

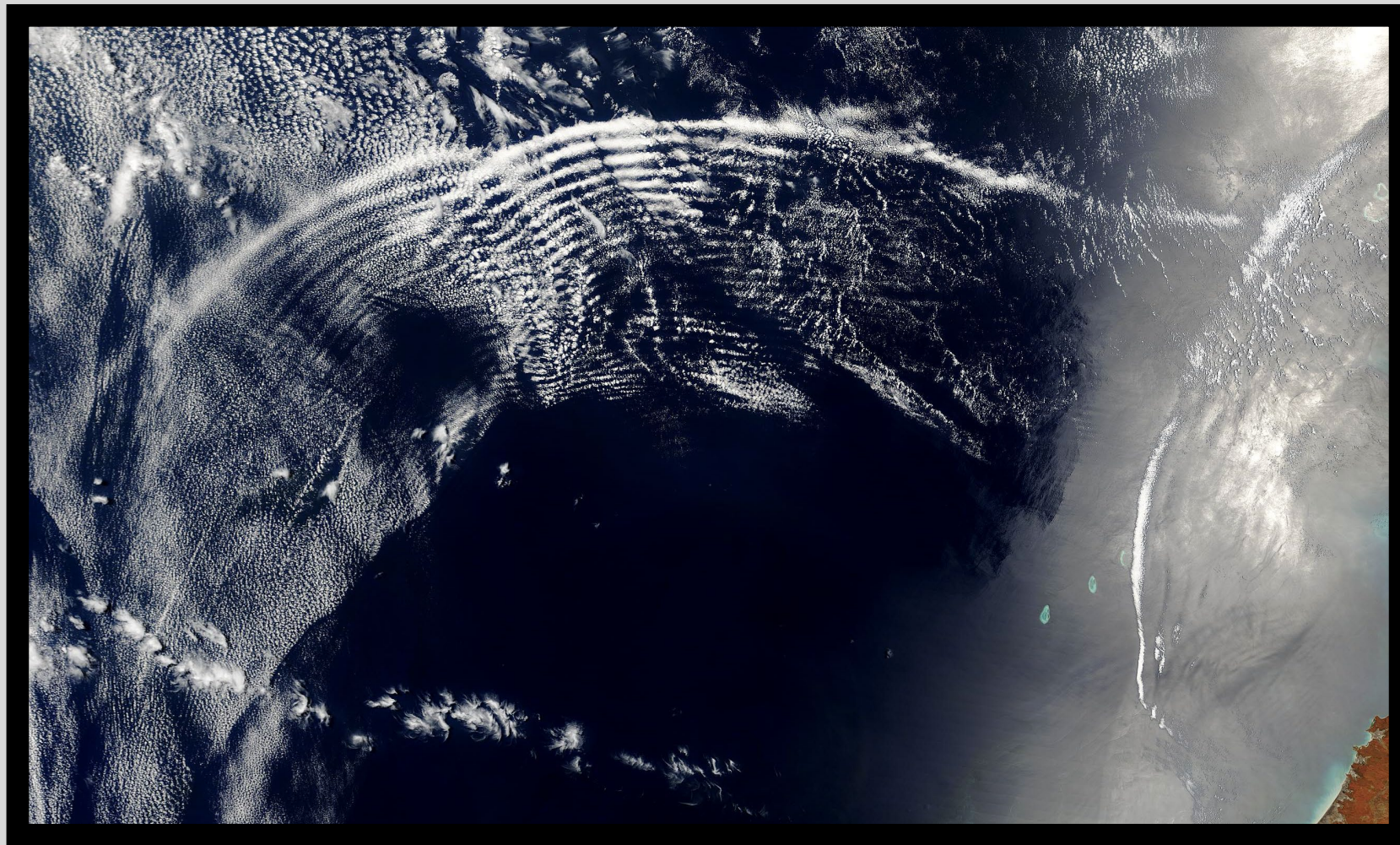
DETECTING
GRAVITY WAVES
WITH
RADIOSONDES
The Wavelet Method

