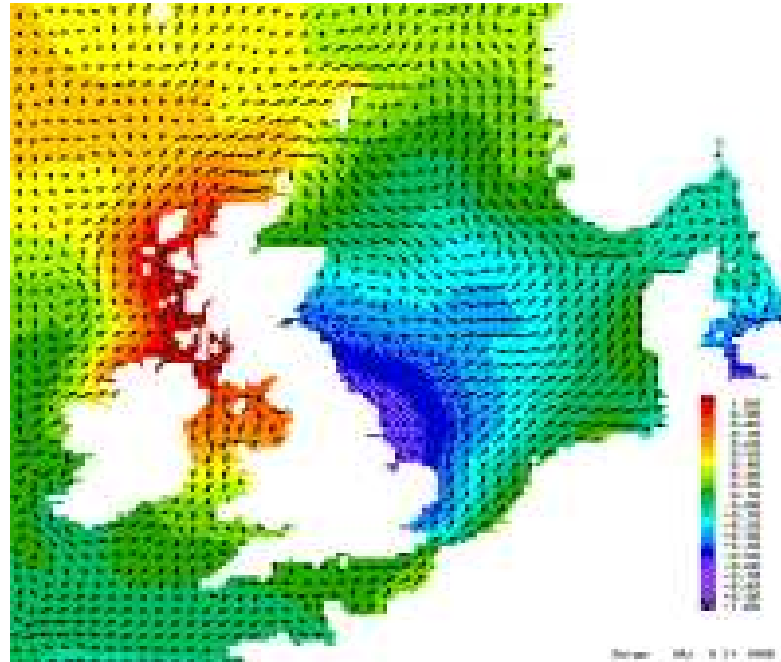


Spatial & temporal models for synthetic oceanographic extremes



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Structure of the talk

- 1 : Storm surges
- 2 : Extreme value methods
- 3 : A spatio-temporal model
- 4 : Application to North Sea storm surges

1 : Storm surges

- **Sea levels:**

Sea level = Mean sea level + Tides + Surges + Waves

- **Surges:**

Surge currents generated by wind stress & air pressure

Distort sea levels, especially in shallow constrained basins

Potentially major contribution to coastal flooding

- **Sea level change:**

Accepted increase in **global mean sea levels**

But are there different trends in **extreme** sea levels... ?

- **Changes in the storm surge climate:**

Increased **storminess** in the NE Atlantic (**WASA, 1998**)

could increase **magnitude** and **frequency** of storm surges

Not much **evidence** for such a change (**Bijl *et al.*, 1999**)

- **Numerical storm surge models:**

Complex **mechanistic models** to describe surge dynamics

(Bode and Hardy, 1997)

- **Analysis of model output:**

Use models to **reconstruct** past storm surge climates

Use EVT to analyse **statistical properties** of model output

(Flather *et al.*, 1998)

2 : Extreme value methods

- **The extreme value approach:**

Methodology for drawing inferences about extreme events,
based only on **data at relatively extreme levels**

EV models are motivated by powerful **asymptotic theory**,
and provide a **relatively robust basis for extrapolation**

- **The GEV distribution:**

Assume that there exist sequences a_n and b_n such that

$$\frac{\max(X_1, \dots, X_n) - b_n}{a_n} \rightarrow G \text{ as } n \rightarrow \infty,$$

when G is nondegenerate.

Then G has a generalised extreme value distribution,

$$F(z) = \exp \left[- \left\{ 1 + \xi \left(\frac{z - \mu}{\sigma} \right) \right\}^{-1/\xi} \right],$$

with parameters μ , σ & ξ .

- **Statistical inference & modelling:**

Assume asymptotics **valid at some finite but extreme level:**

GEV model describes maxima of **sufficiently long blocks**

Estimate model parameters using e.g. maximum likelihood

- **r -largest value model:**

A **generalisation** of the GEV model,
with the same parameters μ , σ and ξ

Describes the joint distribution of the
 r **largest order statistics** in a sequence

Fit to data on the r **largest events** in a block

Makes **more efficient use** of the available data

Asymptotic justification relies on r being **sufficiently small**

3 : A spatio-temporal model

- Let $X_{st}^{(k)}$ = k -th largest surge elevation in year t at site s
- Assume that $(X_{st}^{(1)}, \dots, X_{st}^{(r)})$ has an r -largest model with parameters $\mu(s, t)$, $\sigma(s, t)$ and $\xi(s, t)$
- Model parameters as smooth functions of time & space, using techniques from nonparametric regression

- **Temporal smoothing** (Davison and Ramesh, 2000)

For year t at site s maximise the **local likelihood**

$$\sum_{y=1}^n \phi \left(\frac{y-t}{h} \right) l \left[(\mu_{st}, \sigma_{st}, \xi_{st}); X_{sy}^{(1)}, \dots, X_{sy}^{(r)} \right]$$

Select the **bandwidth** h using e.g. **cross validation**

- **Spatio-temporal smoothing:**

Reduce uncertainty by **incorporating spatial information**

Need to ensure we smooth *only* the temporal trends

Achieve this through a **reparameterisation:**

$$\bar{\mu}_{st} = \mu_{st} / \hat{\mu}_s$$

$$\bar{\sigma}_{st} = \sigma_{st} / \hat{\sigma}_s$$

Use local likelihood to **simultaneously** smooth

the parameters $\bar{\mu}_{st}$, $\bar{\sigma}_{st}$ and ξ_{st} over space & time

