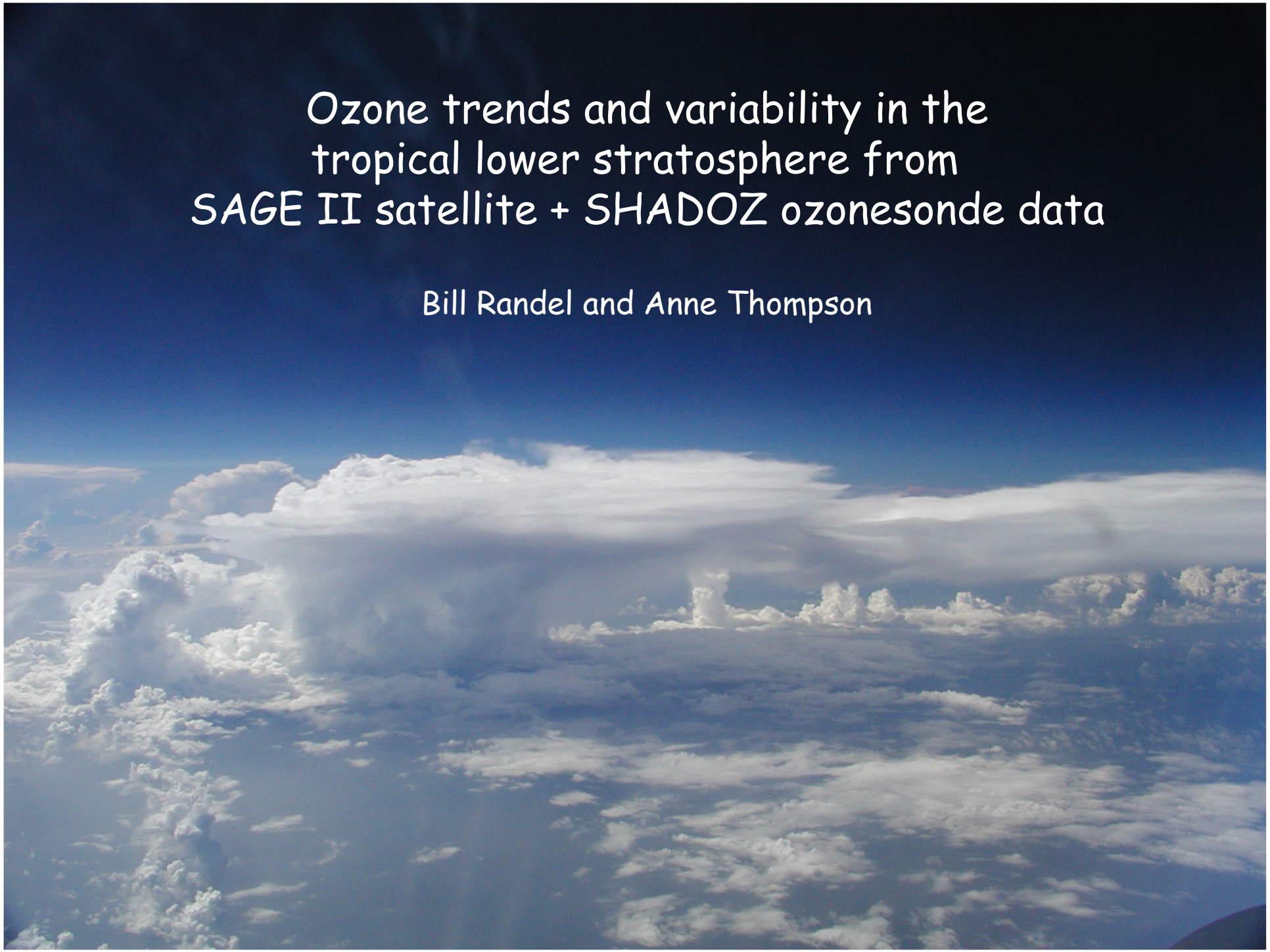


Ozone trends and variability in the tropical lower stratosphere from SAGE II satellite + SHADOZ ozonesonde data

Bill Randel and Anne Thompson

Background:

- Chemistry-climate models predict ozone loss in tropical lower stratosphere (response to increased tropical upwelling).

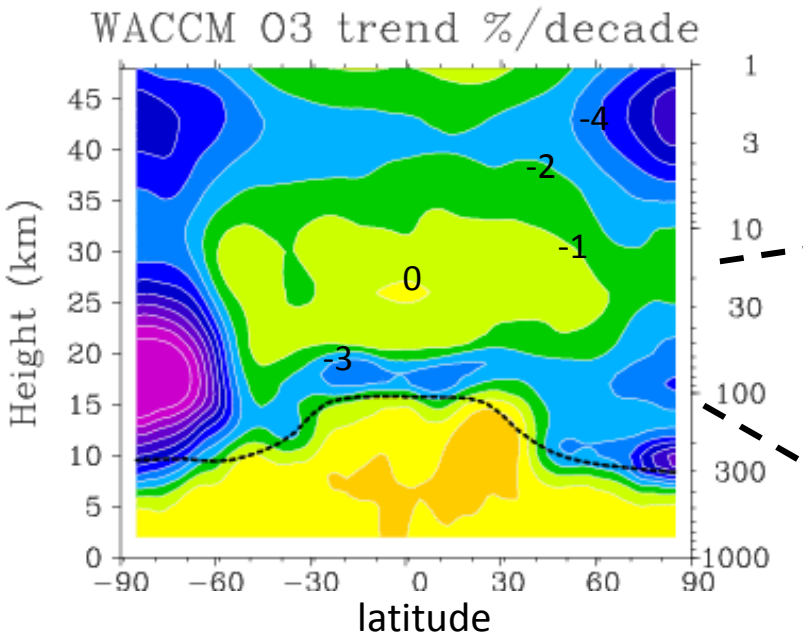
- Lack of continuous high vertical resolution ozone measurements in the tropics after the end of SAGE II satellite

How do we monitor long-term tropical ozone variability?

