World Ocean Circulation

Product User Manual
Ocean Fronts (Theme 2)

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1 Introduction

1.1 Purpose of the document

The present document is the Product User Manual dedicated to the content and format description of the Fronts product.

This is the primary document that users should read before handling the products. It provides an overview of processing algorithms, technical product content and format and main validation results.

1.2 Document structure

In addition to this introduction, this document includes the following chapters:

- Chapter 2 describes Ocean fronts product
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1.3 Applicable & Reference documents

- [RD-1] ESA WOC2019: http://woc2019.esa.int/index.php
- [RD-2] Synthesis of the WOC2019 User Consultation Meeting recommendations http://woc2019.esa.int/files/WOC2019_summary_synthesis.pdf

1.4 Terminology

ACCUA	Analisi della dinamica della Corrente CircUmpolare Antartica
AMSR2	Advanced Microwave Scanning Radiometer 2
ADT	Absolute Dynamic Topography
AI	Artificial Intelligence
AIL	Action Items List
AIS	Automatic Identification System
ASAR	Advanced Synthetic Aperture Radar
ASCAT	Advanced SCATterometer
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
CCD	Contract Closure Document

CCI	Climate Change Initiative
CCMP	Cross-Calibrated Multi-Platform
CFOSAT	Chinese-French Oceanography Satellite
CIESM	Mediterranean Science Commission
CMEMS	Copernicus Marine Environment Monitoring Service
CNES	Centre National d'Etudes Spatiales
CNR	Consiglio Nazionale delle Ricerche
CTD	Conductivity, Temperature and Depth
DP	Data Pool
DTU	Danmarks Tekniske Universitet
DUACS	Data Unification and Altimeter Combination System
EBUS	Eastern Boundary Upwelling System
ECCO	Estimating the Circulation & Climate of the Ocean
ECMWF	European Centre for Medium-Range Weather Forecasts
EFARO	European Fisheries and Aquaculture Research Organisations
EMB	European Marine Board
ENVISAT	Environmental Satellite
EO	Earth Observation
EPB	European Polar Board
EOEP-5	5th Earth Observation Envelope Programme (2017-2021)
ERA	ECMWF Reanalysis
ESA	European Space Agency
ESF	European Science Foundation
EU	European Union
EuroGOOS	European Global Ocean Observing System
FAO	Food and Agriculture Organization of the United Nations
FR	Final Report
FSLE	Finite Size Lyapunov Exponent
GCM	Global Circulation Model
GOCE	Gravity Field and Steady-State Ocean Circulation Explorer
GOOS	Global Ocean Observing System
GMI	Global precipitation monitoring Microwave Imager
GMM	Gaussian Mixture Models
HYCOM	Hybrid Coordinate Ocean Model
IAR	Impact Assessment Report
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICSU	International Council for Science
IGPB	International Geosphere-Biosphere Programme
IUGG	International Union of Geodesy and Geophysics
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IOC	Intergovernmental Oceanographic Commission
ITCZ	InterTropical Convergence Zone

mEOF-r	Multivariate Empirical Orthogonal Functions reconstruction
MoM	Minutes of Meeting
NATL3D	North Atlantic 3D Ocean Currents
NEMO	Nucleus for European Modelling of the Ocean
NOAA	National Oceanic and Atmospheric Administration
NCC	Norwegian Coastal Current
NwAFC	Norwegian Atlantic Front Current
NwASC	Norwegian Atlantic Slope Current
OLCI	Ocean and Land Color Imager
OSSE	Observing System Simulation Experiment
OC	Ocean color
OSCAT	Oceansat-2 SCATterometer
PD	Product Delivery
PM	Project Manager
PMP	Project Management Plan
PUB	Publication
PUM	Product User Manual
QUID	Quality Information Document
RB	Requirement Baseline
REMSS	Remote Sensing Systems
ROMS	Regional Oceanic Modeling System
RTOFS	Real-Time Ocean Forecast System
S3	Sentinel 3
SAR	Synthetic Aperture Radar
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SCOR	Scientific Committee on Oceanic Research
SIED	Single Image Edge Detection
SKIM	Sea surface KInematics Multiscale monitoring
SLSTR	Sea & Land Surface Temperature Radiometer
SOCIB	Sistema d'observació i predicció costaner de les Illes Balears
SODA	Simple Ocean Data Assimilation Ocean/sea ice reanalysis
SSH	Sea Surface Height
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
SoW	Statement of Work
TN	Technical Note
TOPAZ	Tracers of Phytoplankton with Allometric Zooplankton
TUOC	Total Upper Ocean Currents
UCL	Use Case Library
UCM	User Consultation Meeting
UCPC	Upper-layer ocean Circulation Processes e-Catalogue
UI	Upwelling Index

