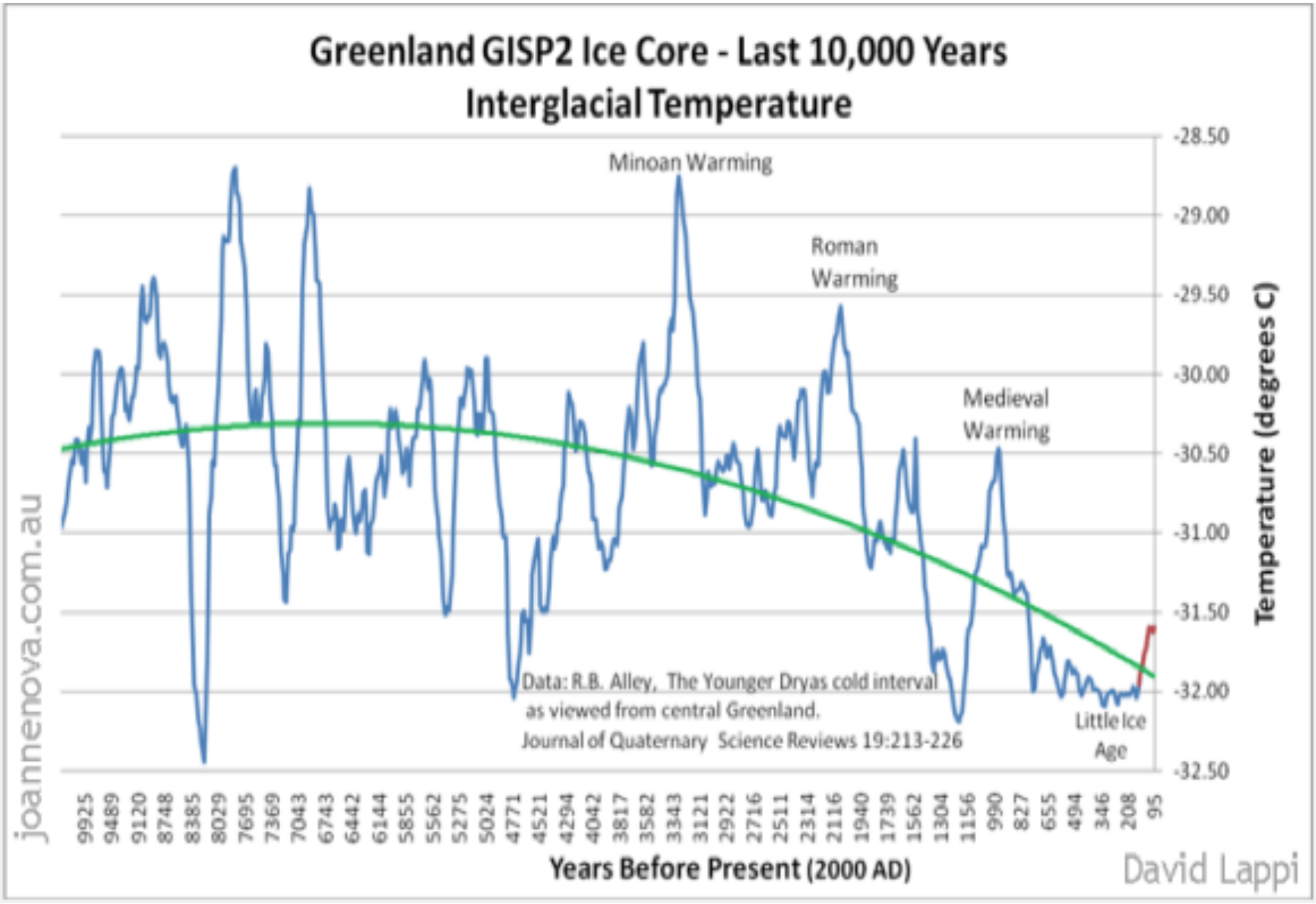
The Heat IS REALLY coming out of the oceans!

Bernie McCune

July 20, 2015

Deep Ocean Temperature Variation

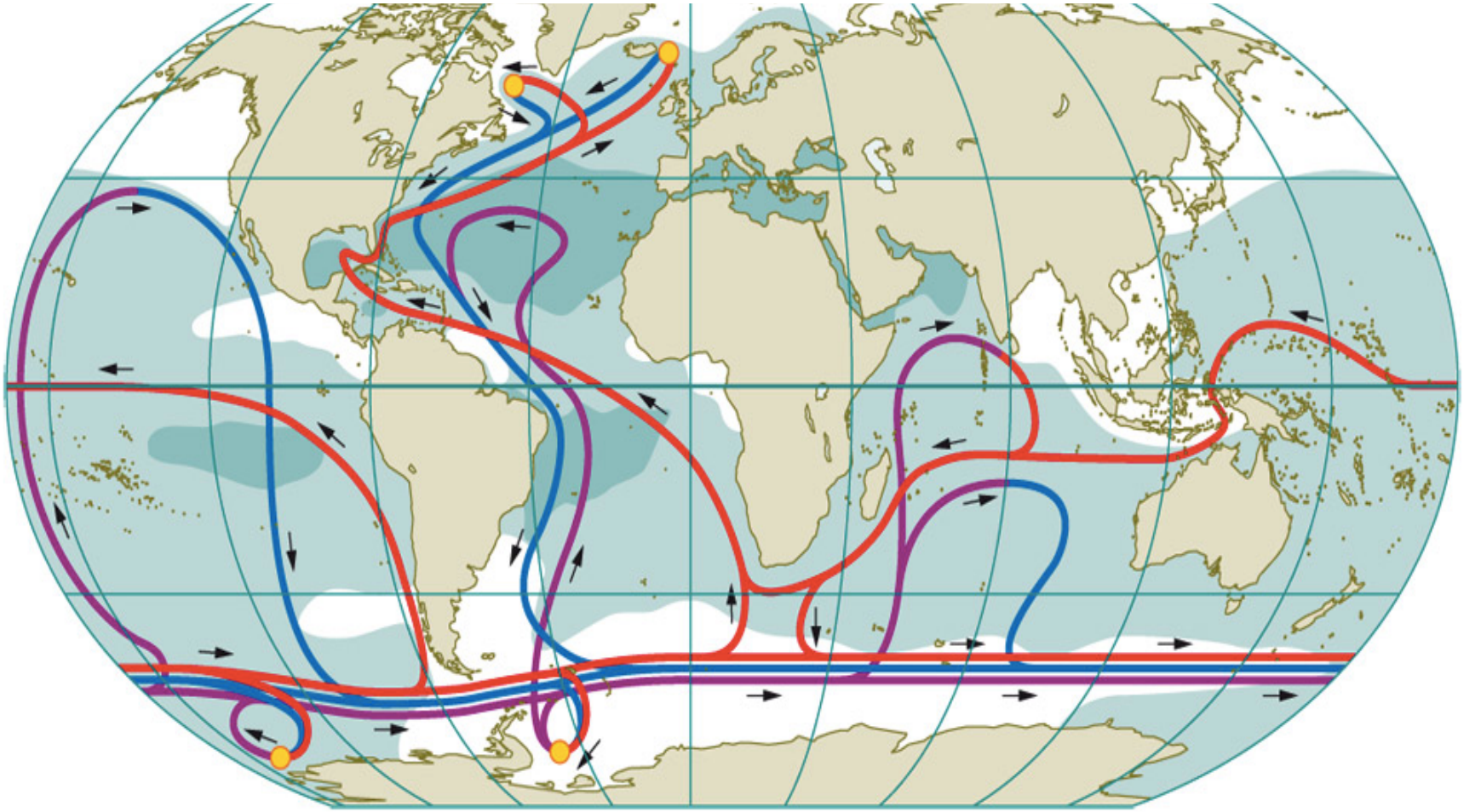
- Capture of long term temperature variation at the earth's poles
- Variation in water temperature of perhaps one degree in a range of 3.5° C to – 1° C or lower
- Especially at the South Pole
- Long term = hundreds of years
- Very subtle and hard to quantify
- Seen in Bond cycles (a type of secondary quantification)


Greenland GISP2 Ice Core - Last 10,000 Years
Interglacial Temperature
Minoan Warming
Roman Warming
Medieval Warming
Little Ice Age
Data: R.B. Alley, The Younger Dryas cold interval as viewed from central Greenland. Journal of Quaternary Science Reviews 19:213-226
-28.50
-29.00
-29.50
-30.00
-30.50
-31.00
-31.50
-32.00
-32.50
Temperature (degrees C)
9925 9489 9120 8748 8385 8029 7695 7369 7043 6743 6442 6144 5855 5562 5275 5024 4771 4521 4294 4042 3817 3582 3343 3121 2922 2716 2511 2314 2116 1940 1739 1562 1304 1156 990 827 655 494 346 208 95
Years Before Present (2000 AD)
joannenova.com.au
David Lappi

