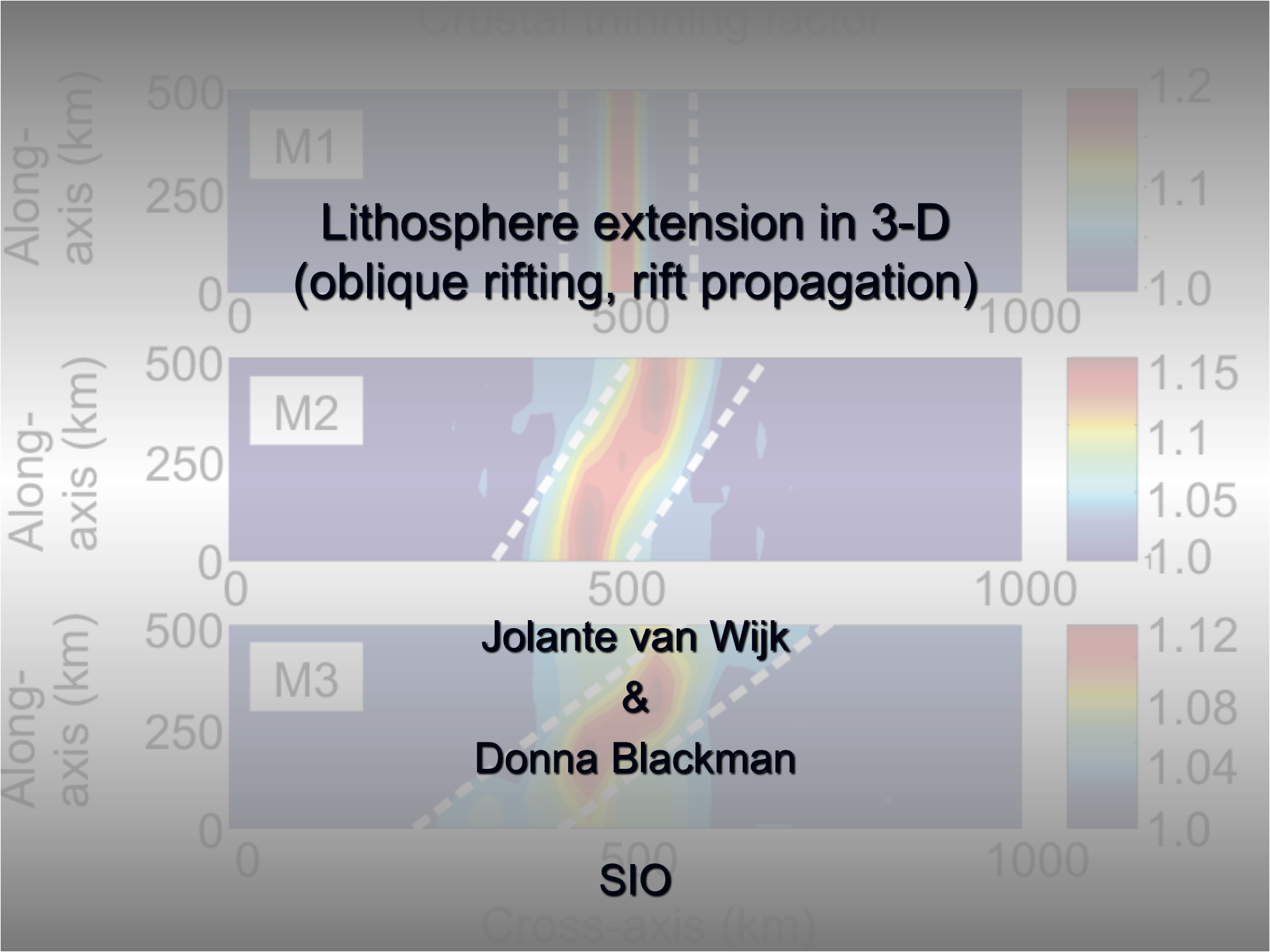


Lithosphere extension in 3-D (oblique rifting, rift propagation)

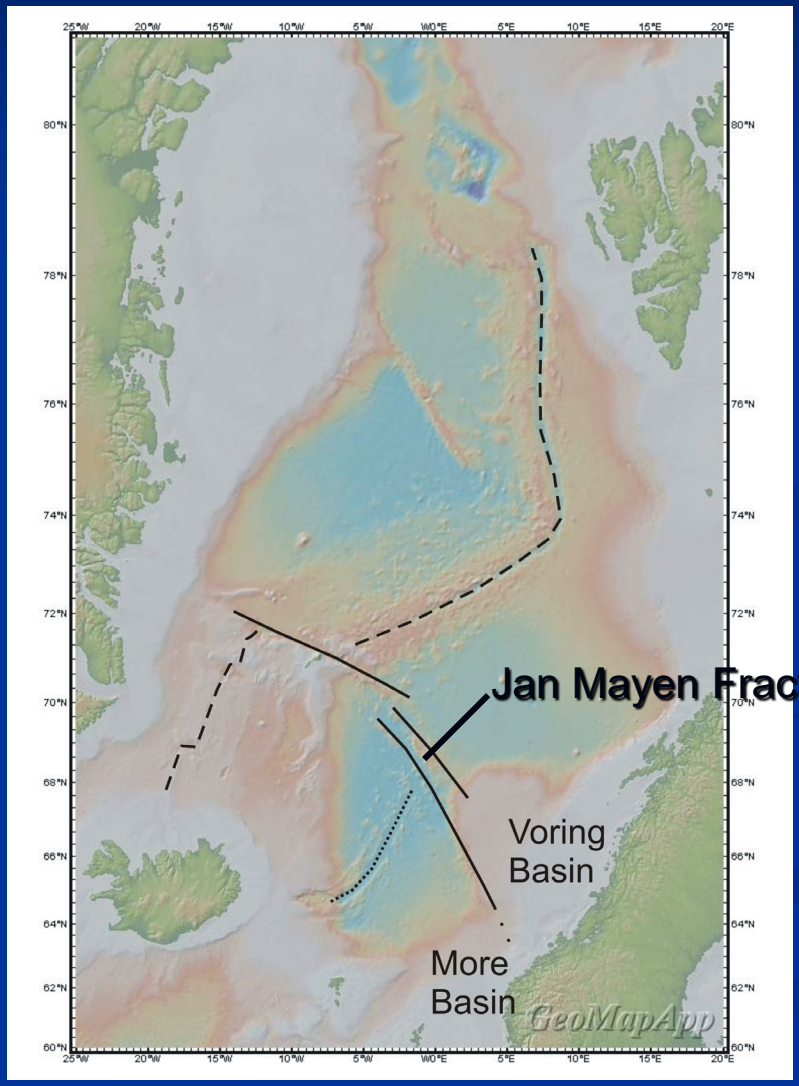
Jolante van Wijk

&

Donna Blackman

SIO

Lithosphere extension: 2-D or 3-D



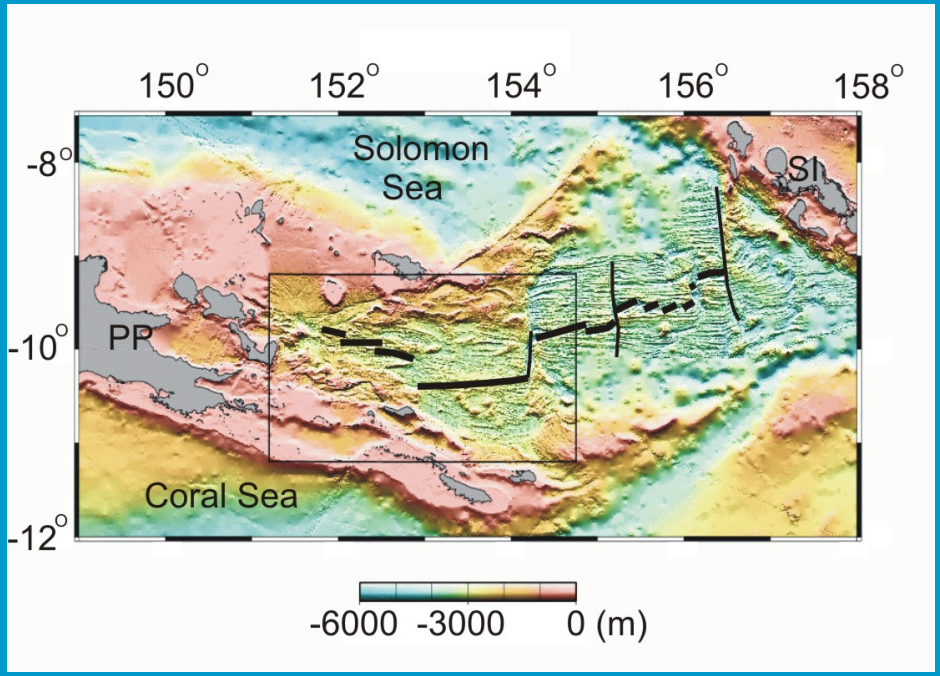
Outline

* 3-D cases and tectonic processes involved
  - -oblique rifting
  - -rift propagation
  - -mantle flow beneath rifts
* Prior modeling approaches
  - -numerical
  - -analogue
* Our approach: Tekton & FELIB
* Other options

