Some of the more “traditional” methods of interpretation

Using these to:

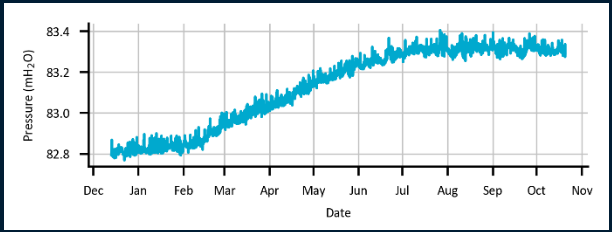
1. Identify **Earth tide** influences

2. Identify **atmospheric** influences

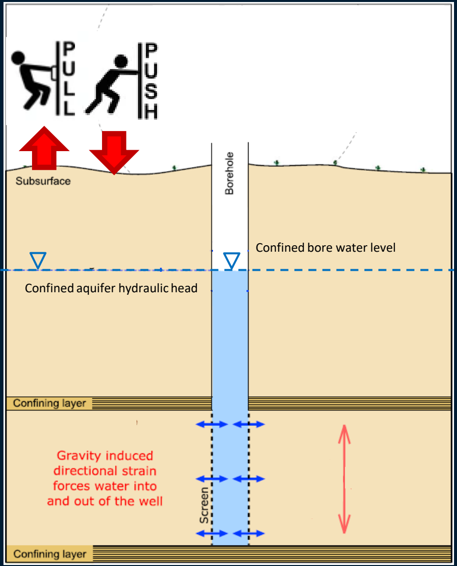
And derive conceptual and quantitative insights from these

1. Are my data affected by **Earth tides**?

$P_{GW}(t)$



1. **Forcing:**
   a) **Earth tide** (gravity) variation at nm to µm scale
2. **Responses:** (i.e. do we see a pressure change?)
   a) Confined aquifer: yes
   b) Open borehole: no
   c) Unconfined aquifer: no

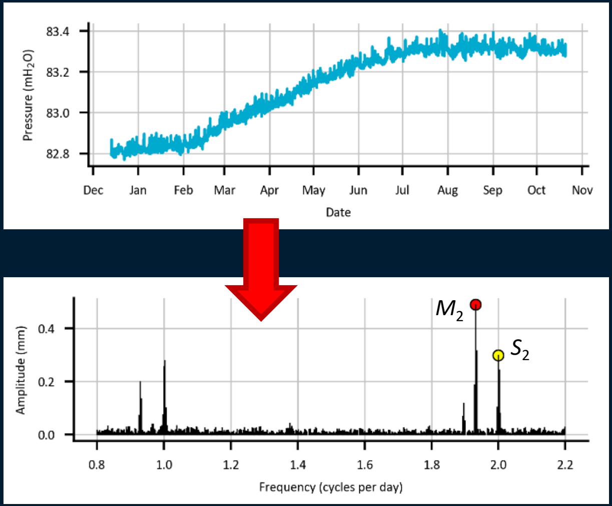


Modified from : McMillan, T. C., Rau, G. C., Timms, W. A., and Andersen, M. S. (2019). Utilizing the impact of Earth and atmospheric tides on groundwater systems: A review reveals the future potential. *Reviews of Geophysics*, 57(2), 281-315.

1. Are my data affected by **Earth tides**?

$P_{GW}(t)$

$A(f)$



Method:
Fourier transform

Result:
Amplitude spectrum for a **continuous range** of frequencies

Regular Python:

```
frequencies = numpy.fft.rfftfreq(GWdata, 1./24.)
amplitudes = numpy.abs(numpy.fft.rfft(GWdata))
matplotlib.pyplot.plot(frequencies, amplitudes)
```

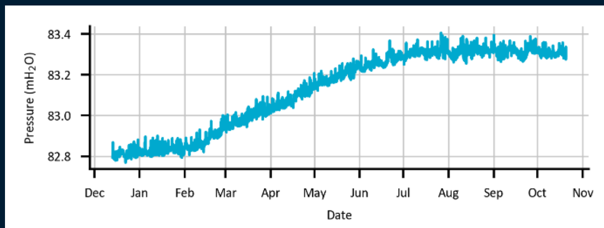
HydroGeoSines package:

```
output = hgs_analysis.Freq_domain.fft_comp(1./24., GWdata)
frequencies = output['freq']
amplitudes = numpy.abs(output['complex'])
matplotlib.pyplot.plot(frequencies, amplitudes)
```

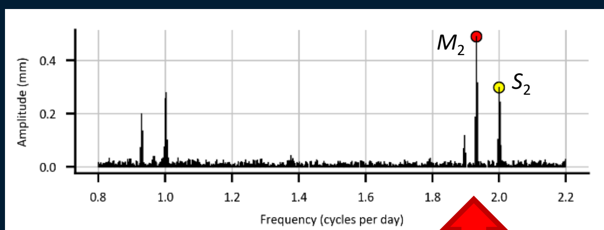
1. Are my data affected by **Earth tides**?

