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EXPERT TEAM ON SATELLITE UTILIZATION AND PRODUCTS

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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 eighth session is invited to:

(a) Take note of this document, and

(b) Recommend any relevant action for consideration by 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, introduces some applications of satellite data/products in ocean and coastal applications, and related issues. In particular, it does not repeat information already given in ET-SUP-7/Doc. 7.3 in 2013.

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.

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.

5. The Group on High Resolution SST (GHRSST; http://www.ghrsst.org/) has provided operational users and science community with SST routinely 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.

WINDS

6. 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 Indian Oceansat-2 [discontinued as of 3 April 2014]. MetOp-B has become operational beginning 2013. Furthermore efforts are being made to make global winds from the Chinese scatterometer HY-2A globally available. KNMI is producing wind products for all these scatterometers on behalf of the EUMETSAT Ocean and Sea Ice SAF (OSI-SAF). These products are extensively calibrated and routinely validated.

7. 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.

8. At present, ERS, QuikSCAT, ASCAT and OSCAT L2 products are produced on behalf of EUMETSAT (http://www.eumetsat.int) in the Ocean and Sea Ice Satellite Application Facility (http://www.osisaf.org). The use of these products is granted to every interested user, free of charge, preserving property rights of EUMETSAT.

SEA SURFACE HEIGHT / SEA STATE / WAVES / OCEAN CURRENTS / SEA LEVEL

9. 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.

10. 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 (2015), Jason-3 by EUMETSAT/NOAA (2015), Jason-CS by ESA (2020) and SWOT by CNES/NASA (2020).

11. Two examples of highly precise satellite measurements of global ocean surface topography were described in a paper presented by Halpern at CGMS-41 held in Tsukuba, Japan, in July 2013: global and regional sea level variations for detection of climate and ocean weather phenomena, such as global sea level rise and upper-ocean heat content eddies, respectively. Ocean weather, which impacts the capability of the ocean to increase or decrease the intensity of tropical storms or hurricanes, is under-sampled with a conventional satellite altimeter which measures ocean surface topography along the nadir direction. Even if the unlikely, but highly fortunate, situation should arise that five conventional satellite altimeters are simultaneously in complementary orbits recording ocean surface topography, the composite dataset would be inadequate to sample a substantial portion of mesoscale motions and all sub-mesoscale eddy motions with adequate temporal resolution. Unlike the global atmosphere, where mean motion is typically 10 times greater than eddy motion, the oceanic eddy motion is 10 times greater than the mean motion. A satellite altimetry ocean surface topography noise level of 1 cm^2/cycle per kilometer corresponds to a 3 cm s^{-1} geostrophic current error in a 10-km-diameter eddy at 45° latitude. This criterion is an objective of a wide swath satellite altimeter mission with a launch readiness date of 2020.

12. 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 altimetric measurements, meaningful measurements can be retrieved in the coastal strip (approximately 0-50 km from the coast with extent varying dependant on local conditions). This need for reprocessing underpins the rationale for considering this as a new branch of altimetry simply referred to as coastal altimetry.

13. Latest development enabled to produce delayed-time coastal altimetry products from different altimetry missions (Envisat, Jason-1, Jason-2, and CryoSat-2); 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.

14. Synthetic Aperture Radars (SAR), operating at C-band like on Envisat, ERS-1 or ERS-2, have offered 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[1]. 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 in across-track, acquired at 100 km (or 200 km for ERS) intervals.

OCEAN PHYTOPLANKTON MEASUREMENTS AND SST[2]

15. When sunlight enters oligotrophic seawater, the red, orange, yellow and green wavelengths are quickly absorbed, leaving blue and violet to penetrate to greater depths. The chlorophyll in phytoplank-

[1] The European Sentinel-1A satellite successfully launched on 3 April 2014 will continue these series of measurements.

[2] The material in this section is reproduced from a paper by D. Halpern, E. Bayler and T. Dickey to be presented at CGMS-42 in Guangzhou, China, 19-23 May 2014.

ton (algae) preferentially absorbs red and blue wavelengths and reflects the green portion of the light spectrum. Concentrations of coccolithophores, composed of calcium carbonate, produce a milky turquoise-blue colour and concentrations of diatoms produce a greenish colour. In the absence of phytoplankton, the ocean's colour appears as blue. Satellite algorithms exploit the energy differences at various ocean colour wavelengths to measure upper-ocean phytoplankton concentrations.

16. Satellite-borne instruments provide phytoplankton abundance measurements over large regions, e.g., equatorial oceans. The Committee on Earth Observation Satellites (CEOS) promotes continuity of 25- and 1-km resolution global ocean colour data products.

17. As on land, photosynthesis has a significant role within the oceans, including biophysical modification of near-surface temperatures. In photosynthesis, microscopic plants such as coccolithophores and diatoms, both of which are phytoplankton algae, convert light energy into chemical energy for phytoplankton growth, forming carbohydrates from oceanic carbon dioxide (CO_2) and water. It has been suggested that the interception of downward penetrating light by absorption of the energy through photosynthesis in the subsurface maximum chlorophyll layer would locally increase the heat content.

18. Measuring spatial and temporal variations of radiant heating is very challenging because of insufficient instrumentation and difficulties in separating bio-optical and physical processes. A few estimates of phytoplankton-generated heating, however, have been made. These results support the view that ocean biology-induced feedback and biophysical coupling are important processes in modelling El Niño and La Niña events.

19. As noted above (§.5) and in CGMS-39 IOC-WP-01 paper (Halpern, 2011), SST observations are routinely and continuously measured by satellites and other platforms, and assimilated into numerical weather prediction models one or more times per day every day. These SST observations represent the integrated (net) result of all processes; therefore, the biological heating effect is already incorporated and no correction need be applied for purposes of weather forecasting. Thus, the biological heating mechanism would have no impact on current operational numerical weather prediction. The biological heating effect, however, would be expected to influence ocean model-generated SST, which affects coupled ocean-atmosphere modelling at seasonal-to-interannual and longer time scales. To improve model-estimated SST, which is a critical coupled model boundary condition for El Niño/La Niña predictions, the United States National Oceanic and Atmospheric Administration (NOAA) incorporates ocean colour data in operational ocean modelling systems.

20. Continuous, high frequency, high-wavenumber global measurements of near-surface phytoplankton abundances are required for other processes. Examples include forecasting occurrences of harmful algal blooms, uptake of atmospheric CO_2 through photosynthesis, downward flux of carbon to deep-sea sediments through zooplankton grazing on phytoplankton, and primary productivity for supporting ecosystem/ecological forecasting. The sustainability of continuous global ocean colour measurements with sufficient accuracy and fidelity in space and time is desirable to improve our understanding of the impact of ocean biology on weather forecasting and El Niño prediction.

PROGRAMMES AND ACTIVITIES PROVIDING USEFUL PRODUCTS FOR OCEAN AND COASTAL APPLICATIONS

21. 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.

22. 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.

23. 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.

24. 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[3]. 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)

25. The ESA eSurge Project (http://www.storm-surge.info/) has been developing a database on Surge Events (SEVs) and a demonstration service (eSurge Live), to provide data – from satellites, in-situ observing networks, and from models and re-analysis tools – on historic and current events to users in time for it to be taken into account in models and forecasts. 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.

COORDINATION FOR TRAINING AND EDUCATION

26. Satellite data continue to be a main source for ocean applications. However, continuing challenges have been raised by the community to identify source & access for satellite resources for application. In the same context, simple collection, access and visualization tools for satellite information (and furthermore, integrated with ground-level observations) are needed. For example, it is generally understood that the EUMETCAST is the main channel for African NMHSs to obtain satellite and associate data and information. Also, during the training workshop on marine forecasting for Gulf of Guinea / West Africa region (http://www.jcomm.info/MF-Training-2014), countries requested EUMETSAT to continue providing technical support for update of the Preparation for Use of Meteosat Second Generation in Africa (PUMA).

27. Close coordination of WMO Space Programme with other training initiatives (e.g. EUMETSAT "classroom", virtual training through WMO-CGMS VLab) has significantly benefited the metocean community through various met-ocean components within the training components. Building on the existing coordination like this, continuous effort has been made by JCOMM and within the metocean community for capacity development – particularly, conduct of training courses and development of training material. Efforts are made to maximize the use of already-developed training material for the following training of similar nature, such as the material available in the VLab and COMET modules for ocean applications.

28. In 2013, WMO/JCOMM and EUMETSAT agreed on a joint effort to promote training on application of satellite wind & wave products for marine forecasting, and NOAA agreed to provide support through trainers/resource personnel. It is intended to extend such partnerships among those Organizations/Agencies that provide training and education opportunities for the metocean community, to ensure synergies and effective use of resources as well as to improve coverage of user requirements for both geographic and topical areas. Participation of national and regional institutions (particularly those who are running regular training courses for marine meteorology) in this joint planning would be particularly welcome.

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[3] 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.