smos+ storms

support to science element

Requirement Baseline (RB)
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1. Introduction

1.1 Purpose and scope

This document is the Requirement Baseline (RB) document of the Support To Science Element (STSE) SMOS+ STORM Evolution project. The **aim** of this document is to ensure that the project specification (work and products) is matched to the Statement of Work (SoW) [RD-1] and contract issued by ESA in terms of requirements and expectations.

1.2 Structure of This Document

This document is organized into the following sections:

- Section 1 is this section that outlines the scope of the activity and the structure of the document.
- Section 2 lists reference documents (including web addresses) and acronyms that are relevant to this activity.
- Section 3 provides an overview of the Aim and Specific Requirements to be addressed by the project.
- Section 4 defines the detail requirements to be addressed classified by project themes.
- Section 5 contained the requirements compliance matrix
- Section 6 contains an appendix describing the data needed for the study.

2. Reference documents and Acronyms

2.1 Applicable Documents (AD)

Applicable documents that contain relevant information for the project are:

[SoW] ESA (2014), Support to Science Element SMOS+STORM Evolution Statement of work, available from ESA-ESA-STSE-SMOS-STORM-Evolution-SoW-Iss-0-Rev-1

[Contract] ESA contract for SMOS+STORM Evolution Ref: 4000105171/12/I-BG

[PM1-MOM] Minutes of the PM1 meeting held on 8-9 Sep 2014, ref. SMOSpluSTORM_EVOLU_MoM_PM1_v1.1, Issue 1.0, dated 16 Sep 2014.

[Proposal] Contractor’s Proposal (ref. SMOS+STORM_Evolution revision 1 dated 14 March 2014)

2.2 Reference Documents (RD)

Reference documents that contain relevant information for the project are:

[RD-1] ESA (2002), Mission Objectives and Scientific Requirements for the Soil Moisture and Ocean salinity Mission, Version-5, available from http://esamultimedia.esa.int/docs/SMOS_MRD_V5.pdf

[RD-2] Ocean Surface Remote Sensing at High Winds with SMOS, Requirement Baseline document, SMOS+STORM Feasibility project, 2013, available from ESA.

[RD-3] Ocean Surface Remote Sensing at High Winds with SMOS, Product Validation Report document, SMOS+STORM Feasibility project, 2013, available from ESA.

[RD-4] Ocean Surface Remote Sensing at High Winds with SMOS, Summary Roadmap, SMOS+STORM project, 2013, available from ESA.

[RD-5] Reul, N., J. Tenerelli, B. Chapron, D. Vandemark, Y. Quilfen, and Y. Kerr (2012), SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes, J. Geophys. Res., 117, C02006, doi:10.1029/2011JC007474.

[RD-6] Reul N. and B. Chapron (2001), SMOS - Salinity Data processing Study Improvements in Emissivity Models (WP 1100 Report), ESA contract N_ 15165/01/NL/SF

[RD-7] Yueh S.H., S.J. Dinardo, A.G. Fore and F.K. Li, 2010, Passive and Active L-band Microwave Observations and Modeling of Ocean Surface Winds, IEEE Trans. Geosci. Remote Sens., vol. 48, no. 8, pp. 3087-3100.

[RD-8] Powell, M. D., S. H. Houston, L. R. Amat, and N Morisseau-Leroy, 1998, The HRD 1122 real-time hurricane wind analysis system. J. Wind Engineer.andIndust. Aerodyn. 77-78, 53-1123 64.

[RD-9] Reul, N., and B. Chapron, 2003, A model of sea-foam thickness distribution for passive microwave remote sensing applications, J. Geophys. Res., 108(C10), 3321, doi:10.1029/2003JC001887.

[RD-10] SMOS L2 OS Algorithm Theoretical Baseline Document, ARGANS tech doc, SO-TN-ARG-GS-0007, 25 January 2013 (available at http://www.argans.co.uk/smos/docs/deliverables/delivered/ATBD/)

[RD-11] SMOS L2 OS OTTs for DPGS, ARGANS tech doc, SO-RP-ARG-GS-0070, 2012 (available at http://www.argans.co.uk/smos/docs/reports/)

[RD-12] E. Anterrieu, P. Waldteufel, and A. Lannes, Apodization functions for 2-d hexagonally sampled synthetic aperture imaging radiometers, IEEE Trans. Geosci. and Remote Sens., vol. 40, no. 3, pp. 2531-2541, Dec. 2002.

[RD-13] Grodsky, S. A., N. Reul, G. Lagerloef, G. Reverdin, J. A. Carton, B. Chapron, Y. Quilfen, V. N. Kudryavtsev, and H.-Y. Kao (2012), Haline hurricane wake in the Amazon/Orinoco plume: AQUARIUS/SACD and SMOS observations, Geophys. Res. Lett., 39, doi:10.1029/2012GL053335

[RD-14] ESA 2010: Monthly RFI monitoring report http://nwmstest.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/smos

[RD-15] Lagerloef, G., R. Colomb, D. Le Vine, F. Wentz, S. Yueh, C. Ruf, J. Lilly, J. Gunn, Y. Chao, A. Decharon, G. Feldman, and C. Swift (20080, The Aquarius/SAC-D mission,*Oceanography*, vol. 21, no. 1, pp. 68–81.

[RD-16] AnguelovaM. D. and F. Webster(2006), Whitecap coverage from satellite measurements: A first step toward modeling the variability of oceanic whitecaps, *J. Geophys. Res.,* vol. 111, C03017.

[RD-17] Levizzani, V., (2008), Precipitation Measurements from Space, 3rd European Conference on Antennas and Propagation, 2006. *EuCAP 2006, 10.1109/EUCAP.2006.4584829*, 1-5.

[RD-18] Hwang, P. A., D. M. Burrage, D. W. Wang, and J. C. Wesson (2011), An Advanced Roughness Spectrum for Computing Microwave L-Band Emissivity in Sea Surface Salinity Retrieval, *IEEE Geoscience and Remote Sensing Letters*, 8, 547.

[RD-19] Font, J., A. Camps, A. Borges, M. Martin-Neira, J. Boutin, N. Reul, Y. H. Kerr, A. Hahne, and S. Meckelenburg (2010), SMOS: The challenging sea surface salinity measurement from space, *Proc. IEEE*, vol. 98, no. 5,49–665.

[RD-20] Donlon, C. J., P. J. Minnett, C. Gentemann, T. J. Nightingale, I. J. Barton, B. Ward, and J. Murray (2002), Towards improved validation of satellite sea surface skin temperature measurements for climate research, J. Climate, 15, 353-369.

[RD-21] Ho, D. T., C. J. Zappa, W. R. McGillis, L. F. Bliven, B. Ward, J. W. H. Dacey, P. Schlosser, and M. B. Hendricks, (2004), Influence of rain on air-sea gas exchange: Lessons from a model ocean. *J. Geophys. Res.*, 109, C08S18, doi:10.1029/2003JC001806.

[RD-22] Paulson, C. A., and G. S. E. Lagerloef, (1993), Fresh surface lenses caused by heavy rain over the western pacific warm pool during TOGA COARE, in EOS Trans. AGU 74.

[RD-23] Wijesekera, H. W., C. A. Paulson, and A. Huyer, (1999), The Effect of Rainfall on the Surface Layer during a Westerly Wind Burst in the Western Equatorial Pacific, *J. Phys. Oceanog.*, 29, 612-

[RD-24] Zine, S., J. Boutin, J. Font, N. Reul, P. Waldteufel, C. Gabarró, J. Tenerelli, F. Petitcolin, J. L. Vergely, M. Talone, and S. Delwart, (2008), Overview of the SMOS sea surface salinity prototype processor, *IEEE T. Geosci. Remote*, vol. 46, pp. 621-645.

[RD-25] Swift, C. T. and R. E. McIntosh, (1983), Considerations for microwave remote sensing of ocean surface salinity,*IEEE T. Geosci. Remote*, vol. 21, pp. 480-491.

[RD-26] Yueh, S. H., R. West, W. J. Wilson, F. K. Li, E. G. Njoku, and Y. Rahmat-Samii, (2001), Error sources and feasibility for microwave remote sensing of ocean surface salinity, *IEEE T. Geosci. Remote*, vol. 39, pp. 1049-1060

[RD-27] Brainerd, K. E., and M. C. Gregg, 1997, Turbulence and stratification on the TropicalOcean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment microstructure pilotcruise, *J. Geophys. Res.*, 102, 10,437 - 10,456.

[RD-28] Araujo, M., C. Limongi, J. Servain, M. Silva, F. S. Leite, D. Veleda, and C. A. D. Lentini, (2011), Salinity-induced mixed and barrier layers in the southwestern tropical Atlantic Ocean off the northeast of Brazil, *Ocean Sci.*, 7, 63–73, 2011, www.ocean-sci.net/7/63/2011/, doi:10.5194/os-7-63-2011

[RD-29] Terray, L., L. Corre, S. Cravatte, T. Delcroix, G. Reverdin, A. Ribes, (2012), Near-Surface Salinity as Nature's Rain Gauge to Detect Human Influence on the Tropical Water Cycle. J. Climate, 25, 958–977, doi: http://dx.doi.org/10.1175/JCLI-D-10-05025

[RD-30] Saunders, P. M. 1967, The temperature at the ocean-air interface, *J. Atmos. Sci.,* 24, 269-273.

[RD-31] Anthes, R. A., R. W. Corell, G. Holland, J. W Hurrell, M. C MacCracken and K. E Trenberth, 2006, Hurricanes and Global Warming—Potential Linkages and Consequences, BAMS, May, 2006, DOI:10.1175/BAMS-87-5-617

[RD-32] Trenberth, K. E and D. J. Shea, 2006, Atlantic hurricanes and natural variability in 2005, GRL, doi:10.1029/2006GL026894

[RD-33] Trenberth, K. E and J. Fasullo, 2007, Water and energy budgets of hurricanes and implications for climate change, J. Geophys. Res., 112, doi:10.1029/2006JD008304

[RD-34] Trenberth, K. E, 2005, Uncertainty in Hurricanes and Global Warming, Science 308, 1753, DOI: 10.1126/science.1112551

2.3 Acronyms and abbreviations

ADB	Actions Data Base
ADT	Advanced Dvorak Technique
AMSRE	Advanced Microwave Scanning Radiometer – E (of EoS Aqua)
AMSR2	Advanced Microwave Scanning Radiometer 2
AMSU	Advanced microwave sounding unit Radiometer onboard NOAA meteorological sat
AOML	Atlantic Oceanographic and Meteorological Laboratory
AQUARIUS	Salinity mission (of NASA/CONAE)
ASAR	Advanced Synthetic Aperture Radar (of ENVISAT)
ASCAT	Advanced SCATterometer (of MetOp)
ATBD	Algorithm Theoretical Basis Document
ATCF	NOAA Automated Tropical Cyclone Forecast system
AVHRR	Advanced Very High Resolution Radiometer
BLEND-HWS	Blended multi-mission oceanic wind speed products
CATDS	Centre d'Archivage et de Traitement des Données SMOS
CBLAST	Coupled Boundary Layer Air–Sea Transfer
CDR	Critical Design Review
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CMIS	Conical Microwave Imager/Sounder
CONAE	COmision NAcional de Actividades Espaciales
DIR	Directory (of the *SMOS+ STORM Evolution project*)
DMSP	Defense Meteorological Satellite Program (of the USA)
DPM	DetailedProcessing Model
ECMWF	European Centre for Medium-Range Weather Forecast
ENVISAT	Environnent Satellite (http://envisat.esa.int)
ESA	European Space Agency
ESL	Expert Support Laboratory
EO	Earth Observation
EU	European Union
ETC	Extra-Tropical Cyclone
FR	Final Report
FROG	Foam, Rain, Oil and GPS-reflectometry
GFDL	Geophysical Fluid Dynamic Laboratory
GFS	Global Forecast System
GHRSST	GODAE High Resolution SST
GMF	Geophysical Model Function
GSFC	Goddard Space Flight Center
Hs	Significant Wave Height (also SWH)
HRD	Hurricane Research Division (of AOML)
H*WIND	NOAA National Hurricane Center Hurricane Wind Analysis products
IODD	Input/Output Data Definition
ITT	Invitation To Tender

IR	Infra Red
JMR	Jason Microwave Radiometer
JPL	Jet Propulsion Laboratory
JRA-25	Japanese 25-Year *Reanalysis* Project
JTWC	Joint Typhoon Warning Center
KO	Kick-Off
L1	Level-1
L2	Level-2
L3	Level-3
MIRAS	Microwave Imaging Radiometer by Aperture Synthesis
MR	Monthly Report
MTR	Mid-Term Review
NAH	NOAA/NWS/NCEP North Atlantic Hurricane Wind Wave forecasting system
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NDBC	National Data Buoy Center
NHC	NOAA National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	U. S. Navy's Operational Global Atmospheric Prediction System
NOP	Numerical Ocean Prediction
NRCS	Normalized Radar Cross-Section
NWP	Numerical Weather Prediction
NWS	National Weather Service
OSCAT	Oceansat-2 Scatterometer
OPS	Observation Processing System (of Met Office)
OS	Ocean Salinity
PALS	Passive/Active L-band Sensor
PM	Progress meeting
PMP	Project Management Plan
PMR	Passive Microwave Radiometry
PMSL	Pressure at Mean Sea Level
PSS	Practical Salinity Scale
QC	Quality Control
RA-2	Radar Altimeter 2 (of ENVISAT)
RD	Reference Document
SAR	Synthetic Aperture RADAR
SAR	Scientific Assessment Report (of *SOS*)
SAP	Scientific Analysis Plan
SatCon	CIMSS Satellite Consensus (SatCon) product
SFMR	Step Frequency Microwave Radiometer
SIAR	Scientific and Impact Assessment Report
SLA	Sea Level Anomaly
SMOS	Soil Moisture and Ocean Salinity (mission)
SMOS-HWS	SMOS High Wind Speed products (surface wind speed and foam-related properties)
SoW	Statement of Work
SSM/I	Special Sensor Microwave Imager (of DMSP)
SSMIS	Special Sensor Microwave Imager Sounder
SST	Sea Surface Temperature

SSS	Sea Surface Salinity
STSE	Support to Science Element
TBC	To Be Confirmed
TC	Tropical Cyclone
TBD	To Be Determined
TDP	Technical Data Package
TDS	Test Data Set
TMI	TRMM Microwave Imager
TN	Technical Note (short report 10-50 pages)
TR	Technical Report (long report > 50 pages)
TRMM	Tropical Rainfall Measuring Mission
UM	User Manual
URL	Universal Resource Locator
WP	Work Package

2.4 Universal Resource Locators (URL)

The following URL links contain relevant information that will be refered to in the document:

[URL-1] ESA web site http://www.esa.int/
[URL-2] STSE SMOS+ STORM Project http://smosstorm.org/
[URL-3] STSE web site http://www.esa.int/stse/
[URL-4] ESA Category1 http://eopi.esa.int/
[URL-5] ESA LPP SMOS webpage http://www.esa.int/esaLP/LPsmos.html
[URL-6] Aquarius webpage http://aquarius.nasa.gov/
[URL-7] SMOS Barcelona Expert Centre http://www.smos-bec.icm.csic.es/
[URL-8] CATDS Expertise Center - OceanSalinity (CEC-OS) http://www.salinityremotesensing.ifremer.fr
[URL-9] LOCEAN SMOS http://www.locean-ipsl.upmc.fr/smos/
[URL-10] ARGANS SMOS L2 Processor http://www.argans.co.uk/projects.html
[URL-11] SMOS Ice Project https://wiki.zmaw.de/ifm/SMOSIce
[URL-12] SPURS experiment http://ourocean.jpl.nasa.gov/SPURS/tindex.jsp
[URL-13] SMOS at ECMWF http://www.ecmwf.int/research/ESA_projects/SMOS/
[URL-14] SMOS L3 and L4 products http://www.cp34-smos.icm.csic.es/smos_mission/smos_mission.htm
[URL-15] ESA EarthnetSMOS https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos
[URL-16] SMOS Mode (EU COST action) http://www.smos-mode.eu/action.html
[URL-17] AOML/NOAA/HRD H*Wind Project http://www.aoml.noaa.gov/hrd/data_sub/wind.html

3. Summary of SMOS+STORM Requirements

3.1 Overview

The requirements presented in this document have been driven from three main sources:

1. The original Statement of Work from ESA [SoW].

2. Our technical proposal [Proposal] and Project Management Plan [PMP].

3. Internal discussion within the SMOS+STORM project team & ESA (PM1-MoM).

4. User Requirements found in the scientific literature and Tropical & Extra-Tropical storm community forum

In general, the multiple sources driving the requirements all lead to a consistent Requirements Baseline.

3.2 Key Requirements and Objectives

The present project has one overall aim which is to ***Demonstrate the performance, utility and impact of SMOS L-band measurements at high wind speeds over the ocean during Tropical and Extra-Tropical storm conditions.***

The specific **requirements** of the SMOS+ STORM Evolution project (referred to as SREQ-# in that document) that will be addressed in that study by the IFREMER-ODL-METoffice-Solab consortium contracted by ESA are:

STORM-RB-SREQ-01: L-band signal response of the ocean in storms	
The team will improve and consolidate our theoretical understanding of the L-band signal response and physical properties that can be inferred over the ocean during the passage of Tropical Cyclone (TC) and Extra-Tropical Cyclone (ETC) systems.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-1.]

STORM-RB-SREQ-02: Evolution of GMF & Retrieval Algorithm	
The team will evolve, implement and validate the STSE SMOS+STORM feasibility project Geophysical Model Function (GMF) and retrieval algorithm for high wind speed conditions.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-2.]

STORM-RB-SREQ-03: Generation of HWS products & validation

The project members will systematically produce and validate L-band SMOS high wind speed products with uncertainty estimates for ETC and TC conditions over the entire SMOS Mission archive.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-3.]

STORM-RB-SREQ-04: Generation of blended HWS products & validation	
The consortium will develop, implement and validate new blended multi-mission oceanic wind speed products with uncertainty estimates incorporating SMOS+ STORM Evolution L-Band measurements at high-wind speeds for TC and ETC events.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-4.]

STORM-RB-SREQ-05: Generation of a Global TC & ETC database	
The project team members will generate a global database of TC and ETC events over the ocean surface with SMOS data and characterize each event using diverse Earth Observation and other observations in synergy.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-5.]

STORM-RB-SREQ-06: OA coupling and MLD for ETC & TC	
The research conducted by the project team will improve our understanding and parameterization of ocean-atmosphere coupling and mixed-layer dynamics for ETC and TC cases.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-6.]

STORM-RB-SREQ-07: Impact for maritime applications	
The analyses conducted in the frame of the project will demonstrate the utility, performance and impact of SMOS+ STORM Evolution products on TC and ETC prediction systems in the context of maritime applications.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-7.]

STORM-RB-SREQ-08: SMOS STORM Promotion	
The consortium will promote the SMOS mission and related products through the SMOS+ STORM Evolution project.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-8.]

STORM-RB-SREQ-09: Scientific publications	
The team will submit scientific peer-reviewed journal article(s) documenting the results of the SMOS+ STORM Evolution project.	
Verification Method	Inspection
Reference in SoW	Section 4.1 [REQ-9.]

4. Detailed Requirements

The detailed requirements are referred to as STORM-RB-DREQ-# in the rest of the document. For each identified theme in our proposal, we describe here below the details requirements.

4.1 Improve physical understanding, retrieval algorithms and product quality for SMOS High Wind Speed products

4.1.1 L-band signal response over the ocean in very high wind speed conditions.

The objectives are:

- ***conduct fundamental research and development*** **to further our knowledge of SMOS L-band signal response** at high very wind speeds associated with TC and ETC events.
- ***Improve the extraction of*** **L-band emissivity properties at high winds**
- ***Analyse the impacts*** **of rain, sea state, SSS and SST on the observed emissivity changes**
- ***Analyze and define which*** **physical properties** (e.g., foam formation properties, breaking wave statistics) **best characterize the sea surface state at very high wind speeds.** Determine how these properties can be inferred from SMOS measurements in very high wind speed conditions.

The detailed requirements to reach these objectives are:

STORM-RB-DREQ-01: Review foam emissivity modeling in Microwave bands	
A review of our understanding of the underlying physics responsible for the observed microwave radio-brightness contrasts at High winds and the peculiarities of L-band with respect higher frequencies will be performed It will include a review and analysis of : -foam emissivity models. -current knowledge on foam and streaks coverage & thickness, - Foam property retrievals methods from radiometer data	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-02: Improved Exploitation of SMOS observations capabilities	
Fundamental research and development shall be conducted to Improve the extraction of L-band emissivity properties at high winds exploiting: - multi-angular (incidence, azimuth), -multi-spatial resolution -polarization properties -recently improved level 1 characteristics (RFI filtering, stability, solar and galactic aspects etc) of SMOS data.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-03: Modeled Geophysical Contributions to SMOS signal in high winds	
A review on the expected impacts of ✓ rain, ✓ sea state, ✓ SSS and SST on the observed emissivity changes at L-band in high winds shall be provided from a sensitivity analysis of well established forward emissivity models. In particular, the project shall consider to provide answers to the following questions: ○ Is the increase in the Tb sensitivity to wind speed at hurricane force (>64 knots) purely driven by surface processes or affected by intense rain events? ○ Do wave parameters need to be accounted for in the wind speed retrieval?	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-04: Theoretical expressions of the expected dependencies of the L-band radio-brightness contrast	
Based on the review, the project will revisit the theoretical (dimensional) expressions of the expected dependencies between L-band radio-brightness contrast, surface wind speed, foam properties (coverage & thickness), rain rate, SSS and SST	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

4.1.2 GMF development & surface wind speed retrieval algorithm

Objectives:

From the results of the review and the analysis of the first version of the SMOS-HWS database, a detailed new "surface wind speed" SMOS-HWS algorithm will be defined in the form of ATBD/IODD and DPM for L-band satellite High wind speed product.

