Changing Statistics of Storm Surges in the Recent Past and in the Foreseeable Future?

A Case Study for Cuxhaven.

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Past Variations

- **Storm surges in Cuxhaven have lead to higher and higher water levels** in the past 100 years.
- **The increase of high tides in Cuxhaven is mostly due to a rise of 30 cm/100 years the mean level of high tides.**
- **The storm-related variations, around the overall trend in the mean water level, has remained stationary in the past 100 years.** A slight increase has taken place since about 1960, but this increase may well be a swing reflecting natural variability.

Scenario for Future Changes due to Global Warming for the Time of Doubled CO_2 Concentrations

- **Standard climate models are too coarse to simulate regional details.** Therefore *downscaling strategies* are required.
- **We pursue a two-step downscaling strategy.**
  First, a scenario derived from a coarse (T21) resolution coupled ocean-atmosphere climate model is dynamically downscaled by means of a *T106 time slice experiment.*
  Then, in a second step, a *statistical model* is designed which relates intra-monthly percentiles of storm-related high tide variations to the monthly mean air pressure distribution.
- **The T106 scenario indicates for the expected time of doubled CO_2 concentrations, in about year 2035, an intensification of the mean northwesterly flow across the North Sea.**
- **The statistical model interpretes the large-scale T106 air pressure distribution change as a tendency towards higher tide levels in Cuxhaven.** The increase of storm related high tides in Cuxhaven is rather small. The 50% percentile is expected to rise by 10 cm whereas the 90% percentile is expected to rise by 12 cm.
- **The storm related increase of water level extremes has to be added to the mean sea level rise, due to ongoing land sinking and thermal expansion of the sea water, of some decimeters.**

The Statistical Downscaling Model

- **The statistical downscaling model is a multiple regression model based on a Canonical Correlation Analysis** which links the anomalous monthly mean air pressure distribution over the Northeastern North Atlantic and Europe to the three-dimensional vector of anomalous intramonthly 50%, 80% and 90% percentiles of storm-related (de-trended) high tide level variations in Cuxhaven.

- **The model is fitted with data from 1970 to 1988.** The CCA identifes two "good" pairs of patterns.

- **The first pair describes an uniform shift of the water level distribution in Cuxhaven.** Its anomalous air pressure distribution describes an northwesterly flow across the North Sea; the storminess, in terms of the intramonthly standard deviation of band-pass filtered pressure variations are enhanced.

- **The second is associated with a broadening (or shrinking) of the distribution.** The 50% percentile is reduced but the 90% percentile is enhanced. The anomalous monthly mean air pressure distribution has a weak local southeasterly component; the overall configuration leads to an intensification of storm activity in the North Sea area.

Verification of the Statistical Model

- **The model is verified with independent data from 1899 to 1969.**
- The *skill* of the resulting regression model is measured by the correlation of in-situ intra-monthly 50%, 80% and 90% percentiles and the estimated percentiles.

50%	80%	90%
.79	.72	.63

- Another measure of skill it the *percentage of explained variance*:

50%	80%	90%
62%	50%	40%

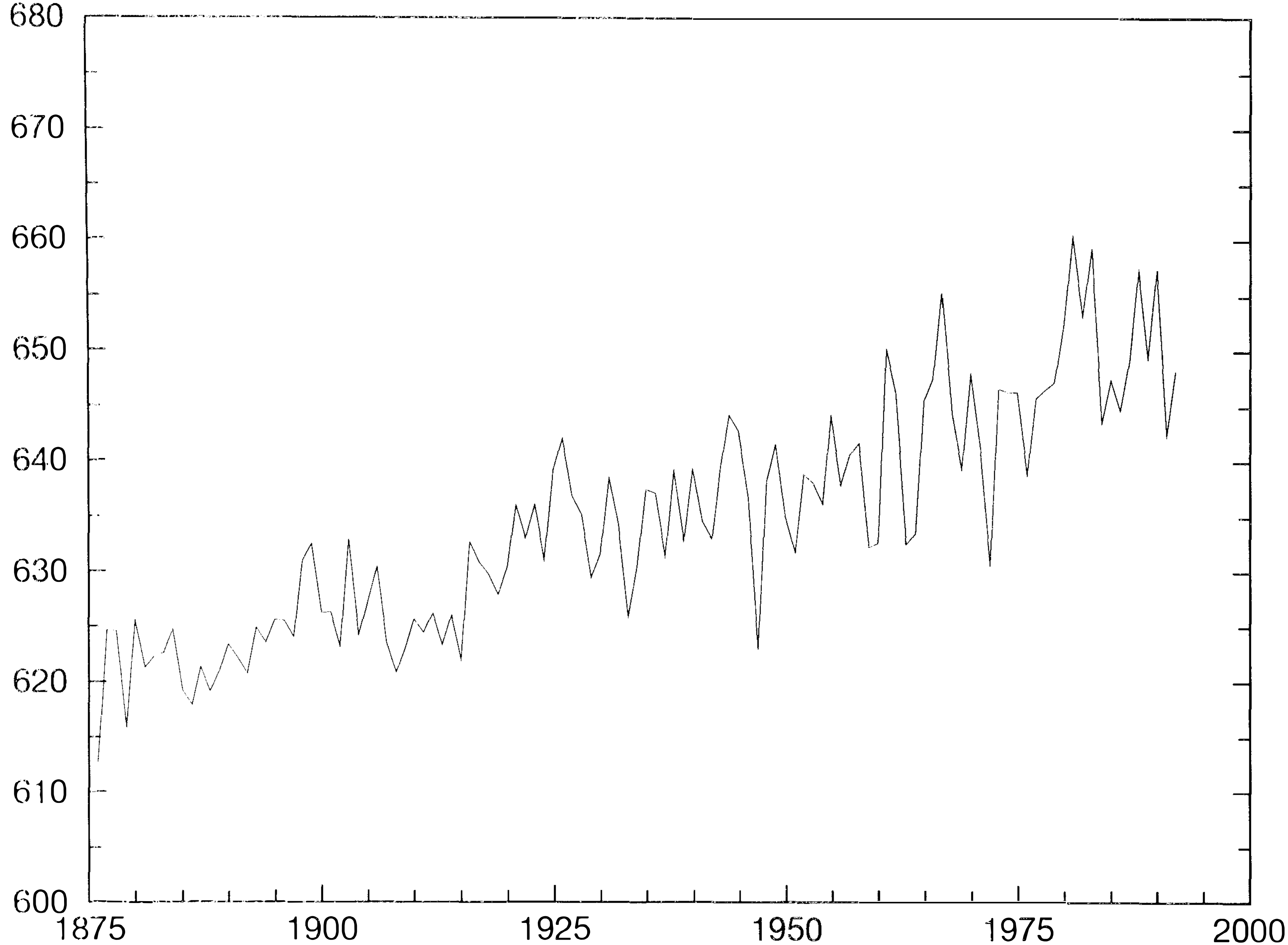
- An inspection of the time series indicates that the statistical model is skillful in reproducing the low-frequency variations. The differences between in-situ data and estimated data are mostly white in time.
- **Byproduct:** The conclusion of no systematic increase of storm-related variability is supported by air-pressure data.

The Combined Two-Step Dynamical/Statistical Downscaling

- **The T106 time slice experiment has been integrated with doubled CO_2 concentrations and SST/sea ice distributions taken from the "transient" base ECHAM T21/LSG coupled climate change experiment.** A total of 6 winters has been integrated so that 18 anomalous (= difference to control run) monthly (DJF) mean air pressure distributions are available.
- **The mean anomalous pressure distribution indicates an enhanced mean northwesterly air flow across the North Sea.** This distribution has CCA coefficients $\alpha_1 = -0.40$ and $\alpha_2 = 0.26$.
- **The regression model** transforms these $\alpha's$ into anomalous precentiles of about 7 cm.
- **The estimated systematic change is comparable with the model generated standard deviations.** Thus, the evidence supplied by the model fails to reject the null hypothesis of "*no change of storm related percentiles*".

Epilogue

Paper is available and has been submitted to a journal.



