Radiative Forcing of LONG-LIVED Non-CO$_2$ Greenhouse Gases

*CH$_4$ (discussed by Ed D.)
*N$_2$O
*Ozone-depleting gases and their substitutes:
  - Chlorofluorocarbons
  - Other chlorinated and brominated chemicals
  - Hydrochlorofluorocarbons
  - Hydrofluorocarbons
*SF$_6$
*Perfluorinated carbon compounds

Direct and Indirect Influences...

Anthropogenic use is addressed by the Montreal Protocol or the Kyoto Protocol

Air sampling at the South Pole
Current and Past Activities in NOAA/ESRL Related to Radiative Forcing of Non-CO₂ Greenhouse Gases

** Observing global changes for non-CO₂ greenhouse gases:**
Global sampling networks, custom instrumentation, high-accuracy standardization air trapped in glacial snow…

** Assessing the significance of observed global changes:**

** Understanding the underlying causes of observed global changes:**
Observing global changes in atmospheric abundance:

Ozone-depleting gases

- HCFC-22
- CFC-11
- CFC-12

Other ozone-depleting gases and substitute chemicals

- HCFC-141b
- HFC-134a
- CH$_3$CCl$_3$
Observing global changes in atmospheric abundance:

Ozone-depleting gases

Parts per billion (ppb)

Nitrous Oxide

Other ozone-depleting gases and substitute chemicals

Parts per trillion (ppt)

HCFC-22

CH₃CCl₃

HFC-134a

HCFC-141b

Parts per trillion (ppt)
Current and Past Activities in NOAA/ESRL Related to *Radiative Forcing of Non-CO$_2$ Greenhouse Gases*

**Observing global changes for non-CO$_2$ greenhouse gases:**
Global sampling networks, custom instrumentation, high-accuracy standardization air trapped in glacial snow

**Assessing the significance of observed global changes:**
Considering measured abundances and laboratory studies of chemical properties:
→ Quantifying radiative forcing changes over time (e.g., as the AGGI)

**Understanding the underlying causes of observed global changes:**
Assessing the Significance of the Observed Changes:

NOAA Annual Greenhouse Gas Index ~ \( \sum (\text{Abundance} \times \text{Radiative Efficiency}) \)

![Graph showing the annual greenhouse gas index with CO2, CH4, N2O, CFC12, CFC11, and 10 other minor gases over different years.]
Current and Past Activities in NOAA/ESRL Related to
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**Assessing the significance of observed global changes:**
Considering measured abundances and laboratory studies of chemical properties:
→ Quantifying radiative forcing changes over time (e.g., as the AGGI)
Considering global emissions inferred from observations:
→ Inferring global-scale, CO₂-equivalent emissions

**Understanding the underlying causes of observed global changes:**
Assessing the Significance of the Observations:

Deriving Global Emissions from observations (as CO₂-equivalent emissions)
(On the climate benefits of the Montreal Protocol on Substances that Deplete the Ozone Layer)

Carbon Dioxide

Ozone-Depleting Substances and Substitutes

Hydrofluorocarbons
Assessing the Significance of the Observations:

Deriving Global Emissions from observations (as CO₂-equivalent emissions)
(On the climate benefits of the Montreal Protocol on Substances that Deplete the Ozone Layer)

- Not included: CH₄, N₂O, PFCs…

Expected Kyoto Protocol Benefit

Carbon Dioxide

Ozone-Depleting Substances and Substitutes

Hydrofluorocarbons
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Considering measured abundances and laboratory studies of chemical properties:
→ Quantifying radiative forcing changes over time (e.g., as the AGGI)
Considering global emissions inferred from observations:
→ Inferring global-scale, CO$_2$-equivalent emissions

** Understanding the underlying causes of observed global changes:**
*Related to sinks:*
  Abundance and variability in the atmospheric hydroxyl radical (OH)
  (OH ties together many issues related to non-CO$_2$ GHGs)
Inferring OH abundance and variability from trace gas observations:

\[
\text{Rate of change} = \text{Emissions} - \text{Loss(OH, k)}
\]

in methyl chloroform
Inferring OH abundance and variability from trace gas observations:

Rate of change = Emissions – Loss(OH, k) in methyl chloroform

Rapid declines in MC emissions allow more direct insights into OH abundance and variability!

* Global OH abundance ≈ 1.1 × 10^6 radicals/cm³

* Interannual OH variability of ± 2% (related to CO/burning?) → Suggests OH is buffered against large changes

See poster later on…
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Considering measured abundances and laboratory studies of chemical properties:
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** Understanding the underlying causes of observed global changes:**
Related to sinks:
   Abundance and variability in the atmospheric hydroxyl radical (OH)
   (OH ties together many issues related to non-CO₂ GHGs)
Related to ecosystem processes and regional sources:
   Quantifying the role of other processes (ocean, land, biosphere, regions)

Working on for the future:
   Quantifying Regional/National emissions—applying Carbon Tracker
to other gases and for verification of Kyoto Protocol targets…
Current and Past Activities in NOAA/ESRL Related to Radiative Forcing of Non-CO₂ Greenhouse Gases

** Observing global changes for non-CO₂ greenhouse gases:

** Assessing the significance of observed global changes:

** Understanding the underlying causes of observed global changes: