Seasonal cycle of ozone in the tropical lower stratosphere: Implications for the relative importance of upwelling and mixing

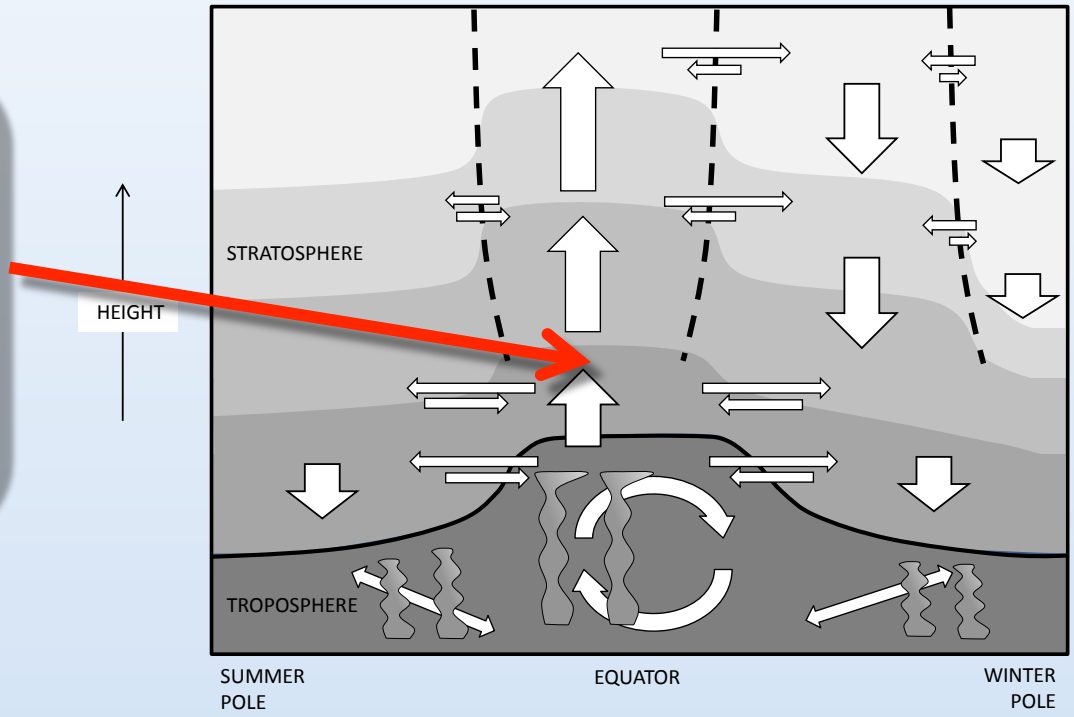
Richard S. Stolarski
Earth and Planetary Sciences
Johns Hopkins University

Symposium in celebration of
Jennifer Logan
Harvard University
10 May 2013

The Problem:
Models predict a speed-up of the Brewer-Dobson circulation with increasing greenhouse gases

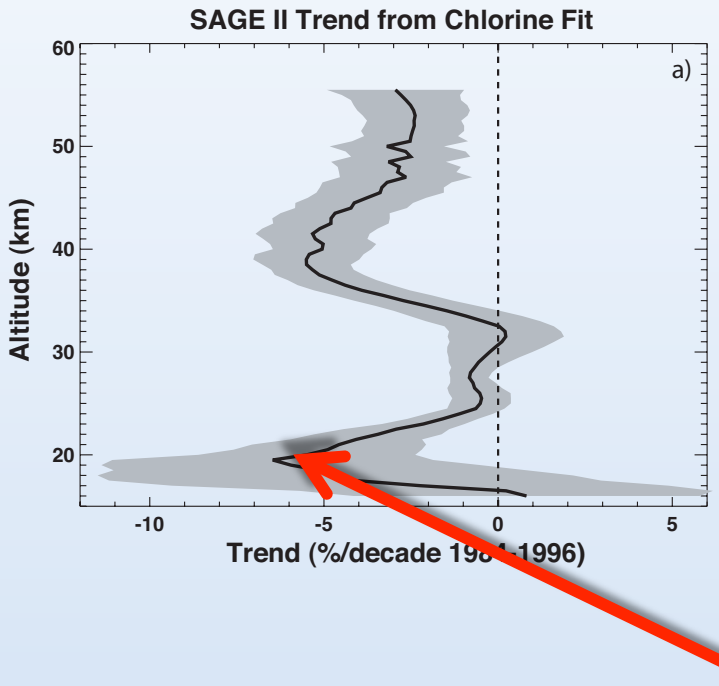
How can we test this prediction?

Increased upwelling in tropics should give negative ozone trend where vertical gradient is largest: i.e. just above tropical tropopause



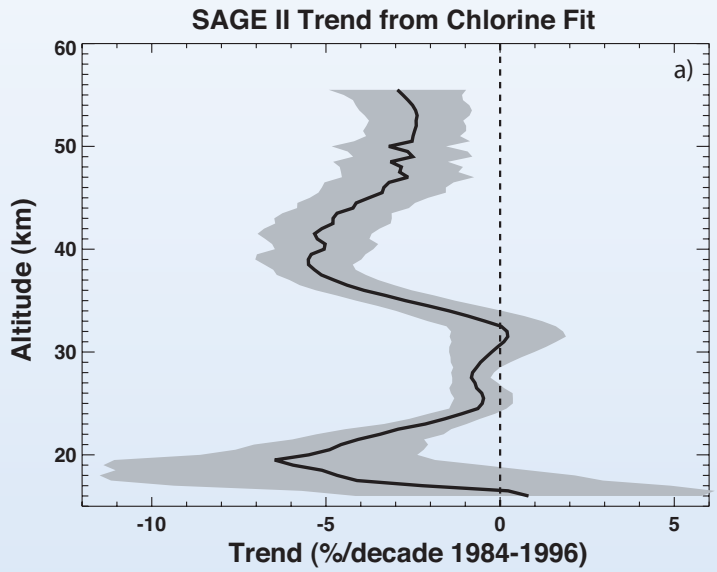
Updated stratospheric transport diagram by Alan Plumb

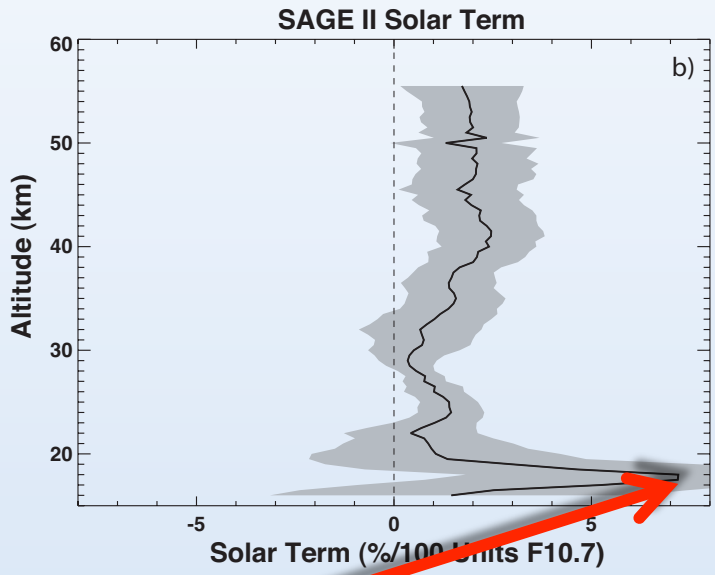
Time-series analysis of SAGE II data from 1984 to 2005 reveal a trend in the tropical lower stratosphere



