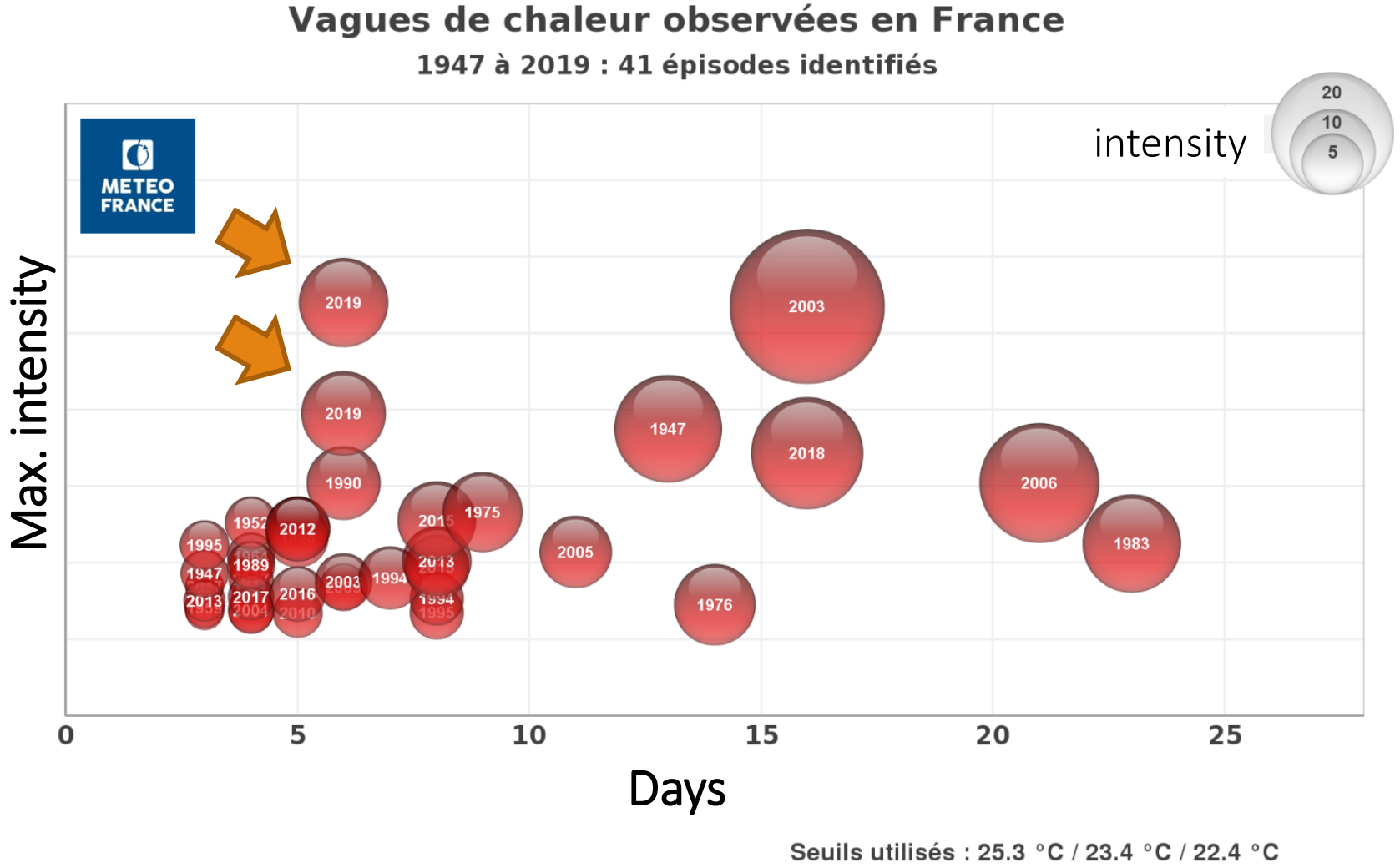
Impact of Heat Wave Episodes in Summer 2019 on the Carbon Flux

inferred through modelling using ICOS Ecosystem stations in France

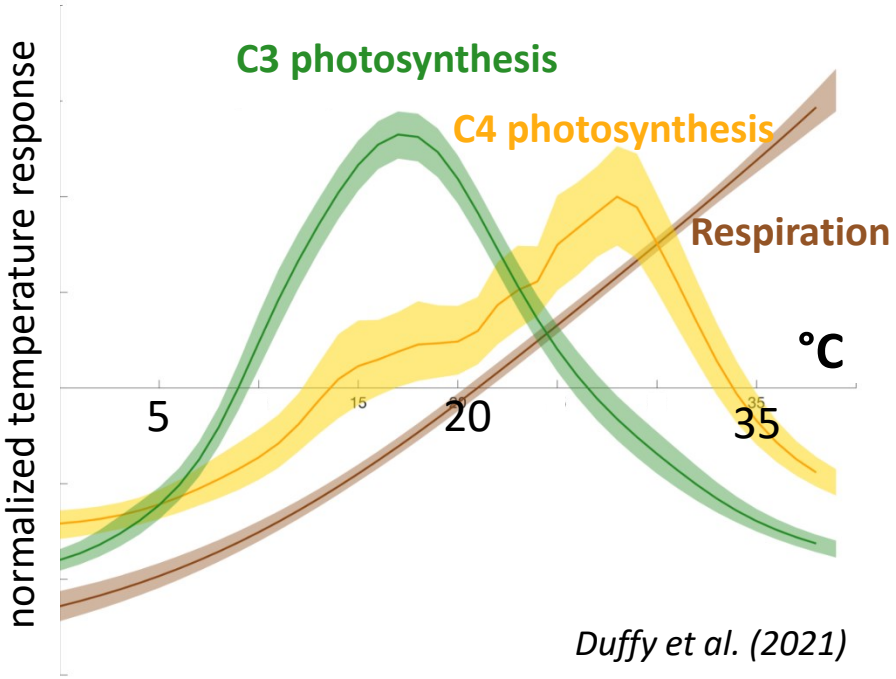
Coimbra, P., **Buysse**, P., **Loubet**, B., Simioni, G., Lafont, S., Berveiller, D., Ruffault, J., Fléchard, C. R., Martin-St-Paul, N., Bornet, F., Brut, A., Calvet, J-F., Chipeaux, C., Cuntz, M., Darsonville, O., Delpierre, N., Dufrêne, E., Galy, C., Gogo, S., Jacotot, A., Klumpp, K., Léonard, J., Lily, J-B., Limousin, J-M., Loustau, D., Marloie, O., Ourcival, J-M, Tallec, T., Voisin, D., Zawilski, B.

