Unique Transport Diagnostics From Airborne In Situ Trace Gas Measurements

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Motivation

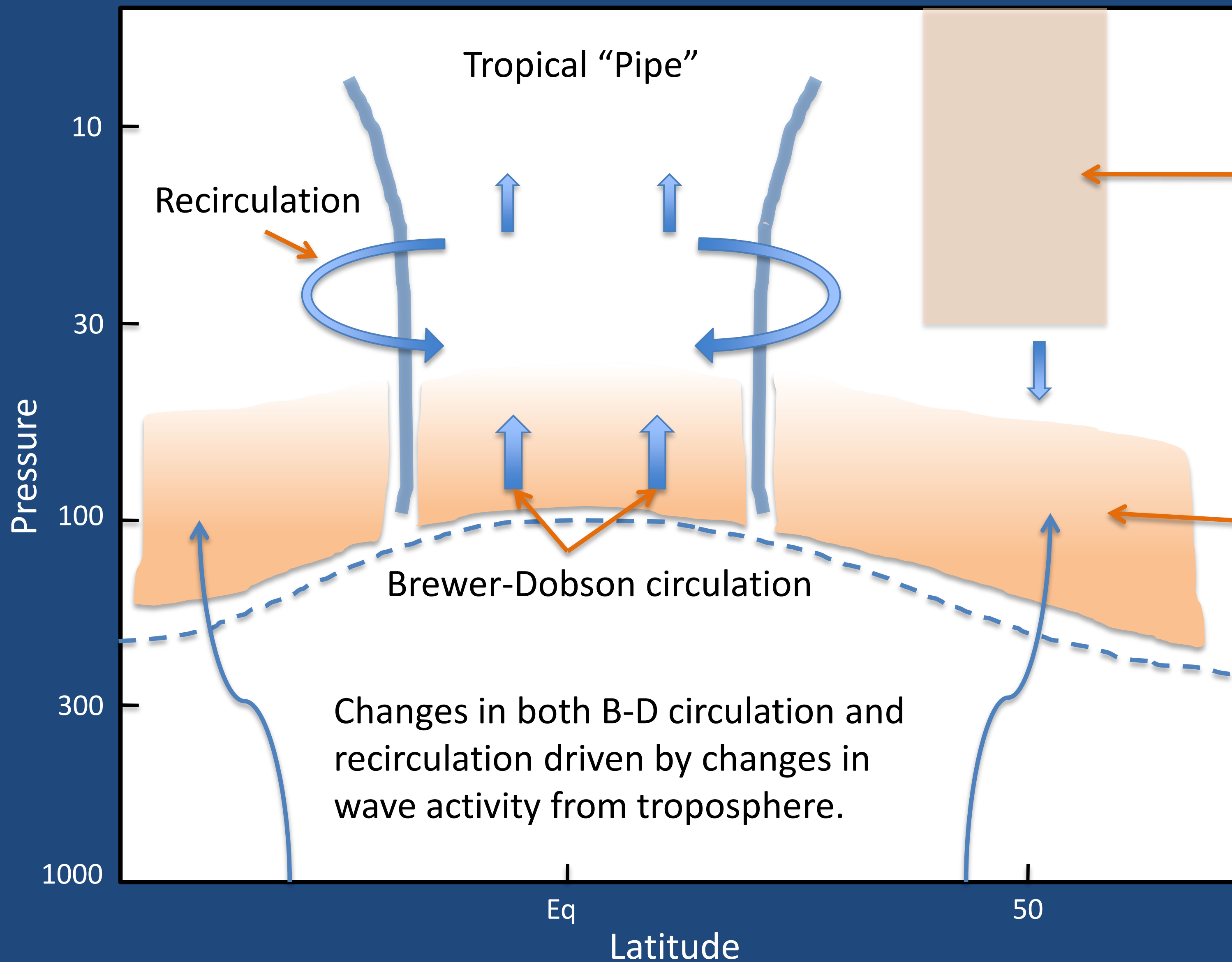
Transport diagnostics from trace gas measurements provide insight into:

- Dynamical (+ chemical) processes
- Sensitivity to change (climate studies)
- Physical process modeling studies
- Chemistry-climate models

Long-term monitoring of these relevant trace gases are critical to help understand greenhouse gas variability.

