The Climate Impacts of Hydrofluorocarbons (HFCs): From the Earth's Surface to the Middle Atmosphere

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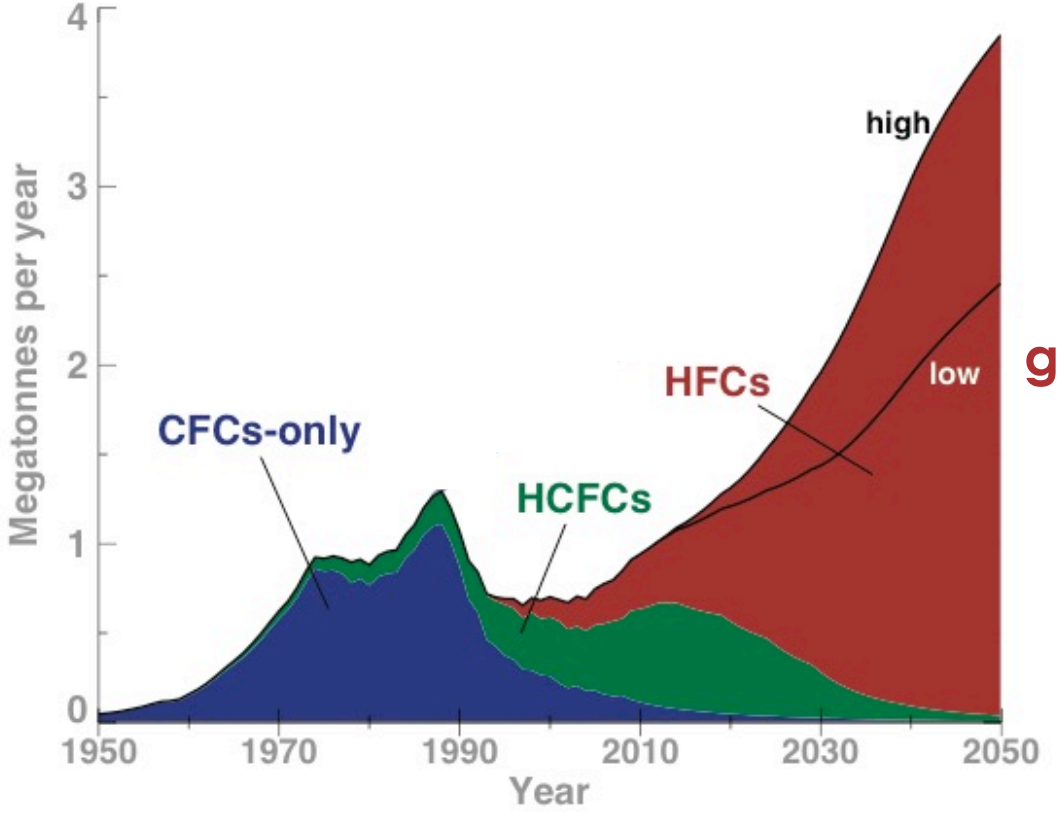
HFCs Replace the CFCs and HCFCs

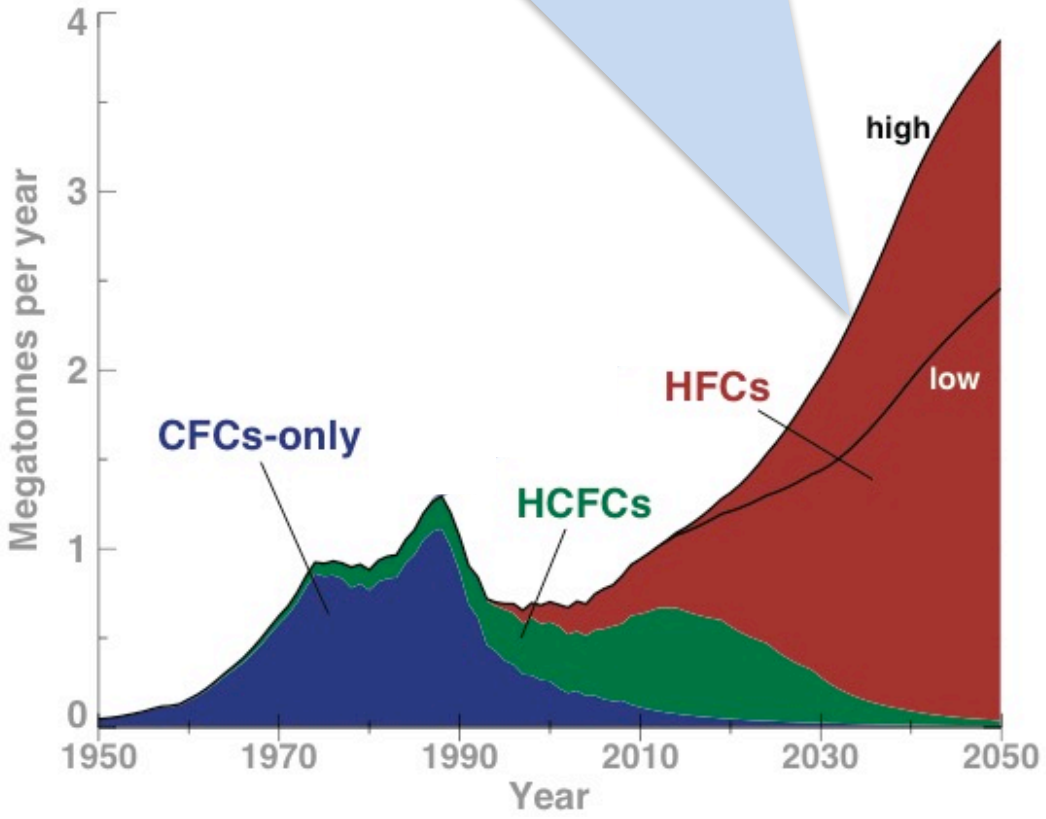
- Second-generation replacements for the CFCs and HCFCs, the ozone-depleting substances that caused the 'ozone hole'
- Strong radiative forcers (GWPs of 1,000-10,000)
- Long-lived (atmospheric lifetimes ~20 years)



