Briefing Note for GAMBLE Workshop on Future Requirements for Altimeter Sea State Data

To be held at ISDGM, Venice, 30th September

1. Introduction

Workshop Aims

The Purpose of the GAMBLE workshop is to hold discussions and provide preliminary recommendations on how the needs of the scientific and operational oceanographic community can be best met in terms of:

- Processing and provision of sea state data from present and planned altimeter missions (JASON, TOPEX, ERS2, ENVISAT, Geosat Follow On, JASON-2, NPOESS,....)
- Defining the ideal characteristics of new altimeter missions beyond 2005.

In addition we aim to provide recommendations for studies that are required to support the above recommendations.

To achieve this aim, in the afternoon the workshop will split into discussion groups along the following provisional themes:

- Climatologies,
- Forecasting/now-casting,
- Coastal studies,
- Process/event studies (e.g. air-sea flux studies, characterizing tropical storms….

Each discussion group will present its own recommendations towards the end of the meeting.

Approach

We suggest the groups first agree a set of requirements for sea state measurements, and use these to develop recommendations for data provision, future missions and studies. To form a basis for the discussions of each group we have provided background information and templates of tables.

Measurement Requirements

The first set of tables lists measurement requirements of sea state parameters:

accuracy,
resolution,
latency – delay from the time of the measurement to its availability to the user'

These are divided into:

"optimum" requirements – the most that could be wished for, and any improvement beyond which would provide little advantage, and
"threshold" requirements – representing a measureable and useful improvement on the present situation.

Whilst the contents of these tables were derived from a comprehensive literature review and from user surveys, they are not intended to represent the "final word". We suggest participants should discuss the content of the tables and amend them where necessary.

Improved Data Provision and Processing

Where useful improvements to data could be achieved through new developments in data provision and / or processing, specific recommendations should be made (e.g. availability of fast delivery data sets, calibration information, provision of higher level gridded data, provision of data sets combining data from several missions….)

Mission Requirements

We have provided template tables for this stage. We suggest the groups discuss the relative benefits of different altimeter types and mission scenarios (see below), and complete the tables with their preferred options.

Further Studies

If further studies are required before sensible recommendations on mission scenarios can be made, these should be noted.

For instance it may be desirable to first simulate the sensitivity of forecast models to the assimilation of data from different numbers of satellites, or to carry out correlation studies to identify whether swath (or image) information from a single satellite is preferable to more independent measurements from a series of satellites measuring along track only.

Background Information

Section 2 provides some background information on the options that may be available for future altimeter missions.

For more information on the different possible types of future altimeter missions, please refer in the first instance to the ALCATEL report provided to GAMBLE, - available on the GAMBLE website (ALCATEL_altconcepts.pdf)

Additional information is available in the WP3 interim report (SWIMSAT, JASON and GANDER), and other papers on the GAMBLE website provide information on Wittex (wittex.pdf), Wide Swath Ocean Altimeter (wsoa.pdf) , Altika, (altika.pdf) and Passive use of reflected GPS signals (gps.pdf).

The templates for the “Requirements Tables” are in WP3_tables.doc.

2. Definitions, Characteristics and Capabilities of Candidate Altimeter Systems

In this section we give a very brief overview of some of the possibilities for future altimeter missions. The options are divided into frequencies, altimeter “type”, and orbit configurations.

2.1 Frequencies

Ka band (35.5 GHz)

- lower power (2W) /mass, smaller footprint: 5 km, lower range noise over ocean (0.8 cm). More attenuated by rain. With Ku band, preference for gas transfer velocity calculations. May also be better for rain rate calculations. Possible new capability over ice (deeper penetration).

Ku band (13.6 GHz)

- long flight proven heritage (Geosat onwards). Higher power (7W)/mass than Ka, footprint 7-10 km, 2.2 cm range noise over ocean (with C-band). Less attenuated by rain than Ka. With Ka band, preference for gas transfer velocity calculations.

C band (5.3 GHz)

- Flight Proven (TOPEX). Used as secondary frequency, primarily for calculation of ionospheric loss. Provides reliable estimates of wave height, and can be used (through correction tables) to calculate wind speed - though C band sigma0 is less sensitive to changes in wind speed. Largely unaffected by rain.
- In combination with Ku (or Ka) can be used to calculate rain rate, also new dual frequency algorithms to estimate wind stress have been proposed.

S band (3.2 GHz)

- Under Flight Testing (ENVISAT). Used as secondary frequency, primarily for calculation of ionospheric loss. Should provide alternative estimates of wave height, and may be used (through correction tables) to calculate wind speed - though expected to be less sensitive to changes in wind speed. Largely unaffected by rain.
- In combination with Ku (or Ka) may be used to calculate rain rate, also new dual frequency algorithms to estimate wind stress may be possible.

