Climate Restoration:

Restore CO2 Levels by 2050

Canadian Club of Rome
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April 1, 2026

Mission: Enable humanity to flourish for millennia to come

A paradigm shift

1. We all want to give our children safe CO2 levels and climate like we were given.
2. Nature has done it and humanity can too.
3. We now know to induce nature to do it again, quickly.
4. The cost is low. It's already in corporate budgets.
5. You need the new facts to give good advice.

Why address climate? To give our children safe CO2 levels and climate like we were given

Useful answers require asking good questions.

For this talk, please adopt this climate restoration framing

The UN climate goal is to “try to keep warming below 1.5 degrees C.”

Or

“Stabilize greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system, in a time frame which allows ecosystems to adapt naturally and enables sustainable development.”

You can resume with the UN goal afterwards, if you choose.

Climate restoration is what we all want

- We want to give our children a safe CO2 level and climate like we were given.
- That means getting CO2 back below 350 ppm by 2050.
- That means removing 1000 Gt CO2 in total. Nature does that over and over in the ice age cycle.
- It’s 60 Gt / year. Just three times the removal that occurred after Mt. Pinatubo erupted.

Net-zero emissions will not restore the climate.

“Less catastrophic” is still catastrophic.

- CO2 today is 50% higher than humans have ever survived, and systems around the planet are beginning to collapse–climate, ecosystems, political, and cultural.

- Net-zero by 2050 is not enough. We want net-zero by 2030.

Climate restoration only makes sense when we address our children and humanity flourishing

Why is climate restoration new?

- The UN framed global warming around development, economics, jobs, and politics.

Can we do both? Can we restore safe CO2 levels while the UN tries to keep warming below 1.5?

Yes.

The UN does not need to change. We do. We can change ourselves.

We can restore safe CO2 levels by 2050

…when we frame the question correctly.

The Club of Rome is positioned to do the reframing.

The following statement defies almost everything we hear about climate and CO2 removal:

Today there is only one pathway to restoring CO2 and climate by 2050.

- Demonstrated by nature, proven safe
- Low cost: Canadians could fund the whole thing for 10c / day per person

Climate restoration means 300 ppm CO2 by 2050

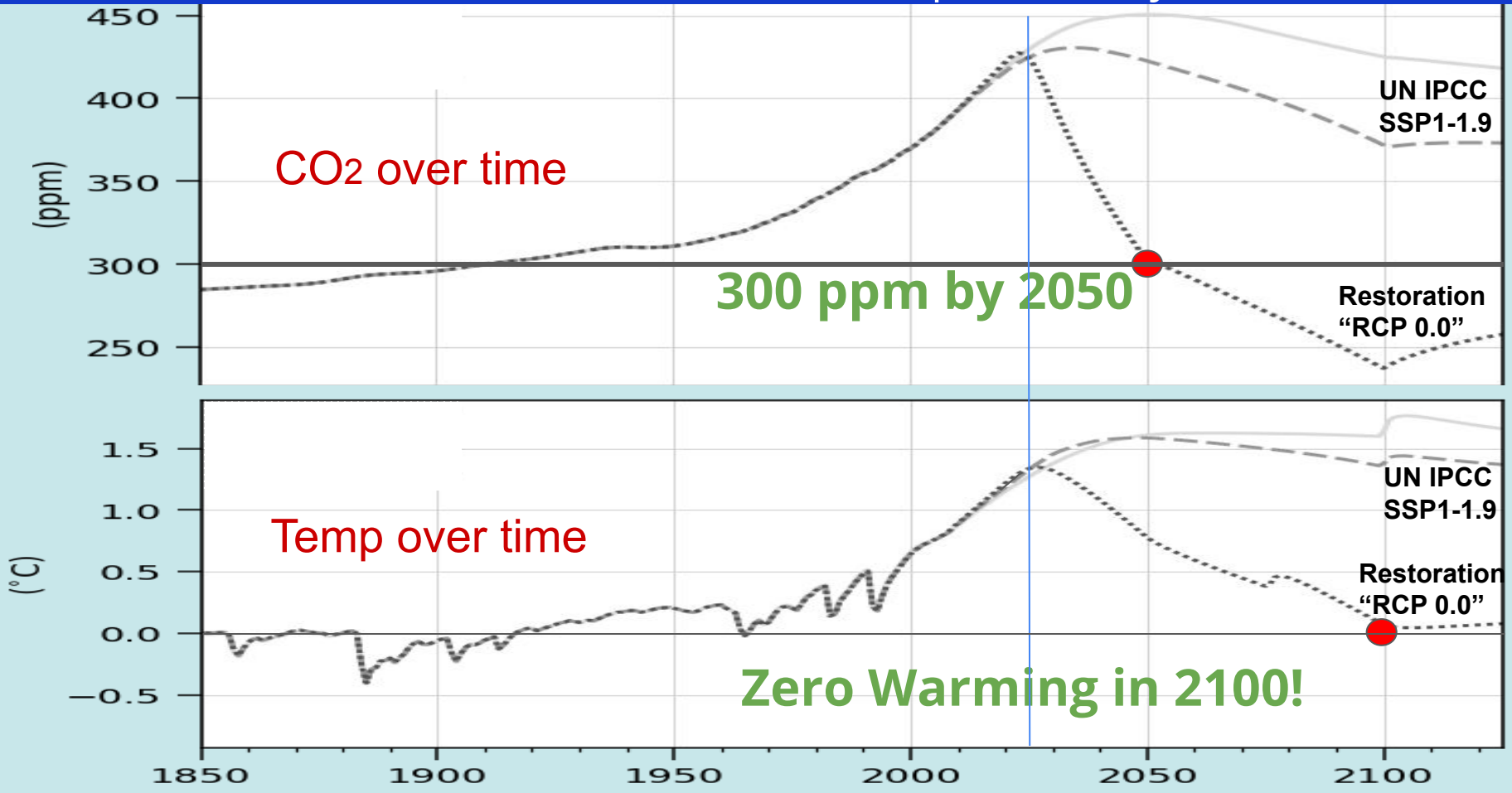
300 ppm is the highest level modern humans have survived long-term

CO2 exceeded 300 ppm 100 years ago

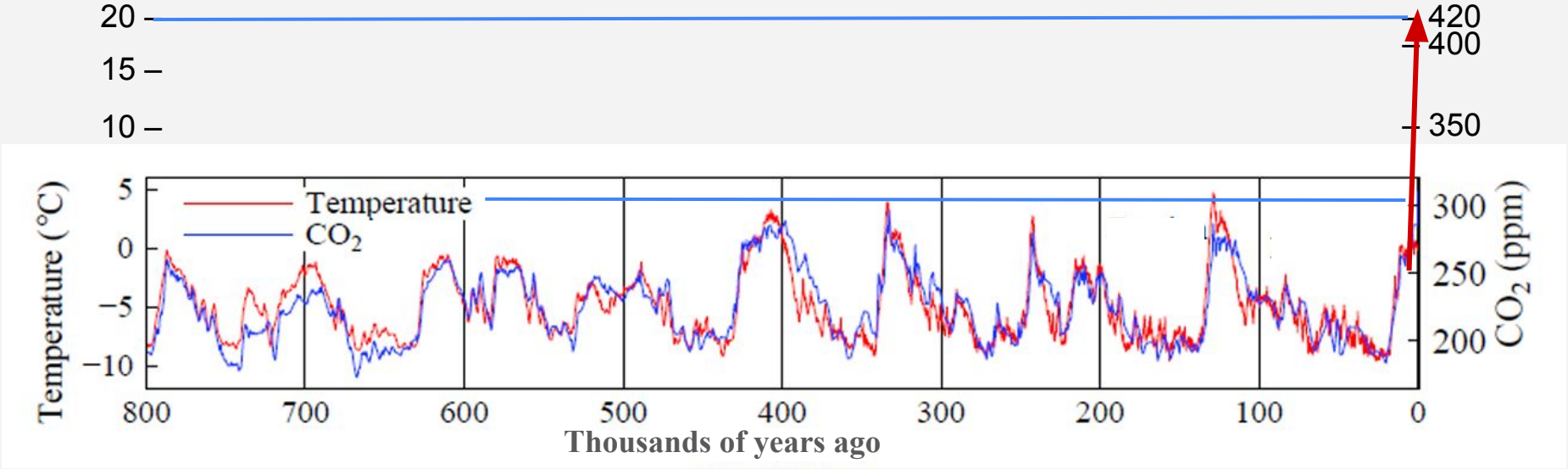
Regarding climate, 300 ppm (from 1926) is about the same as 350 ppm (last seen in 1988) which Dr. James Hansen popularlized.

