The Earth’s Oceans/Climate
What We Don’t Know

February 20, 2016

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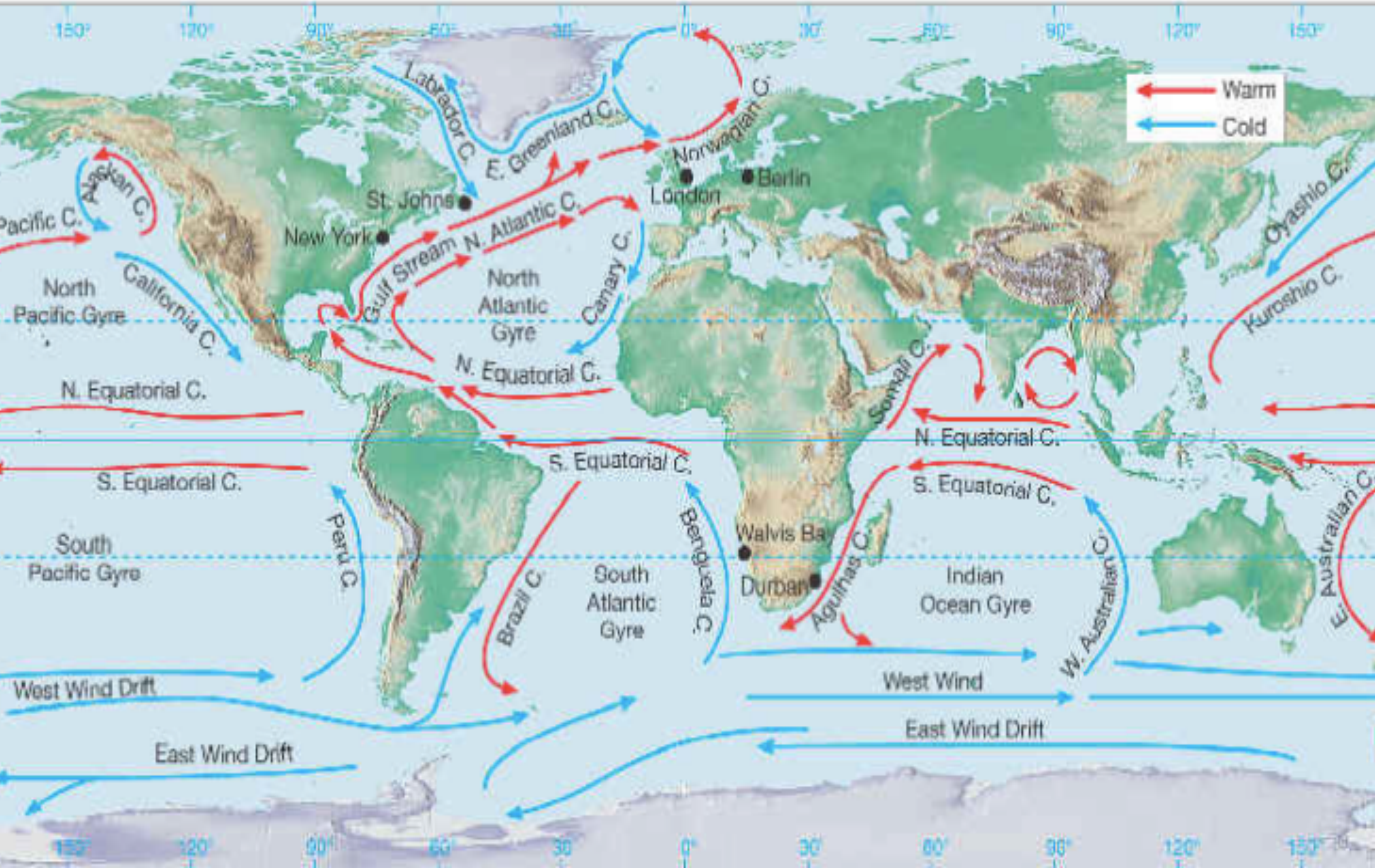
What we Know

- There are generally large uncertainties with regard to our knowledge of the oceans
- Looking only at global effects in the oceans and the climate may blur our understanding
- So - think and analyze regionally with a goal of understanding globally
- Consider 60 to 100 year cycles (and 1000 year Bond cycles) while analyzing the data
- A number of patterns are starting to emerge

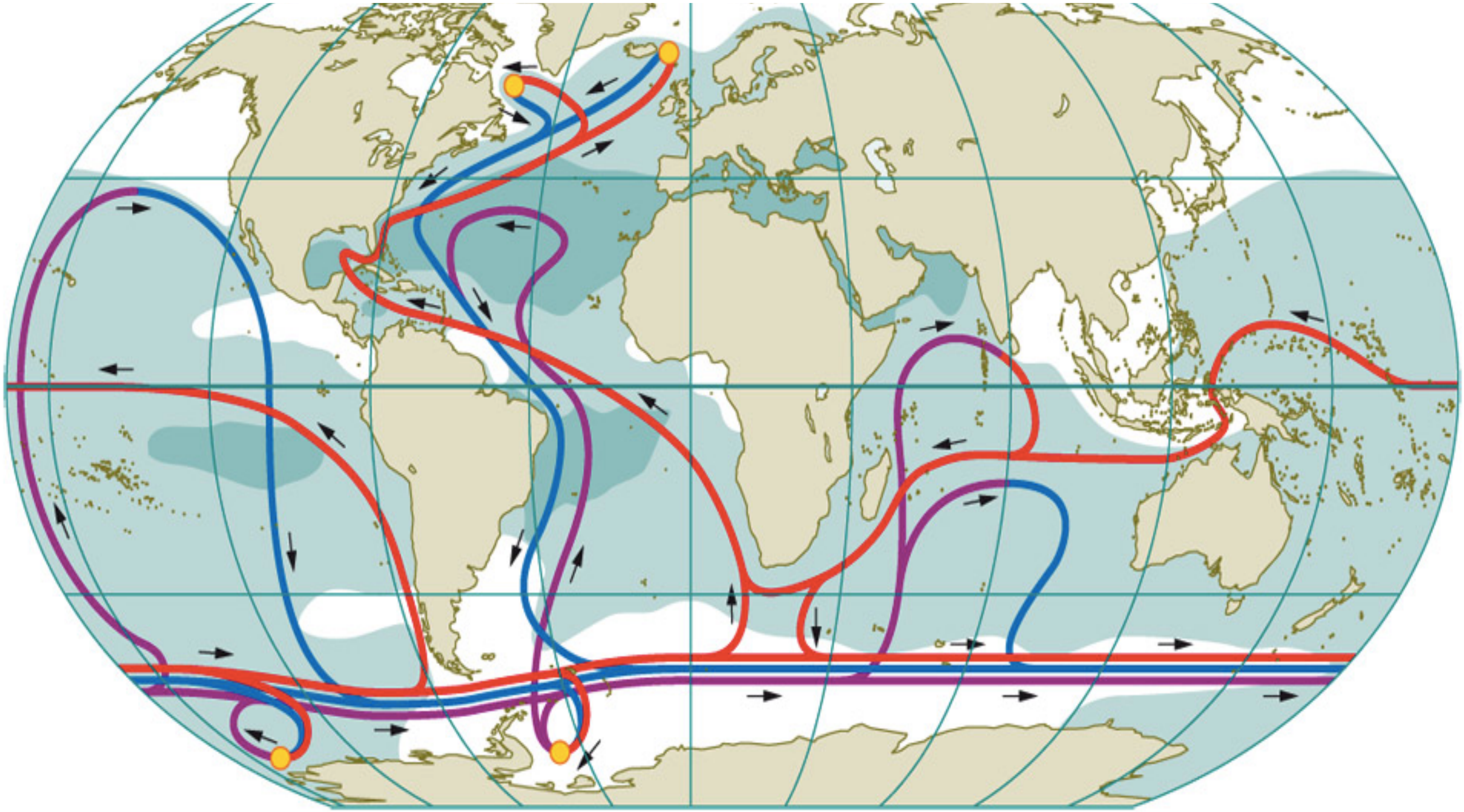
Coriolis/Wind Driven Surface Currents



Overview of Ocean Patterns

- Drivers of circulation – Thermohaline Conveyor Belt, surface, upper, and jetstream winds, surface, mid and deep ocean currents, convection & Tides
- Eddies, down and up welling
- Coriolis forces, geostrophic effects
- Temperature difference, thermal energy, ice formation and saline effects

Global Surface and Deep Currents



1.8 > The worldwide ocean currents of the thermohaline circulation system are extremely complex. The flow of cold, saline surface water (blue) downward and toward the equator can only be clearly recognized in the Atlantic. Warm surface water (red) flows in the opposite direction, toward the pole. In other areas the current relationships are not as clear-cut as they are in the Gulf Stream system (between North America and Europe). The Circumpolar Current flows around Antarctica, and does so throughout the total depth of the water

