STUDY OF ICE CONDITIONS OF THE AZOV SEA USING SATELLITE DATA AND NUMERICAL SIMULATION RESULTS

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Introduction

Azov Sea is covered with ice for almost 3 months, it is necessary to find data containing information about ice conditions. Such information is extremely important for maritime navigation, since a large number of ships can be locked in the ice of the Sea of Azov.

A number of studies on ice conditions were carried out using satellite data.

The greatest distribution of ice in winter 2015-2016

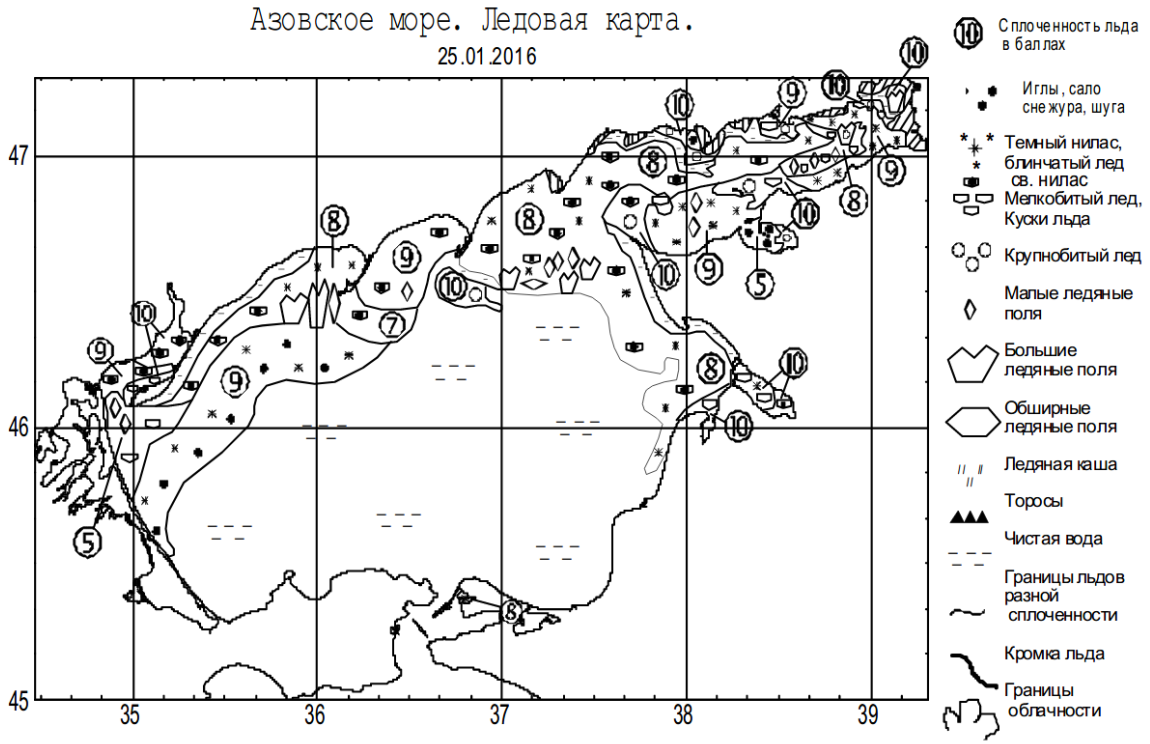
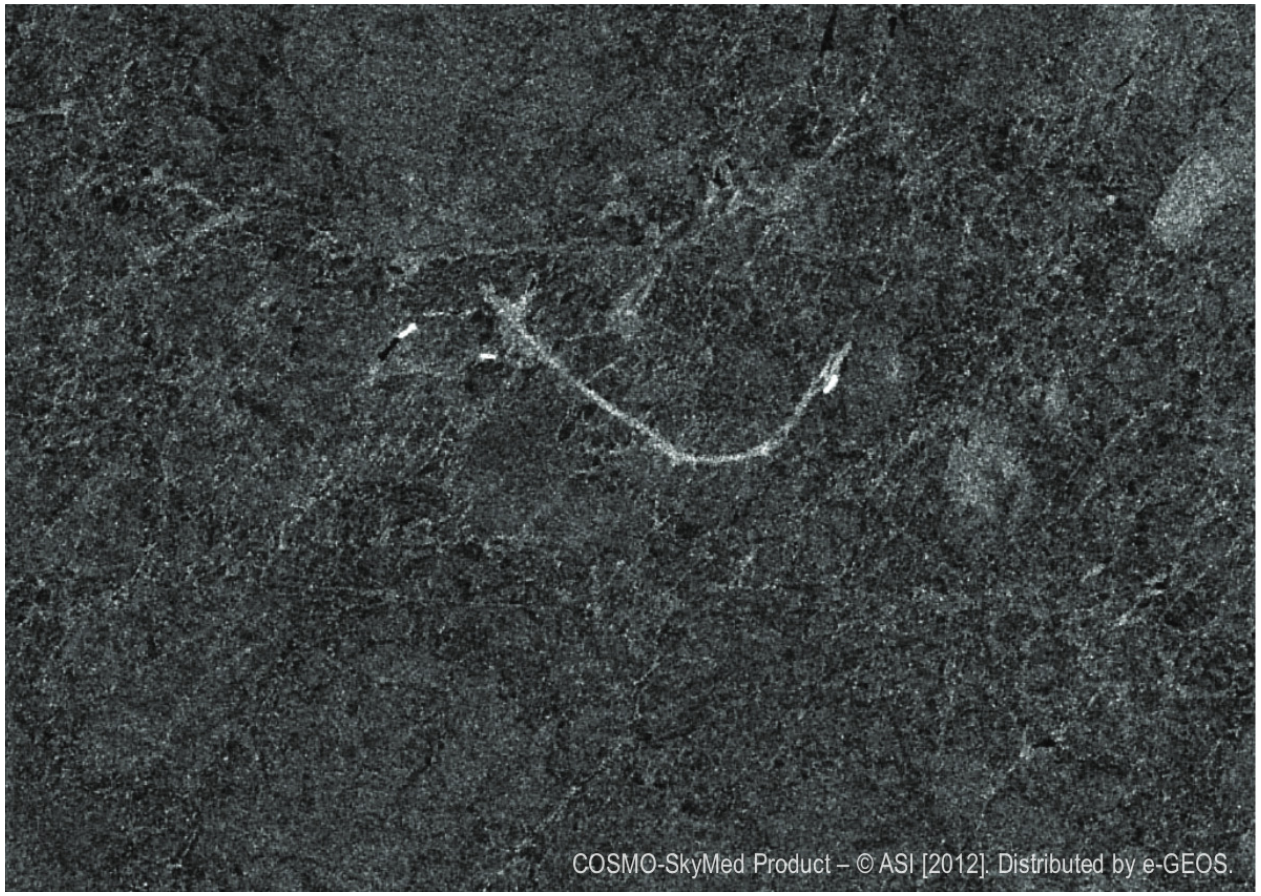


