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Establishment of Near-Real Time Monthly Gridded (T, S, u, v) Dataset from the World Ocean Database (WOD)

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Reference

- Chu, P.C., and C. W. Fan, 2017: Synoptic monthly gridded global and regional four dimensional WOD and GTSPP (T, S, u, v) fields with the optimal spectral decomposition (OSD) and P-vector methods. *Geoscience Data Journal*, DOI: 10.1002/gdj3.48.

Synoptic Monthly Gridded Data

- Synoptic monthly gridded three dimensional (3D) World Ocean Database temperature and salinity from January 1945 to December 2014, **NOAA National Centers for Environmental Information** (NOAA/NCEI Accession 0140938) download

- Synoptic Monthly Gridded WOD Absolute Geostrophic Velocity (SMG-WOD-V) (January 1945 - December 2014) with the P-Vector Method, **NOAA National Centers for Environmental Information** (NOAA/NCEI Accession 0146195) download

Outline

- (1) Optimal Spectral Decomposition (OSD)
- (2) Establishment of Synoptic Monthly Gridded WOD (T, S) Data
- (3) Upper Ocean Heat Content
- (4) Synoptic Monthly Gridded Absolute Geostrophic Velocity (u, v) Data Calculated by the P-vector Method

(1) OSD Method

Effectively using the ocean topographic characteristics

↓

A new spectral ocean data assimilation method without requiring *a priori* knowledge of matrix B

Basis Functions

$$\nabla^2 \phi_k = -\lambda_k \phi_{k,} \quad \left[b_1 \mathbf{n} \bullet \nabla \phi_k + b_2 \phi_k \right] |_\Gamma = 0, \quad k = 1, \ldots, \infty$$

ϕ_k → The eigen functions of the 2D Laplacian Operator

satisfaction of the same homogeneous boundary condition of the assimilated variable anomaly

$b_1 = 0$ → Dirichlet boundary condition

$b_2 = 0$ → Newmann boundary condition

$b_1 \neq 0, \; b_2 \neq 0 \;\; \rightarrow$ Cauchy boundary condition

Basis Function Matrix

Φ Matrix →

$$\mathbf{\Phi} = \{\phi_{kn}\} = \begin{bmatrix} \phi_1(\mathbf{r}_1) & \phi_2(\mathbf{r}_1) & \dots & \phi_K(\mathbf{r}_1) \\ \phi_1(\mathbf{r}_2) & \phi_2(\mathbf{r}_2) & \dots & \phi_K(\mathbf{r}_2) \\ \dots & \dots & \dots & \dots \\ \phi_1(\mathbf{r}_N) & \phi_2(\mathbf{r}_N) & \dots & \phi_K(\mathbf{r}_N) \end{bmatrix}$$

