Towards monitoring climate change on a yearly basis using observational constraints

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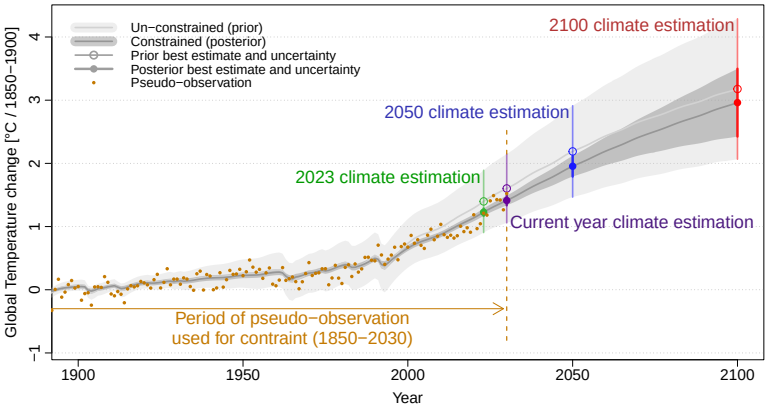
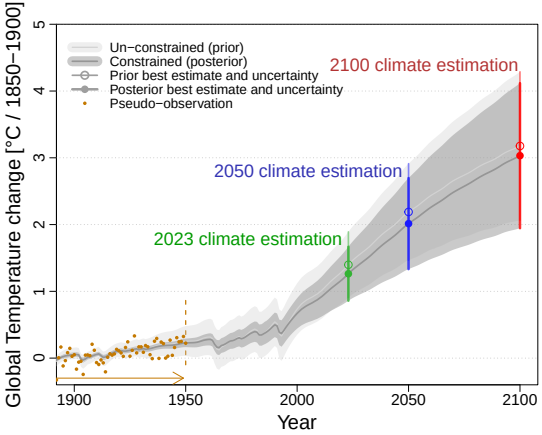
Observational constraint overview

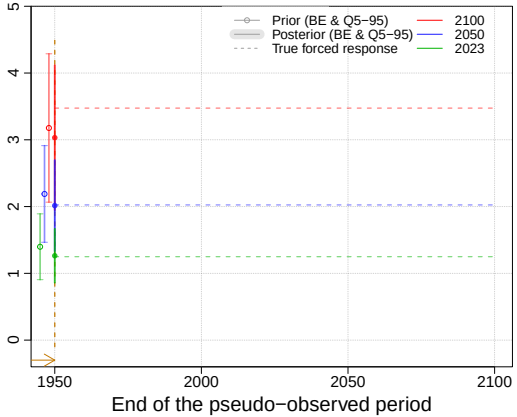


Global temperature of CMIP6 ensemble constrained by pseudo-observations (CNRM-CM6-1 r4i1p1f2) over the period 1850-2030.

- Ribes et al., Making climate projections [...], 2021
- Ribes et al., An updated assessment of past [...], 2022
- Qasmi et al, Reducing uncertainty in local [...], 2022
- IPCC Working Group I Contribution to AR6
- Forster et al., Indicators of Global Climate [...], 2023

Annual update of observational constraint : projected forced warming





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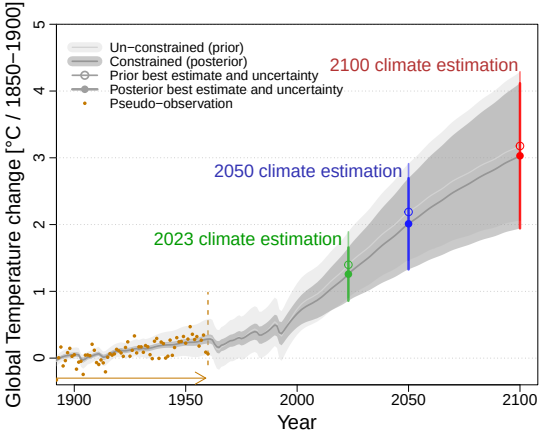

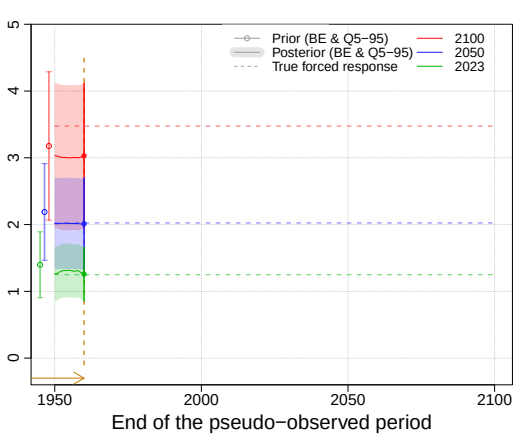

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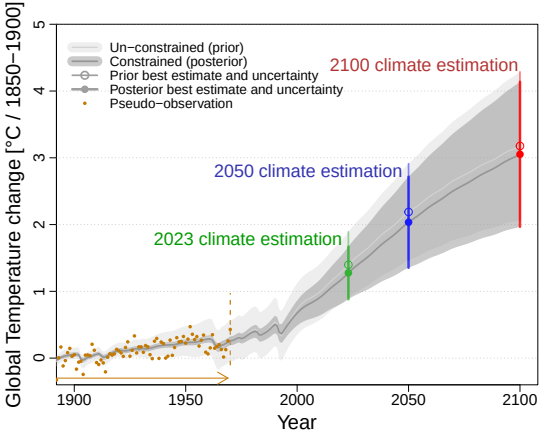

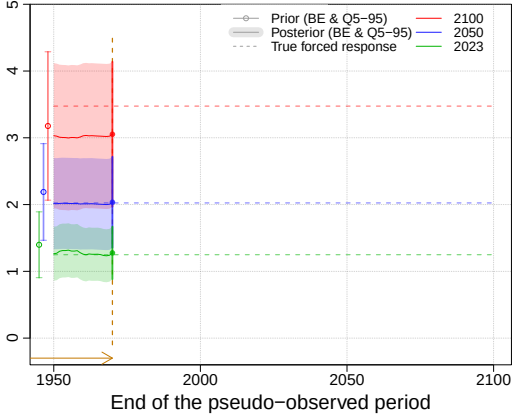

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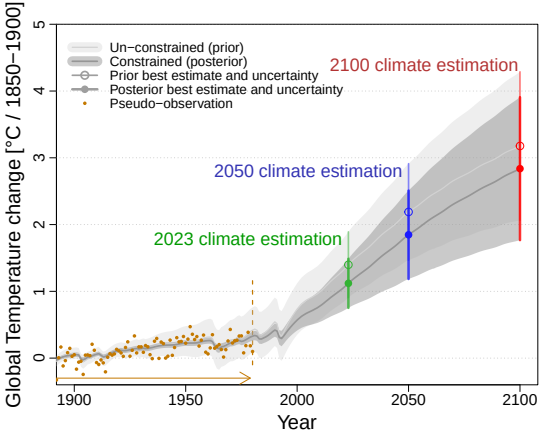

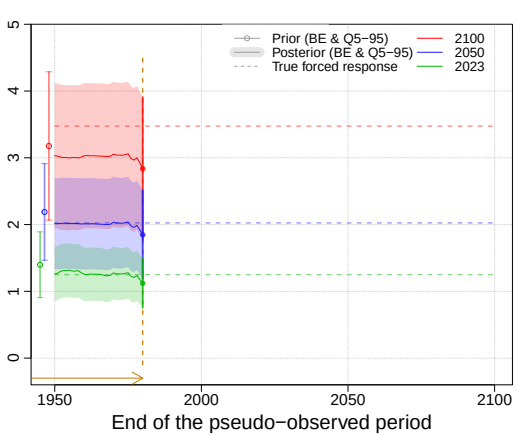

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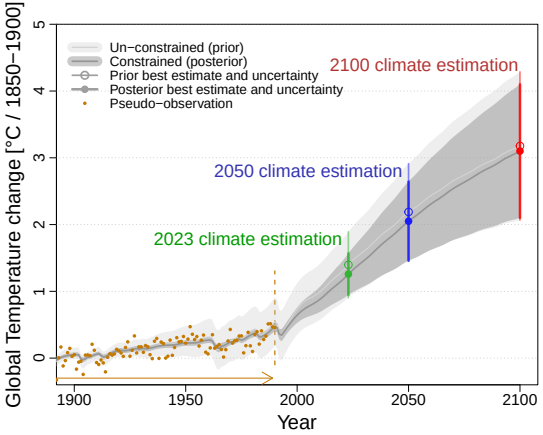

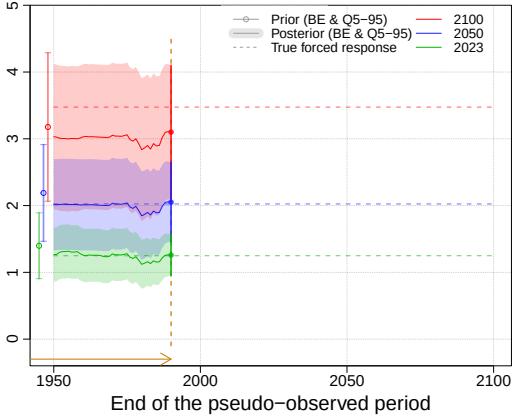

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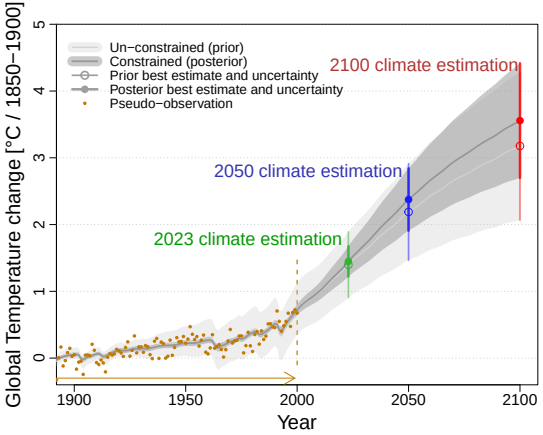

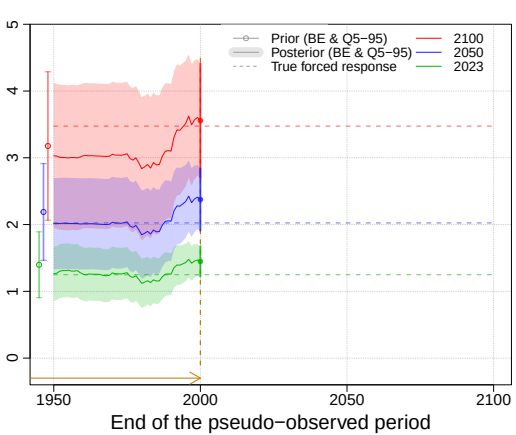

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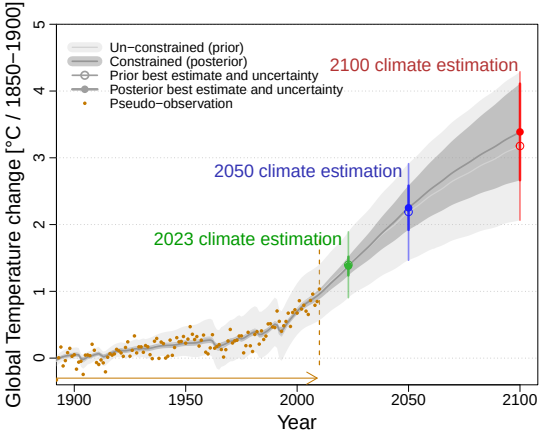

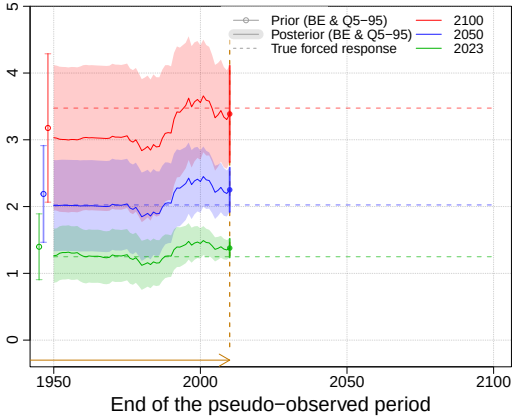

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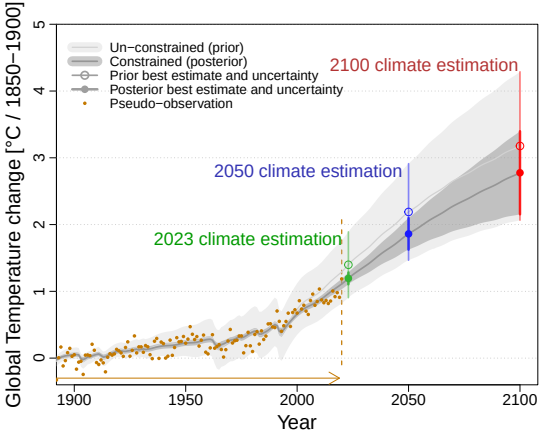

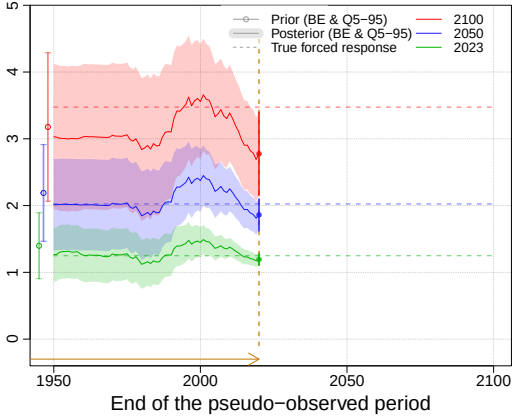

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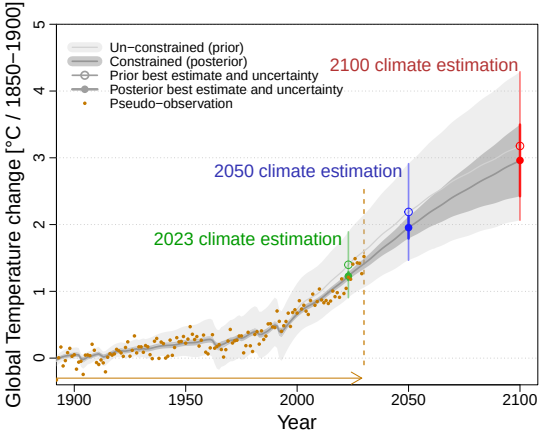

