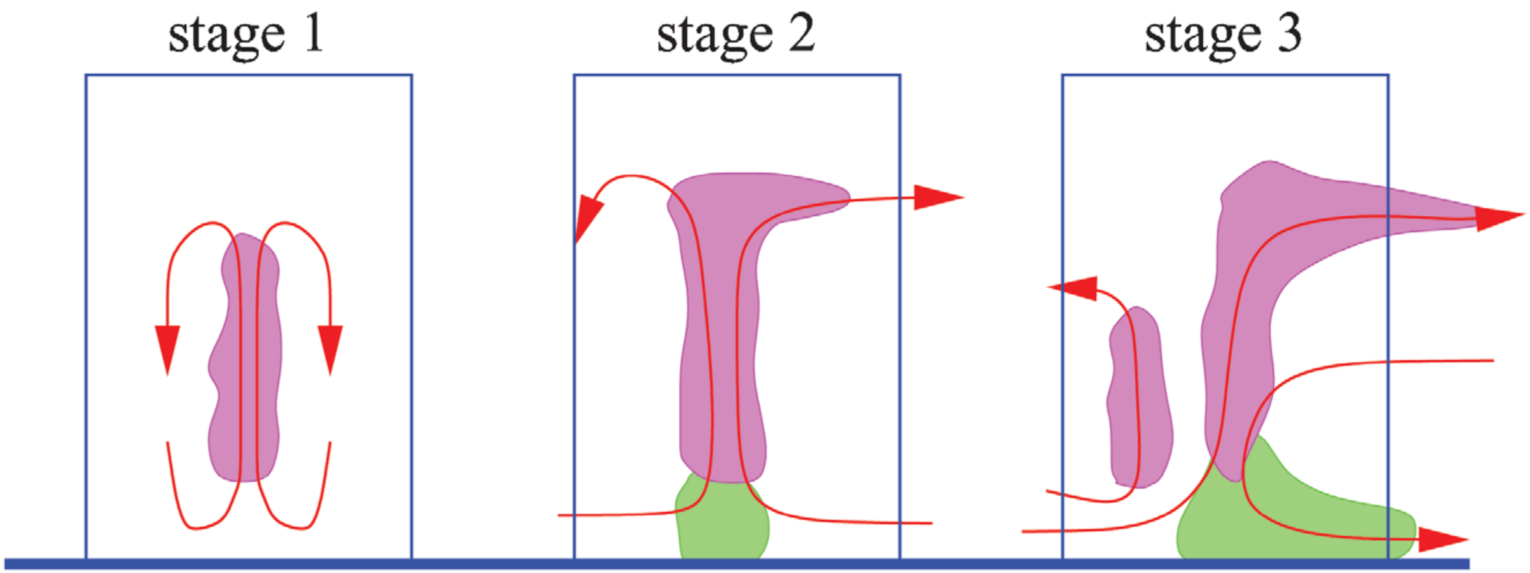
1. BACKGROUND THEORY – NGMS

Convective evolution in a control volume

S1: Shallow convection. NGMS<0

S2: Compensating subsidence reaches the walls at gravity-wave speeds

S3: Both conv. and div. flows have reached the walls, and interior of control volume approaches a statistically steady state. NGMS>0



1. BACKGROUND THEORY (MOLINI ET AL., 2010)

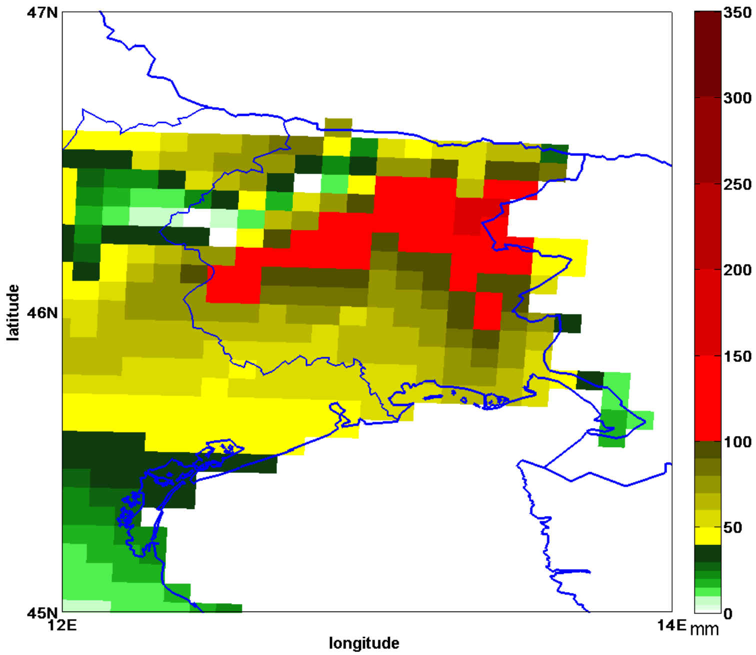
- Study about predictability of convection in equilibrium and non-equilibrium conditions for severe rainfall events in Italy from January 2006 to February 2009.

