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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Now you see it, now you don't: impact of temporary closures of a coal-fired power plant on air quality in the Columbia River Gorge National Scenic Area" *by* D. A. Jaffe and D. R. Reidmiller

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We appreciate the overall positive comments from both reviewers. Below is our detailed response to the review comments.

General Comments Reviewer #1: The submitted manuscript explores air pollution attribution questions for a particular source/receptor configuration in Oregon, USA. The work employs observed air quality and back trajectory analysis over a 13 year period. Interestingly, the period of study contains short intervals when the major source was

not operating. The study is thus an example of a "natural experiment". Results of the present work are contrasted with those of earlier (grey literature) studies of the same source/receptor pairs using Eulerian modelling techniques. The present work is convincing, and apparently not subject to some of the weaknesses of the earlier studies. While there are aspects of the submitted work that will need improvement, it provides both an interesting resolution to a locally important environmental question, as well as a fine illustration of an important mode of analysis. It should be published.

RESPONSE We appreciate the positive feedback on our study.

Specific Comments REVIEWER The abstract should be rewritten. It is far longer than it need be. It should capture the research questions listed on page 4. As it is, the abstract reads as if the work was not based on any particular question or idea, but rather was simply an analysis of an interesting data set. While the technicalities of the paper are not novel, the novelty lies in the way the data and its analysis were deployed to provide answers to an interesting (and important), though highly specific, environmental question.

RESPONSE We have re-written and shortened the abstract to address this concern. The abstract now begins with the sentence "The goal of this study is to identify major point sources that contribute to elevated particulate matter in the Columbia River Gorge, U.S.A. and to quantify their contribution. To answer this question we have analyzed. . ."

REVIEWER Research Questions (Page 4): Research question number 4 (dealing with temporal trends) is only indirectly related to the overall thrust and major issue of the work. It can be deleted without any loss of substance. If this is done, section 3 (e) and the related conclusion paragraph should also be deleted.

RESPONSE We have taken this advice and removed Research Question #4, as well as section (3e) and the related conclusion paragraph)

REVIEWER Figure 3 & page 9, lines 23 to 26: The authors note that “no significant relationship results”, and then in the next sentence say that “closer examination .. illustrates” that a relationship does exist. If a statistical significance analysis shows no relationship, then the question is closed and cannot be opened by any further analysis, discussion or examination.

RESPONSE We agree that the original text is not clear. A linear relationship is not statistically significant, however, we use a t-test to show that there is a significant difference for the high emission months vs the low emission months. This was shown in Table 4 in the original manuscript and we have clarified the language in the text.

REVIEWER There exist a number of instances of arbitrary, or needlessly vague definitions. These should be tightened up. - Page 6, lines 4 & 5: “Portland” and “east CRG” are not well-defined regions. More precise language is needed here. If specific regions are used in the paper, their spatial extent should be marked on Figure 1.

RESPONSE Like most US cities, the city limits of Portland Oregon do not encompass a large fraction of the population and industrial activities. Instead we use the term Portland Metropolitan Area (PMA) which was already defined in the manuscript. For clarity we use PMA whenever we refer to the larger metropolitan region. The terms west gorge and east gorge are now more clearly defined in the text (east of 120o and west of 122o, respectively).

REVIEWER - Page 6, section 3 (a) and Table 1: Months are arbitrary divisions of a year. The authors should repeat their analysis with time blocks ranging from 10 days to 60 days, centered around November to see what sub period of a year (defined by relative day-of- year) has the maximum frequency of high PM days.

RESPONSE Table 1 clearly shows that the unit of months is the appropriate temporal resolution to use.

REVIEWER - The paper refers to “regions” (page 6, line 5); “source region” (page 6,

lines 2 and 4); “categories” (page 7, line 10) and “transport pathway” (page 7, line 27); “backtrajectory categories” (page 9, line 1) in a way which implies these are all equivalent. Careful thought and usage must be applied to make it absolutely clear to readers exactly what is being done.

RESPONSE We have tightened up the language as suggested.. We have replaced “region” with “source regions” and “category” with “backtrajectory category” where appropriate. We feel “transport pathway” is still a reasonable, useful and familiar term to use to indicate the general flow patterns we present.

REVIEWER The authors must specify over what horizontal spatial range their “source regions” (or whatever term they decide is best for this idea) are defined. I assume this will be decided by the range of back trajectories that arises in their analysis.

RESPONSE We have clarified this by stating (in paragraph 2 of Sect. 3.2) that the horizontal spatial range of these “source regions” are $\sim$100 km. The distance from Portland, OR to Wishram is 127 km; the distance from Wishram to Boardman, OR is 114 km.

