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Responses to Reviewer #2

Overview

This study relates winter variability of particulate matter (PM) to changes in the Pacific-North America climate index. The authors use both observations and model simulations of PM. A statistically significant difference in PM is identified between the positive and negative phases of the PNA, particularly in the US Midwest. The authors provide some statistical evidence that changes in meteorology attributable to the PNA is the cause.

Overall the paper is generally clear. I think the research fits will within the scope of ACP and that the results would be well-received by the community. However, I have a number of concerns. I believe the authors can ease these concerns with additional work. I recommend the manuscript for major revision.

General Comments

I have some concern about the definition of the PNA index. It is not clear why the geopotential height in three grid boxes is sufficient. I recommend using a more standard index. For example, the NOAA Climate Prediction Center provides monthly values of the PNA index using the more common EOF loading approach. Also, just looking by eye, the NOAA CPC PNA data appears to differ from the PNAI presented here.

Response:

There are three commonly used definitions of PNAI: (1) PNAI defined by Leathers et al. (1991) ($PNAI_{Leathers}$). This is the definition used in our manuscript. (2) PNAI defined by Wallace and Gutzler (1981) ($PNAI_{Wallace}$) as: $PNAI_{wallace}=\frac{1}{4}\left[z^*(20°N,160°W)-z^*(45°N,165°W)+z^*(55°N,115°W)-z^*(30°N,85°W)\right]$, where * denotes the normalized geopotential height at 500 hPa. (3) PANI defined by NOAA Climate Prediction Center (CPC) ($PNAI_{NOAA}$, http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/month_pna_index 2.shtml). All these three definitions reflect the same atmospheric teleconnections over the region of North Pacific to North America region. The correlation coefficients between $PNAI_{Leathers}$ and $PNAI_{Wallace}$ (or between $PNAI_{Leathers}$ and $PNAI_{NOAA}$) is equal to or larger than 0.94, when we calculate PNAI for 1979–2013 by using the NCEP-2 reanalyzed meteorological data or PNAI for 1986–2006 by using the assimilated GEOS-4 data (see Fig. A below). Therefore it is sufficient to use $PNAI_{Leathers}$ in our study.

By using the PNAI defined by geopotential heights in 3 grid boxes ($PNAI_{Leathers}$) and in 4 grid boxes ($PNAI_{Wallace}$), many previous studies examined the variation and mechanism of PNA as well as the relationship between PNA and surface weather over the U.S. (Yarnal and Diaz, 1986; Carleton et al., 1990; Leathers et al., 1991; Leathers and Palecki, 1992;

Trenberth and Hurrell, 1994; Rodionov and Assel, 2001; Schoof and Pryor, 2006).

There are three reasons for the differences between PNAI shown in our Fig. 2 and that shown by NOAA CPC (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/month_pna_index.shtml). First, the calculation depends strongly on the length of samples. The NOAA CPC PANI has the samples covering all months throughout the year over 1950–present, with the mean value and variance of the time series different from what we have in our calculation of PNAI (in our work we are only concerned with the PNAI for the months of NDJFM over 1986–2013). Second, the NOAA CPC PANI has been smoothed by a 3-month running mean method. Third, the NOAA CPC PANI is calculated by using the geopotential height with seasonal cycle, but the PNAI is our work is calculated by using the deseasonalized geopotential height to isolate the monthly variation.

