Removal of Seasonal Bias from Dobson Spectrophotometer Records with Reanalysis

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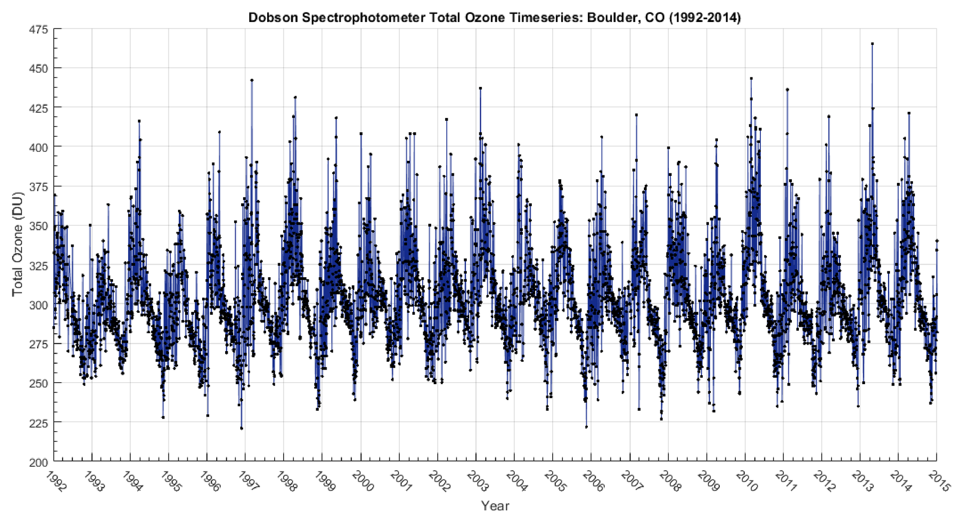
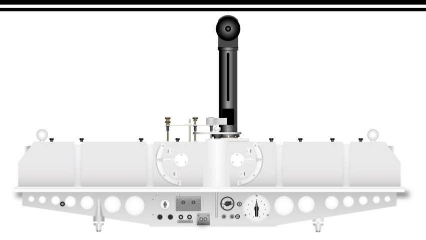
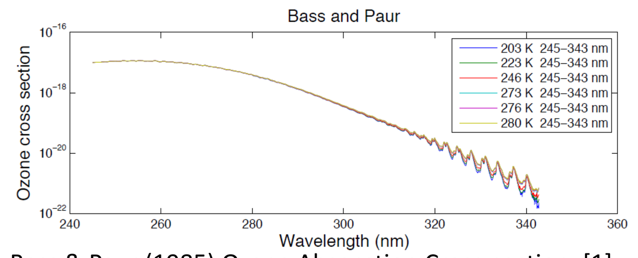
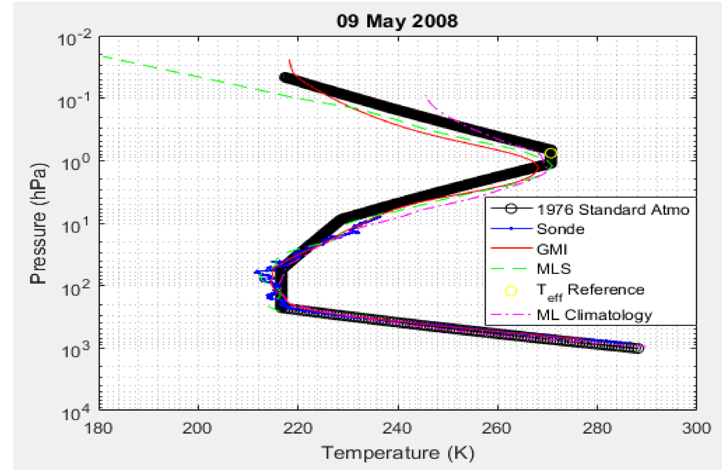
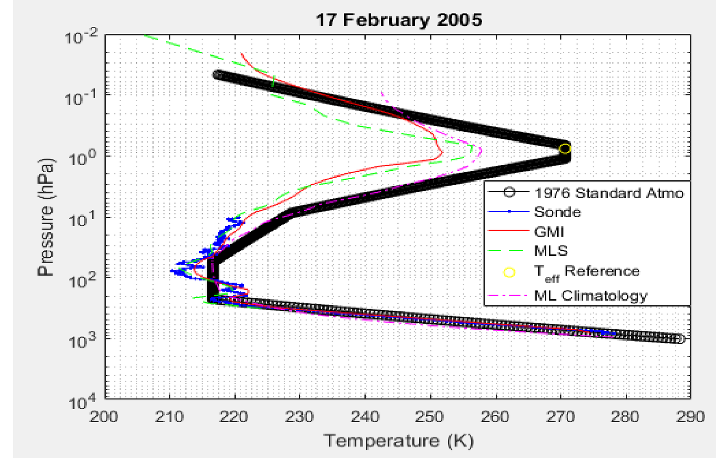




