# Radiative Forcing of Climate by Non-$CO_2$ Atmospheric Gases

ESRL Research Theme Presentation
6 September 2007

Future Forcing Agents

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# General Overview

From a climatic standpoint, is it better to emit gas X or Y?

i. Describe framework for answering this question.

ii. Discuss a collaborative effort to measure and model the components of this framework.

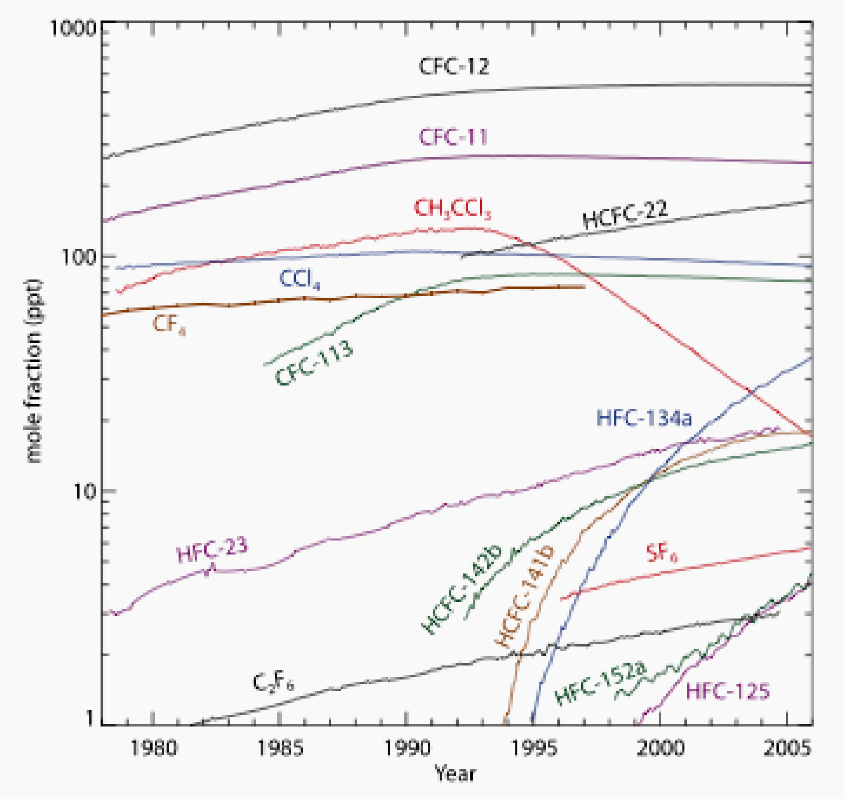
Climatic impact is controlled by:

i. How strongly the gas affects the radiative balance at the tropopause.
*Radiative Efficiency*

ii. How long the molecule persist in the atmosphere.
*Lifetime*

# History

- CFCs regulated by the Montreal Protocol to reduce ozone loss
- The CFCs are greenhouse gases but so are the replacements




IPCC-2007, Fig 2.6, NOAA/GMD & AGAGE measurements

<u>Refrigerants</u>

| <u>CFC-12</u> | → | <u>HCFC-22</u> | → | <u>HFC-134a</u> |
|---|---|---|---|---|
| RE=0.32 | | RE=0.20 | | RE=0.16 |
| $\tau$=100 years | | $\tau$=12 years | | $\tau$=14 years |

Radiative Efficiency (RE)
Absorption Spectrum (IR)
Radiative Transfer Model

Lifetime (τ) of Gas X
Reaction Rates
Absorption Spectrum (UV)
Chemical Model (maybe)

