Modeling the propagation of atmospheric waves from various tropospheric disturbances and studying their influence on the upper atmosphere

Yuliya Kurdyaeva[1,2], Olga Borchevkina[2], and Sergey Kshevetskii[1]
1.I.Kant Baltic Federal University, Kaliningrad, Russian Federation
2.Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation N. Pushkov of the RAS (Kaliningrad Branch), Kaliningrad, Russian Federation

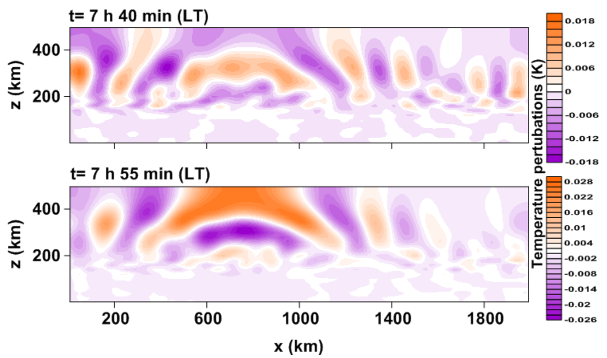
To carry out realistic numerical calculations of processes caused by the vertical propagation of infrasound and internal gravity waves into the upper atmosphere (about 500 km), it is preferable for the model to work at heights from the Earth's surface to the upper thermosphere and have a sufficiently high resolution in time and space to study various scale processes. The three-dimensional hydrodynamic regional model "AtmoSym", used in this study satisfies these requirements.

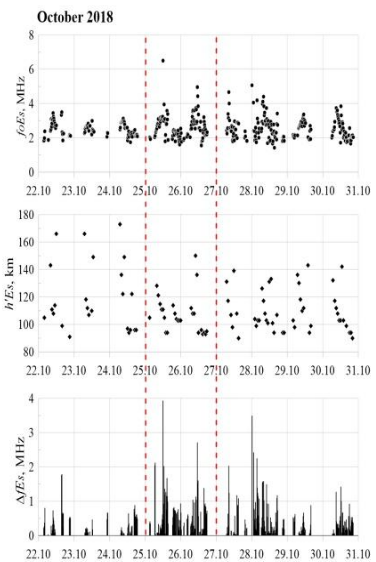
Correct specifying the source of disturbances is usually problematic, since they have a complex structure that evolves over time. The authors suggest using experimental data on pressure variations at the Earth's surface obtained from a network of microbarographs as a source. This issue is reviewed in detail in the article *(Kurdyaeva et al., 2018)*. This work is devoted to modeling results using data on pressure variations at the Earth's surface associated with different tropospheric disturbances (meteorological storm, solar eclipse, solar terminator), and obtained in different ways.

Meteorological storm in the Baltic Sea in 2018

We examined a meteorological storm in the Baltic Sea in October 2018 in Kaliningrad. The vertical propagation of infrasound and internal gravity waves affects the parameters of the lower thermosphere, which is displayed in the formation of areas of increased ionization and the appearance of a sporadic layer E during the meteorological storm.

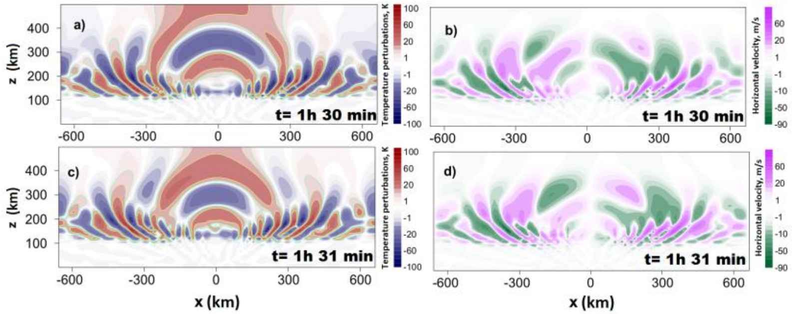
The results of modeling the propagation of waves into the upper atmosphere using data of changes in water level and temperature during periods of dangerous sea and atmospheric phenomena. The model study showed that at the thermospheric heights there are rapidly changing small-scale structures that indicate the existence of waves with periods of about 5 minutes. Waves with periods of about 15 minutes are also observed. The effects caused by the propagation of these waves stay in the upper atmosphere for about 1.5 hours.





