

Bayesian methods for combining climate forecasts

Sergio Pezzulli (*)

1. Bayes theorem
2. An application to forecast El Nino

Caio Coelho (*)

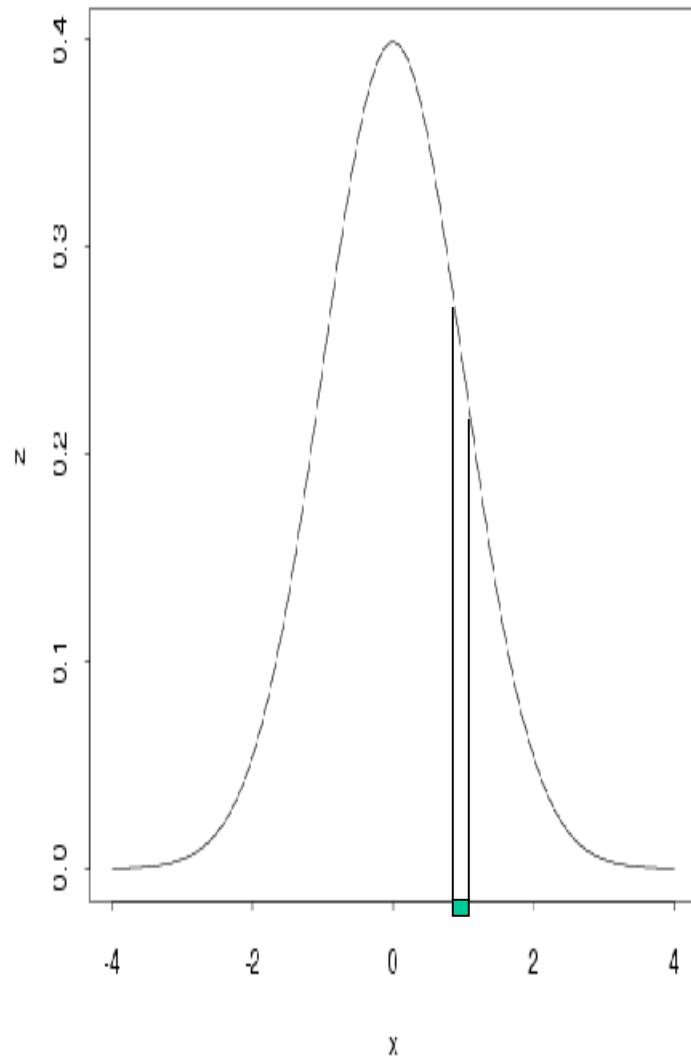
David B. Stephenson (*)

Francisco J. Doblas-Reyes (ECMWF)

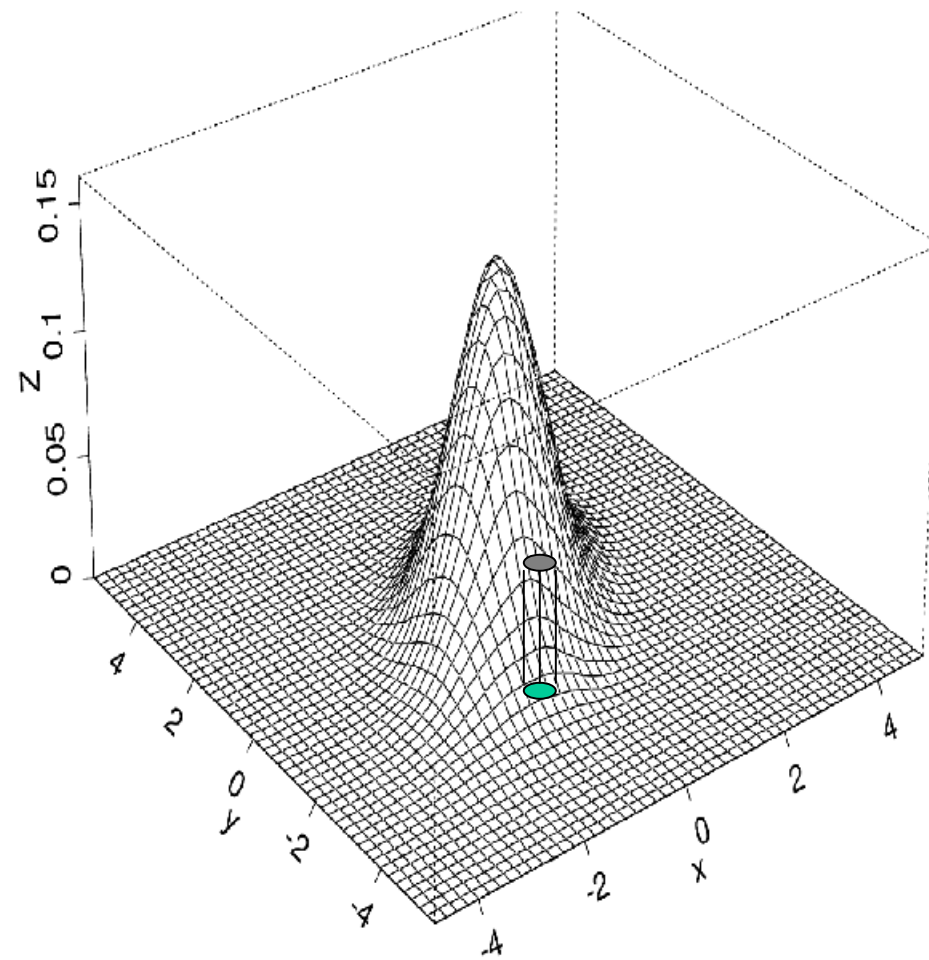
Magdalena Balmaseda (ECMWF)

(*): Department of Meteorology, The University of Reading

Probability density functions (distributions)



