

# **GAMBLE – A Thematic Network to Consider Future Developments in Satellite Altimetry**

<http://www.altimetry.net>

## **Workshop for Theme 2 – Sea State Applications**

**Venue: Istituto Studio Dinamica Grandi Masse, S. Polo 1364, 30125 Venice.**

**Date: Monday 30<sup>th</sup> September 0900-1630**

### **Agenda**

09:30 **Welcome** and local arrangements - Luigi Cavaleri, ISDGM

09:45 **Aims of Meeting** - David Cotton, Satellite Observing Systems (SOS)

10:00 **Review of Interim Gamble Report** - Luigi Cavaleri

11:00 **Priorities for developments in altimeter sea state data:**

Peter Janssen, ECMWF

Jim Gunson UKMO: A statement of interests provided

Jean-Michel Lefevre, Meteo France

Johannes Guddall, DNMI/Max Wave

Susanne Lehner, DLR: Global statistics using SAR data

Francisco Ocampo-Torres, CICESE (Mexico):

14:00 -15:00 **Discussion groups:**

**(a) Forecasting/Nowcasting**

**(b) Climatologies/Process/Event Studies**

15:30 **Combined group discussion** to agree future steps

16:30 - **Close**

### **Attending:**

#### **Gamble partners:**

Luigi Cavaleri, LC (ISDGM) l.cavaleri@isdgm.ve.cnr.it

Tom Allan, TA (SOS) tom@satobsys.co.uk

Peter Challenor, PC (SOC) pc@soc.soton.ac.uk

David Cotton, DC (SOS) d.cotton@satobsys.co.uk

Daniele Hauser, DH (CETP) daniele.HAUSER@cetp.ipsl.fr

Laurent Phalippou, LP (ALCATEL) Laurent.Phalippou@space.alcatel.fr

Eric Thouvenot, ET (CNES) eric.thouvenot@cnes.fr

David Woolf, DW(SOC) dkw@soc.soton.ac.uk

#### **Invited Experts:**

Johannes Guddal, JG (DNMI) Johannes.Guddal@dnmi.no

Peter Janssen, PJ (ECMWF) janssen@ecmwf.int

Jean-Michel Lefevre, JML (Meteo-France) jean-michel.lefevre@meteo.fr

Susanne Lehner, SL (DLR) Susanne.Lehner@dlr.de

Francisco Ocampo-Torres, FOT (CICESE, Mexico) ocampo@cicese.mx

### **Interested Parties (who wish to be included in further discussions):**

Jim Gunson (UKMO) jgunson@metoffice.com

Wolfgang Rosentahl (GKSS) rosenthal@gkss.de

Juan Guijarro (ESA/ESTEC) juan.guijarro@esa.int

# Minutes

## 1. Welcome:

LC welcomed the participants and thanked them for their attendance.

## 2. Workshop Format: (presentation available online as “WP3\_WS\_aims.ppt”)

DC described the proposed format and aims for the workshop. The intention was to provide an opportunity for in-depth discussions, in order to arrive at some recommendations for future priorities for altimeter data.

## 3. Review of Interim Report, (presentation to be made available)

LC presented an overview of the conclusions which followed from the Interim report for GAMBLE WP3. In particular he highlighted issues to be addressed:

How can we improve:

Accuracy of measurements?

Information provided?

Frequency and distribution of data?

What new research is required?

## 4. User Requirements – Presentations by Invited Experts.

### 4.1 Peter Janssen (ECMWF) – copies of notes were handed out at the meeting:

#### 1. Error estimation of model, buoy and altimeter wave height.

PJ looked at four way co-locations of model hindcast, model analysis, in-situ and altimeter data to estimate random errors in each data set. The hindcast output were included as the analysis could include an altimeter dependent error.

Conclusion: Altimeter errors were seen to be low but it is important to consider how data are prepared to provide co-locations (averaging, interpolation,.....)

#### 2. Benefit of flying an additional altimeter on wave height analysis

PJ presented an analysis of the period when both ERS1 and ERS2 wave height data were available. The forecast performance (as represented by scatter index) in significant wave height was improved when data from both ERS-2 and ERS-1 data were assimilated (compared to the assimilation of data from just one altimeter), but the performance with respect to wave period was not improved. If a calibration was applied to the altimeter data prior to assimilation, the best performance was achieved.

It was noted that the orbits of ERS1 and ERS2 were not optimized to maximize impact on assimilation (they were relatively close together in time and space).

Conclusion: It is beneficial to assimilate data from more than one altimeter, but consistent calibrations should be applied, and orbits can be optimised.

