High temperature extreme values in the climate change context: EDF experience

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Collaborative work EDF/R&D Paris 11 University (Orsay)

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Adaptation of the production facilities

- 2003 heat wave $\Rightarrow$ unprecedented temperature levels
- Climate is changing and temperatures are rising $\Rightarrow$ how high could temperature extremes become in the next decades?
- Installation dimensioning or verification $\Rightarrow$ estimation of rare events through the statistical extreme value theory (return levels)
- How to evaluate a temperature return level in a non stationary context?

EVT : Verification of hypotheses

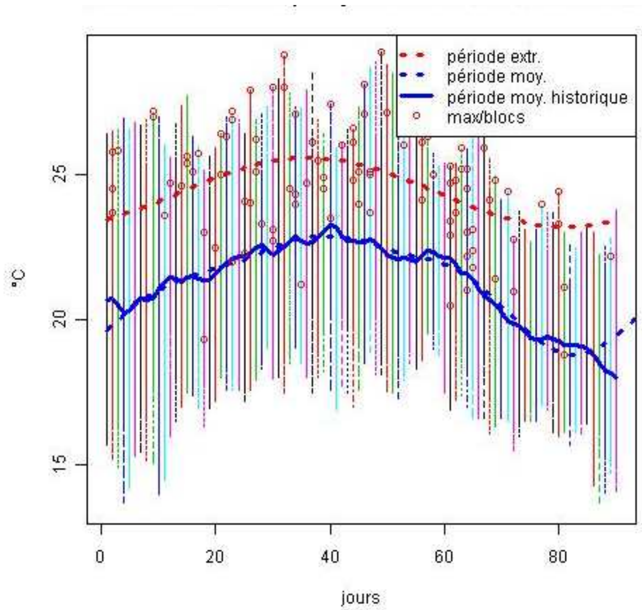
- Independence
  - Calculation of the extremal index θ
    - Air temperature: ≈ 0.5
    - River temperature: ≈ 0.2

- Identical distribution
  - Distribution of the annual maxima

Air temperature

	50-day blocks in summer	
	14/06-02/08	03/08-21/09
Block maxima	102	110
Summer maxima	60	46

River temperature



	block 1	block 2	block 3
77-08	9	22	1

de-seasonalisation + θ

First approach: trends in parameters

- Statistical extreme value theory
  - Identification of trends in the parameters of the extreme value distributions
  - Extrapolation to derive non stationary return levels
  - GEV:

$$\frac{1}{nb}\sum_{t=t_0}^{t_0+365a}\left\{1-\exp\left[-(1+\frac{\xi}{\sigma(t)}(z_a-\mu(t))^{-1/\xi}\right]\right\}=1$$

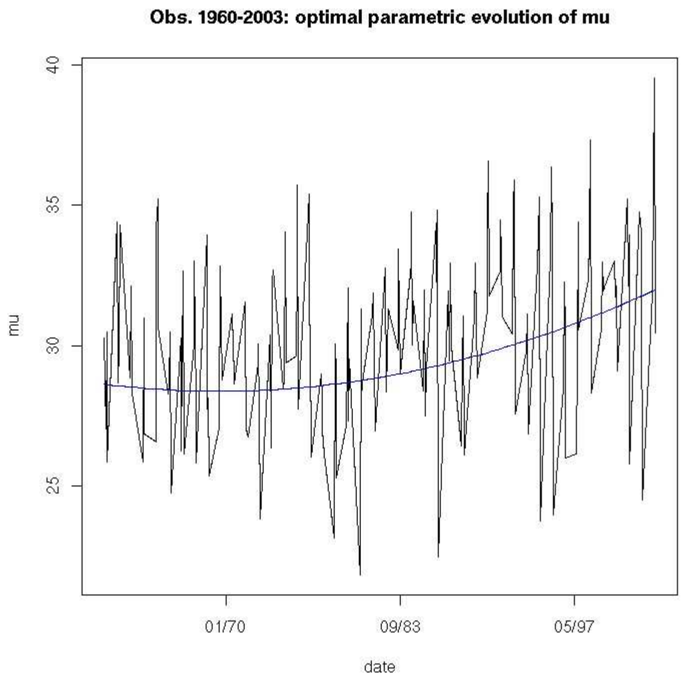
  - POT:

$$\sum_{t\in D(t_0,a)}(1+\frac{\xi}{\sigma(t)}(z_a-u))^{-\frac{1}{\xi}}I(t)=1$$

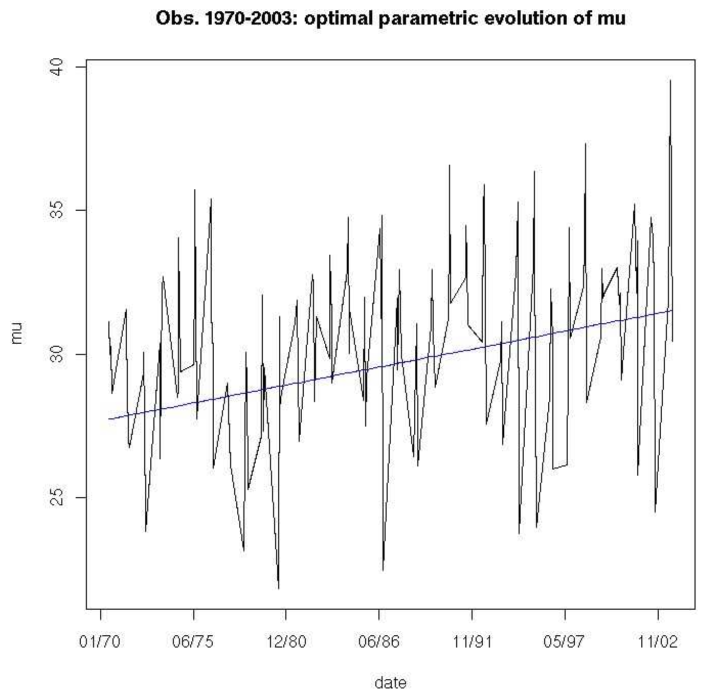
- Main difficulties
  - Trends are identified from relatively short samples of high level values
  - Extrapolation necessitates robust and objective trends: difficult to avoid sample effects
  - Sensitivity to high values in the end of the sample

