# Identification of soil-cooling rains from soil temperature and soil moisture observations

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EGU2019, Vienna, 8 April 2019

# Measurement of rain temperature

- **Precipitation-induced sensible heat into the soil**
  - **Often neglected in Land Surface Models, or**
    - **Rainwater T ~ air T / wet bulb T**
- **Not explicitely simulated in Atmospheric Models**
    - **Rainwater T ~ air T**
- **Not routinely measured now**
  - **Byers et al. (1949)** https://doi.org/10.1175/1520-0469(1949)006<0051:MORT>2.0.CO;2



## MEASUREMENT OF RAIN TEMPERATURE

*By Horace R. Byers, Harry Moses, and Patrick J. Harney*

U. S. Weather Bureau Thunderstorm Project [1]

(Manuscript received 30 May 1948)

ABSTRACT

A technique for measuring the temperature of rain at the ground and the methods for calibrating the equipment used for this purpose are described in this report. A preliminary analysis of the data indicates that significant differences between the rain and ambient air temperatures usually occur in the first portion of the thunderstorm rain period and that the differences in temperature between the ambient air and the rain falling from the latter portion of the storm are small.

# Measurement of rain temperature

- **Byers et al. (1949)** https://doi.org/10.1175/1520-0469(1949)006<0051:MORT>2.0.CO;2
  - **Direct measurements**

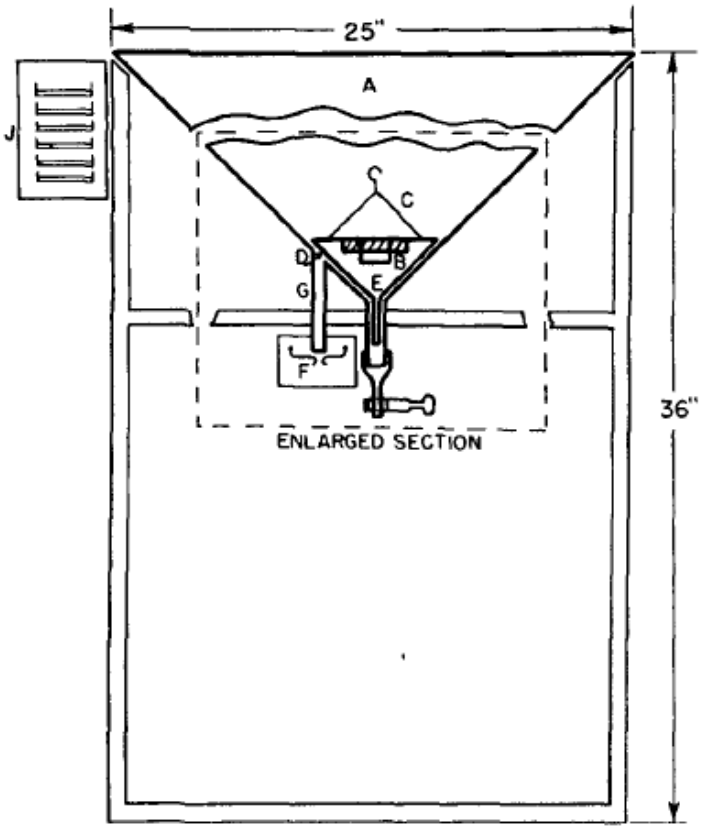


FIG. 1. Schematic diagram of rain-temperature equipment.

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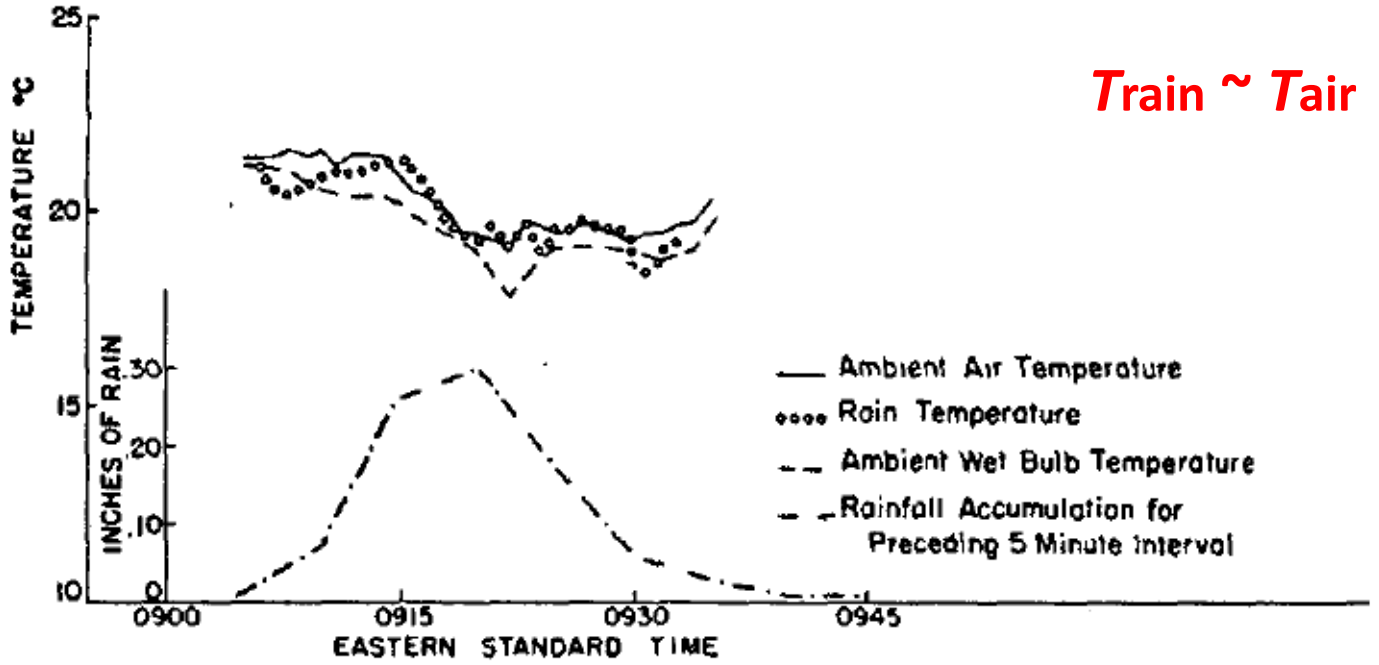