AST ICOS, Reims, 13 Octobre 2021

Context
2019 short episodes with high anomaly



Context
2019 Summer Heat Waves in France



Duffy et al. (2021)

- Land sink depends on temperature (Duffy et al., 2021).
- Extreme events are likely to be more intense and more frequent in the future (IPCC, 2013).
- Uncertainty whether land sink will persist regulating carbon uptake (Duffy et al., 2021).

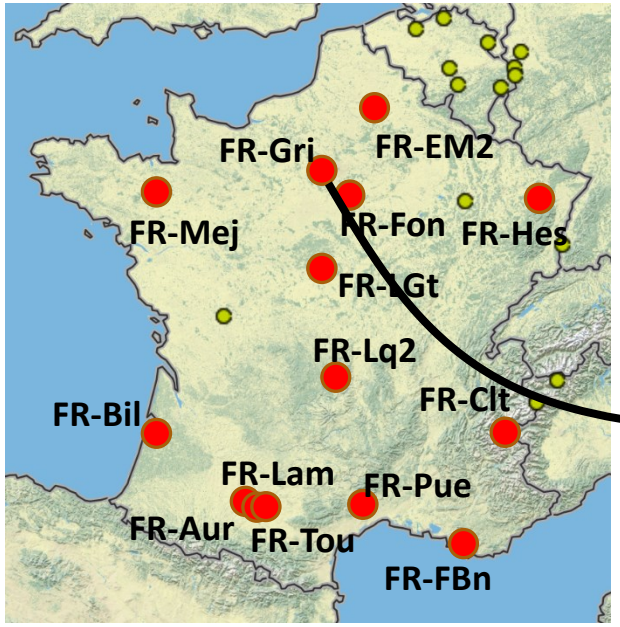
(1) Do heat waves decrease ecosystems' carbon sequestration capacity? (2) Did the ecosystems keep sequestering less carbon even after heat waves ceased?

Material & Methods
Observation Sites

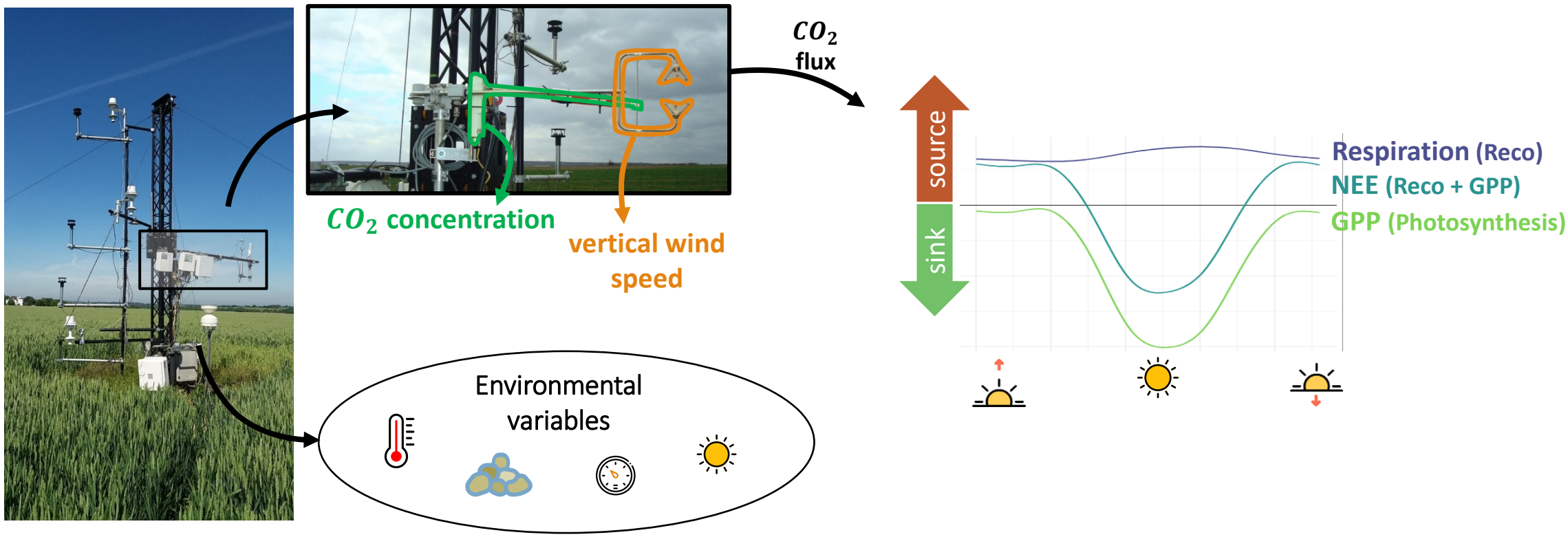
ICOS National Network France

Data from 13 sites

Forests (5)
Cropland (5)
Grassland (2)
Peatland (1)



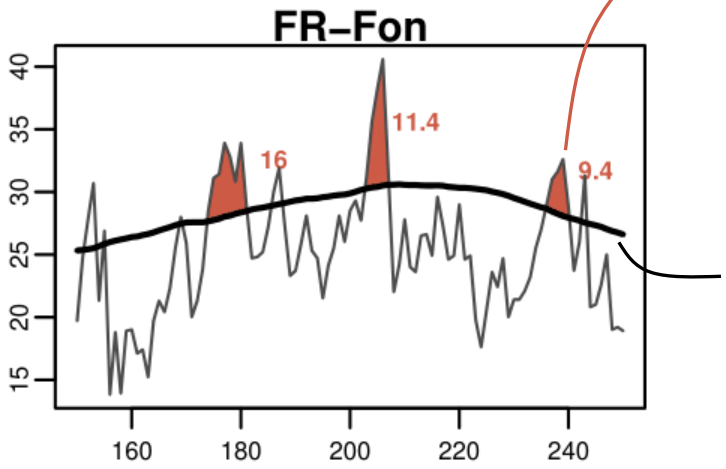
Material & Methods
Observation Sites



All icons: flaticon.com

Material & Methods
Identifying Heat Waves

Temperature
[°C, daily max.]



