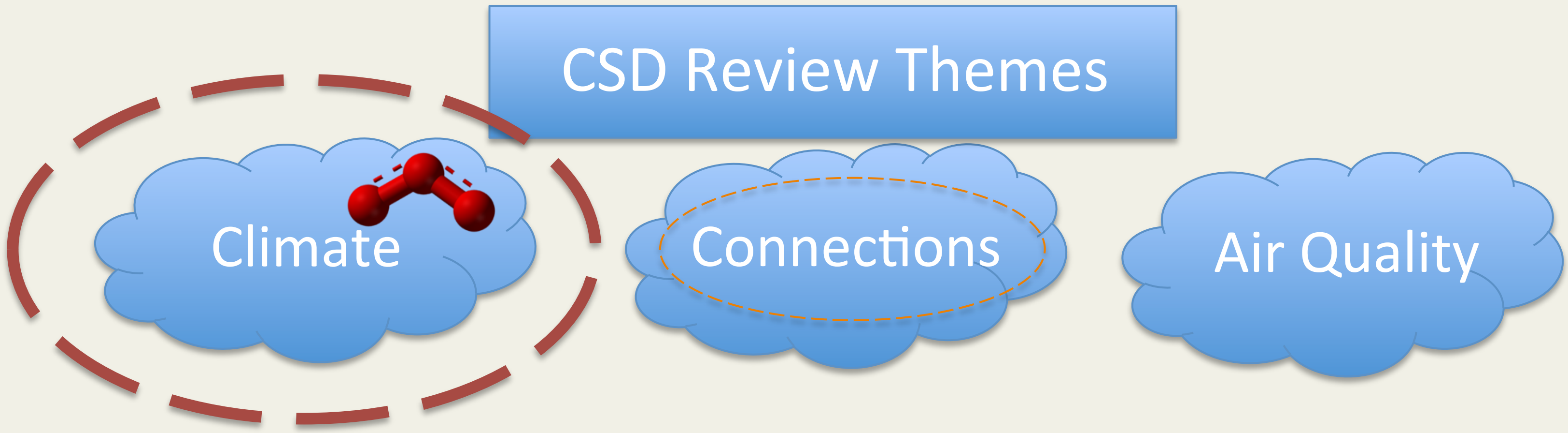
# Climate and the stratosphere research overview

Karen Rosenlof




**CLIMATE:** We expand the nominal definition of climate beyond "usual surface weather conditions" to include state and composition variables throughout the depth of the atmosphere.

In CSD, we study fundamental drivers and processes emphasizing

- Stratospheric ozone layer
- Radiative balance
- Cloud & aerosol processes
- Stratospheric/troposphere interactions

# Where does CSD climate research fit within NOAA's mission?


## Long-Term Goal: Climate Adaptation and Mitigation

*An informed society anticipating and responding to climate and its impacts*

Objective: **Improved scientific understanding** of the changing climate system and its impacts

Objective: **Assessments** of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions

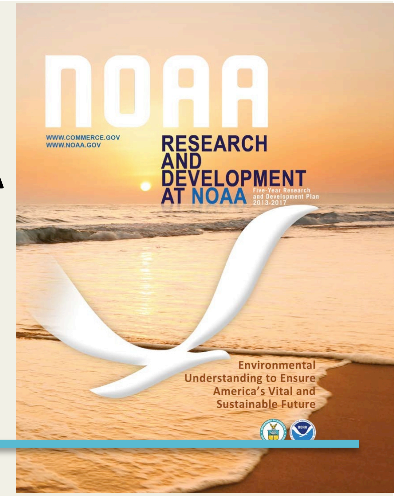
Objective: **Mitigation and adaptation choices** supported by sustained, reliable, and timely climate services

Objective: **A climate-literate public** that understands its vulnerabilities to a changing climate and makes informed decisions

**CSD's strength:**

**-> looking at climate from a chemical species oriented perspective**

## *Bottom line:*




Our climate research addresses the question in the NOAA 5-year plan "What is the state of the climate system and how is it evolving?"
Using the CSD chemistry/climate perspective.

### *How do we do this?*

1) *Study relevant chemical processes in the laboratory*
2) *Develop and deploy instruments*
3) *Analyze data from many sources (field missions, monitoring networks, satellites, model intercomparison projects output)*
4) *Test theories by running models spanning a variety of complexities*
5) *Disseminate findings in scientific journals, at conferences, via assessments and educational outreach*

