P-42. Boulder ozone sonde data analyses for multiple tropopause origins

Irina Petropavlovskikh (1,2) (irina.petro@noaa.gov), Bryan J. Johnson (1), Gloria L. Manney (3,4), Ken Minschwaner (4), Luis Torres (4), Zachary D. Lawrence(4), A. Thompson(5)

(1) GMD, NOAA/ESRL, Boulder, CO, USA , (2) CU/CIRES, Boulder, CO, USA , (3) NorthWest Research Associates, Boulder, CO, USA, (4) New Mexico Institute of Mining and Technology, Socorro, NM, USA; (5) NASA/GSFC, Greenbelt, USA

Picture taken by camera attached to the balloon shows local geography near Boulder Colorado. Rocky Mountains (seen in the background) play role in the variability of ozone sonde profiles related to generation of gravity waves. pictures is courtesy of P. Cullis (NOAA/CIRES).

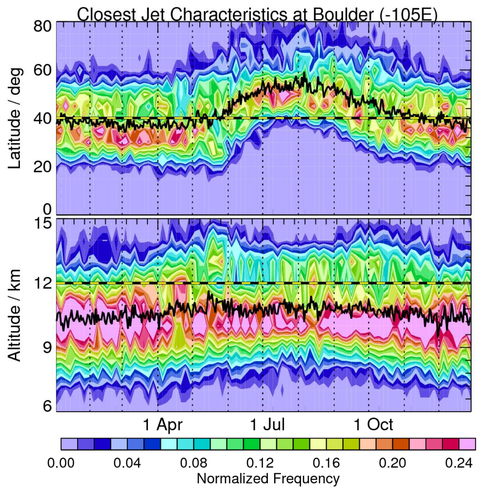


Figure above. Top: *Climatology of subtropical jets. MERRA detects them frequently near the latitude of Boulder (40N).* At analyzed time of the year (May-June), Boulder is very near the "tropopause break", usually just pole-ward, but occasionally just equator-ward. ***Bottom****: Maximum altitude of the jets location the most often occurs at 9-12 km.*

Figure to the right. Frequency in tropopause altitude at Boulder location (MERRA analysis).
a) all occurrences, b) primary c) secondary.

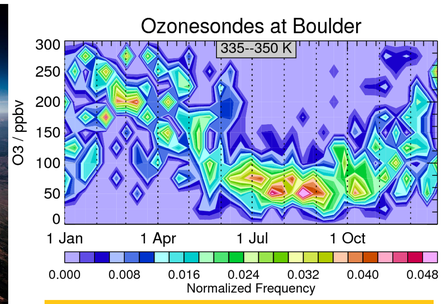
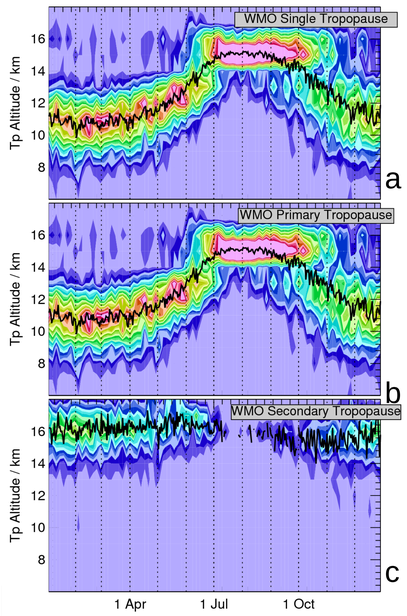
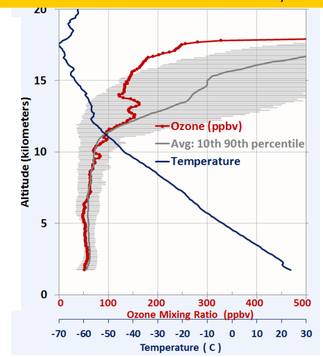


Figure 1. Ozone sonde based climatology of seasonal variability in ozone mixing ratios at 335-350 K potential temperature levels.



GMAO Analysis.
- Meridional "slices" of GMAO ozone fields at Boulder longitude (105 W)
- Runs from GEOS-591, eight times/day (0, 3, 6, 9, 12, 15, 18, 21 UT).
- Ozone is assimilated using only SBUV, so it won't capture all of the small structure near the tropopause -- but it gets some of it when that structure is caused mostly by transport of larger scale features.