300 ppm is objectively proven safe long-term, not speculation.

Models: Removing 60 Gt / year, starting in 2030 can restore safe CO2 and temperature by 2050



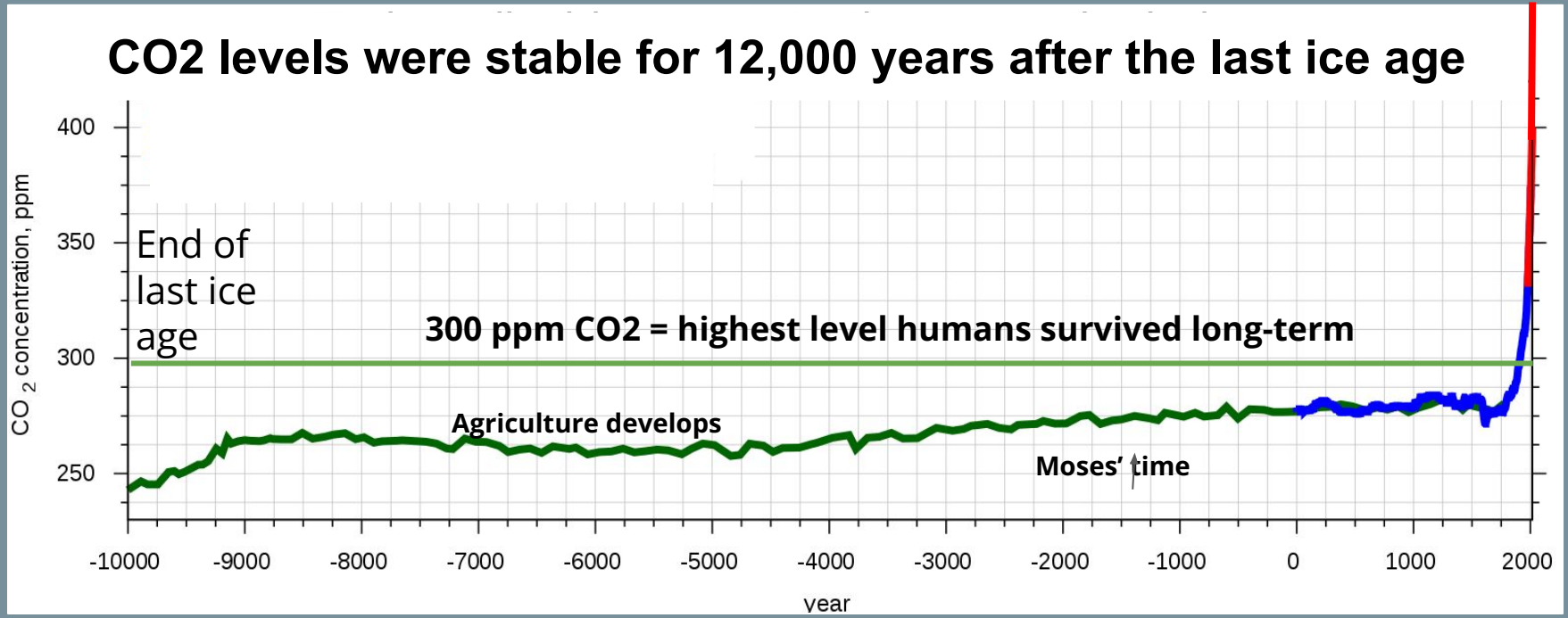
Temperature correlates with CO2



Hansen 2023 Global Warming in the Pipeline

Without restoring CO2 levels, the climate crisis won't end.

The stable, pre-industrial climate enabled us to develop agriculture



Paris goal

Today

Safe levels

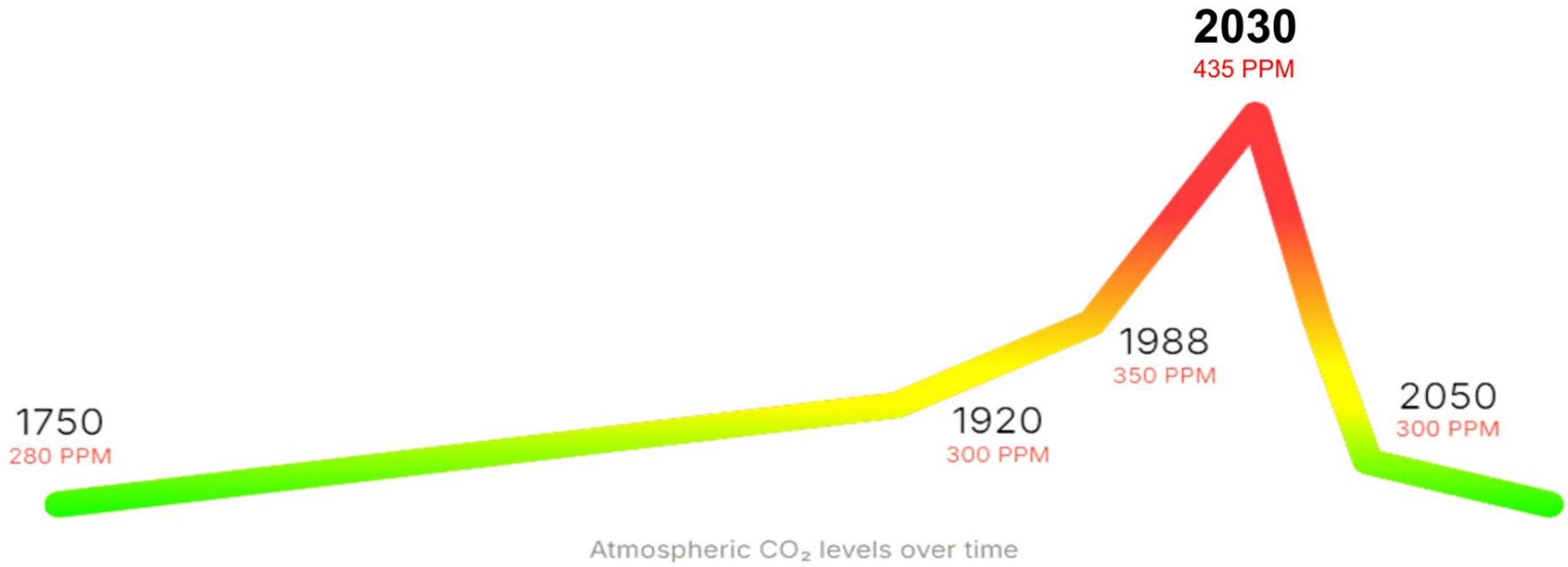
The challenge isn’t scientific

- We discuss the challenge as scientific, but we know that nature has removed the needed CO2 many times in ice age cycles. That cools the planet

