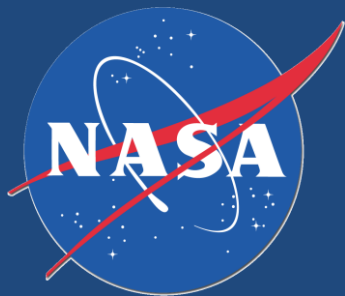


Early Action on HFCs Mitigates Future Atmospheric Change

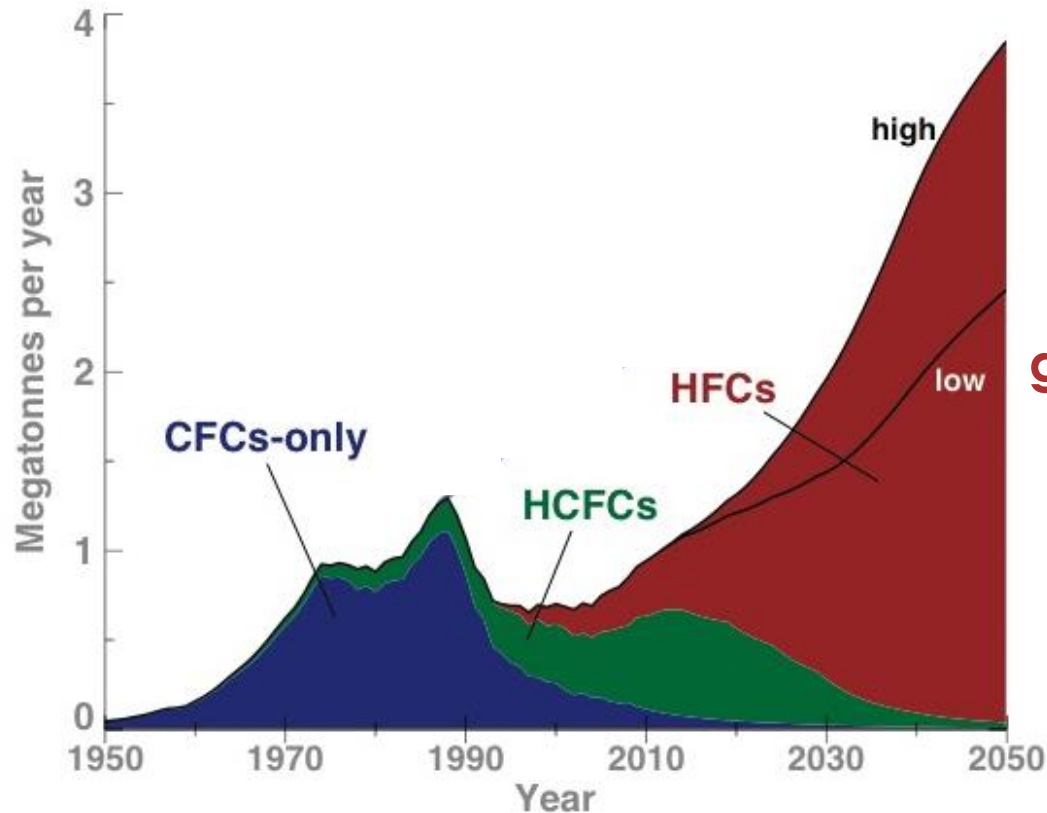
Margaret M. Hurwitz^{1,2}, Eric. L. Fleming^{1,2},
Paul A. Newman¹, Feng Li^{1,3} and Qing Liang^{1,3}



1 NASA Goddard Space Flight Center, USA
2Science Systems and Applications, Inc., USA
3GESTAR, Universities Space Research Association, USA

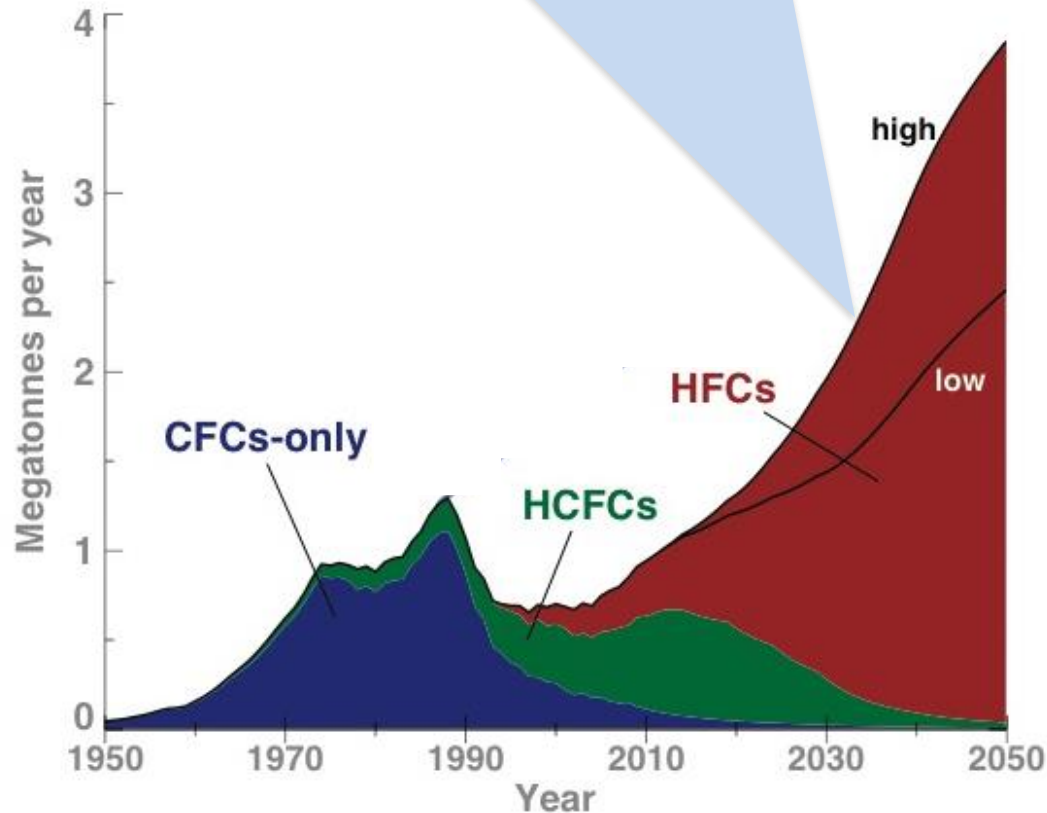
HFCs Replace the CFCs and HCFCs

- Second-generation replacements for the CFCs and HCFCs, the ozone-depleting substances that caused the 'ozone hole'
- Strong radiative forcers (GWPs of 1,000-10,000)
- Long-lived (atmospheric lifetimes ~20 years)



