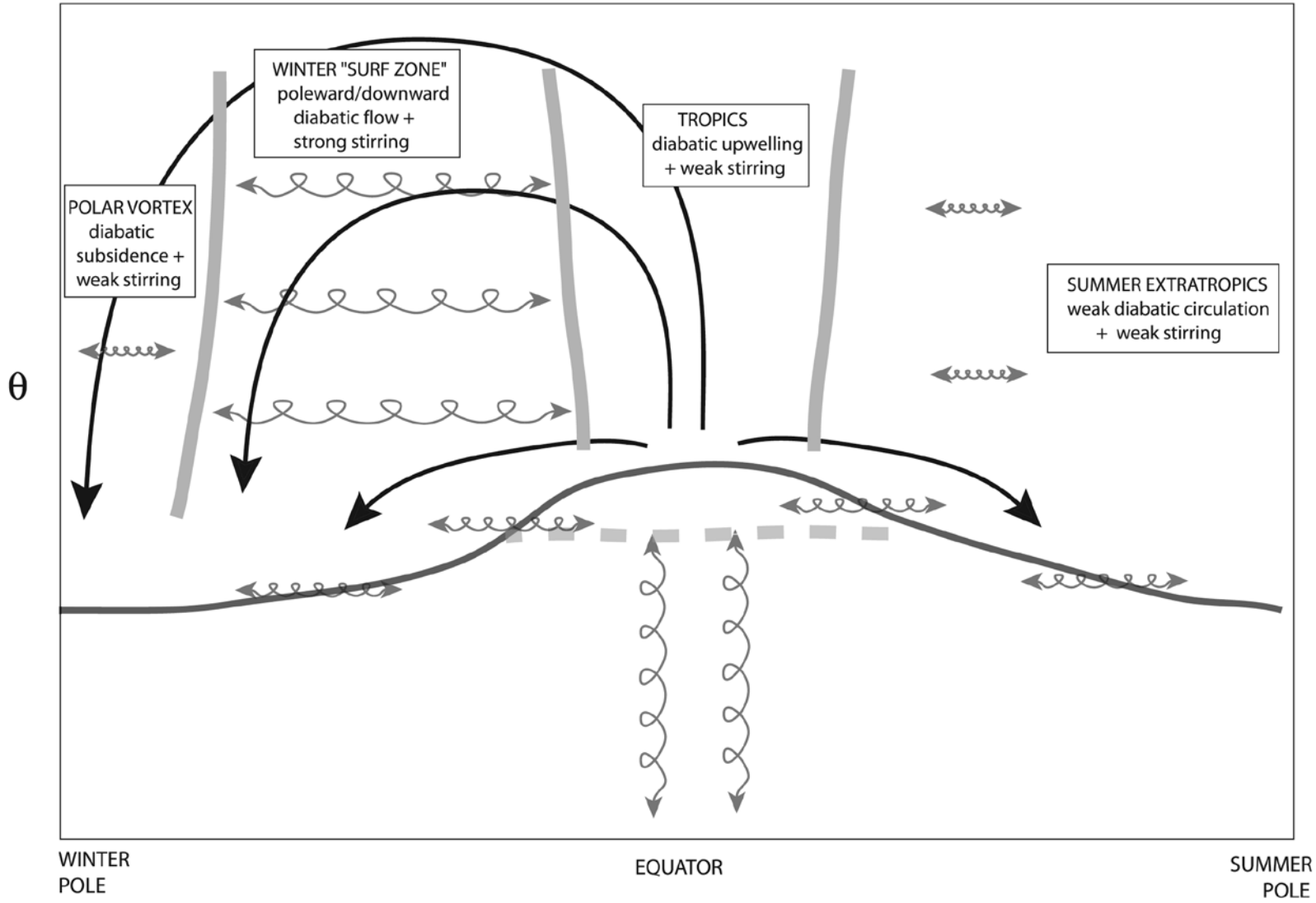
Determining the Strength of the Stratospheric Circulation from Satellite Observations of Trace Gases

Marianna Linz

with R. Alan Plumb, Edwin P. Gerber, Florian Haenel, Gabi P. Stiller, Doug Kinnison, Jessica Neu, and Aman Gupta

eGMAC July 20, 2020

The Brewer-Dobson Circulation

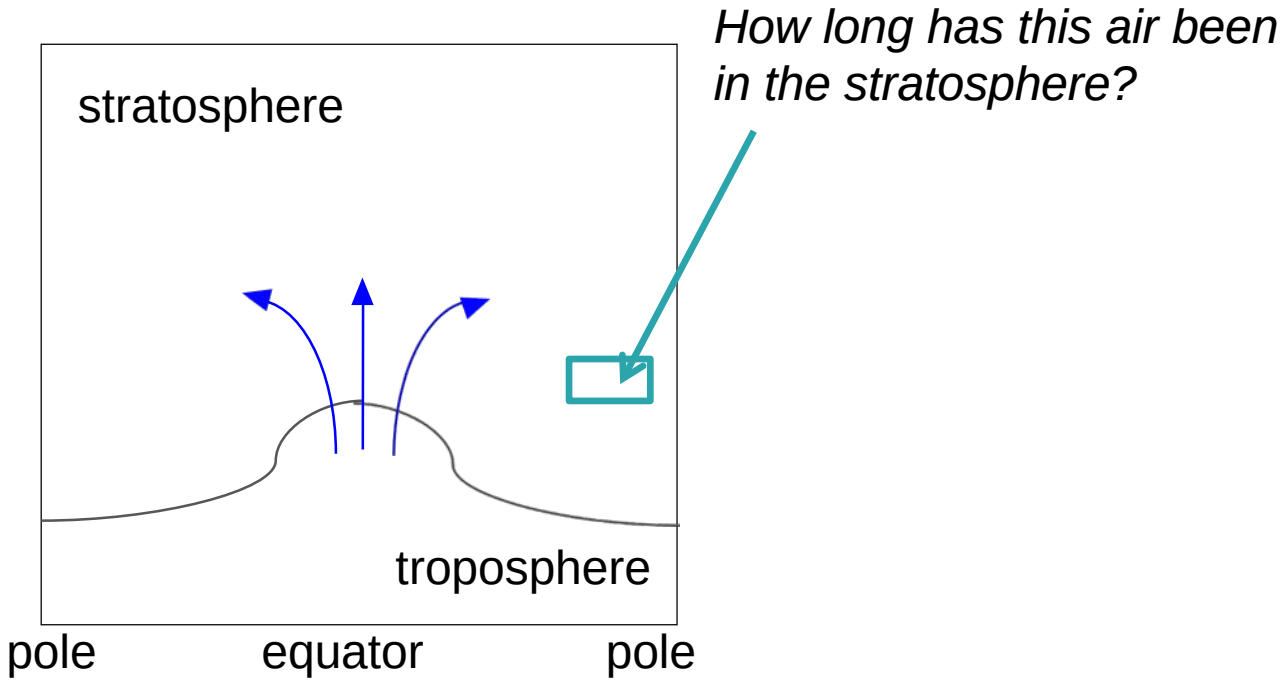


Plumb 2007

How can we measure the Brewer Dobson Circulation?