Lithosphere extension: 3-D processes

Rift propagation

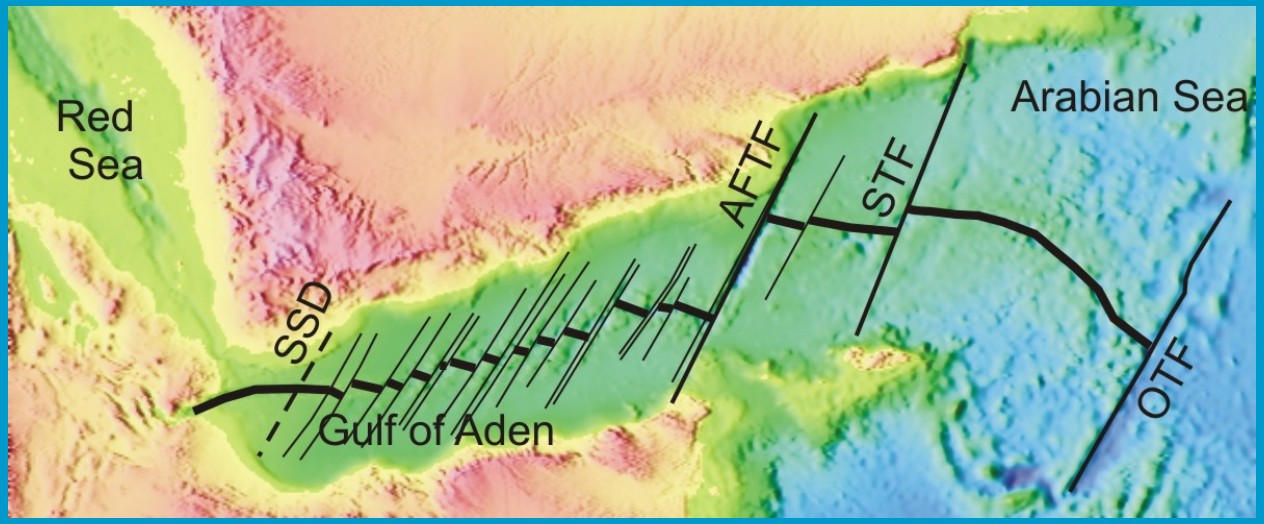
Woodlark Basin



Lithosphere extension: 3-D processes

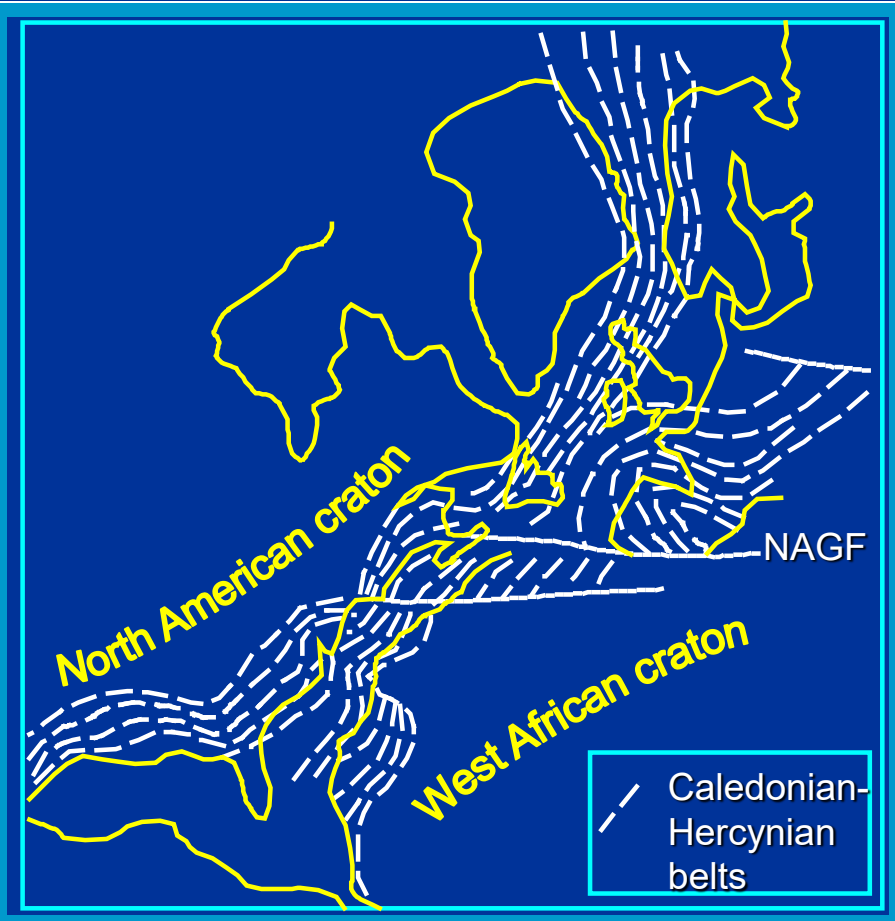
Rift propagation

Gulf of Aden



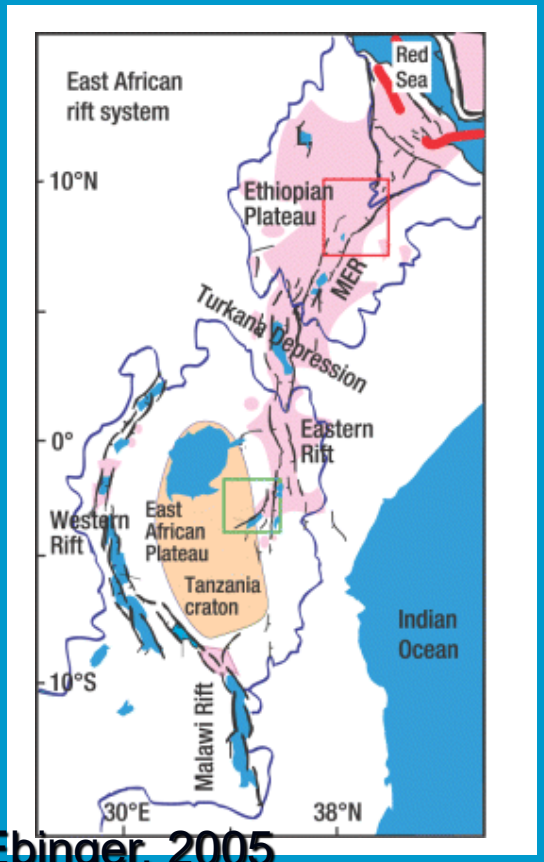
Lithosphere extension: 3-D processes

Pre-structured lithosphere, oblique rifting



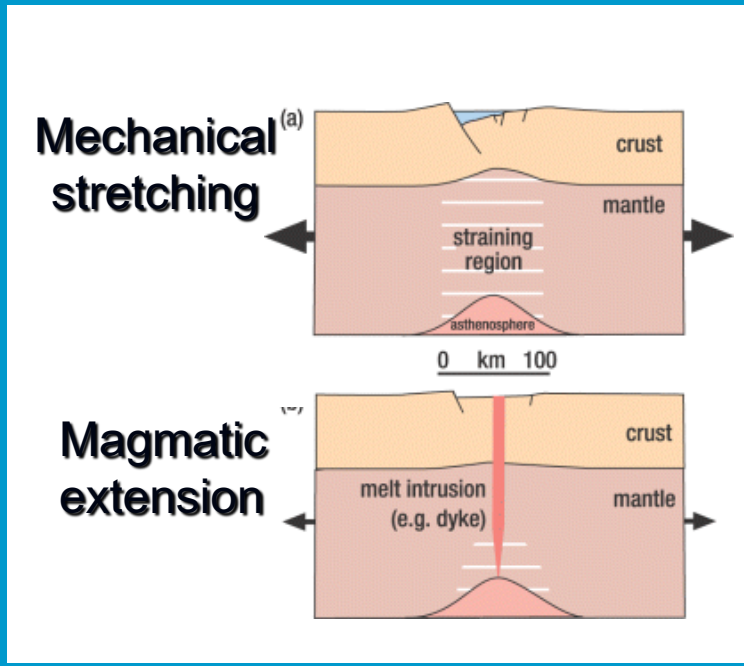
Lithosphere extension: 3-D processes

EARS follows pre-structured lithosphere



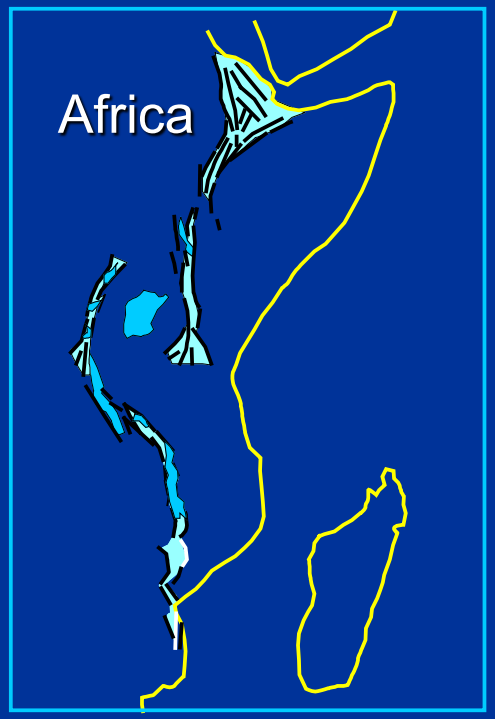
Ebinger, 2005

Extension of continental lithosphere



Lithosphere extension: 3-D processes

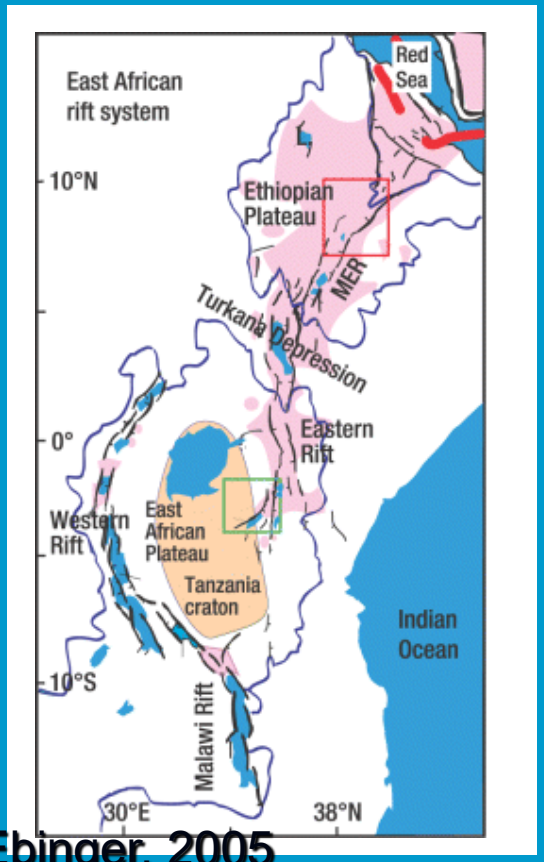
Rift branches



Proterozoic mobile belts

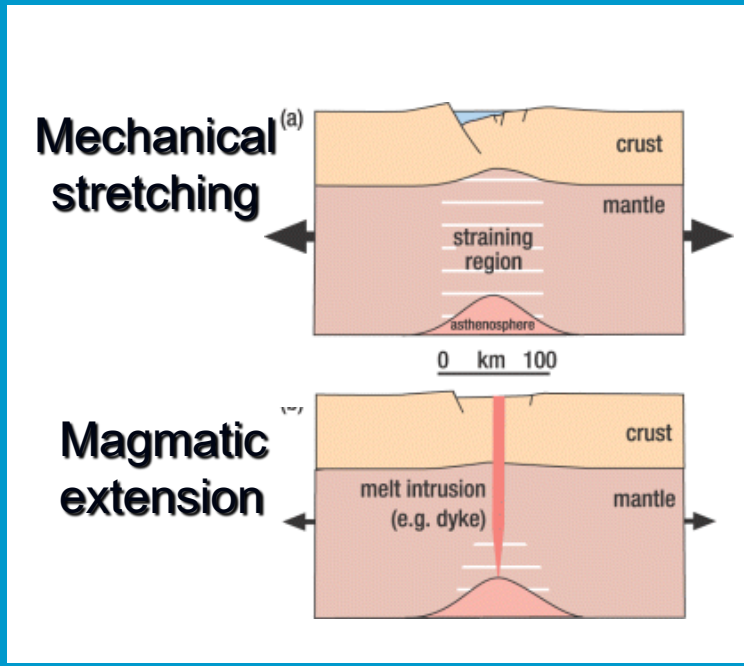
Lithosphere extension: 2-D processes

Decompressional melting during extension



Ebinger, 2005

Extension of continental lithosphere



Lithosphere extension: 3-D processes

Tectonic processes involved

Setup geometry	**lateral variations in lithosphere architecture, different geological provinces**
Boundary conditions	**laterally varying boundary conditions, oblique extension**

Basics needs:

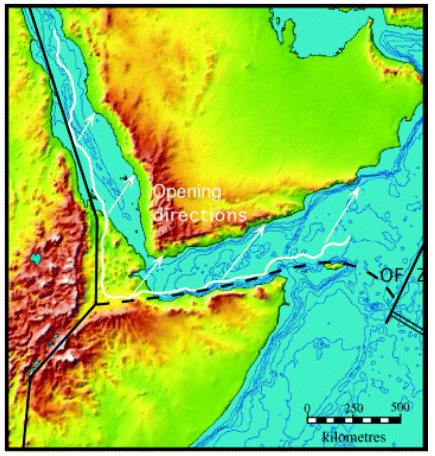
Thermo-mechanical model?
Layered lithosphere?

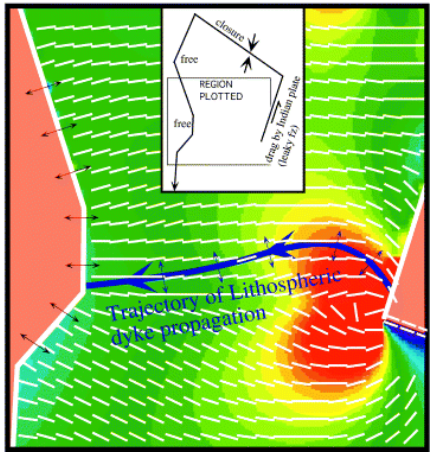
Existing numerical models

Elastic Plate Model: Hubert-Ferrari et al., 2003

Rift propagation (=crack propagation)

Assumption: lithosphere is an elastic plate in which viscous/ductile behavior plays no (important) role

