Monday 3 October 2017, Class #15

Concepts for Today (Basics for Thermodynamics)

- Final words on chemistry
- Weather versus climate
- Lapse Rate (Adiabatic Lapse Rate)
- Ideal Gas Law
- Adiabatic Processes
- Potential Temperature
- Hydrostatic Law
- Scale Height

http://denierlist.wordpress.com/326-2/

Review

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Global Dimming

- **Cooling at the surface of the earth induced by reduced solar radiation reaching the surface, mainly due to sulfur aerosols**
- **Climate researcher James Hansen estimates that "global dimming" is cooling our planet by more than a degree Celsius (1.8°F) and fears that as we curb these types of air pollution, global warming may escalate to a point of no return.**
- **Beate Liepert estimated that there was globally a reduction of about 4% in solar radiation reaching the ground between 1961 and 1990.**
- **Geoengineering solution to increase aerosols to reduce global warming... The health costs are not considered here.**
- **Secondly, would a re-evaluation of the aerosol effect imply that projections to 2100 must be worse than previously suggested? No, according to Gavin Schmidt. Most extreme scenario postulated in TAR (A1F1) already has a big reduction in sulphate aerosol forcing, so no biggie.**

http://www.realclimate.org

Excellent web site for science summaries write at scientist level!

Contrails reduce daily temperature range DTR

Cooler at night and warmer during the day without contrails!

We analysed maximum and minimum temperature data from about 4,000 weather stations throughout the conterminous United States (the 48 states not including Alaska and Hawaii) for the period 1971–2000, and compared these to the conditions that prevailed during the three-day aircraft-grounding period. All sites were inspected for data quality and adjusted for the time of observation

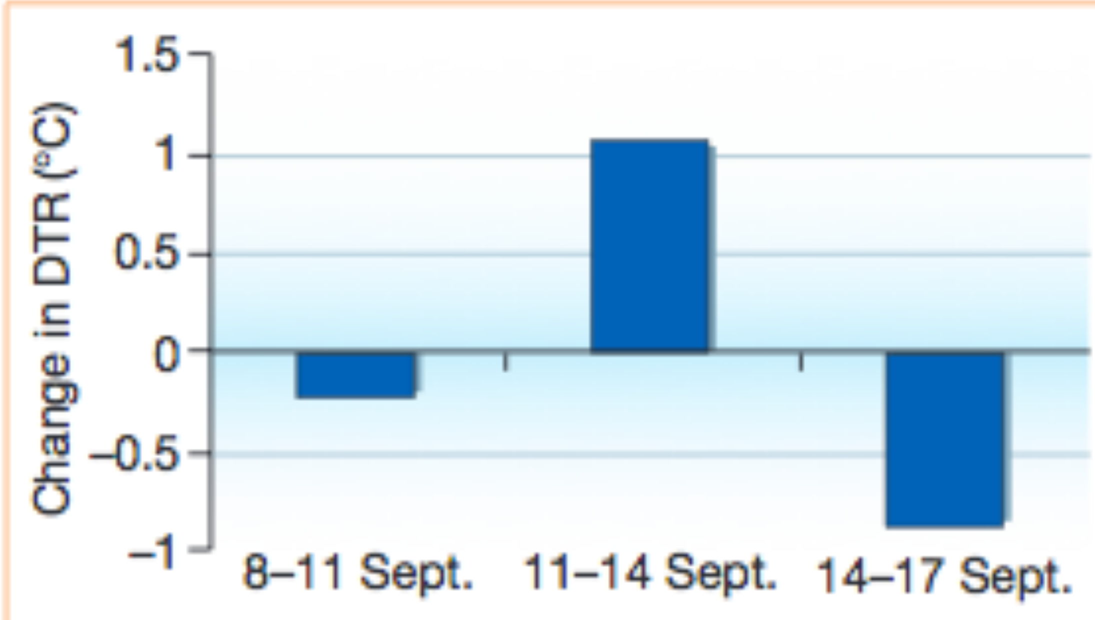


Figure 1 Departure of average diurnal temperature ranges (DTRs) from the normal values derived from 1971–2000 climatology data for the indicated three-day periods in September 2001. These periods included the three days before the terrorist attacks of 11 September; the three days immediately afterwards, when aircraft were grounded and there were therefore no contrails; and the subsequent three days.

Travis et al. Nature 2002

Black Carbon

- Bond et al. 2013, "BC is the second most important human emission in terms of its climate forcing in the present-day atmosphere", 1.1W/m2
- Black Carbon is pure carbon emitted from incomplete combustion and it is what we call soot.
- BC is important "because it absorbs solar radiation, influences cloud processes, and alters the melting of snow and ice cover."
- Large fraction due to anthropogenic emissions
- Can be removed quickly if we reduce emissions! Politics
- Black carbon undergoes regional and intercontinental transport during its short atmospheric lifetime. Atmospheric removal occurs within a few days to weeks via precipitation and contact with surfaces.

