Complex System of the Wind Waves Forecasting in the World Ocean and the Seas of Russia

A. A. Zelenko and Yu. D. Resnyanskii

Hydrometeorological Research Center of the Russian Federation, Bolshoi Predtechensky per. 13, Moscow 123376, Russia

Email: zelenko@mecom.ru

Information on the today's and future state of the sea surface, which is almost always disturbed to some extent by wind waves, is one of the most requested by numerous users of marine hydrometeorological information (navigation, rescue operations, marine fishing, obtaining mineral resources, environmental applications, and many others). The usual way for obtaining this kind of information are operational wind waves forecasting systems.

For the purposes of such forecasting in the Hydrometeorological Center of Russia an integrated system is being developed. The system is configured according to the conjugate scheme “ocean – sea – coastal zone” within the framework of a unified technology, taking into account differences in the spatio-temporal scales of wave processes in oceanic and marine areas. Conjugation is accomplished by continuously exchanging information between different subdomains at the liquid boundaries of nested meshes. The system makes it possible to calculate wave parameters with a resolution of 10–20 km in the World Ocean and ~5 km in the Russian seas with a computing time acceptable for operational applications.

The third generation spectral wave model WaveWatch III (WW3) version 6.07 (WW3DG, 2019) is used for computing the forecasts. The model, which is one of the three most known in forecasting applications (WAM, WW3, SWAN), is based on the numerical solution of the spectral equation of the wave energy balance or wave action.

For the global ocean, the computational domain is constructed by combining a regular geographic grid at low and mid latitudes with near polar grids with a resolution close to the resolution of the geographic grid at its boundaries (Table 1). The combination of such grids is carried out using the IRI (irregular – regular – irregular) technology (Rogers and Linzell, 2018), which provides a relatively uniform spatial resolution (10–20 km) for the entire global area. Unlike the usual geographic grid over the entire global region, this configuration does not violate the grid isotropy at high latitudes.

Table 1. Composite grid configurations for the joint calculation of wind waves in the World Ocean

Grid ID	Grid type	Latitude range	Resolution	Number of nautical grid points
nps10km	stereographic	60° – 89° N	~10 km	152822
reg12mn	geographic	55° S – 65° N	0,2° (~20 km)	754030
sps15km	stereographic	50° – 80° S	~15 km	205425

For the marginal seas, grid configurations with a higher spatial are used (Table 2). The lateral boundary conditions for these grids are generated in the course of solving the task for the global domain (Table 2).

Detailing forecasts in the coastal zone (bays, straits, port waters, etc.) requires an even higher resolution, up to ~100 m. This problem is solved by using conjugated unstructured (triangular) grids supported by the WW3 model. Use of this way allows the grid structure to be adapted to the bathymetry and coastline configuration. The boundary conditions for such grids are generated by a submodel for the corresponding sea (Table 2) within the framework of the general scheme “sea–coastal zone”.

Table 2. Grid configurations for wind waves forecasting in the Russian seas

Region	Grid ID	Grid type	Resolution	Boundary conditions from the mesh	5 day forecast computing time (min)
Arctic Seas	*arc*	stereographic	~5 km	*reg12mn*	20
White Sea	*bel*	geographic	~1 km	*nps10km*	12
Baltic Sea	*balt*	geographic	~2 km	*reg12mn*	10
Bering Sea	*bering*	geographic	~5 km	*reg12mn*	6
Japan and Okhotsk Seas	*JapOhot*	geographic	~5 km	*reg12mn*	6
Black Sea, Sea of Azov, Kerch Strait.	*black* *azov* *kerch*	geographic geographic geographic	~4 km ~1 km ~0,5 km	— — —	15
Caspian Sea, Northern Caspian	*casp* *caspn*	geographic geographic	~2 km ~1 km	— —	18

For setting boundary conditions on the sea surface, which are required for the wave model integration, the products of two global meteorological forecasting models, PLAV (Hydrometeorological Center of Russia) (Tolstykh et al., 2019) and GFS (NCEP/NOAA), as well as of the national mesoscale forecasting system COSMO-Ru (Rivin et al., 2019) are used.

When using 574 computing cores, the calculations of the global wave forecast for 5 days in the configuration of Table 1 take approximately 18 minutes, and under the conditions of parallel calculation of forecasts for the seas (Table 2), the total time spent is about 40 minutes, which is acceptable for operational applications. Starting from November 1, 2022, the technology operates in an experimental quasi-operational mode.

References

Rivin G. S., Rozinkina I. A., Astakhova E. D., Blinov D. V., Bundel' A. Yu., Kirsanov A. A., Shatunova M. V., Chubarova N. Ye., Alferov D. Yu., Varentsov M. I., Zakharchenko D. I., Kopeykin V. V., Nikitin M. A., Poliukhov A. A., Revokatova A. P., Tatarinovich E. V., Churiulin E. V., 2019: COSMO-Ru high-resolution short-range numerical weather prediction system: Its development and applications. *Hydrometeorological Research and Forecasting*, No. 4 (374). P. 37–54 (in Russian).

Rogers W. E. and Linzell R. S., 2018: The IRI grid system for use with WAVE-WATCH III® (Tech. Rep.). Stennis Space Center, MS 39529-5004: Naval Re1486 search Laboratory.

Tolstykh M.A., Fadeev R.Yu., Shashkin V.V., Travova (Makhnorylova) S.V., Goyman G.S., Mizyak V.G., Rogutov V.S., Shlyaeva A.V., Yurova A.Yu. Development of SL-AV global semi-Lagrangian atmosphere model in 2009–2019, 2019: *Hydrometeorological Research and Forecasting*, No. 4 (374), P. 77–91 (in Russian).

WW3DG (The WAVEWATCH III® Development Group), 2019: User manual and system documentation of WAVEWATCH III® version 6.07. Tech. Note 333, NOAA/NWS/NCEP/MMAB, College Park, MD, USA, 326 pp.