

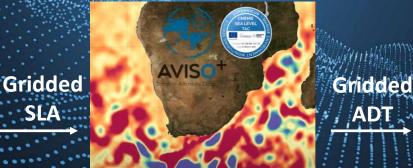


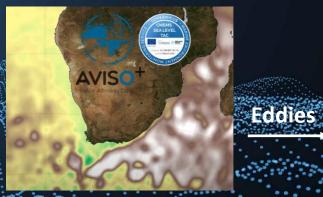
## A New Global Mesoscale Eddy Trajectories Atlas Derived from Altimetry : Presentation and Future Evolutions

Cori Pegliasco, <u>Antoine Delepoulle</u>, Clément Busche, Rosemary Morrow, Yannice Faugère, Gerald Dibarboure

Along-track SLA











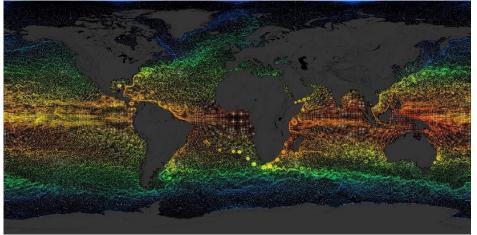
- Context
- Mesoscale Eddy Trajectory Atlas
  - from META2.0 to META3.1exp
  - from META3.1exp to META3.2
- Evolution to a representation with Networks
- Conclusions



## Context



#### **Currents colored by Sea Surface Temperature**



#### **Transport capacity :**

Mesoscale eddies that rotate faster than they move can transport water over long distances, and thus participate to the redistribution of heat, salt, biology and chemical components around the globe.

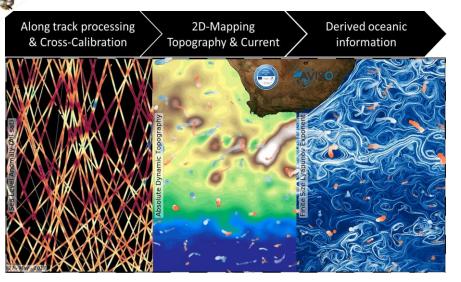
#### Typical size and duration

Mesoscale eddies range from tens to hundreds of kilometers, and span days to years.

#### **Kinetic Energy**

Mesoscale eddies participate to more than 50% of the kinetic energy in the ocean, more than the mean currents.

Credit : NASA/Goddard Space Flight Center Scientific Visualization Studio



#### **Altimetry maps :**

Altimetry satellites provide data since 1993 at global scale, merged into 2D daily maps of Sea Surface Height (SSH) with a resolution of 0.25° x 0.25°.

#### Mesoscale eddies detection :

Cyclonic Eddies are associated with lows in the SSH. Anticyclonic Eddies are associated with highs in the SSH.

Searching for local extrema in the SSH field is often used to detect the centers of mesoscale eddies.

## META: Mesoscale Eddy Trajectory Atlas

## **META2.0**:

Input maps : Sea Level Anomaly (C3S, DT2018)

Detection scheme : based on Chelton et al., 2011 (Oregon State University)

Tracking scheme : Closest eddy in a restricted area

Available on the **AVISO+** website : <u>https://www.aviso.altimetry.fr/en/data/</u> <u>products/value-added-products/global-</u> <u>mesoscale-eddy-trajectory-product.html</u>





## META: Mesoscale Eddy Trajectory Atlas



Available on the **AVISO+** website : <u>https://www.aviso.altimetry.fr/en/data/</u> <u>products/value-added-products/global-</u> <u>mesoscale-eddy-trajectory-product.html</u>



## **DUACS** From META2.0 to META3.1exp

## **META : Mesoscale Eddy Trajectory Atlas**





Available on the **AVISO+** website : <u>https://www.aviso.altimetry.fr/en/data/</u> <u>products/value-added-products/global-</u> mesoscale-eddy-trajectory-product.html



#### <u>Input maps</u> : Absolute Dynamic Topography (<u>C3S</u> & <u>CMEMS</u>, **DT2018**, **DT2021**) <u>Detection scheme</u> : based on <u>Mason et al., 2014</u> (Py-Eddy-Tracker) <u>Tracking scheme</u> : eddies' contours overlap



META3.1exp – META3.2:

DT2018)

a restricted area

<u>Chelton et al., 2011</u> (Oregon State University)

Don't use it

anymore

ΜΕΤΑ

Input map

**Detection** scheme

Tracking scher

https://www.aviso.altimetry.fr/en/data/ products/value-added-products/globalmesoscale-eddy-trajectory-product.html



### **Recommended** for scientific applications

, DT2021) Input maps : Absolute Dynamic Topography (<u>C3S</u> & <u>CMEMS</u>, D Detection scheme : based on Mason et al., 2014 (Py-Eddy-Tracker) Tracking scheme : eddies' contours overlap



3S, DT2018)

a restricted area

## META: Mesoscale Eddy Trajectory Atlas

Don't use it

anymore

**JACS** 

META

Input map

**Detection** scheme

Tracking scher

Available on the **AVISO+** website : <u>https://www.aviso.altimetry.fr/en/data/</u> <u>products/value-added-products/global-</u> <u>mesoscale-eddy-trajectory-product.html</u>

