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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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Review – Wallraff In this paper Dr Wallraff presents a model with which it is shown that atmospheric trace gas ratios may be used as exploitable information for bird navigation. Experimental evidence for olfactory navigation based on the presence of chemical gradients is well summarized in the introduction. A model containing "virtual pigeons" is then developed based on a single dataset of VOCs. An iterative (evolution mimicking) model approach is used to determine a minimum exploitable information basis for navigation to be as successful as real pigeons. The paper represents a thorough statistical

confirmation that spatial gradients in chemicals with suitable atmospheric lifetimes may be used to navigate over distances up to 300km.

The author has made a convincing case for the olfactory basis of navigation and of the presence of exploitable atmospheric ratio gradients based on a limited dataset and has made a call to the field for comment. Although I consider the paper very interesting and eminently publishable, the following main questions should be addressed/included, particularly in view of the desired interaction with the atmospheric community. Main questions

1) Relation of key compounds to atmospheric lifetime and spatial scale. One of the key findings here was the minimum number (13) of exploited compounds to reach optimal navigational performance. (line 393). It would be very helpful to add a table of these compounds to the main part of the paper, with their atmospheric lifetimes and spatial scale of one lifetime. All the VOCs used here have lifetimes governed by OH radical oxidation rates. One could assume an OH radical concentration of 1 x 10ˆ6 molecules cm-3 for all species, so that for example 2,2 dimethylbutane (rate coefficient = 2.23 x 10ˆ-12 cm3 molec-1 s-1, all readily available online) would have an atmospheric lifetime of 5 days. It would be informative to see whether the 13 compounds all have similar atmospheric lifetimes or what lifetime range they span. This can then be related to spatial gradients. Given an average windspeed of 5 ms-1, molecules like monoterpenes (e.g. pinene – lifetime ca. 2 hours) would be transported some 36 km in one lifetime (1/e of initial value), however, the 2,2 dimethylbutane would be much longer. Could it be that the monoterpenes establish local gradients whereas the longer lived alkanes generate regional gradients?

2) Chemistry or turbulence? It is clear that a necessary precondition for the model to operate is that atmospheric ratio gradients exist. An interesting question to consider would be whether these gradients evolve through chemistry or through turbulence (or both). Presently only chemistry is implied here. However, insects for example are known to navigate to odour sorces by exploiting concentration gradients induced by

turbulence (e.g. Murlis et al. Annu. Rev. Entomol. 1992. 37:505-32). Odour signals consist of short bursts of odor of greatly varying intensity. Farther from the source, bursts are on average weaker but they are also slightly longer and there is a lengthened gap between them. Overall, the intermittency of the signal is higher at greater distance. Even on longer scales turbulent mixing from the relatively photochemically aged (cleaner) free troposphere (1.5-10km) into lowermost mixed layer (0-1.5 km) could be significant. Some discussion of this seems warranted, perhaps in connection with the observation on line 652 that summer is better for successful navigation (it has also more OH and more turbulence). Could it be that on short spatial scales the turbulent mixing of the chemical signal is more important while on longer (regional scales) atmospheric chemistry plays an increasingly important role. This is hard to test with the available data. However, since this VOC dataset contains multiple measurements at the same location one could generate a std deviation (proxy for variability) for each VOC at each location. Could then VP navigation be tested to relative standard deviations (variability) rather than concentration ratios?

3) Simply only chemicals in dataset with appropriate lifetime gradients? I wonder if it is inevitable that compounds with lifetimes of 3-5 days should prove most effective when navigating over 300 km scales. Monoterpenes would decay too quick (2 hours or less) and longer lived species e.g. methyl chloride (lifetime 1 year) would not generate sufficiently steep gradients.

4) Use a model dataset (possibly as a future study)? This study is based on a fairly limited VOC dataset for practical reasons. The chemicals in this dataset are emitted at the Earth′s surface (mostly by Man′s activities) and oxidized to a range of photochemical products such as carbonyls, alcohols, acids (which were not measured here). Moreover, it could be that chemicals other than the VOCs or their reaction products are used by pigeons (e.g. ozone (O3), nitrogen dioxide (NO2), sulphur dioxide (SO2), ammonia (NH3)). By examining a comprehensive air-chemistry model generated dataset for a 300x300km region from a day of an actual pigeon release, the model developed by Dr

Walraff here may be applied to further refine the nature of ideal chemical navigation species or pairs. A suitable chemical model would be WRF-CHEM which has a 4km resolution (10km spatial resolution for emissions). This could provide an average three dimensional concentration field for the day in question, or if necessary one that varied with time. That is to say concentrations (of all desired species including the inorganic species) at each point in a 300km radius of the home (and in the vertical). The air chemistry model generates this concentration field based on emission and subsequent removal via chemistry and deposition.

5) Line 386. Please clarify 2,2 dimethylbutane or i-hexane (2-methyl pentane) as is shown in W&A as C5.3.

6) Just a comment on the over ocean navigation mentioned in line 668-669 of the discussion. VOC emission from the ocean is about 100 times less (for example for isoprene) than on land which will limit the olfactory signal to noise for detection. I understand that Albatrosses in the southern ocean return navigate to their home after circumventing the globe for some two years. Can this extreme case also be ascribed to olfactory navigation, and do ocean dwelling birds have a keener sense of smell?

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?

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.

9) Have there been any tracking experiments done (i.e. with a signaling device on the leg). It would be interesting to see whether the pigeon′s flightpath shows any sharp changes in direction which may indicate navigation to a strong olfactory bearing (i.e. particulary smelly smokestack much as a sailor uses a bearing to a lighthouse), or to the more smoothly varying chemical gradients implied here.

Typos/Rephrasing 1) Abstract – “To make the model working” should be changed to “To make the model work” or “To allow the model to function”

2) Introduction line 38, 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?

3) Line 130. 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.

4) Line 133, The units given are for a mixing ratio rather than a concentration. Instead of μM atmospheric chemists generally put μmol/mol or nmol/mol

5) To avoid confusion I suggest replacing “In dependence on” (for example line 268) with Concerning dependence on, or With regard to. . . This is to avoid confusion with “independent”

6) Line 295 “I think you mean explicitly not expressively

Interactive comment on Biogeosciences Discuss., 10, 12451, 2013.