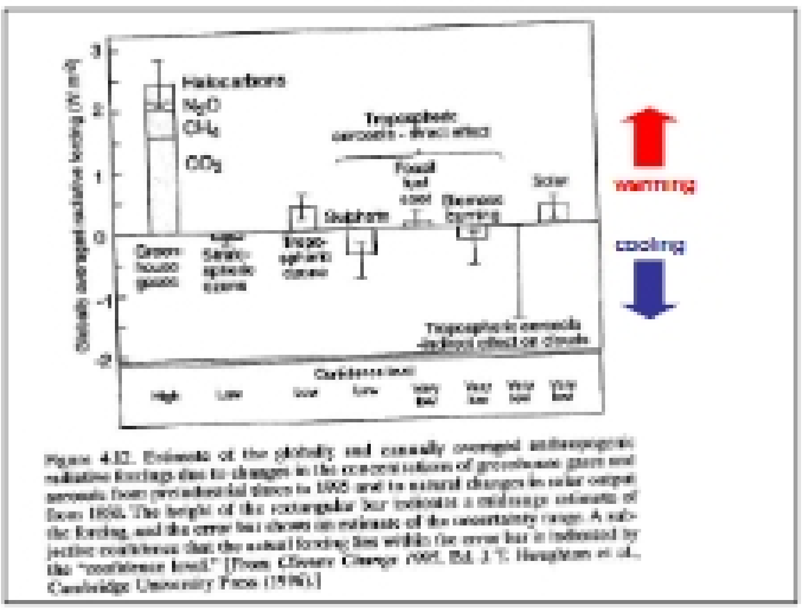
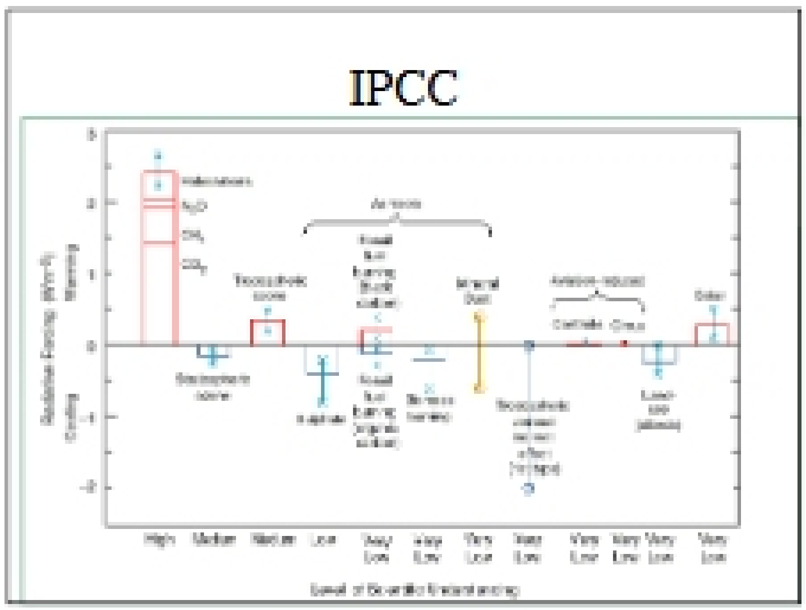
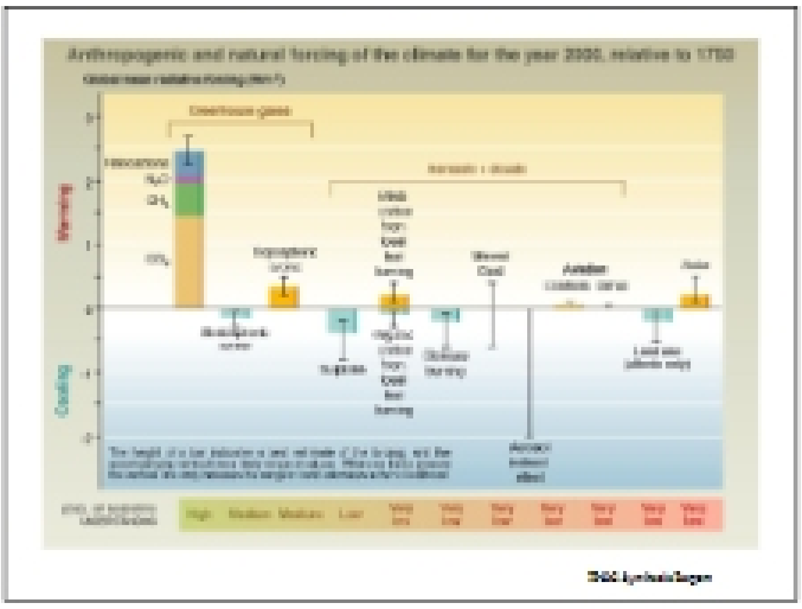