Keaton Blair

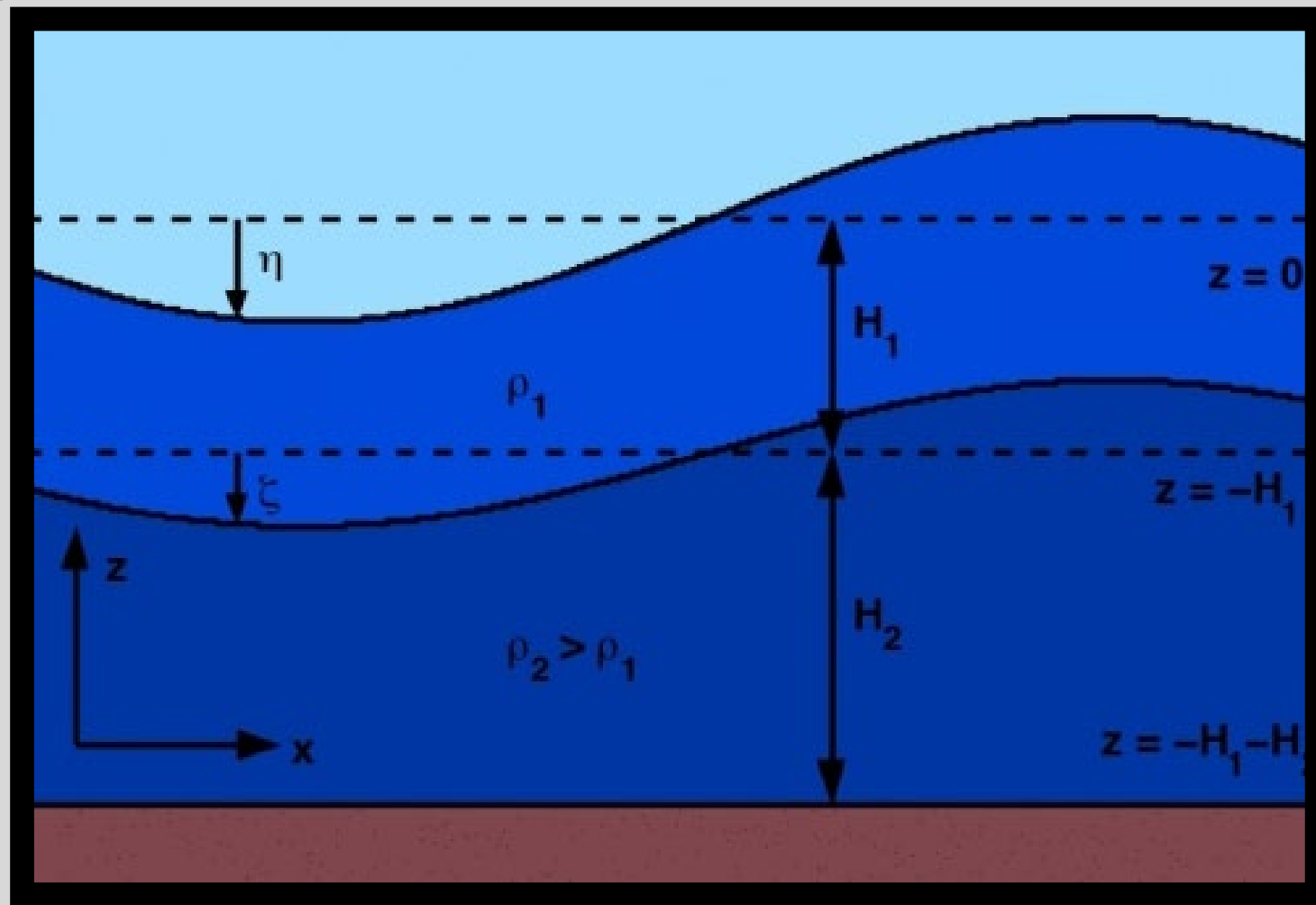


GRAVITY WAVE DETECTION

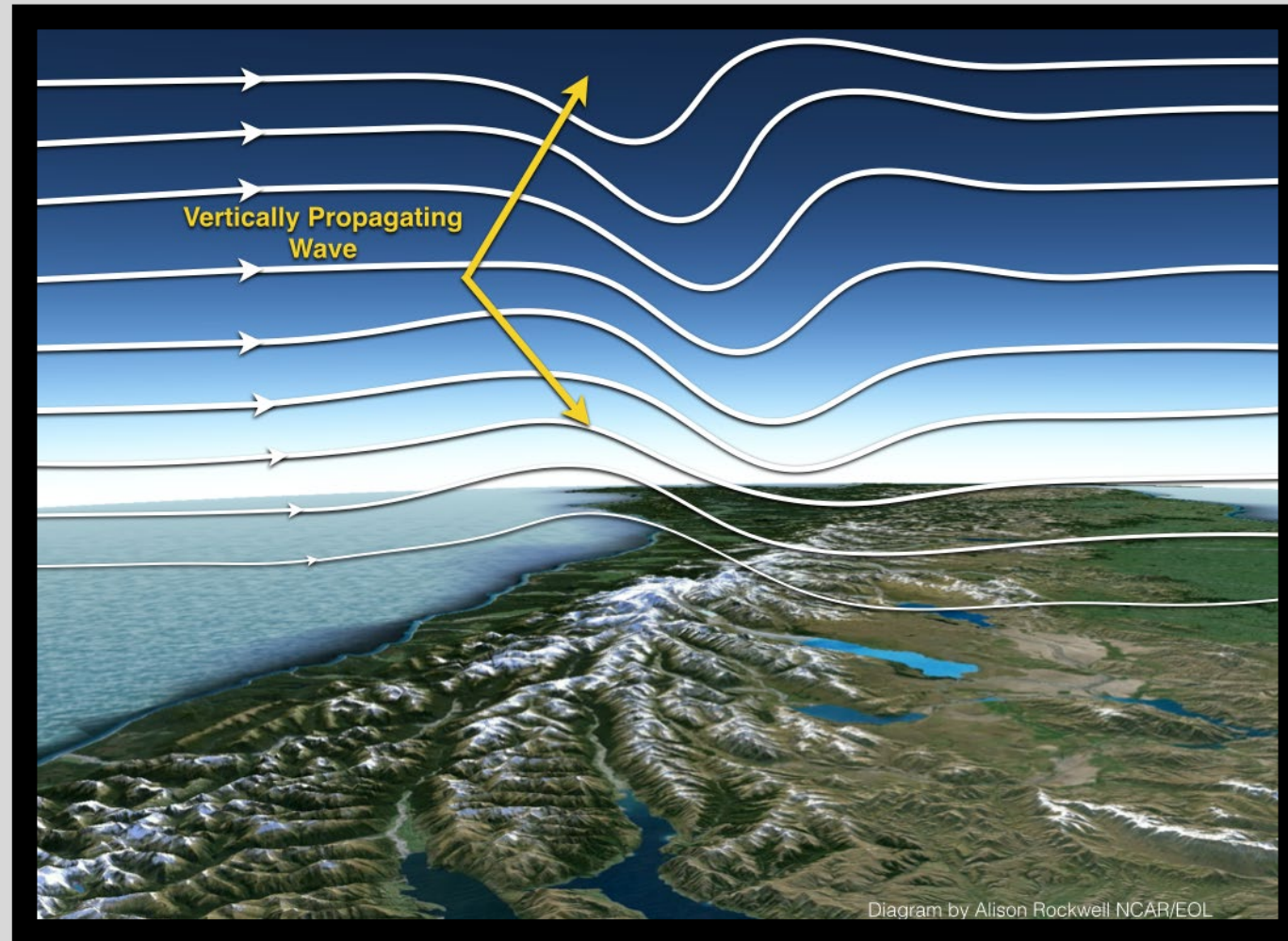
Gravity Waves



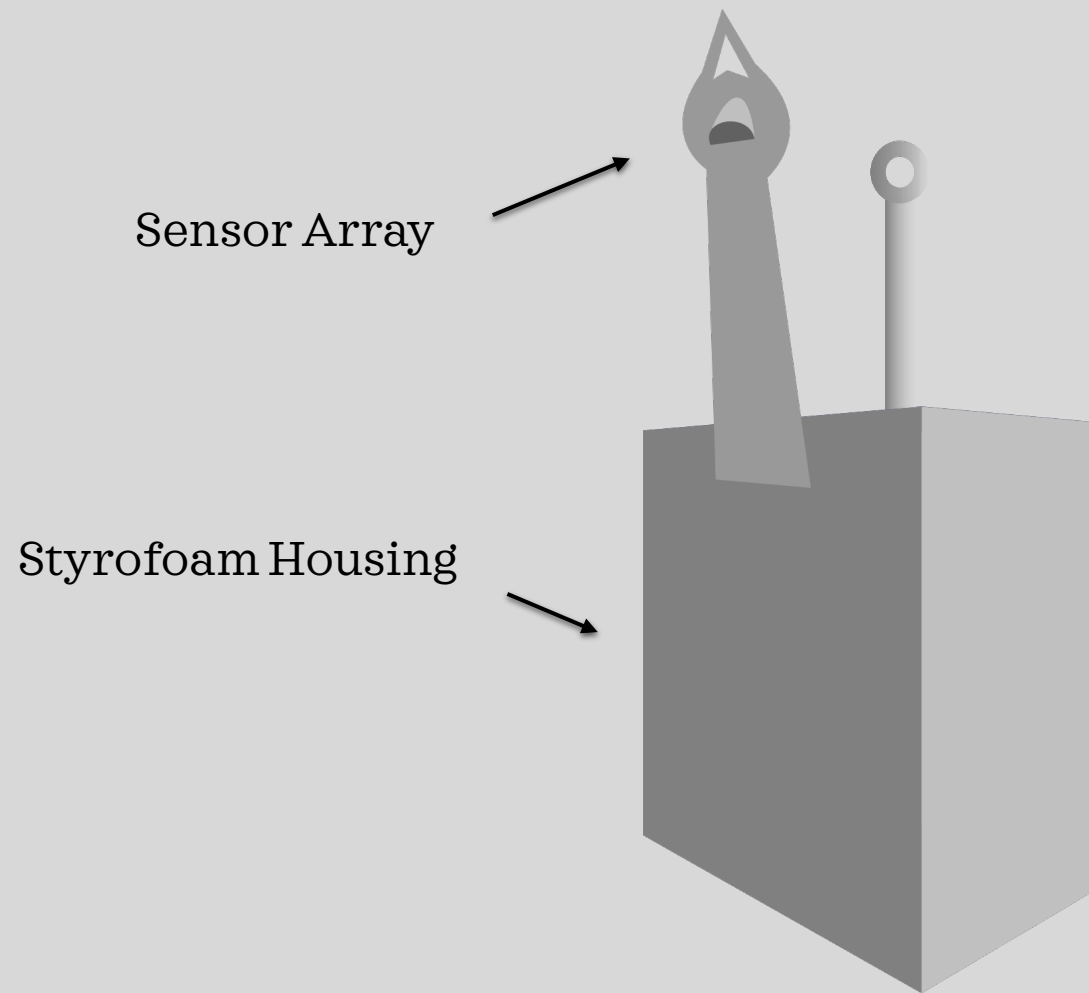
Gravity Waves



Gravity Waves