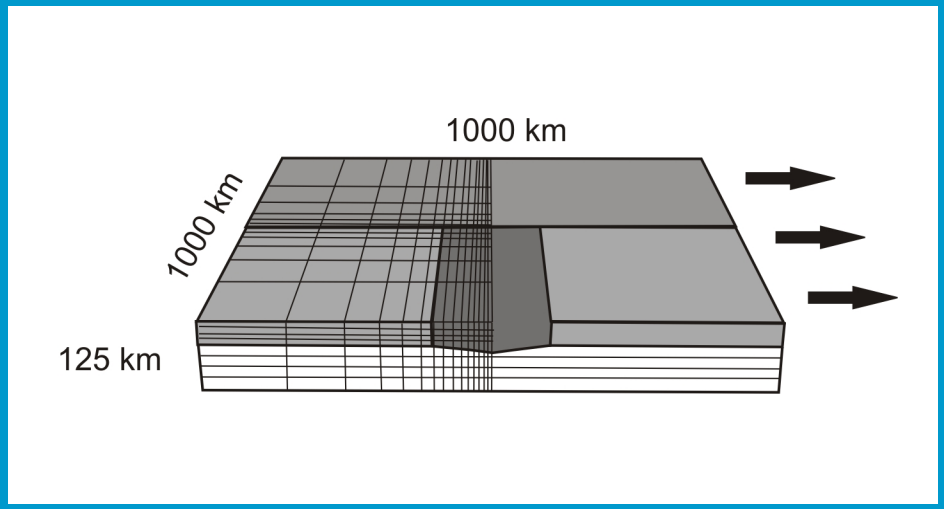




Existing numerical models

Finite Element Models: Dunbar and Sawyer, 1996

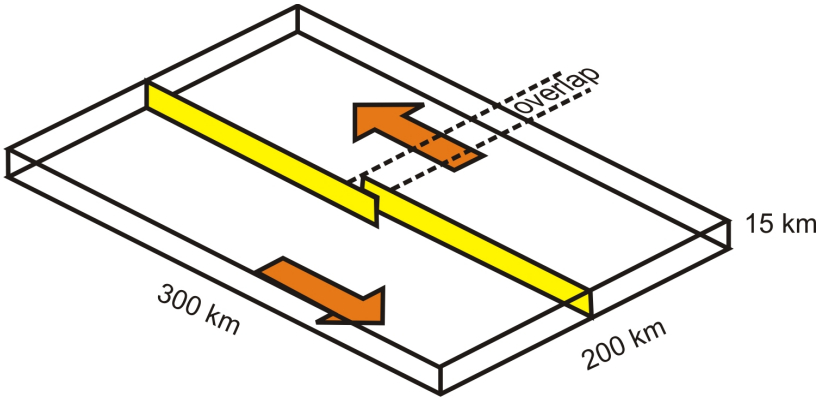
Rift propagation

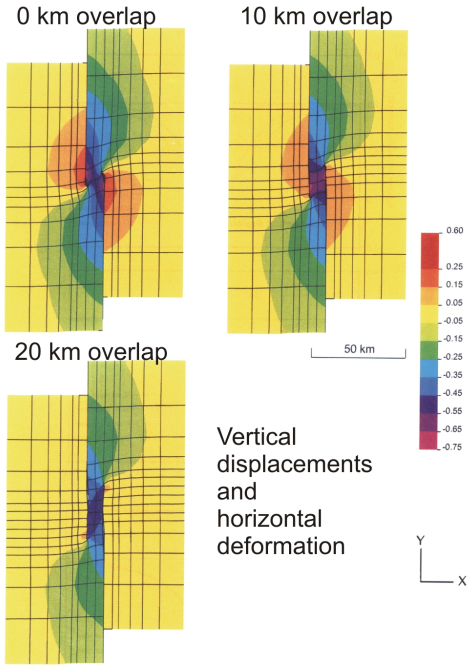


- Symmetrical model
- Equations: creeping flow, heat flow

Existing numerical models

Boundary Element Models: Katzman, ten Brink & Lin, 1995

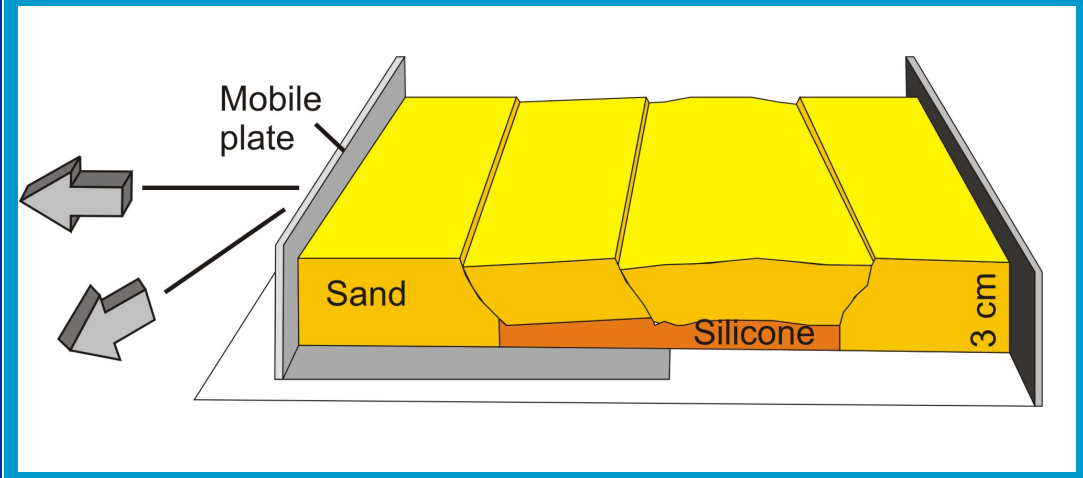


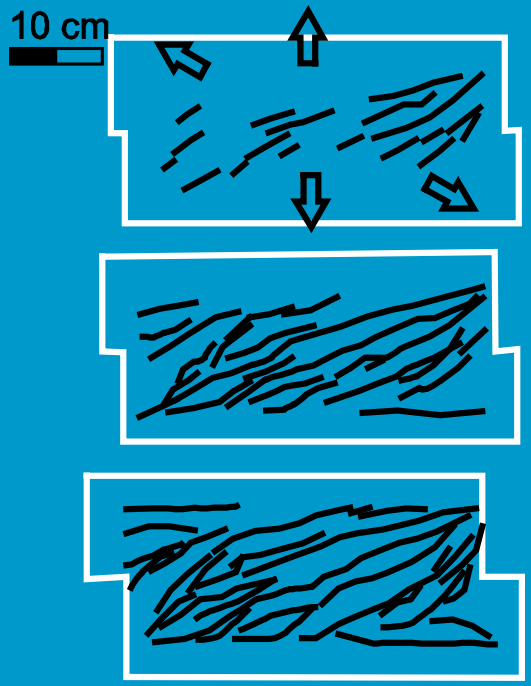


Pull-apart basin formation

Analogue modeling studies

Sand & silicone experiments



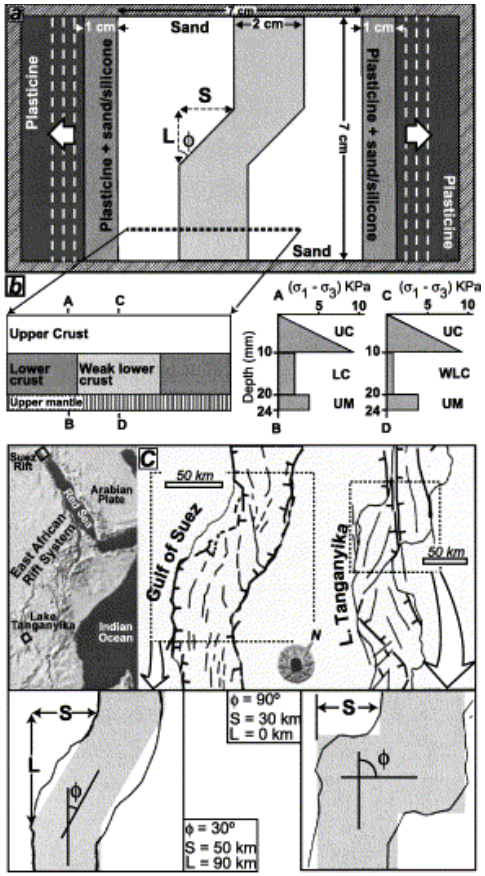


(Tron and Brun, 1991)

\+ fault structures

\- thermal effects, rheology

Analogue modeling studies of oblique rifting



Centrifuge model

\+ fault structures

\- thermal effects, rheology

(Giacomo Corti, 2004)

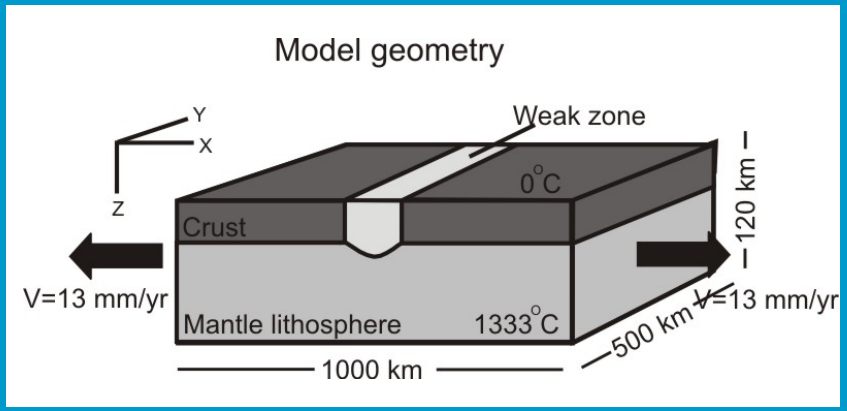
Our modeling approach

Thermo-mechanical model

Finite element model, Lagrangian approach

Mechanical part: based on Tekton

Thermal part: based on FELIB



Numerical modeling of oblique rifting

Mechanical part

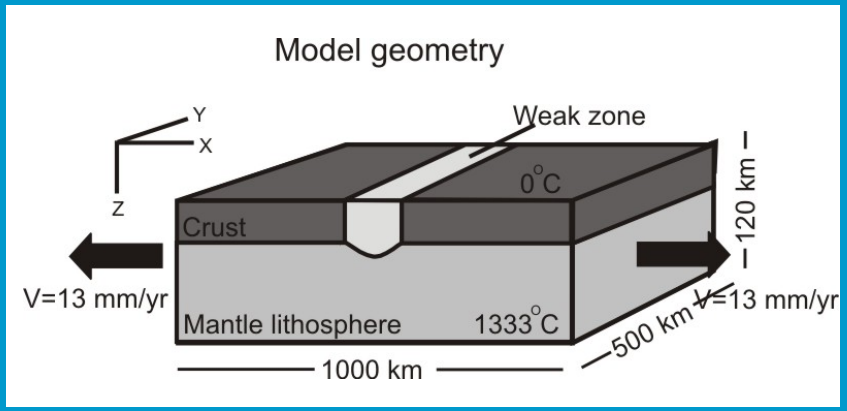
Visco-elastic deformation, correction for plastic/brittle behavior

