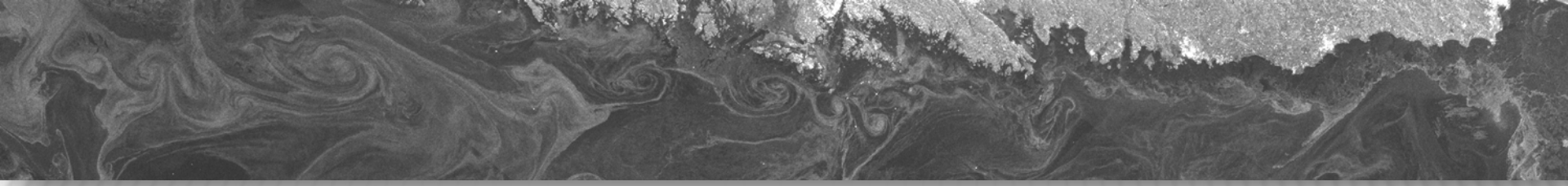

Svetlana Karimova

Ph.D. student

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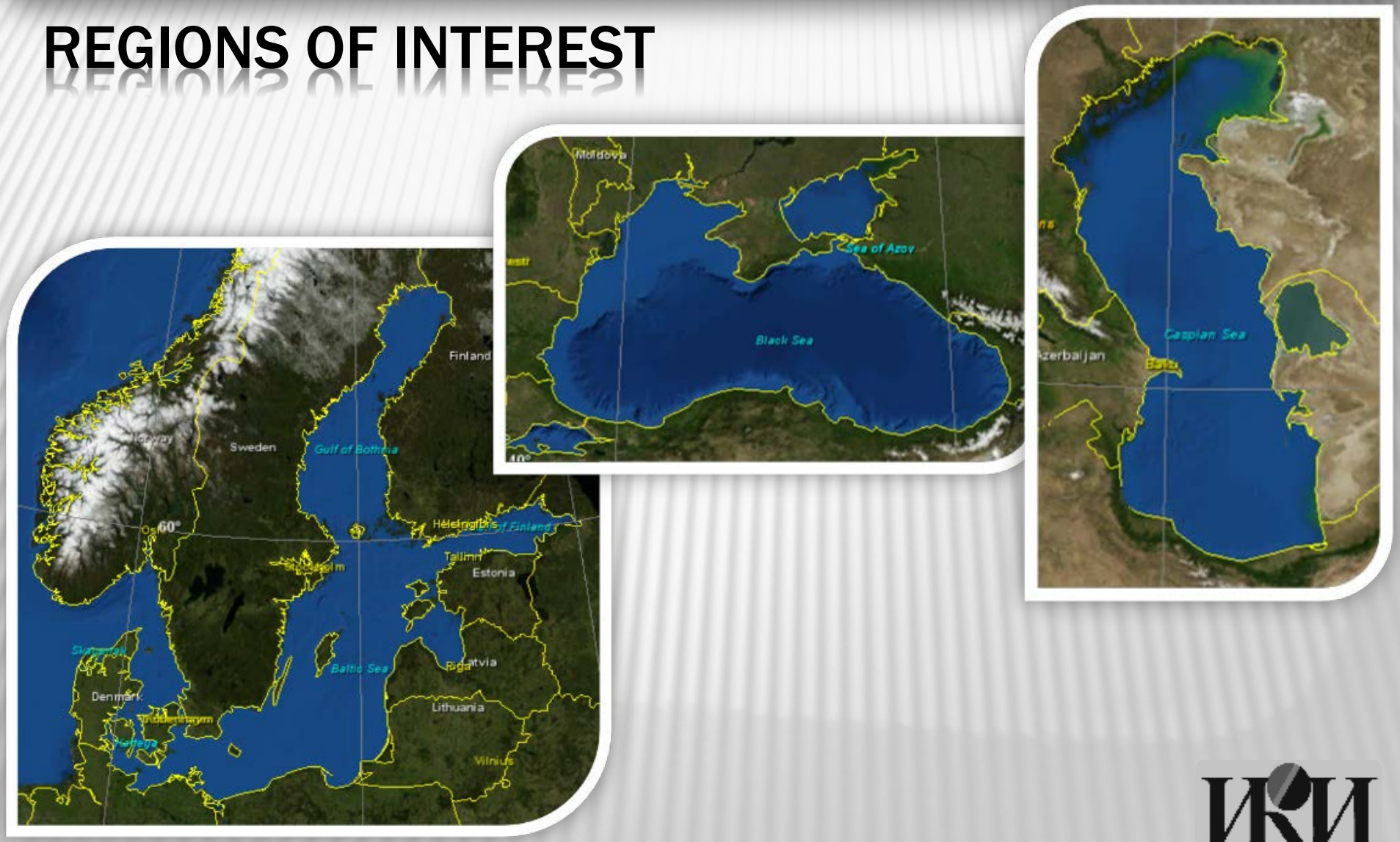
# SAR OBSERVATIONS OF SPIRAL EDDIES IN THE INNER SEAS

# REGIONS OF INTEREST



# AIMS OF THE STUDY

The study is aimed to **retrieve some general statistical information** about spiral (submesoscale) eddies in the Baltic, Black and Caspian seas using satellite SAR data

**Norwegian Sea:**

*Dokken S.T., Wahl T.* Observations of spiral eddies along the Norwegian Coast in ERS SAR images. FFI Rapport 96/01463, 1996.

About 350 ERS-1 SAR images

*Sandven S., J.A. Johannessen, K. Kloster and T. Hamre, Hans J. Sætre.* Satellite Studies of Ocean Fronts and Eddies for Deepwater Development in the Norwegian Sea // Proc. Tenth International Offshore and Polar Engineering Conference. Seattle, USA, 28 May 2 June, 2000.

About 70 ERS-2 SAR images

# DATA DESCRIPTION

Images were obtained in the rolling archives under ESA project C1P.6342

- Envisat ASAR and ERS-2 SAR
- 2009-2010
- medium resolution (150 m)

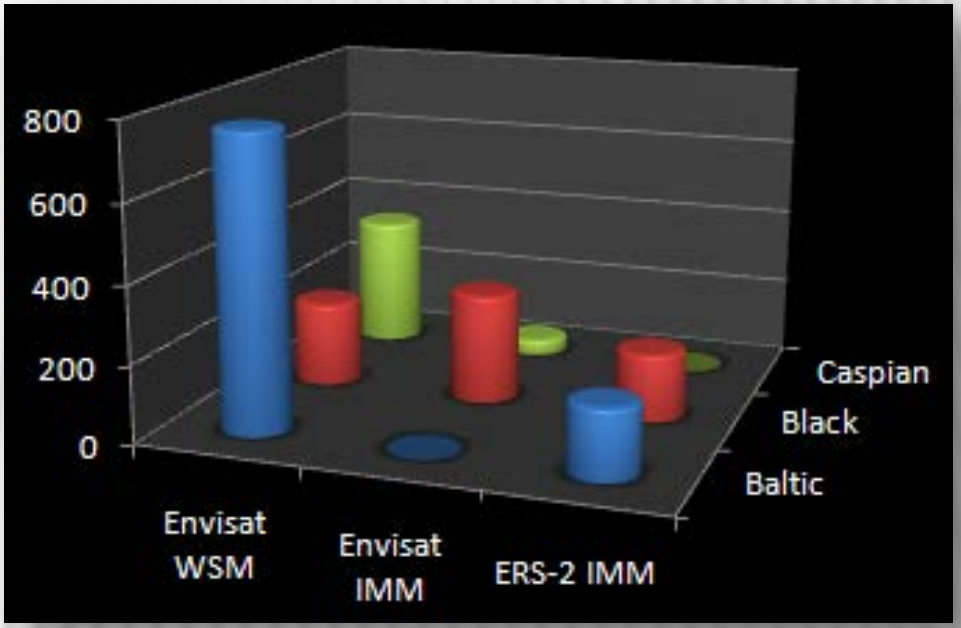
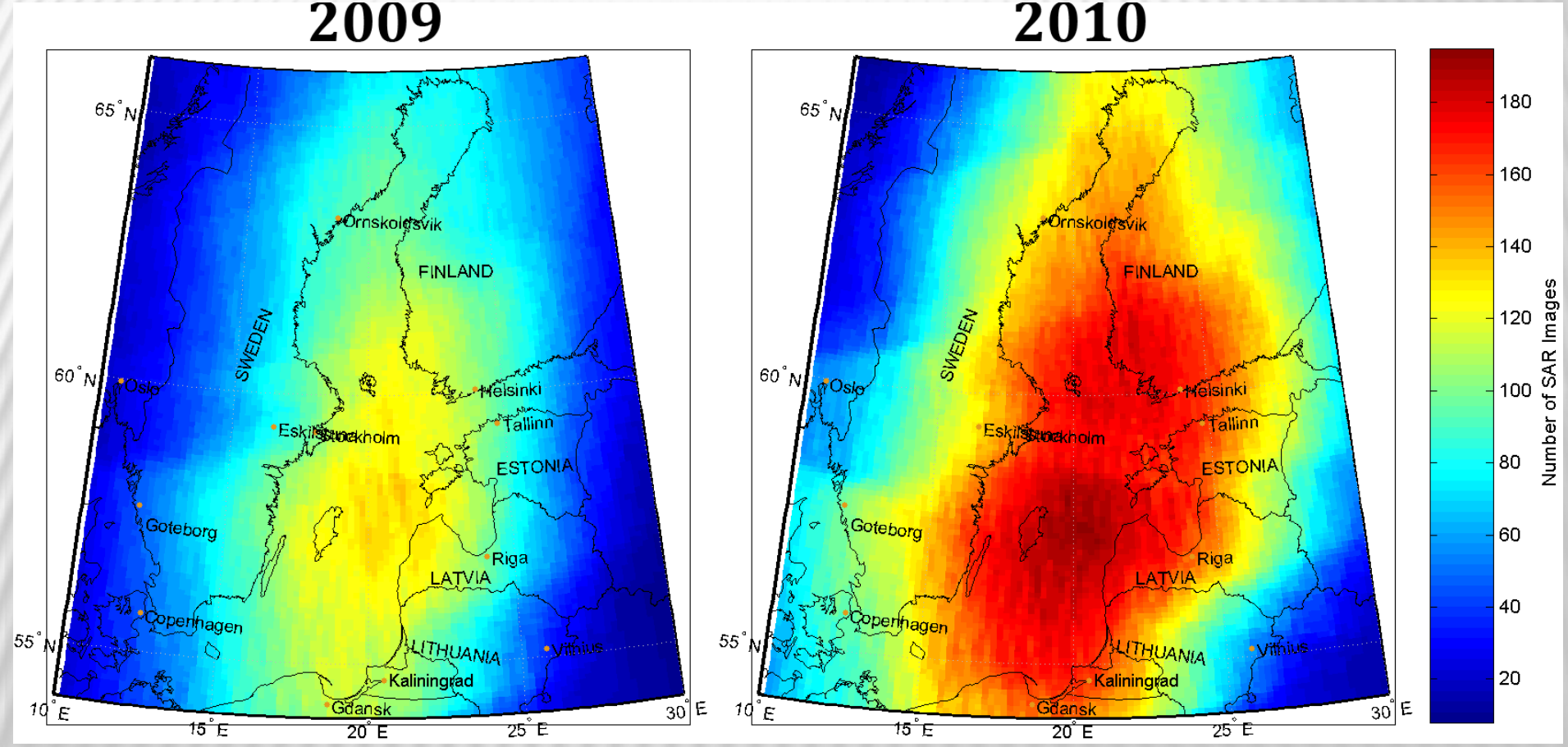