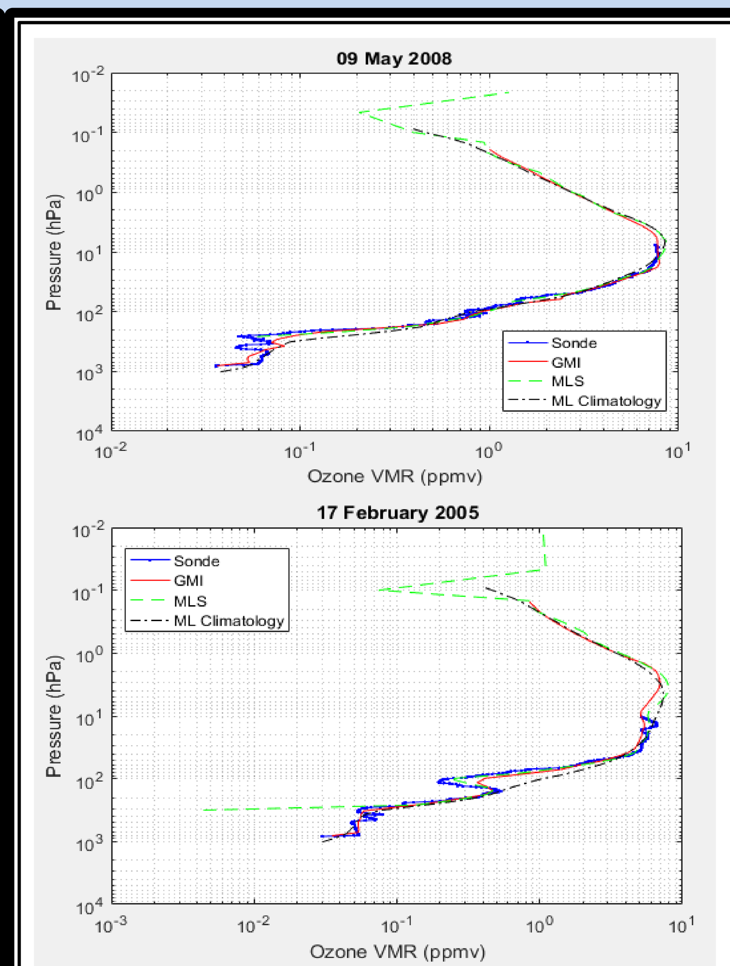


Bass & Paur (1985) Ozone Absorption Cross-Section. [1]