Significant negative trend

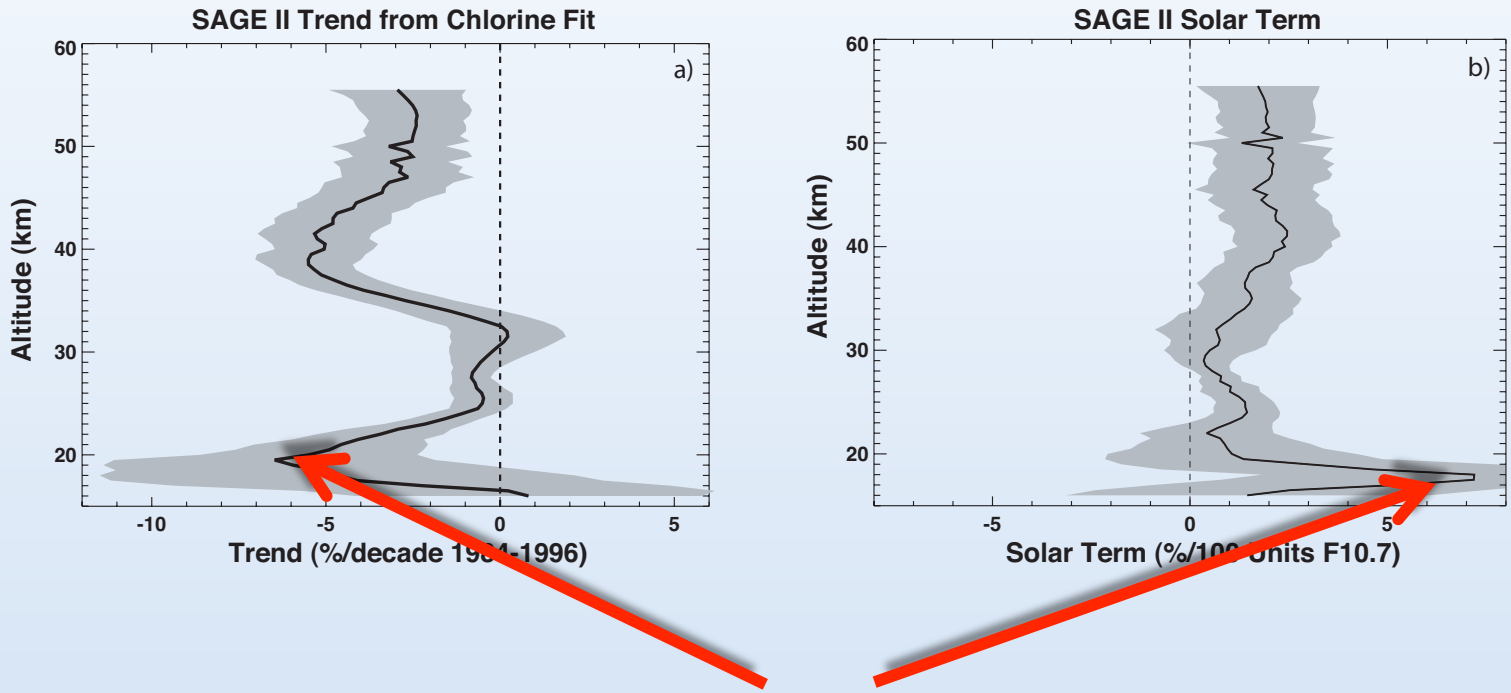
Time-series analysis of SAGE II data from 1984 to 2005 reveal a trend in the tropical lower stratosphere





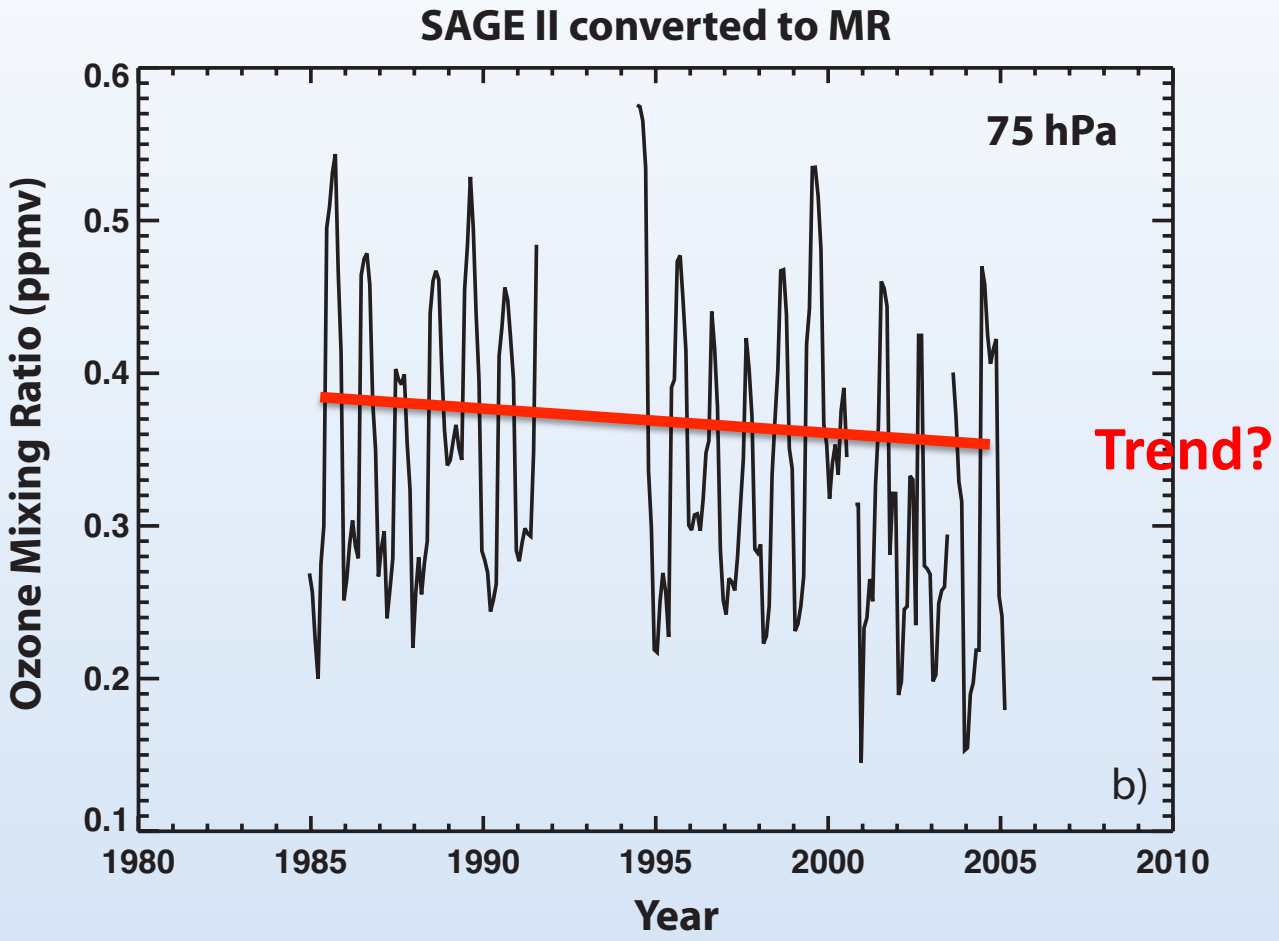
Also significant solar term

Time-series analysis of SAGE II data from 1984 to 2005 reveal a trend in the tropical lower stratosphere



