Is Stratospheric Ozone Recovering as Expected?

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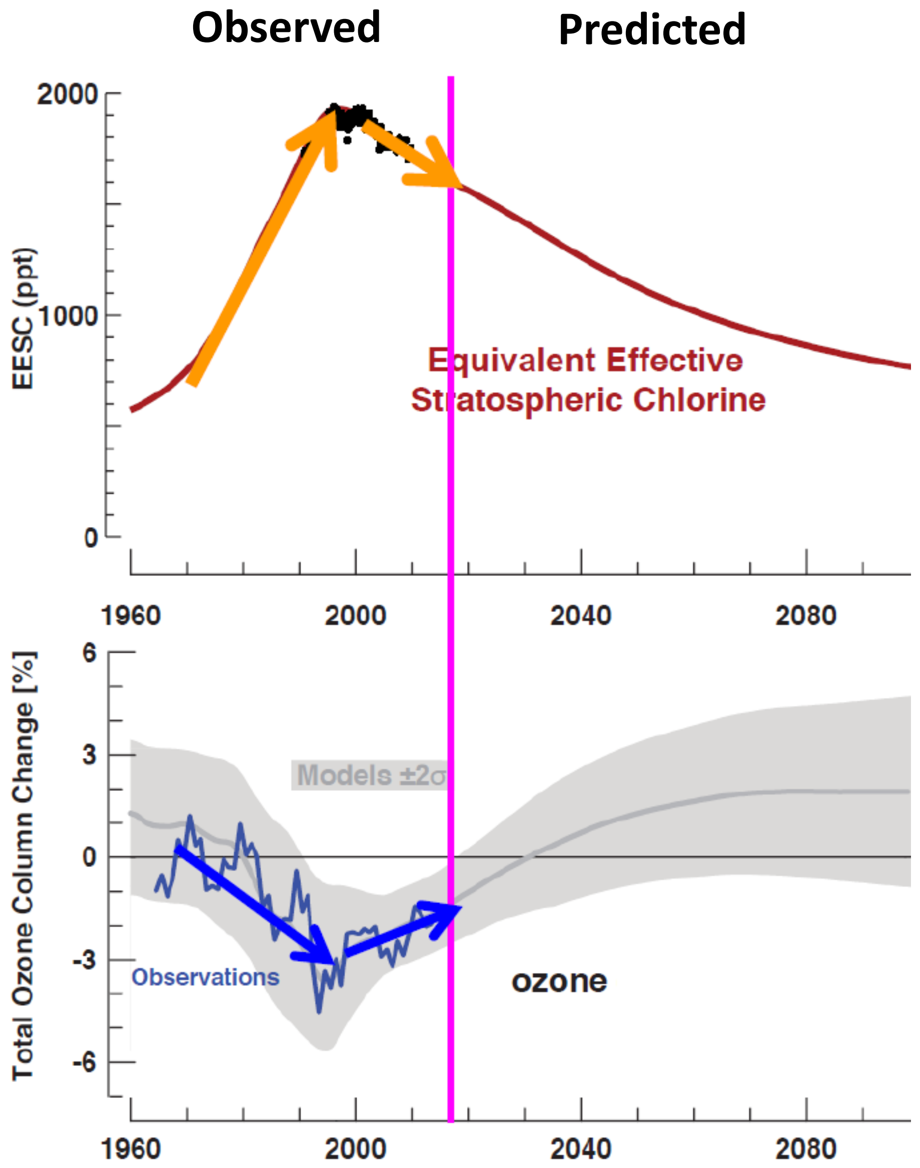
WMO GAW, SPARC, NDACC, NOAA, and many observation and chemistry climate model data providers