HFC projected growth after 2009

WMO Scientific Assessment of Ozone Depletion, 2010

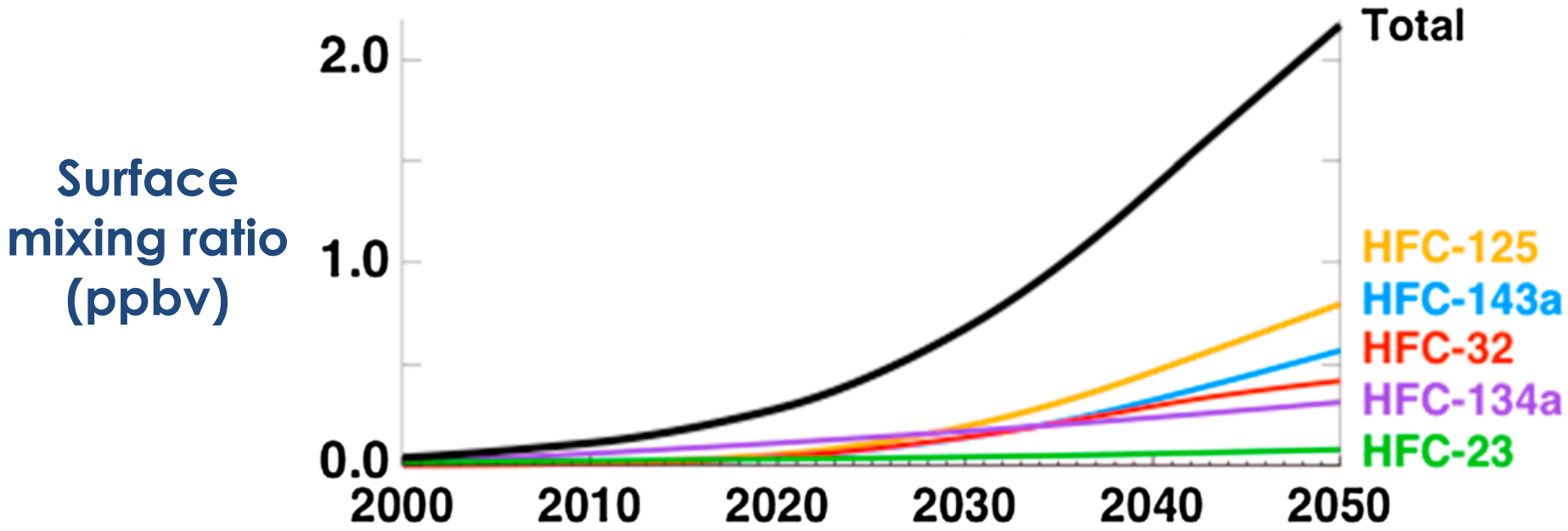
What might the climate and ozone impacts of HFCs be by 2050?



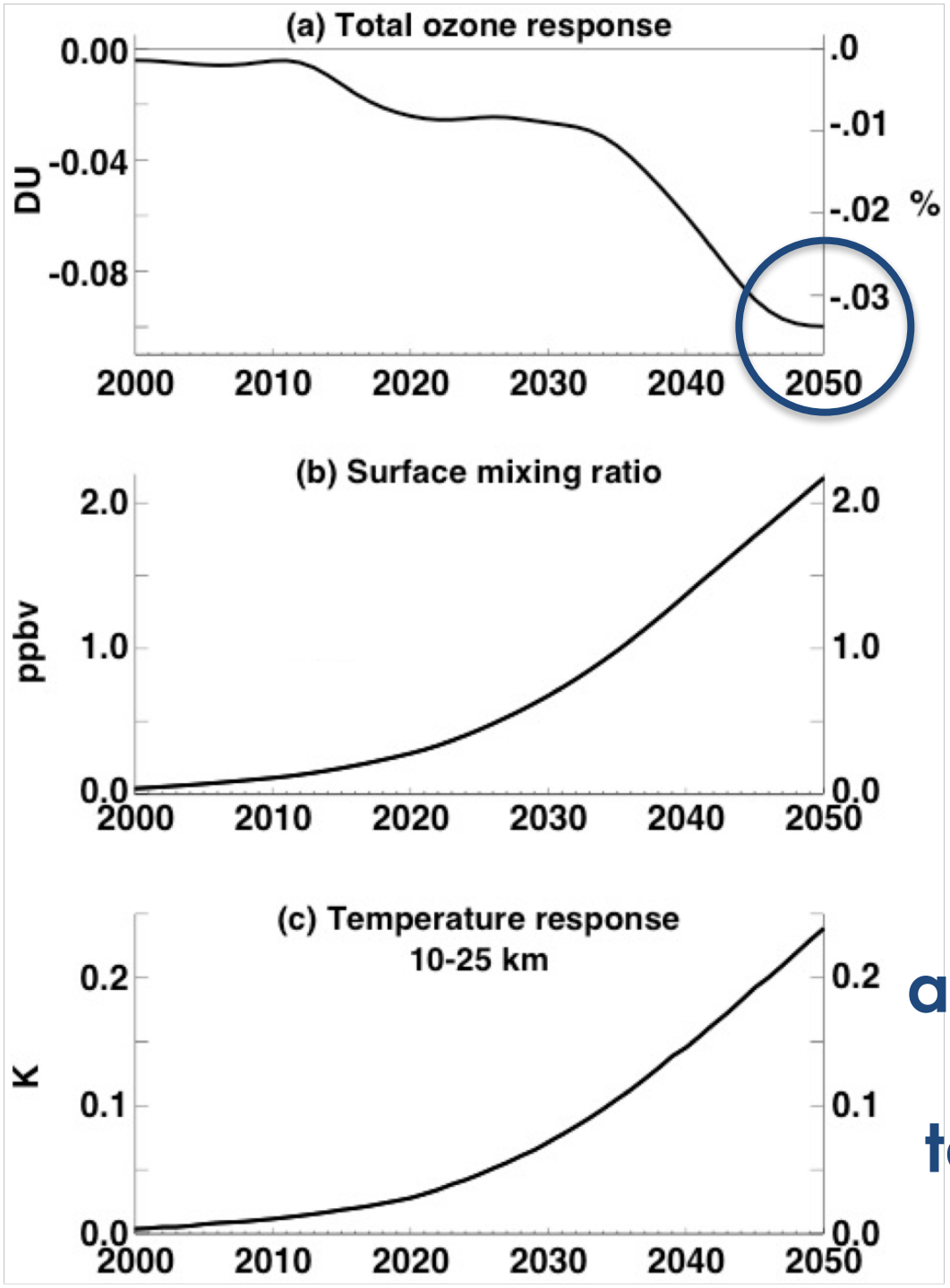
WMO Scientific Assessment of Ozone Depletion, 2010