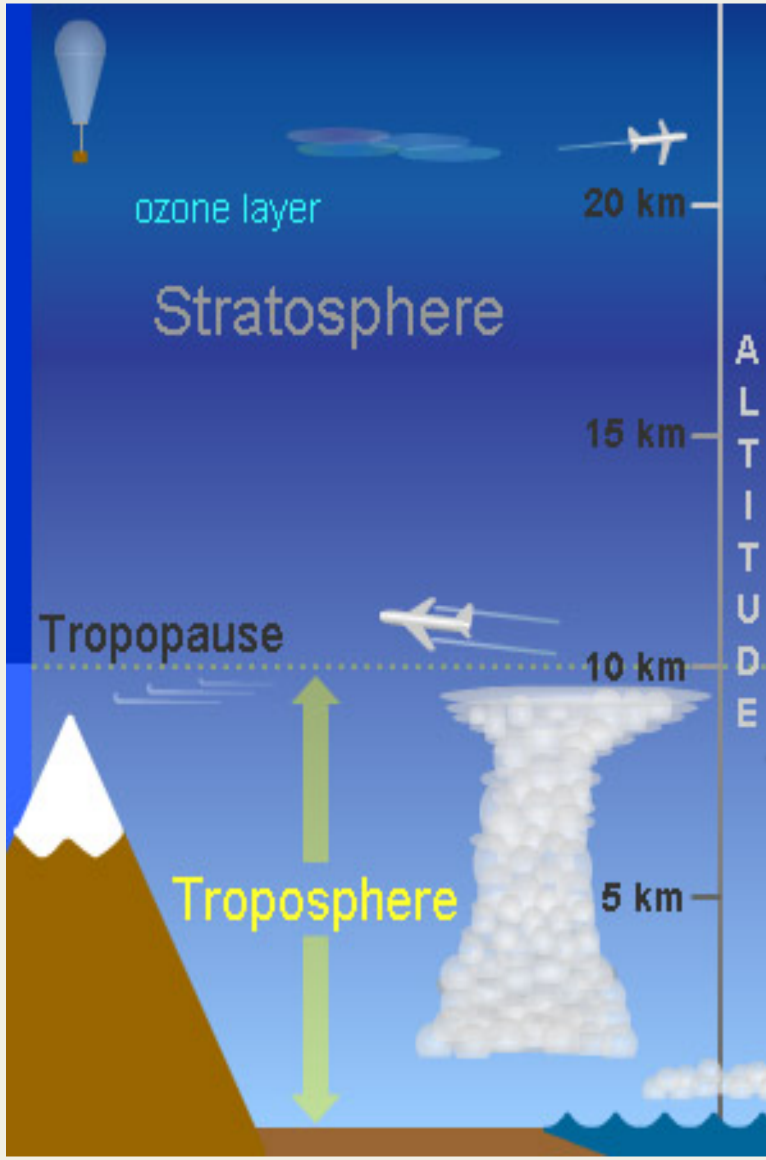
### *Who do we do this for?*

**Industry, government agencies, the scientific community, national and international assessment panels**

# Our climate presentations cover 5 topics

1) Stratospheric $O_3$

3) Global climate analysis




2) Upper troposphere & stratosphere $H_2O$ & aerosols

4) Black carbon and clouds & aerosols

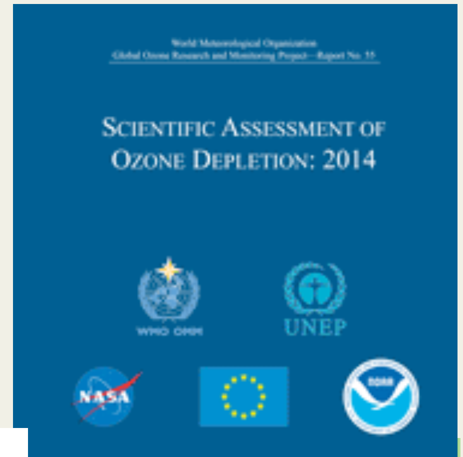
5) Carbon sink

# Topic 1: STRATOSPHERIC OZONE

Goal: Improving understanding of how humans have changed the stratospheric ozone layer and what to expect in the future.

NASA WB-57 in Costa Rica, payload included NOAA $O_3$

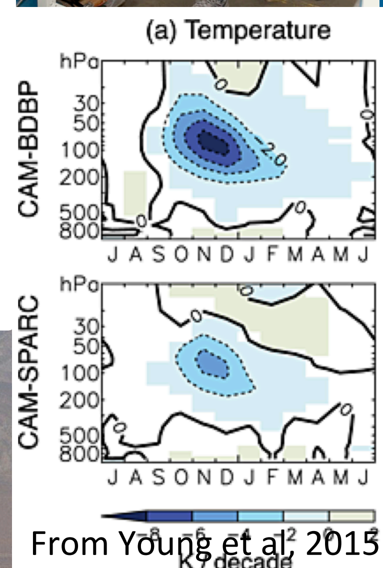
NOAA UAS $O_3$ instrument ($O_3$ Lite)




$H_2O$ & $O_3$ balloon launch, collaborative work with GMD

SEAC[4]RS mission support

NASA ER-2, SEAC4RS payload included NOAA $O_3$

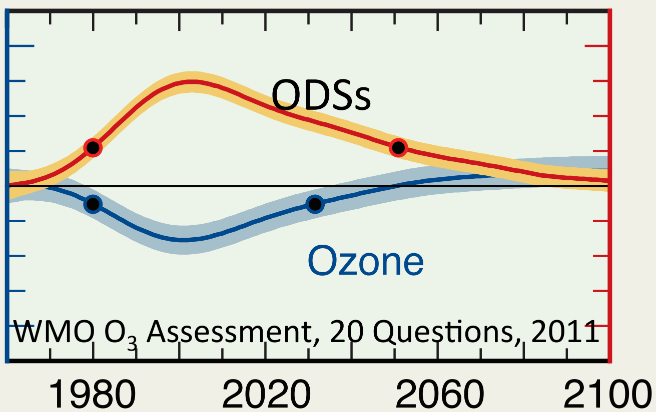



From Young et al, 2015


CSD played leadership roles in WMO $O_3$ assessments

## WHY? Anthropogenic activity changes the stratospheric ozone column, which impacts conditions at the earth's surface.

**Global $O_3$ and $O_3$ depleting species**




| Problem | Cause | Action |
|---|---|---|
| $O_3$ depletion | CFCs | Montreal Protocol (1989) |

- Today: at the start of stratospheric $O_3$ recovery

  **Although CFCs are now regulated, the stratospheric ozone story is not finished.**

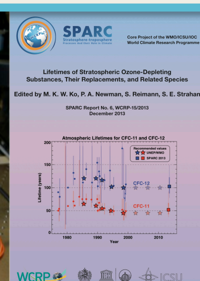
- Substitute refrigerants require testing
- Understand interactions between GHGs & $O_3$

