

Ice modelling: the influence of isostatic adjustment on ice sheet dynamics

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Physical Problem

- Solve the 1D continuity equation

$$\frac{\partial H}{\partial t} = -\nabla(HU) + B$$

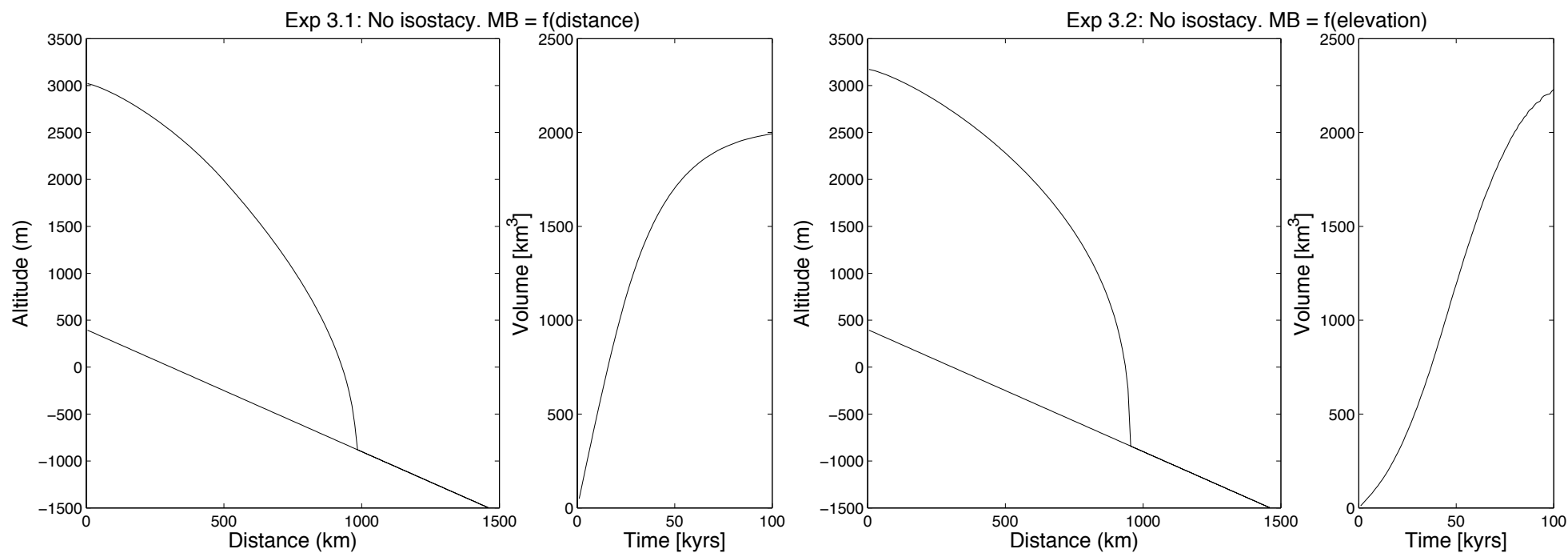
- using the mass balance Ansatz

$$B = \min(B_{\min}, \beta(h - E))$$

as function of elevation

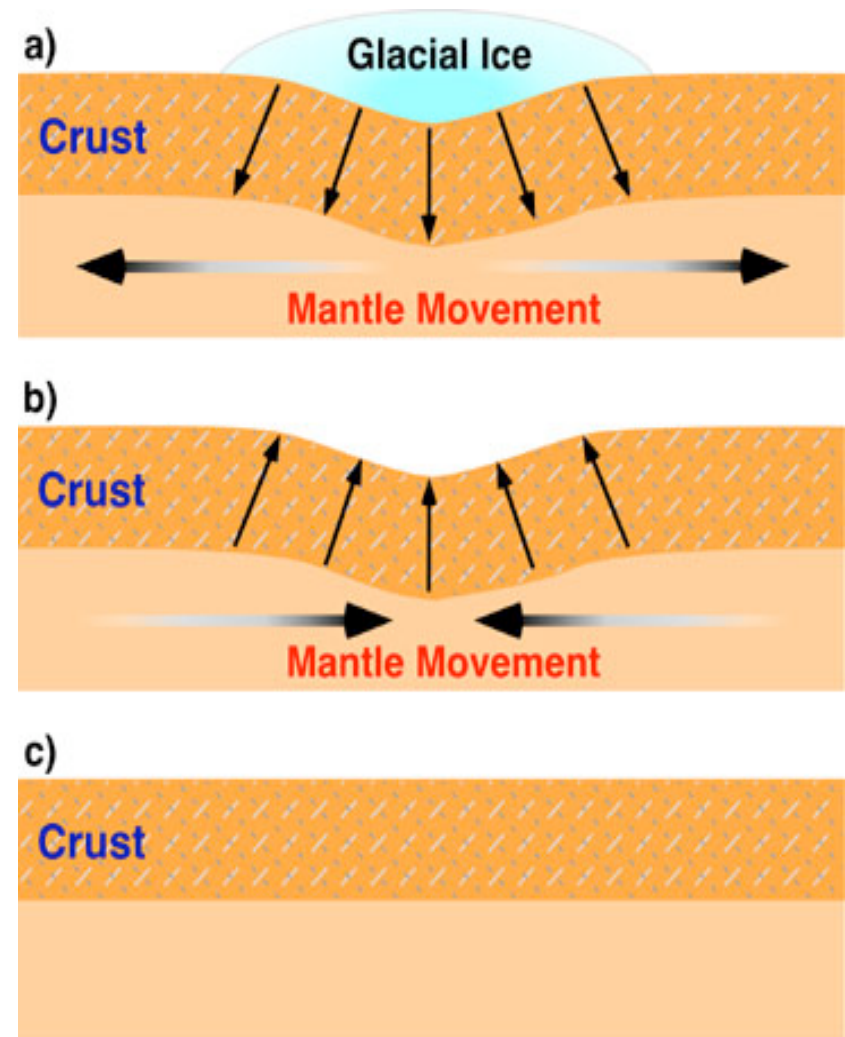
as function of distance

Without isostatic adjustment



- isostatic adjustment
 - # Airy/local isostasy
 - # flexural earth
- exponential relaxation of the earth bedrock