The detailed requirements to reach these objectives are:

STORM-RB-DREQ-05: Definition of the Physical Properties contributing to SMOS signal in high winds	
The physical properties (e.g., foam formation properties, breaking wave statistics) that dominate the observed SMOS signal changes in high winds shall be analyzed and defined.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-06: Retrieval Methods for the Physical Properties	
Methods to infer physical properties of the sea surface (foam formations properties, breaking wave statitistics, wind parameters) from SMOS measurements in very high wind speed conditions shall be determined.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-07: Statistical dependencies of SMOS Tb	
Reliable statistical dependencies of SMOS Tb as function of incidence angle, polarisation, rain rate, wave parameters and surface wind and any other parameter of relevance shall be established from the first version of the SMOS-DB	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-08: Radio Frequency Interference mitigation	
Approaches to mitigate Radio Frequency Interference (RFI) impacts shall be considered in order to be used in the SMOS+ STORM evolution project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-09: SMOS surface wind speed retrieval algorithm GMF	
The SMOS surface wind speed retrieval algorithm GMF (e.g. multiple geophysical variable retrieval algorithm (SMOS High Wind Speed, SHWS) including SST, SSS, wind speed, waves, whitecap distribution…) shall be refined and improved.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-10: SMOS High Wind Speed (SHWS)-ATBD	
Algorithm Theoretical Basis Description (ATBD) document shall be written for the SHWS	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-11: SHWS-ATBD overview description	
The SHWS ATBD shall include an overview description of the background to the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-12: SHWS-ATBD Mathematical description	
The SHWS ATBD shall include a Mathematical description of the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-13: SHWS-ATBD IODD	
The SHWS ATBD shall Describe all related data sources in an Input/Output Data Description (IODD) Chapter, following the template provided in Appendix-1 of the Sow. Any restrictions in the use of any type of data sets (e.g., proprietary campaign data) shall be communicated to the Agency immediately	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-14: SHWS-ATBD DPM	
The SHWS ATBD shall include a Detailed Processing Model (DPM) Chapter that can be used to implement the Algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-15: SHWS-ATBD justifications	
The SHWS ATBD shall document in a separate chapter the scientific justification for specific development choices and trade-offs (including technical considerations justifying the selected methodologies and approach)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-16: SHWS-ATBD Output product contents and format	
The team will use netcdf and specify in the SHWS ATBD the output product contents and format.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-17: HSWS-ATBD Metadata	
The team will design and specify product metadata (based on existing standards) necessary to discover and manipulate data products,	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-18: SHWS-ATBD Risk & Solutions	
The SHWS ATBD shall include chapter documenting the identified risks and in which solutions are proposed.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

4.1.3 Foam property retrieval capability from SMOS data

Objectives:

- Based on the output of previous tasks an algorithm will be proposed here to retrieve directly foam formation properties : whitecap coverage and/or foam-layer thickness as a geophysical product instead of wind speed at the surface of TC and ETC from SMOS radio-brightness contrasts in storms. We anticipate the potential retrieval of both whitecap & streak coverage but also of foam-formation layer thicknesses.

- Write an ATBD for these products

The detailed requirements associated with that task are:

STORM-RB-DREQ-19: semi-empirical parametrization of L-band foam-induced emissivity	
A reanalysis of the semi-empirical parametrization of L-band foam-induced emissivity shall be conducted to provide a physical basis for foam and breaking wave properties (coverage, thickness) retrieval from SMOS data.	
Verification Method	**Inspection**

Reference in SoW	**Section 5.1.2**

STORM-RB-DREQ-20: Foam properties retrieval algorithm	
An algorithm to retrieve oceanic surface properties (foam, breaking wave properties) from L-band data in high winds shall be developed to serve as a basis for a systematic production.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-21: SMOS Whitecap & Foam (WF)-ATBD	
Algorithm Theoretical Basis Description (ATBD) document shall be written for the Whitecap and Foam properties retrieval	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-22: WF-ATBD overview description	
The WF ATBD shall include an overview description of the background to the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-23: WF-ATBD Mathematical description	
The WF ATBD shall include a Mathematical description of the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-24: WF-ATBD IODD	
The WF ATBD shall Describe all related data sources in an Input/Output Data Description (IODD) Chapter, following the template provided in Appendix-1 of the Sow. Any restrictions in the use of any type of data sets (e.g., proprietary campaign data) shall be communicated to the Agency immediately	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-25: WF-ATBD DPM	
The WF ATBD shall include a Detailed Processing Model (DPM) Chapter that can be used to implement the Algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-26: WF-ATBD justifications	
The WF ATBD shall document in a separate chapter the scientific justification for specific development choices and trade-offs (including technical considerations justifying the selected methodologies and approach)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-27: WF-ATBD Output product contents and format	
The team will use netcdf and specify in the WF ATBD the output product contents and format.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-28: WF-ATBD Metadata	
The team will design and specify product metadata (based on existing standards) necessary to discover and manipulate data products,	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-29: WF-ATBD Risk & Solutions	
The WF ATBD shall include chapter documenting the identified risks and in which solutions are proposed.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

4.1.4 Merged Multi-mission wind speed product Algorithm

Objectives

- The complementarity of SMOS-HWS products and added-value with radiometer data (WindSat, AMSR-2, SMAP), scatterometer ones (ASCAT & Oscat) and NWP products (ECMWF & NCEP) will be studied with the aim to produce new blended surface wind speed products including the SMOS high wind speed data. Such capability will be analyzed in detail in this task, blending methodology will be studied with the aim of defining an algorithm to generate such blended wind products.

- As a first objective we plan to merge SMOS data and AMSR2 wind speed retrievals and probably further add the WindSat data and the future SMAP sensor ones. For AMSR2 high wind speed retrieval under rain, we will rely on a new methodology currently being developed by *Zabolotskikh et al.*, 2013

Detailed requirements are:

STORM-RB-DREQ-30: Synergy algorithm	
An algorithm to maximise the synergy between complementary satellite: including SMOS, AMSR-2, WindSat and SMAP and other data (e.g. in situ, weather forecast models, drop-sonde, multi-frequency aircraft radiometers) of high winds shall be developed to serve as a basis for a systematic production of a blended high wind speed product (Blended High Wind Speed, BHWS)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-31: Blended High Wind Speed uncertainty	
A method to provide an estimate of uncertainty for multi-sensor blended wind speed retrievals shall be developed, implemented and validated	
	Inspection
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-32: Blended High Wind Speed (BHWS)-ATBD	
Algorithm Theoretical Basis Description (ATBD) document shall be written for the BHWS	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-33: BHWS-ATBD overview description	
The BHWS ATBD shall include an overview description of the background to the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-34: BHWS-ATBD Mathematical description	
The BHWS ATBD shall include a Mathematical description of the algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-35: BHWS-ATBD IODD	
The BHWS ATBD shall Describe all related data sources in an Input/Output Data Description (IODD) Chapter, following the template provided in Appendix-1 of the Sow. Any restrictions in the use of any type of data sets (e.g., proprietary campaign data) shall be communicated to the Agency immediately	
Verification Method	**Inspection**

Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-36: BHWS-ATBD DPM	
The BHWS ATBD shall include a Detailed Processing Model (DPM) Chapter that can be used to implement the Algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-37: BHWS-ATBD justifications	
The BHWS ATBD shall document in a separate chapter the scientific justification for specific development choices and trade-offs (including technical considerations justifying the selected methodologies and approach)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-38: BHWS-ATBD Output product contents and format	
The team will use netcdf and specify in the BHWS ATBD the output product contents and format.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-39: BHWS-ATBD Metadata	
The team will design and specify product metadata (based on existing standards) necessary to discover and manipulate data products,	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-40: BHWS-ATBD Risk & Solutions	
The BHWS ATBD shall include chapter documenting the identified risks and in which solutions are proposed.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

4.2 Generate & Validate SMOS High Wind Speed Product Databases

4.2.1 Data Set collection and Preprocessing

Objectives:

- to generate first database version to be used internally for algorithm development & GMF improvements
- to collect & process the auxilliary datasets for validation
- to define product Quality indicators

The associated details requirements are as follows:

STORM-RB-DREQ-41: Processing of SMOS archive with the first version of the HWS algorithm	
The SMOS entire archive for years 2012 and 2013 will be processed with the first version of the HWS algorithm in order to prepare a preliminary datasets (SMOS-DB1) usefull for GMF improvments. These datasets will include: -Multi-angular SMOS TB data -SMOS sensor observations parameters (polarisation, RFi flags, incidence & azimuth..) -Retrieved winds from the first version of the HWS algorithm	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-42: Collect Track data	
TC and ETC storm track will be collected from IBtrack database (TC) and from the ERA interim re-analysis of ETC tracks provided by University of Reading (http://www.met.reading.ac.uk/~dispersion/track/docs.html):	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-43: Method to determine SMOS intercepts with Storm Track data	
A method will be developed to detect the useful TC & ETC events in SMOS data based on the Storm track datasets	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-44: Auxiliary datasets collection	
The necessary auxiliary datasets to be used for products developments and validation shall be collected and will populated SMOS-DB1 including: -ECMWF & NCEP atmospheric and surface parameters -WOA SSS & CATDS Level 3 SSS -OSTIA SST -Storm Track parameters (track, Max Wind Speed-Wind Radii,.) And when available • co-localized NDBC buoys surface wind • co-localized SFMR flight transect & surface winds, Rain rate and Tb data • co-localized Altimeter winds • co-localized TRMM, WindSat and SSM/I rain rates (may potentially include GPM sensor data if available)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-45: Preprocessing of Auxiliary datasets	
Some necessary auxiliary datasets to be used for products developments and validation shall be pre-processed (co-localization, spatial & temporal averaging, altitude corrections, ...) to be compared to SMOS observations. These include: • co-localized NDBC buoys surface wind • co-localized SFMR flight transect & data • co-localized Altimeter winds • co-localized TRMM, WindSat and SSM/I rain rates (may potentially include GPM sensor data if available)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-46: SHWS products Quality Indicator	
Suitable Quality Indicator (QI) flags associated with potential errors and a filtering algorithm to communicate to users the quality of data will be defined for the SHWS products	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-47: BHWS products Quality Indicator	
Suitable Quality Indicator (QI) flags associated with potential errors and a filtering algorithm to communicate to users the quality of data will be defined for the BHWS products	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

4.2.2 Building and publishing of a SMOS HWS/BLEND HWS Storm catalog

Objectives

Once the usefull SMOS HWS, SMOS-WF and BLEND-HWS detected events will have been classified and once the available auxilliary data will have been collected and pre-processed for these cases, once the GMF and product retrieval algorithms will have been properly tuned, we plan to build-up a dedicated SMOS-Storm catalog (STORM-DB) with a storm user interface provided with the dataset publication on a dedicated web site.

