Wrap up of Topic #12 on Ocean Circulation

pp 67 in Class Notes

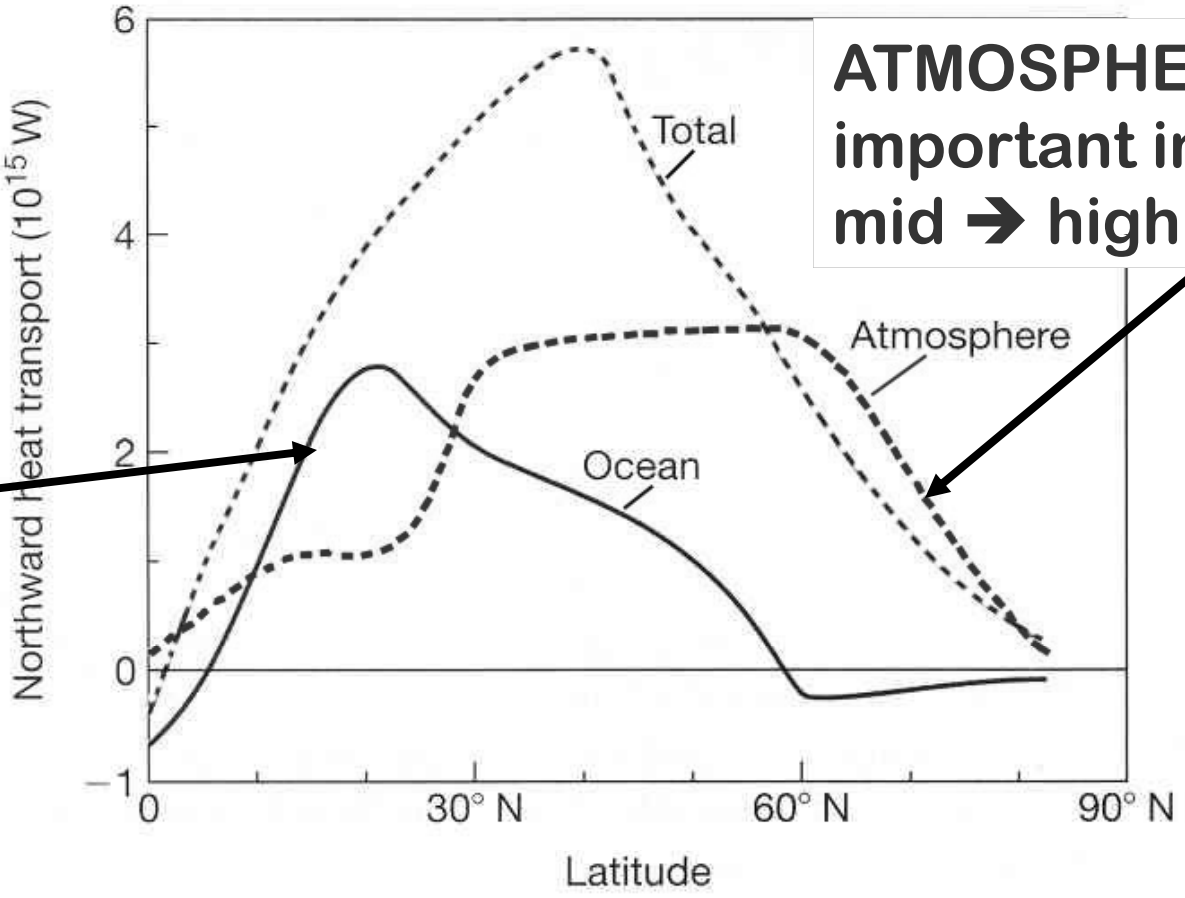
TOPIC #13

NATURAL CLIMATIC FORCING

(& Short-Term Climatic Variability)

pp 69-74 in Class Notes

Both ATMOSPHERE & OCEAN play important roles in BALANCING OUT ENERGY SURPLUS & DEFICIT AREAS:



ATMOSPHERE more important in mid → high latitudes

OCEAN transports MOST of the energy in LOW → subtropical latitudes

Poleward transport of energy in N.H.

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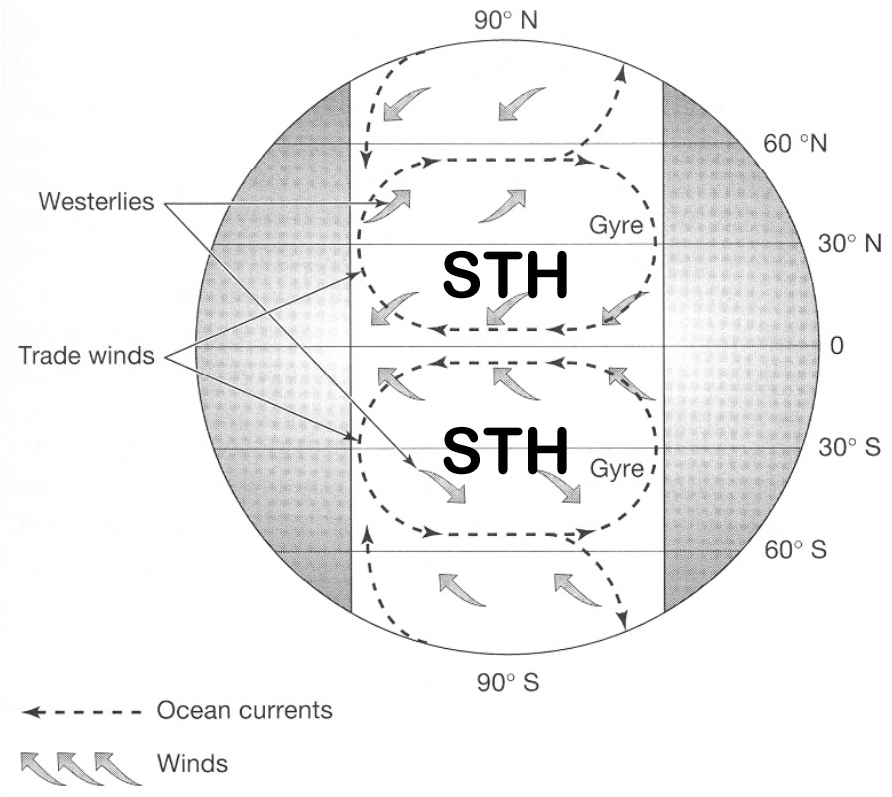
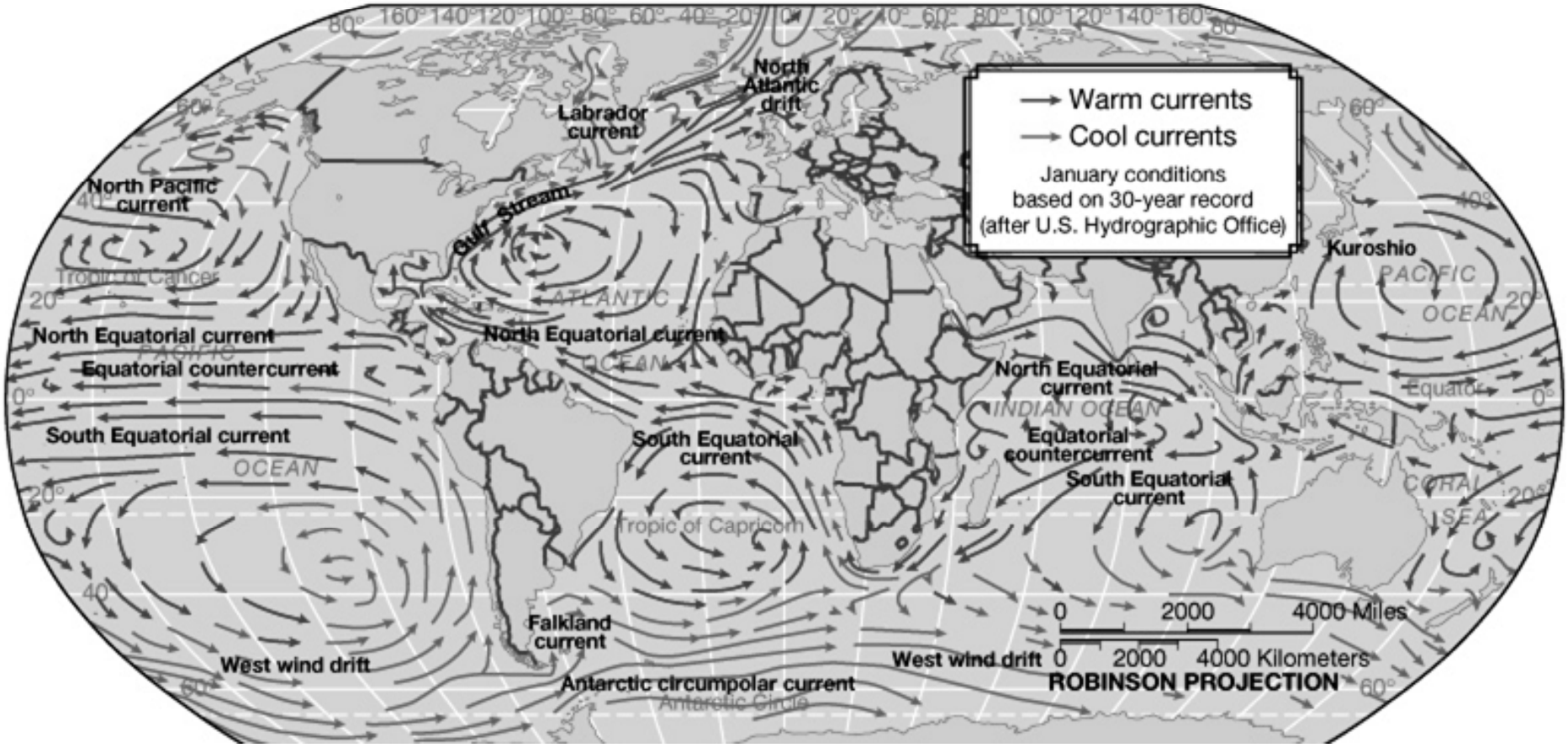
➔Large OCEAN GYRES = WIND DRIVEN

Trade Winds & Westerlies in Oceanic Subtropical HIGH PRESSURE CELLS (STH)

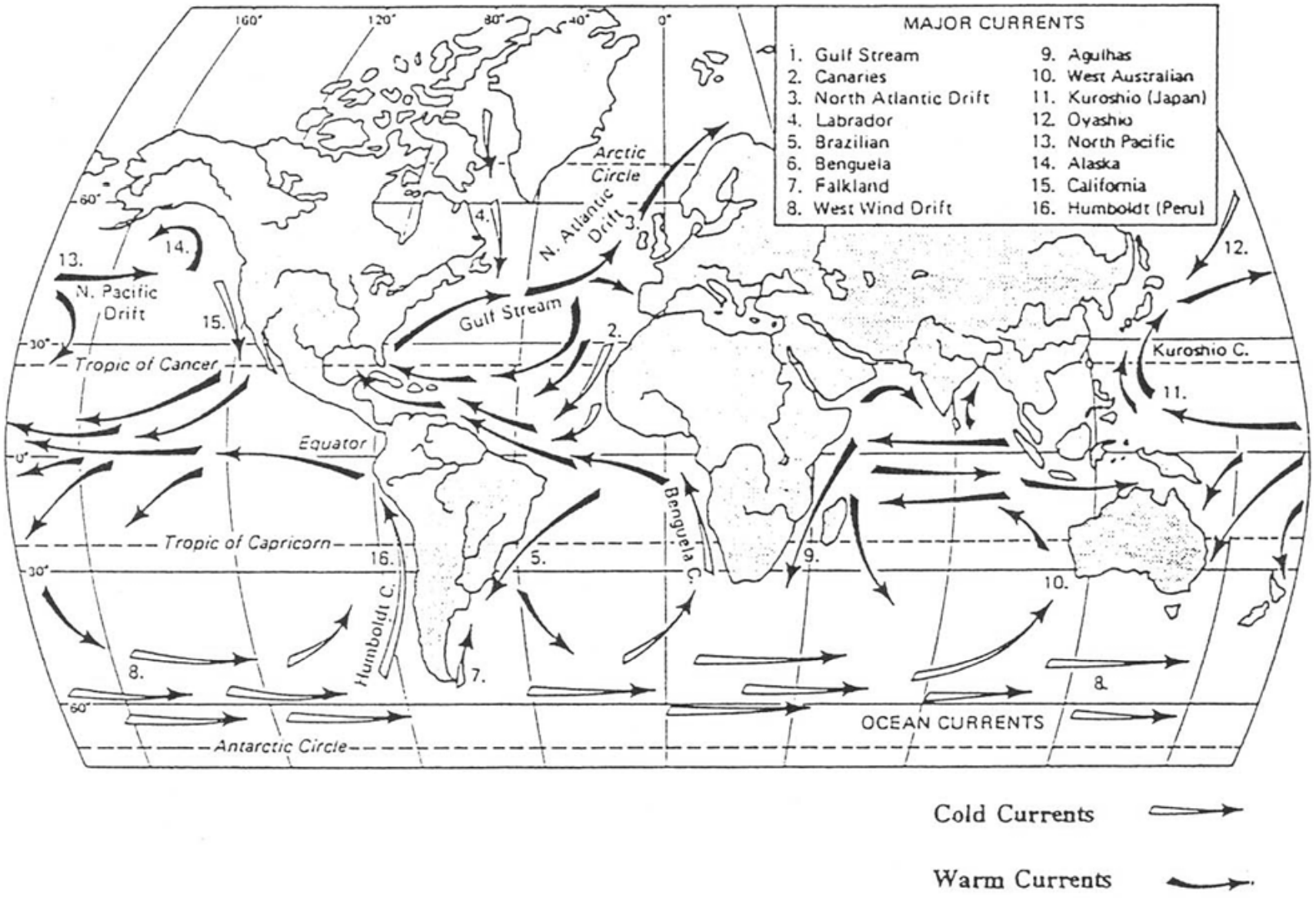


Winds drive <u>SURFACE</u> ocean currents

Energy stored in the ocean can be transferred via WARM OCEAN CURRENTS



WARM & COLD SURFACE OCEAN CURRENTS:



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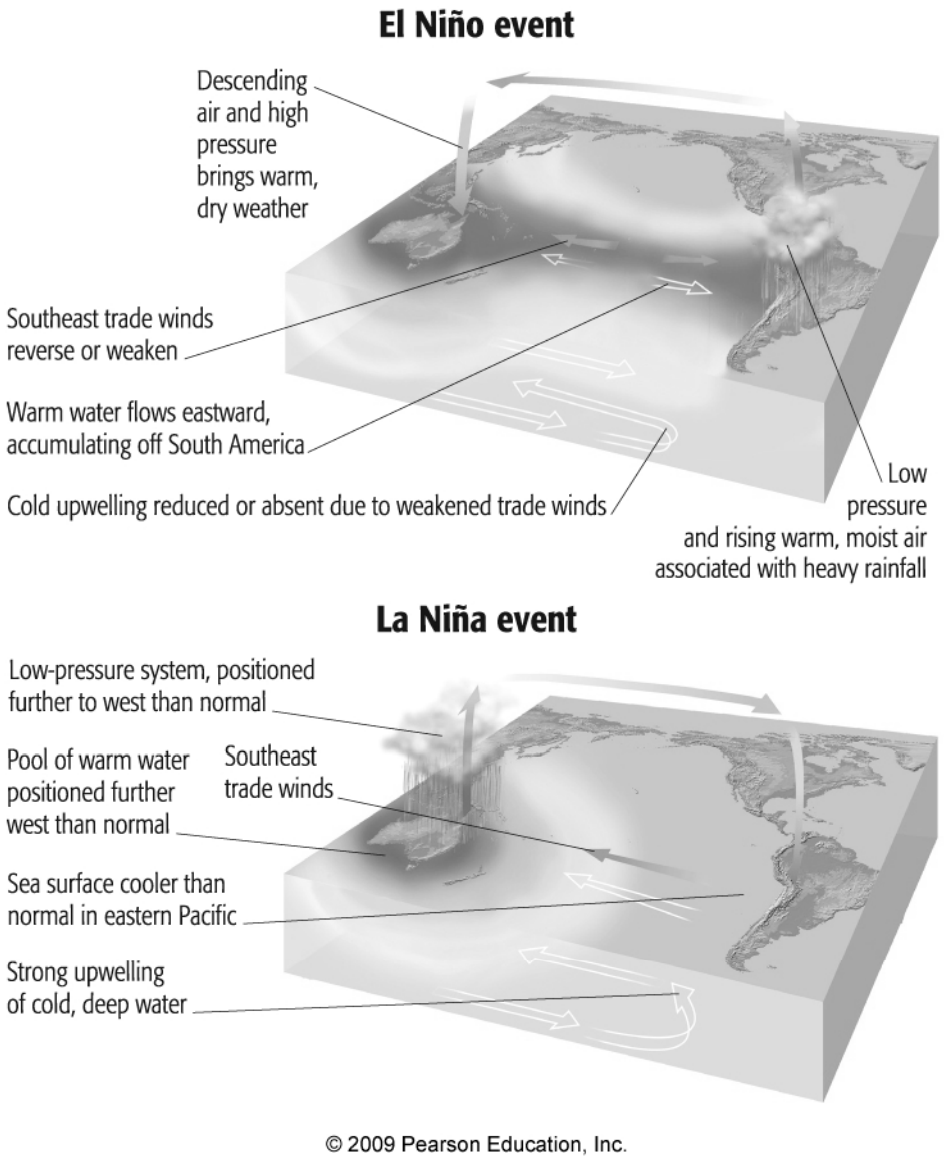
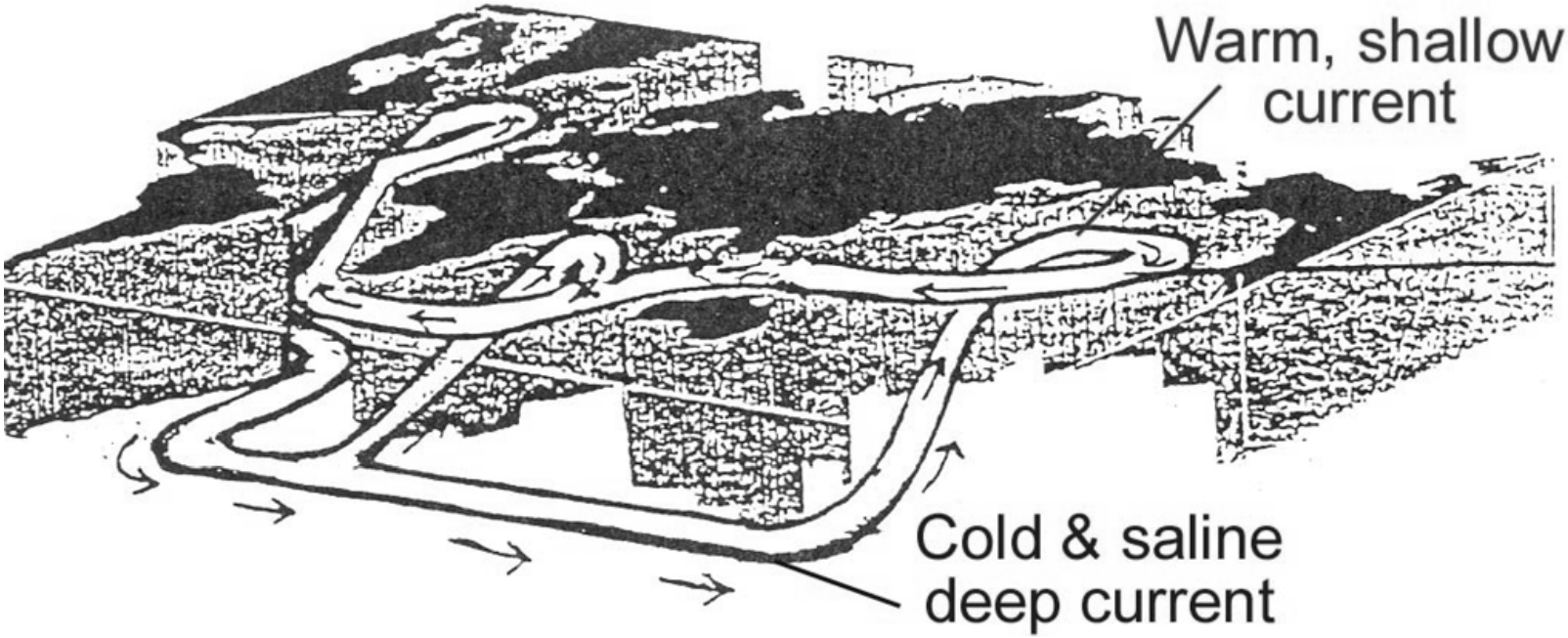
EL Niño & La Niña

ANIMATION



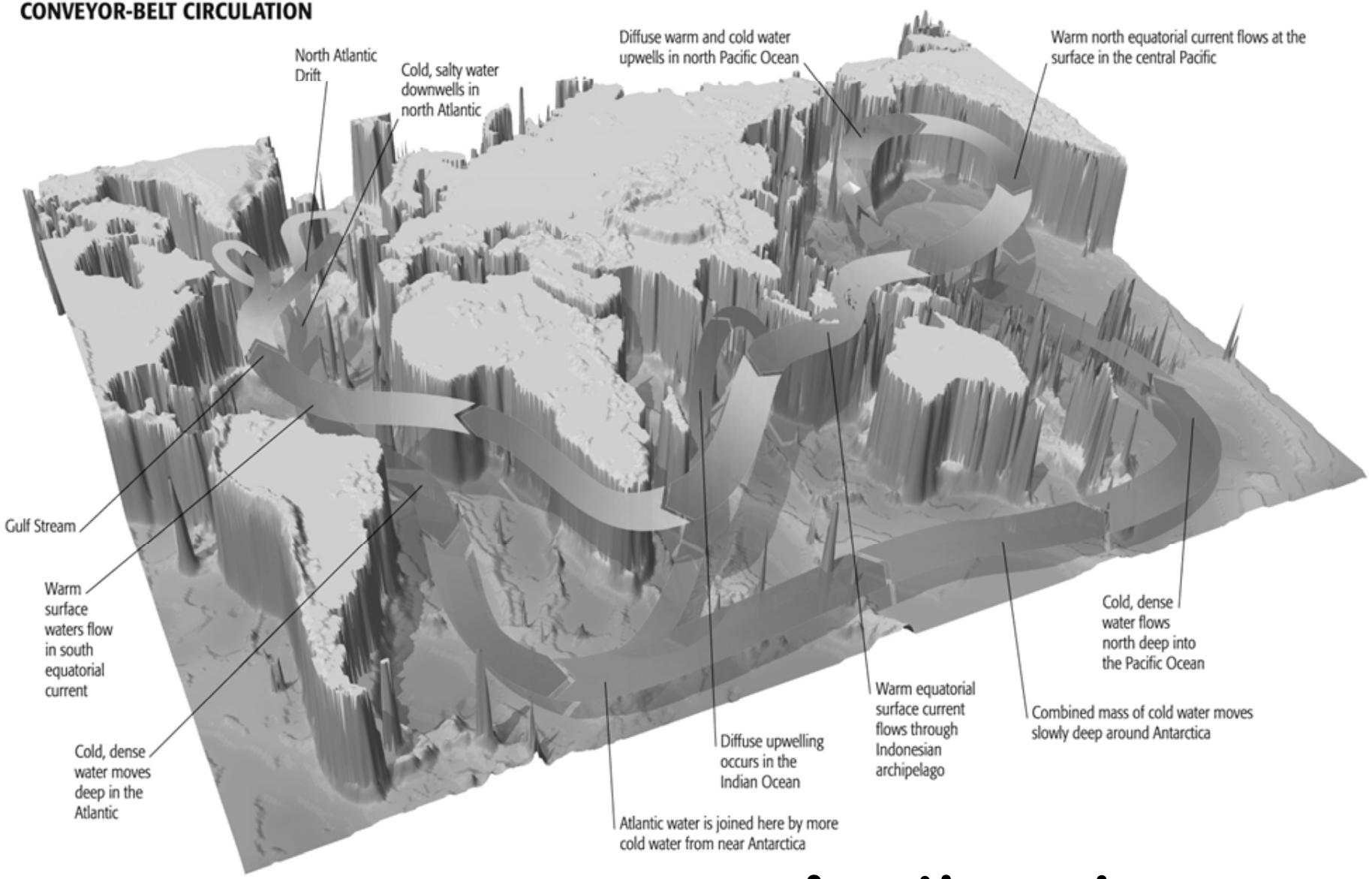
http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

There is also a DEEP OCEAN CIRCULATION – driven by thermal differences AND salinity differences: THERMOHALINE CIRCULATION - "Conveyor Belt"