K → truncated mode number

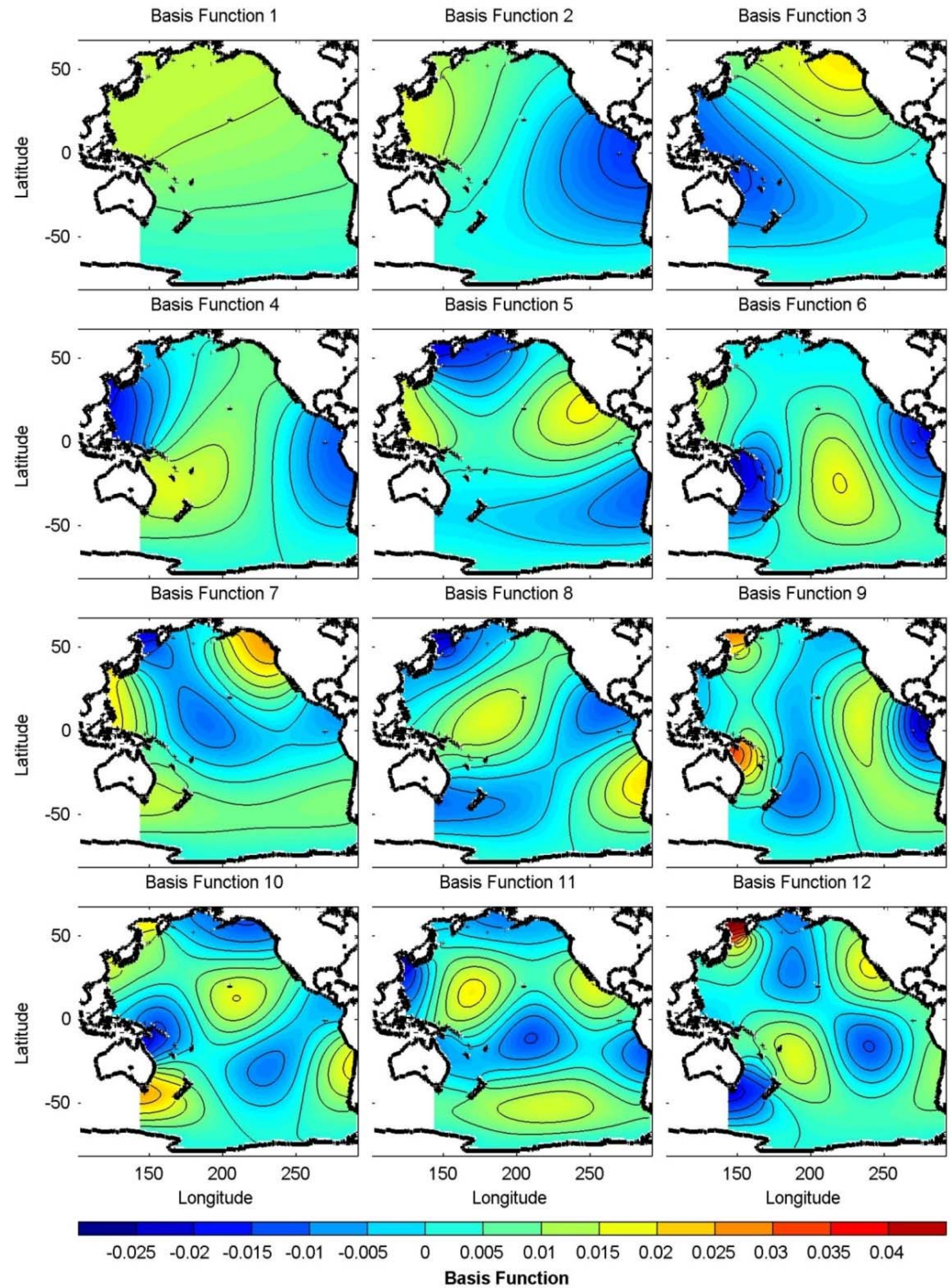
N → number of grid points

First 12 basis functions for the Pacific Ocean at the surface.

DBDB5

Dirichlet boundary condition at the southern boundary (Antarctic),

Newmann boundary condition elsewhere



Spectral Ocean Data Assimilation

$$\mathbf{c}_a = \mathbf{c}_b + f_n \mathbf{s}^{(K)}, \quad s_K(\mathbf{r}_n) \equiv \sum_{k=1}^{K} a_k \, \phi_k(\mathbf{r}_n), \qquad f_n \equiv \sum_{m=1}^{M} h_{nm}$$