*T*rain ~ *T*air

FIG. 8. Air–rain temperature relationships, Type III; 31 August 1947, Station B, Clinton County Air Force Base, Wilmington, Ohio.

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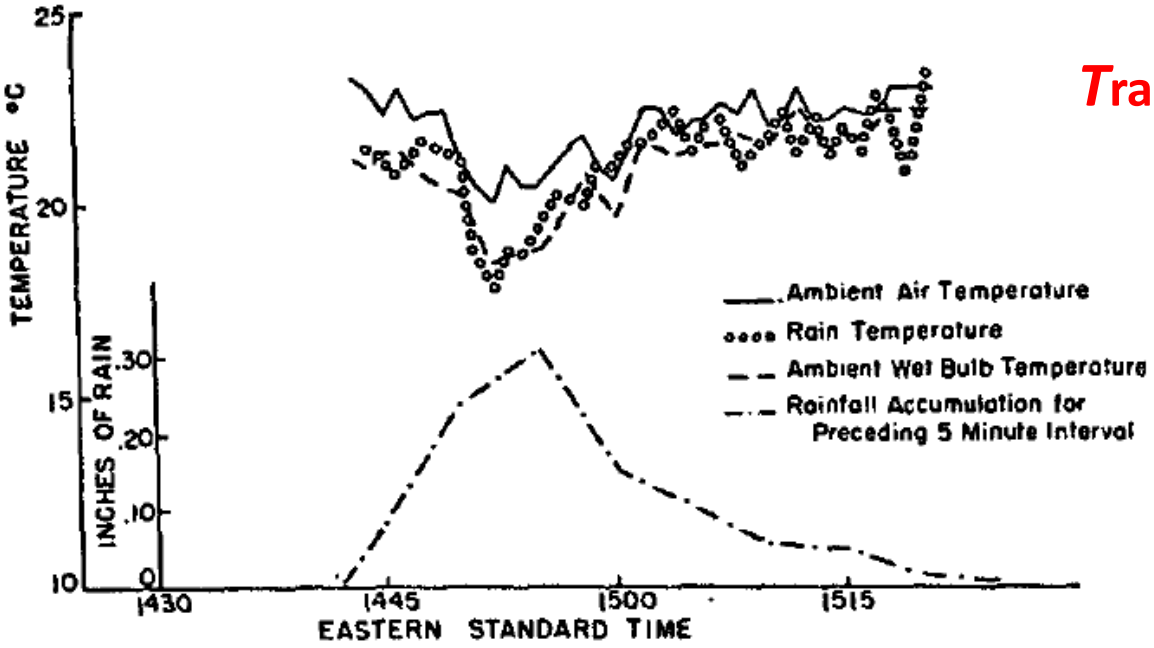


**Train ~ Twb**

FIG. 6. Air–rain temperature relationships, Type I; 14 August 1947, Station B, Clinton County Air Force Base, Wilmington, Ohio.

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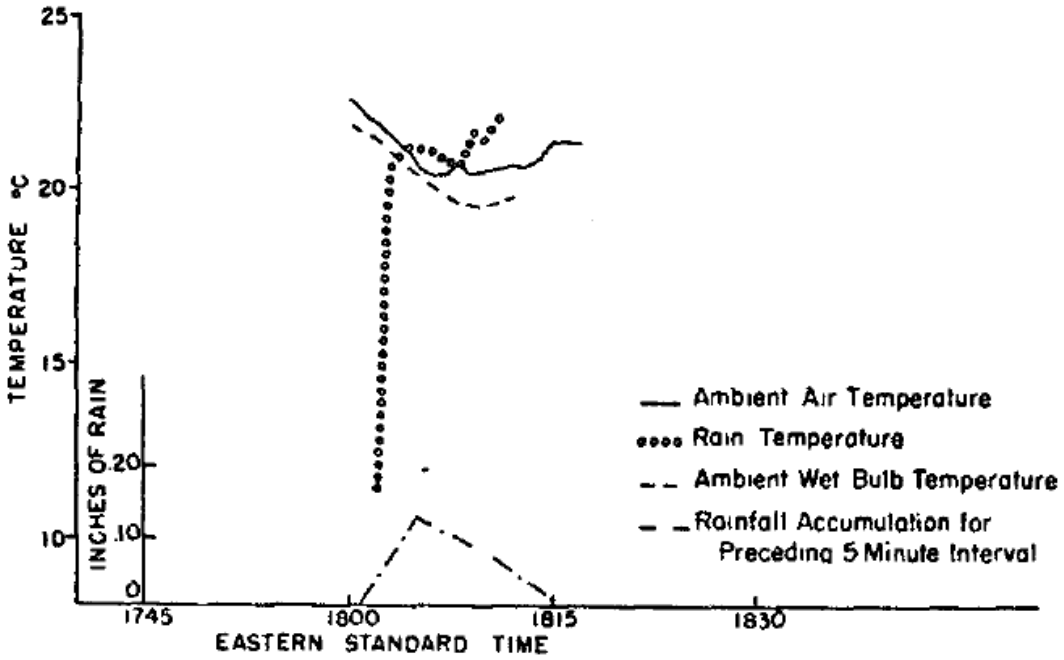


