Lecture 9: The Future

Music to gather by

Learners: *Ice Ages and Climate*

October 2 - November 14, 2019

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Deniers, skeptics, believers, etc.

- Strange words these, to a scientist
- Science Denier: One who does not accept as true the consensus opinion of most of the scientific community.
- Skeptics: all good scientists are skeptics
- Scientists don't "believe" in a theory.

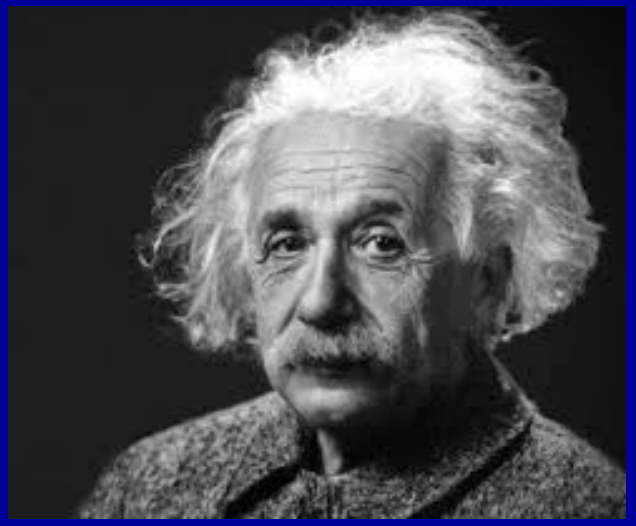
  Once a theory is well established and verified by experiment or observation, we usually behave as if it is true and assume so in doing our work. But we always keep in the back of our mind that it might not always be true. Most scientists dream of the fame and glory that would come from disproving a commonly accepted paradigm.

Topics

- Climate modification
- IPCC reports
- Social aspects of climate

This course didn't cover

- The economic impacts
- It's a "wicked problem"
  - the effort to solve one aspect of a wicked problem may reveal or create other problems.
- I'm a scientist, not a psychologist, social scientist or a religious leader. We need their help with this.

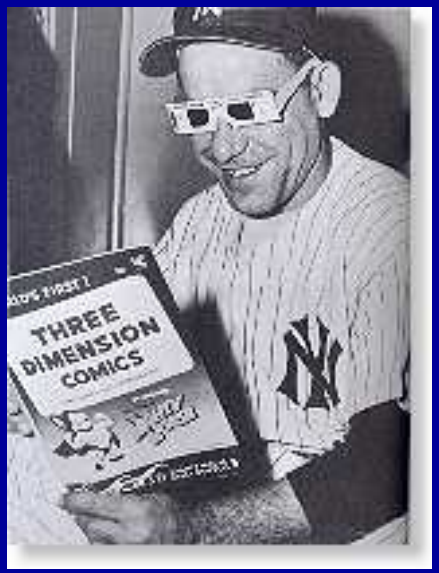


We can't solve problems
by using the same kind of thinking
we used when we created them.