Figure 4.12. Estimate of the globally and annually averaged anthropogenic radiative forcings due to changes in the concentrations of greenhouse gases and aerosols from preindustrial times to 1995 and to natural changes in solar output from 1850. The height of the rectangular bar indicates a mid-range estimate of the forcing, and the error bar shows an estimate of the uncertainty range. A subjective confidence that the actual forcing lies within the error bar is indicated by the "confidence level." [From *Climate Change 1995*, Ed. J. T. Houghton et al., Cambridge University Press (1996).]

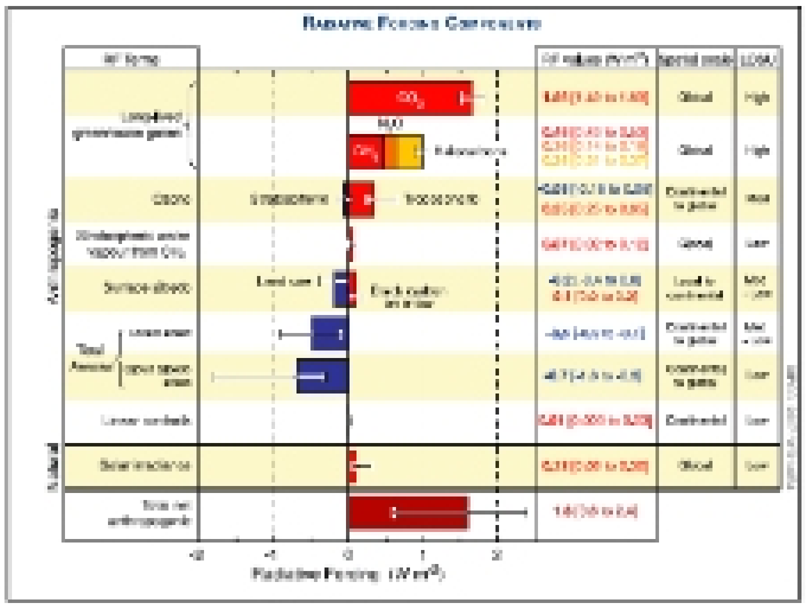
IPCC



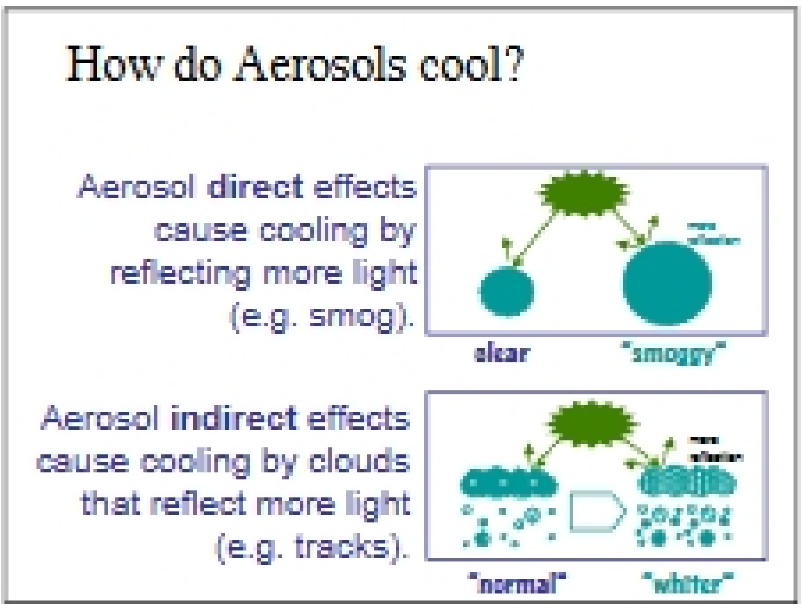
Anthropogenic and natural forcing of the climate for the year 2000, relative to 1750



