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Observation of acoustic normal modes of the atmosphere after the 2022 Hunga-Tonga eruption.

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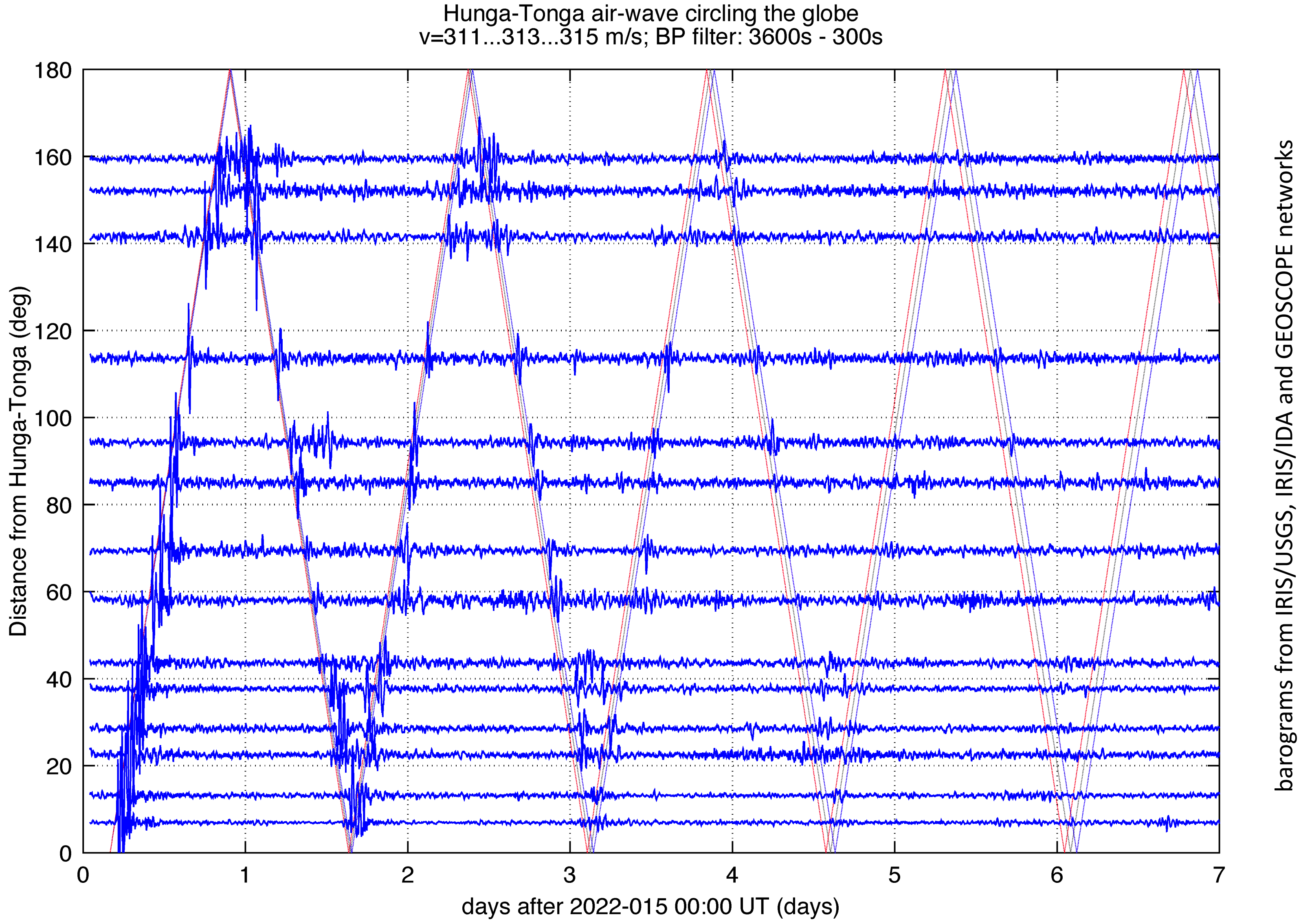
Lamb waves in the atmosphere orbiting the Earth multiple times.

