The Gulf Stream, European climate and abrupt climate change, past and future

Richard Seager
Lamont Doherty Earth Observatory
Palisades, New York

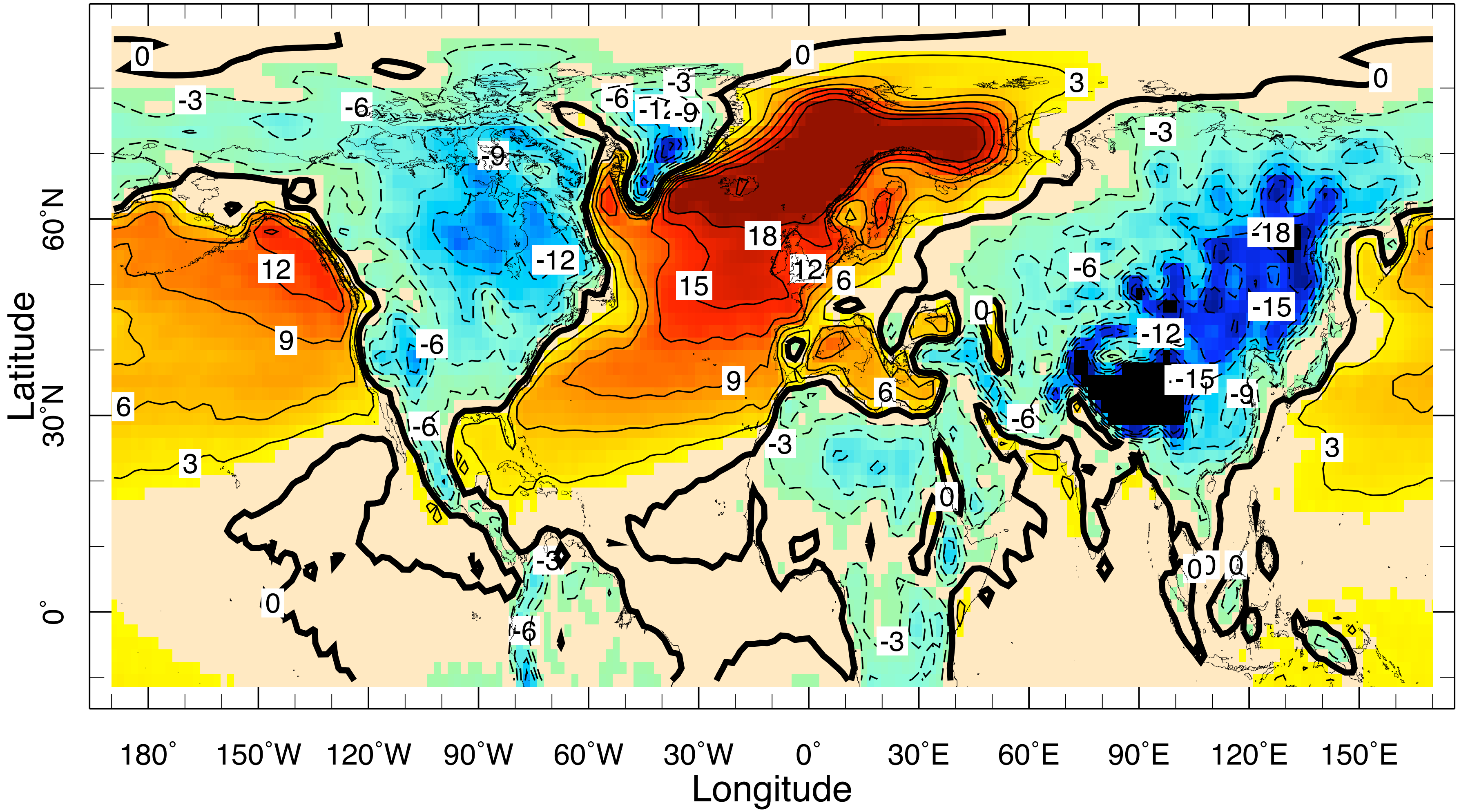
http://www.ldeo.columbia.edu/res/div/ocp/gs

Seager et al. (2002) *Quarterly Journal of the Royal Meteorological Society*
Seager (2006) *American Scientist*
Seager and Battisti (2007) In *The Global Circulation of the Atmosphere*, Schneider and Sobel, Eds., Princeton Univ. Press.

A typical spring day in Torbay, southwest England

A typical summer day in Newfoundland

Departure of Dec, Jan, Feb observed surface air temperature from zonal mean



2 m_above_gnd

A random survey of:

3, 643, 521, 489 people 12 and older
and
3, 867 oceanographers

revealed that almost all think this temperature difference is caused by THE GULF STREAM
(which, itself, was invented by Benjamin Franklin)

‘The Big Chill’, BBC documentary 2003

‘Our ports could be frozen over ... Ice storms could ravage the country ... It would be the biggest change in the British way of life since the last Ice Age ..’

‘In the end there came the terrifying revelation: the Gulf Stream, that vast current of water the keeps us warm, could be cut off.’

Gulf Stream Burials at Sea

Gulf Stream Burials at Sea

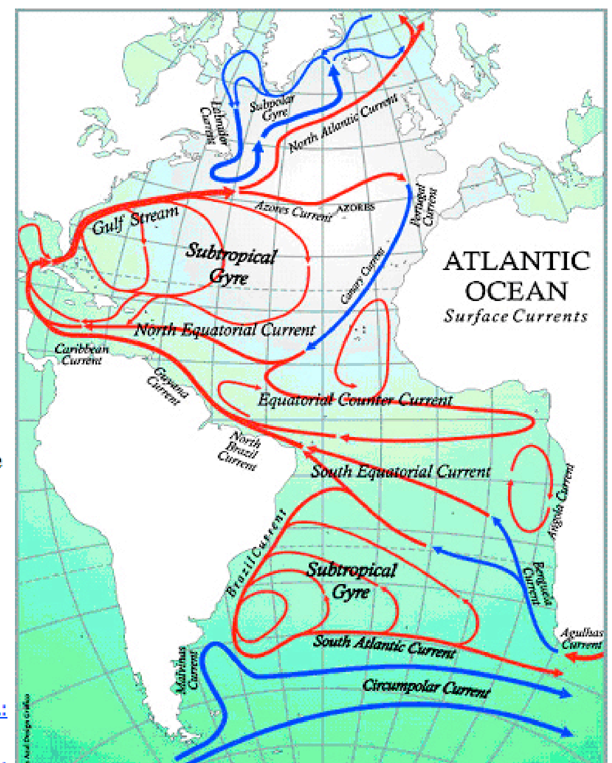
Honor your loved ones final request in the most affordable, dignified and unique way.

Each commitment is only **$125.00**

Call Toll Free to learn more **1-866-369-8069**

***Burial at Sea in the Gulf Stream**, will carry your loved ones ashes up the East coast of the United States, across to Europe, and eventually throughout the Atlantic Ocean's surface current systems.*

One of our clients said "My husband wanted to travel, now in my final tribute to him, he can".



Captain Bruce Sweet is a U.S. Coast Guard licensed Captain and Merchant Marine Mariner with boating experience dating back over forty years. His missions have sent him all over the world, but he makes his home in Jupiter, Florida with his wife Donna and their two children.

Captain Bruce is solely responsible for **Burial at Sea in the Gulf Stream**. He is certified by Sea Services, America's oldest provider of maritime funerals, to commit your loved ones ashes to their final resting place, the Gulf Stream.

View the current status of the Gulf Stream .:

Order Your Gulf Stream Burial at Sea Today .:

and it all started with ...

Matthew Fontaine Maury (Commander, U.S. Navy)

Maury (1855) *The Physical Geography of the Sea*

‘One of the benign offices of the Gulf Stream is to convey heat from the Gulf of Mexico, where otherwise it would become excessive, and to disperse it in regions beyond the Atlantic for the amelioration of the climate of the British Isles and all of western Europe.’

and were this not to happen ...

‘.. the soft climate of both France and England would be as that of Labrador, severe in the extreme, and ice-bound.’

‘Every west wind that blows crosses the stream on its way to Europe, and carries with it a portion of this heat to temper there the northern winds of winter. It is the influence of this stream upon climate that makes Erin the “Emerald Isle of the Sea”, and that clothes the shores of Albion in evergreen robes; while in the same latitude, on this side, the coasts of Labrador are fast bound with fetters of ice.’

Maury (Commodore, Confederate Navy) monument, Richmond, VA, (forever in residence next to Stonewall Jackson)

More modern researchers have picked up this idea (with noted loss of erudition)

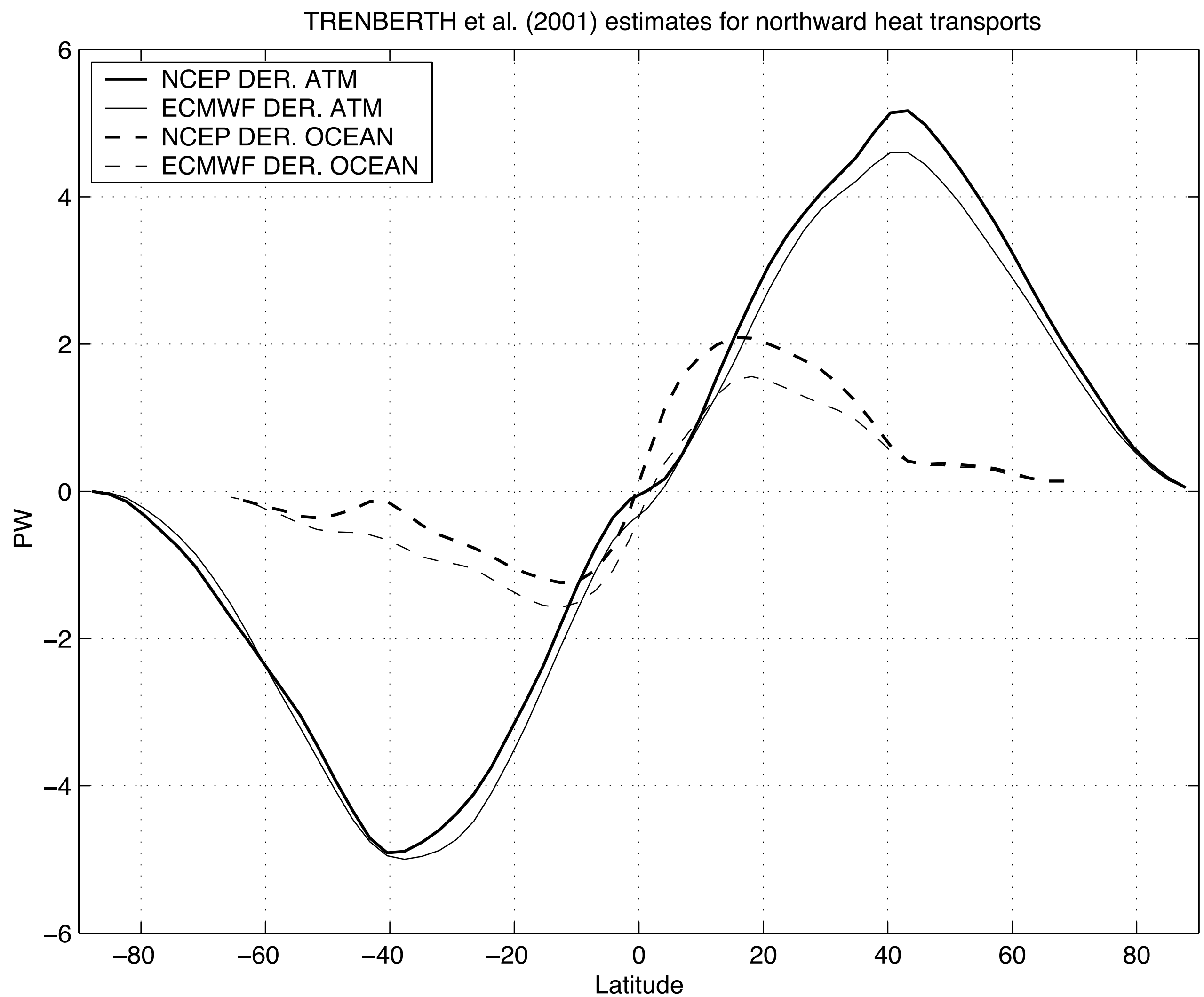
‘The Atlantic thermohaline circulation (THC) is an important component of the global climate system. In the North Atlantic the Gulf Stream transports enormous amounts of heat poleward (1PW) as part of the THC, thereby warming western Europe.’ (Latif et al. 2000)