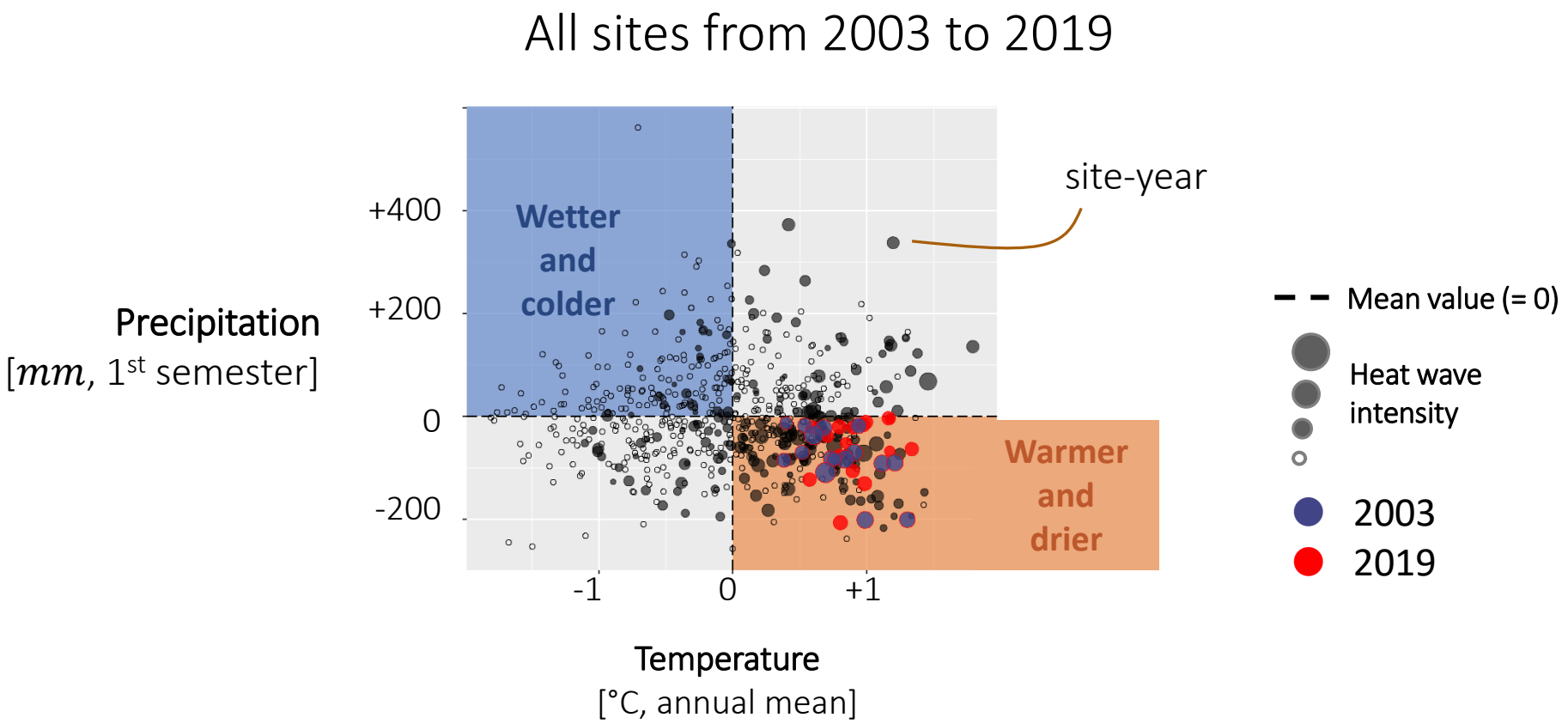
Day of the year

heat wave
>3d, Tmax

baseline (1980-2010)
90th percentile

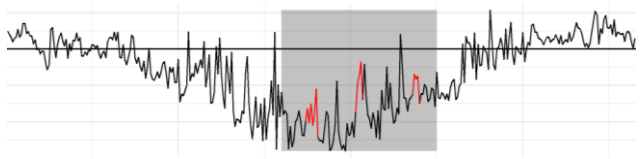
Definition from:
Russo *et al.* (2015)

Data Exploration
Heat waves happen in warmer and drier years



Data Exploration
↓ daily CO_2 sequestration with water stress

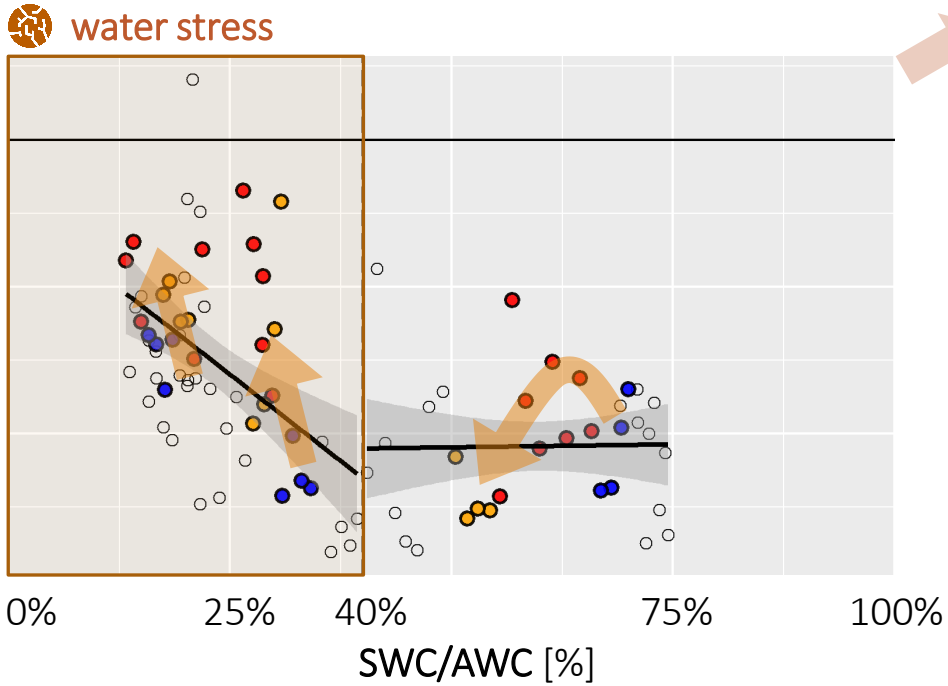
Daily NEE (2019)



Summer

NEE
$[\mu mol.CO_2.m^{-2}.s^{-1}]$

Fontainebleau (Barbeau)



