What is the overall budget for contemporary CO2?

Atmosphere

C. David Keeling developed the first precise and repeatable measurement system for atmospheric CO_2 in the late 1950's. Since 1958, we have had really excellent measurements of the rising concentration of CO_2. CO_2 is not chemically reactive in the atmosphere, so once it's up there, it just blows around on the winds and doesn't decrease unless it gets removed by land plants (photosynthesis) or ocean uptake (dissolution). The atmosphere mixes emissions from everywhere to everywhere in about one year. Since about 1980, these measurements have been made in enough places that we know the total mass of atmospheric CO_2 to about 1% precision.

There are currently about ***800 Gt of carbon in the atmosphere (400 ppm),*** and it's currently increasing at around ***5 GtC/yr (2.5 ppm/year).***

Fossil Fuel Emissions

This is the next-best known part of the global budget, because fossil fuels are worth hundreds of billions of dollars a year and therefore both buyers and sellers keep very careful accounting! Annual global emissions are known to between 5% and 10% accuracy, though the uncertainties are larger for smaller regions over shorter time periods (say, Fort Collins in July of 2015).

Current fossil fuel ***emissions are about 10 GtC/yr***. The total amount of carbon that is available in the ground (fossil fuel ***resource***) is estimated to be at least ***4000 GtC***, and if we count "unconventional" fuels like tar sands and oil shale it may be as much as 10,000 GtC. Note that this number is ***much higher than proven reserves***, which are known to be extractable at a profit. If our descendants burned 5,000 GtC it would produce enough CO_2 to raise atmospheric concentrations by 2500 ppm, minus the amount that was delivered to the deep oceans. Most scientists don't believe this will happen.

Oceans

The oceans contain by far the biggest "labile" reservoir of carbon on Earth. About 90% of the dissolved carbon in the oceans is bicarbonate ion (HCO_3^-) and most of the remainder is carbonate (CO_3^{2-}). The ***oceans contain about 38,000 Gt of carbon***. (Nonlabile $CaCO_3$ in limestone and calcareous sediment is many orders of magnitude greater, but can only exchange with the atmosphere through plate tectonics over many millions of years).

Careful tracing of radiocarbon produced by nuclear weapons testing in 1961-62 has shown that the ***oceans currently absorb about 2.5 GtC/yr*** from the atmosphere. This number has risen steadily as atmospheric CO_2 has increased, and it is expected to continue rising through the 21st Century. The magnitude of this sink on decadal timescales is known to perhaps 30% accuracy.

The ocean sink is relatively well-understood, and the dissolved carbon will likely stay in the deep ocean for at least 1000 years due to very slow mixing. Therefore from the point of view of reducing global warming the ocean is a safe and reliable place to store fossil fuel carbon.

Unfortunately the well-known chemistry of the oceans also indicates that dissolving large amounts of fossil-derived carbon will lead to ***acidification***. There is evidence that very serious biological disturbances will occur if atmospheric concentrations exceed 700 ppm or even 500 ppm.

Land

The total amount of carbon stored in land plants, soils, microbes, and animals is estimated to be about 2000 GtC. It is very unevenly distributed, with most carbon in forests and huge areas of deserts with very little carbon.

The land sink was a surprise because biologists and ecologists expect rates of growth and decay to compensate one another. The total global land sink is about 2.5 GtC/year, and this number is known best as a residual after subtracting atmospheric CO_2 and ocean uptake from fossil fuel emissions. The decadal land uptake is known to maybe 30% accuracy.

