Where does the heat go when the surface temperature trend is flat?

Gerald A. Meehl

Julie Arblaster, John Fasullo, Aixue Hu and Kevin Trenberth

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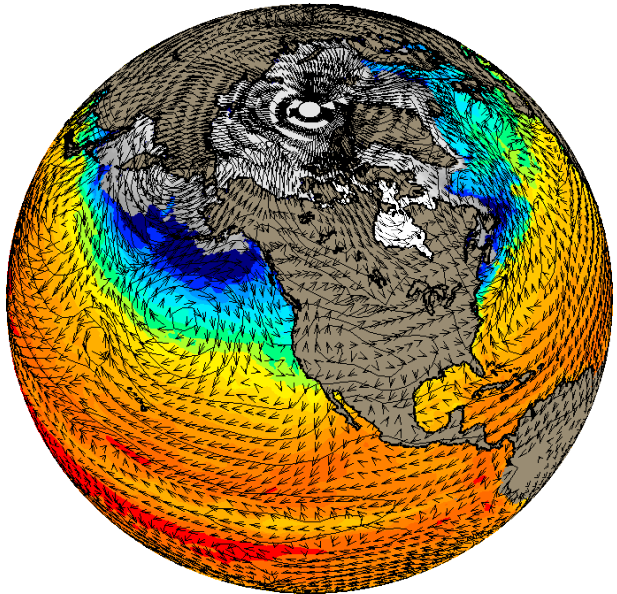
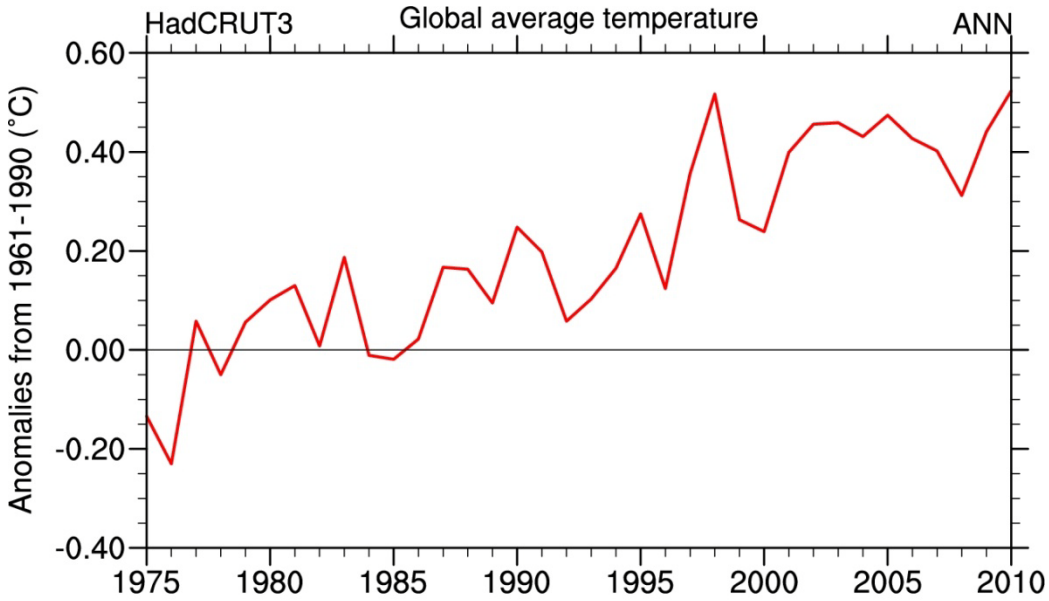
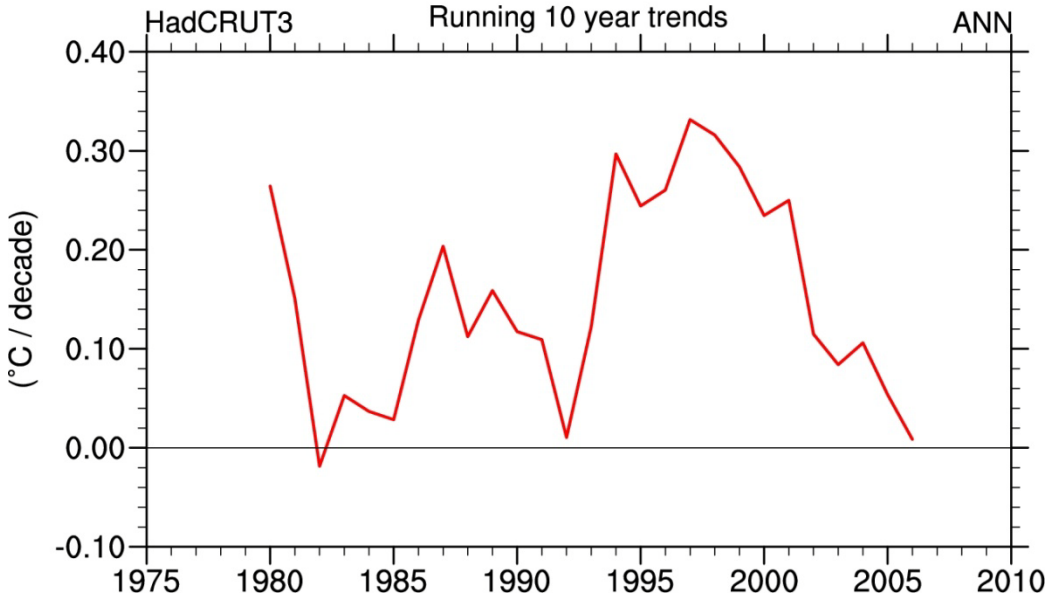