Group velocity u=313 m/s

Orbital period: 35.5 hrs

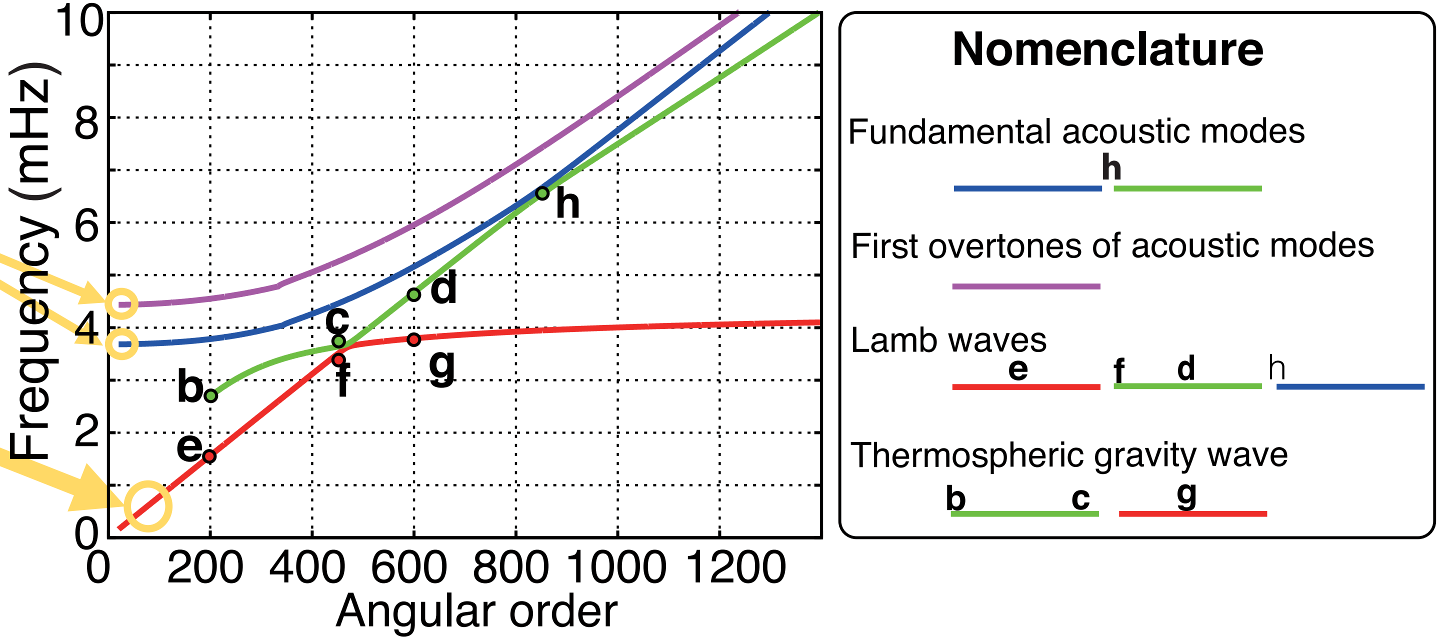


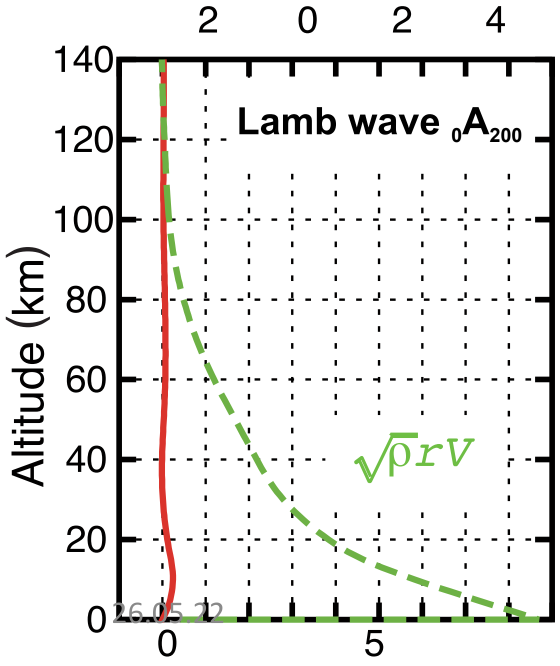
Dispersion diagram for the atmosphere

(Nishida et al., Geophys. J. Int., 2014, Background Lamb waves in the atmosphere)

