

Anonymous Referee 1:

This is an interesting paper about ship-based MAX-DOAS measurements of formaldehyde and nitrogen dioxide performed over the Western Pacific Ocean during the TransBrom campaign in October 2009. As illustrated in this study, these measurements are highly valuable for the validation of satellite observations in this region where correlative data are very sparse. New estimates of the background HCHO and NO₂ concentrations over the remote ocean are derived and concentration enhancements can be observed in the vicinity of the coasts and shipping routes. The different observational data sets and their corresponding retrieval methods are generally well described and the results are clearly presented, although the discussion is very qualitative at some places. I recommend the paper for publication in ACP after addressing the following specific comments:

We thank the referee for the general positive comments. We considered the specific comments in the revised manuscript (see “specific comments” part below).

Specific comments:

1. Title: For a large part, the paper deals with MAX-DOAS observations of HCHO and NO₂. To my opinion, the term MAX-DOAS should therefore appear in some way in the title. Suggestion: ‘Formaldehyde and nitrogen dioxide over the remote Western Pacific Ocean: SCIAMACHY and GOME-2 validation using ship-based MAX-DOAS observations’.

We changed the title according to your suggestion in “Formaldehyde and nitrogen dioxide over the remote Western Pacific Ocean: SCIAMACHY and GOME-2 validation using ship-based MAX-DOAS observations”.

2. Page 15988, lines 1-2: A single NO₂ profile is used to calculate stratospheric NO₂ air mass factors at twilight, in the 88-92_SZA range. It is well known that stratospheric NO₂ shows a strong diurnal variation which has a significant impact on the air mass factors, especially at such large SZAs. Why this effect is not taken into account here? Is it included in the error budget of the stratospheric NO₂ vertical columns?

The photochemical enhancement effect you mention is not considered in our analysis, because we used the standard profile to calculate AMFs. Gil et al. 2008 (NO₂ climatology in the northern subtropical region: diurnal, seasonal and interannual variability, Atmos. Chem. Phys., 8, 1635–1648) showed that the corresponding AMF error is in the order of 5%, which is covered by the error bar (grey-shaded area of Fig. 4). We inserted following paragraph in the revised manuscript for an explanation, also of the error margin shown in Fig. 4 (see your question 4):

“As described in Sect. 3.5, for practical reasons the US standard atmosphere was used to calculate air mass factors. This is an approximation, because the true stratospheric NO₂ profile is unknown. Furthermore, the NO₂ changes rapidly during twilight due to photochemistry, i.e. its profile is a function of SZA. As a consequence of the curvature of the earth and the drastically extended light path during twilight, the photons experience different NO₂ profiles coupled to the local SZA on their way through the stratosphere. This can be considered by applying the actual NO₂ concentrations for each point of the light path, which are derived from a photochemical model (e.g., Hendrick et al., 2006, and references therein). Nevertheless, for a tropical scenario and SZAs between 89° and 91°, Gil et al. (2008) showed that the difference between air mass factors calculated with the standard atmosphere and accurately air mass factors using profiles from a climatology is in the order of 5%. This is in the range of errors in Fig. 4. To account for the effect of unknown NO₂ profiles and other potential error sources related to the radiative transfer modelling, the air mass factors used for converting slant columns into vertical columns as

described above were changed (arbitrarily) by 1. Then, vertical columns were calculated again and the differences to the original results are used as error margin.”

3. Page 15989, lines 7-8: The DOFS ranges from 2 to 3. Is it the case for both NO₂ and HCHO ? I think the authors should show typical examples of NO₂ and HCHO profile retrievals including plots of a priori and retrieved profiles and corresponding averaging kernels. It would help the reader to see where is located the information content and if there are differences between both trace gas species.

(See also question 9 from Referee 2).