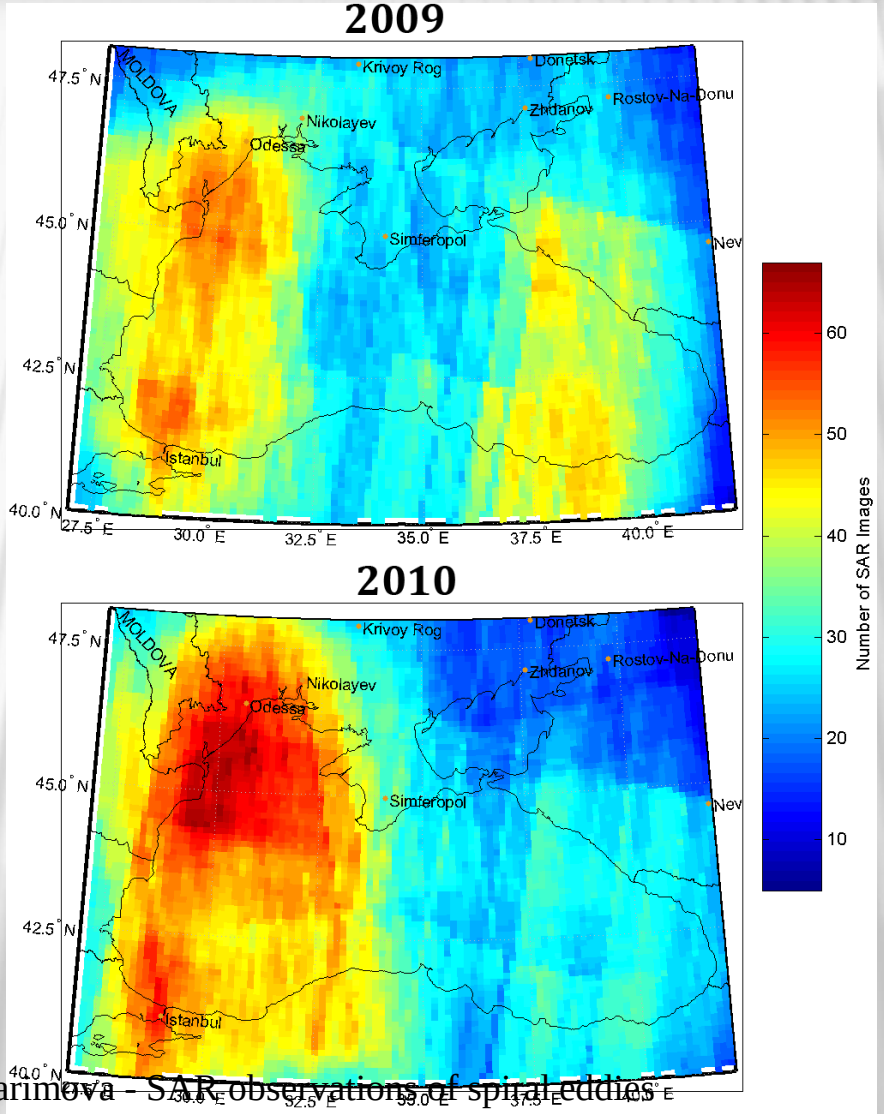

**Table.** 2009/2010

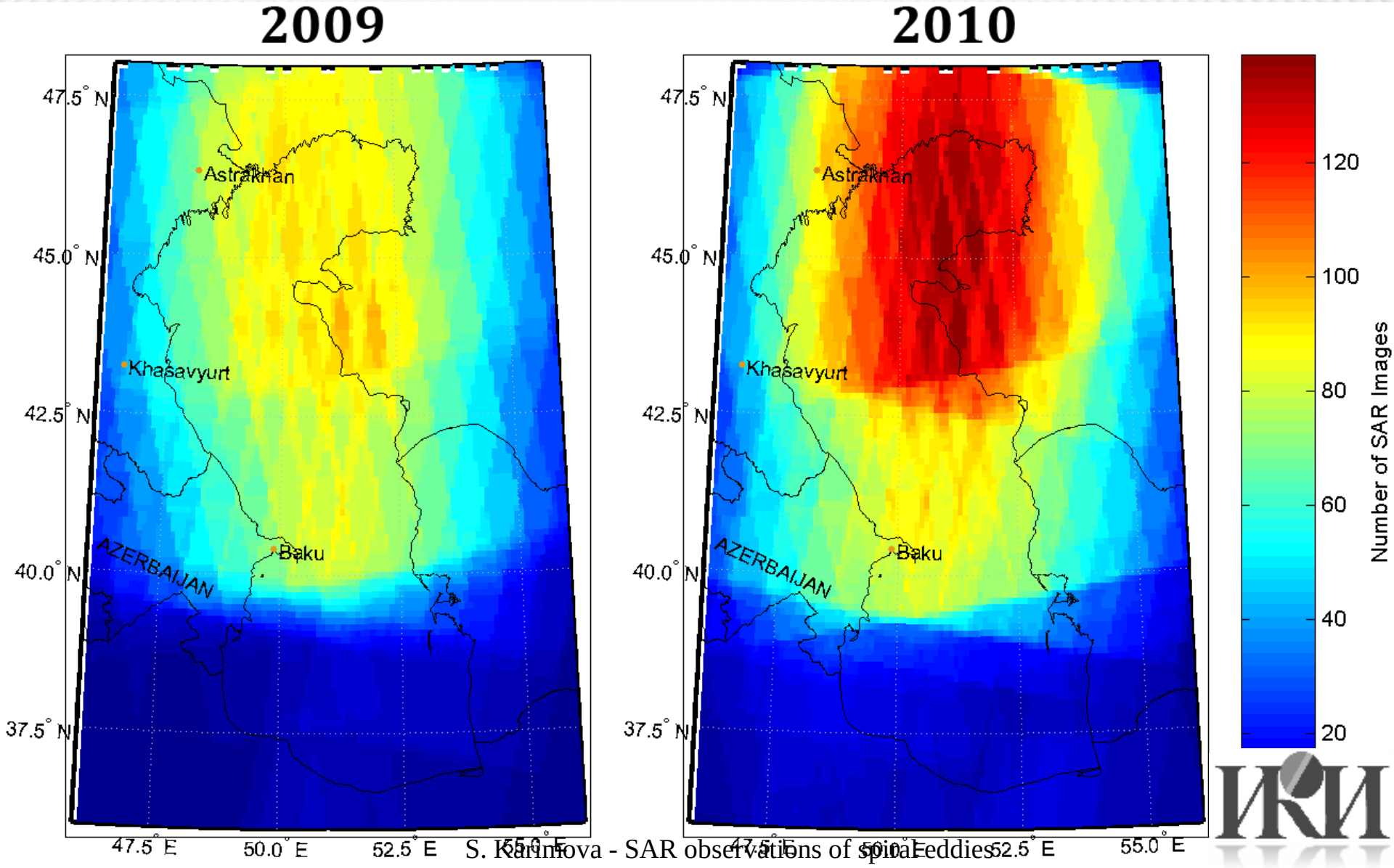
| Sea | WSM | IMM | ERS-2 IMM | Total |
|---|---|---|---|---|
| **Baltic** | 261/506 | 7/15 | 53/128 | 321/649 |
| **Black** | 97/124 | 156/130 | 76/101 | 329/355 |
| **Caspian** | 147/194 | 14/28 | -/- | 161/222 |
| **Total** | **505/824** | **177/173** | **129/229** | **811/1226** |

# BALTIC SEA COVERAGE

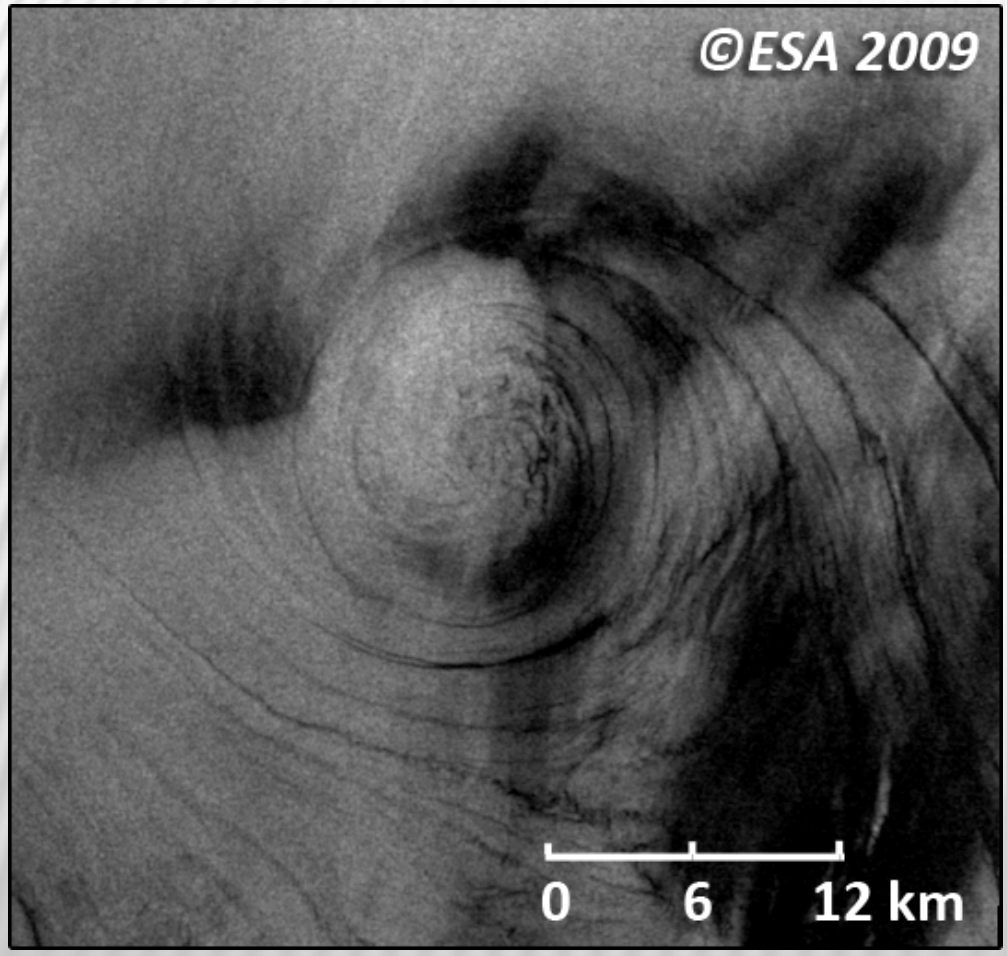


# BLACK SEA COVERAGE



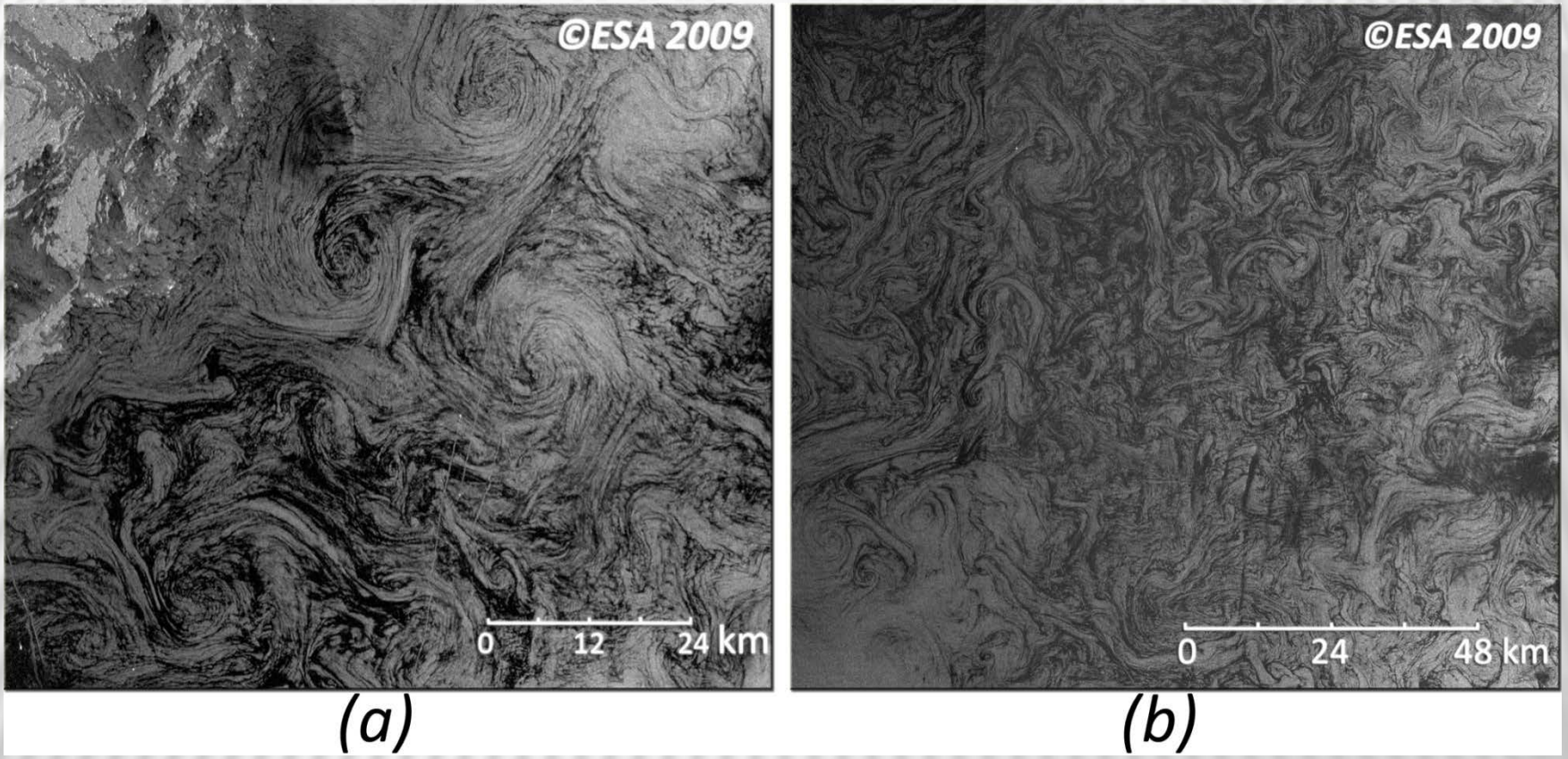

2009
2010
47.5° N
45.0° N
42.5° N
40.0° N
37.5° N
Astrakhan
Khasavyurt
Baku
AZERBAIJAN
47.5° E
50.0° E
52.5° E
55.0° E
120
100
80
60
40
20
Number of SAR Images

# SURFACTANT FILMS: “BLACK” EDDIES-1




At moderate wind speeds eddies usually appear in the SAR images due to the presence on the sea surface of natural films. Such surfactants alter sea surface tension by smoothing the ripples and thus diminishing backscatter cross-section. Surfactant films get involved in the orbital motion of eddies, in such a way imprinting them in radar images.

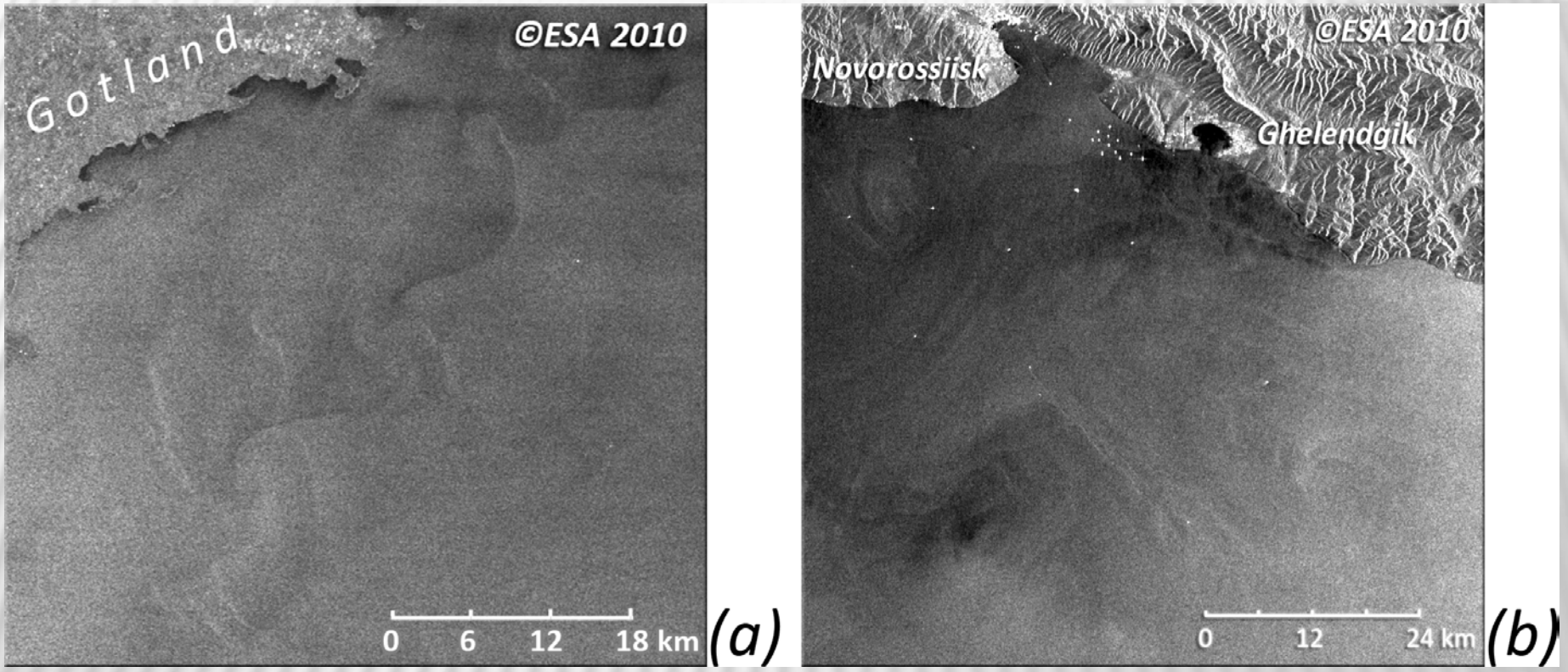
# SURFACTANT FILMS: “BLACK” EDDIES-2




*(a) ERS-2 SAR on 21.06.2009 at 09:47 UTC*

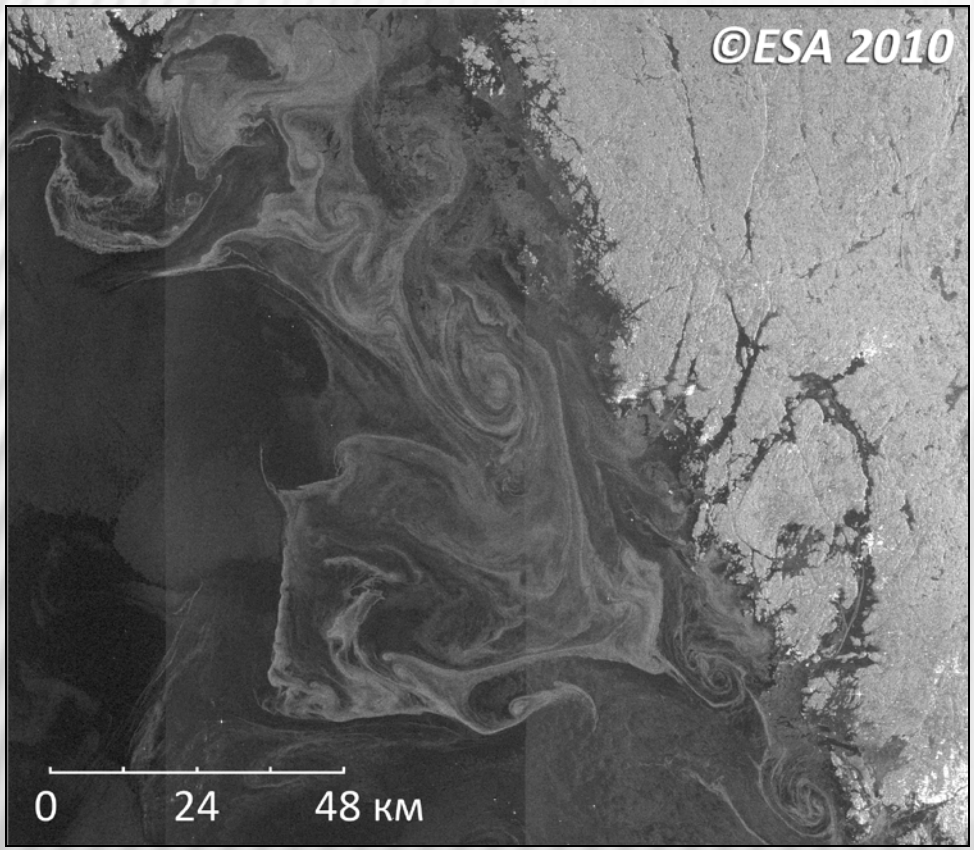
*(b) Envisat ASAR on 25.04.2009 at 09:09 UTC*

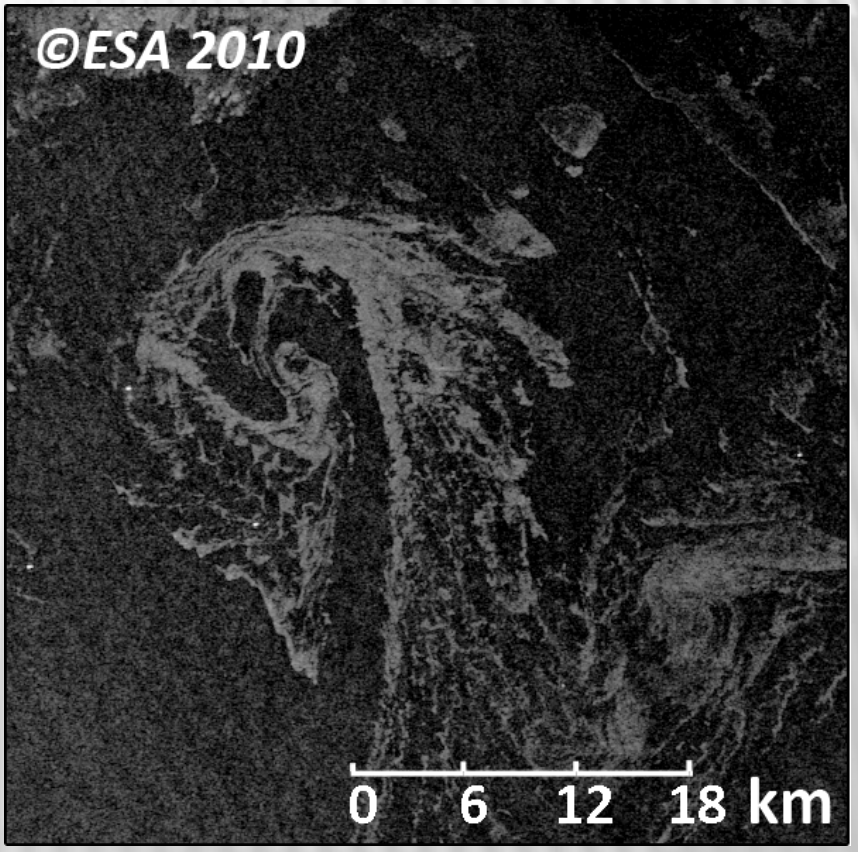
# WAVE/CURRENT INTERACTIONS: “WHITE” EDDIES




*(a) Envisat ASAR image on 14.04.2010 at 20:10 UTC*
*(b) ERS-2 SAR image on 12.03.2010 at 08:14 UTC*

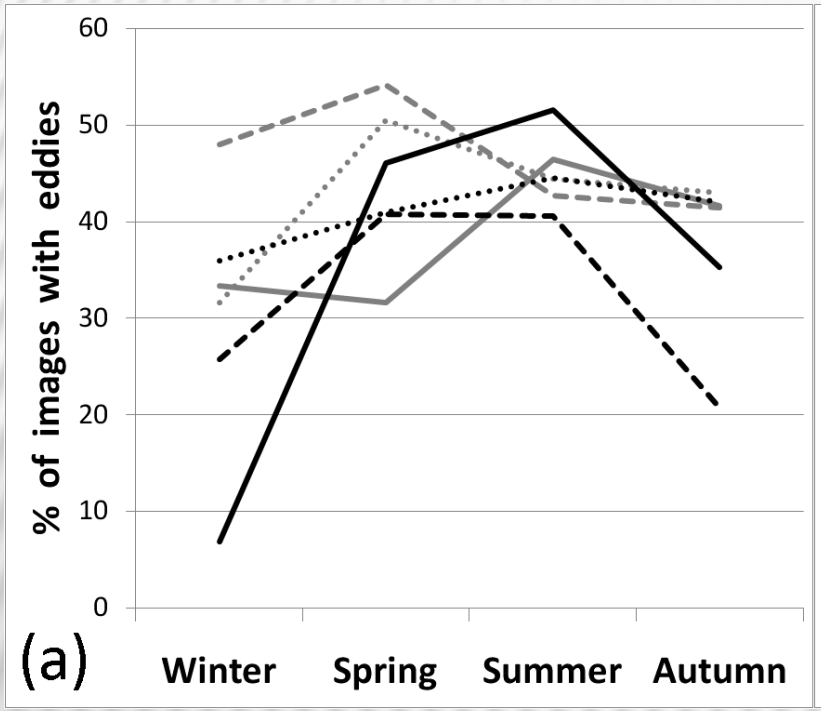
# FLOATING ICE: “ICE” EDDIES

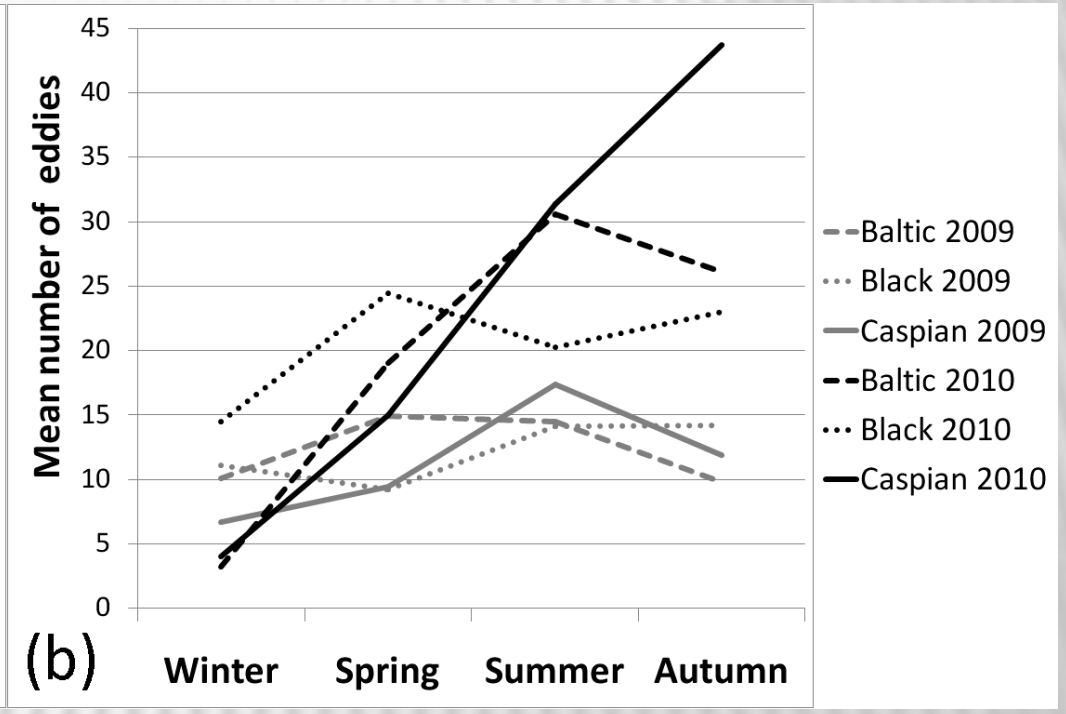



*(a) Envisat ASAR image on 26.01.2010 at 09:36 UTC*
*(b) ERS-2 SAR image on 12.01.2010 at 20:02 UTC*

# FREQUENCY OF EDDY MANIFESTATION

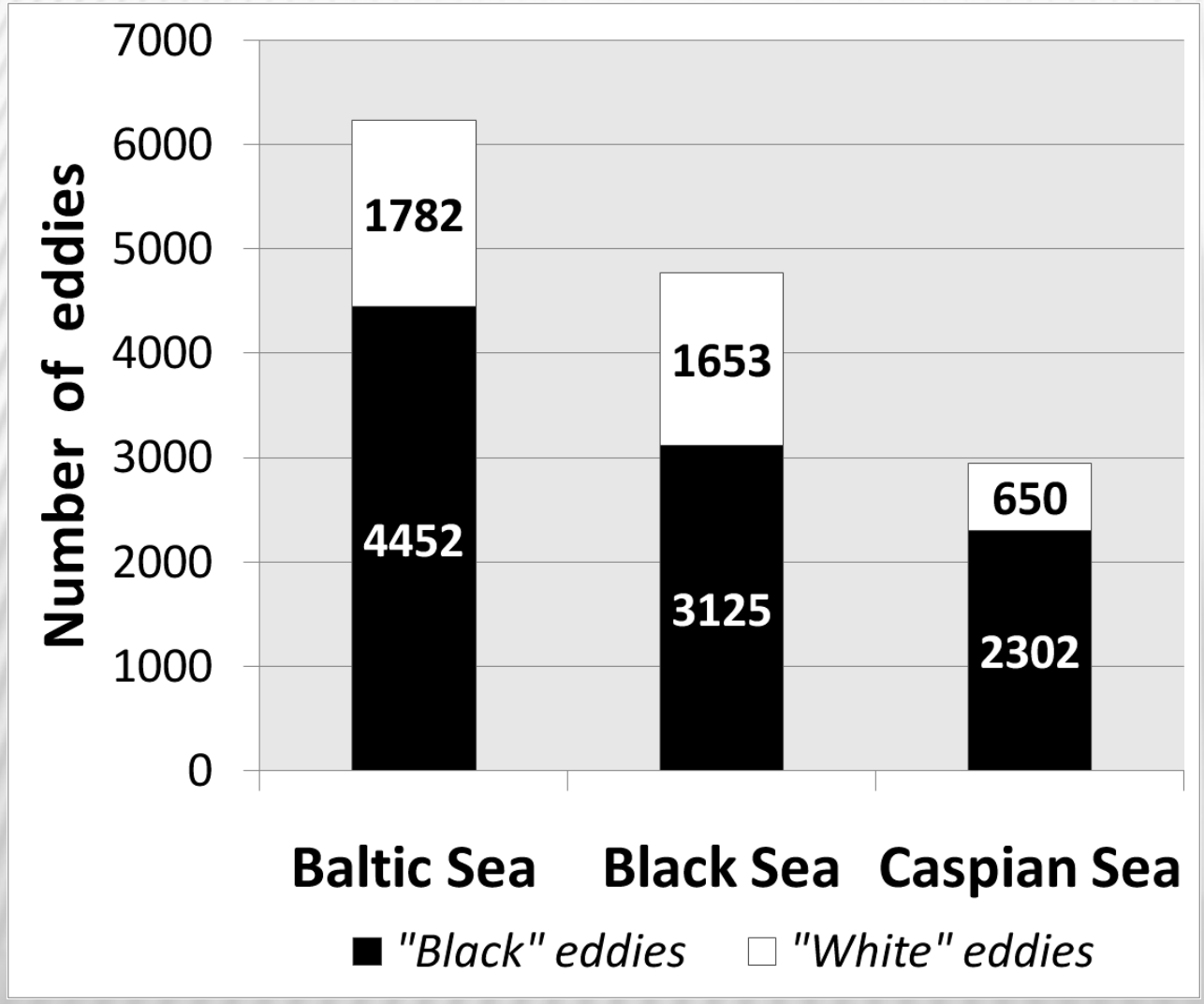



*(a) Share of images with eddies detected in the total number of images analyzed*

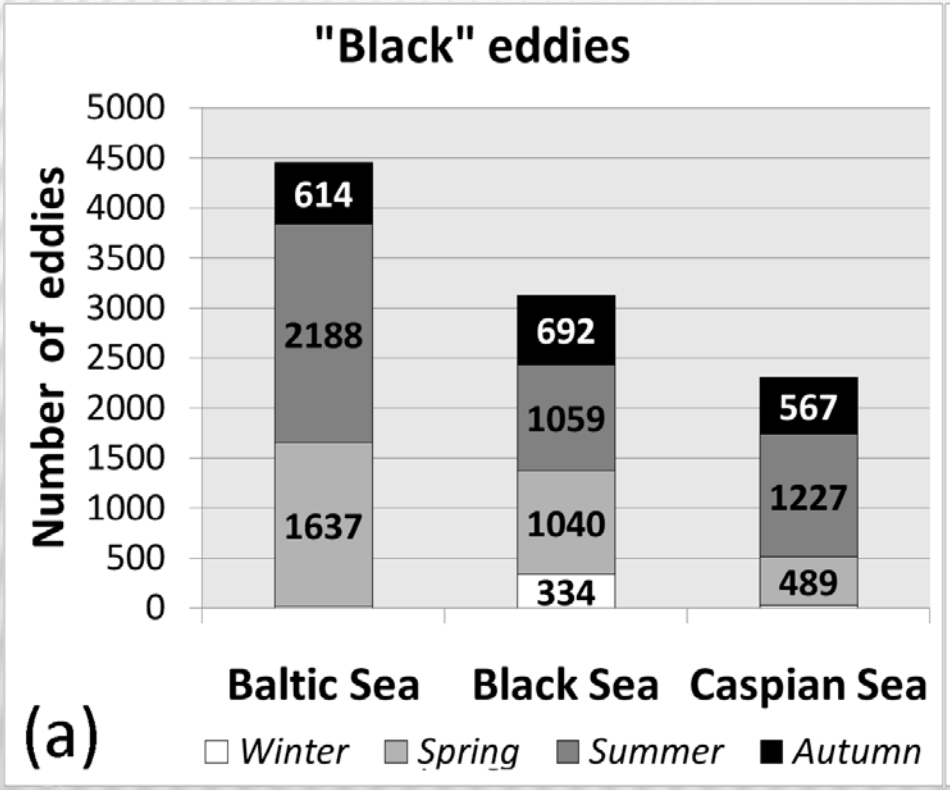
*(b) Mean number of eddies per image (with eddies detected)*

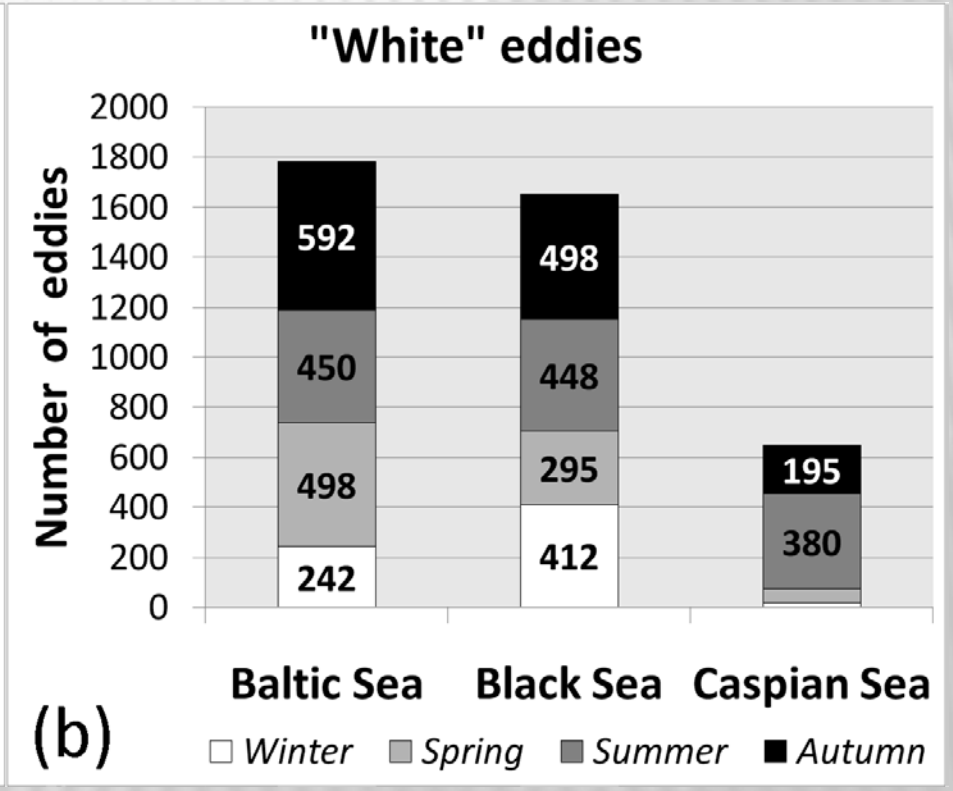
# TOTAL NUMBER OF EDDIES




- totally ca. **14.000** eddies
- **71%** - "black" eddies
- **29%** - "white" eddies
- **98%** - cyclonic eddies

# SEASONALITY IN EDDY MANIFESTATION



# CHARACTERISTIC EDDY SIZE

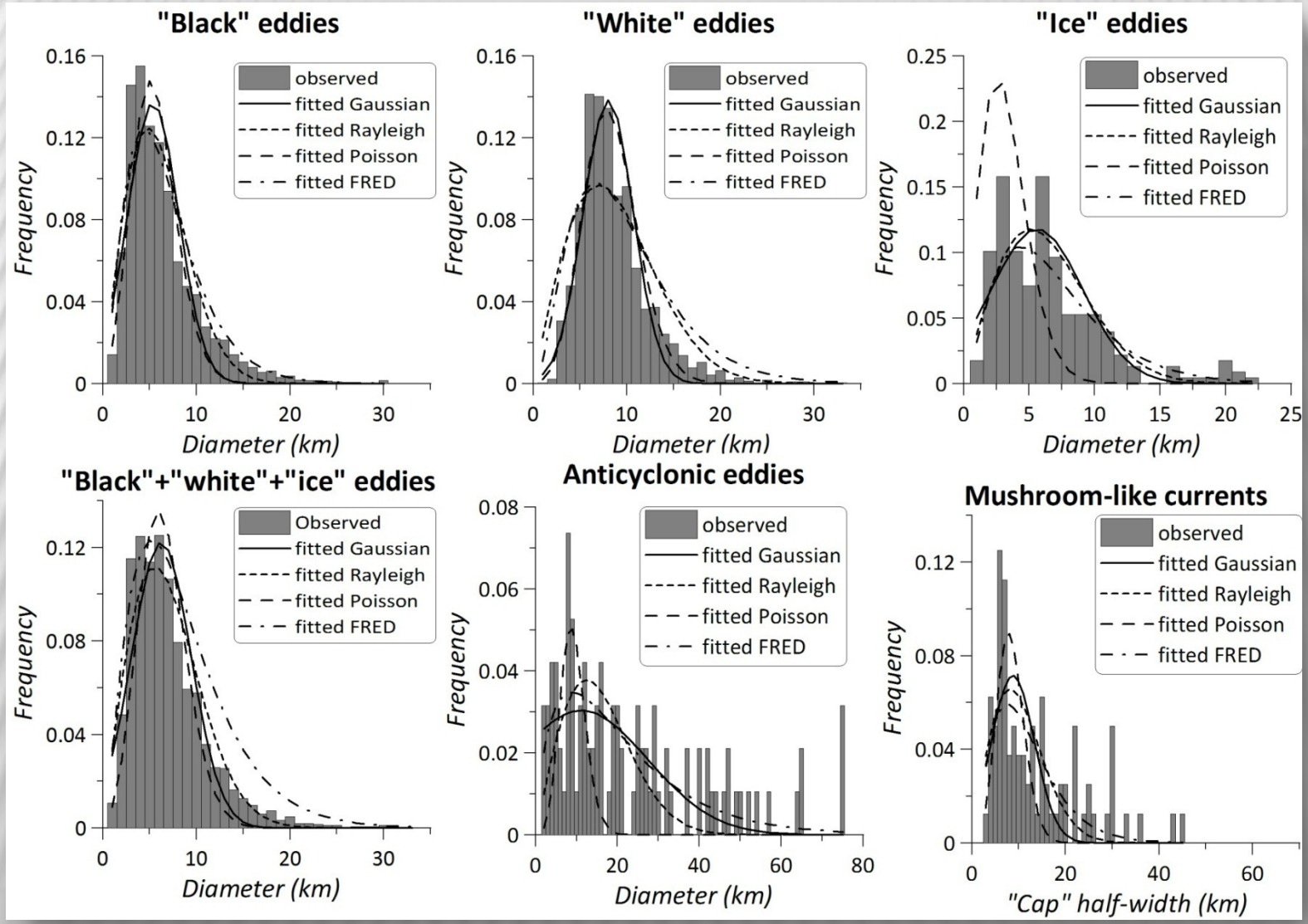
**Table 1.** Sample statistics of the mean eddy size