Ozone's downs and ups



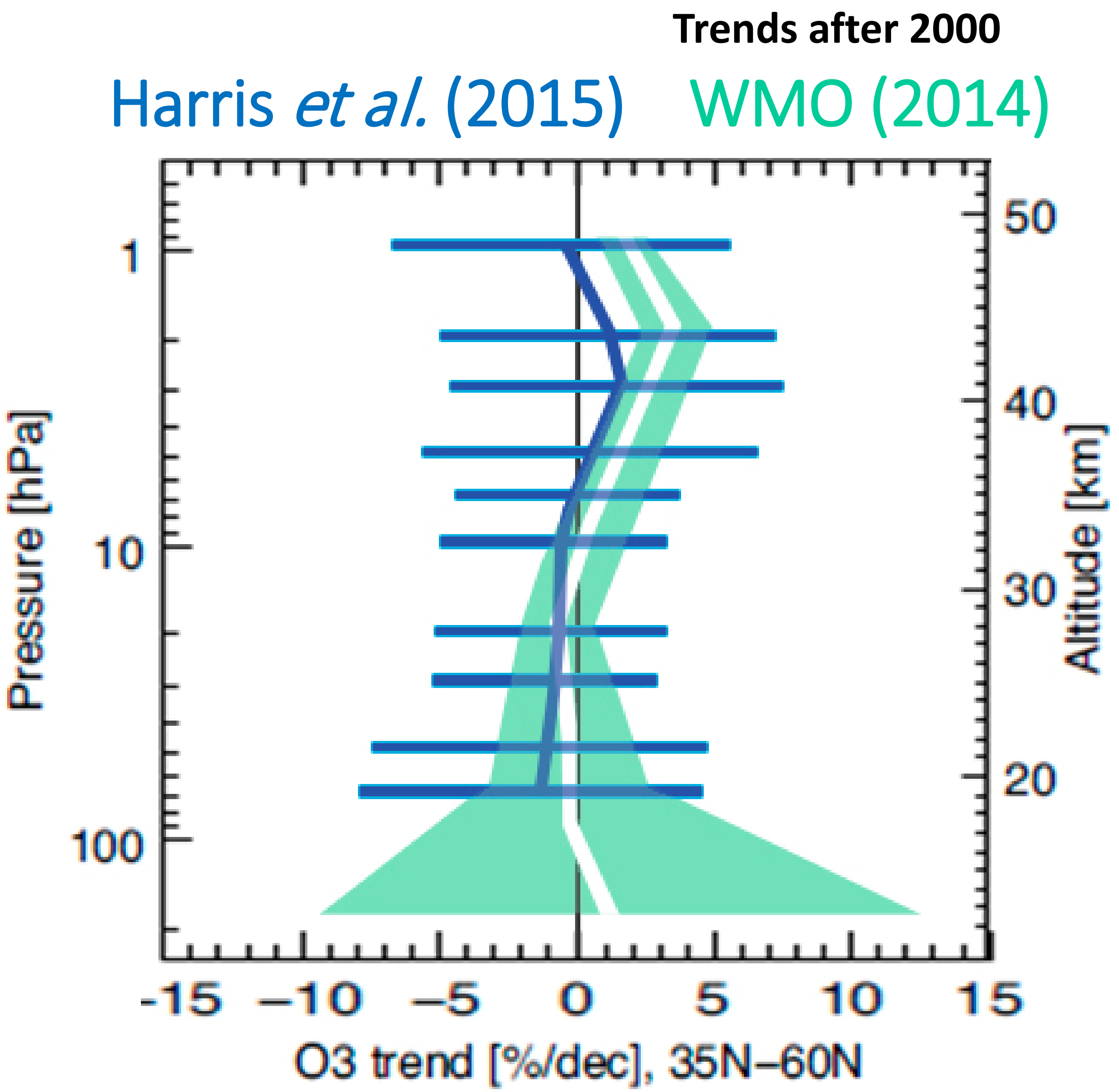
WMO, 2014

- **1960s** – NOAA ozone records
- **1970s** – NOAA ODS records
- **1980s** – Ozone hole is discovered in Antarctica (Bryan Johnson talk)
- **1987:** Montreal Protocol leads to reductions in ozone depleting substances, now down 20-45% from the peak.
- **2016:** Signs of Antarctic ozone layer healing, ground-based and model data (Solomon et al., 2016).

- **Is Stratospheric ozone recovering globally?**

History of WMO and SPARC ozone trend assessments

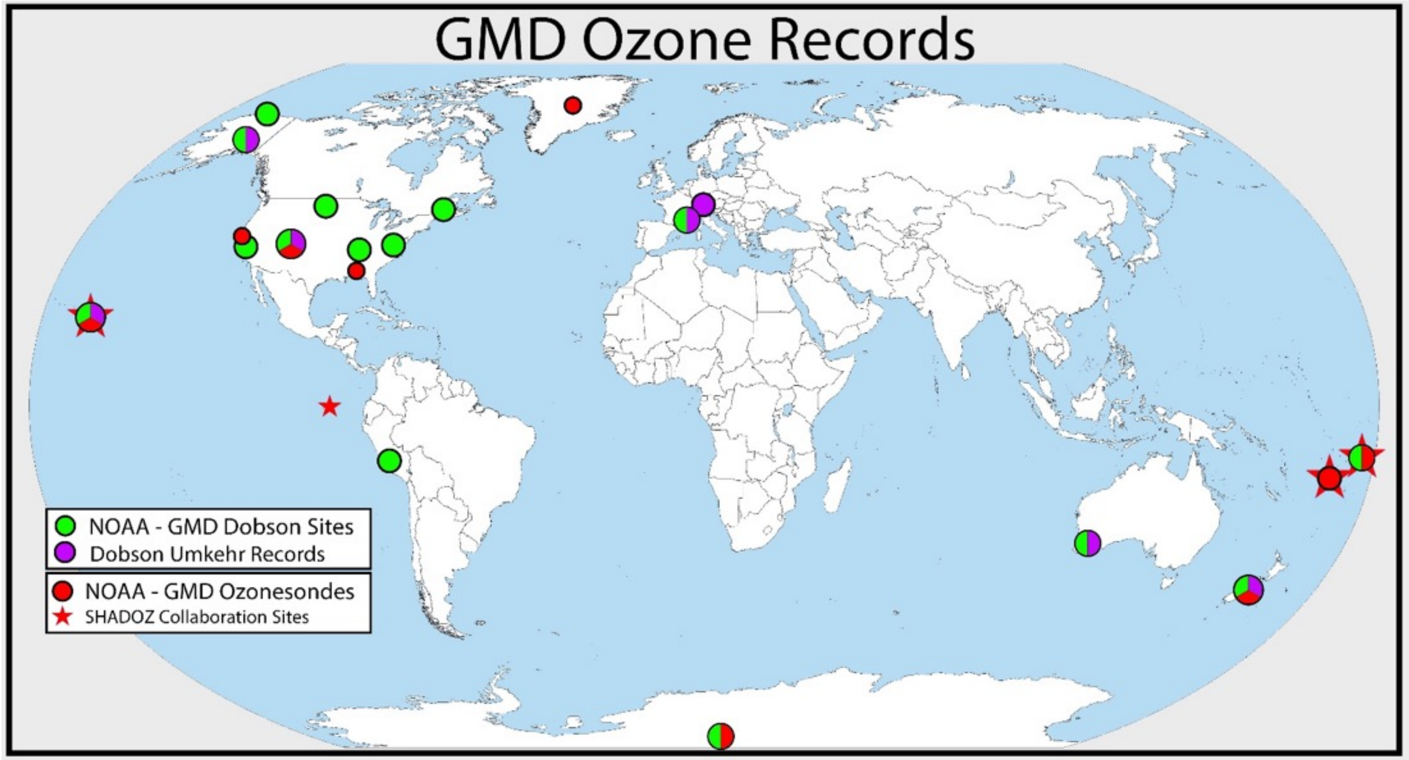
To address the differences between **WMO/UNEP 2014 Ozone Assessment** and **SI2N initiative (Harris et al, 2015)**, a new WMO/SPARC LOTUS (Long-term Ozone Trends and Uncertainties in the Stratosphere) activity was initiated in 2016.



