Investigating the Role of Stratosphere to Troposphere Transport on the Tropospheric Ozone Budget: A Case Study Using Ozonesonde Data from Idabel, Oklahoma

NOAA RESEARCH

Brianna Salazar[1,2], Gary A. Morris[1], Patrick Cullis[1], Robert Heinemann[3], Michael J. Newchurch[4], Michael Ives[5]

[1]NOAA Global Monitoring Laboratory (Boulder, CO), [2]Mississippi State University (Starkville, MS), [3]Oklahoma State University (Idabel, OK), [4]University of Alabama in Huntsville (Huntsville, AL), [5]Trinidad Head Observatory (Trinidad Head, CA)

1. Introduction

Tropospheric ozone is a critical component of the atmosphere, significantly impacting climate and air quality. Concentrations are influenced through processes such as biomass burning emissions, lightning-generated nitrogen oxides (NOx), urban pollution, tropopause folding, and other meteorological phenomena.

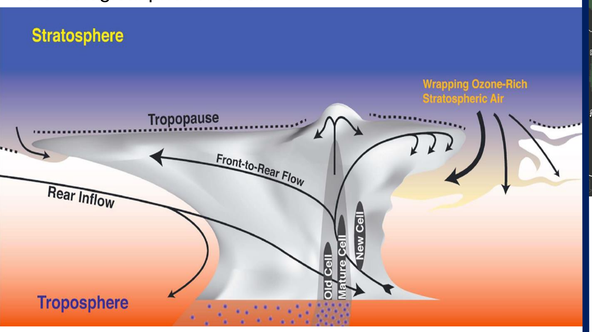
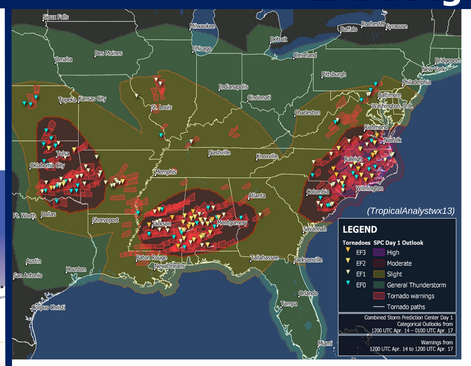


Figure 1. Schematic of ozone air wrapping around the anvil edge (adapted from Houze et al. [1989]).

Tropopause folding influences stratosphere-troposphere exchange (STE) through transporting stratospheric ozone-rich air into the troposphere. For this research, we integrate components of the tropopause folding model (Pan et al. 2014). In this model, there is focus on exchanges from synoptic-scale dynamics associated with upper-level jet streams.

2. Background



From **April 14–April 16, 2011**, a series of tornado outbreaks affected the central to eastern United States, characterized by an enhanced synoptic-scale system. This comprehensive analysis highlights its significance, not only in terms of its severe weather impact, but also in advancing our understanding of atmospheric processes that affect tropospheric ozone levels.

Figure 2. Combined SPC Day 1 Convective Outlooks from 1200Z April 14 – 0100Z April 16 with tornado warnings overlaid. Map produced in QGIS.

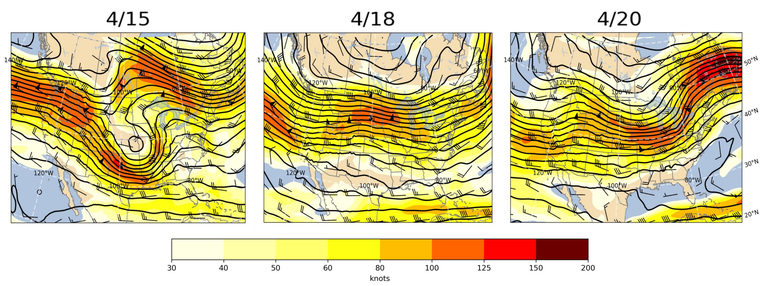


Figure 3. 250 mb Geopotential Heights and Isotachs in decameters and knots respectively at **18Z** using NAM 12 km grib data. These figures illustrate the strong, **negatively** tilted upper-level trough over the central United States. Through its progression, the system weakens as the flow transitions from quasi-zonal to fully zonal.