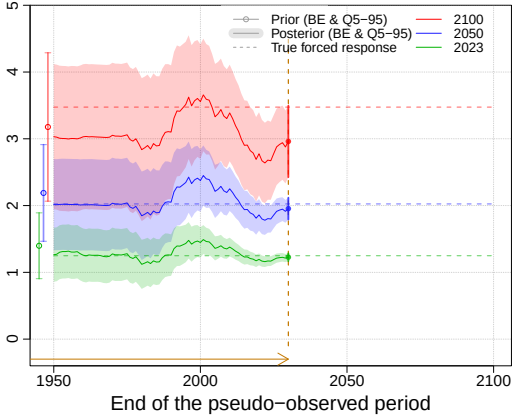

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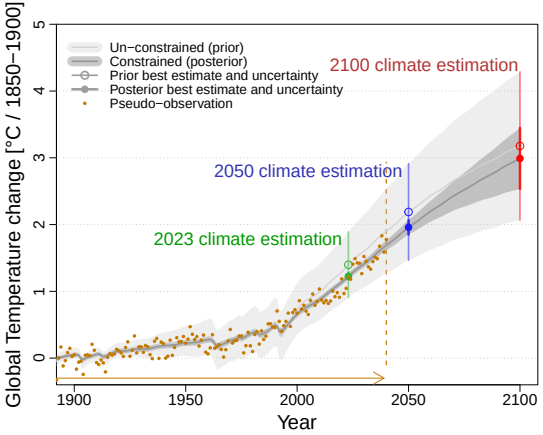

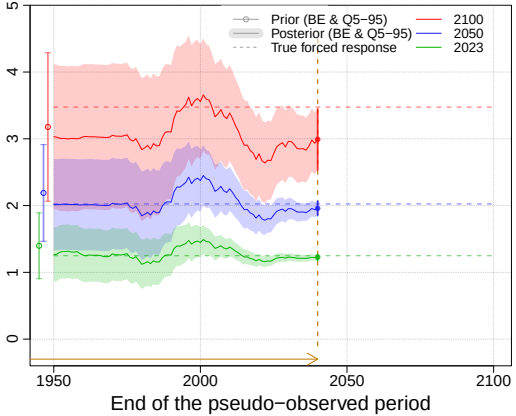

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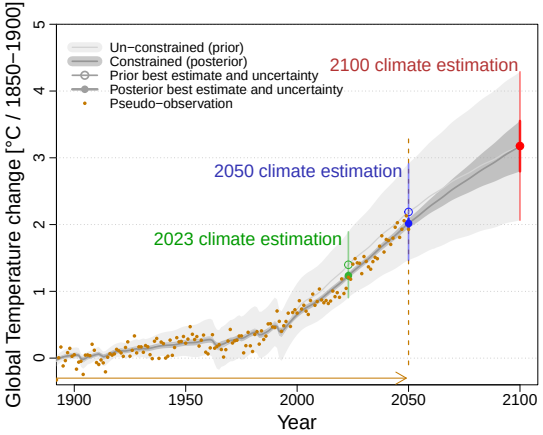

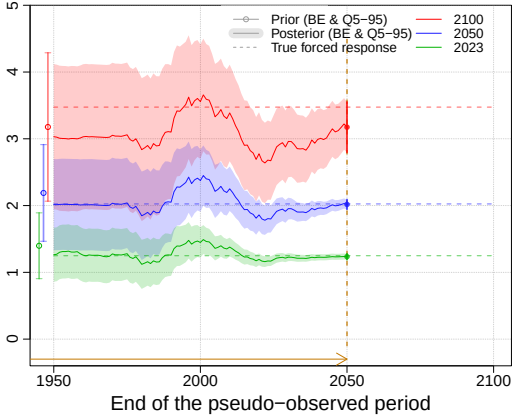

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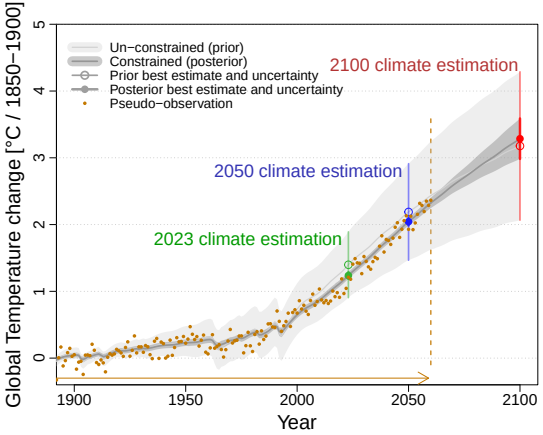

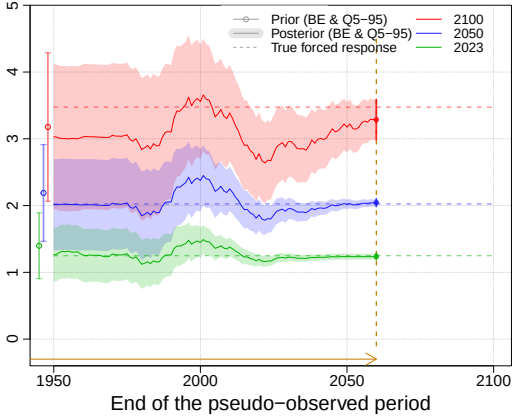

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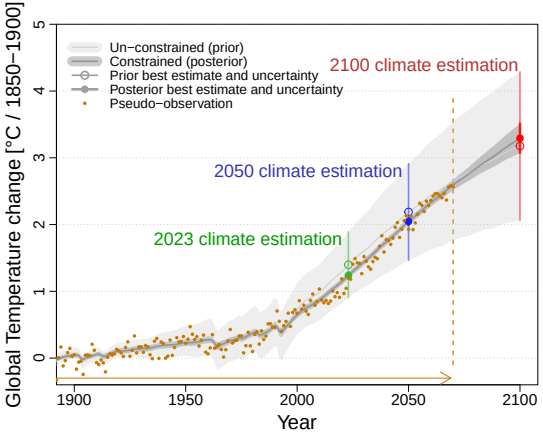

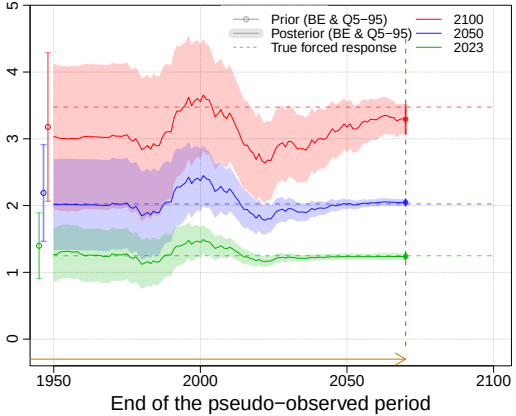

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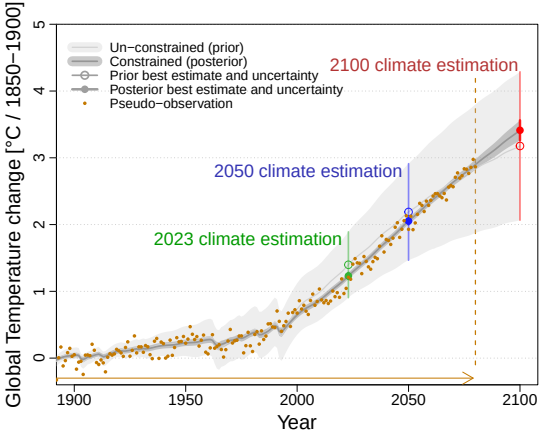

