User Handbook:

Multivariate Inversion of Ocean Surface Topography- Internal Tide (MIOST-IT) Model products

Reference: CLS-ENV-NT-21-0319

Nomenclature: SALP-MU-P-EA-23507-CLS

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D : page deleted I : page inserted M : page modified

List of Acronyms:

GDR	Geophysical Data Record
IT	Internal Tide
MIOST	Multivariate Inversion of Ocean Surface Topographyv
SSH	Sea Surface Height

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1. Overview of this document

The purpose of this document is to describe the products distributed by Aviso+ : Multivariate Inversion of Ocean Surface Topography-Internal Tide (MIOST-IT) Model.

1.1. Acknowledgments

When using the MIOST-IT product, please cite: “Those products were designed, implemented and validated by CLS, OCEAN-NEXT and LEGOS and distributed by AVISO+ (https://www.aviso.altimetry.fr) with support from CNES”.

Reference: Clement Ubelmann, Loren Carrere, Chloé Durand, Gérald Dibarboure, Yannice Faugère and Florent Lyard: Simultaneous estimation of Ocean mesoscale and coherent internal tide Sea Surface Height signatures from the global Altimetry record, in preparation.

1.2. User’s feedback

Each question, comment, example of use, and suggestion will help us improve the product. You’re welcome to ask or send them to aviso@altimetry.fr.

1.3. Format

All the products are distributed in NetCDF with COARDS CF standards.

NetCDF (Network Common Data Form) is an open source, generic and multi-platform format developed by Unidata. An exhaustive presentation of NetCDF and additional conventions is available on the following web site: http://www.unidata.ucar.edu/packages/netcdf/index.html.

All basic NetCDF conventions are applied to files.

Additionally the files are based on the attribute data tags defined by the Cooperative Ocean/Atmosphere Research Data Service (COARDS) and Climate Forecast (CF) metadata conventions. The CF convention generalises and extends the COARDS convention but relaxes the COARDS constraints on dimension and order and specifies methods for reducing the size of datasets. A wide range of software is available to write or read NetCDF/CF files. Application Programming Interfaces (API) made available by UNIDATA (http://www.unidata.ucar.edu/software/netcdf):

- C/C++/Fortran
- Java
- MATLAB, Objective-C, Perl, Python, R, Ruby, Tcl/Tk.

2. Data content and use

MIOST-IT is a new global internal tide solution developed in 2017-2020. This new MIOST-IT model has been designed, implemented and validated by CLS, OCEAN-NEXT and LEGOS within a CNES funded project.

3. Description of the model construction and performances

The method relies on a simultaneous estimation of the mesoscales and coherent internal tides surface signatures. Indeed, the mesoscale signal is known to introduce errors in the tidal estimation (non-zero harmonics in a finite time window). To mitigate that issue, most existing methods subtract the low-frequency altimetry field from AVISO data as a proxy for mesoscales. However, the estimate of the mesoscale is itself contaminated by internal tides (e.g., [Zaron and Ray, 2018]) aliased into a low frequency, which also introduces errors. For these reasons, the MIOST-IT solution is based on a simultaneous estimation, accounting for the covariances of mesoscales and internal tides in a single inversion. In practice, these covariances are expressed as a reduced wavelet basis (local in time and space) for mesoscales and as a plane wave basis (local in space only) for internal tides. The plane wave wavelength and phase speed rely on the first and second Rossby radii of deformation climatology by [Chelton et al., 1998]. Although the inversion cannot be done explicitly (because of the long-time window extending the basis size for the mesoscale), a variational minimization allows for a converged solution after about 100 iterations (typical degree of freedom for the problem).

Four tidal waves have been estimated considering mode 1 and mode 2 of variability, from all altimetry satellites on the period January 1993-june 2017.

This solution stands well in the comparison to other internal tides solution (cf Figure and Table below). In particular, when compared to the Zaron [2019] model which is currently used in the last altimeter GDR databases, we found interesting differences with zones of improvements especially near generation sites, although improvements are not systematic everywhere.

