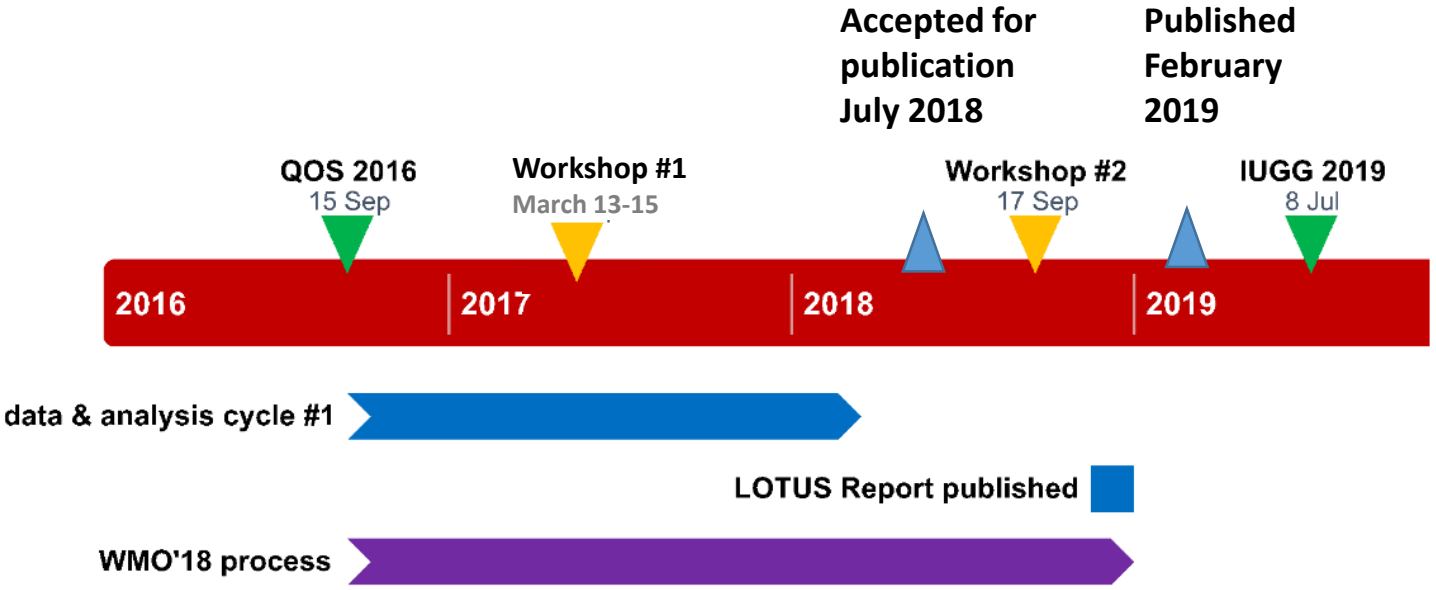
Stratospheric ozone recovery: summary of the SPARC/WMO/IO3C LOTUS analyses

The LOTUS team

SPARC activity

I. Petropavlovskikh, S. Godin-Beekmann, D. Hubert, R. Damadeo, B. Hassler, V. Sofieva, K.-L. Chang, K. Tourpali, W. Ball, S, Frith, J .Wild, L. Froidevaux, S. Davis, D. Degenstein, D. Zawada and 30 participants

