1. Introduction

In this document we provide pro-forma tables to help the Workshop groups in their discussions. The aim is to summarise:

- Priorities in future requirements for altimeter sea-state data.
- Initial recommendations for the configurations of future altimeter missions.
- Work that must be carried out in order to develop the above recommendations.

The information contained within the initial versions of the tables presented here has been compiled following a review of literature, and some direct discussions with end-users. However, they are included to provide a starting point for discussions. Participants are encouraged to question the contents and edit /replace where there is good reason to do so.

2. Suggested Measurement Requirements

It should be emphasised that the requirements listed below are taken as the end-user requirements for the geophysical products as presented to them from service providers. The product that they use may well be a combination of information from different sources. The typical commercial end-user is not too concerned with the source of the information (except in so far as it effects the product reliability and accuracy). Thus the requirements do not reflect the necessary resolution/accuracy expected from the altimeter data source.

"Threshold" requirements should reflect the "next step" on from the resolution/accuracy in the data products currently available. The optimum requirements can be thought to represent the resolution of an "ideal" data source.

2.1 Climatologies

Application	Parameter	Optimum requirements				Threshold requirements			
		Spatial res (km)	Time res	latency	accuracy	Spatial res (km)	Time res	latency	accuracy
Climate Research	Sig. wave hgt [i]Combined / windsea / swell?	50	6hr	months	0.1 m	100	1 mon	3 months	0.1 m
Offshore appls. (climate)	Sig. wave ht. Combined / windsea / swell?	10	6 hr	years	0.1 m	1° x 1°	1 mon	Years	0.1 m
Climate Research	Wind speed	100	10d	10d	0.5 mm yr^{-1}	100	10d	10d	1 mm yr^{-1}
Offshore appls. (climate)	Wind speed	100	NA	NA	1 cm	500	NA	NA	5-10 cm
Climate Research	Wave period Combined / windsea / swell?					200	5d	5d	4 cm
Offshore appls. (climate)	Wave period Combined / windsea / swell?	10	6 hr	years	0.1 s	1° x 1°	1 mon	Years	0.2 s
Climate Research	Wave dirn. [j] Combined / windsea / swell?					200	5d	5d	4 cm
Offshore appls. (climate)	Wave dirn. Combined / windsea / swell?	10	6 hr	years	±5°	1° x 1°	1 mon	Years	±10°
Climate Research	dir. wave spectrum					200	5d	5d	4 cm
Offshore appls. (climate)	dir. wave spectrum					100 km	7d	3hr	15° dirn, 10% wavelength
Joint swh/ period prob. dist fns.					1° x 1°	1 mon	Years	0.1 m / 0.2 s	Joint swh/period prob. dist fns. [9F]
Joint wind/ wave prob. dist fns.					1° x 1°	1 mon	Years	0.1 m /2 ms^{-1}	Joint wind/wave prob. dist fns.
Surface wind stress	Directly estimated wind stress	25	1d	1d	1 cm hr^{-1}	100	1d	1d	1 cm hr^{-1}
Surface pCO_2	Air sea gas transfer velocities	25	1d	1d	1 cm hr^{-1}	100	1d	1d	1 cm hr^{-1}
Others?									

Table 1. User Requirements: Sea State Climatologies

2.2 Forecasting/ Nowcasting

Application	Parameter	Optimum requirements				Threshold requirements			
		Spatial res (km)	Time res	latency	accuracy	Spatial res (km)	Time res	latency	accuracy
near real time	sig. wave ht.	10	20 min	1 hr	0.1 m	30	1 hr	3 hr	0.5 m
assimilation into models	sig. wave ht.	25	3 hr	1hr	0.1 m	100	6hr	1hr	0.1 m
near real time	wave period	10	20 min	1 hr	0.1 s	30	1 hr	3 hr	0.5 s
near real time	wave dir.	10	20 min	1 hr	±5°	30	1 hr	3 hr	±10°
near real time	swell swh	10	30 min	1 hr	0.1 m	30	1 hr	3 hr	0.5 m
near real time	swell period	10	30 min	1 hr	0.1 s	30	1 hr	3 hr	0.5 s
Near real time	swell dir.	10	30 min	1 hr	±5°	30	1 hr	3 hr	±10°
Near real time	dir. wave spectrum	10	30 min	1 hr	*1% max energy*	30	1 hr	3 hrs	1% max energy
assimilation into models	sig. wave ht.	25	3 hr	1hr	0.1 m	100	6hr	1hr	0.1 m
assimilation into models	wave period	25	3 hr	1hr	0.1 m	100	6hr	1hr	0.1 m
assimilation into models	dir. wave spectrum	25	3 hr	1hr	0.1 m	100	6hr	1hr	0.1 m
Others?									

