

# GPS Geodesy Experiments in the East African Rift

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# Agenda

A scenic view of a mountain range with a GPS antenna on the right side. The mountains are covered in green vegetation and partially shrouded in mist. The sky is overcast with grey clouds. The GPS antenna is a white, circular dish mounted on a tall, thin metal pole.

## Introduction

- Africa and the East African Rift
- Main tools

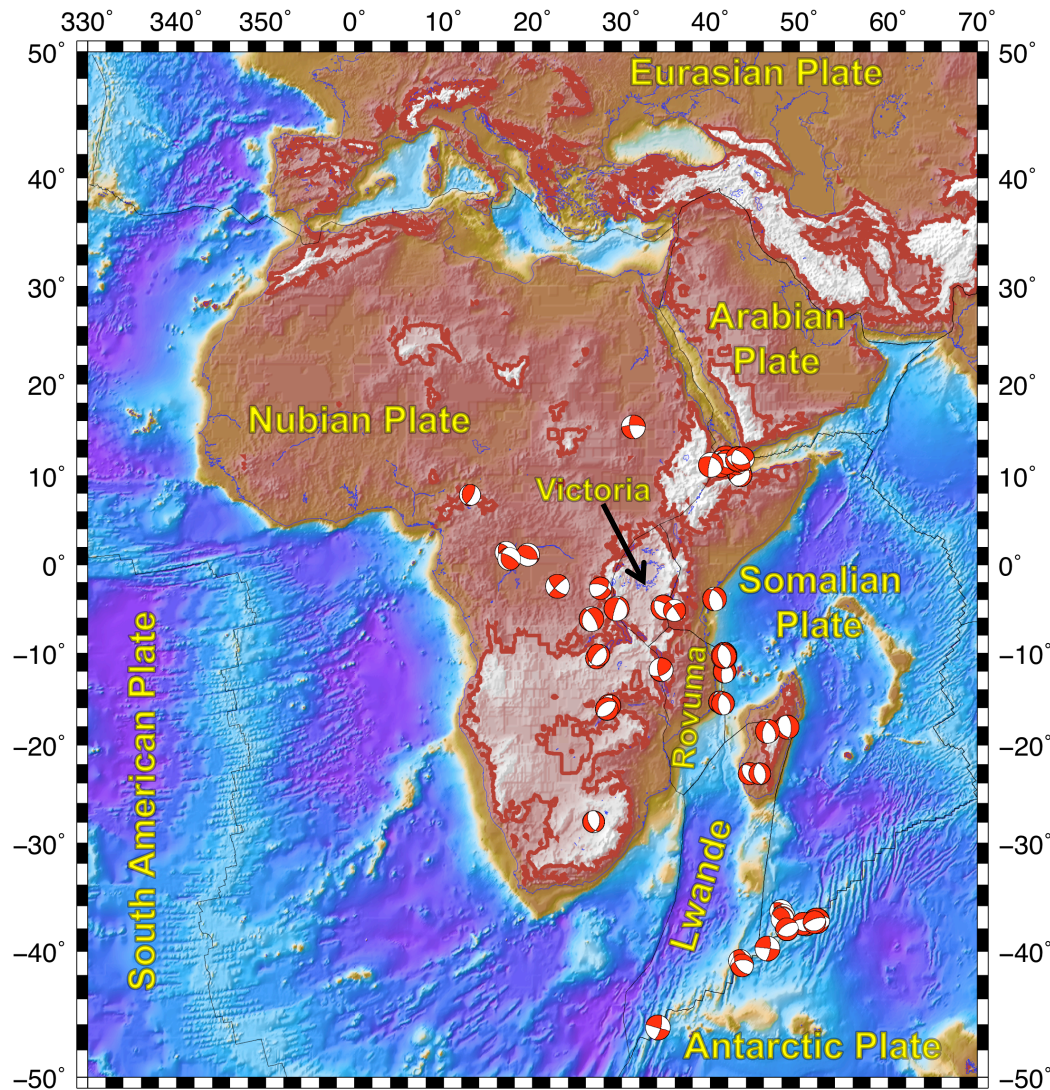
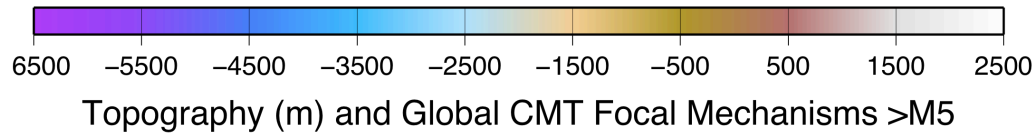
## Key questions

- 4 main questions
- preliminary answers

## Projects

- 4 GPS experiments in the East African Rift

# Africa and the East African Rift



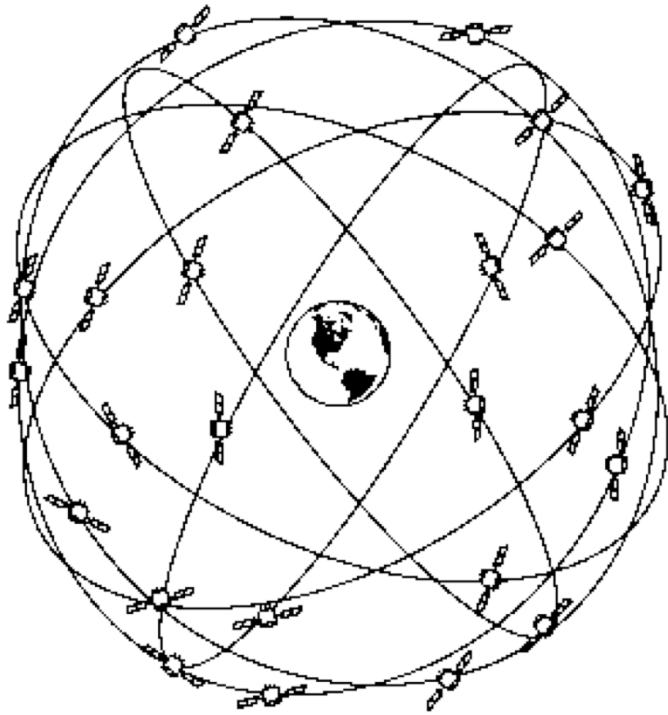
## The East African Rift

- divergent plate boundary
- moderate seismicity
- high topography

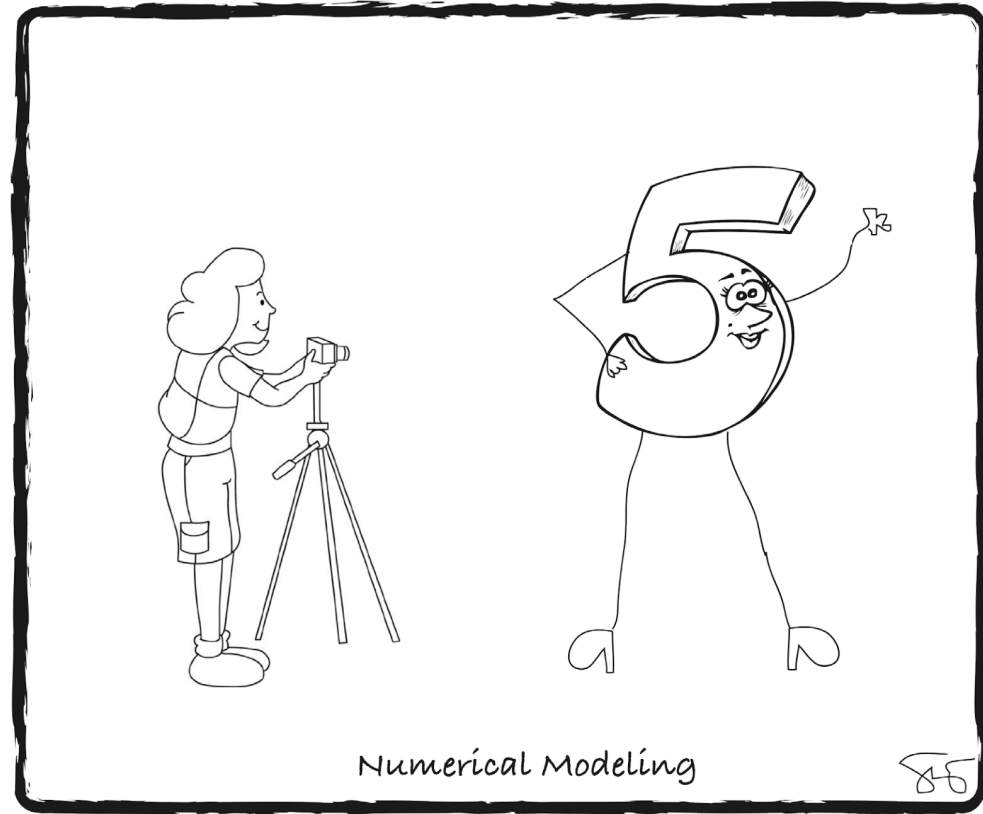
## Motivation

- seismic/volcanic hazards
- natural resources
- ocean basin formation
- physics of continental rifting