$\mathbf{H} = [h_{mn}]$ → the $M \times N$ linear observation operator matrix

$$\boldsymbol{\varepsilon}_a \equiv \mathbf{c}_a - \mathbf{c}_t = (\mathbf{c}_a - \mathbf{c}_b) + (\mathbf{c}_b - \mathbf{c}_t) = \boldsymbol{\varepsilon}_K + \boldsymbol{\varepsilon}_o$$

$$\boldsymbol{\varepsilon}_K \equiv \left[f_n \mathbf{s}^{(K)} - \mathbf{H}^T (\mathbf{c}_o - \mathbf{H}\mathbf{c}_b) \right], \qquad \boldsymbol{\varepsilon}_o \equiv \mathbf{H}^T \mathbf{c}_o - \mathbf{c}_t$$

$$\left\langle \boldsymbol{\varepsilon}_o^T \boldsymbol{\varepsilon}_K \right\rangle = 0$$

$$E^2 = \left\langle \boldsymbol{\varepsilon}_a^T \boldsymbol{\varepsilon}_a \right\rangle = E_K^2 + E_o^2, \quad E_K^2 \equiv \left\langle \boldsymbol{\varepsilon}_K^T \boldsymbol{\varepsilon}_K \right\rangle, \, E_o^2 \equiv \left\langle \boldsymbol{\varepsilon}_o^T \boldsymbol{\varepsilon}_o \right\rangle$$

OSD/OI (KF) Data Assimilation Equations

$$E^2 \rightarrow \min, \quad \partial E^2 / \partial a_k = \partial E_K^2 / \partial a_k = 0, \quad k = 1, \ldots, K$$

$$E_K^2 = \sum_{n=1}^{N} f_n \left[\left(\sum_{k=1}^{K} a_k \phi_{kn} - D_n \right)^2 \right] \rightarrow \min$$

$$\sum_{k'=1}^{K} \sum_{n=1}^{N} (\phi_{kn} f_n \phi_{nk'}) a_{k'} = \sum_{n=1}^{N} \phi_{kn} f_n D_n, \qquad k = 1, 2, \ldots, K$$

$$\mathbf{\Phi F \Phi}^T \mathbf{A} = \mathbf{\Phi F D}, \qquad \mathbf{A} = \left[\mathbf{\Phi F \Phi}^T \right]^{-1} \mathbf{\Phi F D}$$

OSD → $\mathbf{c}_a = \mathbf{c}_b + \mathbf{F \Phi}^T \left[\mathbf{\Phi F \Phi}^T \right]^{-1} \mathbf{\Phi H}^T \mathbf{d}$

OI/KF → $\mathbf{c}_a = \mathbf{c}_b + \mathbf{B H}^T (\mathbf{H B H}^T + \mathbf{R})^{-1} \mathbf{d}$

NCEI/WOD Main Web Site

(https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html/)