Vertical acoustic modes:
excite bi-chromatic Rayleigh waves
(eg. Widmer&Zürn, GRL, 1992)

globe circling Lamb waves
(horizontally polarized)

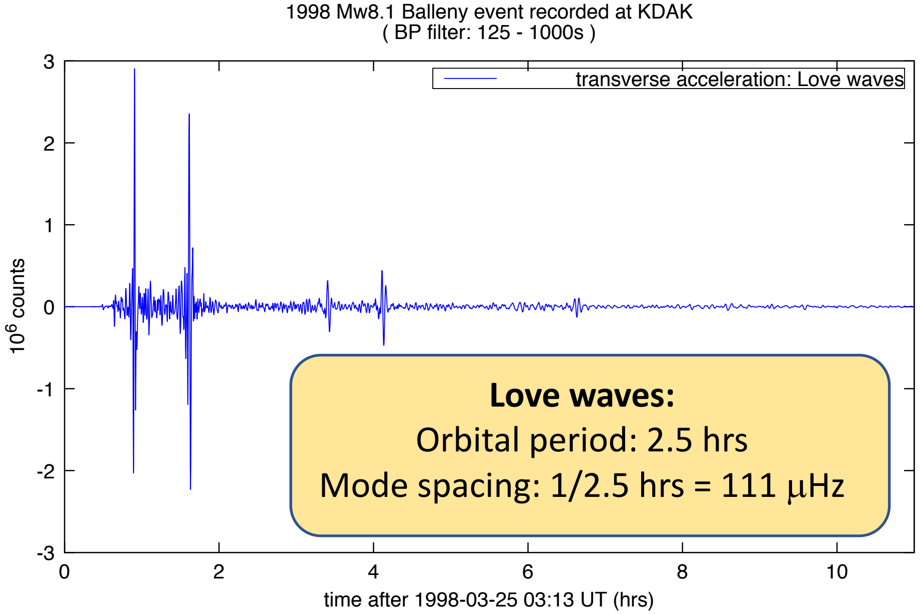


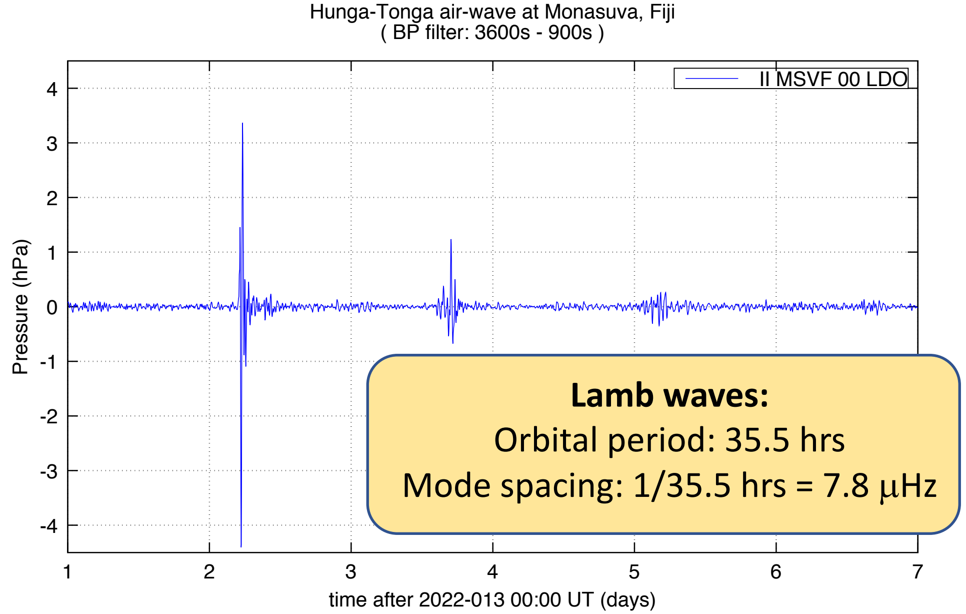


