Aerosol particles and clouds across scales

Prof. (em.) Dr. Andrea I. Flossmann

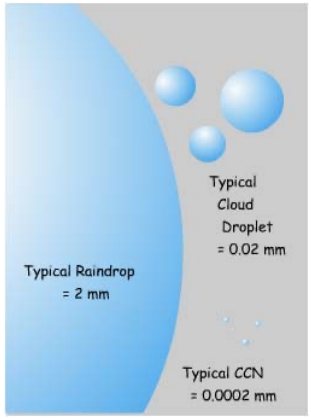
Université Clermont Auvergne

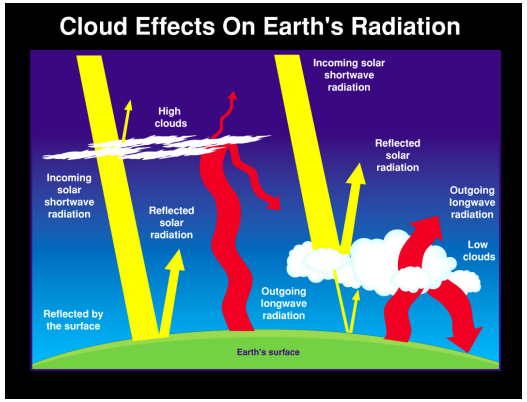
andrea.flossmann@uca.fr

clouds across scales

Clouds

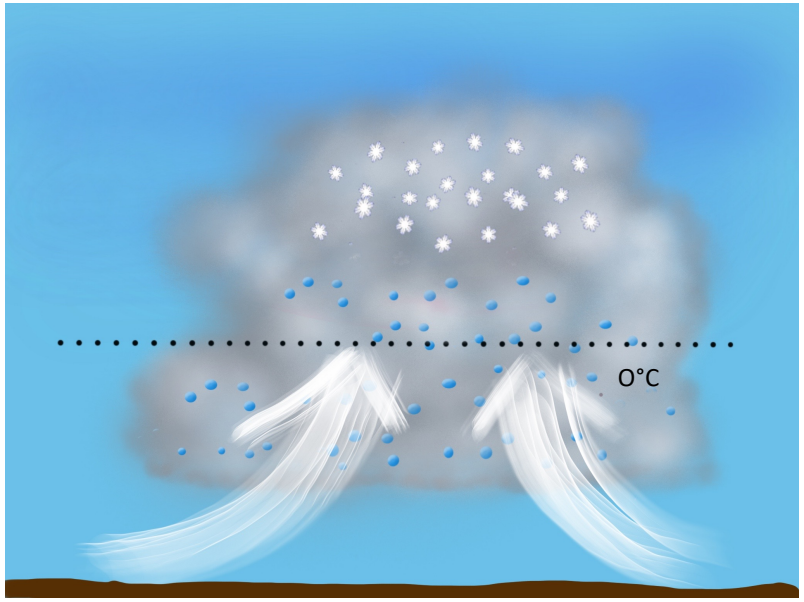
- are composed of drops or ice crystals with sizes between some μm and several mm
- determine our weather
- Contribute to our climate

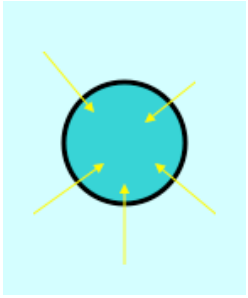


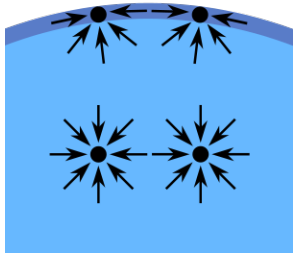


How do clouds form?

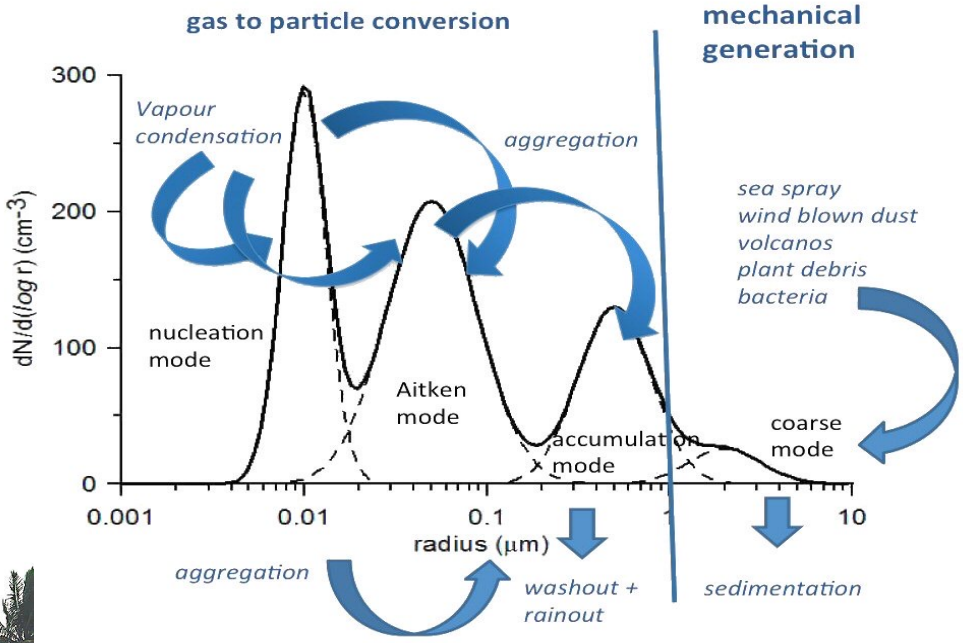
- water vapour is rising, cooling and condensing
- In « clean » air 20*100% rel hum is necessary to stabilize a drop of 9 molecules
- A pre-existing support is mandatory
- => Aerosol particles serve as cloud condensation nuclei or ice nucleating particles





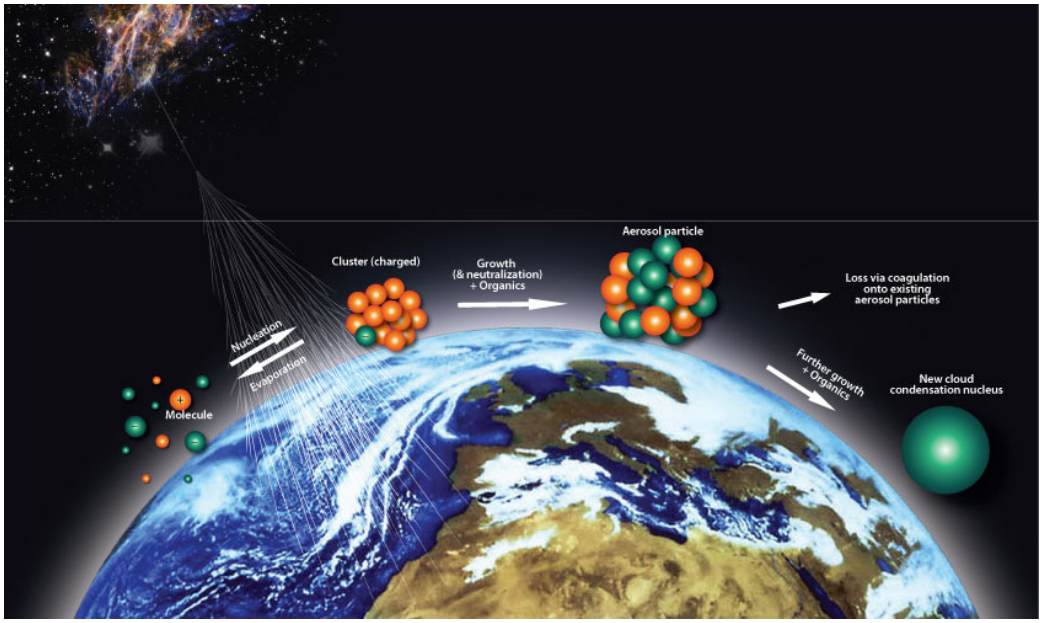


Aerosol particles



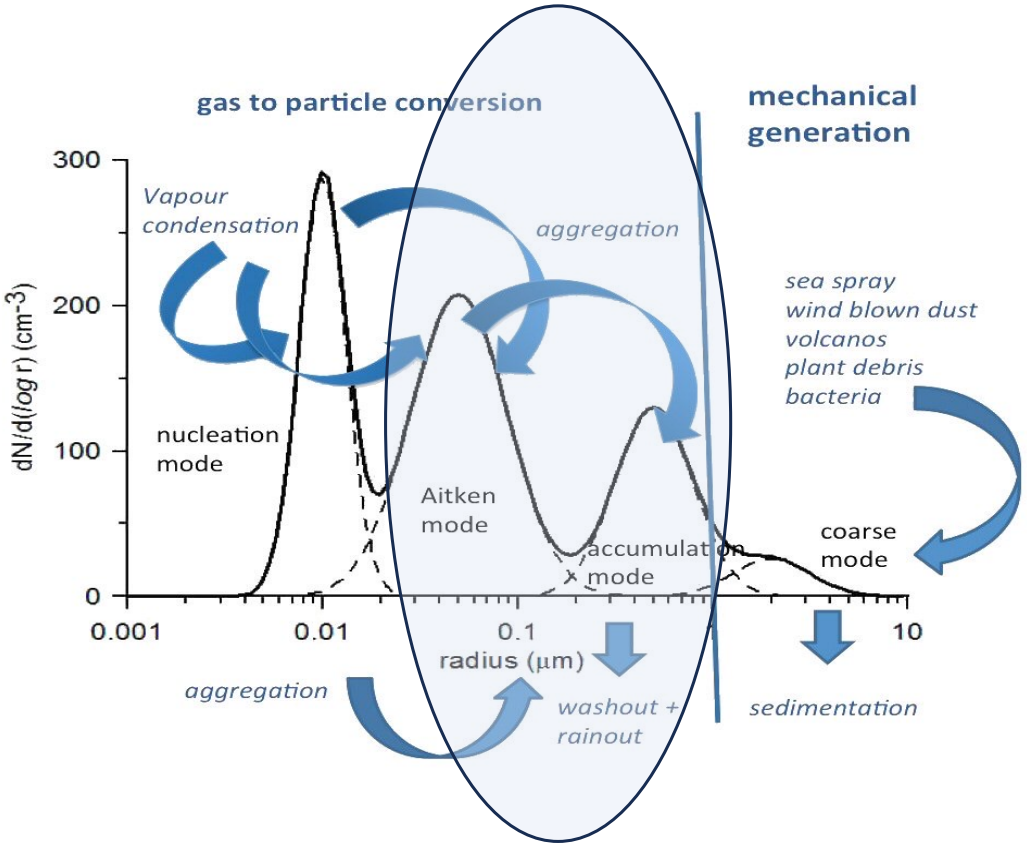
sizes between some nm and several μm

Aerosol particles formed by galactic cosmic rays (CLOUD/CERN)



the Proton Synchrotron provides an artificial source of “cosmic rays”; controlled temperature + additional trace gases

Aerosol particles



Conditions for serving as cloud condensation nucleus (CCN) or ice nucleating particles (INP):

Size: 0.3 μm – 3 μm

CCN: soluble
INP: insoluble

How precipitation is formed?

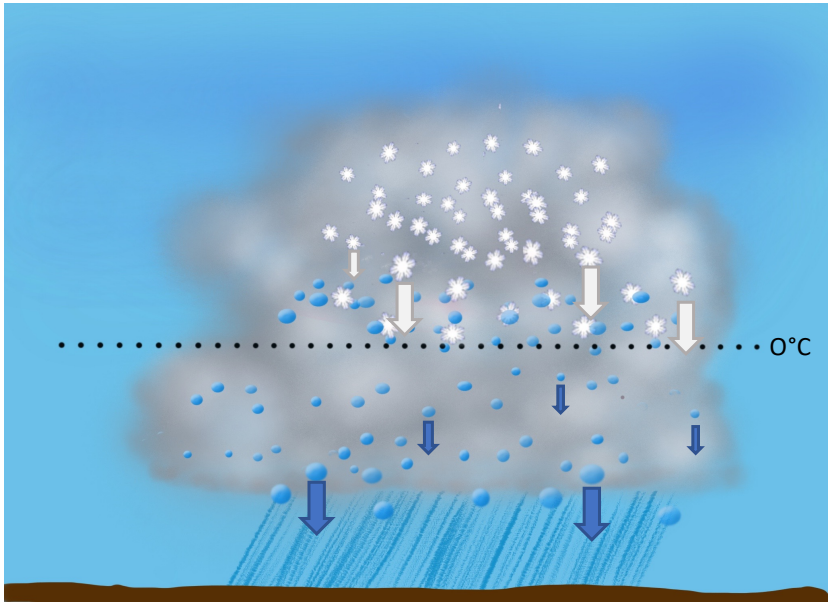
Growth of drops and crystals to millimeter - sizes

