Frontiers in regional-scale seismology and the synergy between seismological and geodetic facilities and capacity building

- overview of leading edge research and future facility needs at regional scales using examples from Antarctica and Africa

- address future opportunities for Int'l collaboration and capacity building using AfricaArray as a model

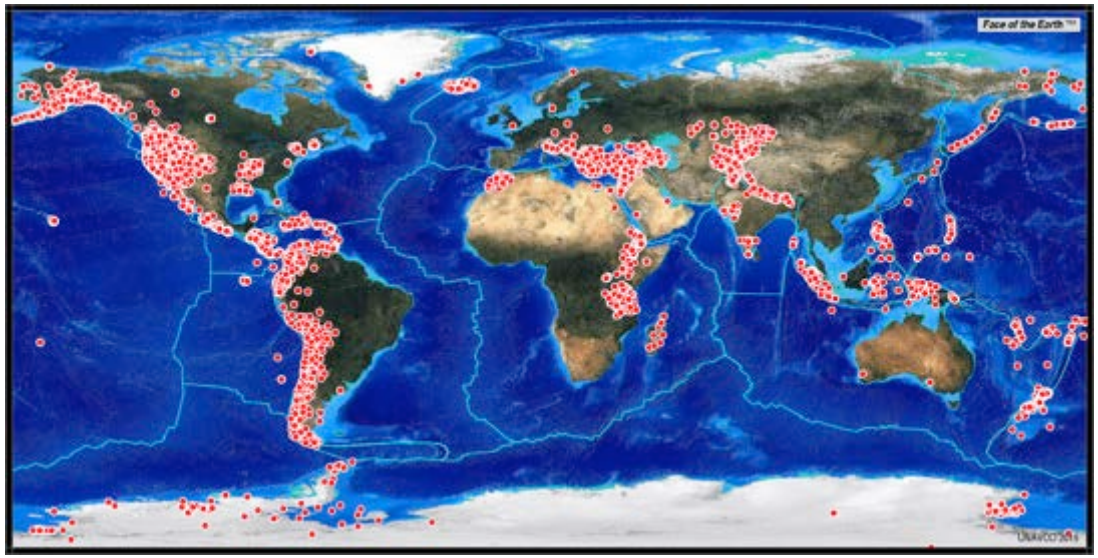
Andy Nyblade

Penn State University

Future Seismic and Geodetic Facility Needs in the Geosciences Workshop, May 4, 2015

IRIS + UNAVCO = TRANSFORMATIVE SEISMOLOGY AND GEODESY AT REGIONAL SCALES

UNAVCO
campaign stations



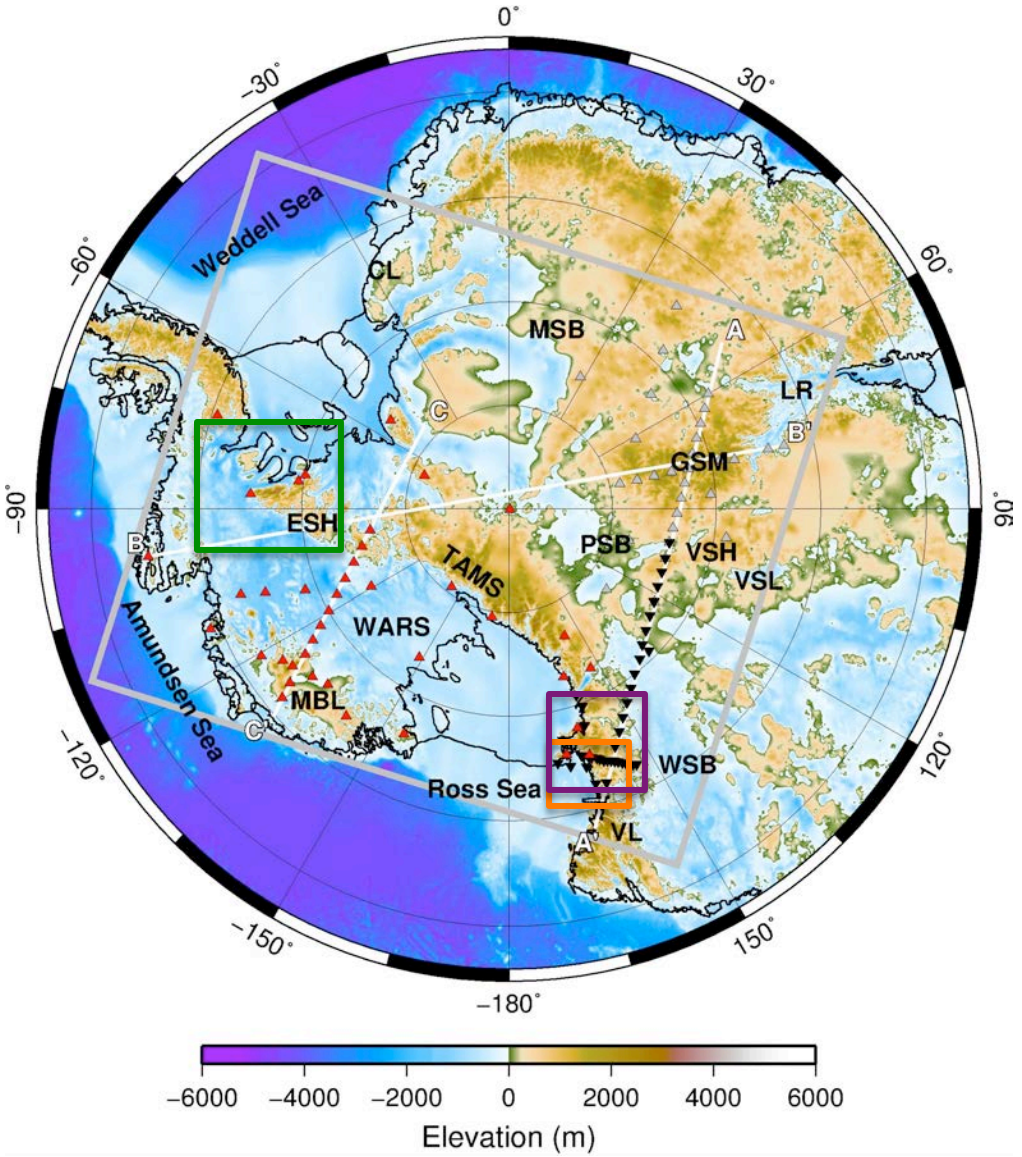
IRIS PASSCAL
deployments

Larger Temporary Seismic and GPS Deployments

TAMSEIS 2000-2003 (black)
AGAP/GAMSEIS 2009-2011(grey)
TAMNNET 2013-2016 (orange)

ANET/POLENET 2009-2018 (red)

WAGN (green)
TAMDEF (purple)



Bed elevation from Bedmap2

A-NET/POLENET- USA-NSF PIs & Key Contributors:

Terry Wilson, Ohio State University
Paul Winberry, Central Washington University
Mike Willis, Cornell University
Doug Wiens, Washington University
Bob Smalley, University of Memphis
Andy Nyblade, Penn State University
Stephanie Konfal, Ohio State University
Eric Kendrick, Ohio State University
Audrey Huerta, Central Washington University
Larry Hothem, USGS
Ian Dalziel, Univ. Texas Institute for Geophysics
Mike Bevis, Ohio State University
Sridhar Anandakrishnan, Penn State University
Rick Aster, Colorado State University

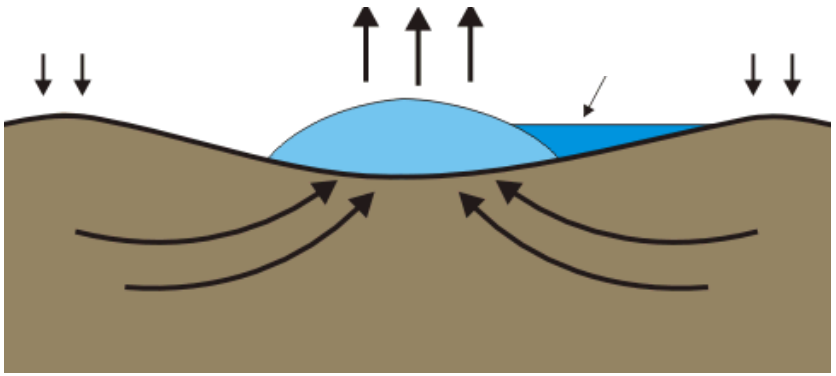
Graduate students and Postdocs !

INSTRUMENT CENTER
IRIS PASSCAL
Program for Array Seismic Studies of the Continental Lithosphere

UNAVCO

Glacial rebound & sea level

GPS: measure rebound

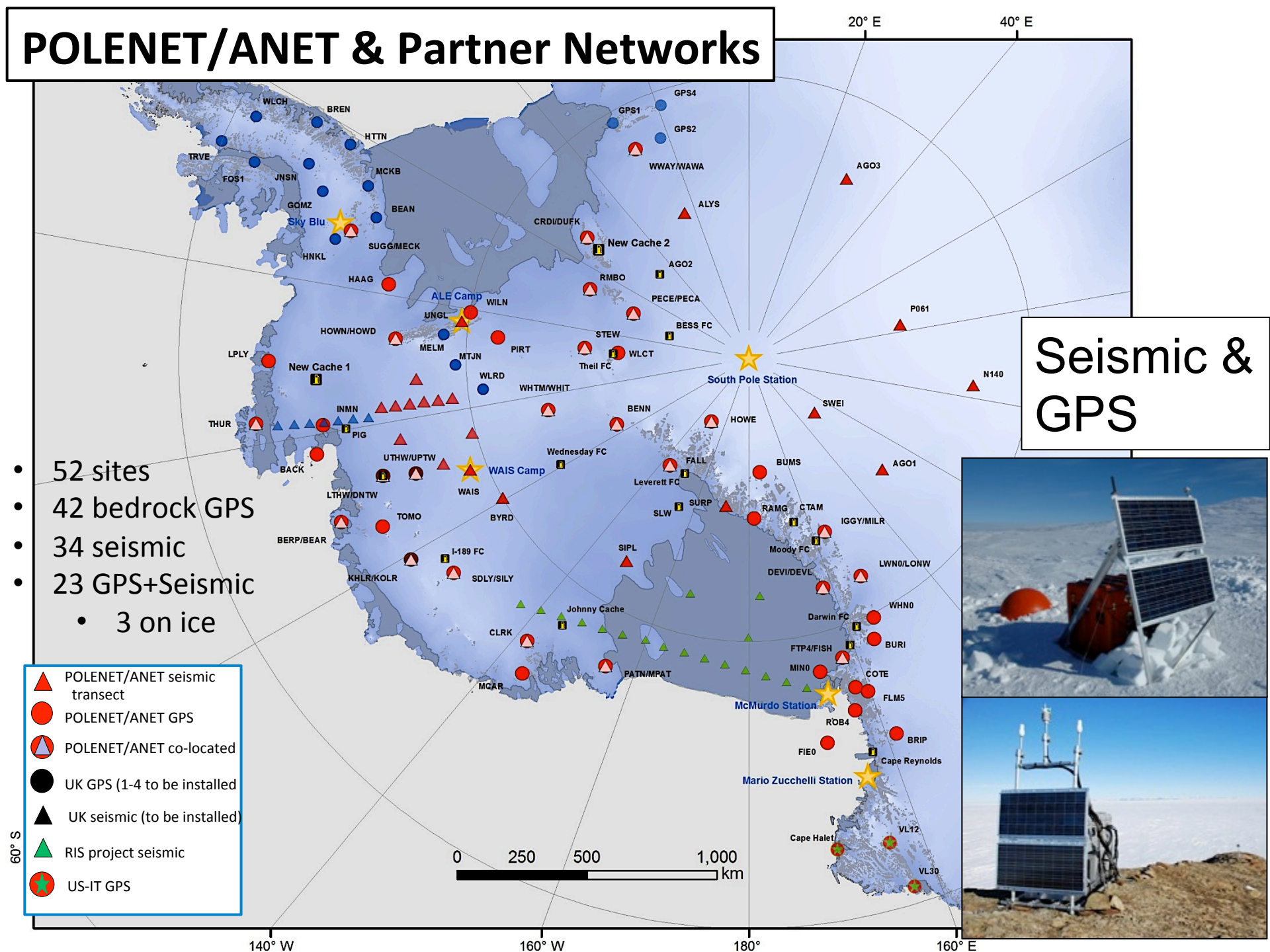


Seismology: measure Earth properties

GIA models: Improve 'rebound' correction for spaceborne measurements: Ice mass change

