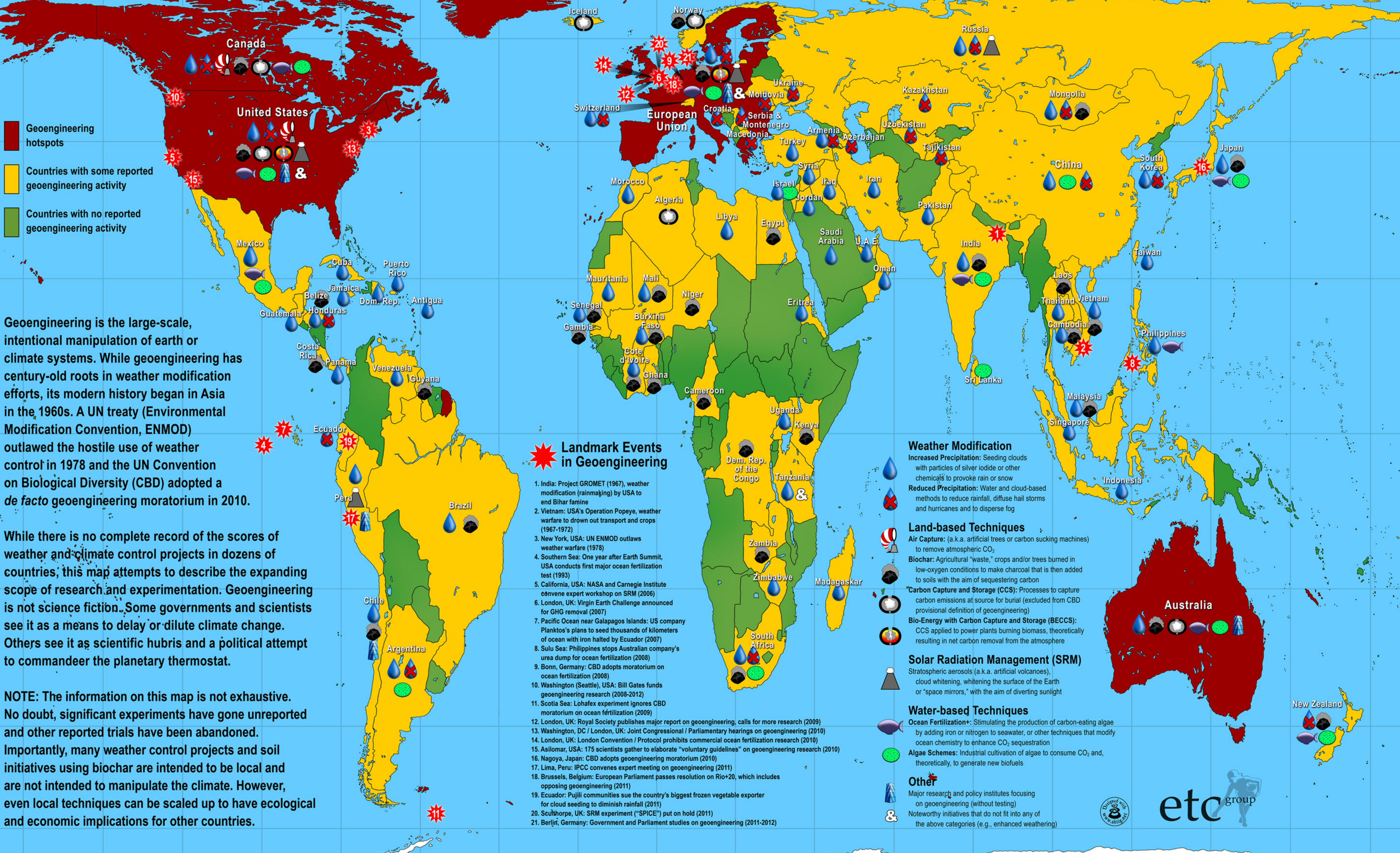


# GEOENGINEERING A HALF-CENTURY OF EARTH SYSTEM EXPERIMENTATION



- Geoengineering hotspots
- Countries with some reported geoengineering activity
- Countries with no reported geoengineering activity

Geoengineering is the large-scale, intentional manipulation of earth or climate systems. While geoengineering has century-old roots in weather modification efforts, its modern history began in Asia in the 1960s. A UN treaty (Environmental Modification Convention, ENMOD) outlawed the hostile use of weather control in 1978 and the UN Convention on Biological Diversity (CBD) adopted a *de facto* geoengineering moratorium in 2010.

