Short-Lived Climate Pollutants (SLCP) and their role in climate change and variability

A. R. Ravishankara:

- Importance of SLPCs
- NOAA's role
- Examples of interconnections:
  - with air quality issues.
  - with stratospheric ozone issues

James Butler:

Short-Lived Non-CO2 Greenhouse Gases

V. Ramaswamy:

Quantitative understanding, with uncertainties, of emissions-to-transport-to-lifetime-to-climate (e.g., temperature, precipitation) using global models, for predictability in the 21st Century

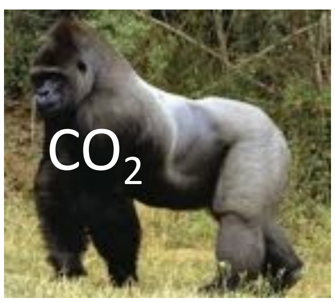
- Role of aerosols in the 20th C and present-day
- Aerosols and climate projections in the 21st C

Importance of SLPCs and NOAA's role

A. R. Ravishankara
NOAA / ESRL / Chemical Sciences Division / Boulder

What are Short-Lived Climate Pollutants (SLCPs)?

GHGs or other constituents that influence radiative balance of Earth system that are short-lived (<10 years?)



- Iconic anthropogenic climate forcer
- Essential issue for:
  - mitigation,
  - adaptation, and
  - understanding

- Climate forcing agents with "short" lifetimes
- Include CH_4 (~10 yrs) and shorter-lived forcers
- Includes many HFCs
- Are chemically active
- Have impacts on other issues
  - Health
  - Precipitation
  - etc.
- Aerosols are a big part of the SLCPs
- SLCPs have been target by U.S. and G-8 nations - NOAA will be responsive to a National need.

Why SLCP?

(1) They can be dealt within through “win-win” options for multiple environmental issues;

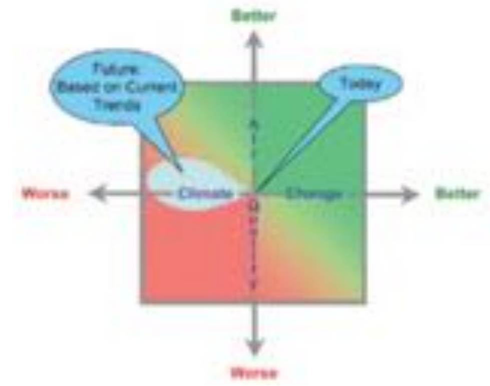
(2) They can be influenced using existing regulations;

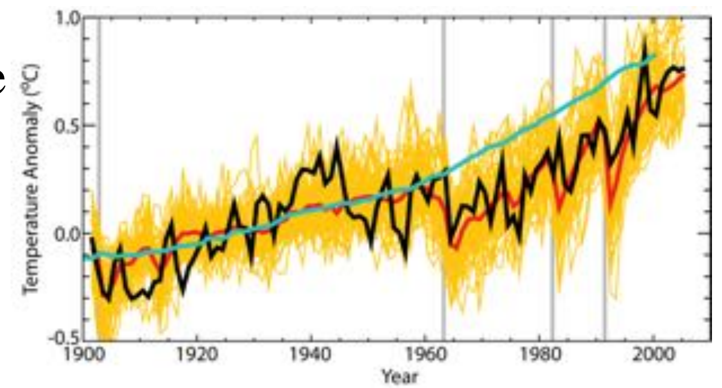
(3) Their shorter lifetimes allow for some immediate relief, while the larger CO_2 issue is being worked on;

(4) Scientific insights on the workings of the climate system could be obtained by changes in these forcers; and

(5) Accounting for them is essential for regional climate change and variability predictions.

(6) NOAA has focused on many issues related to SLCPs (see additional slides)

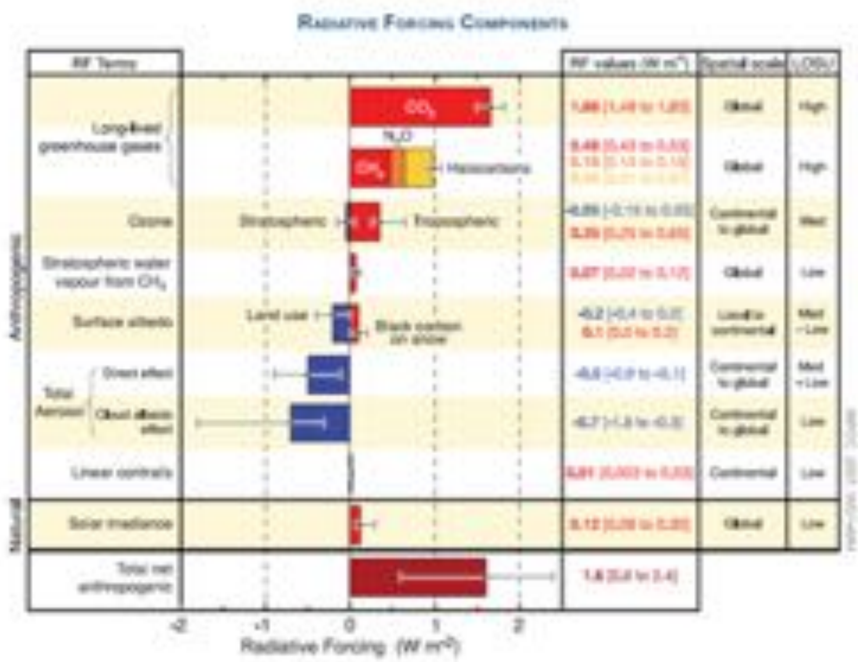


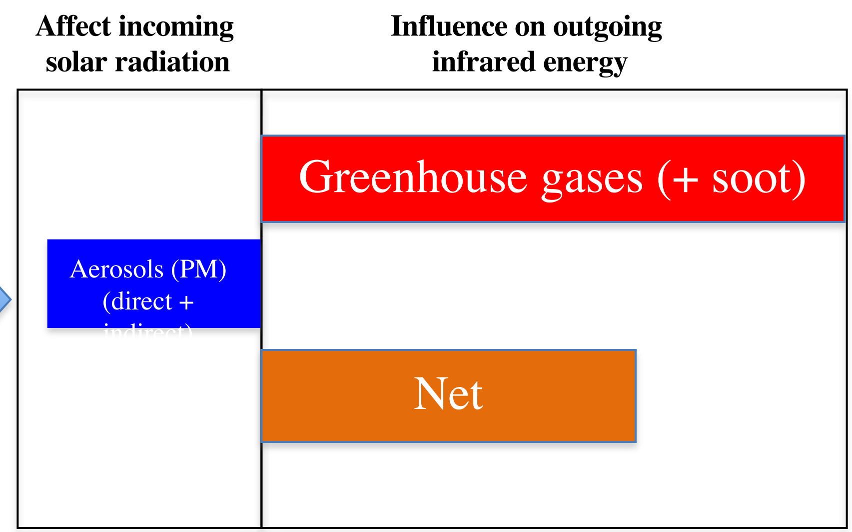


The forcings from aerosols have offset the greenhouse gas forcings and the SLCP greenhouse gases significantly augment CO_2 forcing.

Climate Air Quality Intersections

Simplified Climate Forcing Diagram

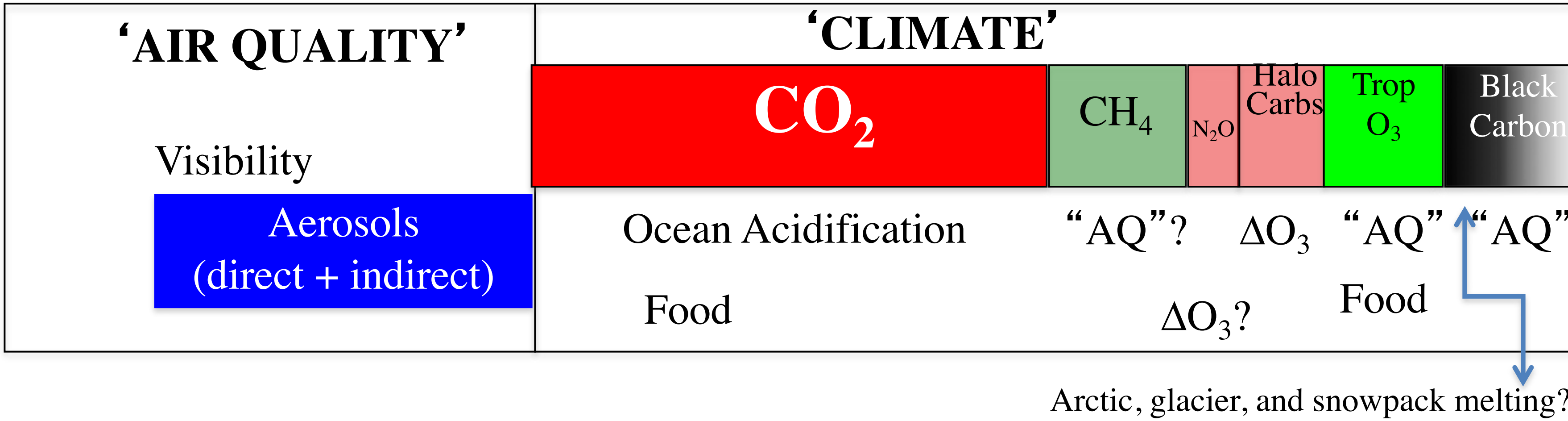




Coupling between anthropogenic climate change and air quality:

- *Air Quality regulations can be a win-win for AQ & Climate*
- *Many states/regions have legislated this approach*
- *One does not need the "predicted climate state" to make relative choices*
- *Direct application of science-based information (e.g., emissions, RF, etc.)*

