Atmos. Chem. Phys. Discuss., 4, S1522–S1529, 2004
www.atmos-chem-phys.org/acpd/4/S1522/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Tropospheric ozone over Equatorial Africa: regional aspects from the MOZAIC data" *by* B. Sauvage et al.

Anonymous Referee #1

Received and published: 11 August 2004

GENERAL COMMENTS:

This discussion summarizes a tremendous amount of observed ozone data, and indeed seeks to address great questions. The detail available in the averages of the many ozone profiles provide is impressive. The discussion will be presentable as a publication after considerable work. Indeed, to be the publication it deserves to be, I strongly advise reformulation of large portions of the text and several figures.

The most general points in this reformulation could be these:

(a) Given the desire to discuss monthly mean profiles in terms of mean winds, it is quite appropriate to restate "conclusions" about factors controlling ozone concentrations very clearly as hypotheses. Alternate hypotheses could be mentioned a bit more frequently. Avoid extended digression when a choice is hard to make. Similarly, make

the concluding discussion of flux more a suggestion than a result. Of course, if you believe you can, submit another paper in parallel that shows that mean winds are sufficient for all your points.

(b) Please recognize that middle and upper tropospheric ozone often have much broader geographic spread and controls than are suggested by 5 or 10 day trajectories.

(c) Seek to formulate discussion of various geographical areas with reference to your larger points; the repetition of detailed analyses highlights the richness of the dataset, but the reader tends to get lost in detail

(d) It will greatly help to arrange and mark figures so that the reader can immediately locate the needed information. Please judiciously add 1-3 figures of flow patterns that you describe in words (streamines). These could replace the small maps found at the end of the paper, Figure 12, and the sketch of the ITCZ and burning areas Streamlines are easier to read than vector graphs.

(e) Make the text reflect better the well accepted mechanisms and timescales of ozone production and especially chemical destruction; descriptions of ozone "deposition" are misleading, as actual reduction by contact with the EarthŠs surfaces is only one of several significant loss processes. There has been much discussion of this in the literature.

(f) Please complete the reference list!

(g) There are many small alterations in expression in English that require attention. I have started a list, but don't think it deserves public discussion.

SPECIFIC COMMENTS:

1. Introduction (3287: 25 ...) Please illustrate the wind systems that you reference extensively in the text. There is a good history of description, especially from Toulouse, and the reviewer is familiar with some of the intricacies. However, the summary of

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ozone distributions and review of the most basic local processes which is a strength of this work justifies the following: publication of streamiline maps of mean wind fields at 2Ű3 levels for at least the extreme seasons, and at least one N-S cross section. There should be labels for the Easterly Jet, the Anticyclone, Harmattan, and Monsoon, SASTA, Intertropical Front (show this!), etc. End of introduction: distinguish your use of TTOC for a general integral of the tropospheric ozone column from the "TTO," a specific method for estimating the column. "TOC" for tropospheric column is the term I would use, since "total" and "column" are somewhat repetitive.

2. The MOZAIC database. This database is perhaps the most significant contribution of the paper, and it is very appropriate to introduce the reader to the specific practical methods and protocol of access and use. There are many aspects of tropospheric ozone which go beyond this extensive mean-profile introduction. Mention also that the database contains water vapor and temperature profiles which are at least as good as the best ozonesondes (if this is true). The paragraph "In order to present a reliable climatology ..." makes a sudden turn in the presentation. (Rhetorically?) What is a climatology? Is it a catalogue of variations which may only be described by month, latitude, longitude, and altitude? Is it rather the set of descriptors which adequately allow some understanding of the ozone concentration which may be expected? While the former idea is a common usage, textbooks of climatology pursue the latter. The ensuing discussion concentrates on the evaluation of the adequacy of sampling of ozone, under the assumption that samples are independent and that the sampling epoch is sufficiently long. If a plane returns to these airports, what ozone value is most likely to be expected? This is an appropriate discussion, but it can be made a bit more brief, while at the same time acknowledging the limitations of the question and the methodology. The paper might make clear that "meaningless means," a common phrase for tropical African ozone describes a different question. That question is the frequent rapid temporal variation and very transient and vertically variable plume features of ozone in the African region. This is tied the consequent difficulty of making a more general "predictive climatology" of more ozone based on common observables, even if

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monthly means can be estimated.

