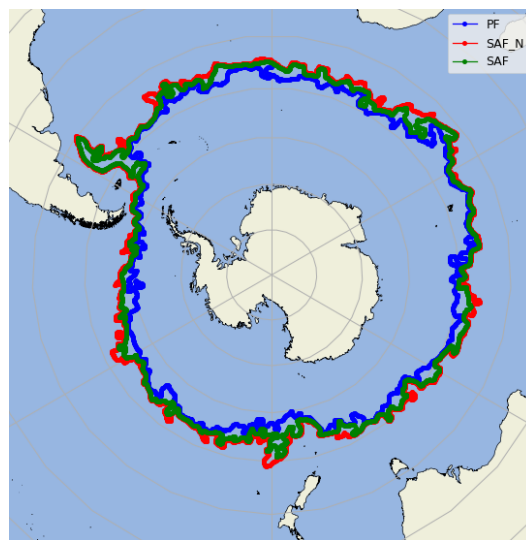




Antarctic Circumpolar Current Fronts Product Handbook

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i.1

Chronology Issues:

Issue:	Date:	Reason for change:
1.0	14/03/2023	1 st issue

List of Acronyms:

ADT	Absolute Dynamic Topography (=SLA+MDT)
AVISO+	Archivage, Validation et Interprétation des données des Satellites Océanographiques
CMEMS	Copernicus Marine Environment Monitoring Service
CNES	Centre National d'Etudes Spatiales
DUACS	Data Unification and Altimeter Combination System
MDT	Mean Dynamic Topography (difference between Mean Sea Surface (MSS) and Geoid)
NetCDF	Network Common Data Format
SLA	Sea Level Anomaly (a.k.a. sea surface height with respect to a mean sea surface)
ACC	Antarctic Circumpolar Current
CTOH	Centre of Topography of the Oceans and the Hydrosphere
PF	Polar Front
SAF-S	Southern branch of the Subantarctic Front
SAF-N	Northern branch of the Subantarctic Front

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1. Overview of this document

This document is the user manual for the **Antarctic Circumpolar Current (ACC) - fronts** products, processed by CTOH. The document is organized as follows:

- Chapter 2; presentation
- Chapter 3; processing: input data and method applied
- Chapter 4; product description, with the different files provided, the nomenclature & the file format
- Chapter 5; how to download products.

2. Antarctic Circumpolar Current (ACC) - fronts

Altimetric absolute dynamic topography data have been used as a proxy to track the time-varying position of the three main fronts of the Antarctic Circumpolar Current (ACC) - the Polar Front, and the northern and southern branches of the Subantarctic Front (SAF-N and SAF-S).

The mean and time-varying positions of the main Southern Ocean polar fronts are calculated from the Copernicus Absolute Dynamic Topography data: the global $0.25^\circ \times 0.25^\circ$ daily product (SEALEVEL_GLO_PHY_L4_MY_008_047). This dataset is used to monitor the position of the three main fronts of the Antarctic Circumpolar Current (ACC) - the Polar Front, and the northern and southern branches of the Subantarctic Front (SAF-N and SAF-S)

Southern Ocean polar front isocontour definitions :

- Polar Front (PF) is associated with the -0.30 m ADT contour;
- Southern (main) branch of the Subantarctic Front (SAF) with the -0.10 m ADT contour
- Northern branch of the Subantarctic Front (SAF-N) with the 0 m ADT contour

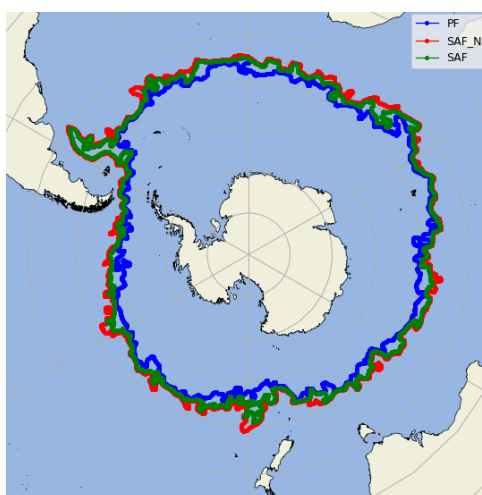


Figure 1: Mean Polar Fronts during the week 2012/03/05

2.1. Acknowledgments

When using the **Antarctic Circumpolar Current (ACC) - fronts** product, please cite "The Antarctic Circumpolar Current (ACC) - fronts product DOI: 10.24400/527896/a01-2023.004 was produced by CTOH and distributed by AVISO+ (<https://www.aviso.altimetry.fr/>) with support from CNES. "

2.2. User's feedback

The product is an **experimental** product.