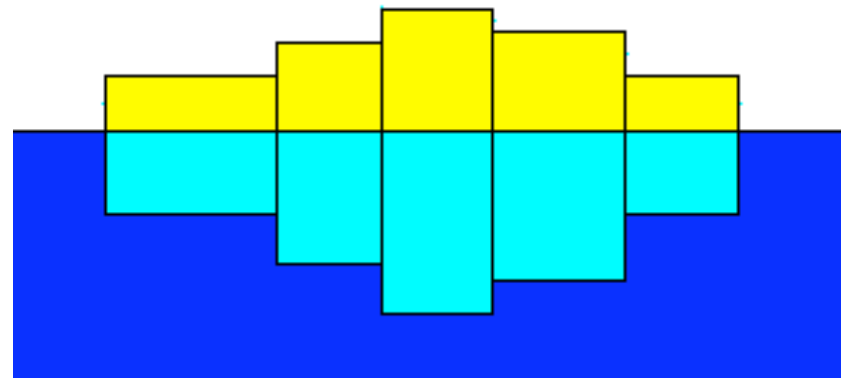
$$\frac{\partial b}{\partial t} = -\frac{1}{\tau}(b + w - b_0)$$



Local isostasy

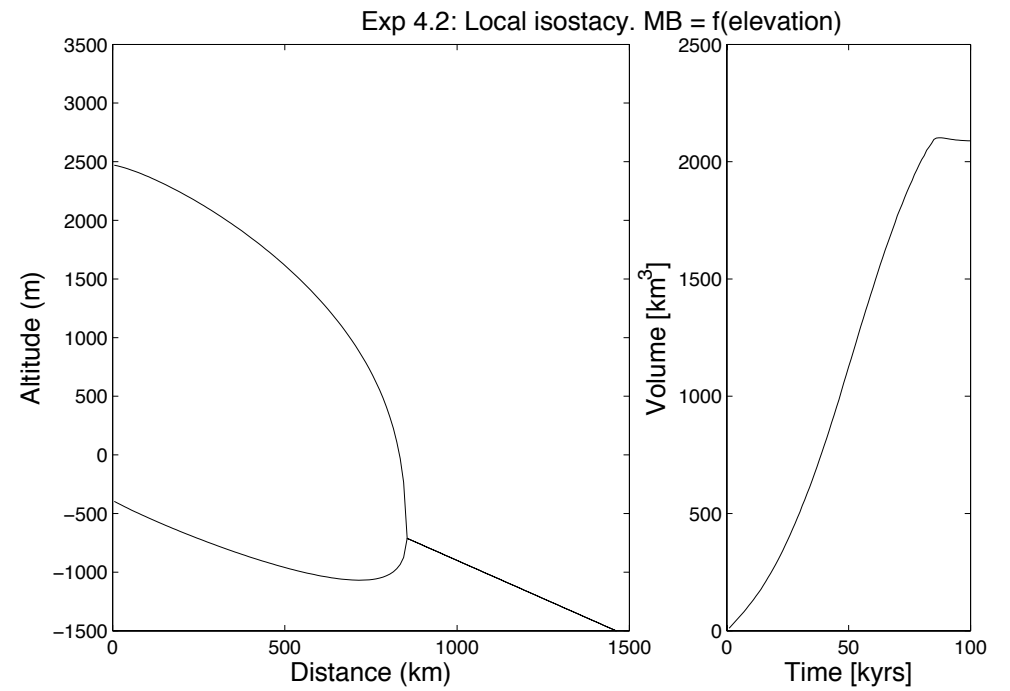
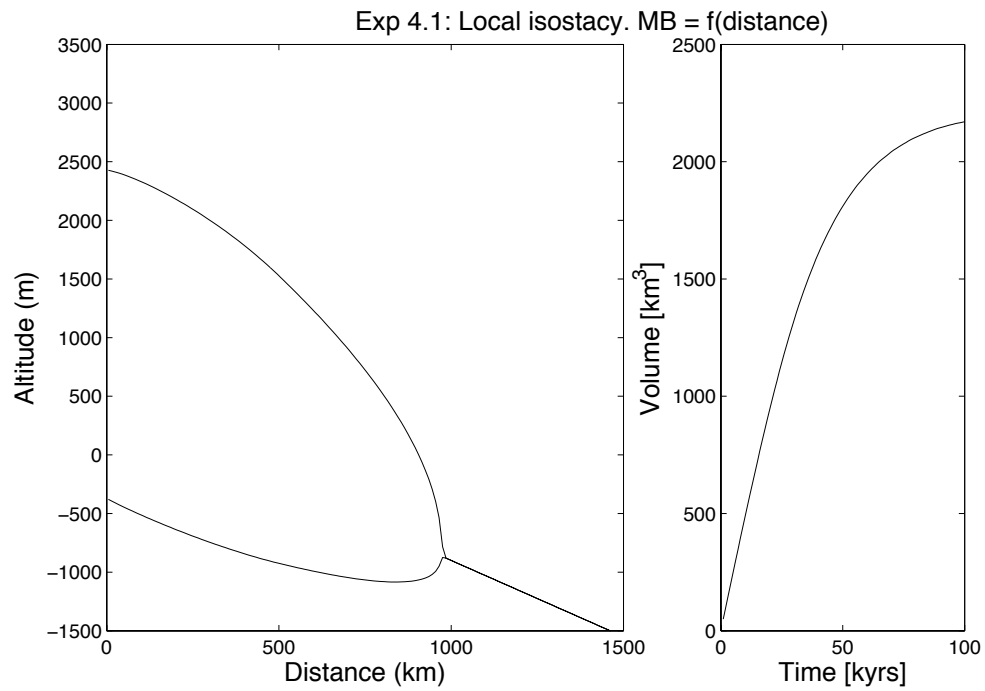


