Using Observations of HNO_3 and N_2O to Quantify HCl and Ozone Sensitivity to Variability of the Stratospheric Circulation

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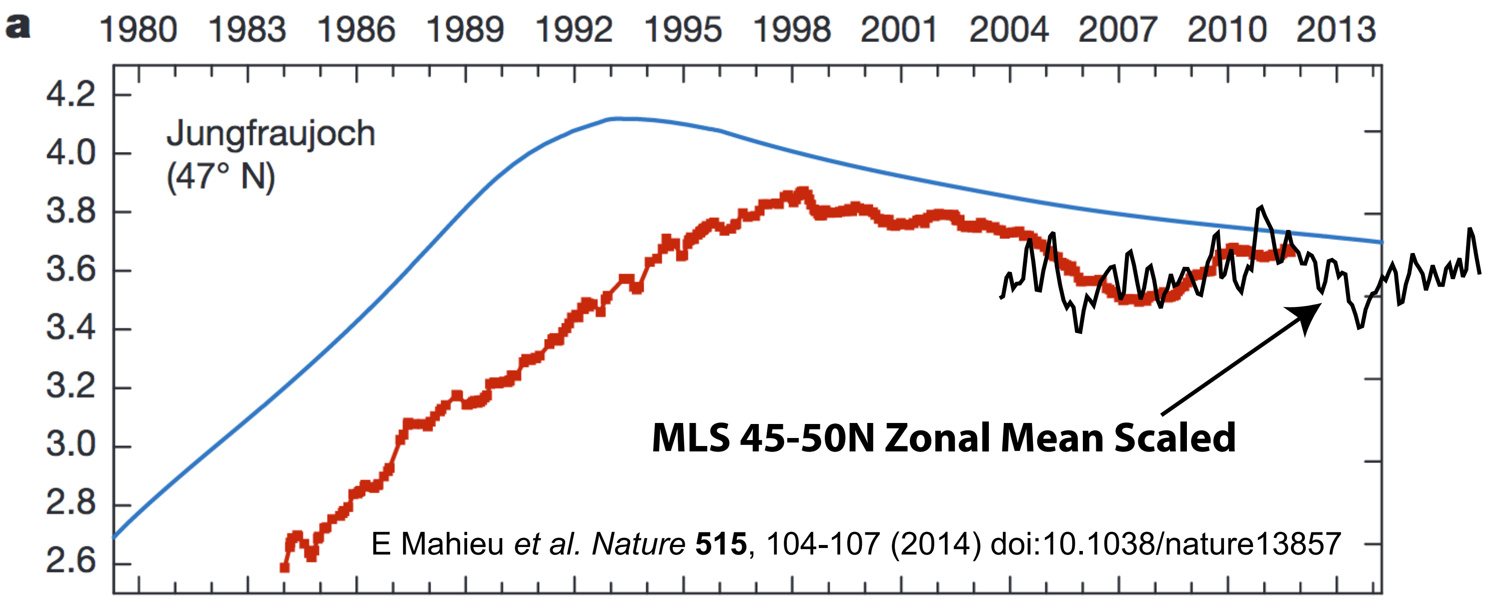
Why do we care about interannual variability in stratospheric dynamics?

- **Interannual variability masks detection of trends**
  a) Masks recovery of chlorine as measured by HCl column amounts
  b) complicates detection of expected upward trend in total ozone or lower stratospheric ozone due to chlorine change

- **On longer time scales, models predict speedup of BDC**
  a) No clear confirmation of these predictions by measurements
  b) Interannual variability of dynamics masks slow predicted change