### **3. Sea State Bias**

Wave height is important in the estimation of “sea-state bias”, one of the major remaining sources of error in the calculation of altimeter range. PJ presented analysis indicating that wave steepness, or more specifically, the Phillips’s parameter, provided a better (practically and theoretically) estimate of sea-state bias than the currently used empirical formulation. His analysis was based on the use of parameters derived from wave model analyses. There was some discussion whether it might be possible to retrieve the necessary parameters directly from the altimeter waveform.

#### **4.2 Jean-Michel Lefevre (Meteo-France) – (presentation available online as “gamble\_venice\_jml.pdf”).**

JML presented recent work from the Meteo-France wave modelling group. They run several wave models at a range of resolutions and spatial scales, with winds from several atmospheric models. Altimeter data are assimilated in the operational wave model. First attempts have been made to assimilate SAR data and some work is still needed in order to take properly into account the SAR frequency cut-off. A recent study compared the performance of the VAG, WAM and Wavewatch-3 wave models. Each has their own characteristics and specialities – perhaps with different aspects of performance “tuned” to suit specific requirements or interests. It was found that most models underestimated severe events.

Assimilation studies showed that assimilation of ERS-2 altimeter data did have a significant impact in reducing overall error, although the representation of individual severe events was not noticeably affected. It was suggested this may simply be due to limited sampling. Studies (for SWIMSAT) have been carried out to assess the effect of assimilation of spectral data, and it was found that such data could be expected to have a longer term impact. Meteo-France plan some investigations to investigate the impact of assimilating data from more than one satellite, both in terms of current missions (Geosat Follow-On, ERS-2 and TOPEX) and for some hypothetical multi-satellite mission scenarios. The importance (perhaps over-riding importance) of accurate wind fields was emphasized on a number of occasions.

#### **4.3 Jim Gunson (UKMO) – statement attached.**

A statement from the UKMO emphasized the importance of information from regions of swell generation and propagation. A need to provide synergy between altimeter sampling and model grids was noted.

#### **4.4 Johannes Guddal (DNMI) – abstract attached.**

JG emphasised the sometimes catastrophic impact of tropical storms on human lives and the environment, and so highlighted the importance of accurate prediction of the consequences of these events (e.g. storm surges). Altimeter data (sea state and sea surface height) could have a central role to play in near real time monitoring systems which feed into short term forecasts.

#### **4.5 Susanne Lehner (DLR) – (Presentation available online as gamble\_venice\_lehner.pdf)**

SL discussed the use of SAR and other radar data, and gave an overview of relevant aspects of the EC Framework V MAXWAVE project. The emphasis here was on the possible derivation of wave parameters in addition to significant wave height.

SL proposed that there was much scope for the joint use of altimeter and SAR data, for instance to establish global climatologies with new parameters, such as wave crest length, expected maximum wave height, groupiness, etc.

SL proposed more detailed studies of altimeter and SAR data in evaluations of estimates of wave period and wind speed, and studies of individual storms. It was also suggested that altimeter waveforms could be subject to more detailed analysis to see if e.g. wave skewness could be extracted. Cryosat (expected launch 2005) will carry a highly advanced radar altimeter with a range of new modes of operation (interferometric and synthetic aperture modes). Although this is a mission to investigate variability in ice-thickness, it is hoped that it will also offer a valuable opportunity to investigate the sea state measuring capabilities of advanced altimeters.

#### **4.6 Francisco Ocampo-Torres, CICESE (Mexico): Wave measurements and Satellite Data Requirements from CICESE –Presentation to be made available**

FOT presented requirements from the perspective of CICESE in Mexico. He noted that the lack of an in-situ monitoring network for the Pacific Ocean meant that accurate and reliable satellite data were especially important. In particular he expressed a requirement for improved accuracy in measuring high waves and a need for other waves parameters other than significant wave height.

It was noted that extremes in wave climate at the western coasts of Southern USA, and Central America, coincided with the El Niño cycle.

#### **5. Discussion Groups:**

After lunch the meeting separated into two discussion groups.

Nowcasting/Forecasting, led by LC, TA, with: PC, LP, JG, PJ, JML, FOT

Climatologies/Process/Event Studies led by DC, with: DH, ET, DW, SL

In the time available discussions were focussed on the priorities for measurements from altimeters, and any work that is required to support the definition of these priorities . A subsequent discussion of desirable mission characteristics (instrumentation, orbit parameters) will be required.

