Integrating models and observations
Data assimilation / Inverse modeling

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Relationship between model and observations

Forward problem

$$y = f(m)$$

f - model

m - input that model result depends on

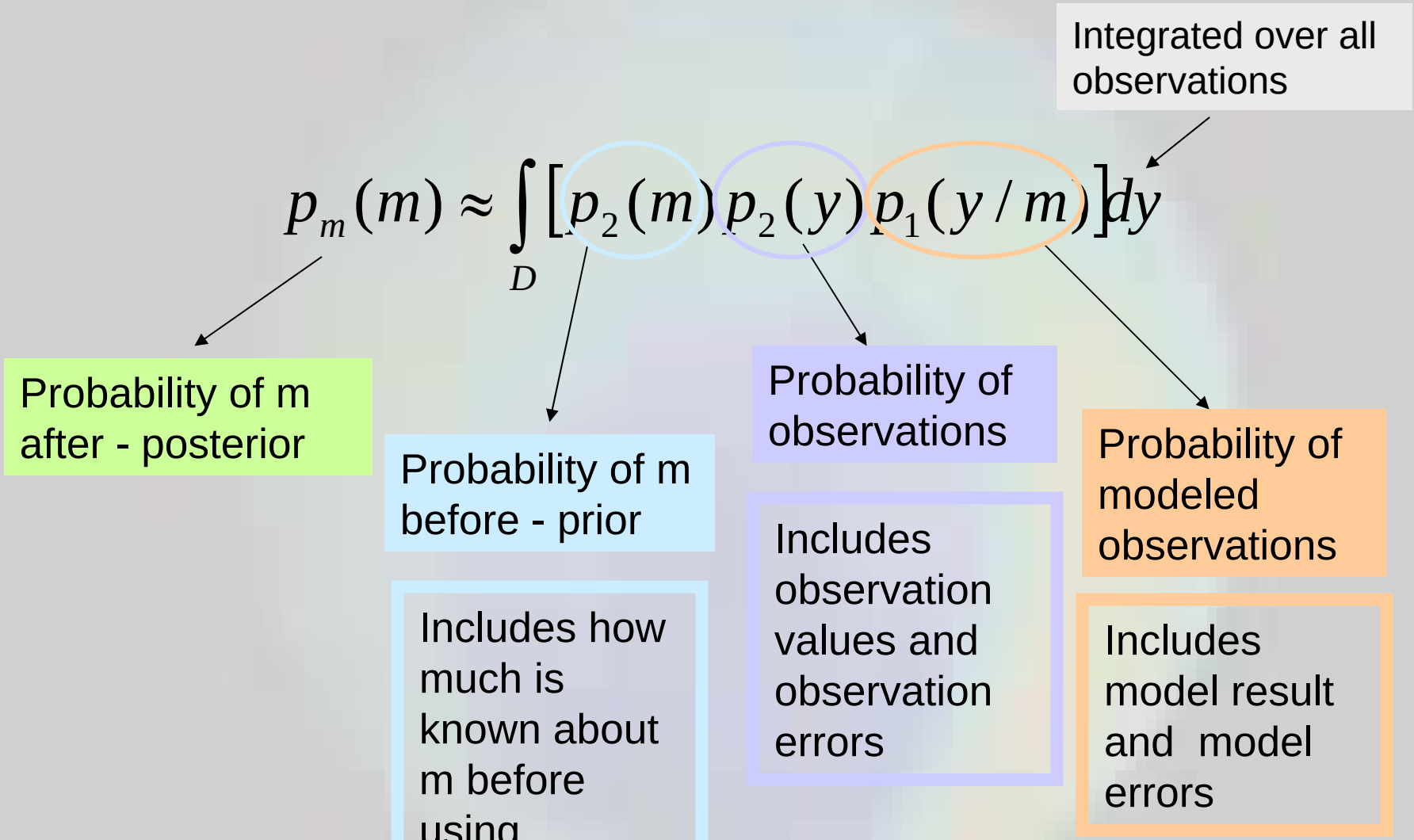
y -simulated observations

Is y “matching” actual observations?

