



UiO : Department of Geosciences
University of Oslo

Helene Muri

Climate Engineering by Modification of the Earth's Radiation Balance



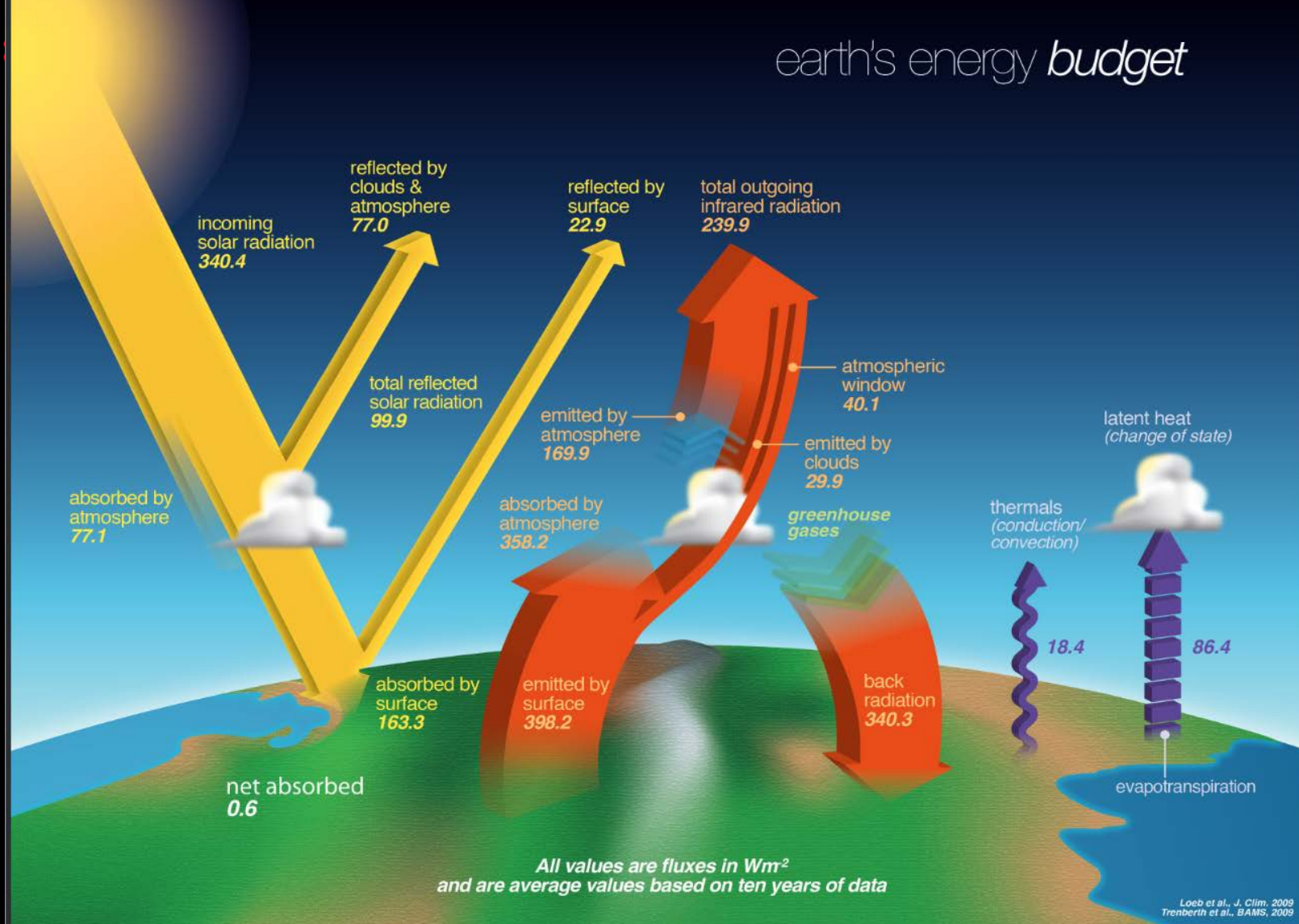
helene.muri@geo.uio.no

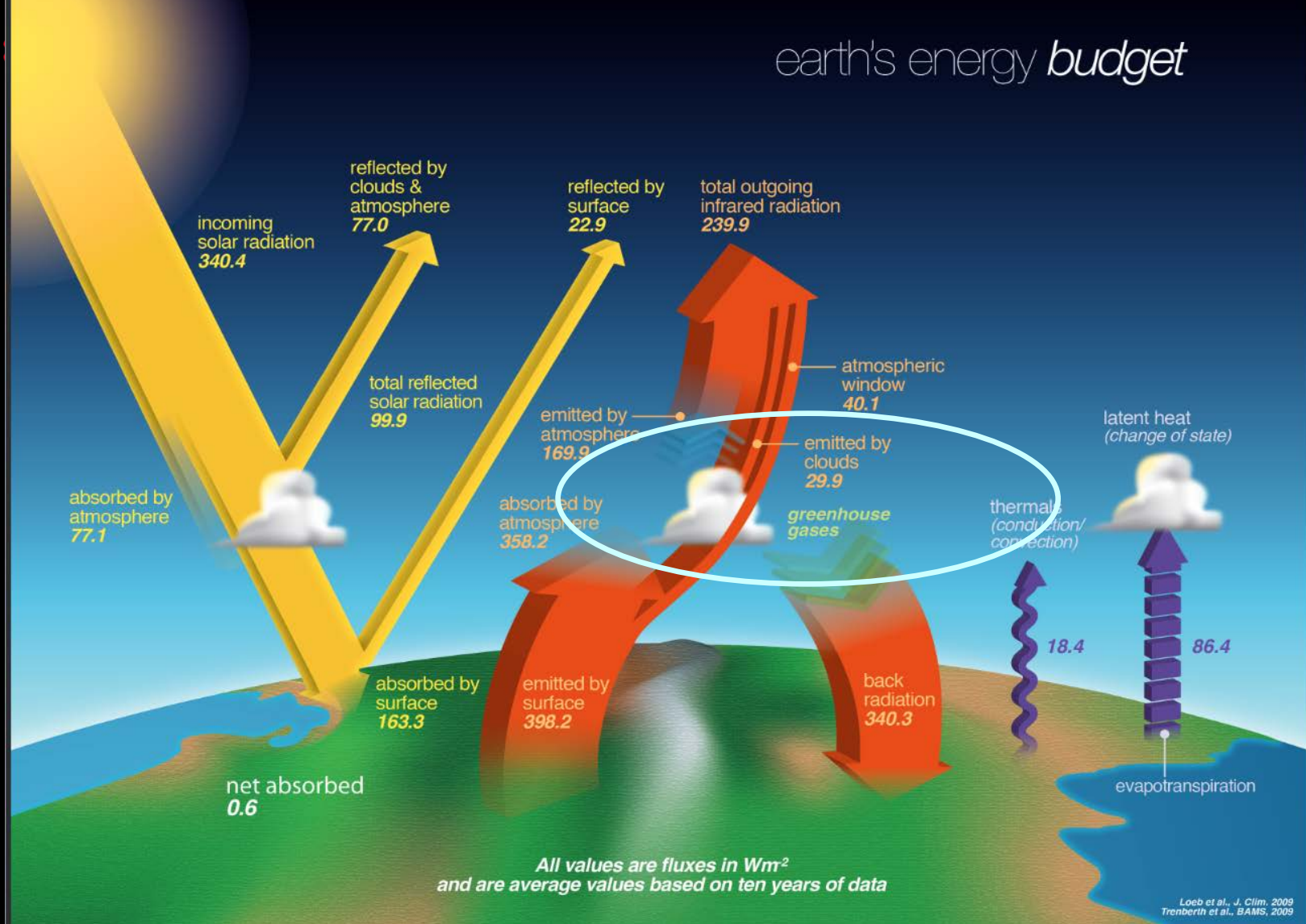


With funding from
The Research Council of Norway

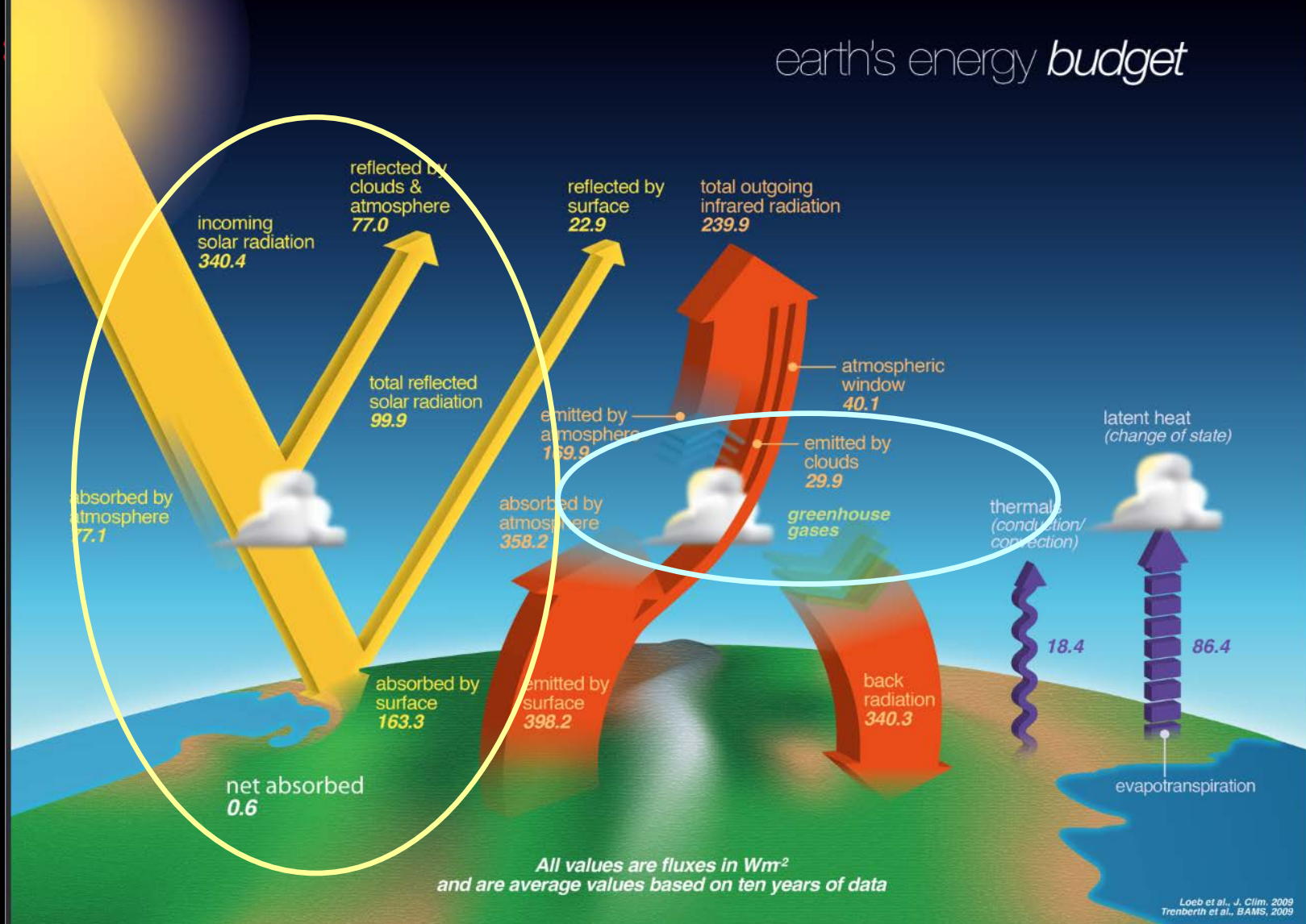
earth's energy *budget*

rch Council