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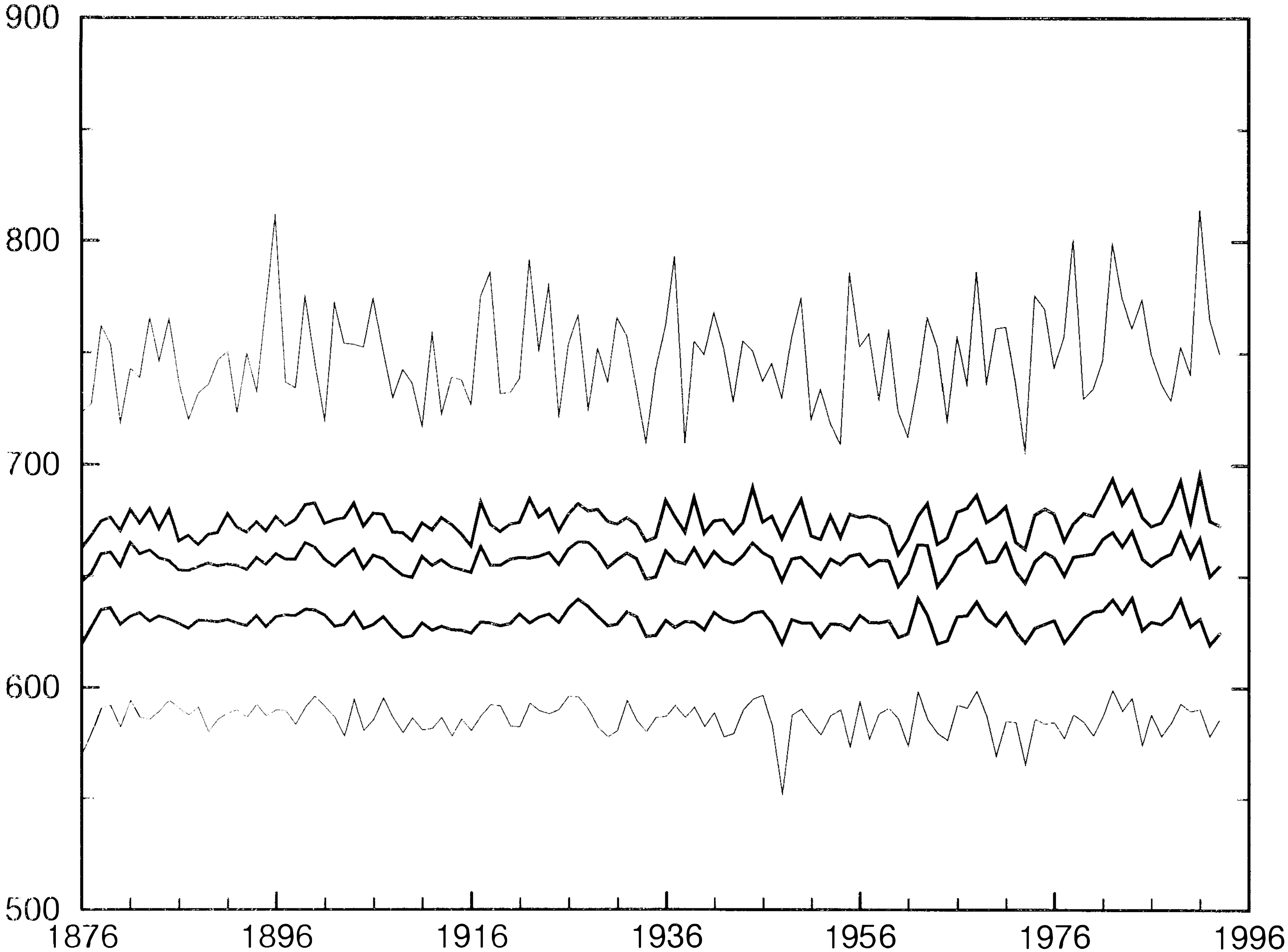

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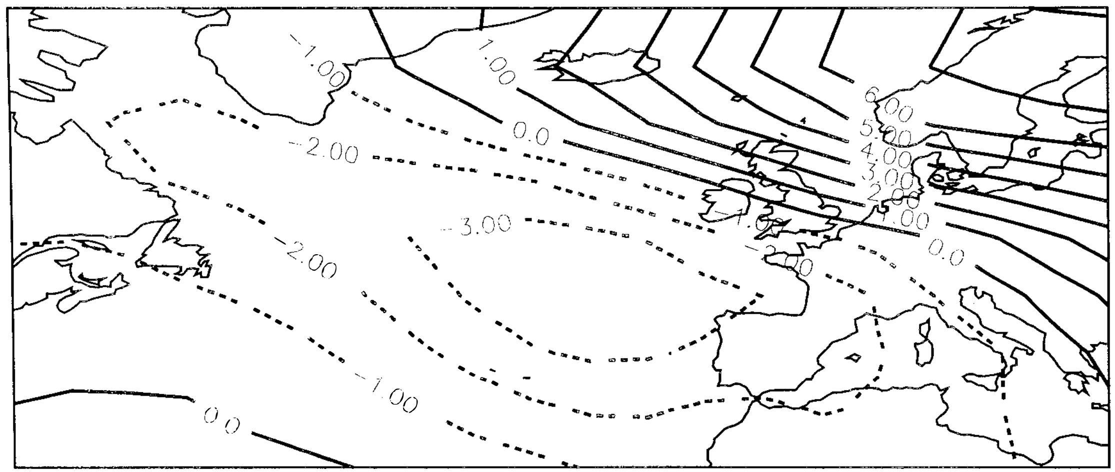

