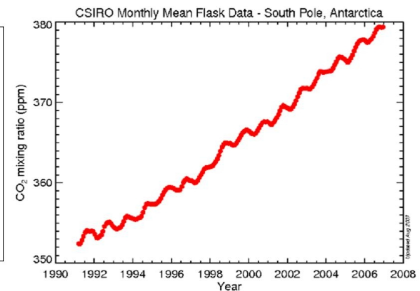
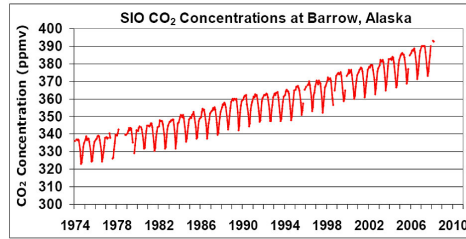
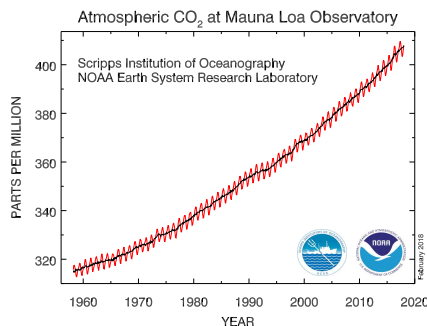


Climate Change: How do we know what we know?

How do we know atmospheric carbon dioxide (CO₂) is increasing?

Measurements from around the globe *all* show an increase of roughly 2 ppmv/yr.

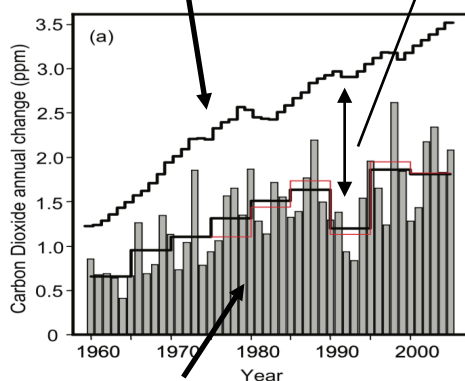


How do we know these CO₂ increases are human-caused?

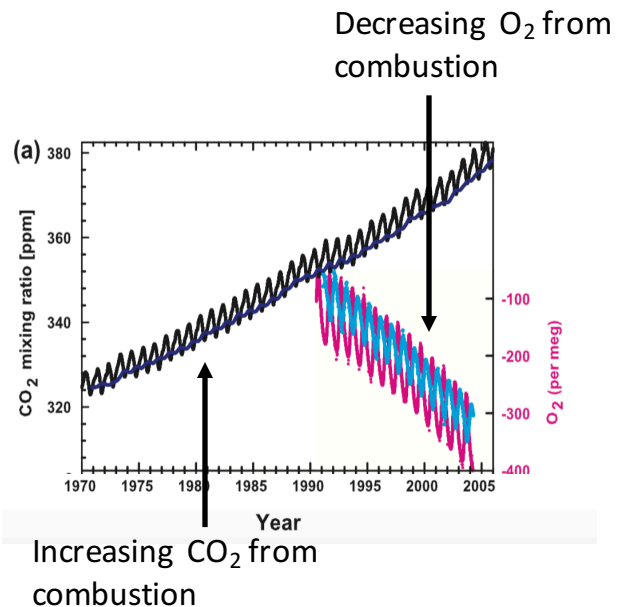
- Fossil-fuel burning accounts for the observed CO₂ increase.
- Oxygen (O₂) is simultaneously decreasing, consistent with a combustion source.