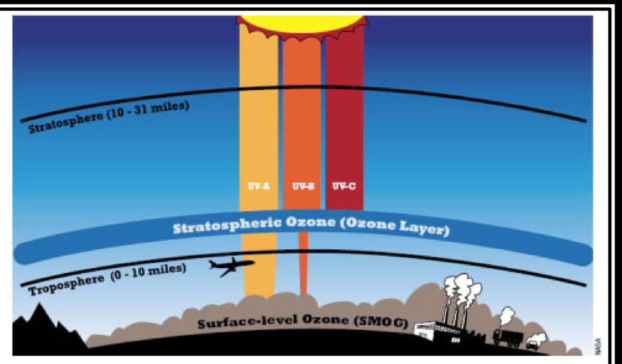


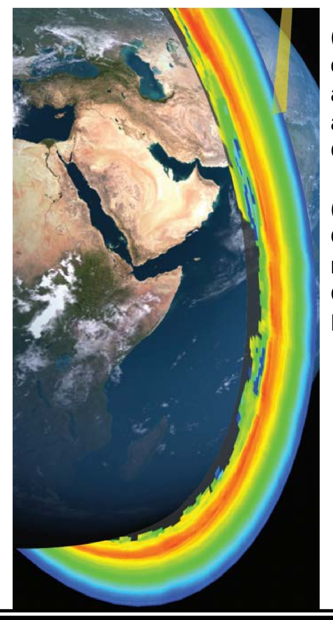
The NOAA Dobson records started in the early 1960's. Total ozone from Dobson is derived through differential spectral measurements of UV irradiance. Total ozone is derived based on lab-determined (i.e. Bass & Paur, 1985) ozone cross-sections that are sensitive to stratospheric temperatures. However, the operational Dobson process assumes a static temperature of −46.3℃. A seasonal-dependent bias between ozone measured by Dobsons and other instruments (i.e. satellites) are caused by this simplification. Ozone-sondes ozone and temperature profiles can be used to determine the ozone-weighted effective temperature to correct Dobson total ozone record, but they are only launched once a week and not at all Dobson ground-based stations. NASA's GMI Chemistry and Transport Model (CTM), combined with the reanalysis product, Modern-Era Retrospective Analysis for Research and Applications (MERRA), is used to determine the effective temperatures to correct the Dobson historical record.



2 Methodology

1. Validate model profiles.
2. Create hourly effective temperatures from model.
3. Adjust historical Dobson record from model effective temperatures (AD wavelength, direct sun measurements only).
4. Validate total ozone temperature adjustments with satellite overpass measurements (OMI, OMPS, SBUV/2).
5. Compare adjustments based on monthly climatology or model to determine value of daily stratospheric temperature corrections.

