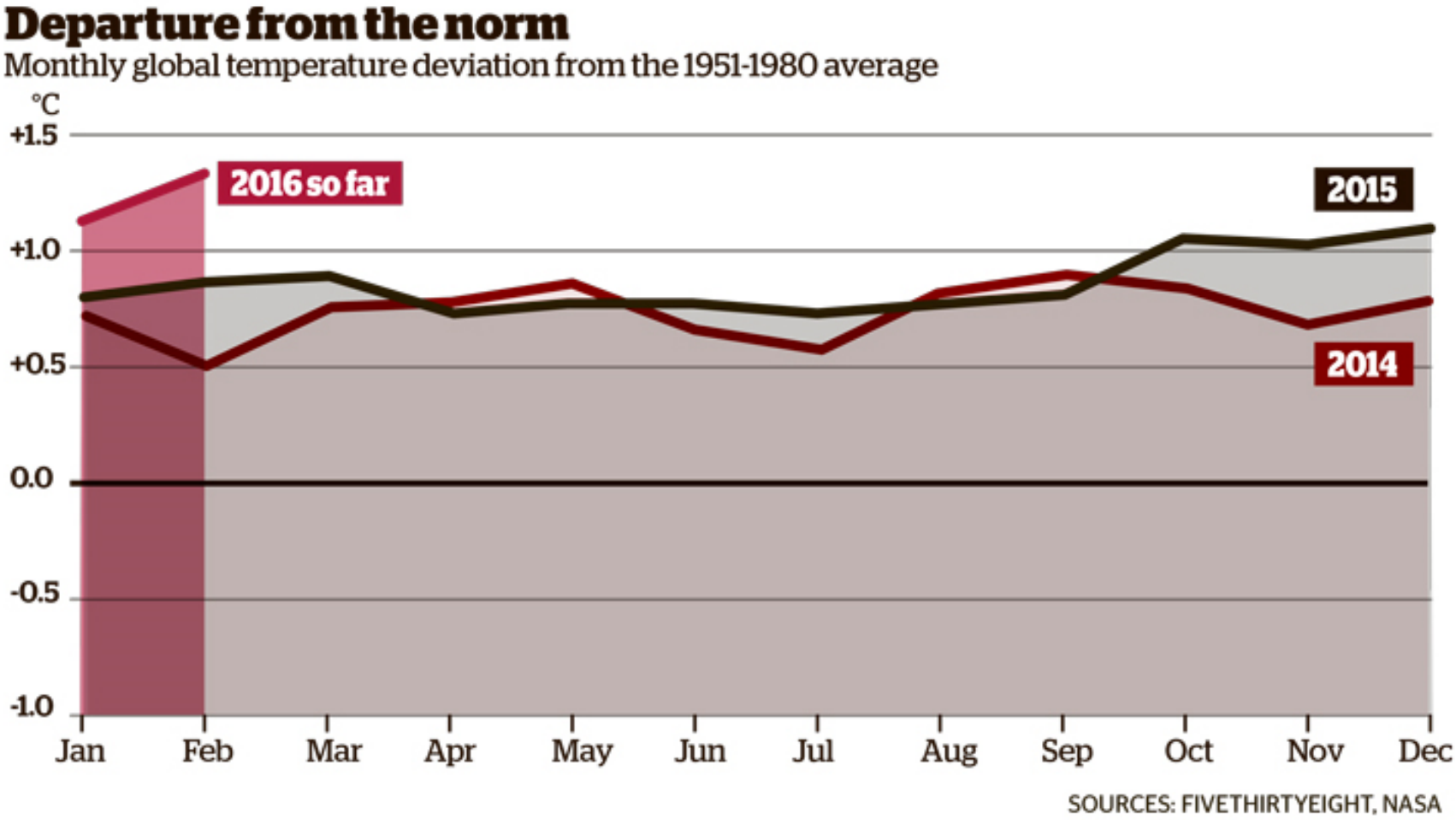
SOME GLOBAL CLIMATE CHANGE SOLUTIONS:

PRESENT TECHNOLOGY

ENVIRONMENTAL ENGINEERING

GEOG 3331 – Lecture 21 Turco: Chapter 14

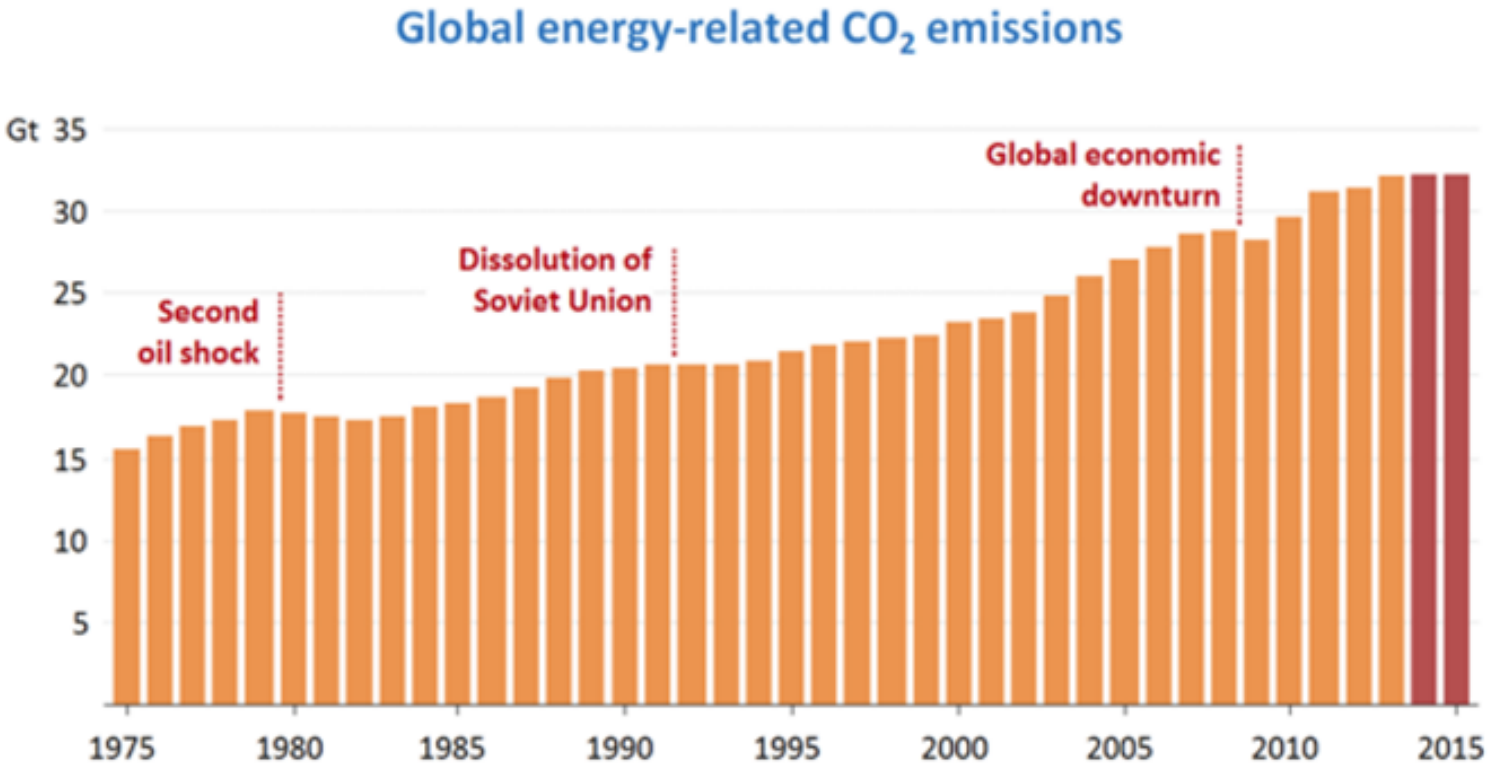
Global Temperature: Departure from Normal



The world lurched beyond 1.5 C global warming limit in recent months and closer to the 2 C

- This has prompted calls for clearer policies aimed at wealthy nations to be carbon-emissions neutral before 2050
- First half of March was hottest on record for Australia with the rest of the planet also on track for more record heat(Bureau of Meteorology
- Climatologist Stefan Rahmstorf (Potsdam Institute of Climate Impact Research):
  - El Nino event in the Pacific is topping up the background warming from climate change by about 0.2 degrees
  - Another half a degree of warming is already locked in.

Global energy-related CO_2 emissions



IEA analysis for 2015 shows renewables surged, led by wind, and improvements in energy efficiency were key to keeping emissions flat for a second year in a row

Source: International Energy Agency (IEA)

- Renewable energy (wind, solar and hydro) accounted for about 90 per cent of additional electricity generation in 2015 (IEA estimate)
- "Renewables have turned out to be an unexpected success story . . . However, cuts in emissions of greenhouse gases from other sectors of the economy - such as agriculture and industry - will be harder to achieve" (Professor Rahmstorf)
- But CO2 levels measured at NOAA's Mauna Loa site in Hawaii jumped 3.05 parts per million (ppm), the fastest increase in 56 years of observations.

Climate Stabilization Wedges

Humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century. A portfolio of technologies now exists to meet the world's energy needs over the next 50 years and limit atmospheric CO2 to a trajectory that avoids a doubling of the preindustrial concentration. Every element in this portfolio has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale. Although no element is a credible candidate for doing the entire job by itself, the portfolio as a whole is large enough that not every element has to be used.

