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The 2016 Infrasound Wanaka Balloon Flight: Precursor to extraterrestrial acoustic research?

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Why study Acoustic Waves in the Stratosphere?

- Acoustic waves are present throughout the atmosphere
- Carry information about processes at the solid Earth/Atmosphere interface and the free atmosphere
- Sound bends away from the surface (usually)
- Wave field is directional in most cases
- Acoustic waves transmit energy to the upper atmosphere ....and can cause distortion in the ionosphere

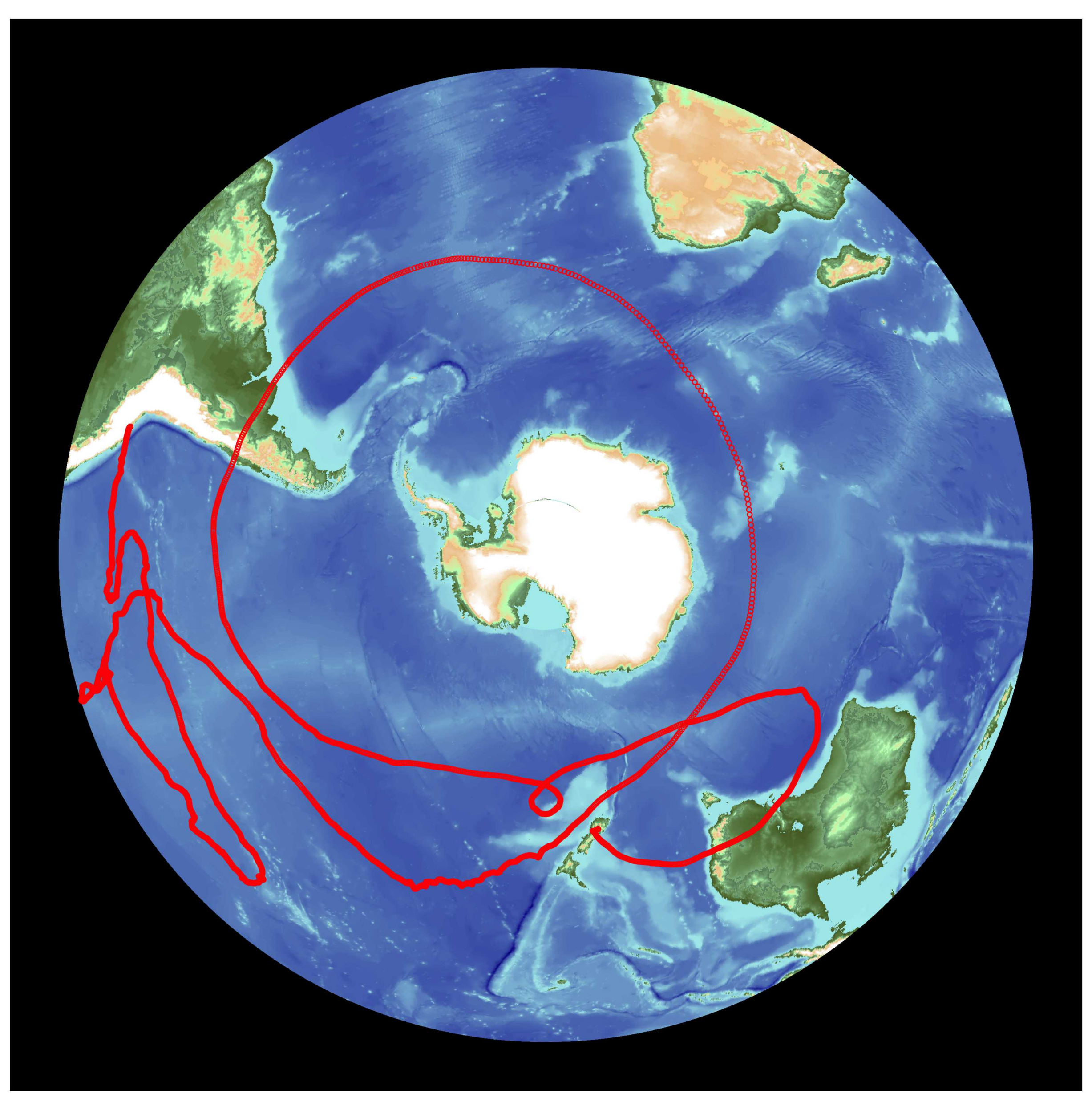
Why Balloons?

