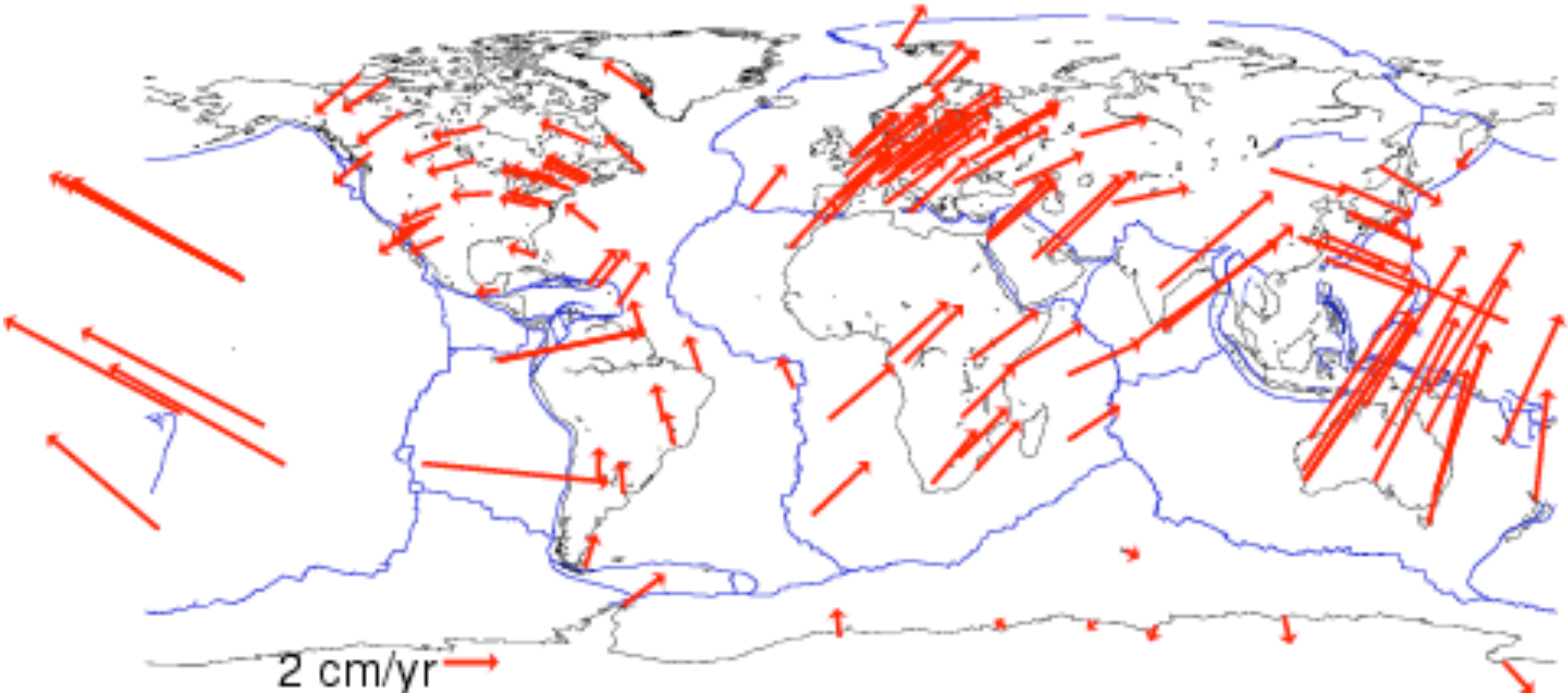
Rio Grande Rift GPS Measurements

Henry Berglund[1], Anne Sheehan[1], Mousumi Roy[2], Steve Nerem[3], Tony Lowry[4], Freddy Blume[5]

[1] CIRES and University of Colorado Department of Geological Sciences
[2] University of New Mexico
[3] CIRES and Univ. Colorado Department of Aerospace Engineering Sciences
[4] Utah State University
[5] UNAVCO

