

## Reviewer Response: acp-2016-1141

We thank Anonymous Referee #1 for the constructive comments on this manuscript. In our response, we first address the overarching concerns of the reviewer, followed by addressing individual comments. Our response to points that the reviewer raises is denoted with bold text. All line numbers in our responses refer to the attached tracked change manuscript.

This paper presents a detailed analysis of a bromine activation event that took place over Barrow in March 2012. This event was probed by BrO and supporting measurements at the surface (in situ and MAX-DOAS), from aircraft (MAX-DOAS), and from satellite. A spectacular finding is the observation of a BrO plume aloft at 0.5-1 km altitude, implying that BrO can be sustained through reservoir recycling reactions within the atmosphere presumably through aerosols. This is a major new finding not only for understanding elevated BrO in Arctic spring but also for explaining the BrO tropospheric background. This paper certainly deserves publication in ACP. The paper can be published pretty much as is in my opinion (I do think the abstract needs some tweaking, see below). However, I found it a struggle to go through because of all the complicated plots of near-raw data forcing me through (I thought) unnecessary details. In my view, Figure 11 makes the paper. The authors might consider cutting back on the figures or simplifying them. This is just a suggestion, however, because the authors might feel that the detail is necessary. Readers like me will be discouraged by the detail and go straight to the abstract, and that's OK.

**Based on the reviewer's suggestion, Figs. 2 and 5 have been moved to the supplemental information. In addition, the now Fig. 9 has been modified to show the LT-VCD as well as the BrO profile to facilitate comparisons between figures.**

I do think that the authors can (and should) broaden the impact of their paper by linking their results to background tropospheric BrO. As they know, there is a lot of current interest in understanding the  $\sim 1$  ppt BrO observed in the troposphere with implications for ozone, OH, and Hg. Heterogeneous recycling in aerosols similar to the springtime Arctic (but at a slower pace) has been proposed to explain the sustained background tropospheric BrO levels but without direct evidence (Parrella et al., ACP 12, 6723- 6740, 2012; Schmidt et al., JGR 121, 11819-11835, 2016; sorry to be pushing my own literature). The present paper offer strong support for this heterogeneous recycling. It would be a neat way to connect the Arctic spring chemistry to the global picture. Brief statements in the Abstract, intro, and conclusions is all that would take.

**This is an excellent point. As suggested, we have added brief statements to the abstract (pg. 1, line 15), intro (pg. 2, line 19) and conclusions (pg. 15, line 5) discussing the implications of this finding for the tropospheric background as**

suggested by the reviewer.

Specific comments: (page, line) 1. Abstract, line 9: disconnected from the surface is vague, I would point out that the plume is at 0.5-1 km altitude.

**We changed this sentence to specify the plume altitude.**

Abstract, lines 10-11: I dont think that the authors can claim as fact that the recycling took place on the co-located supermicron aerosol particles. They can claim evidence that it did. Its too bad that the aircraft didnt carry in situ instrumentation that would provide more correlative information including BrO reservoirs and ozone as well as aerosols. Maybe for the next campaign?

**We have modified this sentence to suggest this recycling took place rather than explicitly say this took place. While the plane did carry an ozone monitor, it was unfortunately not functional for this flight. We are intending to pursue more detailed gas and aerosol chemistry measurements in the future.**

Abstract, line 12: increases the spatial extent of bromine chemistry This is vague. We already know that BrO events extend for great distances horizontally. Maybe the authors mean vertical extent? That would definitely be an appropriate statement.

**The mechanism allows for transport far from the source region, which extends the impacts of this halogen chemistry in both the horizontal and vertical dimension. While we already know BrO events extend for large distances horizontally, these results provide evidence for a likely process governing the BrO spatial extents observed by satellite measurements. This is now clarified in the abstract.**

Abstract, line 14: must be considered in the interpretation of satellite observations Vague, how is that? I didnt see reference to this in the text.

**We argue that the existence of plumes disconnected from the surface would alter the interpretation of satellite observations of enhanced LT-VCDs. We now clarify that we are referring to column observations**

Page 7, line 7: give the source of the tropospheric BrO satellite data (a website can be a useful reference). How was the stratosphere removed?

**We have modified the text in the methods (pg. 4, lines 15-16) to clarify the answer to these questions.**