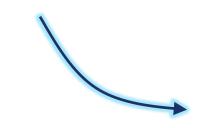


## META3.1exp – META3.2:

<u>Chelton et al., 2011</u> (Oregon State University)

**Recommended** for scientific applications

Input maps : Absolute Dynamic Topography (<u>C3S</u> & <u>CMEMS</u>, **D. 6**, **DT2021**) Detection scheme : based on <u>Mason et al., 2014</u> (Py-Eddy-Tracker) <u>Tracking scheme :</u> eddies' contours overlap



## **META4.0exp – Networks:**

<u>Input maps :</u> Absolute Dynamic Topography (<u>CMEMS</u>, DT2021) <u>Detection scheme :</u> based on <u>Mason et al., 2014</u> <u>Tracking scheme :</u> eddies' contours overlap <u>Management of the interactions : merging and splitting events</u> DT2018)

a restricted area

## META: Mesoscale Eddy Trajectory Atlas

Don't use it

anymore

**JACS** 

ΜΕΤΑ

Input ma

**Detection** scheme

Tracking scher

Available on the **AVISO+** website : <u>https://www.aviso.altimetry.fr/en/data/</u> <u>products/value-added-products/global-</u> <u>mesoscale-eddy-trajectory-product.html</u>



Chelton et al., 2011 (Oregon State University)



**Recommended** for scientific applications

Input maps : Absolute Dynamic Topography (<u>C3S</u> & <u>CMEMS</u>, **D**, **b**, **b**, **b**, **c**, **DT2021**) <u>Detection scheme :</u> based on <u>Mason et al., 2014</u> (Py-Eddy-Tracker) <u>Tracking scheme :</u> eddies' contours overlap

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## **Mesoscale Eddy Trajectory Atlas**

- from META2.0 to META3.1exp
- from META3.1exp to META3.2



## From META2.0 to META3.1exp

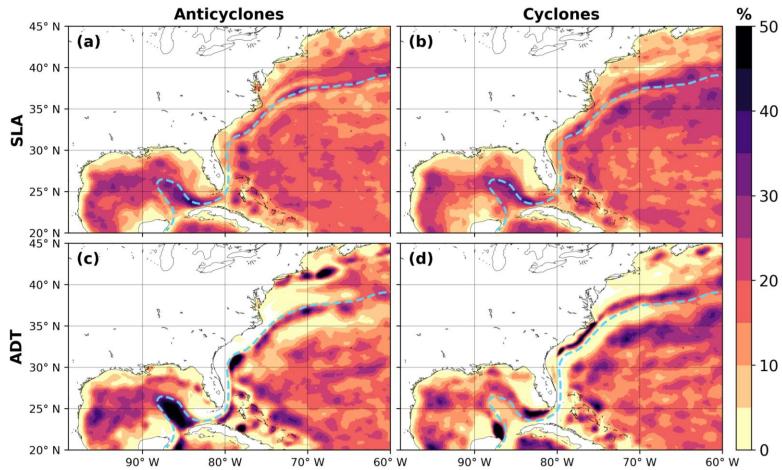
#### Changes in the pre-processing :

DUACS

- SLA → ADT : Detection on the absolute dynamic topography maps allow a better representation of the recurrent and quasi permanent eddies
- 1000 km → 700 km wavelength for the filter : Gradients filtered, largescale efficiently removed

**Reference :** Pegliasco, C., Delepoulle, A., Mason, E., Morrow, R., Faugère, Y., Dibarboure, G., 2022. META3.1exp: a new global mesoscale eddy trajectory atlas derived from altimetry. Earth Syst. Sci. Data 14, 1087-1107 <u>https://doi.org/10.5194/essd-14-1087-2022</u>

## **DUACS** From META2.0 to META3.1exp



 Sea Level Anomaly : Anticyclonic Eddies and Cyclonic Eddies are almost homogeneous in both the Gulf of Mexico and the Gulf Stream
 regions.

Absolute Dynamic Topography : Anticyclonic Eddies and Cyclonic Eddies have distinct

**preferential locations** in agreement with the know structures :

- Anticyclonic Loop Current Eddies flanked
- by Frontal Loop Current Cyclonic Eddies in the Gulf of Mexico
- Alternance of Cyclonic and Anticyclonic
   Eddies bands related to small recirculations
   near the Gulf Stream vein and to large
   detached eddies at larger distance

Percentage of time spend by each pixel within anticyclones detected in (a) SLA and (c) ADT maps and within cyclones detected in (b) SLA and (d) ADT maps. The dashed blue line follows the velocity maximum of the current.