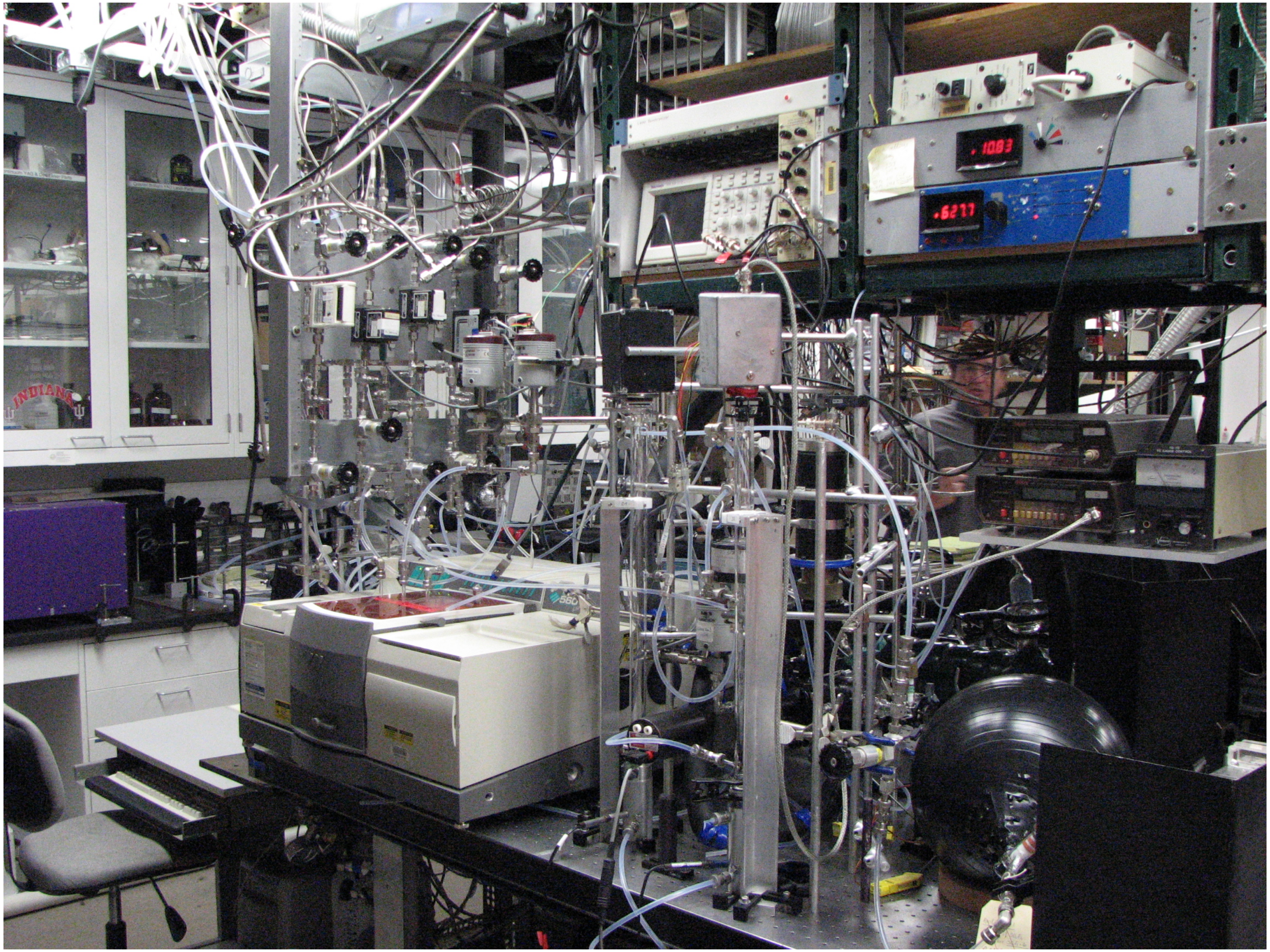
$$GWP_X(T) = \frac{\int_0^T RF_X(t)\,dt}{\int_0^T RF_{CO2}(t)\,dt} = \frac{RE_X \tau \left[1 - e^{-\frac{T}{\tau}}\right]}{Int\ RF_{CO2}(T)}$$

