Sea Level CCI Mid-Term Progress Report

1. Overall Project Status

1.1 Summary of Overall Progress to date

The SLCCI project is now reaching the end of its second year. Important new results have been obtained on various aspects of the altimetry data processing leading to significant improvements of the sea level record, approaching the requested quality for climate study applications. Notably, the uncertainty of the global mean sea level derived from ERS-1 / ERS-2 / Envisat using the new CCI standards has decreased to the mm/year level. Such improvements will allow us to produce Sea Level CCI ECV products of better quality.

Following the completion of the User Requirements activity in January 2011, the project reached another major milestone, i.e., the Algorithm Selection Meeting in May 2012. The final choice of the altimetry standards was achieved during this meeting by an independent panel of 10 external international experts. 50 algorithms had been developed and/or tested, and for each algorithm, Round Robin Data Packages (RRDP) were produced, gathering numerous diagnoses about the sea level data over the whole altimetry period (20 years). The production of the Phase 1 SLCCI ECV products has now started and we expect these to be delivered in September 2012 (for a presentation at the "20 Years of Progress in Radar Altimetry" Symposium). Validation of these ECV sea level products will start at the end of 2012, in due time considering the project completion in July 2013. In parallel, the Systems Engineering team developed the specification of the operational system requirements of the SLCCI project, and was actively involved in the ESA CCI Systems Engineering Working Group and cross-ECV project collaboration.

1.2 Basic Project Data:

1.2.1 Tasks Status

Task 1	Requirements Analysis and Product Spec	07/10	01/11
Task 2	Algorithm dev., inter-comparison, Selection	10/10	06/12
	Extended algorithm dev. (if applicable)		
Task 3	System Prototyping, ECV Production	10/11	09/12
Task 4	Final Product Validation & User Assessment	09/12	07/13
Task 5	System Specification	01/11	09/12

1.2.2 Deliverables status

D1.1	URD	09/11
D1.2	PSD	08/12
D1.3	DARD	08/11

	Uncertainty Characterization Document	09/12
D2.4	Round Robin Data Package	05/12
D2.5	Algorithm Selection Report	06/12
D2.6	ATBD V.1	07/12
D5.1	SRD	06/12
D5.3	SSD V1	09/12
D3.5	Climate Research Data Package	10/12
D4.1	Validation Report	04/13
D4.2	Climate Assessment Report	07/13

1.2.3 Team Composition

- Science Leader – LEGOS (Anny Cazenave, internationally recognized expert in altimetry, sea level and climate research);
- Project Coordination - led by CLS and supported by Logica;
- EO science team - led by CLS and comprises GFZ, isardSAT, DTU Space, LEGOS, National Oceanographic Centre (NOC) and University of Porto;
- Climate Research team is led by the University of Hamburg and is supported by internationally recognized experts from NERSC, ECMWF and LEGOS;
- System Engineering team - Logica and CLS bring together expertise in the development and maintenance of operational sea level science EO algorithms.

2. Requirements Analysis and Product Specification

2.1 User Consultation

The User Requirements have been collected on the one hand from the international framework (GCOS, WMO, WCRP, OCEANOBS'09), and from the climate modeling communities (CMUG), through the analysis of the existing documents, and on the other hand by consulting the Ocean Surface Community. The SL CCI project allowed us to refine the existing requirements focused on global mean sea level by introducing new requirements for the regional mean sea level, the meso-scale signal and the time mean signals.
Some gaps have been identified between the requirements and the state of the art for altimetry. In particular the accuracy required for the global mean sea level trends (0.3 mm/y) which corresponds to the minimum accuracy needed to distinguish the different sources of sea level variability (ocean thermal expansion, ice sheet, land water, glaciers) is not achieved today. Similarly, it is difficult to obtain an accuracy < 2-3 mm on yearly times scales for the interannual sea level variability.