Our Science:
Evaluating multiple roles of SLCPs



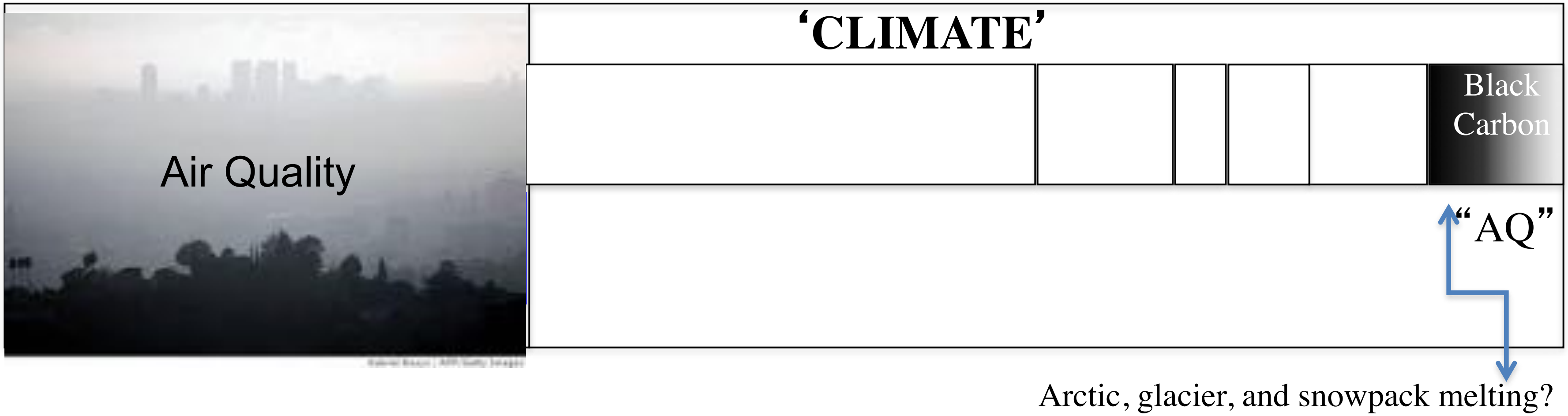
- Air Quality roles: Trop. aerosols, CH_4, trop. O_3, and BC (indoor AQ)
- Visibility: aerosols, (BC)
- Ocean acidification: CO_2
- Stratospheric ozone depletion/changes: Halocarbons (and substitutes?); CO_2, CH_4
- Water supply: (GHGs +aerosols), black carbon
- Food issues: CO_2,- ocean acidification- trop O_3, (aerosols?)

Multiple impacts that need simultaneous considerations:

(1) Science for optimizing for best outcome.

(2) Information for multiple issues!

Soot: the joker in the deck

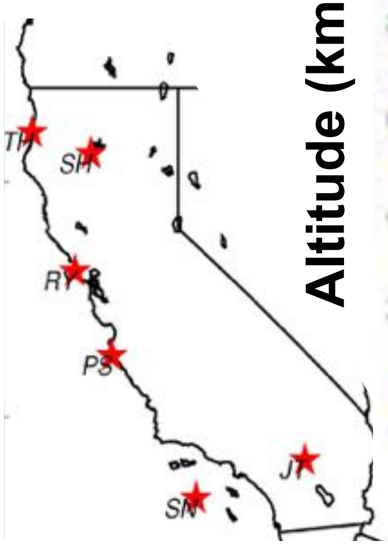


Key questions about soot (and aerosols) – the very short-lived pollutants:

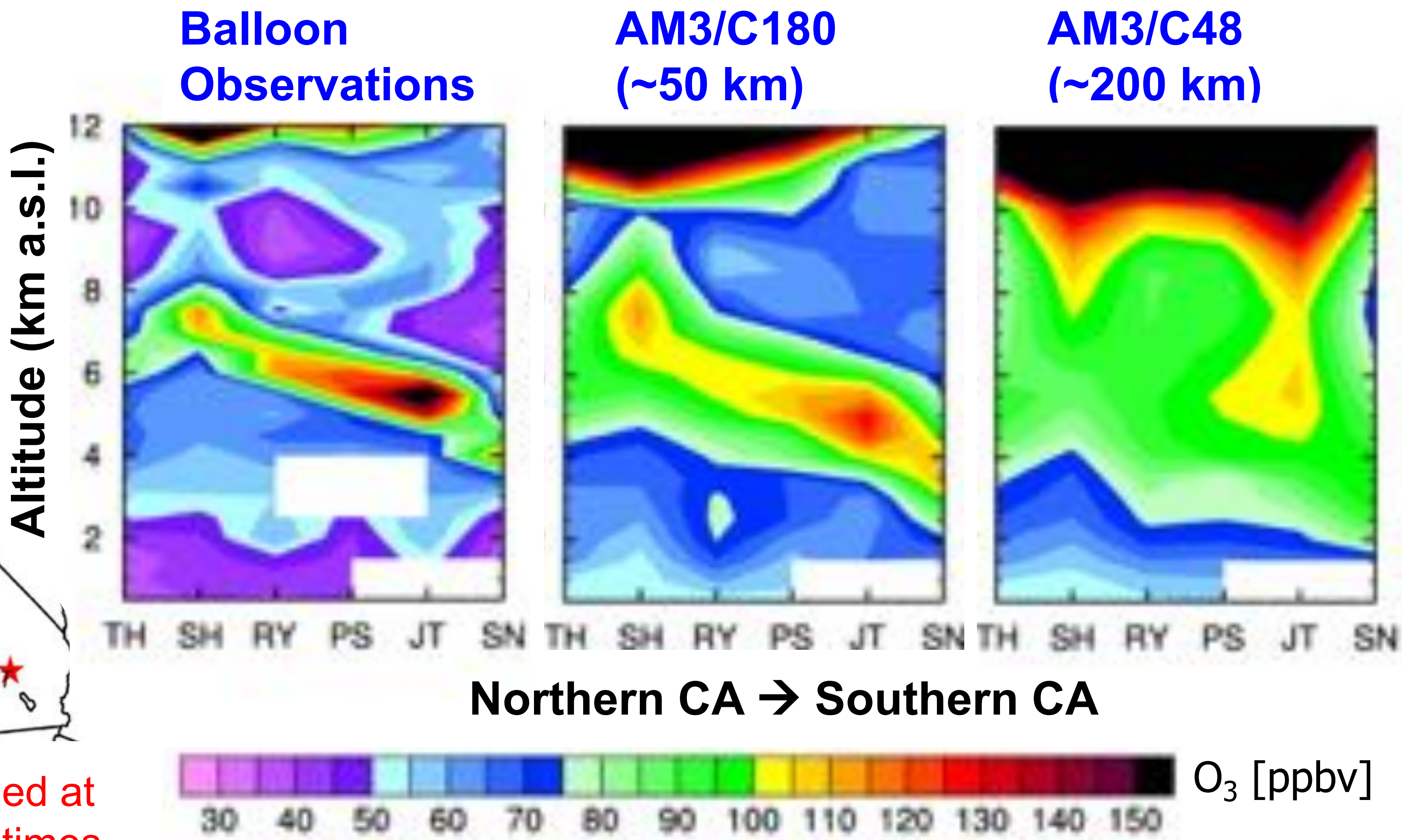
- ***What is the real soot forcing? Quantification of emissions***
- ***What is the net of soot and aerosols? Are they really separable?***
- ***What is the impact of soot on glaciers, snow ice, snow, ice-fields, precipitation?***
- ***Is reducing soot emissions a "no-regret" strategy?***
- ***Direct application of science-based information (e.g., emissions, RF, etc.)***

Key new scientific findings of NOAA

High-resolution atmospheric chemistry-transport model better captures stratospheric ozone intrusions (May 11, 2010)



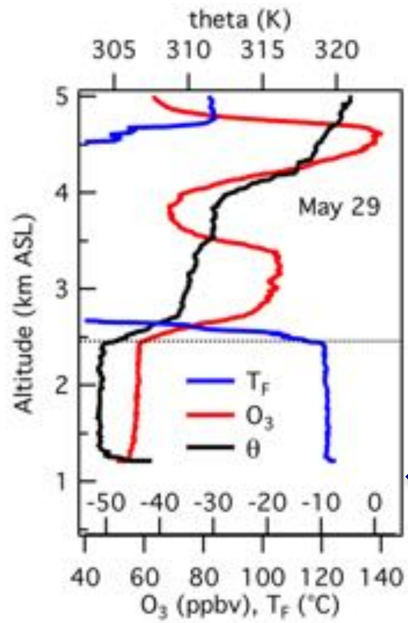
model sampled at location and times of sonde launches



