LA-UR- 98-3338

Approved for public release; distribution is unlimited.

CONF-980920--

Title:

Modeling Study of Infrasonic Detection of 1kT Atmospheric Blast

Author(s):

Kalpak A. Dighe
Rodney W. Whitaker
William T. Armstong

Submitted to:

20th Annual Seismic Research Synposium on Monitoring a Comprehensive test Ban Treaty

September 21-23, 1998

Santa Fe, NM

RECEIVED
APR 13 1999
OSTI

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

Los Alamos
NATIONAL LABORATORY

MODELING STUDY OF INFRASONIC DETECTION OF 1 kT ATMOSPHERIC BLAST

Kalpak A. Dighe, Rodney W. Whitaker and William T. Armstrong
EES-8, Los Alamos National Laboratory, Los Alamos, NM 87545, USA.

Sponsored by DOE

ABSTRACT

A modified version of the 'Pierce code', which provides a theoretical prediction of acoustic-gravity pressure waveforms generated by explosions in the atmosphere, has been used to simulate detectable signal amplitudes from a 1 kT atmospheric detonation at high latitudes upto distances of about 1000 kilometers from the source. Realistic prevailing winds and temperature profiles have been included in these simulations and propagation results for 'with wind' and 'counter wind' conditions are presented. *En route*, the code has been successfully ported from a CRAY/UNICOS platform to a more general UNIX/workstation environment in FORTRAN90. The effects of seasonal variations of winds and temperature at high latitudes will be presented at the symposium.

Key Words: Infrasound, Detection.

OBJECTIVE

The infrasound technique is one the proposed methods for monitoring a Comprehensive Test Ban Treaty. In order for such a treaty to be effective, reliable technologies must be developed to detect and identify explosions. Simply enhancing hardware sensitivity would increase the number of detected signals. One can imagine the task of investigating the mammoth database acquired by the entire International Monitoring System network for potentially interesting signals. Thus, robust analysis techniques must be designed to significantly reduce the number of false alarms that may arise while scrutinizing these data. The present long range propagation study has been undertaken to support this goal and provides a powerful tool for evaluating suspect infrasonic signals and possibly aiding in subsequent decision making for mandating an on-site inspection.

RESEARCH CONDUCTED

Within the infrasound community, a great body of work has been devoted to understanding the propagation of acoustic-gravity pressure waveforms resulting from detonations conducted in the atmosphere. The most notable is the 'Pierce code' from the mid 1960's [1] that was undertaken to predict waveforms from large atmospheric bursts (megaton events) propagating for long ranges (1,000 to 20,000 kilometers). We, at Los Alamos National Laboratory, have modified this code to determine the propagation of higher frequencies modes by using a WKB approach [2]. Recently the 'modified Pierce code' was converted from the older FORTRAN, running under the CRAY/UNICOS system, to the newer FORTRAN 90, while concurrently porting the code to an UNIX workstation environment.

Comparisons of actual recorded data from a recent ANFO (Ammonium Nitrate - Fuel Oil) explosion with those obtained from simulations with the 'modified Pierce code' indicate a high degree of correlation between the two pressure waveforms [3]. These results suggests that the current code may be judiciously utilized to make inferences about the nature of a suspect event by conducting simulations to duplicate the waveforms detected at nearby IMS sites by varying the input parameters to the code. These parameters include (but are not limited to): geodetic range between the source and monitoring systems, azimuthal variations, yield of event, altitude of burst, local temperature (and thus sound speed) profiles and local (at the event site) wind profiles.