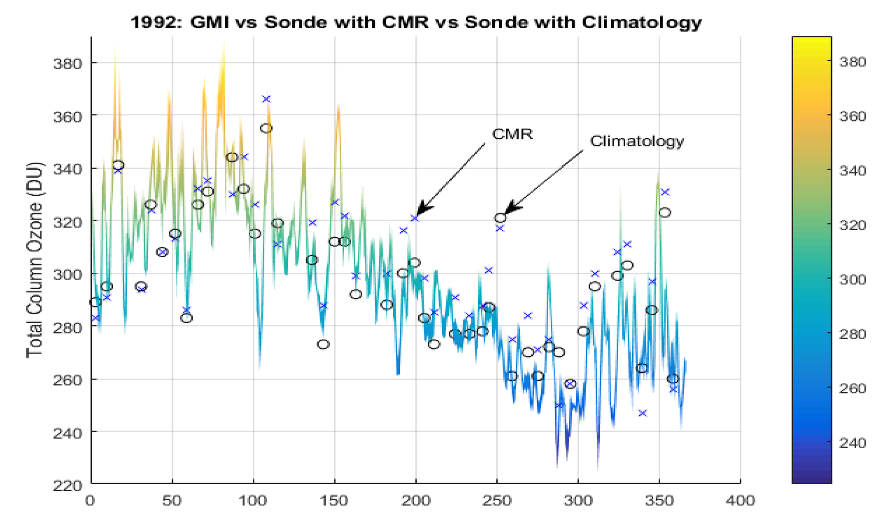


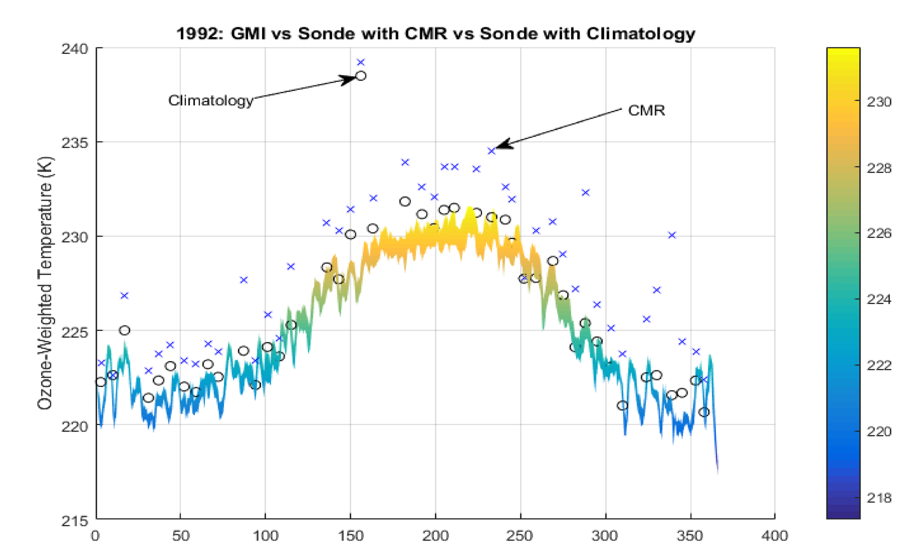


(Above) Illustration of ozone UV absorption in the atmosphere. Credit: NASA

(Left) Illustration of OMPS ozone measurement. Credit: NOAA/NASA

4 Model Validation





Ozone-sondes and Aura's Microwave Limb Sounder (MLS) provide data for validation of the GMI ozone and MERRA temperature profiles, respectively.

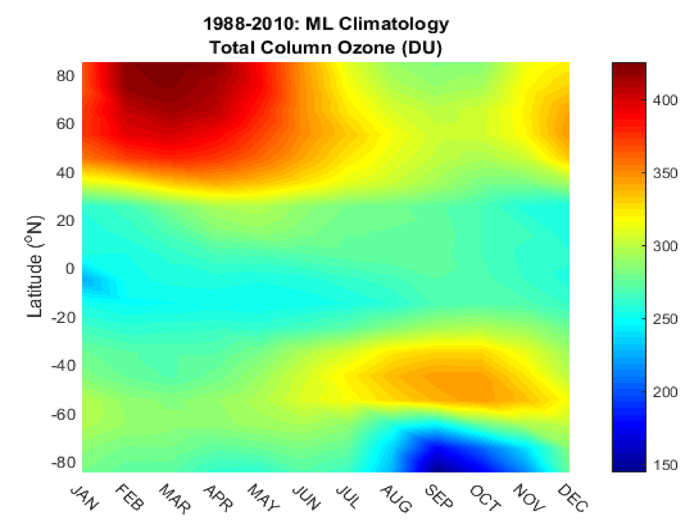
Ozone-sondes burst around 7 hPa and do not reach the extent of the ozone column. Therefore, ozone-sonde profiles are extended through two separate methods:

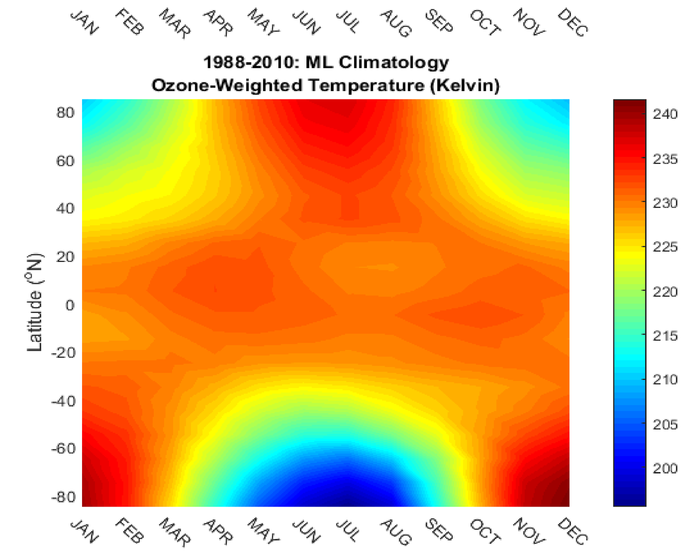
1. Constant mixing ratio (CMR) from burst up to 50 km by using a reference temperature defined by the 1976 COESA Standard Atmosphere.
2. Climatology ozone and temperature profiles.

Ozone-sonde profiles extended with method (2) show the best agreement with model results for Boulder, CO station (see plots of total ozone (top) and effective temperature (bottom) on the left side of the panel).

