Consortium Members

ESA Sea Level CCI

SL_cci CCN5: DTU/TUM Arctic and Antarctic Altimeter Sea Level

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Applicable documents

AD 1 Sea level CCI project Management Plan
CLS-DOS-NT-10-013

Reference documents

RD-1

List of acronyms

Envisat	Environmental Satellite
DTU	Technical University of Denmark
ERS	European Remote Sensing
LRM	Low Resolution Mode
SAR	Synthetic Aperture Radar
SARIN	SAR Interferometric
SLA	Sea Level Anomaly
TUM	Technical University of Munich

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1. Introduction

This report provides the outcome of the SL_cci option work (CCN#5) carried out within collaboration between TUM (Technical University of Munich) and DTU (Technical University of Denmark). The main objective has been to improve sea level estimates in high latitudes, which are often obstructed by the presence of sea ice. This makes it challenging to obtain accurate sea level estimates from satellite altimetry. The input data as well as the data processing is described, and the dataset is validated against several high latitude tide gauges both in the Arctic and the Antarctic.

2. Data processing

2.1. Input data

The improved sea level record was created using satellite altimetry data from 1991 to 2016, providing a dataset covering 25 years. To obtain a record this long, data from multiple altimetry missions were used. Each mission and the corresponding data are described in the following sections.

Various geophysical corrections were applied to the data: dry and wet tropospheric corrections, ionospheric correction, solid earth tide, and geocentric polar tide. The inverse barometric effect has not been corrected for.

2.1.1. ERS-1

ERS-1 data were obtained from the REAPER L2 products and covers the period from August 1991 to September 1994.

2.1.2. ERS-2

Data from ERS-2 was processed with the ALES+ retracker (Passaro, 2017) and covers the period from October 1994 to July 2002.

2.1.3. Envisat

The Envisat mission covers the period from August 2002 to March 2011. As for ERS-2, the altimetric waveforms were retracked using the ALES+ retracker.

2.1.4. CryoSat-2

From April 2011 to April 2017, the high latitude retracked heights were obtained from CryoSat-2 data, which were extracted from either the LARS the advanced retracking system (LARS) at DTU Space in the case of Synthetic Aperture Radar (SAR) and SAR Interferometric (SARIn) data, or from the RADS data product (Scharroo, 2013) in the case of Low Resolution mode (LRM) data. The SAR and SARIn waveforms were retracked using a sub-waveform threshold retracker.

2.2. Data editing

All retracked heights have been masked using a sea-ice mask downloaded from the Norwegian Ocean and Sea Ice Satellite Application Facility (OSI SAF) High Latitude Processing Center (http://osisaf.met.no/p/ice/index.html#conc-reproc-v2). Grid points with an ice concentration above 15% were discarded.

2.3. Achieving the gridded sea level anomalies

To obtain sea level anomalies (SLA) the DTU15 mean sea surface (MSS) was subtracted from the retracked heights.

Using the pulse peakiness and the backscatter for each waveform, retracked heights that were assumed to be acquired over areas with melt ponds were removed. The discrimination thresholds for each mission are listed in Table 1. Deviant data points were excluded using the median-absolute-deviation (MAD) test for outliers.

Table 1 - Discrimination threshold for detecting ocean and leads

Satellite	Ocean	Lead
ERS-1	PP < 1.5, σ^0: 9-15	PP > 21, LEW < 3
ERS-2	PP < 1.5, σ^0: 9-15	PP > 23, LEW < 3
Envisat	PP < 1.5, σ^0: 9-15	PP > 21, LEW < 3
CryoSat-2	RADS	PP(SAR) > 35, PP(SARIn) > 15, LEW < 0.9, St. STD < 4

The intermission biases were then estimated from overlapping time periods and subtracted to get a seamless transition between the data products from the different satellite missions. The complete time series was then adjusted to have a mean value of zero.

Weekly data were gridded using least squares collocation with a second-order Markov covariance function (Andersen, 1999).

3. Results

3.1. Arctic

The trend and seasonality of the altimetry data were obtained by solving the harmonic function using ordinary least squares (see Figure 1). In the Arctic, the fit estimates a trend of 2.2 mm/yr, with seasonal maximum in Autumn and minimum in late Spring.