‘One of the major elements of today’s ocean system is a conveyor-like circulation that delivers an enormous amount of tropical heat to the northern Atlantic. During winter, this heat is released to the overlying eastward moving air masses, thereby greatly ameliorating winter temperatures in northern Europe.’ (Broecker 1997)

First hint that this may all be myth comes from using observations to estimate atmosphere and ocean heat transports

Net radiation at top of atmosphere = divergence of (AHT + OHT)

Net radiation from satellites, AHT from weather obs and models, OHT from residual



Contributions of heat transports and seasonal heat release by ocean to zonal mean temperatures over the NH

- Winter atmospheric HT across 35N = 6PW or 54W/m2
- Annual mean (> winter) ocean HT across 35N = 1.3PW or 11W/m2
- Seasonal ocean heat release north of 35N
  (= heat release - absorbed solar - OHT) = 53W/m2

Assuming climate sensitivity of 2 W/m2 per deg C

Warming of area north of 35N is:

AHT	OHT	storage
27 C	6 C	27 C

Three determinants on European climate
(as a departure from the zonal mean):

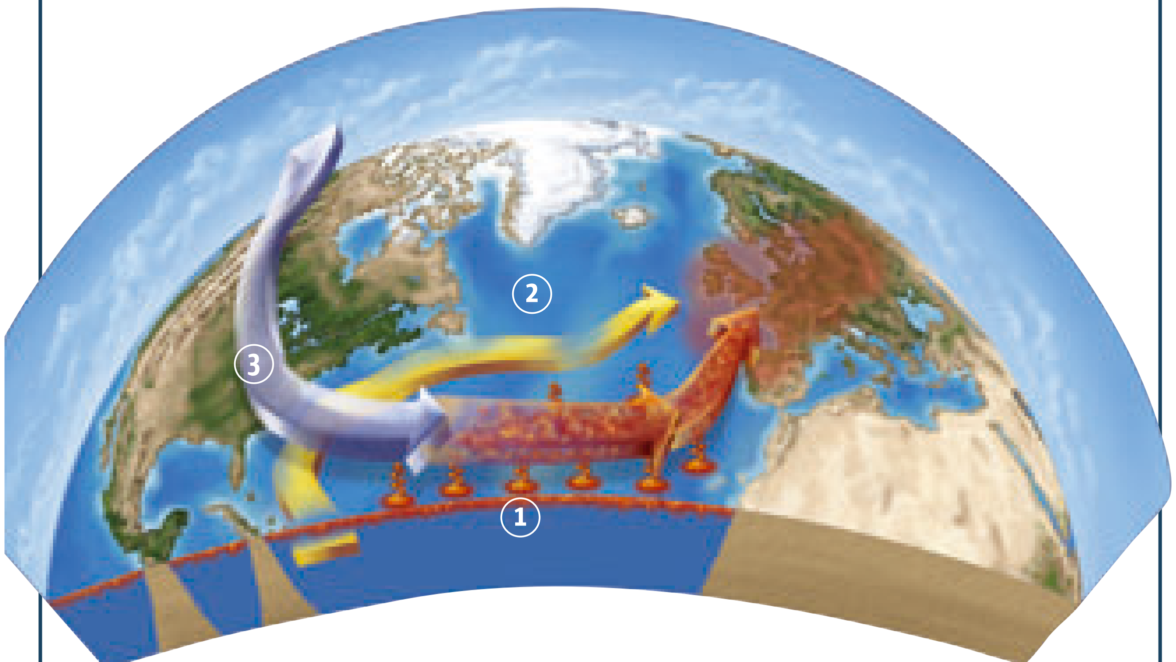
1. Summer storage and winter release of heat from the ocean and its effect on climate downstream

2. The pattern of movement of heat within stationary and transient atmospheric waves

3. The pattern of movement of heat by the ocean and release to the atmosphere

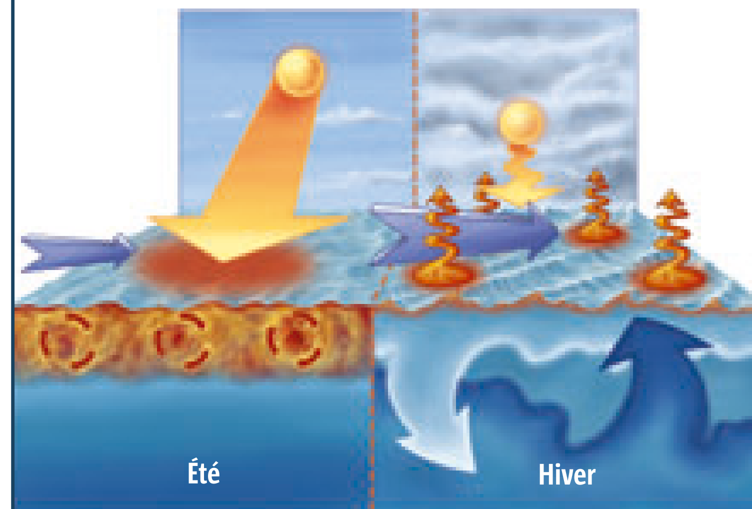
et, dans le français

Fig.2 Trois phénomènes en compétition



TROIS PHÉNOMÈNES PARTICIPENT AU CONTRASTE des températures hivernales entre les côtes atlantiques américaines et européennes, mais dans quelles proportions ? ① Le relargage dans l'atmosphère de la chaleur stockée pendant l'été dans la couche superficielle de l'océan. ② Le transport de chaleur par le Gulf Stream des subtropiques vers le nord et sa libération dans l'atmosphère. ③ Les grands méandres atmosphériques qui, en partie façonnés par les reliefs, s'étendent sur plusieurs milliers de kilomètres. En l'occurrence celui présent à l'est des montagnes Rocheuses, qui souffle depuis le nord de l'air froid sur l'est de l'Amérique du Nord et, depuis le sud, de l'air chaud vers l'Europe de l'Ouest.

Fig.1 L'action des vents



EN ÉTÉ, À LA FAVEUR D'UN ENSOLEILLEMENT PLUS FORT, la surface de l'océan se réchauffe. Les vents qui brassent les eaux superficielles de l'océan redistribuent cette chaleur sur une couche de quelques dizaines de mètres de profondeur. Cette couche dite « de mélange » stocke cette énergie. En hiver, l'ensoleillement est moindre et les vents beaucoup plus violents : l'océan se refroidit en surface et relargue sa chaleur dans l'atmosphère. Les eaux froides superficielles, plus denses (en bleu clair), plongent alors et sont remplacées par les eaux plus profondes, plus chaudes et moins denses (en bleu foncé).

Use Reanalysis data (1949-2000, a byproduct of numerical weather forecasting) to determine the mechanisms for generation of regional climates

Steady thermodynamic energy equation
(T=temperature, u,v,w =velocities, Q=diabatic heating, bar means monthly mean, prime departure from monthly mean)

$$
\begin{aligned}
&-\left\{\frac{\overline{u}}{a\cos\theta}\frac{\partial\overline{T}}{\partial\lambda}+\frac{\overline{v}}{a}\frac{\partial\overline{T}}{\partial\theta}\right\}-\bar{\omega}\left\{\frac{\partial\overline{T}}{\partial p}-\frac{R\overline{T}}{pc_p}\right\}\\
&\quad-\left\{\frac{1}{a\cos\theta}\frac{\partial(\overline{u'T'})}{\partial\lambda}+\frac{1}{a}\frac{\partial(\overline{v'T'})}{\partial\theta}\right\}-\left\{\frac{\partial(\overline{\omega'T'})}{\partial p}-\frac{R}{pc_p}(\overline{\omega'T'})\right\}=-\overline{Q}.
\end{aligned}
\qquad (1)
$$

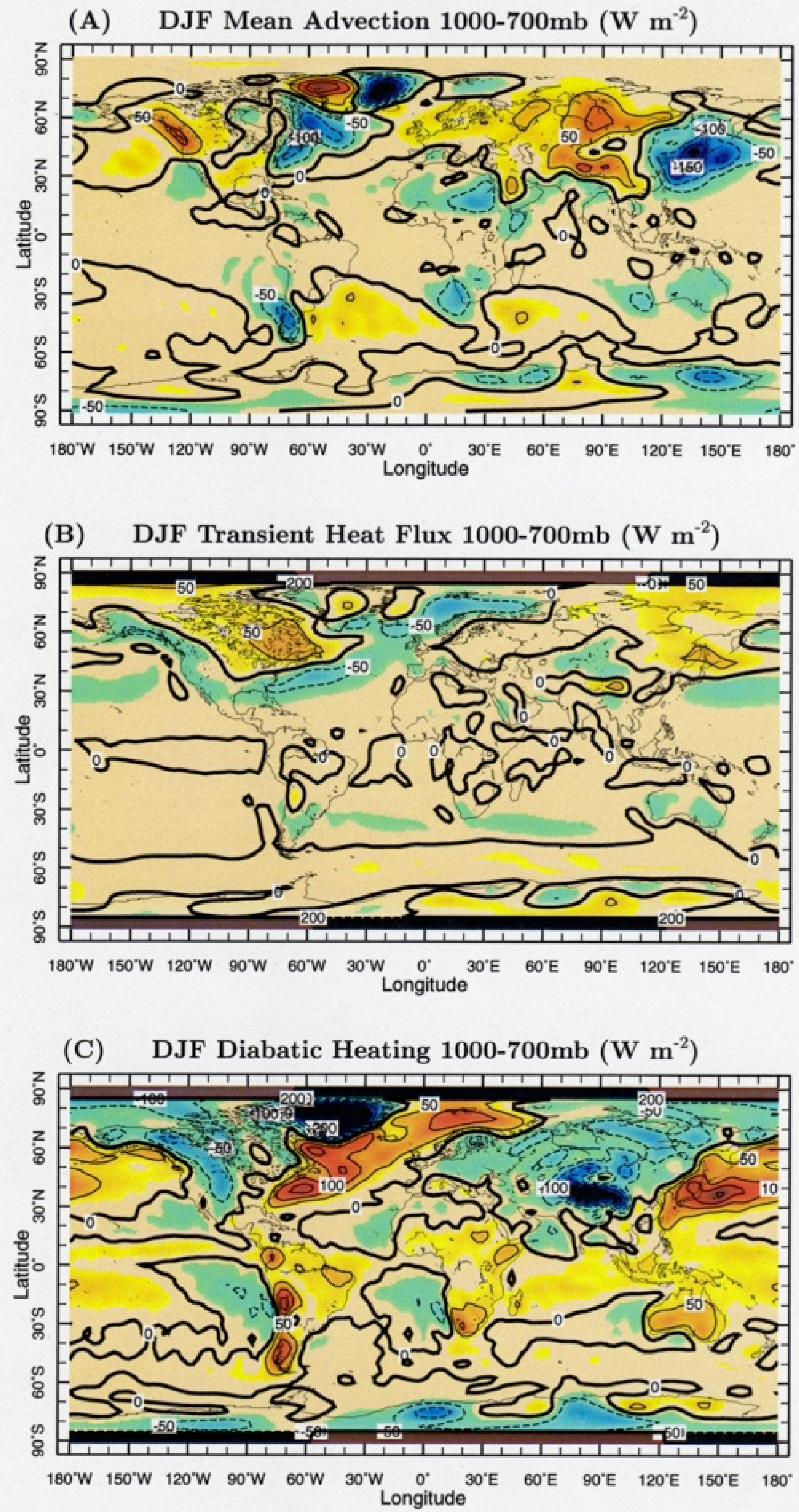
Advection of heat by monthly mean flow + convergence of heat by eddies (storms) = heating