Black Carbon Sources and Processes

BOND ET AL.: BLACK CARBON IN THE CLIMATE SYSTEM

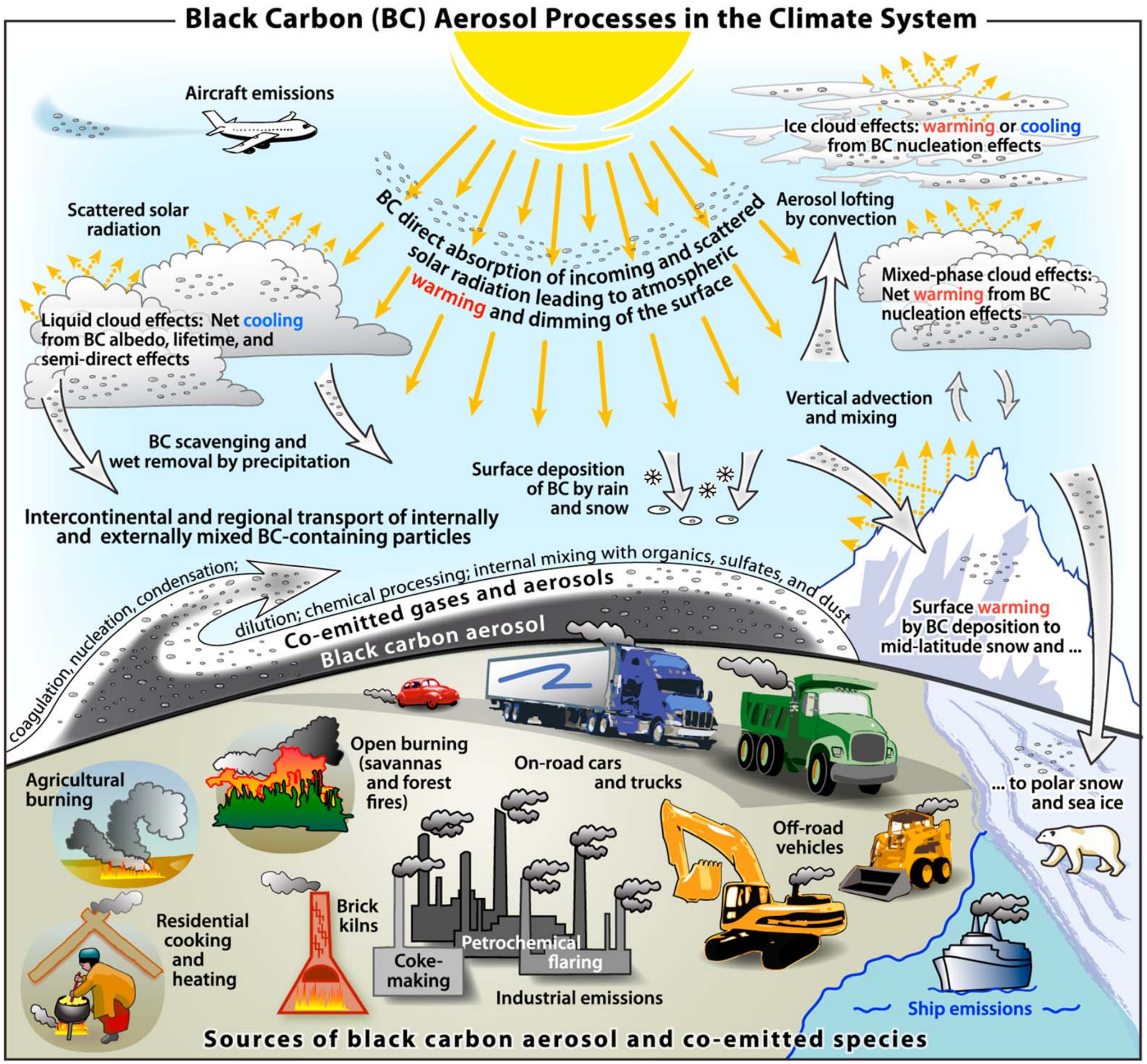


Figure 1. Schematic overview of the primary black-carbon emission sources and the processes that control the distribution of black carbon in the atmosphere and determine its role in the climate system.

[Bond et al. 2013]

sub-Summary

- **Understanding aerosol-cloud interactions is a research-priority!**
- **One of the complexities of black carbon is that the same sources of BC emit other compounds that act to cool the climate, so total impact has large uncertainty.**
- **BC may be very important for the Arctic and Greenland**
- **Climate science is becoming more and more interdisciplinary so we need to work with experts from various group to solve problems!**

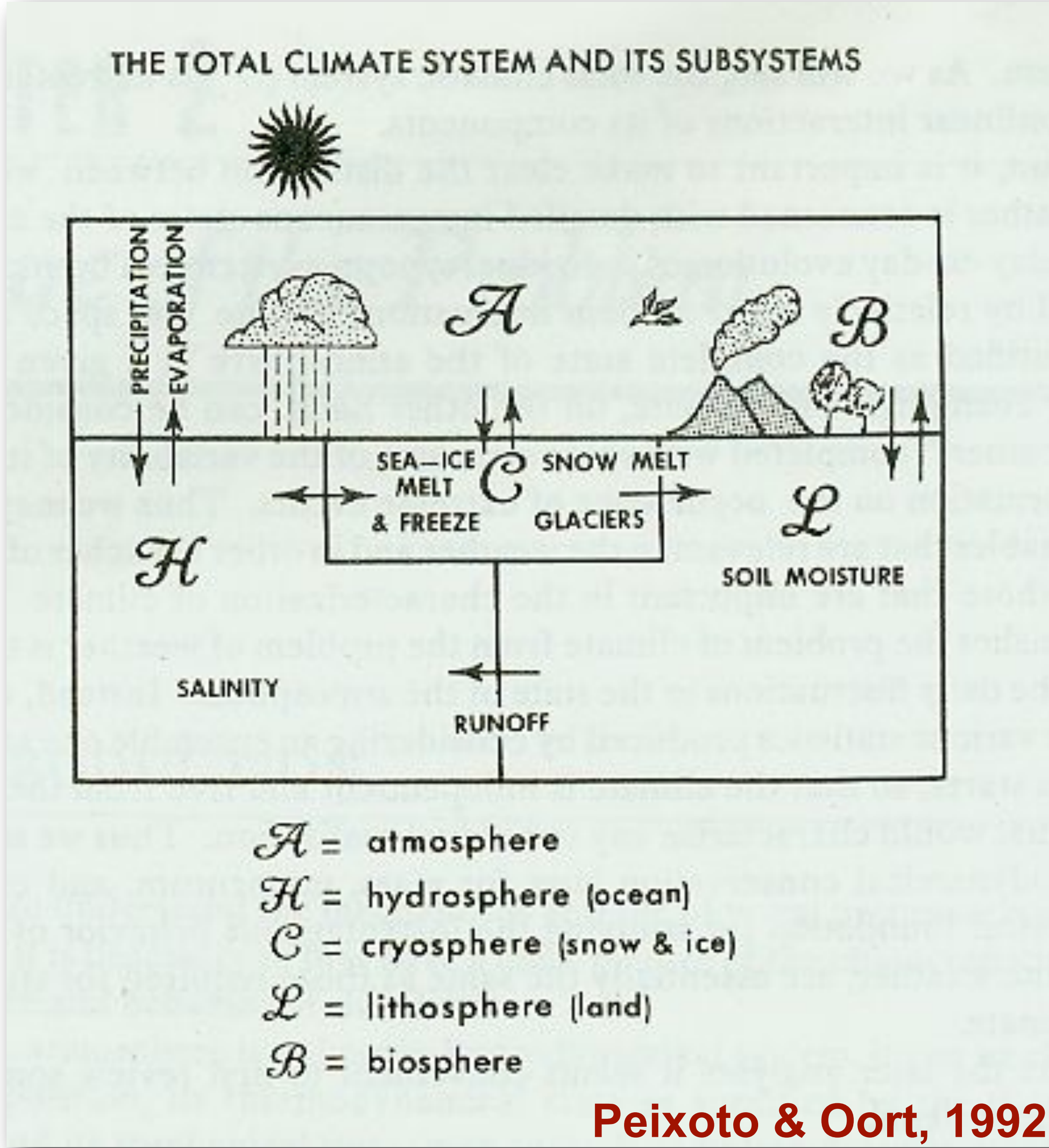
What is the difference between weather and climate?

"Climate is what we expect and weather is what we get."
-Lazarus Long from R. Heinlein's 'Time Enough for Love'

"Climate tells you what clothes to buy, but weather tells you what clothes to wear."
- Anonymous middle school student, [www.ucar.edu/learn/1_2_1.htm]

What is Climate?

- Synthesis of weather in a particular region
- Monthly averages
- Climate influences how life develops in an area
- Life is sensitive to climate events
- Temperature & Precipitation



Peixoto & Oort, 1992

History of Climate Science - S. Weart book web page

Interconnected Components of Climate

Climatological (Average) Sea Ice

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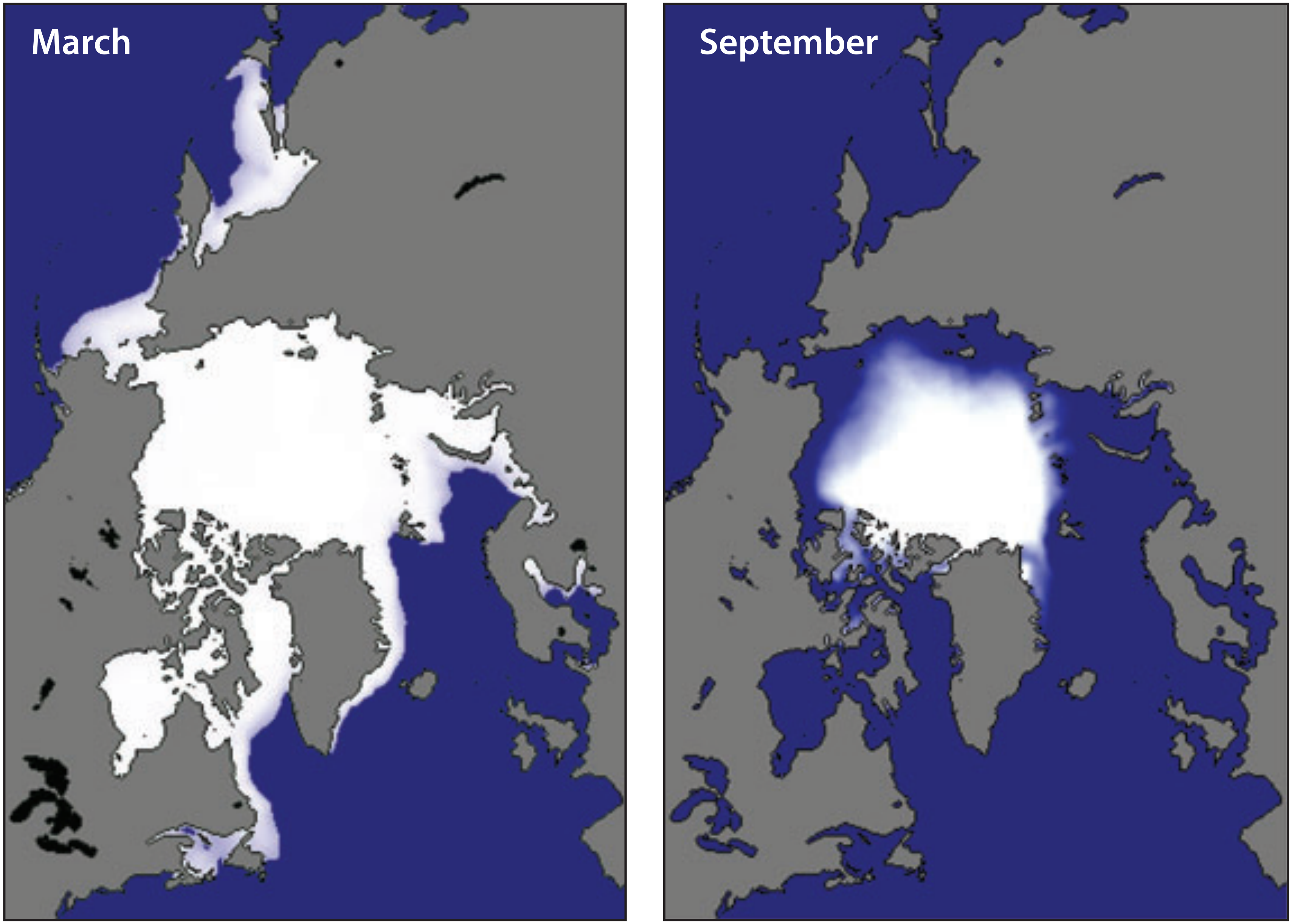
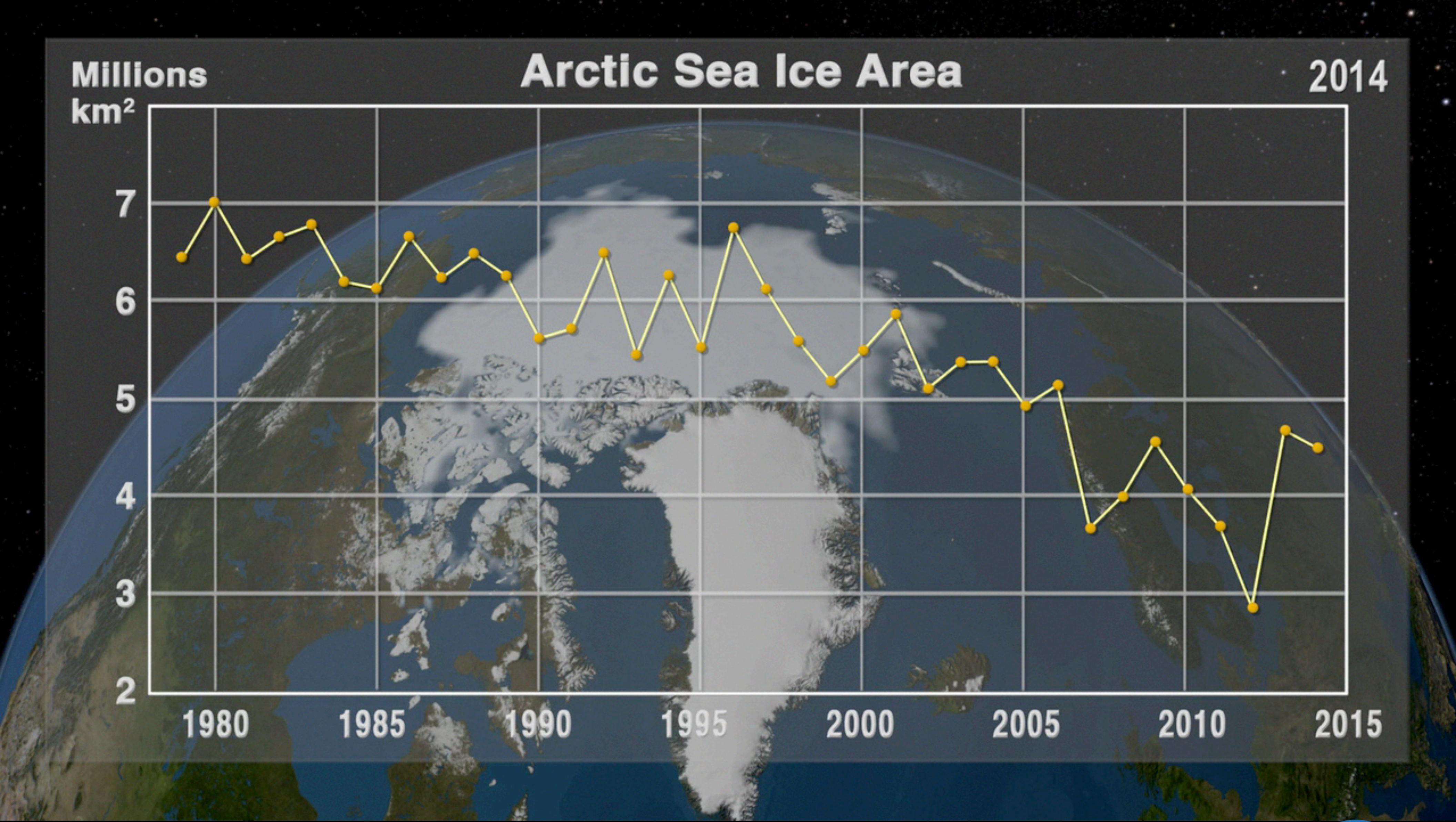


