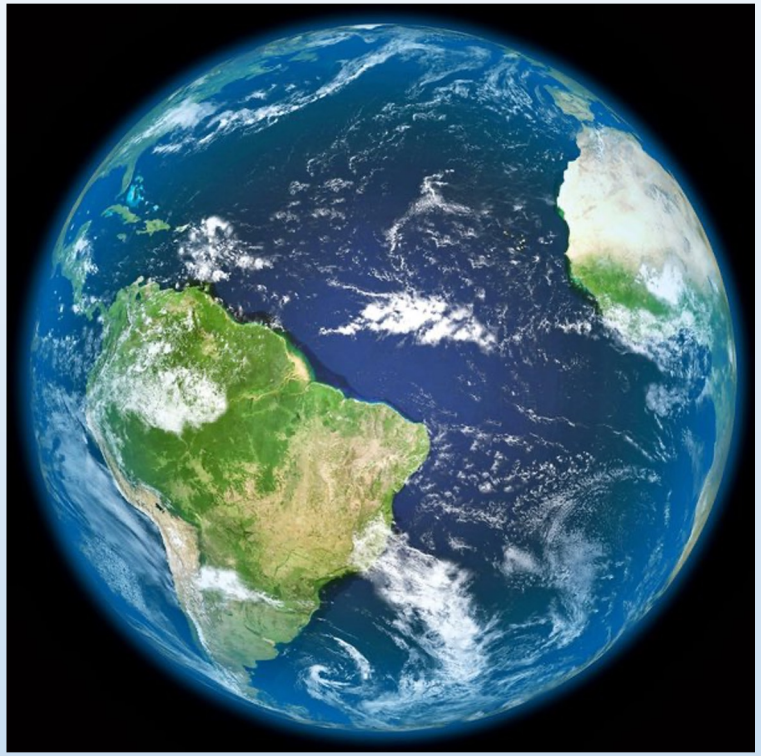
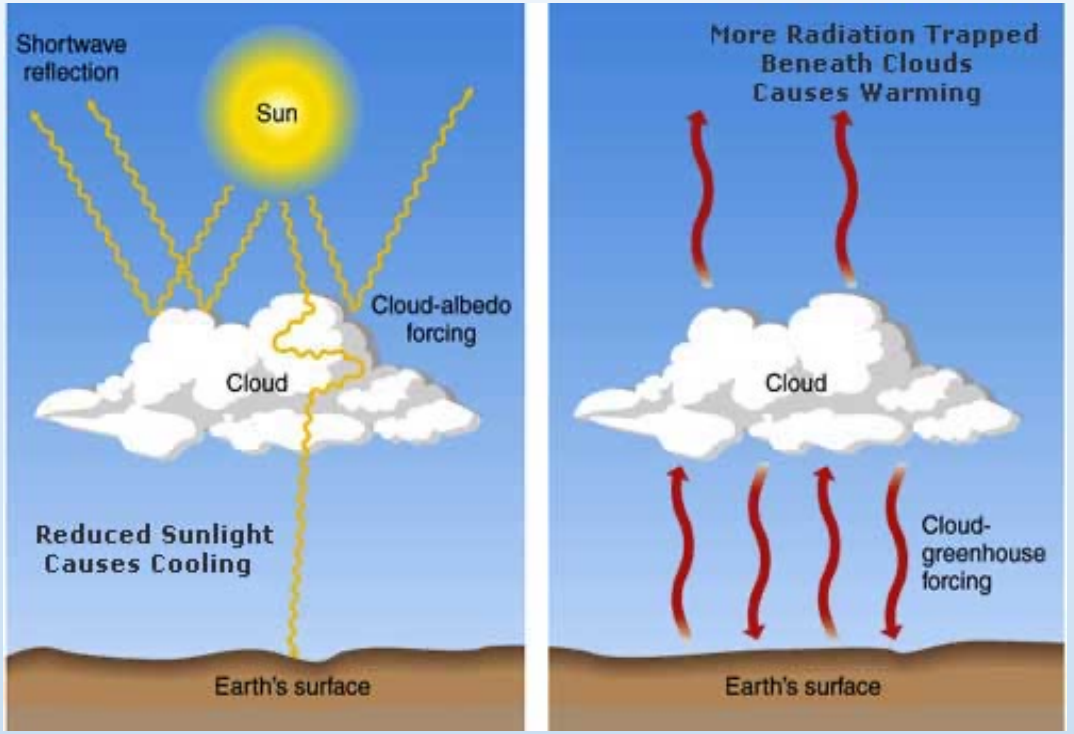
Global Climate Crisis: Science and Solutions

U4CE: April 10, 2022

Climate Science: Key Terms



- **Melting of the Poles:**
  ← **Arctic** = frozen ocean
- **Role of Albedo** →
- **Jet Stream**
- **Ocean Currents**
- **Atmosphere:**
  -- **Troposphere,**
  -- **Stratosphere,**
  -- **Mesosphere,**
  -- **Thermosphere,**
  -- **Exosphere**
- **Melting of the Poles:**
  ← **Antarctica** = land surrounded by ocean ice shelf



Terrestrial: Sources and Sinks: Reduce carbon emissions by switching from fossil fuels to Renewables with storage and efficiency. Drawdown Climate Solutions: Transportation, regenerative agriculture, vegetable based diet, etc.

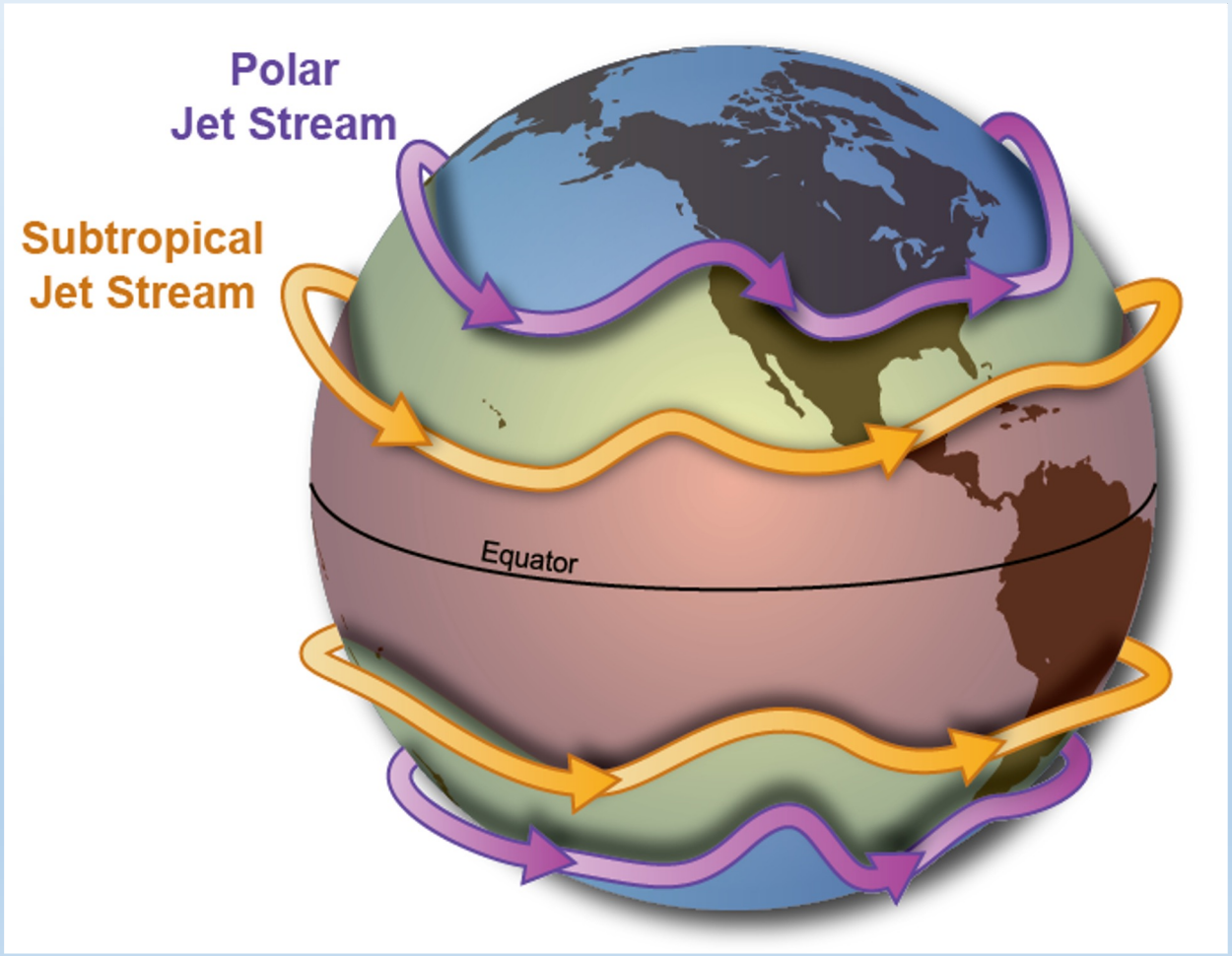
Oceanic: Phytoplankton reflect or absorb heat/CO2; Mechanical upwelling and downwelling technologies