4: Application to North Sea surges

- **'Model data':**

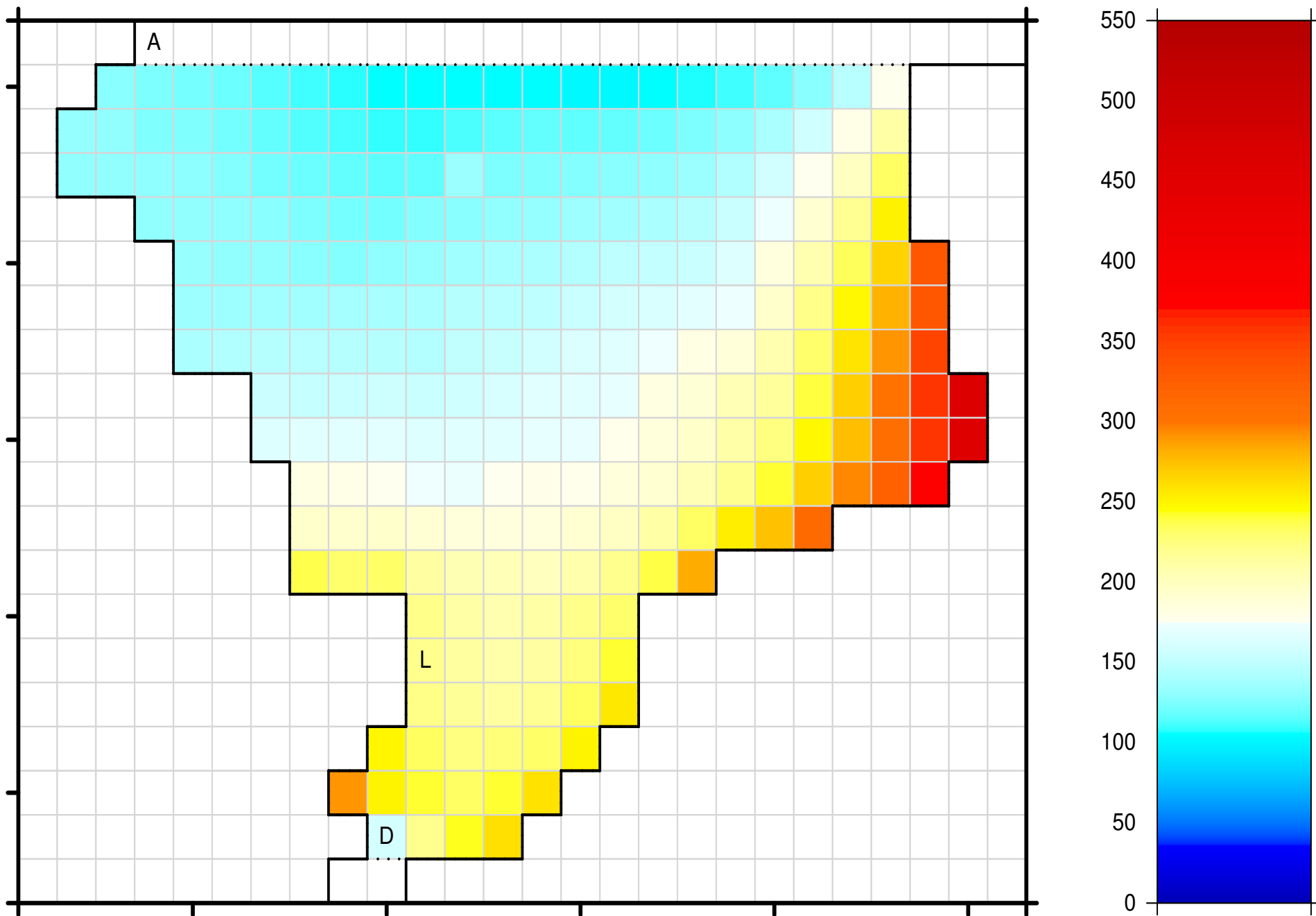
Partial output from a numerical model for
surge & tide dynamics in the North Sea

Forced using meteorological data for years 1955-2000

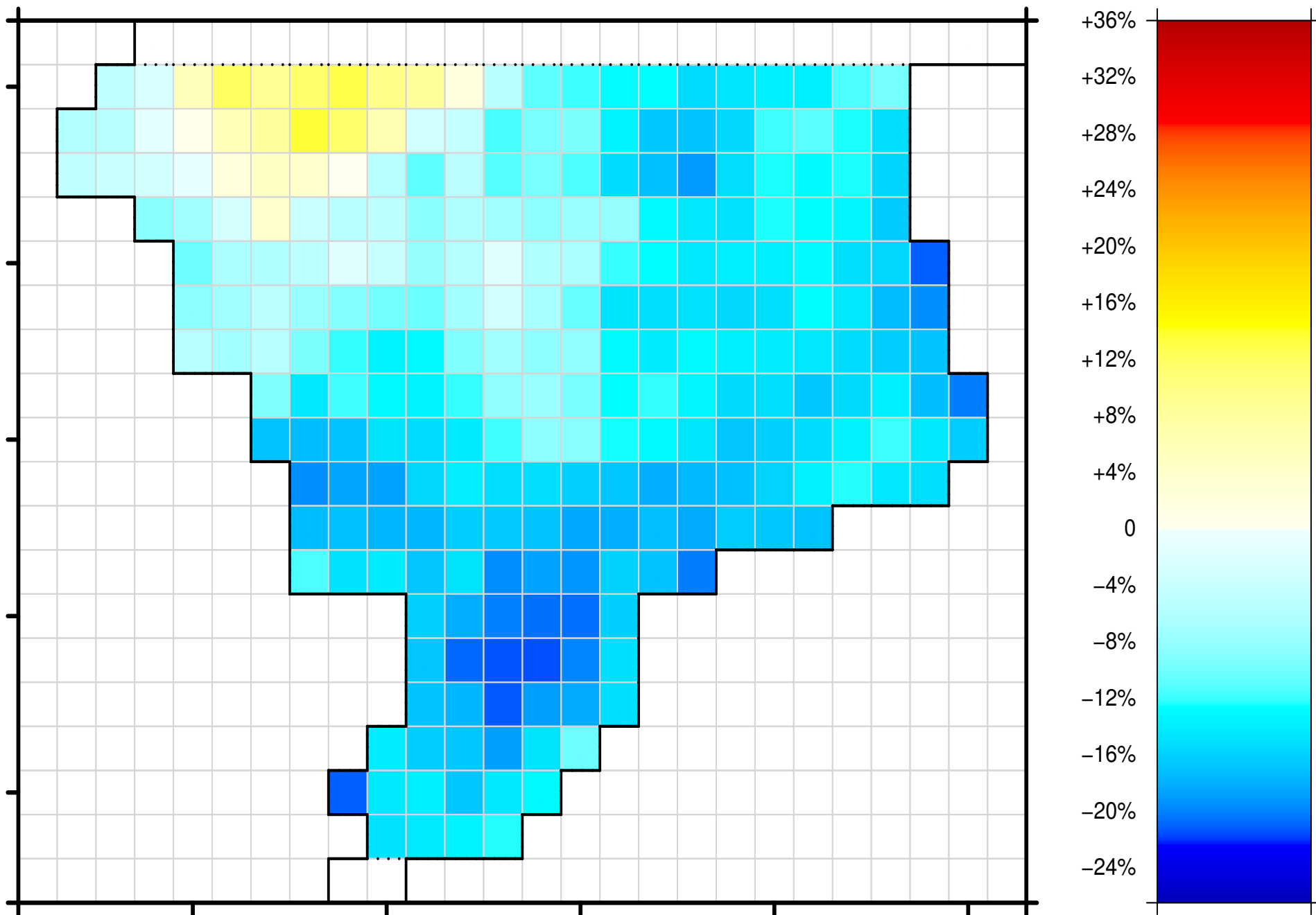
403248 hourly surge elevations for each of 259 grid cells