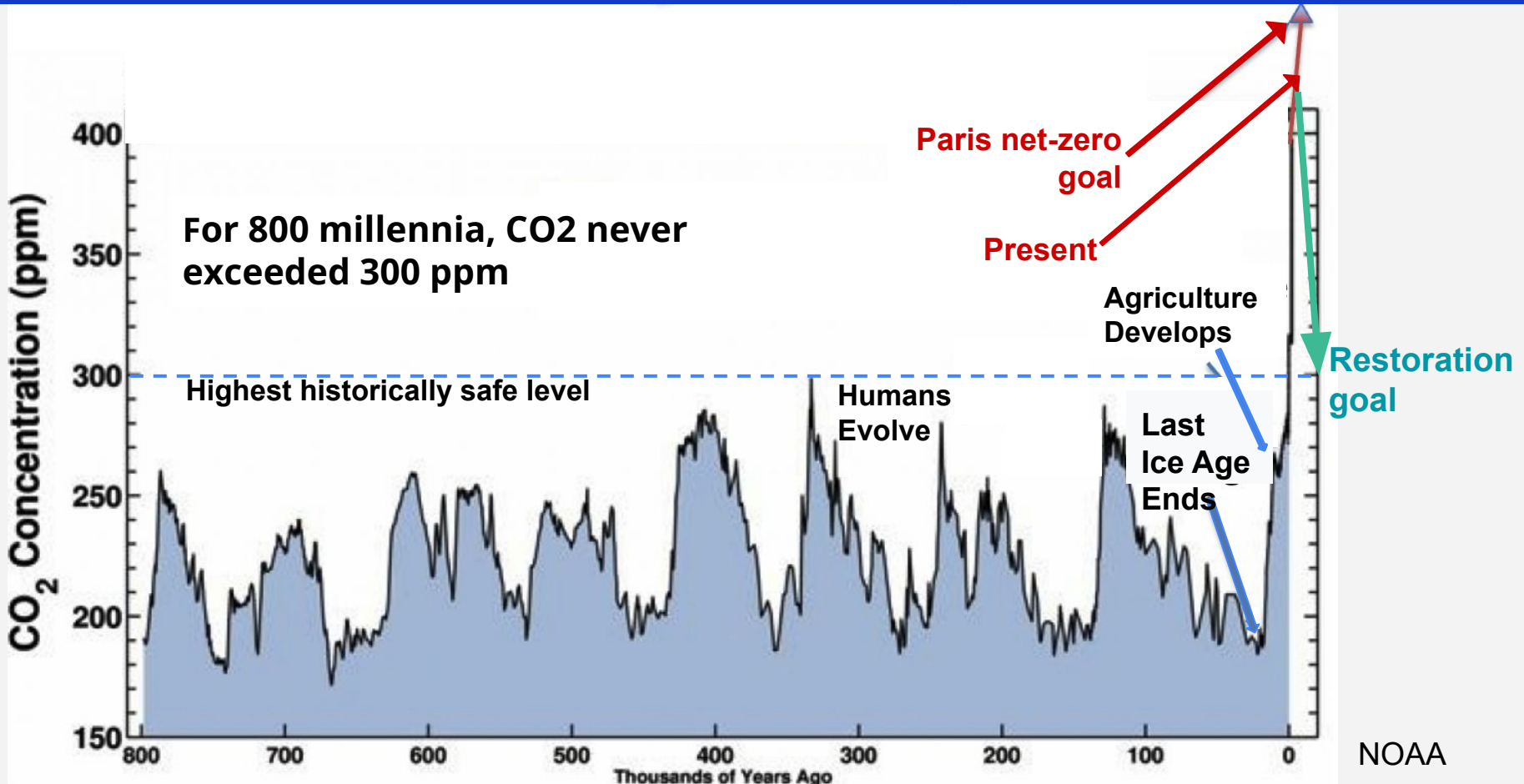
- We know how nature did it..for free. What is stopping us?

- How can the Club of Rome break the gridlock?

Climate restoration: To turn global warming into a ‘blip’



Ice ages show us that nature removed a trillion tons of CO2 many times in the last million years. We can, too.



NOAA

Ocean iron fertilization

Mechanism of CO2 removal in ice ages - discovered in 1990: Iron-rich dust storms increase as continents dry and cool.

Iron—limiting nutrient— fertilizes phytoplankton which grows & removes CO2.

Phytoplankton = foundation of whole marine food web. So in many places, replenishing iron restores fisheries and ocean life.

Inefficient: Typically 1% transfer of phytoplankton carbon to the deep ocean.

Thus scientists wrote about **full-basin OIF**, not understanding the impact of fish. Full-basin is a non-starter: too risky, too expensive, no significant climate benefit.

Controversies:

> “Success would let the oil companies off the hook.
>
> “Turn the ocean into pea soup
>
> Speculative risks: Full basin OIF has never been done and probably never will.

There is no evidence for bad side effects of natural or intentional localized ocean fertilization (LOF)

How much can we spend for climate restoration?

The Pentagon budget is ~$1T / year. That is unlikely to be spent on anything but wars. Ten percent of that, $100B / year might be spent on restoration.

We need to remove 60-100 Gt CO2 / year. $100B / 100B tons = $1/ton.

Any climate solution that works must cost less than $1/ton.

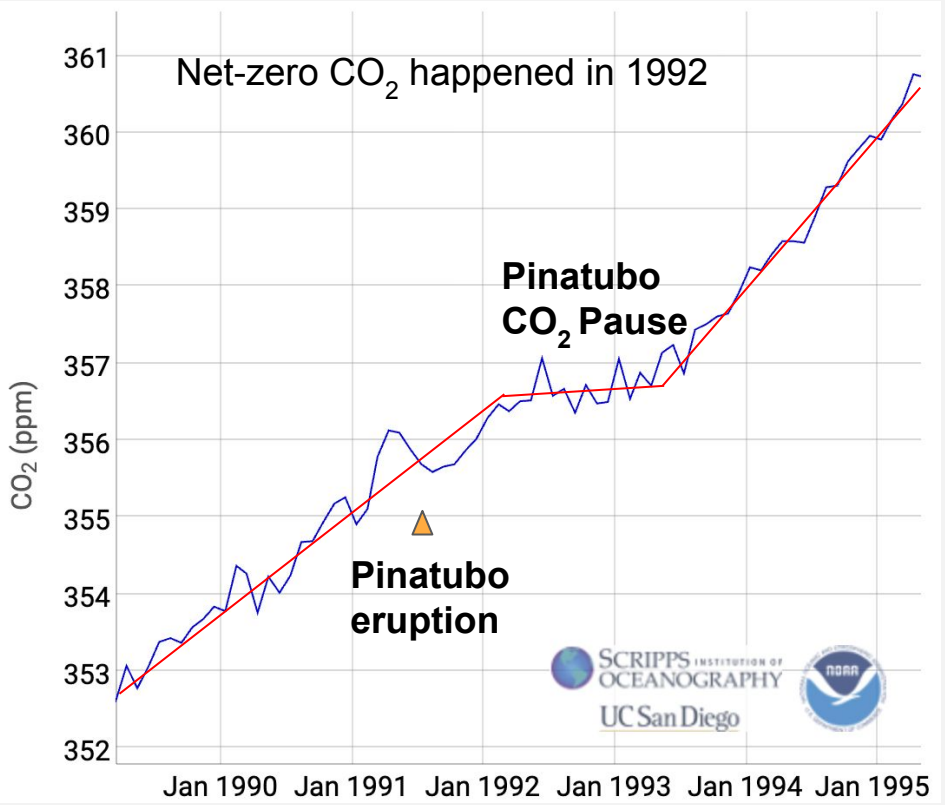
Funded solutions such as DAC, OAE, biochar cost $300 to $1200 / ton.

Cost: Four best-bet climate restoration solutions

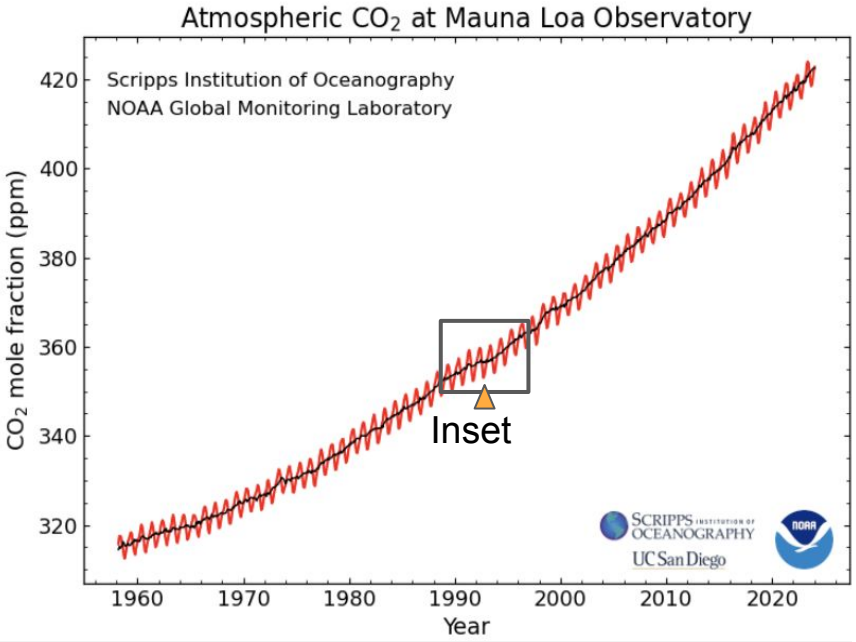
Method	Cost per ton CO_2	Cost / year at 60 Gt scale
Localized Ocean Fertilization (LOF)	< $0.40 (NAS)	<$24 billion
Synthetic limestone OR kelp	$2.5 to $50 (Blue Planet)	$150 billion
Ocean Alkalinization Enhancement (OAE)	$70-$120 (EDF)	$4,200 billion
Direct Air Capture (DAC)	$1200 (Climeworks)	$72 Trillion

