



Sounds of Cyclone

K. Naugolnykh (1), **S. Rybak** (2)

(1) NOAA/ETL/Zeltech, Colorado, USA, konstantin.naugolnykh@noaa.gov / Fax: (303) 497-5862, Phone: (303) 497-6325, (2) N. Andreev Acoustics Institute, Moscow, RUSSIA, rybak@akin.ru / Fax: (095) 126-8411, Phone: (095) 1269072

Sounds of Cyclone

K. Naugolnykh (1), **S. Rybak** (2)

(1) NOAA/ETL/Zeltech, Colorado, USA, konstantin.naugolnykh@noaa.gov, Phone: (303) 497-6325; (2) N. Andreev Acoustics Institute, Moscow, RUSSIA rybak@akin.ru / Phone: (095) 126-9072.

Introduction

Infrasonic radiation of cyclone induced counter propagating sea-surface waves is considered on the basis of modern physical model of cyclone developed by Emanuel, 1995 [1]. The jet anti-wave-guide model of infrasound propagation and refraction in the cyclone perturbed area of atmosphere is used to evaluate refraction and trapping of radiated infrasound by horizontal atmospheric wave-guide that provides the long-distance propagation of infrasound..

Theory

Tropical cyclones produce strong perturbations of atmosphere and the ocean surface accompanying by an acoustical radiation. Infrasonic signals in the 0.1-0.5 frequency band can be observed at a distances of thousands of miles from the cyclone [2]. The effect of infrasound radiation is connected apparently to the interaction of the counter-propagating sea-surface waves that produces a sound radiation of the doubled frequency of the surface wave oscillation. This radiation has the vertical narrow-angle directivity pattern [3] and propagates in the highly perturbed by cyclone domain of atmosphere. The eye wall of the cyclone itself is composed of strong updrafts, reaching magnitudes as large as 15 m s^{-1} . The effect of updraft region can be modeled by

the appearance of vertical anti-wave-guide producing refraction of infrasound. This process is considered on the basis of the ray approximation of the theory of sound propagation. The essential refraction of the infrasound radiated by the sea-surface waves occurs in the atmosphere domain perturbed by the cyclone. Initially vertically directed rays obtain a horizontal direction that provides trapping of the infrasound by the horizontal atmospheric wave-guide and its long distance propagation. The presence of oversaturated water vapor layer in the upper domain of the cyclone can lead to the developments of nonlinear effects of radiation instability [4] of infrasound waves.

Conclusion

Theoretical model of the infrasound generation by cyclone is developed. The infrasound is generated by cyclone-induced counter-propagating sea-surface wave and propagates upward. Then the refraction of infrasound wave by the jet anti-wave-guide leads to its trapping by a horizontal atmospheric wave-guide, providing a long-range propagation.

The nonlinear effects in the oversaturated layer of water vapor can lead to infrasound amplification and development of radiation instability processes.

References

1. Emanuel, K. A., 1995: The behavior of a simple hurricane model using a convective scheme based on subcloud-layer entropy equilibrium, *J. Atmos. Sci.*, **52**, 3960-3968.
2. Tabulevich, V. N., Ponomarev, E. A., Sorokin, A. G., and Drennova, N. N., 2001: Standing sea waves, microsesms, and infrasound, *Izvestia, Atmospheric and Oceanic Physics*, **37**, 218-226.
3. Naugolnykh, K. A., and Rybak, S. A., 2003: Sound generation due to the interaction of surface waves, *Acoustical Physics*, **49**, 88-90.
4. Balmforth, N. J., Ierley, G. R., and Worthing, R., 1997: Pulse dynamics in unstable medium, *SIAM J APPL. MATH*, **57**, 205-251.