Environment and Climate Change Canada
Environnement et Changement climatique Canada

VERIFICATION OF EDDY-PROPERTIES IN OPERATIONAL OCEANOGRAPHIC ANALYSIS SYSTEMS

Gregory Smith[1] and Anne-Sophie Fortin[2]

[1]Meteorological Research Division, ECCC

[2]McGill University, Montréal, Canada

International Verification Methods Workshop, Nov. 2020

Canada

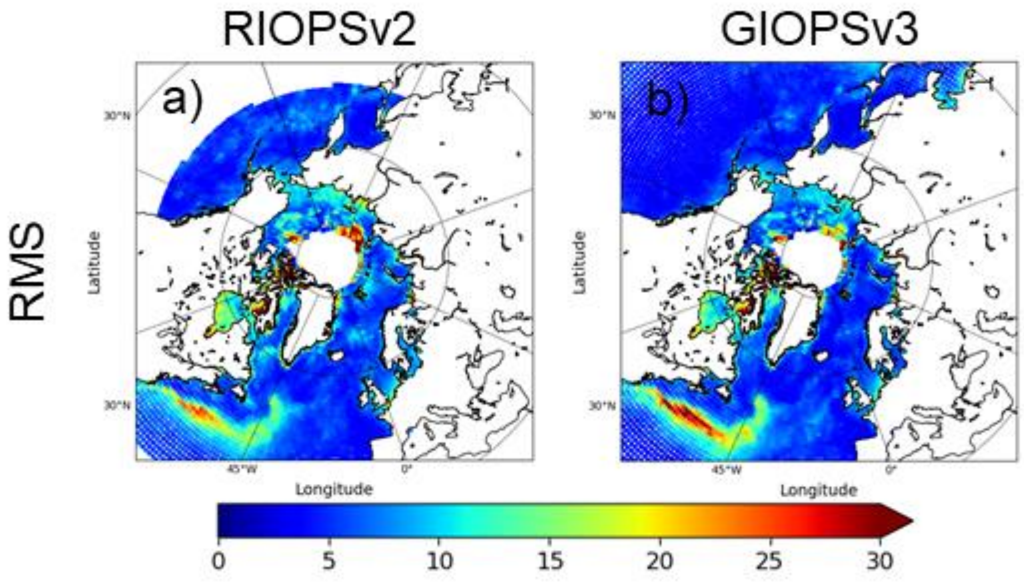
Background and Motivation

- Many ocean eddy tracking studies have been made:
  - Chelton et al. (2011), Mason et al. (2014), Faghmous et al. (2015), Conti et al. (2016), Pegliasco et al. (2020).
- None have been used before for the verification of mesoscale eddies in ocean forecasts (as is routinely done for tropical cyclones)
  - Eddies important for surface currents and many marine applications.
  - Presence of eddies shown to affect cyclone intensification (Ma et al., 2017).
- Here we use an eddy tracking code to evaluate the representation of actual mesoscale eddies in Operational Global and Regional ECCC analyses.
  - Anticipate that RIOPS will have an improved representation of eddies due to its higher spatial resolution (x3).

ECCC Operational Ocean Analysis Systems

- [G,R]IOPS = [Global, Regional] Ice Ocean Prediction System
  - GIOPS = Global 1/4° resolution
  - RIOPS = N.Atl/Arctic/N.Pac 1/12° resolution
- Mercator Ocean Assimilation System (SAM2):
  - Sea surface temperature
  - Temperature and salinity profiles
  - Along-track sea level anomaly from satellite altimeters
- Produce daily ice-ocean analyses from two successive 7-day cycles
  - 3DVAR T/S bias correction, IAU

Somewhat smaller RMS errors in RIOPS over Gulf Stream, but what does this mean in terms of representation of actual eddies?

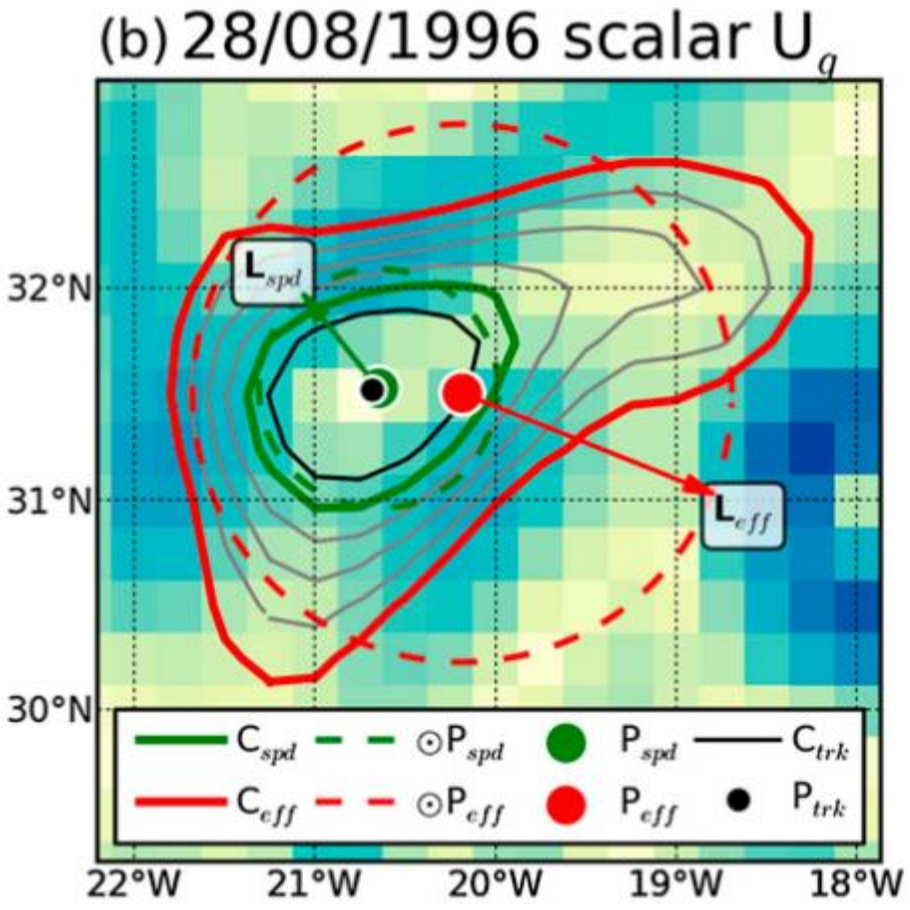


Innovation statistics of sea level anomaly for the period 2016 to 2019.