Thermal part

Heat flow equation
Heat production in crust

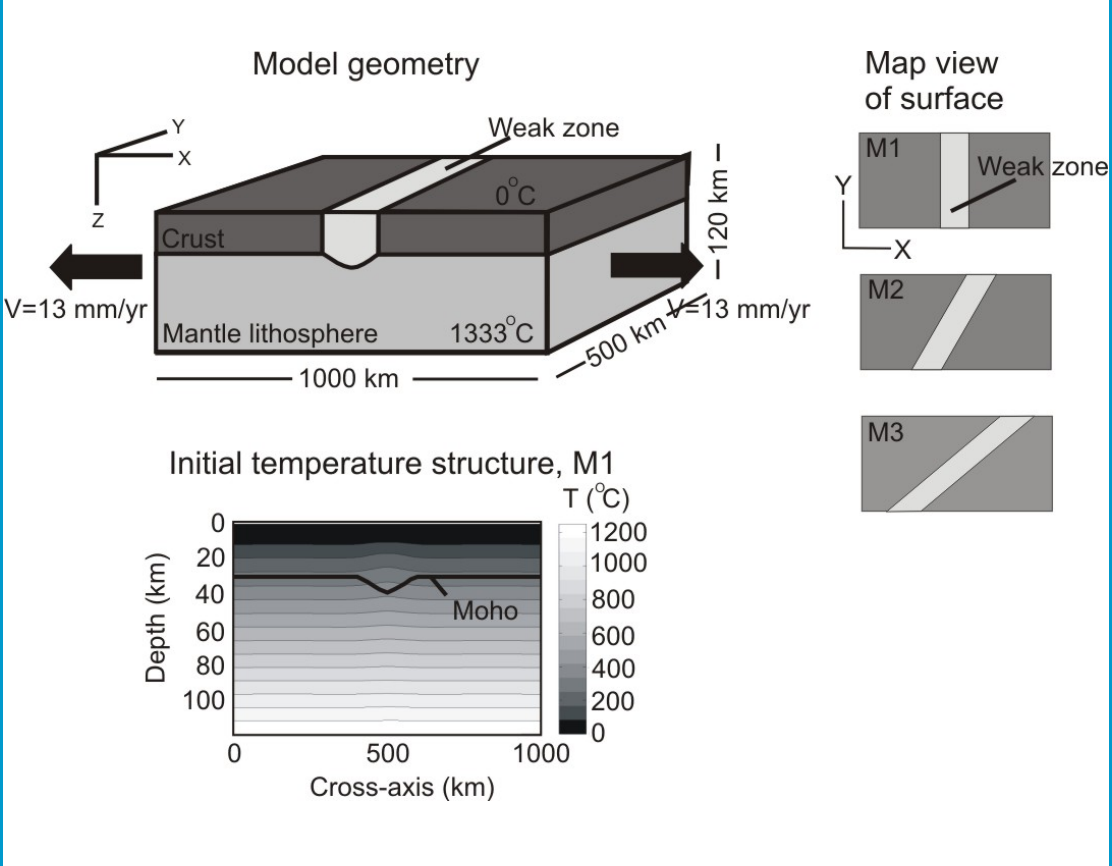
Buoyancy forces

T-dependent power-law rheology

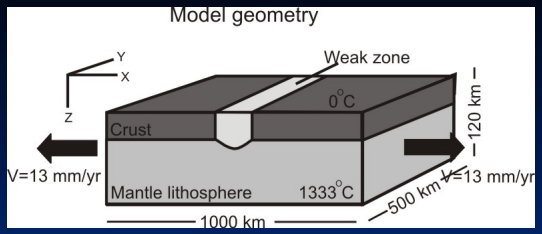


Numerical modeling of oblique rifting

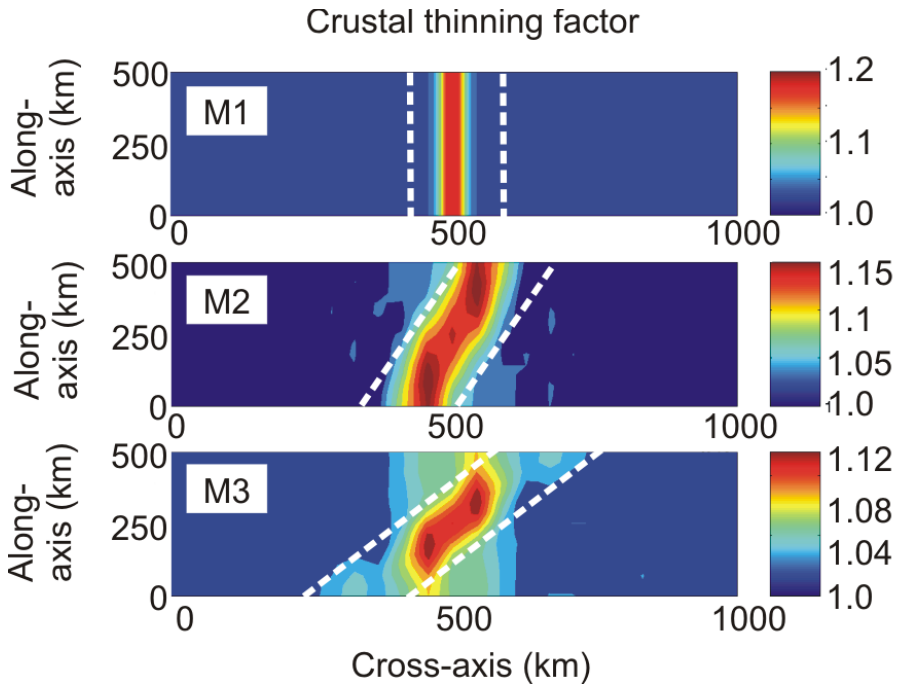
Model setup



Oblique rifting



Results: Map view of model domain, crustal thinning

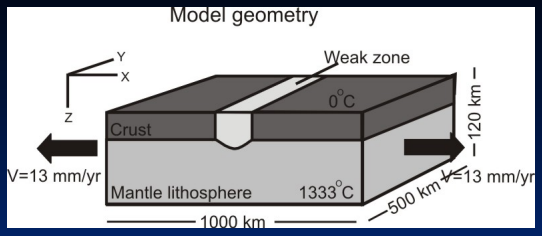


Normal rifting

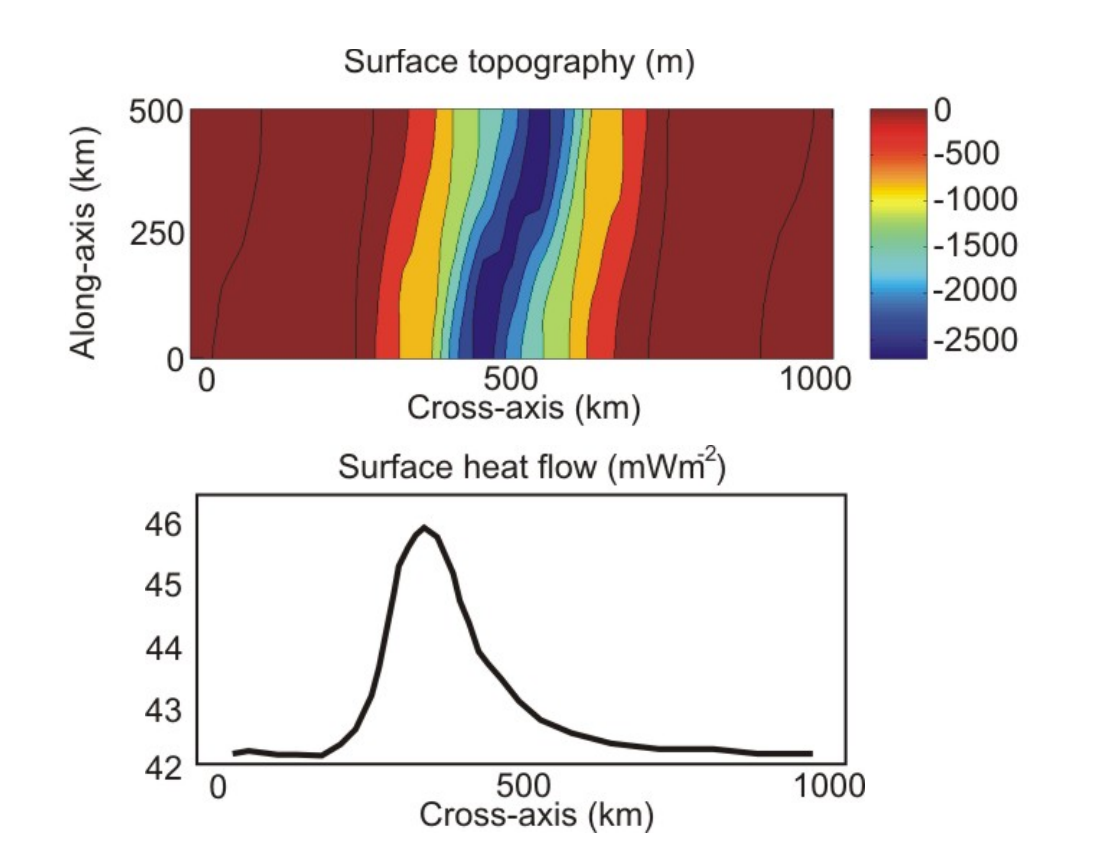
Oblique rifting

Oblique rifting

Oblique rifting

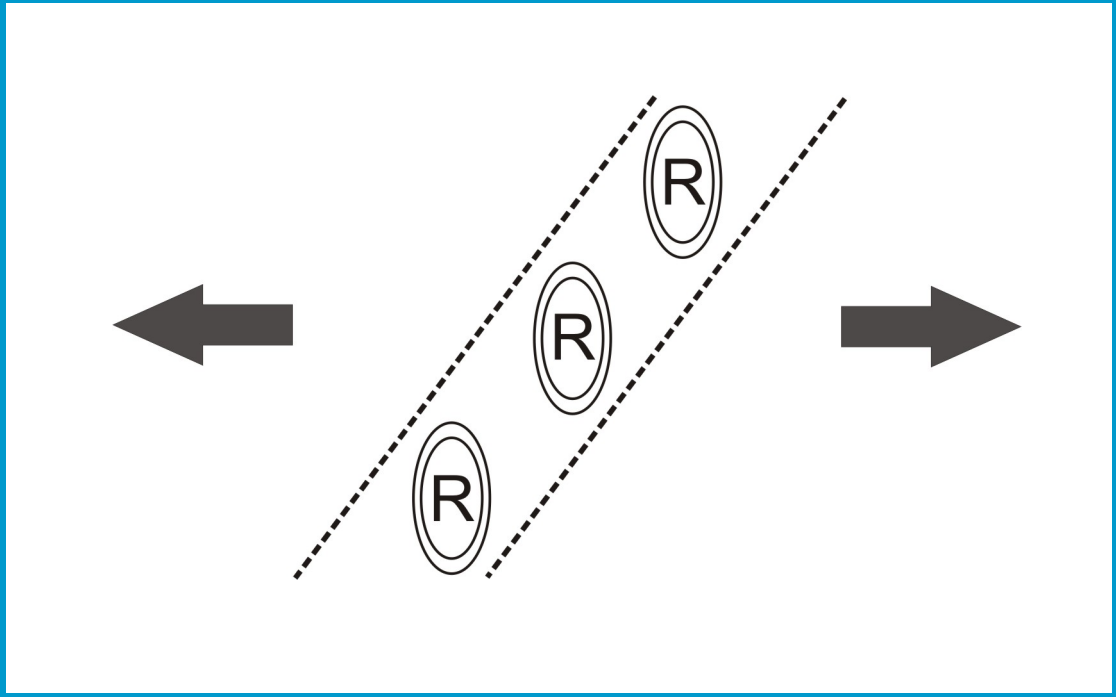


Results: Surface heat flow for oblique rifting test



* Rift zones follow the weak trend as a group, but are individually oriented according to extension direction

