FRM4SM – Fiducial Reference Measurements for Soil Moisture

QA4SM Evolution Test Plan
DT4-2
Version 2.1

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CESBIO

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For any clarifications, please contact support@qa4sm.eu.

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Acronyms

AWST	Angewandte Wissenschaft Software und Technologie GmbH
CCI	Climate Change Initiative
CDRs	Climate Data Records
CEOS	Committee on Earth Observation Satellites
CESBIO	Centre d'Etudes Spatiales de la Biosphère
CMUG	Climate Modelling User Group
DOI	Digital Object Identifier
ECMWF	European Centre for Medium Range Weather Forecasting
ECV	Essential Climate Variable
EODC	Earth Observation Data Centre
ESA	European Space Agency
FAQ	Frequently Asked Questions
FRM	Fiducial Reference Measurements
FRM4SM	Fiducial Reference Measurements for Soil Moisture
GCOS	Global Climate Observing System
GEO	Group on Earth Observation
GEWEX	Global Energy and Water Cycle Experiment
GUI	Graphical user interface
GTOS	Global Terrestrial Observing System
ISMN	International Soil Moisture Network
NASA	National Aeronautics and Space Administration
NRT	Near Real Time
QA	Quality Assurance
QA4SM	Quality Assurance for Soil Moisture
RFI	Radio Frequency Interference
SAR	Synthetic Aperture Radar
SM	Soil Moisture
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture and Ocean Salinity
TC	Triple Collocation
TOPC	Terrestrial Observation Panel on Climate
TUW	TU Wien

1 Introduction

1.1 Purpose and scope of document

The QA4SM Evolution Test Plan, Version 2 describes the technical software testing and scientific validation activities, which are planned during evolution towards QA4SM release 2. The test and validation activities will be performed after completion of this test plan. Test observations and results will be documented in the pertinent Verification Report for release 2. After successful verification, release 2 will be reviewed at a formal Acceptance Review for approval of deployment in the publicly available QA4SM service.

The previous Versions 1 of the Test Plan and Verification Report pertain to QA4SM release 1.

1.2 Document overview

Sections 1 through 4 are introductory sections to introduce the document, provide an overview of QA4SM release 2, introduce the test approach and to describe the availability of required test data.

Sections 5 and 6 focus on technical software testing, which is organised in the form of automatic and manual test cases.

Section 7 describes a scientific approach to the validation of QA4SM results in comparison to independent validation studies, which were performed by other groups.

Section 8 concludes the document with references.

1.3 Target audience

This document is addressed to QA4SM users and stakeholders who want to test the QA4SM online validation service to verify its functionality. This includes in particular the evolution and test team performing the test before release of the upgraded QA4SM service and ESA stakeholders who participate in the acceptance review of the tested release.

Other interested users can use the test plan to independently validate QA4SM. The can contact the QA4SM help desk at support@qa4sm.eu for dedicated support and to clarify questions.

2 Overview of QA4SM release 2

QA4SM evolution within the FRM4SM project started from a publicly available baseline version of the QA4SM service, which was developed in predecessor projects funded by the Austrian research promotion agency FFG (www.ffg.at/en, project numbers 878929, 866004).

This baseline version is comprehensively described in the QA4SM Service User Manual, v1.1 (FRM4SM deliverable D3-1), which is available at https://qa4sm.eu.

Enhancements, which were added in release 1, are described in Version 1 of this Test Plan.

The following major technical and scientific enhancements have been implemented in the evolution towards release 2 within the FRM4SM project:

- SMOS and SMAP Level 2 data were integrated.
- A new feature for users to upload, manage and validate their own soil moisture data has been implemented.
- The user options to define reference datasets were enhanced, so that users can independently select spatial, temporal and scaling references.
- An FRM indicator was introduced to identify representative ISMN sensors. The FRM flag can be used to restrict validation results to representative sensors.
- Handling of validation errors per grid point has been improved to provide better information about the underlying problems which have led to the errors.

The release 2 enhancements are covered by the tests described in sections 6 as summarised in the following tracking table:

Test coverage of enhancements in release 2		
Enhancement	Test Cases	Comments
SMOS and SMAP Level 2 data integration	Section 7.1	QA4SM validation results are compared with independent validations of these datasets.
Upload, management and validation of user data	QA4SM_GUI_UDUF_001, QA4SM_GUI_UDUF_002, QA4SM_GUI_UDUF_003	Manual test cases to verify completeness and proper behavior of the data upload module.
Separation of spatial, temporal and scaling references	QA4SM_GUI_VP_002, QA4SM_GUI_VP_003, QA4SM_GUI_VP_009	These test cases were updated to verify the reference enhancements.
FRM indicator for sensor representativeness	Section 7.4	The quantitative impact of the selected FRM setting on the validation results is evaluated.

Validation error handling per grid point	Section 7.3	See also automated unit test in section 5.

3 Test approach

Several major stages of testing and validation activities are included in overall test approach:

- Automated tests are continuously performed during ongoing development. This helps to catch and fix software issues early in the development process and assure that the software always builds and executes correctly. These tests are described in section 5.
- Interactive manual tests are performed after deployment of a new QA4SM version in a dedicated test service instance with limited accessibility for the development team. The manual test cases described in this document are in this category and are geared to systematically verify the correct execution of all QA4SM features from a user perspective. Dedicated test cases are included for newly implemented enhancements for release 2. The manual tests are described in section 6. Additional testing is performed to verify the proper execution of validations for all integrated datasets.
- Additional random testing is done by internal non-developer users within the project team to catch usability issues, which may otherwise be overlooked by testers who already are fully familiar with the QA4SM service.
- Verification of validation results goes beyond technical testing and is aimed at the validation of QA4SM results by comparison with independent results or methods. The planned results validation activities within the scope of release 2 are described in section 7: QA4SM validation results for the newly integrated SMOS and SMAP Level 2 datasets are compared against independently produced validation results for these datasets. The impact of the selected FRM indicator on the QA4SM validation results is quantitatively evaluated. New unit tests are written to cover the improved error handling per grid point.

4 Test data sets

All required test data for automatic and manual software tests are available within the QA4SM services and its source code repositories.

Automatic tests use test data which are stored in the relevant test directories in the QA4SM repository. Newly required test data are integrated together with the implementation of new test cases, which require such data. Hence, testers can execute all automatic tests directly in the repository with no need of additional resources.

The manual test cases use datasets which are integrated into QA4SM for validation by users. Each test case refers to the specific dataset which is used in the test. No additional data are

required to perform the described manual tests, however, two sample files for the data upload tests QA4SM_GUI_UDUF_001-3 are provided in GitHub and links to these files are included in the test case descriptions.

The activities to compare quantitative validation results compare results, that are generated in QA4SM, with published results of independent validation studies in the available literature. The input data to generate QA4SM results are the same integrated datasets, which will be available to all QA4SM users in release 2. The selected literature results and validation studies for external comparison are referenced in section 7.

5 Automated software tests and user interface tests

Automated tests consist of two groups of unit tests. The first group are tests verifying the service functionalities happening in the back-end part. We test here running validations with different settings (e.g., different reference data set or different methods of calculating anomalies) and check if they provide expected results, both numerical and graphical. We verify also if actions performed on existing validations give expected results (e.g., publishing, archiving, extending life span or deleting results). Additionally, we test actions undertaken by admins, like activating and deactivating user accounts or sending emails. The second group of automated unit tests controls the data flow between the front-end and back-end parts of the QA4SM software. We test here if the back-end part responds correctly to queries coming from the front-end part and if the data sent to the front-end is in the appropriate format and contains the correct information. Within this group there are also tests to verify the set up and update actions for user accounts. In addition to testing QA4SM service functionalities the automatic unit tests also provide information on necessary updates in the software code, due to updates of packages which are used by the application.

All the tests are available in the GitHub repository on the master branch in two directories: The first group is located in the validator/tests/ directory and the second group is in api/tests/. Altogether, over 140 unit tests are set up at the time of writing and additional unit tests are added for each new feature or functionality which is added to the QA4SM service.

The automated tests are run by developers each time when new functionality is added to the service, before committing code changes to the master branch of repository. The tests can be run collectively or individually to test only selected features. All tests are also run automatically once per day and additionally upon every pull request using Github Actions. The results are publicly available in the GitHub repository. A new release of QA4SM is created only if all tests on the master branch pass successfully.

The QA4SM service's metrics calculation back-end *pytesmo* contains its own automated tests in addition to the ones described above. The *pytesmo toolbox* contains a total of more than 230 unit tests covering all toolbox functions, including those used in QA4SM. Tests are run automatically on a daily basis and upon every pull request for code changes using GitHub

Actions. All test result are publicly available in the GitHub repository. Fully successful unit tests are a condition in the repository for releasing a new version of the toolbox, i.e., failed unit tests have to be fixed before a new version can be released.

The graphical user interface (GUI) of the QA4SM application is tested mainly manually. Dedicated automated unit tests verify that the individual components of the GUI are created, but these tests do not cover all GUI functionality. These automated GUI tests are located in the folders of each specific component that is tested. The GUI tests are not run on GitHub, but only locally during the software development process. Comprehensive manual tests involving user interactions with the QA4SM GUI are described in section 6.

6 Manual test cases

In this section, individual test cases are defined to manually verify all relevant QA4SM functions including all features which have been added in the evolution towards release 2. These test cases are executed via the web user interface of the QA4SM service.

The specification of each test case includes the following points:

- Description: The purpose of the test case indicating which functionality is verified.
- Test data: The input or auxiliary data which is required to execute the test case. Typically, all test data is already available in the tested service. Exceptions are explicitly specified.
- Preconditions: Technical requirements or preparatory actions which are needed to start the test.
- Requirements to be tested: Where explicit software requirements have been specified, which are verified by the test case, they are listed.
- Test Steps and Expected Results: The interactive test procedure is described in the form of a step by step execution of the test including detailed user activities in the QA4SM user interface.
    - The expected results describe the expected QA4SM interface responses for each test step.
    - In some cases, failures for specific test steps may imply that the remaining steps cannot be executed and the test case cannot successfully be completed. Each test case is complete when all described test steps have sequentially been executed and the results of each step have been observed.
- Pass/Fail: Each test case passes if the expected results have consistently been observed for all test steps. The test case fails if at least one test step fails in the sense that the actually observed results indicate a failure relative to the specified expected results. In special cases a deviation from the expected result may be acceptable, for example, if the deviation is due to changed circumstances which were not originally foreseen when the test case was developed, the cause of the deviation is understood, a software failure can be excluded and the functionality of the software is not impaired. In such cases the specific situation and understanding are described in the comments to the test case.
- Comments: Relevant observations during test execution are described in this field. This specifically includes test cases with non-trivial pass/fail results as described above. In such situations the comments describe the observed deviations, the understanding of the situation, the origins of the deviation and the rational for the pass or fail conclusion which was taken.

6.1 Testing of the validation algorithm

The tests described here aim to qualify the validation algorithm functioning through its implementation in the QA4SM platform. The algorithm can be imagined as composed of a servicing structure and the core validation routine[1]. The former performs tasks such as collecting the validation settings through the interface, distributing the jobs across the computational cores, handling errors, collecting and displaying the results. The latter consists of the validation methods (e.g. scaling, temporal matching, metrics calculation) implemented in the core Python Toolbox for the Evaluation of Soil Moisture Observations (pytesmo) package[2] and their adaptations. These validation 'building blocks' are subject to Continuous Integration (CI) automated testing. This is a standard in software development and comprises a series of routinely performed tests that compare the code functioning with an expected output (these tests are integrated both in QA4SM and Pytesmo, see section 5), allowing to easily identify detrimental changes to the code.

The tests described in this section are not substitutive but complementary to CI and automated software testing, as they allow to verify not just the individual components of the algorithm (or the building blocks), but the global functioning of the service. In particular, the tests are based on limit cases which allow for a narrow service output within the tested scope.

Test Case QA4SM_VA_metrics - Test self-validation

Description:	Evaluation of a dataset against itself. This limit case allows only one possible output for each validation metric, with the exception of the significance scores, where the sample size effect could impair the result.	
Test Data:	C3S SM combined (v201912)	
Preconditions:	-	
Requirement(s) to be tested:	-	
Test Steps		**Expected Results**
1.	Go to the "Validate" page and select C3S (v201912) as the spatial reference and candidate dataset, then run the validation. In principle, any other dataset (and version) will yield the	The validation metrics results will need to match the following scores: Bias: ~ 0 Mean square error: ~ 0

[1] See the QA4SM Software User Manual (DT3-1, version 1.1) for a complete description of the validation algorithm.
[2] Full documentation available at: https://pytesmo.readthedocs.io/en/v0.6.10/api/pytesmo.html

	same output. Leave all the settings as default and run the validation.	Mean square error bias: ~ 0 Mean square error correlation: ~ 0 Mean square error variance: ~ 0 Pearson's r: 1 Sperman's rho: 1 Pearson's/Spearman's p-value: ~ 0 Residual sum of squares: ~ 0 Unbiased root-mean squared deviation: ~ 0 Note: the results should be as close to the expected values as allowed by the numerical process of the algorithm used. Therefore, a deviation in the order of 8-9 decimal positions can be expected.
Pass/Fail:		
Comments:		

Test Case QA4SM_VA_metrics - Test invalid validation period

Description:	Test the effect of too few points in the sample on the validation output, through the 'Validation Period' settings	
Test Data:	C3S (v201912), ISMN (20210131 global)	
Preconditions:	-	
Requirement(s) to be tested:	-	
Test Steps		**Expected Results**
1.	Go to the "Validate" page and run a validation with the default settings	All metrics are calculated normally
2.	Change the fields in 'Validation Period' to compute a validation with the same starting and ending date	The validation metrics are not generated as the calculation fails due to the inadequate sample size
Pass/Fail:		

Comments:	

Test Case QA4SM_VA_metrics - Test scaling

Description:	Test the effect of rescaling on the metric output
Test Data:	C3S SM combined (v201912), ISMN (20210131 global)
Preconditions:	-
Requirement(s) to be tested:	-