The detailed requirements associated with these objectives are:

STORM-RB-DREQ-48: SHWS ATBD implementation	
The SHWS ATBD shall be implemented	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-49: BHWS ATBD implementation	
The BHWS ATBD shall be implemented	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-50: SHWS products production	
SHWS data products (SHWS-DATA) shall be produced for the period 2010-2015. The production run shall consider a re-processing of all available SMOS data since the end of satellite commissioning and include the quasi-systematic production and distribution of products using recently acquired data.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-51: BHWS products production	
BHWS data products (BHWS-DATA) shall be produced for the period 2010-2015. The production run shall consider a re-processing of all available SMOS data since the end of satellite commissioning and include the quasi-systematic production and distribution of products using recently acquired data.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-52: SHWS products UM	
The team shall write a User Manual (UM) for SHWS-DATA that provides a user-oriented manual. The UM shall report the results QC and verification analysis and all validation results	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-53: BHWS products UM	
The team shall write a User Manual (UM) for the BHWS-DATA that provides a user-oriented manual. The UM shall report the results QC and verificationanalysis and all validation results	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-54: STORM-DB Implementation	
A database (STORM-DB) of relevant data (e.g., SST, rain rates, optical imagery of cloud, SSS, OVW, NOP and NWP outputs) for Tropical Cyclone and Extra-Tropical Cyclone storms will be implemented to cover the period 2010-2015. Each storm shall be named according to the WMO TC naming protocol (http://www.wmo.int/pages/prog/www/tcp/Storm-naming.html) and STORM-DB shall allow users to consider each Storm as an "event case study" allowing synergy exploration of the relevant storm.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.5**

STORM-RB-DREQ-55: STORM-DB Web site & Visualisation tools	
On-line web access and visualisation tools for the STORM-DB shall be implemented.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.5**

STORM-RB-DREQ-56: STORM-DB content	
The STORM-DB will be populated with relevant data required by Scientific Analysis activities	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.5**

STORM-RB-DREQ-57: STORM-DB UM	
A user manual (STORM-UM) shall be written for the STORM-DB system	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.5**

4.2.3 SMOS STORM Product validation

Objectives

- To perform validation of the SMOS High Wind products
- To inform the users of the data product quality

STORM-RB-DREQ-58: Validation Match-Up Database	
A validation Match-Up Database (VMDB) between SMOS-HWS, BLEND-HWS & WF products with in situ and satellite data (buoy, sfmr, scat,..) will be generated	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-59: Quality Assesment Analyses	
Quality metrics will be developed and quality assessment analyses (co-localisation, statistics,etc.) will be performed based on the VMDB	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-60: Products uncertainties	
The project shall develop, implement and validate a method to provide an systematic estimate of uncertainty for SMOS wind speed retrievals	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.3**

STORM-RB-DREQ-61: Products Quality Controls
A quality control and verification analysis of SHWS and BHWS products shall be performed and address verification issues such as format compliance, out of bounds values, flag effectiveness, bugs in the system, and any other aspect relevant to the verification of the data product production runs

Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-62: Validate SHWS & BHWS products	
The SHWS and BHWS products shall be validated through comparison with other independent data sets (e.g. ECMWF, NCEP, GFDL, ASCAT, OSCAT, buoys, SFMR) and any other aspect relevant to the validation of the data product	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

STORM-RB-DREQ-63: Quality assessment reports	
Quality assessment reports will be written to be included into User manuals	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.4**

4.3 Applications in the domain of Ocean-Atmosphere Interactions

4.3.1 Statistical Analysis:

Objectives:

Statistical Analysis of the SMOS-DB will be conducted and compared to other sources of marine surface wind data to emphasize the new scientific content of the products

The details requirements to reach these objectives are

STORM-RB-DREQ-64: Climatologies of SHWS & BHWS products	
Statistical Analysis of the SMOS-DB (SMOS-HWS, BLEND-HWS) will be conducted to generate climatologies of global ocean area with wind speed in excess of 34, 50 and 64 knots. They will be compared to other sources of marine surface wind data such as ASCAT and OSCAT equivalent analyses.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-65: Variability of Extreme Event distributions	
The geographical (per nominal storm basins), seasonal and interannual variability of the extreme event distributions will be provided from a Statistical Analysis of the SMOS-DB and compared to other sources of marine surface wind data	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-66: Correlations with extreme wave and surface heat content	
Statistical Analysis of the SMOS-DB extreme events will be conducted to estimate potential correlations with extreme wave event statistics and seasonal surface cooling.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-67: Reporting the Statistical analysis results	
The results of the Statistical analysis of the high wind ocean features detected in SMOS-DB will be reported in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-68: Statistical analysis results on Project Web page	
The results of the Statistical analysis of the high wind ocean features will be prublished on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.3.2 Impact on Drag Parameterization

Objectives

- ✓ To derive new global climatological maps of surface wind stresses (modulus, divergence and curl) using authoritative studies parametrization of the drag coefficient as function of wind speeds

- ✓ To gain insight into the parametrization of the drag coefficient and its azimuthal variability within storm sectors
- ✓ To demonstrate the added-value/complementarities of SMOS-HWS and Blend-HWS in terms of coverage and wind stress range capability sampling compared to more traditional scatterometer based observations
- ✓ To propose new parameterisation of wind Drag at high wind

The detail requirements to reach these objectives are listed herebelow:

STORM-RB-DREQ-69: Database of wind stress products (WS-DB)	
A database of surface wind stress products including modulus, divergence and curl (WS-DB) will be generated from SMOS-DB products using authoritative studies parametrization of the drag coefficient	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-70: New global climatological maps of surface wind stresses	
New global climatological maps of surface wind stresses will be derived from the WS-DB over the SMOS mission period.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-71: Analysis of Wind Stress azimuthal variability in storms	
A statistical analysis of the WS-DB per storm sector will be performed to gain insight into the parametrization of the drag coefficient and its azimuthal variability within storm sectors	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-72: Wind Stress comparison with other datasets	
Systematic comparisons between SMOS-DB based Wind Stress products and more traditional scatterometer based observations will be conducted to demonstrate the added-value/complementarities of SMOS-HWS and Blend-HWS in terms of coverage and wind stress range capability sampling.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-73: Reporting the Wind Stress analysis results	
The results of the production and analysis of new wind stress products derived from SMOS-DB will be reported in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-74: Wind Stress analysis results on Project Web page	
The results of the Wind Stress analysis will be published on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.3.3 Impact on Ocean Responses to Storms

Objectives

- To improve statistical evaluation of the sea surface cooling amplitude ΔSST_{CW} in the wake of storms now based on the new SMOS wind speed products.

- To demonstrate the interest for TC but also analyse the ocean response to ETC

The detail requirements to reach these objectives are listed herebelow:

STORM-RB-DREQ-75: Sea surface cooling amplitude ΔSST_{CW} in the wake of storms	
Statistical evaluation of the sea surface cooling amplitude ΔSST_{CW} as function of wind speed in the wake of TC and ETC storms will be conducted per basin based on the new SMOS wind speed products.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-76: Reporting the Ocean thermal Response results	
The results of the Sea surface cooling amplitude ΔSST_{CW} statistical evaluation as function of SMOS-DB products and its interest for TC and ETC will be reported in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-77: Ocean thermal Response results on Project Web page	
The results of the Ocean thermal Response analysis will be published on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.4 Applications in the domain of Numerical Weather Predictions

4.4.1 Statistical Analysis

Objectives

- To perform comparison of the SMOS wind speed data with short range forecasts of 10m winds from the Met Office global model background to generate observed minus background values (O-B).

- To refine a suitable quality control (QC) methodology using the supplied QC flags to screen for potentially contaminated observations. Some form of bias correction may also be required prior to use of the data and this will also need to be investigated

The detail requirements to meet these objectives are:

STORM-RB-DREQ-78: Generate observed -background values (O-B)	
SMOS wind speed data will be compared with short range forecasts of 10m winds from the Met Office global model background to generate observed minus background values (O-B).	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-79: Comparison SHWS & (0-B) with other measurements	
The SMOS wind speeds and O-B values will also be compared with collocated scatterometer surface wind measurements from the ASCAT, OSCAT and WindSat instruments	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-80: SMOS products Complentarity	
Analyses will be conducted to examine how SMOS products complement existing scatterometer data and to gauge where the data might be useful to numerical weather prediction (NWP).	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-81: Global performance	
A statistical analysis will be conducted to assess the global performance of SMOS data across a range of meteorological conditions	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-82: Quality control (QC) methodology	
A suitable quality control (QC) methodology will be developed using the supplied QC flags and model-based derived metrics to screen for potentially contaminated observations and to develop forms of bias correction required prior to use of the data in Metoffice Model	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-83: Reporting on the Statistical Analysis	
The results of SMOS-DB products statistical analysis will be provided in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-84: Metoffice Statistical results on Project Web page	
The results of the MetOffice statistical analysis will be published on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.4.2 Assimilation

Objectives

Assimilation experiments will be performed to demonstrate the impact of SMOS wind speed observations on Met Office forecasts and analyses

The detail requirements to meet these objectives are:

STORM-RB-DREQ-89: Diagnosing changes to the mean global atmospheric analyses	
The impact of assimilating SMOS wind speeds into the Metoffice model will be demonstrated by diagnosing changes to the mean global atmospheric analyses e.g. low-level wind field, pressure at mean sea level (PMSL), etc	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-90: Diagnosing Impact through global NWP index	
The impact of assimilating SMOS wind speeds into the Metoffice model will be demonstrated by showing the changes in global model forecasts analysing the changes in the so-called global NWP index	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-91: Forecast variable Comparisons	
The impact of assimilating SMOS wind speeds into the Metoffice model will be analysed by comparing various forecast variables (e.g. wind, surface pressure, geopotential height) with quality-controlled observations valid at the same time/location and calculating the difference in root mean square (RMS) error between the trial and control values	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-92: Reporting on the Assimilation Results	
The results of SMOS-DB products assimilation in the Metoffice Model will be provided in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-93: Metoffice assimilation results on Project Web page	
The results of the MetOffice assimilation analysis will be published on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.4.3 TC Verification