Three examples briefly shown here…

1. Stratospheric Circulation Trends



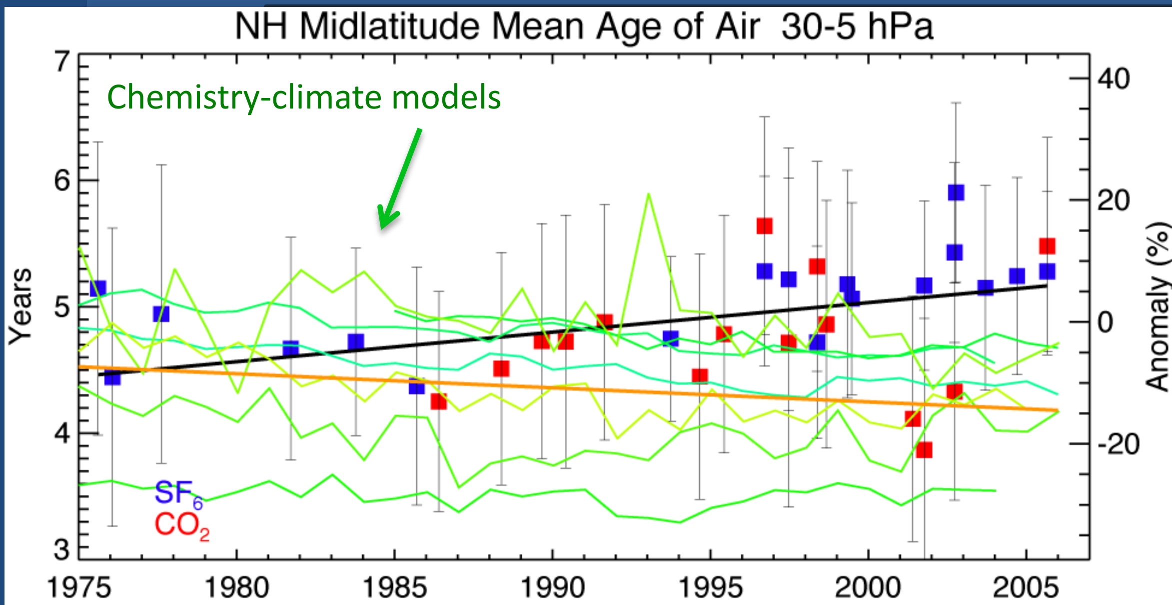
30 year obs data sets:

NH midlat mean age "obs" (Engel et al., 2009).