T tendency due to:

monthly mean advection

convergence of heat by transient eddies

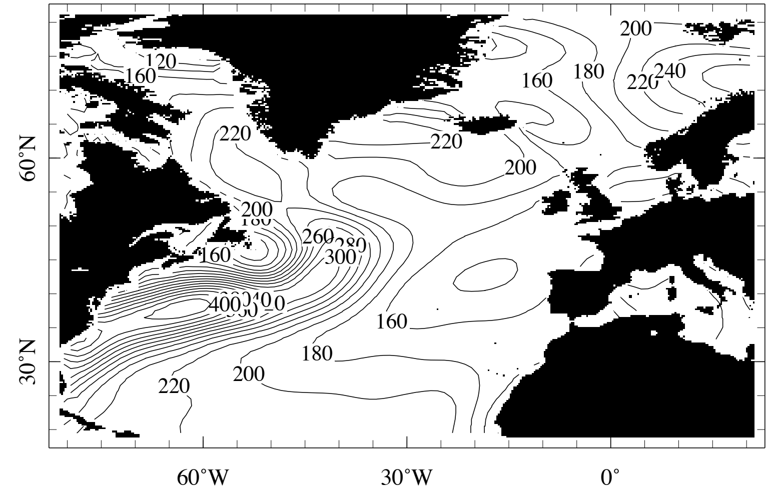
diabatic heating



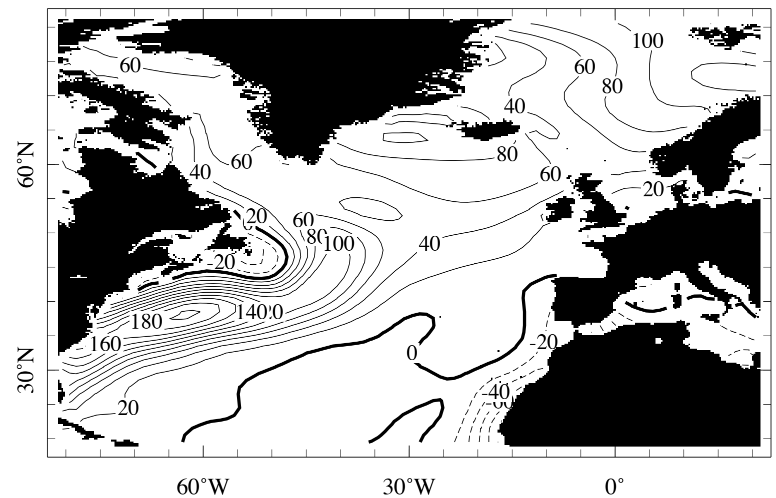
(c.f. Lau '79)

Dividing up the winter ocean heat release

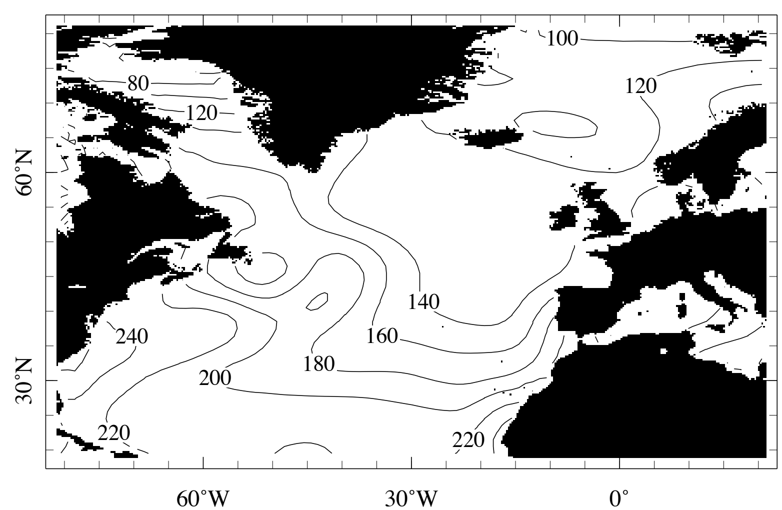
$$Q_{\mathrm{O}\to\mathrm{A}}^{\mathrm{winter}} = \mathrm{OHC} + Q_{\mathrm{O}\to\mathrm{A}}^{\mathrm{local}}.$$



ocean heat flux convergence



local winter ocean to atmosphere heat loss



Model experiments:

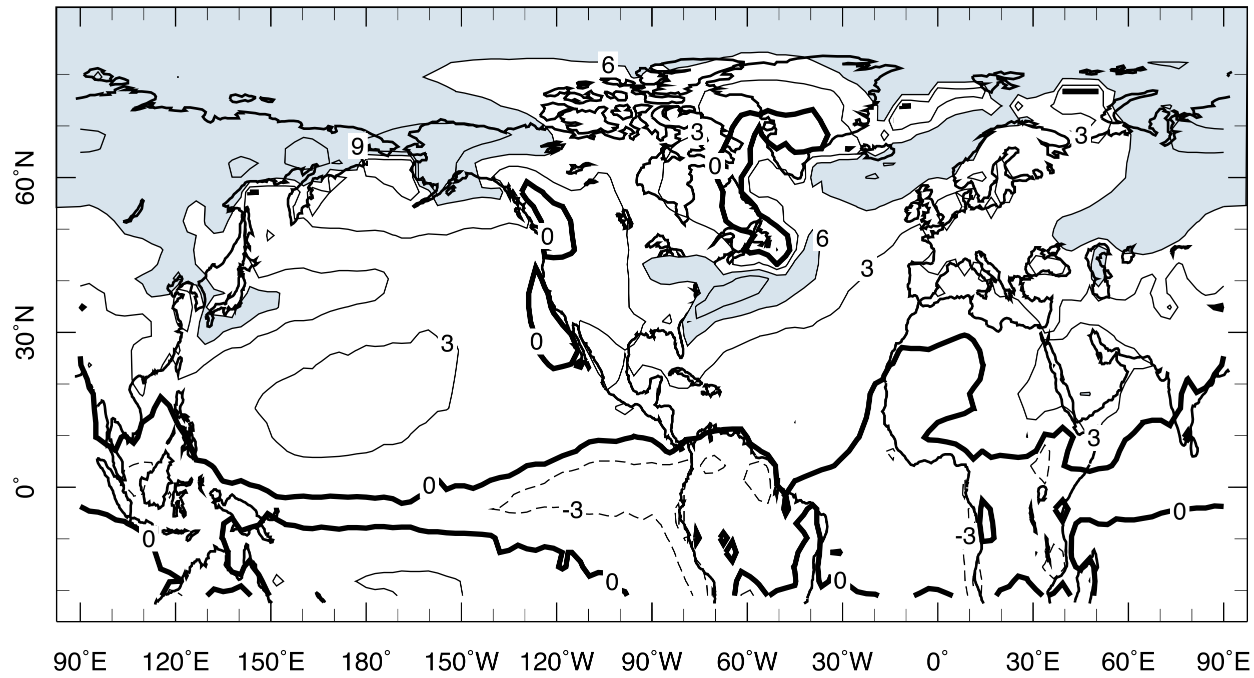
Use state-of-the-art atmospheric general circulation models coupled to:

1. An ocean with an ocean heat transport specified to ensure accurate simulation of sea surface temperature (SST)

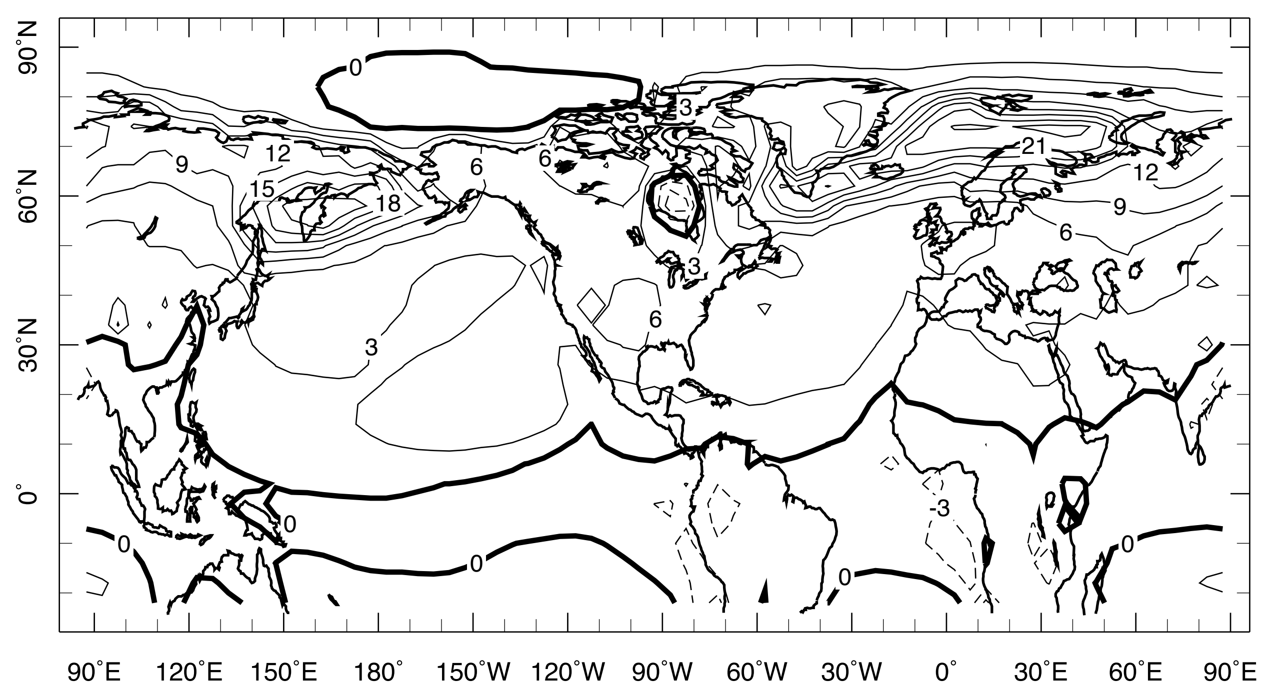
2. An ocean in which the ocean heat transport is zero but which still accounts for seasonal exchange of heat with the atmosphere and space