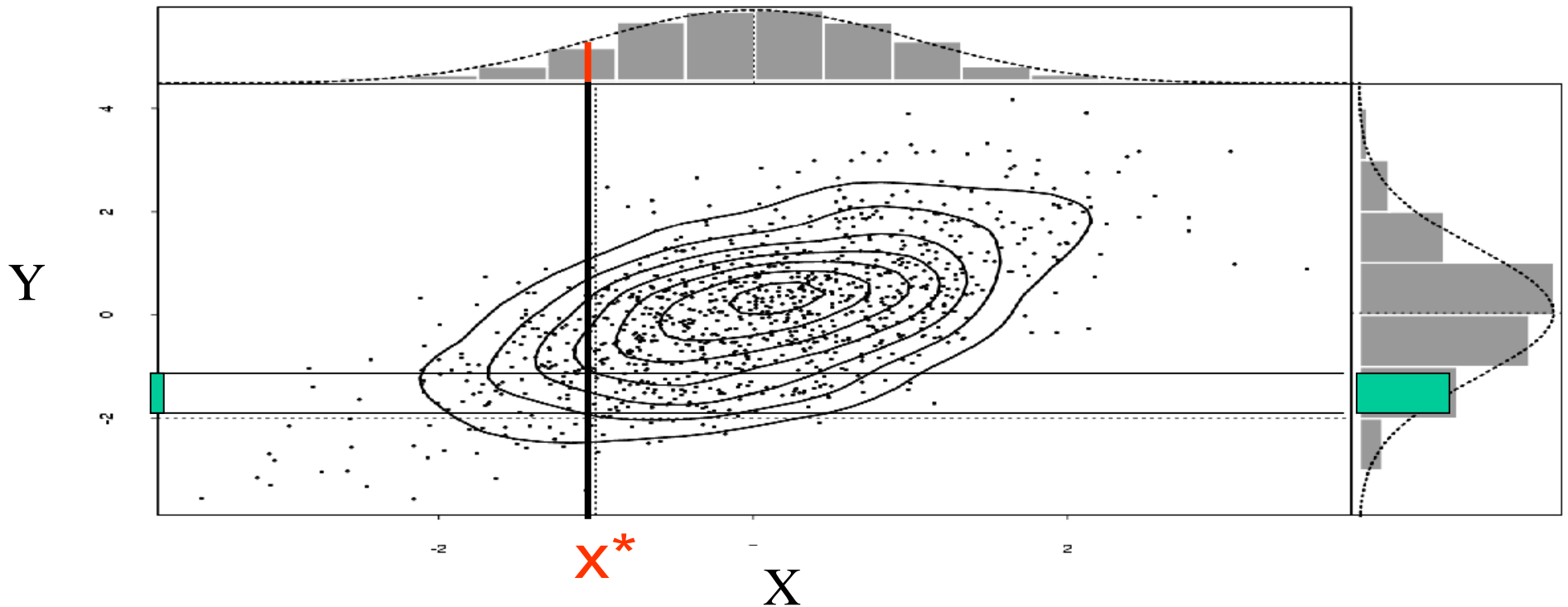
Uni-dimensional



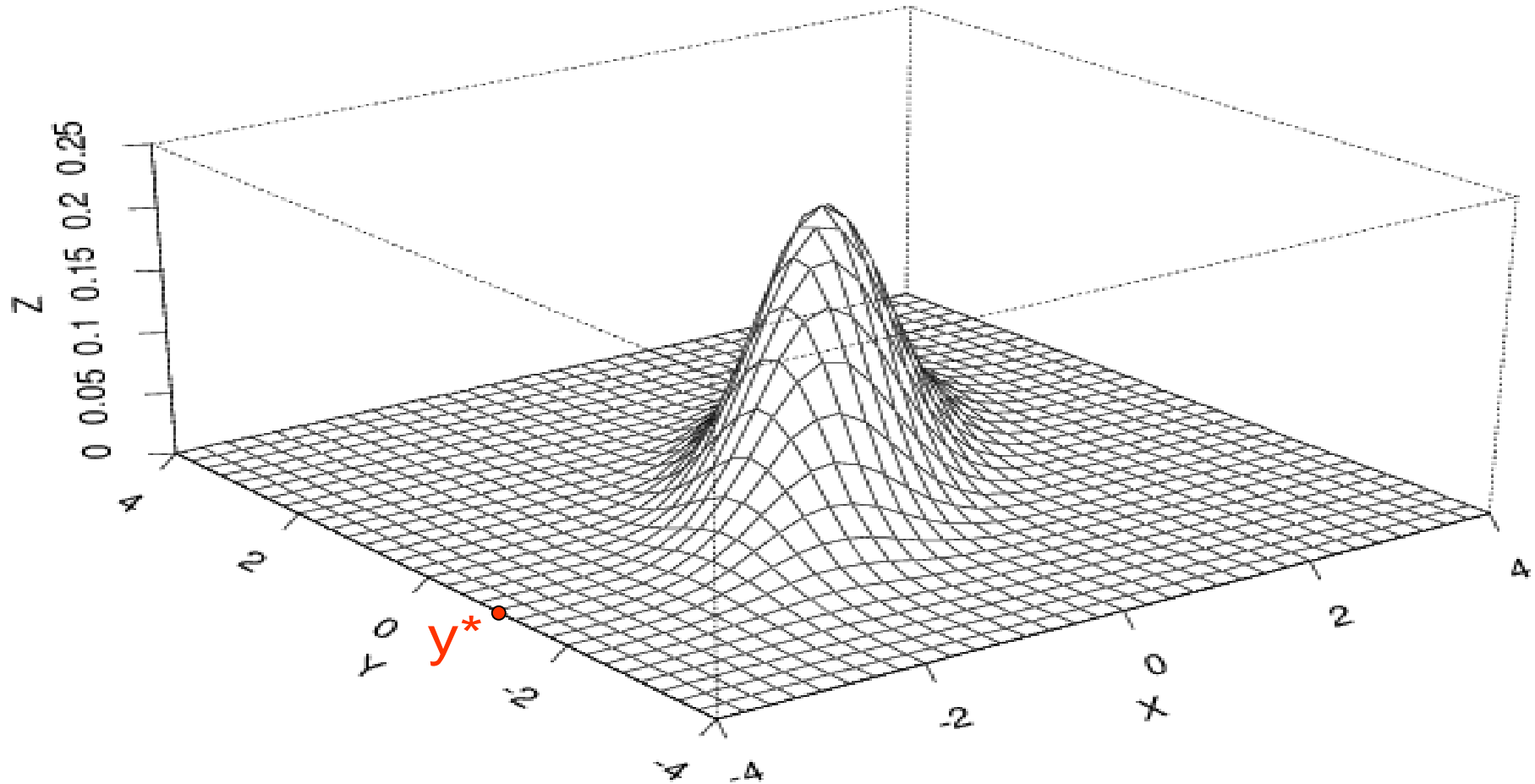
Bi-dimensional
or **Joint**
distribution of X & Y