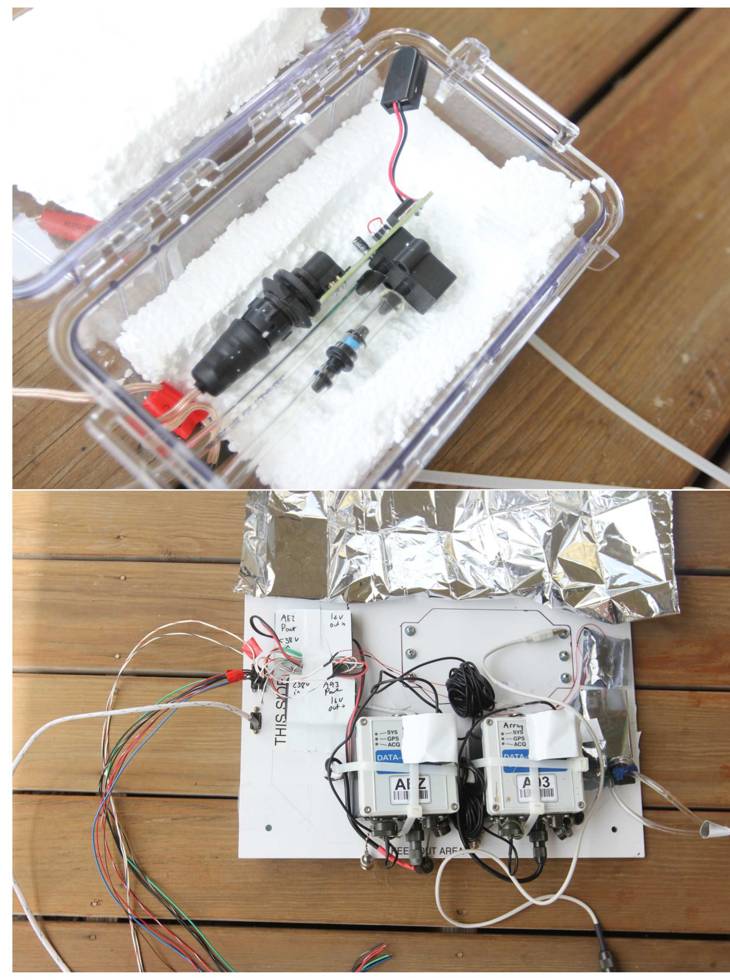
- No investigation of acoustic waves above 8 km in over 50 years
- Wind noise pervasive on the surface
- Balloons/Acoustic research → Future of extra-terrestrial planetary exploration

Wanaka Launch, 2016

- Circumnavigation of Antarctic in 2016
- Hover over microbarom source, south of New Zealand
- Southern Ocean suggest a flux of 0.05 mW/m^2 max acoustic energy
- Thermospheric heating: temperature rise of several degrees Kelvin per day
- Lightning strikes, recorded off the coast of New Zealand (Lamb et al. 2018)
- Bolides? Yet to be determined.

