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Extreme Temperature Forecasts

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A Novel Member-By-Member Postprocessing Framework for Ensemble Temperature Forecasts

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HC3 Research Laboratory
Hydrology, Climate and Climate Change

ÉTS
Le génie pour l'industrie

Member-by-Member PP

- The formula (Van Schaeybroeck and Vannitsem, 2015)

$$X_{t,m}^{pp} = \alpha + \beta\overline{X_t^{raw}} + \left(\gamma_1 + \frac{\gamma_2}{ES_t}\right)\left(X_{t,m}^{raw} - \overline{X_t^{raw}}\right)$$

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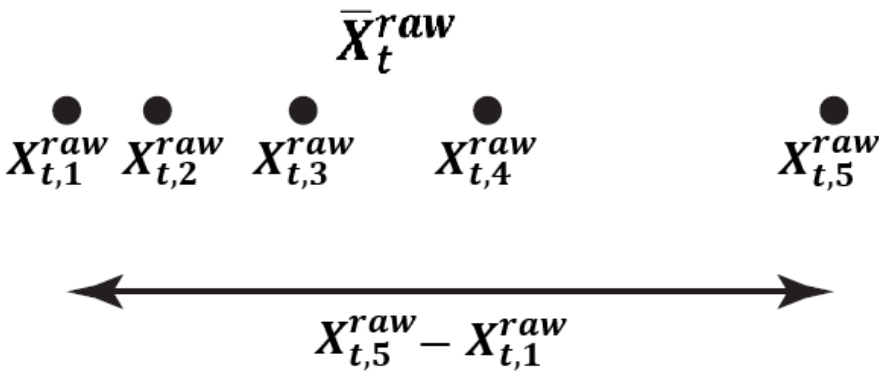

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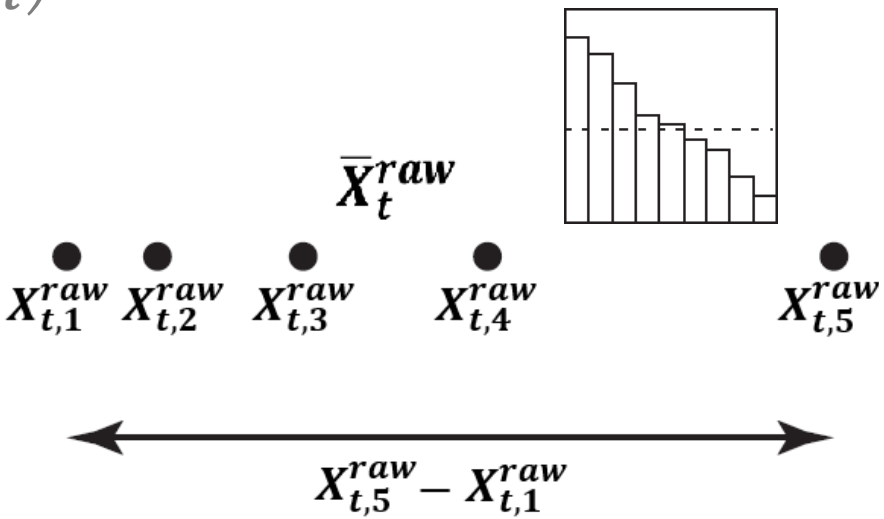

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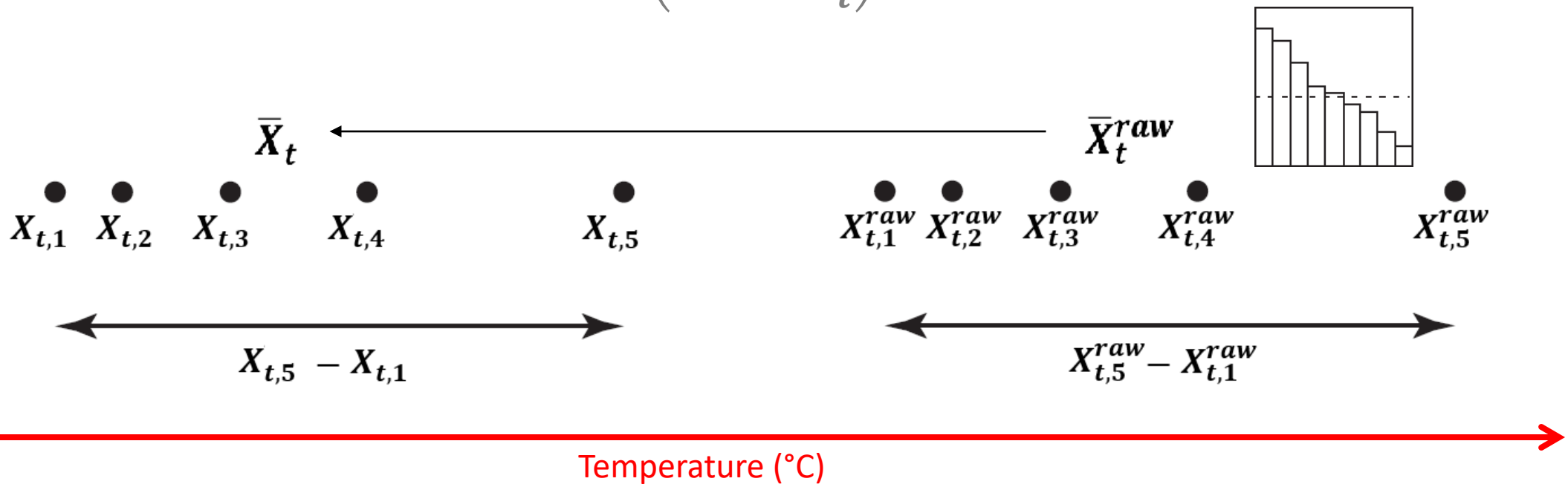

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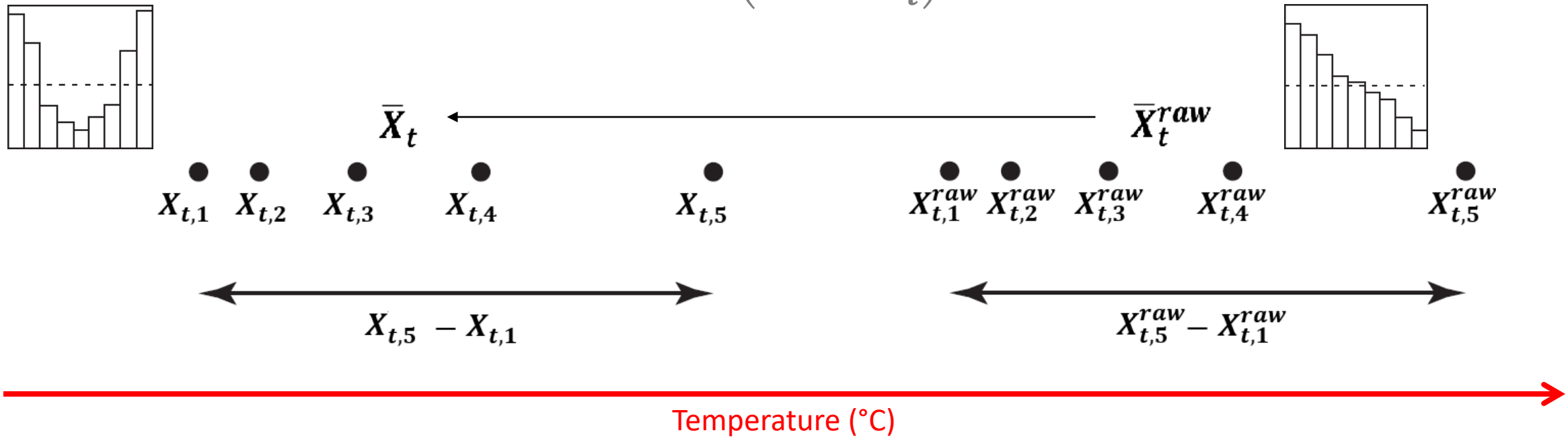

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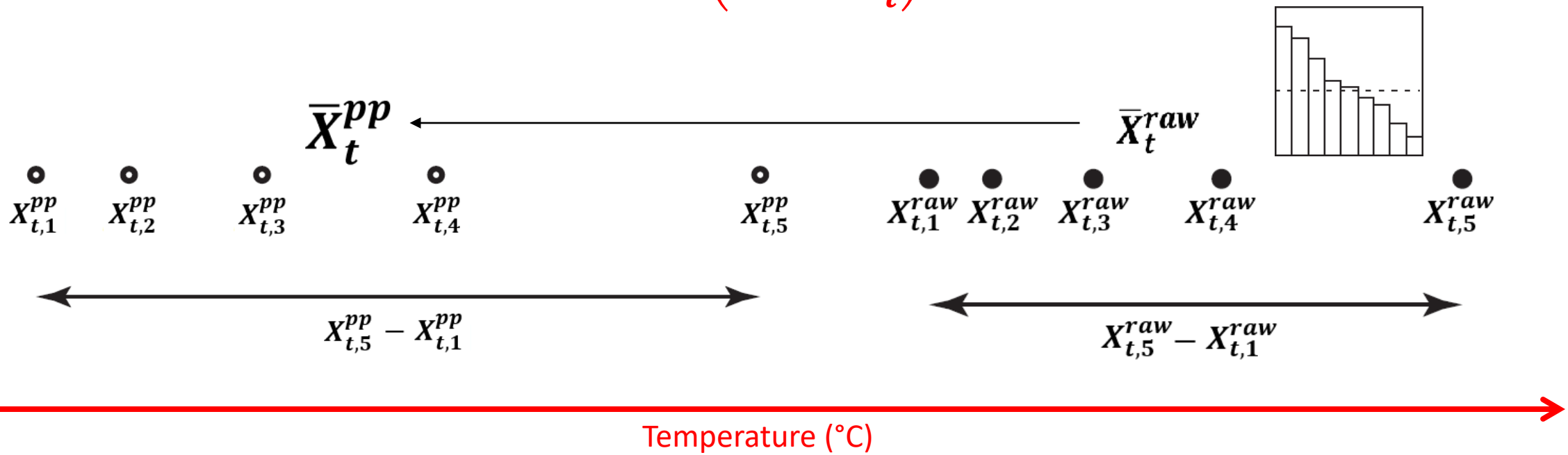