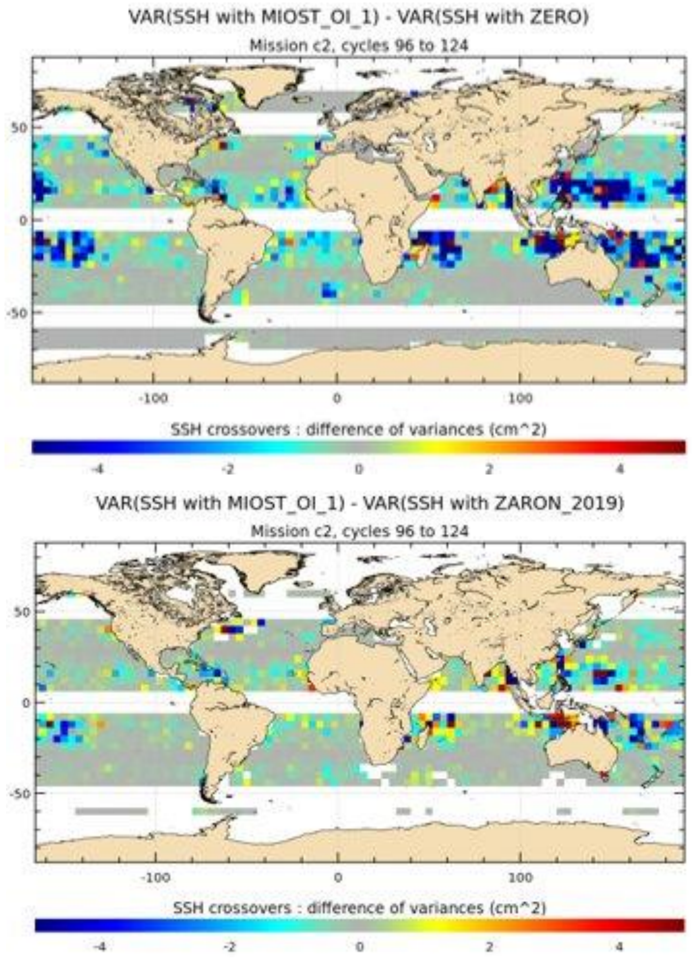

Figure 1: maps of reduction of Cryosat-2 SSH crossovers variance when using the new MIOST-IT M2 model instead of a zero IT correction (above), or instead of the Zaron-2019 M2 solution

Compared models	Global	Tahiti	Hawaii	Madagascar	Gulf of Guinea	Luzon	NATL	NPAC
MIOST – ZERO (cm^2)	- 1.26	- 2.19	- 1.93	- 2.20	-	- 4.26	- 0.24	- 0.60
%	**- 2.40**	**- 9.07**	**- 7.13**	**- 3.86**	-	**- 5.00**	- 0.91	**- 2.74**
MIOST – ZARON_2019 (cm^2)	- 0.16	- 0.43	- 0.16	0.04	-	- 1.12	- 0.10	- 0.02
%	- 0.39	**- 1.92**	- 0.63	0.07	-	**- 1.42**	- 0.38	- 0.09

Table 1: Mean reduction of Cryosat-2 SSH crossovers variance on global ocean, when using the new MIOST-IT M2 model instead of a zero IT correction, or instead of the Zaron-2019 M2 solution (in cm^2 and %). Analysis was conducted on C2 cycles 96-124, which are independent from both the MIOST-IT and the Zaron-2019 models. Negative values indicate an improvement when using the MIOST-IT solution.

The method and the validation diagnostics are further described in Ubelmann et al. (in prep.).

4. Description of the product

The four (M2, S2, K1, O1) internal tide elevations are available for download, distributed on 1/10° grids (amplitude and phase).

A simple prediction algorithm is also distributed within the MIOST-IT package to compute the internal tide height at any location of the world ocean.

4.1. Structure and semantic of provided NetCDF files

In addition to the conventions described above, the files are using a common structure and semantic. For example, headers have a common structure like the MIOST_OI_1_O1_formatCF.nc file :

```
netcdf MIOST_OI_1_O1_formatCF {
dimensions:
	lat = 1801 ;
	lon = 3600 ;
	nv = 2 ;
variables:
	double lat(lat) ;
		lat:long_name = "latitude" ;
		lat:bounds = "lat_bnds" ;
```

```
            lat:units = "Y" ;
            lat:axis = "degrees_north" ;
            lat:valid_min = -90. ;
            lat:valid_max = 90. ;
      double lon(lon) ;
            lon:long_name = "longitude" ;
            lon:bounds = "lon_bnds" ;
            lon:units = "X" ;
            lon:axis = "degrees_east" ;
            lon:valid_min = 0. ;
            lon:valid_max = 359.899993896484 ;
      float lat_bnds(lat, nv) ;
            lat_bnds:comment = "latitude values at the north and south bounds of each pixel." ;
            lat_bnds:units = "degrees_north" ;
      float lon_bnds(lon, nv) ;
            lon_bnds:comment = "longitude values at the west and east bounds of each pixel." ;
            lon_bnds:units = "degrees_east" ;
      int nv(nv) ;
            nv:comment = "Vertex" ;
            nv:units = "1" ;
      int crs ;
            crs:grid_mapping_name = "latitude_longitude" ;
            crs:semi_major_axis = 6371000. ;
            crs:inverse_flattening = 0. ;
      double amplitude(lat, lon) ;
            amplitude:FillValue = 1.844674e+19f ;
            amplitude:units = "cm" ;
            amplitude:long_name = "Sea surface height amplitude due to baroclinic ocean tide at
O1 frequency" ;
            amplitude:grid_mapping = "crs" ;
      double phase(lat, lon) ;
            phase:FillValue = 1.844674e+19f ;
            phase:units = "degrees" ;
            phase:long_name = "Sea surface height phase_lag due to baroclinic ocean tide at O1
frequency" ;
            phase:grid_mapping = "crs" ;

// global attributes:
            :cdm_data_type = "Grid" ;
```

