Refined Altimetry in the Eastern Boundary Upwelling Systems

Implications on eddy transport estimates

[Joan Miro, 1925]

Arthur Capet, Evan Mason, Vincent Rossi, Charles Troupin, Yannice Faugere, Isabelle Pujol and Ananda Pascual

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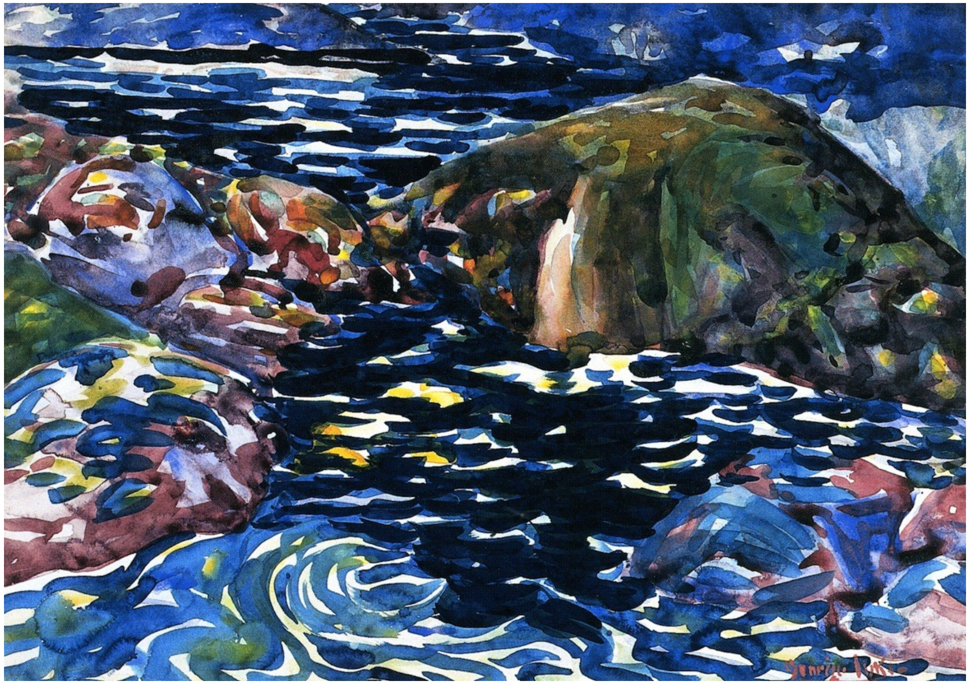

[*George Luks, 1919*]

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New SSALTO/Duacs AVISO sea level anomalies released in April 2014

Poster I.9. Isabel PUJOL : *New release of MyOcean/Ssalto/DUACS products: 21 years of high resolution Sea Level products reprocessed.*

Delayed time, gridded, reference sea level anomalies
1993 → 2013

New SSALTO/Duacs AVISO sea level anomalies released in April 2014

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Delayed time, gridded, reference sea level anomalies
1993 → 2013

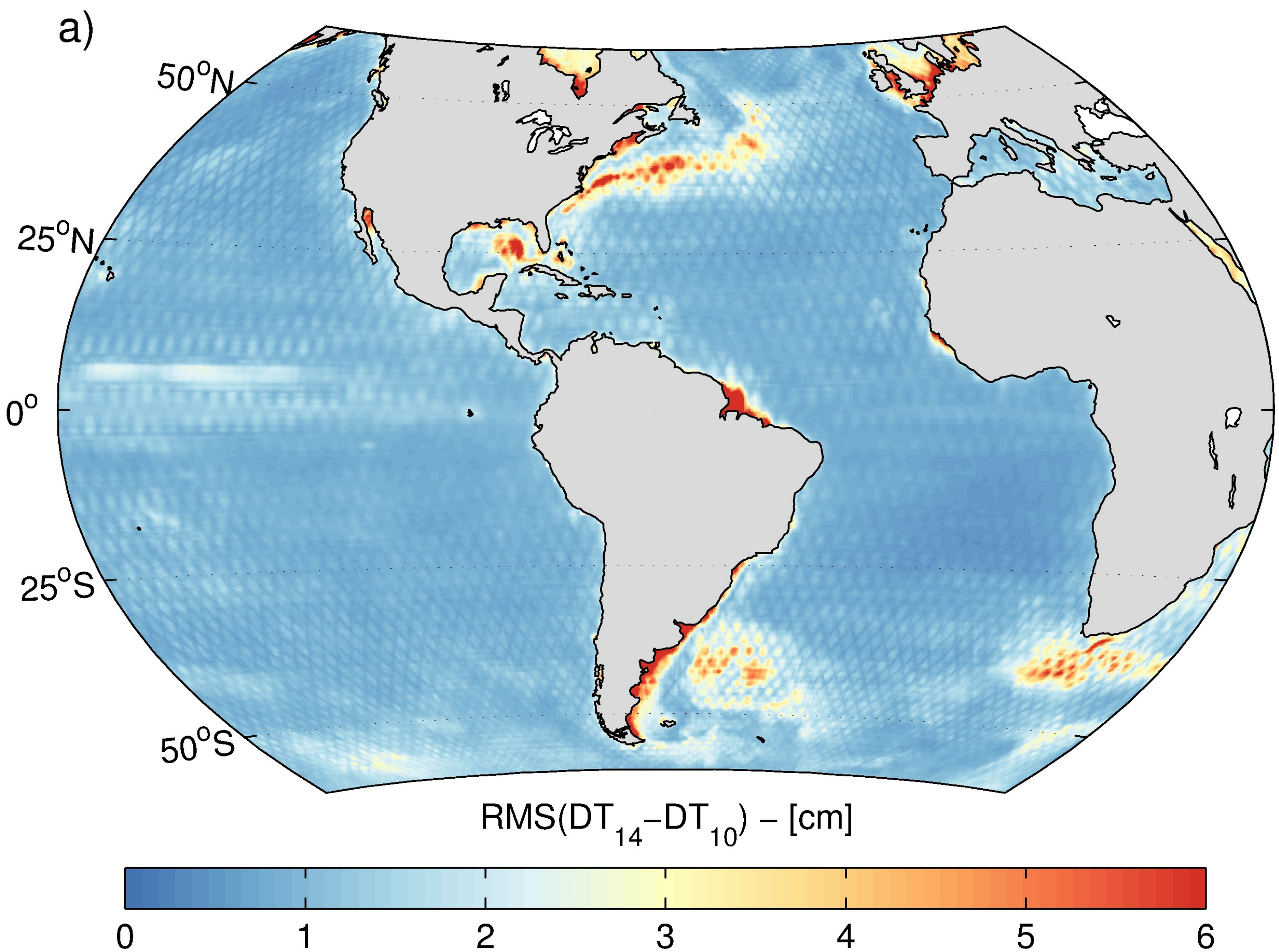
- **DT10**:
  - 1/3° Mercator Grid
- **DT14:**
  - 1/4° Cartesian Grid
  - Refined correlation scales
  - Reduced subsampling and filtering of the along track data