- **Density driven <u>vertical circulation</u> of the ocean**

- **Cold & salty waters are <u>denser</u> than warm & fresh waters**



Another view

TOPIC #13

NATURAL CLIMATIC FORCING

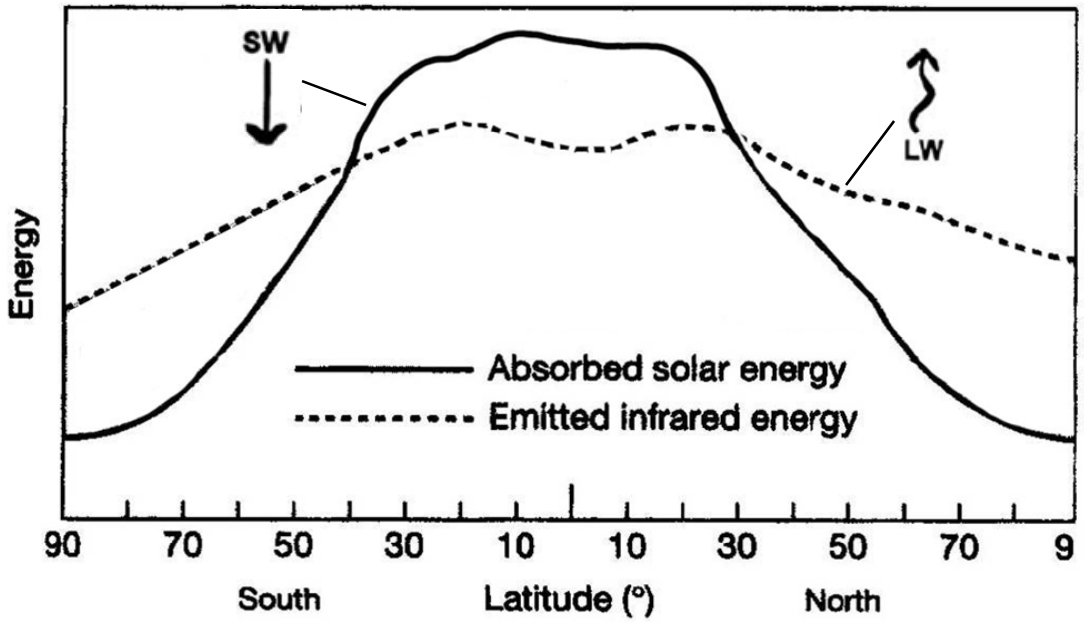
(& Short-Term Climatic Variability)

pp 69-74 in Class Notes

All things are connected. Whatever befalls the earth, befalls the children of the earth.

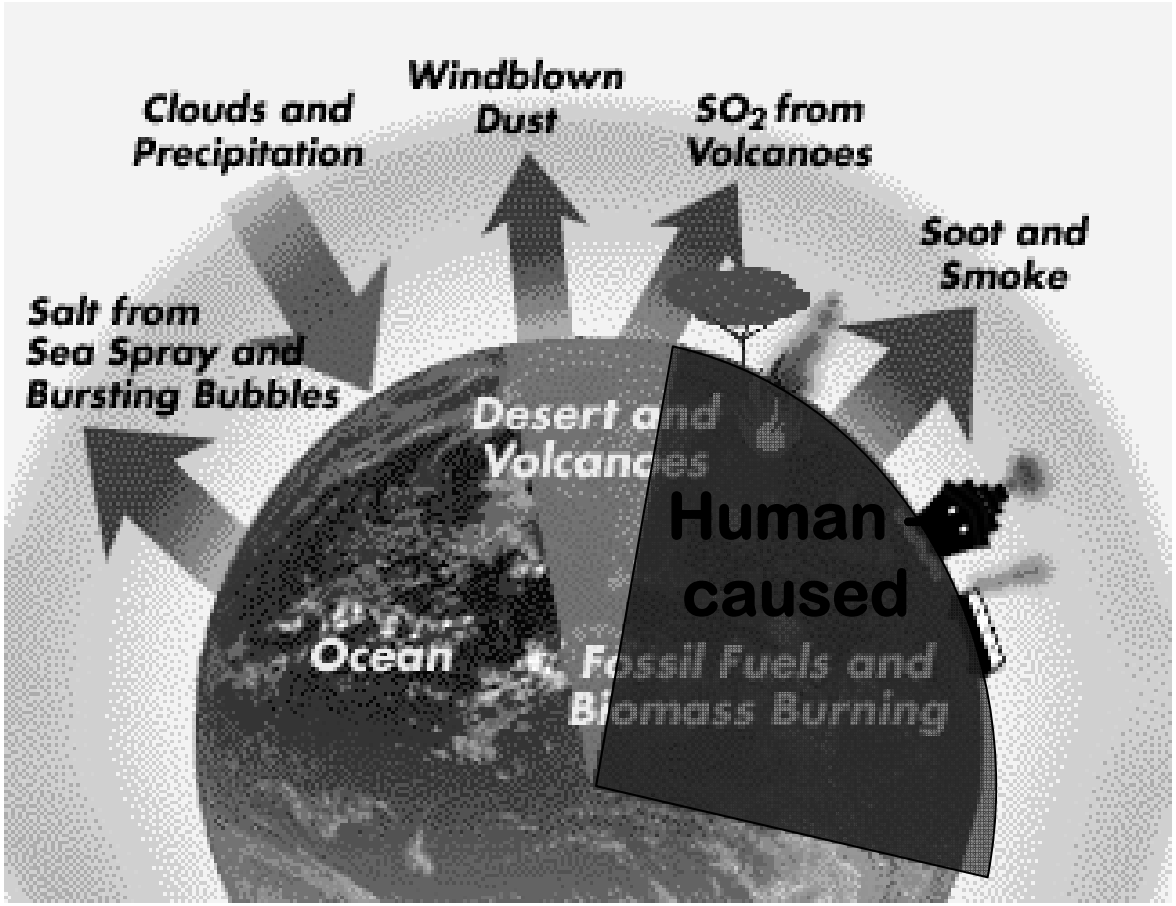
~ Chief Seattle

ENERGY BALANCE (review)



Global climate change / climate variability are due to changes in this balance that are "FORCED"

FORCING = a persistent disturbance of a system



(a longer term disturbance than a perturbation)

NATURAL CLIMATIC FORCING

Earth-Sun orbital relationships, internal atmosphere-ocean variability, solar variability, volcanic eruptions, etc.

vs.

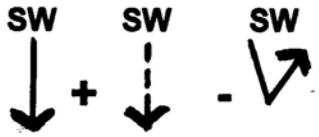
ANTHROPOGENIC FORCING

Human-Enhanced GH Effect, due to fossil fuel burning, land use change, soot & aerosols from industry

REVIEW

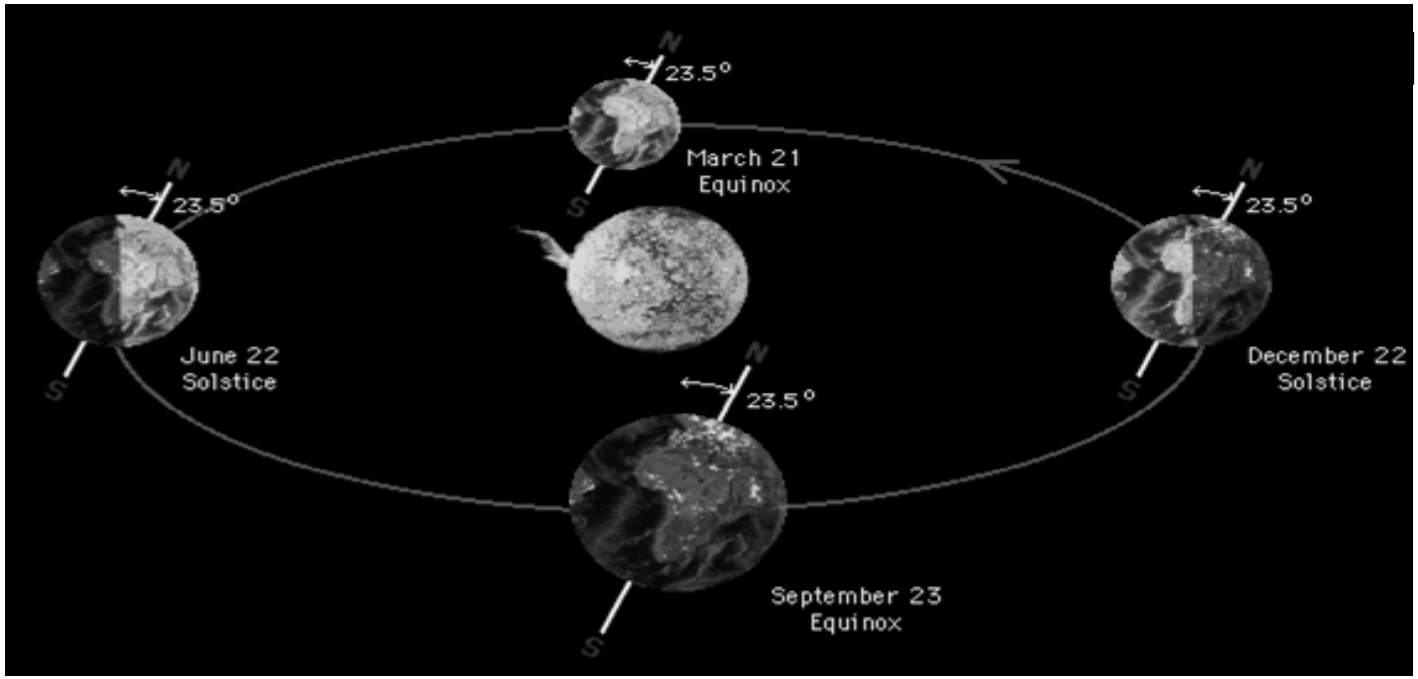
To drive the circulation, the initial source of energy is from the Sun:

Seasonal & latitudinal variations



of solar insolation: 3 Principles →

http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



Seasonal & latitudinal variations of solar insolation:

3 Principles of EARTH-SUN RELATIONSHIPS

(They define the SEASONS in different latitudes!)

#1 OBLIQUITY OF EARTH'S AXIS

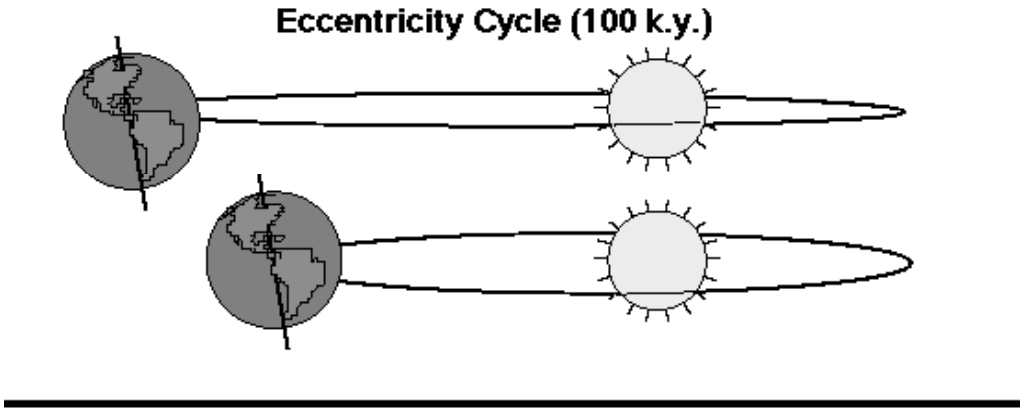
#2 ECCENTRICITY OF EARTH'S ORBIT

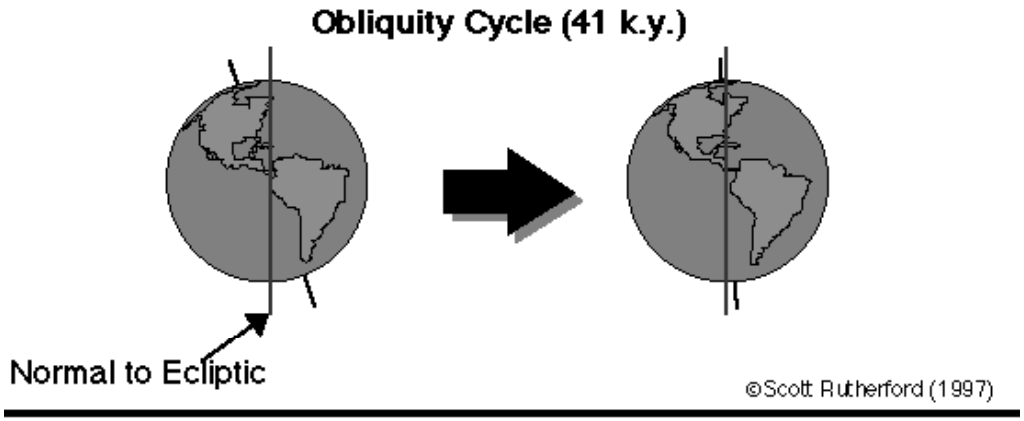
 # 3 Timing of Seasons in Relation to Orbit:

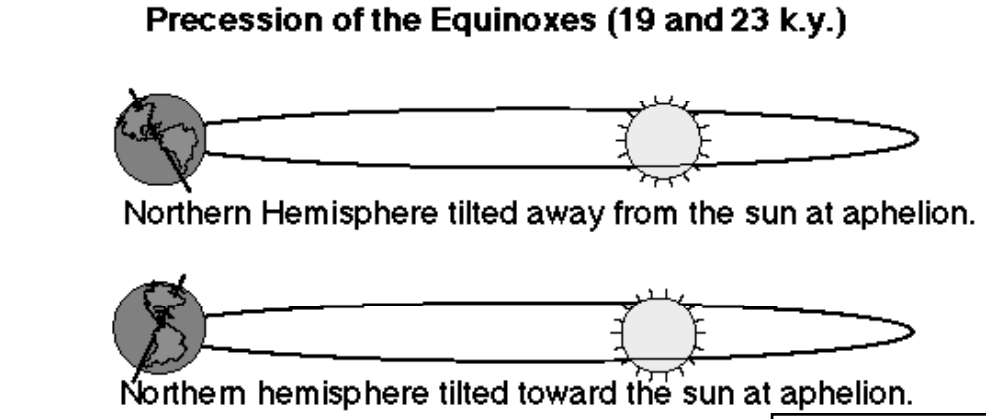
Earth-Sun Orbital Relationships

"astronomical climate forcing"

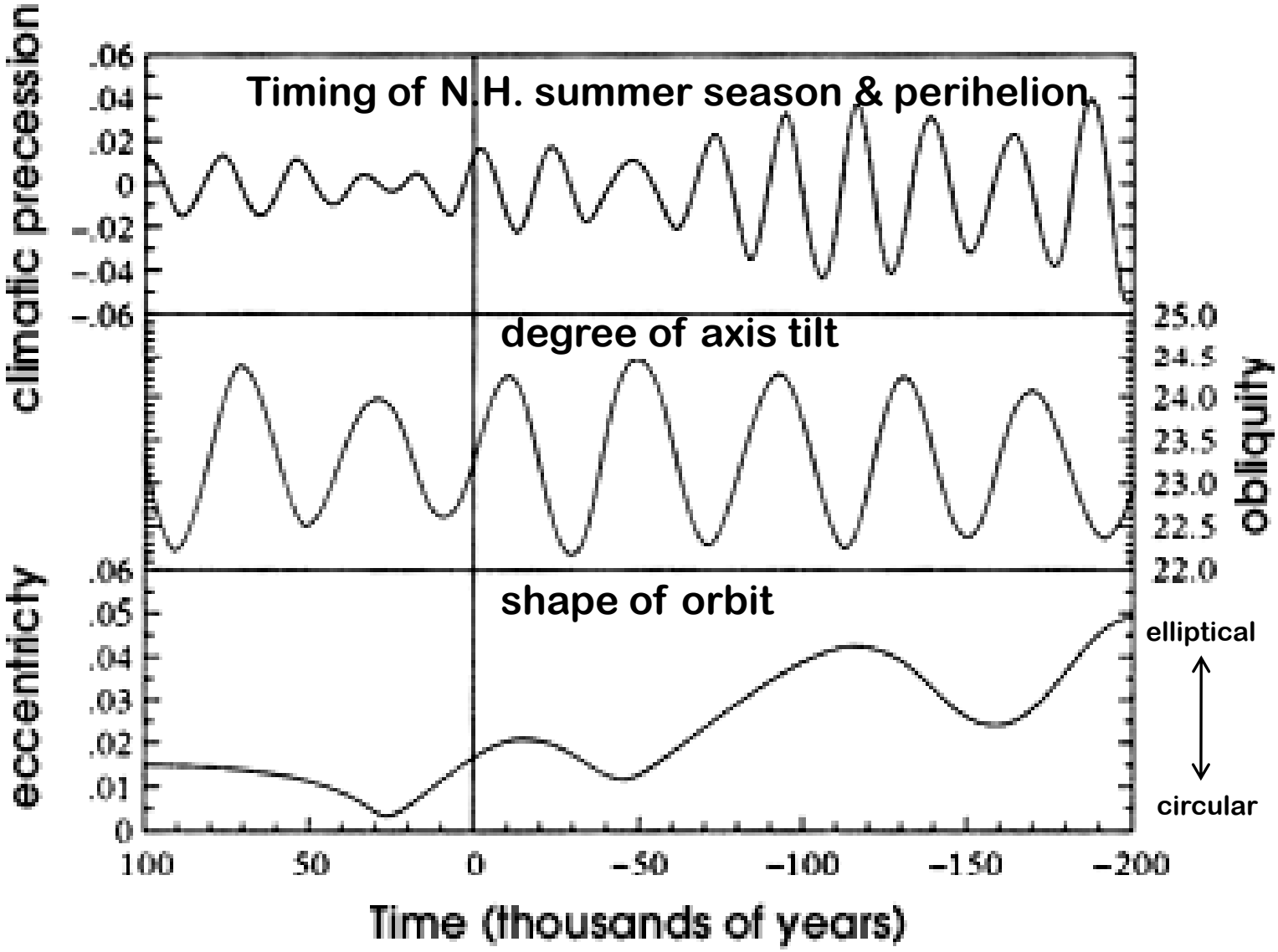
Drives natural climate variability (ice ages, etc.) on LONG time scales (geologic time, past 10,000 to 100,000 years, etc., etc.)



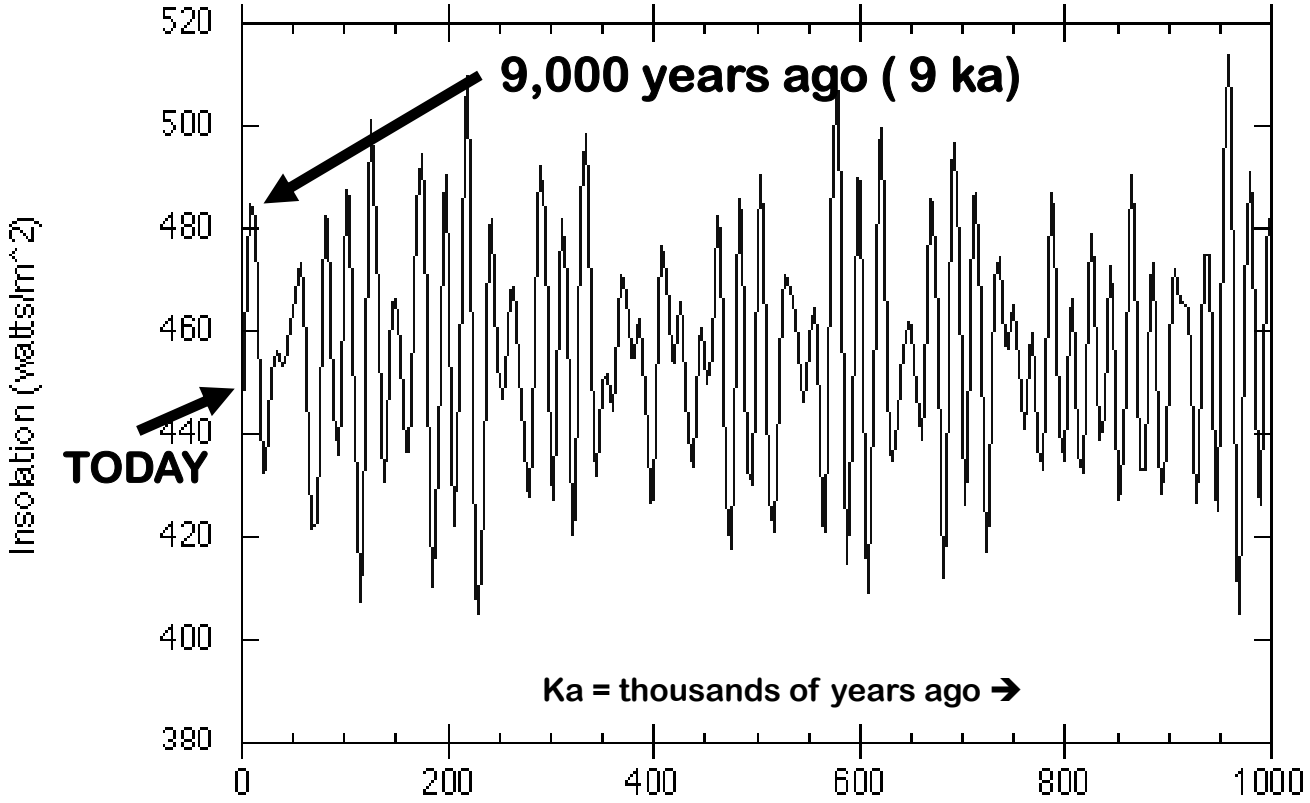




the Future ← TODAY → the Past *(in thousands of years)*



SOLAR INSOLATION calculated for 65 º N latitude from the present to 1 million years ago based on "ASTRONOMICAL CLIMATE FORCING"



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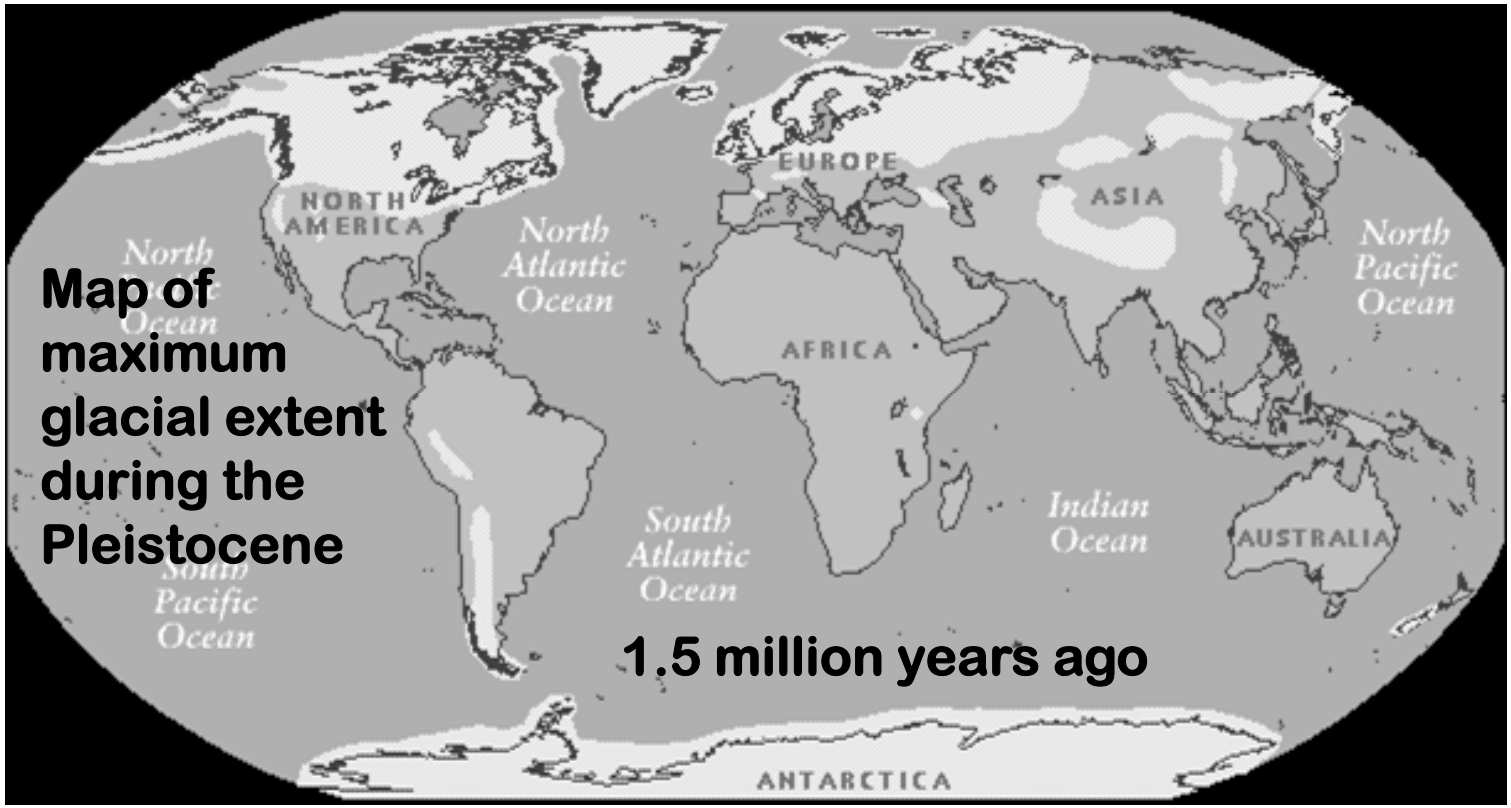
In the Northern Hemisphere, peak summer insolation occurred about 9,000 years ago when the last of the large ice sheets melted. Since then N. H. summers have seen LESS solar radiation.