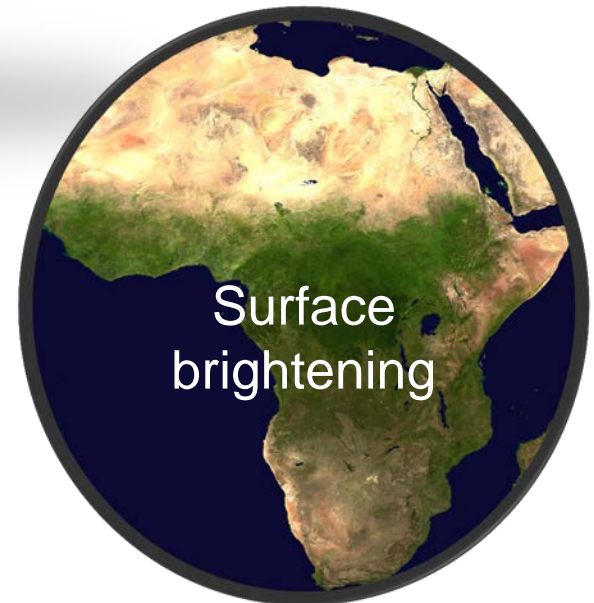
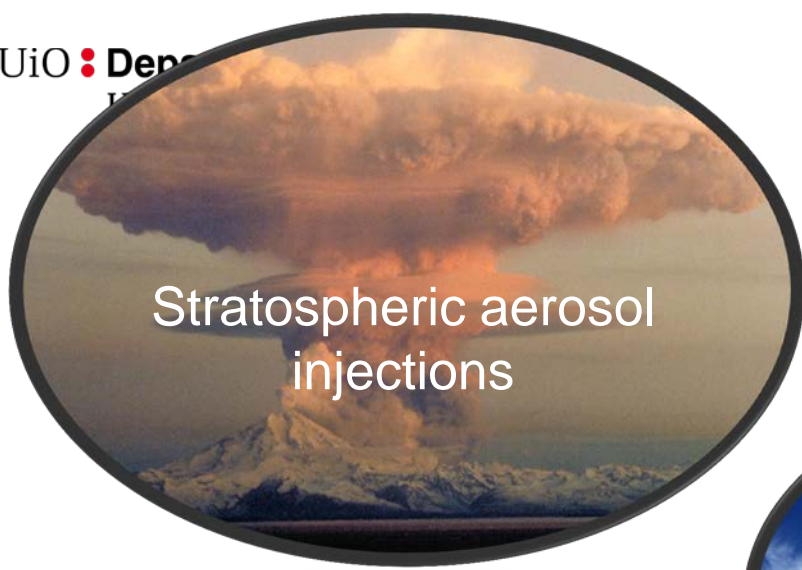


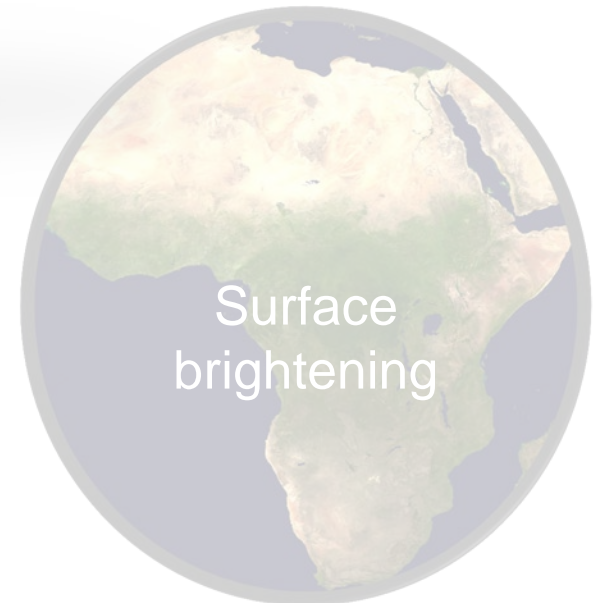
CDR: carbon dioxide removal – acts on the longwave (terrestrial) contribution to the energy balance

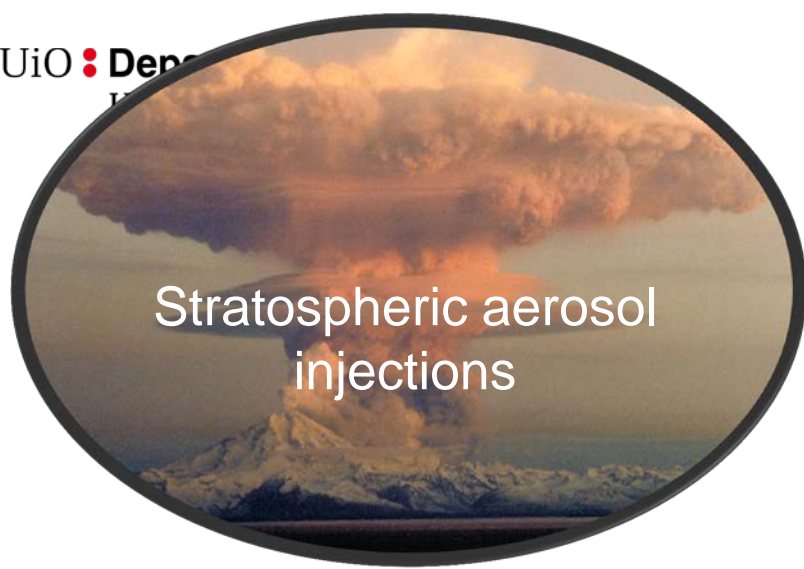


(S)RM: (solar) radiation management – most act on the shortwave (solar) contribution to the energy balance

