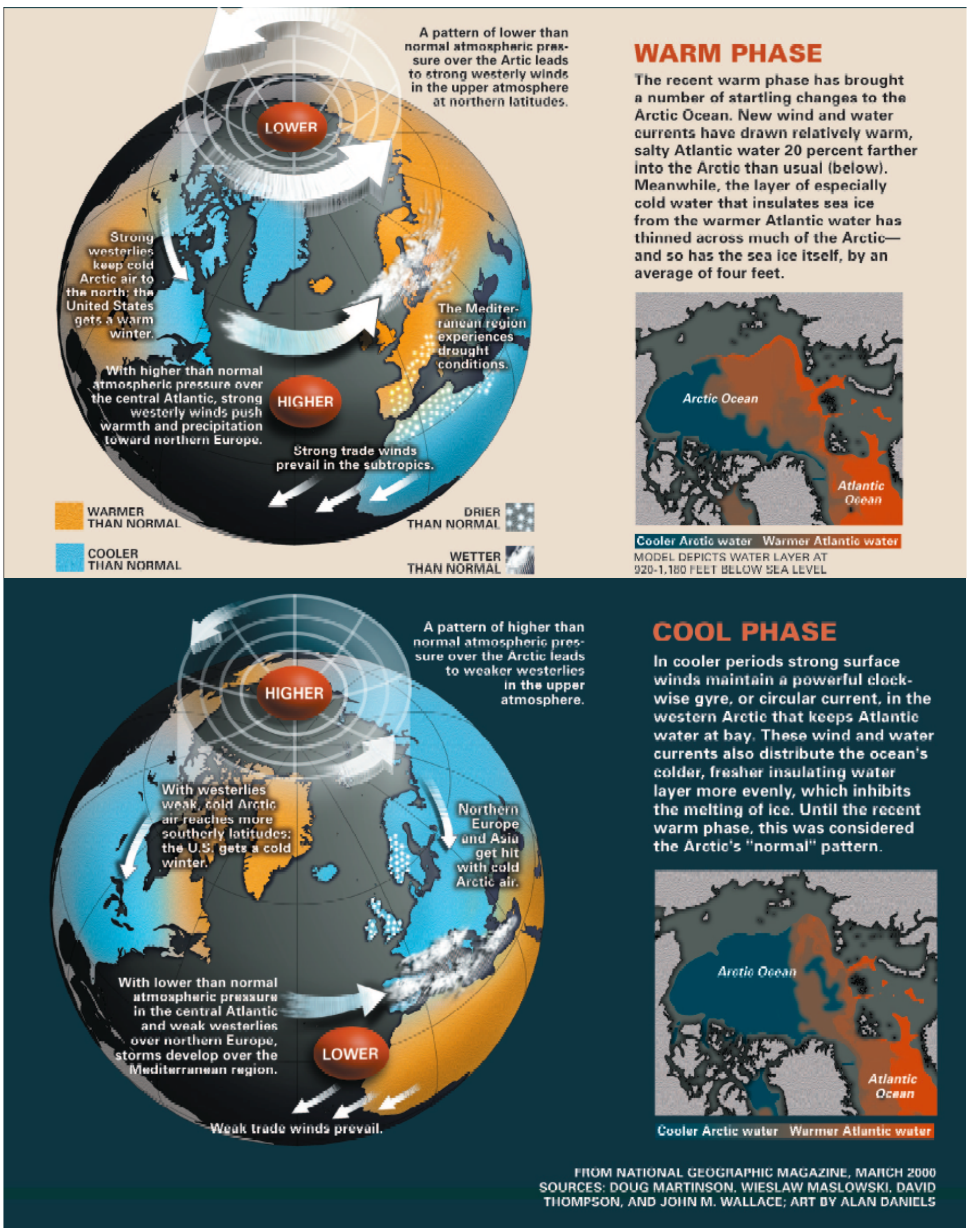
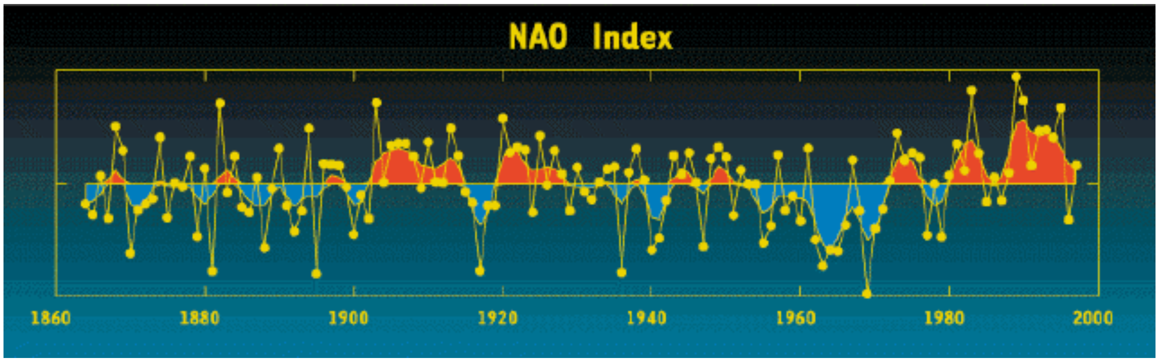
Climate variability