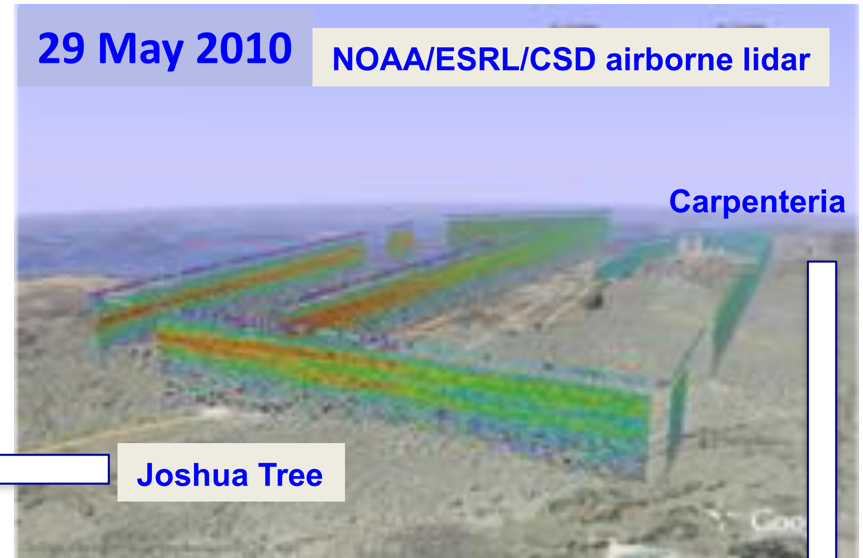
Vertical cross section over California

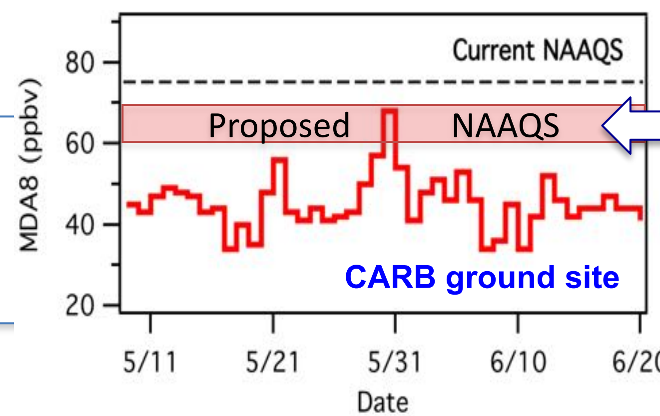
Courtesy: Meiyun Lin (NOAA/ GFDL, Princeton)

Exceedance of proposed NAAQS by stratospheric intrusion over LA Basin



NOAA/ESRL/GMD ozonesonde





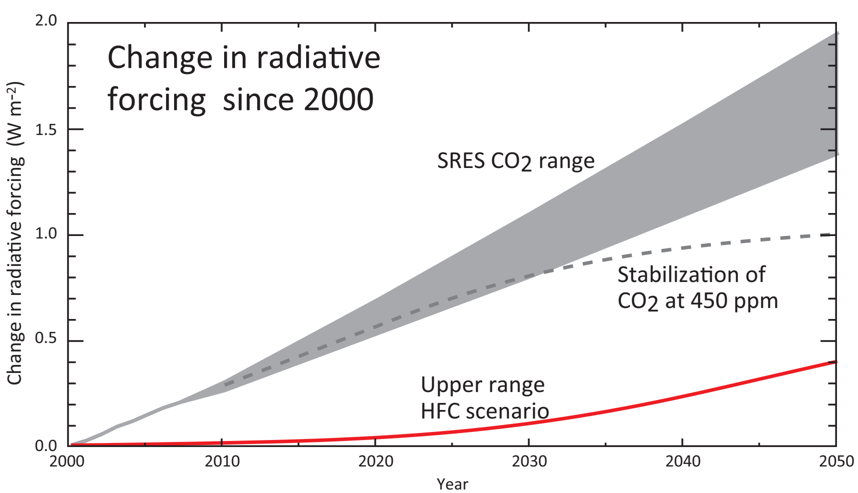
Stratospheric influence on surface ozone in the Los Angeles area during late spring and early summer of 2010 ;
A.O. Langford et al., JGR, vol. 117; DOI: 10.1029/2011JD016766, 2012

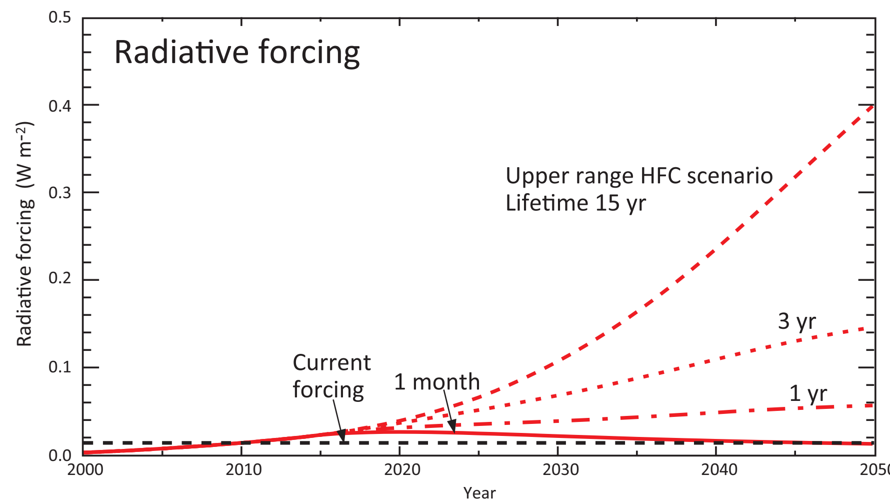
CalNex and IONS-2010 (May 10 – June 19)

Courtesy: Langford NOAA/ESRL/CSD

- Intrusion of stratospheric (ozone rich) air can lead to large surface ozone
- Implications for meeting AQ standards?

HFCs and climate change: Future emissions can be large but can be avoided





- Unabated, future HFC contribution radiative forcing can be large.
- Radiative forcing by future HFC emissions can be ~25% of that of CO_2 future emissions (SRES scenarios).
- Future HFC emissions can significantly hinder the 450 ppm stabilization target.
- There are viable solutions to avoid this situation- with potentially positive side benefits (see attached for NOAA information provision)

Short-Lived Non-CO2 Greenhouse Gases

James Butler
NOAA / ESRL / Global Monitoring Division / Boulder

REVIEW

doi:10.1038/nature10322

Non-CO_2 greenhouse gases and climate change

S. A. Montzka[1], E. J. Dlugokencky[1] & J. H. Butler[1]

Earth's climate is warming as a result of anthropogenic emissions of greenhouse gases, particularly carbon dioxide (CO_2) from fossil fuel combustion. Anthropogenic emissions of non-CO_2 greenhouse gases, such as methane, nitrous oxide and ozone-depleting substances (largely from sources other than fossil fuels), also contribute significantly to warming. Some non-CO_2 greenhouse gases have much shorter lifetimes than CO_2, so reducing their emissions offers an additional opportunity to lessen future climate change. Although it is clear that sustainably reducing the warming influence of greenhouse gases will be possible only with substantial cuts in emissions of CO_2, reducing non-CO_2 greenhouse gas emissions would be a relatively quick way of contributing to this goal.

Greenhouse gases (GHGs) alter Earth's climate by absorbing energy in the lower atmosphere and re-emitting it. Although anthropogenic emissions of CO_2 contribute most to GHG-induced warming, several other gases, such as methane (CH_4), nitrous oxide (N_2O), ozone-depleting substances (ODSs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and perfluorocarbons (PFCs), also affect climate for decades to millennia after being emitted. Because most anthropogenic emissions of these non-CO_2 GHGs are linked to society's

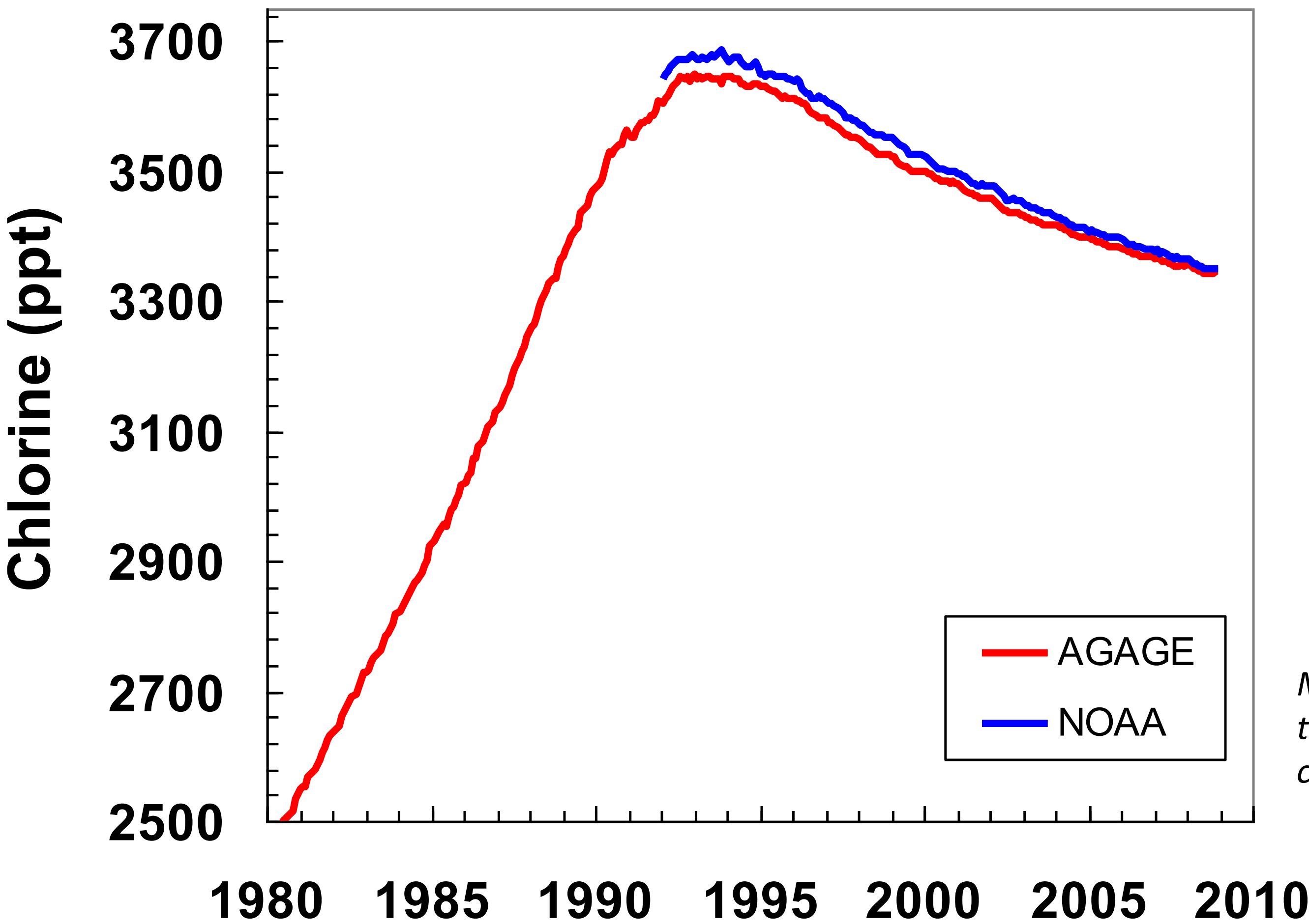
(~20 Gt CO_2-eq yr^{-1} from each; Fig. 1). Since 1990, total emissions of non-CO_2 GHGs have declined to 15 Gt CO_2-eq yr^{-1}, mainly due to reductions in ODSs as agreed to in the Montreal Protocol on Substances that Deplete the Ozone Layer[10,11] (henceforth the Montreal protocol). For a time these reductions were sufficient to offset increases in emissions of other GHGs, but since 2003 continued increases in fossil fuel CO_2 have exceeded those offsets. In 2008, the 15 Gt CO_2-eq yr^{-1} contribution from non-CO_2 GHGs accounted for 30% of all human-