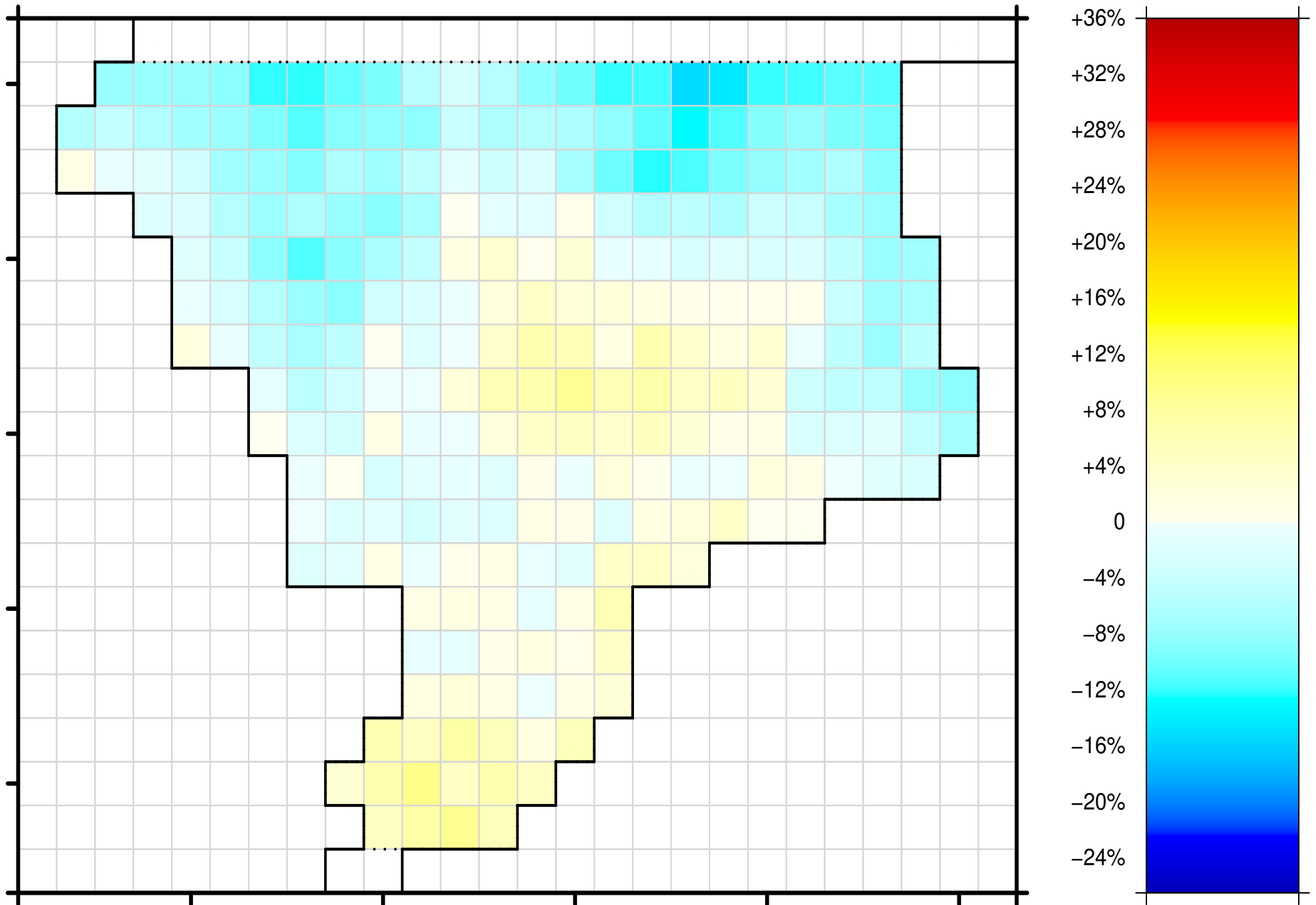
Estimated 50y return levels, based on an r-largest fit at each site