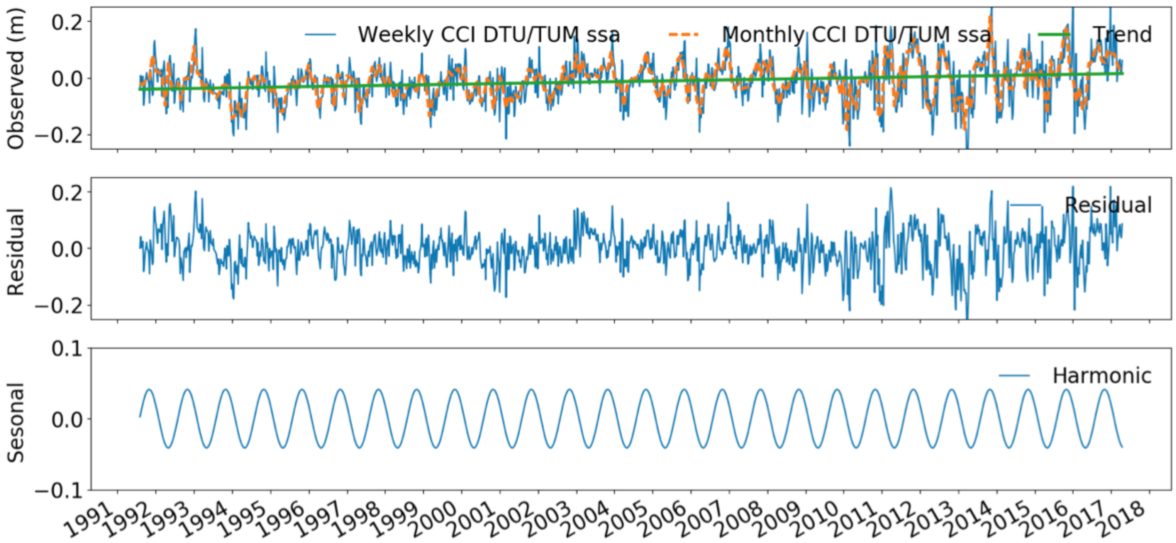

Figure 1 – Time series with trend (top), the residual (middle), and the harmonic function fitted to the data (bottom).

A map of the mean annual trend is seen in Figure 2 for the Arctic Ocean and in Figure 3 for the Antarctic ocean.