Ozone-sonde launch at South Pole. Credit: NOAA/ESRL

3 Calculations





Ozone-Weighted Effective Temperature:

$$T_{effective} = \frac{\Sigma(\bar{T} * O_3)}{\Sigma O_3}$$

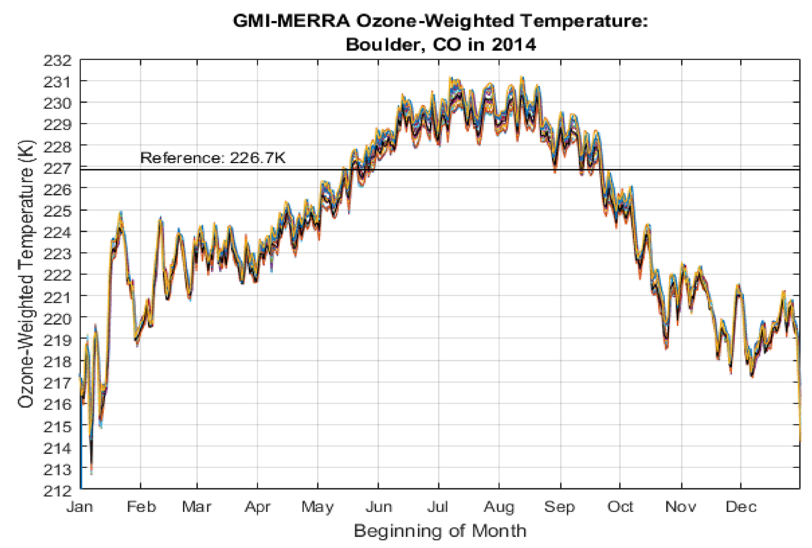
Total Ozone Adjustment to Dobson:

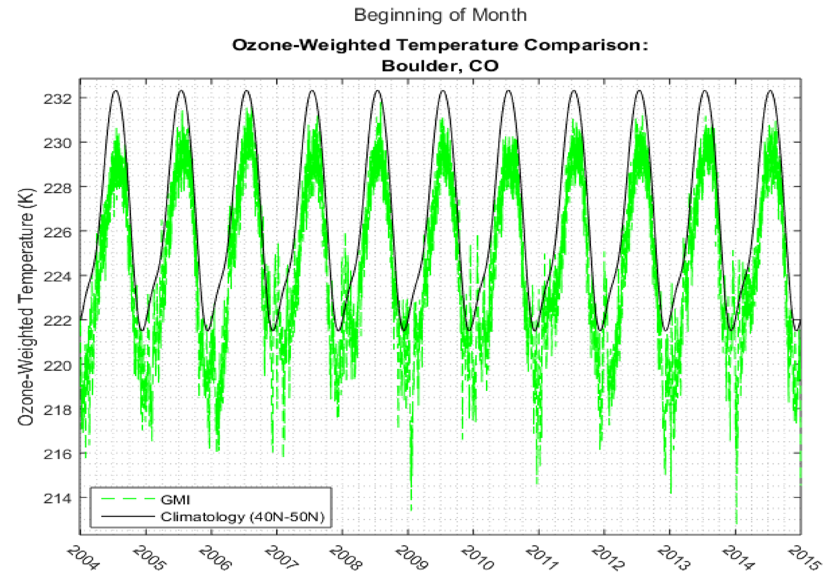
$$TO_{3,new} = TO_{3,old}\left[1 - C_x\left(T_{effective} - 226.7\right)\right]$$

C_x → Cross-section temperature sensitivity
Bass & Paur (BP) = 0.133%/K [3]

McPeters & Labow (ML) seasonal and meridional Climatology [2] is derived from multiple ozone-sonde and MLS (1988-2010) profiles.

Left panel: Zonal and seasonal distributions for total ozone and effective temperature.
Right panel: Seasonal cycle (top) and time series of ozone weighted effective temperature (bottom) derived from ML climatology (black) and GMI/MERRA model (green) for Boulder.