Objectives

The main objective will be to verify the mean impact of SMOS-products on tropical cyclone forecast skill across the whole season

The detail requirements to meet these objectives are:

STORM-RB-DREQ-94: Analysis of the Track forecast error	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products through an analysis of the Track forecast error	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-95: Track forecast skill against CLIPER	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products through comparisons of the Track forecast skill against CLIPER (climatology & persistence)	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-96: Estimate Frequency of superior performance	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products through an analysis of the Frequency of superior performance (for track) i.e. summing up the number of forecasts when the trial error was lower	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-97: Analysis of the Mean change in intensity	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products including an analysis of the Mean change in intensity as measured by 850mb relative vorticity, 10m wind and central pressure.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-98: Analysis of the Mean absolute Error	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products. These verification shall include an analysis of the Mean absolute error of 10m wind and central pressure.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-99: Impact on the Intensity tendency skill score	
Storm track & intensification verifications will be performed to assess the impact of assimilating SMOS products. The Intensity tendency skill score will be evaluated (ability to correctly predict strengthening or weakening). Separate strengthening and weakening scores can also be calculated.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-100: Analyses of Case studies of individual storms	
Case studies of individual storms will also be performed to compare wind speeds from SMOS, scatterometers and NWP forecasts	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-101: Reporting on the TC Verification Results	
The results of the TC verification results will be provided in a comprehensive Scientific and Impact Assessment Report (SIAR) and in peer reviewed journal paper(s) that present all scientific findings and impact assessment results of the project.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-102: TC verification results on Project Web page	
The results of the MetOffice TC verification analysis will be published on the project web page	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.5 Near Real Time Requirements

Data and timeliness requirements required by the project for a NRT demonstration

STORM-RB-DREQ-103: Timeliness requirements required by the project for a NRT demonstration	
SMOS retrieved Wind Speed module delivered @ least at 50 km spatial resolution within a maximum of 6 hours from acquisition shall be needed for an NRT demonstration	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-104: SMOS L1 Data requirements required by the project for a NRT demonstration	
Following the current version of our algorithm, the SMOS data provision requirements for an NRT demonstration into the SMOS ground Segment include: The SMOS L1B products	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-105: SMOS Earth CFI Data requirements required by the project for a NRT demonstration	
Following the current version of our algorithm, the SMOS data provision requirements for an NRT demonstration into the SMOS ground Segment include: SMOS data geometrical parameters obtained using Earth CFI software and including • Latitude of the earth target: lat($\xi, \eta, scene_i$) • Longitude of the earth target: lon($\xi, \eta, scene_i$), • Earth incidence angle at the target: θ($\xi, \eta, scene_i$) • look direction azimut at the target φ($\xi, \eta, scene_i$) , • right ascension of the earth specularly reflected path in the B1950 sky coordinate system *ra*($\xi, \eta, scene_i$) • declination of the earth specularly reflected path in the B1950 sky coordinate system *dec*($\xi, \eta, scene_i$) • cosine director coordinate of the sun $\xi_{sun}, \eta_{sun}(scene_i)$ and aliases • cosine director coordinate of the moon $\xi_{moon}, \eta_{moon}(scene_i)$ • cosine director coordinate of the earth specularly reflected path towards the sun $\xi^{spec}{}_{sun}, \eta^{spec}{}_{sun}(scene_i)$ • cosine director coordinate of the earth specularly reflected path towards the moon $\xi^{spec}{}_{moon}, \eta^{spec}{}_{moon}(scene_i)$	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-106: SMOS ECMWF Data requirements required by the project for a NRT demonstration	
Following the current version of our algorithm, the SMOS data provision requirements for an NRT demonstration into the SMOS ground Segment shall include auxilliary SMOS ECMWF geophysical parameters describing the atmosphere, spatio-temporally interpolated in the xi eta frame of the SMOS antenna instrument. They include: • sea level pressure: P $(\xi, \eta, scene_i)$, • zonal wind speed component at 10 meter height: u_{10} $(\xi, \eta, scene_i)$ • meridional wind speed component at 10 meter height: $v_{10}(\xi, \eta, scene_i)$ • surface wind speed at 10 meter height: $ws_{10}(\xi, \eta, scene_i)$ • wind direction azimut: $\varphi_w(\xi, \eta, scene_i)$ • sea surface temperature: $T_s(\xi, \eta, scene_i)$ • Air temperature at 2m height: $T_{air_{2m}}(\xi, \eta, scene_i)$ • *cloud water mixing ratio at geopential z: $q_w(\xi, \eta, scene_i, z)$, • *atmospheric temperature at geopential z :T $(\xi, \eta, scene_i, z)$ • *relative humidity at geopotential height: r$(\xi, \eta, scene_i, z)$ *Note that the last three variables (*) are vertical profile (function of altitude z) of atmospheric conditions. Currently they ARE NOT included into the SMOS/ECMWF auxilliary datasets. Indeed, in the latter they are provided as vertically integrated variables. In tropical and extratropical storm, the vertical gradients cannot be totally neglected. In our current algorithm version we use estimate from the NCEP GFS 6-hourly products.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

STORM-RB-DREQ-107: SMOS ECMWF Data requirements required by the project for a NRT demonstration	
Following the current version of our algorithm, the SMOS data provision requirements for an NRT demonstration into the SMOS ground Segment shall include additional geophysical data from additional sources (e.g; World Ocean Atlas) include: • WOA2005 sea surface salinity climatology: $SSS_{clim}(\xi, \eta, scene_i)*$ • a landmask (in our current breadboarded version of the algorithm we use an USGS mask to derive a flag landmask($\xi, \eta, scene_i$)=0 if land; =1 if ocean) • a sea-ice concentration (in our current breadboarded version of the algorithm we use SSM/I concentration products delivered by Ifremer/cersat http://cersat.ifremer.fr/data/tools-and-services/quicklooks/sea-ice/ssm-i-sea-ice-concentration-maps) *In addition to the SSS climatology, we are now considering the 10-days SMOS composite Level 3 SSS data averaged over the 10 days preeceeding the storm passages. SSS estimate errors under storm can indeed have a non-negligible impact on the retrieved wind speed in very strong SSS gradient area, like in the Amazon plume or fresh-pool of the East Pacific.	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.6**

4.6 Promotion

Objectives

To consolidate and promote the project outcomes at an open scientific workshop and close the project

The detail requirements to meet these objectives are:

STORM-RB-DREQ-108: SMOS+ STORM Evolution Workshop	
An open invitation SMOS+ STORM Evolution Workshop will be organised by the project to present and discuss the findings of the project with the scientific community. The meeting shall be widely promoted, advertised and arranged at least 12 months in advance	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.7**

STORM-RB-DREQ-109: SMOS+ STORM Evolution Workshop proceedings	
A Workshop Proceedings(WKP) document that provides a reference document for the workshop (this could be in the form of a monograph or an article) will be written	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.7**

STORM-RB-DREQ-110: Study Final Report	
The project will write a Final Report (FR) including : • Introduction • A complete overview of the project (aims, design, development, implementation, data processing, analysis, and conclusions). This section may be reported in the form of a Scientific Journal Article. • A description of the SMOS+ STORM Evolution Workshop proceedings and final conclusions. This section may be reported in the form of a Scientific Journal Article. • A Scientific Roadmap (SR) for future activities that **shall**: a. Provide a critical analysis of all the feedbacks from scientists and institutions that have accessed SMOS+ STORM Evolution products, b. Identify potential strategies for integrating the development methods and models into existing large scientific initiatives and operational institutions, c. Define a scientific development strategy improving the development methods and products, d. Identify scientific and technical priority areas to be addressed in potential future projects in support of ocean surface salinity. • Summary and conclusions • References Any other sections required reporting on the work performed and outcomes of the SMOS+ STORM Evolution project	
Verification Method	**Inspection**
Reference in SoW	**Section 5.1.7**

5. Compliance Matrix

The table below shows the mapping between the numbered requirements given in section 4 to 5 of [SOW] and the numbered requirements given in this document

SoW Requirement		RB Requirement
SoW ID	SoW Requirement text	RB ID
[REQ-1.] Section 4.1	The team will improve and consolidate our theoretical understanding of the L-band signal response and physical properties that can be inferred over the ocean during the passage of Tropical Cyclone (TC) and Extra-Tropical Cyclone (ETC) systems.	**STORM-RB-SREQ-01** STORM-RB-DREQ-01 STORM-RB-DREQ-02 STORM-RB-DREQ-03 STORM-RB-DREQ-04 STORM-RB-DREQ-19 STORM-RB-DREQ-20
Section 4.1 [REQ-2.]	The team will evolve, implement and validate the STSE SMOS+STORM feasibility project Geophysical Model Function (GMF) and retrieval algorithm for high wind speed conditions.	**STORM-RB-SREQ-02** STORM-RB-DREQ-05 STORM-RB-DREQ-06 STORM-RB-DREQ-07 STORM-RB-DREQ-08 STORM-RB-DREQ-09 STORM-RB-DREQ-10 STORM-RB-DREQ-11 STORM-RB-DREQ-12 STORM-RB-DREQ-13 STORM-RB-DREQ-14 STORM-RB-DREQ-15 STORM-RB-DREQ-16 STORM-RB-DREQ-17 STORM-RB-DREQ-18
Section 4.1 [REQ-3.]	The project members will systematically produce and validate L-band SMOS high wind speed products with uncertainty estimates for ETC and TC conditions over the entire SMOS Mission archive.	**STORM-RB-SREQ-03** STORM-RB-DREQ-31 STORM-RB-DREQ-41 STORM-RB-DREQ-42 STORM-RB-DREQ-43 STORM-RB-DREQ-44 STORM-RB-DREQ-45 STORM-RB-DREQ-46 STORM-RB-DREQ-48 STORM-RB-DREQ-50 STORM-RB-DREQ-52 STORM-RB-DREQ-54 STORM-RB-DREQ-55 STORM-RB-DREQ-57 STORM-RB-DREQ-56 STORM-RB-DREQ-58 STORM-RB-DREQ-59 STORM-RB-DREQ-60 STORM-RB-DREQ-61 STORM-RB-DREQ-62 STORM-RB-DREQ-63
Section 4.1 [REQ-4.]	The consortium will develop, implement and validate new blended multi-mission oceanic wind speed products with uncertainty estimates incorporating SMOS+ STORM Evolution L-Band measurements at high-wind speeds for TC and ETC events.	**STORM-RB-SREQ-04** STORM-RB-DREQ-30 STORM-RB-DREQ-31 STORM-RB-DREQ-32 STORM-RB-DREQ-33 STORM-RB-DREQ-34 STORM-RB-DREQ-35 STORM-RB-DREQ-36 STORM-RB-DREQ-37 STORM-RB-DREQ-38