Sea level change predictions

POLENET/ANET & Partner Networks

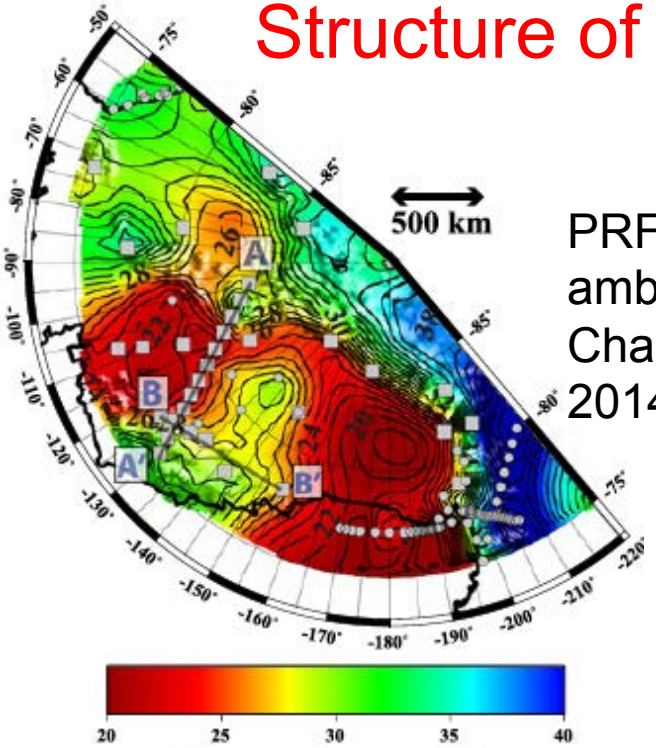


Seismic & GPS

- 52 sites
- 42 bedrock GPS
- 34 seismic
- 23 GPS+Seismic
  - 3 on ice

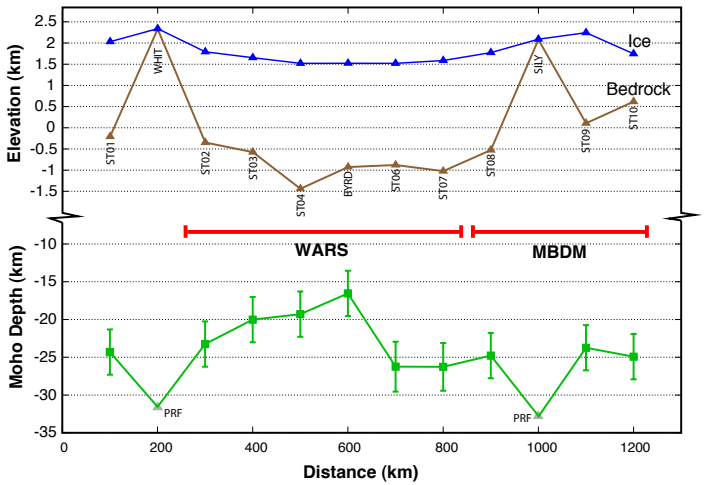
- POLENET/ANET seismic transect
- POLENET/ANET GPS
- POLENET/ANET co-located
- UK GPS (1-4 to be installed
- UK seismic (to be installed)
- RIS project seismic
- US-IT GPS

Structure of the West Antarctic Rift System and Marie Byrd Land

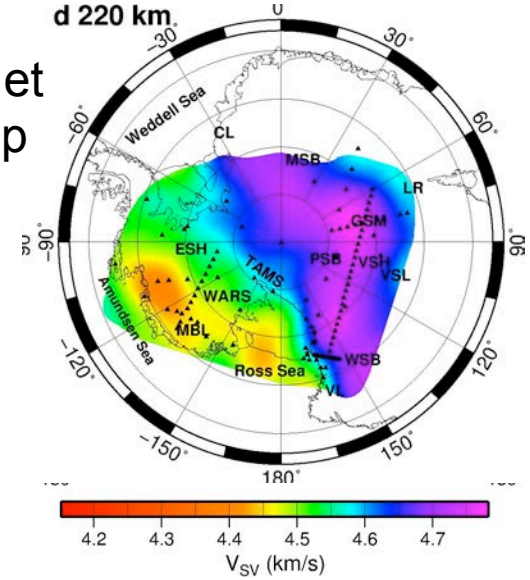


PRFs + ambient Noise Chaput et al., 2014

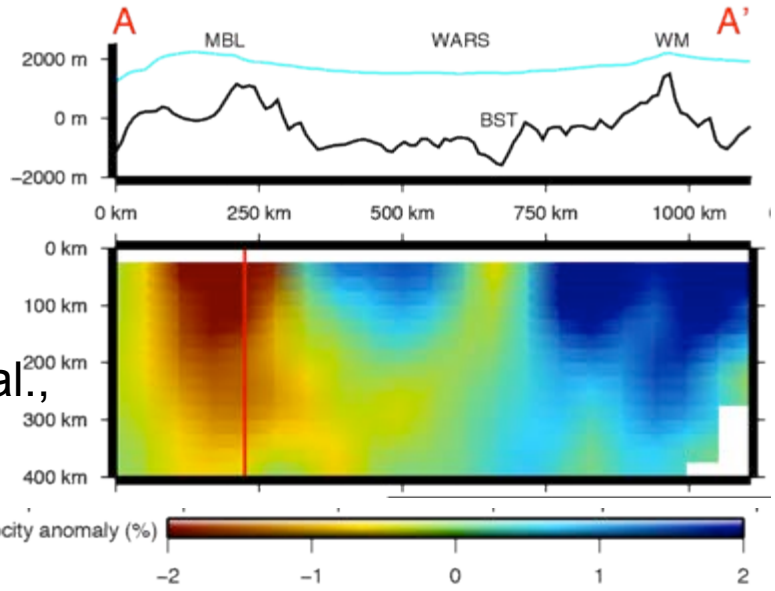
SRFs; Ramirez et al., in prep



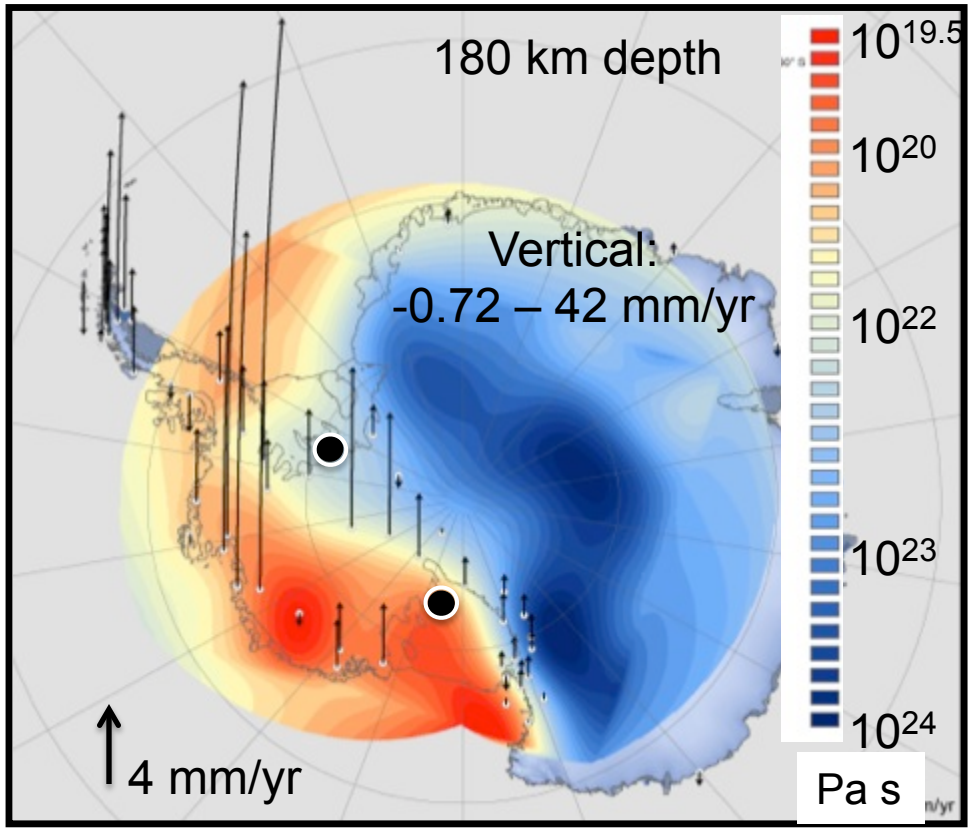
Heeszel et al. in prep



Lloyd et al., in prep



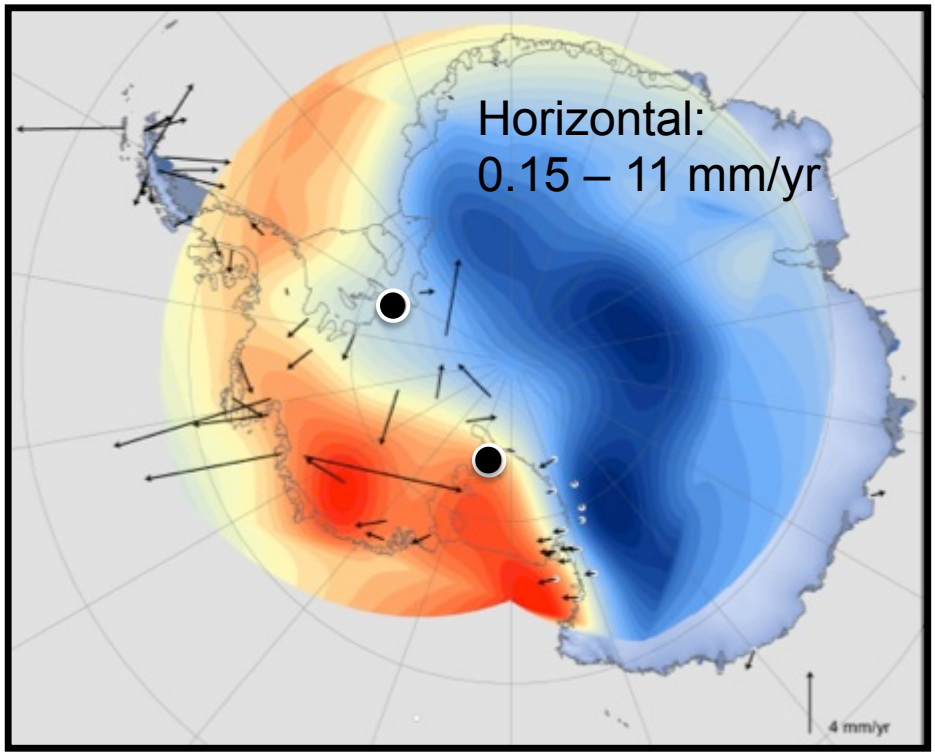
Crustal displacements and mantle viscosity inferred from seismic velocity



Viscosity from Heeszel et al., in prep.