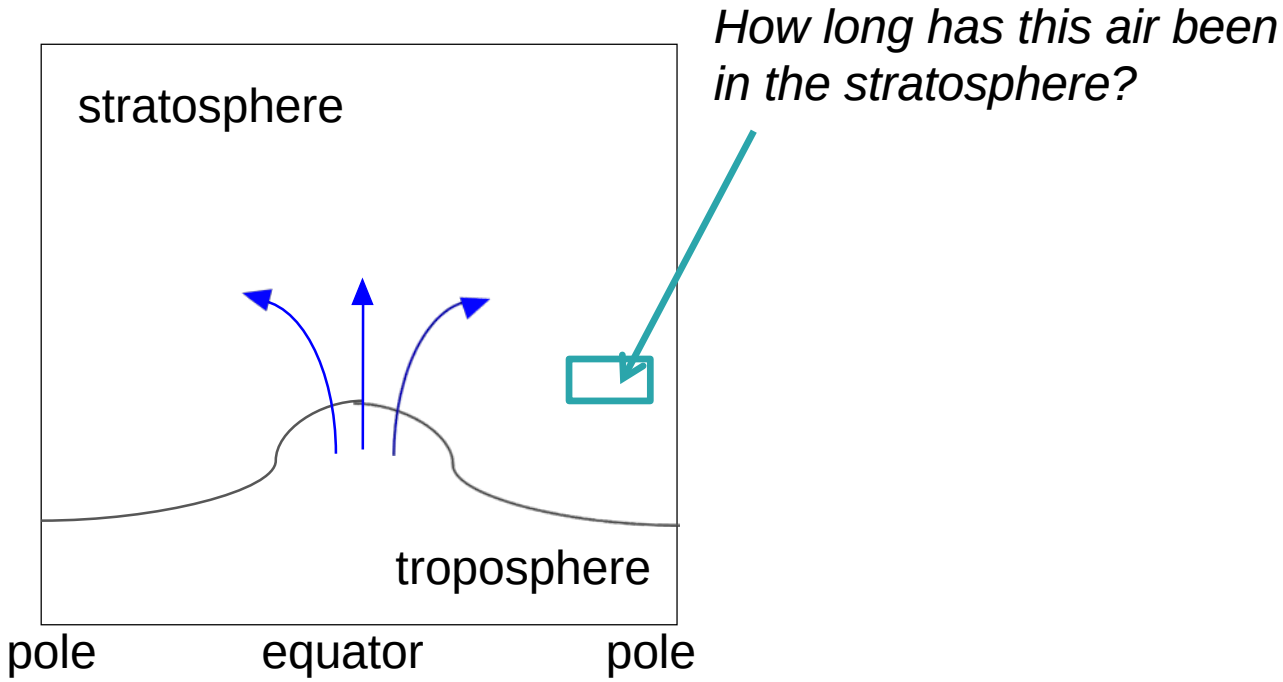
“Age of air” is a useful idealized tracer of the circulation

What is Age of Air?

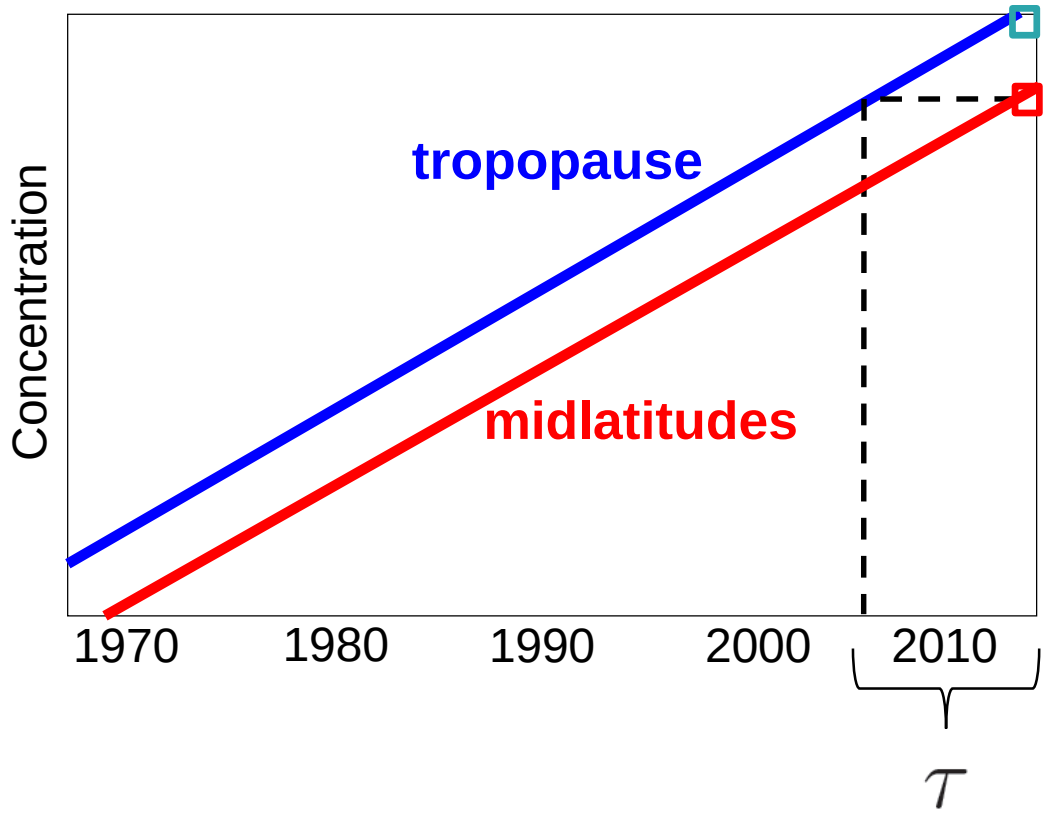


Age can be calculated from observations

What is Age of Air?

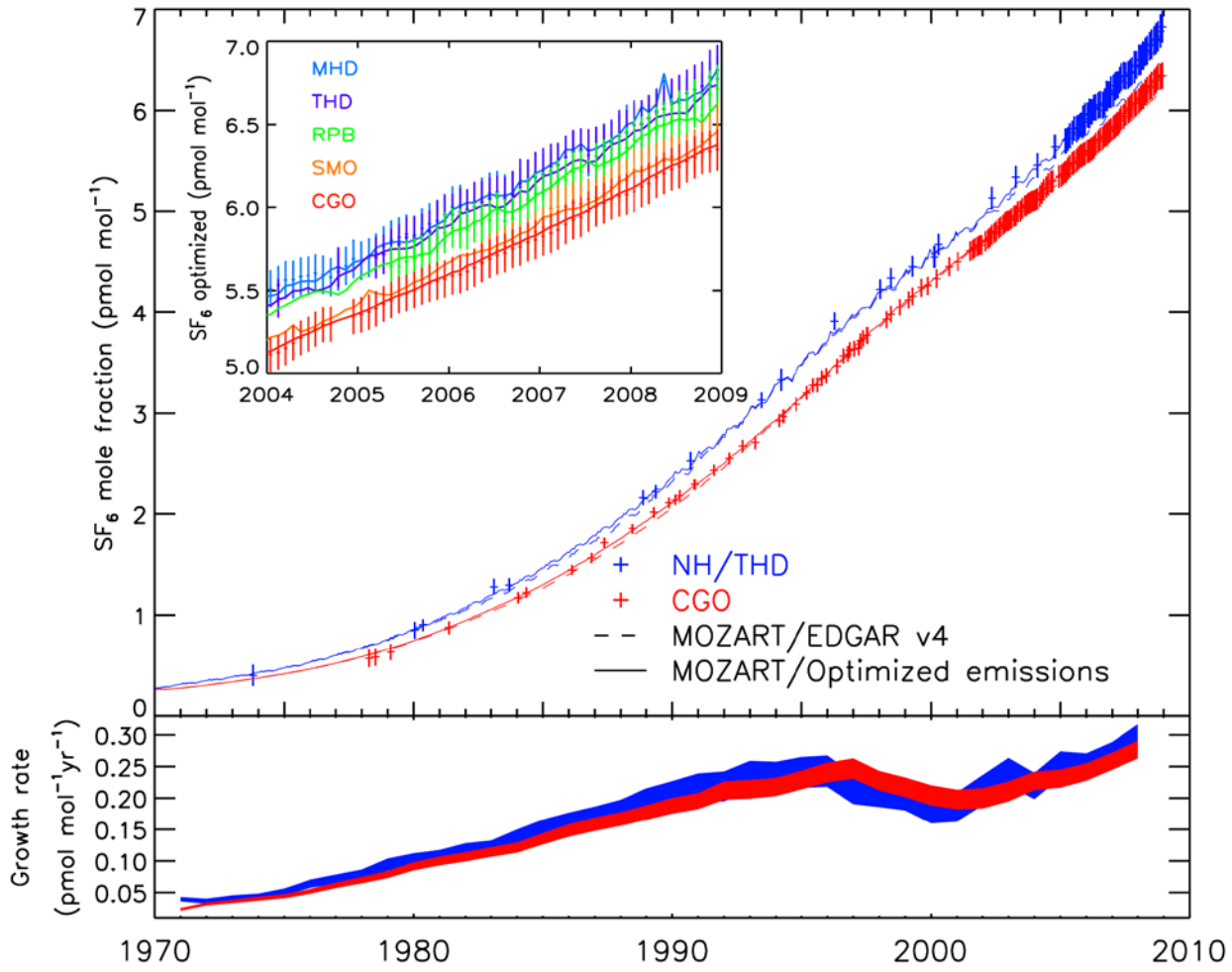


Calculation from observations:

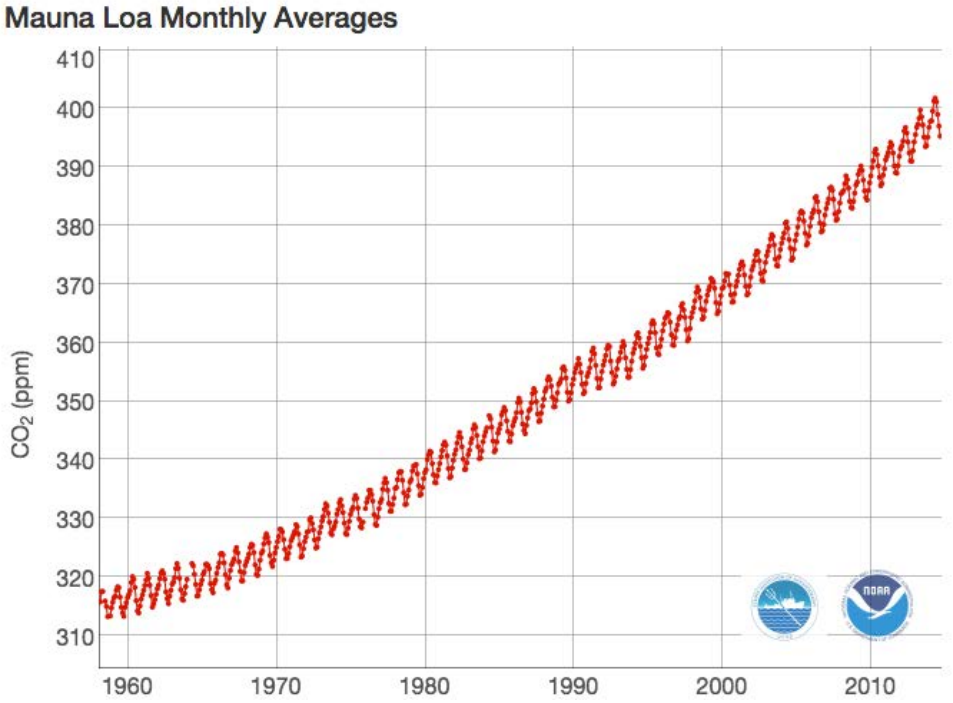


Tracers with an increasing source at the tropopause

SF_6

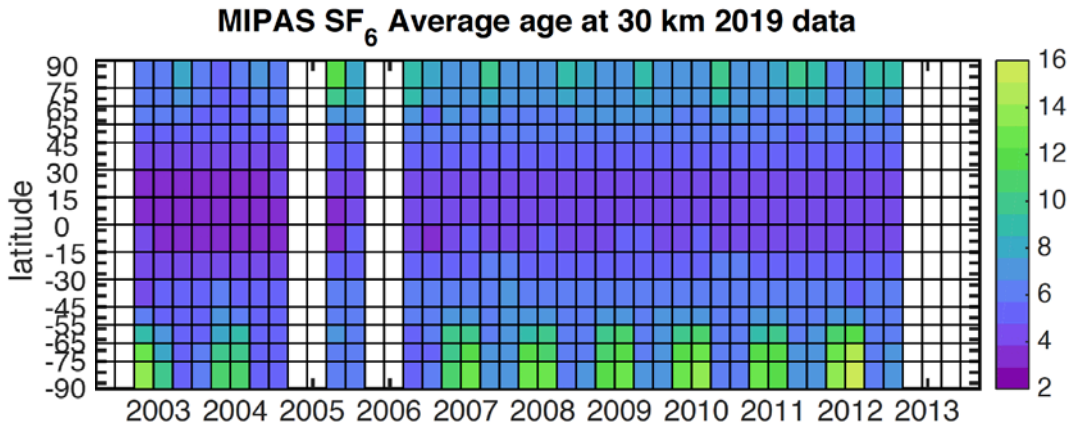


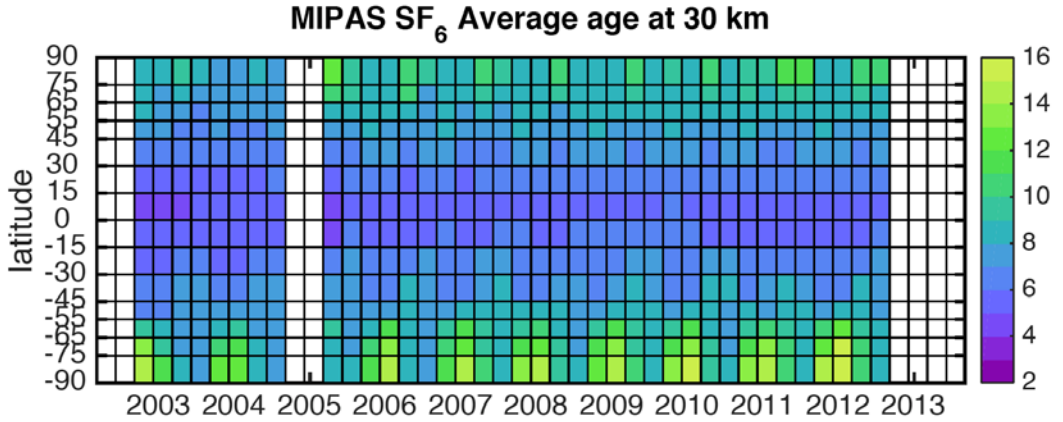
CO_2

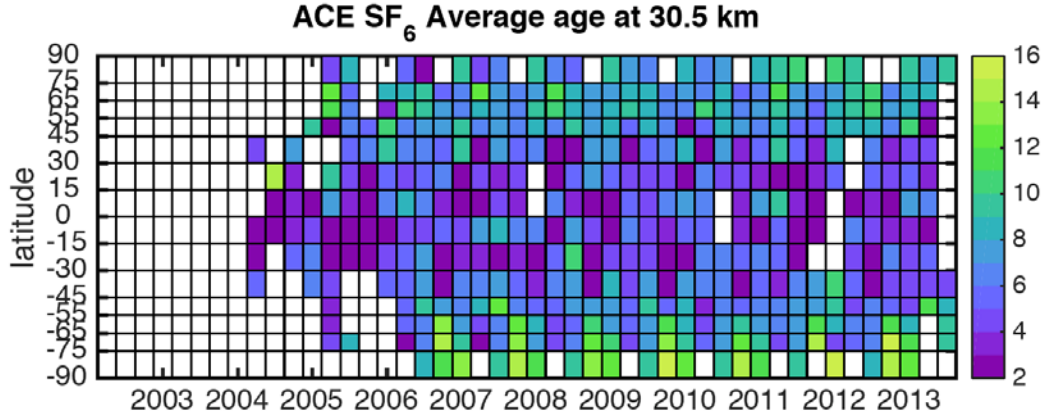


Rigby et al. 2010

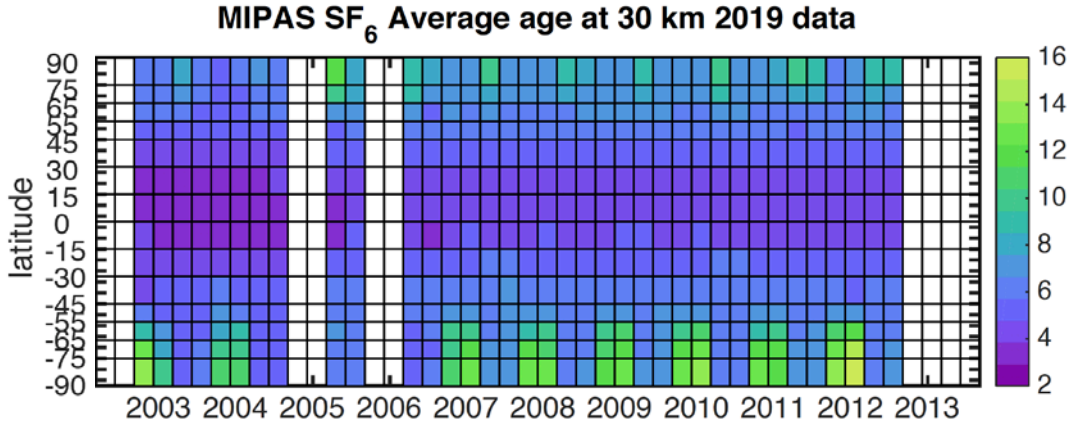
http://www.esrl.noaa.gov/gmd/ccgg/trends/graph.html

