Recirculation, stagnation and ventilation

The 2014 legionella episode

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1. Motivation

An **unprecedented Legionella outbreak occurred on November 2014 nearby Lisbon, Portugal** (Fig. 1). As of 14 October 2014, **403 individuals** became **ill** and **14 died** infected by the Legionella pneumophila bacteria [1]. The outbreak was contracted by inhalation of aerosols, which are so small that can carry the bacteria directly to the lungs, depositing it in the alveoli. Legionella transmission through the atmosphere is unusual, but has occurred a few times in Europe (e.g., Pas-de-Calais (France) in 2006 [2]; Norway in 2005 [3]).

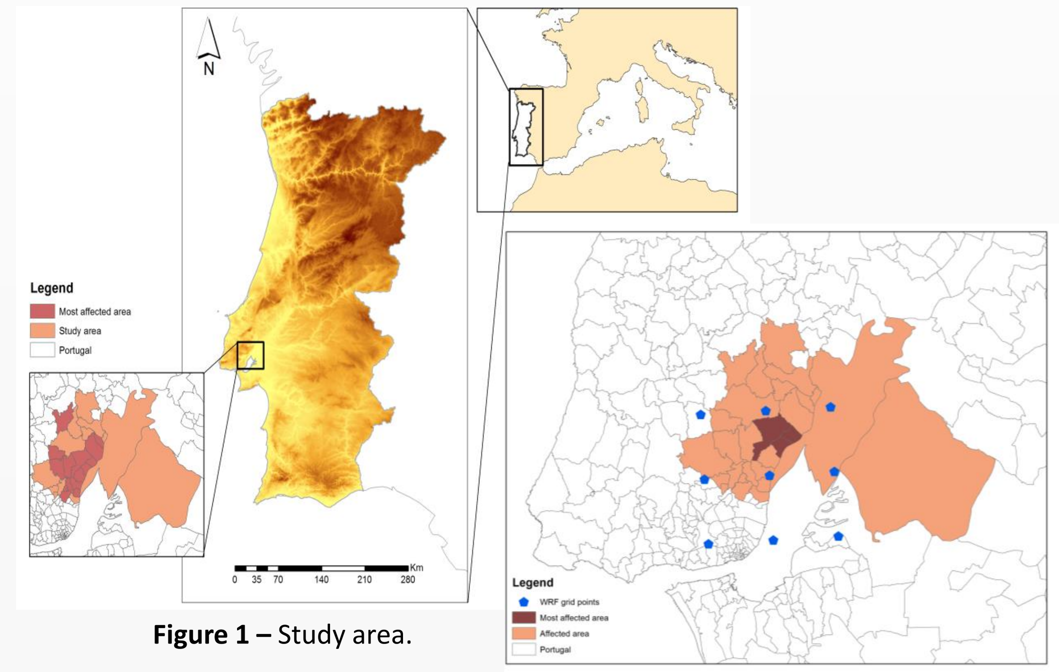


Figure 1 – Study area.

2. Objective

To analyze if the 2014 legionella outbreak event has extreme potential recirculation and/or stagnation characteristics

? Is the study area prone to recirculation/stagnation?
? Was the 2014 event extreme?

3. Data

- **Hourly U** and **V wind onponents** for 1989-2007 and 2014 event (November 2014) from a **high-resolution** (9km) **hindcast regional climate simulation (WRF)**, covering the whole Iberian Peninsula (IP);
- Simulated **U** and **V** components were extracted for a set of 9 points (Fig 1);
- **Reanalyses from the ECMWF** [4] were used to characterise the large atmospheric circulation associated with the 2014 event.