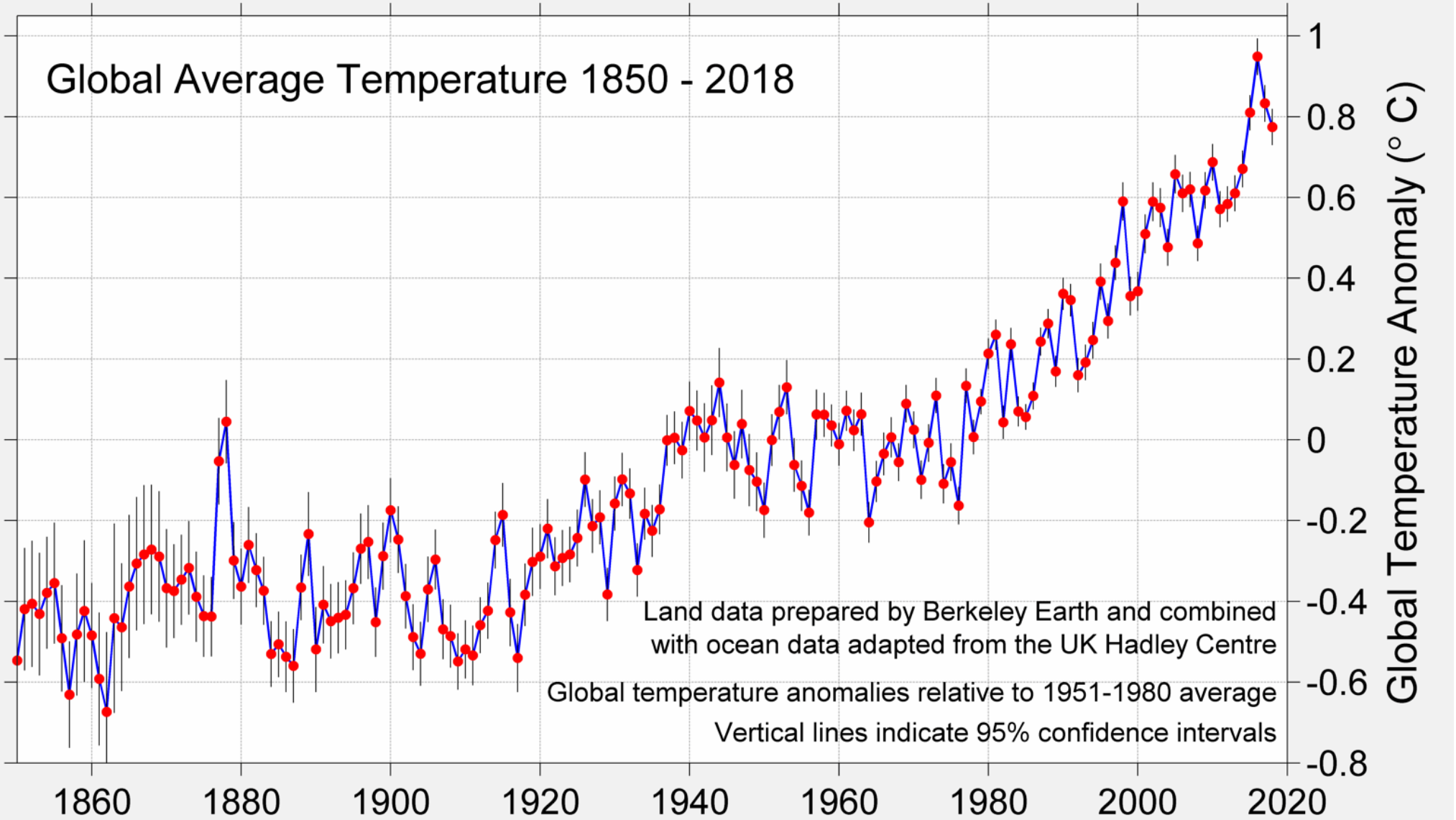
- Albert Einstein

- “It’s hard to make predictions, especially about the future.”