Smith et al. (GMDD, 2020)

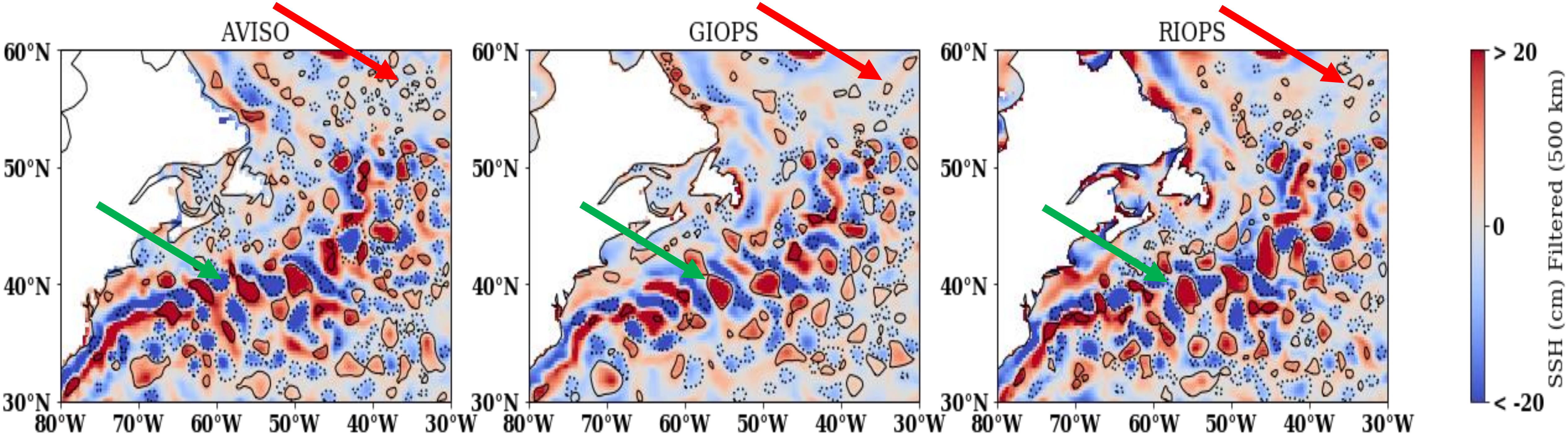
Eddy Identification

- Used py-eddy-tracker (Mason et al., 2014)
- Identifies closed contours of sea level anomaly (SLA) or absolute dynamic topography (ADT) field.
- For a closed contour to be a valid eddy, it must satisfy the following criteria:
    - Only one maxima (minima) allowed
    - Have between 5 and 2000 pixels
    - Must fit a circle with a maximum of 55% error in area
    - The amplitude must be at least twice the contour interval (i.e. 0.4 cm)



Eddy Identified plotted over U geostrophic velocity.
C_{eff} (red solid contour): Cyclonic eddy
P_{eff} (red dot): Centroid of C_{eff}
P_{eff} (red dashed contour): Circle with same area as C_{eff}
Mason et al. (2014)