(2) Synoptic Monthly Gridded (T, S) Data

Monthly Gridded Temperature at 10 m in the Atlantic Ocean

Monthly Gridded Temperature at 1000 m in the Atlantic Ocean

Monthly Gridded Temperature at 10 m in the Pacific Ocean

Monthly Gridded Temperature at 1000 m in the Pacific Ocean

(3) Upper Ocean Heat Content and Climate Change

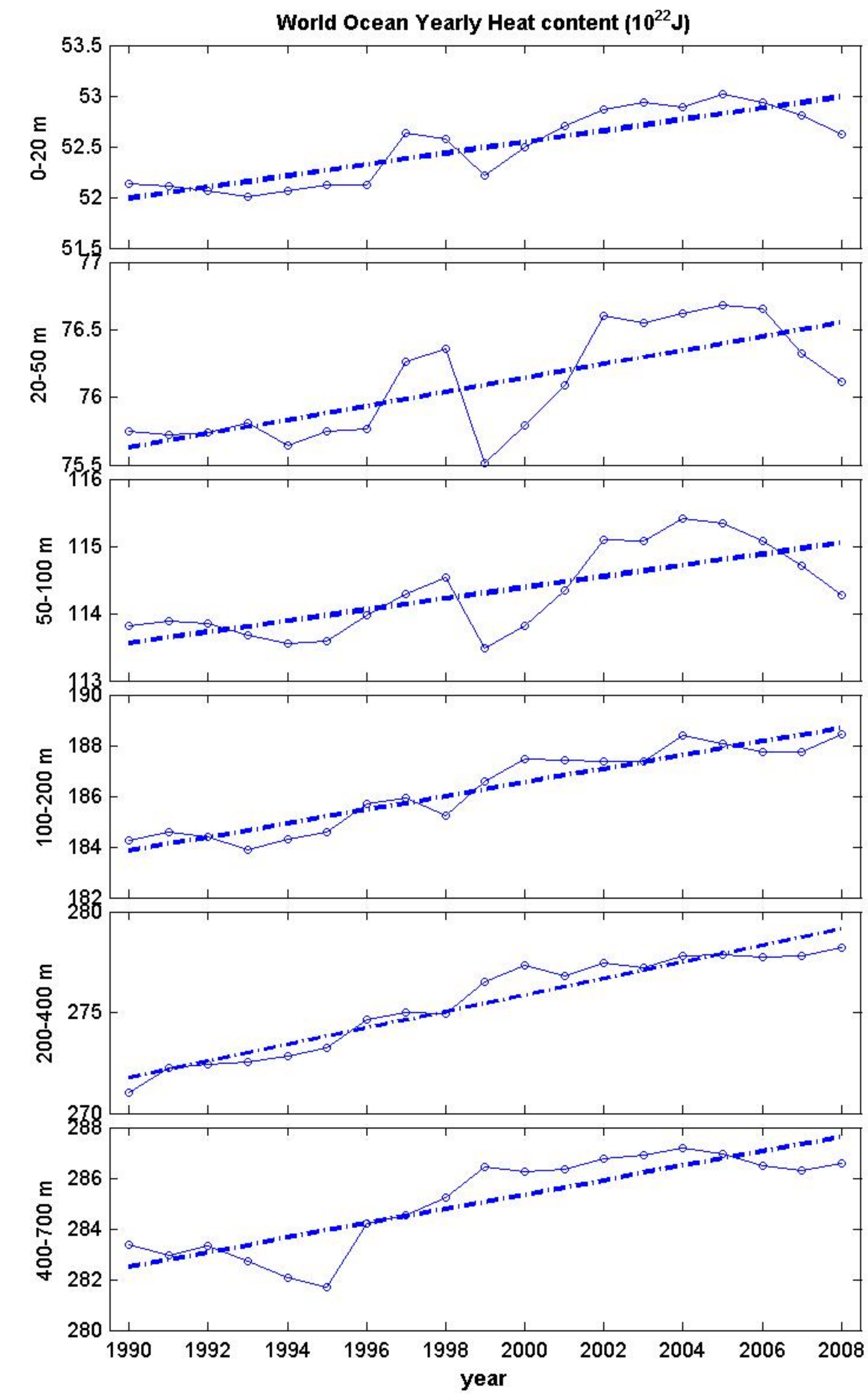
Upper Ocean (0-300 m) Heat Content

$$HC = \int_{-h}^{0} \rho c T dz$$