Joint and **Marginal** distributions

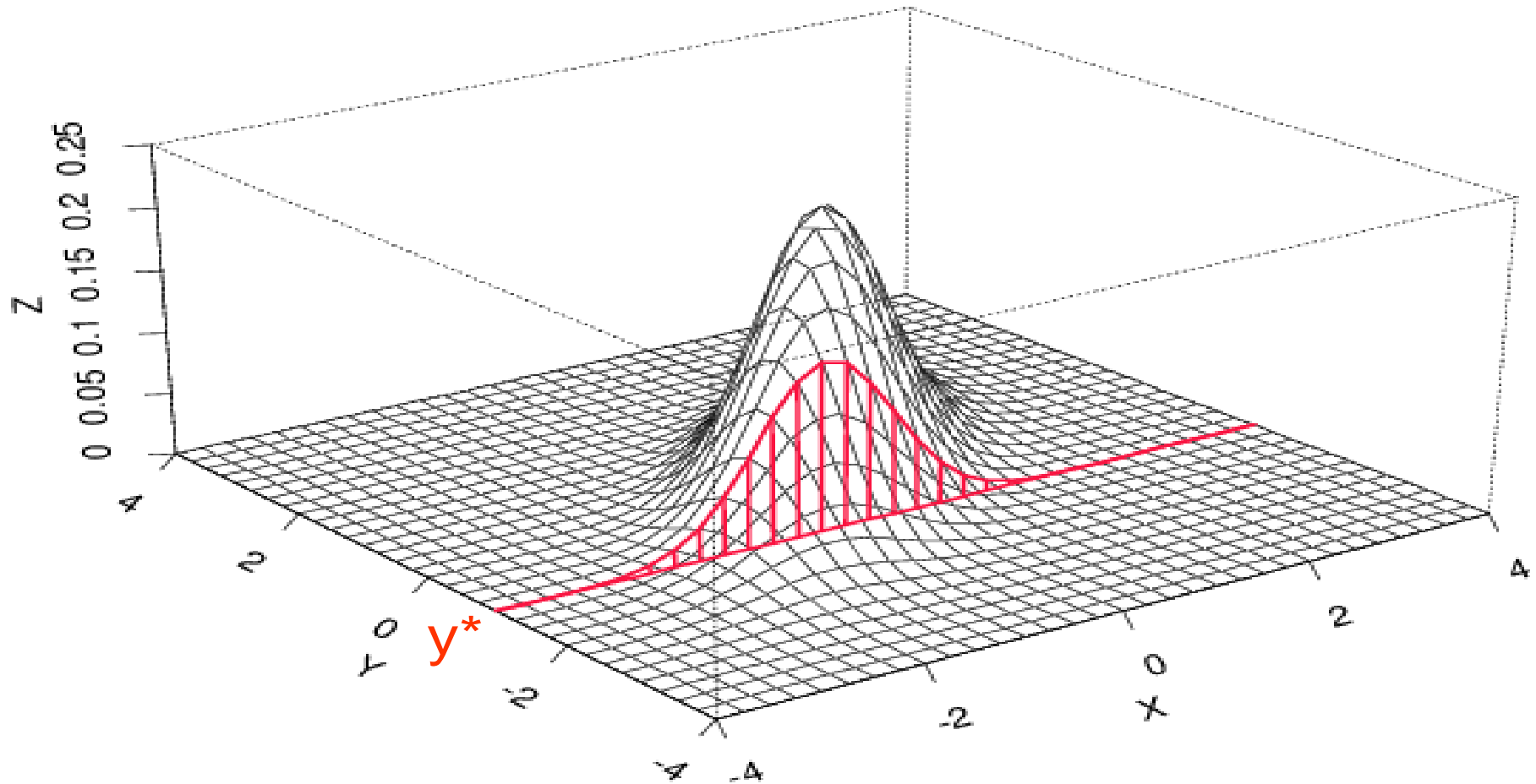
$$p(x^*) = \int p(x^*, y) dy$$



Joint and **Conditional** distributions



Joint and **Conditional** distributions



$$p(x | y^*) = p(x, y^*) / p(y^*)$$

Conditional-chain Rule

$$p(y) p(x|y) = p(x, y) = p(x) p(y|x)$$

Bayes Theorem

$$\begin{aligned} p(x|y) &= p(x, y) / p(y) \\ &\propto p(x, y) \\ &= p(x) p(y|x) \end{aligned}$$

DATA

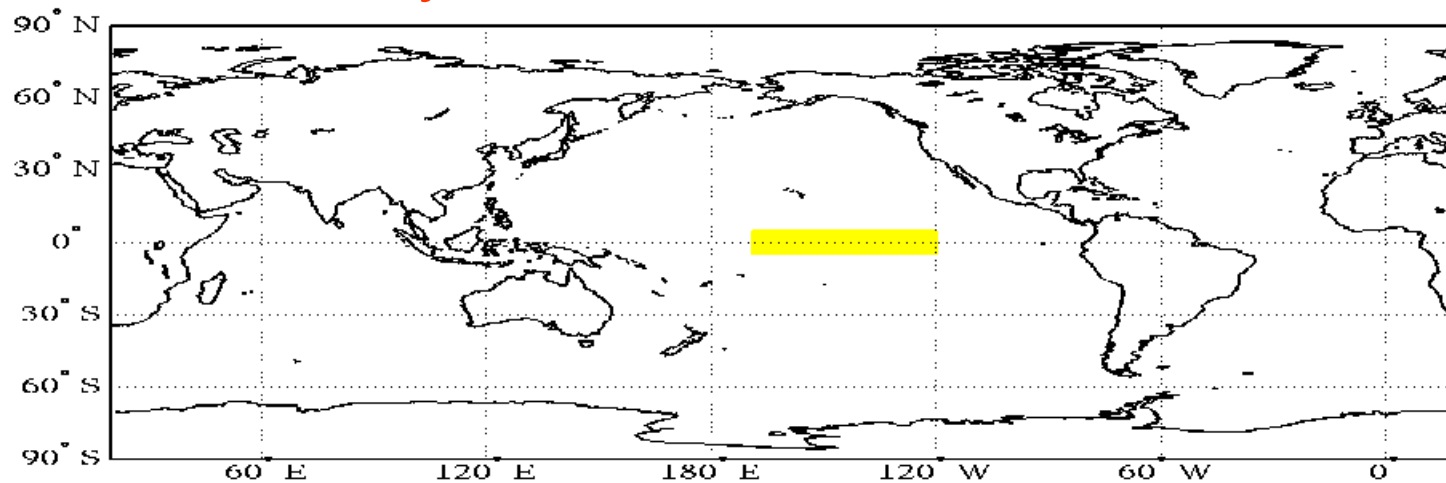
Sea Surface Temperatures (SST)

“at” location Nino 3.4

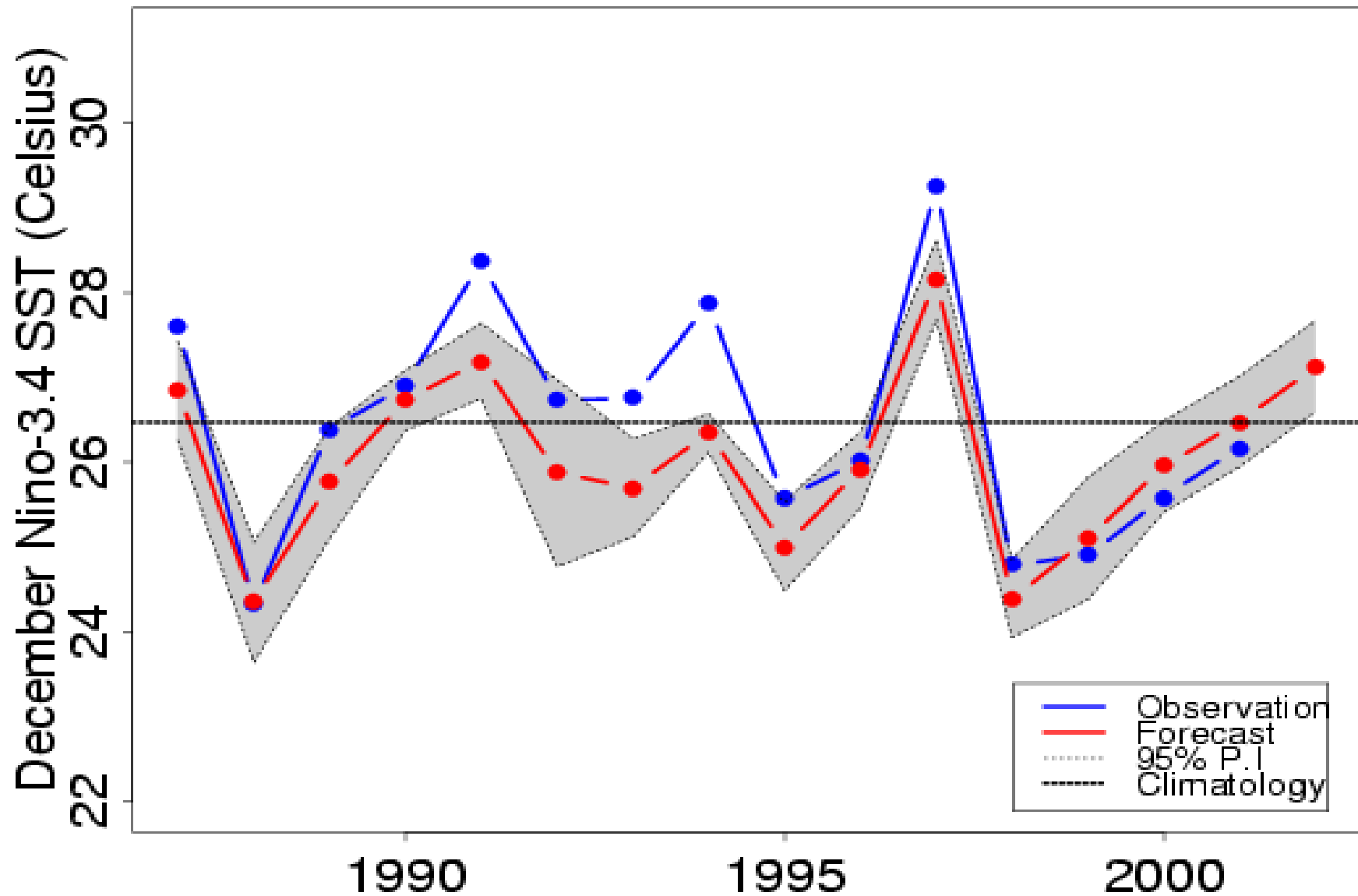
(5S - 5N , 170W - 120W)