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

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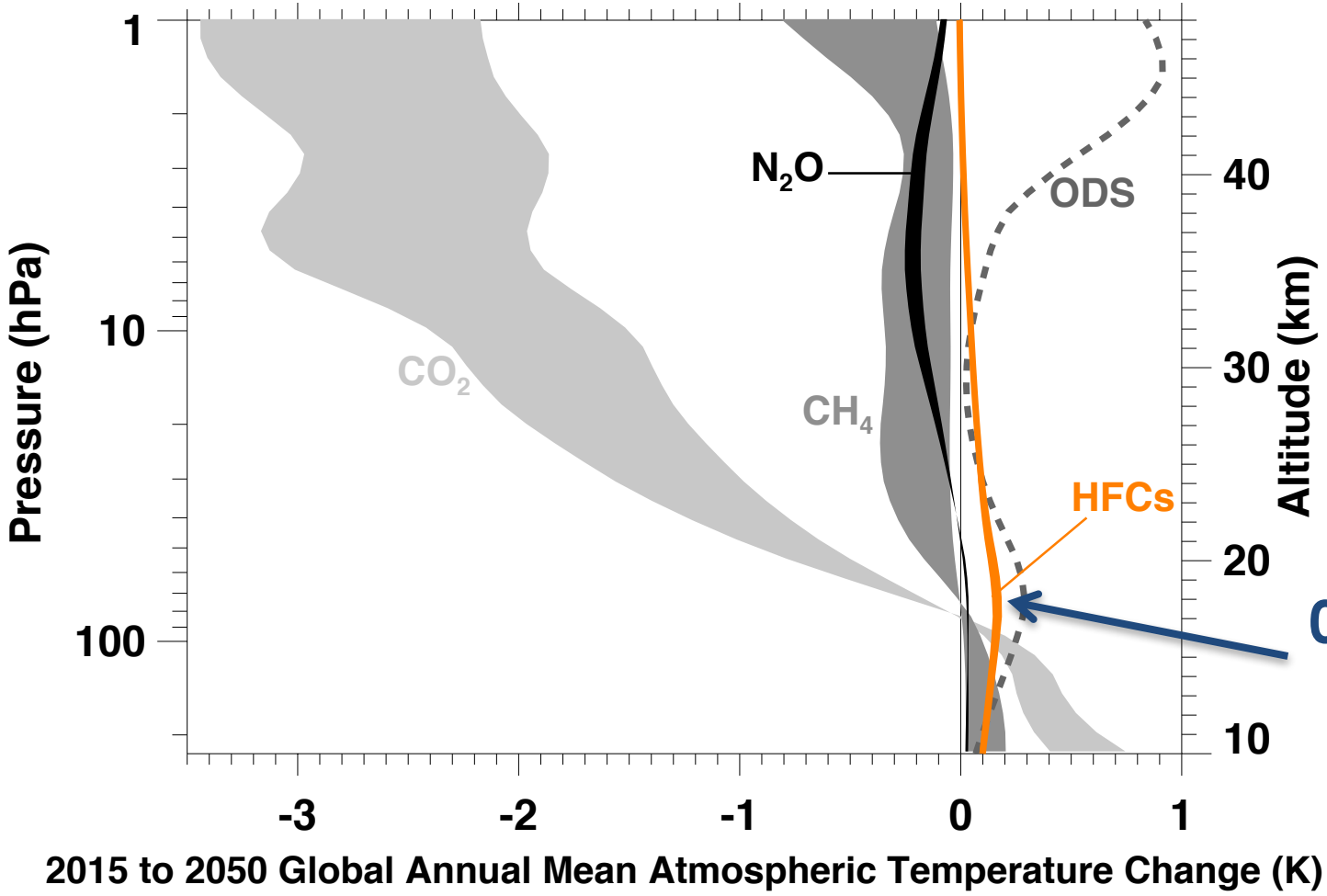
HFCs Contribute to 2050 Atmospheric Change



