Topic 10

- Geoengineering
- Energy Storage

Geoengineering

- Geoengineering is the deliberate large-scale intervention in the Earth's natural systems to counteract climate change.

- Sources:

  ▷ Oxford Geoengineering Programme
  http://www.geoengineering.ox.ac.uk

  ▷ The Royal Society (2009), *Geoengineering the climate: science, governance and uncertainty*,
  ISBN: 978-0-85403-773-5
  https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2009/8693.pdf

Geoengineering Techniques

- Carbon dioxide removal techniques address the root cause of climate change by removing greenhouse gases from the atmosphere.

- Solar radiation management techniques attempt to offset effects of increased greenhouse gas concentrations by causing the Earth to absorb less solar radiation.

Solar Radiation Management Techniques

- Albedo enhancement. Increasing the reflectiveness of clouds or the land surface so that more of the Suns heat is reflected back into space

- Space reflectors. Blocking a small proportion of sunlight before it reaches the Earth.

- Stratospheric aerosols. Introducing small, reflective particles into the upper atmosphere to reflect some sunlight before it reaches the surface of the Earth.

Carbon Dioxide Removal Techniques – 1 of 2

- Afforestation. Engaging in a global-scale tree planting effort.
- Biochar. 'Charring' biomass and burying it so that its carbon is locked up in the soil.
- Bio-energy with carbon capture and sequestration. Growing biomass, burning it to create energy, and capturing and sequestering the carbon dioxide created in the process.
- Ambient Air Capture. Building large machines that can remove carbon dioxide directly from ambient air and store it elsewhere.

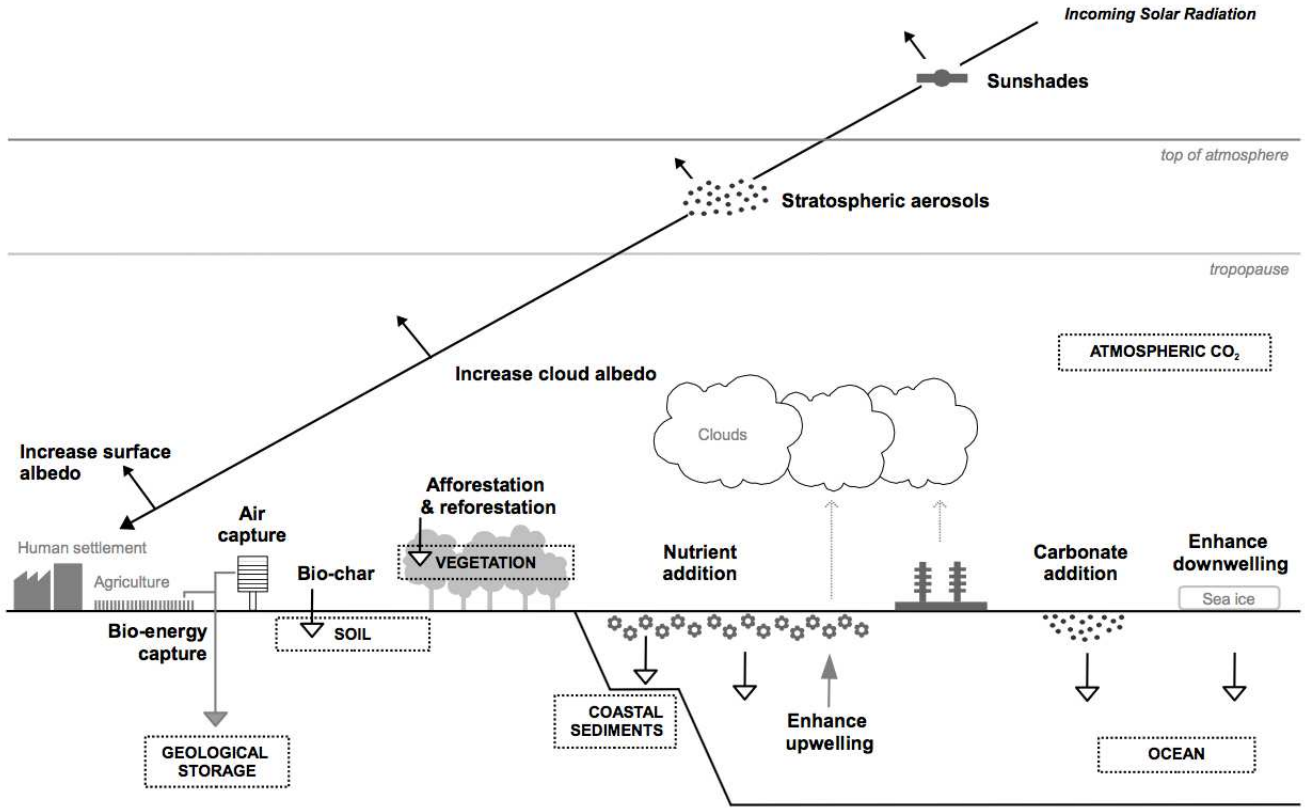
Carbon Dioxide Removal Techniques – 2 of 2