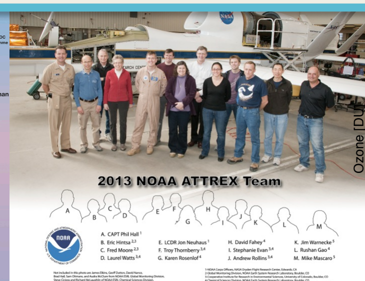
**TODAY'S TALKS/POSTERS**

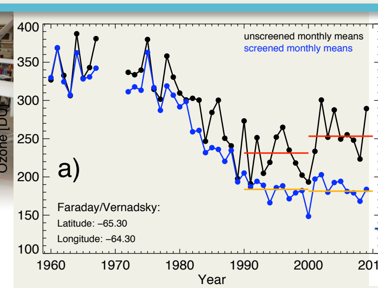
1) Analysis of stratospheric ozone recovery – Birgit Hassler
   - Establishing trend significance requires a well defined time series with uncertainty estimates as well as a known meteorological context.
2) The interaction of $O_3$ depletion, GHG increases, and policy – John Daniel
   - Emerging issues for climate and stratospheric ozone arising from the success of the Montreal Protocol
3) Lab studies of replacement compounds for ODSs – James Burkholder
   - Building blocks for developing chemical mechanisms & models.
   - CSD is an "honest broker" of lab information to industry, regulatory agencies & policy makers

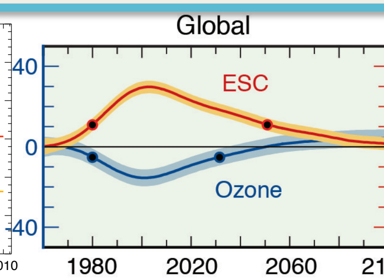
# CSD provides 1-stop shopping for stratospheric ozone science

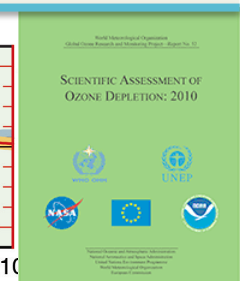
1) Chemical laboratory studies – estimating lifetimes & climate effects of ODSs & replacement compounds ("honest broker" of lab information)
2) *In situ* measurements of ozone from aircraft, lidar measurements of stratospheric ozone in the troposphere – enables process studies
3) Producing data sets for long-term studies – producing tools for the scientific community
4) Data analysis & modeling – understanding trends, variability & processes and making projections
5) Assessment of interactions between climate change & $O_3$ depletion – information for decision makers

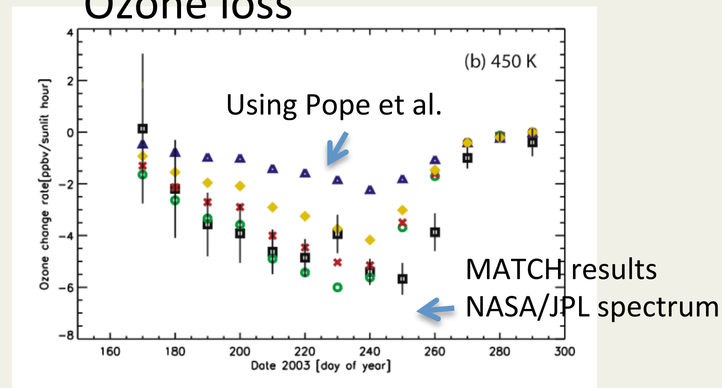




STRATOSPHERIC OZONE

# Rapid response by the CSD Chemical Processes group: Leveraging our standing capability

- Pope et al. (2007) published much smaller ClOOCl UV/vis absorption cross sections than measured previously

Ozone loss




**➔ brought into question the fundamental understanding of polar $O_3$ loss rates**

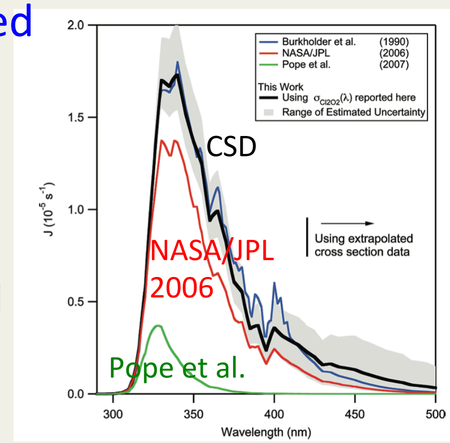
*Poor agreement between observations and model calculations*

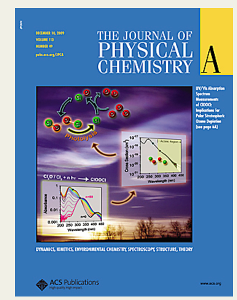
**CSD response:**

➢ Carefully designed laboratory study that measured the ClOOCl UV/vis spectrum using new methods

**CSD Results:**

**Papanastasiou et al.** (2009) ClOOCl spectrum recommended in NASA/JPL 2011, (Chemical Kinetics and Photochemical Data for Use in Atmospheric Studies)




Papanastasiou et al., *J. Phys. Chem. A* **2009,** *113,* 13711–13726.

**Conclusions:**

➢ CSD provided a timely study to resolve critical uncertainties in polar $O_3$ chemistry

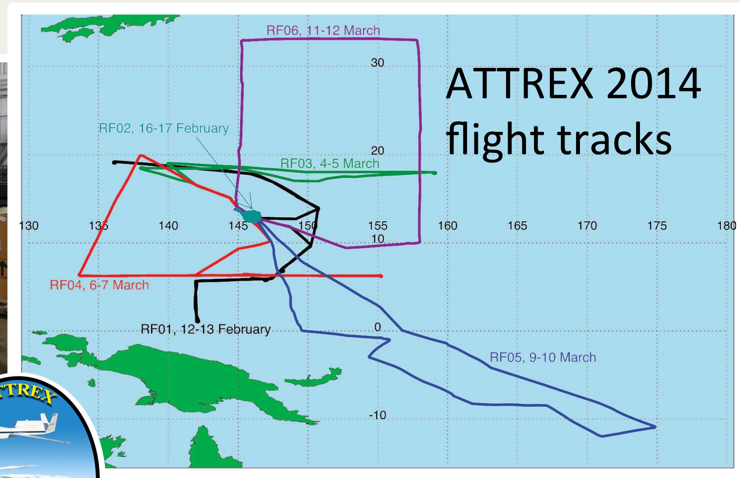
➢ Major revisions in current atmospheric chemical mechanisms are not required to simulate observed polar ozone depletion.