0.19K warming at 80hPa

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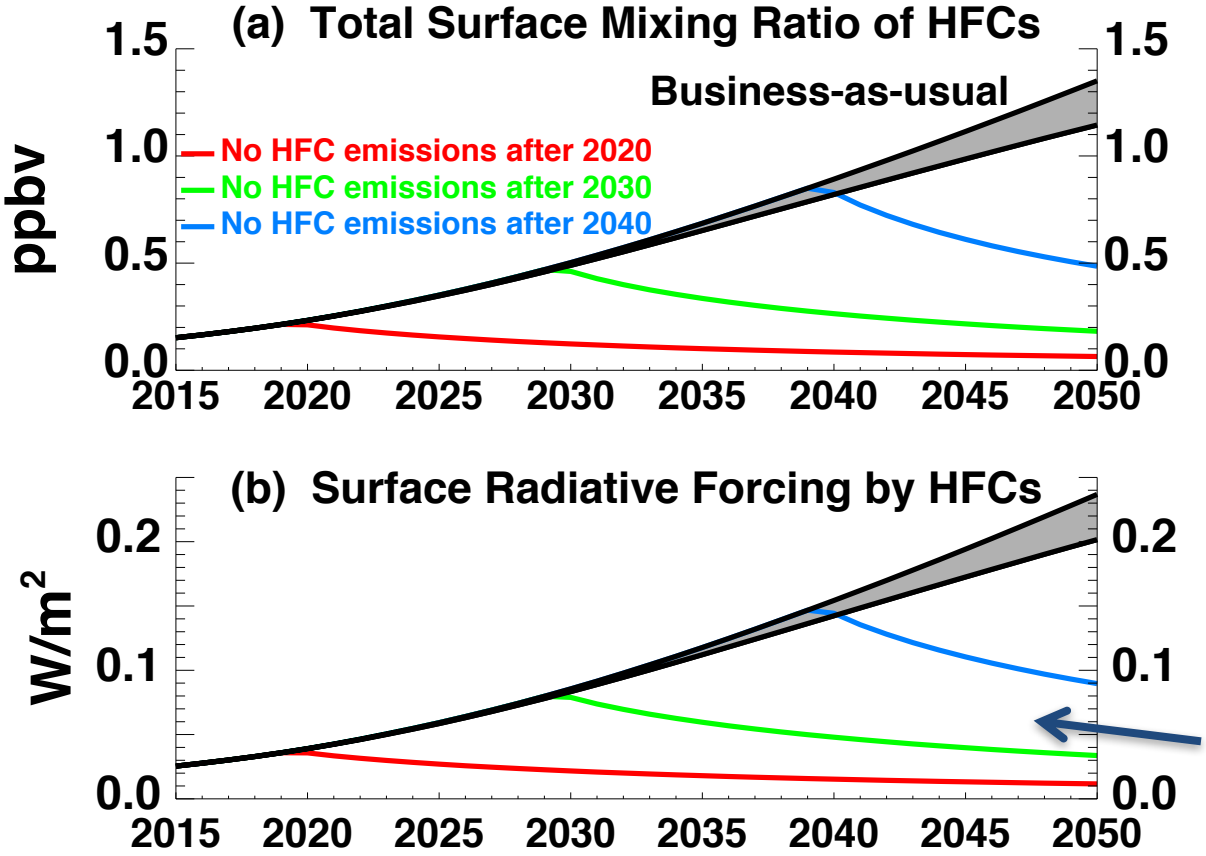
Mitigation Scenarios Reduce Future HFC Emissions