Wilson et al., in prep

● Main LGM ice load centers



Thin crust and weak mantle beneath West Antarctica results in:

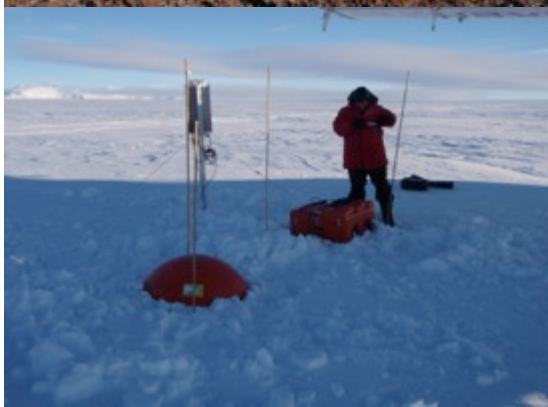
1) relaxation of LGM-induced crustal motion
2) a strong elastic response to modern ice mass change
3) a likely viscoelastic response to centennial ice mass changes

Future opportunities for Int'l collaboration and capacity building

- Synergistic research leads to opportunities for joint geodetic-seismic capacity building activities
  - Autonomous Remote Stations workshop, ISAES, Goa, July 2015

- Int'l collaboration
  - UNAVCO + IRIS already leaders internationally in equipment design, testing, and deployment
  - Frontier area of research with strong international participation



AfricaArray

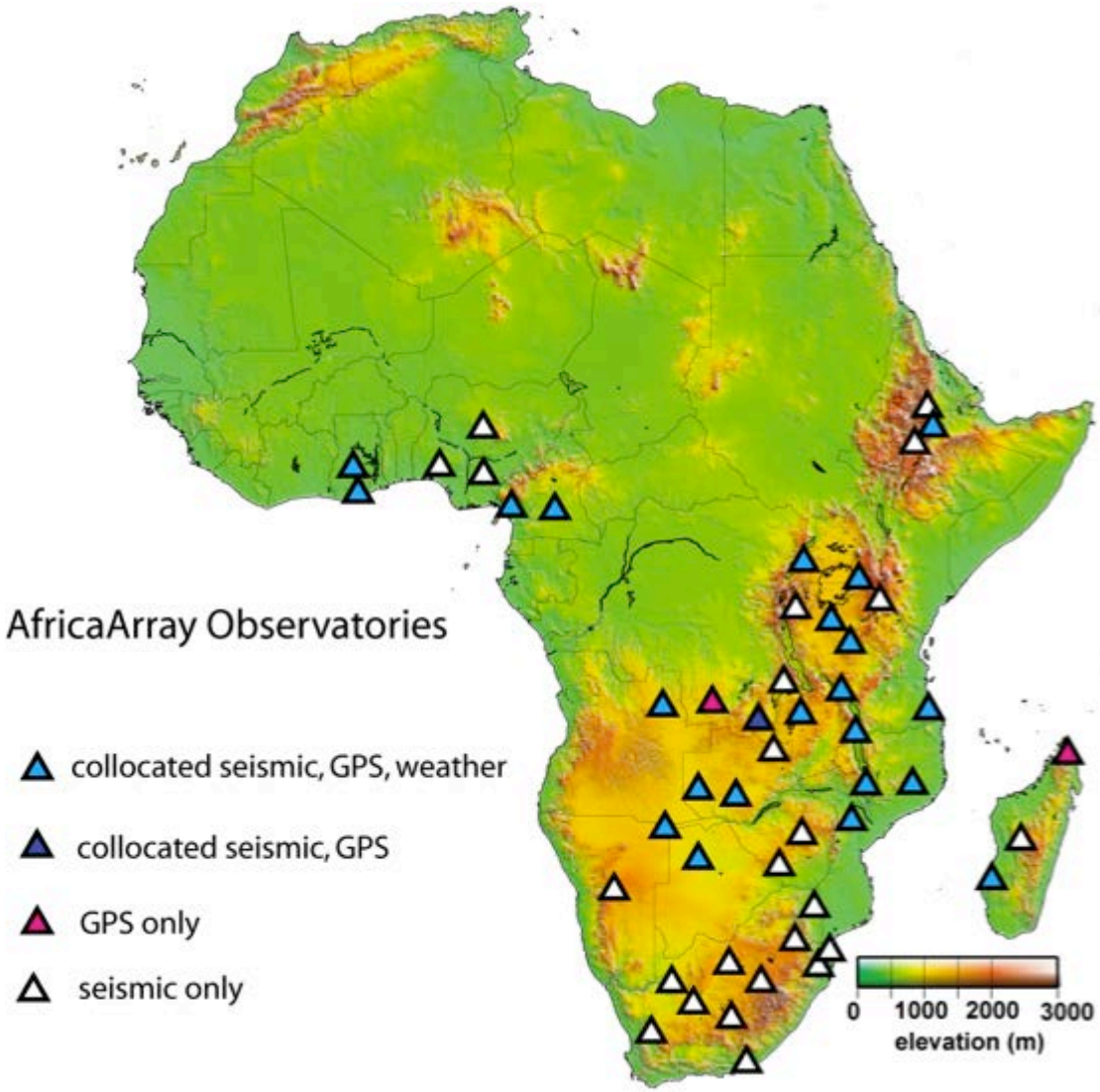
- Started in 2004
  - founding partners: Penn State, Univ. of the Witwatersrand (Wits), Council for Geoscience (aka Geol. Survey of South Africa (+ IRIS support)
  - Intervention to rebuild the geophysics program at Wits
- Key components to a multifaceted initiative:

  1) seismic, GPS, weather networks in Africa

  2) Undergraduate and graduate research and education programs (Africa and US)

  3) Diversity programs in Africa and US

  4) Project based funding + NSF I&F facility support



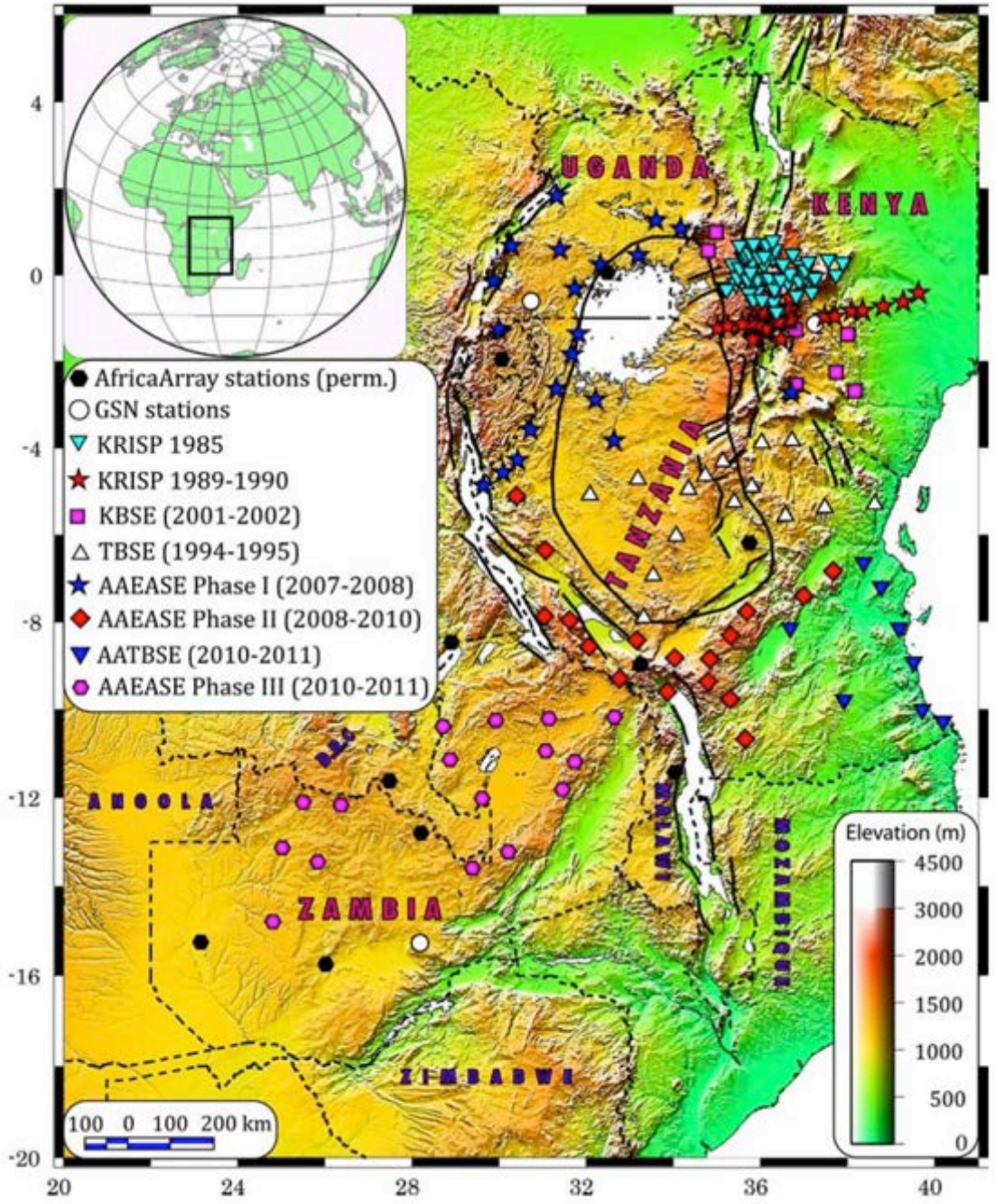
AfricaArray Observatory Network

- 51 stations
- 48 seismic stations
- 27 GPS/met stations
- 19 countries
- Continuous recording
- Data recovery 70-80%
- Data availability: IRIS and UNAVCO
- Data retrieval:
  - A few countries - real-time using cell modems
  - Elsewhere – monthly