WHAT OTHER "NATURAL FORCING" MECHANISMS CAN OCCUR?

At the end of the PLEISTOCENE ICE AGE, gradual warming took place between 15,000 – 10, 000 years ago (due to astronomical climate forcing) . . .

. . . until an ABRUPT END of the warming occurred ➔



☺

➔ a ‘sudden’ COLD climate period occurred!

The “Younger Dryas”

-- lasting for about 1100-1300 calendar years

-- during the final deglaciation of the Pleistocene Ice Age

-- interrupted a warm interval

-- was followed by the subsequent warming of the Holocene (“our” period)

Arctic dryas flower is indicator of cold conditions

An unusual “abrupt” cooling?

☺

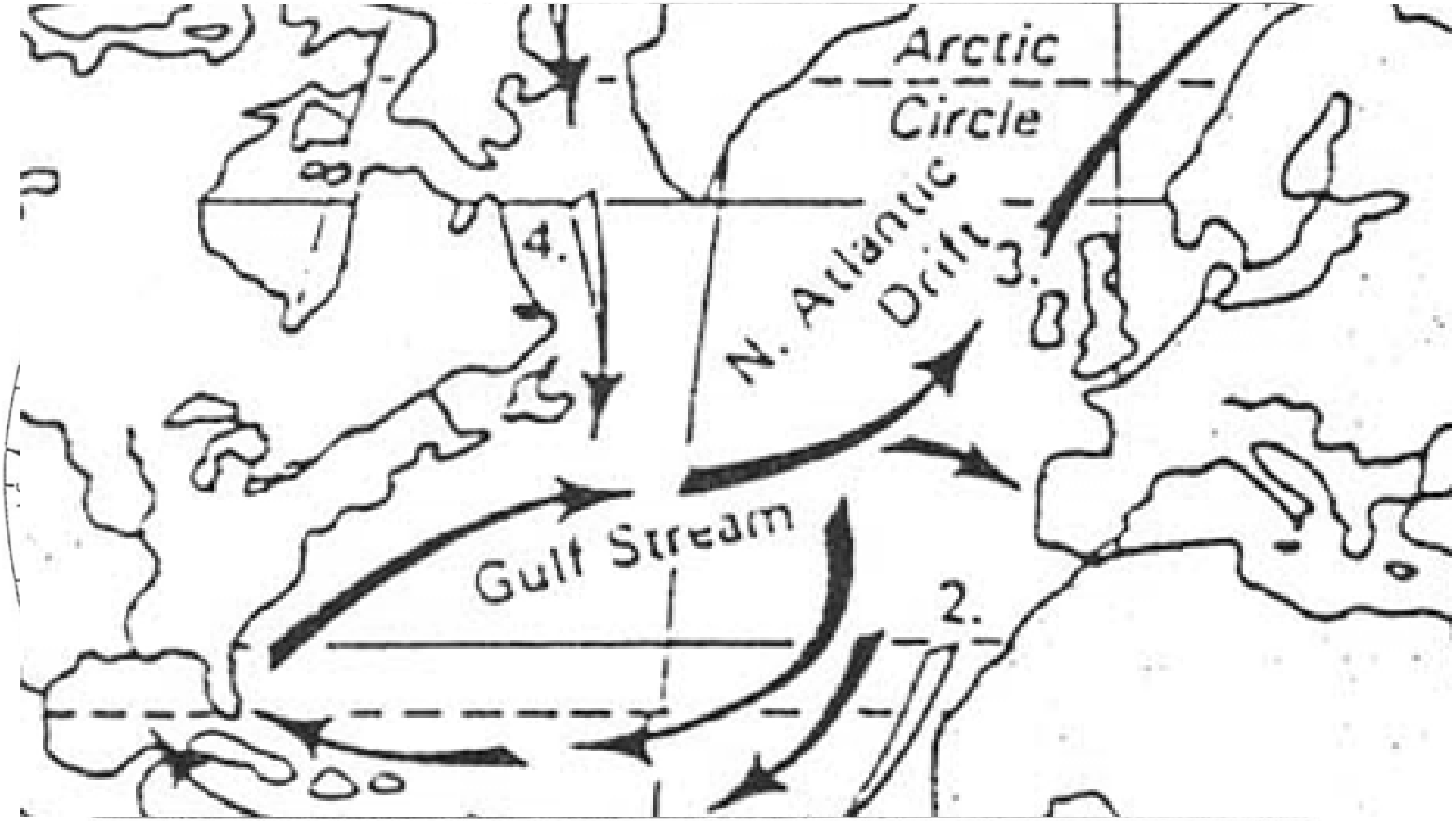
What was the FORCING?

Why this "ABRUPT" shift? & HOW?

Prevailing theory = the Younger Dryas was caused by . . .

- **shutdown of the Gulf Stream & North Atlantic Current**
- **in response to a sudden influx of fresh water**
- **from deglaciation (rapid melting) in North America**

WARM & COLD SURFACE OCEAN CURRENTS:



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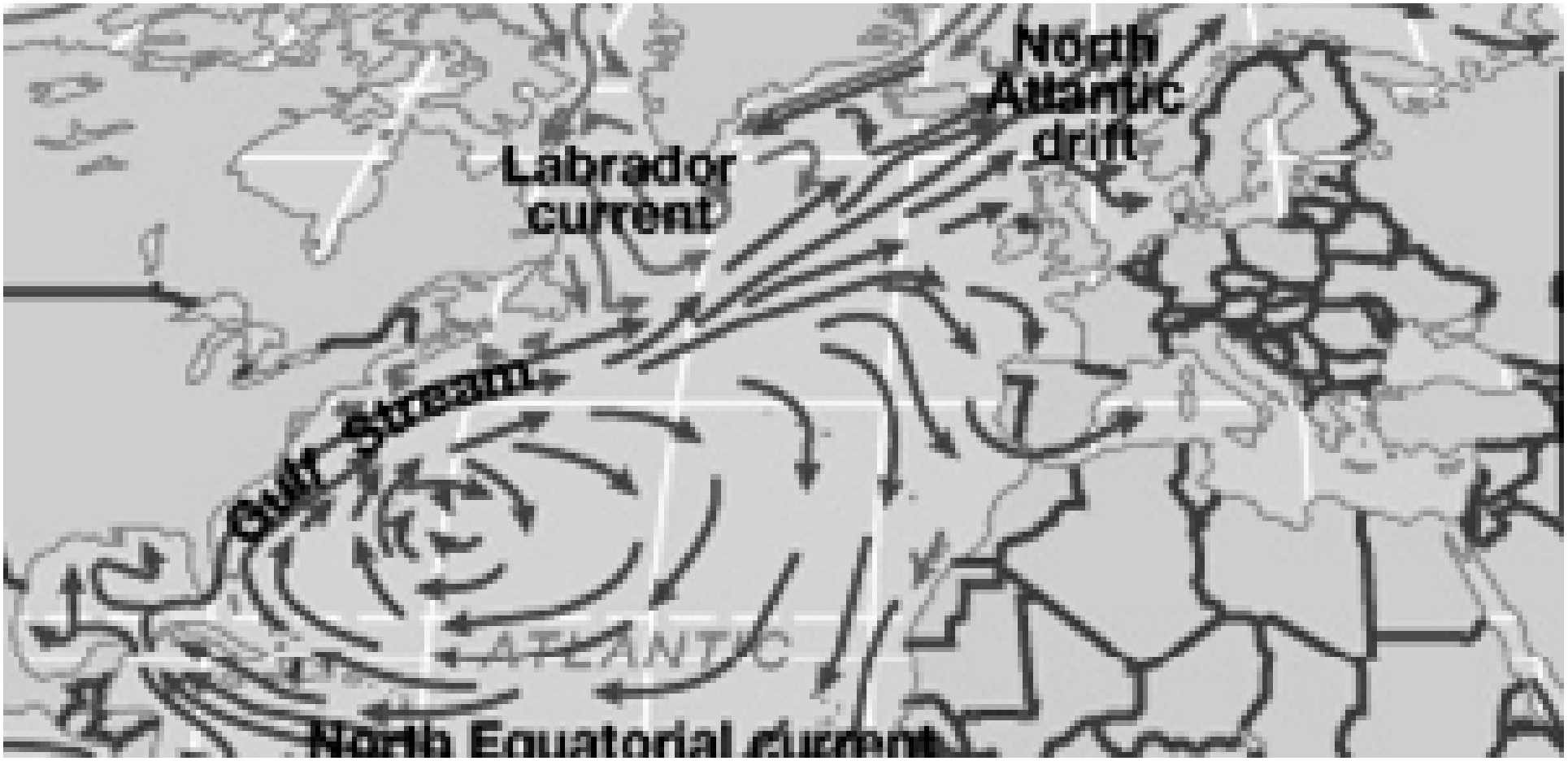
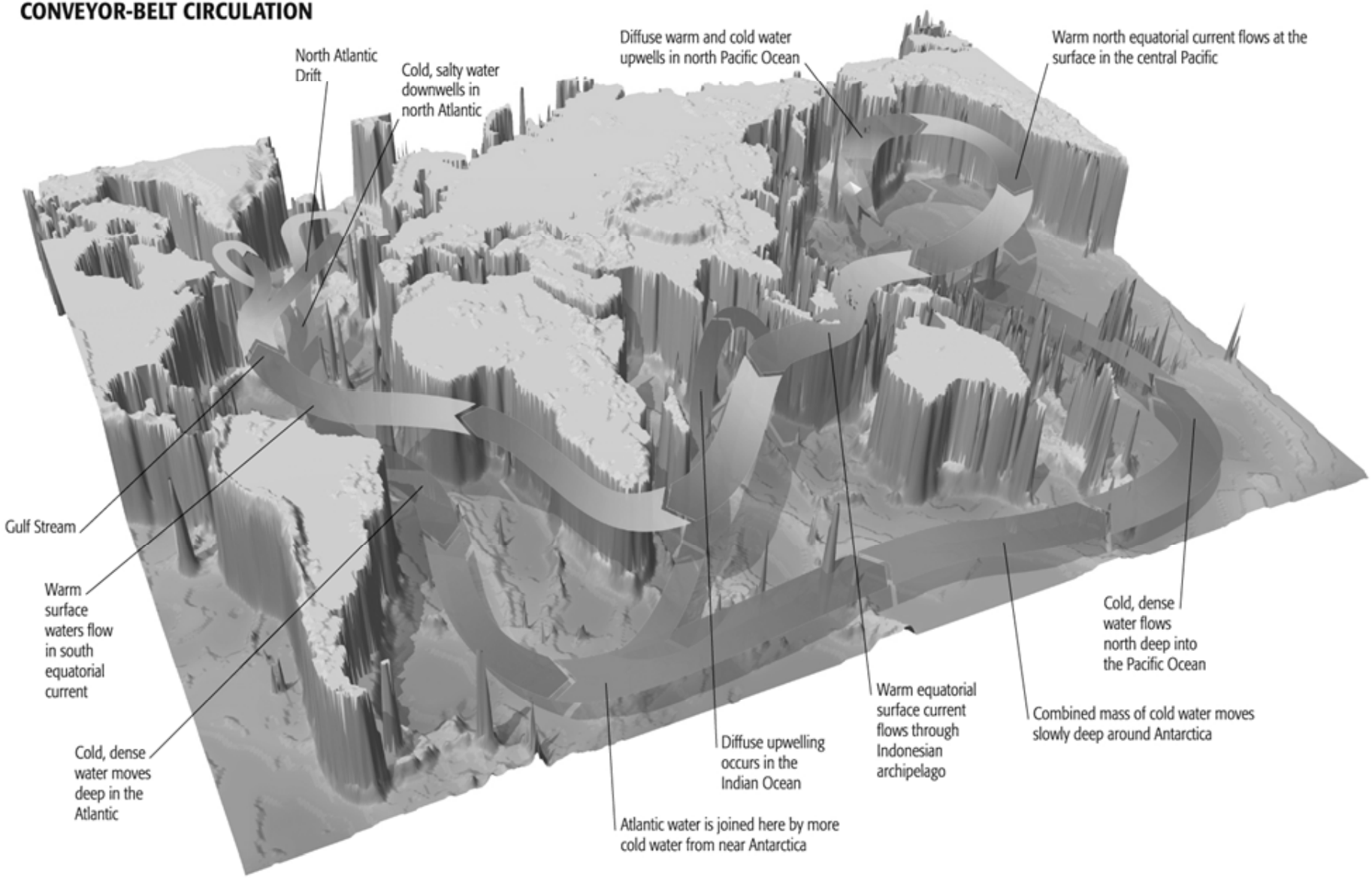
SURFACE OCEAN CURRENTS
-- driven by winds