Cold Water Sink/Convection Points

- Affect the Atlantic deep water circulation
- And the Antarctic circumpolar deep water circulation
- Accumulation in volume and temperature of these deep water reservoirs and periods of these water flows are key to their effects on the natural climate cycles

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

Variations of Temperature

- Present surface ocean/air temperatures are unusually warm
- Average surface ocean/air temperatures are probably commonly 5 to 7 deg C colder
- By accumulating cold water into the deep ocean over a 1000 year cycle, surface temperatures may periodically climb
- Obvious solar variations even minor ones
- These short term warming periods over a few hundred years are called for example “The Roman Warm Period” and the “MWP”

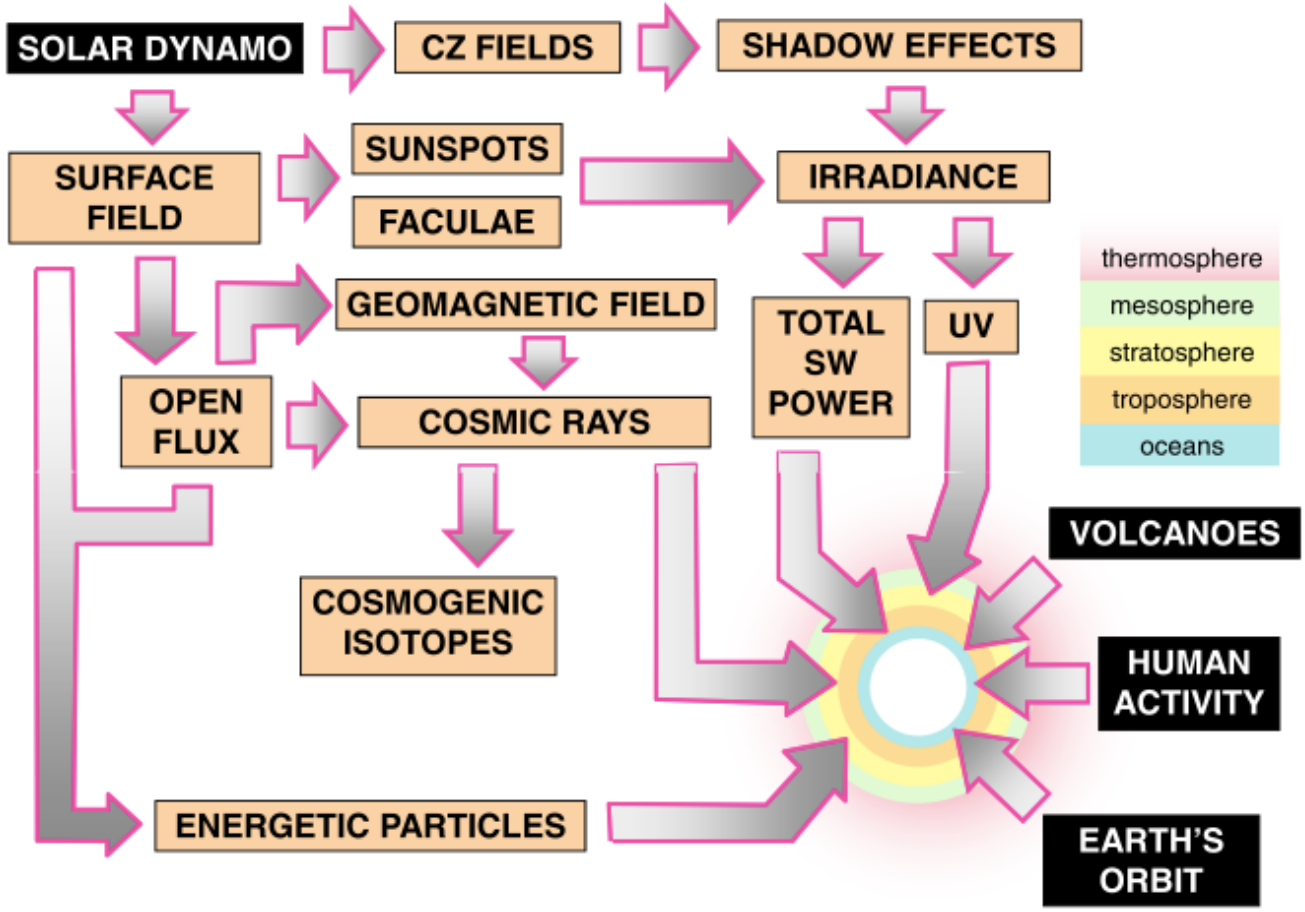


Figure 20. Schematic overview showing various climate forcings of the Earth's atmosphere, with factors that influence the forcing associated with solar variability (irradiance and corpuscular radiation) shown in more detail on the left-hand side, as discussed in section 2.

The rest of the time it is either cold or it is VERY cold!

(probably not only a cold sun)

Or is the change caused only by circulation patterns?

- Large volumes of mostly cold water that is interacting with much smaller volume of warmer surface water
- The speed (generally very slow) of these deep water flows must also have some sort of direct influence on long term climate