Datasets used in LOTUS and WMO Ozone assessment 2018

- Eight combined global datasets created from multiple satellite records
- Ground-based data, total 43 ozone profile records.
- Seven Model datasets from Chemistry-Climate Model Initiative (Ref2 project)

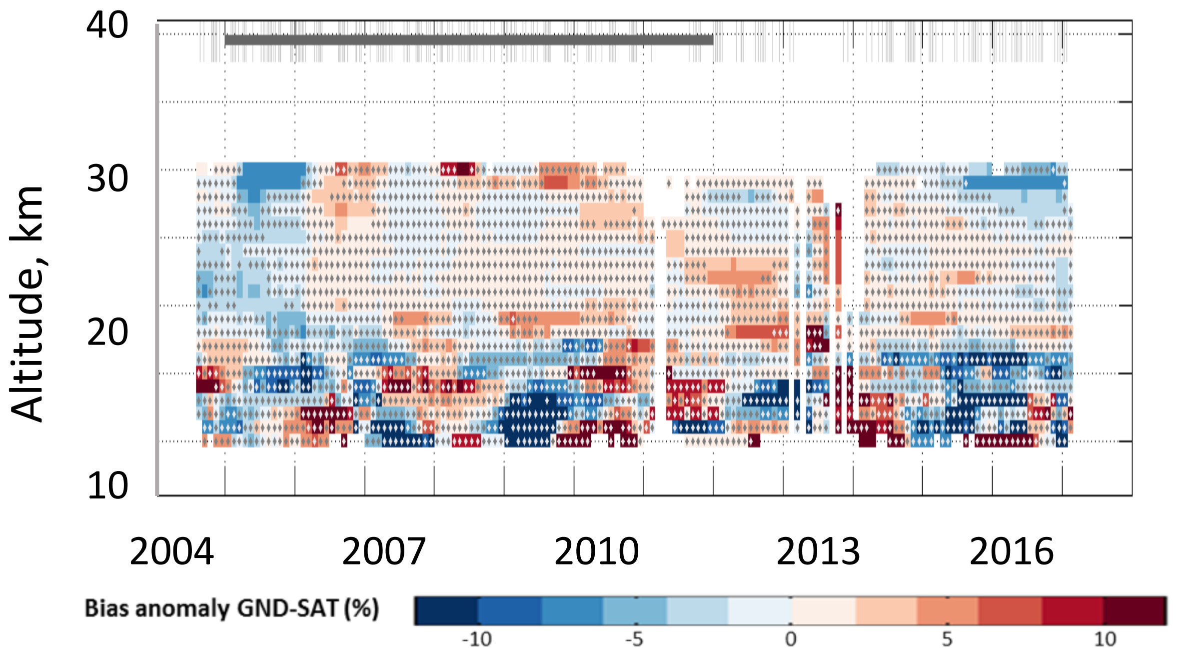
GMD provided 7 **ozonesonde** (including SHADOZ), 6 **Umkehr** and 14 **Dobson** total column records for LOTUS and WMO 2018 trend assessments.



Satellite records: Stability and offsets

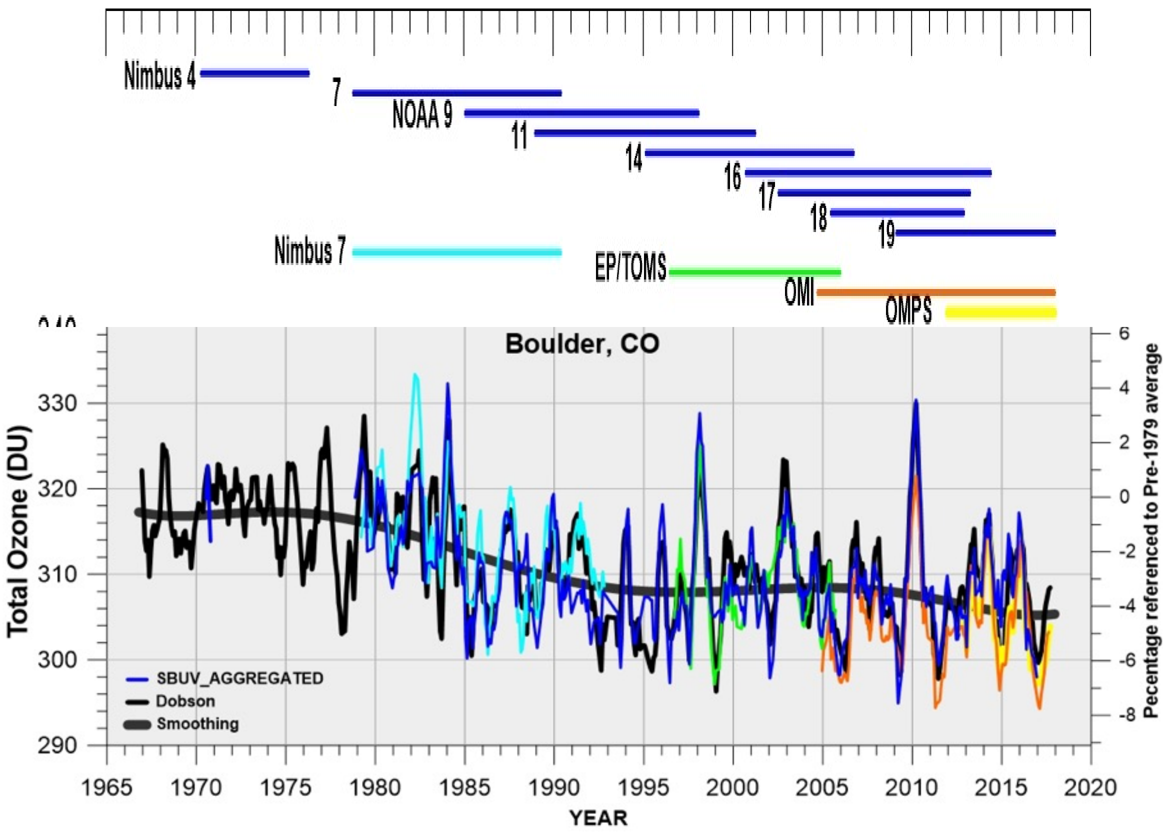
- Use of ground-based data to assess drifts in satellite data
- Remove offsets between satellite records to create combined datasets.