Test Steps		**Expected Results**
1.	Go to the “Validate” page and run a validation with the default settings and the option “Mean/standard deviation” in the “Scaling” field	All metrics are calculated normally. The following metrics scores should be equal to 0: • Bias • Mean square error bias • Mean square error variance
2.	Run a validation with the default settings and the option “None” in the “Scaling” field	All metrics are calculated normally. The following metrics scores should also have a non-zero value: • Bias • Mean square error bias • Mean square error variance
3.	Compare the ouput of step 1. and 2.	The correlation scores for the metrics: • Pearson’s r • Spearman’s rho should be unchanged
Pass/Fail:		
Comments:		

Test Case QA4SM_VA_metrics - Test anomalies calculation

Description:	Indirect verification of the anomalies validation routine by testing that the statistical distance between the calculated anomalies of the spatial reference and candidate data sets is smaller than that between the bulk signals.	
Test Data:	C3S SM combined (v201912), ISMN (20210131 global)	
Preconditions:	-	
Requirement(s) to be tested:	-	
Test Steps		**Expected Results**
1.	Go to the “Validate” page and run a validation with the default settings (in principle, any two data sets expressed in the same measuring units can be selected as spatial reference and candidate for this test). Set the “Scaling” field to “None”.	All metrics are calculated normally
2.	Repeat the validation of step 1. using “Climatology” in the field “Anomalies” and a long term climatology window of at least 20 years.	Verify that the output scores of: • Bias • Mean Square Error are smaller compared to the output of step 1.
Pass/Fail:		
Comments:		

6.2 Testing of the graphical user interface

6.2.1 Creating and managing user accounts

Test Case QA4SM_GUI_CMUA_001 - Test Sign-up Form

Description:	Testing whether the sign up form behaves as expected and if signing up a new user is possible.	
Test Data:		
Preconditions:		
Requirement(s) to be tested:		
Test Steps		**Expected Results**

1.	Go to test.qa4sm.eu/ui//signup	A sign-up form renders, containing:
		• fields:
		  • Username,
		  • Password,
		  • Password confirmation,
		  • Email address,
		  • First name,
		  • Last name,
		  • Organisation,
		  • Country (a drop-down list),
		  • ORCID,
		• a check-box to accept terms, conditions and privacy policy (unchecked);
		• submit button (disabled).
		There is a question mark icon on the right side of each field, providing additional information on the particular field when hovering over.

2.	Insert values: Username: username, Password: username, Password confirmation: username1,	‘Submit’ button enabled.

	Email address: provide an existing email address, check the terms check-box	
3.	Click the ‘Submit’ button	‘The two password fields didn’t match.’ warning shows up under the password confirmation field.
4.	Correct: Password confirmation: username and click ‘Submit’ again	‘The password is too similar to the username. This password is too common.’ warning shows up under the password confirmation field.re
5.	Correct: Password: pass, Password confirmation: pass	‘This password is too short. It must contain at least 8 characters. This password is too common.’ warning shows up under the password confirmation field.
6.	Correct: Username: user1 , Password: *choose a strong password that suits all the* requirements, Password confirmation: *confirm the chosen password* Insert: First name: John, Last name: Smith, Organisation: Some University, Country: choose any country, ORCID: 0000-0000, click the ‘Submit’ button	‘Invalid ORCID identifier’ warning shows up under the ORCID field.
7.	Correct:	• Form submitted;

	ORCID: 0000-0000-0000-0000
	and click ‘Submit’
		• redirection to the page test.qa4sm.eu/ui//signup-complete containing:
		  • notification: ‘Thank you for signing up with the QA4SM Validation Service. You will be notified via email **as soon as your account is activated** by an admin.’ displayed;
		  • ‘Back to landing page’ button.

8.	Click the ‘Back to landing page’ button	Redirection to the home page.
9.	Click the ‘Sign up’ button to go to the sign-up page again and insert: Username: user1, Password: anyPassword, Password confirmation: anyPassword, Email address: username@something.at, and check the terms check-box, and click ‘Submit’	‘A user with that username already exists’ warning shows up under the username field.
10.	Click on the link ‘terms, conditions and privacy policy ’ next to the terms check-box	Redirection to test.qa4sm.eu/ui//terms page.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_CMUA_002 - Test Log in page

Description:	Testing if log in form works as expected	
Test Data:	None	
Preconditions:	Existing user with data provided in the Test Sign-up Form and activated by an admin	
Requirement(s) to be tested:	Test Case QA4SM_GUI_CMUA_001	
Test Steps		**Expected Results**
1.	Go to the test.qa4sm.eu and click the Log in button	A form rendered containing: • a title: 'Please sign in'; • 'Username' and 'Password' fields; • 'Sign in' button; • link to retrieve a password.
2.	Provide data: Username: test_user, Password: test_user and click the 'Sign in' button	A pop-up window shows up informing about an unsuccessful login attempt.
3.	Click on the 'Forgotten your password?' link	Redirection to the test.qa4sm.eu/ui/password-reset page
4.	Go back to the login page and provide data: Username: user1, Password: *password chosen while registering*,	User logged in, redirection to the home page.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_CMUA_003 - Test Password Reset

Description:	Testing if the password reset procedure works properly
Test Data:	None
Preconditions:	Existing user with data provided in the Test Sign-up Form and activated by an admin (remark: the email address must be an existing one); User logged out from the current account - choose 'Profile' => 'Log out' from the navigation bar.
Requirement(s) to be tested:	Test Case QA4SM_GUI_CMUA_001, Test Case QA4SM_GUI_CMUA_002

	Test Steps	**Expected Results**
1.	Go to test.qa4sm.eu/ui/login page and click on the 'Forgotten your password?" link	Redirection to test.qa4sm.eu/ui/password-reset page with an email field and disabled 'Reset my password' button.
2.	Provide a fake email: someUser@some.domain.com and click 'Reset my password' button	Information that there is no user with the given email.
3.	Provide the right email (the one given while registering) and click 'Reset my password' button	Redirection to the page test.qa4sm.eu/ui/password-reset-done, displaying information that password reset instructions have been sent.
4.	Log in to your email address	An emailed entitled '[QA4SM] Password reset for QA4SM webservice' received.
5.	Click on the link in the email	Redirection to the page test.qa4sm.eu/ui/set-password with two input fields (for password and password confirmation) and 'Change my password' button (disabled).
6.	Provide data:	'Change my password' button enabled.

	Password: 123456 Password confirmation: 123456	
7.	Click the 'Change my password' button	Information: "This password is too short. It must contain at least 8 characters. This password is too common. This password is entirely numeric." displayed.
8.	Remove given password and provide a new one: Password: xYbn89Kg Password confirmation: xYbn89	'Change my password' button still disabled.
9.	Choose your own password that fulfill all requirements and confirm it.	'Change my password' button enabled.
10.	Click the 'Change my password' button	'Password change' notification displayed, redirection to the login page.
11.	Log in with the new password	Successful logging in.
12.	Go to your email account and open the link for password resetting again	Information about invalid link displayed with a link to resetting password form provided.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_CMUA_004 - Test User Profile page

Description:	Testing if User Profile renders properly and if it behaves as expected
Test Data:	None

Preconditions:	Existing user account with data provided in the Test Sign-up Form and activated by an admin
Requirement(s) to be tested:	Test Case QA4SM_GUI_CMUA_001, Test Case QA4SM_GUI_CMUA_002

Test Steps		**Expected Results**

1.	Go to test.qa4sm.eu/ui/user-profile	The User Profile renders, containing:
		• fields:
		  • Username (disabled),
		  • Password (empty),
		  • Password confirmation (empty),
		  • Email address,
		  • First name,
		  • Last name,
		  • Organisation,
		  • Country (a drop-down list),
		  • ORCID,
		• 'Save' button (enabled),
		• 'Deactivate my account' button (enabled).
		There is a question mark icon on the right side of each field, providing additional information on the particular field when hovering over.
		Apart from the password fields, all the fields are filled with the information given while registering.

2.	Provide a new password, but without confirming it and click the 'Save' button.	'Password do not match' warning shows up under the password field.
3.	Provide the same password confirmation and click the 'Save' button.	A pop-up window with information that the user profile has been updated shows up; Password saved.

4.	Remove email address	Email address field has red border and red label; 'Save' button disabled.
5.	Press ctrl+z to retrieve the email address	'Save' button enabled again.
6.	Remove values from 'First name', 'Last name' and 'Organisation' fields and click the 'Save' button	A pop-up window with information that the user profile has been updated shows up.
7.	Remove four last digits from the ORCID number and click the 'Save' button.	'Invalid ORCID identifier' warning displayed below the ORCID field.
8.	Remove the ORCID number entirely and click the 'Save' button.	A pop-up window with information that the user profile has been updated shows up.
9.	Expand the 'Country' list, choose any country and click the 'Save' button	A pop-up window with information that the user profile has been updated shows up;
10.	Click the 'Deactivate my account' button	An email with information that the account has been deactivated received; Redirection to the page test.qa4sm.eu/ui/deactivate-user-complete, with: • notification that the account will be removed within the next 7 days; • a link to the landing page.
11.	Click the link 'Back to landing page'	Redirection to test.qa4sm.eu/ui/home
12.	Click the 'Log in' button on the home page and try to log in with the previous data	A pop-up window shows up, informing that the log in attempt failed.
Pass/Fail:		
Comments:		

6.2.2 Home page and Navigation Bar

Test Case QA4SM_GUI_HPNB_001 - Test Home Page - as a not logged in user

Description:	Testing whether home page renders properly and if all the buttons and links redirect to appropriate pages
Test Data:	None
Preconditions:	User logged out from the current account - choose ‘Profile’ => ‘Log out’ from the navigation bar.
Requirement(s) to be tested:	

Test Steps		**Expected Results**

1.	Go to test.qa4sm.eu page	Page renders with:
		• a navigation bar at the top;
		• a carousel with:
		  • three images and attributions in the lower left corner of each image;
		  • carousel caption containing:
		  • title: ‘Quality Assurance for Soil Moisture’;
		  • description: ‘Validation of satellite soil moisture products against in-situ and model reference data';
		  • action buttons: ‘See results’, ‘Sign up’ and ‘Log in’;
		  • carousel indicators - three white rectangles changing their color to blue when the corresponding picture is displayed;
		• a row containing partner’s logos: FFG, ESA, TU Wien Geo, AWST;
		• a row containing a short overview of the service functionalities and information

		on the financial support (left side) and a diagram explaining the platform workflow (right side); • a row containing three screenshots depicting main service functionalities, entitled: 'data set and Settings', 'Results' and 'Download and Visualize'; • a footer containing information about page creators and link to appropriate pages; • a 'go to top' button in the lower right corner.
2.	Click the 'See results' button	Redirection to the 'Published validations' page (test.qa4sm.eu/ui/published-validations).
3.	Go back to the home page and click 'Sign up' button	Redirection to the sign up form (test.qa4sm.eu/ui/signup).
4.	Go back to the home page and click 'Log in' button	Redirection to the log in form (test.qa4sm.eu/ui/login).
5.	Go back to the home page and click one of the carousel indicators	Carousel picture set to the one corresponding to the chosen indicator.
6.	Choose the middle indicator and click the image attribution of the current image	New tab with an ESA website providing current graphics opens.
7.	Inspect partner's logos - click on each logo	Respective websites open in new tabs: • FFG logo - www.ffg.at; • ESA logo - www.esa.int; • TU Wien Geo - www.geo.tuwien.ac.at; • AWST logo - www.awst.at.
8.	Inspect service overview row - click the link to the international soil moisture network (first bullet point)	The international soil moisture network website (https://ismn.earth) opens in a new tab.
9.	Inspect service overview row - inspect information on the financial support, click both available links	Information lists Austrian Space Application Programme and European Space Agency as two sources of financial support.

		Clicking on provided links opens new tabs with FFG (www.ffg.at) and ESA (www.esa.int) websites respectively.
9.	Click on the workflow diagram	The diagram opens in full-screen.
10.	Close the diagram and inspect the row containing screenshots depicting main service functionalities by clicking on a picture, closing it and clicking on the next one	Pictures opens in full-size. They depict 'Validate' page (data set and Settings), 'My validations' page (Results) and single result page (Download and Visualize).
11.	Inspect the footer	The footer contains: 'Created by TU Wien GEO and AWST' information, with links opening TU Wien Geo and AWST websites in new tabs.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_HPNB_002 - Test Navigation Bar

Description:	Testing whether navigation bar buttons behave in the expected way and if they redirect to proper URLs	
Test Data:	None	
Preconditions:	An existing account and a logged in user.	
Requirement(s) to be tested:	Test Case QA4SM_GUI_HPNB_001	
Test Steps		**Expected Results**
1.	Inspect navigation bar buttons	Five buttons: • 'Home' with a home icon, • 'Validate' with a check-box icon, • 'My validations' with a folder icon, • 'Published validations' with a globe icon,

		• ‘Compare validations’ with an icon consisting of four squares, • ‘My datasets’ with an upload icon, two drop-down lists: • ‘Info’ with an i-in-circle icon, • ‘Profile’ with a user icon, (All buttons and drop-down list have yellow border, yellow font color and blue background color.); and ‘QA4SM Validation Service’ link title in the right side of the menu bar.
2.	Hover over each single button and drop-down list	Button’s/drop-down list’s background color changes to yellow and font color changes to white.
3.	Click the ‘Validate’ button	Button’s background color changes to yellow and font color changes to white. Redirection to page: test.qa4sm.eu/ui/validate.
4.	Click the ‘My validations’ button	Button’s background color changes to yellow and font color changes to white. Redirection to page: test.qa4sm.eu/ui/my-validations.
5.	Click the ‘Published validations’ button	Button’s background color changes to yellow and font color changes to white. Redirection to page: test.qa4sm.eu/ui/published-validations.
6.	Click the ‘Compare validations’ button	Button’s background color changes to yellow and font color changes to white. Redirection to page: test.qa4sm.eu/ui/comparison.
7.	Click the ‘My datasets’ button	Button’s background color changes to yellow and font color changes to white.