TOMS/SBUV total ozone

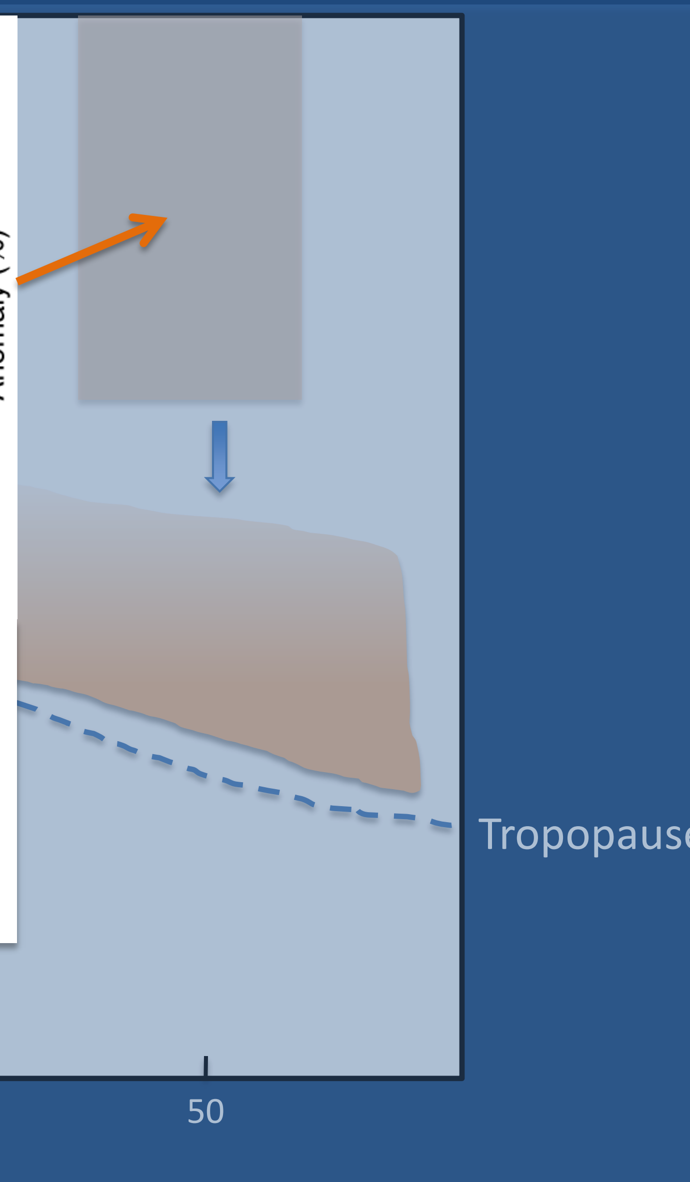
Tropopause

1. Stratospheric Circulation Trends

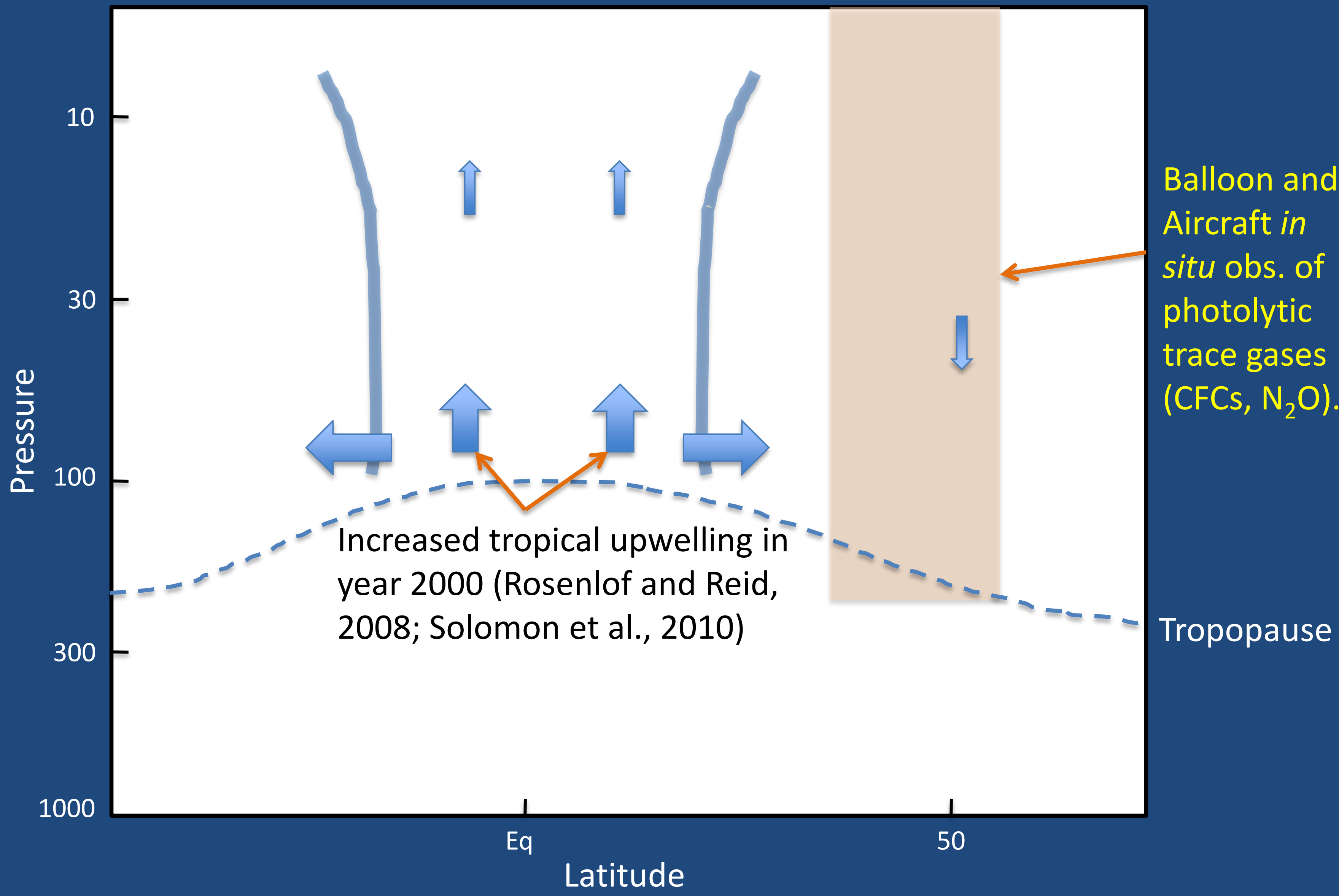


• Modeled and observed mean age trends have different sign.

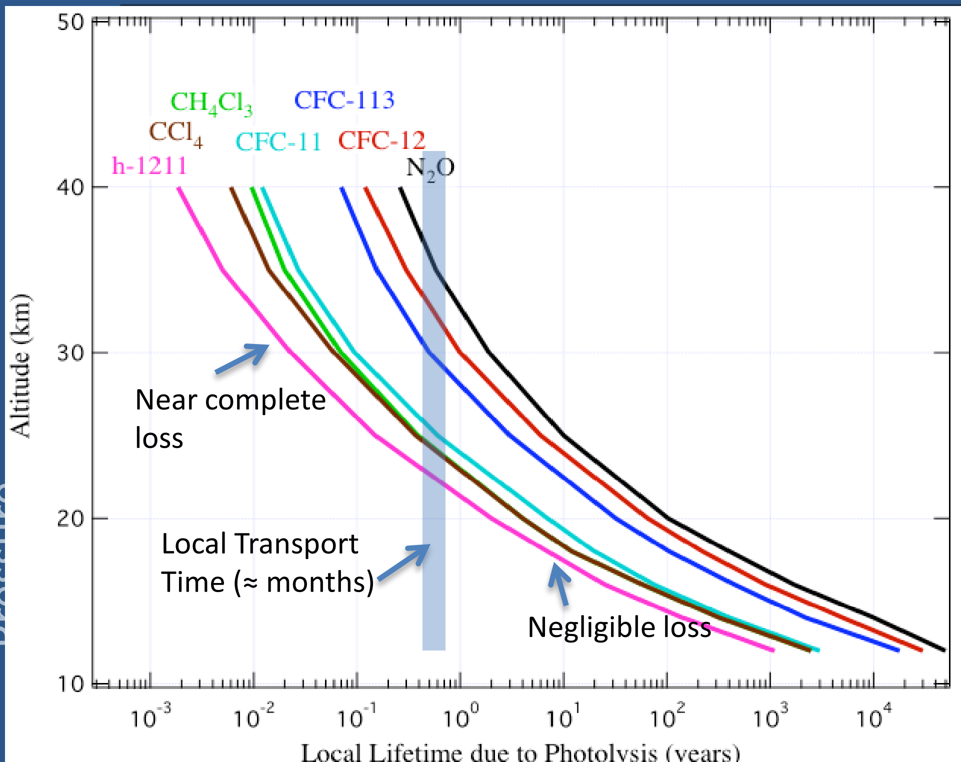
• We used a physical process model (Tropical Leaky Pipe) to show possible B-D and mixing trends consistent with observed age and ozone trends (Ray et al., JGR, 2010).