→ **Finer resolution in DT14.**

1. SSALTO/Duacs revision : Where lies the difference ?

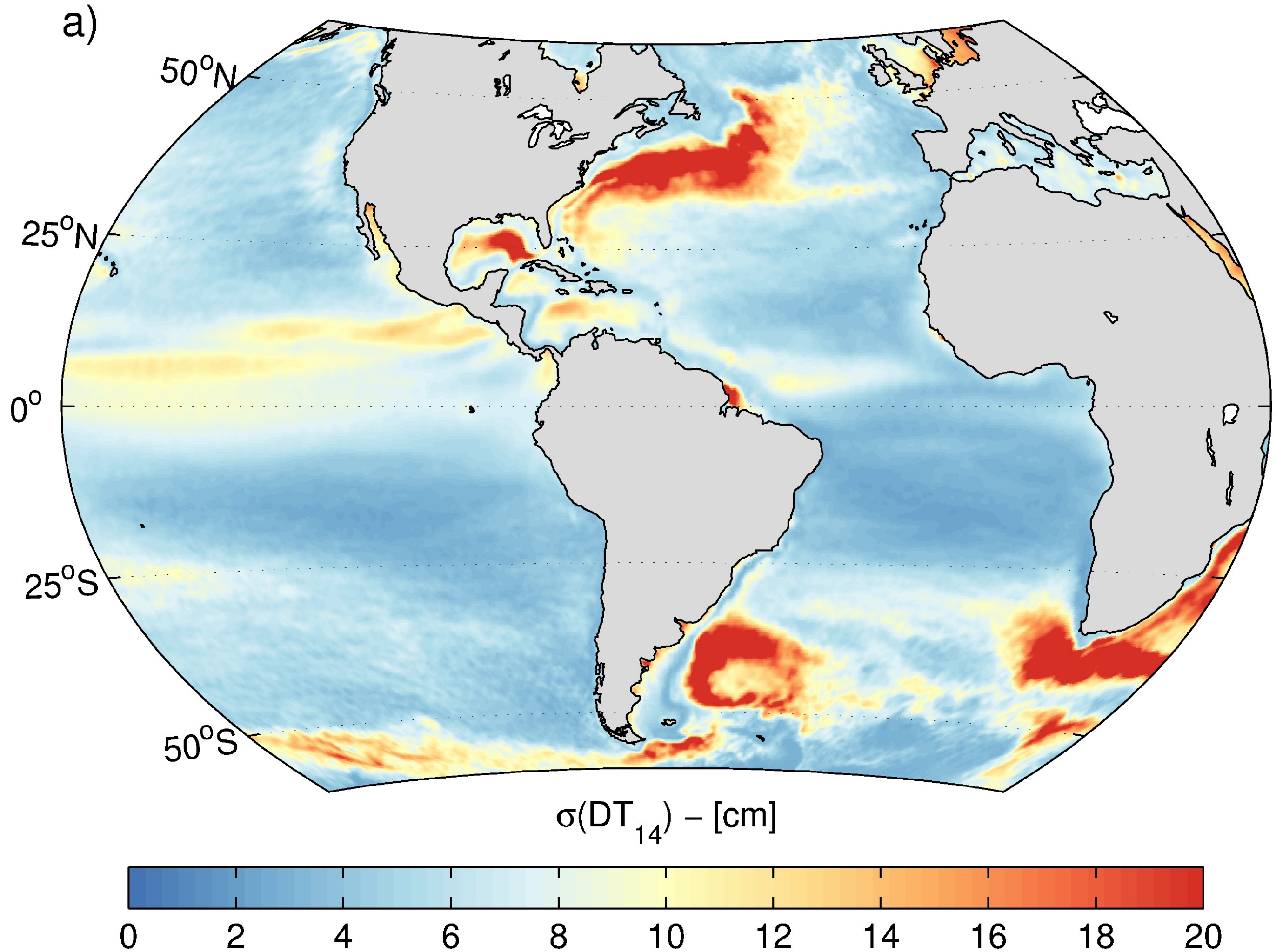
Root Mean Square Difference

$$RMS = \sqrt{\langle (DT14 - DT10)^2 \rangle}$$



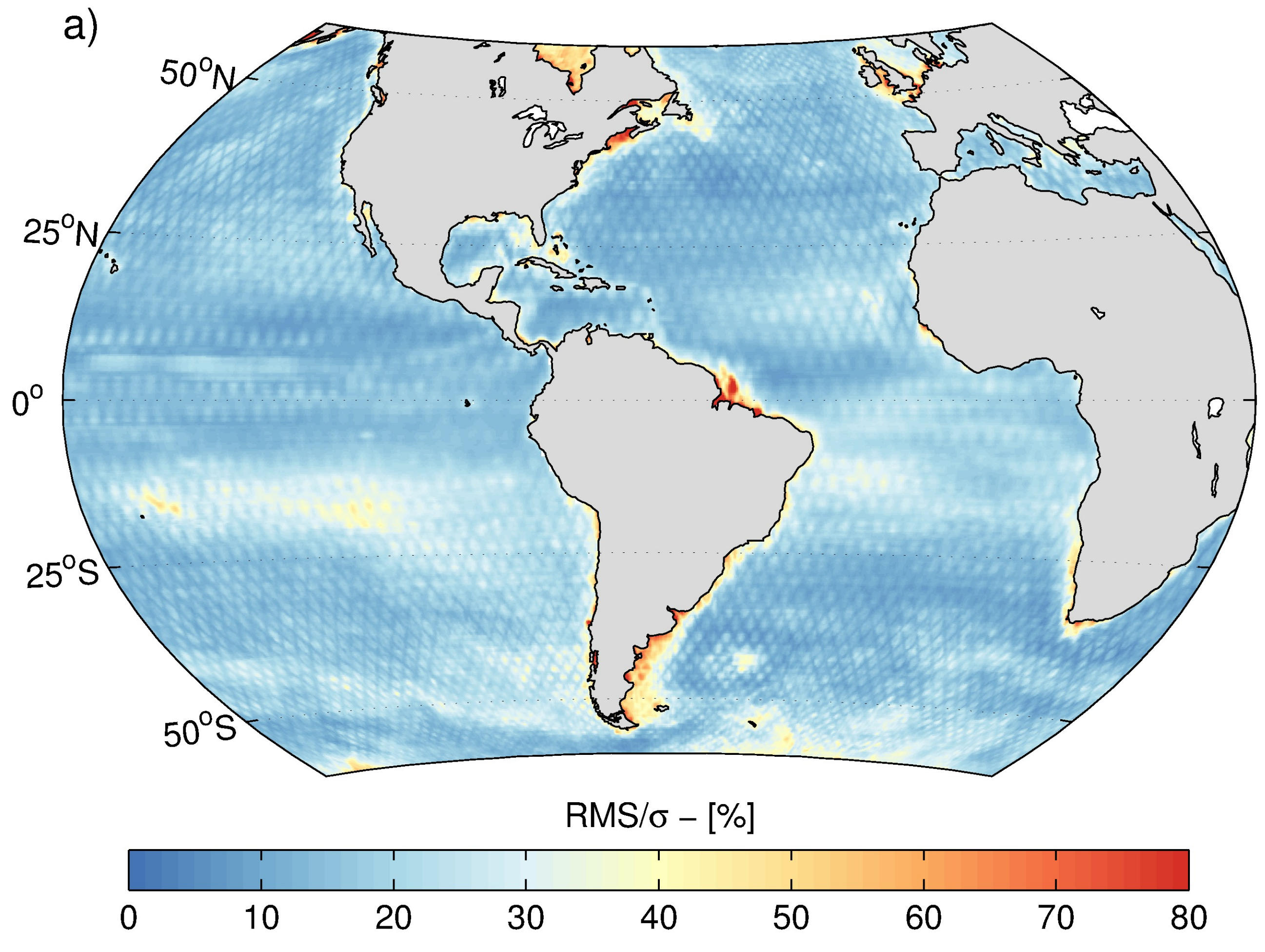
Standard Deviation

$$STD = \sqrt{\langle (DT14 - \langle DT14 \rangle)^2 \rangle}$$



Normalized RMS

$$RMS' = \frac{RMS}{STD}$$

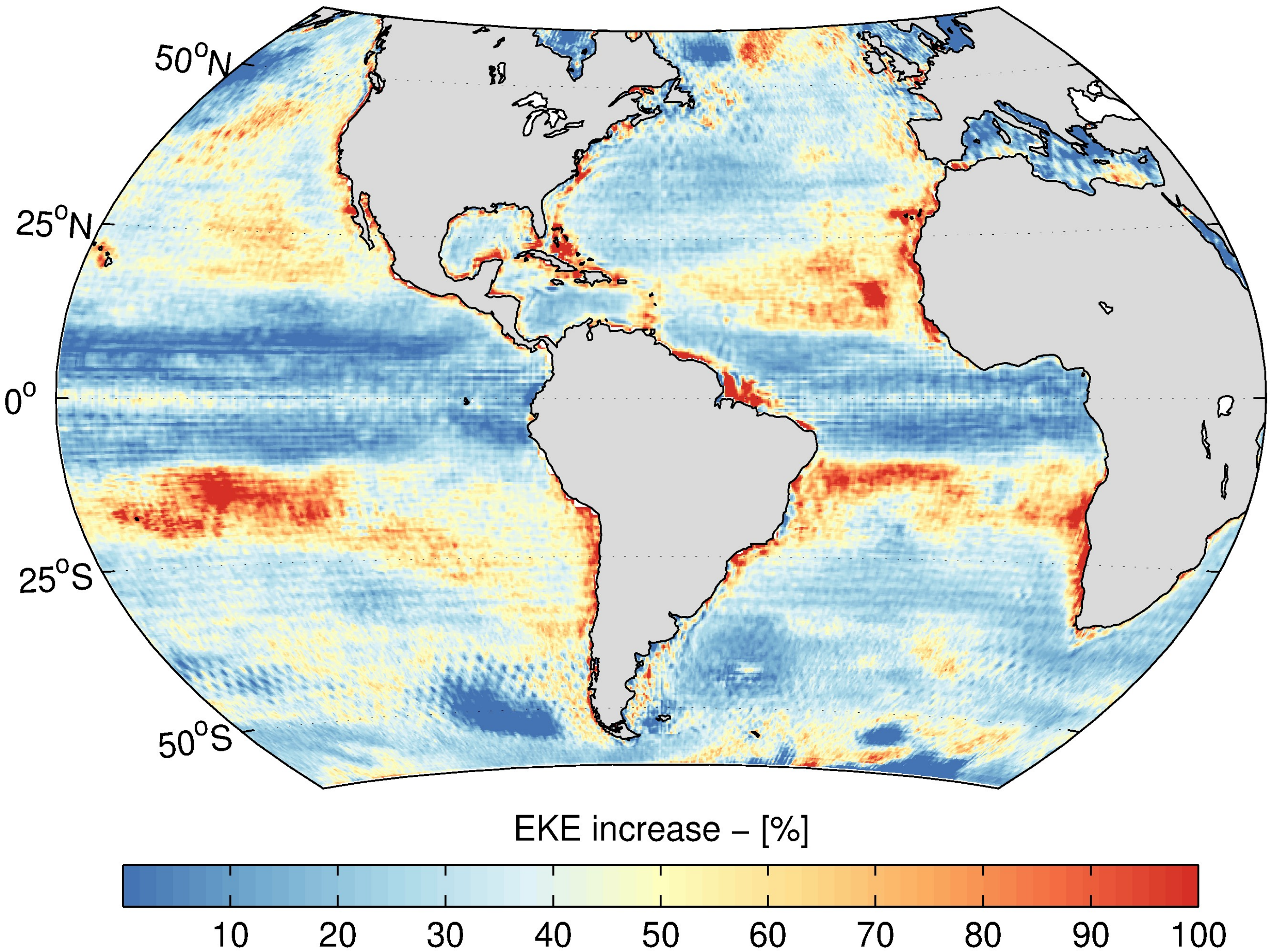


Eddy Kinetic Energy

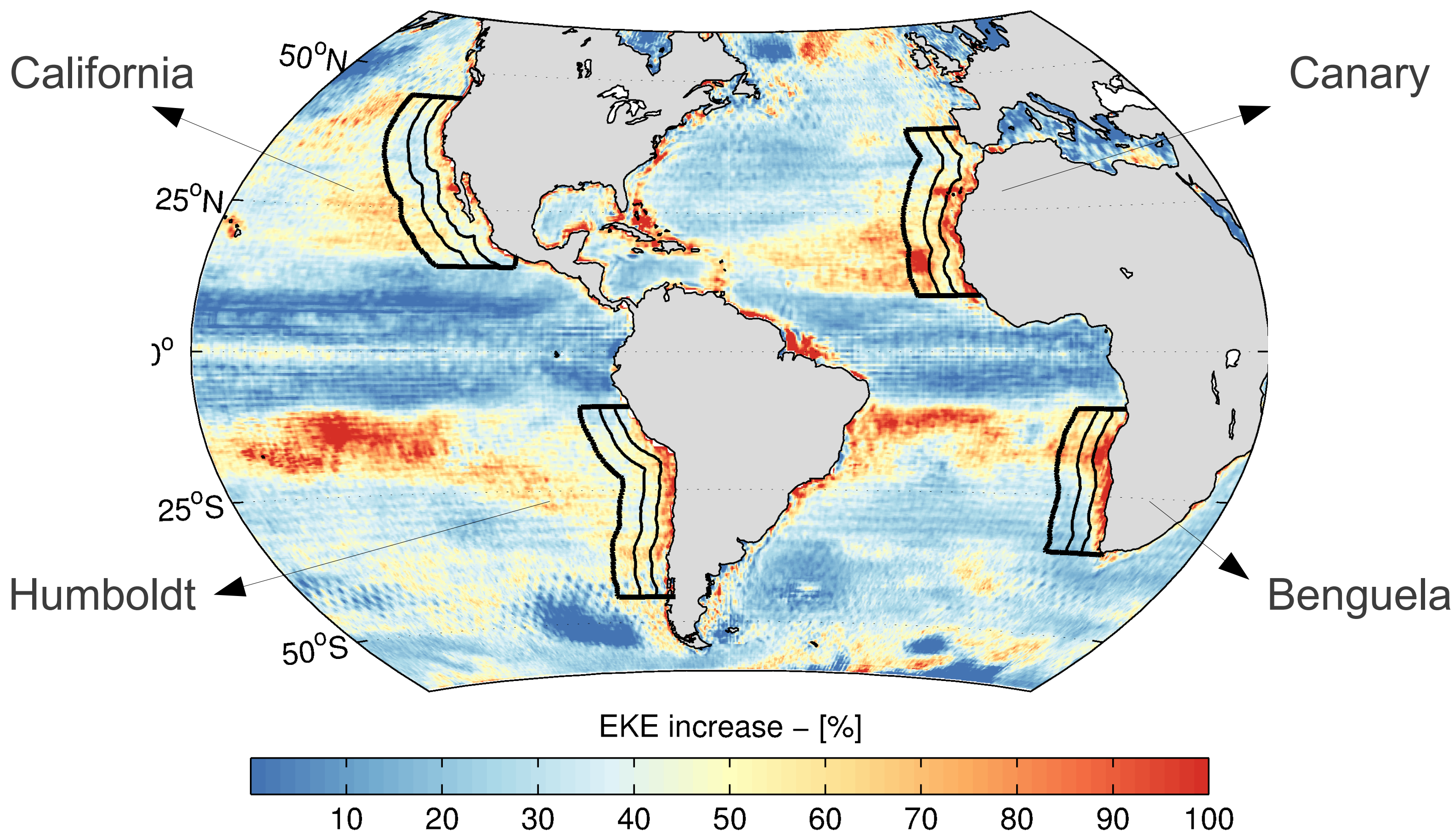
$$EKE = \frac{u'^2 + v'^2}{2}$$

Eddy Kinetic Energy

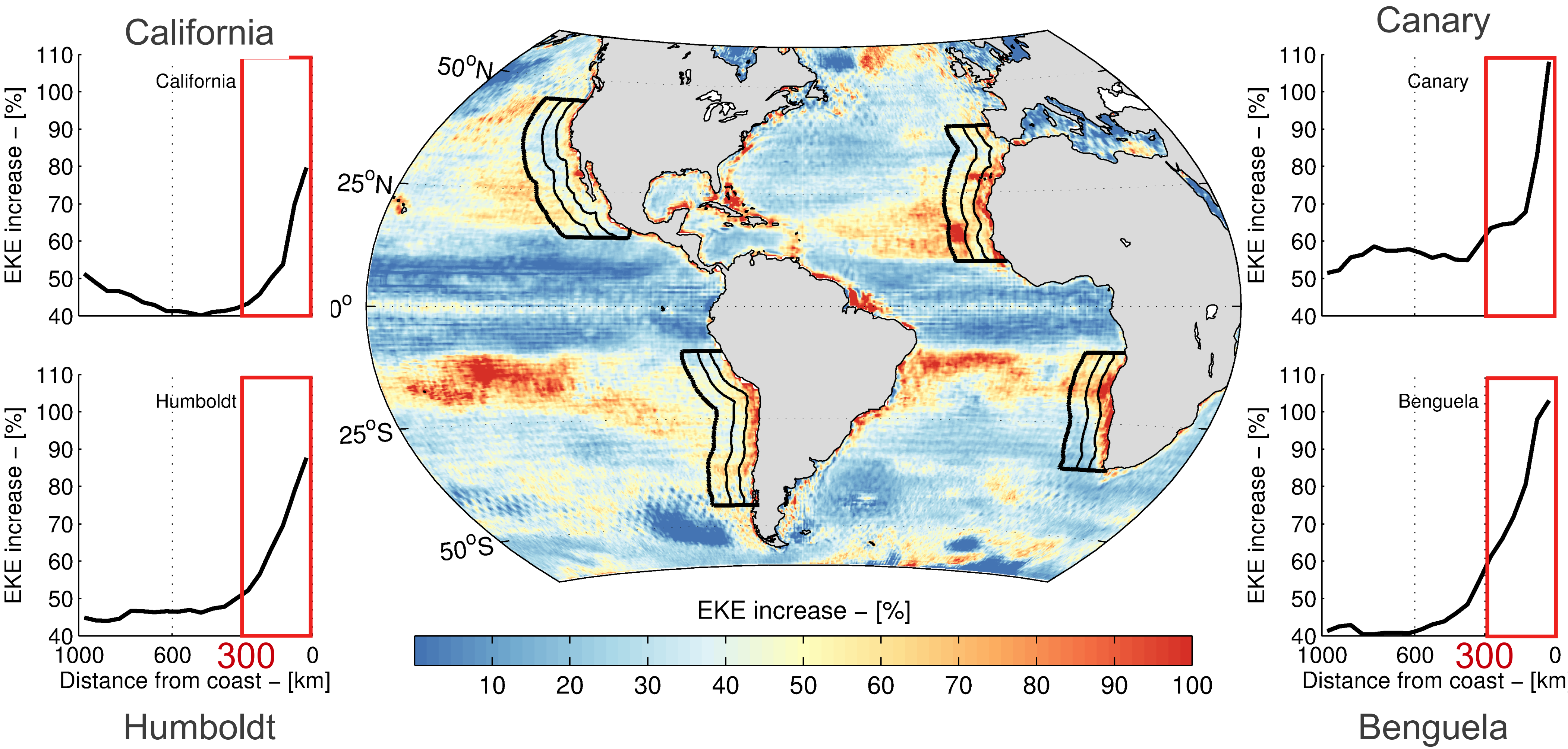
$$EKE = \frac{u'^2 + v'^2}{2} \qquad EKE\ increase = \frac{EKE_{14} - EKE_{10}}{EKE_{10}}$$



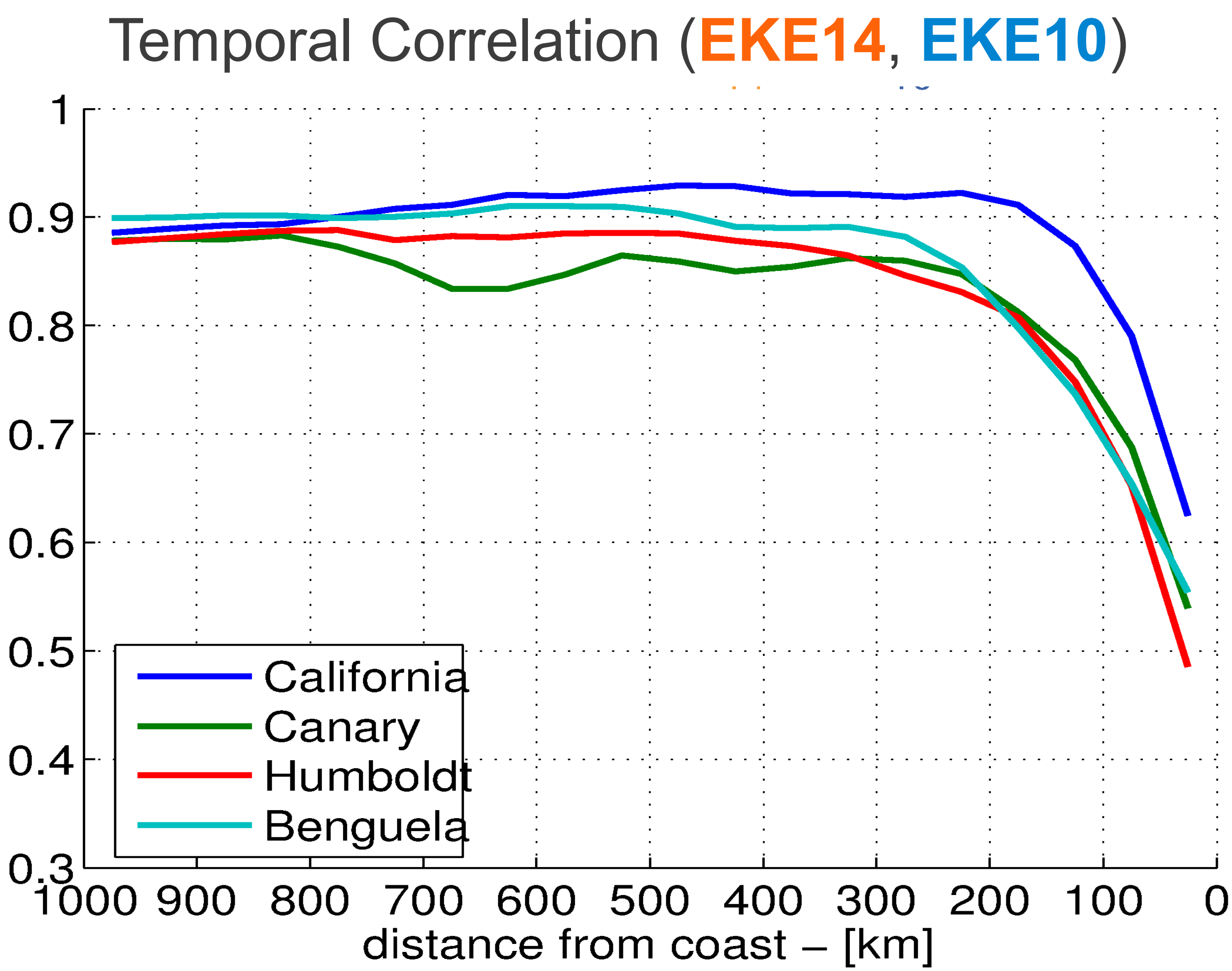
Eastern Boundary Upwelling Systems (EBUS)



$$EKE\ increase = \frac{EKE_{14} - EKE_{10}}{EKE_{10}}$$



DT14 also alters the temporal variabilty



Geostrophic velocities Satellite **VS** Drifters

Geostrophic velocities Satellite **VS** Drifters

- Skill Score :

$$S = \frac{4(1+R)}{2(\frac{\sigma_{sat}}{\sigma_{drift}} + \frac{\sigma_{drift}}{\sigma_{sat}})^2}$$

[Taylor, 2001]

S = 1 → Perfect match
S= 0 → No match

R : Correlation coefficient

σ_{sat} : Standard deviation Satellite

σ_{drift} : Standard deviation Drifters

Geostrophic velocities
Satellite **VS** Drifters

- Skill Score :

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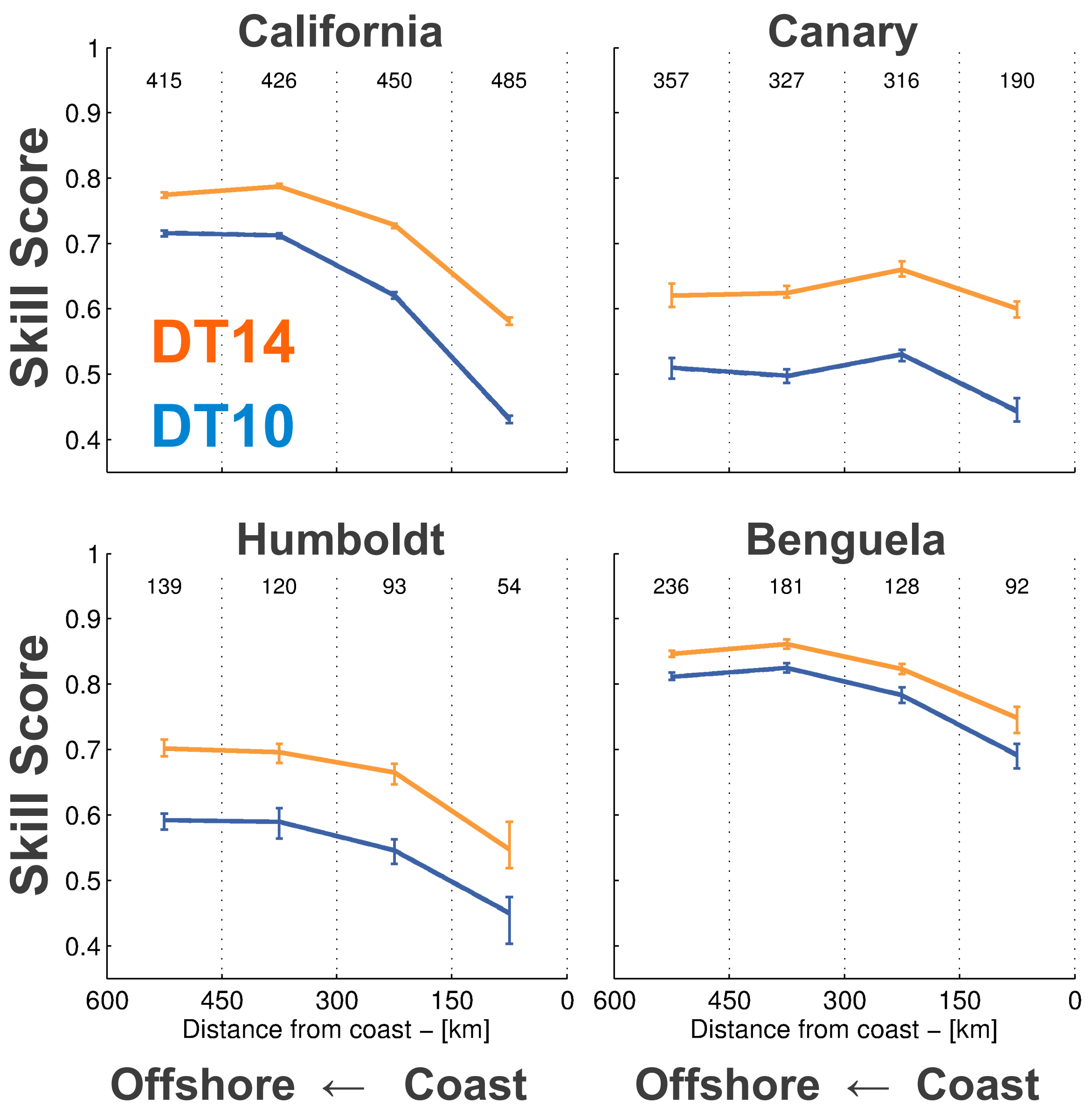

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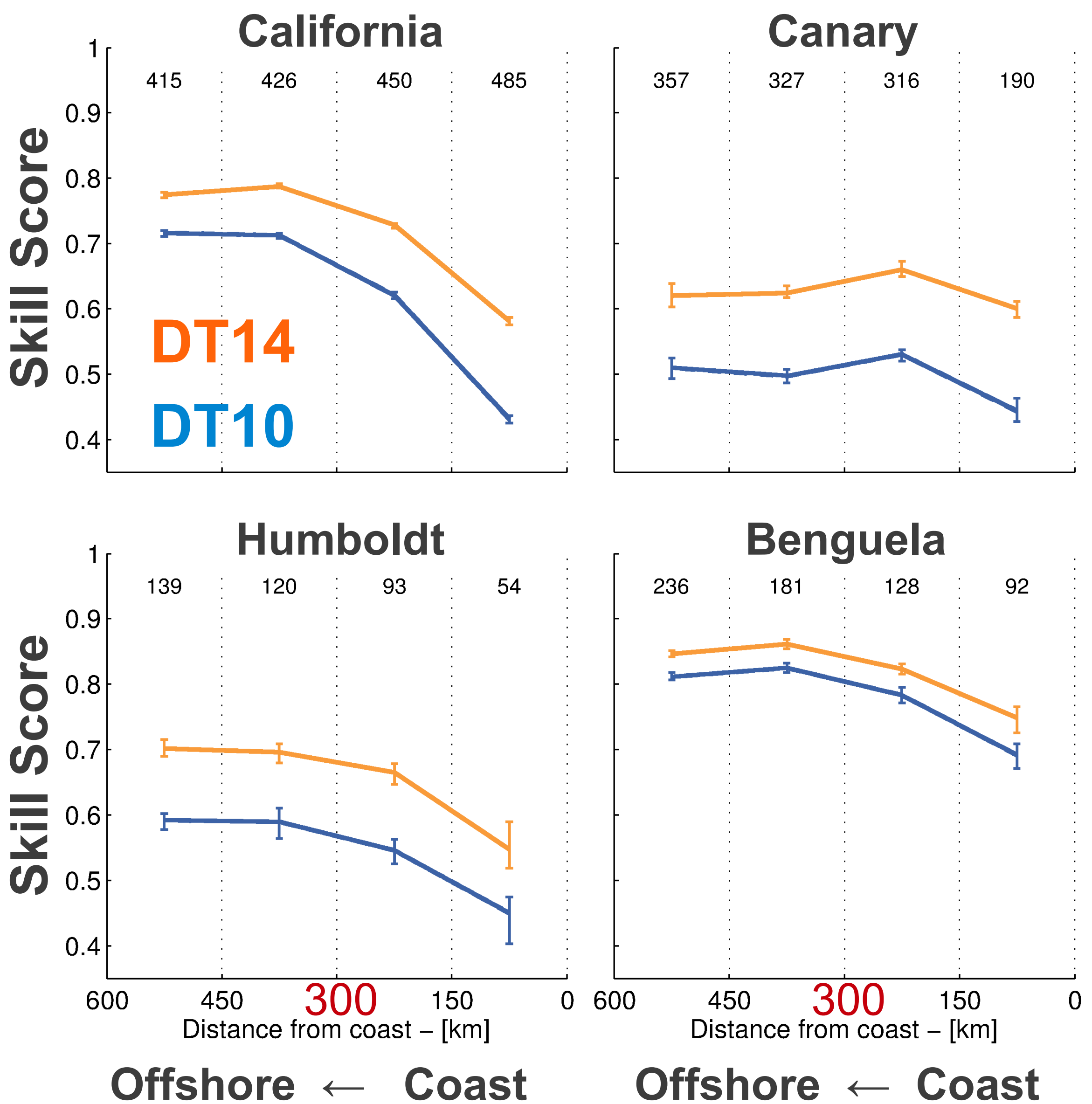
→ Decrease nearshore



