Varying planetary heat sink led to global-warming slowdown and acceleration

Submitted To:
Prof. Saurabh Rathore

Submitted By:
Himani(2023AST2527)
Nirbhay(2011PH10855)
Riddhidipta(2021CS10546)

Analysis of Ocean Heat Content (OHC) and Temperature Anomalies

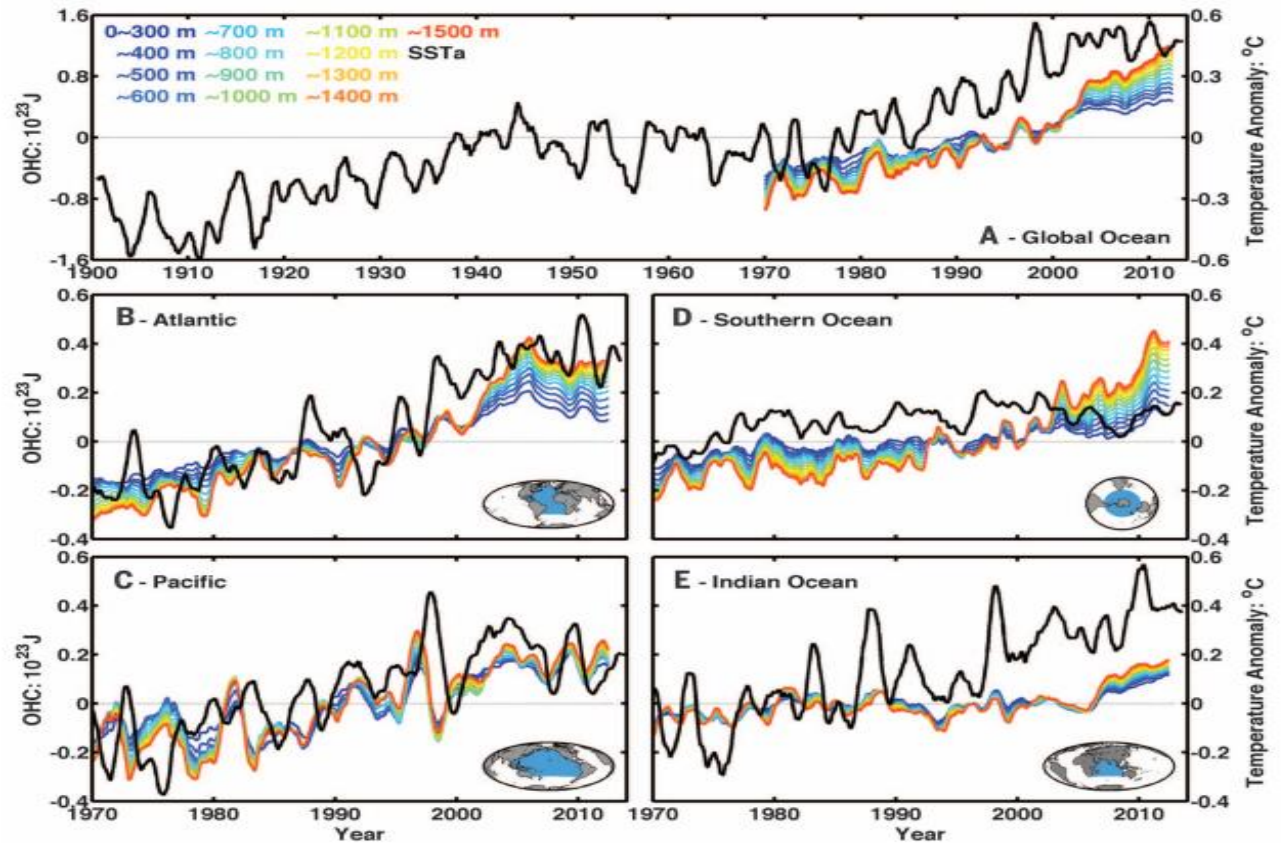

Fig. 1

Analysis of Ocean Heat Content (OHC) and Temperature Anomalies

Overview - SST & OHC analysis (1990s- 2013)

- **Global Ocean** : steady increase in OHC, with direct correlation with SST rise.
- **Atlantic Ocean** : strongly correlated variability in OHC and SST; post 1970
- **Pacific Ocean** : decadal oscillations and long-term trends over OHC and SST interaction
- **Southern Ocean** : strongly correlated increase in OHC and SST at all depth levels, a significant heat uptake
- **Indian Ocean** : accelerating rise in OHC and SST, an increased heat retention

Implications

- Oceanic basins presenting a distinct pattern of heat retention and release
- Increasing heat sink behavior visible at deeper oceanic layers
- Ocean-Climate interactions present extensive regional variability

