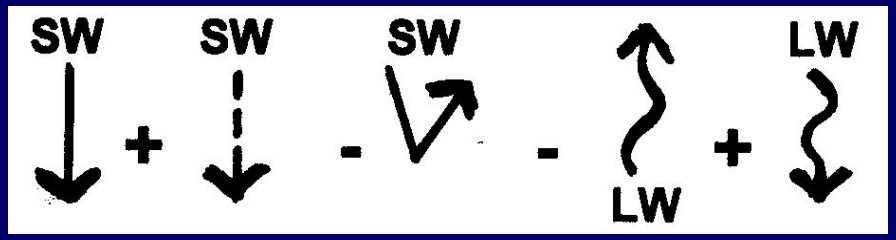
Topic # 11
HOW CLIMATE WORKS – PART II

The next "chapter" in the story:

How differences in **INSOLATION** between low and high latitudes drive atmospheric circulation!

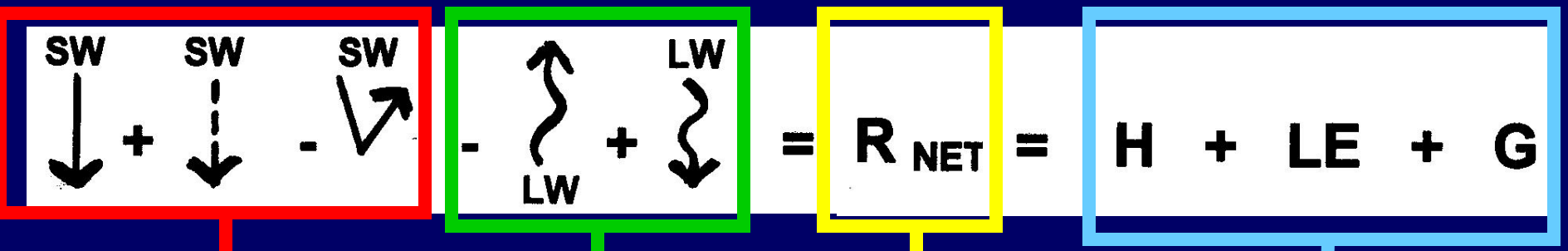
pp 64 in Class Notes

THE RADIATION BALANCE



& THE GENERAL CIRCULATION OF THE ATMOSPHERE

ENERGY IN THE EARTH-ATMOSPHERE SYSTEM



Ultimate source of energy is the SUN (SW)

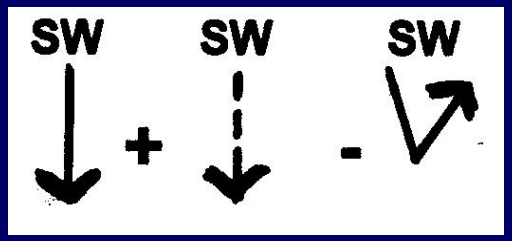
After absorption of SW, LW energy is radiated in & out by EARTH & Atmosphere

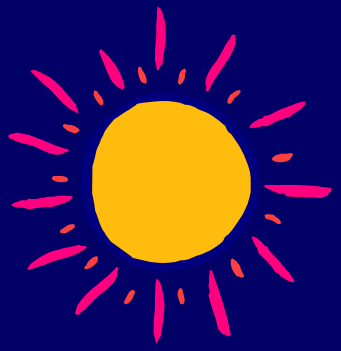
Any NET (leftover) energy

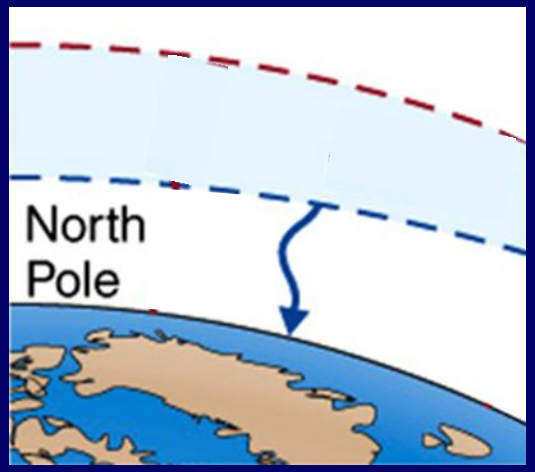
Goes into the HEAT TRANSFER processes that drive **WEATHER & CLIMATE !**

HOW IT ALL FITS TOGETHER:

Incoming Solar SW







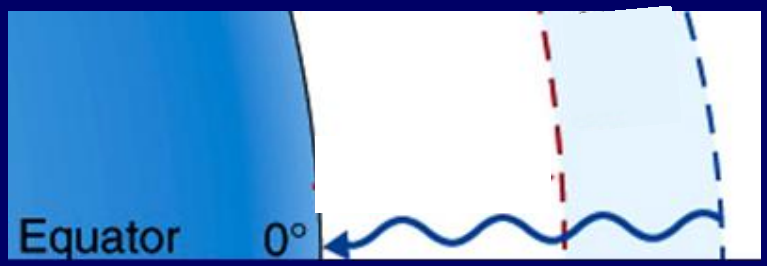
LESS SW is received at the ← Poles

High Latitude

Over the course of a year . . .

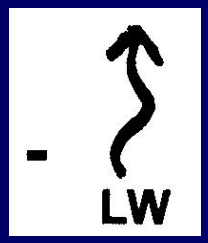
The amount of **INCOMING SW** (Insolation) received and absorbed by the EARTH **varies with LATITUDE**

MORE SW is received at the Equator →



Low Latitude

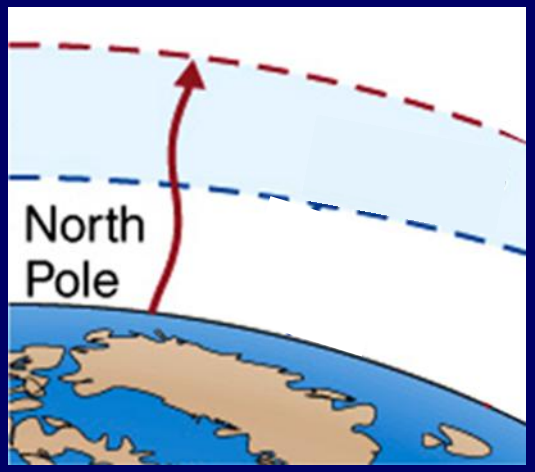
Outgoing terrestrial LW (IR)



The amount of outgoing **TERRESTRIAL LW (IR)** varies by latitude too

Due to the surface temperature &

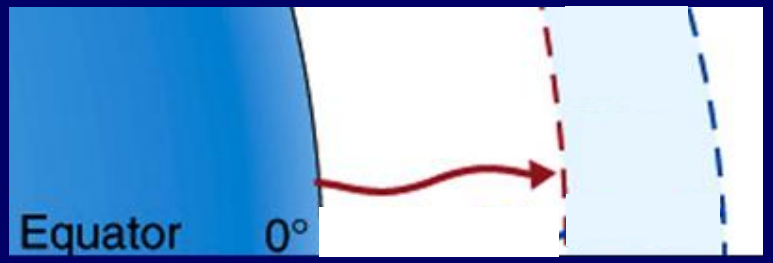
$$E = \sigma T^4$$



High Latitude

Slightly LESS IR is emitted in cooler ← HIGH LATITUDES

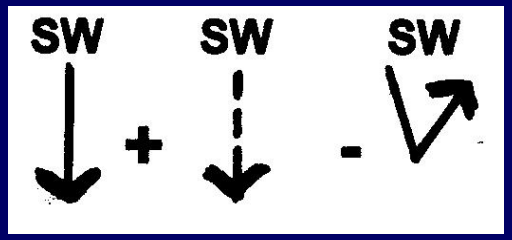
MUCH IR is emitted at warmer **LOW → LATITUDES**,

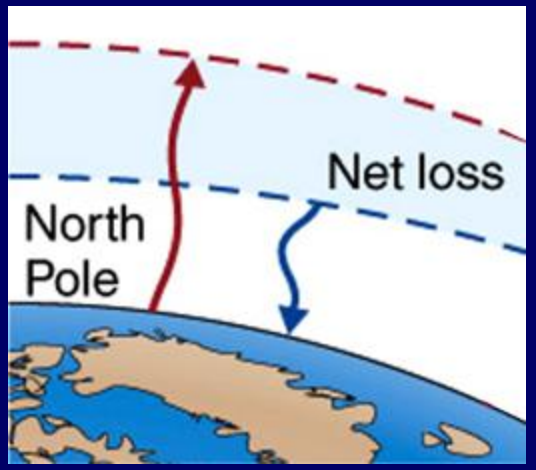


Low Latitude

HOWEVER . . .

. . . the EQUATOR-POLE DIFFERENCES of what comes IN from the SUN

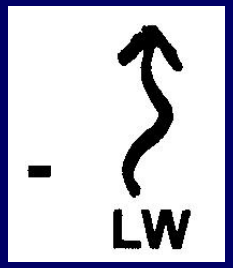


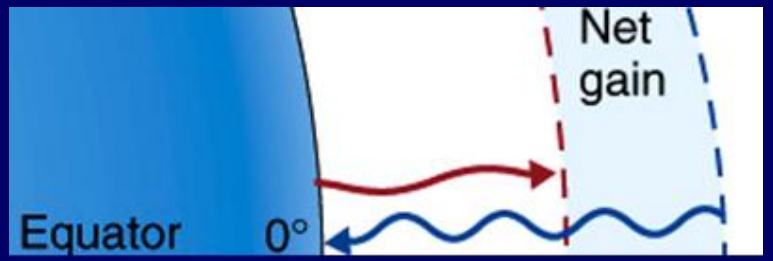


High Latitude

are GREATER than

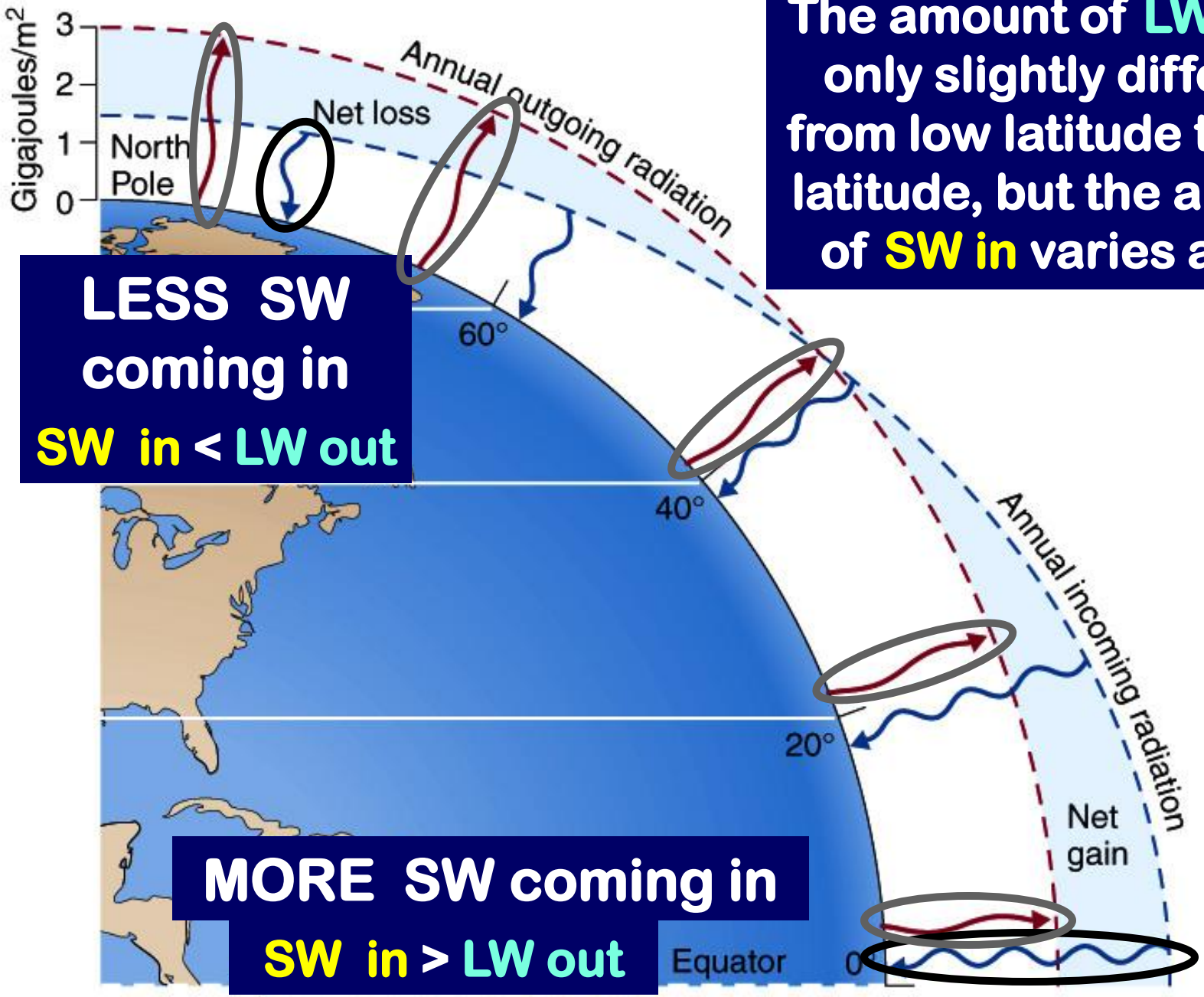
the EQUATOR-POLE DIFFERENCES of what goes OUT from the EARTH