by collision:

drop – drop = raindrop,

crystal - crystal = snowflake,

drop - crystal = graupel/hail



only efficient if enough hydrometeors with different sizes (significant terminal velocities)

ca 1 million drops (of 10 μm) form a raindrop (of 1 mm)

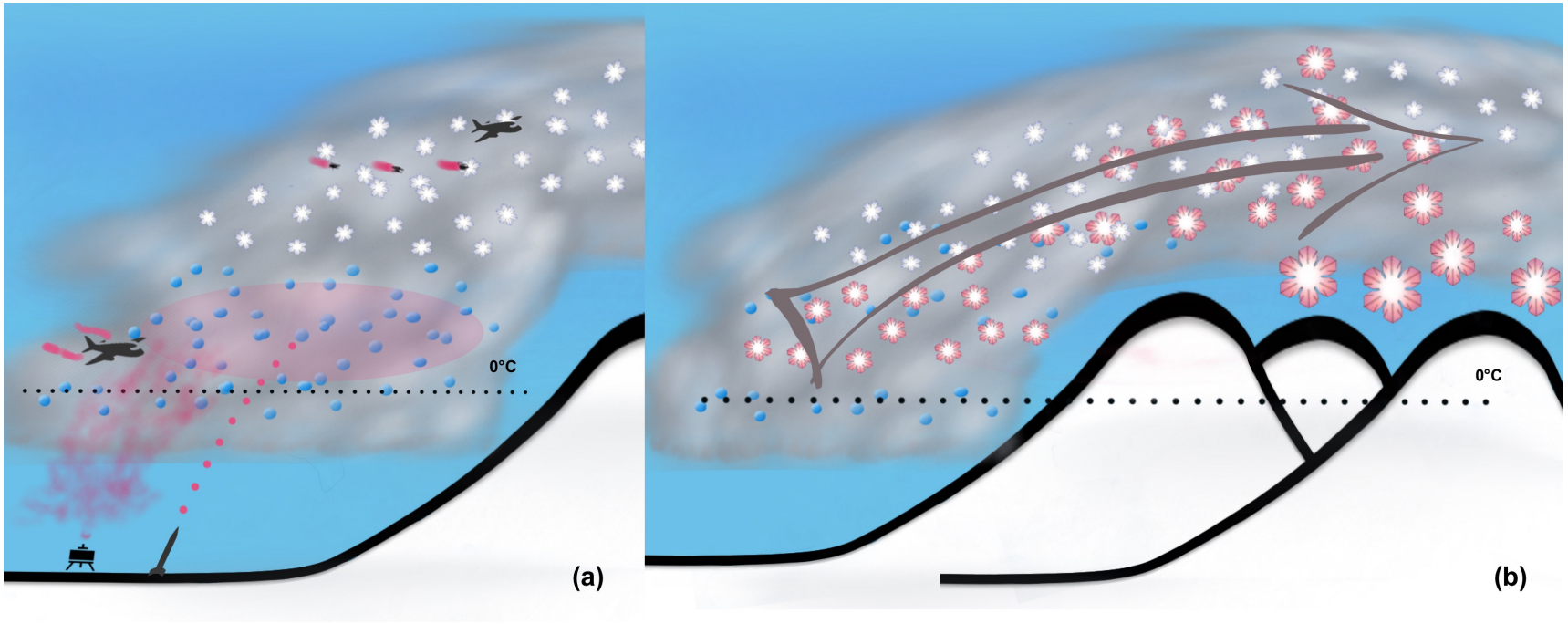
Early 1950 : idea to seed clouds with “appropriate particles” to boost precip formation