| *Eddy type* | *N* | *Range* | *Mode* | *Median* | *Mean* | *St dev* |
|---|---|---|---|---|---|---|
| Baltic “black” | 2826 | 1.2-48 | 4 | 5.3 | 6.4 | 4.0 |
| Baltic “white” | 1114 | 2.3-32 | 7 | 7.6 | 8.5 | 3.8 |
| Black “black” | 1329 | 1.1-66 | 6 | 6.2 | 7.4 | 5.4 |
| Black “white” | 621 | 1.5-32 | 10 | 8.4 | 9.3 | 4.0 |
| Caspian “black” | 1456 | 1.2-38 | 4 | 6.8 | 7.9 | 4.6 |
| Caspian “white” | 461 | 2.8-33 | 6 | 9.0 | 9.7 | 3.6 |

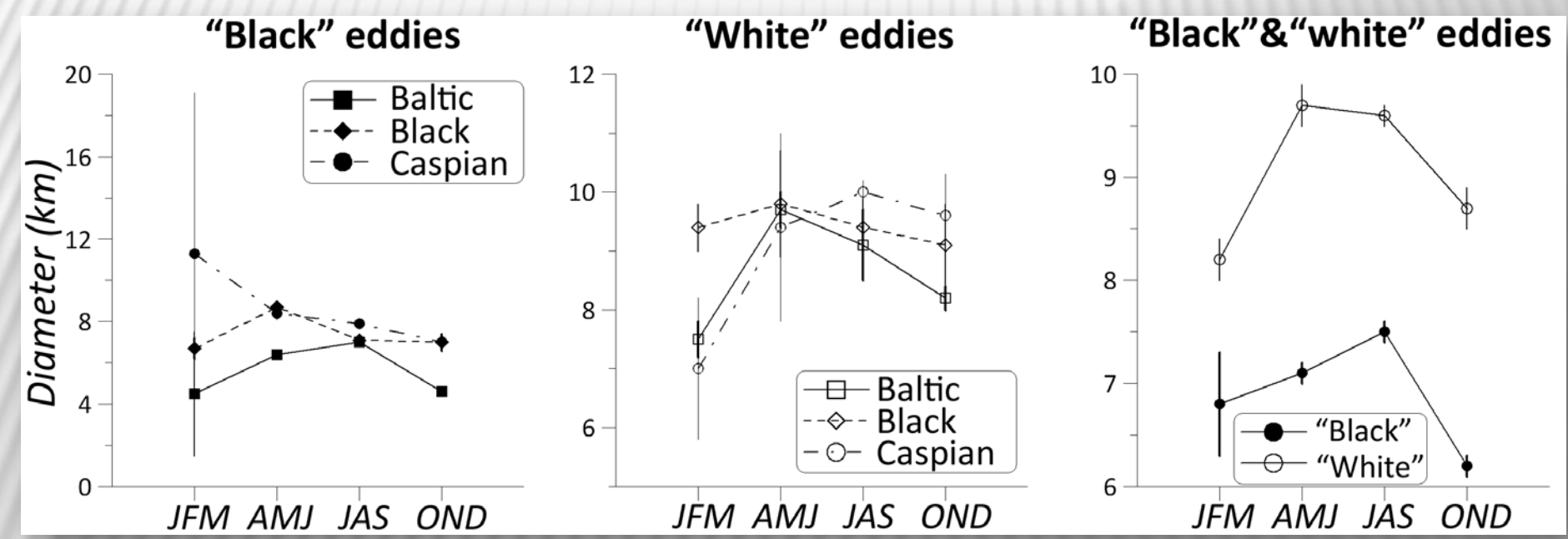
**Table 2.** Values of the baroclinic Rossby radius of deformation (km)

| *Baltic Sea* | *Black Sea* | *Caspian Sea* |
|---|---|---|
| 1-10 | 15-20 (12 in shelf area) | 17-22 (3-8 in shelf area) |