Low Latitude

The amount of LW out is only slightly different from low latitude to high latitude, but the amount of SW in varies a LOT

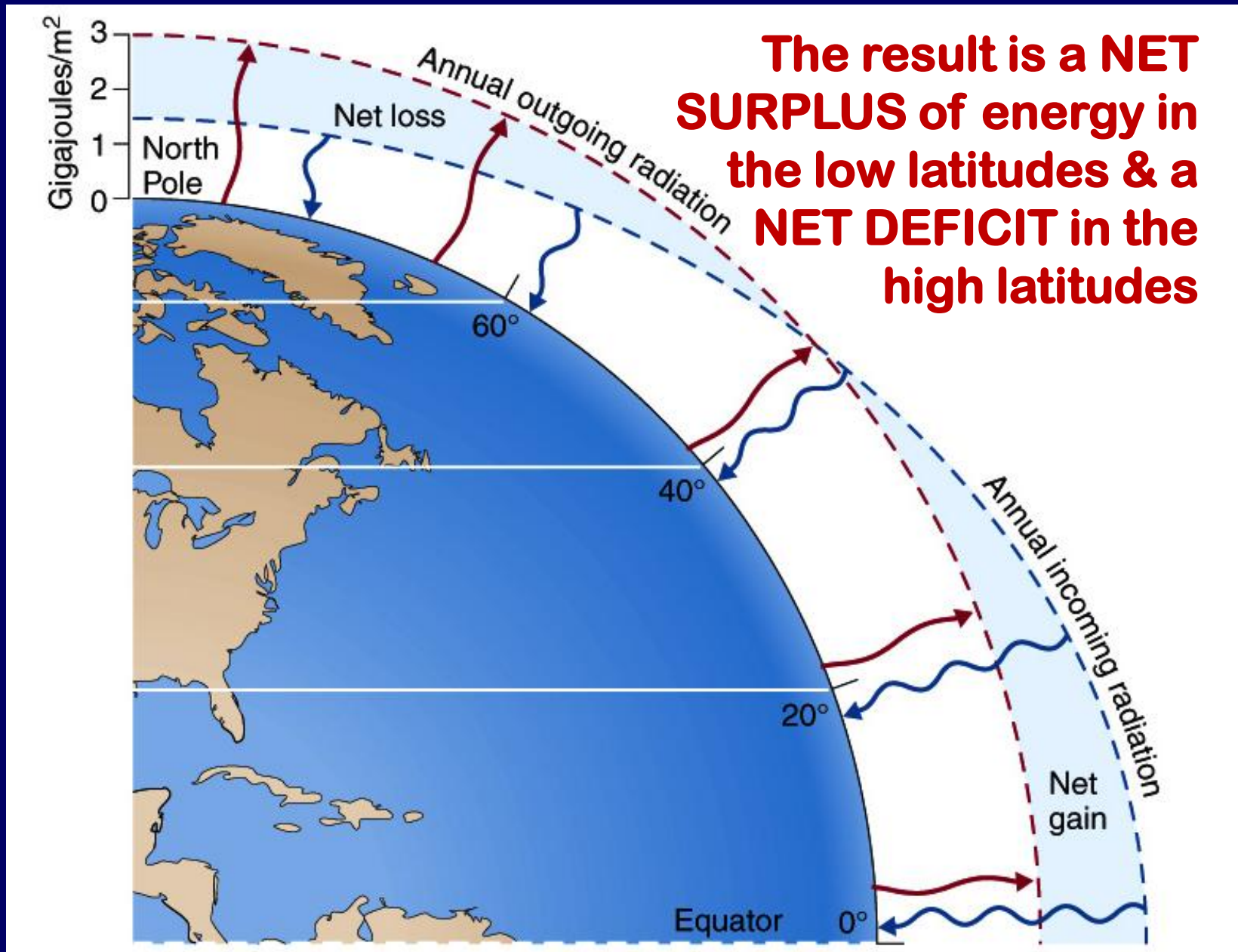


LESS SW coming in

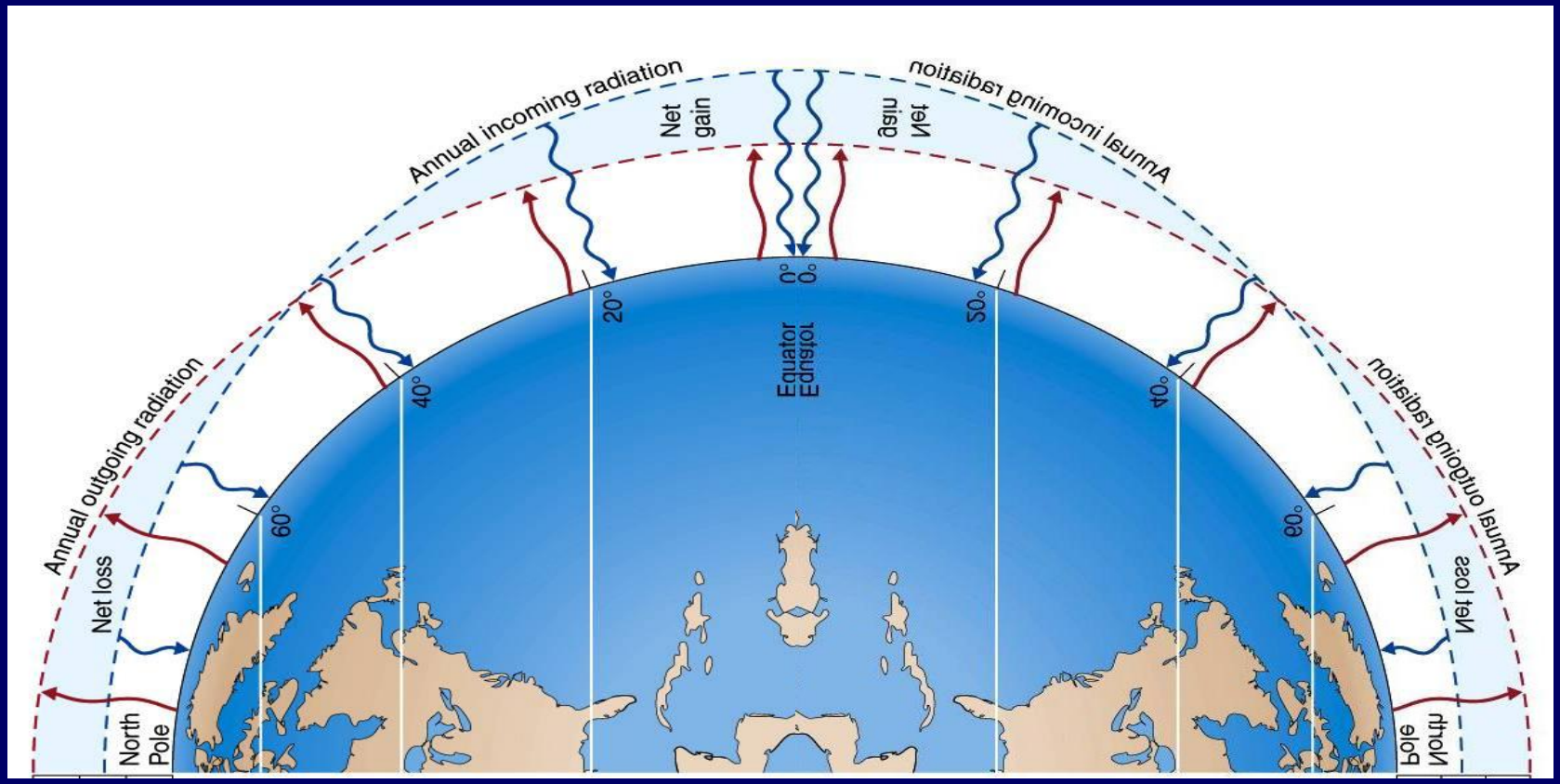
SW in < LW out

MORE SW coming in

SW in > LW out

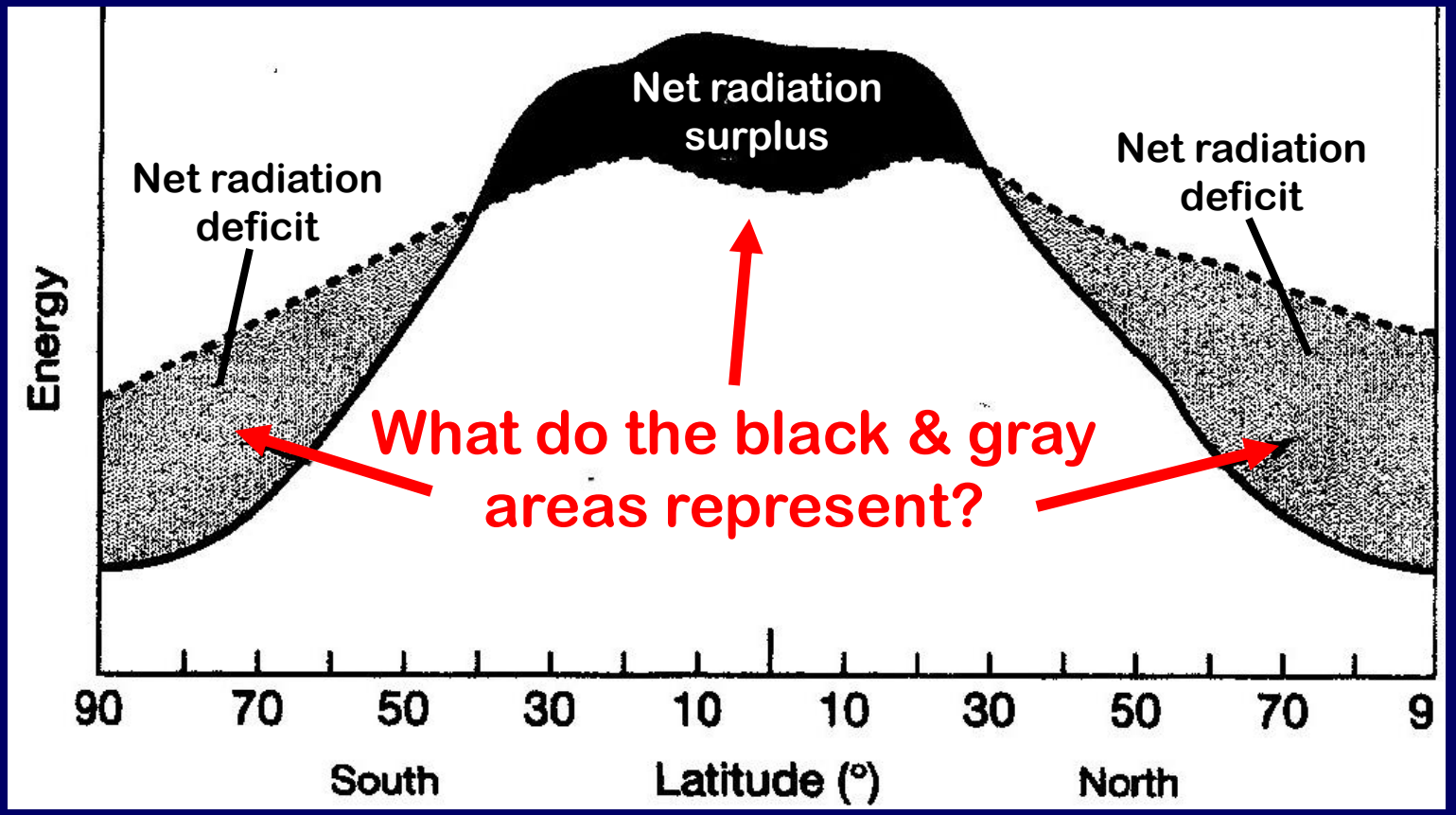


The result is a NET SURPLUS of energy in the low latitudes & a NET DEFICIT in the high latitudes

