EARTH SYSTEM RESEARCH LABORATORY

Serving Society through Science

Atmospheric Chemistry at the Earth System Research Laboratory

An Introduction to the Review*

A.R. Ravishankara
Director, Chemical Sciences Division

James H. Butler
Acting Director, Global Monitoring Division

ESRL Atmospheric Chemistry Review

January 29-31, 2008 ~ Boulder, Colorado

* You are the experts!

– but we want to start from the basics and let you know where we are coming from!

Atmospheric Chemistry at the Earth System Research Laboratory

An Introduction to the Review

A.R. Ravishankara

- Science Foci
- Interconnections
- Approach

James H. Butler

- Linkages & Drivers
- Observations& Networks
- Products&Services

Our Primary Foci

Climate, Stratospheric Ozone, and Regional Air Quality

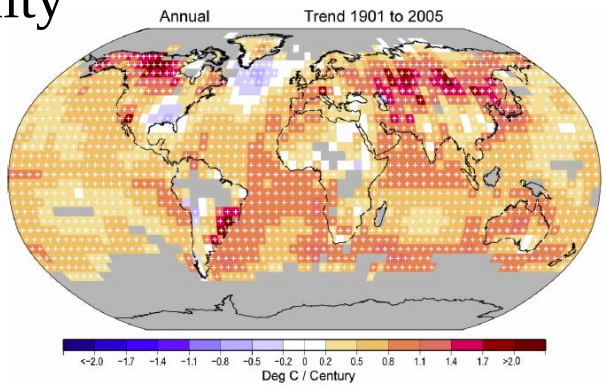
- Climate – Its changes, variability, impacts, and "coping" with climate change

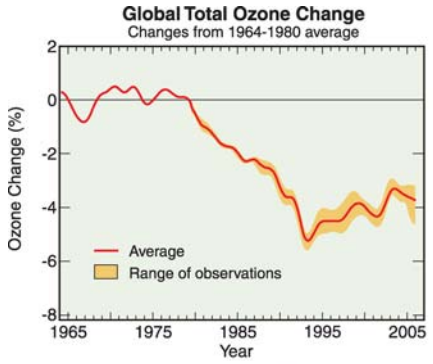
- Stratospheric Ozone – Its changes, the "accountability phase" of the Montreal Protocol, and connection to climate

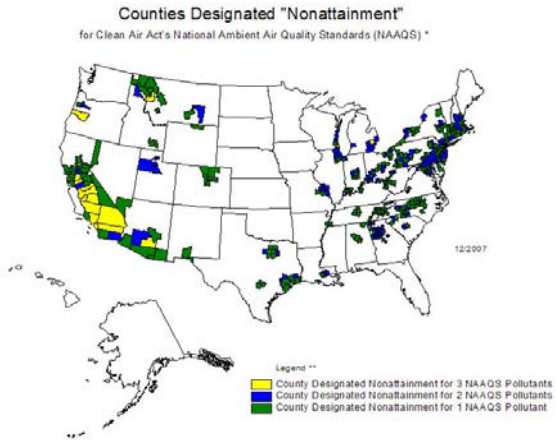
- Regional Air Quality – Its changes (O_3 & PM), policy information for Federal decision and regions/state/local management strategies

