Geo-engineering and its interaction with the Earth System

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The Earth System atmo- hydro- cryo- geosphere

- interconnections
- complexity
- variability
- responsiveness

Geo-engineering

- seabed storage of CO₂
- ocean storage of CO₂
- solar management
- offshore renewable energy
- the "end game"

Interconnections



Source: CSIRO







Responsiveness



4 km : 2.5-3 km: 0.5-1 km of ice

Source: Pollard & DeConto 2009.

Geo-Eng #1 – seabed storage



 Statoil took CO₂ stripped from gas at Sleipner West, North Sea, and re-injected 1000m below the seabed for storage.

> 10 million tonnes CO₂ stored & effects studied by SIO using gravity changes caused by separation of gas and water in the reservoir.

 Repeat surveys at 30 sites suggest overall success of store.

 Incident in same geological formation 300km from Sleipner, under non-CO₂ injection – highlights need to closely evaluate each store.

According to Pacala & Sokolow, 3500
Sleipners needed to remove total 25Gt CO₂ in 50yr.

Potential effects – CO₂ escape, infrastructure

Source: Scripps Institute of Oceanography

Geo-Eng #2 – ocean storage



Source: CO2CRC

CO₂ in the ocean - effects



Pteropod shell [a] exposed to pH change for 48hr [d] & unexposed shell [e]. Source: Orr et al., Nature 2005.

 Ocean taken up ~ 40% anthropogenic emissions i.e. total of ~500Gt CO₂.

 Most change in surface ocean but change affecting deep.

 Suggestion that CO₂ injected to deep ocean is isolated from atmosphere for few 100yr – not proven.

 Injection/storage-leak zones will affect ocean chemistry & marine organisms, e.g. shell growth & other vital processes, but research in infancy.

Geo-engineering – managing solar radiation



Change in ocean surface temperature 1944-2005 caused 350km south migration of subtropical water. Source: Ridgway & Hill, 2009.

- Changes in reflectivity, cloud cover; sulphate injection, space shields.
- Response to rapid heat loss?
- Interact with ocean, which is a vast & efficient heat store.
- Rapid atmospheric heat reductions may affect wind regimes/ocean circulation: in reverse, present warming has seen subtropical water move 350km S over last 50yrs.
- Effects of changing atmospheric chemistry may be profound.

Geo-engineering – renewable energy



Proposed Supergrids involving Europe, Africa & Middle East. Source: Desertec.com.

 Safest & most predictable way of moderating CC is to reduce GHG at source.

 Direct reduction in GHG emissions is achieved by renewable energy schemes, e.g. offshore wind farms.

 EU not only wishes to reduce emissions but meet growing demand and have security of supply.

 Supergrids are underway & involve interconnection of various renewable energy sources from Iceland to Arabia.

Geo-engineering – renewable energy



Floating windmills enable offshore wind farms to extend over much of the continental shelf. Source: Statoil Hywind. coastal seas are becoming crowded as offshore activities increase.

 activities range from transportation, resource extraction [minerals, fish], communications, leisure, environmental protection.

 renewable energy will add to crowding & have -/+ impacts e.g. restriction of other activities vs creation of *de facto* marine protection areas etc.

Geo-engineering – the end game



Components of Earth system are intimately linked & change can ripple through atmosphere to ocean to land.



Source: Snodgrass et al., 1966 Phil Trans Roy Soc.

Geo-engineering – the end game



If offshore renewable energy schemes are viewed as an indirect fore-runner of geoengineering projects, then moves to regulate such activities are now underway.

 US state & federal authorities have set up groups to organise such activities that attempt to balance protection, exploitation & sustainability.