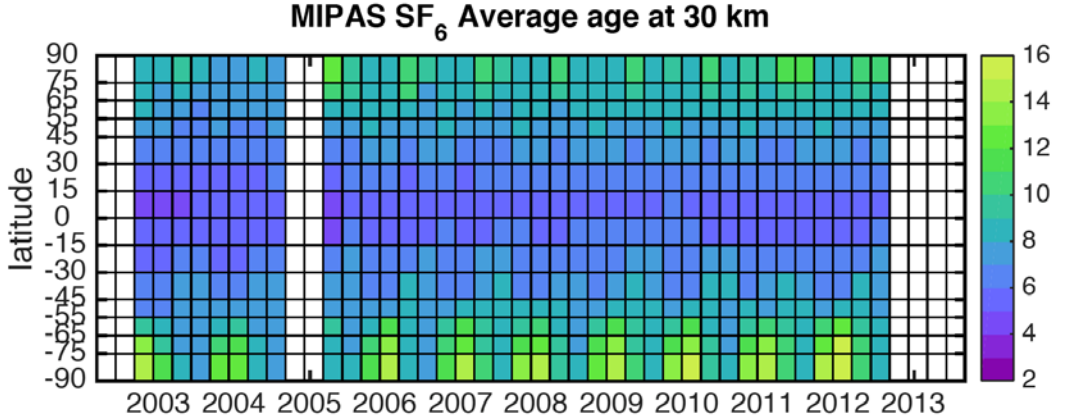


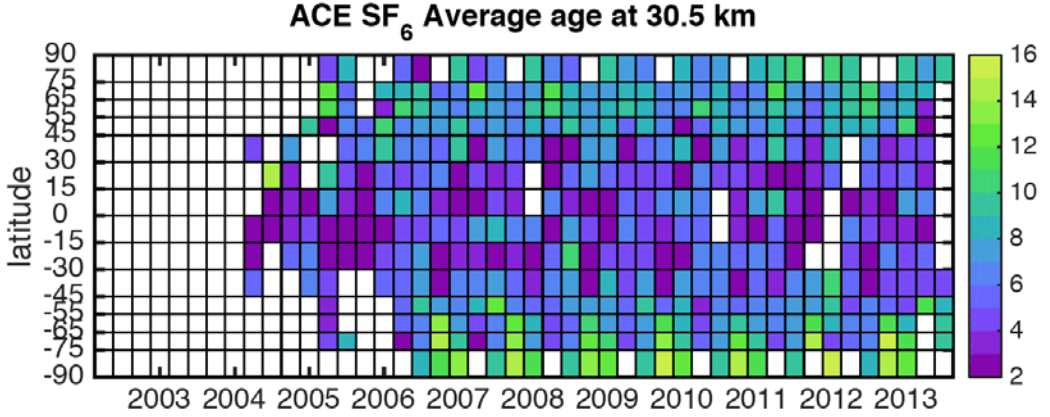




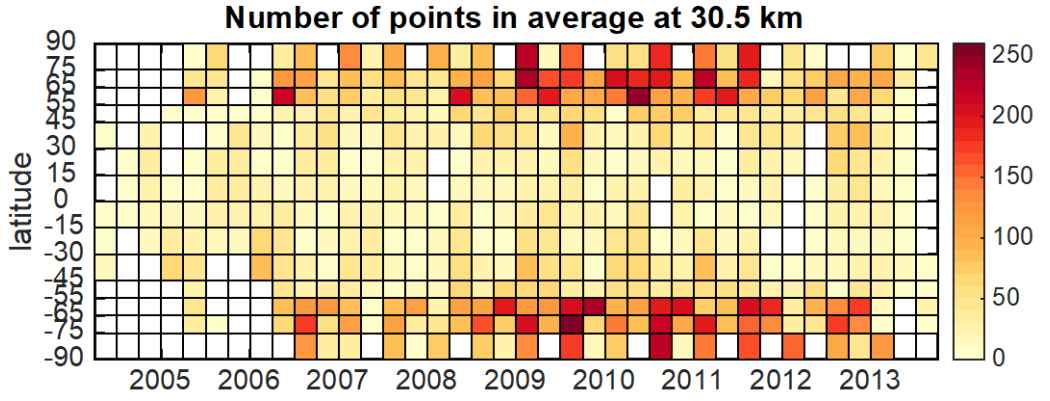
Observed Age of Air from CO_2 and SF_6





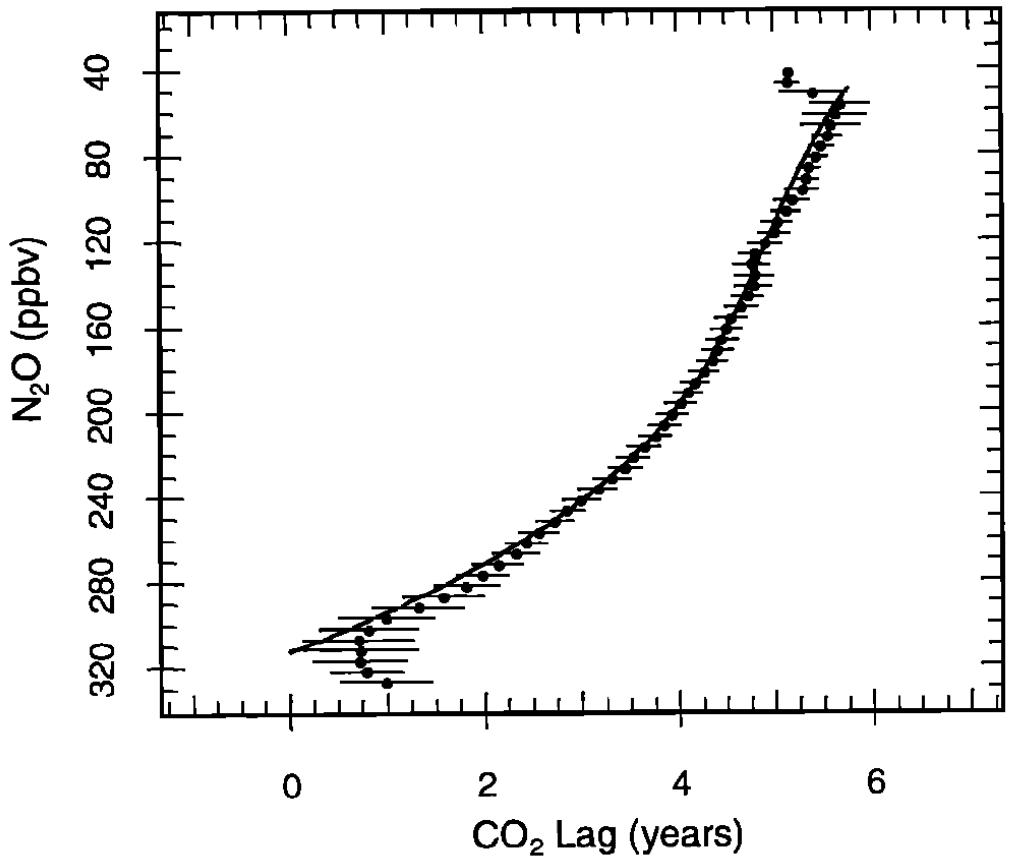


Observed Age of Air from CO_2 and SF_6



N_2O shows a compact relationship with CO_2 age

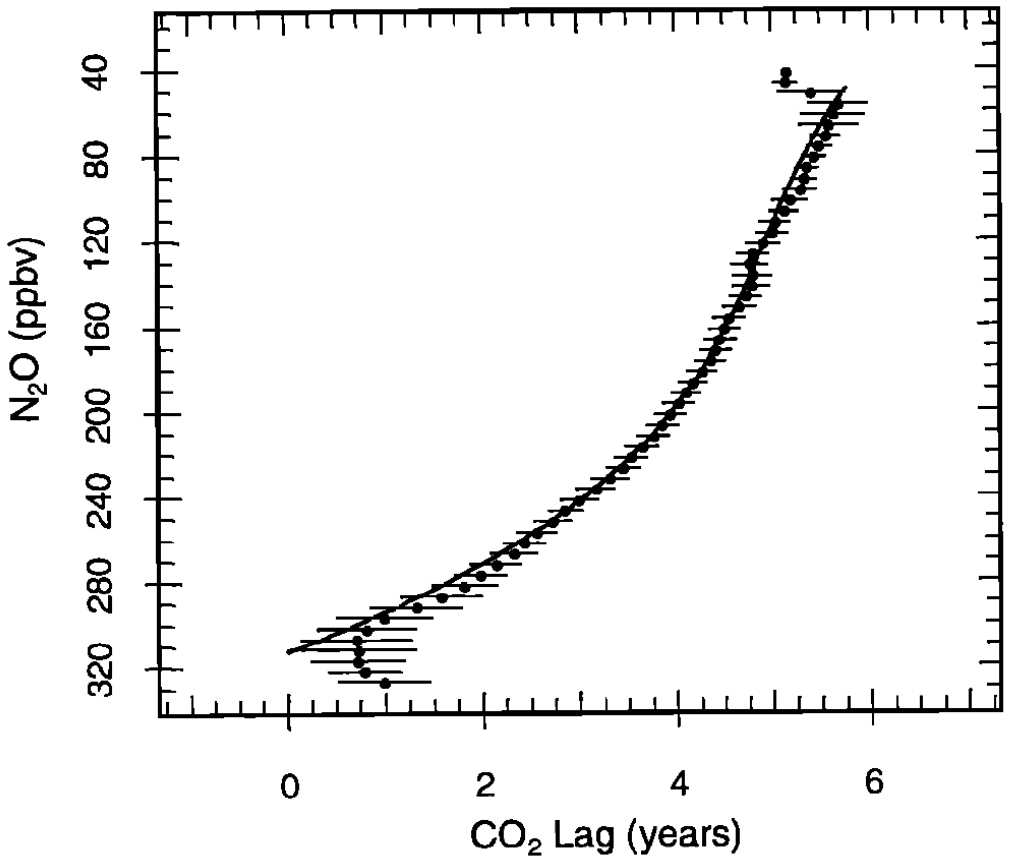
Balloon and aircraft measurements from 1990s



