We thank the two anonymous reviewers for their careful review of our manuscript. We have addressed all the issues/concerns raised by reviewers. Below is our response that addresses the specific comments from each of the two reviewers. [Our response (in italicized font) is preceded by the reviewers' comments for clarity].

Interactive comment on "Source sector and region contributions to BC and PM2:5 **in Central Asia" by S. Kulkarni et al.**
Anonymous Referee #1 (Received and published: 28 May 2014)

This manuscript describes an effort to quantify concentrations and sources of PM in Central Asia. This region appears to not be specifically target by air quality model applications, so this work seems to be a good contribution in that sense. Regional contributions were obtained using the simple "zero-out" method. Future emissions scenarios were also considered.

I suggest the following items for the authors to consider:

1) How are the winter heating emissions currently quantified? This would be good to know since the authors point to this as one of the reasons for underestimations in the PM concentrations.

Authors' Response: *Seasonal variations of residential heating/cooking emissions were not included as the base inventory did not have this information for CA.*

2) The BC surface mean values was found to be around 0.1 ug/m3. That seems very low. Do you have confidence in your apportionment models at such low values?

Authors' Response: *As our estimates are based on chemical transport model, we are confident that we can track concentrations at these levels.*

3) It is not clear to me why the authors chose to have different source regions foranthropogenic emissions, biomass burning emissions, and dust emissions instead. Perhaps the value gained in the analysis overcomes the confusion, but it is not clear.

Authors' Response: *The CA region is strategically located and aerosols at these sites are shown to reflect impact of varied dust (including CA, Western China, Africa and Middle East), biomass burning (including Europe, Siberia, South Asia and North America) and anthropogenic sources (including Europe, South, East and Central Asia, and Russia) depending on the time period.*

So we choose different regions for the anthropogenic, dust and biomass burning in order to capture the impact and the associated seasonality of these main regions on the regional distribution of aerosols in this region. We have more anthropogenic regions to better understand how regional changes in emissions may impact CA PM levels.

4) Why were residential and transportation emissions portioned between model layers 1 and 2? 10% seems like a lot to inject higher up. How high was level 2?

Authors' Response: *Residential and transportation emissions are considered near surface emissions so we portioned them from surface to ~ 100m (AGL altitude of level 2).*

5) How were back (and forward) trajectories calculated? This does not seem to be described in any deal.

Authors' Response: They were calculated using the three dimensional wind fields simulated by WRF model (that were also used as input to the STEM simulations). Details describing the trajectory calculations have been added in section 2 of the manuscript.

Anonymous Referee #2 (Received and published: 24 June 2014)

This manuscript describes modeling analysis of PM seasonal cycles, source type and region contribution, and future emission scenarios over Central Asia (CA). The WRF/STEM model is used to conduct a hemispheric scale simulation at 60km x 60km resolution. Observations at two surface sites in CA and AOD retrieved from MODIS are used to evaluate the WRF-STEM model prediction. The analysis is focused on the source attributions to PM in CA, suggesting dust and residential heating as two major contributors of PM for this region. Additional analysis is conducted on the impact of CA emissions on other regions of the Northern Hemisphere. Future emission scenarios for 2030 are adopted from the WMO/UNCEP report on short-lived climate forcers. Putting these emissions scenarios in the model, the authors find significant increase of PM and BC over CA if current legislation is kept unchanged for pollution abatement measures.

Given little attention has been given to Central Asia, this paper represents new analysis. The paper is well written and well organized. It is suitable for publication in ACP once several revisions have been made, as described below.
Major comments:
1. The model simulation and analysis are largely performed on the scale of the whole Northern Hemisphere, including other Asian regions with large emissions such as China, Europe, and North America. The emissions from CA will account for only a small portion of emissions in NH, thus the source attribution and long-range transport analysis will depend on the model's ability in capturing sources seasonality and abundance in other regions. However, the model evaluation is conducted only based on two surface sites in CA. Almost all the maps of model predictions shown in the paper are of the hemispheric scale, but such results are not evaluated nor do the authors discuss the uncertainties of them. The inconsistency between the scale of the model/results presented and the scale of the focused region is the main shortcoming of this paper.

Authors' Response:
We thank the reviewer for this comment. The primary focus of this paper is Central Asia and we focus our analysis on model performance on the two sites located in this region. We would like to point out that our analysis also includes the long range transport into and out of the region and this brings in the hemispheric scale. The model has been evaluated on a hemispheric scale using MODIS AOD in the domain of interest for this analysis and is described in section 3.1. We have evaluated this model framework in other regions including arctic region and continental US, which are summarized below and now included in the model performance evaluation section.

We have evaluated this model framework in other regions outside CA including arctic region and continental US, which are summarized below. Dallura et. al., 2011 evaluated the performance of the WRF-STEM modeling framework (used in this study) through the case study of the ARCTAS mission DC-8 flight conducted on July 9 2008. The WRF model compared well with observed meteorological variables (including temperature, pressure, wind speed and wind direction) along the flight and correctly simulated the various meteorological processes (i.e. cyclonic circulation, low pressure system, anticyclones and geostrophic wind flows) that facilitate transport of pollutants into the Arctic region. This study also compared CO along the flight and found that the simulated values were able to capture the magnitude and temporal variability seen in observed values. The study also found that the fires from North Asia and anthropogenic CO from China were the major sources contributing to observed CO levels along the flight suggesting that the midlatitude pollution and summertime forest fires/biomass burning transport events were well represented in the STEM model.

