

# **SUPPORTING INFORMATION**

## **ENHANCED SPRING WARMING IN A MEDITERRANEAN MOUNTAIN**

### **BY ATMOSPHERIC CIRCULATION**

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## The intrinsic biophysical mechanism model

The intrinsic biophysical mechanism model is based on the surface energy balance:

$$R_n = S + L_i - \varepsilon \sigma T_s^4 = H + G \quad (1)$$

Where  $R_n$  is net surface radiation,  $S$  is net surface shortwave radiation,  $L_i$  is incoming long wave radiation,  $\varepsilon$  is surface emissivity,  $\sigma$  is the Stephan-Boltzmann constant,  $T_s$  is surface temperature,  $H$  is sensible heat flux,  $LE$  is latent heat flux, and  $G$  is ground heat flux. Sensible heat is defined from the gradient between surface and air temperature and given as:

$$H = \rho C_p \frac{T_s - T_a}{r_a} \quad (2)$$

where  $\rho$  is air density,  $C_p$  is specific heat of air at constant pressure,  $r_a$  is aerodynamic resistance

$$H/\beta \quad (3)$$

Latent heat is expressed as the ratio of sensible heat flux and Bowen ratio. Surface outgoing long wave radiation in (1) can be approximated using a Taylor series expansion with  $T_a$ :

$$T_s^4 = T_a^4 + 4 T_a^3 (T_s - T_a) \quad (4)$$

Linearizing the surface longwave radiation term in Equation (1) and making use of Equations (2) and (3), we obtain a solution for  $T_s$  from Equation 4.

$$T_s = \frac{\lambda_0}{1+f} (R_n^\square - G) + T_a \quad (5)$$

where  $R_n^*$  is an apparent net radiation given by:

$$R_n^\square = S + L_i - \sigma T_a^4$$

and the energy redistribution factor  $f$  is given by:

$$f = \frac{\rho C_p}{4 \sigma T_s^3 r_a} \left( 1 + \frac{1}{\beta} \right) \quad (6)$$

IBPM assumes nearby contrasting land covers share the same atmospheric background, such as air temperature and incoming radiation. Ignoring changes in surface emissivity and ground heat flux, surface temperature change  $\Delta T_s$  can be derived by the first derivative of (5):

$$\Delta T_s = \frac{\lambda_0}{1+f} \Delta S + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f \quad (7)$$

$$\Delta f = \Delta f_1 + \Delta f_2$$

$$\text{With } \Delta f_1 = \frac{-\rho C_p}{4 \sigma T_s^3 r_a} \left( 1 + \frac{1}{\beta} \right) \frac{\Delta r_a}{r_a} \text{ and } \Delta f_2 = \frac{-\rho C_p}{4 \sigma T_s^3 r_a} \left( \frac{\Delta \beta}{\beta^2} \right)$$

$$\Delta T_s \approx \frac{\lambda_0}{1+f} \Delta S + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_1 + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_2$$

where  $\Delta S$  is the change of net shortwave radiation, and  $\Delta f$  is the change in the energy redistribution factor, attributable to changes in surface roughness ( $\Delta f_1$ ) and Bowen ratio ( $\Delta f_2$ ).

**Table S11.** Temperature analysis: weather station location, longitude, latitude, elevation expressed in m asl and record length. We also reported aspects.