GWP of Gas X
for time horizon T

Integrated RF of CO2
Assessed in IPCC

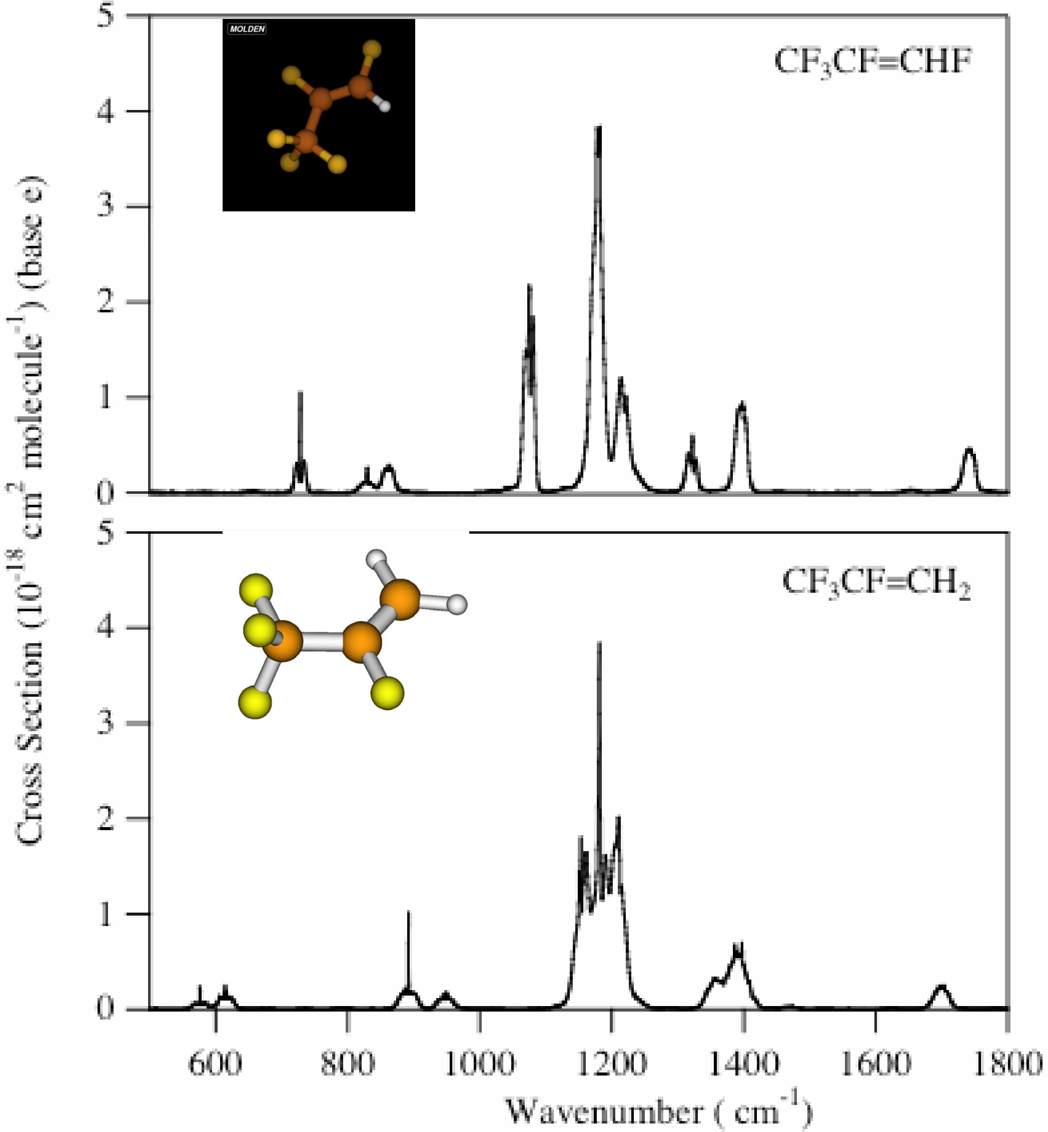
# Laboratory Measurements

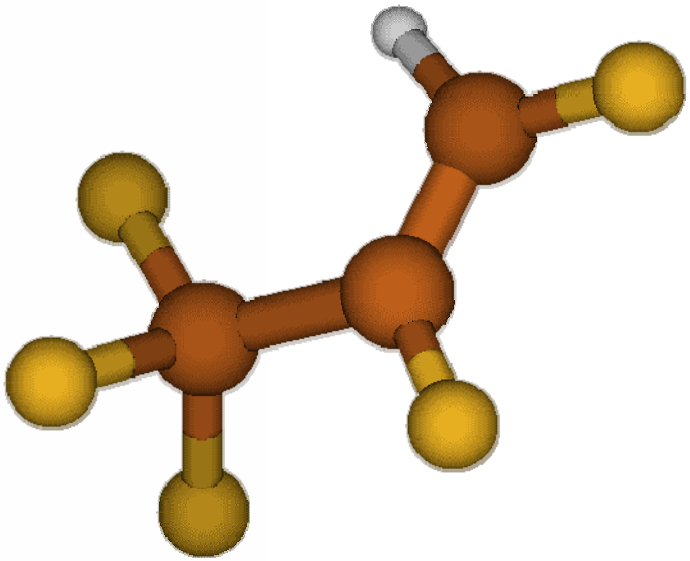
ESRL/CSD/ACP Group: Ravishankara, Jim Burkholder, Ranajit Talukdar, Vassilis Papadimitriou + others