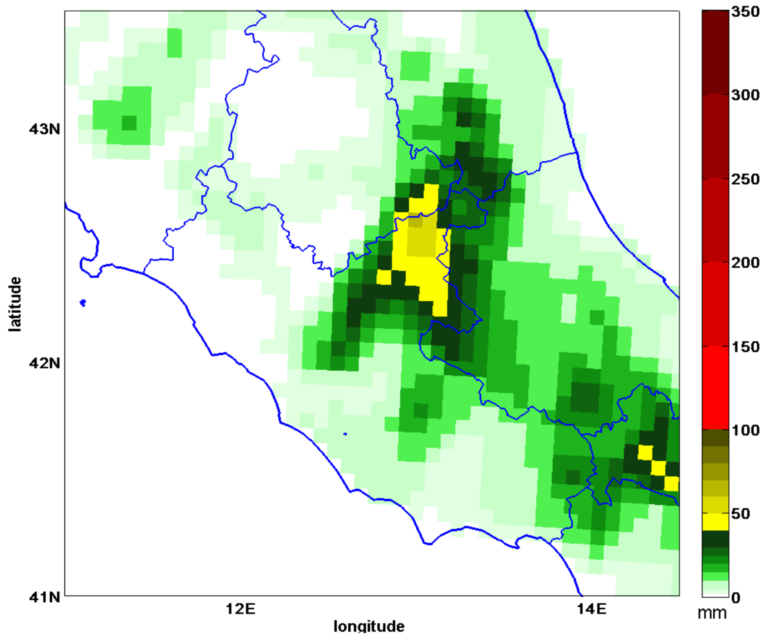
- Previously Molini et al. (2009) developed a procedure to single out heavy rainfall events and to classify them on the basis of:

  - Duration;
  - Spatial extent,
  - Large/small-scale triggering

1. BACKGROUND THEORY (MOLINI ET AL., 2009)

Severe rainfall events classification





Type I events:

- Long-lived (lasting more than 12 hours)
- Spatially distributed (more than 50x50 km^2)

Type II events:

- Brief and localized (lasting less than 12 hours)
- Spatially concentrated (less than 50x50 km^2)

EQUILIBRIUM AND NON-EQUILIBRIUM

HIGH degree of predictability ⟷ **Equilibrium conditions**

↓

The rate of creation of CAPE by forcing is balanced by its consumption by convection

←

Large scale forcing determines the statistical properties of convection and **the spatio-temporal behavior of the** corresponding **severe rainfall events**

$$\frac{dCAPE}{dt} = \begin{pmatrix} Rate\ of\ creation \\ by\ forcing \end{pmatrix} - \begin{pmatrix} Rate\ of\ destruction \\ by\ convection \end{pmatrix}$$

EQUILIBRIUM AND NON-EQUILIBRIUM

LOW degree of predictability ⟷ **Non-Equilibrium conditions**

CAPE is build up from large scale processes over long timescales and removed by sudden triggering of deep moist convection

$$\frac{dCAPE}{dt} = \begin{pmatrix} Rate\ of\ creation \\ by\ forcing \end{pmatrix} - \begin{pmatrix} Rate\ of\ destruction \\ by\ convection \end{pmatrix}$$

Triggering condition determines the spatio-temporal behavior of the corresponding **severe rainfall events**