  – All of relevance to society

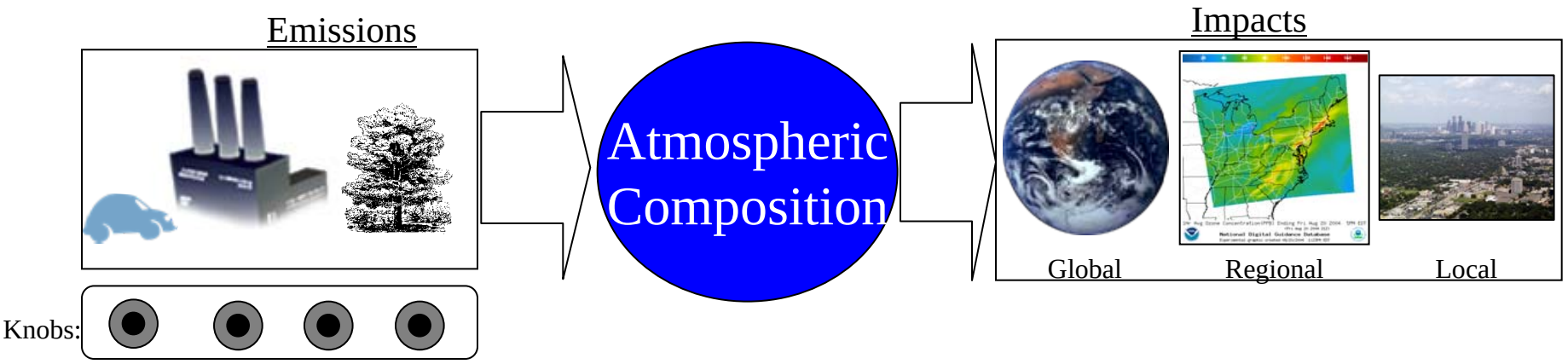
  – Interrelated







Atmospheric Composition: A Crucial Component of the Earth System

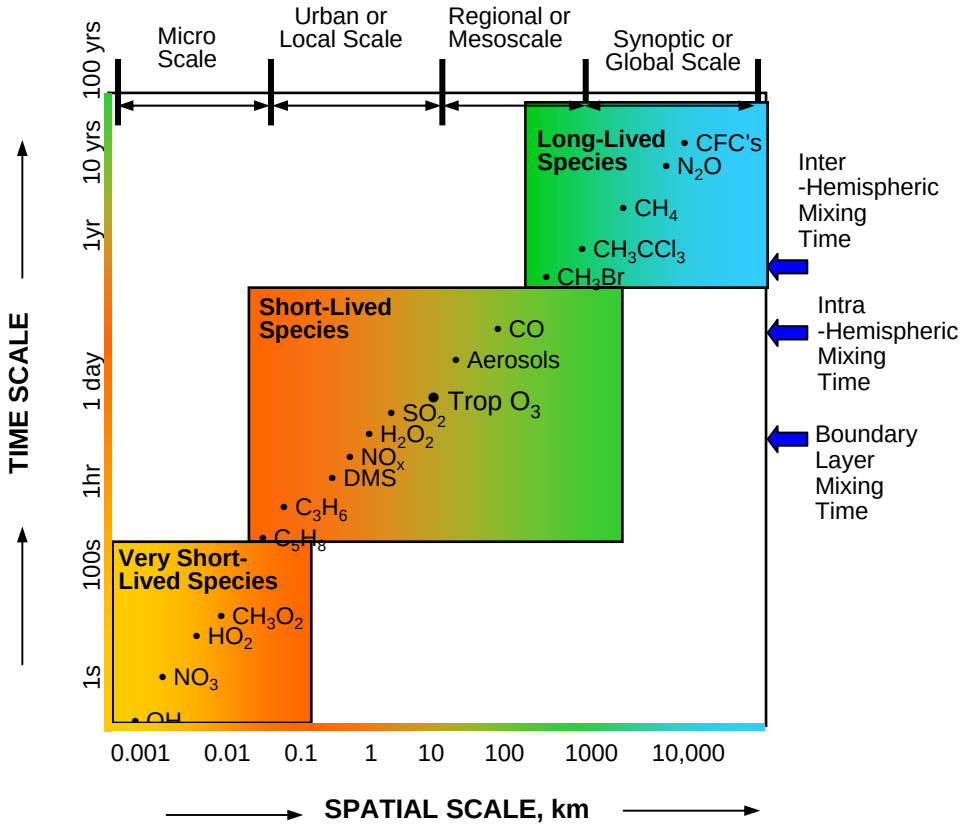


- Accounting for the past
- knowing the present state
- Predicting and projecting the future
- Making choices: Which "knob" to turn? One better than the other?

Our forte:

- Quantify and understand processes
- Represent in "predictive" models or transfer information to global models
- Assess impacts of atmospheric composition and its changes

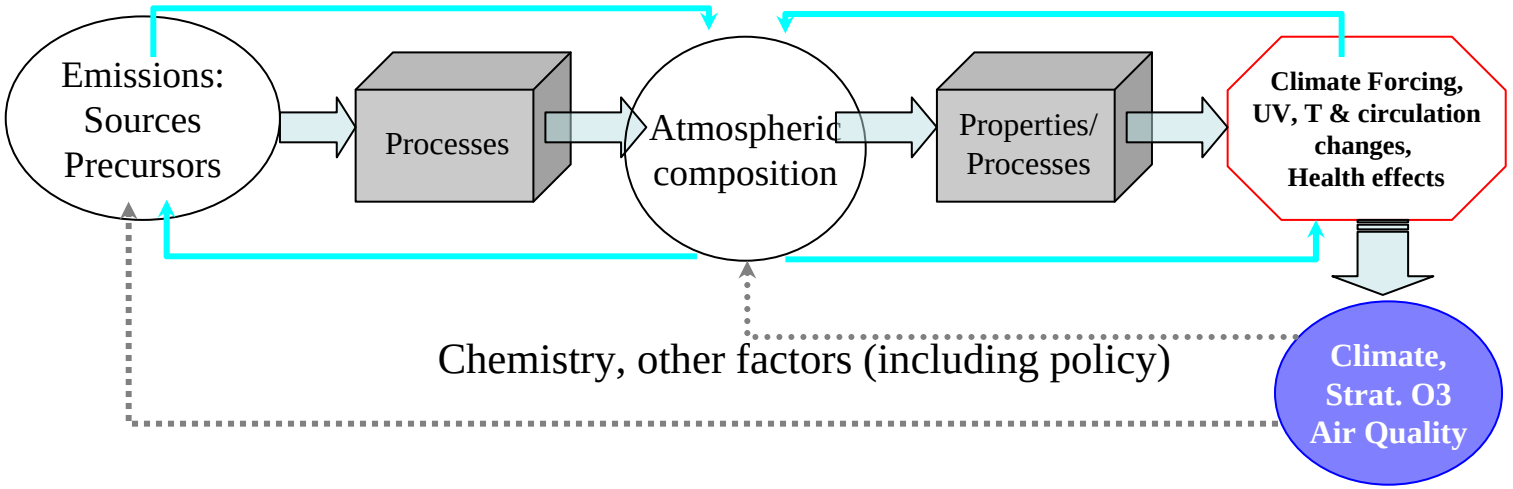
Atmospheric Composition: Dealing with Short- and Long-Lived Chemicals

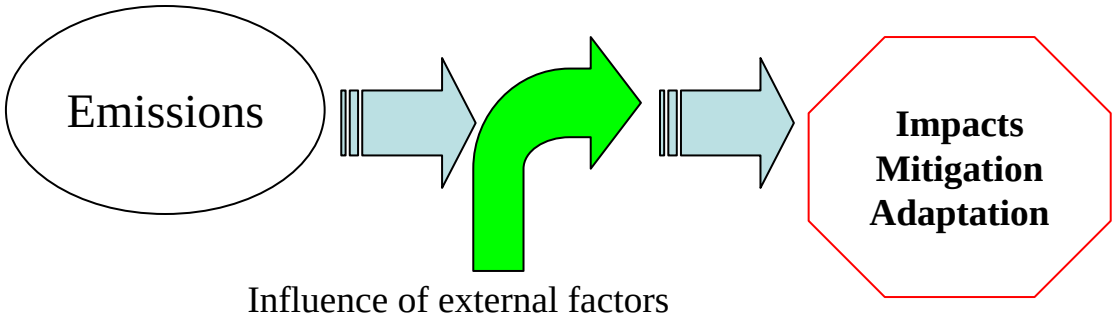


- Long-Lived gases are well-mixed and do not vary rapidly in time (globally).
- Short-Lived species are not well mixed; they are highly variable in space and time.
- Ozone and most of aerosols have added complexity– they are made in the atmosphere.

- Concentrations of shorter-lived gases and aerosols need to be calculated.
- All concentrations have to be calculated for predictions!