Geostrophic velocities Satellite **VS** Drifters

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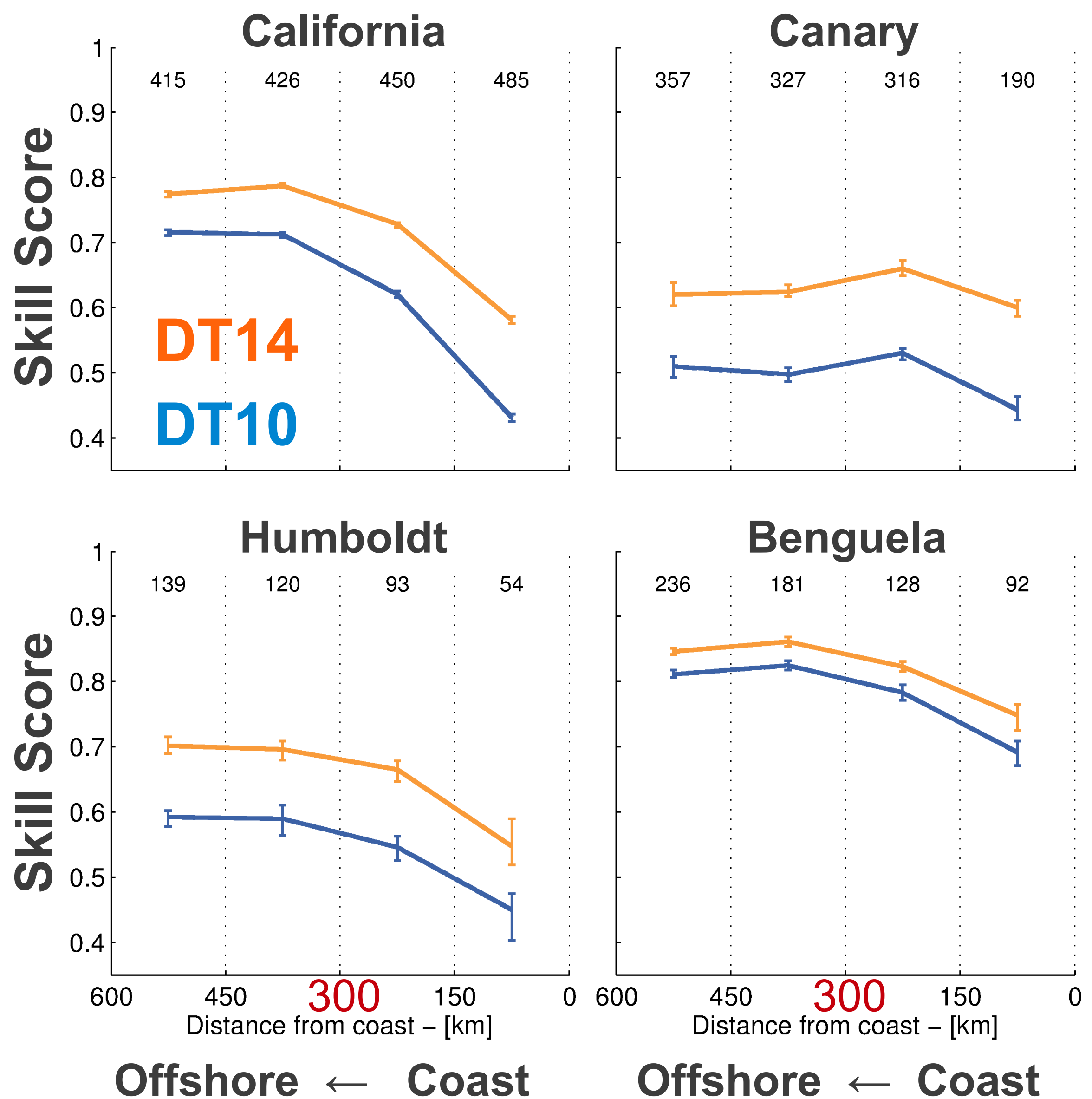
→ Decrease nearshore

→ Improved by **DT14**



Geostrophic velocities
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→ Decrease nearshore

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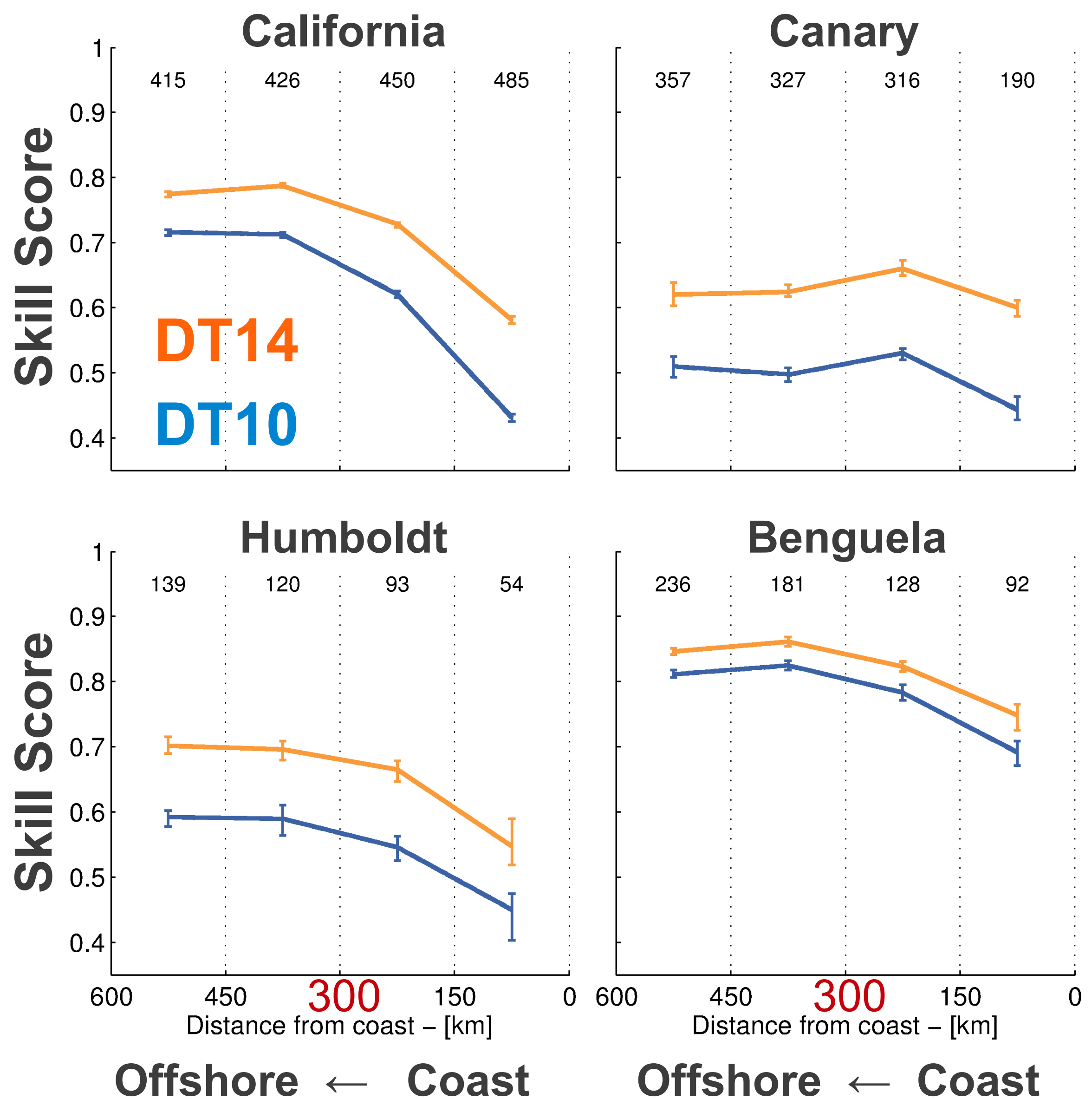
→ Particularly nearshore



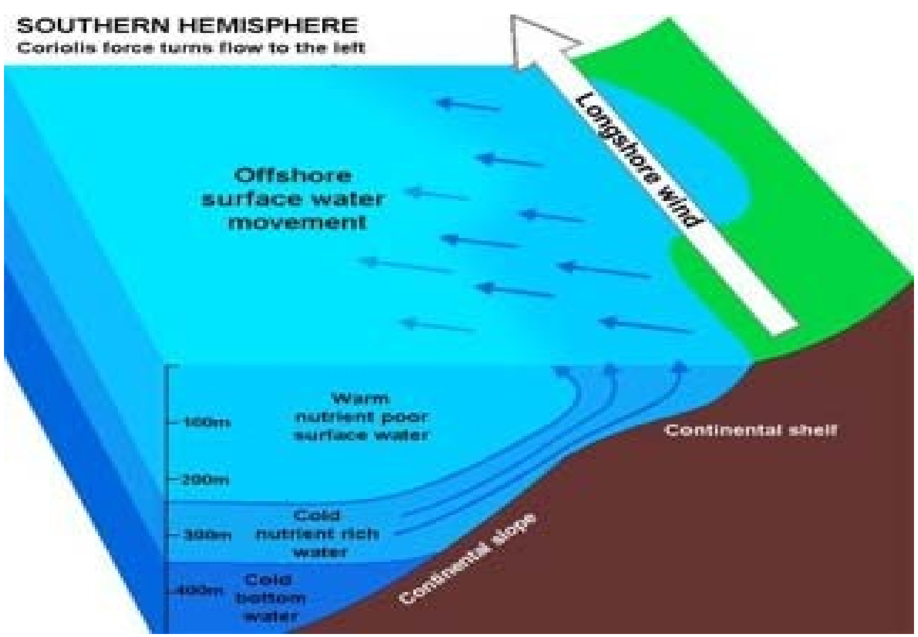
1. SSALTO/Duacs revision :
Where lies the difference ?

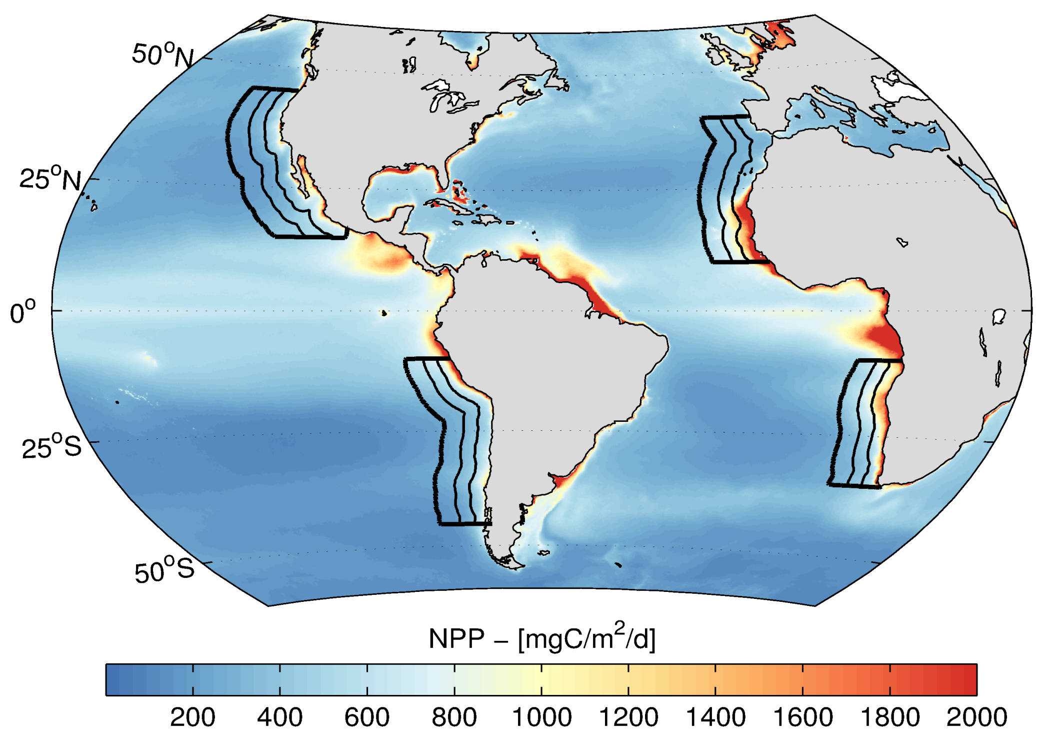
→ DT 2014 enhances the representation of mesoscale circulation in the EBUS

2. What is the role of mesoscale activity in the EBUS ?

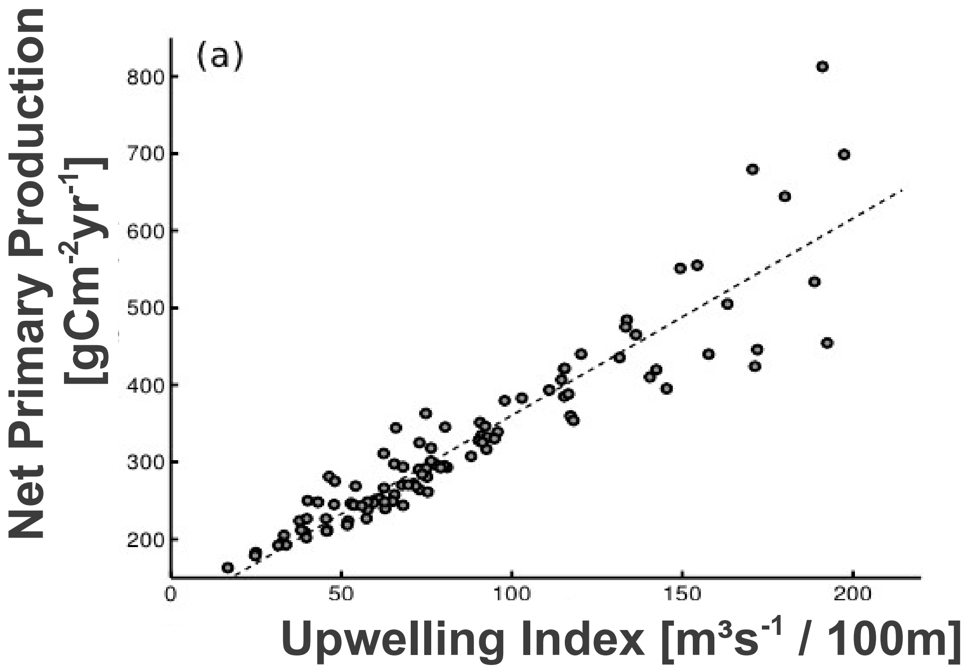
Eastern Boundary Upwelling Systems (EBUS)

- Upwelling of nutrient rich water
- Highly productive regions
- 20 % of global fish catch on 1% of Earth surface



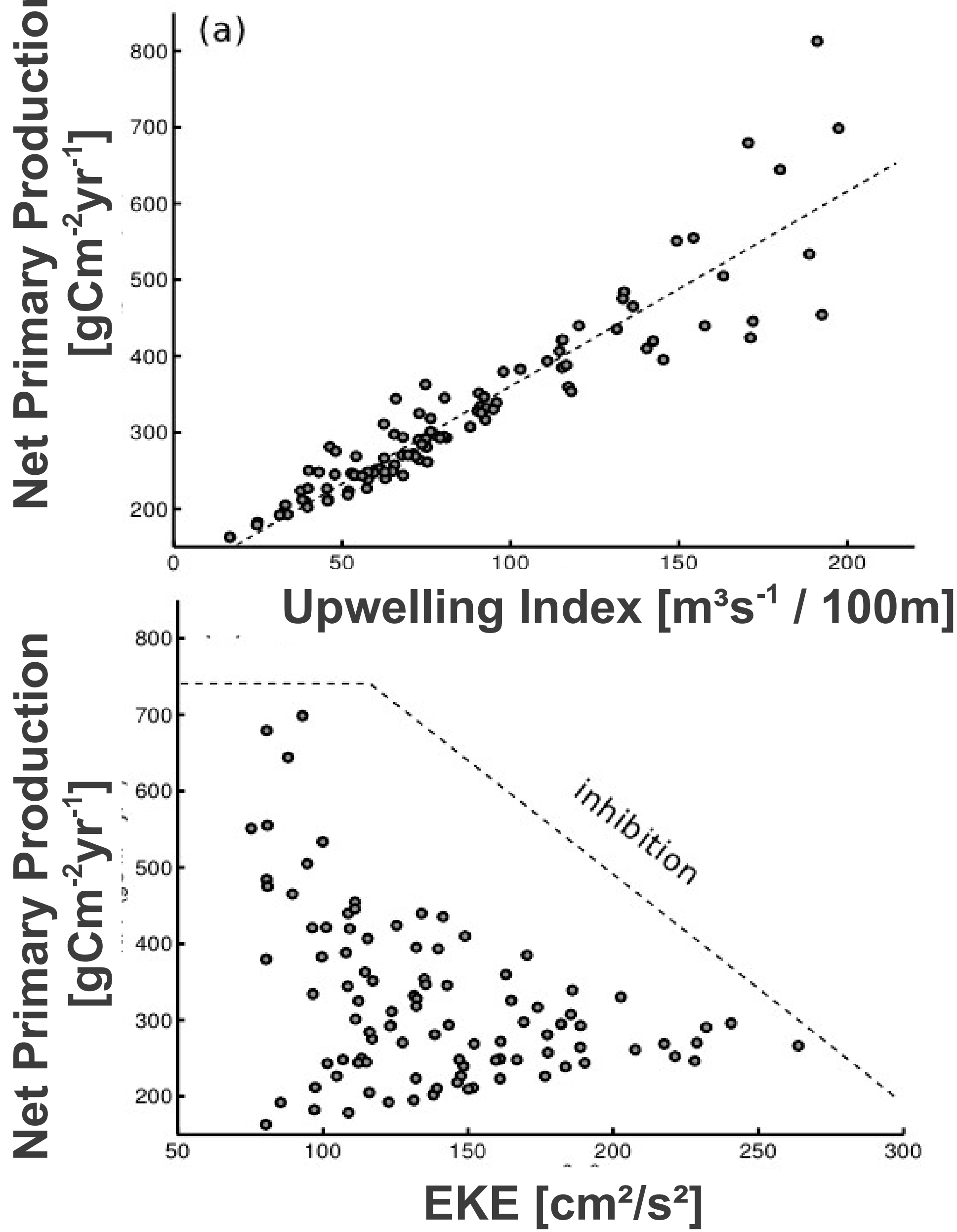


Drivers of NPP variability



[*Lachkar & Gruber, 2012, Biogeosciences*]