***Highlighted topic*** **STRATOSPHERIC OZONE**

# Topic 2: UPPER TROPOSPHERIC/STRATOSPHERIC $H_2O$ AND AEROSOLS

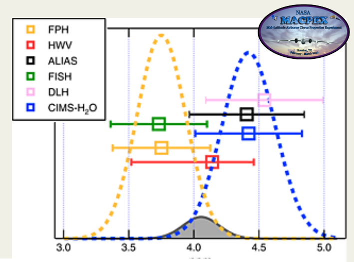
Goal: Improving our understanding of key radiative species through measurements, data analysis and modeling studies.

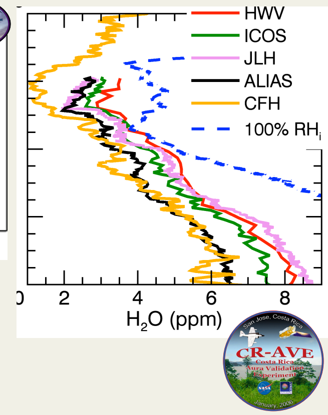
ATTREX 2014

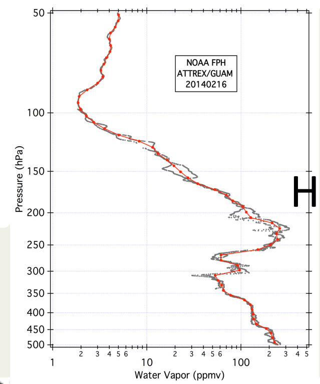



ATTREX 2014 flight tracks

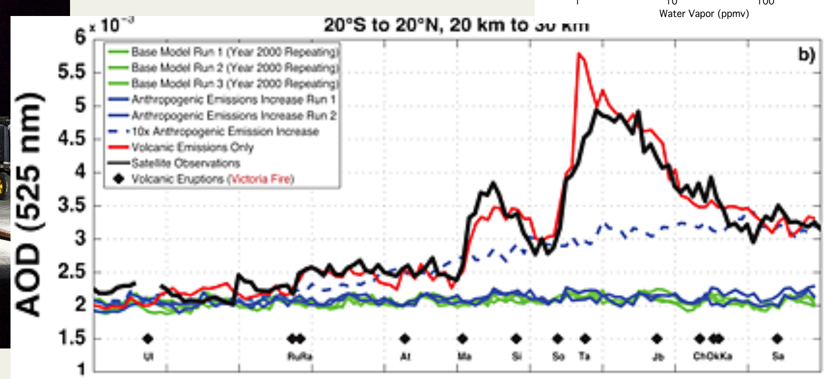

NASA Global Hawk, ATTREX 2014 included NOAA water



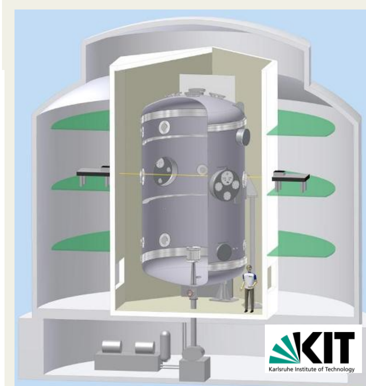




$H_2O$ comparisons




Tropical stratospheric aerosols




AIDA chamber

## WHY? UT/S water vapor and aerosols play important roles in the atmosphere's chemical and radiation budgets.

Our goals:

- Long-term consistent data records (for trends & variability analysis); accuracy (for process studies)
- Fundamental understanding of present day budgets & processes
- Projections for the future

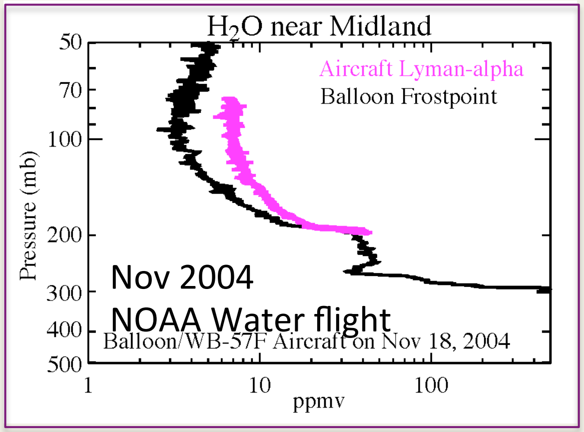
**TODAY'S TALKS/POSTERS**

4) Water in the upper troposphere/lower stratosphere – Troy Thornberry
    - Instrument accuracy, although historically hard to achieve, is key.
    - Unprecedented vapor and ice measurements in the tropical warm pool region

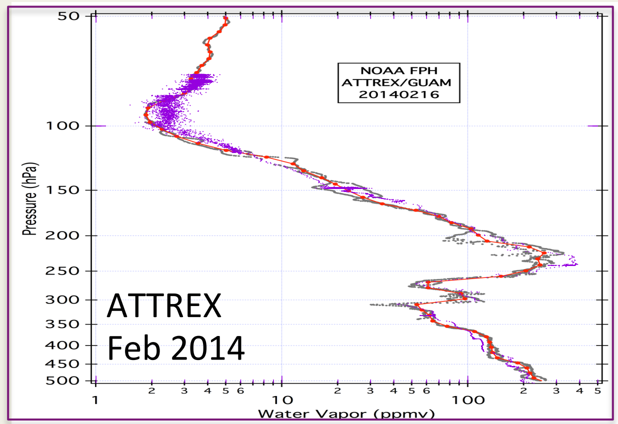
5) Improving the understanding of the stratospheric aerosol layer – Andrew Rollins
    - Small volcanoes play a climate role
    - New stratospheric measurements are needed to understand processes