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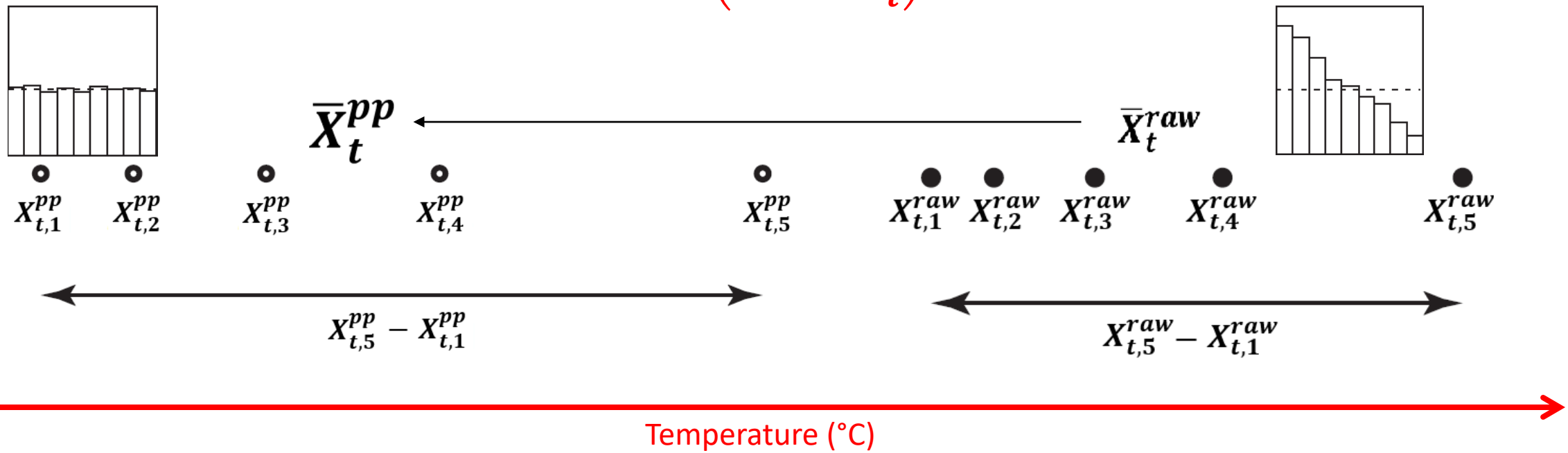

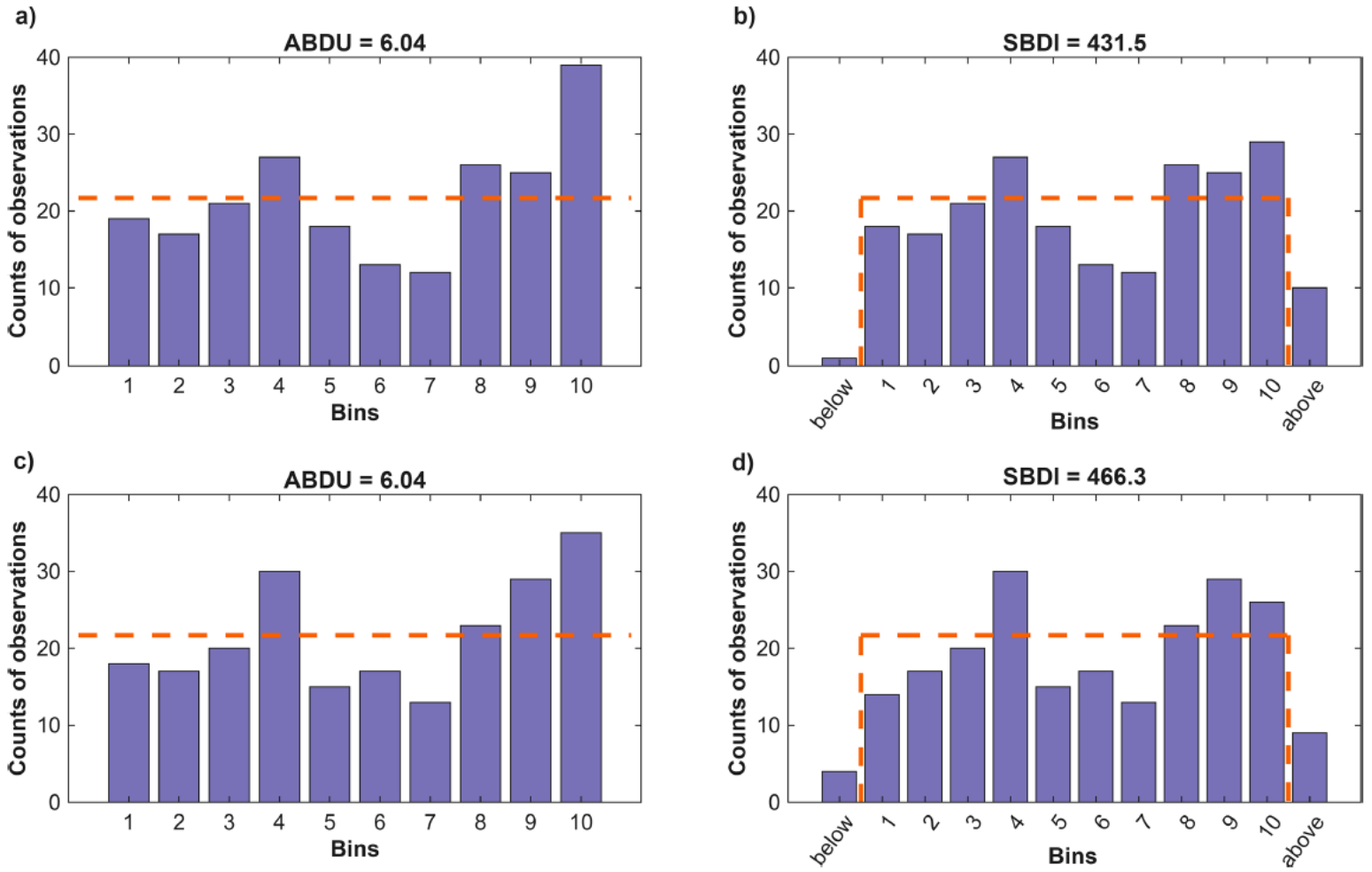

Figure 1. Figure 4 from Oghbaei et al. (2025) showing a conventional examination of rank histogram uniformity might not capture the unreliability of ensemble forecasts.

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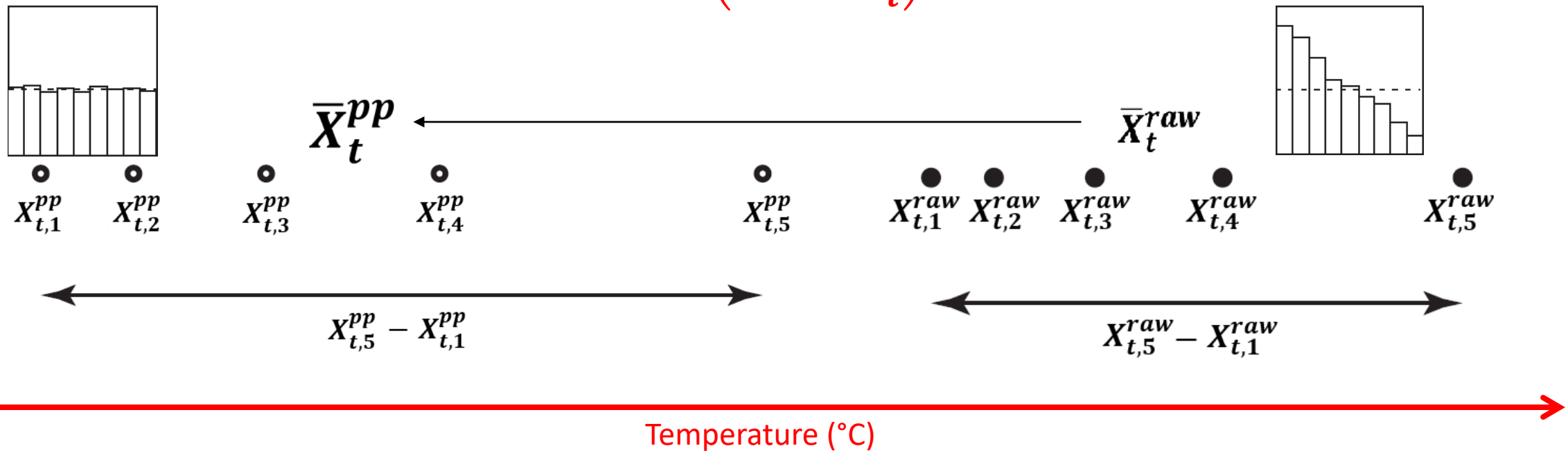