Radiative Forcing Components

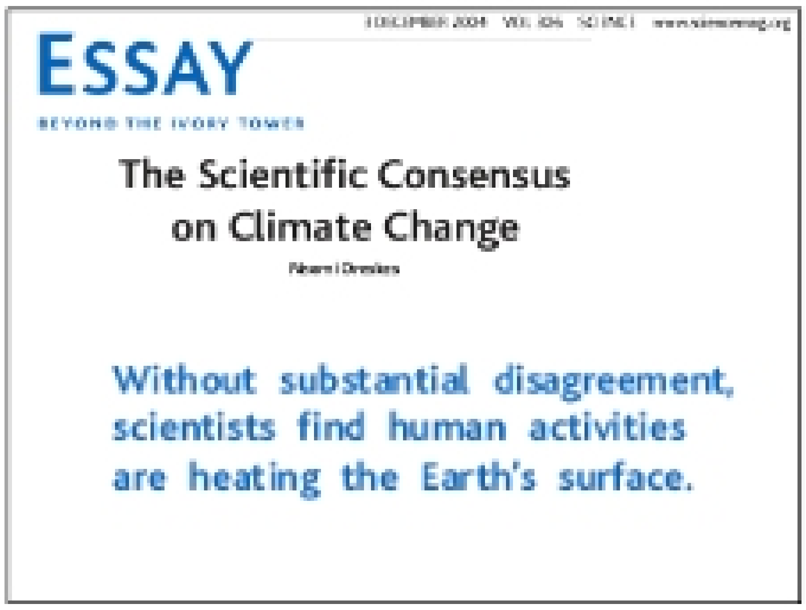


How do Aerosols cool?



Aerosol **direct** effects cause cooling by reflecting more light (e.g. smog).

Aerosol **indirect** effects cause cooling by clouds that reflect more light (e.g. tracks).



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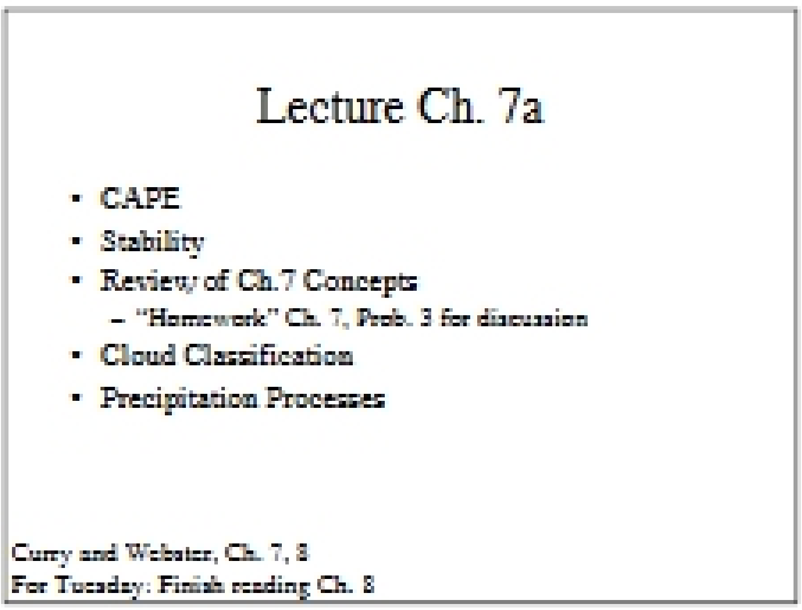
ESSAY

BEYOND THE IVORY TOWER

The Scientific Consensus on Climate Change

Naomi Oreskes

Without substantial disagreement, scientists find human activities are heating the Earth's surface.