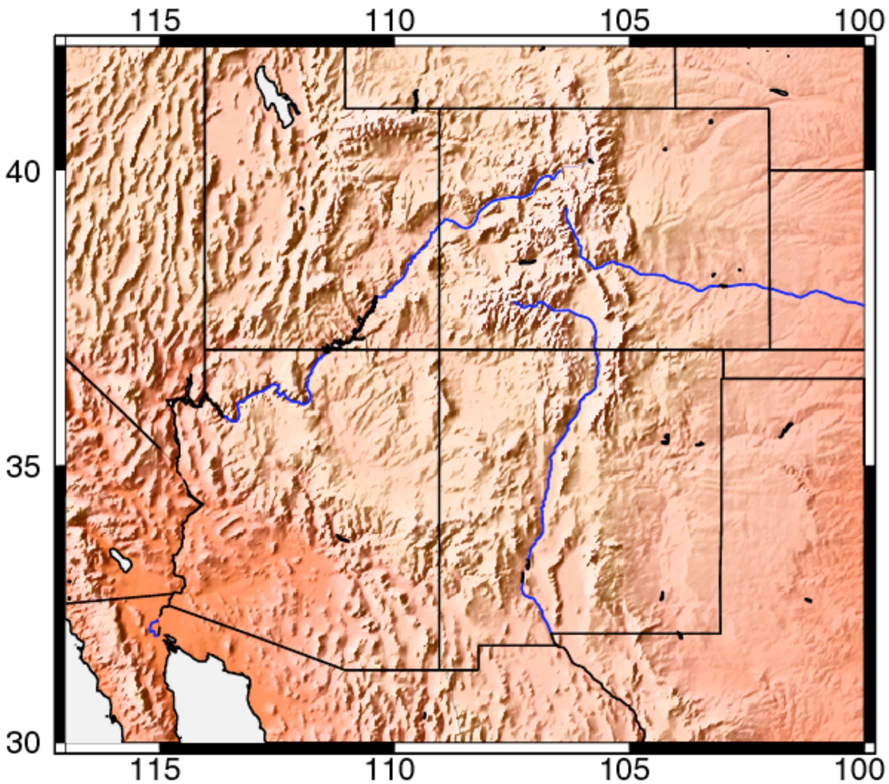
National Science Foundation

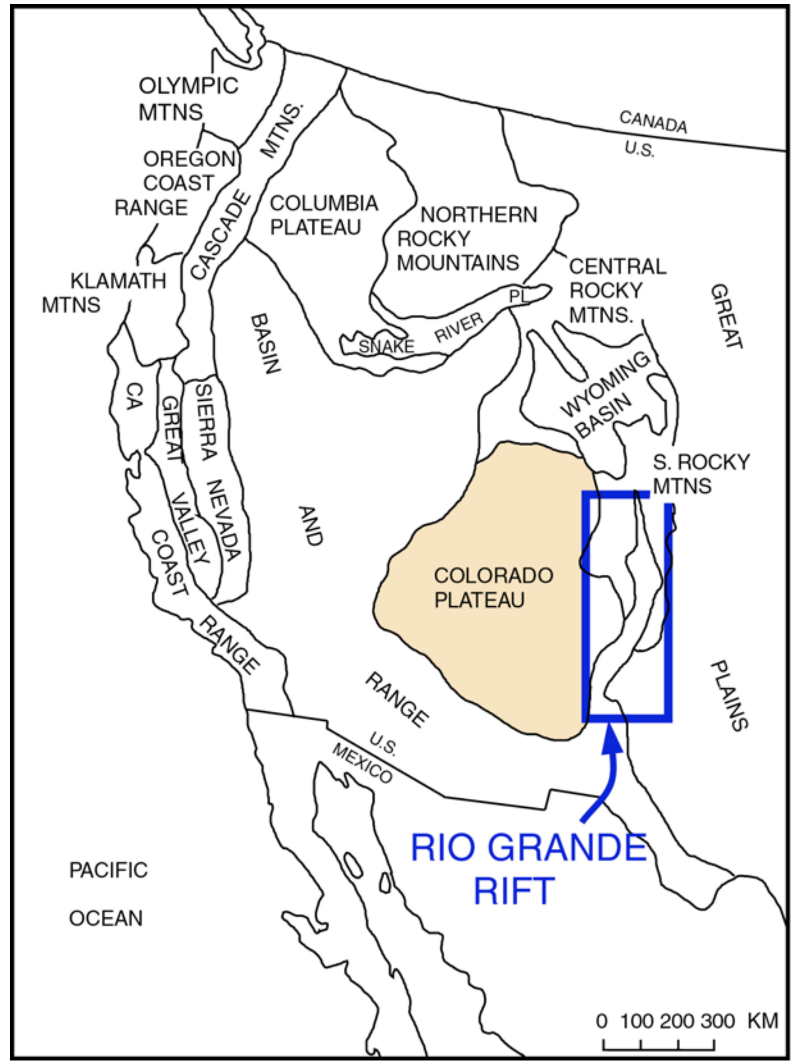