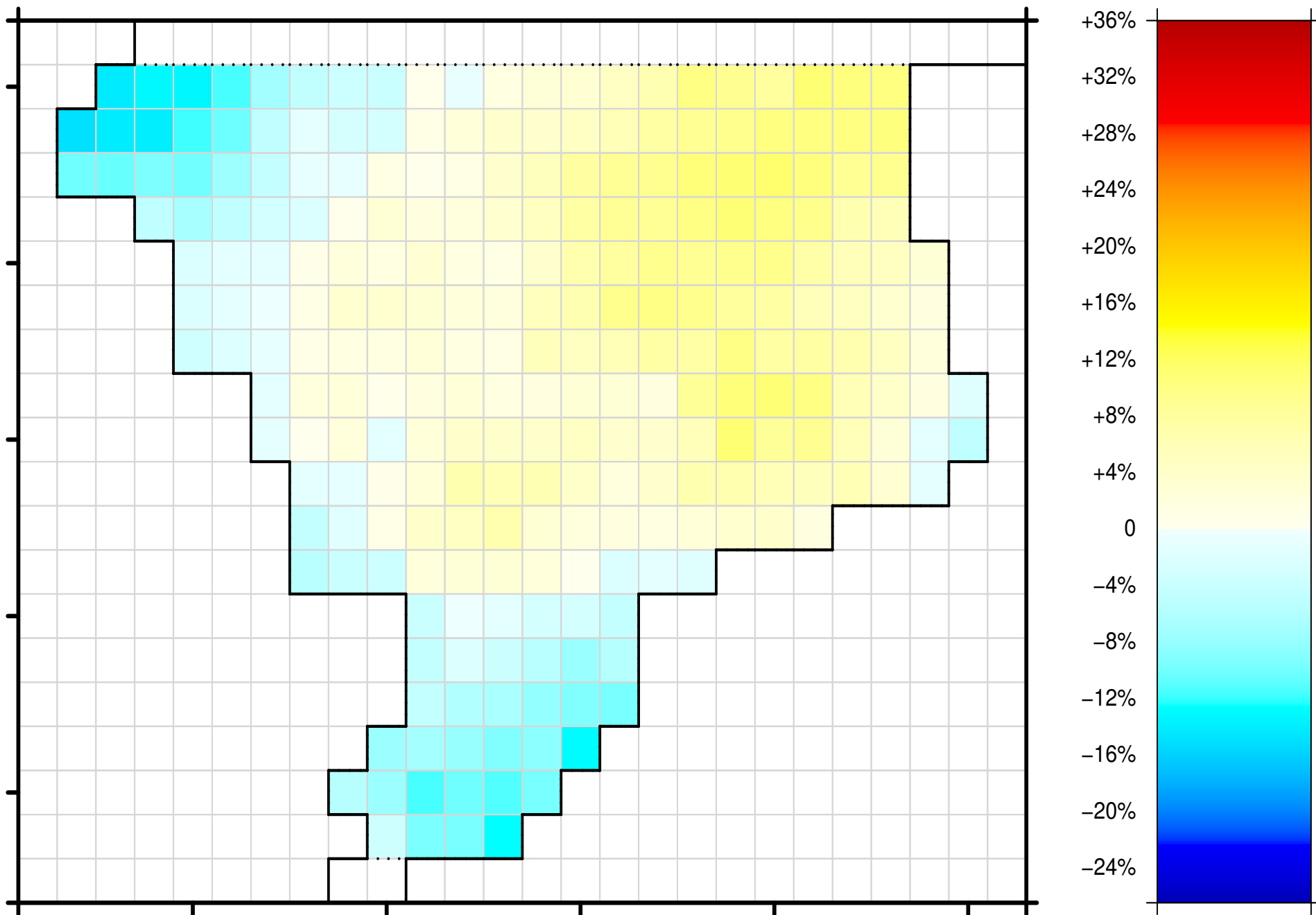
Smoothed deviations in 50y return levels - 1955



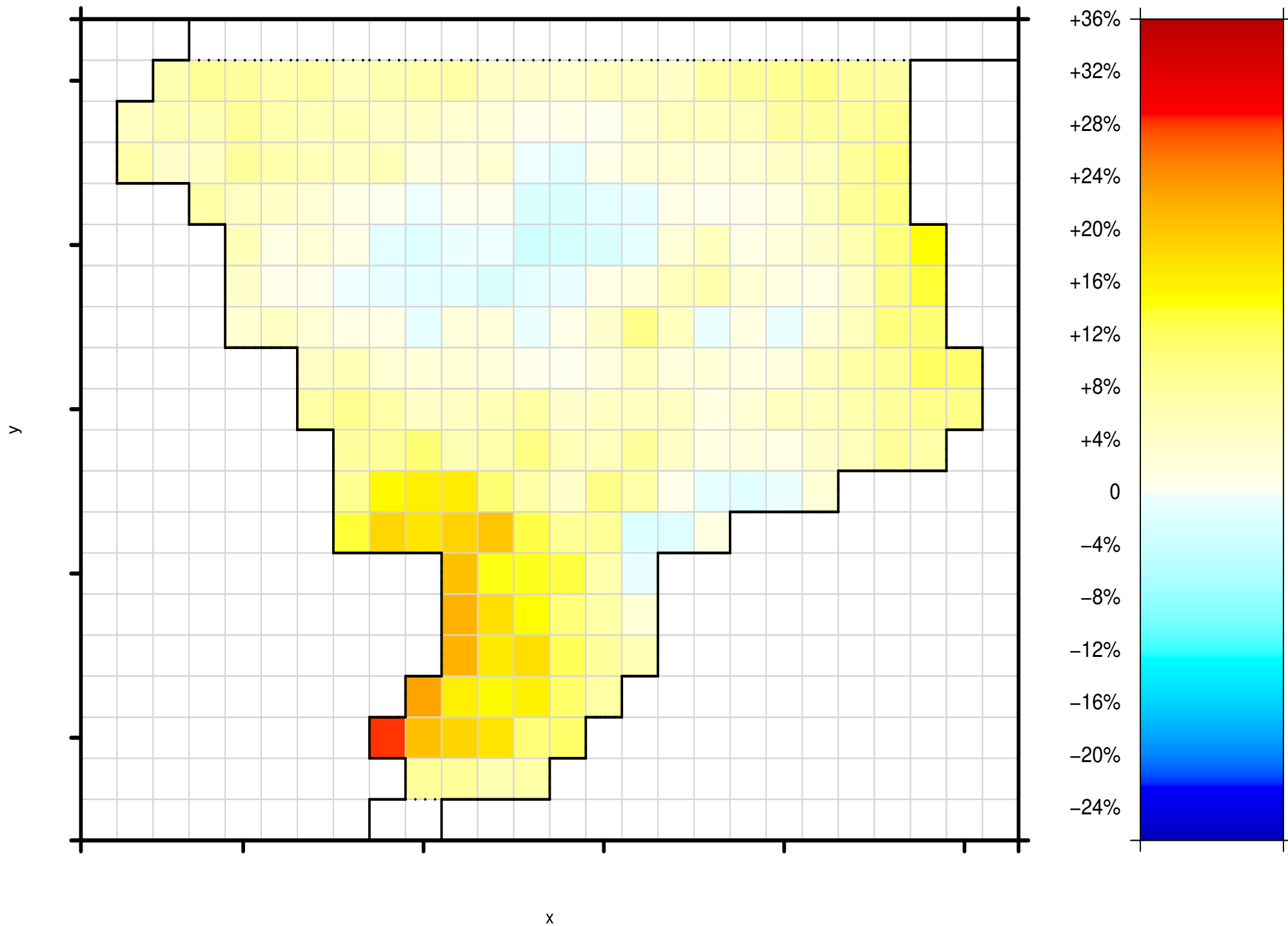
Smoothed deviations in 50y return levels - 1962