Nature Vol 476 No. 43 – August 4, 2011

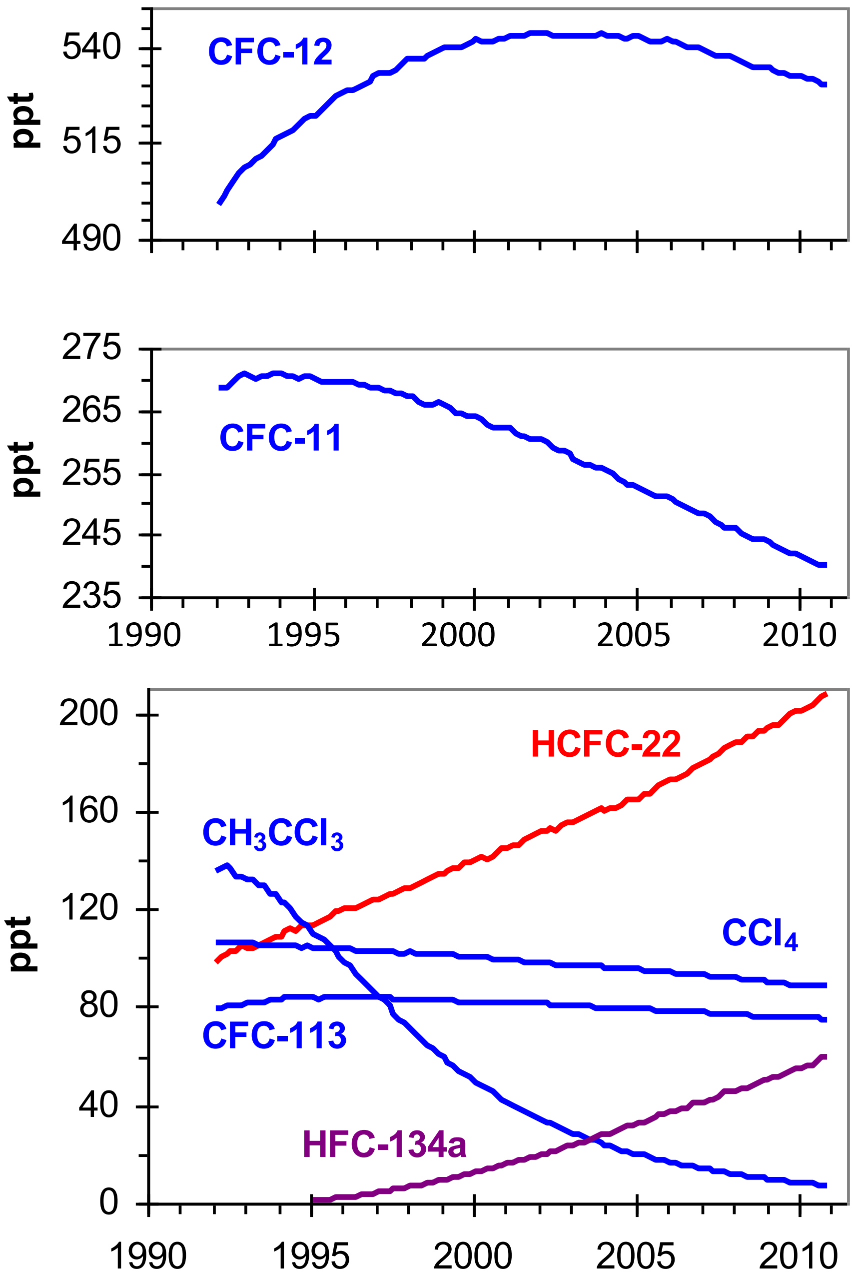
Example: Ozone-depleting gases

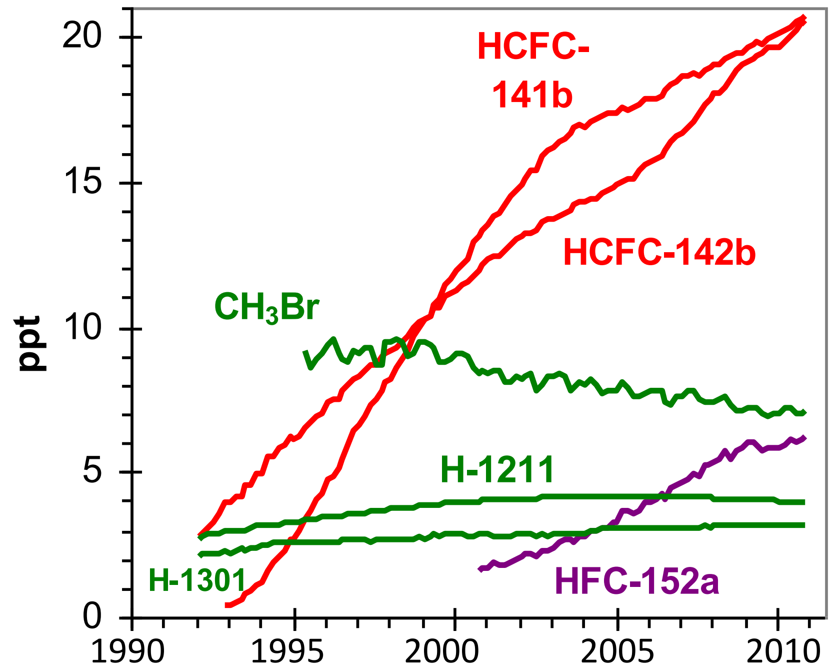
Ozone-depleting Gases

- As a result of the Montreal Protocol, the impact of controlled substances is decreasing.