Examples

1960-2003

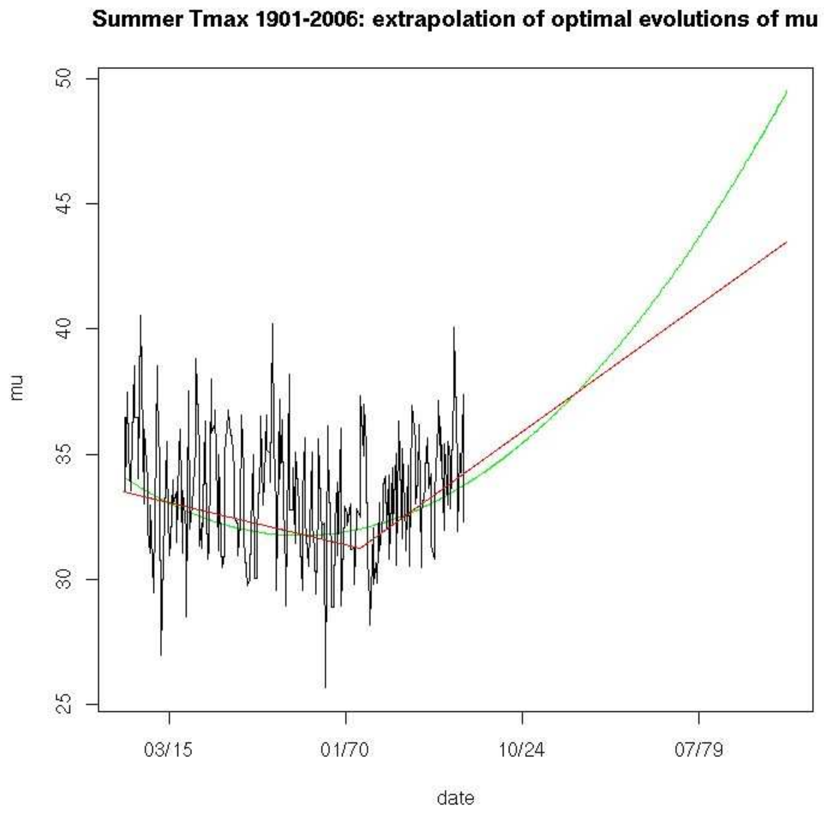


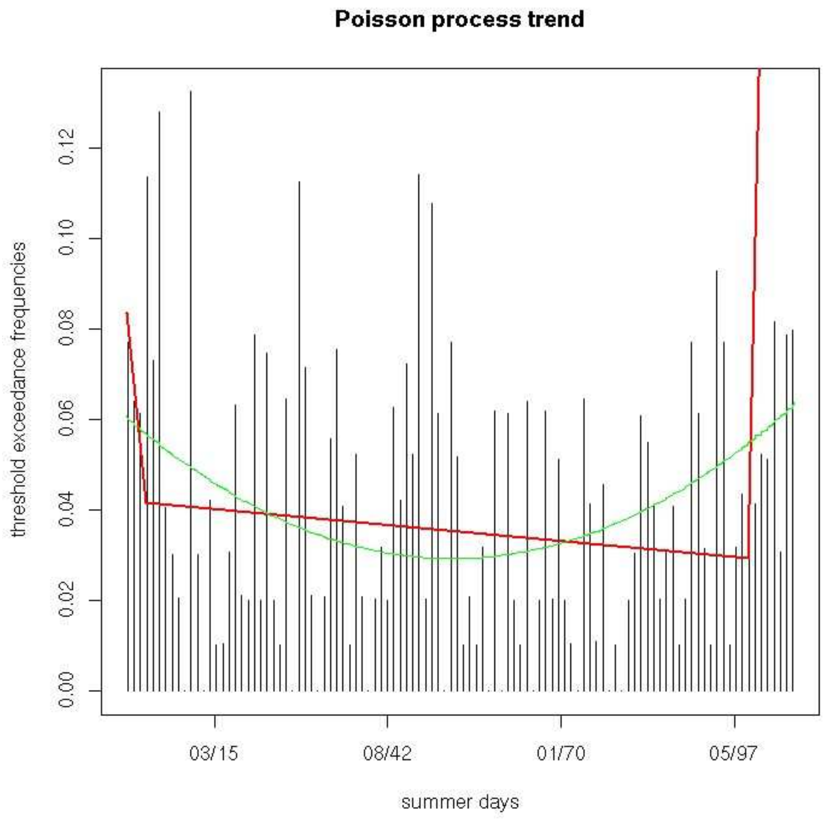
1970-2003



Optimal polynomial trend of μ over 2 different periods

Examples



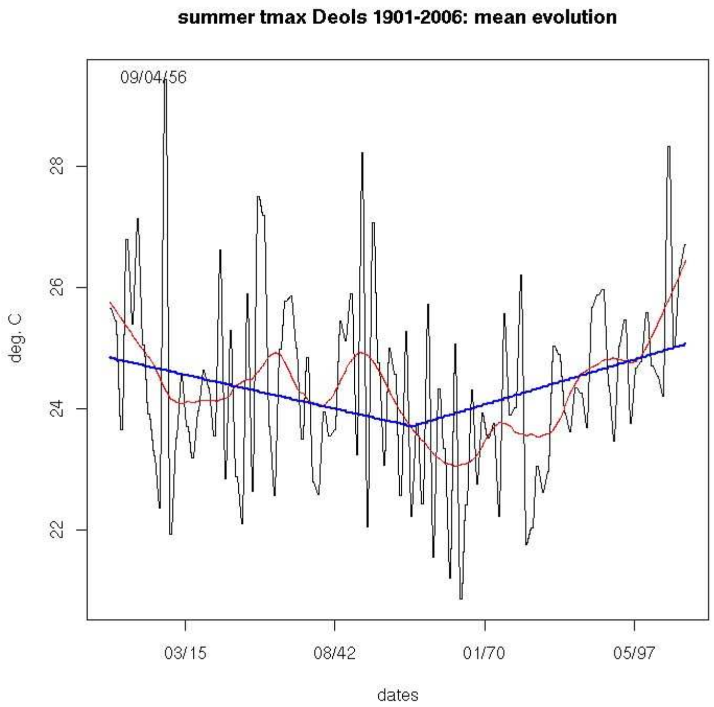


Polynomial or Continuous Piecewise Linear trend extrapolation?