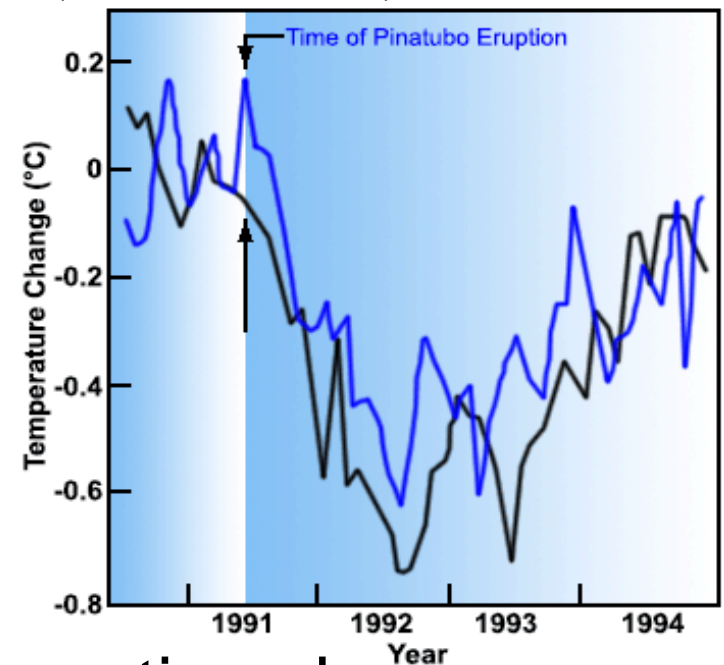
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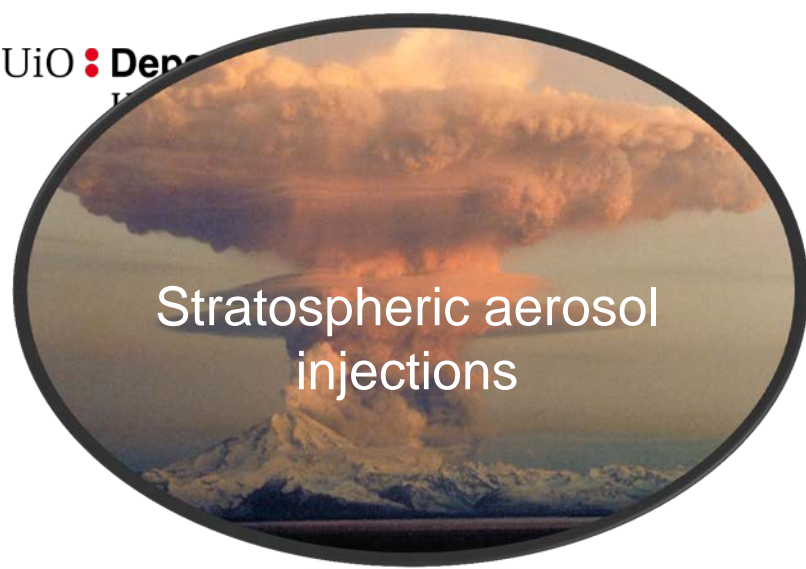




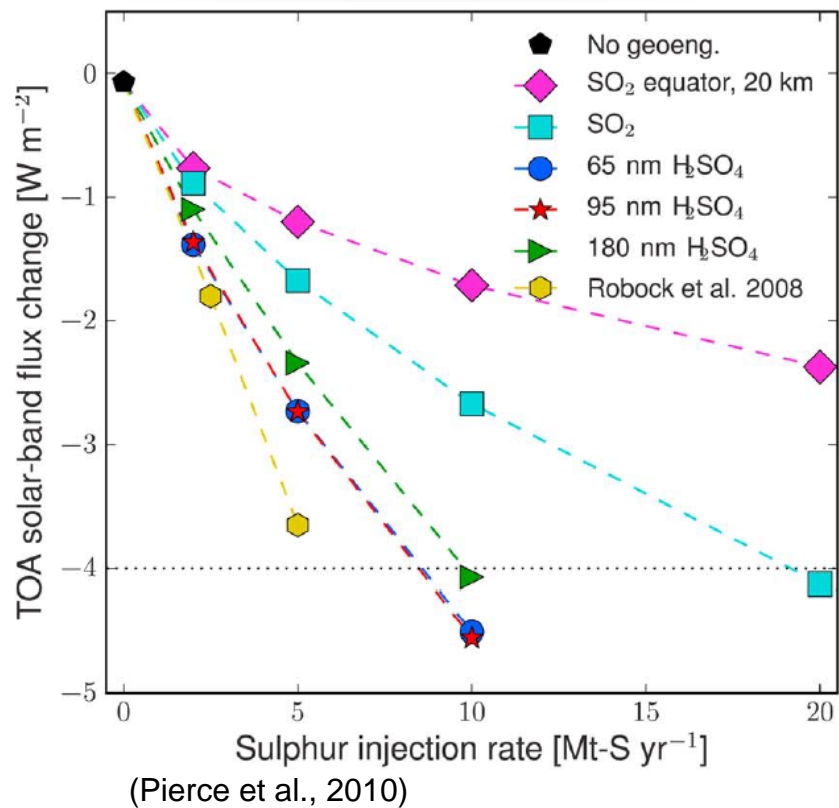
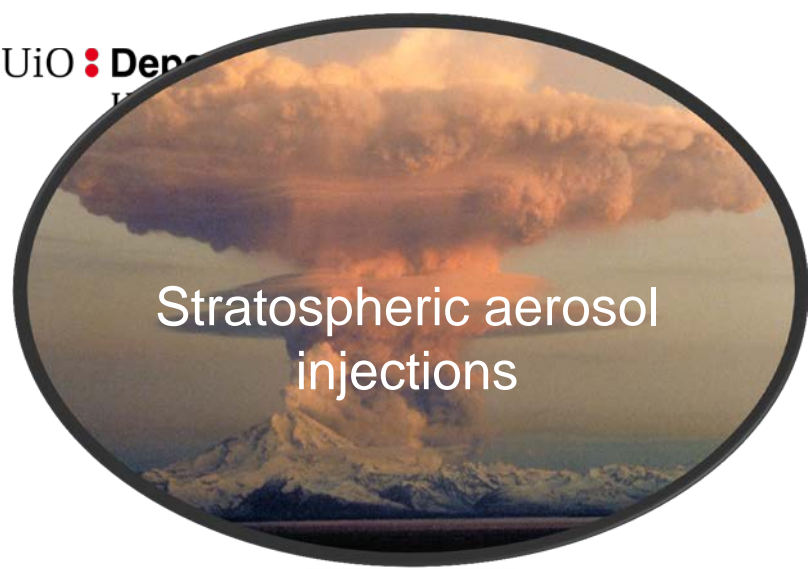
(After Hansen et al., 93)



- Concept: ‘mimic’ volcanic eruptions by injecting reflective aerosol particles (or their precursors) into the lower stratosphere.
- The particles would scatter and reflect solar radiation, increasing the planetary reflectivity, and cool the climate.

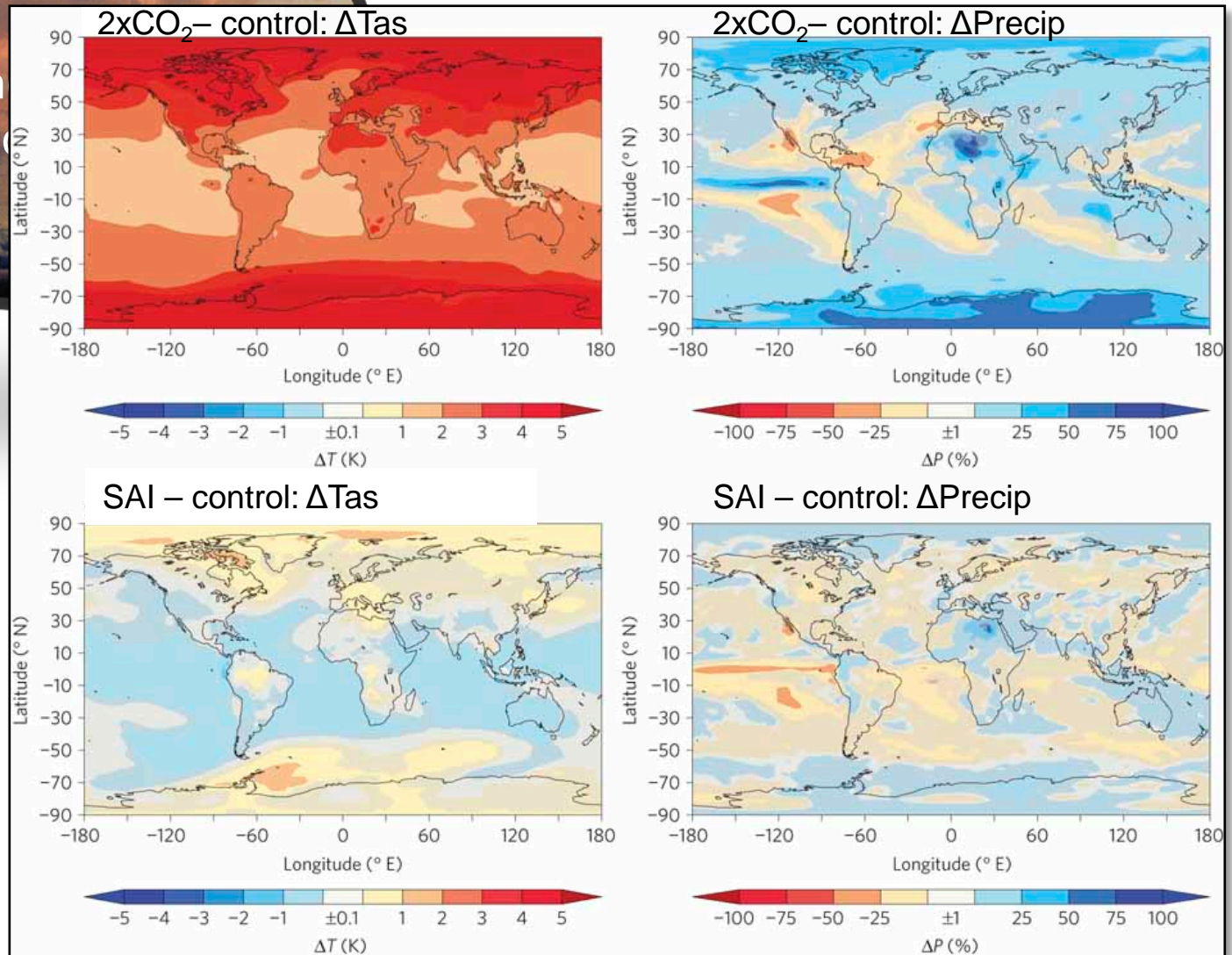


(Robock et al., 2009. Drawing by Brain West)