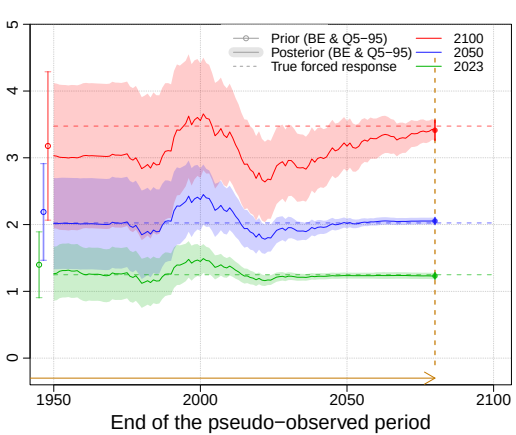

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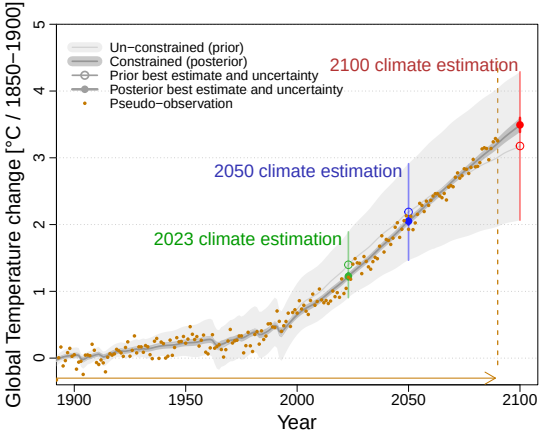

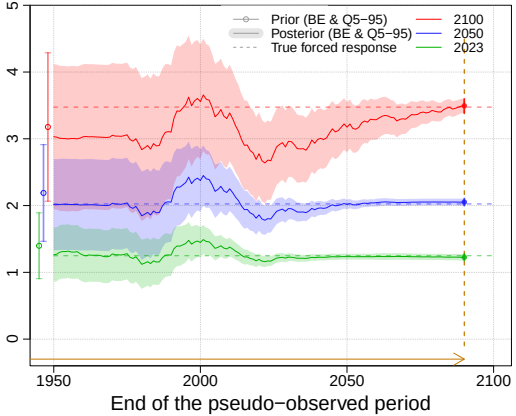

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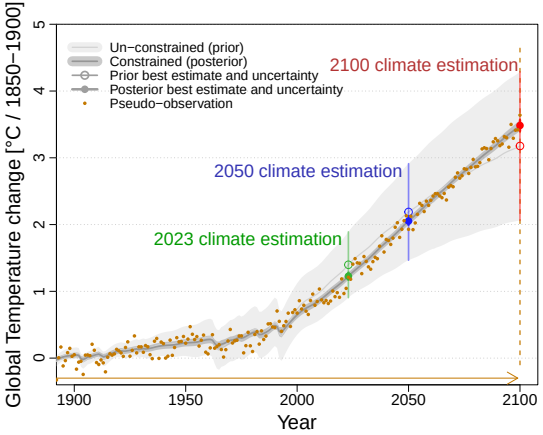
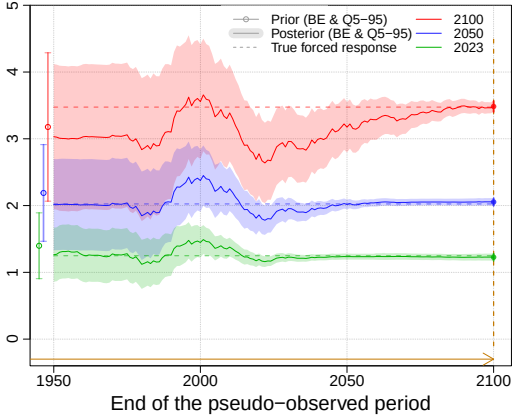
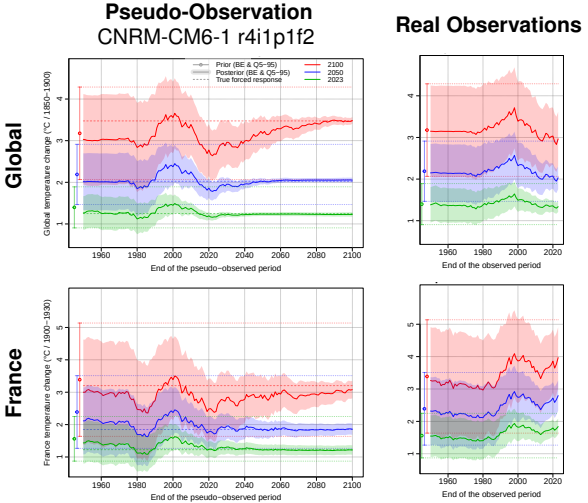




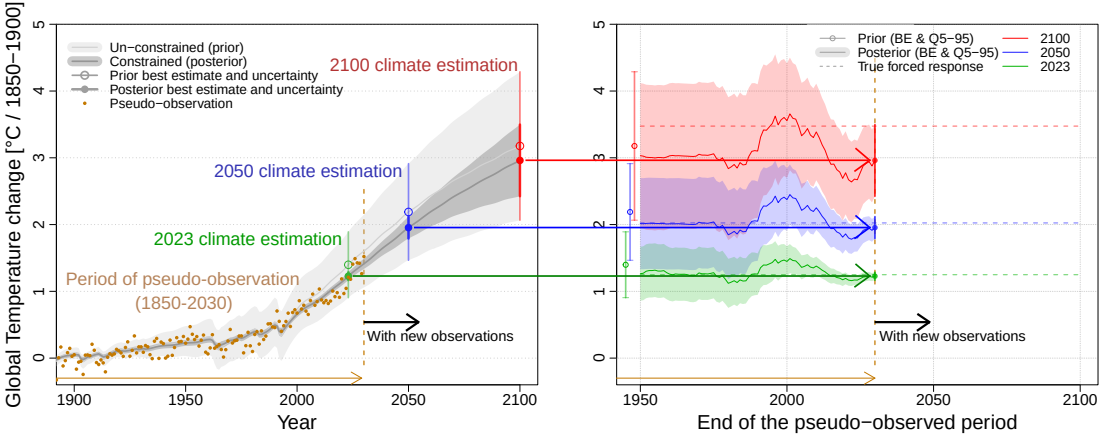
Projected forced warming

Added value of updating forecast constraint warming with new observations :