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MBMP and outlier members

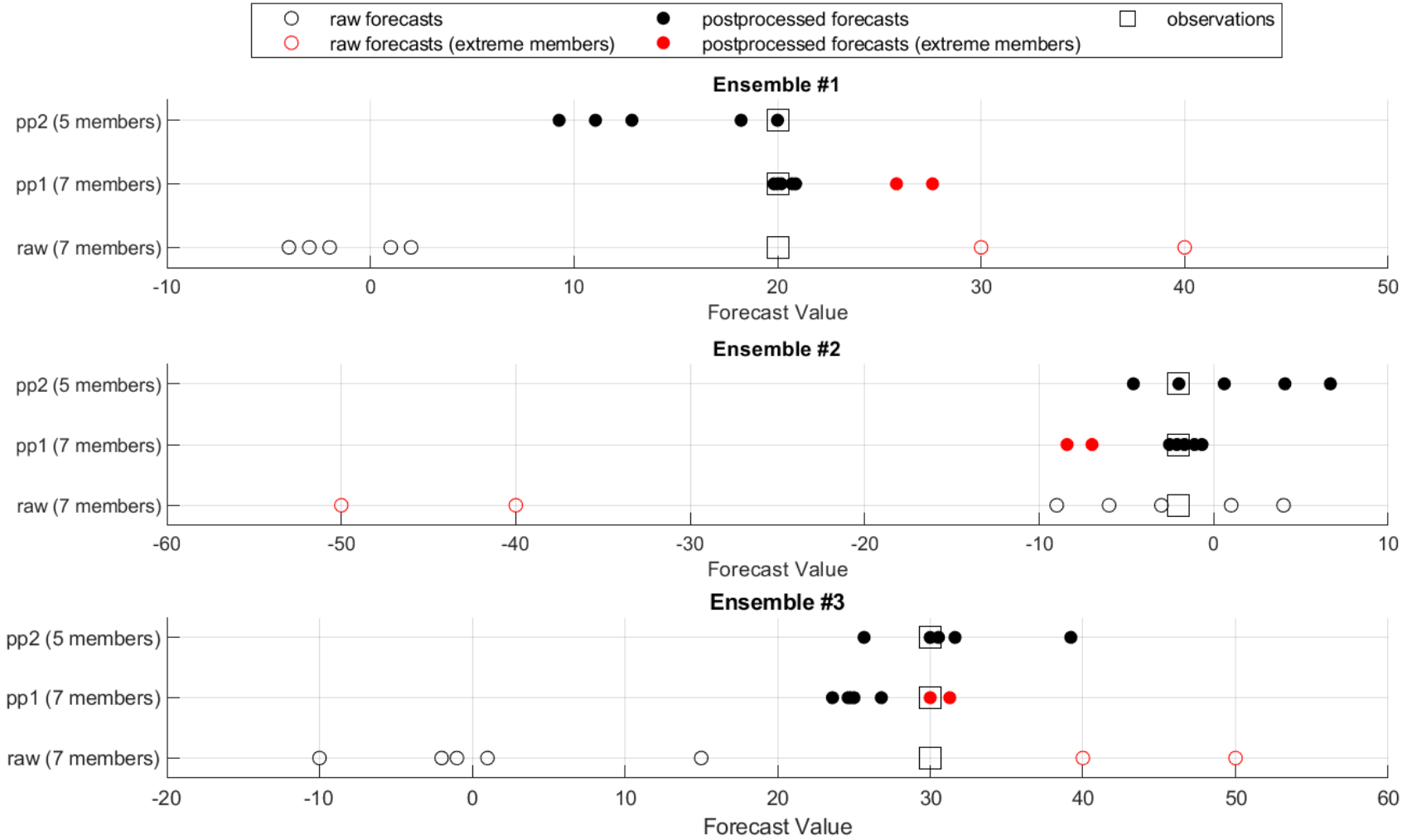


Figure 2. A hypothetical example of a system of three 7-member ensembles (*raw*), being post-processed by standard MBMP (*pp1*), and the same but after removing two of their extreme members shown by red (*pp2*).

MBMP with non-linear transformations

- The formula

$$X_{t,m}^{pp} = \alpha + \beta \overline{X_t^{raw}} + D(X_t^{raw}, \gamma_t, m)$$

- D(•) is the new deviation of a given member from the ensemble mean for the forecast occasion t.

Non-linear Transformations

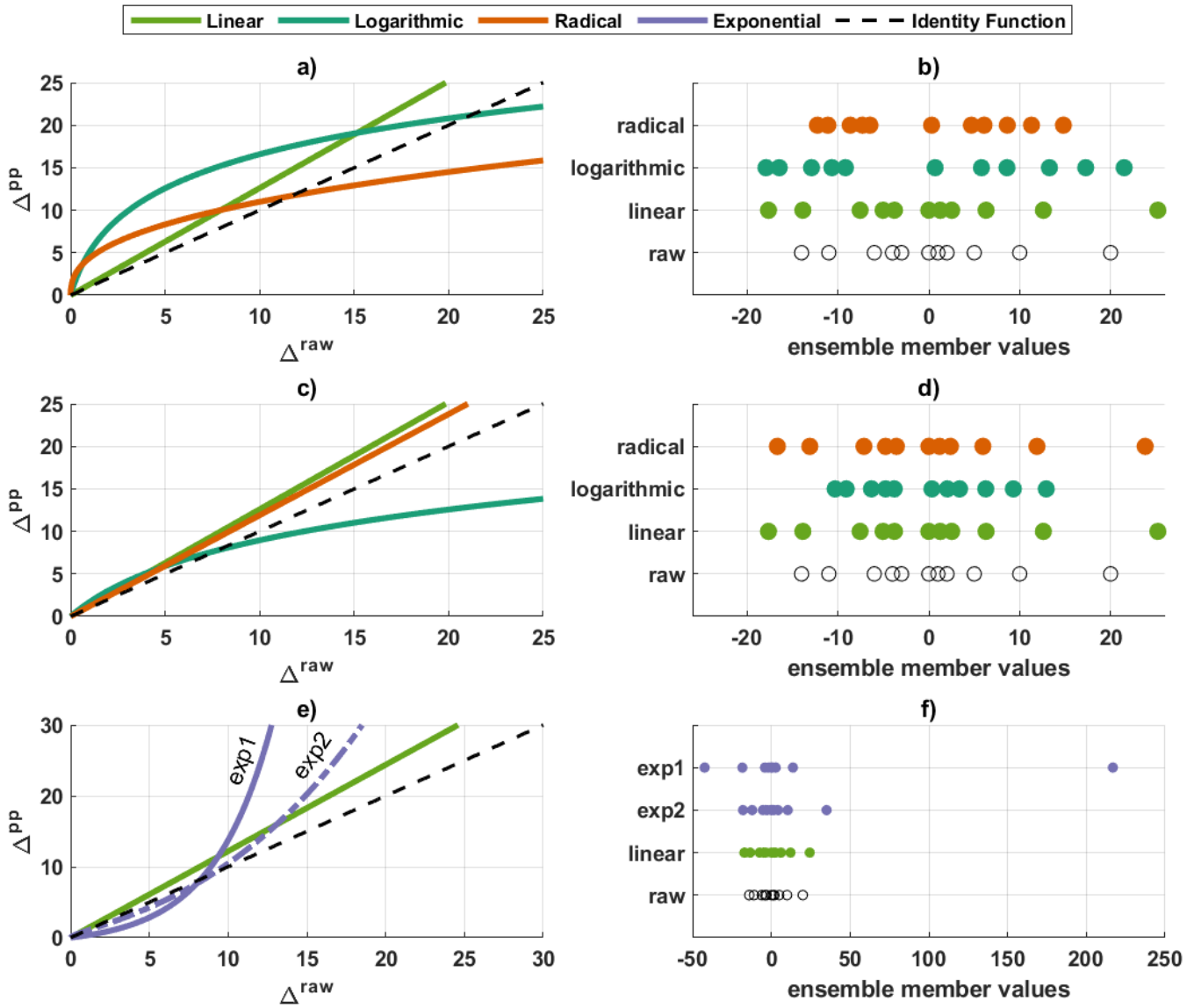


Figure 3: a & c) two instances of logarithmic and radical functions, e) two instances of exponential functions, with b, d, and f) being their corresponding corrections on the hypothetical 11-member ensembles.

Angular MBMP

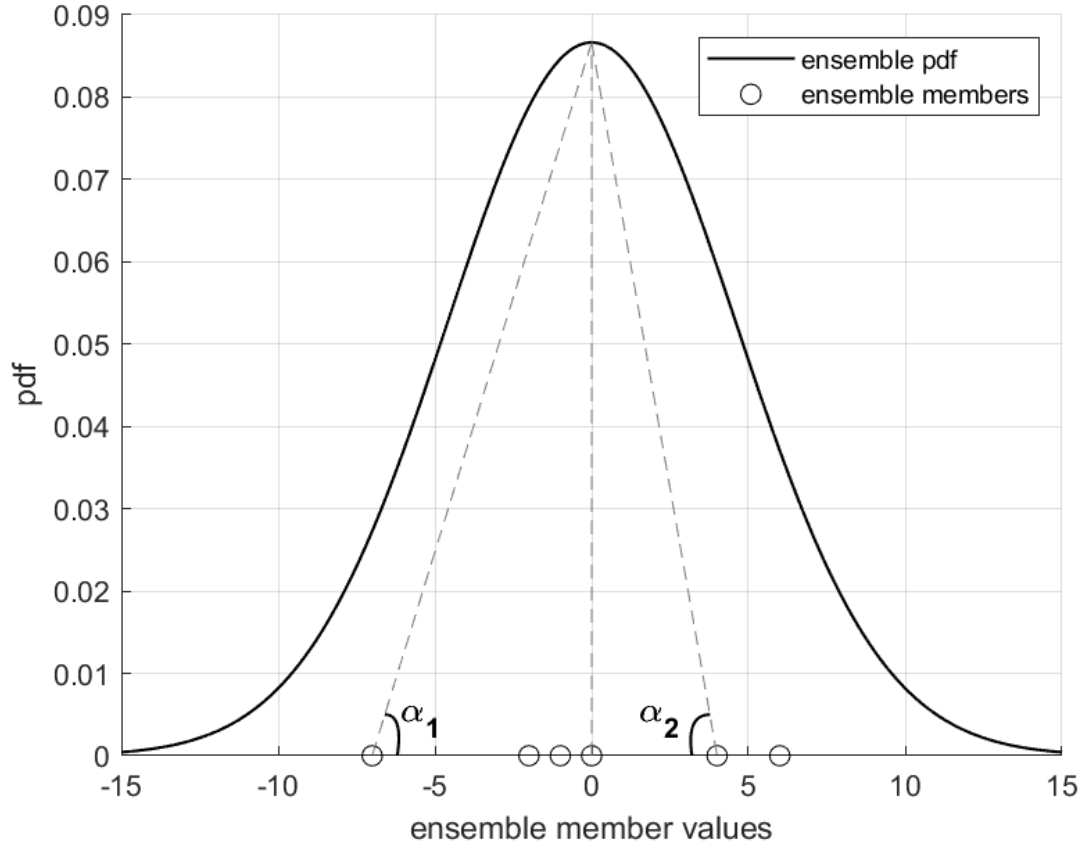
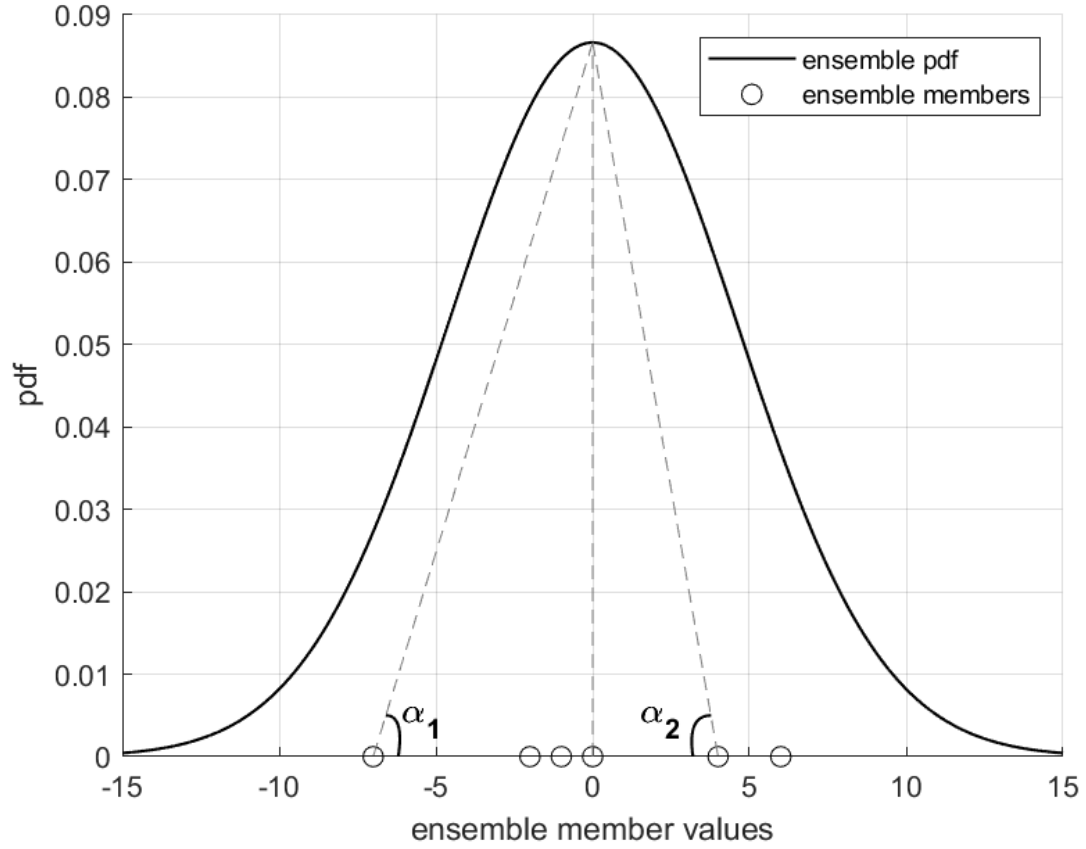


