

Reconstruction of a realistic rainfall field for extreme events happened in mountain area, Lombardy – Italy

EGU General Assembly 2021

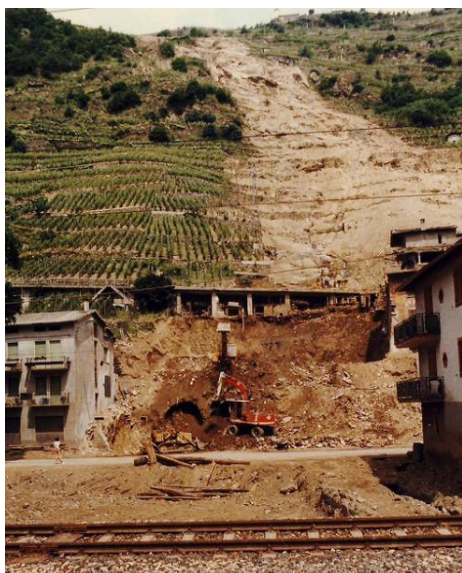
Andrea Abbate, Laura Longoni, Monica Papini



POLITECNICO
MILANO 1863



TRESEDA 1983



BELLANO 1997



TALAMONA 2008



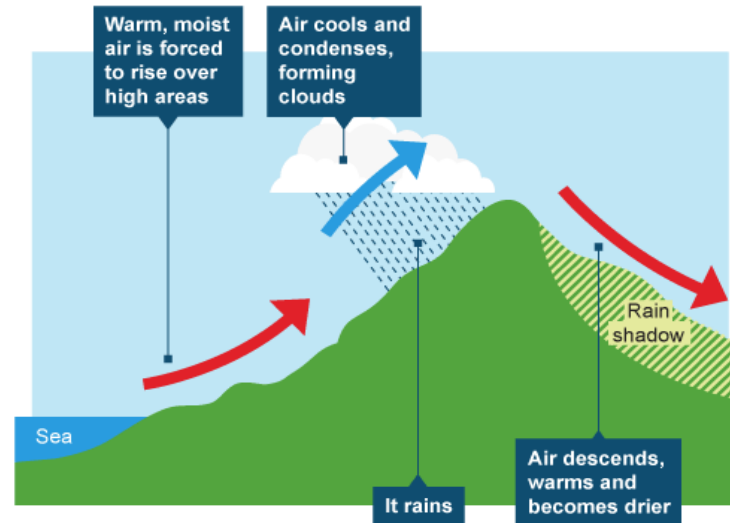
PREMANA 2019



Linear Upslope Model 1D (LUM)

We tested the **Linear Upslope Model** designed for **estimating rainfall records in orographic precipitation**. This model explicitly addresses the dependence of **rainfall intensification caused by the terrain elevation** and evaluates the spatial evolution of a precipitation P (mm) triggered by the local orography h (m). The idea behind the model formulation is the following: when a **humid airflow rises** along a slope, it **starts to condense**, cooling adiabatically and triggering rainfall on the up-slope flank of the mountain range. Beyond the mountain peak, the airflow begins to **descend** and **dries out due to adiabatic warming**, causing a decrease in rainfall.

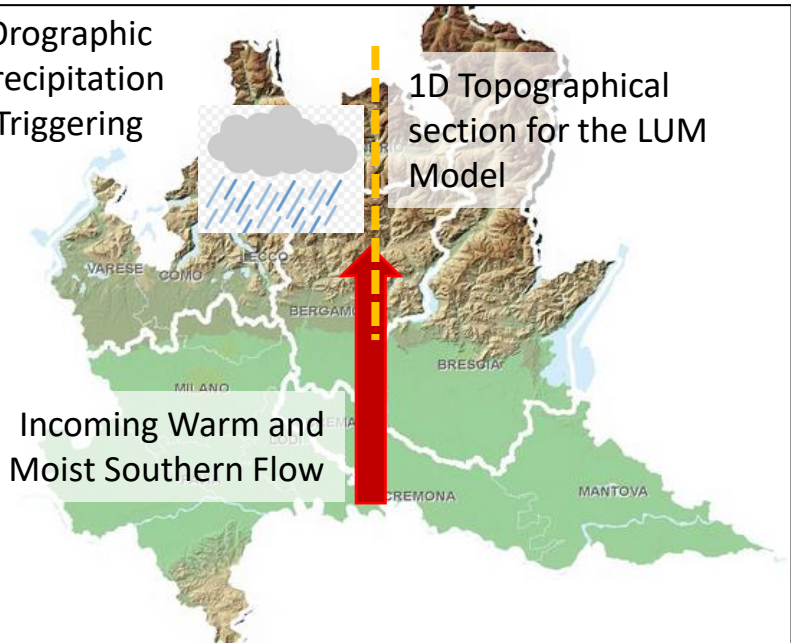
Orographic Precipitation Mechanism in Southern Alps



