Evaluation of the first baroclinic Rossby radius in the Black Sea using reanalysis data and in-situ Argo profiles

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What is the Rossby Radius?

The first baroclinic Rossby radius of deformation R_1 is a horizontal scale at which the Earth rotation's effects become as significant as stratification effects and thus characterizes the scale of mesoscale currents in oceans and seas.

Radius R_1 is important for estimating how correctly numerical models resolve mesoscale motions – it is necessary that the model grid resolution is smaller than characteristic R_1 for that basin. Therefore it is useful to know the distribution of R_1 in the basin as well as its seasonal and interannual variations.

Rossby radius depends on:

- density stratification
- depth
- latitude

Worldwide R_1 varies from several kilometers at high latitudes to several hundred kilometers at low extratropical latitudes.

In the Black sea the variation of R_1 is mainly due to density profile and depth.

Data used in the study:

1. Daily reanalysis of the Black Sea provided by Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu), based on numerical hydrodynamic model implemented over the whole Black Sea basin. The model horizontal grid resolution is 1/36° in meridional direction and 1/27° in zonal (~3 km). It has 31 unevenly spaced vertical levels from 2000 meters depth to the surface.

2. Selected Argo profiles in different locations and seasons in order to validate our results and check the credibility of the obtained maps.

Temporal coverage: 1992-2018 Reanalysis

2005-2018 Argo profiles

Method to calculate the Rossby radius:

The Rossby radius can be defined as
the distance that long baroclinic gravity waves propagate at phase speed c
in time period *T=1/f :*

$$R_n = \frac{c_n}{|f|}$$

$$n = 0,1,2,3,\ldots$$

$f = 2\Omega \sin \varphi$ is the Coriolis parameter
Ω is Earth's angular velocity
φ is the latitude

Method to calculate the Rossby radius:

The Rossby radius R_n can be obtained by solving a Sturm–Liouville eigenvalue problem for the z-dependence of vertical velocity $\psi(z)$:

$$\frac{\partial^2 \Psi(z)}{\partial z^2} + \frac{N^2(z)}{c^2}\Psi(z) = 0$$

with the boundary conditions of rigid-lid and flat-bottom approximation:

$$\Psi(0) = \Psi(-H) = 0$$

$N^2(z)$ is the squared Brunt-Väisälä buoyancy frequency
H is the depth
c is the phase velocity

Method to calculate the Rossby radius:

The approximate solution can be obtained by the so-called Wentzel-Kramers-Brillouin (WKB) method:

$$R_n \approx \frac{1}{|f| n \pi} \int_{-H}^{0} N(z)\,dz = \frac{R_1}{n} \qquad n \geq 1$$

$$R_1 \approx \frac{1}{|f| \pi} \int_{-H}^{0} N(z)\,dz \qquad N(z) = \sqrt{\frac{g}{\rho} \frac{\partial \rho}{\partial z}}$$

$f \approx 9.946264 .10^{-5}\ s^{-1}$

ρ is the potential density referenced to the depth at which N is being calculated

