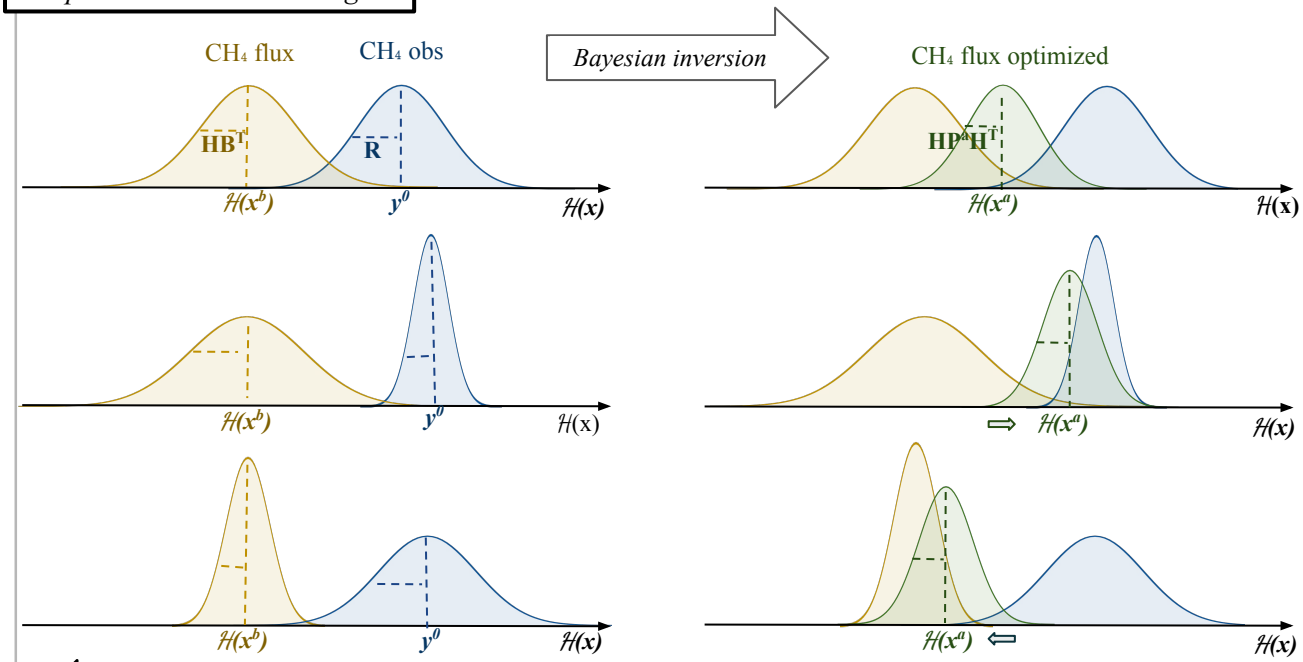
Inversion case studies: *Impact on constraint strength*



B ≈ R → optimal balance, strongest constraint

B ≫ R → observation dominates, posterior close to obs

B ≪ R → prior dominates, posterior close to prior

The ability to constrain a parameter depends on the ratio of prior uncertainty (**B**) to observational uncertainty (**R**).

SELECTING STUDY CASES: NEED TO KNOW UNCERTAINTIES

Sensitivity analysis: *Quantifying uncertainty propagation*

Chemistry | CH_4 fluxes | $\delta^{13}C$-CH_4 signatures

Input uncertainty → determines which constraint case applies and how to set **B**.

Parameter space → Atm. model $\mathcal{H}(x)$ → Concentration space

CH_4 mole fraction | $\delta^{13}C$-CH_4 signal

Output uncertainty → if too high, results are not reliable.

- ➔ **Reduced through improved priors**
- ➔ **Explicitly optimized within the inversion framework -> need B/R Matrix**
- ➔ **Etc.**

R/B mapping: *Integrating uncertainties into the inversion*

B Matrix: Prior uncertainty on parameters

- CH_4 fluxes
- $\delta^{13}C$-CH_4 signatures (if optimized)

R Matrix: Observational + model–observation mismatch

- Instrument errors (CH_4 + $\delta^{13}C$–CH_4)
- Model–observation mismatch, including those linked to:
  - $\delta^{13}C$-CH_4 signatures (if fixed)
  - OH/KIE (if fixed)