All the plates together

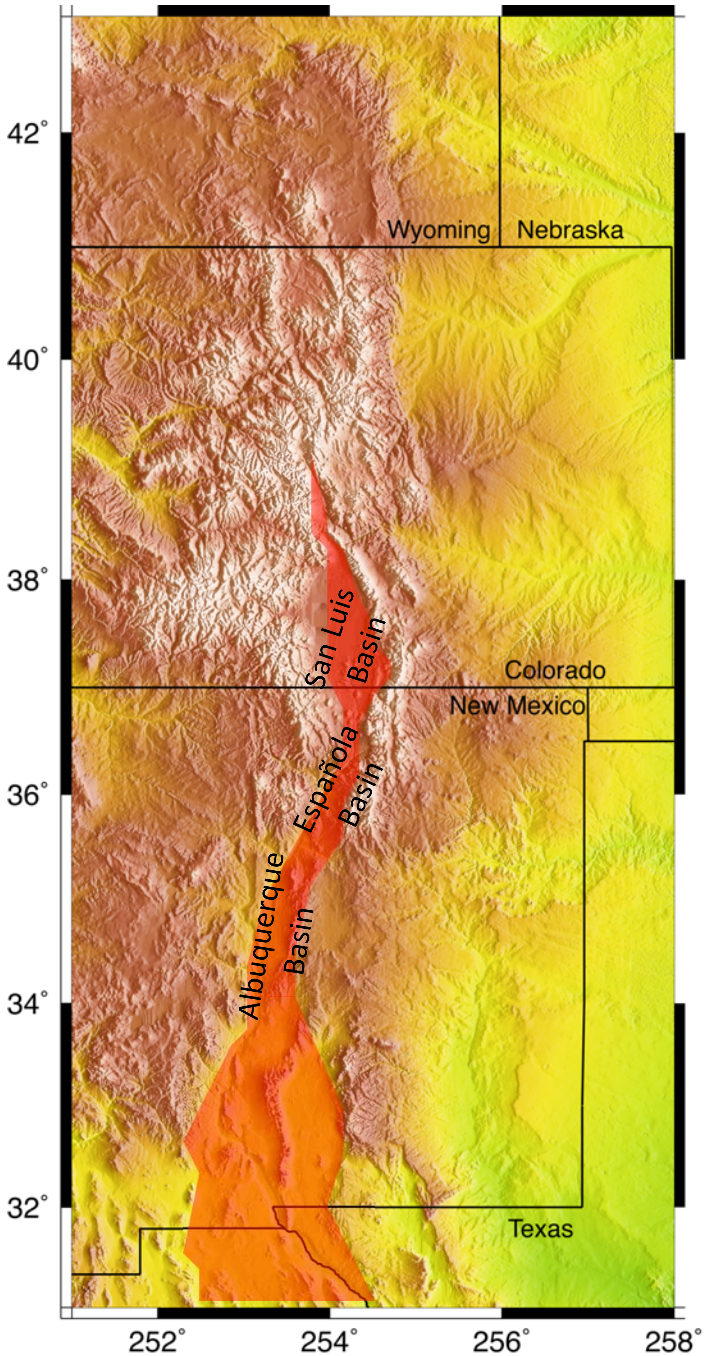


Blue boundaries are the different plates

Tectonic provinces