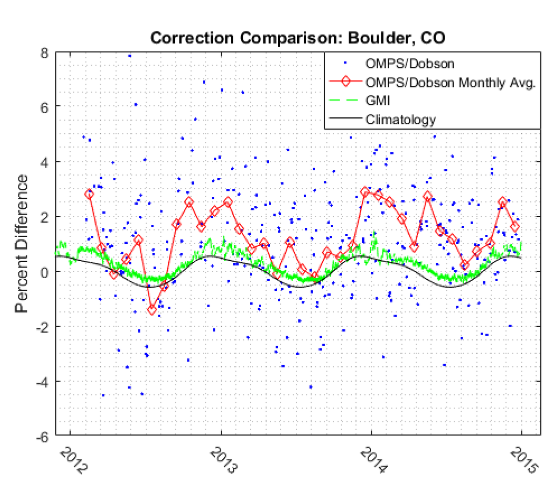
5 Preliminary Results

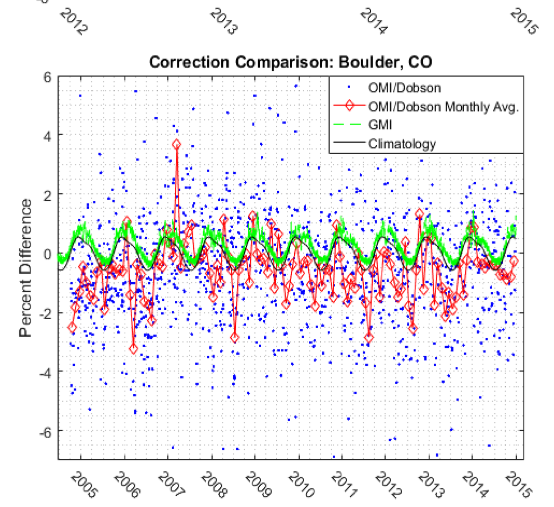
Boulder, CO

DOBSON - OMPS		
Uncorrected RMS	=	8.405
Corrected (via GMI) RMS	=	7.809
Corrected (via Climatology) RMS	=	8.217
Uncorrected R^2	=	0.953
Corrected (via GMI) R^2	=	0.957
Corrected (via Climatology) R^2	=	0.956
DOBSON - OMI		
Uncorrected RMS	=	7.917
Corrected (via GMI) RMS	=	8.148
Corrected (via Climatology) RMS	=	7.889
Uncorrected R^2	=	0.943
Corrected (via GMI) R^2	=	0.943
Corrected (via Climatology) R^2	=	0.943
DOBSON - SBUV		
Uncorrected RMS	=	8.930
Corrected (via GMI) RMS	=	8.830
Corrected (via Climatology) RMS	=	8.758
Uncorrected R^2	=	0.917
Corrected (via GMI) R^2	=	0.920
Corrected (via Climatology) R^2	=	0.920

Amundsen-Scott, Antarctica

DOBSON - OMPS		
Uncorrected RMS	=	6.829
Corrected (via GMI) RMS	=	6.743
Corrected (via Climatology) RMS	=	6.889
Uncorrected R^2	=	0.979
Corrected (via GMI) R^2	=	0.979
Corrected (via Climatology) R^2	=	0.979
DOBSON - OMI		
Uncorrected RMS	=	8.263
Corrected (via GMI) RMS	=	8.098
Corrected (via Climatology) RMS	=	8.240
Uncorrected R^2	=	0.977
Corrected (via GMI) R^2	=	0.976
Corrected (via Climatology) R^2	=	0.977
DOBSON - SBUV		
Uncorrected RMS	=	N/A
Corrected (via GMI) RMS	=	N/A
Corrected (via Climatology) RMS	=	N/A
Uncorrected R^2	=	N/A
Corrected (via GMI) R^2	=	N/A
Corrected (via Climatology) R^2	=	N/A





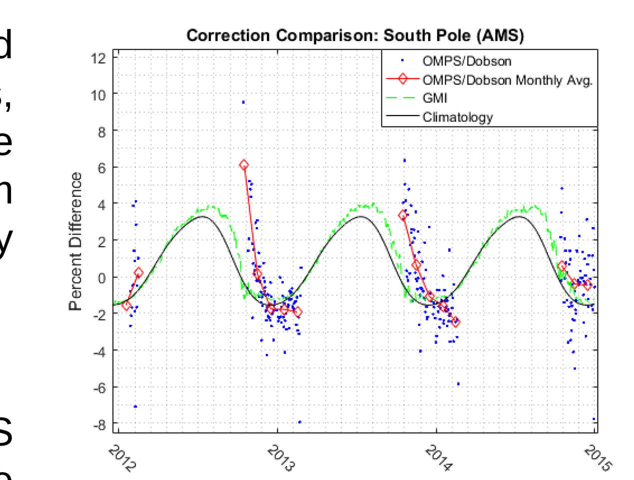
Difference (%), Dobson daily (blue) and monthly (red) total ozone vs. satellites, OMPS (top) and OMI (bottom). Difference (%), effect of effective temperatures from GMI/MERRA (green) and climatology (black).