Problem: large natural variability of clouds

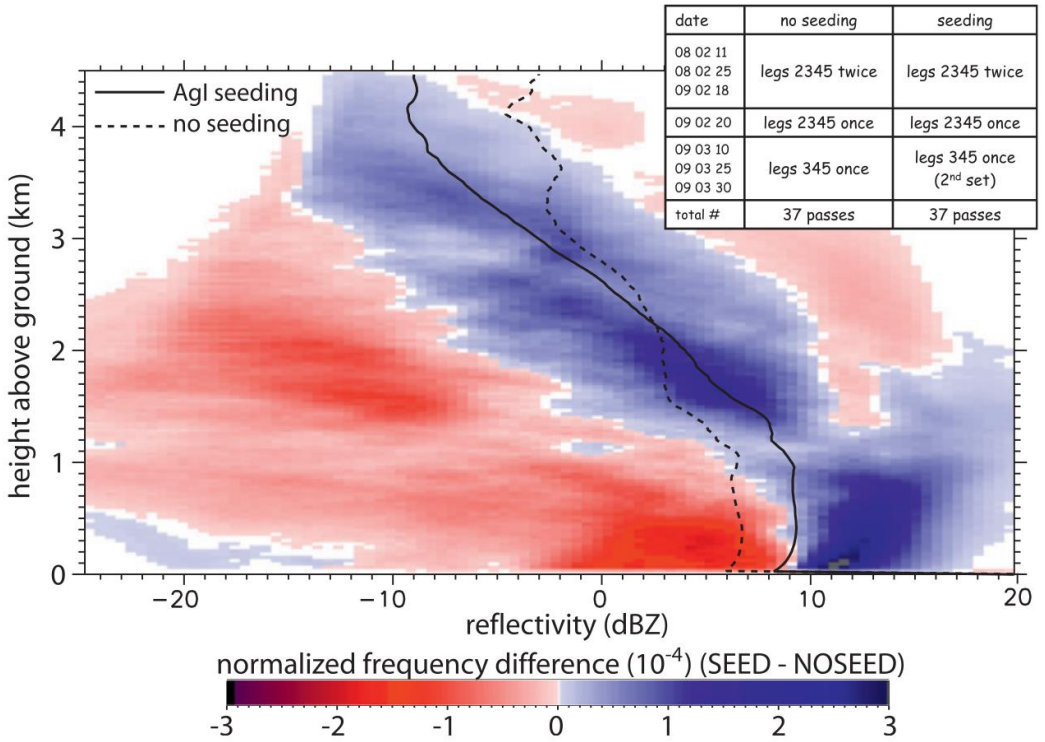
1946: Langmuir, Vonnegut and Schaefer

https://www.novakarchive.com/vintage-magazine-covers/colliers-may-28-1954

Concept of glaciogenic seeding of wintertime orographic clouds

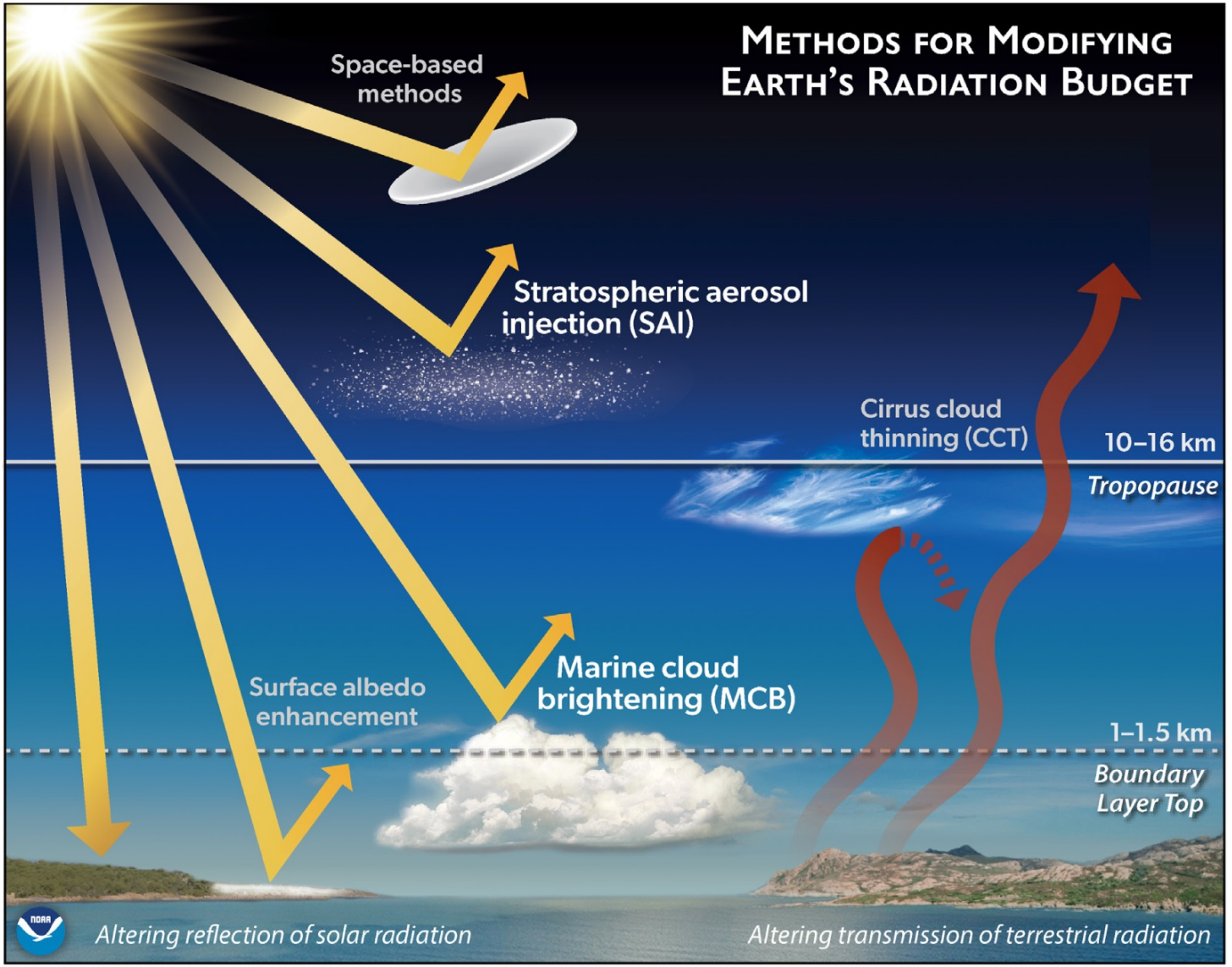


add INP to form crystals that grow via vapor deposition and riming; the additional release of latent heat may invigorate the cloud; ex: the Snowy Precipitation Enhancement Research Projects (SPERP-1 and 2) in the Snowy Mountains of south eastern Australia; the Wyoming Weather Modification Pilot Project (WWMPP); to increase snow pack in catchment basins feeding water reservoirs