The effects of local winds play an unquestionable important role in determining the propagation of infrasound signals to the receiving stations. This is because of the finite physical relationship between the phase velocities of the modes launched by an event and the sound speed (related to temperature) and wind velocity at different altitudes. This relation determines the altitudes from which particular modes will be refracted by the atmosphere (classical ray tracing theory). Therefore, without due consideration of the local winds, erroneous source localization of suspect signals may result. In recent years, a significant amount of research has been dedicated to the understanding of the exact effect of the winds, from ground level upto thermospheric altitudes (~100 kilometers), on infrasonic signal propagation. Bearing this in mind, major objectives of the present study were:

i) To incorporate site specific wind (both zonal and meridional components) and temperature profiles in the code to determine the final pressure waveform, addressing both 'with wind' and 'counter wind' conditions
ii) To characterize the effects of seasonal variations of winds and temperature on the pressure waveforms while retaining the same initial conditions at the source and receiver (yield, location, number of modes, etc.).

During the actual monitoring of a CTBT, one cannot expect to obtain local winds at a desired site in real-time. In fact, it may be impossible if the case at hand involves a suspect signal. As such, one has to rely on empirical wind models to generate the wind profiles at these sites. The Horizontal Wind Model [2] is the one that we chose for this study as it utilizes the most comprehensive database. A brief description of this model follows.

The Horizontal Wind Model

In order to fulfill our objectives, we utilized the Horizontal Wind Model (HWM90) [4] to generate site specific winds. The original HWM was developed for providing global thermospheric winds using data acquired by the Atmosphere Explorer E and Dynamics Explorer 2 satellites. The current model represents the third revision of the original model and includes gradient winds from CIRA-86 (Cospar International Reference Atmosphere) that have been augmented by data acquired with atmospheric diagnostic instruments including incoherent scatter radars, meteor radars, MF (medium frequency) radars rocketsondes and Fabry-Peort interferometers to provide an enormous global data bank. Thus the range of altitudes that HWM90 is now capable of providing zonal and meridional wind profiles for spans from the ground upto about 400 kilometers (and even upto 600 kilometers at some locations).

HWM90 accounts for the major variations throughout the atmosphere including latitude, annual, semiannual, local time (atmospheric tides) and longitude (stationary wave 1) by using low-order spherical harmonics and their expansions, and Fourier series analysis. One can vary geophysical parameters such as geodetic latitude (-90 to +90), geodetic longitude (0 to 2pi), altitude resolution, day number (1 to 365/366) and time of day along with the atmospheric parameters; effects on wind like the atmospheric tides can be turned 'on' or 'off'.

Indeed, if one were to compare wind profiles at a site derived from HWM90 to those measured at the same site by in situ measurements, some systematic deviations from the real profiles are apparent. The deviations may be attributed to the fact that the model generates a cubic spline interpolation in altitude to provide smooth profiles. However, in the absence of directly recorded local profiles, as may occur in the case of signals from suspect sites, the profiles generated by HWM90 serve as invaluable 'best guess' profiles.

Results of Simulations

The work presented in this report resulted from simulations conducted at high latitudes (> 65.0 N). The source location used was the eastern trough region of the Novaya Zemlya island (lat = 73.0 N, lon = 57.0 E) and the receiver location was the proposed Norwegian IMS site at Karasjok (lat = 69.5 N, lon = 25.5 E). A terse list of other input parameters to the Pierce code and the HWM90 model follows:

geodetic range between sites	1175 km
yield of event	1 kiloton - assumed to be a point source
atmosphere considered	0 to 150 km (horizontally stratified layers, each 2 km thick)
number of modes considered	50
alt. of source above ground	0.00 km
alt. of observer above ground	0.00 km
season	fall (August)
time of day	00:00:00 (local midnight)

The wind and sound speed profiles required as input to the Pierce code are shown below.