Difference in January surface air temperature (deg C) with OHT minus no OHT

CCM3 model, fixed sea ice



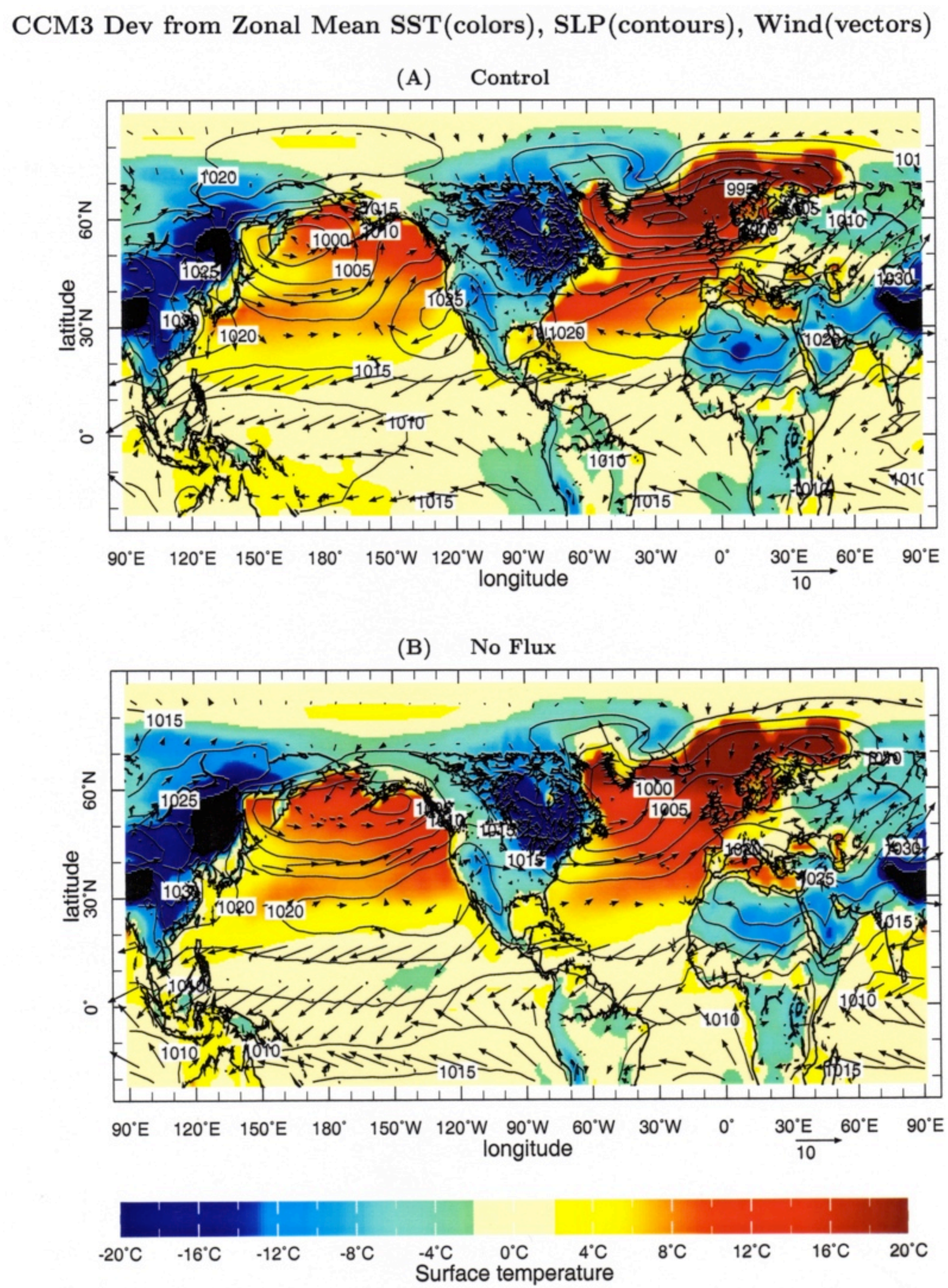
GISS model, interactive sea ice



Departure of winter temperature from zonal mean, CCM3 model

with OHT

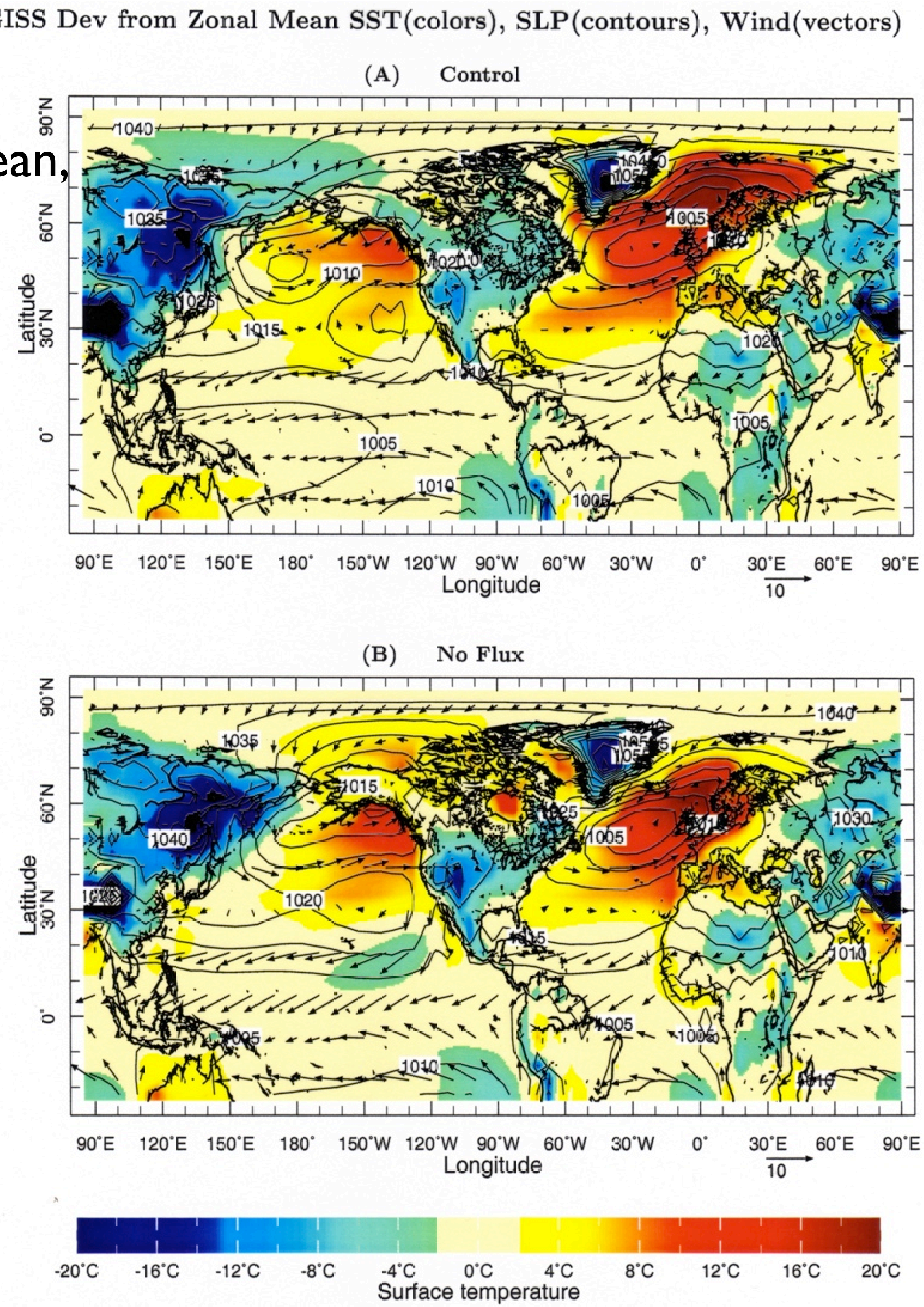
no OHT



Departure of winter temperature from zonal mean, GISS model

with OHT

no OHT



So ocean heat transport warms British Isles, France .. by 2-3 deg C *and eastern N. America by the same amount ...*

... leaving the much larger difference in winter temperature (15-20 deg C) across the ocean to be explained by other processes

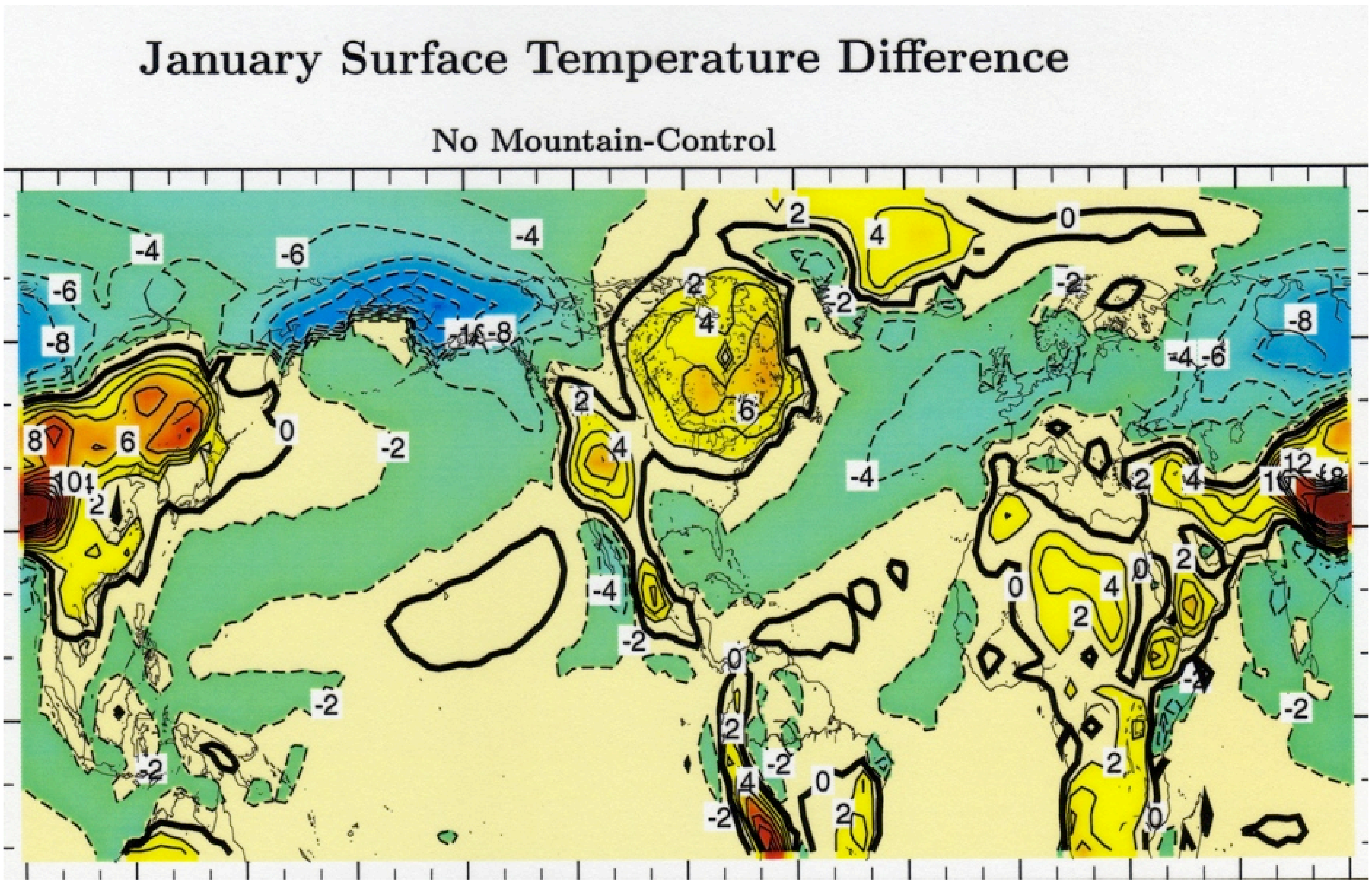
Granted, north of Bergen, OHT keeps winter sea ice at bay making surface air T above and downstream considerably warmer than otherwise would be.

So is the temperature contrast across the N. Atlantic explained by a simple maritime-continental climate distinction?