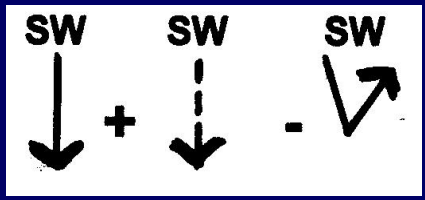


POLE **EQUATOR** **POLE**

Now lets look at a Pole to Pole Transect

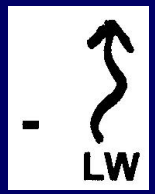


Absorbed solar energy

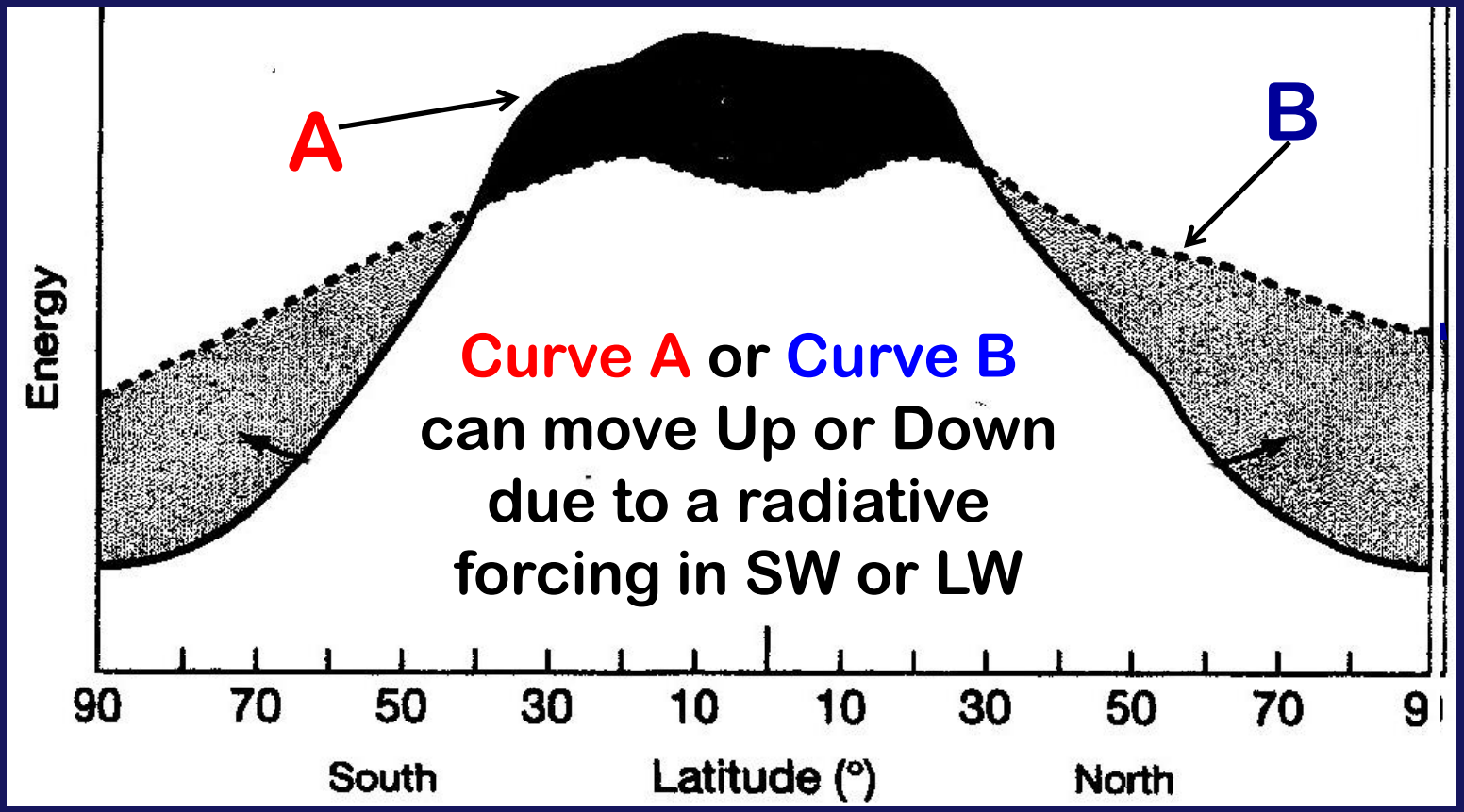


Emitted infrared energy

(at top of atmosphere)



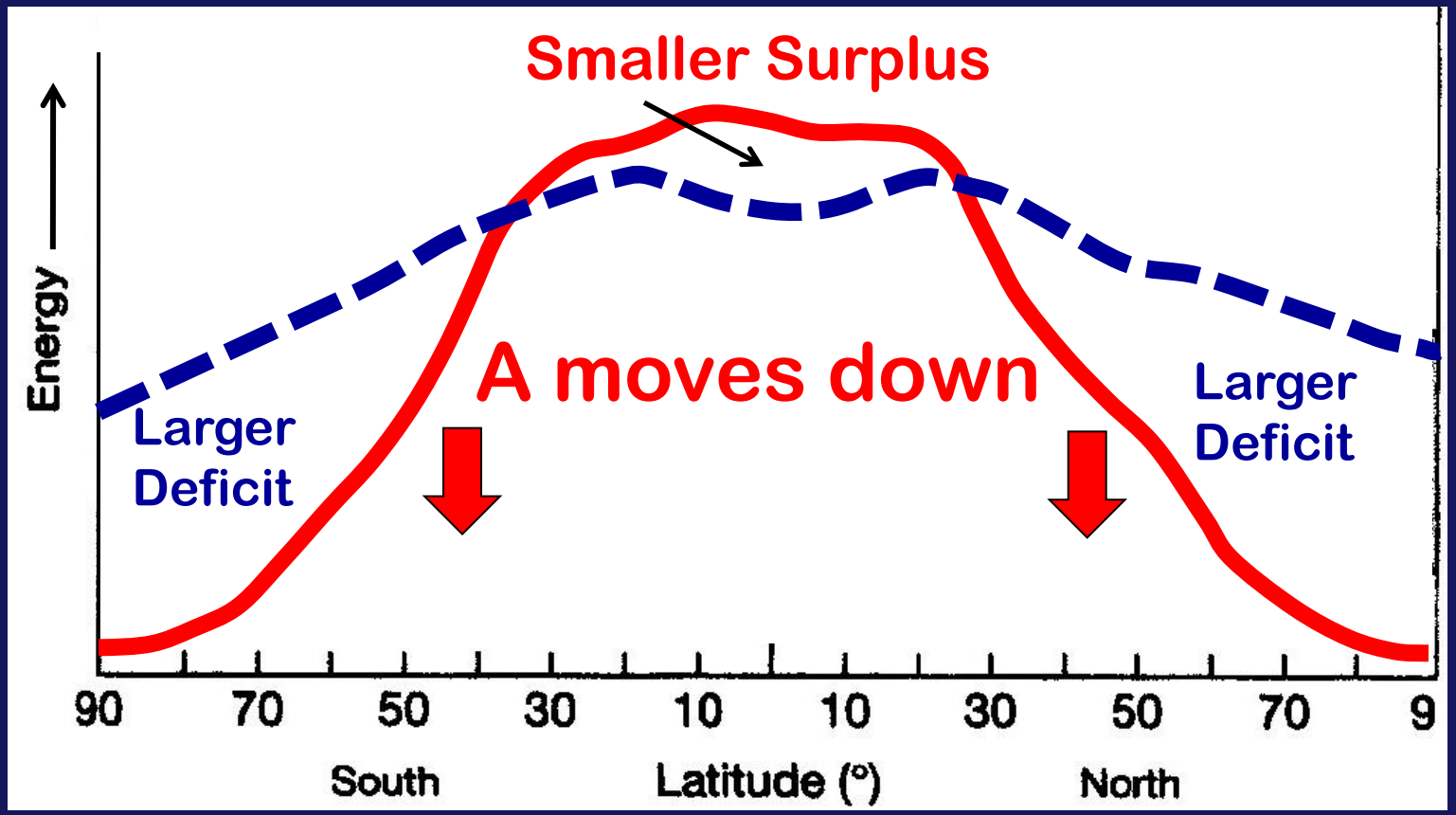
You can use this figure to conceptually "model" CLIMATE CHANGE in your mind!



CURVE A SW + SW - SW

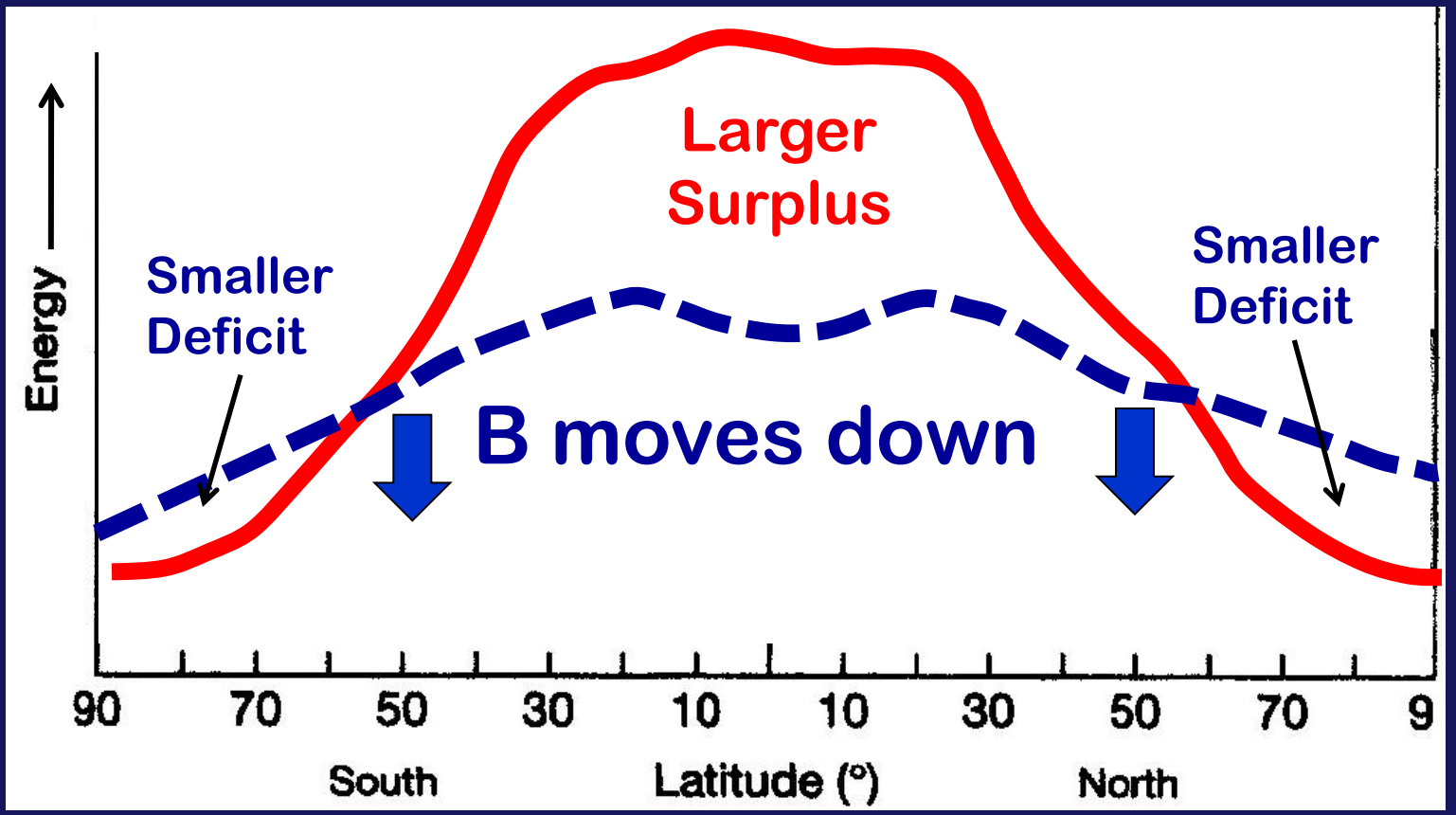
CURVE B LW LW

IF CURVE A moves down: SW ↓ + SW ⇣ - SW ↘



SW ↓ + SW ⇣ - SW ↘ If incoming energy represented by Curve A is reduced (A curve goes down)

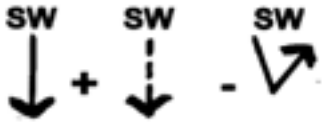
If CURVE B moves down

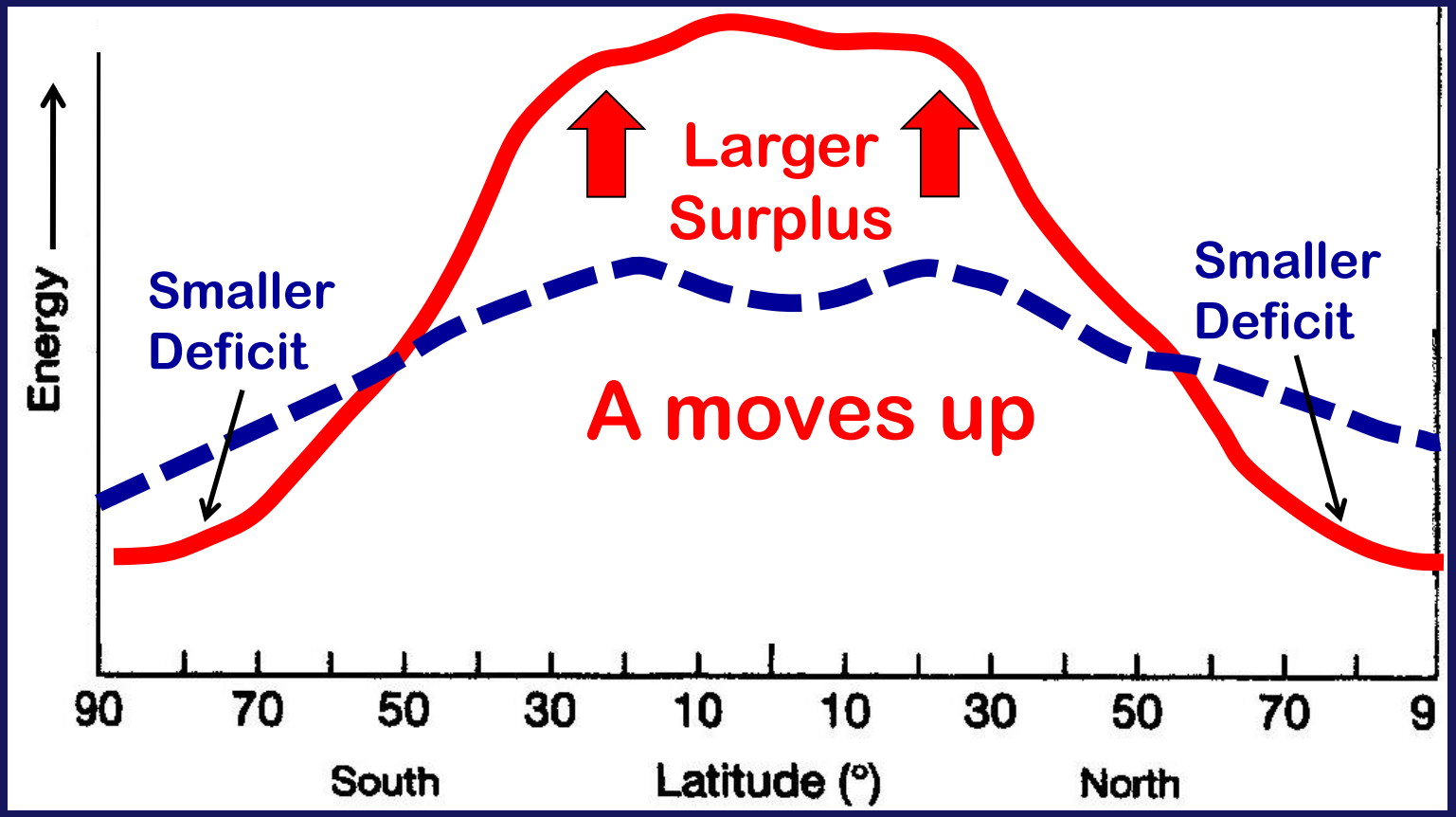


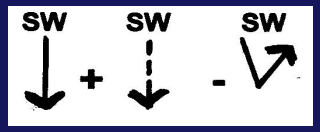
LW

If outgoing energy represented by Curve B is reduced (B curve goes down)