Timeline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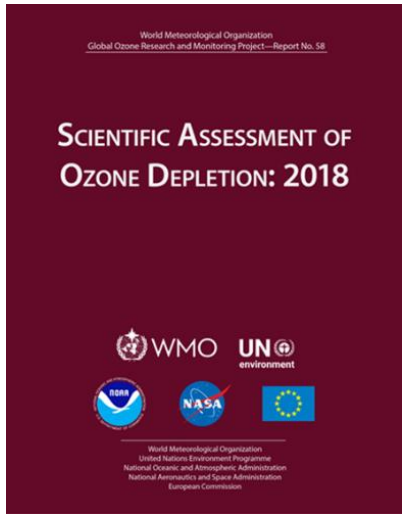
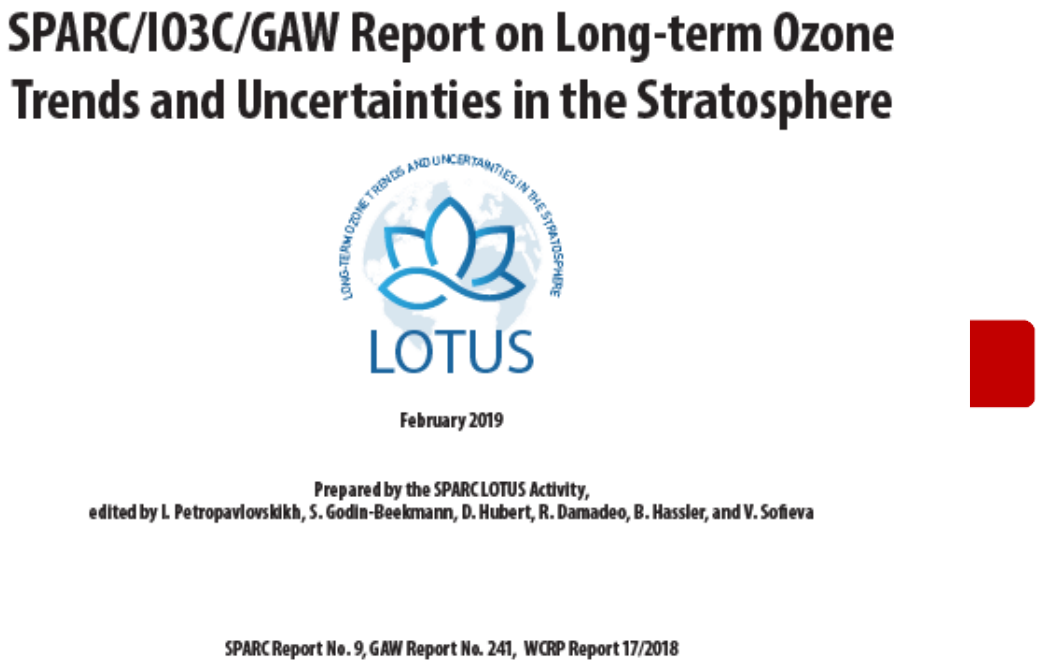
SPARC
GLOBAL ATMOSPHERE WATCH
IOC International Ozone Commission
SPARC/IO3C/GAW Report on Long-term Ozone Trends and Uncertainties in the Stratosphere
LOTUS


World Meteorological Organization
Global Ozone Research and Monitoring Project—Report No. 58
SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2018
WMO
UN environment
NASA