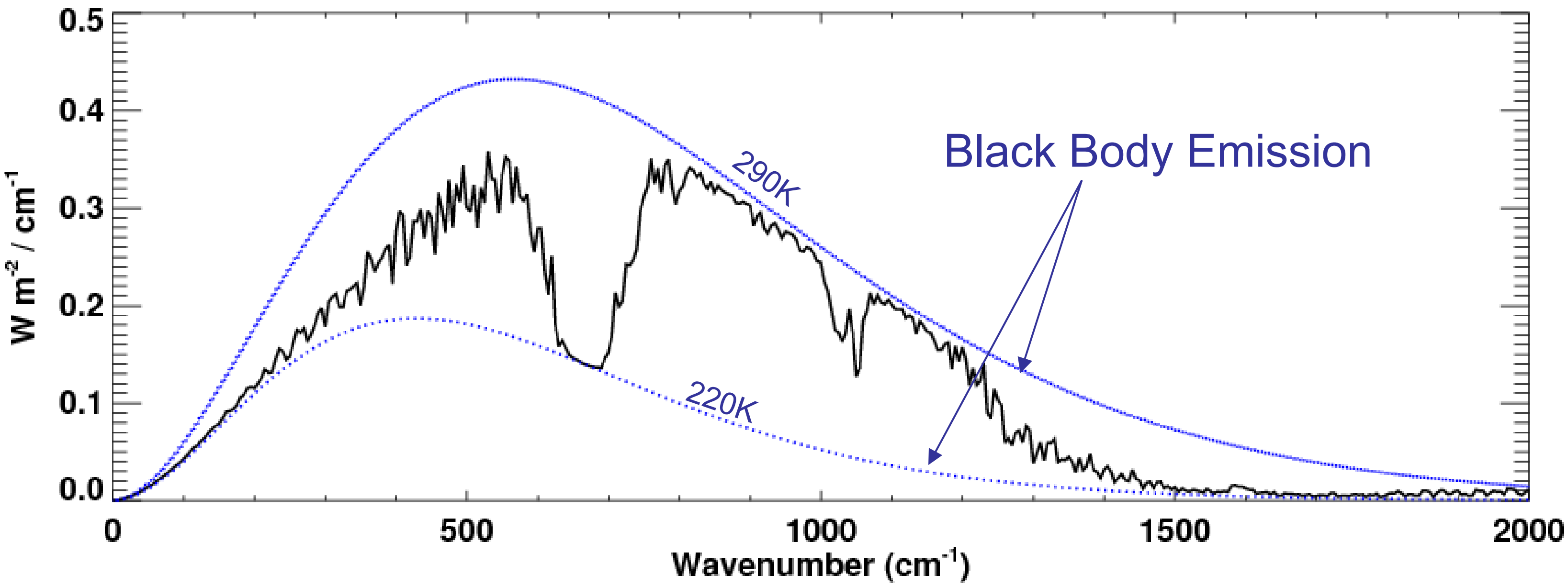
# Infrared absorption spectra

C-F Stretch will make largest contribution to Radiative Efficiency



# Outgoing Infrared Flux at Tropopause



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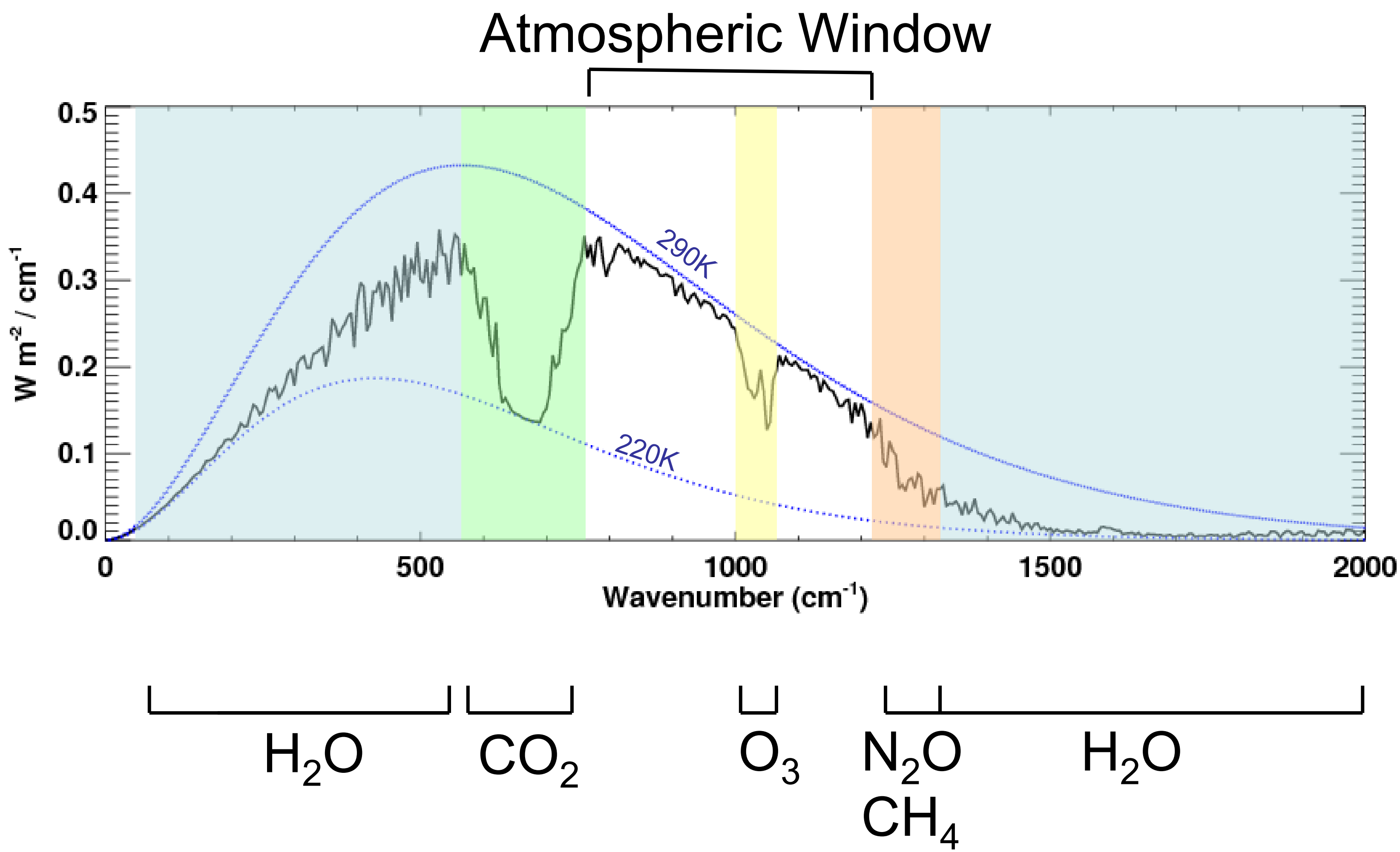

