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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Synoptic influences on springtime tropospheric O_3 and CO over the North American export region observed by TES" *by* J. Hegarty et al.

O. Cooper (Editor)

Owen.R.Cooper@noaa.gov

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This review is by Owen Cooper, editor of this manuscript.

This paper describes the relationship between synoptic circulation patterns over the western North Atlantic Ocean during spring (2005-2006), and TES measurements of tropospheric O3 and CO. I think that the purpose of the paper is sound (although as described below the purpose needs to be more clearly stated), as is the classification of the various synoptic patterns. However I have major concerns regarding the high level of speculation about the actual pollutant transport patterns associated with each synoptic type. Much more back trajectory analysis needs to be conducted to reduce the level of speculation and lend confidence to the transport pathways. Also improvements are required of the PV analysis, and greater consideration needs to be given to the impact of clouds. My current opinion of this paper is that it needs a major revision before it can be published in ACP, as described in my comments below. I am posting my comments now so that the authors have plenty of time to conduct further analyses and respond to my comments. I have not yet had the benefit of reading the comments of the two anonymous referees and their opinions will have a major influence on my final decision as to whether the paper can be published on the ACP website.

Main concerns:

1) Pollution is often hidden in clouds as described by: Crawford J. et al., Clouds and trace gas distributions during TRACE-P, JGR, 108, D21 Article Number: 8818 Published: NOV 4 2003

How are your composites affected by cloud? i.e. how strong is the bias towards clear sky conditions and how much pollution is missed by TES? It would be very helpful to the analysis for you to show a plot for MAM1 with the number of observations per cell and the percent of observations that had to be excluded for cloud.

2) What is the main purpose of the paper? The conclusion seems to imply that it is to show that TES can detect trace gas distributions that are caused by synoptic disturbances, i.e. a verification study. Or is the purpose to more broadly demonstrate the type of trace gas distributions due to cyclones, with TES just being a convenient tool? If this is the point then in the Introduction please present a clear scientific question that you are trying to answer, such as: What are the ozone and CO distribution across the western North Atlantic Ocean and how are they controlled by synoptic weather patterns?

3) Much of the transport description is purely speculative. A much more rigorous back trajectory analysis is required, to provide better estimates of the pollution transport pathways and origins. The specific comments below indicate the points in the paper

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that I think are too speculative.

I suggest you run back trajectory clusters for each TES measurement and then build composite trajectory plots for features of interest in Figures 6 and 8. Then you can state with some certainty what the general transport pathway is for each feature rather than speculating or relying on just one or two cases.

A sample trajectory composite plot can be found in Figure 5 in: Cooper et al., Trace gas composition of mid-latitude cyclones over the western North Atlantic Ocean: A seasonal comparison of O3 and CO, JGR, 107, D7, 10.1029/2001JD000902, 2002.

4) The PV analysis needs to be improved. The upper tropospheric TES retrievals are centered at 316 hPa while PV is shown for 400 hPa, a full km lower in altitude than the center of the TES retrieval. PV can vary dramatically over just a short vertical distance and all of your PV analysis is biased low in altitude in comparison to the TES retrievals. The PV analysis is also limited because you use a fairly coarse PV product (2.5 by 2.5 degrees and only 6 or 7 levels in the troposphere), that is then interpolated to pressure surfaces. Why interpolate the PV values to 400 hPa and not 316 hPa? Or why not just calculate PV yourself using the GFS data which have a much higher vertical and horizontal resolution? Using the GFS vorticity, temperature and wind fields you can use the method of Bluestein [1992] to calculate PV directly on pressure surfaces (I will send this formula to Dr. Hegarty in a separate e-mail). It may take a day or two to write the code to perform the calculations, but once the code is written the calculations should be more efficient than conducting a 3 dimensional interpolation.

Bluestein, H., Synoptic-driven meteorology in mid-latitudes, 431 pp. Oxford University Press, New York, 1992.

Specific comments:

Section 2.3 Please provide some information on the transport patterns that were not classified. Do the ozone and CO distributions from the non-classified data look different from Figure 4? Are you ignoring some important transport events?

page 3 line 71 change to “synoptic-scale mid-latitude cyclone”

page 3 line 76, change to “causing ground-level O_3 mixing ratios to rise, but so far this has only been observed at high elevation sites in the Alps”

page 4 line 82 change to: “distribution of O_3 and its precursors as well as the air mass transport history are required”

line 85 ITCT-2K2 is a west coast inflow study and not relevant to N. American outflow.

line 120 Please be specific as to the region you are referring to in terms of the decrease in mid-latitude cyclones. They clearly decrease over the southeast US where the Bermuda high shifts them further northwards in summer. But does the frequency actually decrease over the northeast USA in summer?

line 301 The comment about continuous vertical mixing producing a well-mixed atmosphere seems overstated. What is the mechanism for this continuous vertical mixing? Stationary lows are not features isolated from the surrounding air masses. There is always air transported in, through and out of a stationary low. Well-mixed implies little variation of ozone and CO with altitude and a smooth moist adiabatic lapse rate. I can’t think of any measurements that show such profiles in mid-latitude cyclones as there always seems to be some layering due to differential horizontal advection. Please be more specific.

line 310 and Section 4.1 Here you imply that elevated ozone at 681 hPa is related to the stratospheric influence at 400 hPa. This would require the stratospheric intrusions to be almost vertical, while they actually slope downward and equatorward, so you would expect the lower tropospheric ozone enhancement to be further south than the upper troposphere enhancement. Please run back trajectories to explore the possibility of an intrusion.