Aura MLS satellite differences from ozonesondes, Hilo



Anomaly of percentage difference SAT-GND wrt median difference in reference period, (Hubert et al, 2018)

Satellites vs Dobson at Boulder

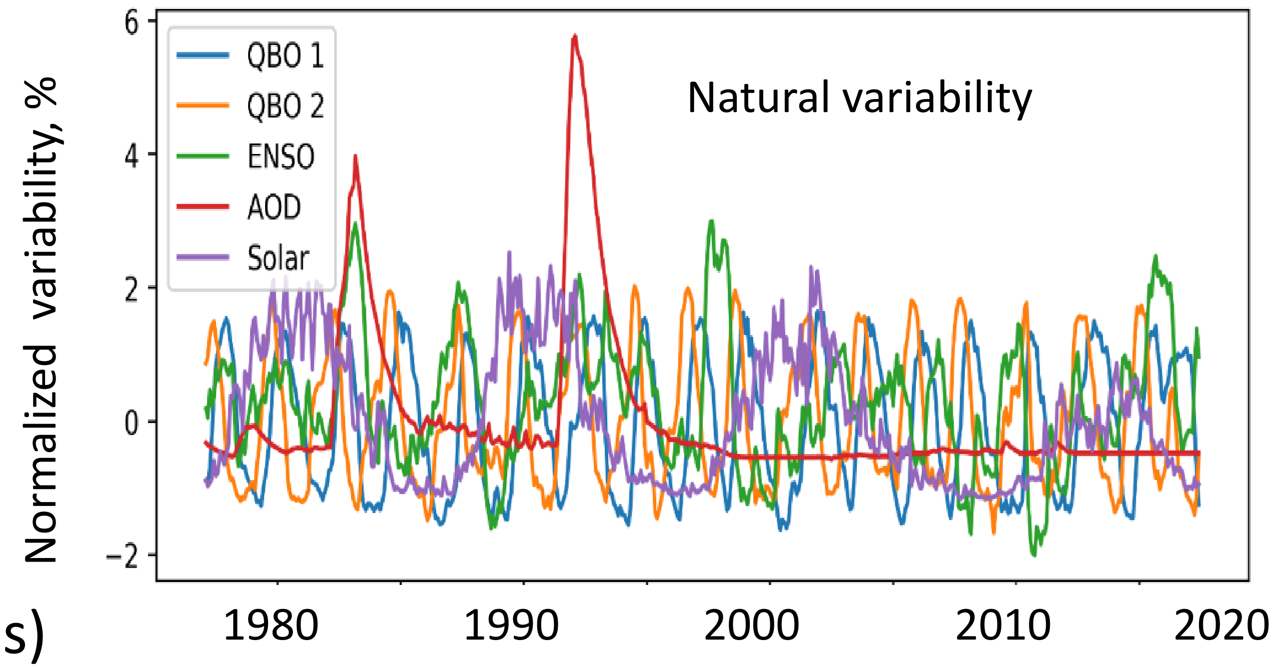


Posters by J. Witte, P. Cullis., K. Miyagawa, G. McConville

Methods for estimating ozone trends

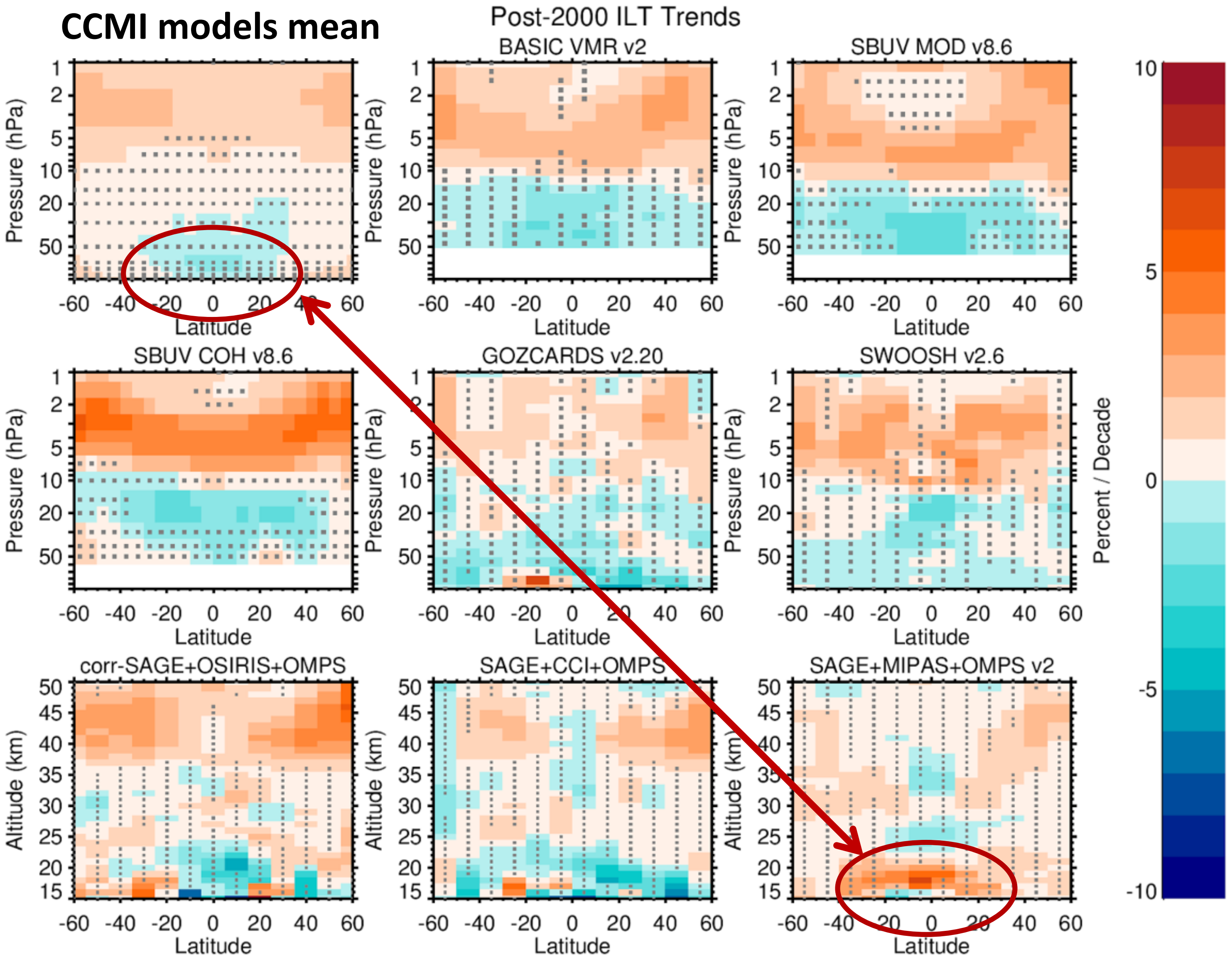
- **Multiple linear regression**
- **Natural variability effects:**
    - 11-years solar cycle (Solar flux 10.7cm)
    - QBO (2 orthogonal components)
    - ENSO (El Nino/La Nino oscillations)
    - Stratospheric aerosols (Volcanic eruptions)
    - Dynamical proxies (Northern Annular Mode,