Atmospheric Composition: Understanding and Quantifying Processes and Properties!





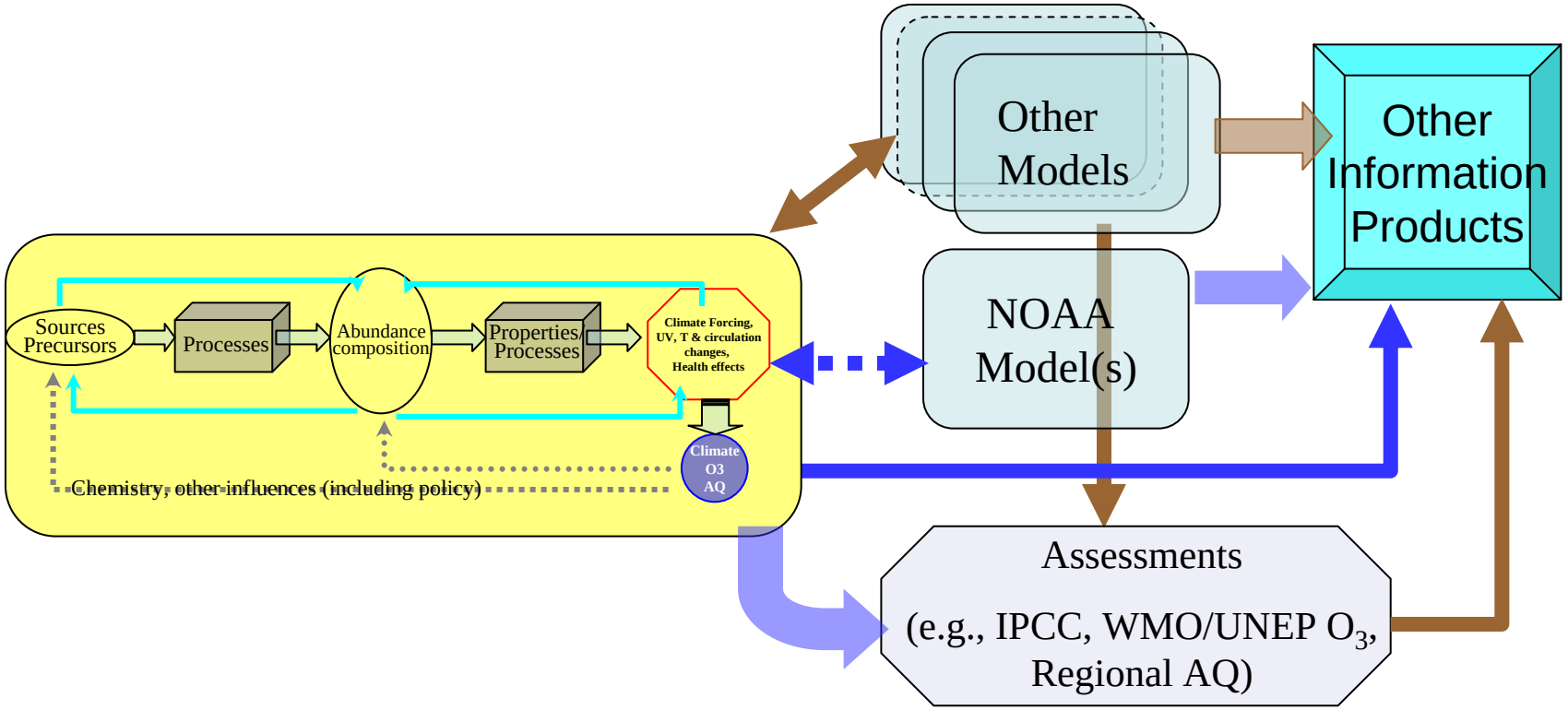
ESSENTIAL for policy
Mitigation, adaptation, etc.

Process studies – multiple ways (& in combination); time and space scale issues

- Intensive campaigns
- Long-term monitoring
- Building from the "fundamentals"

ESRL Efforts and the Relation To Others

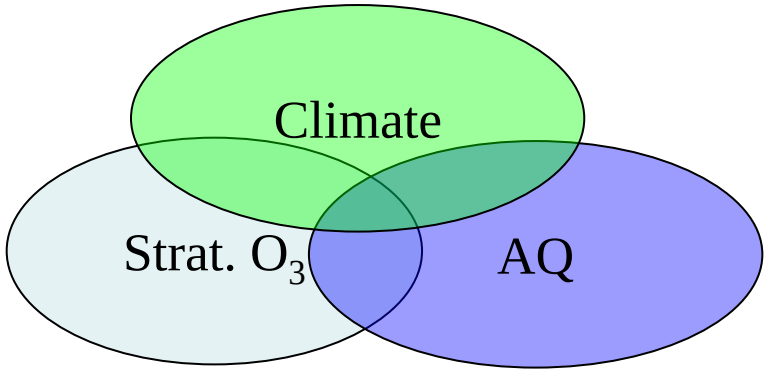
We are one cog – a very important cog – in a large wheel!



Collaborations with other agencies and institutions in almost each step:

- Co-planning and co-execution of field missions
- Interactions in planning programs, priorities, and hand offs
- Work together in taking science to information (e.g., Assessments, …)