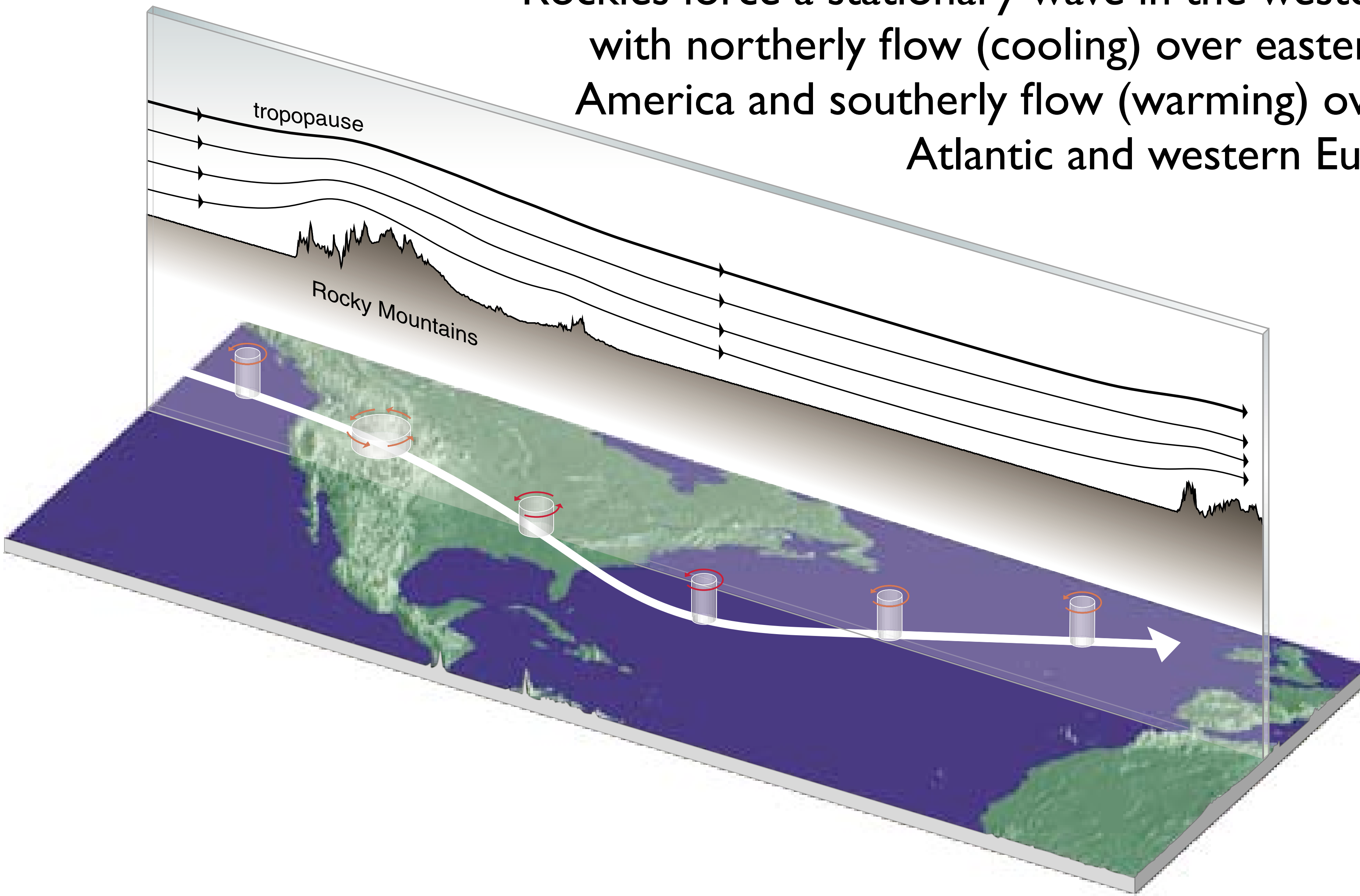
Thanks to the Rocky Mts., *NO*.

Rerun models with a flat Earth

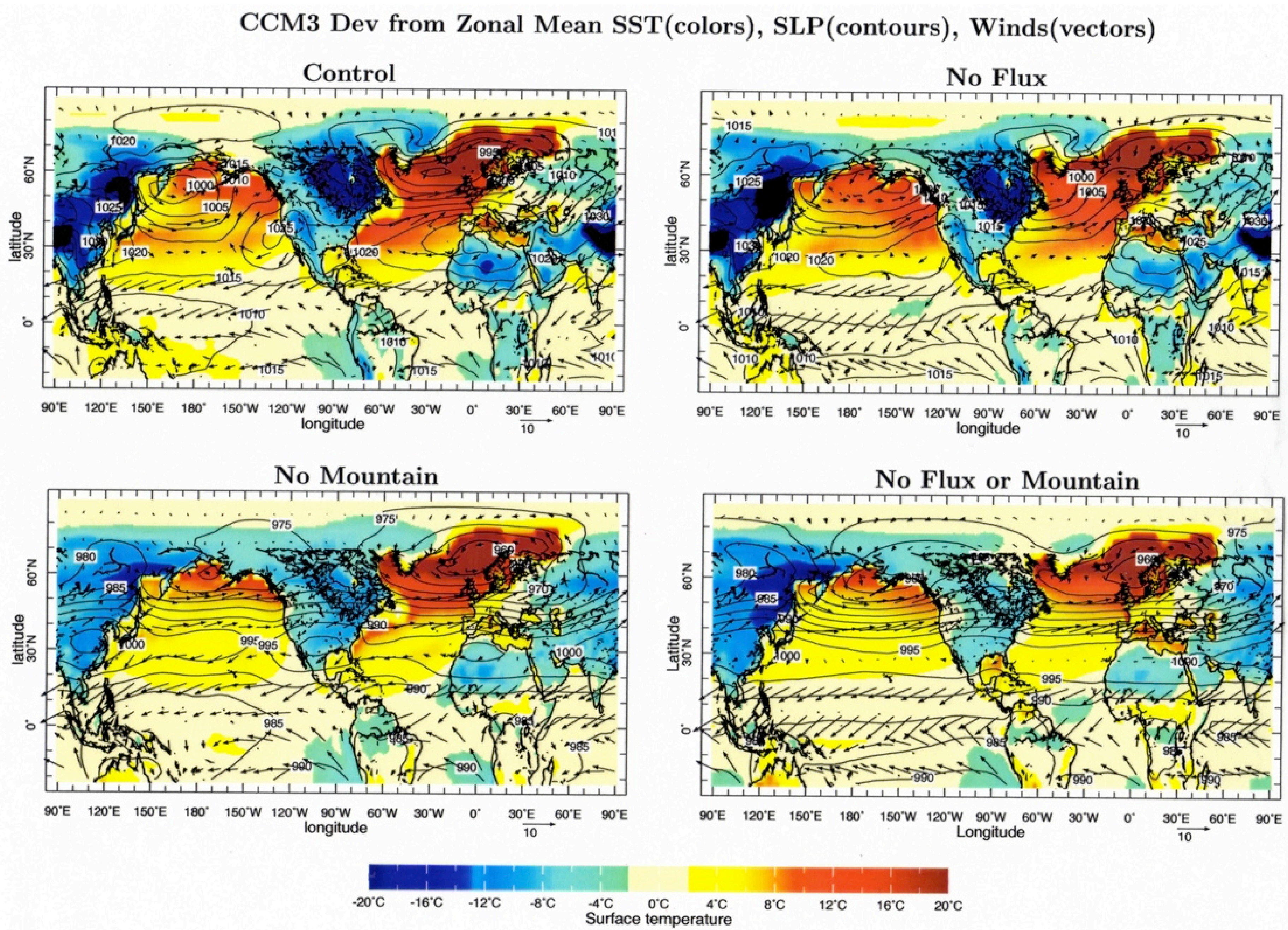
North-south flow forced by mountains cool eastern North America and warm western Europe



Because of need to conserve angular momentum, Rockies force a stationary wave in the westerlies with northerly flow (cooling) over eastern N. America and southerly flow (warming) over E. Atlantic and western Europe



T change due to mountains is caused by deepening of trough over western N. Atlantic and eastern seaboard



So does the larger extratropical ocean heat transport in the Atlantic than the Pacific explain the difference in climate between coastal northwestern Europe and coastal western North America?

TABLE 1. Atlantic minus Pacific near surface coastal air temperature (degC)

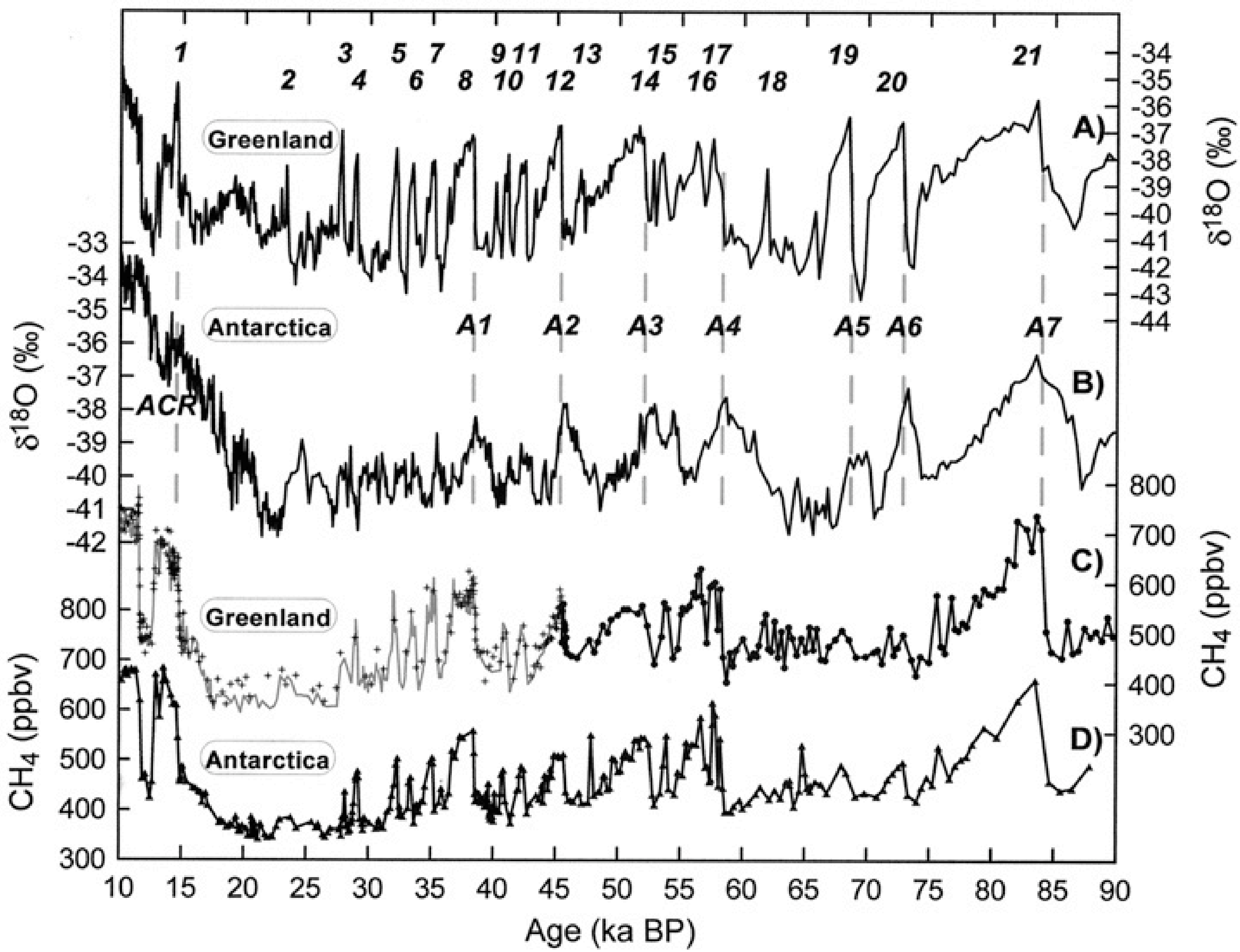
	Observations	GISS-ML		CCM3-ML	
		OHT	no OHT	OHT	no OHT
60°N	7	11	10	9	10
55°N	5	4	7	7	8
50°N	5	5	6	6	5

OHT = ocean heat transport. The Models GISS-ML and CCM3-ML are explained in the text.

