Upper troposphere and stratosphere ozone and water vapor climatologies; requirements and uses; NOAA ESRL CSD contributions

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NOAA ESRL CSD activities include

1) Zonally averaged global gridded ozone time series based on satellite data

2) Both a raw and a gridded ozone data set based on sonde and satellite data

3) Zonally averaged global gridded water vapor time series based on satellite data

4) Use of these data sets in model studies.

NOAA ESRL CSD personnel involved: Karen Rosenlof, Susan Solomon, Birgit Hassler, Paul Young, Sean Davis, Eric Ray

How a climatology is used defines the basic requirements

We compiled (and are refining) zonally averaged time series for ozone and water primarily based on satellite data (initially compiled for a collaboration with a modeling group at Reading). These data hasn't been filtered to the extent that the Randel and Wu ozone set has been, so should provide a better representation of variability, at least on scales longer than a month.

1) For use in radiative heating calculations, both to estimate changes in the mean meridional circulation and to estimate changes in RF due to changes in these constituents.

2) To be used in model simulations (testing impact of using realistic stratospheric ozone on stratosphere and troposphere dynamics).

3) To be used in time series analysis, with the ultimate purpose to study assorted dynamical phenomena in the stratosphere.

4) As comparison to model simulations (ie, CCMVal)

Work on a 3D time series for ozone using sonde and satellite data is ongoing

This will also be used in model runs to assess impact of ozone on climate, in particular looking at pre-ozone hole runs versus runs using current ozone amounts.

Requirements for use in model studies:

1) Input needed from the surface through the stratosphere for CSM model runs and radiative heating calculations.

2) For the Reading model runs, input was also needed for the mesosphere.

3) Monthly averaged data.

4) Latitude gridded; subsequent data sets will also include equivalent latitude gridding

5) Pole to pole coverage.

6) Long temporal coverage, ideally starting before the SH ozone hole was well established.

7) Time series needs to be smooth and continuous.

8) Depending on the type of model run, a similar data set for temperature covering the same time and spatial region may be needed

9) Other model studies need a global water vapor time series for the stratosphere and upper troposphere.

Inputs to zonally average gridded ozone data set:

SME climatology, used for the mesosphere

SAGE-2, upper troposphere to lower mesosphere

HALOE, stratosphere to the lower mesosphere

SBUV (version 8), stratosphere (above 50 mb)

MLS (UARS), stratosphere, Aura MLS can be used after 2004

TOMS (Version 8), used to adjust columns

KNMI ozone climo, used for troposphere, could also use Logan climatology

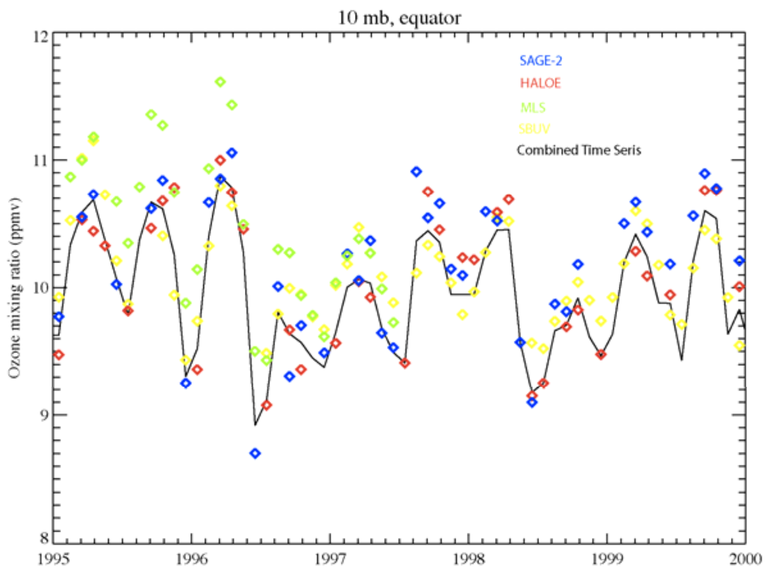
UGAMP ozone climatology (from BADC), used for top 2 levels in the mesosphere

Combining, smoothing, homogenizing included:

1)Using HALOE, which had the best overlap with other datasets, to scale other datasets.