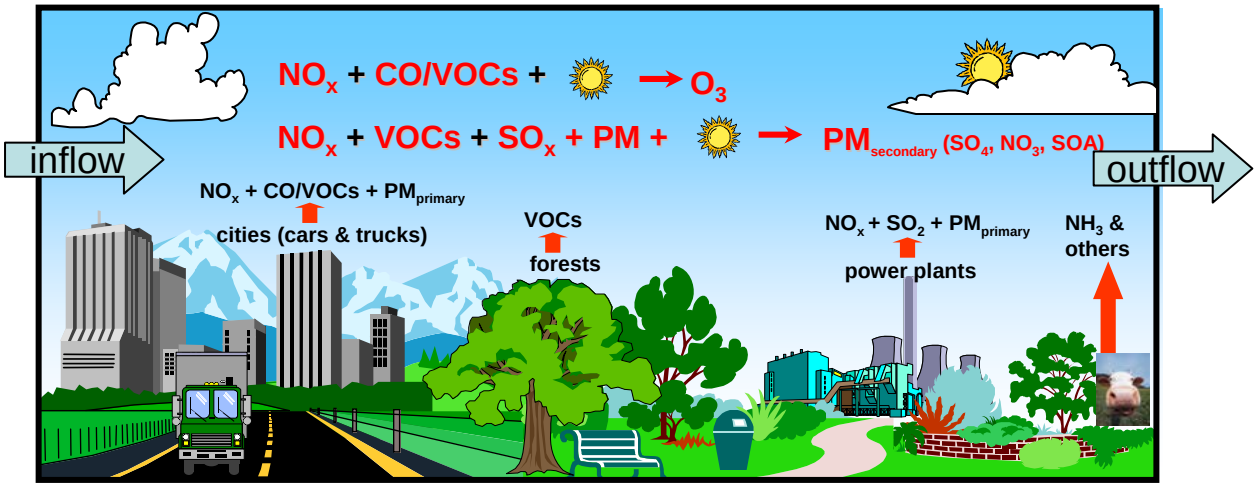
One atmosphere: Three Interrelated Issues



- Many forcing agents are “pollutants.”
- Each issue impacts other two.
- Processes involved in these issues are same or similar.

But, I will first discuss these separately!

Regional Air Quality



Courtesy: James Meagher

Driven by health and welfare issues (urban & regional).

Focused on **ozone and aerosols in lower troposphere / mixed layer**

Key Questions:

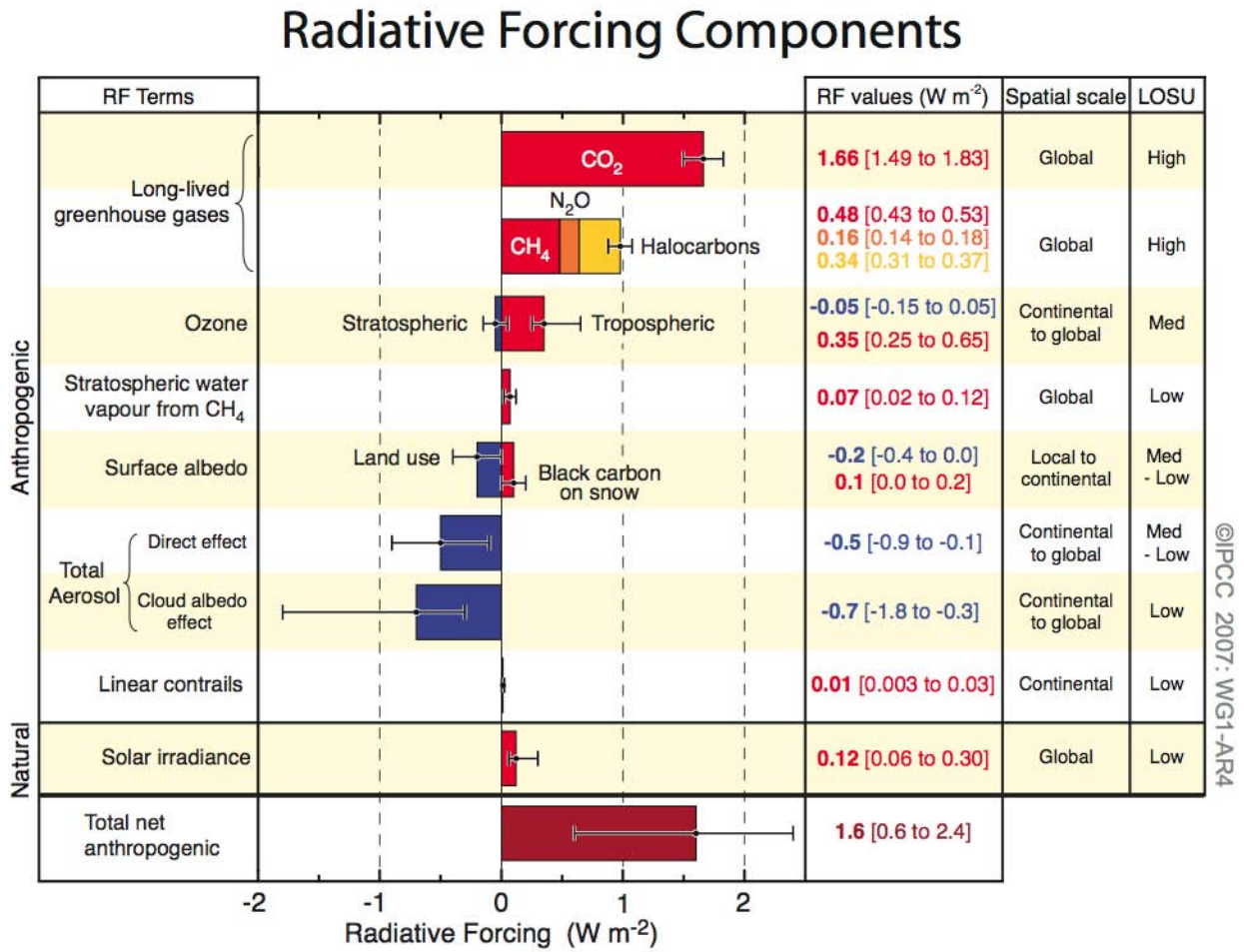
- What are the abundances and sources of O_3 and aerosols?
- What are the processes that control their abundances?
  - Emissions of precursors (and primary aerosols)
  - Chemical processes
  - Small-scale meteorological processes
  - Transport of ozone, aerosols, precursors, etc.