* Asymmetric development of individual rifts



* Rift zones follow the weak trend as a group, but are individually oriented according to extension direction

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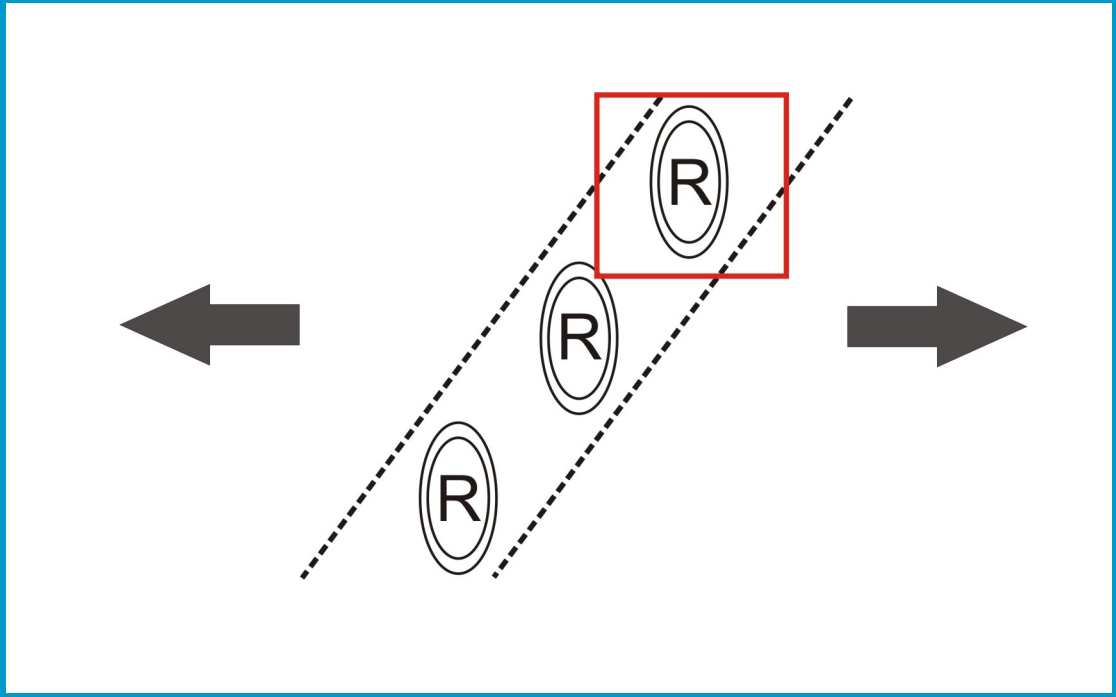
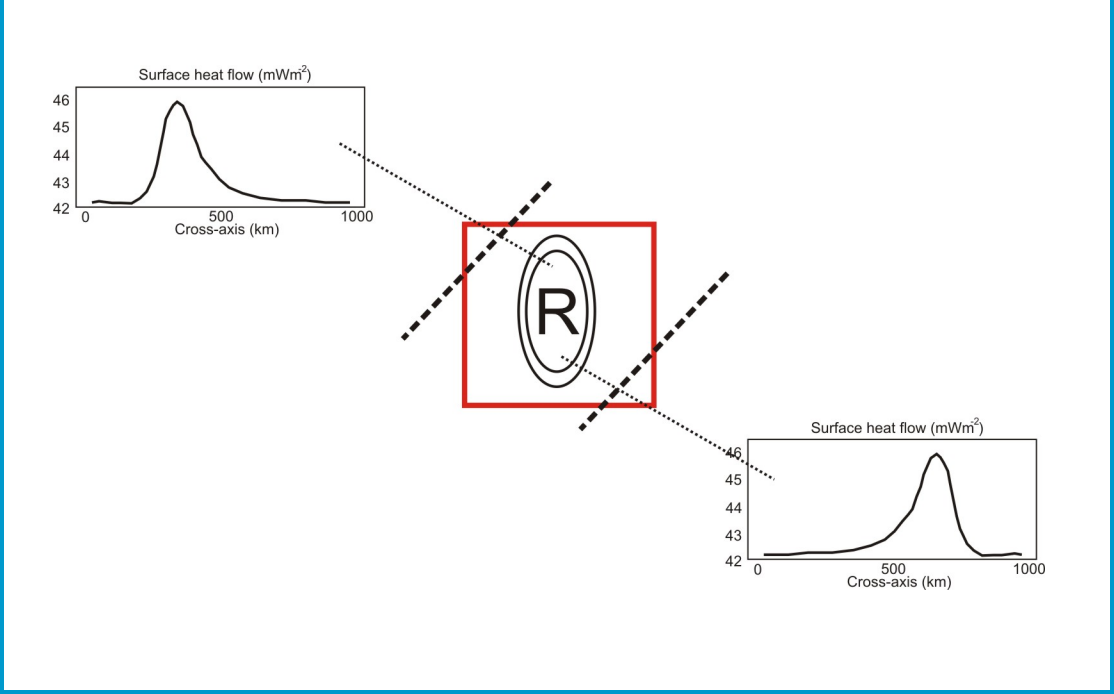
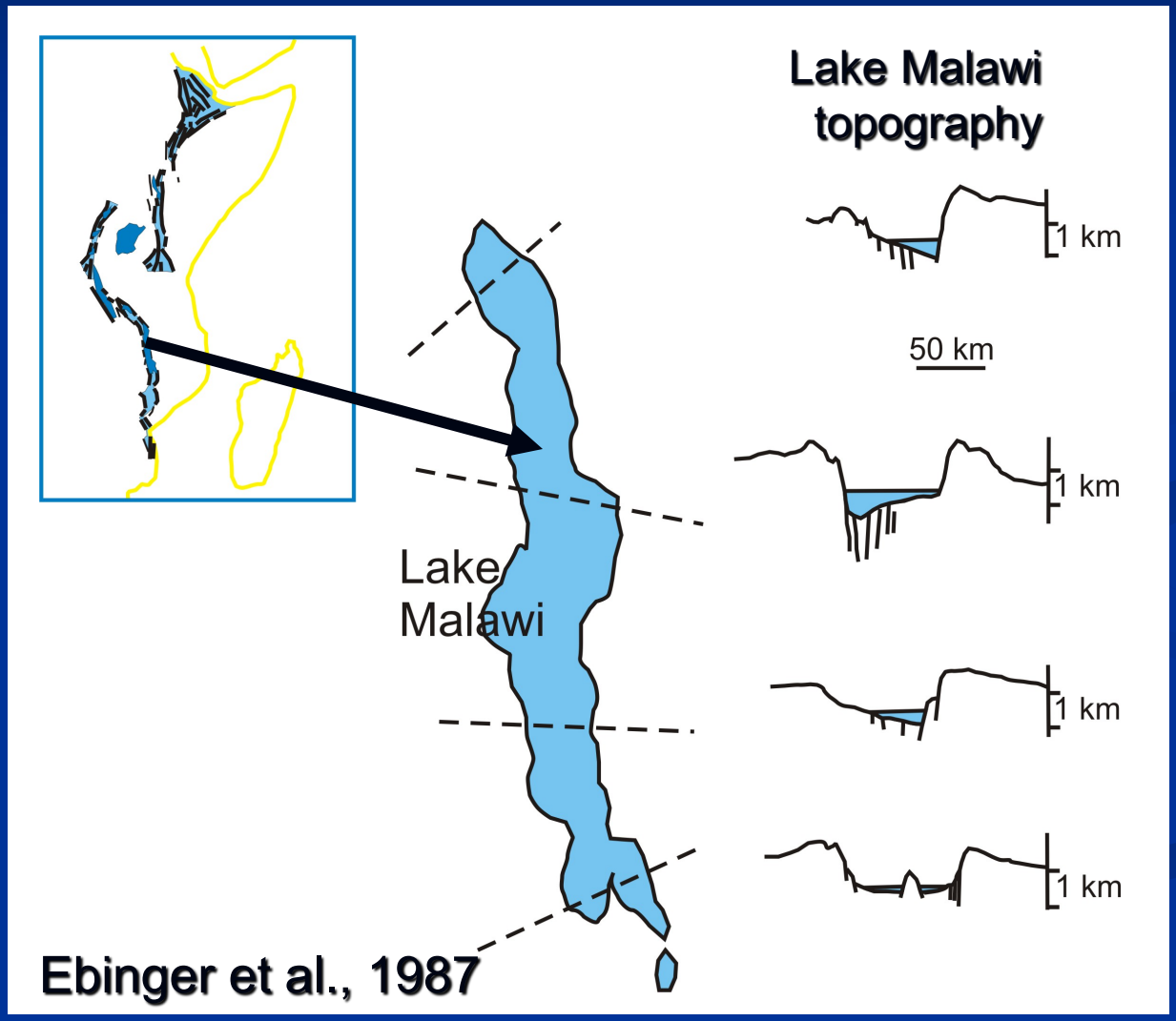


