El Niño Southern Oscillation Product Handbook

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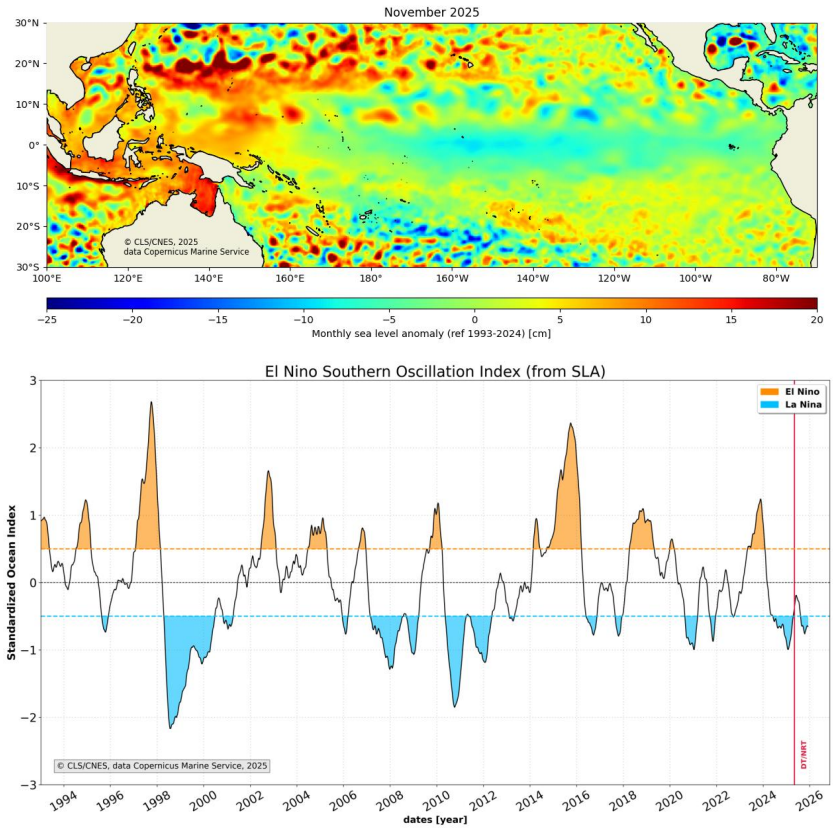

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Chronology Issues:		
Issue:	Date:	Reason for change:
1.0	07/12/2025	1st issue

List of Acronyms:

ADT	Absolute Dynamic Topography (=SLA+MDT)
AVISO+	Archivage, Validation et Interprétation des données des Satellites Océanographiques
C3S	Copernicus Climate Change Service http://climate.copernicus.eu/
CLS	Collecte Localisation Satellites
CMEMS	Copernicus Marine Environment Monitoring Service
CNES	Centre National d'Etudes Spatiales
DUACS	Data Unification and Altimeter Combination System
ENSO	El Niño Southern Oscillation
NetCDF	Network Common Data Format
SLA	Sea Level Anomaly (a.k.a. sea surface height with respect to a mean sea surface)
SST	Sea Surface Temperature

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1. Introduction

In the tropical Pacific, the interaction between the ocean and the atmosphere is responsible for the biggest natural climate phenomenon in the world: the El Niño Southern Oscillation (ENSO), which occurs every 2 to 7 years. El Niño is the warm phase of ENSO. During El Niño, the surface of the water in the central and eastern tropical Pacific is warmer than average. An El Niño event is associated with a typical weakening of surface winds that blow from east to west along the equator. The opposite phase, called La Niña, is when the sea surface is colder than average in the tropical Pacific and easterly surface winds become stronger. Changes in the ocean and atmosphere during El Niño and La Niña events have a big effect on local weather patterns in Southeast Asia and Oceania, the tropical Pacific, South of America and other regions of the world. Both El Niño and La Niña events are also closely linked to important social and economic issues. They can have severe environmental and human consequences when they are at their strongest.

Explanation of the phenomenon, chronology of the events since 1992, forecasting and impacts on the world climate: https://www.aviso.altimetry.fr/en/applications/climate/el-nino.html

2. Overview of this document

This document is the user manual for the El Niño Southern Oscillation (ENSO) Ocean Indicator product, processed by CNES/CLS.