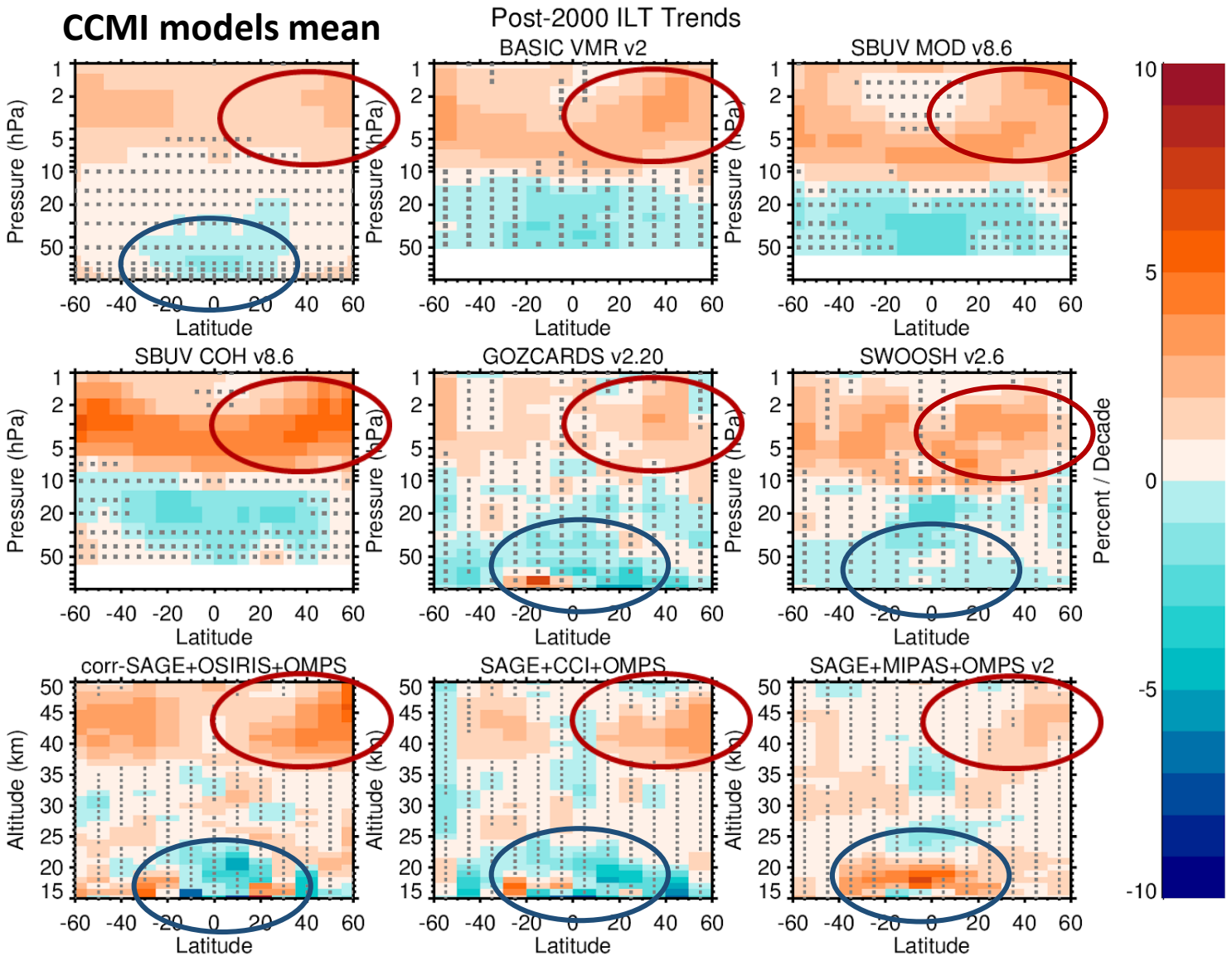

SPARC/IO3C/GAW Report on Long-term Ozone Trends and Uncertainties in the Stratosphere
LOTUS
February 2019
Prepared by the SPARC LOTUS Activity,
edited by I. Petropavlovskikh, S. Godin-Beekmann, D. Hubert, R. Damadeo, B. Hassler, and V. Sofieva
SPARC Report No. 9, GAW Report No. 241, WCRP Report 17/2018
SPARC
Stratosphere-troposphere
GLOBAL ATMOSPHERE WATCH
International Ozone Commission
WCRP
World Climate Research Programme
International Science Council

LOTUS 2018 Report

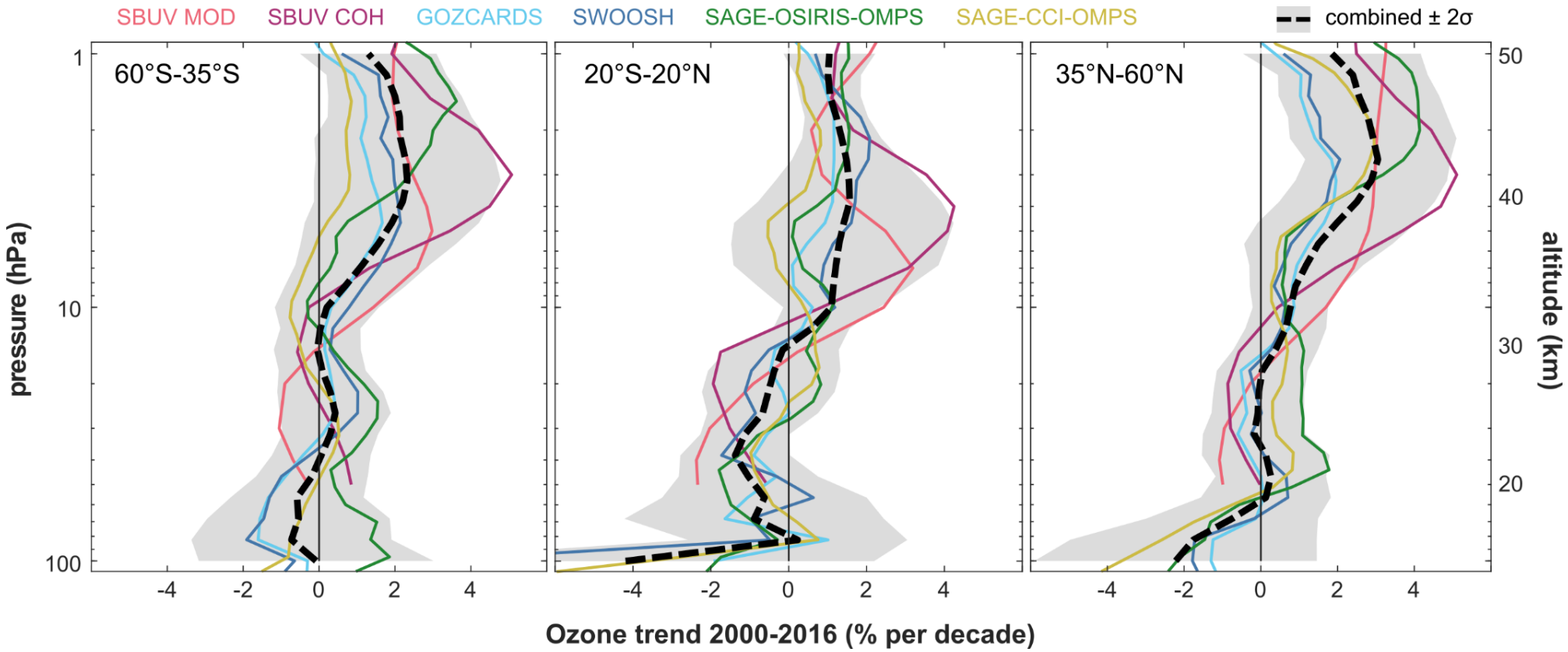
- Executive summary
- Chapter 1: Introduction
- Chapter 2: Observations and model data
- Chapter 3: Challenges for trend studies
- Chapter 4: Methods for estimating ozone trends (The LOTUS trend regression model available online)
- Chapter 5: Time series and trend results
- Chapter 6: Supplemental