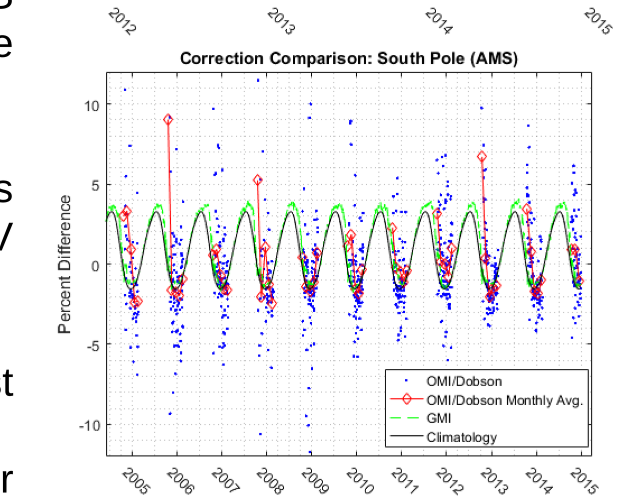
Boulder, CO (left):

- slightly improved agreement with OMPS and SBUV after temperature adjustments
- Opposite effect for OMI
- Climatology-based adjustment shows greater improvement for OMI and SBUV comparisons

Amundsen-Scott, South Pole (right):

- Adjustments from model show most improvement for OMPS and OMI
- Poles demonstrate greatest need for temperature-adjusted total ozone





6 Conclusions and Future Work

- Temperature adjustment for NOAA Dobson total ozone records show small improvement in comparisons with satellite observations.
- Two other ozone cross-sections are available: Daumont, Brion and Malicet (DBM) and Serdyuchenko (IUP) to be used in this study.
- Corrections via daily airmass factor adjustment. Airmass is the ratio of the slant and vertical paths of solar radiation through the ozone layer (μ). The static ozone layer height for Boulder is at 22 km. Daily ozone layer height deviates from 22 km and changes the Dobson total ozone derivation. GMI will be used to find the variability in the height.
- GMI/MERRA2 recently released and will be used for future continuation of this study.

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[1] Johannes Orphal, Johannes Staehelin, Johanna Tamminen, Geir Braathen, Marie-Renée De Backer, Alkiviadis Bais, Dimitris Balis, Alain Barbe, Pawan K. Bhartia, Manfred Birk, James B. Burkholder, Kelly Chance, Thomas von Clarmann, Anthony Cox, Doug Degenstein, Robert Evans, Jean-Marie Flaud, David Flittner, Sophie Godin-Beekmann, Viktor Gorshelev, Aline Gratien, Edward Hare, Christof Janssen, Erkki Kyrölä, Thomas McElroy, Richard McPeters, Maud Pastel, Michael Petersen, Irina Petropavlovskikh, Benedicte Picquet-Varrault, Michael Pitts, Gordon Labow, Maud Rotger-Languereau, Thierry Leblanc, Christophe Lerot, Xiong Liu, Philippe Moussay, Alberto Redondas, Michel Van Roozendael, Stanley P. Sander, Matthias Schneider, Anna Serdyuchenko, Pepijn Veefkind, Joëlle Viallon, Camille Viatte, Georg Wagner, Mark Weber, Robert I. Wielgosz, Claus Zehner, Absorption cross-sections of ozone in the ultraviolet and visible spectral regions: Status report 2015, Journal of Molecular Spectroscopy, Volume 327, September 2016, Pages 105-121, ISSN 0022-2852, https://doi.org/10.1016/j.jms.2016.07.007.
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[3] Redondas, A., Evans, R., Stuebi, R., Köhler, U., and Weber, M.: Evaluation of the use of five laboratory-determined ozone absorption cross sections in Brewer and Dobson retrieval algorithms, Atmos. Chem. Phys., 14, 1635-1648, doi:10.5194/acp-14-1635-2014, 2014.