2.2 Altimeter Types

Basic(B)

For inexpensive microsat deployment as part of constellation. Lower unit costs means a larger number could be deployed at a fixed price.
Single frequency, (Ku) no microwave radiometer. Possible GPS receiver and/or miniaturised DORIS. Lower fuel load would allow less frequent orbit maintenance manoeuvres. Hence would rely on models, cross-overs for range corrections and calibration.

Altika(A)

Second option for inexpensive microsat deployment as part of constellation. Possibly larger unit costs than 'B', but a small constellation still feasible.
Single frequency, (Ka), microwave radiometer. Miniaturised DORIS for orbits and ionospheric delay (plus, possibly GPS).

Doppler Delay (DD)

Another option for micro-satellite deployment. The Doppler shift of the frequency of the radar return echoes is used to reduce the effective footprint of the radar. It then becomes possible to average more pulses –this allows a higher range accuracy or a reduction in the power requirements of the instrument.
The intrinsic higher resolution also makes the instrument potentially more useful for coastal applications.

Standard (Std)

For (primarily) ocean studies, dual frequency, MWR, and DORIS, precise orbit maintenance. Based on TOPEX/JASON/ENVISAT heritage.
Will function as stand alone or as part of constellation
Dual Freq. Ka band deployment possible on microsat platform. Data rate (20-100 kbps)

Synthetic Aperture Radar Operation (SAR)

Records coherent spectrum, allows an effective bigger antenna and hence smaller footprint (using Doppler Spectrum - footprint is 280m). Also gain improved signal to noise ratio. Designed for measurements over ice.
More complex on board processing. Higher data rate (12 Mbps)..
Potential ocean applications from smaller footprint – better resolution of wave, wind, and height (latter, only if high resolution tropospheric corrections available) nearer coasts

Interferometric SAR Mode (ISAR)

Allows a number of different looks at the same surface location. Provides precise attitude for returned signal and hence precise location of reflecting point on ground. Needed for tracking over ground with steep gradients.
More complex on board processing. Higher data rate (12 Mbps).
Possibly some interesting ocean applications, Cryosat data will allow some applications to be tested

Real Aperture "Wave" Radar – SWIMSAT (RAR)

Primary function to provide swath measurement of directional wave spectra. Swath width 200 km, cell size 50 to 90 km. Proposed to have a rotating off-nadir radar and a nadir altimeter (both Ku band).

Off-nadir SAR Interferometric Radar / Swath Altimeter (SW)

An altimeter to measure sea surface height in a swath, beneath and on either side of nadir. Two altimeters operating in SAR interferometric mode, mounted on each end of a boom, provide the swath measurement. A nadir altimeter in the centre provides the calibration and tracking. There is a trade off between the need for greater separation of the SAR mode altimeters (to give greater across track accuracy), and the instability of a long boom. With present designs, swath altimeters will be not able to provide wave height measurements off-nadir.
ALCATEL initial outline gives swath width 63.5 km (on each side of nadir), range noise at the centre of swath 3-4 cm, and along track resolution of 5.3 km.
NASA studies (Rodriguez and Pollard) have considered baseline separation for the SAR altimeters of 6.4m and 10m, for a swath 15-100 km on either side of nadir. They also suggest maximum range noise of 3-4 cm may be expected.

Along Track Interferometry (ATI)

Potentially allows direct measurement of surface currents, if the wave motion can be accurately characterised.

SIRAL

SIRAL is the Ku band Sar Interferometric Radar Altimeter to be flown on Cryosat. It combines conventional altimeter operation with a SAR mode and an interferometric mode
The SAR mode allows extremely high along track resolution (250-300m) , with moderate radiometric resolution (3 db), and an improved signal to noise ratio.
The interferometric mode allows an accurate across track localisation of the reflection point, and may offer the potential for measurement of across track slope.

2.3 Orbit options for Constellations

We suggest four basic options for the configuration of a constellation of satellites.

Option A High Spatial Resolution

(Pairs of) satellites ground tracks separated by ~ 200km and < 1 minute. Will give across track slope (and hence 2D geostrophic velocities).

Option B Uniformly Dense Spatial Coverage

Satellites evenly spread around orbit. Gives uniformly dense spatial coverage. Best option for mapping oceanic eddy fields and surface energy transport. Also best coverage for provision of data to offshore operators

Option C High Temporal Resolution

Satellites placed to repeat ground tracks at more frequent intervals. Best for monitoring evolution of large-scale events (e.g. El Niño).