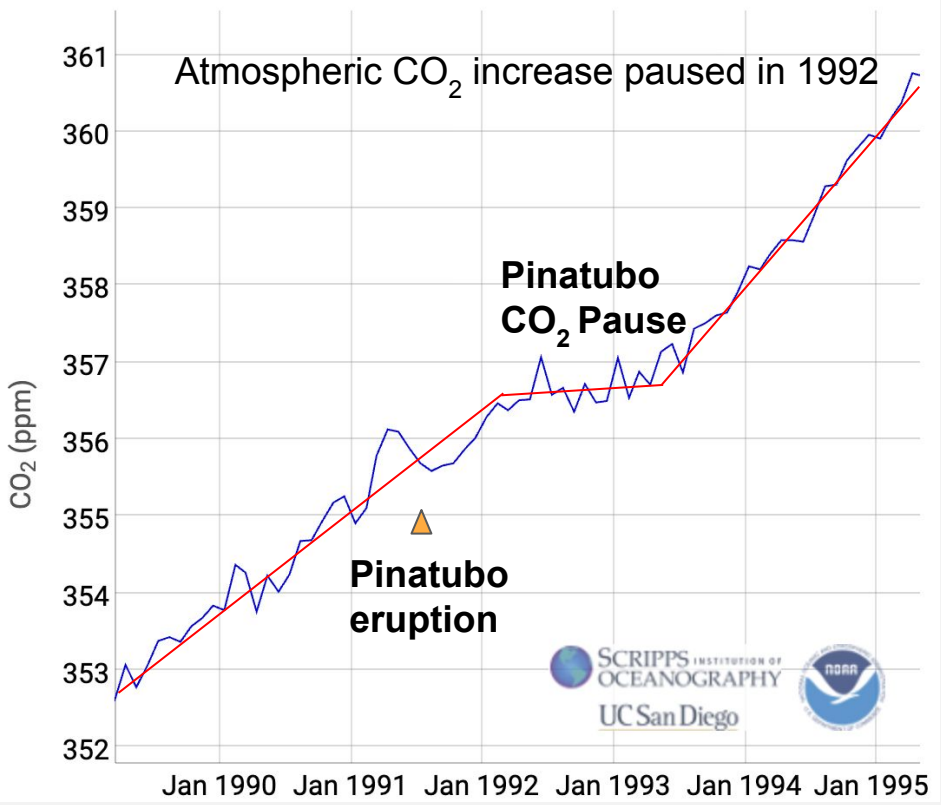
The Pentagon budget is ~ $1 trillion / year.

After the 1991 Mt. Pinatubo eruption, Nature removed 20 Gt CO_2 Using 0.1% of the ocean



Nature removed 20 Gt CO_2 after the Mt. Pinatubo eruption. Using 0.1% of the ocean. There is no reason we can't replicate that result.





Monthly CO_2 Averages (red) and seasonally corrected trend (blue) NOAA

OIF updated: Localized Iron Fertilization (LOF)

In14 years we've learned a few things.

1) The full-basin version is a nonstarter.
2) It's very low-efficiency and NOT what nature does.
3) Mt Pinatubo eruption in 1991. In 1992 we had NET ZERO! Nearly all 22 Gt Co2 emitted "disappeared" from the atmosphere.

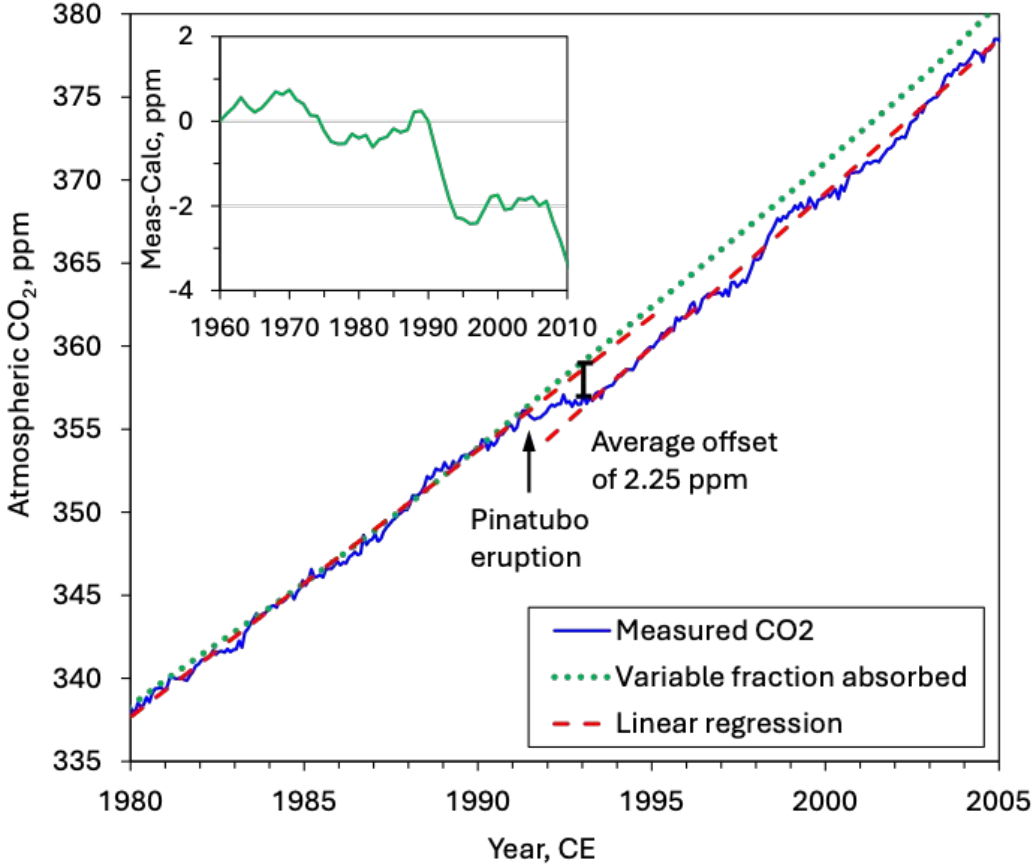
   CDR observed after Mt Pinatubo can be explained by two factors that make it 100X more powerful than the OIF proposed earlier:

   a) **Nutrients that sustain phytoplankton growth - N-fixing.**
   b) **Targeting: Downwelling eddy. There, instead of nearly all of it ending up in fish gullets and exhaled back to the air as CO2— it it gets pulled down to the deep where it C dissolves and is sequestered.**

CO2 -> Biocarbon -> dissolved carbon (mostly bicarbonate).
The ocean holds 40 times more carbon as bicarbonate than the atmosphere holds carbon as CO2.