:license = "http://www.aviso.oceanobs.com/fileadmin/documents/data/License_Aviso.pdf" ;

:product_version = "1.0" ;

:project = "DUACS" ;

:title = "MIOST-IT baroclinic tide elevations" ;

:summary = "Global internal tide solution based on a simultaneous inversion of both mesoscale and internal tide using altimeter measurements available between 01/1993 and 06/2017. Reference: Ubelmann et al., in preparation." ;

:credits = "CLS, OCEAN-NEXT, CNES, LEGOS" ;

:contact = "aviso@oceanobs.com" ;

:references = "https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/internal-tide-miost/" ;

:date_created = "2021-07-09 14:51:15" ;

:history = "2021-07-09 14:51:15:creation" ;

:standard_name_vocabulary = "NetCDF Climat and Forecast (CF) Metadata Convention Standard Name Table v37" ;

:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;

:Conventions = "CF-1.6" ;

:geospatial_lat_units = "degrees_north" ;

:geospatial_lon_units = "degrees_east" ;

:geospatial_lat_resolution = "0.1" ;

:geospatial_lon_resolution = "0.1" ;

4.2. Prediction algorithm

===============
ITPrediction.py
===============

This python script computes the internal tide predictions from MIOST-IT model on given latitude, longitude and time points and creates a netCDF file that contains the predictions.

The user must give an ascii file containing the points positions in space and time, the work directory and the list of waves for which the predictions will be computed.

WARNING: The MIOST-IT grids must be in /work_directory/DATA/
The predictions will be created in /work_directory/PREDICTIONS/
The ascii file must not contain a header

Usage:
=====

python ITPrediction.py argument1 argument2 argument3

argument1: ascii file (column 1: time in days since 1950-01-01,
column 2: latitude in degree North [-90:90],
column 3: longitude in degree East [0:360])
argument2: work directory
argument3: list of waves to take into account in the tidal prediction (can be one or several waves from : M2,S2,K1,O1)

Example of use:
=============

python ITPrediction.py /path/ascii_file.txt /path/work_directory/ M2,K1

Python version used: Python 2.7.12
=================

Test case:
========

>> python ITPrediction.py MeasureDumpGUI_J3_T61_C20.txt ./ M2,K1,O1,S2

File created is: PREDICTIONS/IT_prediction_M2+K1+O1+S2.nc

The prediction/ directory distributed on AVISO+ ftp contains 4 files:
==

- ITPrediction.py : prediction code
- MeasureDumpGUI_J3_T61_C20.txt : example of ascii file to use as argument1
- IT_prediction_M2+K1+O1+S2.nc : output file created by the prediction code if using the example ascii file above
- README.txt : this readme file

5. How to download the product

5.1. Registration

To access data, registration is required. During the registration process, the user shall accept using licenses for the use of AVISO+ products and services.

Register at:

http://www.aviso.altimetry.fr/en/data/data-access/registration-form.html

or, if already registered on AVISO+, connect to your account on the web site to add a product.

5.2. Access Services

The data access on the FTP server is authenticated on ftp://ftp-access.aviso.altimetry.fr/

Note that once your registration is processed (see above), AVISO+ will send you your own access (login/password) by e-mail as soon as possible (within 5 working days during working hours, Central European Time). If you don't enter your login/password, you will only be able to access to the anonymous FTP, where you will not find the data you're interested in.

References

Dudley B. Chelton, Roland A. deSzoeke, Michael G. Schlax, Karim El Naggar, and Nicolas Siwertz: Geographical Variability of the First Baroclinic Rossby Radius of Deformation DOI: https://doi.org/10.1175/1520-0485(1998)028%3C0433:GVOTFB%3E2.0.CO;2 pp 433–460

Clement Ubelmann, Loren Carrere, Chloé Durand, Gérald Dibarboure, Yannice Faugère and Florent Lyard: Simultaneous estimation of Ocean mesoscale and coherent internal tide Sea Surface Height signatures from the global Altimetry record, in preparation.

Zaron, E. D., and R. D. Ray, 2018: Aliased tidal variability in mesoscale sea level anomaly maps. J. Atmos. Oceanic Technol., https://doi.org/10.1175/JTECH-D-18-0089.1

Zaron, E. D., 2019: Baroclinic Tidal Sea Level from Exact-Repeat Mission Altimetry, J. Phys. Oceanogr., DOI: https://doi.org/10.1175/JPO-D-18-0127.1 , pp 193

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