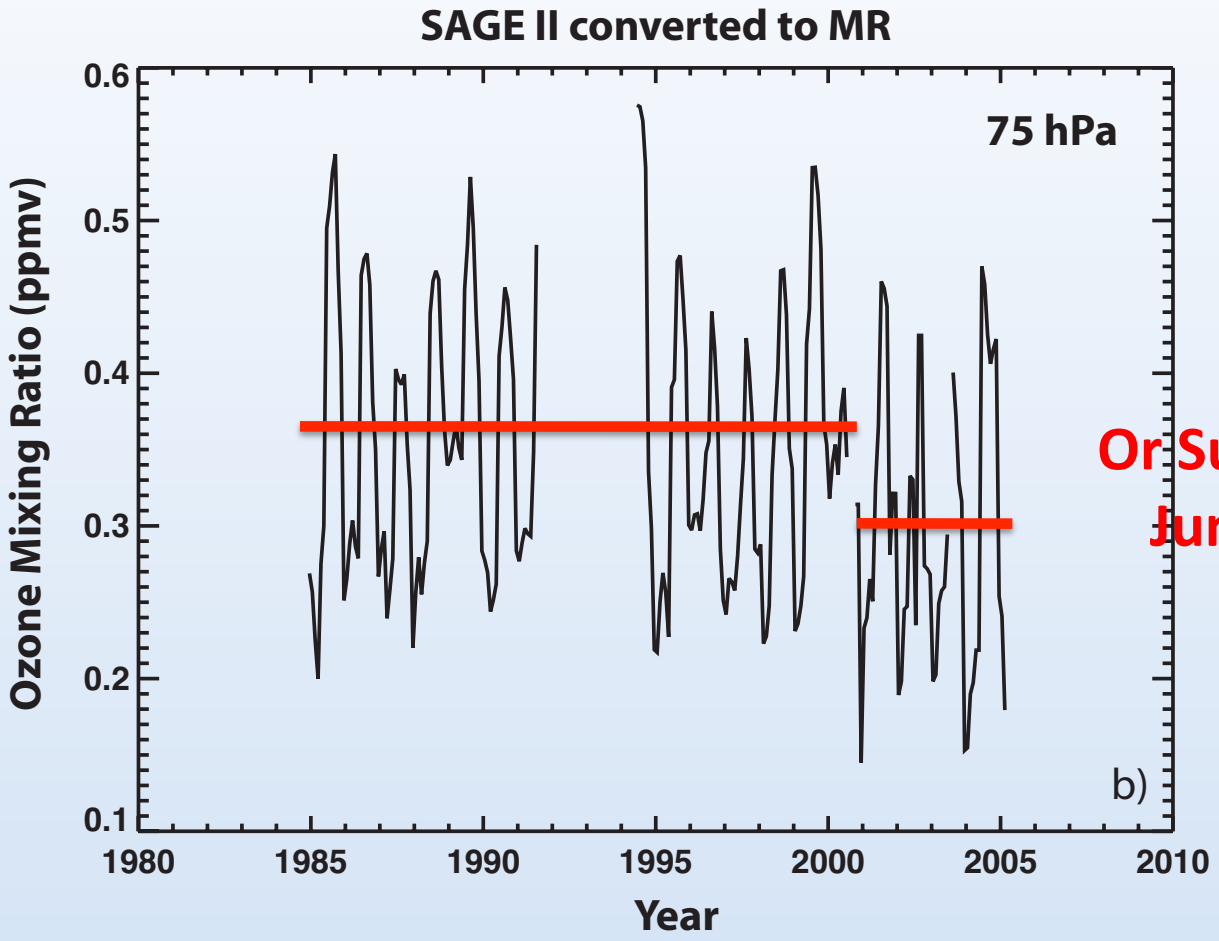
Are these just artifacts of the time series analysis?

SAGE II Data



Stolarski, Logan Symposium

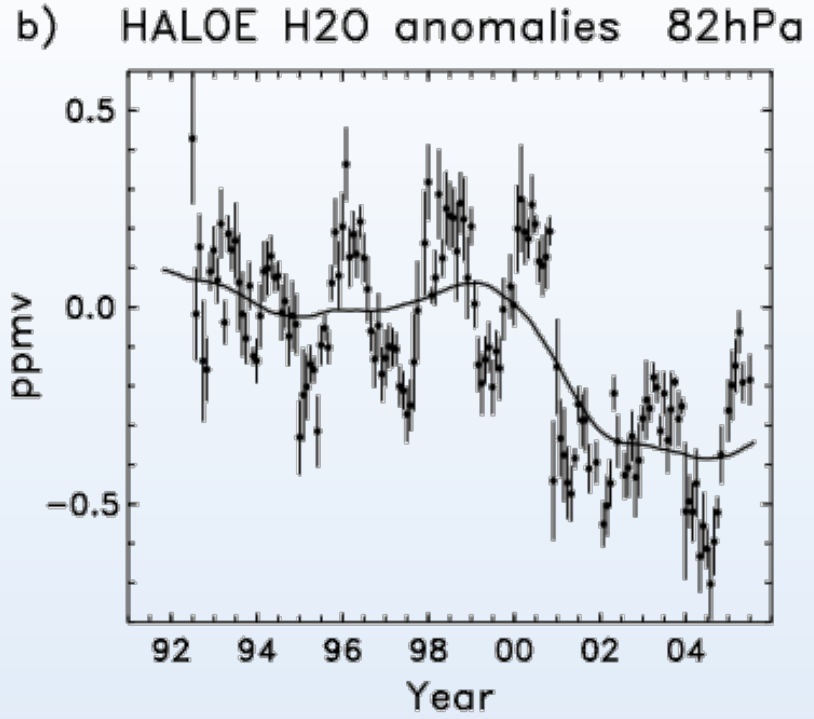
SAGE II Data



Or Sudden Jump?

Stolarski, Logan Symposium

Could Ozone Change be Related to Water Vapor Change Seen by HALOE?