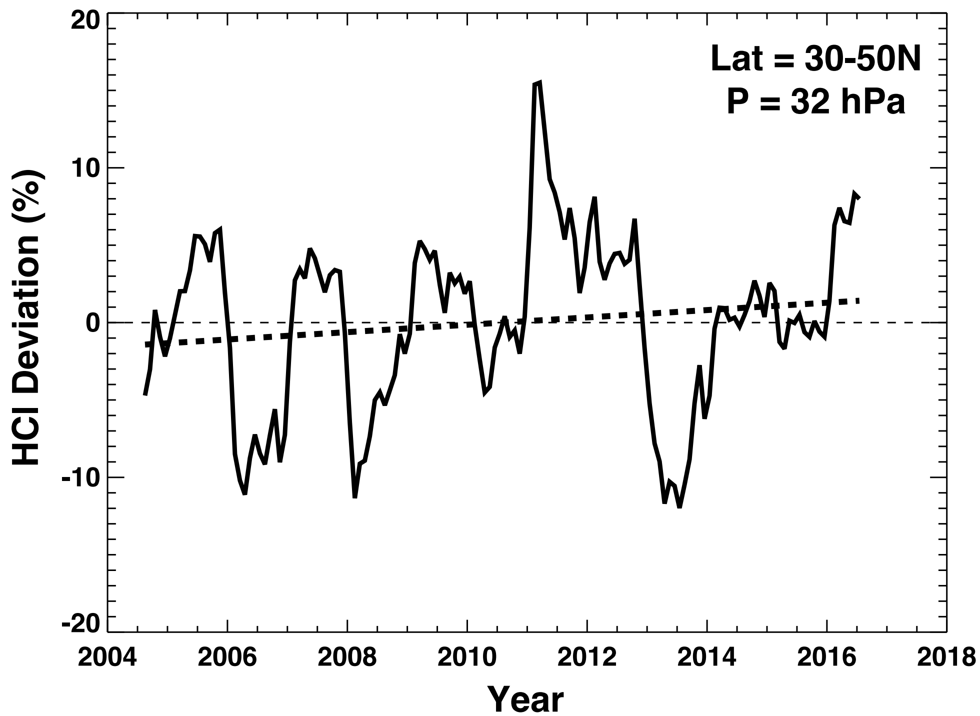
Motivation: HCl column variation at northern



Jungfraujoch data 3-year smoothed
Aura data monthly zonal mean (column 1-100 hPa)

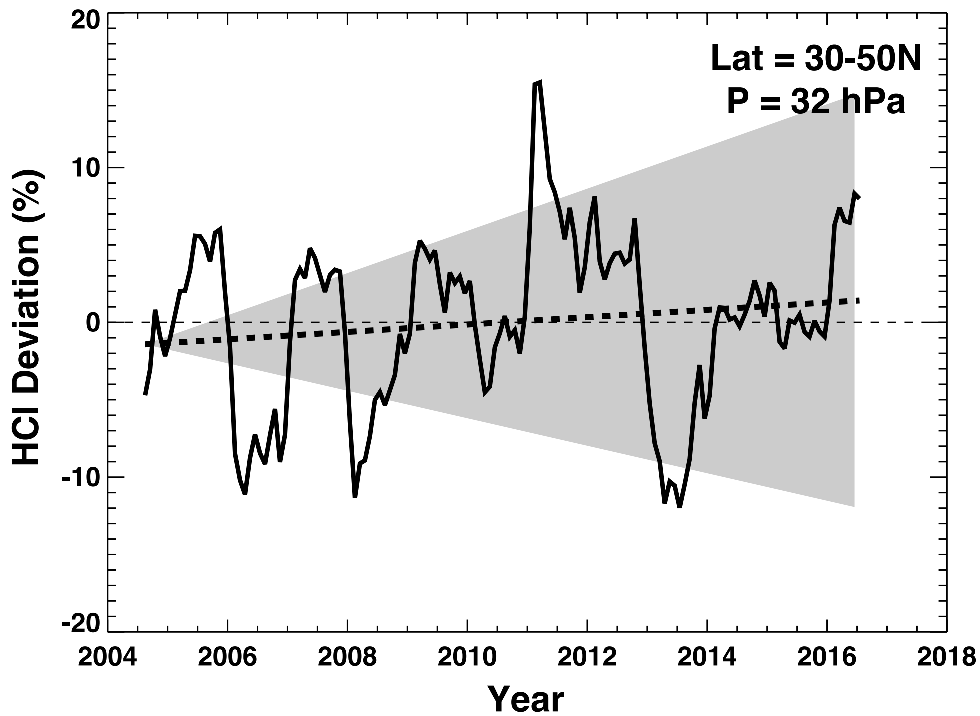
Can we find surrogate for dynamical influence on HCl variation?