Lecture Ch. 7a

- CAPE
- Stability
- Review of Ch.7 Concepts
  - "Homework" Ch. 7, Prob. 3 for discussion
- Cloud Classification
- Precipitation Processes

Curry and Webster, Ch. 7, 8
For Tuesday: Finish reading Ch. 8

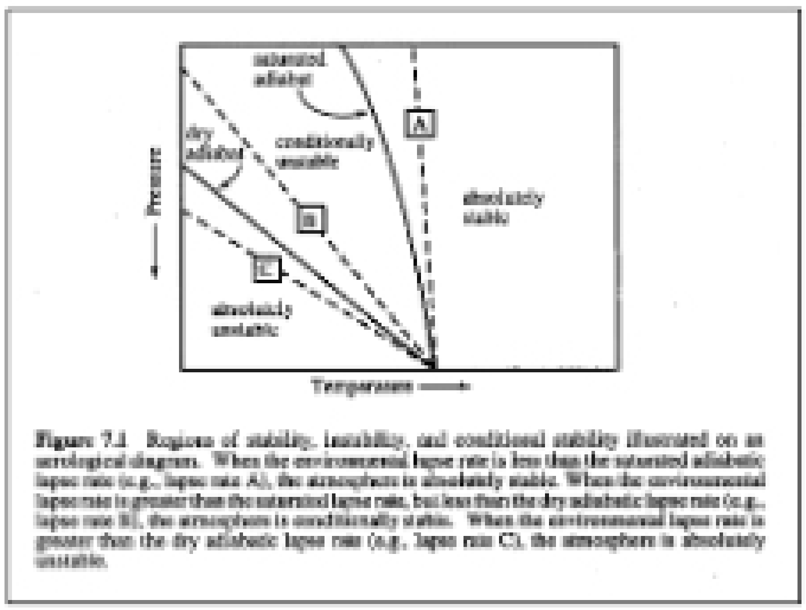


Figure 7.1 Regions of stability, instability, and conditional stability illustrated on an aerological diagram. When the environmental lapse rate is less than the saturated adiabatic lapse rate (e.g., lapse rate A), the atmosphere is absolutely stable. When the environmental lapse rate is greater than the saturated lapse rate, but less than the dry adiabatic lapse rate (e.g., lapse rate B), the atmosphere is conditionally stable. When the environmental lapse rate is greater than the dry adiabatic lapse rate (e.g. lapse rate C), the atmosphere is absolutely unstable.

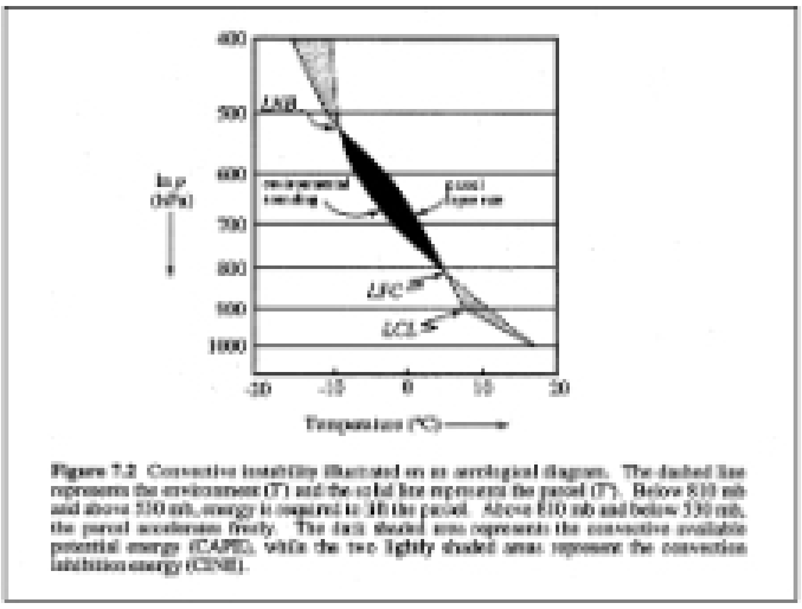


Figure 7.2 Convective instability illustrated on an aerological diagram. The dashed line represents the environment (T) and the solid line represents the parcel (T'). Below 810 mb and above 530 mb, energy is required to lift the parcel. Above 810 mb and below 530 mb, the parcel accelerates freely. The dark shaded area represents the convective available potential energy (CAPE), while the two lightly shaded areas represent the convection inhibition energy (CINE).