Inverse problem (data assimilation)

Find m such that y “matches” actual observations

Probability means: probability of occurrence of a value



Examples to illustrate not to prove inverse theory

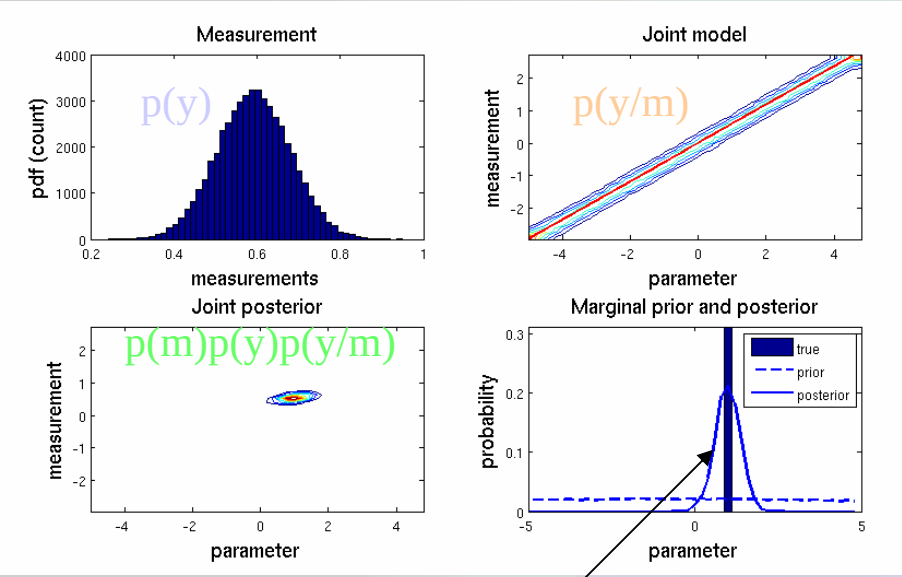
- **The theory is already proven**
- **In practical data assimilation (examples from O'Neill) the theory is applied approximately, within practical limits: resolution, data volume etc**