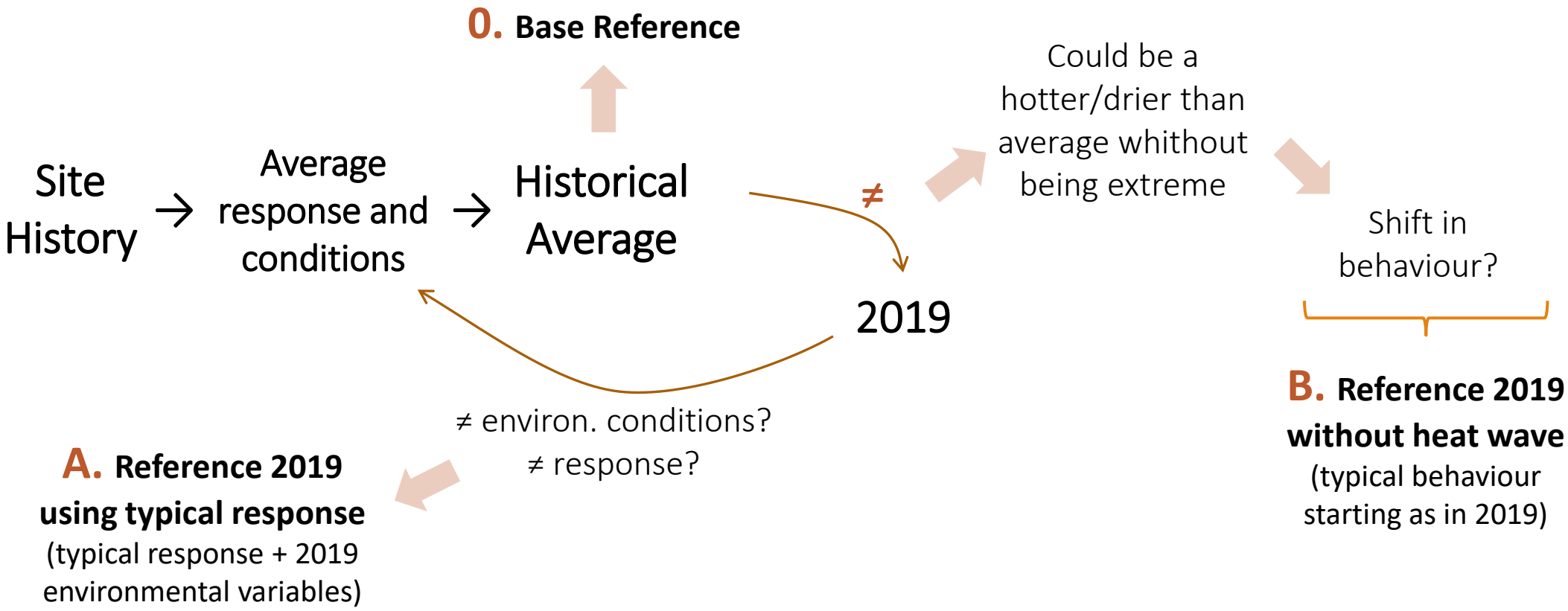
Representative for forests

Summer day

Heat waves:

- Before (4 days)
- During
- After (4 days)

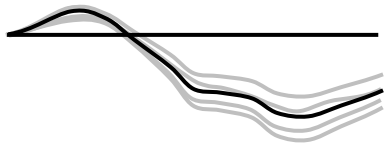
Inferring impact
Why reference years?



Inferring impact
Annual References

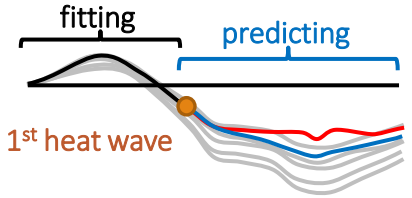
Cumulative NEE

0. Historical Average



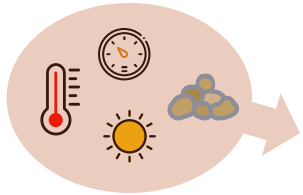
Typical year
Average response and conditions

B. Autoregressive *(ML Regression)*



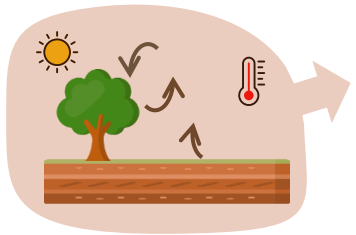
2019 whitout heat wave.
Average fluctuation fitted to 2019

A. Statistical *(ML Regression)*



2019 given typical response.
Average response with 2019 conditions

A. Process based
$NEE = f\ (T, PAR)$

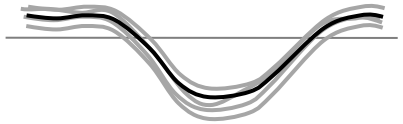


All icons: flaticon.com

Inferring impact
Daily References

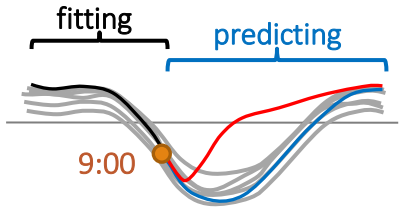
Half-hourly NEE

0. Historical Average



Typical day
Average response and conditions

B. Autoregressive *(ML Regression)*



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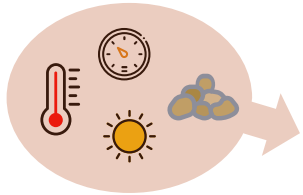

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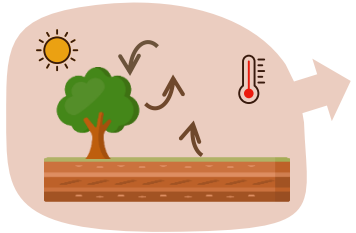
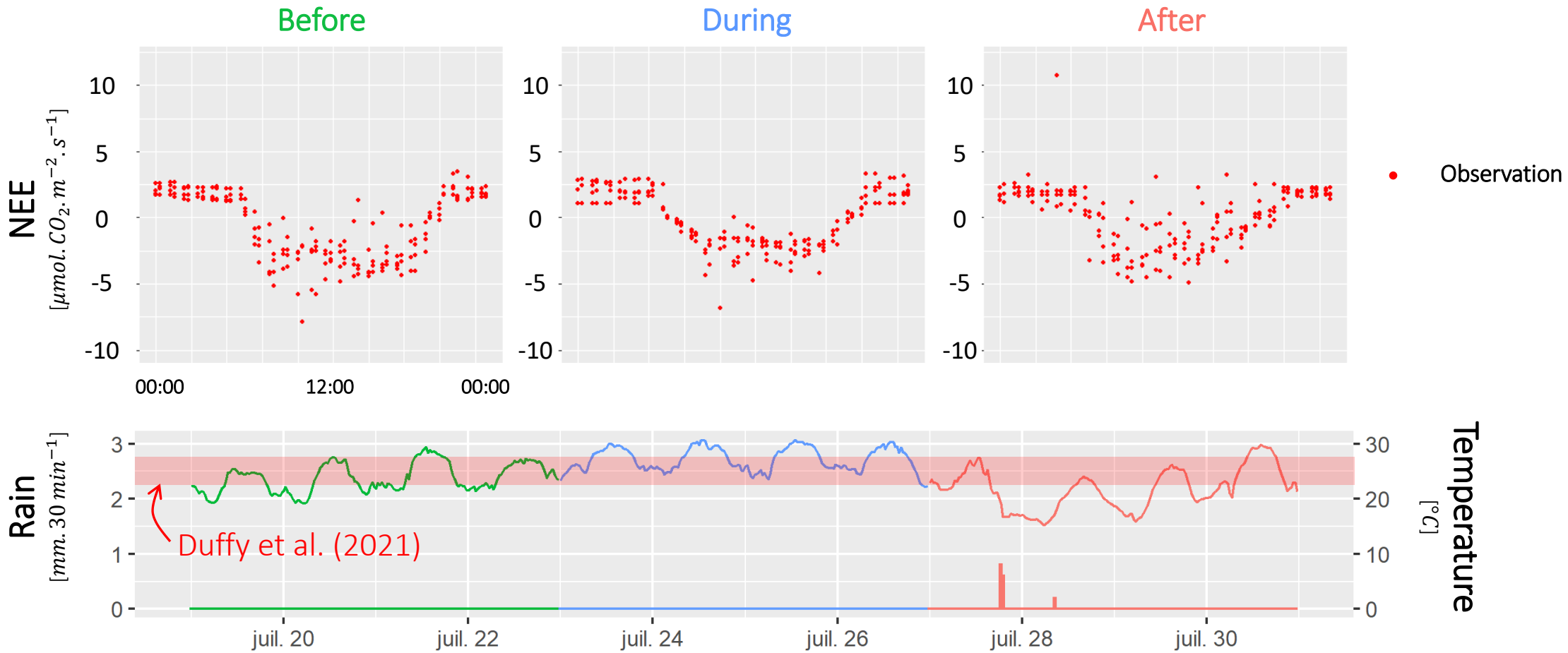