|    | Weather station         | Long.  | Lat.    | Elev. | Record length | Aspect |
|----|-------------------------|--------|---------|-------|---------------|--------|
| 1  | Arphy                   | 3°35'E | 44°01'N | 427   | 1989-2015     | South  |
| 2  | Brenoux-Mende           | 3°32'E | 44°31'N | 1019  | 1980-2015     | North  |
| 3  | Cardet                  | 4°05'E | 44°01'N | 109   | 1980-2015     | South  |
| 4  | Châteauneuf de Randon   | 3°41'E | 44°38'N | 1238  | 1980-2015     | Nord   |
| 5  | Florac                  | 3°35'E | 44°19'N | 595   | 1980-2015     | Nord   |
| 6  | Générargues             | 3°59'E | 44°05'N | 139   | 1980-2015     | South  |
| 7  | Génolhac                | 3°58'E | 44°21'N | 519   | 1980-2015     | South  |
| 8  | Grospierres             | 4°18'E | 44°25'N | 125   | 1980-2015     | South  |
| 9  | Hures-la-Parade         | 3°24'E | 44°15'N | 1028  | 1983-2015     | Nord   |
| 10 | Joyeuse                 | 4°14'E | 44°29'N | 212   | 1980-2015     | South  |
| 11 | La Fage-INRA            | 3°05'E | 43°55'N | 804   | 1980-2015     | South  |
| 12 | La Grand Combe          | 4°01'E | 44°14'N | 415   | 1980-2015     | South  |
| 13 | Lablachère              | 4°13'E | 44°29'N | 300   | 1980-2015     | South  |
| 14 | Langogne-Naussac        | 3°52'E | 44°44'N | 934   | 1980-2015     | Nord   |
| 15 | Le Caylar               | 3°20'E | 43°52'N | 730   | 1980-2015     | South  |
| 16 | Le Collet de Dèze       | 3°56'E | 44°16'N | 485   | 1990-2015     | South  |
| 17 | Le Massegros            | 3°10'E | 44°18'N | 873   | 1980-2015     | Nord   |
| 18 | Le Vigan                | 3°37'E | 43°59'N | 222   | 1980-2015     | South  |
| 19 | Loubaresse              | 4°03'E | 44°36'N | 1220  | 1980-2015     | South  |
| 20 | Mandagout               | 3°38'E | 44°01'N | 485   | 1983-2015     | South  |
| 21 | Mende Ville             | 3°30'E | 44°31'N | 713   | 1980-2015     | Nord   |
| 22 | Meyrueis                | 3°26'E | 44°11'N | 1054  | 1980-2015     | Nord   |
| 23 | Millau                  | 3°01'E | 44°07'N | 712   | 1980-2015     | South  |
| 24 | Mont Aigoual            | 3°35'E | 44°07'N | 1567  | 1980-2015     | South  |
| 25 | Nasbinals               | 3°03'E | 44°40'N | 1284  | 1980-2015     | Nord   |
| 26 | Pont de Montvert        | 3°44'E | 44°22'N | 875   | 1980-2015     | Nord   |
| 27 | Prades le Lez           | 3°52'E | 43°43'N | 85    | 1980-2015     | South  |
| 28 | Saint Christol les Alès | 4°05'E | 44°05'N | 129   | 1980-2015     | South  |
| 29 | Saint Jean du Gard      | 3°53'E | 44°07'N | 220   | 1980-2015     | South  |
| 30 | Saint Martin de Londres | 3°44'E | 43°47'N | 194   | 1980-2015     | South  |
| 31 | Sumène                  | 3°43'E | 43°59'N | 198   | 1980-2015     | South  |
| 32 | Villefort               | 4°00'E | 44°26'N | 620   | 1980-2015     | Nord   |

Missing data: station number and year: 7 (2008); 14 (1997&1998); 27 (1991).

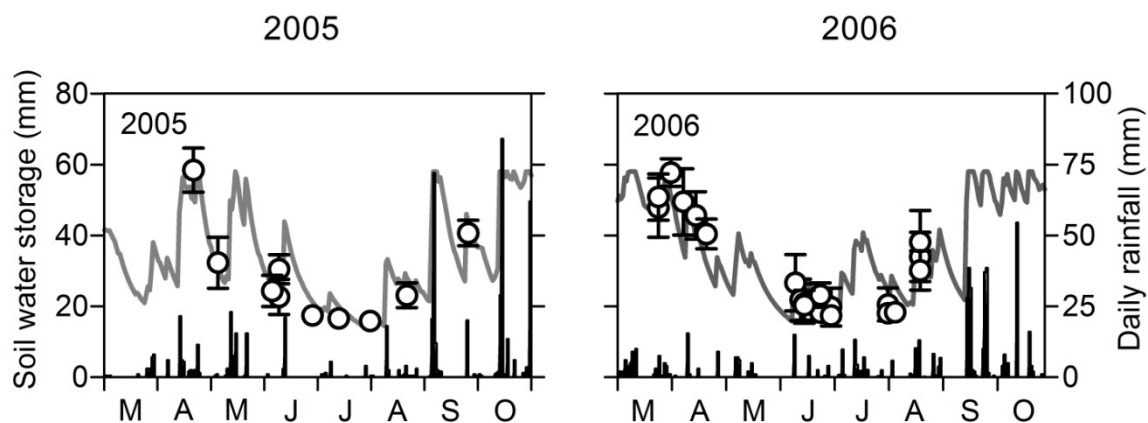
**Table SI2.** Rainfall analysis: weather station locations, longitudes, latitudes, elevations expressed in m asl and record length. We also reported aspects.

| Weather station       | Longitude | Latitude | Elevation | Record length | Aspect |
|-----------------------|-----------|----------|-----------|---------------|--------|
| Châteauneuf-de-Randon | 3°41' E   | 44°38' N | 1238      | 1901-2015     | Nord   |
| Florac                | 3°35' E   | 44°19' N | 595       | 1901-2015     | Nord   |
| Generargues           | 3°59' E   | 44°05' N | 139       | 1901-2015     | South  |
| Génolhac              | 3°58' E   | 44°21' N | 519       | 1901-2015     | South  |
| La Grand-Combe        | 4°01' E   | 44°14' N | 415       | 1901-2015     | South  |
| Le Collet-de-Deze     | 3°56' E   | 44°16' N | 485       | 1901-2015     | South  |
| Le Massegros          | 3°10' E   | 44°18' N | 873       | 1901-2015     | Nord   |
| Mende                 | 3°30' E   | 44°31' N | 713       | 1901-2015     | Nord   |
| Meyrueis              | 3°26' E   | 44°11' N | 1054      | 1901-2015     | Nord   |
| Mont Aigoual          | 3°35' E   | 44°07' N | 1567      | 1901-2015     | South  |
| Nasbinals             | 3°03' E   | 44°40' N | 1284      | 1901-2015     | Nord   |
| Pont-de-Montvert      | 3°44' E   | 44°22' N | 875       | 1901-2015     | Nord   |
| Saint-Jean-du-Gard    | 3°53' E   | 44°07' N | 220       | 1901-2015     | South  |