# Main Tools



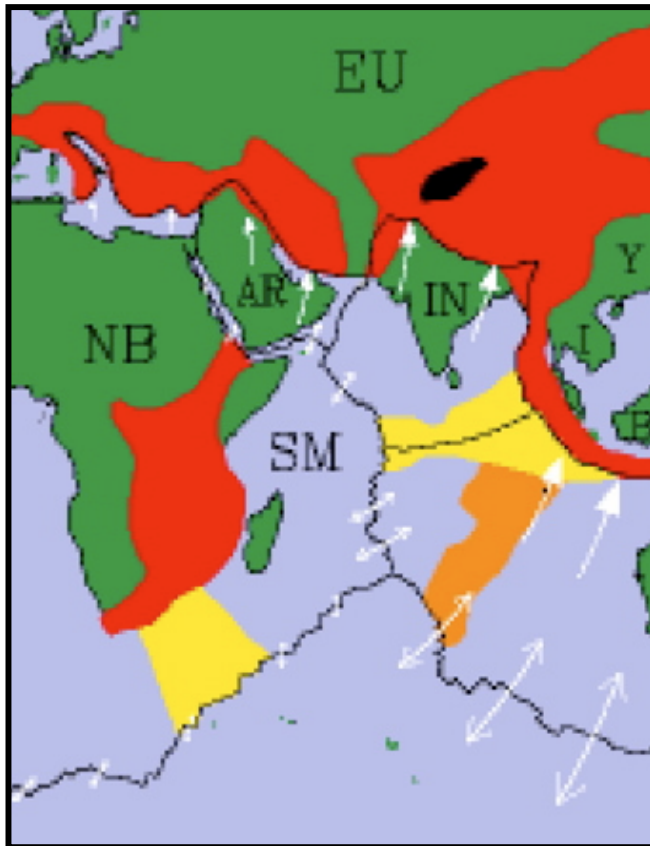
GPS Geodesy



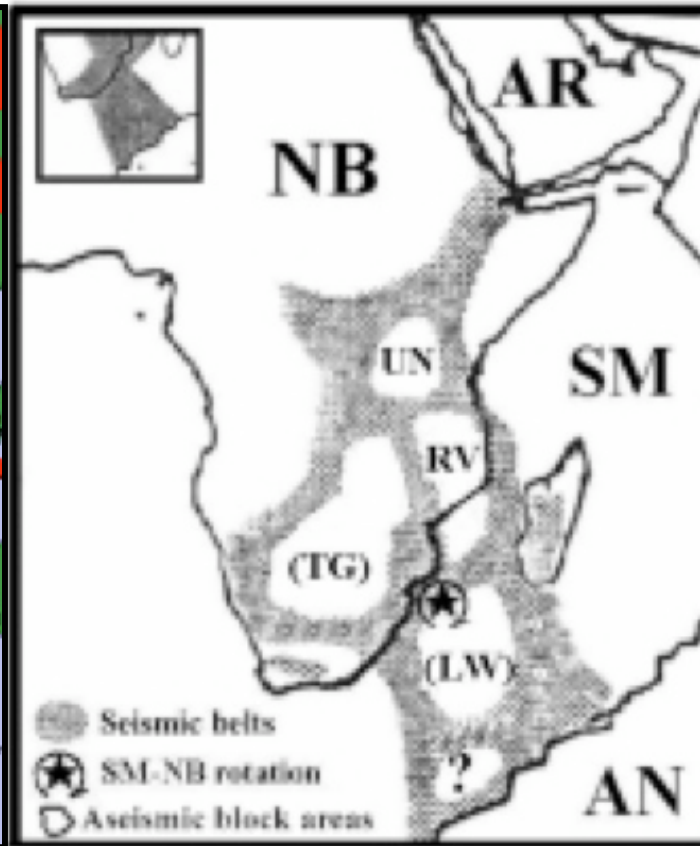
Numerical Modeling

# Key questions

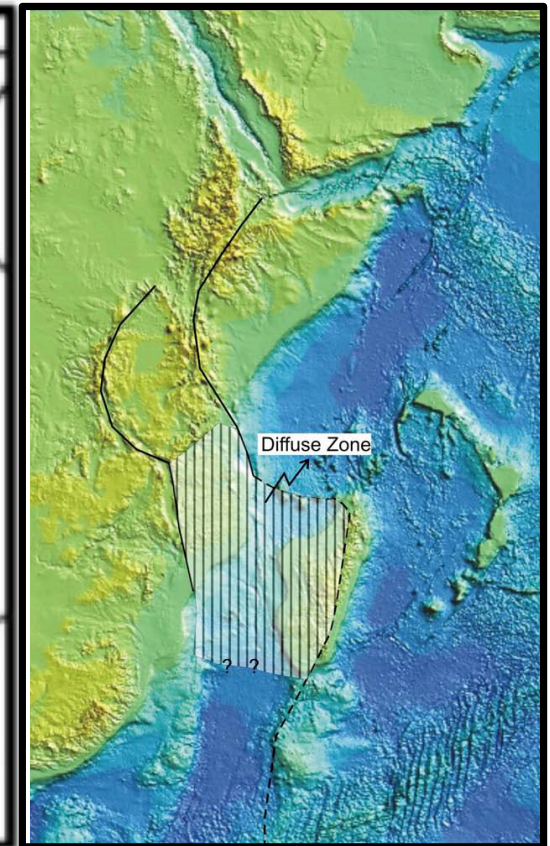
1. What are the **kinematics** of the East African Rift?



