Misuses of Statistical Analysis in Climate Research

Hans von Storch
Max-Planck-Institut für Meteorologie
Hamburg, Germany

Talk presented at the
6 IMSC, Galway
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See detailed paper in
von Storch and Navarra (Eds.):
Analysis of Climate Variability —
Applications of Statistical Techniques.
Springer Verlag 1995, 334 pp.

Many Misuses Arise from ...

- **Obsession with statistical recipes** such as statistical testing.
- **Use of** statistical techniques in a cook book like manner.
- Misunderstanding **of** names such as the decorrelation time.
- The faith in results obtained with **sophisticated techniques.**

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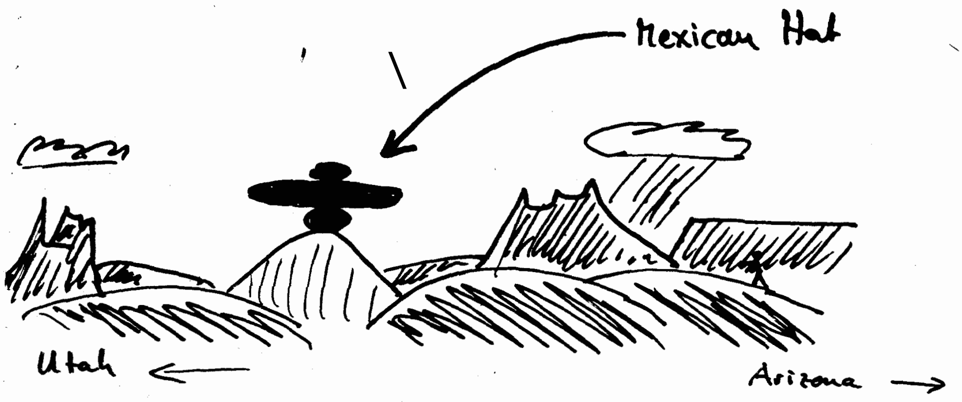


H_0: Mexican Hat is natural

What is the probability to observe th[illegible] stones that form [illegible] Mexican hat just by natural processes ?

Walk thru the desert and sample. Check 10^6 triples of stones.

Result of survey:

$\#$ mexican hats $= 1$

$\#$ other combinations $= 10^{+6} - 1$.

$\Rightarrow p\,(y = \text{Mexican Hat} \,/\, y \text{ is natural}) \leqq 10^{-6}$.

$\Rightarrow$ Reject H_0, accept H_A = Mexican Hat is man-made.

But H_0 is natural.

?

Mexican Hat.