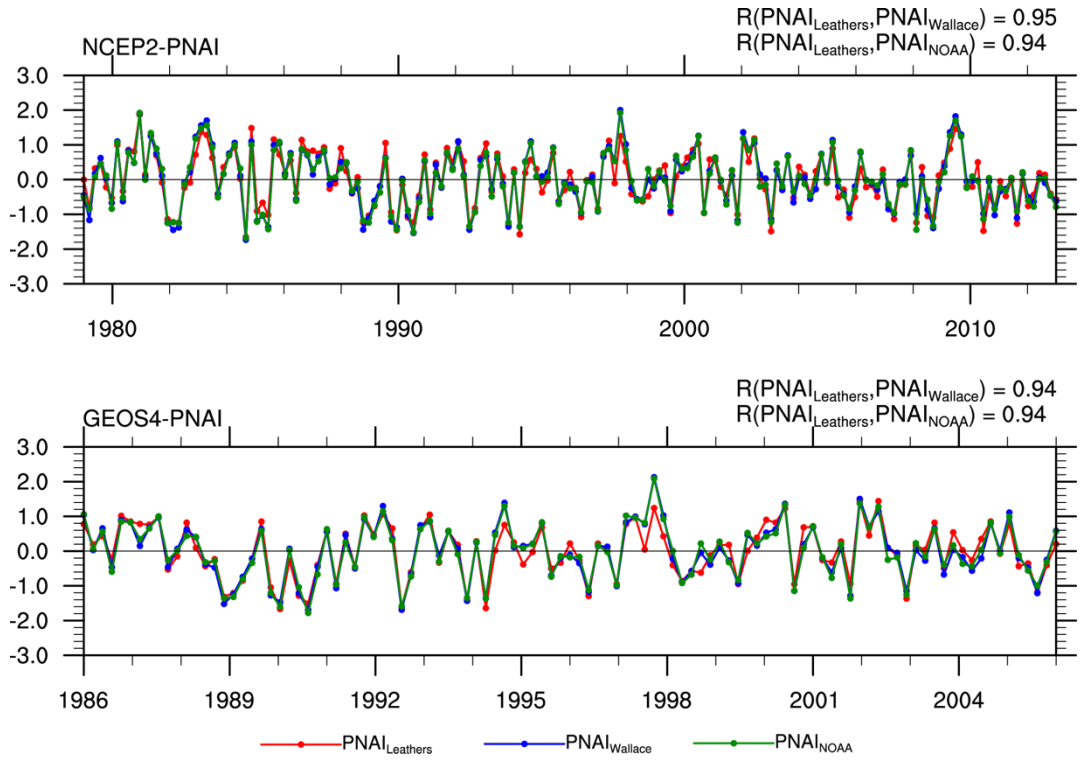

Fig. A. Top panel: Monthly PNAI in NDJFM for years of 1979–2013 calculated using the NCEP-2 data. Bottom panel: PNAI for 1986–2006 calculated using the assimilated GEOS-4 data. The correlation coefficients are marked on top right corner of each panel.

- Most of the analysis focuses on differences between the positive and negative phases of the PNA. It is generally most constructive to isolate the impacts of each phase from neutral conditions. If the authors have motivation to compare positive vs. negative phases, they should include those thoughts in the manuscript.

Response:

The method of compositing the differences between the positive and negative phases of one atmospheric circulation index (ACI) is a commonly

used approach to analyze the impact of the ACI on a specific phenomenon. Most importantly, the composite differences can show the magnitude of the influence of ACI. Such approach has been used in many studies to examine the impact of climate variability on concentrations of aerosols (Di Pierro et al., 2011; Singh and Palazoglu, 2012; Zhu et al., 2012; Jerez et al., 2013; Qu et al., 2015) and on concentrations of tracer gases (Eckhardt et al., 2003; Liang et al., 2005; Jerez et al., 2013; Yang et al., 2014).

- The definition of the PNAI appears to have a significant flaw. I think this may just be a mistake in how the equation is written. By my calculation the denominator of Z*'_i,j is always 0. The summation can be disturbed across the parentheses (since the terms are simply subtracted). The first term generates the average value of Z' (which should be 0 anyway, see below). Summing the second term is trivial since there is no dependence on i or j, so it is multiplied by Nx5 and then divided by Nx5. Thus both terms give the average value of Z': Z'-Z'=0.

The second term of the numerator, by my calculation, should also be 0. The summation of anomalies from a mean will always be equal to 0, if the period used for estimation of the mean and period of anomalies are the same.

This equation needs correction; it is clearly not the algorithm used to produce the data in Fig. 2. Perhaps this is an issue with notation. See additional comment about these equations below.