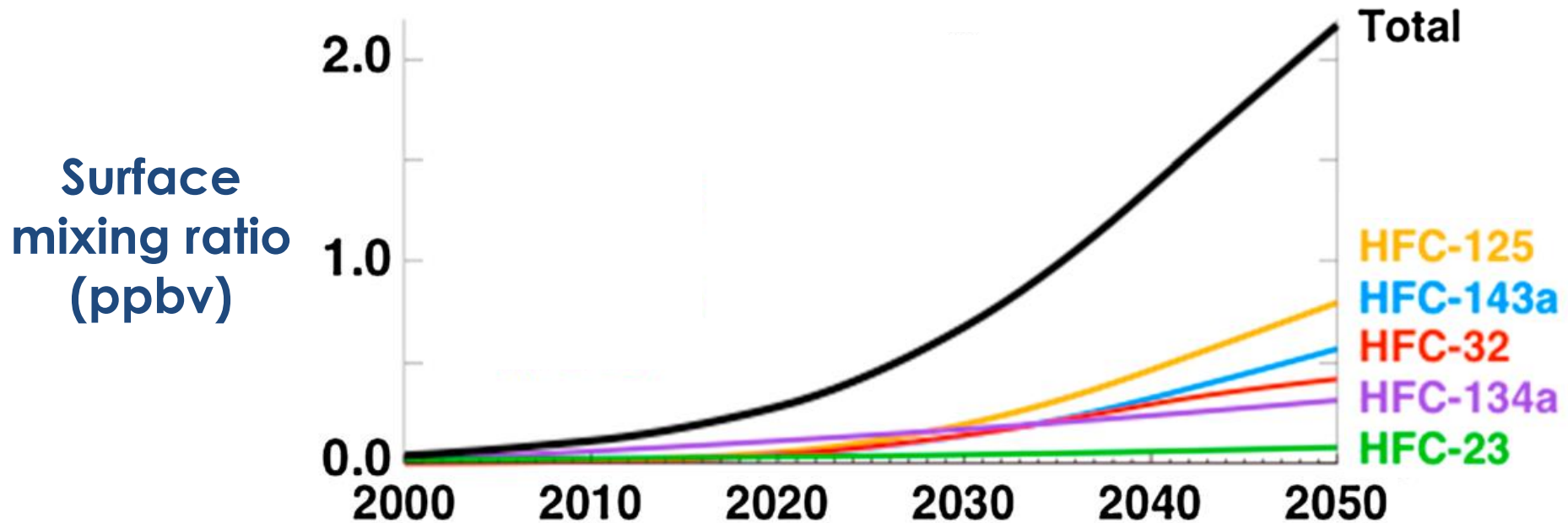
HFC projected growth after 2009

What might the climate and ozone impacts of HFCs be by 2050?

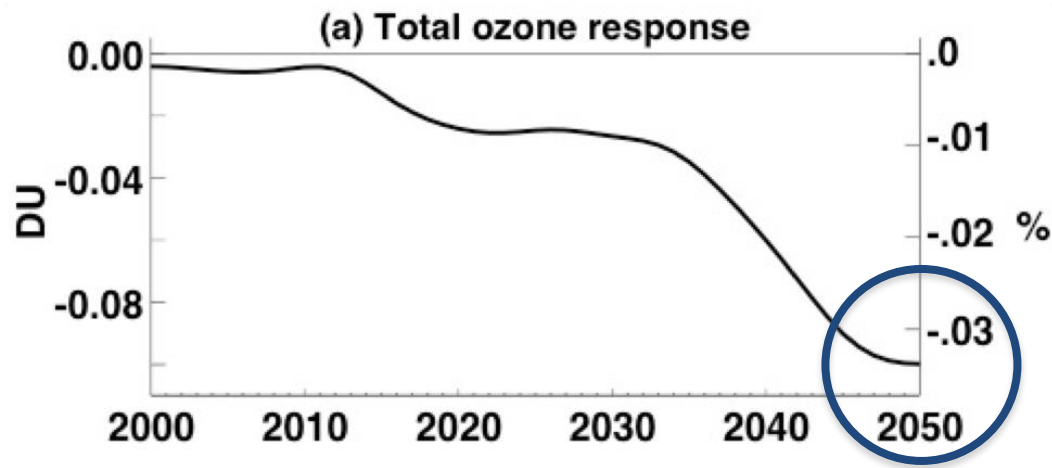


HFCs Effects Simulated with an Atmospheric CCM

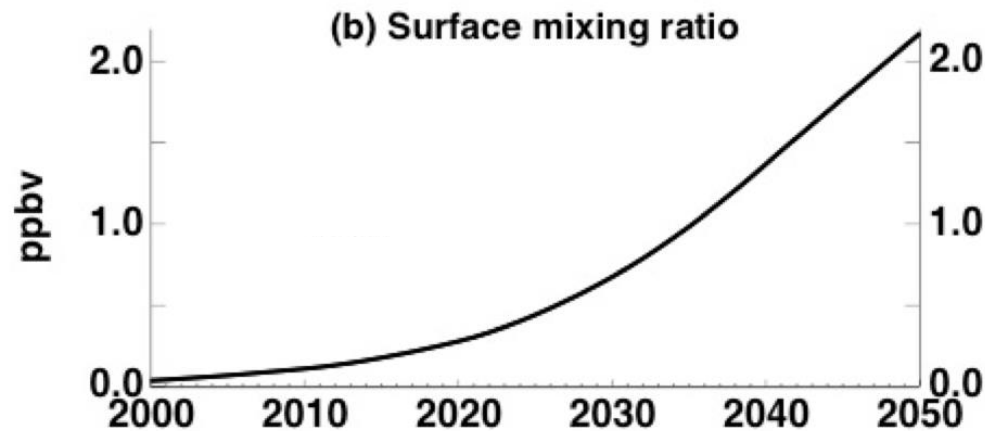
- 2000-2050 simulations with an atmospheric chemistry-climate model (NASA GSFC 2D model, Fleming et al., 2011)
- Includes effects of HFCs on atmospheric temperature, circulation and stratospheric chemistry