Table 2 User Requirements: Nowcasting /Forecasting

2.3 Coastal Applications

It should be noted that the requirements on spatial and temporal resolution for sea state data in coastal applications are especially demanding and, in practical terms, can only be met through a combined monitoring system.

Applica-tion	Parameter	**Optimum requirements**				**Threshold requirements**			
		Spatial res (km)	Time res	latency	accuracy	Spatial res (km)	Time res	latency	accuracy
near real time and climate	sig. wave ht. Combined / windsea / swell?	<5	20 min	1 hr	0.1	10	1 hr	3 hr	0.1 m
near real time and climate	wave period Combined / windsea / swell?	<5	20 min	1 hr	0.1 s	10	1 hr	3 hr	0.1 s
near real time and climate	wave dir Combined / windsea / swell?	<10	20 min	1 hr	±5°	30	1 hr	3 hr	±10°
Near real time	dir. wave spectrum	10	30 min	1 hr	*1% max energy*	30	1 hr	3 hrs	1% max energy
	Joint swh/period prob. dist fns.					1° x 1°	1 mon	Years	0.1 m / 0.2 s
	Joint wind/wave prob. dist fns.					1° x 1°	1 mon	Years	0.1 m /2 ms^{-1}
Erosion, sediment transport, habitat loss	Surface waves (refer above)								
Chemical, biological &physical interactions	Waves and sea surface height (refer above)								
Others?									

Table 3. User Requirements: Coastal Applications

2.4 Process / Event Studies

Application	Parameter	Optimum requirements				Threshold requirements			
		Spatial res (km)	Time res	latency	accuracy	Spatial res (km)	Time res	latency	accuracy
Event and feature studies	e.g. Significant wave height	< 10	<1d	1 hr	0.1m / 10%	200	1d	3 hr	0.1m / 10%
Tropical Cyclones / Hurricanes									
Individual Extreme Waves									
Model validation, inst.. Calibration	Wind speed	5km along track	NA	NA	2 ms^{-1}	10km along track	NA	NA	2 ms^{-1}
Wind stress	Dual frequency σ0					20 km			0.1 ms^{-1}
Improved algorithms	Wind speed					10km along track	NA	NA	1.5 ms^{-1}
Air-sea gas transfer vel	Dual frequency σ0	25	1d	1d	1 cm hr^{-1}	100	1d	1d	1 cm hr^{-1}
Rain rate	Dual frequency σ0					250	30d	90d	10 mm $month^{-1}$
Wave period	Sig wave ht., σ0	50	6hr	months	0.5 s	100	1 mon	3 months	0.5 s
Wave spectra	From non-nadir radar					100 km	7d	3hr	15° dirn, 10% wavelen.
Others?									

Table 4. User Requirements: Process / Event Studies

3. Desirable Altimeter Characteristics

Within this section, the aim is to make initial recommendations for preferred characteristics of future altimeter missions, AND/OR to identify studies necessary to allow these recommendations to be made.
We suggest it may be useful to adopt the following approach:

First identify the critical steps in translating the initial measurement to the end product (i.e. those which may have an impact on the desired qualities (resolution / accuracy) of the end product):

- retrieval algorithms
- corrections (e.g. ionosphere, troposphere)
- calibration
- model assimilation
- combination with other data

What relevant developments can be expected in 2003-2005, and what impact will they have?

- Better geoid information
- Developments in operational models
- Argo float data
- Other in-situ / EO data
- Fast tide gauge data provision

With this in mind, consider how the different user requirements determine the desired characteristics of the altimeter instrument. Refer to the briefing document and other papers on the GAMBLE web site for further information. Relevant issues are:

Frequency

Which frequencies (or combinations of) are preferable for which user requirements?