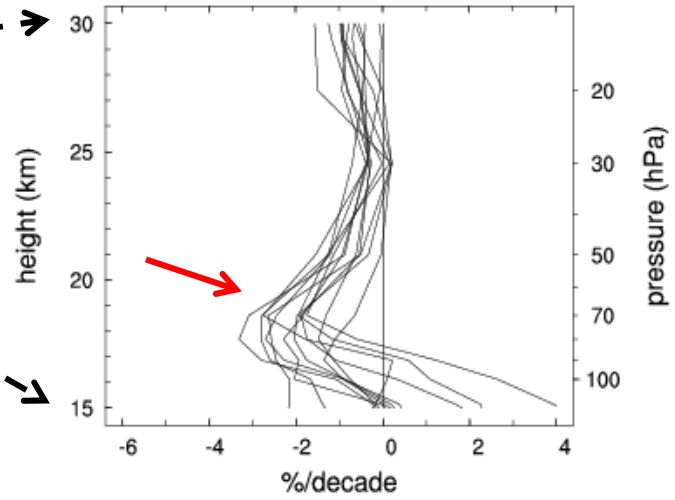
Objective here:

- Explore the use of SHADOZ ozonesondes to update and extend SAGE II measurements after 2005

Simulated ozone trends 1980-2005



Tropical ozone trends
from 12 CCMval2 models

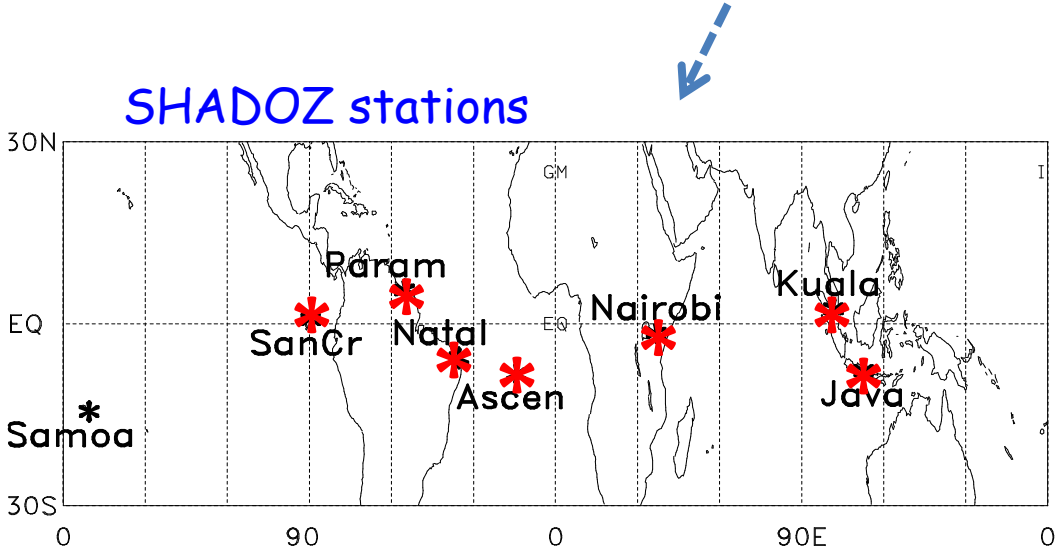


Observations require: long, accurate records,
high vertical resolution (~1 km)

Data:

- SAGE II satellite measurements for 1984-2005
  ~ monthly samples in tropics (covers 15-50 km)

- SHADOZ ozonesondes 1998-2010 (surface to ~35 km)
  use 7 stations within +/- 10° of equator



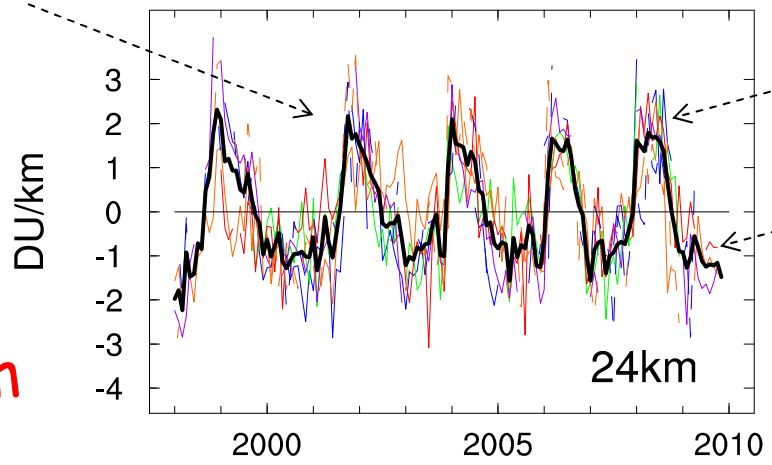
Deseasonalized ozone anomalies from SHADOZ