IF CURVE A moves up:

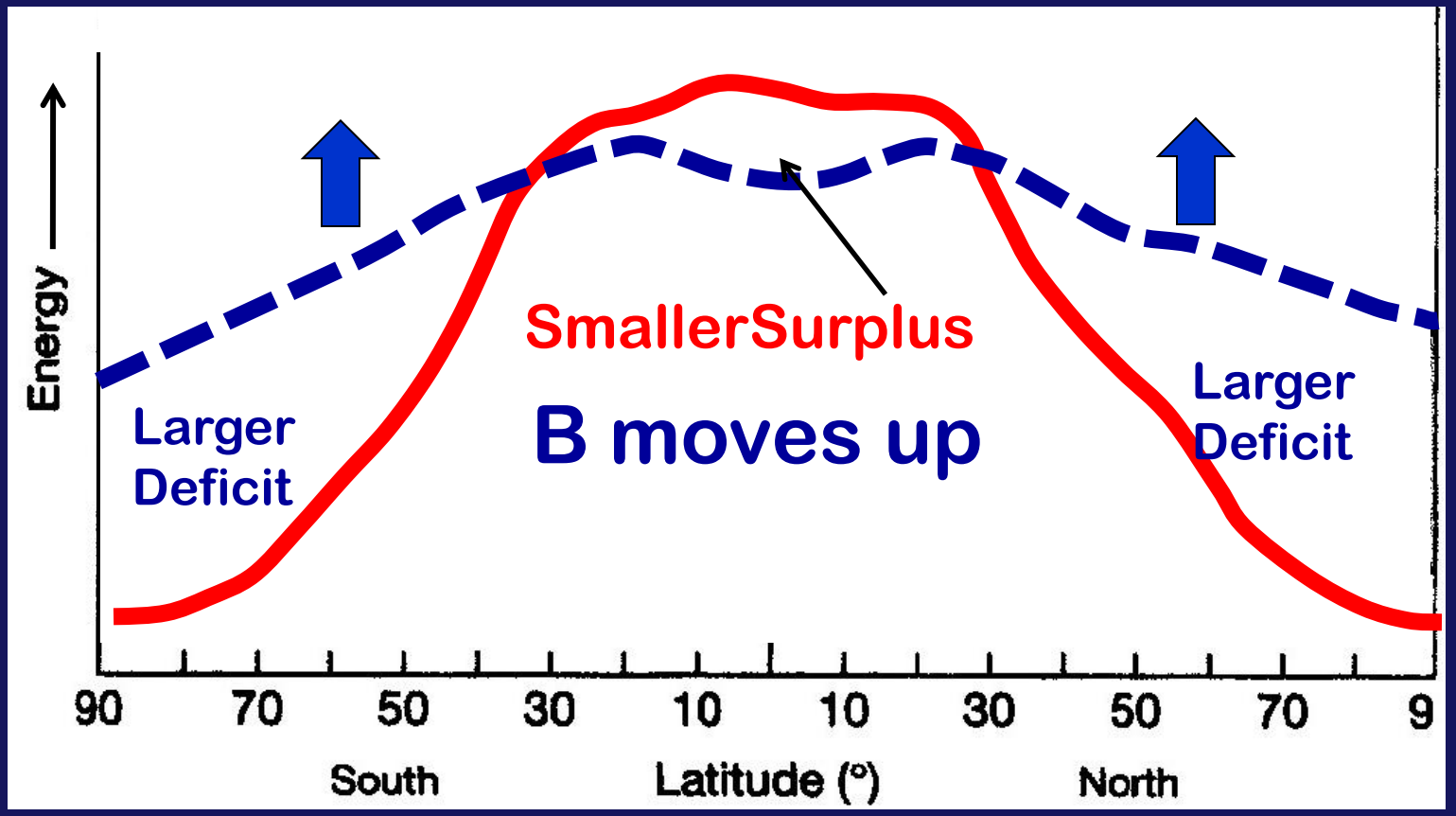




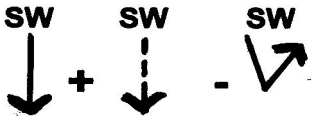


If incoming energy represented by Curve A is increased (A curve goes up)

If CURVE B moves up:



If outgoing energy represented by Curve B is increased (B curve goes up)