In Situ Data Coverage and Ocean Heat Content Variability

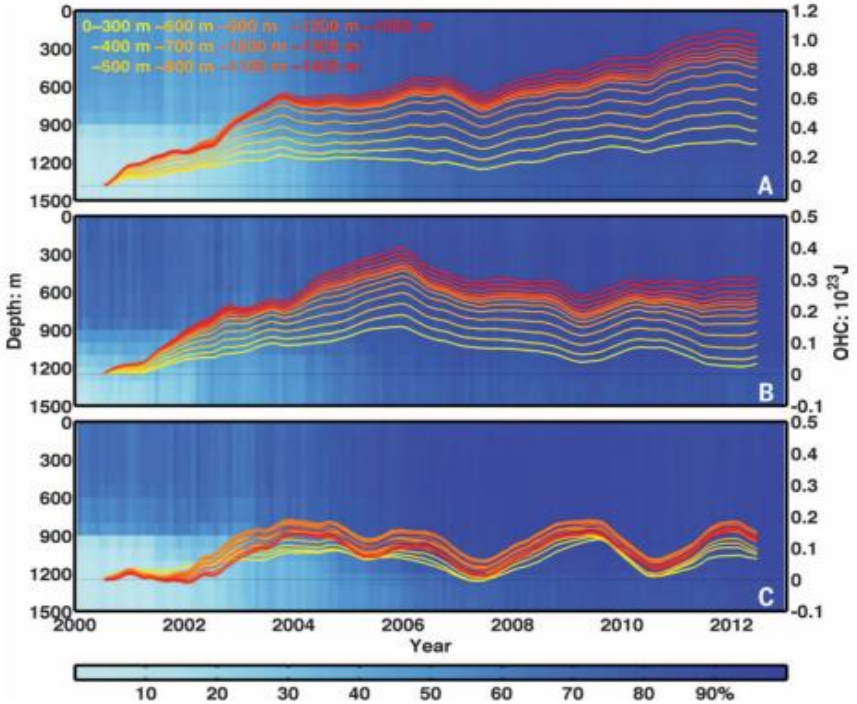

Fig. 2

In Situ Data Coverage and Ocean Heat Content Variability

Overview - Heat Content Analysis

- **Global Ocean** : Increased heat content, especially at shallower depths
- **Atlantic Ocean** : Notable mid-depth heat variability
- **Pacific Ocean** : Distinct mid-depth heat patterns; stable at surface and deeper levels

Implications

- Consistent rise in ocean heat content across all depths since 2000.
- Data indicates increasing oceanic heat absorption, critical for climate analysis.
- The anomalies are relative to year 2000, showing change over time without baseline climatology.