Other Factors

- Geophysical factors - basin size and continent size and location
- Subsurface and above surface ocean activities not previously stated – solar TSI, plate tectonics, mid ocean volcanoes and rift/plate boundary volcanism
- Planetary tilt, polar wobble (Chandler), solar system effects – gravity
- Space weather – a more detailed set of effects beyond simply the sun’s energy output

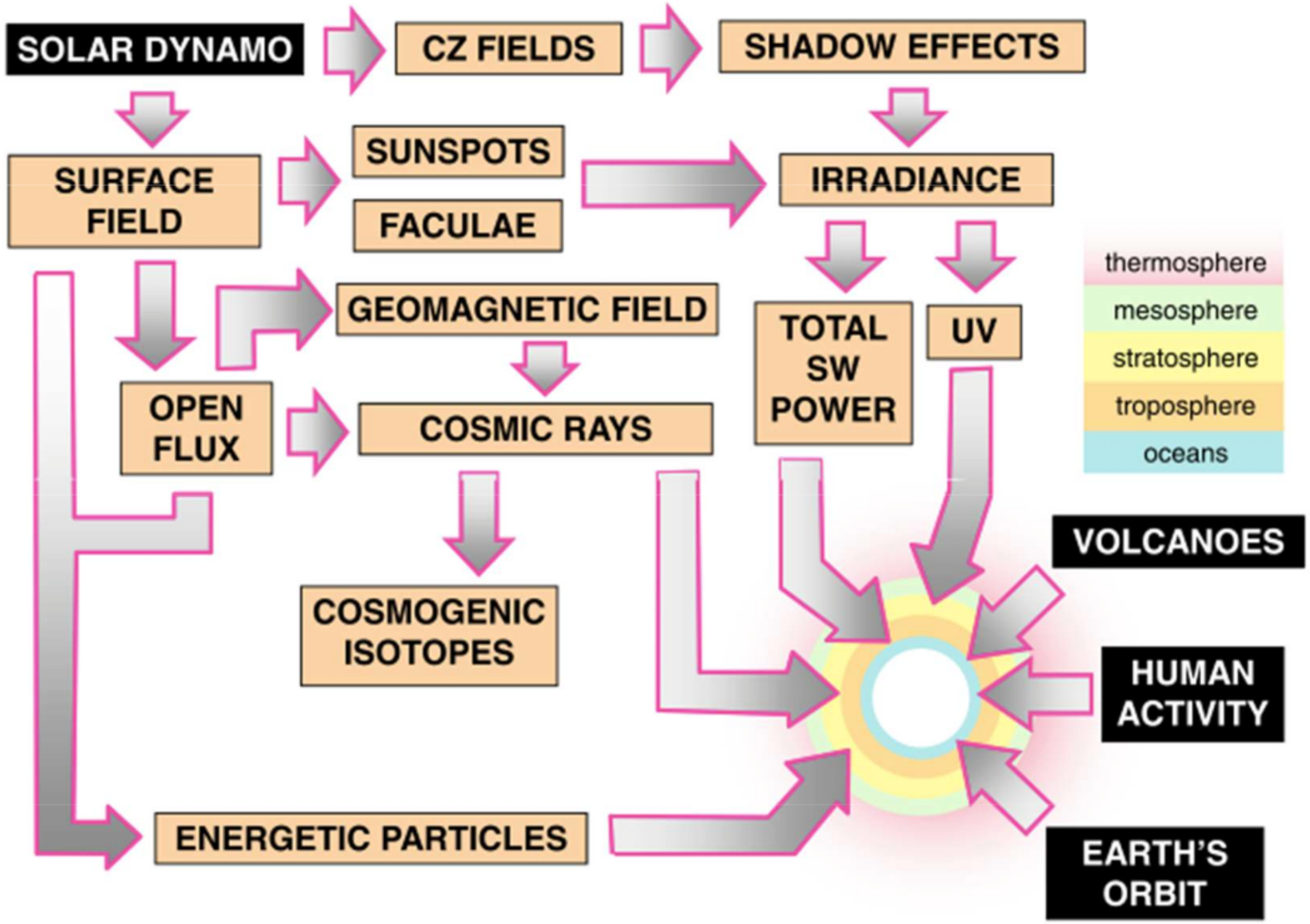


Figure 20. Schematic overview showing various climate forcings of the Earth's atmosphere, with factors that influence the forcing associated with solar variability (irradiance and corpuscular radiation) shown in more detail on the left-hand side, as discussed in section 2.

SOLAR INFLUENCES ON CLIMATE

L. J. Gray,1,2 J. Beer,3 M. Geller,4 J. D. Haigh,5 M. Lockwood,6,7 K. Matthes,8,9 U. Cubasch,8 D. Fleitmann,10,11 G. Harrison,12 L. Hood,13 J. Luterbacher,14 G. A. Meehl,15 D. Shindell,16 B. van Geel,17 and W. White18
Received 5 January 2009; revised 23 April 2010; accepted 24 May 2010; published 30 October

And to a lesser degree

- Chemistry and Biology of the oceans affect CO_2 and Ocean Acidification (OA)
- If you worry about CO_2 increasing in the atmosphere this is a whole other discussion
- So let’s not worry about it today, shall we?

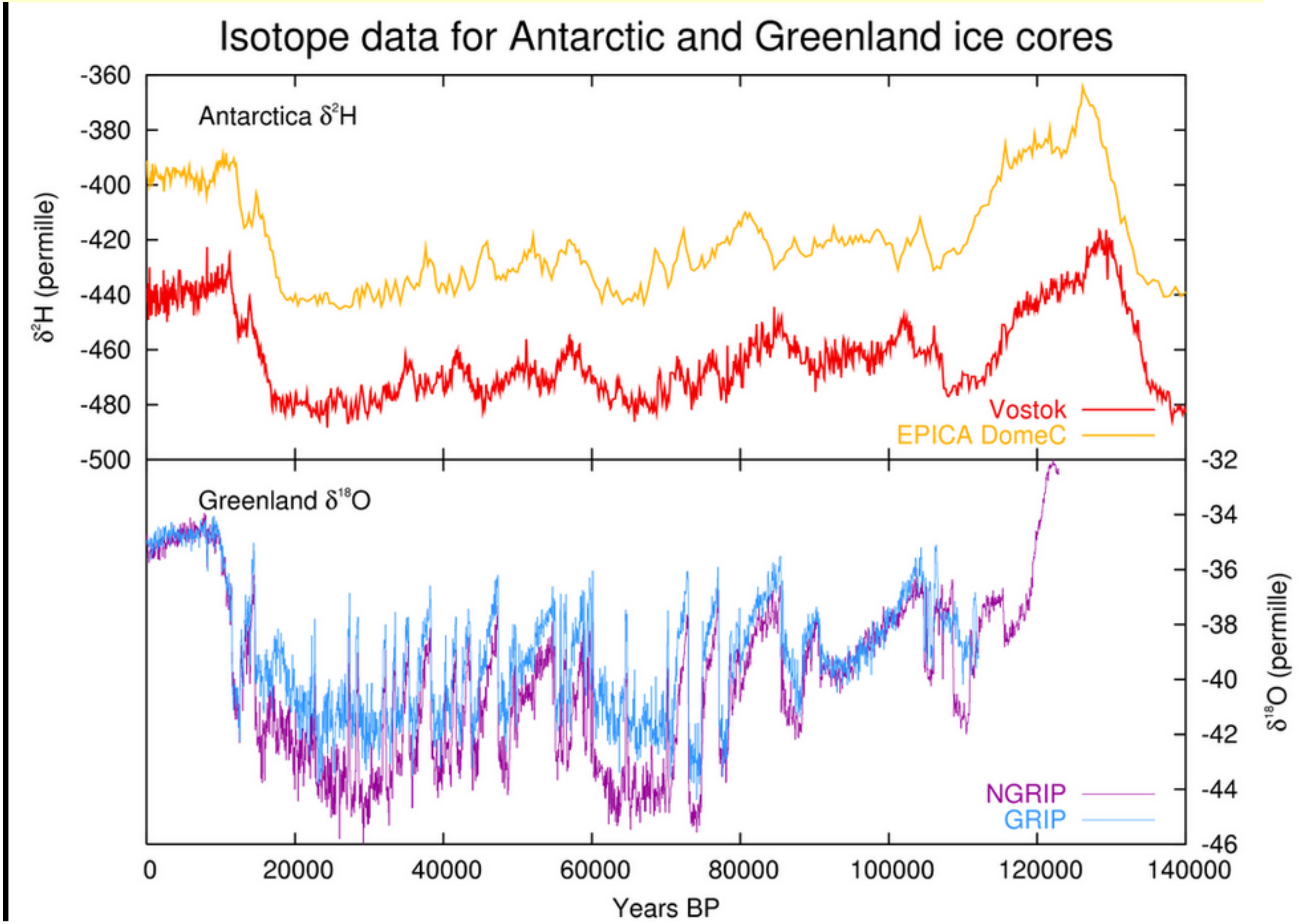
https://en.wikipedia.org/wiki/Dansgaard%E2%80%93Oeschger_event

Dansgaard–Oeschger event

From Wikipedia, the free encyclopedia

Dansgaard–Oeschger events (often abbreviated **D–O events**) are rapid climate fluctuations that occurred 25 times during the last glacial period. Some scientists (see below) claim that the events occur quasi-periodically with a recurrence time being a multiple of 1,470 years, but this is debated. The comparable climate cyclicity during the Holocene is referred to as Bond events.