- Ocean Fertilization. Adding nutrients to the ocean in selected locations to increase primary production which draws down carbon dioxide from the atmosphere.

- Enhanced Weathering. Exposing large quantities of minerals that will react with carbon dioxide in the atmosphere and storing the resulting compound in the ocean or soil.

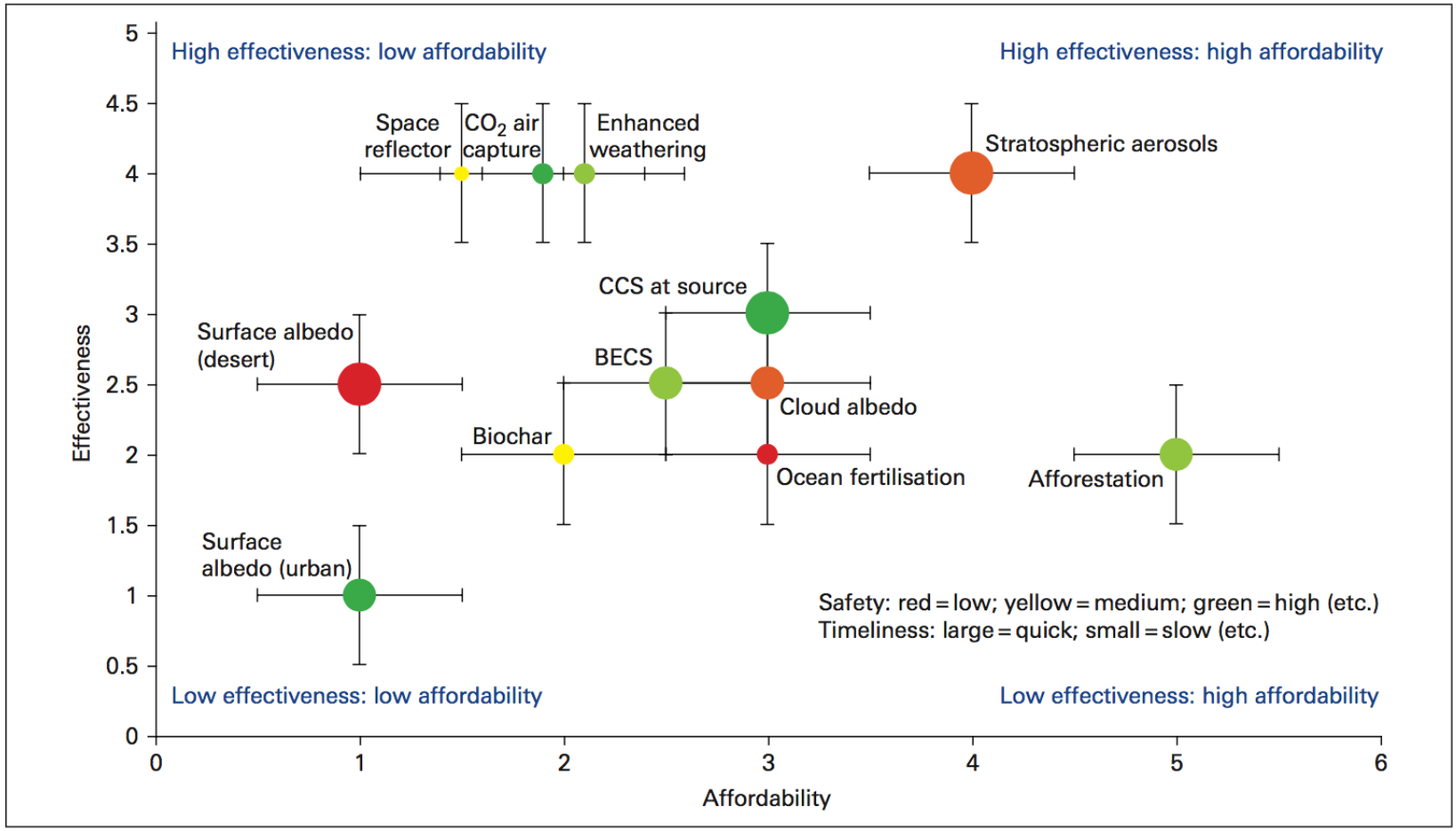
- Ocean Alkalinity Enhancement. Grinding up, dispersing, and dissolving rocks such as limestone, silicates, or calcium hydroxide in the ocean to increase its ability to store carbon and directly ameliorate ocean acidification.