Chapter 5: 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**
- Resolving difference: revisiting the merging process for satellite records and using **homogenized ground-based data records**



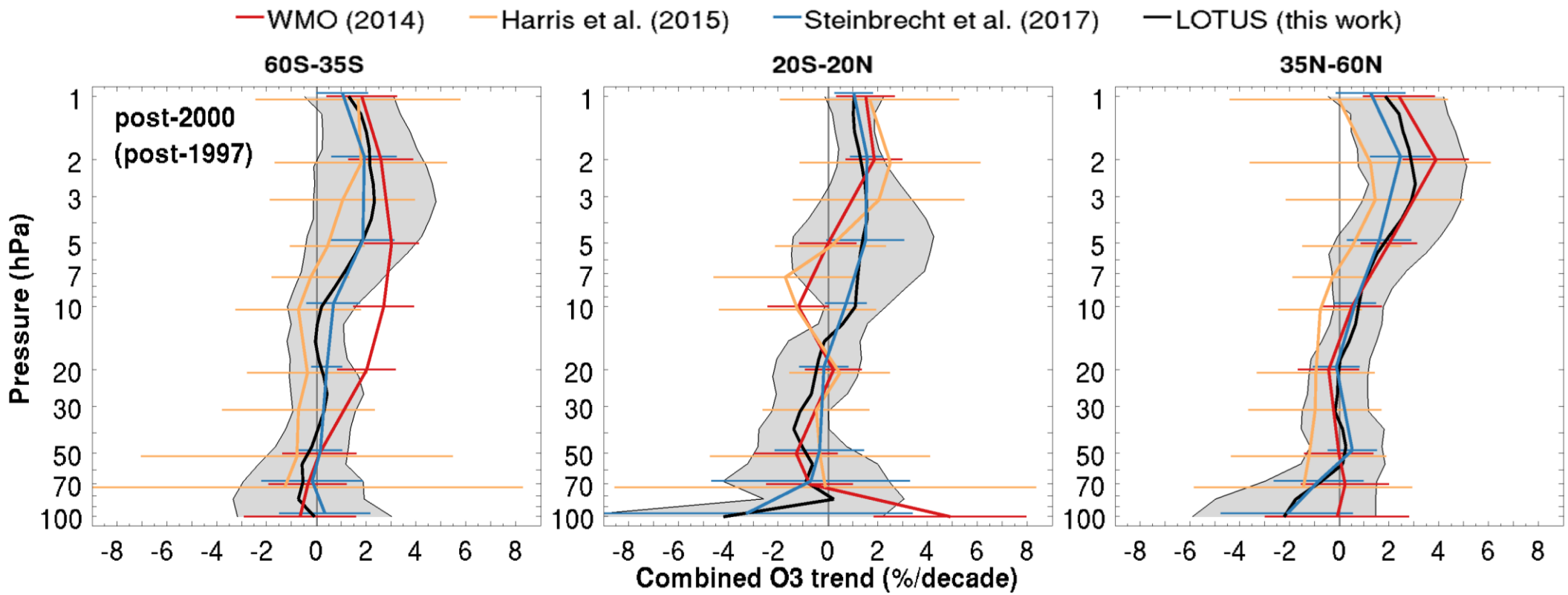
Chapter 5: Trends at Broad Latitude Bands for satellites and uncertainties



- Simple merging of trends but uncertainties need to be carefully considered:

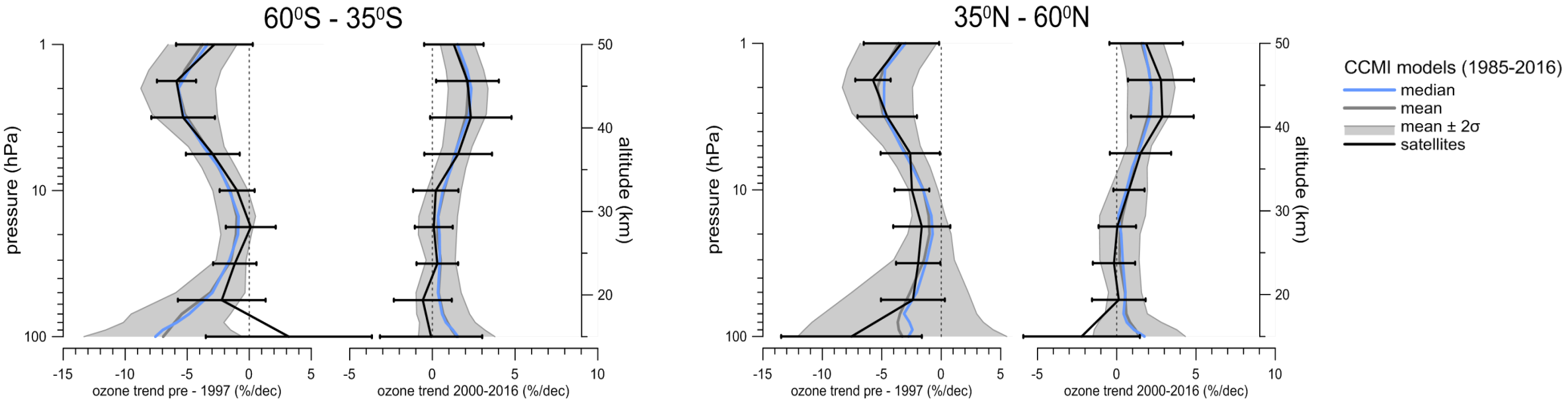
$$\sigma^2_{mean} = max\left(\frac{1}{N^2}\sum_{i,j} C_{i,j}\sigma_i\sigma_j, \frac{1}{n_{eff}}\sum\frac{(x_i-\bar{x})^2}{N-1}\right)$$, where $C_{i,j}$ are the correlations between data set fit residuals

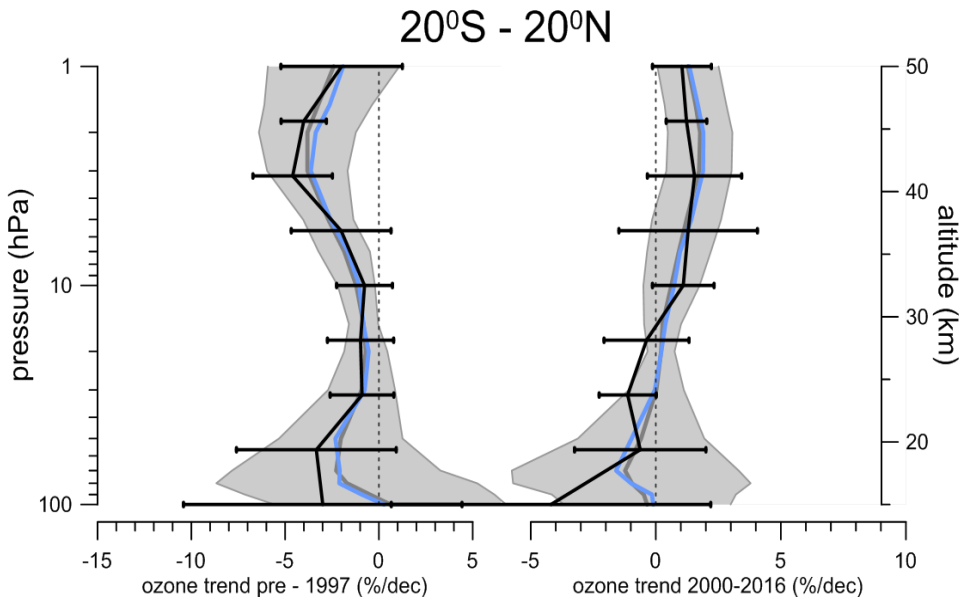
Executive summary: Comparisons of LOTUS with other studies.



- Results are in reasonable agreement with other recent studies (i.e., WMO, 2014; Harris et al., 2015; Steinbrecht et al., 2017)
- Uncertainty estimates vary