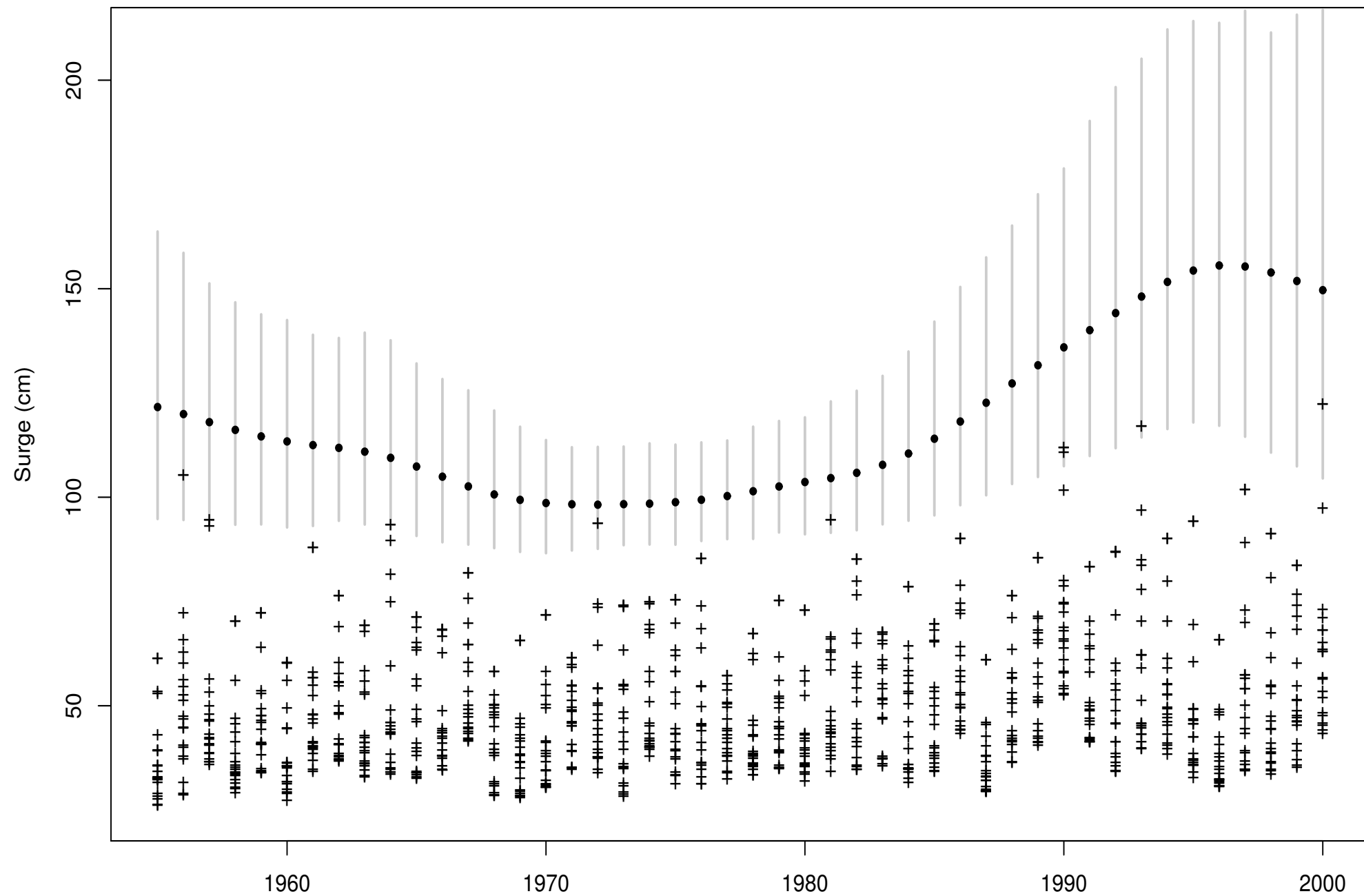
Smoothed deviations in 50y return levels - 1982