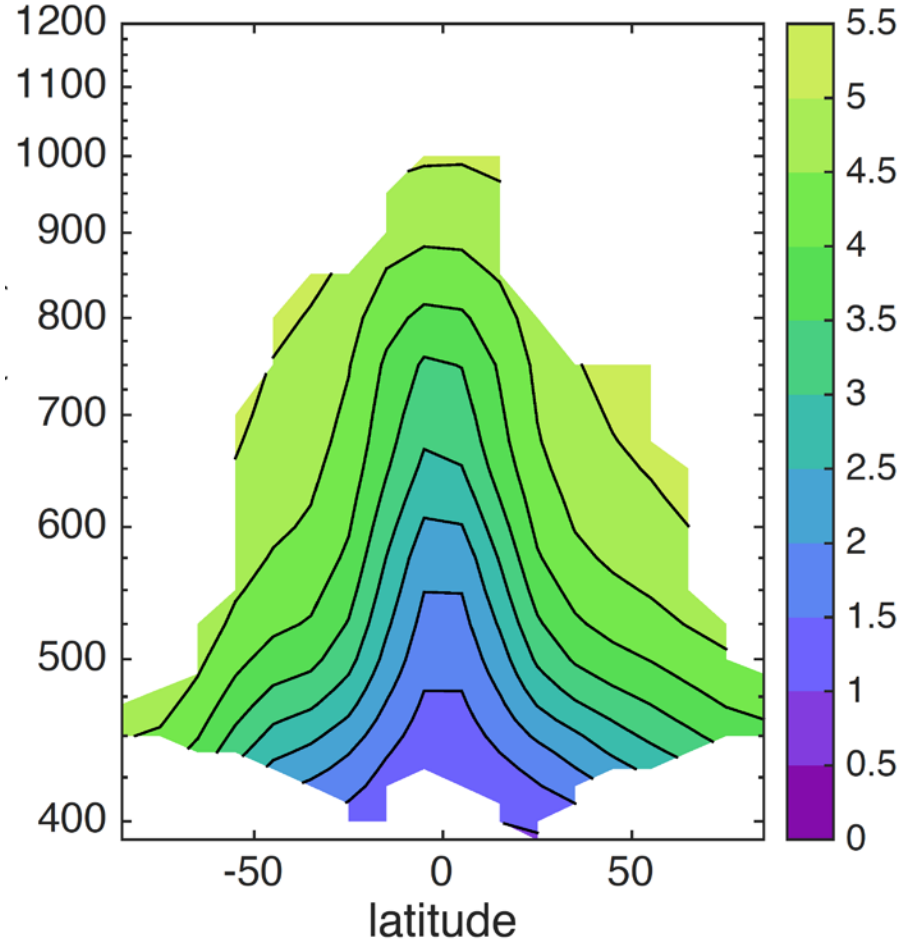
Andrews et al. 2001

N_2O shows a compact relationship with CO_2 age

Balloon and aircraft measurements from 1990s



Age from satellite N_2O, using Andrews 2001

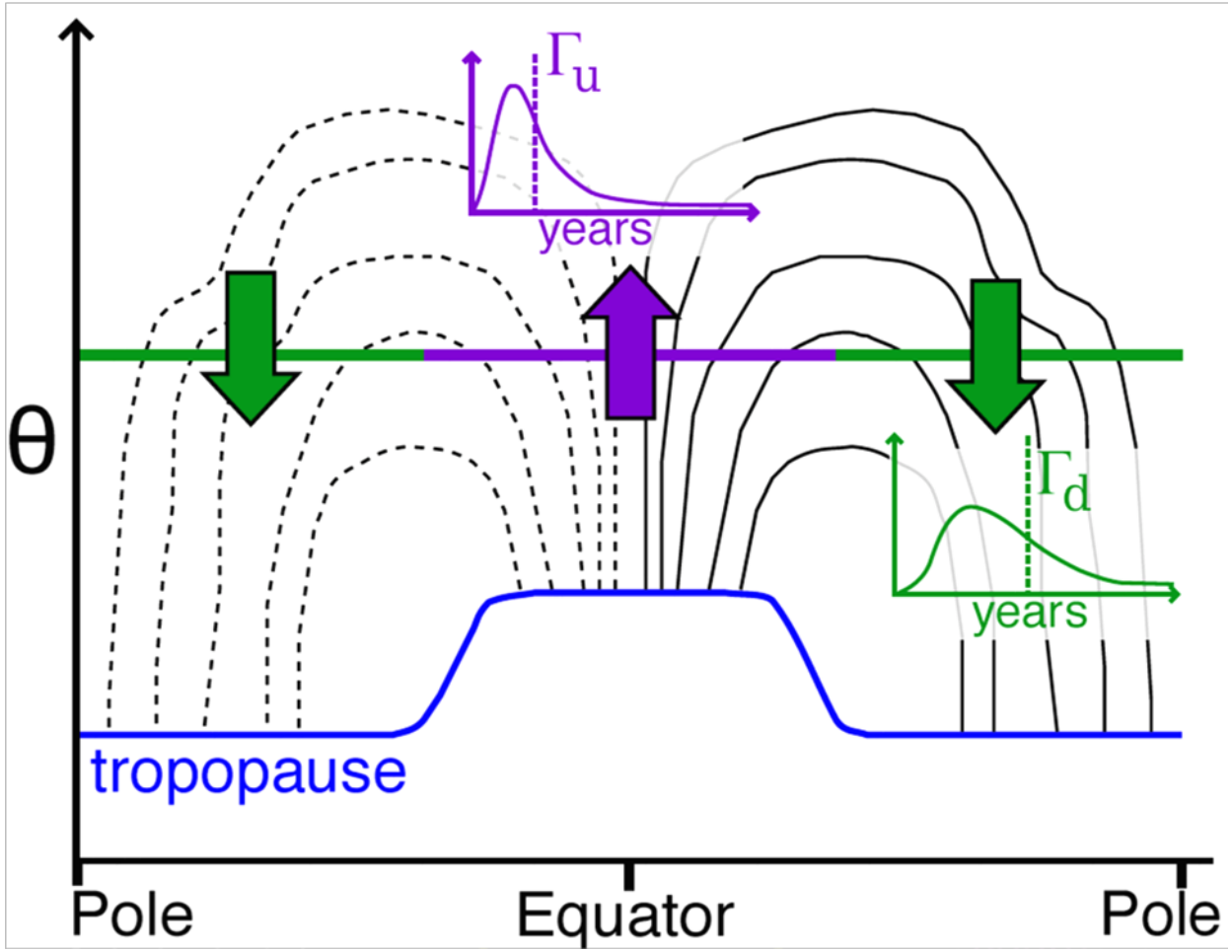