Dansgaard Oeschger Events in Northern Hemisphere, bottom, not so strong in SH.



Temperature proxy from four ice cores for the last 140,000 years, clearly indicating the greater magnitude of the D-O effect in the northern hemisphere

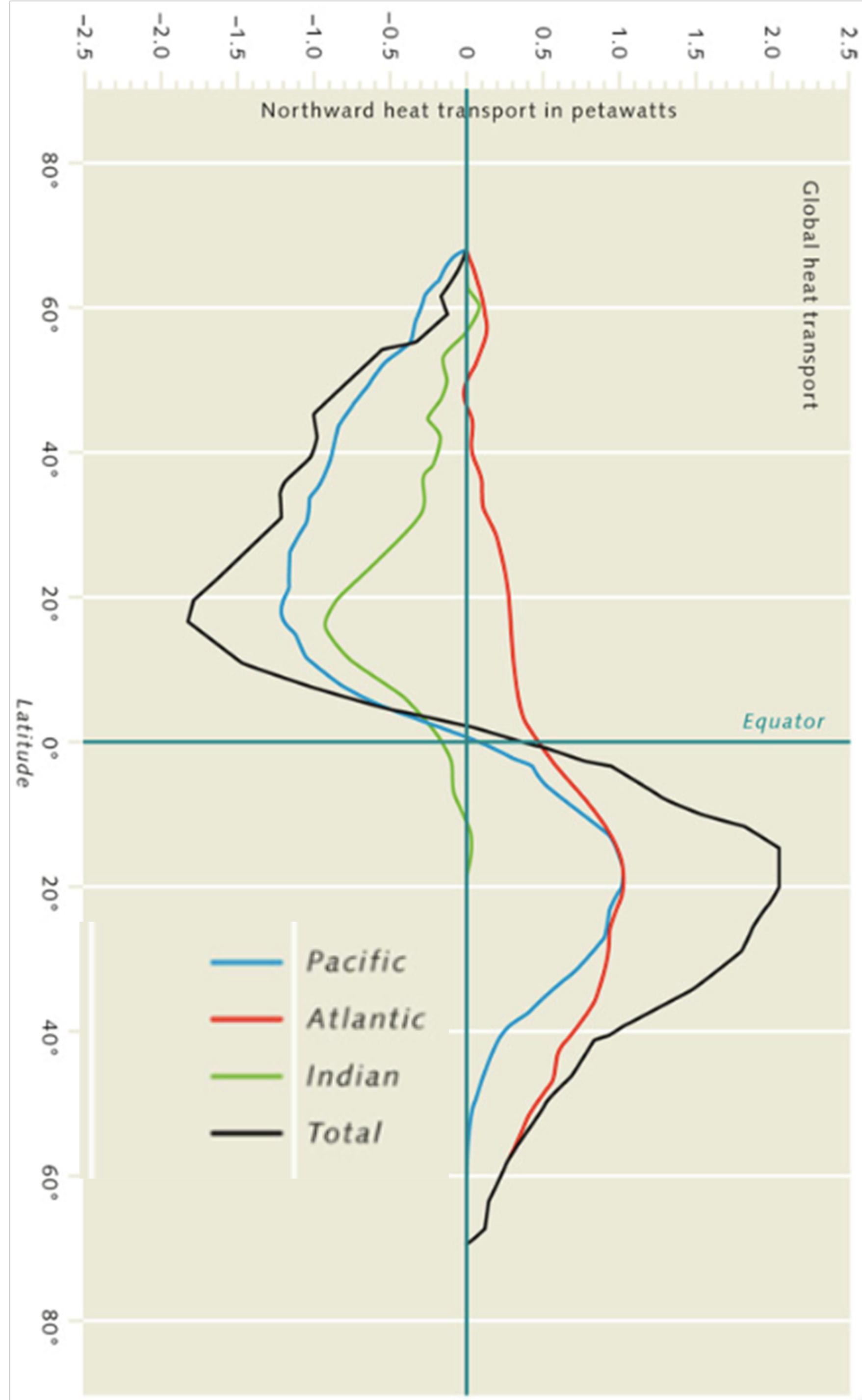
Wallace Broecker

Ocean Circulation-Sea Ice-Storminess-Dustiness-Albedo

- Dansgaard-Oeschger and Younger Dryas cold events
- Lofted dust and sea salt + albedo
- Affects latitudinal thermal gradient <=> storms
- Bi-polar seesaw and THC strength <=> sea ice position changes

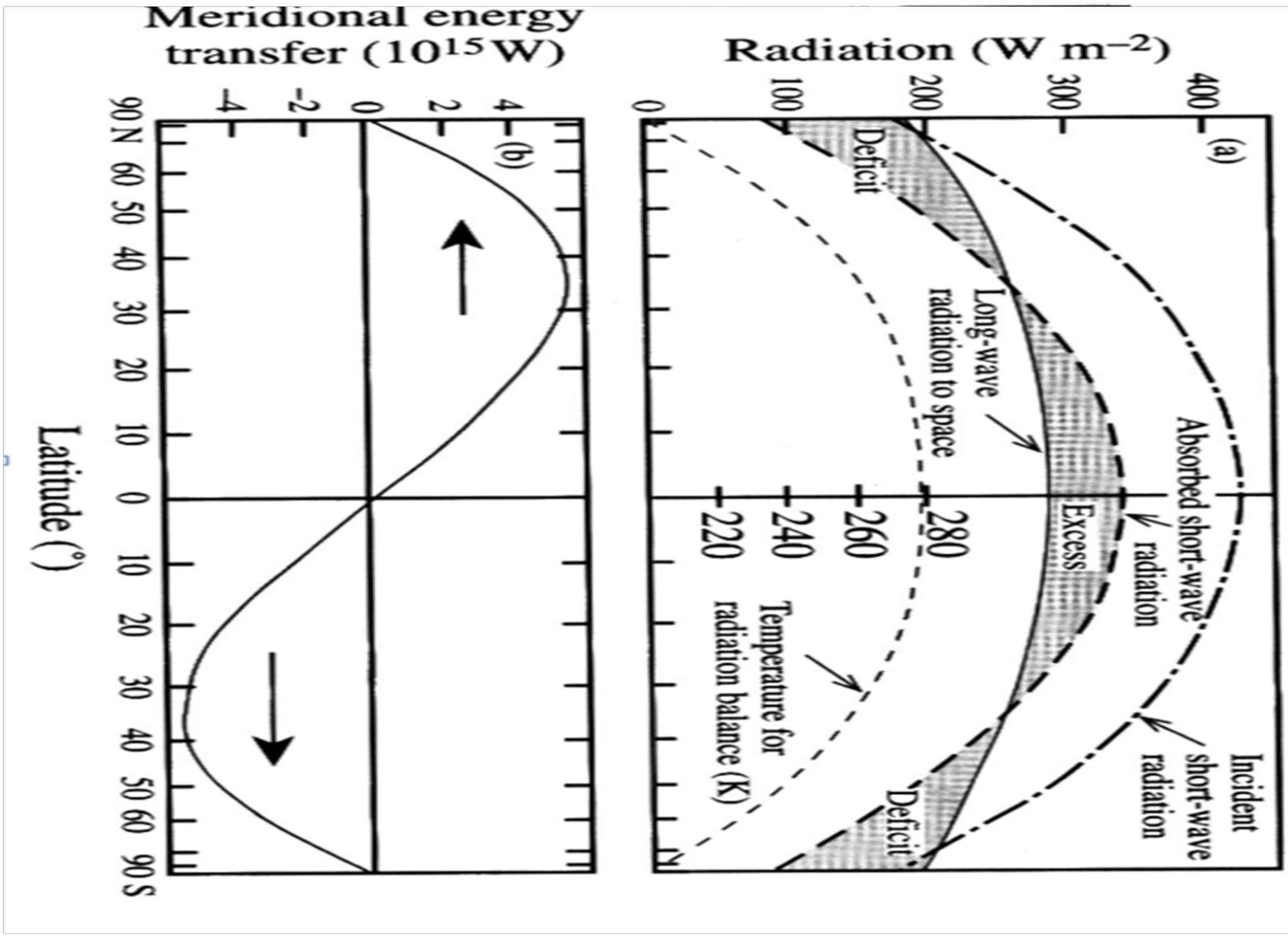
Ocean Wide Thermal Energy Transport

1 petawatt = 10^{15} watts



Variations in the Heat Budget Across the Globe

The calculated short and longwave energy budgets of the Earth-atmosphere system averaged over time as a function of latitude.