See further information about GMAO products at http://gmao.gsfc.nasa.gov/research/merra/



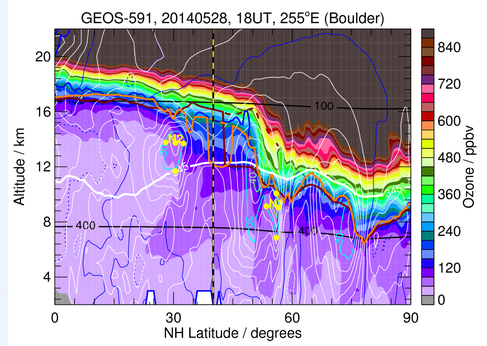
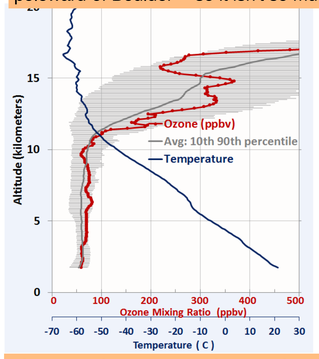


Figure 2. Balloon Launch on May 28 2014 (red), ozone climatology (10% and 90%, grey) for June (based on Boulder sonde 1991-2013 record) and temperature profile (blue).
Figure to the right shows the N-S slice of JETPAC analysis at the longitude of Boulder with wind speeds (white contours) and overlaid ozone from the GEOS5 SBUV. The tropopause break is poleward of Boulder -- so it isn't so much transport of tropical air, but that Boulder is IN the tropics!



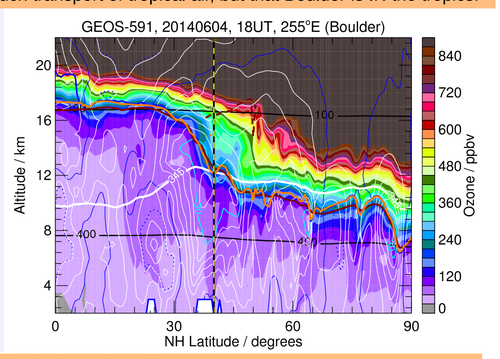
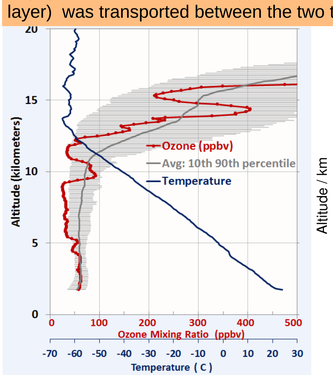


Figure 3. The same as Figure 2, but for balloon launch on June 4 2014
Figure on the right shows ozone from GEOS-591 analysis (18UT, June 4th), with overlaying the primary tropopause around 12 km (dark red line) and the secondary tropopause around 16 km (dark dashed line). MERRA analysis indicates formation of a **double tropopause** over Boulder around 9UT on June 4th , which then persists for several days after that. This is similar to ozone sonde profile variability (left panel) with low ozone found right between the two tropopauses. Therefore it suggests that low latitude air from around the TTL (tropical tropopause layer) was transported between the two tropopauses to the latitude of Boulder.



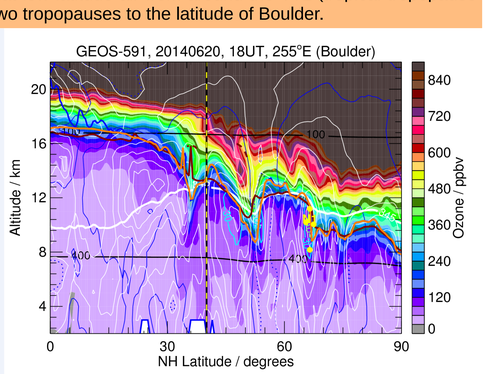


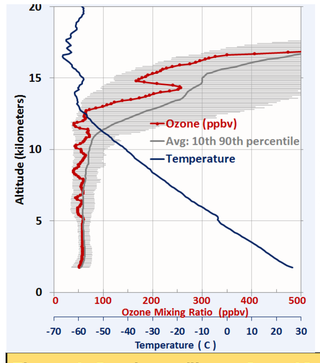
Figure 4. **Same as Figure 2, but for June 20, 2014** (left panel.) MERRA GEOS-591 ozone field on June 20 18UT shows stratospheric air (red) descending into north of Boulder latitude 40ºN (right panel).

Summary of Results

- We use **GMAO's GEOS-5** data assimilation system products, including Modern-Era Retrospective analysis for Research and Applications (**MERRA**), interpolated to Boulder, Colorado, USA (40N, 105W) to assess incidence of upper tropospheric jets that influence UTLS ozone distribution. The proximity of the **subtropical jet** to Boulder results in frequent observations of **multiple tropopauses**.
- Our tools include **back trajectory analysis** coupled with 4D satellite ozone profile data, including those from NASA's Aura Microwave Limb Sounder instrument.
- Filaments causing laminae in ozone profiles observed at Boulder are tracked to **origins in either stratospheric or tropospheric intrusions** using reverse domain-filling (RDF) trajectory methods.
- Ozone variability in the UTLS over Boulder is of importance for **studies of local climatological ozone conditions**, their causes/attribution, and with regard **to EPA ozone regulations** at the mountain sites across the USA.