**Reference :** Pegliasco, C., Delepoulle, A., Mason, E., Morrow, R., Faugère, Y., Dibarboure, G., 2022. META3.1exp: a new global mesoscale eddy trajectory atlas derived from altimetry. Earth Syst. Sci. Data 14, 1087-1107 <u>https://doi.org/10.5194/essd-14-1087-2022</u>

### From META2.0 to META3.1exp

#### Changes in the pre-processing :

- SLA → ADT : Detection on the absolute dynamic topography maps allow a better representation of the recurrent and quasi permanent eddies
- 1000 km → 700 km wavelength for the filter : Gradients filtered, largescale efficiently removed

#### Changes in the detection scheme :

#### **Oregon State University** → **Py Eddy Tracker** :

- Amplitude threshold :  $1 45 \text{ cm} \rightarrow 0.4 \text{ cm}$
- Extremum authorized : multiple → only one
- Contours are available

#### Changes in the tracking scheme :

#### **Restricted area** $\rightarrow$ overlap of contours

Shorten the long lifetime threshold : **28 days**  $\rightarrow$  **10 days** 

- Increase of the number of detected eddies :
   ~30 million → ~75 million
   ~20 million eddies in META2.0 are similar in META3.1exp
- Large META2.0 eddies with 2 extrema are artefact structures and are not present in META3.1exp
   Illustration :

#### https://www.youtube.com/watch?v=4Vs3ZJNMViw

• **Contours** allow better colocation of external data

**Reference :** Pegliasco, C., Delepoulle, A., Mason, E., Morrow, R., Faugère, Y., Dibarboure, G., 2022. META3.1exp: a new global mesoscale eddy trajectory atlas derived from altimetry. Earth Syst. Sci. Data 14, 1087-1107 <u>https://doi.org/10.5194/essd-14-1087-2022</u>



## **Mesoscale Eddy Trajectory Atlas**

- from META2.0 to META3.1exp
- from META3.1exp to META3.2



## DUACS

Altimetry maps are built from the altimetry data and gridded products are at the end of a long processing chain.

Regularly, the parameters of the processing chain are modified to improve the quality of the altimetry maps.

Recently, the processing version changed from DT2018 to DT2021 [1] are :

- New Mean Dynamic Topography (MDT) resolving shorter scales
- New Internal Tides correction
- Evolution of the correlation scales (Lx, Ly, Lt)
- Improvement of the ice-sea transition
- Changes in the energy near the Equator

Statistics from **META3.1exp** illustrates the content of the **DT2018** maps, and **META3.2** illustrates the **DT2021** maps for the all-satellites version.

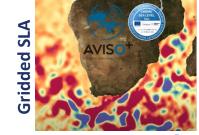
The maps available on the Copernicus Marine Service website are produced with the DT2021 reprocessing.



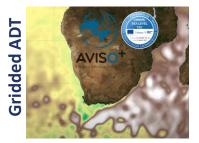
[1] Global Delayed Time SSH maps SEALEVEL\_GLO\_PHY\_L4\_MY\_008\_047 <u>https://doi.org/10.48670/moi-00148</u> <u>https://catalogue.marine.copernicus.eu/documents/QUID/</u> CMEMS-SL-QUID-008-032-068.pdf Corrections Retracking Calibration