Figure 4. Schematic of representative angles to be corrected by Angular MBMP

Angular MBMP formulation



$$\tan\left(\alpha_{t,\,m}^{raw}\right) = \frac{pdf_{t}^{raw}}{\Delta_{t,\,m}^{raw}}$$

$$\alpha_{t,\,m}^{pp} = \theta_{1,\,t} \times \alpha_{t,\,m}^{raw} + \theta_{2}$$

$$D\left(x_{t}^{raw},\,\theta_{t},\,m\right) = \frac{pdf_{t}^{max}}{\tan\left(\theta_{1} \times arctan\left(\frac{pdf_{t}^{max}}{\Delta_{t,\,m}^{raw}}\right) + \theta_{2}\right)}$$

$$x_{t,m}^{pp} = \alpha + \beta \times \overline{x_{t}^{raw}} + D\left(x_{t}^{raw},\,\theta_{t},\,m\right)$$

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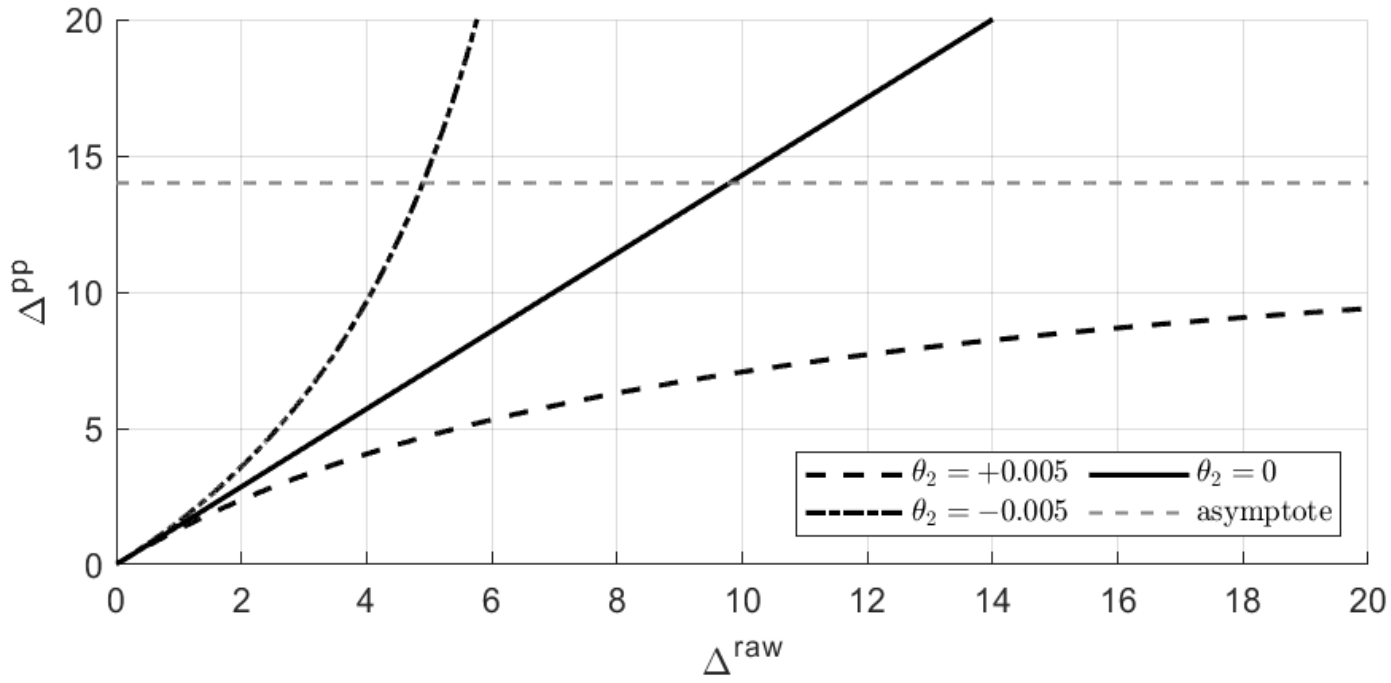

Figure 5. Δ^{pp} as a function of Δ^{raw} for different θ_2 values ($pdf_t^{max} = 0.07$ and $\theta_1 = 0.7$)

Study Site and Data

- 32 catchments across Quebec

- ECMWF temperature forecasts (IFS)
  LT: 2, 5 and 9 days

- ERA5 reanalysis as verifications
  - As good as observations (Tarek et al. (2020))

- 2015-2021: training dataset (3-week window)
- 2022: test dataset

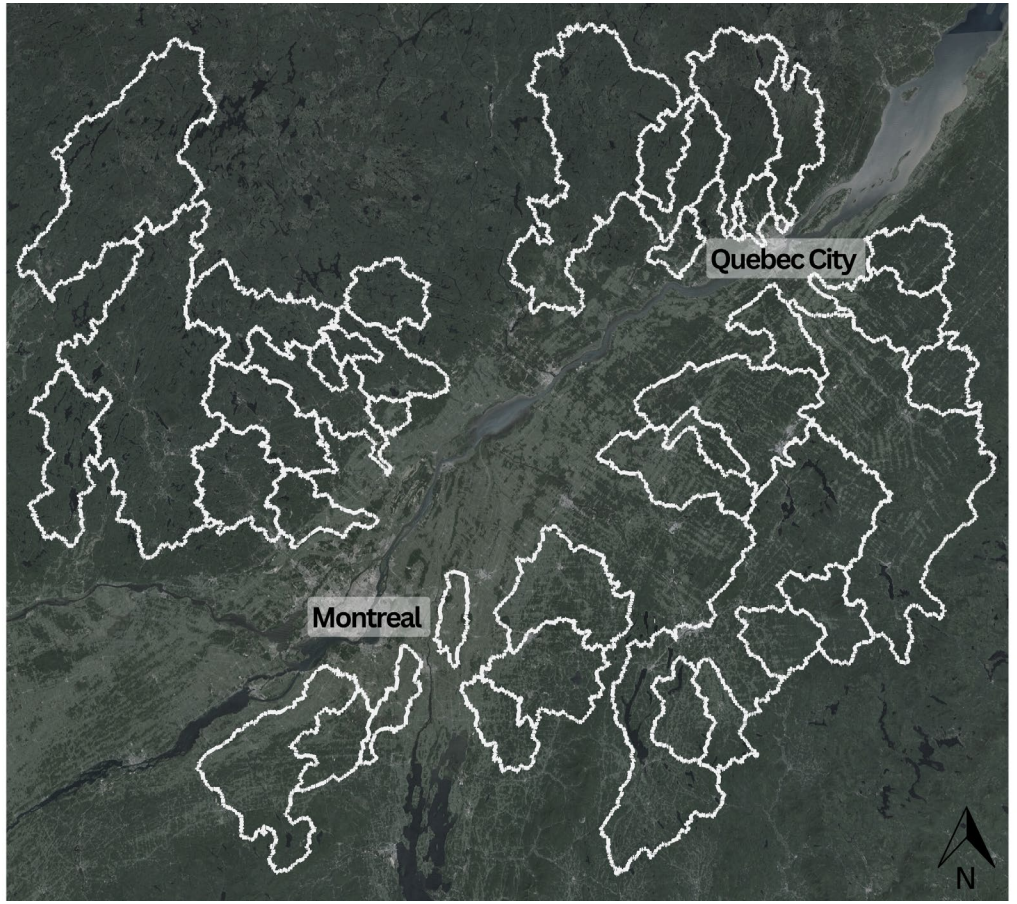

Fig 6. Placement of the catchments

Results

	LT = 2 days		LT = 5 days		LT = 9 days	
	CRPS	RI	CRPS	RI	CRPS	RI
Raw forecasts	1.32	77	1.64	56	2.32	38
MBMP	1.05	45	1.43	39	2.17	35
$NLMBMP_{log}$	1.06	57	1.45	49	2.22	48
$NLMBMP_{rad}$	1.06	55	1.45	48	2.20	37
$NLMBMP_{exp}$	1.12	104	1.48	75	2.22	56
AMBMP	1.01	50	1.42	42	2.23	37

Table 1. Averaged CRPS for all forecasts, and the average Reliability Index (over all basins) for raw forecasts and the proposed methods.