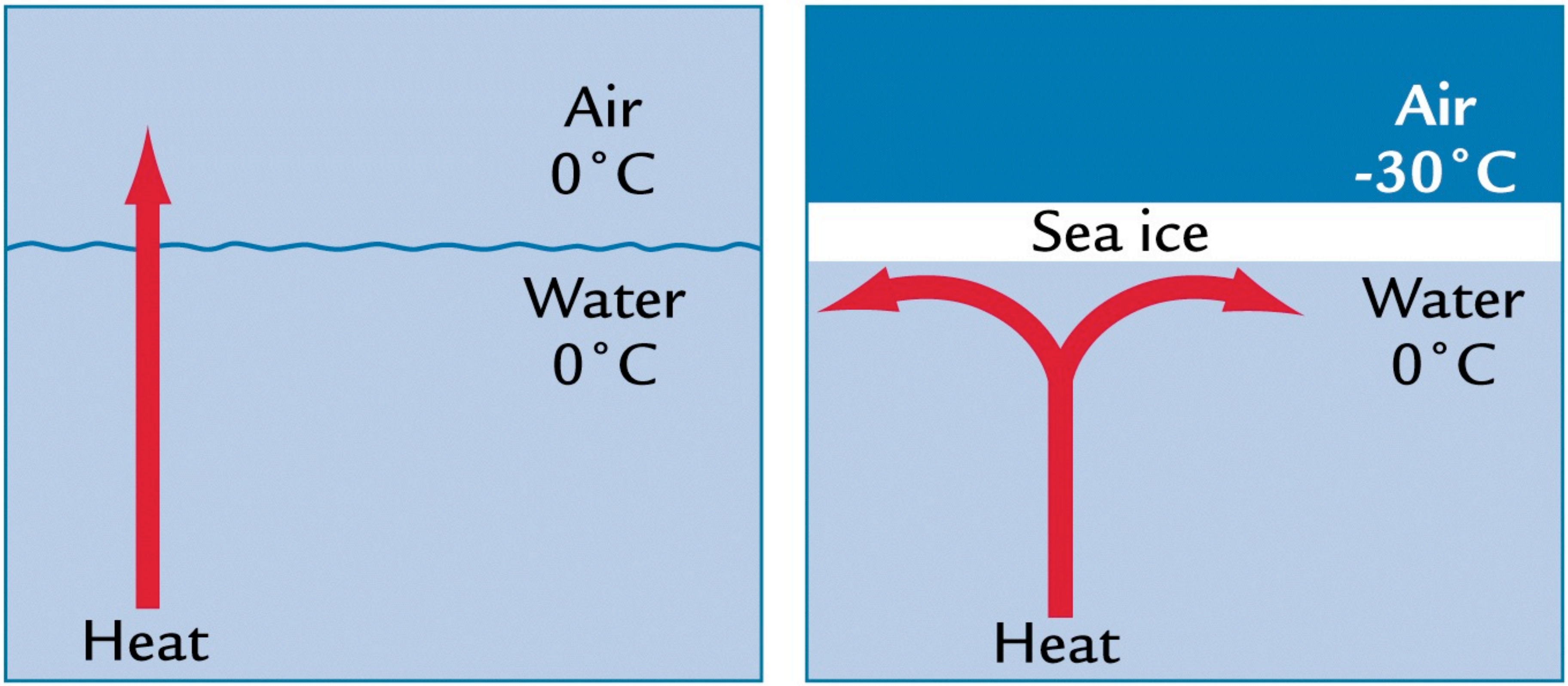
[NSIDC]