December's means of Nino 3.4:

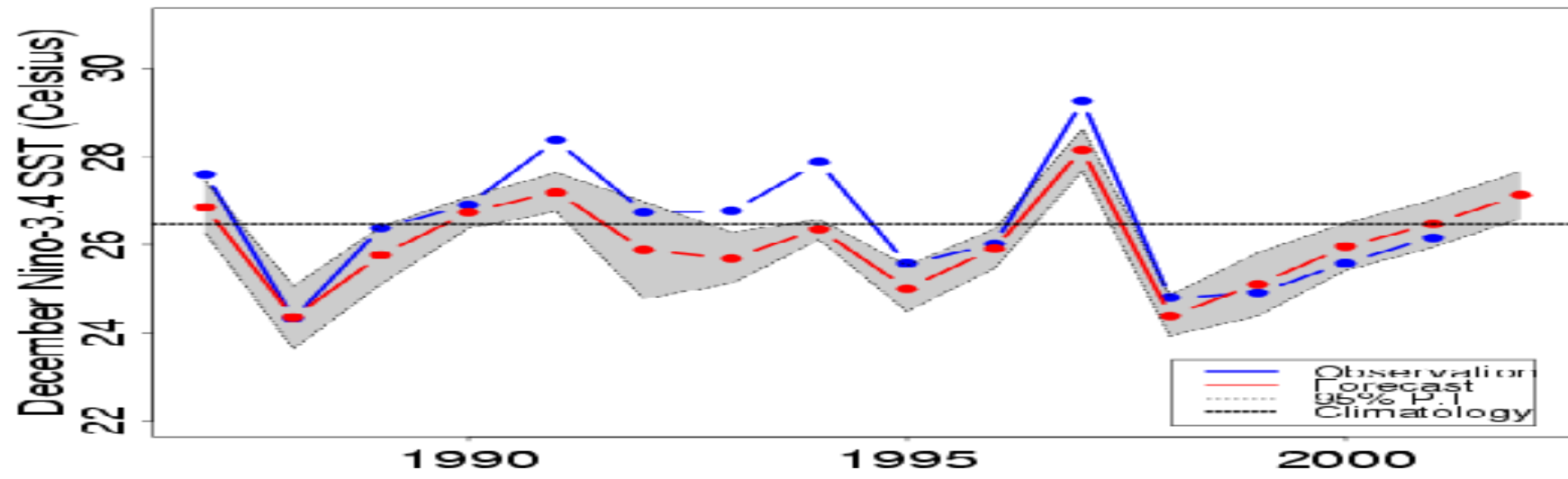
- Reynolds SST : 1950-2001
- ECMWF – System 2 ensemble forecasts: '87-01



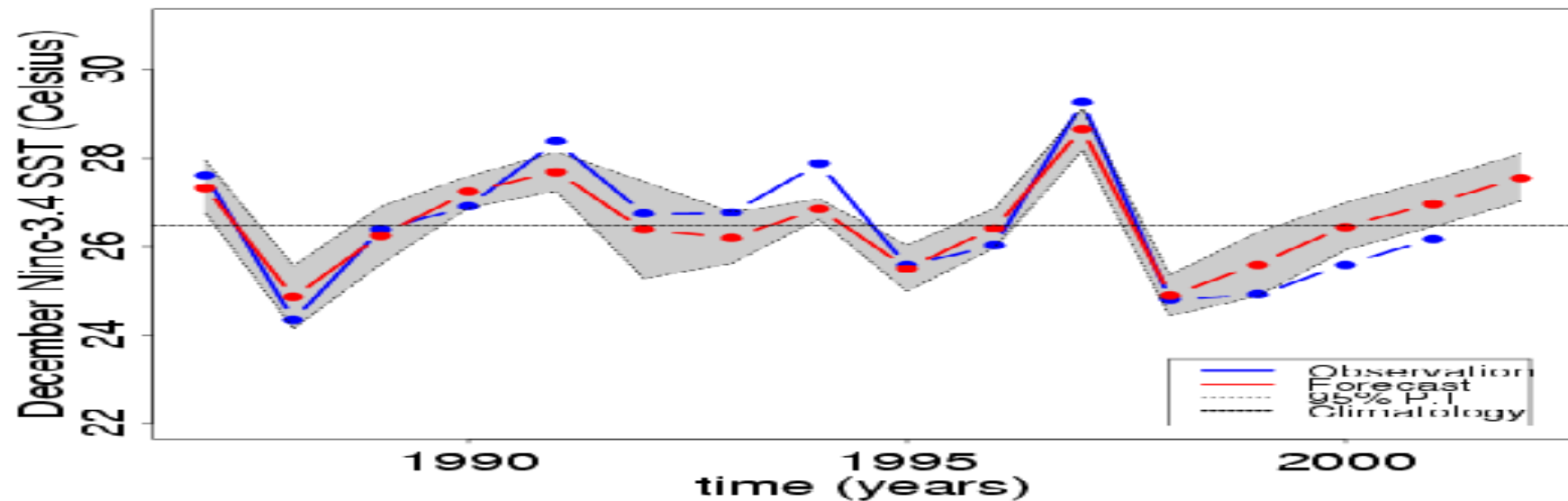
Coupled Model Ensemble Forecast



Ensemble Forecast and Bias Correction



Bias Corrected





Thomas Bayes

1701-1761

An Essay towards Solving a Problem
In the Doctrine of Chances.
Philosophical Transactions
of the Royal Society, 1763