## CSD has made major advances in UT/S water measurements and in the understanding of recent stratospheric aerosol trends

- Our work helped identify a long-standing problem in $H_2O$ with in situ measurement disagreements

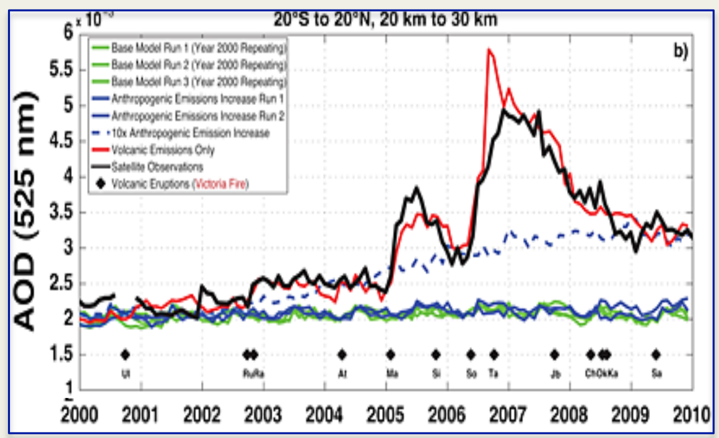



- We have made advances leading to improved agreement and better confidence in accuracy



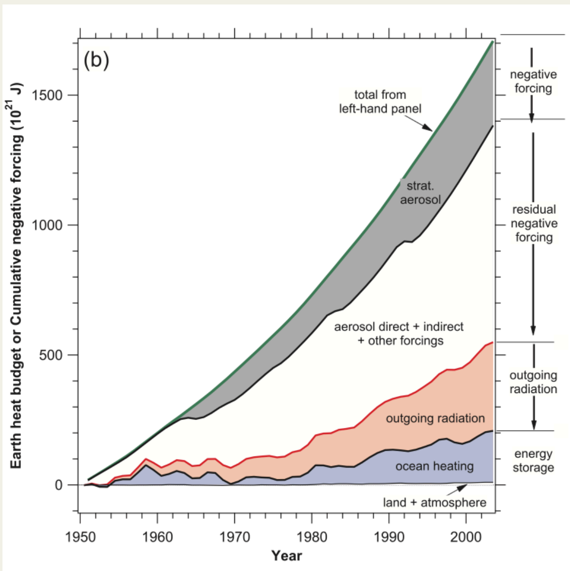

Red: 200m FP
Purple: in flight calibrated NOAA TDL

- Including emissions from small tropical volcanoes, we were able to reproduce aerosol observations in a climate model



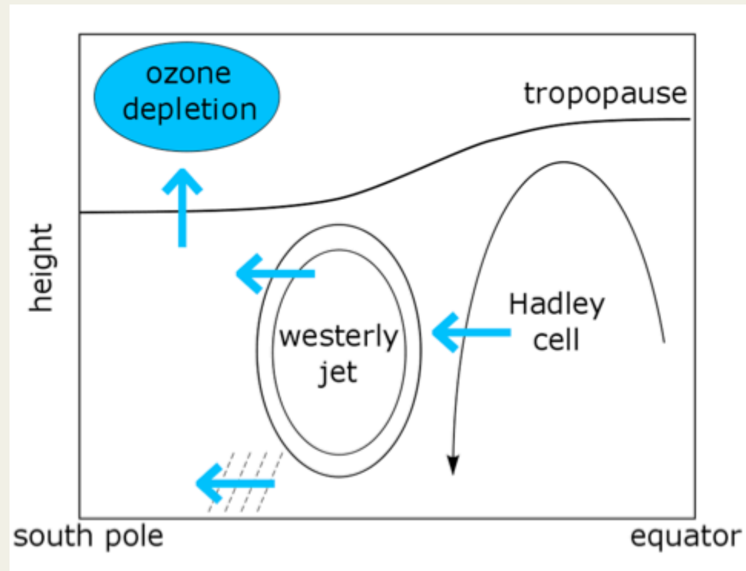
# Topic 3: GLOBAL CLIMATE ANALYSIS

Goal: Critically assessing observations & model output to understand processes and improve projections for the future.




Energy budget derived from observations.

*Portmann talk/poster*




Stratospheric species distributions impact the general circulation throughout the depth of the atmosphere.

*Davis talk/poster*

**WHY? A fundamental understanding of processes in today's climate is needed to make better projections for the future.**

Topics of study:

- Climate and atmospheric composition connections
- Dynamical responses to composition changes
- The earth system energy budget (using data and models)
- Climate feedbacks

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**TODAY'S TALKS/POSTERS**

*Before lunch*

6) Climate studies using a combination of models and observations – Robert Portmann

- Exploit observations whenever possible. Make models accountable.
- Unravel the "why" of model response

*After lunch*

7) Stratospheric composition & atmospheric circulation studies – Sean Davis

- Stratospheric ozone distribution impacts climate
- Detecting changes in the width of the tropics

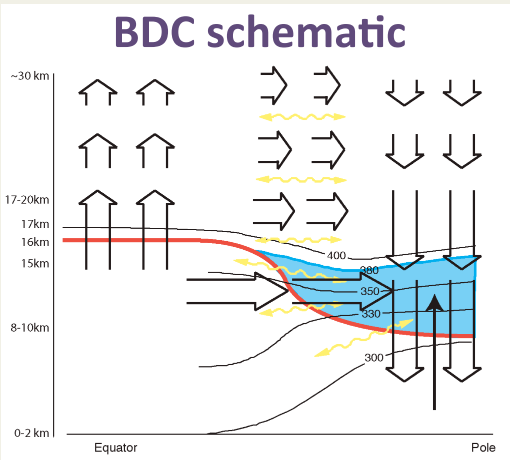
*Tomorrow, a related talk*

Climatology of stratospheric warmings – Amy Butler (6-1)