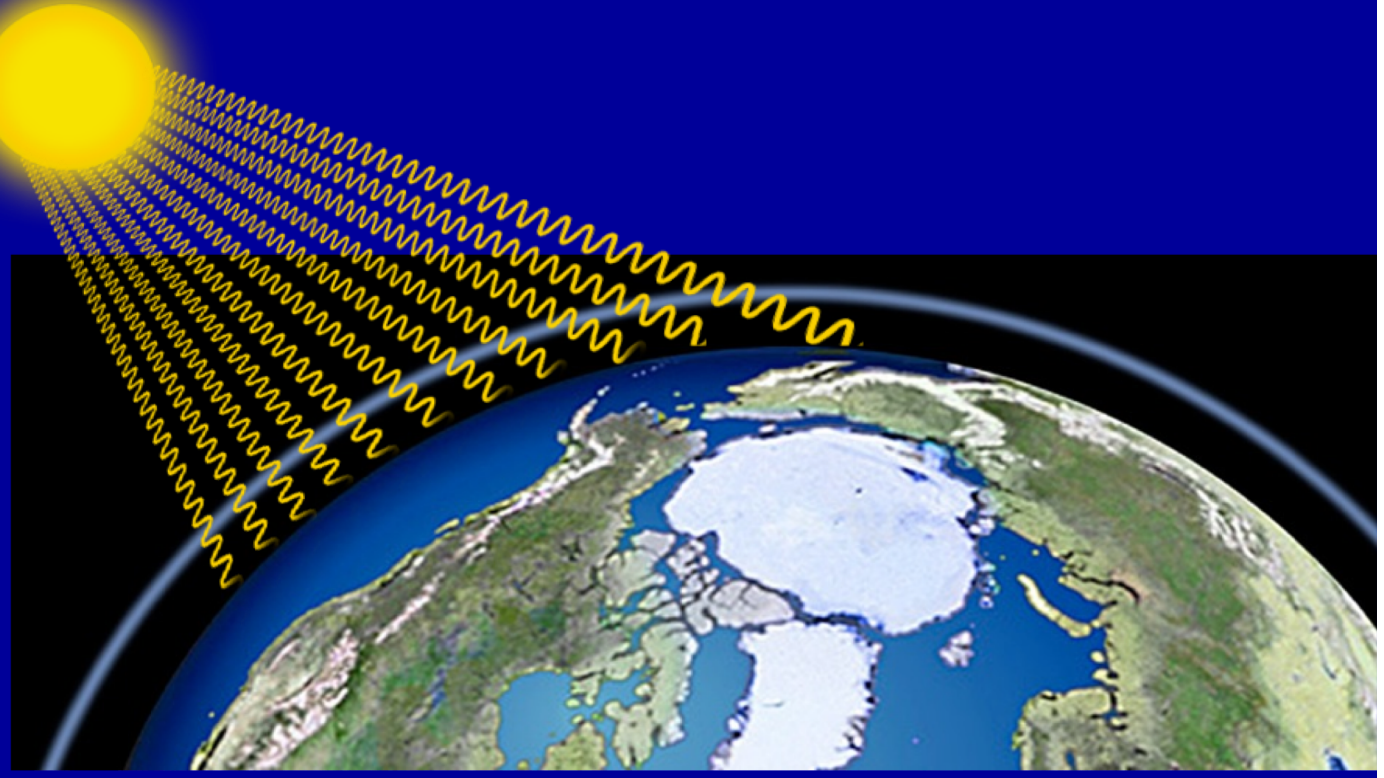
Lawrence Peter "Yogi" Berra



Global Average Temperature



Enough solar energy reaches Earth every hour to fill all the world's energy needs for a full year!



Every second
4 Hiroshima
bombs of Energy is being trapped by the excess greenhouse gases we put in the atmosphere

Credit: Climate Reality

Topics

- Climate modification
- IPCC reports
- Social aspects of climate

‘Geoengineering’ is the deliberate modification of an element of the climate system on a large scale to avoid dangerous impacts of climate change.

AMS, AGU, UK RS

~~Geo-engineering~~

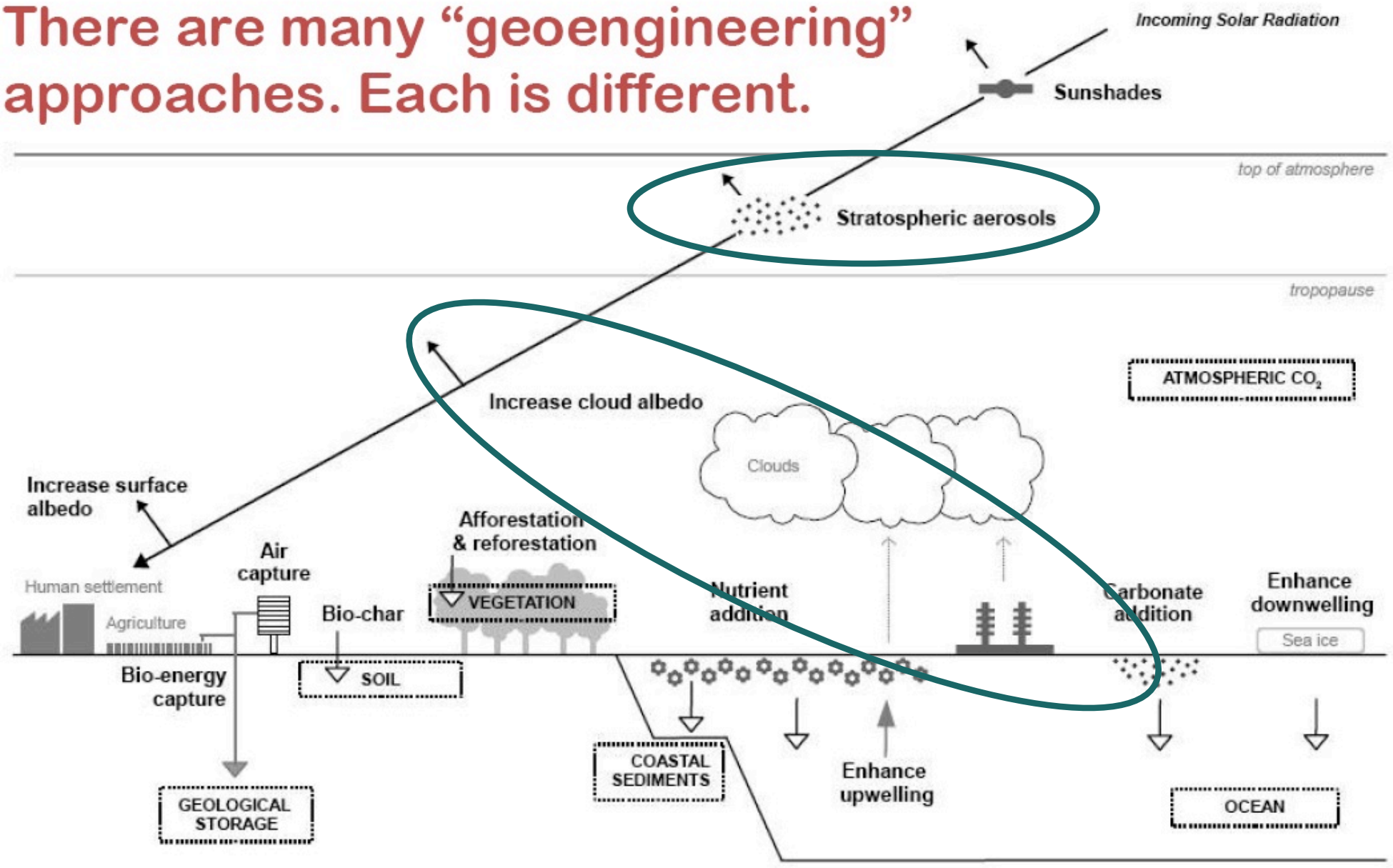
Climate Modification

http://earthobservatory.nasa.gov/Features/Aerosols/

Two main methods of climate modification

- Carbon cycle management
- Solar radiation management
  - (using clouds & aerosols)

There are many "geoengineering" approaches. Each is different.