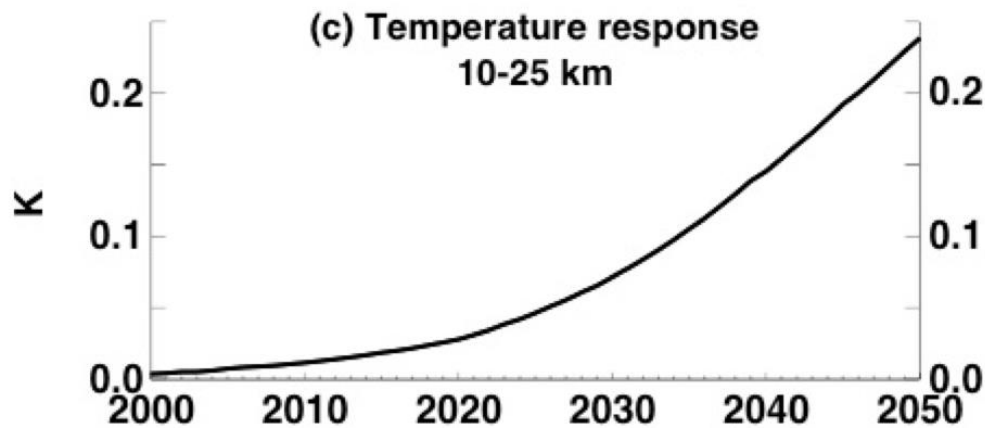
High scenario, Velders et al. (2009) &
Business-as-usual scenario, Miller and Kuijpers (2011)