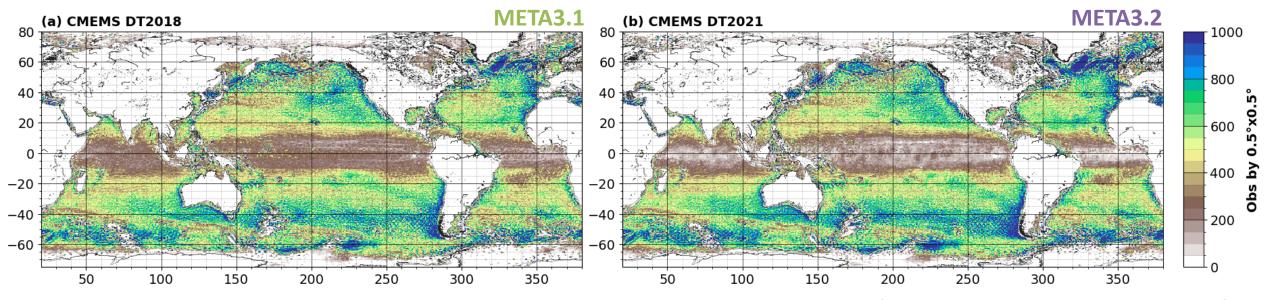
Cross calibration Mapping

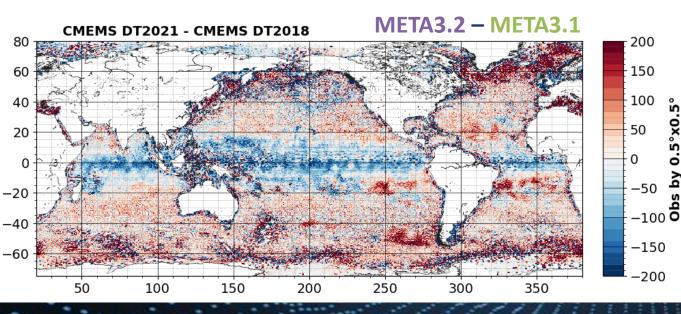


Add MDT



### From META3.1exp (ADT maps DT2018) to META3.2 (ADT maps DT2021)

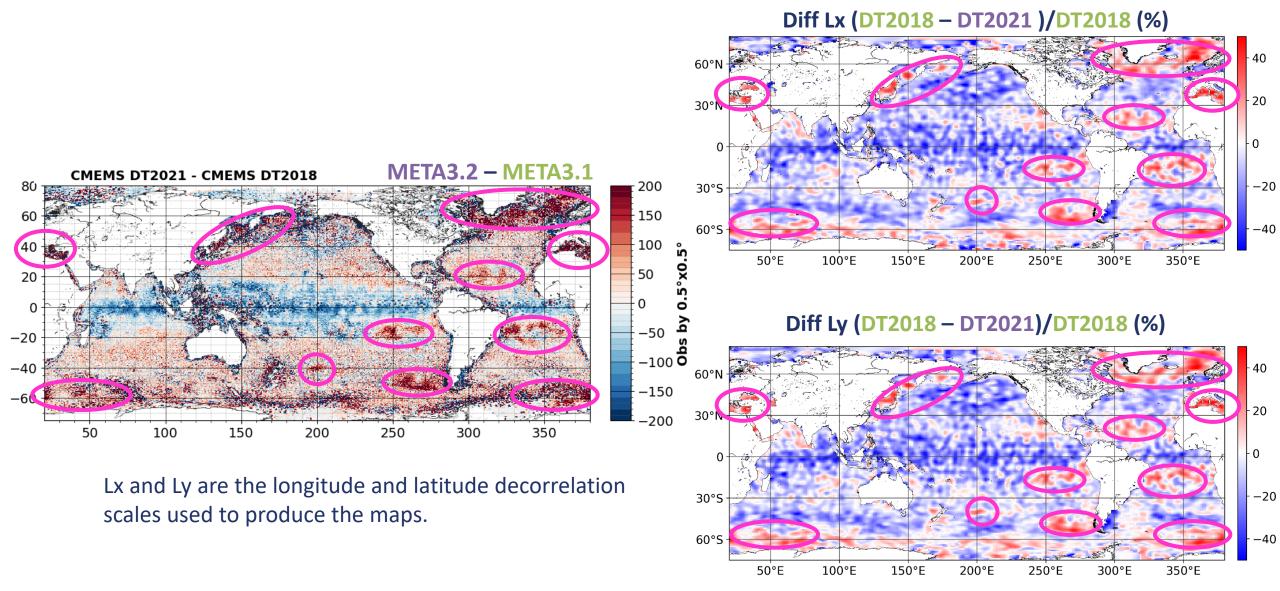




DUACS

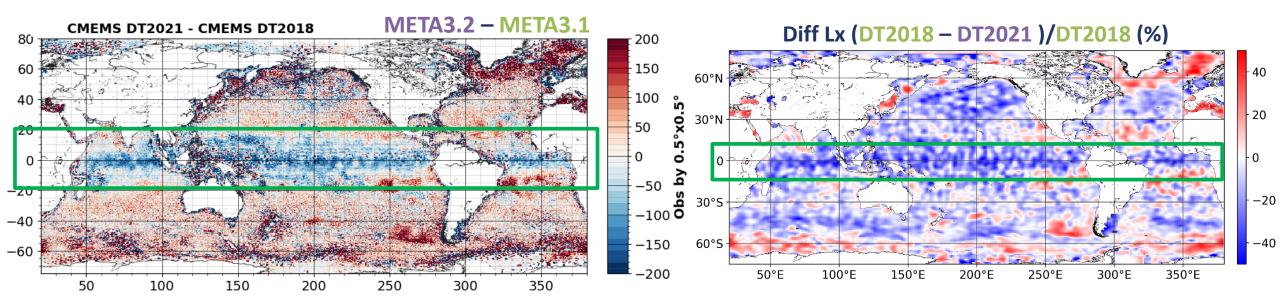
**Top** : number of eddy observations **centers** part of trajectories lasting more than 10 days in 0.5°x0.5° boxes, detected from (a) **DT2018** and (b) **DT2021** Absolute Dynamic Topography daily maps from January 1993 to March 2020.

**Bottom** : Difference of **DT2021** and **DT2018**. Red correspond to more eddy observations in from **DT2021** (META3.2), blue to more eddy observations in **DT2018** (META3.1). DUACS