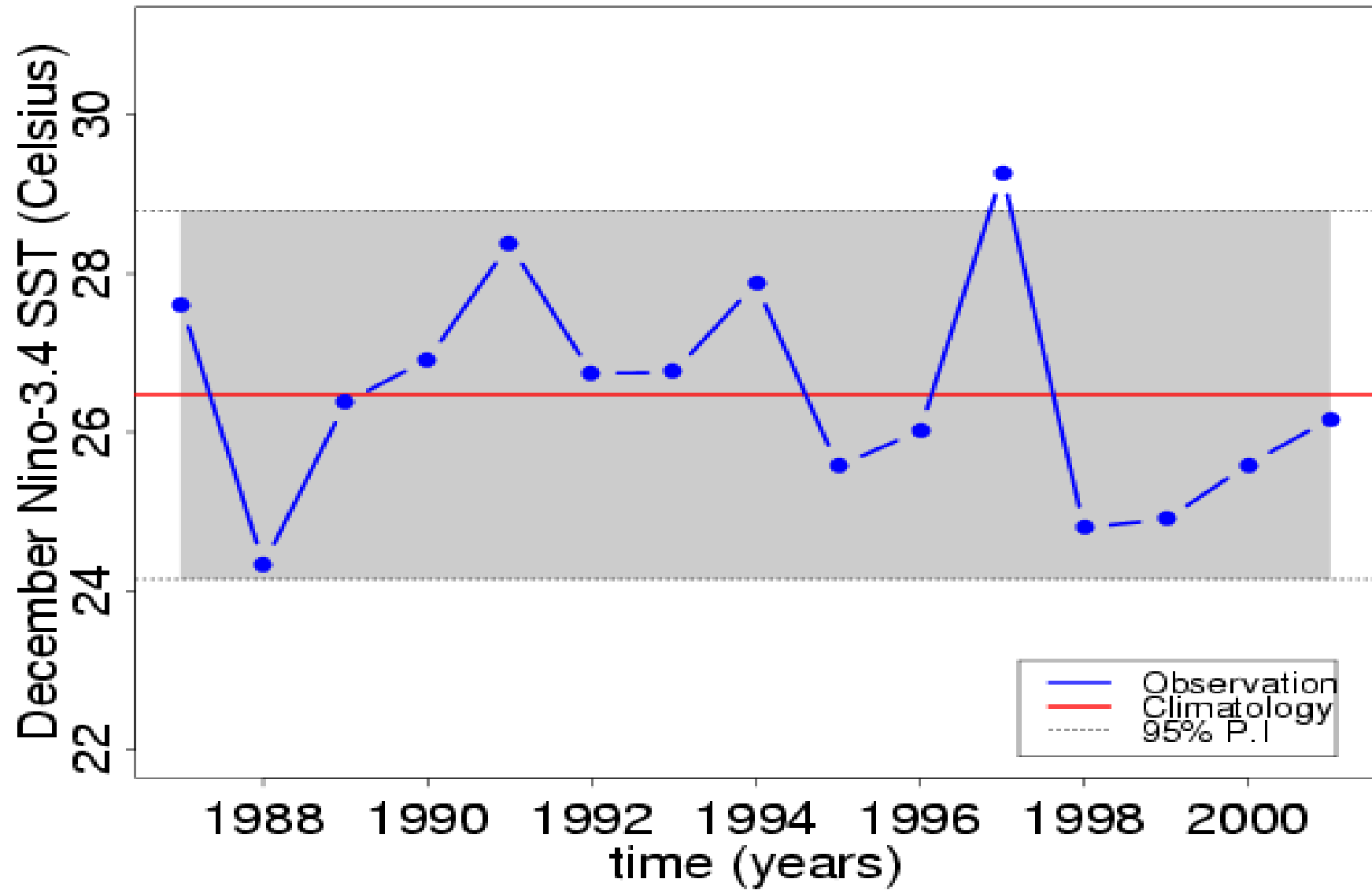
The process of belief revision on any event
W (the weather)
consists in updating the probability of W when new information
F (the forecast)
becomes available

$$p(\mathbf{W} | \mathbf{F}) \propto p(\mathbf{W}) p(\mathbf{F} | \mathbf{W})$$

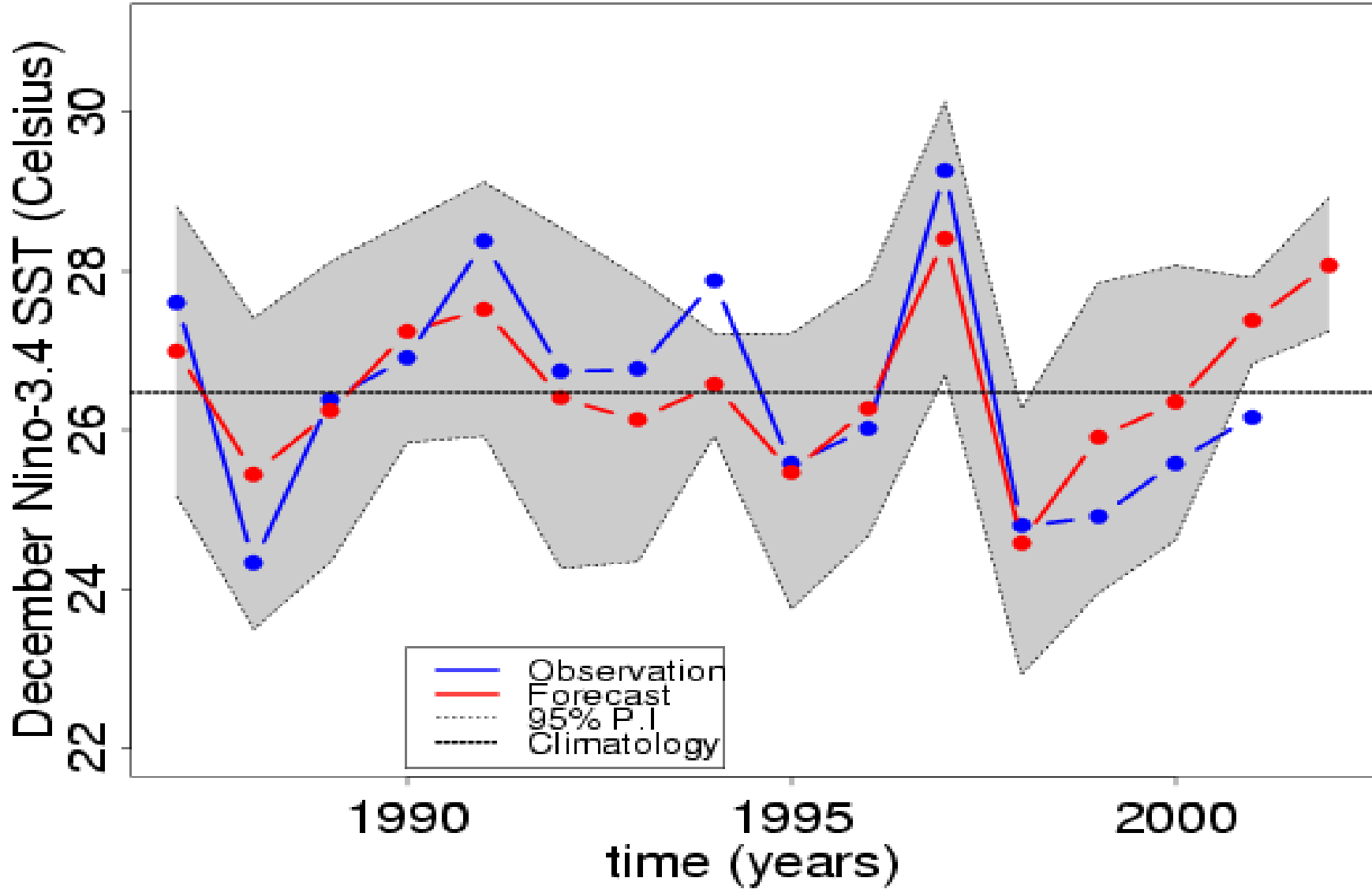
$$p(\mathbf{W}) = \mathbf{N}(\mu, \sigma^2)$$

$$p(\mathbf{F} | \mathbf{W}) = \mathbf{N}(\alpha + \beta \mathbf{W}, \gamma \mathbf{V})$$