Measured tropospheric changes

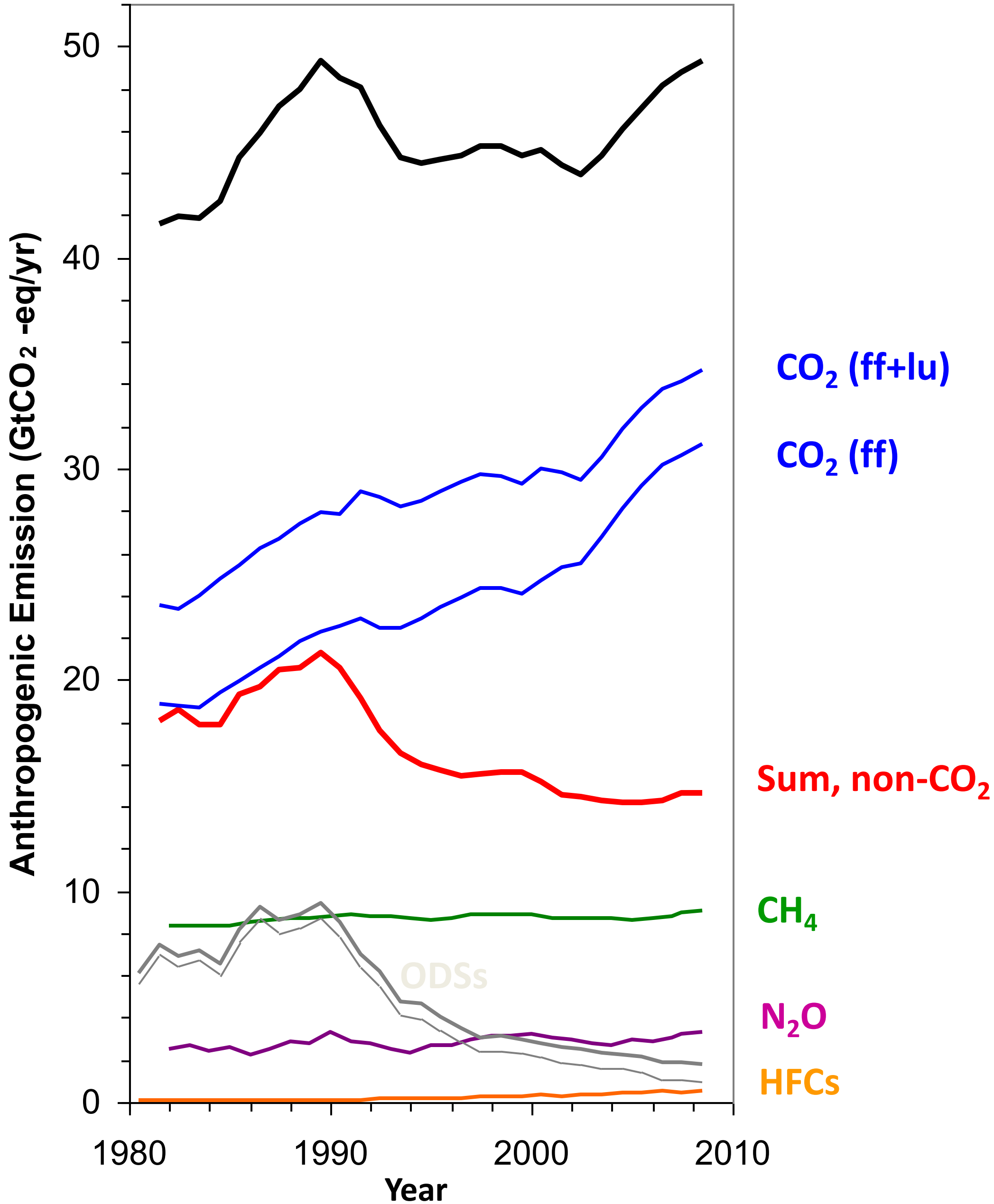




Ozone-depleting Gases

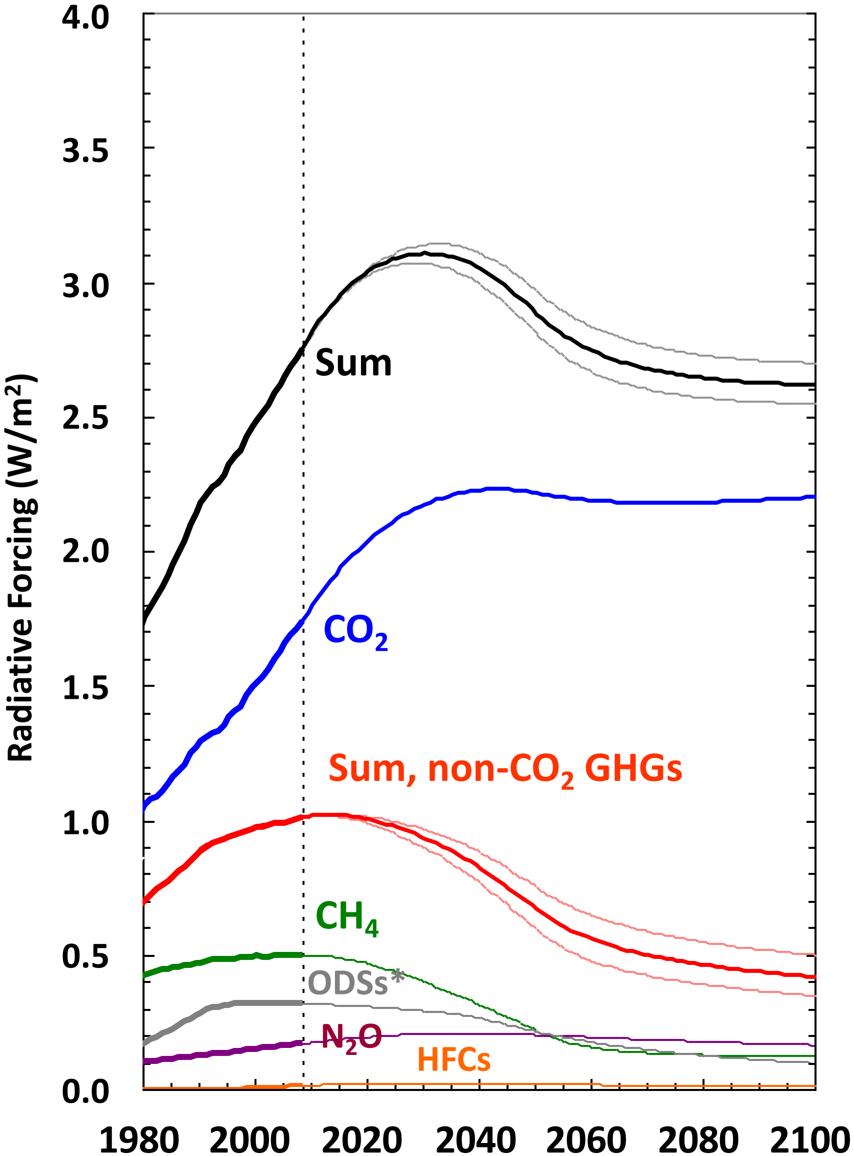
- Most are long-lived
- Some are shorter-lived
- Success comes by addressing all gases
- Reductions began under the Montreal Protocol

How much are we emitting in the way of greenhouse gases?



Anthropogenic Emission ($GtCO_2$ -eq/yr)
50
40
30
20
10
0
1980
1990
2000
2010
Year
CO_2 (ff+lu)
CO_2 (ff)
Sum, non-CO_2
CH_4
ODSs
N_2O
HFCs

How do these changes affect the atmosphere?



- These projections do not include consideration of **feedbacks**:
- Climate on emissions
  - Arctic release
  - Marsh emission enhancements
- Climate on loss
  - CO_2 uptake
  - stratospheric circ.
  - [OH] variability

**ODSs future set by the Montreal Protocol*

Warming effect of short-lived substances

Persistence of climate changes due to a range of greenhouse gases

Susan Solomon[a,1], John S. Daniel[a], Todd J. Sanford[a,b], Daniel M. Murphy[a], Gian-Kasper Plattner[c], Reto Knutti[d], and Pierre Friedlingstein[e,f]

[a]Chemical Sciences Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305; [b]Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder, CO 80307; [c]Climate and Environmental Physics, Physics Institute, University of Bern, 3012 Bern, Switzerland; [d]Institute for Atmospheric and Climate Science, Eidgenössiche Technische Hochschule Zurich, 8006 Zurich, Switzerland; [e]Institut Pierre Simon Laplace/Laboratoire des Sciences du Climat et de l'Environnement, Unité Mixte de Recherche 1572 Commissariat à l'Energie Atomique–Centre National de la Recherche Scientifique–Université de Versailles Saint-Quentin, Commissariat à l'Energie Atomique-Saclay, L'Orme des Merisiers, 91191 Gif sur Yvette, France; and [f]QUEST/Department of Earth Sciences, University of Bristol, Bristol BS8 1RJ, United Kingdom

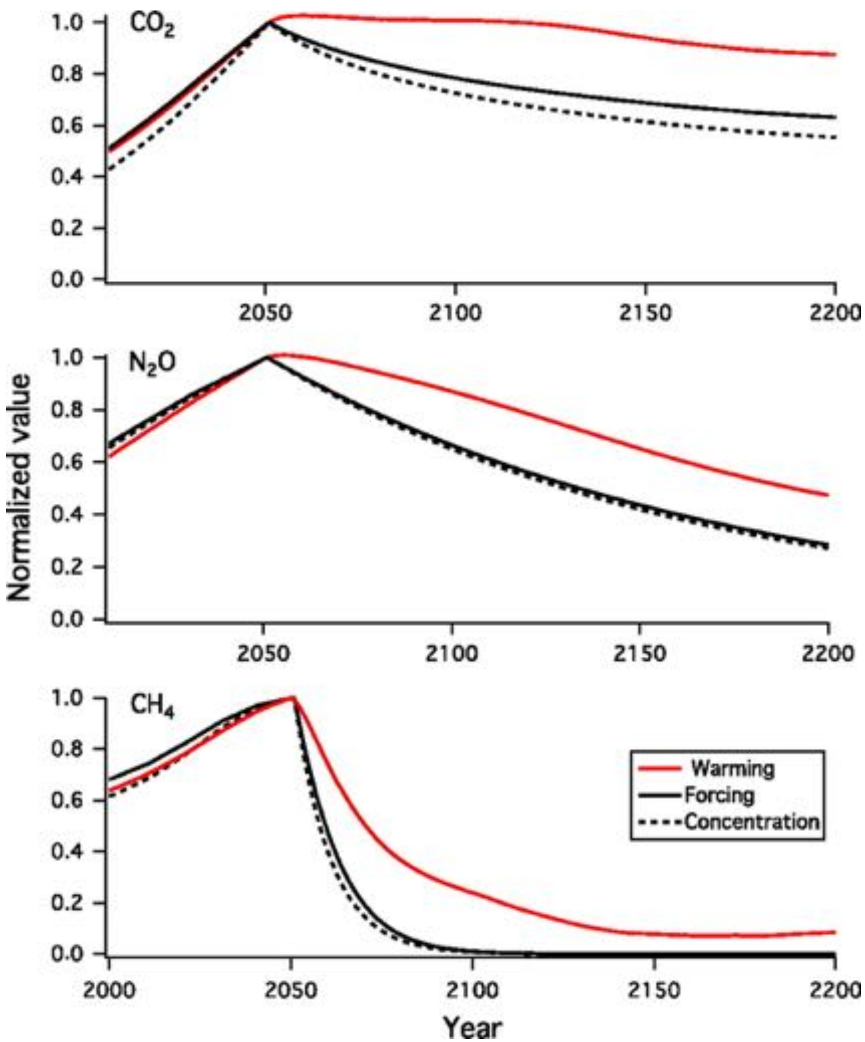
Edited by James E. Hansen, Goddard Institute for Space Studies, New York, NY, and approved August 31, 2010 (received for review May 5, 2010)

Emissions of a broad range of greenhouse gases of varying lifetimes contribute to global climate change. Carbon dioxide displays exceptional persistence that renders its warming nearly irreversible for more than 1,000 y. Here we show that the warming due to non-CO_2 greenhouse gases, although not irreversible, persists notably longer than the anthropogenic changes in the greenhouse gas concentrations themselves. We explore why the persistence of warming depends not just on the decay of a given greenhouse gas concentration but also on climate system behavior, particularly the timescales of heat transfer linked to the ocean. For carbon

different processes and timescales contribute to determining how long the climate changes due to various greenhouse gases could be expected to remain if anthropogenic emissions were to cease.