Andrews et al. 2001

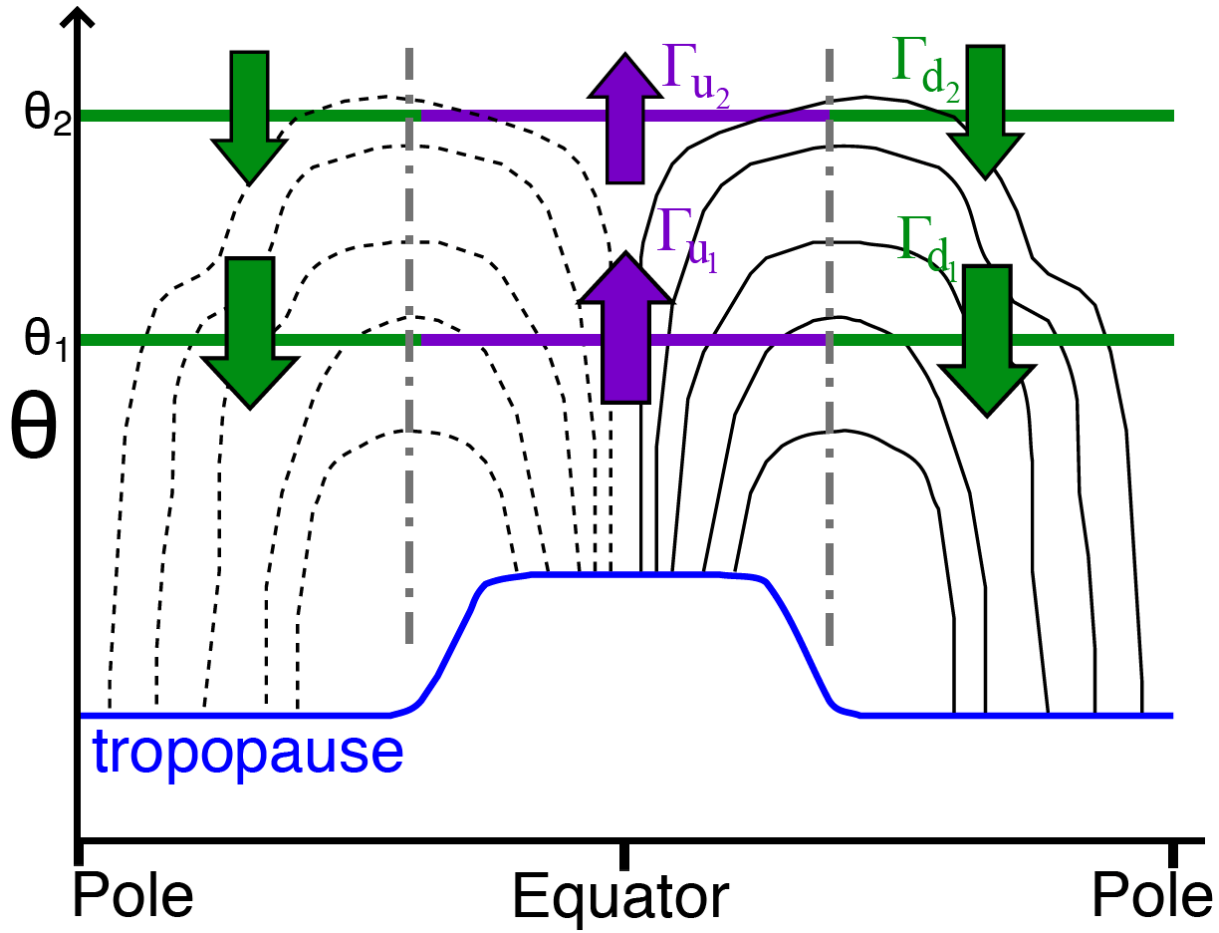
Linz et al. 2017

How can we measure the Brewer Dobson Circulation?

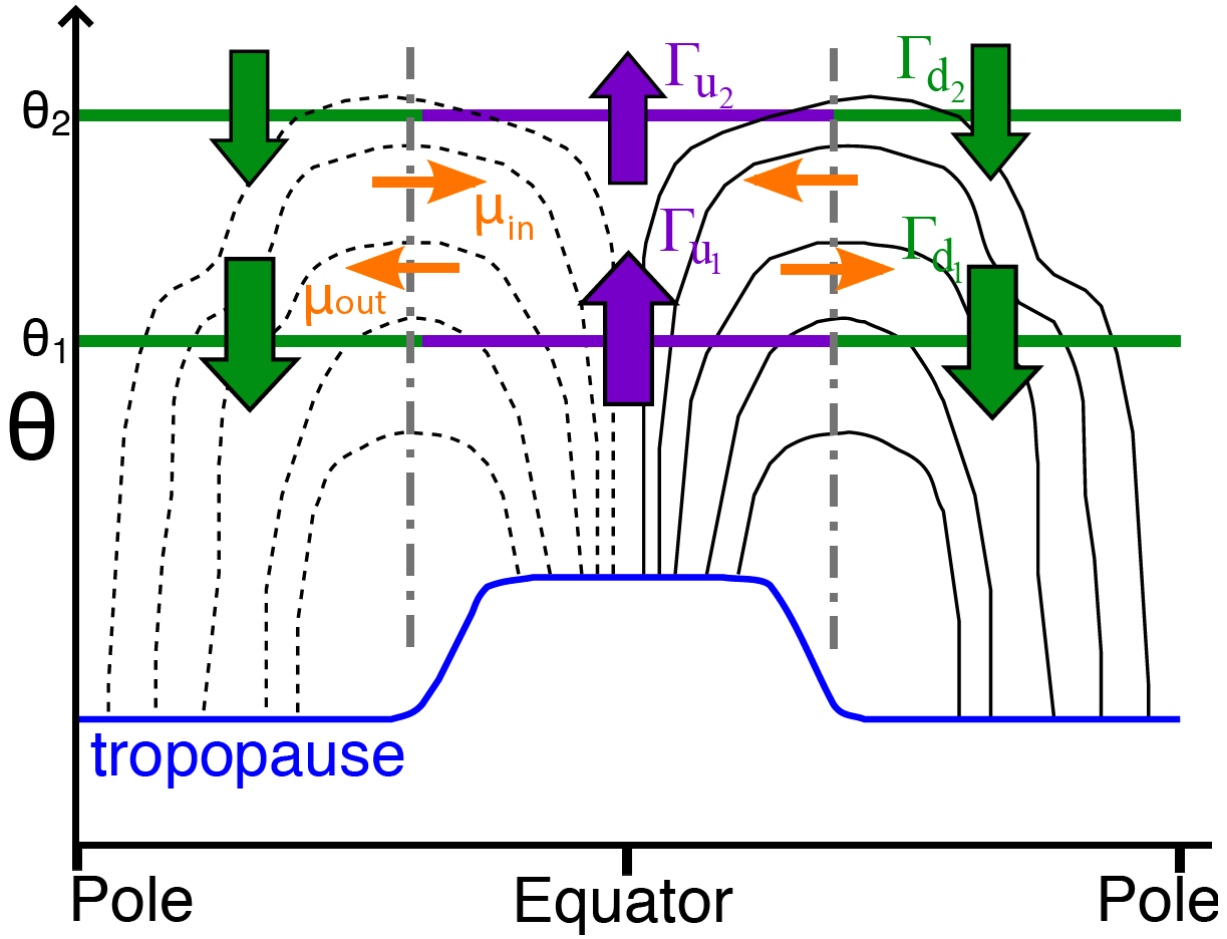
Horizontal age difference gives us vertical transport