Option D Site Specific Coverage

One or more satellites can move orbits to allow improved coverage of important sites

2.4 Ground track Coverage

"Conventional" Nadir Altimeters

Revisit interval	Orbit type	Track spacing at 0°	Track spacing at 45°	Orbit height	Inclination	No of sats
168 days	ERS	16 km	12 km	785 km	98.5°	1
35 days	ERS	79 km	56 km	785 km	98.5°	1
17 days	Geosat *Geosat*	162 km *81 km*	115km *58km*	800 km	108°	1 *2*
10days	Jason *Jason* *Jason* *Jason* *Jason*	316 km *158 km* *105 km* *79 km* *63 km*	223 km *112 km* *74 km* *56 km* *45 km*	1336 km	66°	1 *2* *3* *4* *5*
5 days	*Estimated* *Estimated* *Estimated* *Estimated* *Estimated* *Estimated* *Estimated*	*632 km* *316 km* *158 km* *105 km* *79 km* *63 km* *32 km*	*446 km* *223 km* *112 km* *74 km* *56 km* *45 km* *23 km*	*1336 km*	*66°*	1 *2* *4* *6* *8* *10* *20*
3 days	ERS *ERS* *ERS* *ERS* *ERS* *ERS* *ERS*	918 km *459 km* *230 km* *153 km* *115 km* *92 km* *46 km*	649 km *325 km* *162 km* *108 km* *81 km* *65 km* *32 km*	785 km	98.5°	1 *2* *4* *6* *8* *10* *20*
~1 day	GANDER *GANDER* *GANDER* *GANDER* *GANDER*	2755 km *1375 km* *700 km* *466 km* *233 km*	1950 km *972 km* *490 km* *326 km* *163 km*	~600 km	~80°	1 *2* *4* *6* *12*

Table 1 Ground track spacing for Nadir Altimeter missions. Figures in italics assume satellites are evenly spaced over same orbit.

Wide Swath Altimeter

A wide swath altimeter, with a dual sided 100 km swath (and 15 km cells) on a 10 day (Jason type) repeat orbit would sample most ocean locations twice in that 10 day period (Rodriguez and Pollard.

Hence 1 wide swath altimeter would resolve fields with variability scales of 30 km and 10 days.

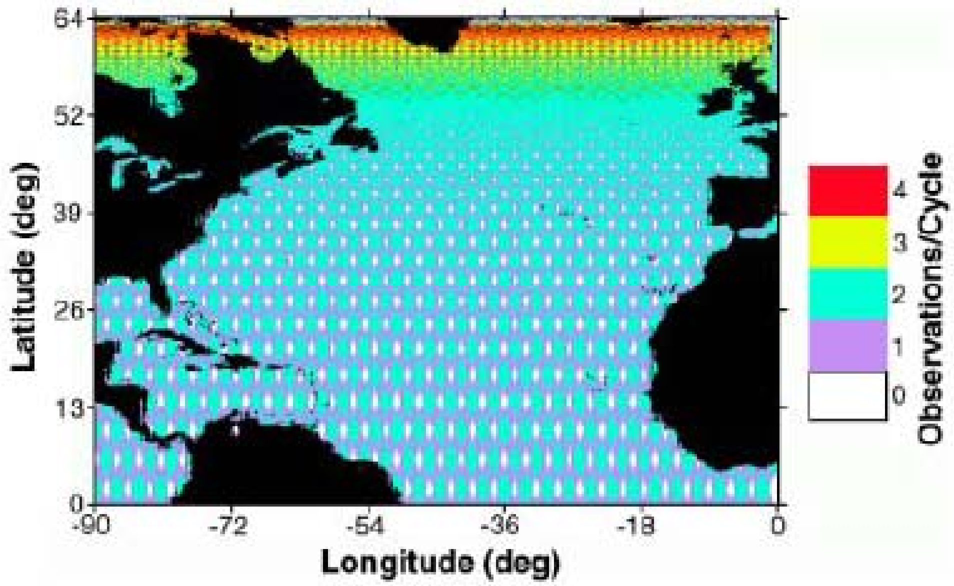

Figure 1 Number of times each surface point is mapped by WSOA (100km dual sided swath) during a 10 day repeat cycle (Rodriguez and Pollard, 2001).

Satellites in > 1 plane on a GANDER type ocean monitoring mission

No. Planes	Sats / plane	Plane spacing	Sat spacing (longitude)	Track spacing at 0°	Track spacing at 45°	Approx revisit interval
1	12	360°	2.1°	233 km	163 km	12 hrs
2	6	90°	4.2°	466 km	326 km	6 hrs
3	4	60°	6.3°	700 km	490 km	4 hrs
1	6	360°	4.2°	466 km	326 km	12 hrs
2	3	90°	8.3°	921 km	645 km	6 hrs
3	2	60°	12.5°	1375 km	972 km	4 hrs

Table 2 Ground track spacing and revisit intervals for a GANDER style microsatellite nadir altimeter constellation, on an ocean monitoring mission (orbit height ~ 600 km, inclination ~80°).