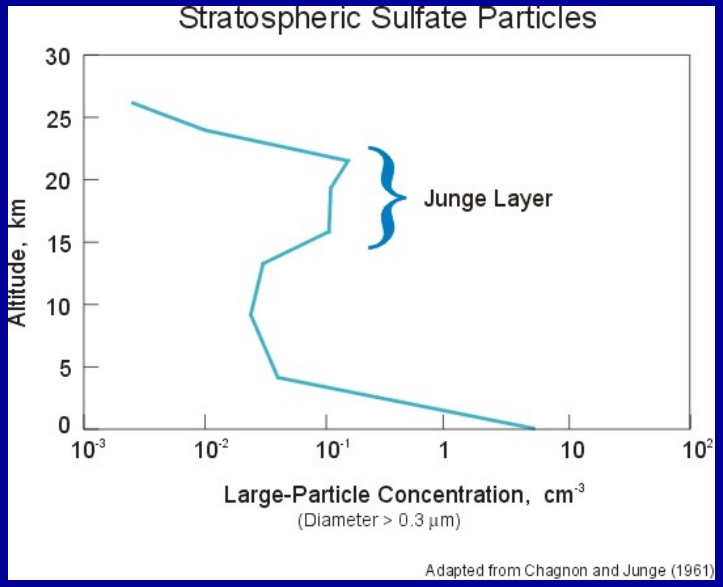


Credit Warren Wiscombe: NASA, GSFC 2013

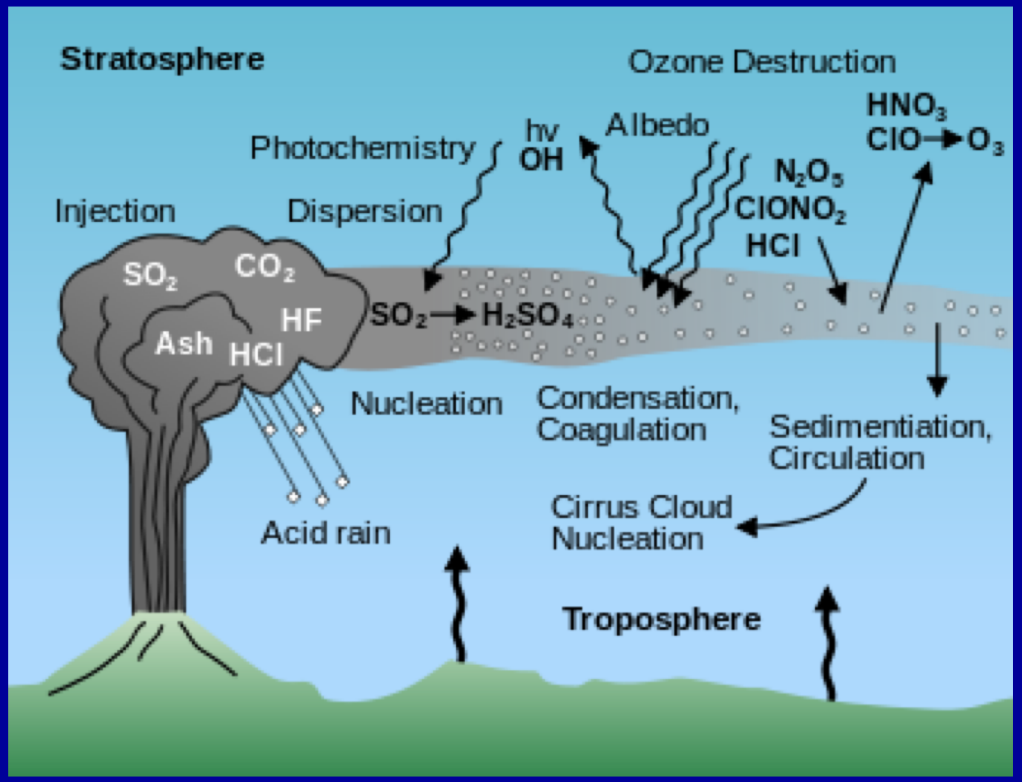
Junge Layer

Volcanic sulfates end up here as sulfuric acid droplets and have a strong cooling effect (aka global dimming) on the planet until they fall out over a few years.

Mt. Pinatubo, June 1991



Modification:
Imitate the natural volcanic action by shooting H_2S and SO_2 into the stratosphere: artillery shells, aircraft or stratospheric balloons.