Orographic Precipitation Triggering

1D Topographical section for the LUM Model

Incoming Warm and Moist Southern Flow



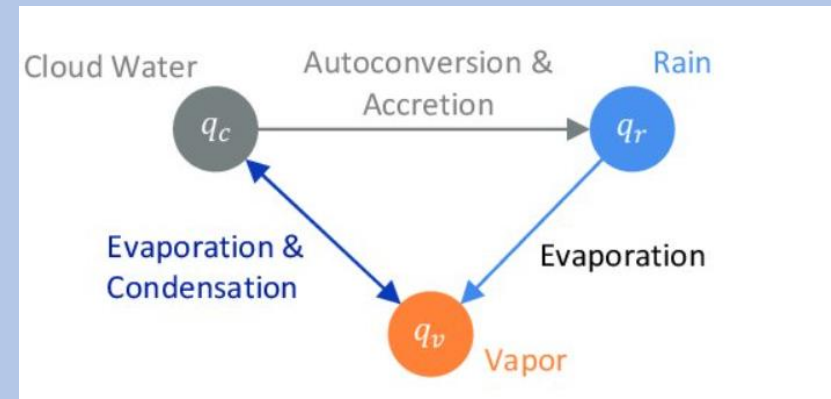
Linear Upslope Model with Microphysics

$$\mathbf{U} \cdot \nabla q_c = S(x, y) - \frac{q_c}{\tau_c}$$

$$P(x, y) = q_s(x, y)/\tau_f$$

$$\mathbf{U} \cdot \nabla q_s = \frac{q_c}{\tau_c} - \frac{q_s}{\tau_f}$$

$$S(x, y) = S_\infty + C_w \mathbf{U} \cdot \nabla h(x, y),$$



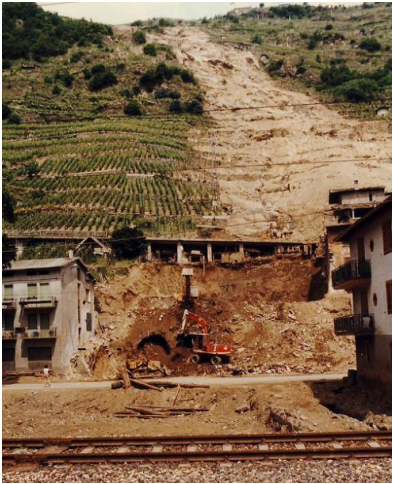
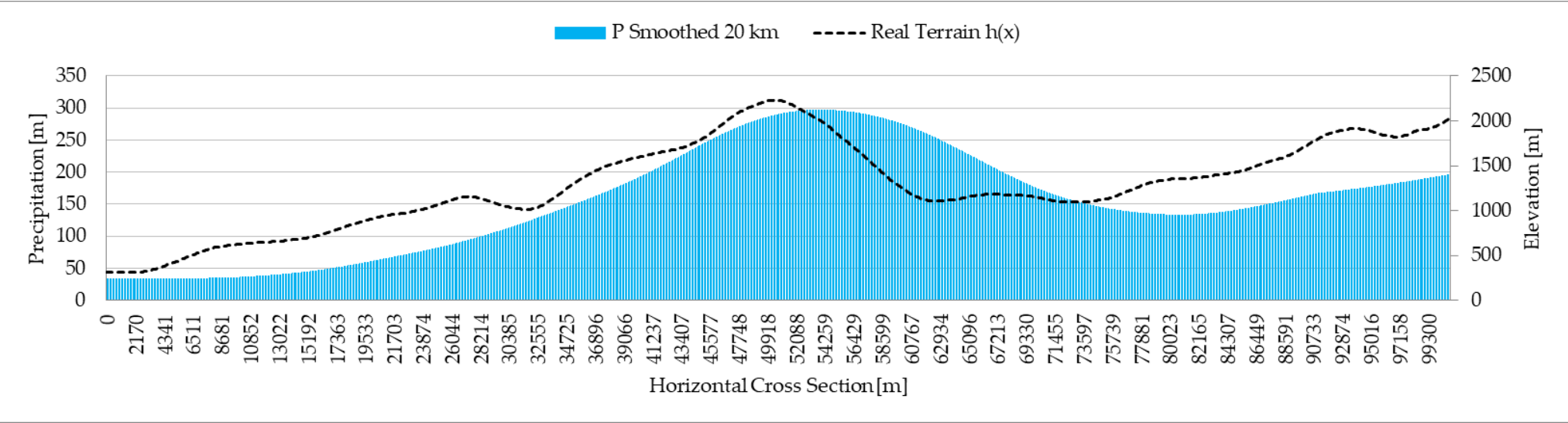
