Global Operational CalVal Plans

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CNES and CLS have a long experience of global Calval methods. Developed 20 years ago in the frame of Topex mission the tools have continue to evolve to include the current flying altimeter constellation (Ka band on SARAL, LRM Ku band on Jason-2 and HY2, LRM and SAR on CryoSat-2) and to prepare the new altimeter technology (SAR mode on Sentinel3).

Our current experience is mainly based on ocean surfaces, but inland water will be included in the next future.

Over ocean, those tools include a wide range of statistical and expert analysis:

- Xover points and Sea level anomalies
- Spectral analysis
- Comparison with models (ECMWF, IRI, …)
- Comparison with in situ networks (tide gages, ARGO float, GPS, Gliders, …)
- Comparison with other satellite data (nadir constellation, GRACE, SSMI, …)

But those tools needs to be strongly revisited to support the SWOT mission (2 D fields, …)
Plan:

- Validation of the Ocean Performance from 10 km to 100 km
- Validation of the Ocean Performance from 100 km to 1000 km
- Validation of Long-Wavelength Height Errors

Notice:

- this is a preliminary analysis, performed to contribute to the draft version of the CalVal plan
- It will be further described in the coming months/years
- CNES project involvement during CalVal and routine phase will be important, including inland water surfaces (in particular the proposal from J.F Cretaux over large lakes). Project involvement will obviously depend on budget availability
In 2014 a DEM of the Lake Poopo (South America) has been computed based on a combination of satellite imagery (set of landsat images) and laser altimetry (Icesat). The Lake Poopo is a very shallow one with high seasonal and inter-annual areal extent (and height) variability. Every year in winter it is inundated and during the rest of the year it shrinks due to very high evaporation.

At inter-annual time scale, this cycle of inundation/drought is also very unstable, with some very wet years contrasting to very dry ones. This DEM, is valid from a minimum surface quite close to the full drought, to high one when the lake is extendedly inundated.
The precision of this DEM has been established at better than 10 cm. It therefore can be used for validation of lake surface extent. For each water extent measured by SWOT we can simply project the corresponding water mask to the DEM and determine the closest theoretical mask deduced from the DEM alone. Repeating this procedure pass after pass will give quantitative validation of water mask inferred from SWOT measurements.

We could also establish a list of lakes under different geographical and morphological conditions with couples of height/extent for various ranges of height (from historical altimetry and satellite imagery data). A set of about 100 lakes among them half located on the Tibetan Plateau already exist (Legos work for Hydroweb database) and will be completed before the launch.

This will serve as an external source of validation for water extent validation although not strictly of land/water classification. If water height is validated by other means, then for each water height measured, a water extent can be calculated using polygon coefficients of the hypsometry curve and compared to the surface extent directly measured by SWOT.
The SWOT LRM nadir altimeter is unable to resolve all these scales due to its noise performance.

Therefore, we’ll mainly rely on data collected by AirSWOT at the time of SWOT data collection. However this will be a local analysis and cannot be extended over several regions.

In regions where AirSWOT will not be available, we can validate some of the smaller mesoscale structures (40-100 km) using 1D SAR nadir altimeter SSH observations collocated in space and time across the SWOT swaths (limited to measurements within a few days). The Jason-CS and Sentinel class altimeters will be flying with a SAR mode, allowing 1D spectral performance of 30-50 km depending on the region.

In addition to the nadir altimeter constellation, we will benefit from the SAR imagery, SST, Ocean color, GPM, … flight data provided by several currently flying or to be launch soon missions.
For example the Sentinel3 Copernicus mission will embark:

Validation of the Ocean Performance from 10 km to 100 km

**The Sentinel-3 Satellite**

**Main satellite characteristics**
- 1250 kg maximal mass
- Volume in 3.89 m x 2.202 m x 2.207 m
- Average power consumption of 1100 W
- 7.5 years lifetime (fuel for 5 add. years)
- Large cold face for optical instruments
- Thermal control
- Modular accommodation for a simplified management of industrial interfaces
- Launch S3A end 2014
- S3B FAR end of 2015

**Observation Data Management**
- 170 Gbit of observation data per orbit
- Space to ground data rate 2 x 280 Mbps X-Band
- 1 contact per orbit
- 3h delivery timeliness (from satellite sensing)
Validation of the Ocean Performance from 10 km to 100 km

- With co temporal and co localized SST, ocean color and along track SAR topography

Key requirements for orbit selection
Instrument Swath and Orbit

- **Sun-synchronous frozen orbit close to 800 km**
  - Required for continuity of optical observations