Vertical Propagation of AGWs from Atmospheric Fronts

We simulate and study the vertical propagation of AGWs generated by significant atmospheric pressure fluctuations caused by instabilities on a moving atmospheric front. This event occurred around midnight between July 17 and 18, 2016 and was associated with the approaching cyclone. Based on the experimental data obtained with four microbarographs, a field of pressure variations on the Earth's surface in the vicinity of the microbarographs was constructed.

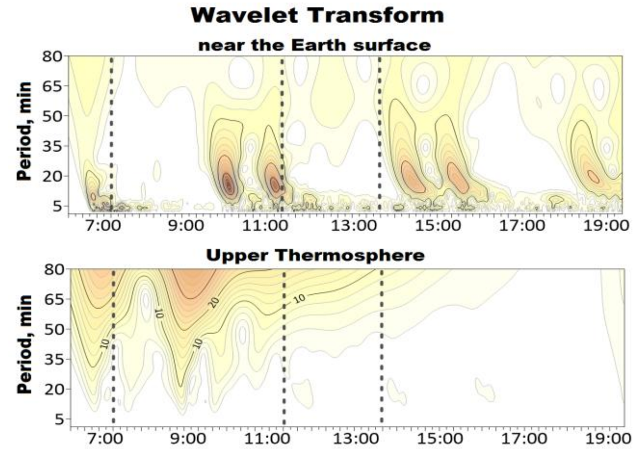


These simulations show that the amplitude of the wave temperature disturbances in the upper atmosphere is approximately 100 K, and the amplitude of the horizontal velocity is 60 m/s. In addition, in the upper atmosphere, a heated zone forms above the source approximately two hours after its activation. This heated zone is most likely formed by very long infrasonic waves propagating very slowly upward from the source due to their properties.

Vertical Propagation of Atmospheric Waves from the Lower Atmosphere during a Solar Eclipse

In the numerical experiment considered in this work, the source of AGW excitation was minute-by-minute variations in atmospheric pressure at the lower boundary of the numerical model given on the Earth's surface. To find the amplitude of the pressure variations, we used the results of a lidar sounding of the lower atmosphere performed in Kaliningrad (54° N, 20° E) on March 20, 2015 on the day of the passage of the solar eclipse. It is assumed that variations in the lidar signal intensity represented the frequency characteristics of pressure variations at a fixed height. The amplitude values of the pressure variations were calculated according to the assumption that the maximum amplitudes of the changes in the observed intensity of the scattered signal corresponding to the amplitudes of the pressure variations.

In the upper atmosphere, at altitudes of ~200 km, disturbances are formed due to the dissipation of AGWs coming from the lower atmosphere; these disturbances propagate with characteristic periods of ~50 min. The propagation direction of these disturbances was opposite to the propagation direction of the solar eclipse region along the Earth's surface.



We numerically studied vertical propagation of atmospheric waves with various perturbations in the troposphere during different events using experimental data. Some of the results were obtained for the first time:

- Infrasonic waves generated by perturbations in the troposphere, which are impossible to detect using Earth sounding methods, cause great influence to condition of the upper atmosphere.
- Evaluation of temperature perturbation and horizontal velocity caused by infrasonic waves propagation was given.
- Atmospheric parameters data during the propagation of solar terminator and solar eclipse with high resolution in time and space were obtained. Specific characteristics of thermospheric perturbations caused by these events are confirmed by results of experimental studies of ionosphere dynamics.
- Propagation of infrasonic and internal gravity waves during meteorological storms can affect forming of the layer with high electron concentration, fixed on ionograms as occurrence of E_s.

About the Author