Homogeneous multi-mission 20 Hz Sea Level Anomaly

L2P products assessment

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Context

Since mid-2021 level 2P 20 Hz data are available on AVISO+ for Sentinel-3A, Sentinel-3B and Jason-3 for near-real-time and short-time-critical timeliness. Sentinel-6A was added in November 2022. Other missions (Swot nadir and HY-2B) could be added soon.

Hereafter the value-added sea level anomaly L2P 20 Hz products are presented.

L2P/L3 is a homogeneous product thanks to the joined effort from :

L2P-SALP (Service d'Altimétrie et de Localisation Précise) project supported by CNES (Centre National d'Etudes Spatiales)
Sentinel-3 Marine Altimetry L2P-L3 Service (operated under an EUMETSAT contract in the frame of the COPERNICUS Programme funded by the European Union)
L3-CMEMS and C3S service implemented by MERCATOR Ocean International

L2P = HOMOGENEOUS & CALIBRATED

Since the launch of TOPEX/Poseidon and ERS-1 in the early 90's more than 10 other Altimetry missions were launched and operated by different agencies. The level 2 data (destinated to expert users) are distributed using different file formats (binary, netcdf) and contain different geophysical standards used to compute the sea level anomaly.

- **L2** : Spurious measurements and biases between missions are detected
- **L2P** : Spurious measurements and global biases are removed, SLA is more homogenous
- **L3** : sea-level is filtered and subsampled and discrepancies between missions adjusted

L2P

- Are easy to use (netcdf format)
- Are homogenous along-track mono-mission products
- Provide the same updated corrections and models
- Contain the sea level anomaly and all the corrections used to compute it and a validity flag
- An inter-mission bias is applied in order to have consistent time series since TOPEX/Poseidon
- Are input to the CMEMS L3 5Hz regional & global system

L2P 20 Hz 2021 standards	J3	S3A/S3B	S6A HR	Swot nadir	HY-2B
L2 used	Official OGDR/IGDR (MLE4 retracking)	Official NRT/STC PDGS (SAR)	Official NRT/STC PDAP (SAR)	Official O/Igdr (MLE4 retracking)	Official SDR NSOA
Orbit	CNES MOE-F	CNES MOE-F	CNES MOE-F	CNES MOE-F	CNES MOE-F
Sea State Bias	Non parametric SSB J3 MLE4	Non parametric SSB S3A	Non parametric SSB J3 MLE4	Non parametric SSB J3 MLE4	NSOAS solution
Ionosphere	Filtered (from L2)	Filtered (from L2)	Filtered (from L2)	Along-track GIM data	Along-track GIM data
Wet troposphere	J3-AMR radiometer	S3A-MWR radiometer	S6A-MWR radiometer	Model computed from ECMWF Gaussian grids	Model computed from ECMWF Gaussian grids
Dry troposphere	Model computed from ECMWF Gaussian grids				
Combined atmospheric correction	MOG2D/TUGO High frequencies forced with analysed+predicted ECMWF pressure and wind field [Carrere and Lyard, 2003; operational version used, current version is 4.0.0] + inverse barometer low frequencies				
Ocean tide	FES2014B [Carrère et al., 2016]				
Solid Earth tide	Elastic response to tidal potential [Cartwright and Tayler, 1971], [Cartwright and Edden, 1973]				
Pole tide	[Desai et al., 2015 + mean pole location 2017 (Ries et al., 2017)]				
Internal tide	Internal tide [Zaron, 2019] HRET v8.1				
MSS	Combined (SCRIPPS,CNES/CLS15,DTU15)				
High frequency adjustment	High frequency adjustment [Tran et al., 2019]			High frequency adjustment [Tran et al., 2019]	

Editing :

Instead of using 1Hz editing based principaly on threshold, 20Hz chain use iterative editing function of SWH.

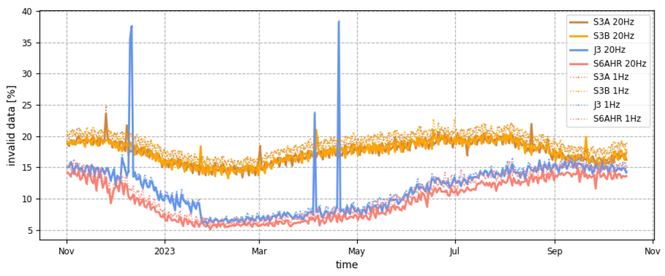
Percentage of invalid data **show similar values for 20Hz and 1Hz data**.