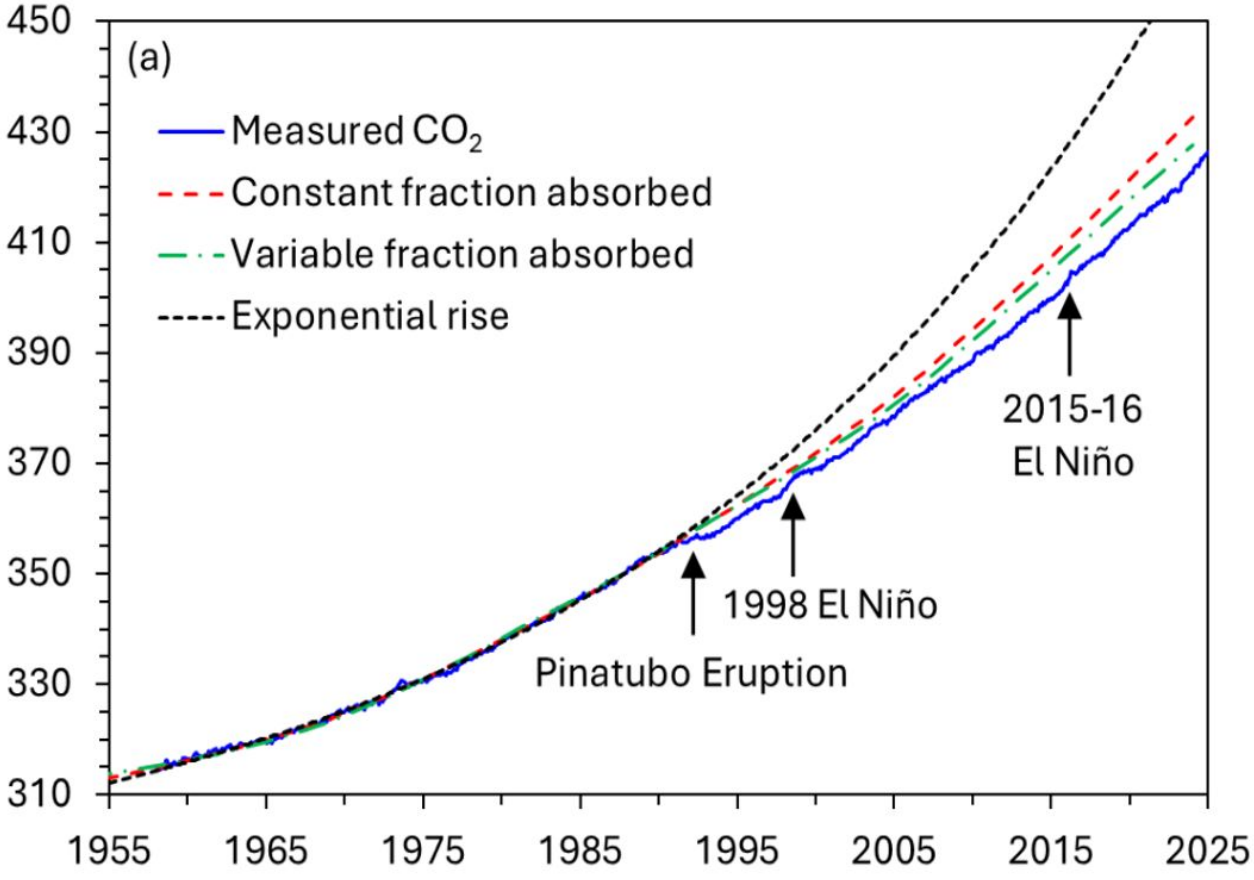
Our analysis of the geological record shows that, of 9 large eruptions since 1500, only 3, including Pinatubo, had this effect.

CO_2 Increase before & after Pinatubo eruption

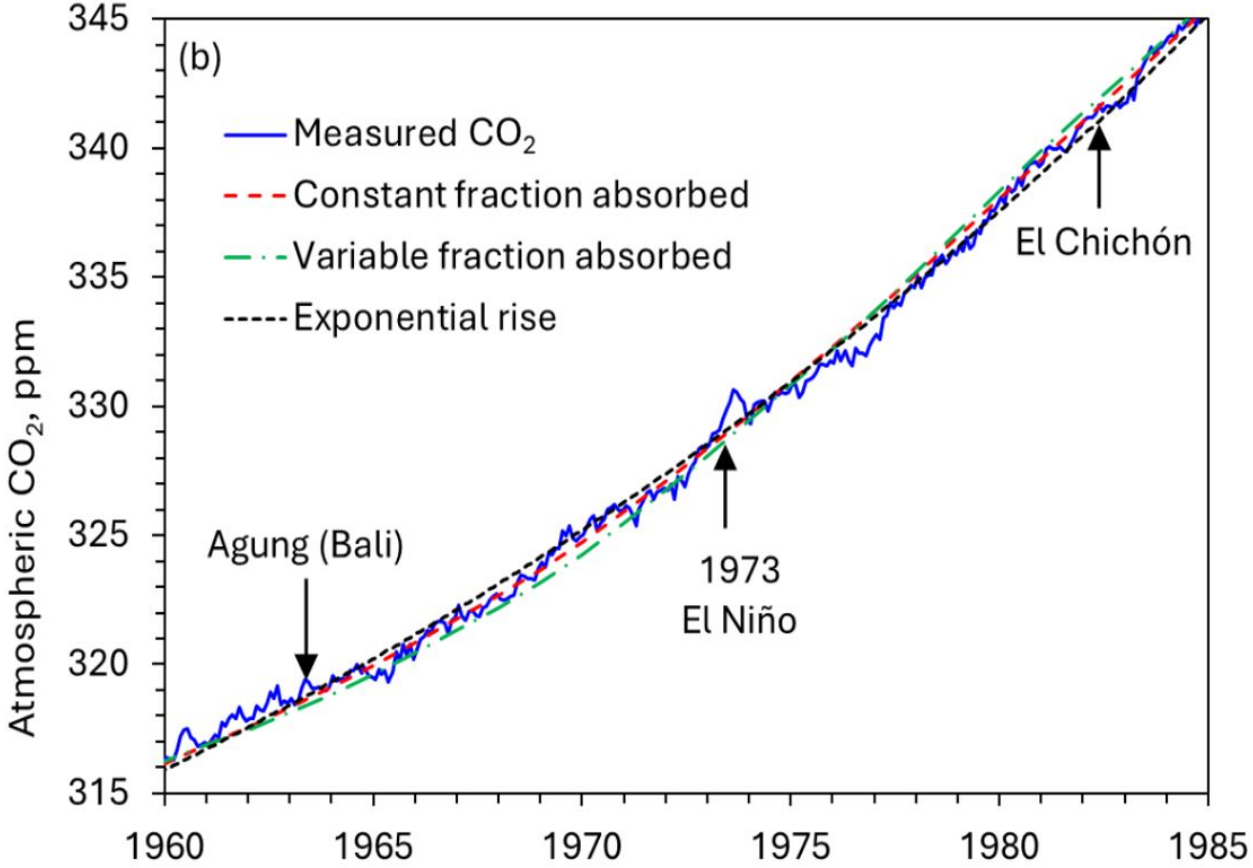


Measured increase in atmospheric CO_2 concentrations compared to linear projections and a projection based on annual CO_2 emissions. Inset is the calculated offset for the annual emission model.

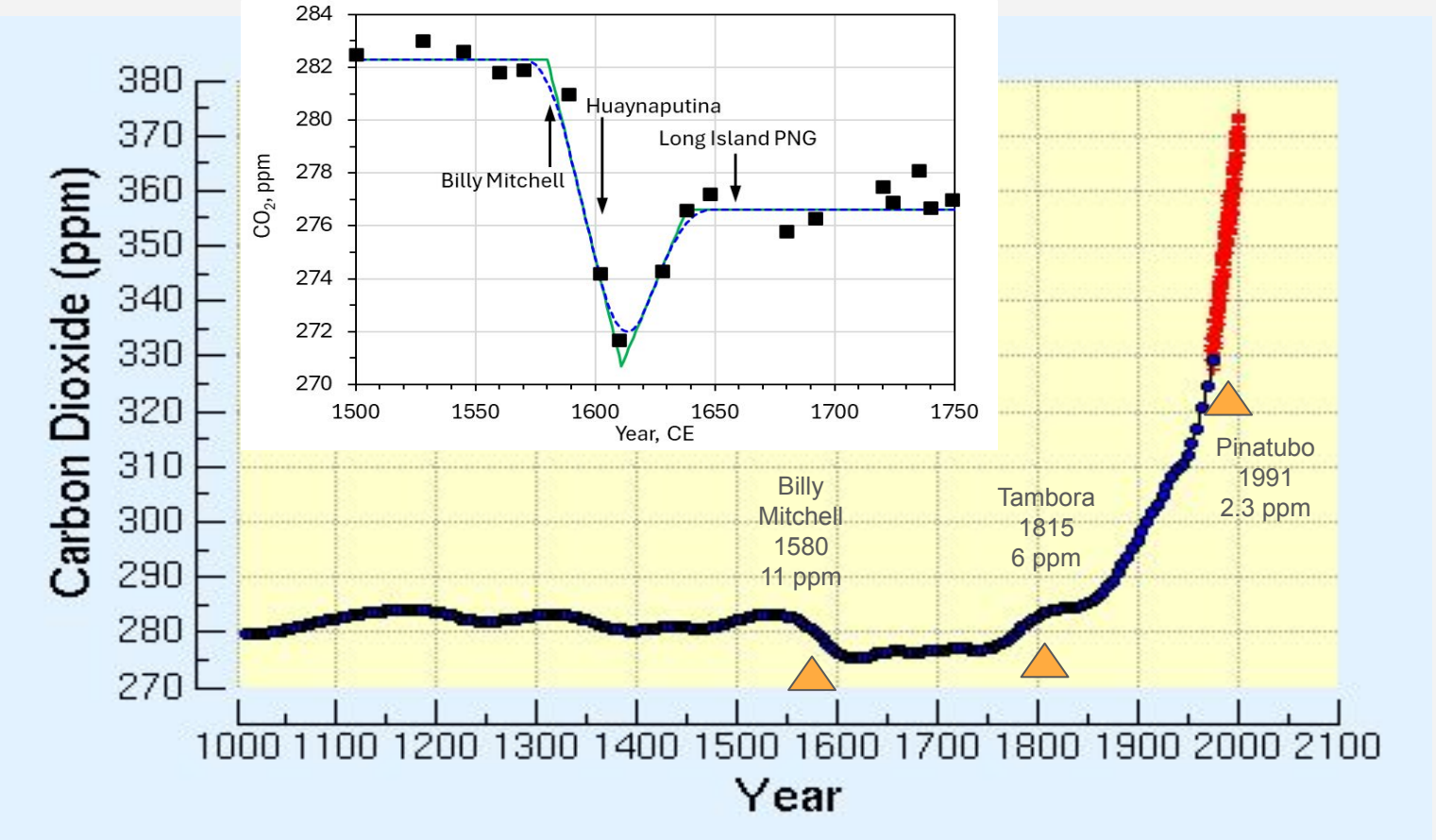
No sign of the carbon coming back after 35 years