4. Methodology

Based on a method developed previously [4,5] and applied to the Lisbon area [6] we computed an objective quantitative measure of air mass stagnation, recirculation and ventilation. For a series of N discrete observations of wind speed and direction in a measuring site $\bar{V}_i = u_i + v_i$ (1) with an averaging interval of T hours, the discrete integral quantities of "resultant transport distance" (L-net vector displacement), "wind run" (S-wind scalar sum) and the "recirculation factor" (R) were calculated, where τ is the wind run time for integration (e.g., 24 hrs):

$$L_{i\tau} = T\left|\sum_{j=1}^{i-\tau+1}\bar{V}_j\right| = T\left[\left(\sum_{j=1}^{i-\tau+1}u_j\right)^2+\left(\sum_{j=1}^{i-\tau+1}v_j\right)^2\right]^{\frac{1}{2}} \quad (2)$$

$$S_{i\tau} = T\sum_{j=1}^{i-\tau+1}\left|\bar{V}_j\right| = T\sum_{j=1}^{i-\tau+1}\left(u_j^2+v_j^2\right)^{\frac{1}{2}} \quad (3)$$

$$R_{i\tau} = 1-\frac{L_{i\tau}}{S_{i\tau}} \quad (4)$$

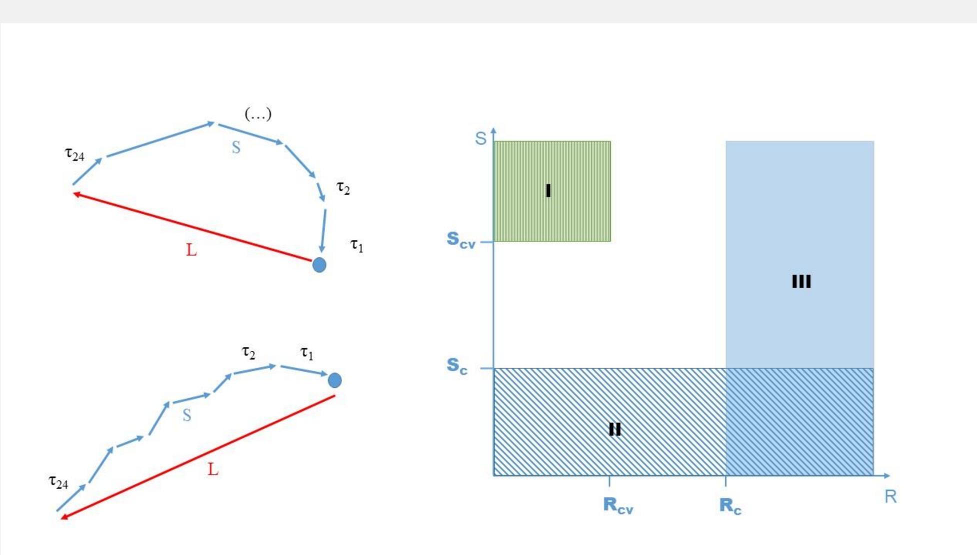


Figure 2 – Schematic illustration of a the net displacement (L, red line) and total displacement (S, blue line) for two sample situations, one with high (top) and other with low (bottom) recirculation potential. The dots mark the starting point. b The areas classified as under I-ventilation, II-stagnation or III-recirculation according to critical transport indices (CTI) values.

Classification of atmospheric conditions regarding recirculation, stagnation and ventilations is achieved by comparing Savg and Ravg to critical values determined for the study region:

- S <= mean (S): site is prone to stagnation
- R >= mean (R): site is prone to recirculation
- S >= P75 (S) and R <= P25(R): site is prone to ventilation

Finally, preferential synoptic conditions were determined for the 2014 LD event based on the previous analysis of a long-term climatological mean for the 1989–2014 October months.