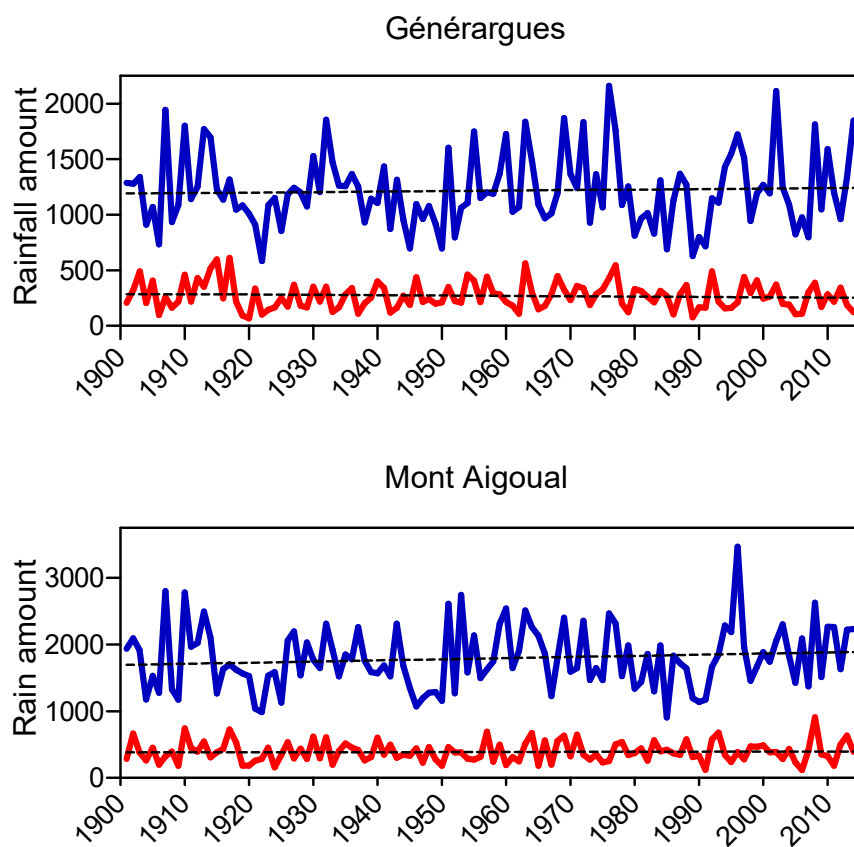
**Fig S11.** The Cévennes National Park (grey area): the park has two nested zones: a central protected zone bounded by the green line, which has an area of 935 km<sup>2</sup>, and an adhesion or periphery zone, which covers 2785 km<sup>2</sup>. The weather stations are indicated by red dots.



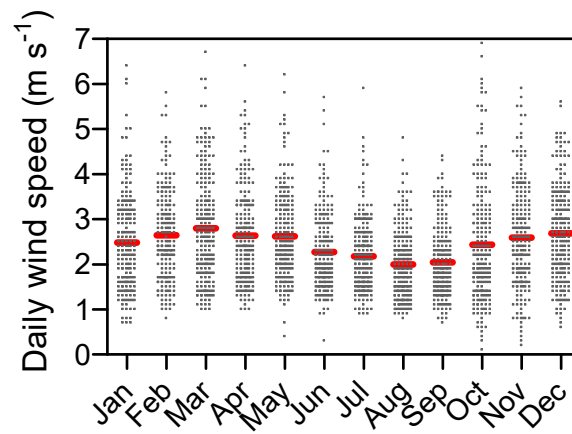
**Fig SI2** Simulated soil water storage in the upper 40 cm (plain line) and observed data (circles with bars showing standard deviation) from March to October in 2005 and 2006. Observed measurements include data from at least 10 pairs of time domain reflectometry (TDR) probes set up in four natural grasslands. Daily rainfall amounts are shown at the bottom (see Boulard et al. 2008).



**Figure SI3** Time courses of yearly (blue line) and April to June (red line) rainfall amount in two contrasted weather stations of the study area: the driest, G  n  rargues and the wettest, Mont Aigoual. Dashed lines are for the non significant linear trends.



**Fig SI4.** Daily wind velocity by month over 2008-2014 observed at Lafage-INRA experimental station (lat. 3°05'E, long. 43°55'N, 804 m asl). Red lines are for averaged values.



**Fig SI5** Time courses of the Bowen ratios averaged over 2005-2015 for grassland (light green filled circle  $\pm$  SD) and coniferous forest (dark green filled circle  $\pm$  SD).