Sverdrup

From Wikipedia, the free encyclopedia

For other uses, see Sverdrup (disambiguation).

The **sverdrup**, named in honour of the pioneering oceanographer Harald Sverdrup, is a unit of measure of volume transport. It is used almost exclusively in oceanography, to measure the volumetric rate of transport of ocean currents. Its symbol is **Sv**. Note that the sverdrup is *not* an SI unit, and that its symbol conflicts with the sievert's symbol. It is equivalent to 1 million cubic metres per second (264,000,000 USgal/s).[1][2] The entire global input of fresh water from rivers to the ocean is equal to about 1.2 sverdrup.[3]

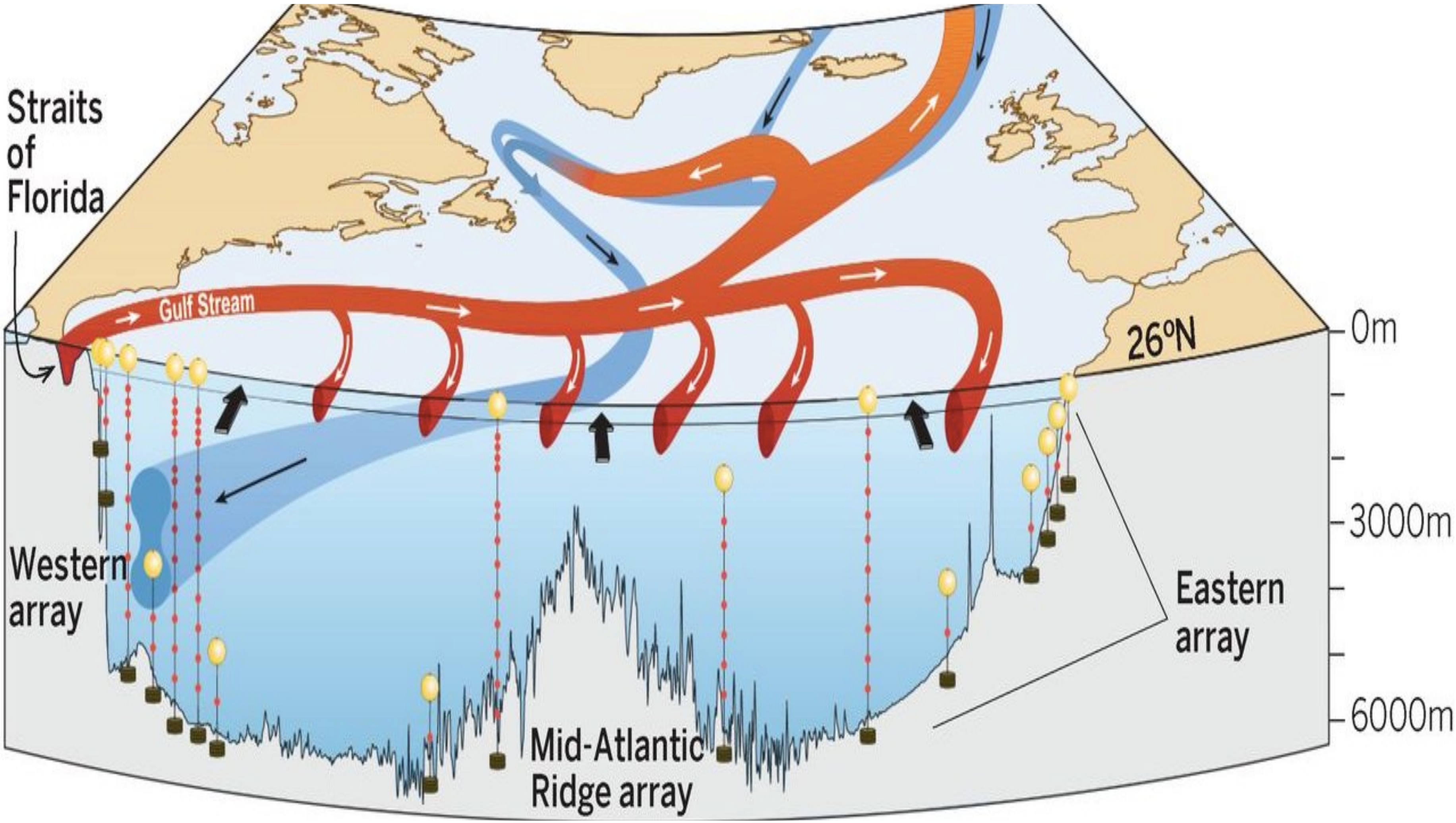
The water transport in the Gulf Stream gradually increases from 30 Sv in the Florida Current to a maximum of 150 Sv south of Newfoundland at 55°W longitude.[4] The heat carried within this volume equals roughly that transported through the atmosphere to make the relatively milder climate of north-western Europe. The Antarctic Circumpolar Current, at approximately 125 Sverdrups, is the largest ocean current.[5]

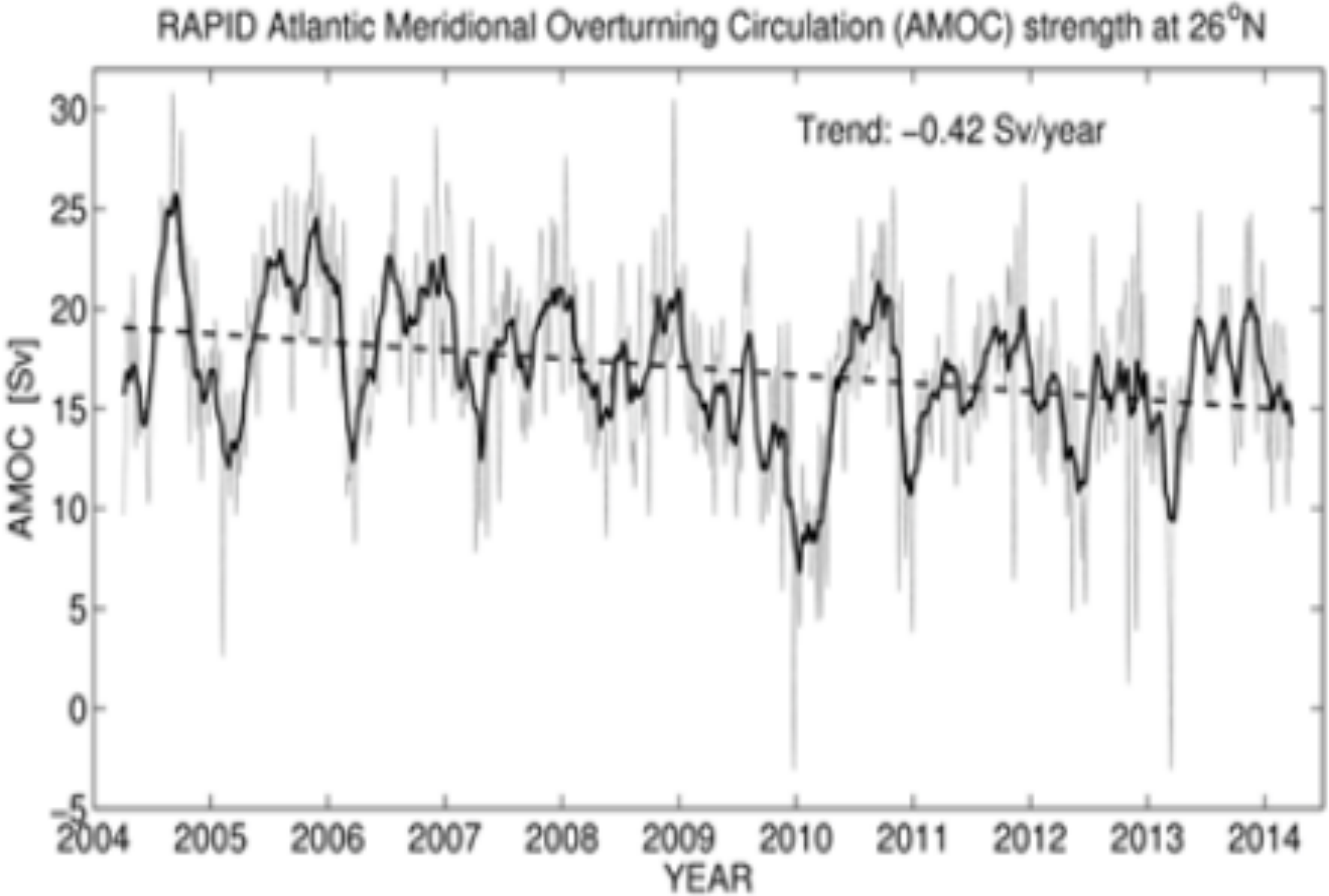
Atlantic Meridional Overturn Circulation

- AMOC is considered by several climate scientists* to be a major driver of climate
- Changes in the salinity of the Atlantic Thermohaline Circulation (ATC) is the controlling factor
- A few alarmists worry that the ATC will completely shut down sometime soon
- Sverdrup (Sv) = 1 million m^3 /sec