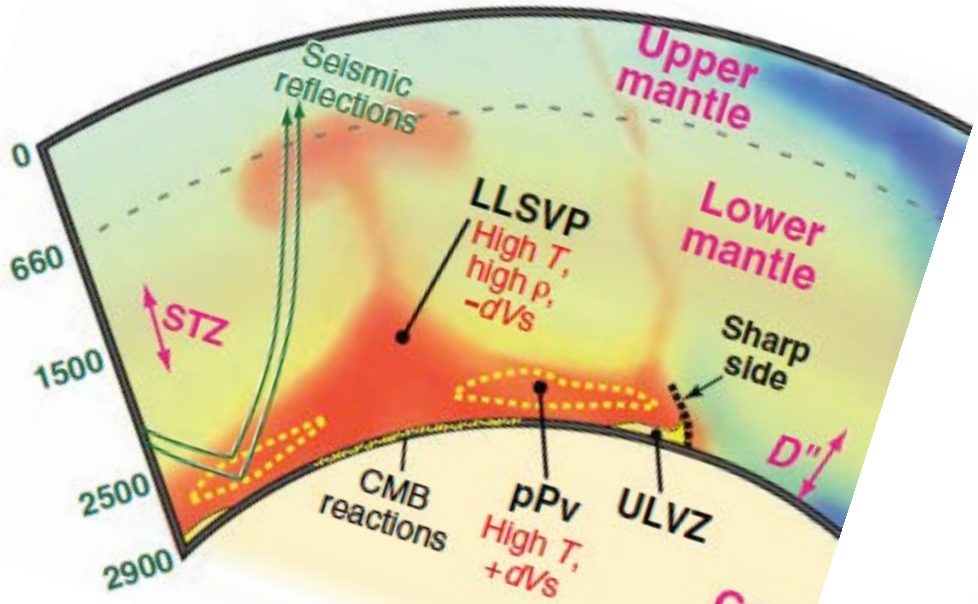
O&M Model

- Highly leveraged
- In-country operator
- Network manager (NSF, PSU, Wits support)
- AA director
- Many stations part of national networks

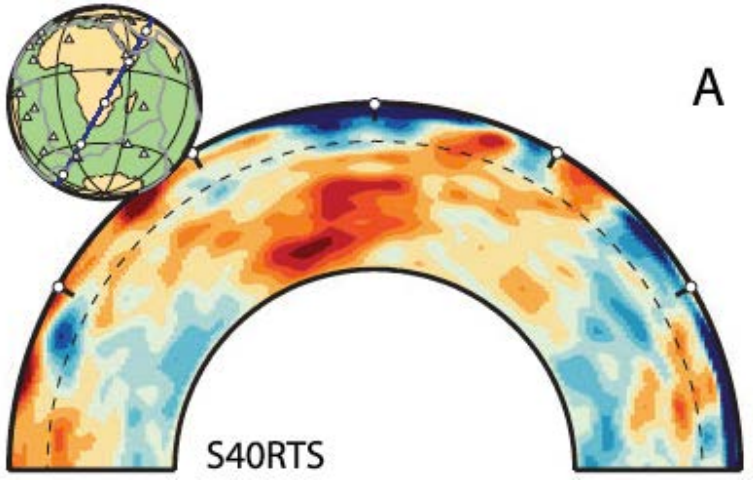
AfricaArray and other temporary networks in East Africa



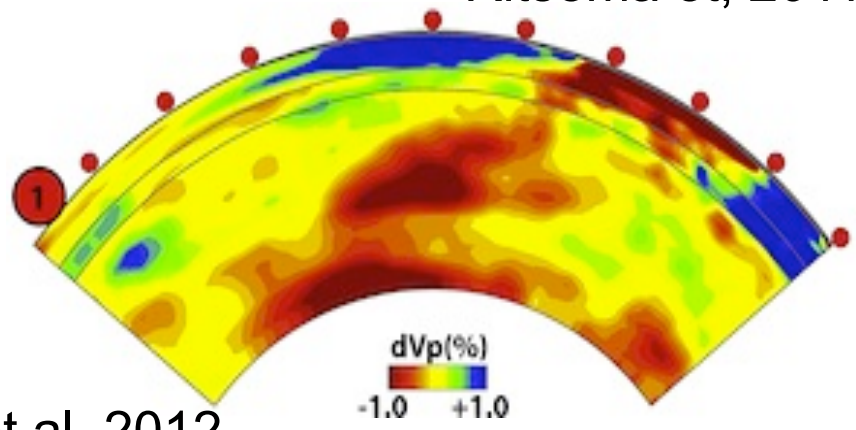
Large low-shear-velocity provinces, Ultralow-velocity zones and Superplumes?