47% of emissions avoided

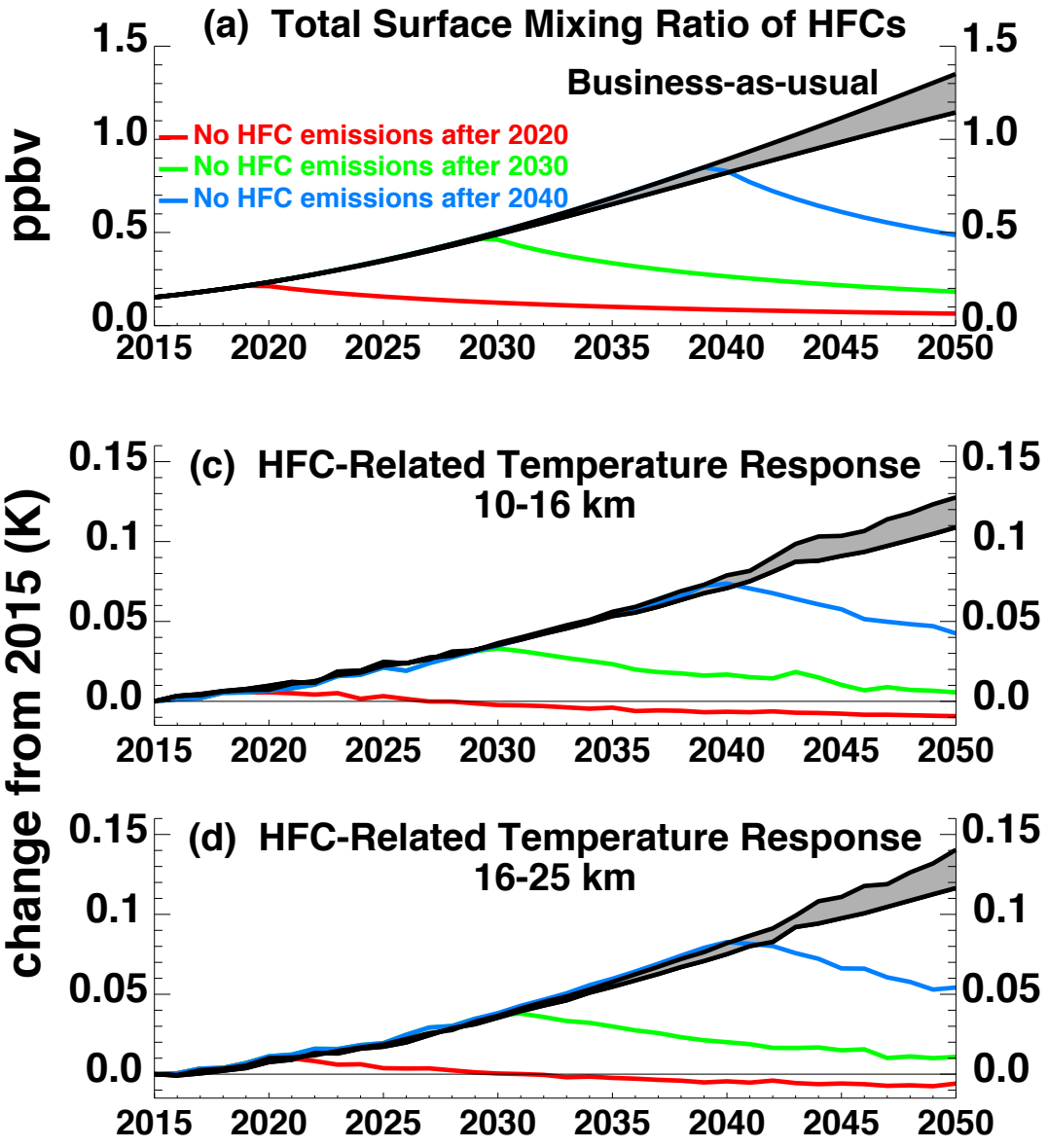
77% of emissions avoided

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

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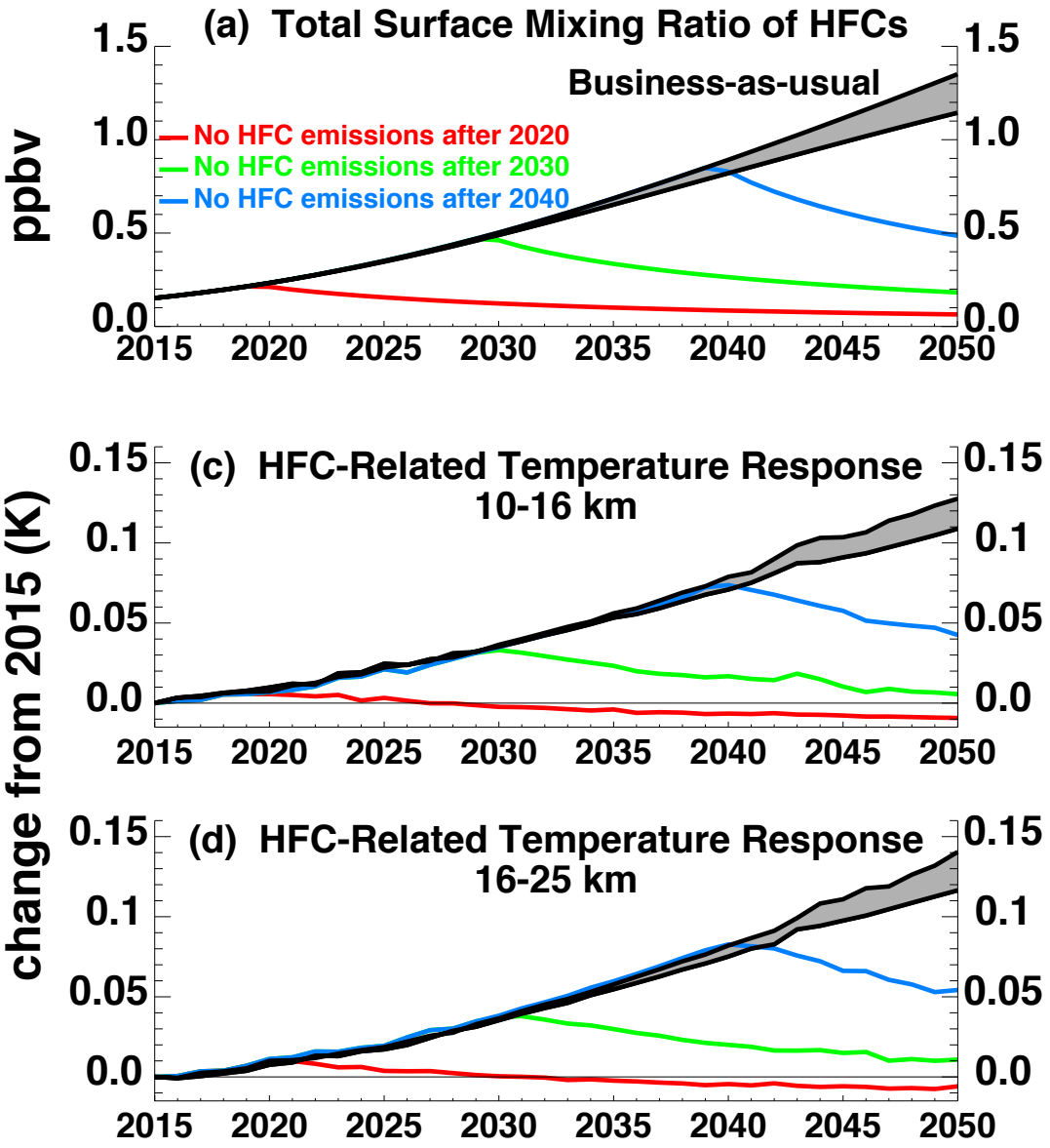
Mitigation Scenarios Reduce Future HFC Impacts