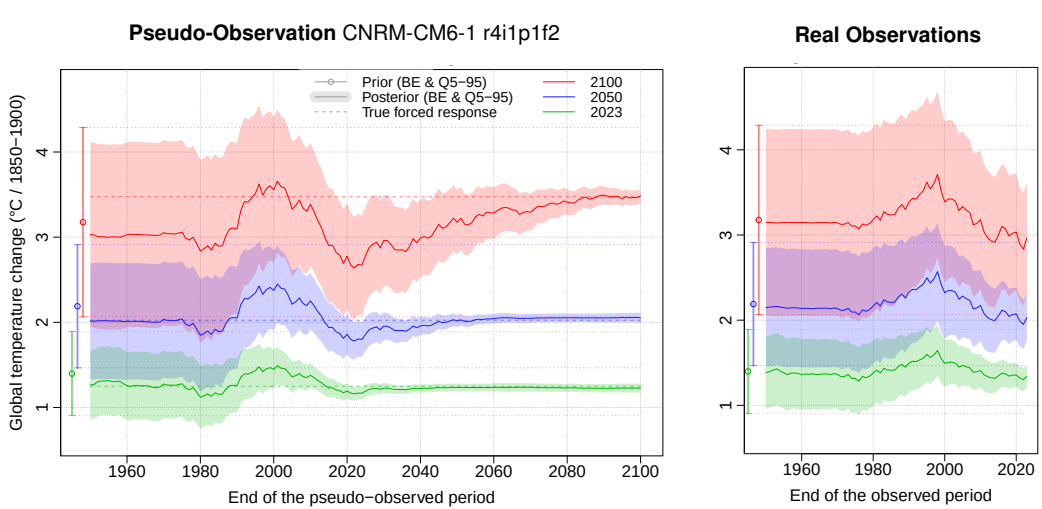
- **The accuracy** of the indicator improves continuously.
- The forced warming estimate **converges well** to the expected value.
- It's **reliable** over time.



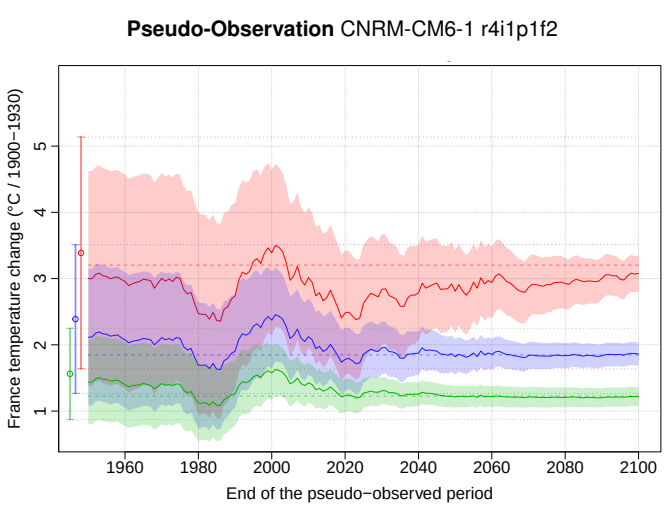
Projected forced warming : overview

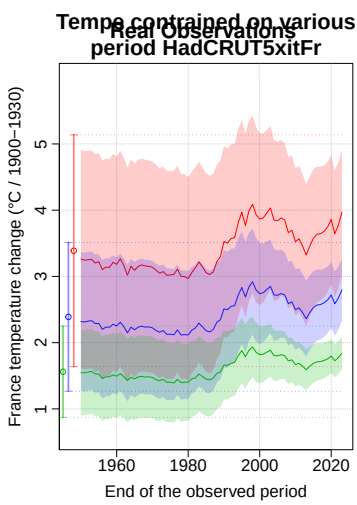


Projected forced warming on global scale



Projected forced warming on local scale : France

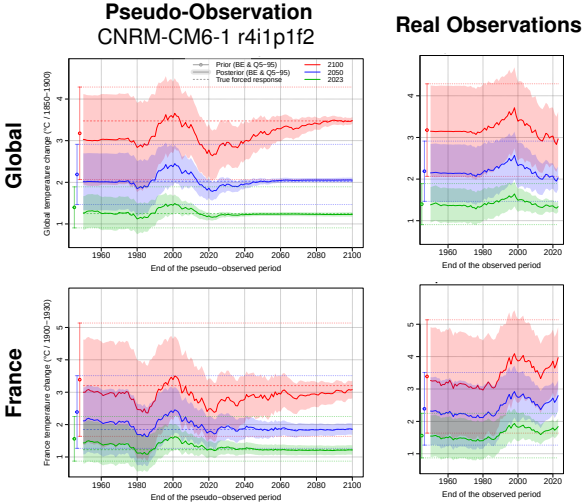




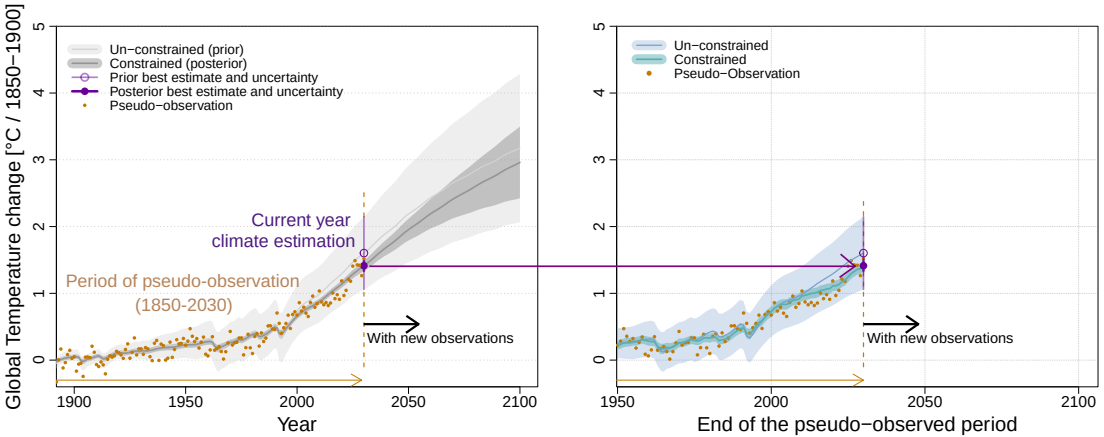
Projected forced warming : conclusions

Characteristics of the projected forced warming, based on a perfect model framework :

- The accuracy of the indicator improves continuously (confidence interval shrinks by 1.5 to 3% with each new observation).
- There is no major year-to-year variability (the forced response is typically shifted by ± 0.05 °C).
- The forced warming estimate converges well to the expected value.
- The true value of forced response is mostly within the constrained confidence interval.