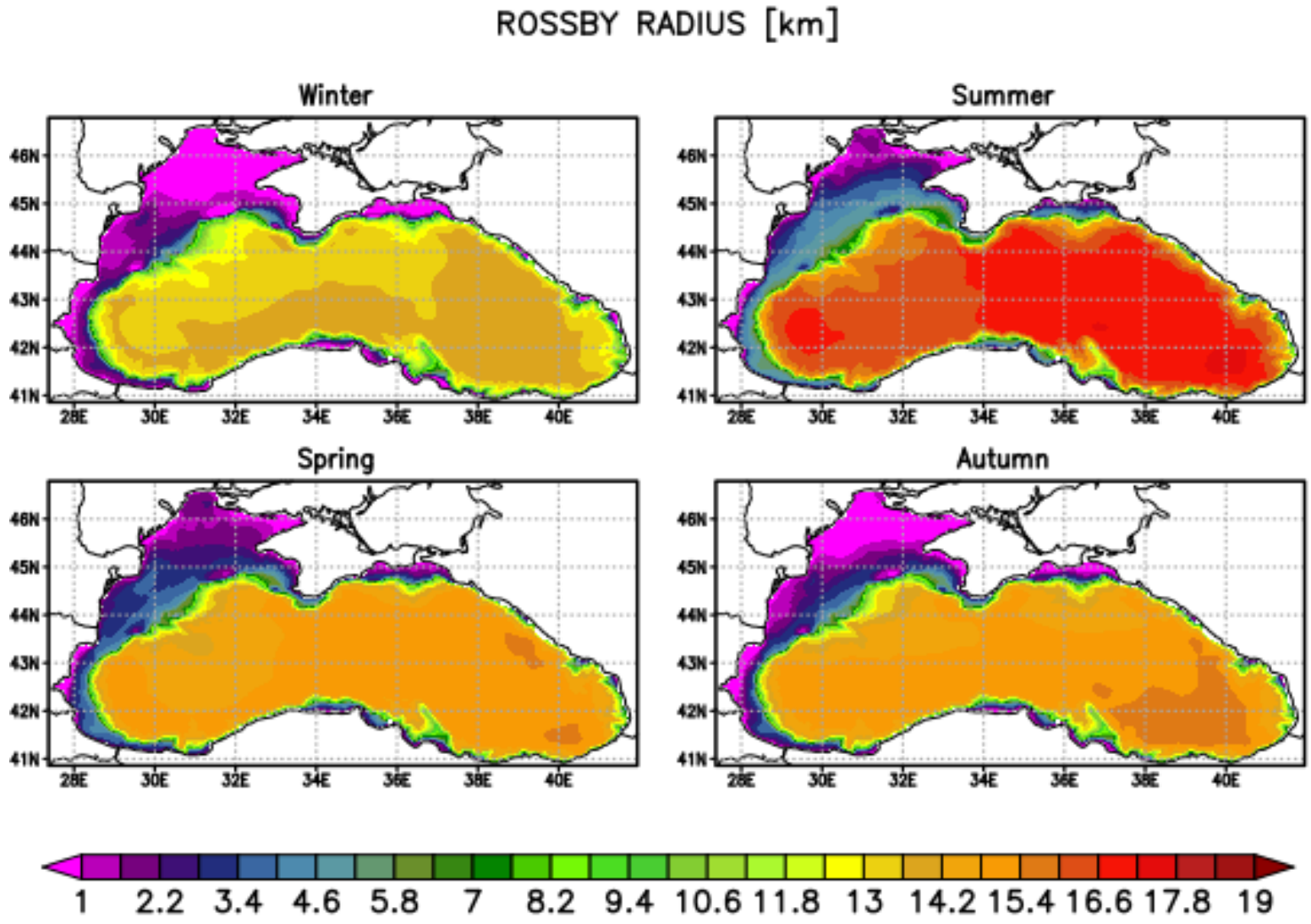
WKB approximations:

WKB approximations are systematically high by about 6.5% than the exact solution.