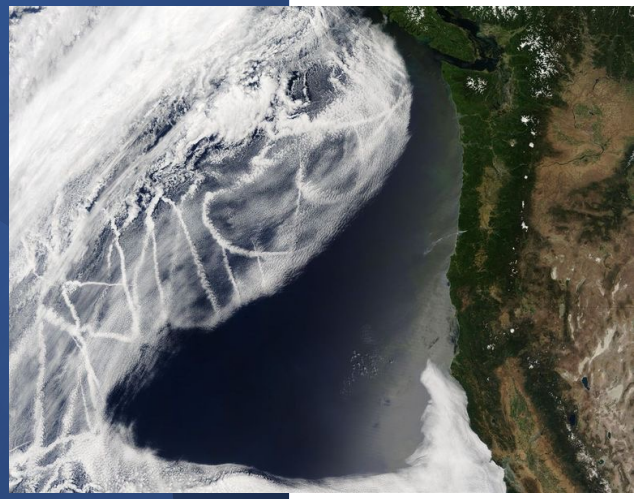


Difference in normalised frequency-altitude display (FAD) of aircraft-based radar reflectivity between seeded and unseeded conditions downwind of ground-based AgI generators in Wyoming, USA (taken from Geerts et al. 2010); there is a substantial increase in reflectivity within the boundary layer, especially near the ground; the mean seeded and unseeded difference is shown by the solid and dashed black lines. The inset shows the matching 37 aircraft passes in seeded and unseeded aircraft legs, based on 5 geographically-fixed cross-wind tracks.