Garnero and McNamara, 2008

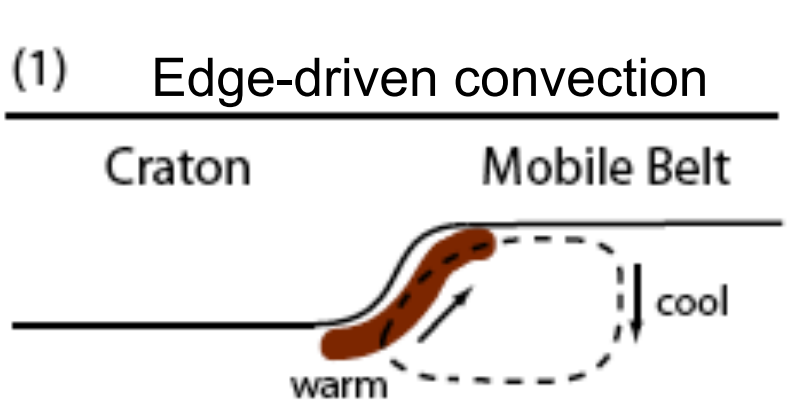


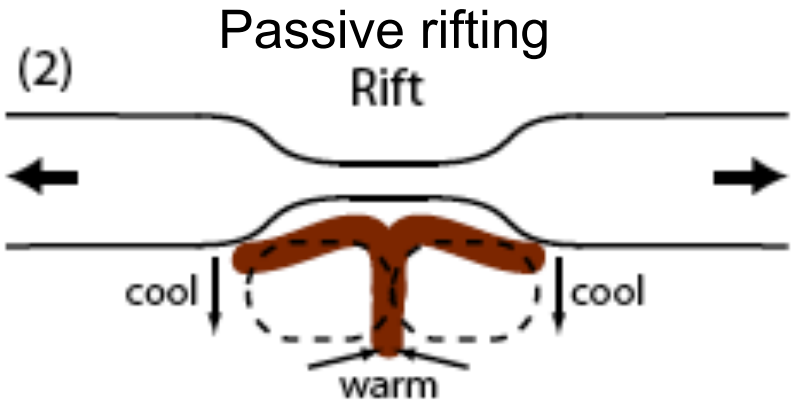
Ritsema et, 2011

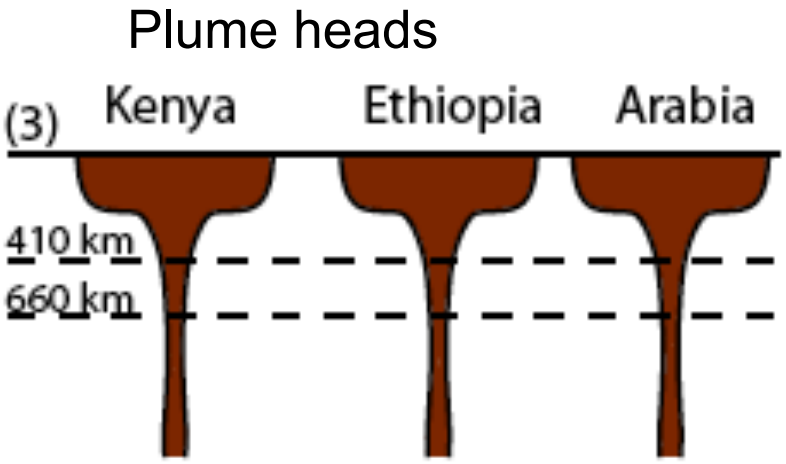


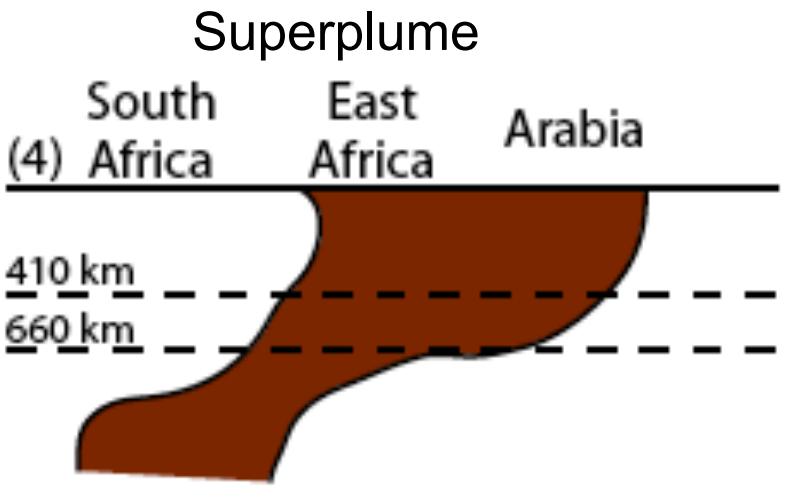
Simmons et al, 2012

Regional tomography – origin of rifting and deep cratonic structure





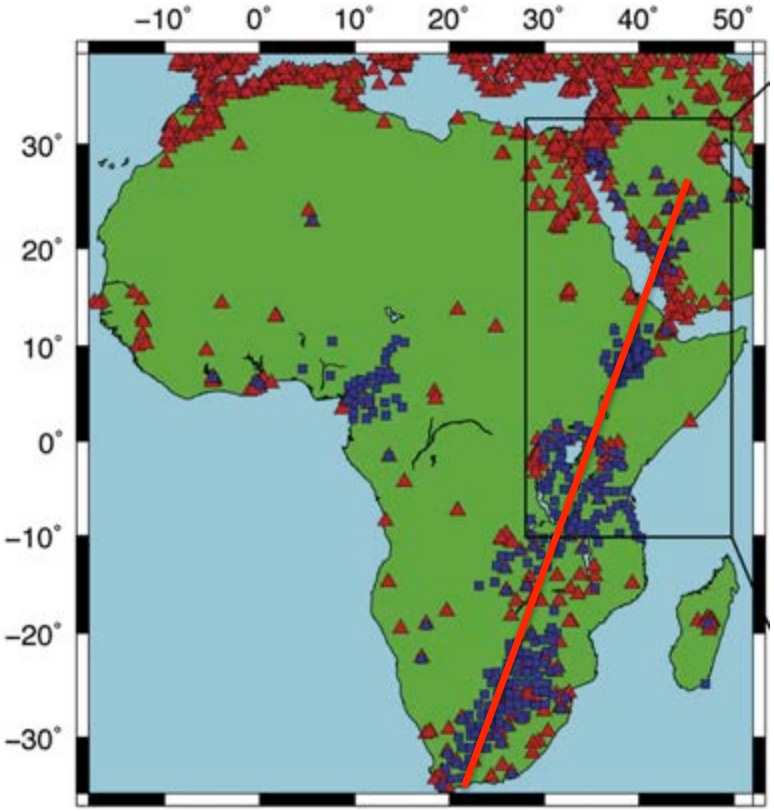


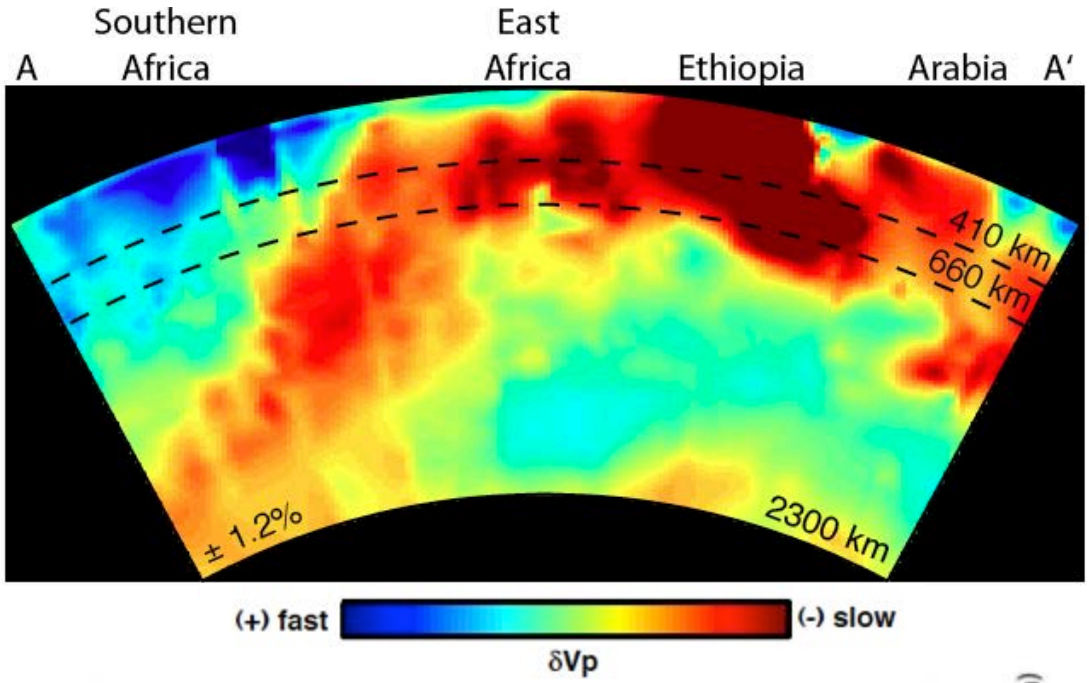


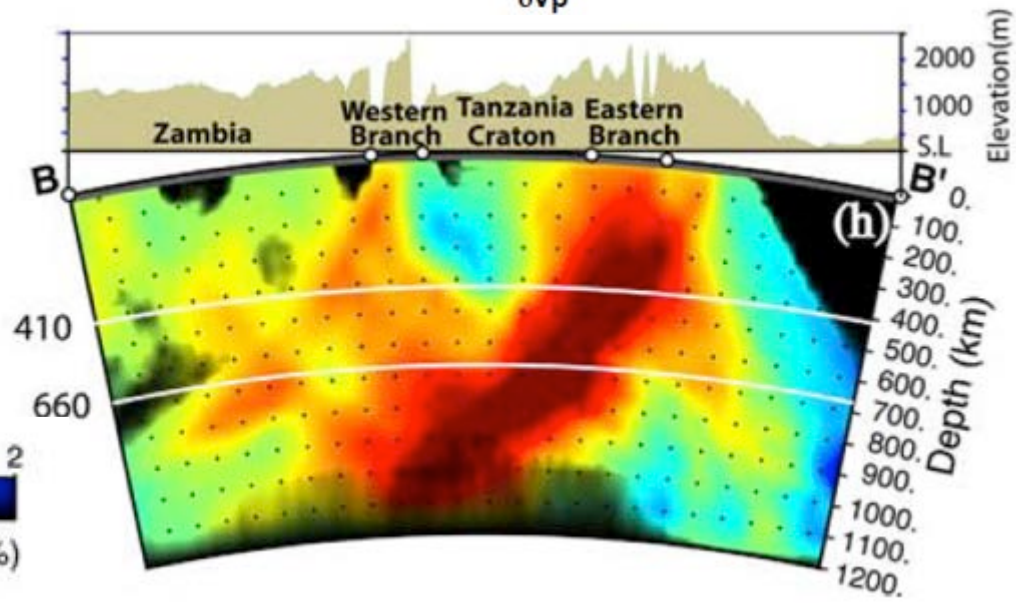
Hansen et al., 2012

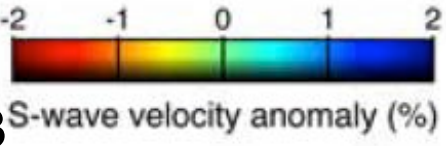
A global/continental scale vs. regional scale tomography

Hansen et al., 2012



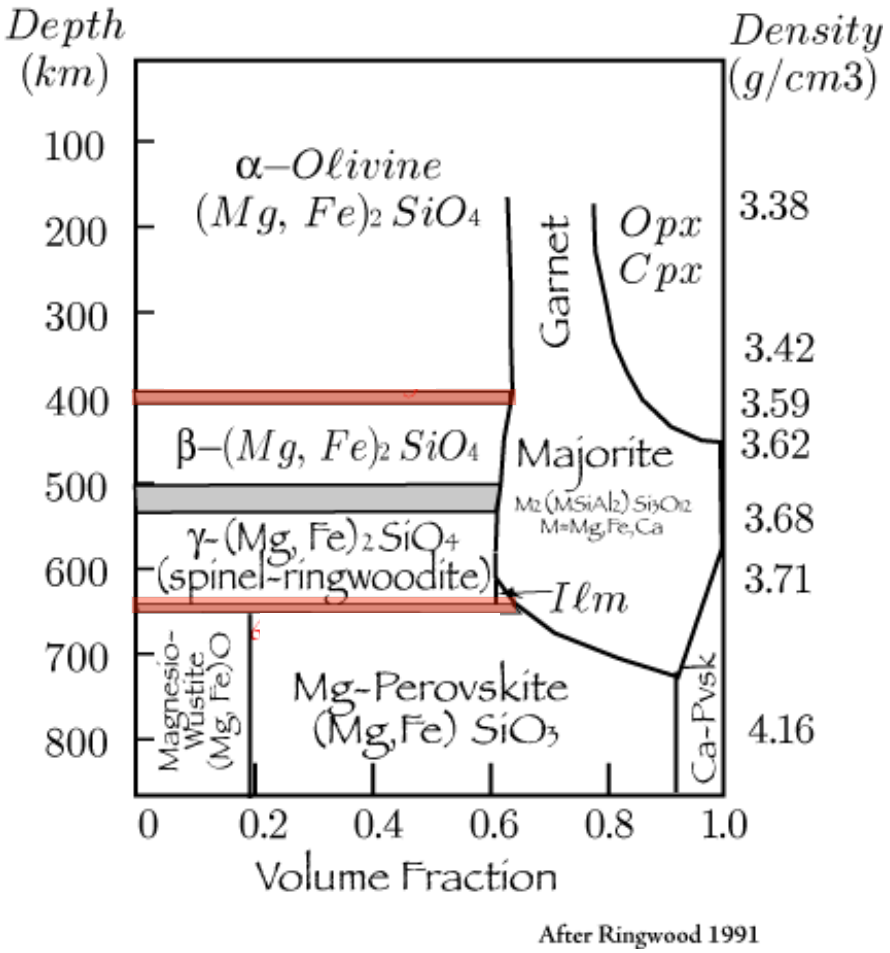


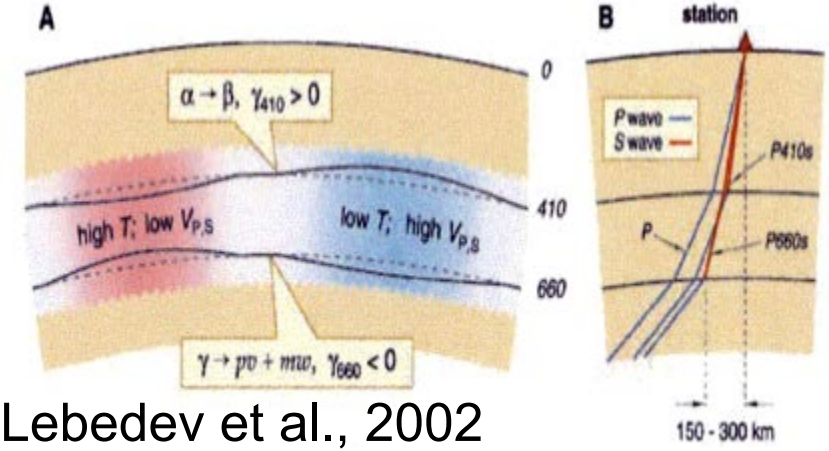




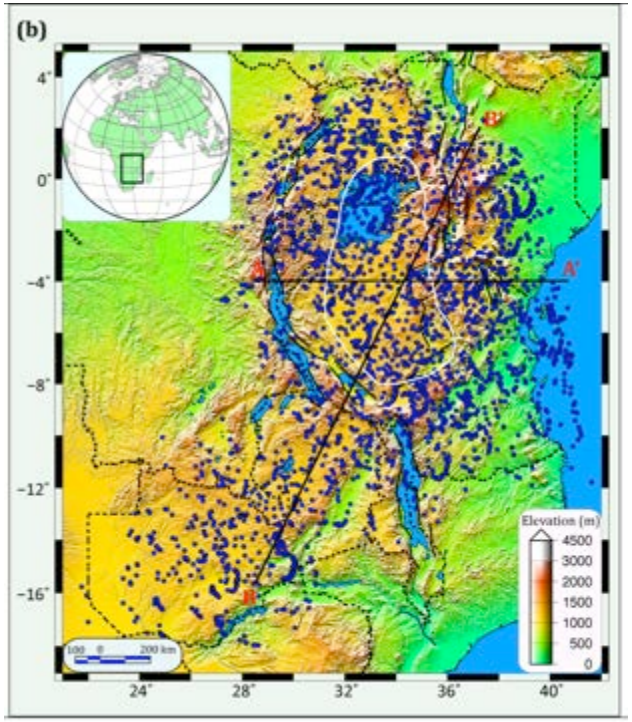
Mulibo and Nyblade, 2013

Using mantle transition zone discontinuities to investigate temperature anomalies