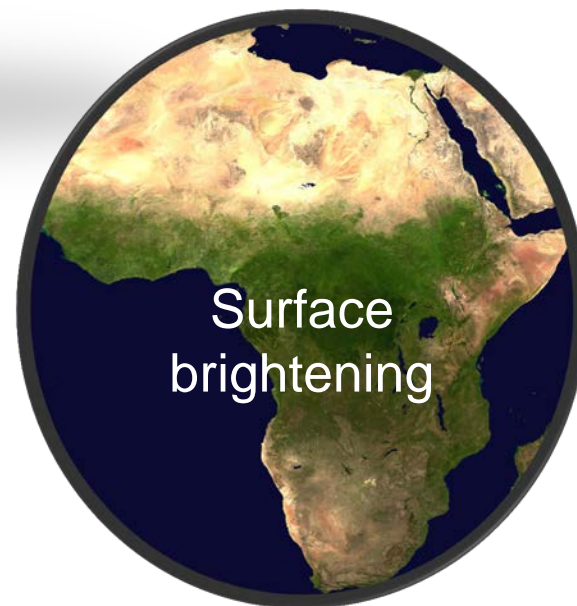
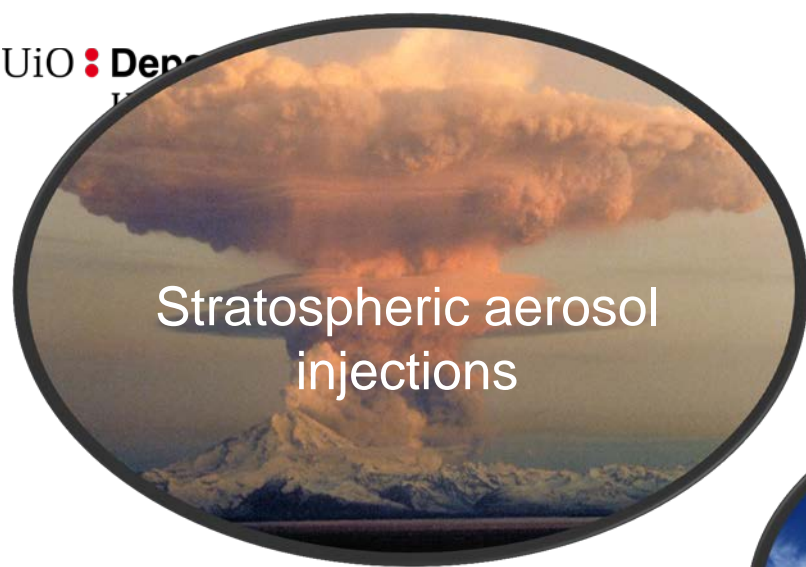


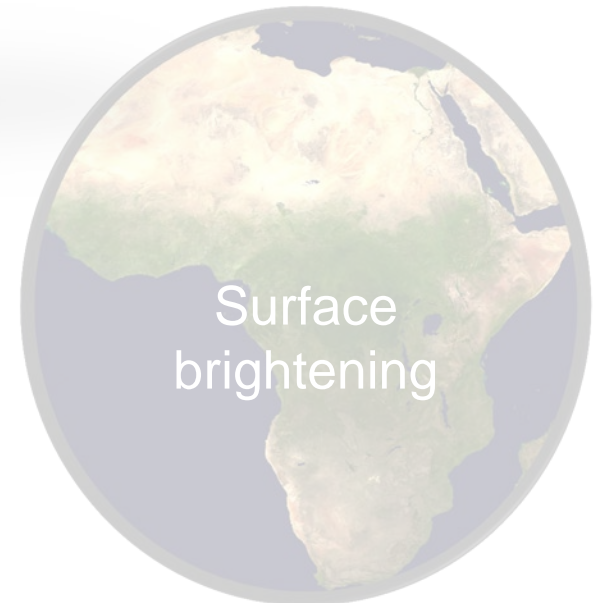
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Stratosph
inje

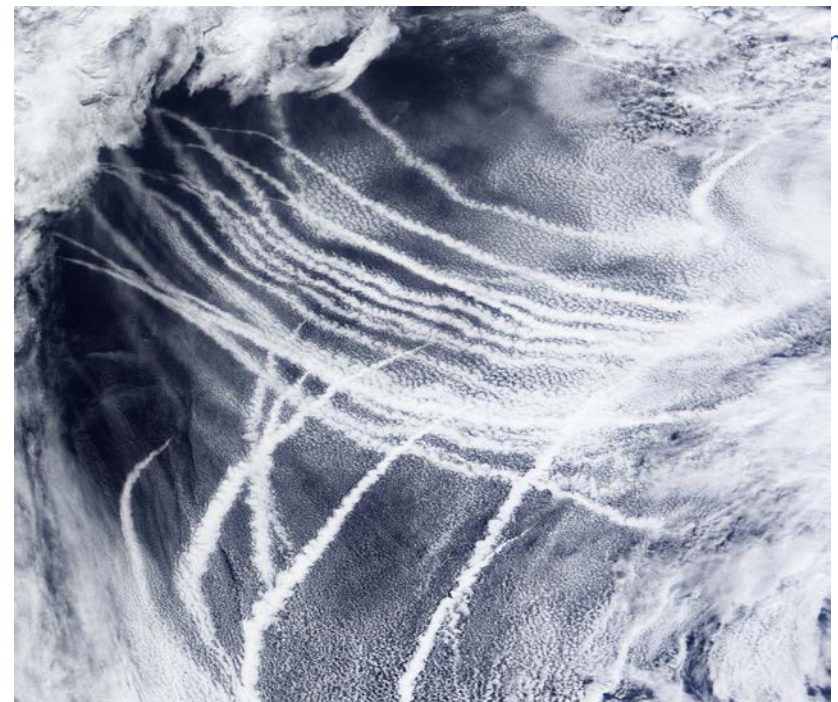


(Pongratz et al., 2012)



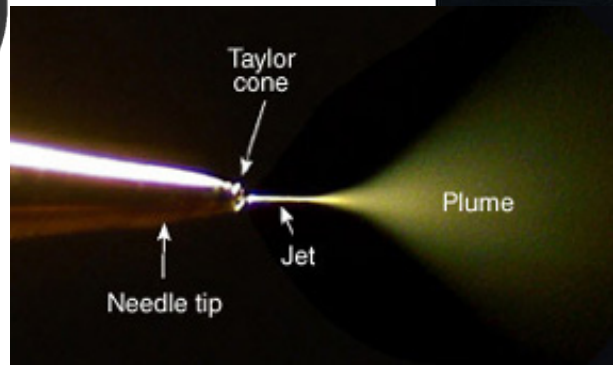
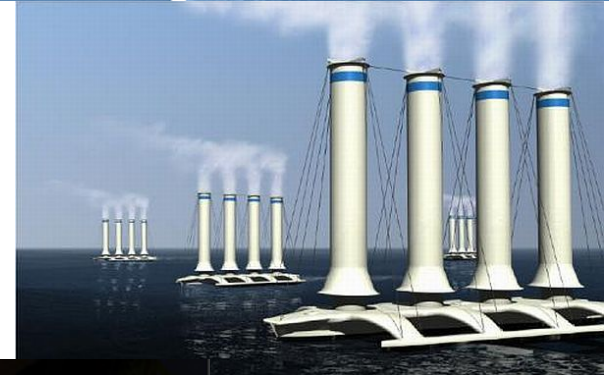
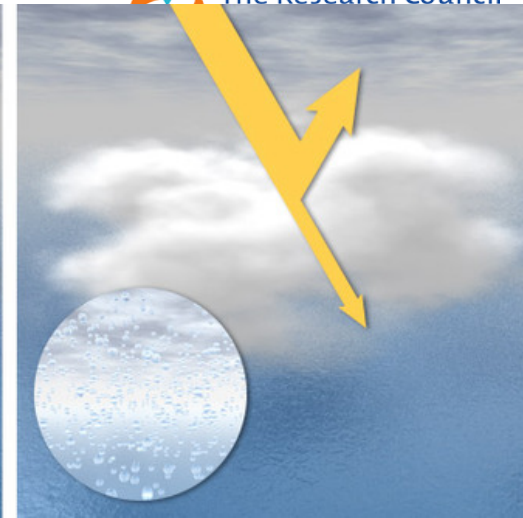


- Concept: brighten clouds to reflect more sunlight.
- Ship tracks analogy



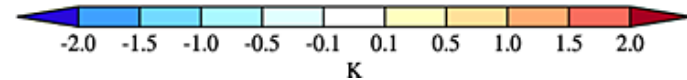
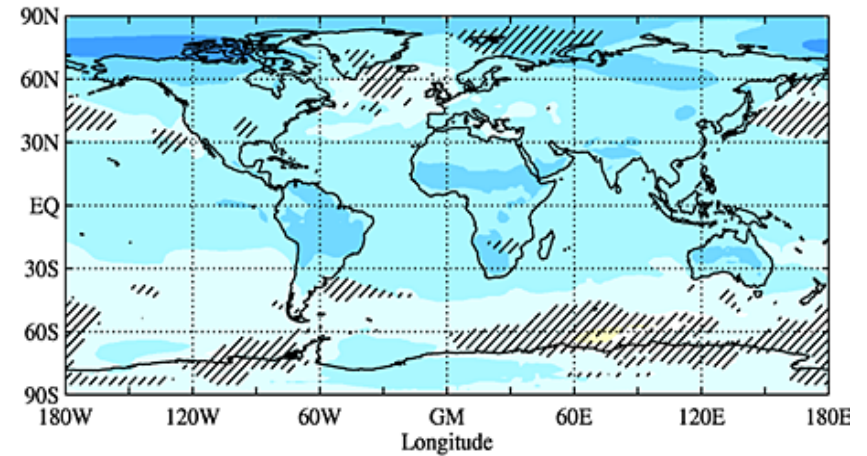
(Source: <http://visibleearth.nasa.gov/view.php?id=66963>.)