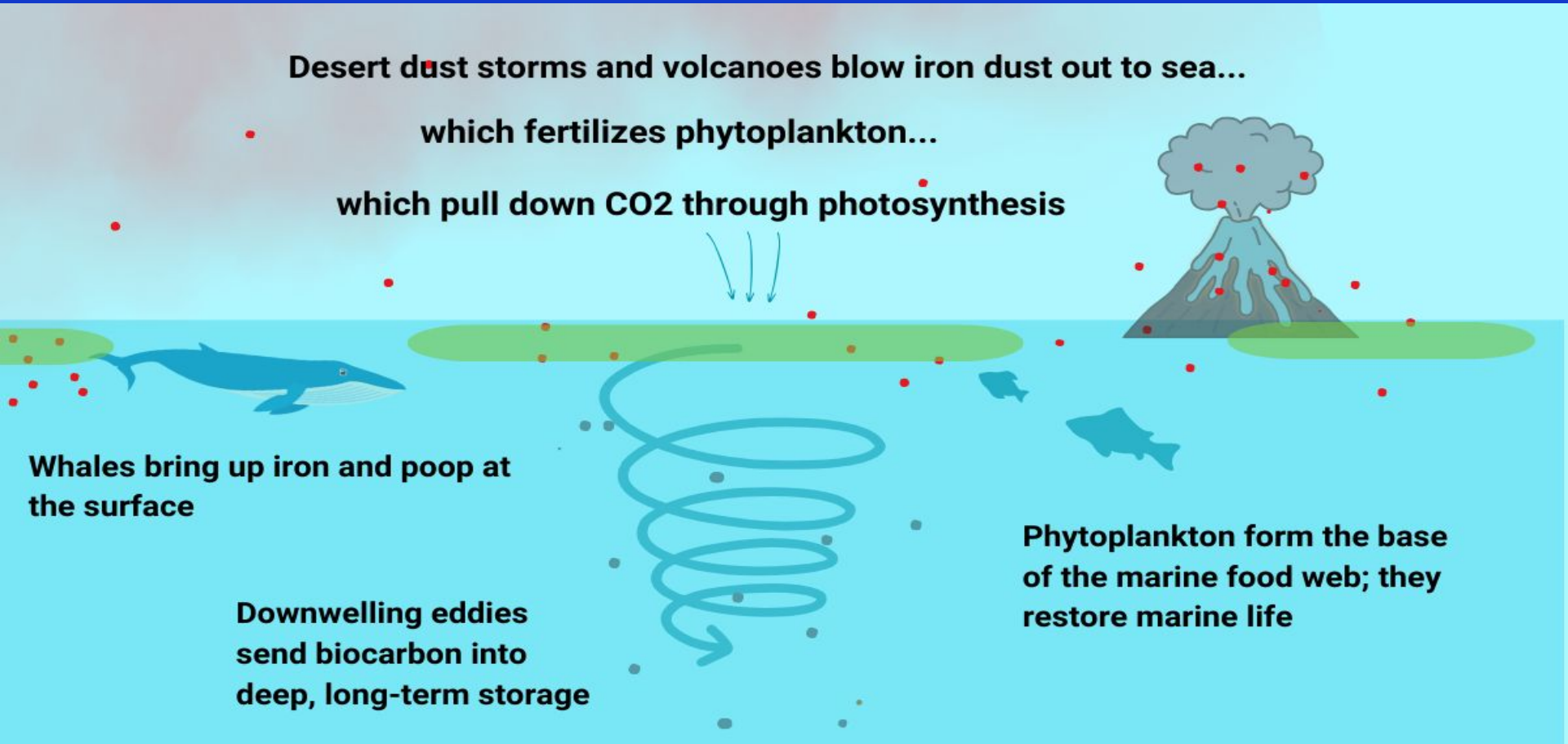
No CO_2 impact from 2 other large eruptions



Nature removed 11 ppm CO_2 after the 1580 eruption, 6 ppm after the 1815 eruption and 2.3 ppm after 1991 Pinatubo eruption



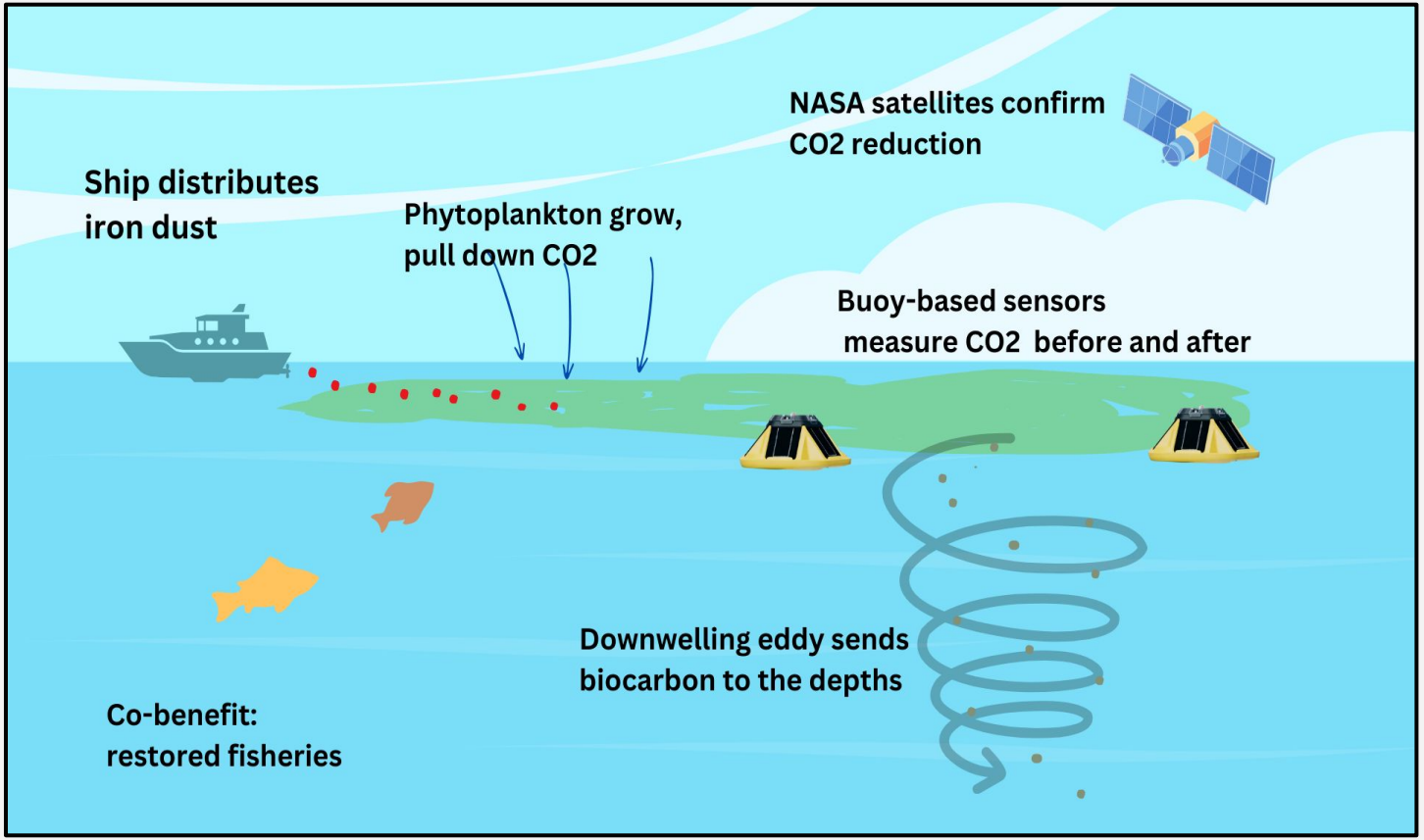
Nature's most powerful CO_2 removal: Photosynthesis in the ocean
She replenishes iron—an essential nutrient & limiting factor for marine life