ORAS4 Reanalysis of Ocean Heat Content and SST Anomalies

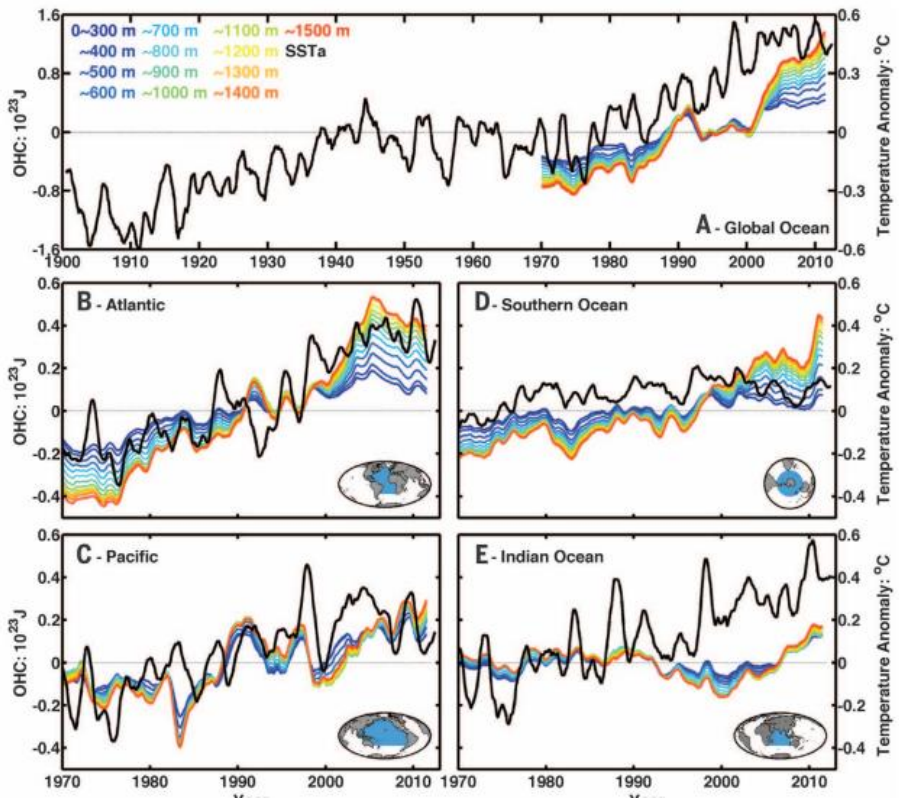

Fig. 3

ORAS4 Reanalysis of Ocean Heat Content and SST Anomalies

Overview: Global and Regional

- **Global Ocean** : Rising OHC trends, with recent decades showing elevated heat storage at multiple depths.
- **Atlantic Ocean** : High variability and sharp increase in OHC coincide with significant SST anomalies.
- **Pacific Ocean** : Varied OHC levels, displaying both short-term fluctuations and long-term warming trends.
- **Southern Ocean** : Consistent upward trend in OHC with a notable recent increase in SST anomalies.
- **Indian Ocean** : Steady growth in OHC and SST anomalies, particularly in the 21st century.

ORAS4 Reanalysis of Ocean Heat Content and SST Anomalies

Implications

- ORAS4 reanalysis provides a more accurate representation of OHC and SST variations.
- Color bands indicate depth-specific heat content changes, while black lines show SST anomalies.
- Enhanced understanding of heat distribution in ocean depths.
- Underlines the importance of oceanic heat in global climate dynamics.
- ORAS4 data improves historical comparisons and aids in the analysis of long-term climate patterns.

Empirical Orthogonal Function Analysis of Ocean Heat Content

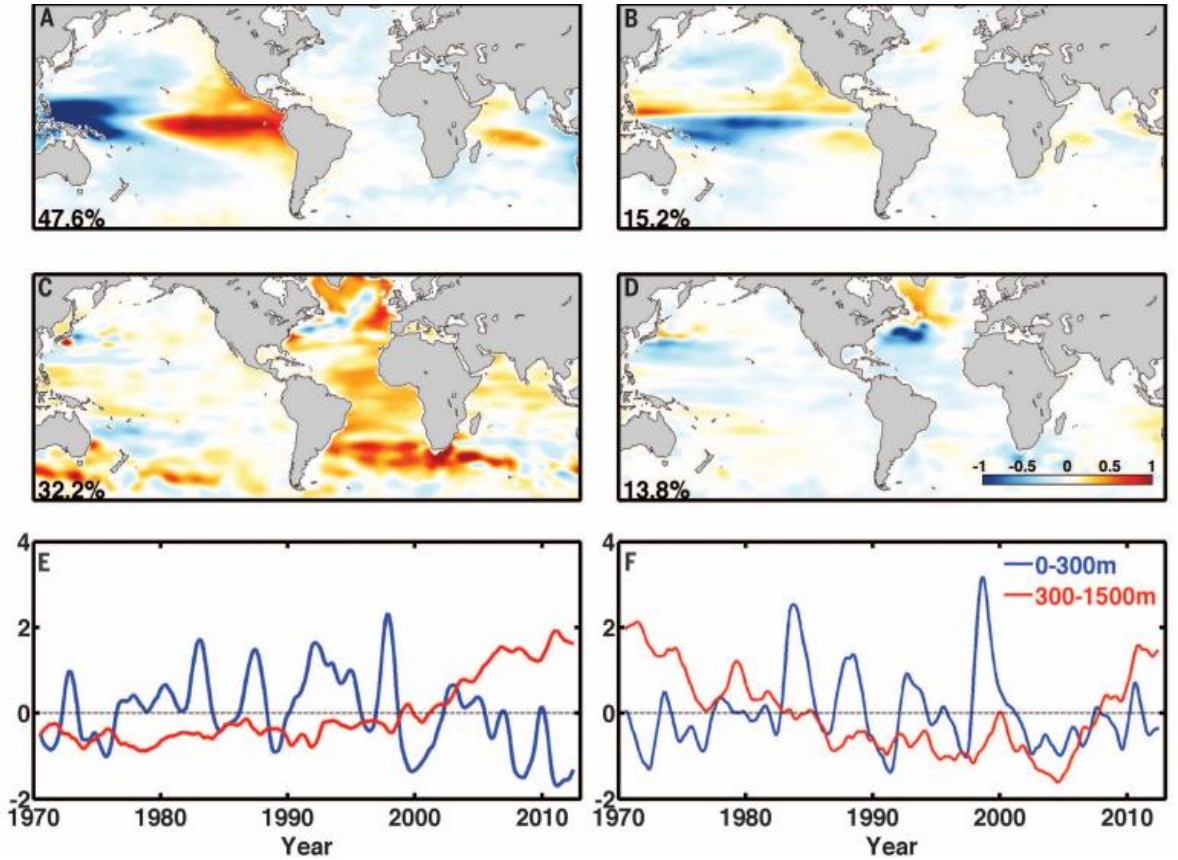

Fig. 4

Empirical Orthogonal Function Analysis of Ocean Heat Content

The graphs provide insights into how different ocean depths contribute to heat content changes, crucial for projecting future climate scenarios.