2) Lots of interpolation & scaled profiles to match TOMS total columns

3) SME climatology (from the 1981-1991) used for the mesosphere



Example at one latitude and one levels for a portion of the time series.
(equator, 10 hPa)

Planned improvements and comparisons:

Satellite measurements used are lacking at the poles, so it required a lot of creative extrapolation. We are now working on incorporating ozone sonde measurements at the poles and LIMS measurements from 1978/9 and using equivalent latitude gridding.

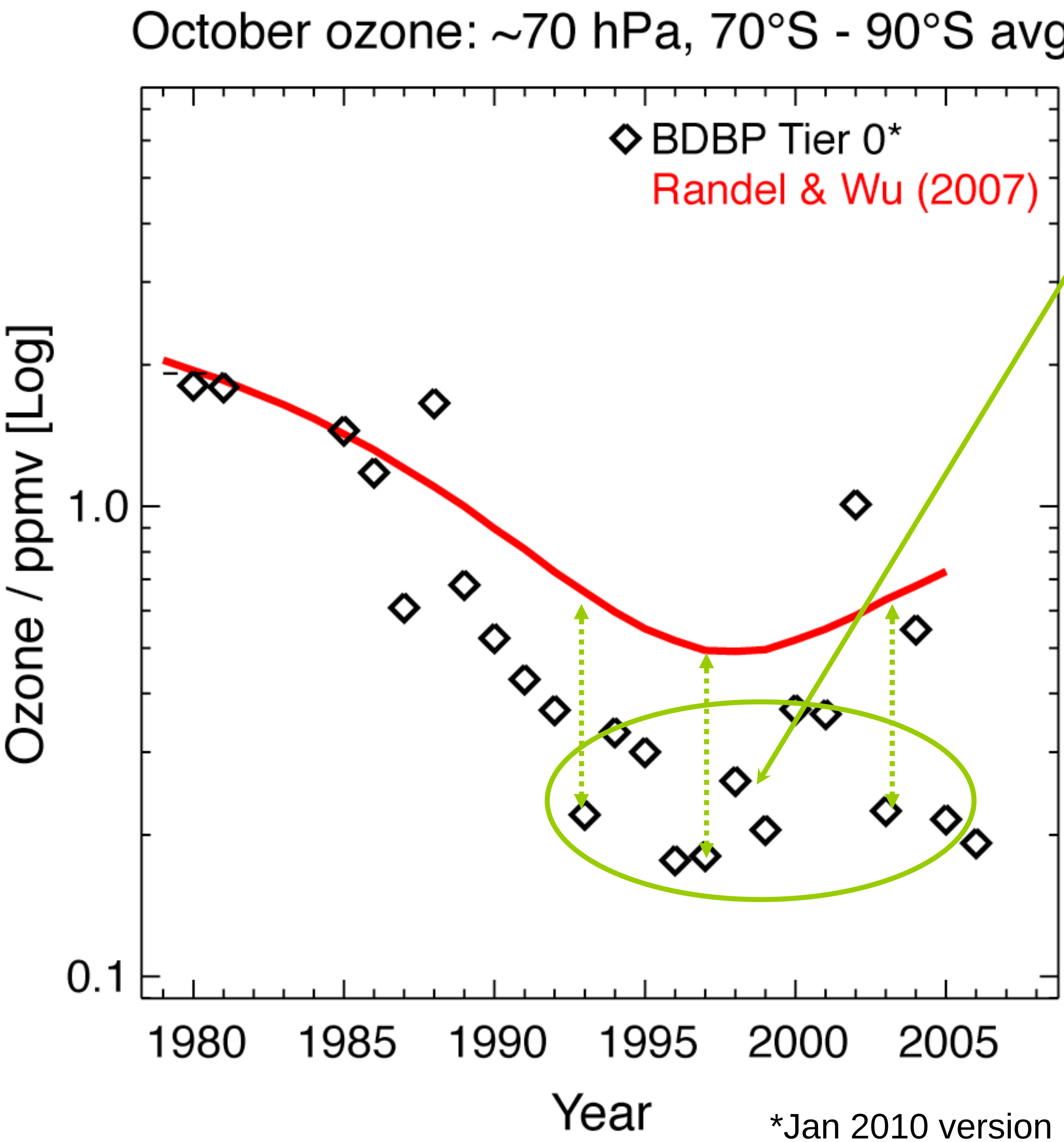
Satellite measurements used are also lacking in the troposphere. That wasn't significant for the study done at Reading, as the tropospheric ozone was model derived. A combination with an improved version of the NIWA ozone data base is planned.