UN	United Nations
URD	User Requirement Document
VR	Validation Report
VT	Visualization Tool
WBS	Work Breakdown Structure
WOC	World Ocean Circulation

2 Ocean Fronts

2.1 Overview

The fronts product contains 1d polylines that represent the detected frontal structures in surface tracers such as the Sea Surface Temperature (SST). The algorithm relies on histogram of population analysis to detect edges pixels and contour following algorithm to retrieve the front structure. Several diagnoses are also retrieved along the fronts such as the tracer value, its gradient and the probability of having a front.

The input of the algorithm is a tracer observation (e.g. SST from SEVIRI), the output is a list of fronts coordinates and their corresponding properties.

2.2 Algorithm

2.2.1 Retrieval methodology

The following product of frontal structures are retrieved from Sea Surface Temperature (SST) remote sensing observation. We consider here the frontal structures as barriers of transport and thus the fronts are detected using population histogram. A front is present if two distincts populations are detected in the processed window.

To run the front analysis, the image is splitted into small windows (which size depends mainly on the resolution of the remote sensing observation).

The analysis can be either performed on a Single Image (Single Image Edge Detection, section 2.2.1.1) or on an ensemble of Images (Multiple Image Edge Detection, section 2.3).

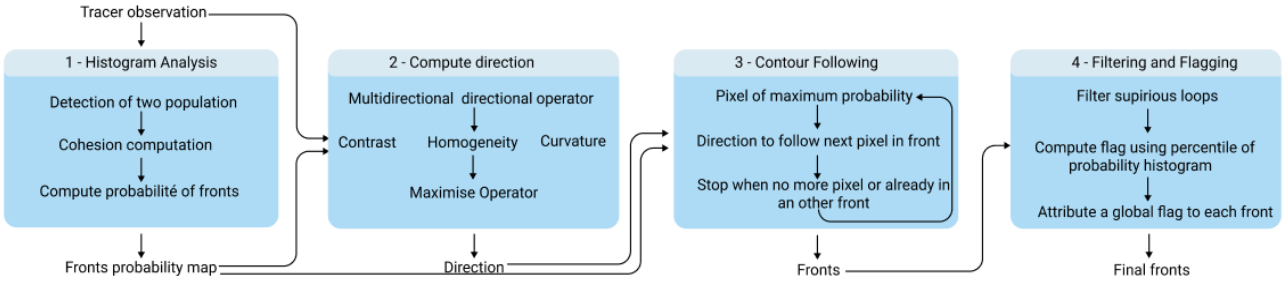
The strategy to compute the probability of fronts is very similar to the one implemented by Cayula and Cornillon (1992, 1994). The crest line following to retrieve a 1d front as a vector from the probability of front maps is a specific algorithm that relies on the property of the image in the neighborhood of the front (contrast, homogeneity, curvature).

2.2.1.1 Single Image Edge detection

This algorithm relies on the fronts detection algorithm SIED (Single Image Edge Detection) detailed in the ATBD []. The input is a tracer image, and the output are vectors representing frontal structures.