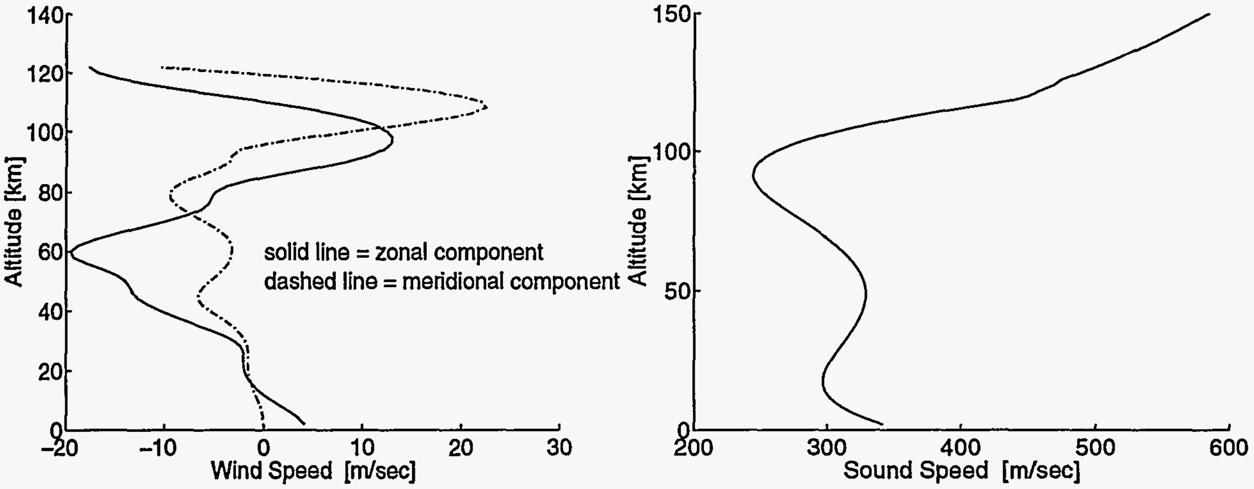

Figure 1. Zonal and meridional components of the wind at lat = 73.0 N, lon = 57.0 E for the month of August are shown on the left. The corresponding sound speed derived from the temperature profile is shown at the right.

Based upon the orientation of the source and receiver described in this case, and the corresponding wind profile, the simulation represents infrasonic waves propagating under 'with wind' conditions. This is because of the standard convention adopted; zonal winds with positive values represent eastward flowing winds (whereas negative values indicate westward moving winds). Similarly, meridional winds with positive values represent northward flowing winds (whereas negative values indicate southward winds).

Figure 2 shows the WKB dispersion curves as output by the modified Pierce code. The first curve represents the first 50 modes that propagate from the ground upto an altitude of about 42-44 kilometers (lower or stratospheric duct), whereas the second curve represents the phase velocities for the same 50 modes that propagate from the ground upto about 110 kilometers (upper or thermospheric duct).