Drivers of NPP variability



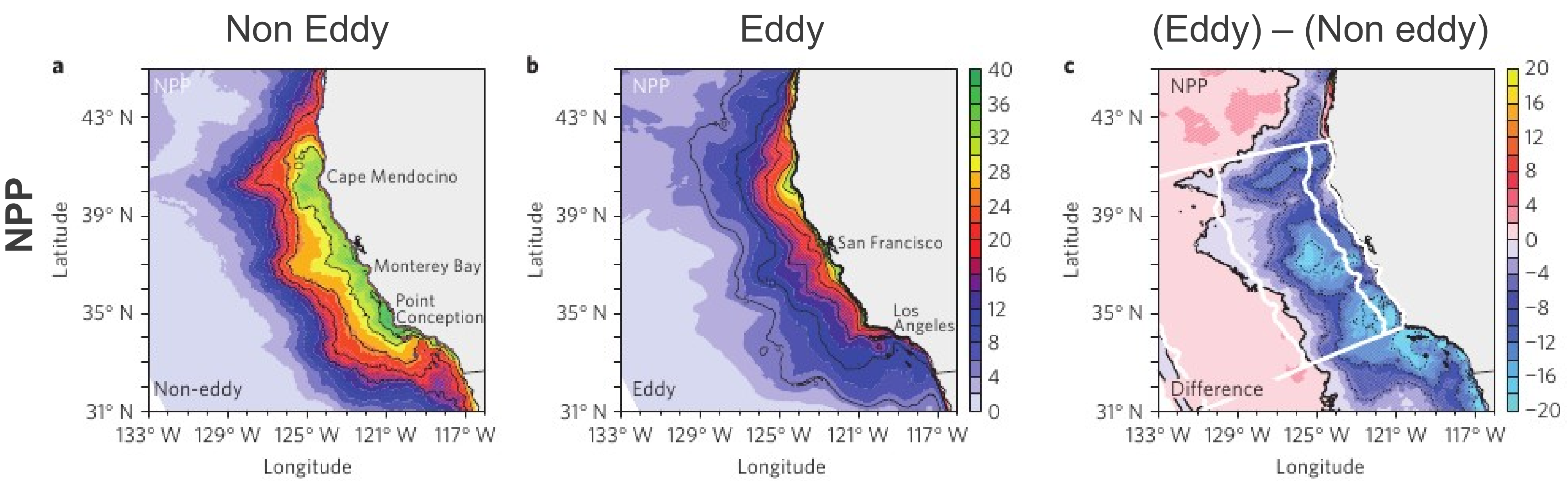
More EKE

→ Less Production

[*Lachkar & Gruber, 2012, Biogeosciences*]

Mesoscale activity in the EBUS

More EKE → Less Production



[Gruber et al 2011, Nature]

Mesoscale activity in the EBUS

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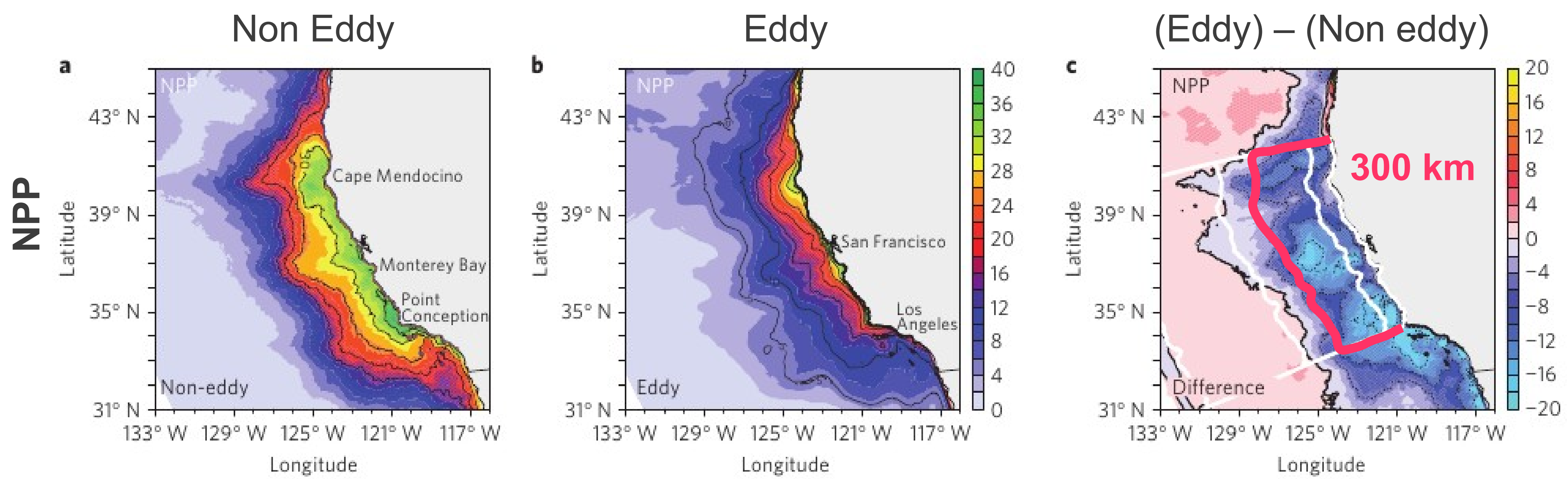
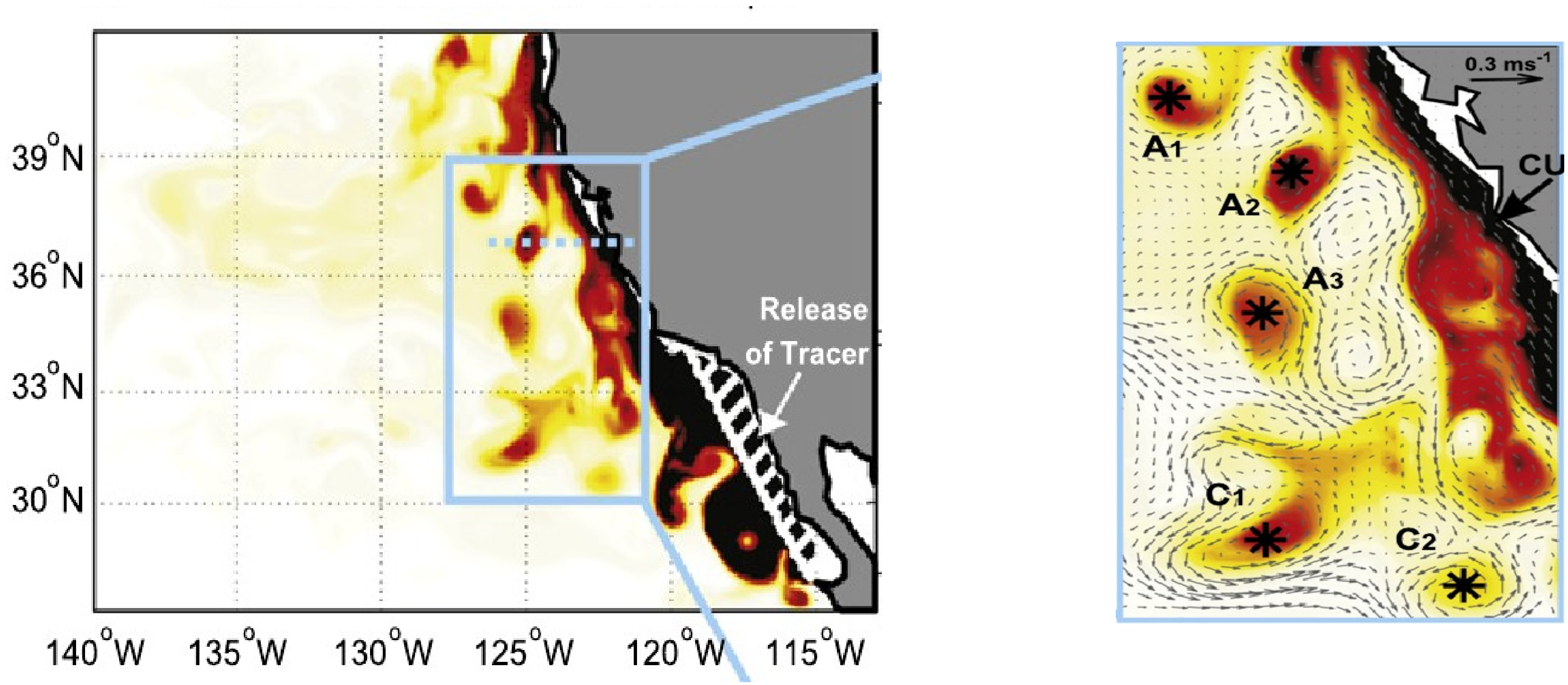


[Gruber et al 2011, Nature]

Mesoscale activity in the EBUS

Offshore export



[Combes et al 2011, Progress in Oceanography]

2. What is the role of mesoscale activity in the EBUS ?

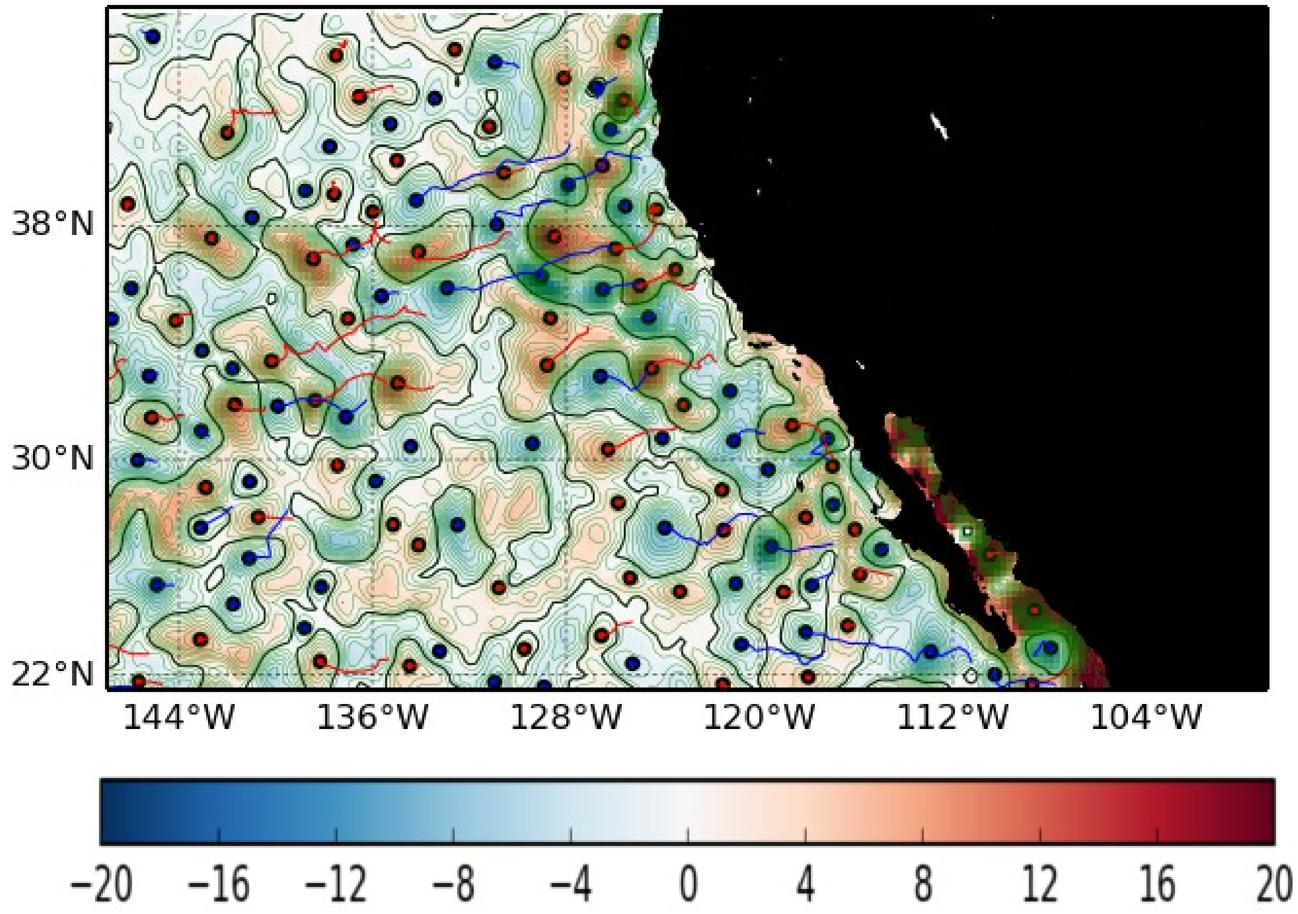
→ Eddies inhibit NPP with offshore export of nutrient-rich waters

3. What is the impact of DT14 altimetry on eddy transport estimates?

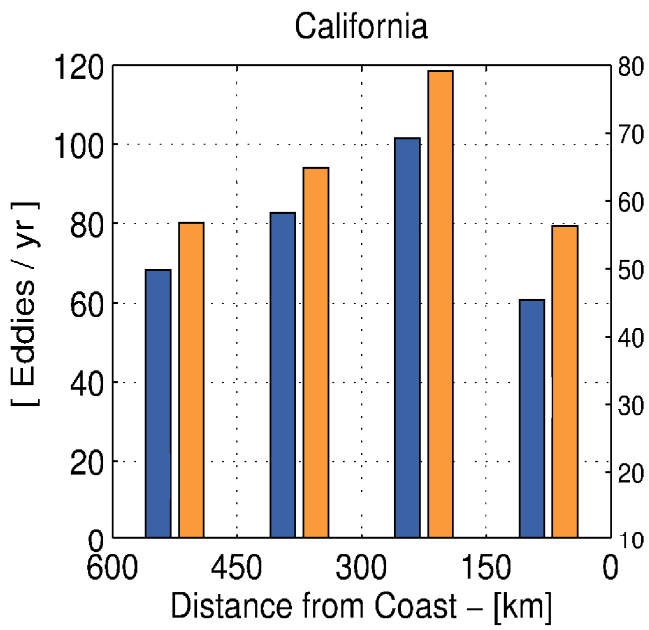
Altimetry → Eddies

Eddy tracking [*Mason et al., 2014*]

Poster I.8. Evan Mason : A new sea surface height based code for mesoscale oceanic eddy tracking