Arctic Sea Ice has declined



http://svs.gsfc.nasa.gov

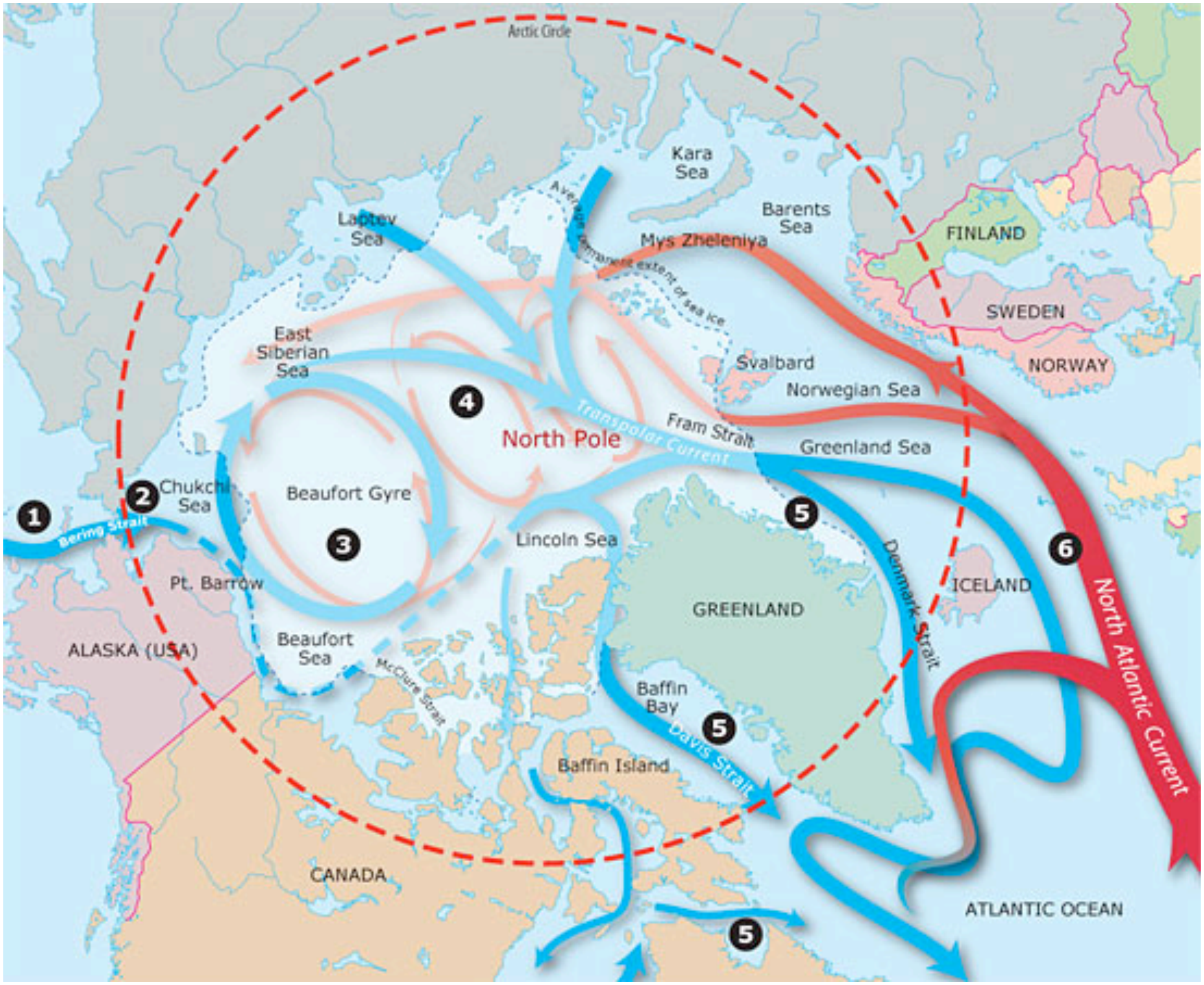
Importance of Sea Ice?



A Without sea ice B With sea ice

Ruddiman, 2001

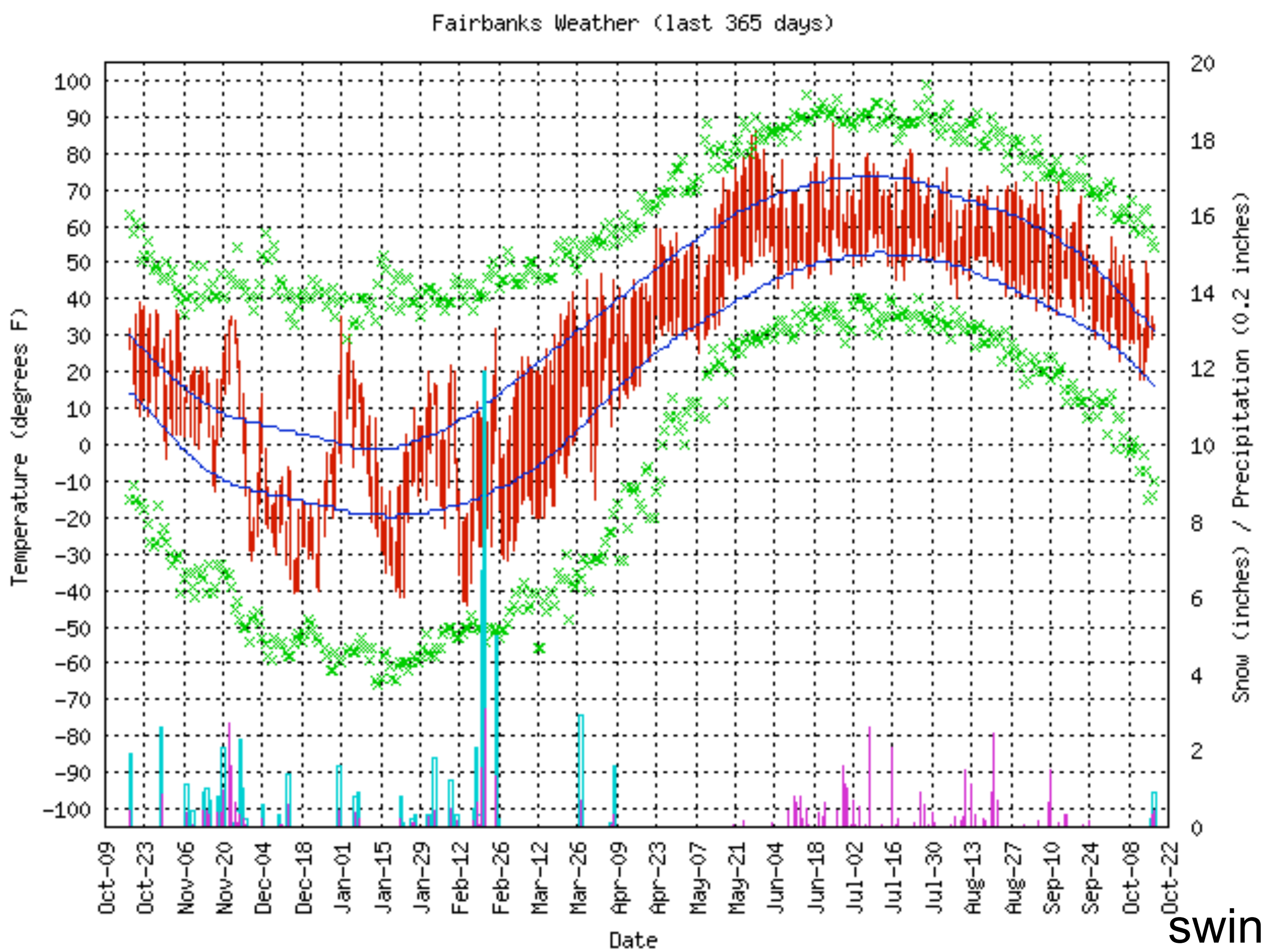
Lots of Warm Water goes into the Arctic (Atlantic Water)