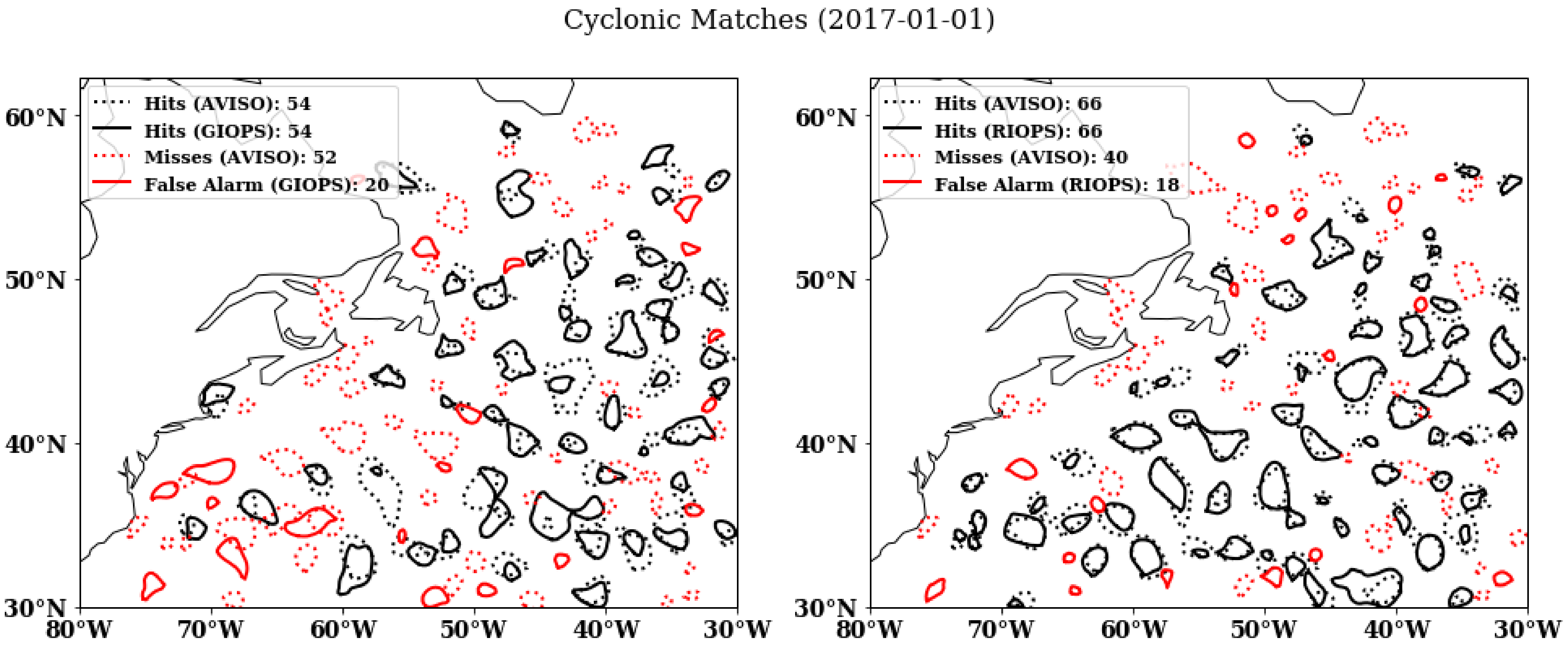
Eddy Identification



- Anticyclonic (solid) and cyclonic (dotted) eddies contours plotted over filtered SSH (2017-01-01)
- Eddies generally well-identified in all three products
- Correspondence of many of the larger features, but smaller-scale features quite different
    - Shows limit of smallest constrained scales

Eddy Matching

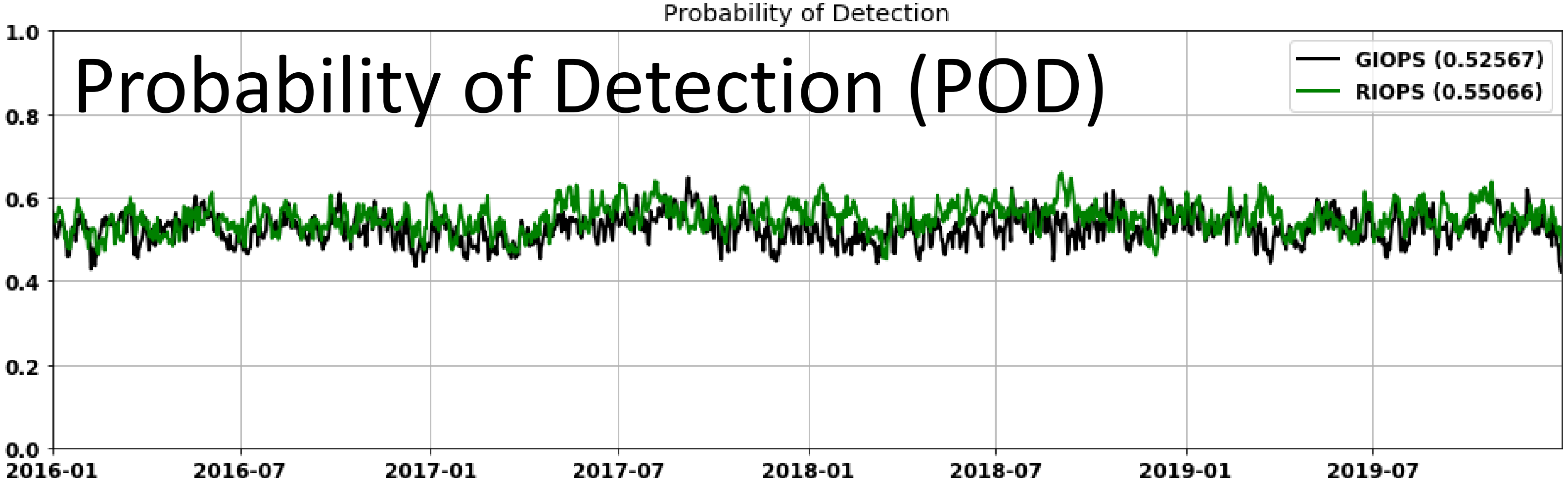
Pair eddies with the lowest cost within 125 km.