George Biddell Airy

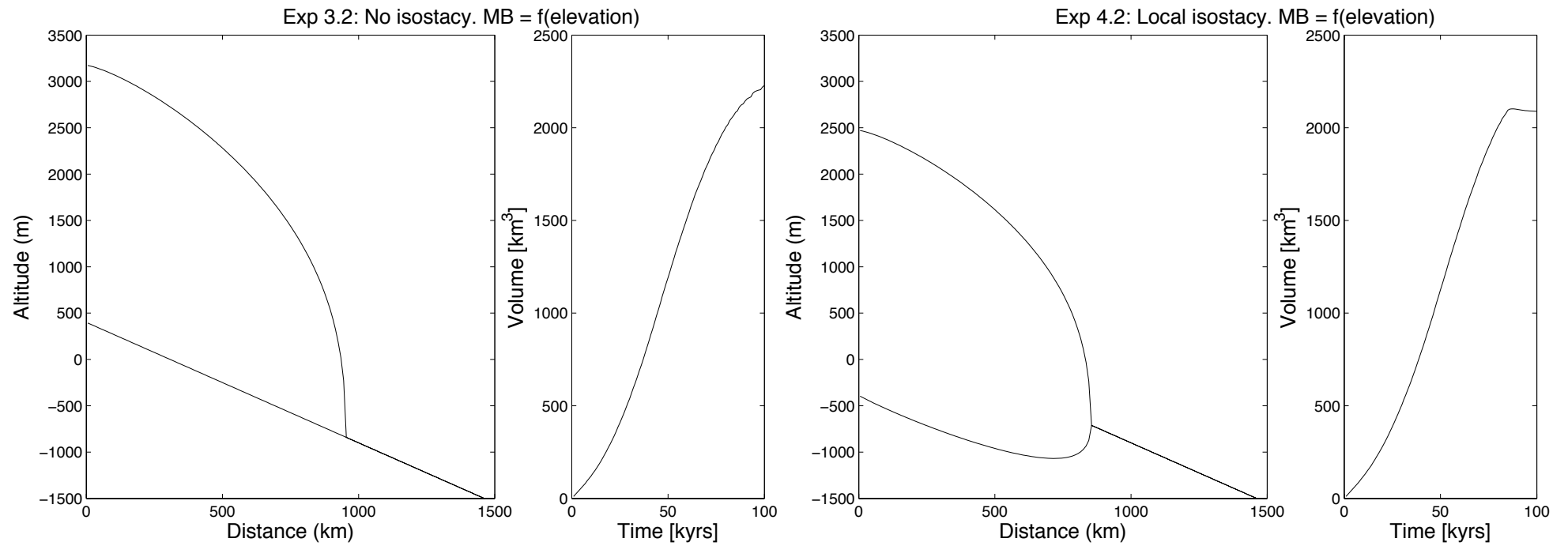


pressure equilibrium due to buoyancy

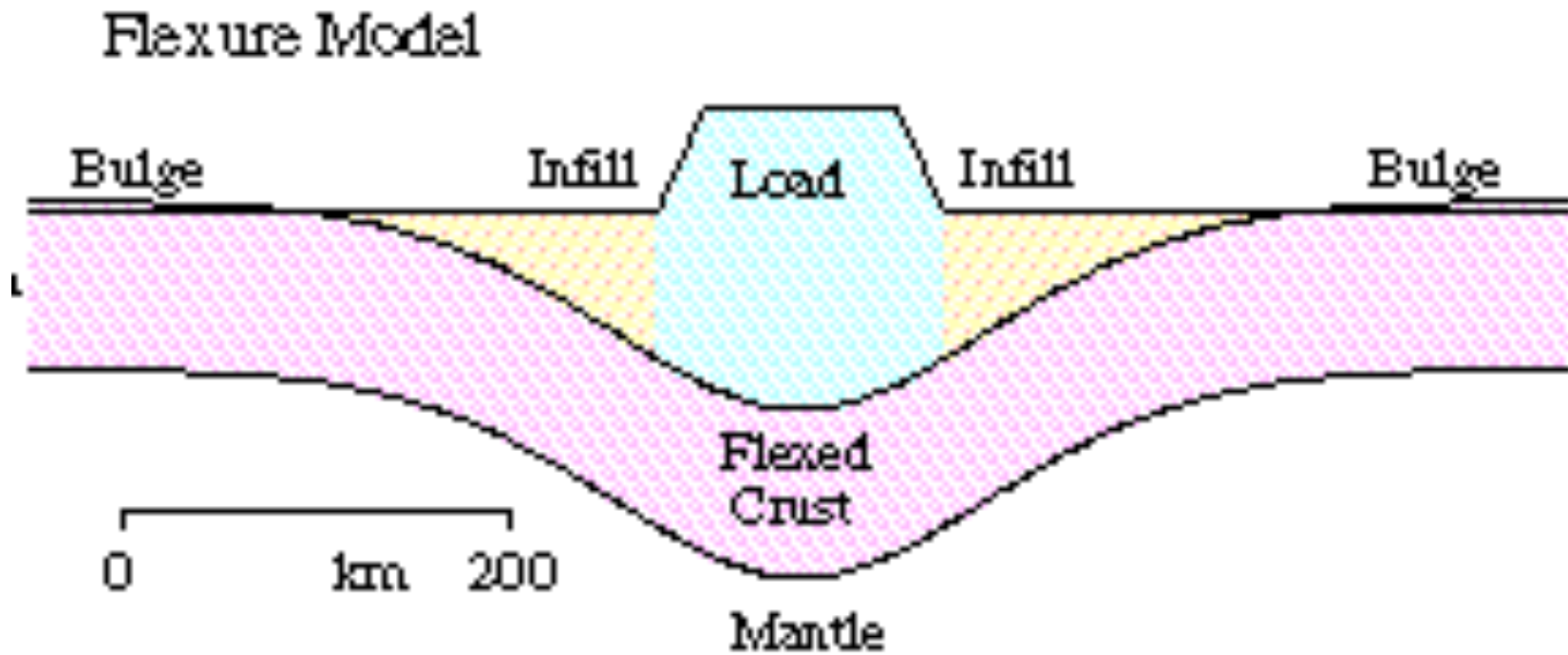
Local isostasy



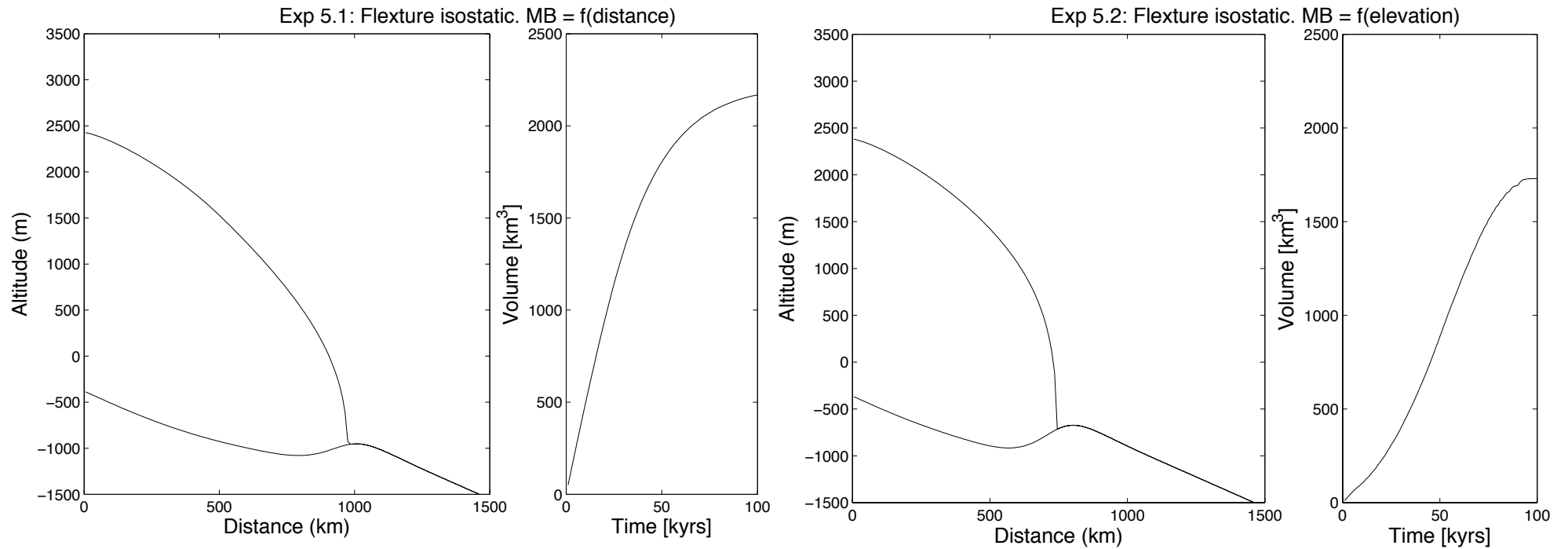
Differences and similarities