The ENSO index is based on the altimeter sea level anomalies over the Nino3.4 region in the Pacific Ocean. The annual, seasonal cycles and 60-day signal have been filtered out and the sea level trend has been removed. The ENSO index is also derived from the sea surface temperature over the Nino3.4 region in the Pacific Ocean. The annual, seasonal cycles and 60-day signal have been filtered out.

Monthly normalized time series are computed.

This document describes the delayed-time version DT2024, released in November 2025.

The document is organized as follows:

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

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3. The El Niño Southern Oscillation (ENSO) Ocean Indicator product

3.1. Acknowledgments

When using the **ENSO Ocean Indicator product**, please cite:

"The ENSO (El Niño Southern Oscillation) Ocean Indicator product is produced and made freely available by AVISO and DUACS teams". AVISO/DUACS, 2025. El Niño Southern Oscillation Ocean Indicator product (vDT2024) [Data set]. CNES. https://doi.org/10.24400/527896/A01-2025.008

3.2. User's feedback

The product is an **operational** product.

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

4. Processing

4.1. Input data

The data used are described in Table 1.

Input data	Variable	Origin
"all-satellite" daily Delayed Time DUACS2024 version https://doi.org/10.48670/moi-00146	Gridded Global **Sea Level Anomalies (SLA)**	Copernicus Marine Service (CMEMS) http://marine.copernicus.eu/
"all-satellite" daily Near-Real-Time DUACS2024 version https://doi.org/10.48670/moi-00149		
NOAA 1/4° Daily Gridded **Optimum Interpolation Sea Surface Temperature (OISST)** V2.1 version	Gridded Global **Sea Surface Temperature (SST)**	Huang et al., 2021 Optimum Interpolation Sea Surface Temperature (OISST) | National Centers for Environmental Information (NCEI)

Table 1: Input products used

4.2. Algorithm

The main processing steps are described in this section.