Goals: Improved process-based "predictive" capability

Providing information needed for the decision makers in states and regions

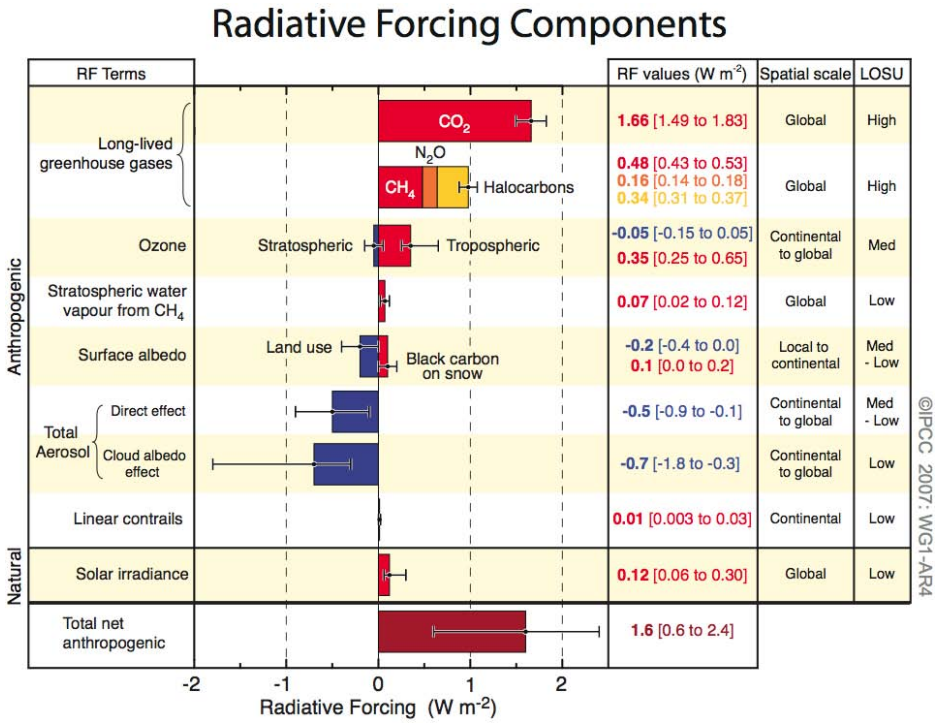
Contributing to development of "chemical weather" forecasting

Climate: Climate Forcing (RF) and Information for Feedbacks



- Globally averaged TOA forcing shown
- Local forcing highly variable at the surface, in the atmosphere, and large variation in space and time
- Variability and uncertainty comes from shorter-lived species.

Climate: Climate Forcing (RF) and Information for Feedbacks



- **CO_2**
- **Non-CO_2 GHGs (including Trop O_3)**
- **Aerosols**

Globally averaged TOA forcing shown

Local forcing highly variable

at the surface

in the atmosphere

large variation in space and time

Variability and uncertainty comes from shorter-lived species.

Key Questions

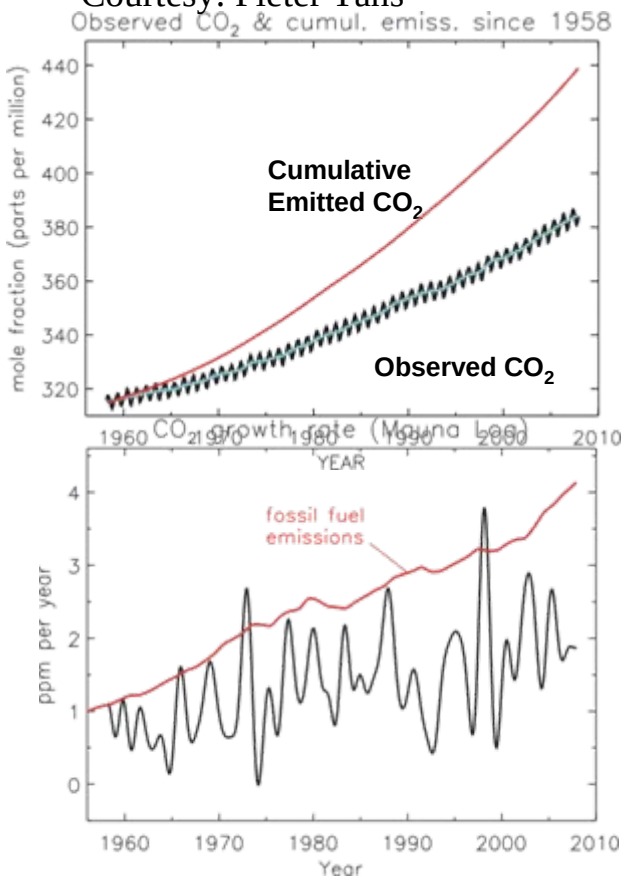
- What are the human-induced forcing on the climate system? (past, now, and future)
- What are the feedbacks?

Goals

- Quantification of the radiative forcing agents
- Process understanding for forcing and feedbacks

Climate Forcing: Carbon Dioxide

Courtesy: Pieter Tans



Currently the largest forcing agent, and growing!

Growth is mostly due to human-influenced emissions (with variations due to other factors).

We know the forcing by CO_2 to date accurately…

True for the future?

Key Questions:

What will be the forcing by CO_2 in the future?

- Emissions
- Carbon Cycle
- Feedbacks

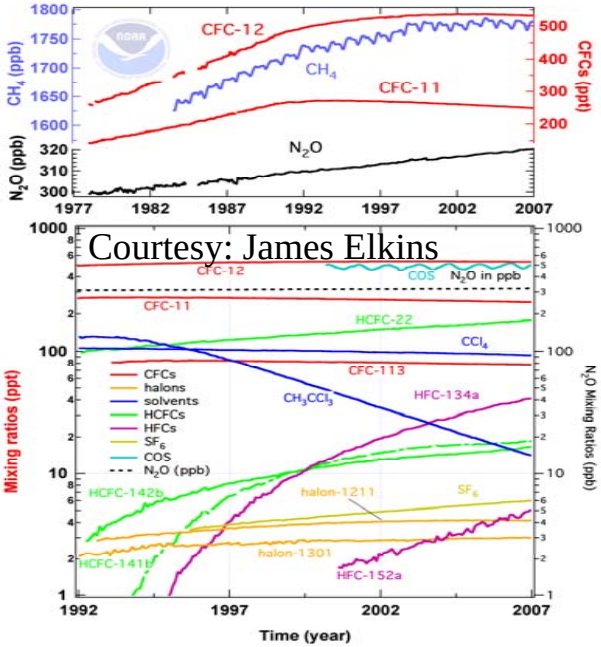
Goal: Continued measurements and understanding of carbon cycle processes to predict/project future concentrations.