**HFCs cause a weak,
net ozone depletion**

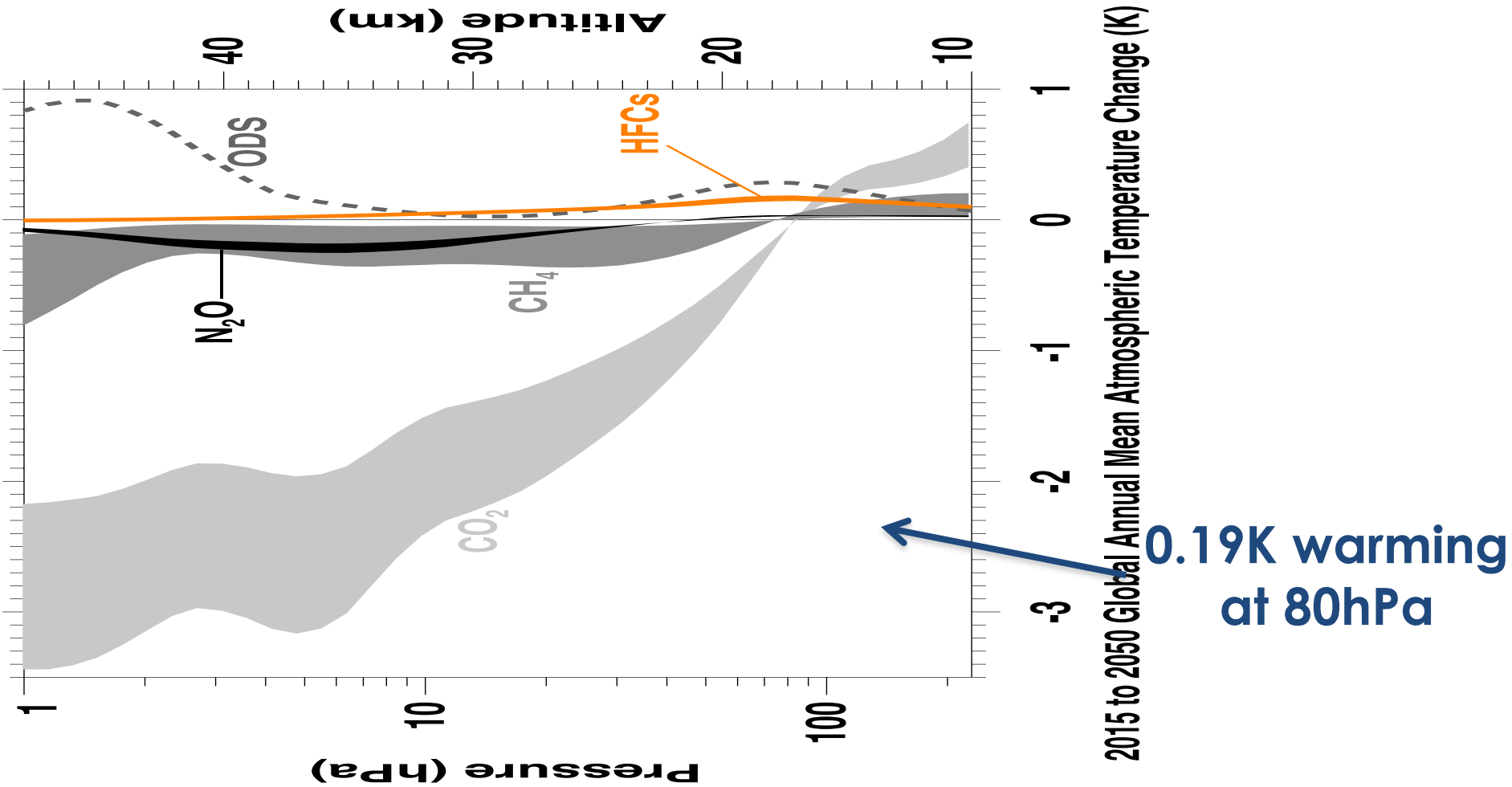


**as atmospheric
concentrations
increase**

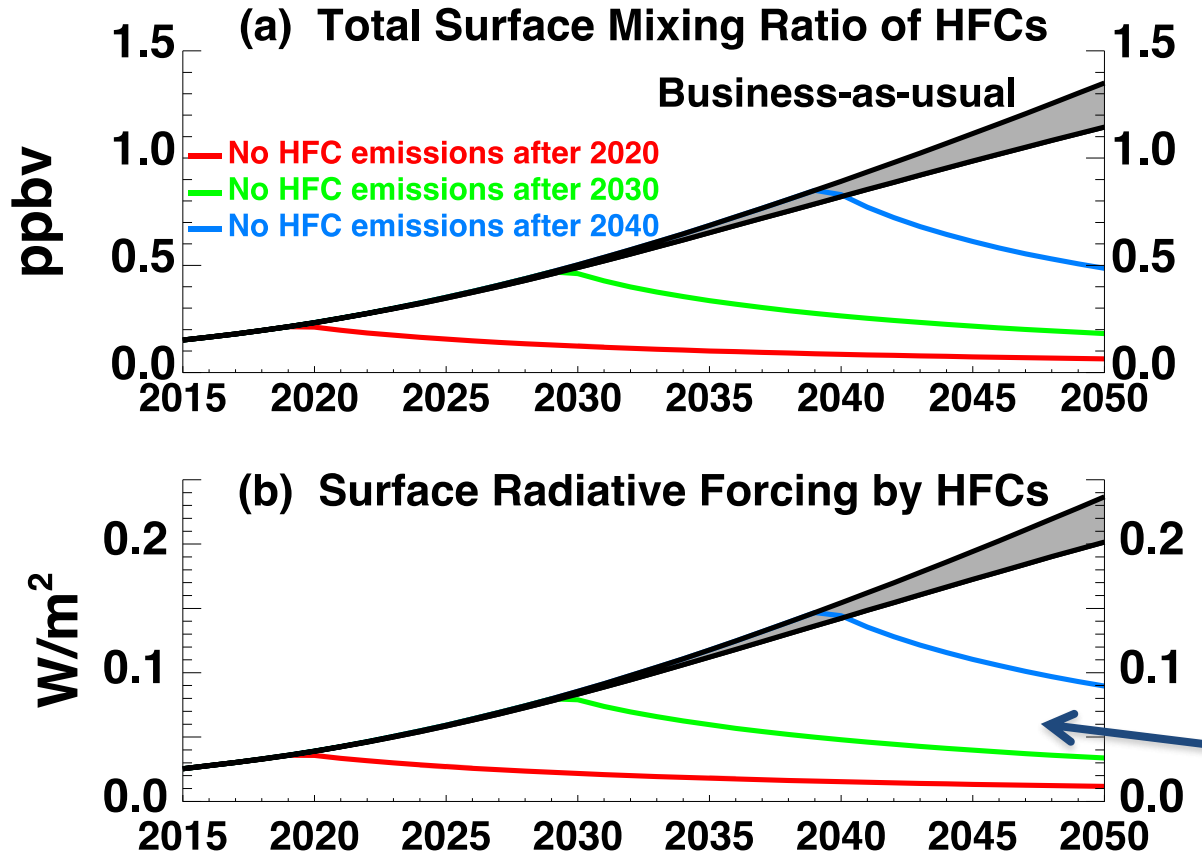


**and upper tropospheric
and stratospheric
temperatures increase**

HFCs Contribute to 2050 Atmospheric Change



Mitigation Scenarios Reduce Future HFC Emissions

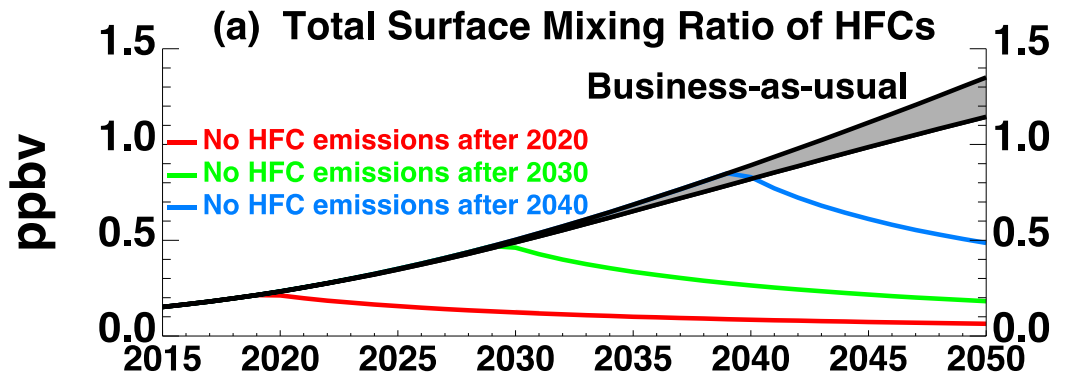


47% of emissions avoided
77% of emissions avoided
95% of emissions avoided

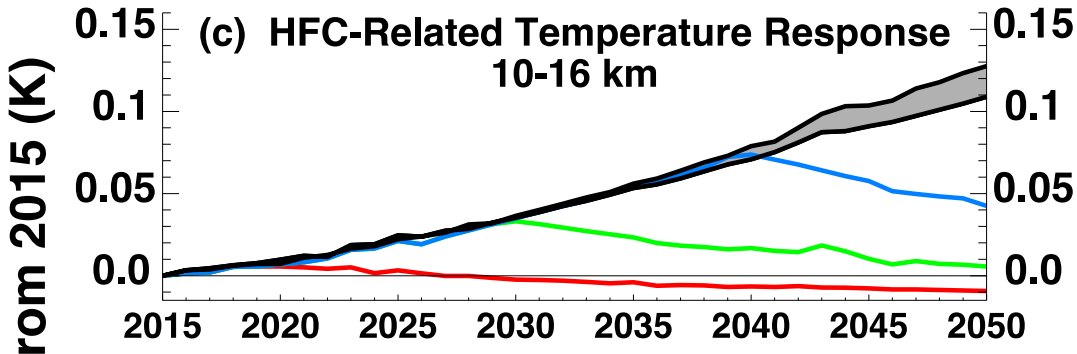
Equivalent reductions in surface radiative forcing

SSP3 and SSP5 scenarios, Velders et al. (2015) & Business-as-usual scenario, Miller and Kuijpers (2011)