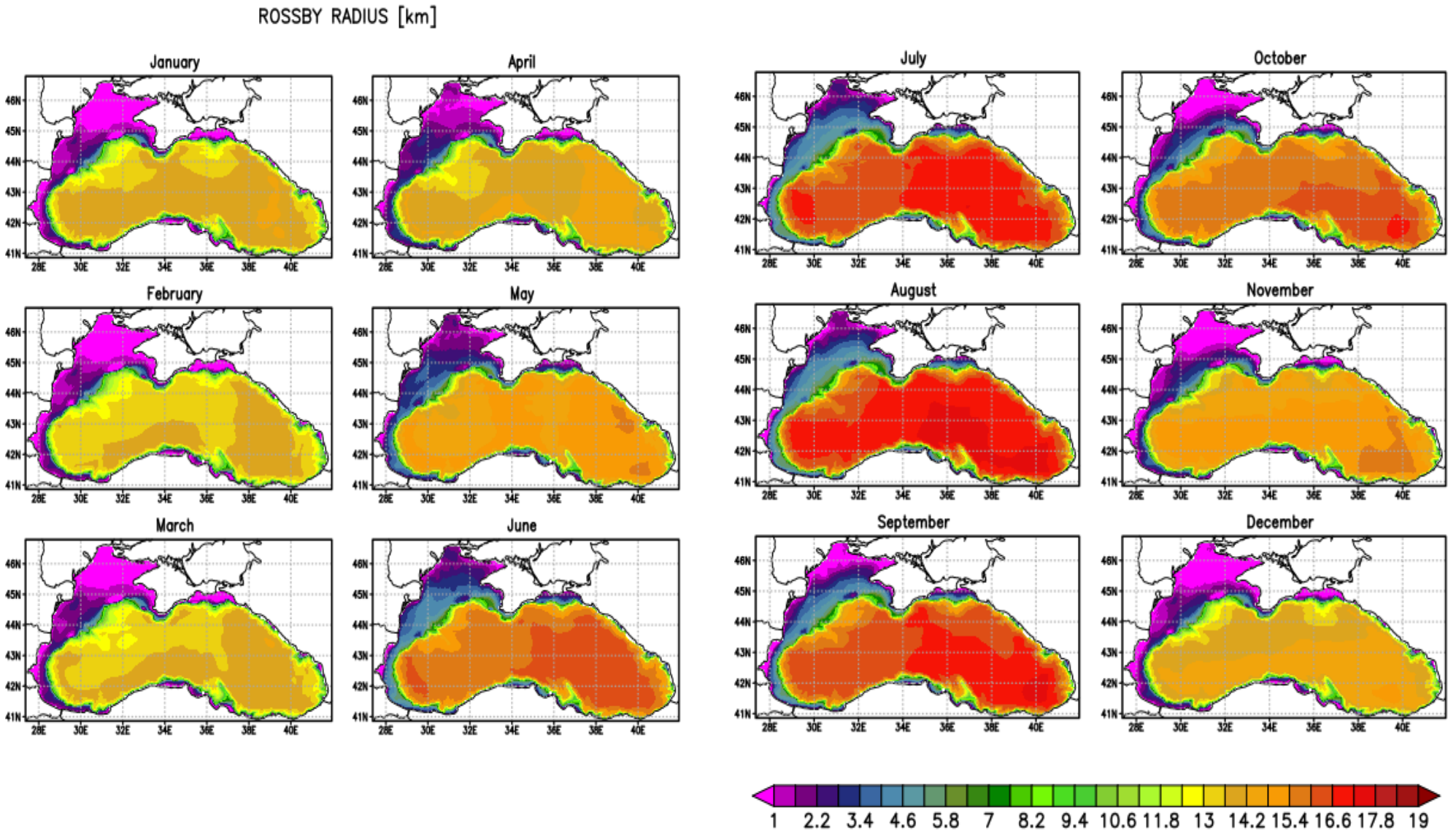
The bigest discrepancies are where the vertical variability of BVF is large, where the halocline and thermocline are strong.

Results: seasonal maps