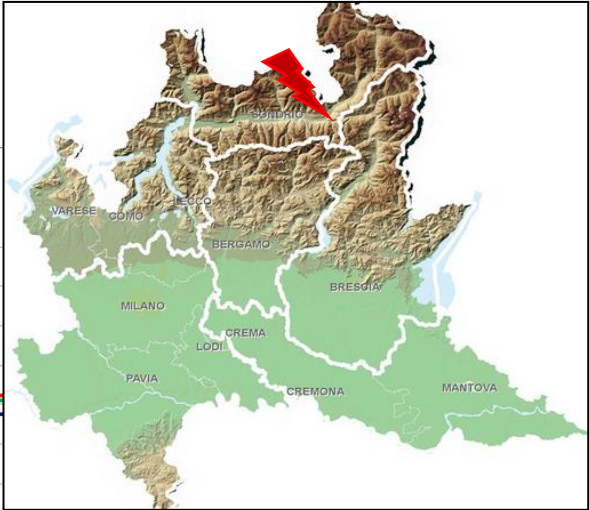
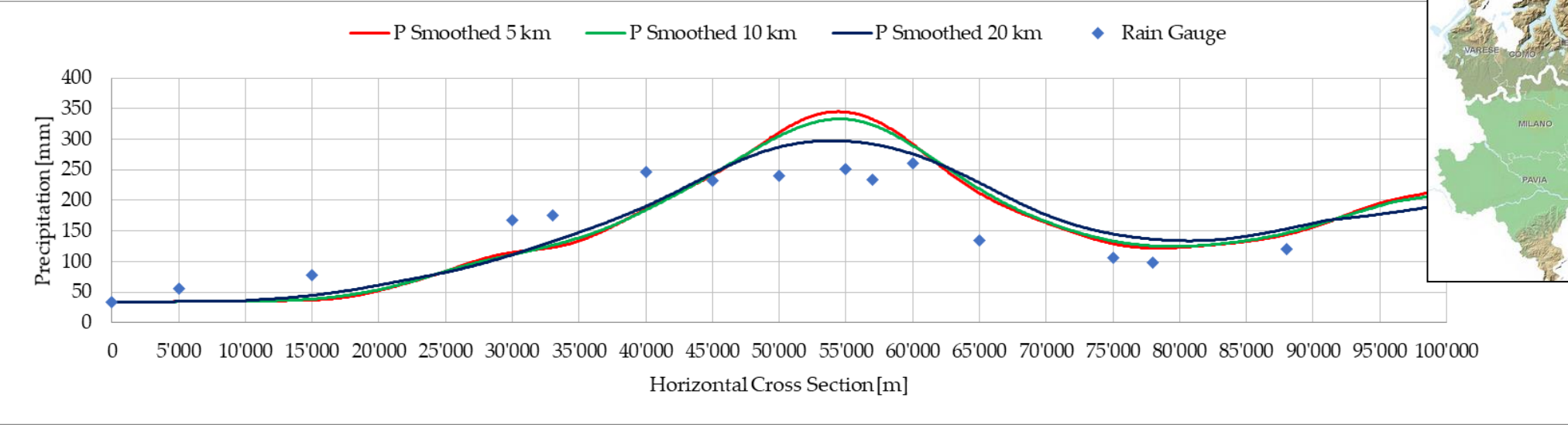
A pair of steady-state advection equations describing the vertically **integrated cloud water density** $q_c(x, y)$ and **hydrometeor density** $q_s(x, y)$. where τ_c is the time constant for **conversion** from cloud water to hydrometeors (i.e., rain or snow) and τ_f is the time constant for hydrometeor **fallout**. The model is vertically integrated, we use average values of the time constants, range from **200 to 2000 s**, representative of the whole column.