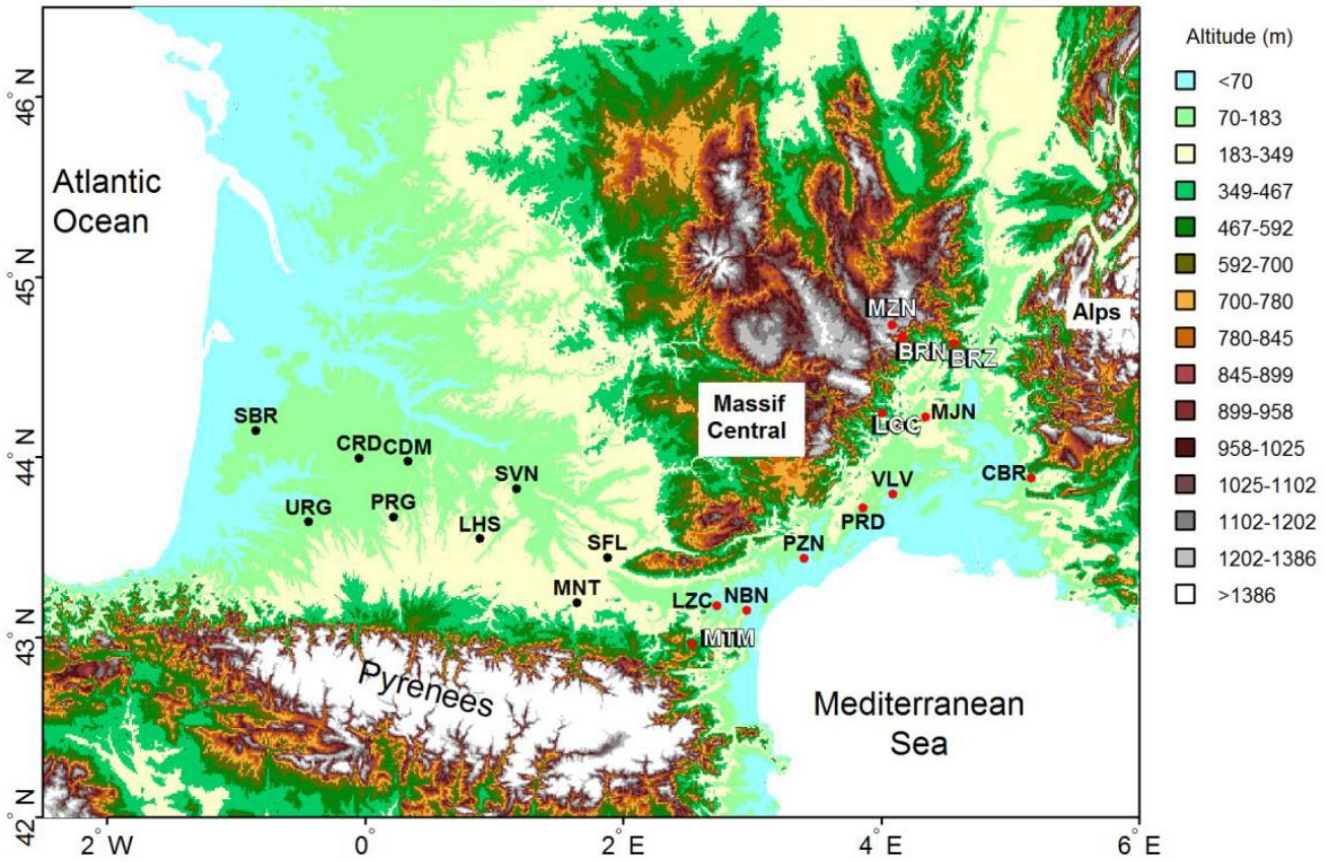

FIG. 7. Air–rain temperature relationships, Type II; 14 July 1947, Station B, Clinton County Air Force Base, Wilmington, Ohio.

