# Balancing act

Human activities have shifted the Earth away from energy balance. As a result, the climate is changing, with the ocean playing a major role in heat absorption.

2015 is thought to be the hottest year on record (http://go.nature.com/ua8JqV), with 2011–2015 being the warmest five-year period — and 2016 is expected to continue the trend, with global mean surface and sea surface temperatures both projected to break records. With the 'Godzilla' El Niño ongoing, and a shift to the positive (or warm) phase of the Pacific Decadal Oscillation (PDO), there are no signs that the current warming will slow down. In fact, warming will be amplified by the positive PDO, after 15 years of being suppressed by a generally negative PDO.

The global mean surface temperature trend is a common method of reporting climate change. This, however, can be confusing to the general public (take, for example, the apparent warming slowdown in recent years), as it doesn't factor in natural variability cycles, such as those mentioned above. It can also be difficult for individuals to reconcile with their personal experience of weather at the local scale, which can influence their perception of global change (P. D. Howe *et al.* *Nature Clim. Change* **3,** 352–356; 2012).

However, as climate change continues, and with it more extreme events, personal experiences can reinforce understanding. Take the exceptionally warm Christmas across the Eastern United States and the lack of snow in the European Alps, and the record rainfalls and associated flooding in parts of the United Kingdom. This came at the end of a year of extremes, and at a time when international attention was still focused on the Paris COP21 negotiations, reinforcing the perception of many that the climate is changing.

If global average temperature trends are not the best method for tracking climate change, what are the alternatives? Climate change is occurring because of an imbalance in the Earth's energy budget. If the energy is in balance (that is, the incoming energy from the sun is equalled by outgoing energy) then the climate would be relatively stable; however, currently, more energy is entering the Earth's atmosphere than leaving. This additional energy is being retained by the atmosphere and planet, with most of it being taken

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up by the ocean. The Perspective on page 138 discusses this energy imbalance and why it is imperative to have multiple measurements of ocean heat content as well as top-of-the-atmosphere radiation for proper imbalance estimates. Better estimates of the energy imbalance, and how this is changing, will facilitate better projections of climate change.

One such highly successful initiative to increase ocean observations is the Argo programme. Argo floats — autonomous floats that provide regular temperature and salinity measurements for the top 2,000 m of the ocean — were first deployed in 1999. Today there are approximately 3,900 floats in operation; a Review Article in this issue (page 145) discusses the first 15 years of Argo and the plan for the coming decade. Argo has provided a wealth of data that was previously unavailable, and does so in near-real time. For example, Argo data were used to analyse ocean heat content changes during the period 2006–2013 (D. Roemmich *et al.* *Nature Clim. Change* **5,** 240–245; 2015). The authors reported an increase of 0.4–0.6 W $m^{-2}$ for the upper 2,000 m. This has now been updated to include data up to November 2015 (see the Correspondence on page 116), with the latest 23 months of data analysed — highlighting that ocean heat content continues to steadily increase. This is just one of the over 2,000 published works that use Argo data.

There are still gaps in the data, with a lack of observations from the deep ocean (<2,000 m). This, combined with the brevity of the more comprehensive upper-ocean record, makes it difficult to quantify what changes have taken place over the longer term. A recently published Letter (P. J. Gleckler *et al.* *Nature Clim. Change* http://dx.doi.org/10.1038/nclimate2915; 2016) collates data from a variety of sources — including the nineteenth-century *Challenger* expedition, modern ship-based measurements and Argo — along with climate model output to estimate heat changes over the full ocean depth for the industrial era. The authors report that the amount of heat absorbed by the ocean has doubled in the past 18 years, relative to the industrial era (1865–2015) as a whole. Approximately a third of the heat accumulation is below a depth of 700 m, which reinforces the need for observations from the deeper ocean to enable close monitoring of ongoing change.

Argo shows what can be achieved through international collaboration and cooperation. Greater understanding of the climate system, and therefore improved projections, will be obtained through ongoing commitment and expansion of the programme, and it should serve as a guide to further international collaboration efforts in observing systems. ❒