No, this contrast remains intact with no ocean heat transport

Relevance to abrupt climate change

90,000 years of Greenland and Antarctic climate



- Rapid warmings (then cooling, then sudden cooling) in Greenland

- No such things in Antarctica

- bimodality in Greenland (Wunsch 2001)

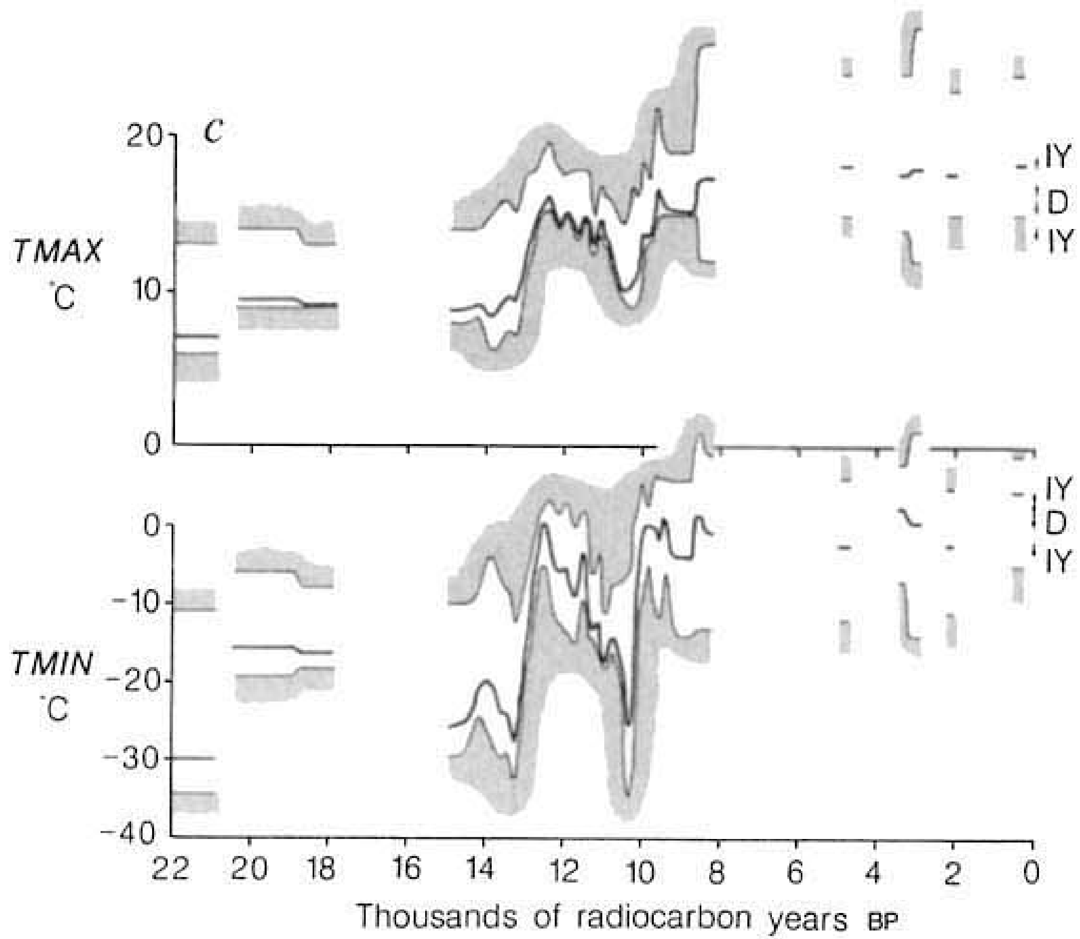
Blunier and Brook (2001)

Most recent abrupt change - the YD - was associated with dramatic cooling in Greenland and W. Europe **in winter** and little cooling in summer

e.g. Atkinson et al. (1987, beetles)

supported by periglacial and glacial evidence summarized by Denton et al. (2005)

max and min T in England

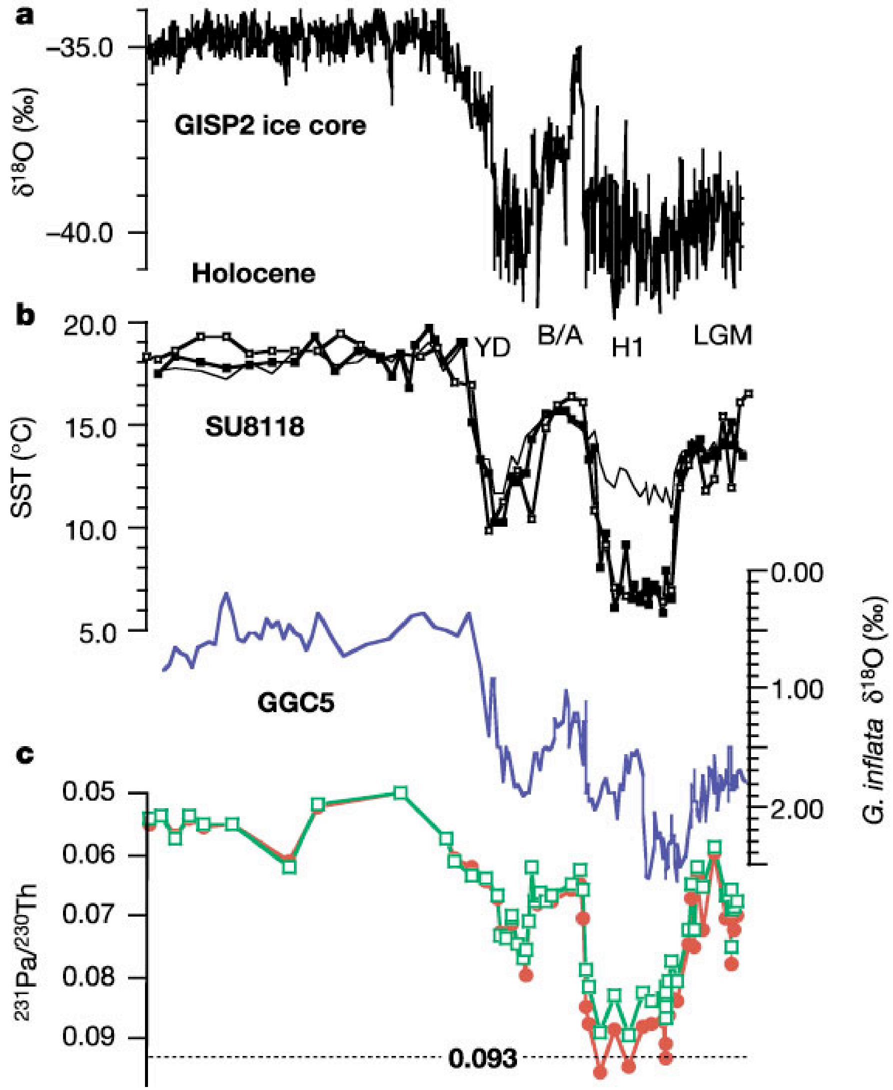


and it was accompanied by abrupt changes in N. Atlantic deep ocean circulation

Greenland

Subpolar N Atlantic SST

overturning circulation proxy, Bermuda rise



Claim:

'drop dead' circulation between LGM and B/A warm transition

Abrupt resumption of MOC ~14.7 kyr BP coinciding with B/A warm period

Partial reduction of MOC in YD

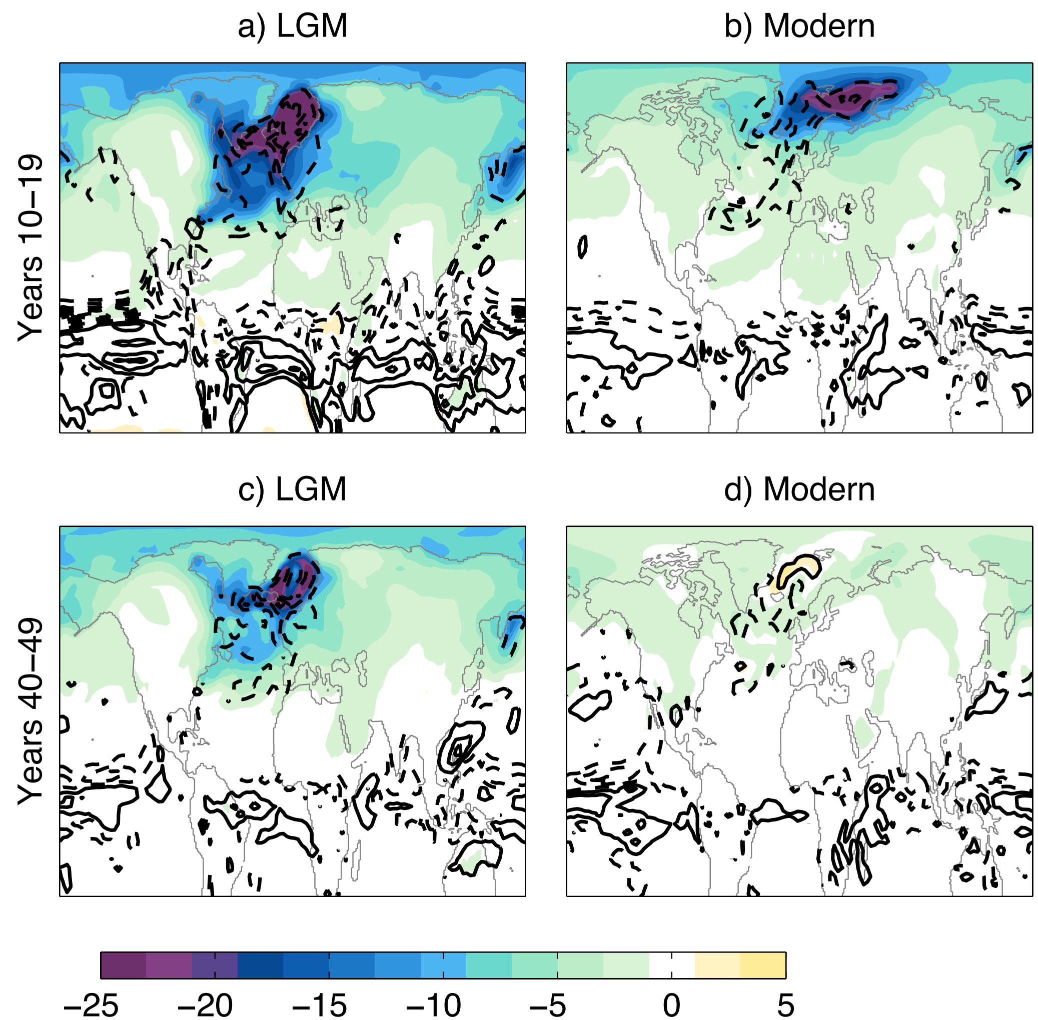
McManus et al. (2004)

However, changes in MOC alone cannot account for Younger Dryas climate change

For MOC off:

- Magnitude of the winter temp change around N. Atlantic (even accounting for sea ice in LGM world) too small
- The magnitude of the tropical/subtropical temperature response too small
- Impact on Asian monsoon unclear
- SH?