A possible way

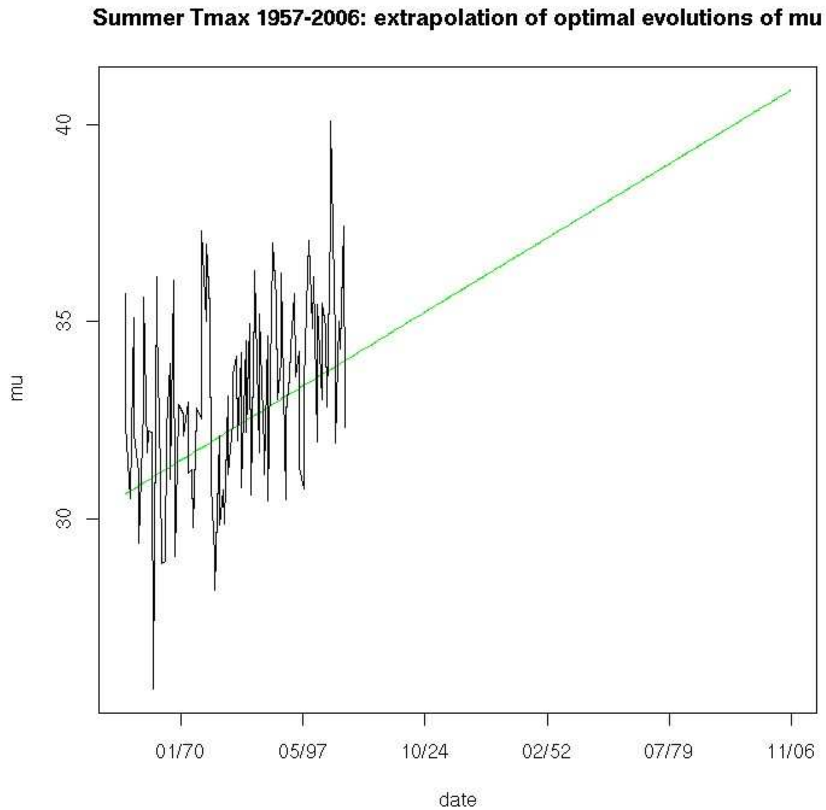
- Determination of an « objective » trend based on the trend in mean

Break point: sept 1956



Trend in mean summer Tmax

$\Rightarrow$



Trend of μ over 1957-2006

30-year Return Levels (air temperature)

Block maxima (GEV)		
Polynomial trend	CPL trend	1957-2006
42,0℃ [40,0 – 43,5]	42,0℃ [39,7 – 43,9]	40,8℃ [39,3 – 42,1]

POT (GPD + Poisson)		
Polynomial trend	CPL trend	1957-2006
39,6℃ [38,8 – 40,9]	-	41,3℃ [35,9 – 38,6]

Link between trends in extremes and trends in the central field

$$Y_t = \frac{X_t - m_t}{s_t}$$

X_t is the observed series; m_t the trend in mean and s_t the trend in standard deviation

The K hypothesis: the extremes of Y_t are stationary

How to test the K hypothesis?

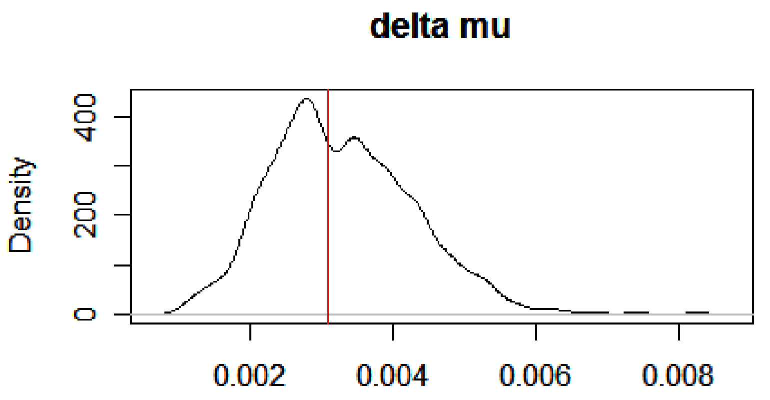
1) define a distance between 2 time functions