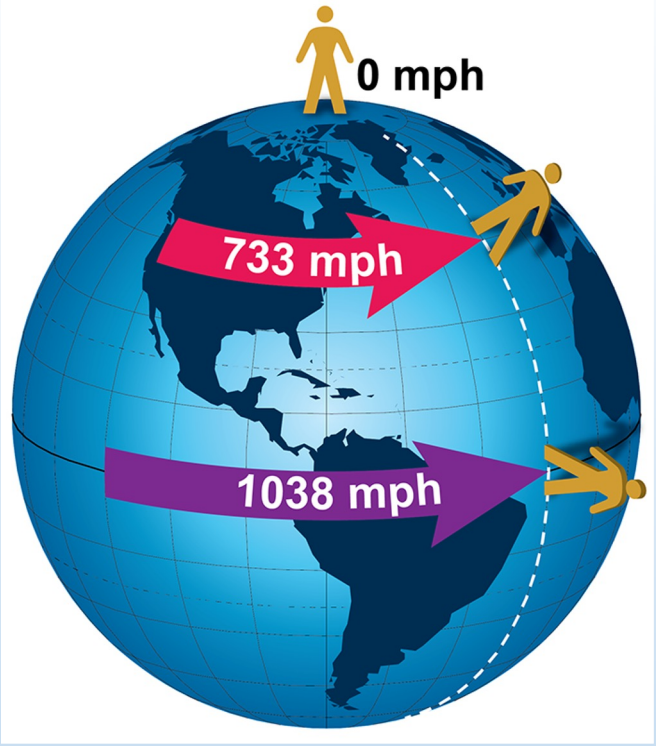
Polar: Both poles are melting. Arctic is 30^{o}C warmer; Antarctic 40^{o}C. Cooling and refreezing polar Ice caps is being considered.

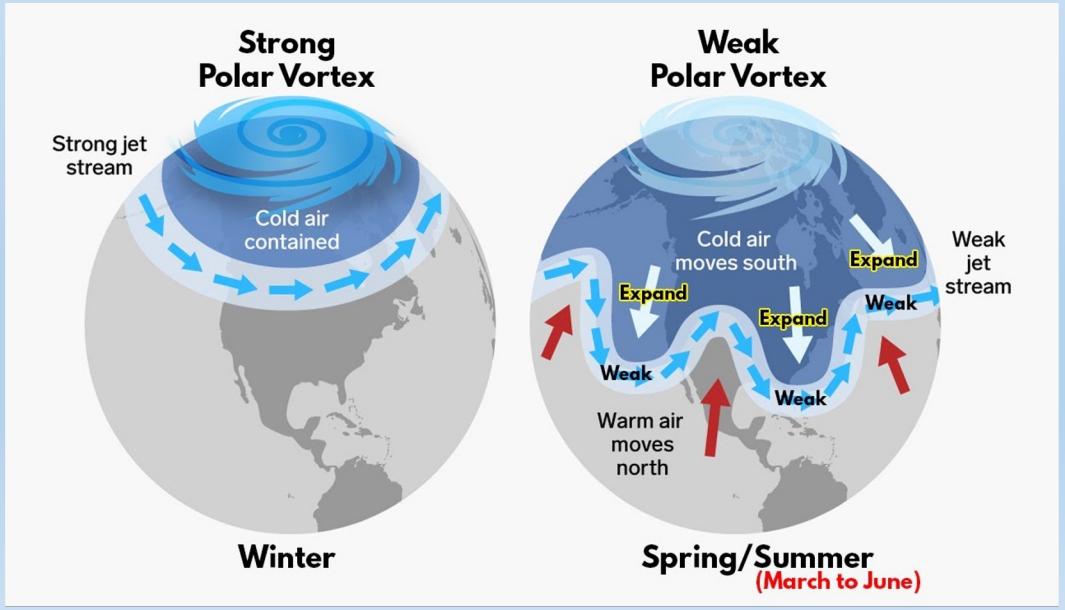
Atmospheric: Enhancing albedo to reflect more sunlight and, especially, cool the poles

Calming the Distorted Jet Stream

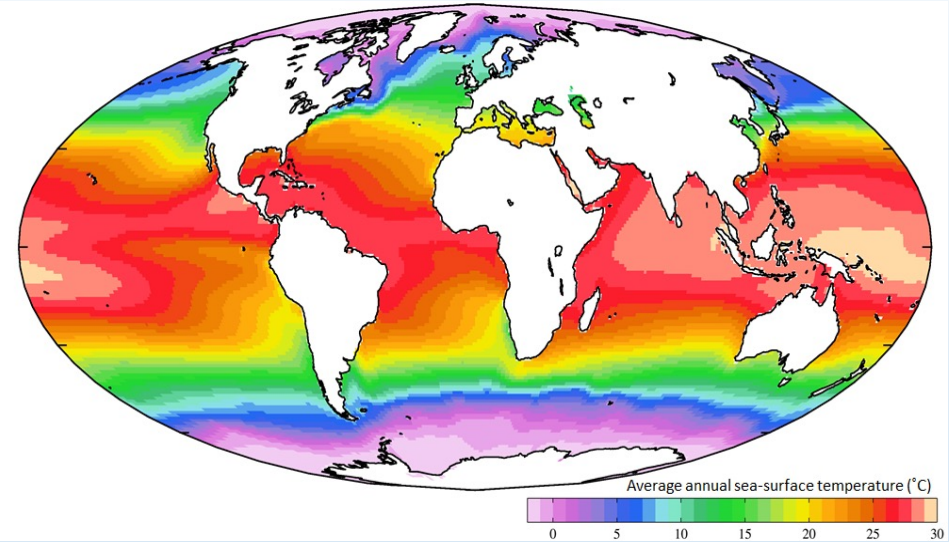
https://youtu.be/Lg91eowtfbw
https://www.weather.gov/jetstream/jet