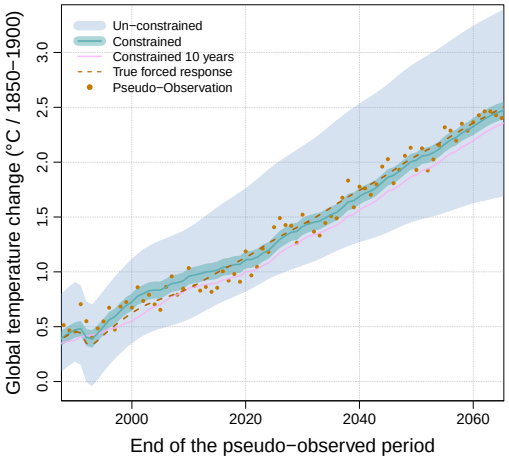


Projected forced warming : overview

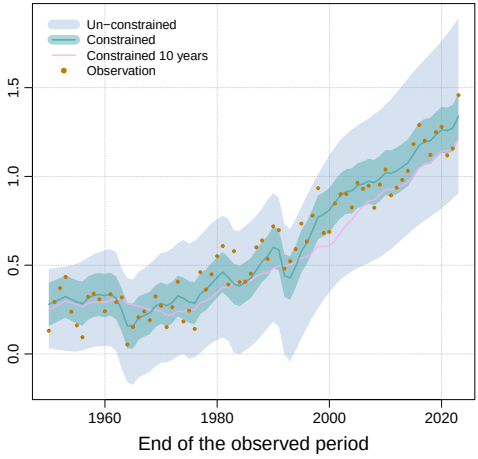


Current year forced warming on global scale

Pseudo-Observation CNRM-CM6-1 r4i1p1f2

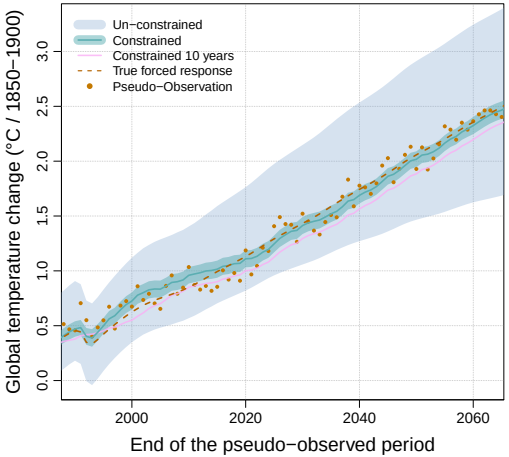


Real Observations

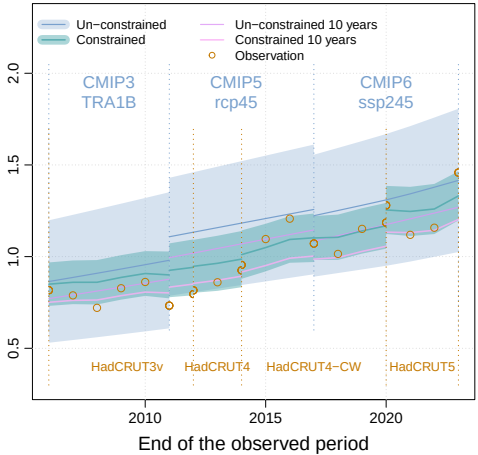


Current year forced warming on global scale

Pseudo-Observation CNRM-CM6-1 r4i1p1f2

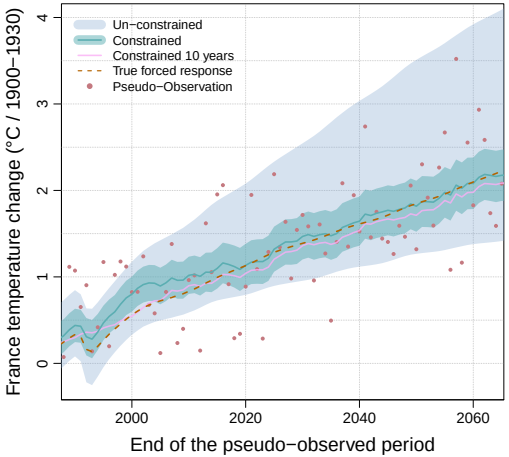


Real Observations in real world



Current year forced warming on local scale : France

Pseudo-Observation CNRM-CM6-1 r4i1p1f2



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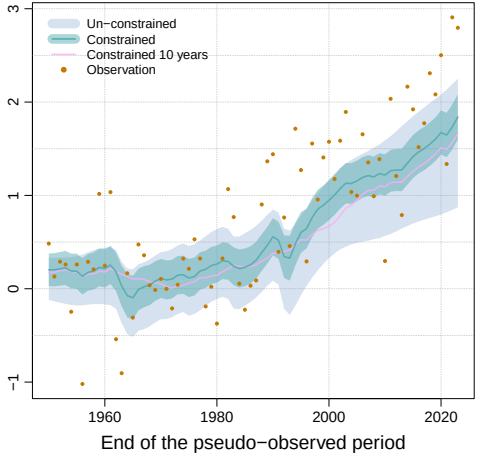


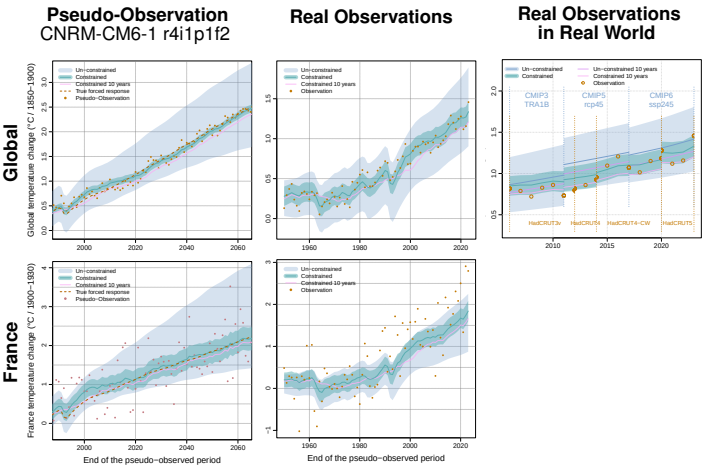
Current year forced warming : conclusions

Characteristics of the current year warming estimate, based on a perfect model framework :

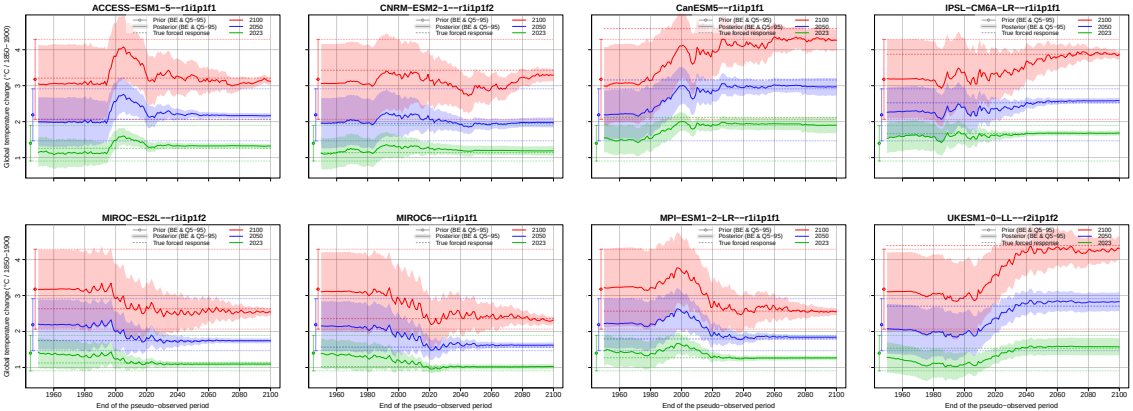
- It's an almost unbiased indicator.[1]
- It's a stable indicator with small standart deviation around the true value.[1]
- Except during volcanic events, the updated estimation for the year N+1 is most of the time greater than the previous estimation for the year N (important for communication).

In a real world, evolutions in reference data (observeed and simulated) can induce non-negligible variations in the current warming estimate. These are relatively larger than variations induced by the addition of one more observed year.