Flexural earth model

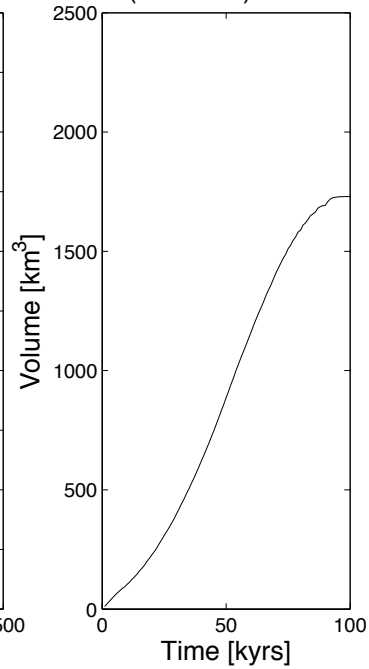
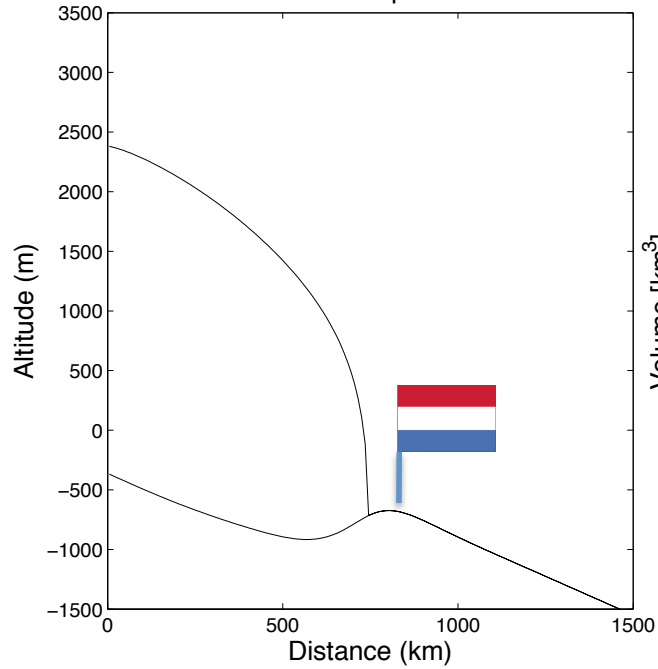


Flexural earth model

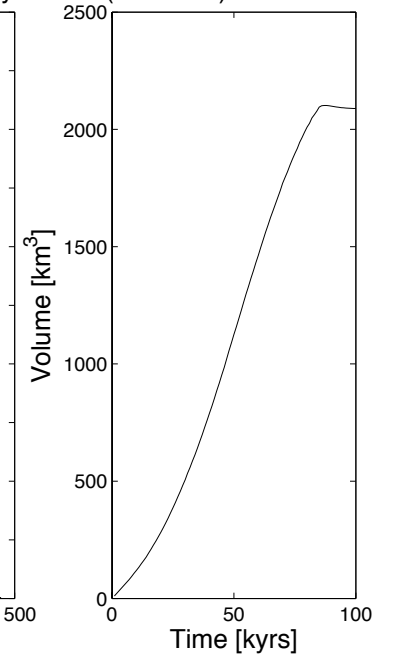
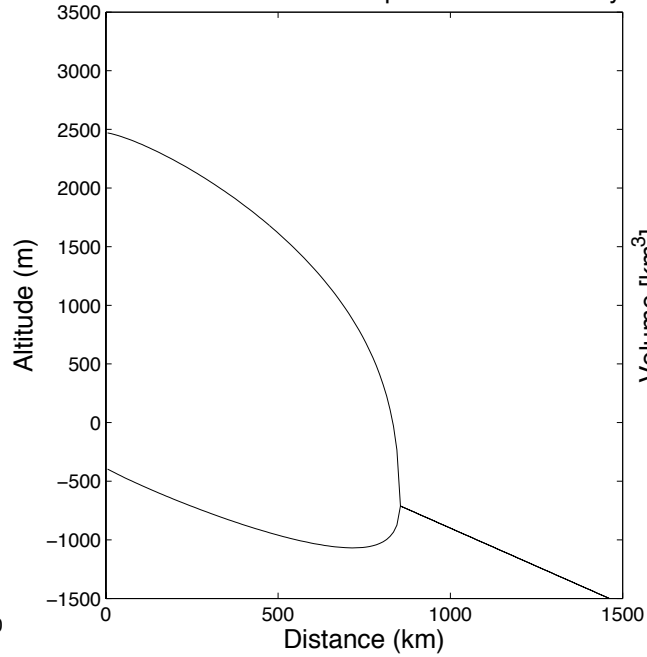