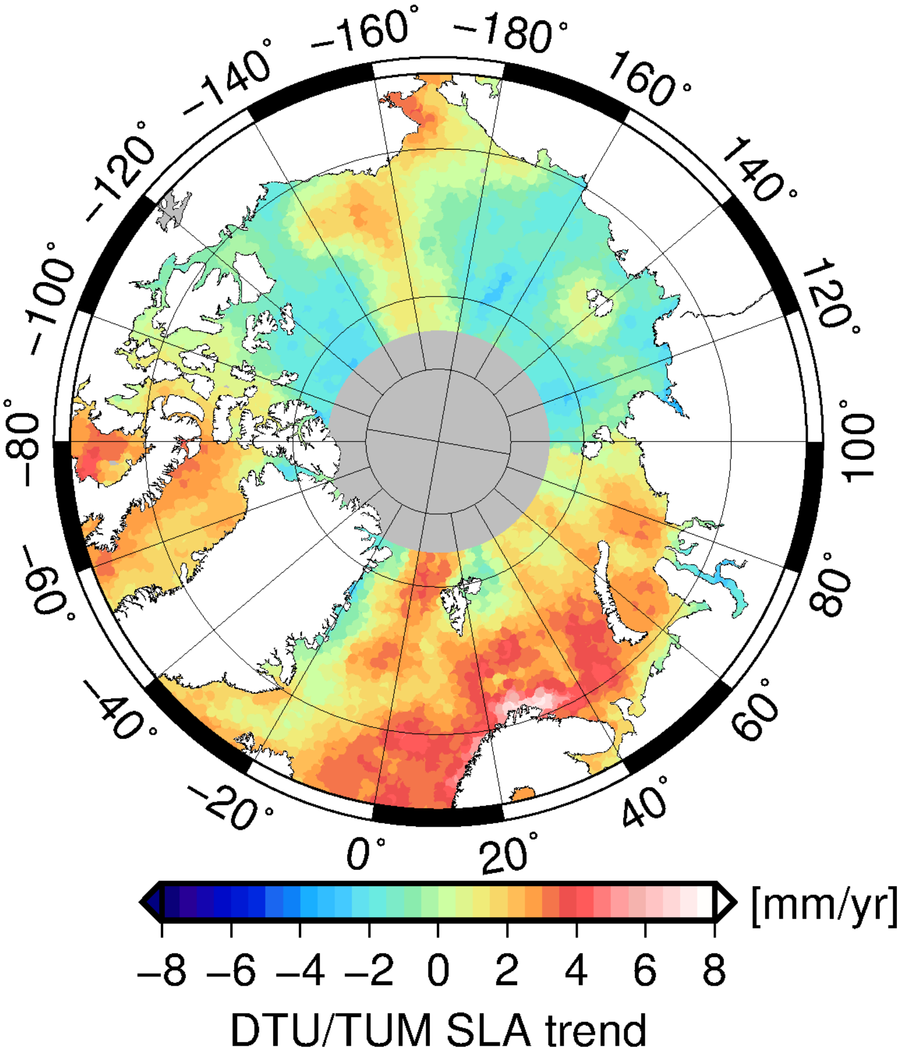

Figure 2 - Mean trend in SLA in the period from 1991 to 2017 for the Arctic Ocean.

3.2. Antarctic

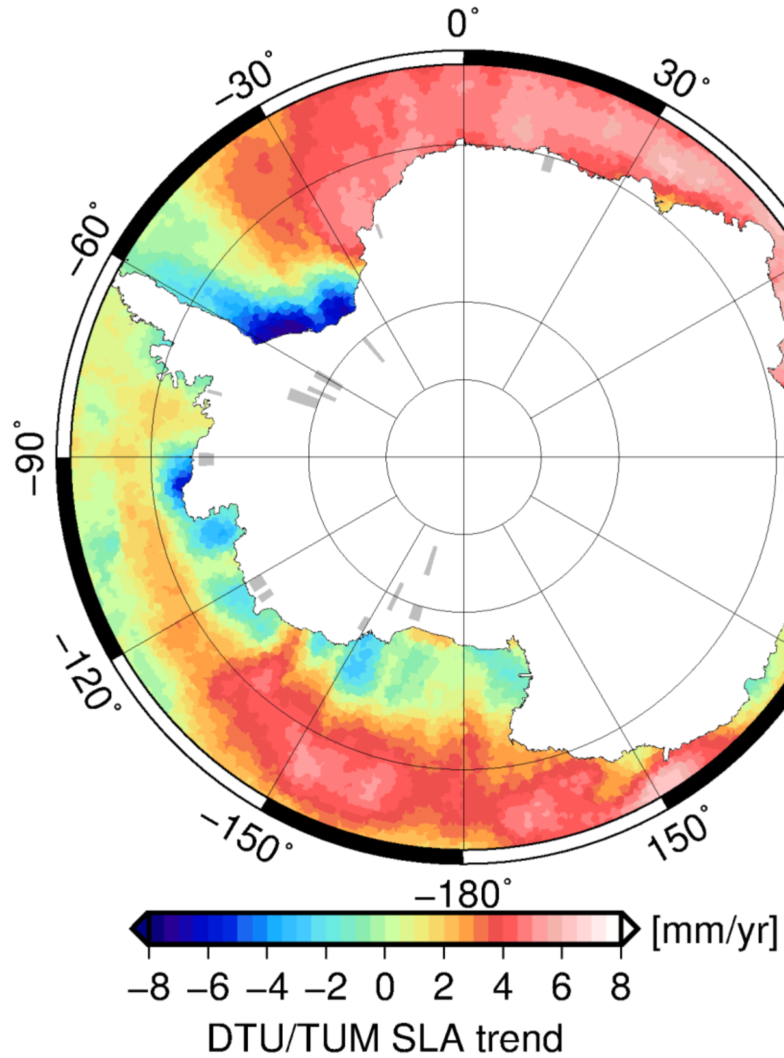

Figure 3 - Mean trend in SLA in the period from 1991 to 2017 for the Antarctic Ocean

4. Validation

A brief comparison with tide gauge data has been performed to evaluate the high latitude data product. Altimetric data were extracted within a radius of 350 km of each tide gauge station, and monthly means are compared.