There are other ozone data sets available or soon to be available; comparisons with these are planned.

- NCAR (Randel and Wu) *(published, widely used in modeling work)*
- NIWA (Bodeker and Hassler)
- NASA/GSFC (Stolarski, based on SBUV)
- Environment Canada (Fioletov and McLinden, using SAGE and SBUV)
- GOZCARDS (NASA MEASURES project, PI; L. Froidvoix) new
- 3D updated version of NIWA (Hassler, Bodeker and Solomon) new

Zonally averaged global gridded ozone time series

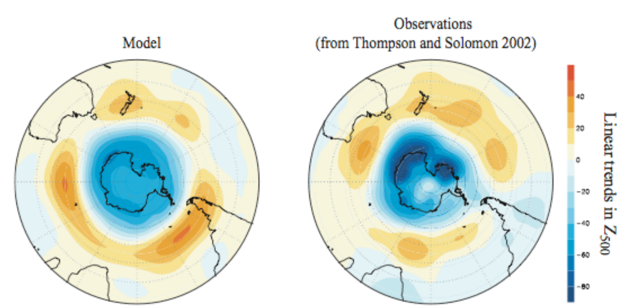
Work on improved NIWA sonde/satellite set ongoing for use in model studies: Hassler, Solomon and Young at NOAA ESRL CSD



*Jan 2010 version

Issue is whether this matters for climate response.

…e.g. the SAM



Gillet & Thompson 2003

Sonde/satellite ozone data set

New ozone data set - improved version of NIWA (BDBP)

Binary DataBase of Profiles (see Hassler et al., 2008, ACP)

Ozone data for BDBP

Various sources:

- SAGE I and II
- POAM II and III
- HALOE
- Ozonesondes

→ Tier 0: QC'd raw data

Regression model

Tier 0 input. Includes:

- EESC
- Linear trend
- QBO
- ENSO
- Solar cycle
- El Chichon / Pinatubo

Regression output

Four 1.x Tiers:

1.1 Anthropogenic

1.2 Natural

1.3 Natural + volcanoes

1.4 All

cf. EESC, solar & QBO terms
for Randel &Wu data

Will be used in model studies assessing sensitivity of depth of polar ozone trends on climate parameters.

Water vapor:

Goal: monthly average global time series

Plan: put together a satellite based series, and then compare or improve with the research quality sondes and other aircraft and ground based measurements.