* Bill Gray and J Curry are prominent ones

Atlantic Meridional Overturning Circulation

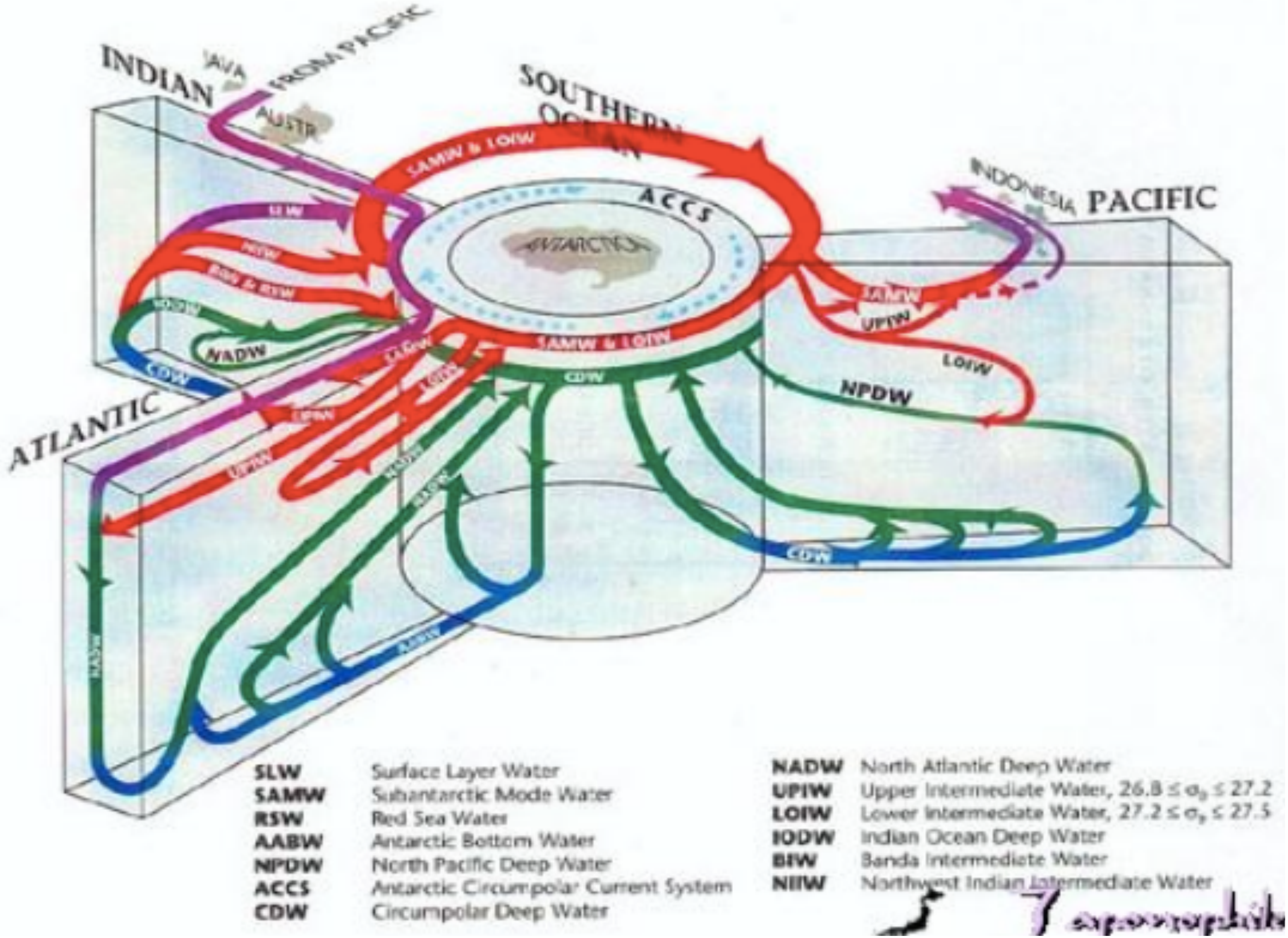




Strong Annual Component variability is a natural periodicity driven by insolation changes.