NCAR

There have been decades (e.g., the past ten years or so) when the observed globally averaged surface air temperature time series shows little or even slightly negative trend (termed "hiatus periods").



However, the net energy imbalance at the top of the atmosphere indicates that a net energy flux into the climate system of about 1 Wm^{-2} should be producing warming somewhere in the system

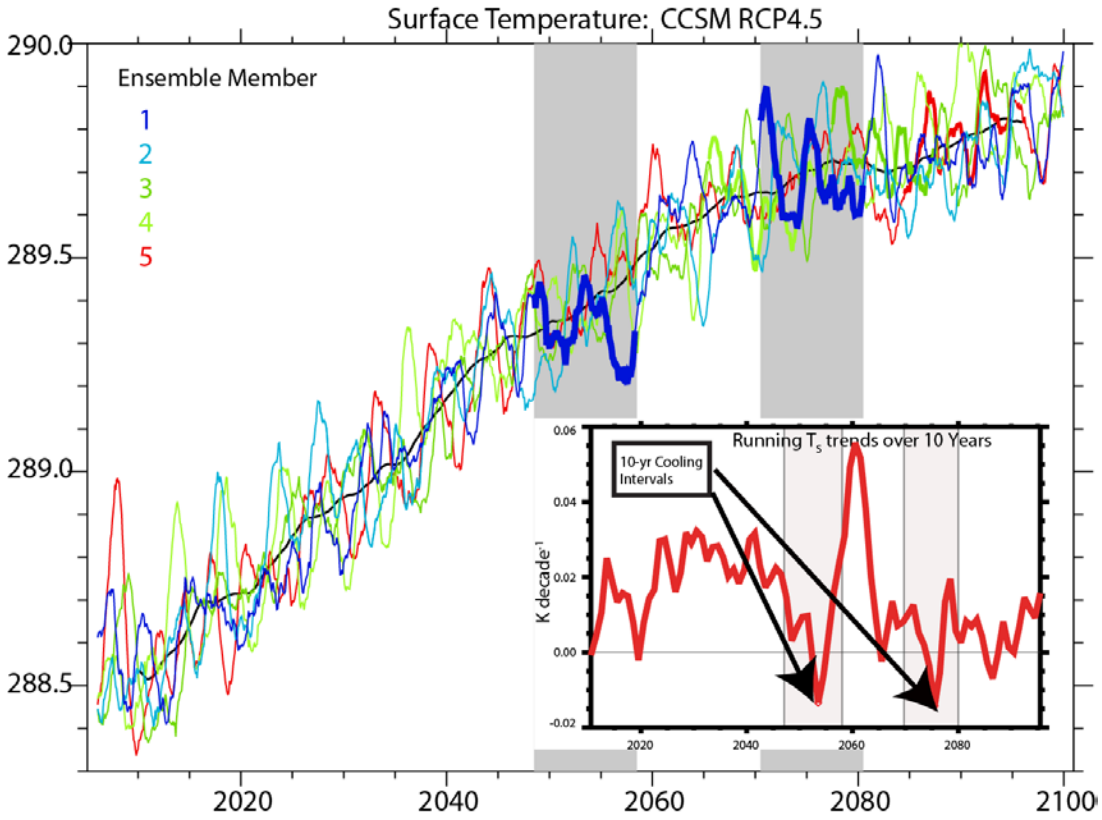


To provide clues as to where to look for this missing heat, here we use CCSM4 and examine 10 year periods of slightly negative globally averaged surface air temperature trend (linear trend is less than -0.10°C)

Five ensemble members of CCSM4 run with RCP4.5 are analyzed.

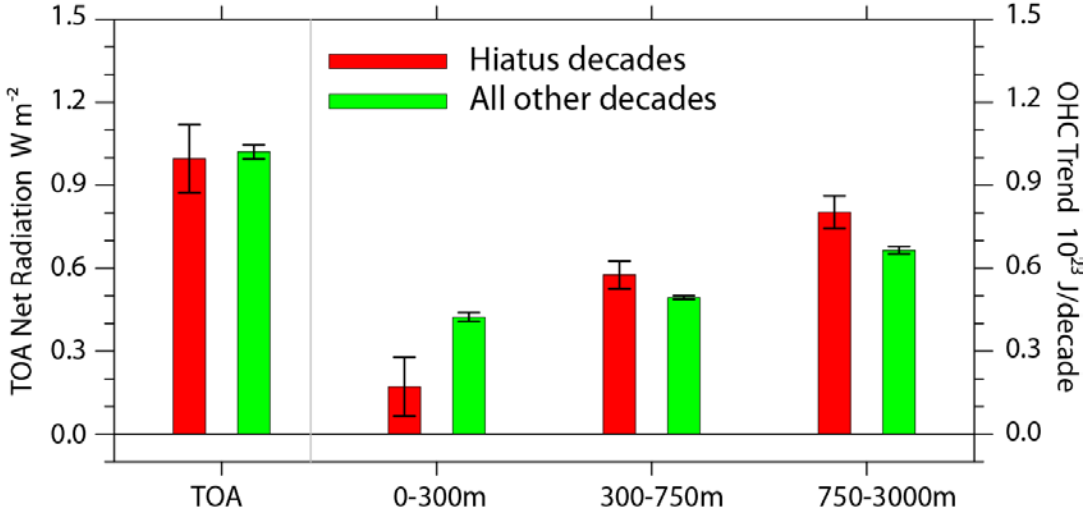
Pick 8 decades from the five ensemble members when the surface temperature trend is less than -0.10°C/decade

