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Seasonal precipitation forecasting by spectral analysis of the large water body levels

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"If you want to find the secrets of the Universe, think in terms of energy, frequency and vibration." - Nikola Tesla

Background

In the late 1980's, the fishing industry of the former USSR had ordered several seasonal prediction projects from the Ocean-Atmosphere Interaction Lab., Leningrad (now St. Petersburg). To accomplish these projects, a spectral decomposition technique was developed and then applied to the North Atlantic SST, Caspian Sea levels, Sea of Okhotsk ice extent, Volga River discharge etc.

This technique required a single input data: the long-term monthly time series of the element to be predicted. The algorithm consisted of the following steps: (1) time series spectral decomposition; (2) for each spectral component, assigning its most recent part as a training pattern and finding its best analog along the historical part; (3) projecting a tendency following the historical analog onto the 1-2 forecasted years; (4) adding up all the forecasted tails.

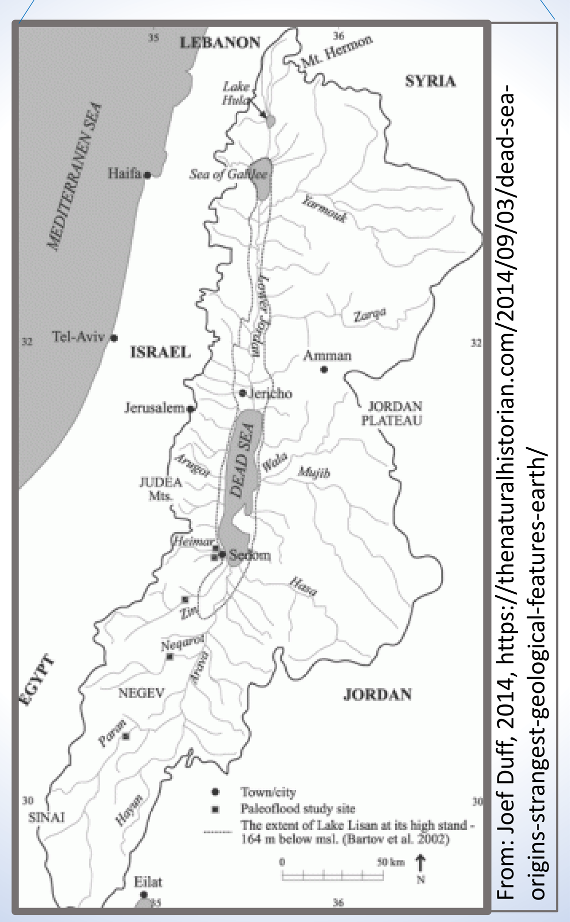
Upgrading the Method

In the present work, a core idea of spectral decomposition and analyzing each spectral component separately was applied to the Dead Sea level monthly data. But, due to the data specifics, the time series was first ***deseasonalized*** and ***detrended***. Steps 2 and 3 of the original technique were replaced by finding a waveform fitting function. This was done using the ***Nelder-Mead simplex algorithm.***

