A Prototype for Remote Monitoring of Ocean Heat Content (ID: 639786)

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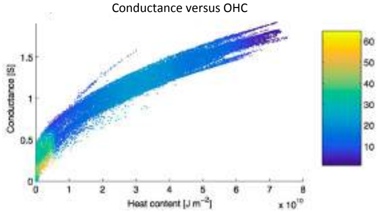
Overview

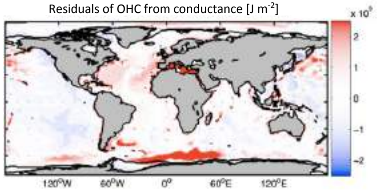
- Ocean heat content (OHC) is a key climate variable that needs to be monitored to know how Earth's energy imbalance is changing, yet observing OHC remains a challenge
- Depth integral of ocean's electrical conductivity ("conductance": C), bathymetry (H), sea surface heights (SSH), and bottom pressures (p_b) are highly correlated with OHC and can be inferred from satellite magnetometers, altimeters, and gravimeters over the global ocean
- An ocean state estimate (ECCO version 4 release 3, or ECCOv4r3) is used to evaluate the fundamental limitations of using C, H, SSH, and p_b to monitor OHC

Conductance is highly predictive of OHC, especially where there is sea ice coverage [Trossman and Tyler, 2019]

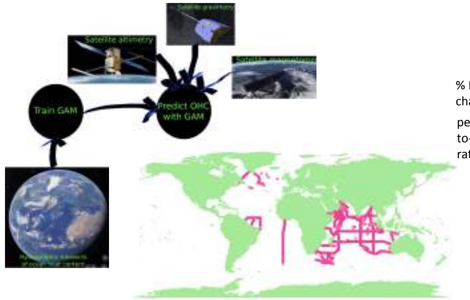
Scatterplot of the 24-year time-averaged conductance versus ocean heat content from ECCOv4r3. The correlation is 0.94. Yellow indicates a higher density of data points than blue.



Residuals from the Generalized Additive Model (GAM) estimate of OHC using only conductance and bathymetry: $OHC=s_0+s_1(C)+s_2(C/H)+s_3(C)s_4(C/H)$. Residuals tend to be smaller in ice covered-regions (75% of the time indicated by black contours), where SSH and p_b are more weakly associated with OHC.



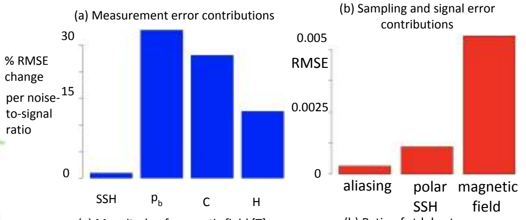
GAM can be trained on hydrography and used to estimate OHC with data from three different satellite missions



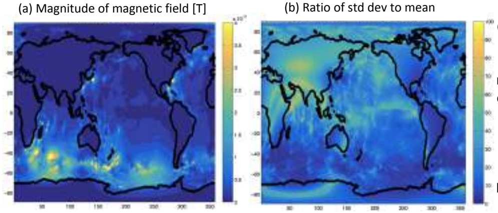
Flowchart for how the remote monitoring system for ocean heat content would work. First, a GAM is trained using hydrographic transect observations. Then the GAM is used to estimate OHC. Also shown is an example combination of transects that leads to a minimal root-mean-square error (RMSE).

$$\hat{OHC} = f_0 + f_1(\hat{SSH}) + f_2(\hat{p}_b) + f_3(\hat{C}) + f_4\left(\frac{\hat{C}}{\hat{H}}\right) + g\left(\hat{SSH}, \hat{p}_b, \hat{C}, \frac{\hat{C}}{\hat{H}}\right)$$

OHC from GAM is most sensitive to bottom pressure errors, but remotely observing conductance using satellite magnetometry may be difficult



(a) Percent RMSE increase per noise-to-signal ratio due to measurement error and (b) additional contributions to the RMSE due to sampling and signal problems. RMSE changes are most sensitive to bottom pressure measurement uncertainties and conductance retrieval error.



(a) Mean value (units in T) and (b) ratio of standard deviation to mean value (in percent) of the radial component of magnetic field from ECCOv4r3. Only including locations with ratio>50% increases RMSE of OHC estimate by 0.5%.

Conclusions

- Ocean's conductance and OHC fields are nonlinearly related but nevertheless highly correlated
- A statistical framework tends to estimate OHC from conductance and bathymetry to within 0.1% on annual time scales and even more accurately where there is sea ice
- A statistical model trained on SSH, p_b, C, and H across hydrographic transects can accurately monitor global OHC (to within 0.35-0.45% RMSE without measurement errors)
- Accounting for measurement error (bottom pressure dominates) and retrievable signals (satellite magnetometry dominates) suggests RMSE may be closer to O(1%)

  - Reference: Trossman, D. S., R. H. Tyler, 2019: Predictability of Ocean Heat Content from Electrical Conductance. Journal of Geophysical Research-Oceans, 124, 667-679, https://doi.org/10.1029/2018JC014740