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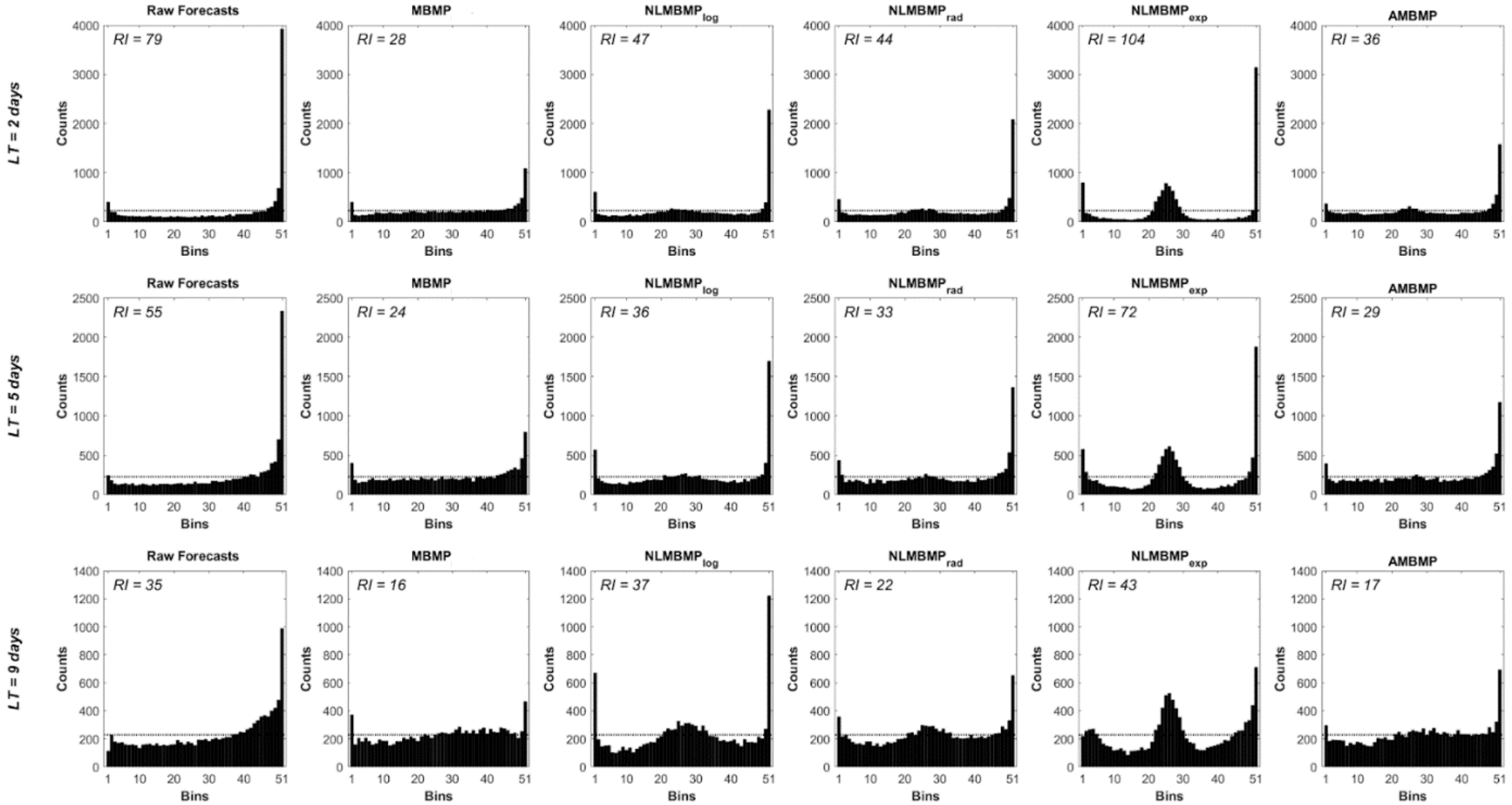


Figure 7. The rank histogram for the Non-linear MBMP variants, Angular MBMP, and standard MBMP. Reliability Index (RI; Delle Monache et al. (2006)) measures the degree to which the histogram is uniform.

Results

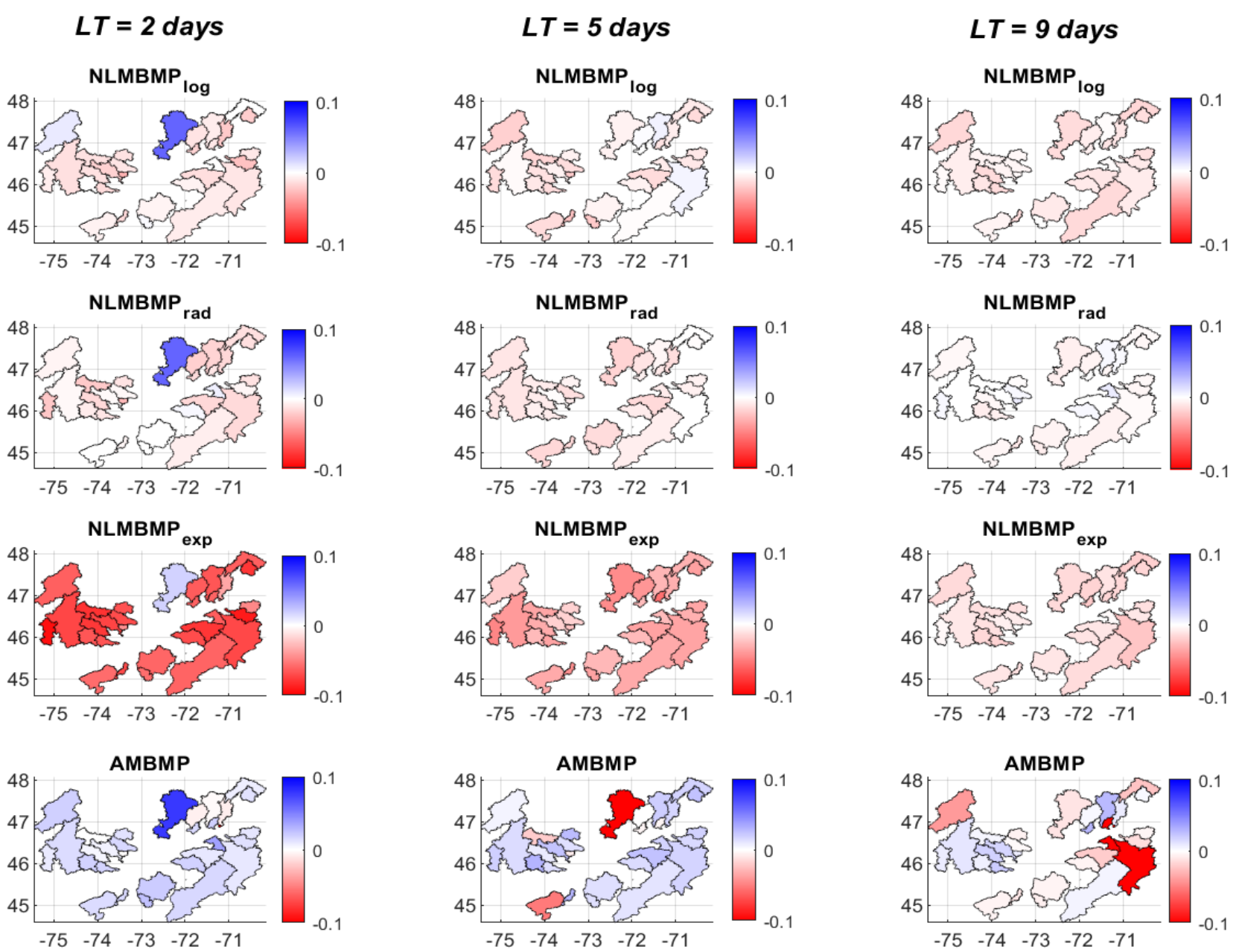


Figure 8. CRPSS values at each basin. Higher values indicate bigger improvement over MBMP.