		STORM-RB-DREQ-39 STORM-RB-DREQ-40 STORM-RB-DREQ-47 STORM-RB-DREQ-49 STORM-RB-DREQ-51 STORM-RB-DREQ-53 STORM-RB-DREQ-58 STORM-RB-DREQ-59 STORM-RB-DREQ-60 STORM-RB-DREQ-61 STORM-RB-DREQ-62 STORM-RB-DREQ-63
Section 4.1 [REQ-5.]	The project team members will generate a global database of TC and ETC events over the ocean surface with SMOS data and characterize each event using diverse Earth Observation and other observations in synergy.	**STORM-RB-SREQ-05** STORM-RB-DREQ-41 STORM-RB-DREQ-42 STORM-RB-DREQ-43 STORM-RB-DREQ-44 STORM-RB-DREQ-45 STORM-RB-DREQ-46 STORM-RB-DREQ-47 STORM-RB-DREQ-48 STORM-RB-DREQ-49 STORM-RB-DREQ-50 STORM-RB-DREQ-51 STORM-RB-DREQ-52 STORM-RB-DREQ-53 STORM-RB-DREQ-54 STORM-RB-DREQ-55 STORM-RB-DREQ-56 STORM-RB-DREQ-57
Section 4.1 [REQ-6.]	The research conducted by the project team will improve our understanding and parameterization of ocean-atmosphere coupling and mixed-layer dynamics for ETC and TC cases.	**STORM-RB-SREQ-06** STORM-RB-DREQ-19 STORM-RB-DREQ-20 STORM-RB-DREQ-21 STORM-RB-DREQ-22 STORM-RB-DREQ-23 STORM-RB-DREQ-24 STORM-RB-DREQ-25 STORM-RB-DREQ-26 STORM-RB-DREQ-27 STORM-RB-DREQ-28 STORM-RB-DREQ-29 STORM-RB-DREQ-64 STORM-RB-DREQ-65 STORM-RB-DREQ-66 STORM-RB-DREQ-67 STORM-RB-DREQ-68 STORM-RB-DREQ-69 STORM-RB-DREQ-70 STORM-RB-DREQ-71 STORM-RB-DREQ-72 STORM-RB-DREQ-73 STORM-RB-DREQ-74 STORM-RB-DREQ-75 STORM-RB-DREQ-76 STORM-RB-DREQ-77

Section 4.1 [REQ-7.]	The analyses conducted in the frame of the project will demonstrate the utility, performance and impact of SMOS+ STORM Evolution products on TC and ETC prediction systems in the context of maritime applications.	**STORM-RB-SREQ-07** STORM-RB-DREQ-78 STORM-RB-DREQ-79 STORM-RB-DREQ-80 STORM-RB-DREQ-81 STORM-RB-DREQ-82 STORM-RB-DREQ-83 STORM-RB-DREQ-84 STORM-RB-DREQ-85 STORM-RB-DREQ-86 STORM-RB-DREQ-87 STORM-RB-DREQ-88 STORM-RB-DREQ-89 STORM-RB-DREQ-90 STORM-RB-DREQ-91 STORM-RB-DREQ-92 STORM-RB-DREQ-93 STORM-RB-DREQ-94 STORM-RB-DREQ-95 STORM-RB-DREQ-96 STORM-RB-DREQ-97 STORM-RB-DREQ-98 STORM-RB-DREQ-99 STORM-RB-DREQ-100 STORM-RB-DREQ-101 STORM-RB-DREQ-102
Section 4.1 [REQ-8.]	The consortium will promote the SMOS mission and related products through the SMOS+ STORM Evolution project.	**STORM-RB-SREQ-08** STORM-RB-DREQ-67 STORM-RB-DREQ-68 STORM-RB-DREQ-74 STORM-RB-DREQ-73 STORM-RB-DREQ-76 STORM-RB-DREQ-77 STORM-RB-DREQ-83 STORM-RB-DREQ-84 STORM-RB-DREQ-92 STORM-RB-DREQ-93 STORM-RB-DREQ-101 STORM-RB-DREQ-102 STORM-RB-DREQ-103 STORM-RB-DREQ-104 STORM-RB-DREQ-105
Section 4.1 [REQ-9.]	The team will submit scientific peer-reviewed journal article(s) documenting the results of the SMOS+ STORM Evolution project.	**STORM-RB-SREQ-09** STORM-RB-DREQ-67 STORM-RB-DREQ-73 STORM-RB-DREQ-76 STORM-RB-DREQ-83 STORM-RB-DREQ-92 STORM-RB-DREQ-101

6. Appendix 1 Summary description of all data products required by the project

This annex gives data product descriptions for all data products currently being proposed for inclusion in SMOS+STORM.

6.1 SMOS L1B data

Product	SMOS L1B	SMOS Fourier component of the brightness temperature
Provider	SMOS Data Processing Ground Segment (DPGS)	
Description	The SMOS Level-1B product is the output of the image reconstruction of the observations and comprises the Fourier component of the brightness temperature in the antenna polarization reference frame, hence brightness temperatures. Level-1B corresponds to one temporal measurement, i.e. the whole field of view– one integration time – and is often called a 'snapshot' as for a camera.	
Source Data	SMOS Level 1B from DPGS	
Source Data Format	DBL	
Reprocessing	DPGS reprocessings ended in	
Source of Error Information	L1 calVal team analyses L2 OS calVal team analyses	
Expected accuracy	The radiometric accuracy is from 2.6 K at boresight to about 4-5 K on the swath edges	
Expected resolution	The products are given in an Equal-area grid system (ISEA 4H9 - Icosahedral Snyder Equal Area projection) with an oversampled spatial resolution of about ~15 km. We consider here T_B data reconstructed in the extended field of view (FOV) domain of the antenna for which the swath width is approximately 1200 km (see Fig. 6 in Font *et al.* 2010). The actual spatial resolution of the reconstructed T_B data varies within the FOV from ~32 km at boresight to about ~80 km at the edges of the swath (43 km on average over the field of view). The probing earth incidence angle is ranging from nadir to about 60°	

6.2 SMOS ECFI data

Product	SMOS ECFI data	SMOS
Provider	SMOS Data Processing Ground Segment (DPGS)	
Description	For a given scene *i*, a series of geometrical and auxilliary geophysical parameter are determined at each antenna cosine director coordinate ξ, η and include • Latitude of the earth target: lat($\xi, \eta, scene_i$) • Longitude of the earth target: lon($\xi, \eta, scene_i$), • Earth incidence angle at the target: θ($\xi, \eta, scene_i$) • look direction azimut at the target φ($\xi, \eta, scene_i$) , • right ascension of the earth specularly reflected path in the B1950 sky coordinate system *ra*($\xi, \eta, scene_i$) • declination of the earth specularly reflected path in the B1950 sky coordinate system *dec*($\xi, \eta, scene_i$) • cosine director coordinate of the sun $\xi_{sun}, \eta_{sun} (scene_i)$ and aliases • cosine director coordinate of the moon $\xi_{moon}, \eta_{moon} (scene_i)$ • cosine director coordinate of the earth specularly reflected path towards the sun $\xi^{spec}{}_{sun}, \eta^{spec}{}_{sun} (scene_i)$ • cosine director coordinate of the earth specularly reflected path towards the moon $\xi^{spec}{}_{moon}, \eta^{spec}{}_{moon} (scene_i)$ • a landmask flag obtained from USGS mask landmask($\xi, \eta, scene_i$)=0 if land; =1 if ocean • a sea-ice flag obtained from SSM/I	
Source Data	The geometrical parameters are obtained using Earth CFI software The landmask is obtained from USGS mask	
Source Data Format	DBL	
Reprocessing		
Source of Error Information		
Expected accuracy		
Expected resolution		

6.3 SMOS Geophysical Auxilliary Informations

Product	SMOS geophysical auxilliary parameters	geophysical auxilliary parameters
Provider	SMSO DPGS & NCEP GFS	
Description	Given the "mean" aquisition time t_i of the SMOS scene #i and the geolocated director cosine coordinates [lat(ξ,η); lon(ξ,η)] for that scene, geophysical auxilliary parameters are spatio-temporally interpolated either from the SMOS ECMWF auxiliary products and/or from the NCEP GFS 6-hourly products or from additional sources (e.g; World Ocean Atlas). They include: • NCEP sea level pressure: P ($\xi,\eta,scene_i$), • NCEP cloud water mixing ratio at geopential z: q_w($\xi,\eta,scene_i,z$), • NCEP atmospheric temperature at geopential z :T ($\xi,\eta,scene_i,z$) • NCEP relative humidity at geopotential height: r($\xi,\eta,scene_i,z$) • ECMWF zonal wind speed component at 10 meter height: u_{10} ($\xi,\eta,scene_i$) • ECMWF meridional wind speed component at 10 meter height: v_{10}($\xi,\eta,scene_i$) • ECMWF surface wind speed at 10 meter height: ws_{10}($\xi,\eta,scene_i$) • ECMWF wind direction azimut: $\varphi_w(\xi,\eta,scene_i)$ • ECMWF wind friction velocity: $U_*(\xi,\eta,scene_i)$ • ECMWF sea surface temperature: $T_s(\xi,\eta,scene_i)$ • ECMWF Air temperature at 2m height: $T_{air_{2m}}(\xi,\eta,scene_i)$ • WOA2005 sea surface salinity climatology: $SSS_{clim}(\xi,\eta,scene_i)$ • ECMWF WAM estimate for the Charnock parameter chnk($\xi,\eta,scene_i$) • ECMWF WAM model peak period of the 1D spectrum: $T_p(\xi,\eta,scene_i)$ • ECMWF WAM model drag coefficient for wind waves: $C_D(\xi,\eta,scene_i)$ • ECMWF WAM model peak period for wind waves: $T_{pww}(\xi,\eta,scene_i)$ • ECMWF WAM model mean square slope: $mss(\xi,\eta,scene_i)$	

	• ECMWF WAM model significant wave height: $H_s(\xi,\eta,scene_i)$ We use a linear interpolation in time and bi-linear interpolation in space to co-register these auxiliiary geophysical data with SMOS data.
Source Data	ECMWF, NCEP and NODC (WOA)
Source Data Format	Buffer and netcdf
Reprocessing	-
Source of Error Information	-
Expected accuracy	-
Expected resolution	-