All icons: flaticon.com

Daily Scale Impact
Font-Blanche – 2nd heat wave

Site under water stress



Daily Scale Impact
Font-Blanche – 2nd heat wave

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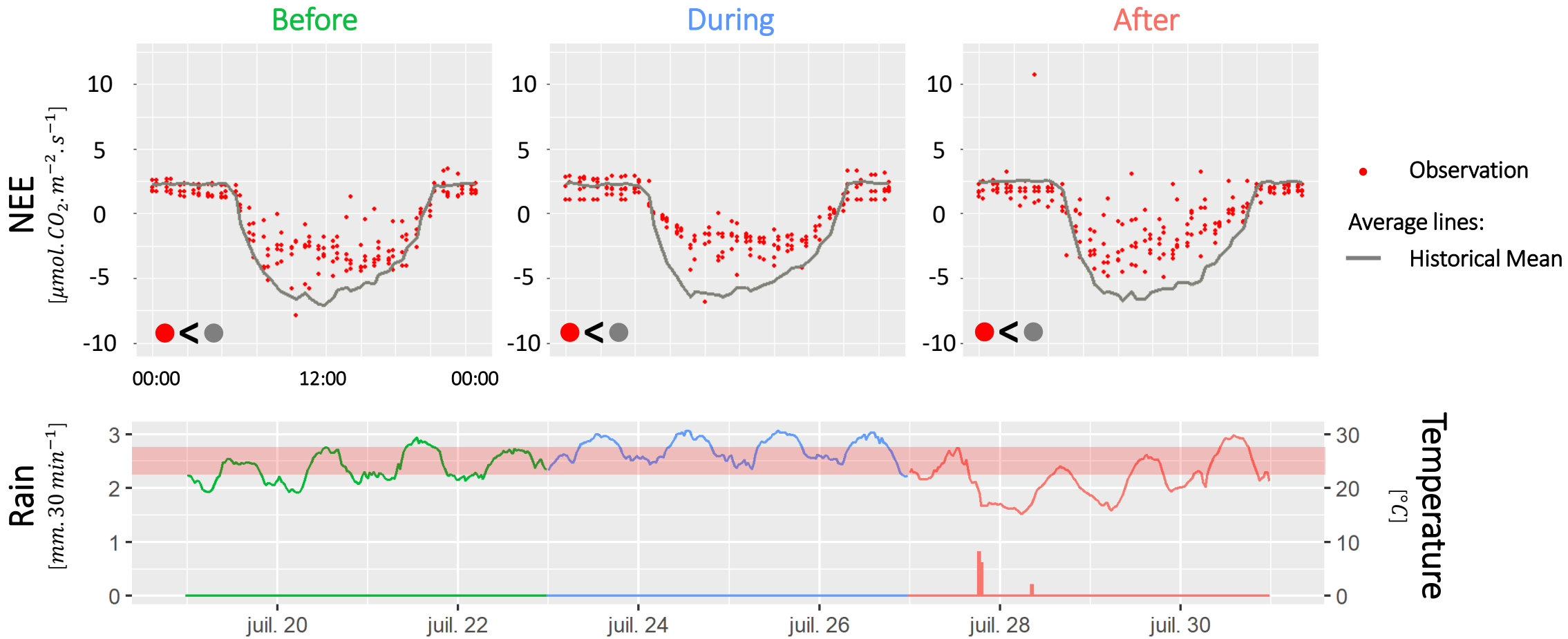

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Font-Blanche – 2nd heat wave

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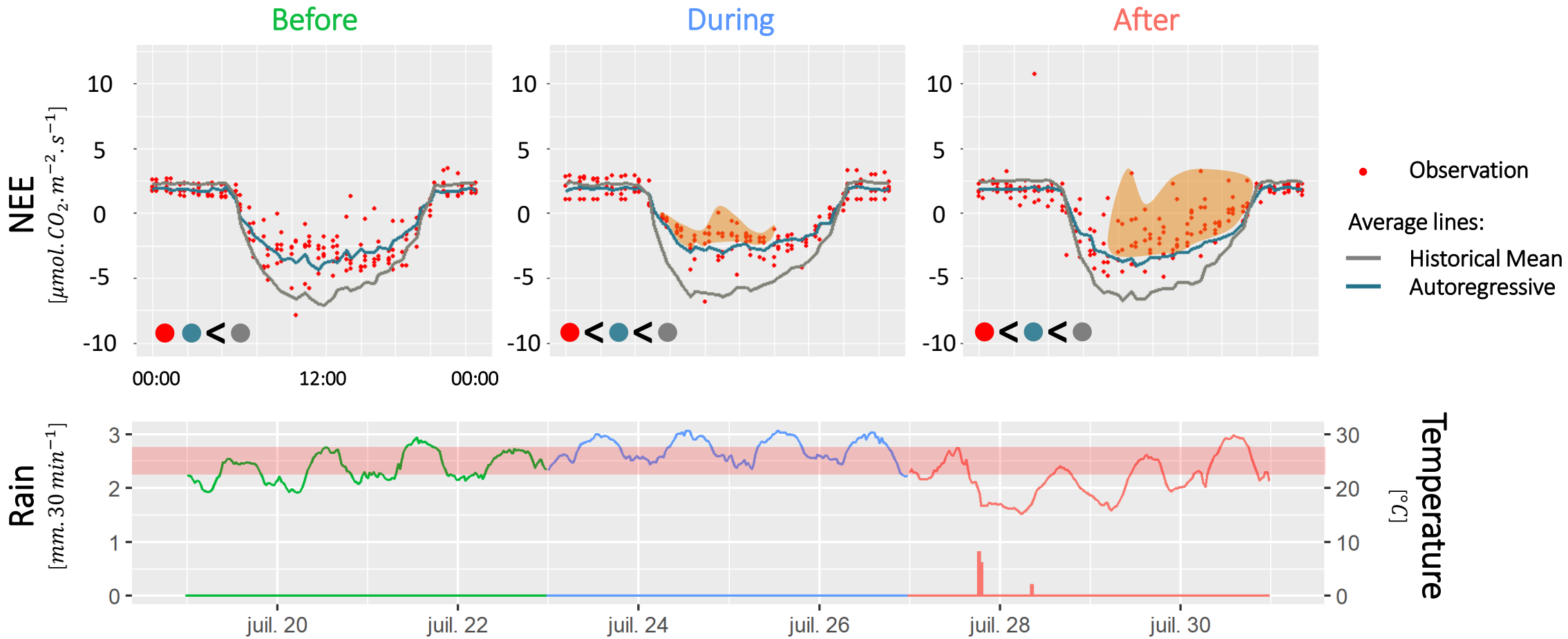