Example 1: **Damped oscillations model**

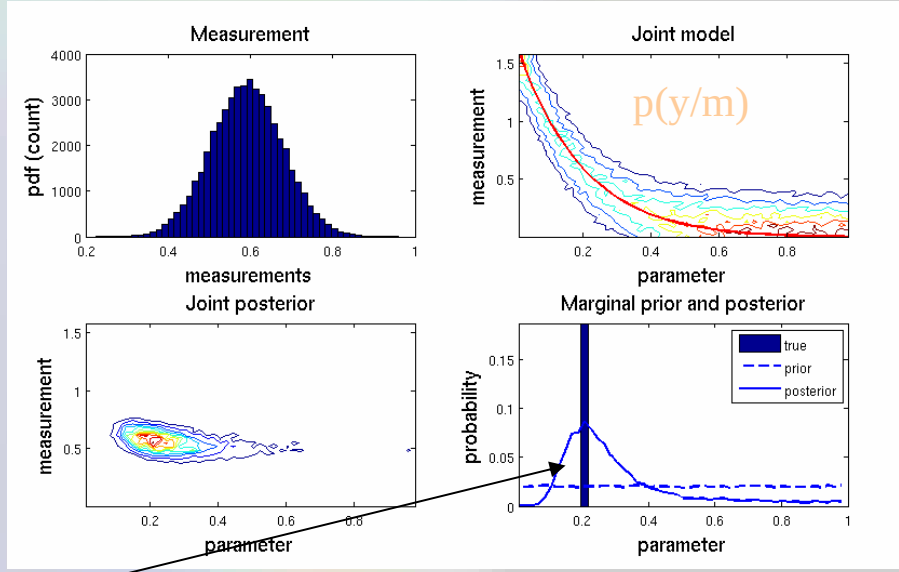
Observation is oscillation amplitude

$$\chi = A_1 e^{(-\lambda+\eta)\tau} + A_2 e^{(-\lambda-\eta)\tau}$$

m is initial condition



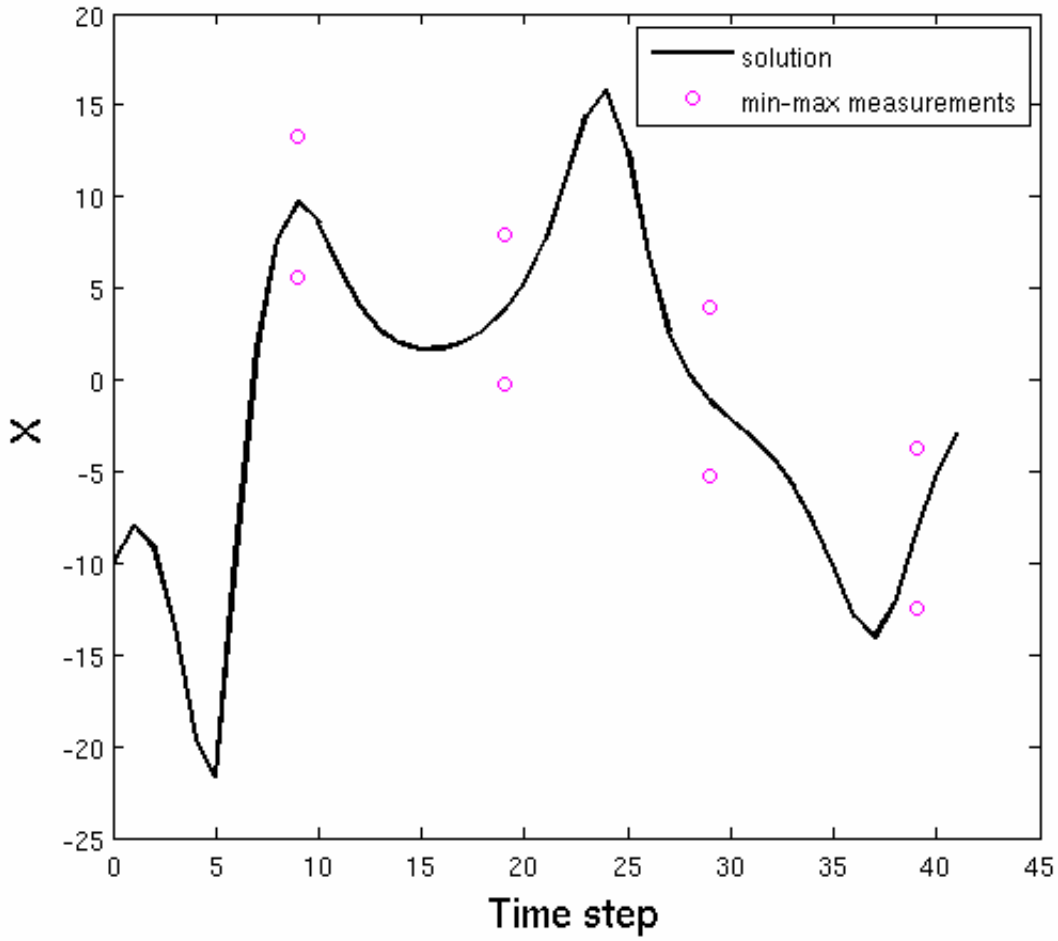
m is natural frequency



$$p_m(m) \approx \int_D [p_2(m)\, p_2(y)\, p_1(y/m)]\, dy$$

Example 2: **Lorenz 3-component model**