*Asymmetric development of individual rifts

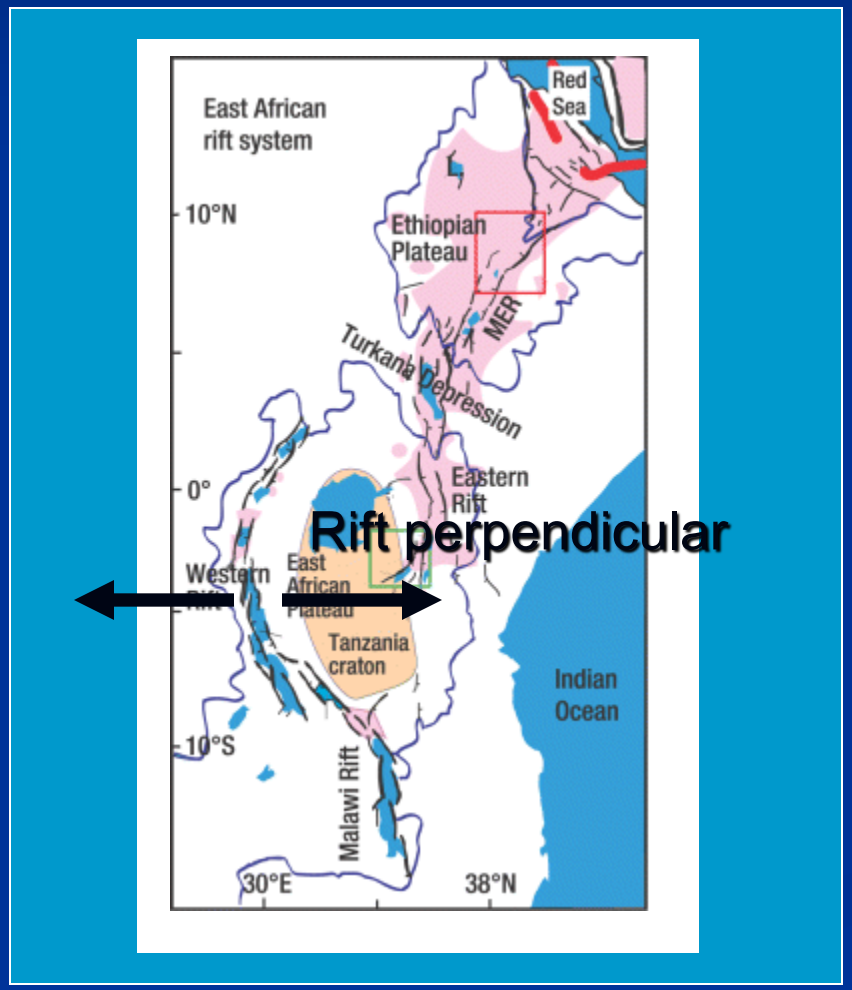
*Alternating asymmetric rifts, linked through accommodation zones