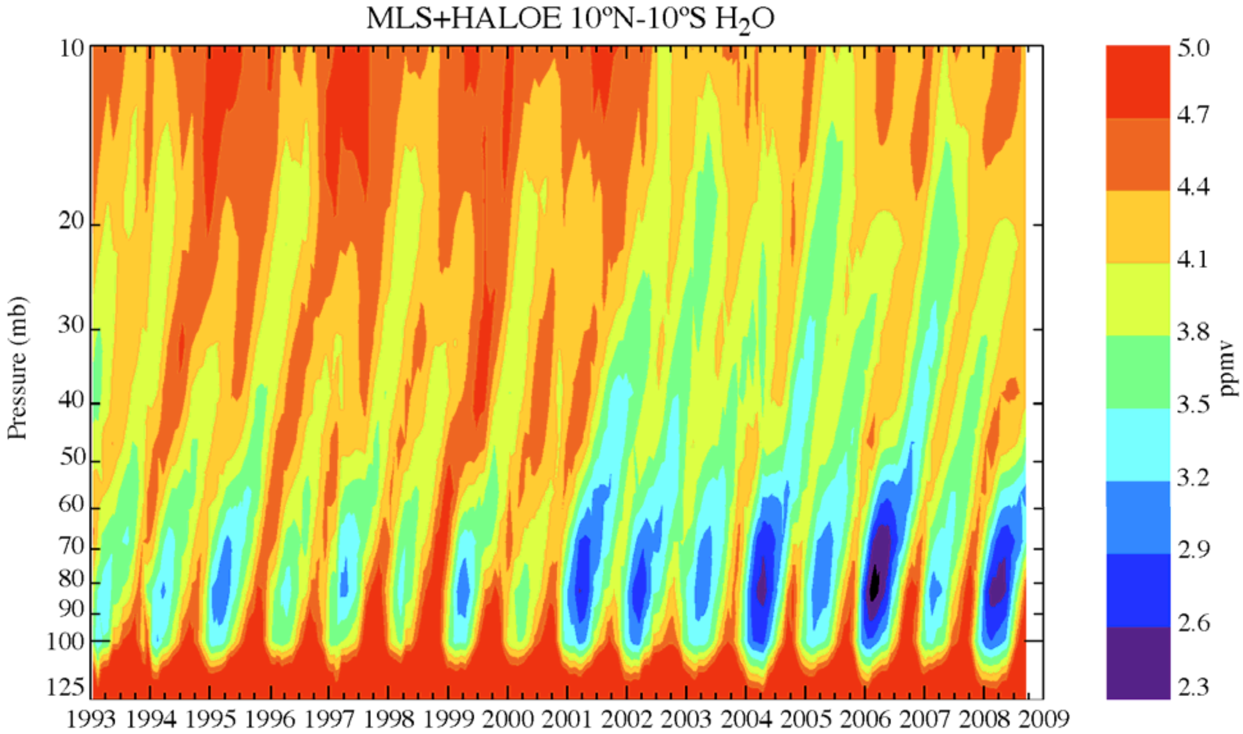
What we've completed: matched up Aura MLS and HALOE in the tropics; working on adding SAGE II. Also working on adding tropospheric humidity from new HALOE retrieval (V20) and AIRS.

Important consideration: accuracy, as there is a fair bit of spread in various observations at stratospheric concentrations. We’ve used both FP sonde comparisons and methane/water relationships in the stratosphere to assess accuracy, and are making adjustments to match to Aura MLS.