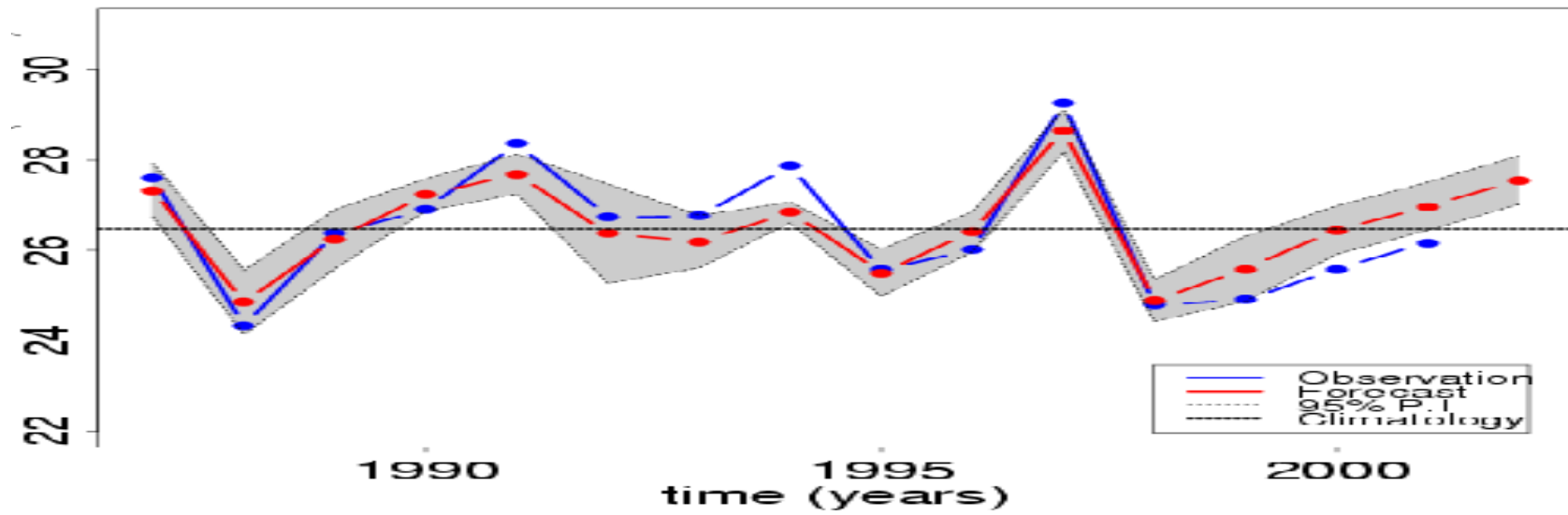
Climatology



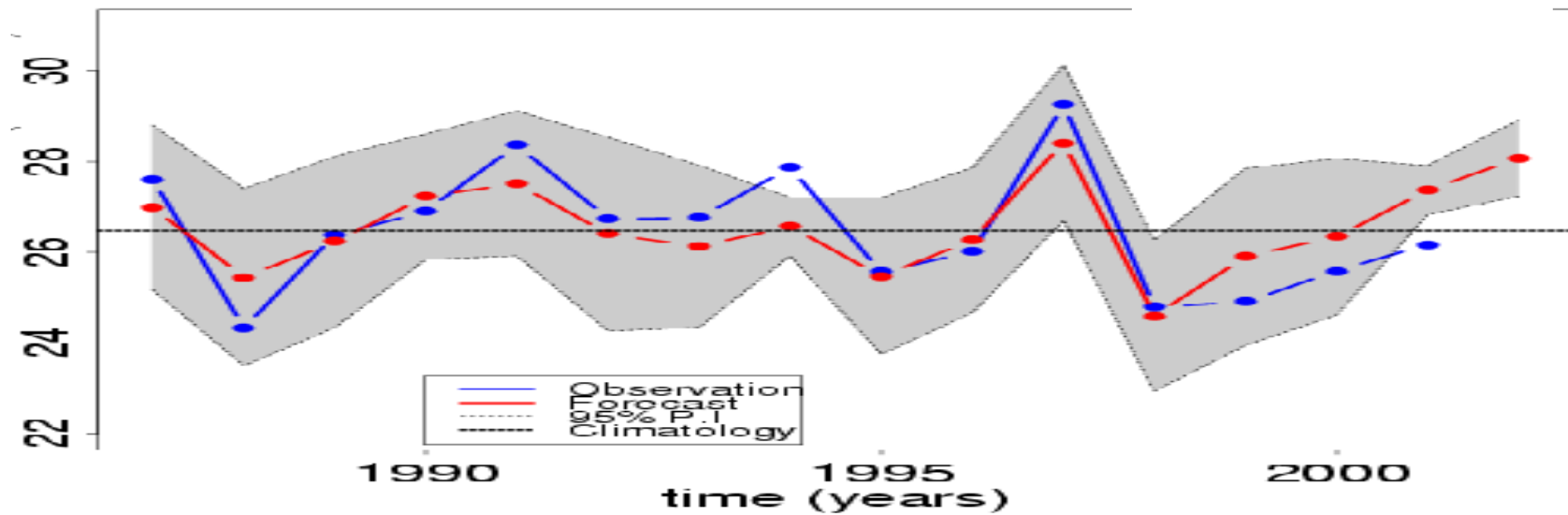
Climatology + Ensemble



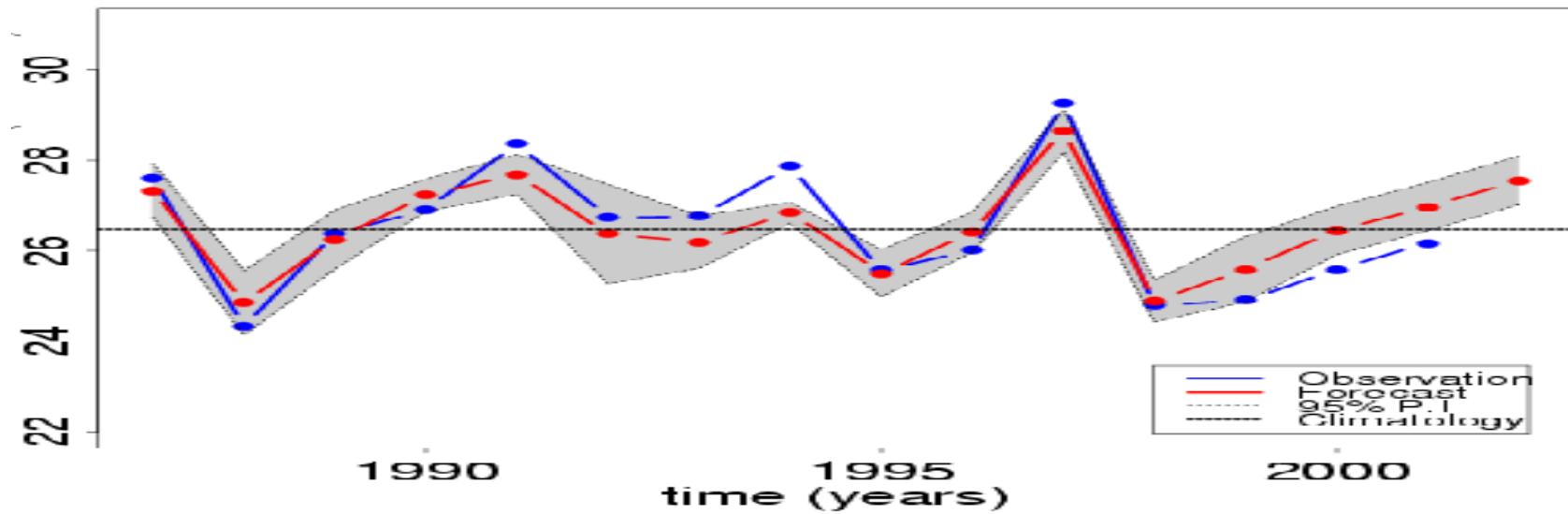
Coupled-Model Bias-Corrected Ensemble Forecast