Simultaneous data for Corrections

What simultaneous data are required:

- Ionosphere – Dual Frequency, DORIS
- Troposphere – Microwave Radiometer
- Orbit information – laser tracking, GPS tracking, DORIS
- Tide gauge data for altimeter calibration.
- Buoy data for altimeter calibration.
- Others?

Technical Capability

- What "type" of altimeter is desirable (basic, standard, SAR mode, etc)?

Orbit Configurations

- What orbit configuration will best satisfy the sampling requirements?

3.1 Climatologies

Application	Parameter	Critical Steps, Auxilary Data	Relevant Future Develop-ments	Main Freq.	2nd Freq	Altimeter "Type"	Mission characteristics			
							Constellation type	No sats	Repeat cycle	Accurate orbit?
Climate Research	Sig. wave hgt [j]Combined / windsea / swell?									
Offshore appls. (climate)	Sig. wave ht. Combined / windsea / swell?									
Climate Research	Wind speed									
Offshore appls. (climate)	Wind speed									
Climate Research	Wave period [j]Combined / windsea / swell?									
Offshore appls. (climate)	Wave period Combined / windsea / swell?									
Climate Research	Wave dirn. [j]Combined / windsea / swell?									
Offshore appls. (climate)	Wave dirn. [j]Combined / windsea / swell?									
Offshore appls. (climate)	Wave dirn. [j]Combined / windsea / swell?									
Climate Research	dir. wave spectrum									
Offshore appls. (climate)	dir. wave spectrum									
Joint swh/ period prob. dist fns.										
Joint wind/ wave prob. dist fns.										
Surface wind stress	Directly estimated wind stress									
Surface pCO_2	Air sea gas transfer velocities									

Table 5: Preferred mission and instrument characteristics: Sea State Climatologies

3.2 Forecasting and Nowcasting

Application	Parameter	Critical Steps, Auxilary Data	Relevant Future Develop-ments	Main Freq	2nd Freq	Altimeter "Type"	Mission characteristics			
							Constellation type	No sats	Repeat cycle	Accurate orbit?
near real time	sig. wave ht.									
assimilation into models	sig. wave ht.									
near real time	wave period									
near real time	wave dir.									
near real time	swell swh									
near real time	swell period									
Near real time	swell dir.									
Near real time	dir. wave spectrum									
assimilation into models	sig. wave ht.									
assimilation into models	wave period									
assimilation into models	dir. wave spectrum									

Table 6: Preferred mission and instrument characteristics: Nowcasting and Forecasting

3.3 Coastal Studies

Application	Parameter	Critical Steps, Auxilary Data	Relevant Future Develop-ments	Main Freq	2nd Freq	Altimeter Type	Mission characteristics			
							Constellation type	No sats	Repeat cycle	Accurate orbit?
near real time and climate	sig. wave ht. [J]Combined / windsea / swell?									
near real time and climate	wave period [J]Combined / windsea / swell?									
near real time and climate	wave dir[J]Combined / windsea / swell?									
Near real time	dir. wave spectrum [7, A,B,D]									
	Joint swh/period prob. dist fns. [9F]									
	Joint wind/wave prob. dist fns. [9F]									
Erosion, sediment transport, habitat loss …,	Surface waves (refer above)[6,A]									
Chemical, biological &physical interactions	Waves and sea surface height (refer above)[6A]									
Others?										

Table 7: Preferred mission and instrument characteristics: Coastal studies

3.4 Event / Process Studies

Application	Parameter	Critical Steps, Auxilary Data	Relevant Future Develop-ments	Main Freq	2nd Freq	Altimeter "Type"	Mission characteristics			
							Constellation type	No sats	Repeat cycle	Accurate orbit?
Event and feature studies	e.g. Significant wave hgt									
Tropical Cyclones / Hurricanes										
Individual Extreme Waves										
Model validation, □inst.. Calibration	Wind speed									
Wind stress	Dual frequency σ0									
Improved algorithms	Wind speed									
Air-sea gas transfer vel	Dual frequency σ0									
Rain rate	Dual frequency σ0									
Wave period	Sig wave ht. , σ0									
Wave spectra	From non-nadir radar									
Others?										

Table 8: Preferred mission and instrument characteristics: Process / Event Studies