Differences and similarities

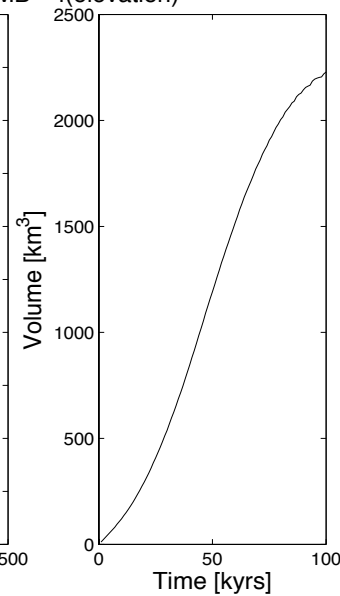
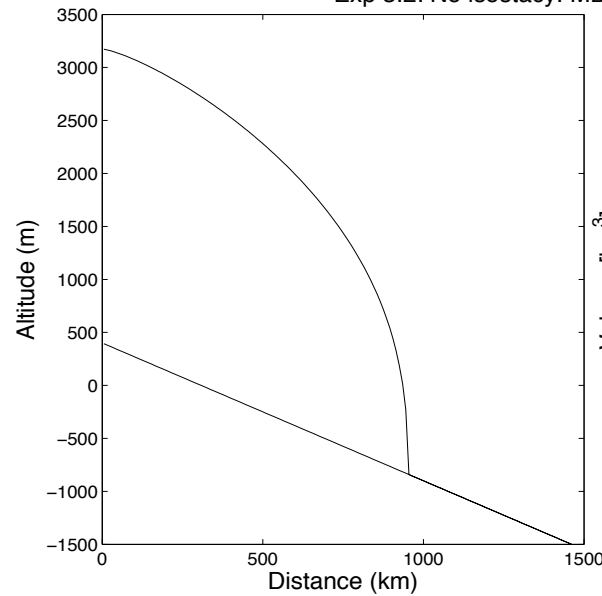
Exp 5.2: Flexure isostasy. MB = f(elevation)



Exp 4.2: Local isostasy. MB = f(elevation)

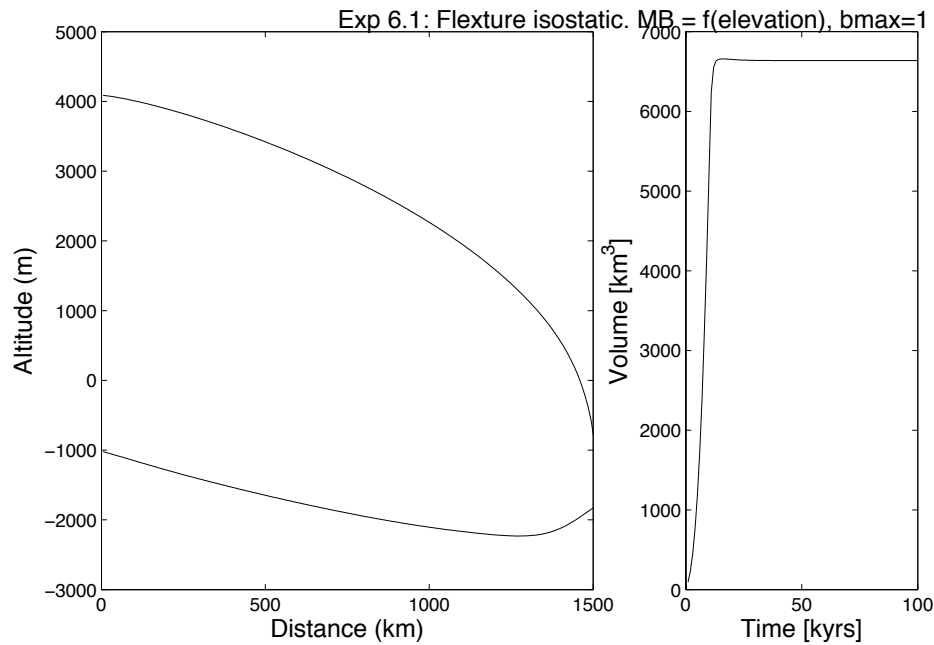


Exp 3.2: No isostasy. MB = f(elevation)