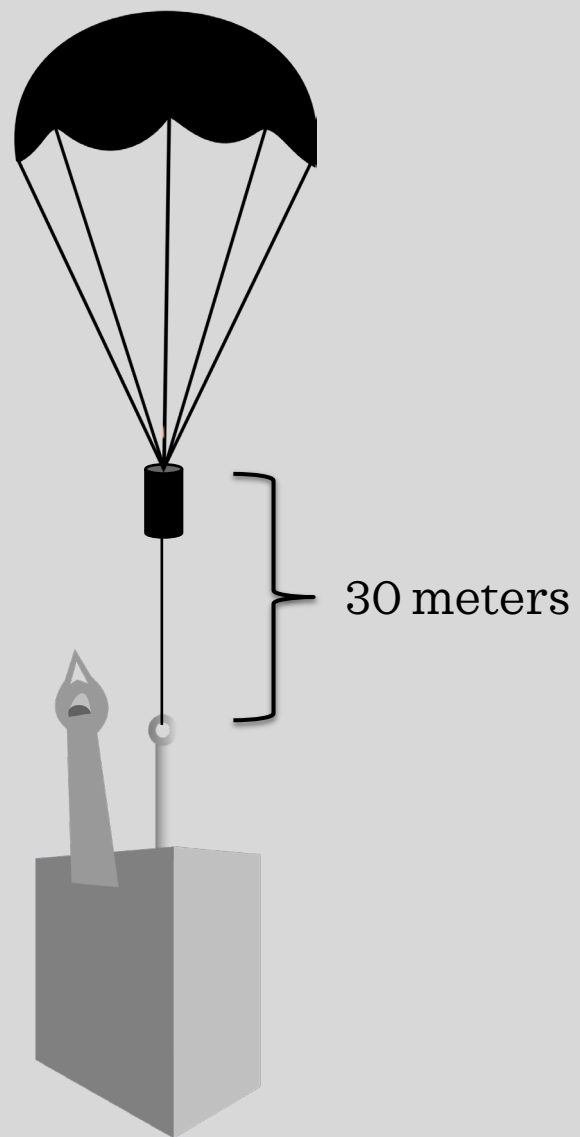


Radiosonde Data

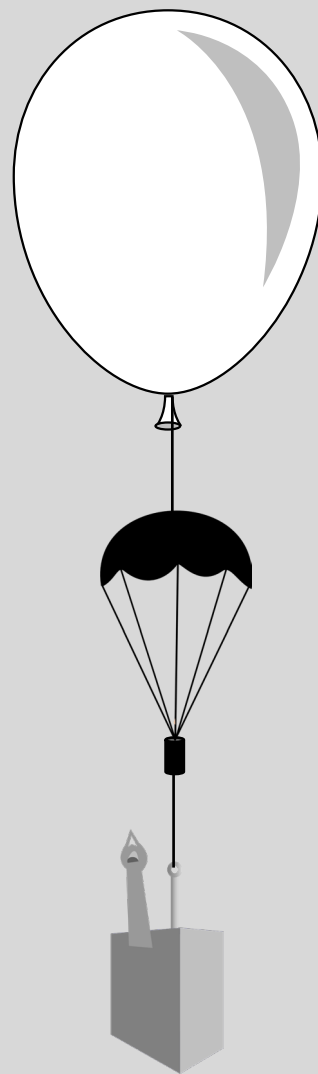


Graw DFM-17
Radiosonde

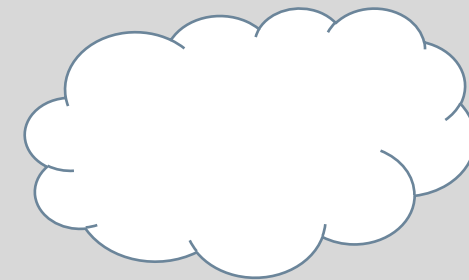
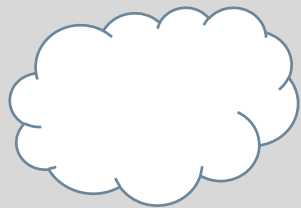
Radiosonde Data