Chapter 5: Comparison of Satellites with Models





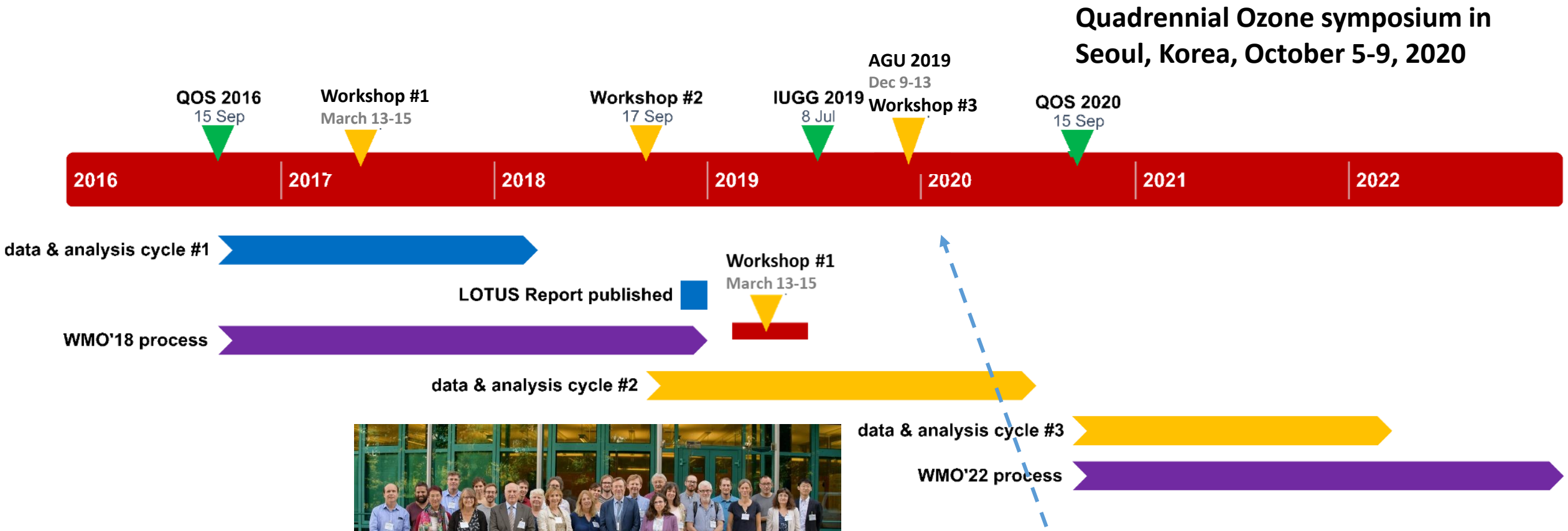
- Satellites show good agreement with models in middle to upper stratosphere
- The agreement in lower stratosphere is within uncertainties of the trends
- Uncertainties in LS trends are large due to large (dynamically driven) atmospheric variability that MLR does not capture (K. Rosenlof and W. Ball presentation)
- Large spread in CCMI trends in low stratosphere

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 (i.e. Ball et al., 2018, Chipperfield et al, 2018).
  - Further analyses are needed
- WMO/SPARC LOTUS report published 2/2019

GAW Report No. 241, doi: 10.17874/f899e57a20b, www.sparc-climate.org/publications/sparc-reports