www.whoi.edu

Monthly Temperature Extremes for Fairbanks

# years 42	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	All-time record
MAX	50	47	53	74	89	96	94	90	84	65	46	44	96
MIN	-61	-58	-49	-24	-1	31	35	27	3	-27	-46	-62	-62



2010-2011

swingleydev.com/weather

Define Climate Variability, & Climate Change

Climate Variability is the variations in the mean state and other statistics (e.g. standard deviations, extremes) on all temporal and spatial scales beyond that of individual weather events.
Variability may be due to

- Natural internal processes (natural variability)
- Variations in natural and external (anthropogenic) forcing

-One year to the next (interannual variability) ex: ENSO
-One decade to the next (decadal variability) ex: PDO
-Multiple decades (multi-decadal variability) ex: slow ocean circulation

Climate Change
Definition 1:Statistically significant change in the mean or variability of the climate that persists for an extended period (decades or more) due to natural or human induced effects (chemical composition or land use). (IPCC - scientists)

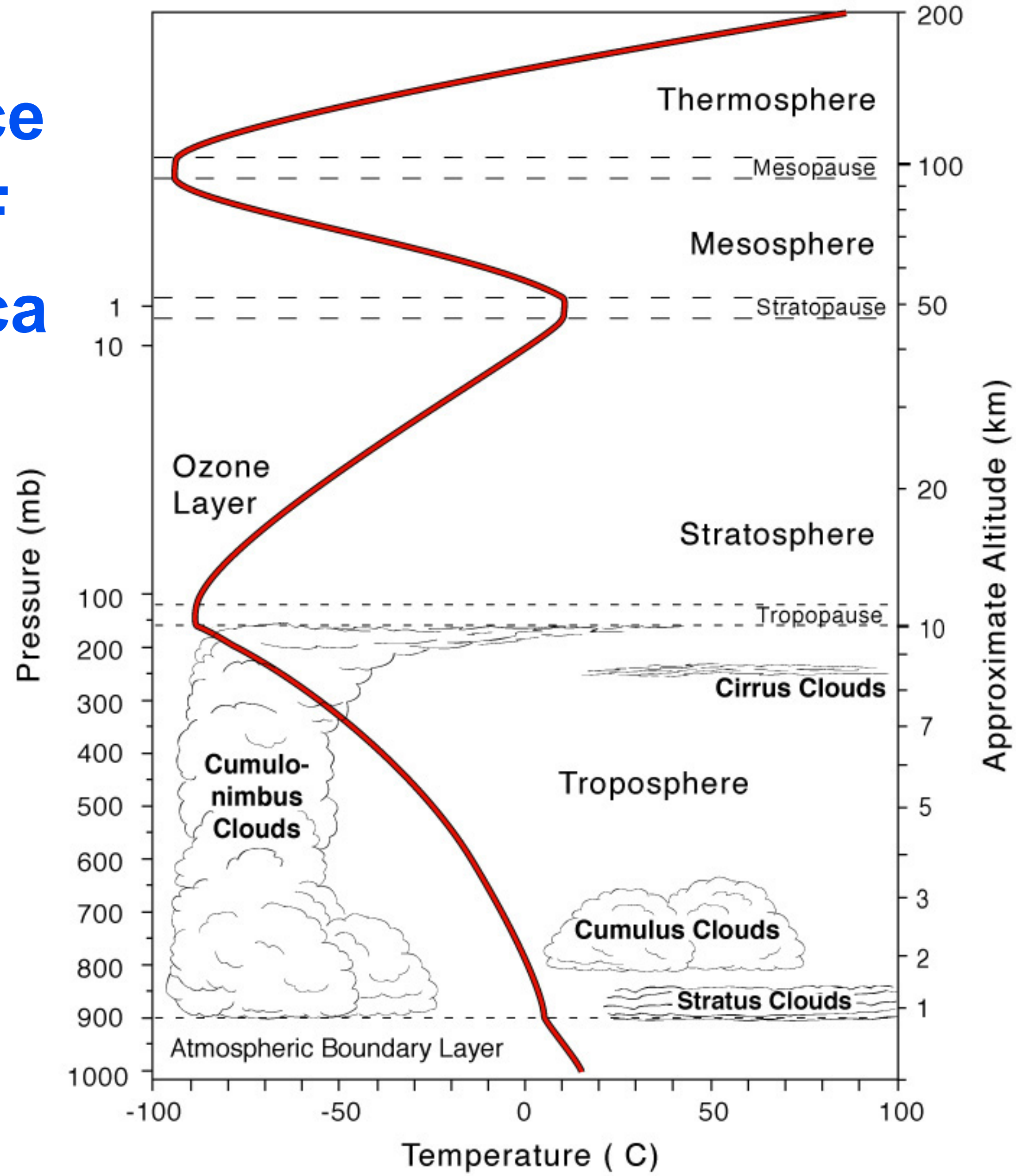
Definition 2: UNFCCC - Change attributed directly or indirectly to human activity which is in addition to natural variability.