Two of these decades from one ensemble member are highlighted here

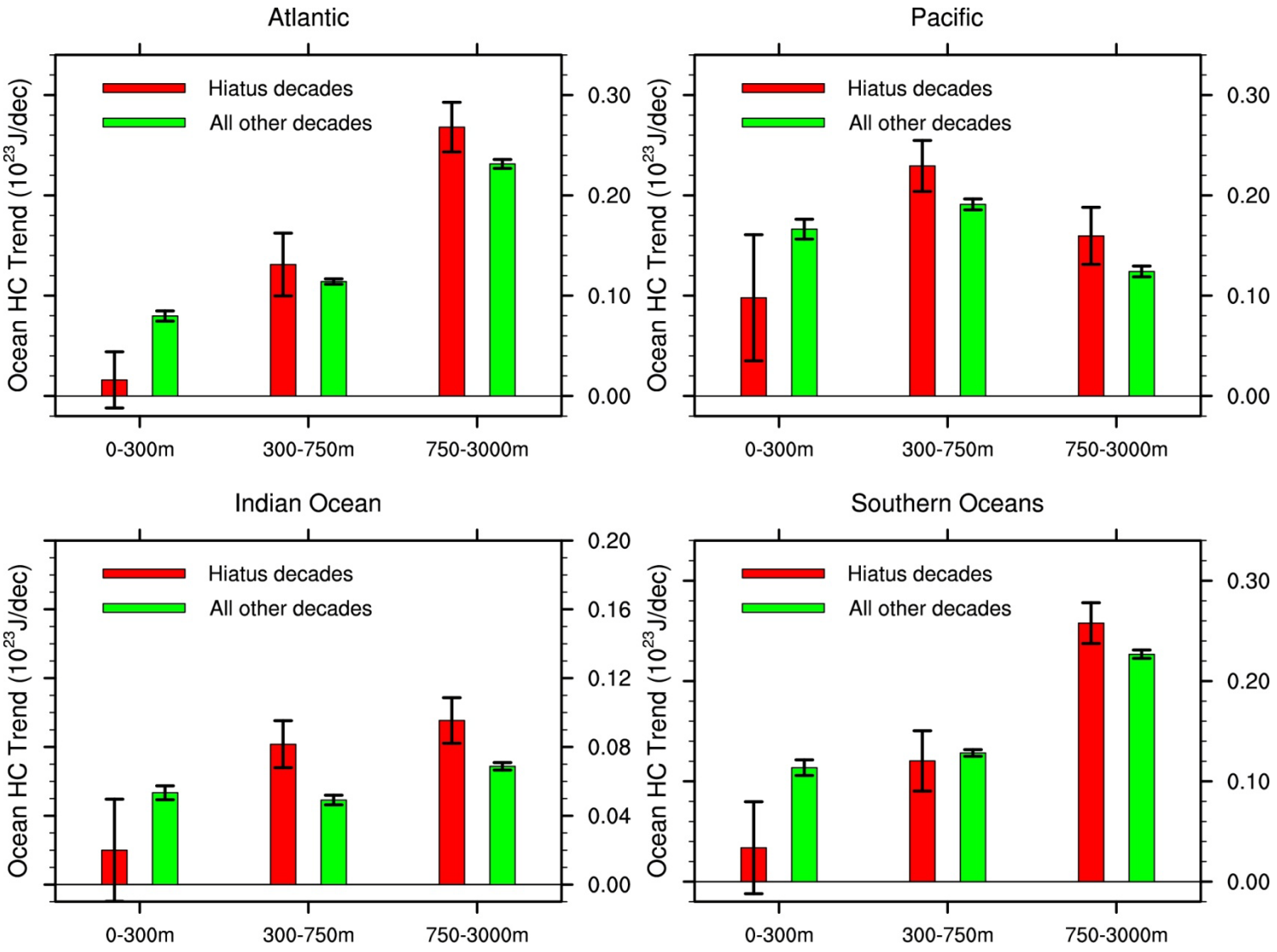


Net top-of-atmosphere radiation in hiatus periods as well as all other decades is about 1 Wm^{-2} (i.e. the system is gaining heat)