		Redirection to page: test.qa4sm.eu/ui/my-datasets.
8.	Click on the ‘Info’ drop-down list	A drop-down list expanded with following options: • ‘About’ with an i-letter icon, • ‘Help’ with a question mark icon, • ‘User Manual’ with a book icon, • ‘Datasets’ with a floppy disc icon, • ‘Terms’ with a briefcase icon. The list has a white background, the option’s background changes to yellow when hovering over it.
9.	Expand the ‘Info’ drop-down list and choose ‘About’	Redirection to page test.qa4sm.eu/ui/about.
10.	Expand the ‘Info’ drop-down list and choose ‘Help’	Redirection to page test.qa4sm.eu/ui/help.
11.	Expand the ‘Info’ drop-down list and choose ‘User Manual’	A new tab with the QA4SM user manual opens.
12.	Expand the ‘Info’ drop-down list and choose ‘data sets’	Redirection to page test.qa4sm.eu/ui/datasets.
13.	Expand the ‘Info’ drop-down list and choose ‘Terms’	Redirection to page test.qa4sm.eu/ui/terms.
14.	Click on the ‘Profile’ drop-down list	A drop-down list expanded with following options: • ‘User profile’ with a user icon, • ‘Log out’ with a log-out icon, • ‘Log in’ with a log-in icon (disabled as the user is logged in) The list has a white background, the option’s background changes to yellow when hovering over it.
15.	Expand the ‘Profile’ drop-down list and choose ‘User profile’	Redirection to page test.qa4sm.eu/ui/user-profile.

16.	Expand the 'Profile' drop-down list and choose 'Logout'	Redirection to home page.
17.	Expand the 'Profile' drop-down list	'User profile' and 'Logout' options disabled, 'Login' option enabled.
18.	Expand the 'Profile' drop-down list and choose 'Log in'	Redirection to test.qa4sm.eu/ui/login page.
19.	Click the 'QA4SM Validation Service' title	Redirection to the home page.
Pass/Fail:		
Comments:		

Test GUI - Test Log in page - redirection after logging in

Description:	Testing if after logging in the user is redirected to the appropriate page	
Test Data:	None	
Preconditions:	An existing account, with a logged-out user	
Requirement(s) to be tested:	Test Case QA4SM_GUI_CMUA_001, Test Case QA4SM_GUI_CMUA_002, Test Case QA4SM_GUI_HPNB_002	
Test Steps		**Expected Results**
1.	Go to the test.qa4sm.eu and click the 'Log in' button on the main page; provide your data after redirection to the log in form	User logged in, redirection to the home page.
2.	Choose 'Log out' from the 'Profile' drop-down list and go to the 'Validate' page	Redirection to the login page.

3.	Provide your data	User logged in, redirection to the 'Validate' page.
4.	Choose 'Log out' from the 'Profile' drop-down list and go to the 'My validations' page	Redirection to the login page.
5.	Provide your data	User logged in, redirection to the 'My validations' page.
6.	Choose 'Log out' from the 'Profile' drop-down list and go to the 'Compare validations' page	Redirection to the login page.
7.	Provide your data	User logged in, redirection to the 'Compare validations' page.
8.	Choose 'Log out' from the 'Profile' drop-down list and go to the 'My datasets' page	Redirection to the login page.
9.	Provide your data	User logged in, redirection to the 'My datsets' page.
10.	Choose 'Log out' from the 'Profile' drop-down list and then choose 'Log in' from the same list	Redirection to the log in page.
11.	Provide your data	Redirection to the 'User profile' page.
Pass/Fail:		
Comments:		

6.2.3 Validate Page

Test Case QA4SM_GUI_VP_001 - Test Validate Page - Render Validate Page

Description:	Testing whether the 'Validate' page renders properly	
Test Data:	None	
Preconditions:	An existing account and a logged in user.	
Requirement(s) to be tested:		
Test Steps		**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/)	Rendered components and buttons: • Data, • Reference, • Map, • Spatial Subsetting, • Temporal Subsetting, • Metrics, • Anomalies, • Scaling, • Name your validation field, • Validate button.
		All the components (apart from the Map and Validation name field) have a question mark icon and a collapse button in the right corner of their headers. The Map component has a collapse button only. The 'Name your validation' field is followed by a question mark icon providing additional help when hovering over.
Pass/Fail:		

Comments:	

Test Case QA4SM_GUI_VP_002 - Test Validate Page - Render Validate Page: Inspect Data Component

Description:	Testing whether the ‘Data’ component on the ‘Validate’ page behaves as expected
Test Data:	None
Preconditions:	An existing account and a logged in user.
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001

Test Steps		**Expected Results**
1.	Go to the ‘Validate’ page (test.qa4sm.eu/ui/validate/) - render default settings	‘Data’ component renders with two datasets: 1. ISMN data set: • version 20210131 global, • variable ‘soil_moisture’, • List of available filters with a ‘Variable in valid geophysical range’ and ‘Quality flag is "good" (G)’ filters switched on, and two parameterized filters (‘Use ISMN networks’ and ‘Use measurements at given depth’) switched on and disabled. 2. C3S SM combined data set, • version v202012 • variable ‘sm’, • List of available filters with a ‘Variable in valid geophysical range’ filter switched on, • ‘Remove data set’ red button (disabled),

		• ‘Add data set’ green button (enabled). ISMN dataset is marked as spatial and temporal reference.
2.	Expand the variable drop-down list for the C3S data set	Only variable ‘sm’ available.
3.	Expand the version drop-down list for the C3S data set	Versions: v201706, v201812, v201912 and v202012 available.
4.	Choose version v201706 from the version drop-down list	Date in the field ‘To’ of the ‘Validation Period‘ component changes to ‘2017-06-30’.
5.	Check the ‘Ascending mode only’ filter and then check the ‘Descending mode only’ filter	Checking the ‘Descending mode only’ filter unchecks the ‘Ascending mode only’ automatically.
6.	Expand the C3S data set drop-down list and inspect the list of available data sets	There is no ISMN dataset available.
7.	Expand the ISMN data set drop-down list and choose ‘GLDAS Noah’	• The list of available versions changes - NOAH025 3H.2.1 set; • the list of available variables changes - SoilMoi100_200cm_inst set; • the list of available filters changes; • validation period component values change to: 2000-01-01 (From) and 2017-12-31 (To); • ‘Remove data set’ button still inactive. • GLDAS dataset marked as spatial and temporal reference.
8.	Expand the C3S data set drop-down list and inspect the list one more time	The ISMN data set available again.
9.	Click on the ‘Add data set’ button	• A new data set tab with default C3S data set settings added below; • ‘Remove data set’ button enabled;

		• 'Include triple collocation metrics' checkbox in the 'Metrics' component enabled.
10.	Inspect the 'Dataset' dropdown list of the newly added data set	ISMN data set available.
11.	Click on the 'Add data set' button three more times	• three additional dataset tabs added with default C3S data set settings; • 'Add dataset' button disabled.
12.	Click the 'Remove data set' button on the GLDAS Noah data set tab	• Tab removed; • 'Add data set button' enabled again; • validation period changes to 1978-11-01 (From) and 2020-12-31 (To); • First data set on the list marked as spatial and temporal reference.
13.	Remove three other data set tabs	• 'Remove data set' button disabled; • 'Include Triple Collocation Metrics' checkbox disabled.
14.	Change one data set to ISMN	ISMN set as spatial reference.
15.	Inspect 'Dataset' list of the C3S tab	ISMN unavailable.
15.	Click 'select...' next to the 'Use ISMN Networks' filter	A dialog window opens, with a list of available ISMN networks, ordered by continents.
16.	Click on 'Europe' checkbox and expand the list using the arrow on the left side	The checkbox next to 'Europe' is marked as checked, the same as all the networks assigned to Europe.
17.	Close the dialog window and open it one more time	The dialog window looks the same as before closing - the same networks chosen, the same list folded and expanded.
18.	Close the 'Select networks' dialog window and click 'select...' next to the	A dialog window opens, with two fields for introducing depth from and depth to and an 'OK' button. Fields 'Depth from' and

	'Use measurements at given depth' filter	'Depth to' are set by default to 0.0 and 0.1 m.
19.	Change 'Depth to' to 0.2 m and click the 'OK' button. Open dialog window again.	After clicking the 'OK' button the dialog window closes. When opened again the field 'Depth to' is set to 0.2 m.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_003 - Test Validate Page - Render Validate Page: Inspect Reference Component

Description:	Testing whether the 'Reference' component on the 'Validate' page behaves as expected	
Test Data:	None	
Preconditions:	An existing account and a logged in user	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001	
Test Steps		**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/)	Component renders with two dropdown lists labeled 'Spatial reference' and 'Temporal reference' and ISMN data set chosen by default in both lists. In the 'Data' component, the ISMN data set is marked as spatial and temporal reference.
2.	Expand the spatial reference dropdown list	There is only ISMN dataset available.
3.	Expand the temporal reference dropdown list	There are both ISMN and C3S data sets available.

4.	Choose C3S as the temporal reference data set	C3S data set in the component ‘Data’ marked as temporal reference.
5.	Change ISMN data set in the ‘Data’ component to ‘GLDAS Noah’	GLDAS Noah set as the spatial reference.
6.	Expand the spatial reference dropdown list	There are both GLDAS and C3S data sets available.
7.	Add another data set in the ‘Data’ component and inspect both spatial and temporal reference dropdown lists – expand and hover over each data set on the list	There are all three data sets available on both lists; When hovering over a data set, the proper tab in the ‘Data’ component gets highlighted.
8.	Choose one of C3S data sets as the spatial reference	Proper C3S data set in the component ‘Data’ marked as spatial reference.
9.	Change version of the C3S data set that is chosen as the spatial reference	Proper version set in the ‘Reference component’.
10.	Change GLDAS data set to ISMN	ISMN set as the spatial reference, C3S left as the temporal reference, information in data sets tab headers updated.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_004 - Test Validate Page - Render Validate Page: Inspect Map Component

Description:	Testing whether the ‘Map’ component on the ‘Validate’ page behaves as expected
Test Data:	None

Preconditions:	An existing account and a logged in user
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001

Test Steps		**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/) and expand the 'Map' component	Component renders collapsed and contains: • a map with: a pencil icon in the upper left corner, • attribution icon in the lower right corner, • bounding box covering Europe, defined by the coordinates given in the 'Spatial Subsetting' component.
2.	Click on the pencil icon in the upper left corner	• Bounding box cleared; • a blue circle with white border shows up next to the cursor.
3.	Click in any place on the map and move the cursor	Drawing a bounding box starts.
4.	Draw a bounding box of any size covering North America and Europe, and click on the map again	• A rectangle bounding box added on the map; • coordinates in the Spatial Subsetting' component updated with values corresponding to the lower left and upper right corners of the drawn rectangle.
5.	Change data set in the 'Data' component to CGLS SSM 1km	• An alert shows up informing that the chosen spatial subsetting is bigger than the one covered by chosen data sets and that the bounds are corrected to fit available subsetting; • bounding box adjusted to the region covered by the chosen dataset.

6.	Draw a new bounding box, bigger than the current one	• The alert shows up again; • bounding box is adjusted to the available spatial subsetting.
7.	Change data set back to C3S SM combined and draw any bounding box	• Chosen bounding box drawn, • updated coordinates in the 'Spatial Subsetting' component.
8.	Click on the button in the lower right corner of the map	An attributions field expands with a link to the Open Street Maps.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_005 - Test Validate Page - Render Validate Page: Inspect Spatial Subsetting Component

Description:	Testing whether the 'Spatial Subsetting ' component on the 'Validate' page behaves as expected	
Test Data:	None	
Preconditions:	An existing account and a logged in user	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001	
Test Steps		**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/)	Component renders with: • four input fields - latitude and longitude of the lower left and upper right corners, labeled respectively; • a trash bin button between fields; • default values of the latitude and longitude of the lower left corner set to 34 and -11.2 degrees respectively;

		• default values of the latitude and longitude of the upper right corner set to 71.6 and 48.3 degrees respectively.
2.	Click on the trash bin button and expand the 'Map' component	• Coordinates field cleared; • bounding box removed from the map.
3.	Input following coordinates: Lat = 40, Lon = -10 for the lower left corner and Lat = 60, Lon = 40 for the upper right corner	Bounding box on the map drawn, corresponding to the given coordinates.
4.	Change the latitude of the lower left corner to 70 degrees	The latitude set to 60 degrees, as it cannot exceed the latitude of the upper right corner.
5.	Change data set to CGLS SSM 1km	• An alert shows up informing that the chosen spatial subsetting is bigger than the one covered by chosen data sets and that the bounds are corrected to fit available subsetting; • spatial subsetting values change to 35.004 and -10.996 degrees for the latitude and longitude of the lower left corner and to 71.996 and 49.996 degrees for the latitude and longitude of the upper right corner.
6.	Input following coordinates: Lat = 40, Lon = -10 for the lower left corner and Lat = 60, Lon = 40 for the upper right corner	The bounding box updated.
7.	Click on the trash bin button	Coordinates and the bounding box adjusted to the default spatial subsetting assigned to the chosen data set,
8.	Change the latitude of the lower left corner to 30 degrees	Value changed back to the default one as the introduced value is smaller than the minimum possible.