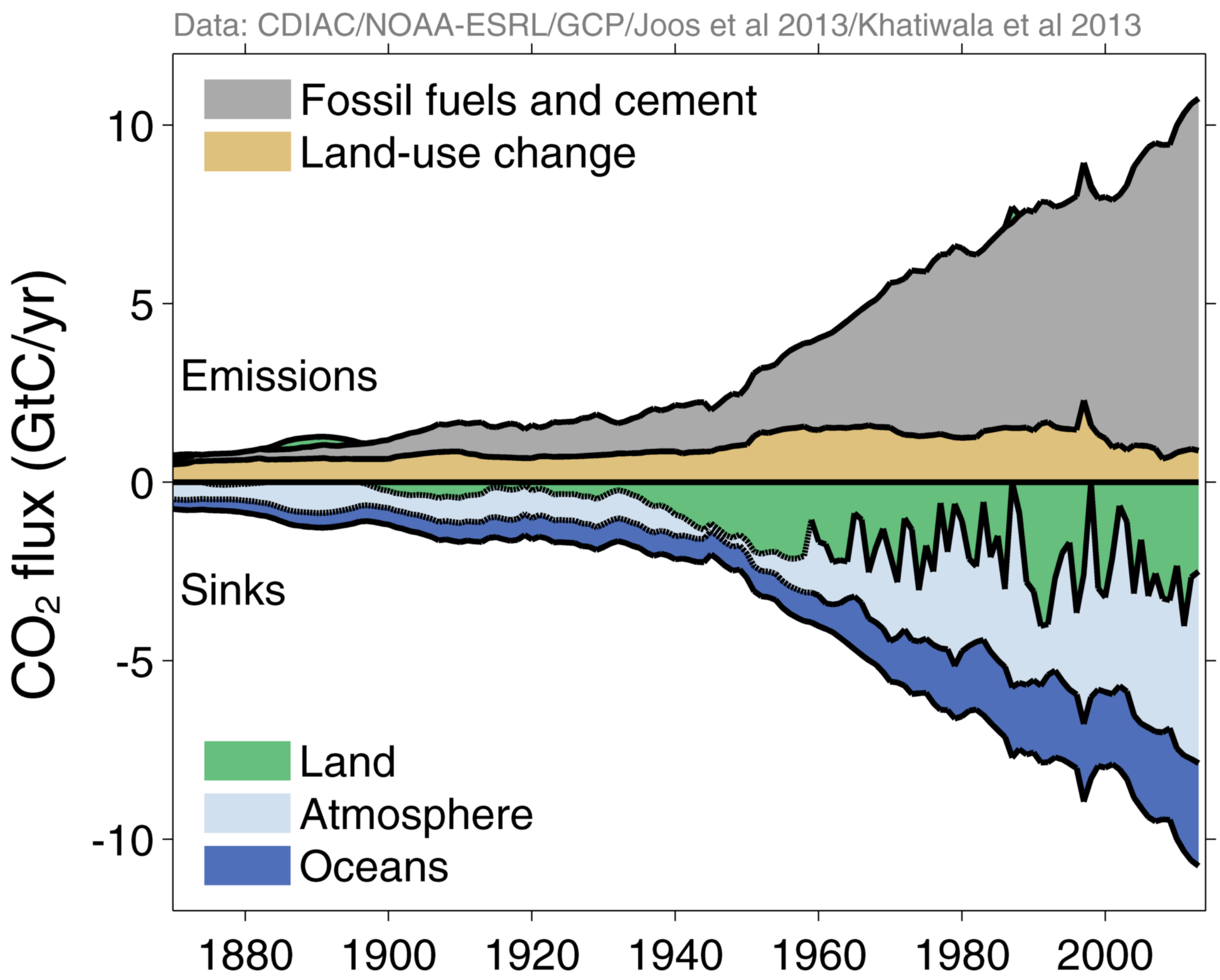
One of the big problems is that we also know that a large amount of carbon is released each year due to deforestation, mostly in the tropics. This is estimated to be about 1 GtC/yr, but the total estimates are not very precise.

So the **total land contribution to CO_2 is about 1 GtC/yr of emissions due to tropical deforestation with 3.5 GtC/yr uptake due to a poorly-quantified combination of CO_2 fertilization, nitrogen deposition, reforestation, and boreal warming.**

Most of the year-to-year variation in the growth rate of atmospheric CO_2 is believed to result from year to year changes in plant growth and decay that arise from climate fluctuations (e.g., heat, cold, drought).

Summary of Contemporary Carbon Budget

Fossil Fuel Emissions	+10 GtC/yr
Deforestation	+ 1 GtC/yr
Ocean uptake	-2.5 GtC/yr
Land uptake	-2.5 GtC/yr
Atmospheric increase	+ 5 GtC/yr


Data: CDIAC/NOAA-ESRL/GCP/Joos et al 2013/Khatiwala et al 2013
Fossil fuels and cement
Land-use change
Emissions
Sinks
Land
Atmosphere
Oceans
CO2 flux (GtC/yr)
10
5
0
-5
-10
1880
1900
1920
1940
1960
1980
2000