4.2.1. Computation of SLA and SST Indexes

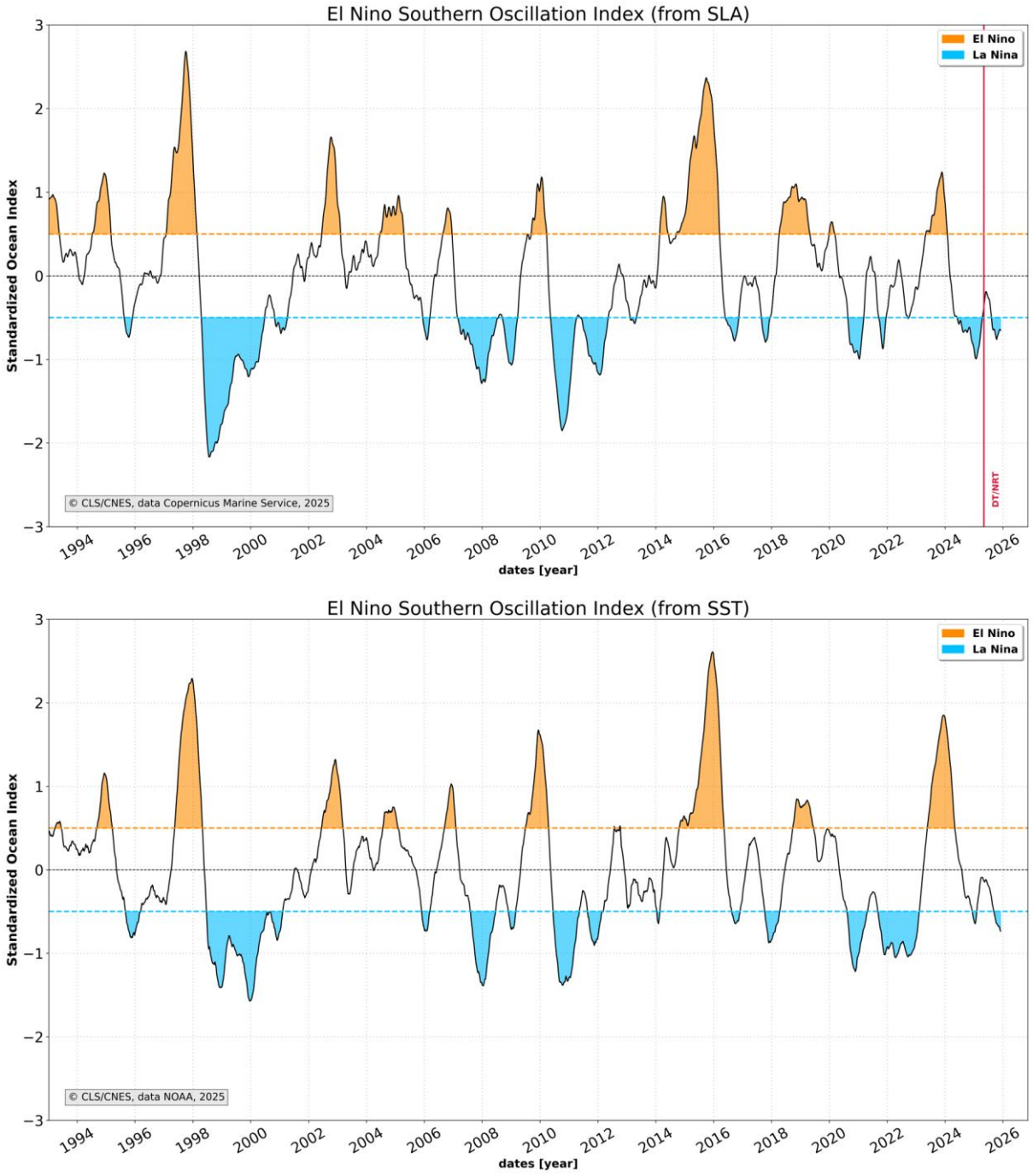

Figure 1: Index of El Niño Southern Oscillation from SLA (top) and SST (bottom)

4.2.1.1. preprocessing

The reference time for the preprocessing is 1993-01-06 to 2024-12-25.

For each 7 days grid and each point of the grid, the coefficients corresponding to the fit in eq 1 are estimated:
2 sets of (K_0, K_1 and sin_$c_{1,2,3}$ and cos_$c_{1,2,3}$) for SLA and SST.

$$for\ X = SLA\ and\ SST, fit\ (X) = K_{X0} + K_{X1} * T + \sum_{i=1}^{n} \left(\text{sin\_}c_{Xi} * \sin\frac{2\,\pi\,T}{p_i} + \text{cos\_}c_{Xi} * \cos\frac{2\,\pi\,T}{p_i}\right) \quad \text{Eq.1}$$

Where
n=3 for SLA and n=2 for SST
p_1=365.25 days
p_2=182.625 days
p_3=60 days (SLA only)
and T is the time of the map.

For the two variables (for X = Sea Level Anomaly (SLA) or Sea Surface Temperature (SST)), the mean and standard deviation over the reference time are calculated:

$$M(X - fit(X))_{ref}$$

and

$$STD(X - fit(X))_{ref}$$

4.2.1.2. Index computation

For each map of day D, we compute

$$index_D = \frac{fit(X_D) - M(X - fit(X))_{ref}}{STD(X - fit(X))_{ref}} \quad \text{Eq. 2}$$

Then a 85-days rolling window filtering is applied and a spatial mean over the Nino3.4 region (5°S to 5°N /190°E to 240°E) is estimated.