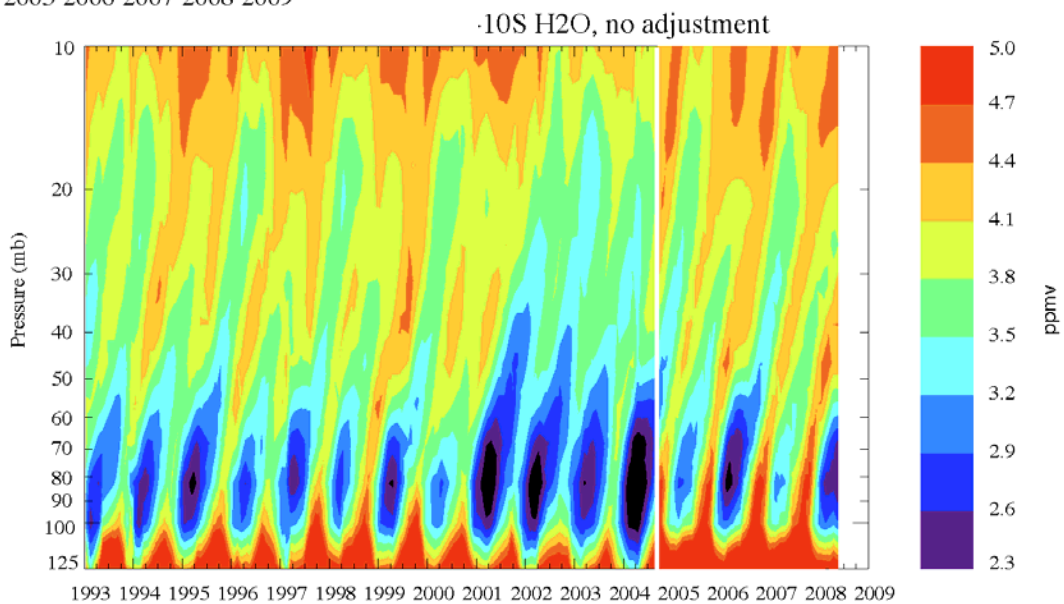
Satellite water vapor data set

Tropical water

after adjustment

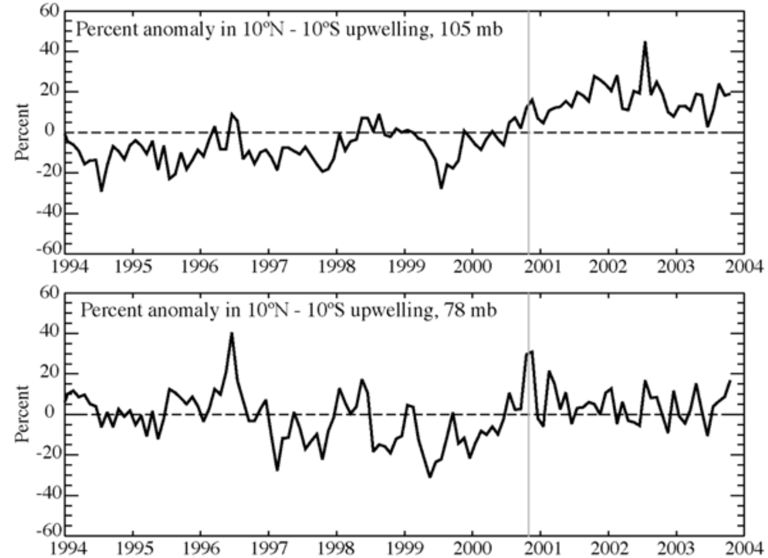


before adjustment

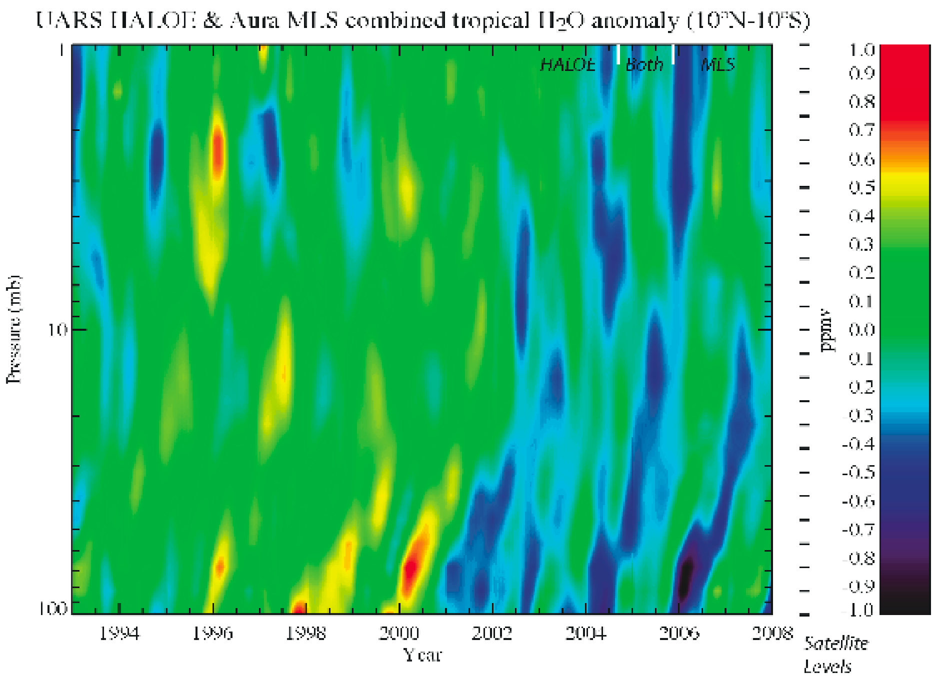


Satellite water vapor data set

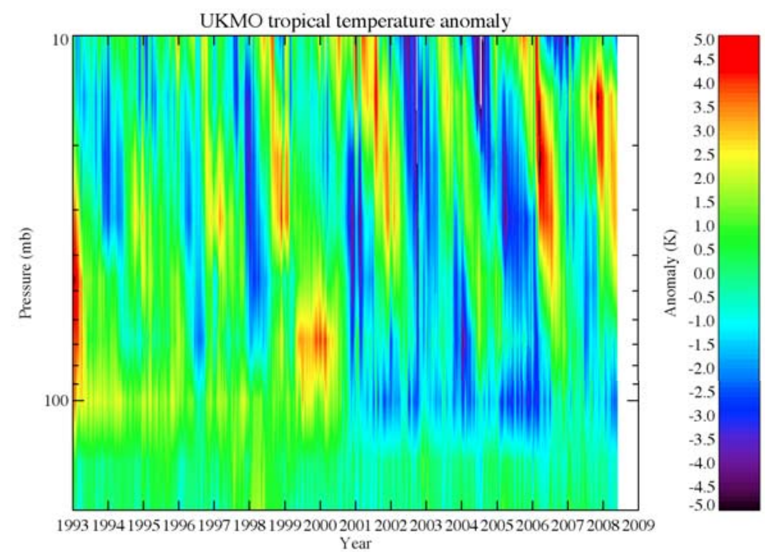
1) Key finding using water time series: Rosenlof and Reid (2008, JGR); water change is a response to enhanced tropical upwelling and decreased tropical tropopause temperatures.



