Argo – monitoring the oceans with profiling floats

Jon Turton, Met Office, Exeter, UK
The origins of Argo

- The concept of a neutrally buoyant float to measure subsurface ocean currents was developed simultaneously and independently in the mid-1950s by Henry Stommel in the USA and John Swallow in the UK.

- The first floats were built by Swallow and consisted of pressure cases made of aluminium scaffold tube and contained a sound source that was tracked acoustically.
From WOCE to Argo

- During the World Ocean Circulation Experiment (WOCE) in the 1990s the Autonomous Lagrangian Circulation Explorer (ALACE) float was developed to measure the deep ocean circulation and temperature.
- This was later equipped with a pressure sensor to record a temperature profile during its ascent – Profiling ALACE (PALACE).
- During WOCE nearly 600 PALACE floats were deployed demonstrating the potential of the technology for measuring ocean temperature profiles and circulation.
The Argo design

• In 1998 a plan for a global array of profiling floats to measure temperature and salinity was drawn up and agreed internationally (OceanObs99)

3,300 randomly distributed floats at 3x3 degrees average spacing

At that time we did not think we could do ice-covered ocean or marginal seas, so the aim was for 3,000 floats in the global oceans between 60N and 60S
Argo floats

Accuracy T \sim 0.005\textdegree \text{C}, salinity \sim 0.01 \text{ (uncorrected)}, position \sim 100\text{m}
Argo floats

- Standard floats provide CTD to 2,000m depth
  - ~70 vertical levels with Argos,
    ~9 hrs transmission time
  - Up to 1,000 levels with Iridium,
    ~5 mins transmission time
  - Lifetime ~150 profiles (or as many as 250 profiles with lithium batteries)
Growth of the Argo array

Around 30 countries contribute to the Argo array

Argo Network Growth

- Argentina
- Australia
- Brasil
- Canada
- Chile
- China
- Costa Rica
- Denmark
- Ecuador
- European Union
- Finland
- France
- Germany
- Greece
- India
- Ireland
- Italy
- Japan
- Korea
- Mauritius
- New Zealand
- Norway
- Pakistan
- Netherlands
- New Zealand
- Panama
- Spain
- South Africa
- Turkey
- UK
- USA
Over the last 10 years Argo has collected more profiles than in the previous 100 years.

Argo
1 million in 10 years

All historical observations
0.5 million
In the last decade Argo has revolutionized our ability to observe the global oceans - by November 2012, Argo had collected its millionth profile, twice the number obtained by research vessels during all of the 20th century.

Over 3,800 floats presently operating.

Apex, Arvor, Navis, Nova & S2A
A large part of the western Pacific is covered by EEZs.
Concurrence to deploy Argo floats in EEZs was given by SOPAC.
Argo data management

- All Argo data is freely available in real-time to ensure its widest use for forecasting and scientific research via the WMO GTS and the two Argo GDACs (in US and France)
- The data are also freely available after scientific QC (in delayed-mode) via the GDACs
- At 15th May 2014 Argo had produced
  - 1,235,443 profiles of which 812,950 had gone through delayed-mode QC
Sustaining Argo

- 800 floats/year will sustain a core 3,000 float array if the average float lifetime is 3¾ years
- Each float has a lifetime cost of ~$25k, including
  - the float hardware (~$17k)
  - deployment costs
  - data transmission (~150 profiles over 4 years life)
  - data management
- Overall cost of the core 3,000 float array ~$20M per year
Float technology improvements

- Iridium communications to increase data throughput and minimize time at surface (allows floats to be operated in the marginal seas, e.g. Mediterranean)
- Iridium downlink allows the mission profile to be modified while the float is at sea (vertical sampling, cycle time etc.)
- Operation in high latitudes (ice-avoidance, store profiles while under ice)
- High resolution temperature profiles through the surface layer
- Shallow seas (modified Apex used in the Baltic)
- Deep Argo floats for observing the abyssal oceans
- Bio-geochemical measurements (Bio-Argo)
Deep Argo

• New float designs capable of going down to 6,500m
  – Apex deep: in February 27, 2013 set a record diving to a depth in excess of 6,000m in the Puerto Rico trench
  – goal of at least 150 profiles using lithium batteries
  – need improved CTD sensor, accuracy of deep measurements not yet known

• Over the next 2 years it is expected that as many as 40 deep Argo floats will be deployed internationally, with perhaps 30% of the array having deep capability in the future
Bio-Argo

- Brings together advances in miniature, low power biogeochemical sensors and autonomous float platforms for observing the “biological” ocean
- In recent years, new generations of profiling floats have been developed and deployed with sensors for:
  - dissolved oxygen, chlorophyll fluorescence, nitrate and particulate backscattering; these are ready to transition to wider use
  - pH, radiometry (PAR, downwelling irradiance), transmissometry and CDOM are on their way
Biogeochemical floats

NAVIS

CDOM
Chlα
b_{bp} (700)

O₂

Eds (λ)
PAR

Chlα
b_{p}

NO₃

C_p (660)

PROVOR

CDOM
b_{bp} (λ)
b_{bp} (λ)

Eds (λ)

O₂

C_p (660)

APEX

Chlα
b_{bp} (700)
b_{bp} (λ)

Lus (λ)
Argo enhancements

- Original ‘core’ Argo design was for 3,000 floats in the ice-free deep oceans between 60 °N and 60 °S
- Requirement for data from high latitudes (under seasonal ice)
- Also, certain ocean regions require a higher (∼ ×2) density of floats
  - Marginal seas (presently 176 floats including Nordic Seas)
  - Western Boundary Current regions
  - Equatorial regions, e.g. in Pacific for improved observation and prediction of El Niño/Southern Oscillation (ENSO) phenomena
Argo enhancements imply a need for over 4,000 active floats
Summary

• In the last 10 years Argo has revolutionized our ability to collect temperature and salinity data from the oceans – it is the only technology able to provide global coverage.
• Over the next 10 years it is likely to revolutionize our ability to collect bio-geochemical data from the oceans (focusing on regions that are hotspots for climate change) and to monitor the deep ocean temperature and salinity.