Рис. 3 **Наибольшее распространение льда в зимний период 2015-2016 гг.**

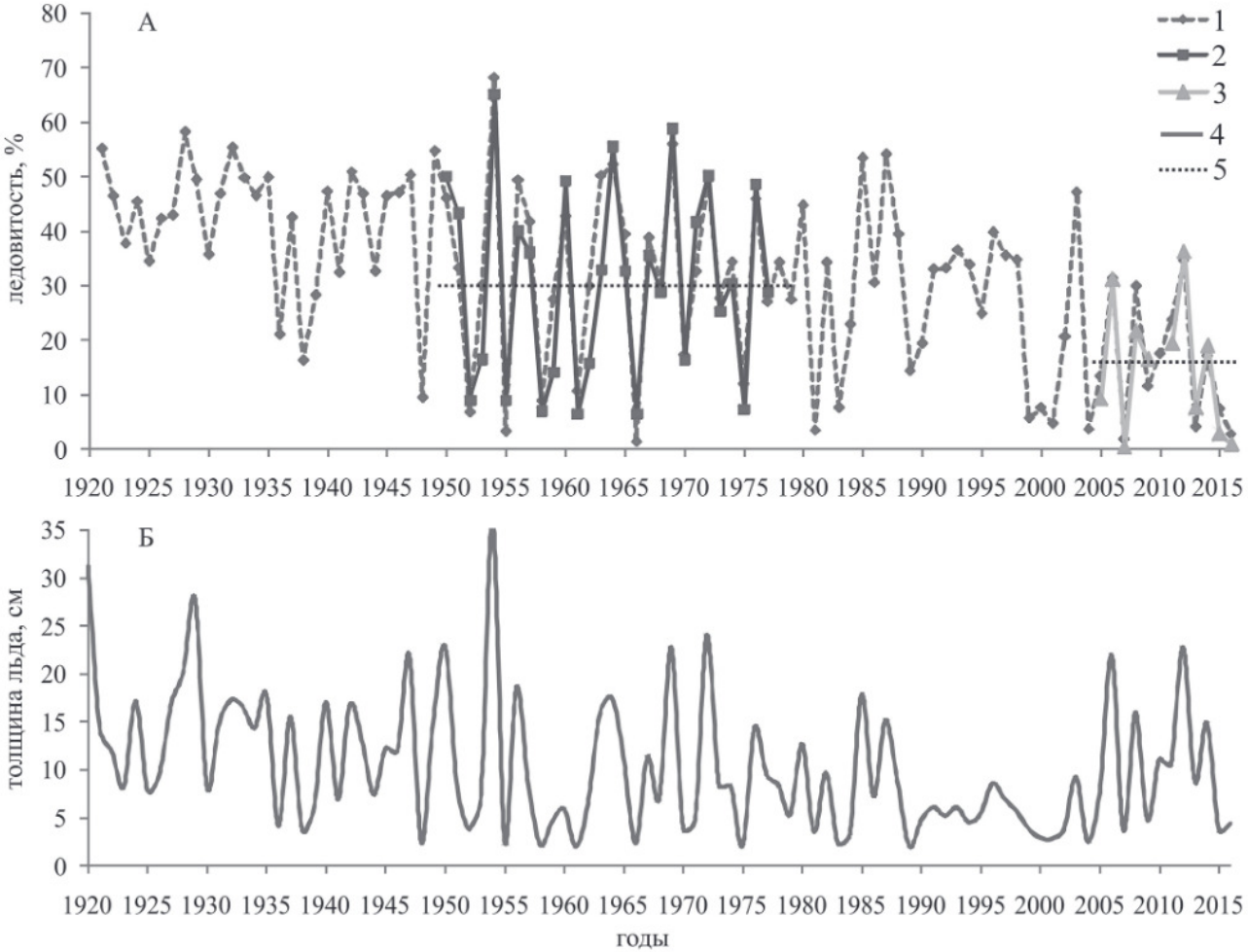
An array of images of the NOAA series in the visible and infrared ranges was used as the source data.

Р. В. Боровская Исследование ледовых условий азовского моря и керченского пролива в зимний период 2015-2016 гг. И оценка их влияния на промысловую обстановку и процесс миграции и нагул рыбы // Труды Южного научно-исследовательского института рыбного хозяйства и океанографии. 2017. Т. 54. № -1. С. 35-41.