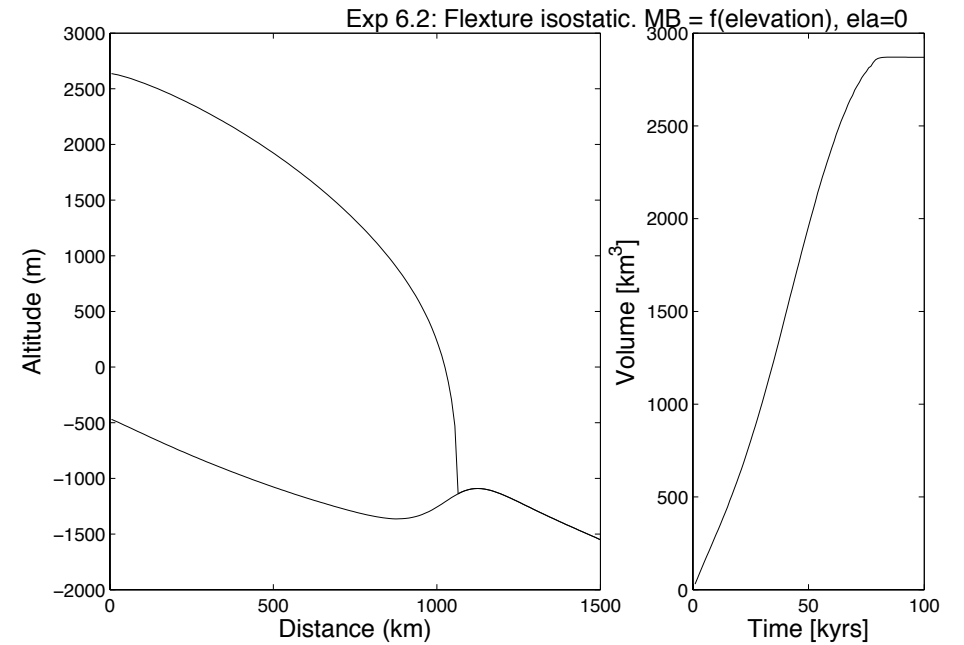


Influence mass balance parameters

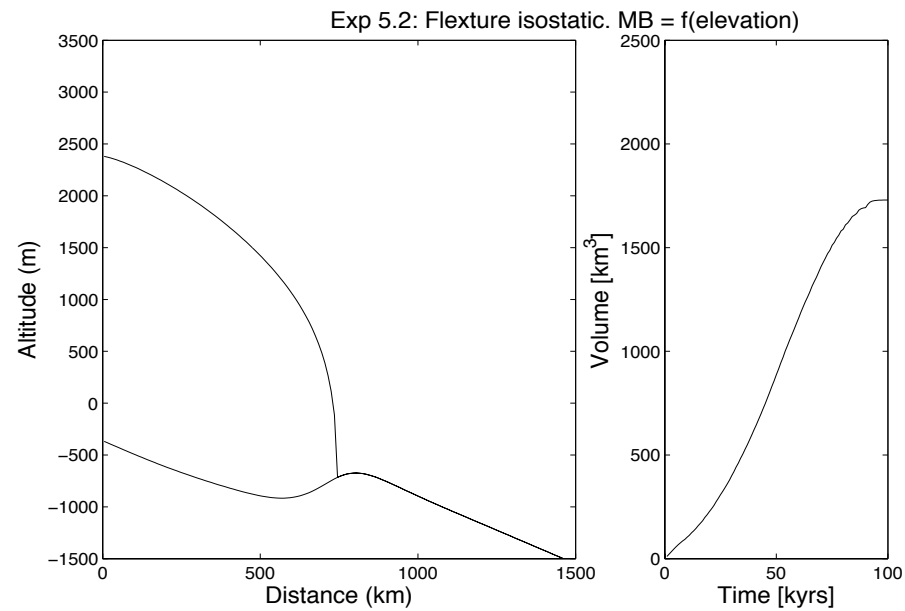
Increase Bmax: 0.1m/a → 1m/a



Increase ela: 250m → 0m

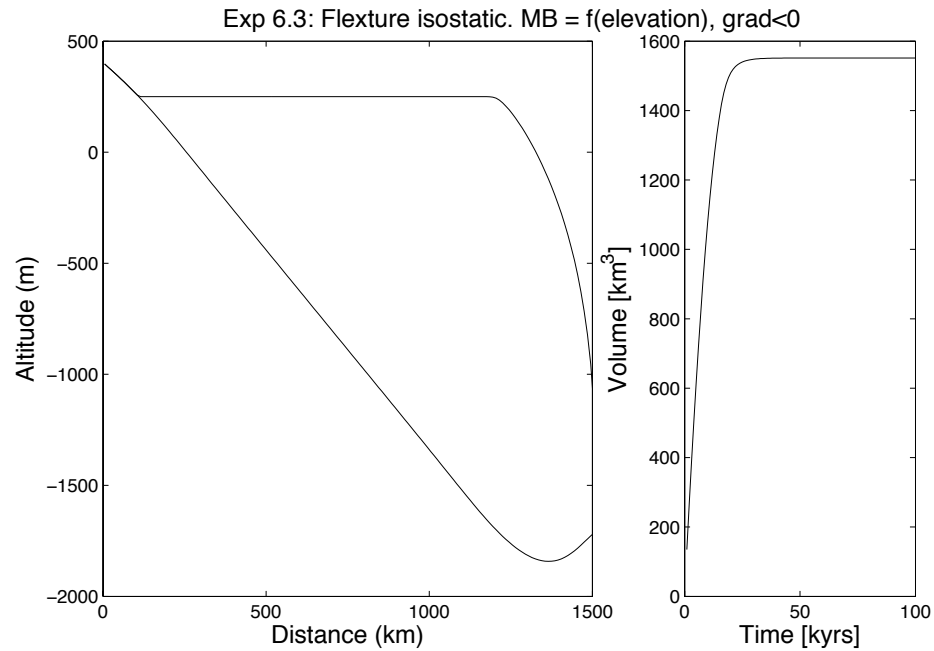


Unchanged:

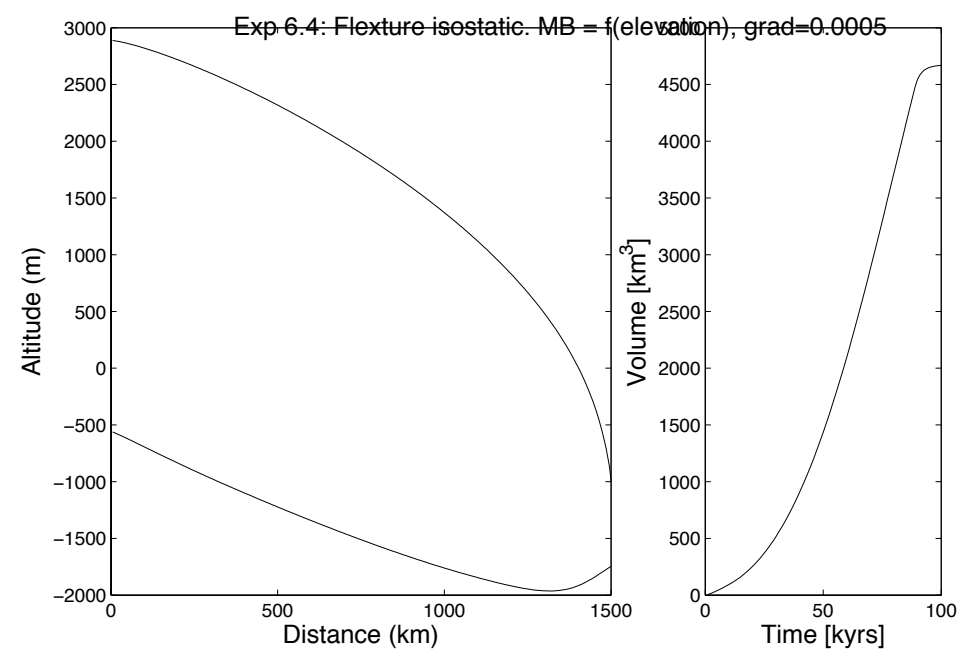


Influence mass balance parameters

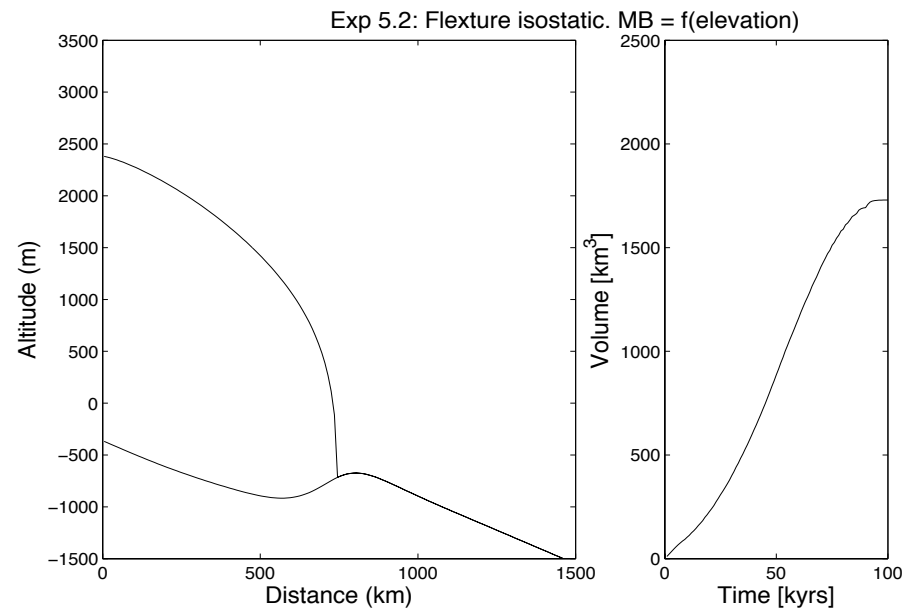
negative gradient: $0.005/a \rightarrow -0.005/a$