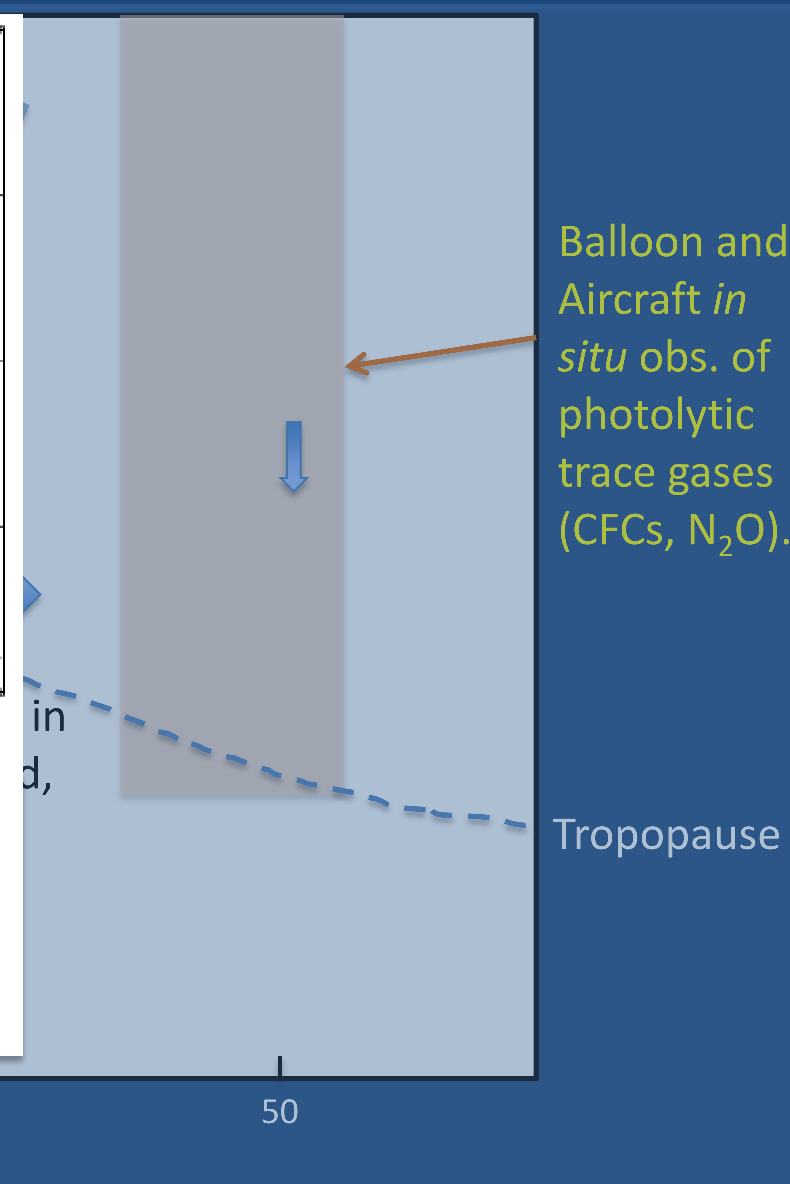
2. Stratospheric Circulation Rapid Change