Here we discuss a few examples of climate variability. Note that the climate varies over many timescales, and the relevant components of the climate system differ depending on the timescale that you are interested. At long timescales, the deep ocean, the ice sheet, even plate tectonics, all contribute to climate variability…

Annular modes

At middle and high latitudes, significant portion of the week-to-week, month-to-month, year-to-year variations are in terms of to-some-extent zonally symmetric changes in wind and pressure. The zonal symmetry is less in the northern hemisphere, where the annular mode is also known as the Arctic Oscillation or the North Atlantic Oscillation.





The concept of annual modes helps us to interpret various changes in middle and high latitudes in a more unified framework. However, the processes that drive the annular modes are not well understood. To the first order, the time series of the annular modes are consistent with a normally distributed red-noise process with an e-folding timescale of ~10 days. The 10-day timescales comes from the wave-mean flow interaction that we discussed (when baroclinic eddies propagate away from the jet stream, they converge zonal momentum and strengthen the jet). There is good evidence that the annular modes would not exist in the absence of positive feedbacks between the induced changes in the zonal wind and the wave fluxes. There is evidence that stratospheric changes (due to changes in ozone and greenhouse gases e.g.) may change the annual mode (in fact explain the recent trend in the annular modes). There are other potential drivers, such as sea ice, midlatitude SST. On interannual timescales, the heat capacity of the thick wintertime ocean mixed layer also provides memory from one year to another.

Volcanic eruption

Volcanic eruption can affect the climate by its SO2 emission. Sulfate aerosols formed from the emitted SO2 perturbs the radiation field. Minor volcanic eruptions are constrained within the troposphere, where aerosols have a short residence time and are removed within a few weeks. Major eruptions however produce powerful plumes that penetrate into the stratosphere, where the residence time is much longer (2-3 years). The June 1991 eruption of Mt. Pinatubo in the Philippines is a recent example.