Pinatubo eruption June 1991

Some of the pros and cons

PRO

- Potent: Could offset all warming from doubling CO_2
- Affordable and feasible
- We know it works – big volcanic eruptions cool Earth this way
- Beautiful sunsets

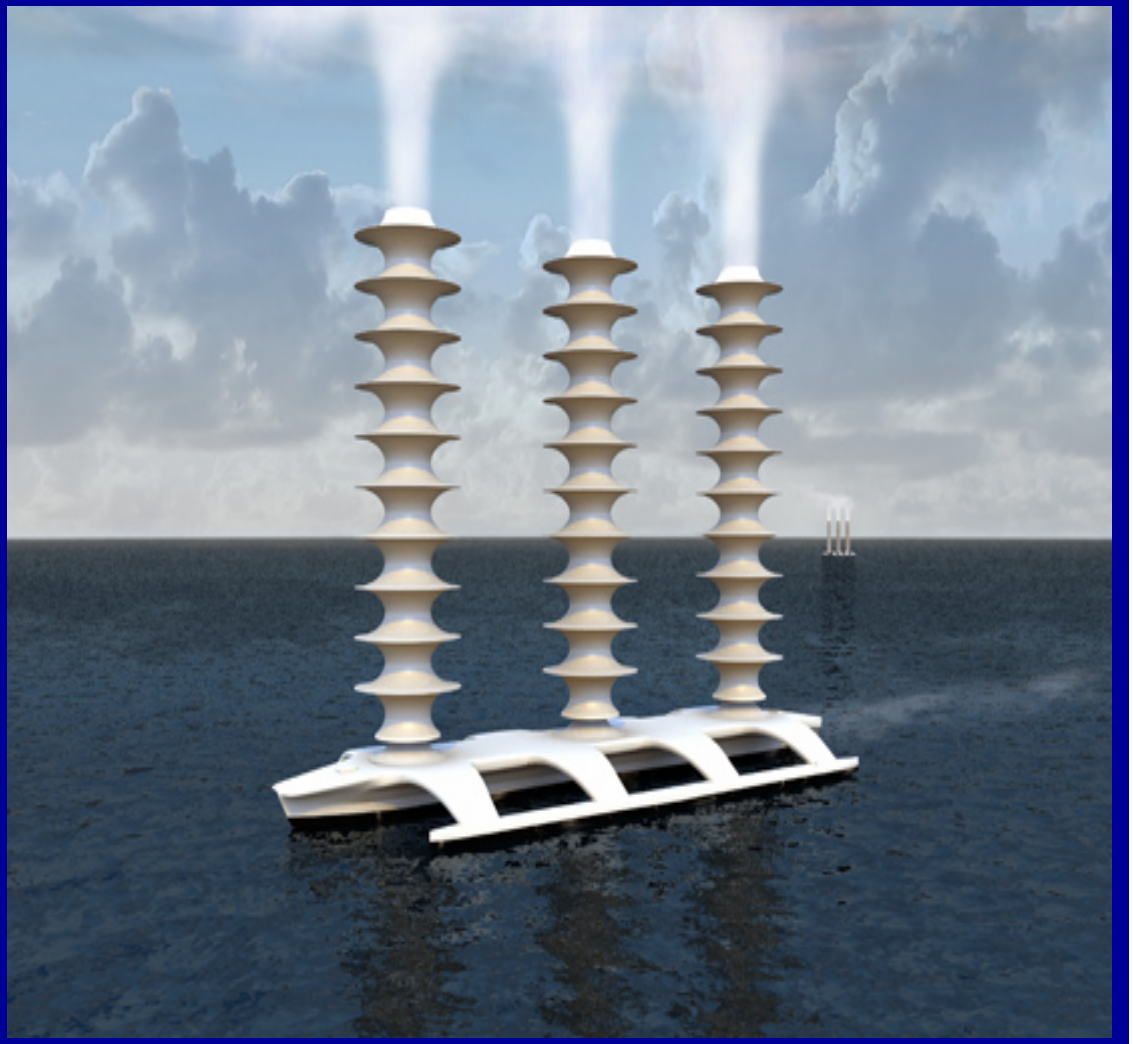
CON

- Reduces rainfall
- Alters regional climates
  - local famines?
- Cools tropics, not poles
- Won't stop ocean acidification
- Can't stop, else sudden pulse of warming CO_2 takes over
- Will make sky whiter

Unintended consequences??
Need to reduce CO_2 emissions anyway.
Should be, and is being, debated.