Pass/Fail:	
Comments:	

Test Case QA4SM_GUI_VP_006 - Test Validate Page - Render Validate Page: Inspect Validation Period Component

Description:	Testing whether the ‘Validation period’ component on the ‘Validate’ page behaves as expected	
Test Data:	None	
Preconditions:	An existing account and a logged in user	
Requirement(s) to be tested:	Test Validate Page	
Test Steps		**Expected Results**
1.	Go to the ‘Validate’ page (test.qa4sm.eu/ui/validate/)	Component renders with two sub-fields named Validation Period and Temporal matching. The Validation Period part consists of two date fields described with From and To labels, with default dates set to 1978-11-01 (From) and 2020-12-31 (To). The Temporal matching field contains an input field labeled ‘Window size’ and two arrows enabling changing values in the field. By default, 12 hours is set.
2.	Click first on the ‘From’ field and then on the ‘To’ field	In both cases a calendar widget shows up.
3.	Expand the calendar on the ‘From’ field and choose January from the month drop-down list and 2021 from the year drop-down list	No date to choose available, as the date ‘To’ is set to be 2020-12-31

4.	Change date ‘From’ to 2020-11-01, click on the calendar on the field ‘To’ and choose October from the month drop-down list	No date available as the date ‘From’ is set to 2020-11-01;
5.	Press upper arrow next to the ‘Window size’ field and hold it	Value increases to 24 hours and stops.
6.	Press lower arrow next to the ‘Window size’ field and hold it	Value decreases to 1 hour and stops.
7.	Insert to the ‘Window size’ field value bigger than 24 hours	Value 24 hours set.
8.	Insert to the ‘Window size’ field value smaller than 1 hour	Value 1 hour set.
9.	Try to insert value 1.5 hours	Value 15 hours set, as there is no possibility to introduce a decimal separator.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_007 - Test Validate Page - Render Validate Page: Inspect Metrics Component

Description:	Testing whether the ‘Metrics’ component on the ‘Validate’ page behaves as expected	
Test Data:	None	
Preconditions:	An existing account and a logged in user	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001	
Test Steps		**Expected Results**

1.	Go to the ‘Validate’ page (test.qa4sm.eu/ui/validate/)	Component renders with two checkboxes, described as ‘Include Triple Collocation Metrics’ and ‘Bootstrap Triple Collocation metric confidence intervals (Warning: very slow)’, both descriptions are followed by question mark icons providing additional information when hovering over, both checkboxes are disabled.
2.	Click on the ‘Add data set’ button in the ‘Data’ component	• ‘Include Triple Collocation Metrics’ enabled, • ‘Bootstrap Triple Collocation metric confidence intervals’ disabled;
3.	Check ‘Include Triple Collocation Metrics’ box	‘Bootstrap Triple Collocation metric confidence intervals’ enabled;
4.	Check ‘Bootstrap Triple Collocation metric confidence intervals’ box and uncheck ‘Include Triple Collocation Metrics’ box	Both boxes get unchecked;
5.	Check both checkboxes and remove a data set, so only one data set is left	Both boxes get unchecked;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_008 - Test Validate Page - Render Validate Page: Inspect Anomalies Component

Description:	Testing whether the ‘Anomalies’ component on the ‘Validate’ page behaves as expected
Test Data:	None
Preconditions:	An existing account and a logged in user

Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001	
Test Steps		**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/)	Component renders with one drop-down list labeled Method, with the 'Do not calculate' set by default.
2.	Expand the Method drop-down list and choose 'Climatology'	Two empty input date fields show up, labeled 'From' and 'To'.
3.	Expand the calendar widget on the 'From' field, choose January 10, 2021, expand the calendar widget on the 'To' field and choose January 2021	The earliest possible date to choose is January 10, 2021.
4.	Choose January 20, 2021 on the calendar widget on the 'To' field and expand the calendar widget on the 'From' field	The latest possible date to choose is January 20, 2021.
5.	Expand the Method drop-down list and choose '35 day moving average'	Both date selection fields disappear again.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_009 - Test Validate Page - Render Validate Page: Inspect Scaling Component

Description:	Testing whether the 'Scaling' component on the 'Validate' page behaves as expected
Test Data:	None
Preconditions:	

Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001	
Test Steps		**Expected Results**
1.	Go to the ‘Validate’ page (test.qa4sm.eu/ui/validate/)	Component renders with one drop-down list, labeled Method, with the ‘No scaling’ set by default
2.	Expand the dropdown list and choose any other method	A ‘Scale to’ dropdown list shows up, with ISMN data set chosen by default. The ISMN data set marked as scaling reference in the ‘Data’ component.
3.	Expand the ‘Scale to’ dropdown list and hover over each option	Both ISMN and C3S datasets (those available in the ‘Data’ component) shown on the list. When hovering over an option the respective tab in the ‘Data’ component gets highlighted.
4.	Choose C3S as the scaling reference	C3S data set marked as scaling reference in the ‘Data’ component
5.	Add another data set in the ‘Data’ component and remove the C3S component set as scaling reference	First data set on the list set as the scaling reference; Proper information added to the data set tab header in the ‘Data’ component.
6.	Expand the ‘Method’ drop-down list and choose method ‘No Scaling’	‘Scale to’ drop-down list vanishes. None of data set is marked as scaling reference;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VP_010 - Test Validate Page - Start a default validation

Description:	Testing service behavior after starting a validation
Test Data:	None
Preconditions:	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_001 to 009

	Test Steps	**Expected Results**
1.	Go to the 'Validate' page (test.qa4sm.eu/ui/validate/), do not change any settings, enter name 'test validation' in the 'Name your validation' field, click the 'Validate' button.	Depending on validations existing in our database it is possible that a modal window opens informing that there exists already a validation with the given settings. It may refer to a validation of the current user, to a validation of another user or the a published validation. There are two buttons on the modal window: 'See the existing validation' and 'Run your own validation'. If the window showed up, go to point 2, if not to point 3.
2.	If the modal window shows up: Click the 'See the existing validation' button	Redirection to the page with results of the existing validation.
3.	Get back to the 'Validate' page, enter name 'test validation' in the 'Name your validation' field and click the 'Validate' button. If the modal window shows up, choose 'Run your own validation'	Redirection to the page test.qa4sm.eu/ui/validation-result/validation_id (where validation_id is a random universal unique identifier) with information about running validation.
4.	Wait until receiving an email about finished validation and refresh the	Validation results displayed in three separate components entitled 'Summary:

	page (or go to it using the link given in the email)	test validation', 'Summary statistics' and 'Result files'.
Pass/Fail:		
Comments:		

6.2.4 My Validations Page

Test Case QA4SM_GUI_MVP_001 - Test My Validations Page - Render My Validations Page

Description:	Testing whether the 'My Validations' page renders properly	
Test Data:	None	
Preconditions:	Start 3 different validations with the default settings, but a different spatial reference dataset (to be able to choose a different spatial reference dataset than ISMN, there cannot be ISMN in dataset pool), give each validation a different name (e.g. test_val_1, test_val_2, test_val_3);	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010	
Test Steps		**Expected Results**
1.	Go to the 'My validations' page (test.qa4sm.eu/ui/my-validations)	Page renders with: • a title - 'My validations'; • a sorting form, labeled 'Sort by', is rendered with two drop-down lists - one for the sorting feature (by default set to 'Date') and the second one for the order (by default set to 'descending'); • validation results rows are rendered for each validation that has been run; each row contains:

		• a header with icon (depending on the validation status it can be a calendar, a spinner, a triangle with an exclamation mark, a book, a box or a ban symbol), date and time of the validation start (in case the validation is a copy of the original, the copy date), validation name and button to change it (or a question mark icon, if the validation has been published); • a body containing information on data sets used for validations, validation status and action buttons; Remark: If more than 10 validations have been run, pagination is added and displayed below validation rows.
2.	Change sorting feature to ‘Name’	Validation rows ordered by validation names in the descending order;
3.	Change order to ‘ascending’	Validation rows ordered by validation name in the ascending order;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_MVP_002 - Test My Validations Page - Inspect Validation Results Row

Description:	Testing whether Validation Results Row renders properly and if the action buttons works as they should
Test Data:	None

Preconditions:	Run your own validation with default settings, GLDAS Noah data set as the spatial and temporal reference and name ‘default_validation’, wait until it finishes;	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_MVP_001	
Test Steps		**Expected Results**
1.	Go to the ‘My validations’ page (test.qa4sm.eu/ui/my-validations)	Validation row with the newest validation rendered at the top. The row’s header contains: • a calendar icon, • date and time of the validation start, • name: default_validation followed by a pencil button; The row’s body contains: • Data: 1. ‘C3S, v202012, sm’, 2. GLDAS Noah, NOAH025 3H.2.1, SoilMoi100_200cm_inst (spatial, temporal reference) • Status: ‘Done’; • action buttons: ◦ ‘View results’ folder button, ◦ ‘Archive’ box button, ◦ double arrow drop-down list with options: ▪ Download graphs, ▪ Download NetCDF File, ▪ Load Validation Settings, ▪ Delete Validation Run, ▪ Extend Life Span;
2.	Hover over the header calendar icon	Information about the expiration date shows up.

3.	Click on the pencil button next to the validation name	• An input field shows up, filled with the current validation name (empty if there was no name provided); • floppy disc and ban icon buttons displayed.
4.	Click on the ban button	• Input field closed; • name not changed; • pencil button displayed.
5.	Click on the pencil button again and change the validation name to 'test_validation' and press the floppy disc button	• Name changed; • input field closed; • floppy disc and ban icons hidden; • pencil button displayed.
6.	Click on the folder button	Redirection to the page test.qa4sm.eu/ui/validation-result/validation_id (where validation_id is a random universal unique identifier).
7.	Go back to the 'My validations' page and click on the 'Archive' box button and click 'ok' on the pop-up window	• Results archived; • the box button changed into an 'Un-archive' calendar button; • the header calendar icon changed into a box icon.
8.	Hover over the box icon in the header	Information about the validation being archived displayed.
9.	Expand double arrow drop-down list	no 'Extend Life Span' option (not needed for archived results).
10.	Click the 'Un-archive' calendar button and confirm it on the pop-up window	• Results unarchived; • the box icon changed back to the calendar icon; • the calendar button changed back to the box button; • 'Extend Life span' option available again.
11.	Expand the double arrow drop-down list and click on the 'Download Graphs' option	A dialog window for downloading a .zip file opened.

12.	Cancel downloading, expand the double arrow drop-down list and click on the 'Download NetCDF File' option	A dialog window for downloading a result file opened.
13.	Cancel downloading, expand the double arrow drop-down list and click on the 'Load Validation Settings' option	Redirection to the 'Validation' page' with settings of the current validation set.
14.	Go back to the 'My validations' page, hover over the calendar icon and note the date given in the information, expand the double arrow drop-down list and click on the 'Extend Life Span' and confirm it on the pop-up window	New validation expiry date set to be 60 days (including time not only date) from now, the expiry date can be checked when hovering over the calendar icon in the header;
15.	Expand the double arrow drop-down list and click on the 'Delete Validation Run' and confirm it on the pop-up window	• Validation deleted; • appropriate validation row removed; • no access to the results - the link from the email informing about finished validation does not work anymore.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_MVP_003 - Test My Validations Page - Cancel running validation

Description:	Testing if 'Cancel validation' button works as expected
Test Data:	None
Preconditions:	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010

Test Steps		**Expected Results**

1.	Go to ‘Validate’ page, choose ERA5-Land as the reference data set, start a new validation and go to ‘My validations’ page and inspect the running validation row	• Started validation is listed as the first one;
		• there is a spinner icon in the upper left corner of the header;
		• validation status is ‘Scheduled’;
		• the available action buttons are:
		  • a square ‘Cancel validation’ button available,
		  • ‘View results’ folder button,
		  • double arrow drop-down list with options:
		  ○ Delete Validation Run,
		  ○ Extend Life Span;
		The rest of the row looks like in case of finished validations.

2.	Wait around one minute and inspect the Status field	Validation status changed to ‘Running x%’ where x is a integer number between 1 and 100.
3.	Click the ‘Cancel validation’ button	• Validation stops; • icon changes to a ban symbol; • status changes to ‘Canceled’; • ‘Cancel validation’ button vanishes.
4.	Click the folder button and inspect the validation results page	Only validation summary available, with the same information as for a finished validation, but instead of the number of errors there is information that the validation was canceled. No ‘Publish’ button available.
Pass/Fail:		
Comments:		

6.2.5 Managing validation results from Validation Results Page

Test Case QA4SM_GUI_VRP_001 - Test Validation Results Page - Render Validation Result Page

Description:	Testing whether the 'Validation Result' page renders properly	
Test Data:	None	
Preconditions:	Run a validation with default settings, GLDAS Noah data set as the spatial and temporal reference, and name 'default_validation', wait until it finishes	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010	
Test Steps		**Expected Results**
1.	Go to the link from the email informing about the validation has been completed	Validation results displayed in three separate components: • 'Summary: default_validation', followed by a pencil button - containing all the validation settings, used data sets and action buttons (Delete, Renew, Archive, Publish, Load settings), • 'Summary statistics' (collapsed by default) - containing mean, median and standard deviation calculated for all available metrics and a button for downloading a .csv file with the summary; • 'Result files' - containing two plots, two buttons for downloading results (graphs and netCDF file), a drop-down list for choosing a metric to display (by default set to '# observations');
Pass/Fail:		

Comments:	

Test Case QA4SM_GUI_VRP_002 - Test Validation Results Page - Inspect Summary component

Description:	Testing whether the ‘Summary’ component contains all the expected information and if the action buttons behave properly
Test Data:	None
Preconditions:	Run a validation with default settings, GLDAS Noah data set as the reference, and name ‘default_validation’, wait until it finishes
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001

Test Steps		**Expected Results**
1.	Go to the link from the email informing about the validation has been completed and inspect the ‘Summary’ component	Information in the summary component body: • validation date and time (start and finish), • list of compared datasets: **1-C3S SM combined (v202012, sm)** Filters: • Variable in valid geophysical range; **0-GLDAS Noah (NOAH025 3H.2.1, SoilMoi0_10cm_inst)** Filters: • Variable in valid geophysical range; • Soil not frozen and no snow-cover; • Spatial filter bounding box: [34.0, -11.2, 71.6, 48.3] • Validation period / temporal filter: Jan. 1, 2000, midnight UTC to Dec. 31, 2017, 11:59 p.m. UTC.