TRESEDA 1983:

tau c [1/s]	4500.0
tau f [1/s]	500.0
U [m/s]	18.6

Microphysical parameters

Incoming airflow velocity

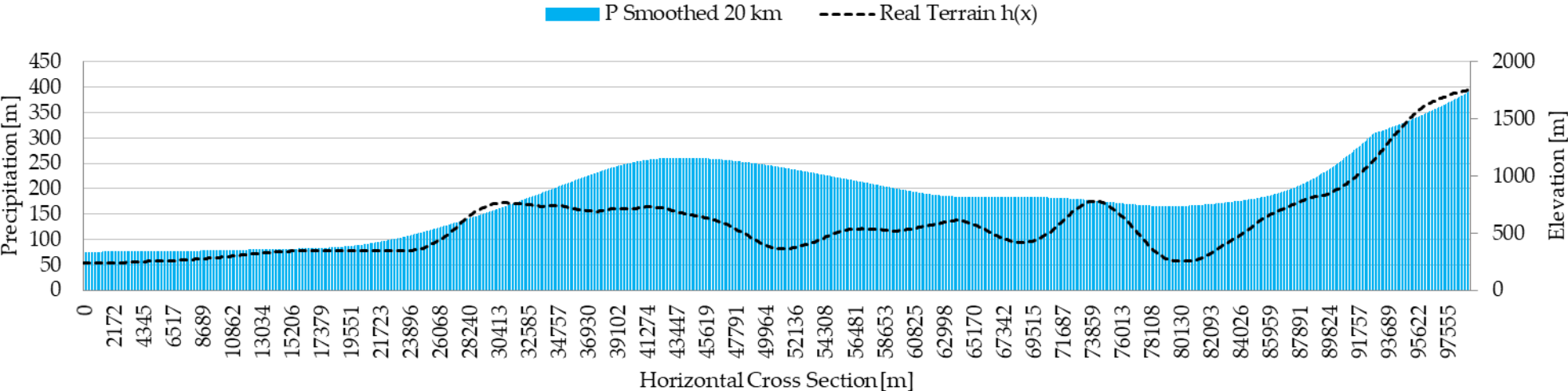
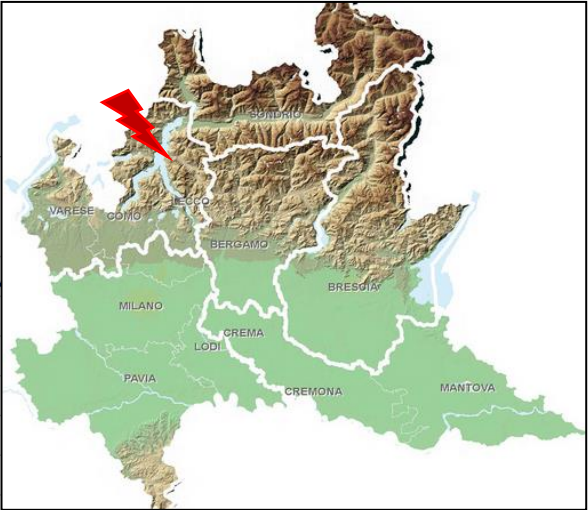
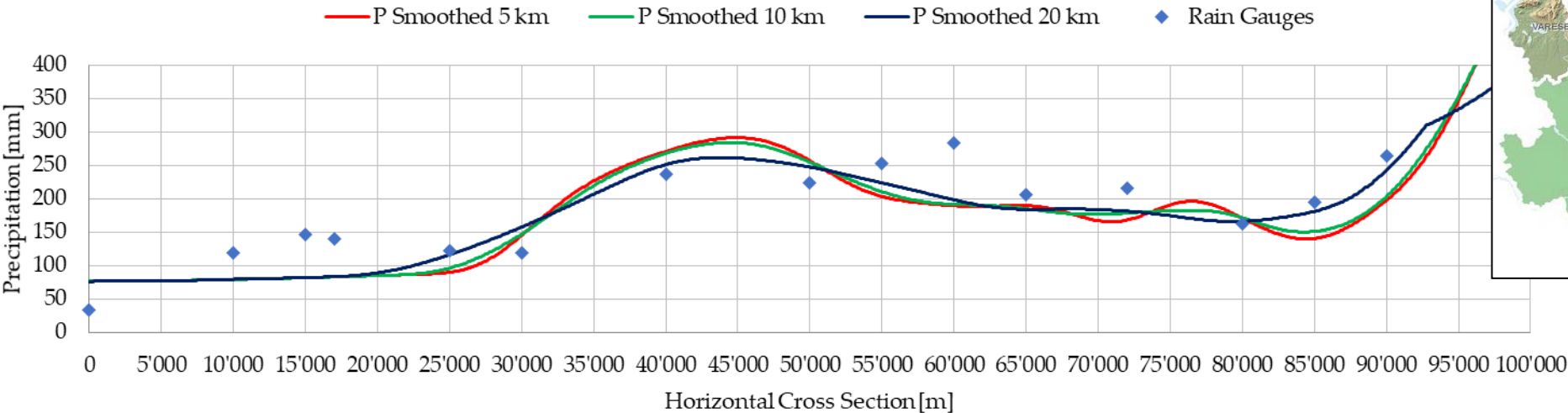


BELLANO 1997:

τ_c [1/s]	3500.0
τ_f [1/s]	750.0
U [m/s]	20.8

Microphysical parameters

Incoming airflow velocity

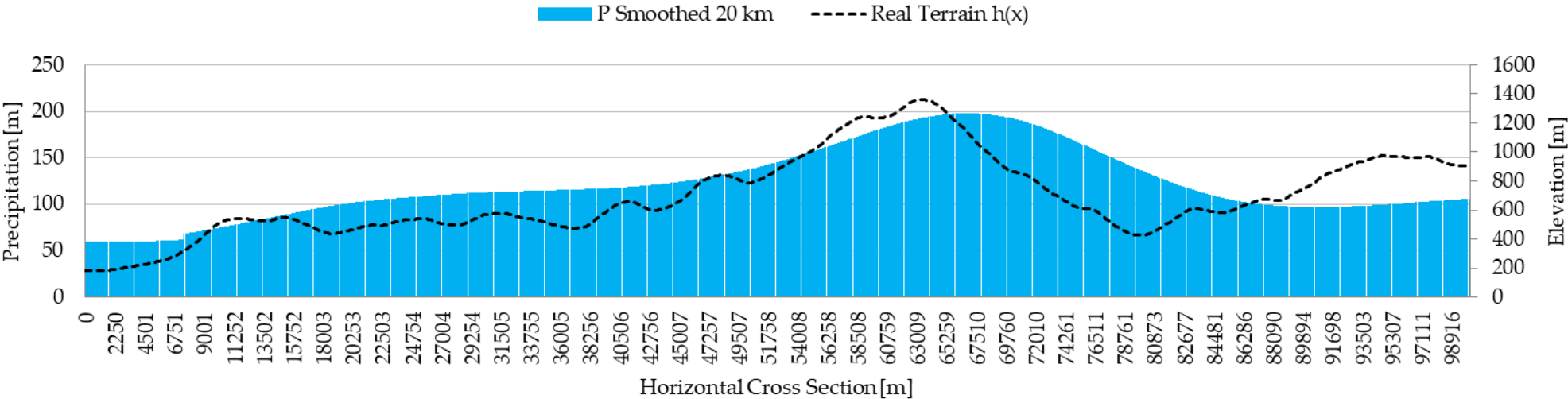
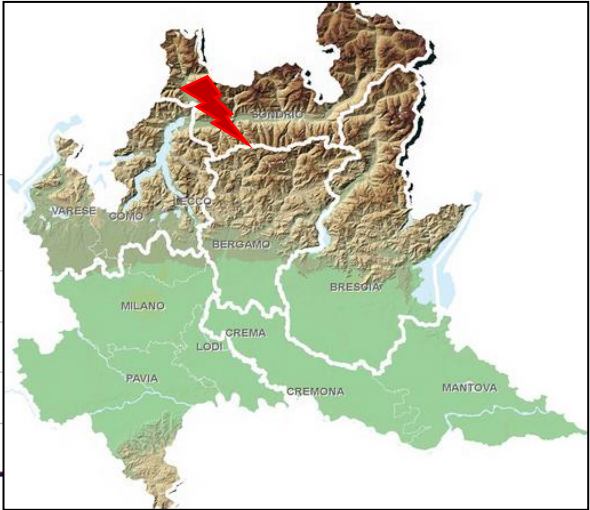
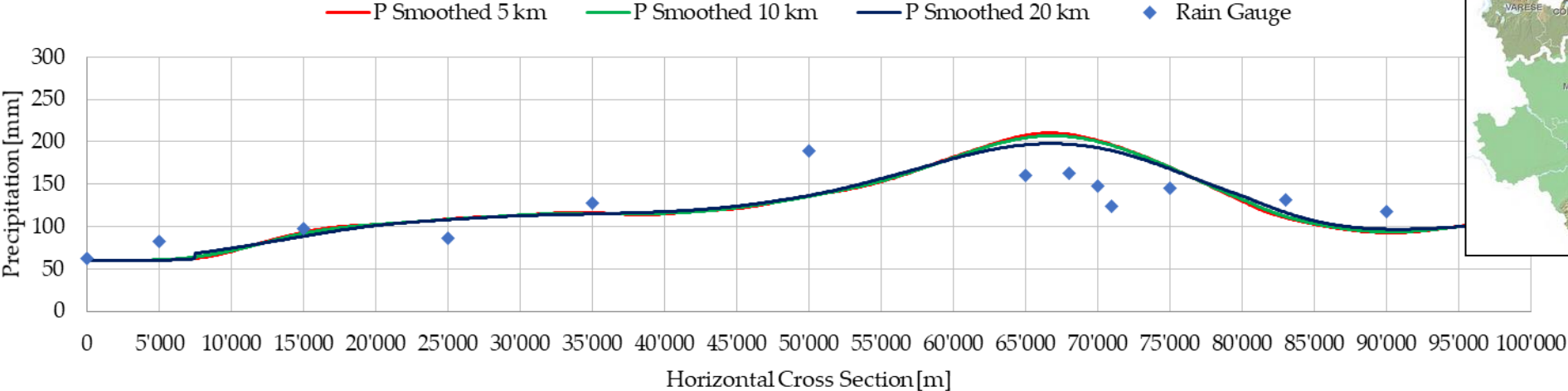


TALAMONA 2008:

τ_c [1/s]	2500.0
τ_f [1/s]	1000.0
U [m/s]	15.8

Microphysical parameters

Incoming airflow velocity

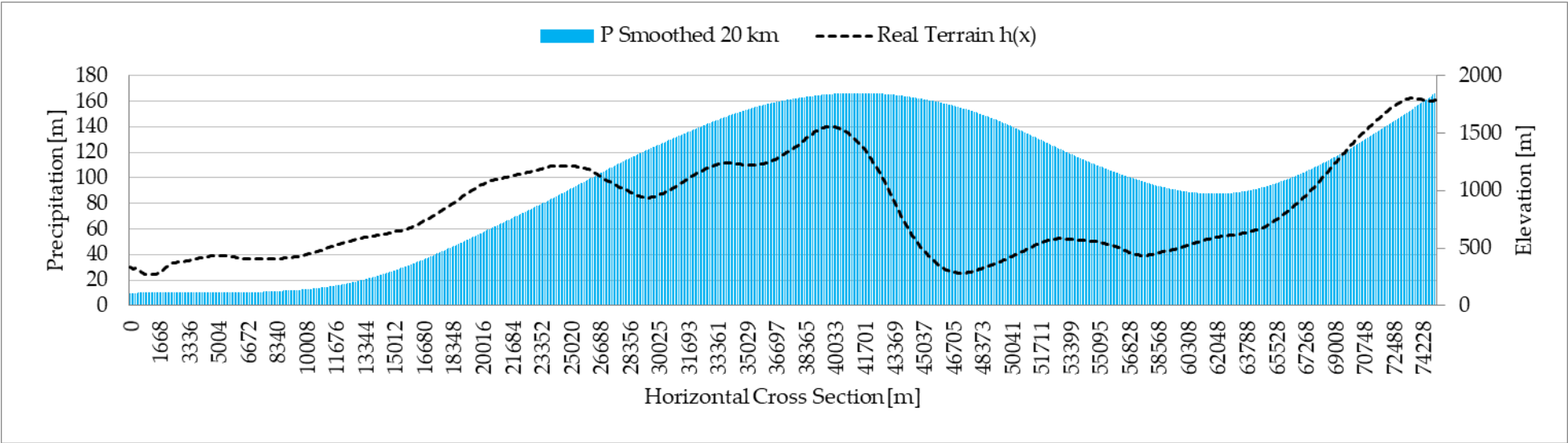
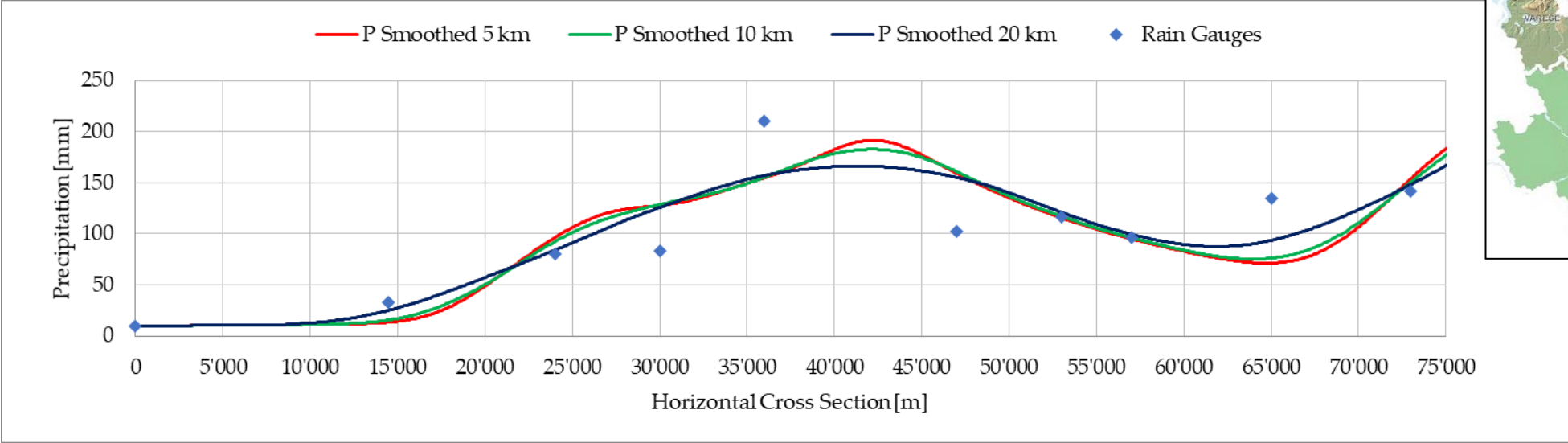
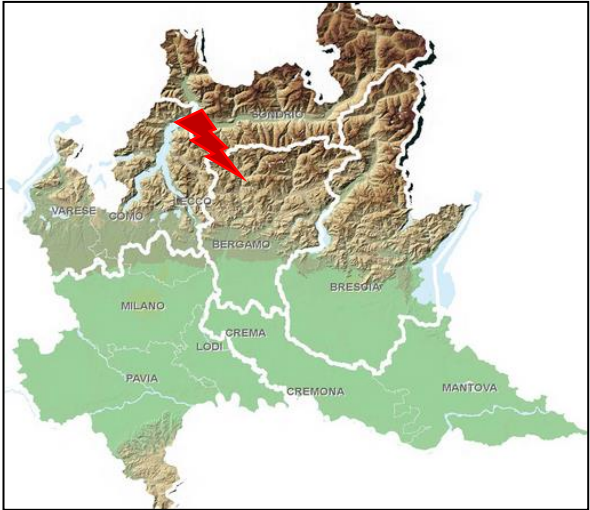


PREMANA 2019:

τ_c [1/s]	1000.0
τ_f [1/s]	500.0
U [m/s]	22.2

Microphysical parameters

Incoming airflow velocity



SOME DISCUSSIONS AND OPEN PROBLEMS:

PROS:

- The Linear Upslope Model LUM may be suitable in reproducing CRITICAL RAINFALL EVENTS we have INVESTIGATED: 1983 – 1997 – 2008 – 2019;
- The errors in respect to recorded rainfalls at RAIN GAUGES are relatively small;
- The model can be extended 2D simply with FFT transformation and easily implemented in Python Language (on going research).