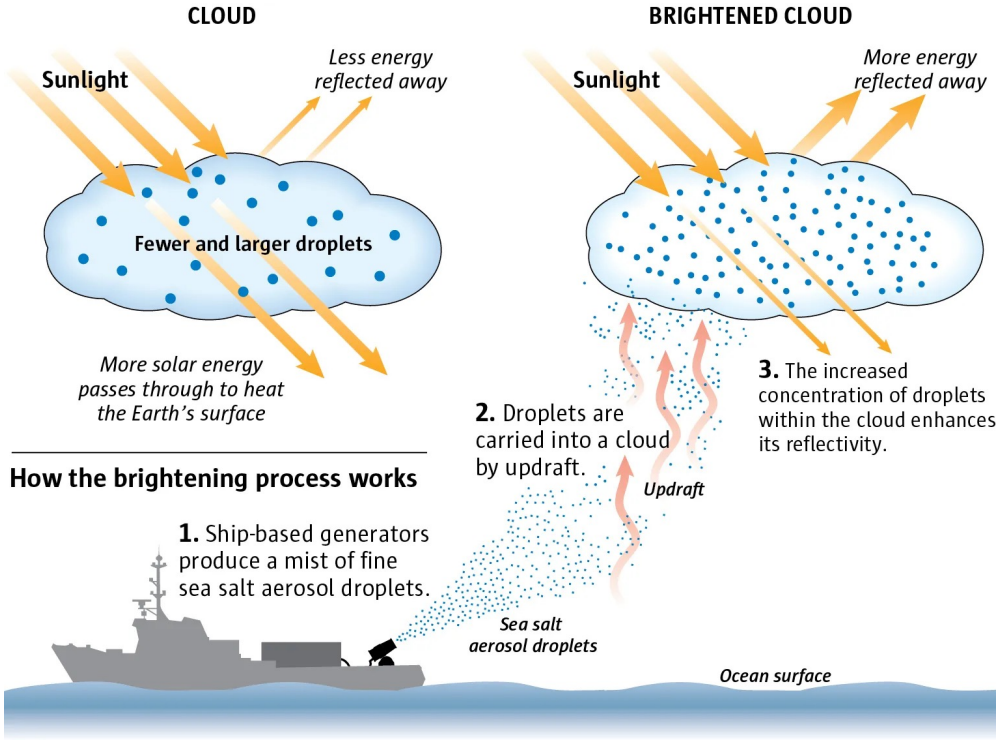
Discussion: seeding for geoengineering (solar radiation management)



Principe of marine cloud brightening



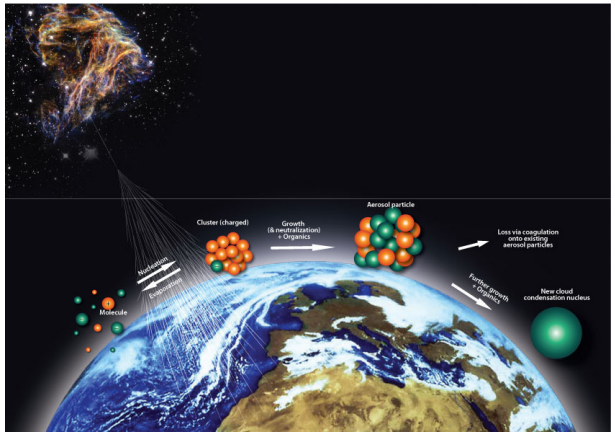
ship tracks



2023 Great Barrier Reef (Australia)

Effect of APs from galactic cosmic rays?

Debate wrt role for past, present and future climate change still ongoing
Pre-industrial role?



Questions?