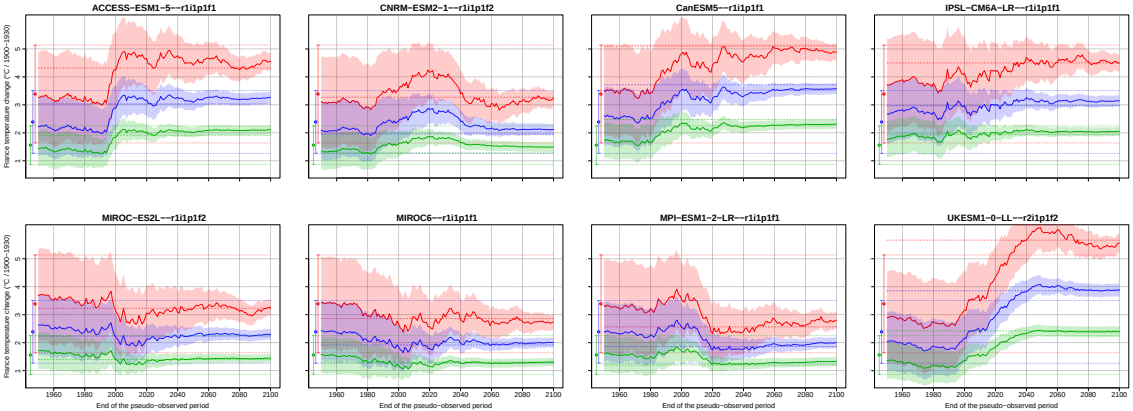
[1] *See Evaluation section for more details.*



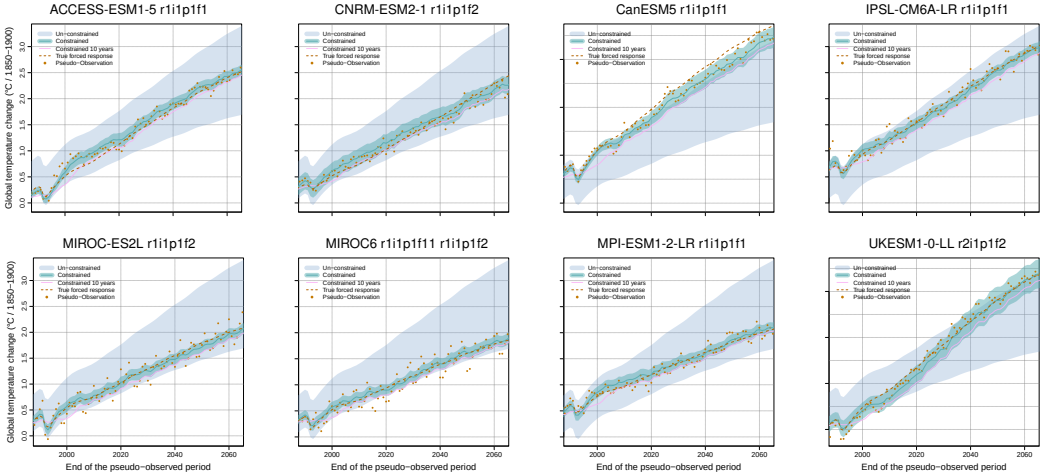
Projected forced warming on global scale



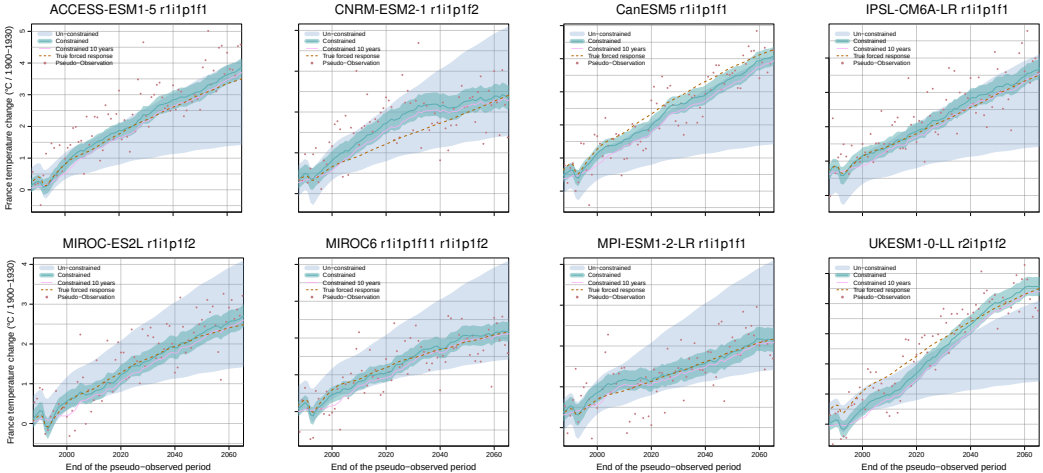
Projected forced warming on local scale : France



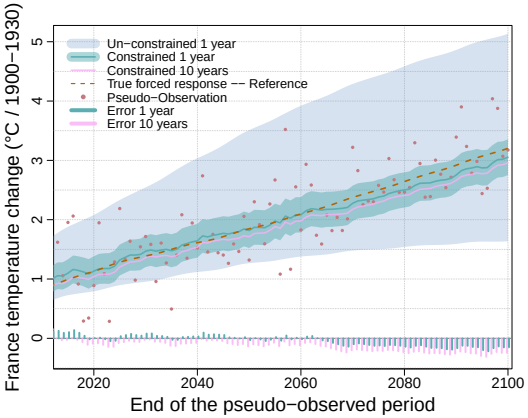
Current forced warming on global scale



Current forced warming on local scale : France



Statistics of the current year warming estimate

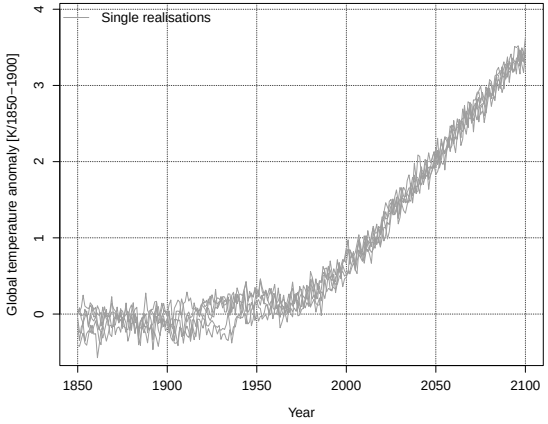


	biais		std		RMSE	
	1-y	10-y	1-y	10-y	1-y	10-y
Global	-0.025	-0.133	0.0435	0.045	0.058	0.14
Local	-0.048	-0.178	0.102	0.112	0.165	0.218

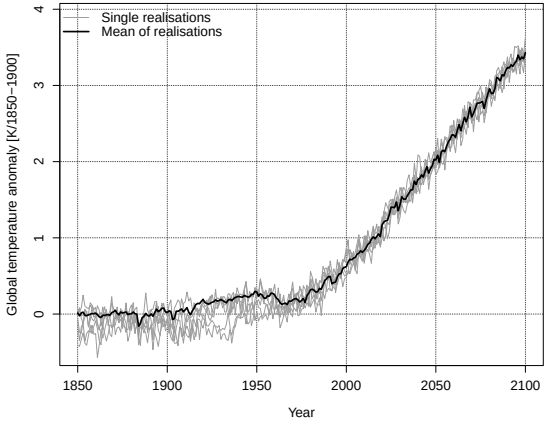
Statistics of the current year warming estimate