Response:

Thanks for pointing out the typographic errors. We now have the following corrected equation in the revised manuscript:

$$Z^{*'}_{i,j} = \frac{Z'_{i,j}}{\sqrt{\frac{1}{n\times 5}\sum_{i=1}^{n}\sum_{j=1}^{5} Z'^{\,2}_{i,j}}}$$

- There are significant trends in PM2.5 and aerosol composition over this time period (hints of thus can be seen in Fig. 5c). The EPA AQS data should be detrended (in addition to removing seasonality) in order to best detect interannual variability. It needs to be shown that differences arise from true variability and not other factors (emission regulations). Indeed, just by eye, most of the positive phase months are in the early part of the period and negative at the end. This could introduce an artifact of emission regulations.

Response:

This is a good point. We have redone the composite analyses for observed aerosol concentrations by detrending the observations from the EPA-AQS. The revised differences in aerosol concentrations between positive and negative PNA are similar to the results in our previous version of manuscript (those obtained without detrending); the horizontal distributions are about the same but the magnitudes of the differences in aerosol concentrations are slightly smaller. We have updated Figs. 3, 4 and Table 1, and have changed the descriptions in the text accordingly.

- How are regional averages performed? A US-scale average will generally be more heavily weighted by the East Coast since there are more sites in that region. Some of the regional average numbers presented (US, western US, eastern US) should be reassessed.

Response:
We agree with the Reviewer. We have added a sentence in Sect. 3 to clarify this: "It should be noted that, in our analyses above, the locations of measurements and the numbers of samples were different for different aerosol species. The regional averages were also influenced by the uneven distributions of observational sites in different regions. Therefore, model results from the GEOS-Chem simulation will be used to further analyze the impacts of PNA on aerosols in the U.S., as presented in the subsequent sections."

- The figures are very hard to view. I recommend breaking up some of them to allow larger maps. Figures 3, 5, and 6 are particularly hard to read. The data in the maps is useful and necessary.

Response:
The original figures are not so small. The current very small figures were caused by the landscape pages of ACPD. It is expected that the figures will be easier to view when each of these figures can take up a whole portrait page in its ACP version.

Specific Comments - Page 33210, Line 6: "...Air Quality System of Environ- mental . . ." should be ". . .Air Quality System of the Environmental. . ."

Response:
Changed.

- Page 33215, Line 4: It is unclear if 5 days of observations are required or 5 observational periods. A single observational period could be 5 days long.

Response:
We have clarified this as "… there were at least 5 observation records within each month."

- Page 33217, Line 14: The notation here is confusing. The equation defining Z' should not have two references to i (i is listed as an input and the summation variable).

Response:
Corrected.

- Page 33218, Line 2: "PANI" should be "PNAI".

Response:
Changed.

- Page 33218, Line18: I do think contiguous Salt Lake is an identifiable location.

Response:

We have changed “the contiguous Salt Lake” to “the contiguous Salt Lake (northern Utah)”.

- Page 33219, Line 9: Why is 90th percentile used? 95th percentile is more standard.

Response:

The 90% confidence level for t-test is also commonly used in previous studies to examine the impacts of atmospheric circulation on aerosols (Schultz et al., 2007; Wu et al., 2008, 2013; Gong et al., 2010; Hirdman et al., 2010; Qian et al., 2011; Jerez et al., 2013; Huang et al., 2014; Gettelman et al., 2015).

- Figure 2: The difference between Figure 2a and 2b is not clear. The panels have slightly different labels, but the data and highlighted +/- points appear identical.

Response:

The Fig. 2a (Fig. 2b) was the PNAI for analyzing observed $PM_{2.5}$ (individual aerosol species) over 1999–2013 (2000–2013). Figs. 2a and 2b are almost identical for the highlighted +/– points except for those in year 1999. See Sect. 2.3 for our definitions of PNA+ and PNA–.

- Page 33222, Line 23: Again, you cannot use the variable i in the summation notation since its already used to denote the month of interest.

Response:

We have changed *i* to *m*, *n* to *M*, and the revised equation is:

$$DM_m=(C_m - \frac{1}{M}\sum_{m=1}^{M} C_m)/\frac{1}{M}\sum_{m=1}^{M} C_m$$

- Table 3 – The mass flux values seem a little low. I recommend double-checking the calculation.

Response:

We have checked our calculation and the results are right.

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