ENVISAT altimetry and its role in operational oceanography

P.Y. Le Traon, IFREMER

Outline

- ENVISAT altimetry: a major contribution to the altimeter constellation
- Altimetry and operational oceanography from 2002 to 2012
- Conclusions/perspectives

A celebration: 10 years of marine observations with ENVISAT
ENVISAT altimetry

- Radar Altimeter (RA-2)
  - Improved from ERS-1 and ERS-2
- DORIS
  - Precise orbit determination
- MWR
  - Microwave radiometer, derived from ATSR/M on ERS-1
- Orbit very well suited for mesoscale variability monitoring
- Together with other dedicated altimetry missions, ENVISAT provides continuity of sea surface topography measurements from polar orbit
ALTIMETER MISSIONS (adapted from Wilson et al, 2001)

**Launch Date**

| Year | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|

**Reference Missions - Higher Accuracy/Medium Inclination**

- **Jason-1** Fr./USA (12/01)
- **Jason-2** Europe/USA
- **Jason-3** Europe/USA
- **Jason-CS** Europe/USA

**Complementary Missions - Medium Accuracy/Higher Inclination**

- **ENVISAT** Europe (3/02)
- **Sentinel-3A** Europe
- **Sentinel-3B** Europe
- **Saral/AltiKa** Fr./India
- **HY-2A** China
- **HY-2B** China
- **CRYOSAT-2** Europe

**Design Life**

- **GFO** USA (2/98)
  - *Proposed*
- **GFO-2** USA
  - *Operating*
- **SWOT** USA/France

**Extended Life**

- **Sentinel-3C/D**
  - *Proposed*
- **Sentinel-3B** Europe
  - *Operating*
- **Jason-CS** Europe/USA
  - *Proposed*
- **Jason-CS** Europe/USA
  - *Proposed*
- **Cryosat-2** Europe
  - *Proposed*
Sea level can be mapped with an accuracy of 5 to 10% of the signal variance.

Velocity mapping error from 20 to 40% of the signal variance.

A large part of mapping errors is due to high frequency (< 20 days) and high wavenumbers signals.
Eddy Kinetic Energy in the Mediterranean Sea (Pascual et al., 2004) from multiple altimeter missions => need multiple altimeter missions for surface velocity monitoring
Comparison with tide gauges and drifters data shows that 4 altimeters in real time are needed to achieve a similar accuracy as 2 altimeters in delayed mode (hindcasting) (Pascual et al., 2009)
The altimeter constellation: the today vision

- Much better understanding of the value of multiple altimeters (thanks T/P-Jason-1 and Jason-1/2 tandem missions and ENVISAT).
- Better understanding of errors through extensive validation and intercalibration exercises.
- Stronger requirements from real time applications (e.g. surface currents). Need to rely on multiple altimeters (reduce the risk of a single failure). Real time applications require 4 altimeters.
- New challenges (mesoscale/submesoscale, coastal, coupling physics/biology), operational oceanography and applications require higher space/time resolution (e.g. SWOT).
The value of multiple altimeters: Gulf Stream meanders and eddies (courtesy G. Dibarboure)

Contribution of ENVISAT for mesoscale circulation monitoring
Cyclonic and Anticyclonic Eddies with Lifetimes $\geq 16$ Weeks
(35,891 total)

Number Cyclonic=18469
Number Anticyclonic=17422

Average lifetime: 32 weeks
Average propagation distance: 550 km
Average amplitude: 8 cm
Average horizontal radius scale: 90 km

Total number of observations: $\sim$1.15 million

Chelton et al., 2011
Cyclones and Anti-cyclones diverge!

Meridional propagation: **Cyclones** (cold-core eddies) tend **poleward**. **Anti-cyclones** (warm-core eddies) tend to propagate **equatorward**;

Divergent propagation occurs away from strong jets and bathymetric features. (Morrow et al., GRL, 2004)

Seasonal Modulation in the EKE Field of the South Pacific Ocean

SECC intensity vs. EKE level in SECC-SEC

High resolution altimetry reveals anisotropic quasi-zonal jet-like features (striations) (e.g. Maximenko et al., 2008; Melnichenko et al., 2010; Scott et al., 2008, Chelton and Schlax, 2008; Centurioni et al., 2008)

Details of the dynamics are not yet understood. Recent studies outline important roles played by eddies, Rossby waves, beta-plumes and instabilities.
Decadal Predictions of the Kuroshio Extension Dynamic State based on Multiple Satellite Altimeter Missions (B. Qiu)

Altimeter-derived KE paths: Oscillations between stable and unstable state

Stable yrs: 1993-94, 2002-04, 2010-


AVISO satellite altimeter data: 10/1992-08/2010

RMS amplitude of SSH variability (> 2 years)
Altimetry and the development of operational oceanography

• Impressive **progress over the last 10 years**
• Operational global and regional systems are now providing regular descriptions and forecasts of the ocean state
• Links with applications (societal needs)
• Systems are **strongly dependent** on the availability of multiple altimeter data:
  ➢ Sea level is a strong constraint to infer the 4D ocean circulation through data assimilation.
  ➢ Only can high resolution altimetry constrain the mesoscale circulation in ocean models.
A practical demonstration of the feasibility & utility of high-resolution, global analyses & short-range forecasts of 3D temperatures, salinities and currents

Global operational oceanography

The GODAE main demonstration phase (2002-2008) was phased from the start with the launch of Jason-1 and ENVISAT
Argo, altimetry and operational oceanography

A major challenge in 2000 => set up a real time global in-situ observing system to complement satellite observations

Development of the international Argo programme => end of 2007, 3000 floats worldwide measuring temperature and salinity to a depth of 2000 m.

Altimetry and Argo are now systematically jointly used for ocean and climate research and for ocean analysis and forecasting.
MyOcean
GMES Ocean Monitoring and Forecasting Service
European Operational Oceanography
Data assimilation and modelling capabilities

Operational oceanography now uses high resolution models with data assimilation: 1/12° (global), 1/36° (regional) (MyOcean)

This poses much stronger requirements for an altimeter constellation

Availability of multiple altimeters is essential (degradation of results when an altimeter fails!)

Critical role of ENVISAT and S3A&B

MyOcean/Mercator-Ocean global 1/12° model with multiple altimeter data assimilation
High resolution altimetry and Deep Horizon oil spill (J. Lillibridge, NOAA)
Fukushima

MyOcean Global Ocean capacity

MyOcean Global Ocean Service

P. Bahurel
Mercator Ocean
Summary

- **2002-2012** : a decade of major achievements in oceanography
  - Satellite altimetry : ENVISAT and Jason
  - Global operational oceanography : GODAE
  - Argo and the global in-situ observing system

- These major successes partly result from a well thought and planned integrated approach : in-situ, satellite and modelling

- **Major contributions of ENVISAT. Congratulations to ESA !**

- Need to ensure a long term high resolution operational altimeter system : Sentinel missions (3A&B) - Jason-3/Jason-CS and other contributing missions (e.g. Alti-Ka, HY-2).

- Need to ensure in parallel the consolidation of the in-situ observing system (Argo for the next decade) and operational oceanography services (GMES/MyOcean).