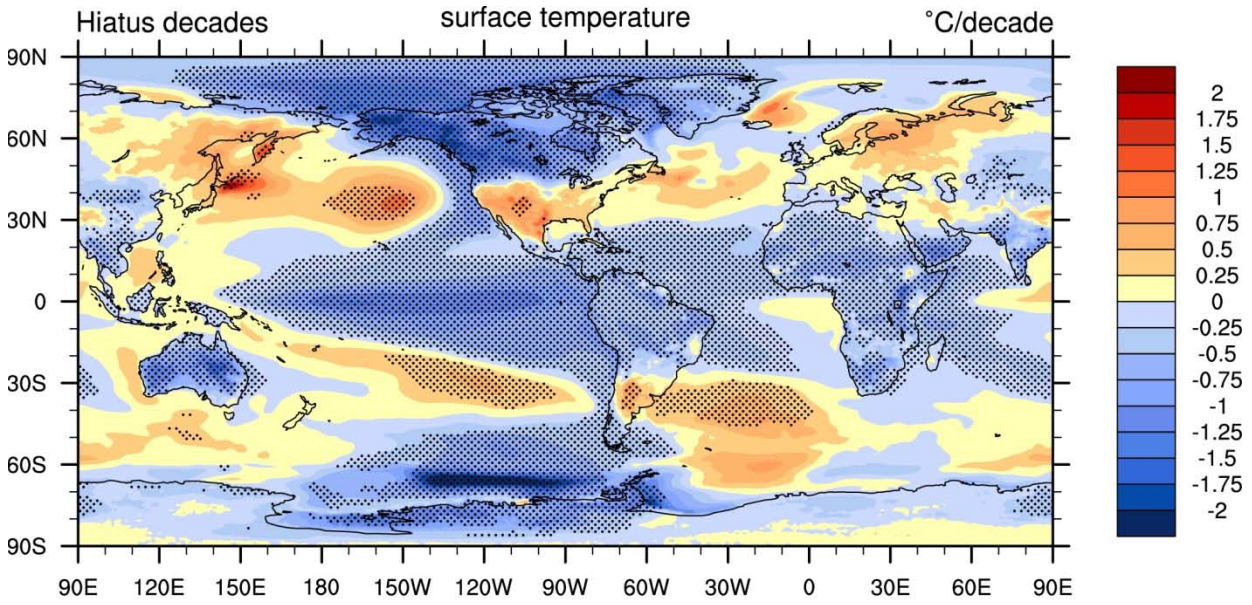
During hiatus periods, trends of upper ocean heat content are reduced, but are greater in layers below 300m



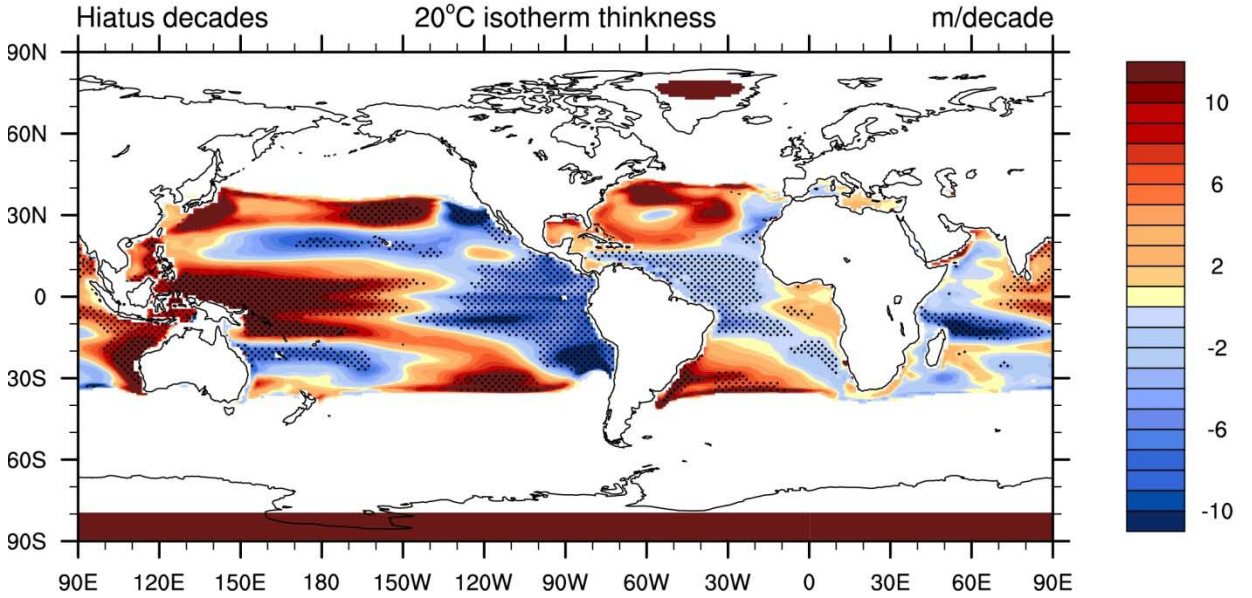
In Atlantic and Southern Ocean, layer below 750m is gaining significantly more heat
In Pacific, it's the mid-ocean layer (300-750m)



