Meteorology and Climate Sciences
REU Program 2015

Convection and Redistribution of Tropospheric Ozone in Central Amazonia

Randy J. Chase[1], Jose D. Fuentes[2], Tobias Gerken[2], Dandan Wei[2], Courtney Schumacher[3], Luiz A. T. Machado[4], Rosa M. Nascimento dos Santo[5], Stephen R. Springston[6]

[1]Department of Earth Sciences, State University of New York The College at Brockport, Brockport, NY, USA;
[2]Department of Meteorology, Pennsylvania State University, University Park, PA, USA; [3]Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA;
[4]Instituto Nacional de Pesquisas Espaciais (INPE), Saõ José dos Campos, SP, Brazil; [5]Universidade do Estado do Amazonas, Manaus, AM, Brazil;
[6]Brookhaven National Laboratory, Upton, NY, USA

Introduction

Greenhouse gases and their effects on atmospheric radiation are well known and important in understanding Earth's climate. The redistribution of the greenhouse gases, specifically ozone (O_3), in the tropical troposphere is not fully understood. Convection influences the vertical distribution of O_3 in the troposphere, perturbing the known radiative balance of the troposphere and subsequently the climate. In the tropics, the transport of O_3-rich air to the boundary layer can also influence air chemistry above the rainforest.

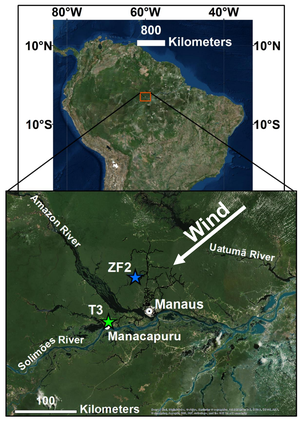
Objectives

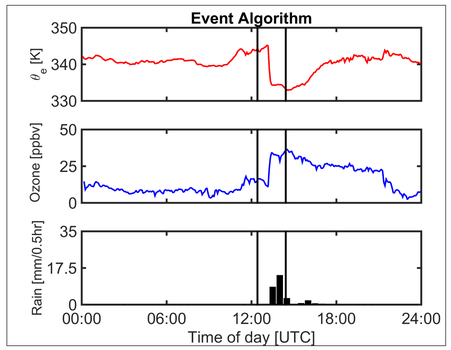
Present results of O_3 enhancements caused by convective-type storms and advection of an anthropogenic air mass.

Investigate the magnitude of O_3 enhancements resulting from mesoscale convective systems (MCSs) for two sites in the central Amazon region of Brazil.

Methods

Data were collected as part of the GOAmazon project 2014/15.



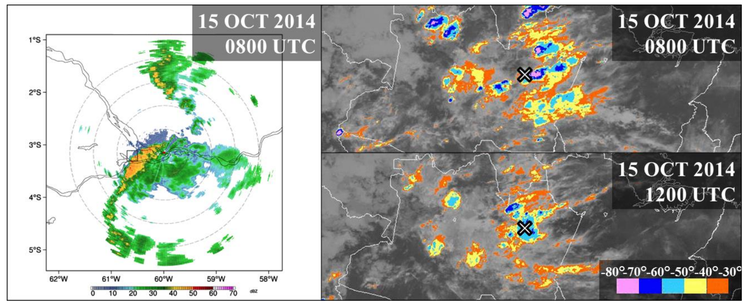


There were two sites, one upstream (ZF2) and one downstream (T3) of the tropical megacity of Manaus, Brazil.

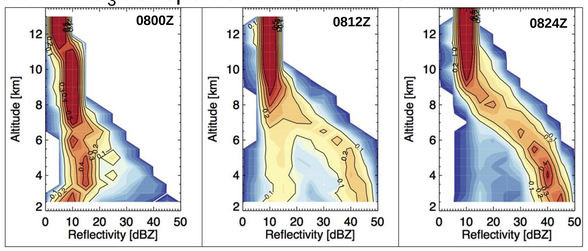
Surface (< 100 m) O_3 and meteorological data were recorded from April 2014 to January 2015. Equivalent potential temperature (θ_e) was used as a tracer for downward transport of air. An algorithm considered a drop of 2.5 K in θ_e and an increase of 3 ppbv in O_3 to classify the transport of O_3 (T3 included precipitation in the algorithm).

S-Band radar data and the GOES-13 channel 4 images were used to identify the presence of MCS presence and understand storm characteristics.