Radiosonde Data

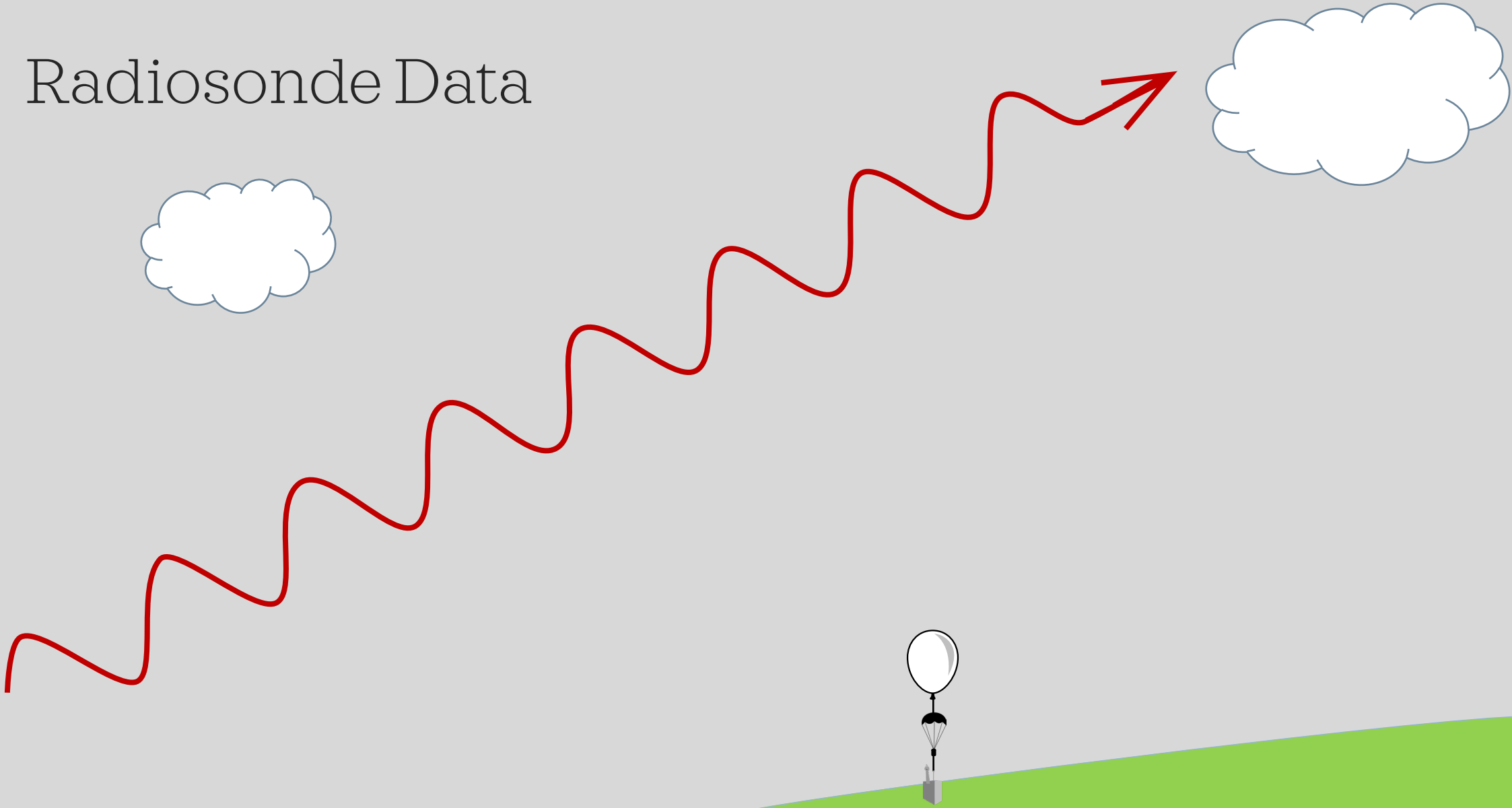


Radiosonde Data

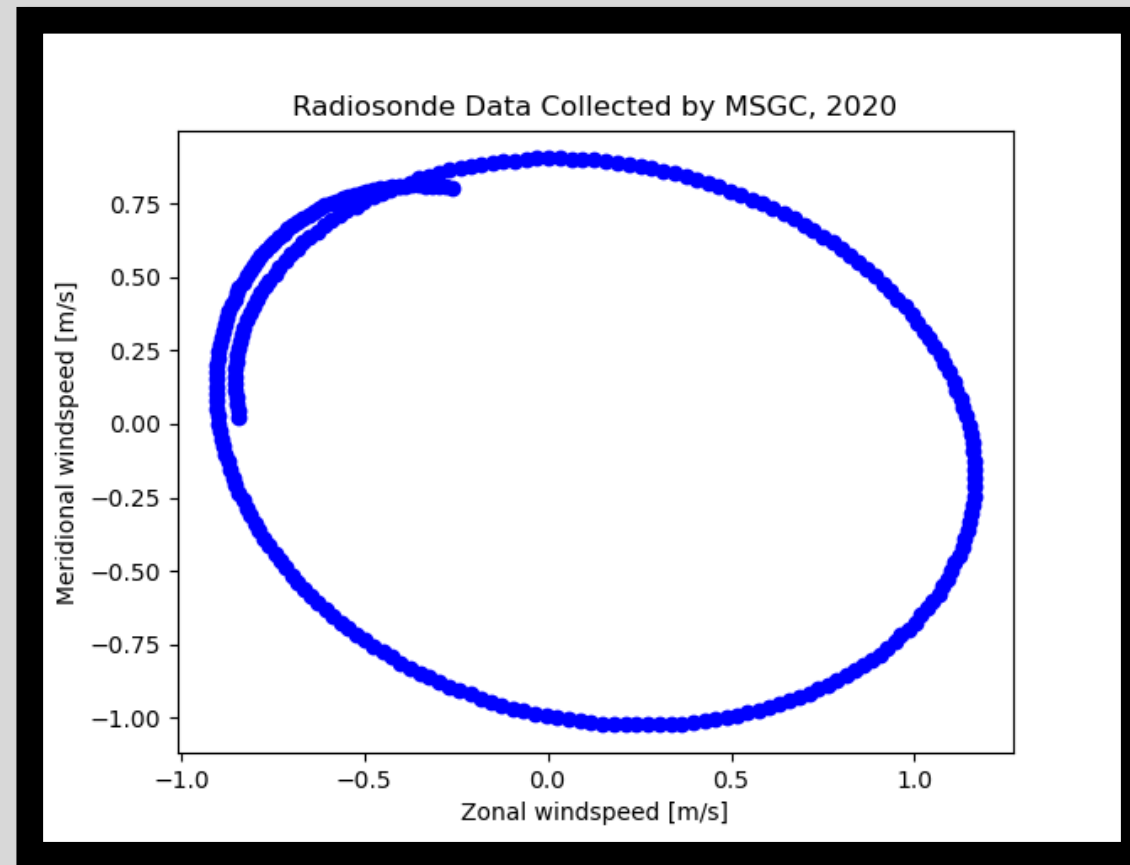




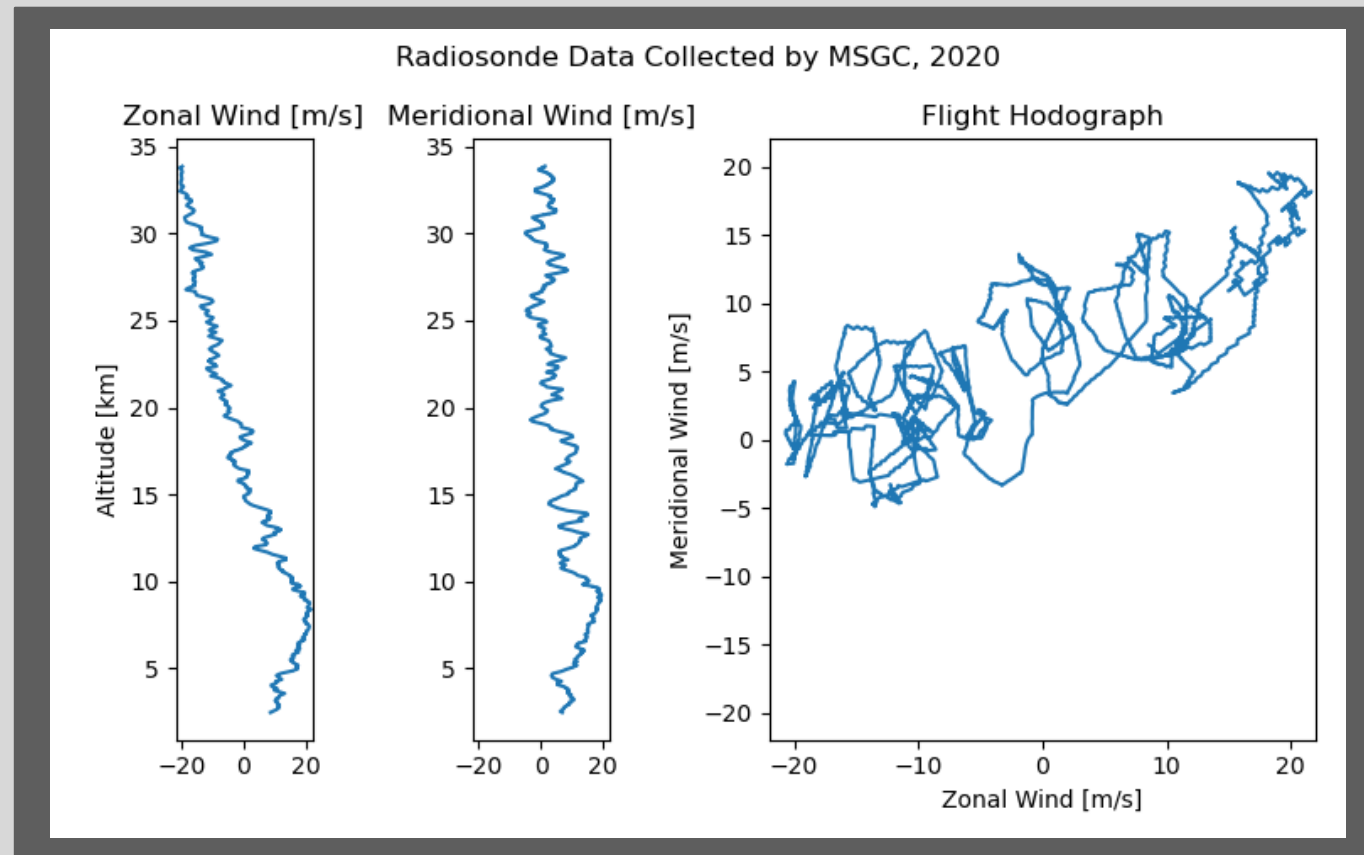
Radiosonde Data



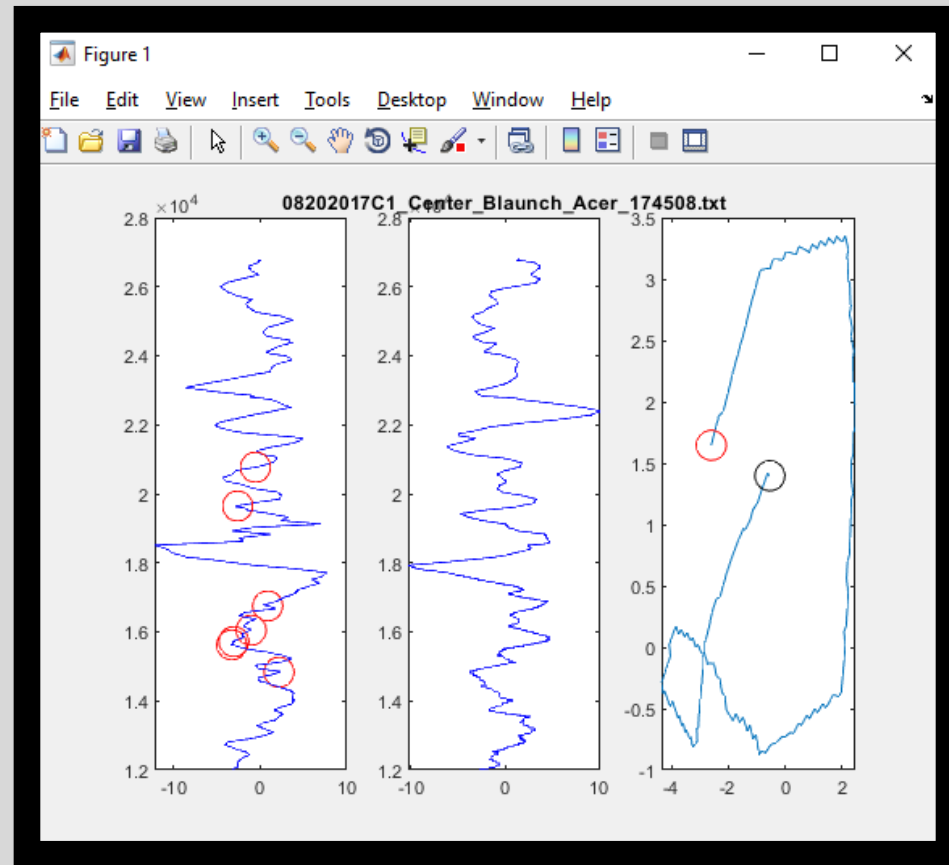
Radiosonde Data



Radiosonde Data



Hodograph Method