During hiatus periods, SSTs in most tropical oceans are anomalously cool; subtropical ocean areas are anomalously warm

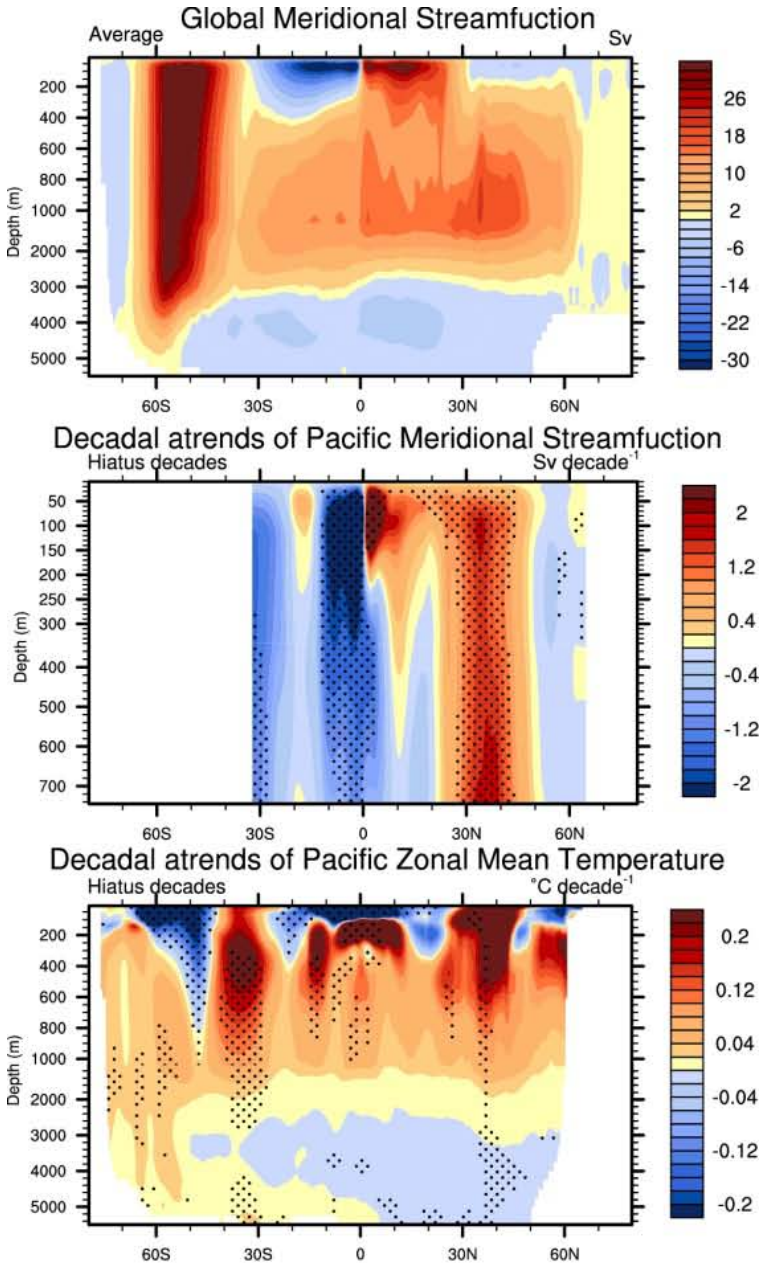


Anomalous 20°C isotherm depth during hiatus periods shows most subtropical ocean areas have thicker warmer layers