circulation change (mass flux anomaly plotted)



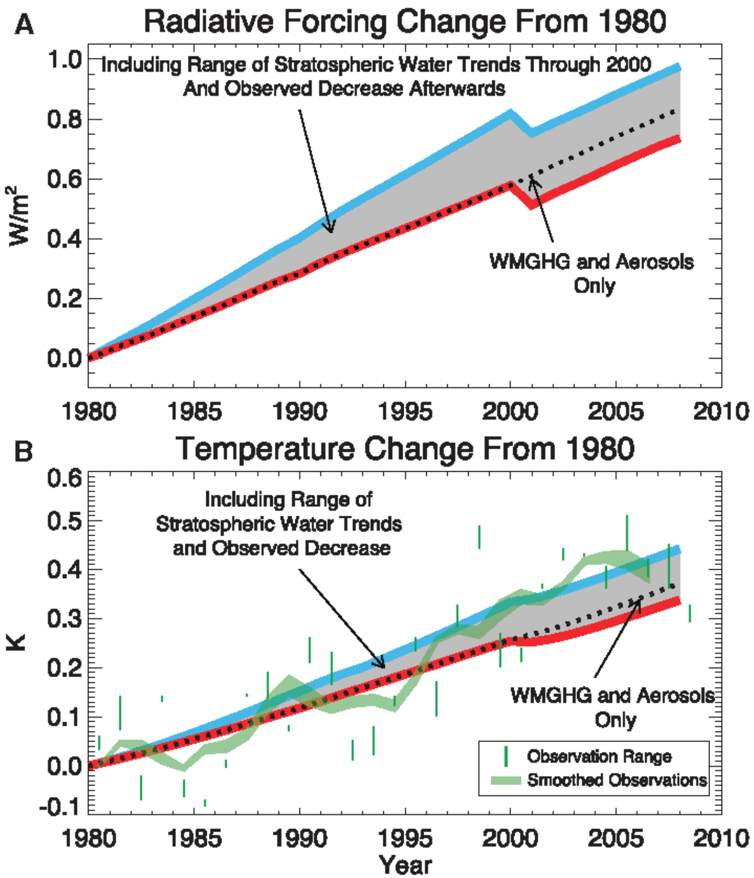
significant post 2001 anomaly



Satellite water vapor data set

UT/LS tropical temp change

2) Key finding using water time series: Solomon et al. (2010, Science); 2001 stratospheric water drop had an impact on radiative forcing and surface temperatures.



