Untangling Groundwater Head Series Using Time Series Analysis and Pastas

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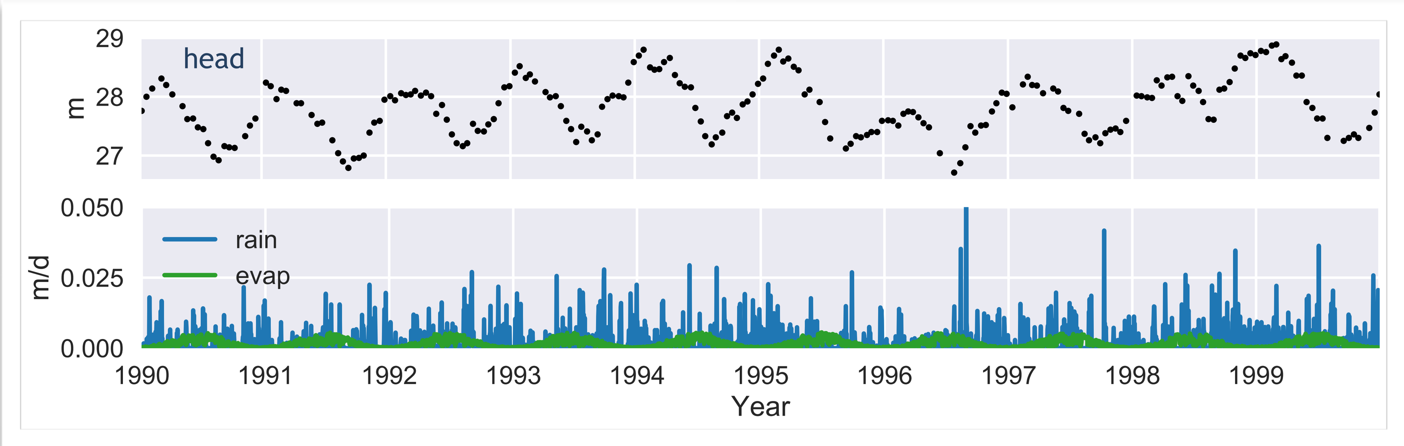
Introduction

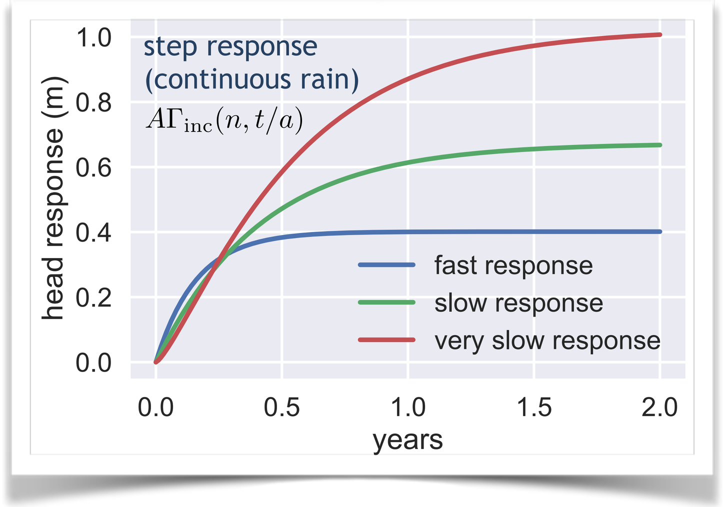
Heads vary as a result of a variety of stresses on the aquifer, including rainfall, evaporation, pumping, and variations in surface water levels. One of the common objectives of groundwater models is to untangle measured groundwater head variations into contributions from these different stresses. Time series analysis with response functions is a relatively new groundwater modeling technique to model groundwater dynamics at observation wells. The method is fully data-driven. It requires measured time series of the head in an observation well and of the stresses on the aquifer. No other knowledge, including knowledge of aquifer parameters, is required. In this poster, the capabilities of the new Python package PASTAS are demonstrated.