***T*rain << *T*wb < *T*air**

**Hailstones melting before reaching the surface ?**

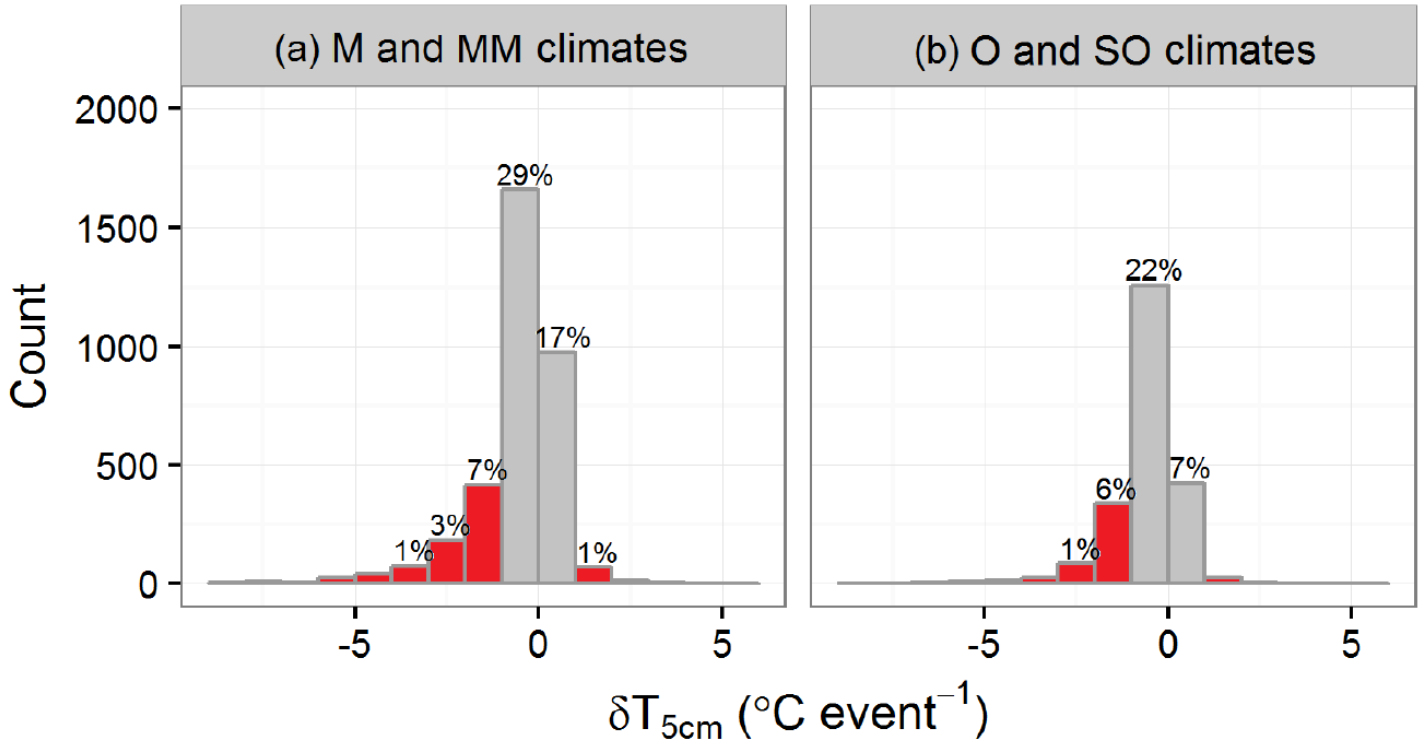
# Identification of soil-cooling rains

- **SMOSMANIA: 21 stations in SW France > 10 years, every 12 minutes**
  - **Calvet et al. SOIL 2016** https://doi.org/10.5194/soil-2-615-2016



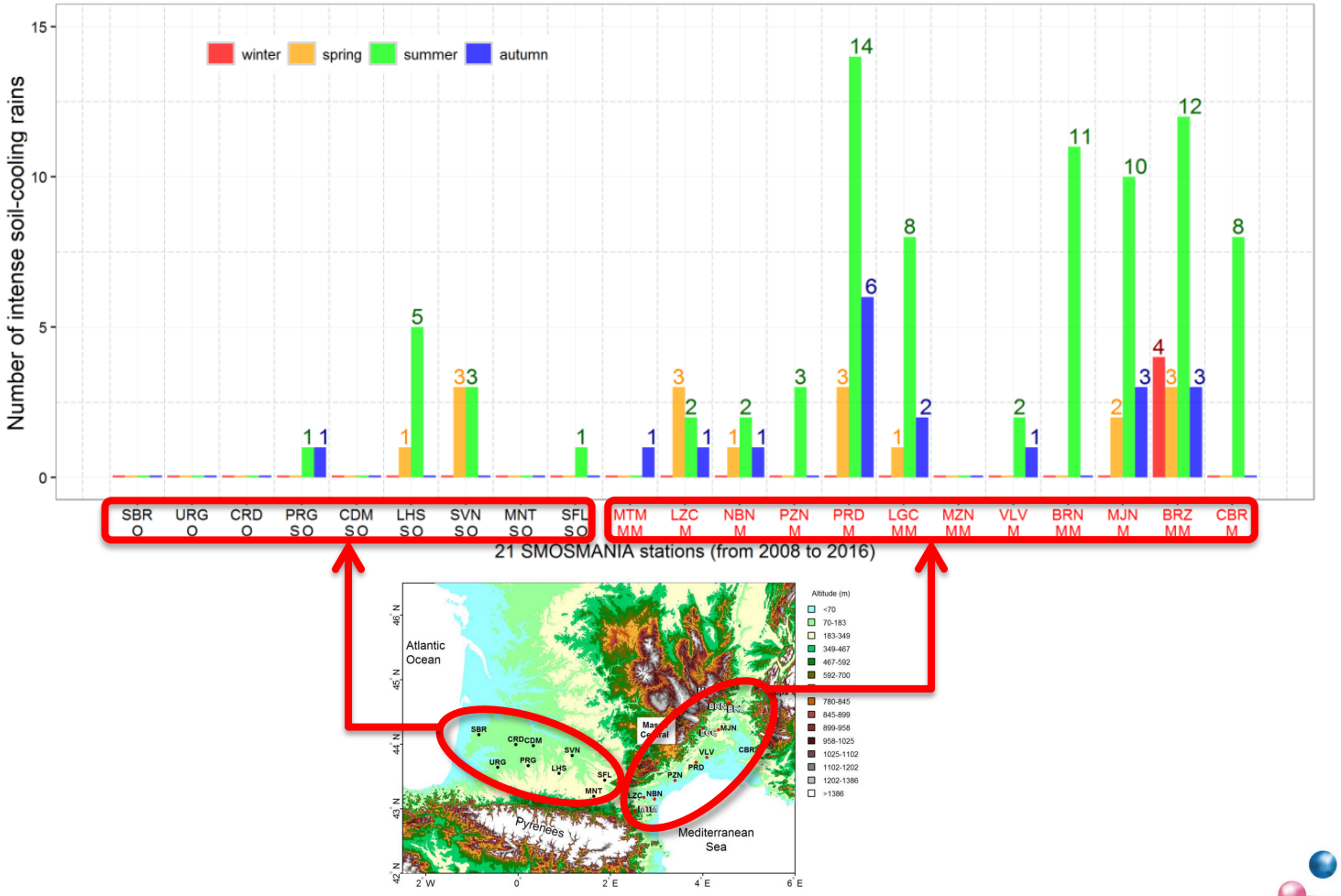
# Identification of soil-cooling rains

- **~30 marked raifall events (> 5 mm) per year per station impacting soil moisture at 5cm (≥ +0.05 m3m-3)**