While there is no complete record of the scores of weather and climate control projects in dozens of countries, this map attempts to describe the expanding scope of research and experimentation. Geoengineering is not science fiction. Some governments and scientists see it as a means to delay or dilute climate change. Others see it as scientific hubris and a political attempt to commandeer the planetary thermostat.

NOTE: The information on this map is not exhaustive. No doubt, significant experiments have gone unreported and other reported trials have been abandoned. Importantly, many weather control projects and soil initiatives using biochar are intended to be local and are not intended to manipulate the climate. However, even local techniques can be scaled up to have ecological and economic implications for other countries.

### Landmark Events in Geoengineering

- India: Project GROMET (1967), weather modification (rainmaking) by USA to end Bihar famine
- Vietnam: USA's Operation Popeye, weather warfare to drown out transport and crops (1967-1972)
- New York, USA: UN ENMOD outlaws weather warfare (1978)
- Southern Sea: One year after Earth Summit, USA conducts first major ocean fertilization test (1993)
- California, USA: NASA and Carnegie Institute convene expert workshop on SRM (2006)
- London, UK: Virgin Earth Challenge announced for GHG removal (2007)
- Pacific Ocean near Galapagos Islands: US company Planktos's plans to seed thousands of kilometers of ocean with iron halted by Ecuador (2007)
- Sulu Sea: Philippines stops Australian company's urea dump for ocean fertilization (2008)
- Bonn, Germany: CBD adopts moratorium on ocean fertilization (2008)
- Washington (Seattle), USA: Bill Gates funds geoengineering research (2008-2012)
- Scotia Sea: Lohafex experiment ignores CBD moratorium on ocean fertilization (2009)
- London, UK: Royal Society publishes major report on geoengineering, calls for more research (2009)
- Washington, DC / London, UK: Joint Congressional / Parliamentary hearings on geoengineering (2010)
- London, UK: London Convention / Protocol prohibits commercial ocean fertilization research (2010)
- Asilomar, USA: 175 scientists gather to elaborate "voluntary guidelines" on geoengineering research (2010)
- Nagoya, Japan: CBD adopts geoengineering moratorium (2010)
- Lima, Peru: IPCC convenes expert meeting on geoengineering (2011)
- Brussels, Belgium: European Parliament passes resolution on Rio+20, which includes opposing geoengineering (2011)
- Ecuador: Pujili communities sue the country's biggest frozen vegetable exporter for cloud seeding to diminish rainfall (2011)
- Sculthorpe, UK: SRM experiment ("SPICE") put on hold (2011)
- Berlin, Germany: Government and Parliament studies on geoengineering (2011-2012)

### Weather Modification

- Increased Precipitation:** Seeding clouds with particles of silver iodide or other chemicals to provoke rain or snow
- Reduced Precipitation:** Water and cloud-based methods to reduce rainfall, diffuse hail storms and hurricanes and to disperse fog

### Land-based Techniques

- Air Capture:** (a.k.a. artificial trees or carbon sucking machines) to remove atmospheric CO<sub>2</sub>
- Biochar:** Agricultural "waste," crops and/or trees burned in low-oxygen conditions to make charcoal that is then added to soils with the aim of sequestering carbon
- Carbon Capture and Storage (CCS):** Processes to capture carbon emissions at source for burial (excluded from CBD provisional definition of geoengineering)
- Bio-Energy with Carbon Capture and Storage (BECCS):** CCS applied to power plants burning biomass, theoretically resulting in net carbon removal from the atmosphere

### Solar Radiation Management (SRM)

- Stratospheric aerosols (a.k.a. artificial volcanoes), cloud whitening, whitening the surface of the Earth or "space mirrors," with the aim of diverting sunlight

### Water-based Techniques

- Ocean Fertilization:** Stimulating the production of carbon-eating algae by adding iron or nitrogen to seawater, or other techniques that modify ocean chemistry to enhance CO<sub>2</sub> sequestration
- Algae Schemes:** Industrial cultivation of algae to consume CO<sub>2</sub> and, theoretically, to generate new biofuels

### Other

- Major research and policy institutes focusing on geoengineering (without testing)
- Noteworthy initiatives that do not fit into any of the above categories (e.g., enhanced weathering)