WARM & COLD sea surface temperatures (SST's)

← ←

CONVEYOR-BELT CIRCULATION



The theory says . . .
the Thermohaline circulation could have been SHUT DOWN if:

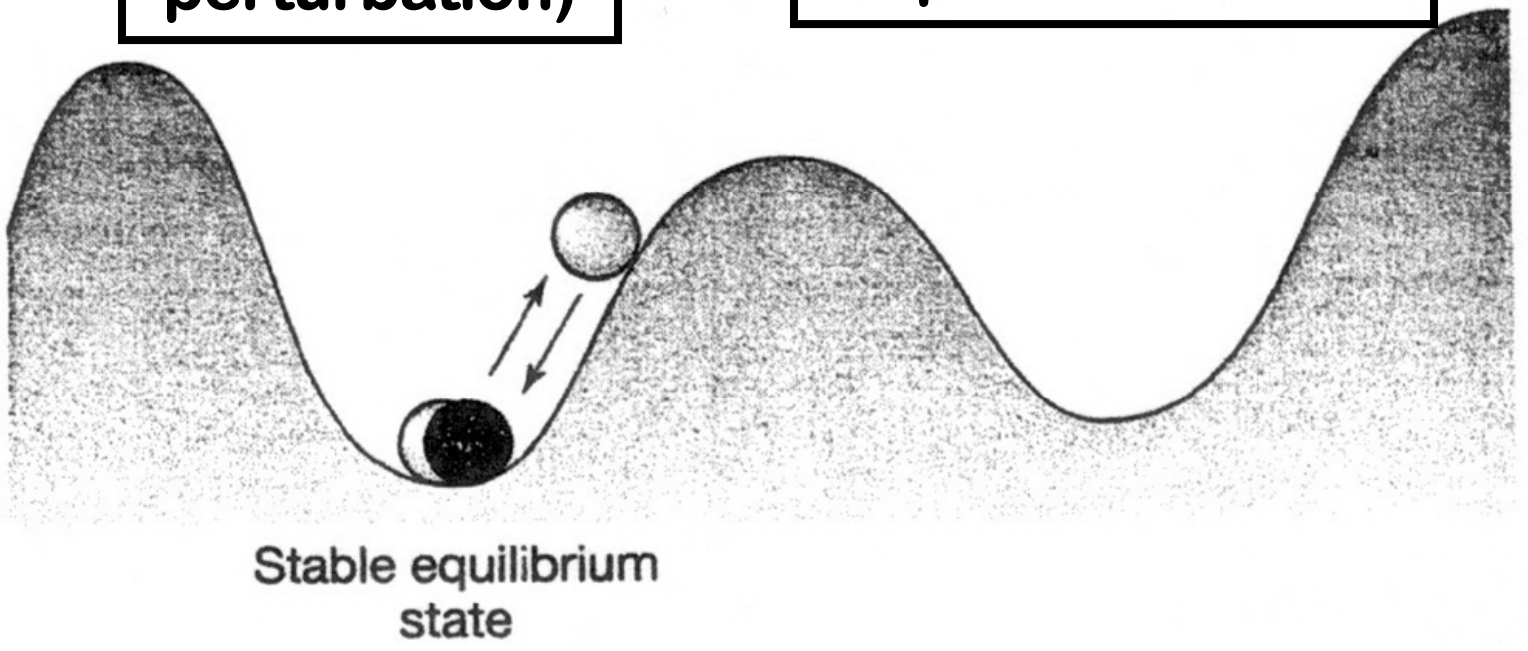
Cold & salty waters of N. Atlantic

Current stopped sinking b/c the salinity was diluted by a sudden influx of FRESH water (from melting glaciers)

REMEMBER EQUILIBRIUM STATES?

STABLE EQUILIBRIUM STATE :

A modest disturbance (short-term perturbation) → **response that tends to return the system to its equilibrium state**



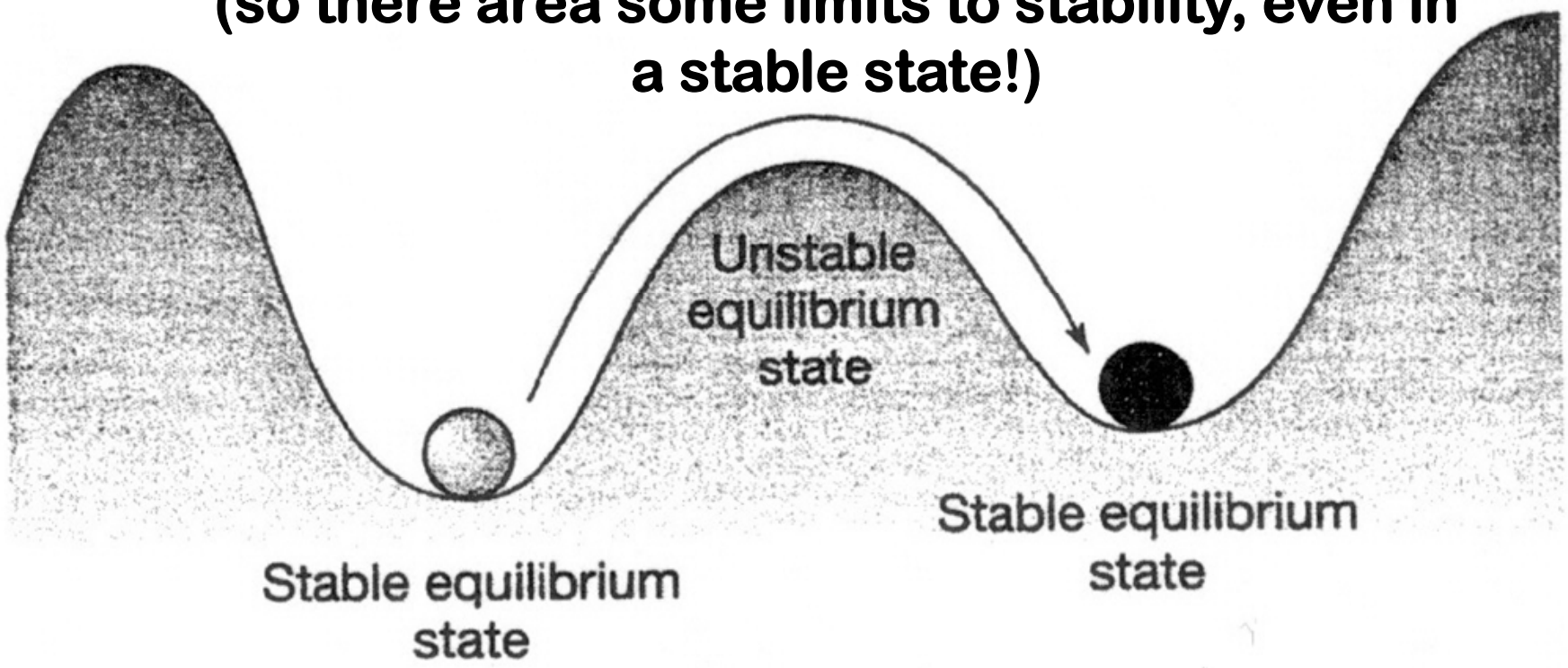
Review

A LARGE or more persistent disturbance, i.e.

a FORCING

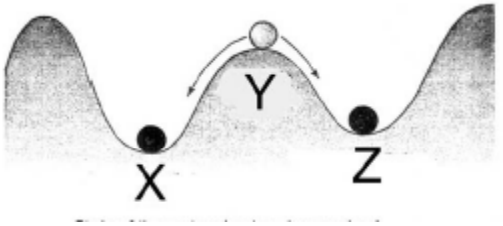
can carry the system to a <u>different</u> equilibrium state

(so there area some limits to stability, even in a stable state!)

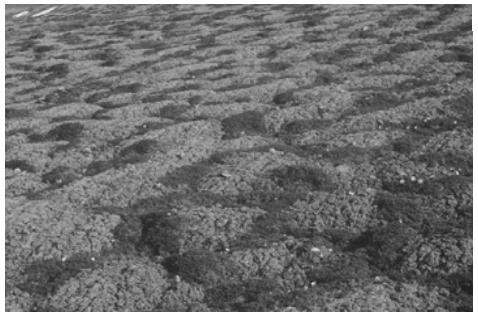


Review

AFTER the "SWITCH" the global climate became "locked into" a new state:



-- Greatest effect
in Europe



-- Forest ➔ tundra

-- in Scandinavia (dryas plant)

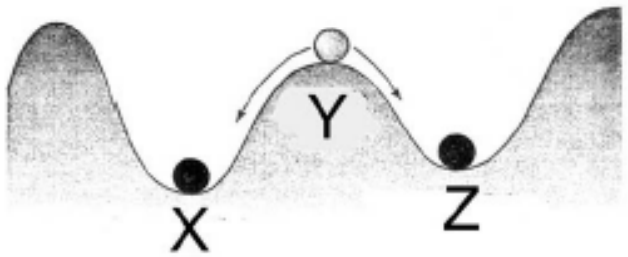
-- Glaciation & increased snow
in mountain ranges
around the world.

then . . . the Younger Dryas ended very "suddenly" ~ 11,570 years BP

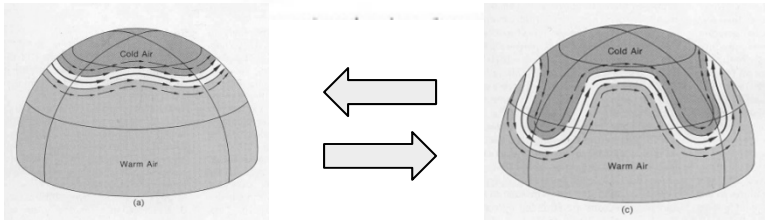
☺

"ABRUPT" CLIMATE SURPRISES can happen!

These rapid changes appear to reflect a type of "flickering" or "switching" between preferred states of the Atmosphere - Ocean System which provides a different view of how the climate changes , e.g.



Preferred mode #1



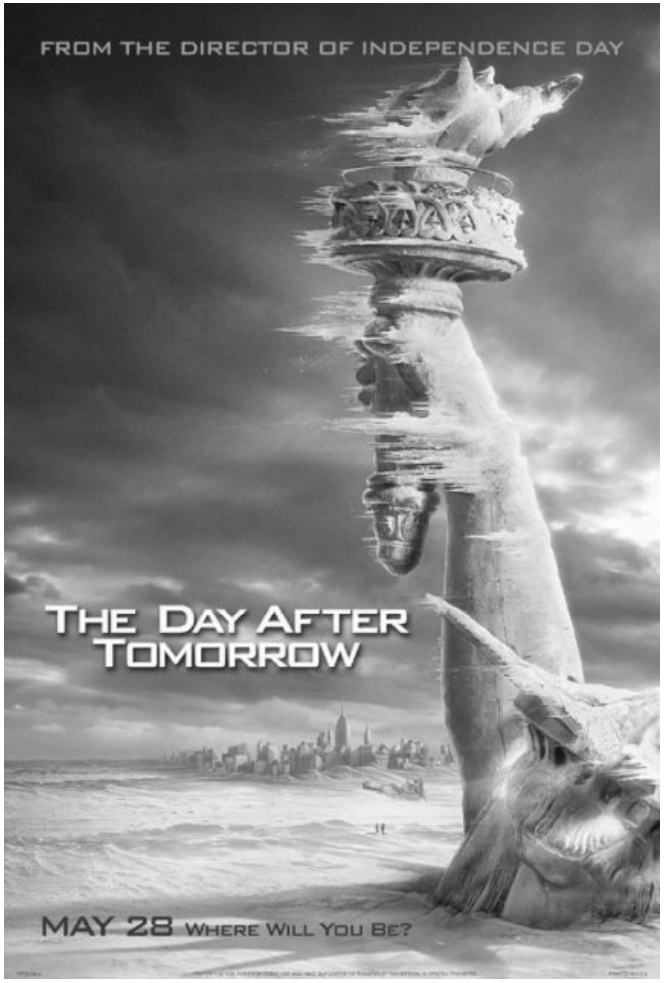
Preferred mode #2

<u>Thus far</u> our Holocene climates have been relatively stable and warm by comparison!