A convective time scale for equilibrium and non-equilibrium conditions

A convective adjustment timescale τ_C is estimated from the rate at which instability (measured by CAPE) is being removed by convective heating (Done et al., 2006)

$$\tau_C = \frac{CAPE}{\frac{dCAPE}{dt}} = \frac{CAPE}{0.045 \cdot i_R}$$

Equilibrium conditions

Non-Equilibrium conditions

Convective timescale

τ_{CS} **~ 6 hours**

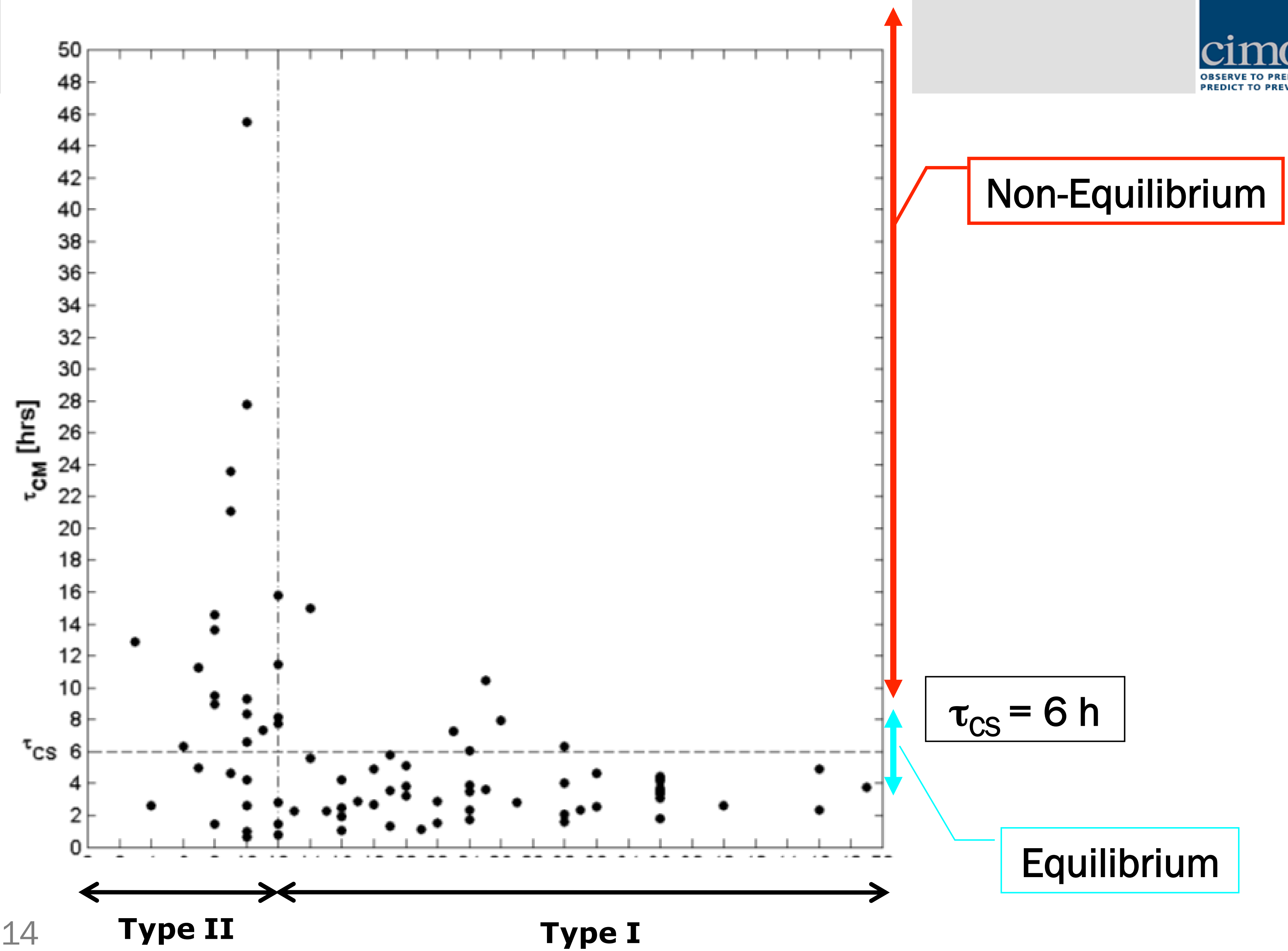
1. BACKGROUND THEORY (MOLINI ET AL., 2010)

- For the study period, 81 severe events took place, of which:
  - 51 events of Type I (>12 h and extending more than 50x50 km^2)
  - 30 events of Type II (<12 h and extending less than 50x50 km^2)

Are the differences between these two types of event associated with different mechanisms of control of precipitation by dynamical processes in the atmosphere?