		• Temporal matching window size set to 12 hours. • Validation metrics calculated from absolute values. • Triple collocation analysis was deactivated. • Bootstrapping of confidence intervals for Triple Collocation Analysis was deactivated. • Scaling method: No scaling. • Information on processing time in minutes • for 0% (0 of 21145) of the processed locations (grid points) the validation metrics could not be calculated. • calendar icon and information on the cleanup date.
2.	Click on the pencil button next to the validation name	• An input field shows up, filled with the current validation name (empty if there was no name provided); • floppy disc and ban icon buttons displayed.
3.	Click on the ban button	• Input field closed; • name not changed; • pencil button displayed.
4.	Click on the pencil button again and change the validation name to ‘test_validation’ and press the floppy disc button	• Name changed, • input field closed, • floppy disc and ban icons hidden, • pencil button displayed;
5.	Click the ‘Load Validation Settings’ button	Redirection to the ‘Validation’ page’ with settings of the current validation set;
6.	Click the ‘Publish’ button	A ‘Publish results’ dialog window shows up
7.	Close the ‘Publish’ window, click ‘Archive’ button and confirm it on the pop-up window	• Results archived, • the ‘Archive’ button changed into an ‘Un-archive’ calendar button,

		• information on the validation expiry changed into information about results being archived;
8.	Click the ‘Un-archive’ button and confirm it on the pop-up window	• Results unarchived, • the ‘Un-archive’ button changed back to the ‘Archive’ one, • information about expiry date shown again;
9.	Click the ‘Renew’ button and confirm it on the pop-up window	New validation expiry date set to be 60 days from now (if this option is chosen the same day as the validation was run, there will be no visible effect);
10.	Click the ‘Delete’ button and confirm it on the pop-up window	• Validation deleted, • user redirected to the ‘My validations’ page • no access to the results - the link from the email informing about finished validation not working anymore;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VRP_003 - Test Validation Results Page - Inspect Summary Statistics component for validation with only one data set validated

Description:	Testing whether the ‘Summary Statistics’ component renders properly and provide a .csv file
Test Data:	None
Preconditions:	Run a validation with default settings, GLDAS Noah data set as the spatial and temporal reference, and name ‘default_validation’, wait until it finishes;
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001

Test Steps		**Expected Results**

1.	Expand the ‘Summary Statistic’ component	• Short introduction,
		• table with columns:
		  • ‘Metric’,
		  • ‘Mean’,
		  • ‘Median’,
		  • ‘IQ range’
		  • ‘data set’
		  and rows referring to the number of observations and following metrics:
		  • Bias,
		  • Mean square error,
		  • Mean square error bias,
		  • Mean square error correlation,
		  • Mean square error variance,
		  • Pearson’s r,
		  • Pearson’s r p-value,
		  • Residual sum of squares,
		  • Root-mean-square deviation,
		  • Spearman’s ρ,
		  • Spearman’s ρ value,
		  • Unbiased root-mean-square deviation
		• ‘Download .csv table’ button;

2.	Click the ‘Download .csv table’ button	Dialog window for downloading .csv files opens;
3.	Save the .csv file and open it	File contains exactly the same table as the one rendered on the website.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VRP_004 - Test Validation Results Page - Inspect Summary Statistics component for validation with multiple data sets validated with triple collocation checked

Description:	Testing whether the 'Summary Statistics' component renders properly and provide a .csv file
Test Data:	None
Preconditions:	Go to the validate page, add another data set and change it to GLDAS Noah, leave ISMN data set as the spatial and temporal reference, check the triple collocation checkbox in Metrics component, leave other settings as set by default, start a validation and wait until it finishes;
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001

Test Steps		**Expected Results**

1.	Expand the 'Summary Statistic' component	• Short introduction,
		• table with columns:
		  • 'Metric',
		  • 'Mean',
		  • 'Median',
		  • 'IQ range'
		  • 'data set'
		and rows referring to the number of observations and following metrics (separately for each validated data set):
		  • Bias,
		  • Mean square error,
		  • Mean square error bias,
		  • Mean square error correlation,
		  • Mean square error variance,
		  • Pearson's r,
		  • Pearson's r p-value,
		  • Residual sum of squares,
		  • Root-mean-square deviation,

		• Spearman's ρ, • Spearman's ρ value, • TC scaling coefficient, • Unbiased root-mean-square deviation; • 'Download .csv table' button;
2.	Click the 'Download .csv table' button	Dialog window for downloading .csv files opens.
3.	Save the .csv file and open it	File contains exactly the same table as the one rendered on the website.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VRP_005 - Test Validation Results Page - Inspect Result files component for validation with only one data set validated

Description:	Testing whether the 'Result files' component contains all the produced plots and results	
Test Data:	None	
Preconditions:	Run a validation with default settings, GLDAS Noah data set as the spatial and temporal reference, and name 'default_validation', wait until it finishes;	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001	
Test Steps		**Expected Results**
1.	Inspect 'Result files' component	Component renders with: • two plots - a boxplot on the left side and a map plot on the right side, both referring to the number of observations; • a drop-down list containing names of metrics to be shown on the plots;

		• two buttons for downloading results - ‘Download graphs’ on the left side of the drop-down list and ‘Dowload NetCDF’ on the right side of the drop-down list;
2.	Expand the drop-down list and choose a metric after metric until the end of the list	With every single metric new two plots show up - a boxplot on the left and a map plot on the right - with respective metric name in their titles;
3.	Click on the boxplot	A full-size plot opens as a gallery window
4.	Close the boxplot preview and click on the map plot	A full-size plot opens as a gallery window
5.	Close the map plot window and click the ‘Download graphs button’	A dialog window for saving a graphs zip file opens; Default name to save is ‘validationId_graphs.zip
6.	Save the file and open it	The zip file contains all the files shown on the website in two formats .png and .svg; Boxplot’s file name follows the pattern ‘boxplot_metricName’; Map plot’s file name follows the pattern: ‘overview_referenceName_and_data setName_metricName’.
7.	Click the ‘Download NetCDF’ button	A dialog window for saving the result netCDF file opens; Default file name to save is ‘0-GLDAS.SoilMoi0_10cm_inst_with_1-C3S_combined.sm’;
8.	Save the netCDF file and check it’s size	The saved file should have size around 12 Mb;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VRP_006 - Test Validation Results Page - Inspect Result files component for validation with multiple data sets validated with triple collocation checked

Description:	Testing whether the ‘Result files’ component contains all the produced plots and results
Test Data:	None
Preconditions:	Go to the validate page, add another data set and change it to GLDAS Noah, leave ISMN data set as the spatial and temporal reference, check the triple collocation checkbox in Metrics component, leave other settings as set by default, start a validation and wait until it finishes;
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001

Test Steps		**Expected Results**
1.	Inspect ‘Result files’ component	Component renders with: • two plots - a boxplot on the left side and a map plot on the right side, both referring to the number of observations; • a drop-down list containing boxplot classification (note that this is related to ISMN dataset used as the spatial reference); • a drop-down list containing names of metrics to be shown on the plots; • two buttons for downloading results - ‘Download graphs’ on the left side of the drop-down list and ‘Dowload NetCDF’ on the right side of the drop-down list;
2.	Expand the boxplot classification drop-down list and sequentially select option after option until the end of the list	With every single classification option a boxplot changes.

3.	Expand the drop-down list and sequentially select metric after metric until the end of the list	With every single metric a new boxplot on the left and two map plots on the right side - with respective metric name and data set pairs in their titles; For triple collocation metrics (TC: metricName for data setName) only one map plot is generated on the right side; For TC, Pearson's r p-value and Spearman's rho p-value there is no boxplot classification drop-down list.
4.	Click on the boxplot	A full-size plot opens as a gallery window, navigation arrows display to navigate between different boxplots produced for the chosen metric.
5.	Close the boxplot preview and click on one of the map plots	A full-size plot opens as a gallery window, navigation arrows display to navigate between plots.
6.	Close the map plot window and click the 'Download graphs button'	A dialog window for saving a graphs zip file opens; Default name to save is 'validationId_graphs.zip.
7.	Save the file and open it	The zip file contains all the files shown on the website in two formats .png and .svg; Boxplot's file name follows the pattern 'boxplot_metricName' for unclassified boxplots and boxplot_metricName_classificationShortName; Map plot's file name follows the pattern: 'overview_referenceName_and_data setName_metricName'.

8.	Click the 'Download NetCDF' button	A dialog window for saving the result netCDF file opens; Default file name to save is '0-ISMN.soil_moisture_with_1-C3S_combined.sm_with_2-GLDAS.SoilMoi0_10cm_inst.nc';
9.	Save the netCDF file and check it's size	The saved file should have size around 0.5 Mb;
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VRP_007 - Test Validation Results Page - Copying validation belonging to another user

Description:	Testing whether copying validation belonging to another user works as expected	
Test Data:	None	
Preconditions:	Logged in user	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VRP_001	
Test Steps		**Expected Results**
1.	Go to the link https://test.qa4sm.eu/ui/validation-result/4625c806-35f8-40b0-85ee-c633492e1ec2	Validation results displayed in three separate components: • 'Summary: validation_for_testing_copying, followed by a question mark icon (informing that there is no possibility of changing name because the validation does not belong to the current user, when hovering over) - containing all the validation settings,

		used data sets and action buttons (Copy validation and Load settings), • ‘Summary statistics’ (collapsed by default) - containing mean, median and standard deviation calculated for all available metrics and a button for downloading a .csv file with the summary; • ‘Result files’ - containing two plots, two buttons for downloading results (graphs and netCDF file), two drop-down lists for choosing a metric to display (by default set to ‘# observations’) and boxplot classification (by default set to ‘unclassified’).
2.	Click the ‘Copy validation’ button	Pop-up window shows up informing that the validation will be copied and added to ‘my validations’ list.
3.	Click ‘Ok’ on the pop-up window	Redirection to the result page of the copied validation
4.	Inspect new result page	Validation results displayed in three separate components: • ‘Summary: Copy_of_validation_for_testing_copying followed by a pencil button - containing all the validation settings, used data sets and action buttons (Delete, Renew, Archive, Publish, Load settings) • ‘Summary statistics’ (collapsed by default) - containing mean, median and standard deviation calculated for all available metrics and a button for downloading a .csv file with the summary; • ‘Result files’ - containing two plots, two buttons for downloading results (graphs

		and netCDF file), two drop-down lists for choosing a metric to display (by default set to '# observations') and boxplot classification (by default set to 'unclassified').
Pass/Fail:		
Comments:		

6.2.6 Publishing validations and managing published results

Test Case QA4SM_GUI_PVMRP_001 - Test Validation Results Page - Test Validation Publishing

Description:	Testing whether publishing window renders properly and if publishing works as expected	
Test Data:	None	
Preconditions:	Go to the 'Validate' page and run a validation with the default settings and name 'test_validation_to_publish', wait until it finishes and open it. Go to the user's profile and fill the profile with data: First name: Sam, Last name: Smith, Organization: University, ORCID: 0000-0000-0000-0000, save data;	
Requirement(s) to be tested:	Test Case QA4SM_GUI_VP_010, Test Case QA4SM_GUI_VRP_001	
Test Steps		**Expected Results**
1.	Click on the 'Publish' button	A modal window for publishing opens with: • a short introduction saying 'Please check the metadata your results will be published with. If you want to permanently set your author details,

		you can do so on your profile page.' - with 'profile page' redirecting to user's profile; • a title - Validation of C3S SM combined v202012 vs ISMN 20210131 global • description - 'QA4SM validation of soil moisture data: C3S SM combined v202012 vs ISMN 20210131 global. URL: https://test.qa4sm.eu/ui/validation-result/{validationID}/. Produced on QA4SM (https://test.qa4sm.eu)' - where validation Id is the id of the validation being published; • keywords: soil moisture, validation, qa4sm, C3S, ISMN; • name: Smith, Sam; • affiliation: University; • orcid: 0000-0000-0000-0000; • information that the publishing result cannot be undone; • 'Cancel' and 'Publish now!' buttons, both enabled; Each of the fields is followed by a question mark icon than provides additional information when hovering over it.
2.	Remove the title	Publish button disabled, field's frame changes color to red.
3.	Press ctrl+z to retrieve the title and remove description	Publish button disabled, field's frame changes color to red.
4.	Press ctrl+z to retrieve the description and remove ale the keywords	Publish button disabled, field's frame changes color to red.
5.	Press ctrl+z to retrieve the keywords, remove the name	Publish button disabled, field's frame changes color to red.

6.	Press ctrl+z to retrieve the name and remove affiliation and orcid	Nothing happens. Publish button still active.
7.	Press ctrl+z to retrieve the affiliation and ORCID, remove qa4sm from the keywords and press ‘Publish now!’ button	‘Missing required keyword’ warning displayed below the keywords field.
8.	Press ctrl+z to retrieve the removed key word and remove four last digits of the orcid number and press publish button	‘Invalid ORCID identifier’ warning displayed below the ORCID field.
9.	Press ‘Cancel’ button	Publishing windows closes
10.	Open the publish window again and press ‘Publish now!’ button	Publishing window closes and in place of action buttons there is an information about publishing being in progress. After some time (usually a few seconds): • page refreshes, • two buttons show up - ‘Load settings’ and ‘Pin validation’, • information about validation being published added along with its DOI number and link to the ZENODO website, • pencil button in the header is replaced with a question mark icon saying (when hovering over) that changing name of a published validation is not possible.
11.	Go to ‘My validations’ page	Validation row with the published validation changed: • there is a book icon in the header saying that the validation has been published (when hovering over), • pencil button in the header is replaced with a question mark icon saying (when

		hovering over) that changing name of a published validation is not possible, • no ‘Archive’ button, • no ‘Extend Life Span’ and ‘Delete Validation Run’ options when expanding double-arrow drop-down list.
12.	Go to ‘Published validations’ page	The validation added to the published validations list.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_PVMRP_002 - Test Published Validations Page - Render Published Validations Page

Description:	Testing whether the ‘Published validations’ page renders properly	
Test Data:	None	
Preconditions:	A validation created and published during Validation Publishing test	
Requirement(s) to be tested:	Test Case QA4SM_GUI_PVMRP_001	
Test Steps		**Expected Results**
1.	Go to ‘Published validations’ page (test.qa4sm.eu/ui/published-validations)	Page renders with: • a title - ‘Published validations’, • short introduction containing links Zenodo (https://zenodo.org/) and DOI (https://www.doi.org/) services, • sorting form, labeled ‘Sort by’ is rendered with two drop-down lists - one for the sorting feature (by default set to ‘Date’) and the second one for the order (by default set to ‘descending’),

		• validation results rows rendered for each validation that has been published; each row contains:
		  • a header with a name on the left side and DOI number (being a link to the results published on ZENODO) on the right side,
		  • a body containing information on data sets used for validations, creation date and action buttons;
		Remark: If more than 10 validations have been run, pagination is added and displayed below validation rows;

Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_PVMRP_003 - Test Published Validations Page - Inspect Validation Results Row

Description:	Testing whether Validation Results Row renders properly and if the action buttons works as they expected	
Test Data:	None	
Preconditions:	A validation created and published during Validation Publishing test	
Requirement(s) to be tested:	Test Case QA4SM_GUI_PVMRP_001, Test Case QA4SM_GUI_PVMRP_002	
Test Steps		**Expected Results**
1.	Go to ‘Published validations’ page (test.qa4sm.eu/ui/published-validations)	Validation row with the newest published validation rendered at the top; The row’s header contains: • validation name,

		• DOI assigned during publishing, being a link to the results published on Zenodo (on the test instance the link might not work properly, as publishing here is done through Zenodo Sandbox)
		The row's body contains:
		• Data:
		'C3S, v202012, sm',
		ISMN, 20210131 global, soil_moisture (spatial, temporal reference)
		• Created: date of creation;
		• action buttons:
		  • 'View results' folder button,
		  • 'Load Validation Settings' round arrow button,
		  • 'Pin validation' plus button.

