Ocean Heat Content Estimate

an overview

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Ocean heat content: a key measure of Earth’s energy imbalance
State of knowledge in IPCC-AR5

0-700m OHC

Uncertainty in 0-700m OHC

IPCC-AR5 (2013)

Progress after IPCC-AR5

Lyman et al. 2010, Nature
### Ocean heat content

How OHC calculated and why it is so uncertain?

#### Annual number of temperature profiles by instrument type

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>XBT</td>
<td>MBT</td>
</tr>
<tr>
<td>CTD</td>
<td>Argo</td>
</tr>
</tbody>
</table>

#### 1. XBT bias

- **Levitus 2009**

#### 2. Sampling

January - March 1971 temperature data distribution at 600 m depth

#### 3. Anomaly used: Climatology

Ocean data coverage from sea surface to 6000m (3 by 3 degree resolution)
Sources of uncertainties in OHC estimate (Boyer et al. 2016):

Using 8 mapping methods, 6 XBT correction schemes, 3 climatology.

1. Mapping method (gap-filling)
2. XBT bias
3. Choice of climatology (dependent on Mapping)
4. Data quality

Question: are these methods equally good???
XBT bias: >10 correction schemes are proposed and used in the OHC estimate. One correction scheme (CH14) has been identified and recommended by community.

There are both Temperature and Depth errors, but only Z error is considered!
Correction schemes are thoroughly inter-compared (Cheng et al. 2018, JAOT)

Using the recommended method, or the best 2~3 methods could substantially reduce the XBT error.

Use simple gridded average to get global mean OHC

Use IAP mapping
• Mapping (Gap-filling): ocean data are not global

Ocean data coverage from sea surface to 6000m (3 by 3 degree resolution)
• **Conservative error** in traditional mapping method, leads to an underestimation of long-term warming trend

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**Improving OHC estimate: Mapping**

Temperature difference (Aug1992 – Aug1971) at 600m

- **Ishii**
- **EN4**

NCEI

1971 Jan-Mar, 600m Observation

Contour interval: 0.25

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**ENOI-DE/CMIP5**
A new mapping method *(Cheng&Zhu, 2016; Cheng et al. 2017)*

- Larger localization radius (~25 degree)
- Better spatial covariance (CMIP5 models)
- EnOI framework
- Iterative runs (localization radius: 25-, 8-, 3-degree)

Fractional coverage of the mapping method used in IAP-mapping *(Cheng et al. 2017)*
Improving OHC estimate: Mapping

A visual check:

Significant improvement by IAP-gap-filling method: looks more reasonable
Evaluate the mapping method by a “Subsample test”

Sampling error = Reconstruction - Truth

Truth (full coverage): Argo data; Reanalysis data; High-resolution Model outputs
Sampling error from late 1950s to 2014.

Reconstruction of historical temperature change is reliable by using the new mapping.
Sampling error \sim 0°C from late 1950s to 2014.
The decadal/multi-decadal OHC change is reliable

On inter-annual scale, the noise is comparable with signal before Argo era.
Improving OHC estimate

[Graph showing ocean heat content (OHC) and CO₂ concentration over time, with a focus on the period Aug. 2015 - Jul. 2018. The graph indicates a rising trend in both OHC and CO₂ concentration from 1960 to 2020.]

OHC baseline 1960-2015

CO₂

Aug. 2015 - Jul. 2018

Cheng et al. 2018 EOS
Long-term ocean warming: quicker than IPCC-AR5

For the assessment period in IPCC-AR5: 1971-2010
Ocean heat content: a key measure of Earth’s energy imbalance

Ocean heat content

- Quasi-annual
- Inter-annual (i.e. ENSO)
- Decadal (i.e. PDO, AMO)
- Long-term (i.e anthropogenic forced)

Where is global warming going?

Ocean
- Atmosphere 2.3%
- Continents 2.1%
- Glaciers & ice caps 0.9%
- Arctic sea ice 0.8%
- Greenland Ice Sheet 0.2%
- Antarctic Ice Sheet 0.2%

Ocean 93.4%

Geophysical Research Letters

Ocean loses heat during El Nino

Ocean gains heat during El Nino

Trenberth et al. 2016

Not reliable
Some confusions
- A paper to be submitted

Larger rate of change than AR5
Less known
An ongoing effort

Mapping

• How reliable is OHC on different temporal/spatial scales?
• Can we further identify problems in mapping and then improve?

Synthetic Observations

Truth (Argo-period data, Reanalysis, Model)

Reconstruction

Subsample

Mapping

Compare and Quantify Errors
An ongoing effort

Now we use 1/4° reanalyses (C-GLORSv5) to uncertainty the errors (Subsample test)

Signal-to-noise ratio of OHCT on three different time scales

1980-2015

Wang et al. submitted
An ongoing effort

Now we use 1/4° reanalyses (C-GLORSv5) to uncertainty the errors (Subsample test)

Quasi-annual: <18 month
Inter-annual: 18 month ~ 8 years
Decadal: >8 years

Wang et al. submitted
Thanks!

IAP data, OHC: http://159.226.119.60/cheng/
Now we use 1/4º reanalyses (C-GLORSv5) to uncertain the errors (Subsample test)

- OHCT: Larger variability for both reanalysis and reconstruction than net EEI at TOA.
- Decreasing error with time
- Much smaller error after smoothing (18-month running mean)
Improving OHC estimate

Long-term ocean warming: more consistency among groups

BAMS state-of-climate 2014

Simple gridded average, less stable

BAMS state-of-climate 2017
Inter-annual scale variability (ENSO, 5ºS~5ºN)

- ONI
- GMST
- Precipitation
- OHC0-100m
- OHC0-2000m
- OHCT 0-2000m

Dashed: ORAS5
Solid: observation
Ocean energy budget

Ocean energy budget (referred to 1960)

- Consistency between observational OHC and TOA observations.
- No missing heat: Improved OHC estimate
- Robust global warming

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Energy (10^{22} Joules)

Year


0–300m
300–700m
700–2000m
2000m–bottom

93% TOA (Allan et al. 2014)
2017 was the warmest year on record for global ocean

Global Ocean Heat Content Change at upper 2000m

Baseline 1981-2010
- Reduce the geographical variation of XBT bias (CH14)
Inter-annual scale variability: regional

- **e.g. ENSO**

**Noise**
(Spread among three observational datasets)

**Signal**
(OHC regressed onto ONI)

**OHC variability**

- **Wang et al. 2017**

*(Images of maps showing OHC variability with different lag values, illustrating signal and noise components.)*