BUT could such an "ABRUPT" shift happen today?

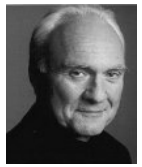
THE DAY AFTER TOMORROW

(pure fiction based on a tiny bit of real science!)



Paleoclimatologist "hero" Jack Hall (Dennis Quaid)

Vice President Becker



Professor Rapson

President Blake

NOAA Scientist

NASA Scientist

Remember – in today's class we are focusing on:

NATURAL CLIMATIC FORCING

Earth-Sun orbital relationships, internal atmosphere-ocean variability solar variability, volcanic eruptions

not

ANTHROPOGENIC FORCING

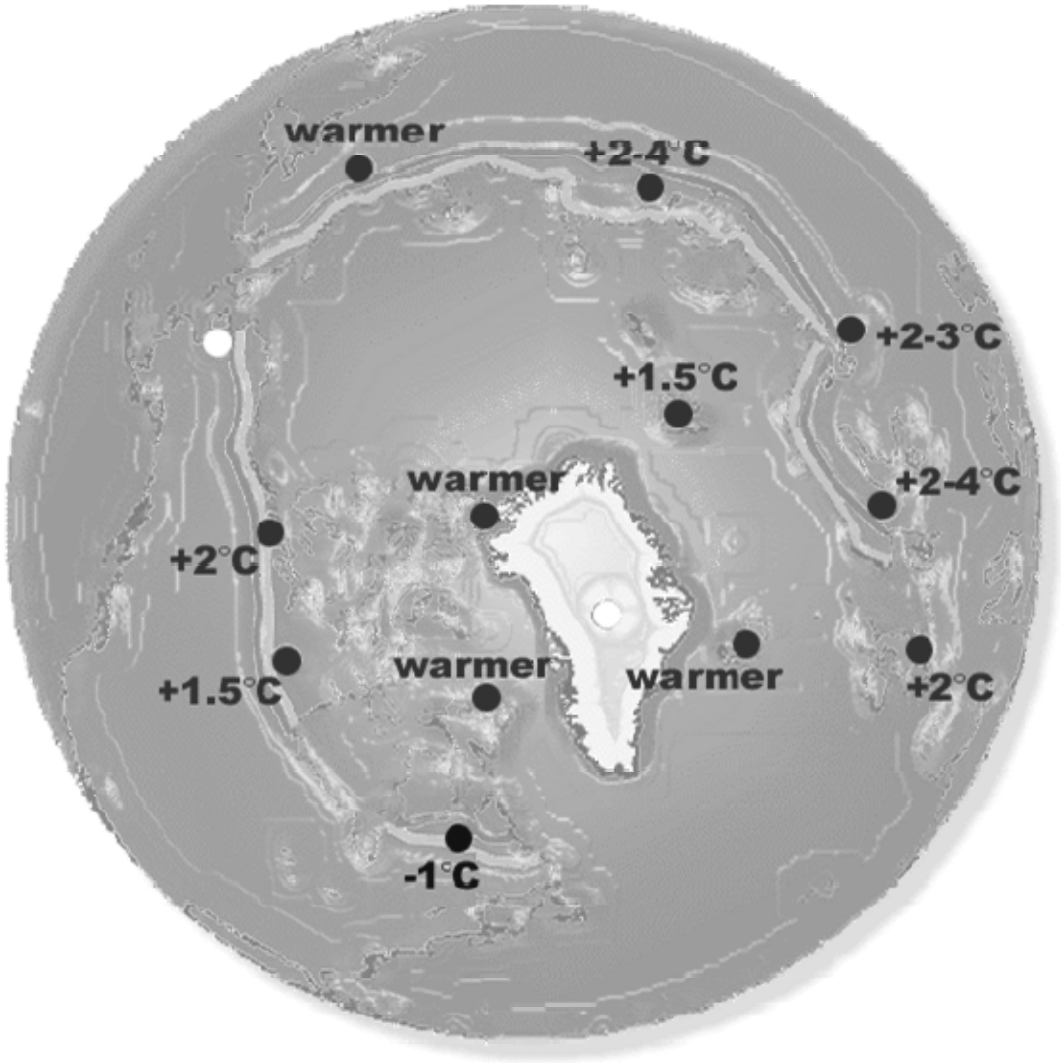
Human-Enhanced GH Effect

Mid-Holocene warm period
(~ 6,000 years ago)

Generally warmer than today, but only in summer and only in the northern hemisphere.

Cause =

“astronomical climate forcing”



SHORT-TERM CLIMATE VARIABILITY

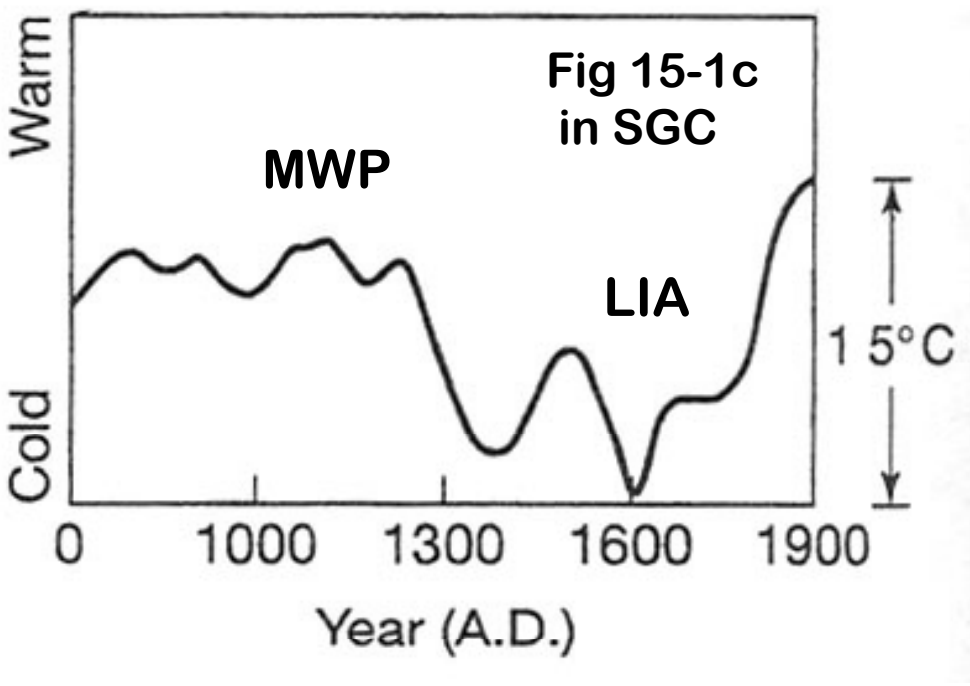
(century, decade, inter-annual time scales of the last 10,000 years – the HOLOCENE.)

Medieval Warm Period (MWP)

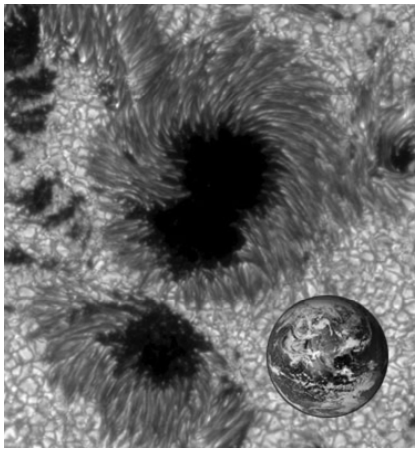
9^{th}-14^{th} centuries (800-1300)

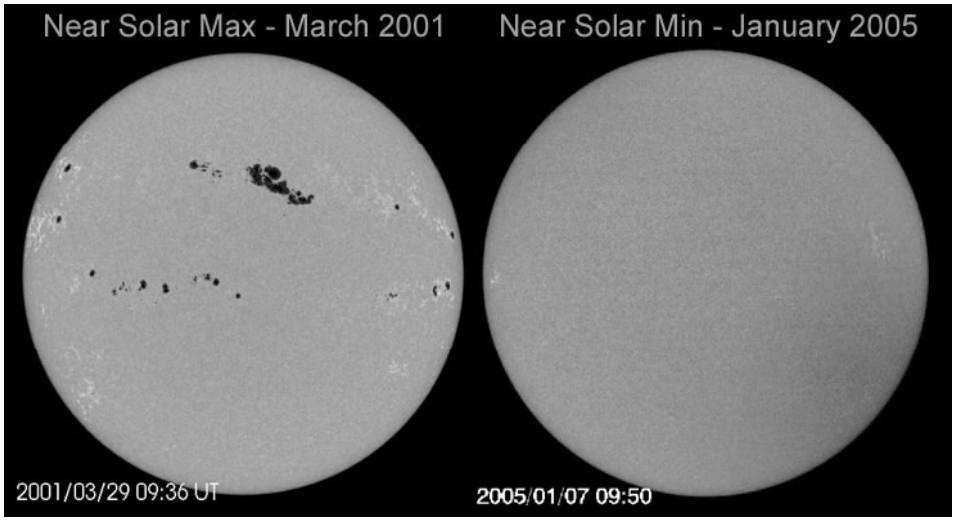
Little Ice Age (LIA)

15^{th} – 19^{th} centuries (1400-1800) esp. 1600 -1800



ANOTHER POSSIBLE NATURAL FORCING: SOLAR VARIABILITY



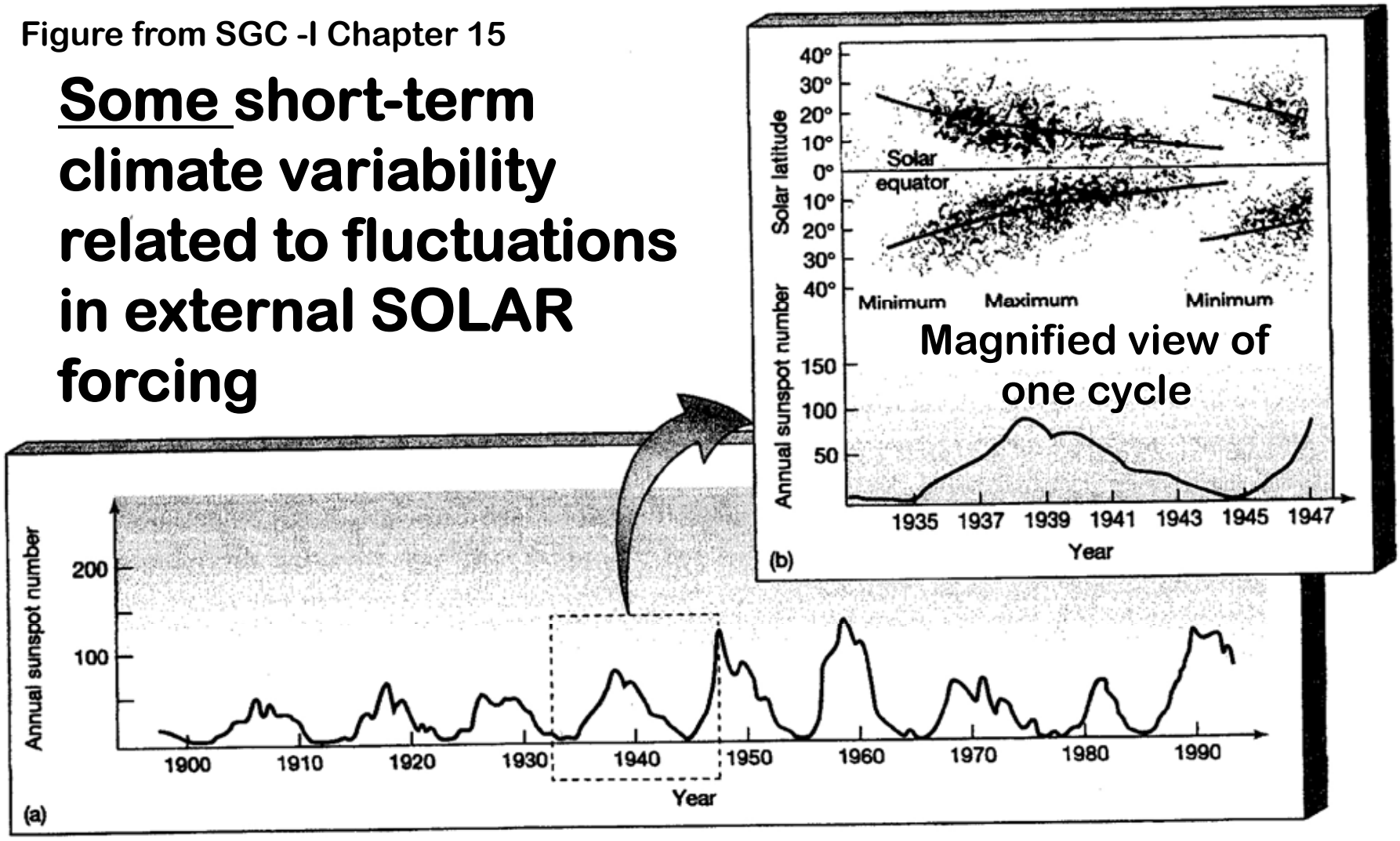


Sunspot maxima = MORE solar brightness (warmer temps)