2.2 International Scientific coordination

The Sea Level CCI Project is closely connected to international activities related to global and regional analyses of the climate system specifically activities within the

WCRP, such as CLIVAR or CLIC. The ESA CCI on sea level has also cooperated with two EU projects, notably MONARCH-A (dedicated to the Arctic climate; led by NERC), which is a candidate model for bringing several ECVs together in a joint use and evaluation, and MyOcean. The role played by CCI partners (CLS, NERSC, DTU, University of Hamburg), ensures a good coordination between the two projects. Although the sea level ECV does not have a direct linkage with other ECV projects, a potential synergy has been identified with the SST ECV as well as the two recently launched CCI projects on sea ice and ice sheet. In parallel, close collaboration with Meteo-France has been set up.

2.3 ECV products description

Two types of products will be produced as part of the SLCCI project, the Fundamental Climate Data Records product and the Essential Climate Variable product. The first one is a mono-satellite product containing the sea level time series measured at the nadir of each satellite together with the geophysical corrections applied in the calculation. The second one is a multi-satellite product containing monthly averaged of sea level anomalies.

Fundamental Climate Data Record						
Parameter	**Sensors**	**Spatial coverage**	**Spatial Resolution**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Along track Sea Level	Radar altimeter from : ERS-1 ERS-2 Envisat GFO T/P Jason-1 Jason-2	Latitude bound: -82°/82° -82°/82° -82°/82° -72°/72° -66°/66° -66°/66° -66°/66°	7 km	e.g. 1991-1996 1995-2003 2002-2010 2000-2008 1993-2005 2001-2010 2008-2010	1 s	100 GB
Explanatory text: The FCDR (**SL_FCDR**) is a mono-mission product generated from an altimeter level-2 product, such as geophysical data records (GDR). It contains along-track sea surface height (SSH) estimates over the ocean with a quality control indicator to remove spurious measurements. It also contains the altimeter standards applied in the SSH calculation, such as the geophysical corrections, the mean sea surface, etc. In addition, information derived from the cross-calibration of the SSH between all the missions is provided, in order to remove the global SSH bias and to homogenize long spatial scale errors (due to orbit calculation for instance). This Sea level ECV product is associated with altimetry Level 2.						

Sea Level ECV						
Parameter	**Sensors**	**Spatial coverage**	**Spatial grid**	**Temporal coverage**	**Temporal resolution**	**Total Data Volume**
Gridded Sea Level	Radar altimeter from : ERS-1 ERS-2	Latitude bound: -82°/82°	25km	1993-2010	monthly	1G

	Envisat GFO T/P Jason-1 Jason-2					

Explanatory text:
One type of ECV product is defined herein: it is composed of monthly averaged sea level anomalies (SLA) derived from SLA grids calculated after merging together measurements from all altimetric missions into monthly grids with a spatial resolution of 1/4 degrees. Additionally, the product contains oceanic indicators. This corresponds to static files over the whole altimeter period describing the evolution of the SLA grids above described. Several indicators are provided such as the temporal evolution of the global mean sea level (MSL) with the global trend, the regional MSL trends, the amplitude and phase of the main periodic signals (annual, semi-annual). Finally, the product contains also the errors of oceanic indicators: This corresponds to the errors of the oceanic indicators, especially those concerning the estimation of the global and regional MSL trends.
This sea-level ECV product is associated with altimetry Level 4.

3. Algorithm Development, Inter-comparison and Selection

3.1 Results of Round Robin inter-comparison

50 Sea Level corrections, instrumental or geophysical, have been developed and/or tested. For each algorithm, Round Robin Data Packages (RRDP) gathering numerous diagnoses have been produced. All results have been synthesized by the Earth Observation Team in 12 validation reports, 1 for each Sea level component. The whole altimetry period (20 years) has been considered to produce the RRDP, and the new algorithms have been applied on up to 7 missions (ERS-1, ERS-2, Envisat, Jason-1, Jason-2, T/P, and GFO). Finally, a selection meeting was organized on the 2-4 May in Toulouse with 10 invited external international experts who helped selecting the algorithms to be used for the product generation, thus insuring an independent selection process.
The production of such extensive results has been made possible by the coordinated work of a pan-European organization (the consortium) from the development to the selection and by the implementation of a common, dedicated and robust testing infrastructure (database, diagnostics processing chain) based on the DUACS existing system allowing to compare each individual algorithms.