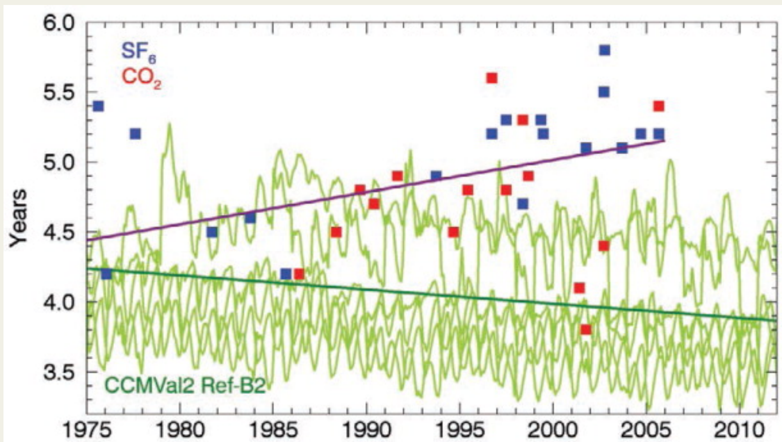
# Changes in stratospheric transport; using measurements and models

Climate models predict **increases** in the **Brewer Dobson circulation** (BDC) with increasing GHGs. Analysis of observations shows the response may be more complicated.

**Why is this important?** The BDC brings anthropogenic species into the stratosphere and transports stratospheric $O_3$ into the troposphere. Trends can impact transport of VSLSs and tropospheric ozone budget.




NH mid latitude age of air




Adjusting model mixing trends in a **tropical pipe model** can produce model/ measurement agreement in age of air and ozone. (Ray et al., JGR, 2010 )

Consideration of **trends in tropical-midlatitude mixing** as well as in the BDC may be needed for to reproduce age of air trends in GCMs.

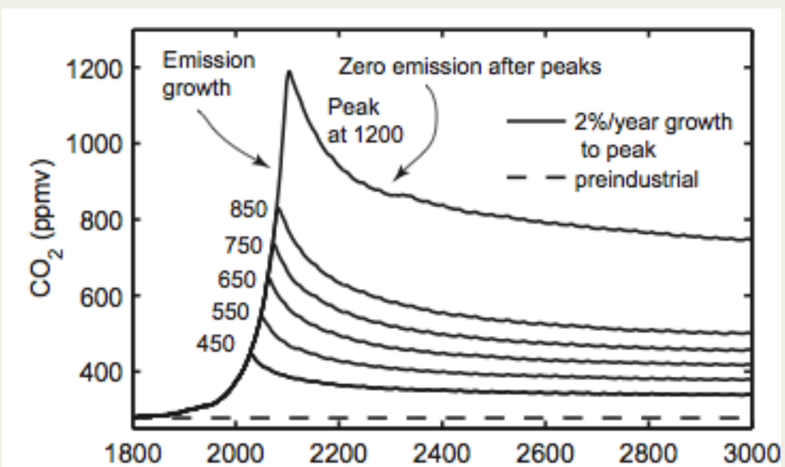
***HIghlighted topic***

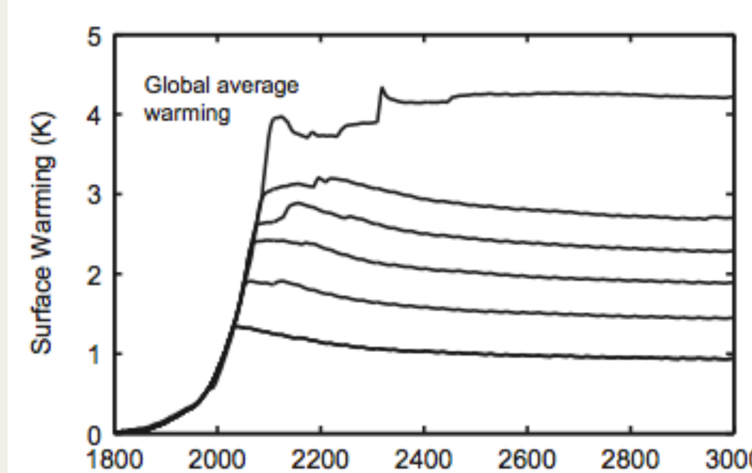
**Global Climate Analysis**

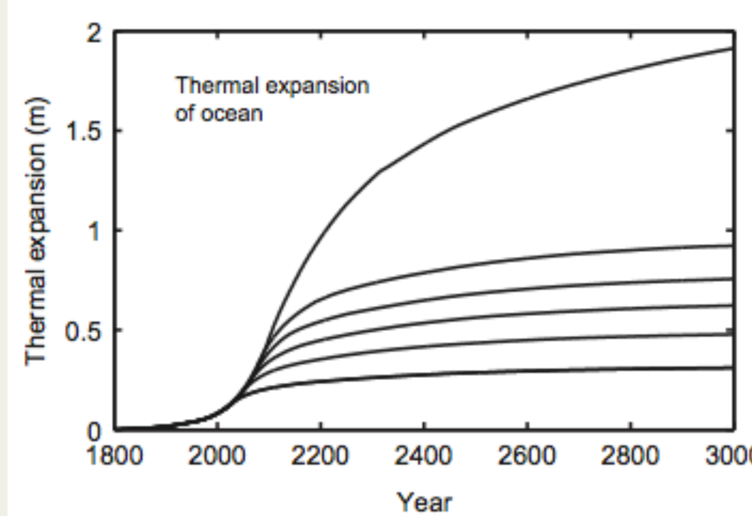
High Impact Climate Study: **Irreversible climate change due to carbon dioxide emissions: Susan Solomon et al., Proc Natl Acad Sci, 2009.**

**Take home message: $CO_2$ forced climate change is irreversible for 1,000 years**

Following cessation of emissions, removal of atmospheric carbon dioxide decreases radiative forcing, but is largely compensated by slower loss of heat to the ocean, so that atmospheric temperatures do not drop significantly for at least 1,000 years.