2.	Click on the folder button	Redirection to the page test.qa4sm.eu/ui/validation-result/validation_id (where validation_id is a random universal unique identifier);
3.	Go back to the published validations page and click the Load validation settings button	Redirection to the 'Validation' page' with settings of the current validation set;
4.	Click the 'Pin validation' button and choose 'ok' on the pop-up window	'Pin validation' plus button changes into 'Un-pin' X button
5.	Go to 'My validations' page	Pinned validations list added, with rows referring to each pinned validation and containing a validation name and four action buttons: • folder button for opening results, • download button for downloading graphs, • download button for downloading netCDF result file,

		• X button for unpinning a validation;
6.	Get back to the ‘Published validations’ page and click the ‘Un-pin’ button and choose ‘ok’ on the pop-up window	‘Un-pin validation’ X button changes into ‘Pin’ plus button, a pop-up window shows up informing that the validation has been removed from the list of pinned validations.
7.	Go to ‘My validations’ page	No ‘Pinned validations’ list.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_PVMRP_004 - Test Pinned Validations List

Description:	Testing whether the ‘Pinned validations’ list renders properly and if the action buttons behave as expected	
Test Data:	None	
Preconditions:	Go to ‘Published validations’ page (test.qa4sm.eu/ui/published-validations) and click the ‘Pin validation’ button.	
Requirement(s) to be tested:	Test Case QA4SM_GUI_PVMRP_001, Test Case QA4SM_GUI_PVMRP_002	
Test Steps		**Expected Results**
1.	Go to the ‘My validations’ page and click the folder ‘View results’ button	Redirection to the page test.qa4sm.eu/ui/validation-result/validation_id (where validation_id is a random universal unique identifier);
2.	Go back to the ‘My validations’ page and click the ‘Download graphs .zip’ button	A dialog window for downloading a .zip file opened;
3.	Cancel downloading, click the ‘Download NetCDF File’ button	A dialog window for downloading a result file opened;

4.	Cancel downloading and click the 'Un-pin validation' button and confirm on the pop-up window.	The 'Pinned validations' list vanishes.
Pass/Fail:		
Comments:		

6.2.7 Validation comparison module

Test Case QA4SM_GUI_VCM_001 - Test Render Validation Comparison Module

Description:	Testing if comparison module renders properly	
Test Data:	None	
Preconditions:	Logged in user	
Requirement(s) to be tested:		
Test Steps		**Expected Results**
1.	Go to test.qa4sm.eu/ui/comparison	A Validation Comparison module rendered with: • Dataset configuration tab; • Validations selection tab; • Spatial extent tab; • 'Compare' button. All tabs have their title on the left side of the header and a question mark icon on the right side, which displays help text when hovering over. The Spatial extent tab has a collapse button.
2.	Inspect 'Dataset configuration' tab	The tab consists of two components:

		• Spatial Reference selection with 'Dataset', 'Version' and 'Variable' drop-down lists. By default, fields are set to 'ISMN', '20210131 global' and 'soil_moisture' respectively. • Non-reference datasets section with a checkbox labeled 'Multiple non-reference datasets' and a question mark icon, providing help text when hovering over. The checkbox is unchekced by default.
3.	Inspect 'Validations selection' tab	The tab consists of one component labeled 'Validations available for comparison', containing a drop-down list and an 'Add validation' button. If there are no validations available with the chosen spatial reference dataset, then the 'Add validation' button is disabled.
4.	Inspect 'Spatial extent' tab	The tab contains a disabled check box labeled 'Include all points from the selected validations and a question mark icon providing help text when hovering over.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VCM_002 - Test Validation Comparison Module

Description:	Testing if comparison module behaves as expected
Test Data:	None
Preconditions:	Logged in user,

	Existing at least two validations with the same spatial reference dataset, but with common spatial subsetting and one validation with two non-reference datasets.	
Requirement(s) to be tested:	QA4SM_GUI_VCM_001	
Test Steps		**Expected Results**
1.	Render the 'Compare validations' module and press 'Compare' button	A warning pops up informing that there were no validations chosen for comparison.
2.	In the 'Dataset configuration' section choose the dataset and its version which you used as the spatial reference in at least two validations	The list of validations available for comparison updates.
3.	In the 'Validations selection' section select two validations with common spatial range you want to compare from the drop-down list, every time confirm your choice with the 'Add validation' button	Two red buttons added below the drop-down list. Each button contains a trash bin icon and a label: 'Remove: Validation date: ..., Non-reference-dataset: ...'; 'Add validation' button disabled; The checkbox in the 'Spatial extent' section enabled.
3.	Remove one of the added validations	'Add validation' button enabled again.
4.	Retrieve the removed validation, check the 'Spatial extent' checkbox and click the 'Compare' button and wait until results are generated	'Validation comparison results' section shows up, consisting of: • Comparison summary tab, • Selected comparison extent tab, • Comparison statistics tab, • Comparison plots tab. Comparison plots tab renders unfolded. Other tabs render collapsed. All tabs have: • their titles in the middle of their headers,

		• a question mark icon that provides help text when hovering over, • collapse buttons.
5.	Remove one validation from the list	'Validation comparison results' section vanishes. The 'Spatial extent' checkbox gets unchecked and disabled.
6.	Check the 'Multiple non-reference datasets'	All the chosen validations vanish and the list of validations available for comparison updates. If there is no validation with the chosen spatial reference dataset that contains two non-reference datasets, the list is empty. Go to point 7. If there exists, for the chosen spatial reference dataset, a validation with two non-reference datasets, go to point 8.
7.	Choose the spatial reference dataset for which there exists a validation with two non-reference datasets	The list of validations available for comparison updates.
8.	Choose on validation from the list and confirm it with the 'Add validation' button.	A red button added below the drop-down list. 'Add validation' button disabled;
9.	Click the 'Compare' button	'Validation comparison results' section shows up, consisting of the same sections as in point 4.
10.	Remove the chosen validation	The 'Validation comparison results' section vanishes.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_VCM_003 - Test Validation Comparison Results Section

Description:	Testing if comparison module results part renders and behaves as expected	
Test Data:	None	
Preconditions:	Logged in user, Existing at least two validations with the same spatial reference dataset, but with common spatial subsetting (not necessarily the same).	
Requirement(s) to be tested:	QA4SM_GUI_VCM_001, QA4SM_GUI_VCM_002	
Test Steps		**Expected Results**
1.	Choose the spatial reference dataset, for which there exist at least two validations with one non-reference data set, from the 'Spatial reference selection' drop down window; Choose two validations for comparison from the 'Validations available for comparison' list; Click the 'Compare' button	'Validation comparison results' section shows up, consisting of: • Comparison summary tab, • Selected comparison extent tab, • Comparison statistics tab, • Comparison plots tab.
2.	Unfold and inspect 'Comparison summary' tab	The tab contains two columns with summarized information about each validation used for comparison. The summary consists of: • validation date and time (start and finish), • list of compared data sets, • spatial filter bounding box, • validation period / temporal filter, • information about validation metrics,

		• information about triple collocation analysis, • information about bootstrapping of confidence intervals for Triple Collocation Analysis, • information about scaling reference, • information about Scaling method.
3.	Unfold and inspect 'Selected comparison extent' tab	The tab contains: • information that all the points were taken into account during the comparison process, • a plot showing spatial extent of the comparison with bounding box referring to each validation (if chosen validations cover exactly the same region, there will be only one bounding box visible), • a button labeled 'Download image'.
4.	Click the spatial extent plot	A full-size plot opens as a gallery window.
5.	Close the gallery and click the 'Download image' button	A dialog window for saving the picture opens, with default name 'spatial_extent' and .png format.
6.	Close the dialog window and unfold and inspect 'Comparison statistics' tab	The tab contains • a table with four columns containing: metric name, median values for each metric for each validation, differences between median values coming from two validations; • a button labeled 'Download .csv table'.
7.	Click the 'Download .csv table' button	A dialog window for saving the table in .csv format opens, with default name 'Comparison_summary'.
8.	Save the file and open it	The file contains exactly the same table as the one displayed on the page.
9.	Inspect 'Comparison plots' tab	The tab contains:

		• a boxplot depicting a chosen metric for each validation and the difference between them, • a map of the common spatial subsetting, depicting difference of the chosen metric, • two buttons labeled 'Download image' located under each plot, • a drop-down list with available metrics.
10.	Click on the boxplot	A full-size plot opens as a gallery window
11.	Close the boxplot preview and click on the map	A full-size plot opens as a gallery window
12.	Close the map plot window and click any of the 'Download image' button, close the dialog window and click the second one	Every time a dialog window for saving a plot opens, with a default name 'plot0_metric_name' for the boxplot and 'plot1_metric_name' for the map.
13.	Choose another metric from the metric drop-down list	Plots update according to the chosen metric.
Pass/Fail:		
Comments:		

6.2.8 User datasets uploading form and list of uploaded files

Test Case QA4SM_GUI_UDUF_001 - Test Uploading User Data - Uploading File

Description:	Testing if the file is uploaded along with its metadata.
Test Data:	Test file, Wrong test file
Preconditions:	Logged in user, Existing netCDF file prepared according to our guidelines

Requirement(s) to be tested:	

Test Steps		**Expected Results**
1.	Go to ‘My datasets’ page https://test.qa4sm.eu/ui/my-datasets	The page contains: • A title: ‘My datasets’; • Uploading section with two buttons ‘Select file’ and ‘Upload file’ and information that no file has been chosen yet; • List of uploaded files or information that no files have been uploaded yet, if that is the case.
2.	Click the ‘Select file’ button	‘Upload your own data’ window opens, with a link to the file standard guidelines on the help page and a button labeled ‘Add file’.
3.	Click the ‘Add file’ button	Window for choosing a file opens. Only zip and netCDF files are visible for upload.

4.	Choose a proper netCDF file to upload and close the window	• File name displayed;
		• ‘Add file’ button label changed into ‘Change file’;
		• Metadata form displayed, with four fields labeled:
		  ○ Dataset name,
		  ○ Dataset display name (optional),
		  ○ Version name,
		  ○ Version display name (optional),
		and question mark icons on the right side of each field, showing guidelines for each field, when hovering over them;
		• ‘Save’ button displayed, but deactivated

5.	Provide: • ‘test_dataset’ as dataset name, • ‘Test dataset’ as dataset display name, • ‘test_version’ as version name, • ‘Test version’ as version display name	‘Save button’ gets activated.
6.	Click the ‘Save button’	Uploading file window closes.
7.	Click the ‘Select file’ button again	Uploading file window opens, filled with the data provided in the previous steps.
8.	Close the window and click the ‘Upload file’ button	Page gets blocked, a spinner shows up, information about uploading file and its progress is displayed.
9.	Wait until the file is uploaded and the list of uploaded file gets refreshed	A new tab with information on the uploaded file added.
10.	Click the ‘Select file’ button again and choose a netCDF file that do not fulfill guidelines (Wrong test file), provide dataset name and version name and submit the file	Error message shows up ‘Provided file does not fulfill requirements. Provided metadata could not be saved. Please try again or contact our team.’
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_UDUF_002 Test Uploading User Data - Uploaded File Panel

Description:	Verifying if a panel showing information of an uploaded file displays properly and if all the anticipated actions can be performed on the file
Test Data:	Test file
Preconditions:	Logged in user,

	Uploaded netCDF file	
Requirement(s) to be tested:	QA4SM_GUI_UDUF_001	
Test Steps		**Expected Results**
1.	Go to 'My datasets' page https://test.qa4sm.eu/ui/my-datasets and inspect the list of uploaded files	Above the first panel there is folded information about user file management, with 'Read more' link. There are as many panels as many files have been uploaded so far.
2.	Click 'Read more' link	Full information on user file management displayed, with 'Read less' link displayed.
3.	Click 'Read less' link	Information folded again.
4.	Inspect user data panel	The user data panel contains: • A header with the file size on the left side and the upload date on the right side; • A body with information on: ○ dataset – its name, version (from the metadata form) and variable (as derived from the file), ○ coordinates names derived from the file, ○ action buttons.
5.	Hover over dataset name, version name, variable and coordinates names	Cursor appearance changes and tooltips show up explaining possible name changes.
6.	Click on the dataset name	Text field opens with the current name in it, save and cancel buttons show up.
7.	Click the cancel (ban icon) button	Text field closes, name does not change, buttons vanish.
8.	Click on the dataset name one more time, change the name to 'My	Text field closes, name changes, buttons vanish, a green notification shows up in the

	dataset' and click the save (floppy disc) button	upper right corner saying that the metadata has been updated.
9.	Click on the version name	Text field opens with the current name in it, save and cancel buttons show up.
10.	Click the cancel (ban icon) button	Text field closes, name does not change, buttons vanish.
11.	Click on the version name one more time, change the name to 'My version' and click the save (floppy disc) button	Text field closes, name changes, buttons vanish, a green notification shows up in the upper right corner saying that the metadata has been updated.
12.	Click on the variable, latitude, longitude and time names	Dropdown lists and cancel buttons show up.
13.	Unfold and inspect each dropdown list (do not click on any names)	All dropdown lists contain the same list of variable names, those are variable names retrieved from the uploaded file.
14.	Click the cancel buttons next to the latitude, longitude and time dropdown lists	Latitude, longitude and time dropdown lists and cancel buttons vanish
15.	Unfold the variable dropdown list and choose a different name	Name changes, the list and cancel button vanish, a green notification shows up in the upper right corner saying that the metadata has been updated.
16.	Click the 'Remove dataset' button	A pop-up window shows up requesting about removal confirmation
17.	Click yes on the pop-up window	The dataset panel is removed from the list.
Pass/Fail:		
Comments:		

