**Atmospheric
Chemistry
and Physics
Discussions**

# *Interactive comment on* "On the roles of circulation and aerosols in the decline of mist and dense fog in Europe over the last 30 years" *by* G. J. van Oldenborgh et al.

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Thank you for the constructive comments. Below we list the replies to the comments and suggestions. We added an explicit attribution to the valuable suggestion that global warming leads to increased downwelling radiation, hence decreasing night-time cooling and radiation fog.

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Major comments

1. *Bottom of p. 23994, top of p. 23995, and Fig. 4: I find it difficult to understand what Fig. 4 shows and how the authors calculated spatial correlation. It doesn't help that the x-axis has no title. As best I can tell, the authors calculate the rank correlation between visibility trends and emission trends in 2.5° grid boxes, then the correlation between trends aggregated in progressively larger grid boxes, with Fig. 4 showing how correlation varies with the size of the grid box. The authors should explain this more clearly in the text and refer to readers to prior work only to get specific details.*

   We have added the title 'minimum visibility' to the X-axis. The graph shows how the spatial correlation varies with the cut-off of the minimum visibility, all at the same grid box size. We have clarified the explanation.

   'In Fig. 4 we extend the analysis of Vautard et al (2009) to lower visibilities: a comparison of the pattern of visibility trends on a map of Europe with the pattern of $SO_2$ emission trends. For a range of cut-offs from 100 m to 10 km we computed the spatial rank correlation between the trend in the number of days with minimum visibility less than the cut-off and the EMEP $SO_2$ emission trends over 1990–2007 (Streets et al, 2006). The two data points before 1990 in the emission dataset have large uncertainties and have been omitted. The visibility trends have been computed on the same $2.5° \times 2.5°$ grid as the emission data, covering 10° W–35° E, 37°–60° N, demanding at least two stations in each grid box. The grid box value was computed as the average of the trends of the stations, weighted with the inverse error squared. Finally, a rank correlation was chosen as we can only assume a monotonic decrease of visibility with aerosol concentrations at most sites in Europe, but not necessarily a linear decrease.

   To compute the significance of the correlations, the spatial autocorrelation has to be taken into account: the 88 grid boxes with data are not all independent. A

spatial autocorrelation function was computed from all pairs of grid boxes. From this graph the decorrelation scale was estimated to be 4° for the trend in the number of days with visibility smaller than 2 km to 2° for 200 m (Sterl et al, 2007). This gives rise to estimates of 50 degrees of freedom for 2 km, to 88 for 200 m. The corresponding one-sided confidence levels at $p < 0.05$ are indicated by the green line.'

2. *Lines 21-23 on p. 23998 and Fig. 11: The authors show that the number of days with dense fog is most highly correlated with precipitation 2–4 months previously and argue it is an effect of moist soil from previous rain providing sufficient moisture to form fog under subsequent clear conditions. I find it difficult to believe that rain 60–120 days earlier will provide sufficient evapotranspiration to the atmosphere for fog to form such a long time later. What is the timescale for positive soil moisture anomalies to decay away? Is it possible that there is "memory" in the large-scale atmospheric circulation (perhaps from ocean temperature anomalies) such that circulation anomalies producing spring precipitation tend to be followed by circulation anomalies producing summer fog?*

To start with the second point, the seasonal forecasting community has searched long and hard for this kind of memory in the circulation over Europe, with negative results. The summer circulation over Europe is not predictable to an appreciable extent from persistence or sea surface temperatures a few months earlier (see e.g. van Oldenborgh et al, J. Climate, 2005).

On the other hand, evidence has been shown that spring precipitation in Europe does lead to skill in summer temperature forecasts via soil moisture, e.g. in Ferranti and Viterbo, J. Climate, 2006; Fisher et al Geoph. Res. Lett., 2007; Vautard et al, Geoph. Res. Lett., 2007.

If the soil moisture signal is strong enough in summer to affect temperature, we assumed it would be strong enough to affect early-morning humidity. We have added these references to the text to strengthen the argument.

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Minor comments

1. *Lines 22–23 on p. 23988: I don't think it is quite the case that fog isolates the ground from upper atmospheric layers. Rather, fog often accompanies surface stratification, which is the cause of the isolation.*

   We meant that the fog layer is decoupled from the free atmosphere. Changed to 'isolating the ground from atmospheric layers above the fog'.

2. *I don?t think Fig. 3 and lines 14-22 on p. 23993 are necessary. I believe that it is well- accepted that increased aerosol concentrations contribute to greater optical thickness of fog. Also, Fig. 3 is ambiguous in that it does not demonstrate that the fog could not have formed merely by nighttime cooling whether irrespective of fireworks.*

   We have deleted the example of the New Year's fog. However, the climate research community is not convinced that this is the case, judging from reactions to presentations of this research at the EGU conference (Vienna 2009). We therefore retained the rest of the paragraph.

3. *Line 12 on p. 23994: "monotonous" should be "monotonic".*

   Thank you.

4. *The text size of the titles, labels, and legend in Fig. 5 is too small.*

   These have been enlarged.

5. *Line 19 on p. 23998: the authors should use a more specific and objective description than "beautiful day".*

   Replaced by 'clear-sky day'.

6. *Line 1 on p. 24000: "Balkan" should be "Balkans".*

   Thank you, replaced twice.

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7. *Lines 4-5 on p. 24003: The meaning of "these numbers scale with the aerosol emissions" is not clear to me.*

We hope the following rephrasing clarifies this obscure sentence.

'If the dependence of low visibility on fog is primarily through aerosol concentrations rather than directly through the meteorological influence, the effect of a change in the weather statistics on low visibility will be smaller in the future than it is today. It is not possible to differentiate between direct meteorological influences and indirect ones through the aerosol concentrations for given emissions statistically based on the limited data we have available.'

8. *Outlook section: Another factor that could promote decreased fog in the future is the increase in downwelling IR radiation from more CO2 in the atmosphere that reduces surface radiative cooling.*

Thank you for suggesting this possibility, which we added to the text:

'Finally, as suggested by a reviewer, the cooling on clear nights will decrease due to increased downwelling long-wave radiation, the primary mechanism of global warming.'

9. *Figs. 12, 13, 14, 15, 17, and 18: the largest positive and negative colors have values of +1 and -1 rather than (I assume) +10 and -10.*

In Figs. 12 and 13, the left-hand panels have scales up to 1, the right-hand side a scale up to 5. Given that the winter-mean geostrophic wind varies from 0 to 10 m/s, this implies that the number of dense fog days varies by up to 10 per year, which is compatible with the observed total numbers. For 2km mist the same holds.

Fig. 14 has an arbitrary scale, we did not reduce the vorticity to a physical unit. It was meant only to show the patterns, the magnitude is not used.

Fig. 15 shows correlation coefficients, which run from $-1$ to $+1$.

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As noted in the text, Figs. 17, 18 have a more detailed scale than the corresponding Fig. 2 to better show the patterns.

10. *In the various figures and text that deal with the geostrophic wind and geostrophic vorticity, it would be helpful to clarify what elevation they correspond to (the surface?).*

    We indeed meant the geostrophic wind at the surface, this has been added to the text.

11. *Fig. 16: Why not show meridional wind trend or SLP trend?*

    The trends in meridional wind are very small. We wanted to show the trend in zonal geostrophic wind rather than SLP to emphasise the correspondence with Fig. 18.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 23987, 2009.