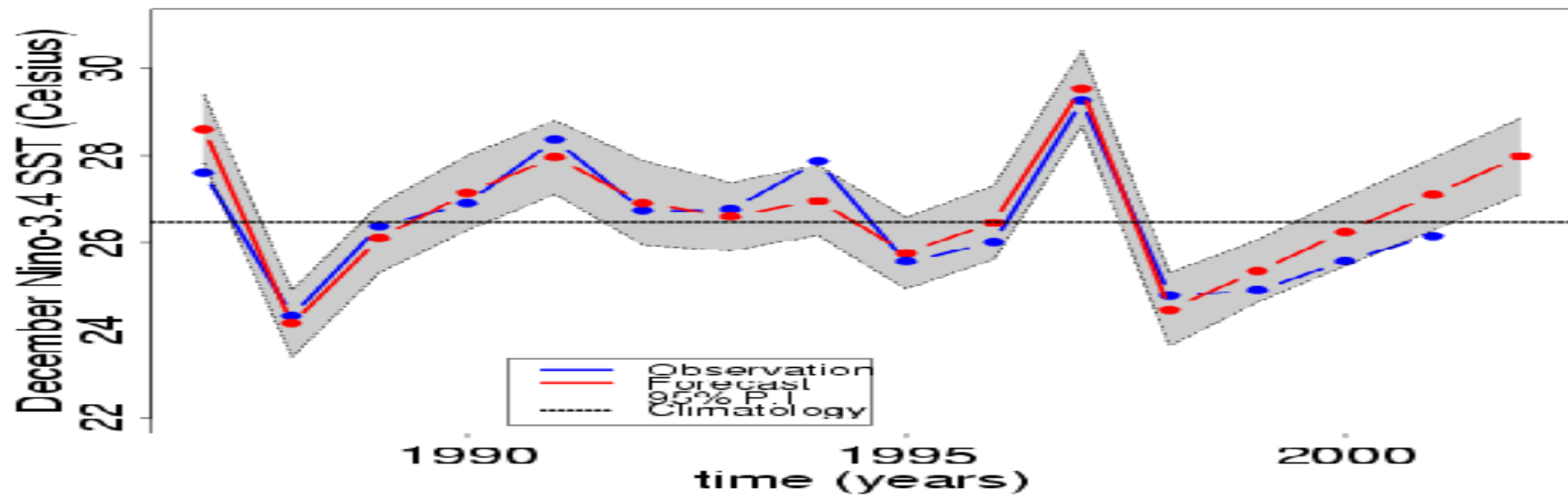
Climatology + Ensemble



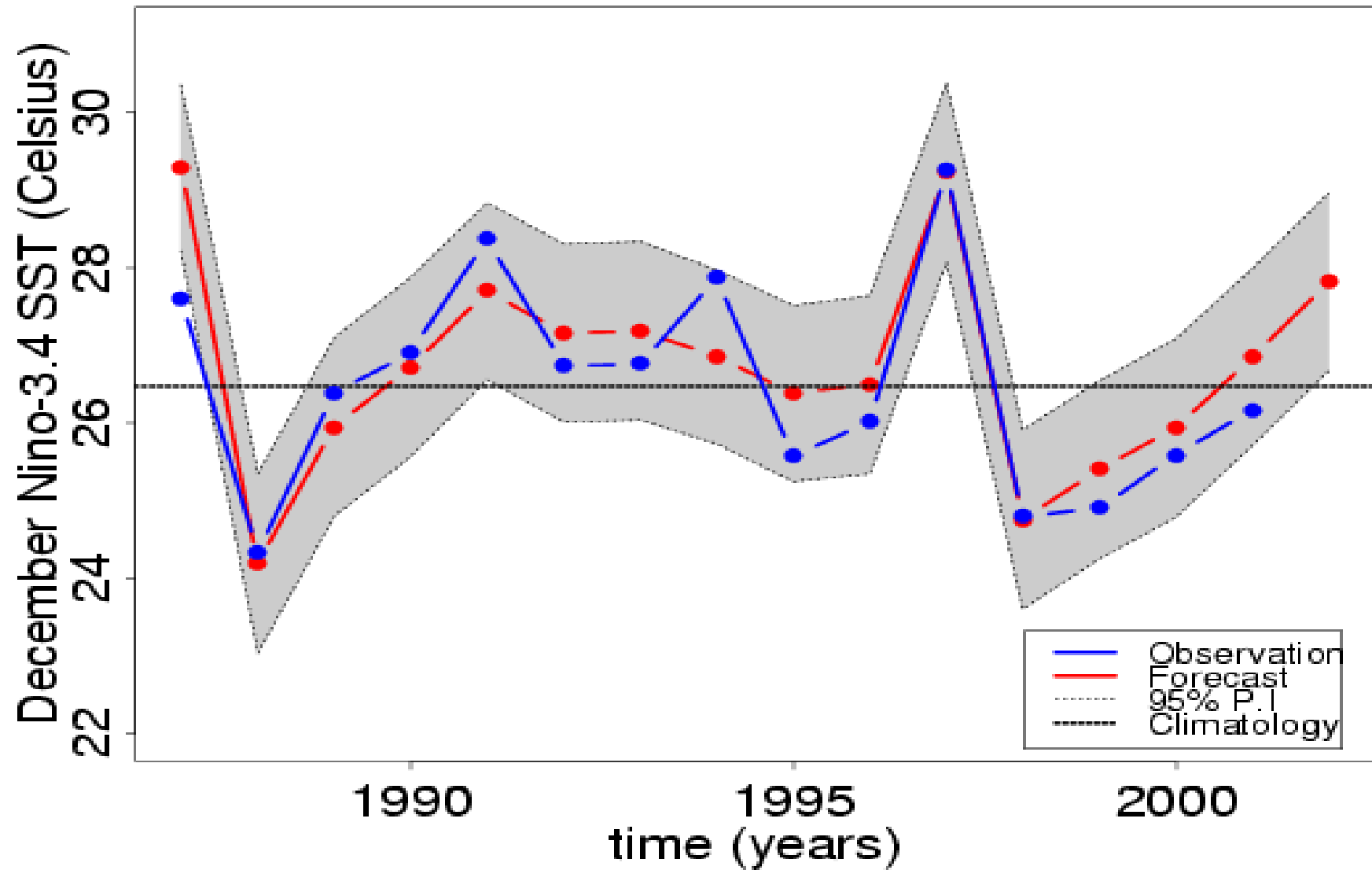
Coupled-Model Bias-Corrected Ensemble Forecast