Sunspot minima = LESS solar brightness (cooler temps)

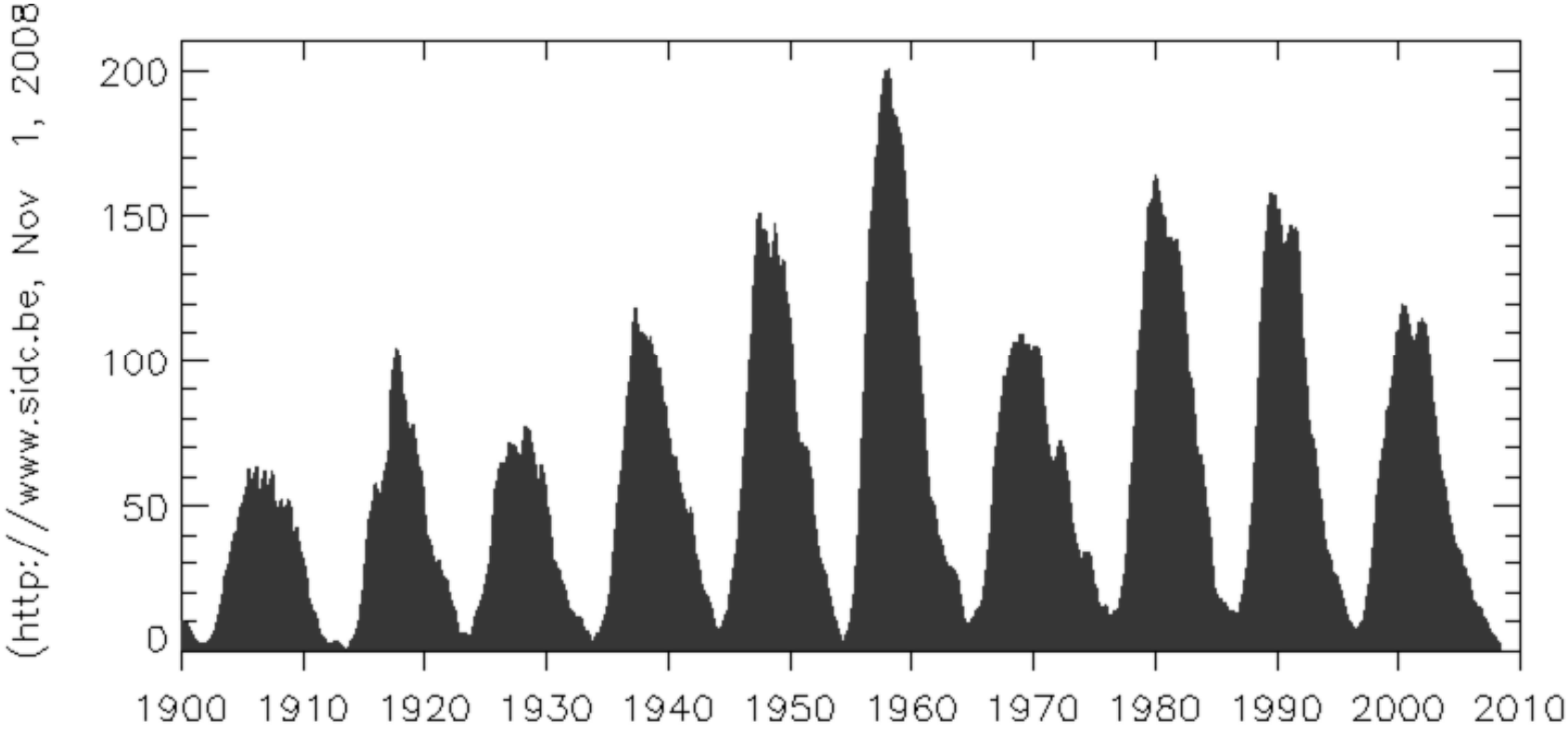
Figure from SGC -I Chapter 15

Some short-term climate variability related to fluctuations in external SOLAR forcing



sunspot minima = LESS solar brightness

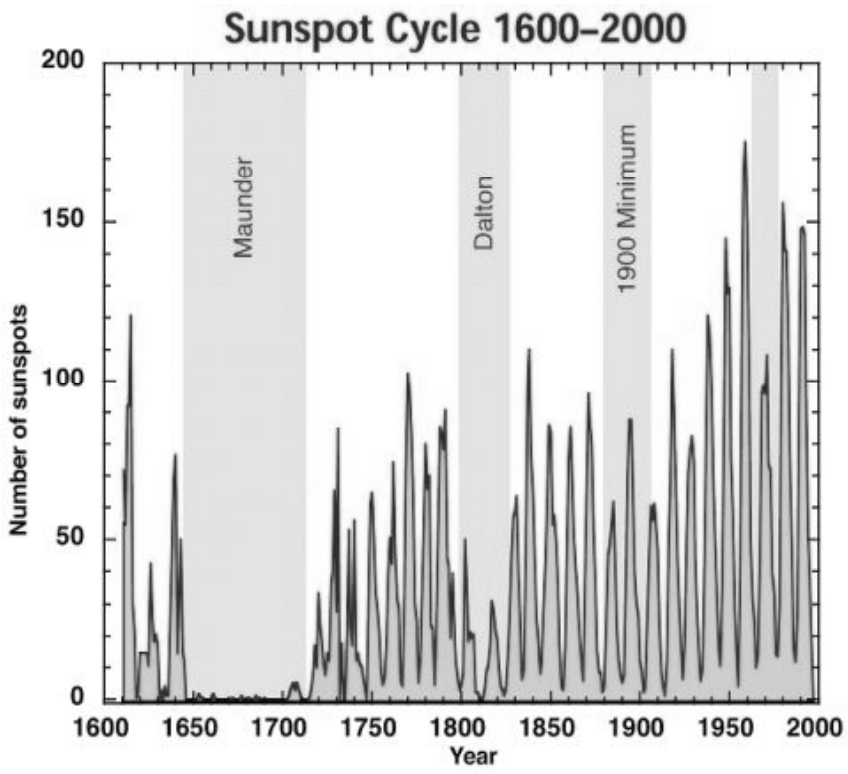
Sunspot cycles (quasiperiodic)



Sunspot maxima = MORE solar brightness (warmer temps)

Sunspot minima = LESS solar brightness (cooler temps)

Maunder Minimum (cooler)
(1645 -1715)
linked to "Little Ice Age"
(1600-1800)

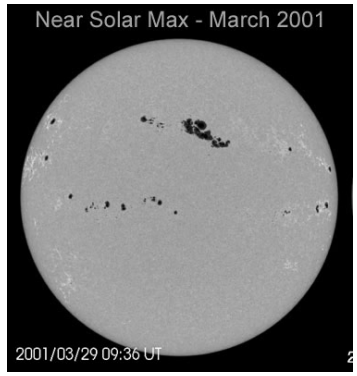


But uncertainties remain!
What MECHANISM transfers brightness drop to lower temperatures?

Dalton Minimum (1795 – 1825)
-- also cooler
-- lots of large volcanic eruptions then too

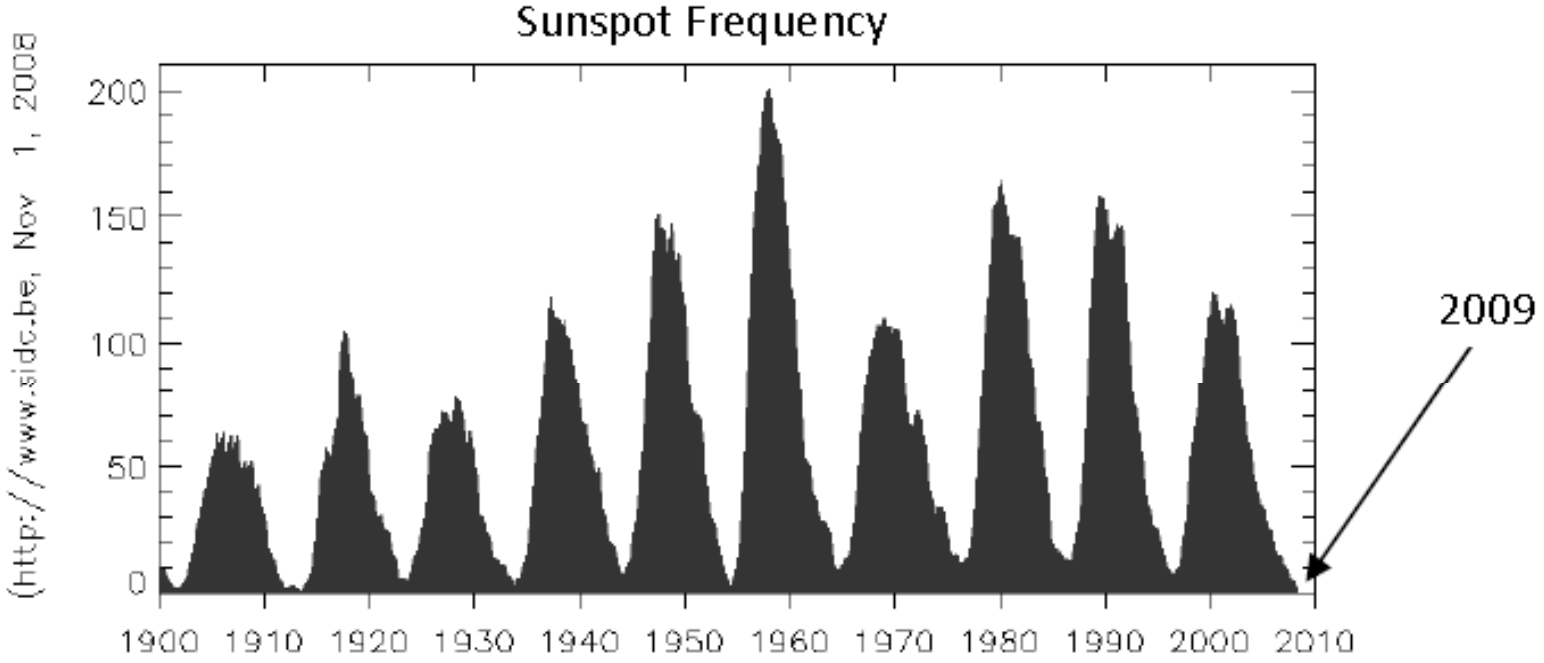
Since the Dalton Minimum, the Sun has gradually brightened – we just came out of a "Modern Maximum" (max in 2001)

BUT . . .
The increase in solar brightness during the recent "Modern Maximum" accounted for only:



- **about ½ of the temperature increase since 1860, and**
- **less than 1/3 since 1970**

The rest is attributed to <u>greenhouse-effect warming</u> by most experts in solar forcing.



We are now (2009) in a SOLAR MINIMUM – but something is unusual about the current sunspot cycle!

- minimum has been unusually long
- number of "spotless" days has not been equaled since 1933
- the vigor of sunspots (in terms of magnetic strength and area) has greatly diminished
- another Maunder-like period?
- Return of activity within the year? Time will tell . . .

NEXT:

VOLCANIC FORCING!!!!

(We'll save that for after TEST #3)