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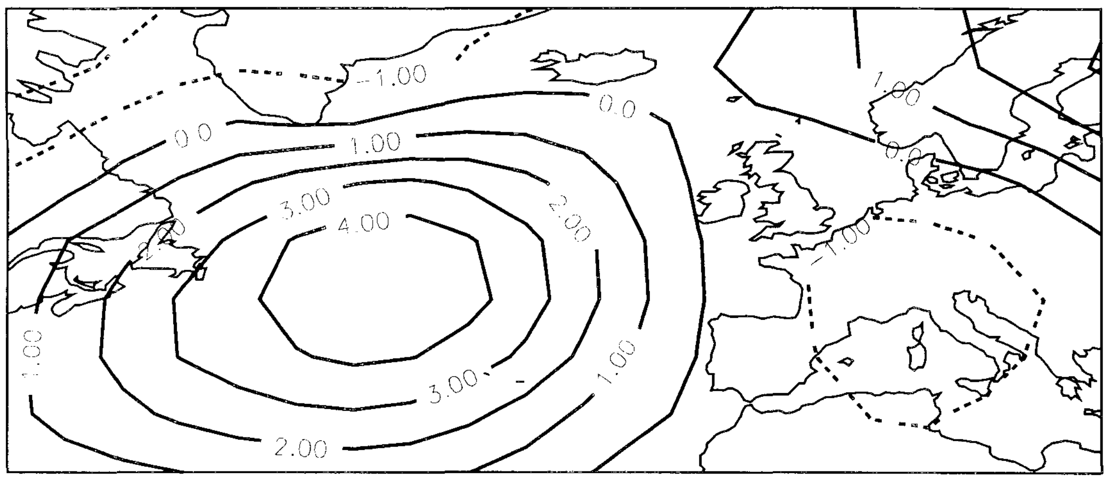

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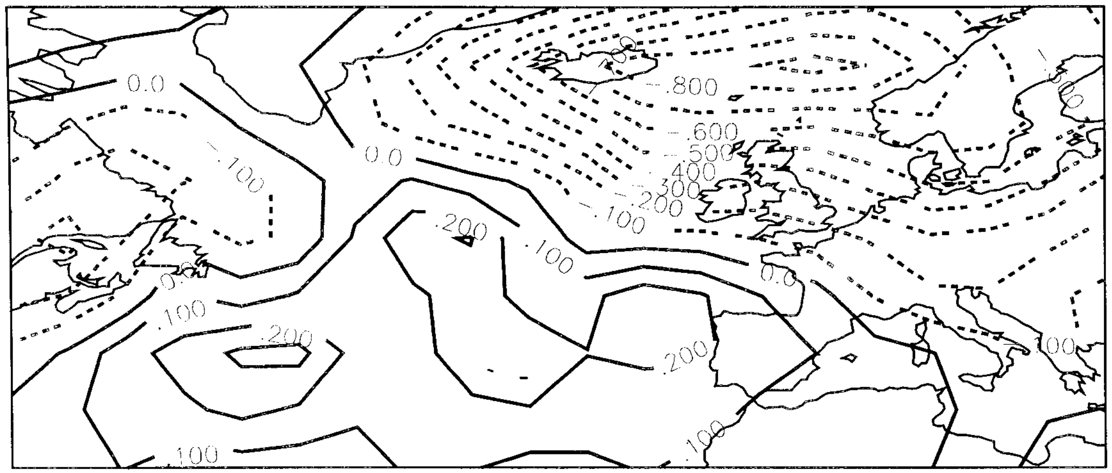
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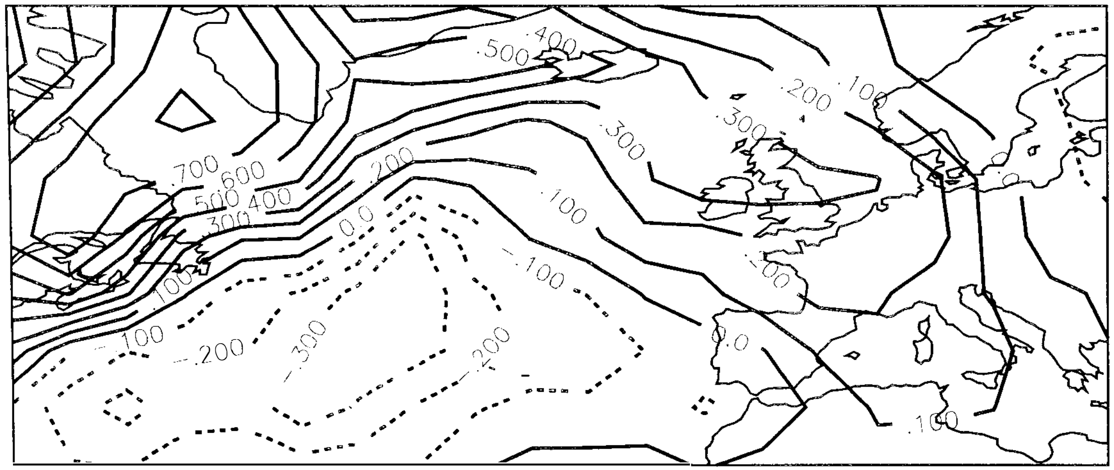