3. Meteorological Analysis

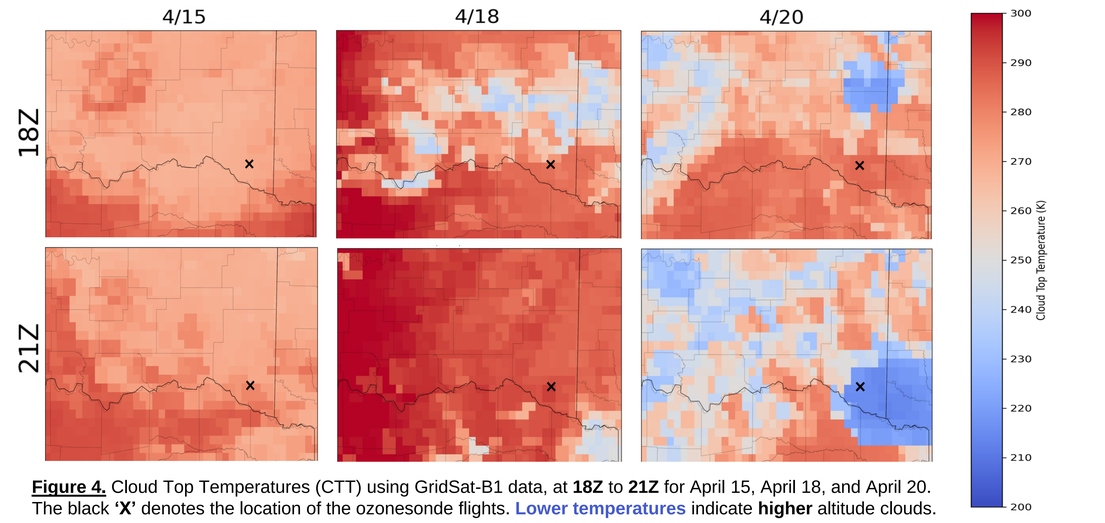


Figure 4. Cloud Top Temperatures (CTT) using GridSat-B1 data, at **18Z** to **21Z** for April 15, April 18, and April 20. The black **'X'** denotes the location of the ozonesonde flights. **Lower temperatures** indicate **higher** altitude clouds.

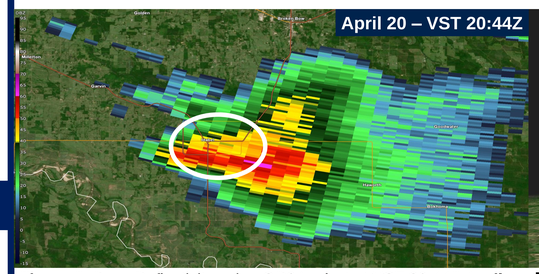


Figure 5. Base Reflectivity using GR2Analyst at **VST 20:44Z April 20.** The white circle is the location of Idabel, OK. This confirms localized convection at this location.

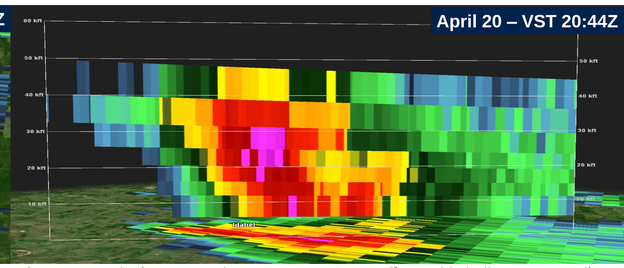


Figure 6. Vertical cross section at **VST 20:44Z April 20.** This indicates an anvil height between 40 to 50 kft which is equivalent to 12 to 15 km. This coincides with the lower CTTs (200 K to 215 K).

4. Ozonesonde Measurements

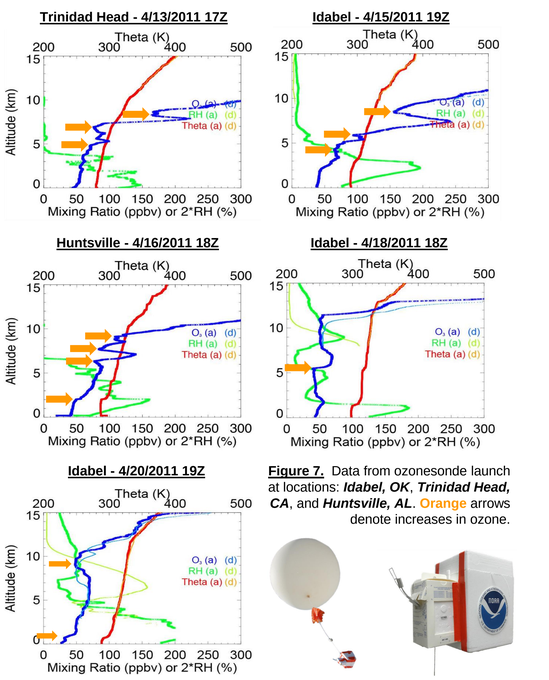


Figure 7. Data from ozonesonde launch at locations: ***Idabel, OK***, ***Trinidad Head, CA***, and ***Huntsville, AL***. **Orange** arrows denote increases in ozone.