$HC = HC_{\mathrm{mean}} + HC_{\mathrm{seasonal}} + HC_{\mathrm{anomaly}}$

EOF Analysis → HC_{anomaly}

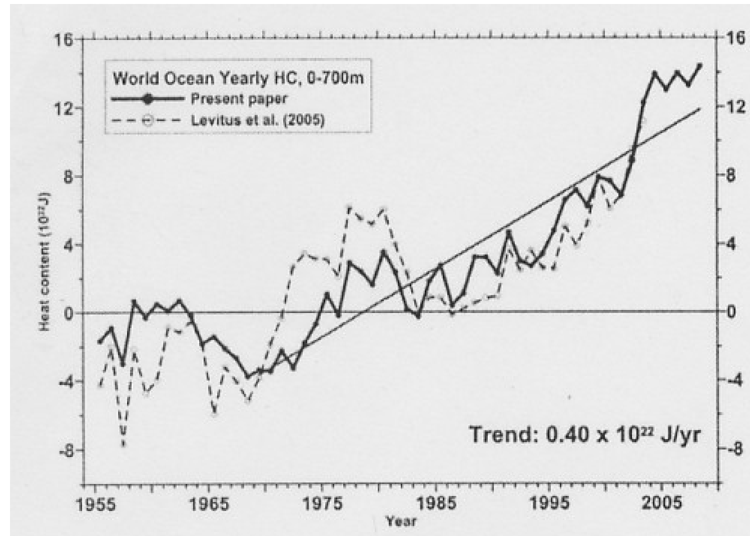
→ Global Ocean Dipole Modes



World Ocean Yearly Heat content (10^{22}J)
0-20 m
20-50 m
50-100 m
100-200 m
200-400 m
400-700 m
year
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

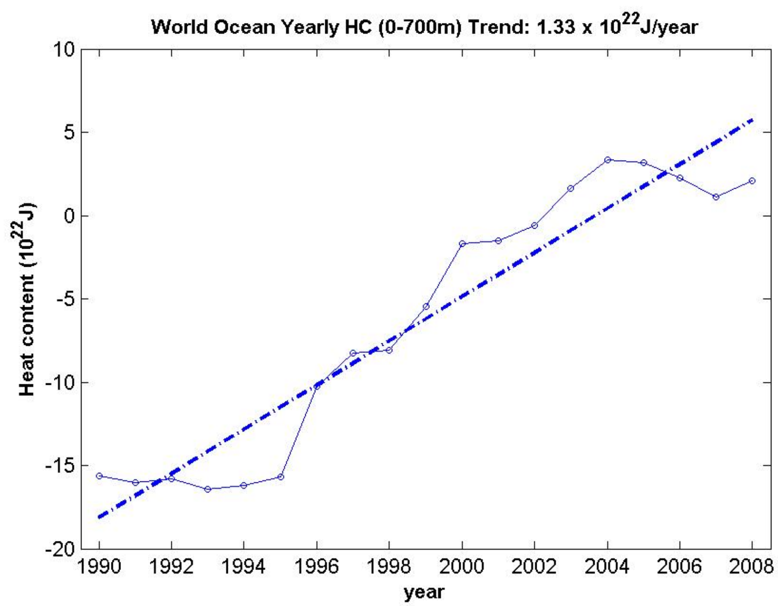
Trend of Upper Ocean (0-700 m) Heat Content