in the western US

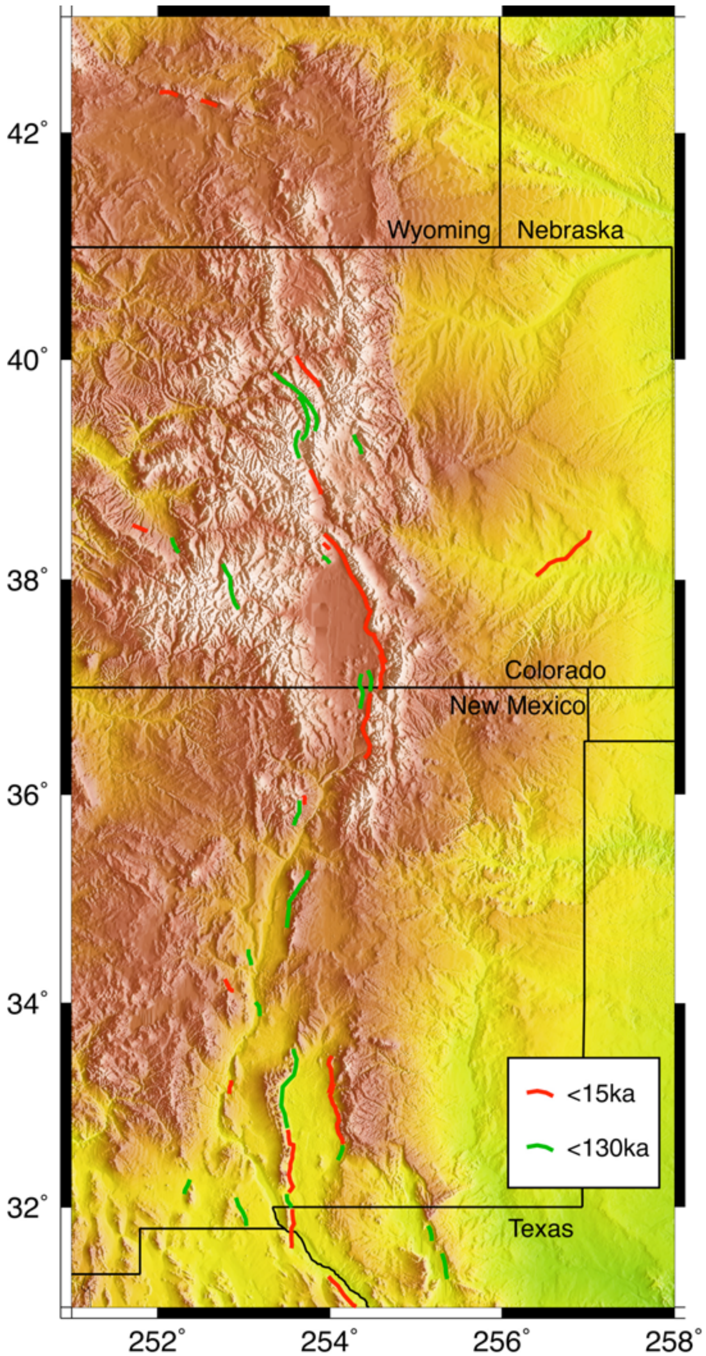






Surface Expression of the Rio Grande Rift Includes:

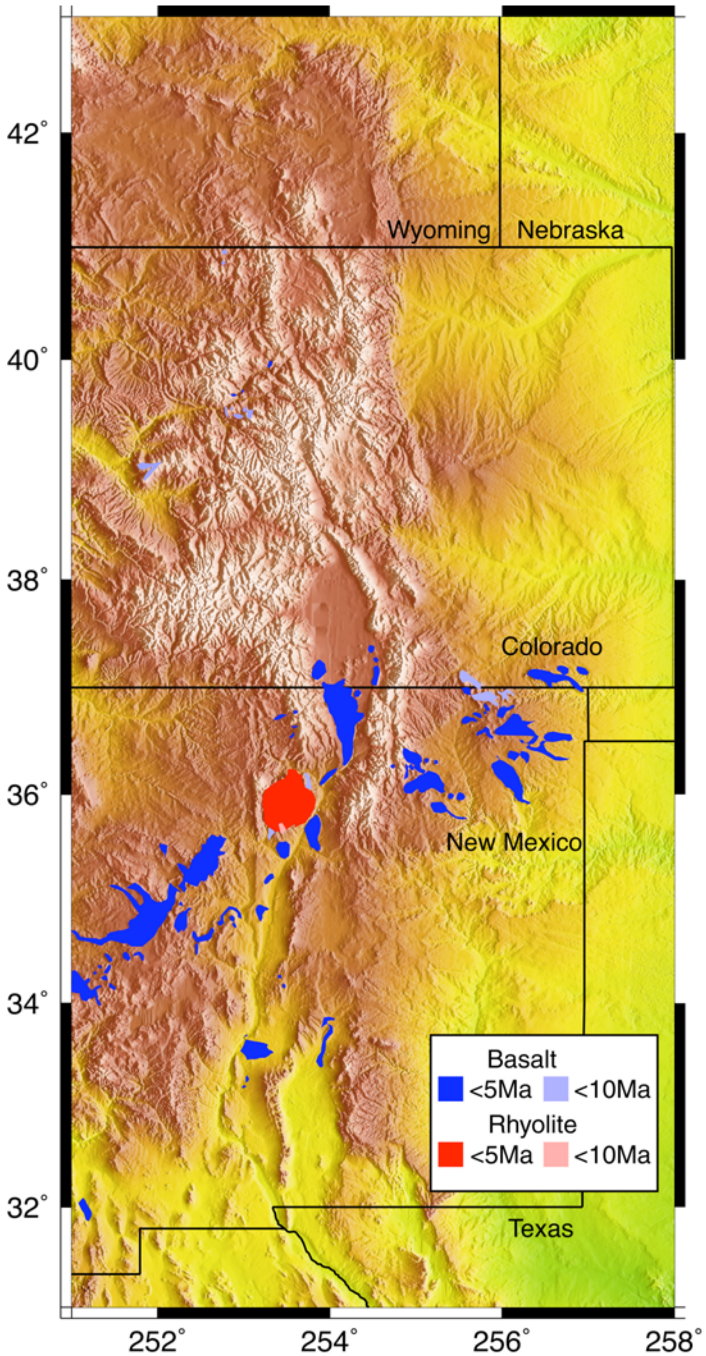
- Rift basins - sedimentation 21 Ma – present



Surface Expression of the Rio Grande Rift Includes:

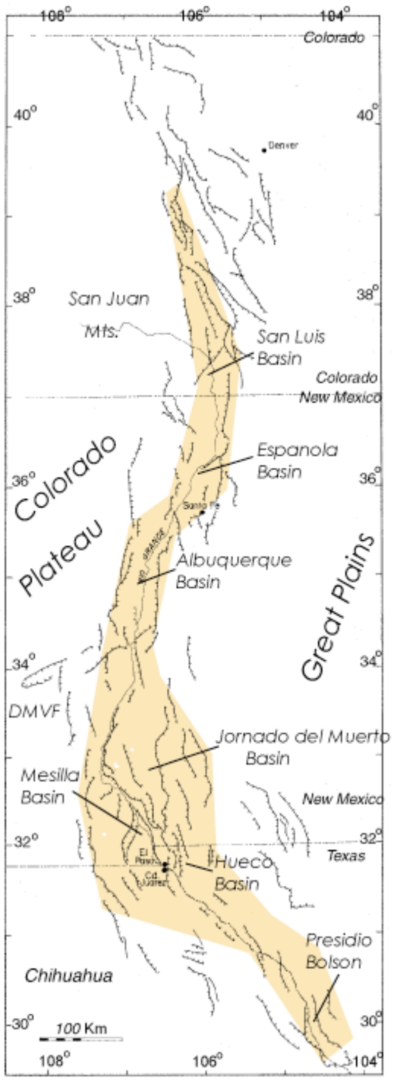
- Rift basins (fault-bounded half-grabens) with rapid sedimentation & stratal rotation 21 Ma – present