Advances in modeling have led to improved Atmosphere-Ocean General Circulation Models (AOGCMs) as well as to Earth Models of Intermediate Complexity (EMICs). Although a detailed representation of the climate system changes on regional scales can only be provided by AOGCMs, the simpler EMICs have been shown to be useful, particularly to examine phenomena on a global average basis. In this work, we use the Bern 2.5CC

Proceedings of the National Academy of Sciences Vol. 107 No. 43 – October 26, 2010



Warming impact of short-lived substance

Solomon S et al. PNAS 2010;107:18354-18359

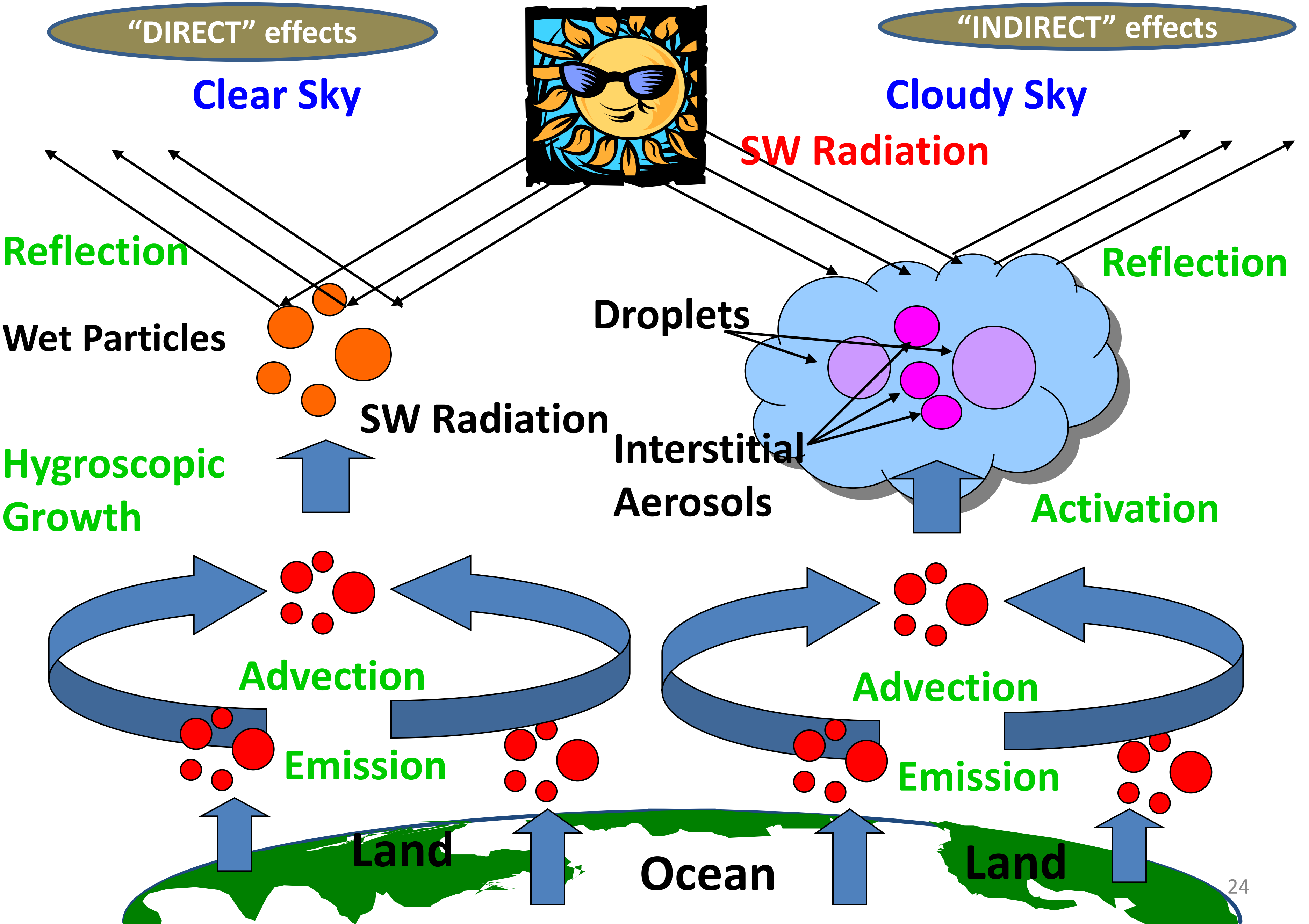
Aerosols and their role in Climate Change and Variability

V. Ramaswamy
NOAA/ GFDL, Princeton

Quantitative understanding, with uncertainties, of emissions-to-transport-to-lifetime-to-climate (e.g., temperature, precipitation) using global models, for predictability in the 21st Century

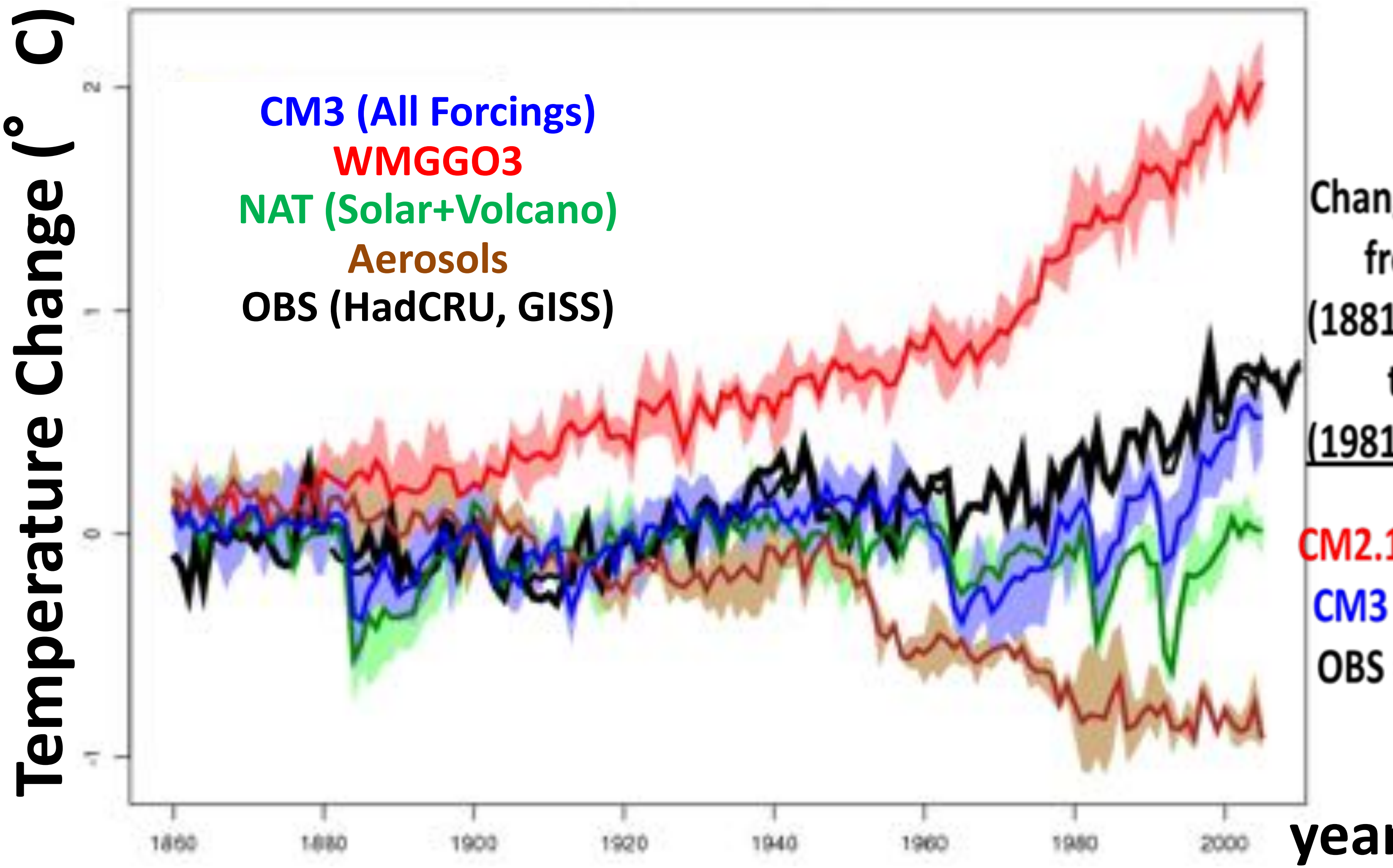
- Attribution to GHGs versus aerosols in the 20th C and present-day
- Aerosols and climate projections in the 21st C

Aerosol-Cloud-Climate Interactions



Surface Air Temperature change

[*WMGGO3* ***(warming)*** *and Aerosol* ***(cooling)*** *effects dominant*]



Change (°C) from (1881-1900) to (1981-2000)