- Spray sea water.
- Sea salt aerosols can act as cloud condensation nuclei to make clouds denser.
- Aerosols also directly reflective.

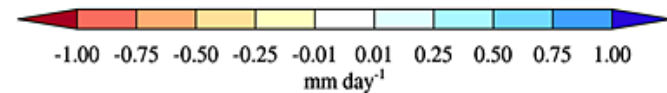
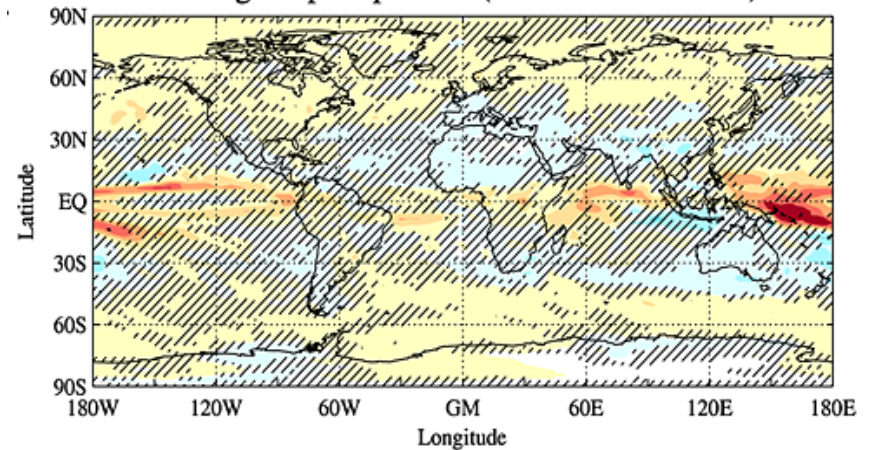




Change in near surface temperature (G3-SSCE - RCP4.5)



Change in precipitation (G3-SSCE - RCP4.5)



(Alterskjær et al., 2013)

(Wang et al., 2011)

0.0 0.2 0.4 0.6 0.8 1.0

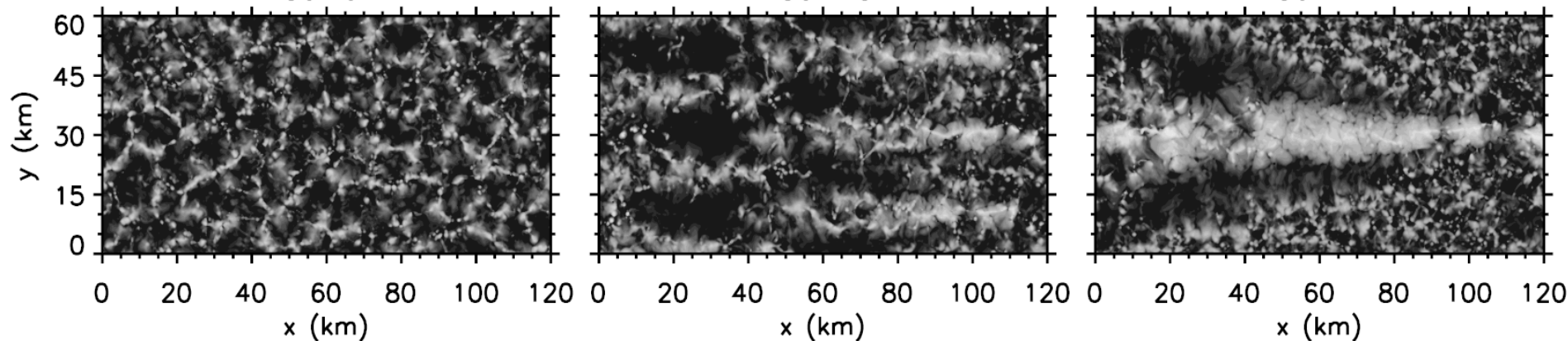
(a) cloud albedo



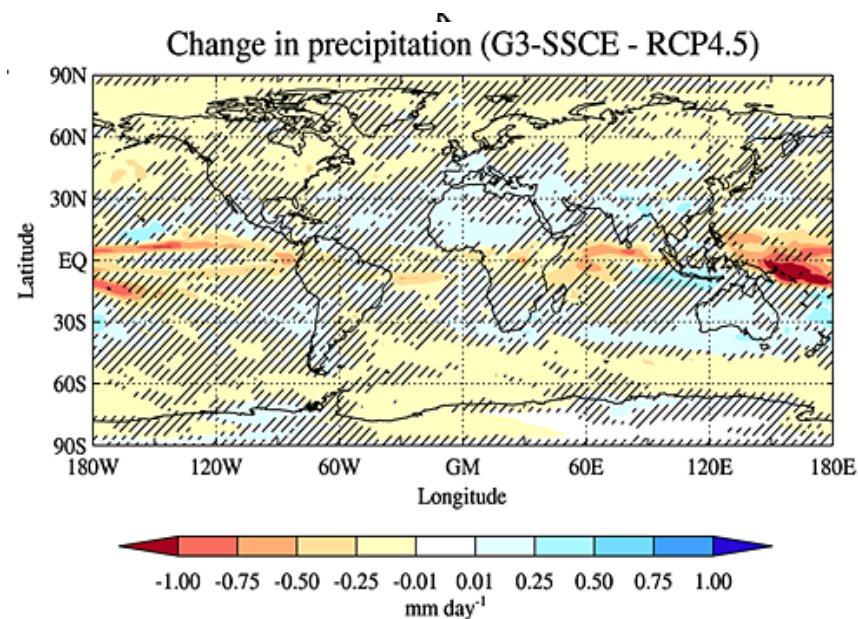
W50-U

W50-P3

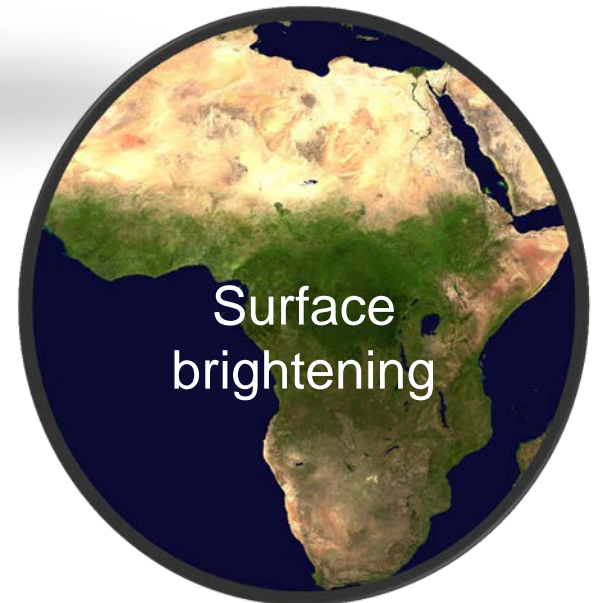
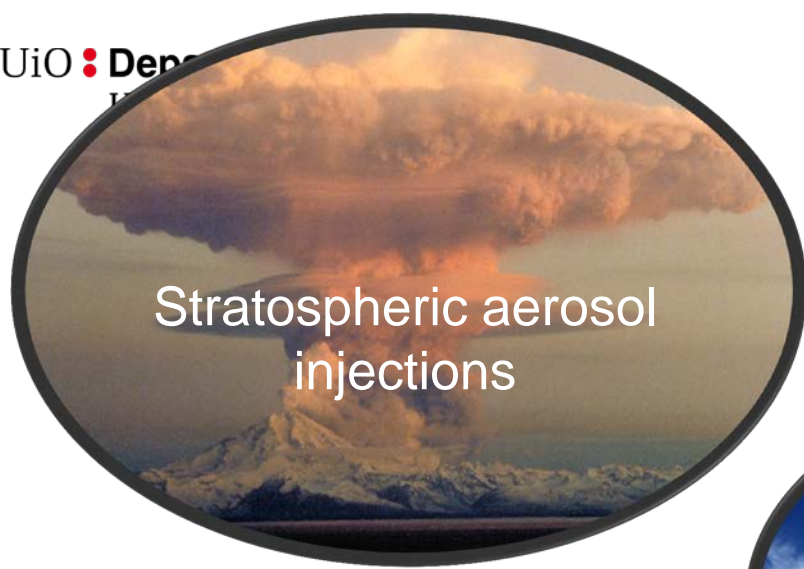
W50-P1