Short values of τ_c → Equilibrium conditions ↔ ? ↔ **Type I events**

Long values of τ_c → Non-Equilibrium conditions ↔ ? ↔ **Type II events**



50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
τCM [hrs]
τCS
Non-Equilibrium
τCS = 6 h
Equilibrium
Type II
Type I

1. BACKGROUND THEORY (MOLINI ET AL., 2010)

Thus, the underlying hypothesis was supported by the findings:

- ✓ Type I events (90%) are largely associated to equilibrium conditions and hence more predictable
- ✓ Type II events (66%) are characterized by non-equilibrium conditions and consequently are expected to be hardly predictable

2. PROPOSED HYPOTHESIS

- Can tropical indices such as SF and NGMS be used successfully to characterize predictability also in the Mediterranean, mid-latitude environment?

- If so, how well do they distinguish between type I and II severe rainfall events (as τ_c does)?

- According to Raymond and Fuchs (2009), it would be expected to find high SF values and NGMS>0 for type I (~stratiform) events, and lower SF values and NGMS<0 for type II (~convective) events.

3. METHODOLOGY

- Work out the spatial mean NGMS and SF for every severe rainfall event (59) from January 2007 to February 2009. Both for each event's rainfall area and the whole ECMWF reanalysis domain

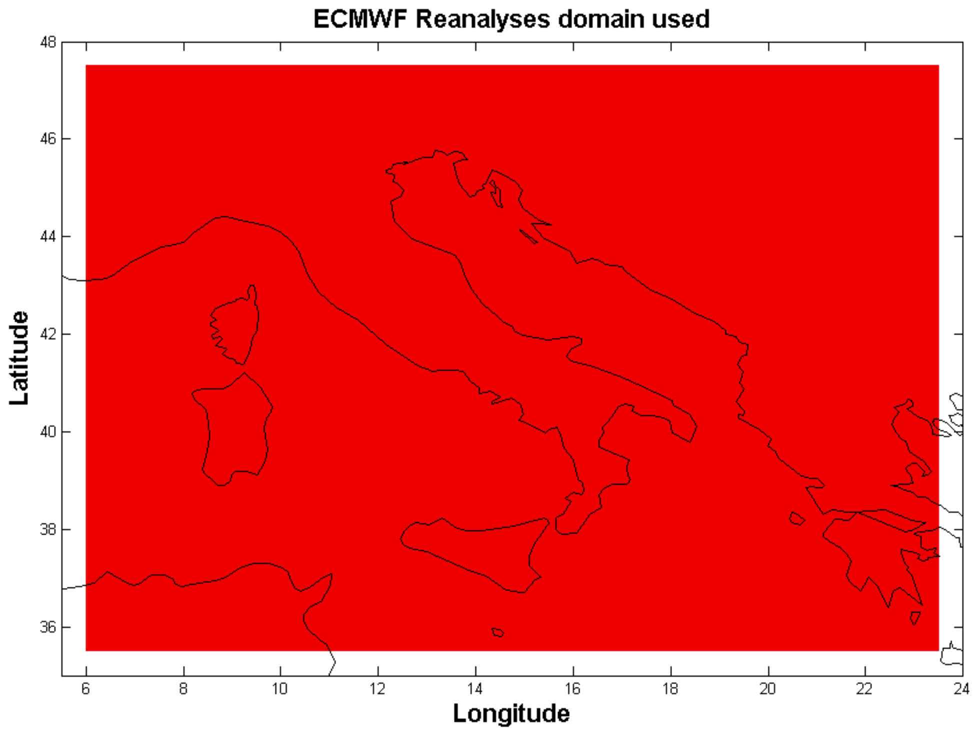
- Atmospheric variables from ECMWF ERA-INTERIM reanalyses (spatial res. 0.60º, temporal res. 3h)

- Such data has been spatially interpolated to the same grid as precipitation (spatial res. 7x7 km^2, temporal res. 1h)