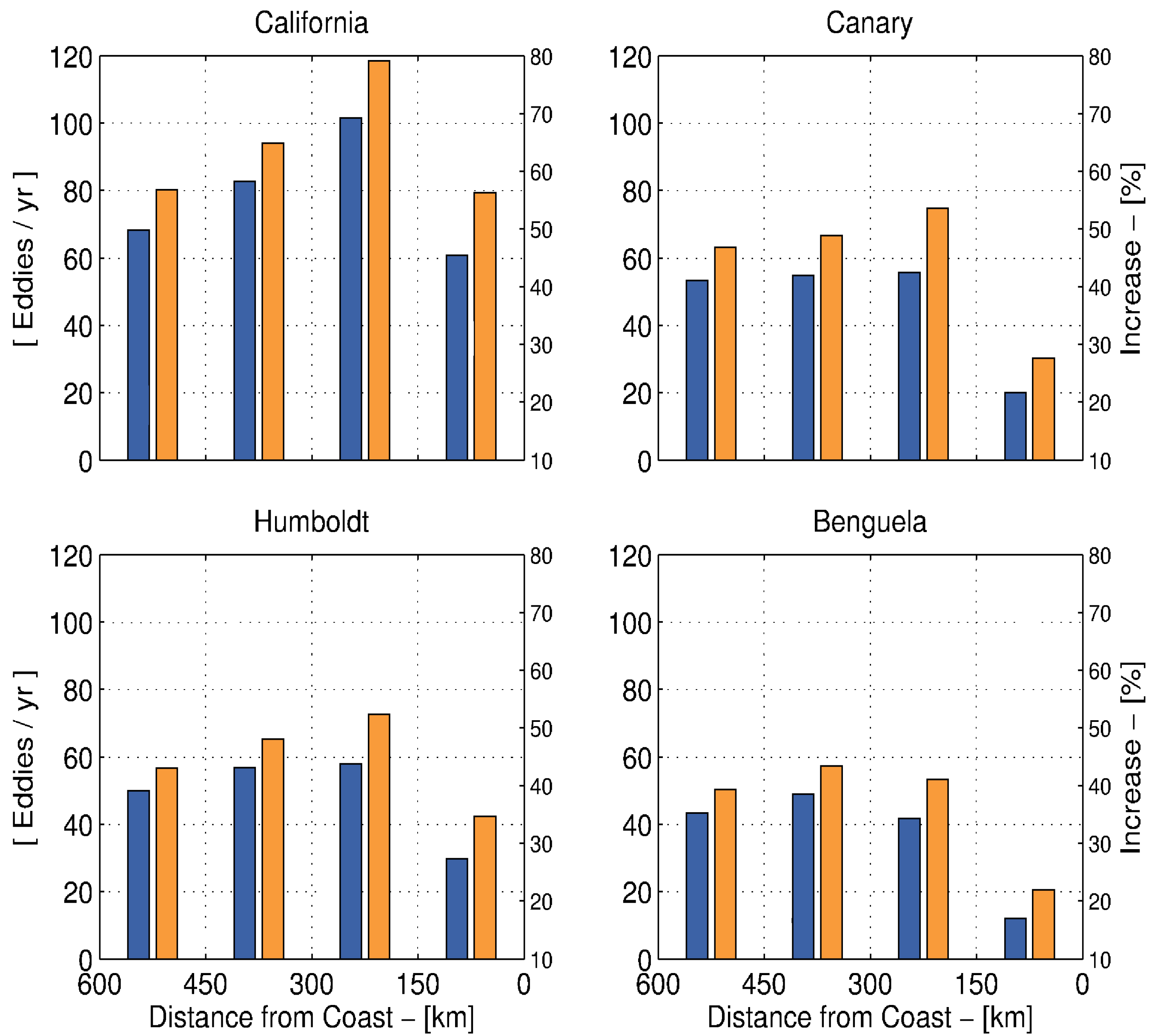


Eddy Tracking on DT10 and DT14



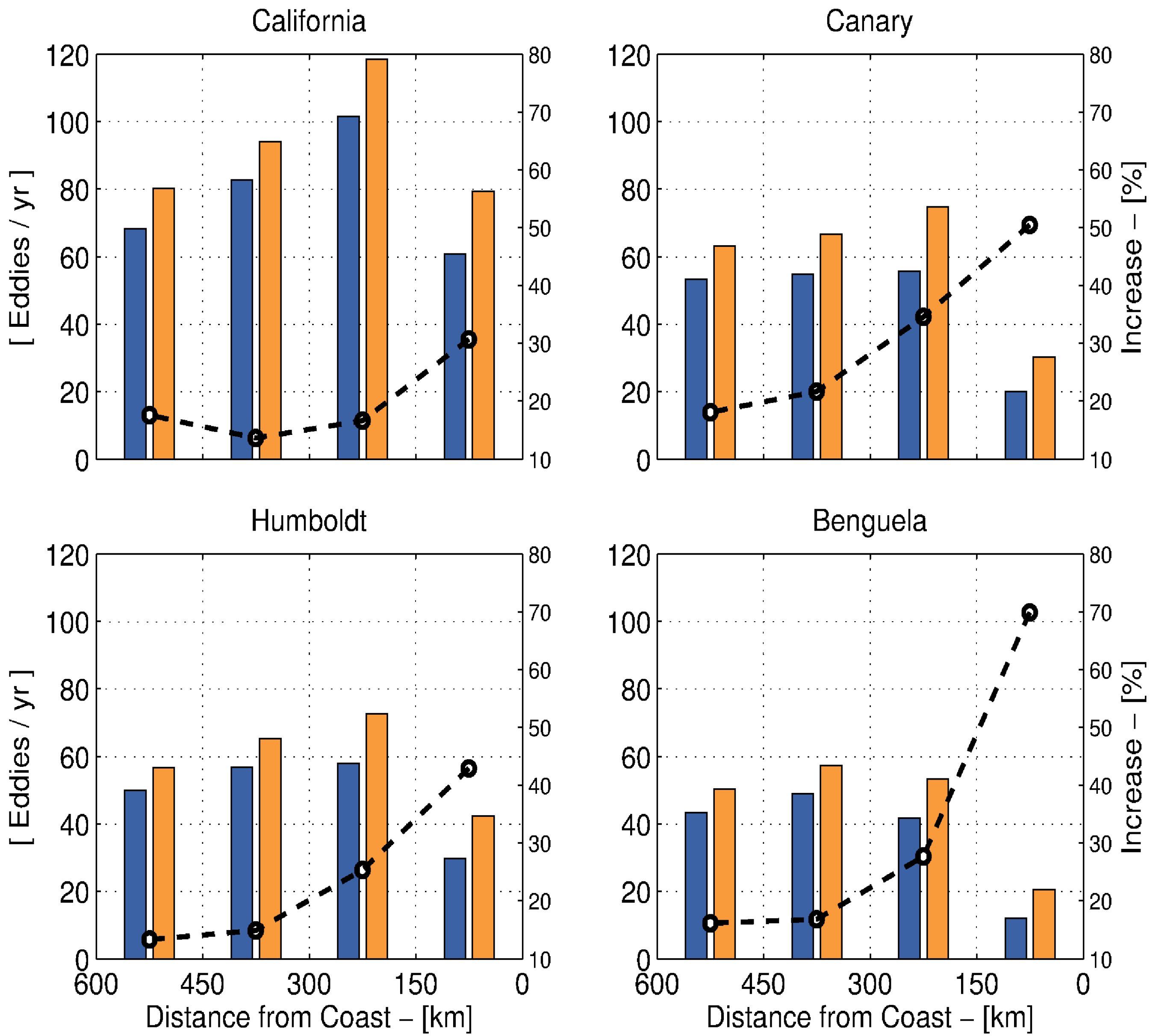
Eddy Tracking on DT10 and DT14

- More Eddies using **DT14**



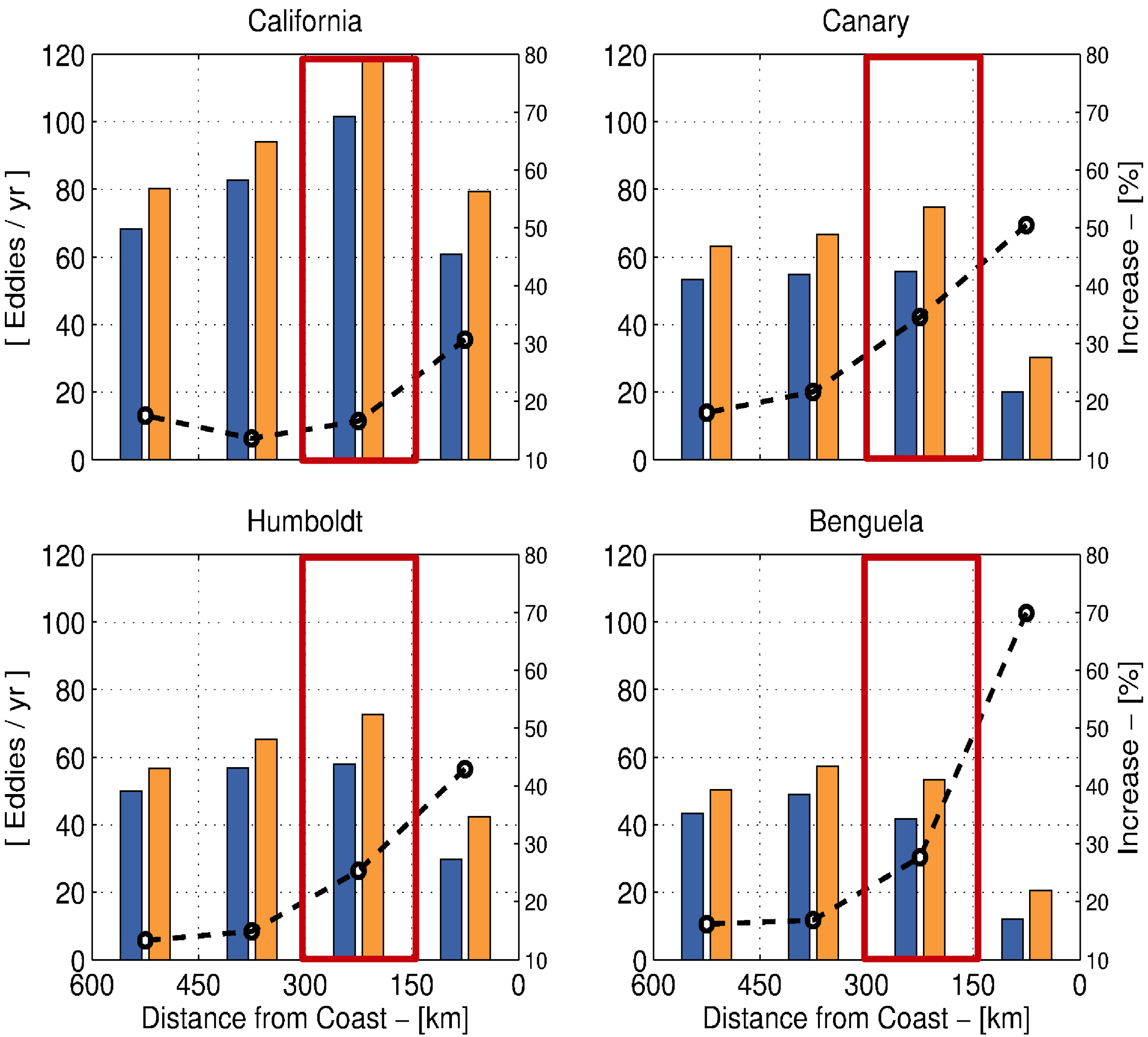
Eddy Tracking on DT10 and DT14

- More Eddies using **DT14**
- Increase near the coast

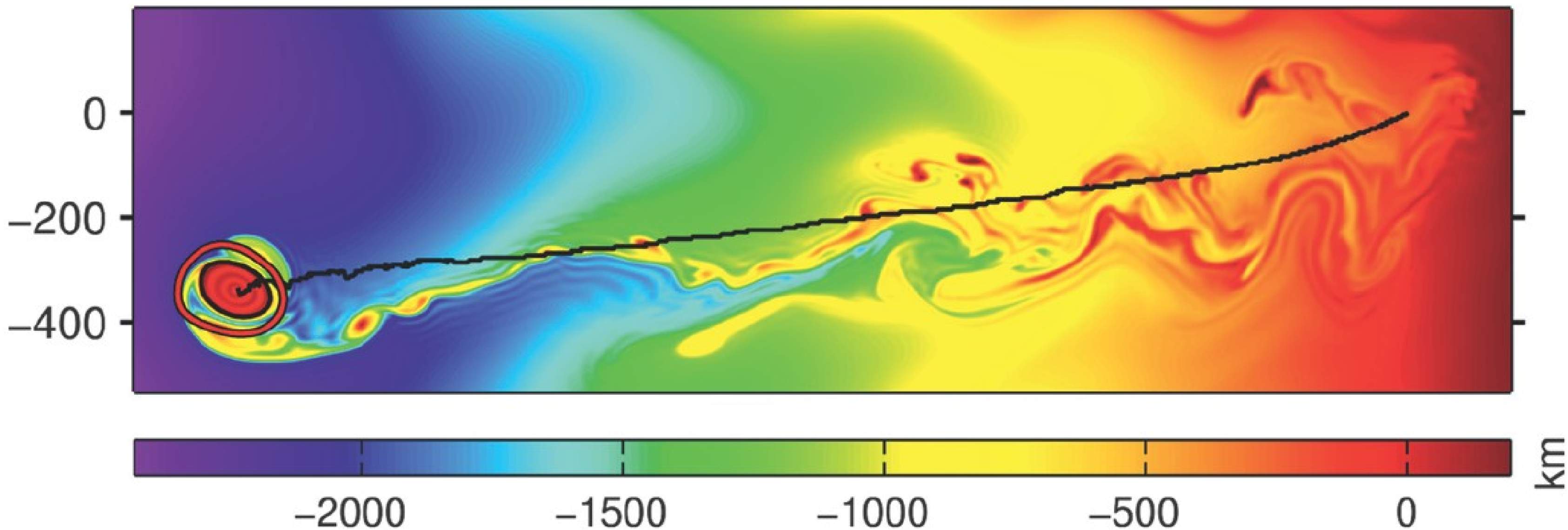


Eddy Tracking on DT10 and DT14

- More Eddies using **DT14**
- Increase near the coast
- Highest eddy densities within **300 km**



More eddies → more transport ?



[*Early et al. 2011*]

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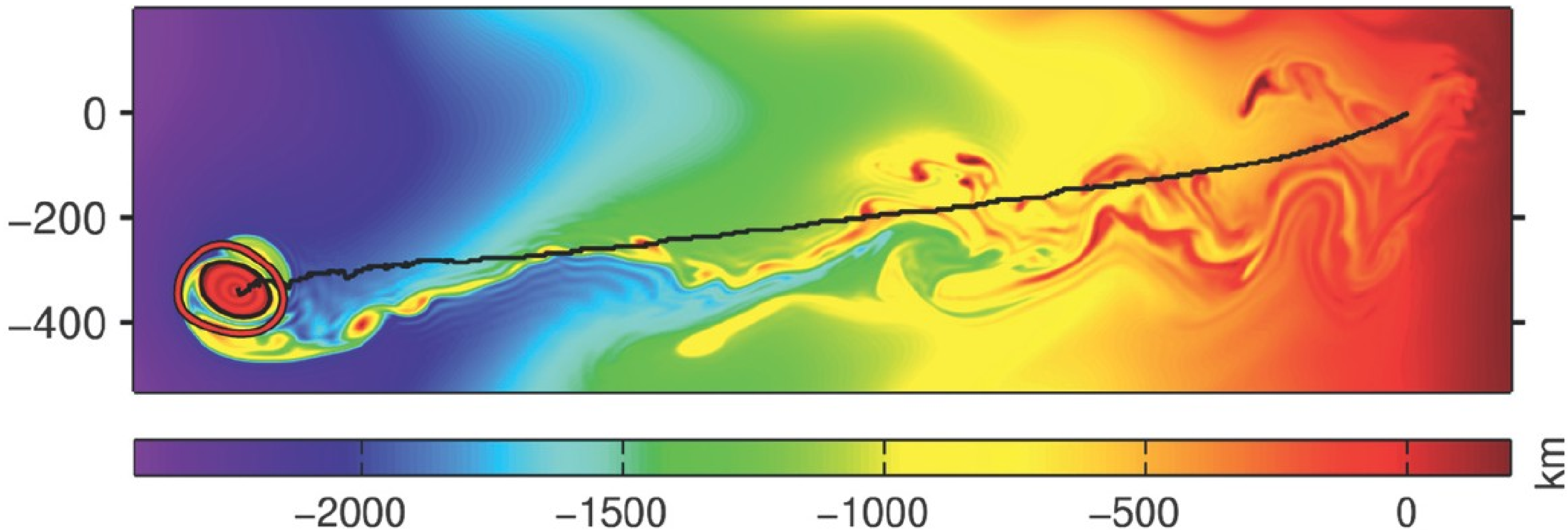

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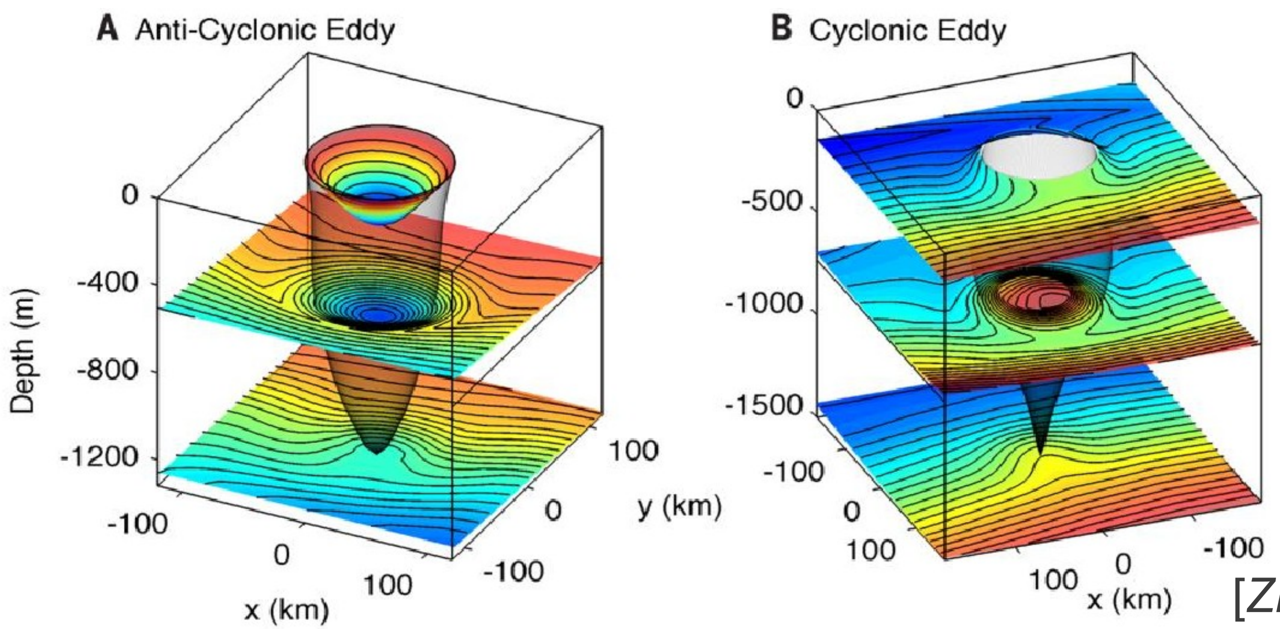
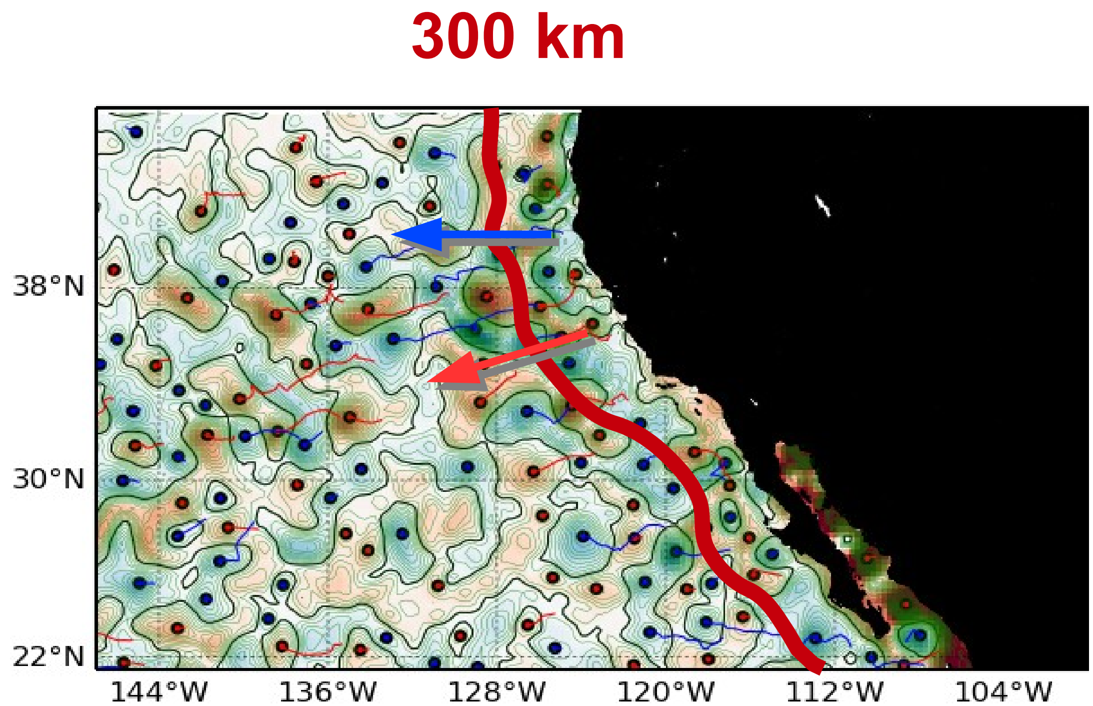