S. Pacala and R. Socolow (13 AUGUST 2004 VOL 305 SCIENCE www.sciencemag.org)

Energy Efficiency and Conservation

1. Increase fuel economy for 2 billion cars by 100%
   - Vehicle size, power, weight

2. Reduced use of vehicles by decreasing car travel by 50%
   - Urban design, mass transit, telecommuting

3. Efficient buildings: cut carbon emissions by 25% in buildings and appliances, projected for 2054

4. Efficient coal plants 60% instead of 40% efficiency (compared with 32% now)
   - High-temperature

Fuel Shift

5. Gas baseload power: Replace 1400 GW with 50%-efficient coal plants with gas plants

Carbon Capture and Storage (CCS)

6. Capture CO2 at baseload power plant, CCS at 800 GW coal or 1600 GW natural gas

7. Capture CO2 at H2 plant, CCS at plants of 250 MtH2/year (coal) or 500 MtH2/year (natural gas)

8. Capture CO2 at synfuels plant

Nuclear Fission

Renewable electricity and fuels

9. Nuclear power for coal power Add 700 GW (twice the current capacity)
   - Nuclear proliferation
   - terrorism
   - waste

10. Wind power for coal power, add 2 million 1-MW-peak windmills on land or offshore
   - multiple uses of land - windmills are widely spaced

11. PV power: Add 2000 GW-peak PV

12. Wind H2 in fuel-cell car for gasoline in hybrid car, add 4 million 1-MW-peak windmills

13. Biomass fuel for fossil fuel

Forests and Agricultural Soils

14. Reduced deforestation, plus reforestation, afforestation, and new plantations.

- Decrease tropical deforestation to zero
  instead of 0.5 GtC/year
- and establish 300 Mha of new tree plantations (twice the current rate)
- Land demands of agriculture, benefits to biodiversity from reduced deforestation

15. Conservation tillage: apply to all cropland (10 times the current usage)

- reversibility
- verification

Global environmental engineering

- Turco: Chapter 14
  - Technological solutions to obstinate environmental problems
  - More ‘action’ rather than less
- Problem of approach
  - Looking for cures rather than prevention
  - Problems of scale, uncertainty and surprise

Difficult issues

- Substances that deplete the ozone layer
- Global warming
  - Solar radiation management
  - Carbon dioxide removal

The Benefit of Smog

- Ozone depletion increases exposure to UV radiation
- Photochemical smog (ozone) protects from UV radiation

- Problem: smog is toxic

Fill up the ozone hole

- Recall the critical roles of Cl and ClO:
  - $Cl + O_3 \rightarrow ClO + O_2$
  - $ClO + O \rightarrow Cl + O_2$
  - Net: $O + O_3 \rightarrow 2O_2$

- Can we clean up the catalysts?
  - Light hydrocarbons (e.g. propane) convert Cl to HCl
  - Add them to Antarctic stratosphere in the spring to counteract the release of Cl

Problems

- How to get the hydrocarbons to the stratosphere
  - A dozen specially designed planes (Turco)?
- How to mix the hydrocarbons
  - Polar stratosphere is *not* well mixed at this time
  - Can't just dump a bunch of hydrocarbons and expect it to become evenly distributed
- Polar stratospheric clouds
  - Can turn HCl right back into Cl
  - Hydrocarbons could possibly make things worse