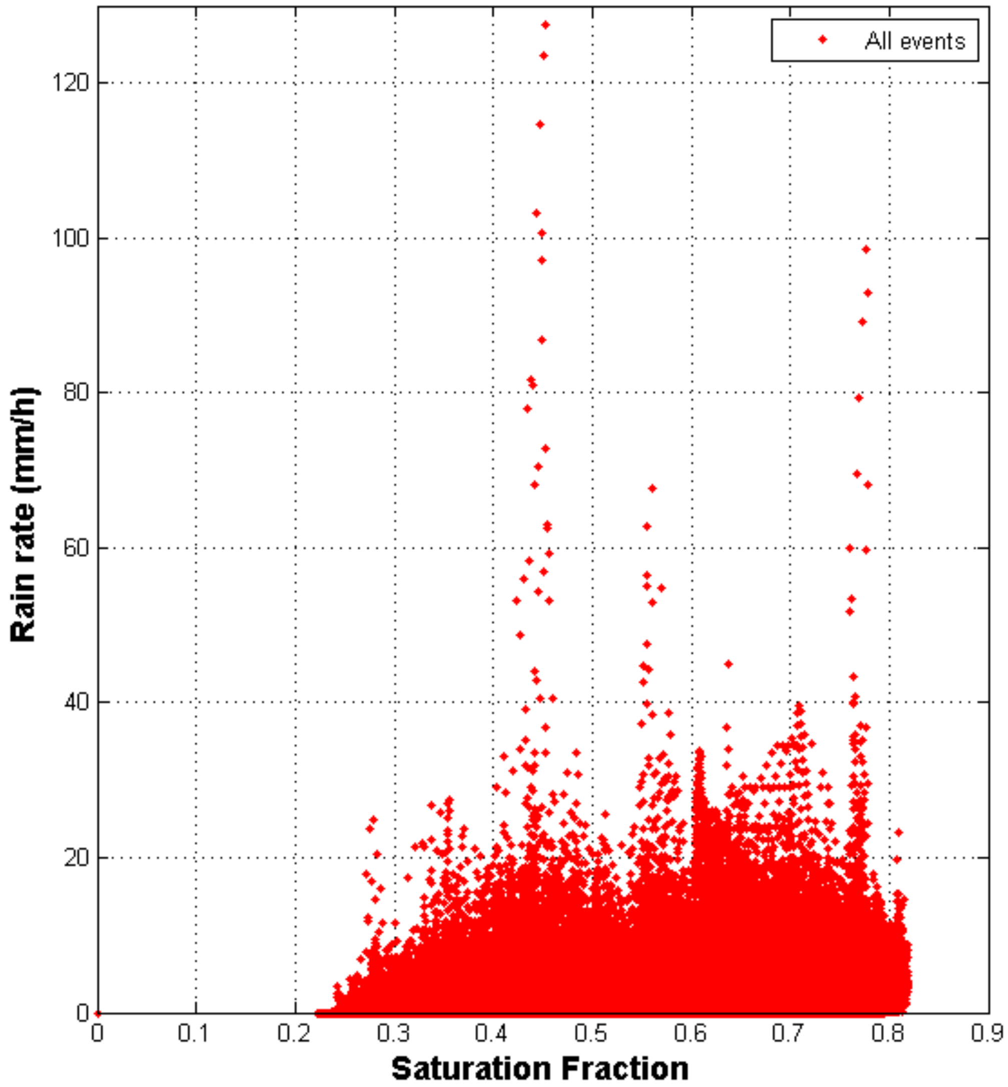
3. METHODOLOGY

- Calculations done for every 3-h model timestep laying within the event time window

- NGMS was also calculated for the same timesteps but for all domain gridpoints, to see any possible difference to just checking those events rainfall areas