Observations in X component at different times

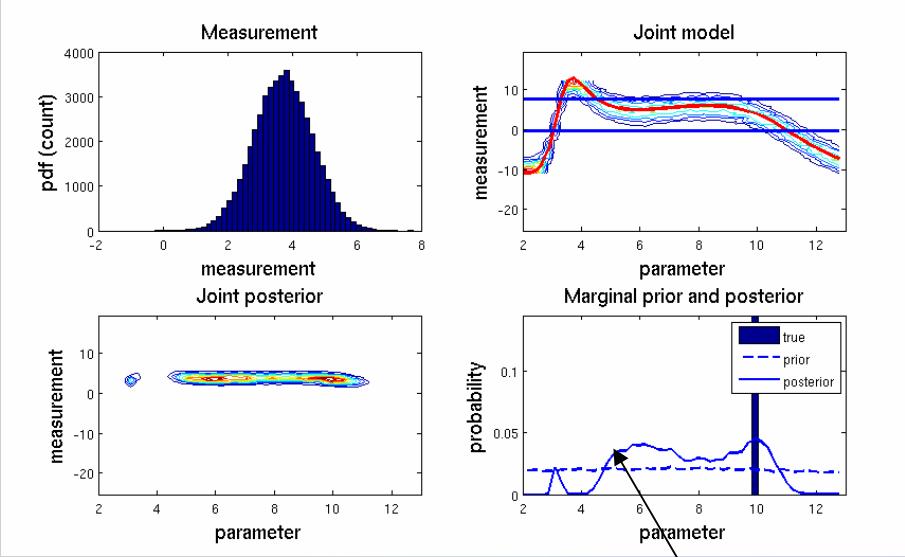


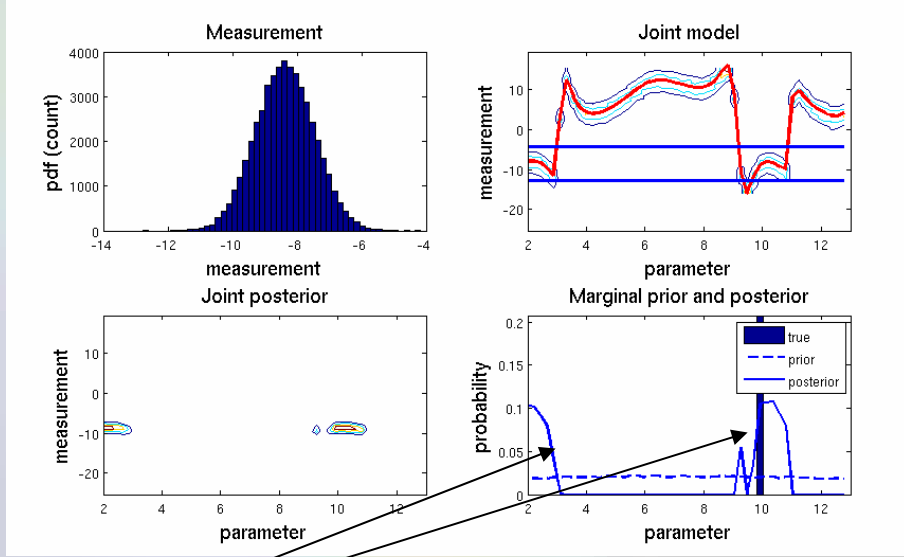
Dots represent min and max values in the observation range for each observation time

Observations every 10 time steps

m is vector of model coefficients

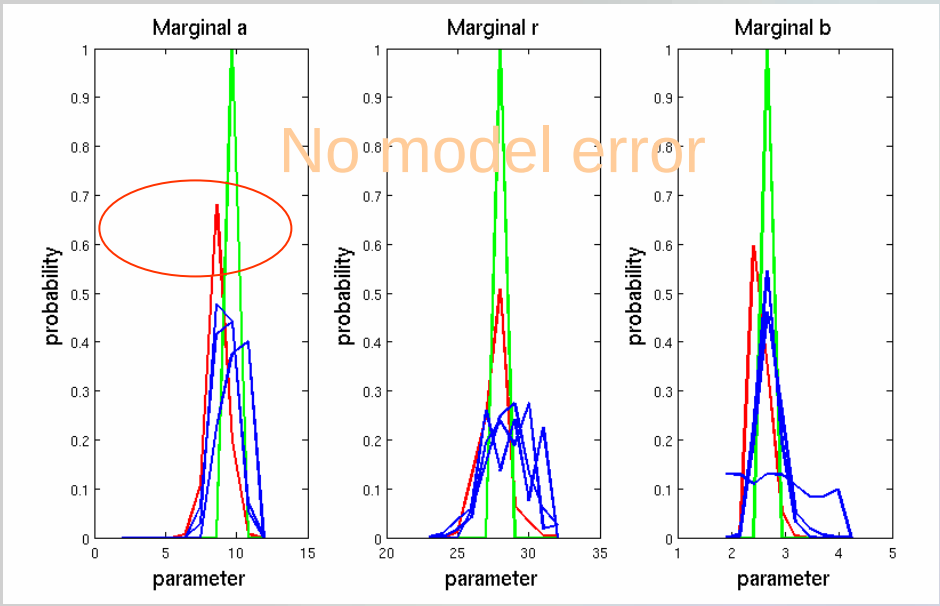
Example of 2 different observation times