Marine sky
brightening



(Alterskjær et al., 2013)





Stratospheric aerosol
injections



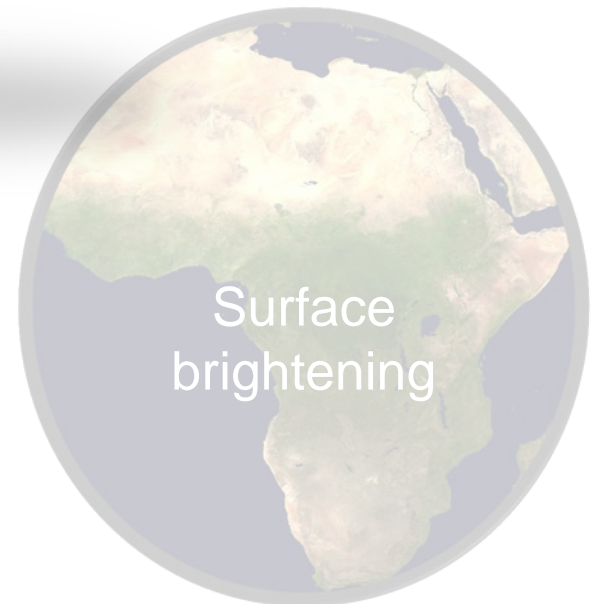
Space
mirrors



Cirrus cloud
thinning

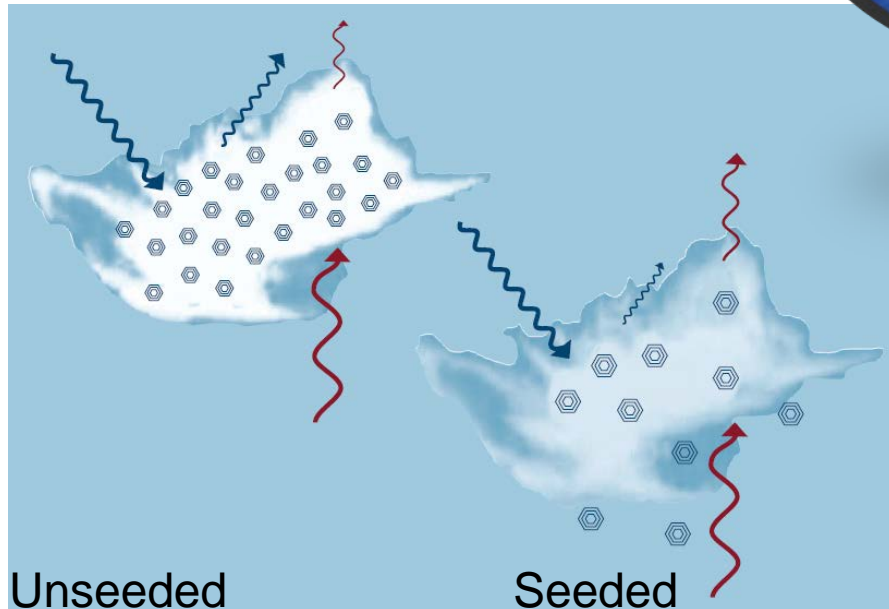


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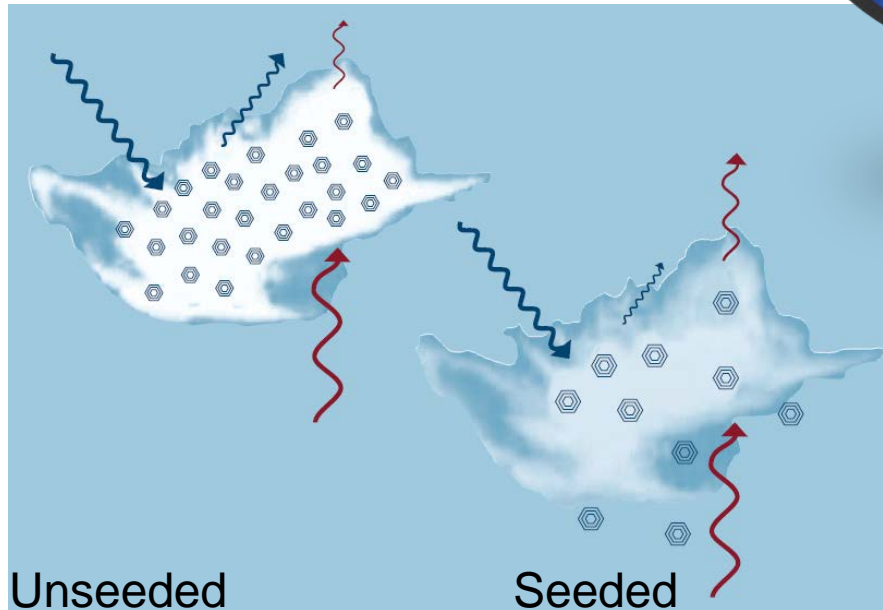
Surface
brightening

- Concept: deplete high level, heat trapping ice clouds.
- Seed the clouds with very effective ice nuclei.
- Grow large ice crystals that fall out of clouds.
- Release more **LW** radiation.
- Dependant on low levels of pre-existing ice nuclei.



(After Storelvmo et al., 2013)

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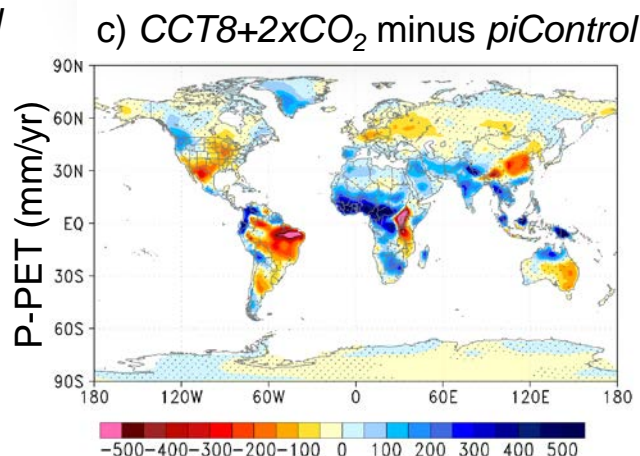
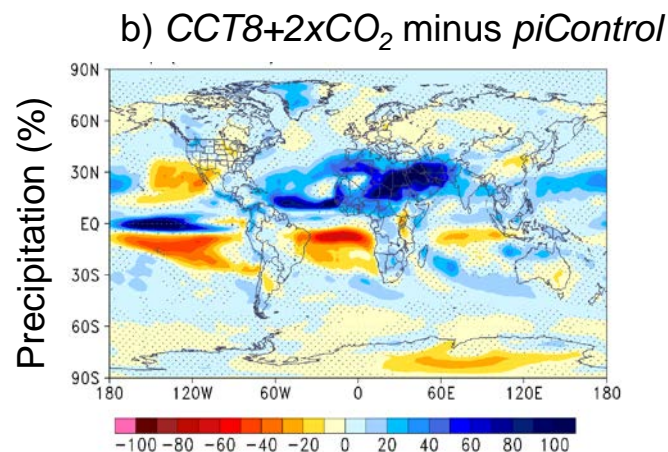
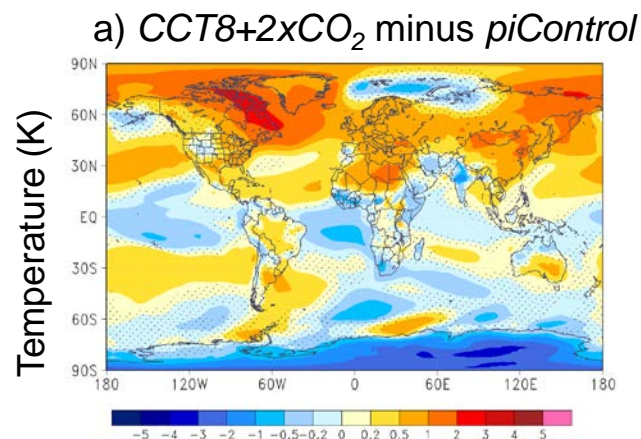
(After Storelvmo et al., 2013)



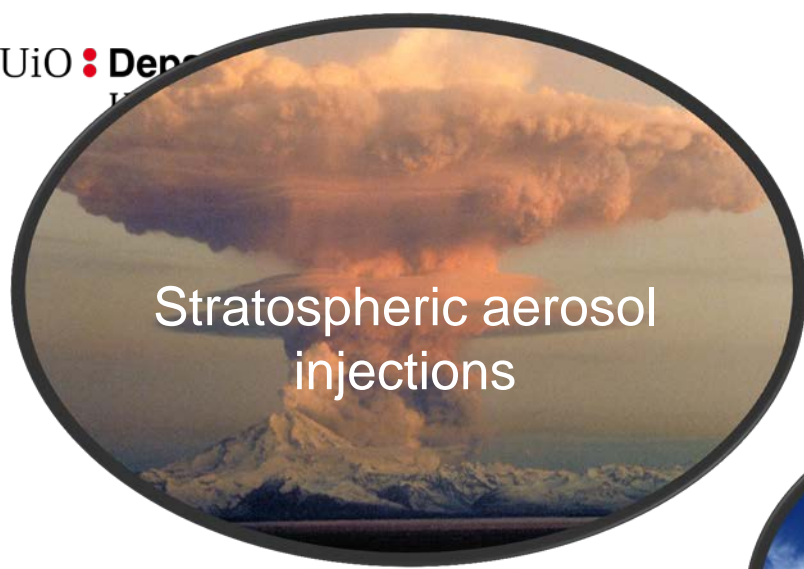
(Credit: Kevin Clifford/Drone America)



- Intensification of the hydrological cycle.
- Resultant temperature/ climate response dependant on location of clouds, seeding strategy, ...