5. Results and Discussion

1989-2007

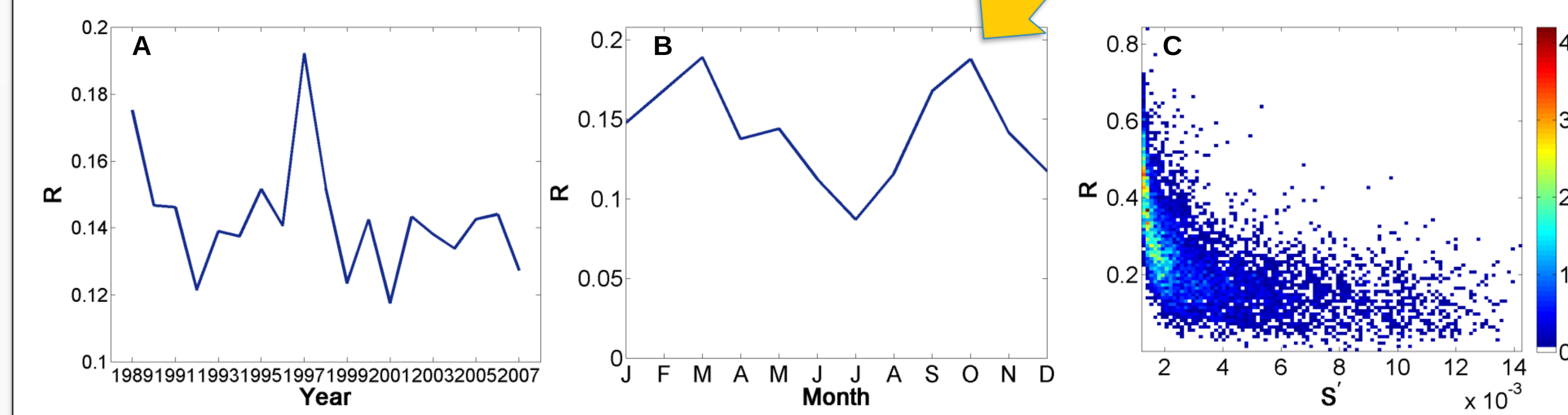


Figure 3 – (A) Yearly and (B) Monthly distribution of R; (C) Percent occurrence plots of R versus S'; (D) Cluster distribution of Ravg versus Rsd.

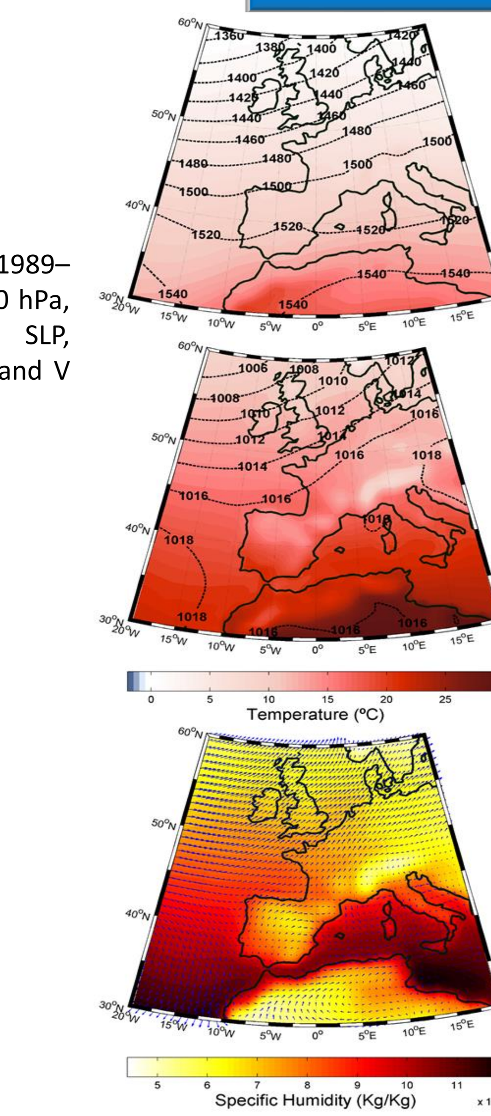


Figure 4 – Monthly October means (1989–2014) for Tmax (ºC) at 2 m, Temp 850 hPa, specific humidity at 1000 hPa, SLP, geopotential at the 850 hPa, and U and V wind components at 1000 hP.