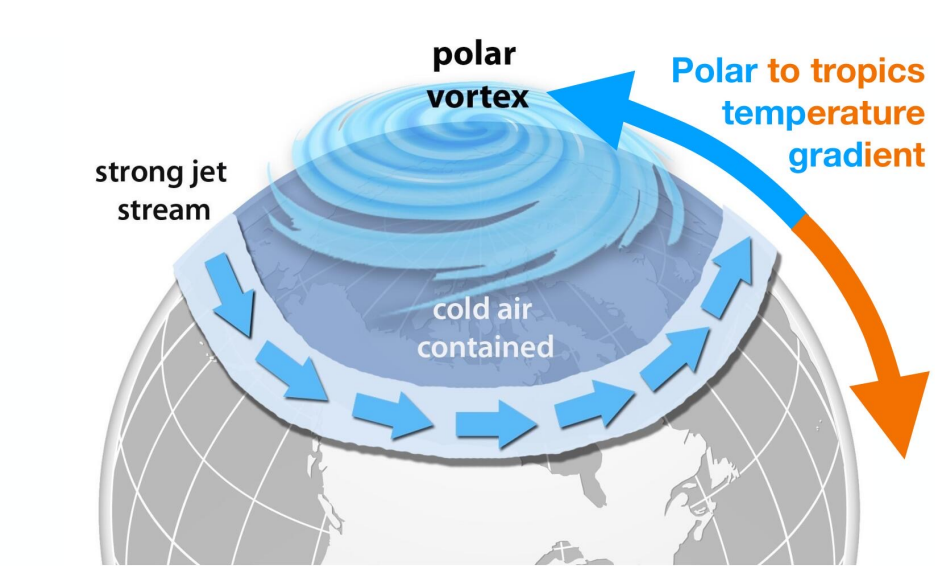


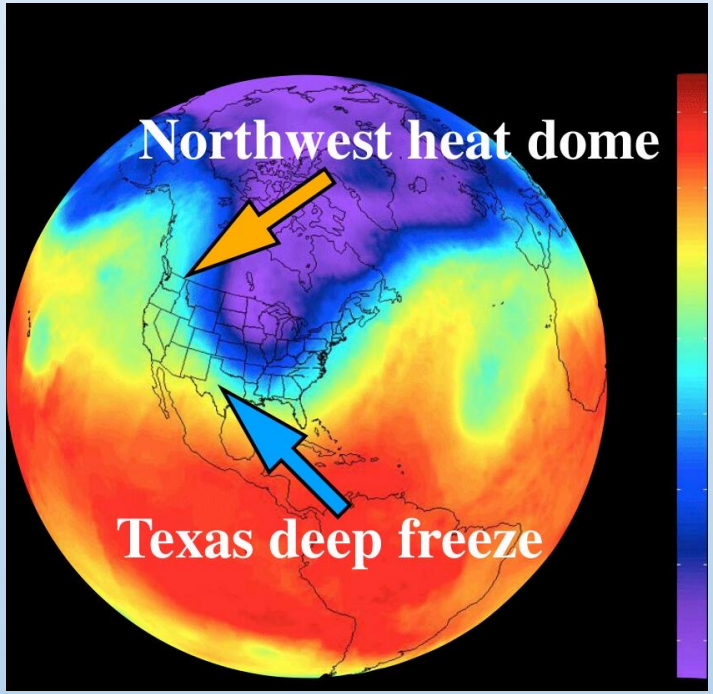


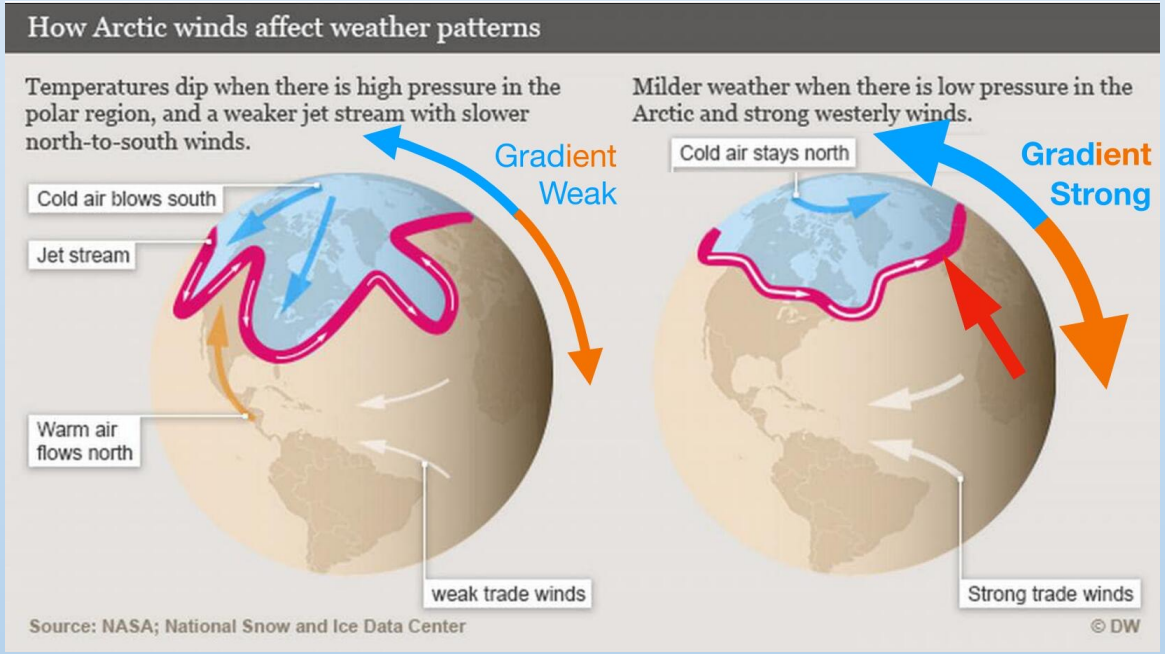


Polar to Tropics Temperature Gradient

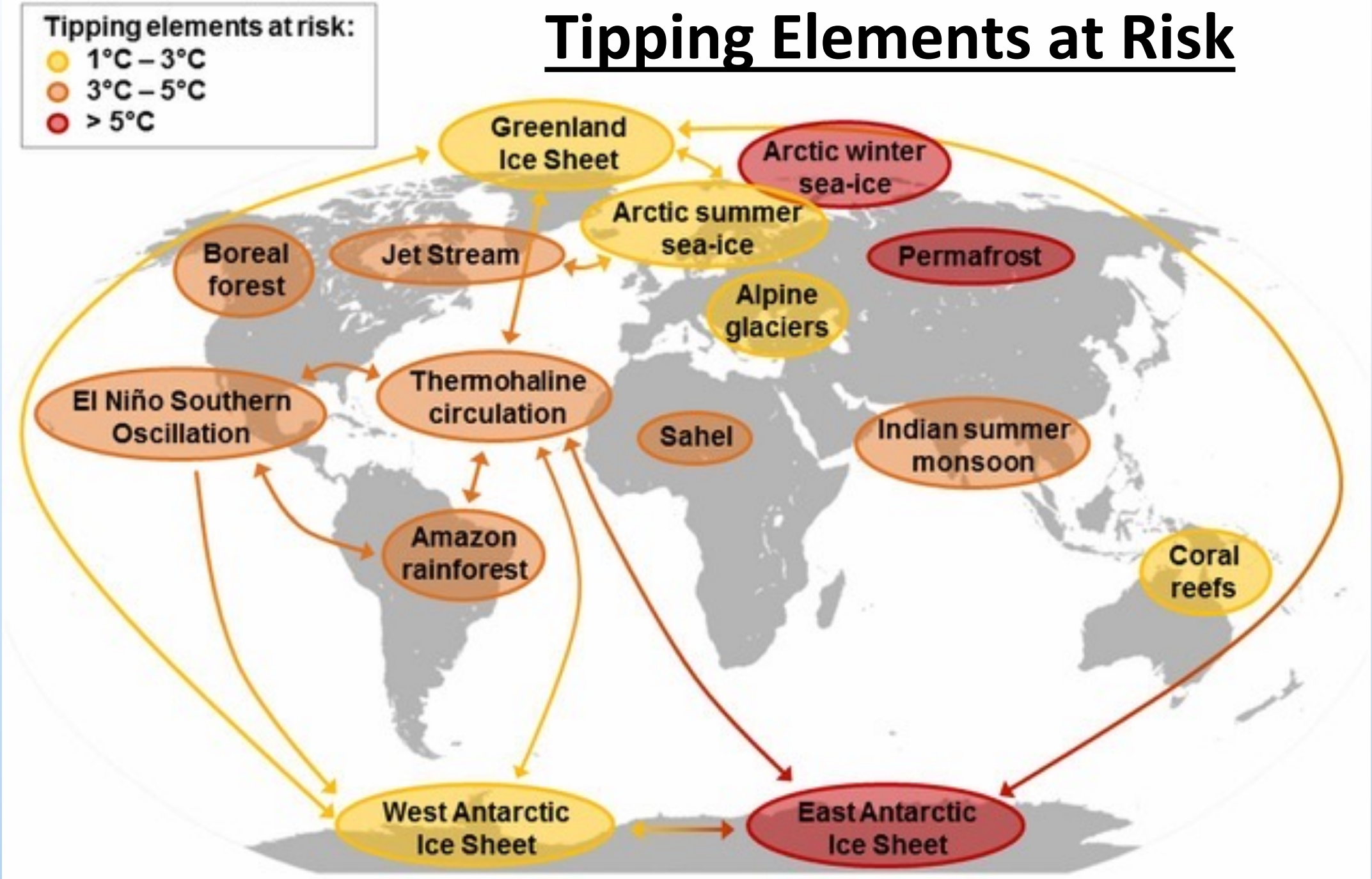






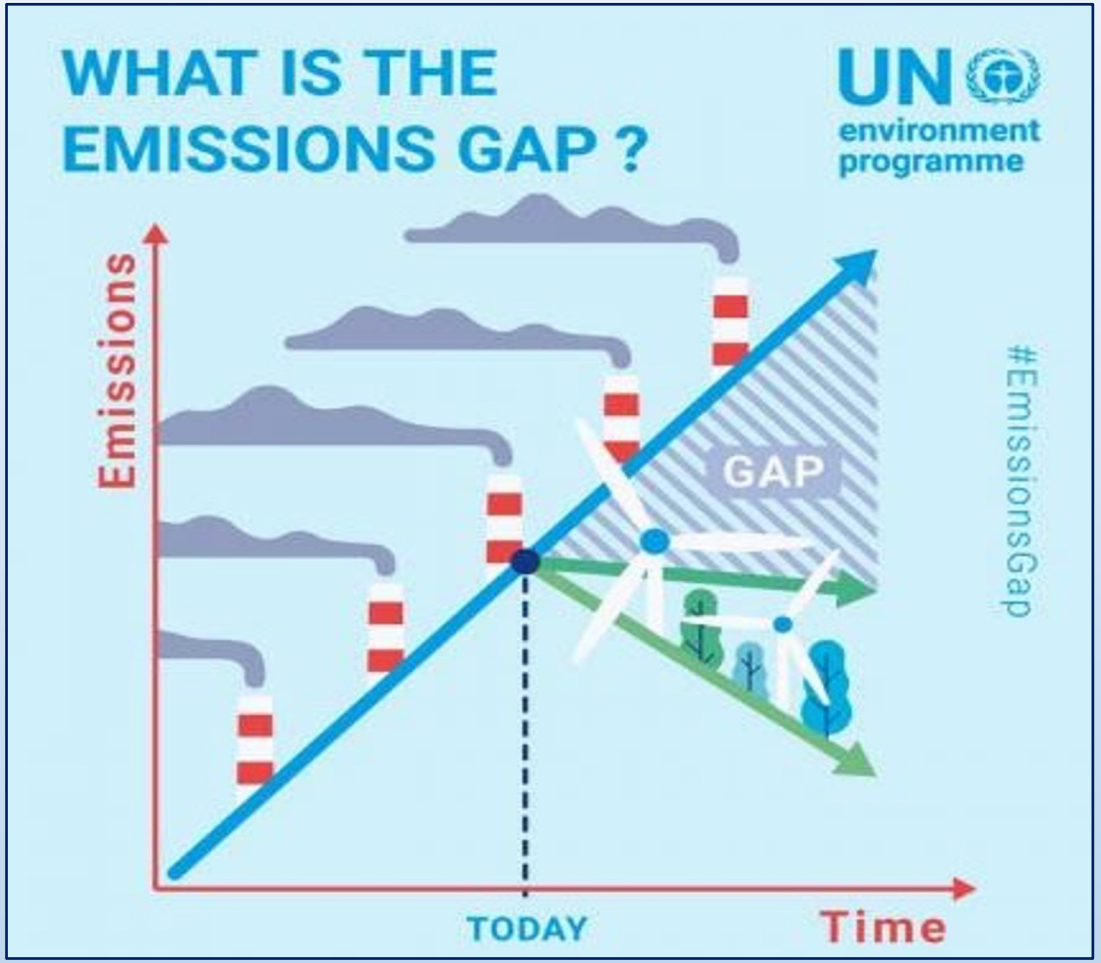


Tipping Elements at Risk

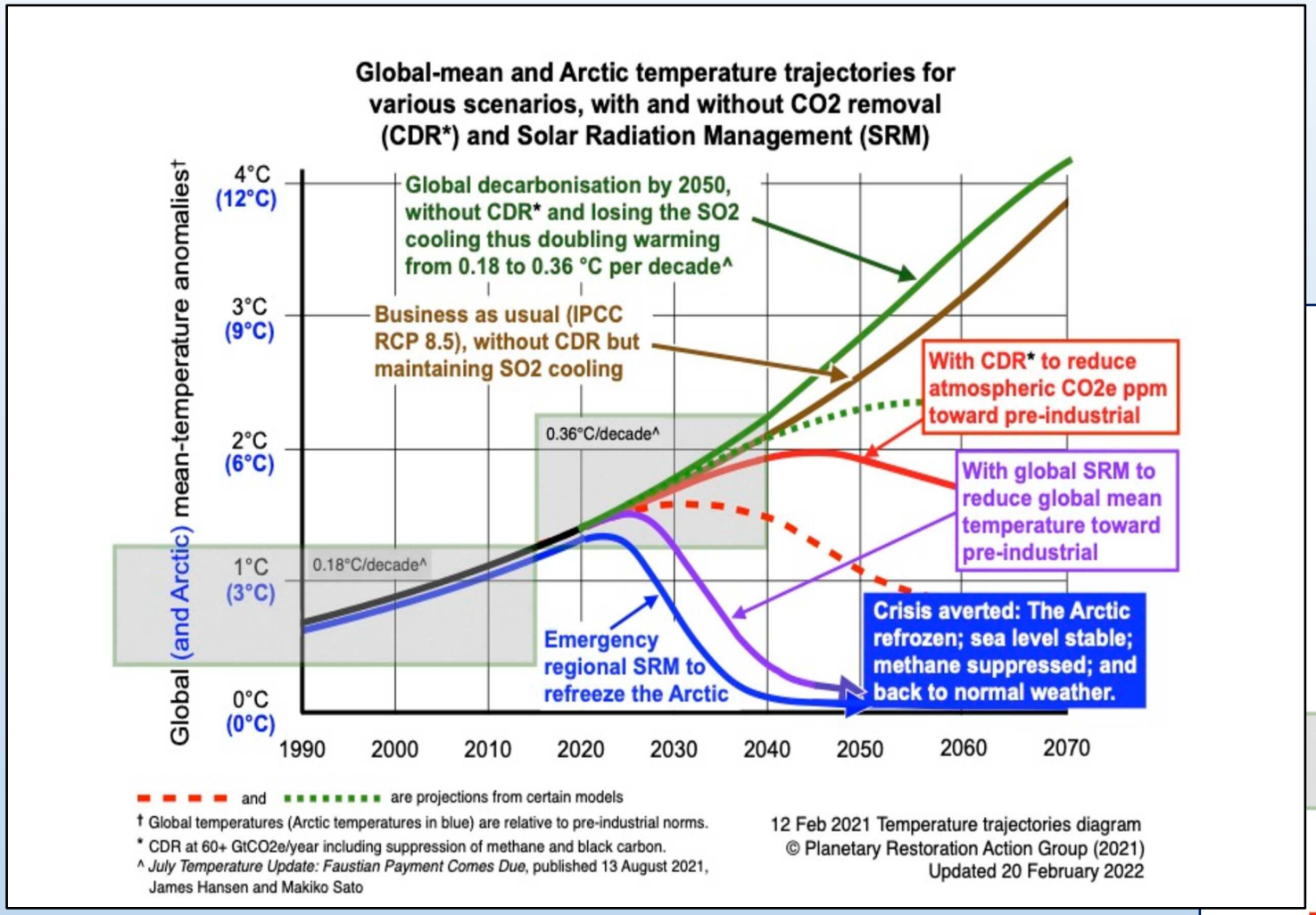


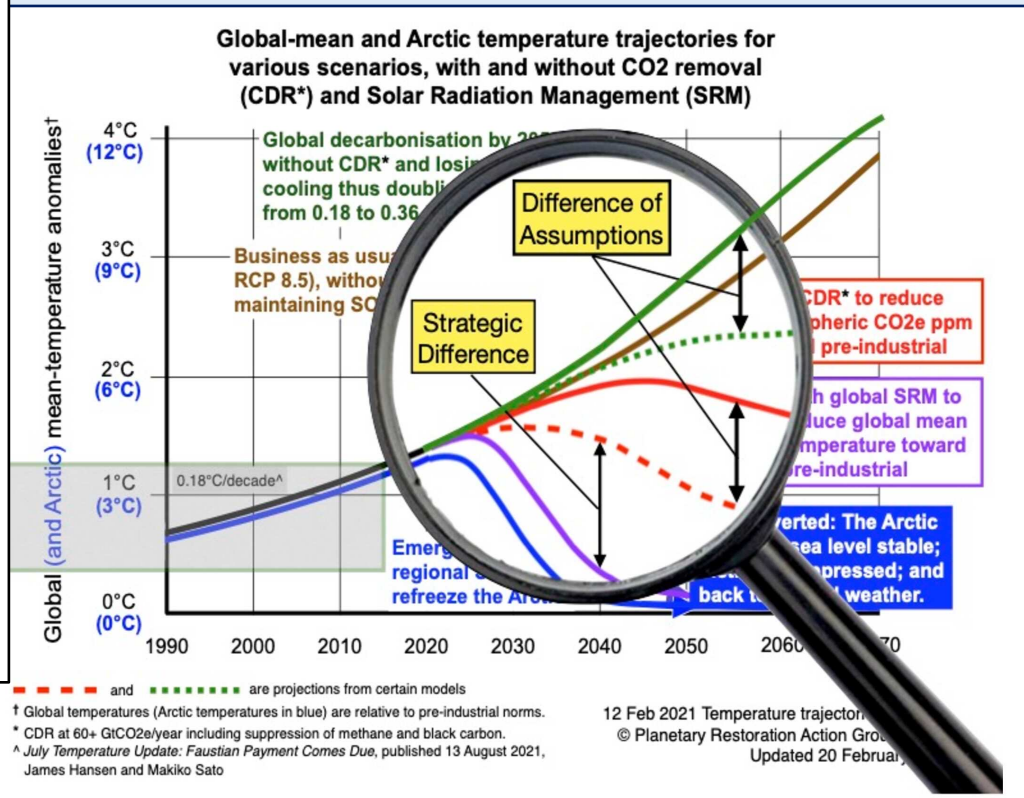
The Gap

- Understanding the Gap between Emissions Reduction/Carbon Sequestration and what is needed to restore a livable climate balance is critical to understanding the need for urgent action -- beyond terrestrial climate solutions.
- How wide is the gap?
- What is the timeline for action?
- Is there a role for Climate Engineering? Risks (unintended consequences) and Rewards