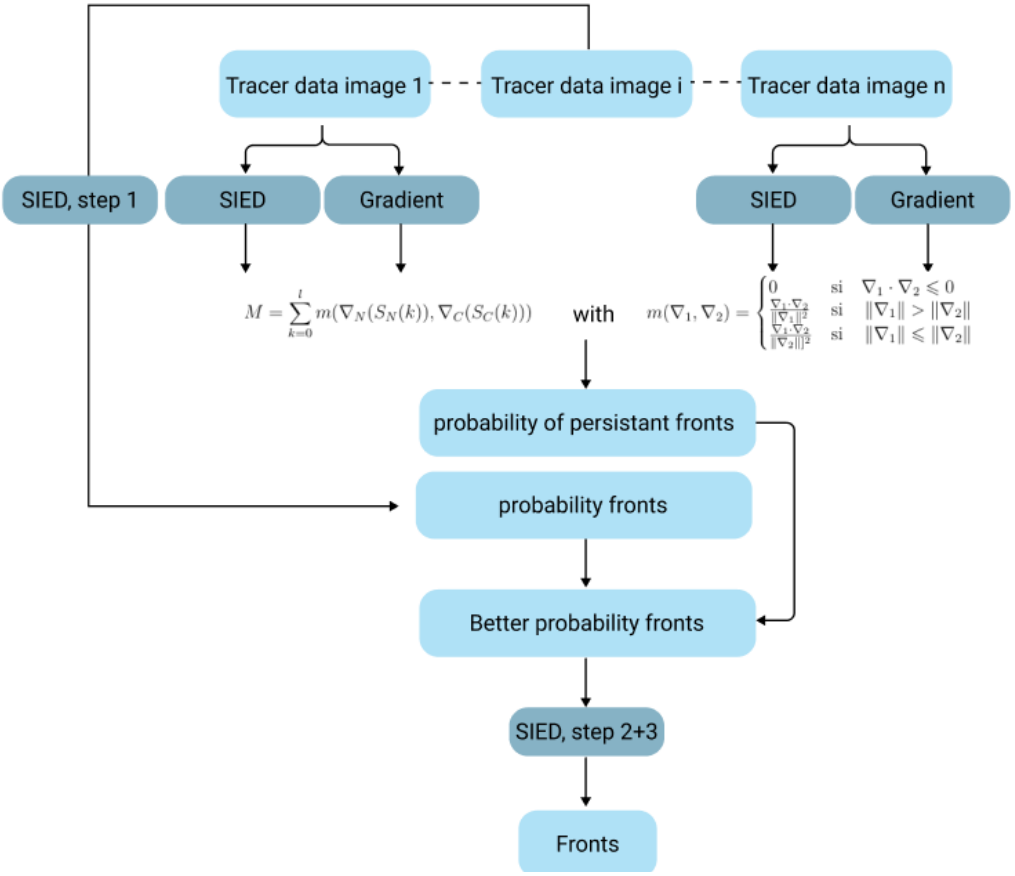
The algorithm is splitted into 4 parts.

- Histogram analysis
- Contour following
- Compute direction of fronts
- Flagging and smoothing



2.2.1.1 Multiple Image Edge detection

The multi-image algorithm aims at retrieving fronts that have been missed by the single image algorithm because of a cloud or noise on the single image processed. If a front is detected in other images close in time they can be added to the single image. The method implemented is similar to the one described in the ATBD [].



2.2.2 Limitations

2.2.3 Differences with previous version (if relevant, phase 2)

2.3 Product Description

2.2.1 spatial information

The resolution of the fronts corresponds to the one of the input tracer data:

Sensor	Spatial resolution
Microwave OI L4	25 km
SEVIRI L3C	~ 5 km

Table 1: Spatial resolution by sensor

2.2.1 temporal information

One dataset (file) is produced for each input file, thus the temporal resolution is the same as the input tracer

Sensor	Temporal resolution
Microwave OI L4	1 day
SEVIRI L3C	1 hour

Table 2: Temporal resolution by sensor

Sensor	Temporal period
Microwave OI L4	2010/01/01 -> 2021/12/31
SEVIRI L3C	2011-08-01 -> 2021-12-31

Table 3: Temporal period by sensor

WARNING: Microwave OI L4 sensor data may be degraded in the period 2010-2012 as no AMSR data were available

2.2.1 product content

The product contains the following variables:

- List of fronts, each list contains a list of pixel for the following variables
  - lon: Longitude
  - lat: Latitude
  - row: Corresponding row in the original tracer file
  - col: Corresponding column in the original tracer file
  - dir: Direction of the front
  - sst: sst tracer value at the location (ºK)
  - sst_grad_lon: sst gradient along longitude coordinate (ºK/km),
  - sst_grad_lat: sst gradient along latitude coordinate (ºK/km)
  - sst_grad: sst gradient norm (ºK/km)
  - sst_quality_level: if a quality level is attributed to the original tracer, the quality level is reported here
  - probability: Probability of having a front as computed per the histogram of population analyses
  - flags: Flag value attributed to the pixel
- Attribute for each front (list):
  - flag_front: flag attributed to the front derived from the ‘flags’ variable
- Meta data (one string value):
  - 'time_coverage_start': Start time validity for the input dataset
  - 'time_coverage_end': End time validity for the input dataset

2.2.1 file name convention

The file naming follows this convention:

[sensor]_[variable]_woc_t[theme number]_%Y%m%dT%H%M%S.json

with [sensor] the satellite sensor or the type of product used, [variable] the geophysical quantity that has been used, theme number the area that has been chosen (area that corresponds to theme 1, 2, 3 or 4).

Example of file name for fronts retrieved using SEVIRI SST image:

seviri_sst_woc_t2_20180416T040000.json

2.2.1 file format

The file is a json file that contains a dictionary. Data can be loaded using common json reading libraries.

2.2.1 metadata