Use of mean winds: It is not at all evident to the reviewer that mean winds are adequate for most of the statements in this review. Proof of this might involve a whole different paper. Is there some other literature supporting this that can be cited? It seems likely that the transports by mean winds are most similar to mean transports in the lower troposphere. Jenkins et al. [2004] found the use of individual trajectories useful, although setting the transports in a mean-wind context. Chatfield et al. 2004 mostly considered transport in the middle and upper troposphere: in these regions, variability of trajectories over 5-1 of days was extremely important in locating origins, some trajectories, tracing back to West and Central Africa, at varying times and levels. .

3. Distributions and variability There are many topics in this long section; quite a few ideas, but it makes for hard reading. A review can only point out a few topics, but the whole section could well be recast. As mentioned, all explanations should be written as conjectures ... "seems to be," "might be" belong in these paragraphs.

Gulf of Guinea. Lower troposphere: All three Lower Troposphere sections are stronger contributions, since few-day back-trajectories and local influences are generally more helpful. Additionally, as mentioned, these regions are generally not easily sampled by satellite platforms with their broad geographic view.

Note on style: at first, there is a compilation of details regarding technique followed by the hypotheses. Later in the paper, there are hypotheses presented followed by the supporting details. This second technique was much easier to read, and could be used more. Please make sure that it is clear when we move to a new hypothesis, as you frequently do. p. 3293: "Background ozone" – describe briefly what you mean by a background: 10 ppb? 30 ppb? Why (briefly)? p. 3294 and many succeeding pages: "deposition" is often mentioned. Deposition is often quite slow compared to ozone reaction with terpenes, isoprene, NO. Even reaction of O(1D) with H2O and O3 with HO2 can be become somewhat large (˜5 day lifetime) when the absolute humidity

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becomes very large. There is a reference to "wet deposition." This is not known to affect ozone consequentially. The authors may mean to describe wet deposition of nitrogen oxide compounds; if so, it is important to mention that wet deposition may tend to limit ozone production; this is a slow effect, better just to leave it out. Generally, a thorough check through the paper to relate to photochemical theory would help.

Comments about regional vs continental-scale (indeed, intercontinental-scale) can be omitted. Both processes operate, sometimes alternating. Lagrangian studies will not be very precise in regions with deep boundary layers or cloud mixing, since momentum (wind) is often not well mixed.

p. 3295: transport from fire regions to the Gulf of Guinea taking 10 days. Is this based on mean winds? What are typical times with real winds? Gulf of Guinea: Lower troposphere: concentrations mentioned seem to fall short of peak concentrations shown, e.g., 45, 55 ppb. Maybe these are averages: in any case, labels would aid the reader and maintain interest.

Middle troposphere: For many middle and upper troposphere regions described, seasonal or annual variance is smaller or not much larger than other temporal variance. Please mention this fact in your climatology. The growing satellite database indicates very large-scale features, frequently intercontinental, at these levels. [Edwards et al, JGR, 2003] This work also clearly explains a tendency for emissions in one hemisphere to loft and move to the other.

Lightning sources for ozone near or from Africa. Dickerson et al, 1984 seems to be the first to make a point of tropical lightning and downwind ozone in this region. In the reviewer's opinion, Smyth et al., 1996, described this clearly in terms of the SAFARI/TRACE-A observations. One reference or two will suffice to explain the wide variety of lightning NOx estimates available until recently. Figures in the range 3-10 Tg per year seem to be a more recent consensus; the reviewer feels that figures outside this range are disregarded. In fact, the altitude of "virtual emission" to the free tropo-

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sphere seems to be just as important as the global emission total, since the altitude of emission of NOx has long been known to be important (Additional emissions figures of 3-7 Tg/yr from lightning are not often very consequential for effects after a storm in the Earth's boundary layer, for example, while they may have very large effects aloft.)