strong QBO signal at 24 km

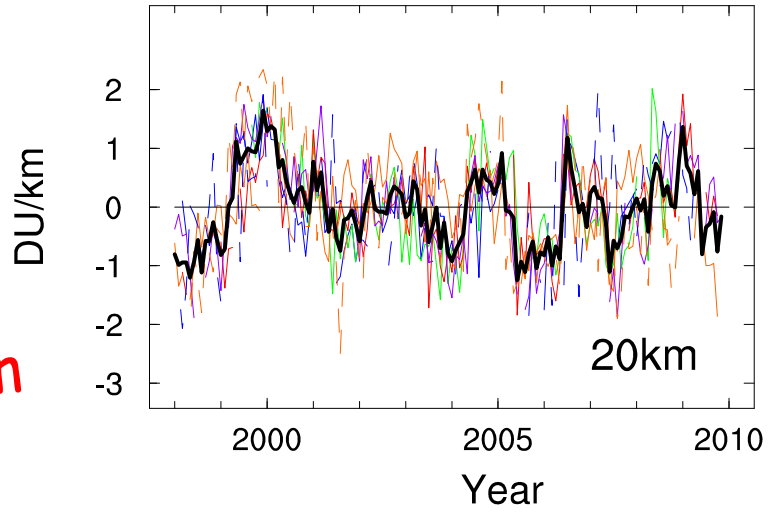
Color: individual stations

Black: average

24 km



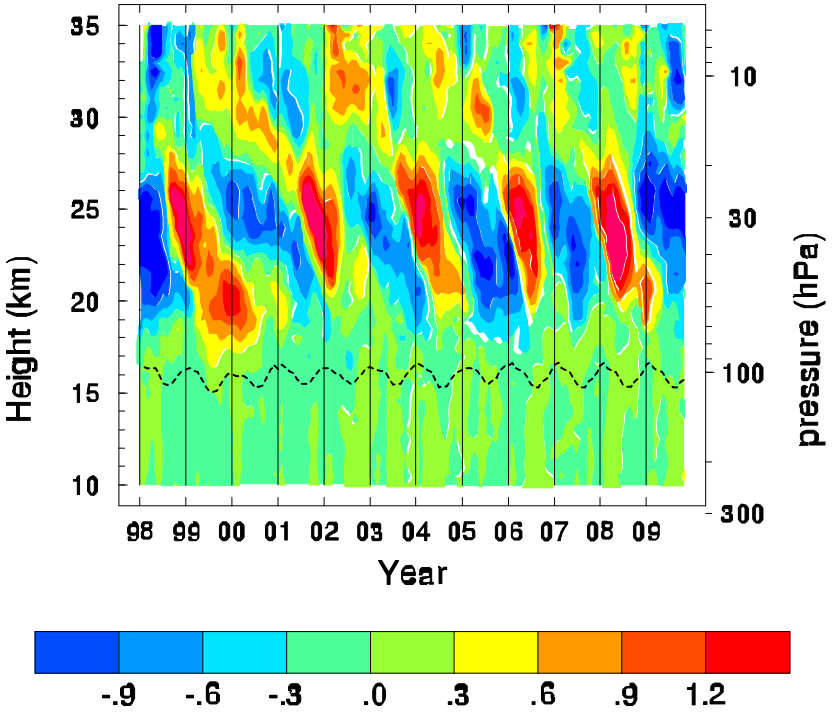
20 km



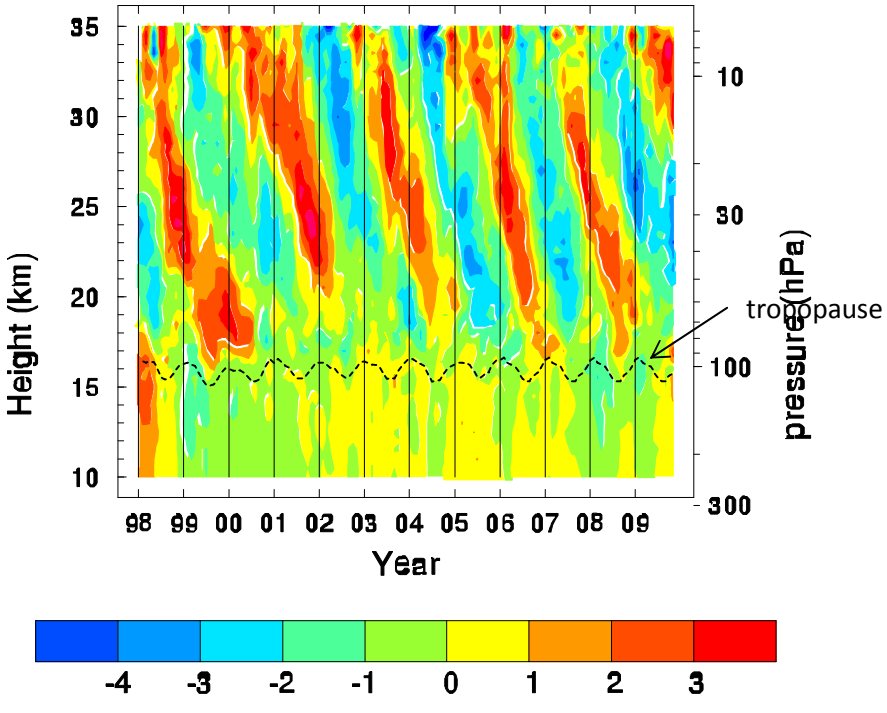
Time series of SHADOZ data 1998-2009

Note downward propagating QBO signals in both ozone and temp.

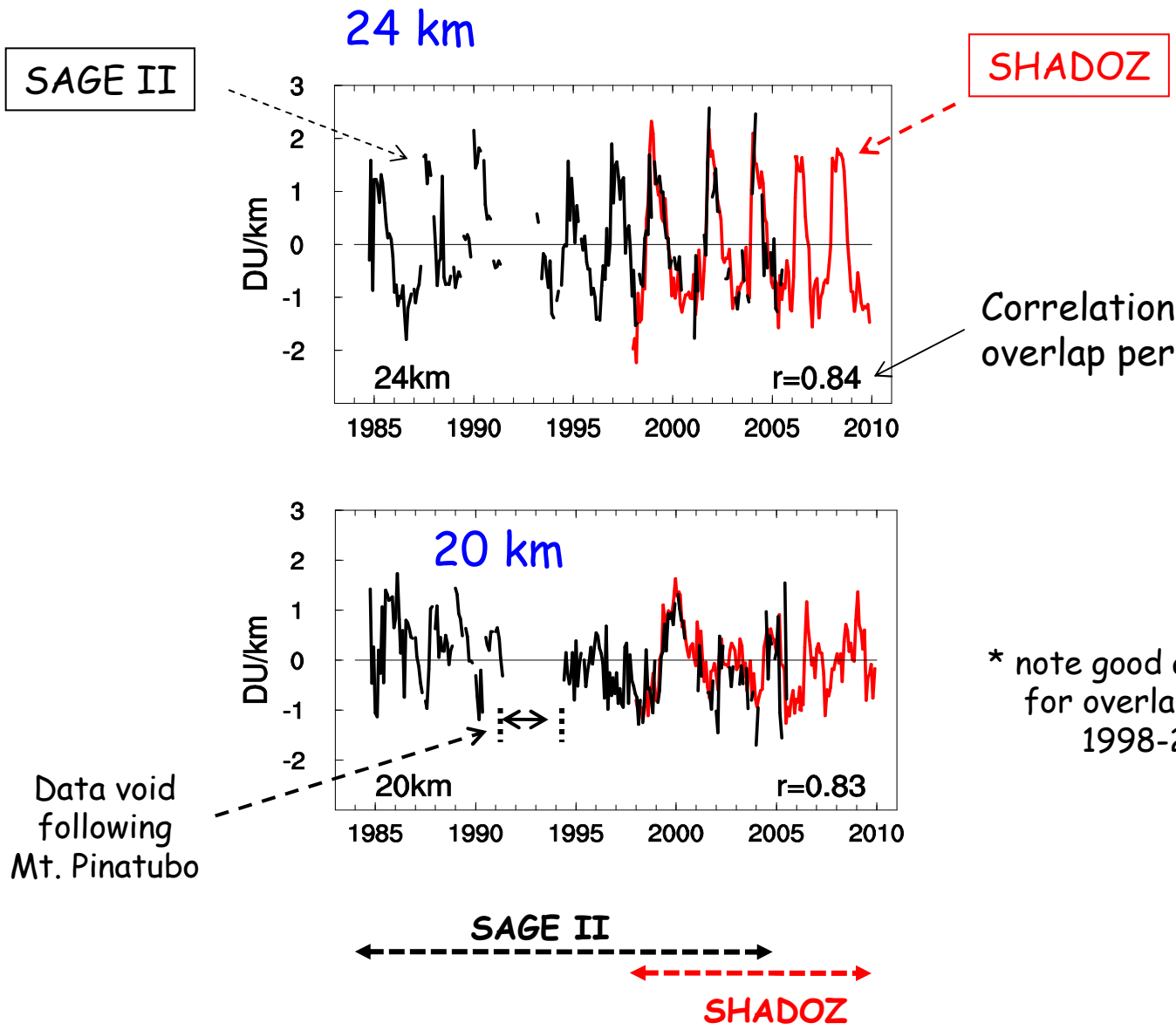
Ozone density (DU/km)