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

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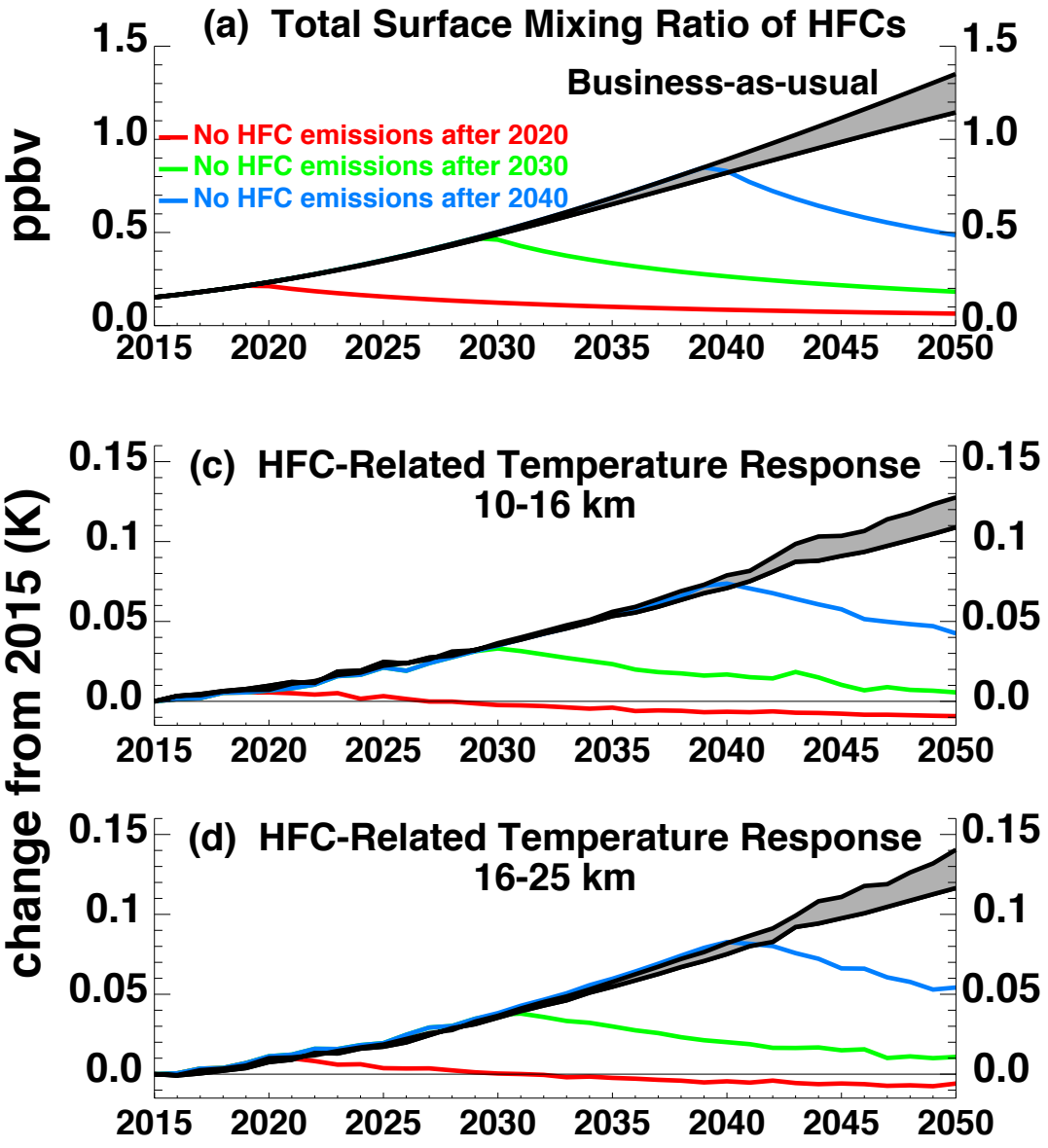
Mitigation Scenarios Reduce Future HFC Impacts



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

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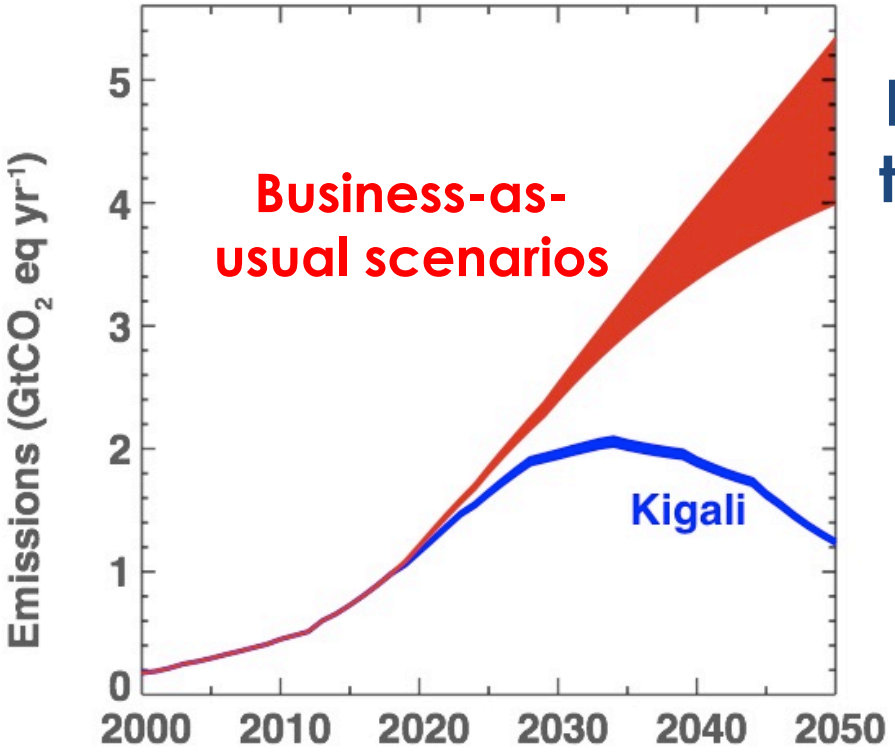
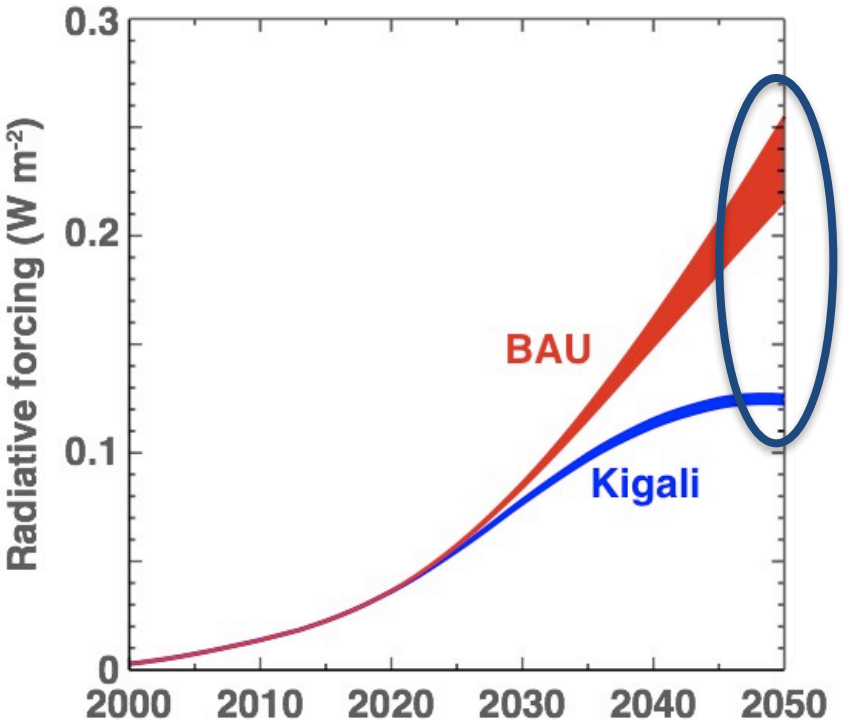
Kigali Amendment Reduces HFC Radiative Forcing