Linz et al. 2016

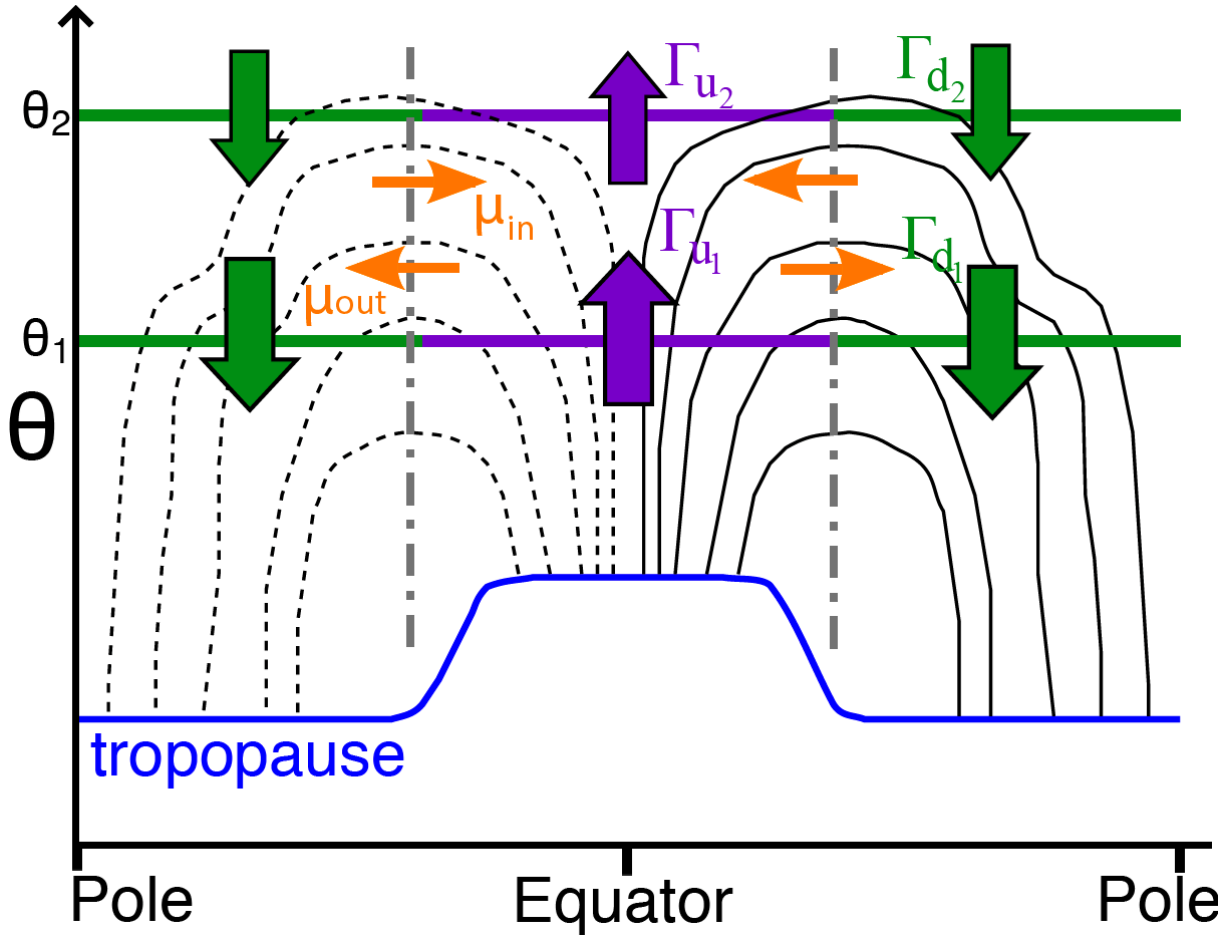


Linz et al. in prep.



Linz et al. in prep.

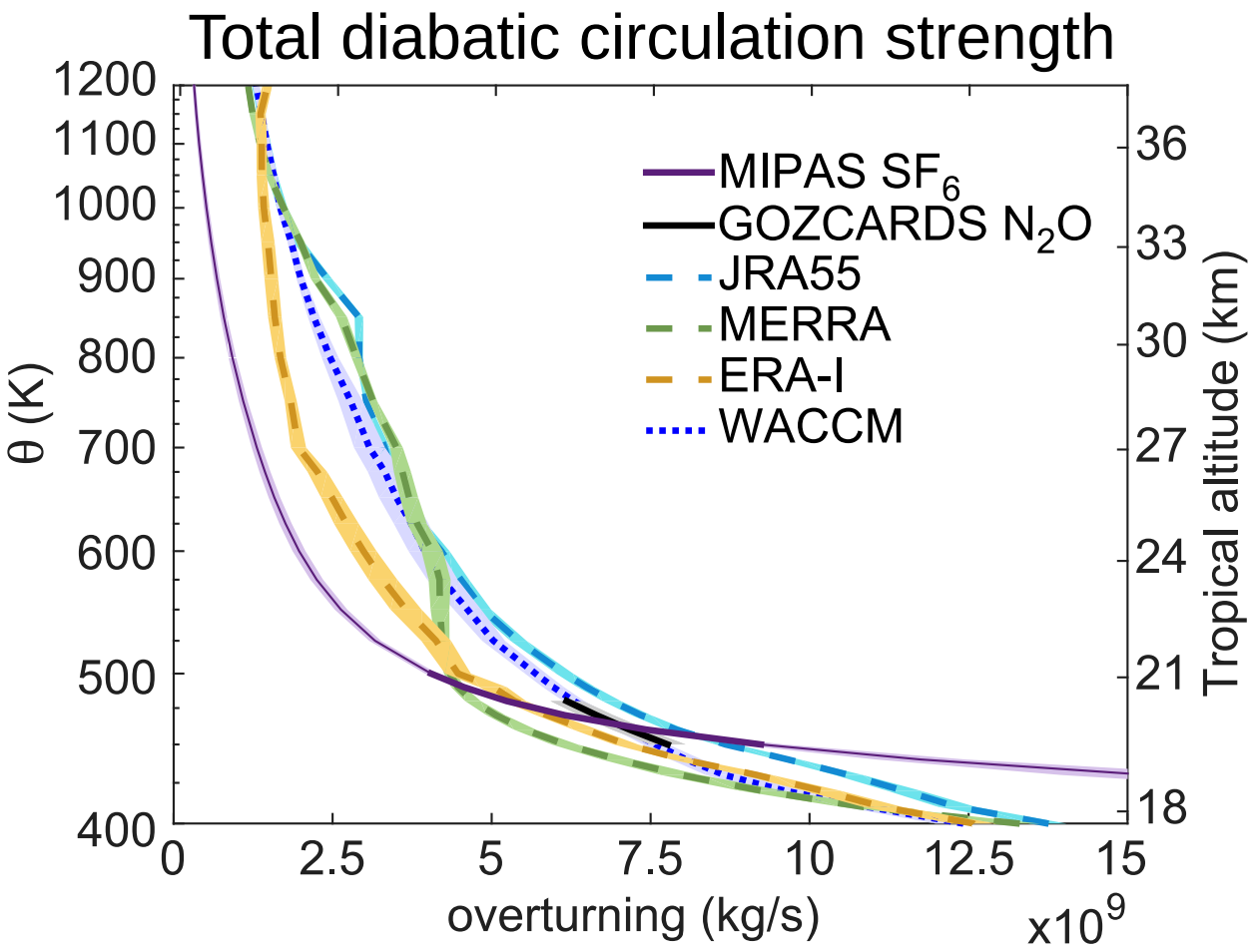
Vertical age gradient gives us horizontal mixing



Linz et al. in prep.

Let’s measure the
Brewer Dobson Circulation!

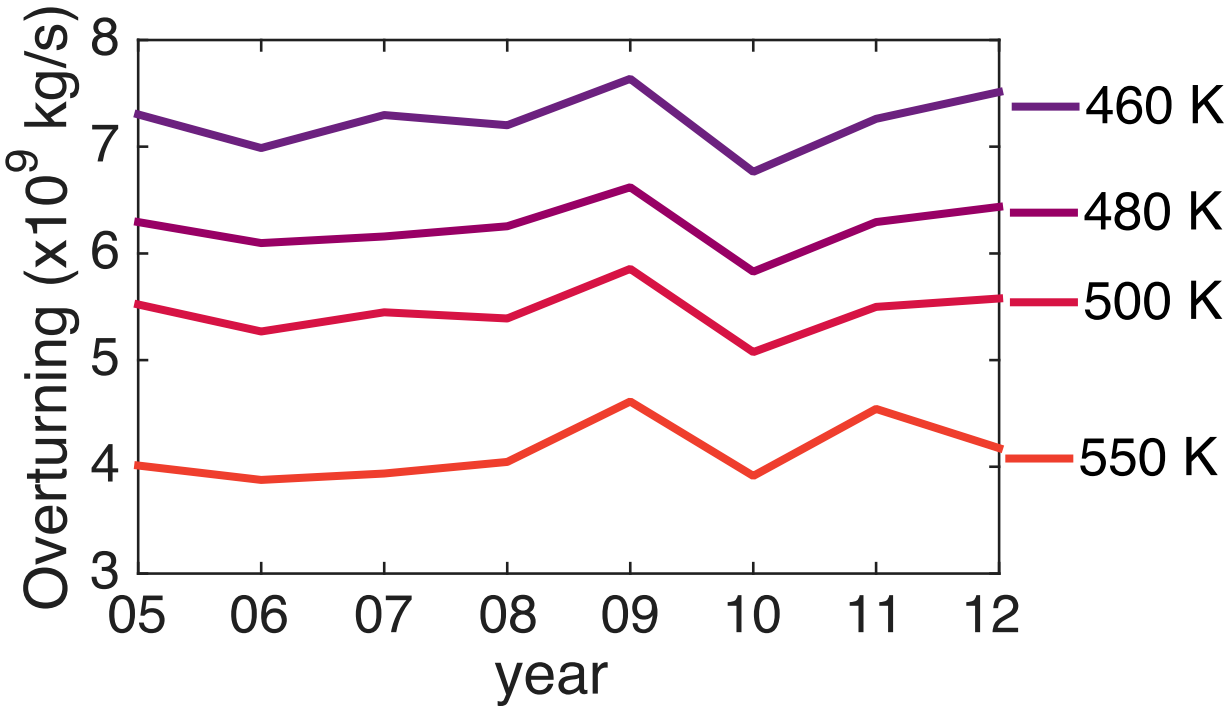
Horizontal age difference: two data products agree