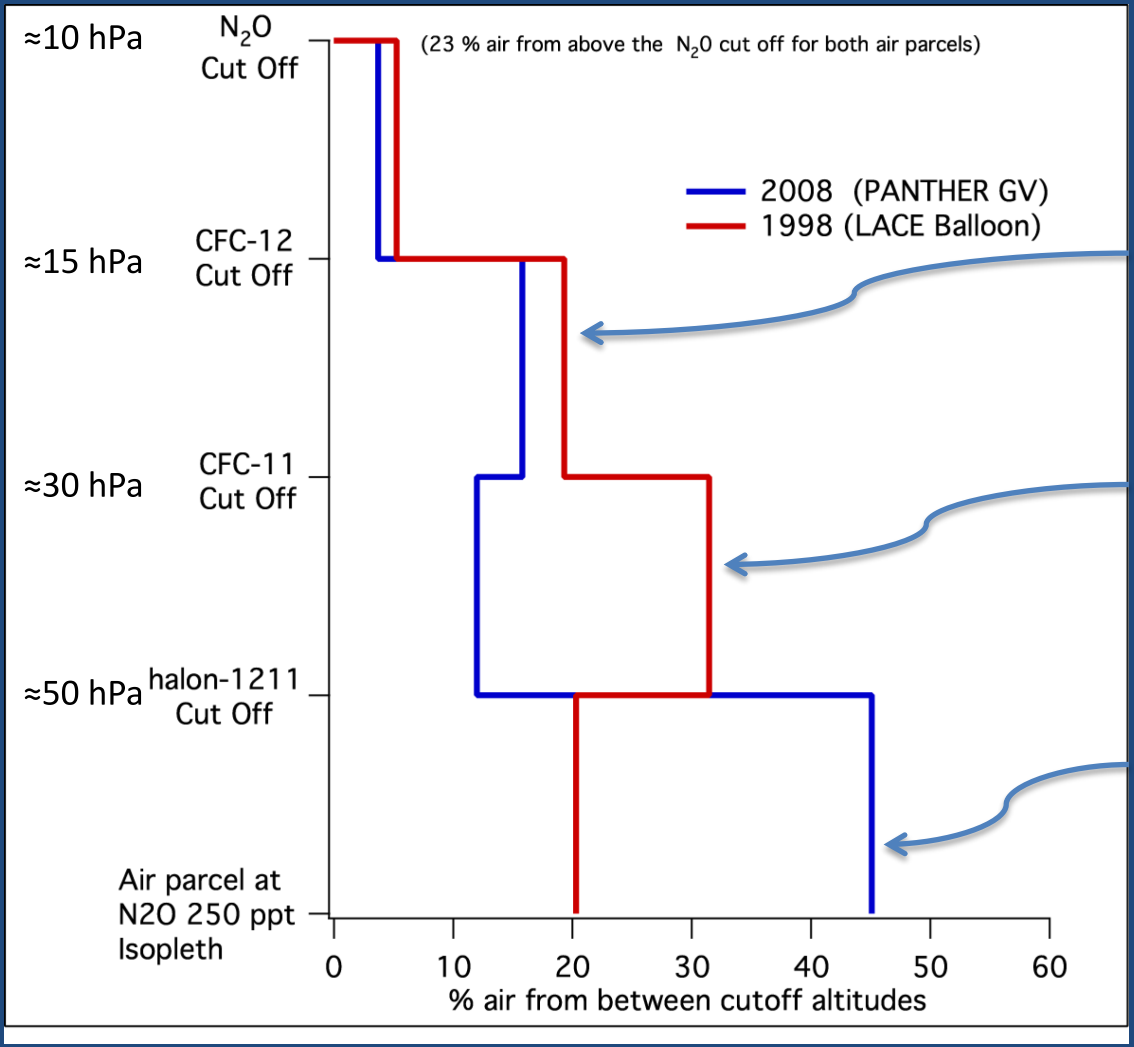
2. Stratospheric Circulation Rapid Change



- Take advantage of logarithmic change in local lifetime of photolytic trace gases as a function of altitude to calculate vertical profile of circulation changes after 2000.



Profile of Stratospheric Circulation Changes Implied by Photolytic Tracer Correlation Changes