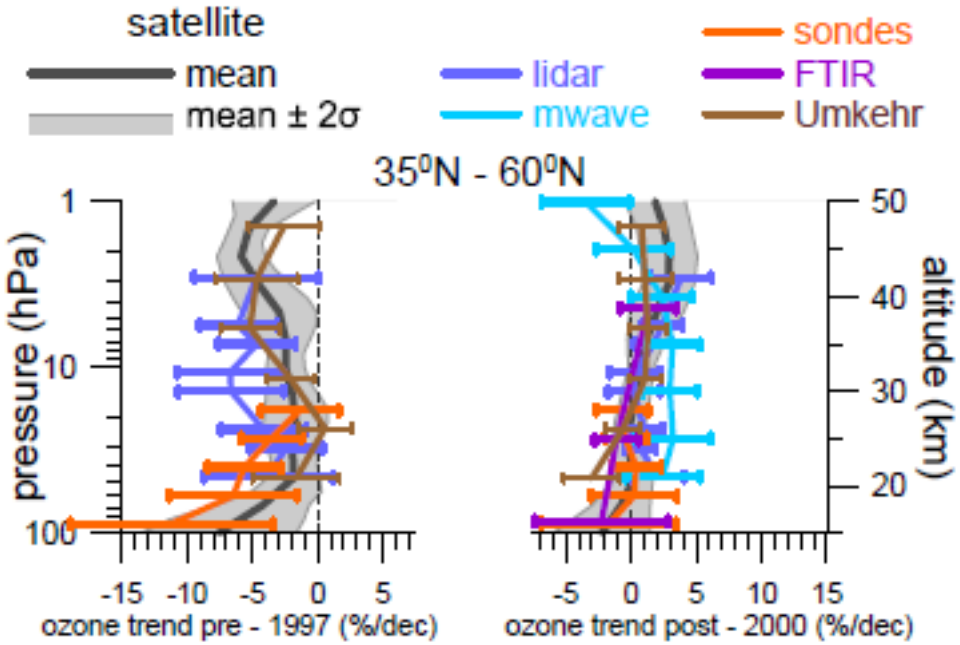
Timeline for 2022 Ozone assessment

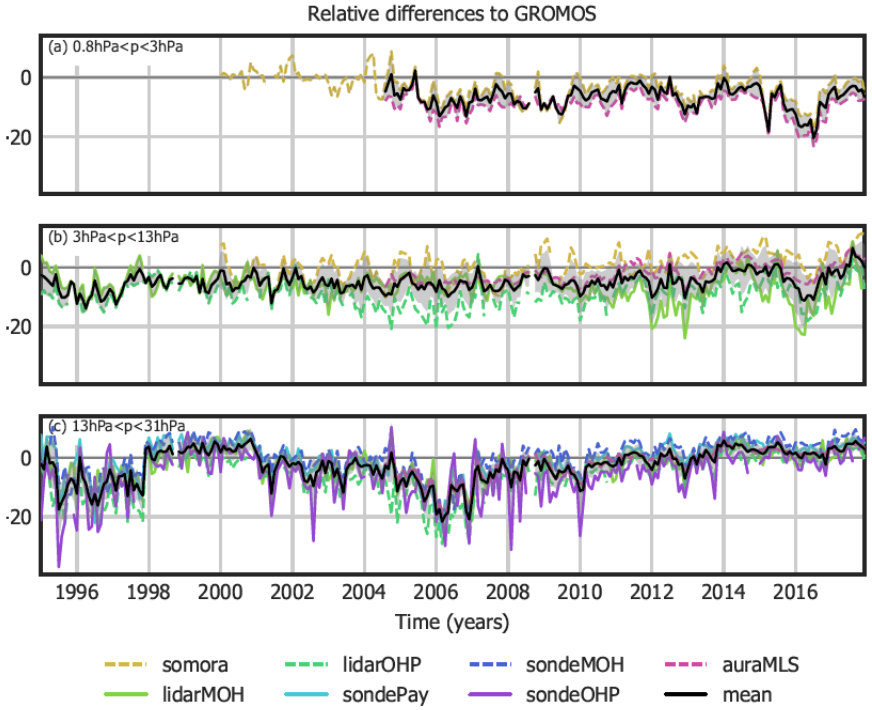


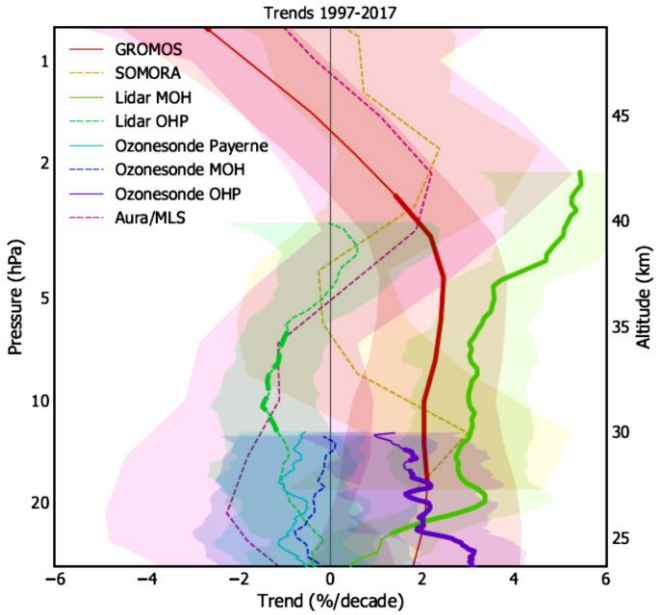
A119. Stratospheric composition change, its impact on climate and understanding of uncertainties in data records.

LOTUS phase 2:

- LOTUS 2 Workshop, Geneva, September 17-19, 2018
- Thoroughly investigate drifts in satellite & GB data and implement corrections (O3S-DQA ozonesonde homogenization, Bernet et al., 2019).







LOTUS phase 2:

- LOTUS 2 Workshop, Geneva, September 17-19, 2018
- Thoroughly investigate drifts in satellite & GB data and implement corrections (O3S-DQA ozonesonde homogenization, Bernet et al., 2019).
- Expand trend studies:
  - Optimization of trend model for GB records: sampling biases, measurement uncertainties, dynamical proxies, seasonal trends. (more in S. Godin-Beekman presentation)
  - Coherence between stratospheric ozone, total column and tropospheric ozone (i.e. Arosa ozone history, “The Light Climatic Observatory Arosa” by Staehelin and Viatte, 2019),
  - Ozone in polar regions

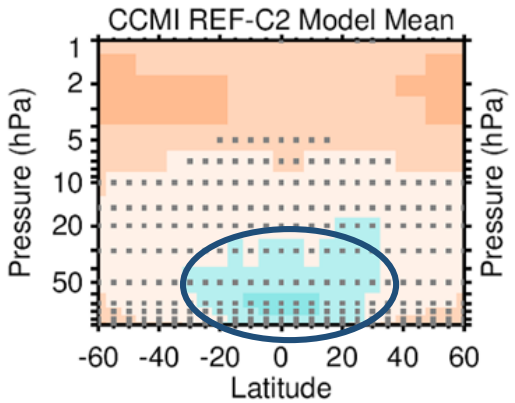
Assets:

- LOTUS multiple linear regression (MLR) trend model, download from https://arg.usask.ca/docs/LOTUS_regression
- Dynamical linear model (DLM; Laine et al., 2014; Alsing, 2019: github.com/justinalsing/dlmmc)