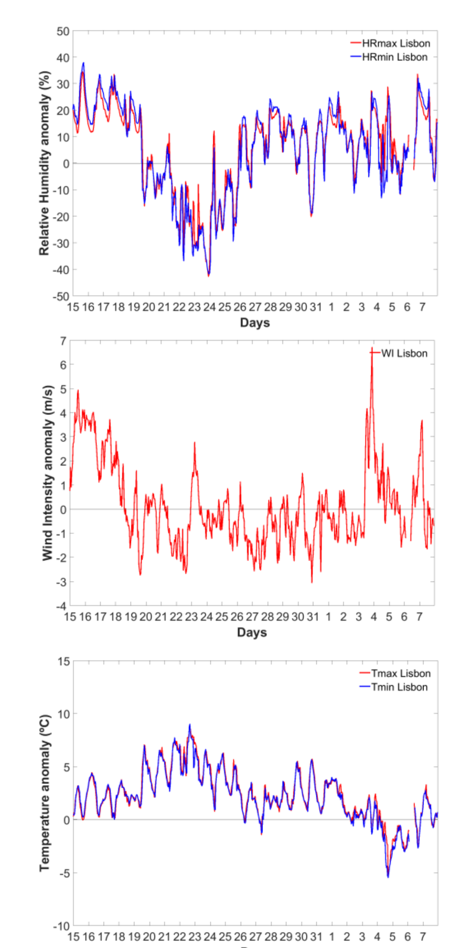
The monthly and annual variability of **R**, **S** and **L** were computed (Fig. 3A and 3B), as well as daily mean and standard deviation of **R** (Ravg and Rsd), **S** (Savg and Ssd) and S' (S'=S/24x3600) for all grid points (Fig.3C and 3D). The 19-yr distribution of the recirculation factor and wind run is presented in Fig. 3C as percentage occurrence plots, where the ranges of **R** and **S'** values were divided into bins of 100 × 100 and the percent of observations falling in each bin was calculated.

- The months of March and October usually present high R values (Fig. 3B)
- The results regarding the 1989–2007 period indicate a dominance from the stagnation events through most of the study period (42%) relatively to the minority occurrence of recirculation (18%) and ventilation (17%) events. Clearly, the airshed has a tendency to higher R and lower S' values, depicting low (i.e., poor) ventilation conditions through the study period, which is highlighted by the results presented in Fig. 3C.

The month of October (1989–2014) is characterized by the setting of the Azores high pressure south of the Azores archipelago and by a low-pressure center placed just northwest of the British Isles (Fig. 4). The westerly flow is accompanied by low winds in Iberia, a maximum temperature at 2 m of approximately 20ºC, and specific humidity values of approximately 7 kg/kg (Fig. 4).

2014

- The 2014 event was particularly severe as most of the days were classified either as stagnation (53%) or recirculation (23%) situations and just a few were unclassified, while none were classified as ventilation.
- The average R factor for the event period (**R_{EVENT}=0.2326**) was above the historical period average presented in Fig. 3B and is close to the percentile 80 of the total R sample for the 1989–2007 period.



- The area was affected during most of the event by high temperature (anomalies of up to 9ºC) and low wind speed (with anomalies very often of less 2 m/s). Relative humidity oscillated, presenting two periods when RH negative anomalies were high (15/10 until 18/10 and from 26/10 forward) being also negative during most of the days when the incubation took place (Fig. 5).
- The 2014 event shows a high-pressure (A) center over the Iberian Peninsula extending from the surface, with high temperatures in the lower troposphere (as depicted by the 850 hPa temperature field), which are associated to reduced cloud cover and precipitation over these regions (Fig. 6).
- The corresponding anomalous fields confirm that these days were characterized by positive temperature values all over Iberia, north-eastern Mediterranean, and eastern France.
- There were present optimal meteorological conditions for the proliferation of the Legionella pneumophila bacteria

Figure 5 - Maximum (Tmax) and minimum (Tmin) temperatures, maximum (HRmax) and minimum (HRmin) relative humidity and Wind intensity in Lisbon