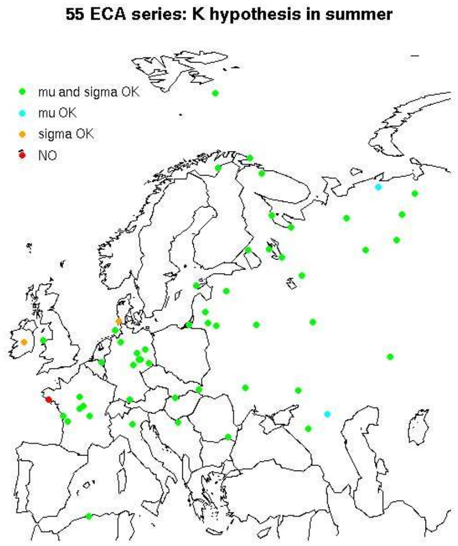
$$\Delta(f,g) = \left(\frac{1}{T}\int (f(t) - g(t))^2 \, dt\right)^{1/2}$$

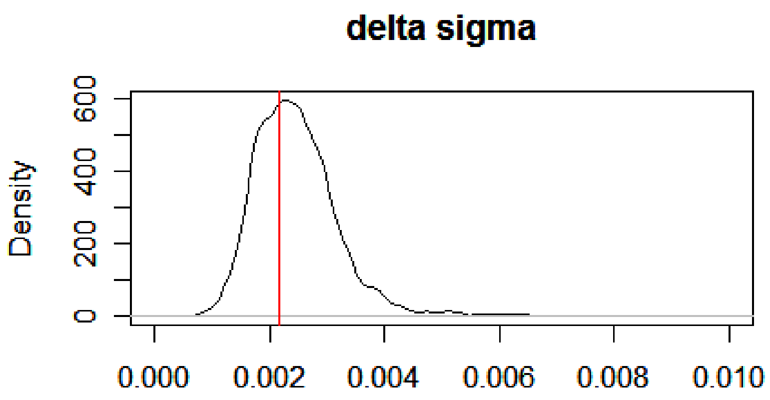
2) compute a statistical table for Δ under K

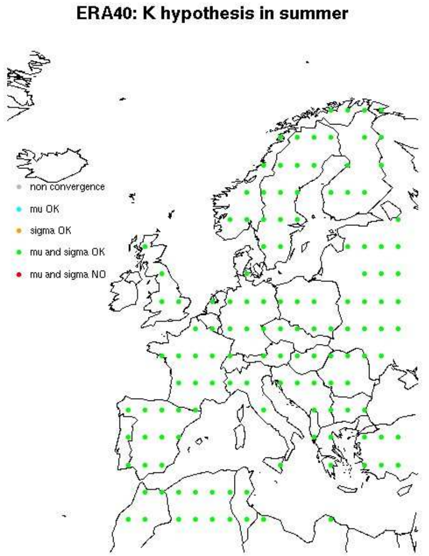
- 1000 samples of the stationary GEV law (ξ_Y, μ_Y, σ_Y)
- Estimate GEV parameters: 1) constant 2) time varying
- Compute Δ

Results


delta mu
Density
0
200
400
0.002
0.004
0.006
0.008


55 ECA series: K hypothesis in summer
mu and sigma OK
mu OK
sigma OK
NO

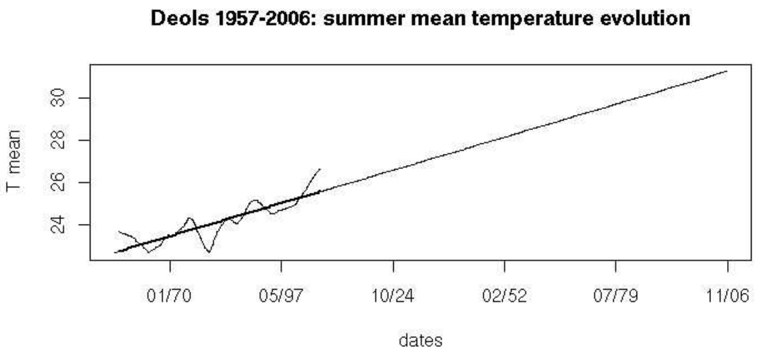

delta sigma
Density
0
200
400
600
0.000
0.002
0.004
0.006
0.008
0.010


ERA40: K hypothesis in summer
non convergence
mu OK
sigma OK
mu and sigma OK
mu and sigma NO