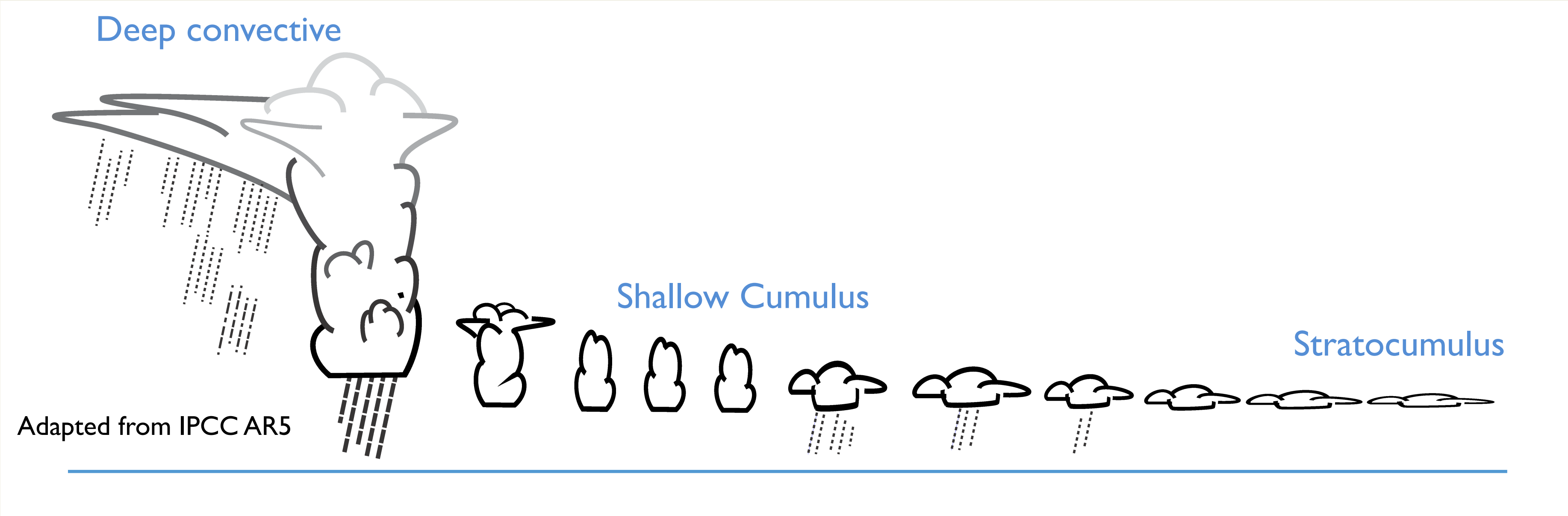




*Highlighted topic*

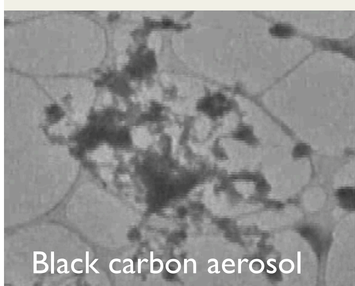
**Global Climate Analysis**

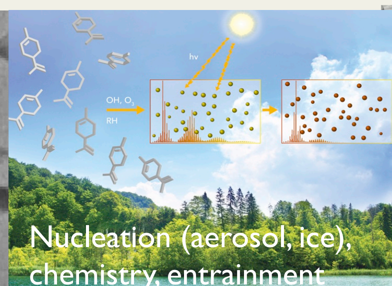
# Topic 4: Tropospheric aerosols & Aerosol-Cloud-Precipitation processes

Goal: Improving our basic understanding of cloud and aerosol processes to produce better simulations for the current and future climate.

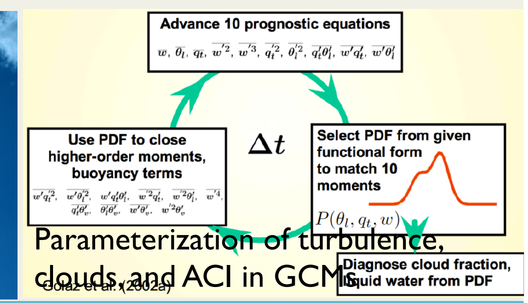



*Future plans include greater collaboration with NOAA global modelers.*



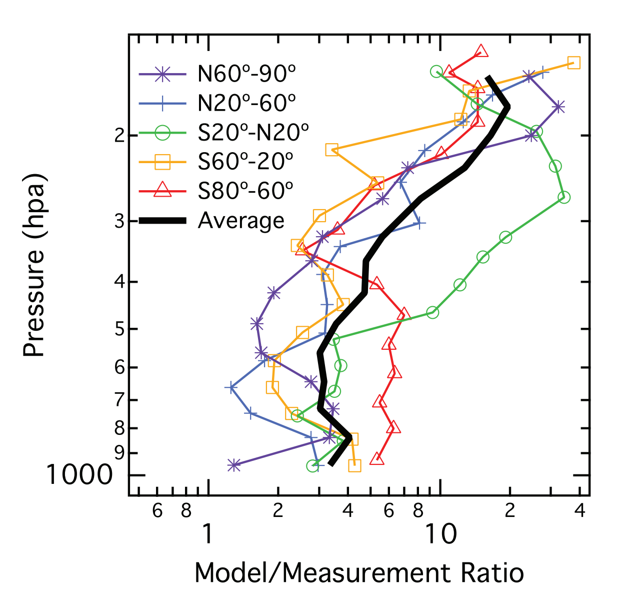





## WHY? Clouds and aerosols are important for the earth's radiative balance, and are significant sources of uncertainty in climate models.