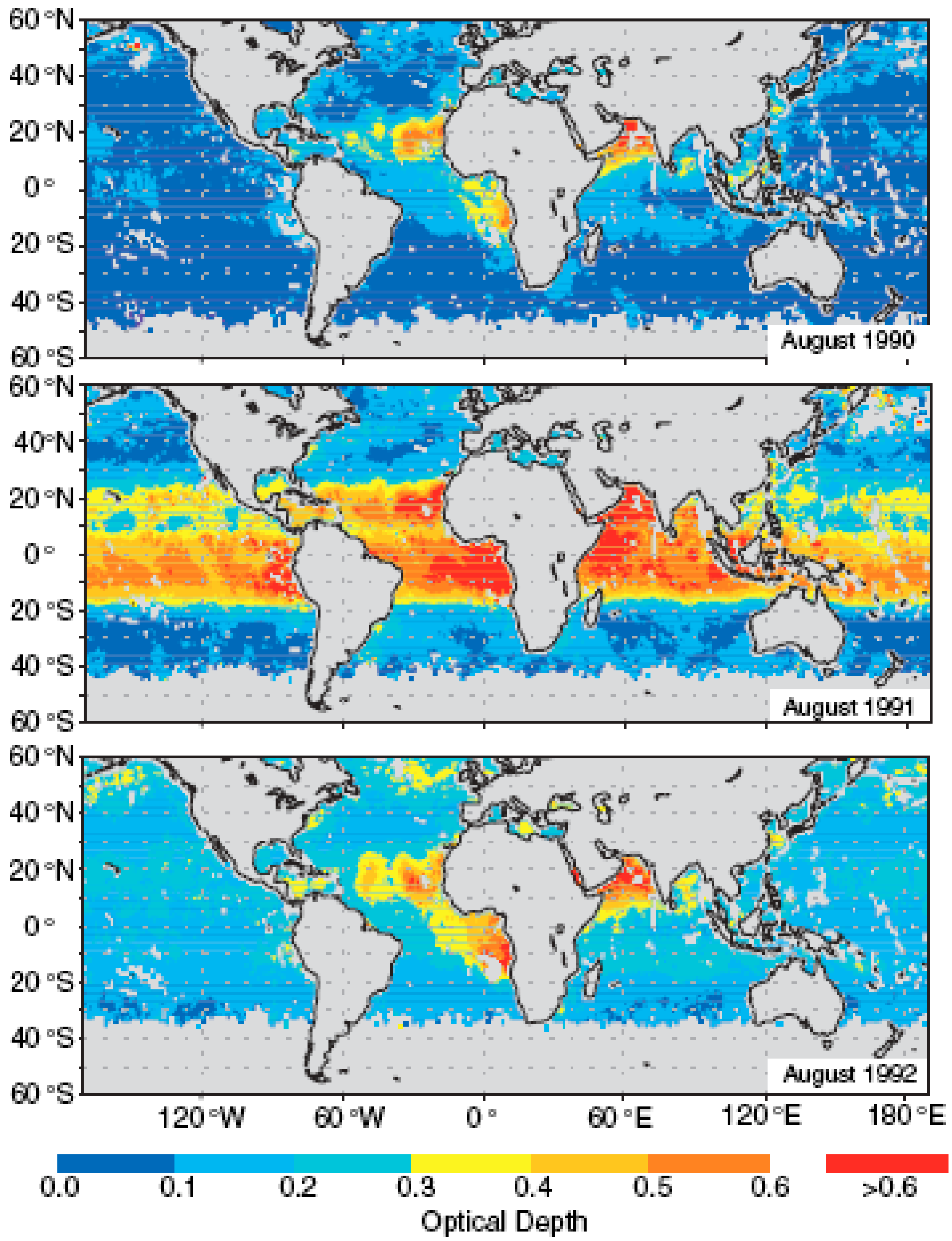


Fig. Total optical depth of atmospheric aerosols.

Note that optical depth reaches 0.6 following the eruption. Does this mean that the solar input is reduced by exp(-0.6)~0.5? This reduction is for the direct solar beam. Because much of the scattered light is in the forward direction, the net reduction in solar energy input (direct plus diffuse) is about 3%. This causes significant cooling in the global mean surface air temperature.

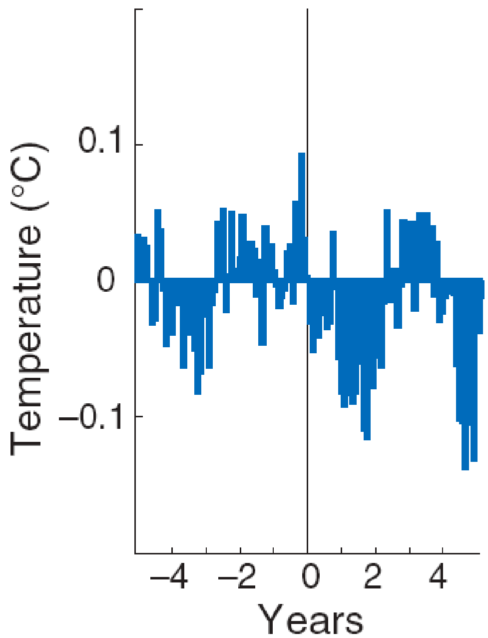


Fig. Composites of global mean surface air temperature anomalies around the time of seven major volcanic eruptions. The right plot is adjusted for variability due to El Nino, Arctic oscillation, and the PNA pattern.