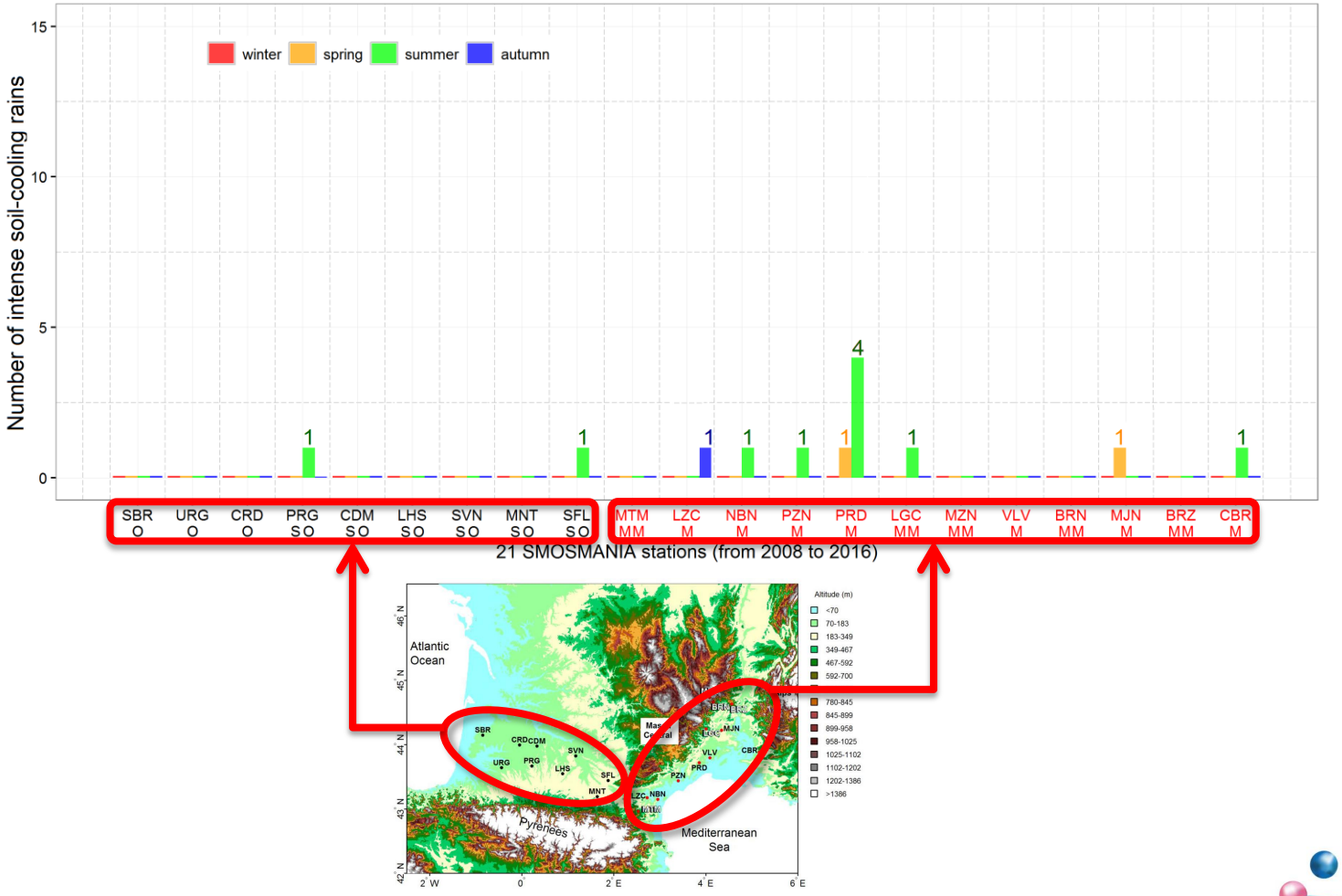
# Identification of soil-cooling rains

- **122 events from 2008 to 2016 (drop in $T_{5cm} \leq -1.5$ K in less than 12 minutes)**



# Identification of soil-cooling rains

- **13 events from 2008 to 2016 (wetting down to -10 cm in less than 12 minutes)**