5. HYSPLIT Back Trajectories

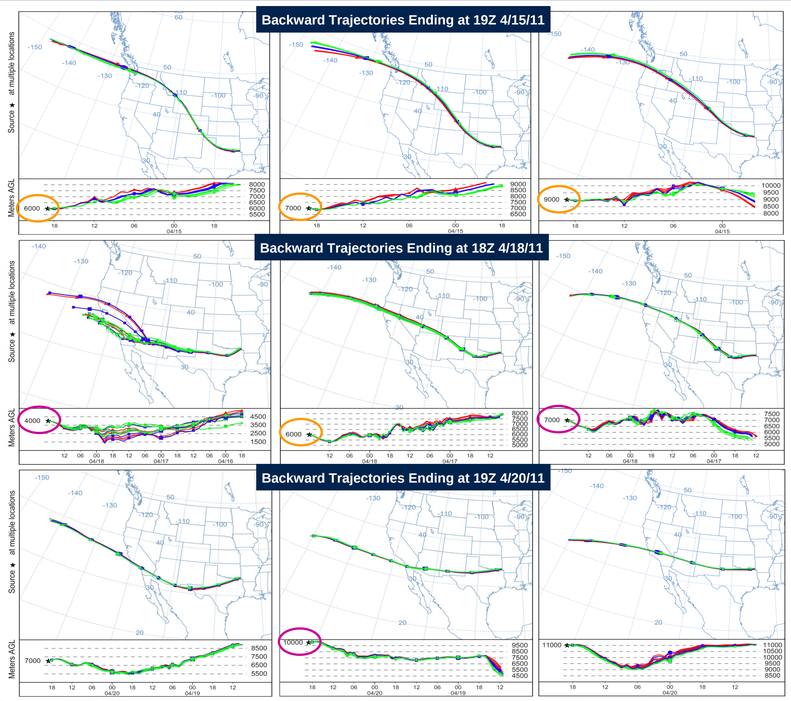


Figure 8. HYSPLIT Back Trajectories generated for levels that experienced ozone enhancement. In areas with strong tropospheric ozone enhancement, it is important to identify the layers of ***descent,*** where ozone air is descending into the troposphere. **Orange** circles denote ***descent***. **Purple** circles denote ***ascent.***

6. Key Findings

April 15, 2011 - Idabel

Prime example of ***tropopause folding*** bringing significant amounts of ozone into the troposphere. *Trinidad Head* and *Huntsville* both show notable similarities of the feature discovered in Idabel's ozonesonde launch on 4/15. Backward trajectories indicate air masses descended from the mid-tropospheric levels, implying stratospheric air intrusion. To further verify this, a potential vorticity analysis will need to be conducted.

April 18, 2011 - Idabel

To be determined… There is a layer near **9 km** that increases in relative humidity above the increase in ozone concentration (roughly around *15-20 ppbv* **~5 km**). Backward trajectories indicate descent from mid-tropospheric levels, implying stratospheric air intrusion. There potentially could be remnants from localized convection from the Pacific Northwest region that traversed to Idabel.

April 20, 2011 - Idabel

Determined to be ***anvil wrapping***. Sharp increase in ozone **~1 km** and returns to a steady increase. By **~10 km**, ozone production increases significantly. Backward trajectories confirm descent at higher altitudes, consistent with stratospheric intrusions. Radar indicates localized convection with maximum heights between 12 to 15 km and Low CTTs between 200 K to 215 K that suggests higher altitude clouds at the same heights.

7. Future Work

Utilize high-resolution radar imagery and GOES/MODIS satellite imagery to intersect with HYSPLIT back trajectories in identifying convective activity from Pacific regions.

Analyze a targeted balloon-driven dataset where we would launch ozonesondes on the front side and back side of convective systems to compare these profiles

8. References

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For more information:
brianna.salazar@noaa.gov