Options for future missions
Recommendations

The Gamble Team

CONSTELLATION OPTIMIZATION (WP8)

Recommendations are based onŹ

SSH REQUIREMENTS ***SEA-STATE REQUIREMENTS***

Objectives

Coverage/sampling

Performances

Near-real time needs

described inŹ:

- **WP2 , SSH error budgets and recommendations**
- **WP3, sea-state error budgets, future detectability**
- **WP5, Offshore Operators workshop**

Taking into accountŹ

- **WP4, Orbit Determination and Satellite tracking performances**
- **Existing and anticipated altimetric missions characteristics**
- **State of existing and emerging technologies, platforms**
- **Estimated time to develop and bring into operation**
- **Cost optimization**

Recommendations have been expressed for 3 time frames

- **Short-term (2004-2007)**
- **Mid-term (2008-2011)**
- **Long-term (> 2011)**

Few High level recommendations

- **WP2 :** The minimum requirement will be to continue flying a two satellite configuration with one long-term precise mission (T/P/Jason series)...This can be very significantly improved with an optimized three satellite configuration(reduction of sea level and velocity mapping errors by a factor of about 2 to 3)....to resolve the high frequency and high wavenumber signals, a constellation of more than 6 satellites and/or use of wide swath techniques would be required.

- **WP3 :** Improved sampling in time and space (10-30 km/1h-6h) by satellite constellation and/or wide swath altimeters (e.g. SWIMSAT), availability of wave directional and wave period information by SAR and/or new concepts SWIMSAT)....Improved performances at coast....Near-real time availability of data (1-3 hours).

- **WP5 :** For offshore operations, need to gain accurate knowledge of ocean currents...with improved spatial resolution...Wave-height is the most important, but needs improved space-time resolution...wave direction and period, swell and extreme waves need to be predicted better.

The altimetric situation in 2004-2007

Today

- T/P, optimized mission, launched in August 92, 10 days repeat orbit, 66° inclination, ending...
- Jason-1, T/P follow-on, launched in December 2001, designed for 5 years.
- *ERS2, no more on-board recording , only downloading data over ground-stations.*
- GFO, launched on 1998, 17 days repeat orbit, single-frequency altimeter.
- ENVISAT, launched on March 2002, 35 days repeat orbit, 98° inclination, designed for 5 years.

Flying in 2005

- CRYOSAT (ESA), optimized for ice observation, but will work over the Ocean, repeat cycle of 369 days, sub-cycle of 30 days, non sun-synchronous orbit of 92° inclination, 720 km altitude, POD with Doris and SLR, but single frequency altimeter, no redundancy, no radiometer, no near-real time capabilities, designed for 3 years.

Concerns for the 2004-2007 period

- *Today, based on this configuration of 4 operational satellites, Ocean dynamics research and operational systems like DUACS, Mercator, FOAM, are meeting their mission, BUT this situation will not last for very long (some of these satellites are getting old).*
- *Sea-state near-real time needs are not satisfied, i.e. only 2 satellites with Wind/Wave 3 hours real-time capabilities (Jason, ENVISAT) (cf Météo-France tests). Continuous SWH spectra measurements are needed to improve the sea-state forecasts, and would also lead to improved corrections of altimeter range data (Sea-state bias correction).*

Recommendations relative to the 2004-2007 period

Considering the 2004-2007 panorama in altimetry and related concerns, the Gamble Team recommends:

- **To maintain current missions**
  - **as long as they are producing exploitable data,**
  - **Even in a degraded configuration (due for instance to deficiencies of one frequency of dual-frequency altimeters, radiometer, POD systems...),**
    - Assuming the impact is not incompatible with the objectives
    - Using dedicated tools and/or models to compensate (tropo/iono model, cross-over minimization, accurate mean sea surfaces...) .
- **To maintain T/P-Jason tandem mission as long as possible because of its proven usefulness (cf. Le Traon et al., Fu et al papers)**
- **To maintain the near-real time capabilities with the shortest possible delay in data delivery (< 2 days for SSH, < 5 hours for wind/wave) for feeding the operational systems on time (e.g. DUACS for SSH towards Mercator, FOAM, Topaze, MFS, ECMWF, Météo-France for wind/wave through GTS system...)**

Recommendations relative to the 2004-2007 period (cont 'd)

- **To maintain the satellite laser tracking, because of its significant contribution in POD and because of its backup interest.**
- **To prepare the use of CRYOSAT altimeter over the Oceans by:**
  - **Ensuring the IGDR/GDR data production and access to the Ocean users**
  - **Developing appropriate techniques for processing the data**
    - Using the repeat sub-cycle (30 days), after constructing, from multiple altimetric time series, accurate reference mean sea level profiles along CRYOSAT tracks
    - Developing GIM and Doris dual-frequency ionosphere models (note that solar activity is at a minimum during 2004-2007)
    - Improving wet troposphere models, based on other in-flight radiometers,
    - Studying the capability of near-real time products for ocean applications (2 days) and sea-state forcast (< 5 hours)

Anticipated situation in the 2008-2011 period

Today, only one altimetric mission is scheduled

- Jason-2/OSTM, (MOU to be signed in 2004 for a launch end of 2007) The follow-on to Jason-1, same orbit, same performances, real-time capabilities, continue the unique long time series accuracy of T/P and Jason-1 altimetric missions.
- Wide Swath Ocean Altimeter demonstration expected on Jason-2, a unique opportunity of direct mapping of SSH and current velocity field. However, this is a non operational mission which has a limited ocean coverage.