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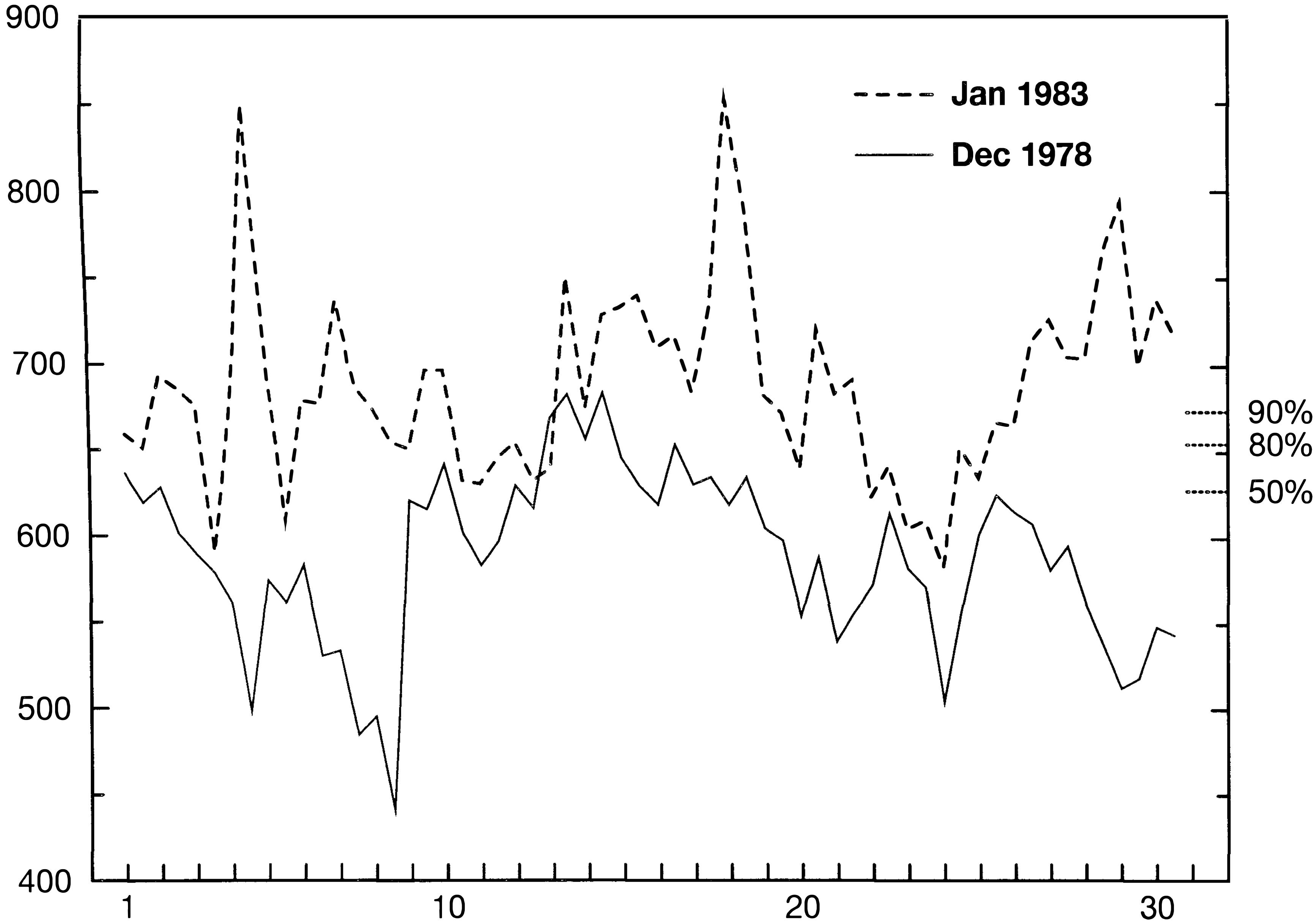