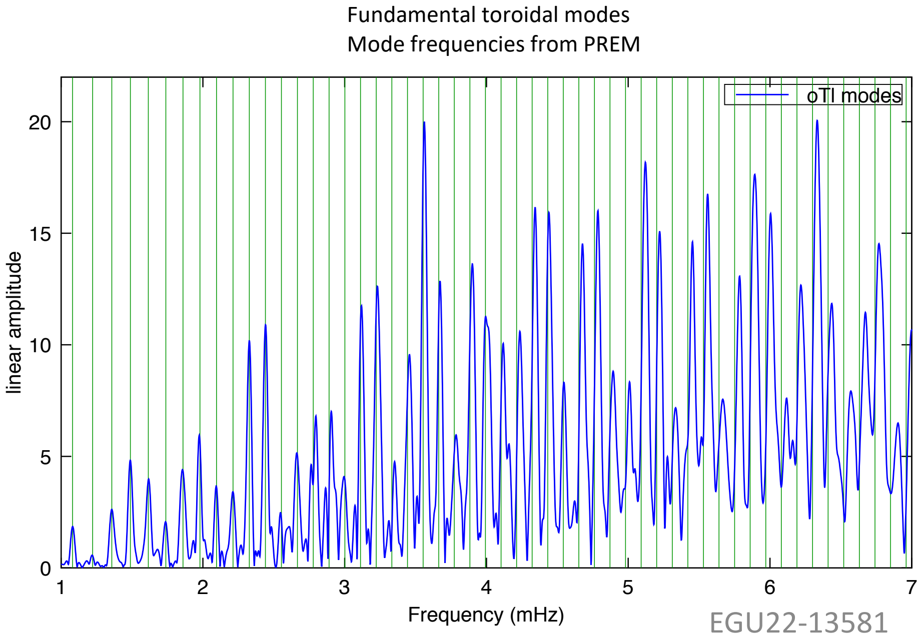
For Lamb waves *u=c* and hence we can use Jeans Formula to predict mode frequencies for any angular order.

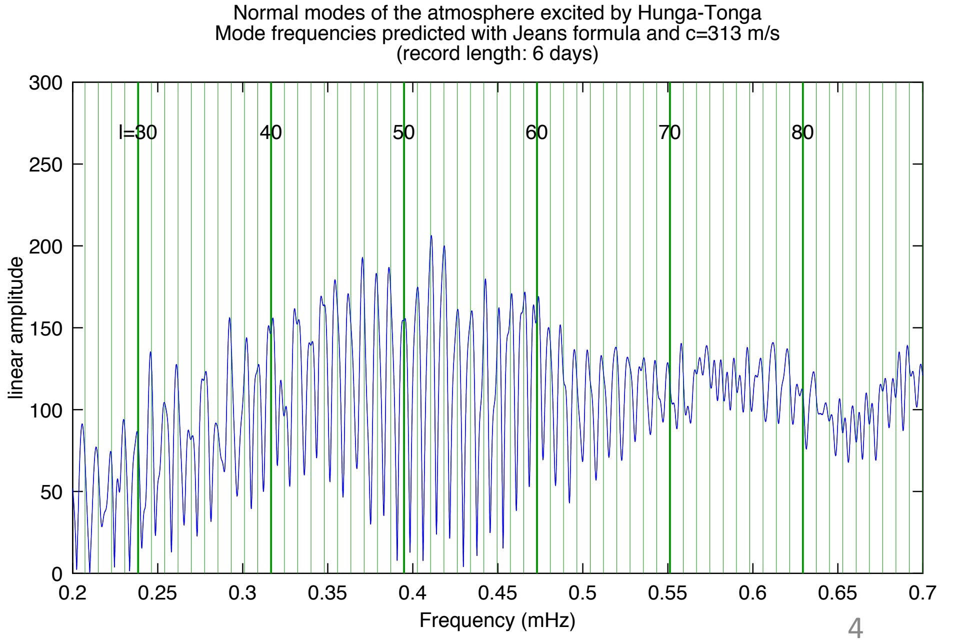
$$k = \frac{\ell + 1/2}{R} = \frac{\omega_\ell}{c}$$