NB :

- More data are edited for Sentinel-3 due to ice in polar regions, as they have 98,6° inclination versus 66° for Jason-3/Sentinel-6A.
- Land data are excluded.
- Increased invalid data for Jason-3 from 05/12/2022 to 23/12/2023 is related to a bad parameter of DIODE conf for interleaved orbit, when JA3 was in open loop. The peaks for J3 in Dec 22 and Apr 23 are due to radiometer wet tropospher correction at DV or out of threshold

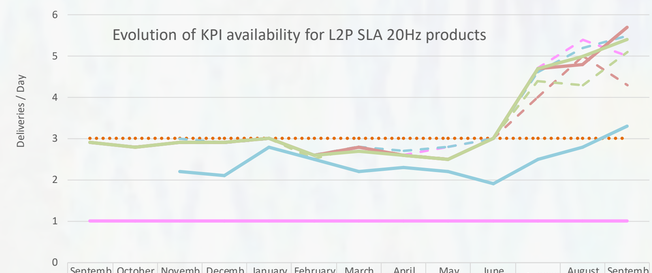
Daily percentage of invalid 20Hz & 1Hz stc L2P data (without land, 2022-11-01 - 2023-10-15 23:59:59)

	nbr	min	mean	med	max	std
S3A 20Hz	349	13.45	17.45	17.6	23.56	1.713
S3B 20Hz	349	13.3	17.46	17.67	20.98	1.71
J3 20Hz	349	5.902	11.51	12.11	38.19	4.065
S6AHR 20Hz	349	5.128	9.729	9.877	14.83	3.111
S3A 1Hz	349	14.61	18.79	18.98	24.75	1.737
S3B 1Hz	349	14.39	18.84	19.1	22.66	1.752
J3 1Hz	349	5.843	11.87	12.3	38.45	4.068
S6AHR 1Hz	349	5.711	10.81	11.13	16.63	3.406



Availability

L2P 20 Hz products are produced on a best effort basis and delivered 3 times per day since December 2021 (except for Jason-3 STC, as L2 input products are only distributed once per day). Since July 2023, L2P 20Hz production frequency was further increased.



	September 2022	October 2022	November 2022	December 2022	January 2023	February 2023	March 2023	April 2023	May 2023	June 2023	July 2023	August 2023	September 2023
target	3	3	3	3	3	3	3	3	3	3	3	3	3
NRT S3A	2.9	2.8	2.9	2.9	3	2.6	2.8	2.6	2.5	3	4	5	4.3
NRT S3B	2.9	2.8	2.9	2.9	3	2.5	2.8	2.6	2.5	3	4.4	4.3	5.1
NRT J3	2.9	2.8	2.9	2.9	3	2.6	2.7	2.6	2.8	3	4.7	5.4	5
NRT S6AHR			3	2.9	3	2.6	2.8	2.7	2.8	3	4.6	5.2	5.5
STC S3A	2.9	2.8	2.9	2.9	3	2.6	2.8	2.6	2.5	3	4.7	4.8	5.7
STC S3B	2.9	2.8	2.9	2.9	3	2.6	2.7	2.6	2.5	3	4.7	5	5.4
STC J3	1	1	1	1	1	1	1	1	1	1	1	1	1
STC S6AHR			2.2	2.1	2.8	2.5	2.2	2.3	2.2	1.9	2.5	2.8	3.3

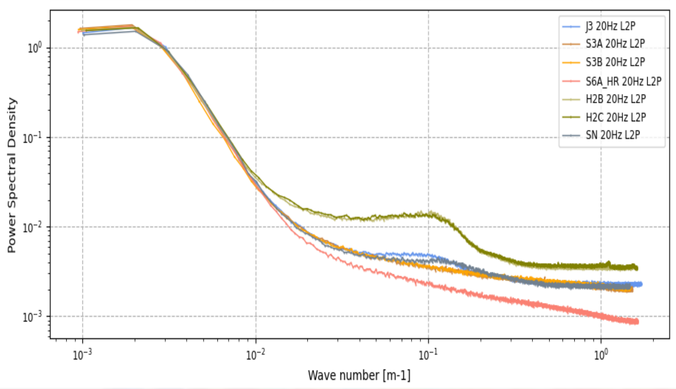
Average of number of daily deliveries of L2P 20 Hz products over a month

Noise : sentinel 6A less noisy

The LRM missions (Jason-3, Swot nadir and HY-B/C) have 20Hz and 1Hz plateau, as well as spectral hump. For Jason-3 and swot nadir, HFA (Tran 2019) was applied which reduces the noise and the spectral hump. SAR missions show a spectral slope (« red noise ») for scales lower than 50 km, likely linked to swell occurrences.
Power density spectrum of L2P 20 Hz SLA shows good agreement for the long wavelengths (steep oceanic slope).