At the same time, the presence of these aerosols warms the lower stratosphere:

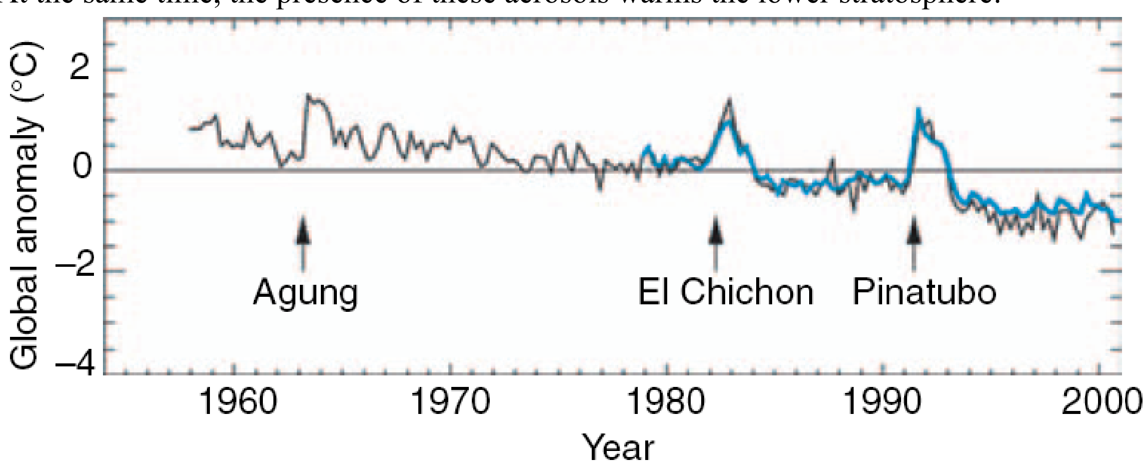
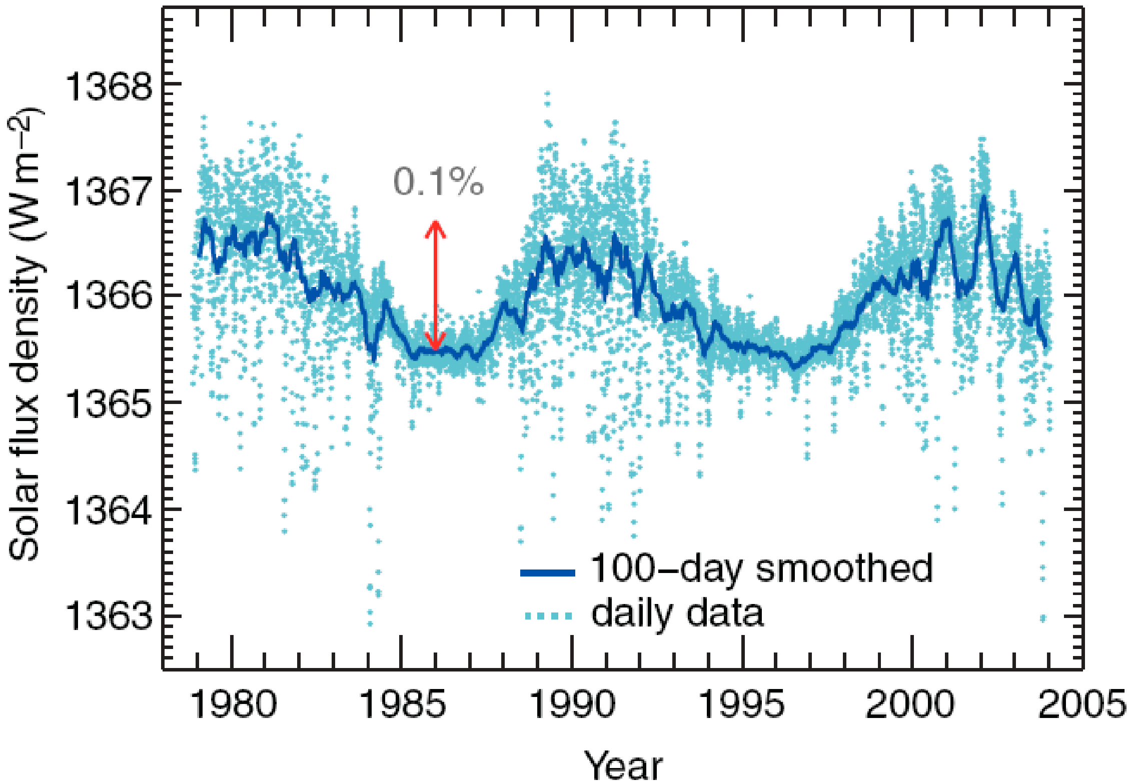