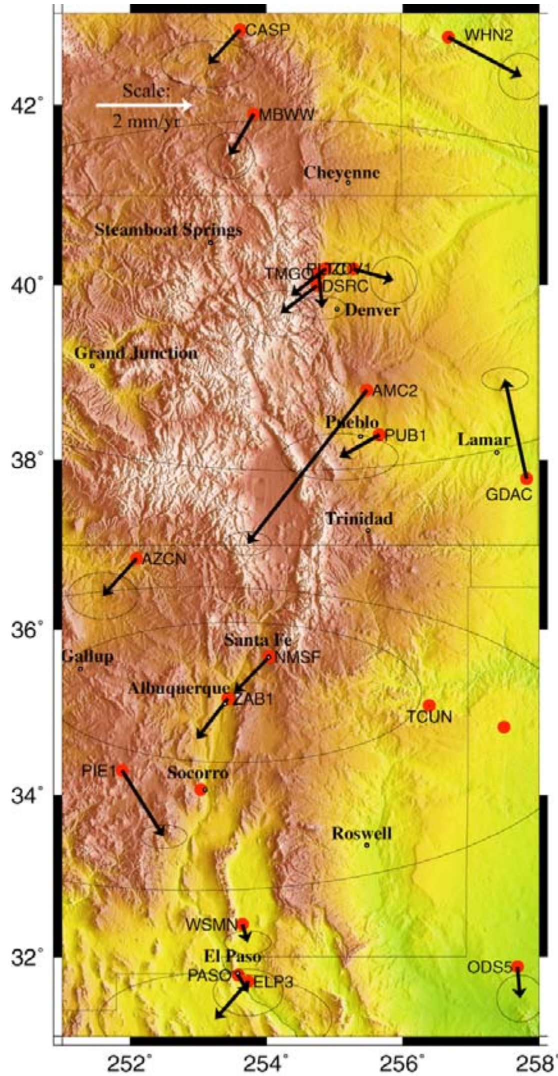
- Active faults showing one or two M~7 latest Quaternary events



Surface Expression of the Rio Grande Rift Includes:

- Rift basins (fault-bounded half-grabens) with rapid sedimentation & stratal rotation 21 Ma – present
- Active faults showing one or two M~7 latest Quaternary events
- Volcanism





Extension rate not well known – estimates are anywhere from 0.1 mm/yr to 5 mm/yr depending on measurement method

Is the Rio Grande Rift Currently Active?

Previously Determined Spreading Rates of Rio Grande Rift:

- 4 - 5 mm/yr extension in Rio Grande Rift (VLBI) *(Argus and Gordon, 1996)*
- 0.3 - 1 mm/yr (Geologic methods and trilateration) *(Woodward, 1977; Cordell, 1982; Savage et al., 1980)*
- Compare to 3 cm/yr on San Andreas Fault, > 10 cm/yr on East Pacific Rise
- Long time periods necessary between GPS measurements to accurately determine regional and local displacements

Some Questions We'd Like To Answer

- If the rift is currently active what rate is it extending at?
- Does the rate of extension vary in the north-south direction?
- How far north has the rift propagated?
- Why are the rift basins wider in the southern portions of the rift?

Deformation in the RGR

What drives rifting?