4.1. Arctic Ocean

In the Arctic Ocean the time series derived from the altimetric data product have been compared with the Ny-Ålesund (78.9N,11.94E) and Prudhoe Bay (70.4N, 148.5W) tide gauge stations. Data were downloaded from the Permanent Service for Mean Sea Level (PMSL) data base (http://www.psmsl.org).

Figure 4 and Figure 5 shows the comparison of the observed SLA from the two tide gauges. The Ny-Ålesund tide gauge shows a good agreement between the satellite data and the in-situ data, whereas the in-situ and satellite data does not show the same correlation for Prudhoe Bay.

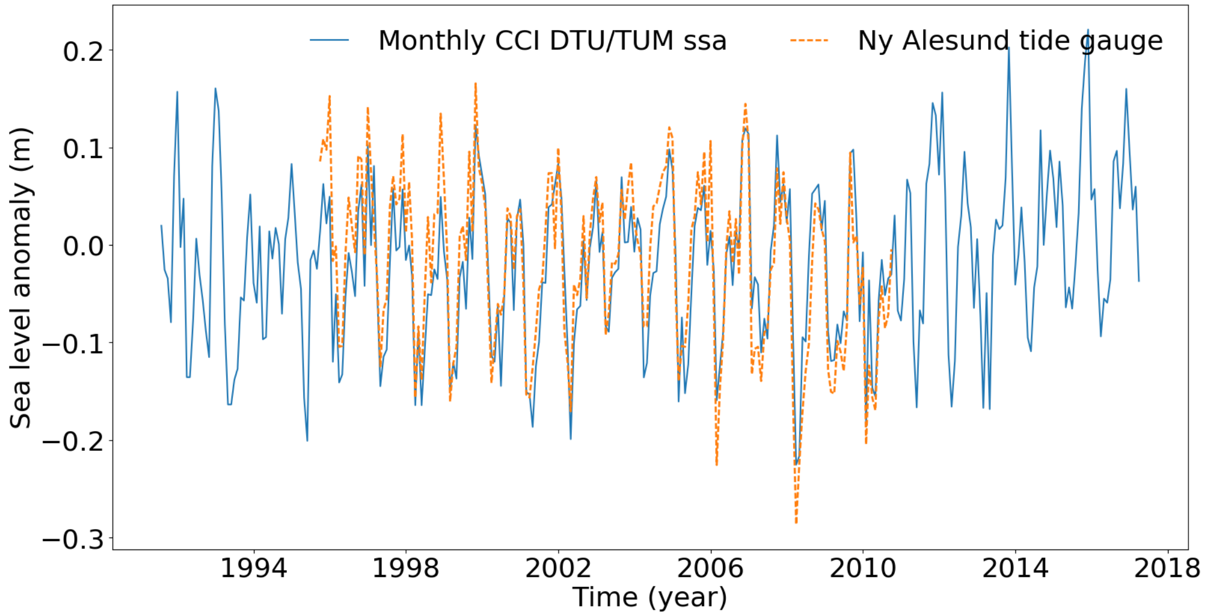

Figure 4 - Ny-Ålesund time series. Comparison of monthly data from altimetry and tide gauge.