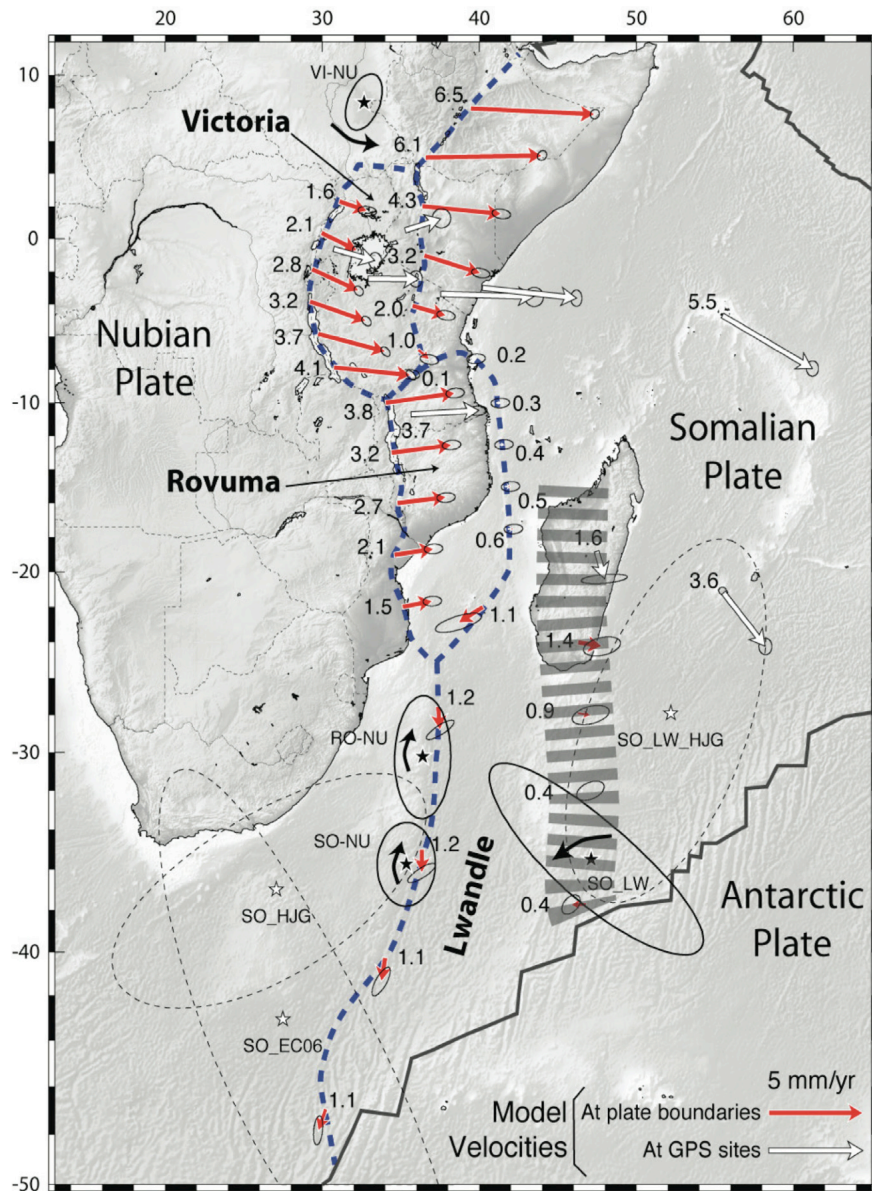
Gordon and Stein, 1992:  
EAR = a diffuse plate boundary



Hartnady, 2002:  
EAR = 4 rigid plates embedded within Nubia-Somalia plate boundary



Kusky et al, 2010  
Eastern EAR =  
diffuse plate boundary



## Data

- GPS & DORIS velocities
- earthquake slip vectors
- SWIR: transform azimuths & spreading rates

## Conclusions

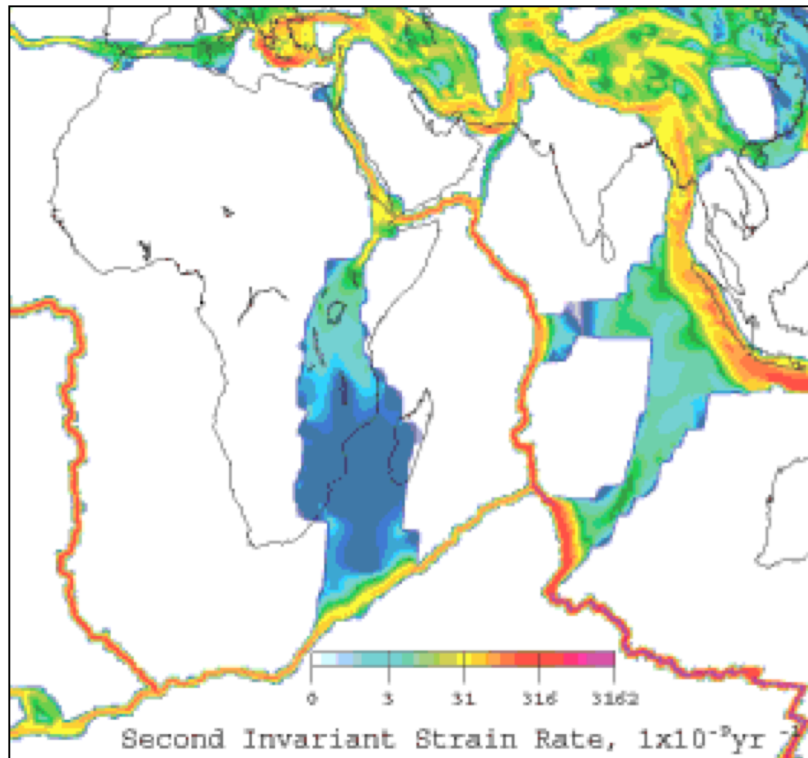
- 3 sub-plates: Victoria, Rovuma, Lwandle
- Consistent motion of 3.2Ma
- Victoria rotates CCW wrt Nubia
- Rovuma, Lwandle CW wrt Nubia