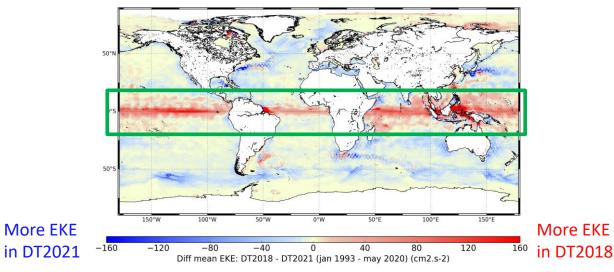
18

## From META3.1exp (DT2018) to META3.2 (DT2021) : Lx and Ly changes

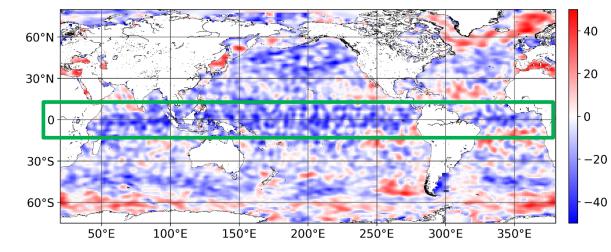


Diff of mean EKE DT2018 – DT2021

DUACS

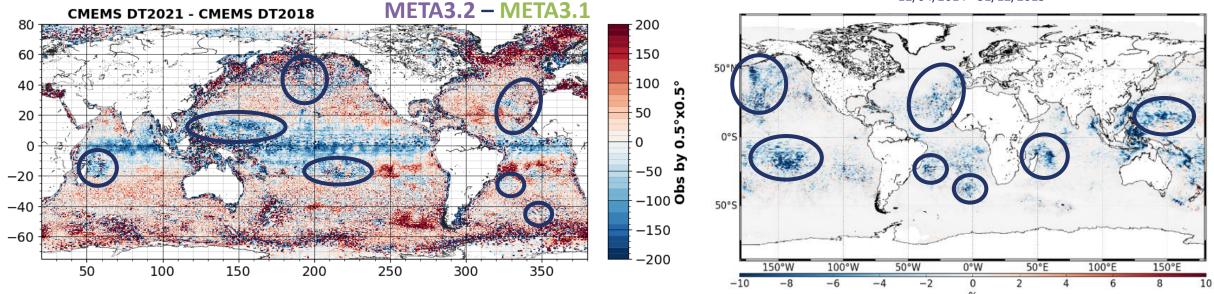


#### Diff Ly (DT2018 - DT2021)/DT2018 (%)



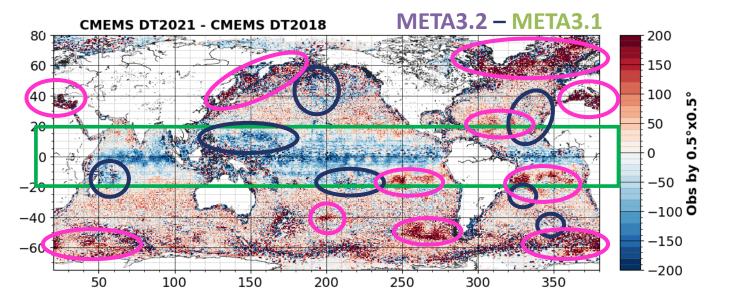
#### **EKE reduction (%) when applying Internal Tide correction**

**DT2021 – DT2018** 12/04/2014 - 31/12/2015



DUACS

Less EKE due to the Internal Tide correction in **DT2021**  $\rightarrow$  Less detected eddies in **META3.2** 



- → More eddies are detected in META3.2 due to a better representation of the mesoscale from Lx and Ly adjustments in DT2021
- → Less eddies are detected in META3.2 in the Equatorial Band because of the reduction of the EKE in the DT2021 reprocessing due to the increase of the decorrelation scales
- → Less eddies are detected in META3.2 in the areas where the internal tide correction decreases the EKE in DT2021

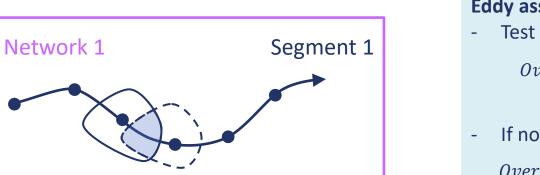


## **Evolution to a representation with Networks**

**Use META3.2 detected eddies** 



#### META4.0exp – Networks : construction DUACS



#### Eddy association : overlap of the contours

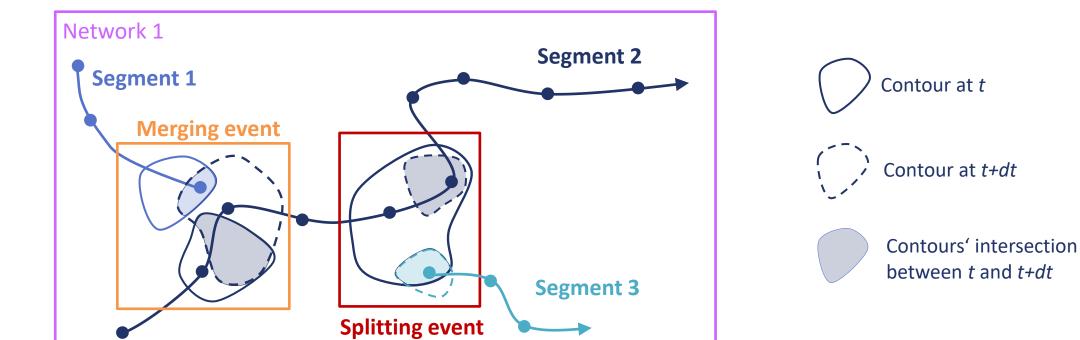
Test if

$$Overlap Ratio_{union} = \frac{\text{Area} (\text{Eddy}_t) \cap \text{Area} (\text{Eddy}_{t+dt})}{\text{Area} (\text{Eddy}_t) \cup \text{Area} (\text{Eddy}_{t+dt})} \ge 10\%$$

