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MOPITT Observation of Large Horizontal Gradients of CO at the Synoptic Scale

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INTRODUCTION

Carbon monoxide (CO) generated from incomplete combustion of fossil fuel is one of the major pollutants in the atmosphere. The MOPITT (Measurements Of Pollution In The Troposphere) instrument, on board the Terra satellite, is now measuring this atmospheric gas from space for the first time. With the MOPITT CO data, a phenomenon of large horizontal gradients of CO at the synoptic scale was observed. The horizontal concentration of CO varied rapidly by 50-100% in ~100 km across a noticeable boundary. This phenomenon lasted one to several days and spanned horizontally 500 -1000 km, appearing at almost all heights of CO retrievals from 850 mb to 250 mb. Preliminary results from the study on the phenomenon is presented in this poster.

EXAMPLES

The phenomenon was first found in north-east of China on 24 August 2000 (Drummond, 2002). An earlier study on biomass burning in North America leads us to find more cases. The fire data enable us to differentiate the phenomenon from a similar phenomenon caused by biomass burning. The example cases are illustrated as follows.

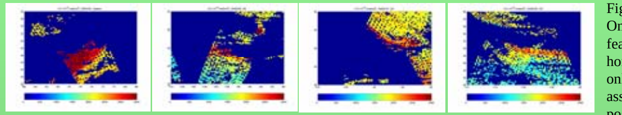


Figure1. Cases observed in Quebec, South Dakota, Ontario, and North Dakota. They share common features of: 1) 50-100% of CO increase cross short horizontal distance (a noticeable boundary), 2) lasting only one to several days, and 3) high CO appearing associated with cloudy areas (missing values) implying possible ascending airflows.

A CASE OVER LAND WITH A COLD FRONT

A case with a front system was found on August 15, 2000 in North Dakota.

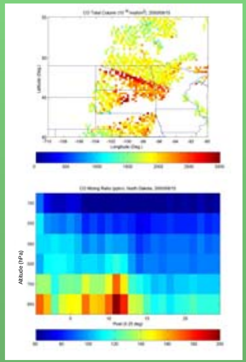


Figure 2. The upper panel (2a) shows a horizontal view of the large CO gradient in CO total column and the location of the largest CO gradient is indicated with a line (This line is used in other figures as a location reference). The lower panel (2b) shows the cross section of vertical CO mixing ratio. The cross section is normal to the line in the upper panel, extending from the side with high CO to the side with low CO for 24 pixels with the line at the middle. The values are averages aligned with the direction of the line.

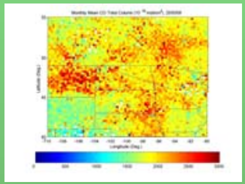


Figure 3. When the monthly mean is taken, the large CO gradient disappears. Notice the high CO values in the State of Montana where large fire events occurred in August 2000.

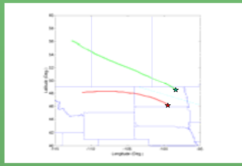


Figure 4. Back trajectories in 24 hours at 1.5 km show the air parcel in the side with high CO (red) coming from polluted air from biomass burning in Montana, while the clean air on the other side (blue) coming from Canada. The dashed line is in the same location as that in Figure 2a.

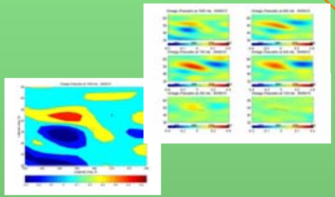


Figure 5. Vertical air flow is showed in a contour map at 1000 mbar (lower left panel) and images at 6 heights (upper right panel) with NCEP reanalysis ω data. The ascending air flow (blue) and the descending air flow (red) appear to associate with high CO and low CO on the respective side of the reference line (see Figure 2).

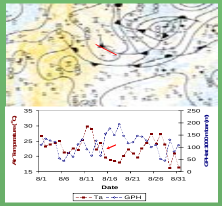


Figure 6. The change in air flow was caused by a cold frontal system. A passage of a cold front is indicated by the rapid drop in temperature and increase in pressure at the surface (lower panel) and on a weather map (upper panel, the red line is in the same location as that in Figure 2a).

A CASE OVER LAND WITH A LOW PRERSSURE SYSTEM

A case with a low pressure system was found on August 5, 2000 in Texas. In this case, the air flow is associated with a low pressure system as shown in Figure 10.