Stamps et al. 2008  
3 sub-plates

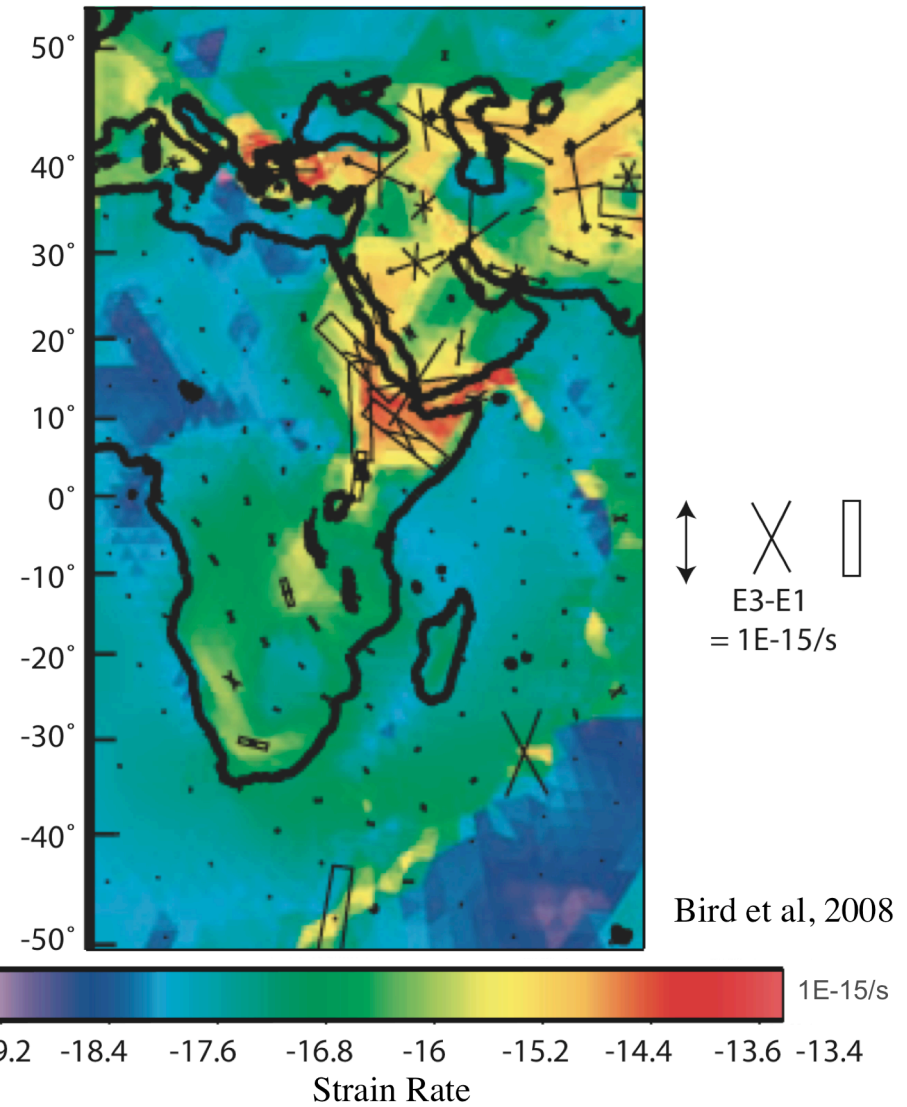
# Key questions

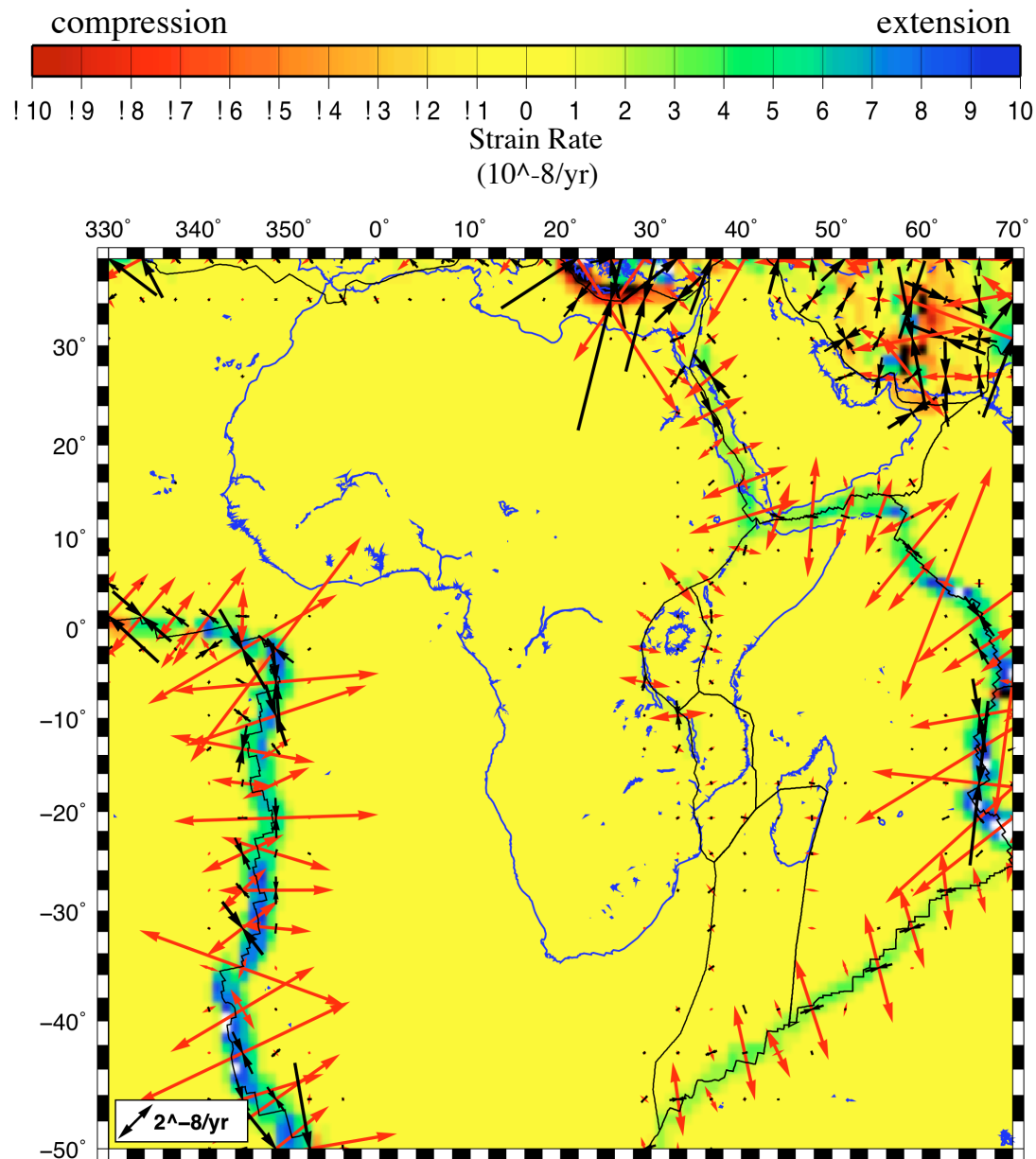
## 2. How is **strain** distributed in the East African Rift?

Kreemer et al, 2003



Global Strain Rate Map





## Data

- GPS & DORIS velocities
- seismic moment tensors
- kinematic model velocities  
(Stamps et al, 2008; REVEL)

