S. Wijffels: **Ocean Observations for Climate: Progress and Challenges**

The oceans comprise the largest active planetary reservoir for heat, water and carbon, and as a result they play a crucial role in climate, particularly at longer timescales. Obtaining the necessary ocean observations to understand and predict climate remains a tough technological and resource challenge. However, great progress has been made in the last decade on several fronts:

- a revitalization of the science of measuring/understanding sea surface temperature and the development of in situ well calibrated multi-mission products
- the global Argo array has extended broad-scale real-time high accuracy ocean profile observations to 2 km depth globally and is delivering the first global real-time subsurface salinity data stream
- the global eXpendable BathyThermograph network transitioned from a broad-scale mission to monitor ocean mass and heat transports
- we now have the bones of an ocean carbon monitoring network
- we have achieved a decade of high accuracy multi-mission surface altimetry observations and demonstrated the feasibility and value of gravity measurements
- the tropical moored array is now expanding to all ocean basins

Sustaining what we have achieved remains the key challenge as much of the ocean observation system is funded on research budgets. Key priority areas for future expansion include:

- the oceans under ice, which are still essentially a blind spot in the observing system but undergoing rapid change
- the deep ocean below Argo - now recognized as significant energy sink and player in ocean thermal expansion
- developing the carbon/biogeochemistry monitoring system to help close global and regional budgets
- observing waves and their role in coupling the ocean and atmospheric momentum budgets
- expanded direct observations of the ocean circulation field and key interbasin fluxes
- exploiting and assessing the value of salinity observed from space

Susan Wijffels, CSIRO Wealth from Oceans Flagship, Australia

Dr Susan Wijffels aims to quantify and understand the role of the ocean in climate, and key aspects of the large-scale ocean circulation and global ocean change. She is recognized for her contributions to the design, implementation and exploitation of the Global Ocean Observing System (GOOS). Dr Wijffels' current projects include: studying the variability of the Indonesian Throughflow and its role in climate (the international INSTANT project) and follow-on long-term monitoring and improvement of its

representation in climate models; leading Australia's contribution to the global Argo project (she is co-chair of the International Argo Steering Team); and quantifying global ocean change that has taken place over the past 50 years, including the anatomy and drivers of ocean warming, how changes in the Earth's hydrological cycle are expressed in large-scale changes to the ocean salinity field, and if and how climate models exhibit these behaviours.

Working with colleagues at NASA, Dr Wijffels discovered and corrected small but systematic biases identified in 70 per cent of measurements in the Global Ocean Observing System. On the basis of the corrected data, a team of Australian and American climate researchers, including Dr Wijffels, calculated that the world's oceans warmed and rose at a rate 50 per cent faster in the last four decades of the twentieth century than documented in the 2007 IPCC Fourth Assessment Report.
She contributed to the discovery of broad-scale and rapid warming of the abyssal oceans, with implications for the planetary energy budget and rate of sea level rise. This informs our understanding of the sea level budget and rates of global warming and drives an international effort to design a more comprehensive deep ocean observing system. She currently leads the Dynamic Ocean Theme in CSIRO's Wealth from Oceans Flagship.