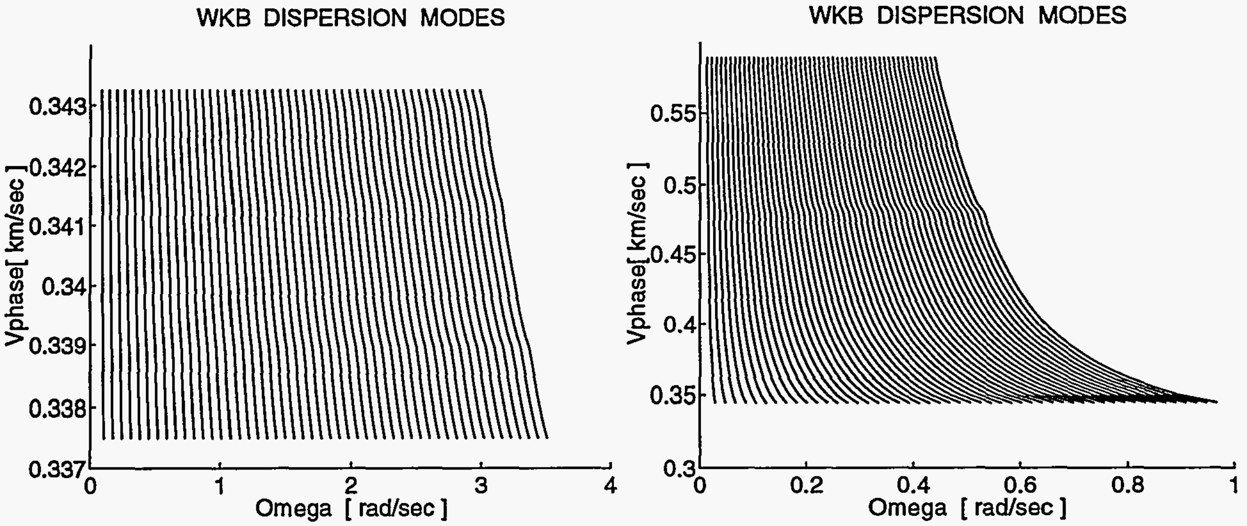

Figure 2. WKB dispersion curves for the first 50 modes propagating via the stratospheric duct (left) and for those propagating via the thermospheric duct (right).

Separate integrations are performed within each of these ducts to determine their contributions to the final waveform at the receiver. Figure 3 (next page) shows the individual stratospheric and thermospheric returns, and the sum of the two which would be the actual (predicted) signal recorded at the receiving station.