6.4 TC tracks

Product	IBtrack	TC tracks data
Provider	NOAA International Best Track Archive for Climate Stewardship (IBTrACS) tropical cyclone dataset (Knapp et al. 2010), version v03r05 and available at http://www.ncdc.noaa.gov/ibtracs/.	
Description	The positions and along track maximum winds of tropical cyclones are obtained from the International Best Track Archive for Climate Stewardship (IBTrACS) tropical cyclone dataset (Knapp et al. 2010), version v03r05 and available at http://www.ncdc.noaa.gov/ibtracs/. This reanalysis covers the period 1950-2013. The IBTrACS dataset records the 10-min maximum wind speed along with tropical cyclone track locations at 6-h intervals, which we convert to 1-min values by dividing by 0.88 (Knapp et al. 2010). This conversion allows wind speeds from IBTrACS data to be compared on the Saffir–Simpson scale, which uses a 1-min maximum wind speed definition. Track data include 6 hourly: Position, Maximum Sustained Winds, Minimum Central Pressure, Storm Name, Radius of Maximum Winds, Radius of Outermost Closed Isobar,	
Source Data	The IBTrACS project combines information from numerous tropical cyclone datasets:	

	RSMC Miami, RSMC Honolulu, RSMC Tokyo, RSMC New Delhi, RSMC La Reunion, RSMC Nadi, TCWC Perth, TCWC Darwin, TCWC Brisbane, TCWC Wellington, **CMA-Shanghai Typhoon Institute,** **Joint Typhoon Warning Center,** **Hong Kong Observatory,** **NCDC DSI-9635** **NCDC DSI-9636** **UCAR ds824.1**
Source Data Format	Netcdf
Source of Error Information	NOAA/WMO check the quality of storm inventories, positions, pressures, and wind speeds, passing the information on to the user
Expected accuracy	-
Expected resolution	6 hourly along track

6.5 ETC tracks

Product	ETC tracks	Extra-Tropical cyclone track data
Provider	NERC through the NERC Unit for Thematic Information Systems (NUTIS) and the Universities Global Atmospheric Modelling Progamme (UGAMP). Kevin Hodges from University of Reading (http://www.met.reading.ac.uk/~dispersion/track/docs.html):	
Description	The tracks are from the ERA interim re-analysis 6-hourly and are based on the vorticity but they have the MSLP and 925hPa and 10 m height winds attached. They cover the periods Year 2010-2014 Data are splitted into Northern and Southern Hemisphere and per months	
Source Data	ECMWF ERA interim re-analysis 6-hourly	
Source Data Format	Ascii	
Reprocessing	-	
Source of Error Information	-	
Expected accuracy	-	

Expected resolution	6 hourly along track

6.6 AMSR-2 Data

Product	AMSR-2 L1B TBs	Brightness Temperatures from AMSR-2
Provider	Japan Aerospace Exploration Agency (JAXA) GCOM-W1 Data Providing Service (https://gcom-w1.jaxa.jp)	
Description	The great success of AMSR-E (2002-2011) revolved to the design of its successor AMSR2, launched on the Japanese GCOM-W1 satellite on 18 May 2012. AMSR-2 is the Advanced Microwave Scanning Radiometer 2 on board GCOM-W1 satellite which substituted Aqua AMSR-E and was launched mid-may 2012. The antenna of AMSR2 rotates once per 1.5 seconds and obtains data over a 1450 km swath. This conical scan mechanism enables AMSR2 to acquire a set of daytime and nighttime data with more than 99% coverage of the Earth every 2 days. The AMSR2 sensor characteristic for each frequency channel is given in Table 1.	

Center Freq.	Band width	Pol.	Beam width	Ground res.	Sampling interval
GHz	MHz		degree	km	km
6.925/7.3	350	V/H	1.8	35 x 62	10
10.65	100		1.2	24 x 42	
18.7	200		0.65	14 x 22	
23.8	400		0.75	15 x 26	
36.5	1000		0.35	7 x 12	
89.0	3000		0.15	3 x 5	

Table 1. AMSR2 channel Set

L1B data include:

- Swath data with geolocation information
- Brightness temperatures
- ½ orbit starting from northern/southern-most latitudes

Source Data	Japan Aerospace Exploration Agency (JAXA) GCOM-W1 Data Providing Service (https://gcom-w1.jaxa.jp)
Source Data Format	All products are in HDF5 format
Reprocessing	
Source of Error Information	JAXA
Expected accuracy	±1.5 K
Expected resolution	

Center Freq.	Ground res.

		<table><tr><th>GHz</th><th>km</th></tr><tr><td>6.925/7.3</td><td>35 x 62</td></tr><tr><td>10.65</td><td>24 x 42</td></tr><tr><td>18.7</td><td>14 x 22</td></tr><tr><td>23.8</td><td>15 x 26</td></tr><tr><td>36.5</td><td>7 x 12</td></tr><tr><td>89.0</td><td>3 x 5</td></tr></table>

6.7 SCATTEROMETER data

Product	Scatterometer Winds
Provider	KNMI
Description	Scatterometer winds (equivalent neutral wind speed in m/s and direction (degrees) from Seawinds, ASCAT and OSCAT. OSCAT data is delivered on experimental demonstration basis
Source Data	ASCAT and OSCAT raw satellite data
Source Data Format	BUFR and netCDF (part of the data)
Reprocessing	No (unless for selected cases)
Source of Error Information	OSI SAF
Expected accuracy	Better than 2 m/s in wind component RMS with a bias of less than 0.5 m/s in wind speed for wind speed below 30 m/s.
Expected resolution	ASCAT 25 km and 12,5 km, and OSCAT 50 km (plans exist for 25-km OSCAT)

6.8 SFMR flight data

Product	SFMR flight data	
Provider	NOAA/AOML/HRD	
Description	The Hurricane Research Division collects Stepped Frequency Microwave Radiometer (SFMR) data sets on some of the tropical cyclones they fly into. They collect these data sets from the NOAA P3 aircraft that are equiped with the sensors and process them at the end of each Field Program. Starting in 2007, SFMR data is also available from USAF flights. The processed surface winds and rain rate from the SFMR are included in the data files for each mission, as well as the raw temperature outputs for each frequency. Similarly, SFMR data from NOAA flights is included in the NetCDF version of each flight's data.	

Source Data	ftp.aoml.noaa.gov/ hrd/pub/data/sfmr/
Source Data Format	NetCDF
Reprocessing	
Source of Error Information	Uhlhorn, E. and P. Black, 2003: Verification of remotely sensed sea surface winds in hurricanes. J. Atmos. Ocean. Tech., v. 20, 99-116.
Expected accuracy	~4 m/s surface wind speed accuracy- validated against the co-located observed dropsonde surface wind speed measurements from 10 to 50 m/s
Expected resolution	Radial resolution ~3km

6.9 Altimeter SWH & Wind data

Product	Altimeter Wind/Wave Products	Significant Wave Height Surface Wind
Provider	Ifremer via GlobWave: http://globwave.ifremer.fr/	
Description	Inter-calibrated wave related parameters from all available satellite altimetry missions including consistent quality flag and error characterization, together with ancillary data from ECMWF numerical models such as distance to coast, bathymetry and sea surface temperature Near-surface wind speeds (U_{10}) from satellite altimeter backscatter data are estimated during high wind conditions Using the algorithm of Quilfen et al., 2011	
Source Data	ESA Envisat RA: 26/08/2002-2012 CNES/NASA Jason-1: 15/01/2002 -3/07/2013 CNES/NASA Jason-2: 01/12/2008 onwards SARAL/AltiKa: 03/2013-onwards	
Source Data Format	CF compliant NetCDF, as defined within the GlobWave project	
Reprocessing	Reprocessing to apply High wind algorithm	
Source of Error Information	GlobWave Validation reports (http://www.globwave.org) Yves Quilfen, Doug Vandemark, Bertrand Chapron, Hui Feng, and Joe Sienkiewicz, 2011: Estimating Gale to Hurricane Force Winds Using the Satellite Altimeter. *J. Atmos. Oceanic Technol.*, **28**, 453–458. doi: http://dx.doi.org/10.1175/JTECH-D-10-05000.1	
Expected accuracy	Approx. 20 cm significant wave height– provided within	

	data stream ~2m/s for wind speed up to 30 m/s
Expected resolution	Equal to the altimeter footprint, approc 5-10km, along-track

6.10 Buoy WS data (NDBC, MeteoFrance, ..)

Product	Buoy Winds	Surface winds
Provider	Ifremer via GlobWave: http://globwave.ifremer.fr/	
Description	Buoy data mostly come from the National Data Buoy Center (NDBC) located along the coast of United States of America, the Tropical Atmosphere Ocean (TAO) located in the Equatorial Pacific array, and from Météo-France and UK Met office (MF-UK) located off the English, Ireland, and French coasts. NDBC and MF-UK provide hourly data, while TAO provide 10-min measurements. The latter are temporally averaged to estimate hourly buoy parameters. The buoy data include: wind speed at the anemometer height, wind direction (or the corresponding zonal and meridional wind components), sea surface and air temperatures, and relative humidity (or dew point). As the satellite wind retrievals correspond to wind observations at 10m above the ocean surface, the buoy winds are converted to 10-m height using (1/7) power expression (Hakeem, 1993).	
Source Data	Data for Europe is currently provided by the **POSEIDON** network provided by HCMR, **Puertos del Estados** – a Spanish government organisation that has several measurement networks to provide information about the physical features (including wave behaviour), **UK Met Office** which owns a network of buoys covering areas in regional UK waters and the Atlantic Ocean and, **Meteo-France** - the French national meteorological organisation which owns a network of buoys covering areas off the coast of France in the Mediterranean and Atlantic Oceans. Other networks include the **NODC** - the National Oceanographic Data Centre owns one of the largest buoy archives in the world. The archive contains several hundred US-owned buoys across the world measuring a multitude of wave parameters, and **CDIP** - the Coastal Data Information Program measures, analyses, archives and disseminates coastal environment data for use by coastal engineers. CDIP maintains a buoy network of the California	

	coasts which measures wave parameters.
Source Data Format	Netcdf
Reprocessing	
Source of Error Information	http://globwave.ifremer.fr/
Expected accuracy	<1 m/s but usually unavailable in hurricane force
Expected resolution	Hourly or 10 min