Kigali Amendment added to the Montreal Protocol in October 2016



~50% reduction in HFC radiative forcing in 2050

Calculations courtesy of Paul Newman & Guus Velders

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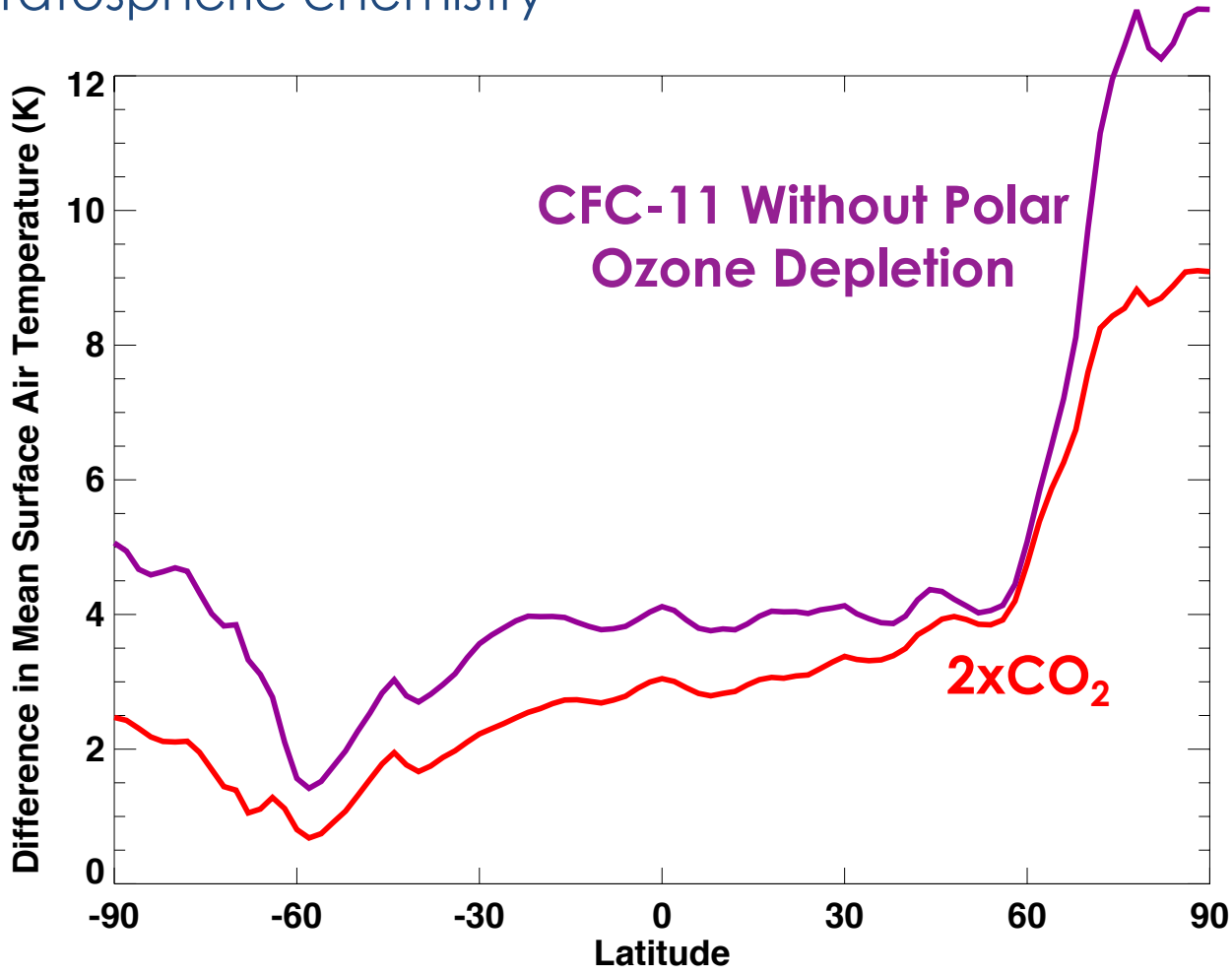
HFC Proxy Suggests Response Similar to CO_2