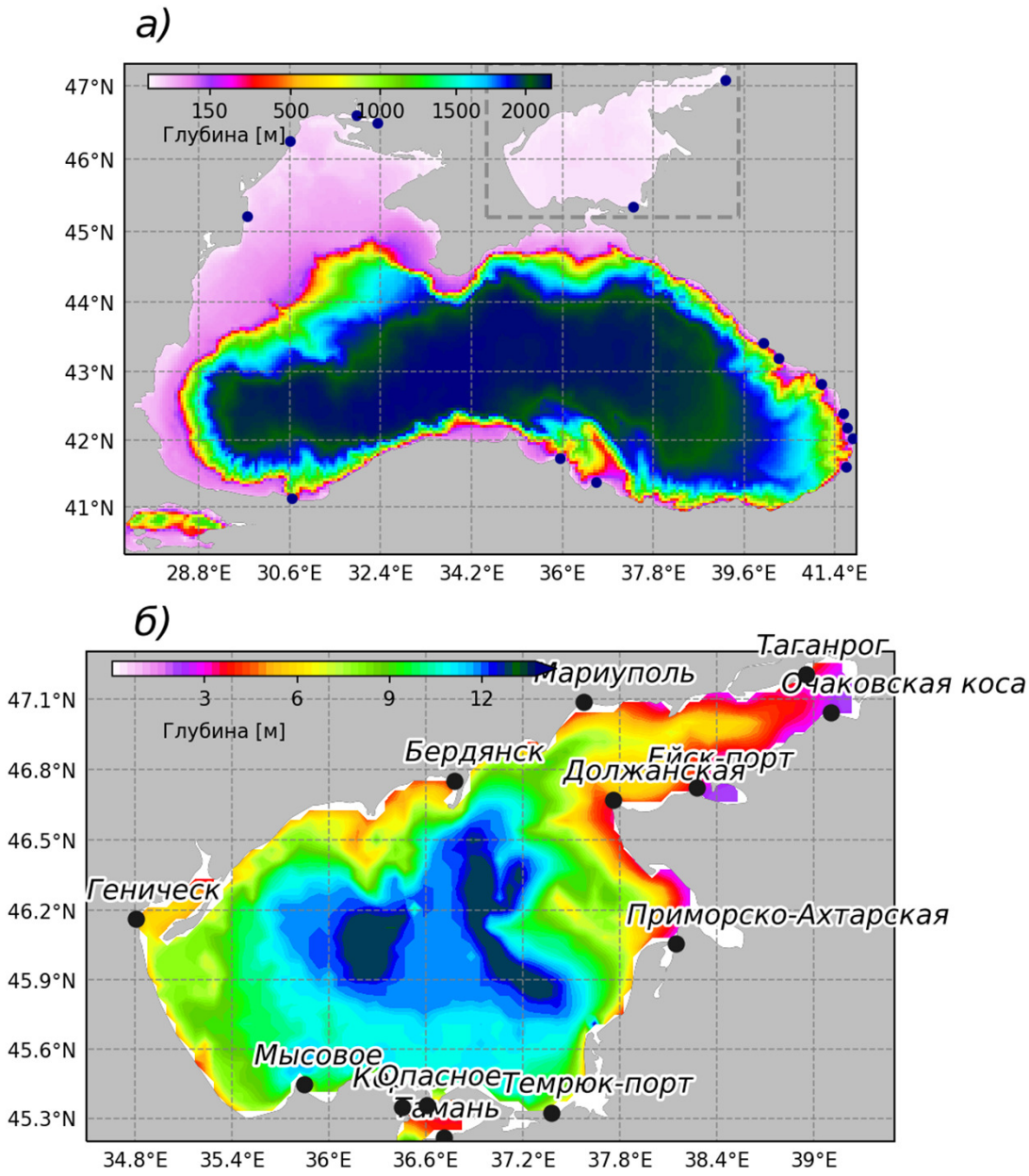
Fragment of a COSMO-SkyMed (E-GEOS, Italy) snapshot with a resolution of 3 m dated February 18. Increase of the location of ships in the frozen water area of the Azov Sea

Л. Пиетранера, Л. Чезарано, Ю. И. Кантемиров Пример мониторинга ледовой обстановки и судоходства в замерзшей акватории Азовского моря и Керченском проливе по данным COSMO-SkyMed // ГЕОМАТИКА 2012, №1, с 72 – 76



The long-term dynamics of ice cover (A) and ice thickness (B) in the Sea of Azov: 1 - the results of the model calculation of ice cover; 2 - ice cover by materials (Hydrome-theoretical conditions ..., 1986); 3 - estimation of ice cover from satellite images MODIS (Terra / Aqua); 4 - average for November – March ice thickness, calculation results; 5 - average ice-vitality per period

Л.В. Дашкевич, Л.Д. Немцева, С.В. Бердников Оценка ледовитости Азовского моря в XXI веке по спутниковым снимкам Terra/Aqua MODIS и результатам математического моделирования // Современные проблемы дистанционного зондирования Земли из космоса. 2016. Т. 13. No 5. С. 91–100



Calculated domain configuration:

a) - bathymetry [m]

b) - zoom in the region of the Azov Sea and the position of coastal hydrometeorological stations (HMS) (black dots).

Material

Product name	Source	Spatial resolution	Study period
NEMO	___	1/24°	2014 – 2016
ERA5	ECMWF	1/4°	2014 – 2016
OSTIA	Copernicus	0,05°	2016 – 2018
IMS	NSIDC	4 км	2014 – 2019
MODIS	WorldView	250 м	2014 – 2019
Aqua/MODIS	OceanColor Web	0,05°	2003 – 2019

NEMO (Nucleus for European Modelling of the Ocean)

The vector invariant form of the primitive equations in the (i,j,k) vector system provides the following six equations (namely the momentum balance, the hydrostatic equilibrium, the incompressibility equation, the heat and salt conservation equations and an equation of state)

$$\frac{\partial U_h}{\partial t} = -\left[(\nabla \times U) \times U + \frac{1}{2}\nabla (U^2)\right]_h - f\mathbf{k} \times U_h - \frac{1}{\rho_0}\nabla_h p + D^U + F^U$$