Previous missions will be reaching the end of their lifetime

Strong Concerns for the 2008-2011 period

- ***As indicated in WP2, WP3 and WP5 Gamble reports, one single operational Jason2/OSTM mission is not acceptable with regard to SSH, Sea-State, and operational requirements (e.g. DUACS error mapping higher than 20 % with only one satellite, a limited 13 % impact of altimetric SWH data assimilation into WAM sea-state model).***
- ***Moreover, because of the launch of Jason2/OSTM now scheduled end of 2007 at the earliest, there is a high probability to have a very damaging gap between the Jason-1 and Jason2/OSTM missions, and so a gap in the time series***
- ***In case of an unexpected nightmare scenario, i.e. a failure of Jason-2/OSTM at launch time or few months after the launch, and no other altimeters flying, there is no backup at all!***
- ***Such a situation is incompatible with high priority issues related to Global Ocean monitoring, coastal area survey and water resources management, as indicated in the European GMES program, and not suitable at all to support operational ocean monitoring programs like MERSEA and MFS in Europe, or Mercator and FOAM at the national level, which are part of the International GODAE initiative.***

Recommendations relative to the 2008-2011 period

Considering the anticipated altimetric mission situation in 2008-2011 and the strong concerns which have been expressed, specially those related to supporting European Environmental high priority programs and the Ocean International GODAE global vision, the Gamble Team recommends:

- **To maintain current missions, even in a degraded configuration, and their real-time capabilities as long as exploitable data are provided.**

- **To ensure the launch of the Jason2/OSTM satellite in a timely manner, without further delay beyond end of 2007, in order to avoid any potential gap in data coverage from the Jason-1 mission.**

- **To activate, if relevant, a Jason1/Jason2-OSTM tandem mission (Jason 1 orbit being shifted mid-way from the current orbit).**

- **To encourage the in-flight demonstration of new techniques, new concepts to provide high resolution, including Wide swath radars (WSOA, SWIMSAT), new altimeters for future micro-satellite constellations (Gander, AltiKa, doppler, laser altimeters), over-ocean GPS reflections. This is to assess respective performances and appropriateness of these systems with regard to requirements for future missions (> 2011).**

Recommendations relative to the 2008-2011 period (cont'd)

- **To demonstrate WSOA on-board Jason2/OSTM and to involve Pis/CoIs in the in-flight assessment.**
- **To consider and encourage public/private partnership to support future multi-satellite constellations adapted to Sea-State operational requirements (with an optimum of 4 satellites flying at the same time) and consequently to SSH high resolution requirements.**
- **To decide, within the next months, at least one complementary mission to Jason-2/OSTM for flying in 2008. Such a two satellite constellation is the minimum acceptable configuration, even if not optimum, for dynamic topography needs, but it does not meet the Sea-State operational requirements**

Recommendations relative to the 2008-2011 period in order to fulfill the SSH minimum requirement

Considering the absolute need and the high priority urgency for at least one conventional high inclination mission, complementary to Jason2/OSTM, the Gamble team recommends a strong endorsement of the EC, with support of space and operational agencies, for deciding, before mid-2004, one of the two following options which are realistically feasible within such a limited lead time:

1 .**“ Proven technology” basic option**

- **Poseidon 3 B altimeter (replica of the Jason2/OSTM one) :**

  - On-board a micro-satellite platform (UK AO opportunity?) with laser retro-reflector for orbit determination (10 cm class orbit capability) and appropriate attitude control/knowledge (0.1°) - Repeat cycle at 35 days (ERS type) or at 17.5 days (GFO type), to take advantage of past reference mean passes (800 km class altitude, better for micro sat, considering Grace and Goce contributions to the earth gravity field)

  - Or, as a passenger on-board an opportunity satellite (no orbit choice)

  – Or, on-board a Jason 2B clone (same satellite and same payload as Jason 2/OSTM, including 1 cm class POD and radiometer)

- **Real-time capability needed**

Recommendations relative to the 2008-2011 period in order to fulfill the SSH minimum requirement

2 **"New technology" partly developed option**

- **AltiKa single-frequency altimeter and integrated radiometer (phase B completed)**
  - **Micro-satellite platform (UK AO opportunity ?), equipped with laser retro-reflector for orbit determination (10 cm class orbit), and appropriate attitude control/knowledge (0.1°)**
    - **Doris POD system and/or highly performing GPS receiver on-board as an option (< 4 cm class orbit)**
    - **Repeat orbit at 35 days (ERS type) or at 17.5 days (GFO type) to take advantage of past reference mean passes (800 km class altitude, better for micro sat, better for assimilation, considering Grace and Goce contributions to the earth gravity field determination)**
  - **Or passenger on-board an opportunity satellite (no orbit choice)**
  - **Real-time capability needed**