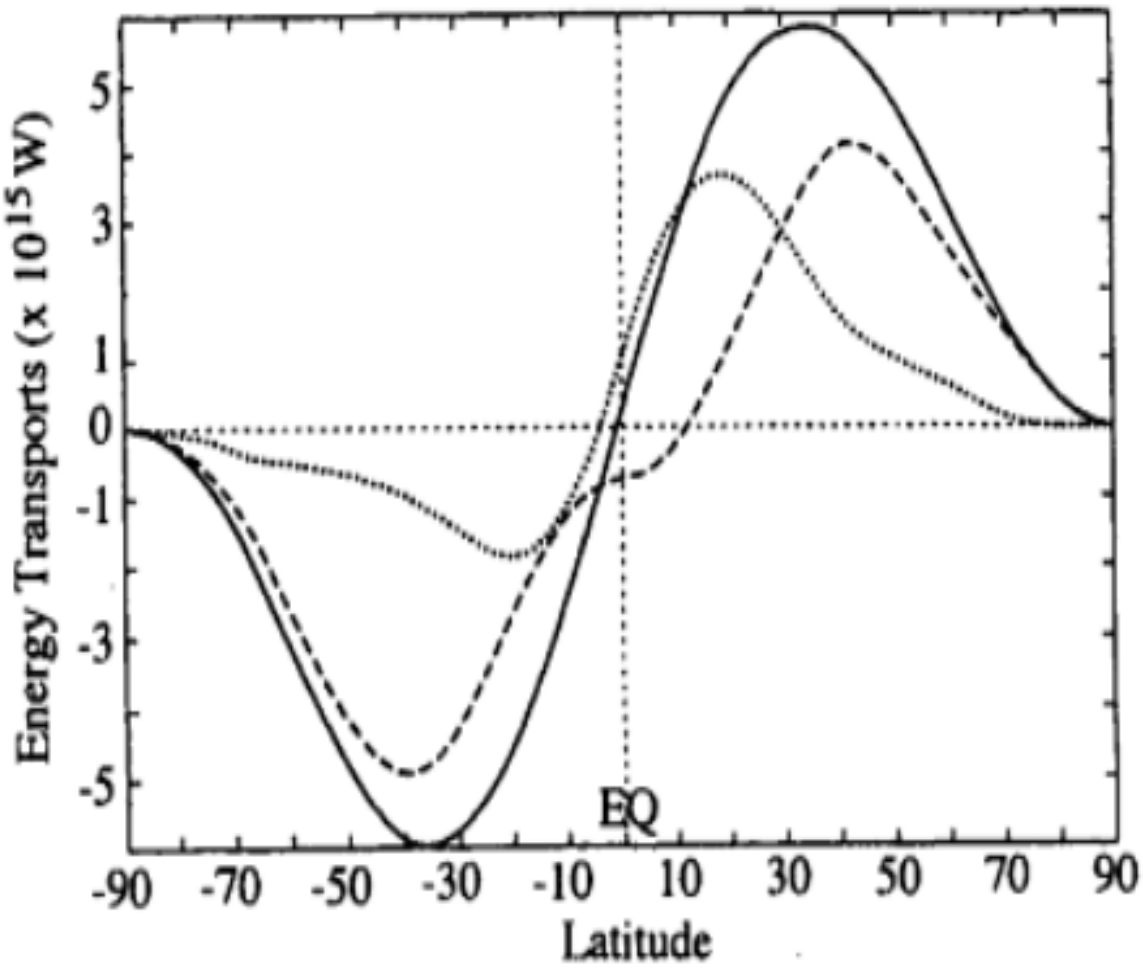
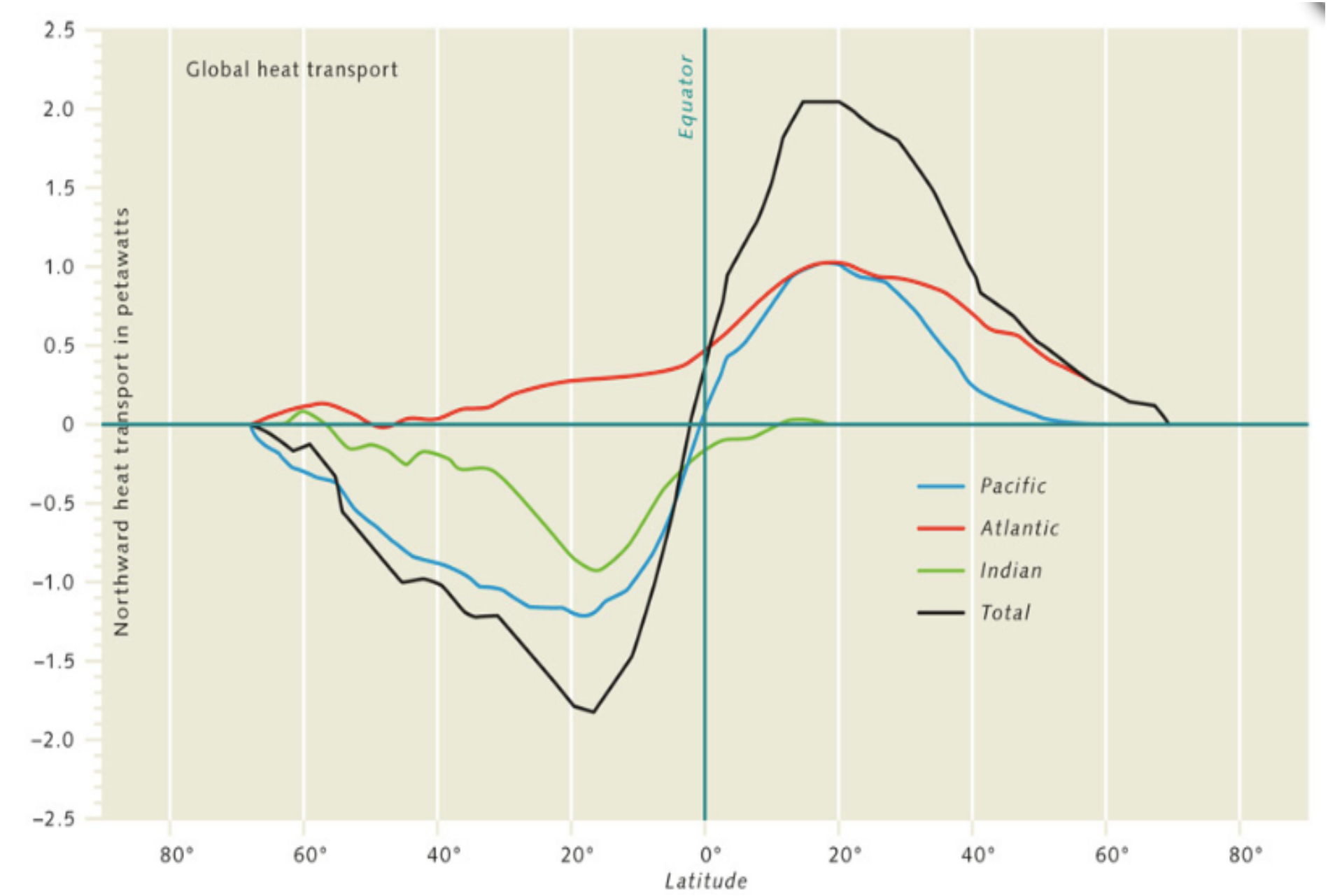
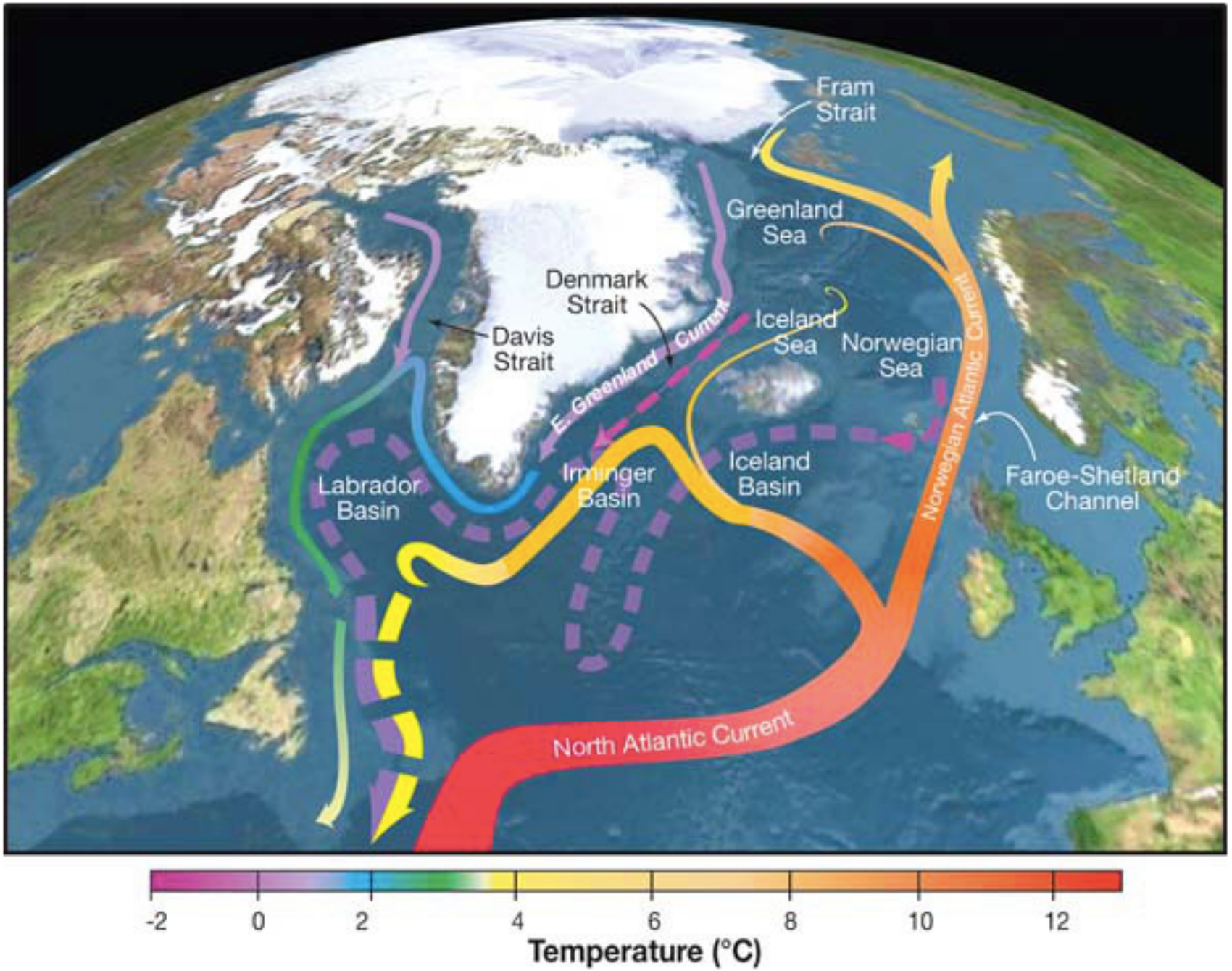


Figure 12.5 Annual mean northward energy transports required to equalize the pole–equator radiative imbalance. The solid line represents the top-of-the-atmosphere radiation budget, the dashed line represents the atmosphere, and the dotted line represents the ocean (From Zhang and Rossow, 1997).