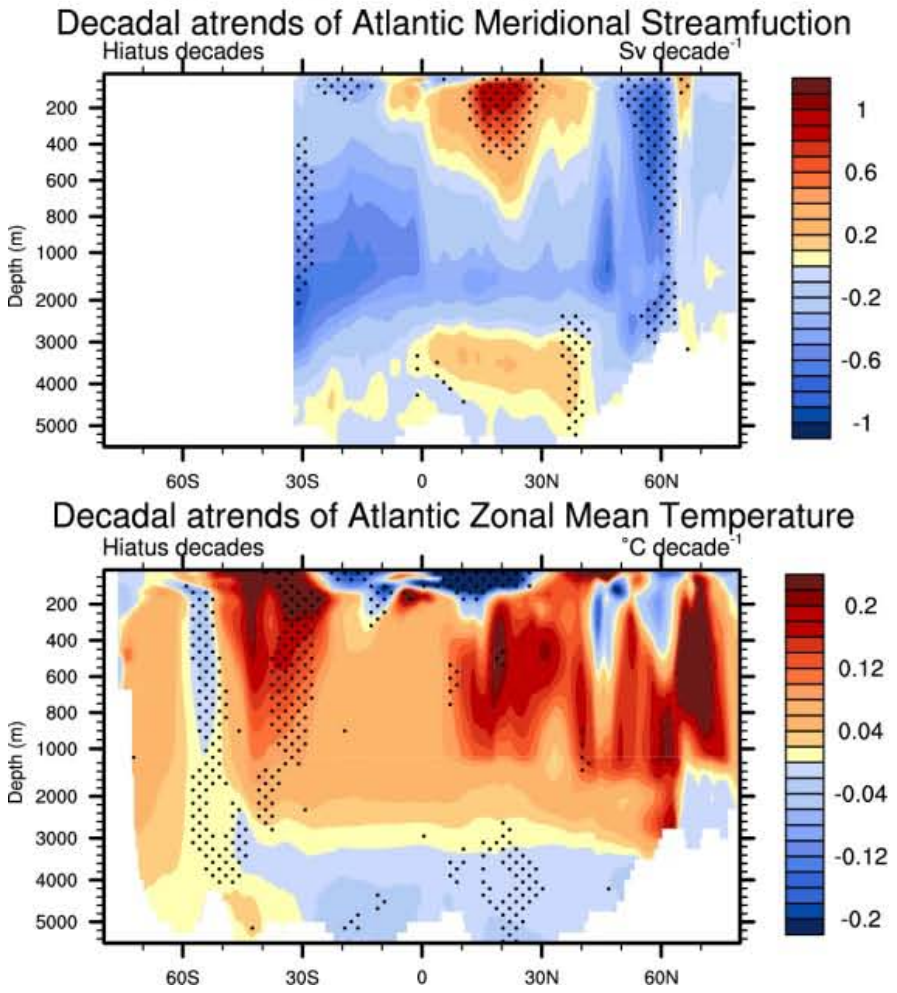


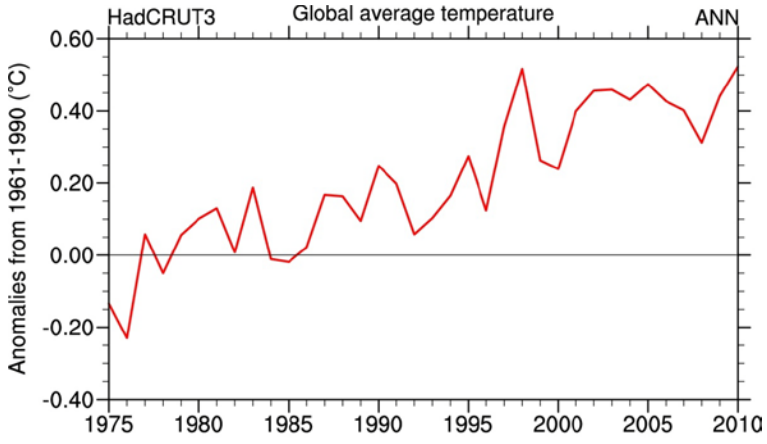
In the Pacific during hiatus periods, the subtropical cells are intensified, bringing up cool water in the equatorial tropics and taking warm water down in the subtropics

