

## How ocean profile products are used – climate change applications

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Royal Meteorological Society meeting "From HMS Challenger to Argo and beyond"

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# Talk Outline

- Earth's energy imbalance
- The role of the ocean in climate: energy; sea level; water; carbon
- Insights from ocean profile measurements
- Summary + discussion











## For a stable climate: incoming energy = reflected energy + emitted energy 4

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## Greenhouse gases reduce emitted energy



## Global warming is the result of excess solar energy accumulating in the Earth System



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The RATE of global warming is defined by Earth's Energy Imbalance (EEI)

#### Met Office Hadley Centre The symptoms of Earth's Energy Imbalance..





#### Ocean warming accounts for > 90% of EEI



von Schuckmann et al (2016)









Surface temperature change is a **poor** indicator of EEI on decadal timescales



Palmer and McNeall (2014); von Schuckmann et al (2016)



Ocean heat storage change is a **robust** indicator of EEI on decadal timescales



Palmer and McNeall (2014); von Schuckmann et al (2016)



Ocean profile observations reveal the spatial patterns of the global warming signal



Wijffels et al (2016)



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### Ocean heat content change to assess climate models



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Hadley Centre

Gleckler et al (2016); see also Cheng et al (2016)



**Gleckler et al (2016)** 



20<sup>th</sup> century sea level change

Church et al (2011)



Church et al (2011)

Meyssignac et al (submitted)



Church et al (2011)

IPCC AR5; see also UCKP18 projections



The ocean response is key to future global and regional sea level change..





Combining ocean profile data with ocean dynamical models (ocean reanalysis) to gain insights into ocean climate variability and change:







Comparison of northward heat transport between GloSea5 reanalysis and observations from the RAPID-MOCHA array





Dynamical insights from propagation of density anomalies in the North Atlantic

#### **Met Office Hadley Centre**

## AMOC change is key to future regional sea level change



Gregory et al (2017)

90° N

## Met Office Using the ocean as a "rain gauge"



One of the most important aspects of global warming is the changing water cycle

Durack and Wijffels (2010)



The ocean acts as a **sink of carbon**, reducing the climatic impact of human  $CO_2$  emissions

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Estimated change in sea water pH caused by human created CO <sub>2</sub> between the 1700s and the 1990s, from the Global Ocean Data Analysis Project (GLODAP) and the World Ocean Atlas



- The ocean is an important sink for heat and carbon in a changing climate and essential to our understanding of global and regional sea level
- Ocean profile observations have offered important insights into changes in: Earth's energy imbalance; sea level; the water cycle; carbon storage/ocean acidification
- In particular, profile observations offer improved signal-to-noise compared to land and atmosphere measurements
- Continuation and extension of the ocean profile networks is fundamental to advancing our ability to make useful predictions of the climate system on a range of timescales



# Questions and discussion..



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