4.2.2. Computation of SLA and SST maps

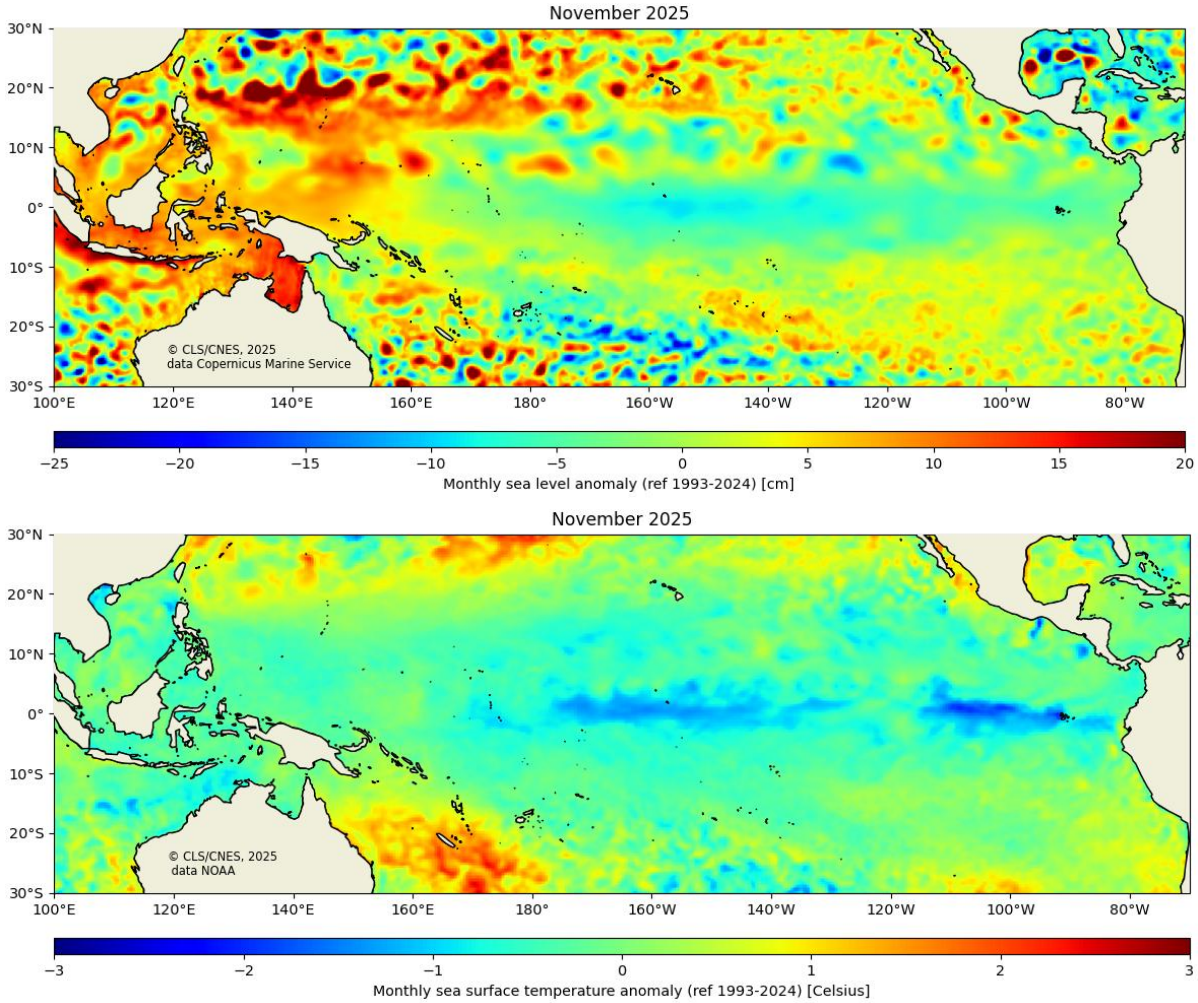

Figure 2: Monthly means of Sea Level Anomalies (top) and Sea Surface Temperature (bottom) over the Tropical Pacific, annual and seasonal cycles removed.

The processing is the monthly average Over 30°S to 30°N / 100°E -290°E of:

$$fit(X_D) - M(X - fit(X))_{ref}$$

5. Description of the product

5.1. Product general content and specifications

Covered period	Spatial coverage	Delivery format	Update
01/01/1993 – ongoing, the end date is updated every month	Maps: 30°S to 30°N 100°E -290°E	Maps of Sea Level Anomalies monthly mean over the Tropical Pacific, annual and seasonal cycles removed (png file) Maps of Sea Surface Temperature monthly mean over the Tropical Pacific, annual and seasonal cycles removed (png file)	Every month
	Index: Nino3.4: 5°S to 5°N 190°E to 240°E	Normalised Index of Sea Level Anomalies over the Nino3.4 region (png and netcdf files) Normalised Index of Sea Surface Temperature over the Nino3.4 region (png and netcdf files	

Table 2: Characteristics of the El Niño Southern Oscillation product.

5.2. Nomenclature of files

As described in Table 2, there are:

5.2.1. Maps of Sea Level Anomalies and Sea Surface Temperature monthly means:

https://www.aviso.altimetry.fr/fileadmin/images/data/Products/indic/enso/Msla_MoyMens_PacTrop_latest.png
https://www.aviso.altimetry.fr/fileadmin/images/data/Products/indic/enso/Sst_MoyMens_PacTrop_latest.png
The previous maps are also available here:
https://bulletin.aviso.altimetry.fr/html/produits/indic/enso/welcome_uk.php

5.2.2. Normalised Indexes of Sea Level Anomalies and Sea Surface Temperature:

Figures:
https://www.aviso.altimetry.fr/fileadmin/images/data/Products/indic/enso/Msla_nino34_index.png
https://www.aviso.altimetry.fr/fileadmin/images/data/Products/indic/enso/Sst_nino34_index.png
Netcdf files:
Msla_nino34_index.nc
Sst_nino34_index.nc

5.3. 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”.