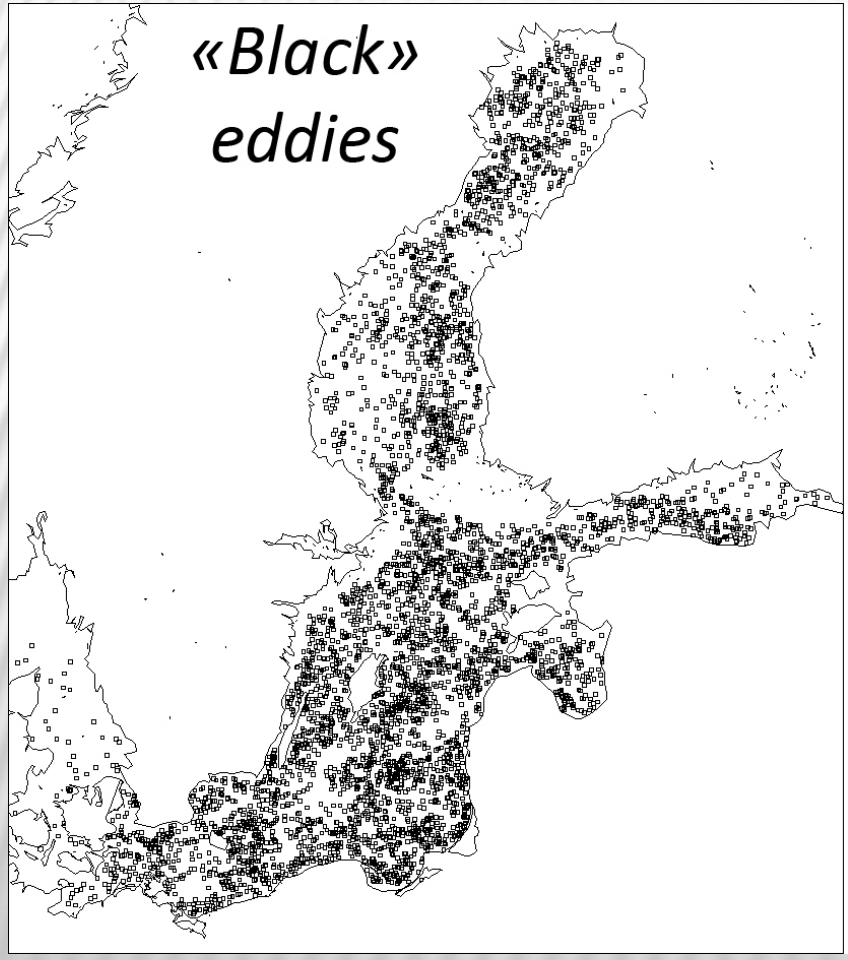
# HISTOGRAMS OF DIAMETER DISTRIBUTION

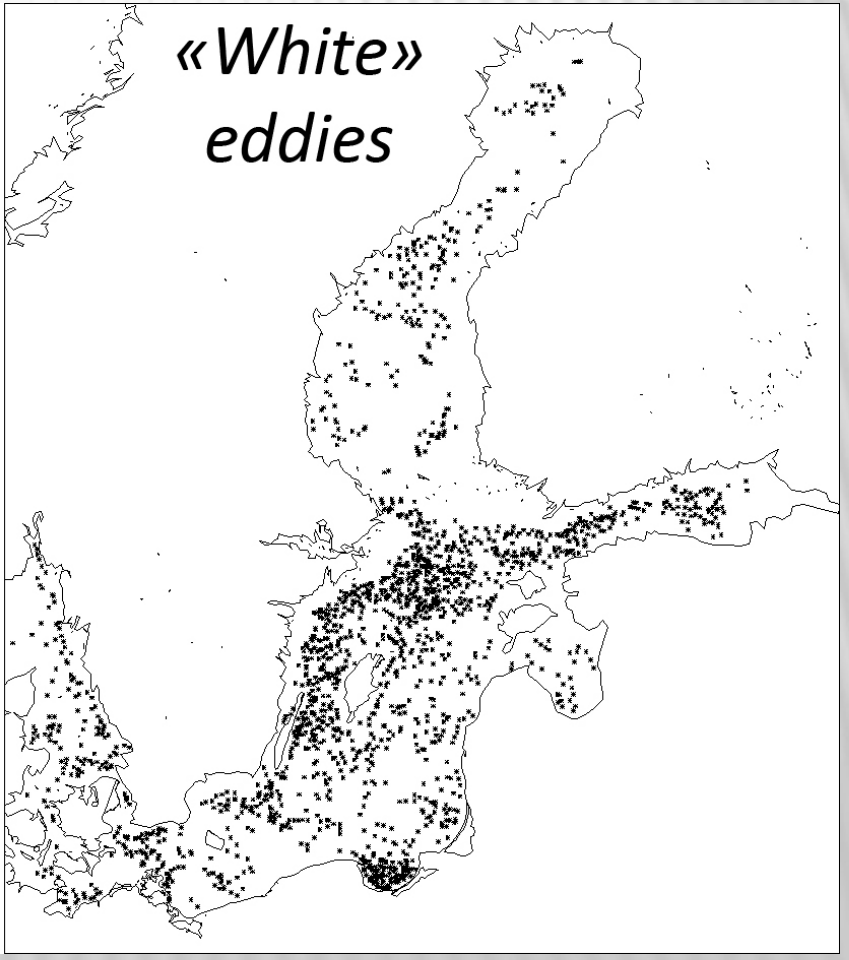


# SEASONAL VARIABILITY OF EDDY SIZE



# BALTIC SEA – NON-NORMALIZED

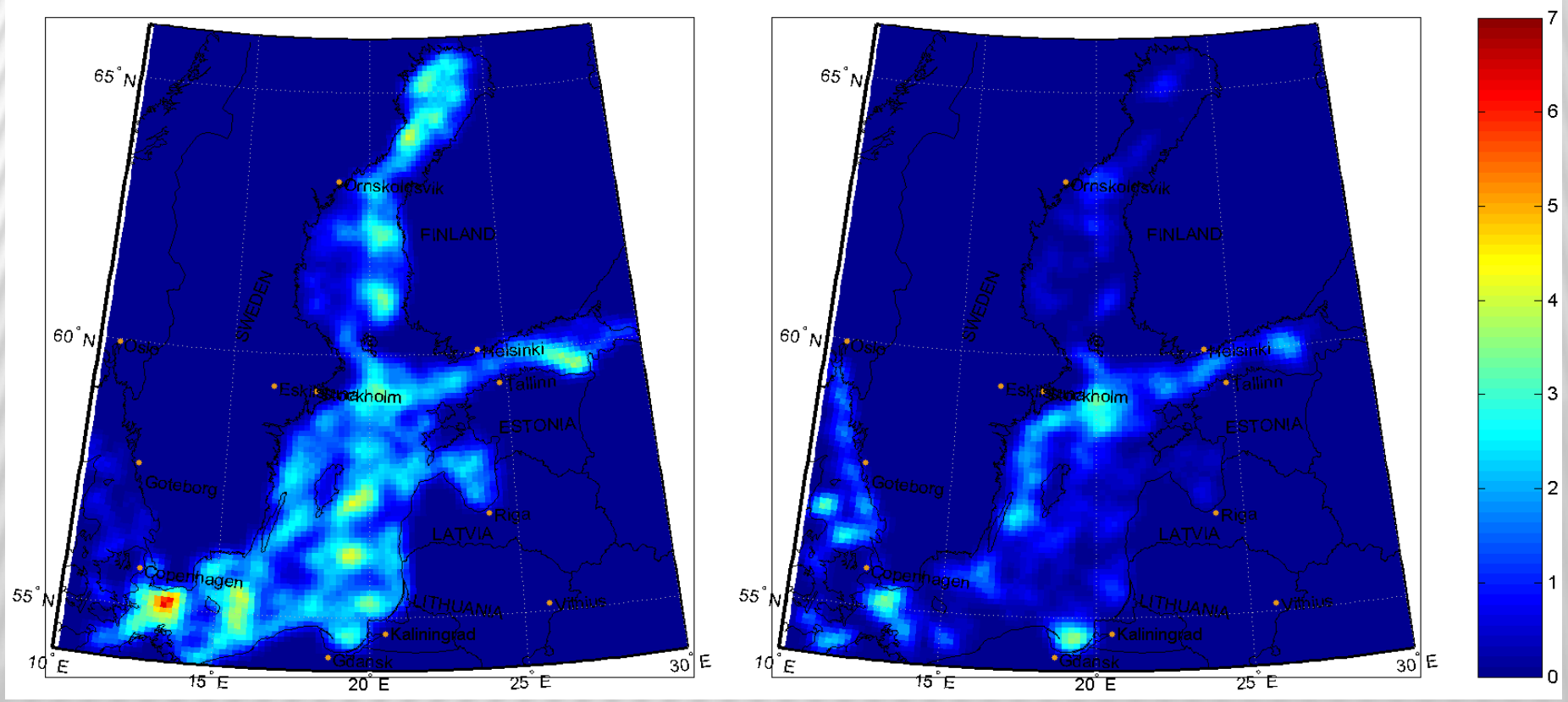


# BALTIC SEA – NORMALIZED SCHEMES

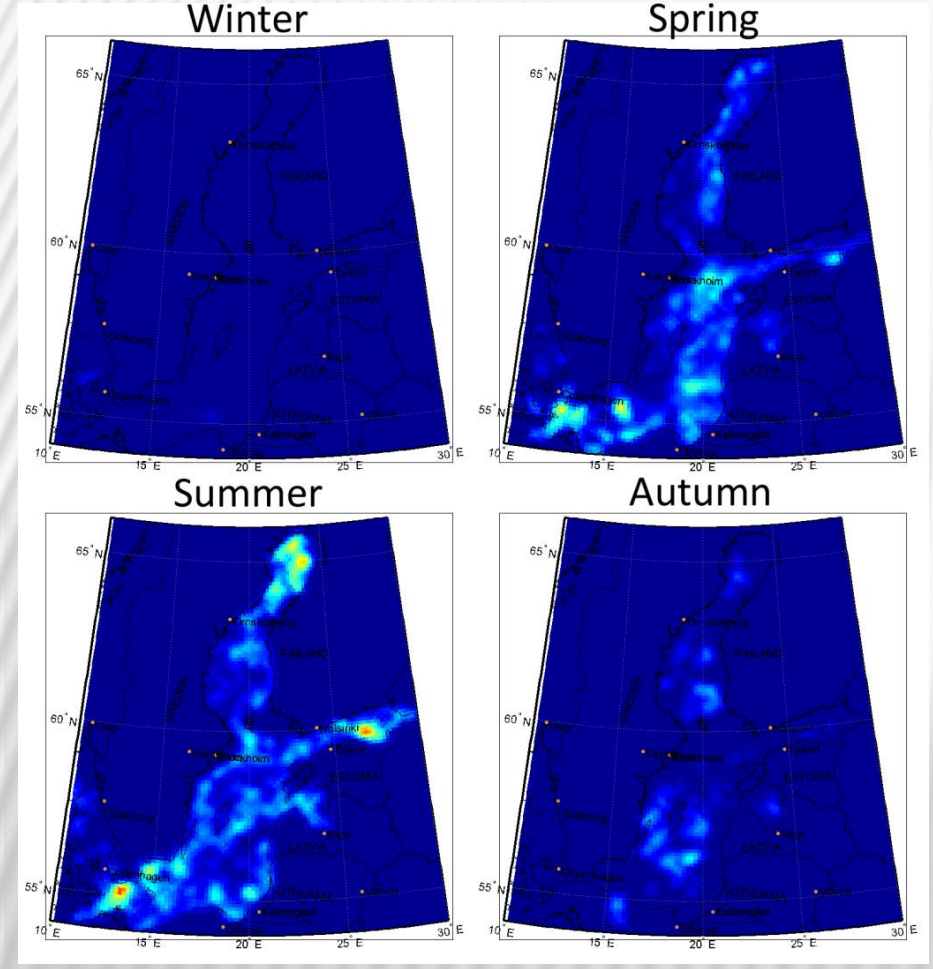
## “Black” eddies

## “White” eddies

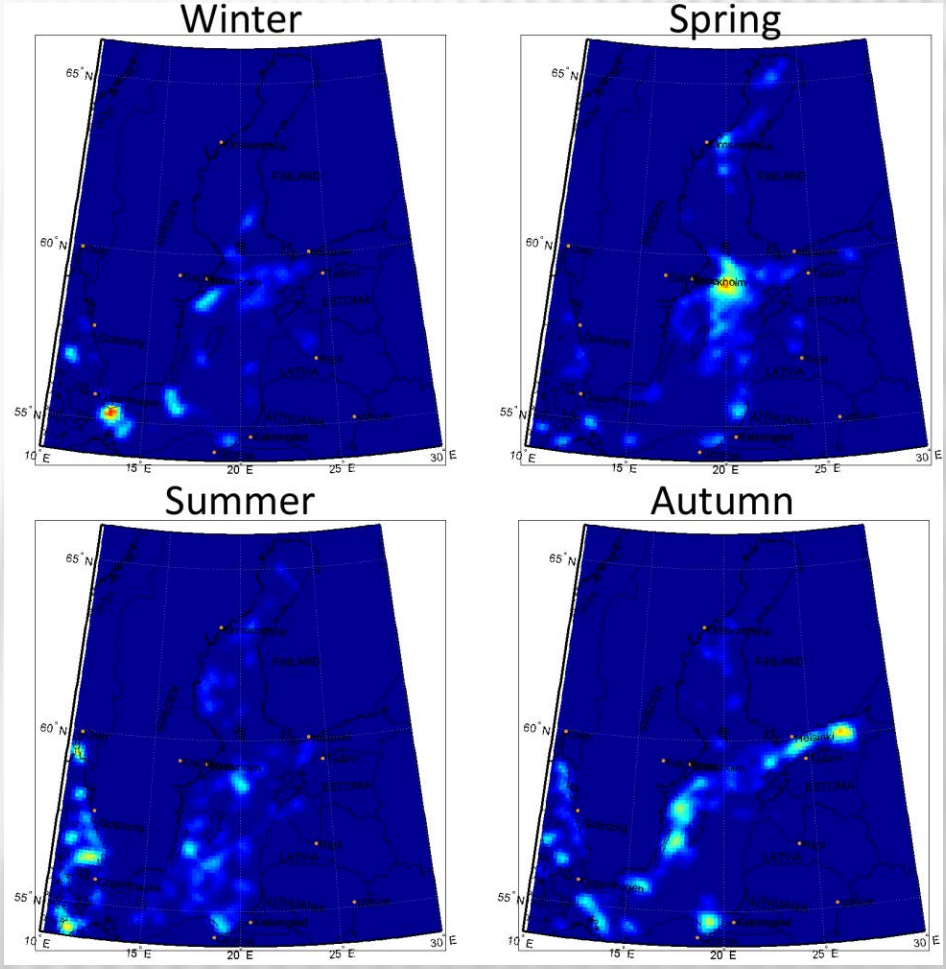


# SEASONALITY OF EDDIES IN THE BALTIC SEA

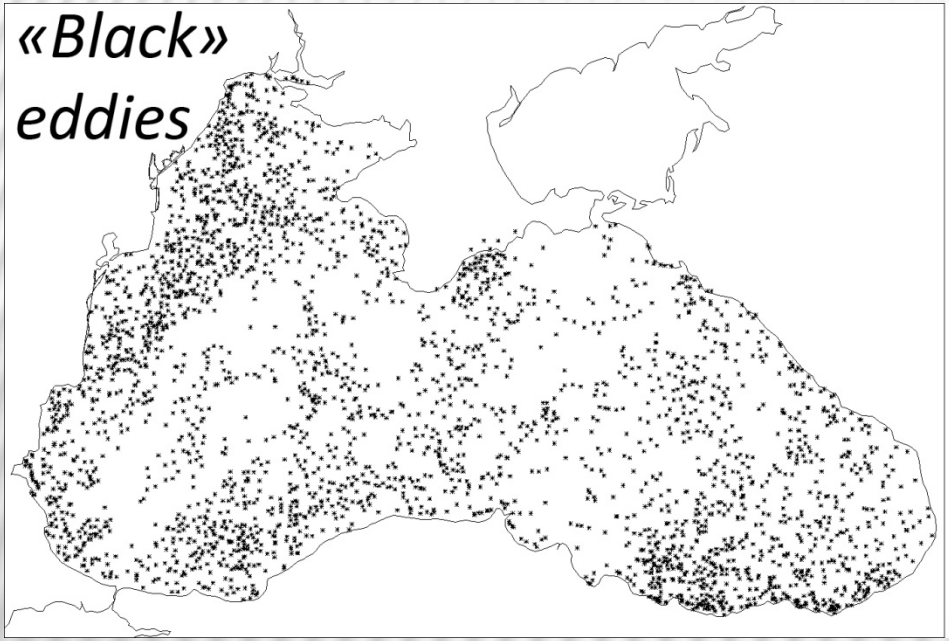
## “Black” eddies

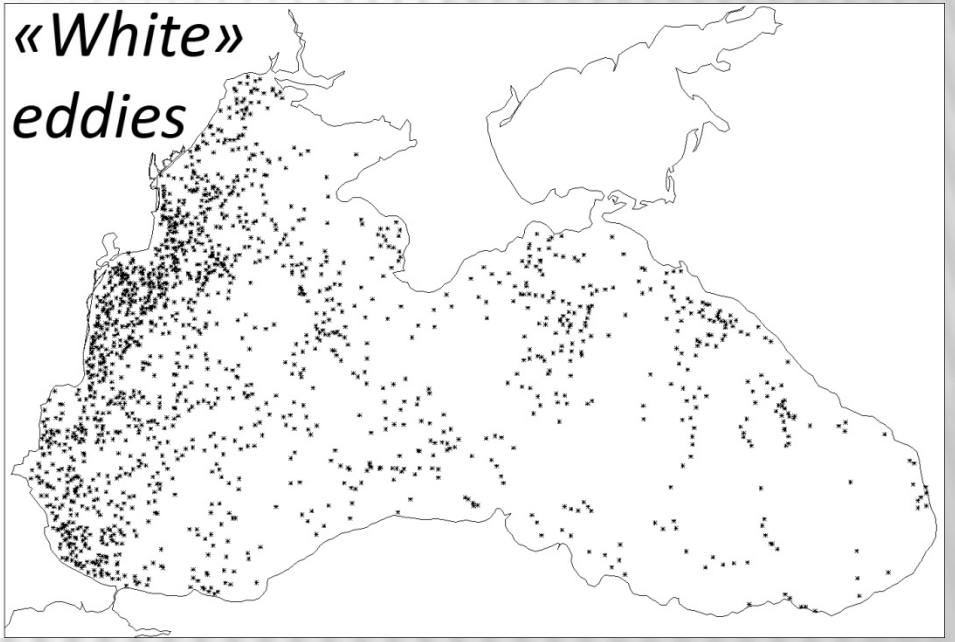



## “White” eddies



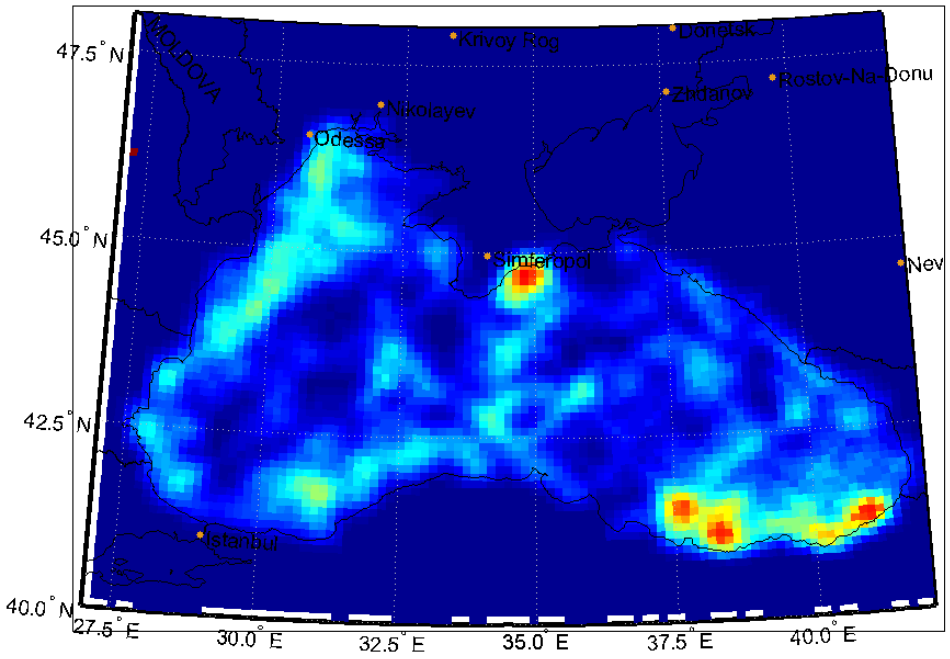
# BLACK SEA – NON-NORMALIZED



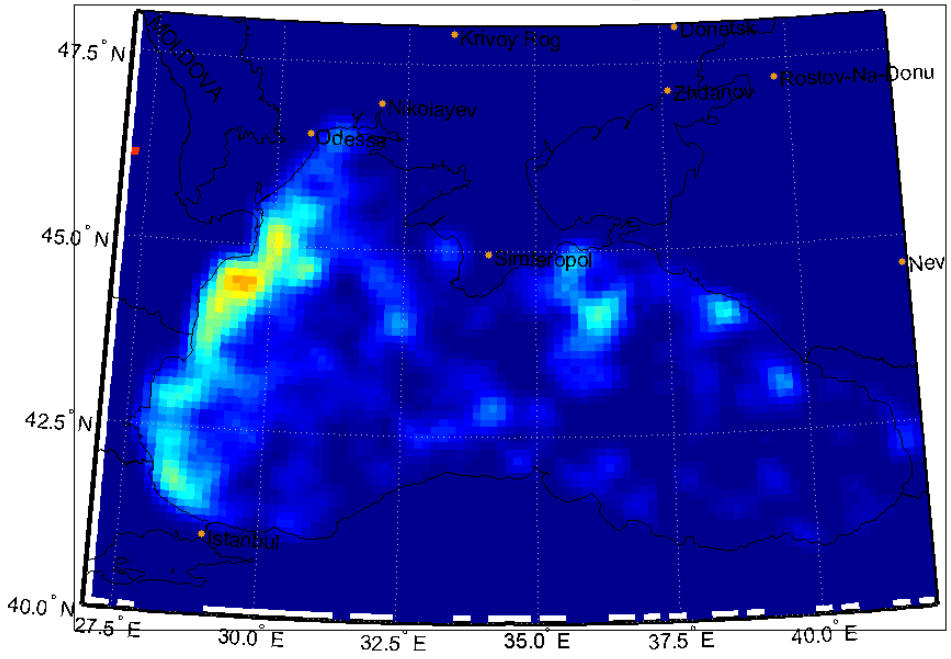



# BLACK SEA - NORMALIZED

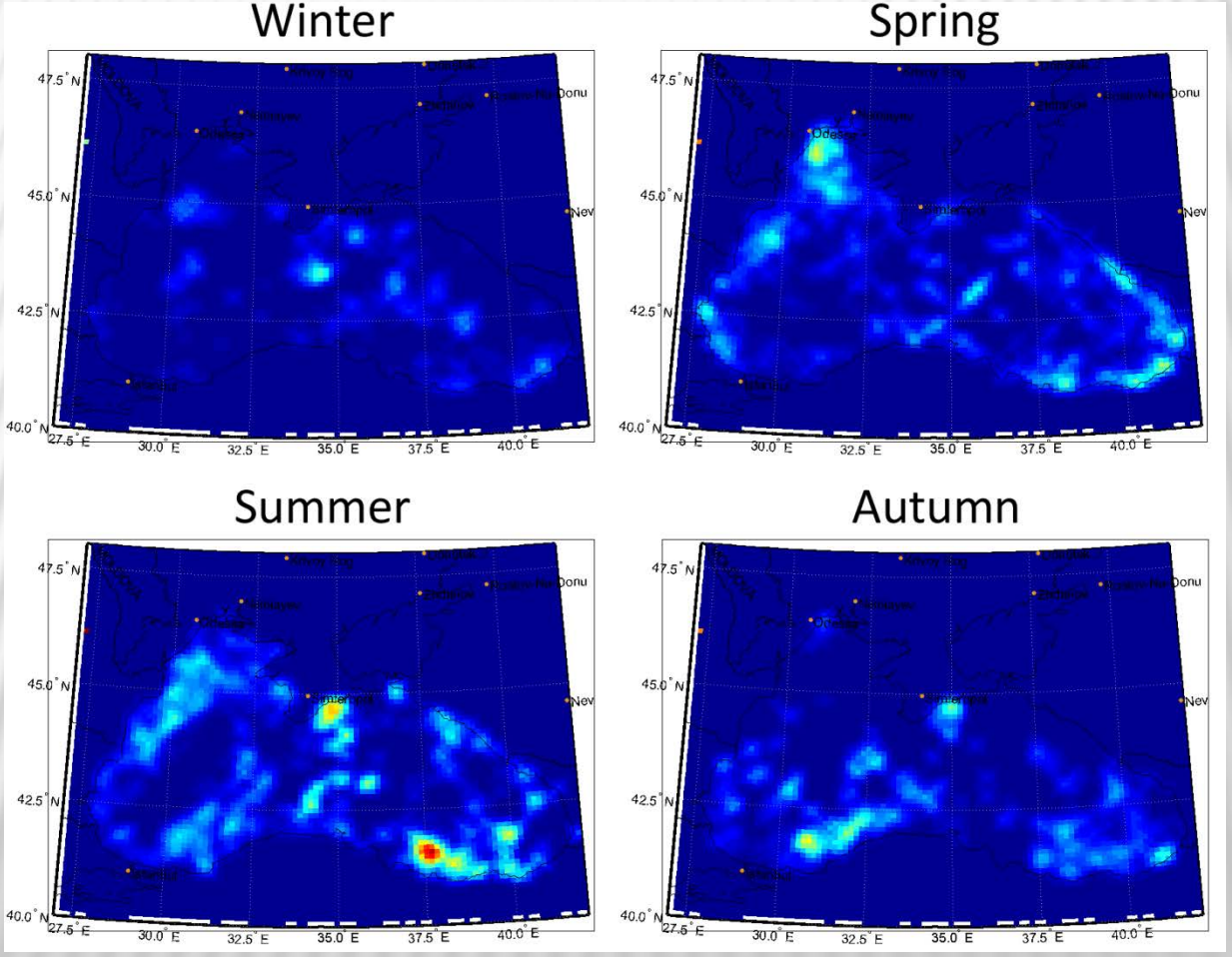
"Black" eddies



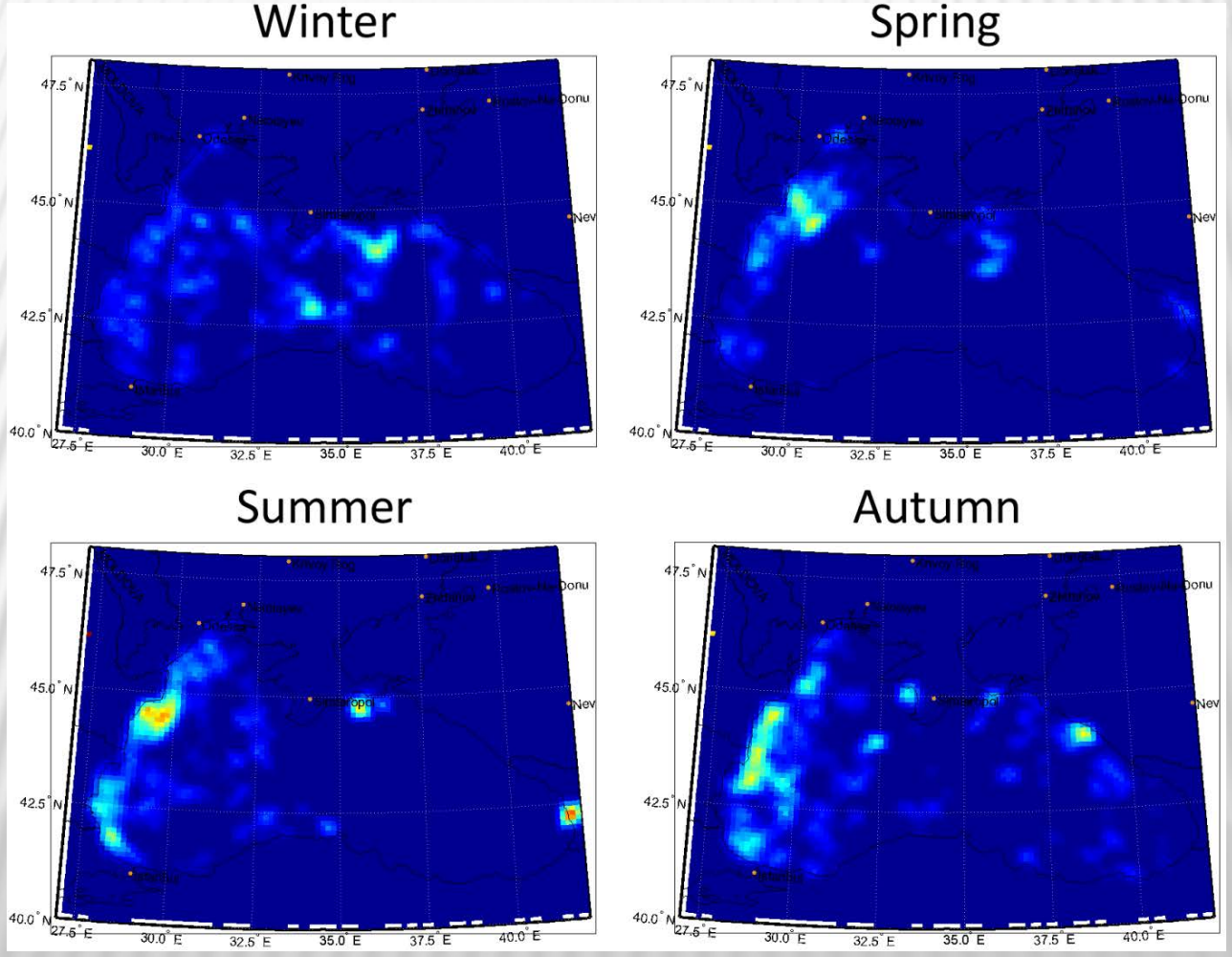

"White" eddies