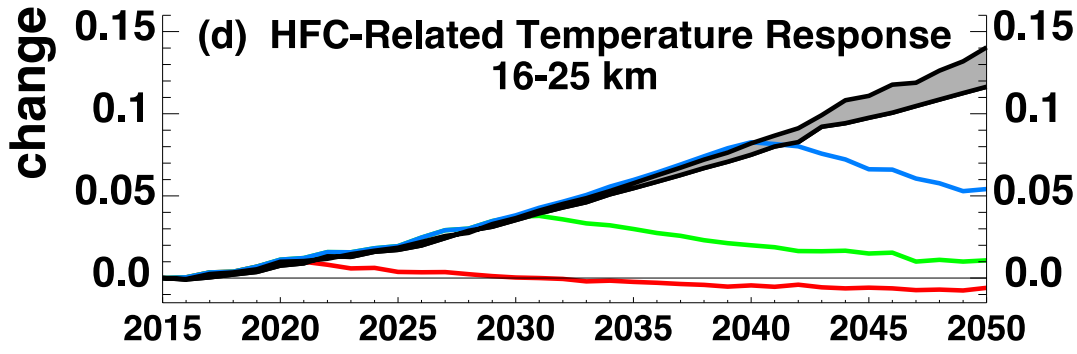
Mitigation Scenarios Reduce Future HFC Impacts



If all HFC emissions were to stop by 2040...
47% of HFC emissions avoided

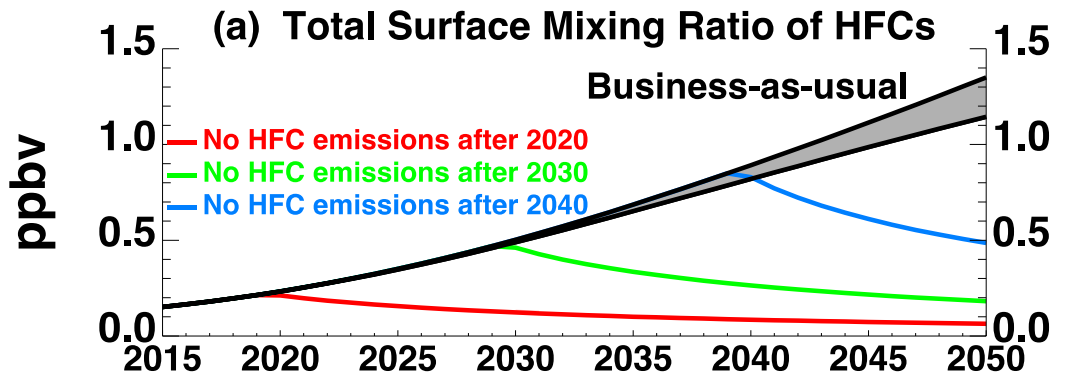


~1/3 of upper tropospheric warming avoided



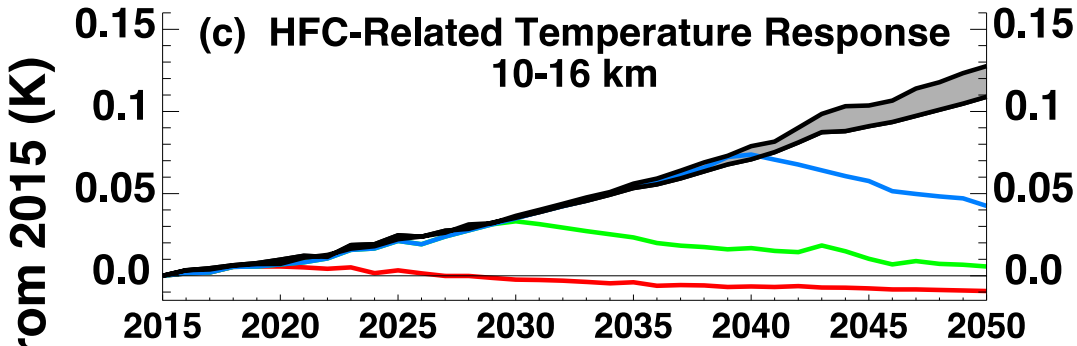
~1/3 of lower stratospheric warming avoided

Mitigation Scenarios Reduce Future HFC Impacts

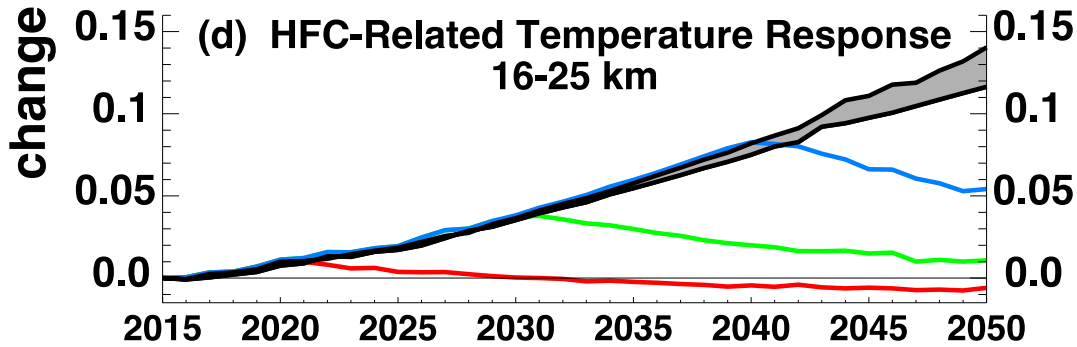


If all HFC emissions were to stop by 2030...