  Southern Annular Mode, Eddy Heat Flux, tropopause pressure

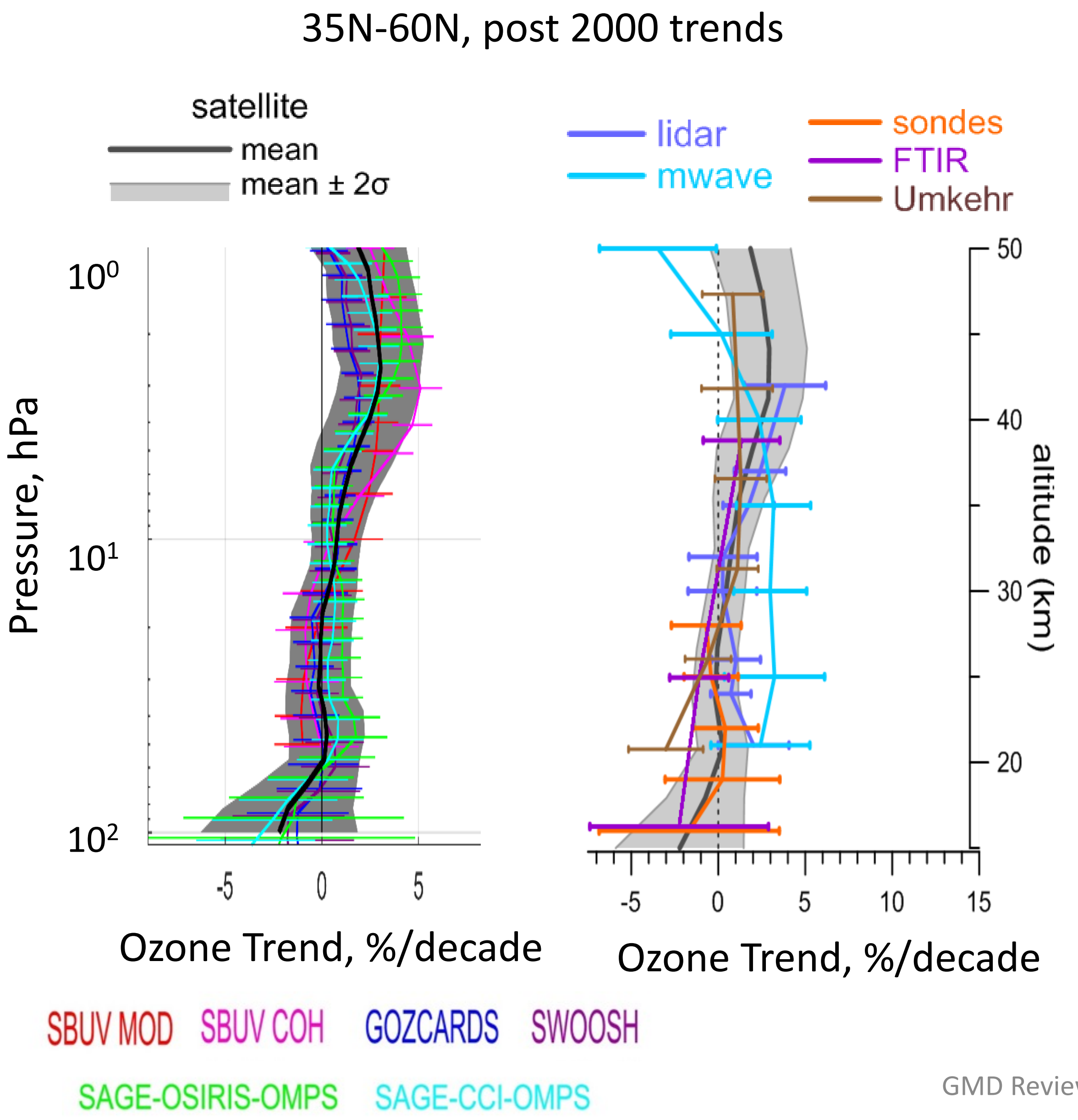


Trend Results: 7 CCMI Models and 8 Satellite combined records

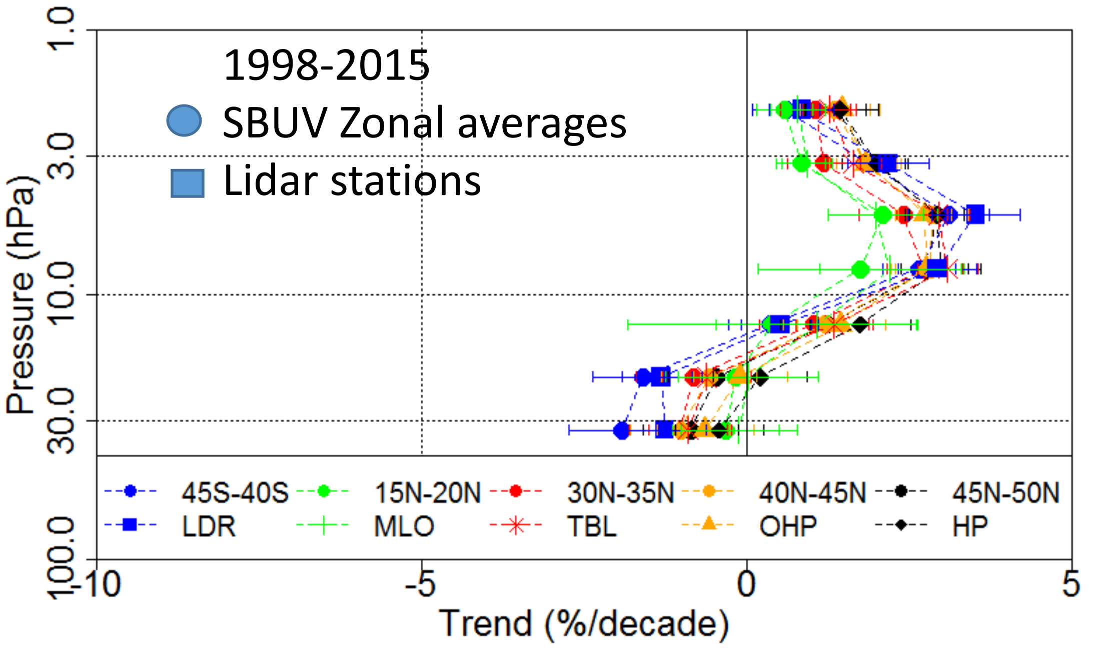
- "LOTUS" multiple regression trend analyses applied to all datasets.
  - https://arg.usask.ca/docs/LOTUS_regression/
- 8 combined satellite records show **similar trend patterns** but clear **discrepancies** exist
- **Upper stratospheric trends agree** with CCMI model expectations, but **lower stratospheric trends are varied and uncertain (Ball et al, 2018)**