Fig 1. Schematic of Geoengineering Techniques



Black arrowheads indicate shortwave radiation, white arrowheads indicate enhancement of natural flows of carbon, grey downward arrow indicates engineered flow of carbon, grey upward arrow indicates engineered flow of water, dotted vertical arrows illustrate sources of cloud condensation nuclei, and dashed boxes indicate carbon stores. Source Vaughan and Lenton (2011, Climate Change)

Fig 2. Evaluation of Geoengineering Techniques



Source: The Royal Society (2009)

High Effectiveness Techniques

- Stratospheric aerosols
  - ▷ Look at the effect of the three volcano eruptions in Figures 24 and 25 of Topic 2.
- Afforestation

We shall examine stratospheric aerosols and afforestation next.

Stratospheric Aerosols

- Sulfate aerosols, namely hydrogen sulfide H_2S and sulfur dioxide SO_2, are the best understood aerosols due to observation of the effects of volcanic eruptions and they are gasses, which facilitates delivery,

- Studies to date suggest that the stratospheric aerosols can be used to exactly counter balance projected increased CO_2 emissions.

- Mt Pinatubo eruption suggests considerable side effects: reduced stratospheric ozone, reduced precipitation in Asia and Africa, etc..

- Fast, stratospheric aerosols would start to reduce temperatures within one year

- Feasible, mass involved is less than a tenth of the current annual payload of the global air transportation. Commercial transport aircraft already reach the lower stratosphere. Fleet size required would be about the same as Southwest and United combined: 1500 airplanes.

- The biggest risk is that CO_2 will continue to increase while stratospheric aerosols are applied so that temperatures will increase sharply if application stops.

Afforestation (Replanting)

- Terrestrial ecosystems store about 2,100 GtC in living organisms, leaf litter, and soil organic matter, which is almost three times that currently present in the atmosphere.

- Ready for immediate deployment and starts CO_2 reductions immediately

- Slow to reduce global temperatures.

- Few undesirable side effects except for potential land use conflicts and biodiversity implications

- Forests in the tropics and sub-tropics tend to cool the surface by increasing evaporation and transpiration, while forests in the mid and high latitudes tend to warm because they are much darker than the underlying snow and therefore absorb more solar radiation.

- Carbon stored in vegetation is not securely sequestered in the long-term, as it can easily be released by fire, drought, or deforestation.

Energy Storage

- Go through Heming Wang extra credit slides.

Carbon Sequestration Methods

- Go through Jinxue Chen extra credit slides.