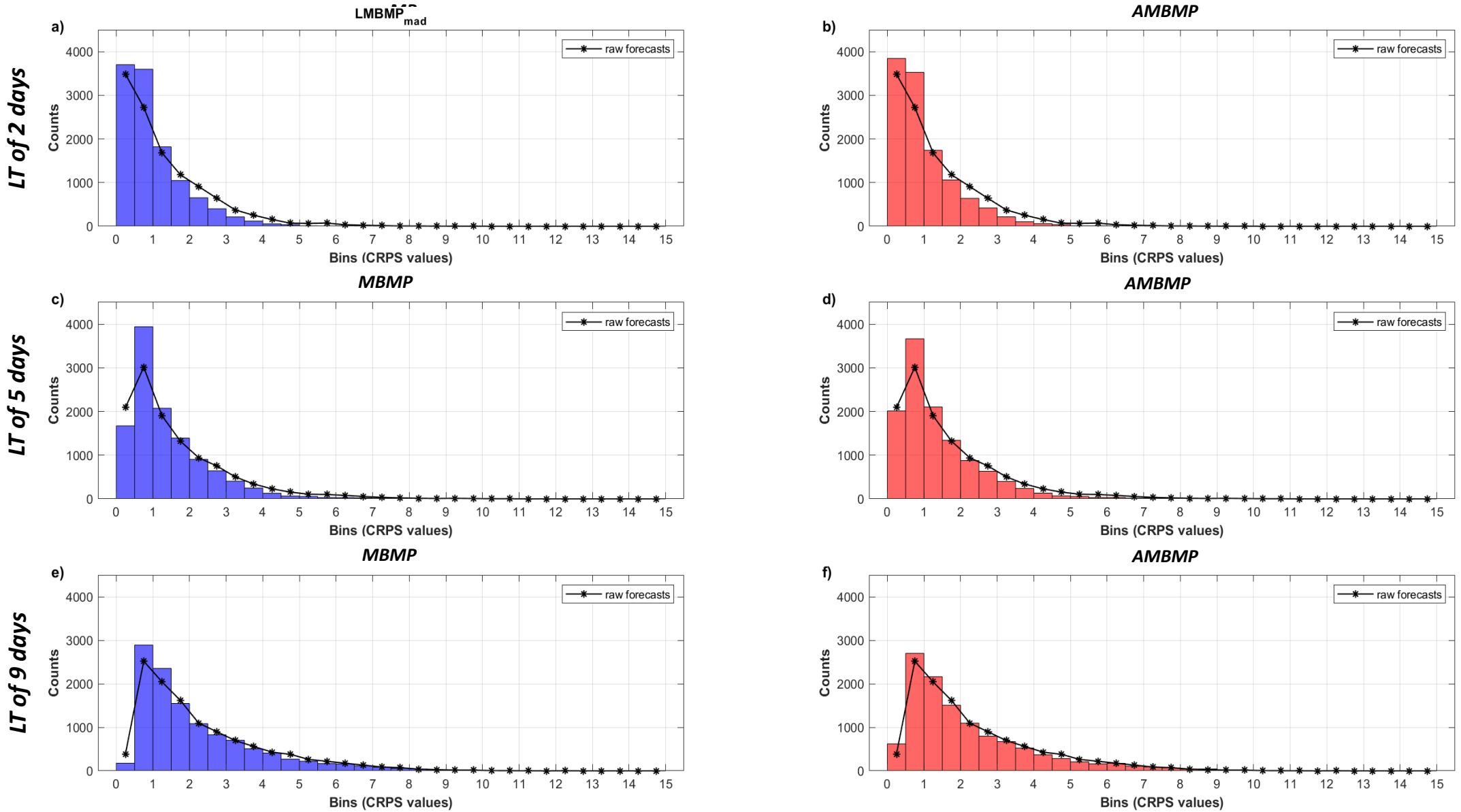


Figure 9. The histogram of CRPS values of the post-processed forecasts by *MBMP* (left side) and *AMBMP* (right side) across all lead-times.

Discussion

MBMP

$$X_{t,m}^{pp} = \alpha + \beta \overline{X_t^{raw}} + \left(\gamma_1 + \frac{\gamma_2}{ES_t} \right) \left(X_{t,m}^{raw} - \overline{X_t^{raw}} \right)$$

Discussion

MBMP

One unique, optimal γ

$$X_{t,m}^{pp} = \alpha + \beta\overline{X_t^{raw}} + \left(\gamma_1 + \frac{\gamma_2}{ES_t}\right)\left(X_{t,m}^{raw} - \overline{X_t^{raw}}\right)$$

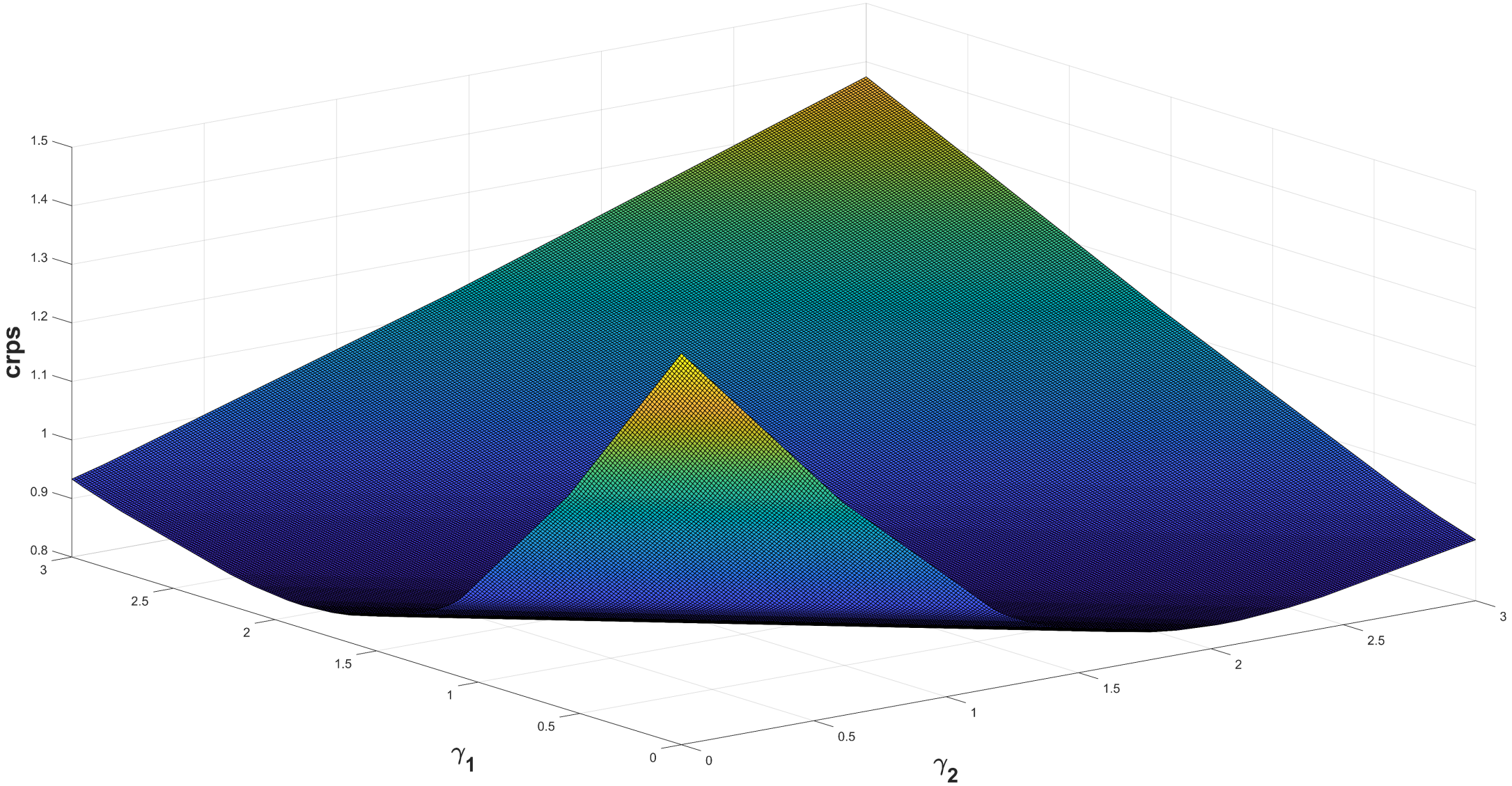
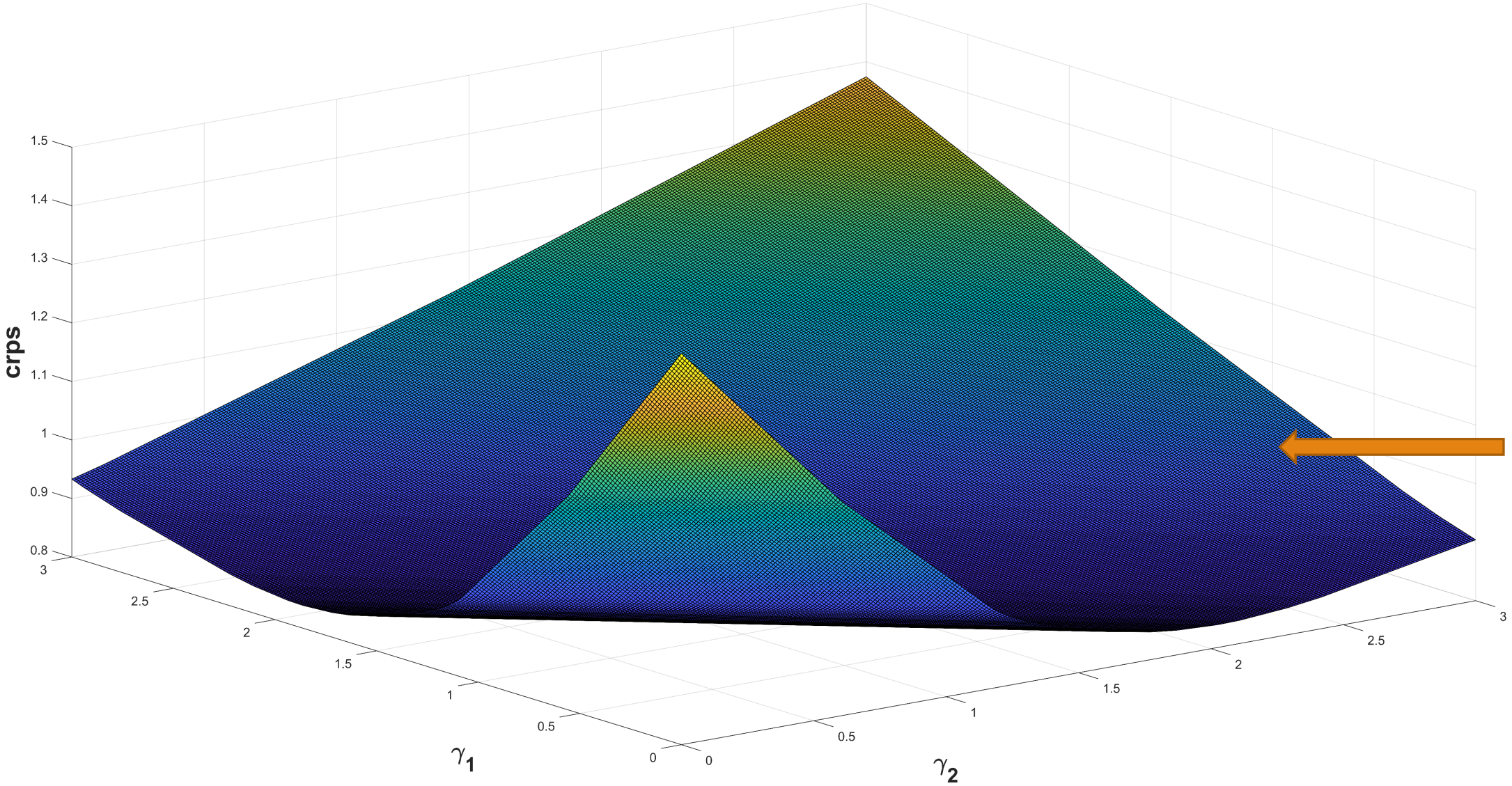


Figure 10. CRPS values for an arbitrary test forecast for different pairs of γ_1 and γ_2.