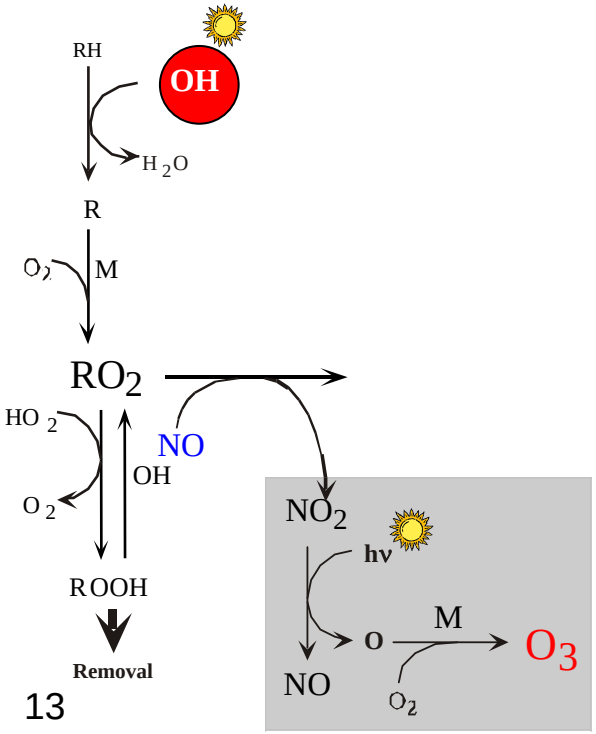
Climate Forcing: Non-CO_2 Greenhouse Gases

Key Questions (CH_4, N_2O, halocarbons…):

- What are the abundances and sources of long-lived non-CO_2 greenhouse gases?
- What are the processes that control their abundances?

Goals: Develop prediction capabilities.
Elucidate the impact on the atmosphere.



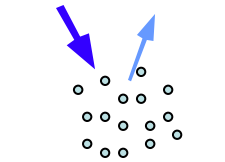


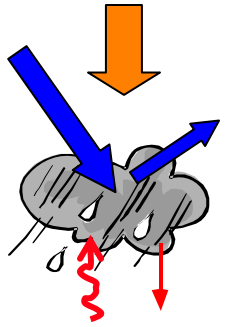
Key Questions (tropospheric O_3):

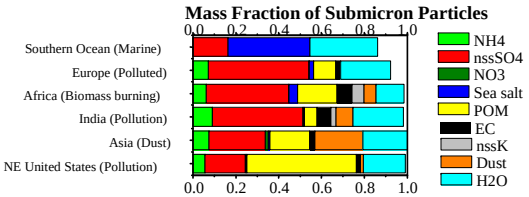
- How can we quantify tropospheric O_3 (now and in the future) for forcing and feedbacks?
- What are the sources?
  - In the lower troposphere?
  - In the upper troposphere?
- What are the sinks?

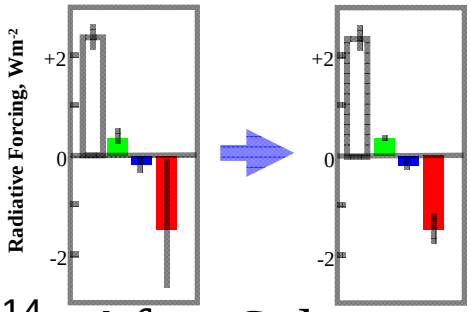
Goal: Quantification of precursors and processes to derive concentrations and impacts on atm.

Climate: Aerosols









After Schwartz

- Aerosols scatter and absorb incoming radiation (a daytime process)- there is a large uncertainty in the quantification of this process.

  Key Questions: What are the concentrations, trends, and properties of aerosols? What is the relation between emissions and aerosol's abundance/properties?

- Aerosols also *modify* clouds: amounts, properties and distribution (&vice-versa). The Indirect Effects

  Highly uncertain, but key for predictions and impacts

  Key Question: Can we quantify a few important effects?

- Aerosols come in multiple flavors:

  Composition, size, physical state, surface properties, etc.

  Key Question: Can we develop the capability to predict these parameters?

Goal: Characterize influence of aerosol and aerosol - cloud interactions (radiation and precipitation) on climate to a "usable" level now and enable future predictions.

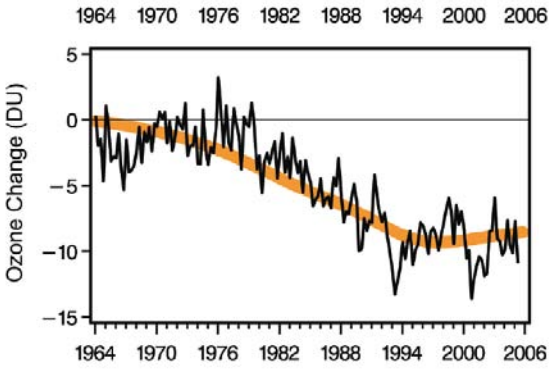
Stratospheric Ozone

Key Questions:

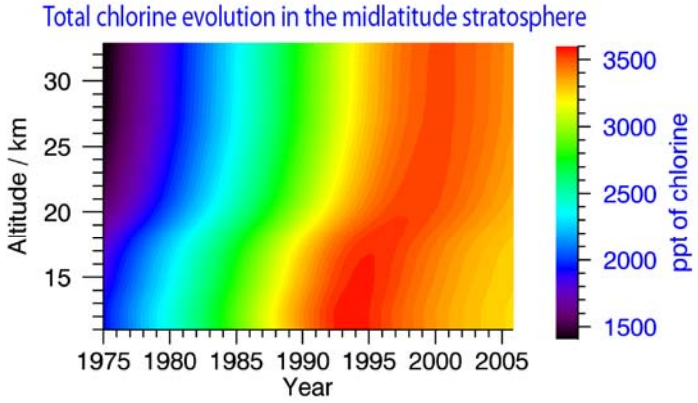
Stratospheric O_3 abundances: What are the past and current levels? (column, vertical profile, global, etc.)