77% of HFC emissions avoided

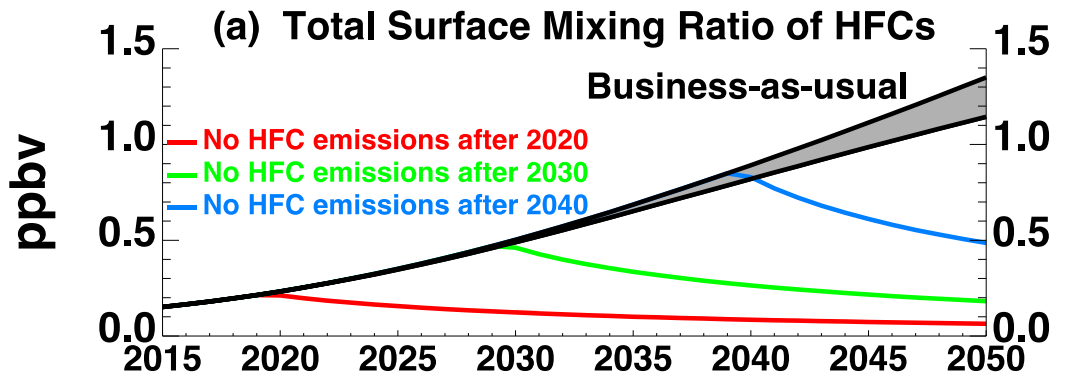


>90% of upper tropospheric warming avoided



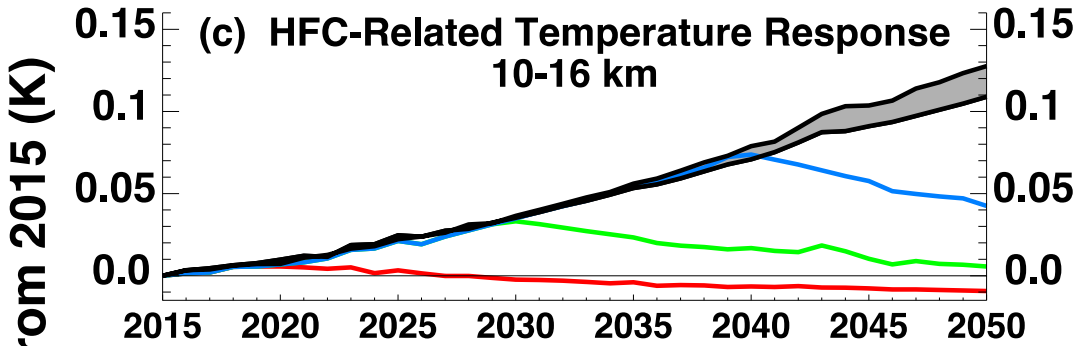
>90% of lower stratospheric warming avoided

Mitigation Scenarios Reduce Future HFC Impacts

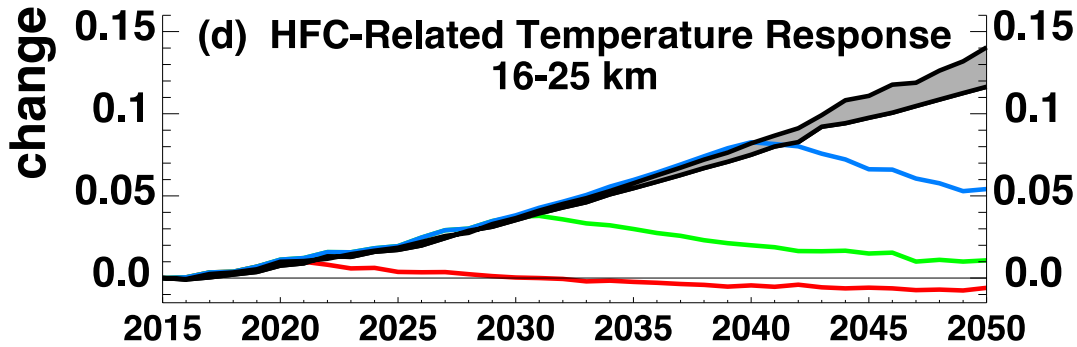


If all HFC emissions were to stop by 2020...

95% of HFC emissions avoided



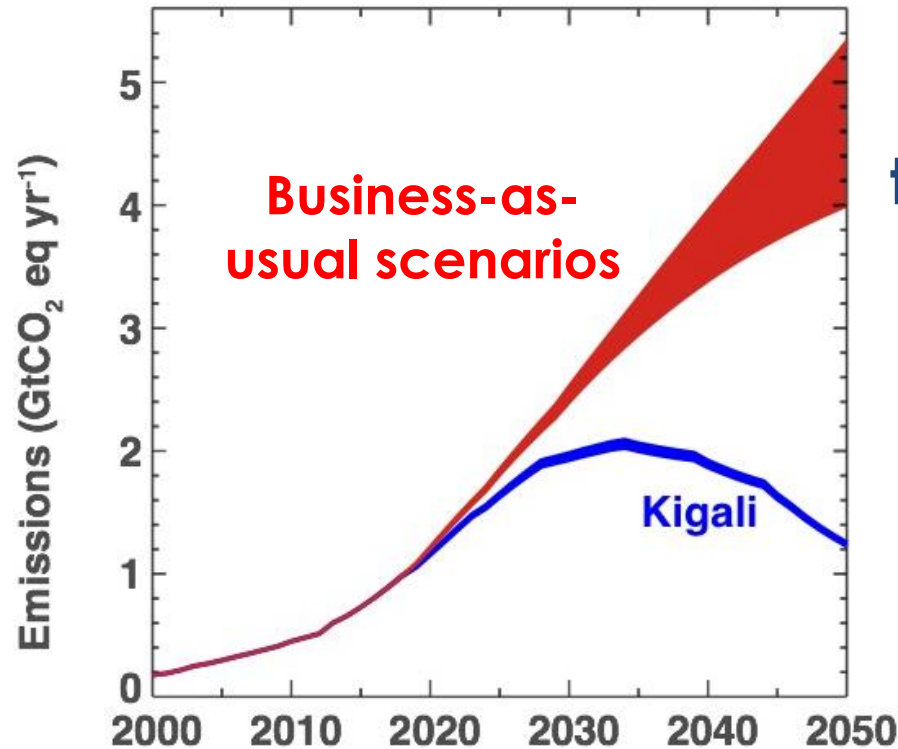
>99% of upper tropospheric warming avoided