Problem

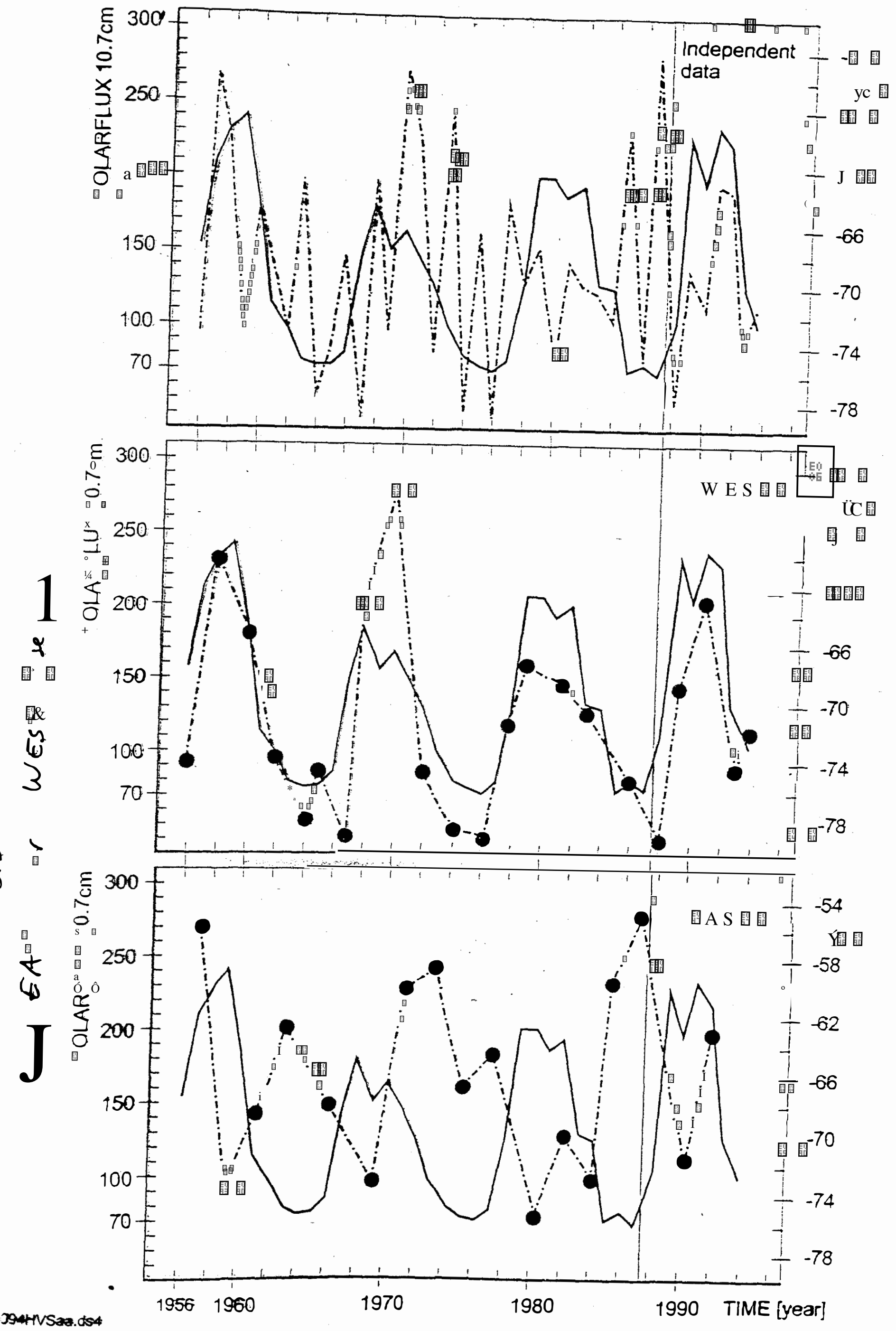
Nullhypothesis was formulated
<u>after</u> the observation has been made.

Example: Solar flux, the QBO and
stratospheric data.
(Labitzke & van Loon)

<u>Question</u>: Is any analysis of historical data
[illegible] of a Mexican Hat?

North Pole 30hPa JF temperature

Labitzke & van Loon 88



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The Case of

Misleading Names ...

... the DECORRELATION TIME

(see Thiébaux & Zwiers, 1984)

t-test continued

nullhypothesis $\mu = 0$.

n samples available to estimate $\hat{\mu}$ and $\hat{\sigma}$.

$$t = \frac{\hat{\mu}}{\sqrt{\frac{1}{n}} \cdot \hat{\sigma}}$$

$Var(\hat{\mu}) = \frac{1}{n} \cdot \sigma^2$ 4 the [illegible]ples [illegible] independent.

$$\Rightarrow \quad t \approx \frac{\hat{\mu}}{\sqrt{Var(\hat{\mu})}}$$

Equivalent Sample Size.

What if $\{x_1, \ldots x_n\}$ are serially correlated. Let's assume

$$x_{t+1} = \alpha x_t + \text{white noise}$$

Then the t-test is not applicable.