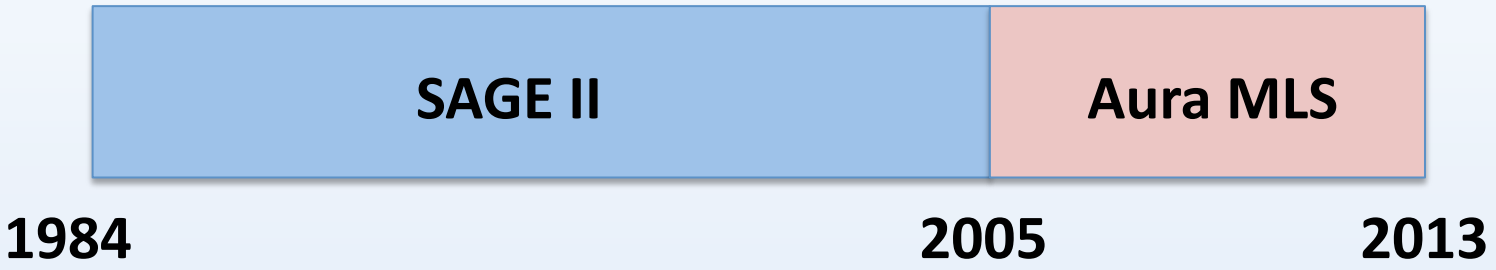


Decreases in stratospheric water vapor after 2001: Links to changes in the tropical tropopause and the Brewer-Dobson circulation

William J. Randel,[1] Fei Wu,[1] Holger Vömel,[2] Gerald E. Nedoluha,[3] and Piers Forster[4]

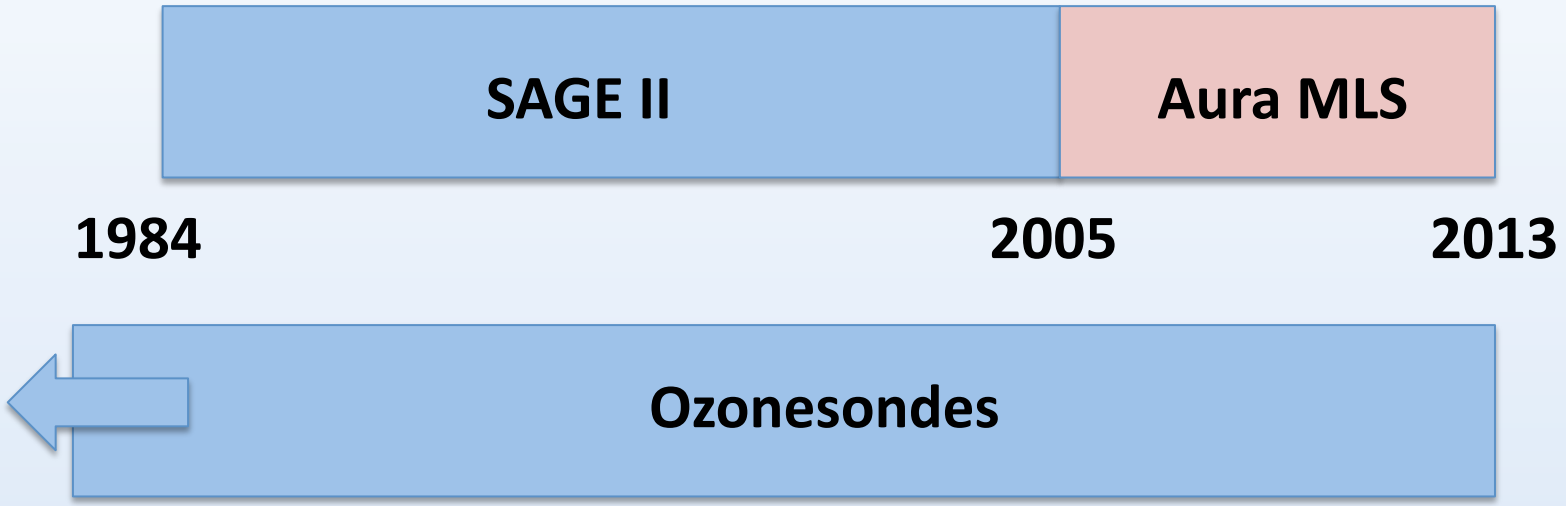
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D12312, doi:10.1029/2005JD006744, 2006

We need a longer data set



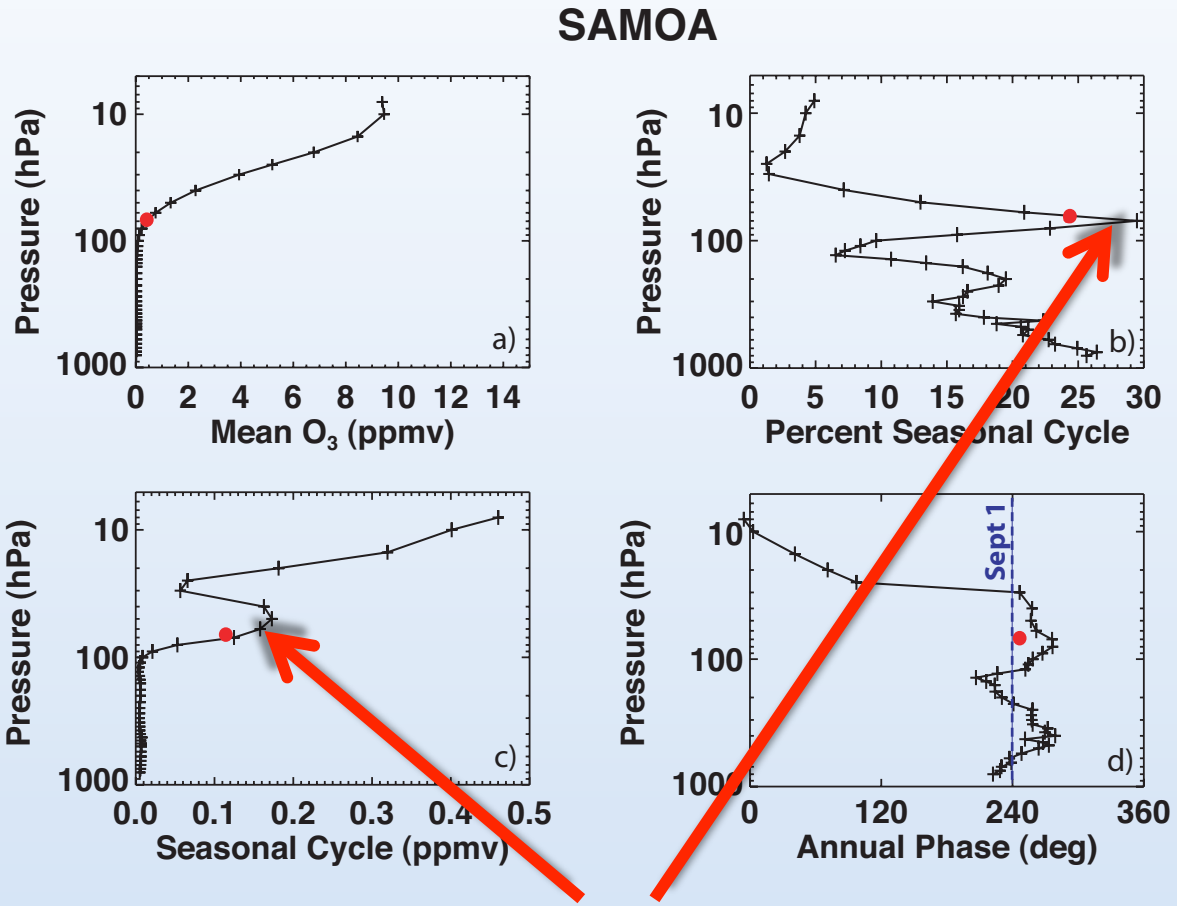
Aura MLS continues the profile data set, but with minimal overlap and differing vertical resolution and coverage

