

## ***Interactive comment on “Variations in O<sub>3</sub>, CO, and CH<sub>4</sub> over the Bay of Bengal during the summer monsoon season: Ship-borne measurements and model simulations” by Imran A. Girach et al.***

**Anonymous Referee #1**

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Title: Variations in O<sub>3</sub>, CO, and CH<sub>4</sub> over the Bay of Bengal during the summer monsoon season: Ship-borne measurements and model simulations by Girach et al.  
2016 General remark: This paper is based on the surface (ship-borne) measurements of ozone, CO and methane over the Bay of Bengal (BoB) during summer/monsoon months of year 2009. The main objective of this study is to investigate the spatio-temporal variations of trace gases. The WRF-chem simulations have been compared. Case studies, mostly reduced levels of ozone during rainfall events have been investigated in details. Inferences from surface measurements over the land (India subcontinent) have been used to study the en route transformation (net O<sub>3</sub>). The data and

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analysis is good but the discussion needs somewhat better and concrete interpretation. The paper may be accepted but following aspects need improved or more considerations. (1) Dividing BoB in regions southern, central and north, etc. is not impressive as transport of air mass is highly variable. I agree with categorization based on the trajectories. Characterizing the air masses measured over coastal and open oceans are valuable. (2) Significant data measured during the stationary phase (of ship) has been used. Typically, researchers reject such data. I think data measured during this period should not be used. (3) En route transformation of ozone has been assessed with reference to several station based measurements over the land. Instead of relying on observations, model data should be used/compared to estimate the en-route transformation of ozone. (4) Methane data have been overlooked, or else, can be removed from the draft. (5) There are too many Figures (16), some data plots are repeated. Therefore, improved representations of figs and tables are also required. (5) There is scope of improving English. Excessive use of "WE" "OUR" "FIRST", etc. is not desirable. Following detailed and specific comments should be considered.

#### Abstract:

Page 1, Line 32-33 "simulations for a low-O3 event on August 10, 2009.....transporting ozone-rich airmasses" This sentence seems contradictory as low -ozone is explained by transport of ozone rich air?

#### Introduction:

Page 2, Line 64 "The marine regions adjoining South Asia, despite being far from direct anthropogenic activities," It is not really true, marine regions of AS and BoB are surrounded by polluted land of SEA and SA. If authors like to convey that there are no significant emissions (except ships) then it is well understood and do not require to mention "despite being far from...."

Page 3 line 69: "The airmasses exposed to ....." better to rewrite , "exposed " is not an appropriate choice.

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Page 3 Line 70-72: "In situ measurements over the.....transformation." This is not well written , please re-write.

Page 3, Line 81-83: "Both the export of .....transport of ...synoptic scale dynamics and monsoonal circulations" This is not well written what is the difference (scientifically) between export and transport.

Page 3, Line 85: "highly conducive for the accumulation of trace species". It is not clear , do the outflows from continents stop over BoB? I mean ACCUMULATION is not an appropriate choice?

Page 3, Line 96: "and an unnamed campaign" this does not sound good, write under "other campaigns "etc.

Pag3, Line: 103 ", which influences the oxidation capacity of the atmosphere" This is not required, in other seasons oxidation capacity can also be influenced due to higher levels of VOCs. So it is not unique for this season.

Pag4, Line: 106 "remote sensing of.." here, there is no need to give examples of TES or AURA, it is in general true for any remote sensing technique.

Page4, Line: 114-115 and elsewhere

"spatial and temporal variations in ozone" should be "spatial and temporal variations of ozone"

Page4, Line: 117 "We investigate ...we have ..greater detail." Please re-write "we" has come twice?

Page4, Line: 118-120: This may be deleted

2. The cruise track and background conditions.

Page 4, Line 123-124: Revise as "Figure 1 shows the cruise track of the Oceanic Research Vessel (ORV) Sagar Kanya during the CTCZ campaign (cruise number SK-

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261).

This section is partly explained in a rather lengthy caption (Fig1). Try to adjust most explanations in this text sections but not in captions.

"To take time series measurements, the ship was kept stationary at 89° E, 19° N for fifteen days (July 22 to August 06, 2009)."

Usually researchers reject the measurements when ship is stationary , as it is proved that exhaust from ship influences the measurements of trace constituents. An explanation is required how it is ensured that ship's exhaust did not influence measurements around the measurement location?

Line 129-131: "The average prevailing wind patterns at 925 hPa during the cruise period are obtained from NCEP/NCAR reanalysis (<http://www.esrl.noaa.gov/psd>; Fig. 1). The prevailing westerly or south-westerly winds are conducive for the transport of ozone and its precursors from the Indian landmass to the BoB during the summer monsoon season." revise as here: "The average wind pattern at 925 hPa (NCEP/NCAR reanalysis; <http://www.esrl.noaa.gov/psd>) during the cruise period is shown in Figure 1. The prevailing westerly and southwesterly winds transport ozone and its precursors from the Indian landmass to the BoB during study period."

Line 133: Phase B (INTEX-B), Does this correspond to Indian summer season?

Line 134: Relatively high NO<sub>x</sub> emissions are located over parts of eastern and southern India.? This is arguable if compared with emissions over IGP and western India (which is not shown). So change the sentence accordingly.

### 3. Experimental details and data

Page 5, Line 146 "This instrument was based on the principle.." something like this is better "This instrument works on the principle.." Page 5, Line 135-154 "Trace gas measurements affected by the ship exhaust ....." This is the issue when ship is stationary, irrespective of wind direction.

Page 5, Line 164-165 following should be better "at 5-minute of integration time using an automatic weather..."

