Detrended Fluctuation Analysis of Precipitation Time Series

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Measurement

unit: \[\frac{V}{(S\cdot t)} = \frac{m^3}{(m^2\cdot s)} = m/s\]
resolution: 0.1 mm (per day)
problems:
• moisture due to fog and clouds not registered
• strong influence of wind
• inaccuracy due to evaporation
• separate determination in case of snow and ice
⇒ errors up to 25%
Patterns and properties

- range not negative
- spiky structure
- broad distribution
- seasonal average
- seasonal standard deviation
Deseasonalisation

\[ T_i = t_i - \langle t_i \rangle \]

\[ Y_n = \sum_{i=1}^{n} T_i \]
Detrended Fluctuation Analysis (DFA)

1. create profile
2. segments of scale-size \( S \)
3. polynomial fit in each segment
4. calculate variance for each
5. average over all segments and square root

after: J. W. Kantelhardt et al.
Detrended Fluctuation Analysis

\[ Y_n = \sum_{i=1}^{n} T_i \]

\[ Y_i(S) = Y_i - p_v(i) \]

\[ F_v^2(S) = \langle Y_i^2(S) \rangle = \frac{1}{S} \sum_{i=1}^{S} [Y_{(v-1)S+i}(S)]^2 \]

\[ F(S) = \sqrt{\frac{1}{K_S} \sum_{\nu=1}^{K_S} F_\nu^2(S)} \]

\[ F(S) \sim S^\alpha \]

\[ \alpha = 0.5 \quad \text{uncorrelated} \]
\[ \alpha > 0.5 \quad \text{long-range corr.} \]
\[ \alpha < 0.5 \quad \text{anti-correlated} \]
DFA $\leftrightarrow$ (auto-) correlation function

$$C(S) = \langle \tau_i \tau_{i+S} \rangle = \frac{1}{N-S} \sum_{i=1}^{N-S} \tau_i \tau_{i+S}$$

Correlation function

$$C(S) \sim S^{-\gamma}, \quad 0 < \gamma < 1$$

Long-range correlations

$$\alpha = 1 - \frac{\gamma}{2}$$

Relation of exponents

$$\alpha = \frac{1}{2}(1 + \beta)$$

Relation to exponent of power spectrum
Effects of non-stationarities on DFA

\[ \hat{t}_i = t_i + A \cdot \sin \left( \frac{2\pi \cdot i}{T} \right) \]

\[ \hat{t}_i = t_i + A \cdot \left( \frac{i}{N} \right)^{\eta} \]
Analysis of precipitation time series

![Graph showing detrended fluctuation analysis of precipitation time series for different locations: Cicero (semi-humid), Hawaii (semi-arid), Horog (semi-arid), and Karlsruhe (semi-humid).]
Analysis of precipitation time series

Moskau (semi–humid)  Petropavlovsk (humid)

Plymouth (semi–humid)  Sydney (humid)
Classification in terms of water balance

![Histogram showing frequency distribution of water balance categories for detrended fluctuation analysis of precipitation time series.]

- arid
- semi-arid
- semi-humid
- humid

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Comparison to temperature analysis

classification in terms of climate region

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Conclusion

• most analysed precipitation time series are just slightly correlated or uncorrelated (long-range)
• series of some sites have bigger fluctuation exponents up to 0.67 (Ipagua)
• unrelated to climate and geography
• but: in many cases short-range correlations exist

Perspectives

• Multifractal Analysis (MF-DFA)
• Fourier Phase Randomization Method (nonlinearity)
• Modelling

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References