Spectral SLA L2P 20Hz (2023-07-01 to 2023-07-11 23:59:59)

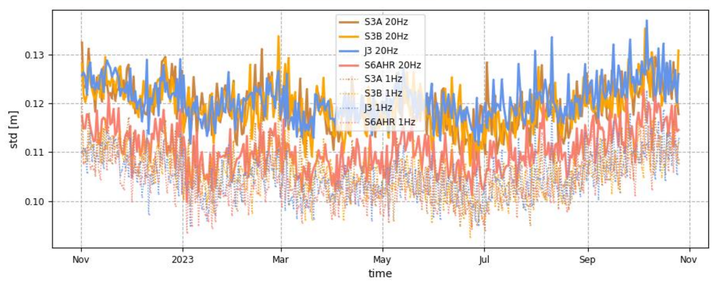
	nbr	min	mean	med	max	std
J3 20Hz L2P	1701	0.001133	0.005705	0.002337	1.676	0.06058
S3A 20Hz L2P	1568	0.001005	0.006083	0.002247	1.793	0.06786
S3B 20Hz L2P	1568	0.001025	0.006081	0.002309	1.73	0.06634
S6A_HR 20Hz L2P	1734	0.0004372	0.004564	0.001098	1.737	0.06316
H2B 20Hz L2P	1542	0.00186	0.008063	0.003568	1.689	0.06507
H2C 20Hz L2P	1542	0.00172	0.007953	0.003705	1.663	0.06335
SN 20Hz L2P	1442	0.001056	0.006012	0.002226	1.518	0.06136



Daily standard deviation of valid L2P STC sea level anomaly is in average between 10,4 cm (S6A) and 10,6 cm (J3) for 1Hz. **For 20Hz it is more spread ranging (in average) from 11.1 cm for Sentinel-6A** over 12.0 cm for Sentinel-3 to 12.1 cm for Jason-3. The standard deviation at crossovers results to the same conclusions.

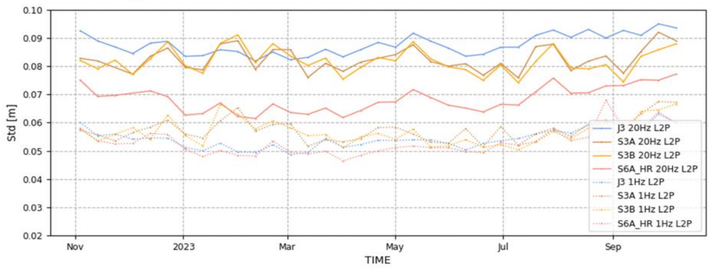
Daily std of valid 1Hz & 20 Hz stc L2P sla (|lat|<66, without caspian sea) (2022-11-01 - 2023-10-25 23:59:59)

	nbr	min	mean	med	max	std
S3A 20Hz	359	0.1083	0.1195	0.1196	0.1325	0.004591
S3B 20Hz	359	0.1072	0.1195	0.1192	0.1353	0.00445
J3 20Hz	359	0.1115	0.1208	0.1204	0.137	0.004125
S6AHR 20Hz	359	0.0998	0.1105	0.1101	0.1228	0.004376
S3A 1Hz	359	0.09393	0.106	0.1059	0.1212	0.004821
S3B 1Hz	359	0.09264	0.1058	0.1056	0.1209	0.004696
J3 1Hz	359	0.09489	0.1051	0.1047	0.1225	0.004579
S6AHR 1Hz	359	0.09357	0.104	0.1034	0.1166	0.004632



Xover std of L2P 20Hz & 1Hz stc (no selection)

	nbr	min	mean	med	max	std
J3 20Hz L2P	35	0.08184	0.08766	0.08675	0.095	0.003588
S3A 20Hz L2P	33	0.07583	0.08256	0.08177	0.09205	0.00423
S3B 20Hz L2P	35	0.07414	0.08184	0.08173	0.09112	0.004316
S6A_HR 20Hz L2P	34	0.06144	0.06822	0.06727	0.07717	0.004443
J3 1Hz L2P	35	0.04868	0.05437	0.05359	0.06305	0.003499
S3A 1Hz L2P	35	0.05147	0.05747	0.05731	0.06744	0.004016
S3B 1Hz L2P	35	0.05034	0.05668	0.05577	0.0666	0.004416
S6A_HR 1Hz L2P	35	0.04643	0.05304	0.05201	0.06791	0.004588



Download data :

- **AVISO+ website** https://www.aviso.altimetry.fr/en/data/products/sea-surface-height-products/global/along-track-sea-level-anomalies-l2p.html
- **EUMETSAT website** EUMETCAST
- **Copernicus website** https://resources.marine.copernicus.eu/product-detail/SEALEVEL_GLO_PHY_L3_NRT_OBSERVATIONS_008_044/INFORMATION

The following other L2P products are also available on AVISO+ :

- 1Hz sea level anomaly (S3A/S3B/S6A) Near-Real-Time (NRT ~ <4h after the sensing start time of the product) and Short-Time-Critical (STC ~ <2 days)
- 1Hz sea level anomaly delayed time (DT ~<3 months) (TP,ERS-1, ERS-2,EN, SARAL/AltiKA, J1, J2, J3, HY-2A, HY-2B, C2, S6A).
- 1Hz significant wave height and wind speed products (S3A/S3B/S6A) NRT