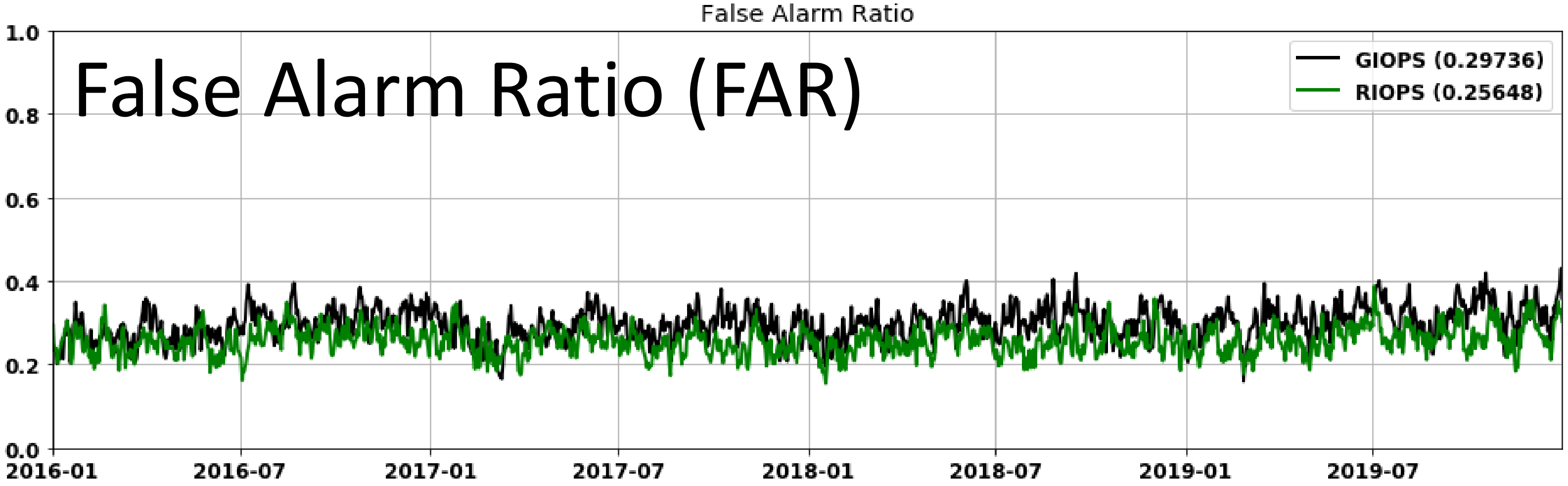


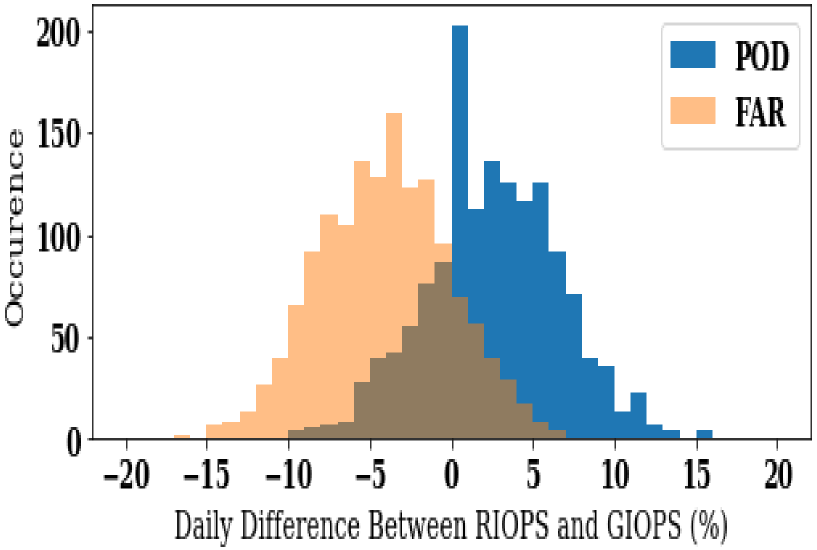
Eddy Matching

$$POD = \frac{Hits}{Hits + Misses}$$

$$FAR = \frac{False\ Alarms}{Hits + False\ Alarms}$$







Mean differences (RIOPS-GIOPS)