Deseasonalized HCl Anomalies at 32 hPa for 30-50N Latitude Band



Small Positive Trend

Deseasonalized HCl Anomalies at 32 hPa for 30-50N Latitude Band



Small Positive Trend

No Statistical Significance

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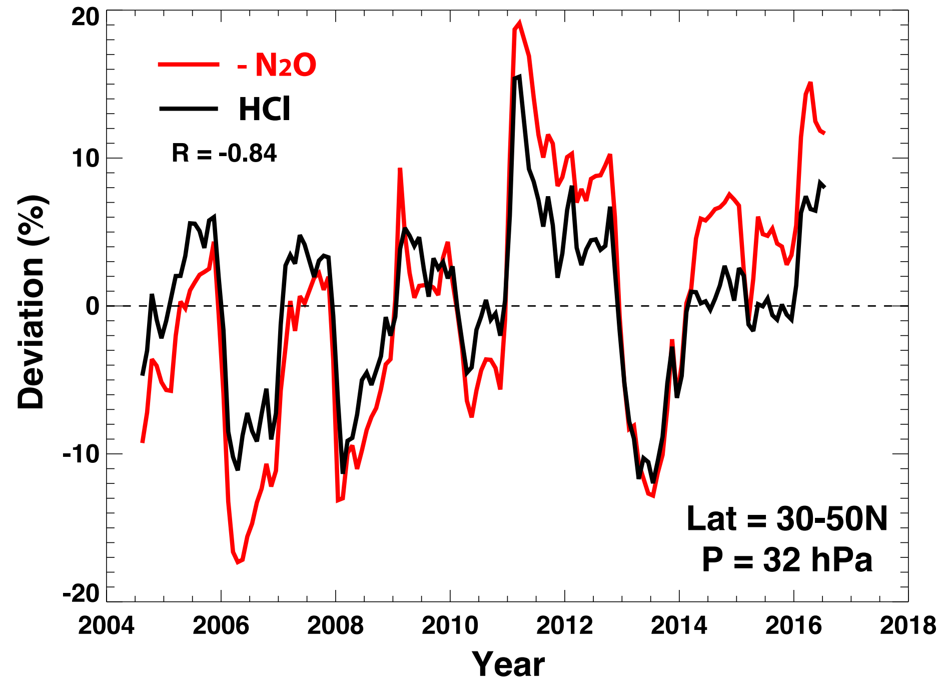
Consider altitude profiles of N_2O and HCl from Aura MLS

- N_2O and HCl both respond to dynamical changes through their spatial gradients
- They are anti-correlated at a given latitude and pressure level

> **Suggests that N_2O variations could be used to model/ remove variability in HCl observations to reveal trend**



Monthly mean anomalies of N_2O and HCl from Aura MLS measurements at 32 hPa averaged between latitudes of 30 to 50N.

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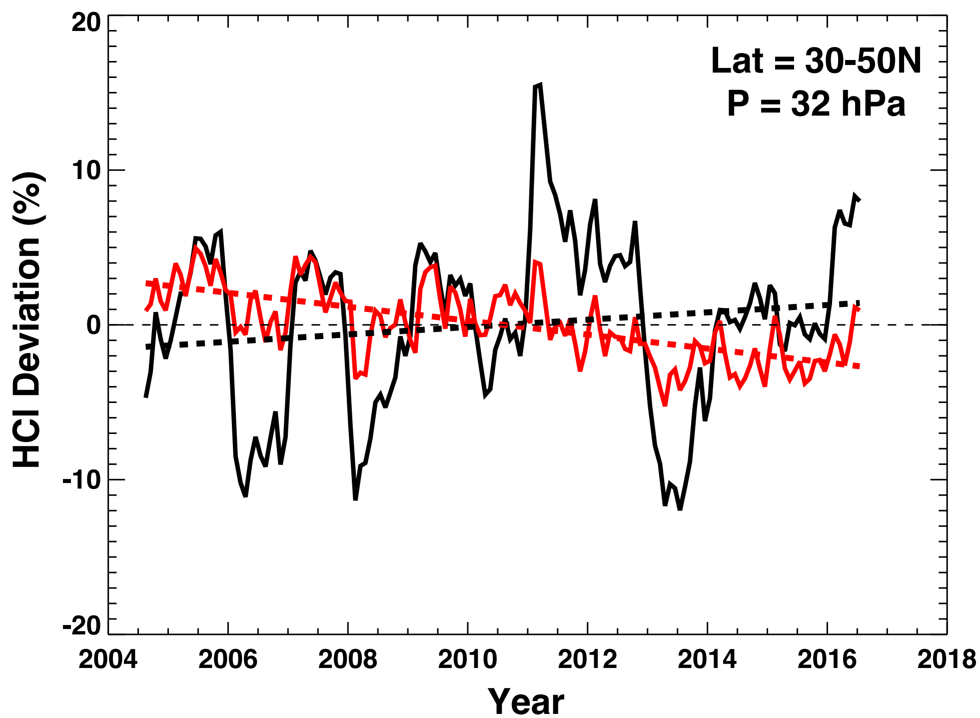
HCl Anomalies with seasonal cycle and N_2O co-variation removed