REVIEWER Table 2: The authors must explain how the classification that results in this table was performed. They must explain this in a way that makes it clear how they avoided bias in the classification. This is generally done by the investigators devising a classification scheme (a set of rules or criteria) and then allowing unbiased and uninformed but competent technicians to perform the classification.

RESPONSE This is a good suggestion. We have modified the manuscript by inserting the text below in paragraph 2 of Sect. 3.2 to give more information on how the trajectories were classified: “West Gorge refers to cases where the majority of trajectories originated or crossed through the Portland metropolitan region (west of 122°W) and east gorge refers to cases where the majority of trajectories originated east of 120°W. Categories 1 and 5 were assigned in cases when at least 90% of the 39 trajectories had transport pathways within 30° of 270° and 80° respectively, for the 24 hour tra-

jectory time. These directions (270° and 80°) are the primary orientation of the CRG within at least 100km of the Wishram site."

Technical Comments REVIEWER In a number of places the abbreviation U.S. is used. For an international journal, the full country abbreviation U.S.A. should be used.

RESPONSE We have changed all mentions of "U.S." to "U.S.A."

REVIEWER The unit "short ton" may not be understood by international readers.

RESPONSE We have converted all mention of short tons to metric tons.

REVIEWER Figure 4: The information contained in this figure is all in table 5. The figure should be deleted.

RESPONSE Given the relatively low number of figures and tables in this manuscript, we are inclined to retain Fig 4 as it illustrates the effect of the power plant emissions on PM in the CRG very clearly. Table 5 provides more detailed information, but Fig. 4 is the "take home" message for the manuscript.

REVIEWER Text, Table 4 and Figure 3: The text implies 163 available data points. Table 3 has a total of 152 data points. Figure 3 (by rough count) has approximately 137 data points. This apparent disagreement must be clarified.

RESPONSE We have clarified this in the text (paragraph 2 of Sect. 3.4). There are 163 months with emissions data (June 93-Dec 06), but only 152 months that also have corresponding PM2.5 data. Of these 152 months, 121 have NOx emissions > 100 metric tons, and 31 have < 100 metric tons. Table 4 has been corrected.

Reviewer #2

General Comments REVIEWER This paper exploits long term, frequent ambient monitoring to deduce the effects of a particular coal-fired power plant on air quality in the Columbia River Gorge by examining the change in air quality during periods of plant shut down. It is an excellent demonstration of how monitoring can be used to substitute

for an economically or technically infeasible experiment (in this case, shutting down a major regional power plant), and also presents an opportunity to compare the observed air quality increment associated with the power plant with that predicted by modeling its effects. While the case in point is of limited interest outside the Pacific Northwest region of the United States, the methodology is widely applicable, and thus the paper addresses global interests. Overall, the work appears to be carefully done and well documented. There are, however, some aspects of the presentation that could bear improvement. These are noted below, and are not intended as a rejection of the quality or the validity of the work, but suggestions for improving the paper.

RESPONSE Again, we appreciate the positive feedback on our study.

Specific Comments: REVIEWER The Abstract contains too much background material, and should be revised to focus on describing the "found experiment," noting the salient technical and methodological components of the work, and briefly highlighting the major findings. The other material, such as the legal requirements, should be addressed in the Introduction section.

RESPONSE We have shortened the length of the abstract to focus on the main research questions and novel results.

REVIEWER The Introduction section should be reorganized to better separate the presentation of the purpose and the methodology of the paper from the history and local conditions in the Columbia River Gorge and surrounding region. Making two separate sub-title sections would be appropriate.

RESPONSE We have done some rewriting of the introduction, but have chosen not to separate the make two sections out of the introduction into two sections.

REVIEWER The four science goals should be re-ordered to follow a natural priority: - "Can we use emissions data from the Boardman plant to quantify its contribution to PM2.5". . . is the obvious lead question – but I recommend it be restated as "Can we

use emissions variation over time from the Boardman plant to quantify its contribution to PM2.5". . .. - "What can backtrajectories tell us". . . should be re-stated to be more specific, reflecting interest in determining the power plant's contribution to high PM2.5 days (implicit in section 3.2 and Table 2). - "How do these results compare to the previous work". . . - "Has there been any trend in PM2.5 concentrations". . . is most relevant to the current analysis in the context of increasing or decreasing impact of the Boardman plant (e.g. by changing plant usage, altered SOx or NOx aerosol conversion rates, etc.). The text in Section 3.5 suggests that the change is not large enough to be detected in visibility in the CRG (the underlying motivation for the monitoring). If there is a significant trend, or if others (e.g. Malm, 2002) have suggested there is, this discussion should be enlarged to show the analysis and point to causes of any discrepancy between reports; if not, the authors may choose to eliminate this entirely.