Temperature (K)

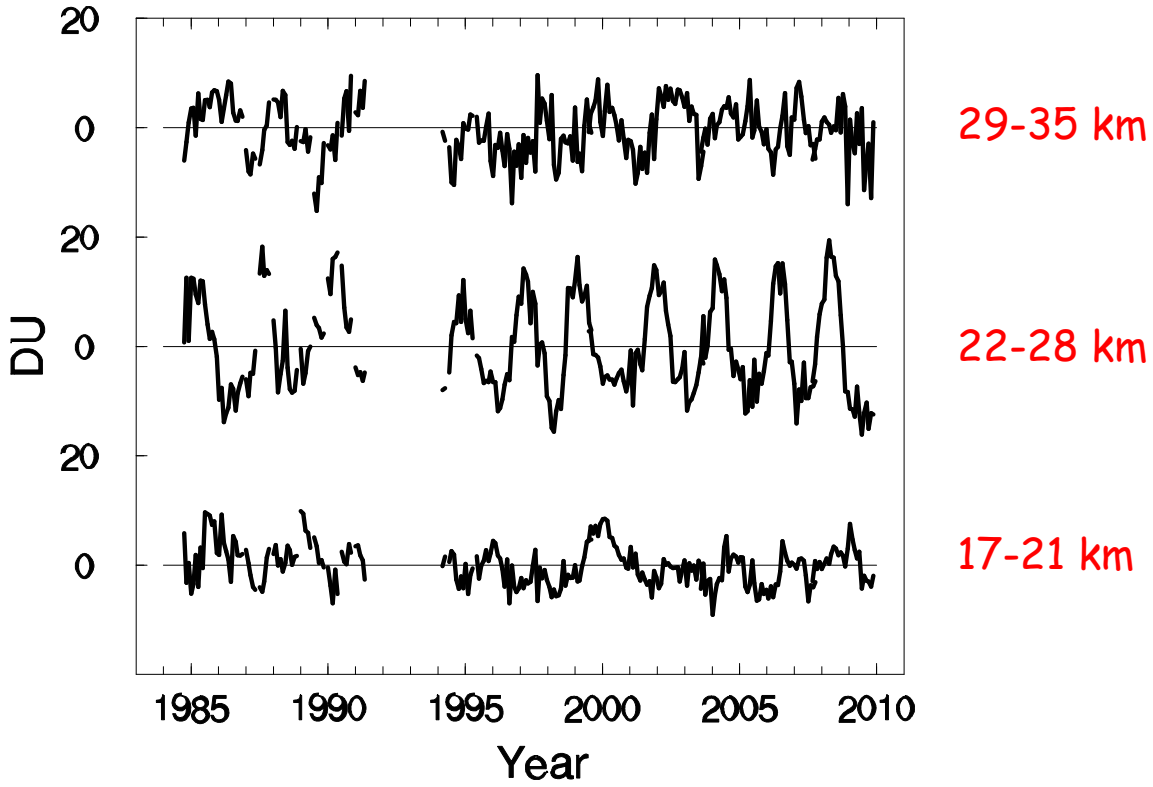


Combining SAGE II and SHADOZ data



Time series of combined SAGE II + SHADOZ ozone

Ozone anomalies (DU) for different altitude layers

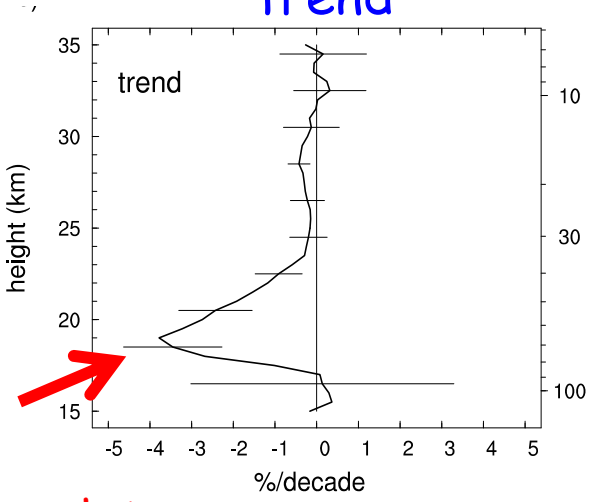


Multivariate regression model fits for combined SAGE II + SHADOZ data 1984-2009

$$O_3(t) = A*\text{trend} + B*\text{ENSO} + C*\text{QBO1} + D*\text{QBO2}$$

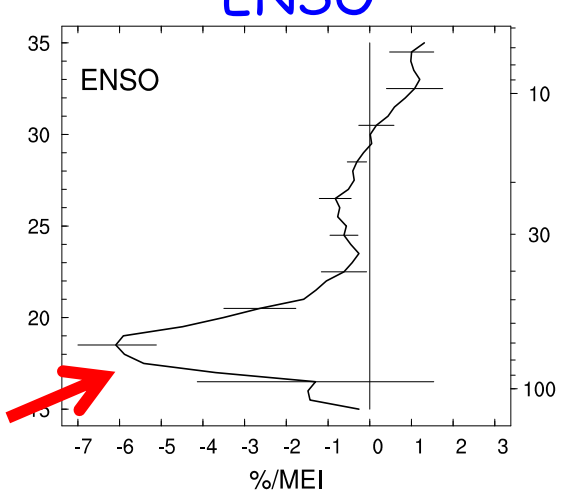
- A*trend: linear trend
- B*ENSO: multivariate ENSO proxy
- C*QBO1 + D*QBO2: orthogonal QBO proxies