CONS:

- The model is rather sensible to Microphysical parameters:
 - τ_C : Cloud Conversion Time of the Rainfall;
 - τ_F : Rainfall Fallout;
- In principle cannot be applied to Convective Rainfalls but is suitable for Stratiform Rainfalls;

OPEN PROBLEMS

Sometimes Orographic Precipitation exhibit a combination among of Stratiform and Convective nature of precipitation. In order to keep the Linearity of the model even if we would try to reproduce convection:

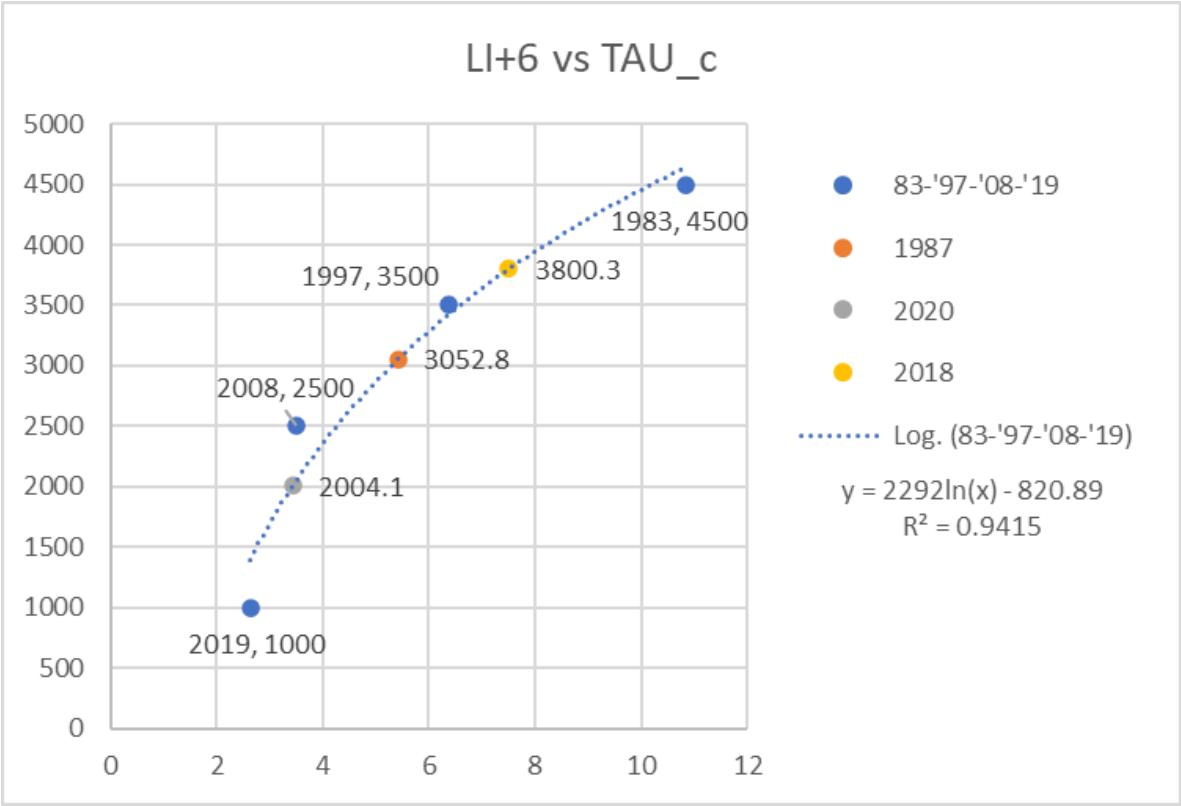
- **Can the parameter τ_C and τ_F be expressed as a function of Radiosounding Parameters that identify a Thunderstorm Like Environment?**
- **How can these parameter be modified in time? Are they constant in space?**

Preliminary Results: Correlation among LUM coefficient TAU_C and Radiosounding parameters and indexes

«Calibration Event»	LI	TAU_C	LI + 6
2019	-3.37	1000	2.63
2008	-2.51	2500	3.49
1997	0.36	3500	6.36
1983	4.84	4500	10.84