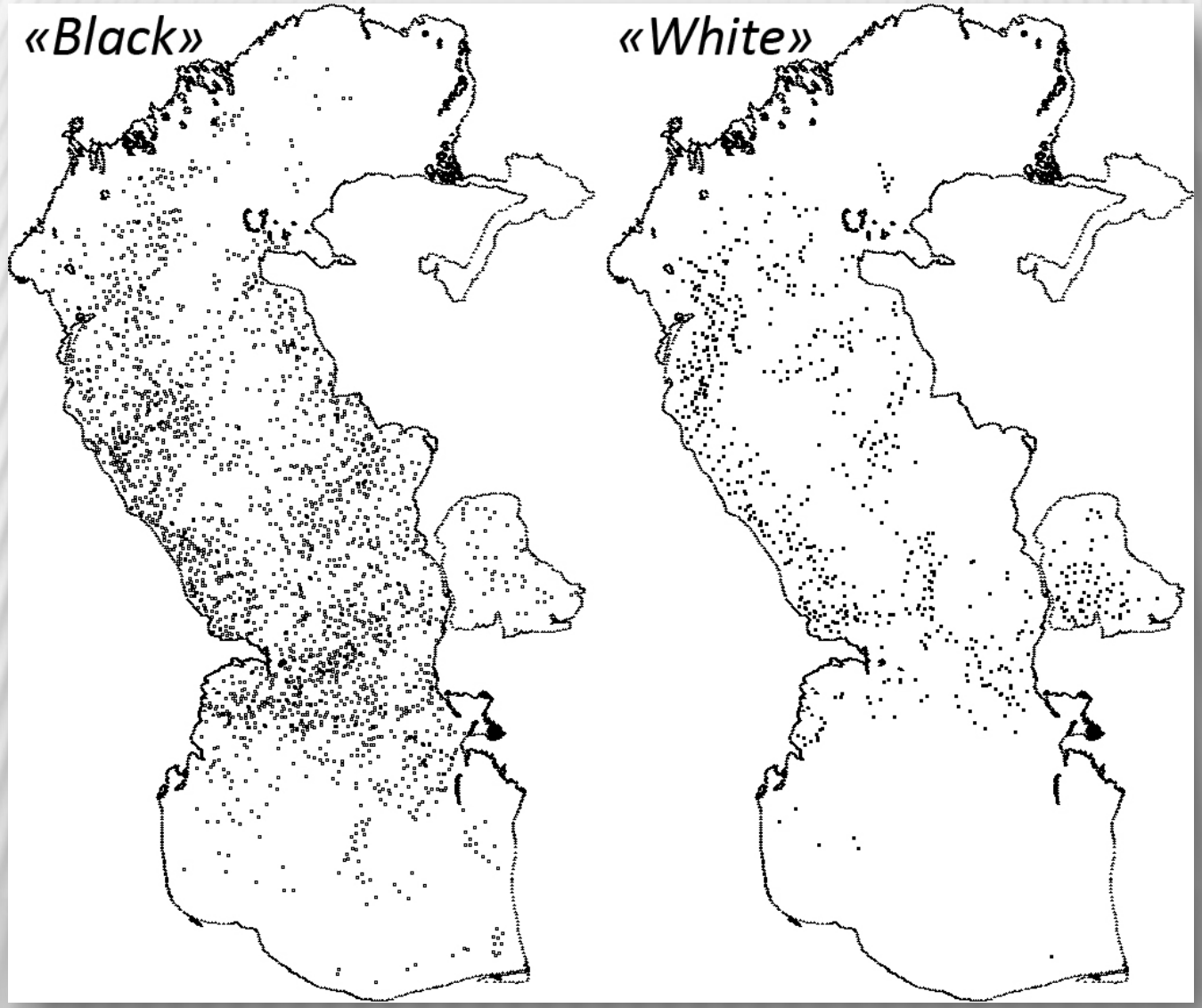
# SEASONALITY OF “BLACK” EDDIES



# SEASONALITY OF “WHITE” EDDIES



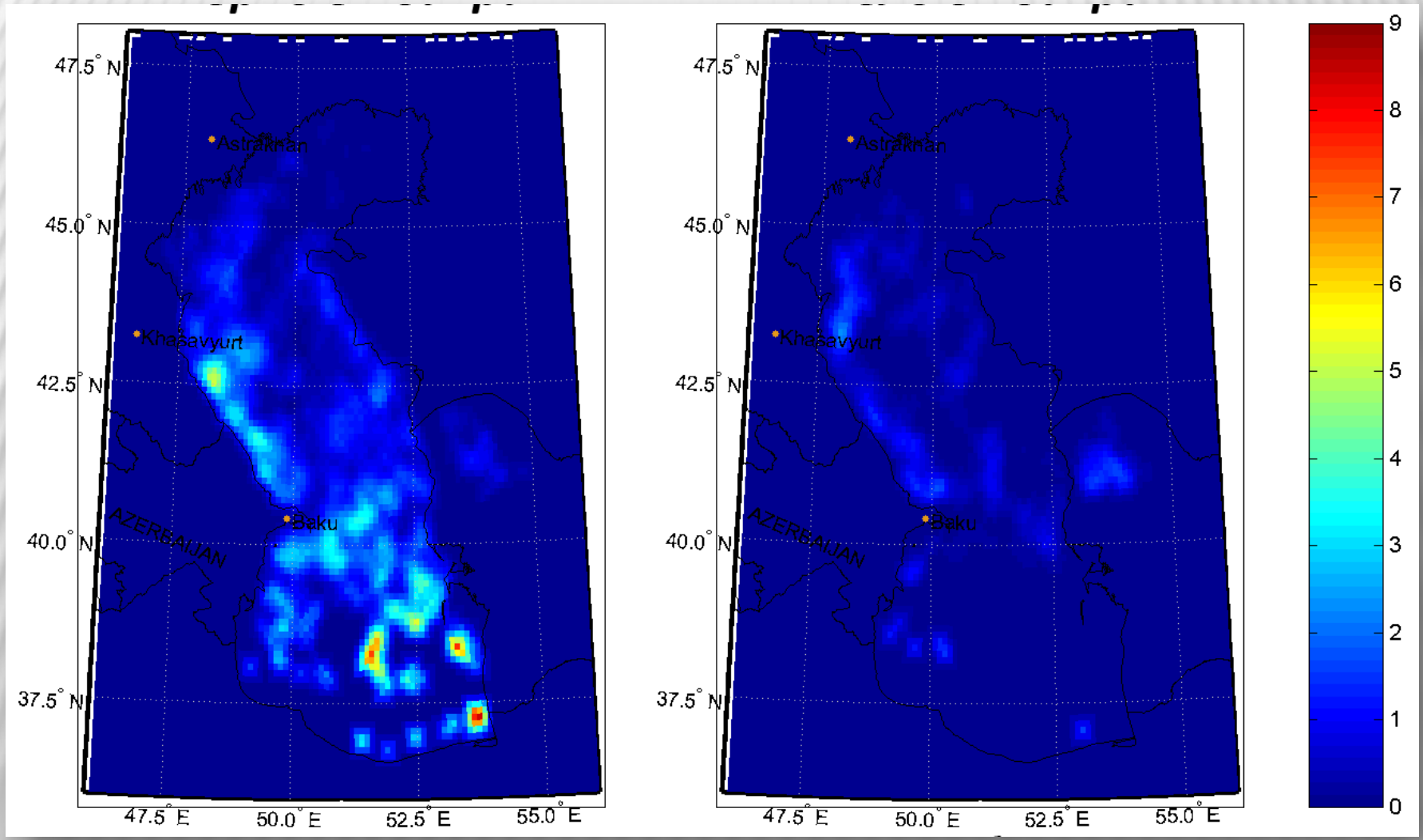
# CASPIAN SEA – NON-NORMALIZED



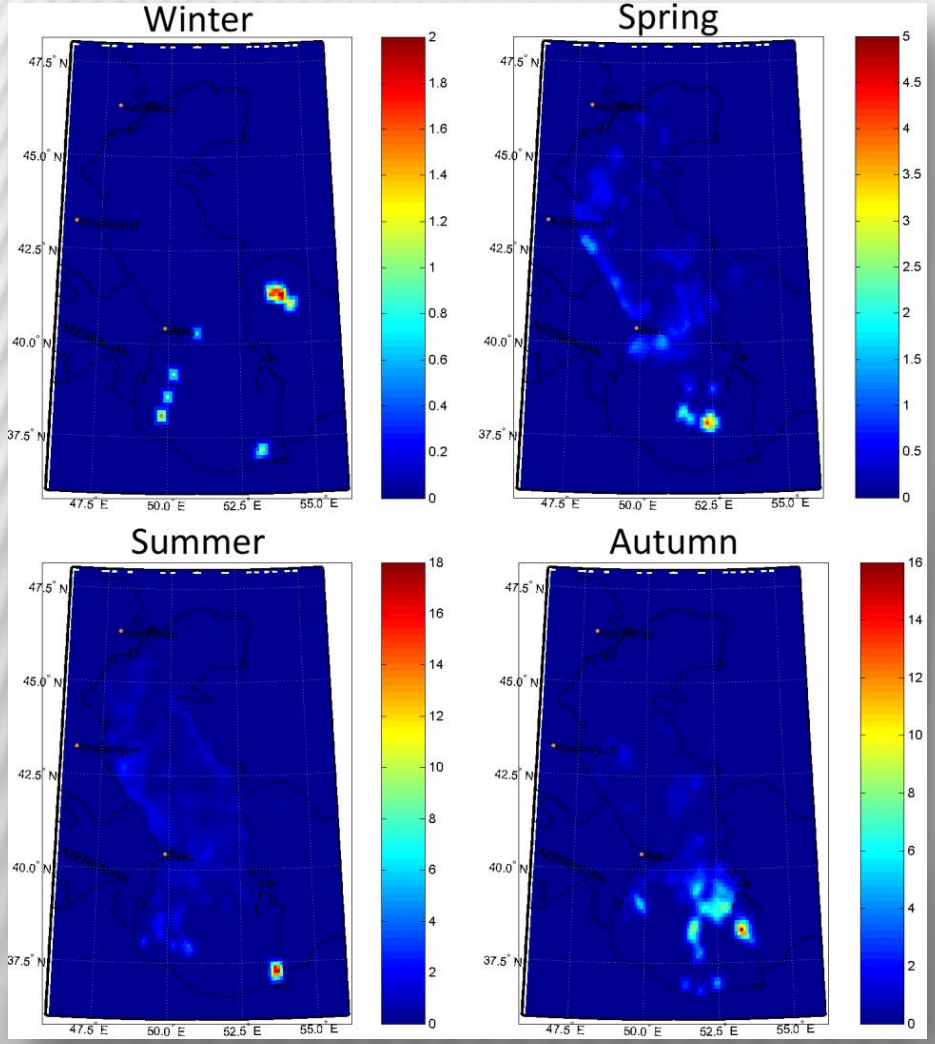
# CASPIAN SEA - NORMALIZED

## “Black” eddies

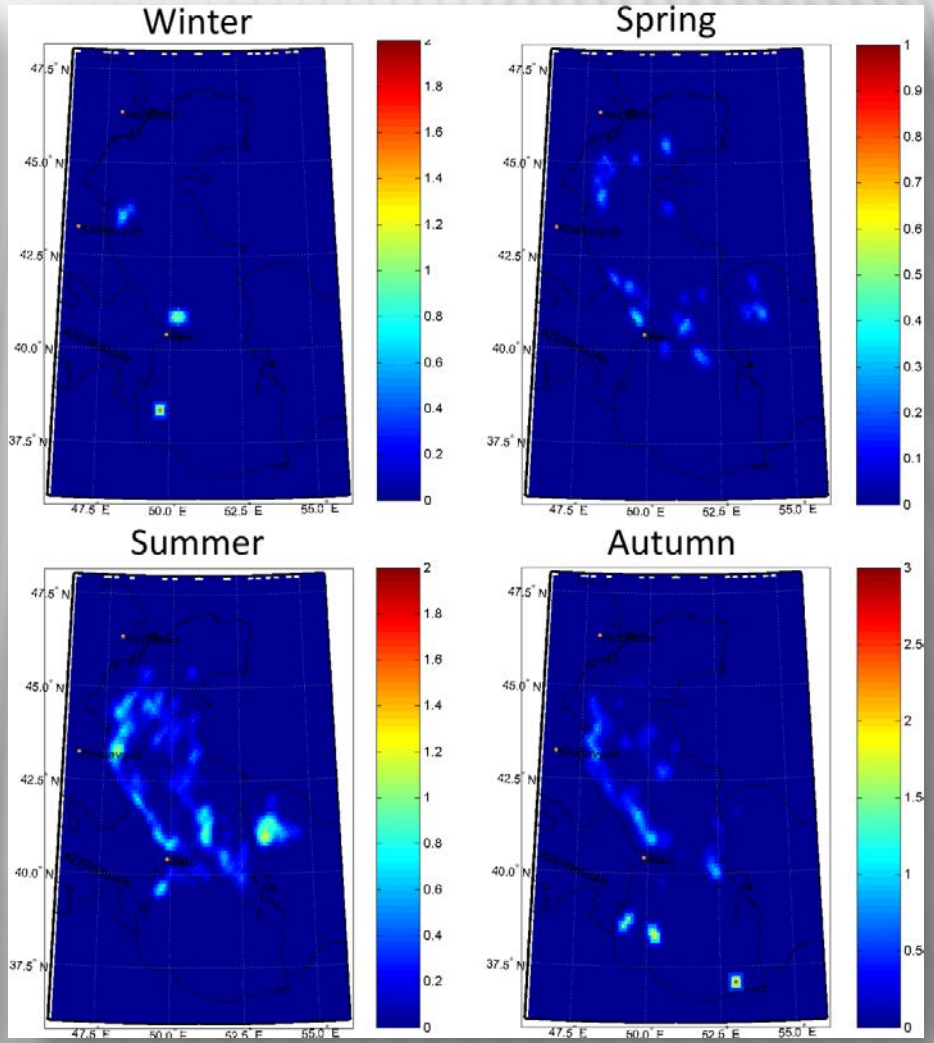
## “White” eddies



# “Black” eddies




# “White” eddies



# ORIGINATION OF EDDIES/EDDY CLUSTERS

**In some particular cases:**

1) barotpopic (shear) instability
2) peculiar features of shoreline
3) instability on fronts

**In general (eddy clusters):**

1) baroclinic instability
2) specific (impulsive) wind forcing
3) convection in the near-surface water layer

*Analysis provided seem to prove the convection hypothesis though the influence of baroclinic effects should be assessed*

# CONCLUSIONS

Analysis of spatio-temporal eddy distribution showed that spiral eddies presumably come into being as a result of convection in the near surface layer.

Manifestation of eddies due to surfactant films (“black” eddies) depends on near-surface wind speed and amount of surfactant films (and consequently chlorophyll a concentration).

Eddies visible due to wave/current interactions (“white” eddies) demonstrated to manifest in the regions with the highest near-surface wind speeds with resulting intense drift currents.

Advanced statistics with excluded impact of near-surface wind field inhomogeneity are needed.

# THANKS A LOT FOR YOUR KIND ATTENTION!

Special thanks to:

- **Dr. Olga Lavrova, Dr. Marina Mityagina, Tatiana Bocharova** (*IKI RAS*) for providing the data;

- **Dr. Martin Gade** (*UHH*) for his precious help