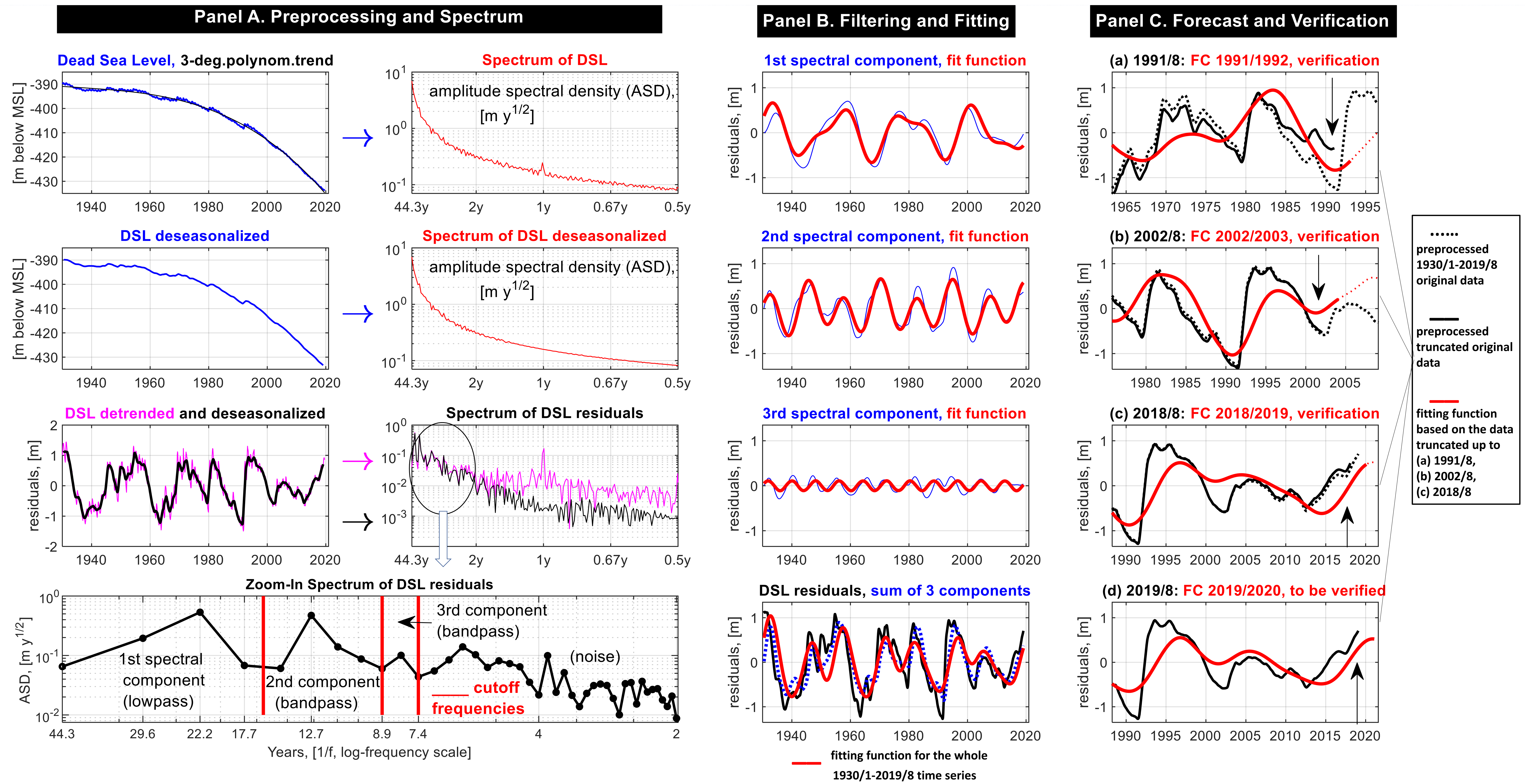
Deseasonalizing and detrending the input data: long-term monthly data time series

Spectral decomposition of the residuals and filtering the main spectral components

For each main spectral component, finding the fitting function and its extrapolating. Adding up the forecasted tails



The Dead Sea is a hypersaline lake in a closed drainage basin that lies between Jordan and Israel. The Dead Sea represents a dead end to all its tributaries, including its largest source of new water, the Jordan River.



Upgrading the Applicability

(1) A seasonal forecast for ***the Dead Sea level tendency*** may be produced by adding up the forecast for the regular part (spectral components) and downward trend (caused by operating the Dead Sea Works evaporation ponds and water consumption from the Dead Sea tributaries, mainly the Jordan River) of the Dead Sea level time series.

(2) The Dead Sea is located in the middle of its vast drainage area (~42,000 km^2), stretching in the nearly meridional direction for ~450 km and crossed by the westerlies bringing precipitation into the region. Therefore, ***the regional seasonal precipitation tendency*** may be predicted using only the regular part of the level data, which reflects a regularity of multiple natural processes yielding precipitation that causes streamflow and runoff into the Dead Sea.

Results

The proposed technique was verified for the unexpectedly rainy winters of 1991/1992, 2002/2003, and 2018/2019, with the input data being cut off by the month of August preceding each rainy season. It was found that the forecasted tendency of the Dead Sea levels does reflect the tendency of the regional precipitation in the coming season.

Discussion and Conclusion

The Levant precipitation is typically of a convective type. This makes using the regional rain gauge records hardly effective for producing a regional seasonal forecast. Applying the proposed technique for even such a representing rainfall record as of Jerusalem, produces much more white-noisy spectrum than that of the Dead Sea levels. The various spatial techniques for constructing a regional representing precipitation time series yielded the dissimilar results, while the Dead Sea level data (preprocessed as shown), ***accounting for streamflow and runoff over the complex terrain of the Levant region*** might serve as a workable proxy for a regional precipitation forecast.

Open Questions:

- Is it worth using the whole available data or only the last decades?
- Which frequencies might be considered noise and disregarded?
- How to best estimate a first guess set for the Nelder-Mead algorithm?
- How to quantify the precipitation totals' forecast out of the water level tendency forecast, besides the qualitative estimation?

References:

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