Spatial Heat Content Patterns

- Upper 300m (A&B): Strongest variations in the tropical Pacific, aligning with ENSO dynamics.
- 300-1500m (C&D): Marked warming in the Atlantic and around the Antarctic Circumpolar Current.

Variability Explained

- Upper 300m (A): 47.6% of the variability, indicating significant influence of surface processes.
- 300-1500m (C): 32.2% of the variability, suggesting deep ocean processes play a substantial role.

Empirical Orthogonal Function Analysis of Ocean Heat Content

Temporal Trends

- Upper 300m (E - Blue Line): Shows oscillating pattern reflecting short-term climate variations such as ENSO.
- 300-1500m (F - Red Line): Indicates a long-term warming trend with less pronounced oscillations.

Implications

The first EOF captures the dominant mode of ocean heat content variability, with significant implications for understanding ocean heat uptake and its influence on global climate patterns.

Ocean Heat Content Variation in the Atlantic and Pacific

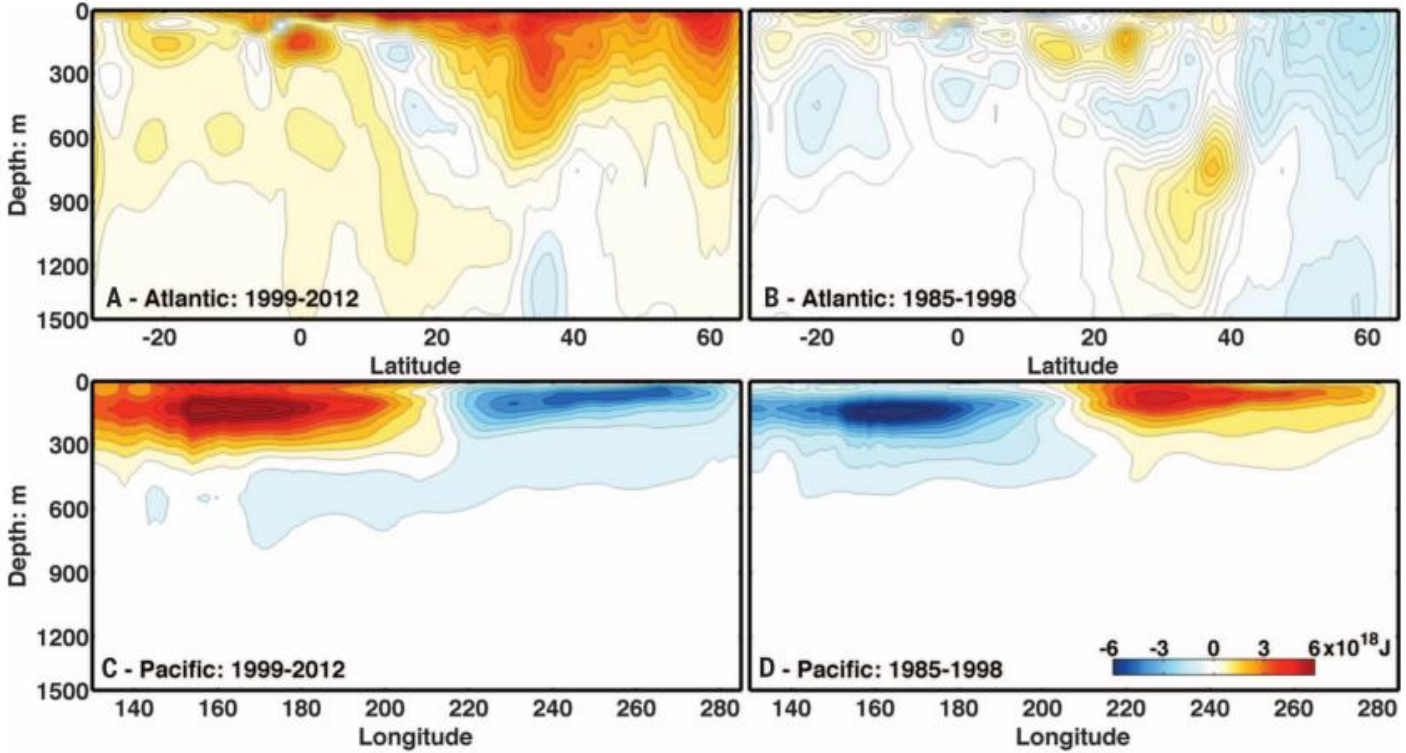

Fig. 5

Ocean Heat Content Variation in the Atlantic and Pacific

Changes in heat content are critical indicators of oceanic contributions to global climate dynamics, with implications for understanding climate change trends.