- Importance of older tectonic events:
  - Pre-Laramide and Laramide (last major orogeny)
  - Post-Laramide intrusion of Tertiary volcanics

- Plate boundary forces: migration of the Medocino TJ and evolution of the SAF

- Continent-scale forces: motion of NA and asthenospheric drag on cratonic keel, effect of deep mantle

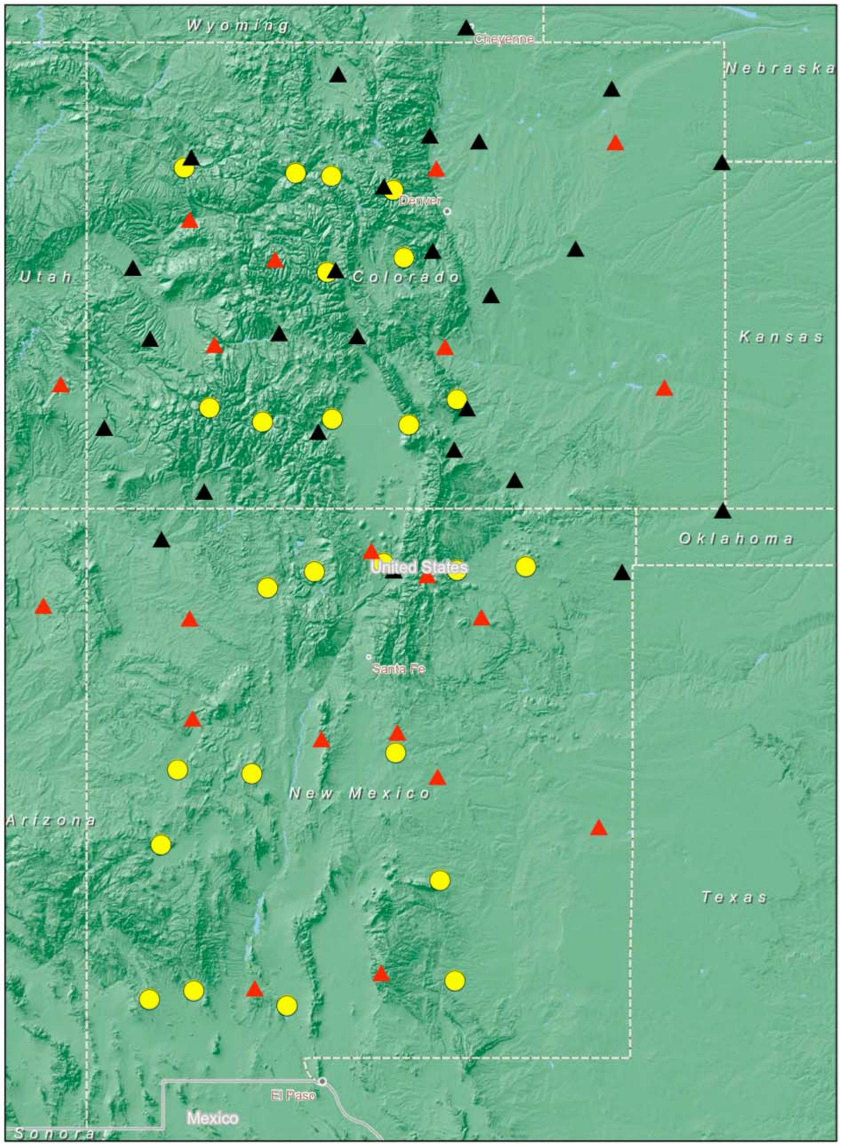
- Gravity → local buoyancy forces (imagine honey spreading out on a table)

Colorado Plateau: some unanswered kinematic questions

- How much has the CP rotated ?

- How much strike-slip motion is accommodated during the post-Laramide opening of the RGR ?

-Nature of the present-day deformation rate field?