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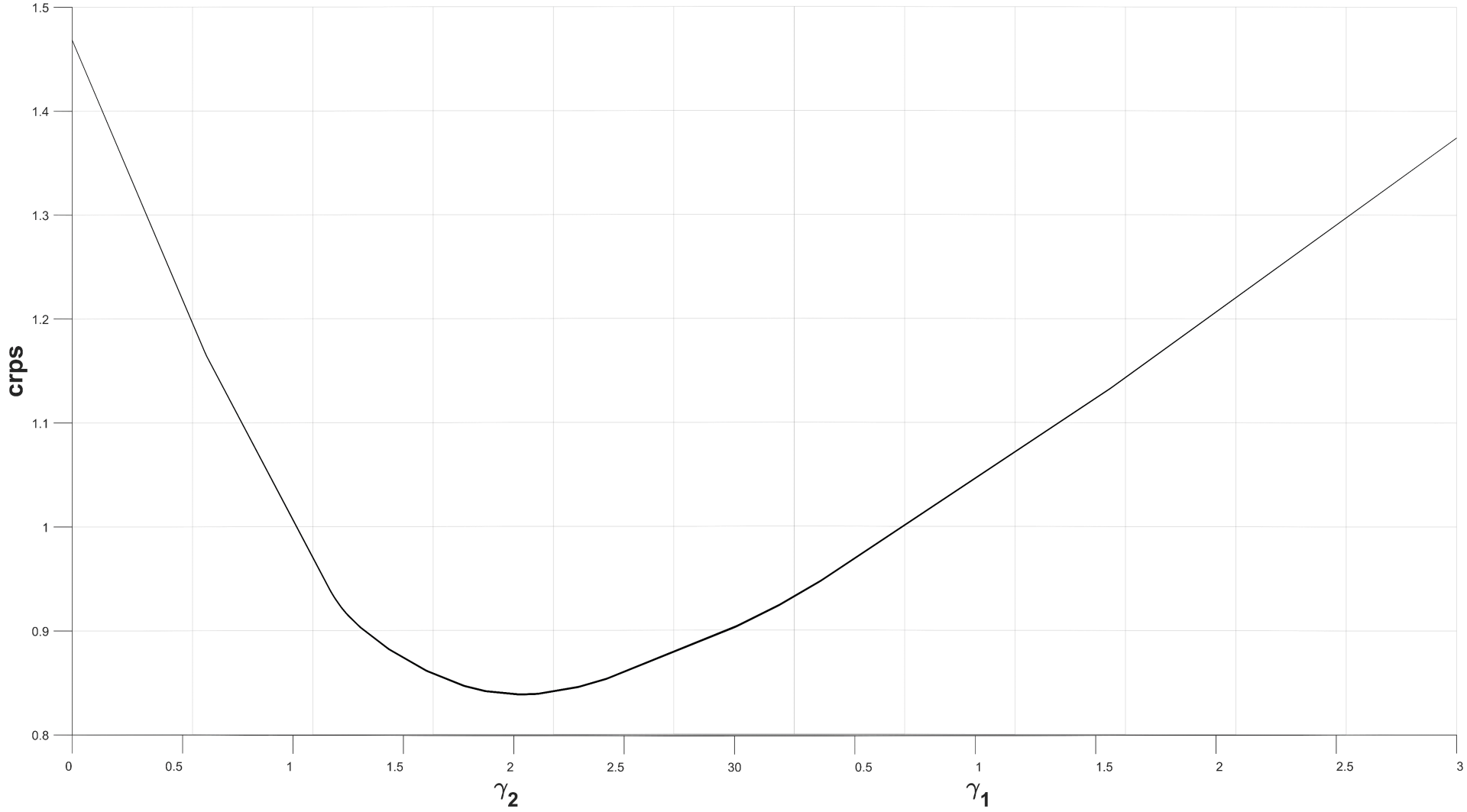
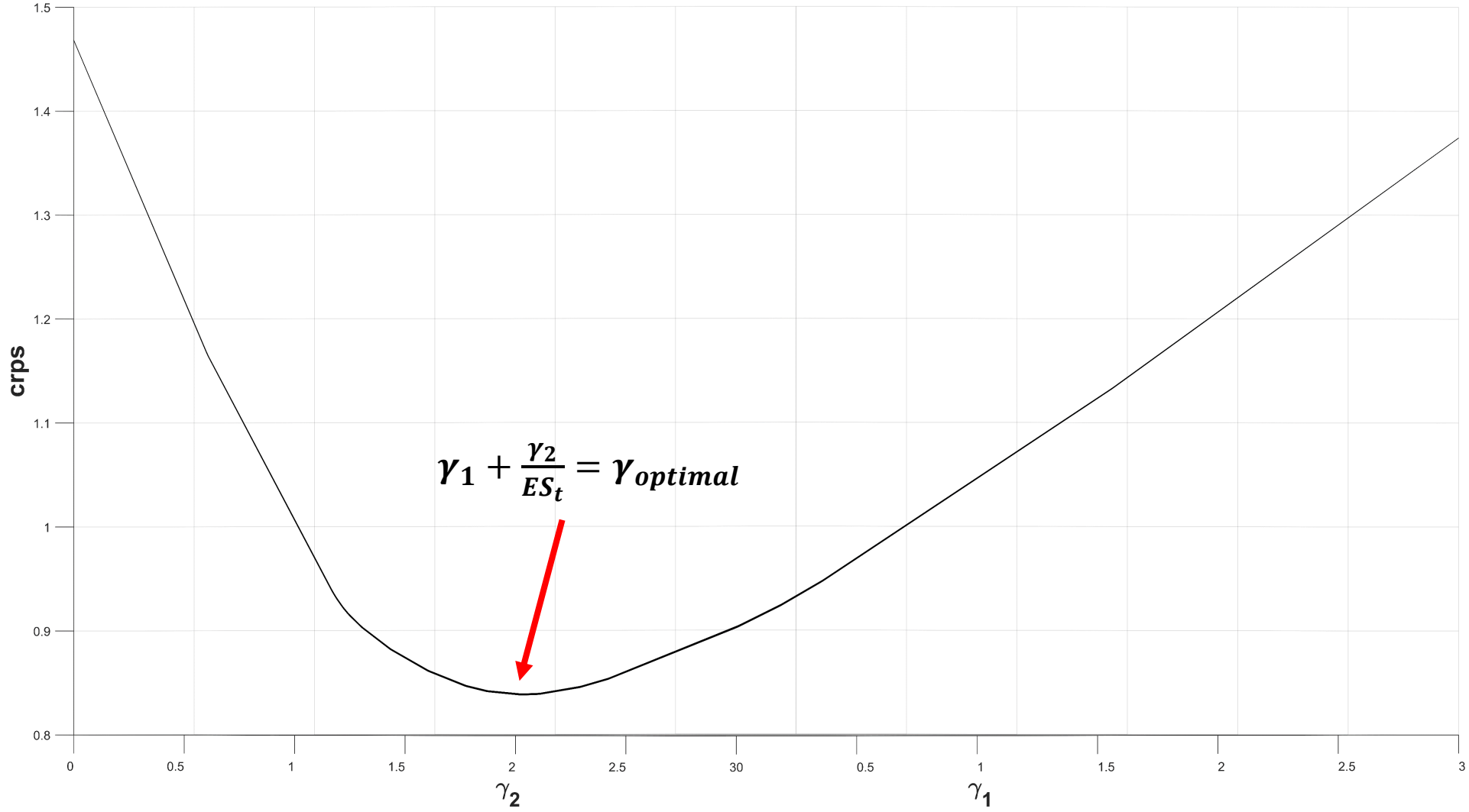


Figure 11. CRPS values for an arbitrary test forecast for different pairs of γ_1 and γ_2 (side angle).