Draft reports from the discussion groups conclusions are included in the appendix:

## **6. Final Discussion:**

It was agreed that SOS would circulate draft reports of the two discussion groups. After final versions were agreed, these documents would form the basis of further email based discussions to define:

- a. Priority data requirements and data specifications.
- b. Research Priorities / Recommendations.
- c. Mission Recommendations.

We suggest that ISDGM and SOS will provide guidelines and a timetable for these discussions, with the GAMBLE timetable in mind (see below)

## **7. Significant Dates**

7/8 November 2002 GAMBLE Sea surface Height / Orbits workshop at TU Delft.

January 2003: GAMBLE Mid Term Review.

April 2003: Deadline for GAMBLE Sea State Work Package Final Report.

## **8. Actions**

**ALL – before end October**

Read, correct and return minutes (to LC and DC)

**ALL – before end October**

Read, discuss, correct and add to discussion group reports (return to LC and DC).

These will then form the basis for the continuing discussions

**SL,JML, FOT – before end October**

Provide copies of presentations to DC

**DC, LC – before end October**

Provide guidelines and timetable for further email discussions.

**DC – 1<sup>st</sup> week November**

Circulate finalised minutes and discussion group reports, and post on GAMBLE web page

# Appendices:

## **1. Draft Report from GAMBLE Sea State Workshop: Discussion Group on Nowcasting and Forecasting:**

Forecasting Group

TDA, PDC, PJ, J-ML, JG, LC

Following the guidelines agreed in the morning session the group considered the following topics:

Data requirements:

- Forecasting models
- GANDER-type constellations
- Other?

Data quality:

- Accuracy required
- Sampling
- Need for new parameters

Space segment:

- Type of altimeter
- Single platform or constellation?
- How many (if constellation)?

It was agreed that continuous monitoring of sea state from polar-orbiting satellites was of prime importance to the 3 distinct categories of 'users':

- Marine/climate research
- Meteorological forecasting
- Development of commercial services

The accuracy achieved in the measurement of significant wave height by present-day altimeters was estimated to be  $\pm 25\text{cm}$  and this was considered sufficient for all practical purposes. The figure quoted by space agencies is  $\pm 50\text{cm}$  and it was recommended that this should be modified to an achievable error of  $25\text{cm}$ , or if preferable, an equivalent figure proportional to the significant wave height (6%?).

Unlike the requirement for the precise measurement of ocean topography there was no requirement by the wave community to lay down repeat orbits. Neither was there the same requirement for precise position fixing. An approximately uniform distribution, in space and time, is a desirable characteristics.

It was agreed that ideally wave height measurements should be delivered every 6 hours with a spatial separation over the globe of 200km. This would require between 10 – 12 platforms if a constellation of altimeters was the preferred solution. At present there are 5 in polar orbit. The 200 km limit would be complied with in the stormy extratropical zone. A larger spacing would exist, and be acceptable, at lower latitudes.

It would be essential with such a constellation to ensure good inter-calibration between the different instruments.

After measurements of significant wave height, information on surface wave spectra was considered the most important requirement. This may be provided by future sensors now on the drawing board (such as Swimsat) but it is not possible with present-day technology.

Wave direction could be derived, however, from the wave mode of Envisat's ASAR. It remained to be seen how well this information might be combined with the information on Hs and period which could be extracted from altimeters. It was also important to assess the impact of the wind velocity information provided by QuikSCAT and soon to be supplemented by the scatterometer carried on the Japanese ADEOS II. It should be recognised, however, that the usefulness of scatterometers was limited in semi-enclosed seas such as the Mediterranean and Baltic Sea. The limitations of altimeters in coastal zones must also be recognised. They failed to provide meaningful observations within a coastal strip 15 – 20km wide.

Finally, it was pointed out that the greatest damage from the sea was caused by storm surges over low-lying areas such as Bangladesh. In those situations it was imperative to link measurements of storms to increase in sea level.

## **2. Draft Report from GAMBLE Sea State Workshop: Discussion Group on Climatology / Event / Process Studies**

PDC, DH, ET, SL, DW

In the time available the group concentrated on assessing data requirements:

### **Climatologies**

#### **Wave Climatologies**

- (b) Whilst it is clear that improved sampling would reduce errors in climatologies, and allow a reduction in the grid size, a higher priority was placed on the need for wave parameters in addition to significant wave height.
- (c) These parameters could include wave period, wave direction, and swell parameters (height, period and direction), and joint distributions (e.g. of wave height / period,  $H_{max}/H_s$ ).
- (d) In addition it was felt that more use could be made of joint analyses of altimeter and SAR data - for climatologies of e.g. groupiness, expected maximum wave heights, crest length.
- (e) One key issue is gaining the acceptance of any new climatology by the user community. The offshore community have a certain "attachment" to tried and test methodologies.