It's called "Localized Ocean Fertilization" (LOF)
Here's how intentional LOF could work

Distribute dust from a ship to downwelling eddies with optimal formulation

Measure CO2 removal directly with buoys and NASA satellite data



Localized Ocean Fertilization (LOF) is not OIF
It is vastly better

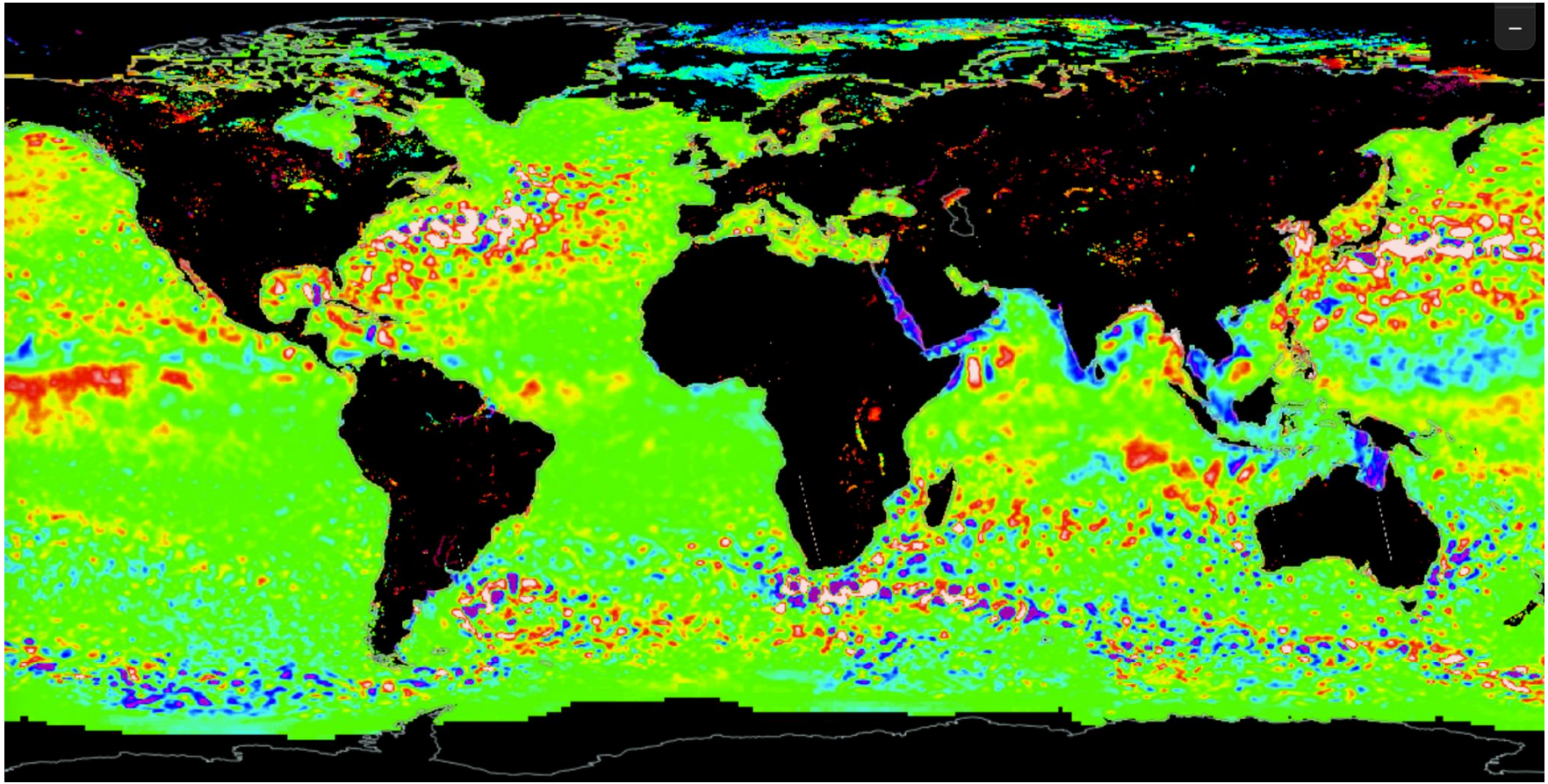
OIF Problems

- **It doesn't scale**: It's limited to about 1 Gt CO2 / year.
- **It's risky**: It requires full-basin application–and risks turning the ocean into "pea soup".
- **Nutrient robbing**: It sinks diatoms to the seafloor, removing their minerals from the ocean.
- **It's expensive**: at least 100 times more expensive for measurement.

LOF Benefits

- **Efficient**: Uses < 1% of the ocean area to remove all the CO2 we need.
- **Inexpensive**: < $1 / ton CO2 removed; Probably < $.10 / ton.
- **No nutrient robbing**: The biomass dissolves back into the sea water when it sinks in the eddy.
- **Simple atmospheric CO2 measurement** using buoys & satellites.
- **Safe**: It's what nature does & there are **no** reports of bad side effects.

Eddies are common. Downwelling (red); upwelling (blue)



Why was OIF promoted when it’s a non-starter?

Oceanographers could not explain the observed 18 Gt CO2 removal via phytoplankton. There is not enough nitrate in the ocean. Alternate theories were proposed. They don’t fit observed data:

1. Land plant growth
    a. Tree ring data shows reduced terrestrial growth.
    b. O2/CO2 ratio in 1992 corresponded to ocean photosynthesis.
2. Ocean cooling
    a. Articles agree that ocean cooling accounts for 0.35 Gt reduction for <2 years (2% of removal).
    b. Cooling doesn’t account for multi-decade removal.
3. Full basin OIF

New data & innovation calls for LOF

1. **Satellite data** (NASA OCO-2) shows essentially zero atmospheric CO2 removal in non-eddy regions; High removal rates in downwelling eddies.
2. **Historical eruption CO2 data** show multi-decade CO2 removal only following eruptions with ashfall in regions with eddies.
3. **Nitrogen-fixing bacteria** increasing phytoplankton growth (near Tonga)
4. **Atmospheric CO2 removal** measurement techniques makes LOF easily testable.
    a. Surface buoys: Perimeter CO2 flux measurement
    b. Satellites: OCO-2, OCO-3, GOSAT, ESA CO2M

The funds for LOF are already budgeted

- Nearly 2000 companies have net-zero commitments
- Some, like Microsoft, are already investing more than $100M each
- Together, the voluntary carbon market is already $1T / year

Why aren’t those funds being used for LOF and climate restoration?

- The papers are still in peer review;
- Scientists are just starting to learn about it.

Clearly it's crazy to claim we could restore the climate afflordably. After all, people say the following:

1. "If we could restore the climate for $1 billion a year, we'd be doing it already."
2. "There's no peer-reviewed literature"... yet
3. "No one has invested in it"... yet
4. It's nuts to think we could remove 60 Gt CO2 / year through a natural process.
5. "It's too dangerous: hundreds of articles say so— just ask AI.
6. "We need at least another ten years of science before we can prove it's safe, effective, and scalable.
7. "The London Convention / London Protocol and EPA have NEVER permitted ocean fertilization.
8. "Certifying carbon credits using atmospheric CO2 removal has never been done and won't work. The MRV will never be approved.
9. "Greenpeace and other environmentalists will never allow this.
10. "If it works, LOF would let oil companies off the hook and we can't allow that
11. "Messing with the climate on a large scale is geoengineering, which is outlawed by the UN.
12. "Messing with the ocean is scary and the public will never allow it.
13. "Even if it could be done, it would need lots of government support.