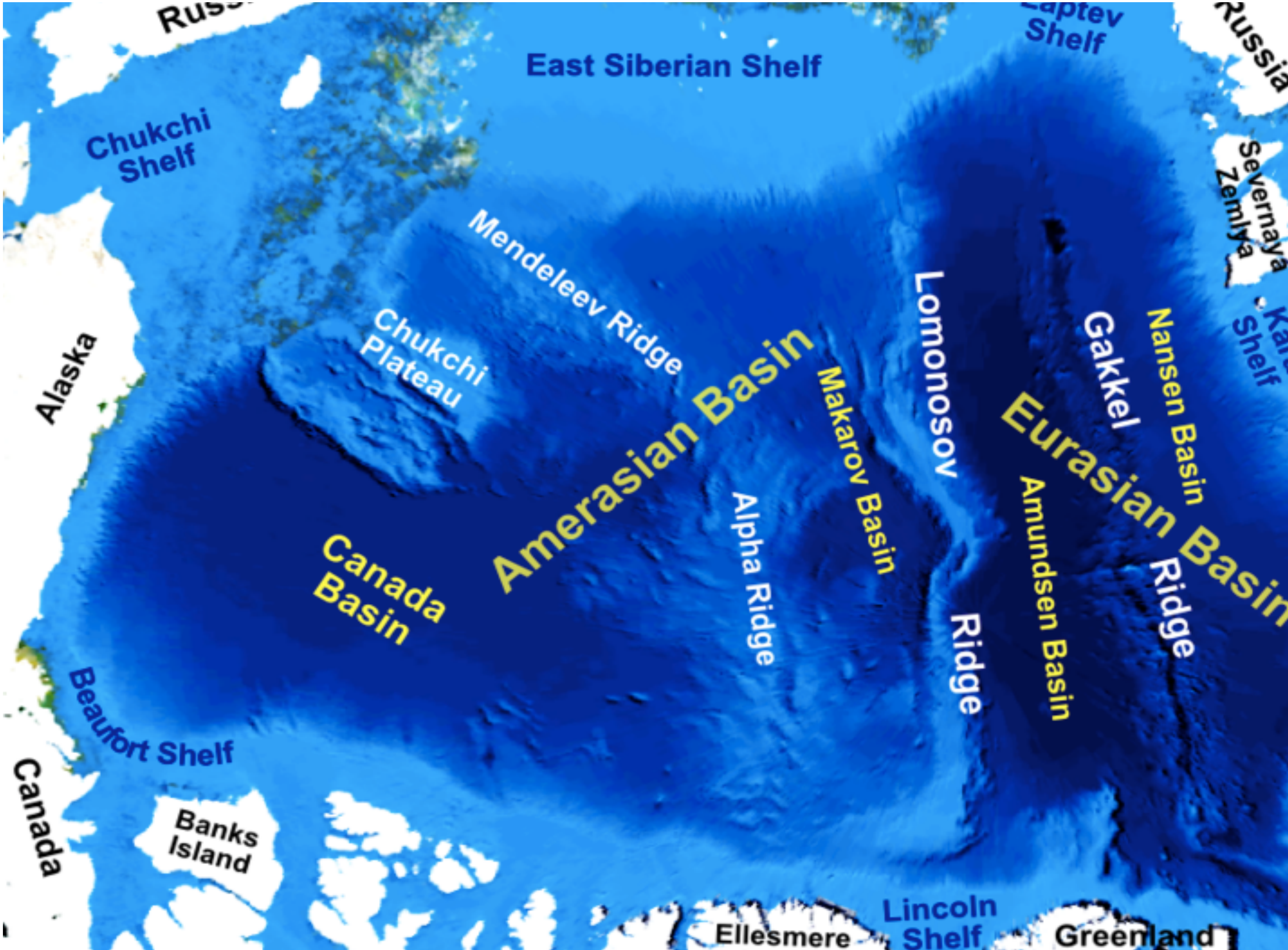
Some interesting Sv facts

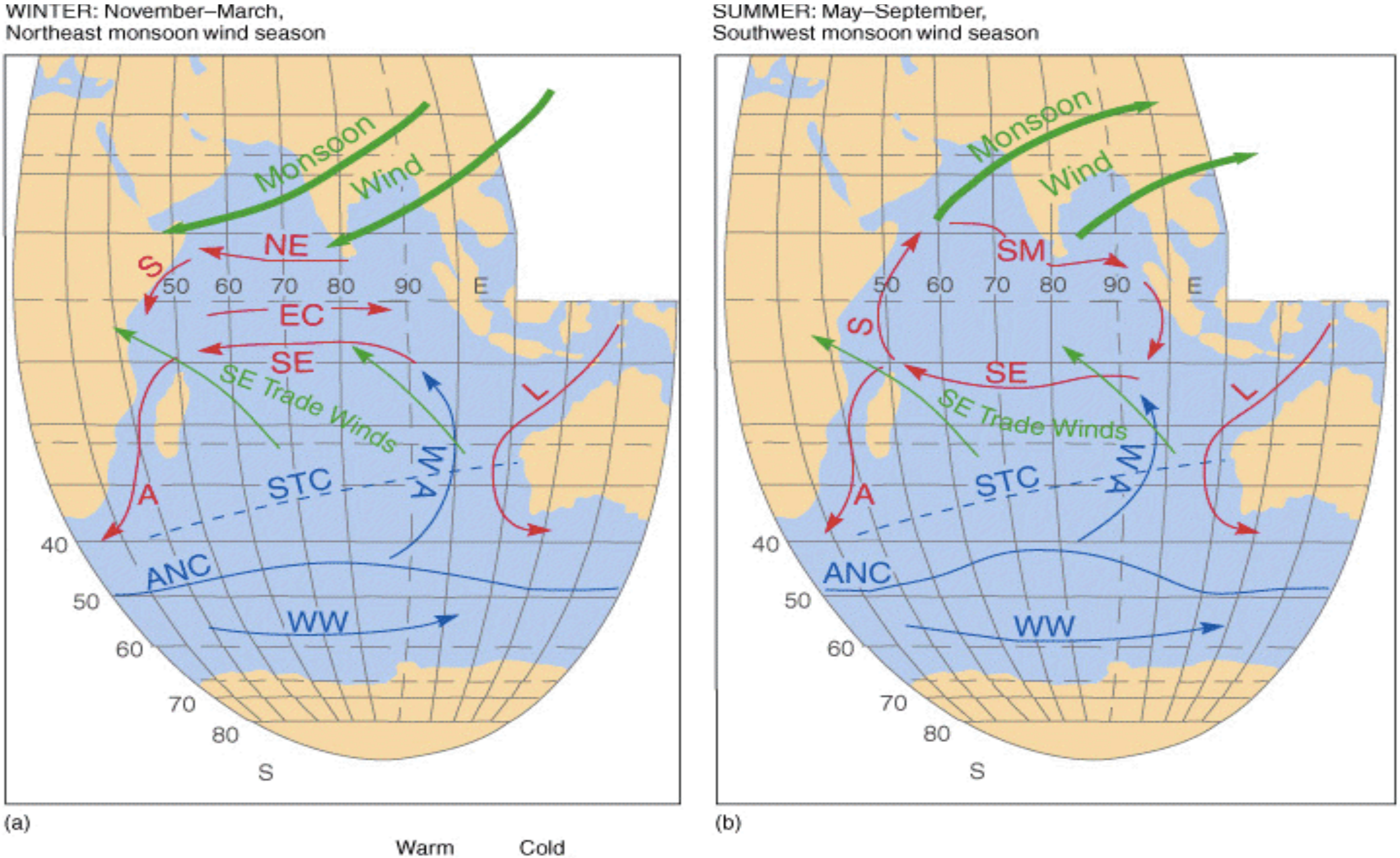
- Total fresh water input to the oceans = 1.2 Sv
- Gulf Stream (THC component = 25%) is 30 Sv in the Florida Current and 150 Sv just south of Newfoundland
- The Antarctic Circumpolar Current is 125 Sv
- 1 Sv = 264 million gallons/sec


INDIAN
JAVA
FROM PACIFIC
AUSTR
SOUTHERN OCEAN
SAMW & LOIW
ACCS
INDONESIA
PACIFIC
SLW
SAMW
UPIW
LOIW
NADW
CDW
NPDW
ATLANTIC
UPIW
SAMW & LOIW
CDW
AABW
NADW
SLW Surface Layer Water
SAMW Subantarctic Mode Water
RSW Red Sea Water
AABW Antarctic Bottom Water
NPDW North Pacific Deep Water
ACCS Antarctic Circumpolar Current System
CDW Circumpolar Deep Water
NADW North Atlantic Deep Water
UPIW Upper Intermediate Water, 26.8 ≤ σ₀ ≤ 27.2
LOIW Lower Intermediate Water, 27.2 ≤ σ₀ ≤ 27.5
IODW Indian Ocean Deep Water
BIW Banda Intermediate Water
NIIW Northwest Indian Intermediate Water

Arctic and Indian Oceans

- Arctic ocean is tiny - about 2.8% of the total earth’s surface
- Average depth of the Arctic ocean is about 4000 ft
- The Arctic ocean is ringed by land shelves that are in quite shallow water (100s of feet deep)
- Indian ocean is about 14% of the surface
- Indian ocean has an average depth of 13,000 feet similar to the Pacific and Atlantic oceans


East Siberian Shelf
Laptev Shelf
Russia
Chukchi Shelf
Severnaya Zemlya
Mendeleev Ridge
Lomonosov Ridge
Gakkel Ridge
Nansen Basin
Kara Shelf
Chukchi Plateau
Amerasian Basin
Makarov Basin
Eurasian Basin
Alaska
Amundsen Basin
Alpha Ridge
Canada Basin
Beaufort Shelf
Canada
Banks Island
Lincoln Shelf
Ellesmere
Greenland



CURRENTS: A—Agulhas EC—Equatorial Countercurrent
L—Leeuwin NE—North Equatorial S—Somali
SE—South Equatorial SM—Southwest Monsoon
WA—West Australian WW—West Wind Drift

CONVERGENCES: STC—Subtropical ANC—Antarctic

Data Analysis

- Big data – we are starting to be inundated with data and model output (which is not data)
- Data quality needs to be assessed and assured
- Both data and the analysis of the data needs to be considered for appropriateness
- Parameterization of the data for use in models is never straight forward
- With enough good quality data over appropriate periods of time – we should see real patterns emerge

Data

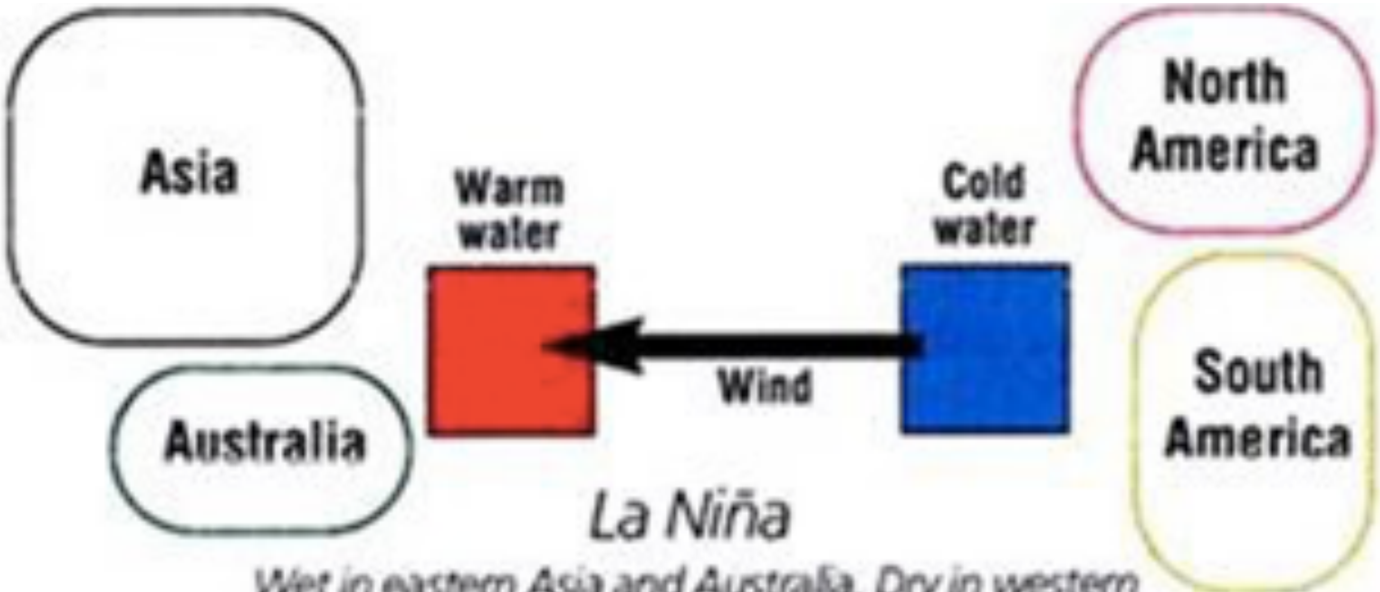
- What we mostly do not know about all the aspects of the climate relates to the lack of data in the following cumulative way:
  - from far enough in the past
  - from places on the planet (especially the oceans and beyond urban land areas)
  - of certain types (pH, temp, salinity etc.)
  - with enough quality and quantity
- We have lots of theories

Patterns and Predictions

- With established patterns we will have a much better chance to develop models that will have some predictive power
- Patterns of 60 year cycles are beginning to pop up everywhere
- ENSO patterns have large effects in the Pacific basin but also have global connections