- 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



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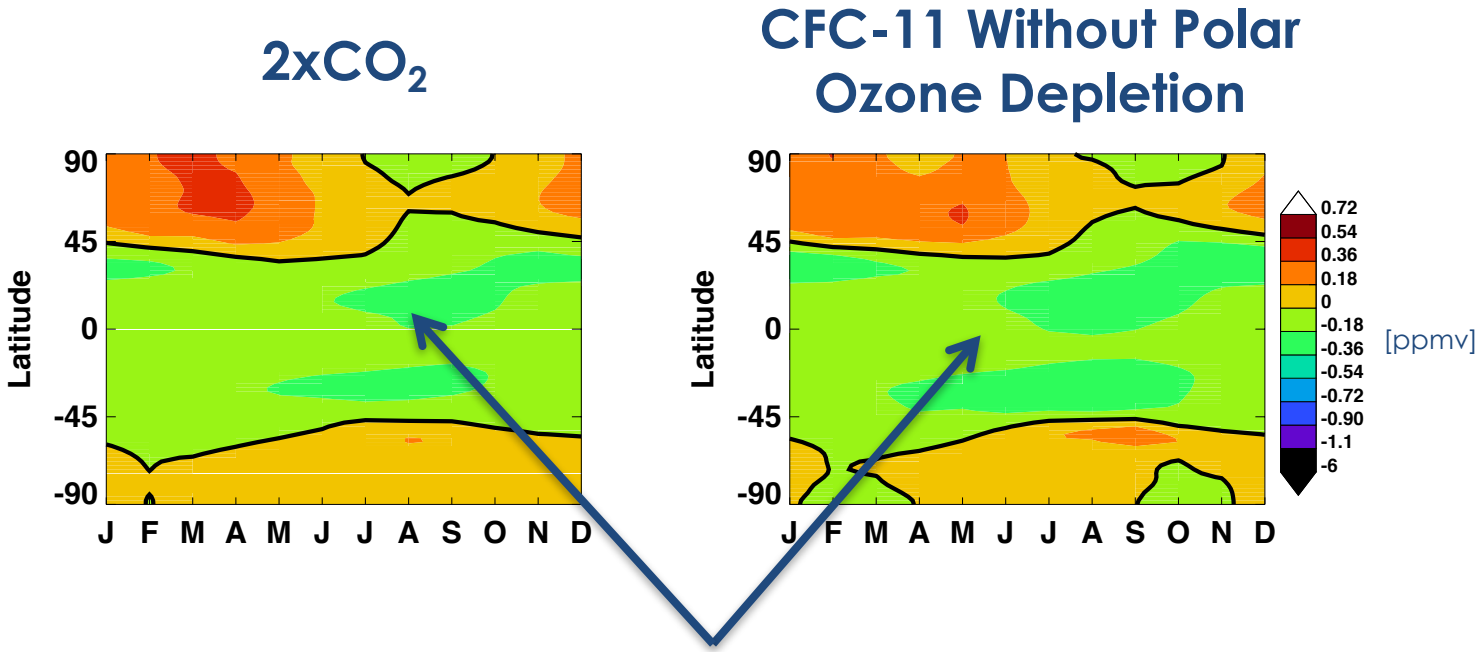
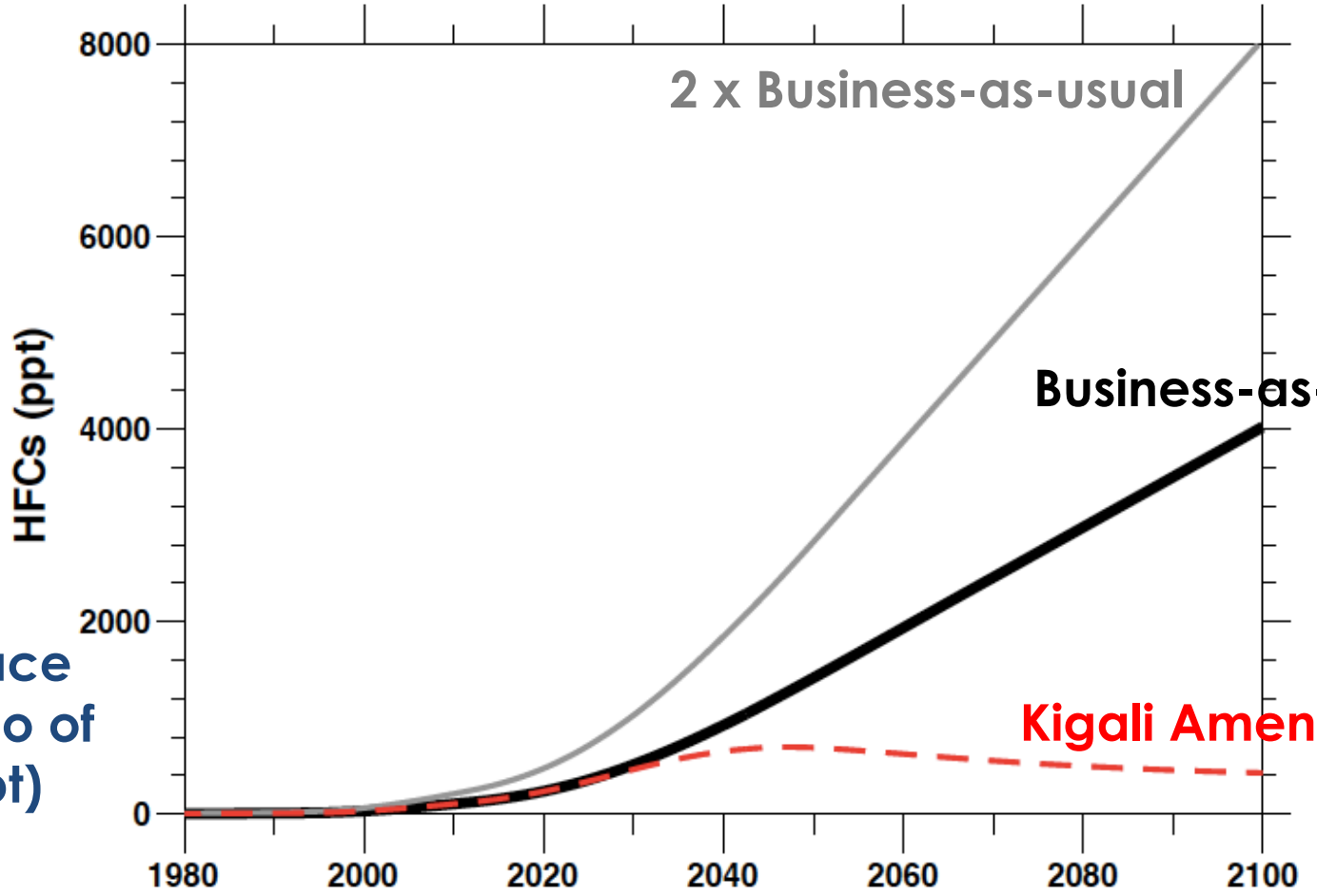
Annual Cycle of Ozone Response at 70hPa



Response pattern indicates enhanced Brewer-Dobson circulation

Planned GEOSCCM simulations will quantify the surface climate impacts of HFCs



Total Surface Mixing Ratio of HFCs (ppt)

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
- Sensitivity simulations suggest that HFCs warm the surface and enhance the Brewer-Dobson circulation, similarly to CO_2
- Kigali Amendment to the Montreal Protocol is designed to reduce the anticipated radiative forcing by HFCs