Therefore, each and every 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.

3. Processing

3.1. Input data

The data used are described in Table 1.

Product	Input data	Variable	Origin
PF SAF-S SAF-N	0.25°x0.25° daily Delayed Time DUACS2021 version https://doi.org/10.48670/moi-00148	Gridded Global Absolute Dynamic Topographies (ADT)	Copernicus Marine Service (CMEMS) http://marine.copernicus.eu/

Table 1: Input product used

3.2. Algorithm

The original technique, developed by Sallée et al. (2008), assumes that iso-contours of satellite absolute dynamic topography (ADT) can be proxies for the traditional sub-surface hydrographic definition of the main Southern Ocean fronts. The technique identifies an ADT contour that coincides with a maximum sea surface height gradient, that is itself associated with a sub-surface front.

In the presence of time variations in intensity, splitting, and merging of fronts, we cannot expect the primary fronts to be uniquely defined or identified by a single ADT contour at every time. They can be ambiguous at certain times within their zone of strong amplitude variability. However, Sallée et al (2008) found that a single satellite ADT contour can be associated with the sub-surface definition of the front so that most of the time (for instance, 98% in the case of the PF), they would be colocated based on a suite of traditional definitions. We note that this SSH contouring method can be influenced by large-scale sea level rise or more local phenomena, and it is not precise enough to study the long-term evolution of the fronts' position.

Sallée et al. (2008) defined the iso-contours using their own Absolute Dynamic Topography field, constructed using DUACS/AVISO sea level anomalies from the period 1993-2005, and a Mean Dynamic Topography field that combined available Southern Ocean Argo profiles (1999-2006) and a long-term historical Southern Ocean Data Base of temperature-salinity profiles (<http://woceSOatlas.tamu.edu>), with a reference level of no motion chosen at 1500 m. ADT isocontours were then validated by statistically comparing them against the following traditional subsurface hydrographic definition of the main Southern Ocean fronts :

Polar Front (PF) is defined as the northern limit of the Antarctic Winter Water (AAWW) as the tongue of 2°C water at 200 m (Orsi et al., 1995).

Subantarctic Front (SAF) can be defined as the maximum in the meridional gradient of temperature at 300 m, and this was used by Sallée et al. (2008) to define their SAF contour.

The ADT isocontour depends strongly on the Mean Dynamic Topography (MDT) surface used, and its zero reference level. For Sallée et al. (2008), this reference level was at a fixed 1500 m depth, and the ADT isocontours for the SAF were set at 1.2 m, and at 0.95 m for the PF. In this early version, the polar fronts had one value per longitude, and meanders were not tracked.

In follow-up work, Sallée et al. (2008b) extended the estimate to track 3 major polar fronts : they calculated **two branches of the SAF and the PF**, following the isocontour definition of Sokolov and Rintoul, 2007. The three ADT isocontours were set as : the SAF-N at 1.35 m; the SAF-S at 1.2 m; and 0.95 m for the PF. These contours all used the Sallée et al. (2008) MDT with a zero reference level at 1500 m.

Recent updates :

Tracking the polar fronts using an ADT isocontour technique is still based on the principle described in [Sallée et al. 2008] but with the following changes:

- it has been extended over a longer period
- it is now able to represent meanders of the ocean fronts

We note that to represent the meanders, the front is now defined with latitude & longitude parameters at each weekly timestep, and is no longer on a fixed longitude grid.

Latest version changes:

1) Since 2018, these iso-contours have been updated using the mean dynamic topography (MDT) from CNES-CLS2013 (Rio et al., 2014) that includes more data and allows for a varying reference level, depending on the data depth (Rio et al., 2011). In the Southern Ocean's frontal region, these new MDT products range from -30 to +0 cm, giving an offset in the mean iso-contours compared to Sallée et al (2008)'s fixed 1500 m reference level contours. These new definitions of the Southern Ocean Front isocontour definitions, based on the MDT CNES-CLS2013, have been validated against in-situ sections south of Australia by Auger (2018).

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2) This version is now able to represent meanders of the ocean fronts, with circumpolar fronts that can loop and have multiple latitude-longitude positions in their weekly maps. In order to represent the meanders, the front latitude and longitude parameters now depend on time.

4. Description of the product

4.1. Product general content and specifications

Covered period	Spatial coverage	Delivery format
1993 – 2021	ACC	3 files for the weekly positions of the 3 polar fronts

Table 2: Characteristics of the Antarctic Circumpolar Current (ACC) - fronts Product.

