Recirculation, stagnation and ventilation

The 2014 legionella episode

A. Russo (1), P.M.M. Soares (1), C.M. Gouveia(1), R.M. Cardoso (1), R.M. Trigo (1)

(1)Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal,

acrusso@fc.ul.pt

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]).

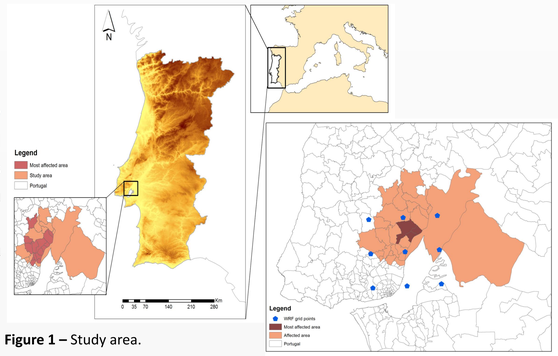


Figure 1 – Study area.

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 components** 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 $\overline{V}_i = u_i + v_i$ (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):

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

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

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

5. Results and Discussion

1989-2007

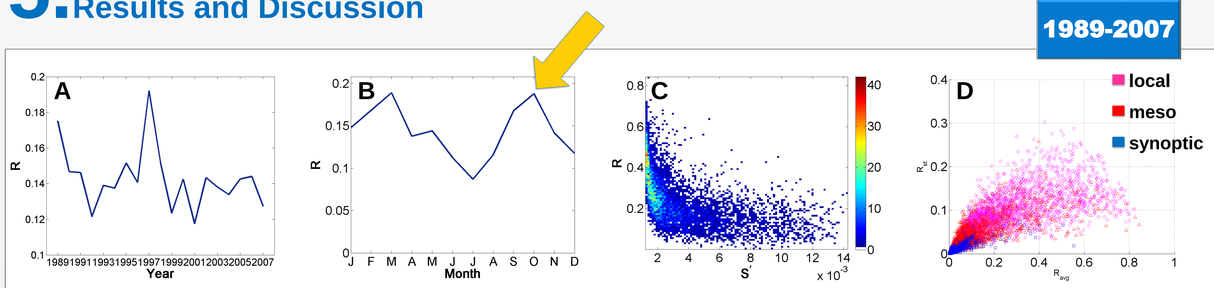
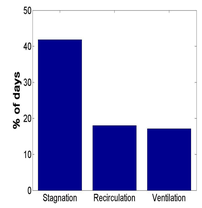


Figure 2 – (A) Yearly and (B) Monthly distribution of R; (C) Percent occurrence plots of R versus S'; (D) Cluster distribution of Ravg versus Rsd.

The monthly and annual variability of **R**, **S** and **L** were computed (Fig. 2A and 2B), 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.2C and 2D). The 19-yr distribution of the recirculation factor and wind run is presented in Fig. 2C 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.

- This airshed has a tendency to higher **R** and lower **S'** values, depicting low (i.e., poor) ventilation conditions, which are mostly produced by local-scale motions (Fig. 2D) according to Russo et al. [6] approach.
- The months of March and October usually present high R values (Fig. 2B)



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

Figure 3 – Percentage of days classified as stagnation, recirculation or ventilation. A total of 23% of the days were unclassified.

2014

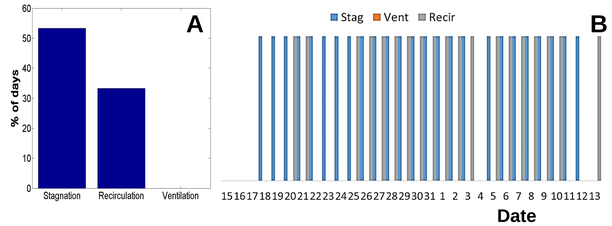


Figure 4 – (A) Percentage of days and **(B)** days classified as stagnation, recirculation or ventilation, for the period between 15/10/2014 and 13/11/2014.

- The 2014 event was particularly severe as most of the days were classified either as stagnation or recirculation situations and just a few were unclassified (Fig. 4), while none were classified as ventilation.
- The average R factor for the event period was above the historical period average (R_{EVENT}=**0.2326**) presented in Fig. 2B.

- During the event, the recirculation results are supported by the meteorological situation and transport of particulate matter (PM10) [1].
- Temperatures higher than the monthly average were recorded for the month of October and this was the warmest October in mainland Portugal since 1931, including an 11 days heat wave during the 17–27 October period [1].
- Particularly, for the days of the event Tanom > 7° C as seen in Fig. 5 (A and B), with a persistent nocturnal thermal inversion associated to a predominant NE and NNE wind with 2–3 km/h speed measured at a local station [1].
- Specific humidity presents positive anomalies comparatively to the 1981-2010 period (Fig. 5 C and D).
- Top weekly records and three surpasses of PM10 were registered in the local air quality station [1]. This was attributed to a strong episode of Saharan dust transported to mainland Portugal (Fig. 6).

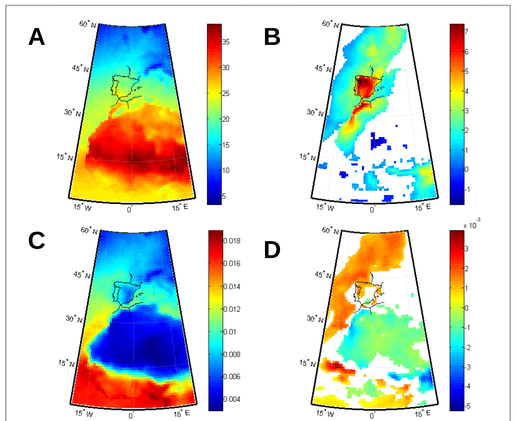


Figure 5 – (A) Maximum temperature fields (ºC) at 2 meters and **(C)** specific humidity (kg/kg) composite for event days (left panel) and the corresponding anomalies **(B and D,** right panel**)** regarding the 1981-2010 period.

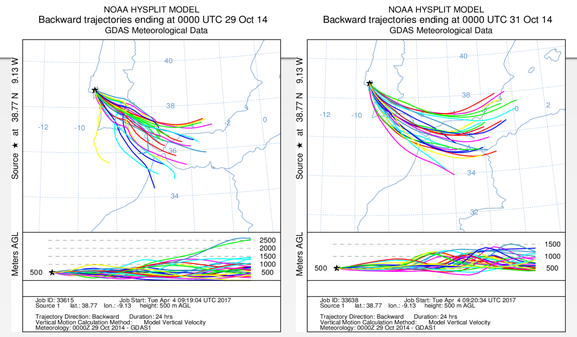


Figure 6 – Hysplit back-tajectories for the days 29/10/2014 and 31/10/2014.

6. Final remarks and future work

- The study analysis the 2014 Portuguese legionella outbreak event regarding its extreme potential recirculation and/or stagnation characteristics.
- The preliminary results for the 1989-2007 period clearly indicate that the airshed is prone to stagnation, as these events have a dominant presence through most of the study period (42%), relatively to the occurrence of recirculation (18%) and ventilation (17%) events.
- The 2014 episode is exceptional and most of the days are classified as stagnation or ventilation.
- During the event, temperatures where exceptionally high and an intrusion from the Sahara desert affected the Iberia Peninsula.
- The outcomes are expected to support Portuguese authorities on the implementation of strategies for a sustainable management of environmental risks.

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