POD: 2.3%

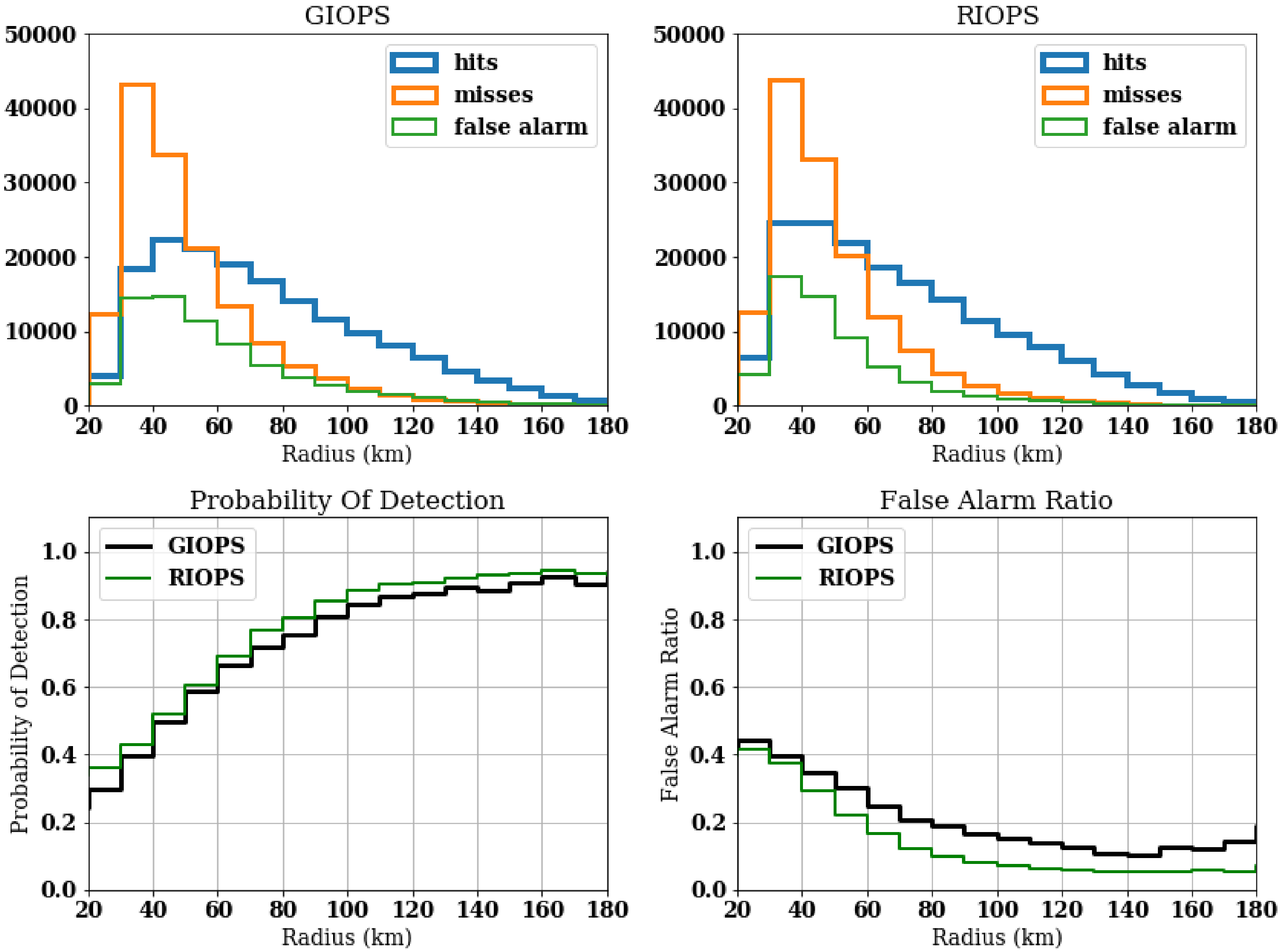
FAR: -3.9%

$$POD = \frac{Hits}{Hits + Misses}$$

$$FAR = \frac{False\ Alarms}{Hits + False\ Alarms}$$

Eddy Matching – As a Function of Radius

- More than half misses and false alarms have a radii less than 50 km.
- Maybe AVISO (altimetry) limited capacity to capture small wavelengths, resulting in more misses at smaller radii, or GIOPS & RIOPS represent less small eddies
- POD increases with size of radii.
- FAR decrease with size of radii.

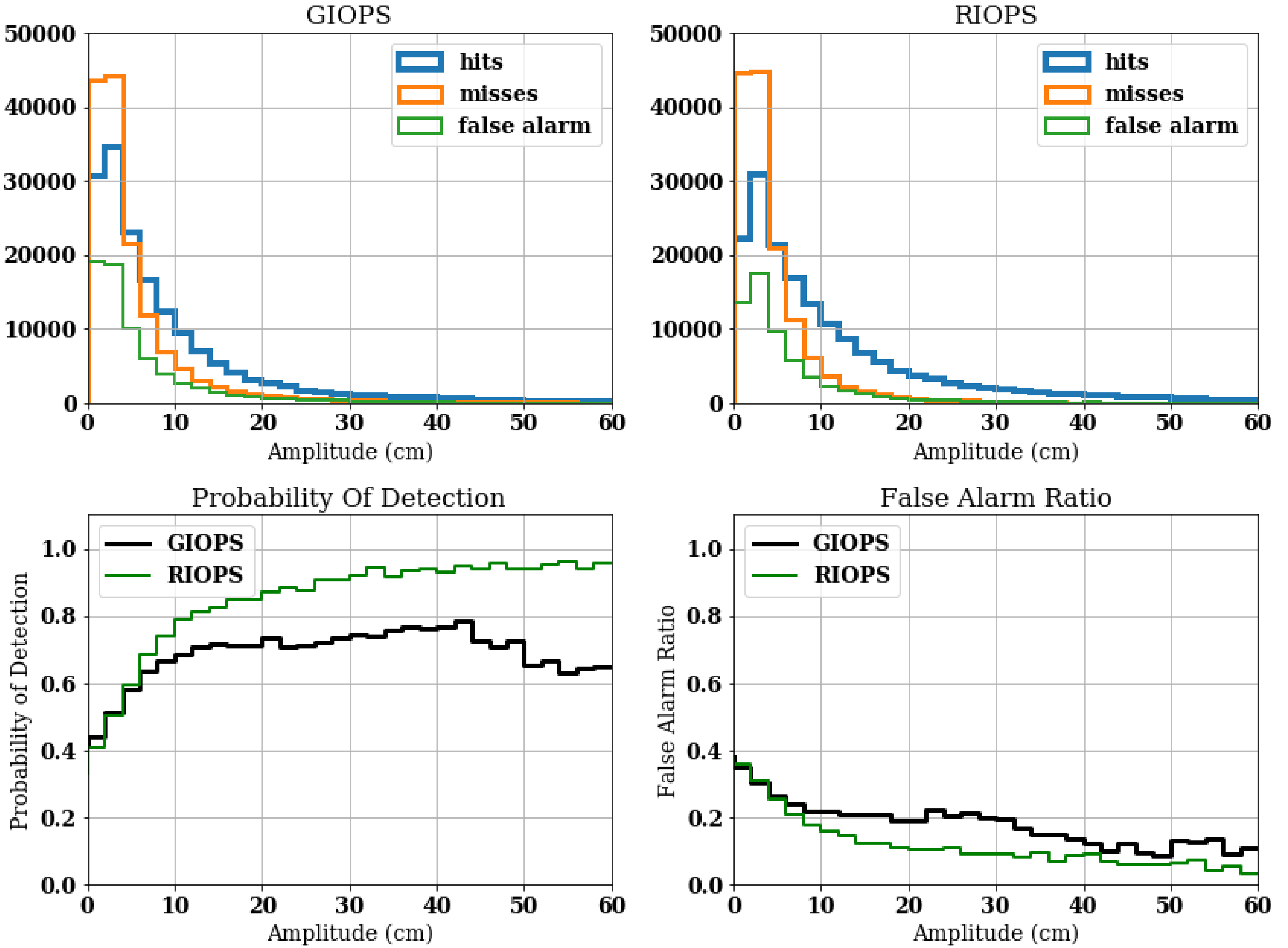


Eddy Matching – As a function of Amplitude

- POD increases with amplitude

- FAR decrease with amplitude

- Most eddies have small amplitudes (< 10 cm); RIOPS and GIOPS show similar scores
  - Room for improvement!