We need a longer data set



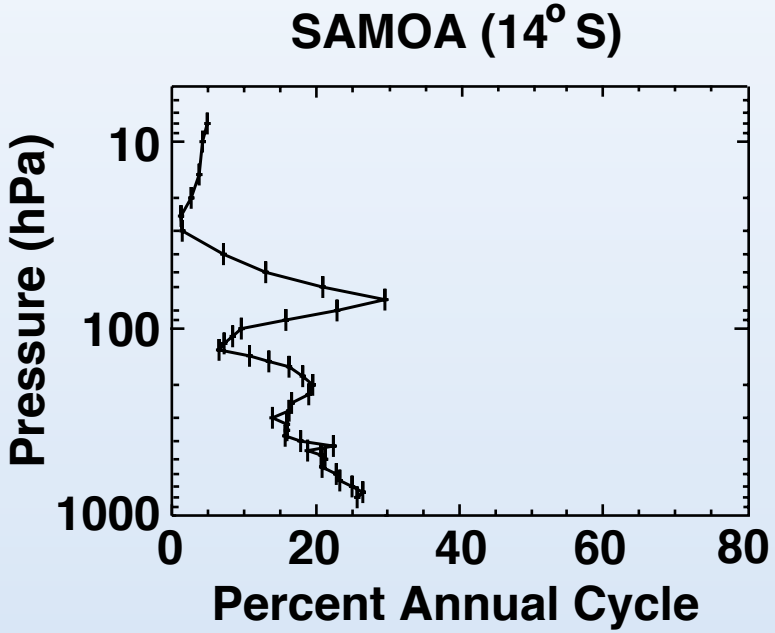
Ozonesondes provide the key to comparing the characteristics of SAGE II and MLS data

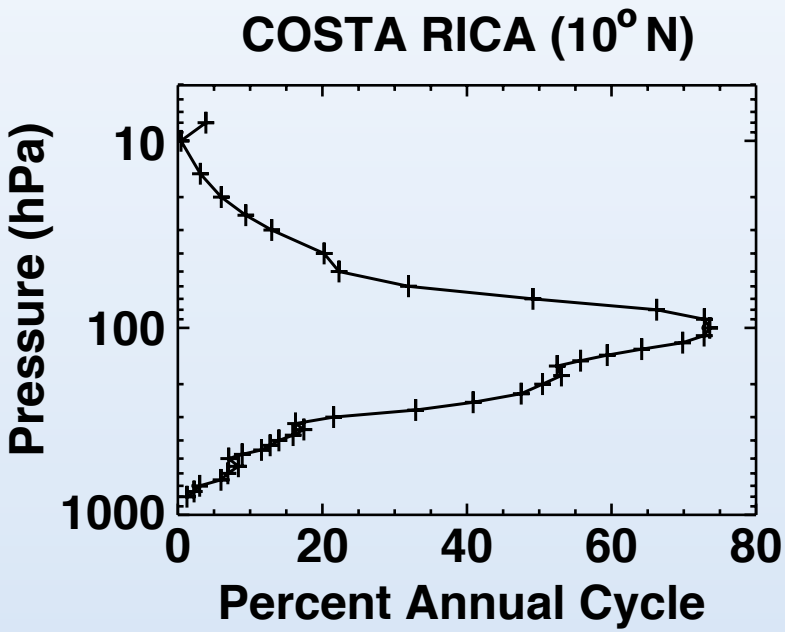
Characteristics of Tropical Lower Stratospheric Ozone Variation Determined by Ozonesondes



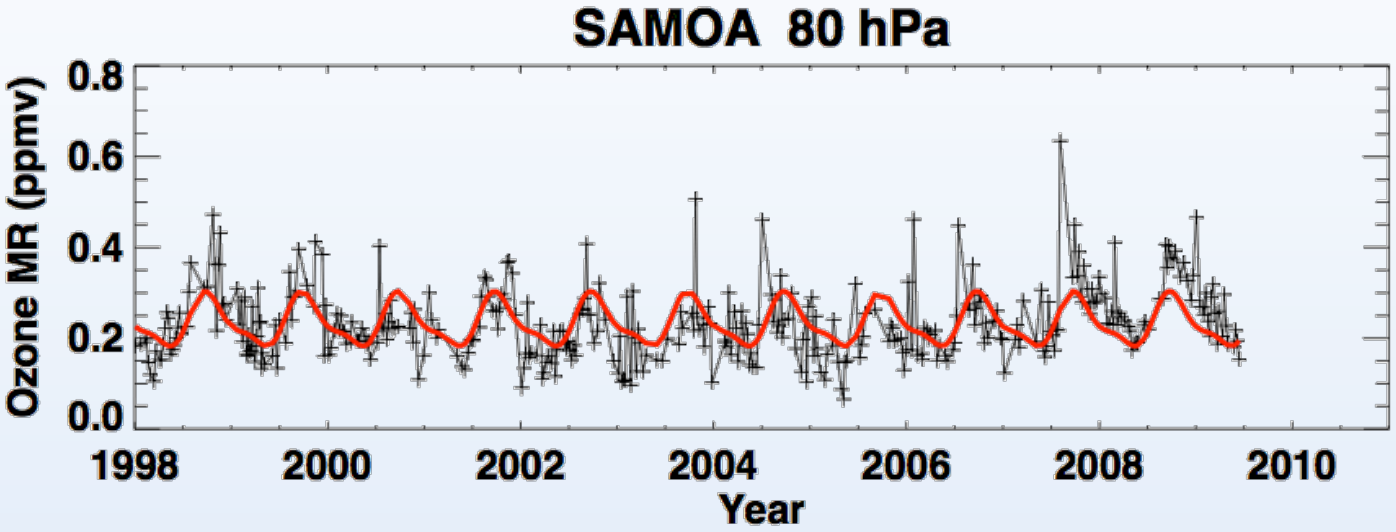
Note annual magnitude peak in lower stratosphere