- Resolving difference: revisiting the merging process, i.e. using **GMD ground-based data records**



Trend Results: Comparison of Satellites with Ground-based Stations



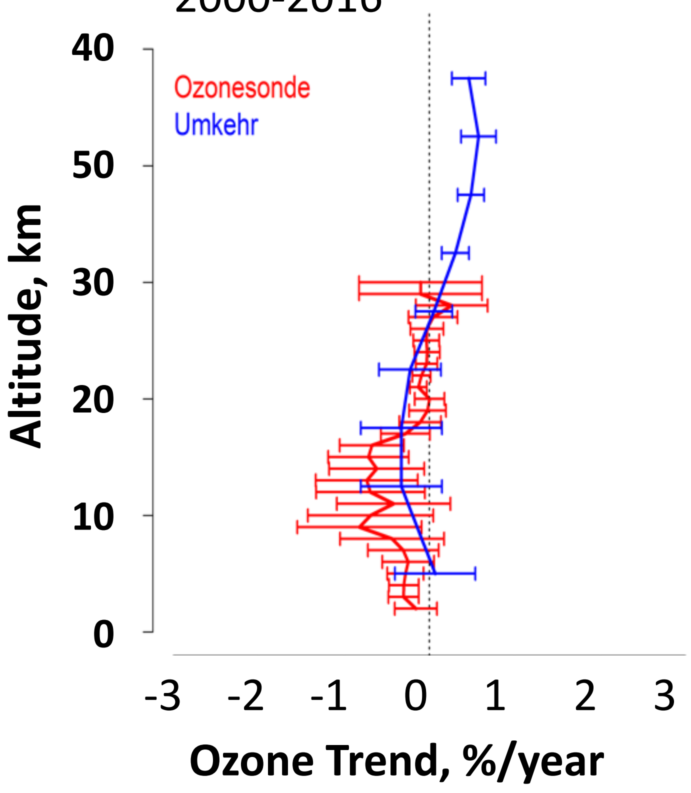
- Consistency in Ground-based (GB) and satellite trends provide confidence in derived trends
- GB broad band trends are influenced by limited sampling (even single-station coverage), thus larger uncertainties
- However, GB ozone observations in the upper and middle stratosphere are representative of zonally averaged trends, but within narrow bands