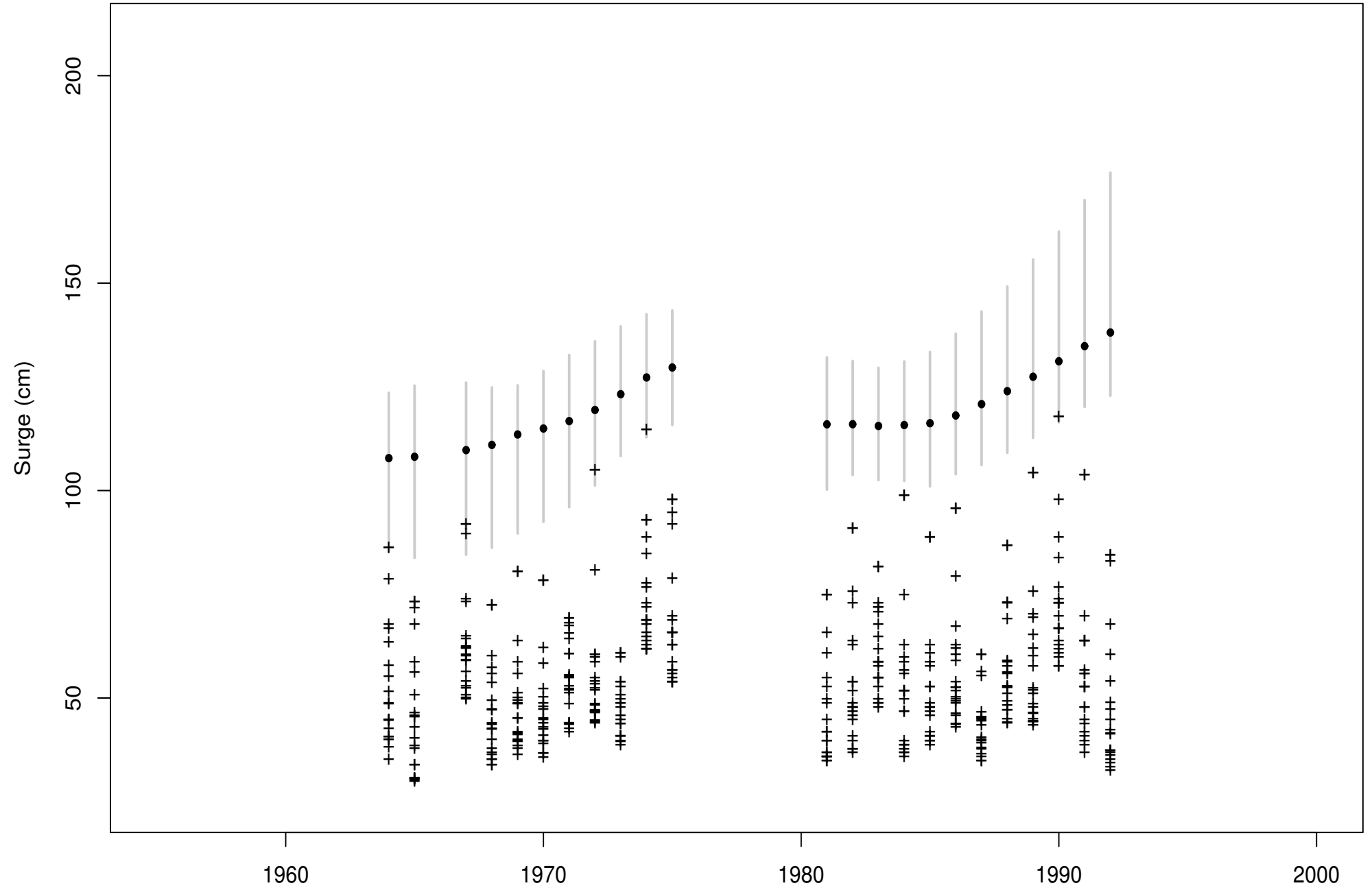
Smoothed deviations in 50y return levels - 1990