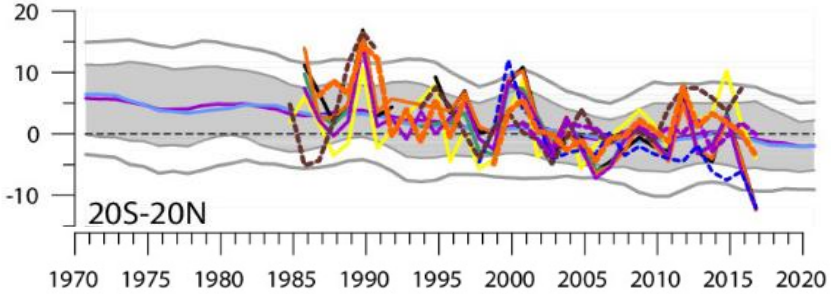
LOTUS phase 2:

- LOTUS 2 Workshop, Geneva, September 17-19, 2018
- Thoroughly investigate drifts in satellite & GB data and implement corrections (O3S-DQA ozonesonde homogenization, Bernet et al., 2019).
- Expand trend studies
- Use of Climate transport models for trend attribution and Involvement of CCMI PI's in LOTUS trend studies
- Explore trends in UTLS in conjunction with other SPARC efforts, i.e SPARC OCTAV-UTLS activity
- New and updated datasets for trend analyses in UTLS: **limb satellites, ozonesonde, lidar and aircraft records are essential!**

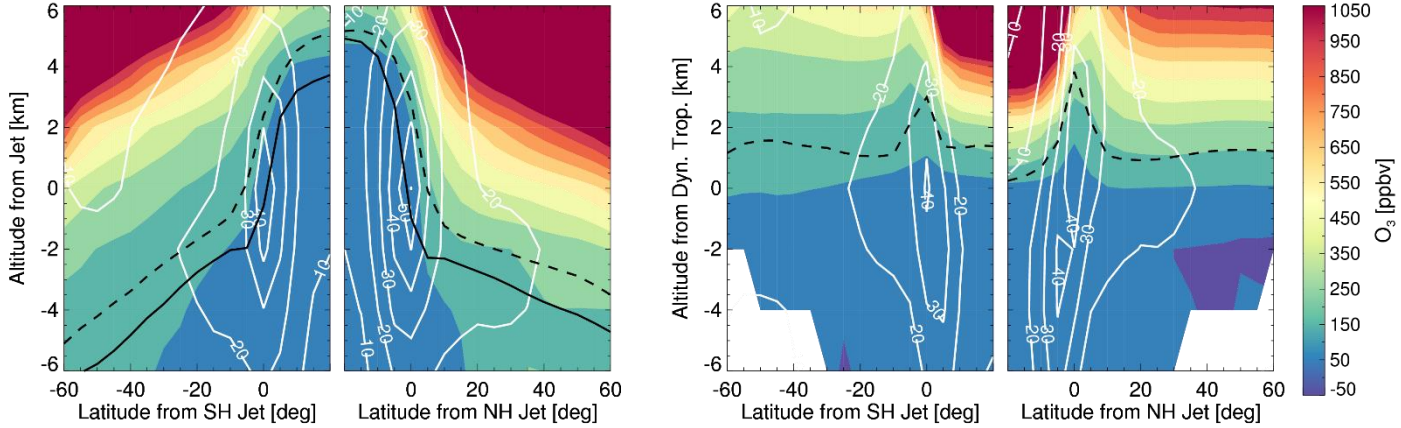
OCTAV – UTLS
Observing Composition Trends and Variability in the UTLS
(P. Hoor, L. Millan, I. Petropavlovskikh)



Lower stratosphere (70 hPa)



MLS, DJF 2011-2013, 2 PVU tropopause, Subtropical Jet



OCTAV-UTLS

- account for dynamically induced variability of tracers and trends
- quantify trends and variability in UTLS composition by applying consistent analysis methods using cross platform observations
- See poster M21p-266

Future activities and team collaborations

- **Optimization** of the LOTUS trend model for **detecting trends in low stratosphere** and attribution to dynamical processes.
- Address **discrepancies in ground-based and satellite trends.**
- Focus on **correction of drifts and instrumental re-characterization** issues in individual instrumental records
- **Extended and revised datasets** to be submitted to the LOTUS ftp site for the second phase of the data analyses **by 2020**.
- Investigation of the **impact of measurement uncertainties on the derived trends**
- Use of level 2 data to **reconcile instrumental record biases and associated step changes** remaining in combined records (BASIC approach in collaboration with the TUNER SPARC activity).

Thank you for collaboration from the LOTUS team!
Until the next time at the Quadrennial Ozone symposium in Seoul, Korea, 2020