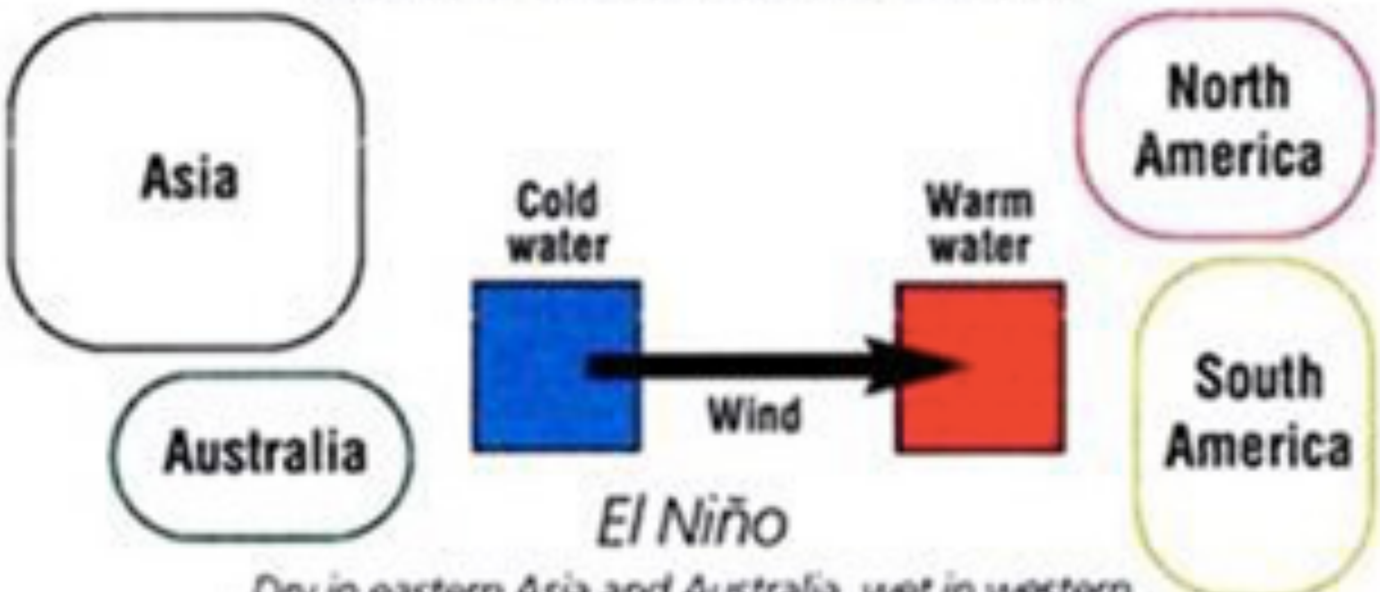
Connections and Phases

- There are some strong connections from ENSO and PDO events to ocean/atmosphere phenomenon
- Phasing of these phenomenon in a global sense can be seen
- There may not be direct correlations but there do seem to be teleconnections
- Interesting phasing characteristic is the out of phase temperature record between Japan and NM



La Niña

Wet in eastern Asia and Australia. Dry in western South America and the southwestern U.S.



El Niño

Dry in eastern Asia and Australia, wet in western South America and the southwestern U.S.

Other Examples

- NH versus SH seasonal phase relationships
- 60 year out of phase Arctic and Antarctic ice accumulation “see-saw”
- El Nino – La Nina short term effects on the southwestern weather (El Nino warm and wet – La Nina cool and dry)
- PDO direct correlation to NM precipitation (dry in cold phase and wet in warm phase)
- There is a need to develop interpretive skill using appropriate time lines

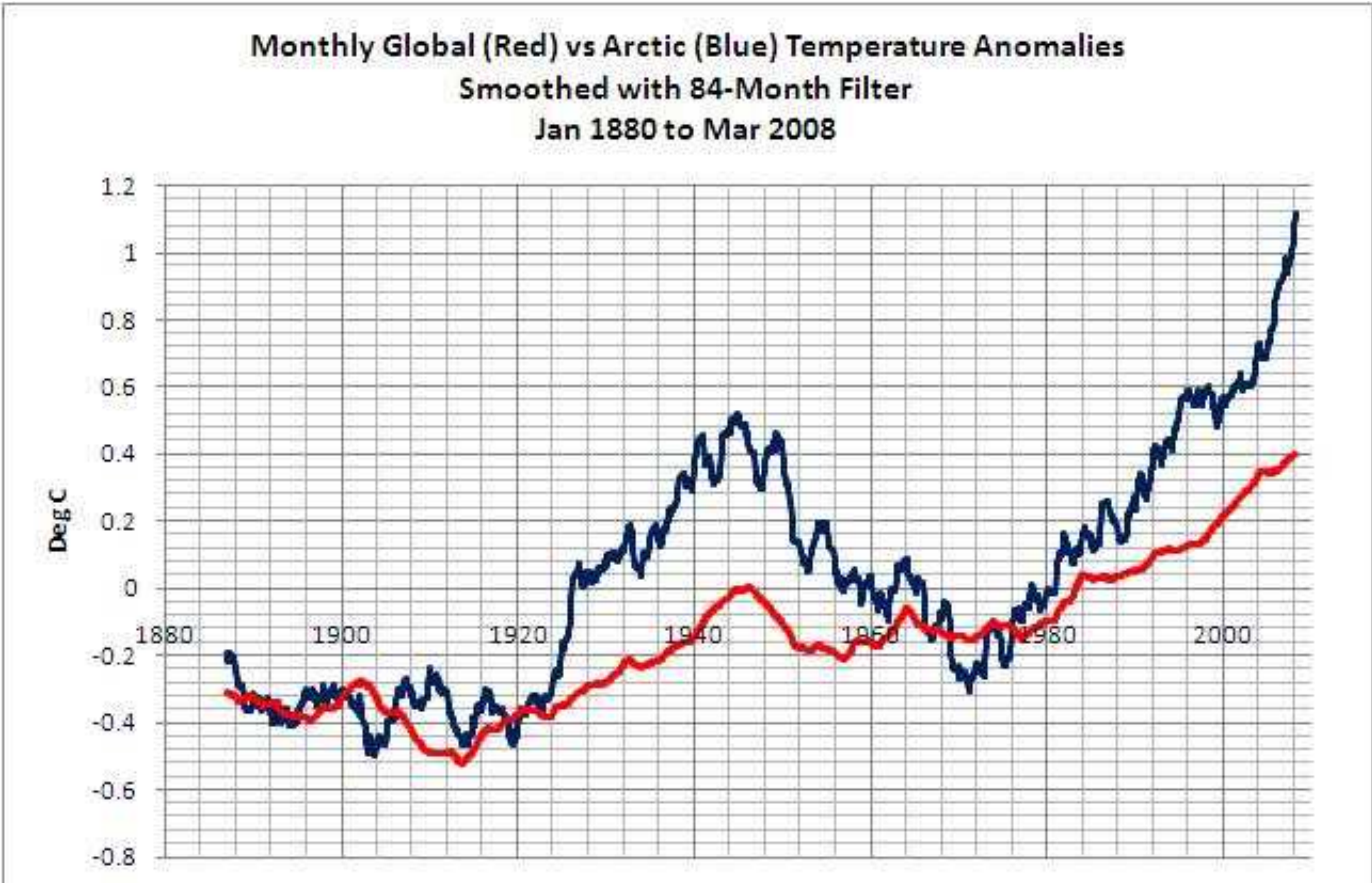
More

- AMO cooling and warming phases are directly tied to NM temperatures
- PDO and AMO effects other regions of the earth in a phased fashion
- In NM - PDO cooling may put us into drought conditions while at the same time AMO warming may increase our temps in NM and cause the eastern US to be very wet

Arctic Amplificaton

- Arctic air warms 2X that of the rest of NH temperatures
- Solar thermal energy applied to Arctic cold dry air has 3X the effect of the energy applied to tropical warm moist air
- This same effect occurs during cooling trends where temperature drops 2X below NH temps
- This is a characteristic of air properties and has nothing to do with radiative effect of CO_2 and snow or ice extent

https://rclutz.wordpress.com/2015/08/24/arctic-amplification/



El Nino 1941:The global climate anomaly1940–1942: **Stefan Brönnimann**
Institute for Atmospheric and Climate Sciences, ETH, Zürich, Switzerland