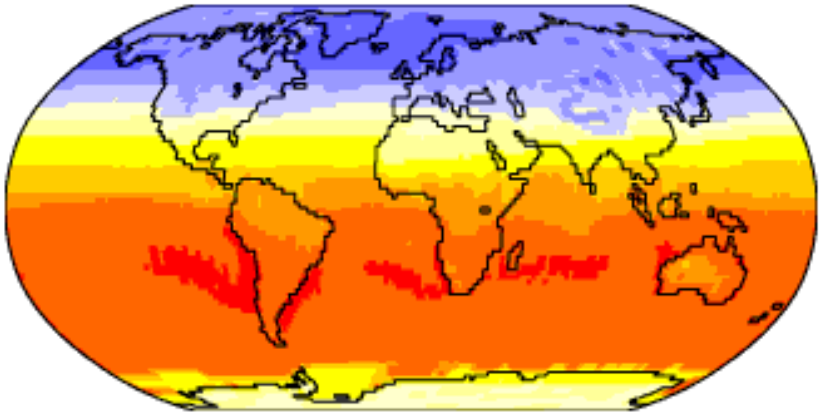


Short-Wave Radiation

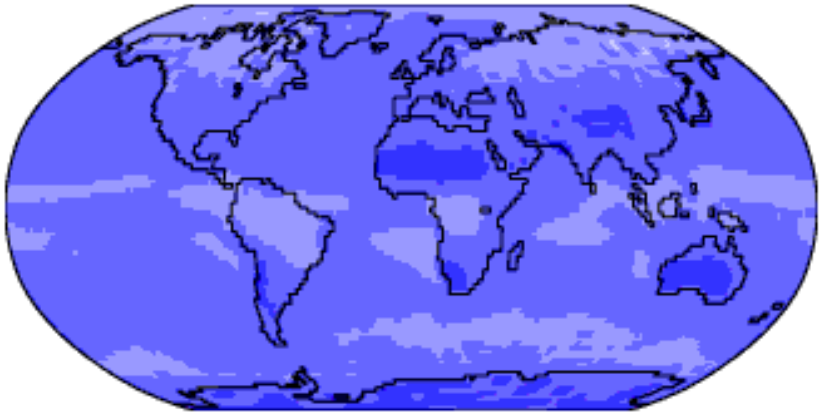
Dec

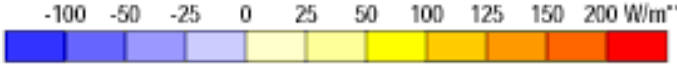
R_{NET}

Net Radiation



Long-Wave Radiation



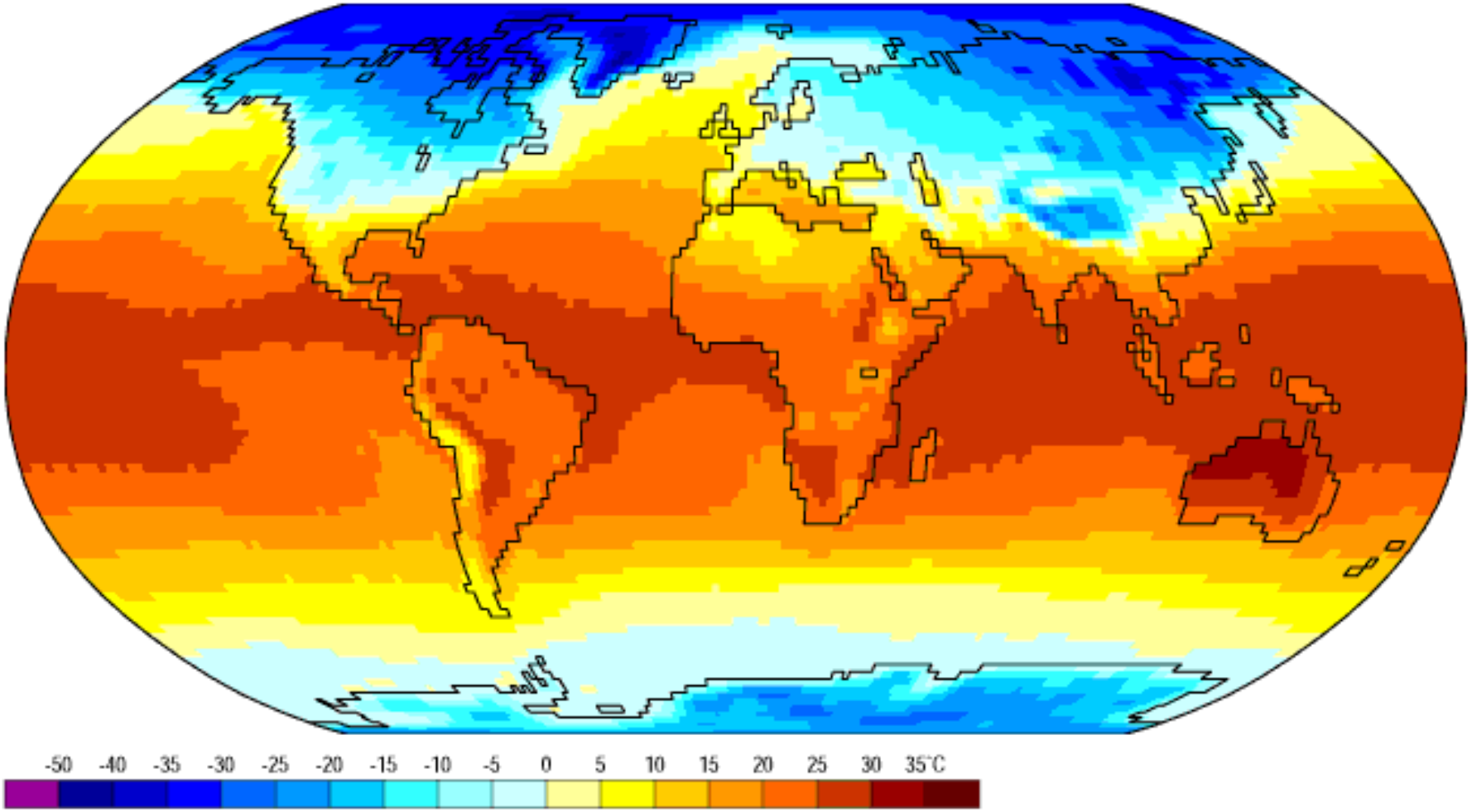


Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

http://geography.uoregon.edu/envchange/clim_animations/

Air Temperature

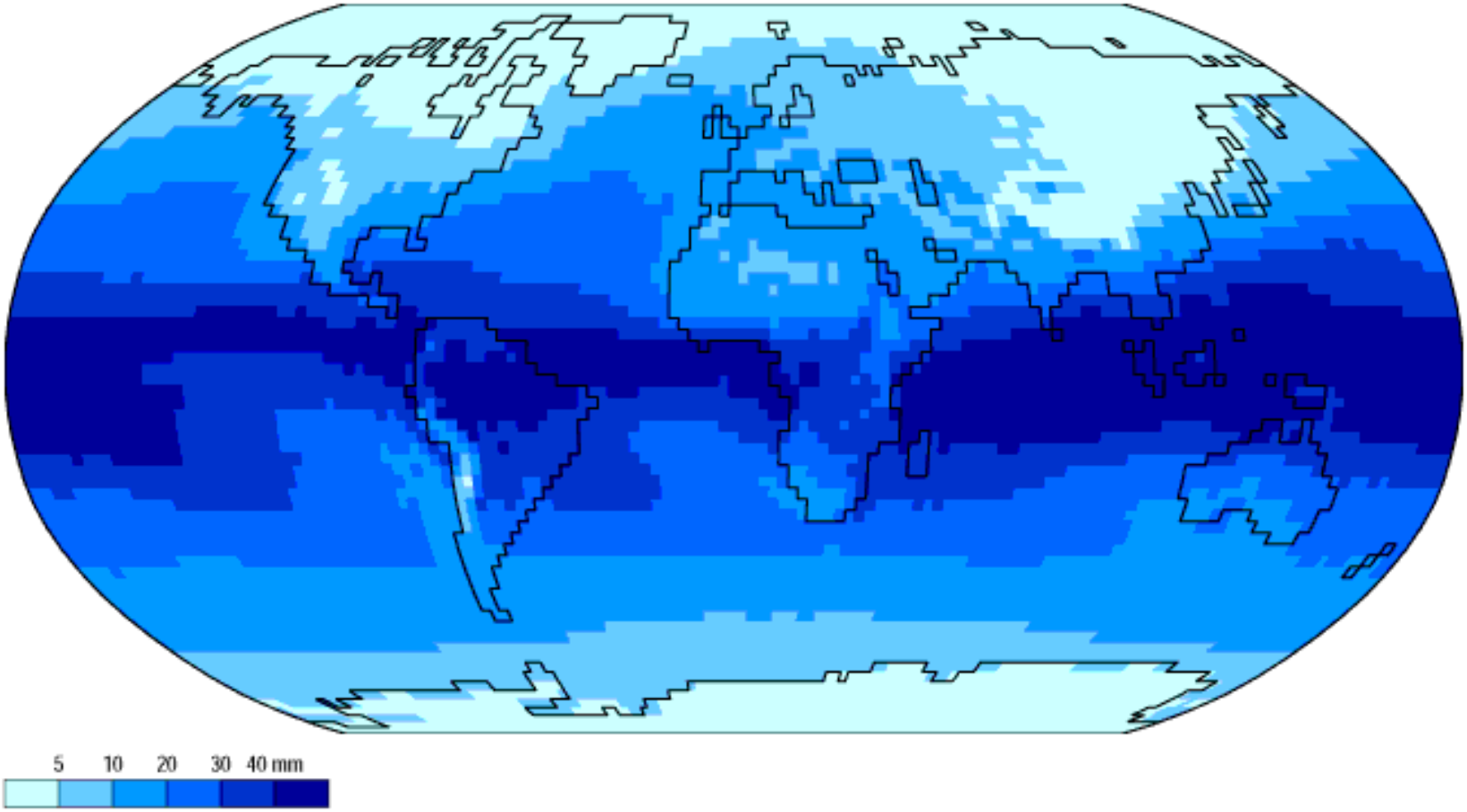
Dec



Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Precipitable Water

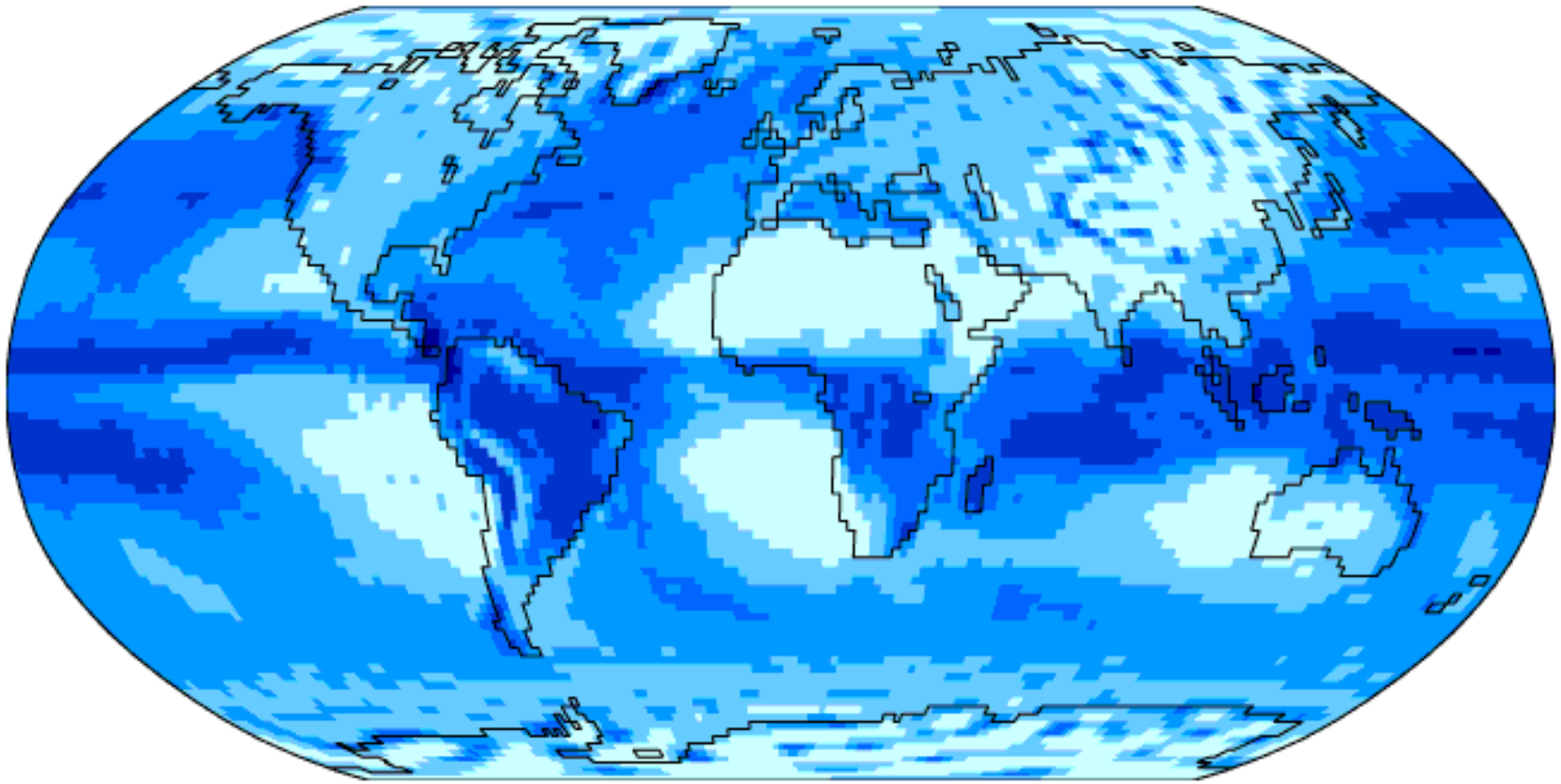
Dec



Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Precipitation

Dec



10 50 100 200 400 mm

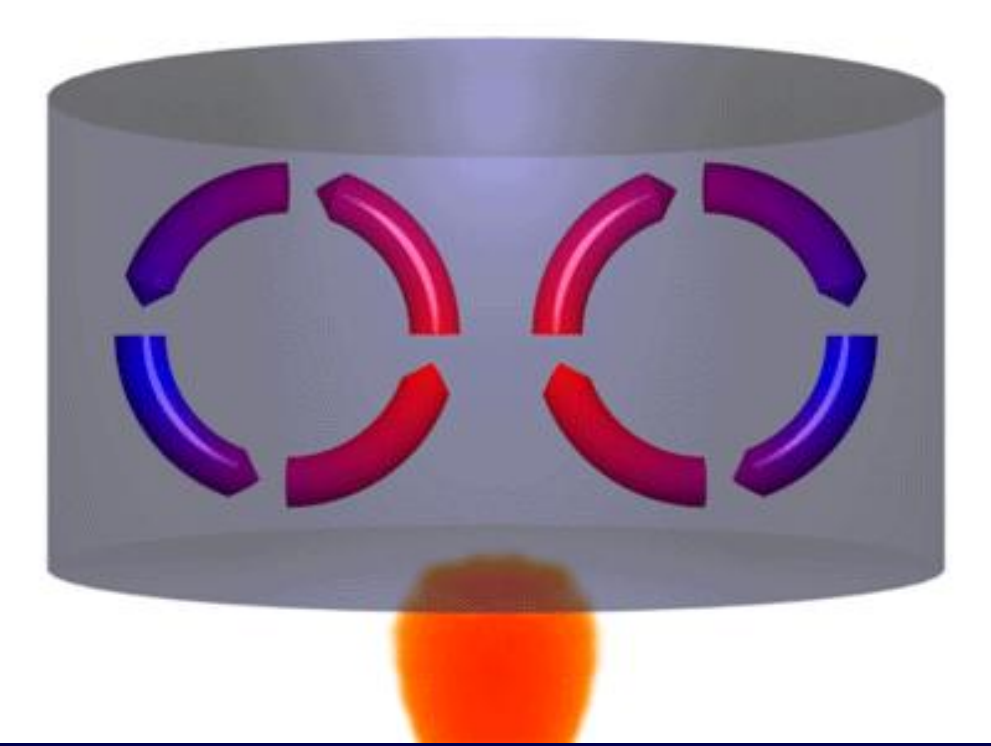
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

CLICKER QUESTION:

Are you here today?

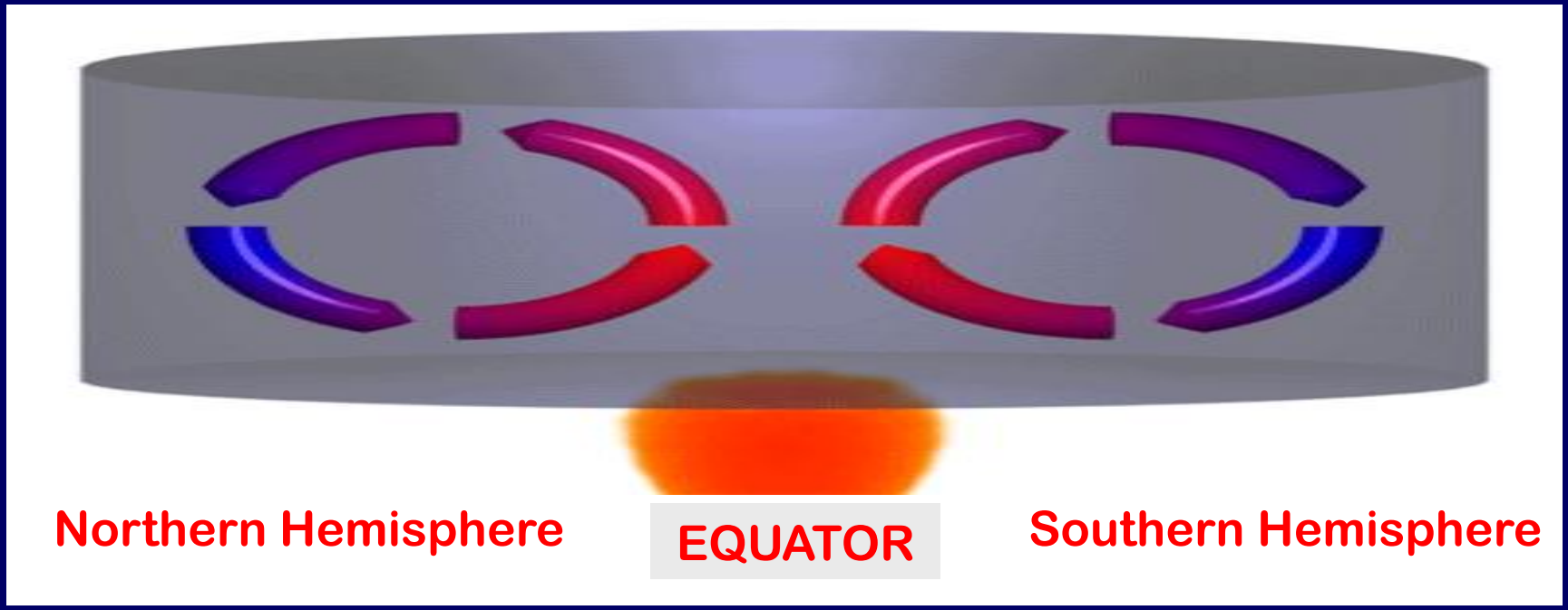
1) YES
2) No
3) Physically
   but not mentally

CONVECTION!