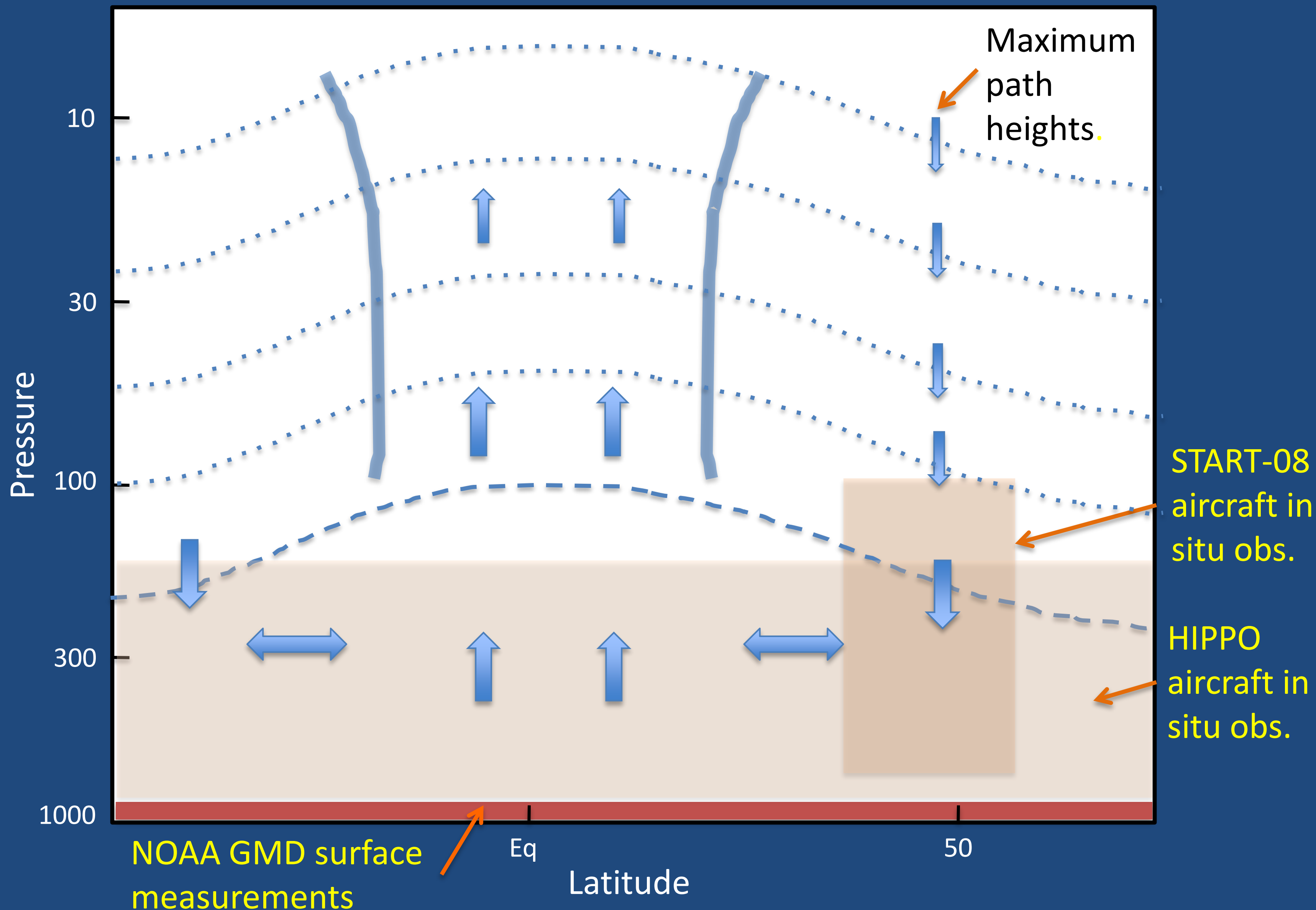


Small changes above 30 hPa consistent with observed small mean age changes at this level.

20% less air from between the halon-1211 and CFC-11 cut off altitudes in 2008.

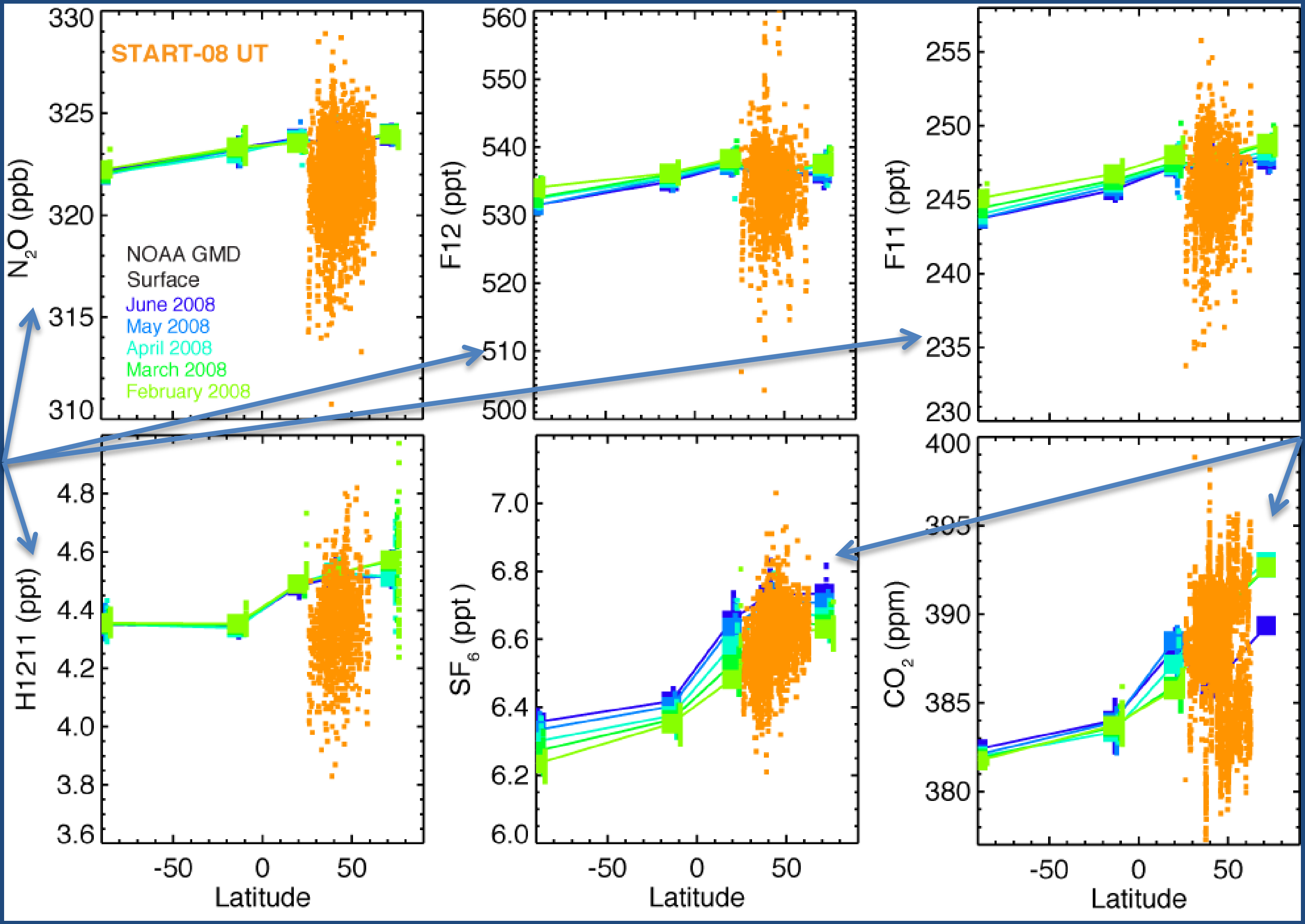
25% more air from below the halon-1211 cut off altitude in 2008.