(Kristjansson et al., 2015)



Stratospheric aerosol
injections



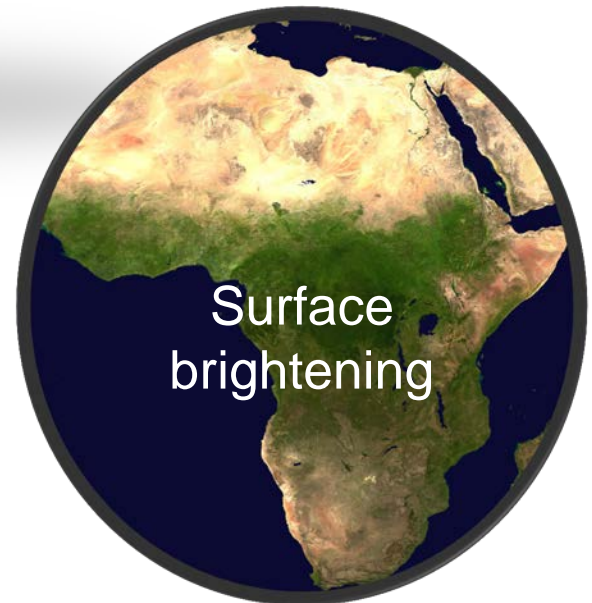
Space
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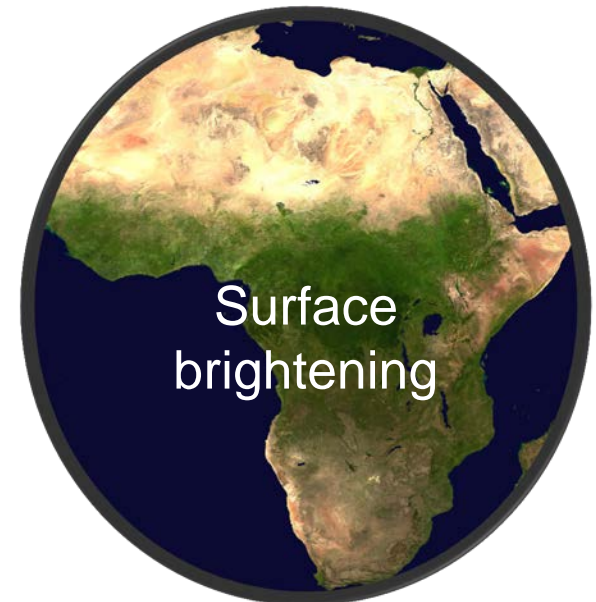
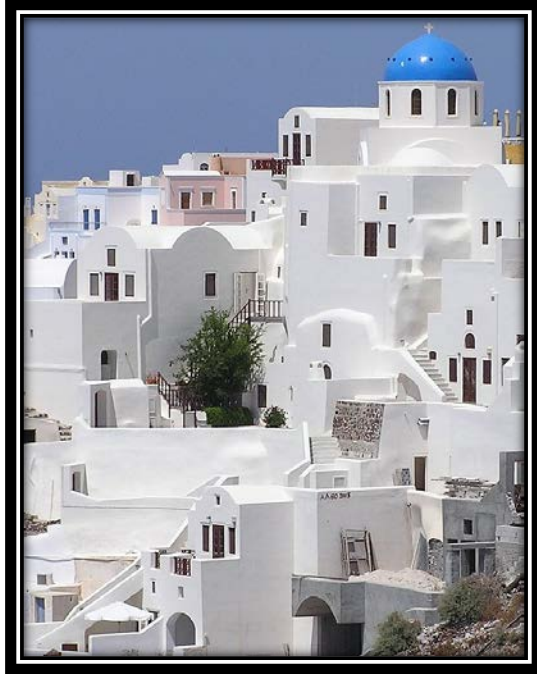


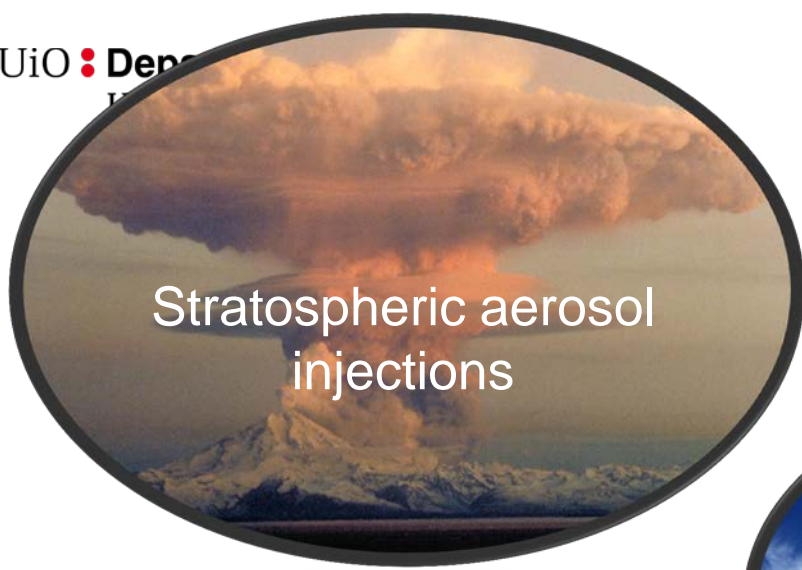
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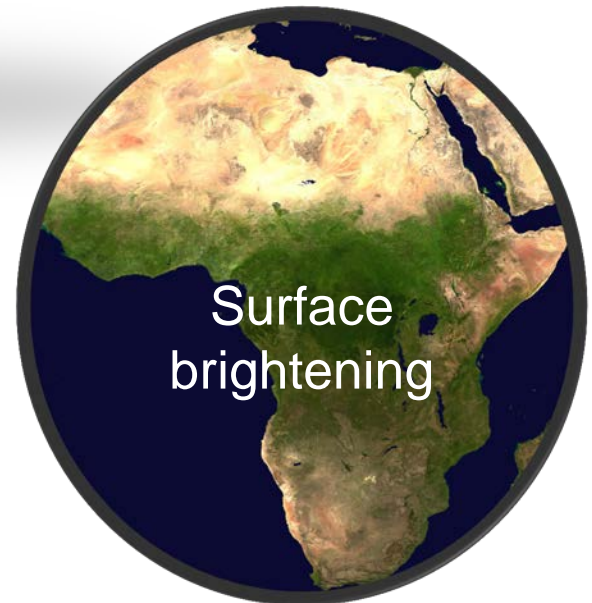
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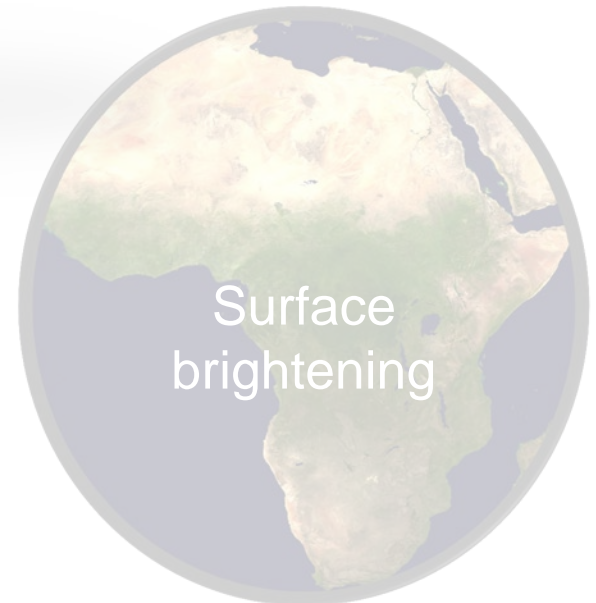
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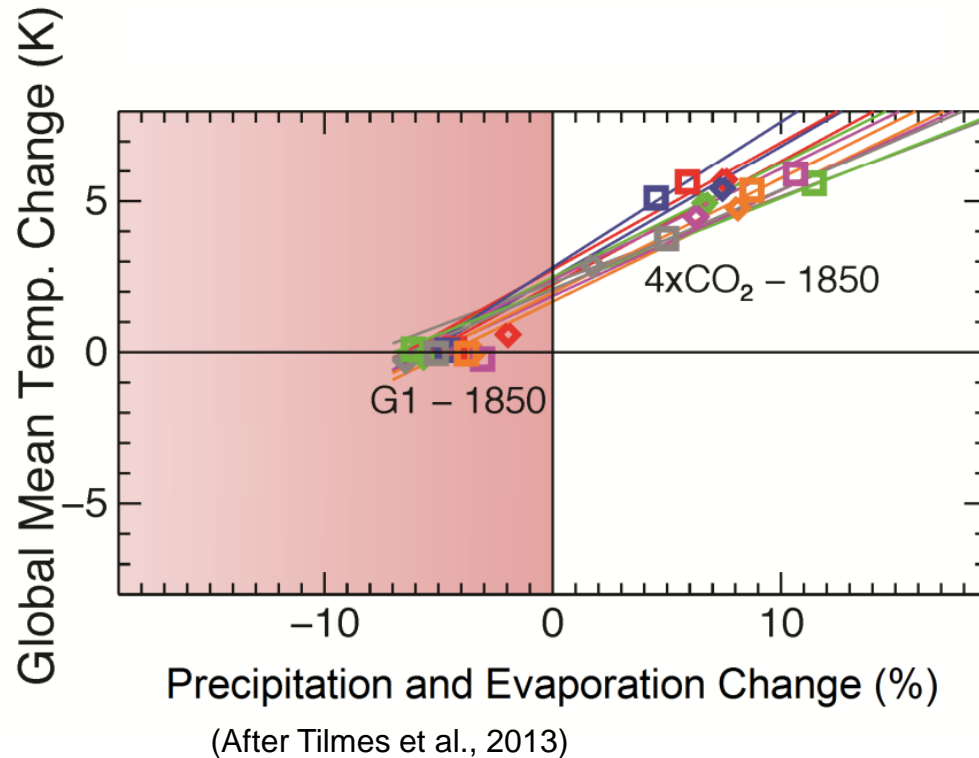