Heating

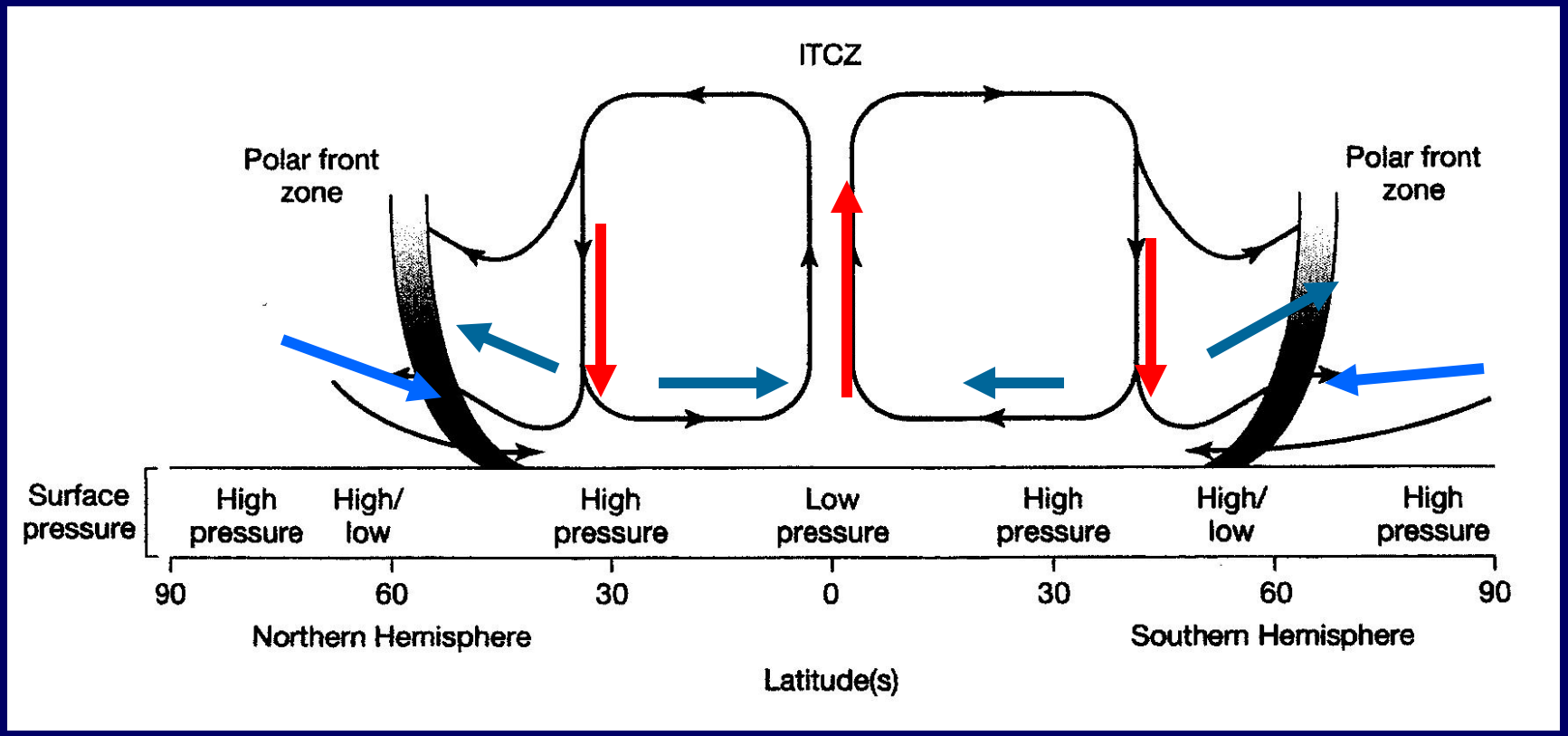
Global-scale air motions are driven by thermal differences:



COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS



COLD POLAR REGIONS

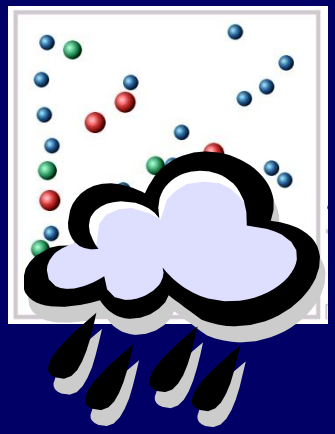
HOT TROPICS

COLD POLAR REGIONS

From SGC Chapter 4

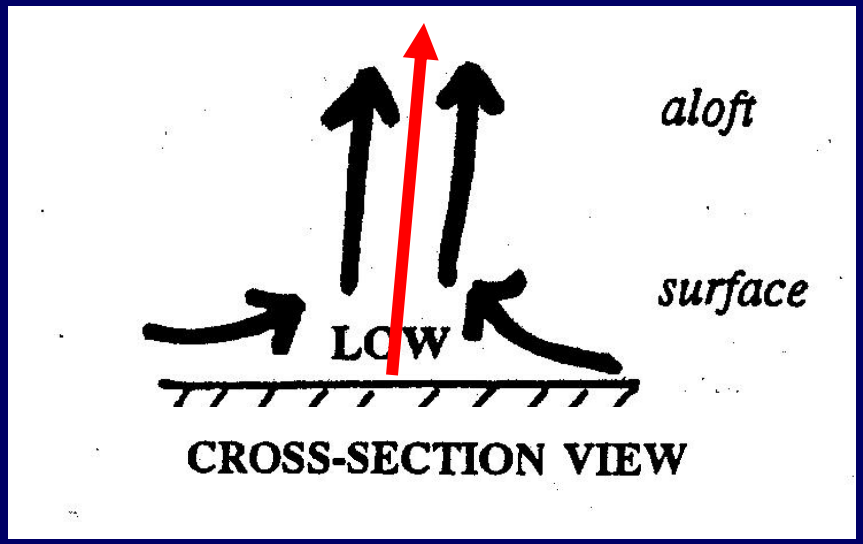
LOW PRESSURE AREAS:

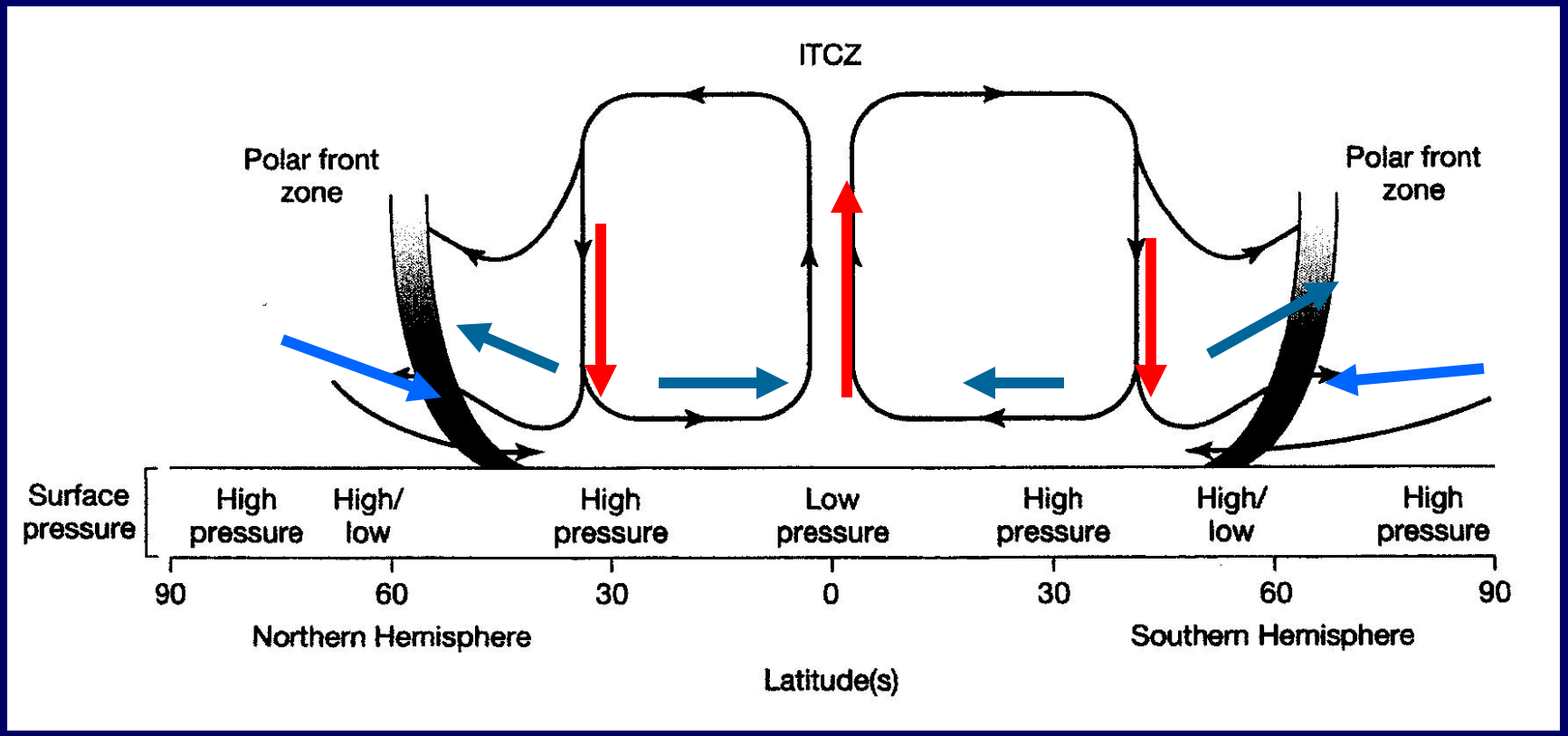
Hot surface ➔ Rising air ➔ **expansion and cooling** of air, and condensation of water vapor



➔ **clouds, and possibly precipitation . . .**

HUMID REGIONS





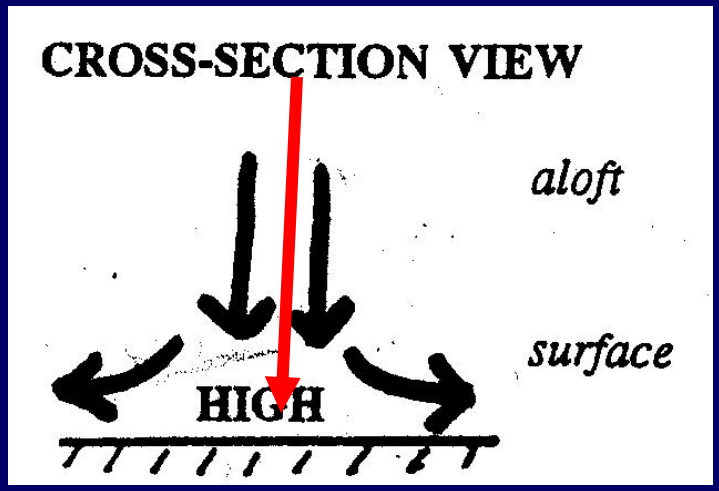
COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

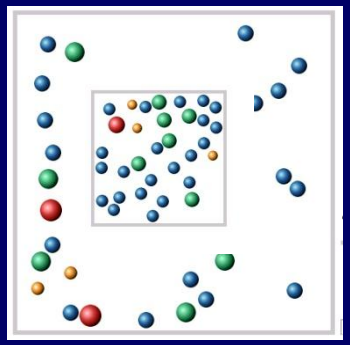
From SGC Chapter 4

The opposite of rain = subsidence (sinking air) In HIGH PRESSURE ares!



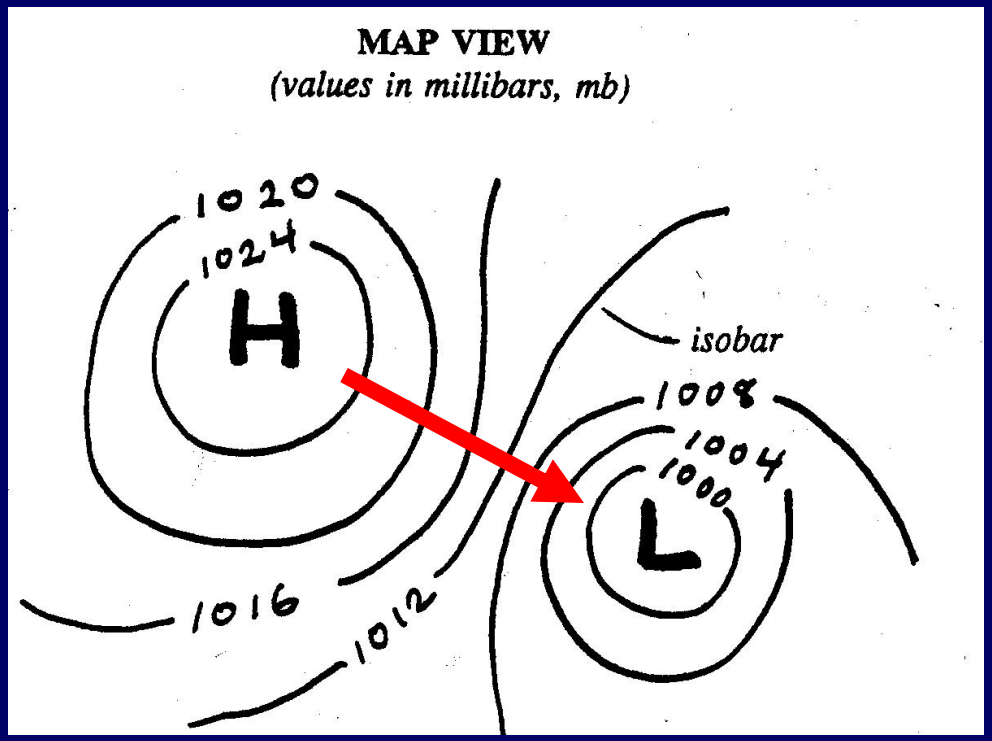
HIGH PRESSURE AREAS:

Forced sinking
(e.g. in HADLEY CELL)
leads to "**compaction" and warming of the sinking air**