Atlantic Ocean Heat Trends

- Recent Period (A: 1999-2012): Significant heat content increase at various depths, notably between the equator and 40°N.
- Earlier Period (B: 1985-1998): More moderate changes in heat content, less depth penetration.

Pacific Ocean Heat Trends

- Recent Period (C: 1999-2012): Pronounced heat content increase at shallow depths, especially around the equator.
- Earlier Period (D: 1985-1998): Variability in heat content with less clear pattern, particularly at deeper levels.

Salinity's Influence on Deep Ocean Heat Content

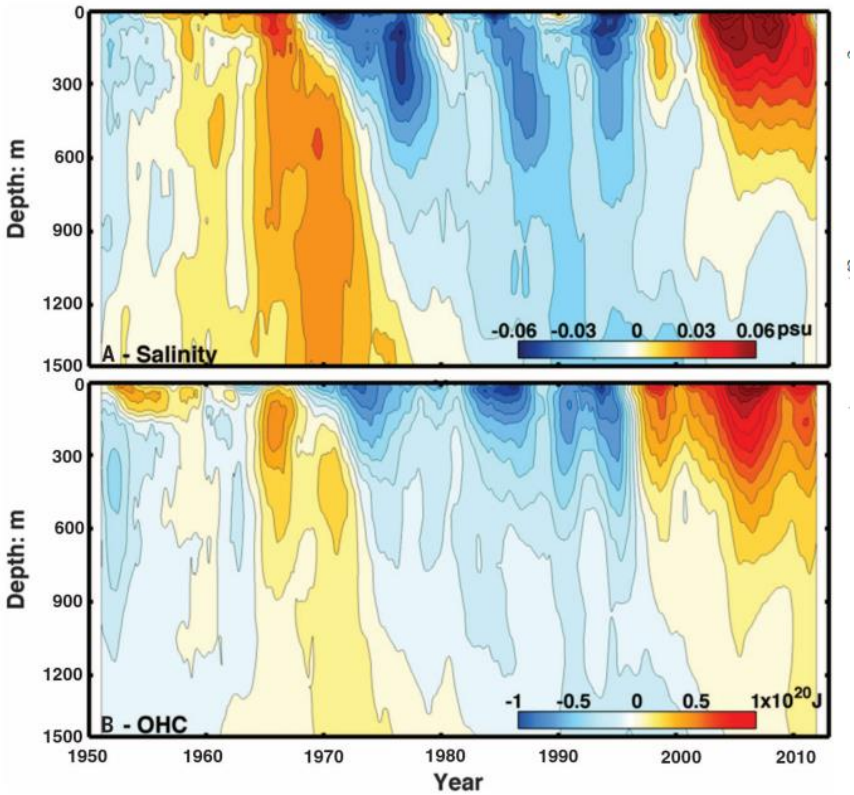

Fig. 6

Salinity's Influence on Deep Ocean Heat Content

Understanding these patterns is crucial for climate prediction and highlights the importance of salinity in ocean heat dynamics and its wider climatic impacts.

Salinity Trends (A)

- Positive salinity anomalies in the North Atlantic have rapidly extended to 1500m in the 21st century, reaching levels unprecedented since records began.
- Contrast with previous decades' negative anomalies aligns with shifts from rapid surface warming to a warming hiatus.

Ocean Heat Content (B)

- OHC increases correspond with periods of positive salinity anomalies, suggesting deep convection as a key mechanism.
- The trend of increasing OHC with salinity changes underscores the importance of salinity in the ocean heat uptake and storage.

Salinity's Influence on Deep Ocean Heat Content

Long-term Perspective

- Historical view since 1950 shows salinity and OHC cycles correlating with climate shifts, indicating a multi-decadal pattern of variability

Climate Implications

- Salinity changes in the subpolar North Atlantic likely trigger shifts in deep-water formation and ocean circulation, affecting global climate patterns
- This cycle suggests a natural variability that operates alongside anthropogenic influences on the climate system