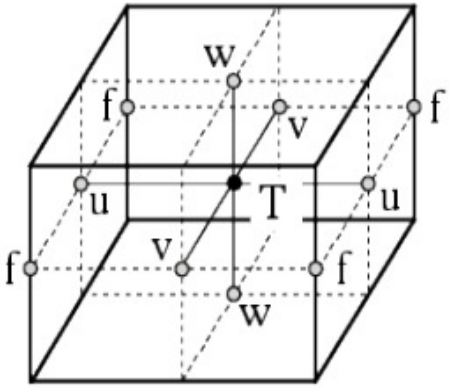
$$\frac{\partial p}{\partial z} = -\rho g$$

$$\nabla \cdot U = 0$$

$$\frac{\partial T}{\partial t} = -\nabla \cdot (TU) - D^S + F^T$$

$$\frac{\partial S}{\partial t} = -\nabla \cdot (SU) - D^S + F^S$$

$$\rho = \rho(T,S,p)$$



- "C" grid in Arakawa's classification

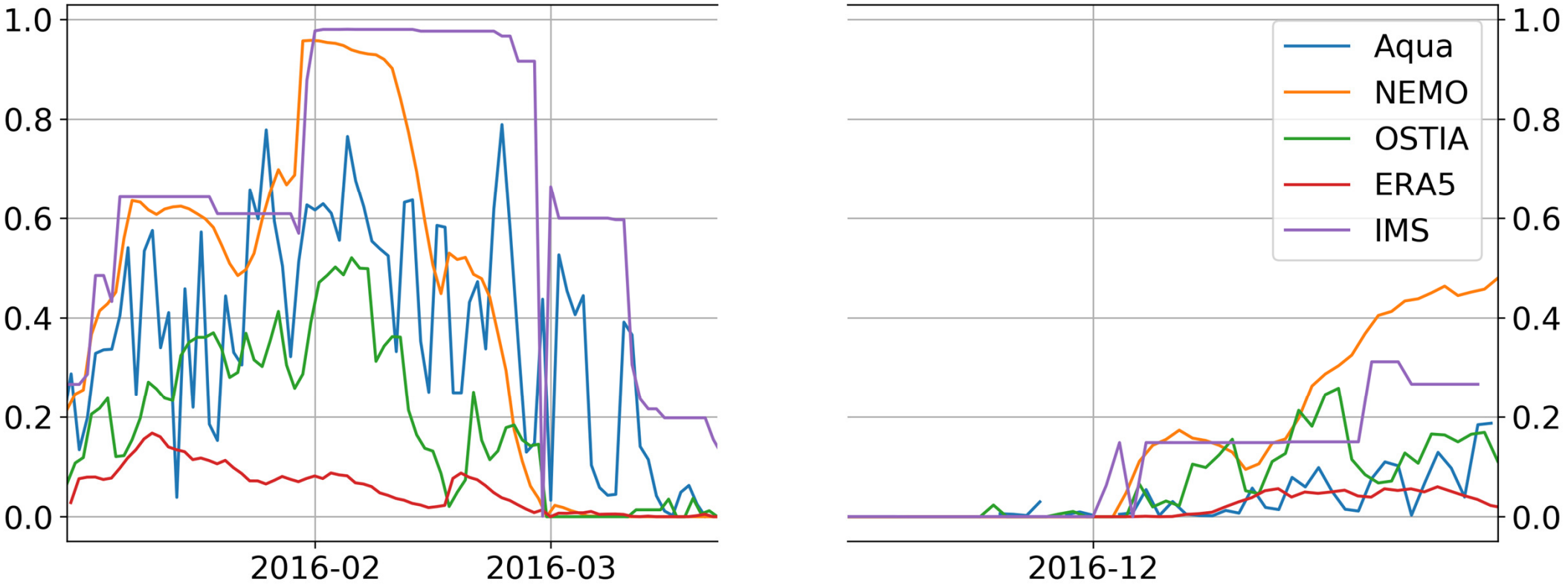
$\mathbf{U} = \mathbf{U}_h + w\mathbf{k}$ is the the vector velocity

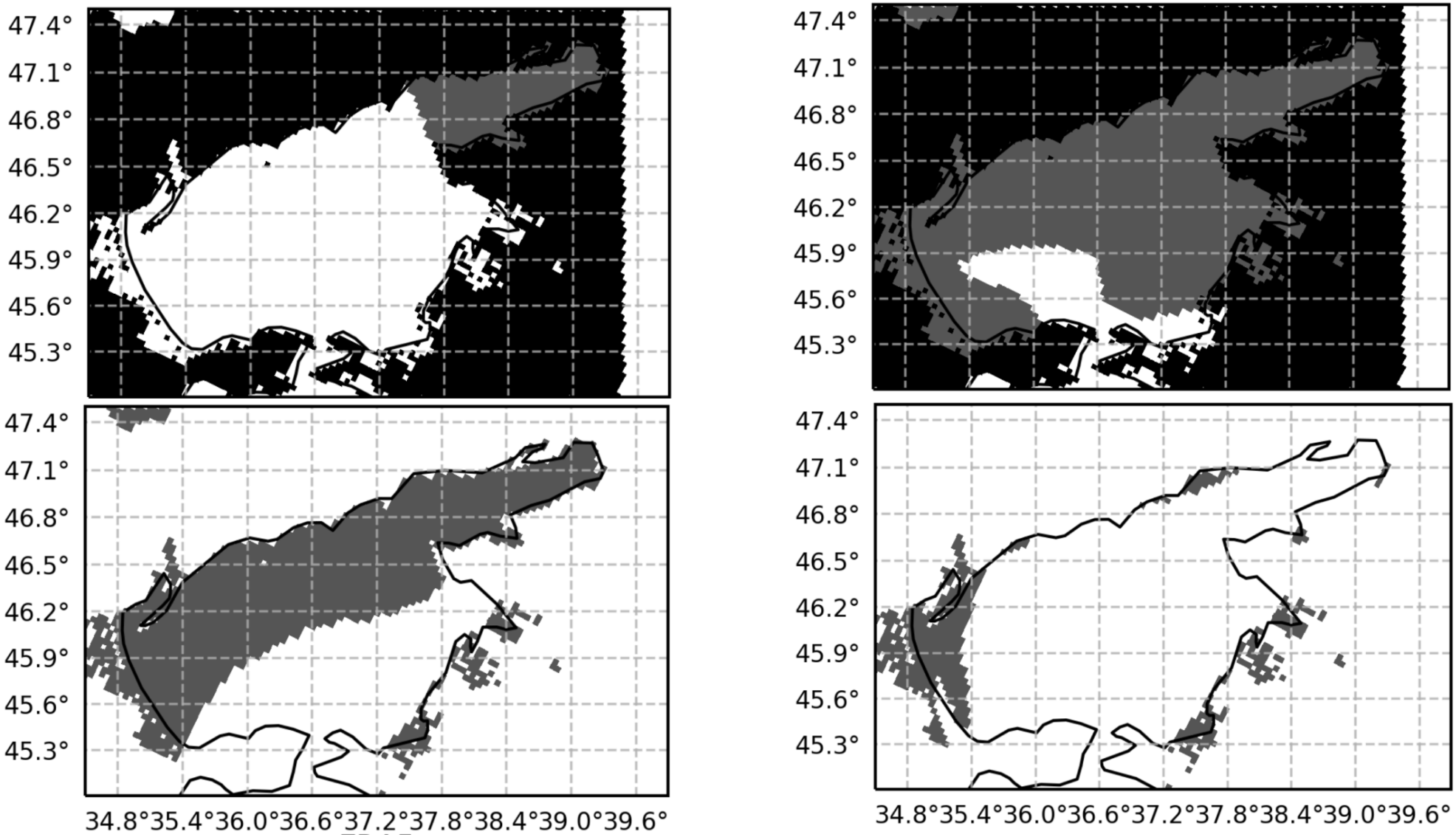
$f = 2\,\boldsymbol{\Omega}\,\mathbf{k}$ is the Coriolis acceleration