Fig. Globally averaged temperature in the lower stratosphere (15-20km) from radiosonde (black) and the microwave sounding unit (blue).

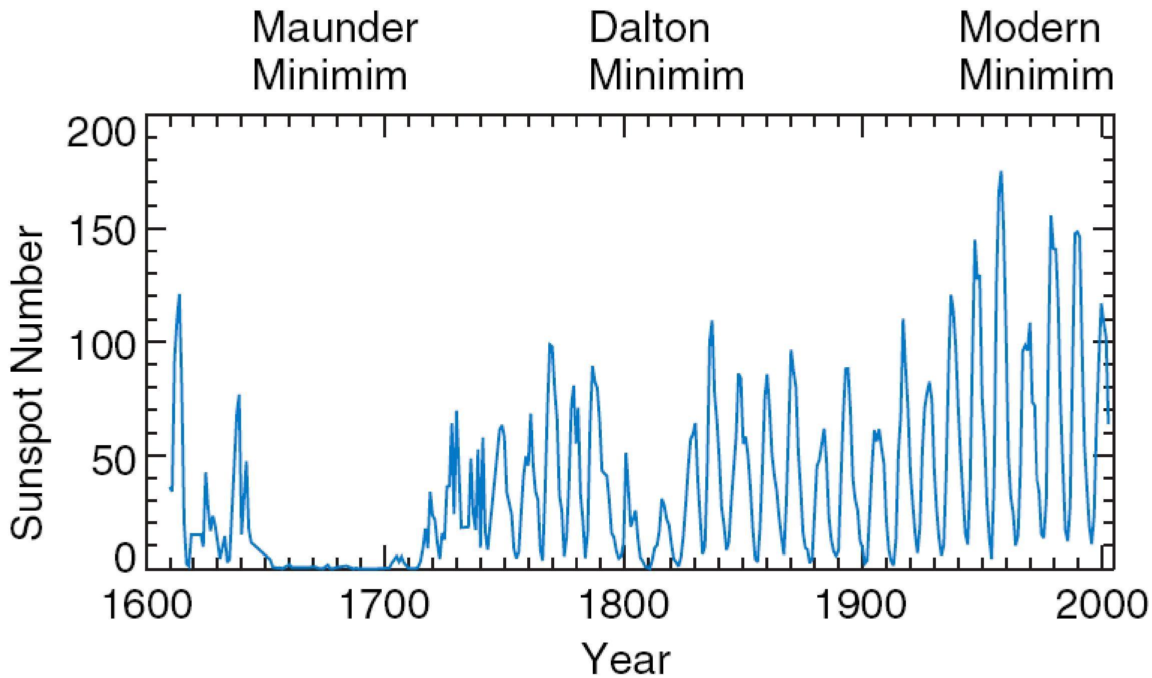
The cooling effect of volcanic aerosols on surface air temperature has inspired some to propose injecting aerosols to the stratosphere (by naval rifles, e.g.) to counter global warming due to doubling of CO2.

Solar variability

Currently, solar flux density varies by about 0.1% over a solar cycle. This corresponds to <0.1C change in Earth's emission temperature. Some believe solar variations could have a greater impact, but convincing physical processes have not been identified.



Earlier in time, solar flux density may have changed more and may be a few percent less in the so-called Maunder minimum. This is thought to have caused the little ice age, when Earth was colder on average. Some suggest that climatic changes then caused severe drought and might explain the social unrest at that time in China.



Maunder
Minimim
Dalton
Minimim
Modern
Minimim
200
150
100
50
0
Sunspot Number
1600
1700
1800
1900
2000
Year