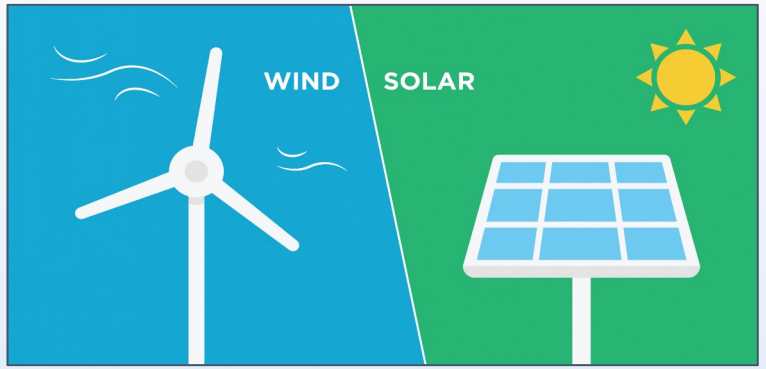


Another Way to View the Gap



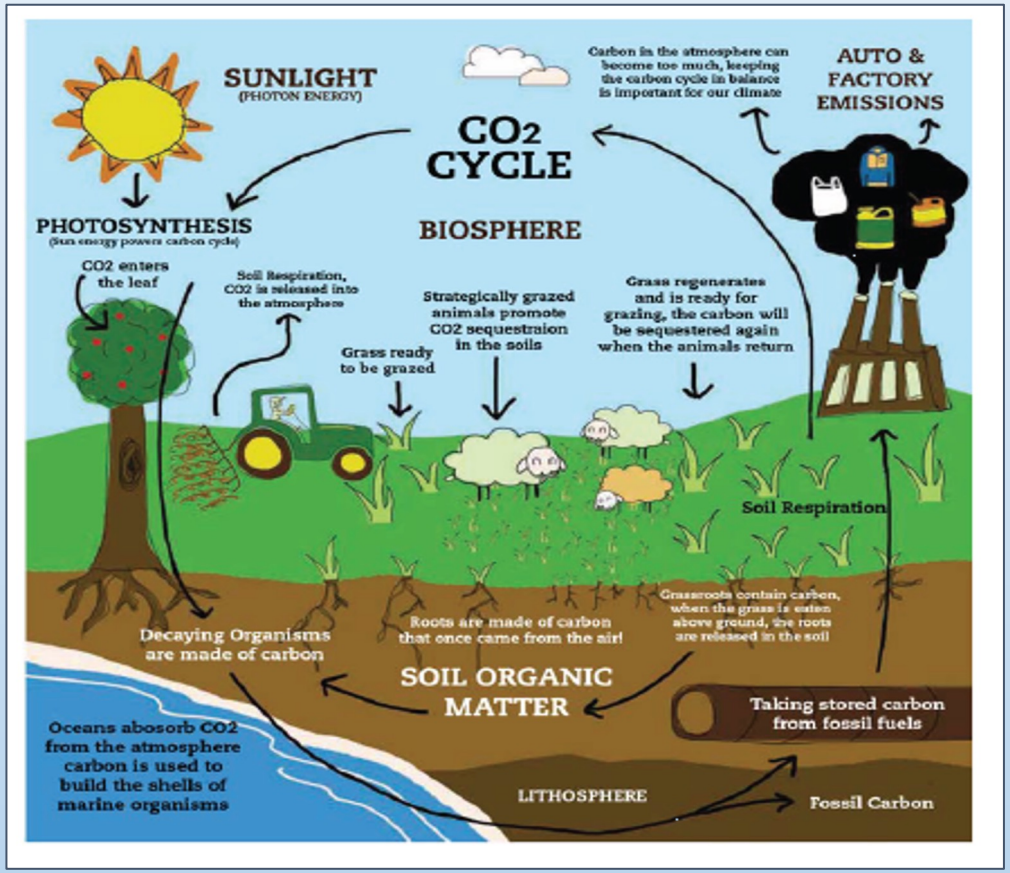


Terrestrial Solutions



Terrestrial: Sources and Sinks

- **Emissions Reduction (ER): Reduce carbon emissions** by switching from fossil fuels to Renewables with storage and efficiency.
- **Carbon and other Greenhouse Gas Sequestration (CS):** Regenerative agriculture, reforestation, protecting wetlands
- Other Climate Solutions as per **Drawdown:** Transportation, vegetable based diet, refrigerant management, etc.



DRAWDOWN CLIMATE SOLUTIONS

Electricity

Wind Turbines (#2) (On and Offshore)

Proliferation of turbines, dropping costs and heightened performance can supply the world with clean power. Wind farms are at the forefront of addressing global warming.

Rooftop Solar (#10)

As cost falls, economies of scale in manufacturing and advances in phototechnology make rooftop solar available worldwide.

Energy Storage

Vital to reduce emissions from polluting "peaker" plants and shift to variable renewables.

Solar Farms (#8)

Tapping the sun's unlimited clean and free fuel using large-scale arrays of hundreds, thousands, or millions of photovoltaic panels.

Building and Cities

Green Roofs

Use soil and vegetation as living insulation and reflect solar energy. Both reduce energy use for heating and cooling.

Insulation

One of the most cost-effective ways to improve energy efficiency, both in new construction and retrofitting older buildings.

Net Zero Buildings

With zero net energy consumption, net zero buildings produce as much energy, through onsite renewables, as they use in a year.

Walkable Cities

Prioritize two feet over four wheels through planning and design. Emissions decrease with less driving and more walking.

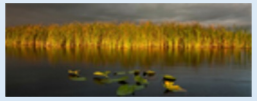
Forestry and Land Use

Indigenous People's Land Management

Growing acreage under secure indigenous tenure can increase carbon stocks and reduce greenhouse gas emissions.

Tropical Forests (#5)

Have suffered extensive clearing, fragmentation, degradation and depletion of biodiversity. Restoring them may sequester as much as six gigatons of carbon dioxide per year.



Coastal Wetlands

Salt marshes, mangroves and sea grasses provide vital habitat, flood protection and water filtration, and sequester huge amounts of carbon.

Afforestation/ Reforestation

Creating forests where there were none and restoring those that were depleted draws carbon in and distributes it into the soil.

Women and Girls

Family Planning (#7)

Securing women's right to voluntary, high-quality family planning dramatically improves the health and well-being of women and their children. Smaller families create less emissions.

Educating Girls (#6)

Lays a foundation for vibrant lives for girls and women, their families and their communities. It also avoids emissions by curbing population growth.

Materials

Refrigerant Management (#1)

The primary chemical refrigerant, HFCs, is a potent greenhouse gas. Emissions are avoided by managing leaks and disposal and by ultimately phasing out the use of HFCs with less harmful alternatives.

Industrial Recycling

Reduces emissions when new products are made from recovered materials, and can also address the challenge of resource scarcity.

Food and Farming

Reduced Food Waste (#3)

Uneaten food squanders resources and generates 8% of GHG emissions. We can greatly reduce waste as food moves from farm to fork.

Plant-Rich Diet (#4)

Meat-centric diets come with a steep climate price tag: 1/5 of global GHG emissions. Plant-rich diets dramatically reduce emissions and chronic disease.

Silvopasture (#9)

Integrating trees and pasture into a single system for raising livestock sequesters carbon while improving animal health and productivity.

Regenerative Agriculture (#11)

Carbon-rich soil increases organic matter, enhances and sustains soil health, sequesters carbon, and improves productivity.

Transportation

Mass Transit

Riding a streetcar, bus, or subway averts greenhouse gases, relieves traffic congestion and reduces air pollution.

High Speed Rail

One of the fastest way to travel between 100 to 700 miles, high speed rail can reduce emissions up to 90%.

Electric Vehicles

If powered by solar energy, carbon dioxide emissions from EVs drop by 95% compared to gas-powered cars.

Electric Bikes

The most environmentally sound means of motor transport in the world today.

Coming Attractions

Ocean Farming

Small-scale farms can provide food and biofuel, while oysters filter nitrogen and seaweed sequesters CO_2.

Living Buildings

Benefitting both people and the planet, living buildings produce more energy than they use.

Marine Permaculture

Floating, latticed structures grow rich kelp forests and foster marine life, while sequestering billions of tons of carbon dioxide.

Telepresence

Enabling people who are geographically separated to interact, it reduces emissions by reducing travel.

DRAWDOWN SOLUTIONS

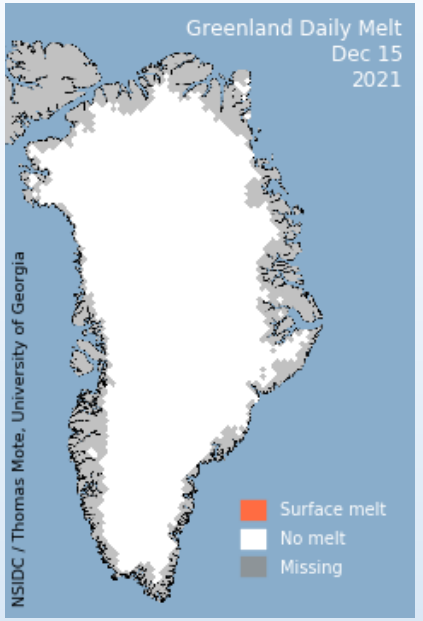
"When it comes to global warm ing we've been focusing too much on the problem instead of the solution... Regenerative development actually heals the future as opposed to stealing from it, which is what we're doing today." ~ Paul Hawken, *Drawdown*

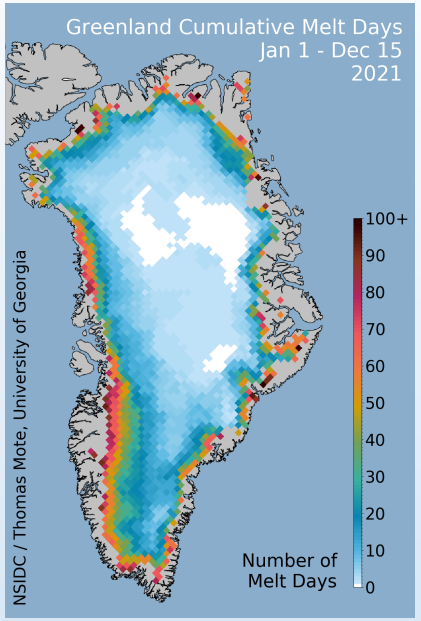
Rank	Solution	Sector	TOTAL ATMOSPHERIC CO_2 REDUCTION (Gt)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	Refrigerant Management	Materials	89.74	N/A	$-902.77
2	Wind Turbines (Onshore)	Electricity Generation	84.80	$1,226.37	$7,425.00
3	Reduced Food Waste	Food	70.53	N/A	N/A
4	Plant-Rich Diet	Food	66.11	N/A	N/A
5	Tropical Forests	Land Use	61.23	N/A	N/A
6	Educating Girls	Women and Girls	59.60	N/A	N/A
7	Family Planning	Women and Girls	59.60	N/A	N/A
8	Solar Farms	Electricity Generation	38.80	$-80.80	$5,023.91
9	Silvopasture	Food	31.19	$41.09	$869.37
10	Rooftop Solar	Electricity Generation	24.80	$450.14	$3,457.63
11	Regenerative Agriculture	Food	23.15	$57.22	$1,020.10
12	Temperate Forests	Land Use	22.61	N/A	N/A
13	Peatlands	Land Use	21.57	N/A	N/A
14	Tropical Staple Trees	Food	20.19	$120.07	$520.97
15	Afforestation	Land Use	19.06	$28.71	$382.33
16	Conservation Agriculture	Food	17.36	$37.53	$2,119.07
17	Tree Intercropping	Food	17.20	$146.09	$22.10
18	Geothermal	Electricity Generation	16.60	$ 155.48	$1,024.34
19	Managed Grazing	Food	16.34	$50.48	$735.27