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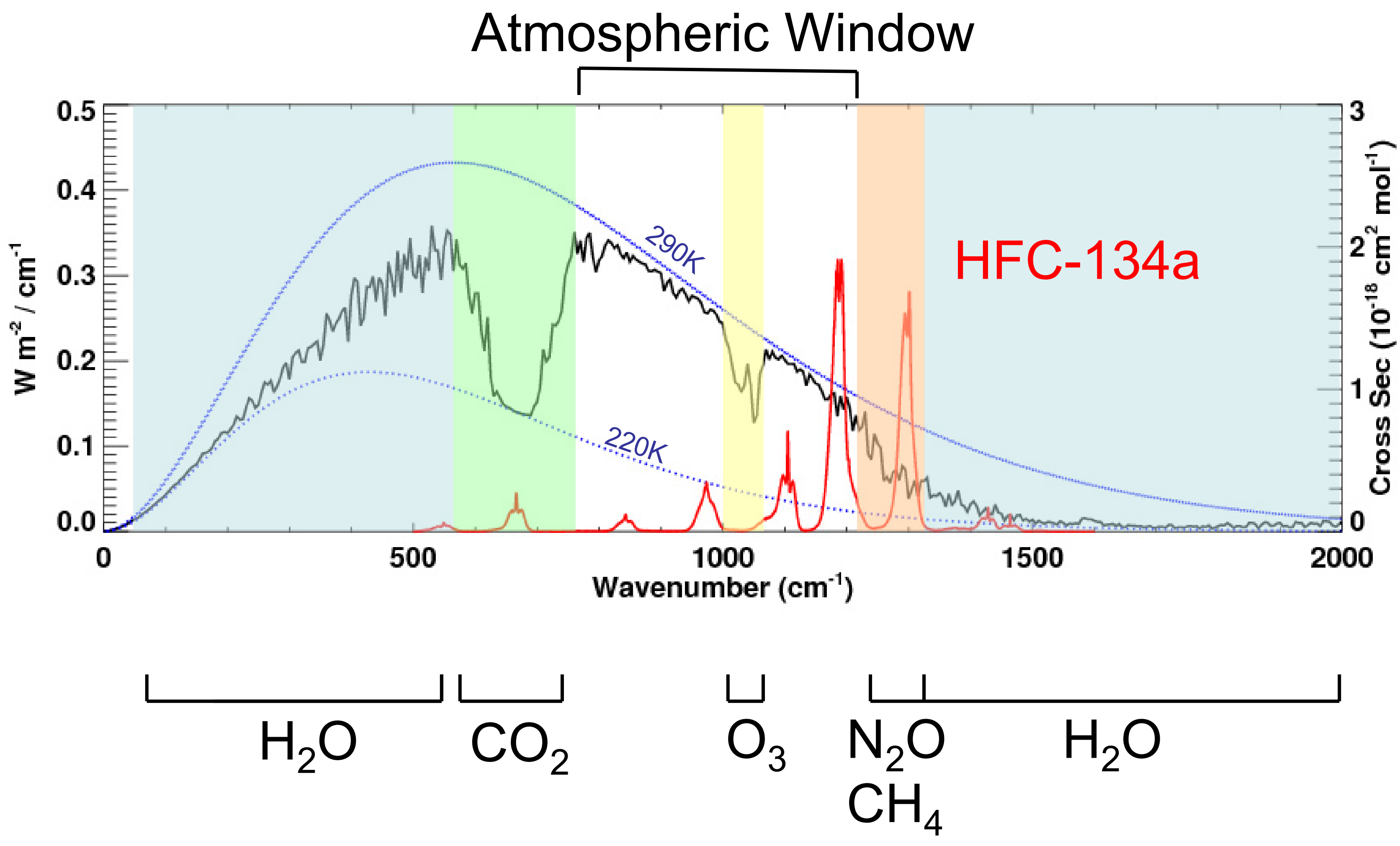
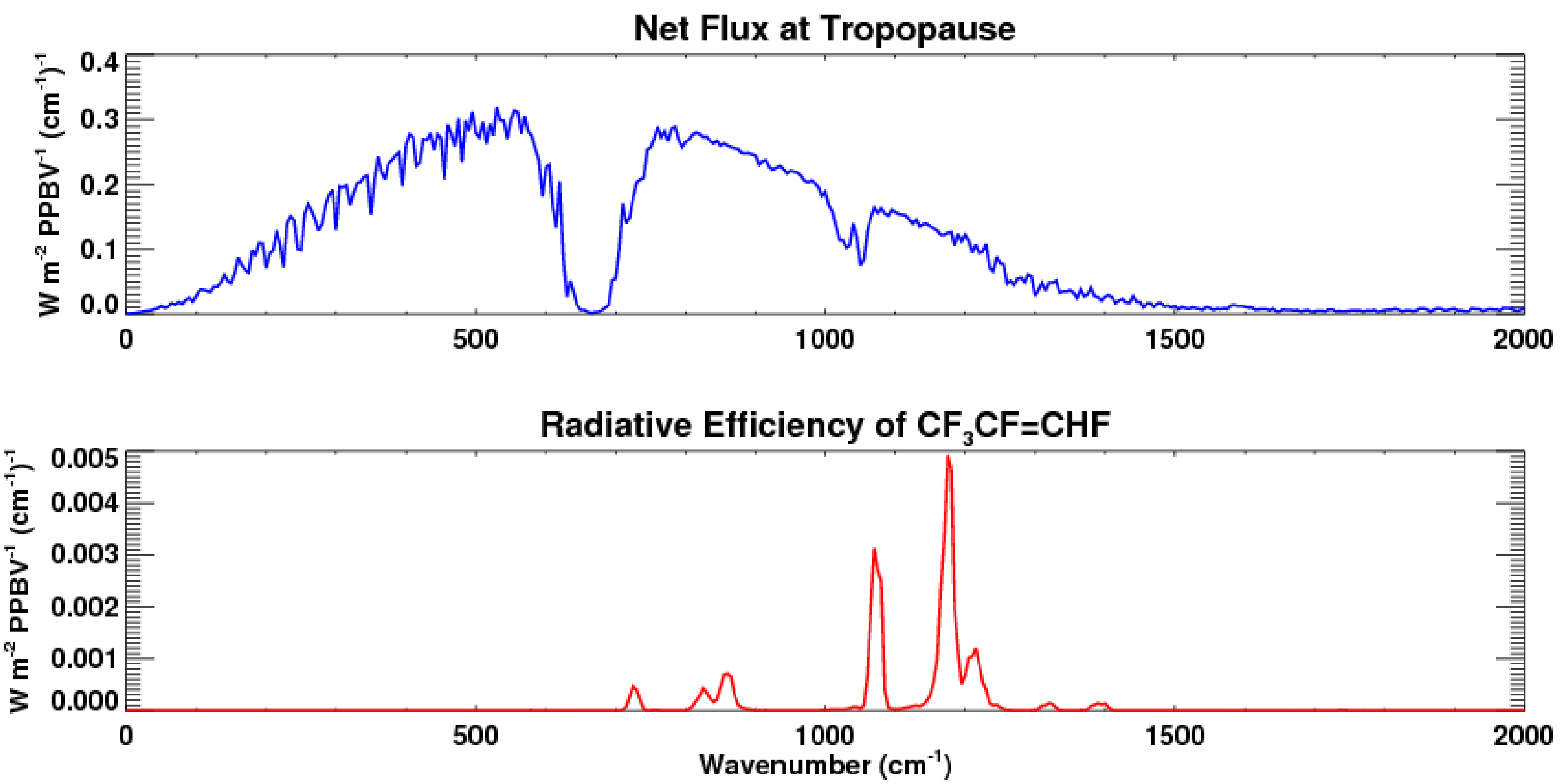


