Anonymous Referee #2

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This paper describes data prescribing the boundary conditions affecting the near sur- face air-chemistry at the South Pole; more specifically the conditions are sought that lead to occasional episodes of surprisingly high levels of NO in the lowest 50 m or so of the atmosphere.

This is a complex discussion: NO levels may depend on large scale meteorology (ad- vected air from the oceans), small scale mixing (boundary layer stability), sunlight, and the actual chemistry sources and sinks. The paper faces a significant challenge is presenting the reader with these processes, their importance, and the supporting data (from different campaigns) in a manner that tells the story and supports the conclu-
sions. It is this challenge that I found wanting.

Response: We have made a number of revisions in response to RC1 including a four-season overview at the beginning of Section 2 and a figure that summarizes the NO observations for all four years and shows the variability in actinic flux, solar elevation angle and timing the breakup of the ozone hole for 2006-2007. This then sets the stage for the subsequent discussion in Section 2.

I think the paper is difficult to read: this may be in part because much of it is not my field, but I suggest that most readers will suffer similarly given the interdisciplinary nature of the discussion. The authors therefore need to help set the story better, and I suggest that two or more schematics would be most helpful. The source, mixing and ventilation of the boundary layer, with the chemical pathways (in snow, air and advected aloft) overlaid. This coupled to maps (as per figure 1, 5 and 8) with an overlay of wind roses, rather than x-y plots (figure 1 again).

Response: We have now included reference to Davis et al. (2008, esp. his Fig. 2) which outlines many of the processes at work on the high plateau. New text added in the introduction includes:

"*Past work (Neff, 1999) found evidence for the effect of stratospheric ozone depletion on the tropospheric circulation in the Austral spring over the interior of Antarctica. A key question then was the potentially combined effects of changes in the radiative environment (via UV photolysis) and concomitant changes in the near-surface meteorology affecting NO. The complexity of all the potential processes affecting NO are well captured graphically in Davis et al. (2008, Figure 2) where they identify atmosphere-surface exchange processes, plateau drainage, continental outflow, lower latitude transport, and boundary layer-free troposphere exchange as the key meteorological processes.*"

As noted above we have set the stage for the discussion in Section 2 with a new figure summarizing the year-to-year differences in the four field programs. We find the x-y plots to be a good short summary of the intra-seasonal changes in the larger scale circulation but have added wind roses in the supplemental material that highlight the changes in more detail than in our new Fig. 2. This new supplemental figure also summarizes the changes in cloud fraction versus 300-hPa wind direction through the three subseasons.

The authors should think of a clearer nomenclature for wind direction, as "157.5" and "337.5" implies a very highly modal air flow, rather than, for example "the SSE and NNW sectors" (I assume this is what the authors meant). Perhaps even include a sailors' compass for those less familiar with these terms, but emphasise that such sectors have natural angular range bin of a quarter of a right angle. These would then fit nicely with wind roses of either 8 or 16 direction bins. Finally on the topic, such schematics would stress that 'North' at the South Pole is nominal, and the meridian is taken.

Response: As noted above, we have added wind roses in the supplemental material and changed angular descriptions to the SSE etc nomenclature suggested by the reviewer in Fig. 1. We agree with the reviewer that wind roses reveal the angular ranges more explicitly. In the supplemental figure we have also added wind direction/cloud fraction roses. These show that low cloud fraction in the period JD310-340 can be associated with a much narrower range of directions of 300 hPa winds (SE to ESE) than might be concluded from just wind roses. These also confirm our assertion that higher cloud events are associated with winds aloft from the direction of west Antarctica while there is a major shift in cloud/wind direction in early December

The schematic of the boundary conditions would greatly assist with giving meaning (and importance) to the whole of Section 2. Each section describes some meteorolog- ical phenomenon, but not why it matters. The reader (at least this one) was left with a wealth of information dangling, without a mechanism to sift for importance for the overall Question. All of the information presented may be vital to the argument, but, I would ask the authors to check each statement here for Invasion of the Interesting Fact (which isn't actually critical).

Response: Section 2 has been significantly revised in response to RC1 which also addresses this comment.

Perhaps (again for the non-specialist reader) the conclusions could be presented as a "recipe for a perfect NO event", that is, High NO is likely to happen when (a) and (b) and (c) or (a) and (d) but not (d) etc.

Response: Unfortunately we have found there is no simple recipe for a perfect NO event. In fact our stepwise linear regression in Appendix A shows different variables dominate each of the four seasons that we studied. We have revised the first few paragraphs of our conclusions as follows to make this point clearer:

"*Earlier work (Davis et al. 2008; Neff et al. 2008), primarily based on 2003 data which included direct sodar measurements of boundary layer depth, presented a straightforward conceptual model that linked high NO to the presence of shallow boundary layers, light winds, and stronger surface inversions. In our examination of four seasons of observations, explanation of the initiation and evolution of high NO episodes as well as intra-seasonal to interannual variability proved more challenging. Using four spring-to-summer seasons of observations, we have described the influence of the synoptic- to-mesoscale weather patterns and their seasonal cycle on stable boundary layer characteristics at the South Pole in the spring-summer period that set the stage for high NO episodes. These included*

1) The relative unimportance of katabatic forcing compared to the accelerations due to synoptic and mesoscale scale pressure gradients from November through January. In fact, visualizations of near-surface airflow using ERA-I (Dee et al. 2011) revealed complex mesoscale circulations that belied any simple explanation of accumulation pathways for NO.

2) The effect of clearing skies locally that led to rapid radiative losses and the formation of very shallow inversion/boundary layers and high NO. Given observations only at the SP, the geographical extent of such radiation-driven boundary layers is unknown but worthy of further field observations. Unfortunately aircraft measurements of NO in 2003 (Davis et al. 2008) were not permitted between -40^{o}W and 120^o E (the clean air sector), an area which encompasses a large almost horizontal plane extending four hundred km east of the SP. However, the one flight along 120^{o}E at the edge of this plateau showed NO in excess of 400 pptv between 100 and 400 km from the SP at the same time NO concentrations were dropping at the SP.

3) The three-phase transition in spring for 300-hPa winds over the SP. These three phases corresponded to a) a late winter regime of transport of moisture over west Antarctica to the interior when the circumpolar trough is at its maximum and opens the possibility for the transport of NO precursors from northerly latitudes, b) an early spring semi-bimodal regime with 300 hPa winds alternating between northwest and southeast quadrants during November and early December as part of the seasonal cycle, followed by c) an early summer regime favoring 300-hPa winds from the Weddell Sea and warmer cloudy conditions. During the second phase, 300-hPa winds from the southeast favored clear skies, light surface winds and shallow inversions conducive to high NO concentrations at the same time the total column ozone was still low allowing higher actinic fluxes. 300-hPa winds from the northwest favored warm-air advection and cloudy conditions resulting in deep boundary layers and low NO concentrations."