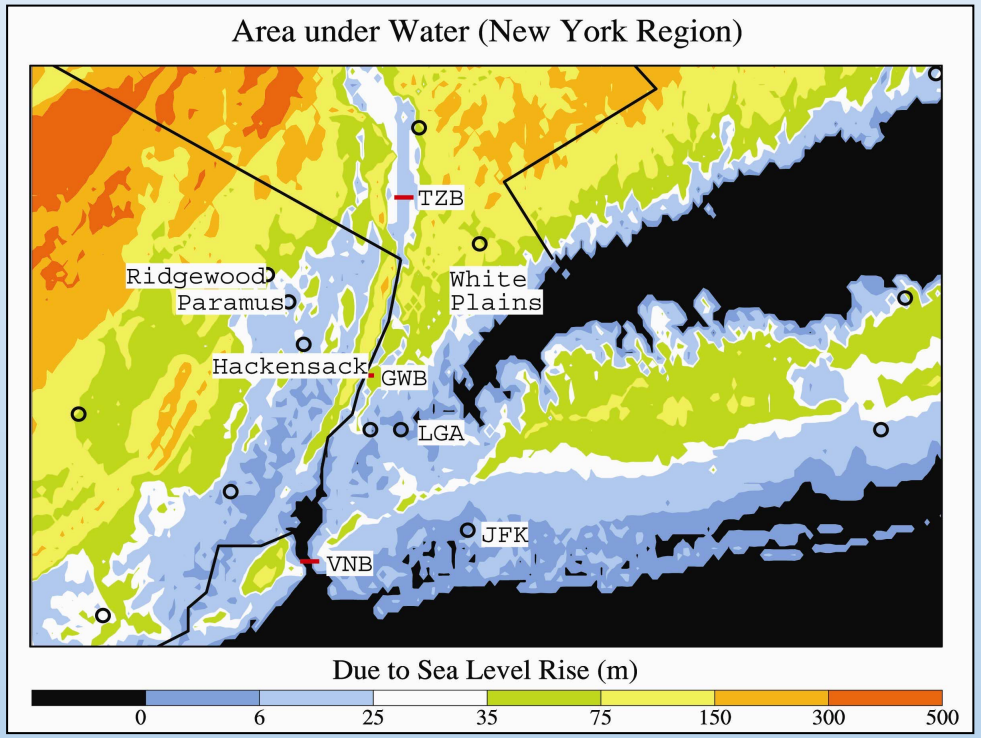
Polar Melting Exacerbates Sea Level Rise

Need for Arctic Cooling:

- [Base of the Greenland ice sheet is melting faster than we thought] **2/21/22**
- [Himalayan glaciers are melting at an extraordinary rate, research finds] **12/20/21**





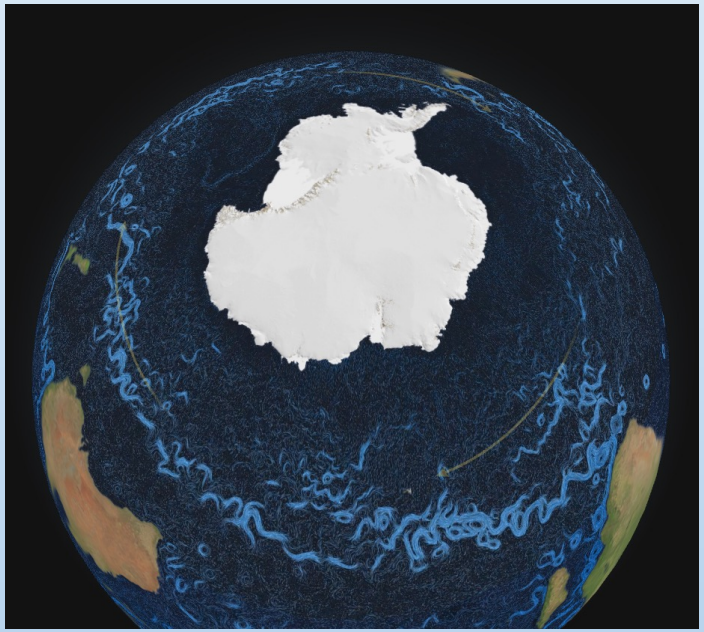


Antarctic: The New York Times

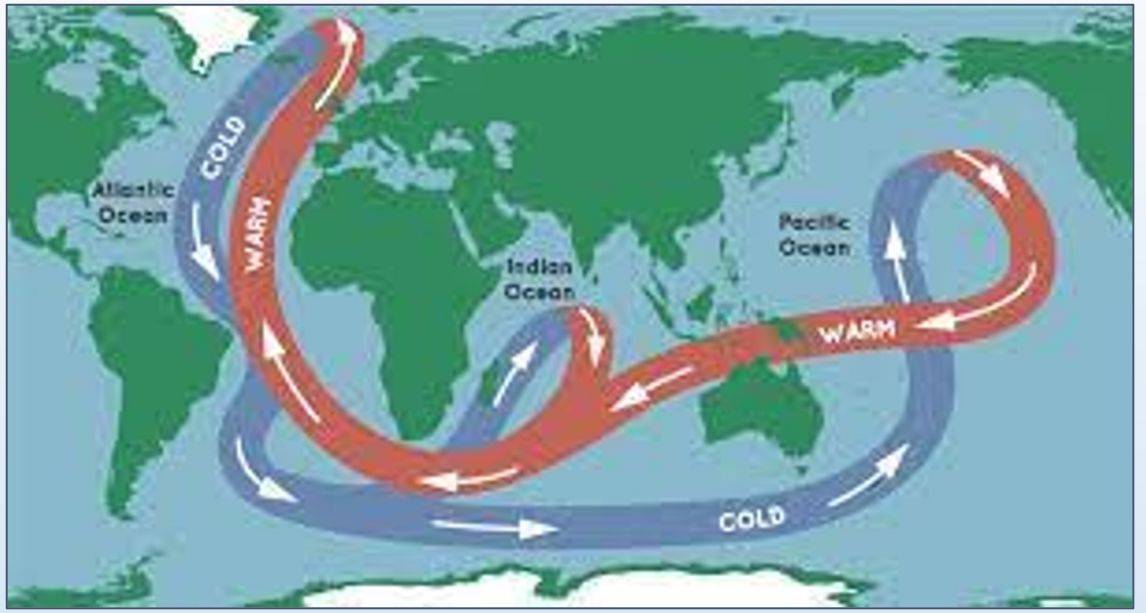
[Rising From the Antarctic, a Climate Alarm]: Wilder winds are altering currents. The sea is releasing carbon dioxide. **12/13/21**

The Southern polar shelf ice melting is from below due to the **Antarctic Circumpolar Current,** which receives water the from the Atlantic, Pacific and Indian oceans

The melting of both poles and warmer oceans are accelerating sea level rise (SLR)



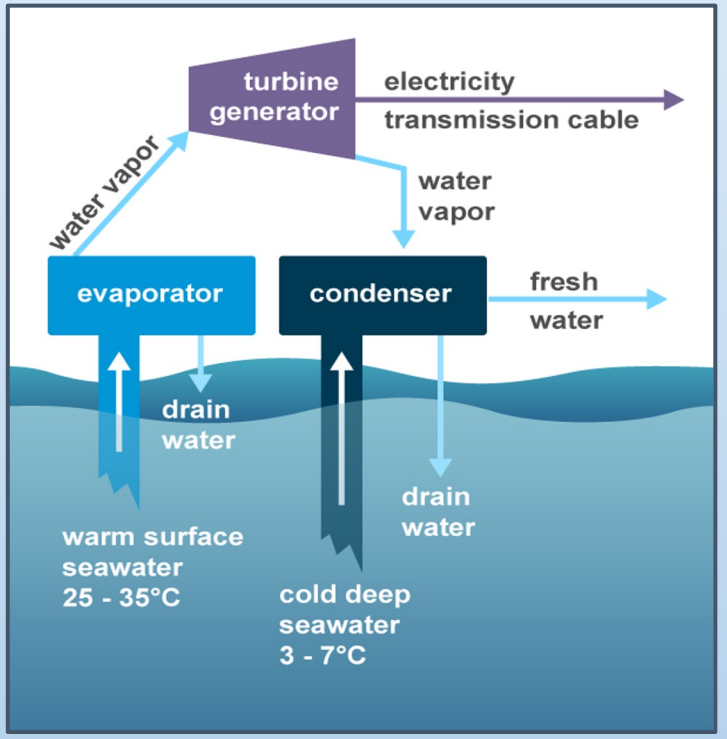
Oceanic



State of the Oceans:

- Ocean acidification
- Coral bleaching; loss of Great Barrier Reef
- Impact of Loss of Whales
- Plastic proliferation

Ocean Thermal Energy Conversion (OTEC) is a process that can produce electricity by using the temperature difference between deep cold ocean water and warm tropical surface waters. OTEC plants pump large quantities of deep cold seawater and surface seawater to run a power cycle and produce electricity.