Interpretation:

$P_{GW}(t)$



$A(f)$

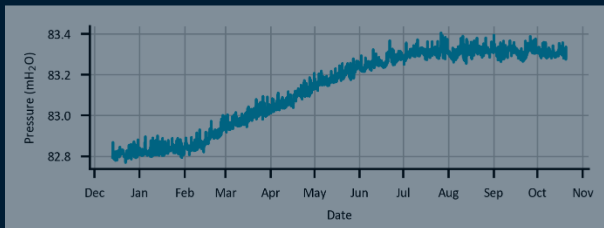


- M_2 amplitude is **dominant**
- Indicates **confined** conditions

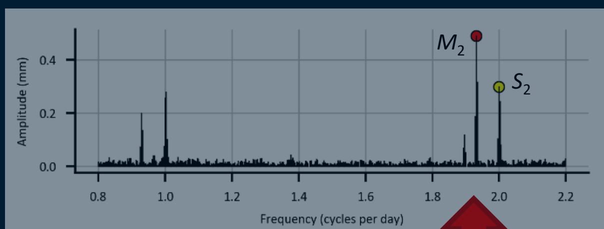
1. Are my data affected by **Earth tides**?

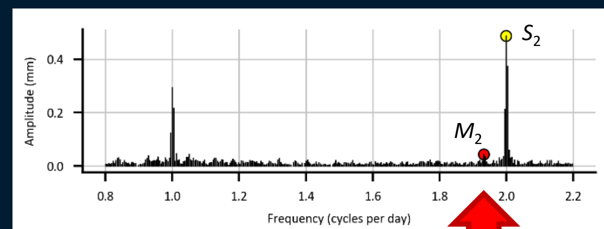
Interpretation:

$P_{GW}(t)$



$A(f)$



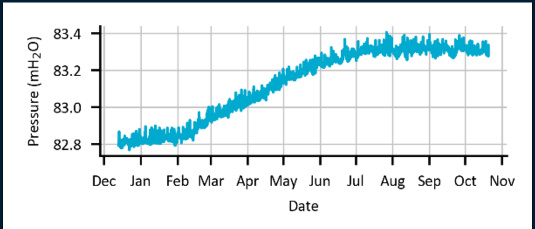


- M_2 amplitude is **dominant**
- Indicates **confined** conditions

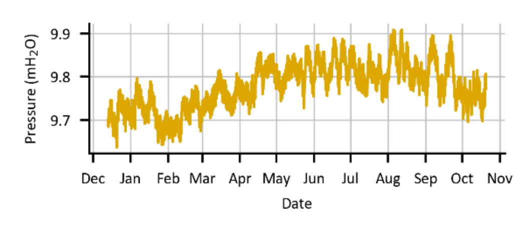
- M_2 amplitude is **negligible**
- Indicates **unconfined** conditions

2. Are my data affected by **atmospheric influences**?

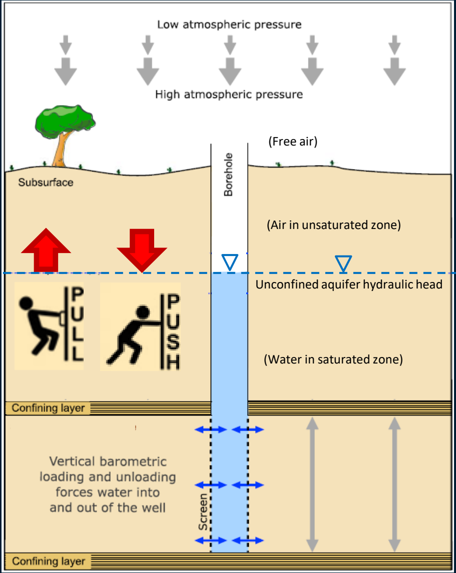
$P_{GW}(t)$



$P_{BA}(t)$



1. **Forcing:**
   a) **Barometric pressure** variation at mm to cm scale
2. **Responses:** (i.e. to a change in load)
   a) Open borehole: none
   b) Confined aquifer: directly proportional
   c) Leaky (semi-confined) aquifer: variably proportional
   d) Unconfined aquifer: none