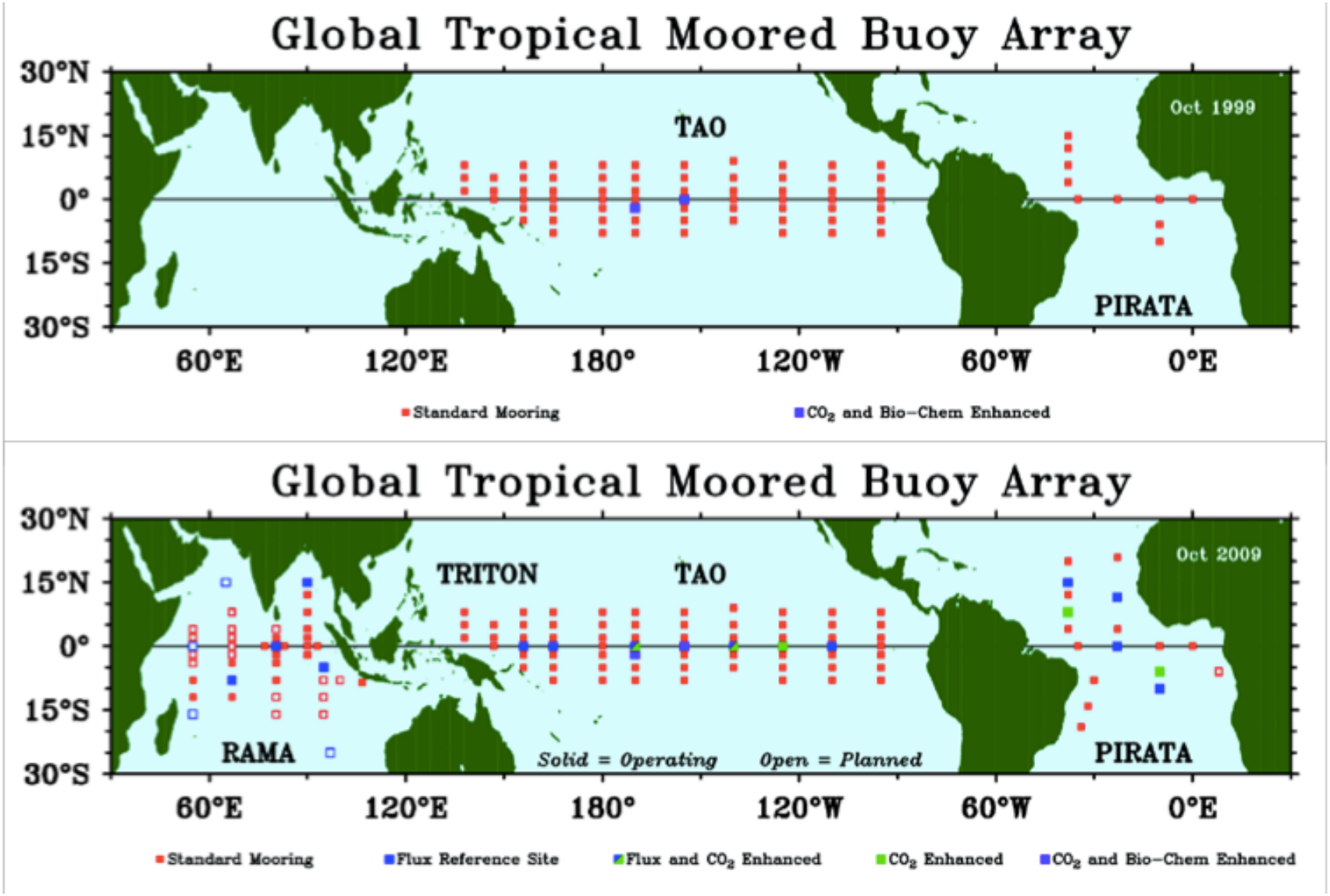

Global heat transport
Equator
Northward heat transport in petawatts
2.5
2.0
1.5
1.0
0.5
0
−0.5
−1.0
−1.5
−2.0
−2.5
80°
60°
40°
20°
0°
20°
40°
60°
80°
Latitude
Pacific
Atlantic
Indian
Total

Atlantic Meridional Overturning Circulation AMOC

- Look at the Atlantic since the Atlantic Multidecadal Oscillation is a significant climate driver
- Survey of the Global Tropical Moored Array system
- This system has only been in existence for about 2 decades
- Observe some short term trends in the pattern


Fram Strait
Greenland Sea
Denmark Strait
Davis Strait
E. Greenland Current
Iceland Sea
Norwegian Sea
Norwegian Atlantic Current
Labrador Basin
Irminger Basin
Iceland Basin
Faroe-Shetland Channel
North Atlantic Current
-2
0
2
4
6
8
10
12
Temperature (°C)

Array as it was in October 1999

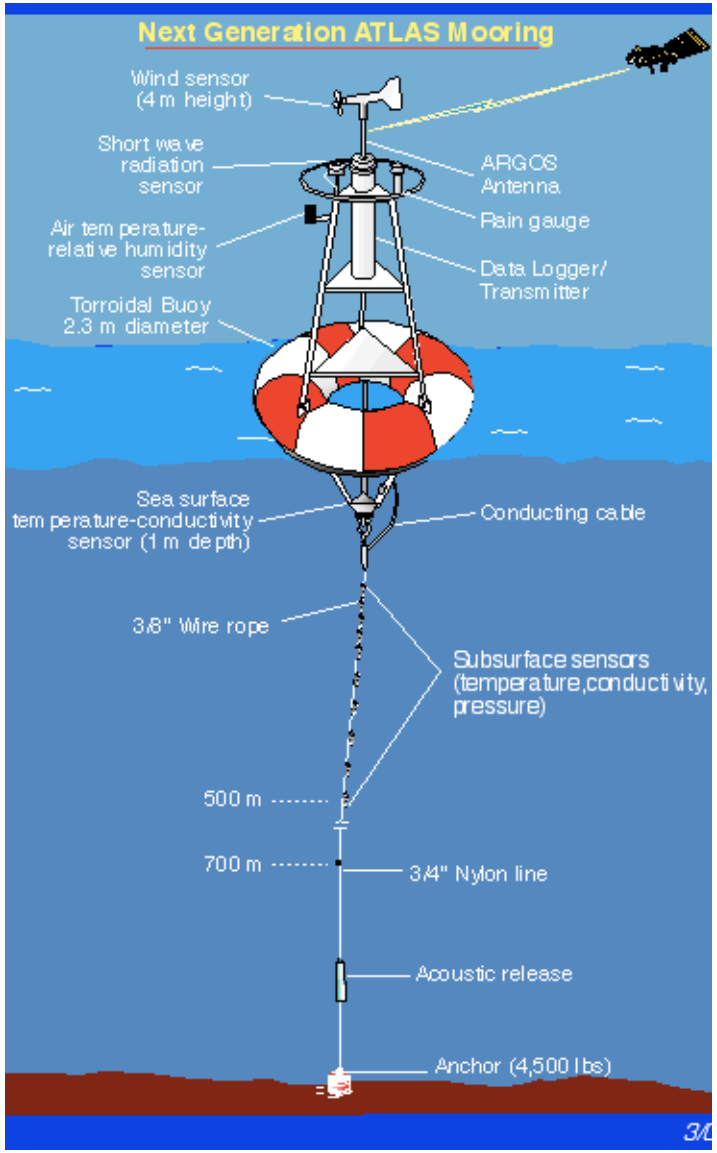


Array as it was in October 2009

Short History

- Beginnings with the TAO moored system in Pacific
- 1985 ATLAS with 35% of 67 buoys in place by 1994 (total planned = 77)
- Temp, Salinity, Wind vel, sea state, & later ocean vel ("flux" sites) and temp & salinity to 750 meters
- TAO/Triton network 2000 Japanese support

ATLAS Mooring



PIRATA/RAMA

- Pilot Research [Moored] Array In Tropical Atlantic
- Began 1999-2000 with 10 deployed
- Completed in 2005-6 about 40
- RAMA = Indian Ocean began in 2004
- Total planned 46 moorings with 3 instrumented to 4000 meters

- Anemometers -- RM Young, Vaisala
- Compasses -- Ritchie, KVH
- Air Temp. -- Airflo Instruments, Artais, Magnavox
- Water Temp. -- PSI, Baytech, Magnavox
- Barometers -- Rosemont, Setra
- Humidity -- Rotronics
- Precip. -- Friez (heating tipping bucket), RM Young
- Pyranometer -- Licor
- Visibility -- Belfort
- Inclinometers -- Schaevitz, Columbia Research
- Angular Rate Sensor -- BEI, Systron Donner Inertial Div
- Wave Height Sensor -- Schwartz EO
- Magnetometer -- General Oceanics, Watson Industries
- Heave-Pitch-Roll Sensor -- Datawell Hippy
- Positioning --Telonics, SITEX, Trimble, Synergetics
- Tides -- Aquatrak, Bartex
- Salinity -- Sea-Bird Electronics
- ADCP -- RD Instruments

Calibration

NDBC strives to provide its customers with the highest quality data possible. NDBC calibrates each sensor prior to deployment. After two years of service, sensors still in operation at an NDBC station are replaced with recently calibrated instruments so that those on station can be returned to NDBC for post-deployment calibration analysis as well as refurbishment and recalibration.