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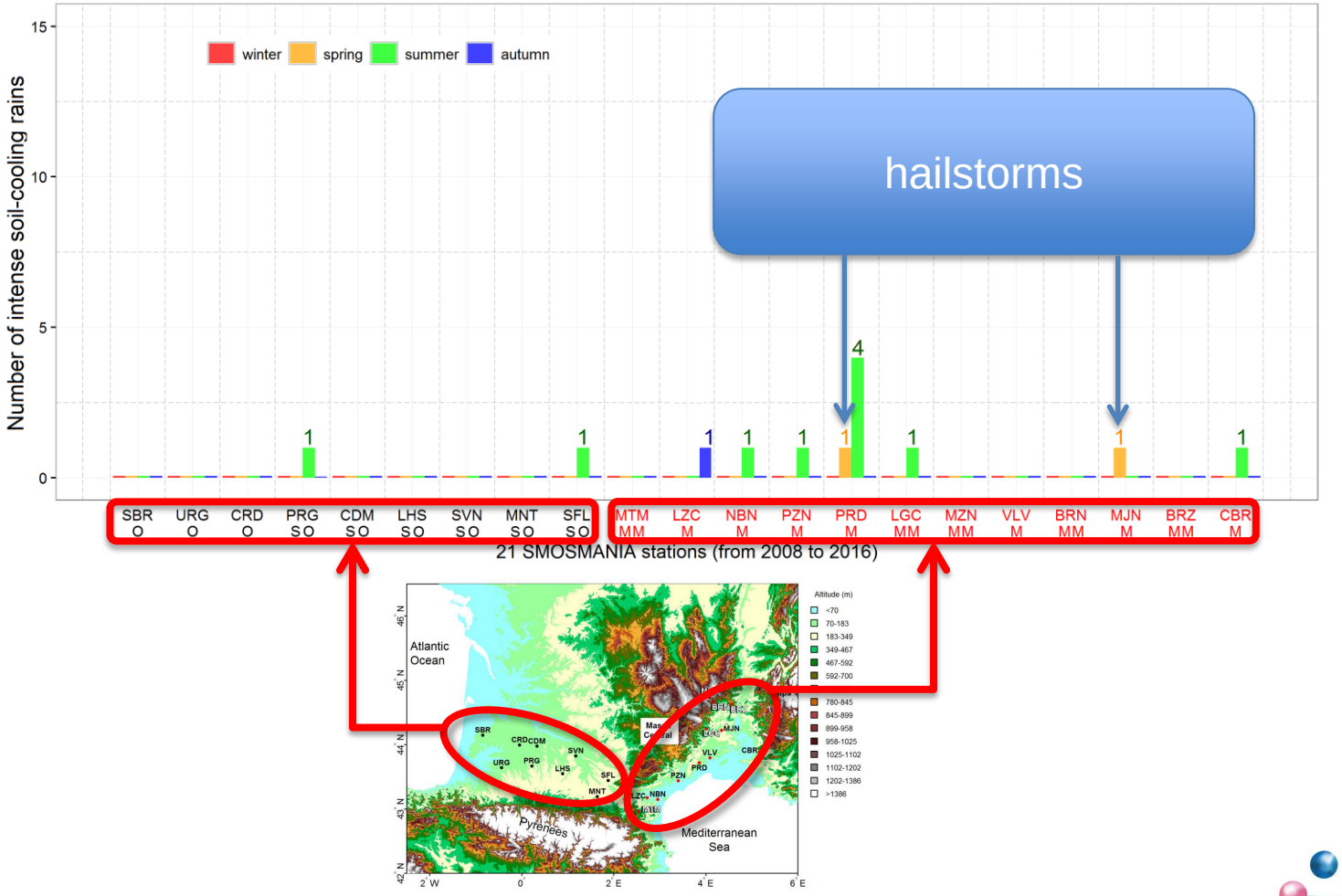


# Rainwater temperature from topsoil obs?

- **During intense precipitation within 12 minutes precipitation-induced sensible heat into the soil is:**

$$C_{5cm}^{t_1}\left(T_{5cm}^{t_1}-T_{5cm}^{t_2}\right)\Delta z = C_{water}\left(VSM_{5cm}^{t_2}-VSM_{5cm}^{t_1}\right)\left(T_{rain}^{t_2}-T_{rain}^{t_1}\right)\Delta z$$

- **Rainwater temperature**

$$T_{rain}^{t_1} = T_{5cm}^{t_2} - \frac{C_{5cm}^{t_1}}{C_{water}} \frac{\left(T_{5cm}^{t_1}-T_{5cm}^{t_2}\right)}{\left(VSM_{5cm}^{t_2}-VSM_{5cm}^{t_1}\right)}$$