line 325-328 This transport pathway is also described by Owen et al. [2006] with

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regards to transport to the Azores.

line 335-336 The DA always has some portion that is of a lower stratospheric origin. The sentence should be reworded to: “...because it transports drier air from the upper troposphere and lower stratosphere to the mid-troposphere with some strong systems allowing for direct transport to the lower troposphere.”

line 341 change to: “...were mainly due to the position...”

line 350 It’s not clear which cyclone in MAM4 you are referring to. The cyclone in the northeast of the figure is outside of the classification box so it is not likely part of the classification. The cyclone to the west is upwind of the western Atlantic so its DA cannot be influencing the study region. Is MAM4 the result of the position of the cyclones, or more the result of the large anticyclone over the western Atlantic?

line 386-395 In comparing the ozone/CO slopes between this study and earlier studies you need to be very careful that you account for changing emissions of NOx and CO in North America. As described by:

Parrish, DD, Critical evaluation of US on-road vehicle emission inventories, ATMOS. ENVIRON. Volume: 40 Issue: 13 Pages: 2288-2300. 2006 and Kim, SW, et al., Satellite-observed US power plant NOx emission reductions and their impact on air quality, GEOPHYSICAL RESEARCH LETTERS Volume: 33 Issue: 22 Article Number: L22812, 2006

The older O3/CO slopes are the result of NOx and CO emissions ratios that no longer exist. So we shouldn’t expect the later TES values to exactly match the older estimates

line 424-425 Please explain why the averaging kernels shift upwards.

line 461 do you mean westerly to southwesterly flow?

line 510 What do you mean by significant upper level CO features? Statistically significant, or simply elevated? Also when discussing upper tropospheric CO you need to make sure you aren’t really looking at lower stratospheric CO. As shown in Cooper et al 2002, CO in the vicinity of 316 hPa with values of 100-110 can easily be in the lower stratosphere where aged CO can accumulate.

Cooper et al., Trace gas composition of mid-latitude cyclones over the western North Atlantic Ocean: A seasonal comparison of O3 and CO, JGR, 107, D7, 10.1029/2001JD000902, 2002.

Section 4.3 The inland cyclone for MAM4 likely has nothing to do with the CO in the Atlantic, which is likely to be aged. So which cyclone transports the CO to the Atlantic? What do back trajectories show? On line 525 you speculate that high ozone and low CO indicate a stratospheric origin. But what do the back trajectories show? On line 532 you state that the averaging kernel shifted upwards to 500-550 hPa, so if it is centered on the mid-troposphere, wouldn’t the retrieval have equal influence from both the upper and lower troposphere?

lines 538-541 The discrepancy between the ozone and PV is likely due to the vertical separation. Another potential problem is that PV is not well conserved once it enters the troposphere. If the intrusion is more than a couple of days old the PV values can diminish while the ozone values stay fairly high.

Line 551-552 I am skeptical that the inland cyclone in MAM4 is responsible for the ozone and CO south of 40 N in the western Atlantic. The cyclone seems to be too far away and this pollution could have been left behind by the downstream cyclone. Back trajectories would make this more clear.

Line 570 Here you are assuming that the intrusions extend straight down rather than sloping to the south. What do back trajectories indicate?

line 647-648 Please describe how this case study differs from the similar mechanism described by Owen et al., 2006.

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line 659 Please elaborate on what you mean by loss rate. Are you saying that CO is oxidized and/or diluted?

line 664-666 The speculation on the transport pattern could be confirmed or rejected with the use of back trajectories.

line 684 Here you state that the exported pollution was undoubtedly from North America, but the back trajectories on May 14 do not support this statement as they don’t reach the polluted North American boundary layer. Also the ozone mixing ratio of 70 ppbv and the CO mixing ratio of 110-115 ppbv could just be air transported downwards from the mid- or upper troposphere.

line 693-698 This transport pattern is similar to the one described by Owen et al. [2006] that transports pollution to the Azores at low altitude. Some comparison between the two studies would be useful.

lines 701-703 This sentence makes it sound like there are only 6 possible transport patterns, when really there were many more, they were just not very clear.

References Please check that all recent JGR papers in the reference section have the correct citation. For example I noticed that the correct citation for Cooper et al. 2002 should be: Cooper O. R., et al., (2002), Trace gas composition of midlatitude cyclones over the western North Atlantic Ocean: A conceptual model, J. Geophys. Res., 107 (D7), doi:10.1029/2001JD000901.

Figures: Figure 1 What does the kink at the top of the DA arrow indicate? Is this supposed to describe a real feature? Because the WCB rises above the CCB, please overly the red arrow on top of the green arrow.

Figures 2, 3, 6, 8 Please label each panel with the corresponding map types.

Figure 3: to be more relevant to the analysis replace PV at 400 hPa with PV at 316 hPa, or 300 hPa.

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Figure 5 make the axes the same in both panels

Figure 9 make the axes the same in both panels

Figure 10 make the SLP contours darker make the text larger and darker in the trajectory plot, as much of it is illegible. Why are the CO observations offset slightly to the right?

Figure 11 and 13 in both figures make the SLP contours darker and increase the size and darkness of the text in the trajectory plots

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 19743, 2008.