Stratospheric O_3 changes: What are the causes?

- Ozone Depleting Substances (ODS):
  - How much?
  - From what source(s)?
  - What does the future hold?
- What are the chemical and transport processes?



Global O_3 trends



EESC trends in time and vertical

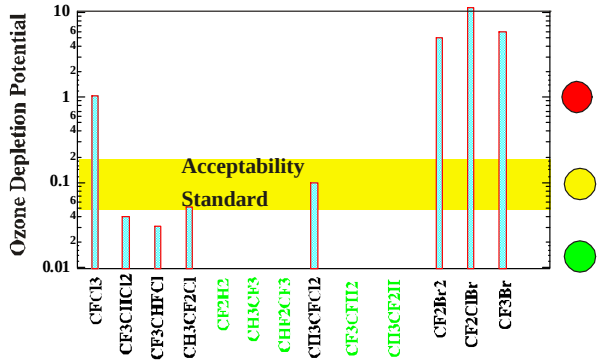
Goal: Identify, understand, and quantify the processes that cause stratospheric ozone depletion.

Stratospheric Ozone, continued

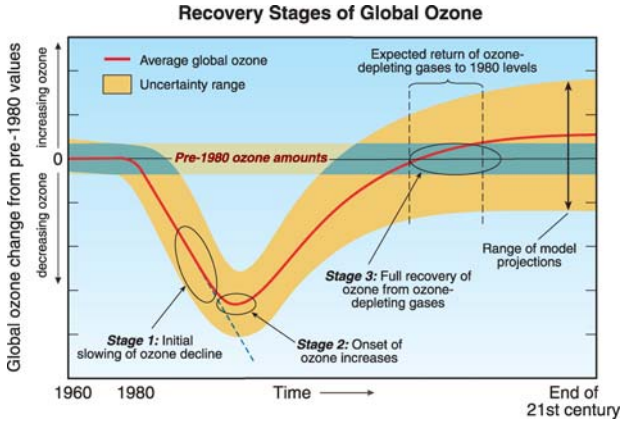
The "accountability" phase of Montreal Protocol and stratospheric O_3:

Key Questions:

- Substitutes for ODSs- how good are they?



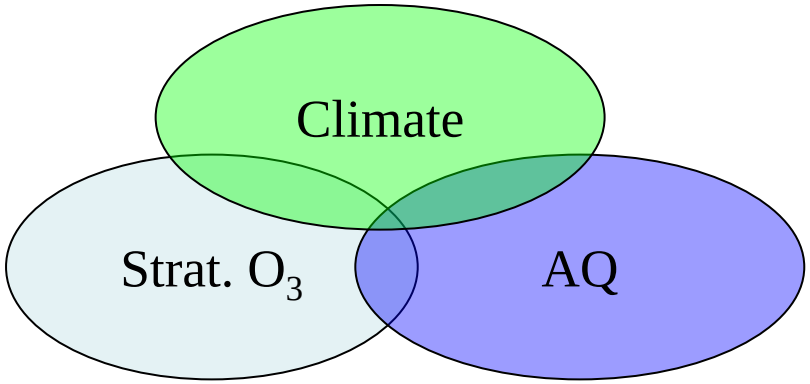
- Recovery of O_3 layer- When? Where will it observed? By how much?
- How does climate change influence recovery?



- Connections to other Earth System issues?
- Other benefits of the Montreal Protocol?

Goal: "Shepherd" the O_3 layer through the accountability phase.

Interconnections



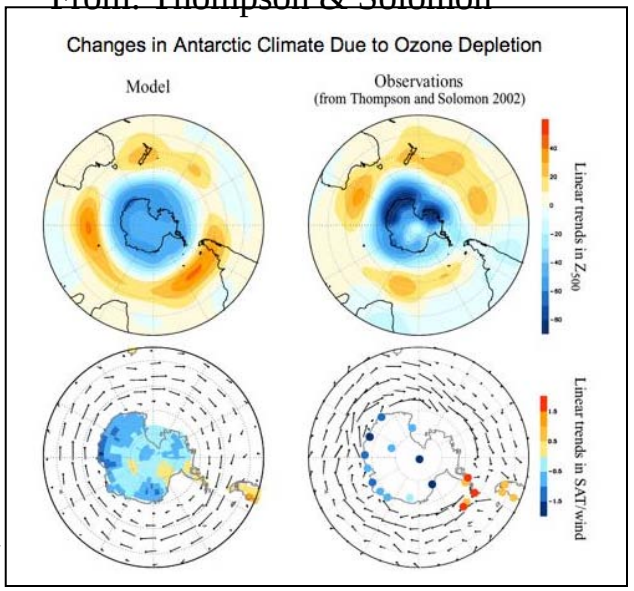
- Climate and Stratospheric ozone
- Climate and air quality
- Stratospheric ozone and air quality

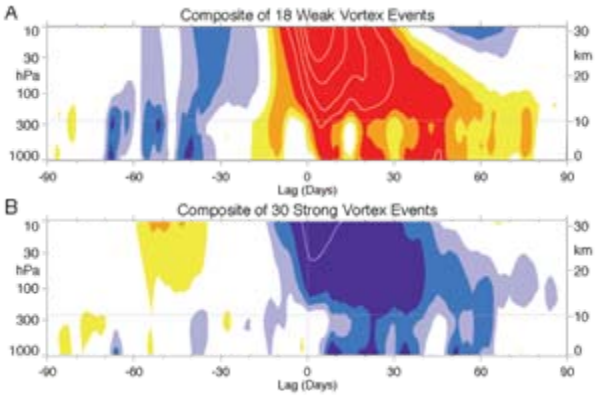
Climate and Stratospheric Ozone

Many connections between climate and stratospheric ozone issues:

- Role of stratospheric ozone depletion/changes on climate
  - Globally
  - Polar regions
- Influence of climate change on ozone layer recovery
  - Tropospheric changes
  - Changes in temperature
- Role of ODSs as climate gases
- Stratospheric changes as indicators of trop changes
- Interactions to think about
  - Mitigation options, e.g., biofuels and N_2O