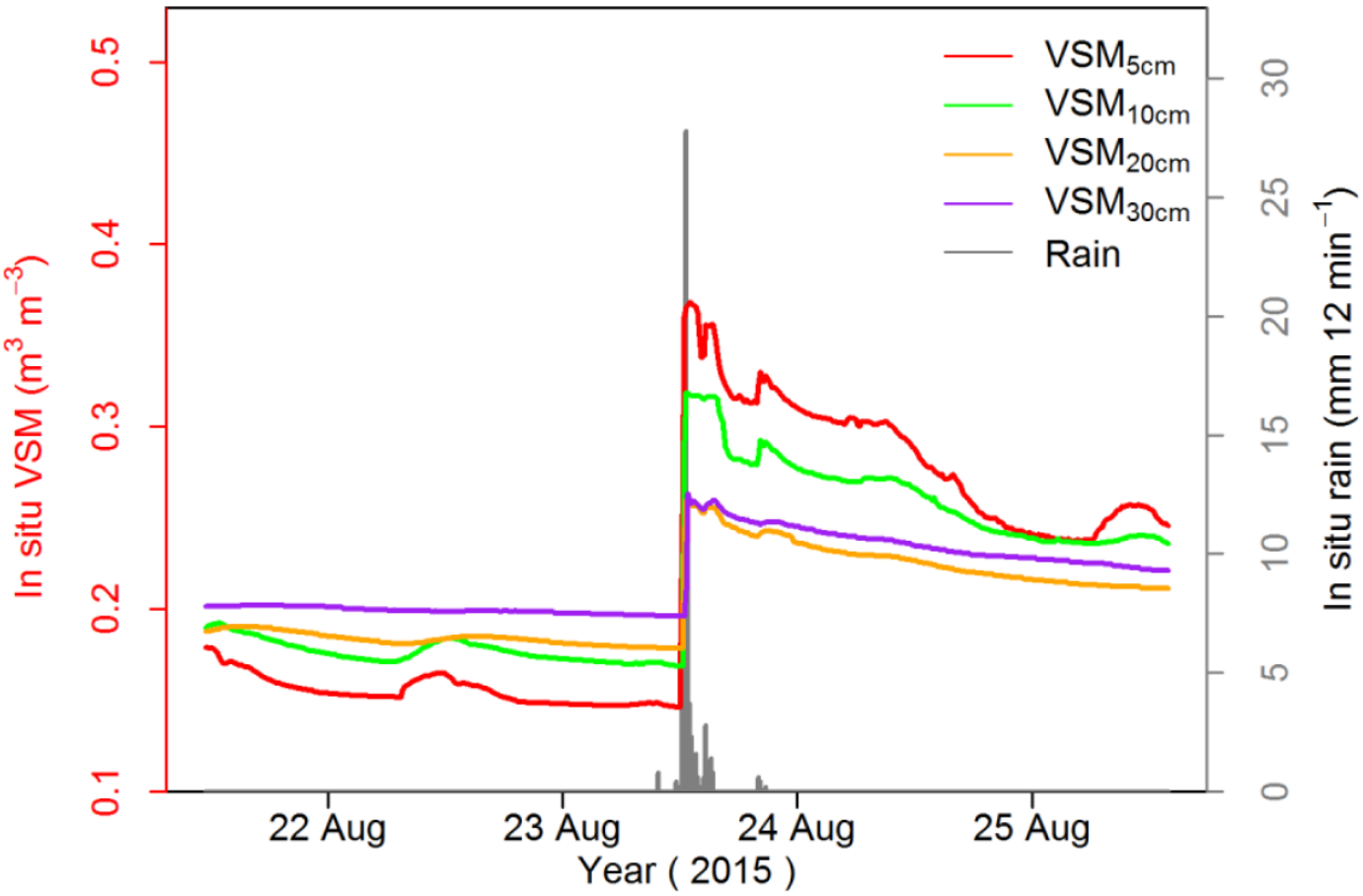
- **Melting hailstones**

$$T_{rain}^{t_1} = T_f = 0\ ^{\circ}\mathrm{C}$$

$$I = \frac{1}{L_f}\left\{C_{5cm}^{t_1}\left(T_{5cm}^{t_1}-T_{5cm}^{t_2}\right) - C_{water}\left(VSM_{5cm}^{t_2}-VSM_{5cm}^{t_1}\right)\left(T_{5cm}^{t_2}-T_f\right)\right\}\Delta z$$

# Rainwater temperature from topsoil obs?

- **Example: Prades-le-Lez – 23 August 2015**



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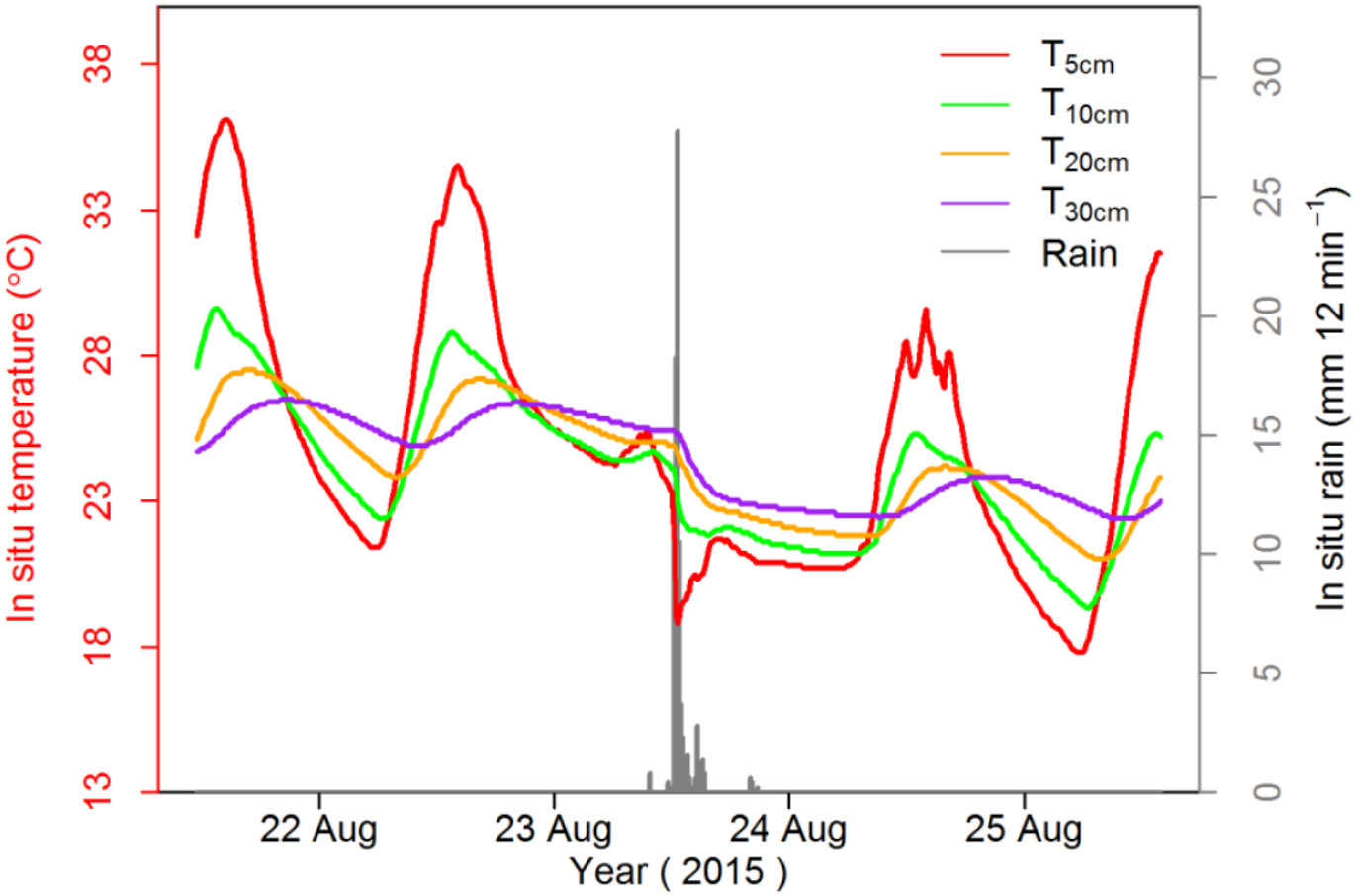