Purpose GTO/AMB System

- obtain data to further study El Nino/ENSO
- study Atlantic meridional gradient mode/warm events
- obtain data on Indian Ocean di-pole (like ENSO)
- document mean seasonal cycles - such as African, Asian, Australian & American monsoons
- track the intraseasonal Madden-Julian oscillations

Notes on Purpose

- the last stated purpose is to study global warming
- all data are short term (at most couple of decades) yet . . .
- some are stretching to find a human print on the data trends (linear vs cyclical (sine) signs)
- fixed array in time and space (elaborate)

Mooring Array Issues

- Servicing – very difficult and expensive
- Loss due to extreme environment - and unmooring (drifting buoy)
- Security – pilfering – damage - an engineering problem
- Restriction of placement and mooring due to heavy fishing traffic

Data Quality and Future

- Occasional data gaps and buoy failures due to previously noted issues (and funding)
- Rumors of shutting down the moor buoy program are noise created to showcase funding issues
- Argo and moored buoy program are different and both are necessary
- Sverdrup - Sv = a flow of 10^6 M^3 /sec or 264* 10^6 US gallons/sec (Harald Sverdrup)

TAO Example Data

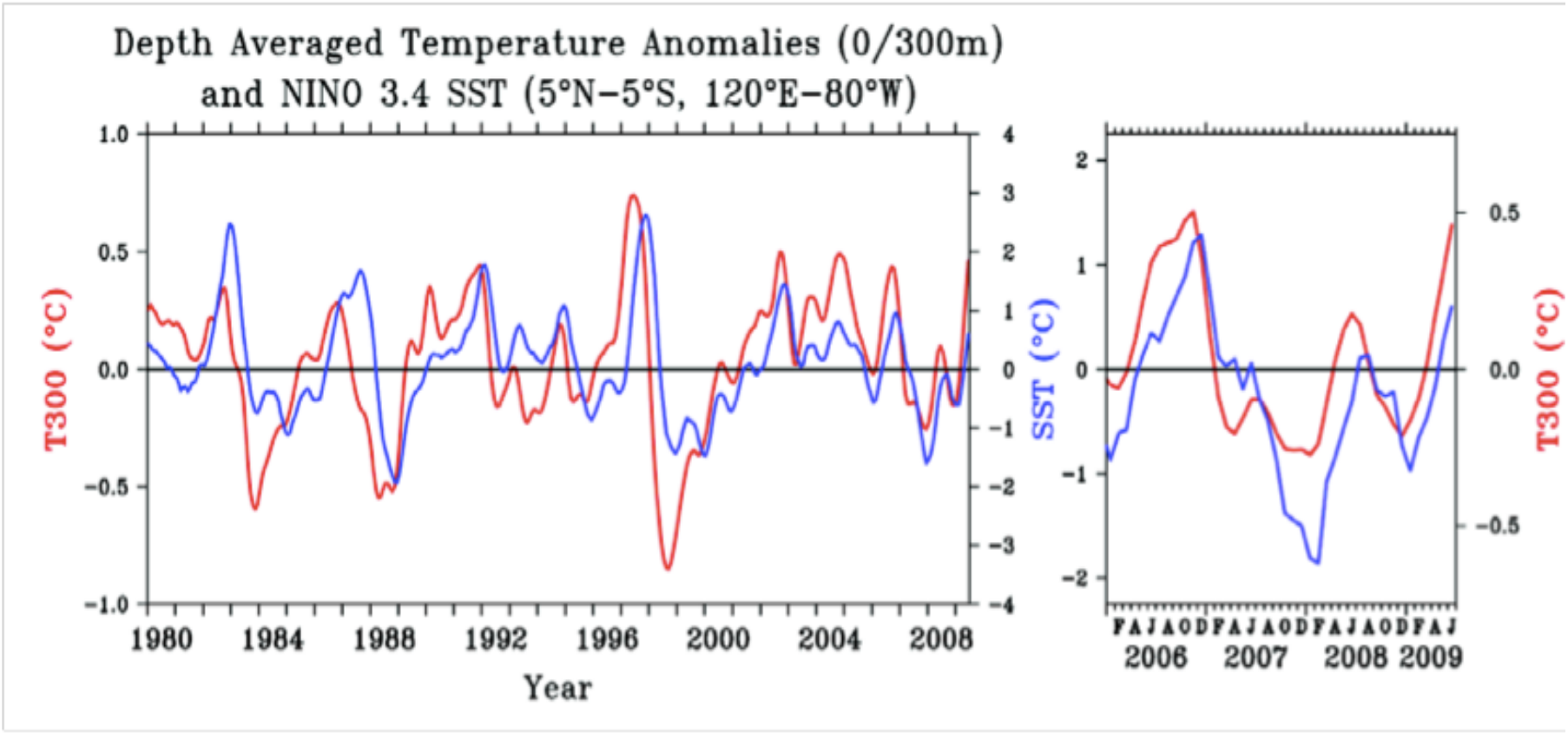
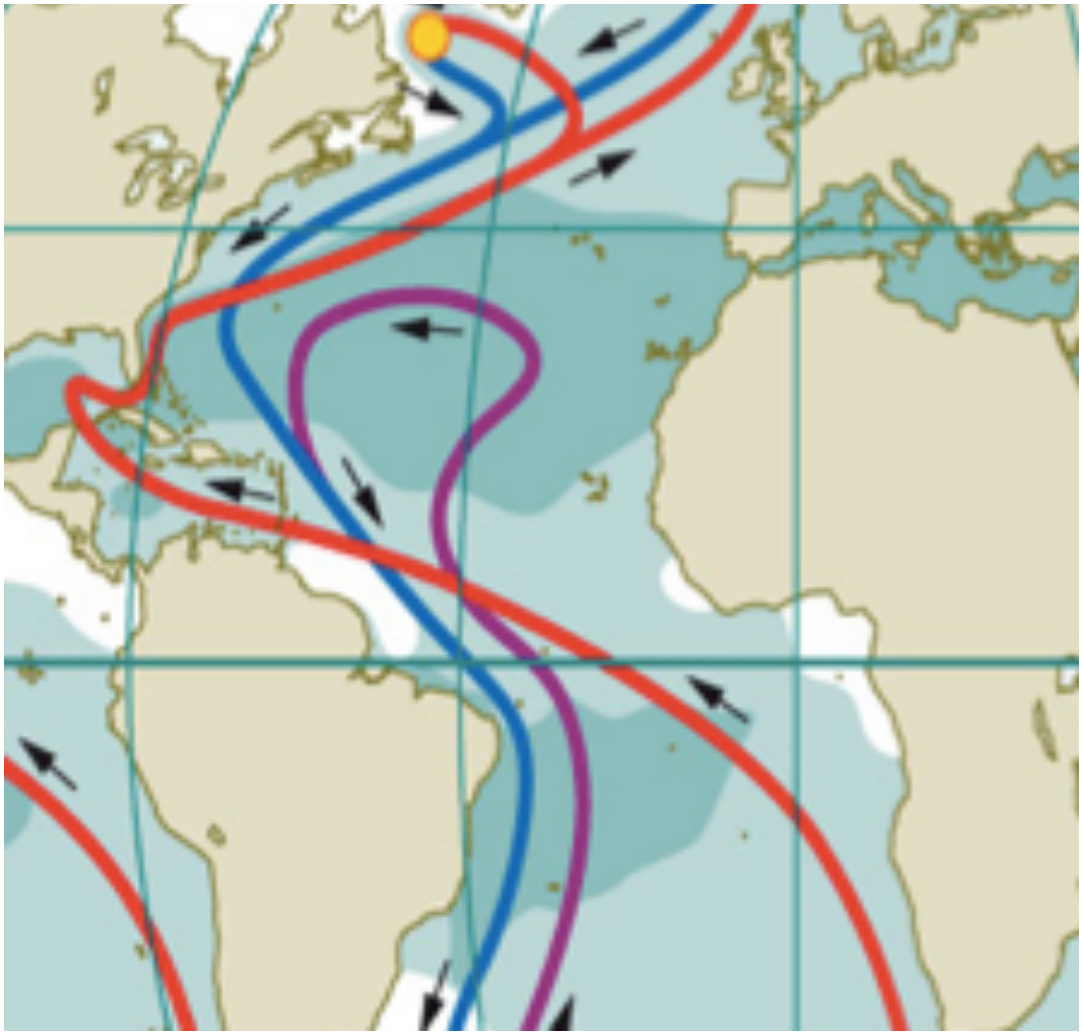


Figure 2. Depth-averaged temperature (T300) and Niño3.4 SST for January 1980 to June 2009. Monthly values in left panel have been smoothed with a 5-month running mean. The right panel shows the last three years of the record (unsmoothed) to highlight developing El Niño and La Niña conditions over 2006–09. Note the different scales for T300 and NINO3.4 SST in the two panels (after [93]).