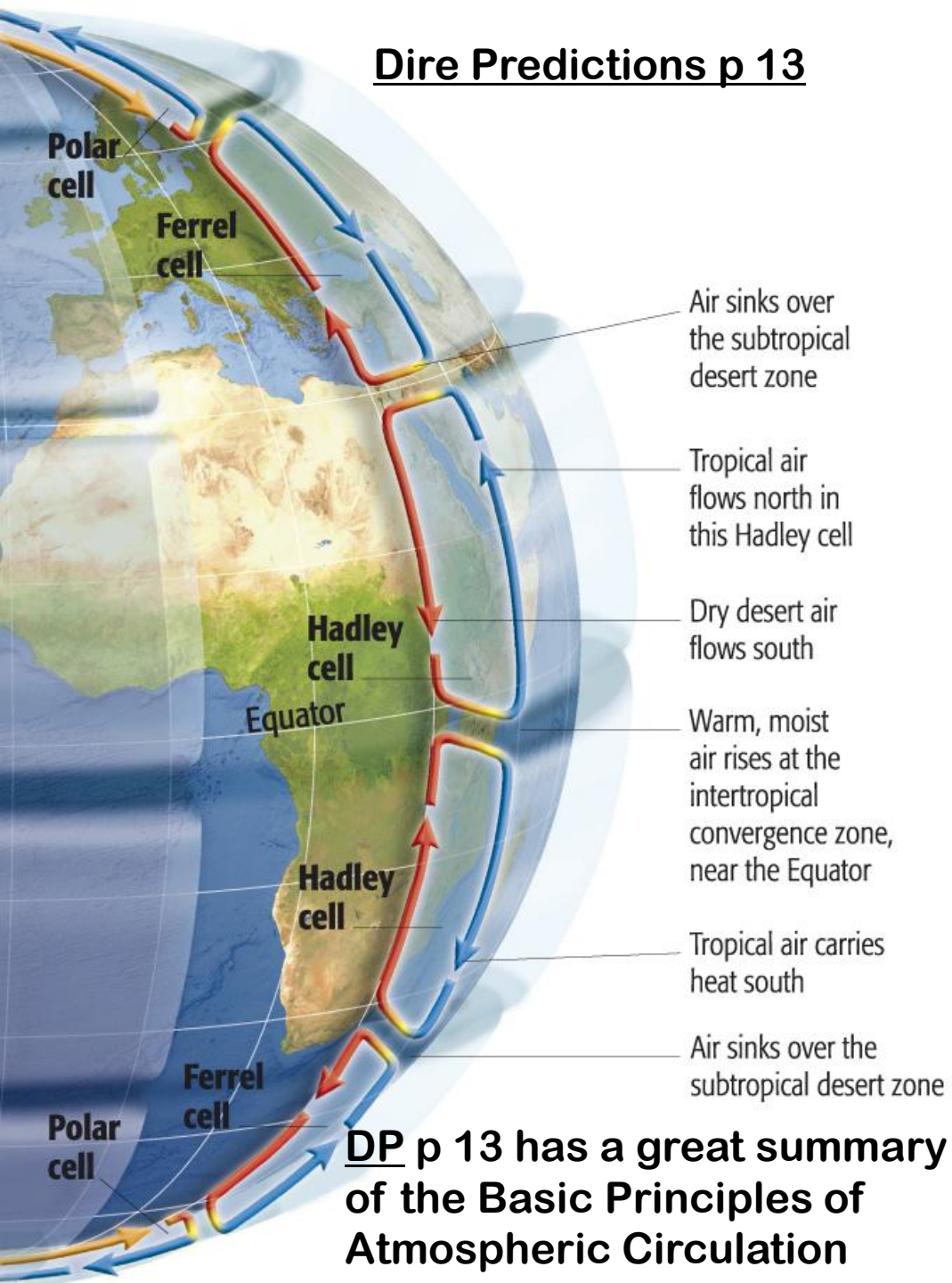


Air warms → increase in the water vapor holding capacity
→ clear skies, dry air and
ARID REGIONS / DESERTS!

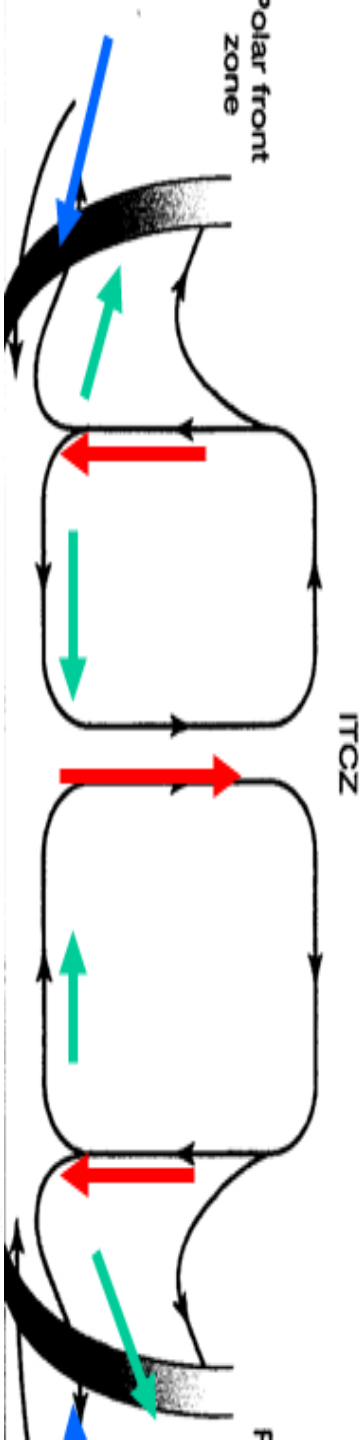
In general: **surface winds tend to flow from HIGH Pressure to LOW Pressure areas**



Dire Predictions p 13



DP p 13 has a great summary of the Basic Principles of Atmospheric Circulation

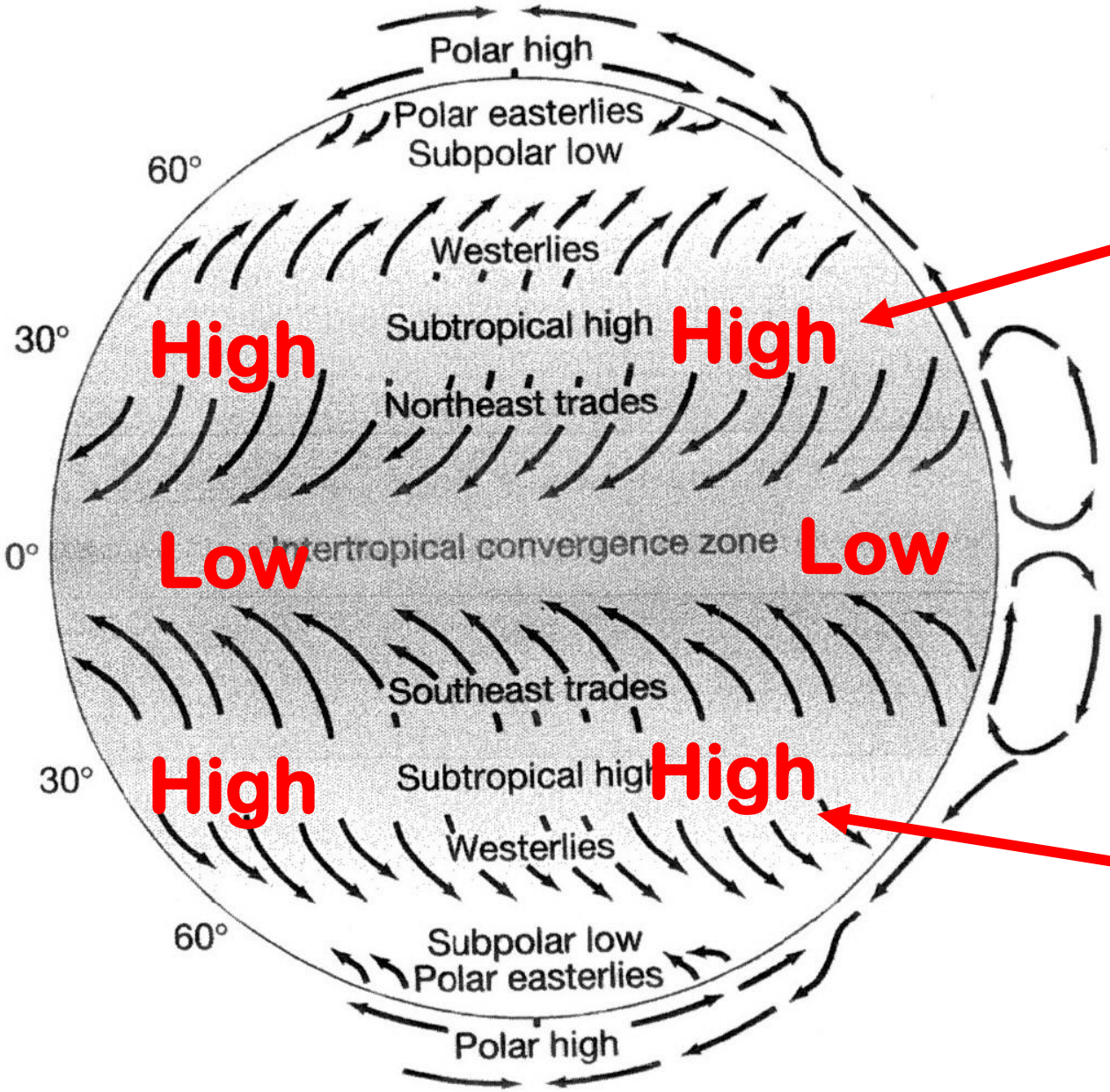


cold polar air
vs.
warm low lat air

sinking dry subtropical air

sinking dry subtropical air

warm low lat air
vs.
cold polar air

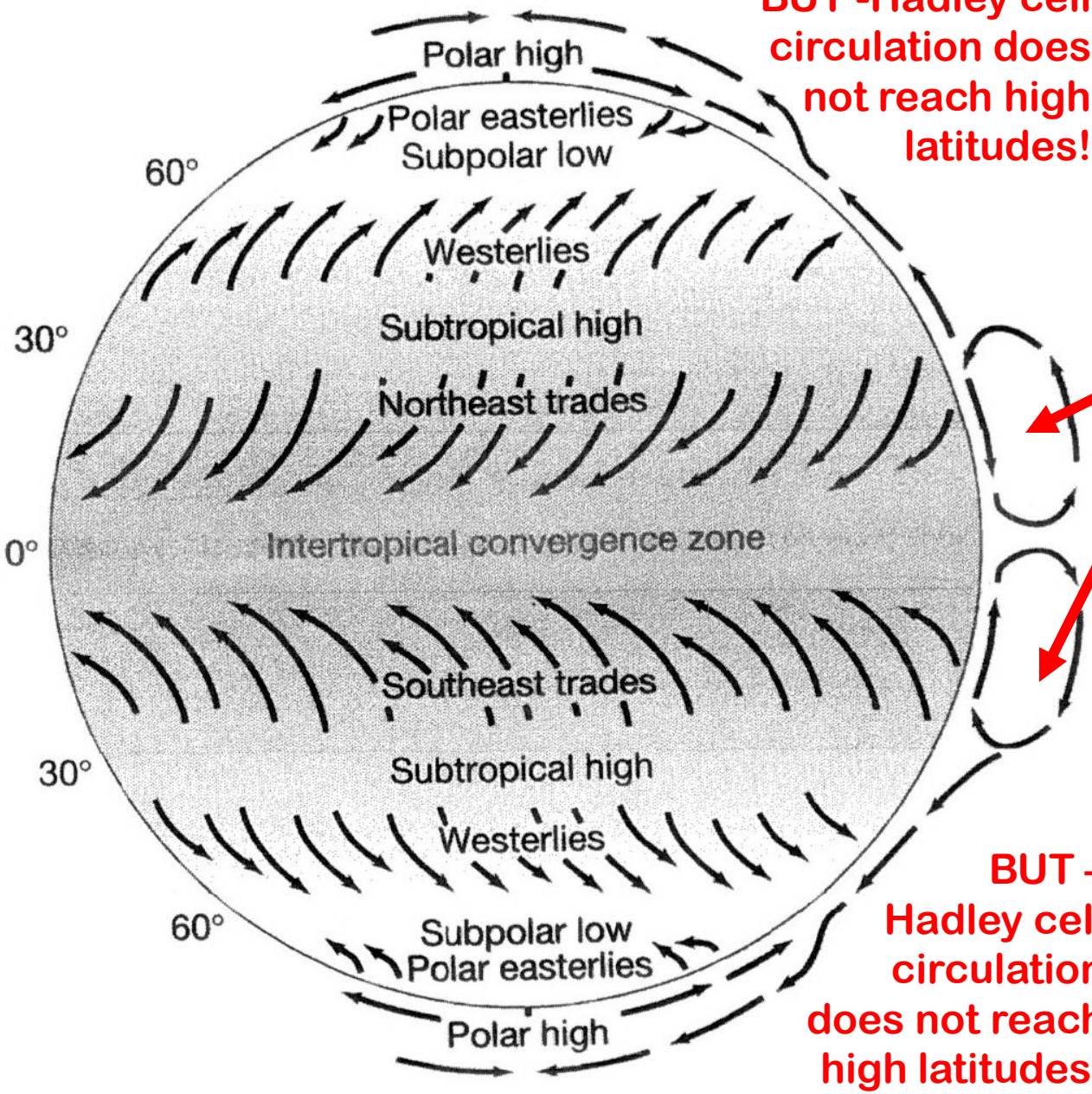


Sub-tropical HIGH PRESSURE

Intertropical Convergence ITCZ (low pressure)

Sub-tropical HIGH PRESSURE

From SGC Ch 4



BUT -Hadley cell circulation does not reach high latitudes!

BUT – Hadley cell circulation does not reach high latitudes!