Modifying low marine clouds (Latham, 1990)

- Flettner rotor ship sprays seawater up
- Resulting salt particles nucleate clouds
- More clouds, less sunlight at surface



You don't need to create clouds to reflect more sunlight, just modify them to have smaller drops

Credit Warren Wiscombe: NASA, GSFC 2013

Harness the energy in jet stream? (1.5×10^{15} watts) (an aside)

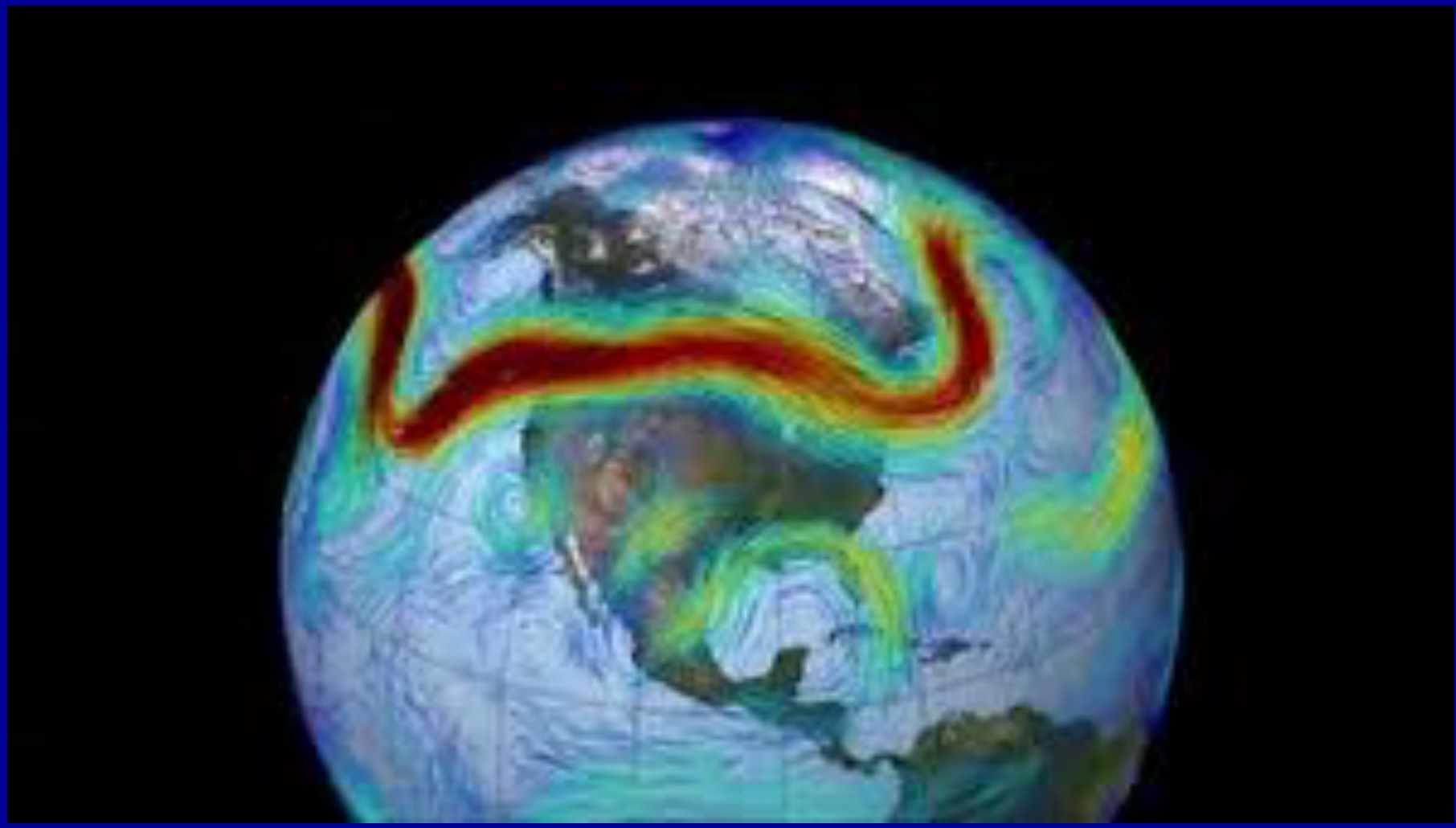
1% would take care of power requirements; 100 times the energy used

- Archer & Caldeira [*Global assessment of high-altitude wind power*, IEEE T. Energy Conver., **2**, 307–319, 2009] claim that the jet streams can generate the total power of 1700 TW, and that the climatic impact will be negligible.

Premature, but humans are an ingenious bunch!

- Miller, Gans, & Kleidon [*Jet stream wind power as a renewable energy resource: little power, big impacts*. Earth Syst. Dynam. Discuss. **2**, 201–212, 2011] claim that the jet streams can generate the total power of only 7.5 TW, and that the climatic impact will be catastrophic.