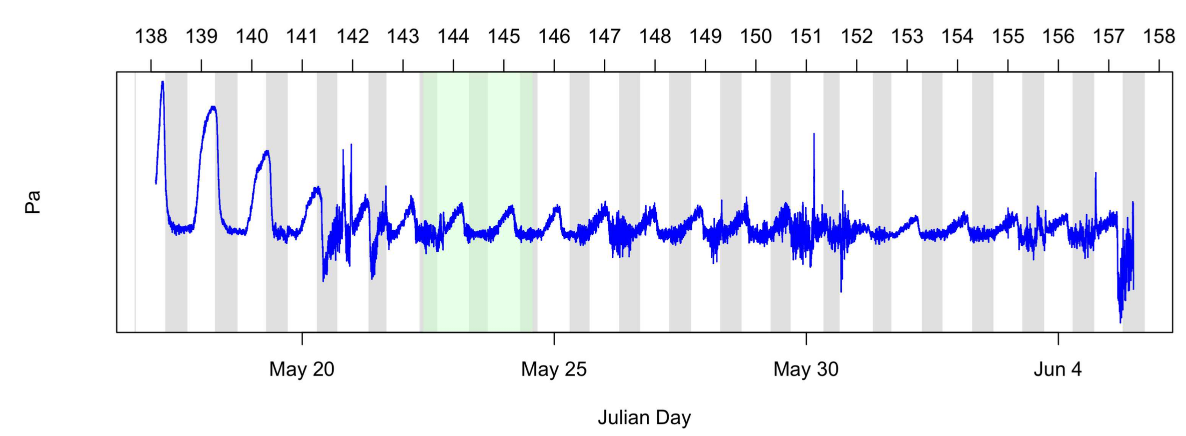
Flight Trajectory





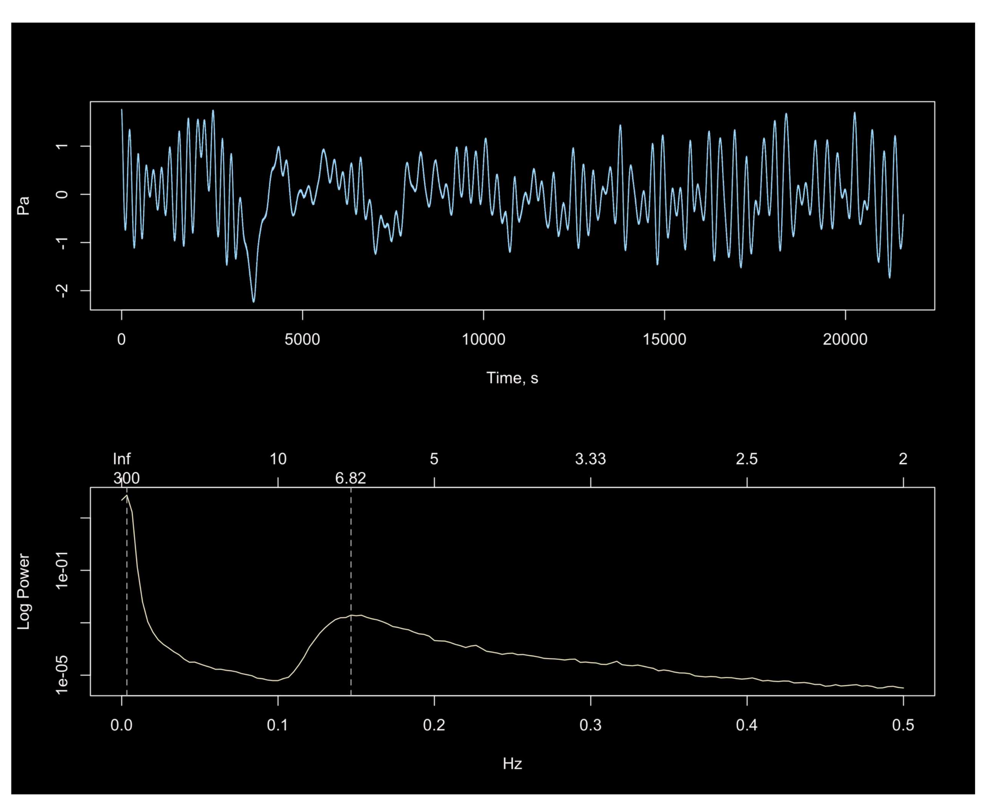
- Boise Infrasound Microphones
- DataCube recoder (400 sps)
- Reftek Recorder (up to 1000 sps)
- Power Supply (batteries)