Test Case QA4SM_GUI_UDUF_003 - Test Uploading User Data - Running A Validation With User Data

Description:	Verifying if the validation can be run with the uploaded data

Test Data:	Test file
Preconditions:	Logged in user
Requirement(s) to be tested:	QA4SM_GUI_UDUF_001, QA4SM_GUI_VRP_001, QA4SM_GUI_MVP_002

Test Steps		**Expected Results**
1.	Go to 'My datasets' page https://test.qa4sm.eu/ui/my-datasets and upload a netCDF file, providing: • 'test_dataset' as dataset name, • 'Test dataset' as dataset display name, • 'test_version' as version name, • 'Test version' as version display name	A new tab with information on the uploaded file added.
2.	Verify if the names of variable and coordinates are the one used in the file	If the file indicated as the test data in this test case is used, the names should be: • soil_moisture (soil_moisture) for Variable, • lat for Latitude, • lon for Longitude, • Time for Time
3.	Go to 'validate' page https://test.qa4sm.eu/ui/validate, unfold dataset dropdown list and scroll to the top of the list	'Test dataset' name is on the top of the list
4.	Choose 'Test dataset' from the dropdown list	'Test version' set as version and 'soil_moisture' set as variable.
5.	Leave other settings as they are and start a validation by clicking the 'Validate' button. Go to 'My validations' page	Validation results displayed, as described in the test case QA4SM_GUI_VRP_001.

	https://test.qa4sm.eu/ui/my-validations, wait until the validation finishes and open it.	
6.	Go to 'My datasets' page and find the 'Test dataset' panel	The 'Remove dataset' button belonging to the dataset is deactivated.
7.	Go to 'My validations' page, remove the validation with the uploaded dataset and go back to 'My datasets' page (Removing validation is described in e.g. test case QA4SM_GUI_MVP_002)	The 'Remove dataset' button belonging to the dataset is active again.
8.	Remove the dataset, go to the 'Validate' page and unfold the dropdown list with datasets	'Test dataset' is no longer available on the list.
Pass/Fail:		
Comments:		

7 Verification of outputs and results

Different to the more technical test cases in the previous section, this section is geared towards more holistic activities to validate the QA4SM service.

Having provided a first verification of the QA4SM service in the first version of the QA4SM Evolution Verification Report (DT4-3, Version 1.1), the Test Plan (and relative Verification Report) for Release 2 of QA4SM focuses on the main back-end[3] improvements that have been made ever since. These consist of the following:

- Integration of SMOS Level 2 (hereafter SMOSL2) in the service
- Integration of SMAP Level 2 (hereafter SMAPL2) in the service
- Handling and communication of (known) processing errors
- Integration of Fiducial Reference Measurements flag (hereafter FRM-flag) from ISMN in QA4SM

7.1 Verification of SMOS Level 2 integration

SMOSL2v700 has been integrated in the QA4SM service after downloading from the official data portal[4]. The original file system, provided in daily netCDF files from July 2010 to January 2022, was first converted to the typical QA4SM file structure, where a regular cell system is used to sub-divide the original ISEA4h9 grid into manageable chunks[5], further converted to the Orthogonal Multidimensional Array Representation[6]. This makes the accessing and reading of the files more time-efficient during the validation process. The original data and the ISEA4h9 grid sampling of the SMOSL2 data was preserved in the process (**Error! Reference source not found.**). Based on recommendations from the CESBIO team (see SMOSL2 validation guidelines in section 0), the following fields from the original data set were included in the reprocessed files:

- Soil_Moisture: An estimate of SSM obtained through a successful retrieval of this parameter
- Soil_Moisture_DQX: The RSTD of Soil_Moisture corresponding to its successful retrieval
- Chi_2_P: Goodness of fit indicator
- RFI_Prob: Probability of RFI contamination over a 12-day window
- N_RFI_X, N_RFI_Y: Counts the number of daily RFI per polarisation (X,Y)
- M_AVA0: Initial number of BT available measurements in L1c
- Science_Flags: Scene and acquisition quality flags

[3] i.e., related to the validation algorithm or the input data, and not to the GUI
[4] https://earth.esa.int/eogateway/catalog/smos-science-products, accessed on 12th July, 2022
[5] https://github.com/TUW-GEO/pygeogrids
[6] https://cfconventions.org/cf-conventions/v1.6.0/cfconventions.html#_orthogonal_multidimensional_array_representation

- Days, Seconds: acquisition time information

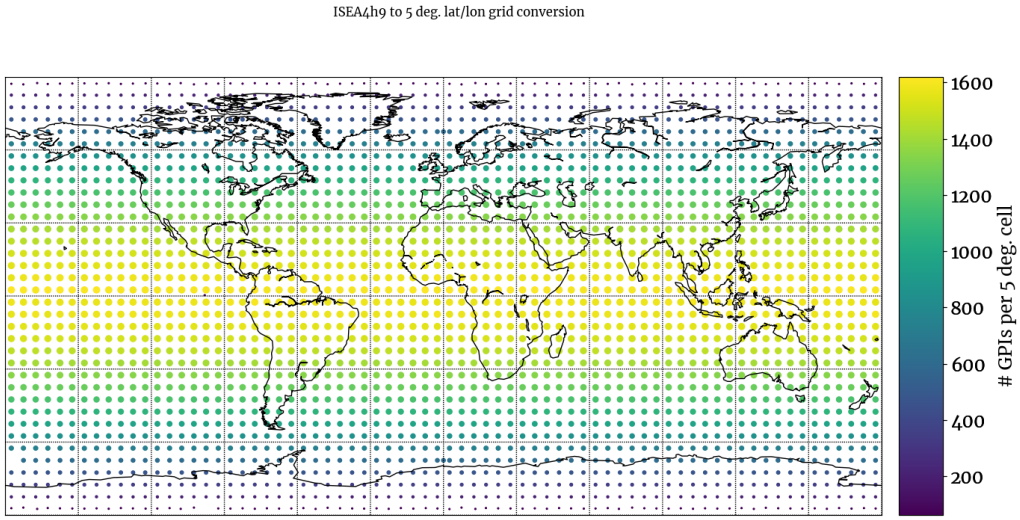

Figure 1: Heat map showing the number of ISEA4h9 gpis included in the cell grid chunks.

Based on the data set fields, the following flags are included in the service:

Flag	**Event to flag**	**Status**	**Relevant field**
Variable in valid geophysical range	Out of range retrieved SM	Mandatory	Soil_Moisture
High confidence filtering of RFI	Single- and multi-orbit RFI probability > 0.1	Optional	1. Rfi_Prob 2. (N_RFI_X + N_RFI_Y)/M_AVA0
Good confidence filtering of RFI	Single- and multi-orbit RFI probability > 0.2	Mandatory	1. Rfi_Prob 2. (N_RFI_X + N_RFI_Y)/M_AVA0
Exclude strong topography in scene	Strong topography	Mandatory	Science_flags (FL_Topo_S= 0)
Exclude presence of ice in scene	Ice in scene	Optional	Science_flags (FL_Ice=0)
Exclude presence of dry/wet/mixed snow in scene	Snow in scene	Optional	Science_flags (FL_Frost=0, FL_Snow_Mix=0, FL_Snow_Wet=0, FL_Snow_Dry=0)

Exclude open water in scene	Open water	Optional	Science_flags (FL_OW=0)
Set quality retrieval threshold	Retrieval judged poor when goodness of fit < 0.05	Recommended	Chi_2_P

In addition, the observation timestamp is given by the combination of the two fields: 'Days' (days since 1st January 2000) + Seconds (Seconds since start of acquisition day).

7.1.1 Test Cases

7.1.1.1 Test SMOSL2-1: comparison with independent validation run

A comparison of the validation results obtained with QA4SM and independently will be made. The independent validation will be run by CESBIO (e.g., Gibon et al., in review) using ISMN as spatial reference data set. Identical settings will be replicated in QA4SM where possible. In case the exact settings cannot be replicated, they will be discussed in the exercise and either integrated in QA4SM or excluded based on the outlined reasoning. The same version of the data sets (e.g., ISMN versions and reprocessing might have an impact) will be exchanged between the groups to ensure consistency. Both are expected to yield the same sets of scores with only minimal deviation (ideally, up to machine precision, and at least below the significant figure).

In order to test the User Upload feature, a second, down-scaled cross-validation test will be run using a smaller subset of in situ data and over a shorter validation period. The data set will be prepared, filtered and validated by the CESBIO team and shared with the QA4SM team. It will then be validated against the integrated SMOSL2 data set and with the independent results. The same expectations in terms of agreement precision as highlighted above apply to this case study.

7.1.1.2 Test SMOSL2-2.1: test impact of flags

The correct flagging integration in QA4SM for SMOSL2 is ensured through Continuous Integration (CI) tests[7]. However, the impact of the various flags in terms of data availability and validation outputs can be verified with a global validation against a distributed data set – for instance, ERA5. The impact of the high and good confidence filtering of RFI, as well as the retrieval quality indicator Chi_2_P will be tested. It is expected that relaxing the filtering will impact the validation scores negatively, while increasing the validation sample. When relaxing

[7] here: https://github.com/awst-austria/qa4sm/blob/frm4sm-release-2/validator/tests/test_filtering.py

the filtering, geographical patterns should emerge in the (degradation of the) validation scores, which can be explained by sources of error, e.g. RFI hotspots.

The validations will be run against ERA5 with spatial extent: lower left (lat, lon) [34.0, -11.2]; upper right (lat, lon) [71.6, 48.3]. SMOSL2 will be selected as spatial reference to evaluate the spatial impact of the masking. The following filter settings will be applied:

Test case	**Flag(s) active**
Frozen ground/snow conditions	• Variable in valid geophysical range • Good confidence filtering of RFI • Exclude strong topography in scene • Exclude presence of frozen ground in scene • Exclude presence of ice in scene • Exclude presence of dry/wet/mixed snow in scene • Exclude open water in scene
High confidence RFI filtering (> 0.1 [-])	• Variable in valid geophysical range • High confidence filtering of RFI • Good confidence filtering of RFI • Exclude strong topography in scene • Exclude open water in scene
Retrieval low quality threshold (>0.05)	• Variable in valid geophysical range • Good confidence filtering of RFI • Exclude strong topography in scene • Exclude open water in scene • Set retrieval quality threshold
Retrieval medium quality threshold (>0.1)	• Variable in valid geophysical range • Good confidence filtering of RFI • Exclude strong topography in scene • Exclude open water in scene • Set retrieval quality threshold
Retrieval high quality threshold (>0.3)	• Variable in valid geophysical range • Good confidence filtering of RFI • Exclude strong topography in scene • Exclude open water in scene • Set retrieval quality threshold

7.1.1.3 Test SMOSL2-2.2: comparison with SMOS L3

SMOS L3 was integrated in the service at QA4SM release 1. Although the data set differs considerably from SMOSL2 - mostly in terms of spatial sampling and temporal observation bidding, but also provided flags – an inter-comparison of the two data sets will be performed against in situ and distributed networks. Such analysis will increase confidence in the correct integration of both data sets, as well as respond to an interesting scientific question on performance loss from L2 to L3 format. It is expected that the two data sets will perform similarly at the global level, with reasonable geographic patterns that can be explained through our understanding of the differences in the two products. The specific configuration used for the validation is detailed below (**Error! Reference source not found.**). SMOSL2 is c hosen as temporal reference since it corresponds to the exact acquisition time of the satellite. A window of 12 hours around each observation for the temporal matching should provide a reasonable compromise between observation consistency between the products and validation sample size. The flags are chosen to be consistent between the two SMOS-derived products; the largest inconsistency is that a retrieval quality threshold is applied to the SMOSL2 data only. However, note that, due to the collocation routine, the “strictest” flagging settings will apply, since a collocated time stamp to be used in the validation will always include an observation from all three data sets.

	SMOSL2	**SMOSL3**	**ERA5**
version	v700	339 Descending	v20190613
spatial reference			X
temporal reference	X	+- 6 hours	+- 6 hours
Selected flags	Variable in valid geophysical range Good confidence filtering of RFI Exclude strong topography in scene Exclude presence of frozen ground in scene Exclude presence of ice in scene	Variable in valid geophysical range Exclude strong topography Exclude ice in scene Exclude frozen soil and snow conditions Exclude surface waterRFI probability threshold set to 0.2 [-]	variable in valid geophysical range soil not frozen

	Exclude presence of dry/wet/mixed snow in scene Exclude open water in scene Retrieval quality threshold set to 0.05 [-]		
val. period	01-07-2010 to 31-03-2019		
spatial extent	Lower left (lat, lon): 24.27°; -125.7° Upper right (lat, lon): 49.264°; -66.778°		
Scaling	No scaling		
Other	Validation of bulk signal		

7.1.2 Methods of the comparison

The validation settings will be replicated through the use of the QA4SM interface as configured in the latest release at the time of writing of the validation report. The comparison of the independent and QA4SM results will be carried out on the basis of the available outputs - in the form of visual interpretation of the validation plots and additionally through analysis of the results netCDF file. The following aspects will be considered:

Agreement of the results. The distance between the validation scores of the independent source and the QA4SM validation will be assessed considering both the aggregated result (i.e. the median score of all the considered validation points) and the spatial distribution of the results. Where possible, the differences will be explained by taking into account possible mismatches in the origin of the data used, the strictness of data filtering and pre-treatment and the validation method employed.

SMOSL2 validation guidelines. Validation methods specifically for SMOSL2 exist in technical reports, i.e. the SMOS 3rd Mission Reprocessing Campaign Level 2 SM v700 Overall Qualification document (SO-TN-CB-GS-0095, Issue 2.a.). Such guidelines will be taken into account and used in the verification exercise; where deviating from the existing best practices documents, on which QA4SM is founded, they will be discussed.

