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An Investigation of Mesoscale Wave Processes in the Surface Layer Using Synchronous Measurements of Atmospheric Parameters and Admixtures

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Abstract—We present the results of experimental investigations of mesoscale wave processes in the surface layer based on the data of multiyear synchronous minute-by-minute measurements of atmospheric parameters and admixtures on a network consisting of five stations spaced 1–6 km apart. The concentrations of sulfur dioxide, carbon oxide, nitrogen oxide and dioxide; the mass concentration of aerosol; and the temperature and pressure, wind velocity and direction, and relative humidity were measured synchronously. Polarization relations for all the measured parameters have been obtained for different periods and wavelengths. The azimuth of mesoscale wave propagation is detected to depend on the mean wind velocity. It is shown that the densities of elastic and horizontal energies of mesoscale waves are essentially different on different scales.

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INTRODUCTION

Of the entire spectrum of atmospheric variations, mesoscale processes have been the least investigated. Previously, researchers constructed spectra of the fluctuation of atmospheric parameters and performed their time averaging over a large number of samples [1]. In this case, mesoscale processes made the least contribution to the total variance of atmospheric parameters. Studies [2, 3] showed that processes such as IGWs, which relate to the mesoscale minimum, must considerably contribute to the dynamics and energetics of the atmosphere. It is also known that macroturbulent processes, convective instability, and the Kelvin–Helmholtz instability substantially complicate the fields of atmospheric parameters [4].

We have shown previously that the intensity of mesoscale processes in the surface layer is not constant; sometimes these processes considerably contribute to the variance of atmospheric parameters, including surface admixtures [5, 6]. Experimental investigations of the spatial structure of mesoscale variations in atmospheric parameters and, in particular, polluting admixtures require complex experiments that are difficult to organize: data collection points located at relatively small distances from each other and frequent measurements of admixture concentrations and other atmospheric parameters.

To investigate mesoscale processes in the surface layer, we used data from minute-by-minute synchronous measurements in the period 1996–1999 on the network of five automatic stations in the town of Al'met'evsk (53° N, 51° E), Republic of Tatarstan, Russia. The observation points are located at distances of from 1 to 6 km from each other. The stations simultaneously measured the surface concentrations of sulfur dioxide, carbon oxide, and nitrogen oxide and dioxide; the mass concentration of aerosol; the temperature and pressure; the wind velocity and direction; and the relative humidity.

We detected that coherent-in-space variations in admixture concentrations are frequently observed in the surface layer. These variations often coincide in time with analogous variations in the wind velocity or the relative humidity. The periods of these variations vary from 5 min to 16 h. The lifetime of significant variations always exceeds 4–6 periods of the wave, several hours, and sometimes 24 hours. Such variations are observed quite frequently and, as a rule, nearly synchronously at all stations. The appearance of these variations does not depend on the time of the day. This study continues the investigations of mesoscale variations in the surface layer published in [5–7].

Thus, we previously investigated [5] the time characteristics of synoptic, seasonal, diurnal, and mesoscale intensity variations and their interrelations. Study [6] presents the results of investigating mesoscale variations in admixture concentrations and performs a comparative analysis by the methods of Fourier and wavelet transforms, when the properties of predominant periodicities are determined. Work [7] is devoted to the study of properties of local and planetary waves from synchronous measurements of admixtures. In