Negative Trend

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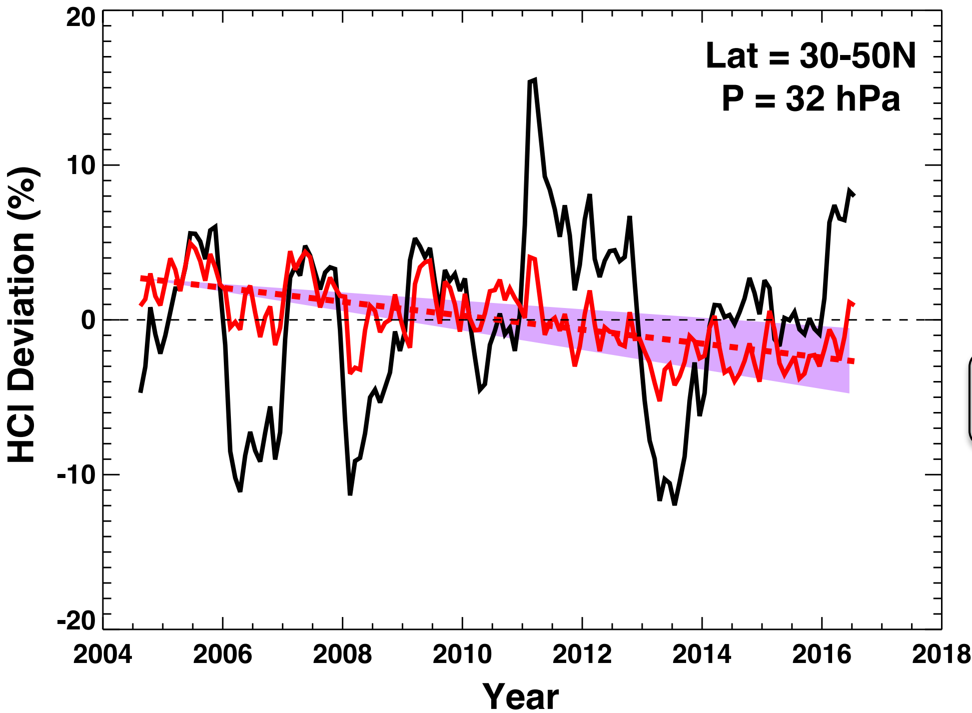
HCl Anomalies with seasonal cycle and N_2O co-variation removed



Negative Trend

Statistically Significant at 2σ

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Fit linear trend to HCl time series at each altitude of reported MLS measurements