*HIPPO BC measurements compared to global models*




**TODAY'S TALKS/POSTERS**

8) Black carbon in the climate system – Joshua Schwarz
- Pole to pole measurements allow critical examination of modeling abilities

9) Aerosol, clouds, and precipitation in the climate system – Graham Feingold
- Fundamental process understanding of the aerosol-cloud-precipitation system -- unique within NOAA.

10) Role of aqueous chemistry in organic aerosols – Barbara Ervens
- Chemical reactions in clouds are considered a significant source of SOA—CSD work is leading to improved representation of these processes in global and regional models

11) Boundary layer clouds and their representation in models – Jan Kazil
- Use of high-resolution simulations provides fundamental understanding of processes and mechanisms leading to better parameterizations to improve climate models

## Topic 5: OCEANIC CARBON SINK

Goal: Use measurements to reduce uncertainties in estimates of oceanic processes that ultimately convert atmospheric $CO_2$ to organic material.

## Why? To improve estimates of ocean productivity ($CO_2$ sink)

Demonstration of using expertise gained via a long history of using atmospheric LIDARs and applying that knowledge to a NOAA relevant issue.

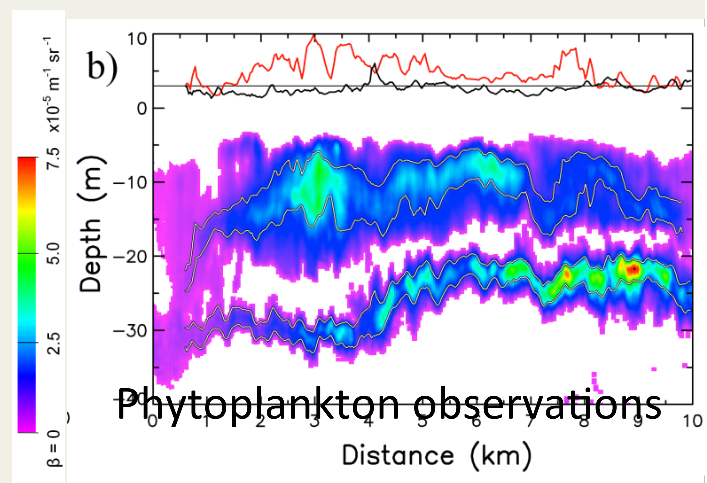
**TODAY'S TALK/POSTER**

12) Thin plankton layers in the ocean – James Churnside

- New airborne LIDAR measurements improving knowledge of thin layers of plankton -> improved estimates of productivity. (plankton photosynthesis is ~50% of the primary productivity on earth)

Arctic experiment, 2014


FLOE LIDAR in aircraft



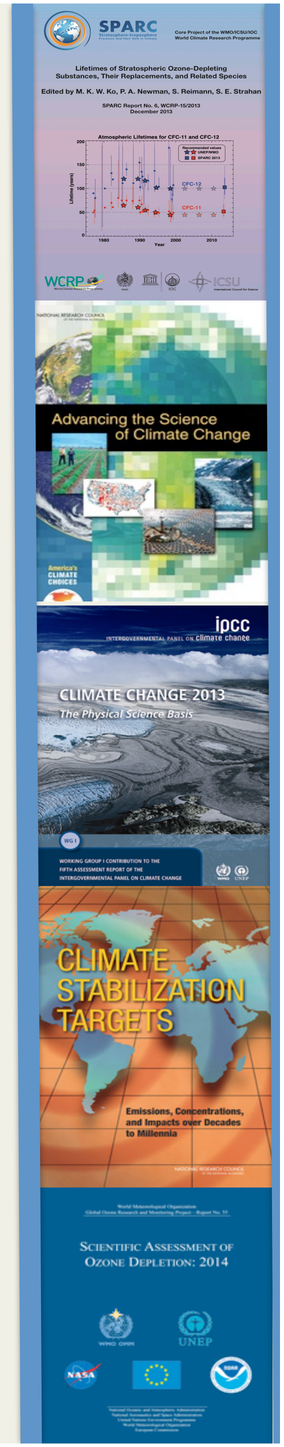
Phytoplankton observations

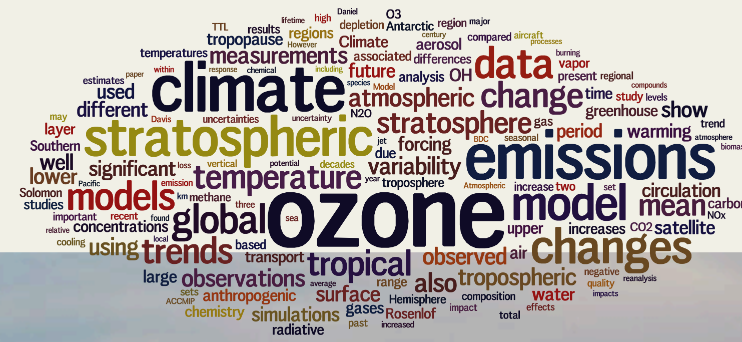
# FINAL REMARKS

CSD has made **significant contributions** to climate and ozone **assessments**, NRC reports, WCRP reports, and studies initiated **by international climate organizations** as well as serving **leadership roles** in these activities.

CSD studies have been done in **collaboration** with other NOAA OAR laboratories, NCAR, ESRL divisions, NASA, DOE, university partners and institutes worldwide.

We will continue our three-pronged approach, using **observations**, **laboratory studies** and **modeling**, to address chemistry/climate issues.







Thank you for your attention