If not, test

 $Overlap Ratio_{minimal area} =$ 

$$\frac{\text{Area}\left(\text{Eddy}_{t}\right) \cap \text{Area}\left(\text{Eddy}_{t+dt}\right)}{\min(\text{Area}\left(\text{Eddy}_{t}\right),\text{Area}\left(\text{Eddy}_{t+dt}\right))} \ge 99\%$$

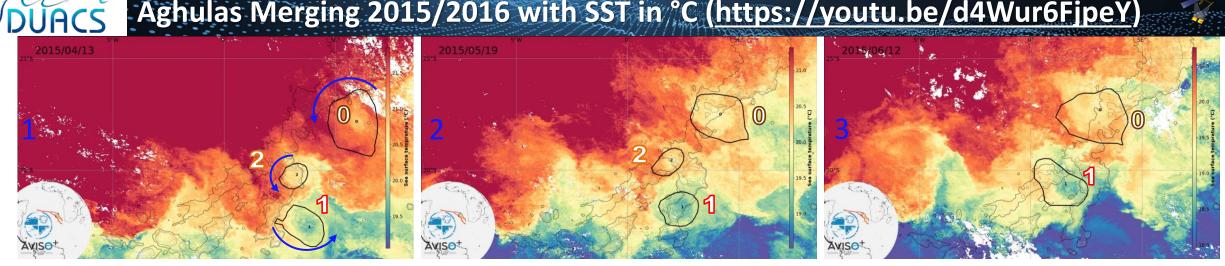


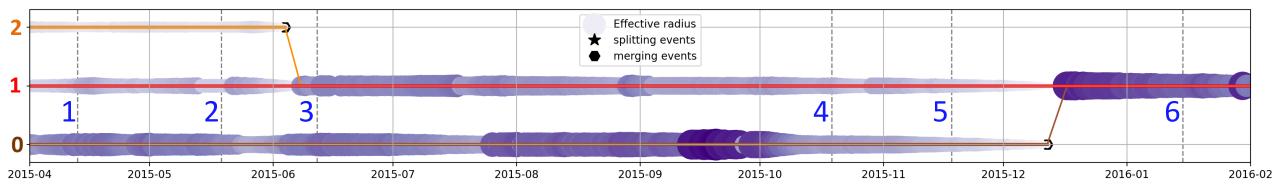
Network experiencing a merging and a splitting event

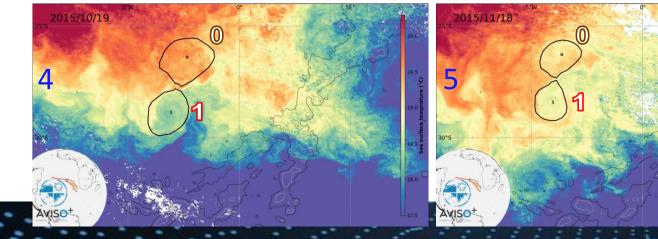
Network with a

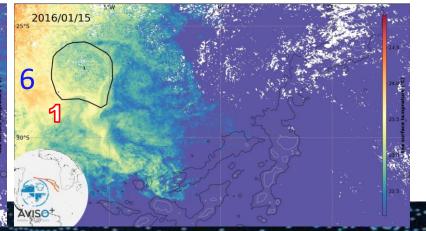
unique segment

## Aghulas Merging 2015/2016 with SST in °C (https://youtu.be/d4Wur6FjpeY)









## **DUACS** META4.0exp – Networks : global statistics

For the period 1993 – 2022 :

- ~2.1 million networks
- ~2.8 million segments
- ~72 million detected eddies (~2,5 million by year)

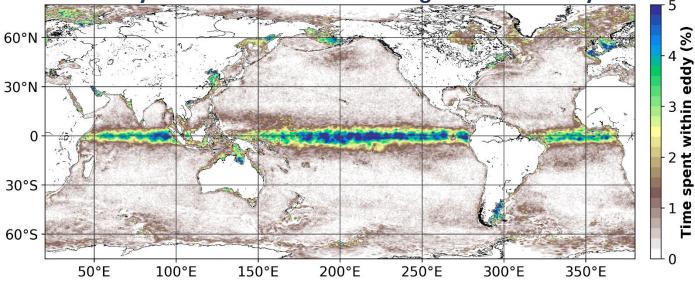
## **Lonely eddies and networks lasting less than 10 days :** ~0.9 million networks

- ~1.1 million segments
- ~4 million detected eddies (5% of the dataset) Location :
- In the Equatorial Band
- In shallow areas
- At high latitudes