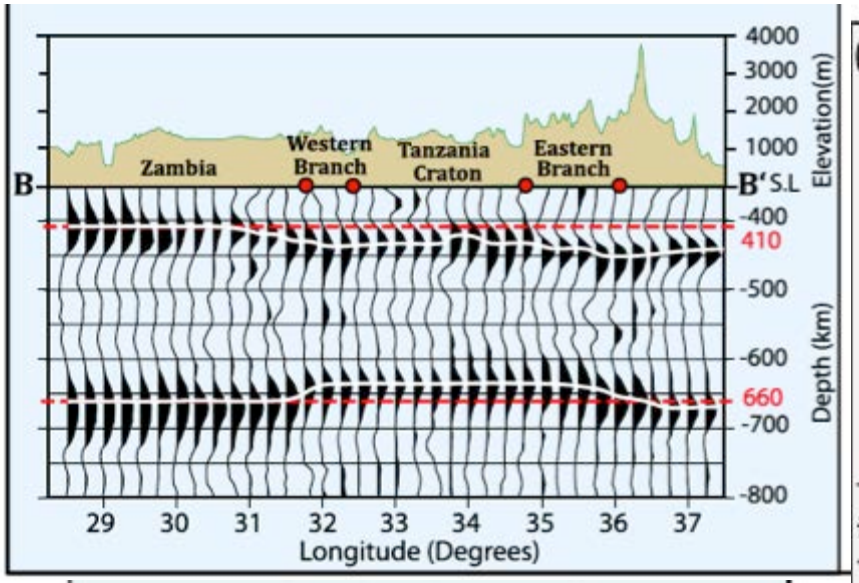


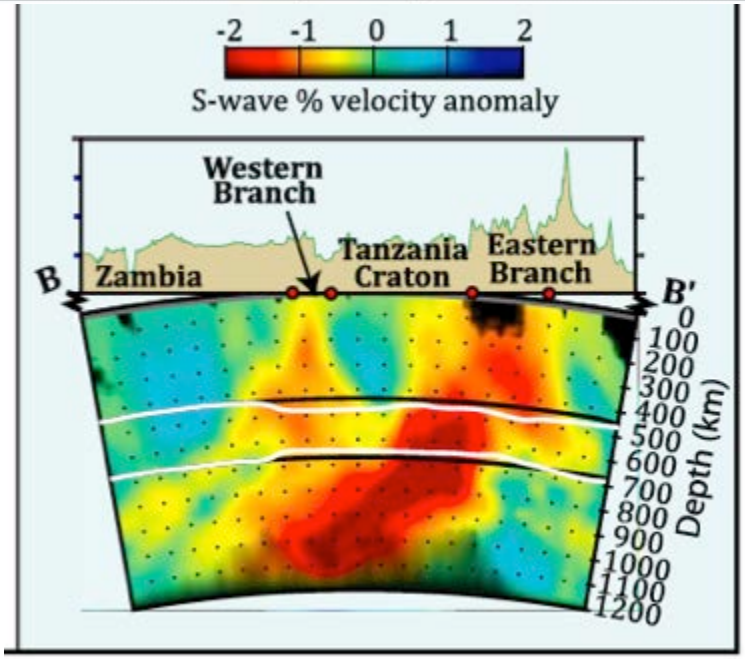


Lebedev et al., 2002

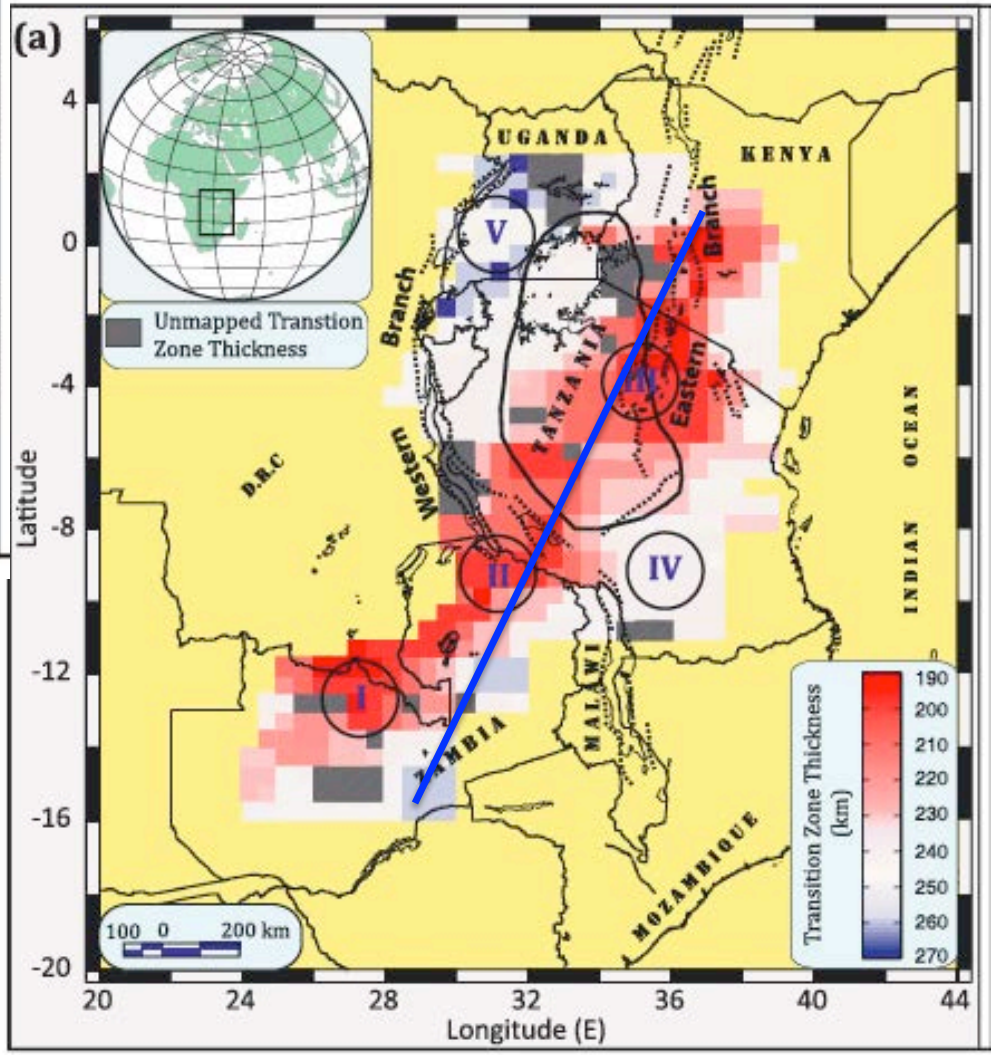


Mulibo and Nyblade, 2013





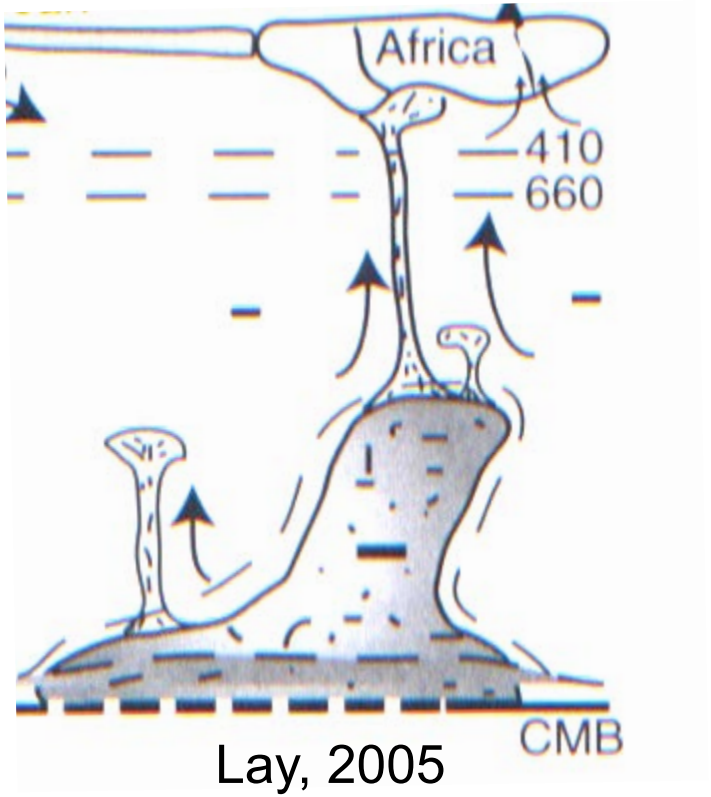
Mulibo and Nyblade, 2013



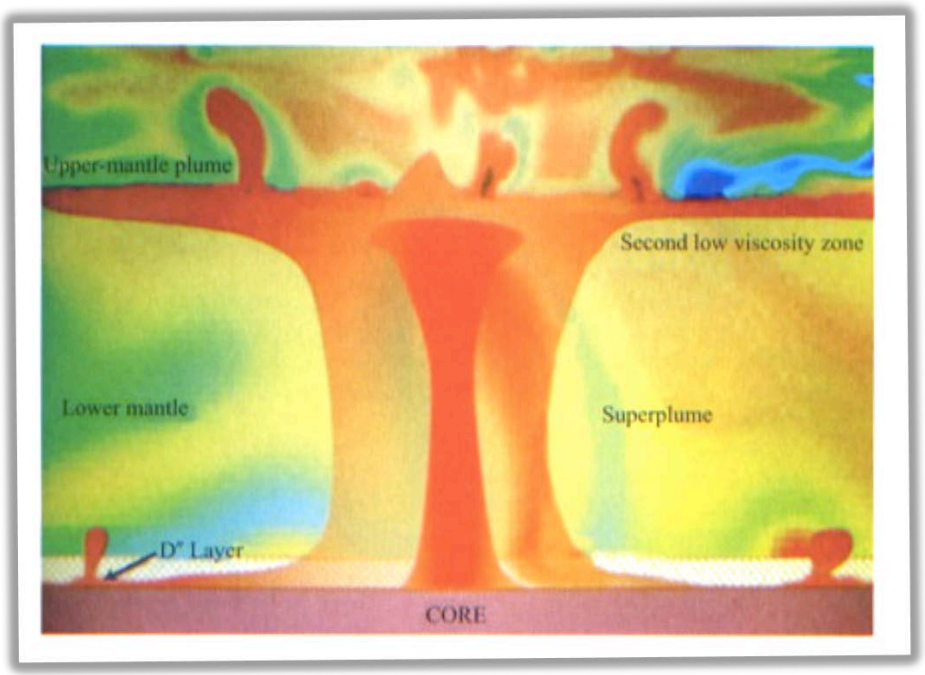
180-300 K anomaly across the transition zone

The African superplume (structure) is a whole-mantle feature and the origin of E. African Cenozoic tectonism is rooted in lower mantle dynamics