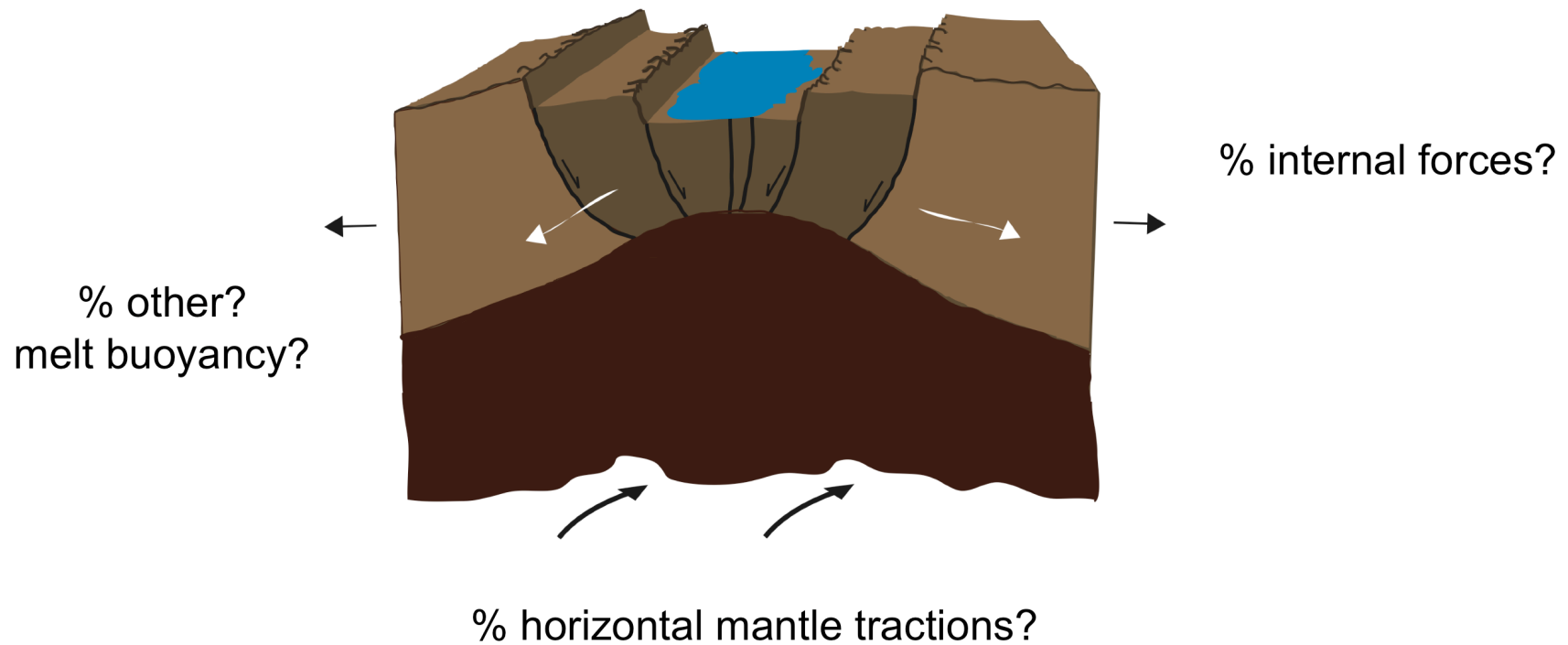
## Model Features

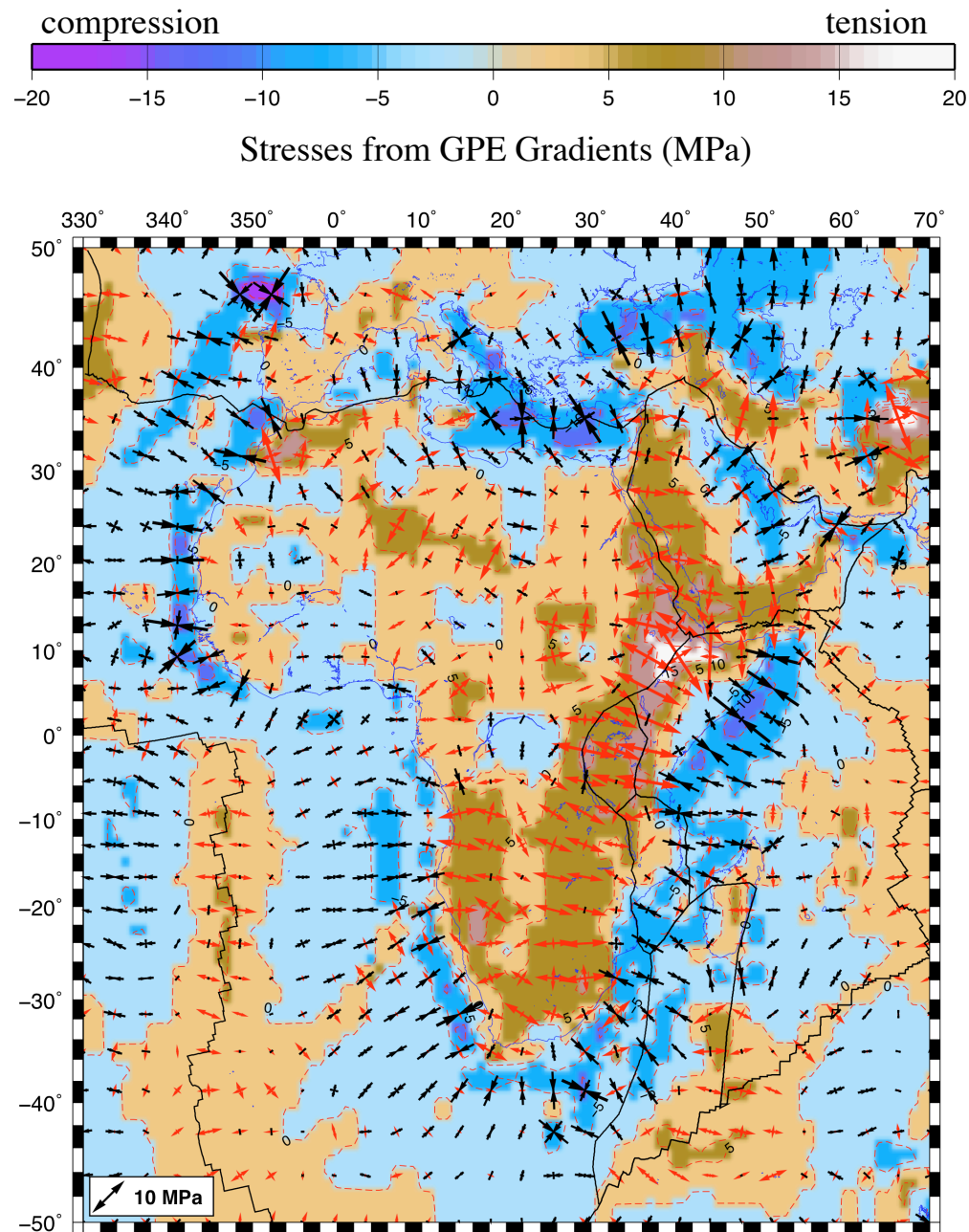
- localized strain at boundaries
- small strains across EAR
- higher strains in Malawi, Rukwa, Natron, and Main Ethiopian Rifts
- Rigid plate interiors

Stamps et al. in prep.

# Key questions

3. What is the **budget of forces** acting to initiate and sustain rifting?





Stamps et al. 2010

## Input

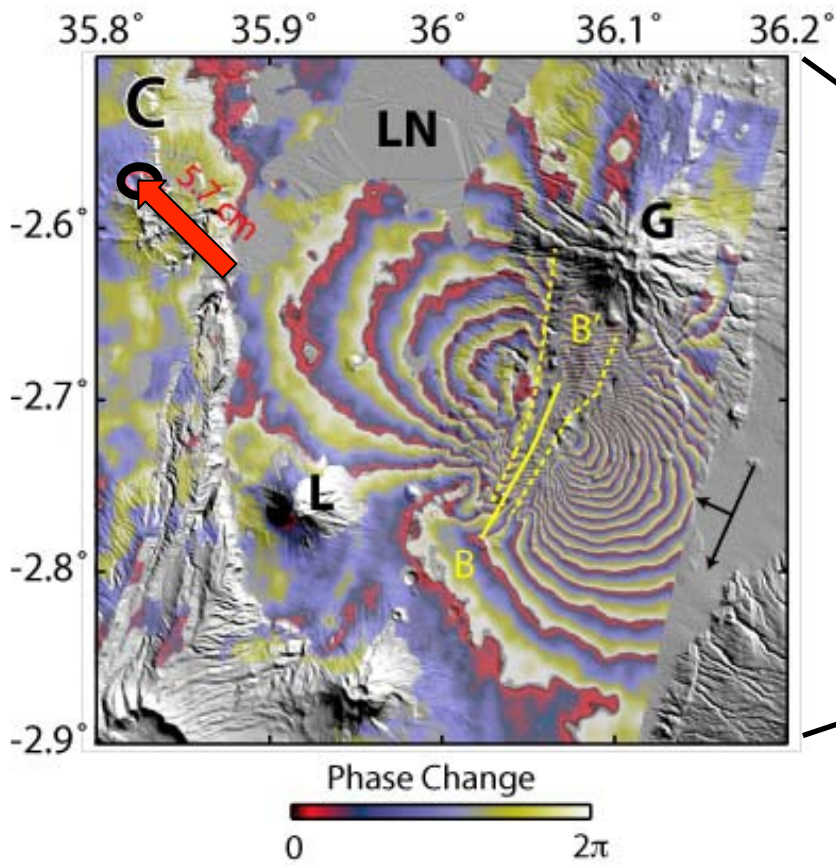
- CRUST2.0 (crustal densities & crustal thicknesses)
- lateral density variations in upper mantle
- isostatic compensation

## Model Results

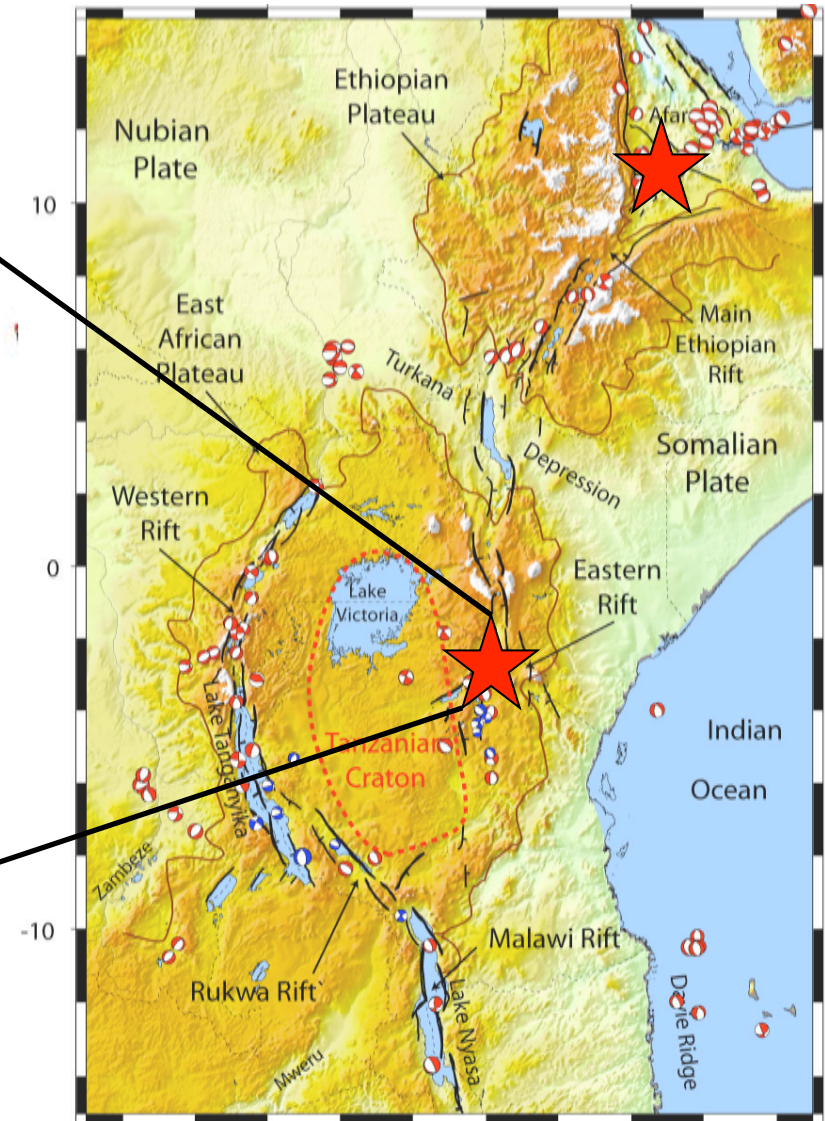
- E-W tension across EAR
- 5-20 MPa vertically averaged stress
- compression in oceanic basins
- tension along ridges