# Radiative Efficiency Calculation

Radiative Forcing: change in flux at tropopause after stratospheric temperatures adjust

Line-by-line Radiative Transfer Model



# Lifetime Determination

**Loss in the Troposphere**

1. Reactive
   especially w/ OH
2. Rain out
3. Deposition

**Loss in the Stratosphere**

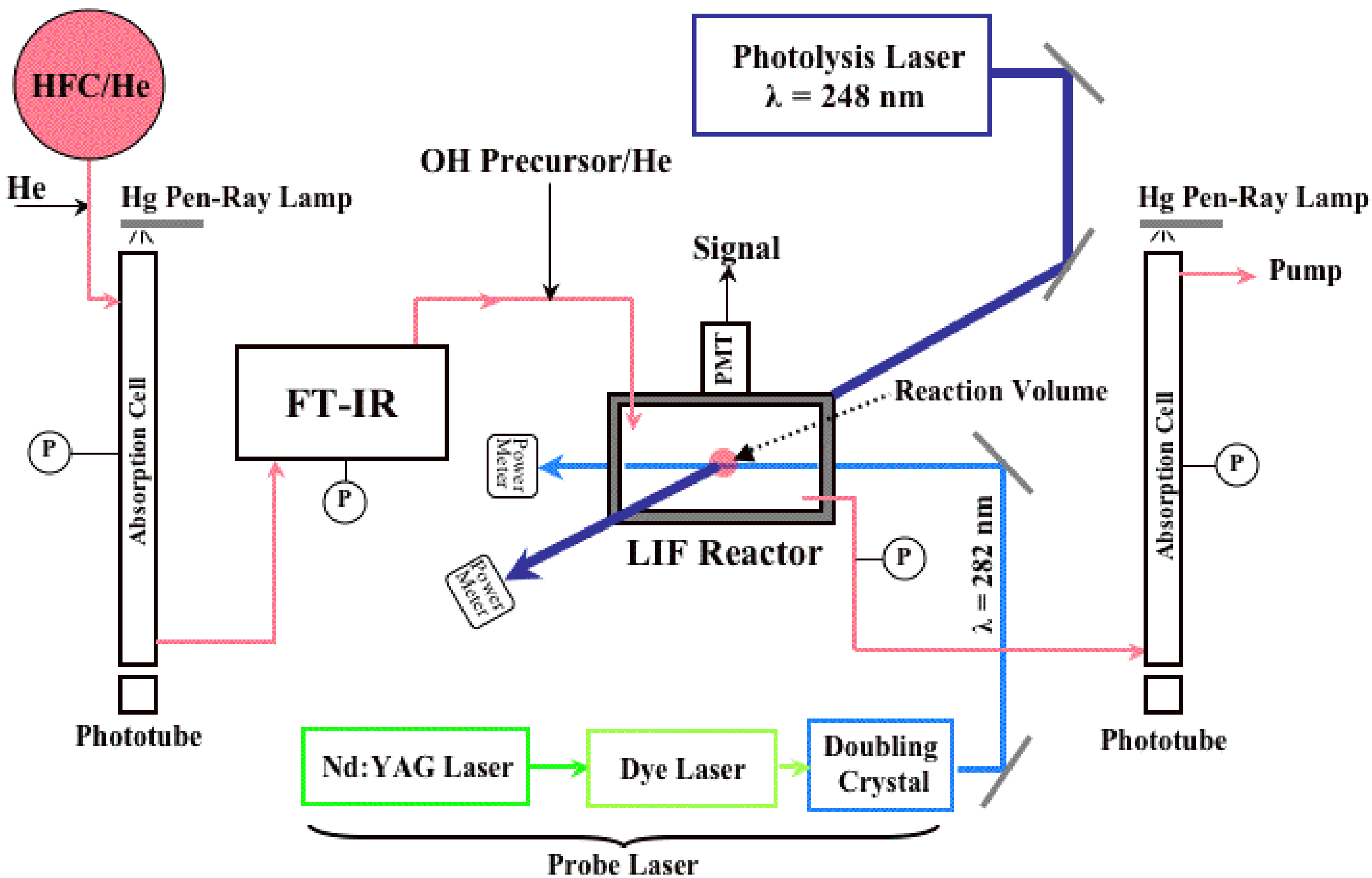
1. Reactive
   OH, Cl, $O(^1D)$
2. Photolysis (UV)