RESPONSE Well...we prefer our original style. To us, the first question was to identify sources using the backtrajectories, not assume that the power plant was responsible. Only after the backtrajectories clearly pointed to the power plant, could we use the emission data to understand its contribution. Both reviewers suggested that the discussion of trends in PM2.5 in the CRG is extraneous to the main thrust of our study, so we have eliminated research question #4, Sect. 3.5 and the last paragraph of the conclusion.

REVIEWER The authors should address and resolve the implicit contradiction between their critique of the model results in "Columbia River Gorge Air Quality Study, Science Summary Report, Pitchford et al., 2008", which performed poorly because of the use of large grid wind fields, and their use of the coarse grid wind fields in the HYSPLIT reanalysis data base used to construct back trajectories.

RESPONSE This is a valid point. We acknowledge that the coarse resolution of the HYSPLIT wind fields may lessen our certainty in source attribution. To address this question we have done some additional analysis using local wind data to corroborate the backtrajectory results. We used data from the only met station in the CRG at the

Columbia Gorge Regional Airport (16 km west of the Wishram (NWS site; KDLS). The station data were obtained from www.mesowest.utah.edu). We calculated the daily mean wind vector (speed + direction) for the 50 highest PM2.5 days and found that: - Of the 50 worst PM2.5 day at Wishram, 31 days (62%) have wind data at KDLS - Of the 20 worst PM2.5 days that occur in Nov, 15 days (75%) have wind data at KDLS - Of those 15 days, 11 days (73%) have an easterly component to their mean daily wind vector (i.e., 60° - 160°) The figure below (or attached) compares the daily vector wind with the backtrajectory category in the manuscript:

What we found is a very good correspondence between the back-trajectory category and the daily vector wind. For example, days with back-trajectory categories of 1 (west gorge highly probable) occur with vector winds clustered near 270 degrees. On days where the back-trajectory category was 5 (east gorge highly probable), the wind vectors cluster around 90 degrees, albeit with some variations. On only one day are the wind vectors clearly inconsistent with the back-trajectory category.

We have added a few sentences to the manuscript to describe this analysis and the results: "Because the HYSPLIT backtrajectories were calculated with coarse meteorological data, we also used local winds measured at the Dalles, Oregon municipal airport to corroborate the trajectory classifications. For this we calculated daily average (24 hr) vector winds. Of the 16 days, with backtrajectory categories 5 (East Gorge highly probable), 13 had sufficient local wind data to make this comparison. Of these 13 days, 10 had daily average wind directions between 60-160°, consistent with easterly flow and our backtrajectory classification."

REVIEWER The paper mixes metric and English units (e.g. "short tons"); please clarify or use only metric units.

RESPONSE We have amended the text, figures, tables and captions to use the term "metric ton" and corrected numbers where appropriate.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 14235, 2009.

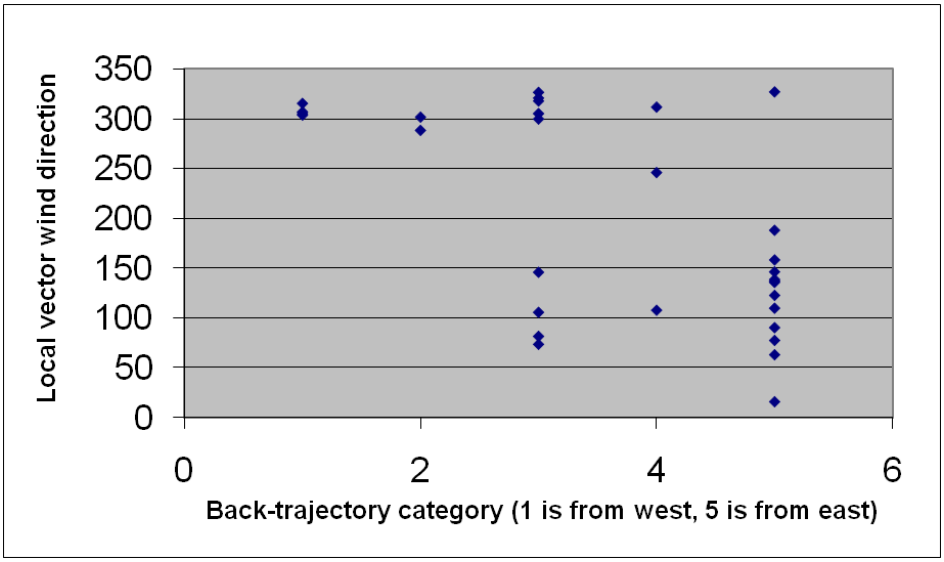

Fig. 1. Local vector winds vs Back trajectory classification