LOF from pilot to full-scale (35 - 300 km eddies) by 2030

Year	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Stage	**Pilot**	Scaling	Scale 2	At scale	At scale	**At scale**
Issues resolved	Permits, approvals	Optimize process	Test alternate locations	Reduce costs	Continue optimizing	Full scale
# locations	**1**	**1**	**3**	**10**	**20**	**35**
Site diameter (km)	100	200	300	300	300	300
Removal rate Gt CO2 / year	**0.2**	**0.8**	**5.2**	**17.2**	**34.5**	**60.4**
Cost ($ / ton CO2)	$0.021	$0.017	$0.013	$0.011	$0.009	$0.009
Total cost ($M)	**$4**	**$13**	**$69**	**$184**	**$295**	**$516**

Timeline

2026: Publish papers, Funding for pilot

2027: Pilot, funding for optimization

2028: Optimization; Find optimal locations; get permits

2029: Scale-up

2030: Net-zero achieved.

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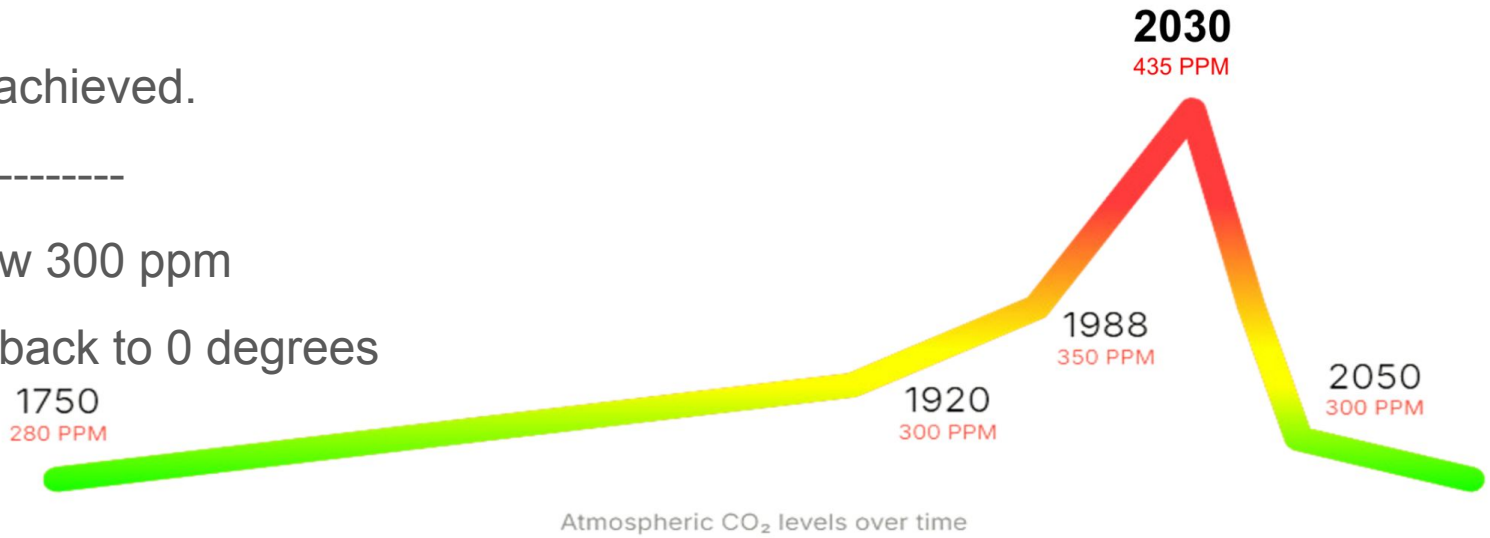
2050: CO2 below 300 ppm

2100: Warming back to 0 degrees



Could the Club of Rome break the climate gridlock?

And if so, how might that happen?

1. Focus on giving our children safe CO2 levels.
2. Emphasize solutions that are affordable at scale.
3. Insist that now is the time for action, not debate.
4. Emphasize that the cost of *not* restoring is…everything we hold dear, while the cost of restoration is negligible.
5. Safety is ensured with data, not speculation. As with every responsible project, monitoring will occur and we can course-correct as needed.

Mission: Enable humanity to flourish for millennia to come

A paradigm shift

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2. Nature has done it and humanity can too.
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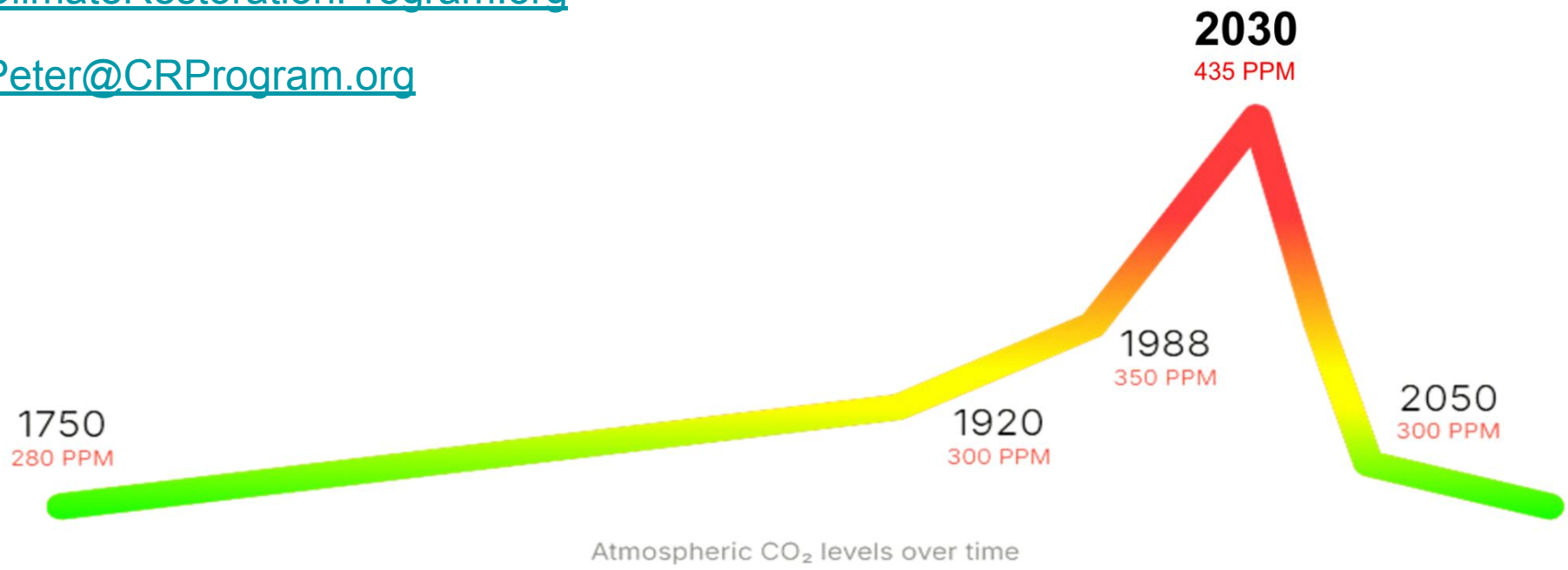
5. You need the new facts to give good advice.

Resources

ClimateRestoration.substack.com

ClimateRestorationProgram.org

Peter@CRProgram.org



Abstract:

Our climate is a disaster; net-zero won't restore it. We seek climate restoration: safe CO2 levels for future generations ("Humanity flourishing for millennia to come").

Analysis shows nature removed 20 Gt CO2/year after the Pinatubo eruption, and that carbon remains removed 35 years later. The only hypothesis explaining this is Localized Ocean Fertilization ("ocean eddy fertilization"), which is safe, understood, and low-cost. Corporations have sufficient funds budgeted for net-zero. What is stopping implementation? Who is the gatekeeper, and how do we open the gate?

Club of Rome: Its main objective is to further the sustainability of the global ecosystem including the survival of humanity.

Climate restoration: The facts

1. The goal of climate action is restoring safe CO2 and climate—like we had 50-100 years ago.
2. Achieving that will requires removing 1,000 Gt tons of CO2. That comes to 60 Gt / year.
3. Nature got us near net-zero in 1992, after Pinatubo. Natural processes removed 20 Gt CO2, for free, without planning or optimization.
4. Replicating that effect through biomimicry is projected to cost <$1 /ton CO2.
5. No significant environmental problems have been reported in 13 ocean tests of iron fertilization.
6. Amply funded permanent CDR methods (DAC, OAE…) still cost $350 to $1200 / ton CO2.
7. Barriers to LOF at <$1 /ton CO@ are not technical, but social and political.