Generate Scores for Position and Size

Cost of matching

$$cost = \sqrt{\left(\frac{A_1 - A_2}{A_1}\right)^2 + \left(\frac{R_1 - R_2}{R_1}\right)^2 + \left(\frac{distance}{125\ km}\right)^2}$$

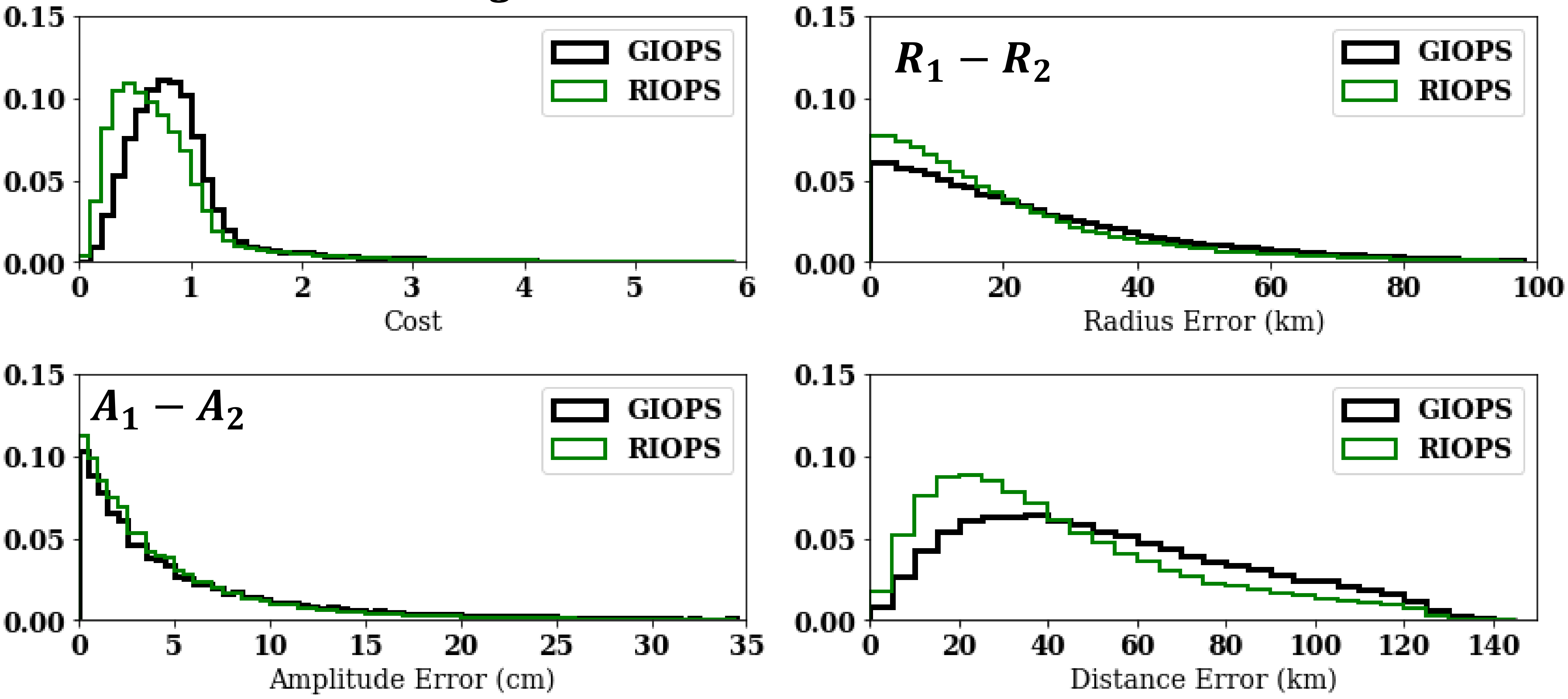
Where $A = Amplitude, R = Radii$

$$cost = \sqrt{\left(\frac{A_1 - A_2}{A_1}\right)^2 + \left(\frac{R_1 - R_2}{R_1}\right)^2 + \left(\frac{distance}{125\ km}\right)^2}$$

Generate Scores for Position and Size

Normalized Histograms

Hits Costs



Conclusion

Demonstrated that eddy matching is able to detect and quantify the improved representation of eddies in RIOPS as compared to GIOPS

- Improvement in POD (2.3%), FAR (-3.9%)
  - mainly for eddies larger than 50 km radius and 10 cm in amplitude
- Improvement in position and size

Future work

- Develop methods to objectively identify limits in small-scales
- Apply code to other regions
- Investigate error as a forecast lead-time
- Implement eddy identification in near real time
- Intercomparison with other operational systems (Mercator, UKMET…)

Acknowledgements

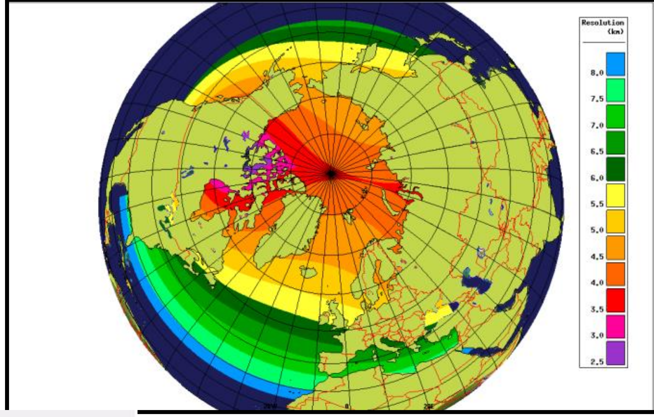
This study has been conducted using E.U. Copernicus Marine Service Information