CAPE

The amount of energy available for the upward acceleration of a particular parcel is called the *convective available potential energy* (*CAPE*). On a thermodynamic diagram whose area is proportional to energy (e.g., the tephigram; see Section 6.6), *CAPE* is proportional to the area enclosed by the two curves that delineate the temperature of a parcel and its environment, as illustrated by the darker shaded region in Figure 7.2. The amount of *CAPE* of a parcel lifted from a height *z* (at or above the *LFC*) to the *LNB* is given by the vertical integral of the buoyancy force between these levels

$$CAPE(z) = \int_z^{LNB} g\,\frac{T'-T}{T}\,dz \qquad (7.24)$$

where the units of *CAPE* are J kg^{-1}. If the environment is in hydrostatic equilibrium we can use (1.25) and (3.9) to obtain

$$CAPE(p) = \int_{p_{LNB}}^{p} R_d\left[T_v' - T_v\right] d(\ln p) \qquad (7.25)$$

CAPE is defined only for parcels that are positively buoyant somewhere in the vertical profile. The term *convective inhibition energy* (*CINE*) is analogous to *CAPE* but refers to a negative area on the thermodynamic diagram.

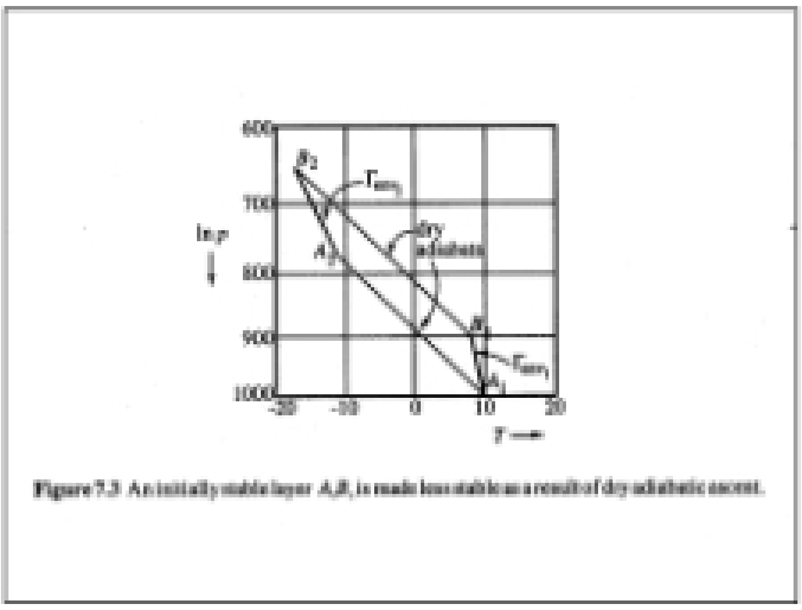


Figure 7.3 An initially stable layer A_1B_1 is made less stable as a result of dry adiabatic ascent.