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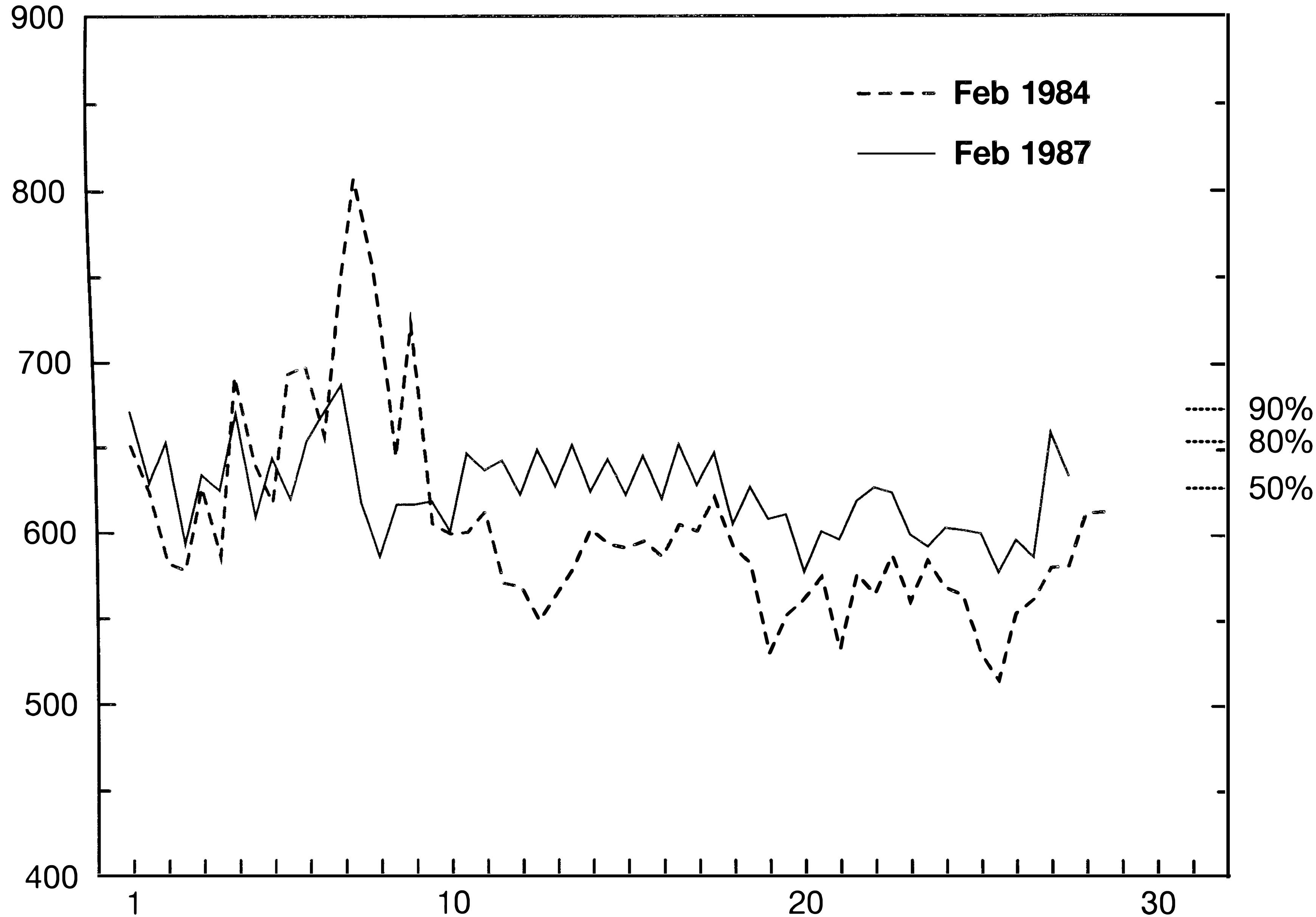

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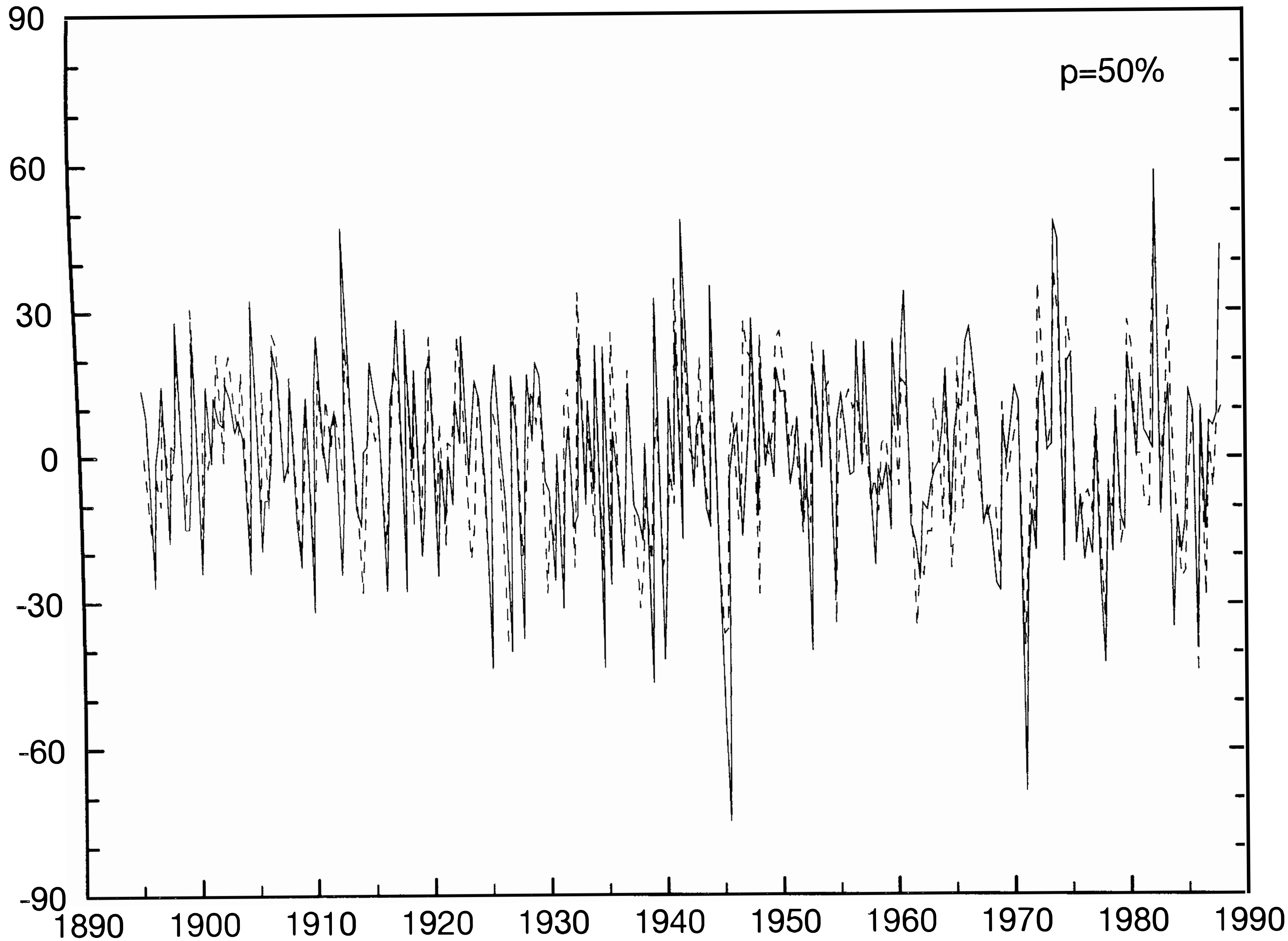