Temperature Profile in Atmosphere

- Most recognized variable
- Global average T @ surface of earth 288˚K, 15˚C, or 59˚F
- Coldest -128˚F in Antarctica to warmest of
- •wmo.asu.edu (extreme)

Lapse rate - temperature decrease with height

Layers of Atmosphere
- Troposphere
- Stratosphere
- Mesosphere



[Neelin 2011]

- **Concepts**

  1. **Ideal Gas Law**
  2. **First Law of Thermodynamics**
  3. **Adiabatic process**
  4. **Potential Temperature (Poisson's law)**
  5. **Adiabatic Lapse Rate**
  6. **Hydrostatic Relationship**
  7. **Scale Height**

Ideal Gas Law

Starting point for describing atmospheric behavior is the ideal gas law!

$$pV = nR^{*}T$$

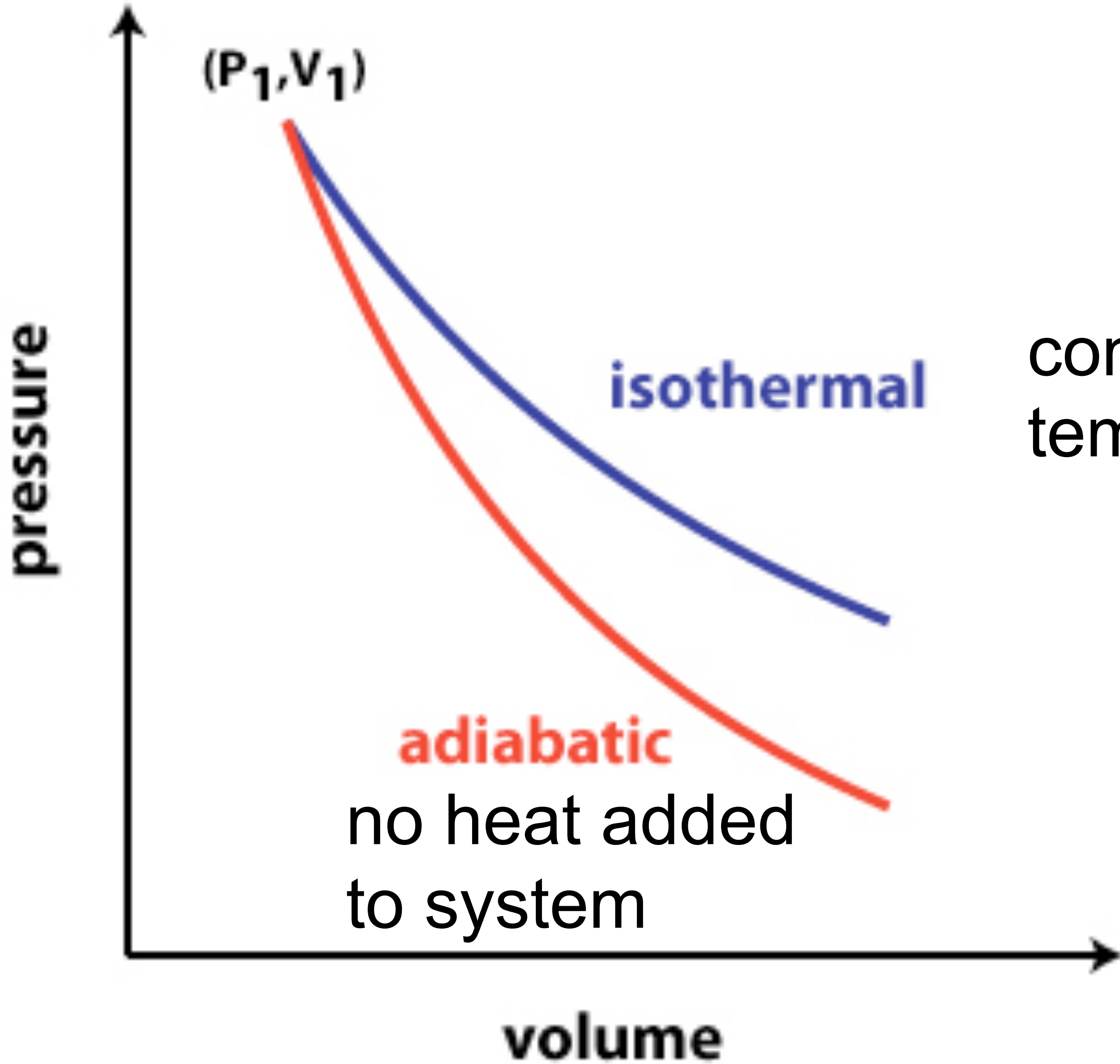
single gas, n=moles, R* universal constant

$$p = \rho RT$$

- Equivalent form used for gas mixture like air
- p pressure, ρ density, R gas constant, T temperature
- T=constant then, p goes down, then density goes down, gas expands

Sample problem if there is time.

Pressure - Volume Diagram



constant temperature

no heat added to system

Thermodynamic Energy Equation

$$c_v \frac{DT}{Dt} + p \frac{D\alpha}{Dt} = J$$

Term 1 — Term 2 — Heating rate of system due to diabatic processes

c_v is specific heat, T temperature, p pressure, α specific volume (1/ρ), J - diabatic heating (add heat):

diabatic: **radiation**, **conduction**, **latent heat release**

term 1: Internal energy
term 2: Rate of work by the fluid system, convert thermal energy to fluid motions (solar heating moves the atmospheric air)

Adiabatic Processes

$$c_v \frac{DT}{Dt} + p \frac{D\alpha}{Dt} = 0$$

no heat added to system, J=0

$$c_v dT + p d\alpha = 0$$

Differential form of this equation

$$c_p dT - \alpha dp = 0$$

Another form of thermodynamic equation under adiabatic conditions

Integrate these two to get Poisson's equations:

$$T^{c_v} \alpha^{R} = constant$$

Evolution of a state variable during an adiabatic process

$$T^{c_p} p^{-R} = constant$$

Potential Temperature

Potential temperature Θ is defined as that temperature the system would have if compressed or expanded adiabatically to a reference pressure of p_o=1000 hPa.

$$T^{c_p} p^{-R} = constant$$

$$T^{c_p} p^{-R} = \Theta^{c_p} p_o^{-R}$$

$$\Theta = T\left(\frac{p_o}{p}\right)^{\frac{R}{c_p}}$$

Many atmospheric motions are adiabatic since expansion work is much faster than heat transfer (less than a day vs multiple days)
==> potential temperature is conserved

