Understanding Ozone-Sonde Trends and Variability in UTLS.
Using Dynamical Coordinates for Consistent Analysis of UTLS Composition.

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Introduction

Ozone trends in the upper troposphere/lower stratosphere (UTLS) remain highly uncertain because of sharp spatial gradients and large variability caused by competing transport, chemical, and mixing processes near the upper tropospheric jets and extra-tropical tropopause, as well as inhomogeneous, spatially and temporally limited observations of the region.

Subtropical jets and the tropopause act as transport barriers, delineating boundaries between atmospheric regimes controlled by different processes; they can thus be used to separate data taken in those different regimes for numerous purposes, including trend assessment.

As part of the Observed Composition Trends And Variability in the UTLS (OCTAV-UTLS) Atmospheric Processes And their Role in Climate (APARC) activity, we assess the effectiveness of several coordinate systems in segregating air into different atmospheric regimes. **The main focus of this paper is on the ozonesonde-MLS comparison.**

The goal of this study is to show the effect of different coordinate systems on ozone variability and trends in UTLS and assess the reduction in trends uncertainties due to separation of airmasses into different dynamical regimes.

Coordinate systems that display the least uncertain trends are the one that most accurately represent the trace gas (ozone) long-term changes in the UTLS. Further analyses are needed to understand spatial and temporal biases in the infrequently-sampled ozonesonde records.

Methods

- Trends are ordinary least squares fit to O3 monthly mean and seasonal averages, expressed as %/decade.
- Depending on the coordinate system and its ability to account for tracer gradients at transport barriers between different air masses (e.g., at the tropopause or jet cores), the binning process can induce artificial variability on top of the inherent atmospheric variability (e.g., induced by non-conservative processes).
- Lower sampling frequency records, such as ozonesonde data, may introduce monthly biases (so-called outliers) in the analyzed time series, potentially influencing trend and uncertainty assessments (under investigation).

Datasets

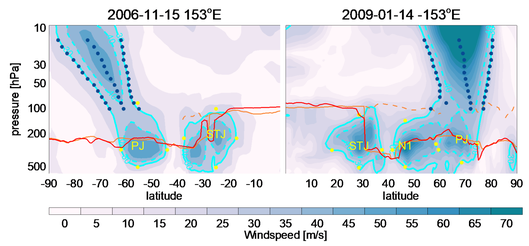
Ozonesondes	**Sterling et al (2018), Stauffer et al (2022)**
Lidars	Steinbrecht et al. (2009), McDermid et al (1995)
CARIBIC-2	Brenninkmeijer et al (2007)
START08	Pan et al (2010)
TACTS/ESMVAL	Muller et al (2016)
PGS	Oelhaf et al (2019)
Aura MLS (v5)	**Waters et al (2006)**
ACE-FTS (v4)	Bernath et al (2005)

Bolded font indicates records used for trend analyses in the poster

Please contact Luis Millan for data luis.f.millan@jpl.nasa.gov

More information about atmospheric variability in dynamical coordinate systems can be found at:
Millán et al (2024) doi:10.5194/egusphere-2024-144

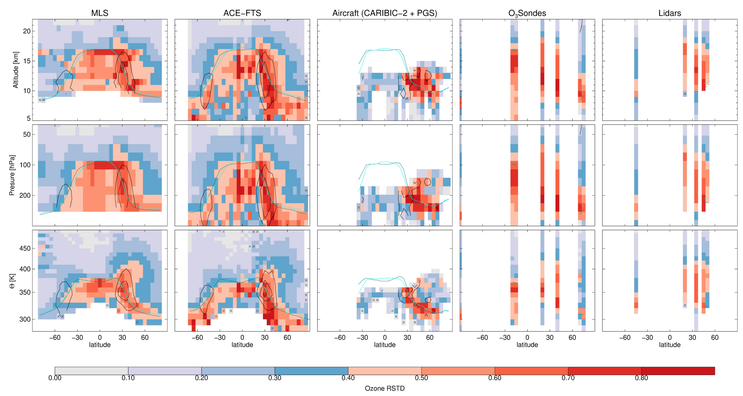
Dynamical Characterization of UTLS



JETPAC enables mapping to multiple dynamical coordinates
Cross-sections of MERRA2 wind speed with jet, subvortex, WMO tropopause, and dynamical tropopause classification information overlaid. Adapted from Manney et al. (2011)

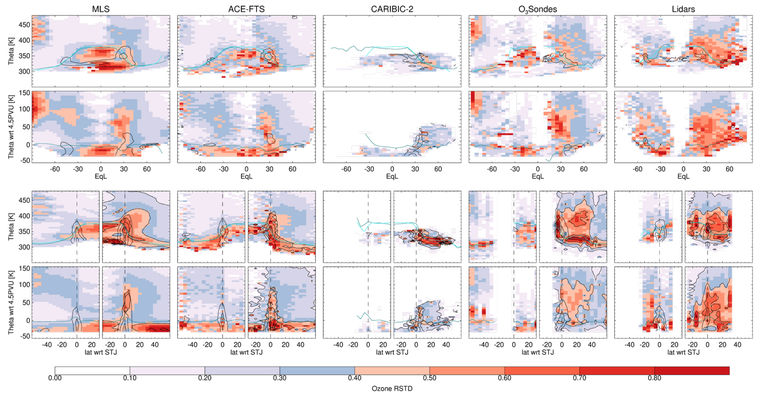
Coordinate mapping

We examine the effects of different coordinate systems (Millan et al, 2024) on the representation of geophysical variability in UTLS ozone through production of 2005-2018 DJF climatologies.