From: Thompson & Solomon

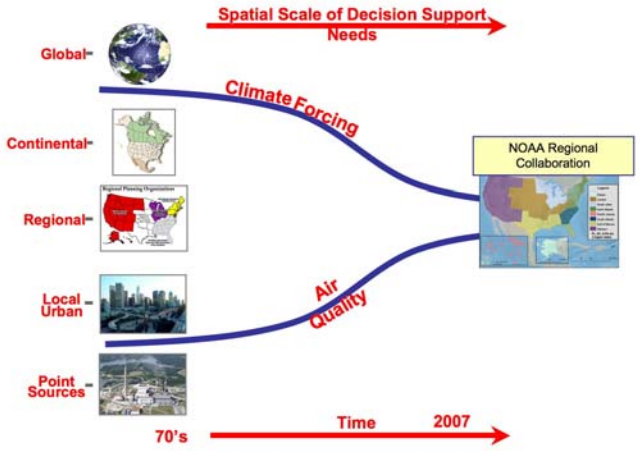


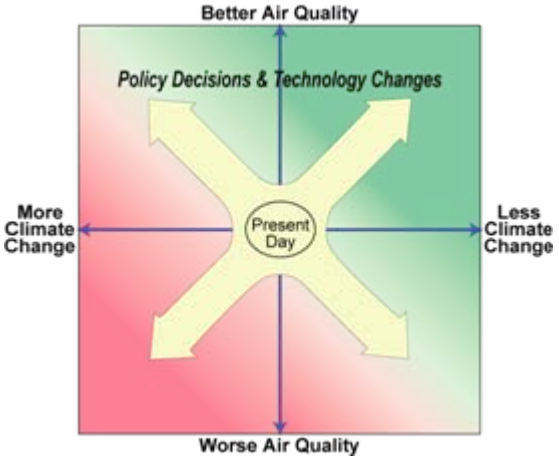


Baldwin and Dunkerton, 2001

Weather from above. A weakening (red) or strengthening (blue) stratospheric vortex can alter circulation down to the surface. The diagrams show composites of the NAM index. (A) Composite of 18 week vortex events. The thin horizontal line indicates the approximate tropopause.

Climate and Air Quality





- Spatial scales of climate change and air quality are converging.
  - Attributions of climate change on regional scales
  - Air quality changes extending to regional scales

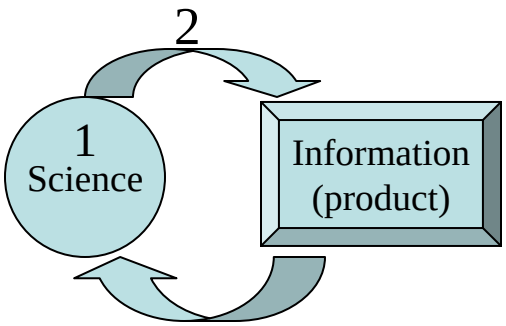
  Essential to consider together for climate & AQ

- Changes in climate will influence air quality.
  - Different (evolving) backgrounds
  - Ways to cope with emissions

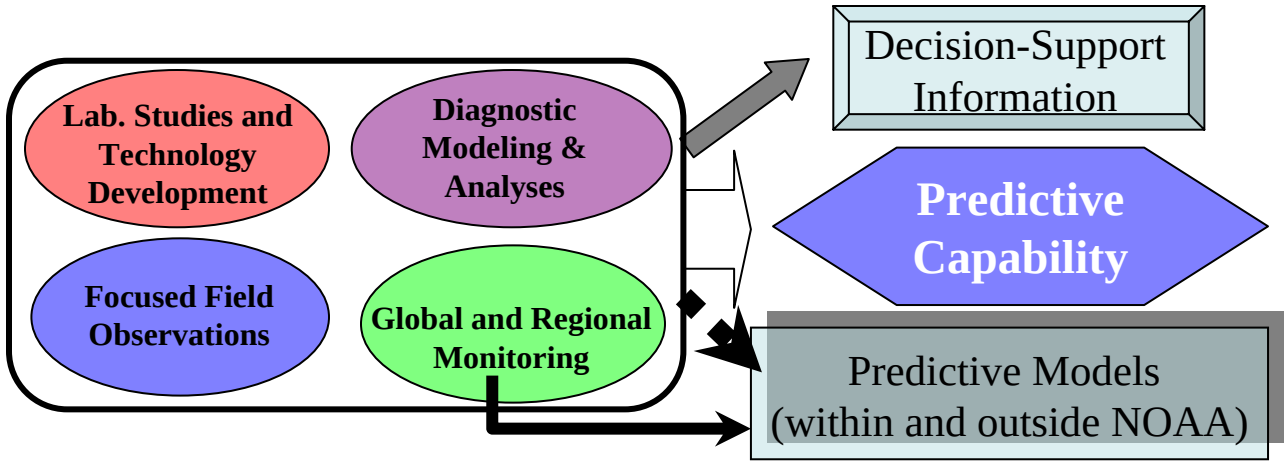
- Air quality improvement strategies may not always help climate change issues and vice-versa.

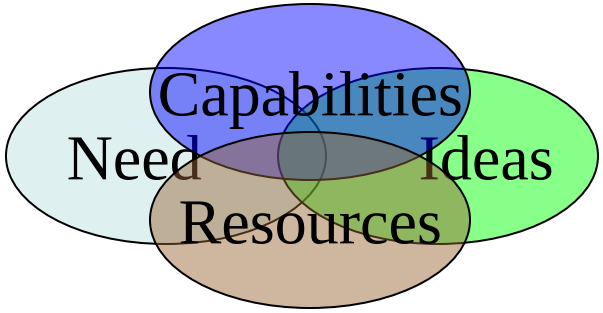
- Address these issues synergistically.
- Provide usable information (including new science efforts) to decision makers.

Our Goal and Approach



- Do the science.
- Carry science to information products.





Weighing these factors!

Intangible, but key to success!

Over to Jim Butler