Coming soon :

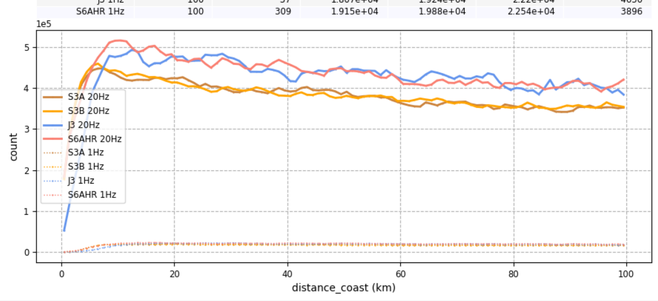
- **SWOT 20Hz L2P data**
- **Sea-Level TAC L3 NRT/STC 5Hz global data** (the European 5Hz L3 product is already available since Nov 2022 Pujol et al., 2023). This requires upstream altimeter L2p products available with a 20Hz resolution over the global area.
- **Reprocessed data L2P NTC V4.0 DT24 standards**
- **NRT/STC 1Hz & 20Hz L2P data switch to DT24 standards** (Early 2024) see also C.Kocha "30 years of sea level anomaly reprocessed to improve climate and mesoscale satellite data", OSTST 2023).

Coastal approach : more points with lower noise

20 Hz data allow to get more points at coast.
Also, these points show lower standards deviation than the 1Hz data allowing good confidence to use these data.
Sentinel S6A shows the best configuration with the most of available data with the lower standard deviation.

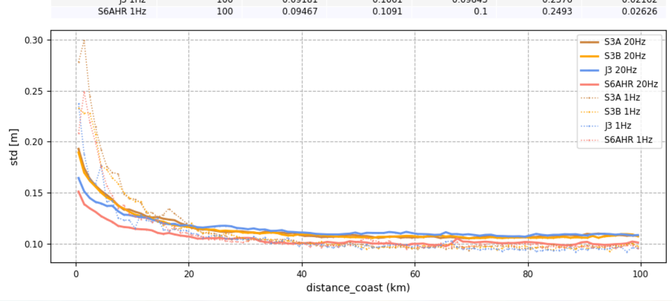
count sla val_wo_22_lat66 S3A STC 20Hz binned stats (2022-11-01 - 2023-10-25 23:59:59)

	nbr	min	mean	med	max	std
S3A 20Hz	100	1.813e+05	3.809e+05	3.81e+05	4.482e+05	3.591e+04
S3B 20Hz	100	1.779e+05	3.817e+05	3.789e+05	4.601e+05	3.582e+04
J3 20Hz	100	5.204e+04	4.241e+05	4.348e+05	4.94e+05	6.464e+04
S6AHR 20Hz	100	1.839e+05	4.341e+05	4.329e+05	5.167e+05	4.497e+04
S3A 1Hz	100	189	1.618e+04	1.685e+04	1.915e+04	3207
S3B 1Hz	100	174	1.609e+04	1.657e+04	1.888e+04	3173
J3 1Hz	100	37	1.807e+04	1.924e+04	2.22e+04	4650
S6AHR 1Hz	100	309	1.915e+04	1.988e+04	2.254e+04	3896



std of valid 1Hz & 20 Hz stc L2P sla (|lat|<66, without caspian sea) in function of coastal distance (2022-11-01 - 2023-10-25 23:59:59)

	nbr	min	mean	med	max	std
S3A 20Hz	100	0.105	0.1143	0.1081	0.193	0.01529
S3B 20Hz	100	0.1051	0.1136	0.1077	0.1895	0.01465
J3 20Hz	100	0.1066	0.1145	0.1103	0.1644	0.01016
S6AHR 20Hz	100	0.09731	0.1047	0.101	0.151	0.009109
S3A 1Hz	100	0.09305	0.1129	0.09851	0.2995	0.03589
S3B 1Hz	100	0.09231	0.1106	0.09896	0.233	0.02883
J3 1Hz	100	0.09181	0.1061	0.09843	0.2376	0.02162
S6AHR 1Hz	100	0.09467	0.1091	0.1	0.2493	0.02626



Conclusion

- More than **1 year** of data at high resolution **(20Hz/350m)**
- **Homogeneous & calibrated** data set
- Adapted **iterative editing function of SWH**
- In average, 20Hz is noisier than 1Hz data.
- **On the coast, 20Hz allows more data with lower standard deviation** than 1Hz.
- Sentinel 6A show good results with the lower noise in general and more points on the coast.
- Further validations need to be done to confirm this preliminary study.

OSTST meeting 2023