Acoustic Signals, Unfiltered, Full-Flight



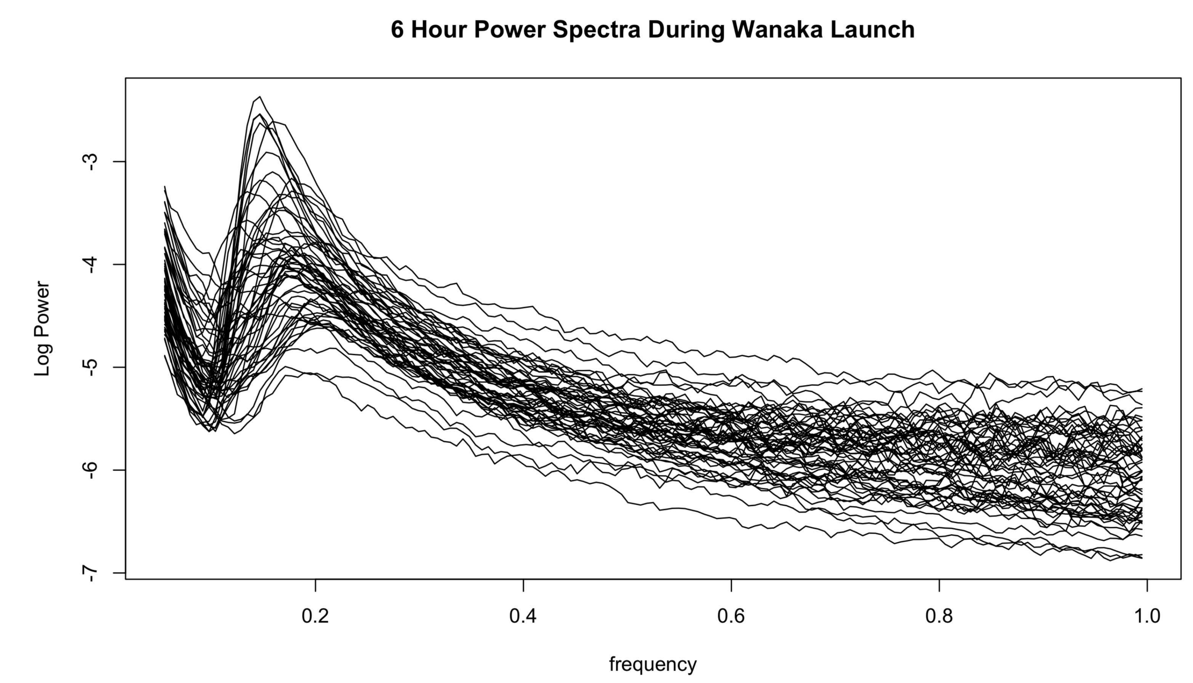
Note Day/Night oscillatory behaviour.

6 Hours, Unfiltered



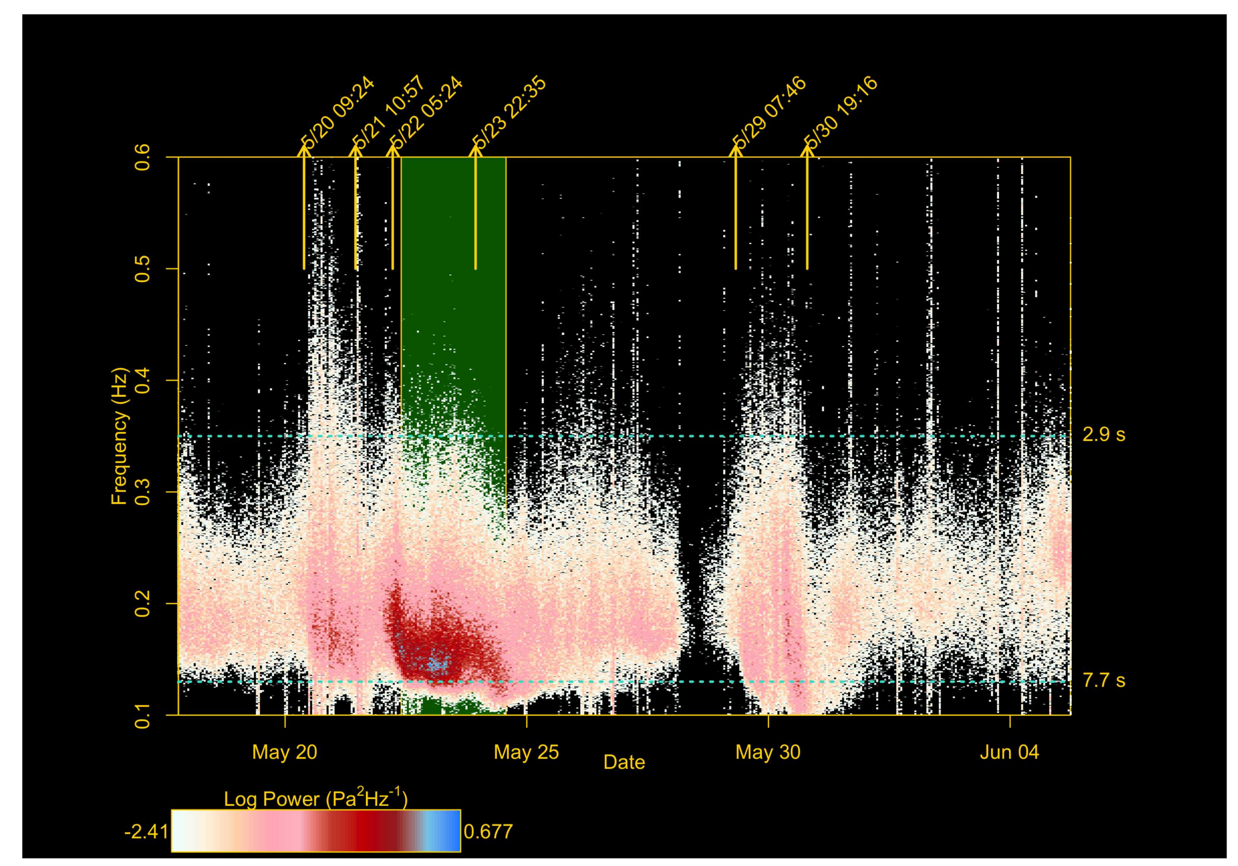
6 Hours extracted during Loop-De-Loop, when the microbarom peaked.