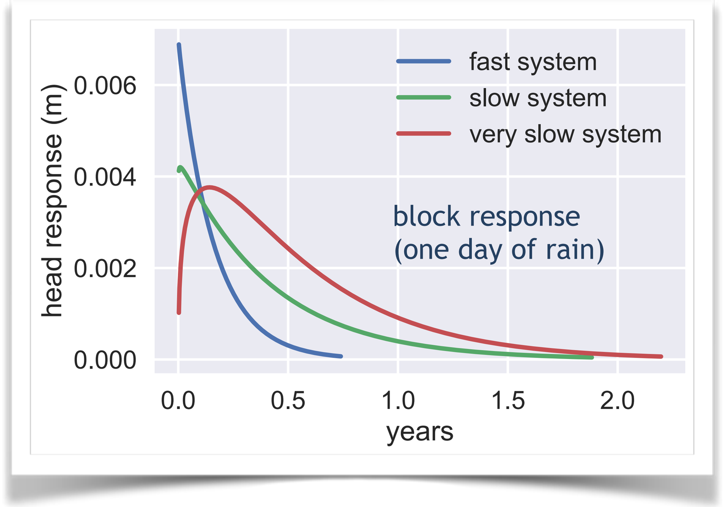
Approach

Step 1: Start with observed heads, rainfall and reference evaporation (and possibly other stresses)

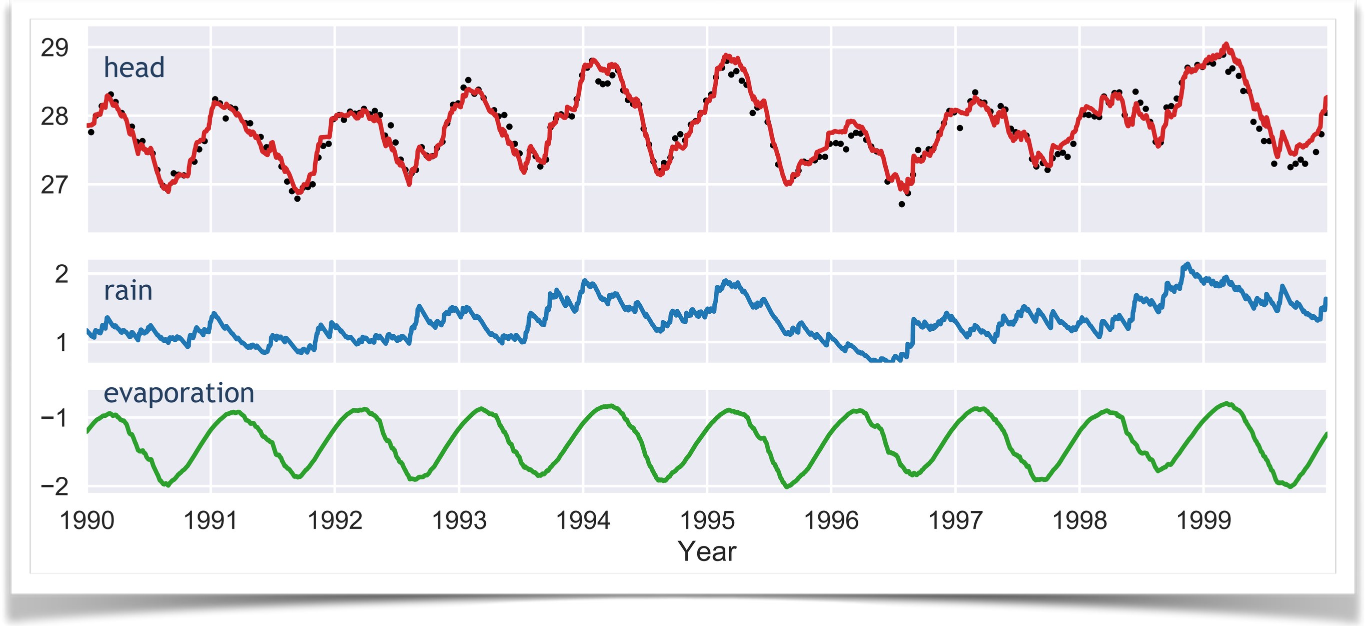


Step 2: Adjust parameters A, n, a of response function(s) to get the best match between observed and modeled heads