Southern Tropics Appear to be Different from Northern Tropics

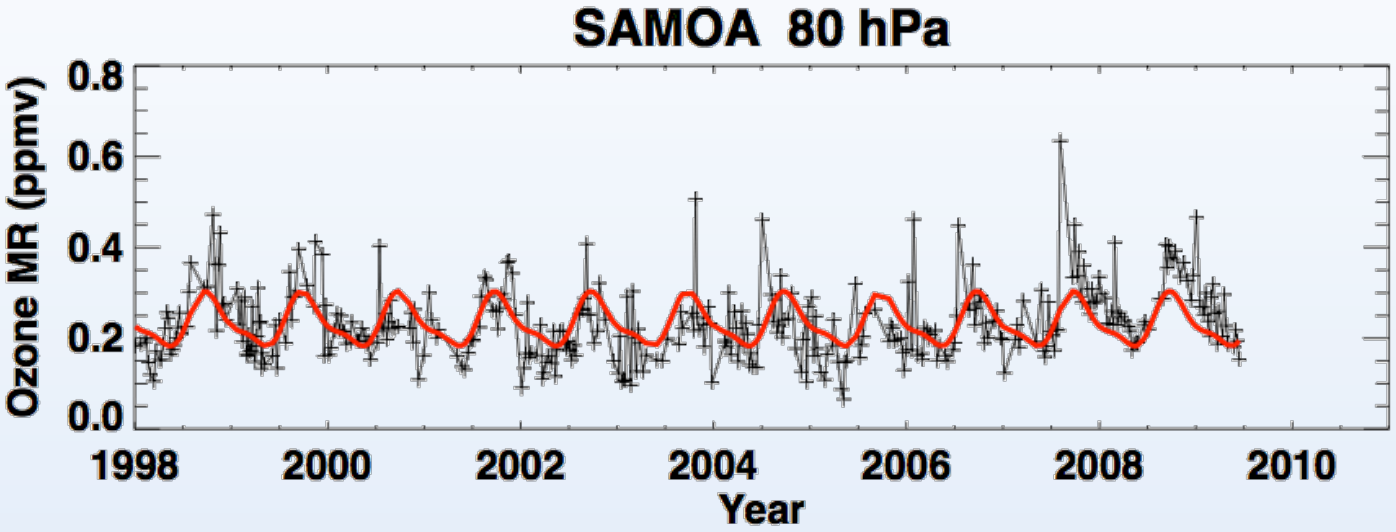


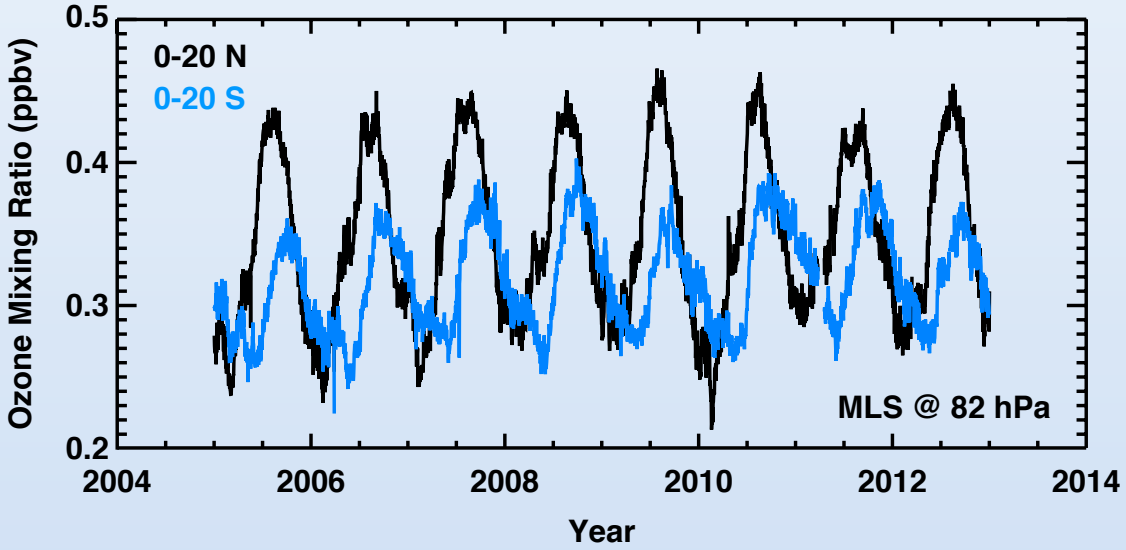


Seasonal Cycle at Samoa (14ºS)