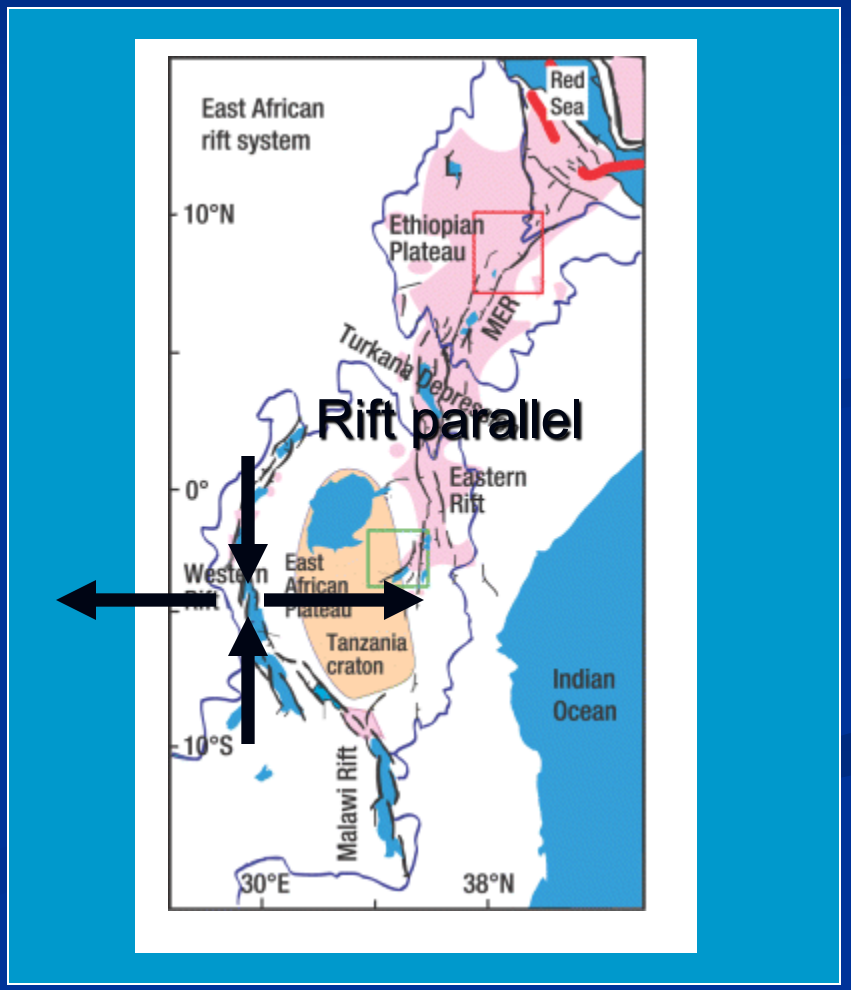


Example of alternating rift asymmetry can be found in the Malawi Rift



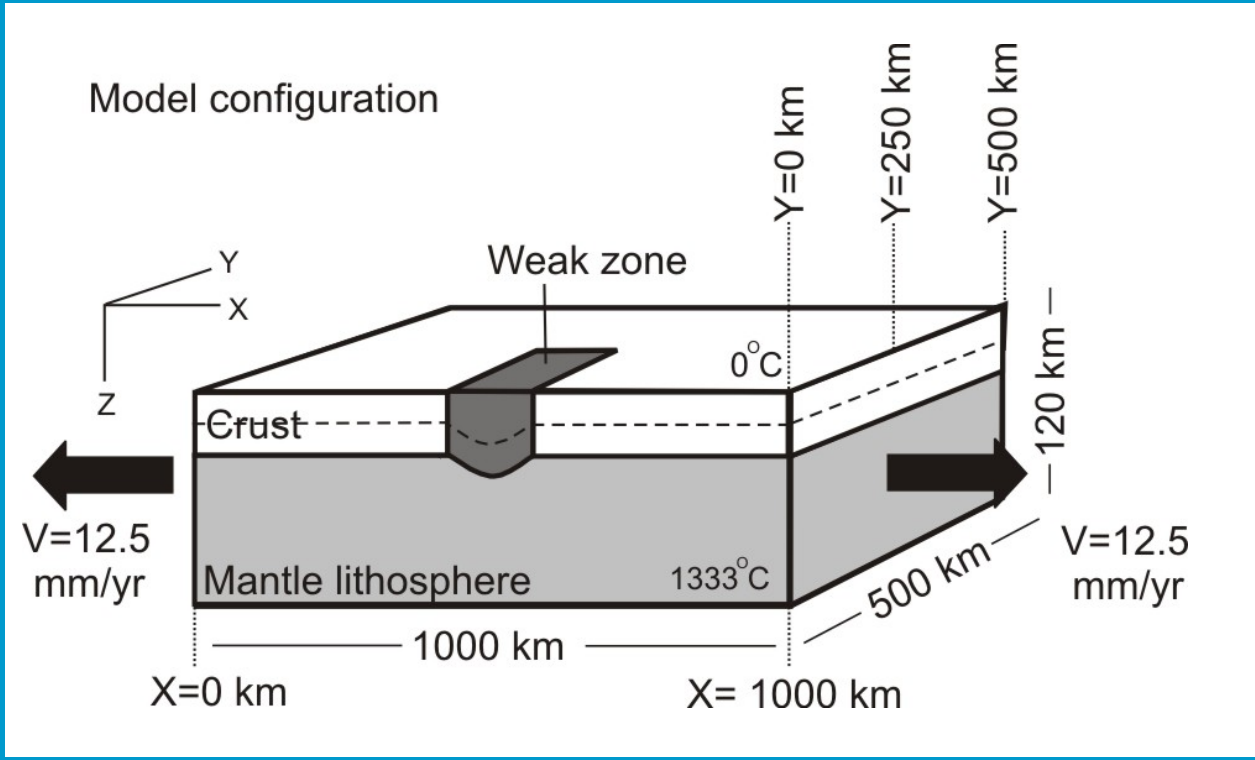
Mantle flow beneath rift basin





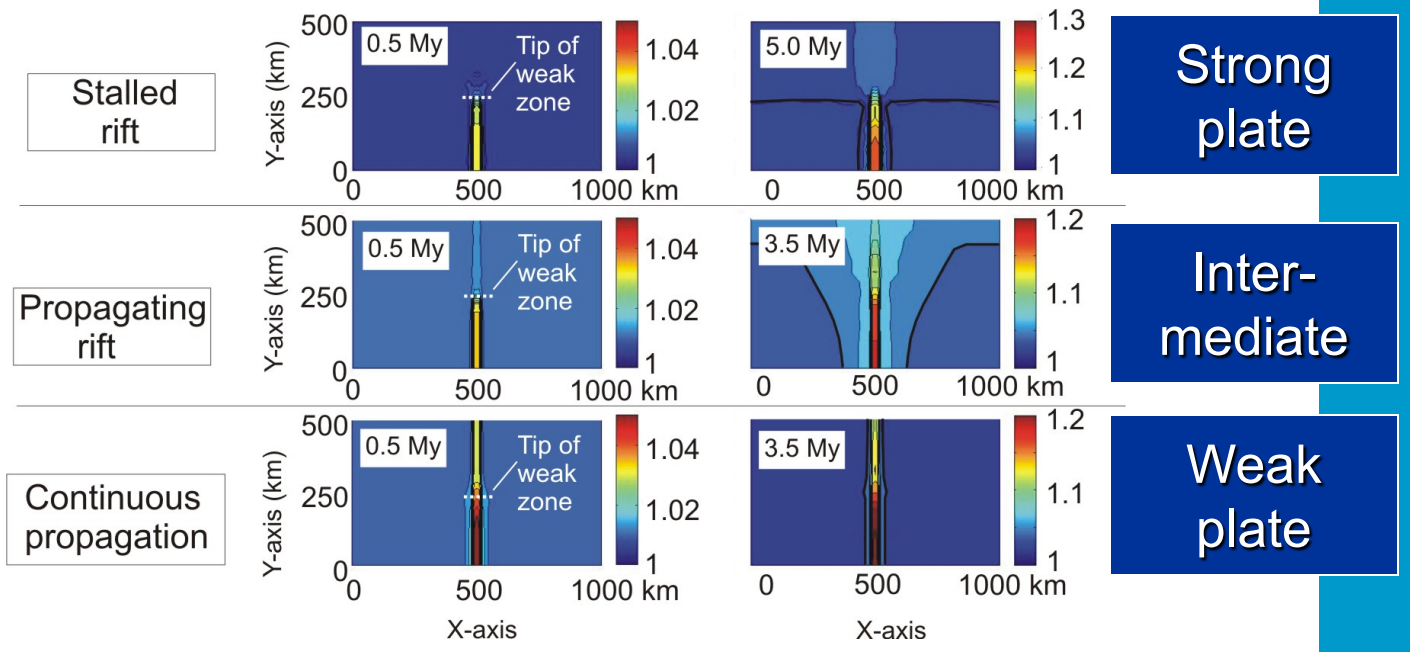
Rift propagation modeling

Model setup



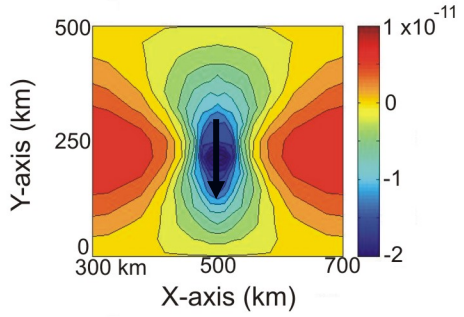
Rift propagation: end-member modes

Evolution of crustal thinning, map view of model domain

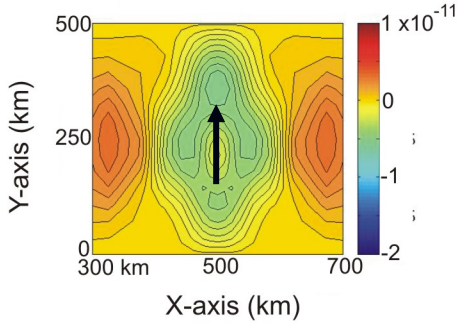


Rift propagation: end-member modes

Rift-parallel component of velocity field, map view



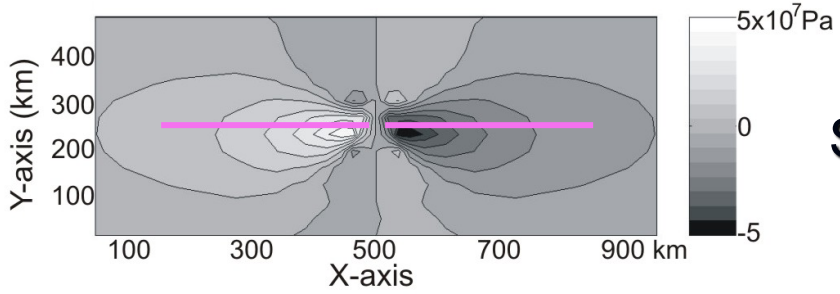
Stalled rift



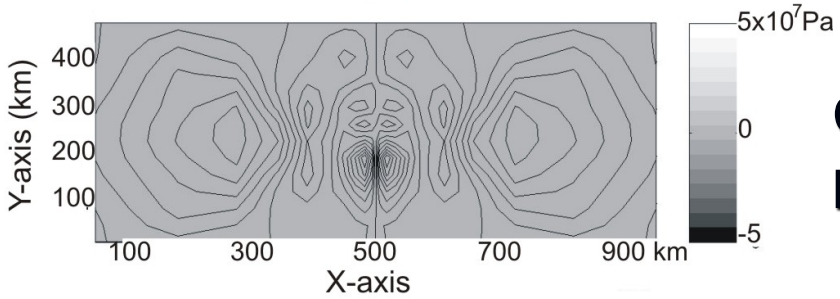
Continuous propagation

