Spatial interpolation of SLA along-track measurements using Diva
Application to the coastal area of the NW Mediterranean Sea

Charles Troupin1, Alexander Barth2, Jean-Marie Beckers3, & Anaïda Pascual4
1IMEDEA (CSIC-UIB), Esporles, SP AIN
2GHER (ULg), San-Tilman, BELGIUM

Interpolating sparse in situ data onto a regular grid (gridding) is a common task in ocean sciences. There are numerous ways to do it, leading to a wide range of result qualities and numerical performances. We present the application and the adaptations of the Data-Interpolating Variational Analysis (Diva) to perform gridding on along-track sea-level anomaly (SLA) measurements.

Introduction - what are the problems?

Interpolating sparse in situ data onto a regular grid is a common task in ocean sciences. There are numerous ways to do it, leading to a wide range of result qualities and numerical performances. We present the application and the adaptations of the Data-Interpolating Variational Analysis (Diva) to perform gridding on along-track sea-level anomaly (SLA) measurements.

Analysis parameters

Two main parameters determine an analysis with Diva:

- The correlation length scale L, which measures the radius of influence of a data point. It is estimated by fitting the data correlation function to a theoretical function. The estimated value is \( L \approx 0.5 \).
- The signal-to-noise ratio \( \lambda \), which translates the confidence in the data, not only considering the measurement noise, but also the representativeness error. \( \lambda \) is estimated by cross-validation: several tracks are removed, then the analysis field is computed at the locations of the removed points, and finally the value of \( \lambda \) that minimizes the RMS of the misfits (data minus analysis at data location) is selected. The estimated value is \( \lambda \approx 3.0 \) (no units), though the analysis is not sensitive to this parameter.

Results

The results obtained with Diva, using the same data, are very close to AVISO maps (Figure 2). The different processing of the data (sub-sampling, filtering, ...) as well as different interpolation methods explain the slight discrepancies between the fields.

In order to produce daily fields for a 20-year period, the interpolation process has to be repeated hundreds of times, thus the computation time for a single interpolation plus the generation of the corresponding error field has to be kept as low as possible.

Space and time-averaged analysied fields

The time series of mean SLA (Figure 4), computed from the data or from the gridded fields, display the same features, with a typical seasonal cycle and the local extrema are correctly reproduced with both methods.

The time-averaged fields (Figure 5) obtained with Diva and AVISO only have little differences, while the main features are localised at the same places and with the same SLA amplitude. The high-resolution of the Diva fields provides more information in the coastal area.

Conclusions - assets of the method

- Diva is consistent method with a limited number of parameters and a natural consideration of the domain geometry.
- The software can be easily tailored to allow for automatic process and deal with large quantity of observations, without the need of sub-sampling or data reduction.
- The results of the interpolation are close to those provided by AVISO: the daily fields display the same features in the Mediterranean Sea (Figure 6), the seasonal cycles of the SLA are consistent with the along-track data (Figure 4) and the variance of the gridded fields follow the evolution (Figure 8).

Acknowledgements

The research leading to the last developments of Diva has received funding from the European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 283607, SeaDataNet 2, and from project EMODNET (MARE:2008/03 - Lot 3-Chemistry - SIZ-531432) from the Directorate-General for Maritime Affairs and Fisheries. Additional funding from the Local Government of the Balearic Islands (CAIB-51/2011 Grant) is also acknowledged. C. Troupin post-doctoral position is funded by MyOcean2 EU FP7 project.

References


How to get the code?

Diva source is available at https://gher.ulg.ac.be/medialink/index.php?DIVA and distributed under the terms of the GNU General Public License (GPL).

http://www.imedea.uib-csic.es and an online version is available for simple analysis:
https://gher-diva.flywheel.co.uk/web-via/Diva.html.

Download:

SLA data (delayed-time, updated products, unfiltered and not sub-sampled) are obtained from the AVISO FTP server.

Conversion:

The method is particularly well adapted to this type of data, since:

- it is designed to easily deal with large numbers of measurements (millions if desired, see Figure 3): no sub-sampling, no clustering;
- the geometry of the domain directly influences the interpolation through a natural adaptation of the covariance function: no need to separate the sub-basins prior to the interpolation;
- the low number of parameters allows a straightforward implementation to produce a complete data set.

Method - variational analysis

The gridded field (or analysis) is obtained as the solution of a cost function that penalizes:

1. The misfit between the measurements and the gridded field and 2. the regularity of the gridded field. The minimization of the cost function is done with the help of a finite-element technique: the solution is computed in a set of triangles covering the domain of interest, and the continuity of the solution across the triangles is assured.

Numerical cost

The timed averaged error field (Figure 7) reflects the data coverage. The largest errors are observed in coastal areas.

Comparison of the variances

The signal variance of Diva and AVISO products are consistent (Figure 8) and the noise reduction due to the interpolation is evidenced in the right panel.

Figure 1: The domain of interest and the data points (5149 measurements) for the period 6-13 May 2009, during which Envisat, Jason-1 and Jason-2 were available. The triangles constitute the finite-element mesh employed to solve the interpolation problem. For the global mesh on the Mediterranean Sea, the typical size of a triangle is 0.5°, while for the close-up view, this size is 0.1°.

Figure 2: Gridded SLA produced by AVISO (left) and Diva for the 14 February 2009 and the 15 May 2010.

Figure 3: Complied with a standard compiler (gfortran), the code provides an analysis with 5 million points in less than 23°60' on a 426 x 161 grid. Computer: processor (Intel Core(TM) 2 3.60 GHz CPU, 3.0 GHz, 3 M Cache, 1200 MHz, each size: 1280 KB).

Figure 4: Evolution of the space-averaged SLA (whole period and close-up view on 2006-2008) obtained from the along-track data and the gridded fields: the seasonal cycle and the local extrema are correctly reproduced with both methods.

Figure 5: Time-averaged SLA obtained for AVISO (14 October 1992 – 19 January 2011) and Diva (24 September 1992 – 9 July 2012).

Figure 6: Space-averaged error field obtained with Diva: the time evolution is mainly driven by the data availability.

Figure 7: Time-averaged error field obtained with Diva. The error is normalized by the variance of the background field. The geometry and repetitiveness of the altimeter tracks as well as the lower availability of coastal data are clearly visible.

Figure 8: Standard deviation of the SLA with respect to time (whole period and close-up view on 2006-2008), estimated from the along-track data and the gridded fields.