Pros and Cons of the Poseidon 2B option

- ↗ **A relatively cheap scenario, Poseidon 3B about half the price of Poseidon 3A (if both are built at the same time).**
- ↗ **Satellite and payload development feasible in the limited time frame available (4 years), if decided soon**
- ↗ **Dual-frequency altimeter appropriate for ionospheric correction (solar activity is maximum around 2010) and for secondary objectives, i.e. rain, gas transfer at the air-sea interface**
- ↗ **A Jason 2B satellite (replica of Jason2/OSTM), developed in parallel with Jason 2A, is a unique opportunity of having a very low cost complete altimetric system ready in 2008 (with 1 cm class POD and radiometer)**

- ↘ **No radiometer on-board if microsat (but meteo models are much improved thanks to assimilation of in-flight radiometer data)**
- ↘ **No POD on-board if microsat (but cross-over analysis may provide sufficient accuracy for meso-scale resolution)**

Pros and Cons of the AltiKa option

- ↗ **A consistent altimetric mission, with radiometer and POD (if Doris and/or GPS option selected)**
- ↗ **A new class of compact radar instrument adapted to specific applications (coastal, ice, inland...) if Doris on-board for driving adaptative tracker**
- ↗ **New technology, research support may be expected from space agencies. Would be a demonstrator of future GANDER type satellite constellations,**

- ↘ **Project cost relatively higher, with respect to Poseidon 3B option, because new technology altimeter development**
- ↘ **Project development schedule feasible but not easily compatible with a short delay of 4 years**
- ↘ **Single-frequency altimeter not very sensitive to ionosphere, but not adapted for secondary objectives, i.e. rain, gas transfer**

Recommendations for the period after 2011

Because, as recommended in European environmental monitoring programs (e.g. Global Monitoring for Environment and Security), there is a need to sustain an optimum altimetric service compatible with operational requirements and new research perspectives of the Ocean (mesoscale, coastal, tides, Sea-state, cf WP2, WP3, WP7 recoms...), ice and inland water survey, the Gamble team recommends EC, space and operational agencies:

- to maintain the T/P-Jason series over the long term to keep alive this unique reference time series which started in 1992 and which is essential in many applications because of its high accuracy, consistency and robustness
- To decide a **demonstration** in-flight SWIMSAT mission. This is an innovative high-resolution instrument for measuring directional spectra, wind speed, significant wave height, dominant wavelengths, wave slope statistics, providing a unique contribution for constraining much better sea-state models and improving forecasts
- To investigate potential of measurements, by low altitude satellites, of GPS reflections over ocean to measure sea-state

Recommendations for the period after 2011

- to develop and provide robust **operational** altimetric systems for systematic and continuous high resolution sampling of the Ocean ("Ocean Watch" concept) by:

- deciding soon a series of multi-purpose Gander/AltiKa/Ku redundant altimeters in order to produce low-cost (effect of mass production) altimeters with integrated radiometers, which can provide the required < 3 cm range accuracy, on board a micro-satellite

- deciding, for a launch early in 2011, a multi-satellite constellation (a minimum of 3 satellites completed by the NPOESS altimetric mission), based on low-cost, mass-produced micro-satellites and simultaneous launches. Preferential orbits are ERS or GFO ones, but other orbits may be acceptable. < 10 cm class POD based on laser and low-class GPS and altimeter cross-overs minimization. Laser, Doris and/or geodetic GPS tracking optional for more accurate, independent, robust POD. Real-time capability.
  Can be developed and built in a relatively short delay (i.e. ready in 2011), meet the high resolution requirements for both SSH and wind/wave. Multi-satellite system.

- deciding, for a launch soon after 2011, an operational Wide Swath radar altimeter mission, after WSOA/Jason2 demonstration return, preferably on a high inclination sun-synchronous 10-20 days repeat orbit (non sun-synchronous orbit may be acceptable). Nadir altimeter needed. Very precise attitude knowledge needed. POD preferable. On board radiometer preferable. Real-time capability. *Provides unique high resolution. But, a single system whose failure stops the high resolution mission, if no backup ready for a quick launch or if no other altimeter flying at the same time. Not designed for sea-state.*

General Recommendations

The Gamble team:

- Encourage space and operational agencies (CNES, ESA, Eumetsat, NASA, NOAA...) to define a common long term strategy, based on previous recommendations
- Point out the vital link of these recommendations with the running of operational European environmental survey programs, like GMES and MERSEA, which rely on an uninterrupted adapted data production service! The benefits encompass many aims central to GMES, including the monitoring of long term climate change (sea level), improved understanding and prediction of inter-annual and seasonal climate variability (el Niño, NAO), and enhancing security and safety of offshore operations (including shipping, exploration and defense)