Caveats. All verification exercises will be run using the validation parameters available through the QA4SM platform, including the modifications made for Release 2. The same settings used in the verification exercise (or modified as a result) will be available in the public service

instance after approval of the release. This leaves limited flexibility for integration of methodological changes, which regardless need to comply with the validation best practices.

7.2 Verification of SMAP L2 data integration

The Soil Moisture Active Passive (SMAP) Level 2 product[8] at 36 km sampling (EASE grid) was integrated in the QA4Sm platform during the Release 2 development phase, to complement the already integrated SMAP L3 data set. For this data set, reprocessing as done for SMOSL2 (Section 7.1) was performed. Setting up the flagging parameters was considerably more straightforward as the SMAPL2 product is provided with only "good" observations available. The acquisition time fields provided with the official products were used to obtain the correct measurement time.

7.2.1 Test SMAPL2-1

The implementation of SMAPL2 will be evaluated through a qualitative comparison against selected literature sources. The following sources are selected based on the current availability of (reference) data in the QA4SM service:

- Chen, F., Crow, W. T., Bindlish, R., Colliander, A., Burgin, M. S., Asanuma, J., & Aida, K. (2018). Global-scale evaluation of SMAP, SMOS and ASCAT soil moisture products using triple collocation. *Remote Sensing of Environment*, *214*, 1-13.
- Zhang, R., Kim, S., & Sharma, A. (2019). A comprehensive validation of the SMAP Enhanced Level-3 Soil Moisture product using ground measurements over varied climates and landscapes. *Remote sensing of environment*, *223*, 82-94.

7.3 Verification of error handling and logging in QA4SM

As any other software, QA4SM is subject to errors that may come (for instance, but not limited to) from the incorrect coding implementation of a certain feature, issues in the input data structure or processing or software design issues. For our purpose, the software errors of QA4SM can be differentiated between 'known' and 'unknown' errors. The latter are related mostly to errors of the developers and generally cause an unforeseen malfunctioning of the software. For this reason, they are quite obvious to spot and, while it is not always easy to pinpoint their cause, it is generally immediate to know whether they have been fixed. Once they are caught and fixed, CI test are created to check that future changes in the code will not cause the same condition (see Section 5). Due to their unpredictable nature, they cannot be caught in advance, and QA4SM relies on user feedback to find and fix these bugs - although most times this happens already in development and deployment. 'known' errors, instead, happen when one of the processes that occur during the validation (e.g., data collocation, rescaling, metric calculation, ...) fails due foreseen data issues. These are mostly related to the

[8] https://nsidc.org/data/spl2smp/versions/8

availability of data which, however, could be restrained by different parameters, such as the temporal matching window (too narrow), the chosen time frame (only few data points included), validation area (e.g. open water and topography is permanently masked in a few data sets), metric calculation convergence (e.g. correlation of constants) or the back-end threshold for the minimum number of data points needed to compute a metric. Figure 2 schematizes the generic handling of these errors in the validation process.

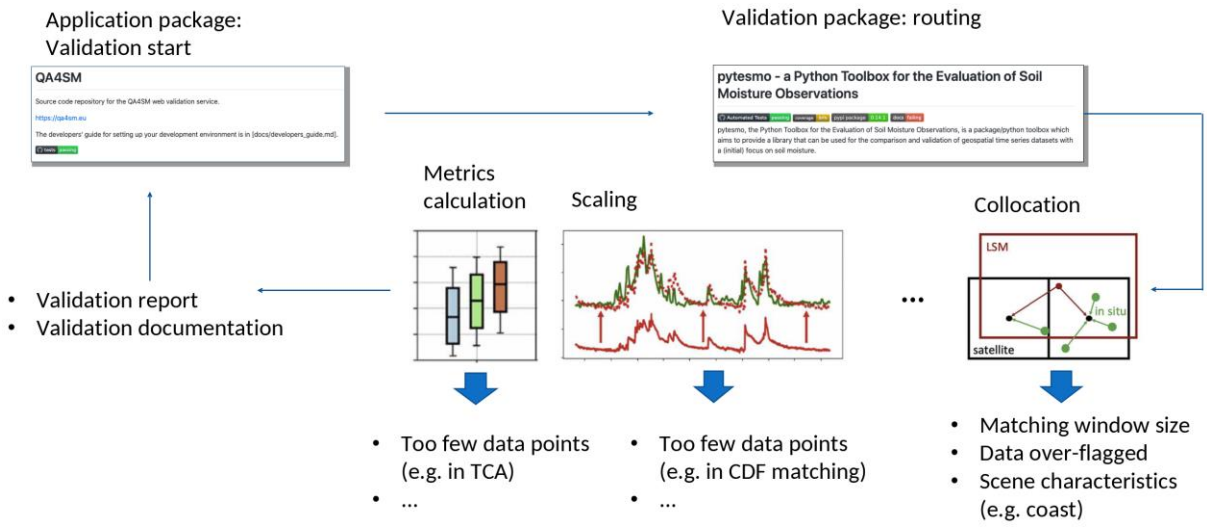

Figure 2: Diagram of the module-based handling of 'known' errors in QA4SM

At QA4SM Release 2, the error handling and communication will be updated to be more transparent to the user. The errors will be linked to the module they originate from, and an automatically generated explanation will be provided.

The verification of the proper implementation of the error handling will be split in 2 parts: Unit tests that verify that the validation backend returns the correct error codes will be implemented in the pytesmo library (See Section 5). Tests that verify that these return codes are correctly logged and displayed will be done in QA4SM.

7.3.1 Pytesmo unit tests for error handling

The upcoming version of pytesmo will introduce 9 return codes that are returned together with the validation results for each compared time series. These are passed as integer values, but are also assigned names in the pytesmo error handling module, which should be used in any derived code:

- OK (0): Return code for successful validation
- INSUFFICIENT_DATA (1): If the metrics calculation is not performed due to insufficient data
- METRICS_CALCULATION_FAILED (2): If the metrics calculation failed for other reasons
- TEMPORAL_MATCHING_FAILED (3): If the temporal matching failed due to errors in the code.

- NO_TEMP_MATCHED_DATA (4): If the temporal matching did not return any data, e.g. because of insufficient data for temporal matching.
- SCALING_FAILED (5): If the scaling failed, e.g. due to insufficient data.
- VALIDATION_FAILED (6): If the validation failed due to other reasons not yet foreseen.
- NO_GPI_DATA (7): If there is no data to compare for a given GPI.
- DATA_MANAGER_FAILED (8): If the call to the data manager to get the data failed, e.g. due to implementation issues or corrupted files.
- UNCAUGHT (-1): The default value assigned in the initialization of the metric results. This should in any case be overwritten by one of the previous values. The presence of this code in the result indicates an error in the error handling code.

The codes VALIDATION_FAILED and UNCAUGHT are intended to capture behavior which is currently not foreseen and should help the developers to identify and fix program malfunctions. These therefore cannot be tested. The other codes are tested as follows:

- OK: By asserting that the status attribute in the results of a successful validation unit test is set correctly.
- INSUFFICIENT_DATA: By running a validation with time series of only 5 samples and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.
- TEMPORAL_MATCHING_FAILED: By running a validation with a custom temporal matcher that raises an exception and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.
- METRICS_CALCULATION_FAILED: By running a validation with a custom metrics calculator that raises an exception and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.
- NO_TEMP_MATCHED_DATA: By adding an empty dataset in a validation of more than 2 datasets. The joint temporal matching of all datasets will therefore return an empty data frame and trigger the NoTempMatchedDataError. The proper handling will be ensured by asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.
- SCALING_FAILED: By running a validation with CDF matching with time series of only 5 samples and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.
- NO_GPI_DATA: By running a validation with 2 datasets of which one does not have any data, and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.kj
- DATA_MANAGER_FAILED: By running a validation with a custom data manager that raises an exception and asserting that (1) all metrics are set to NaN and (2) the status attribute is set correctly.

7.3.2 Verification of QA4SM error handling

The pytesmo unit tests already verify that the error codes are returned in the correct way. The QA4SM tests only need to verify that the return codes are properly handled by QA4SM. This includes

- Properly inferring the number of failed GPI validations to display in the validation summary.
- Inclusion of map plots for error codes so that users can visually investigate at which locations validations failed, and for which reasons.

To tests these features, two testcases will be set up:

- A validation without scaling with only a short time window will be run, in order to trigger the INSUFFICIENT_DATA return code of pytesmo. As a result, 100% of the validations should fail, and the map of return codes should show values of 1 at the locations of the spatial reference.
- A validation with a longer time window which should run successfully. The map of return codes in this case should show values of 0 at the locations of the spatial reference.

7.4 Verification of Fiducial Reference Measurements flag integration

The FRM-flag developed in the course of the project has been integrated in QA4SM[9] and can be applied to the ISMN reference data set (only on ISMN version v202301, which will be included as part of release 2) to use only a subset that is most representative of the surface soil moisture state as observed by the satellite. The full technical description of the flag generation, its methodology and integration in the ISMN database will be described in the "FRM Protocols and Procedures for space borne microwave radiometer retrieved soil moisture products" (FPP_SM). The flag is integrated in QA4SM as a multiple choice between:

- FRM-flag not active. This includes:
    - Unknown: assigned to all sensors for which no errors were assessed (mostly for sensors in layers below 10 cm depth)
    - Undeducible: errors estimates were computed but the FRM-flag could not be calculated for the specific ISMN subset due to lack of data or was not considered trustworthy due to large spread in the confidence intervals of the Triple Collocation (TC) estimate.
    - Not representative: TC estimate < 0 dB
- FRM-flag 'Representative': 0 < TC estimate < 3 dB

[9]here: https://github.com/awst-austria/qa4sm-preprocessing/blob/23d4dc088f7508a445f1b78dcd93a6eedc8580ff/src/qa4sm_preprocessing/ismn_frm/collect.py#L25dont dont

- FRM-flag ‘Very representative’: TC estimate > 3dB

This verification activity will assess the correct filtering of ISMN based on the above described thresholds. This includes a check for completeness in the output file (in case that the FRM flag filter is active, the results should ONLY include ISMN data flagged as “very representative”, otherwise all of the above described flags will be included in the results, and comparison box plots will be created accordingly. We also assess the impact of the FRM-flag on the validation outcome. This will be tested for several data sets that are provided at different resolutions, to verify the impact of the FRM-representativeness at different scales. It is expected that activating the flag will produce an improvement in the validation scores, with the improvement margin becoming narrower as the resolution of the validated data set moves from the FRM-flag resolution of 0.25°.

8 References

Cosh, Michael, C. Montzka, A. Al Bitar, A. Berg, R. Bindlish, H. Bogena, F. Cabot, T. Caldwell, S. Chan, A. Colliander, W. Crow, N. Das, G. de Lannoy, E. Lopez-Baeza, W. Dorigo, A. Gruber, S. Hahn, T. Jagdhuber, S. Jones, Y. Kerr, S. Kim, C. Koyama, M. Kurum, F. Mattia, K. McColl, S. Mecklenburg, B. Mohanty, P. O´Neill, T. Pellarin, G. Petropoulos, M. Piles, R. Reichle, N. Rodriguez-Fernandez, C. Rüdiger, T. Scanlon, D. Spengler, P. Srivastava, S. Suman, R. van der Schalie, W. Wagner, U. Wegmüller, F. Camacho, and J. Nickeson (2020): Soil Moisture Product Validation Best Practice Protocol. Version 1.0.

Al-Yaari, A., S. Dayau, C. Chipeaux, C. Aluome, A. Kruszewski, D. Loustau, and J.-P. Wigneron 2018. "The AQUI Soil Moisture Network for Satellite Microwave Remote Sensing Validation in South-Western France" Remote Sensing 10, no. 11: 1839. https://doi.org/10.3390/rs10111839.

Dorigo, W., Himmelbauer, I., Aberer, D., Schremmer, L., Petrakovic, I., Zappa, L., Preimesberger, W. and others (2021). The International Soil Moisture Network: serving Earth system science for over a decade. Hydrol. Earth Syst. Sci., 25, 5749–5804. https://doi.org/10.5194/hess-25-5749-2021.

Dorigo, W., Wagner, W., Albergel, C., Albrecht, F., Balsamo, G., Brocca, L., … Lecomte, P. (2017a). ESA CCI Soil Moisture for improved Earth system understanding: State-of-the art and future directions. Remote Sensing of Environment. https://doi.org/10.1016/j.rse.2017.07.001.

Fernandez-Moran, R., Al-Yaari, A. , Mialon, A. , Mahmoodi, A , Al Bitar, A. ,De Lannoy, G., Lopez-Baeza, E., Kerr, Y., Wigneron, J.-P. (2017): SMOS-IC: An alternative SMOS soil moisture and vegetation optical depth product, Remote Sens., 9, 457; doi:10.3390/rs9050457.

Gruber, A., Scanlon, T., van der Schalie, R., Wagner, W., and Dorigo, W.: Evolution of the ESA CCI Soil Moisture climate data records and their underlying merging methodology, Earth Syst. Sci. Data, 11, 717–739, https://doi.org/10.5194/essd-11-717-2019, 2019.

Gruber, A., De Lannoy, G., Albergel, C., Al-Yaari, A., Brocca, L., Calvet, J.C., Colliander, A., Cosh, M., Crow, W., Dorigo, W., and others 2020. Validation practices for satellite soil moisture retrievals: What are (the) errors?. Remote Sensing of Environment, 244, p.111806.

Mousa, B. G., & Shu, H. (2020). Spatial evaluation and assimilation of SMAP, SMOS, and ASCAT satellite soil moisture products over Africa using statistical techniques. Earth and Space Science, 7, e2019EA000841. https://doi.org/10.1029/2019EA000841.

Wilkinson, Mark D.; Dumontier, Michel; Aalbersberg, IJsbrand Jan; Appleton, Gabrielle; et al. (15 March 2016). *"The FAIR Guiding Principles for scientific data management and stewardship"*. Scientific Data. 3: 160018. https://doi.org/10.1038/sdata.2016.18.