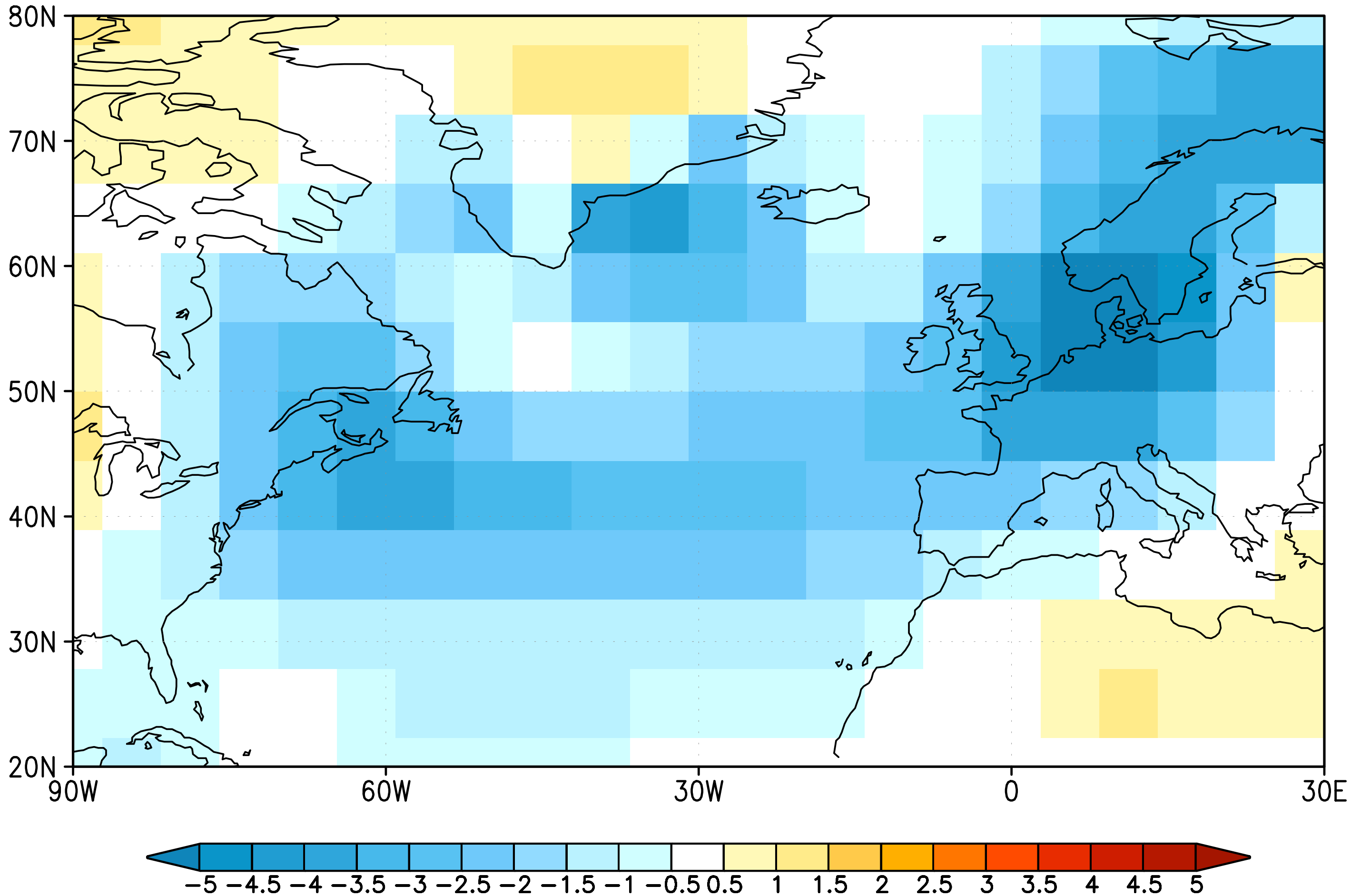
DJF T and P change for MOC off



Cheng et al. (2006)

European temperature is actually more sensitive to a forced change to a zonal (E-W) jet and storm track:

Surface air T change, zonal jet minus modern climatology



van de Schrier et al. (2007)

Implications for anthropogenic climate change

Climate model projections of the 21st Century do show, to varying extents, a weakening of the N. Atlantic meridional overturning circulation forced by subpolar surface warming and freshening

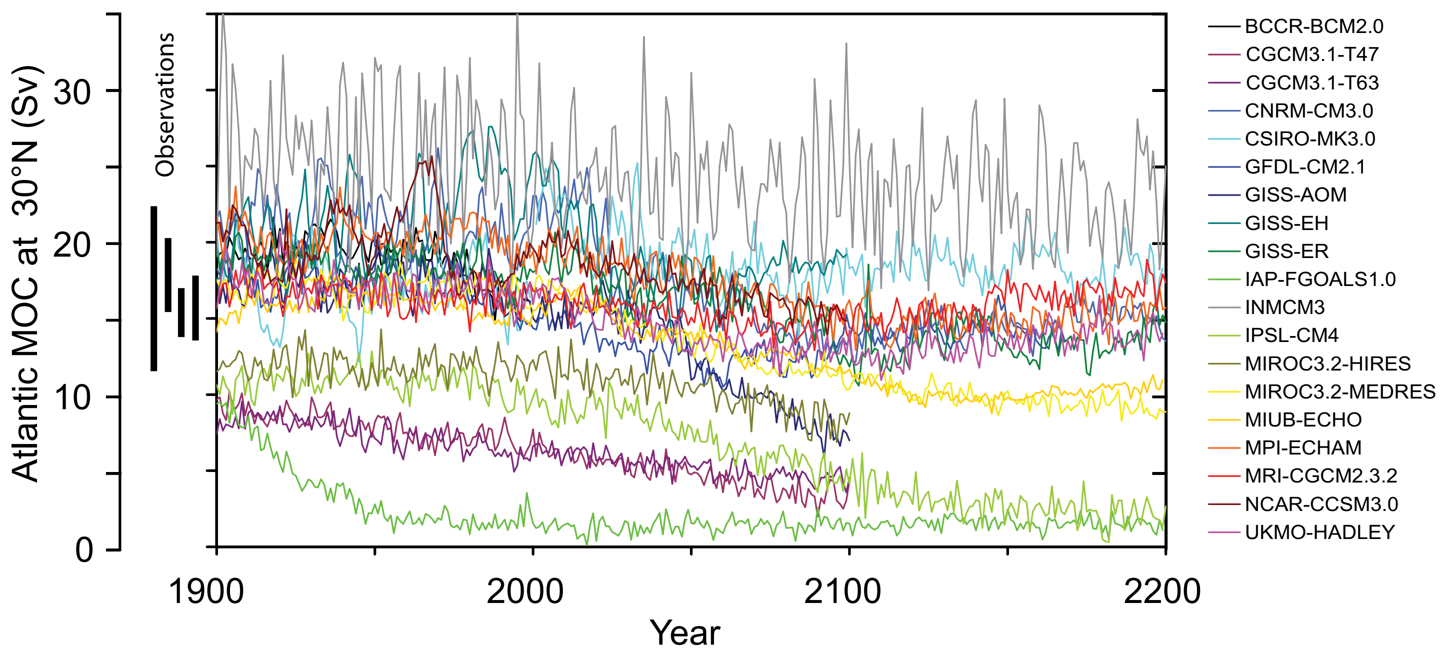


Figure 10.15. *Evolution of the Atlantic meridional overturning circulation (MOC) at 30°N in simulations with the suite of comprehensive coupled climate models (see Table 8.1 for model details) from 1850 to 2100 using 20th Century Climate in Coupled Models (20C3M) simulations for 1850 to 1999 and the SRES A1B emissions scenario for 1999 to 2100. Some of the models continue the integration to year 2200 with the forcing held constant at the values of year 2100. Observationally based estimates of late-20th century MOC are shown as vertical bars on the left. Three simulations show a steady or rapid slow down of the MOC that is unrelated to the forcing; a few others have late-20th century simulated values that are inconsistent with observational estimates. Of the model simulations consistent with the late-20th century observational estimates, no simulation shows an increase in the MOC during the 21st century; reductions range from indistinguishable within the simulated natural variability to over 50% relative to the 1960 to 1990 mean; and none of the models projects an abrupt transition to an off state of the MOC. Adapted from Schmittner et al. (2005) with additions.*

Despite this weakening of the MOC, the North Atlantic region and surrounding regions are still projected to warm as radiation wins

Projected T change (IPCC 2007)

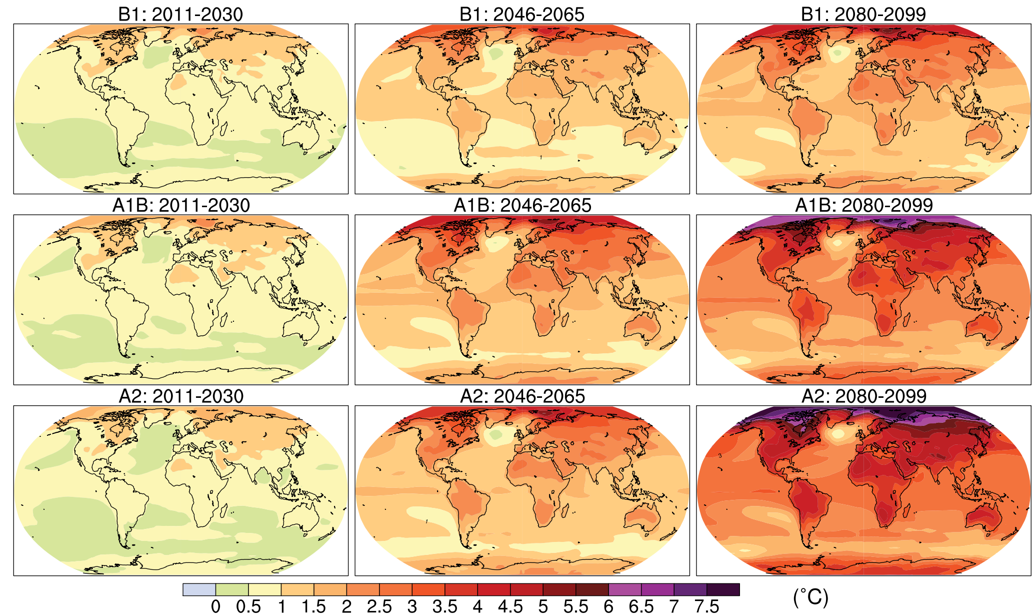


Figure 10.8. *Multi-model mean of annual mean surface warming (surface air temperature change, °C) for the scenarios B1 (top), A1B (middle) and A2 (bottom), and three time periods, 2011 to 2030 (left), 2046 to 2065 (middle) and 2080 to 2099 (right). Stippling is omitted for clarity (see text). Anomalies are relative to the average of the period 1980 to 1999. Results for individual models can be seen in the Supplementary Material for this chapter.*

Which is consistent with the limited T impact of an MOC shutdown (Vellinga and Wood 2002)