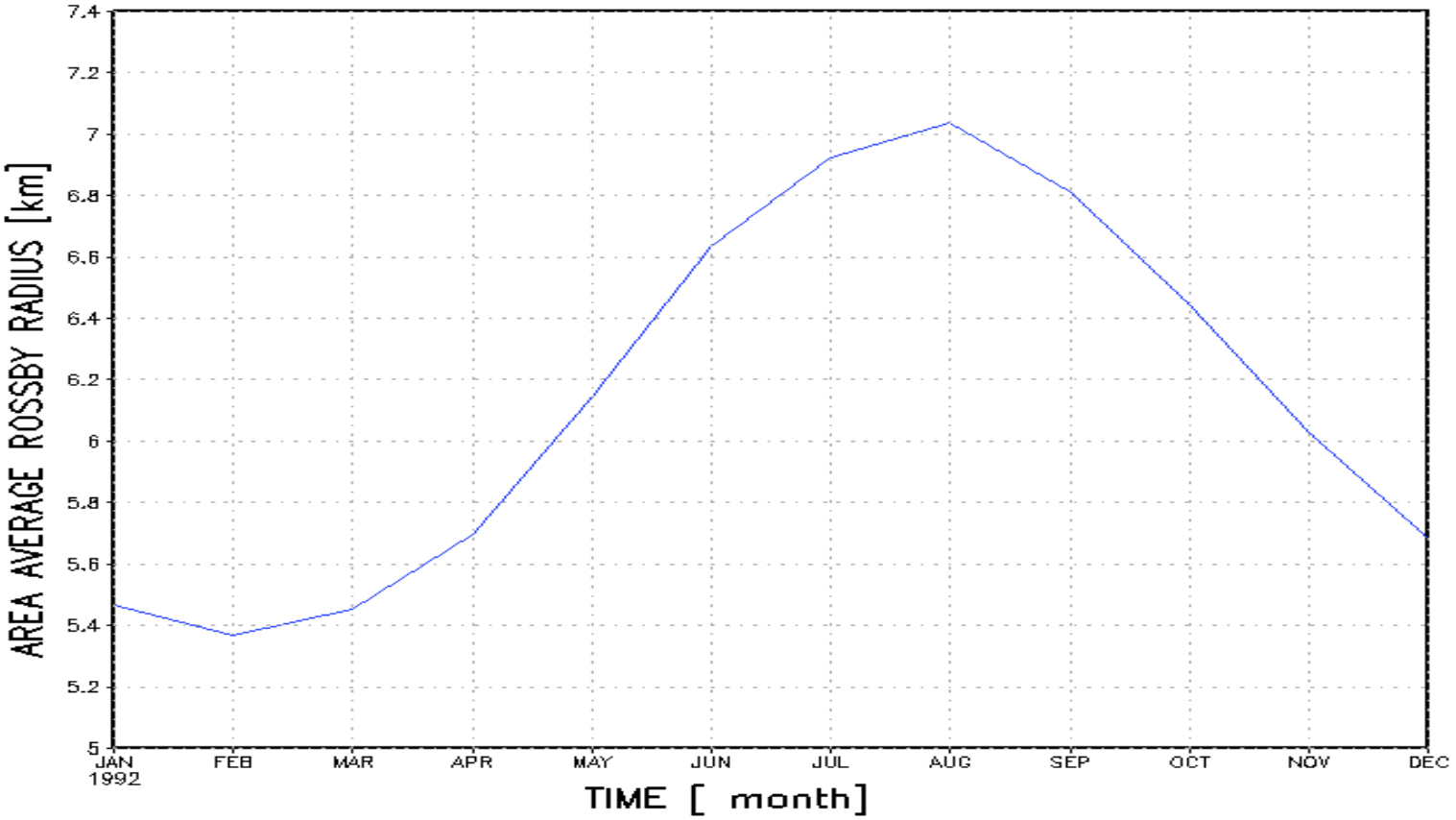
The Rossby radius is calculated as described for each day and each grid point of the Black Sea. Then the results are averaged.