6.11 TRMM

Product	TRMM3B42	Rain Rate
Provider	NASA GSFC DISC http://disc.sci.gsfc.nasa.gov/precipitation/	
Description	The TRMM 0.25° 3B42 daily product (http://disc.sci.gsfc.nasa.gov/precipitation/documentation/TRMM_README/TRMM_3B42_readme.shtml) is used to estimate accumulated rainfall under cyclones. This product is a blend of TRMM multisatellite precipitation analysis and of rainfall geostationary infrared observations when the former is not available. It is calibrated to match monthly satellite/rain gauge analyses.	
Source Data	TRMM-adjusted merged-infrared (IR) precipitation TRMM VIRS TRMM-TMI GMS, GOES-E, GOES-W, Meteosat-7, Meteosat-5, NOAA-12 data.	
Source Data Format	HDF	
Reprocessing		
Source of Error Information	Huffman G. J., D. T. Bolvin (2012). TRMM and other data precipitation data set documentation (ftp://meso-a.gsfc.nasa.gov/pub/trmmdocs/3B42_3B43_doc.pdf). Lonfat M., F. D. Marks, and S. S. Chen (2004), Precipitation distribution in tropical cyclones using the Tropical Rainfall Measuring Mission (TRMM) microwave imager: A global perspective, *Mon. Wea. Rev.*, **132**, 1645–1660, doi: http://dx.doi.org/10.1175/1520-0493(2004)132 < 1645:PDITCU > 2.0.CO;2. Jiang, H., and E. J. Zipser, 2010: Contribution of tropical cyclones to the global precipitation from 8 seasons of TRMM	

	data: Regional, seasonal, and interannual variations. *J. Climate*, **23**, 1526–1543. Hu, A. and G. A. Meehl, 2009: Effect of the Atlantic hurricanes on the oceanic meridional overturning circulation and heat transport. *Geophys. Res. Lett.*,**36**,L03702, doi:10.1029/2008GL036680. Chen, Y., E. E. Ebert, K. J. E. Walsh, and N. E. Davidson (2013), Evaluation of TRMM 3B42 precipitation estimates of tropical cyclone rainfall using PACRAIN data, J. Geophys. Res. Atmos., 118,2184-2196, doi:10.1002/jgrd.50250.
Expected accuracy	This product has already been used to estimate rainfall under TCs by Jiang and Zipser (2010)and Hu and Meehl (2009), and is used in the National Aeronautics and Space Administration Hurricane Data Analysis Tool (http://disc.sci.gsfc.nasa.gov/daac-bin/hurricane_data_analysis_tool.pl). Recently, Chen et al. (2013) have compared TC rainfall from 3B42 daily data to gauge observations in the Pacific. The 3B42 TC rainfall has some biases on coastal and island sites but is accurate on atoll sites, suggesting that this dataset is suitable for the analysis of TC rainfall over the open ocean.
Expected resolution	Spatial coverage extends from 50 degrees south to 50 degrees north latitude 0.25-degree spatial resolution 3-Hourly

6.12 WindSat

Product	**RSS WindSat Data Products** v7.0.1	**Wind Speed & Rain Rate**
Provider	Remote Sensing Systems (ftp://ftp.remss.com/)	
Description	The WindSat Polarimetric Radiometer was developed by the Naval Research Laboratory (NRL) Remote Sensing Division and the Naval Center for Space Technology for the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO). It was launched on January 6, 2003 aboard the Department of Defense Coriolis satellite. WindSat was meant to demonstrate the capabilities of a fully polarimetric radiometer to measure the ocean surface wind vector from space. Prior to launch, the only instrument capable of measuring ocean wind vectors were scatterometers (active microwave sensors). In addition to wind speed and direction, the instrument can also measure sea surface temperature, soil moisture, ice and snow characteristics, water vapor, cloud liquid water, and rain rate. **Product Name** | **Product Description**	

Time	Minutes since midnight GMT Fractional hour of day GMT
Sea surface temperature	Temperature of top layer (skin) of water ~1 mm thick
10-m wind speed	Wind speed using 10.7 GHZ channels and above
10-m wind speed	Wind speed using 18.7 GHZ channels and above
Columnar atmospheric water vapor	Total gaseous water contained in a vertical column of the atmosphere
Columnar cloud liquid water	Total cloud liquid water contained in a vertical column of the atmosphere
Rain rate	Rate of liquid water precipitation
All-weather 10-m wind speed	Wind speed derived using all channels and three separate algorithms to obtain winds in all weather conditions
10-m wind direction	Oceanographic-convention wind direction, relative to north

Source Data	WindSat
Source Data Format	Binnary files
Reprocessing	v7.01
Source of Error Information	Remote Sensing Systems: http://images.remss.com/papers/windsat/rss_windsat_report_on_nrl_winds.pdf http://images.remss.com/papers/rsspubs/RSS_Rain_Validation_Report.pdf
Expected accuracy	Wind speed ~1-1.5 m/s Wind direction:~50°-20° for WS<5 m/s Wind direction: <20° for WS >5 m/s Rain Rate: satellite and buoy rain rates agree to 3.4%
Expected resolution	Daily products -orbital data mapped to 0.25 degree grid divided into 2 sets of maps based on ascending and descending passes

6.13 SSMI/I F15,F16 & F17

Product	SSMI/I F15,F16 & F17	Wind Speed & Rain Rate
Provider	Remote Sensing Systems (ftp://ftp.remss.com/)	
Description	The Special Sensor Microwave Imager (SSM/I) and the Special Sensor Microwave Imager Sounder (SSMIS) are satellite passive microwave radiometers. This series of instruments has been carried onboard Defense	

	Meteorological Satellite Program (DMSP) satellites since 1987. These are near-polar orbiting satellites. The instruments are referred to by satellite number starting with F08 and are listed in the table below. Currently operating instruments are: F15, F16, F17 and F18. Ocean measurements we derive from the radiometer observations include Surface Wind Speed, Atmospheric Water Vapor, Cloud Liquid Water, and Rain Rate.

Product Name	Product Description
10-m surface wind speed	Wind speed using 18.7 GHz channel and above
Columnar atmospheric water vapor	Total gaseous water contained in a vertical column of the atmosphere
Columnar cloud liquid water	Total cloud liquid water contained in a vertical column of the atmosphere
Rain rate	Rate of liquid water precipitation

Source Data	SSMI/F15, F16 & F17
Source Data Format	Binnary files
Reprocessing	v7.01
Source of Error Information	Remote Sensing Systems: http://images.remss.com/papers/rsspubs/RSS_Rain_Validation_Report.pdf
Expected accuracy	Wind speed ~1-1.5 m/s Rain Rate: satellite and buoy rain rates agree to 3.4%
Expected resolution	Daily products -orbital data mapped to 0.25 degree grid divided into 2 sets of maps based on ascending and descending passes

6.14 SAR Wave data

Product	Sentinel1 wave mode Level2 OCN product	Wave spectra and integrated wave partition parameters (Hs,Wl,Dir)
Provider	ESA/ODL	
Description	Wave spectra retrieved from Sentinel1 wave mode observations are part of a nominal Level2 OCN product that will be generated by the IPF in the	

	ground segment. However, L2 products will not be distributed before the end of Level2 cal-val phase at the beginning of 2015. ODL will process Level2 wave spectra from L1 data for the second semester of 2014 in order to get some first dataset to play with.
Source Data	Sentinel1 SAR wave mode
Source Data Format	Netcdf
Reprocessing	Early processing by ODL then nominal ESA product.
Source of Error Information	Sentinel1 Level2 cal-val report to be available by end of 2014.
Expected accuracy	Better that 5% accuracy on the dominant wavelength and 5° in direction.
Expected resolution	One imagette every 100km

6.15 Met Office model background fields

Product	UM background fields	
Provider	Met Office	
Description	Global model background fields are short range (T+6 hrs) forecasts of the atmospheric state. These forecasts are produced as part of the routine operational suite using the Met Office Unified Model (UM) system. The required background fields are normally held in the Met Office archive for a period of 5 years.	
Source Data	Met Office forecasts	
Source Data Format	PP (post processing) format - proprietary file format for meteorological data developed by the Met Office.	
Reprocessing	None	
Source of Error Information	Background error files are also archived.	
Expected accuracy	Various	
Expected resolution	Expected model configuration for the study period: Horizontal resolution: N512, 0.35 x 0.23 degrees (25 km in mid-latitudes) Vertical resolution: 70 vertical levels, lid ~80 km.	

6.16 SMOS wind speed

Product	SMOS wind speed	
Provider	SMOS+STORM project team	

Description	SMOS wind speed retrievals at 10m reference height as produced by the HWS algorithm. Observation data should include as a minimum: date, time, latitude, longitude, wind speed, brightness temperatures, plus relevant sensor parameters (e.g. incidence/azimuth angle) and QC/error information (e.g. RFI flags) to be agreed with the Met Office.
Source Data	SMOS wind speed retrievals
Source Data Format	NetCDF or ascii
Reprocessing	
Source of Error Information	Estimated error in wind speed (m/s)
Expected accuracy	TBD
Expected resolution	TBD, but around 50km will be suitable

6.17 Meteorological observations database

Product	Database of meteorological observations	
Provider	Met Office	
Description	For the purposes of data assimilation trials and verification a full range of all available meteorological observations will be required. These include both conventional observations and satellite observations as archived in the Met Office Meteorological DataBase (MetDB). Observations are archived for a period of at least 5 years.	
Source Data	Meteorological observations	
Source Data Format	BUFR, other	
Reprocessing	None	
Source of Error Information	Met Office diagnosed/assumed errors for each different type of observation	
Expected accuracy	Various	
Expected resolution	Various	

6.18 SST and sea ice analysis

Product	OSTIA analyses	
Provider	Met Office	

Description	The Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) will be required as boundary conditions for data assimilation trials with SMOS data. Daily OSTIA analyses of SST and sea ice are archived at the Met Office for a period of 5 years.
Source Data	OSTIA
Source Data Format	NetCDF
Reprocessing	None
Source of Error Information	
Expected accuracy	SST products have zero mean bias and an accuracy of ~ 0.57 K compared to in situ measurements.
Expected resolution	Analysis on 1/20 ° grids (~ 6 km)

6.19 CLIPER (Climatology & Persistence)

Product	CLIPER	
Provider	Met Services / Met Office	
Description	Several meteorological centres who monitor TCs have developed models which forecast the tracks of TCs up to three days ahead using methods based on past climatology in the area and persistence. These are known as CLIPER models and are generally accepted as a benchmark against which NWP models can be assessed. The Met Office has obtained CLIPER software for all TC basins which has been incorporated into the TC verification scheme. Hence, for each NWP model analysis and forecast which is verified, the equivalent CLIPER forecast is also verified.	
Source Data	CLIPER	
Source Data Format		
Reprocessing		
Source of Error Information		
Expected accuracy		
Expected resolution		