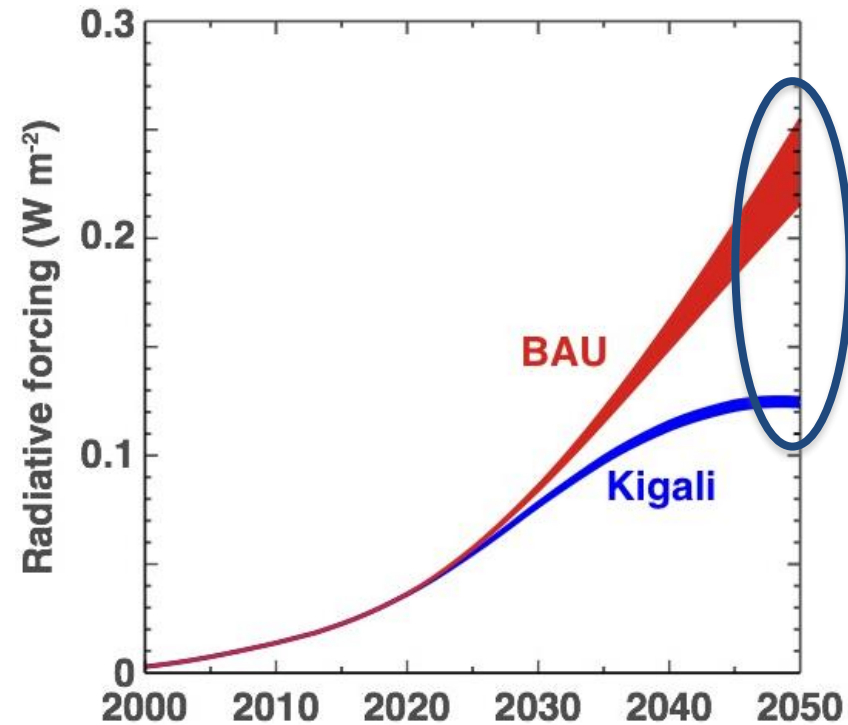
>99% of lower stratospheric warming avoided

Kigali Amendment Reduces HFC Radiative Forcing

Kigali Amendment added to the Montreal Protocol in October 2016



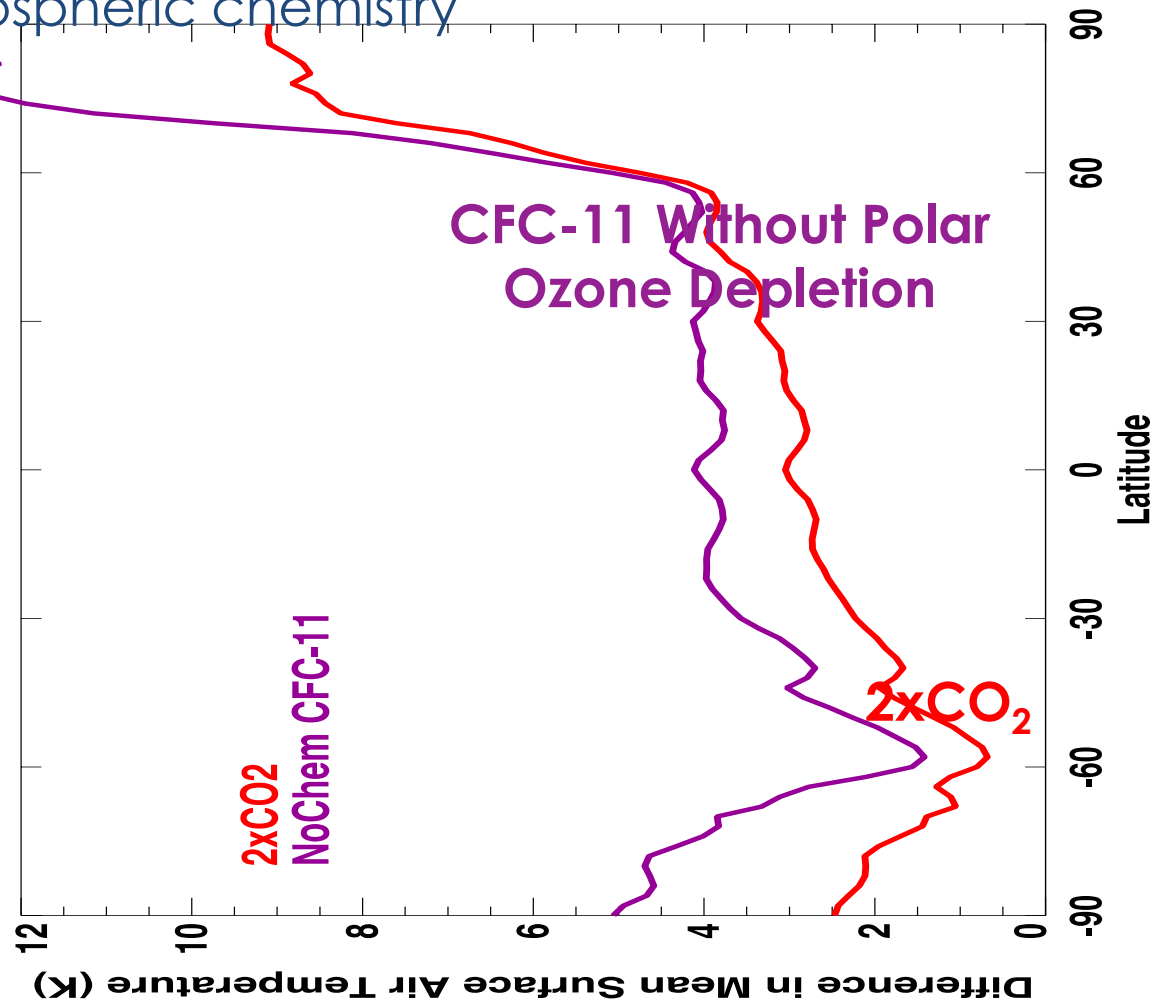
~50% reduction in HFC radiative forcing in 2050