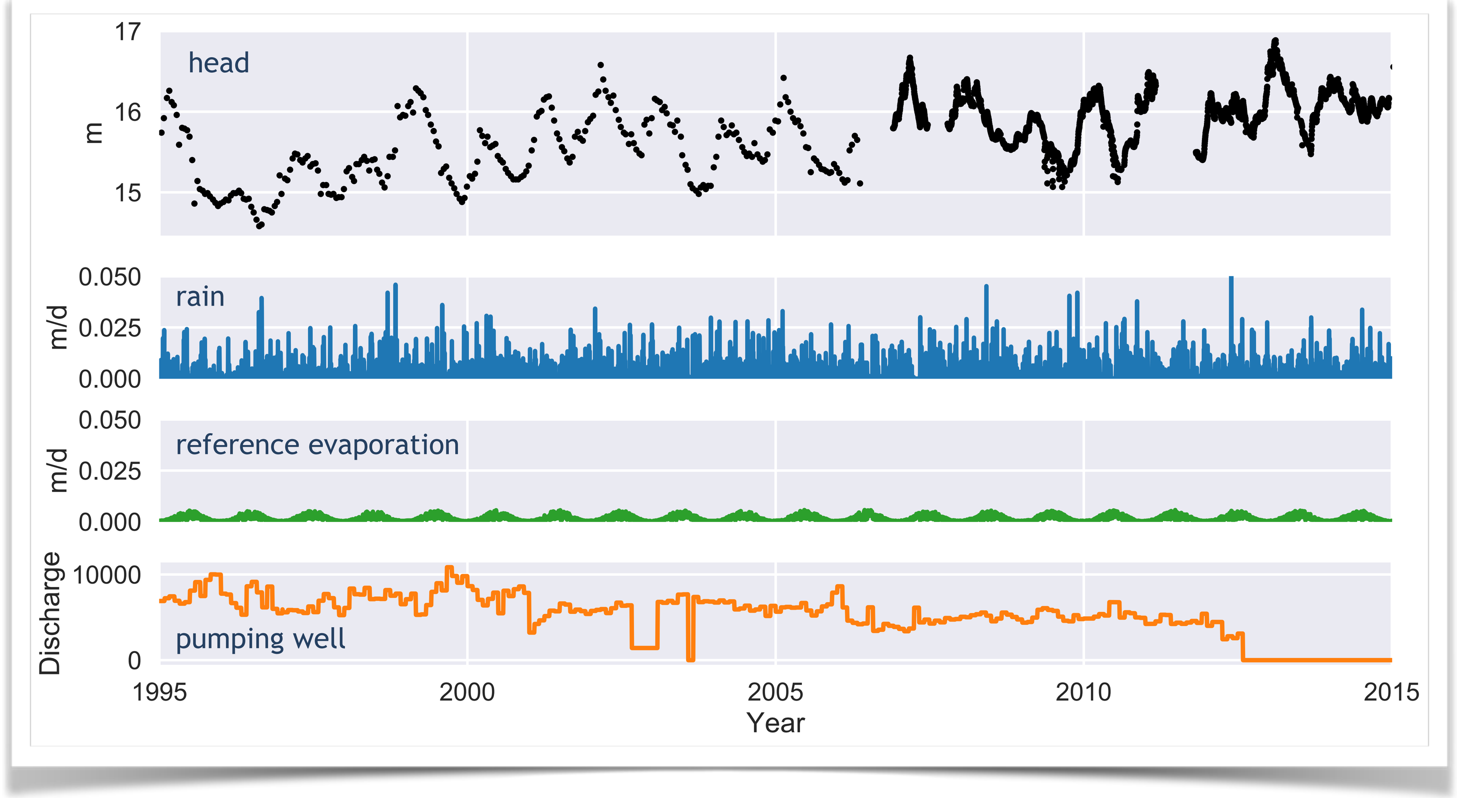
Step 3: Plot model results and separate contributions of all stresses