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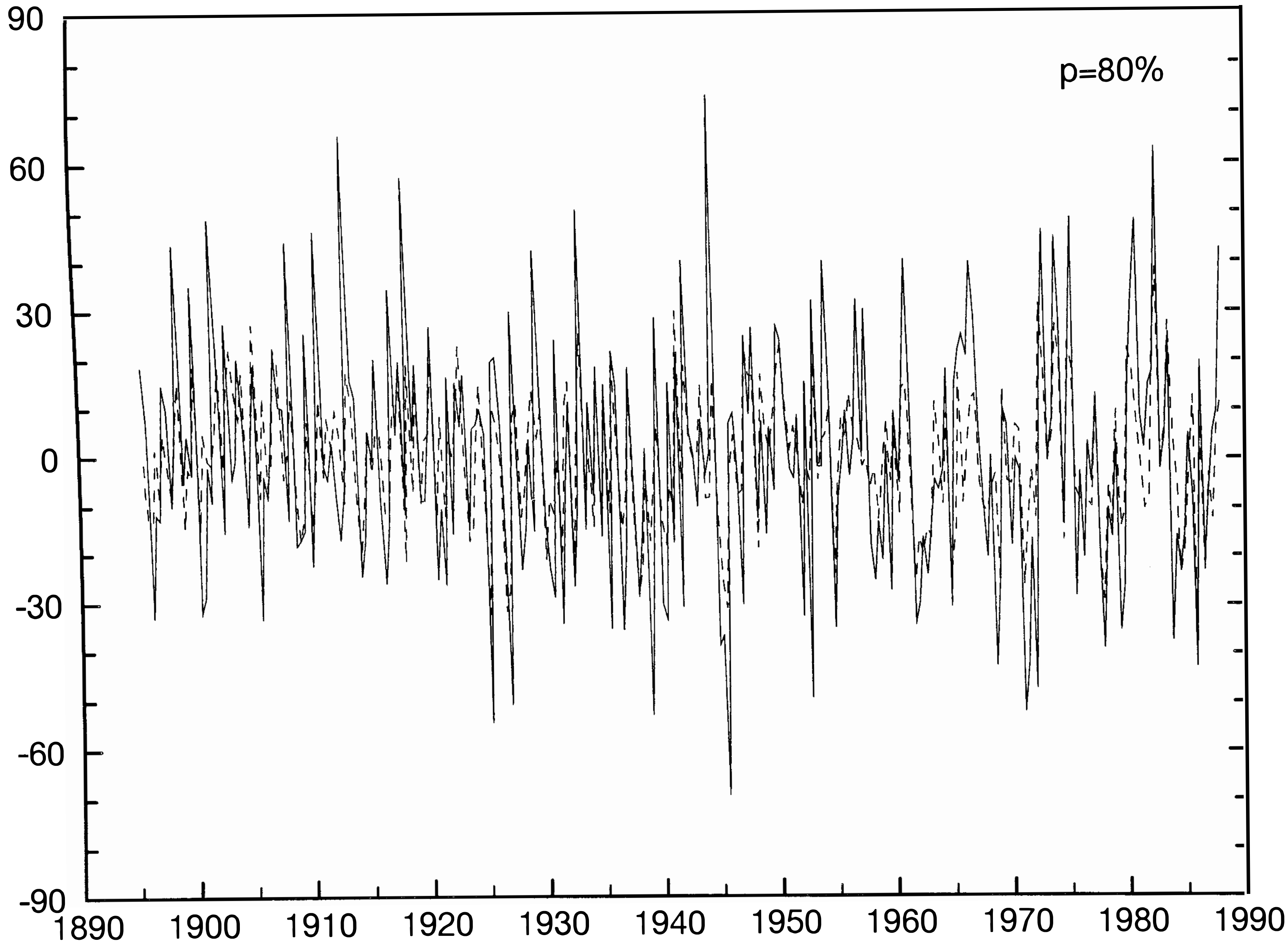