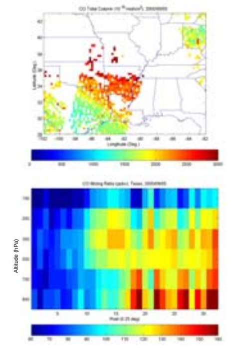


Figure 7. The same as in Figure 2. In this case, the cross section starting from the side of low CO (pixel 1 in the lower panel). The location of the largest CO gradient is indicated with a reference line.

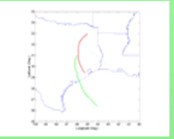


Figure 8. Similar to Figure 4, back trajectories in 24 hours at 1.5 km show the air parcel in the side with high CO (red) coming from polluted air over land, while the clean air (low CO) is on the other side (blue) coming from sea. The dashed line is in the same location as that in Figure 7.

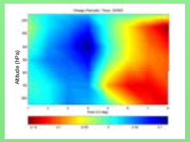
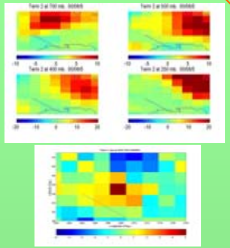


Figure 9. With NCEP reanalysis ω data, the vertical air flow along a cross section normal to the line in Figure 7 is shown. The ascending air flow (red) and the descending air flow (blue) appear to associate with high CO and low CO on each side of the reference line.

Figure 10. This weather map shows an associated low pressure system (the red line is in the same location as the reference line in Figure 7).

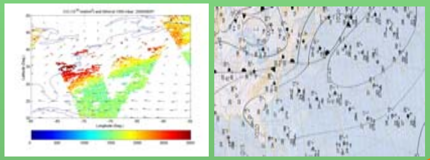


$$\underbrace{(\nabla^2+\frac{f_0^2}{\sigma}\frac{\partial^2}{\partial p^2})\omega}_{A}=\frac{f_0}{\sigma}\frac{\partial}{\partial p}\underbrace{[\vec{V}_g\cdot\nabla(\frac{1}{f_0}\nabla^2\Phi+f)]}_{B}+\underbrace{\frac{1}{\sigma}\nabla^2[\vec{V}_g\cdot\nabla(-\frac{\partial\Phi}{\partial p})]}_{C}$$

Figure 11. Using the quasi-geostrophic equation (above), the differential vorticity advection (B term) and the temperature advection (C term) are estimated (relative changes are showed as 1st term in lower panel and 2nd term in upper panel). The temperature advection on upper levels (higher than 700 mb) and the differential vorticity advection on low levels (lower than 700 mbar) may explain the difference between the vertical air flow on each side of the reference line.

A CASE OVER SEA

Figure 9. Over sea, the phenomenon appears to be related to horizontal wind shear, as shown in this example on August 7, 2000, near the coast of Florida (9a, left panel). With a high pressure system over Atlantic ocean (9b, right panel), the clear air was moving from ocean to land while the polluted air was blown in the opposite direction (notice the good agreement between CO spatial pattern and the shift of wind directions). The missing values may imply possible ascending flow, although this is not fully supported by NCEP reanalysis ω data.



DISCUSSION AND CONCLUSIONS

❖We studied a phenomenon of large horizontal gradients of CO at the synoptic scale observed by MOPITT. This may be the first observation of variation of tropospheric chemical species at the synoptic scale over large areas. Previous studies have suggested a close linkage between synoptic processes and air pollution patterns in the surface, especially in urban areas. Chung et al. (1999) found high CO episodes associated certain synoptic processes in Hong Kong. Wang et al. (2003) reported rapid changes of air pollutants, such as CO and O_3, during cold front passages in Hong Kong. This rapid change of air pollutants in the vicinity of atmospheric fronts was also observed in other locations (Kunz and Speth, 1997; Ryaboshapko et al., 1996). The variations of atmospheric species at synoptic scale can be easily overlooked when compositing data at long time steps or running models at coarse resolution. Therefore, considering the variations in data processing and atmosphere modelling is important. MOPITT, with its capability to detect the variations, provides a useful data set to address the issue.

❖Two cases over land are studied in detail with NCEP/NCAR Reanalysis data, trajectory analysis, the quasi-geostrophic theory, and weather maps. We found that this phenomenon often correlates with a shift in the vertical wind direction on the two sides of a boundary. This boundary is mostly aligned with the transition between downward and upward airflows, with ascending air motion correlating with high CO on one side and descending motion with low CO on the other side. We also briefly show a case over sea. It appears that the phenomenon is related to horizontal wind shear.

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Acknowledgments

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