#### **Air-Sea Flux Climatologies**

- (f) Climatologies of air-sea fluxes (momentum, heat, gas, freshwater) are important for climate studies. Altimeters offer the possibility for direct measurements of surface wind stress, and air-sea gas transfer velocities.
- (g) Presently available estimates of global mean air-sea gas transfer velocities vary by a factor of two. Thus any improvement on this resolution would be beneficial. An accuracy to aim for (in a climatology) could be 50% (or 10 cm / hr) on a monthly averaged 2 x 2 degree grid.

### **Event Studies**

Priorities are:

- Improving or verifying the accuracy of altimeter measurements of high winds and waves.
- New algorithms are known to be required for measurements of winds greater than 15 m/s (the backscatter to wind speed relationship changes fundamentally at high winds).
- Altimeter measurements of high waves (> 15m) are thought to be accurate, but there are few in-situ ground truth data to confirm this.
- Joint use of altimeter/SAR and perhaps altimeter/Optical data sets to provide profiles of individual severe events.

### **Process Studies**

For detailed studies of ocean wave processes it was suggested more sophisticated processing of the altimeter signal should be attempted. For instance

- Analysis of the waveform shape (averaged if necessary) could provide estimates of: Kurtosis/skewness, pdf of surface elevation,

- Estimate of steepness would be of use to offshore operators and also for better estimates of sea state bias.

Cryosat altimeter data over the ocean should be requested, to allow:

- Analysis of phase information from Cryosat altimeter
  - Analysis of returns from altimeter “sub-cells”, possible from ISAR mode of Cryosat
- Plus....

### **3. Suggested use of altimetry in Storm Surge Forecasting connected with Tropical Cyclones.**

Submitted to the GAMBLE meeting, Venice, 30 September,  
By Johannes Guddal.

#### **Abstract.**

Storm surges connected with landfalls of Tropical Cyclones are perhaps the most dramatic, damaging and suddenly occurring between natural disasters. Up to half a million people are believed to have perished only through one night with a storm surge hitting Bangladesh. The prominent drivers of extreme storm surges in the tropics are the tropical cyclones and their wind fields. These are intensive atmospheric cyclones, with sustained wind speeds even beyond 100kts, and propagating rapidly over large distances. Conventional forecasting of cyclone developments seeks to predict the intensity and movement track of the cyclone, with a rough parameterization of the wind/pressure fields around the eye of the cyclone. Wind/pressure fields are necessary forcing fields for the numerical models to predict storm surges. The state-of-art leaves much to be improved regarding the quality of such forecasting. This document suggests the inclusion of global tropical altimetry, and, optionally scatterometry, to improve the accuracy of storm surge forecasting.

#### **Possible inclusion of altimetry and scatterometry.**

The operational mode of a storm surge forecasting model has the following phasing:

1. Initialization, which normally means using the prognostic fields from a previous prognosis or a 'warming up' of the model with analytical wind/pressure fields.
2. Provision of forcing fields for wind/pressure, normally from a large responsible computer center such as the Japan Meteorological Agency.
3. Ocean Model operation 2 – 5 days, predicting future development of sea level including tides in a region such as the South China Sea.
4. Performing verification statistics by comparison with tidal gauges etc.

It is strongly believed that inclusion of altimetry (and scatterometry) becomes beneficial under phase 1 and 4, perhaps in phase 2 as well. Much of the lack of accuracy in sea level forecasting is due to inadequate initialization, as well as a too rough description of the acting wind fields.

#### **Altimetry/scatterometry products that may help in storm surge forecasting.**

Near real time gridded sea level and wind fields could be 'sold' to responsible centers in the Tropical Cyclone Programme, or to regional/national forecasting agencies in closer contact with disaster mitigation mechanisms. These would again be used to update the corresponding numerical fields, and thereby have a positive impact on the forecasting accuracy.

#### ***4. Statement Summarising the UK Meteorological Office Interests with Respect to GAMBLE (Wave Prediction and Modelling).***

Submitted to the GAMBLE meeting, Venice, 30 September,  
By Jim Gunson

The Met Office runs a spectral wave model to provide sea-state forecasts and hindcasts for a variety of customer needs. The model is run both globally and regionally for the European and UK waters. An important need is the accurate representation of long-period swell propagation. Good quality satellite observations of wave height and wind speed from an altimeter, and the two-dimensional wave energy spectra from the SAR, are highly desirable. A synergy of the wave model with the satellite observations over regions of swell generation would greatly improve the sea-state forecasts.