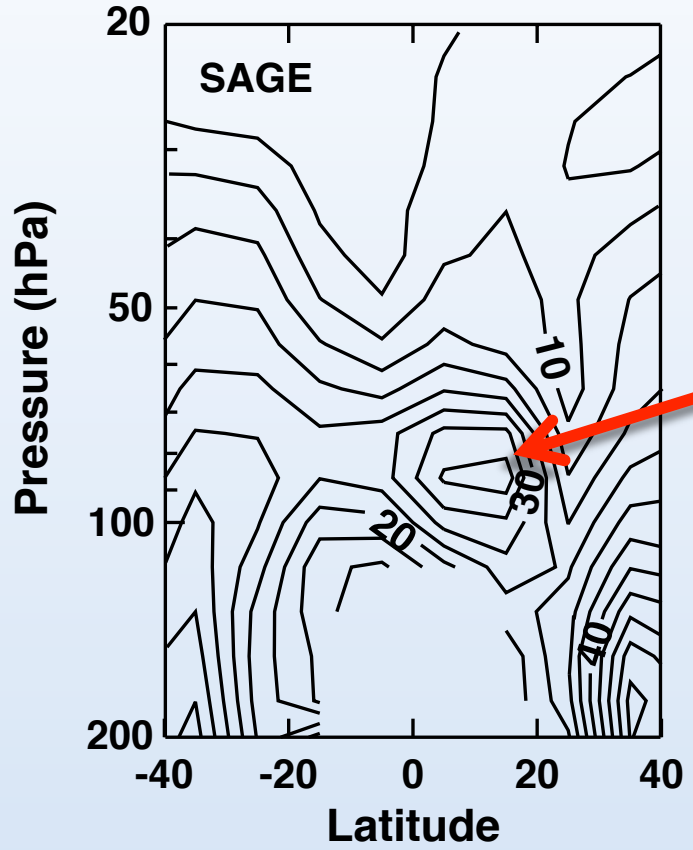


Seasonal Cycle of Southern and Northern Tropics from MLS data



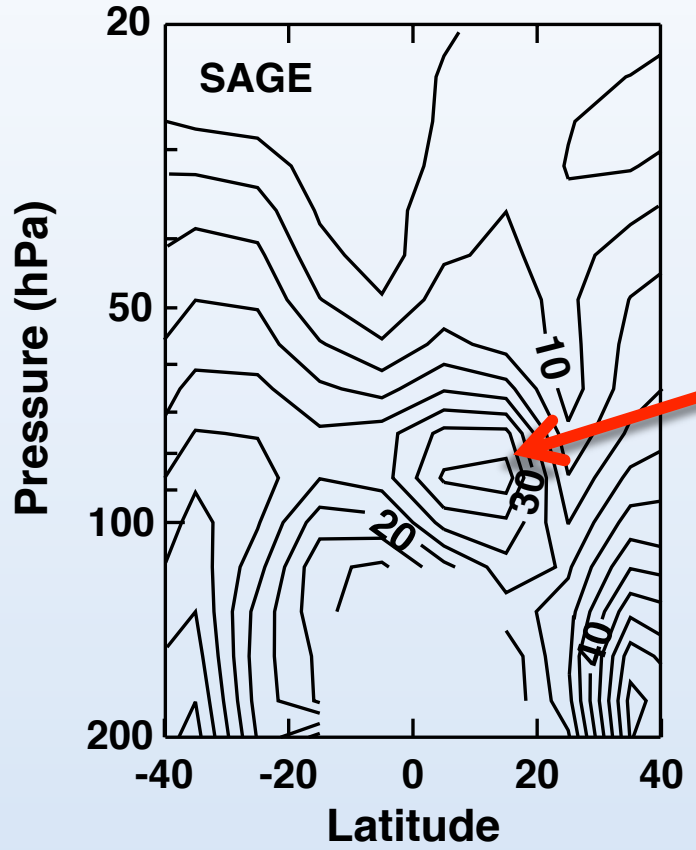


Annual Magnitude Altitude/Latitude Structure



Larger Amplitude in Northern Tropics than in Southern Tropics

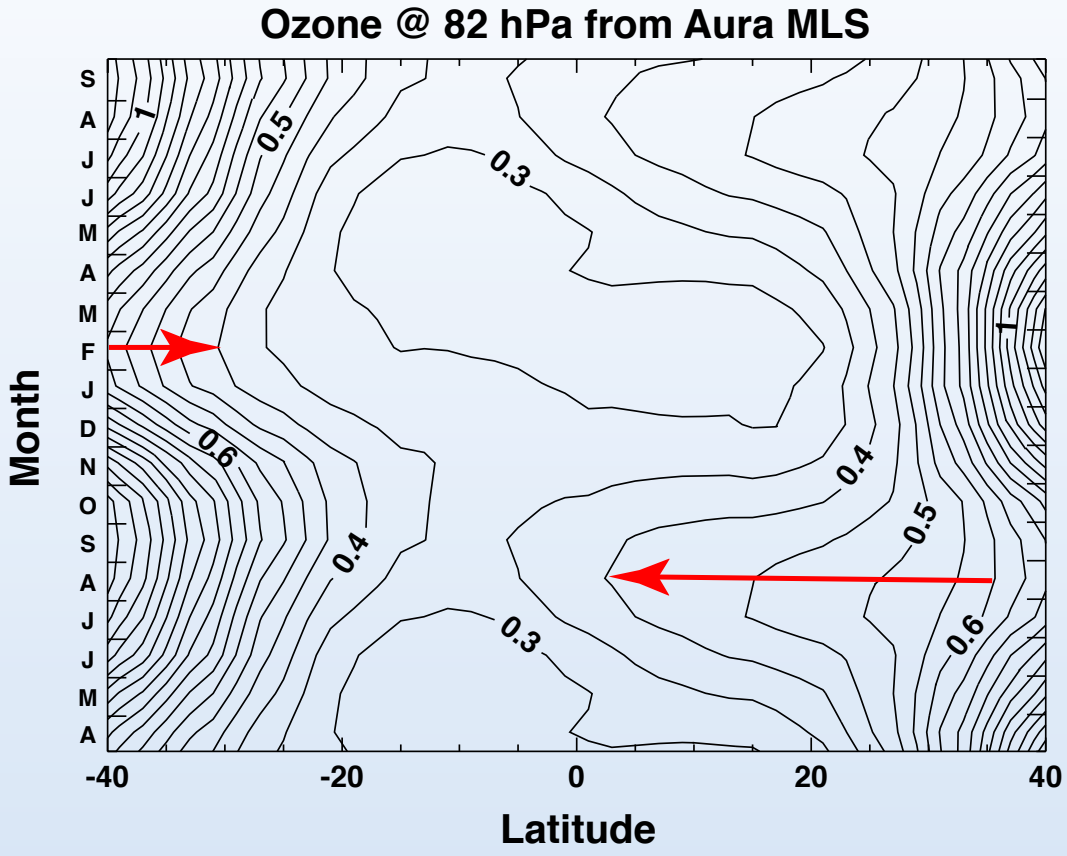
Annual Magnitude Altitude/Latitude Structure



Larger Amplitude in Northern Tropics than in Southern Tropics

Why?

Latitude/Time Contours of Ozone at 82 hPa from MLS measurements



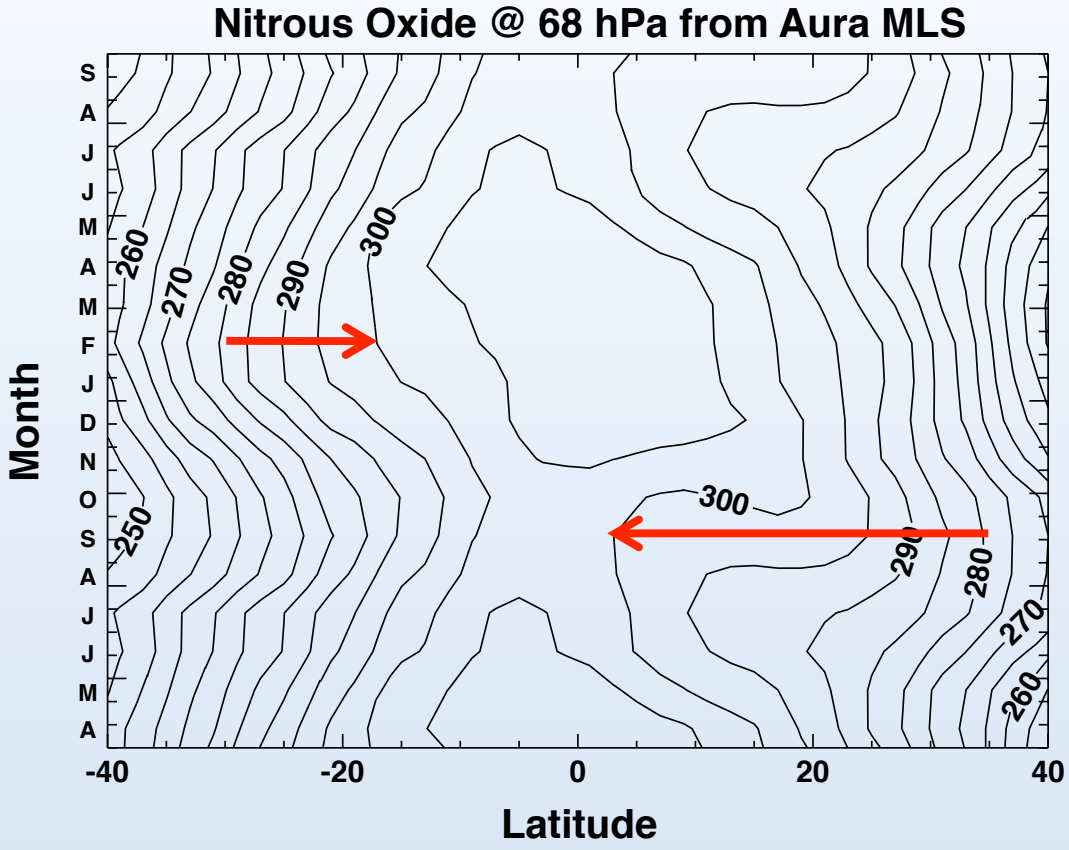
Northern Summer

Northern Winter

Northern Summer

Note spreading of high ozone mixing ratio contours into tropics in late Northern summer