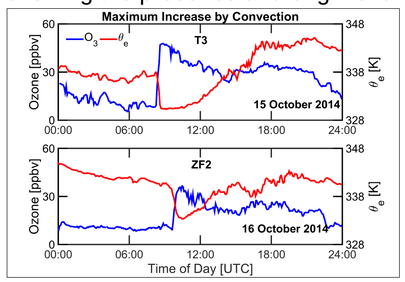
Convective Transport



Satellite images and radar scans provide characteristics of the storms associated with O_3 transport on 15 October 2014.



Contoured-frequency-by-altitude diagrams (CFADs) show echo tops exceeding 12 km and a descending arm of high reflectivity, from ~ 6 km to the surface, showing the presence and origin of a strong downdraft.

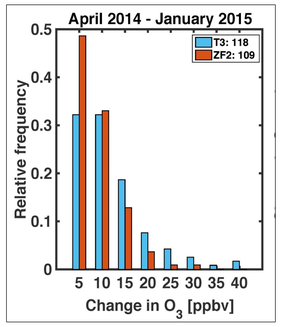


Ozone enhancements were associated with simultaneous decreases in θ_e.

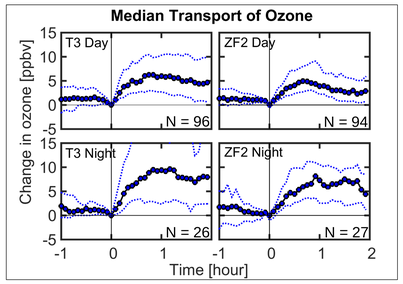
At T3, O_3 increased by ~40 ppbv on 15 October 2014.

At ZF2, O_3 increased by ~28 ppbv on 16 October 2014.

Large events increased O_3 for up to 2 hours.

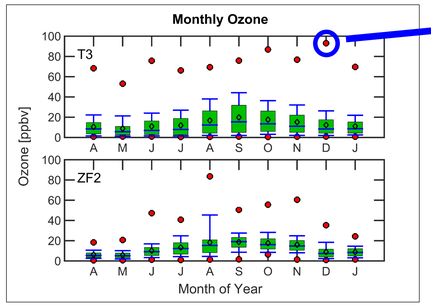


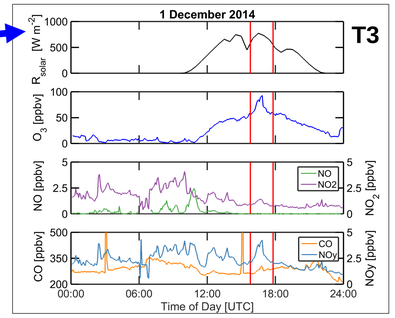
Frequency of O_3 enhancements at T3 and ZF2 study sites.



Increases in O_3 lasted 2 hours. Median increases: daytime 6 ppbv and 4 ppbv and nighttime 10 ppbv, and 8 ppbv for T3 and ZF2, respectively.

Anthropogenic Transport





Monthly O_3 interquartile ranges were larger for T3 than ZF2 likely in response to the influences of the City of Manaus.

Monthly maximum O_3 mixing ratios were consistently larger at T3 (> 50 ppbv) than ZF2, where only dry-season mixing ratios occasionally exceeded 50 ppbv due to increased biomass burning.

In December 2014, at the T3 site O_3 mixing ratios reached 93 ppbv. This event was associated with modest increases in nitrogen dioxide (NO_2) and carbon monoxide (CO). Combined with direction information, the NO_2 and reactive nitrogen (NOy) data provided evidence of the advection of an air mass altered by the City of Manaus.

Conclusions

Mesoscale convective systems enhanced the regional atmospheric boundary layer with as much as 4 – 10 ppbv of O_3 for periods lasting up to 2 hours. Such O_3 enhancements initiated a series of chemical reactions involving biogenic volatile organic compounds, hydroxyl radicals, and methane[1] which likely impacted the loadings of greenhouse gases in the lower atmosphere.

Urbanization, exemplified by the City of Manaus, can enhance NO_x and CO levels in downwind area, resulting in the enhanced formation of O_3 whose levels can reach 90 ppbv.

Acknowledgments

The U.S. Department of Energy Office of Biological and Environmental Research's Climate and Environmental Sciences Division supported the field studies (grant SC0011075). RJC received support from the National Science Foundation (grant AGS-1263225) to participate in this research.

References

[1]Gerken, T., Wei, D., Chase, R.J., Fuentes, J. D., et al. (2016). Downward transport of ozone rich air and implications for atmospheric chemistry in the Amazon Rainforest. Atmospheric Environment 124: 64-76.