So far, it is not clear why measurements at Thumba, Thiruvananthapuram have been discussed in this draft. Objective of using the Thumba data is missing.

## 5. Results and Discussion

Page 6 Line 205: "period of the summer monsoon season" can be deleted. "summer season" is being repeated again and again.

Page 6 Line 206-207: revise as here

"The mixing ratios of trace gases show large spatio-temporal variations over the BoB."

Page 6 Line 207-209: can be summarized as "Levels of O<sub>3</sub> and CO varied in the ranges of 8-54 nmol mol<sup>-1</sup> (with average of 29.7±6.8 nmol mol<sup>-1</sup>) and 50-198 nmol mol<sup>-1</sup> ( average of 96±25 nmol mol<sup>-1</sup>), respectively. "

Page 7, line 220-221: " In addition to sailing across the BoB....." use of stationary ship data is questionable, strong justification is required or remove this data.

Page 7, line 238-242: " Similar variations in O<sub>3</sub> mixing ratios and residence time over continental India indicate the influences of transport from ..... and en route photochemistry."

This does not go well. In this paper, it is explained that there is en route formation of ozone, so ozone is formed also over the oceanic region. Therefore this relationship study between residence time (over land) and a secondary species is meaningless. However, to some extent it is meaningful for primary pollutants such as CO and also for CH<sub>4</sub>. These processes: source strengths, vertical mixing or dilution, and en route photochemistry (or their variability) are not occasional but are continuous. Therefore, and overall, consistent discussion using the residence time calculation is required. It is expected to see best relation between CO and residence time, at least better than O<sub>3</sub>.

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Why CH<sub>4</sub> is not influenced by the change in residence time?

Page 7-8, line 250-287: This discussion should be shortened, this lacks completeness. All inferences have been derived using two point measurements at Thumba and Anantpur. I feel, if model is doing good job then rely on model data for such discussion. Otherwise question may arise ; 1. Os the distribution of ozone and southern India homogeneous over central/southern India? 2.Is en-route transport from India the only factor controlling ozone over BOB? downdraft of O<sub>3</sub>-rich/poor air, or transport from other regions such as SEA are not relevant? Therefore, detailed discussion insightful analysis is required, otherwise, just shorten this part. 5.2 WRF-Chem simulations:

Throughout the draft: It is not nice to see frequent use of "we", "our" and "first time". please try to minimize the use of such words.

Page 9, line 292-293: "variations in the meteorological parameters simulated by the model are briefly evaluated" This analysis is beyond the scope of this paper, I suggest to remove Figure 8.

Page 9, line 312: " that is the mean value subtracted from the mean diurnal pattern,.."  
This is not clear?

Page 9, line 315: "Ship exhaust contaminated the observations for a period of time between 5 to 14 hours long;.." Here is the entire issue of using stationary data. Questions: How it is ensured that rest of hours were not impacted by ship exhaust? why this period (5-14 hr) is fixed on each day? Second, how about residual air mass (aging of ship exhaust), which can definitely change photochemistry of O<sub>3</sub> during rest of the hours. Suggestion: Do not use stationary phase data, you have got great deal of other results to focus on.

Page 10, line 345-346: "We suggest that, in the presence of ozone-poor airmass aloft, a downdraft would result in reductions in surface ozone mixing ratios." This is reasonable but if mid-tropospheric air (typically O<sub>3</sub> higher than at surface) is down-drafted then one

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may have opposite scenario. This needs to be mentioned.

Page 12-13, line 432-442: The cause of seasonality is explained in very general terms, and these are well known. Or at least new insights have not been presented about the seasonality. I suggest to remove this part.

Table: Table1: Only references are not enough. Please prove unique/salient features of the option for different atmospheric processes in second column and third can be used for the references. Little more elaborated table is required which will justify the options used for atmospheric processes.

Table 2: Revise as here: "Table 2. A comparison of average surface O<sub>3</sub> mixing ratios measured at various sites during summer monsoon period.\*boundary layer ozone over the Arabian Sea. " Also Arrange the Table properly, for example, Ahmedabad data are coming at 3 different rows. Better to show "mean +/-1-sigma format" rather showing mean and 1-sigma in two different columns.

Table 4: Last row "No name" , better leave it blank

Figure 1. Caption is very lengthy. What is the unit of wind speed (m/s)? Is NO<sub>x</sub> data corresponding to period of observations? Revise the map so that NO<sub>x</sub> emission over entire (southern/central) continents is covered. This is required as back trajectories pass through the beyond the domain shown in present map.

Figure 2. Revise the map as suggested for Figure1 (to show the distributions of trace gases over entire southern and central India).

Figure 4. The color scale should be further resolved (1km is not good enough, at least 500m would be better), as I only see the red (mostly). Also show symbol along the trajectories for each back day. This will help to understand "residence hour" calculation.

Figure 5. Why UT is used in time series plot, while LT is used in a diurnal plot? Better to use LT in all plots (other figures also). Again captions are too long, legends and colors are good enough, no need to mention or repeat same in text (caption).

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Figure 6. This figure is not impressive and not required (already you have 16 figs). Instead, A few lines in text should be okay.

Figure 8. This is redundant figure, already results have been summarized in Table 3. I suggest to remove this Figure.

Figures 5 and 9 can be combined: I do not understand why same data (residual hours) have been plotted in 3 different panels. Keep just one (may be in bottom panel). Instead of residual hours (right y-axis), plot WRF chem results.

Figure 10. Again, there is need to shorten the caption, do not explain the legends in details.

Figures 11 and 12 can be merged: Instead of Figure 12, plot temp data in left-y axis in Fig11. No need for Figure 12.

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