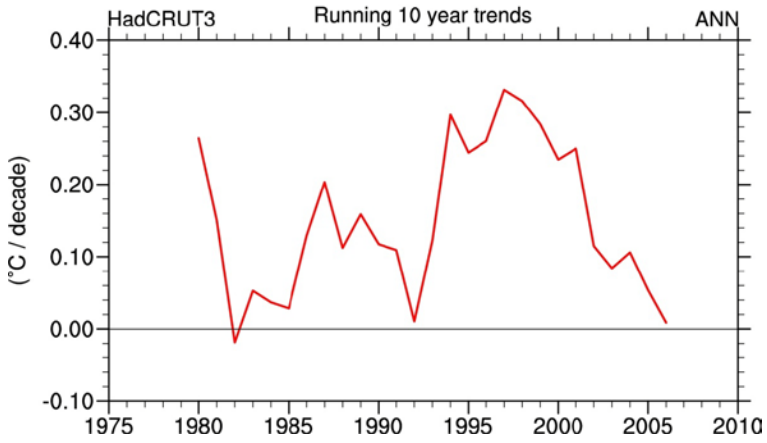
Warmer water at depth at high southern latitudes indicates a weakening of the Antarctic Bottom Water formation

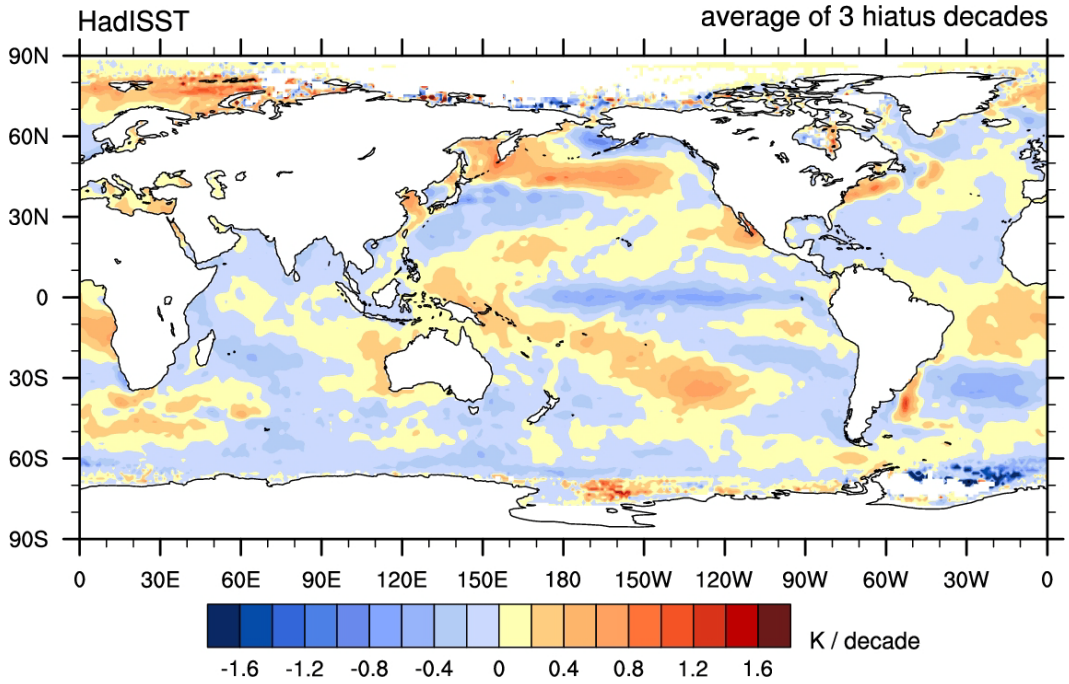


In the Atlantic during hiatus periods, stronger anomalous sinking in the subtropics, weaker sinking at high northern latitudes produces warmer water at depth at those latitudes









Three recent observed hiatus decades show negative IPO pattern as in CCSM4

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The deep ocean

During hiatus periods:

-- the upper 300 meters of the ocean have a significant 60% reduction in globally averaged heat content trend compared to other decades average.

--corresponding deep ocean heat content trends increase significantly (+18% in the layer 300-750m; +19% in the 750-3000 m layer).

-- More heat during hiatus periods is mixed into the 300-750m ocean layer by strengthened ocean subtropical cells in the Pacific accompanied by lower SSTs in the tropical Pacific and higher SSTs in the subtropics

--Warmer water at depth in the North Atlantic and decreased deep water formation around Antarctica contribute to greater heat content trends below 750 m in those basins during hiatus periods.