Balloon Low Frequency Acoustic Spectra



What causes variability in microbarom spectra during flight?

Balloon Acoustic Spectrogram



(Bowman & Lees, 2018. Green Shaded is Loop-de-loop section.)

Flux Estimated at Ocean Surface versus Stratosphere

- Acoustic Energy Flux on balloon estimated from frequency spectrum of wave forms:

$$E \frac{2}{N} \sum_{\omega_a}^{\omega_b} \frac{P \omega_k \omega_k^2}{\rho c}$$

- $\text{Flux}_{Balloon} = 0.047$ mW/m^2
- Estimate acoustic power of ocean microbarom (source):
  - 100 km radius circle
  - sum the Hasselmann integral
- $\text{Flux}_{Ocean} = 0.052$ mW/m^2

Energy Transfer

Acoustic wave dissipation heats the upper atmosphere:

Earlier Work

- 30 K/day heating from microbarom (Rind, 1977)
- 0.03 K from explosions (Drobzheva and Krasnov, 2006)
- ≈ 13 K/day from thunderstorms (Krasnov et al., 2007)

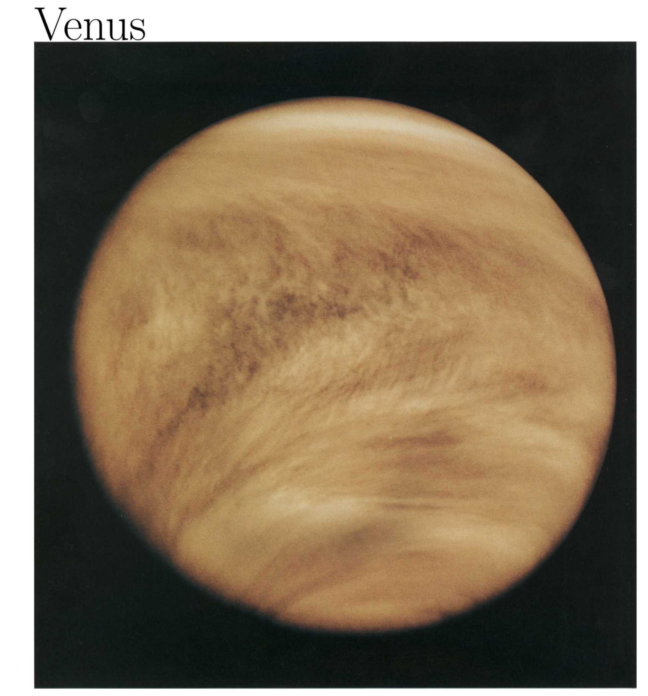
Bowman and Lees (GRL, 2018)

- Up-going energy flux 0.047 mW/m^2
- 1 to 10 K thermospheric heating rate per day

Planetary Exploration: Balloon Borne Missions

Seismology on gaseous planets: Acoustic Waves on floating platforms

Venus



Jupiter

Quote: "This hotspot, by process of elimination, must be heated from below, and this detection is therefore strong evidence for coupling between Jupiter's lower and upper atmospheres, probably the result of upwardly propagating acoustic or gravity waves." O'Donoghue, J. et al., Nature, 2016 http://dx.doi.org/10.1038/nature18940

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