

## ***Interactive comment on “Ratios among atmospheric trace gases together with winds imply exploitable information for bird navigation: a model elucidating experimental results” by H. G. Wallraff***

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Let me start my reply to the kind referee's comment with a general remark. This paper makes a look into the atmosphere from the birds' point of view. Birds know nothing about sources of VOCs, lifetimes, turbulent mixing, transport, oxidization etc. They are merely thought to respond to ratio patterns of adaptively selected VOCs which are correlated with winds at home and thereafter encountered at distant sites. W&A have shown that navigationally exploitable ratio gradients do exist; this paper shows that necessary full exploitation can be performed with the help of home-site winds. It

C3981

was not the aim of these papers to explain how it is possible that these exploitable atmospheric conditions do exist. Attempts to solve this question should be made in a following step which inevitably requires interdisciplinary cooperation. Therefore, I would very much appreciate if one or another of the community of scientists dealing with atmospheric chemistry and meteorology would have a look on the related problems, would consider potential solutions and, at best, would contact me. Future approaches could either make use of my spatial data set of 46 VOCs, analysing them under intra-atmospheric aspects, or, for instance, could try to invent a general atmospheric model making the outcomes described by W&A and here understandable. Also, any hint on existing data, which potentially could be analysed with respect to ratio gradients, would be welcome (gradients of single compounds not necessary, but measurements of two or more should be simultaneous).

Having this preface in mind, I think that some of the questions raised by Dr. Williams should be postponed to hopefully forthcoming investigations aimed to clarify the air-chemical background of the present study. Here my present-state replies:

“1) Relation of key compounds to atmospheric lifetime and spatial scale. ...”

Reply: Need lifetime and spatial scale not be considered together with further parameters such as spatial distribution of sources and their emission rates, which are (to me) completely unknown? 13 was the minimum number of VOCs leading to optimal navigational performances, but only seven of them were identical in each of the 20 optimal iteration runs (Fig. 3). The majority of the “top VOCs” have not been chemically identified (Table S1), so that lifetimes cannot be given. If desired, I can transpose Table S1 to the main part, but I cannot give more conclusive data. So far I cannot see in what way lifetime per se can be crucial; I would not expect that each molecule should survive a travel over a distance of 100 or 200 km. Anyway, these are questions not to be tackled in the present paper.

“2) Chemistry or turbulence? ...”

C3982

Reply: Cannot be decided here. Collected air samples average over 2 h and pigeons may do it in a similar way (see point 5 on page 12478, line 2).

“3) Simply only chemicals in dataset with appropriate lifetime gradients? ...”

Reply: See item 1.

“4) Use a model dataset (possibly as future study)? ...”

Reply: Yes, future; would be fine if you would go ahead. An actual pigeon release at one particular site would not help very much. In summer, conditions are always similarly suitable, and VOCs sampled on many days combine to a sufficiently compatible pattern.

“5) Line 386 (now p.12467, line 10, and Table S1). Please clarify 2,2 dimethylbutane or i-hexane (2-methyl pentane) as is shown in W&A as C5.3.”:

Reply: 2,2 dimethylbutane is correct (see Fig. 3 in W&A). Did I misunderstand the nomenclature rules? I thought: n-butane (4 C's) plus 2 methyl groups = i-hexane (6 C's). Wrong?

6) Over ocean navigation.

Reply: Yes procellariiform seabirds have a particularly well-developed sense of smell (for related recent results see Gagliardo et al. 2013).

“7) My understanding is that following release the pigeons circle the release point multiple times before heading off in a particular direction. Has/can the radius of this circle be measured ? Is it related to the ambient wind speed inversely?”

Reply: Behaviour of pigeons upon release is quite variable, temporal and local. Often some irregular circles or loops, sometimes more, sometimes less, often meandering routes, sometimes straight away. This point inspires me to complete item 5 on p.12478 after line 4 with some additional messages telling that the required time span can be spent in a crate or container at ground level and that, also at the home site, the pigeons

C3983

need not fly around, but may experience winds in aviaries only 3-4 m high. Altitudes of some 500 m or similar and wind changes over such heights are never experienced by the pigeons.

“8) Since surface emissions vary strongly with time of day (e.g. Yassaa et al. Atmos. Chem. Phys., 12, 7215-7229, 2012), it would be good to state at what times the VOC samples were taken in the text.”

Reply: All times of day. Could be given for each of the 224 air samples, but would be useful only if a related analysis would be made. Is the periodicity different or similar in different compounds? If it is similar, ratios would not be strongly affected. As concerns pigeon releases: No regular dependence on time of day could be observed.

“9) Have there been any tracking experiments done? ...”

Reply: In recent years, many GPS tracking studies have been made. Clear responses to conspicuous visual features have been observed, but to my knowledge no sharp direction changes which recognizably could have been related to olfactory input (would be difficult to detect).

“Typos/Rephrasing” (points 1-8):

Reply: Thank you. Purely linguistic changes will be made in a revised version, but there are some items concerning the content:

“2) Introduction line 38 (now p. 12453, line 17), point three should be reworded for clarity. Does the author mean that the pigeons are taken to the release site and the incident air is there artificially turned by 180° before reaching the pigeons, or does this mean the artificial turning occurs at the homesite?”

Reply: This appears to be a complete misunderstanding which I do not understand. Nowhere is any artificial turning of air (the direction of airflow through airtight containers is irrelevant). Pigeons were transported in filtered air to a given site (e.g. 30 km north), were allowed there to smell unfiltered air during 3 h, were then transported with filters to

C3984

another site in the opposite direction from home (e.g. 30 km south) and released there under nasal anaesthesia. They flew, on average, towards the compass direction which would have led them home from the air exposure site (in the example: southward). I shall reconsider the whole paragraph which I tried to keep as short as possible.

"3) Line 130 (now p. 12457, line 8). It would be interesting to state here whether the 3.5m measured wind direction was adjusted for ground friction (i.e a SW wind at the ground could well be a W wind at 500m). See also line 421 where this could also be relevant."

Reply: See point 7 above. I shall consider both points adequately in a revised version. For an atmospheric model, these aspects may be important, but not for the birds.

"4) Line 133 (now p. 12457, line 11), The units given are for a mixing ratio rather than a concentration. Instead of  $\mu\text{M}$  atmospheric chemists generally put  $\mu\text{mol/mol}$  or  $\text{nmol/mol}$ ."

Reply: Thank you. I'll try to learn the difference between concentration and mixing ratio.

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