Atlantic General Circ Patterns



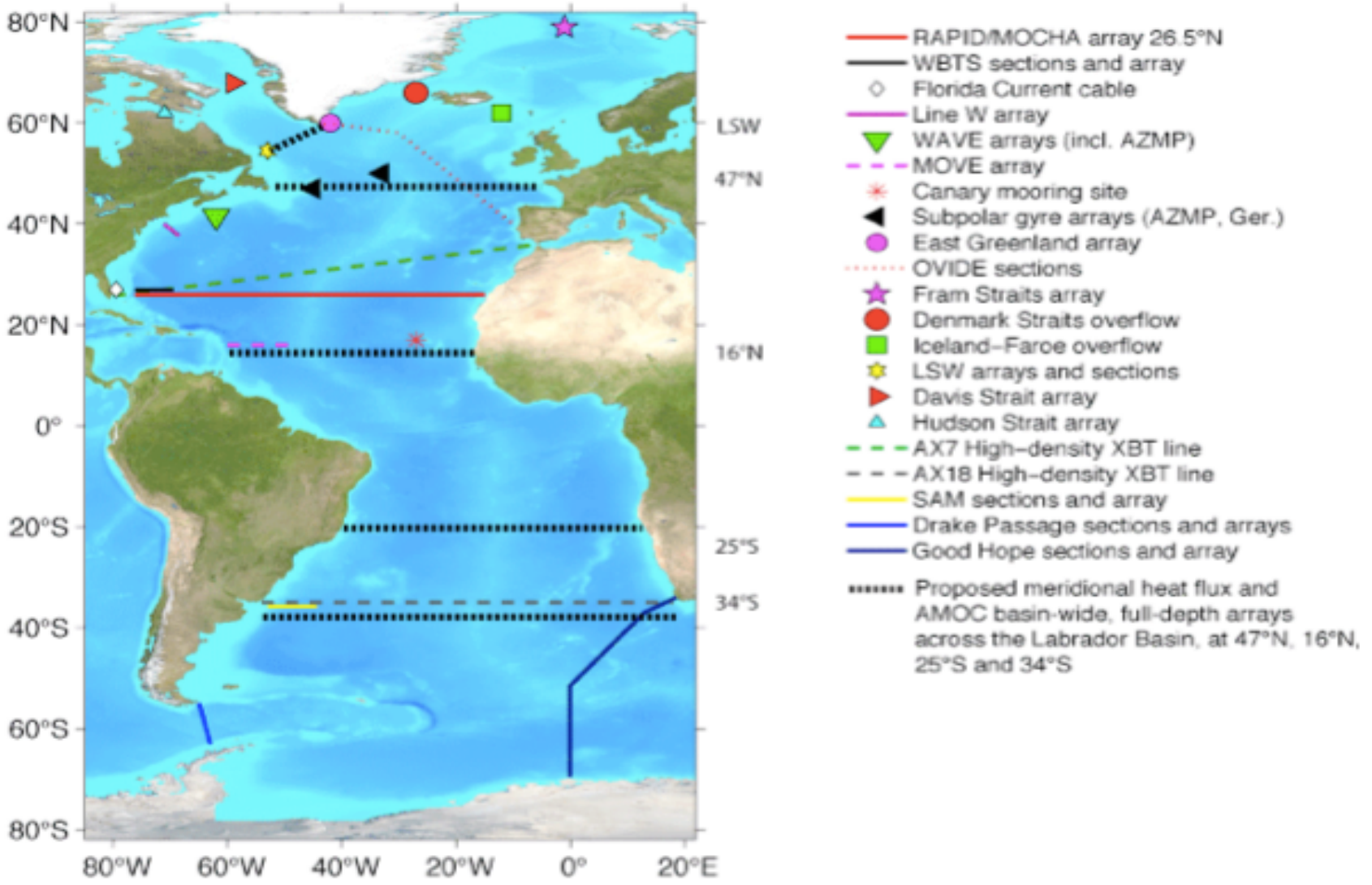
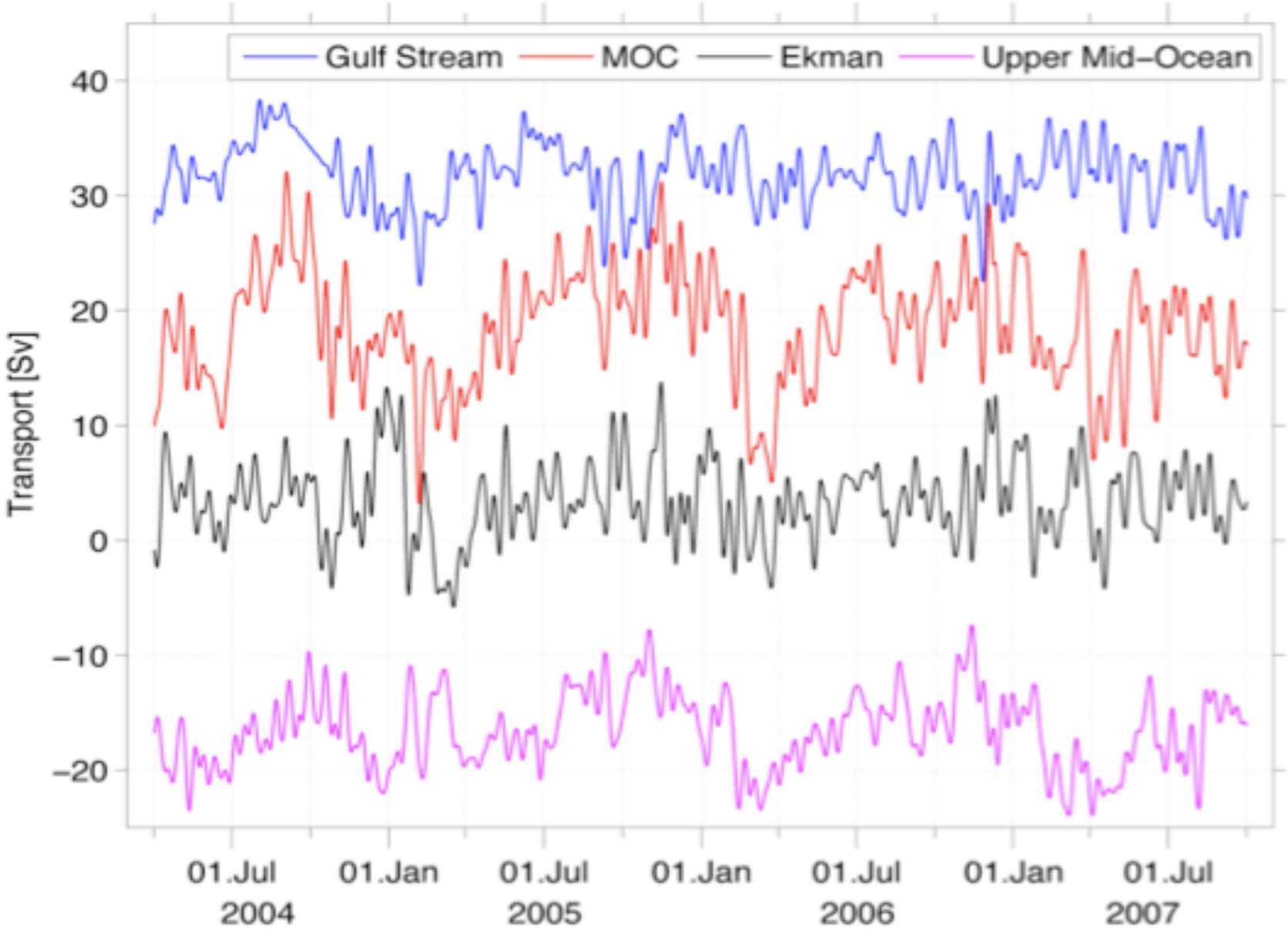
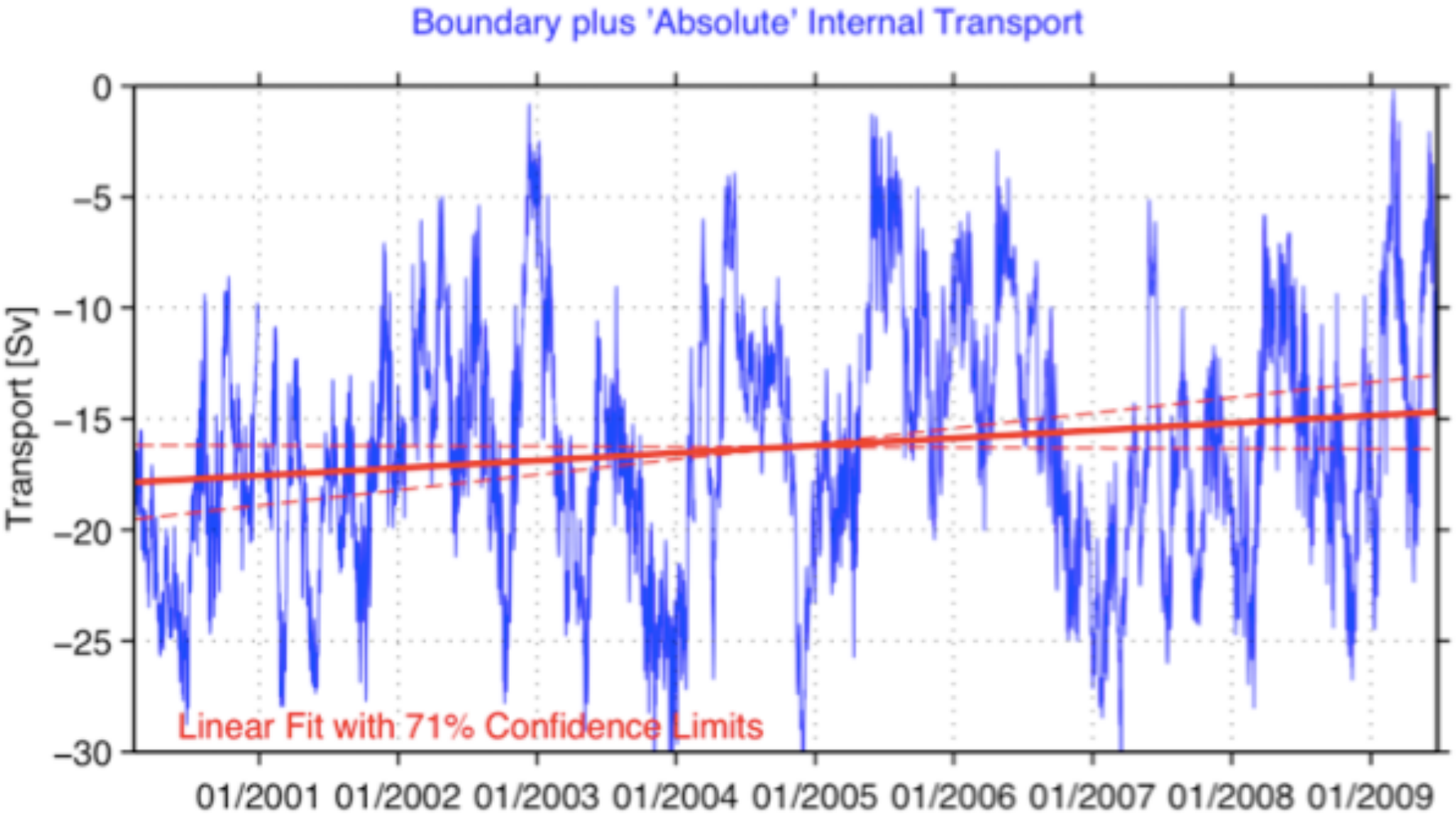