Daily Scale Impact
Font-Blanche – 2nd heat wave

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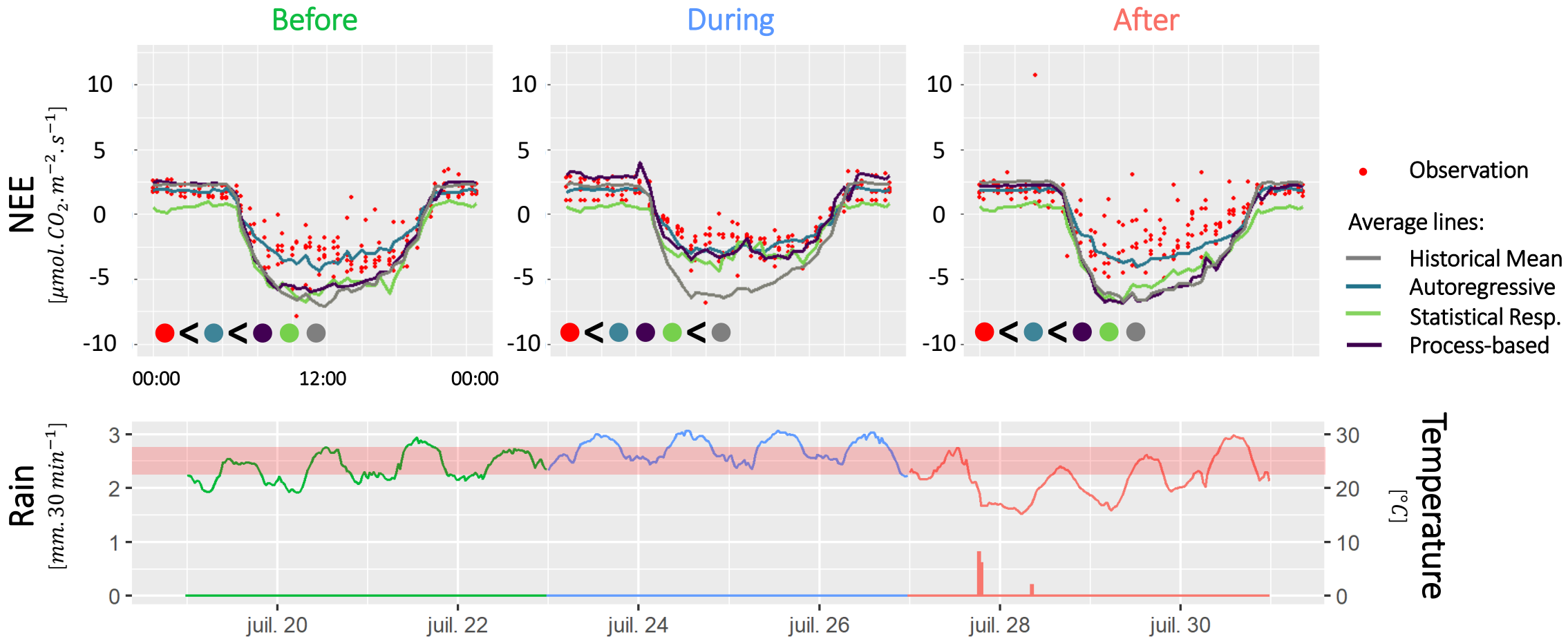
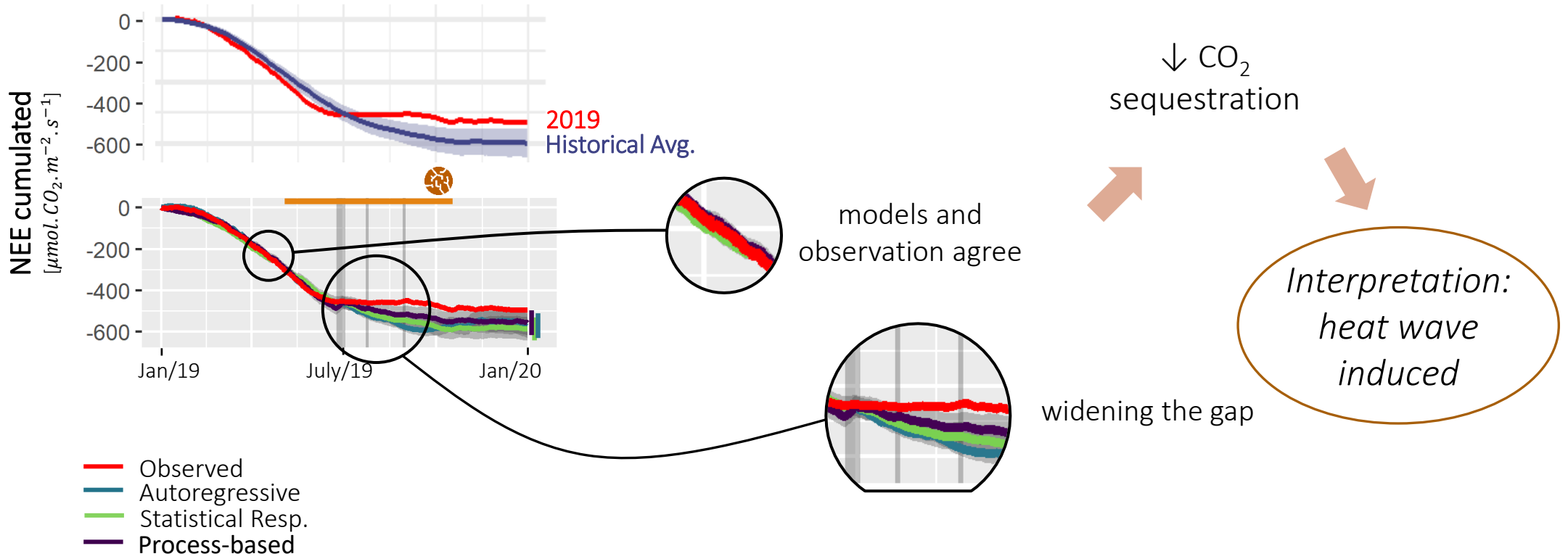
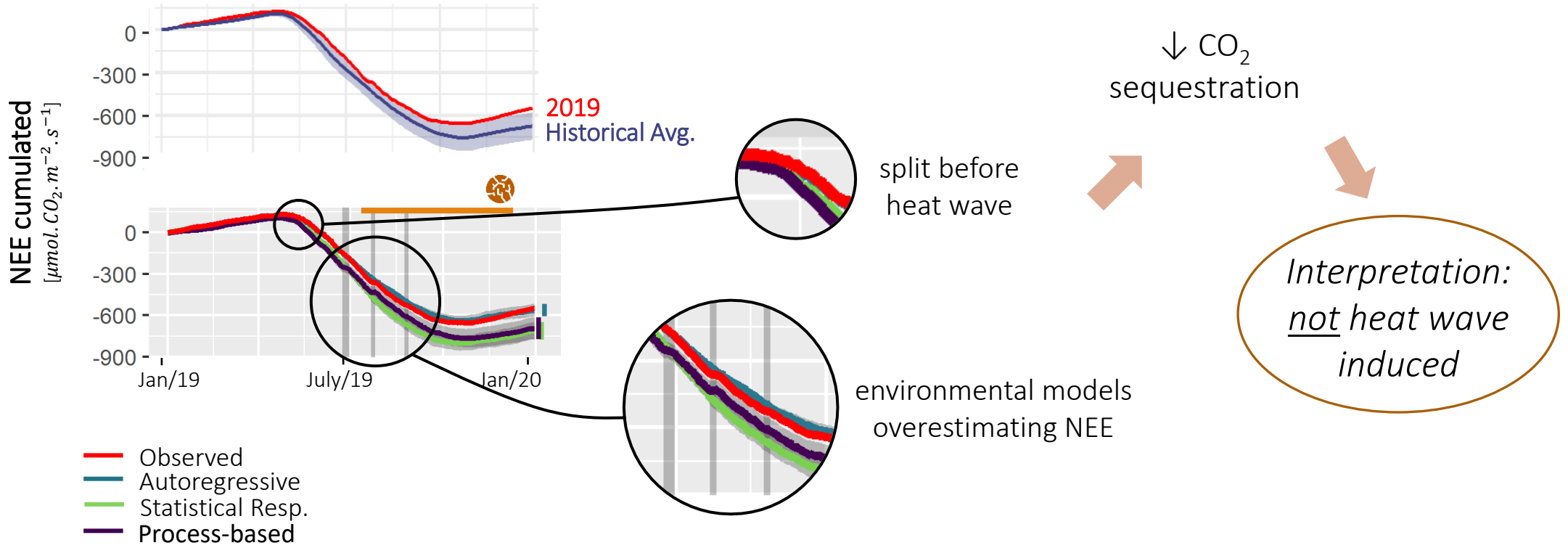