Air parcel displaced vertically under adiabatic conditions will experience a temperature decrease (P decrease, θ the same), adiabatic warming

Surfaces of constant Θ

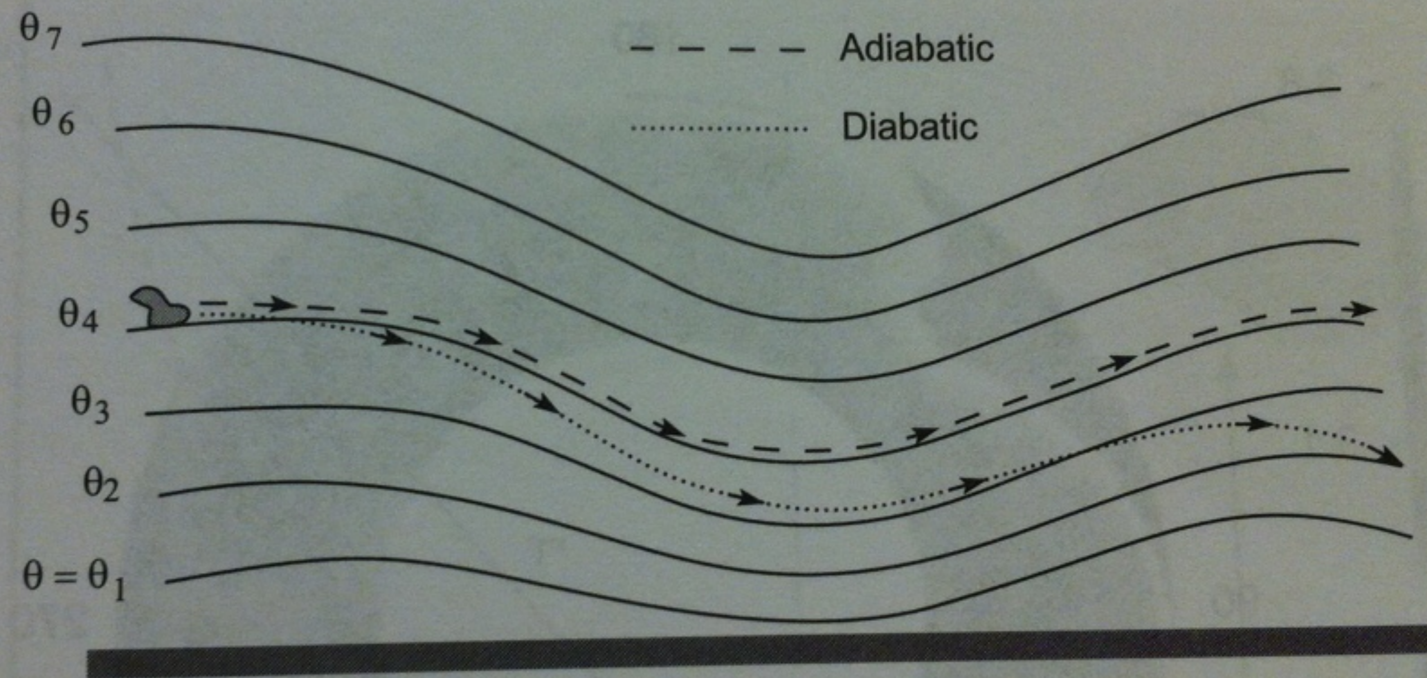


Figure 2.9 Surfaces of constant potential temperature θ. An air parcel remains coincident with a particular θ surface under adiabatic conditions (dashed), whereas it drifts across θ surfaces under diabatic conditions (dotted).

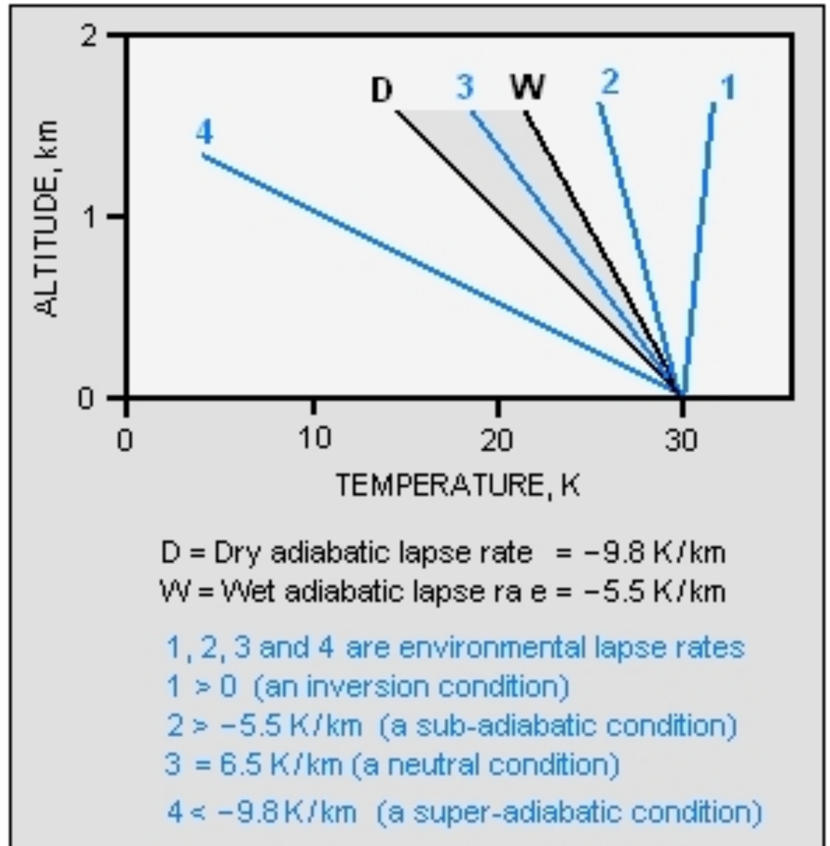
[Salby 2012]

Dry Adiabatic Lapse Rate

$$\Gamma = -\frac{dT}{dz} = \frac{g}{c_p} \quad = 9.8 \text{ K/km}$$

6.5 K/km is the average global lapse rate
Moisture is ignored above and if there was moist adiabatic processes included then this decrease with height would be smaller. Explain

atmospheric stability



Source: Milton Beychok
Various lapse rates defining the change of atmospheric temperature with altitude.

http://www.eoearth.org/view/article/170859/