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brightening



Surface
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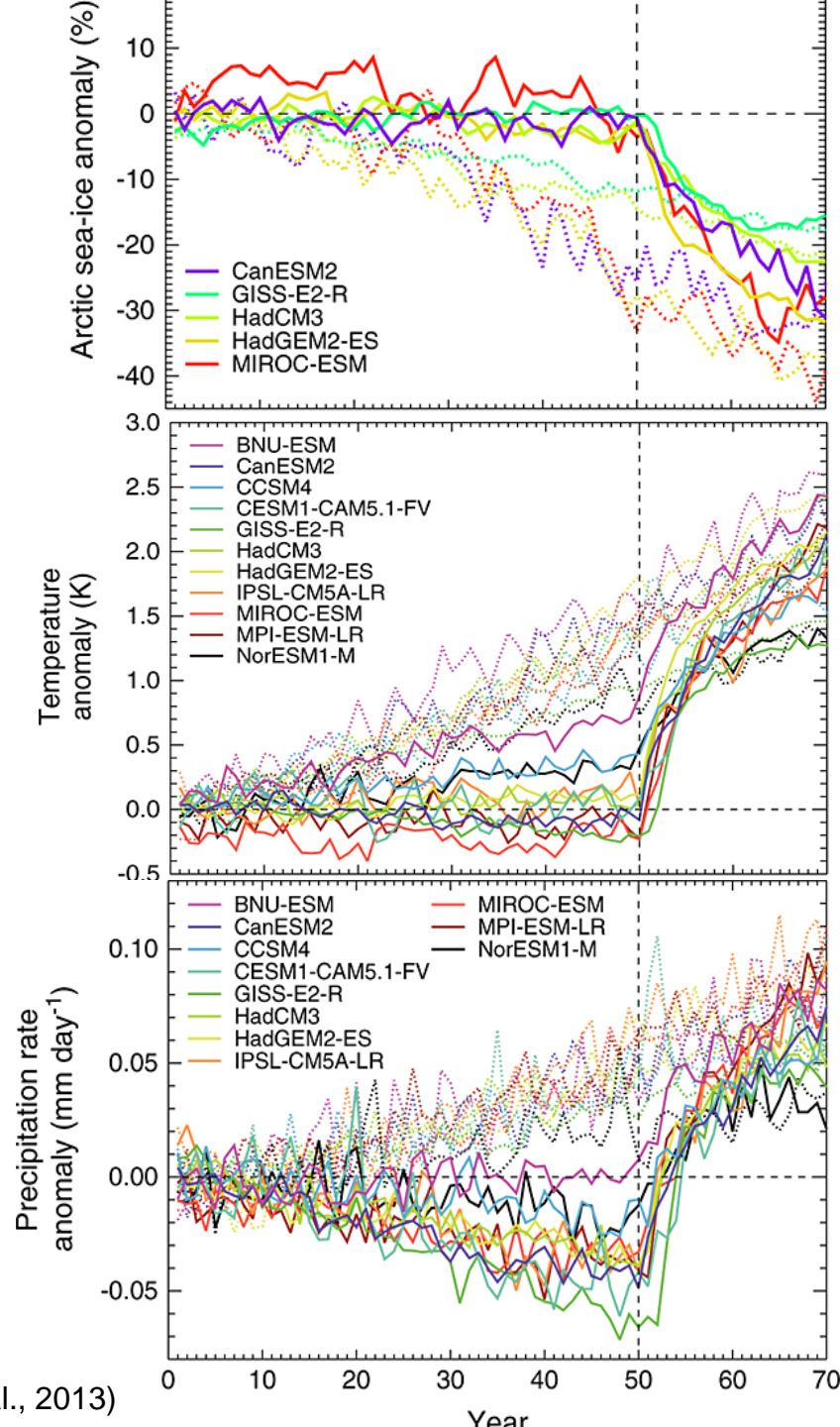




- Concept: Place mirrors in space to reflect sunlight before reaching Earth.
- Astronomical deployment costs.
- Modelling can reveal fundamentals of RM types like SAI.

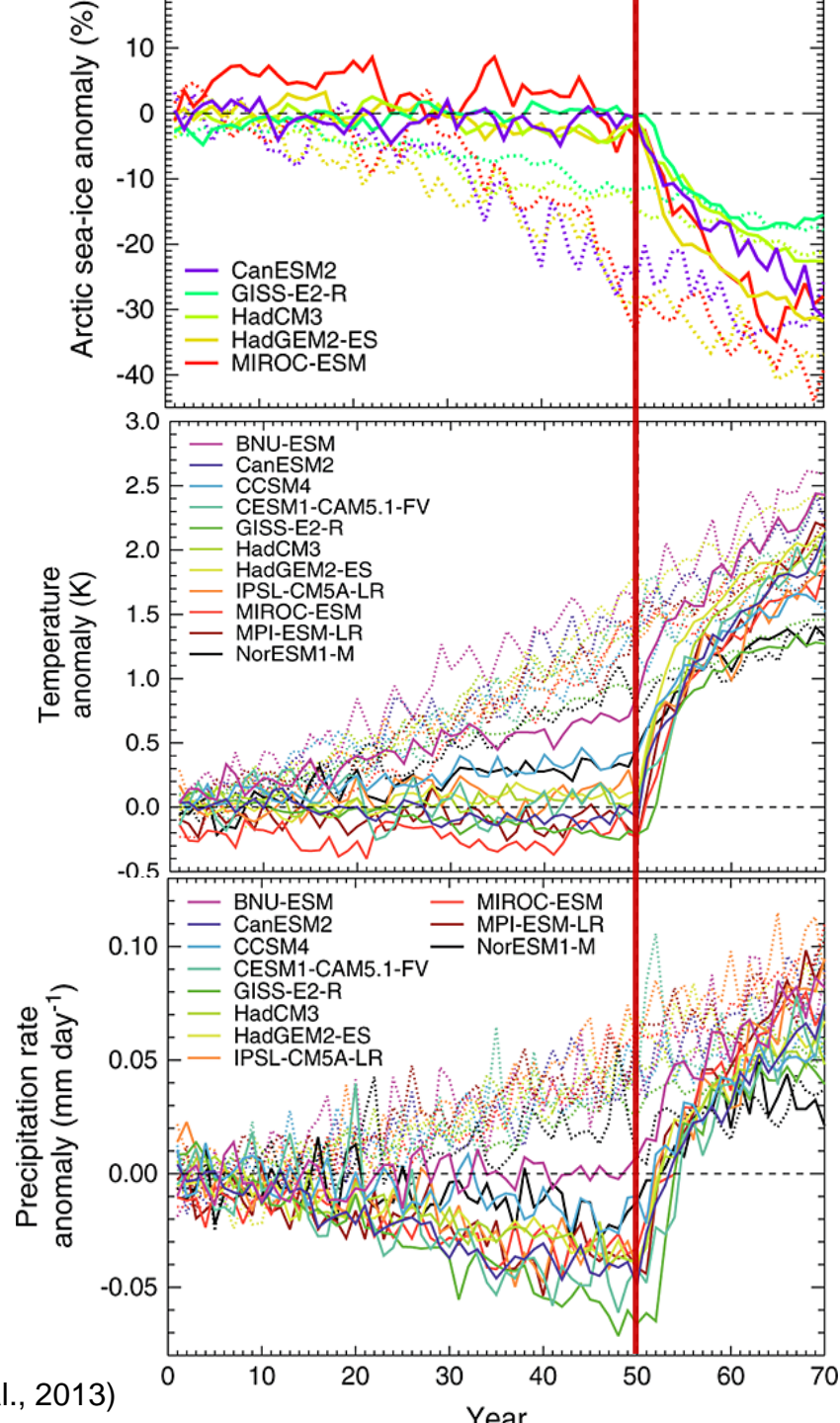
Termination 'shock'

- If large-scale deployment would suddenly stop
→ Not a comfortable place to be ...



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- Termination effect problem.
- Technical maturity low(‘ish)