Global Average OH estimates (Montzka)

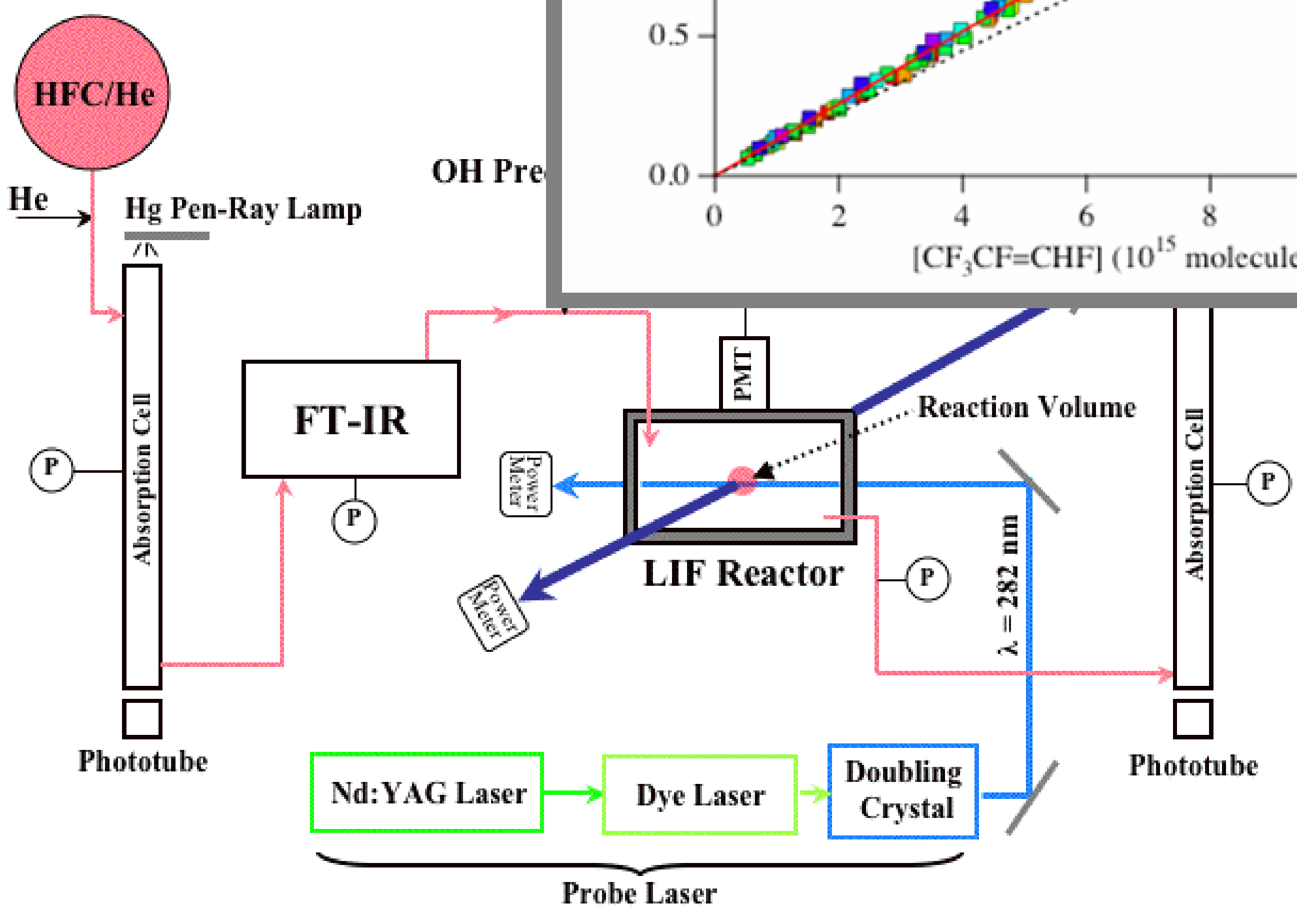
Stratospheric Chemical Model
Guaranteed long lifetime