[*Zhang et al. , 2013, GRL*]

Eddy transport estimates

$$Q = \frac{1}{T}\sum_{i=1}^{n} V_i$$



Q [Sv]   : Eddy export (0-300 km) → (>300km)

T [Years] : Duration of the tracking experiment

n   [-]   : Number of Eddies Crossing the boundary

V_i [m³]   : Individual Eddy Volume

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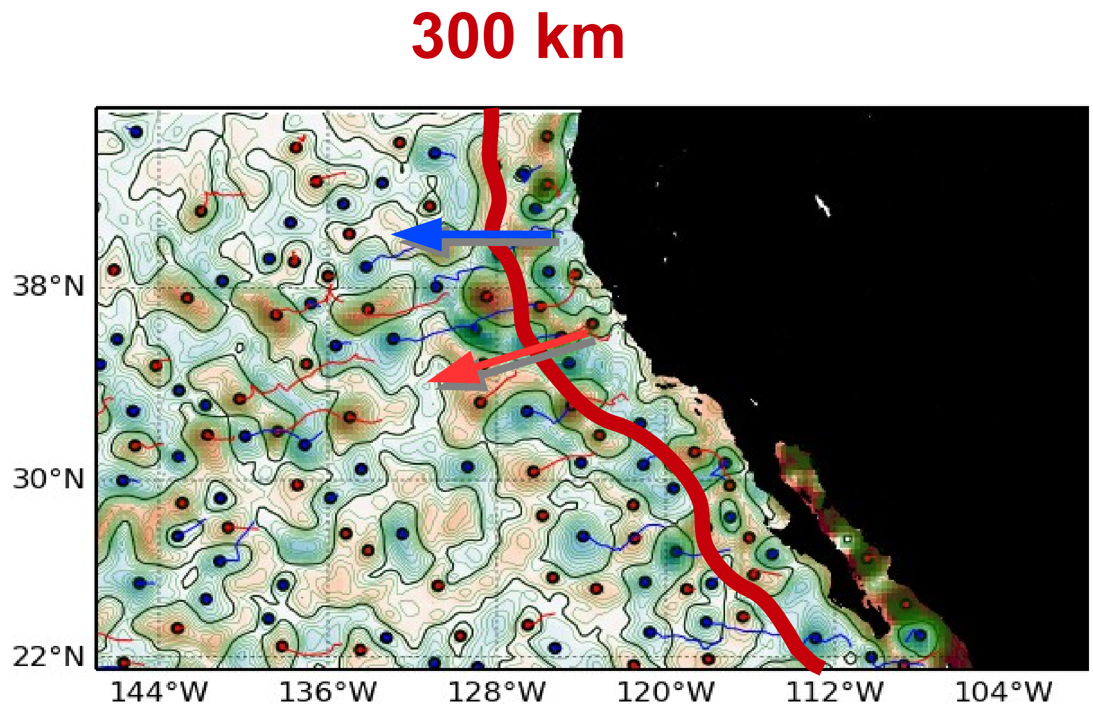

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Volume estimates require vertical information

- Interest : Q_{14}/Q_{10}

- Axial Symmetry :

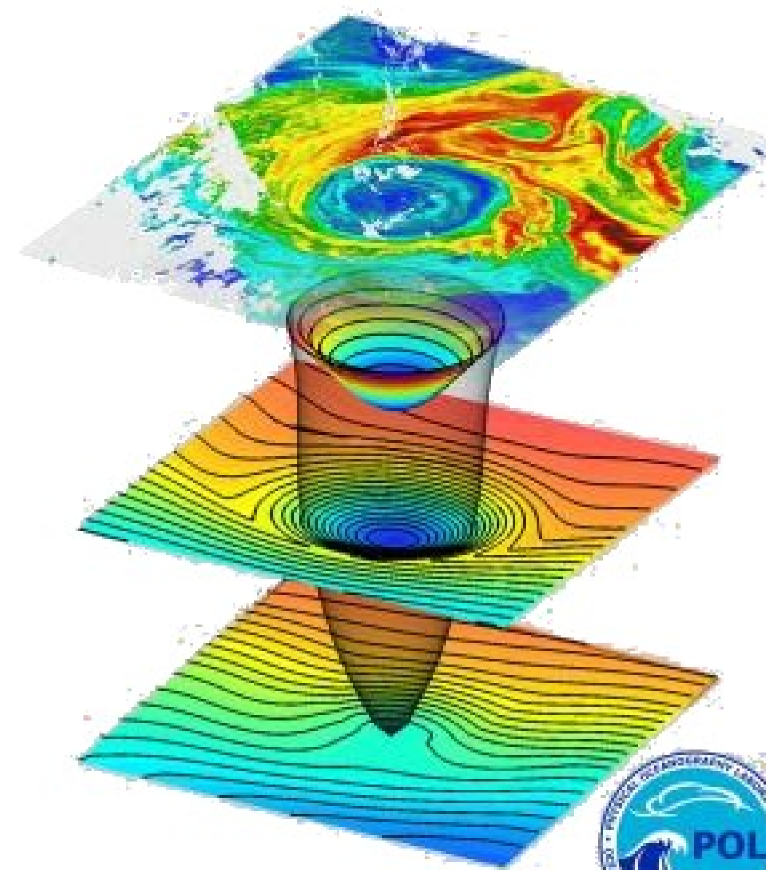
$$V = \pi \int [R(z)]^2 \, dz,$$

- Separability :

$$R(z) = r.H(z)$$

→ Simplification

$$\frac{Q_{14}}{Q_{10}} = \frac{\sum_{i=1}^{n_{14}} r_{14,i}^2}{\sum_{j=1}^{n_{10}} r_{10,j}^2}$$



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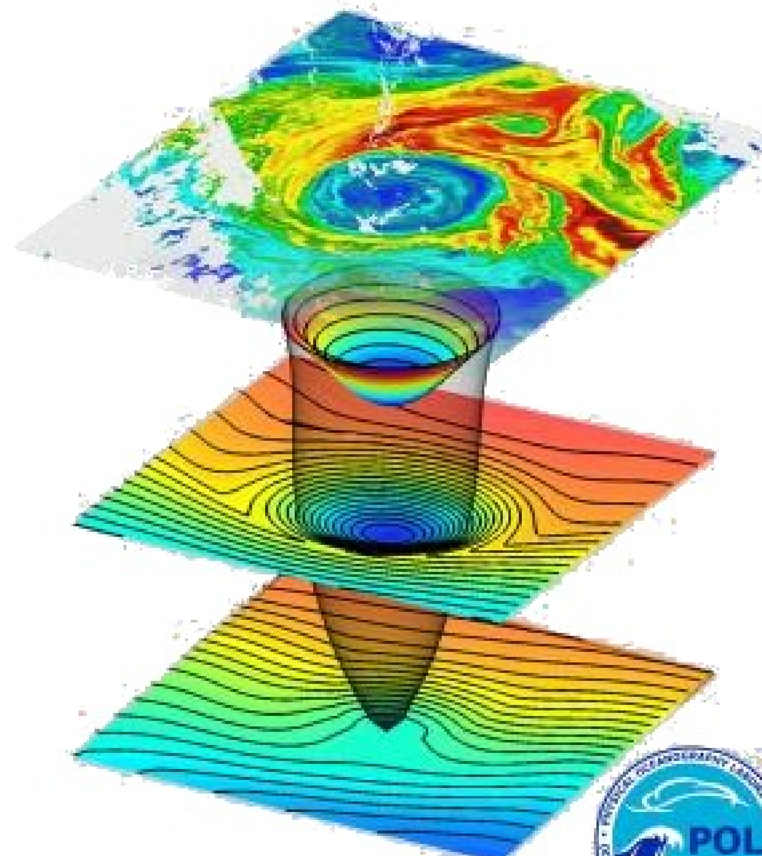
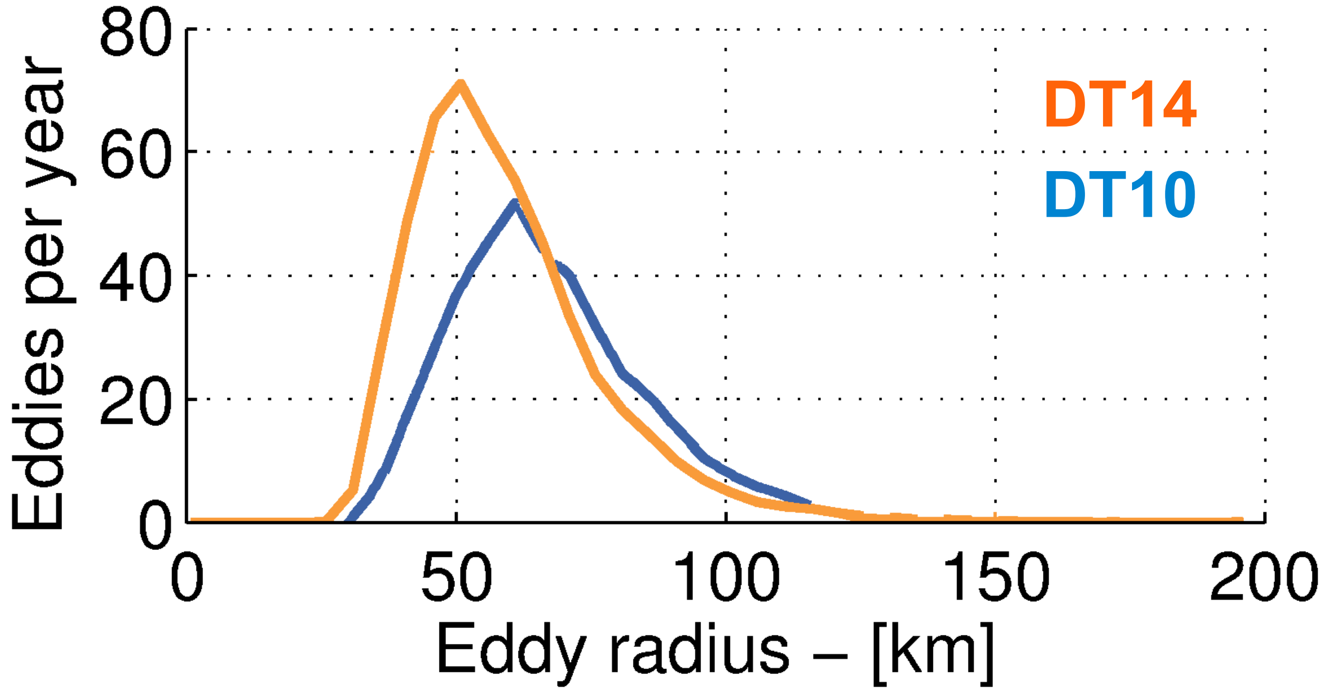
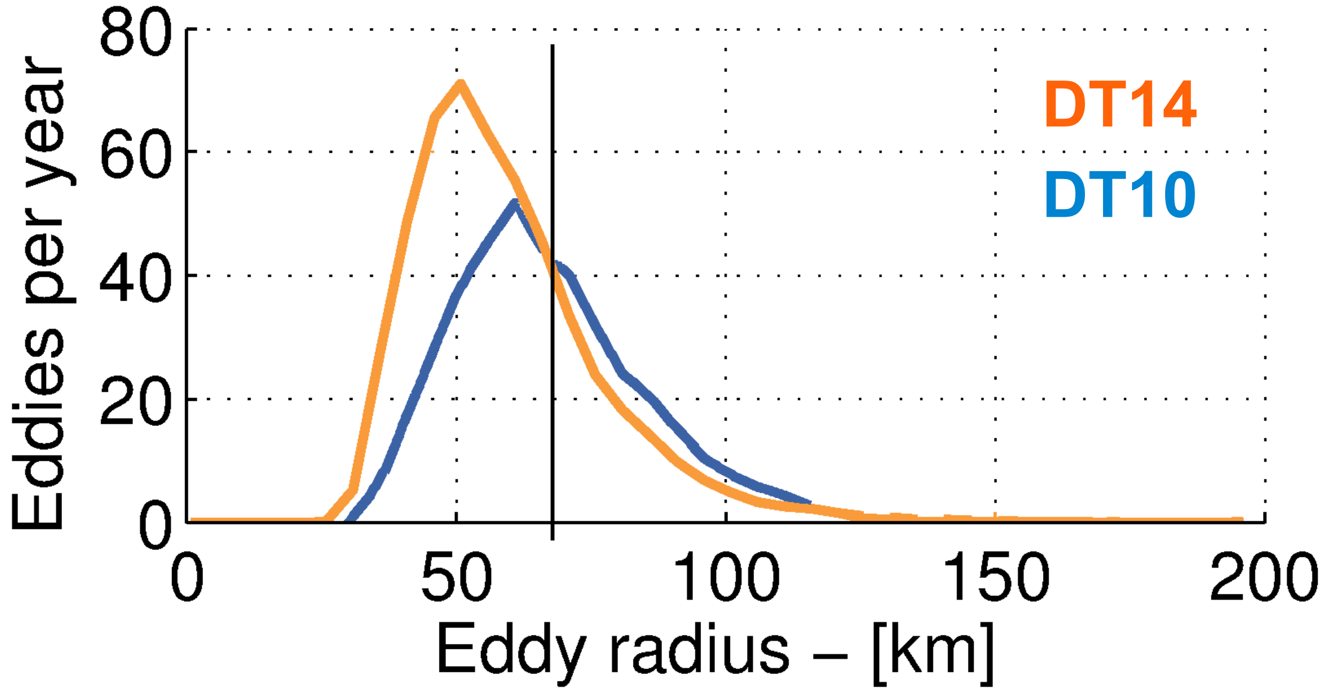


Eddy properties also changed !



Eddy properties also changed !

More small eddies   Less large eddies



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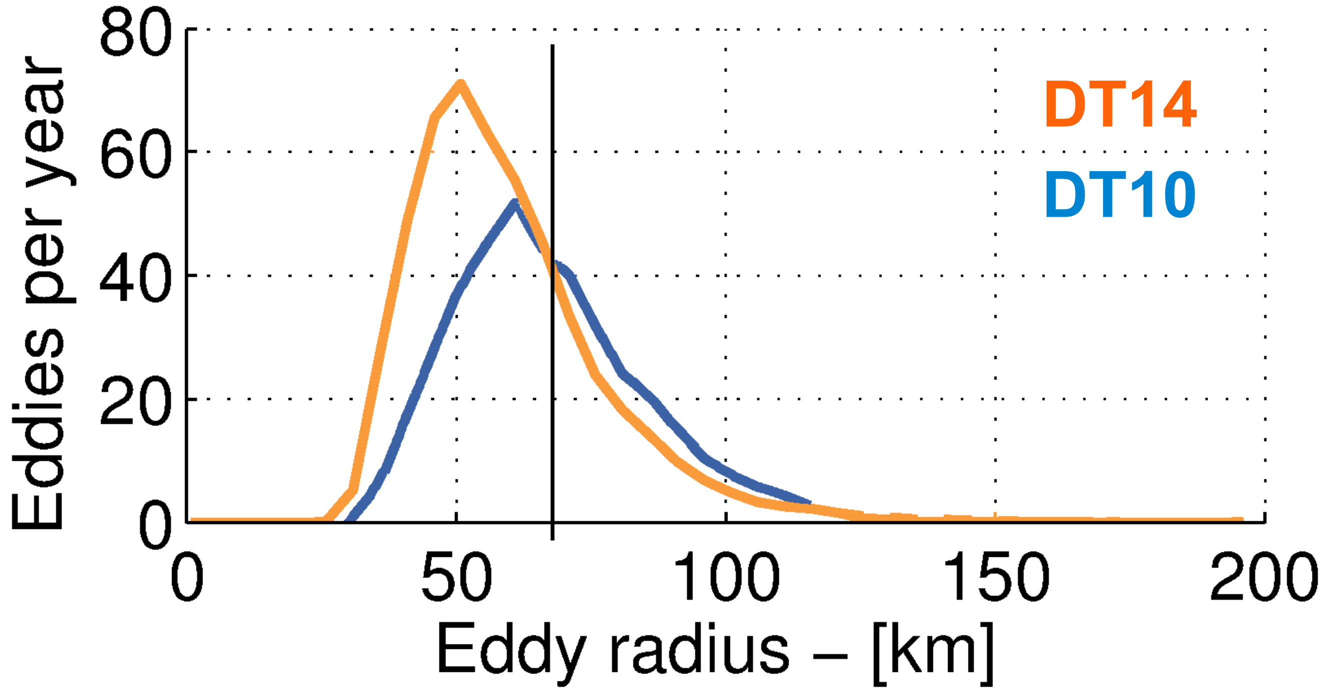