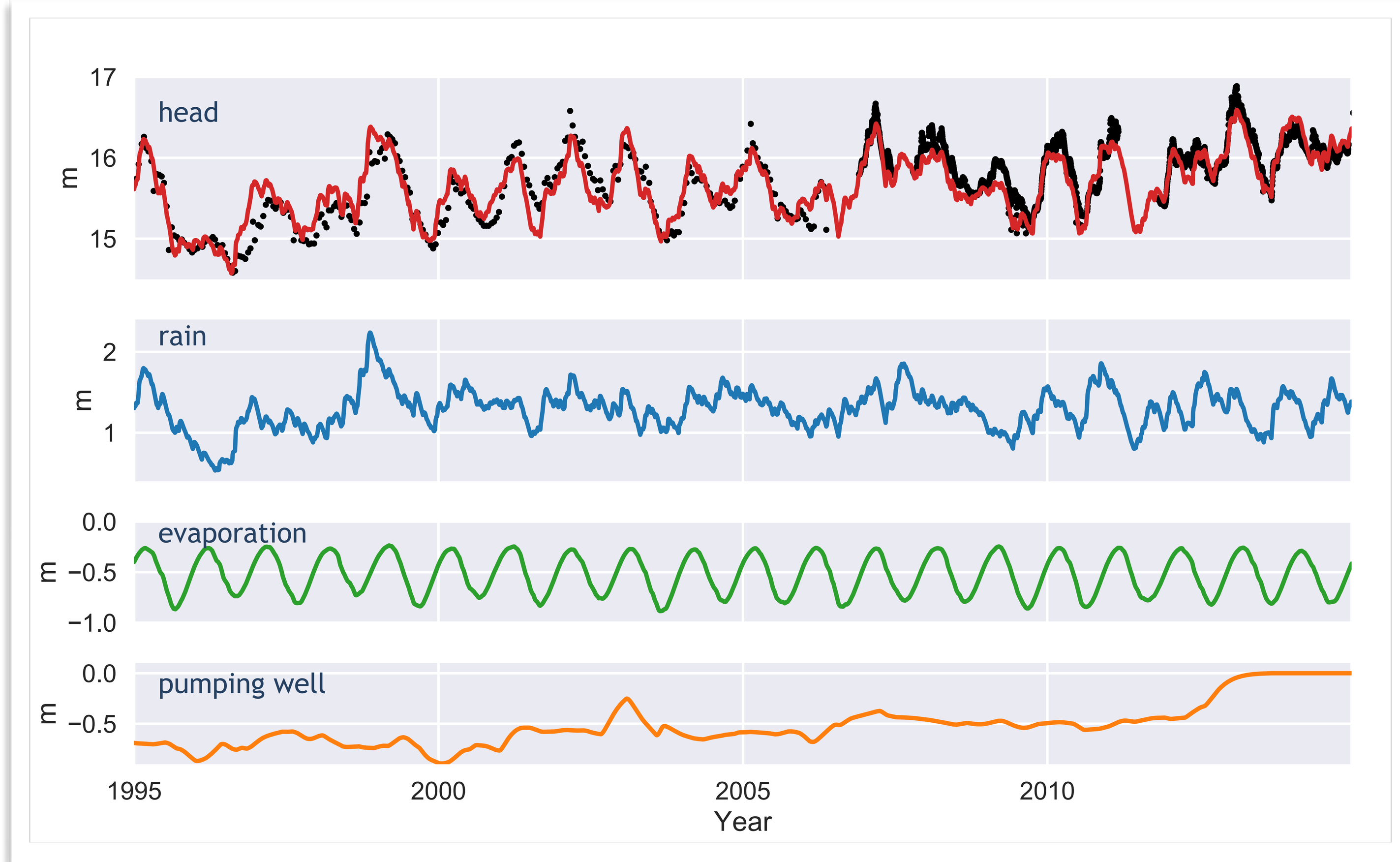
PASTAS model script

```
# many utilities to load time series data
In[1]: ho = load_data('head.csv')
       rain = load_data('rain.csv')
       evap = load_data('evap.csv')

# import pastas, create model and add stress model
In[2]: import pastas as ps
       ml = ps.Model(oseries=ho)
       sm = ps.StressModel2(stress=[rain, evap],
                rfunc=ps.Gamma, name='rainevap',
                settings=('prec', 'evap'))
       ml.add_stressmodel(sm)

# compute solution and get summary statistics
In[3]: ml.solve()

Out[3]:

Model Results head                  Fit Statistics
============================        ================
nfev      39                        EVP        92.93
nobs      644                       NS          0.93
noise     NoiseModel                Pearson R2  0.96
tmin      1985-11-14 00:00:00       RMSE        0.11
tmax      2015-06-28 00:00:00       AIC         9.23
freq      D                         BIC        36.04
warmup    3650                      __
solver    LeastSquares              ___

Parameters (6 were optimized)
==============================================
              optimal            stderr
rainevap_A   684.818305   ± 3.58911e+01 (5.24%)
rainevap_n     1.018548   ± 1.79814e-02 (1.77%)
rainevap_a   149.759071   ± 1.09608e+01 (7.32%)
rainevap_f    -1.267258   ± 6.18514e-02 (4.88%)
constant_d    27.879381   ± 6.89482e-02 (0.25%)
noise_alpha   52.974026  ± 6.53101e+00 (12.33%)
```

Untangling three stresses



Quantify contribution of each stress



Advantages of PASTAS

- Untangle contributions of all stresses
- Confidence intervals of results
- Free and Open Source
- Transparent and extendable
- Run models with scripts
- Fully reproducible

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PASTAS

Plans for the (near) future

- Threshold nonlinearity
- Root zone module
- System changes
- Multiple wells simultaneously

Source code and Installation

Source code: **`https://github.com/pastas/pastas`**
Python installation: **`pip install pastas`**