AVAILABILITY AND REQUIREMENTS OF SATELLITE INFORMATION FOR OCEAN APPLICATIONS

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Summary and Purpose of Document

This document provides a brief overview on the satellite information availability, corresponding requirements, and issues regarding the ocean applications.

ACTION PROPOSED

The seventh session is invited to:

(a) Take note of this document, and

(b) Recommend any relevant action for consideration by the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM).
DISCUSSION

INTRODUCTION

1. Satellite observations have clearly demonstrated usefulness in providing information for ocean applications, operational and research-based, to improve simulation and forecasting of ocean states, and more recently for coastal applications. The communities of interest continuously identify requirements for satellite information in support of the associated ocean and coastal applications, described primarily in the WMO Rolling Review of Requirements (RRR) / Observing Systems Capability Analysis Tool (OSCAR: Find “Ocean” theme at http://www.wmo-sat.info/oscar/observingrequirements).

2. This document, while not excluding any other applications and issues that are not described herein, introduce some applications of satellite data/products in ocean and coastal applications, and related issues.1

3. Among applications of satellite information is the assimilation into numerical models, including global and regional ocean models of ocean currents, waves and storm surges. Also, the quality and usability of EO products depend upon good calibration of the satellite sensors, as well as use of reliable retrieval algorithms. In this context, it is important to note that satellite data applications create great synergies when considered together with in situ data, re-analysis and verification tools. The table below briefly describes in situ, satellite and model sources to obtain those information/products.

Table: Sources of Metocean data
(excerpt from JCOMM SFSPA Observations User Requirement Document)

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1 See also a WMO Working Paper to CGMS 39 (2011), on “Requirements of Satellite Information for Coastal Inundation Forecasting and Warning”
PARAMETERS AND PRODUCTS USED FOR METOCEAN APPLICATIONS

**SEA SURFACE TEMPERATURE**

4. Sea Surface Temperature (SST) is one of the variables essential to monitoring and simulating ocean state, and to correctly determine the heat and momentum fluxes across the air-sea interface. It affects the variations of surface energy exchange at the ocean-atmosphere interface and present thermal condition at the sea surface as well. The amount of SST data has increased dramatically thanks to satellite measurements.

**Group on High Resolution Sea Surface Temperature (GHRSSST)**

5. The Group on High Resolution SST (GHRSSST; [http://www.ghrsst.org/](http://www.ghrsst.org/)) has provided operational users and science community with SST measured by the satellite constellation. It also provides a framework for SST data sharing, best practices for data processing and a forum for scientific dialog, bringing SST to the user.

6. A variety of satellite SST data (Level 2 through 4) are available on GHRSSST Global and Regional Data Assembly Centres (GDAC/RDACs) in Australia, Japan, USA and Europe. Each RDAC provides its own satellite SST data in a common GHRSSST format specification, which is a netCDF file following the Climate Forecast (CF) convention. A full product specification can be found in the GHRSSST Data processing Specification (GDS).

7. The ocean modelling community is the key user of GHRSSST (the initial requirements for GHRSSST were set by GODAE). GHRSSST has been actively communicating with the JCOMM Expert Team on Operational Ocean Forecasting Systems (ETOOFS), scientific panels of the Global Climate Observing System (GCOS) and WMO to review and meet requirements for ocean modelling. In doing so, GHRSSST has significantly contributed to the WMO RRR, through analysing and transferring GHRSSST requirements to WMO RRR/OSCAR in data assimilation, quality control, product usage and latency, and observing system experiments. Moreover, GHRSSST plans to carry out its own gap analyses and ensure that the Statement of Guidance reflects current capabilities in SST.

**Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA)**

8. The multi-satellite SST product has been produced by the United Kingdom MetOffice through the MyOcean project. It provides an estimate of the foundation SST, ocean temperature at a depth which is free of diurnal variations. The analysis has been designed to meet the needs of applications requiring high-resolution space-time scales including global numerical weather prediction and operational ocean models. It is used by environmental, marine, meteorological and climate organizations and research institutions for seasonal forecasts, climate change detection, environmental approach, productivity. The product consists of daily gap-free maps of sea surface temperature, referred as L4 product, at 0.05° x 0.05° horizontal resolution, using both in situ and satellite observations. These products are not distributed via GEONETCast, but MyOcean sourced data are distributed via the internet (see [http://www.myocean.eu/web/24-catalogue.php](http://www.myocean.eu/web/24-catalogue.php)).