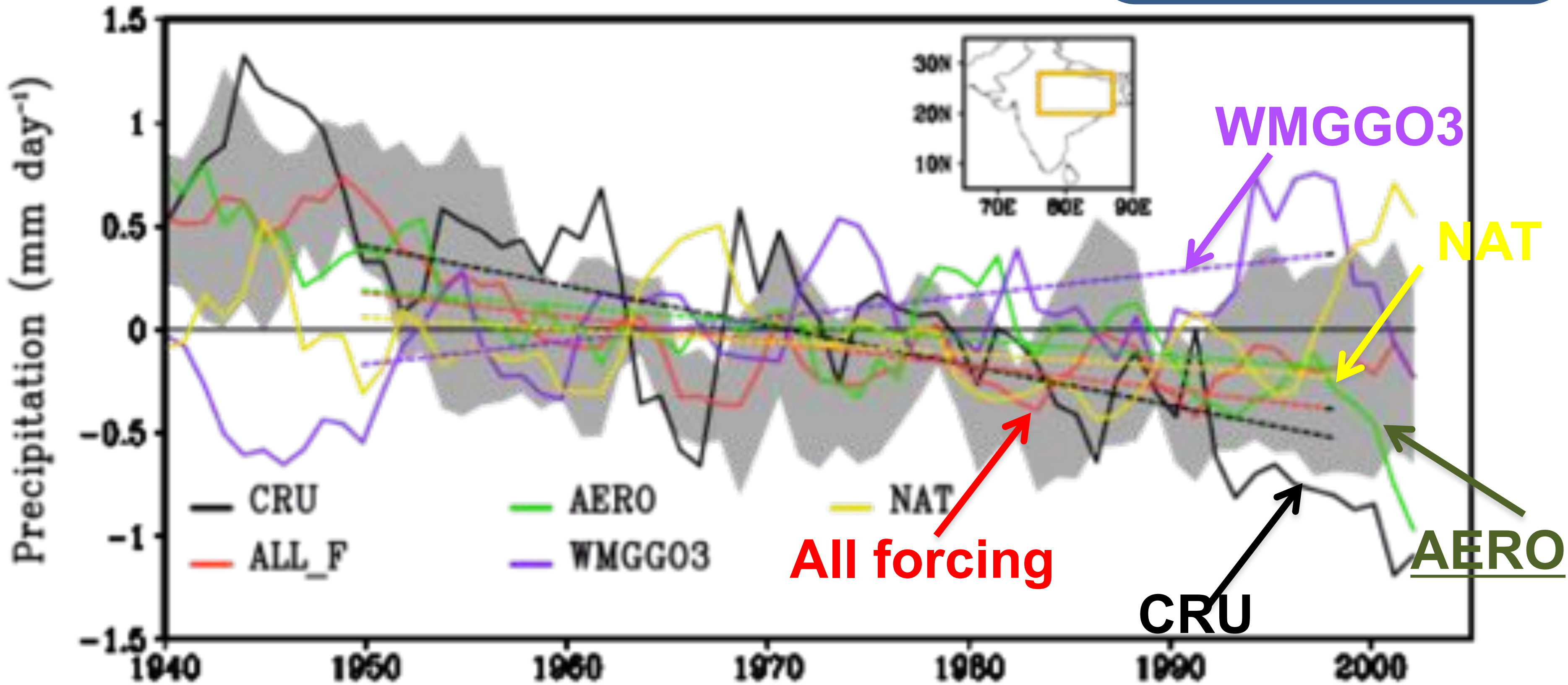
CM2.1 = 0.74
CM3 = 0.23
OBS = 0.51

Horowitz et al. (in preparation)

Attribution of the weakening of the South Asian summer monsoon using GFDL CM3: 20th Century simulations

Linear trends of average JJAS rainfall over central-northern Indian (mm day^{-1})

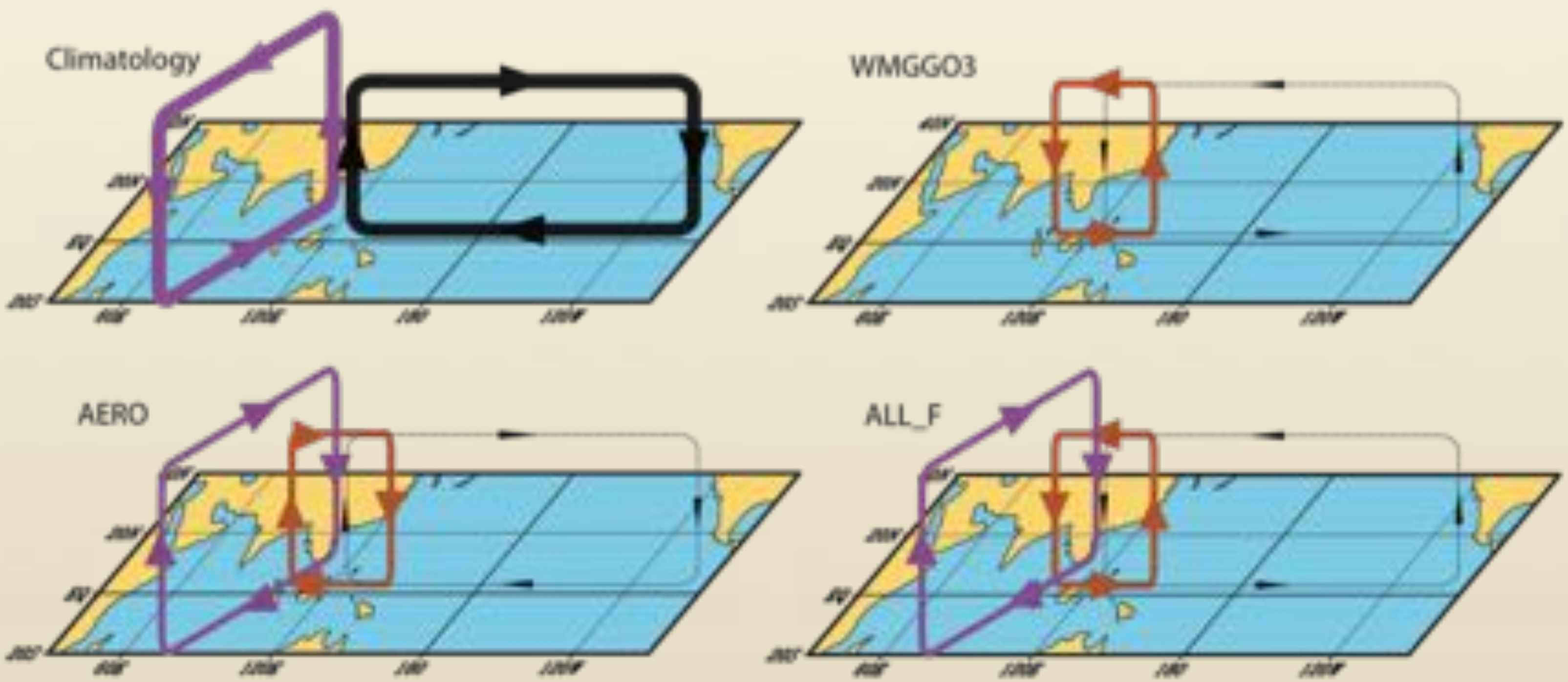
- *AERO trend opposite in sign to WMGGO3*
- *AllForc trend compares well with CRU (Obs)*



Bollasina et al. (Science, 2011)

How Hadley and Walker circulations respond to green-house gases and aerosols? Regional-scale forcing is also important

Climatology **GG**

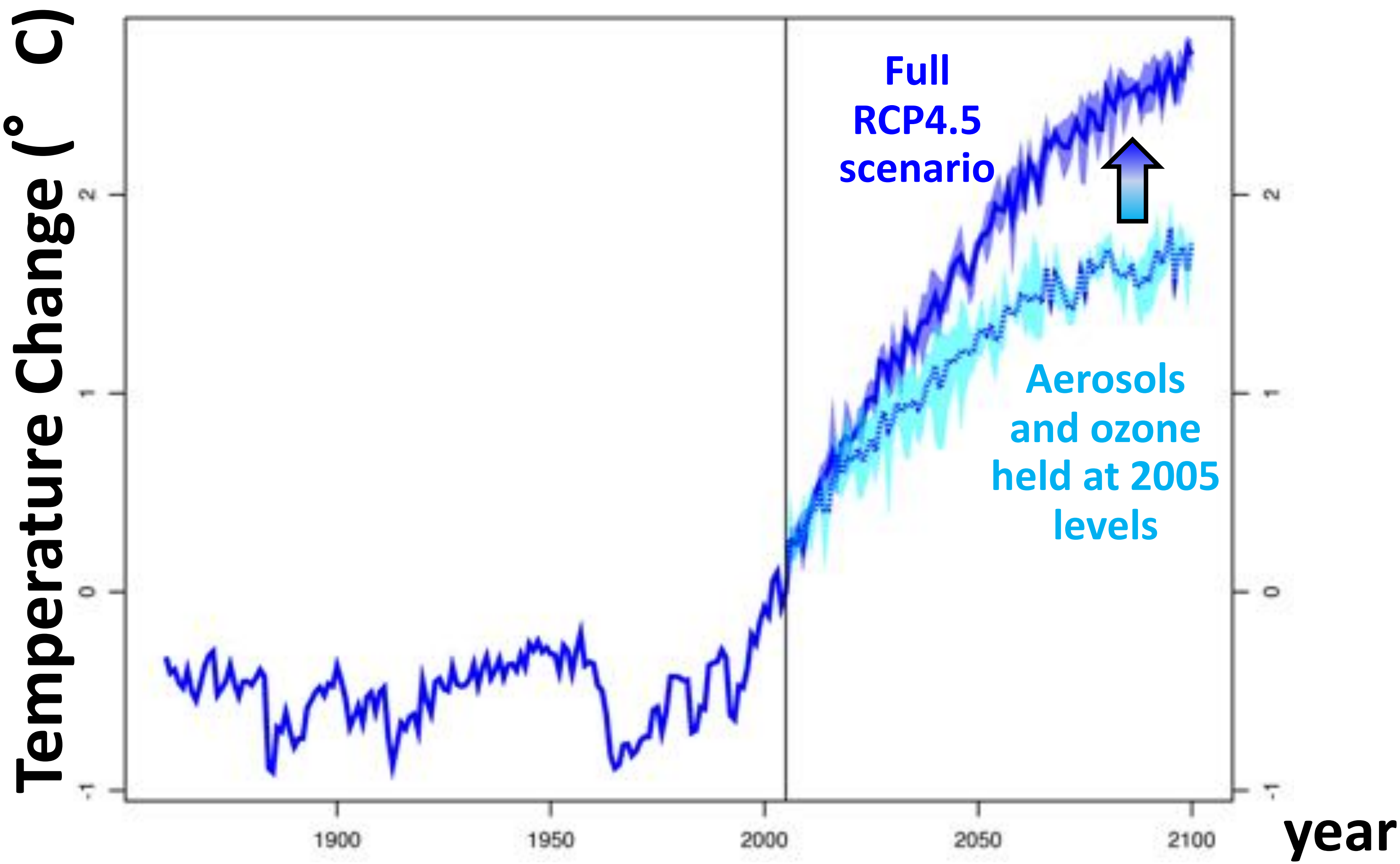


AERO **All forcing**

North-South pattern of basic mechanism evident in earlier simulations

Chen and Ramaswamy (1996); Ramaswamy and Chen (1997)