3. Stratospheric Descent Into Troposphere



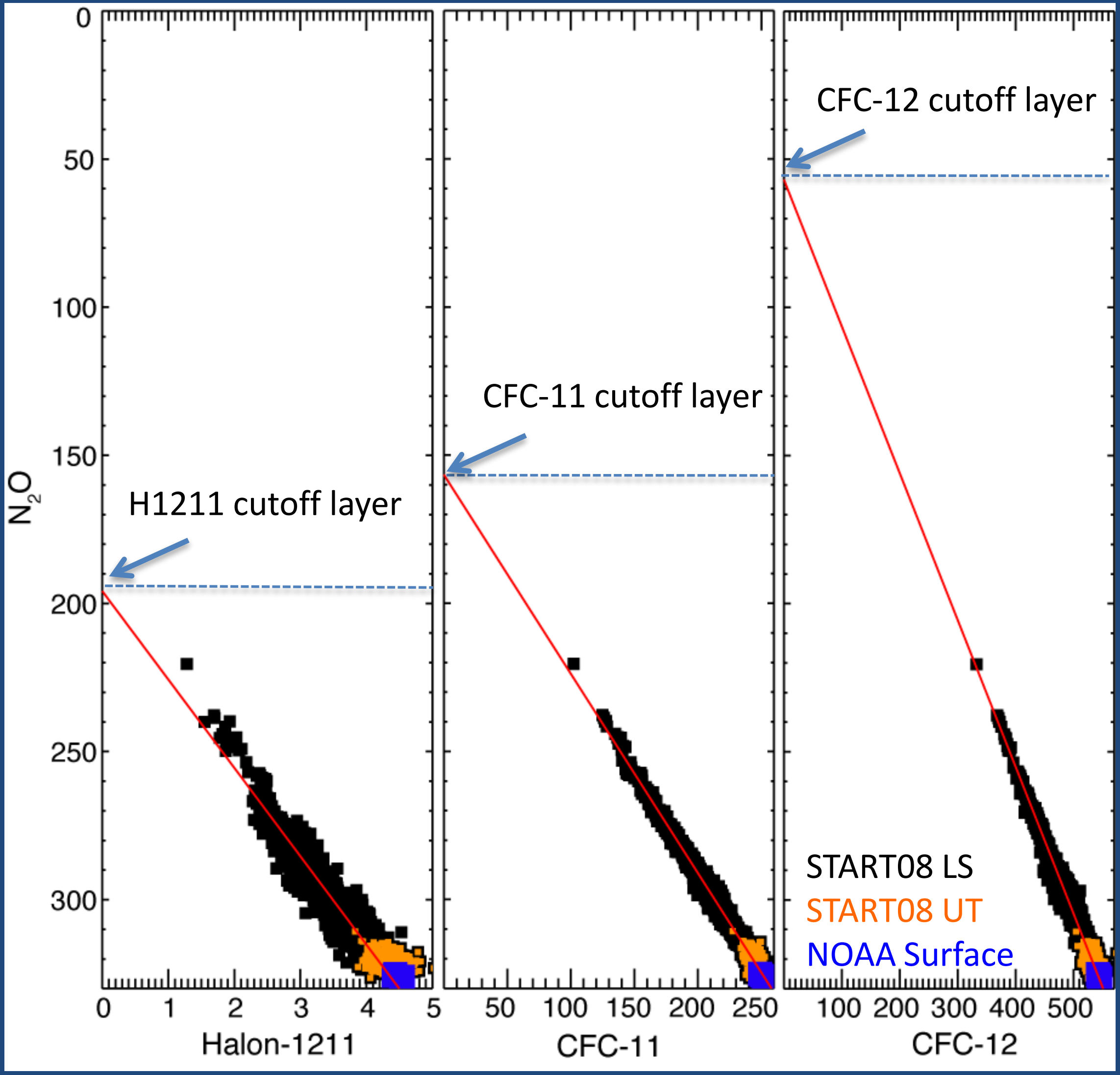
Surface and Free Tropospheric Tracer Gradients