WAVELET METHOD

Wavelet Transform

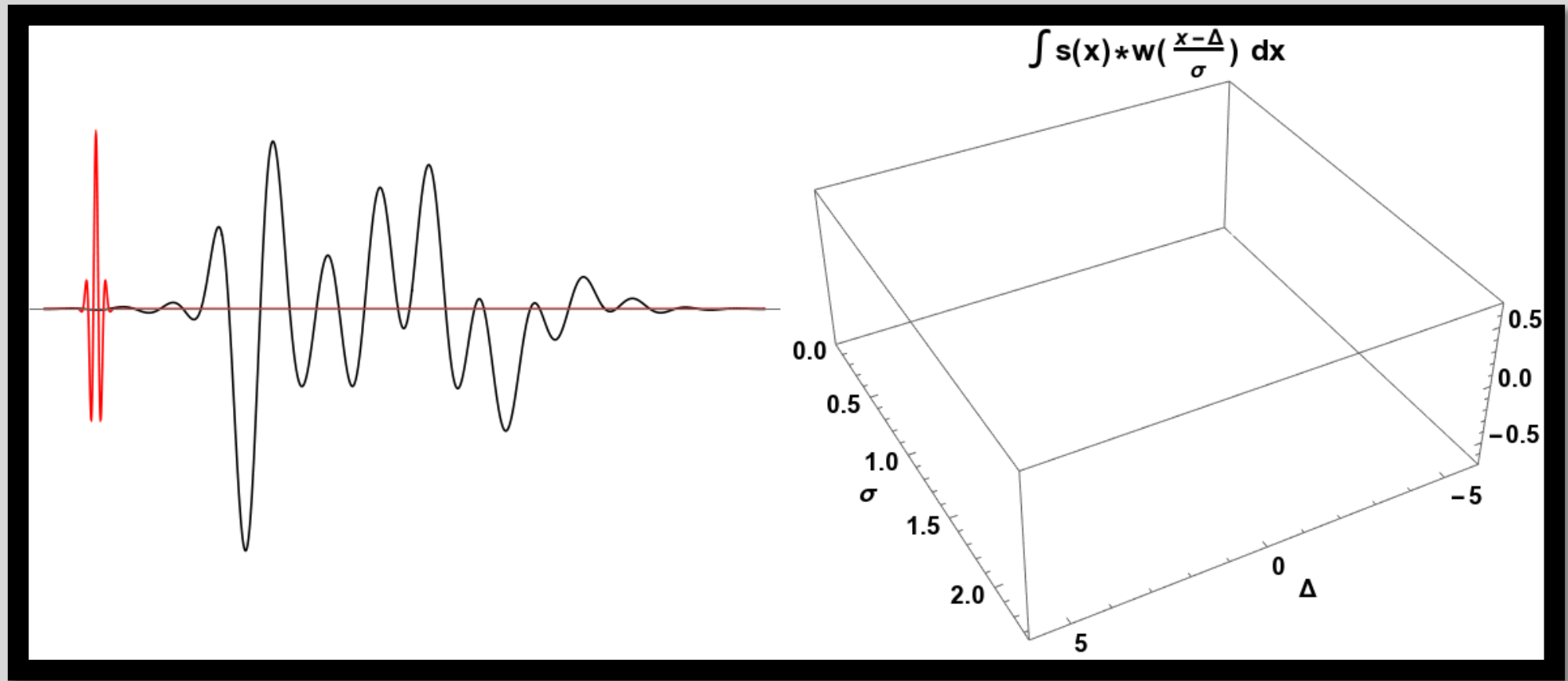


$$e^{-1/4} e^{i \omega_0 \eta} e^{-\eta^2/2}$$

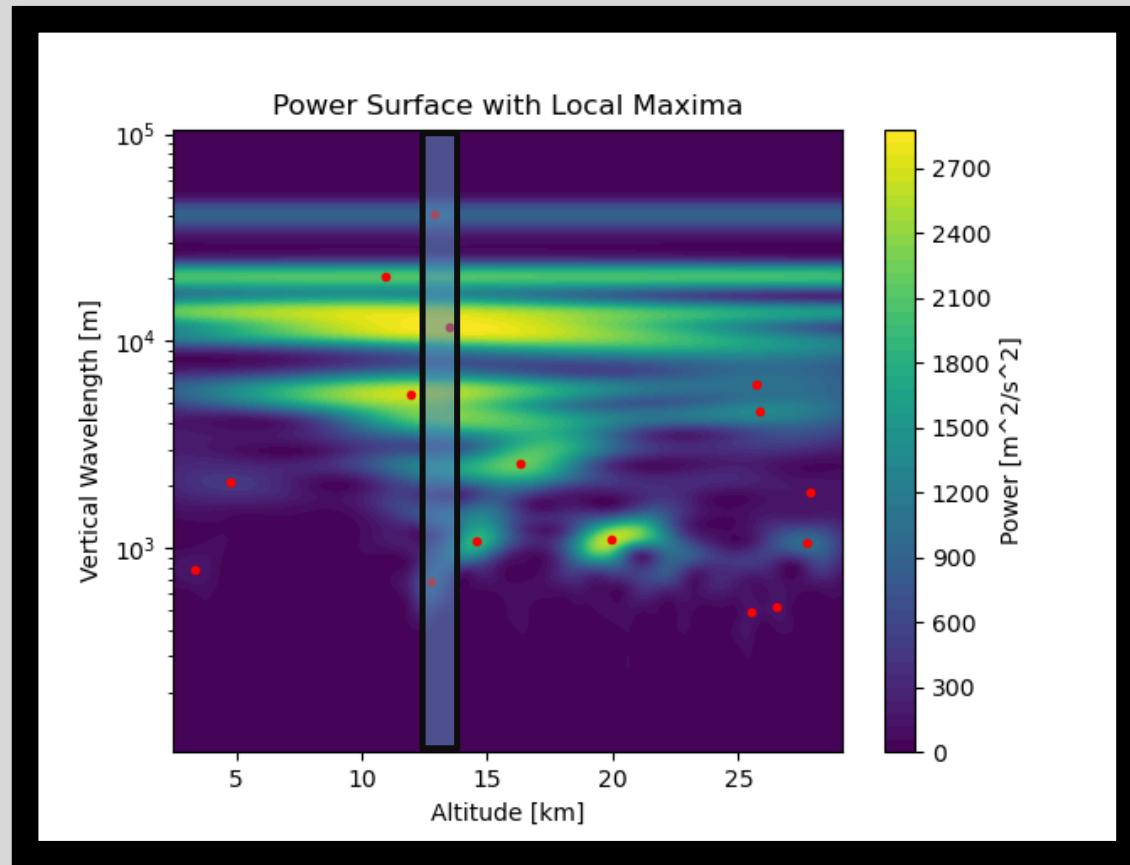
with step Δt and length N ,

$$\sum_{n=0}^{N-1} x_k \psi^* \left(\frac{(k-n)\Delta t}{s} \right)$$

Wavelet Transform