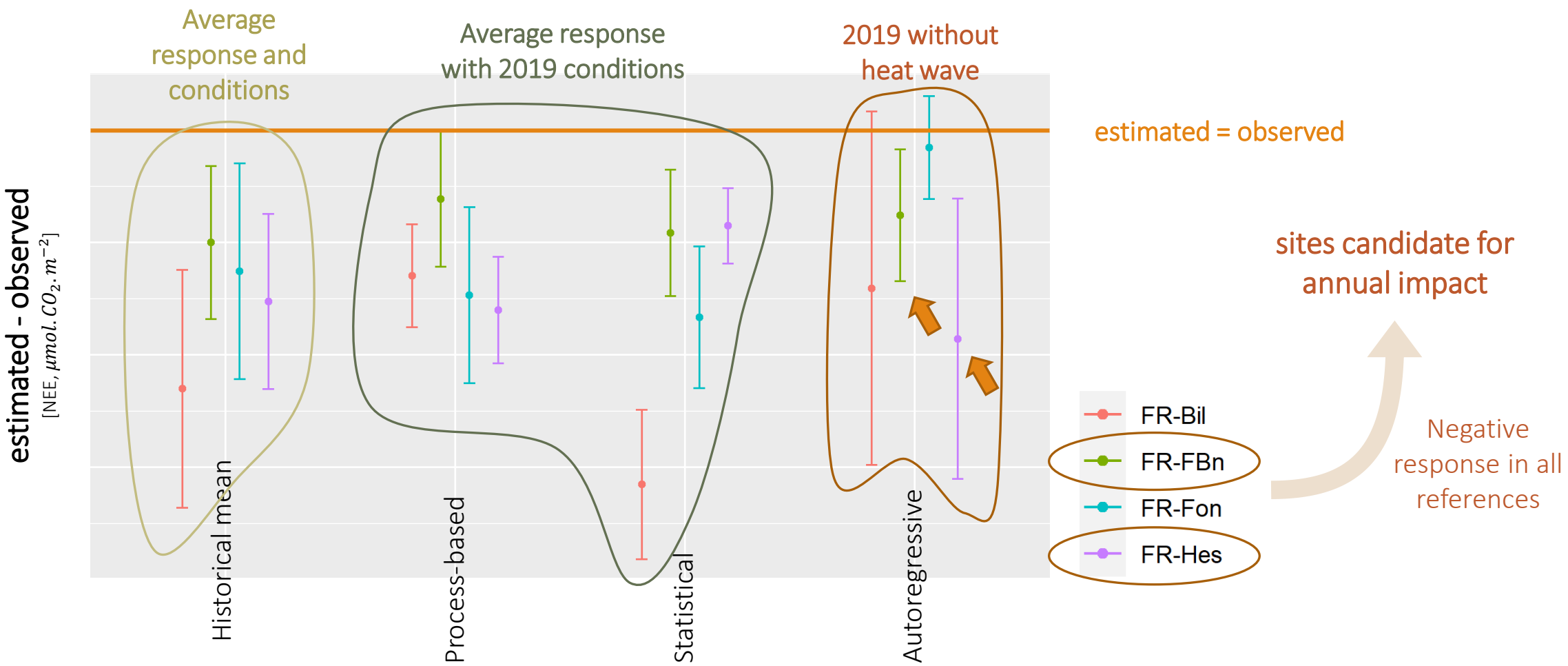
Annual Impact
Font-Blanche



Annual Impact
Fontainebleau (Barbeau)