0.4×10^{22} J/yr
(1958-2008)
(Levitus et al.,GRL, 2009)
Without Argo data

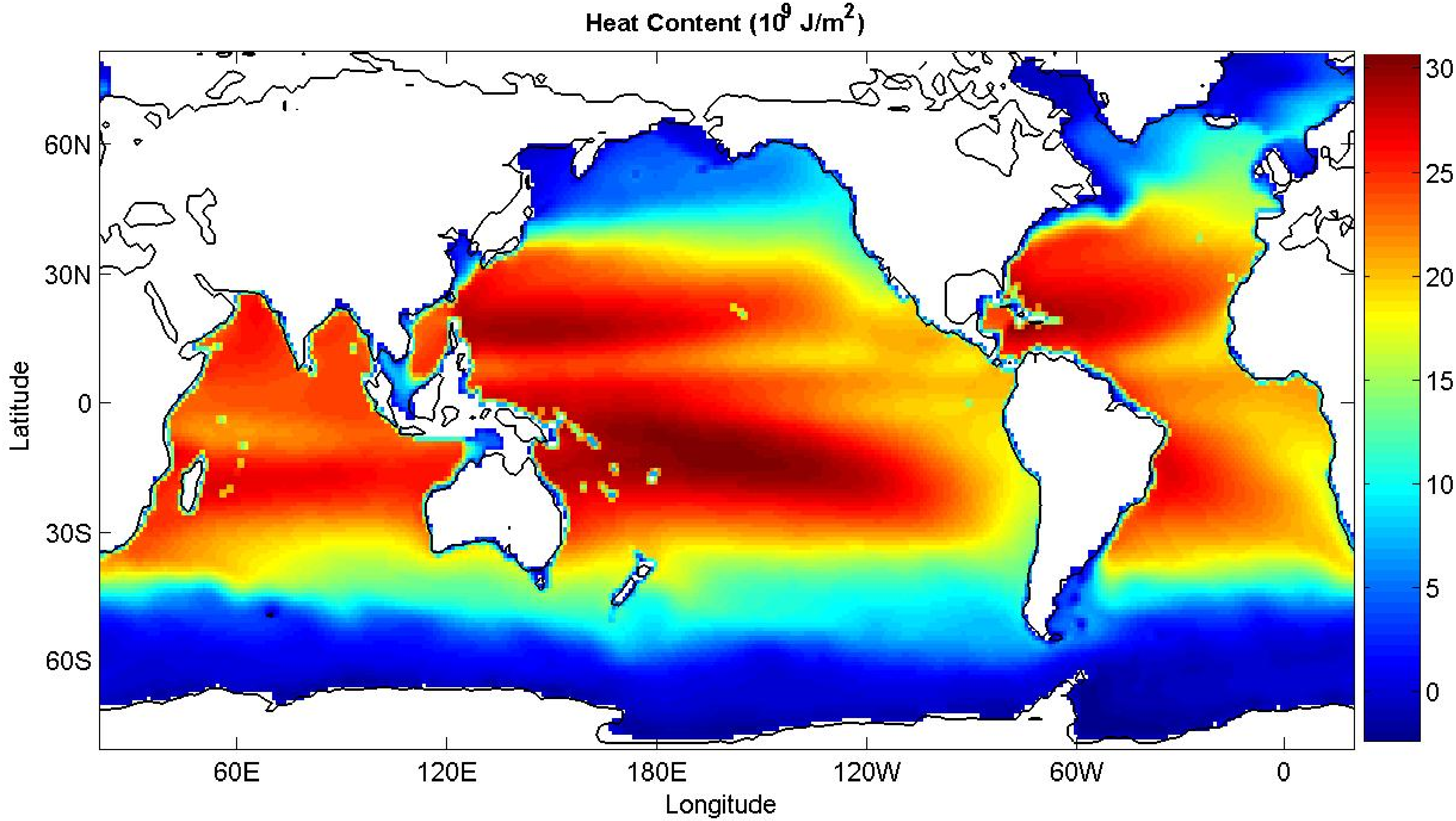


1.3×10^{22} J/yr
(1990-2008)

With Argo data

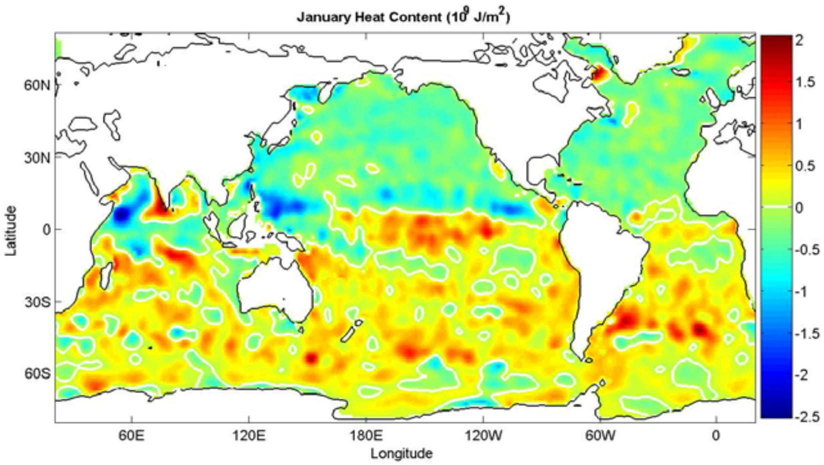


Upper Ocean (0-300 m) Mean Heat Content (J/m^2) (1961-2017)