CO₂ produced by fossil fuel burning

CO₂ uptake by land and ocean



Observed atmospheric CO₂ increase



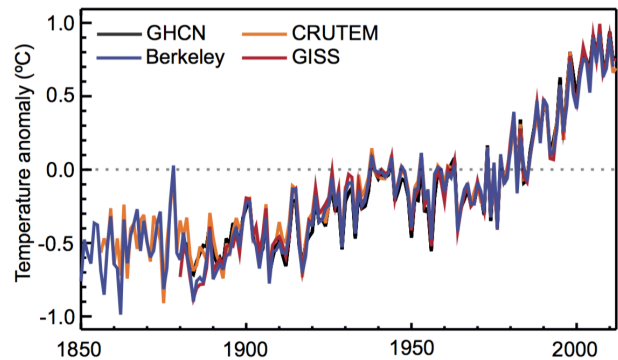
Notes

- CO₂ measurement image from <https://scripps.ucsd.edu/programs/keelingcurve/2013/05/20/why-scientists-still-collect-co2-in-flasks/>
- CO₂ data are from <http://cdiac.ess-dive.lbl.gov/trends/co2/csiro/>. CO₂ concentrations are measured in parts per million by volume (ppmv). A concentration of 280 ppmv (the preindustrial value) means that 0.000280 of any given volume of air is occupied by CO₂.
- Comparison between fossil fuel CO₂ and atmospheric increase from [Denman et al. \(2007\)](#) (IPCC AR4 WG1 Ch.7). Comparison of CO₂ and O₂ trends is from [Forster et al. \(2007\)](#) (IPCC AR4 WG1 Ch.2)
- For more see nadirjeevanjee.com/lectures

Climate Change: How do we know what we know?

How do we know atmospheric temperatures are increasing?

Different temperature datasets from land-based thermometers consistently show an increase.



How do we know this temperature increase is human-caused and not due to natural variability?

- Observed warming is outside the range of variability produced by climate models
- Models only reproduce observed warming when forced by observed CO₂ increases
- Warming from natural variability would draw heat from ocean, but ocean heat content (OHC) is steadily rising

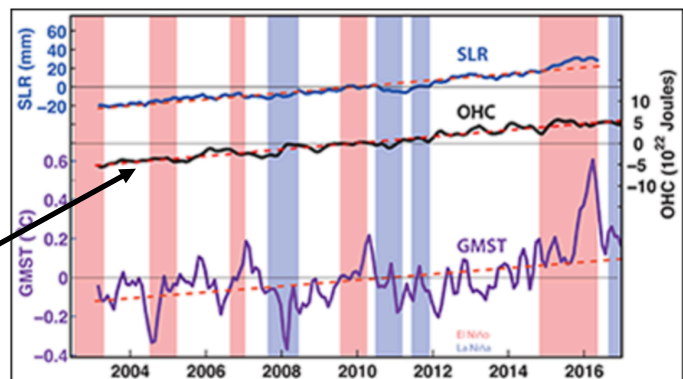
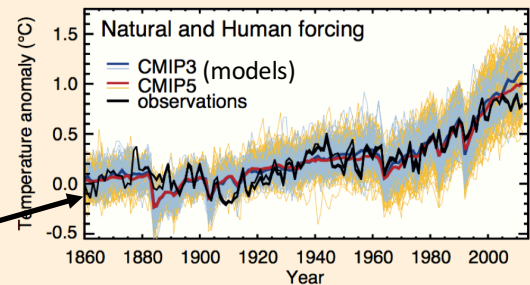
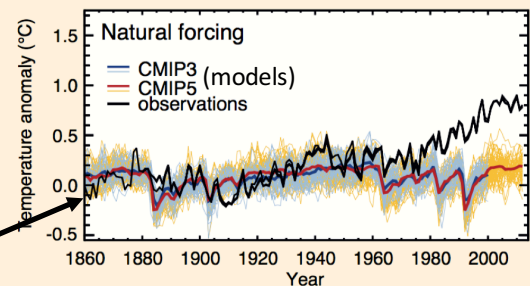


Fig. 2. Changes in OHC, global mean surface temperature (GMST), and sea level rise (SLR) during the past decade. All values are 2-month means; the

Notes

- Land-based temperature reconstruction is from [Hartmann et al. 2013](#) (IPCC AR5 WG1 Ch.2). Land-only warming is roughly 1.5 times larger than land+ocean warming.
- Comparison between the CMIP3 and CMIP5 ensembles of climate models and observed land+ocean temperatures are from [Bindoff et al. 2013](#) (IPCC AR5 WG1 Ch.10)
- Ocean heat content (OHC) record is from [Cheng et al. 2019](#), <https://eos.org/opinions/taking-the-pulse-of-the-planet>