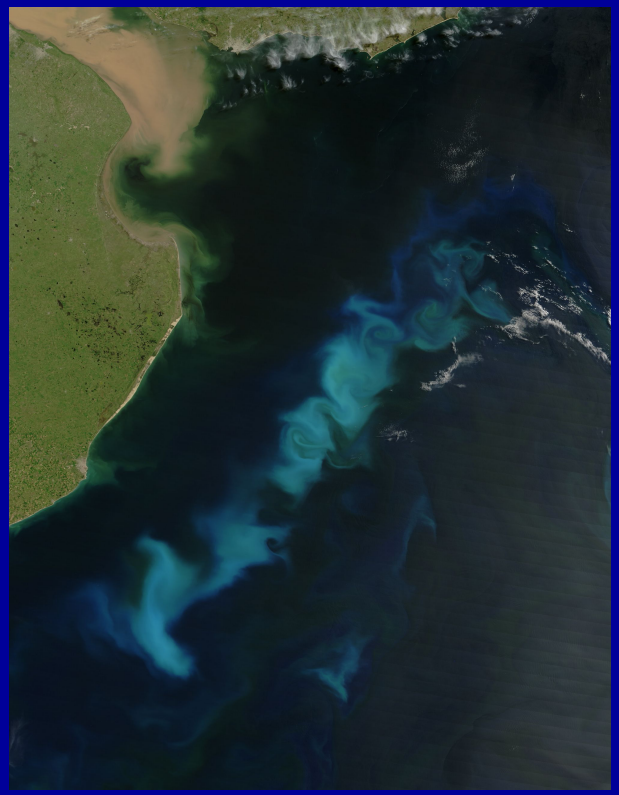
Polar jet stream

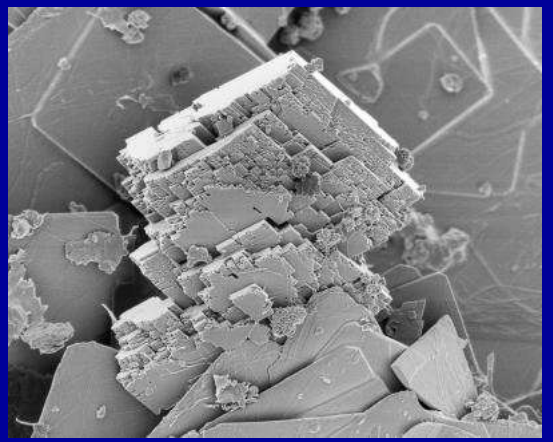


Cloud reflectivity modification

- Cirrus stripping
  - high cirrus transmits sunlight
  - blocks infrared
  - add chemicals at high altitude
- Marine cloud brightening
  - Esp. white clouds with small droplets
  - Twomey effect: small aerosols condense rainless clouds (e.g. contrails)

Stimulated algal production (middle). Artificial weathering (right). Artificial trees (left).





Topics

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- IPCC reports
- Social aspects of climate

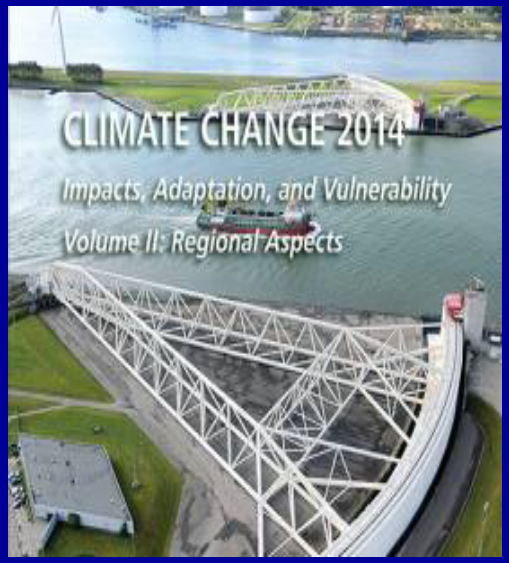
It's an International problem, so here comes the UN.

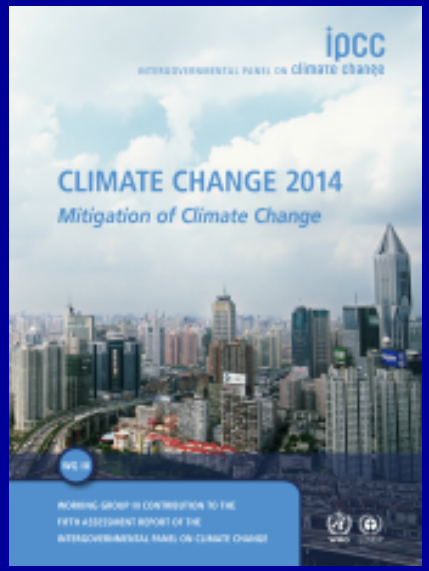
Intergovernmental Panel on Climate Change
IPCC

3 Major IPCC working groups

Assessment reports
major working group reports
(almost 800 authors)
Various supporting materials