The code py-eddy-tracker developed by Evan Mason and Antoine Delepoulle

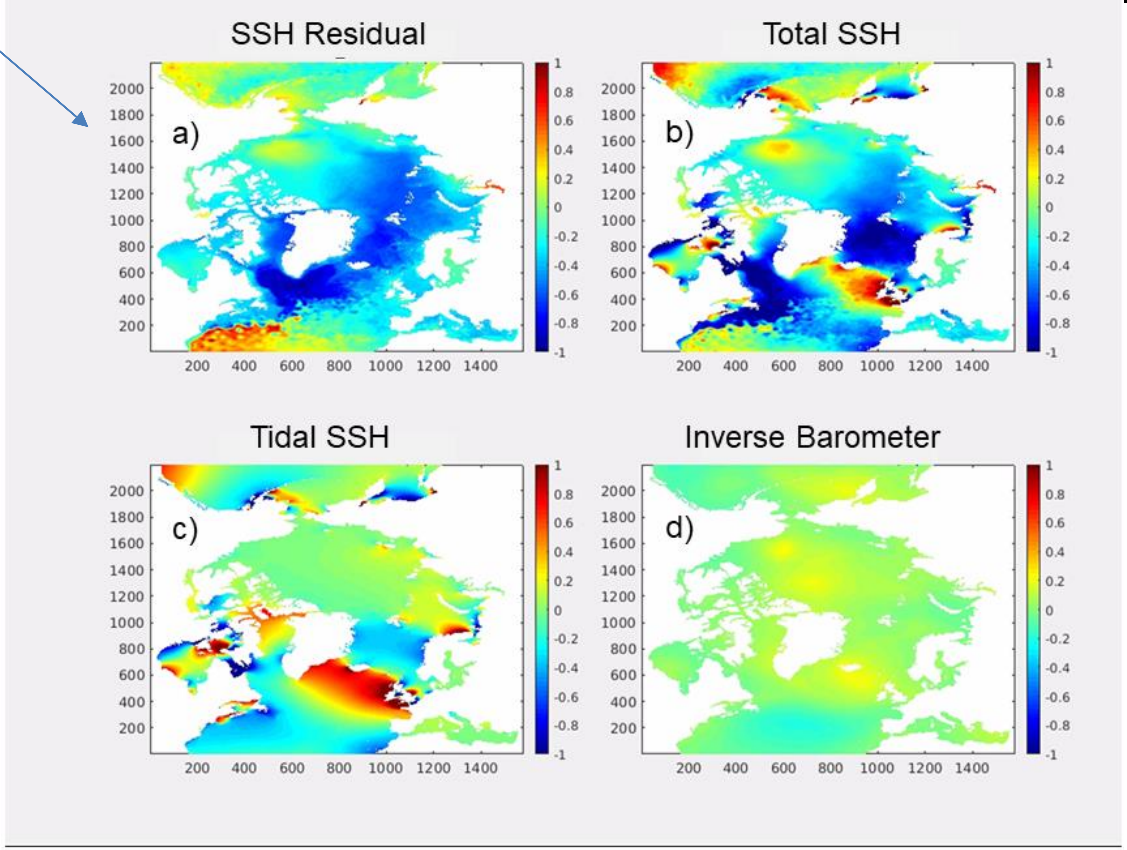
Special thanks to Antoine Delepoulle for answering all our questions

DATA ASSIMILATION IN RIOPS

- Produces daily ice-ocean analyses from two successive 7-day cycles
  - 3D bias correction, 7-day IAU
  - Novel online harmonic analysis for tides
  - Atmospheric pressure
- Mercator Ocean Assimilation System (SAM2):
  - Sea surface temperature
  - Temperature and salinity profiles
  - Sea level anomaly from satellite altimeters
- Ocean analysis blended with 3DVar Ice analysis
  - SSM/I, SSM/IS, AVHRR, ASCAT, AMSR2
  - CIS charts, Radarsat image analyses
  - Uses ice analysis error in blending
- Implemented July 2019



Model resolution



Smith et al. (GMDD, 2020)