- connection across the mid-mantle is broad but poorly understood



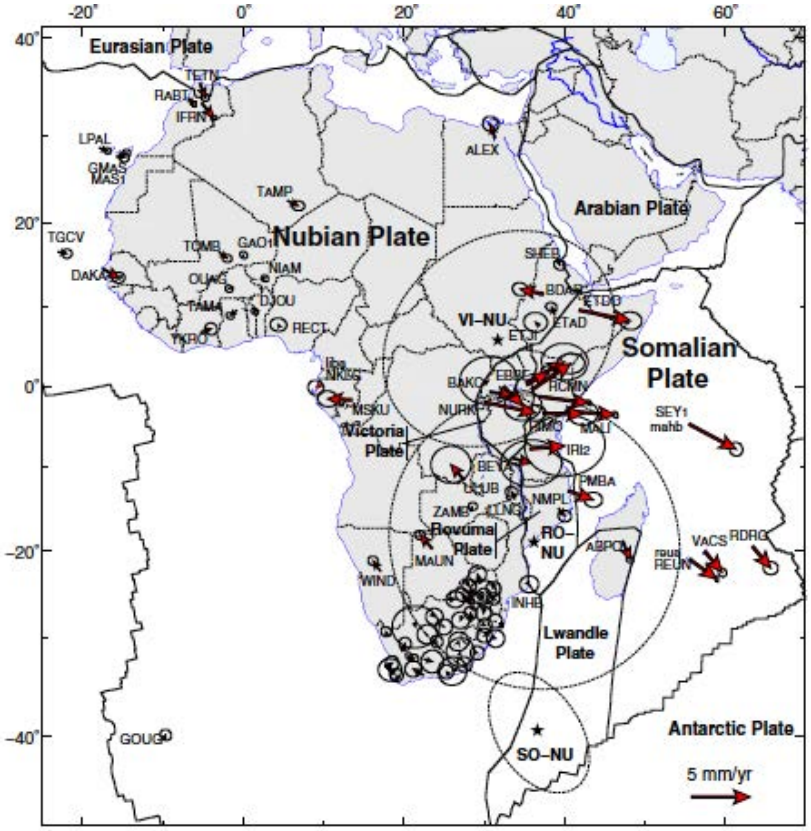
Lay, 2005



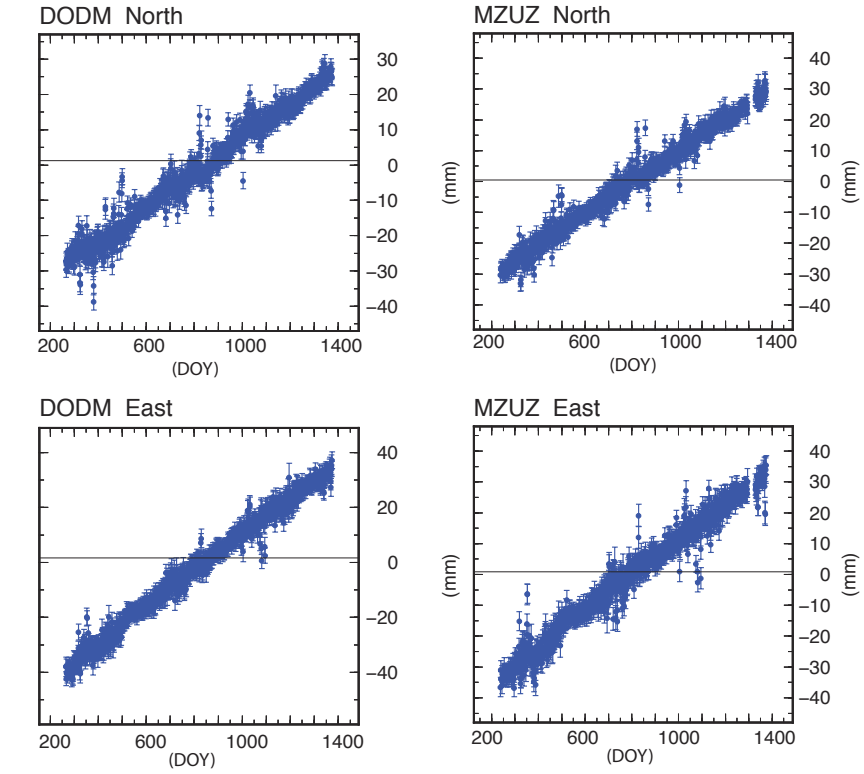
Yuen et al, 2007

GPS studies – understanding the plate boundary developing above the superplume

- GPS added to AfricaArray network starting in 2010
- Role of gravitational potential energy and viscous coupling between mantle and lithosphere



Saria et al., 2013



(from Sarah Stamps)

International Collaboration – The AfricaArray Model

- Education and training is key (human capacity building)
  - PhD, MS, BS, technician
    - Completed: 60 BSc honours, 18 MS, 11 PhD, 13 Postdocs
    - 96 underrepresented minority undergraduate students in US
- Partnerships built from the bottom up – grass roots organization
  - 19 Universities; 25 Gov't organizations; 19 companies; 6 academic and industry societies; IRIS and UNAVCO
- Sustained engagement by partners
  - AfricaArray is 10 yrs old
- Low tech
  - research network with long latency in data return

Future International Collaboration

- **International collaborations within UNAVCO and IRIS are extensive already and vital**
- **AfricaArray & Polenet possible because of strong core programs in IRIS and UNAVCO**
  - **data management, technical support, equipment, training**
- **Future opportunities for new AfricaArrays and Polenets?**
  - **Many, as long as core facility programs remain strong**

Future Needs for Making the Next Big Advances in Our Science at Regional Scales

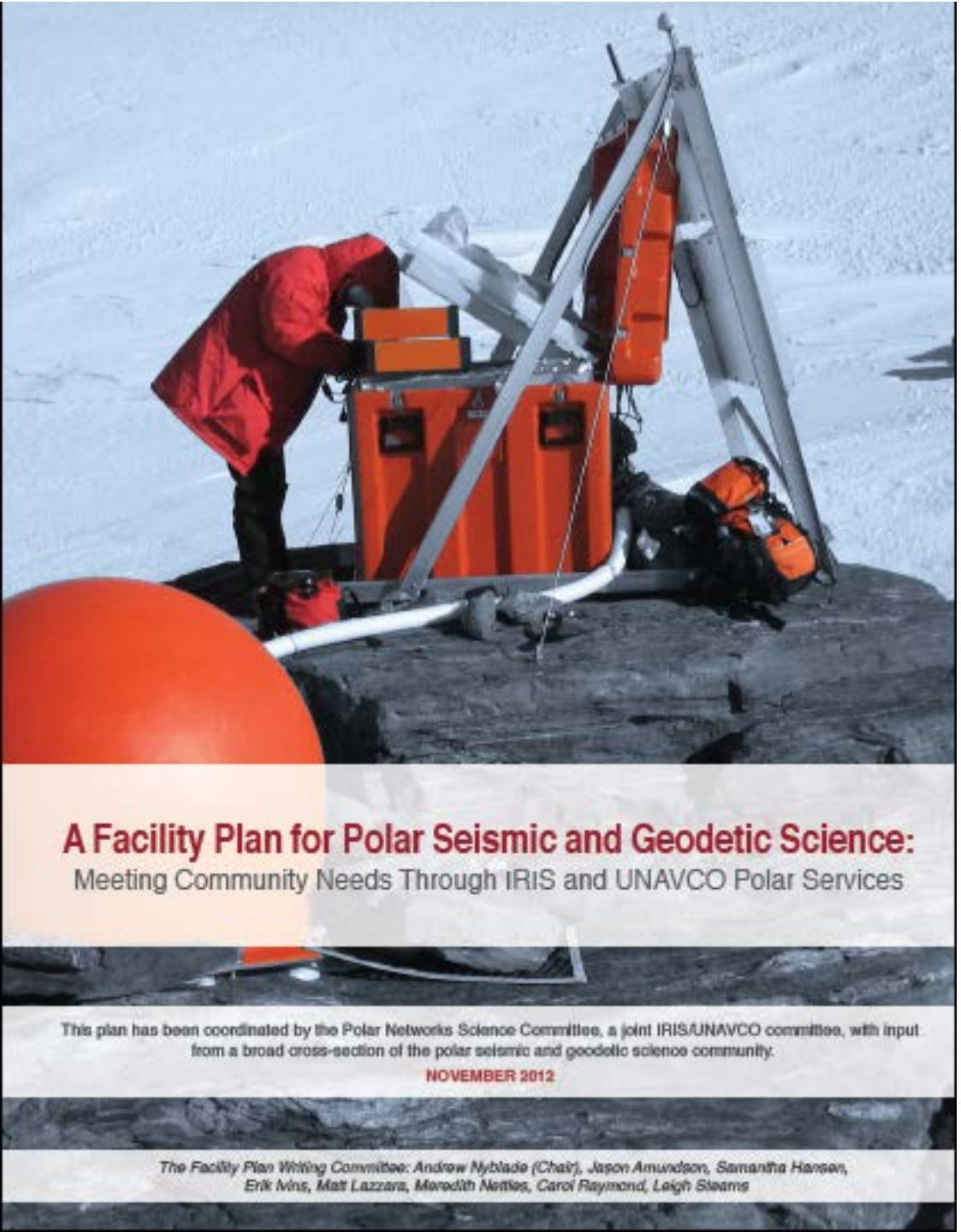
- **A robust, state-of-the art portable instrument pool**
  - **initial capitalization of seismic equipment from NSF but subsequent major additions from outside of NSF (is this a sustainable model? i.e., someone else buys the equipment and NSF supports its O&M)**

- **Highly skilled technical staff that also provide training to students, postdocs, faculty**
  - **we tend to forget the core educational function that the facilities provide!**

Future Needs for Making the Next Big Advances in Our Science at Regional Scales

- **Increasing demand for improved resolution and rising field costs are challenges for the current way of doing our science. Expanding the frontier in our science requires:**
  - ***cheaper, better, lighter, stronger, more easy to deploy, broader bandwidth, portable telemetered sensors!***

- **Generational advances in our field have been driven by technological advances**
  - **WWSSN, GSN, force-feedback seismometer, GPS**
  - **we (the community with facility engagement) have a need to identify and help develop the next breakthrough technologies**



A Facility Plan for Polar Seismic and Geodetic Science:

Meeting Community Needs Through IRIS and UNAVCO Polar Services

This plan has been coordinated by the Polar Networks Science Committee, a joint IRIS/UNAVCO committee, with input from a broad cross-section of the polar seismic and geodetic science community.

NOVEMBER 2012

The Facility Plan Writing Committee: Andrew Nyblade (Chair), Jason Amundson, Samantha Hansen, Erik Ivins, Matt Lazzara, Meredith Nettles, Carol Raymond, Leigh Stearns

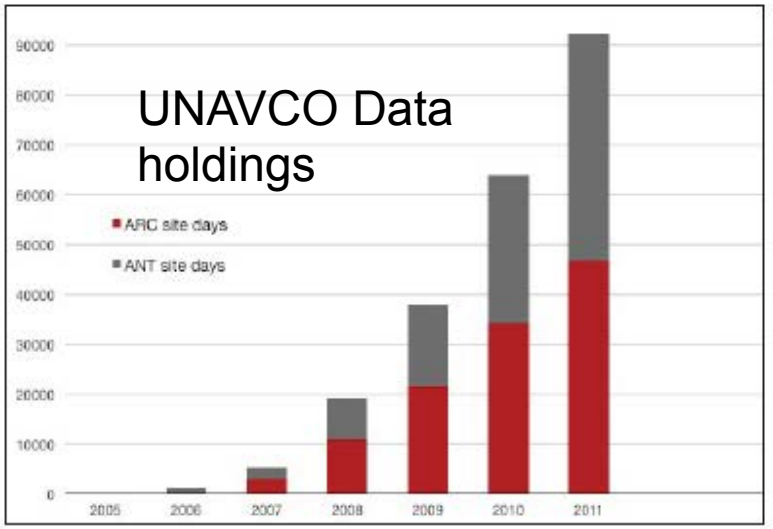


Fig 3a: UNAVCO polar data holdings showing nearly 100,000 site days in the archive (Dec 2011).