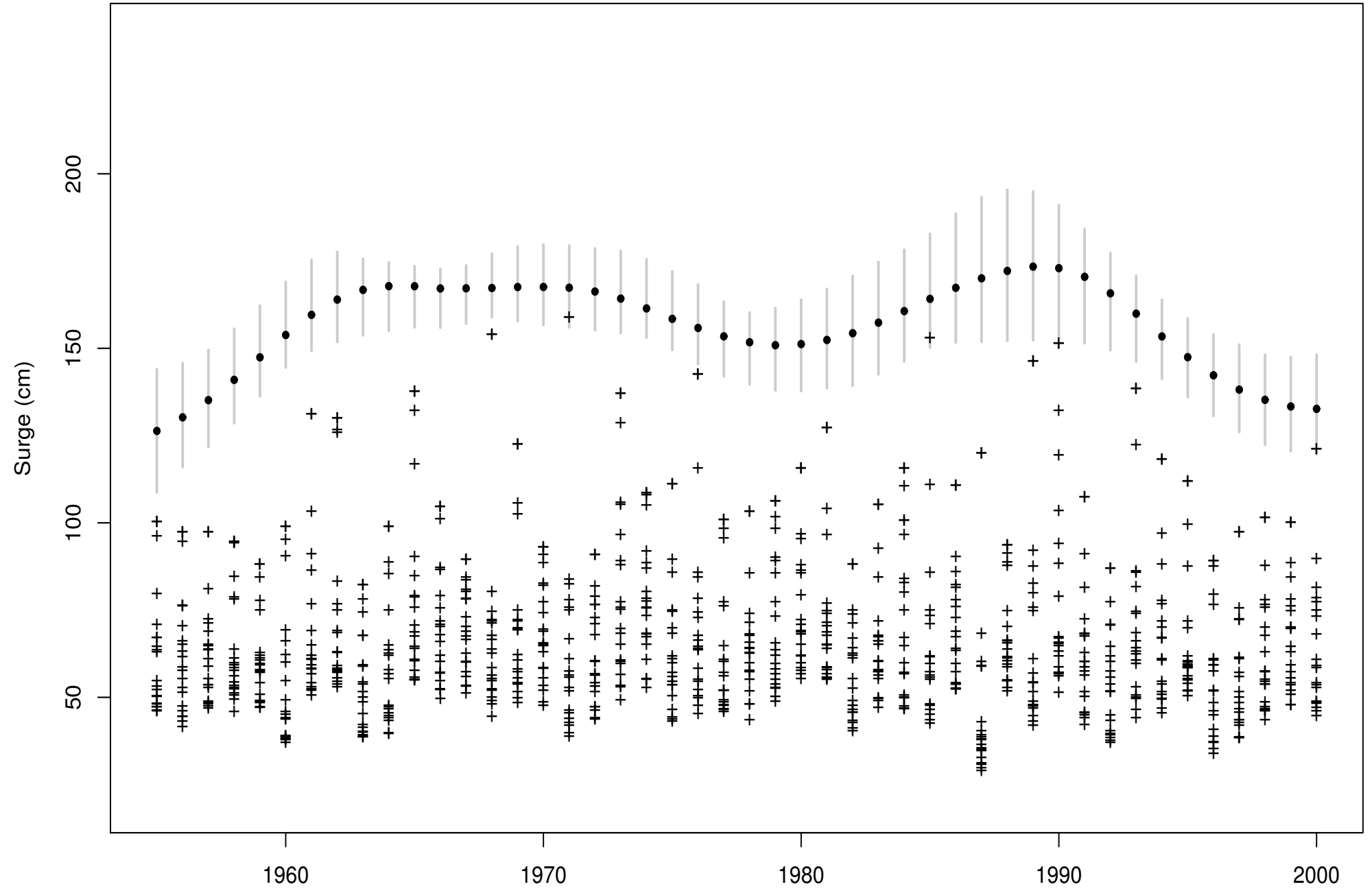
Aberdeen – model output



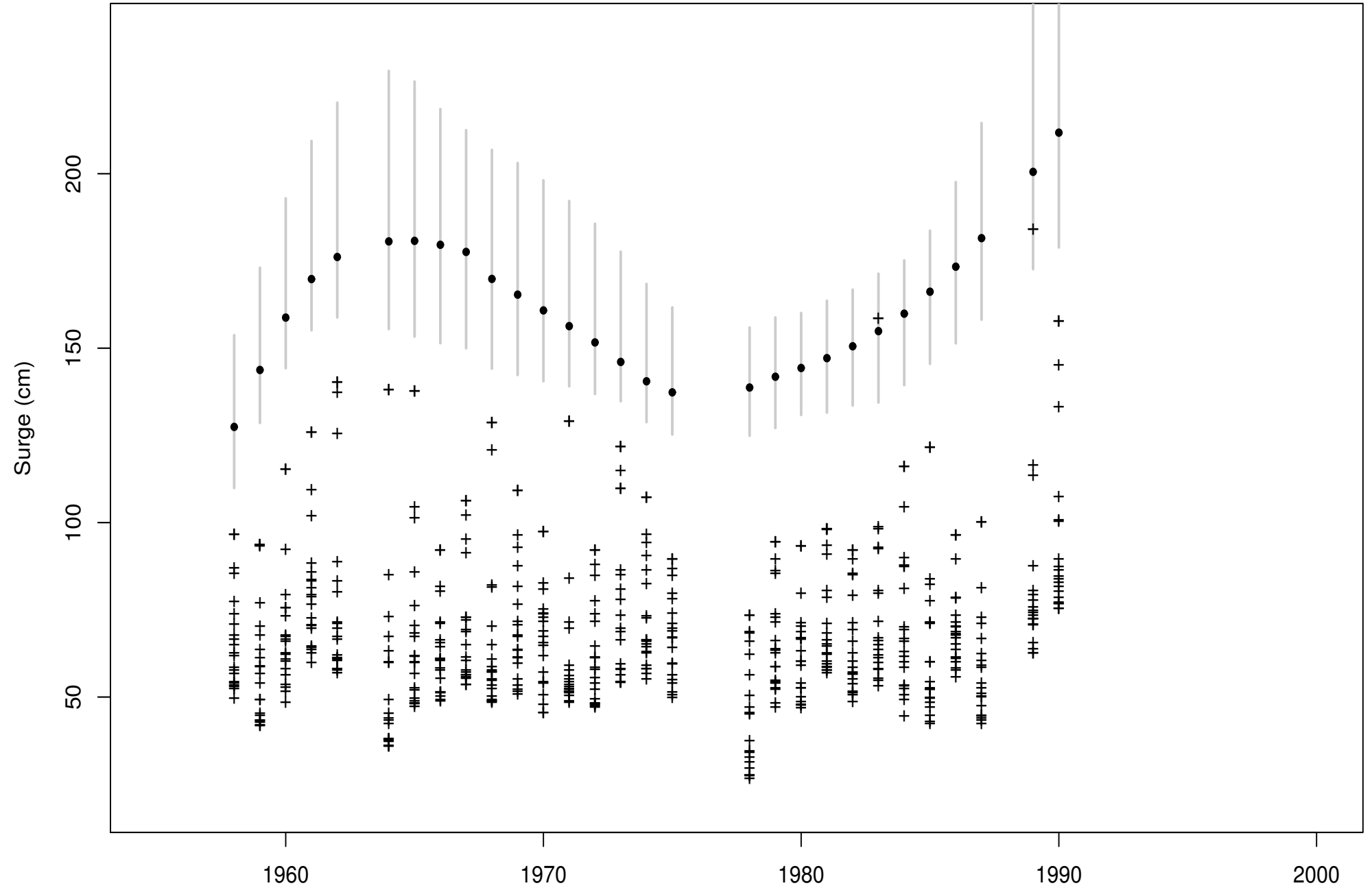
Aberdeen – observational data



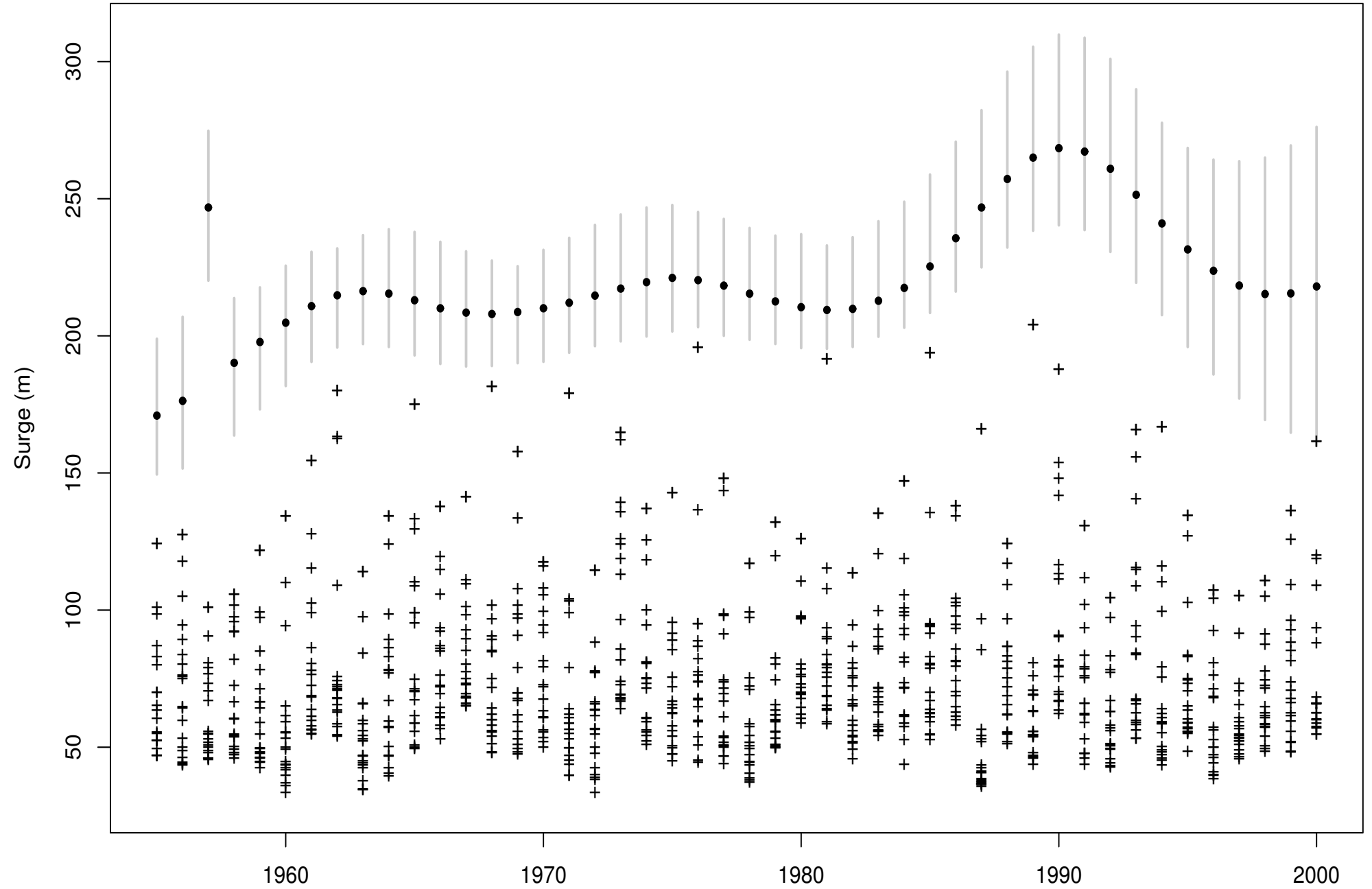
Dover – model output