Possible Climate Restoration Technologies:

- Farming of Phytoplankton that reflects heat or absorbs CO_2
- Mechanical upwelling and downwelling technologies

Carbon Dioxide Removal (CDR) from the Oceans

Approaches being considered include:

- Iron, nitrogen, or phosphorus fertilization
- Artificial upwelling and downwelling
- Seaweed cultivation; aka phytoplankton farming (Algae)
- Recovery of ocean and coastal ecosystems, including large marine organisms
- Ocean alkalinity enhancement to reduce acidification
- Electrochemical approaches.

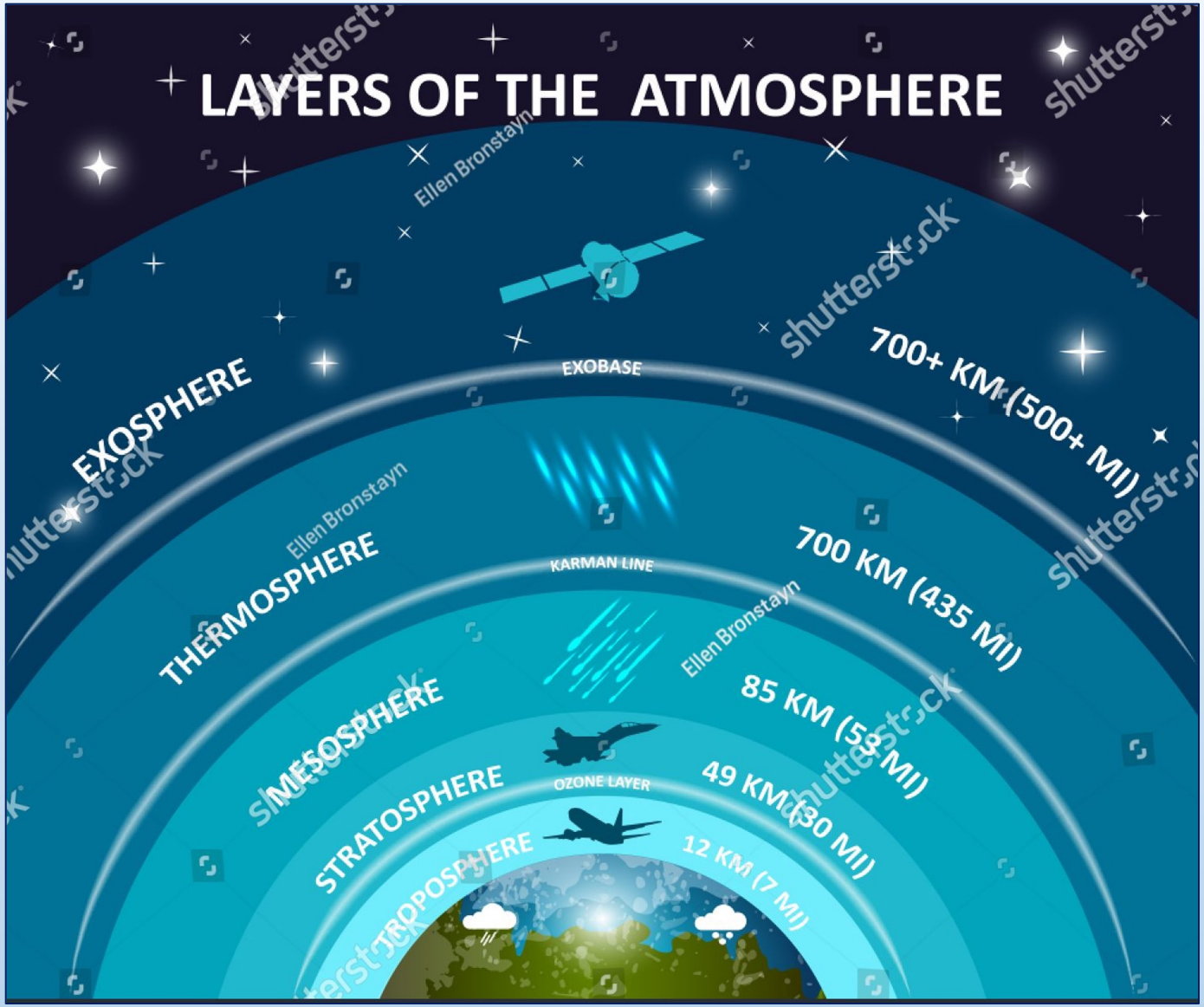
Six Ways to Remove Carbon Pollution from the Sky

1) **Forests: Protection and Reforestation**
2) **Farms: Regenerative Agriculture**
3) **Bio-energy with Carbon Capture and Storage (BECCS)**
4) **Direct Air Capture**
5) **Carbon Mineralization**
6) **Ocean-based Concepts: (see above)**