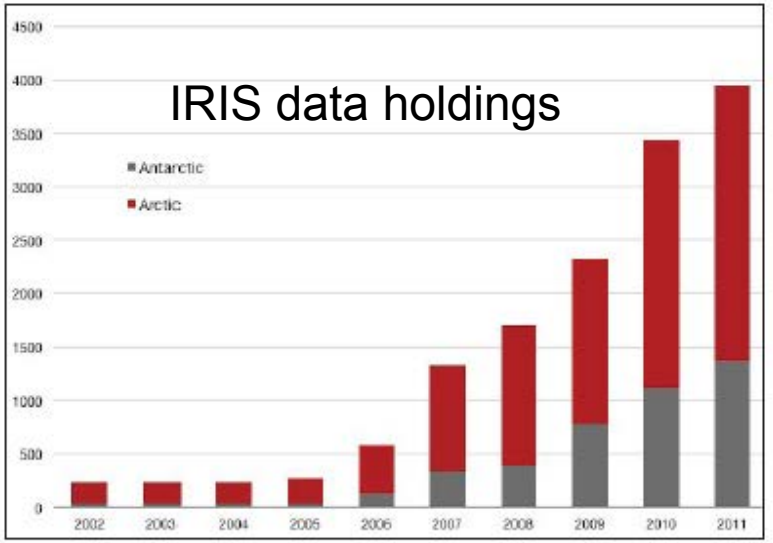
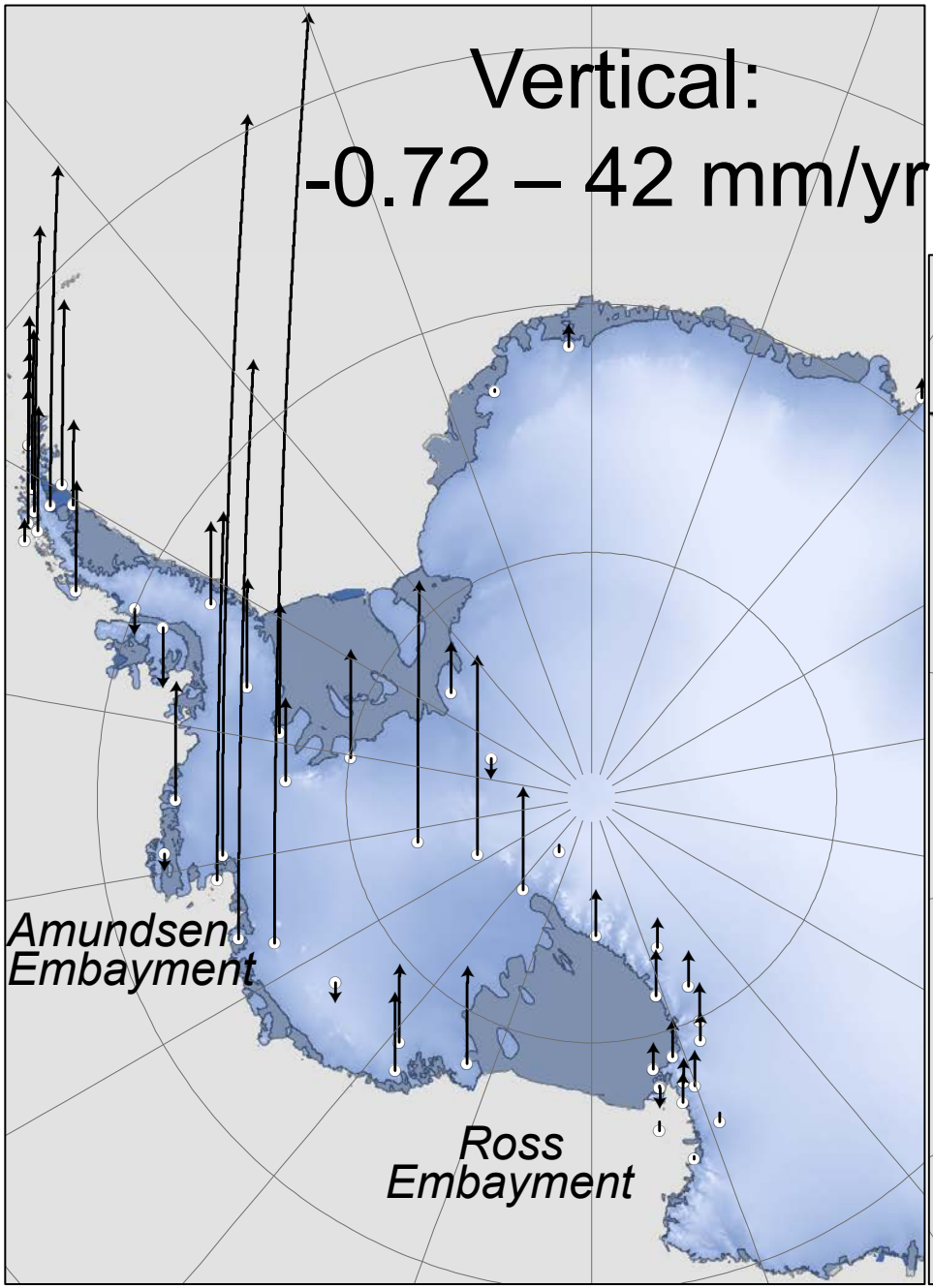
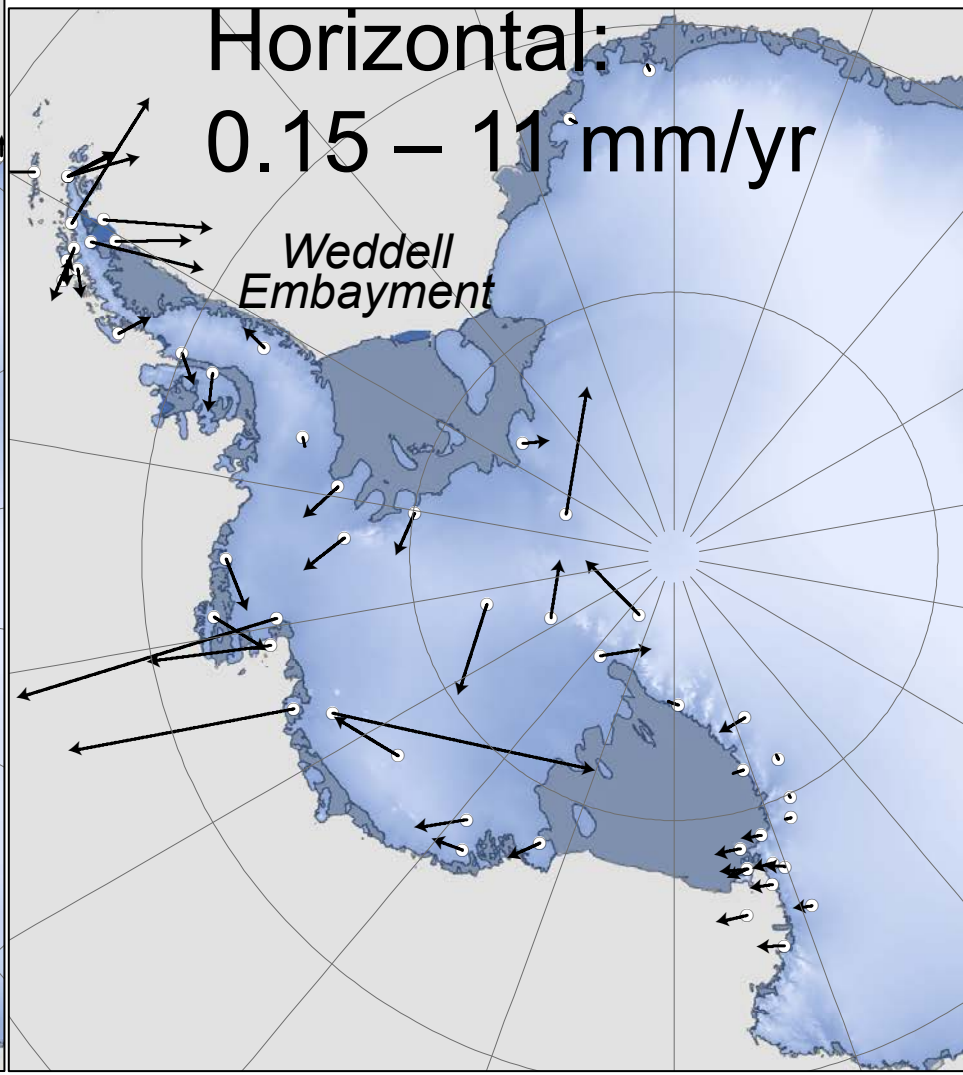


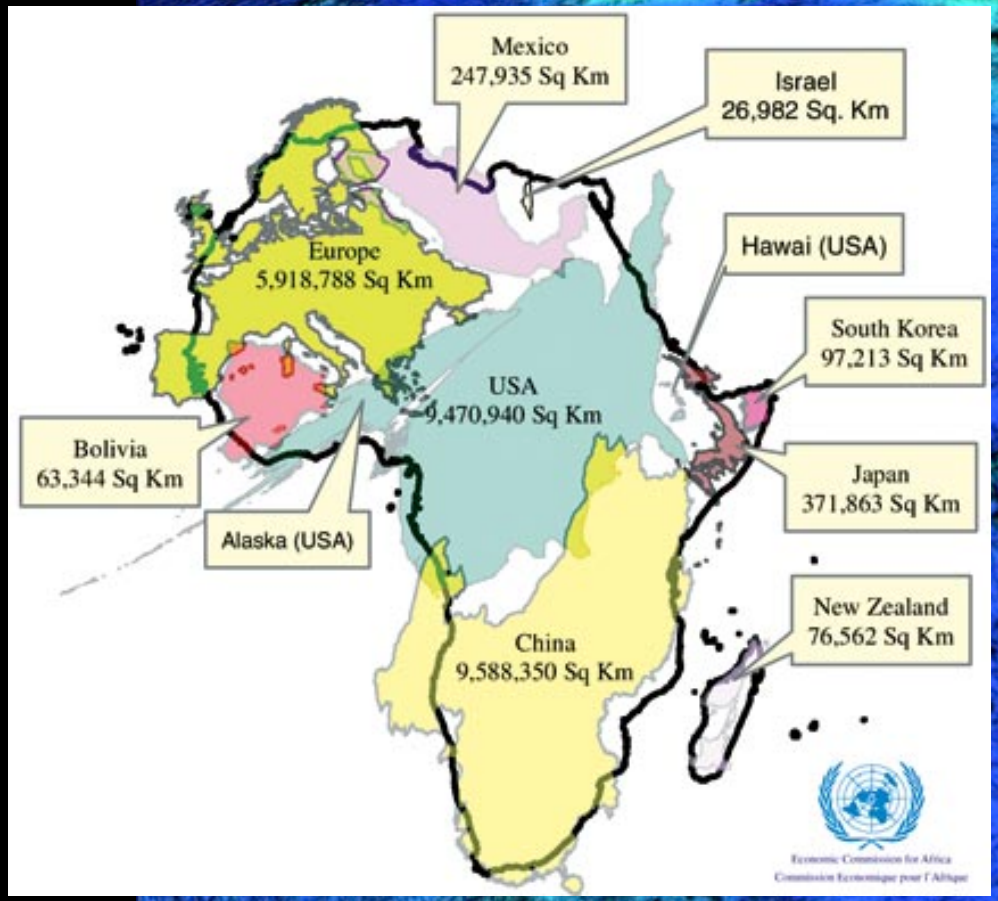
Fig 3b: Cumulative SEED data archived at IRIS DMC (GB) from polar stations.

Crustal Displacements

Wilson et al., in prep






Mexico
247,935 Sq Km
Israel
26,982 Sq. Km
Hawai (USA)
Europe
5,918,788 Sq Km
South Korea
97,213 Sq Km
USA
9,470,940 Sq Km
Bolivia
63,344 Sq Km
Japan
371,863 Sq Km
Alaska (USA)
New Zealand
76,562 Sq Km
China
9,588,350 Sq Km
Economic Commission for Africa
Commission Economique pour l'Afrique

Permanent Stations

Ghana

Zambia