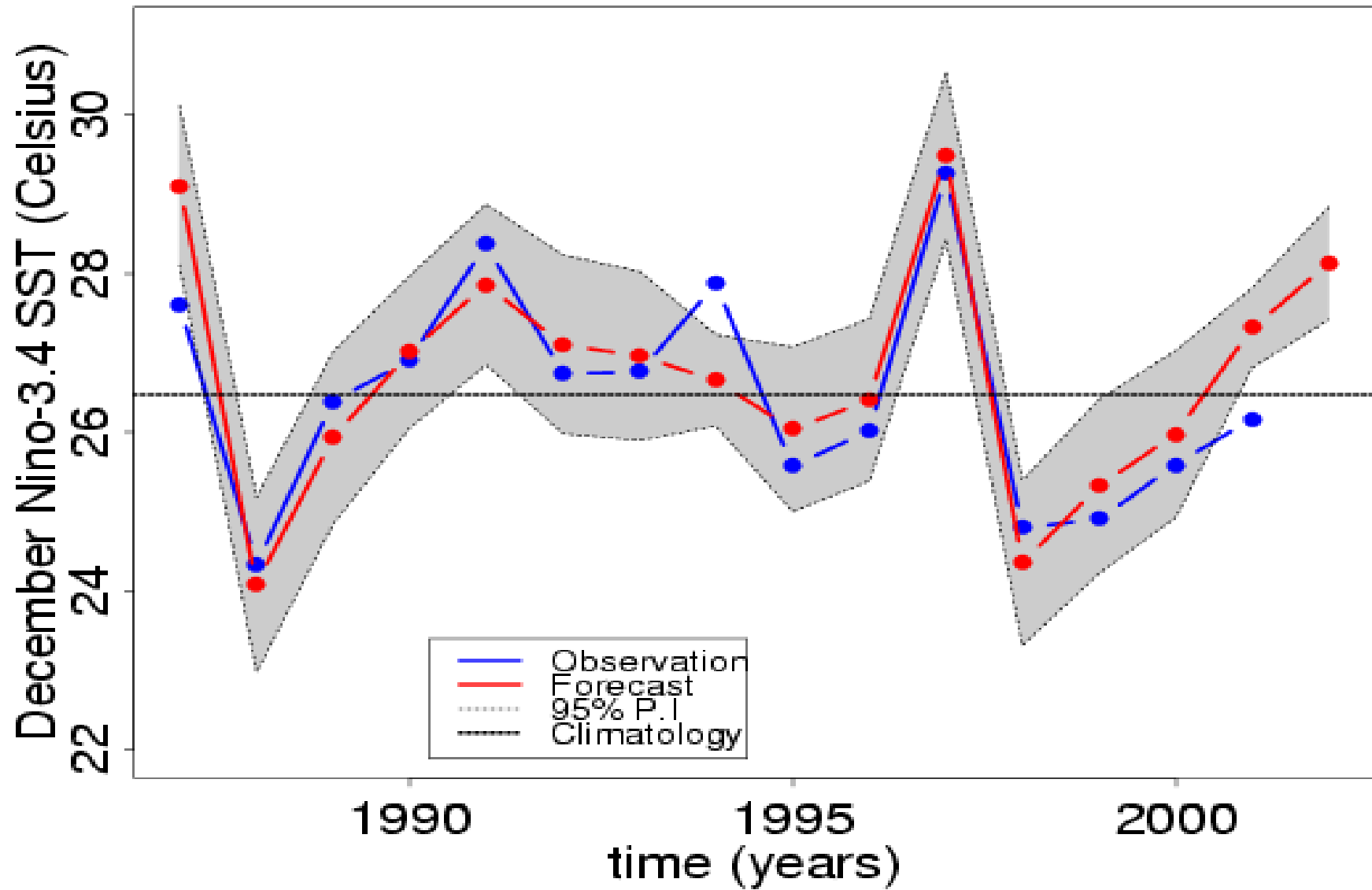
Empirical Regression Model + Ensemble



Empirical Forecast

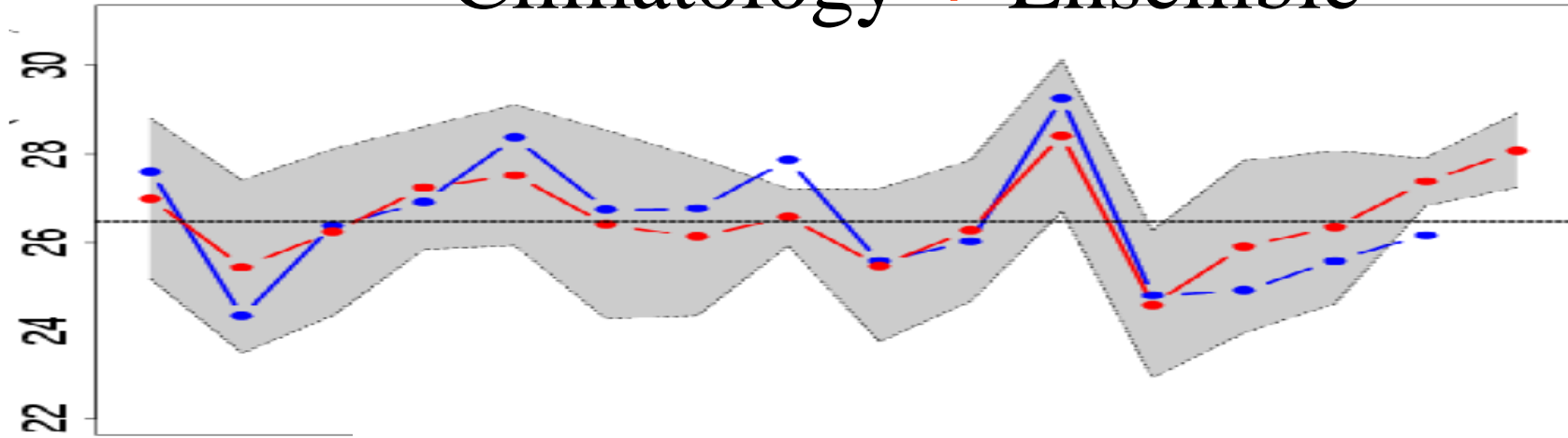


Empirical + Ensemble

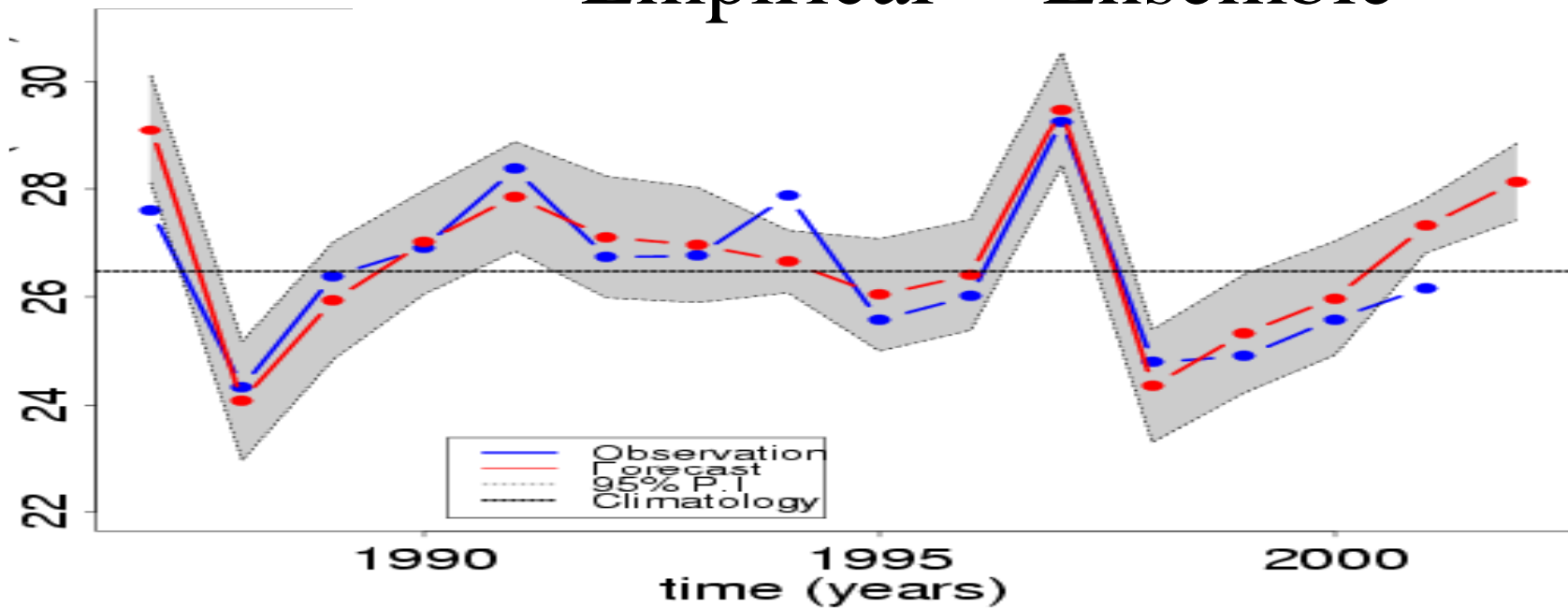


A vs B

Climatology + Ensemble



Empirical + Ensemble



Conclusions

- Bayes calibration provides more realistic forecast uncertainty intervals
- More sophisticated empirical models can improve the combined forecast
- For more details email me

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