The study by Huang et al., 2012 used the STEM model to simulate summertime sectoral and regional contributions to BC over continental US and evaluated the model performance aloft and at surface using measurements from ARCTAS mission DC8 flights conducted on June 20 and 22 and 24 that sampled over California and IMPROVE (Interagency Monitoring of Protected Visual Environments) surface site network. Huang et al., 2012 found that the predicted BC values captured many of the vertical features seen in the flight observations with a tendency to over predict surface BC and > 4km. The comparison of predicted BC with observed values from the IMPROVE network showed that the model was able to capture the gradients in BC values with high concentrations in western and eastern NA regions with slight positive and negative biases over the mountain regions and the eastern US and CA.

Since the Huang et al., 2012 study was focused on summer, we evaluated the simulated BC values with IMPROVE BC observations for the simulation time period (i.e. April 2008 – July 2009) used in this study. The IMPROVE BC analysis is limited to 27 sites on the US west coast (i.e. west of 120 W) to be consistent with the focus of this paper (i.e., long range transport of pollutants on a hemispheric scale). The mean observed and modeled BC for the West Coast sites are ~0.16 and 0.19 μg m−3 (n = 3759 points) with mean bias and RMSE of 0.03 μg m−3and ~ 32 % respectively. The mean simulated/observed BC at surface sites is ~ 1.2, which compares well with the corresponding ratio of 1.6 reported in the global model performance over North America region by Koch et al., 2009. The detailed analysis of the IMPROVE BC sites and associated seasonality will be the addressed in a future paper.

These studies indicate that the simulated transport patterns are able to capture the main important features of the hemispheric flows at the scale discussed here for improving the current understanding of the source receptor relationships of aerosols at intercontinental scales. The prediction of aerosol mass and composition at the hemispheric scales is also quite good, but has considerably higher uncertainties associated with emission estimates (in particular forest fires/biomass burning and natural dust emissions) and wet removal processes (Bates et al., 2006).

2. In discussion of the emissions and future emission scenarios, it will be more informative for the readers to obtain a quantitative understanding of the emissions changes and the resulting changes in PM concentrations. I suggest the authors compile the results in a table, for example, listing how much BC emissions are increased in the current legislation scenario in 2030 and the resulting changes in BC concentrations. The

table should be focused on CA. Currently these results are shown in the supplementary materials and by figures which are hard to read.

Authors' response:

We appreciate the reviewer's comment. We have compiled a summary table that shows the change in emissions and concentration over the Central Asia region defined in the domain. This summary is included in section 3.8 that discusses the future emission scenarios along with the following text.

To get a regional perspective of how the future emission changes would specifically impact the CA region (See Fig. 1 for the CA region definition used in this study), we have summarized the changes in emissions and the corresponding concentrations in Table 1.The reference 2030 emissions scenario reports an increase in emissions of BC, SO_2 and $PM_{2.5}$ over Central Asia by ~ 22, 17 and 14 % respectively w.r.t to base 2005 levels. However, the corresponding BC, SO_4 and anthropogenic portion of PM2.5 decrease by ~ 5, 12 and 5 % respectively. This suggest that on average the concentration levels go down even though CA emissions increase due to long range transport of pollutants into CA region from the surrounding regions, but locations within CA still increase when dominated by local sources. The Low GWP emission scenario predicts decrease in BC and $PM_{2.5}$ emissions by 31% and 10% respectively with the corresponding decrease in concentrations by ~ 37% and 10 % respectively, while SO2 emissions remained same as the reference 2030 scenario. The lowest + 450 ppm scenario shows a consistent decreasing trend in emissions and concentration of all the species. This analysis suggests that the impact of the changes in major source region emissions and their subsequent transport to Central Asia will play a major role in determining the future aerosol levels in CA.

Table:1 Summary of changes in Central Asia region (See figure 1 for Central Asia region definition) emissions and concentration under the future emission scenarios (See Sect. 3.8 for more details)

Emission Scenario	**Emissions Gg yr^{-1}**			**Emissions change (%) w.r.t to base 2005**		
	BC	SO_2	PM_{25}	BC	SO_2	PM_{25}
Base 2005	39	1130	197			
Reference 2030	47	1326	224	22.1	17.3	13.9
Low GWP 2030	27	1325	177	-31.1	17.3	-10.1
Lowest GWP + 450	21	1058	115	-46.9	-6.4	-41.5

	Concentration (µg m^{-3})			**Concentration change (%) w.r.t to base 2005**		
	BC	SO_4	PM_{25}	BC	SO_4	$PM_{2.5}$
Base 2005	0.17	3.04	4.26			
Reference 2030	0.16	2.65	4.03	-4.2	-12.6	-5.3
Low GWP 2030	0.11	2.64	3.85	-36.6	-13	-9.5
Lowest GWP + 450	0.10	2.04	3.06	-38.5	-32.9	-28

Minor comments:
1. pg 11357, line 21: % changed to percentage
   Done
2. pg 11357, line 26: “are” changed to “is”
   Done
3. pg 11360, line 8: remove “is” after in turn
   Done

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