BUT $\quad \mathrm{Var}(\bar{x}_n) = \sqrt{\frac{1}{n_e}}\,\sigma^2 \quad$ with $\quad n_e = \frac{1-\alpha}{1+\alpha}\, n$

so that

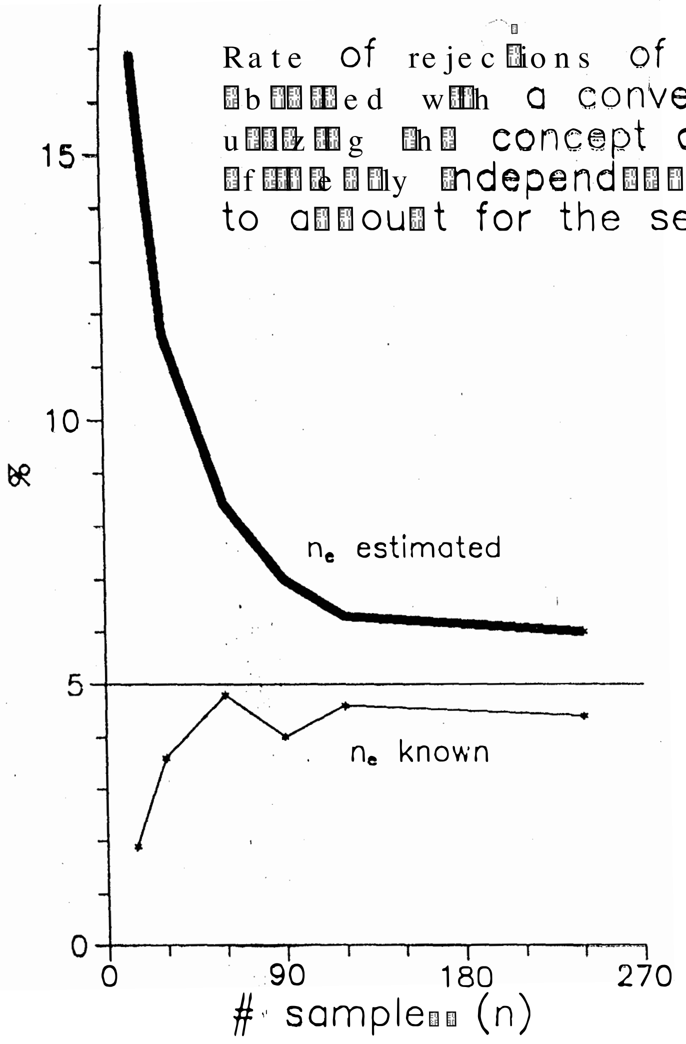
$$t_e(x_1, \ldots x_n) := \frac{[illegible]}{\frac{1}{n_e}\,[illegible]} = \frac{y}{\sqrt{\mathrm{Var}\, y}}$$

⟹ RECIPE

1) Calculate / estimate [illegible] from data
2) Calculate t_e
3) Calculate p-value of t_e from t-distribution with $n_e - 1$ degrees of freedom
4) Make decision [illegible] nullhypothesis

Fine ?

... We made [illegible] Monte Carlo experiment with [illegible] AR(1)-process [illegible] 0.6 and variable [illegible] With [illegible] correct n_e and [illegible] estimated [illegible]



100 Monte Carlo Simulation were done for an AR(1)-process with memory 0.6.

NOTEBOOK C: GO GRA DAT N→E
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What to do?

... if $n_e \geq 30$ use Gauß-test

.... if [illegible] $\leq$ [illegible] use [illegible]Table-Look-Up[illegible] test

(Zw[illegible] & von Stor[illegible] J[illegible]Climate 1995)

Decorrelation time τ of an AR(1)-process

(*) $$X_t = \alpha X_{t-1} + Z_t$$

[with $\alpha < 1$, Z_t = white noise] is

$$\tau = \frac{1+\alpha}{1-\alpha} \geq 1$$

Process (*) is equivalent to

(**) $$X_{t+k} = \alpha^k X_{t-1} + Z'_t$$

with white noise Z'.