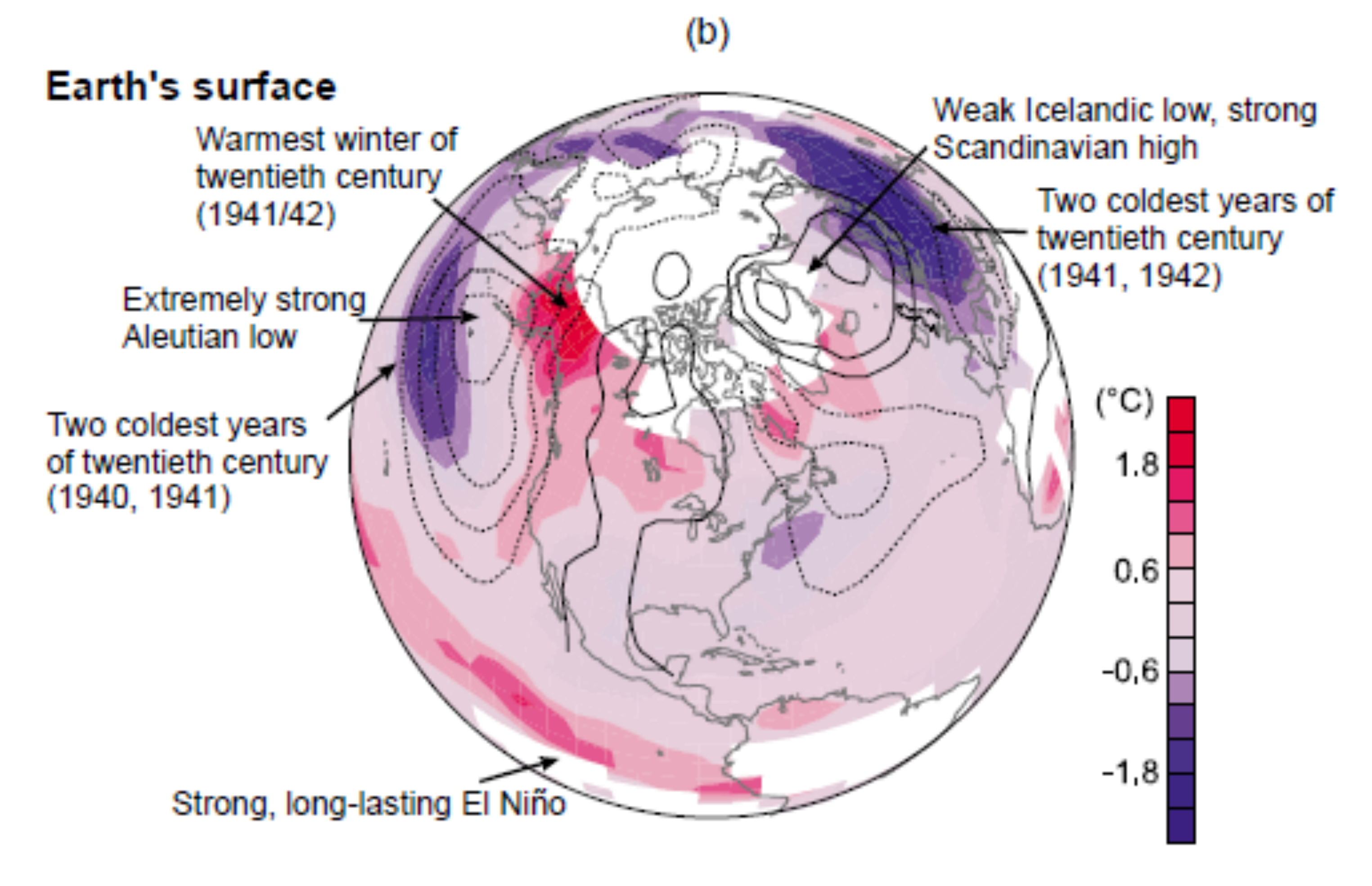


Fig. 7 Averaged anomaly fields (with respect to 1961–1990) from January 1940 to February 1942 of (a) temperature and geopotential height (contours, interval 20 gpm, zero contour not shown) at 100 mbar and (b) surface temperature (HadCRUT2v, Jones and Moberg 2003) and SLP (contours, interval 1 mbar, zero contour not shown, Trenberth and Paolino 1980).

El Nino 1941

- Arctic warming in Alaska but cold weather events in Europe and Siberia
- Clearly not global in its effects
- Black swan weather events that break an ongoing climate pattern (so far impossible to predict)
- Example – PDO warming occurrence during 1958-60 bringing moisture to NM in the middle of a drought (same for the 2014-15 El Nino)

Ripple – Stadium Wave - Delay

- These longitudinal effects are driven by what?
- Coriolis and wind effects on ocean surface currents?
- Deep currents
- It seems that the patterns show the sea surface effects are shorter term while deep ocean currents are longer term
- Where does the 60 year cycle come from?

Atlantic Meridonal Overturning Circulation

- AMOC patterns follow a 60 year cycle
- There is a case where TSI correlates directly with Arctic temperatures (next slide)
- Does the sunspot cycle drive the 60 year cycle?
- No direct correlation to TSI is found in other temperature records especially in the tropics
- But by shifting TSI by about 11 years correlation can be seen (Stadium wave effects?)

Variable solar irradiance as a plausible agent for multidecadal variations in the Arctic-wide surface air temperature record of the past 130 years

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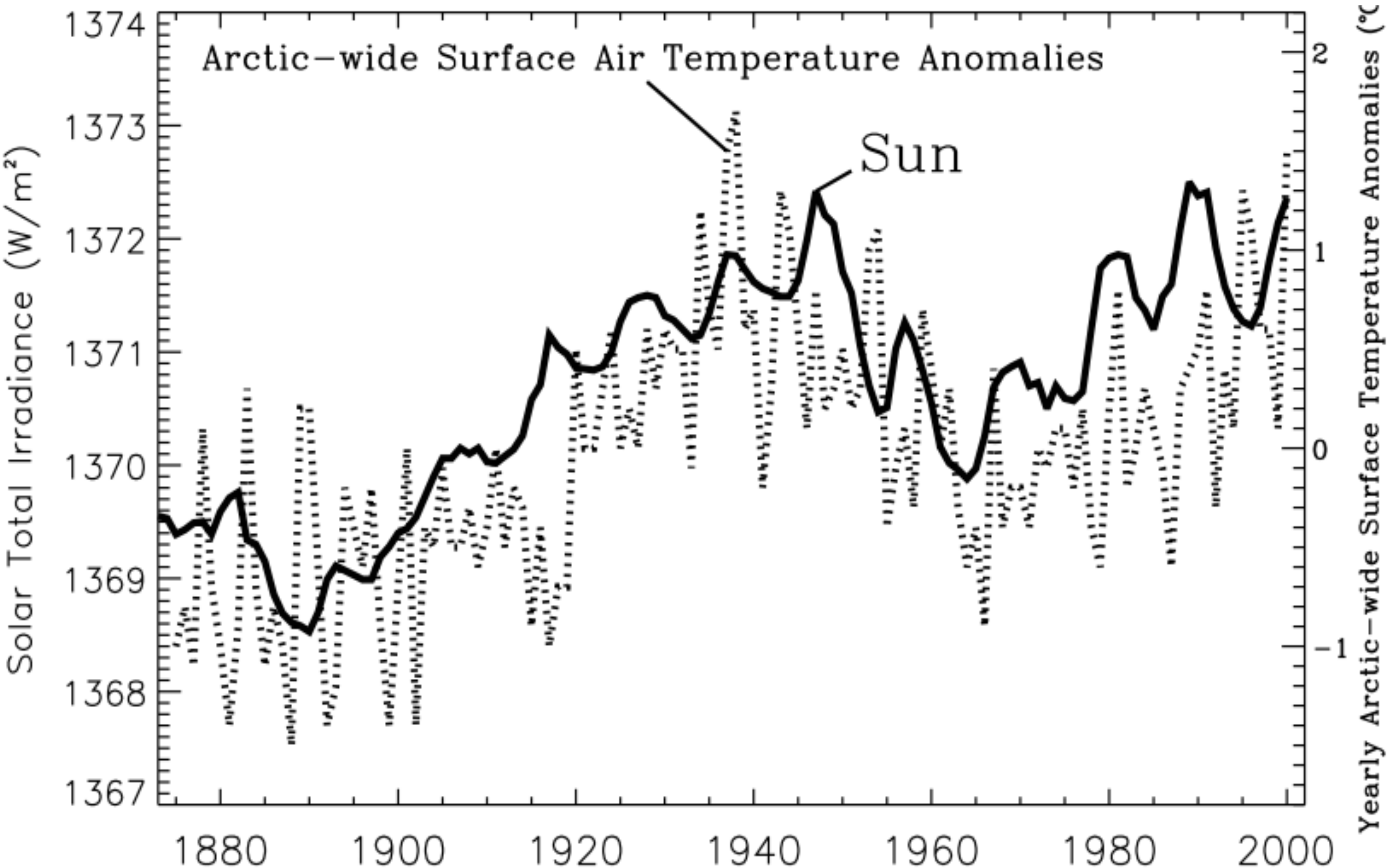
Received 9 May 2005; revised 12 July 2005; accepted 29 July 2005; published 27 August 2005.



Conclusion

- We have a lot of data and a lot of theories
- There are a lot of patterns and connections
- But we are still quite ignorant of what is going on in/with the oceans or the climate
- I would expect that within the next 20 or 30 years will know a lot more
- Plenty enough knowledge and time to stop us all from frying (either in reality or in our minds)