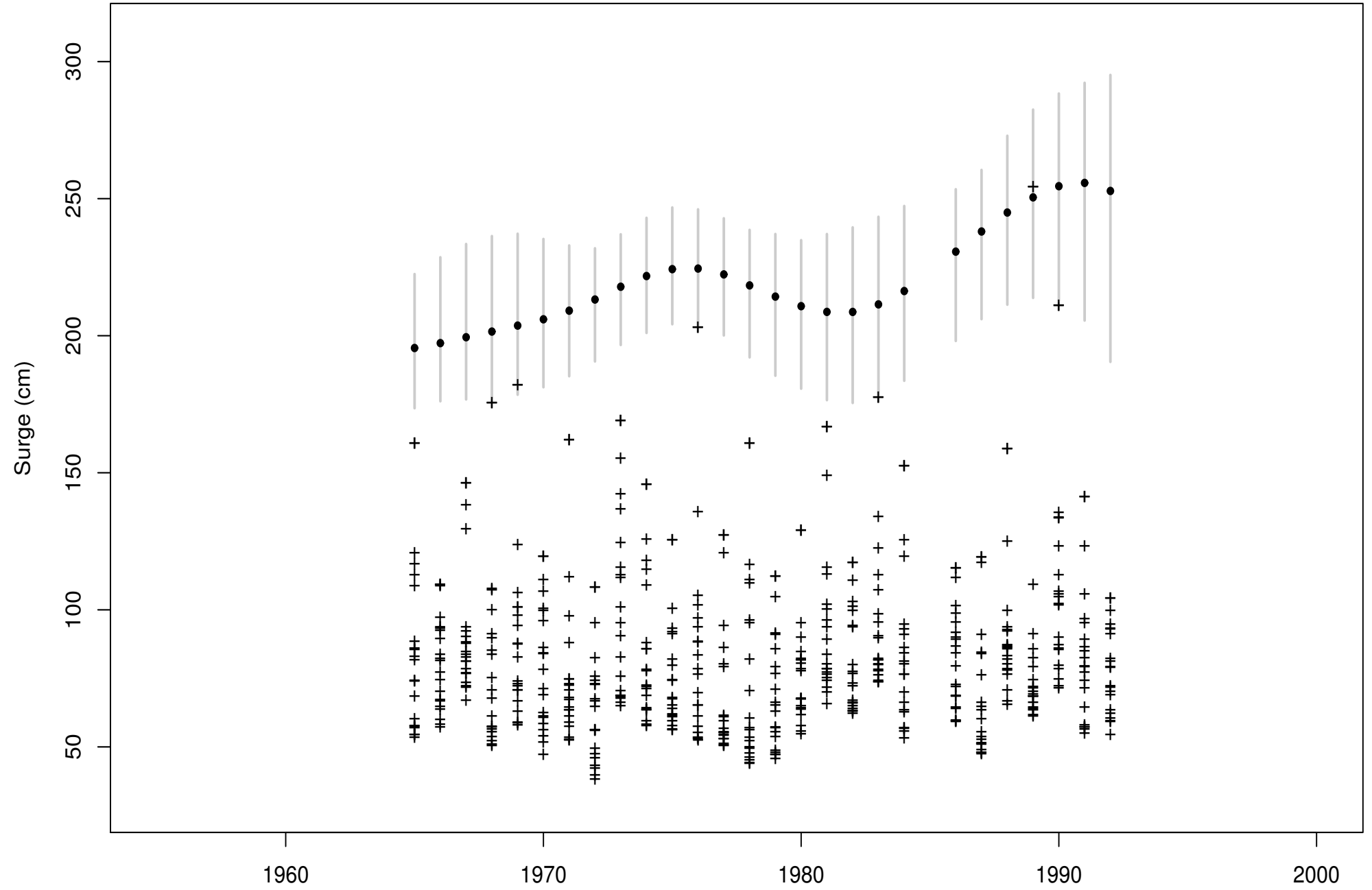
Dover – observational data



Lowestoft – model output



Lowestoft – observational data



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