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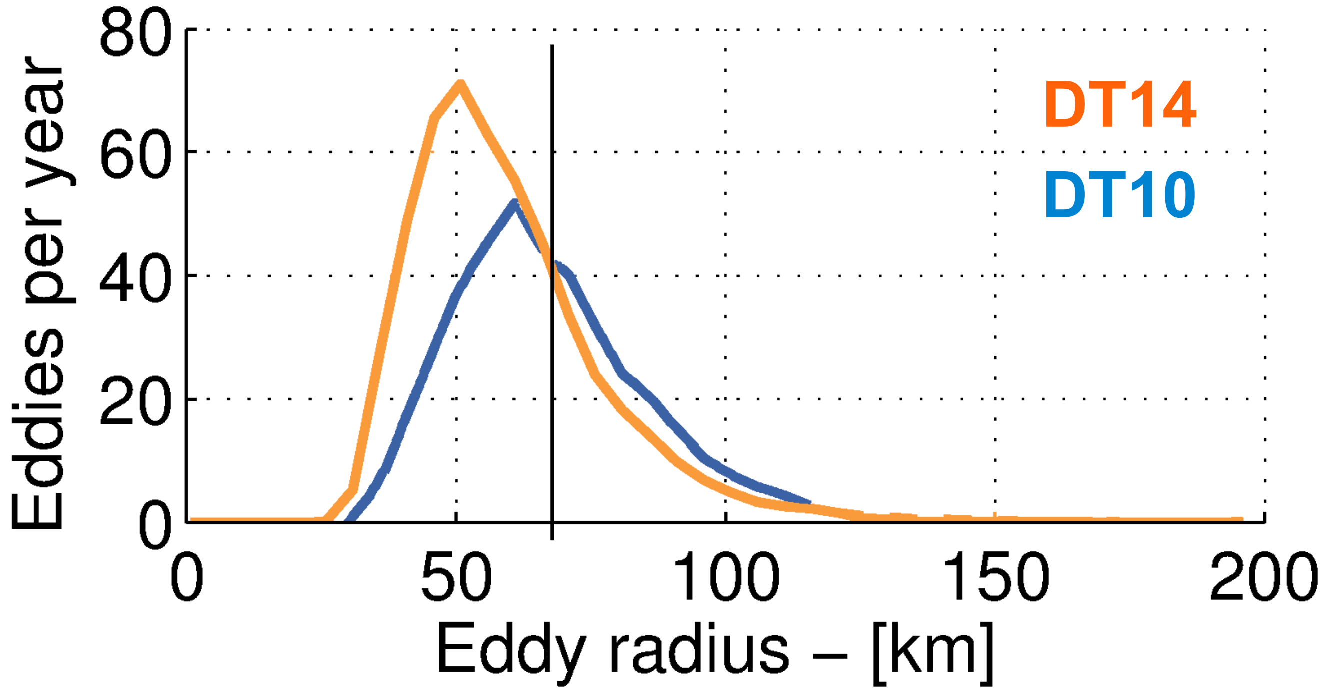

$$\frac{Q_{14}}{Q_{10}} = \frac{\sum_{i=1}^{n_{14}} r_{14,i}^2}{\sum_{j=1}^{n_{10}} r_{10,j}^2}$$

n_{14}/n_{10} **+12.4%**

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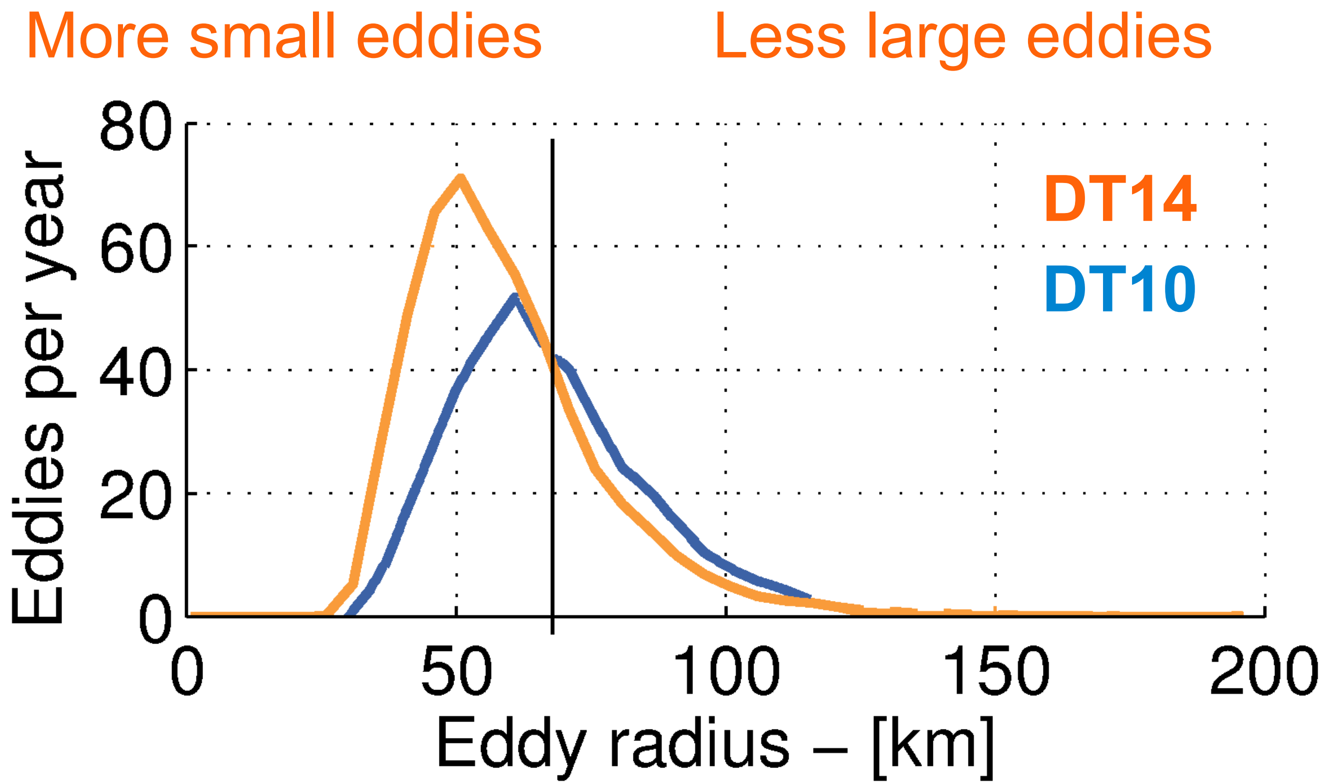

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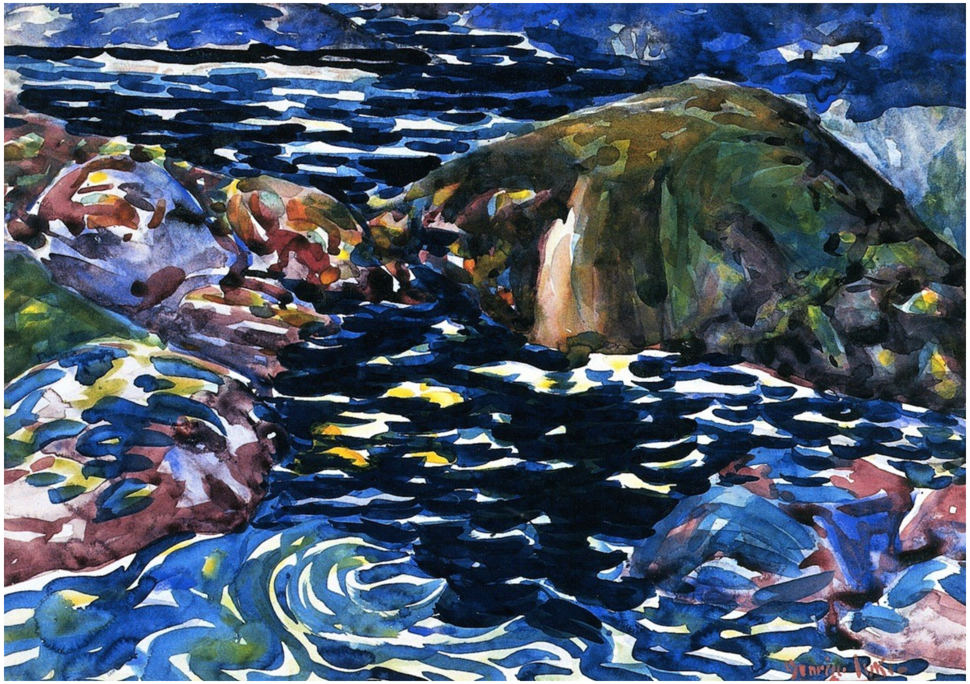
n_{14}/n_{10} **+12.4%**

Q_{14}/Q_{10} **-12.5%**

3. What is the impact of DT14 altimetry on eddy transport estimates?

→ DT14 depicts more abundant and smaller eddies, which leads to smaller transport estimates

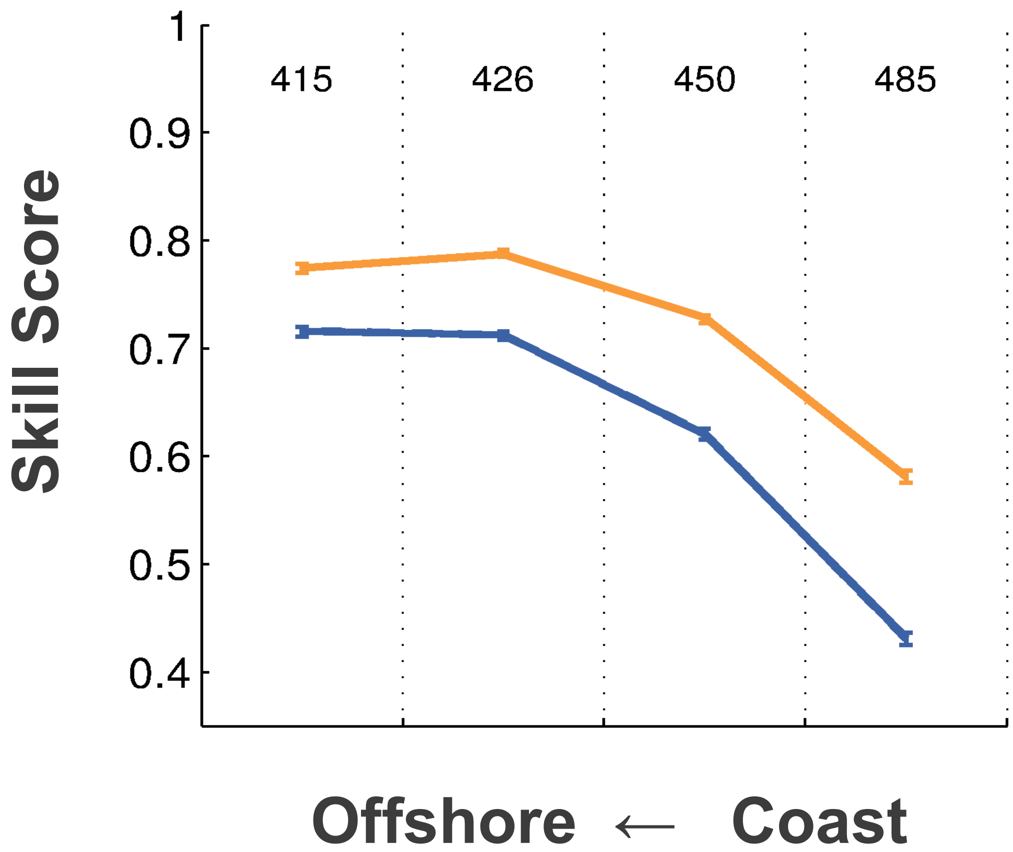
Conclusions



Conclusions (1 / 2)

→ **DT 2014 enhances** the representation of mesoscale circulation in the EBUS

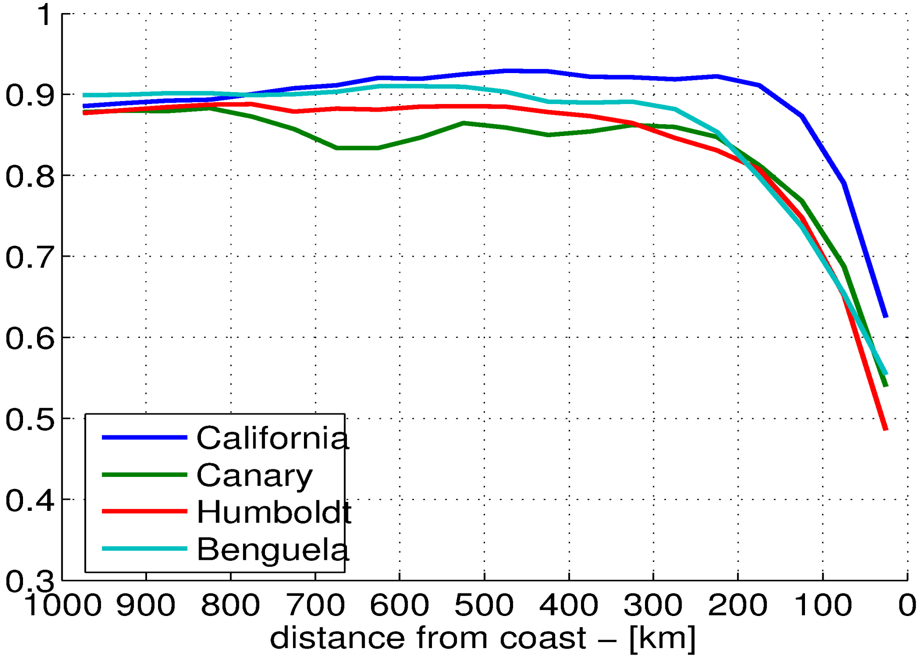
Geostrophic velocities :
Satellite VS Drifters



Conclusions (1 / 2) → Implications

→ **DT 2014 enhances** the representation of mesoscale circulation in the EBUS

Temporal Correlation (EKE14, EKE10)



Offshore ← **Coast**

Conclusions (1 / 2) → Implications

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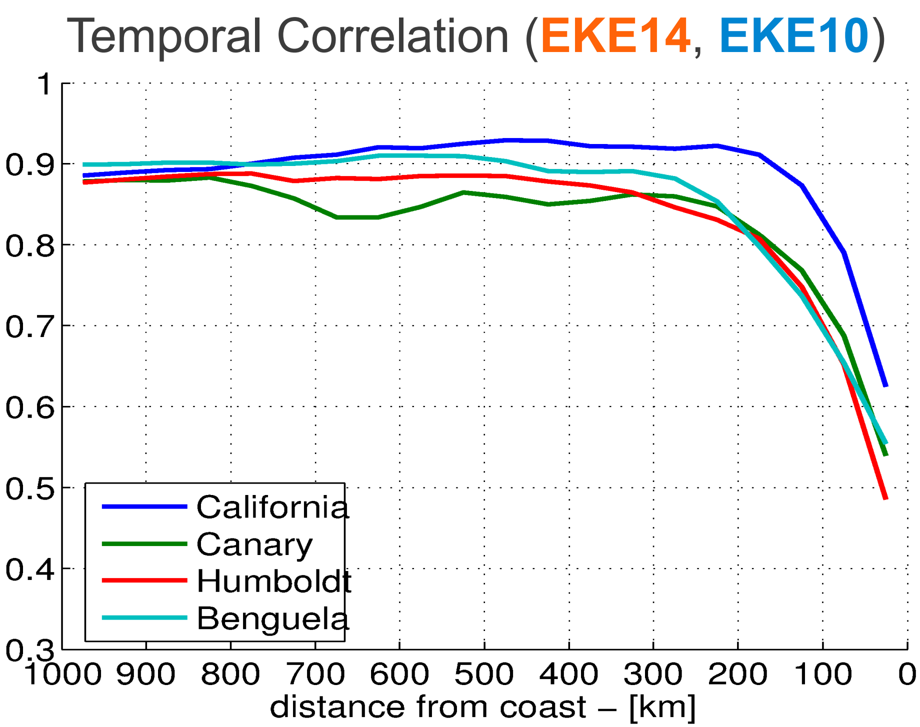

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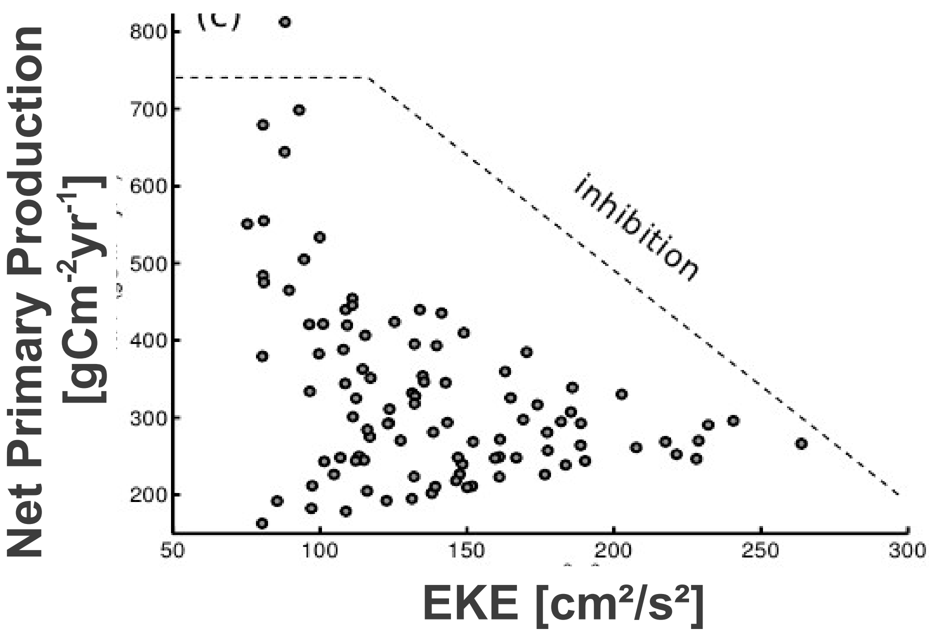
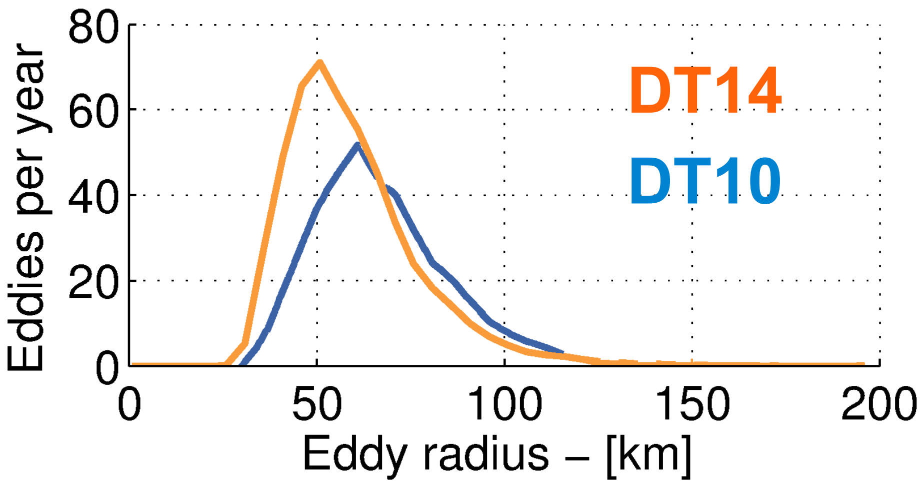


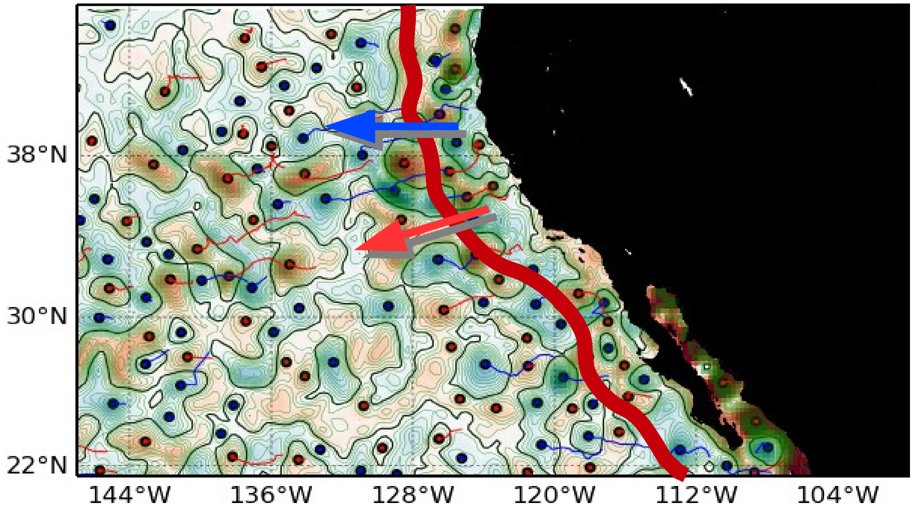
[Rossi et al., *2008, Nonlin. Processes Geophys.,*]

[*Lachkar & Gruber, 2012, Biogeosciences*]

Conclusions (2 / 2)

→ DT14 depicts more abundant and smaller eddies, which leads to **smaller transport estimates**





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n : **+12.4%**

Q : **-12.5%**

Conclusions (2 / 2) → Implications

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Horizontal eddy energy flux in the world oceans diagnosed from altimetry data

Chi Xu[1], Xiao-Dong Shang[1] & Rui Xin Huang[2]

[1]State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, China, 510301, [2]Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA.