HFC Proxy Suggests Response Similar to CO₂

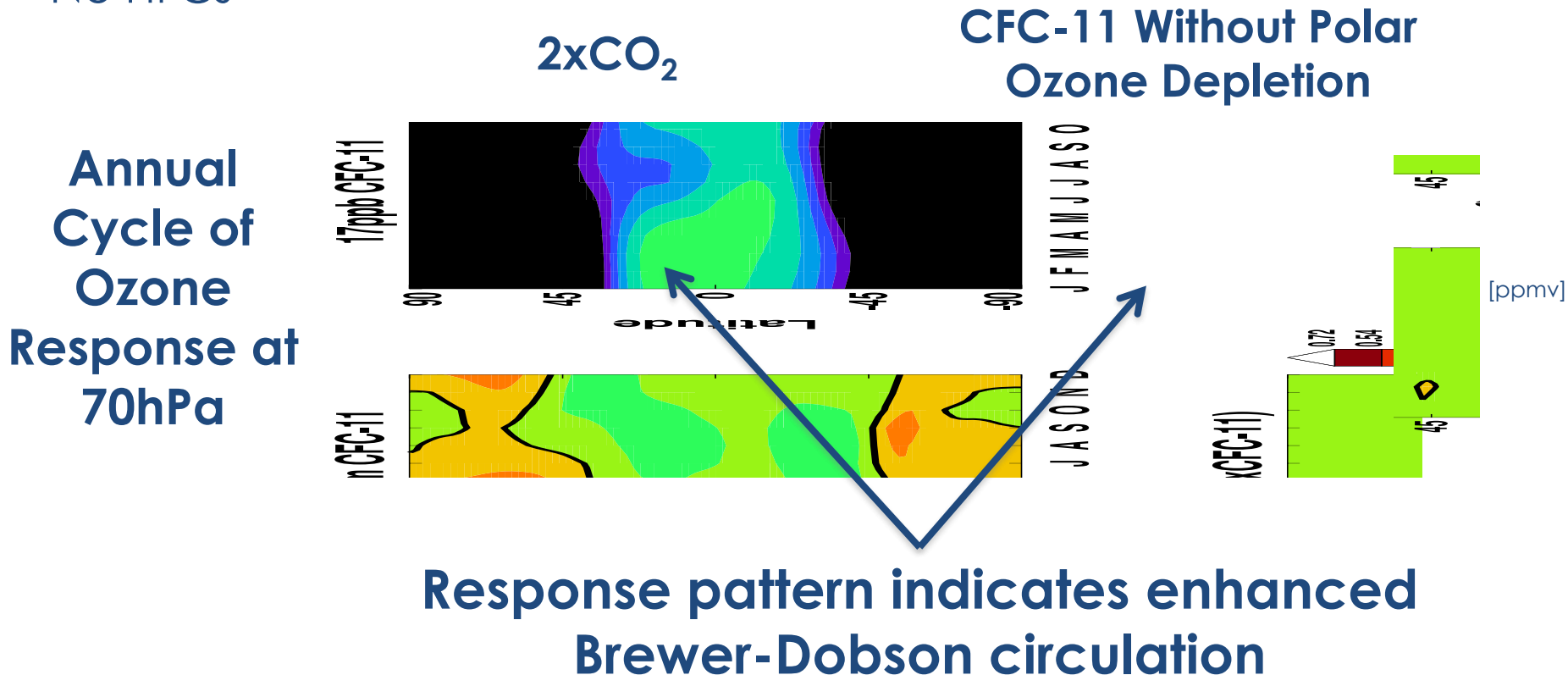
- Sensitivity simulations with the ocean-atmosphere GEOS chemistry-climate model (updated from Li et al., 2016)
- Interactive stratospheric chemistry
- No HFCs

**Annual
Mean
Surface
Warming**

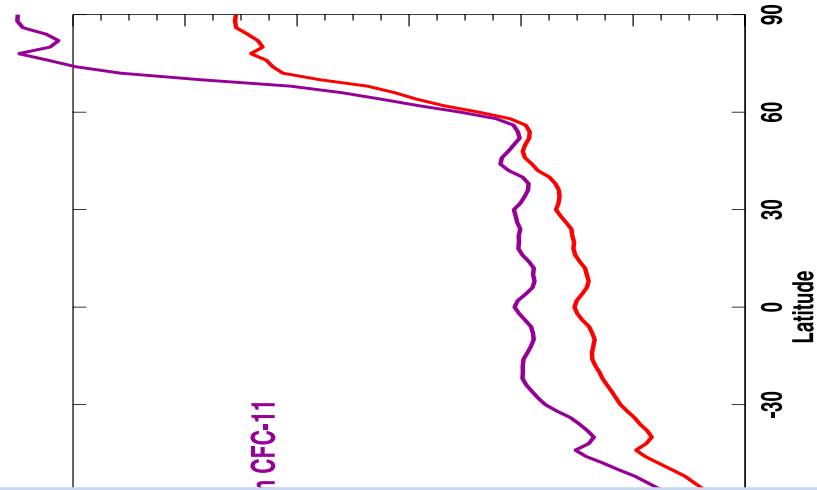
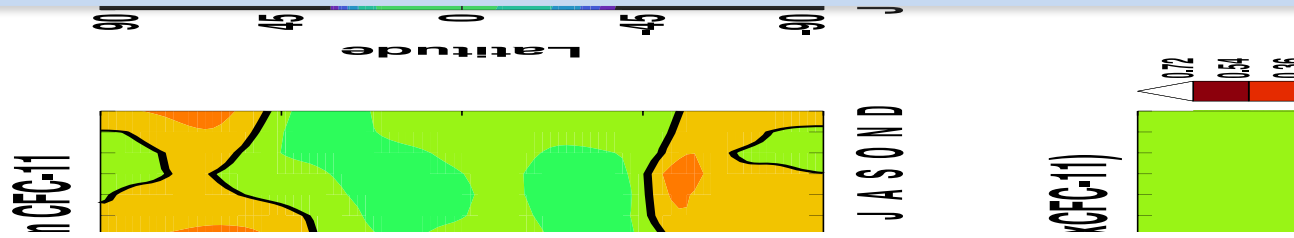


HFC Proxy Suggests Response Similar to CO₂

- Sensitivity simulations with the ocean-atmosphere GEOS chemistry-climate model (updated from Li et al., 2016)
- Interactive stratospheric chemistry
- No HFCs



GEOSCCM simulations with fully coupled HFCs are in progress ...



Summary

- HFCs could contribute substantially to anthropogenic climate change by the mid-21st century, particularly in the upper troposphere and lower stratosphere
- HFC mitigation scenarios demonstrate the benefits of taking early action in avoiding future atmospheric change
 - More than 90% of the climate change impacts of HFCs can be avoided if emissions stop by 2030

Hurwitz, M. M., E. L. Fleming, P. A. Newman, F. Li, and Q. Liang (2016). Early action on HFCs mitigates future atmospheric change. Environmental Research Letters, 11, 114019, doi:10.1088/1748-9326/11/11/114019.