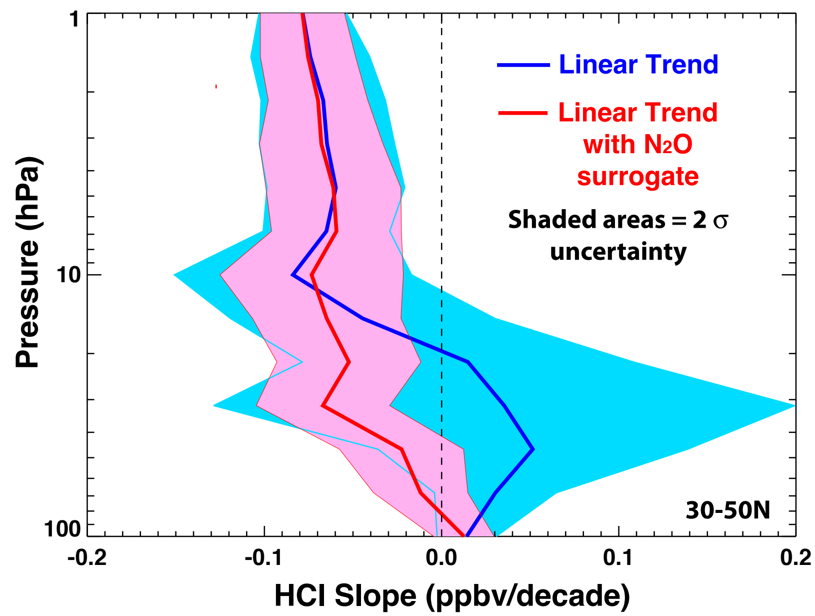
- **First use simple linear trend model**

  $HCl = \mu + \alpha \cdot trend + \beta \cdot seasonal + \varepsilon$

- **Then add term for N_2O anomalies**

  $HCl = \mu + \alpha \cdot trend + \beta \cdot seasonal + \gamma \cdot N_2O + \varepsilon$

Trend changes sign with smaller uncertainty

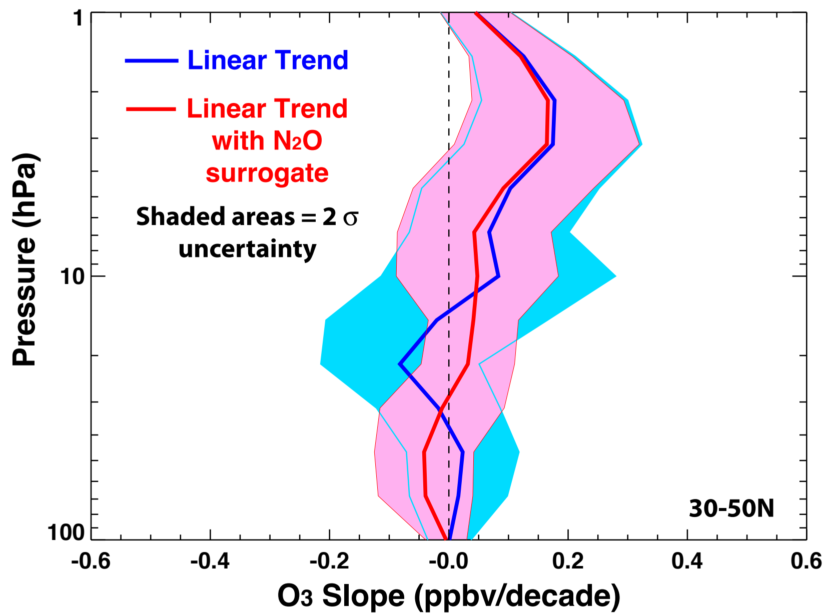


HCl slope from August 2004 through August 2016 from MLS data between 30 and 50 N latitudes. Shaded areas are 2σ uncertainty estimates for trend.

What about O_3?