trend



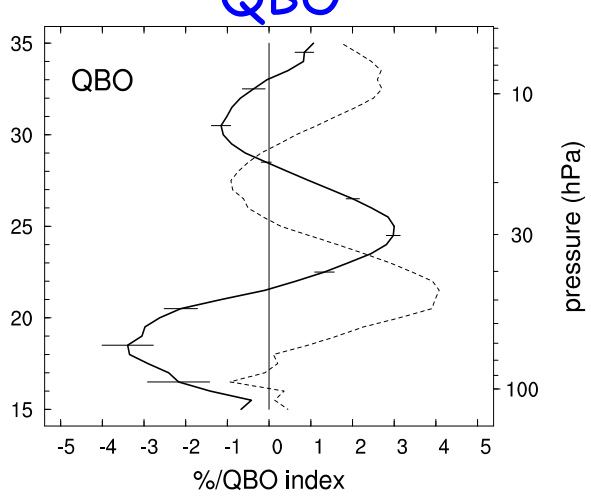
Long-term ozone decrease in lower strat.

ENSO



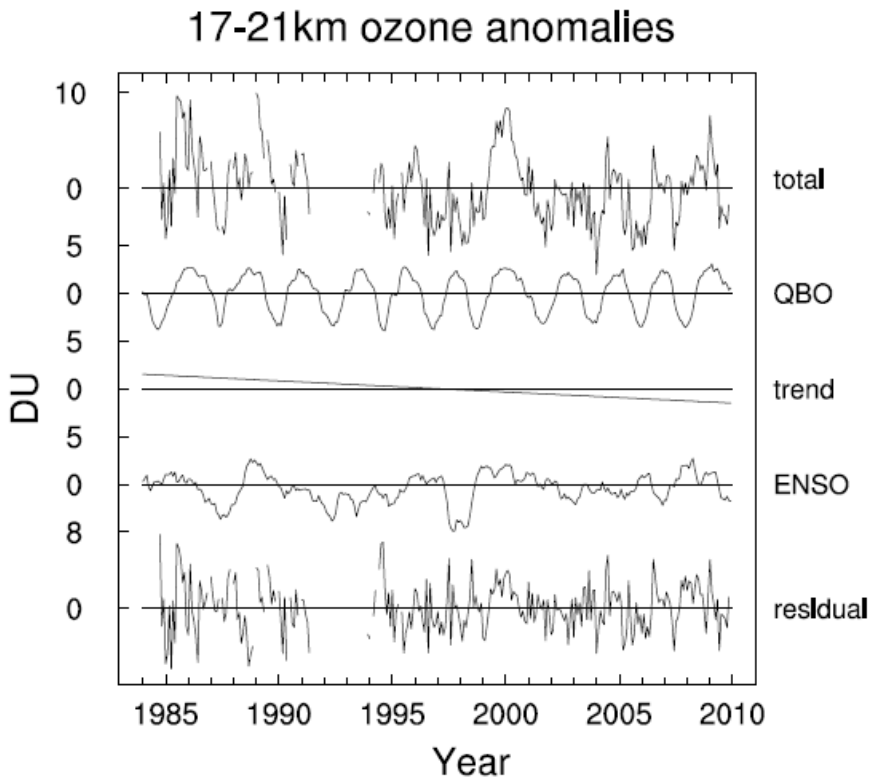
Ozone decreases for ENSO warm events
* Response to increased upwelling. Randel et al GRL 2009

QBO



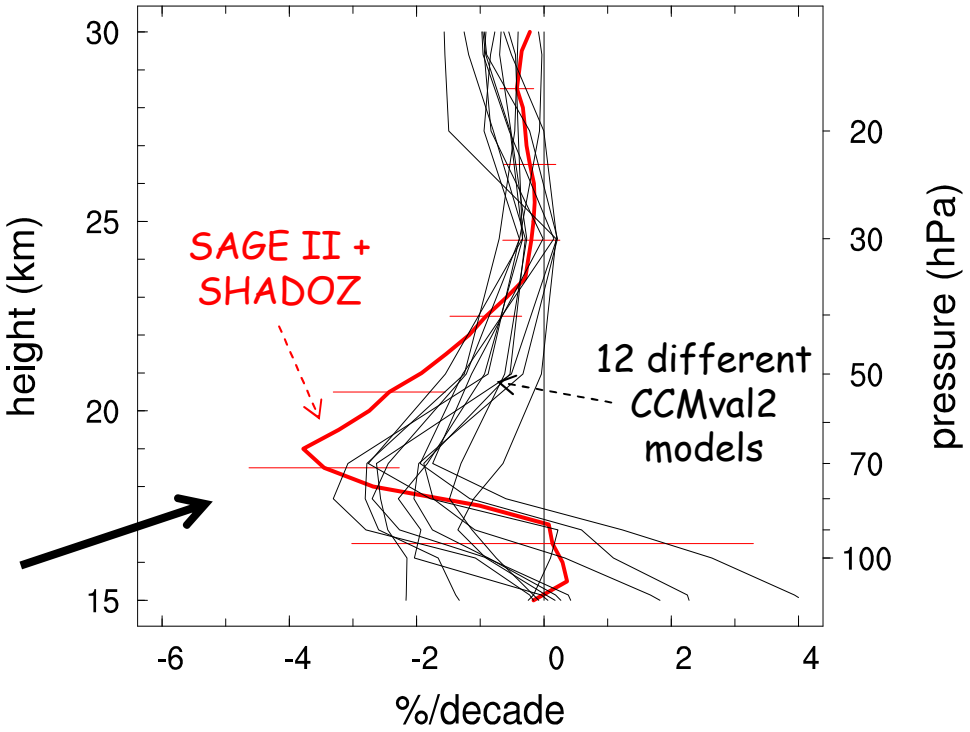
Coherent QBO signal over 15-35 km

Components of ozone variability in tropical lower stratosphere



Trends from SAGE II + SHADOZ compared to results from CCMval2 models

Ozone trends in percent per decade for 1984-2009



Significant negative ozone trends in tropical lower stratosphere

Key points:

1)SHADOZ data provides opportunity to extend SAGE II record in the tropics. Note availability of many SHADOZ stations; continuity would be more difficult with few stations. (also ozonesonde sampling poor > 30 km)

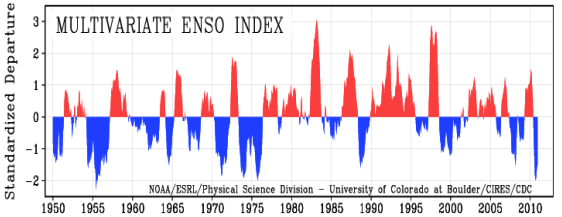
- long overlap (1998-2005) and similar high vertical resolution a key for combining data sets
- excellent overlap agreement validates quality of both data sets
- important to continue SHADOZ record to the future
- tropical lower stratosphere is a complicated region (trends, ENSO, QBO effects)

2) Combined time series for 1984-2009 exhibit significant negative trends in tropical lower stratosphere (-3%/decade near 19 km).

Reasonably consistent with results from CCMval2 models.

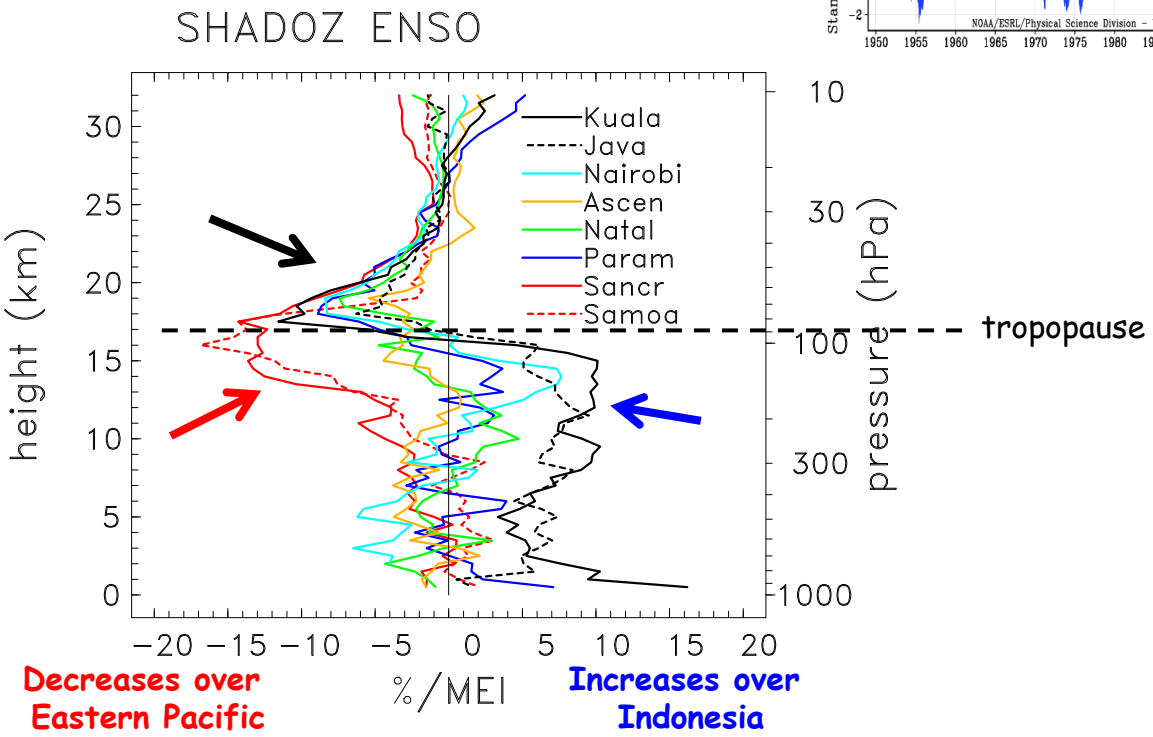
Paper accepted in JGR. Please email or ask for a preprint.