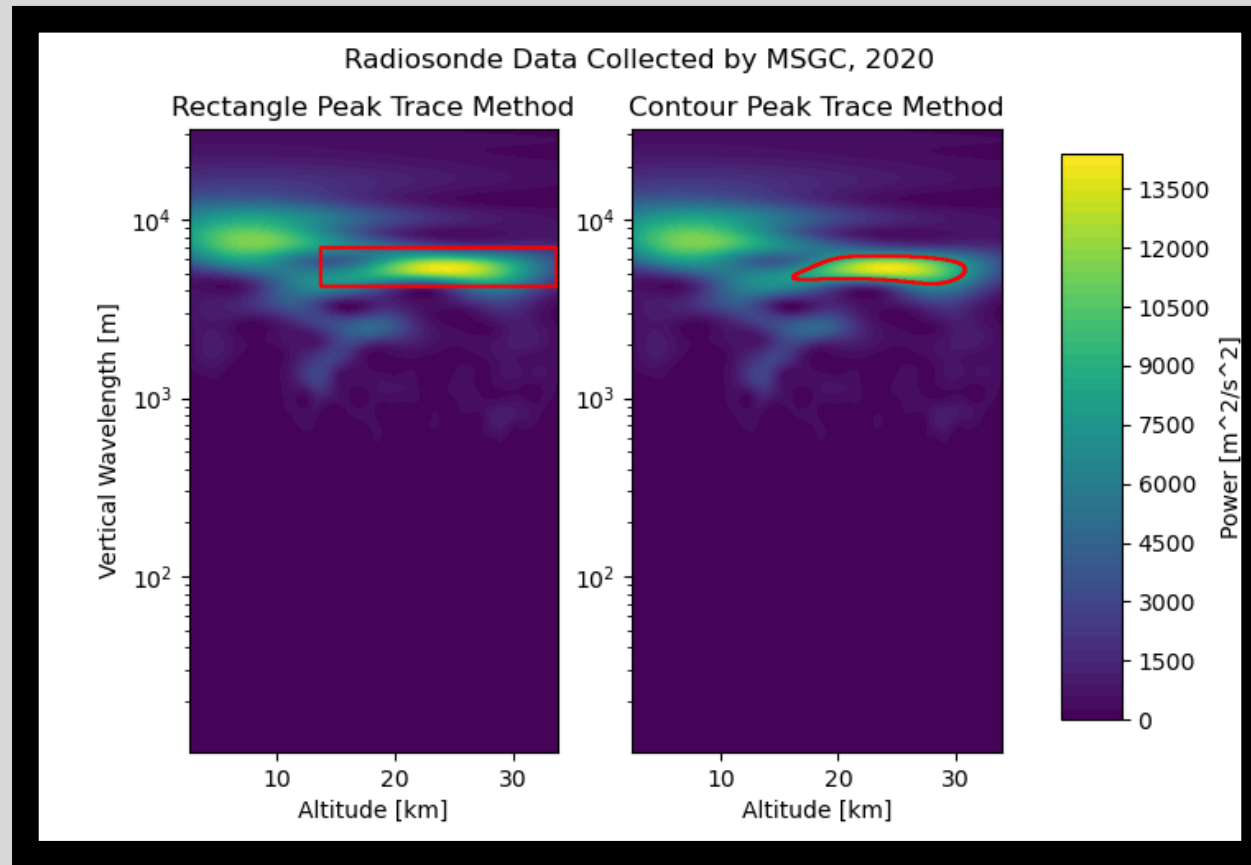
Power Surface



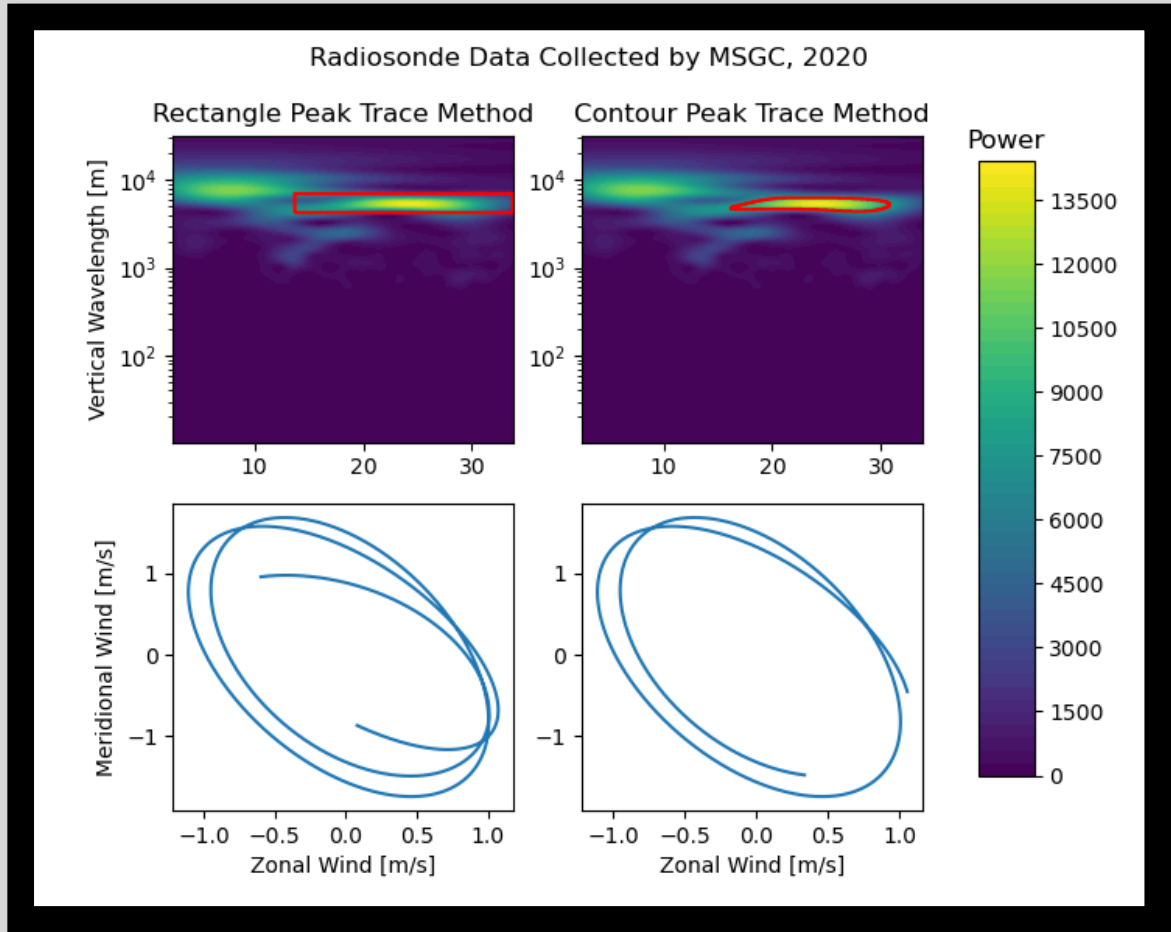
$$P_n(s) = |U_n(s)|^2 + |V_n(s)|^2$$

$$\lambda = \frac{4\pi s}{\omega_0 + \sqrt{2 + \omega_0^2}}$$

Power Surface

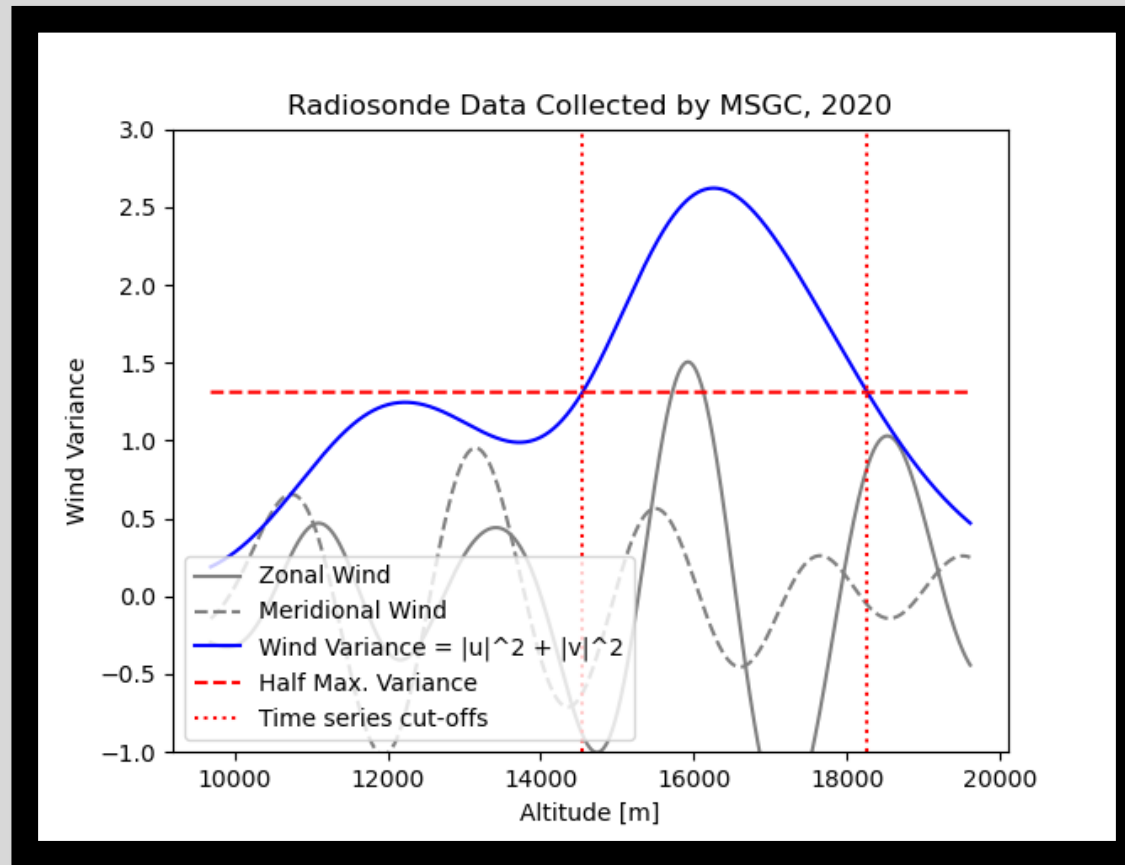


Time Series Reconstruction



$$x_n = \frac{\delta j \sqrt{\delta t}}{C_\delta \psi_0(0)} \sum_s \frac{W_n(s)}{\sqrt{s}}$$

Half Max Power Filtering



Stokes Parameters

$$\theta = \frac{1}{2} \tan^{-1} \left(\frac{2 \operatorname{Re}\{u\} \operatorname{Re}\{v\}}{\operatorname{Re}\{u\}^2 - \operatorname{Re}\{v\}^2} \right)$$