Rift propagation: end-member modes

Horizontal shear stress, map view



Stalled rift



Continuous propagation

What works fine

* Flexibility of geometry, initial setup and boundary conditions

* Application to deformation of oceanic lithosphere

* Modeling of large scale structures

Improvements needed

* Modeling of smaller scale structures

* Grid spacing, calculation time

* Remeshing, large deformation

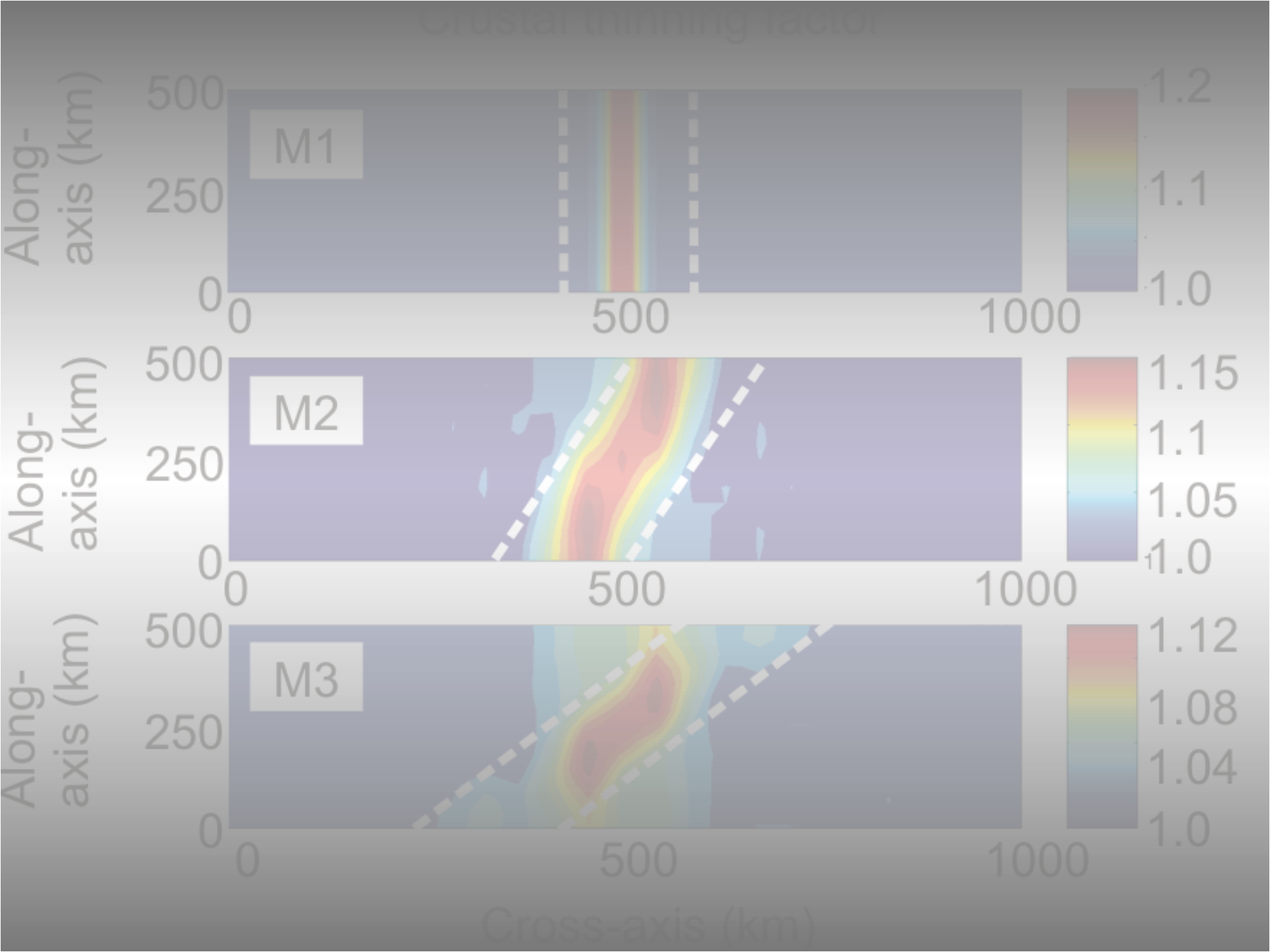
* Brittle/ductile behavior

Other options

SNAC?

Commercial codes such as

ANSYS
ABAQUS
…..
FLAC


Crustal thinning factor
M1
M2
M3
Along-axis (km)
Cross-axis (km)
0
250
500
1000
1.2
1.1
1.0
1.15
1.05
1.12
1.08
1.04