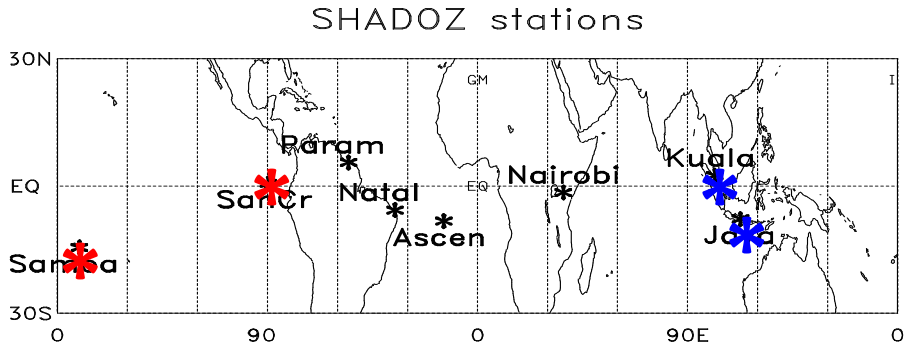
ENSO fit for SHADOZ data 1998-2009

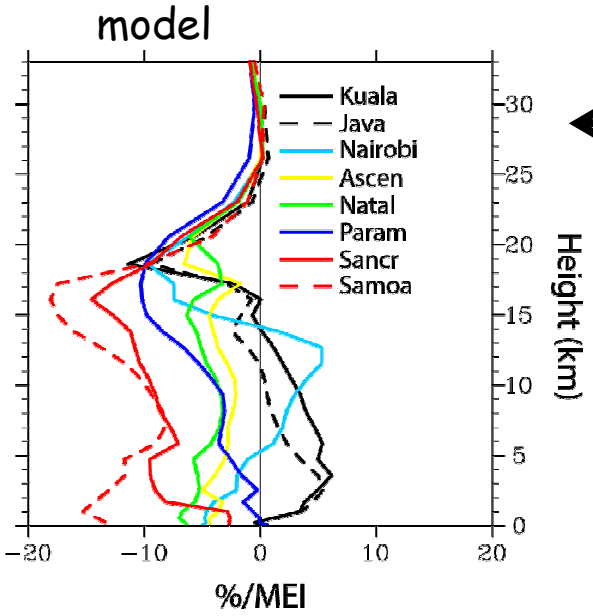


Zonally uniform response in lower stratosphere

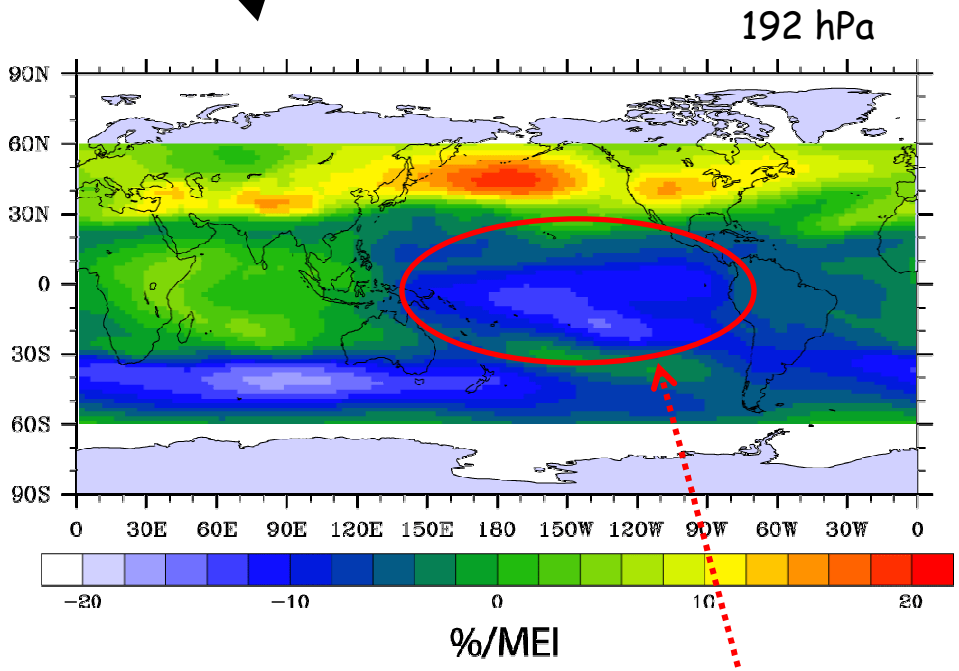
Strong longitudinal variation in upper troposphere

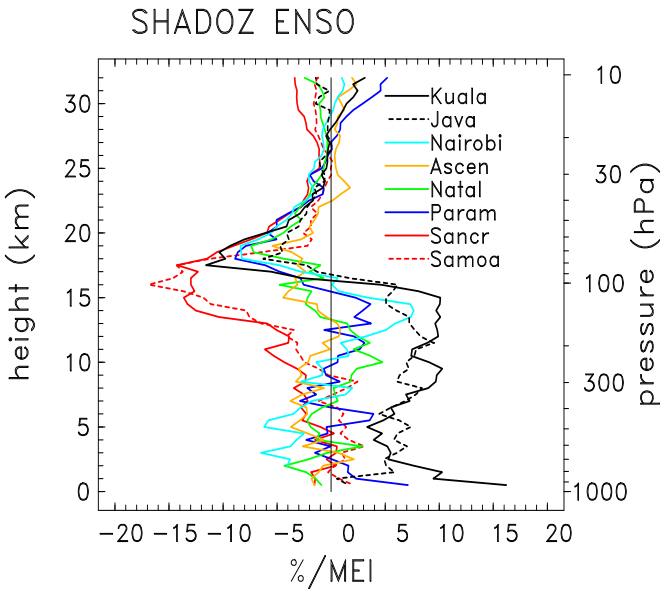






CAM-chem model calculations:
SST forcing for ENSO,
but no variable emissions



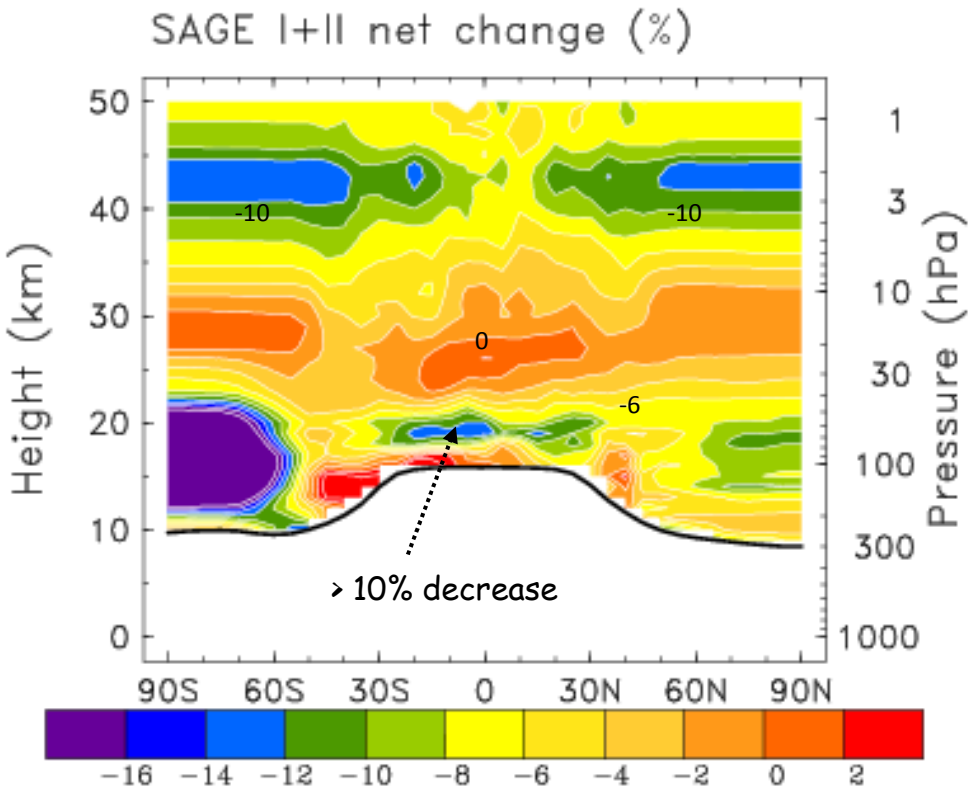


Ozone decrease during
ENSO 'warm events'