smaller gradient: $0.005/a \rightarrow 0.0005/a$

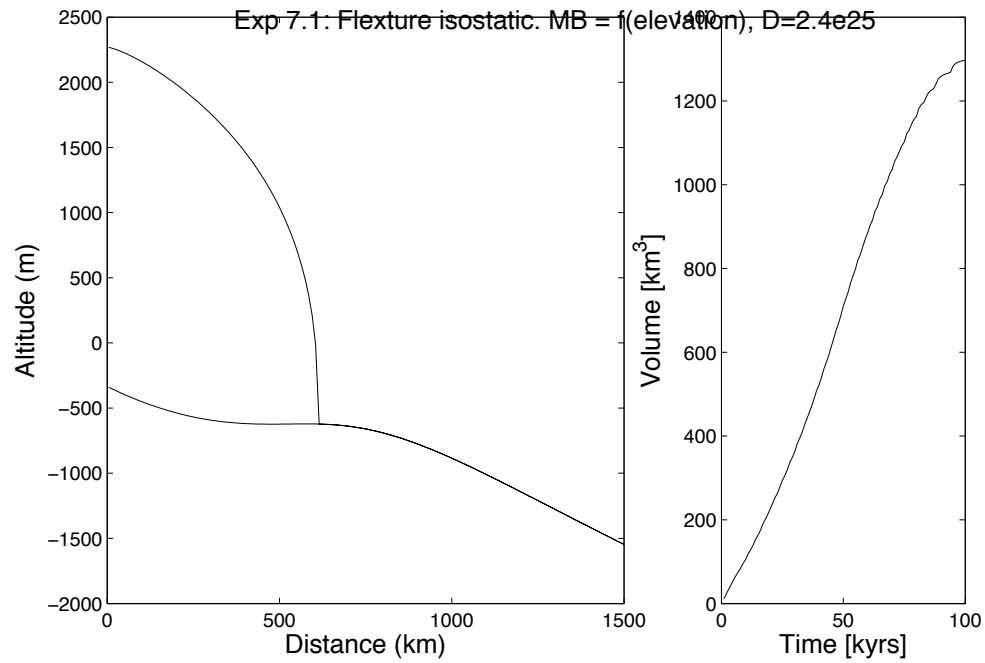


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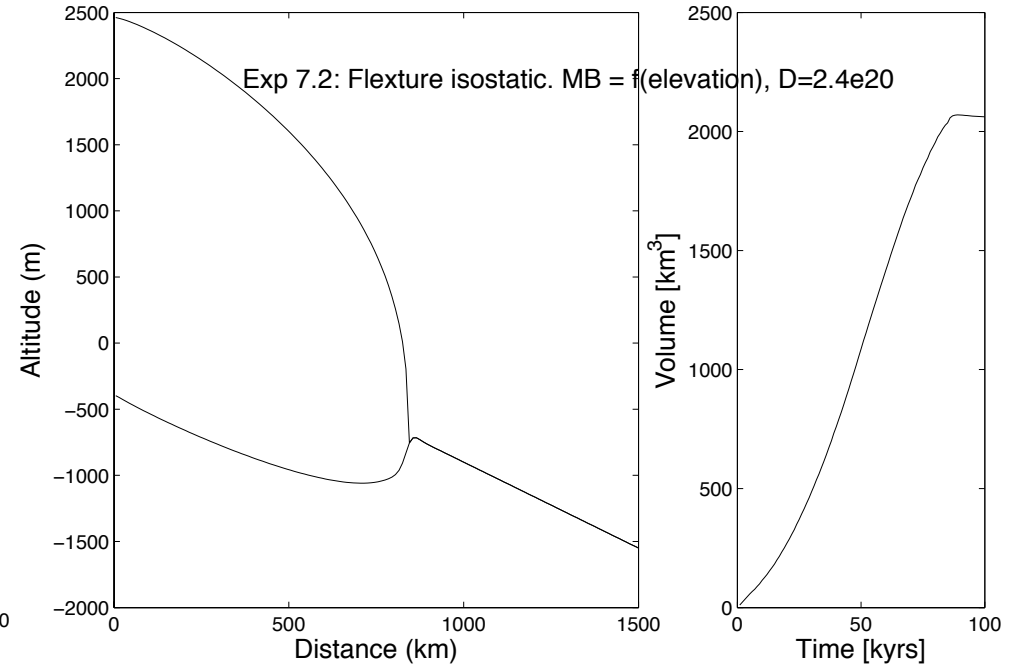