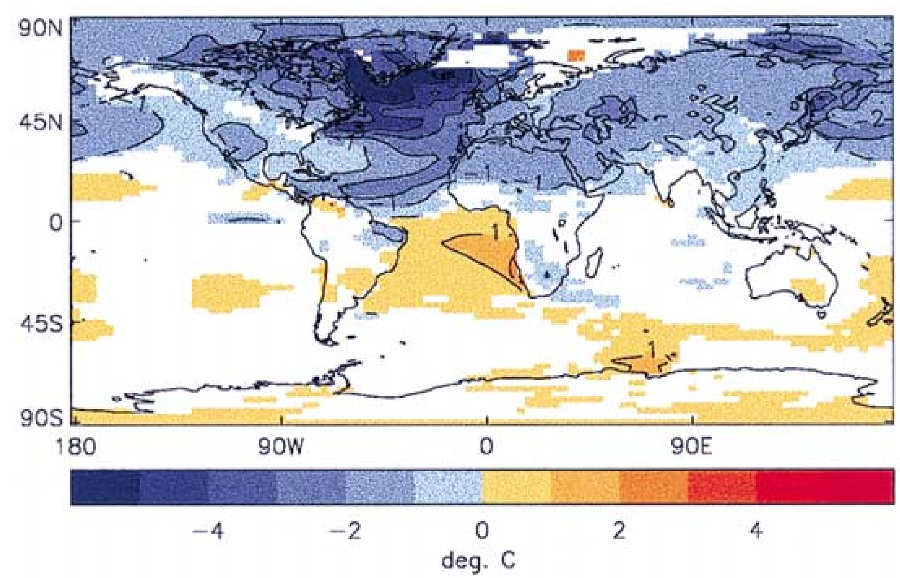
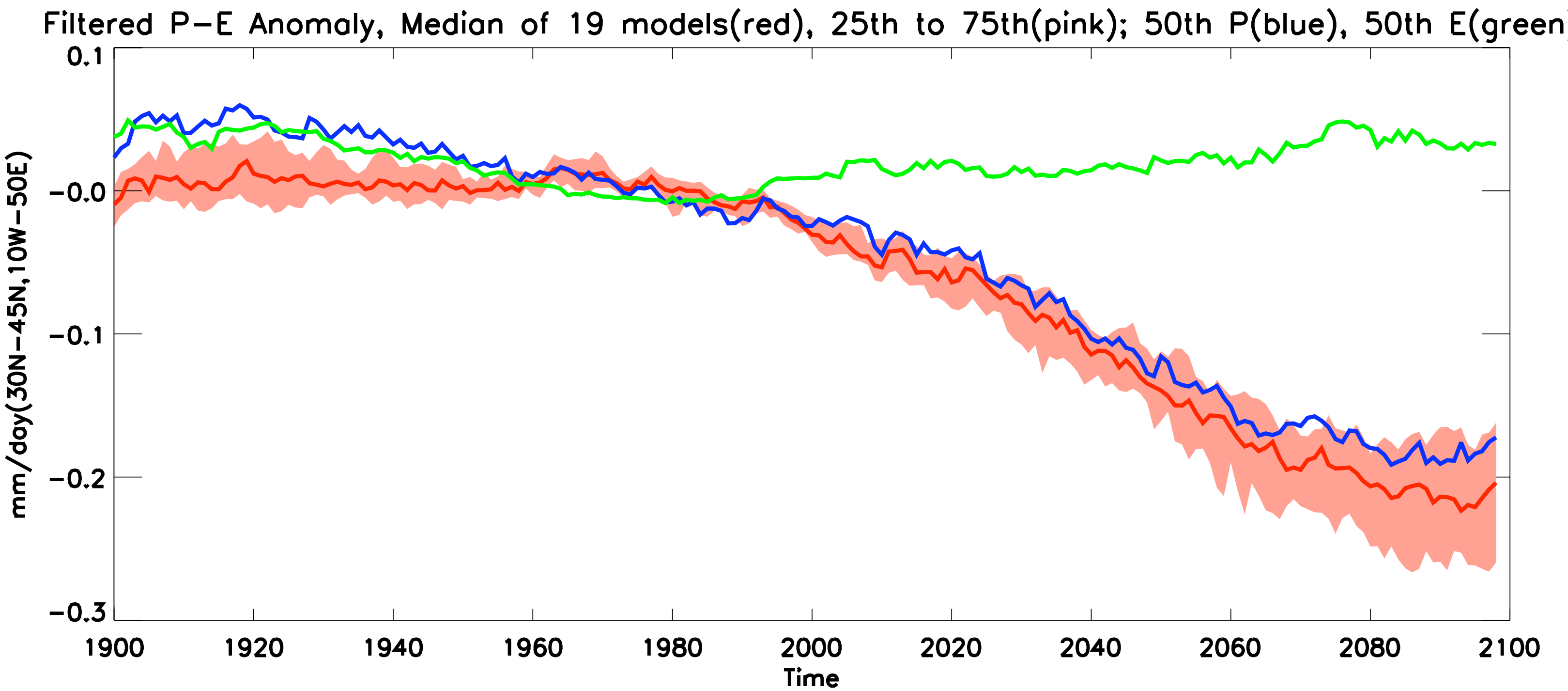
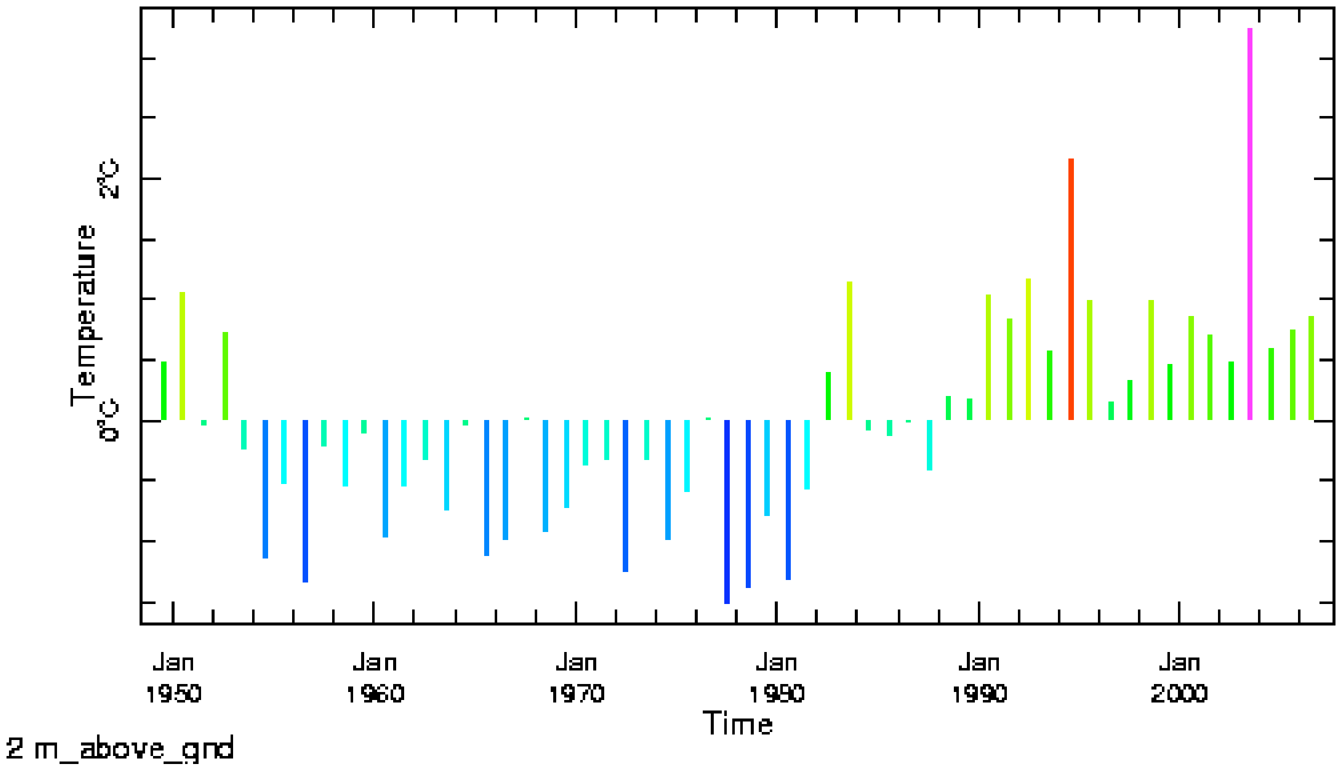


Figure 3. Change in surface air temperature during years 20–30 after the collapse of the THC. Areas where the anomaly is not significant have been masked.

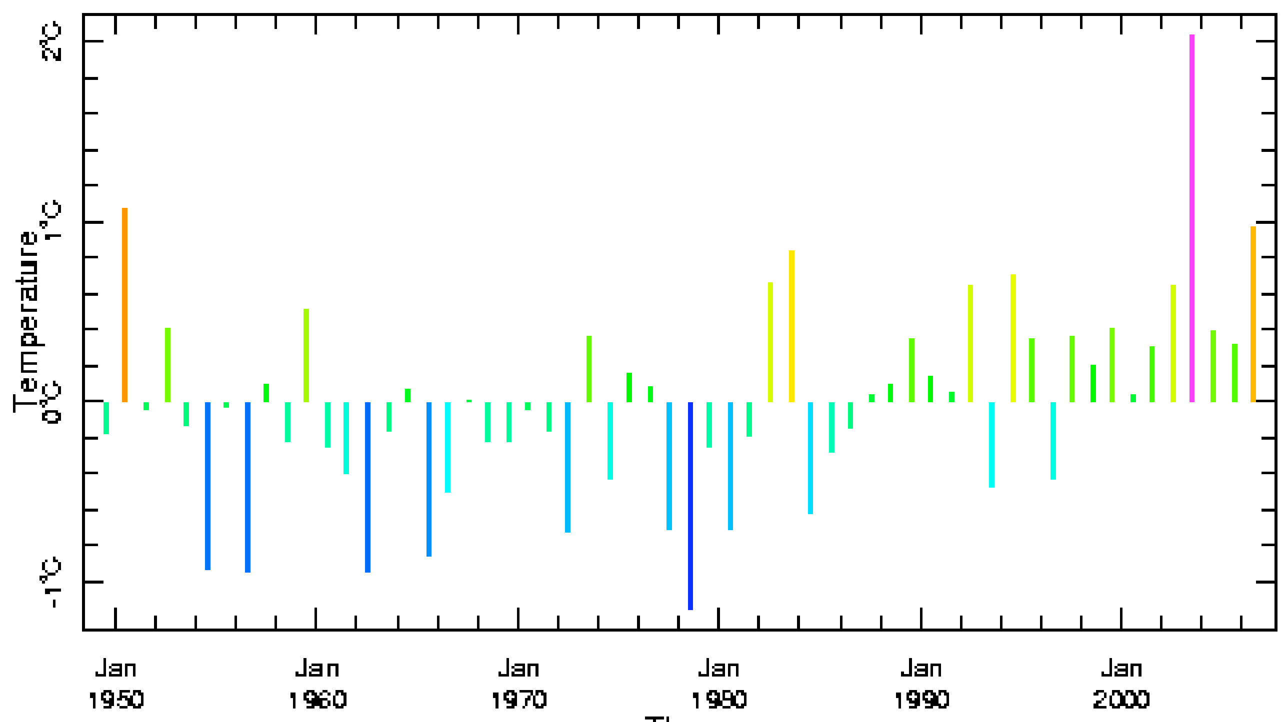
Which is not to say Europe has not climate change to worry about



Models robustly produce an imminent, or already underway, further aridification of Mediterranean region that is scary (and has nothing at all to do with ocean circulation).



Maximum summer T anomaly over W. Europe 1949-2006



Minimum summer T anomaly over W. Europe 1949-2006

Conclusion

The climate system is so rich, complex, and still not well understood that the current emphasis on the limited impacts of the Gulf Stream and North Atlantic Ocean circulation is ***a serious distraction of effort and resources*** when many regions of the world face a truly worrying future, even in the near-term.

Priorities should shift to:

Subtropical droughts
Summer heat waves
Loss of glacial ice forcing sea level rise
Severe storms and extreme weather
Water, water, water (and not so much temperature)