

Interactive comment on “Rapid intercontinental air pollution transport associated with a meteorological bomb” by A. Stohl et al.

Anonymous Referee #2

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General Comments

This paper describes model studies, supported by satellite observations, of the very rapid transport of pollutants over intercontinental distances in conditions associated with rapidly-deepening cyclones, termed meteorological bombs, and evaluates their potential for transport of short-lived trace-gases such as NO_x. This is the first description and evaluation of tracer transport in these conditions, and as such is a valuable addition to the literature. While the model studies themselves are of considerable interest, the GOME observations provide powerful support for the rapid-transport phenomenon described. The paper is well written and is arranged in a clear and intelligent way. My only significant concern is with the estimation of impacts on NO_x using inert tracer techniques; however, suggestions to remedy this are provided below. I recommend publication in ACP once the following comments have been addressed.

Specific Comments

(1) Use of a fixed-lifetime NO_x tracer is very helpful in elucidating the pathways for transport, but does not allow realistic quantification of the impacts of the transport described on tropospheric NO_x. NO_x generally has a lifetime much shorter than 2 days in the boundary layer (where much of it may be destroyed), and may be strongly affected by regeneration from species such as PAN in the free troposphere in certain meteorological conditions (which the bomb conditions described may or may not favor). Some suggestions:

(a) "A rough calculation suggests" (abstract, line 17) should be replaced with "We estimate that" - this is the best that the present technique can provide, although the support from GOME for the November episode suggests that the estimate is reasonable.

(b) Referring to the inert NO_x tracer as just "NO_x" should be avoided when providing quantitative estimates of concentrations, to prevent confusion. (e.g., on Page 2122, line 20)

(c) Horowitz et al. [1998] estimate that about 12.5% of NO_x emitted over the US is exported from the regional boundary layer in summer, much of it in the form of PAN. Comparison with the export efficiency in these studies would provide a suitable scaling factor for emissions that would take into account the shorter polluted boundary layer lifetime without needing to alter the model runs already performed. (Liang et al. [1998] note slightly higher export of NO_x in November).

(2) The paper does not explain why transport of short-lived tracers should be of interest. Rapid horizontal transport of NO_x once in the free troposphere may merely displace the location of subsequent ozone formation, and might therefore have little direct impact on air quality or on climate. In contrast, efficiency of vertical transport between the polluted boundary layer and the free troposphere does affect these global impacts. Better justification of why ICT of short-lived traces might be important is needed in the first paragraph of section 1.2.

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(3) Page 2104, line 1: "The danger of bombs.....often not well predicted by weather forecast models". The FLEXPART model used here relies heavily on driving meteorological fields from ECMWF analyses/forecasts. How well do the fields capture transport during these extreme phenomena? The evolution of the conditions is nicely detailed in Figure 2, and while consistency with the GOES image in Figure 3 is encouraging, it is not clear that tracer transport is correctly predicted. Has anyone from the ECMWF assessed the performance of their model in this type of conditions?

(4) Page 2109, line 11: The high spatial resolution used by the model here isn't supported by high temporal resolution, and therefore may not be a great benefit in the current studies. Particles covering 50 degrees in 20 hours (page 2114) may cross as many as 15 grid points in the 3-hour time interval between meteorological fields! The errors introduced by overshooting meteorological boundaries in this case may be small due to the rapid, coherent flow, but to make use of the higher spatial resolution future studies would greatly benefit from driving meteorology at hourly resolution. (Add "spatial" before "resolution" on page 2109, line 13).

(5) The attempt to put this episode in a wider, climatological context (Section 4) is valuable. However, use of a different technique (based on CO emissions and discrete rather than continuous removal) makes it difficult to assess how typical the November 2001 episode was. How common are the larger events such as this one? Do they always have an associated feeder system (provided by cyclone C2 in the present case) which may lift polluted air if located in the right position - or is this relatively rare?

(6) The caveat on the impacts on O₃ formation (Page 2122, lines 24-25) is helpful; however, it would be worth adding here that high levels of other tracers will be co-transported in these conditions, and hence key parameters such as the NO_x threshold value for O₃ formation may be substantially different from what they are in the background troposphere.

Page 2122, line 19: the climatology studies appear to have used CO emissions rather

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than NO_x emissions - this should be mentioned in the first paragraph of page 2121.

Page 2124, line 10: emphasize that this 2-3 pptv enhancement is a temporal average (presumably), but that the transport phenomenon is highly episodic.

Figure 2: The thick gray lines used to outline the continents are not very clear - a thinner white line might provide a better contrast against the background colors used.

Technical Corrections

Page 2103, line 6: "it's" should be "its"

Page 2110, line 11: "exploded" carries the analogy a little far - it should either be put in quotes, or replaced with "formed"

Page 2111, line 26: insert "a" before "thousand"

Page 2112, line 10: "Lysis", while technically an antonym of genesis, is usually only used in a medical context. "Disappearance" would be better here (or alternatively termination, demise, or collapse).

Page 2122, line 3: 3-5 per thousand (if that is what is intended) would be better written as 0.3-0.5%.

The use of bracketed alternatives should be suppressed; they are a convenient abbreviated format for scientific notes, but are not appropriate in a paper, where they break the flow of the text and hence make it more difficult to understand. Principal occurrences are at p.2108, l.16; p.2117, l.24 and l.29; p.2121, l.28; p.2122, l.2 and l.10. In each case, the alternatives can easily be presented in a clause at the end of the sentence; in the first case, for example "Even a cloud fraction of 10% can lead to an underestimation of up to 100% in the GOME measurements if the cloud is above the NO₂ layer, or an overestimation of 50% if it is below the layer." (This particular sentence could be simplified still further, as an underestimation of 100% indicates that the layer is missed completely).

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