$\mathbf{D}^U$, D^T, D^S – are the parameterisations of small-scale physics for momentum, temperature and salinity;

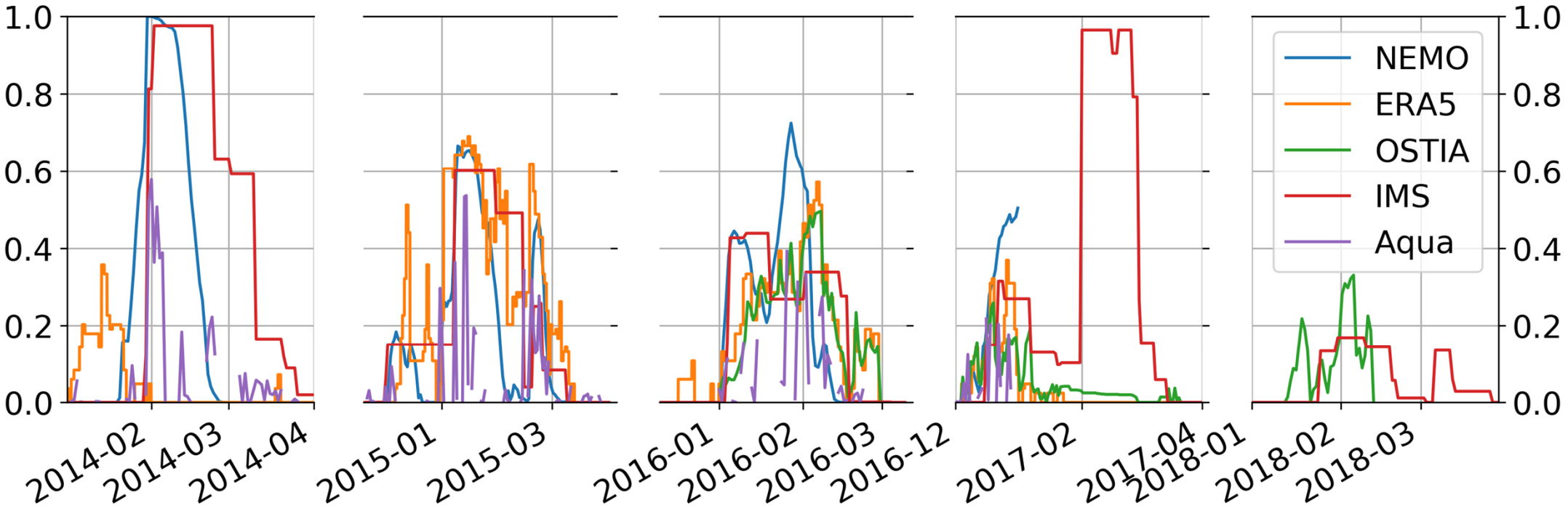
$\mathbf{F}^U$, F^T, F^S – surface forcing terms.