Influence flexural parameters

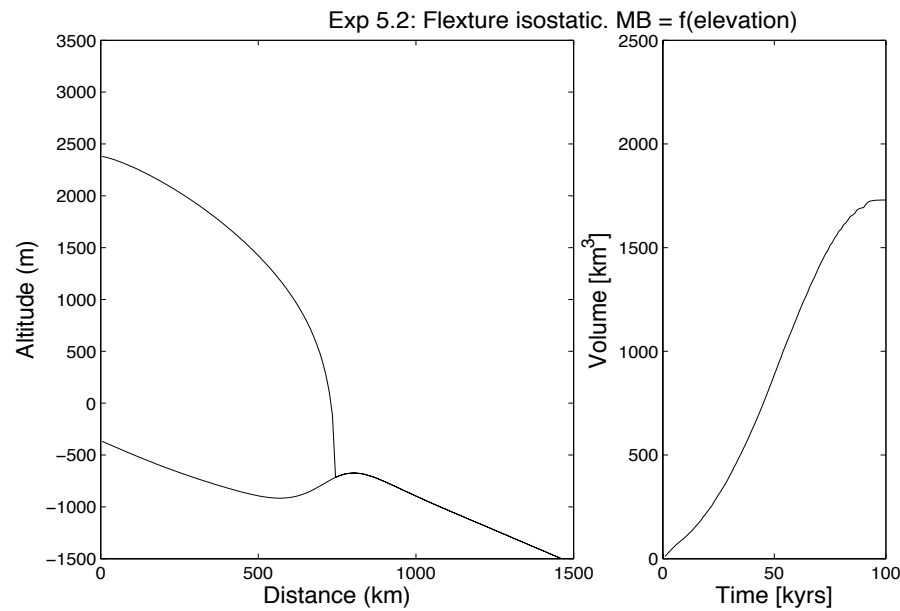
increase rigidity by a factor of 100



decrease rigidity by a factor of 1000

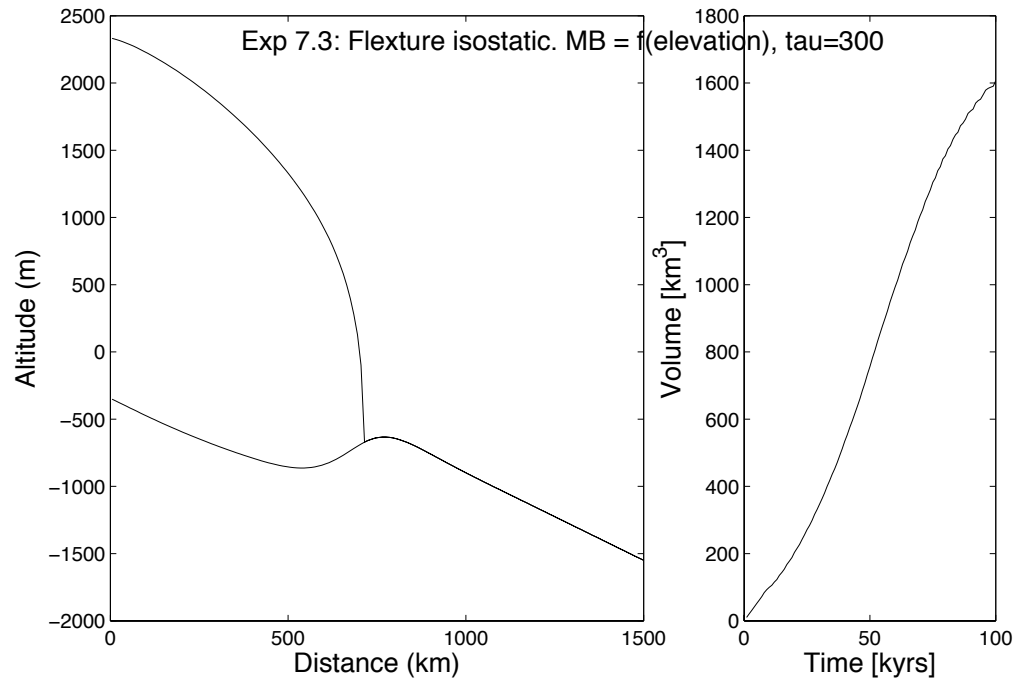


Unchanged:

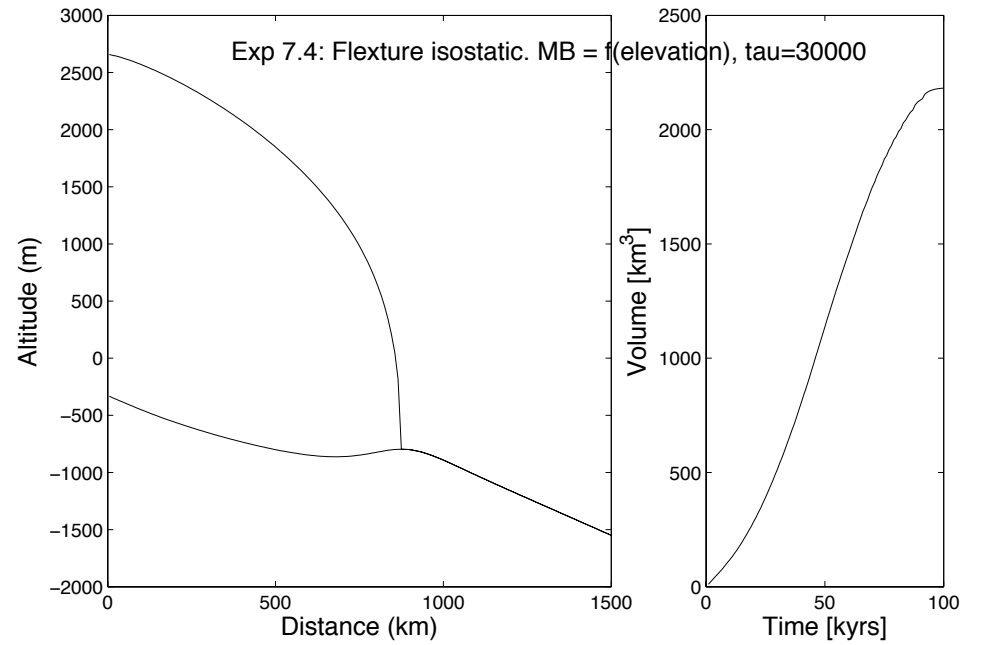


Influence flexural parameters

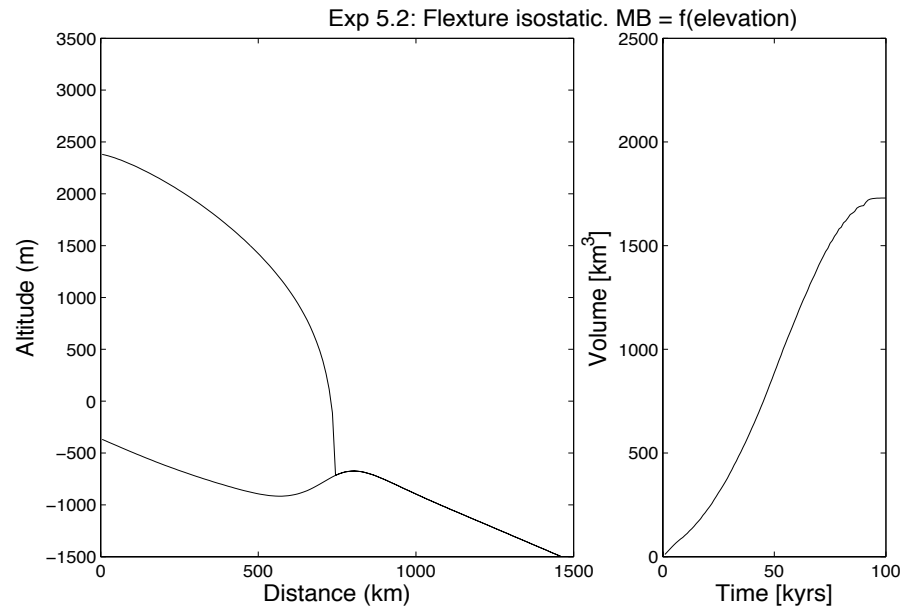
decrease relaxation time: 3000a->300a



increase relaxation time: 3000a->30000a



Unchanged:



Conclusions

- Isostatic adjustment decreases ice volume
- “elevation - mass balance feedback”
- Isostasy increases ablation
- decreasing $B_{max}/ELA/\text{gradient}$ -> more ice
- higher rigidity -> less ice
- longer relaxation time -> more ice



Which planet might that be?