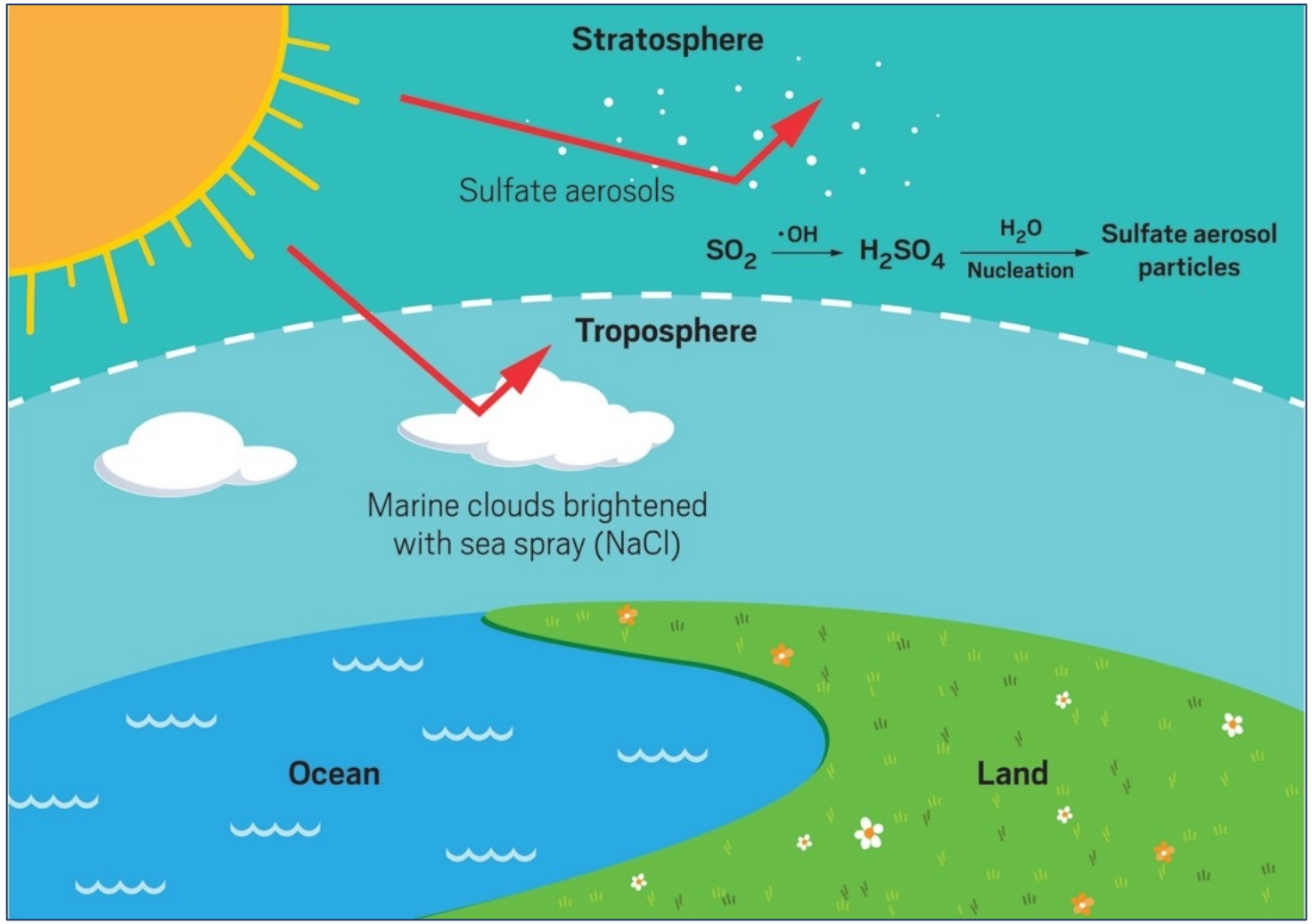
The Future of Carbon Removal…

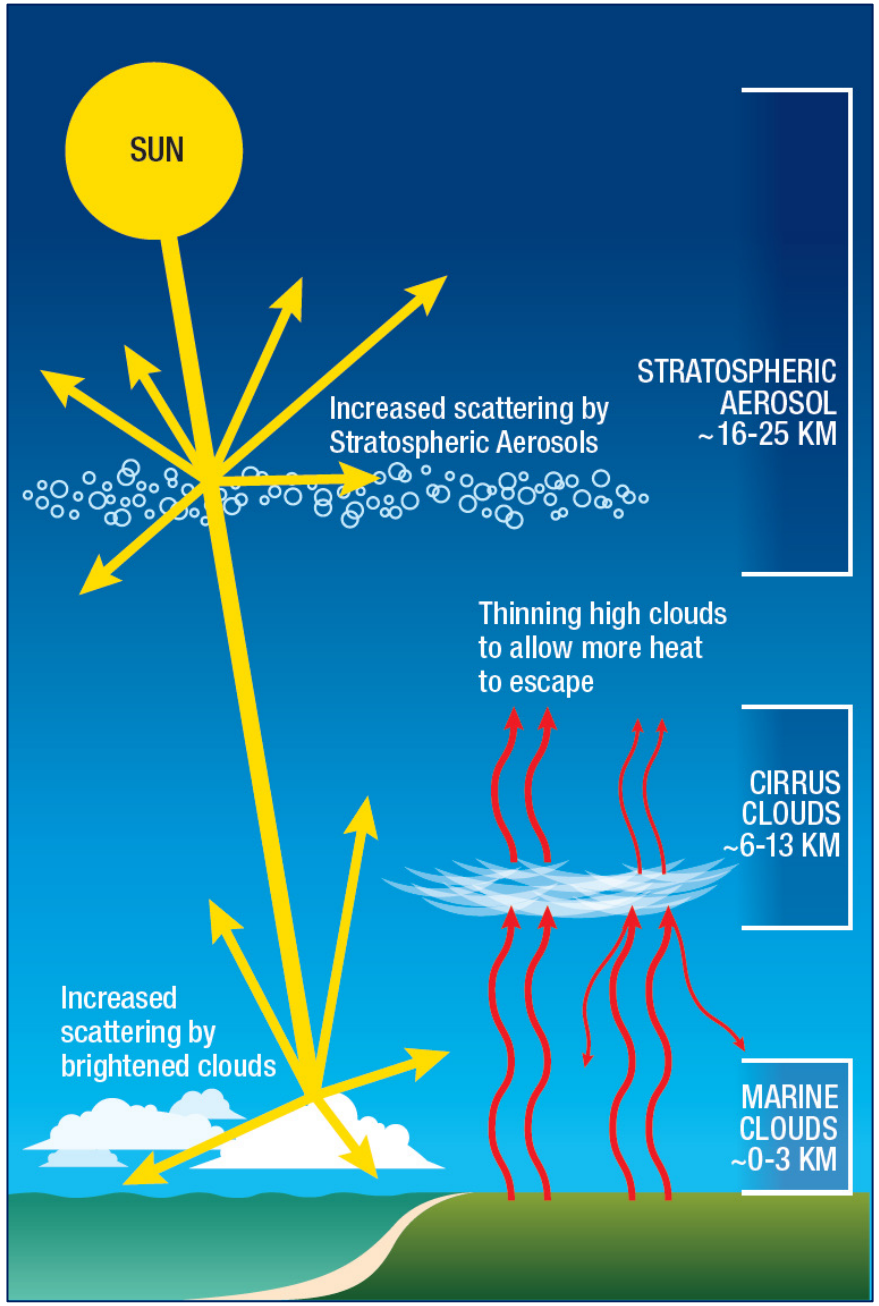
https://www.wri.org/insights/6-ways-remove-carbon-pollution-sky

Atmosphere


LAYERS OF THE ATMOSPHERE
EXOSPHERE
EXOBASE
700+ KM (500+ MI)
THERMOSPHERE
KARMAN LINE
700 KM (435 MI)
MESOSPHERE
85 KM (53 MI)
STRATOSPHERE
OZONE LAYER
49 KM (30 MI)
TROPOSPHERE
12 KM (7 MI)
Ellen Bronstayn

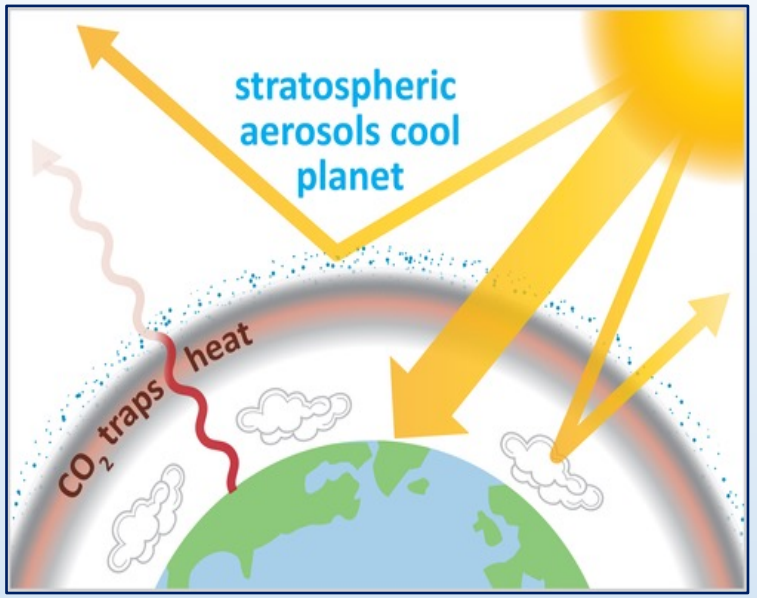
Marine Cloud Brightening (MCB) and Stratospheric Aerosol Injection (SAI)





What are the Differences between Albedo Modification and Carbon Dioxide Removal (CDR)?

Geoengineering technologies are conventionally organized into two main categories. **Albedo modification** (also referred to as **'solar radiation management' [SRM]** or 'solar geoengineering') methods include technologies designed to reflect a small fraction of incoming sunlight back to space in order to attenuate anthropogenic changes In temperature and other climate variables. Examples of **albedo modification technologies** include **stratospheric aerosol injection (SAI)** and **marine cloud brightening (MCB).** SAI would introduce small particles into the upper atmosphere to scatter sunlight back to space; MCB would spray seawater into low-lying marine cloud formations thereby whitening clouds and increasing their **albedo (reflectivity).**



Carbon dioxide removal (CDR) (also **'air capture'** or **'direct carbon removal' [DCR]),** by contrast, seeks to draw down and sequester carbon dioxide from the air, so as to reduce the overall concentration of CO2 in the atmosphere. CDR methods include **direct air capture of carbon dioxide by chemical means using industrial-scale plants**, and **bio-energy with carbon capture and storage**, which combines carbon capture technology with biomass as an energy source to produce "negative emissions" of CO2.

While CDR methods entail novel technologies, innovative processes, and new technical configurations, the most plausible carbon extraction techniques **closely resemble existing mitigation approaches (such as afforestation, sustainable land-use management, and carbon capture and storage),** and hence present few (if any) wholly original problems. In fact, in economic analyses of mitigation, bio-energy with carbon capture and storage plays a major role in most scenarios of aggressive emissions cuts.

Albedo modification technologies, would be relatively **fast-acting (yielding results in years to decades),** comparatively **inexpensive** (costing as little as $1 to $10 billion per year), and extremely high-leverage in their effects (a gram of aerosol in the stratosphere can offset the warming effect of a ton of carbon dioxide, representing a factor of a million to one).

Climate-modeling studies show **that albedo modification is surprisingly effective, offsetting many but not all climate risks associated with global warming.** Indeed, the results of these studies, combined with observations of the effects of natural perturbations of the atmosphere such as volcanic eruptions, suggest there is little doubt that albedo modification could limit global mean temperature rise to 2°C. These attributes make albedo modification a potentially hugely disruptive technology on a truly global scale. Because of these large differences between albedo modification and carbon dioxide removal methods, the Keith Group focuses only on albedo modification.

https://keith.seas.harvard.edu/albedo_modification_v_cdr

Other forms of Cooling the Planet and Refreezing the Arctic

- **MEER: Mirrors for Earth's Energy Rebalancing (MEER:ReflEction):** Resource-Driven Engineering Leveraging Earth's Chemistries to Immediately Offer Remediation
- Anthropogenic aerosols and greenhouse gases (GHG) enter the atmosphere as peoples exercise their unalienable rights in pursuit of well-being and prosperity. Once airborne, the aerosols cool the Earth almost as much as co-emitted GHG warm it. This balancing act has masked an additional 1C of warming, should the aerosols disappear when phasing out the fossil fuels without compensatory solar radiation management. In this scenario, existing knowledge about ecosystem responses project a probable biological annihilation of already shifting and collapsing ecosystems. Rarely discussed, the inconvenient truth of the cooling effect of anthropogenic aerosols renders the sum of incremental adaptation measures insufficient for halting an ongoing extinction episode of complex life on this planet, regardless of the scale and speed of their implementation.
- Here, we step back to take a holistic view of planet Earth to design a geoengineering project compatible with the laws of physics, empirical evidence of ecosystem functioning, and crucially the material, energy, economic, and sociopolitical constraints. *MEER:ReflEction* applies aluminum-coated glass mirror arrays for solar radiation management. We find it feasible and necessary to deploy the mirror arrays within single-digit years to fully rebalance Earth's energy. We find the cost for full implementation comparable to the projected increase in risk to global assets by 2030 in the event of inaction. We present decisive advantages and co-benefits, including a concurrent global transition to 100% solar energy, that make *MEER:ReflEction* the only feasible plan available to *homo sapiens* that optimizes its survival as a species and future prosperity as a people
- **https://drawdown.psu.edu/poster/mirrors-earths-energy-rebalancing-meerreflection-resource-driven-engineering-leveraging**

Thank you!

Manna Jo Greene, Ulster County Legislator
Chair, Ulster County Climate Smart Committee
mannajo@aol.com
845-687-9253 or 845-807-1270

Environmental Director
Hudson River Sloop Clearwater, Inc.
mannajo@Clearwater.org