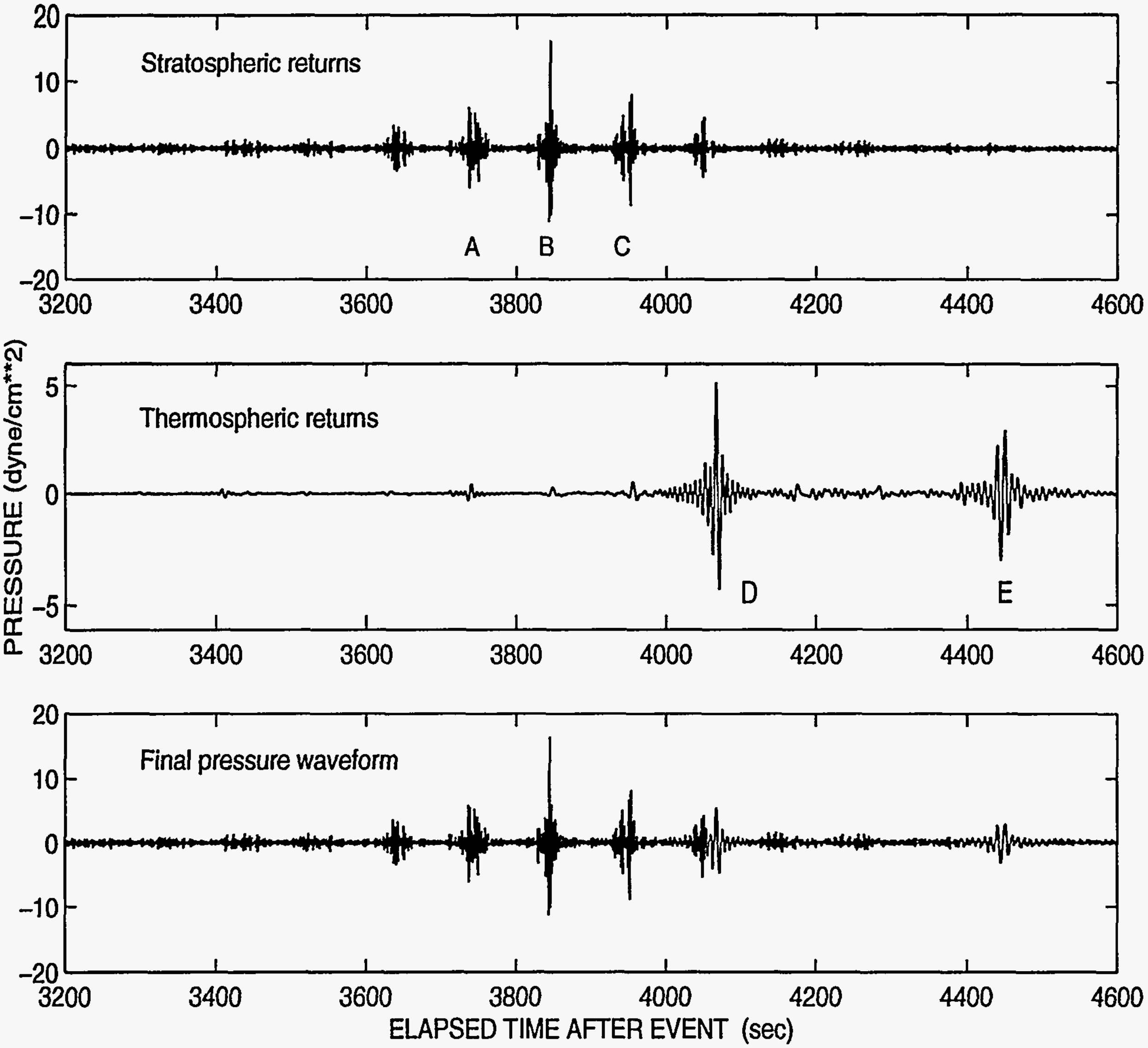

Figure 3. Individual stratospheric and thermospheric returns from a simulated 1 kT explosion. The signal actually recorded by the infrasound instruments at the receiving station would be the sum of the two (lowermost panel). The geodetic range between the source and receiver is 1175 [km] and gives the propagation speed for each of the five features marked A through E: A = 0.3133 [km/sec], B = 0.306 [km/sec], C = 0.298 [km/sec], D = 0.281 [km/sec] and E = 0.264 [km/sec].

To simulate the 'counter wind' condition, we simply move the location of the receiver 180 degrees from its present location to a site at a geodetic distance of 1175 kilometers on the opposite side of the great circle path connecting the source and receiver. The final predicted waveform is shown below (Fig. 4).