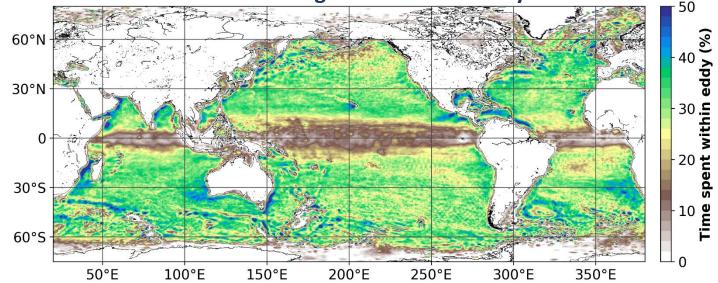
#### Networks lasting at least 10 days :

- ~1.2 million networks
- ~1.7 million segments
- ~68 million detected eddies Location :
- In the major currents
- In known eddy favorable areas
- Very few in the Equatorial Band

#### Lonely eddies and networks lasting less than 10 days



#### Networks lasting at least than 10 days



## **DUACS** META4.0exp – Networks : global statistics

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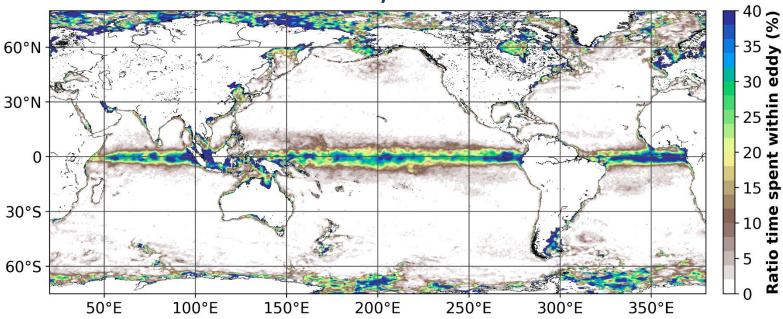
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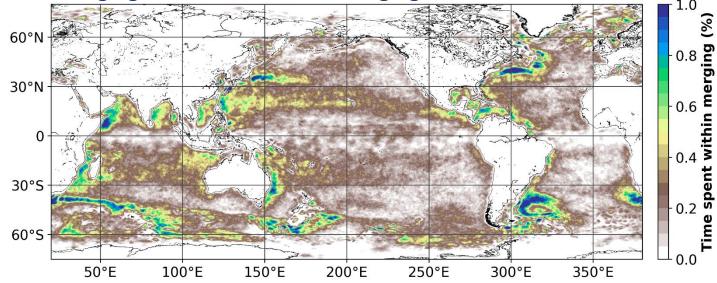
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#### Ratio short / all networks

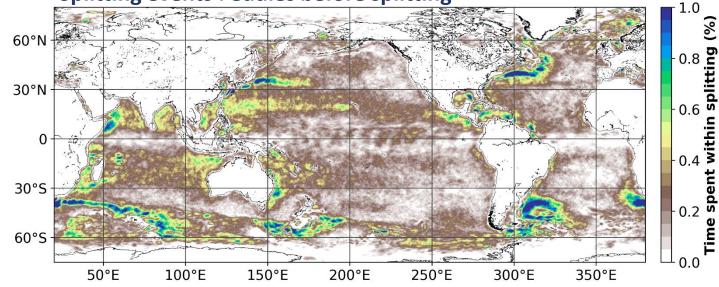


## **META4.0exp** – Networks : global statistics



#### Merging events eddies after merging

#### **Splitting events : eddies before splitting**



### Interactions in networks lasting more than 10 days :

- 83% Networks with no interactions
- ~280 000 merging events

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- ~280 000 splitting events
- ~95% of the events occur in networks lasting more than 30 days



## Conclusions





# META2.0 Don't use it anymore

Publication in ESSD <u>https://doi.org/10.5194/essd-14-1087-2022</u> META3.1exp : A new Global Mesoscale Eddy Trajectories Atlas derived from altimetry

# **Recommended** for scientific applications

Eddy dataset												
Product	Satellite	DOI	Authenticated access service	Frequency	Data period	Handbook						
Merged version 3.2 delayed- time	allsat	10.24400/527896/a01- 2022.005.220209		yearly	From Jan 1993 to February 2022	Handbook						
	twosat	10.24400/527896/a01- 2022.006.220209	see your MY AVISO+									
	allsat	10.24400/527896/a01- 2022.005.210802	Available on demand (aviso@altimetry.fr)		From Jan 1993 to August 2021	Handbook (1rev0)						
	twosat	10.24400/527896/a01- 2022.006.210802										

Data access on AVISO : <u>https://www.aviso.altimetry.fr/en/data/products/value-</u> <u>added-products/global-mesoscale-eddy-trajectory-</u> <u>product/meta3-2-dt.html</u>

META3.1exp – META3.2

- Regular temporal updates
- DOIs for the different versions
- Handbook
- Newsletter when a new dataset is released