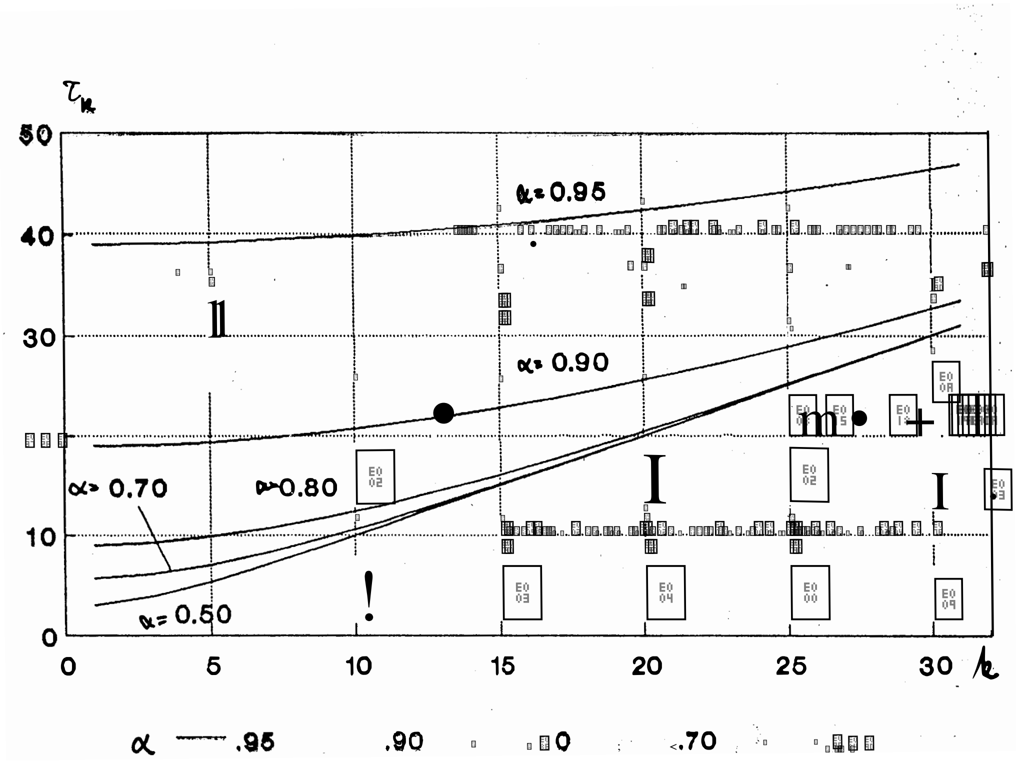
The decorrelation time of (**) is

$$\tau_k = \frac{1+\alpha^k}{1-\alpha^k} \cdot k \geq k$$

and

$$\lim_{k \to \infty} \frac{\tau_k}{k} = 1$$

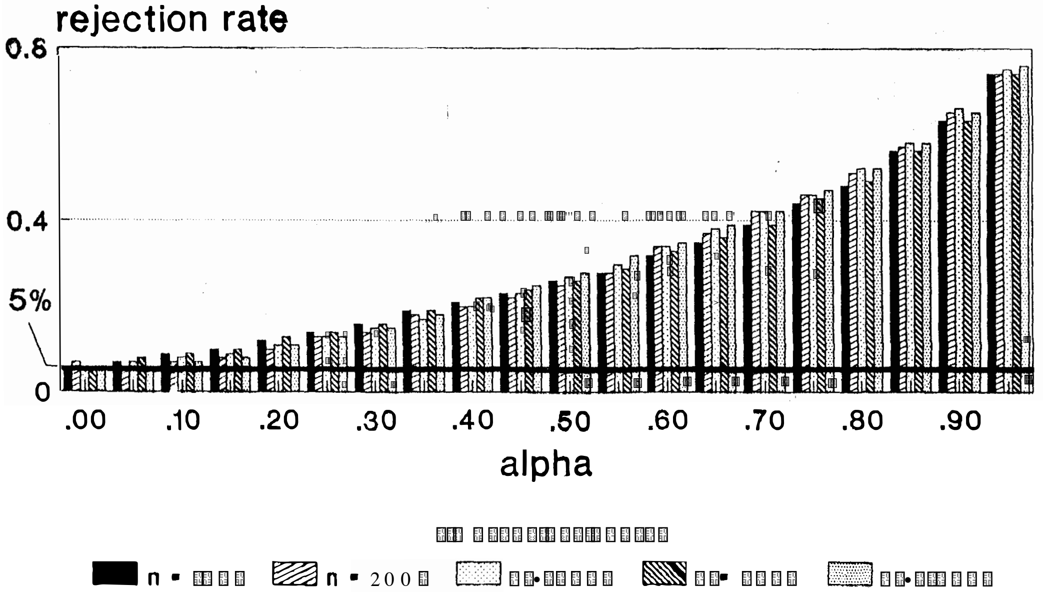
Thus, for sufficiently large time increments the decorrelation time is equal to the time increment independent of the "memory" α of the system.