Direction of Propagation

$$\hat{\omega} = f \frac{u_{\parallel}}{v_{\perp}}$$



Intrinsic Frequency

$$k_h^2 = \frac{f^2 m^2}{N^2} \left(\frac{\hat{\omega}^2}{f^2} - 1 \right)$$



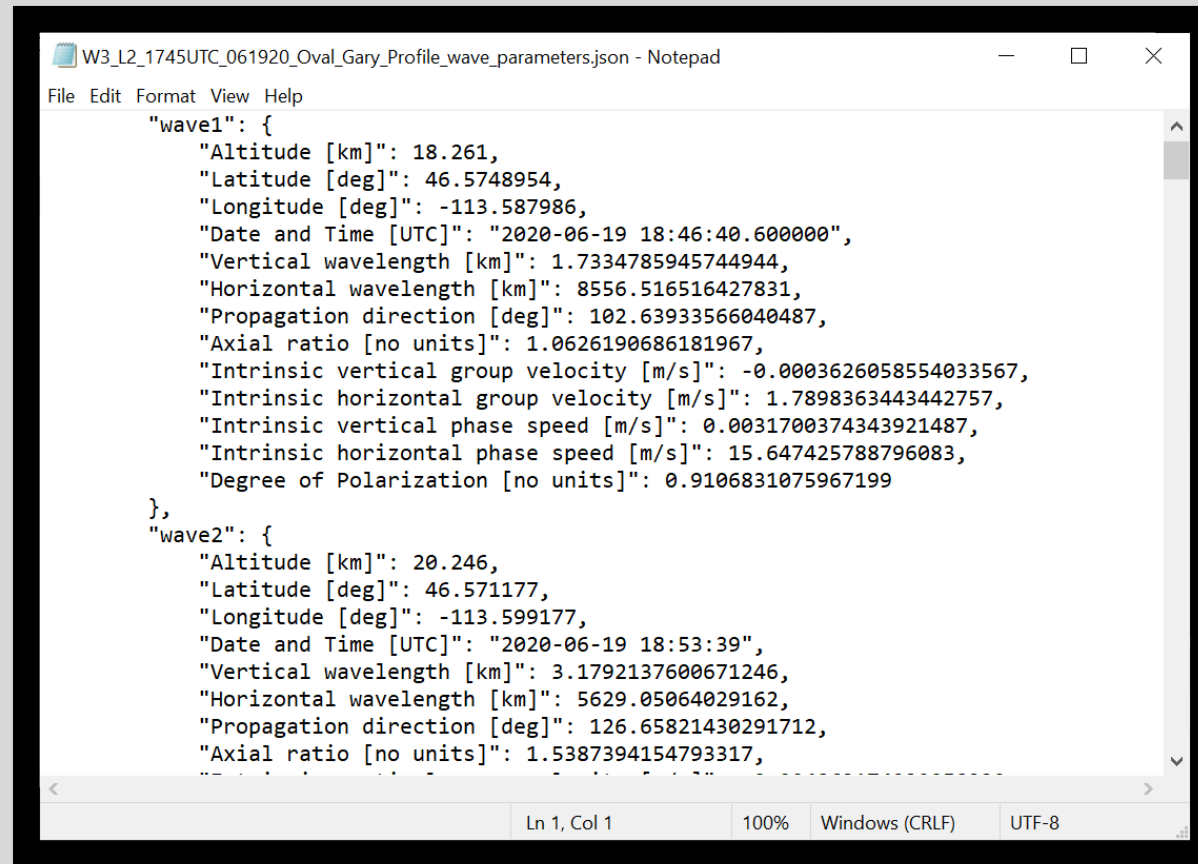
Horizontal Wavenumber

$$\hat{c} = \frac{\hat{\omega}}{k_h}$$



Intrinsic Horizontal Phase Speed

Example Output



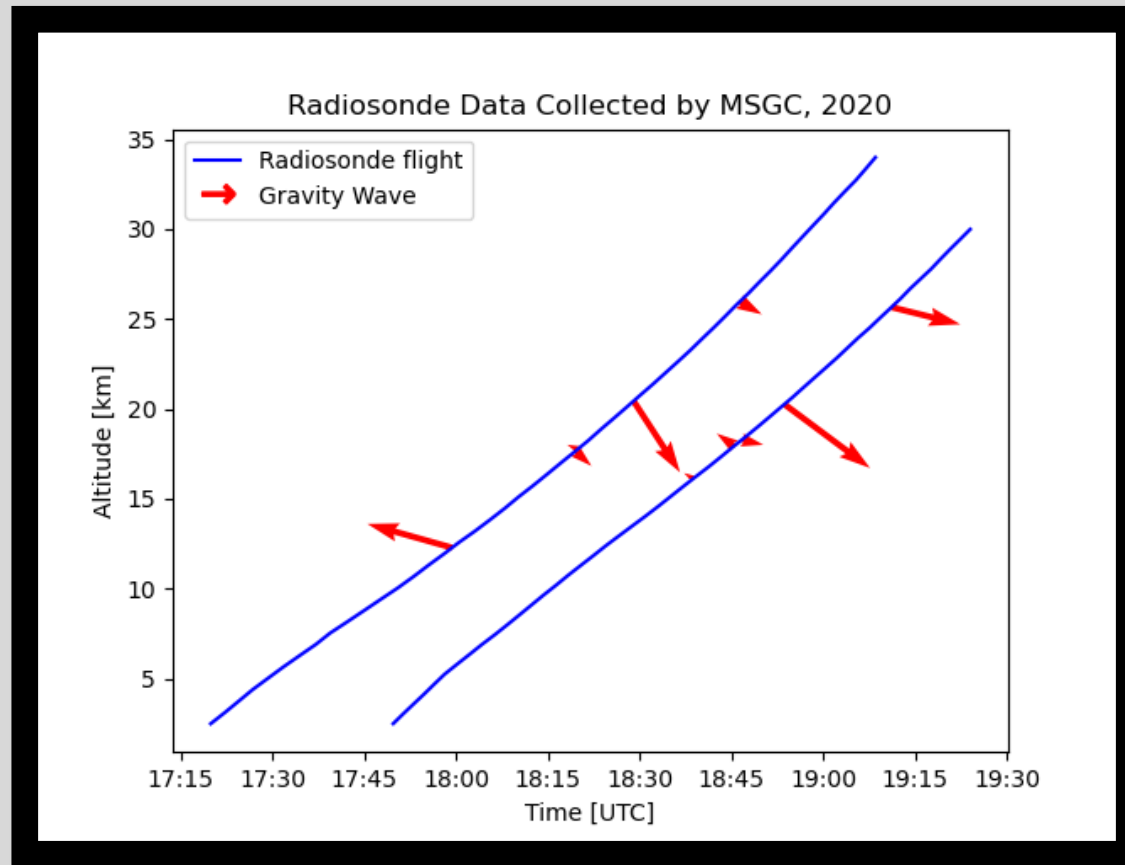
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W3_L2_1745UTC_061920_Oval_Gary_Profile_wave_parameters.json - Notepad
File Edit Format View Help
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    "Longitude [deg]": -113.587986,
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    "Vertical wavelength [km]": 1.7334785945744944,
    "Horizontal wavelength [km]": 8556.516516427831,
    "Propagation direction [deg]": 102.63933566040487,
    "Axial ratio [no units]": 1.0626190686181967,
    "Intrinsic vertical group velocity [m/s]": -0.0003626058554033567,
    "Intrinsic horizontal group velocity [m/s]": 1.7898363443442757,
    "Intrinsic vertical phase speed [m/s]": 0.0031700374343921487,
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    "Degree of Polarization [no units]": 0.9106831075967199
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}
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UM BOREALIS SUMMMER FLIGHTS



UM BOREALIS SUMMMER FLIGHTS





Future Research

- Total solar eclipse 2020 ballooning campaign
- Investigate choice of wavelet scales
- Improve wave outlining algorithm
- Improved automated wave validity checks
- Statistical significance testing
- Test other methods for background removal
- Graphical User Interface

Sources

- *Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC*
<https://visibleearth.nasa.gov/images/69463/atmospheric-gravity-waves-and-internal-waves-off-Australia>
- <https://www.eol.ucar.edu/deepwave/eo>
- <https://uwaterloo.ca/applied-mathematics/current-undergraduates/continuum-and-fluid-mechanics-students/amath-463-students/internal-gravity-waves>
- <https://svg-clipart.com/black/xmm2Yhp-parachute-clipart>
- <https://svg-clipart.com/outline/5svSFQH-new-outline-balloon-clipart>
- https://upload.wikimedia.org/wikipedia/commons/9/95/Continuous_wavelet_transform.gif
- Torrence, C., and G. P. Compo, 1998: A Practical Guide to Wavelet Analysis. *Bull. Amer. Meteor. Soc.*, **79**, 61–78, [https://doi.org/10.1175/1520-0477\(1998\)079<0061:APGTWA>2.0.CO;2](https://doi.org/10.1175/1520-0477(1998)079<0061:APGTWA>2.0.CO;2).