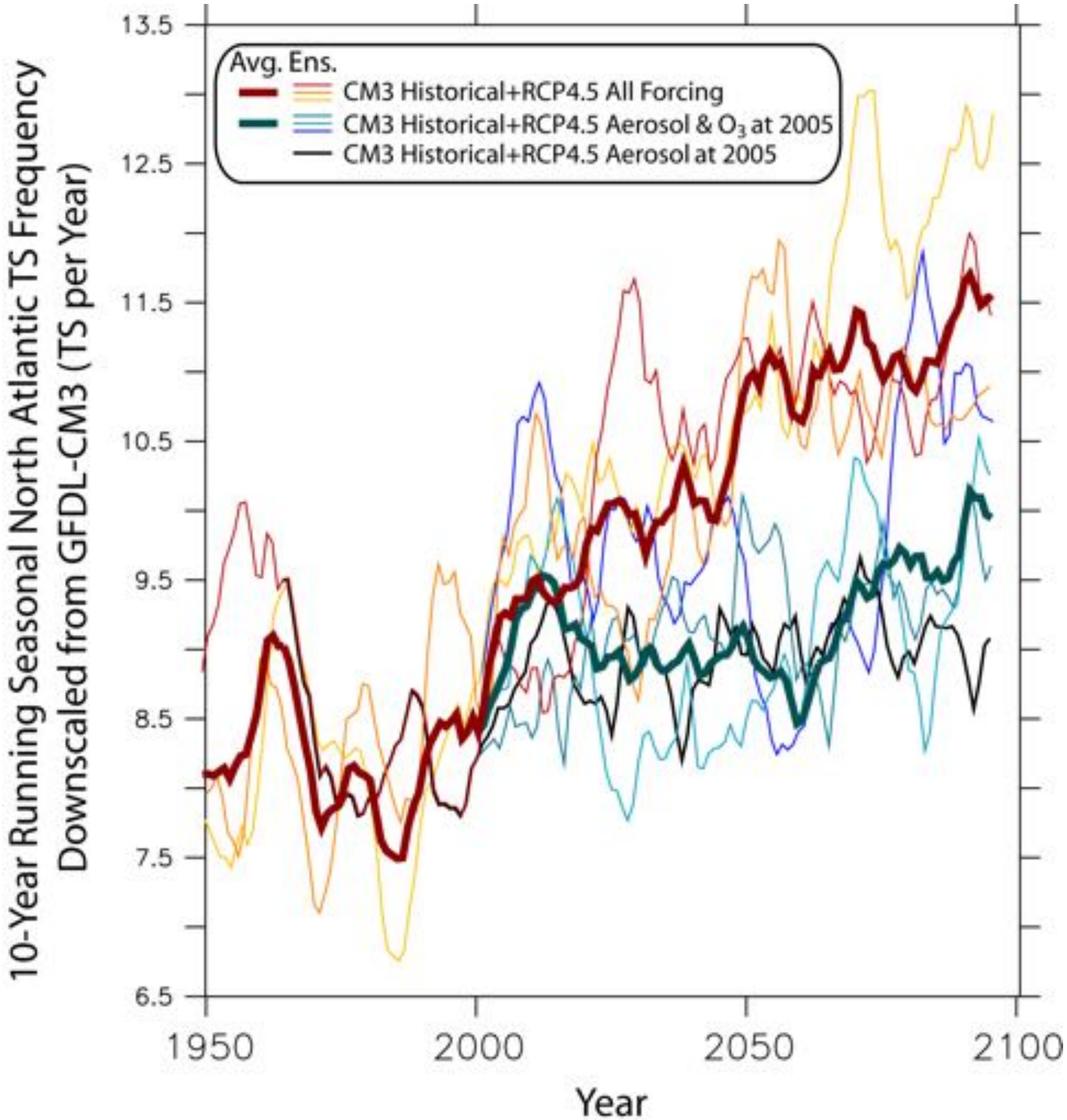
Surface Air Temperature (RCP4.5 scenario)



Large additional warming projected from aerosols over 21st century

Levy et al. (submitted, JGR)

Aerosols key for NA TS projections



All Forcing

No future aerosol or O_3

No future aerosol

Projected aerosol changes lead to increase in NA TS frequency over 1st half of 21st century

Villarini and Vecchi (2012, Nature C.C.)

Aerosols and their role in Climate Change and Variability

Key Uncertainties

Quantitative understanding, with uncertainties, of emissions-to-transport-to-lifetime-to-climate (e.g., temperature, precipitation) using global models, for predictability in the 21st Century

- Spatial distributions of aerosols and their properties ➔ **Forcing, with uncertainties**
- Regional climate trends in temperature and precipitation
- Atmospheric trends (e.g., changes in lapse rate)
- Relative impacts versus long-lived greenhouse gases ➔ **Quantifying with uncertainties**

Synopsis

- There is a great demand for information on SLCPs
- NOAA (with its partners) has the expertise and capabilities to fulfill these needs
- Have already developed great partnerships with regions, states, and other users (e.g., State Dept.)
- Have developed long-term collaborations with extramural community to carry out such research
- Have NOAA facilities that are well suited for this work and collaborations

The END

Additional Material

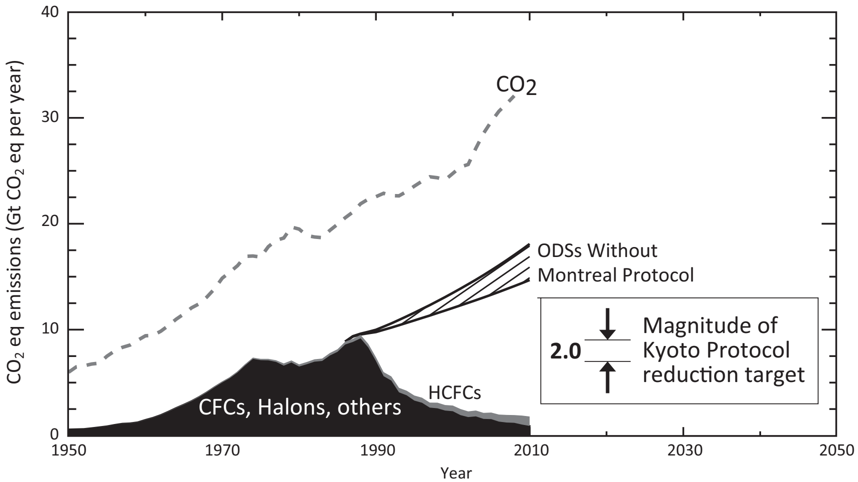
SLCP and NOAA’s efforts

NOAA has focused on many issues related to SLCPs:

- The physical and chemical nature of these species;
- How they have forced the climate system;
- How they will contribute in the future;
- What are the telltale signatures of these forcers; and
- What have been and will be the impacts of these changes on climate, air quality, and precipitation

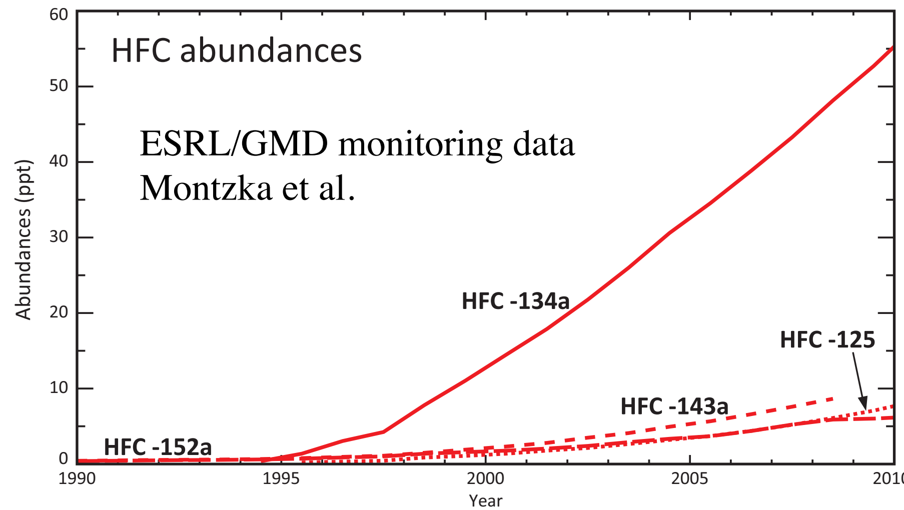
Montreal Protocol, HFCs, and Climate

MP effectively protected climate



- ODS-Phase out led to a drop of ~ 8.0 $GtCO_2eq$ per year (1988 -2010)
- The avoided annual ODS emission (~ 10 Gt CO_2eq in 2010 alone)
  - **x5** the Kyoto target for 2008-2012 (1st commitment period)
- ODS decrease: one of the largest intentional global GHG emission reductions to date

HFCs increased because of MP



- Consumption of HFCs is increasing rapidly
- Consequent atmospheric growth rate of some HFCs are increasing very rapidly (some as much as 10% per year)
- The current contributions of HFCs to radiative forcing is still small (<1% of GHGs)

Back up Slide for Short-Lived Non-CO2 Greenhouse Gases (Jim Butler)