	Global						France					
	biais		std		RMSE		biais		std		RMSE	
	1-y	10-y	1-y	10-y	1-y	10-y	1-y	10-y	1-y	10-y	1-y	10-y
ACCESS-ESM1-5	0.040	-0.076	0.053	0.028	0.066	0.081	-0.103	-0.249	0.094	0.094	0.207	0.285
CNRM-ESM2-1	-0.046	-0.163	0.103	0.090	0.112	0.186	0.075	-0.039	0.168	0.151	0.287	0.249
CanESM5	-0.223	-0.366	0.041	0.048	0.227	0.370	-0.045	-0.217	0.099	0.116	0.155	0.256
IPSL-CM6A-LR	-0.008	-0.133	0.047	0.056	0.047	0.144	-0.064	-0.206	0.107	0.092	0.212	0.234
MIROC-ES2L	-0.042	-0.133	0.028	0.029	0.050	0.136	-0.026	-0.135	0.104	0.106	0.126	0.175
MIROC6	0.017	-0.067	0.033	0.042	0.037	0.078	-0.082	-0.173	0.074	0.075	0.139	0.197
MPI-ESM1-2-LR	0.025	-0.058	0.026	0.035	0.036	0.068	0.003	-0.080	0.098	0.093	0.125	0.139
UKESM1-0-LL	-0.083	-0.241	0.046	0.058	0.094	0.248	-0.277	-0.465	0.153	0.162	0.332	0.499
Total median	**-0.048**	**-0.178**	**0.102**	**0.112**	**0.165**	**0.218**	**-0.025**	**-0.133**	**0.0435**	**0.045**	**0.058**	**0.14**

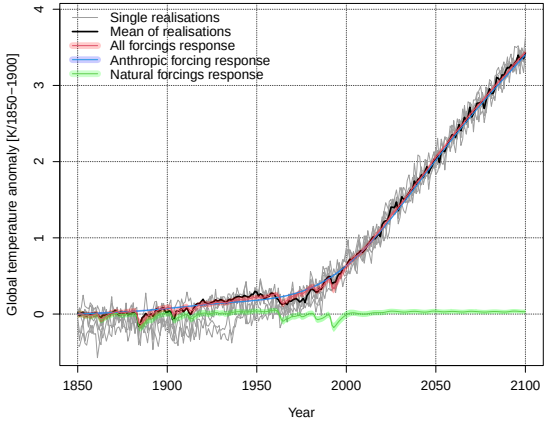
Compute forced response : Illustration



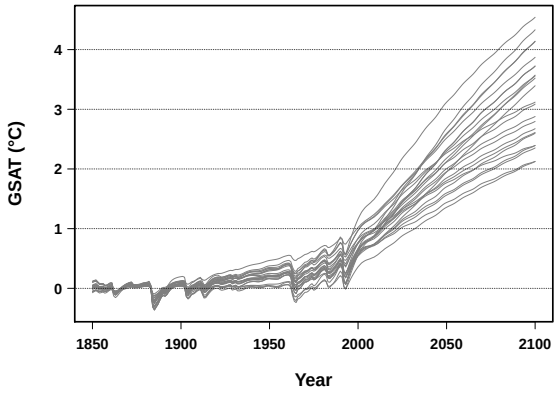
Compute forced response : Illustration



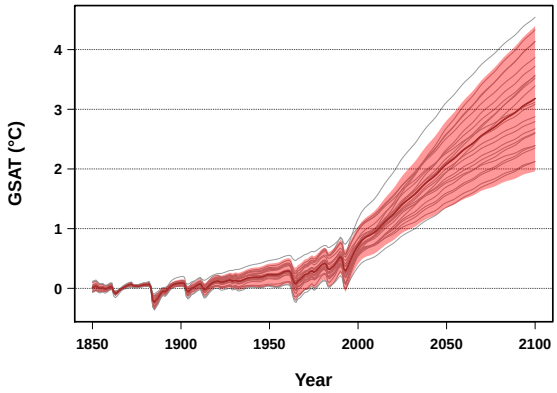
Compute forced response : Illustration



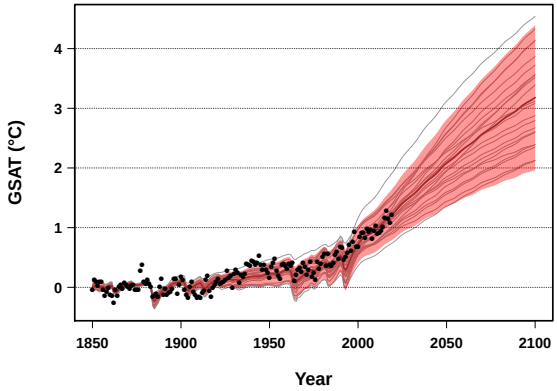
Constraint method : Illustration



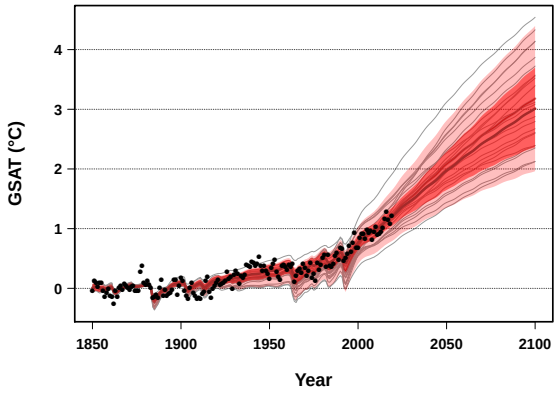
Constraint method : Illustration



Constraint method : Illustration



Constraint method : Illustration



Constraint method : Calculation

$$\boldsymbol{x} = \begin{pmatrix} x^{all}_{1850} \\ \vdots \\ x^{all}_{2100} \end{pmatrix}, \qquad \boldsymbol{y} = \begin{pmatrix} y_{1850} \\ \vdots \\ y_{2023} \end{pmatrix}.$$

Prior: $\boldsymbol{x} \sim N(\boldsymbol{\mu}, \boldsymbol{\Sigma}_{\text{mod}})$,

Obs: $\boldsymbol{y} = \boldsymbol{H}\boldsymbol{x} + \boldsymbol{\varepsilon}$, with $\boldsymbol{\varepsilon} \sim N(\boldsymbol{0}, \boldsymbol{\Sigma}_{\text{obs}})$,

We compute: $p(\boldsymbol{x}|\boldsymbol{y})$

$\boldsymbol{x}$: total forced response, 1850–2100,
$\boldsymbol{\Sigma}_{\text{mod}}$: model error covariance,
$\boldsymbol{H}$: observation operator,

$\boldsymbol{y}$: observations, 1850–2023,
$\boldsymbol{\Sigma}_{\text{obs}}$: observation error covariance,
$\boldsymbol{\varepsilon}$: error in observations (i.v. + meas.),

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There are 4 inputs: $\boldsymbol{y}, \boldsymbol{\mu}, \boldsymbol{\Sigma}_{\text{mod}}, \boldsymbol{\Sigma}_{\text{obs}}$. *#Kriging, #KalmanFiltering*