**Other temperature data**

9. Other than those dataset within RDACs, some brightness temperature (Level 1B) data are available on:

- AVHRR: NOAA Comprehensive Large Array-Data Stewardship System (CLASS) ([http://www.class.ngdc.noaa.gov/saa/products/welcome](http://www.class.ngdc.noaa.gov/saa/products/welcome))
- AMSR2: GCOM-W1 Data Providing Service ([https://gcom-w1.jaxa.jp/auth.html](https://gcom-w1.jaxa.jp/auth.html))
**Issues/Challenges**

10. Ongoing activities within the JCOMM framework include a coordination between GHRSSST and the ETOOFS in reviewing OOFS requirements for SST, identifying SST priorities and trade-offs for OOFS, and identifying gaps in SST measurement systems to support OOFS – in the short-term (1-2 years) and longer-term (10-20 years). Some issues and future challenges that have been discussed between GHRSSST and ETOOFS include:

- The Advanced Along-Track Scanning Radiometer (AATSR) is no longer operational, therefore reference dataset to build HRSST should be replaced – for example, with the high quality subset of MetOp Advanced Very High Resolution Radiometer (AVHRR);
- The loss of Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) calls for alternative/redundant capability in microwave SST measurements, such as the Advanced Microwave Scanning Radiometer 2 (AMSR-2) on GCOM-W of JAXA, or the microwave imager (MWI) on the Chinese HY-2 series;
- Geostationary SST (e.g. through relocating Meteosat-8) would greatly facilitate future coupled assimilation over the Indian Ocean domain.

**WINDS**

**Scatterometer Wind**

11. The scatterometer is a satellite instrument that provides global measurements of the wind speed and direction at the sea surface. There have been scatterometers in orbit since 1992. First the SCAT instrument mounted on ERS-1 and ERS-2, later on the Seawinds on QuikSCAT. Currently there are three operational scatterometers providing worldwide data: the Advanced Scatterometers (ASCAT) on MetOp-A and MetOp-B, and OSCAT on the Oceansat-2 spacecraft of the Indian Space Research Organization (ISRO). MetOp-B has become operational beginning 2013. Furthermore efforts are being made to make global winds from the scatterometer (SCAT) of China’s HY-2A globally accessible. KNMI is producing wind products for all these scatterometers on behalf of the EUMETSAT Ocean and Sea Ice Satellite Applications Facility (OSI-SAF). These products are extensively calibrated and routinely validated.

12. Scatterometer wind data are important sources of information for Numerical Weather Prediction, oceanography and climate studies. They also provide key information for hindcast studies of past storms, and for assimilation in wave and storm surge forecast models to improve the forecasting of upcoming events, as well as for nowcasting. Satellite SAR (Synthetic Aperture Radar) can measure speeds, both in the coastal zone and in the open ocean where no in situ measurements are possible.

13. The loss of QuikSCAT significantly reduced forecaster situational awareness, ability to observe extreme winds, and verify warnings. However, international partnerships between NOAA and EUMETSAT (Metop-A,B,C ASCAT) and most recently ISRO (OceanSat-2, OSCAT) have significantly mitigated the loss of QuikSCAT (Sienkiewicz et al; 2012 2).

14. At present, ERS, QuikSCAT, ASCAT and OSCAT L2 products are produced on behalf of EUMETSAT (http://www.eumetsat.int) in the OSI-SAF (http://www.osisaf.org). The use of these products is granted to every interested user, free of charge, preserving property rights of EUMETSAT. However, the Near Real-Time (NRT) OSCAT data can only be used by European, non-commercial users.

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15. A recently emerging requirement is on a coordinated development/extension of integrated satellite and in situ Ocean Surface Vector Winds (OSVW), and its application for marine forecasts, similar to GHRSSST products for SST. Regarding a related effort for capacity development, since November 2009, NOAA, EUMETSAT, NASA and the International Oceanographic Data Exchange (IODE) programme of UNESCO/IOC have jointly conducted several training sessions on applications of satellite ocean surface vector winds for operational marine forecasting, in collaboration with JCOMM capacity building efforts.

**SEA STATE / WAVES**

*Open-Ocean Altimetry*

16. Satellite altimetry can provide accurate estimates of the changes to the sea surface, through the analysis of radar echoes from the sea surface that allows the measurement of sea surface height, significant wave height and surface wind speed.

17. Sea surface height anomaly data products provide the primary information upon which ocean models restore the ocean circulation fields to the true state through data assimilation. Current missions include Jason-1 (CNES/NASA) and -2 (EUMETSAT/NOAA/CNES/NASA), CryoSat-2 (ESA), Saral (CNES/ISRO) and HY-2A (CAST); to be followed/added by Sentinel-3 by ESA (2014), Jason-3 by EUMETSAT/NOAA (2013), Jason-CS by ESA (2017) and SWOT by CNES/NASA (2020).

18. Many studies have been undertaken to demonstrate the impact of satellite altimetry on ocean modelling/forecasting. At present, it is recommended that four polar orbiting, narrow-swath altimeters (with at least one in the so-called reference high altitude orbit of TOPEX/Poseidon and Jason) are required for consistent quality sea surface height analysis products in real-time (Pascual et al; 2008). This has given rise to the concept of a satellite constellation which requires the coordination of many international programs to achieve and at present is an aspirational and on-going, multi-agency effort in the context of CEOS.

19. At present, the ocean modelling community relies on the expertise in the Ocean Surface Topography Science Team (OSTST; [http://sealevel.jpl.nasa.gov/science/ostsciencteam/](http://sealevel.jpl.nasa.gov/science/ostsciencteam/)) and space agencies to provide the best available products, rather than in-house processing typical in weather forecasting. Some of essential requirements (largely met by current data systems) for future extension in the use of altimetry products for ocean modelling are:

- Close linkages to expertise;
- Rapid response to system and product changes;
- Clear procedures for management of product changes;
- Real-time response for satellite changes and robust communications.