Figure 3. Observational programs presently measuring components of the AMOC (see also Tab. 1).

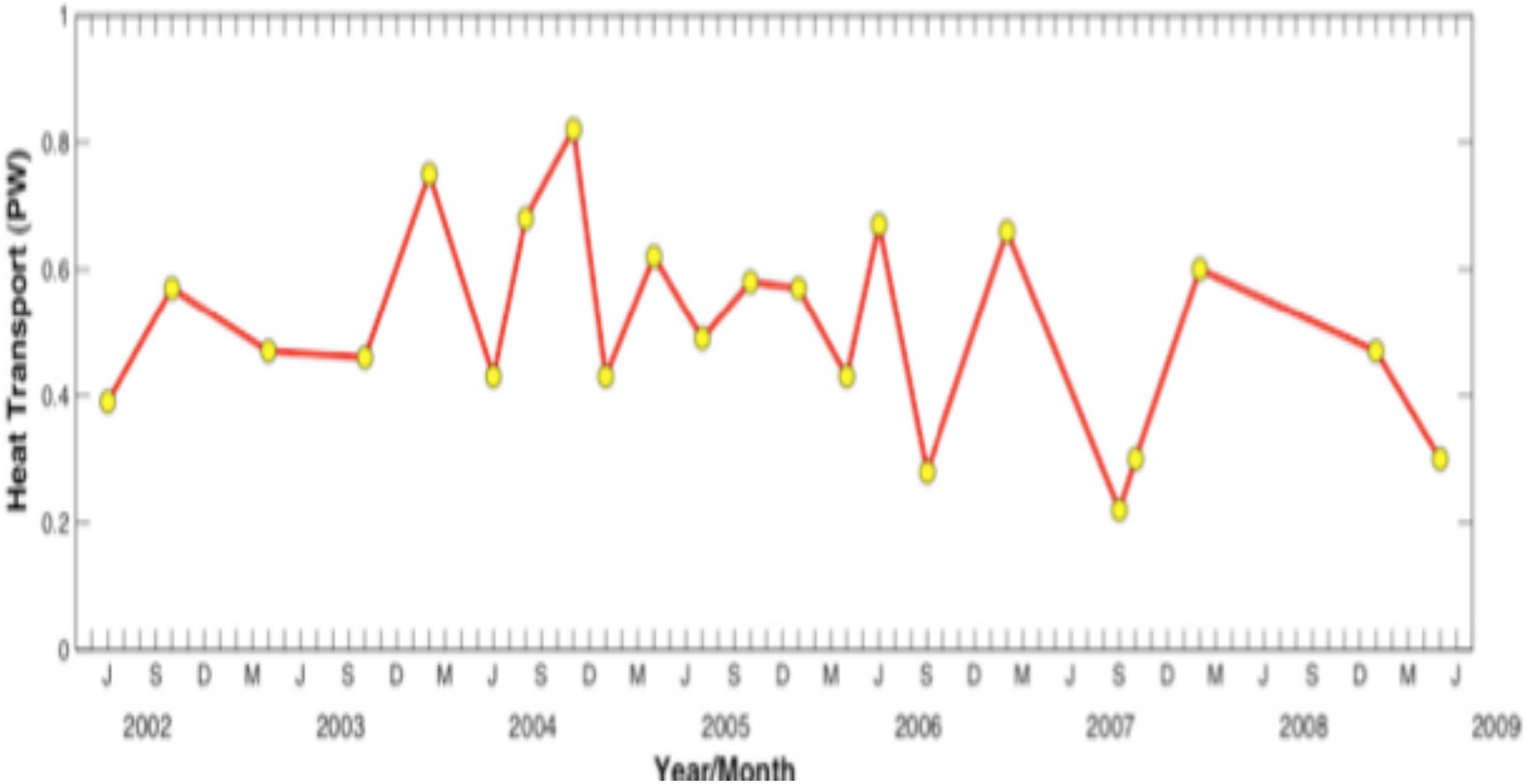
Early Atlantic Flow Rates/Directions

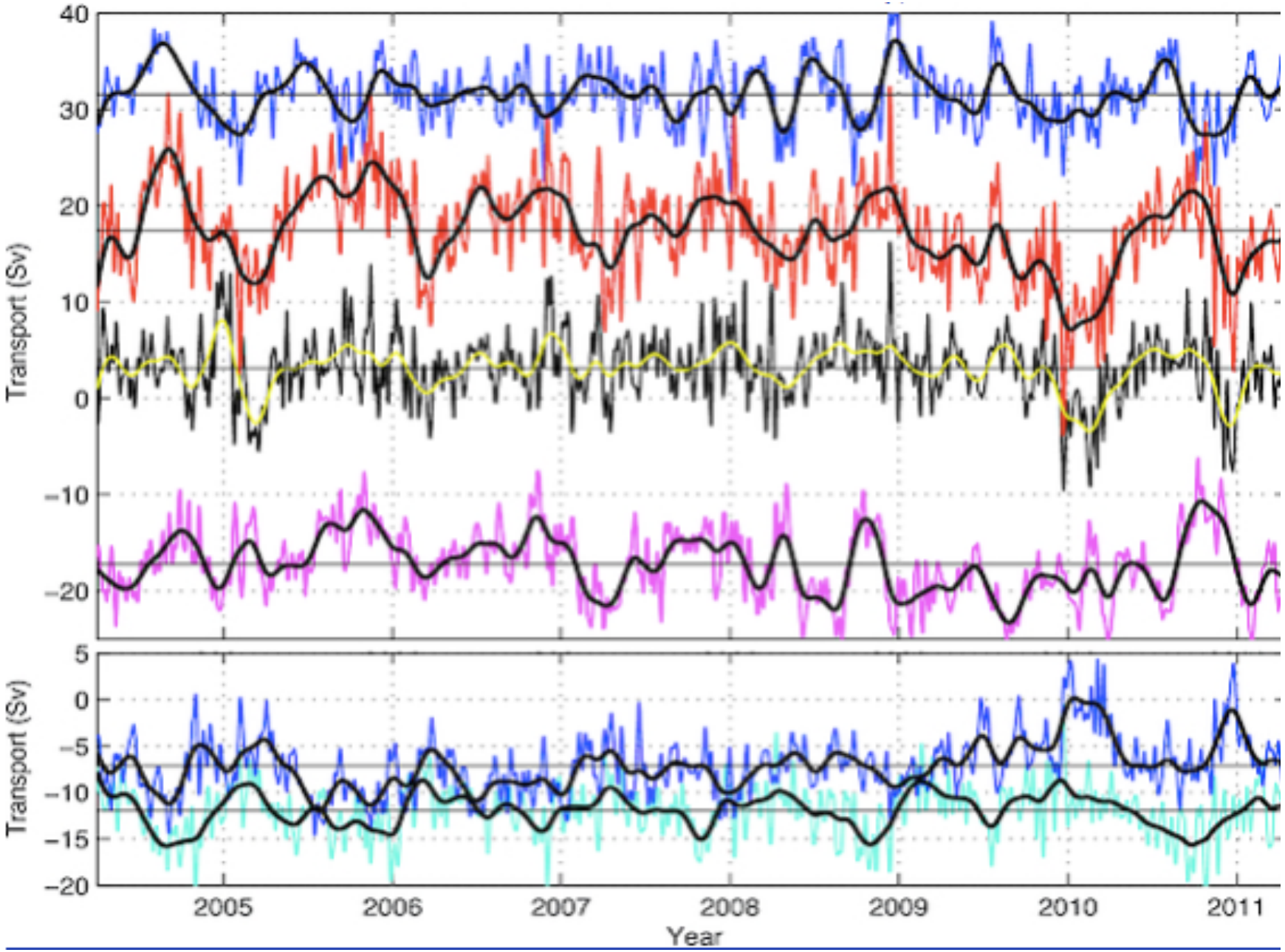


AMOC southbound NADW Transport

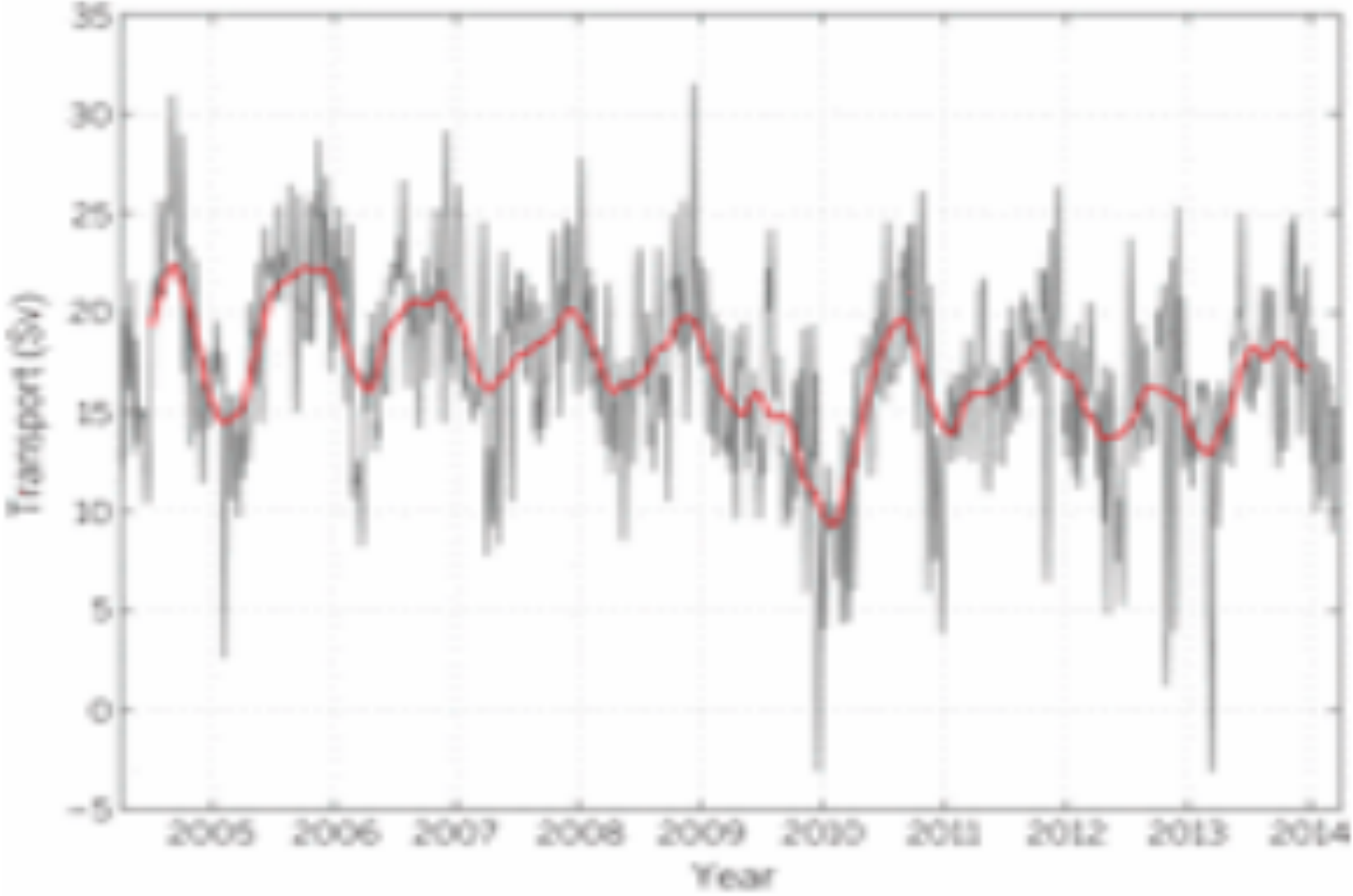


Heat Transport @ 35° S




40
30
20
10
0
−10
−20
Transport (Sv)
5
0
−5
−10
−15
−20
Transport (Sv)
2005
2006
2007
2008
2009
2010
2011
Year

MOC 2005-2014



Volume of Water

- Gulf Stream flow rates = 31.8 Sv
- MOC = erratic highs 30 Sv lows almost 0
- MOC average 18 Sv to 12 Sv
- Antarctic Circumpolar flow = 125 Sv (highest)
- Upper Mid-ocean Transports UMO 16.8 Sv
- Ekman 3.5 Sv
- MOC= UMO + Ekman + Gulf Stream
- Changes in all these flow volumes are very interactive and dramatic at times

Brief MOC discussion

- MOC is critical to climate effects and is responsible for 90% of heat transport
- amount of ocean heat flux 1.3 PW
- A dramatic flow decline occurred in 2009-10 caused by wind anomaly and increase in geostophic flow
- southward flow of the top 1100 m intensified
- deep layer south flow from 3000-5000 weakened

Conclusion

- Moored arrays give us some remarkable new information on what is going on in the oceans
- Data set is very short in all cases
- Using this brief data set for climate exploration must be done with caution
- With 30 or 40 year trends, we should begin to understand the large role that oceans play in climate control