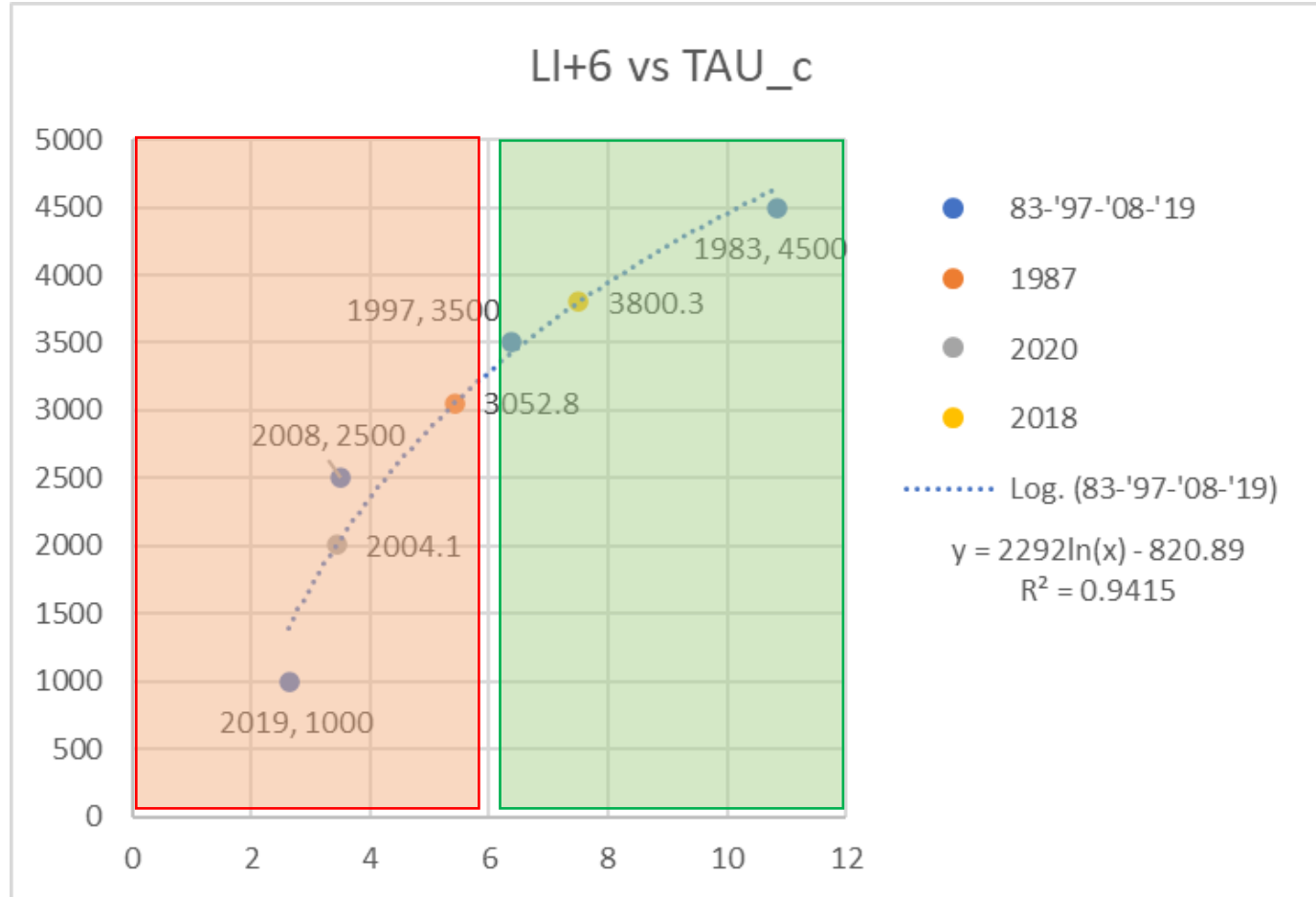
The **lifted index (LI)** is the temperature difference between the environment $T_e(p)$ and an air parcel lifted adiabatically $T_p(p)$ at a given pressure height in the troposphere (lowest layer where most weather occurs) of the atmosphere, usually 500 hPa (mb). The temperature is measured in Celsius.

- LI is generally scaled as follows:
- LI 6 or Greater, Very Stable Conditions
 - LI Between 1 and 6 : Stable Conditions, Thunderstorms Not Likely
 - LI Between 0 and -2 : Slightly Unstable, Thunderstorms Possible, With Lifting Mechanism (i.e., cold front, daytime heating, ...)
 - LI Between -2 and -6 : Unstable, Thunderstorms Likely, Some Severe With Lifting Mechanism
 - LI Less Than -6: Very Unstable, Severe Thunderstorms Likely With Lifting Mechanism



«Check Event»	LI	TAU_C	LI + 6
1987	-0.58	3052.8	5.42
2020	-2.57	2004.1	3.43
2018	1.51	3800.3	7.51

Preliminary Results: Correlation among LUM coefficient TAU_C and Radiosounding parameters and indexes



Thunderstorm not likely

- LI 6 or Greater, Very Stable Conditions
- LI Between 1 and 6 : Stable Conditions, Thunderstorms Not Likely

Thunderstorm likely

- LI Between 0 and -2 : Slightly Unstable, Thunderstorms Possible, With Lifting Mechanism (i.e., cold front, daytime heating, ...)
- LI Between -2 and -6 : Unstable, Thunderstorms Likely, Some Severe With Lifting Mechanism
- LI Less Than -6: Very Unstable, Severe Thunderstorms Likely With Lifting Mechanism

TAU_C is more critical and variable because it contains all the information about the CLOUD MICROPHYSICS that is characterized by highly non linearities of the phenomena inside. Therefore, there is a WIDE RANGE OF VALUES (500-5000 s). Probably, TAU_C is higher for more Stratiform like events and is lower for Thunderstorm Episodes.

For the **TAU_F** it not seems that there are slightly differences among events. The motivation is that TAU_F has a physical meaning related to the fallout of precipitation. Fallout velocity is around 5-6 m/s that in respect to the column of the atmosphere (6-10 km depending on type of phenomena) can be assessed around 1000-2000 s.

Further References:

Abbate, A.; Papini, M.; Longoni, L. Extreme Rainfall over Complex Terrain: An Application of the Linear Model of Orographic Precipitation to a Case Study in the Italian Pre-Alps. *Geosciences* 2021, 11, 18.

<https://doi.org/10.3390/geosciences11010018>

Smith, R. B., & Barstad, I. (2004). A Linear Theory of Orographic Precipitation, *Journal of the Atmospheric Sciences*, 61(12), 1377-1391.

Barstad, I., & Smith, R. B. (2005). Evaluation of an Orographic Precipitation Model, *Journal of Hydrometeorology*, 6(1), 85-99.