Figure for GEOS-591 show SBUV O3 field measured on 28 May 2014 and assimilated in the GEOS-5 model. Vertical ozone profiles are plotted as the meridional cross-section along the longitude of Boulder over North America with jet and tropopause classification information overlaid; fields are displayed on the GEOS-5 model levels in the vertical. Yellow letter/number combinations indicate the locations of jet cores according to the classification scheme described in the text, lowest numbers are for strongest jets in each hemisphere; yellow dots indicate the identified locations of the edges of the jet region (at grid points, thus not exactly matching contours). **Orange lines** show the 4.5 PVU dynamical tropopause and **dark red lines** the WMO (thermal) tropopause; **dashed lines show** the secondary tropopause, if present. Thin black nearly-horizontal lines show 400 and 100 hPa pressure levels (the 400 hPa contour is not horizontal because the model levels are terrain following at that pressure). Thick white line shows the 345 K potential temperature level.

Lucchesi, R., 2013: File Specification for GEOS-5 FP-IT. GMAO Office Note No. 2 (Version 1.2), 60 pp, available from http://gmao.gsfc.nasa.gov/pubs/office_notes.



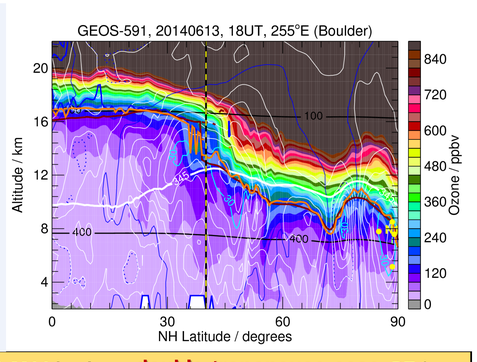
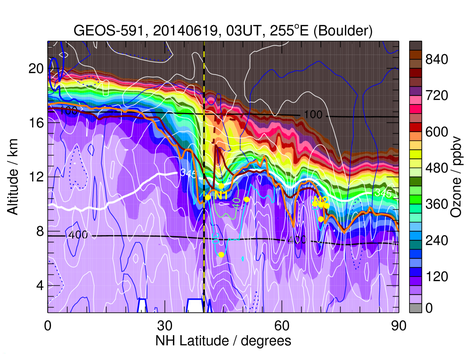
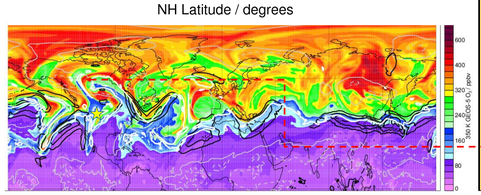


Figure 4. Sonde profile on June 13 2014 is also a double tropopause case. DT forms over Boulder around 18UT on the 13th and persists for some days. At 18 and 21UT (in particular, but also at later times), there's a suggestion in GEOS-591 ozone of the laminar structure seen in the sonde (later times are not shown). Therefore it suggests that low latitude air from around the TTL (tropical tropopause layer) was transported between the two tropopauses to the latitude of Boulder.



GEOS-591 ozone vertical meridional cross section map (left) shows *huge* tongue of stratospheric air descending over/near Boulder starting around 3UT on the 19th. By 18UT on June 20th it has mostly moved north of Boulder, but the high lamina in sonde profile near 17 km is clearly discernible in the GEOS591 ozone field (Fig. 4, right panel). The second laminae near 12km is also captured by model. So that structure does seem to be related to Strat/Trop exchange.

Map on the left for June 20 2014 show dynamically driven variability in ozone field at 350 K potential temperature level (GEOS-591). White contour denotes the 4.5 PVU surface (i.e. dynamical tropopause). It suggests that enhanced ozone seen in sonde profile at 14 km altitude (Figure 4) was horizontally transported (along the isentrope) down to Boulder from higher latitudes in long, fairly narrow tongue of stratospheric air .



Summary of Results

- In addition, observations indicate that air from the tropical tropopause layer (TTL) can be transported into regions with **multiple tropopauses over the middle latitudes in the vicinity of the subtropical jets**.
- Detailed studies of several ozone profiles collected over Boulder in June/July 2014 help with **determining techniques for future analysis** of a larger dataset that goes back to 1978.

Summary of Results

- We analyze **ozonesonde data** launched in June-July 2014 to determine the origins of laminae observed in the upper troposphere/lower stratosphere (UTLS).
- Boulder ozone profile measurements tend to feature structures with multiple layers in the troposphere, so called laminae.
- These have been shown to be related to several phenomena, including **stratospheric air intrusions** that are transported to the location of measurements **and local gravity wave perturbations** (Boulder is located near the Rocky Mountain range where gravity waves are prevalent).