*Coastal Altimetry*

20. Until recently, altimeter data near the coast were usually discarded as being inaccurate or difficult to interpret. Through reprocessing the radar echoes and improving some of the corrections that need to be applied to the altimetry measurements, meaningful measurements can be retrieved in the coastal strip (approximately 0-50 km from the coast with extent varying dependant on local

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This need for reprocessing underpins the rationale for considering this as a new branch of altimetry simply referred to as coastal altimetry\textsuperscript{4}.

21. Coastal altimetry can play a prominent role in storm surge and coastal inundation research, as it directly measures the total water level envelope (TWLE), i.e. the sea level taking into account tides, waves, effects of a storm surge, and (usually) precipitation and river flows. It can also provide important information on the wave field in the coastal strip, aiding the development of more realistic wave models that in turn can be used to improve the forecast of wave setup and overtopping processes.

22. Latest development enabled to produce delayed-time coastal altimetry products from different altimetry missions (Envisat, Jason-1, Jason-2, and CryoSat); the COASTALT study (see http://www.coastalt.eu/), funded by the European Space Agency (ESA), and PISTACH funded by the French Centre National d'Études Spatiales (CNES) have developed techniques/algorithms to recover useful measurements of sea level and significant wave height in coastal waters, as well as implementing and promoting new applications.

23. In many areas with limited infrastructure, satellite observation may be the only feasible way to consistently measure met-ocean parameters. Such developments, in the future, may enable integrating the altimeter-derived measurements of sea level, wind speed and significant wave height into coastal ocean observing systems: Several parameters derived from altimetry can contribute to forecasts of tropical cyclone paths, including wind speed and wave height, mesoscale circulation and the tropical cyclone heat potential, as well as improvement of tide knowledge by direct assimilation of the data into hydrodynamic models.

24. In the future, an improvement of the re-tracking process (parameter retrieval through fitting a waveform model to the waveforms near land-sea boundaries), as well as of an optimised correction of ocean tides, water vapour, and sea state bias, are needed.

\textbf{Synthetic Aperture Radar}

25. Synthetic Aperture Radars (SAR), operating at C-band like on Envisat, ERS-1 or ERS-2, offer the unique ability to provide continuous global directional information on wave field for various uses such as input to numerical weather prediction models (NWP) as well as ocean wave climate tools. Through the GlobWave project by ESA (see http://www.globwave.org), wave mode products correspond to small measurements called wave cells (or imagettes) which are approximately 5 km along-track by (up to) 10 km across-track, acquired at 100 km (or 200 km for ERS) intervals.

\textbf{PROGRAMMES AND ACTIVITIES PROVIDING USEFUL PRODUCTS FOR OCEAN AND COASTAL APPLICATIONS}

26. AVISO (http://www.aviso.oceanobs.com) is a French-based data provider that serves both Europe and international groups. A registration form is available online to request access to products.

27. The NASA PODAAC Physical Oceanography Distributed Active Archive Center (PODAAC; http://podaac.jpl.nasa.gov/) provides access to data through anonymous ftp, OPeNDAP and Thredds. The products supported are restricted to those for which NASA is a partner.

28. Radar Altimeter Database System (RADS; http://rads.tudelft.nl/rads/rads.shtml) provides a harmonised, validated and cross-calibrated sea level data base from satellite altimeter data. It is

available to all international operational centres. The product includes all available altimeters. The RADS products use the standard data format specified by the OSTST.

29. The ESA’s GlobWave (http://www.globwave.org/) allows easy access to a uniform set of along-track satellite wave data from all available altimeters (spanning multiple space agencies) and from ESA Synthetic Aperture Radar (SAR) data. The main parameters are:

- Altimeter: Significant Wave Height and Backscatter Coefficient (Sigma0)
- SAR: Swell Significant Wave Height, dominant wavelength (per spectral partition) and mean direction (per spectral partition)

30. The ESA eSurge Project (http://www.storm-surge.info/) has been developing the eSurge Event Analysis and Repository Service (SEARS). This project was initiated from the recommendations and actions made at the first JCOMM Symposium on Storm Surges (JCOMM2007SSS, see http://www.surgesymposium.org/), that called for improved access and application of satellite Earth Observation (EO) data to obtain necessary information before/during/after storm surge and coastal inundation events. The SEARS contains (and is in process of populating) a wide variety of satellite data for a range of storm surge events (SEVs), including measurement of wind (scatterometer), waves, colour/sediment concentration, SST and coastal altimetry. It also contains relevant non-satellite data such as tide gauges and numerical model outputs.

5 In the JCOMM framework, and supported by ECMWF, those operating centres of wave forecasting have been conducting a routine intercomparison of wave model forecast verification (WFV) since 1995. Recently, JCOMM has been cooperating with the GlobWave project to expand the verification to include 1-D and 2-D spectral quantities, satellite quantities, and to investigate the continued development of spatial inter-comparison techniques.