Annual Impact
Overview NEE estimations for forests

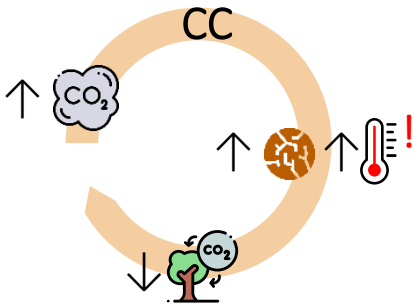


Take-home messages

- **Some sites behaved as under a heat wave even outside episodes.** Sites are expected to underperform in terms of carbon sequestration during extreme heats, however this behavior was also seen before and more strongly after heat waves.

- **Ecosystems in 2019 sequestered less carbon than average.** All forest sites studied responded stronger than usual to conditions warmer and drier than usual. In half of those we detected a shift in the annual carbon sequestration after the heat waves suggesting a impact from those extreme event visible in the year scale.

- **The carbon sequestration potential of forests and agricultural lands is threatened by heat waves.** Due to climate change, the frequency and intensity of heat waves (and droughts) is expected to increase. In the absence of any process faster than it, we are partially losing their help in the fight against it.



Thank you for your attention!

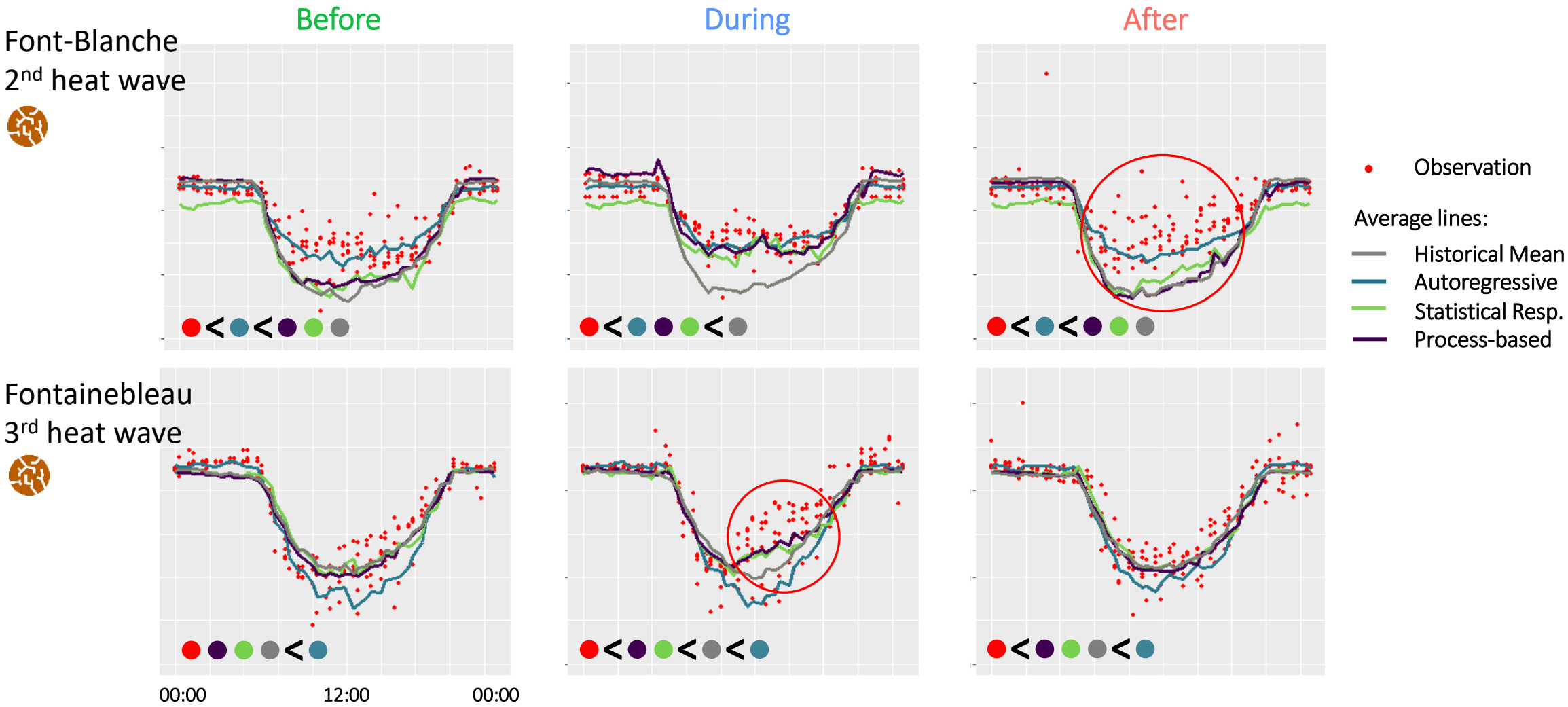
Reserve Utile

$$initialRU = 0$$

$$SW_t = \begin{cases} RU, & t = 1 \\ SW_{t-1} - ETR_t + P_t, & t > 1 \end{cases}$$

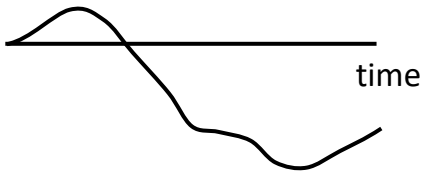
if $SW_t > RU : SWt = RU$ (lost)
if $SW_t < 0$: restart avec $RU + 1$
where, ETR and P are gapfilled data.

Daily Scale Impact



Inferring impact
Modelling

2019 NEE



Environmental Model
(Known Response)

$$NEE = f(\mathrm{T}, \mathrm{PAR})$$

GPP: $f(T, PAR)$, $Farquhar$

R_{eco}: $f(T)$

Statistical Environmental Model
(Typical Response)

$$NEE = \beta^i_T \times T + \beta^i_{VPD} \times VPD + \beta^i_{SWC} \times SWC + \beta^i_{PAR} \times PAR$$

i = week of the year (annual), 30-min (daily)

Purely-statistical Model
(Typical Behaviour)

$$NEE_{2019} = \sum \beta_i^{before} \times NEE_i$$

i = control years

Annual Uncertainty