τ_k
50
40
30
10
0
0
5
10
15
20
25
30
k
α= 0.95
α= 0.90
α= 0.70
α=0.80
α= 0.50
α .95
.90
.70

Kulkarni & von Storch, 1995

Rejection Rates of Mann-Kendall Test For Serially Correlated Data; Risk 5%
(AR(1)-process with specified alpha)



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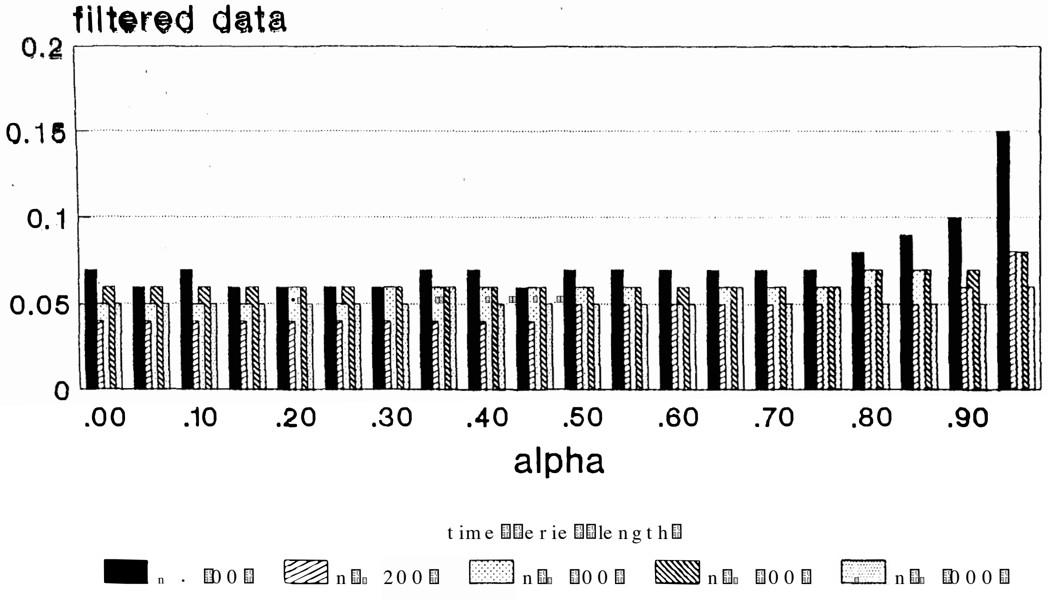

CONCLUSION

Statistics is ...

not **a** *Wunderwaffe* **to extract a wealth of information from a limited sample of observations**

but an indispensable tool in the evaluation of limited empirical evidence

For extracting more information from a data set about the underlying structure assumption about the underlying structure are to be made. In general, such assumptions have to be justified by additional information unrelated to the data (for instance from numerical experimentation or theoretical reasoning).