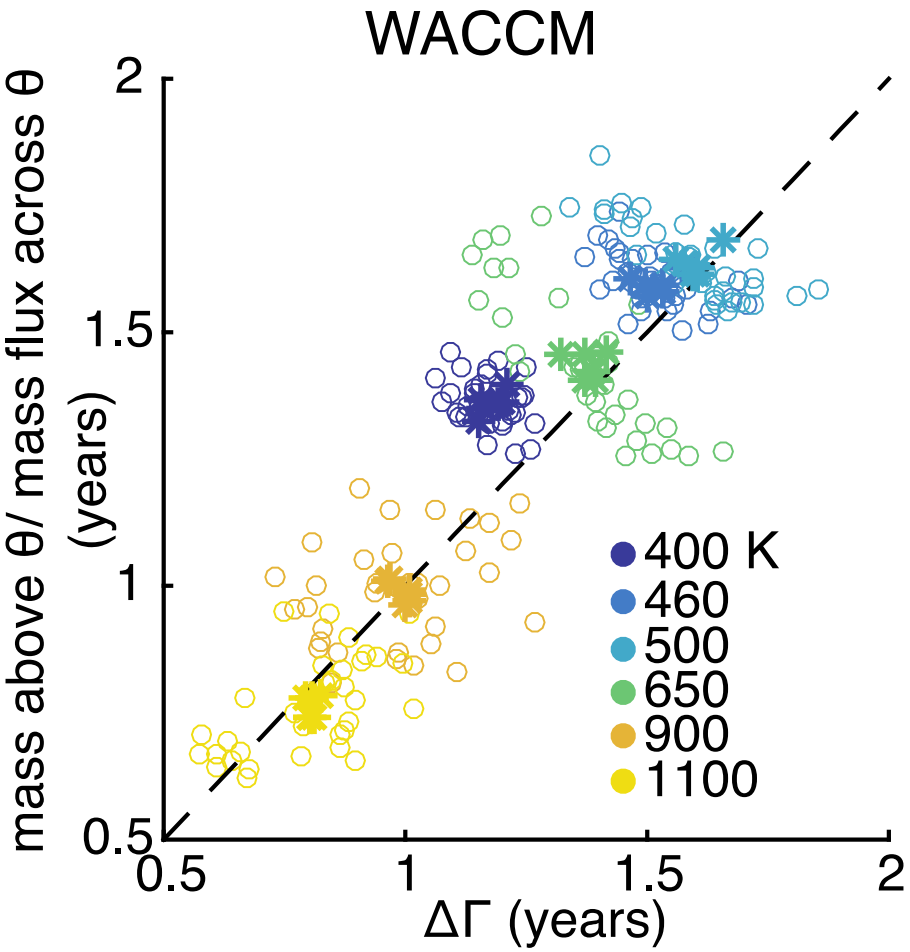


Data set	**460 K overturning (x10^9 kg/s)**
MIPAS SF_6-age	**7.43**
GOZCARDS N_2O	**7.17**
WACCM	7.11
ERA-Interim	6.48
JRA 55	7.90
MERRA	5.52

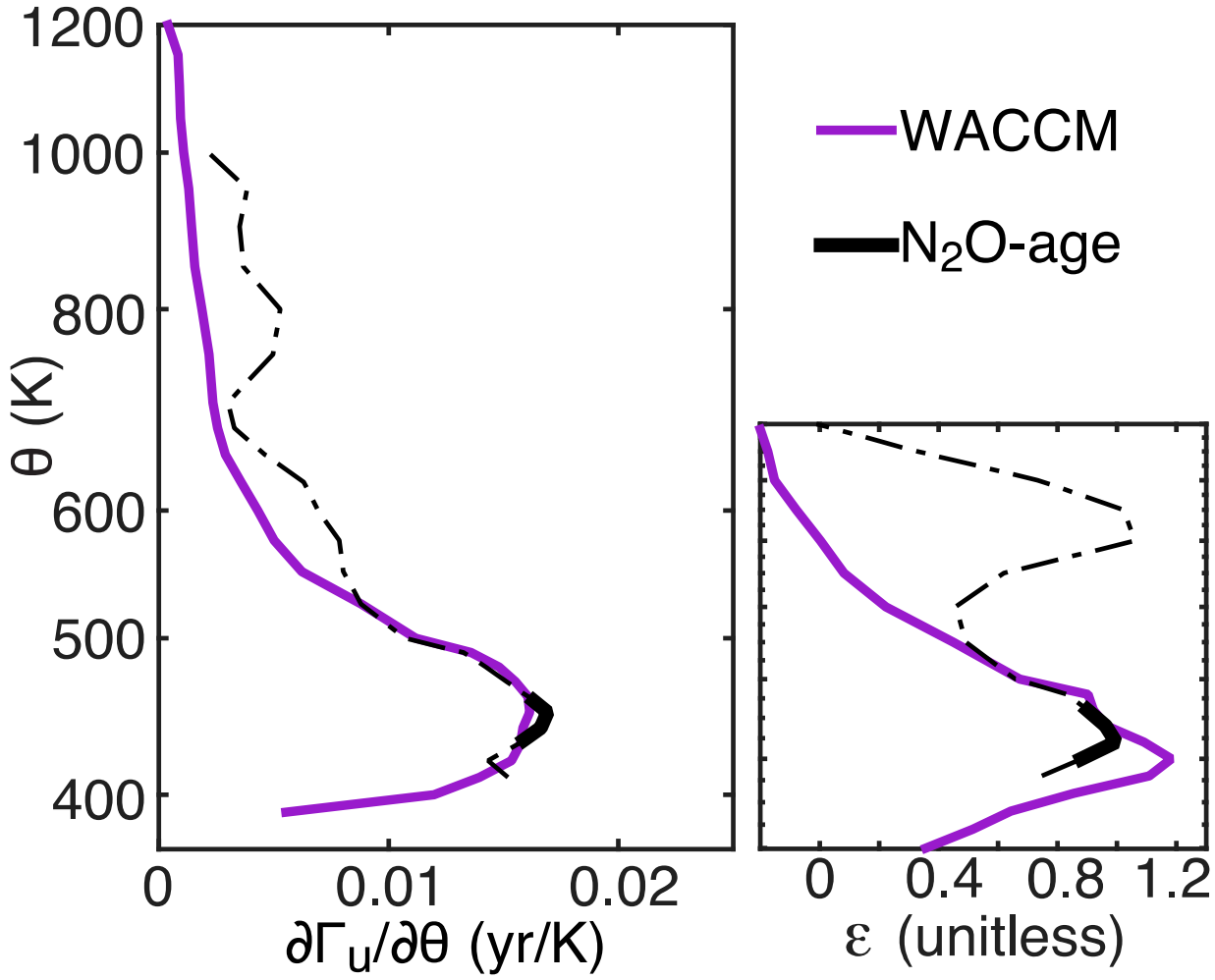
Linz et al. 2017

“Overturning” time series from N_2O





Vertical age gradient and mixing efficiency



$$\epsilon = \frac{\mu_{in}}{\mu_{out} - \mu_{in}} = \frac{\mu_{in}}{\partial \mathcal{M}/\partial \theta}.$$

Linz et al. in prep.

Age can be determined from satellite measurements

Better to use multiple tracers, including in situ

We use age to find the strength of both the diabatic circulation and the isentropic mixing

At 460 K: Circulation strength of 6.3 - 7.6 x10^9 kg/s

$$\epsilon = \frac{\mu_{in}}{\mu_{out} - \mu_{in}} = \frac{\mu_{in}}{\partial \mathcal{M} / \partial \theta}.$$

Mixing efficiency of ~0.8