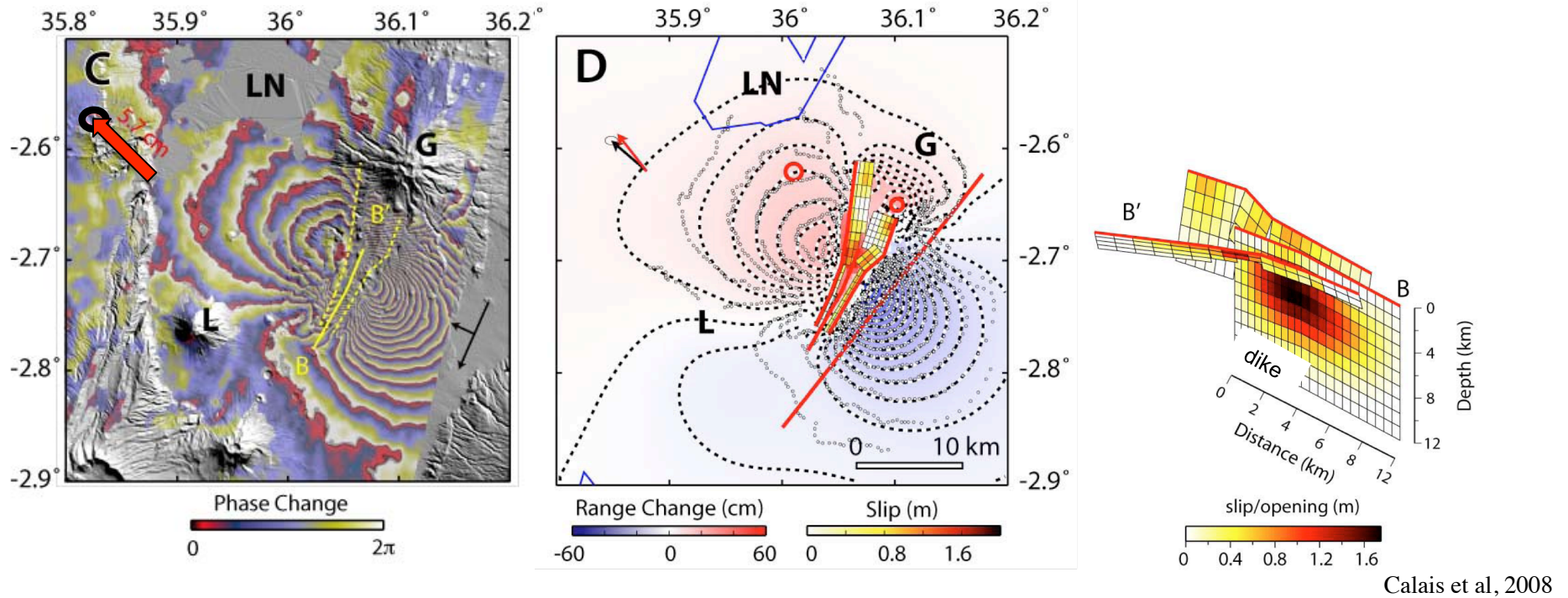
# Key questions

4. What is the **role of magmatic intrusions** in the early phases of rifting?



2007 Natron Diking Event



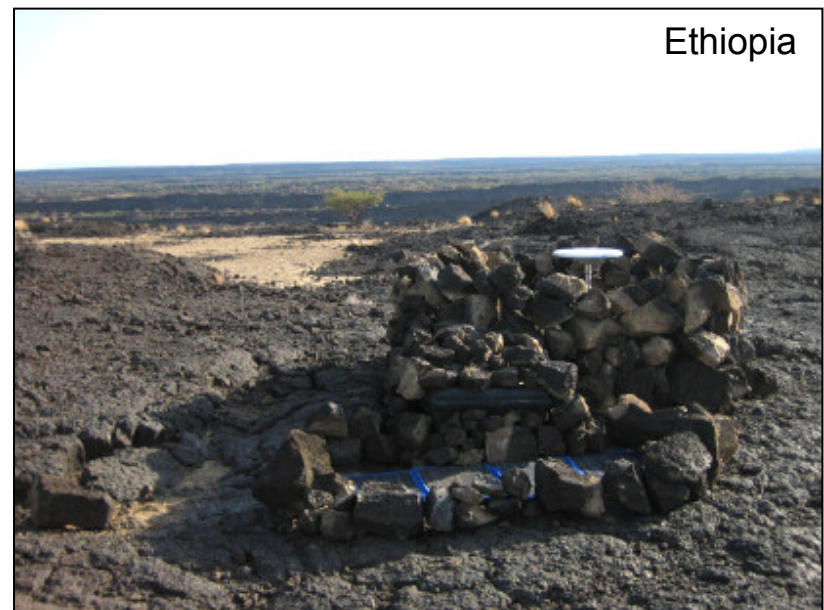


- Main event: July 17, 2007  $M_w$  5.9
- Aseismic slip preceded main event
- Border fault motions:  $5.6 \pm 0.9$  cm vertically,  $5.7 \pm 0.4$  cm horizontally N49°W
- Cumulative seismic moment release not enough to explain border fault motion
- Aseismic slow slip required to explain motion on border fault