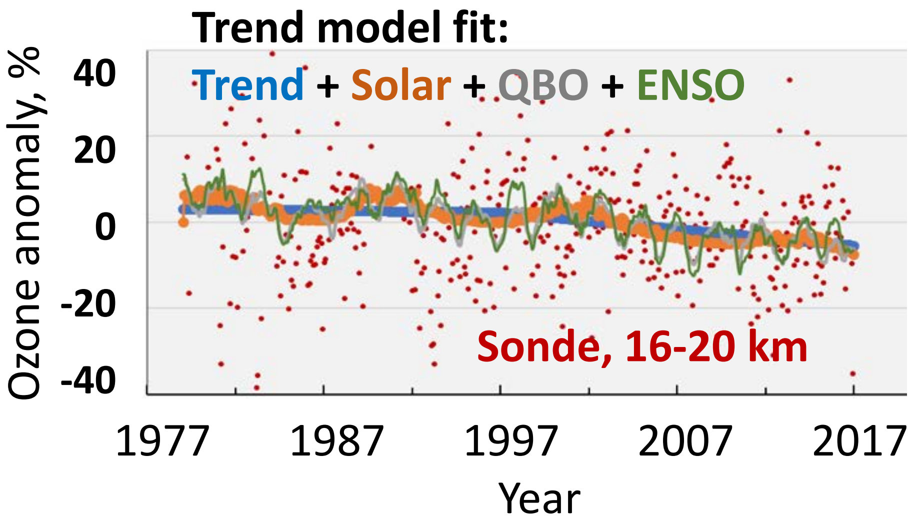
Adapted from Zerefos et al. (2018)

GMD records: Measuring long-term changes in stratospheric and tropospheric ozone

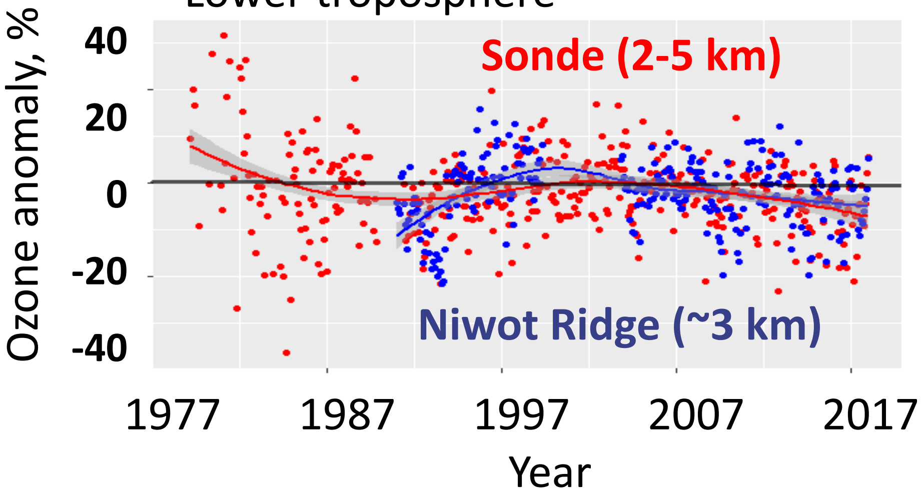
Boulder, 2000-2016



Lower stratosphere



Lower troposphere

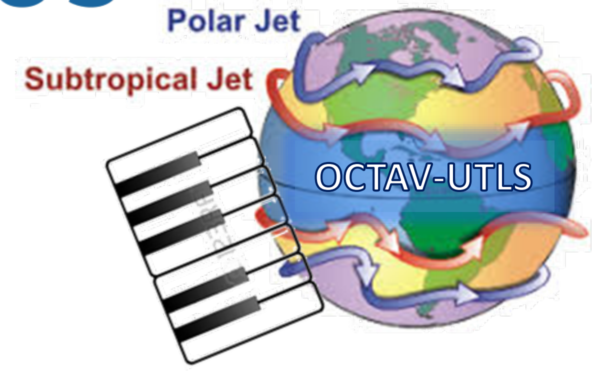


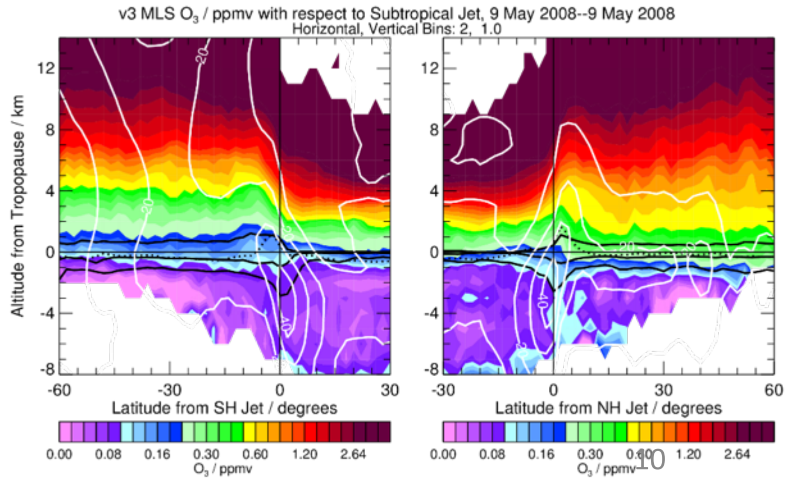
- **LOTUS 2018 and Ozone Assessment 2018 used GMD data.**
- **GMD helped to develop statistical models to interpret trends in ozone profiles and total column.**
- **Lower stratosphere and troposphere – larger variability and thus harder to detect trends and attribute sources.**
- **Ozonesonde homogenization improves confidence in trends**
- **Further work is needed**

Oral presentations on Wed by A. Gaudel, D. Tarasick, A. Langford
Poster: A. McClure, K-L Chang, K. Miyagawa, K. Minschwanner