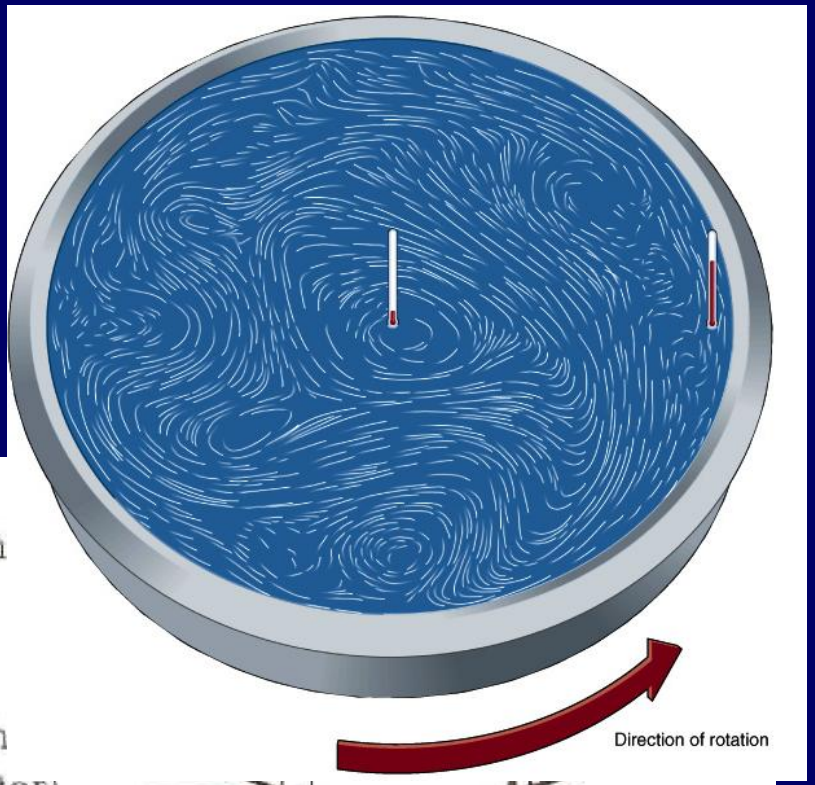
Hadley Cells transport warm air poleward as SENSIBLE HEAT

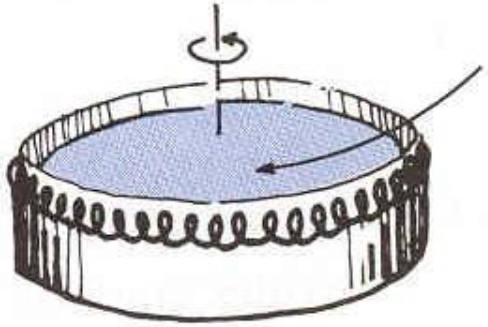
HADLEY CELLS = key drivers!

Convection cell transfer of thermal energy from low latitude area of energy SURPLUS to higher latitude area of energy DEFICIT

Why Hadley convective cell transport breaks down at higher latitudes:

Back to p 65

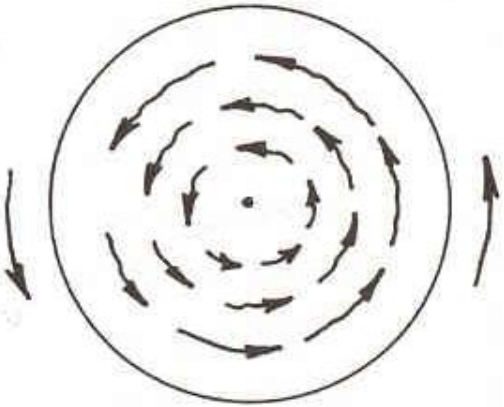


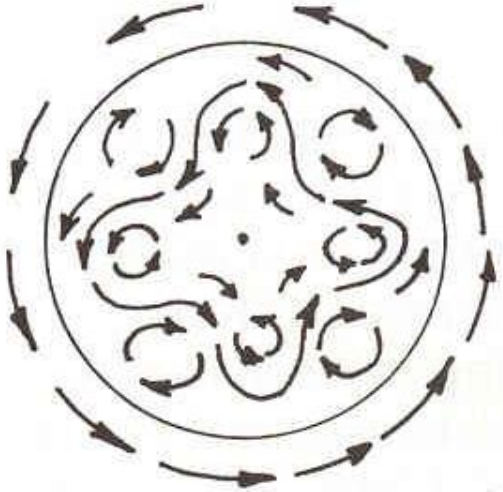


Heatin
(equator)

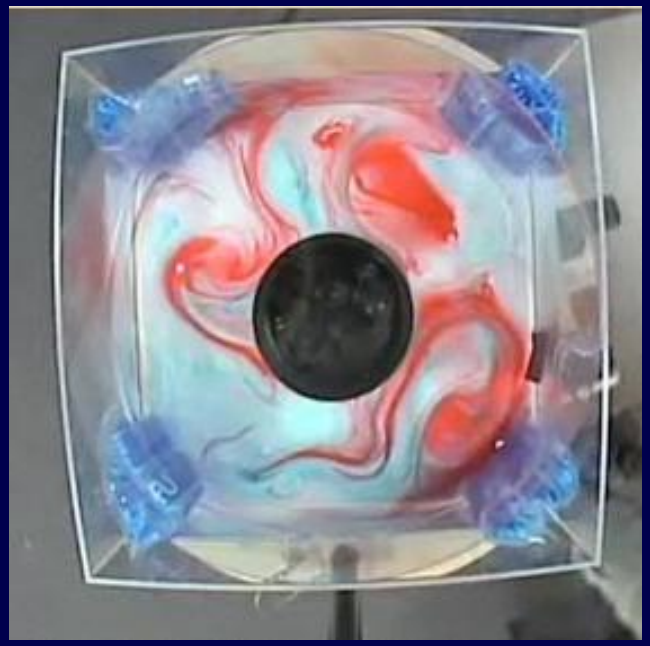
(a) Slow rotation

(b) Faster rotation



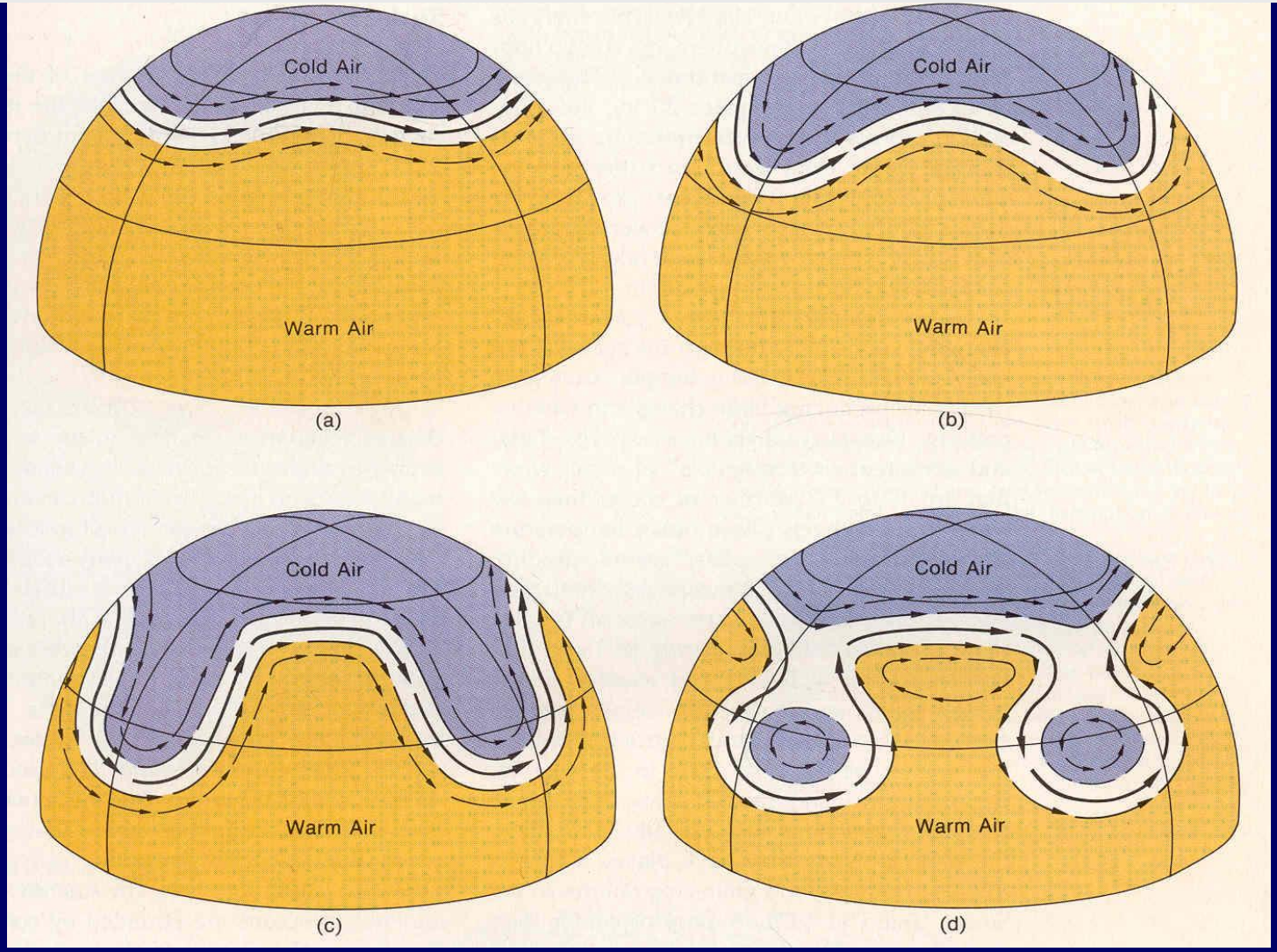


A DEMONSTRATION OF THE DISHPAN



http://www.windows2universe.org/earth/Atmosphere/global_circulation_lsop_video.html

UPPER LEVEL "ROSSBY WAVE" CIRCUMPOLAR WINDS !



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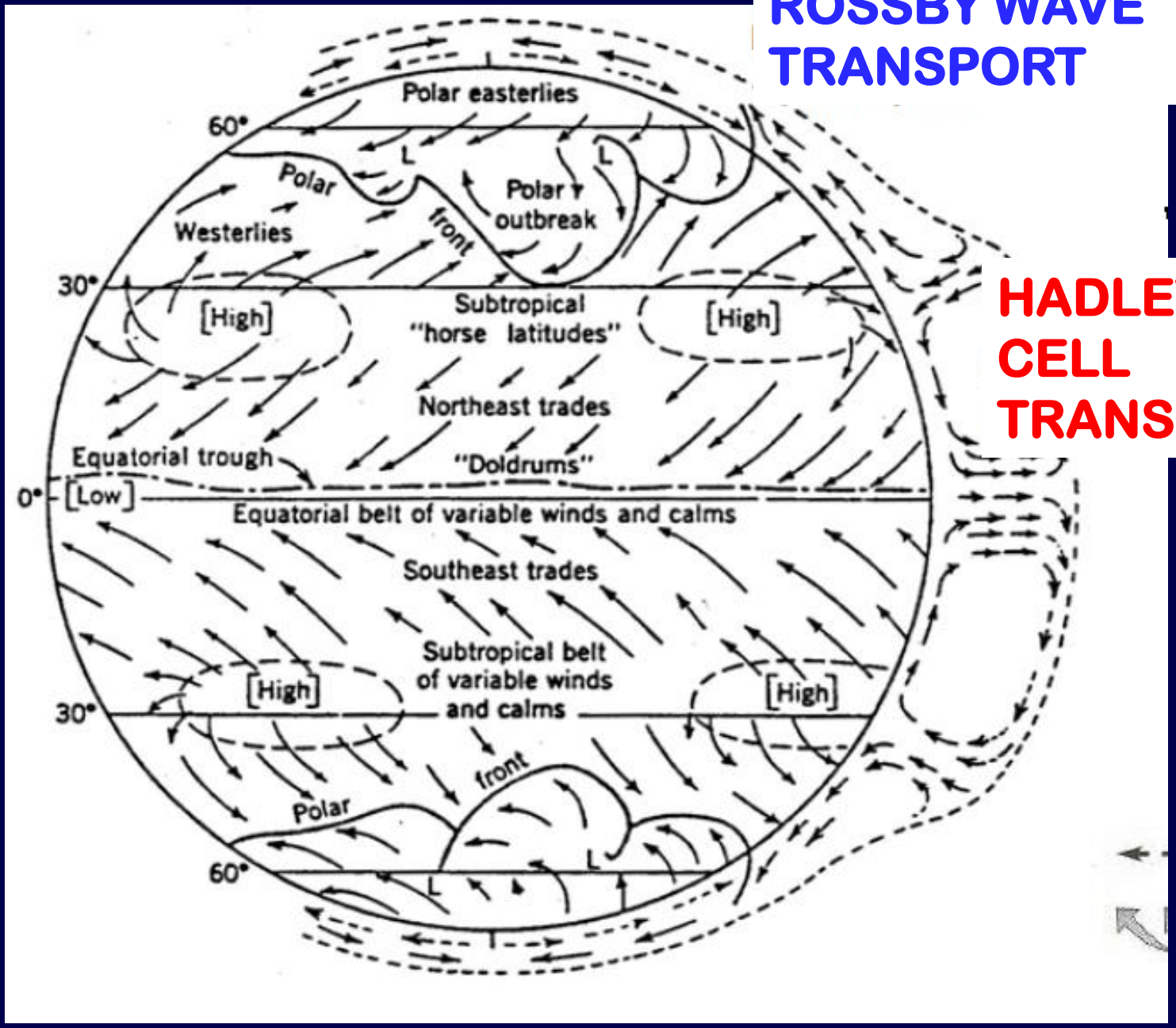
"Wave" transport of SENSIBLE HEAT (in lobes of warm air) instead of Hadley cell transport!

ROSSBY WAVE TRANSPORT



HADLEY CELL TRANSPORT

A LINKING TO LIFE SUSTAINABILITY SEGMENT:

Photographic artist
Chris Jordan

Linking-to-Life Part C
is NOW POSTED

And ready for you to do!!

SEE YOU
ON FRIDAY!!