I. The Physical Science Basis
II. Impacts, Adaptation and Vulnerability
III. Mitigation of Climate Change





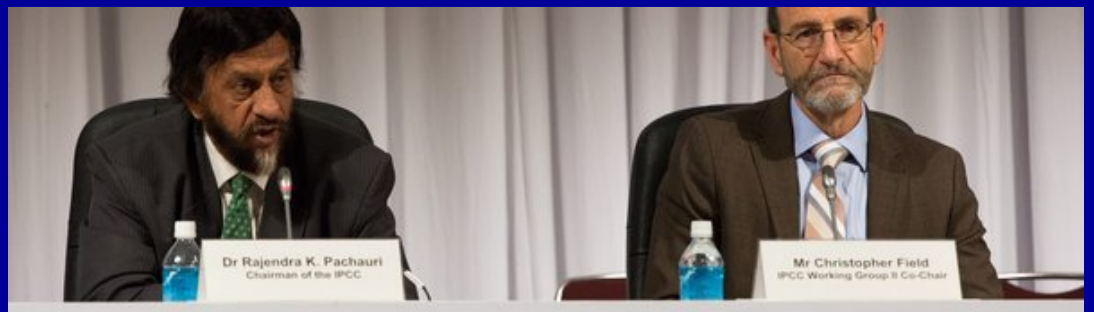
http://www.ipcc.ch/working_groups/working_groups.shtml

Summary for Policymakers

Governmental endorsement of the summary is by "Approval".

Approval signifies that the material has been subject to detailed, line-by-line discussion, leading to agreement among the participating IPCC member countries (in consultation with the scientists).

http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml



IPCC Reports

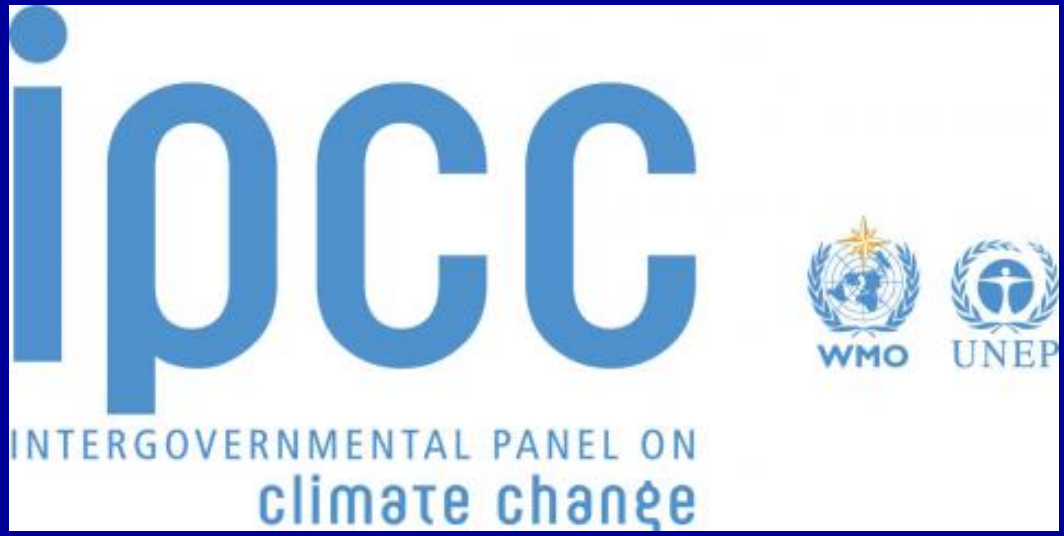
- IPCC reports are developed through multiple rounds of drafting and review.

IPCC member Governments endorse the report based on a dialogue between those who will use the report – the governments – and those who write it – the scientists.

- Endorsement is intended to underpin the report's authority.
- Endorsement does not guarantee any government action.

Assessment Reports, AR
1990, FAR, First
1995, SAR, Second
2001, TAR, Third
2007, AR4, forth
2014, AR5, fifth

Not infallible. Mention error in AR4.



Progression in IPCC reports

- First (FAR 1990): …report says they are certain that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases, resulting on average in an additional warming of the Earth's surface.
- Second (SAR 1995): The balance of evidence suggests a discernible human influence on global climate.
- Third (TAR 2001): Since the mid-20th century, most of the observed warming is "likely" (greater than 66% probability) due to human activities.
- Fourth (AR4 2007): Most of the global average warming over the past 50 years is "very likely" (greater than 90% probability) due to human activities.
- Fifth (AR5 2014): Human influence on the climate system is clear. It is extremely likely (95-100% probability) that human influence was the dominant cause of global warming between 1951-2010.

Laudato Si' (Praised Be)

24 May 2015

http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

Paris accord: COP21
aka 2015 Paris Climate Conference

Dec 7,8, 2015

- First international agreement on GHG
- Limit ΔT to $<2^{o}C$ (already have $0.8^{o}C$)
  - Try to hold ΔT to $<1.5^{o}C$
- Statements of intention with tracking
- Arguments about enforcement

Rio Earth Summit in 1992
established the Conference of Parties (hence COP)

http://www.cop21paris.org