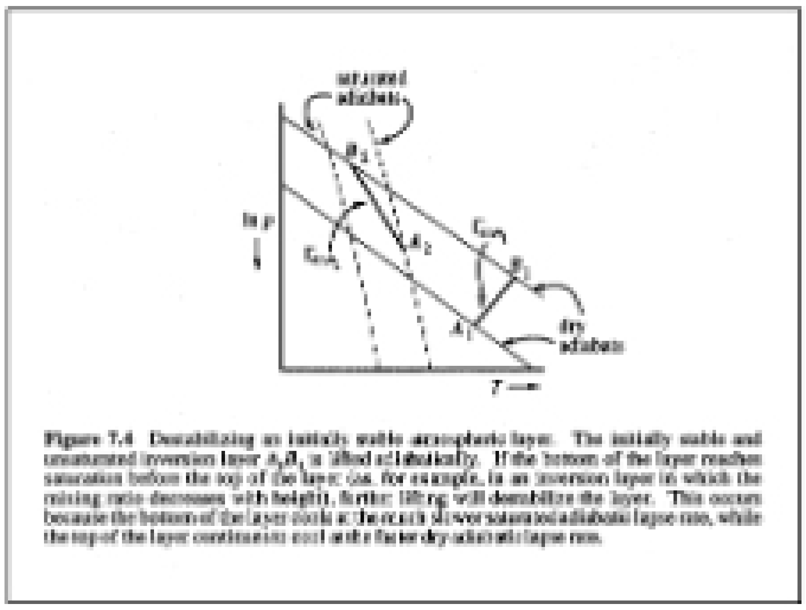


Figure 7.4 Destabilizing an initially stable atmospheric layer. The initially stable and unsaturated inversion layer A_1B_1 is lifted adiabatically. If the bottom of the layer reaches saturation before the top of the layer (as, for example, in an inversion layer in which the mixing ratio decreases with height), further lifting will destabilize the layer. This occurs because the bottom of the layer cools at the much slower saturated adiabatic lapse rate, while the top of the layer continues to cool at the faster dry adiabatic lapse rate.

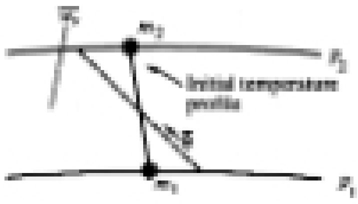


Figure 7.5 Vertical mixing of air parcels, m_1 and m_2, without condensation. Two air parcels, initially at different pressure levels, mix at an intermediate pressure level. The potential temperature of the mixture is a mass-weighted average of the individual parcels' potential temperatures. Mixing of an entire layer results in a constant potential temperature $\overline{\theta}$ throughout the layer. This destabilizes an initially stable layer and stabilizes an initially unstable layer. Because the dry adiabat corresponding to $\overline{\theta}$ does not intersect the average mixing ratio line, $\overline{w}_s$, the mixing process is dry adiabatic and no condensation occurs.

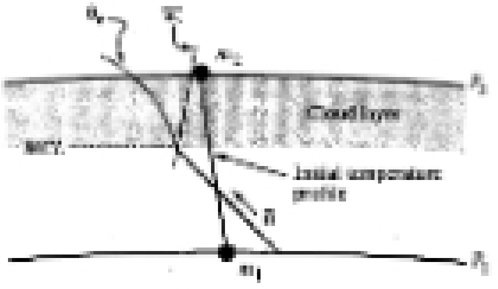


Figure 7.6 Vertical mixing of air parcels, m_1 and m_2, with condensation. If the mixing of two air parcels results in an average potential temperature, $\overline{\theta}$, that intersects the average mixing ratio line, $\overline{w}_s$, then from the level of intersection upwards, condensation will occur and the final temperature distribution will follow a saturated adiabat, θ_e. The lapse rate below the cloud layer moves towards the dry adiabatic lapse rate, while the lapse rate within the cloud layer moves towards the saturated adiabatic lapse rate.

Connecting this course to current research…

Start from two sections of *Curry & Webster*:

Parameterization of Cloud Microphysical Processes (Section 8.6), pages 241 – 244. Understand the ideas behind the equations on page 242 and note the remarks on page 244.

Cloud-radiation Feedback (Section 13.4), especially the last 2 paragraphs of Section 13.4.1 on pages 368, 369, and the last paragraph of Section 13.4 on page 374.

What do we mean by "parameterization"?

Some physical processes are too poorly understood, and/or they occur on too small space and time scales, so we cannot adequately represent them in global numerical climate models.

For example, clouds and cloud-radiation interactions are important to climate and to modeling climate change.

We don't know how to include these processes correctly, but we cannot afford to omit them.

A working definition of "parameterization":

A parameterization is an algorithm or rule for obtaining the statistical effect, of an ensemble of small-scale processes (e. g., cloud processes), on the large-scale prognostic fields computed explicitly in a model (e. g., wind, pressure, temperature, humidity).

In general, the parameterization must be explicit, in the sense that the statistical effect can be computed as a function of the large-scale variables themselves.

Example: cloud fraction might be a function of humidity.

First, some background.

We define "climate sensitivity" as the equilibrium change in global average surface atmospheric temperature in response to doubling the present atmospheric concentration of carbon dioxide. (There are many alternative definitions).

Many (but not all) reputable models have sensitivities ranging from about 1.5 deg C to 4.5 deg C. This range is an old result. It has not changed in nearly 30 years. Why?