In recasting these comments, please pay attention to advances published by Edwards et al. [JGR, 2003], Jenkins et al. [2003, 2004, this journal], Chatfield et al. [GRL, 2004, JGR, 2003] and comparisons with models made by Martin et al [JGR, 2002]. Edwards et al pointed out that atmospheric layers are frequently exposed to lightning shortly after the biomass burning season ends. Similarly, multiple influences from Northern Africa are explicitly tracked in Chatfield et al. [2004].

Central Africa: Angola and Congo

[3297 ...] Lower Troposphere. This region is a much studied area. Many authors have noted recirculation over South and Central Africa. (See Garstang, Annegarn, Swap, SAFARI-2000 special section, JGR). This implies both direct and accumulating effects of fires. Mechanisms of lofting have been described for TRACE-A [Browell et al, Fuelberg et al, Chatfield et al., JGR, 2006].

Middle Troposphere: Both this region and the East Africa region have complex influences, involving variations in trans-central-African flow. [Krishnamurthi et al., JGR, 1996, updated in Chatfield et al., GRL, 2004]. Various analyses of TOMS tropospheric ozone suggest very broad but variable patterns running across Central Africa and into the Atlantic; sometimes there is strong inflow from the Indian Ocean. Sometimes that inflow is low-ozone, sometimes high ozone. There are both seasonal and interseasonal controls on this flow. [Martin et al. 2002, Chatfield et al. 2004].

East Africa. [3301...] Lower Troposphere: Please strike comments about Nairobe and Kigali; proximity to surface emissions and ozone reaction seems to be the major controlling influence, not latitude. This is actually brought up in the next paragraphs. I do not undrstand the sentence starting "The oceanic origin of the southeasterlies,

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bringing air on contrary of Angola ..." Please restate.

Middle Troposphere: See comments about Angola and the Congo. Winds can vary considerably. Mean winds probably do not not describe all features; Chatfield et al [JGR, 2003] describes a very polluted airmass that flows from this region all the way down the eastern side of Africa and into a low-pressure system at the southern end of Africa.

Section 4: Comparison with TTOC's [3303] This section needs to be made complete. There are vague allusions to TTO as measured from satellite, but total ozone column (TOC) from various authors (Thompson, Fishman, Kim/NewchurchĚ) should be presented to make the discussion clear. Please make specific the conclusions you reach when you make integrals of ozone concentration between 700 and 200 hPa and then compare to these methods. You can fairly easily assess the effect of the lack of sampling between 200 and tropopause; often the effect is relatively small upon seasonal cycles.

A major influence on the ozone column and the "ozone paradox" is hardly mentioned. In several portions of the year, the mid-upper troposphere above West Africa is influenced by a region of very little pollution or lightning, namely the Pacific, the north tropical Atlantic, and a very small continental area of Central America. In other portions of the year, it is more influenced by East Africa and the intermittently high ozone regions of South Asia, Southeast Asia etc. Observations of TTO or other ozone column measurments, such as those composited in Chatfield et al [2004] suggest that these differences can have a major effect. West Africa has very different influences than South Africa, the South Atlantic, and even Brazil.

Section 5: Budget Computation. [3304] It might be a good idea to omit this. It is carefully thought out and an good exercise. However, the technique used necessarily requires considerable discussion and defense of approximations. This is worthwhile if models with detailed treatments of all these processes seem to be missing some

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basic feature. If the budget figure differs greatly from calculated budgets [Roelofs, et al., JGR, 1997 portions of other modeling papers], and there are also clear differences in detail, then it makes sense to discuss empirical and simulated budgets.

Summary and Conclusions.

Some very tentatively drawn regional contour maps of ozone for 3 levels in the regions, for each of four seasons, survey would seem to help bring the whole discussion together. Outside the region of your sampling, you could use SHADOZ or other data to set general values. (Make these contours grey if you think that they are not to be considered as relevant.)

Naturally, points that are not very well resolved (see above discussion) do not belong in the conclusions unless clear suggestions for their resolution are needed and can be made on the basis of this work.

Interactive comment on Atmos. Chem. Phys. Discuss., 4, 3285, 2004.