#### **Online documentation :**

#### <u>Welcome to py-eddy-tracker's documentation! — py-eddy-tracker v3.6.0+27.g9d408e5.dirty documentation</u>

🕈 py-eddy-tracker	<b>Eddy detection</b> Method to detect eddies from grid and display, with various parameters.			Network				VV Z
				Warning				Try it! <
	3. 60 C	8 720 cm	12 <sup>-1</sup>	Network is under development, API could move quickly!			LAN	
v3.5.0 Search docs					_24 Bass		3 4 4	
INSTALLATION	Display contour & circle	Display identification	Radius vs area					
How do I get set up ?				Network segmentation	Network Analysis	Replay segmentation	Network group process	
TOOLBOX GALLERY: Py eddy tracker toolbox General features Eddy detection Grid Manipulation Time grid computation Tracking Manipulation Tracking diagnostics	Shape error gallery	Get mean of grid in each eddies	Eddy detection : Med	Follow particle	loannou case	Network basic manipulation	process	
<ul> <li>External data</li> <li>Polygon tools</li> <li>Network</li> <li>GRID MANIPULATION</li> <li>Eddy identification</li> <li>Load, Display and Filtering</li> <li>Spectrum</li> </ul>	Eddy detection : Gulf stream	Eddy detection and filter	Eddy detection on SLA and ADT		GitHul	<b>b</b> <u>https://git</u>	:hub.com/Ant	<u>:Simi/py-eddy-tracker</u> 🧲

**META4.0exp – Networks** 



## **Questions?**

More informations about networks : poster SC32022\_009 - Monitoring the mesoscale eddies interactions with the altimetry constellation

adelepoulle@groupcls.com

#### Monitoring the mesoscale eddies interactions with the altimetry constellation

Cori Pegliasco<sup>1</sup>, Antoine Delepoulle<sup>1\*</sup>, Clément Busché<sup>1</sup>, nary Morrow<sup>e</sup>, Yannice Faugère<sup>1</sup>, Gérald Dibarboure

#### Introducti

Managing interactions between mesoscale eddles (e.g. merging and splitting events) is necessary to properly understand the dynamics of these structures. The Mesoscale Eddy Trajectories Atlas - Networks is an experimental dataset that will be available soon on the AVISO+ website (www.aviso.altimetry.fr) Networks are composed of consecutive mesoscale eddles linked by interactions. Even if numerous networks only count one segment, long lived networks are composed of multiple segments experiencing interactions. We illustrate here how those interactions can be represented and investigated for a specific ionalized overlapid events off West Australia An analysis of synthetic particles advected forward in time by the surface currents derived from the Absolute Dynamic Topography is proposed

#### **Data & Methods**

Eddy detection : Input maps : Daily Delayed Time Absolute Dynamic Topography from 1993 to 2022 [1] Algorithm : py-eddy-tracker [2,3,4] Parameters : As described in [3]

The detected eddles are also used in META3.2 [5], available on the AVISO+ website (www.aviso.altimetry.fr). See an illustration here https://www.youtube.com oh?v=xw-XeFaD3GL

Watch the eddies!

Scheme 1.

Representation of a

network. Points are the consecutive eddles

centers. Lines represent

contours at t and dashed

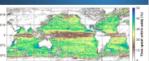
lines contours at t+dt.

Shaded areas are the

contours intersection

For the period 1993 - 2022 -2.1 networks -2.8 million segments -72 million detected eddles (0.5% not appoplated in networks

**Global Statistics** 



Time spent within networks 2 10 days

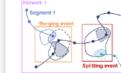
Eddy tracking

From one day to another, we search for overlapping contours Consecutive eddles with an overlap ratio intersection / union ≥ 10% (if not, the overlap ratio intersection / minimal area must be 2 99%) in a 7 days time window

constitute a network

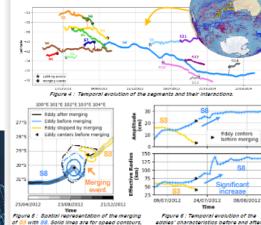
#### Inside each network, segments are consecutive eddles linked by interactions

Seament 2

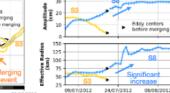


The segment that continues (segment 2) after a merging or a splitting event is

- the one with the highest overlap ratio intersection / union
- A lonely segment (without interactions) is a network by itself



dashed lines for effective contours



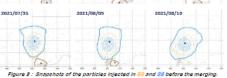
the merging even



Advection parameters

2021/07/16

Coherence (%) =  $\frac{N_{\text{particles after advection}}}{N_{\text{particles after advection}}}$ 1/20° synthetic particles Advection for 5 days particles before advection Time step of 6 hours Flaure 7: Median (black square), 25<sup>th</sup> -75<sup>th</sup> percentiles (thick lines) and 5th - 95th percentiles of the segments' dally forward coherence distribution 2021/07/23 2021/07/26 Last eletection of St 0 2021/08/05 2021/08/10



The 88 particles wrap around 88 core, and the new structure stays stable

Lifetime between 10 - 30 days 56% Networks 42% Segments Interactions 83% Networks with no interactions

Networks lasting at least 10 days :

Global statistics (Figure 1) :

-68 million detected eddles

-1.2 million networks -1.7 million segments

-280 000 merging events (Figure 2 -280 000 splitting events (Figure 3) -95% of the events occur in networks lasting more than 30 day

Figure 2 : Time spent within splitting eddles

Figure 3: Time spent within eddles after merging







Figure 1