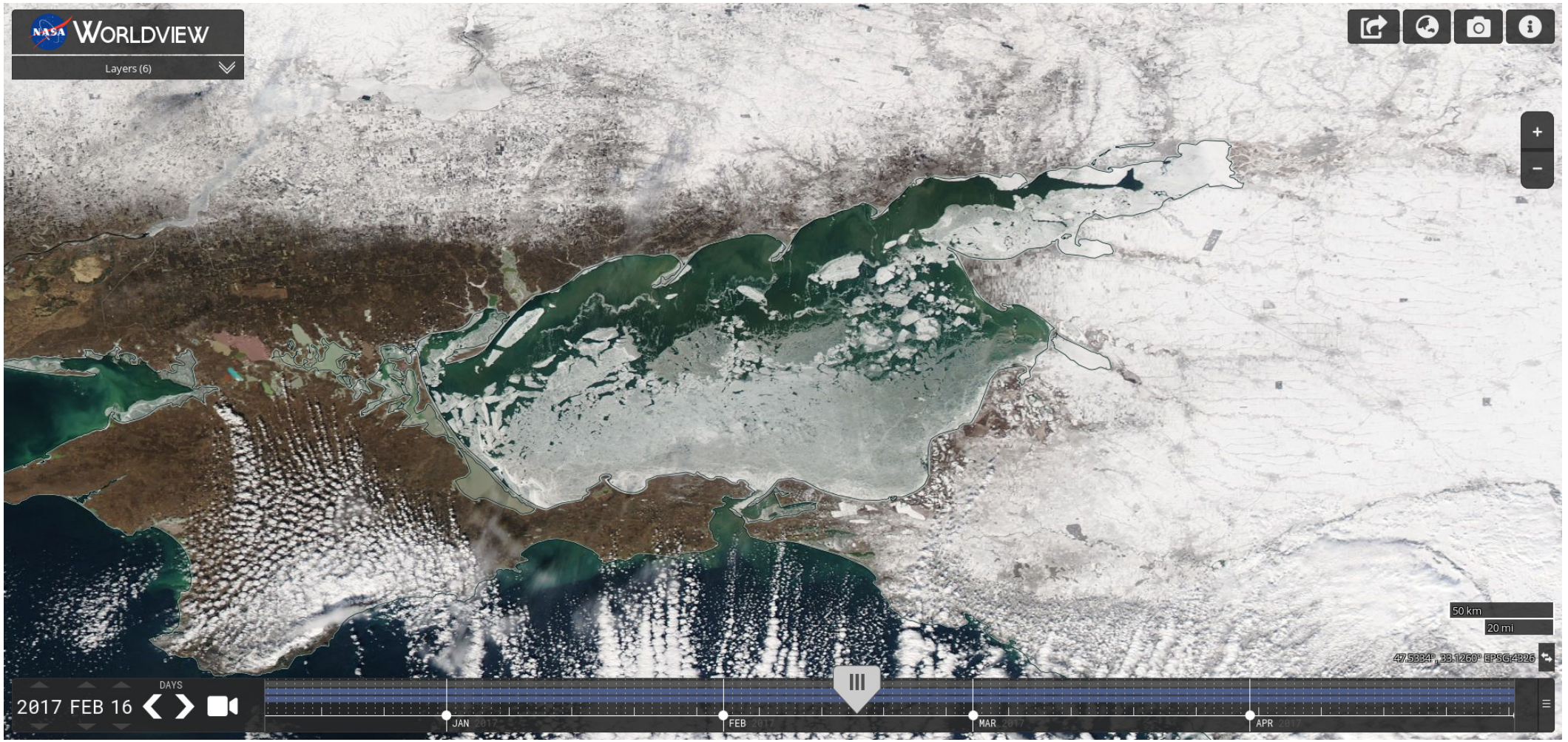
Seasonal variability of ice conditions



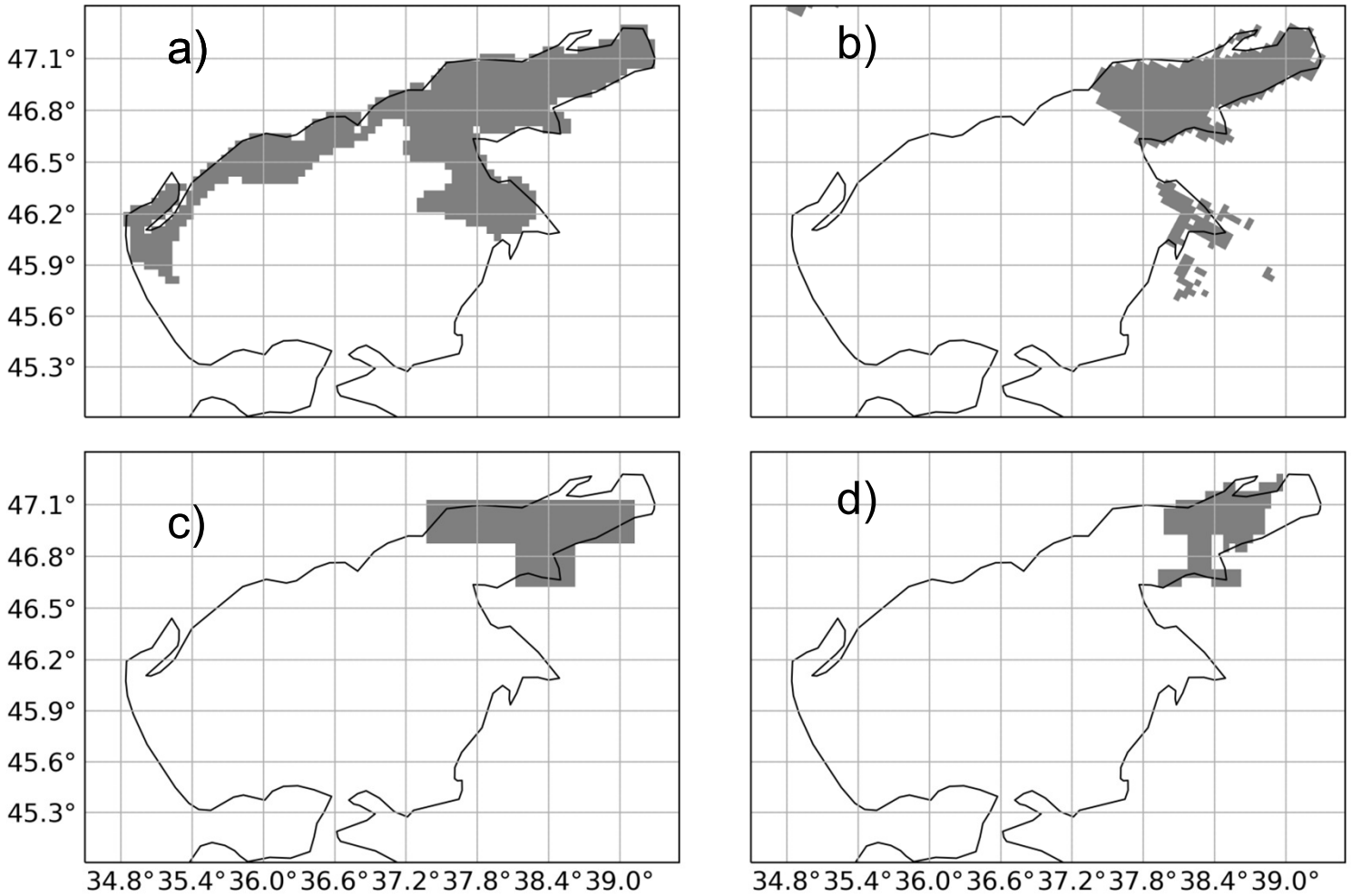

47.4°
47.1°
46.8°
46.5°
46.2°
45.9°
45.6°
45.3°
34.8°35.4°36.0°36.6°37.2°37.8°38.4°39.0°39.6°

