Detection of air pressure and temperature and wind change associated with the 2022 Tonga eruption and energy estimate transported by the atmospheric waves

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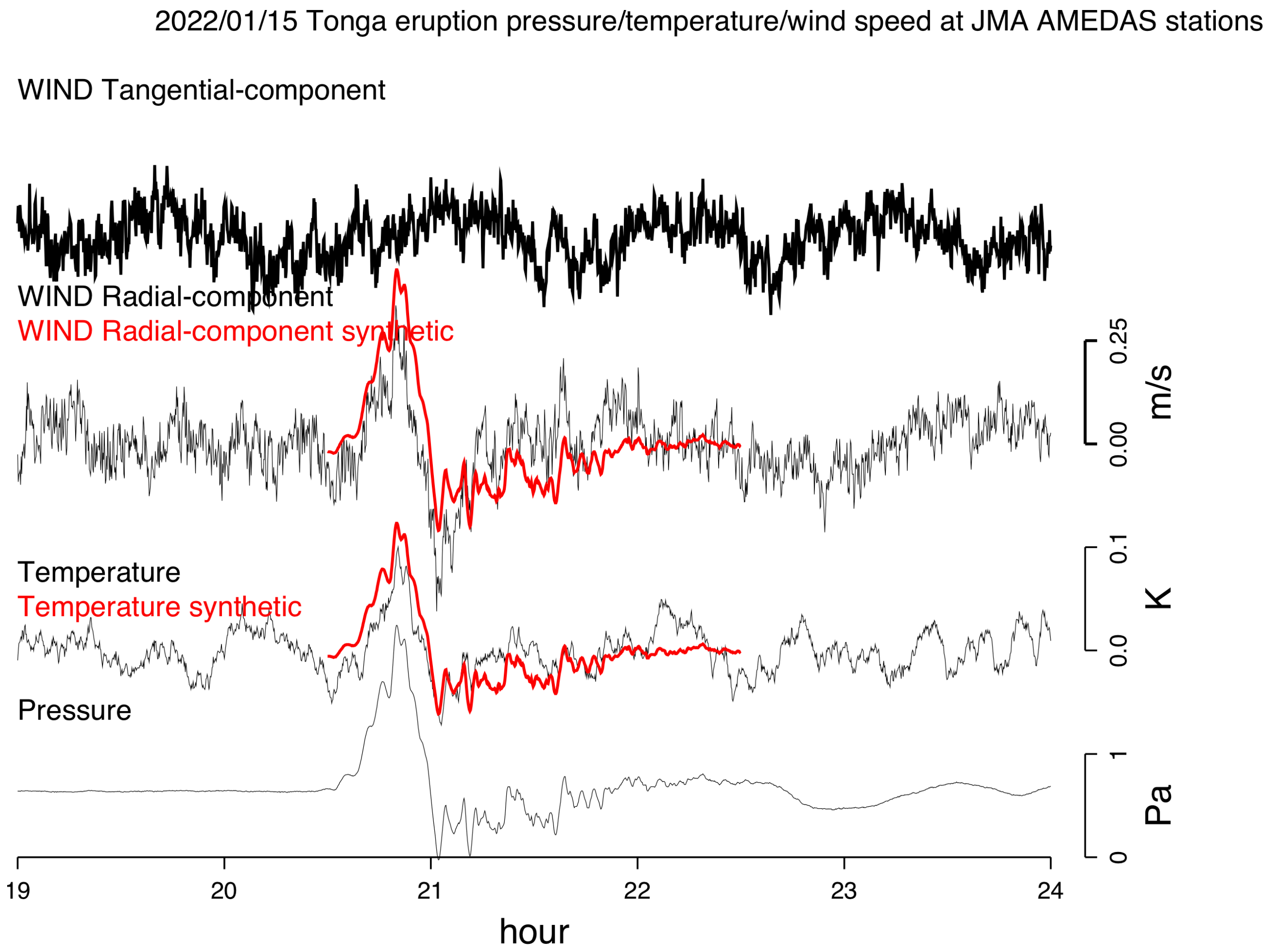
The pressure data of atmospheric acoustic gravity waves radiated from the 2022 Tonga eruption recorded by JMA AMeDAS show that similar waveforms of the atmospheric boundary wave (Lamb wave) characterized by a 20 min–long peak with a amplitude of 1.6hPa followed by negative peaks with amplitudes of about -0.5hPa arrived at the speed of about 300m/s. Traveling times to southwestern Japan and Chichijima is faster than to the rest of Japan by about 1-3%, reflecting the atmospheric conditional difference along the propagating paths.

We expect a temperature change due to adiabatic compression by the atmospheric boundary waves and a wind speed change due to a flow in the waves. Individual temperature and wind speed records measured by AMeDAS do not show obvious those changes because of the high background noise level, however, in the JMA Mutsuhito observatory large vault, which is under a small environmental disturbance, detected a change in room temperature synchronized with the atmospheric pressure change. After aligning of the temperature and wind records at the times of maximum waveform cross-correlation coefficient of atmospheric pressure records, we stacked 10-second sampling temperature and wind speed data and detected distinct temperature and wind speed changes that were synchronized with the atmospheric pressure change. Wind speed changes were observed only in the direction from Tonga to the AMeDAS station, and no corresponding changes were observed in the direction orthogonal to it. The temperature and wind speed variations (waveforms) were in good agreement with those predicted from the pressure variation based on adiabatic compression and a linear wave theory, with maximum values of 0.10 K and 0.34 m/s, respectively.

In addition to the direct atmospheric boundary wave from Tonga along a minor arch, a further Earth-circling atmospheric boundary wave was also observed in the stack pressure waveform. The atmospheric boundary wave polarity reversal predicted from propagation in a spherically symmetric atmosphere, the mean propagation velocity and distance decay rate of the atmospheric boundary wave were obtained.

Neglecting wind effects and azimuthal dependence of energy radiated from the volcano and assuming that the atmospheric boundary wave measured by AMeDAS spread isotropically in all directions from the Tonga volcano eruption, the total wave energy (sum of kinetic, internal, and potential energy) transported by the atmospheric boundary wave is estimated to be 9.4x10^17 ~ 1.1x10^18 J, taking into account the scale height and distance decay ratio of the atmospheric boundary wave. This is about 1/7th of the amount of the energy injected into the atmosphere estimated by Watada and Kanamori [2010] from long-period seismic waves (Rayleigh waves) during the 1991 Pinatubo volcano eruption.

Keywords: 2022 Tonga eruption, Atmospheric acoustic gravity waves, Atmospheric pressure and temperature and wind speed change, Estimate of the total atmospheric wave energy , JMA AMEDAS, Atmospheric Lamb wave


2022/01/15 Tonga eruption pressure/temperature/wind speed at JMA AMEDAS stations
WIND Tangential-component
WIND Radial-component
WIND Radial-component synthetic
Temperature
Temperature synthetic
Pressure
0.25
0.00
m/s
0.1
0.0
K
1
0
Pa
19
20
21
22
23
24
hour