Destroy CFCs with Lasers

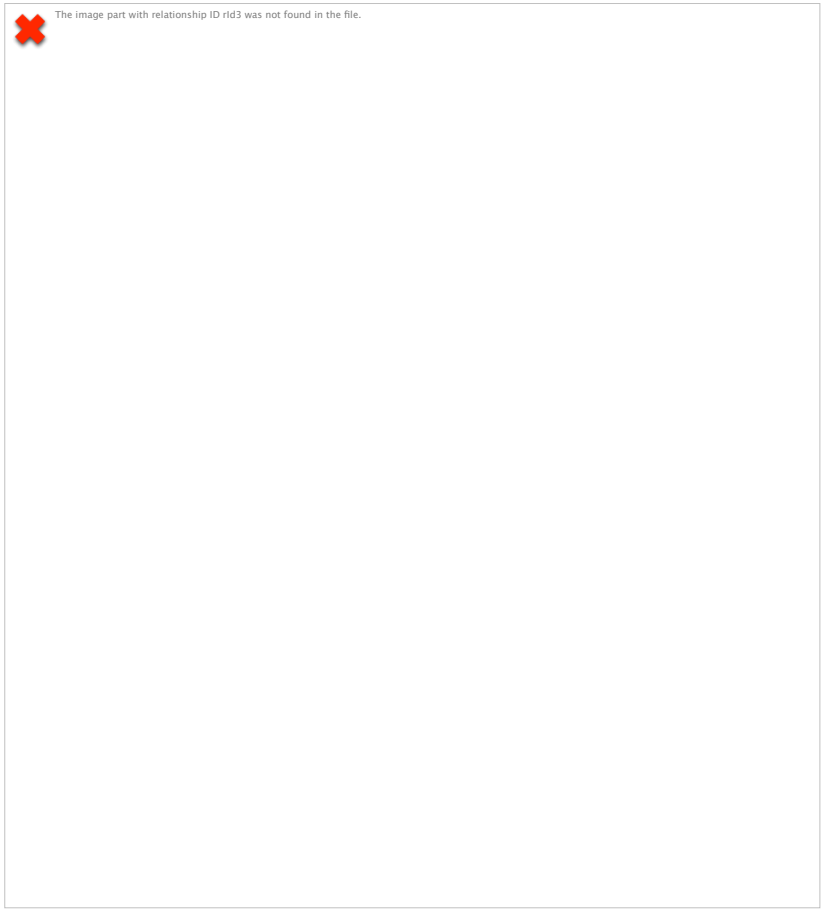
- No tropospheric sink for CFCs
  - Only sink is via the stratosphere
  - Dissociated by UV rays
- 'Create' a sink with UV laser beams
  - Tune multiple wavelengths so that in combination they dissociate CFCs
  - Bathe the troposphere over a short time period (10 years or less) to cleanse it

Problems

- Very expensive
  - Turco estimates thousands of lasers must be built and gigawatts of energy supplied
- Probably not good for wildlife

Absorb CFCs with Zeolites

- Zeolite: a substance with molecule-sized pores
  - Microscopic sponge
- Can be designed to absorb specific compounds
- Sprinkle CFC zeolite dust in the troposphere



Problems

- Appropriate zeolite does not yet exist
- Would the zeolite dust ever release the CFCs?
  - Decomposition
  - Warm temperatures

Destroy CFCs with Bacteria

- Similar, natural compounds (e.g. CH_3Cl) are digested by certain species of bacteria
- Other strains of bacteria are used to help clean oil spills
- Could we find/engineer bacteria that eat CFCs?

- Problem: not yet, anyway

Cooling the Greenhouse

- Take advantage of the cooling effect of aerosols
- Create a sulphate layer in the stratosphere
  - Volcanic eruptions can have cooling effect
  - Offset the heat trapped by GHGs
  - Sulphates are waste products from fossil fuels
- Sulphates eventually fall back into troposphere
  - Need a continuous supply

Problems

- How do we get it there?
  - Turco says aircraft are simply unfeasible
  - Suggests converting it to COS, which is quite stable in the troposphere
    - Problem: COS is toxic

- "Stratoshield", "SPICE": 25 km hose, suspended by balloons, with sulphates pumped into the sky

More problems

- No more blue sky
- Have to determine the correct amount to use
- Requires constant loading
  - If shield production stops, global warming will be rapid
- Massive local climatic changes
- CO_2 already acidifying the ocean
- Large potential for surprises

Cloud whitening

- Backed financially by Bill Gates
- Inject sea salt aerosols into clouds, making them "whiter"
  - Increase albedo

- May require immense scale
- Also produces local climate shifts and leaves CO_2 problem untouched

Ocean nourishment

- Marine biosphere productivity is generally limited by nutrients rather than CO2
- Could create enhanced phytoplankton growth by "fertilizing" with iron filings

- Uncertain costs
- Unknown environmental side effects

Artificial Trees

- Dr. Wallace Broecker
- 60 million CO_2 removal "scrubbers"
  - Specialized plastic
  - 50' by 8'

Real trees

- Net carbon removal occurs only *while trees are growing*
  - Mature trees are a carbon reservoir, but not a carbon sink
- Reforesting: potential sink for 1-2 GtC/year
  - Could continue for several decades
  - Combine with ending deforestation

Carbon sequestration and storage (CCS)

- Trapping and storing CO_2 from power plants and placing it in long-term storage
  - Saltwater aquifers
  - Deep ocean

Nuclear winter

- Aftermath of global thermonuclear war
- Black, sooty smoke produced by the combustion of urban areas
  - Soot aerosols absorb shortwave but not longwave radiation
  - "Antigreenhouse effect"
  - Cooling of surface by 10-20°C for years
- Atmospheric heating from soot could destroy ozone layer

Finally!

- Final Exam
  - Saturday, April16
  - 1 pm – 4 pm
  - RC 2003

- Cumulative
- Similar format as midterm
- Some questions more broadly based
- Some geopolitics

The End?

- Not really
- Most of our problems are less intractable than nuclear winter
- Needed:
  - Understanding the problems
  - Big and small solutions
- However, this is the end of this course!