3.2 Expected Product Improvements

We expect to significantly improve the ECV products and in particular the regional/local sea level trends which are of utmost importance for coastal areas. Preliminary results showed also that the uncertainty of the global MSL trend derived from ERS-1 / ERS-2 / Envisat using the new CCI standards decreased to the mm/year level thanks to the specific effort done on these missions. It is also important to mention that significant progress have been made on the characterization of the errors.

4. System Prototyping and ECV Production

4.1 Data Gathering and Data Quality

30 types of data were necessary to run the algorithms and to perform the inter-comparison and selection task: satellite and ancillary data from 6 altimeter missions (ERS-1, ERS-2, Envisat, Jason-1, Jason-2, T/P, GFO) as well as in situ data. Among all required input datasets, several issues were raised, causing a delay in the development planning. Moreover, we had to deal with a wrong phasing of the SLCCI project with the ESA reprocessing activities (e.g., Envisat and ERS data reprocessing). Strong efforts have been made by the SL project in terms of coordination: several meetings and teleconferences with ESA and CNES were organized in order to mitigate this issue. This allowed the SLCCI project to benefit from the optimal input data from the external projects. Notably a very good link could be established between the SLCCI project and the Envisat Quality working group, with very positive feedbacks through specific presentations at the 3 last QWG meetings.

4.2 Product Generation

The processing chain and associated database has been finalized in May 2012, taking into account the outcome of the selection meeting. The production of the Phase 1 SLCCI ECV products started by mid-May 2012 and we expect to deliver them in September 2012. Thanks to the new and homogeneous algorithm used, we expect this new ECV dataset to improve the sea level data , notably the trends at regional scales.

5. Product Validation and User Assessment

5.1 Product Validation (plans)

These products will be validated with two approaches. First a direct comparison between the new ECV and the V0 reference product (Aviso) will be performed using the RRDP infrastructure developed in this project. Then assessment of the product quality will be performed through an assimilation exercise and through comparisons with climate and ocean model outputs products.

5.2 Uncertainty Characterization

The RRDP exercise allowed us to better characterized the uncertainty, with estimates of different climate products: global mean sea level, regional mean sea level, meso-scale activity, etc., as defined in the URD. Consequently, this allows us to verify if the new products answer or not to the user requirements.

5.3 ECV Data Access and exploitation

Reprocessing and validation of the 18 years of altimetry data taking into account all altimeter missions will be performed in 3 months, to have them ready for the "20 Years of Radar Altimetry" Symposium to be held in Venice, 24-29 September 2012. This is a big challenge. Moreover, despite its relatively good maturity, the sea level ECV is not really used by the climate models for their validation. The ESA CCI program represents a very good opportunity to enhance closer links between modeling and observations.

6. System Specification

The System Requirements Document (SRD) serves to provide a complete set of system requirements for an SLCCI operational system based on DUACS, an existing operational system. Reuse of DUACS is undertaken in context of ECSS standard Q-ST-80C on system reuse, with hardware and software specification reasoned in the forthcoming System Specification Document (SSD) V1 based on architectural specification standard ISO 42010. Major operational software sub-systems will comprise of the Production Chain (used in Task 3), alongside Monitoring, Product Management, and Product Access subsystems.
Sustainability is a crucial aspect of the specification of the SLCCI operational system, as longevity of the system beyond the end of the CCI program needs to be ensured. Key requirements include provision for future algorithm changes in order to accommodate the system to future science developments (and not solely to CCI Phase I Task 3, an archiving facility for operational long term data preservation of ECV products, and architectural consideration to ensure a means for pan-ECV product integration for future users).

7. Plan to complete Phase 1

Three kinds of activities are necessary to complete Phase 1. First, once the ECV time series has been produced, the validation activities have to be performed by each members of the CRG. In parallel, the WP5 system tasks and notably the reports describing the future system has to be finalized. Then, and it is probably the most important, the SLCCI team will promote the ECV products by writing scientific articles and participating to international meetings, such as the 20 year of altimetry meeting in September 2012.

8. General comments/feedback to ESA

This program allowed setting up an efficient pan-European organization and a robust approach for improving the sea level products as needed for climate research. It has also facilitated the link with the climate scientists and their needs in

terms of ECVs. The transverse activities, coordinated at high level by ESA, were necessary but still need to be reinforced and anticipated for the Phase 2.

9. List of Relevant Scientific Publications