The ratio of the area of ice to the surface area of the Azov Sea




NASA WORLDVIEW
Layers (6)
+
−
50 km
20 mi
47.5334°, 33.1260° EPSG:4326
DAYS
2017 FEB 16
JAN 2017
FEB 2017
MAR 2017
APR 2017

4 Jan 2016

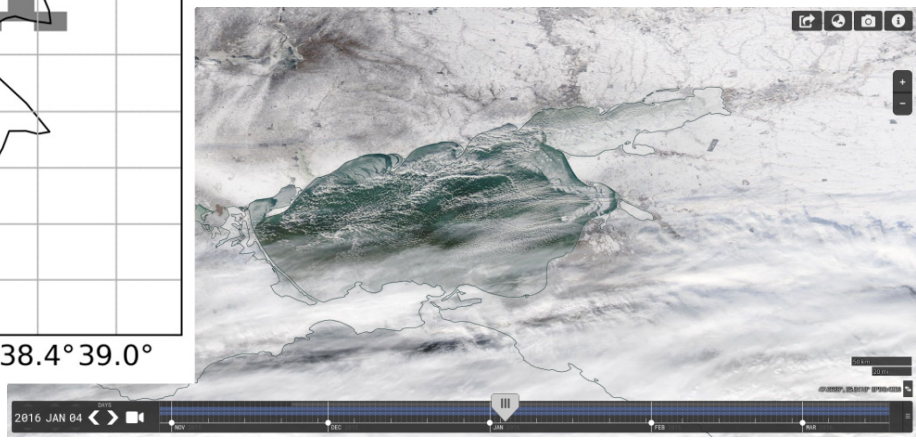


a) NEMO

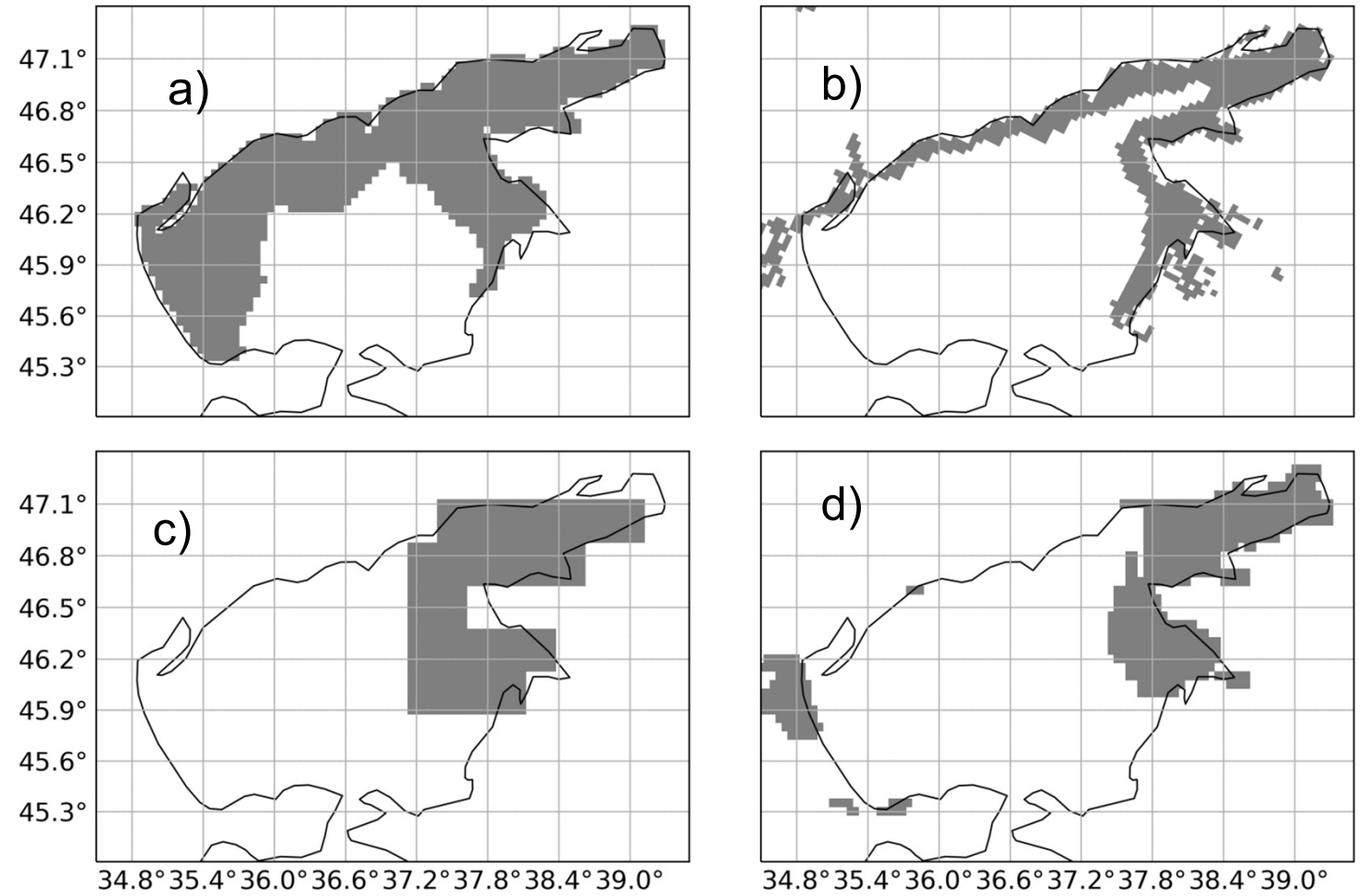
b) IMS

c) ERA5

d) OSTIA



26 Jan 2016



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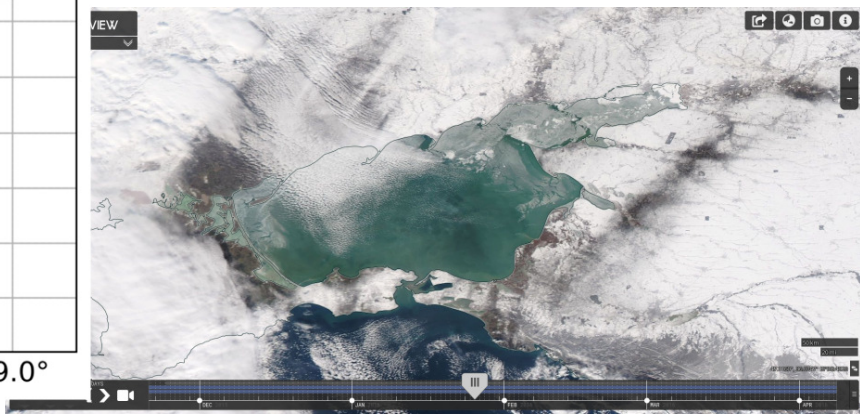
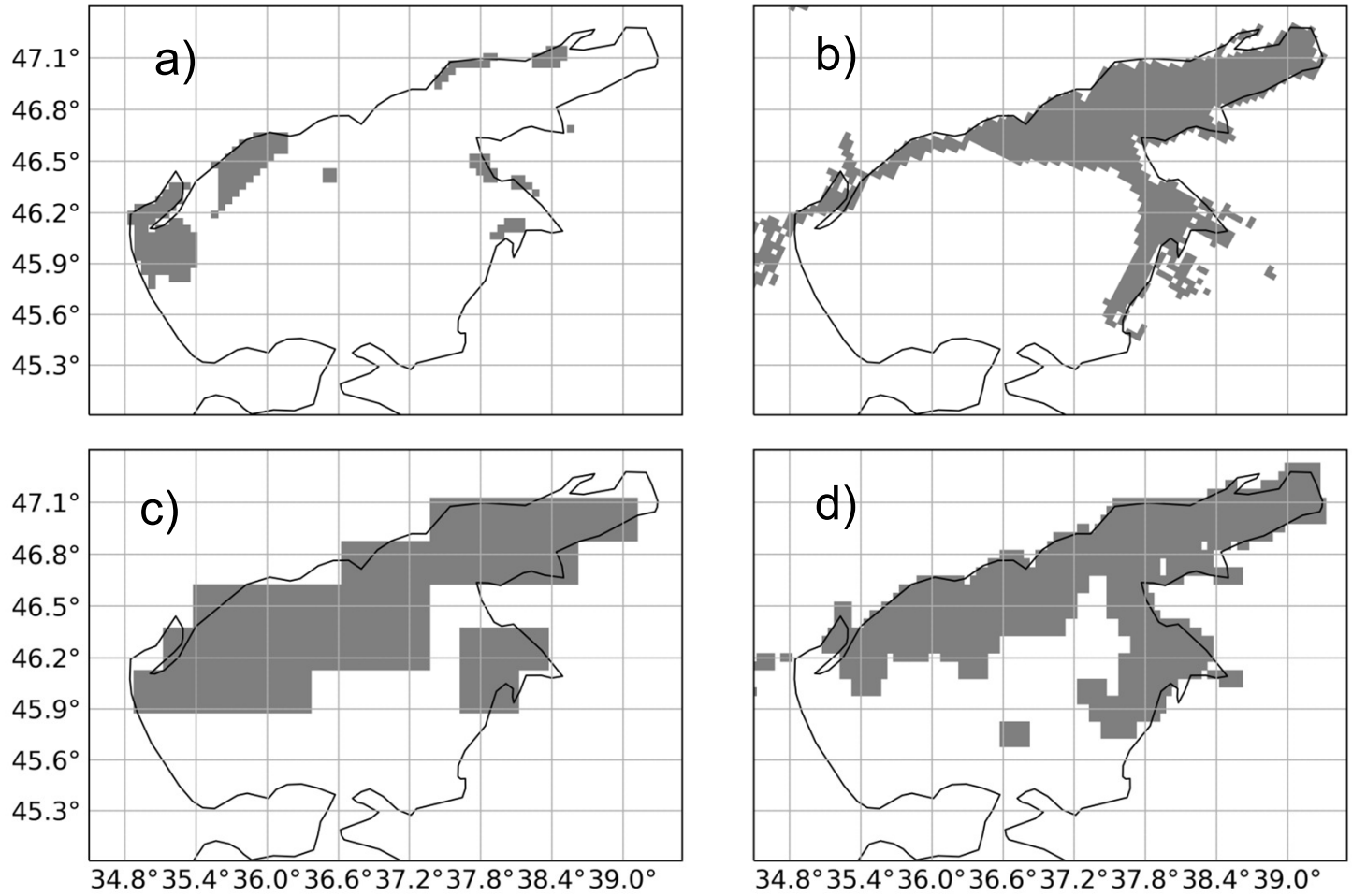


7 Feb 2016



a) NEMO
b) IMS
c) ERA5
d) OSTIA

Conclusion

Based on the analysis of NEMO, ERA5, OSTIA, IMS data and MODIS optical range images, it can be seen that the overall dynamics of the sea ice manifestation coincide.

In all cases, ice initially forms in the Taganrog Bay, and then off the northern coast and further, depending on weather conditions, ice can occupy the entire surface of the Sea of Azov.

However, a more detailed analysis shows that the products in question differ from MODIS optical images. However, MODIS also has problems - data are not available in cloudy weather, which is common in winter.

Thanks for attention