Results: monthly maps

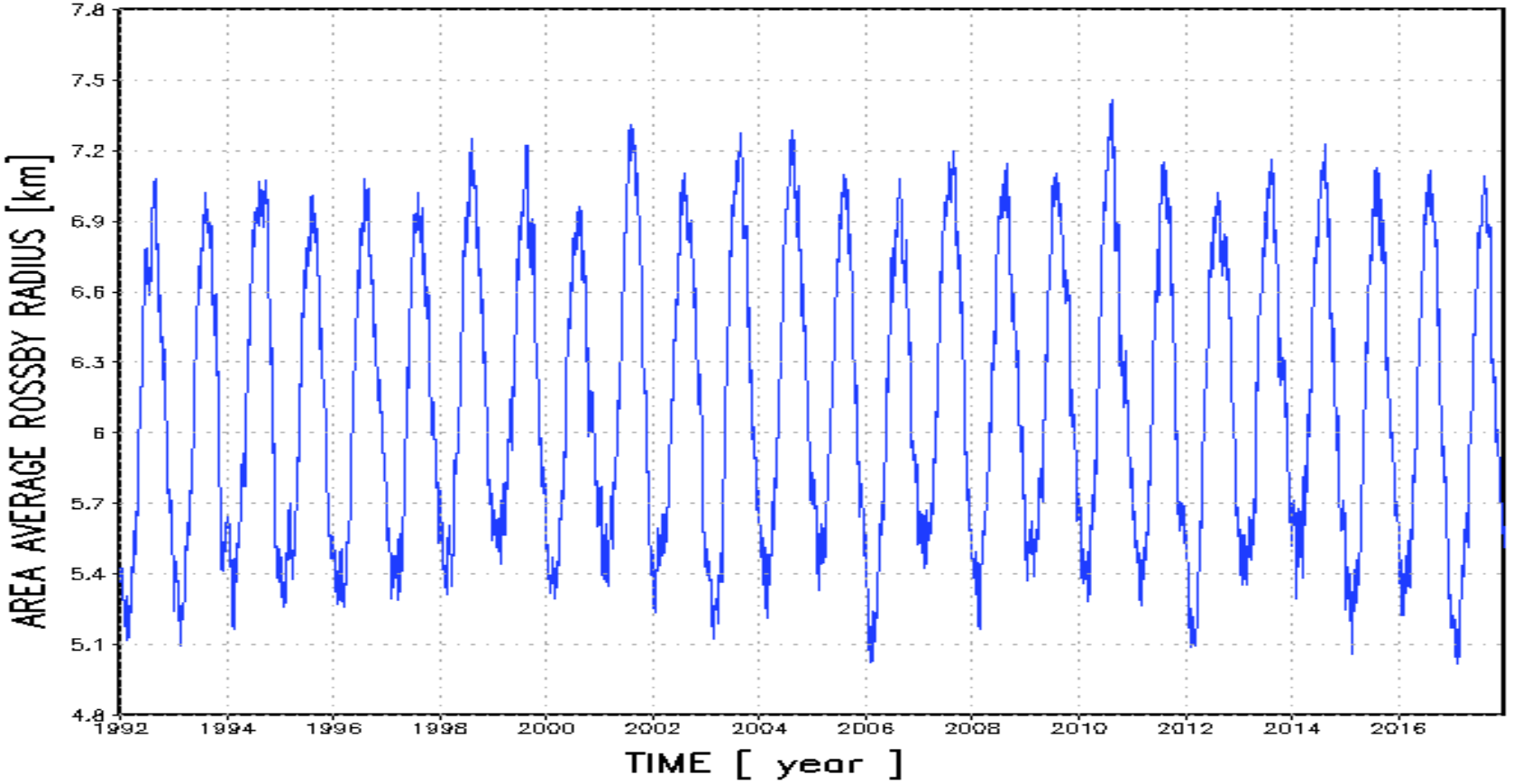


Results (from reanalysis):



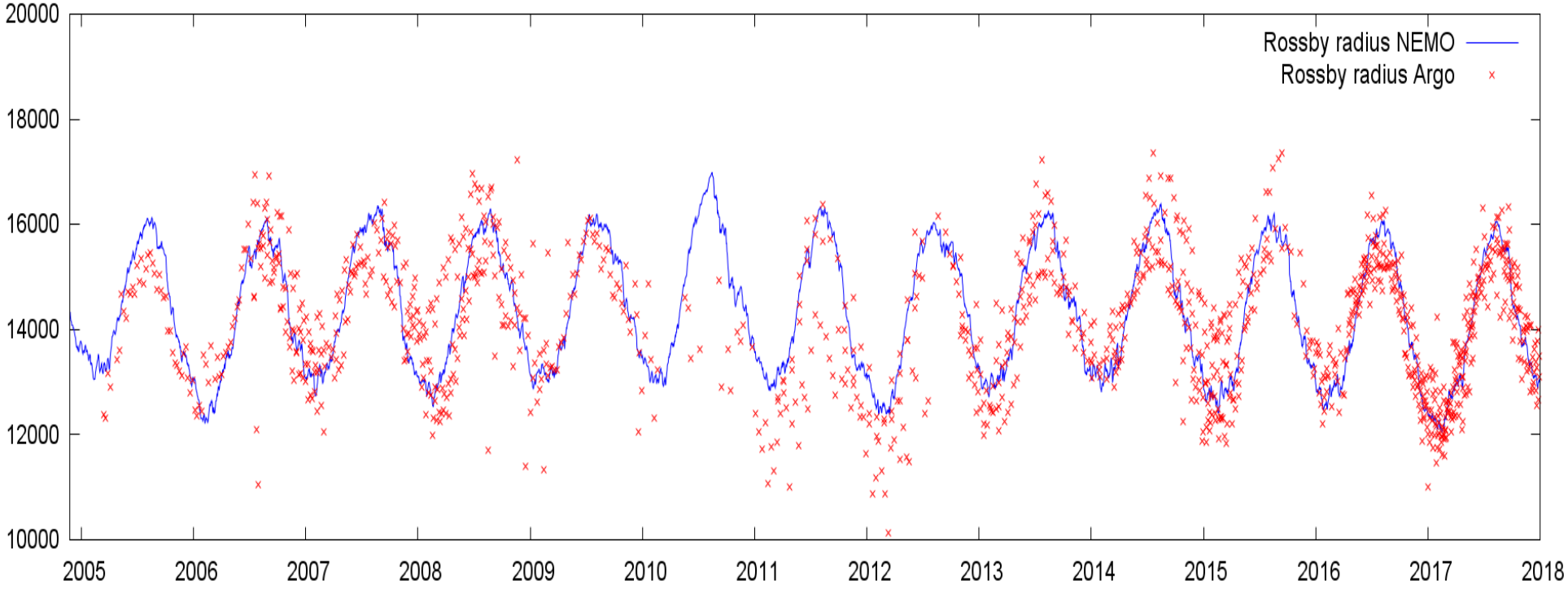
- almost harmonic variation
- the maximum is in August with $R_1 \approx 7$ km,
- the minimum is in February with $R_1 \approx 5{,}35$ km.

Results (reanalysis):



There is an weak positive trend from 1992 to 2010 due to increasing sea water stratification in the warmer climate.

Comparison between the Rossby Radius from the model and from the in-situ Argo profiles:



THANKS

FOR YOUR ATTENTION!