# Rainwater temperature from topsoil obs?

- **Example: Prades-le-Lez – 23 August 2015**

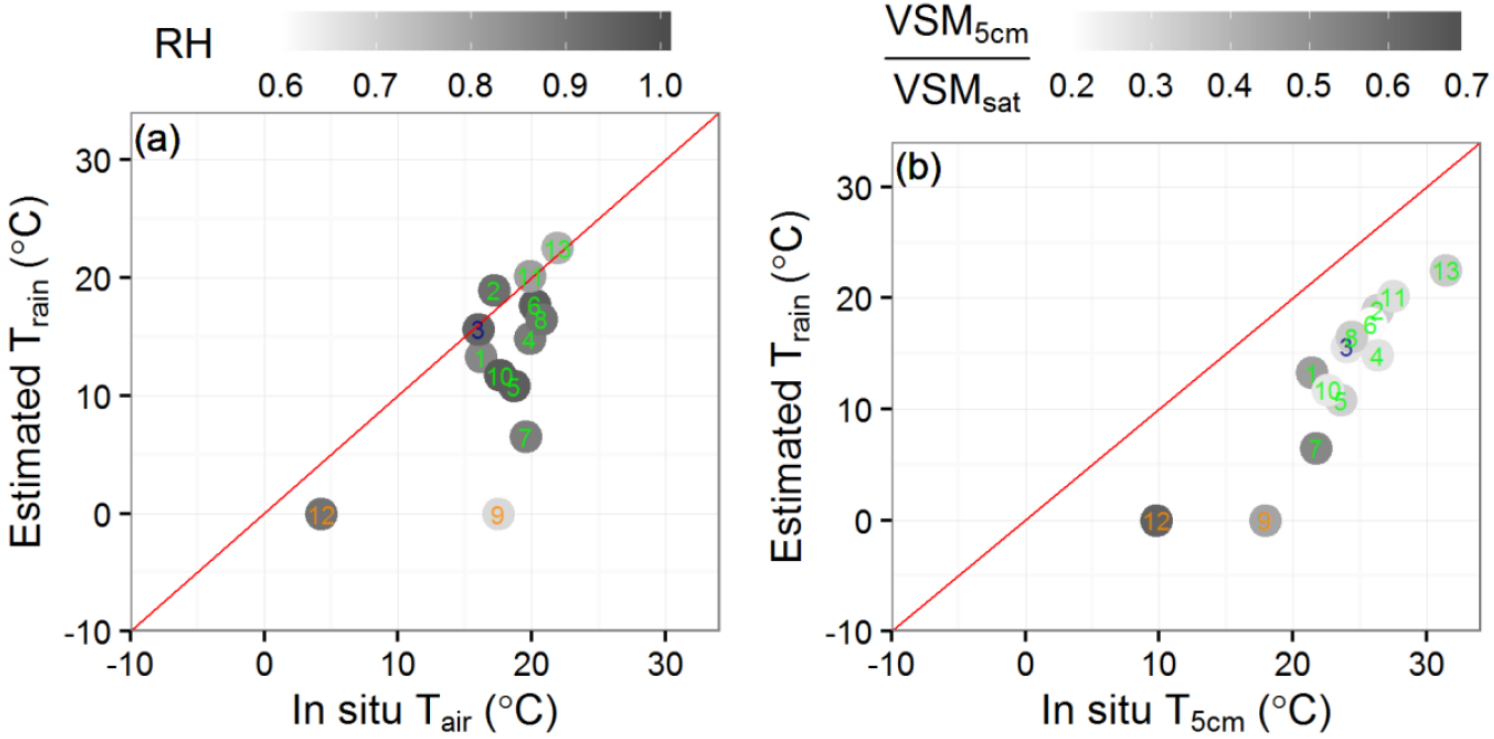
**Precipitation-induced sensible heat into the soil**

$T_{rain}$ **~ 6 degree C**
$T_{5cm}$ **~ 22 degree C**

**~ 800 W m-2**

# Rainwater temperature from topsoil obs?

- **13 events from 2008 to 2016 (wetting down to -10 cm in less than 12 minutes)**




***T*rain cooler than *T*air (-5 K on average) and than *T*5cm (-11 K on average)**

# Conclusions

- **Rainwater temperature can be**
  - **much cooler than air T**
  - **very much cooler than topsoil T**

- **Precipitation-induced sensible heat flux into the soil**
  - **should be accounted for in**
    - **Land Surface Models**
    - **Irrigation models (irrigation water temperature)**

- **Rainwater temperature should be measured**
  - **develop and test new devices**
  - **potential applications in agriculture, soil erosion monitoring, etc.**

- **More details in Zhang et al. ACP 2019 (https://doi.org/10.5194/acp-19-5005-2019)**