Photolytic tracers - can determine where the air has been, "high road" tracers



"Age" tracers – can determine transport time scales and surface latitude origins, once "high road" part has been removed.

Stratospheric Fractions From Photolytic Tracer Correlations

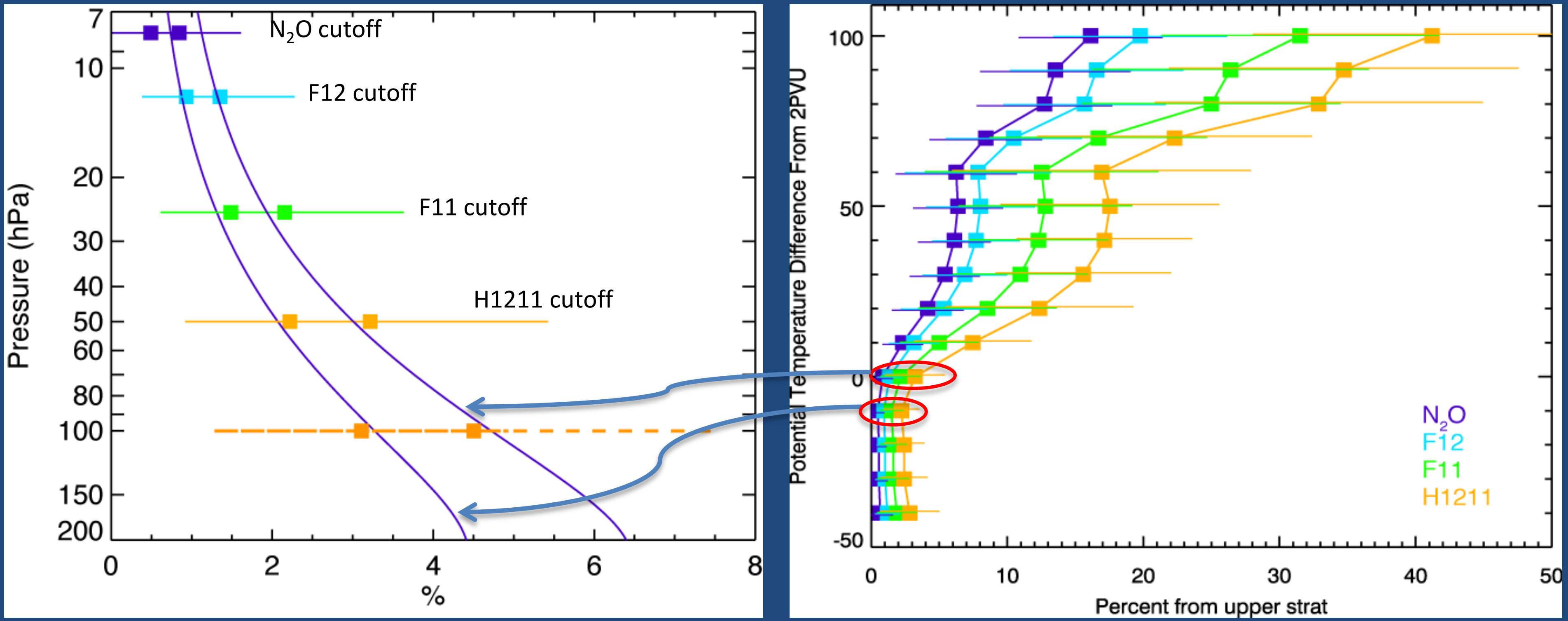


Any decrease in a photolytic tracer is due to mixing from above the cutoff layer, where the mixing ratio is zero, with surface values.

Define the fraction of air from above each molecule cutoff layer by:

$$F = \frac{\chi(Surface) - \chi(\chi_{N_2O})}{\chi(Surface)}$$

Stratospheric Fraction (“High Road”) Profiles of Air in the UTLS



Extratropical UT air contains a mixture of 2-8% air from above 100 hPa and up to 2% from above 10 hPa.

Summary

- Three examples of transport diagnostics derived from measurements were shown to demonstrate the importance of long-term monitoring of the relevant trace gases to help understand:
  - Stratospheric circulation (Brewer-Dobson and mixing) trends and rapid shifts.
  - Details of the mixture of stratospheric air in the troposphere.
  - Chemistry-climate model predictions.

- Without these measurement-based transport diagnostics it is difficult to fully understand observed greenhouse gas variability.