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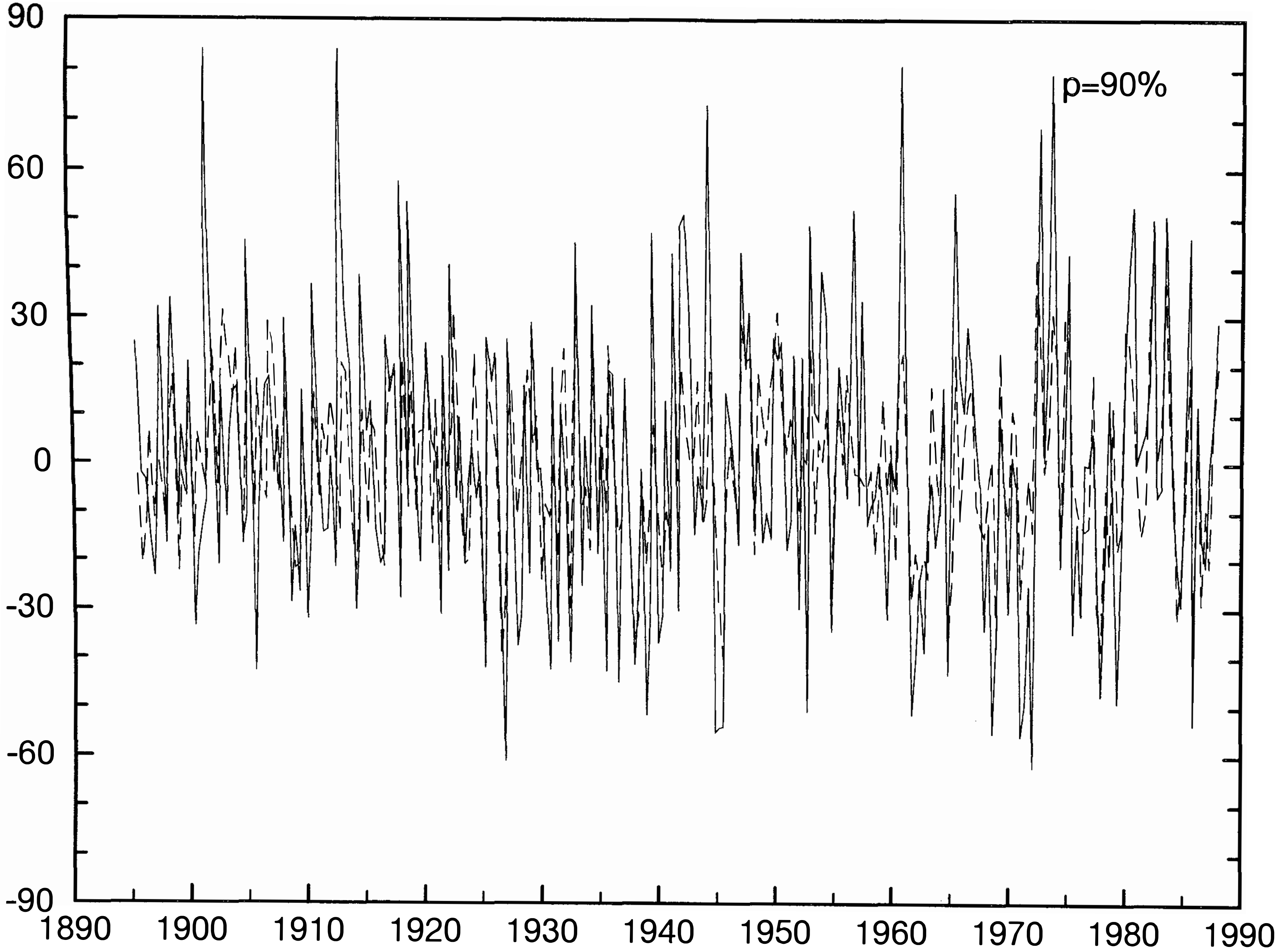
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