$$\frac{1}{\tau} = \frac{1}{\tau_{Trop}} + \frac{1}{\tau_{Strat}}$$

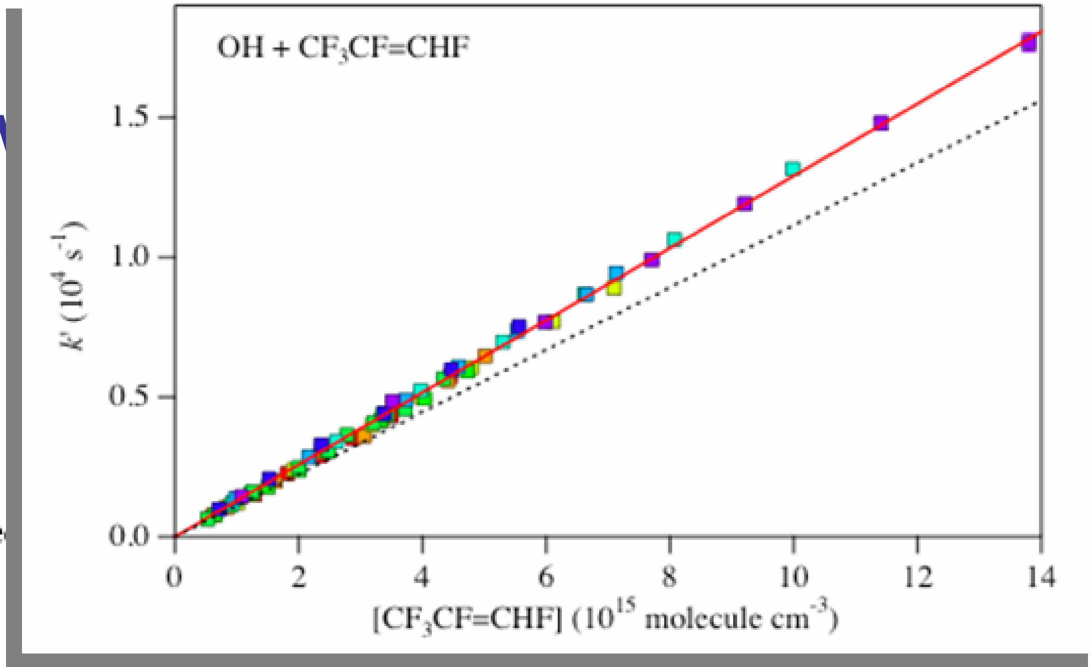
# Flow Reactor



# Flo



HFC/He
He
Hg Pen-Ray Lamp
OH Pre
Absorption Cell
P
FT-IR
P
Power Meter
Power Meter
PMT
Reaction Volume
LIF Reactor
P
λ = 282 nm
Absorption Cell
P
Phototube
Phototube
Nd:YAG Laser
Dye Laser
Doubling Crystal
Probe Laser

OH + CF3CF=CHF
k' (10^4 s^-1)
0.0
0.5
1.0
1.5
0
2
4
6
8
10
12
14
[CF3CF=CHF] (10^15 molecule cm^-3)

# Examples of Future Forcing Agents being evaluated at NOAA/ESRL

| | |
|---|---|
| $SO_2F_2$ | Fumigant; Replacement for $CH_3Br$; Lifetime uncertain |
| $CF_3CF{=}CH_2$<br>$CF_3CF{=}CFH$ | Refrigerant; Mobile air conditioning<br>Replacement for HFC-134a ($CF_3CFH_2$) |

<u>CFC-12</u>
RE=0.32
$\tau$=100 years
Stratospheric Photolysis
GWP=11,000

→

<u>HFC-134a</u>
RE=0.16
$\tau$=14 years
Reaction w/ OH (slow)
GWP=4,470

→

<u>CF3CF=CFH</u>
RE=0.26
$\tau$=10 days
Reaction w/ OH (fast)
GWP=4

**Finding chemicals with short lifetimes is key.**

# Future

Life Cycle Assessment (LCA)

“Evaluation of the environmental impact of a compound over its life span, from production to end-of-life”

Including:

- Global Warming Potential (GWP)
- Ozone Depletion Potential (ODP)
- Photochemical Ozone Creation Potential (POCP)
- Atmospheric Degradation Products
- Containment
- Energy Efficiency