**Conclusions:** magma intrusions accommodate strain during the initial stages of rifting



## Current Projects



# Kinematic constraints on mantle-lithosphere interactions

## Tanzania GPS

### Main Objectives

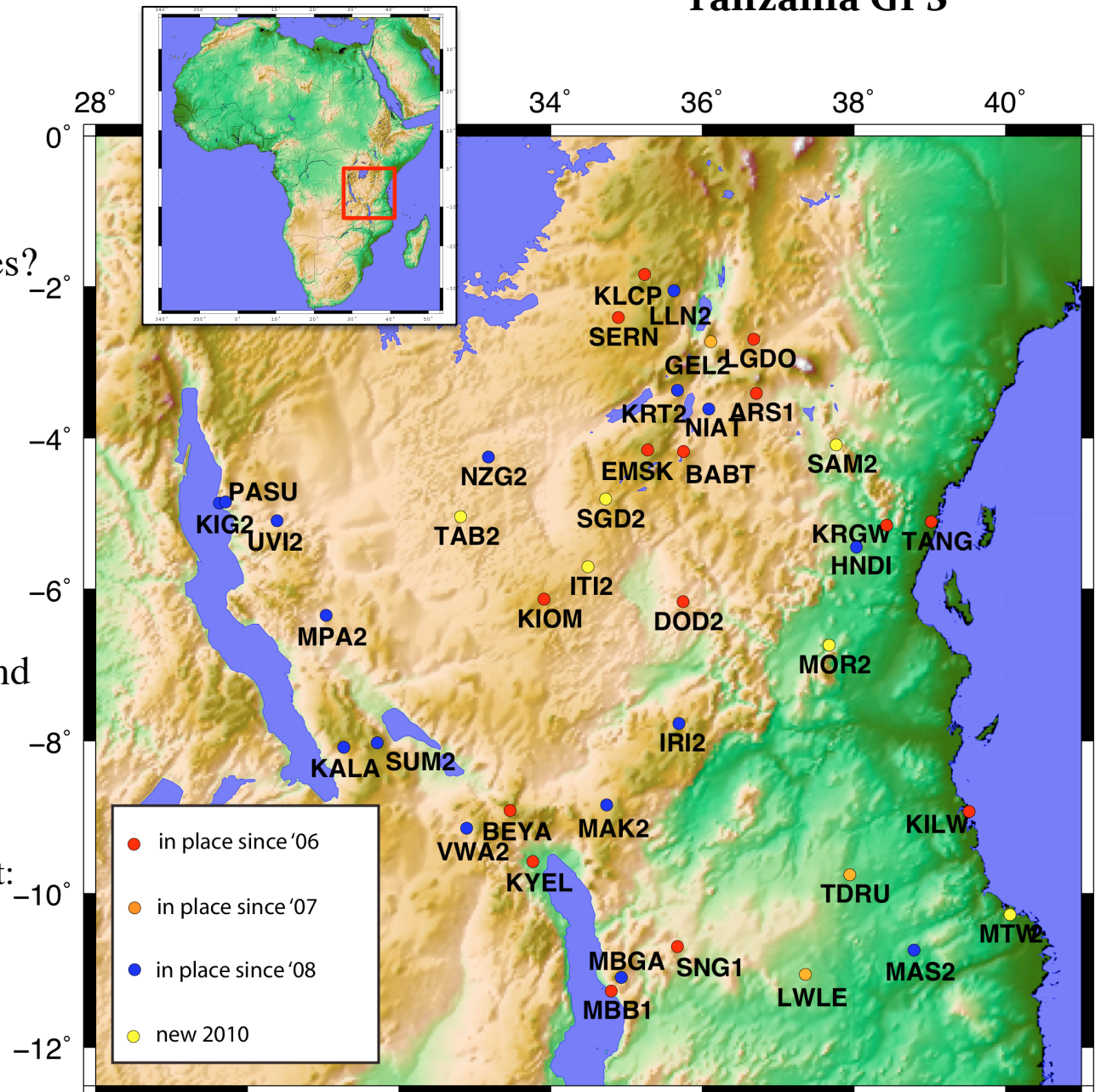
- What are the kinematics?
- What are the large-scale forces?

### Influence of water?

- Lake Victoria
- Dry/wet seasons
- 2.5 yrs observation (Blewitt and Lavallée, 2002)

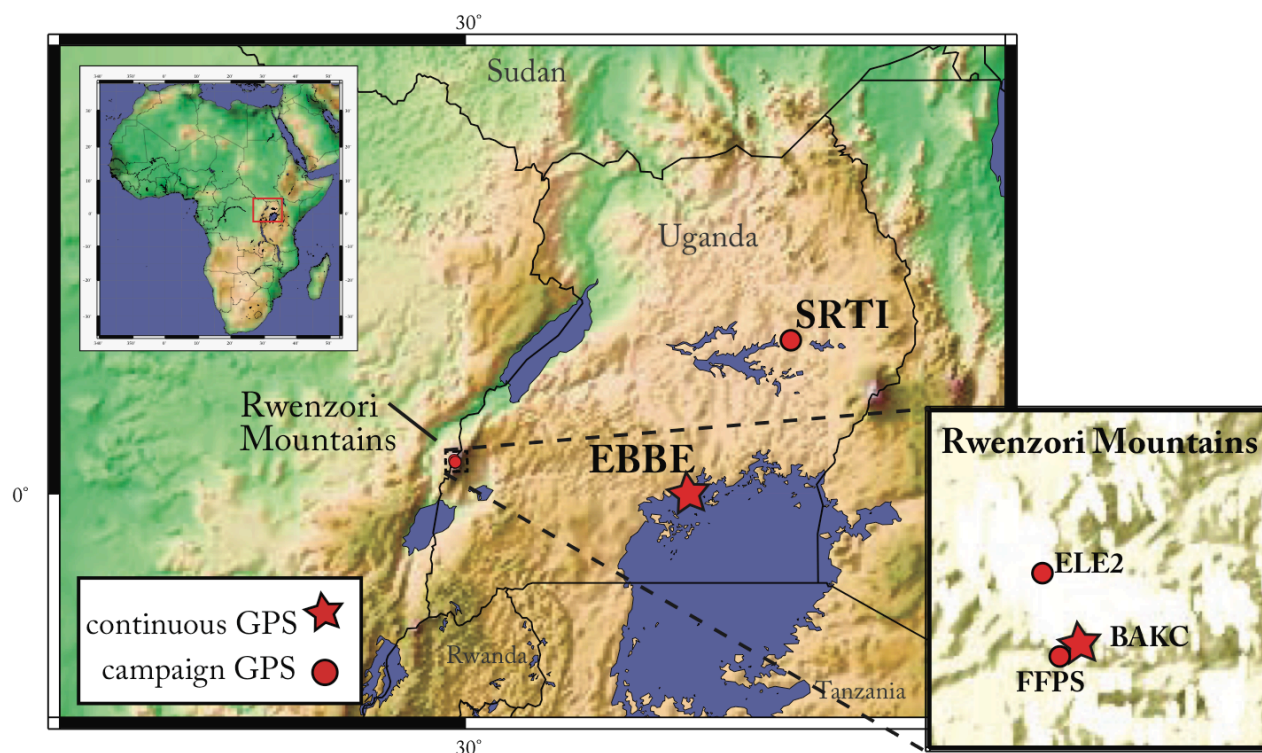
For further information, please visit:

<http://web.ics.purdue.edu/~ecalais/projects/ear/tanz/index.html>



# RiftLink: Structural expression of extreme rift-flank uplift

## Uganda GPS



## Main Objectives

- What are the vertical and horizontal motions of the Rwenzori block?
- Is the Rwenzori block rotating clockwise with respect to Nubia?

## Influence of water?

- Lake Victoria
- Dry/wet seasons
- Freezing and thawing in the Rwenzori Mountains
- 2.5 yrs observation (Blewitt and Lavallée, 2002)

For further information, please visit:

[http://www.riftlink.de/englisch/project\\_b1.htm](http://www.riftlink.de/englisch/project_b1.htm)

# Magma-tectonic processes in an active transitional rift from seismic, GPS and modeling studies in Afar

Ethiopia GPS

## Main Objectives

- What is the role of magmatism during the early stages of rifting?

## Influence of water?

- Not expected
- Only a few days of rain

For further information,  
please visit:

<http://web.ics.purdue.edu/~ecalais/projects/ear/daure/index.html4t>



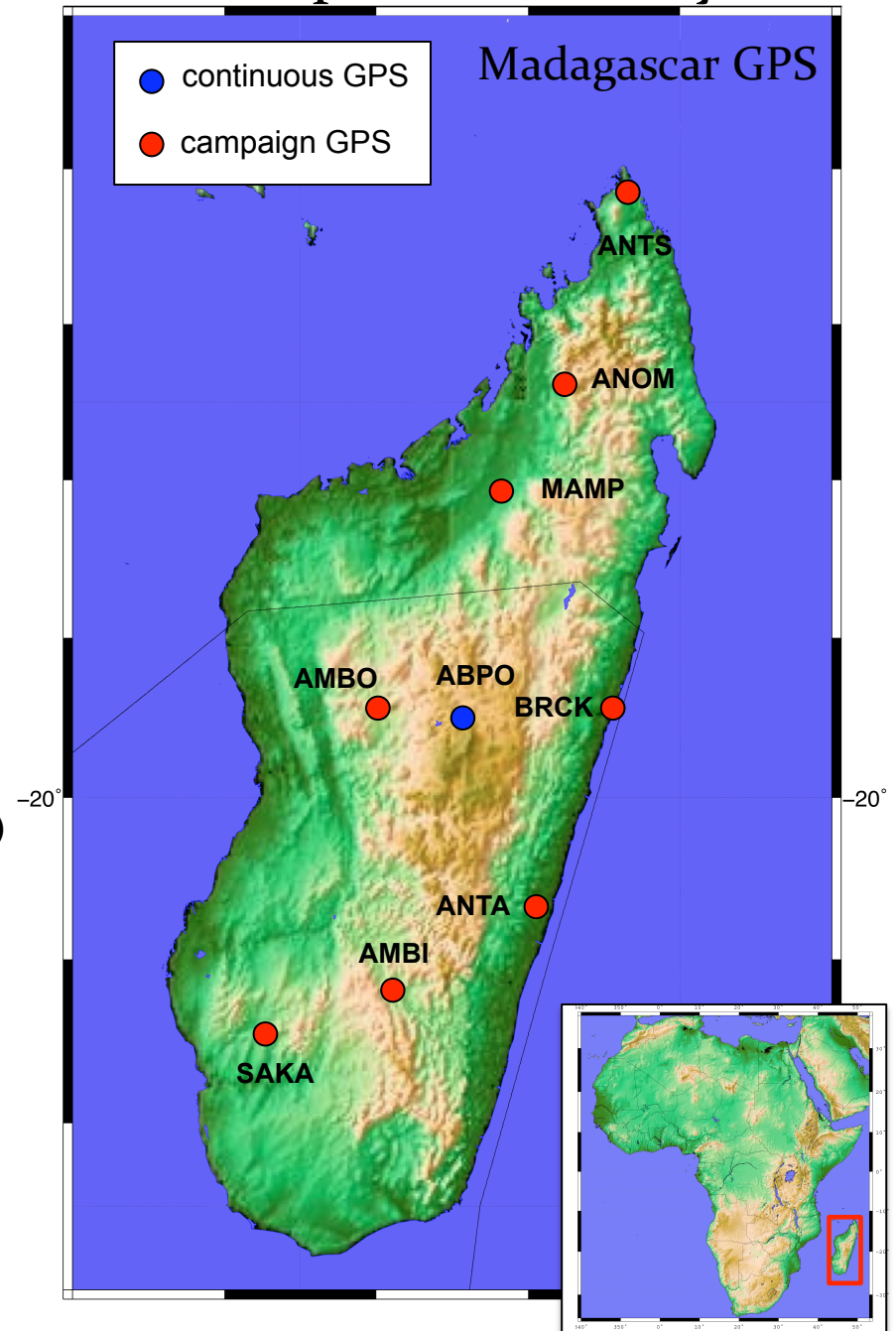
# Kinematic constraints on the Lwandle-Somalia plate boundary

## Main Objectives

- Is Madagascar rifting apart diffusely?
- How is strain accommodated across the island?
- Where is the Lwandle-Somalia plate boundary?
- What forces are driving Madagascar away from Africa?

## Influence of water?

- Dry/wet seasons
- 2.5 yrs observation (Blewitt and Lavallée, 2002)



# Agenda

The background of the slide is a photograph of a mountainous landscape. In the foreground on the right, a white GPS antenna is mounted on a metal pole. The middle ground shows a valley with some vegetation and a road, partially obscured by mist or low clouds. The background features a range of rugged mountains under a bright, overcast sky.

## Introduction

- Africa and the East African Rift
- Main tools

## Key questions

- What are the kinematics of the East African Rift?
- How is strain distributed across the East African Rift?
- What is the budget of forces acting to initiate and sustain continental rifting?
- What is the role of magmatic intrusions in the early stages of rifting?

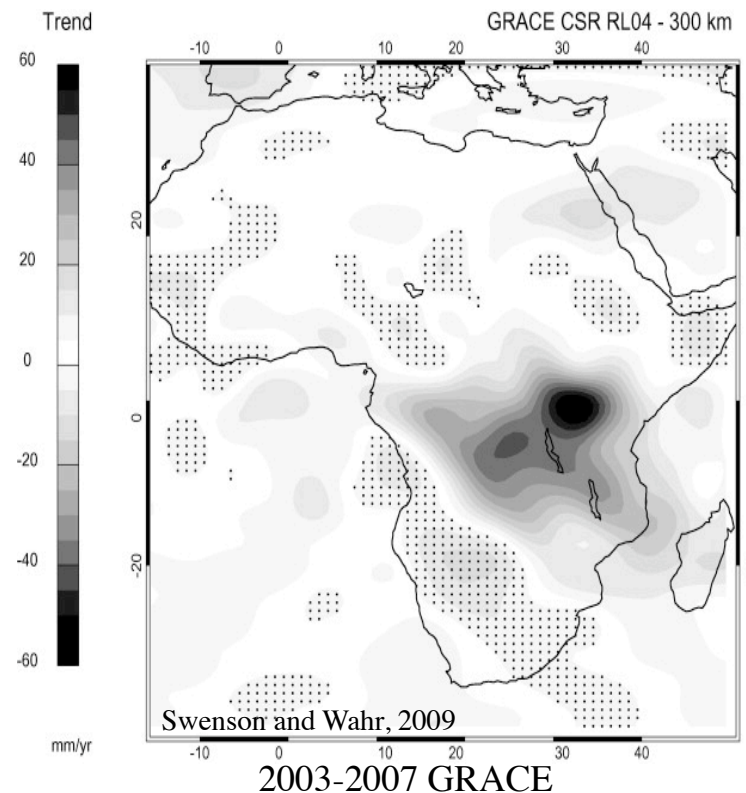
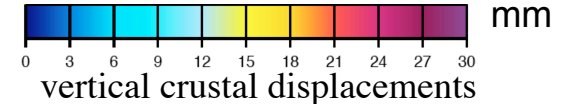
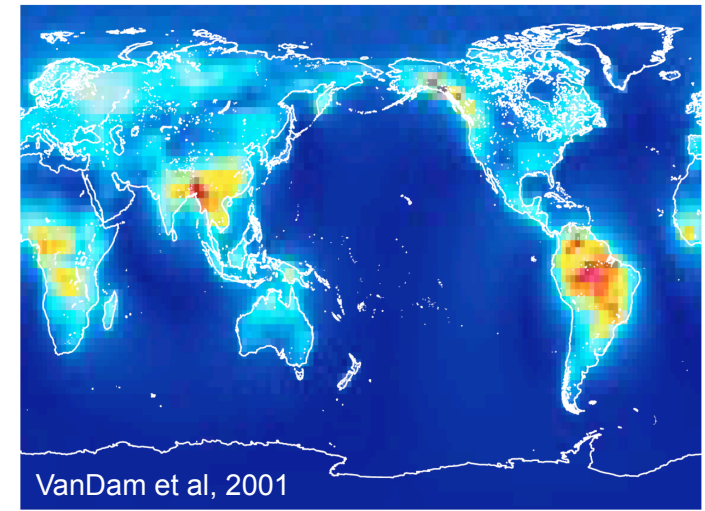
## Projects

- Tanzania: Kinematic constraints on mantle-lithosphere interactions
- Uganda: Structural expressions of extreme rift-flank uplift
- Ethiopia: Magma-tectonic processes in an active transitional rift from seismic, GPS and modeling studies in Afar
- Madagascar: Kinematic constraints on the Lwandle-Somalia plate boundary

# Relationship with hydrologic signals

## Atmospheric and Hydrologic Loading

- Van Dam et al, 2001:
  - vertical crustal displacements up to 30mm in Africa
  - horizontal crustal displacements up to 5mm
- Blewitt and Lavallée, 2002:
  - suggest a 2.5 year minimum observation period is needed to average out seasonal patterns
- GRACE observations of mass change:
  - show significant mass reductions in Lake Victoria region which may result in crustal deformation



# Relationship with hydrologic signals

- Horizontal velocities are expected to be 2-4 mm/yr in central EAR
- Hydrologic signals can affect these small motions (Van Dam et al, 2001; Blewitt and Lavallée, 2002)
- GPS signal has a temporal pattern
- We need studies to address the hydrologic component in time-series