Latitude/Time Contours of N_2O at 68 hPa from MLS measurements



Northern Summer

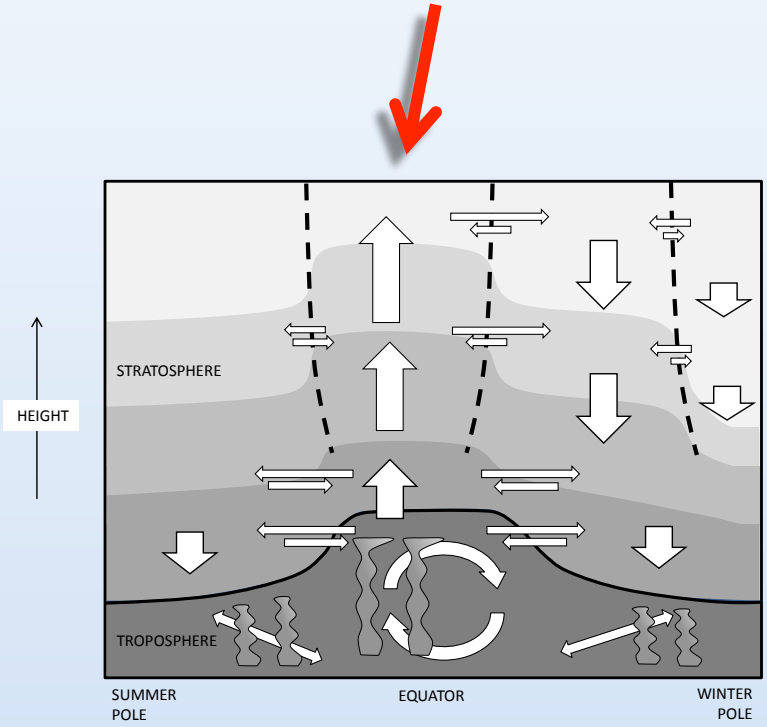
Northern Winter

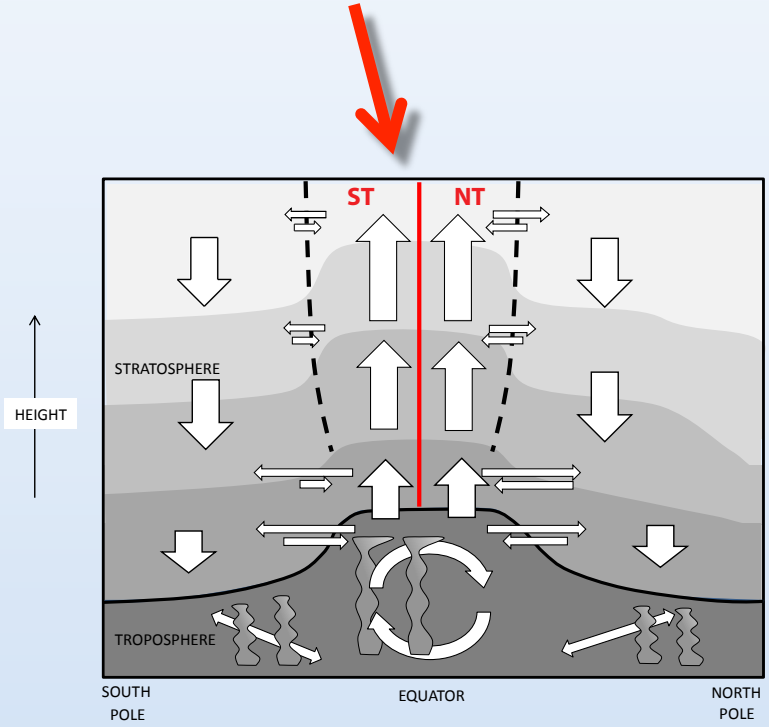
Northern Summer

Demonstrates that it is transport, not ozone chemistry, that leads to asymmetry

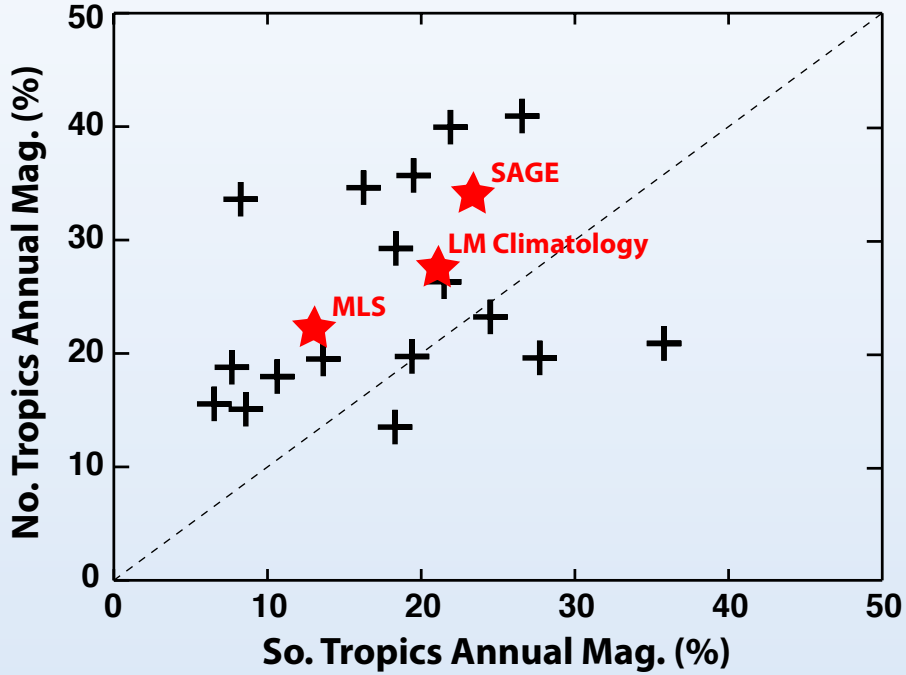
The above results imply a modification of the conceptual model for transport in the tropics

We have to combine the two pictures of the tropical leaky pipe: the summer/winter contrast with the north/south contrast.



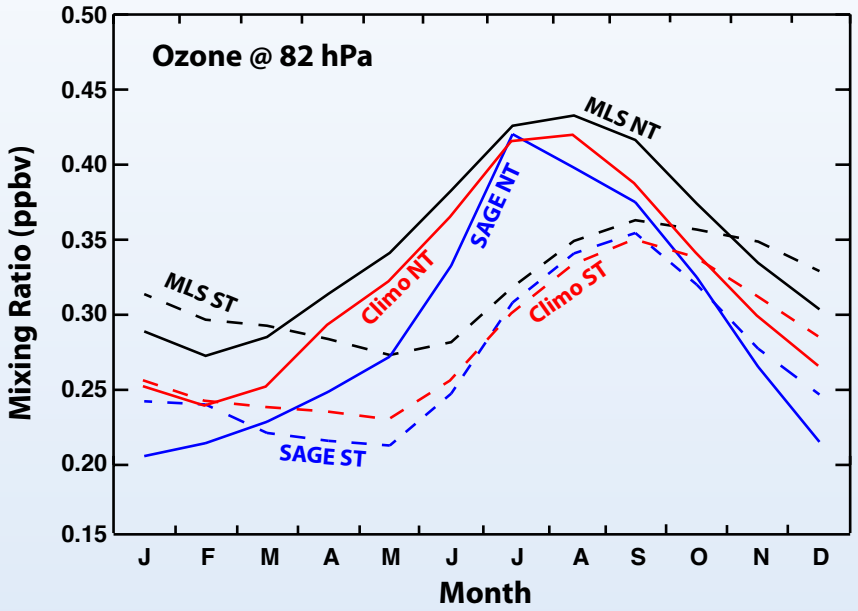


North/South Asymmetry in CCMVal2 Models



We hope that the ozone seasonal cycle can be used to test how models represent the relative roles of upwelling and mixing into the tropics

Comparison of Data Sources



We need to understand the differences in the seasonal cycle from data sources to be able to extend SAGE II time series

Climatology is from McPeters and Labow [2012], which is an update of McPeters, Labow, and Logan [2007]. Data represents a melding of ozonesonde and Aura MLS data.

Stolarski, Logan Symposium 2002

2002

Stolarski, Logan Symposium