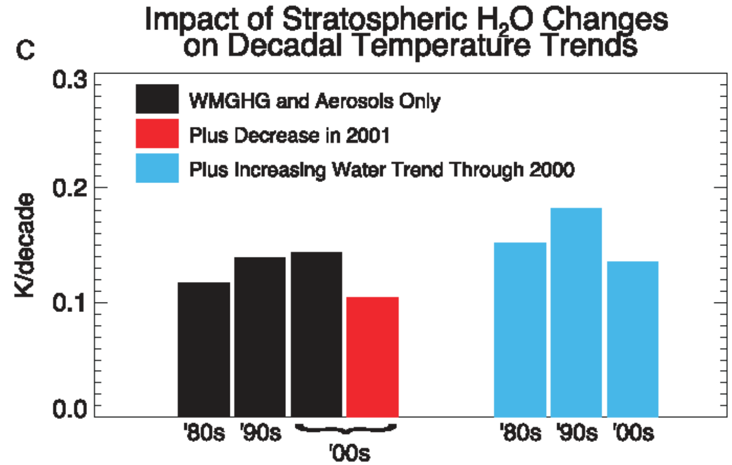


Fig. 3. Impact of changes in stratospheric water vapor on surface climate. **(A)** Time series of the changes in radiative forcing since 1980 due to well-mixed greenhouse gases (WMGHG), aerosols, and stratospheric water vapor. The forcings of CO_2, CH_4, and N_2O are obtained from historical mixing ratios (*38*). The forcing of the Montreal Protocol gases is calculated from their radiative efficiencies and observed mixing ratio time series (*39*). The time dependence of the tropospheric aerosol forcing is taken from Goddard Institute for Space Studies (GISS) model input (http://data.giss.nasa.gov/modelforce/RadF.txt), but scaled so that total aerosol radiative forcing from 1985 to 2004 is -1.1 W m^{-2}, following (*40*). The shaded region shows the stratospheric water contribution calculated from an assumed range of decadal trends from 1980 to 2000 of 0 (red line) to 0.5 ppmv per decade (blue line) along with the observed decline prescribed after 2000. **(B)** Measured and modeled temperature changes relative to 1980. Three different observed global temperature records were used [from the National Climate Data Center (NCDC), Climatic Research Unit (CRU), and GISS records], with the green markers indicating the range across the three data sets in each year. The green shaded line shows the range of the 5-year running mean of the three data sets. **(C)** Decadal warming rates arising from (i) the WMGHG and aerosols alone (black), as well as (ii) that obtained including the stratospheric water decline after 2000 (red) and (iii) including both the stratospheric water vapor decline after 2000 and the increase in the 1980s and 1990s (cyan). Smooth lines show the warmings calculated by the Bern intermediate complexity climate model, which does not simulate internal variability from one year to another. Volcanoes have not been included in the radiative forcing. The climate sensitivity of the model used is 3°C for a doubling of atmospheric CO_2, and the transient climate response is 1.7°C, slightly less than the mean of the range of models assessed by the IPCC (*1*). The colors of the bars in (C) correspond to the respective lines shown in (A) and (B).

Satellite water vapor data set

Final note:

There has been no estimate of uncertainties made for our combined time, zonally averaged time series of water or ozone.

For model sensitivity runs, which is what these have been developed for, it's not as critical.

For use in studies aimed at detecting climate trends, error analysis is needed.

Ongoing International Collaborations

Collaboration with University of Reading

1) (OZONE) There have been two papers published in Climate Dynamics (2010) using our zonally averaged ozone data set. These are "Climate model simulations of recent decades with improved stratospheric representation: variability and trends in the stratosphere" and "Climate model simulations of recent decades with improved stratospheric representation: variability and trends in the troposphere", first author is Mauro Dall'Amico.

2)(WATER) HALOE/MLS data set will be used in radiative transfer modeling with by one of Keith Shine’s students

SPARC Collaborations

1) (OZONE) The ozone series was also used in CCMVal model comparisons, this is published in ACP, “Objective assessment of ozone in chemistry-climate model simulations”, first author is Alexey Karpechko

2)(WATER) Will be used in the ongoing SPARC H_2O assessment activity (WAVAS-2)

New Zealand Collaboration

1)Working with Greg Bodeker (formerly at NIWA, now at Bodeker Scientific) on development of sonde/satellite ozone climatology

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Comparisons with additional international data sets and inclusion of other satellite/sonde data is desired.