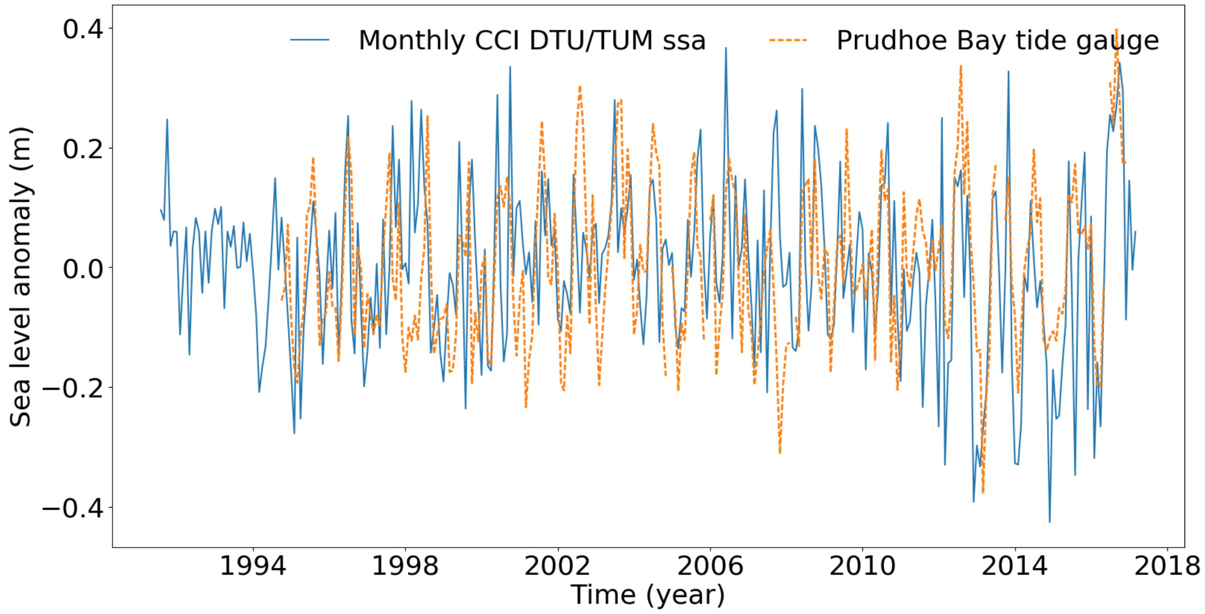

Figure 5 - Prudhoe Bay time series. Comparison of monthly data from altimetry and tide gauge.

4.2. Antarctic Ocean

On the southern hemisphere, the altimetric data are compared to the tide gauge stations Syowa (69.5S, 39.36E) and Faraday (65.15S, 64.16W). As Figure 6Figures 6 and Figure 77 show, the

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correlation between satellite and in-situ data is not as convincing as for the Ny-Ålesund tide gauge in the Arctic Ocean.

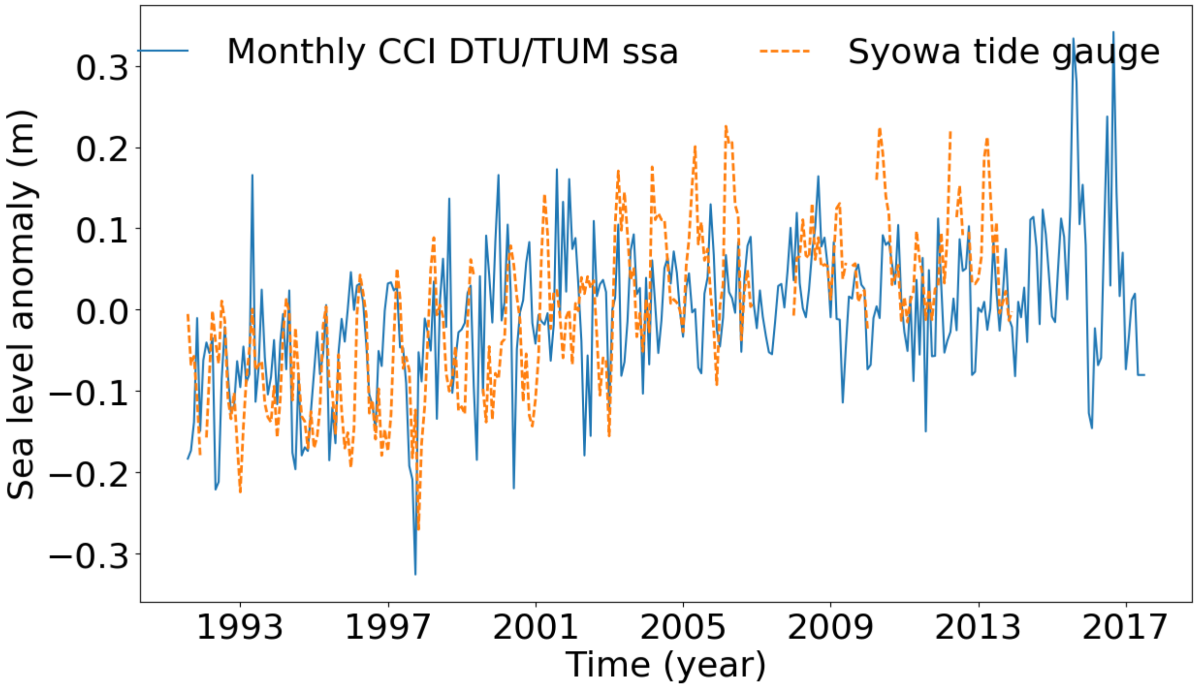

Figure 6 - Syowa time series. Comparison of monthly data from altimetry and tide gauge.