Analogy between Love- and Lamb-waves



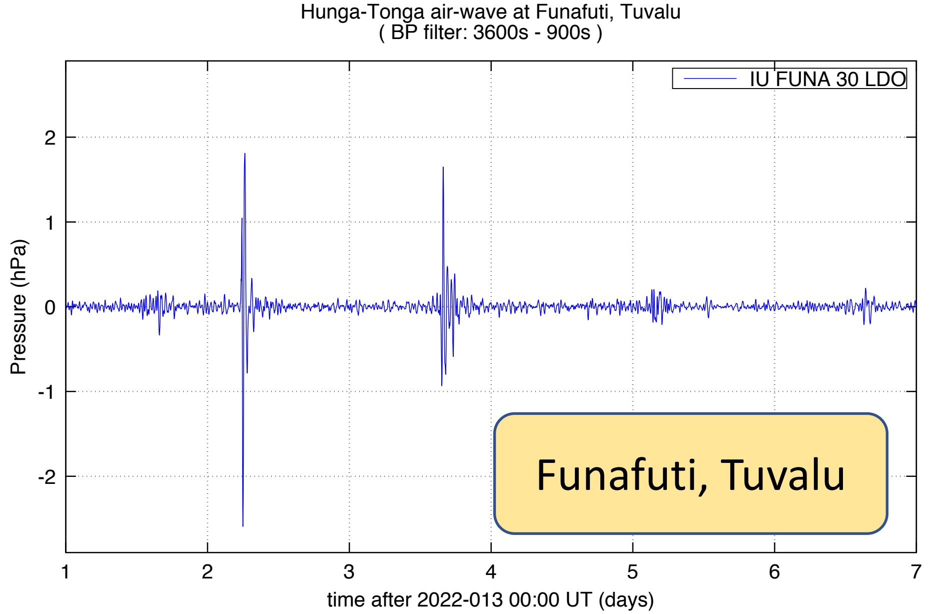


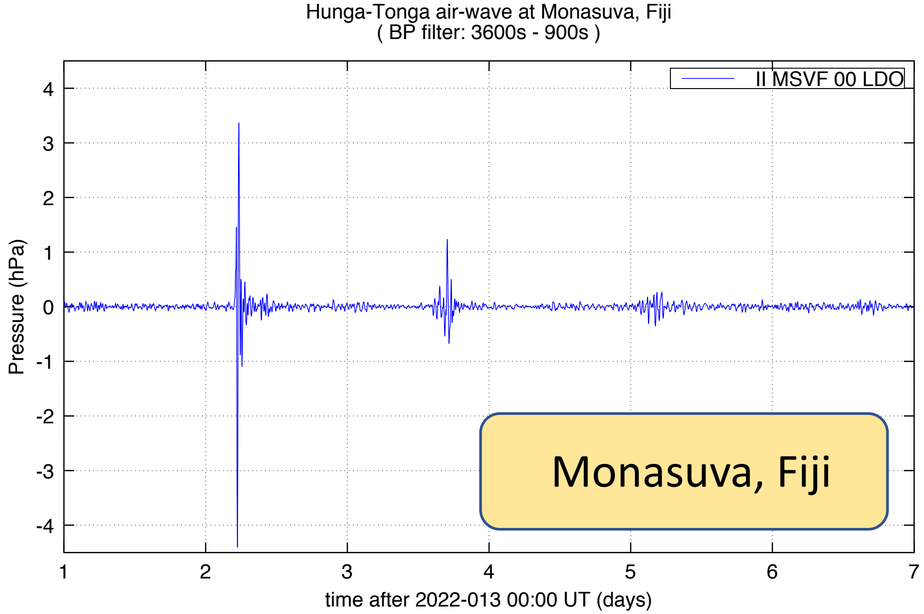


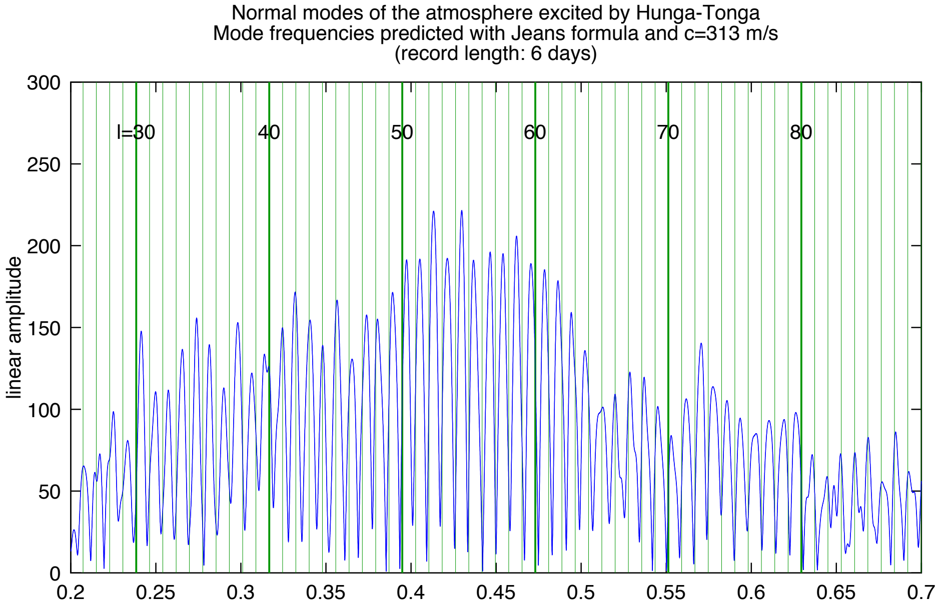


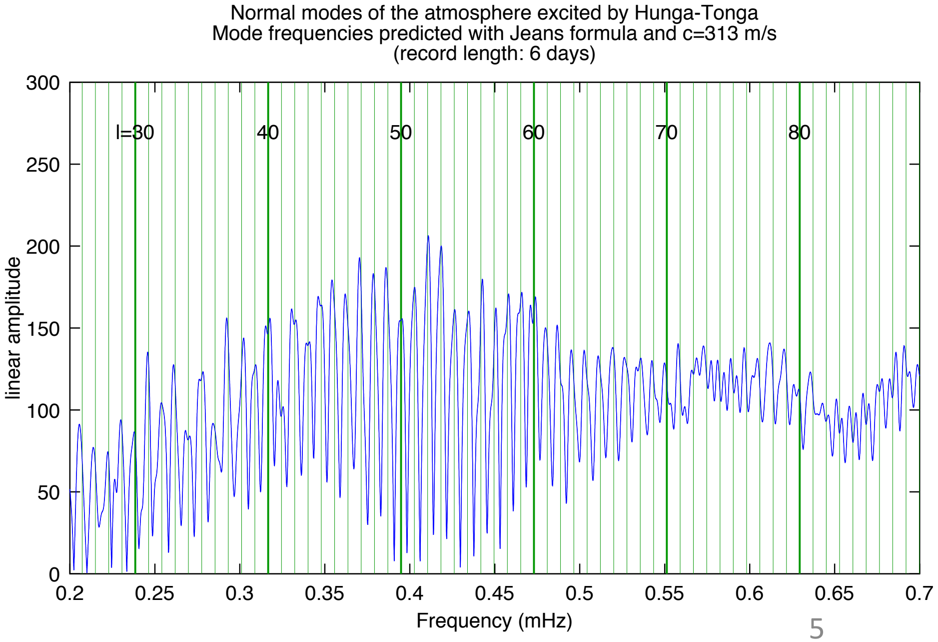
Note: large peak frequency shifts away from predicted mode frequencies.

This renders interpretation of peak frequencies difficult.









Conclusions

Honga Tonga has excited globe circling Lamb waves.
These can be observed for at least 4 full orbits, where one orbit takes ~35.5 hours.

Constructive and destructive interference between waves that have left the source in opposite direction leads to a global pattern of standing waves: normal modes of the atmosphere.

On favorable source-receiver great circles these modes can be observed as discrete peaks in the Fourier spectra of barograms between 0.2 – 0.7 mHz.

The observed spacing between adjacent modes of 7.8 μHz (=1/35.5 hrs) confirms our normal mode hypothesis.

Heterogeneities in the global atmosphere (wind, temperature,...) lead to large peak frequency shifts such that spectral peaks cannot be unambiguously attributed to a particular spherical harmonic degree.