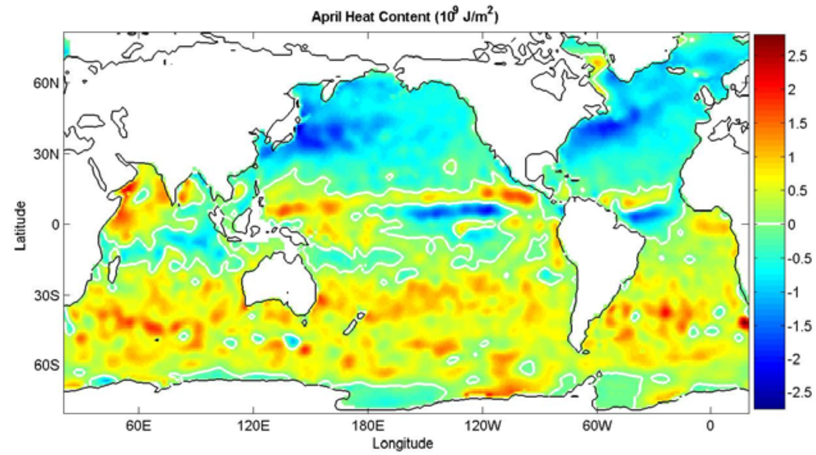


Seasonal Variability of Upper Ocean (0-300 m) Heat Content (J/m^2) (1961-2017)

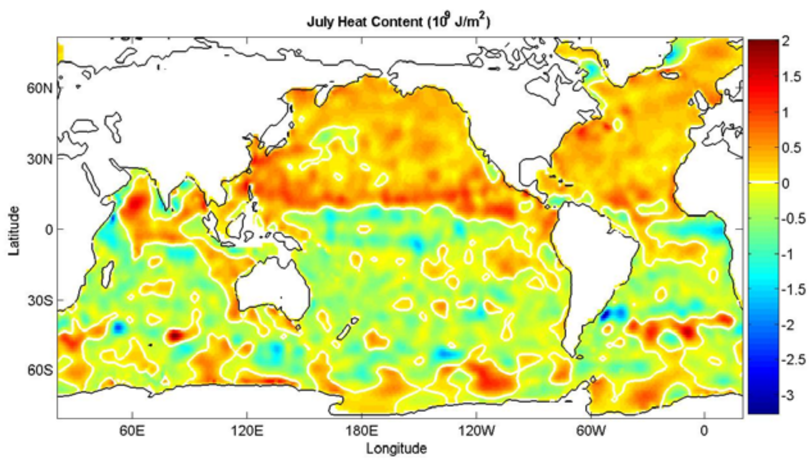
January



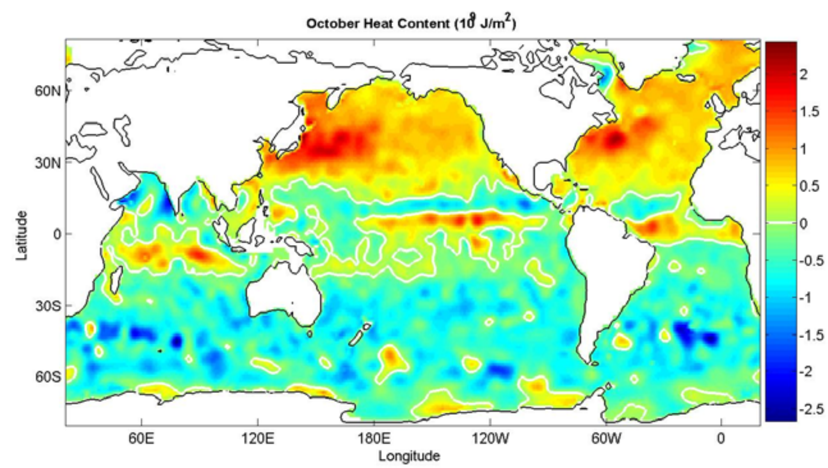
April



July



October



Conclusions

- The datasets are quality controlled by NCEI
- They are easily downloaded from the NCEI website