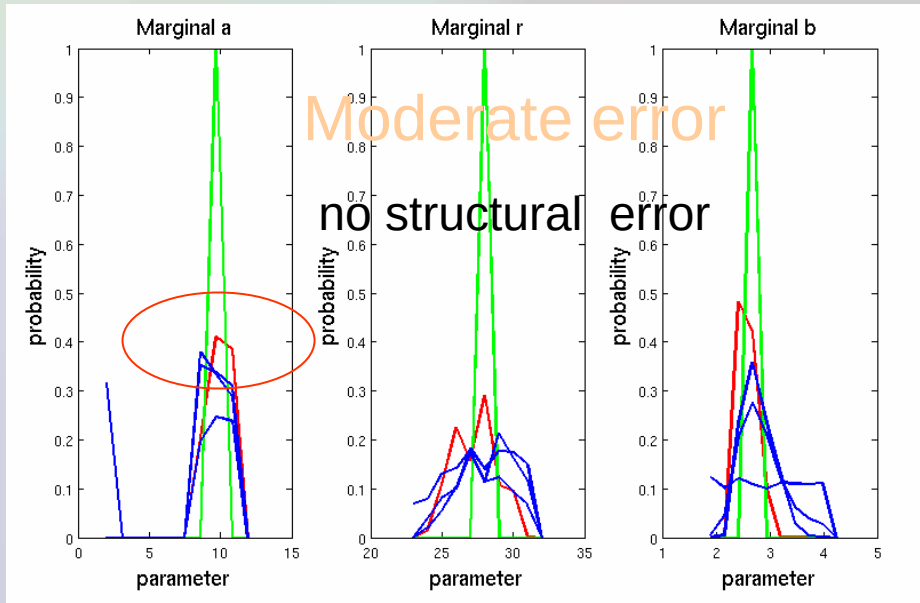
Complex p(m) for each observation individually

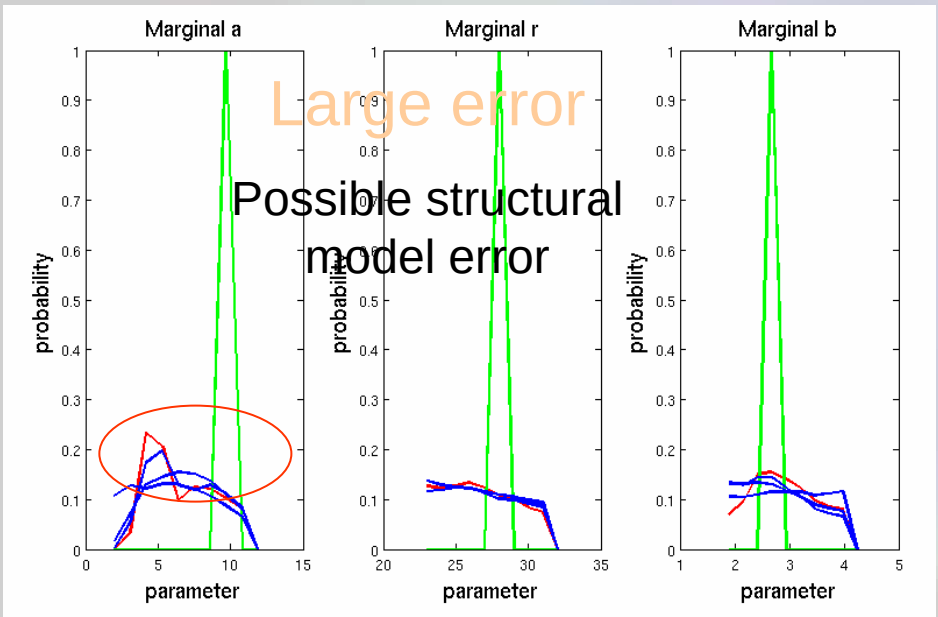
Inverse result for all parameters in the model and all observations combined



Green is true value

Red is final result of assimilation





Summary

- **Excellent results without model error**
- **Good results with non-structural model error**
- **Non-informative results with large model error**

Could models be improved by data assimilation?

- **New research**
  - **climate and weather/process models**