4.2. Nomenclature of files

CTOH_NorthernSubantarcticFront_weekly_1993_2021

CTOH_SouthernSubantarcticFront_weekly_1993_2021

CTOH_PolarFront_weekly_1993_2021

4.3. NetCDF

The products are stored using the NetCDF CF format. NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The NetCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The NetCDF software was developed at the Unidata Program Center in Boulder, Colorado. The NetCDF libraries define a machine-independent format for representing scientific data. Please see Unidata NetCDF pages for more information on the NetCDF software package: <http://www.unidata.ucar.edu/packages/netcdf/>

NetCDF data is:

- Self-Describing. A NetCDF file includes information about the data it contains.
- Architecture-independent. A NetCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- Direct-access. A small subset of a large dataset may be accessed efficiently, without first reading through all of the preceding data.
- Appendable. Data can be appended to a NetCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a NetCDF dataset can be changed, though this sometimes causes the dataset to be copied.
- Sharable. One writer and multiple readers may simultaneously access the same NetCDF file.

The NetCDF version provided here is version 4 “classic”.

4.4. Structure and semantic of NetCDF files

Variable name	Description	Units
PF or SAF_S or SAF_N	Latitudes of Polar Front Latitudes of Southern Subantarctic Front Latitudes of Northern Subantarctic Front	Degrees North
longitude	Longitude of the front position	Degrees East
time	days since 1950-01-01 00:00:00 UTC	Days

Table 3: Structure and semantic of the Antarctic Circumpolar Current (ACC) - fronts files.

5. How to download a product

5.1. Registration

To access data, registration is required. During the registration process, the user shall accept using [license](#) for the use of AVISO+ products and services.

- if not registered on AVISO+, please, fill the form and select the product '**Antarctic Circumpolar Current (ACC) - fronts**' on <http://www.aviso.altimetry.fr/en/data/data-access/registration-form.html>
- if already registered on AVISO+, please request the addition of this '**Antarctic Circumpolar Current (ACC) - fronts**' product on your personal account on <https://www.aviso.altimetry.fr/en/my-aviso-plus.html>

5.2. Access Services

Note that once your registration is processed (see above), AVISO+ will validate your registration by e-mail as soon as possible (within 5 working days during working hours, Central European Time). The access information will be available in your personal account on <https://www.aviso.altimetry.fr/en/my-aviso-plus.html>.

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- Sokolov, S., and Rintoul, S.R., 2007: Multiple jets of the Antarctic Circumpolar Current south of Australia. *J. Phys. Oceanogr.*, 37, 1394-1412.

7. Appendix A. Product header

Example given below for the file : CTOH_NorthernSubantarcticFront_weekly_1993_2021:

```
netcdf CTOH_NorthernSubantarcticFront_weekly_1993_2021 {
dimensions:
    time = UNLIMITED ; // (1513 currently)
    longitude = 3628 ;
variables:
    float SAF_N(time, longitude) ;
        SAF_N:_FillValue = 2.147484e+09f ;
        SAF_N:standard_name = "latitude" ;
        SAF_N:long_name = "Latitudes of Northern Subantarctic Front at
associated longitudes" ;
        SAF_N:units = "degrees_north" ;
    float longitude(time, longitude) ;
        longitude:_FillValue = 2.147484e+09f ;
        longitude:standard_name = "longitude" ;
        longitude:long_name = "Longitude of the front Position" ;
        longitude:units = "degrees_east" ;
    float time(time) ;
        time:_FillValue = 2.147484e+09f ;
        time:standard_name = "time" ;
        time:long_name = "Time" ;
        time:units = "days since 1950-01-01" ;

// global attributes:
    :title = "SAF_N Position computed from Copernicus Global ADT" ;
    :description = "Northern Subantarctic Front weekly position,
computed from weekly averaged Copernicus Delayed Time ADT product. ADT
contour 0 is used. Front identification method is from Sallee (2008), but
adapted with the new ADT dataset." ;
    :doi = "10.24400/527896/a01-2023.004" ;
    :source = "http://marine.copernicus.eu/services-
portfolio/access-to-
products/?option=com_csw&view=details&product_id=SEALEVEL_GLO_PHY_L4_REP_OB
SERVATIONS_008_047" ;
    :reference = "Sallée, J. B., K. Speer, and R. Morrow, 2008:
Response of the Antarctic Circumpolar Current to Atmospheric Variability.
J. Climate, 21, 3020-3039, https://doi.org/10.1175/2007JCLI1702.1" ;
    :institution = "CTOH/LEGOS/CNRS-CNES-IRD-Université de Toulouse
III" ;
    :Conventions = "CF-1.6" ;
    :copyright_statement = "Copyright CTOH/LEGOS" ;
    :distribution_statement = "Free with clear reference" ;
    :authors = "Original version: JB Sallee/LEGOS-CTOH, This new
version: Matthis Auger/CTOH" ;
}
```

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