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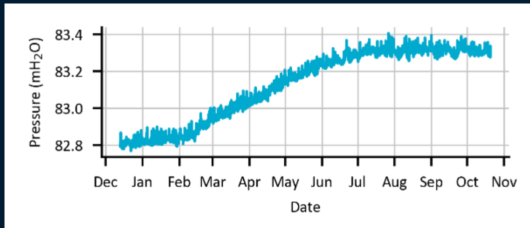
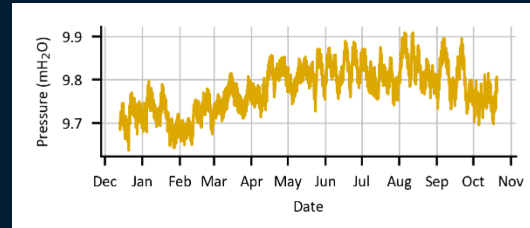
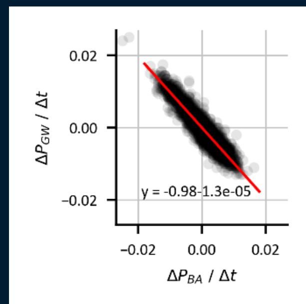
2. Are my data affected by **atmospheric influences**?

$P_{GW}(t)$



$P_{BA}(t)$





Method:
Linear regression

Result:
Barometric efficiency from slope

Regular Python:

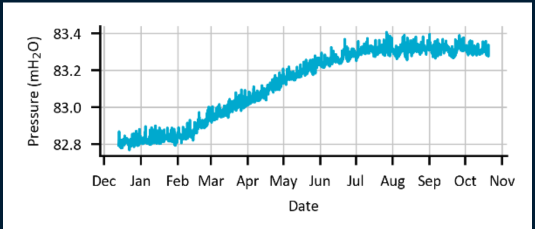
BE = scipy.stats.linregress (**dBP_dt**, **dGW_dt**)[0]

HydroGeoSines package:

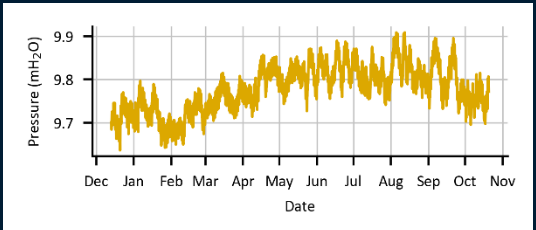
BE = hgs_analysis.Time_domain.BE_linear_regression(**dBP_dt**, **dGW_dt**)

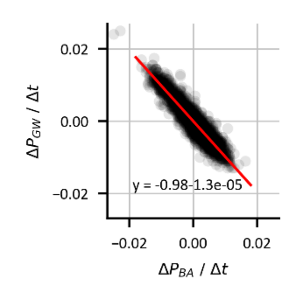
2. Are my data affected by **atmospheric influences**?

$P_{GW}(t)$



$P_{BA}(t)$





Interpretation:

- BE ≈ 1 : confined aquifer
- BE ≈ 0 : unconfined aquifer
- 0 < BE < 1 : semi-confined / leaky aquifer

2. Are my data affected by **atmospheric influences**?

Deriving further benefit from barometric efficiency estimates:

- Aquifer specific storage is commonly calculated as:

$$S_s = \rho_w \, g \, (C_f + C_w \, \eta_e)$$

- It can instead be defined as a function of barometric efficiency, as:

$$S_s = \rho_w \, g \, C_w \, \eta_e \, \boldsymbol{BE}^{-1}$$

Barometric efficiency

Aquifer effective porosity

Density of water,
≈ 997 kg/m^3

Gravitational acceleration,
≈ 9.8065 m/s^2

Compressibility of water,
≈ 4.58×10^{-10} Pa^{-1}

Recap of "traditional" methods of interpretation:

1. Identifying **Earth tide** influences via:
   - Fourier transform

     → Aquifer confinement status

2. Identifying **atmospheric** influences via:
   - Linear regression

     → Aquifer confinement status

     → Confined aquifer specific storage