- **Topography mission requirements**
  - Repeat cycle > 20 days
  - Needed for optimum Topography mission spatial sampling
  - Minimization of aliasing

- **Ocean Colour mission requirements**
  - 2-day global coverage with 2 satellites, 4 days with one
  - Implies a sub-cycle of 4 days
  - Local time of observation shall be > 10 hr to avoid morning haze

- **Sea Surface Temperature mission requirements**
  - Local time at node shall be < 11 h to avoid skin effects

<table>
<thead>
<tr>
<th>Orbit type</th>
<th>Repeating frozen SSO</th>
</tr>
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<tbody>
<tr>
<td>Repeat cycle</td>
<td>27 days (14 + 7/27 orbits/day)</td>
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<tr>
<td>LTDN</td>
<td>10:00 hr</td>
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<tr>
<td>Average altitude</td>
<td>815 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>98.65 deg</td>
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</tbody>
</table>
For scales larger than the ocean swath, the along-track spectra from the SWOT altimeter and KaRIN must coincide (within the noise floor capabilities of the altimeter). Therefore, the KaRIN along-track spectrum for these scales will be validated by direct comparison against the simultaneously measured SWOT nadir altimeter spectrum.

Spectral estimates will be performed for all cross-track pixels in the SWOT swath, to validate the consistency of the KaRIN data and the effect of variations in the wet troposphere, EM bias, and ionospheric corrections that are made based on the nadir altimeter and radiometer measurements.

Other altimeter missions flying during this period can also provide additional validation data, for tracks which are collocated in space and within a few days of the SWOT observations.
To validate the global performance of SWOT and its consistency with the Topex-Jason long-wavelength climate data set, we utilize the cross-over data set obtained by using cross-overs between the KaRIN data, the SWOT altimeter, and the Jason and Sentinel-class operational altimeters operating at the time of the SWOT launch.

The resulting global differences will be analyzed using spherical harmonic analysis, and the resulting spectrum will be compared against the long-wavelength spectral requirements for the ocean surface.
First we will map the SWOT SSH values and compare if to models outputs, altimeter along track constellation, DUACS maps, FSLE maps, …. This is already done in 1D for current altimeter validation (radiometer toward AMSU shown below) and can be done either globally, regionally, separating Asc/Dsc tracks, ….

Examples of some tools: simple mapping …
Due to its large swath (120km), collinear tracks will be superimposed above 26° of latitude. Therefore, the along track maps can be hardly readable. Over one cycle, or for a subcycle) data can be projected on a regular grid with 1km/1km resolution. For a 22 day cycle, each box will contain at least 1 point but usually more (Typically at least 2 above 26°, and 3 above 60°). This step can be useful to constitute a basis of comparison with other space born instruments, models... but also to homogenize the coverage and compute relevant statistics.

Examples of some tools:
Using collinear swath overlaps
Examples of some tools:
Cross Over diamonds ...

✓ Due to SWOT orbital geometry, the usual nadir altimetry crossover points do not exist anymore as isolated points: the closest configuration to the nadir cross-overs are ascending/descending tracks crossover and are diamond-shaped.

✓ Thanks to the wider surface, the selection of relevant crossovers can be limited to a small time tag (much smaller than the usually taken 10 days for nadir altimetry).

✓ For this diagnosis, geometrical and correlation studies should be pushed forward to analyze the best configuration(s) to evaluate the parameters performances with a good temporal/spatial compromise.
Examples of some tools: *Spectrum analysis*

- Unlike for the nadir constellation mission, the error budget and specifications are declined per time scales through spectral formalism.
- The assessment of the error budget will therefore include a great part of spectral analysis. They consist in Mean periodograms and can be completed by envelopes of spectral density in order to have a quantification of the relevance of the average.
Another type of comparison: nadir / KaRIN overlaps.

For the parameters presenting a very short correlation distance (<60km), these zones are of interest. They are also very numerous and can evidence Ascending Descending discrepancies / errors.

Examples of some tools:
Monomission crossover segments Nadir/KaRIN
Examples of some tools:
And Multimission crossover segments

✓ Same as above but taking into account the nadir altimeter virtual constellation
Conclusion

- SWOT will be a very demanding mission …
- Some of the CalVal tools have been described in the CalVal plan and recalled here
- We will largely use SWOT/SWOT data but the comparison with other space born data (SAR, SST, Color, …) will be certainly of high interest
- This Global analysis will also include some inland water targets in the future