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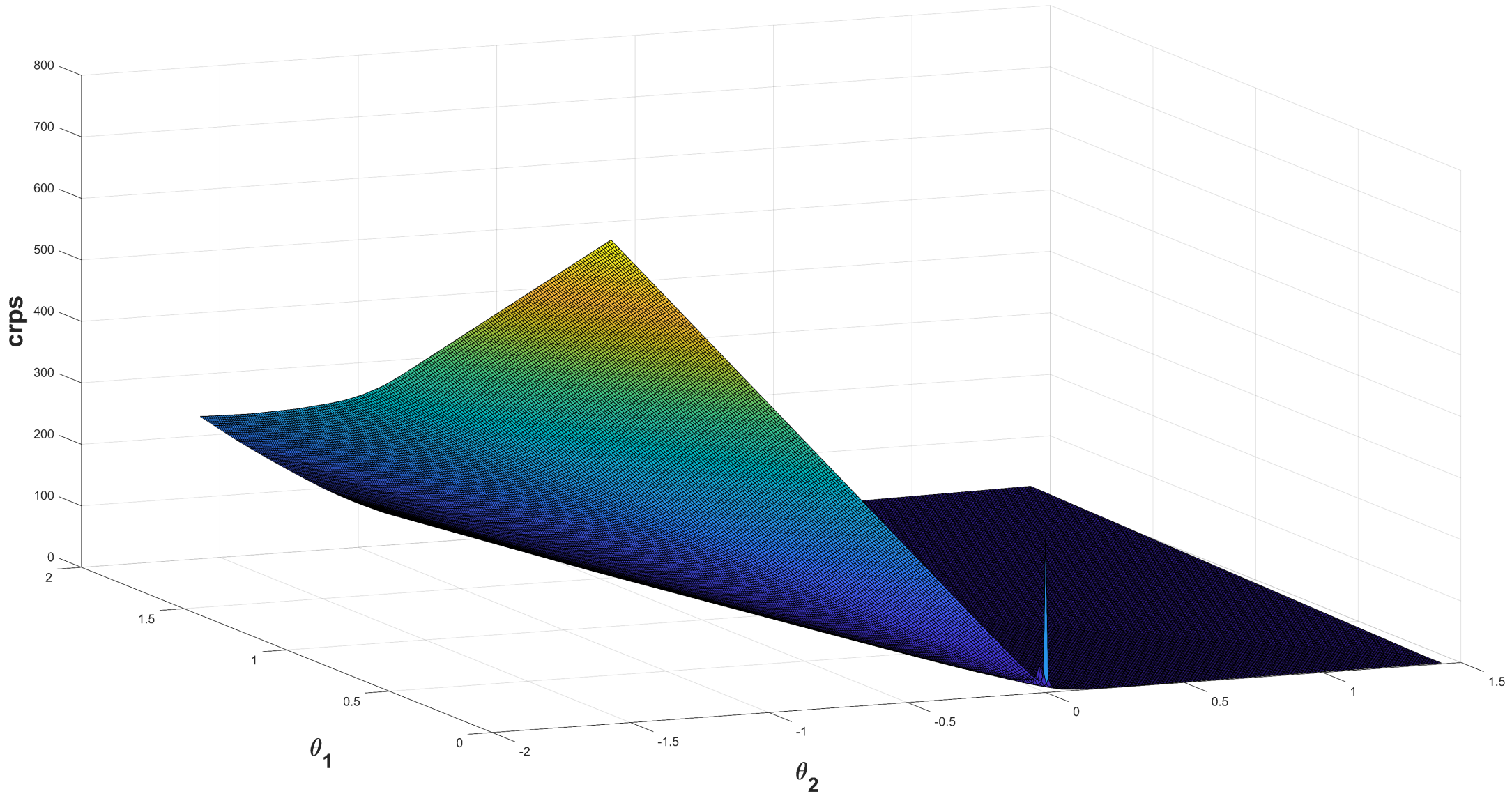
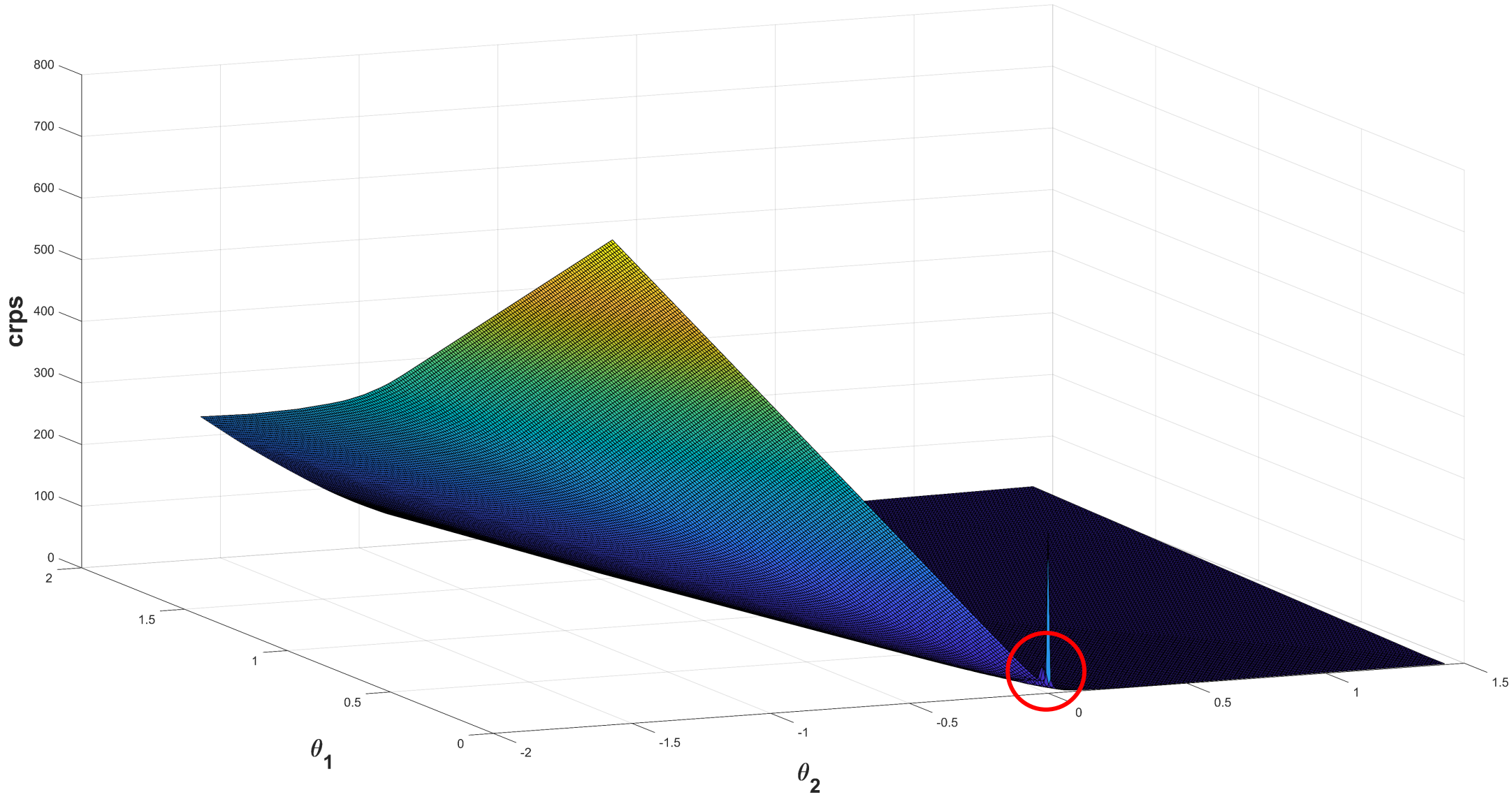


Figure 12. CRPS values for an arbitrary test forecast for different pairs of θ_1 and θ_2.



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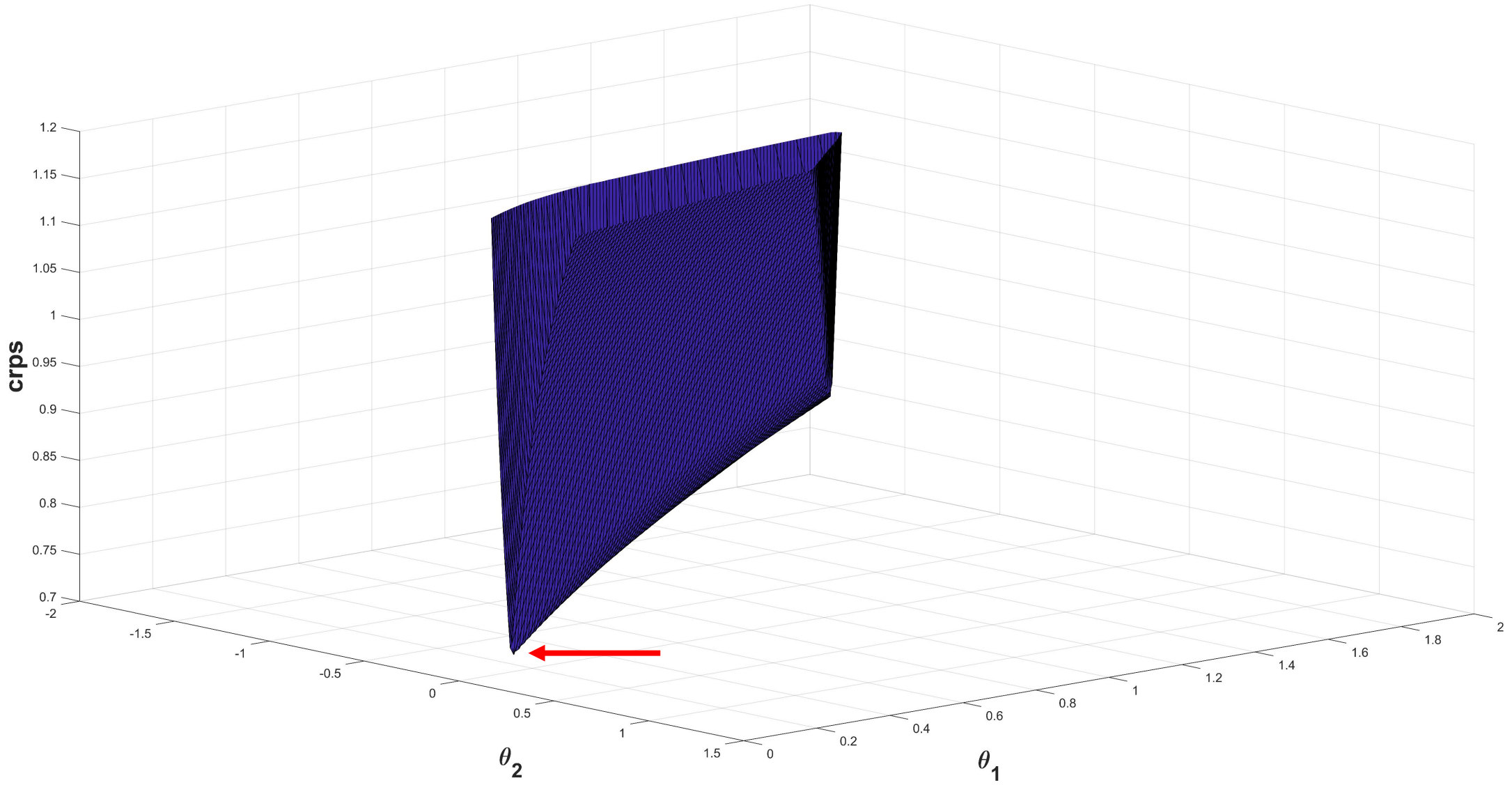

Figure 13. CRPS values for an arbitrary test forecast for different pairs of θ_1 and θ_2 (side angle).

Conclusion

1. Non-linear transformation do not take raw ensemble spread into account; therefore, they do not work well.

2. AMBMP can be implemented with other well-known distributions.

3. AMBMP can be tested on other variables such as precipitation.

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THANK YOU

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