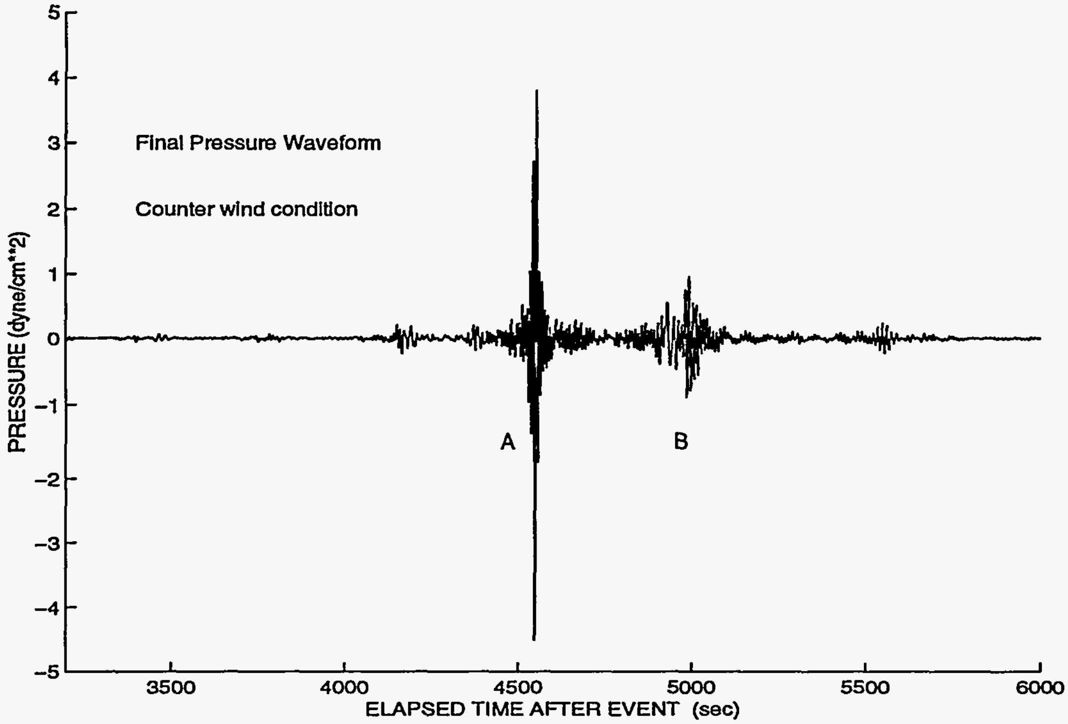

Figure 4. The predicted signal that would be recorded at a monitoring station 1175 kilometers on the opposite side (on the great circle path) of the same source. The travel velocities for the two features A and B are: A = 0.258 [km/sec] and B = 0.237 [km/sec].

CONCLUSIONS AND RECOMMENDATIONS

Comparisons of the waveforms from recent field experiments of ANFO explosions with those predicted by our codes have shown great agreement, thus lending credibility to the waveform predictions of the codes. Based on these results and those conducted on the ideal duct case (isothermal duct, no wind condition), we propose to carry out simulations of atmospheric explosions using realistic winds in the Asian subcontinent region, addressing issues such as amplitude detectability thresholds at proposed IMS sites in the vicinity. Examples of these case studies may be shown at the symposium.

In the numerical modeling of long range propagation of infrasonic signals, the effects of winds at the event site play an important role in determining the acoustic-gravity pressure waveforms detected at the monitoring station. We have incorporated realistic wind profiles rendered by the HWM90 model. However, the cases that were presented here had the source and receiver at nearly similar latitudes. Therefore, the wind profiles, as generated by HWM90 at either of these locations were very similar. Signal propagation between a source and monitoring stations that are located across latitudes from each other need to be investigated next. This is because one can expect the wind profiles at the source and receivers to be dramatically different. Comprehensive studies of this nature can help define the amplitude detectability of the infrasonic component of blast waves as a function of position of source, range of IMS monitoring stations, and seasonal variations of wind profiles.

Further, the seasonal variation of winds (notably, the zonal component) may influence the propagation of infrasonic signals appreciably as well. Figure 4 shows the seasonal variation of the winds. Results obtained by conducting simulations based on these variations will be presented at the symposium.