In the revised manuscript, we provide plots with retrieved profiles (VMR vs. altitude) for NO₂ and HCHO including the a priori profile (Fig. 10 and 16 in the revised manuscript. Please note that the timeseries of profiles is already shown in the original manuscript as color plots in Fig. 9 and 15). Fig. 10 and 16 show also examples of averaging kernels clearly indicating that most sensitivity is close to the ground.

4. Sections 4.1, 4.2, and 4.3: time-series of stratospheric NO₂, tropospheric NO₂, and HCHO vertical columns appearing in Figures 4, 8, and 13 are discussed. Although error bars corresponding to MAX-DOAS measurements are plotted in these figures, nothing is said in the paper on how those error bars are calculated. This should be added in the revised version of the manuscript.

For the error displayed in Fig. 4 (stratospheric NO₂), see reply to point 2. The errors for trop. VCs are worst case errors of 20% of the retrieved vertical column resulting from sensitivity tests. (See Sect. 3.5 (data analysis), we state “Retrieval studies under different scenarios have shown that this profiling algorithm is capable of reproducing the trace gas column within an error of 20% and the volume mixing ratio (VMR) in the lowest 500m within 25 %; for these studies and more information on the principles of MAX-DOAS profile algorithms see (Wittrock et al., 2012; Wittrock, 2006).”). As the region was very remote and trace gas concentrations low, all slant columns with less than 20% fit error (for HCHO even 30%) had to be used to gain a sufficient number of observations for the profiling. Therefore we decided to apply those worst case errors. In the revised manuscript we clarified what the errors (strat. NO₂, trop. NO₂, HCHO) in corresponding figures are.

5. Page 15997, line 22: How do you estimate the detection limit for HCHO ? Using the same method as for NO₂ ? If yes, this should be mentioned.

Yes, we used here the same method as for NO₂. This is indicated in the revised manuscript. (See also reply to points 15 and 18 of Referee 2).

Technical corrections:

Page 15978, line 4: For me, -20_S means 20_N, so the – sign should be removed. Same correction at page 15999/line 12 and page 16001/line 6

Changed as suggested.

Page 15979, line 4: ‘Visible’ should be replaced by ‘visible’

Changed as suggested.

Page 15980, line 24: ‘ground-based’ instead of ‘ground based’

Changed as suggested.

End of Section 1, page 15981: A short description of the different sections of the paper would help the reader.

Provided in the revised manuscript.

Page 15982, lines 6-19: Adding a table summarizing the different weather conditions encountered during the cruise would help the reader.

Provided in the revised manuscript.

Page 15985, line 17: 'visible' instead of 'Vis'

Changed as suggested.

Page 15987, line 12: '...given in Pinardi et al. (2012), the 335-357 nm fitting window...' instead of '...given in (Pinardi et al., 2012), a fitting window from 335-357 nm...'

Changed as suggested.

Page 15989, first sentence of Section 4.1: I suggest to replace it by '...due to photolysis of N₂O₅ causing NO₂ to increase during the course of the day, e.g. a recent study found an increase of ... for the subtropics (Gil et al., 2008).

Changed as suggested.

Page 15992, line 16: 'Takashima et al. (2011)' instead of '(Takashima et al., 2011)'

Changed as suggested.

Page 16000, line 13: Remove the comma between regions and where.

Changed as suggested.

Page 16011 (Fig. 2): This figure is not very clear for me. What represent the grey shape and the orange rectangle ?

It should be the ship (seen from the top) and the instrument pointing orthogonally to its movement. The rectangle and the clouds are symbols for the funnel and the plume illustrating "bad" wind directions (polluting the measurements). The caption of Fig. 2 is changed in the revised version with better description of the elements of this figure.

Page 16013 (Fig. 4): 'grey' instead of 'gray'

Changed as suggested.

Page 16016 (Fig. 7): Replace 'The Cruise Track is indicated.' by 'the cruise track is indicated by the white line.'

Changed as suggested.

Page 16020 (Fig. 11): The cruise track would appear better if plotted in white as in Fig. 7.

Changed as suggested.