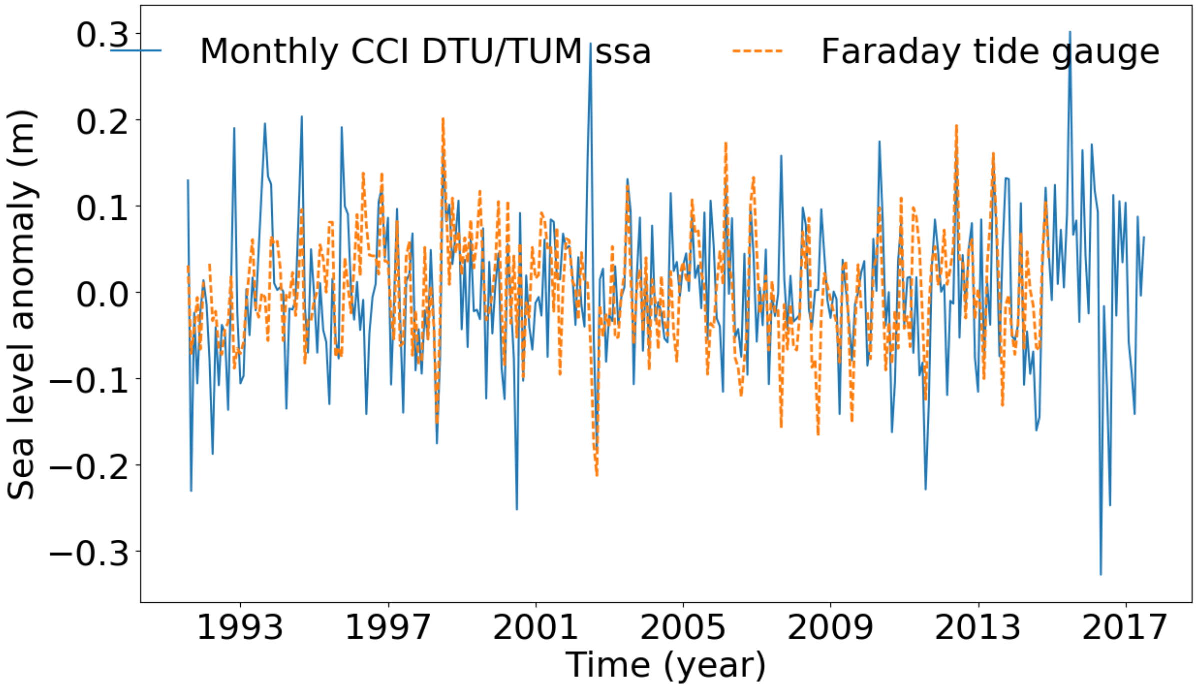

Figure 7 - Faraday time series. Comparison of monthly data from altimetry and tide gauge.

5. Discussion and conclusions

The sea level record presented here provides 25+ years of satellite altimetry data at high latitudes. Although several improvements have been made to obtain a more accurate sea level record, some challenges still remain.

The presence of sea-ice might still hamper the sea level retrieval due to the difficulty of discriminating between ocean, leads, and sea-ice covered regions, where useful sea levels can be determined. Sea-ice cover not only causes erroneous height estimates in the summer time when melt ponds are present, but it also lowers the data availability in winter time.

The inter-mission bias estimation is very simple and could be introducing some errors, especially to the trend in SLA.

Further investigations could include a more detailed validation study against tide gauges and other data products.

In the future, it would also be useful to include SARAL/AltiKa and Sentinel-3 data to the sea level record.

6. Obtaining the high latitude sea level record

The high latitude sea level anomalies are made freely available to the users under request at info-sealevel@esa-sealevel-cci.org.

7. References:

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