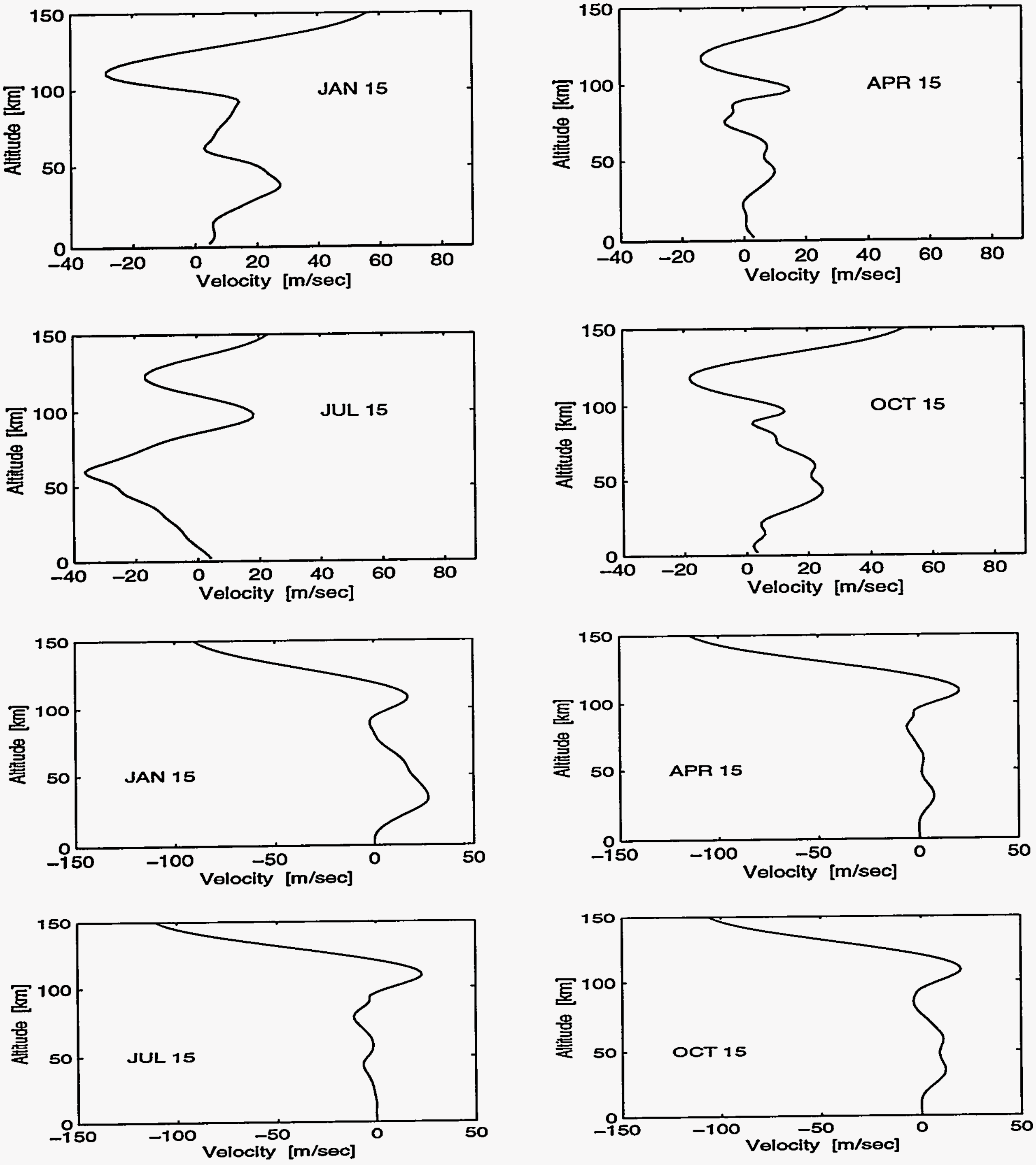

Figure 5. Seasonal variations of zonal (top 4 plots) and meridional velocities (bottom 4 plots) are shown for lat. = 73.0 N, and lon.= 57.0 E. The profiles have been generated using the HWM90 model.

REFERENCES

1. Pierce, A. D. and J. W. Posey, Theoretical prediction of acoustic-gravity pressure waveforms generated by large explosions in the atmosphere. Prepared for Air Force Cambridge Research Laboratories, Office of Aerospace Research, USAF, Bedford, MA, 1970.

2. Hunter, J. H. and R. W. Whitaker, (in preparation, 1998).

3. Hunter, J. H. and R. W. Whitaker, Numerical modeling of long range infrasound propagation, presented at the Infrasound workshop for CTBT monitoring, Aug. 25-28, 1997, Santa Fe, NM.

4. Hedin, A. E., E. L. Fleming, A. H. Manson, F. J. Schmidlin, S. K. Avery, R. R. Clark, S. J. Franke, G. J. Fraser, T. Tsuda, F. Vial and R. A. Vincent, Empirical wind model for the upper, middle and lower atmosphere. JATP, vol. 58, no. 13, pp. 1421-1447, 1996.

5. Fleming, E. L., S. Chandra, J. J.Barnett and M. Corney, Zonal mean temperature, pressure, zonal wind and geopotential height as a function of latitude. Adv. Space Res., vol. 10, no. 12, pp. (12)11-(12)59, 1990.