4. RESULTS – RAINFALL AREA



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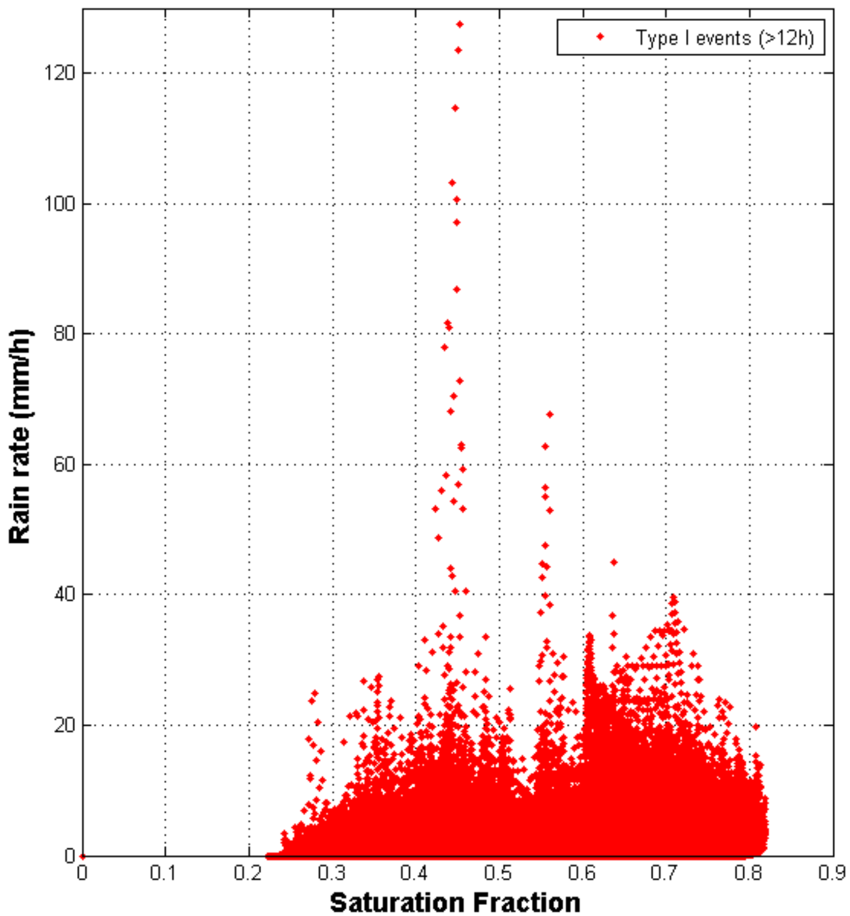