Examples of typically used Y-coordinates (altitude, pressure, and potential temperature). Note the redistribution of ozone relative standard deviation (**RSTD=100*σ/μ**, STD and mean O3) levels representing variability across these three coordinates.

RSTD associated with dynamical coordinate binning

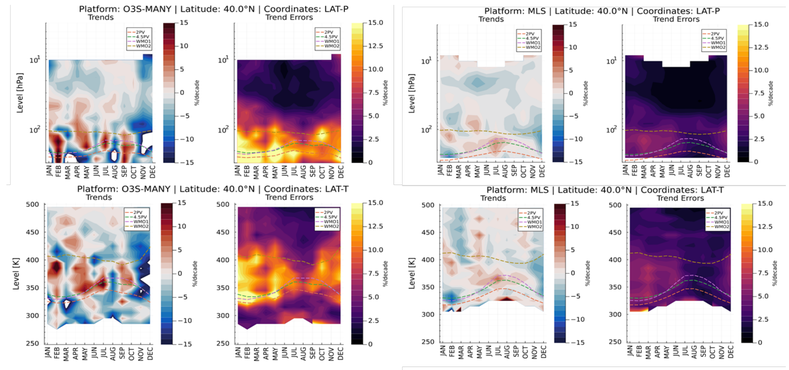


- Across all datasets potential temperature-based coordinates result in reduced binned variability compared to that for altitude-based coordinates.
- Tropopause based coordinates lead to reduced binned variability around the tropopause
- Dynamical tropopause coordinates lead to lower binned variability than WMO tropopause coordinates
- The use of equivalent latitude-potential temperature coordinates leads to the most substantial reduction in binned variability across the UTLS through all datasets and all seasons.
- (Above are conclusions from Millan et al., 2024).

Trend Analyses

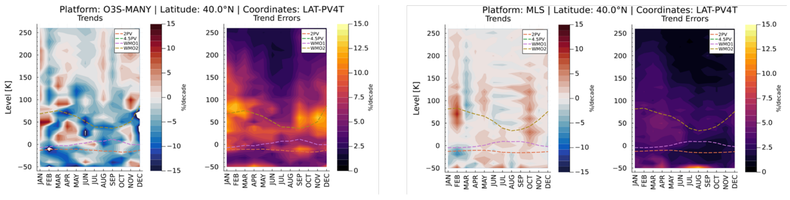
We investigate how dynamical tropopause coordinates reduce uncertainties in monthly mean (MM) and seasonal trends in ozonesonde and MLS records.

Pressure vs. Potential Temperature Coordinates

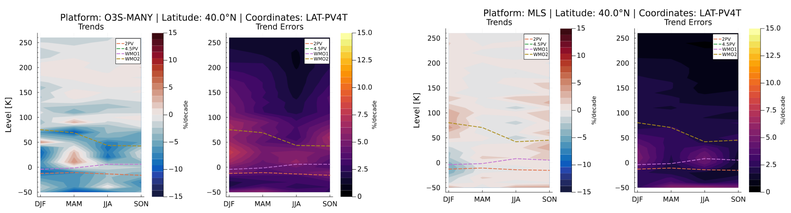


Ozonesonde (O3S-MANY, 2 left panels) and MLS (V01.00, 2 right panels) MM trend analyses. For each set of panels, left column shows trends (%/decade) and right column provides trend uncertainties (%/decade). Top row shows results for datasets binned vertically in pressure and bottom panels are for Theta (Potential Temperature) coordinates. Also shown are monthly averaged tropopauses (TP) for 2PVU (red), 4.5PVU (green), the first (orange) and second (gold) WMO tropopauses (WMO - "primary" and WMO2-"secondary"). In Theta coordinates, the uncertainty in ozonesonde trends is reduced near the TP, but it is still significantly larger than in MLS trends.

Use of Tropopause as reference for binning



Binning profile data relevant to tropopause (4.5PVU) shows that trends immediately above (up to the secondary TP) and below the 4.5PVU tropopause (zero level) become less extreme in ozonesonde data. This coordinate almost completely removes negative trends in MLS data. The uncertainty of the trends is also largely reduced in ozonesonde trends and somewhat reduced in MLS trends near the tropopause (zero line).



- Combining data into **seasonal records reduces sampling biases** in ozonesonde data and reduces uncertainties in both ozonesonde and MLS trends. However, the magnitude of MLS trends remains different from ozonesonde results.
- **Further analyses are needed to test the sampling biases in the ozonesonde data (i.e. subsample MLS data over ozonesonde station geographical location, matching with the dates of sonde launches), and how to improve horizontal binning.**

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