5.4. Structure and semantic of NetCDF files

Variable name	Description	Dimensions	Units or Type
time	days since 1950-01-01	(time)	days
enso	filtered El Niño-Southern Oscillation (from SLA or SST) index	(time)	count

6. How to download a product

Two services for downloading:

HTTPS service:

https://data.aviso.altimetry.fr/aviso-gateway/data/indicators/enso/

CNES AVISO THREDDS Data Server access:

https://tds%40odatis-ocean.fr:odatis@tds-odatis.aviso.altimetry.fr/thredds/catalog/el-nino-southern-oscillation/catalog.html

7. Bibliography

Huang, B., C. Liu, V. Banzon, E. Freeman, G. Graham, B. Hankins, T. Smith, and H.-M. Zhang, 2021: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1, Journal of Climate, 34, 2923-2939. doi: 10.1175/JCLI-D-20-0166.1

8. Appendix A. Product header

8.1. SLA

```
netcdf Msla_nino34_index {
dimensions:
	time = 1718 ;
variables:
	float time(time) ;
		time:_FillValue = NaNf ;
		time:units = "days since 1950-01-01" ;
		time:calendar = "gregorian" ;
	double enso(time) ;
		enso:_FillValue = NaN ;
		enso:standard_name = "filtered sea level anomaly index" ;
		string enso:long_name = "filtered El Niño-Southern Oscillation (from SLA) index" ;
		enso:units = 1LL ;

// global attributes:
		string :title = "El Niño-Southern Oscillation (ENSO) phase variations index" ;
		:institution = "CLS" ;
		:references = "https://www.aviso.altimetry.fr" ;
		:convention = "CF-1.7" ;
		:credit = "CLS,CNES" ;
		:contact = "" ;
		:source = "The values are based on the delayed-time and near real time altimeter
sea level product [DT2024] produced by Copernicus Marine Service." ;
		:license = "" ;
		:area = "PACIFIC" ;
		string :comment = "Zone: 190-240°E; 5°S-5°N; Event: DT/NRT, Date: 2025-05-07" ;
		string :processing = "time=[1993-01-06,2025-12-03]; lat=[-5.0, 5.0]; lon=[190, 240];
step time:7.0 days; step lat:0.125°, lon:0.125°; reference 1993-01-06 to 2024-12-25; fit = K0
+ K1*T + SUMi[ sin_ci*sin(2*Pi*T/period_daysi) + cos_ci*cos(2*Pi*T/period_daysi) where T
= time-reference in days; remove periods [365.25  182.625  60.   ] days; remove mean and
trend; z-score calculation; rolling window over 85 days" ;
}
```

8.2. SST

```
netcdf Sst_nino34_index {
dimensions:
	time = 1718 ;
variables:
	float time(time) ;
		time:_FillValue = NaNf ;
		time:units = "days since 1978-01-01T12:00:00" ;
		time:calendar = "proleptic_gregorian" ;
	double enso(time) ;
		enso:_FillValue = NaN ;
		enso:standard_name = "filtered sea surface temperature anomaly index" ;
		string enso:long_name = "filtered El Niño-Southern Oscillation (from SST) index" ;
		enso:units = 1LL ;

// global attributes:
		string :title = "El Niño-Southern Oscillation (ENSO) phase variations index" ;
		:institution = "CLS" ;
		:references = "https://www.aviso.altimetry.fr" ;
		:convention = "CF-1.7" ;
		:credit = "CLS,CNES" ;
		:contact = "http://marine.copernicus.eu/services-portfolio/contact-us/" ;
		:source = "The values are based on the delayed-time and near real time OISST from
NOAA." ;
		:license = "http://marine.copernicus.eu/services-portfolio/service-commitments-
and-licence/" ;
		:area = "PACIFIC" ;
		string :comment = "Zone: 190-240°E; 5°S-5°N; Event: DT/NRT, Date: 2025-11-19" ;
		string :processing = "time=[1993-01-06,2025-12-03]; lat=[-5.0, 5.0]; lon=[190, 240];
step time:7.0 days; step lat:0.25°, lon:0.25°; reference 1993-01-06 to 2024-12-25; fit = K0 +
K1*T + SUMi[ sin_ci*sin(2*Pi*T/period_daysi) + cos_ci*cos(2*Pi*T/period_daysi) where T =
time-reference in days; remove periods [365.25  182.625] days; remove mean and trend; z-
score calculation; rolling window over 85 days" ;
}
```


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