Conclusions and Next Steps

- Ozone is recovering in the **upper stratosphere**
  - Magnitude and patterns are consistent in different datasets and in model simulations.
  - recovery trends (2-3 % per decade) in NH are the most significant.
- Lower stratosphere
  - Large uncertainties and discrepancies between models and observations.
  - Complicated ozone variability due to dynamical effects or ODS replacements (Ball et al., 2018).
  - Further analyses are needed **– GMD ozone records can help!**
- WMO/SPARC LOTUS report to be published (May 2018)!
- Future plans:
  - Thoroughly investigate drifts and implement corrections
  - Expand trend studies: total column data, tropospheric ozone and ozone in polar regions
  - Explore trends in UTLS in conjunction with other SPARC efforts, i.e OCTAV-UTLS activity (I. Petropavlovskikh, G. Manney, P. Hoor)
  - **– GMD ozonesonde records are essential!**

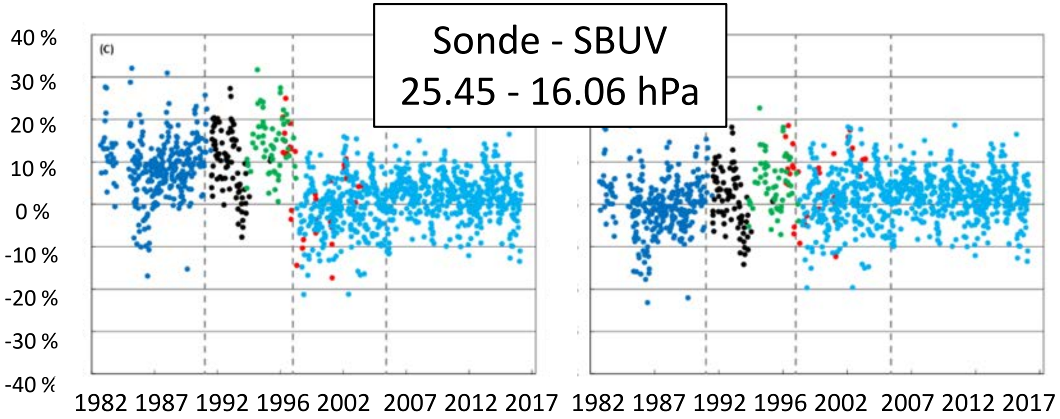




B) Measuring long-term changes in stratospheric ozone

– *To allow an understanding of ozone column changes by altitude (ODS+GHG+transport)*

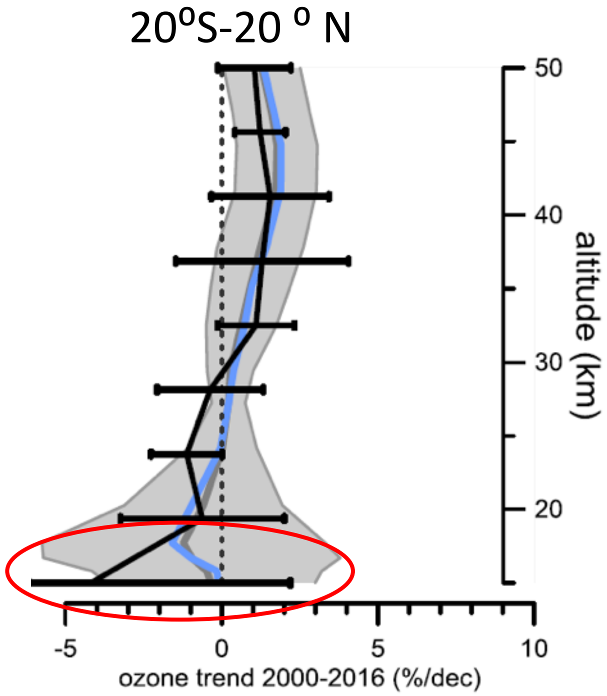
Is ozone in lower stratosphere still decreasing? Ball et al (2018) analyses are based on satellite records



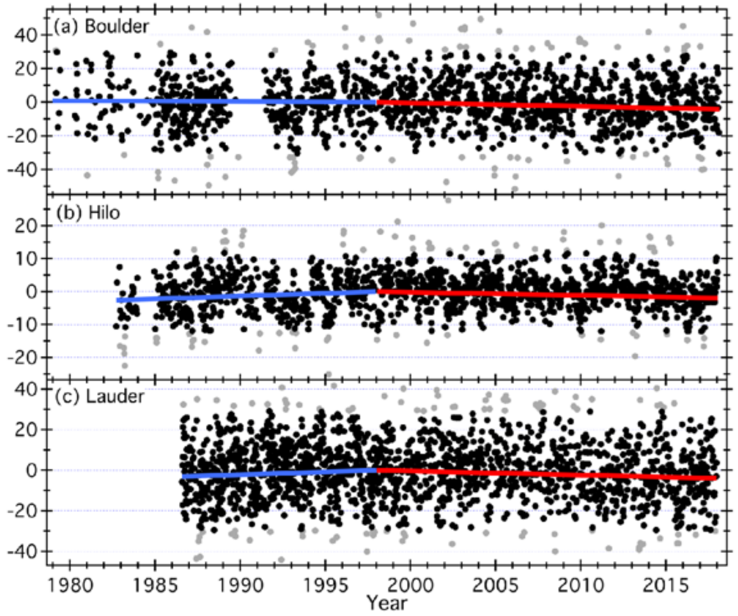
Homogenization for GMD (Sterling et al, 2018) and SHADOZ (Witte et al, 2017) ozonesonde data - improved records for future trend analyses

SHADOZ Sites: https://tropo.gsfc.nasa.gov/shadoz

Oral presentation by Witte



Satellite and **CCMI** model averaged trends (LOTUS, 2018, Ozone Assessment) - disagreement between models and observations?



Trends in the low stratosphere will be soon assessed from homogenized ozone-sonde data in tropics and middle latitudes.

Negative trends in ozonesonde and models (Wargan, 2018)