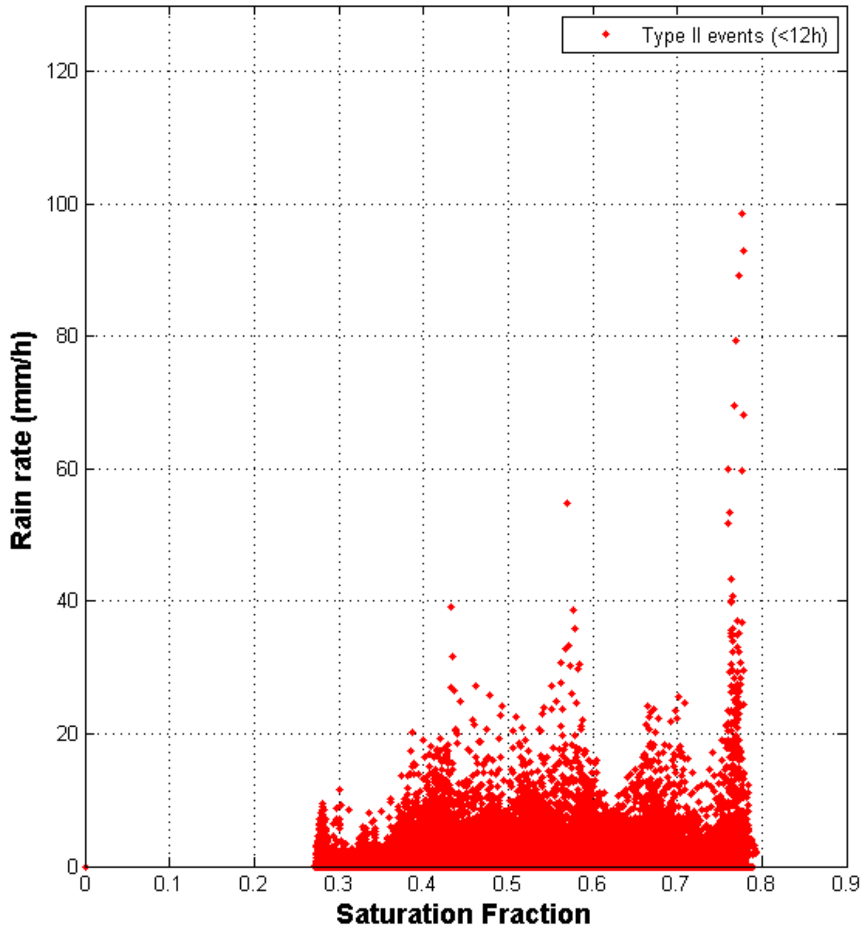

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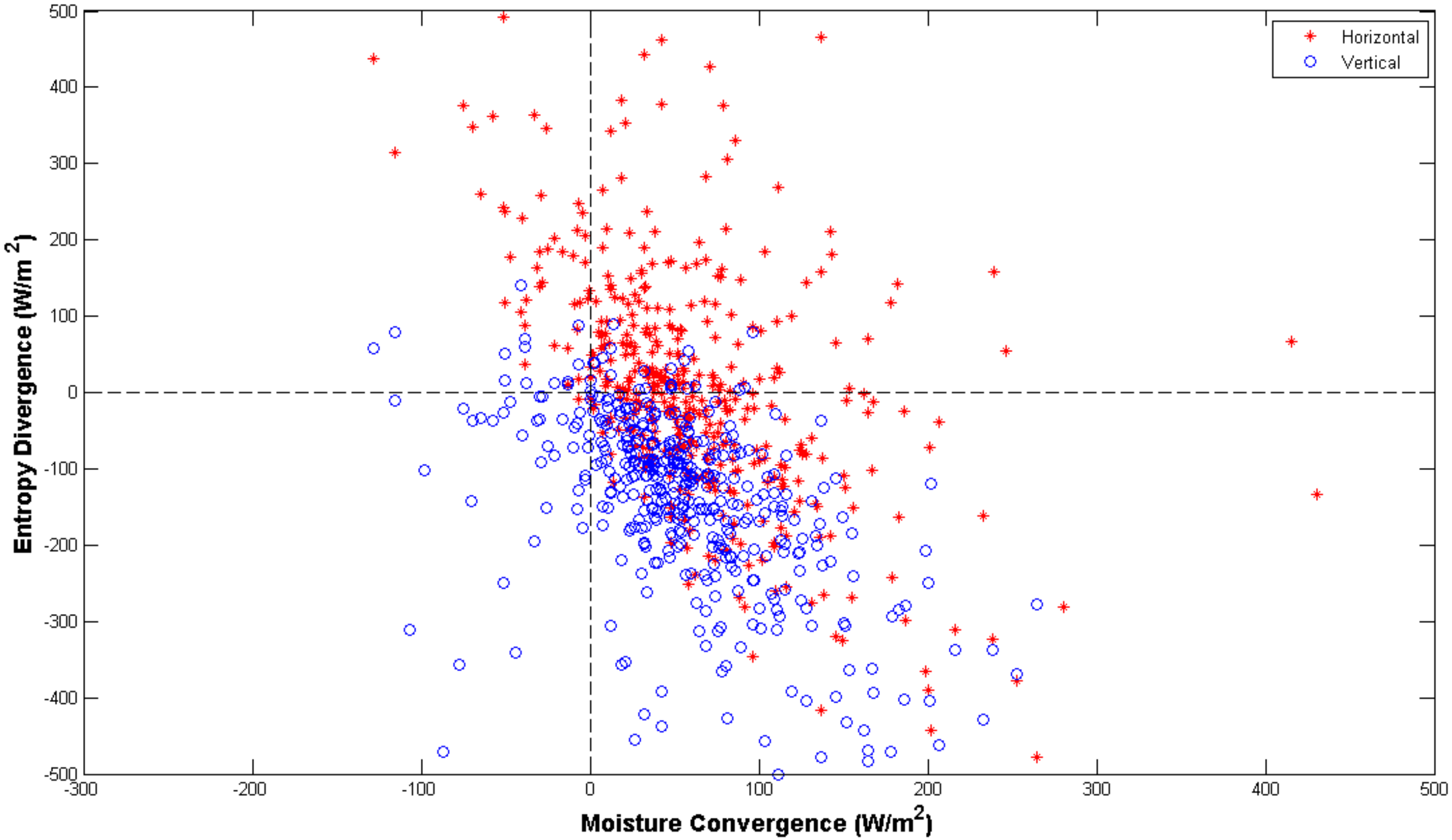
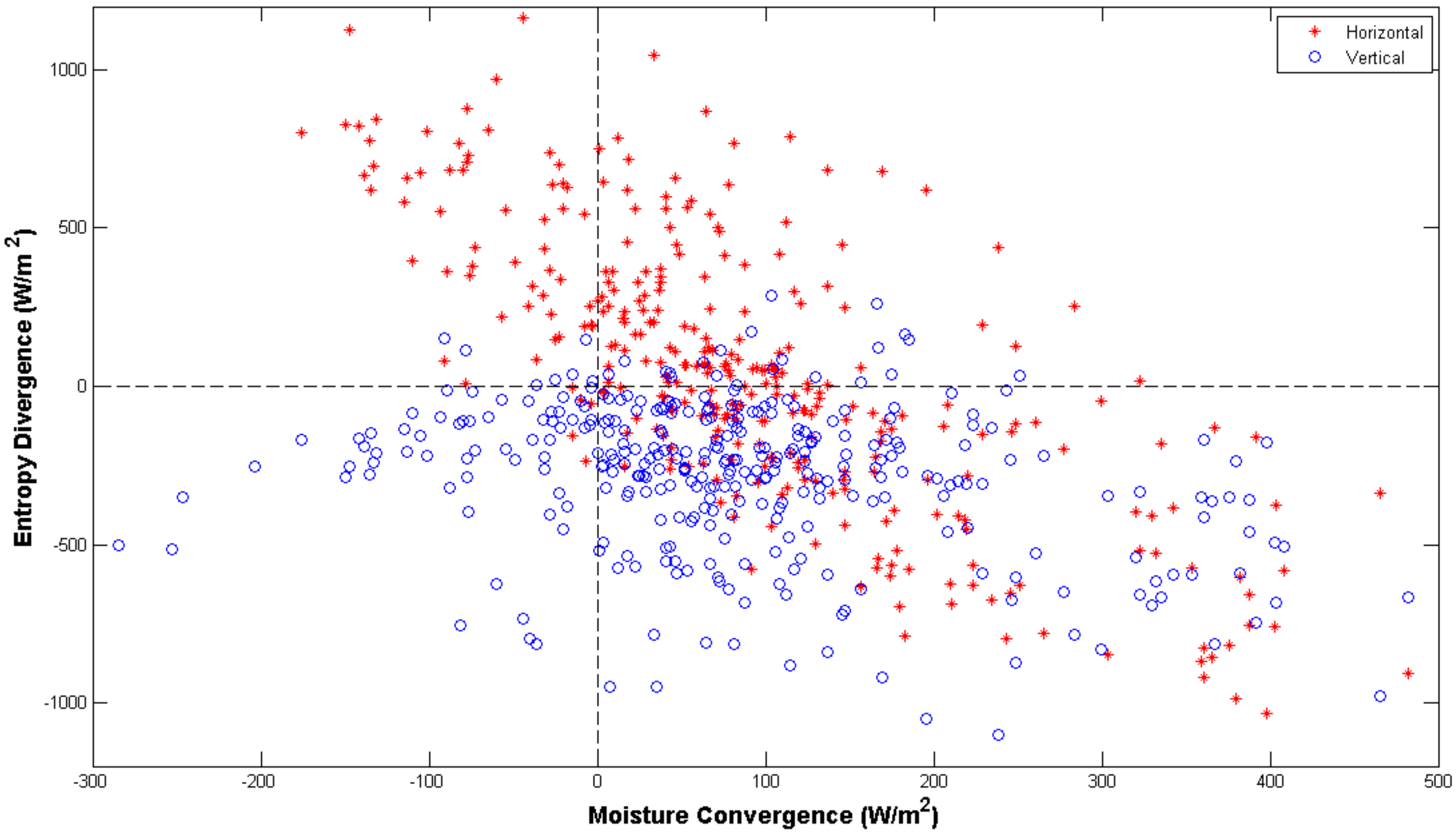


4. RESULTS – WHOLE ECMWF DOMAIN



5. CONCLUSIONS

- Our SF against rain rates in the Mediterranean environment fit to some extent the observational data in the tropics. Type II cases better?

- The vertical contribution term (basically negative) of NGMS usually dominates over horizontal advections (positive and negative)

- Not clear what NGMS<0 means in the Mediterranean... Further studies needed to check its potential predictability use (similarly to τ_c)

- Future work: calculate for continuous data timeseries, not just individual events; vertical mass fluxes, etc.

Thank you all for the attention!

Hvala na pozornosti i ugodan dan!