Derivation of Return Levels

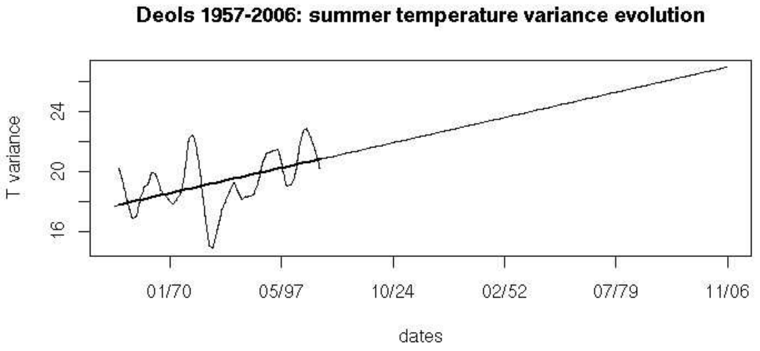
- Extrapolation of mean and variance trends
  - GEV

$$\frac{1}{nb}\sum_{t=t_0}^{t_0+365a}\left\{1-\exp\left[-((1+\frac{\xi}{\sigma_Y}(\frac{z_a-m(t)}{s(t)}-\mu_Y)^{-1/\xi}\right]\right\}-1=0$$



  - POT

$$\sum_{t\in D(t_0,a)}(1+\frac{\xi}{\sigma_Y}(\frac{z_a-m(t)}{s(t)}-u))^{-\frac{1}{\xi}}I_Y-1=0$$



Use of climate model results

- Stationary context over fixed periods
- Change in mean and variance derived from climate simulations
  - $m(k) = m_{obs} + \Delta m_{model}$ $s(k) = s_{obs} + \Delta s_{model}$

Model	2021-2050		2046-2065	
	Mean change	Standard deviation change	Mean change	Standard deviation change
Extrapolation	1,31	0,18	1,99	0,29
DMI-ARPEGE	2,03	0,29	3,57	0,81
DMI-ECHAM5	0,47	0,01	1,47	-0,02
KNMI-RACMO	0,89	0,17	2,62	0,33
MPI-ECHAM5	0,70	0,09	2,20	1,16
SMHI-BCM	-0,03	-0,11	1,38	0,46
SMHI-ECHAM5	1,05	0,21	2,49	0,31

ENSEMBLES project simulations

30-year Return Levels

Model	Block maxima(GEV)		POT (GPD + Poisson)	
	2021-2050	2046-2065	2021-2050	2046-2065
Extrapolation	40,3 [39,5-41,1]	41,2 [40,3-42,0]	40,3 [33,3-47,4]	41,4 [34,1-48,6]
DMI-ARPEGE	41,4 [40,6-42,3]	44,6 [43,7-45,5]	41,4 [34,2-48,7]	44,6 [36,8-52,4]
DMI-ECHAM5	39,0 [38,2-39,8]	39,9 [39,1-40,7]	39,0 [32,2-45,8]	39,9 [32,9-46,9]
KNMI-RACMO	39,9 [39,1-40,7]	42,2 [41,3-43,0]	39,9 [32,9-46,9]	42,2 [34,7-49,5]
MPI-ECHAM5	39,5 [38,7-40,3]	41,2 [40,4-42,0]	39,5 [38,2-40,8]	41,2 [34,0-48,4]
SMHI-BCM	38,1 [37,3-38,9]	41,3 [40,5-42,1]	38,1 [31,4-44,8]	41,3 [34,0-48,5]
SMHI-ECHAM5	40,2 [39,4-41,0]	42,0 [41,1-42,8]	40,2 [33,1-47,2]	42,0 [34,6-49,3]

Discussion

- Necessity to check EVT hypotheses

- Extrapolation of trends in EV distribution parameters
  - Sample effects
  - Trend « objectivity »
  - ⇒ no more than 30 years

- Use of the link between trends in mean and variance and trends in extremes
  - Test developed
  - Observation series ⇒ trends in extremes mostly due to trends in mean and variance
  - Derivation of long period return levels from the changes in mean and variance of the central field ⇒ more robust
  - Return Levels for the end of the century

Thank you for your attention

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