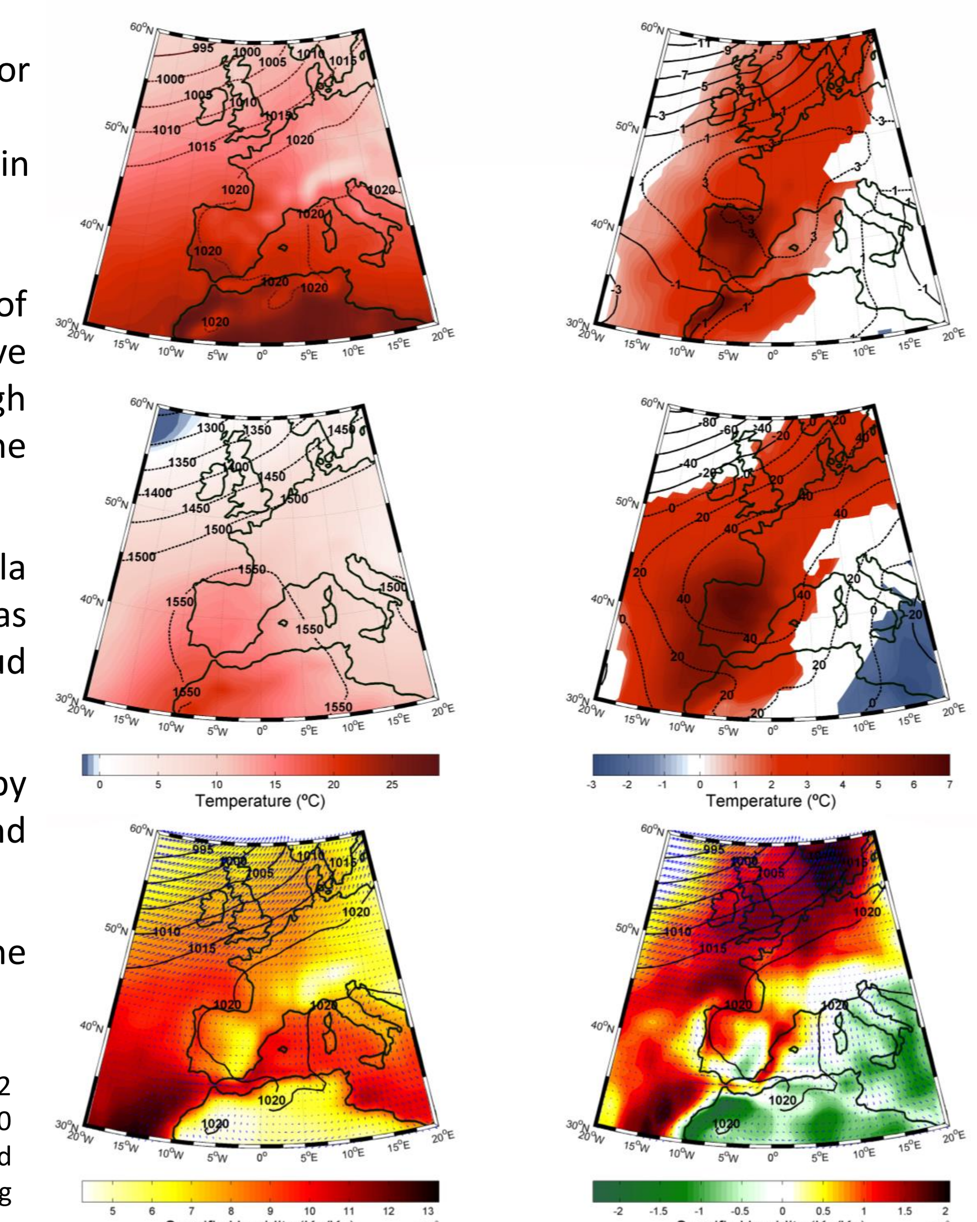


Figure 6 - Composites for maximum temperature field (° C) at 2 m and SLP (top panel); temperature and geopotential at 850 hPa (center panel); and specific humidity, U and V wind components at 1000 hP (lower panel) and the corresponding anomalies (right panel) regarding the 1981–2010 period.

6. Final remarks

- ***The preliminary results for the 1989-2007 period clearly indicate that the airshed is prone to stagnation.***
- ***The 2014 episode is exceptional and most of the days are classified as stagnation or recirculation.***
- ***During the event, temperatures where exceptionally high and an intrusion from the Sahara desert affected the Iberia Peninsula.***

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