courtesy JF Lamarque

Extra slides

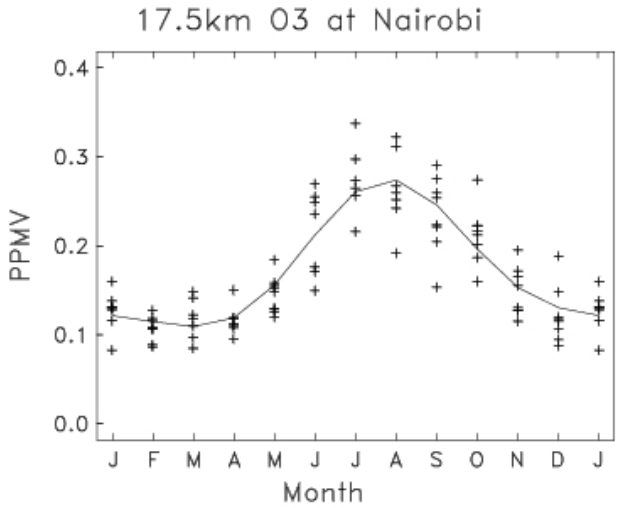
Trends derived from SAGE I+II data expressed as net changes over 1979-2005



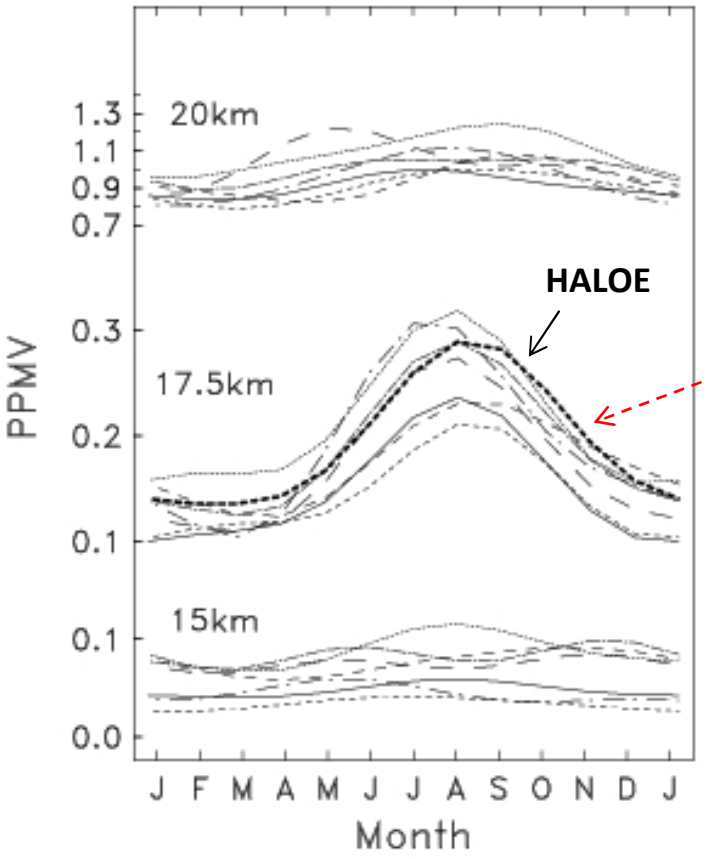
Randel et al, JGR, 2007

A large seasonal cycle in ozone above the tropical tropopause

Seasonal cycle
at Nairobi



Seasonal cycle at
7 SHADOZ stations 10 N-S



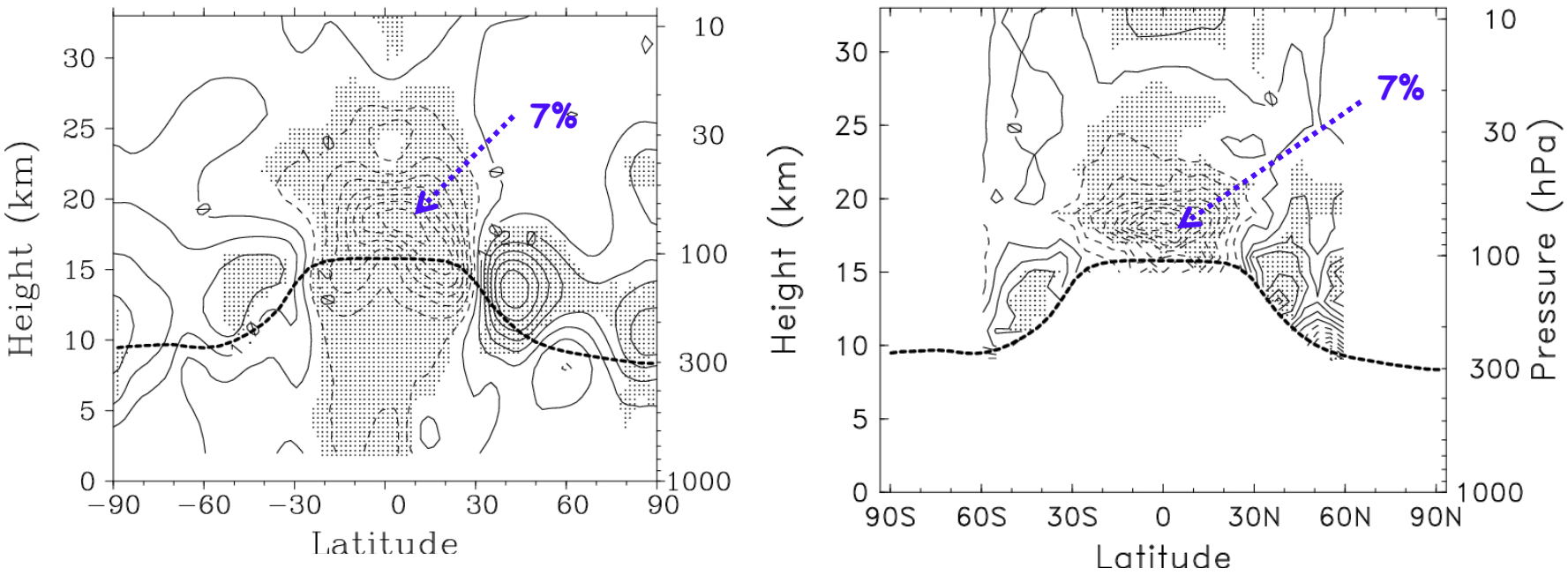
large annual cycle
at all stations, over
narrow vertical layer

Randel et al, JAS, 2007

ENSO effects on zonal mean ozone

WACCM ozone

SAGE II observations
1984-2005



Units: ozone % / MEI

Randel et al, GRL, 2009