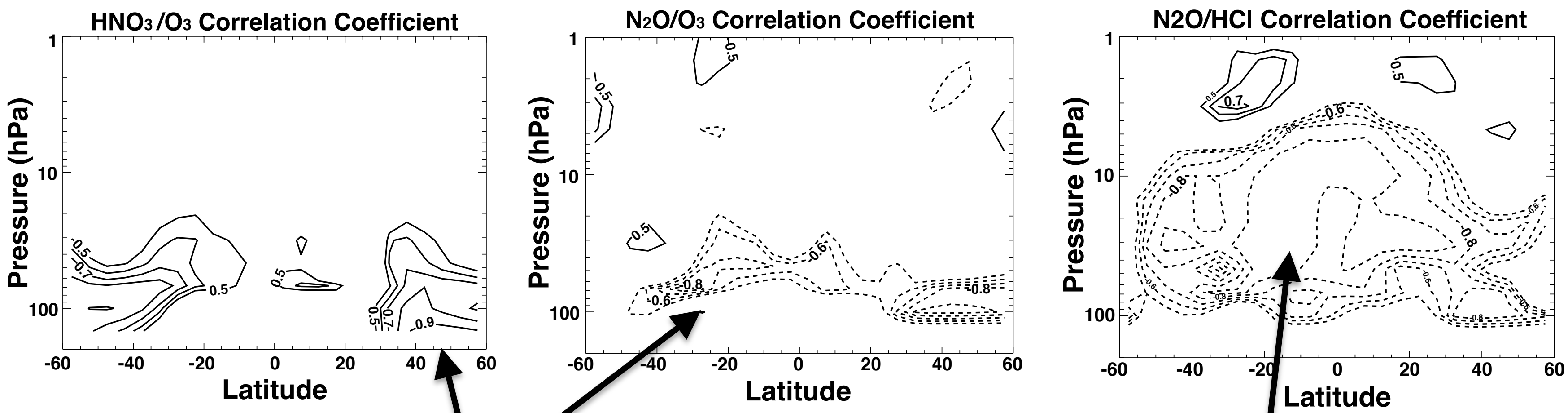
- Using N_2O as fitting term reduces uncertainty in O_3 trend
- Using HNO_3 yields similar results (not shown)
- Calculated trend becomes positive in middle stratosphere as expected, but results are not significant

Accounting for dynamical variability in O_3 trends will be more difficult



O_3 slope from August 2004 through August 2016 from MLS data between 30 and 50 N latitudes. Shaded areas indicate 2σ uncertainty estimates of the trend.

Usefullness of dynamical tracer depends on correlations that are determined by gradients



O_3 and N_2O or HNO_3 are strongly correlated only in the lower stratosphere

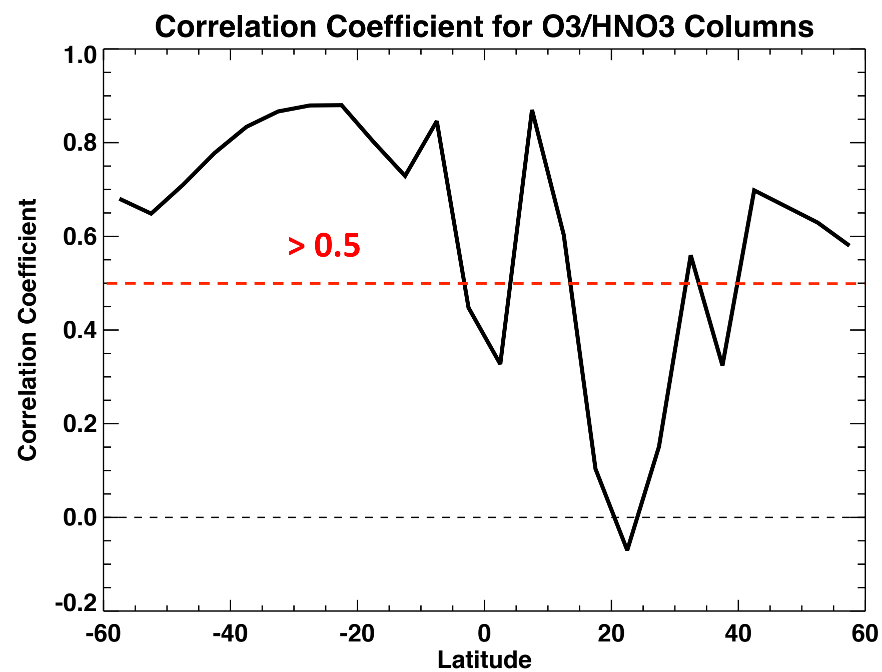
HCl and N_2O strongly anti-correlate over most of stratosphere

Only correlations < -0.5 and > 0.5 shown

Can we do better using column HNO_3 with column O_3?

- Correlation is > 0.5 over entire SH and between 40-60N
- Warrants further examination

Would be very useful as we could extend study back in time using column measurements from NDACC stations



Conclusions

- Dynamical variability introduces uncertainty into trend analysis of chemical constituents such as O_3 and HCl
- Many studies have used dynamical surrogates such as QBO, ENSO, AMO in trend models to try to remove (explain) this variance
- We propose using constituent correlations to accurately model the “whole dynamical” impact on species variability
- We have shown important example of removing variability in HCl measurements from Aura MLS by using measurements of N_2O