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Oceanic Mass Transport by Mesoscale Eddies

Zhengguang Zhang,[1] Wei Wang,[1]* Bo Qiu[2]

[1]Physical Oceanography Lab, Qingdao Collaborative Innovation Center of Marine Science and Technology, Ocean University of China, Qingdao, P. R. China. [2]Department of Oceanography, University of Hawaii at Manoa, Honolulu, HI, USA

*Corresponding author. Physical Oceanography Lab, 5 Yushan Road, Qingdao 266003, P. R. China. E-mail: wei@ouc.edu.cn

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Global heat and salt transports by eddy movement

Changming Dong[1,2,3], James C. McWilliams[2], Yu Liu[3] & Dake Chen[1]

Conclusions (2 / 2) → Implications

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Oceanic Mass Transport by Mesoscale Eddies

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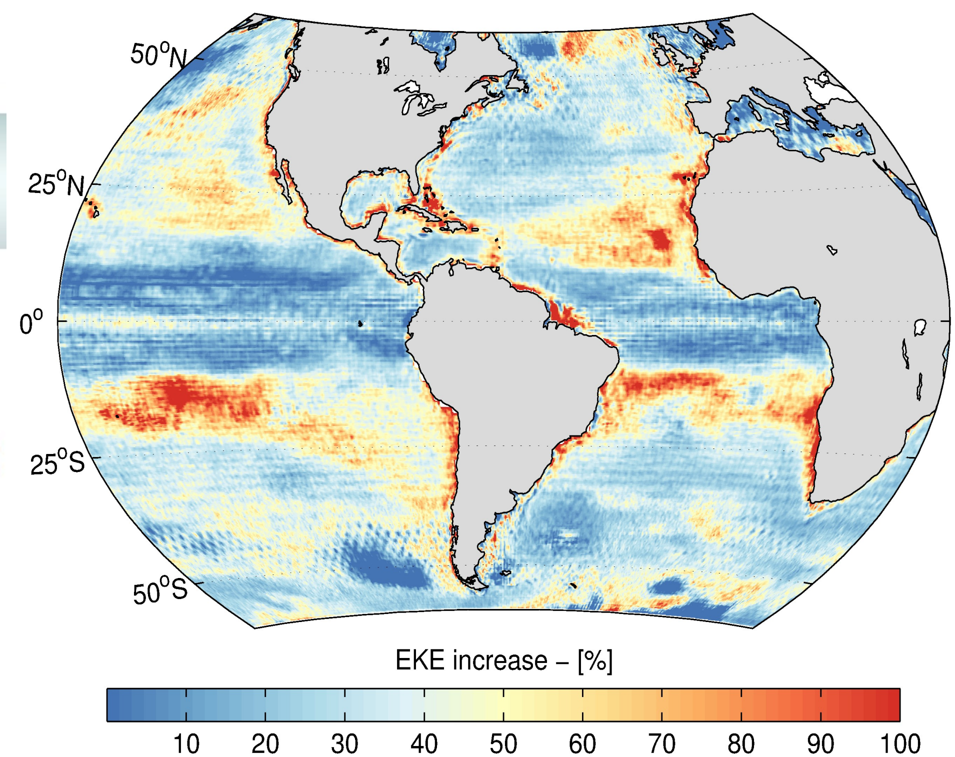
[1]Physical Oceanography Lab, Qingdao Collaborative Innovation Center of Marine Science and Technology, Ocean University of China, Qingdao, P. R. China. [2]Department of Oceanography, University of Hawaii at Manoa, Honolulu, HI, USA

*Corresponding author. Physical Oceanography Lab, 5 Yushan Road, Qingdao 266003, P. R. China. E-mail: wei@ouc.edu.cn



Thank you for your attention

- More information on
  - AVISO DT 2014 revision

Poster I.9. Isabel PUJOL

  - Eddy Tracking

Poster I.8. Evan MASON

Poster II.5. Romain Escudier

Geostophic velocity magnitude Satellite **VS** Drifters

- Percentage Bias :

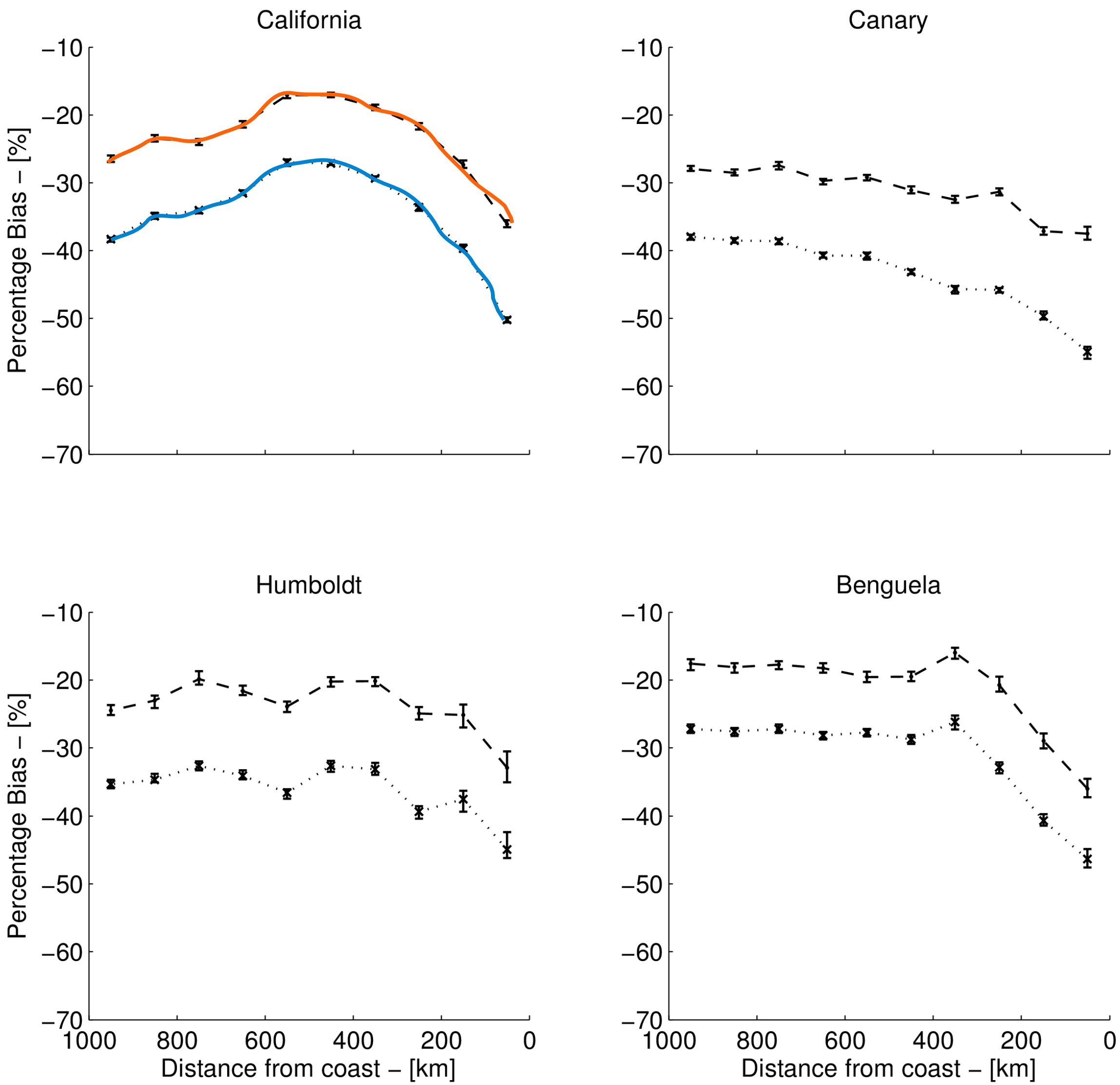
$$PB = \frac{\overline{(v_{sat} - v_{drift})}}{\overline{v_{drift}}}$$

→ Systematic under-estimation.

→ Improved by DT14 but still consequent

[28-52 %] → [18-36 %]

DT10 **DT14**

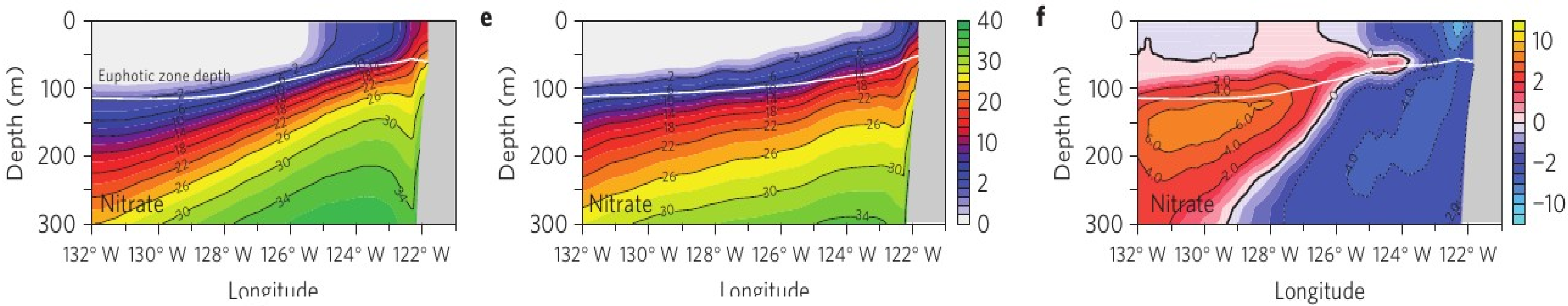


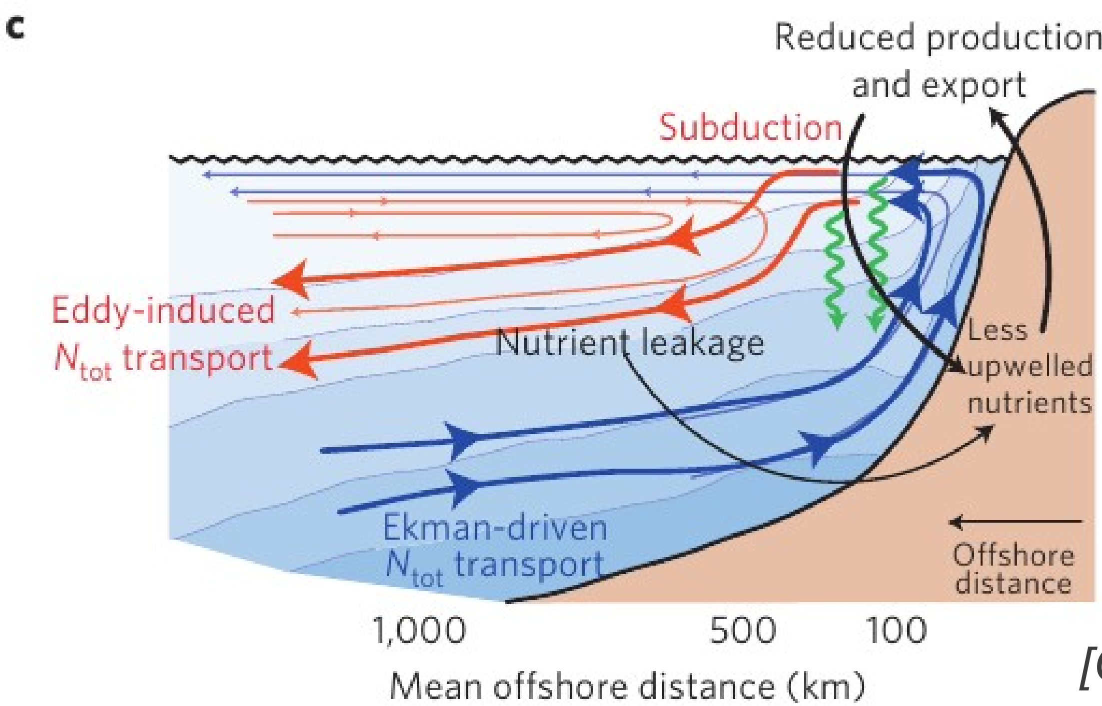
Mesoscale activity in the EBUS

Offshore export and Subduction

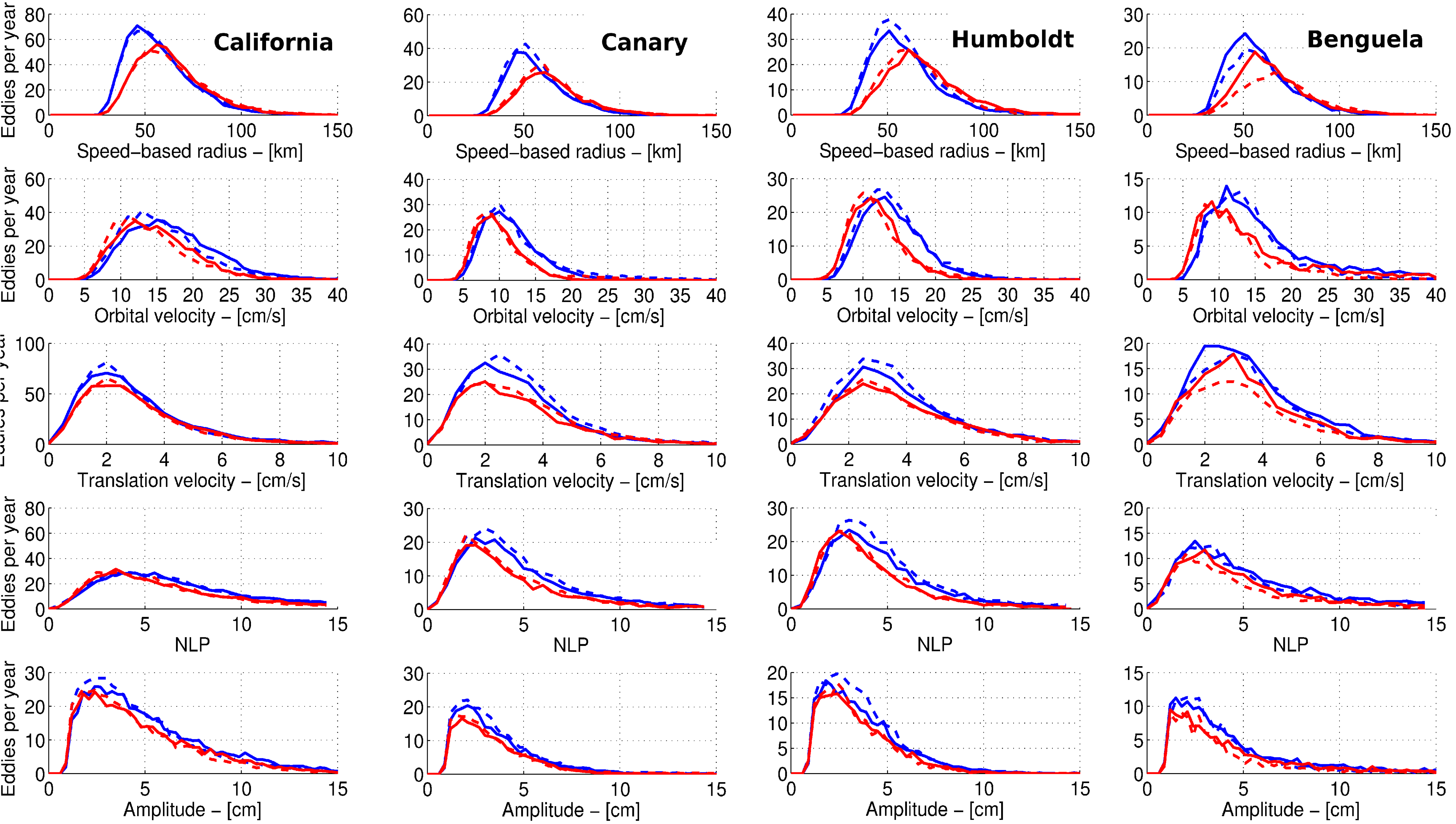
Non Eddy | Eddy | (Eddy) – (Non eddy)

Nitrate





[Gruber et al 2011, Nature]


California
Canary
Humboldt
Benguela
Eddies per year
Speed–based radius – [km]
Orbital velocity – [cm/s]
Translation velocity – [cm/s]
NLP
Amplitude – [cm]

3. What is the impact of DT14 altimetry on eddy transport estimates?

→ DT14 depicts more abundant and smaller eddies, which leads to smaller transport estimates

	California	Canary	Humboldt	Benguela	**Average**
n_{14}/n_{10}	+8.5%	+18.2%	+11.1%	+11.8%	**+12.4%**
Q_{14}/Q_{10}	-13.8%	-10.5%	-16.1%	-9.6%%	**-12.5%**
Q_{14} (Sv)	[5.0 – 14.9]	[2.8 – 8.5]	[4.3 – 13.1]	[3.6 – 10.9]	