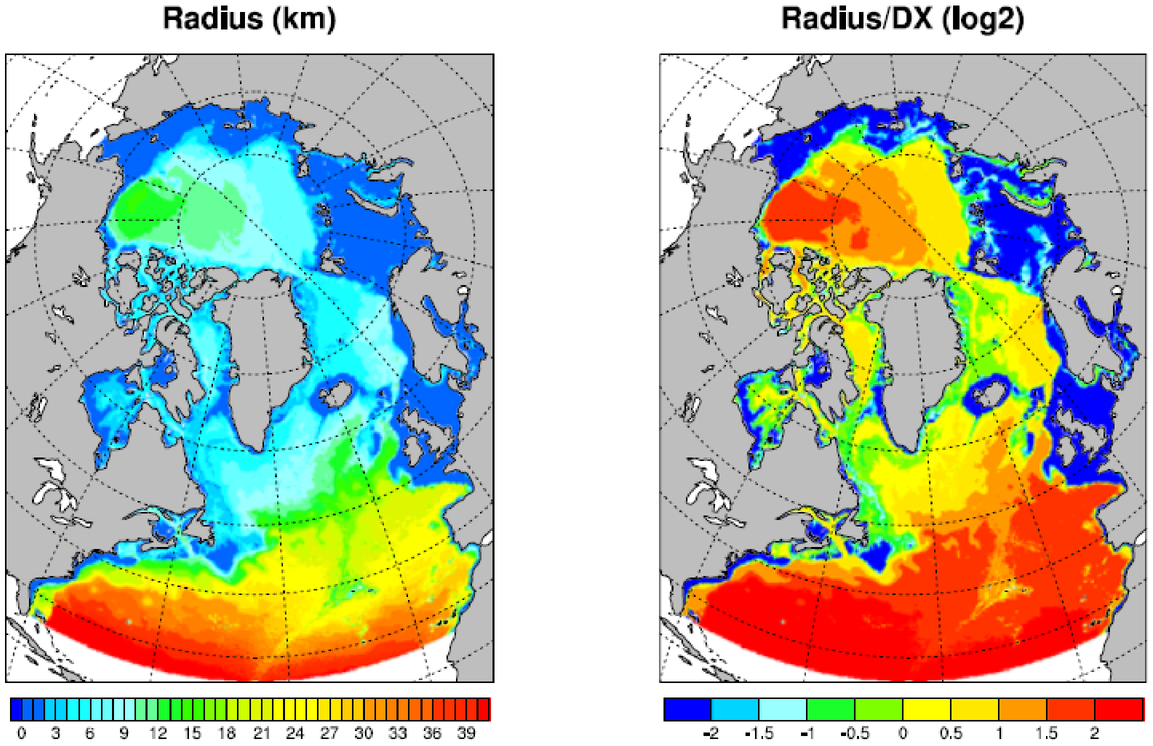
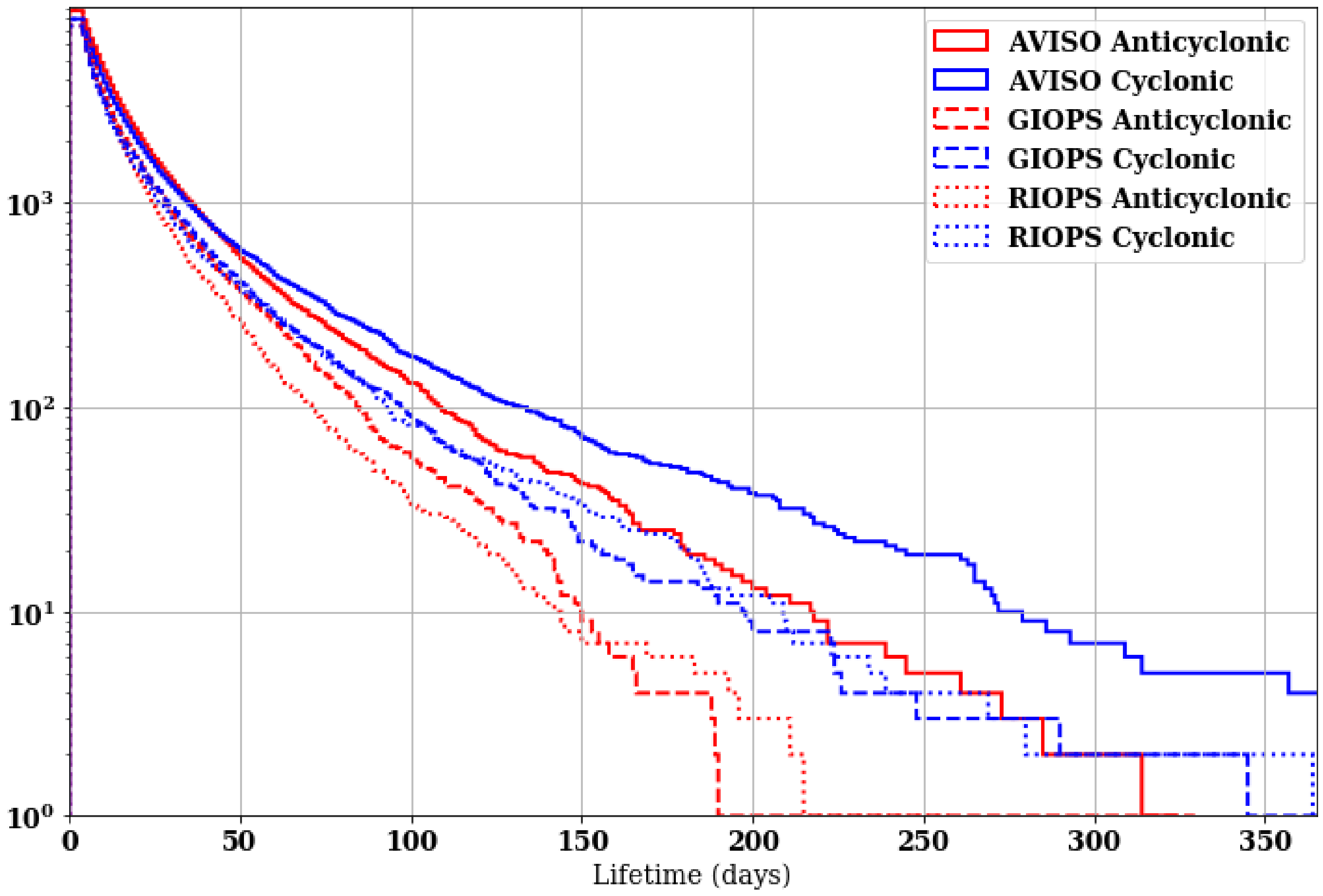


Figure 2. First Rossby radius of deformation (left, in kilometres) and Rossby radius relative to the local resolution in log 2 (right). Grossly speaking, the right panel shows where model is eddy resolving (values above 1, that is, 2 model points to resolve a baroclinic eddy), eddy permitting (between 0 and 1) or does not resolve eddies (values below 0.)

Dupont et al. (2015)

Supplementary - Eddy Tracking - Lifetimes

Cumulative lifetime for anticyclonic (red) and cyclonic (blue) eddies in the Gulf Stream.



Supplementary – Eddy Matching

Cumulative histograms of eddies in the Gulf Stream.