Rio Grande Rift GPS Experiment - 2006-2010

25 monuments installed 2006-2007 and will log data until 2010

26 campaign measurements taken in 2001 and repeated in 2008

Plus we will be including all the already existing Plate Boundary Observatory (PBO) stations in our project

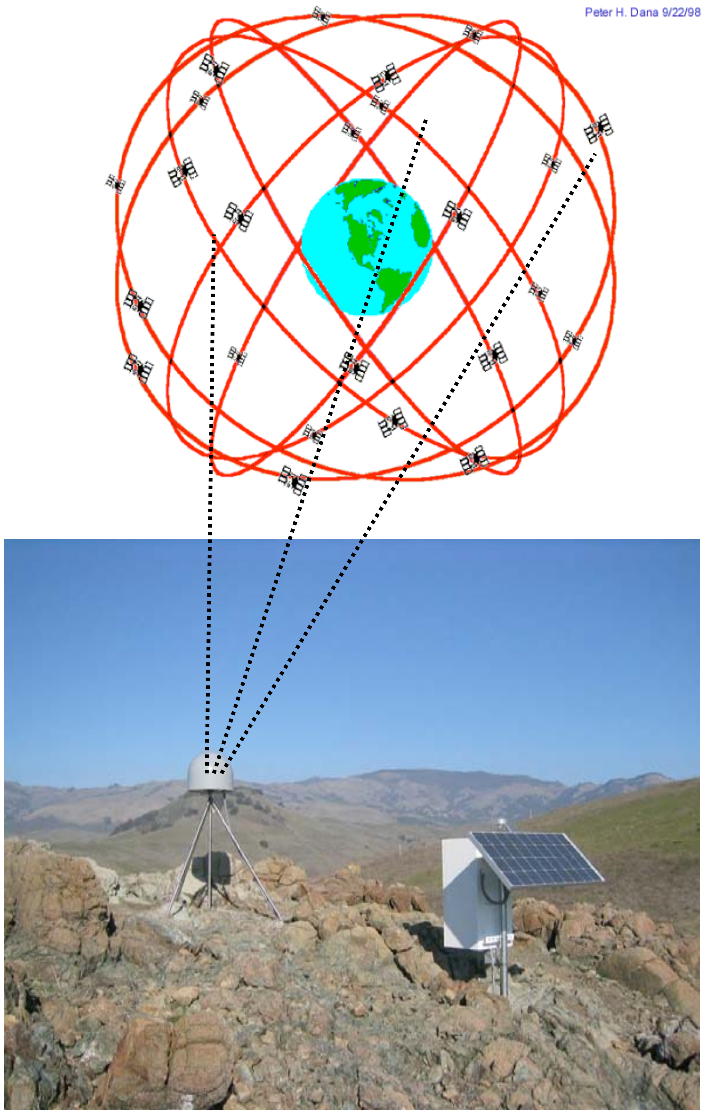
Project Goals

Accurately determine crustal deformation rates in the Rio Grande Rift and southern Rocky Mountains using high precision GPS.

Establish high precision set of measurements with which to compare future measurements.

Site RG01 near Pie Town, NM
Site RG02 near Belen, NM
Site RG03 near Capitan, NM
Site RG04 near Encino, NM
Site RG05 near White Signal, NM
Site RG06 near Faywood, NM
Site RG07 near Las Cruces, NM
Site RG08 near Hope, NM
Site RG09 near Lindrith, NM
Site RG10 near Cebolla, NM
Site RG11 near Taos, NM
Site RG12 near Cimarron, NM
Site RG13 near Dorsey Mansion State Park, NM
Site RG14 near Meeker, CO
Site RG15 near McCoy, CO
Site RG16 near Heeney, CO
Site RG17 near Empire, CO
Site RG18 near Twin Lakes, CO
Site RG19 near Tarryall, CO
Site RG20 near Red Mountain Pass, CO
Site RG21 near Creede, CO
Site RG22 near Del Norte, CO
Site RG23 in Great Sand Dunes National Park, CO
Site RG24 near Rye, CO
Site RG25 near Datil, NM

High-precision GPS



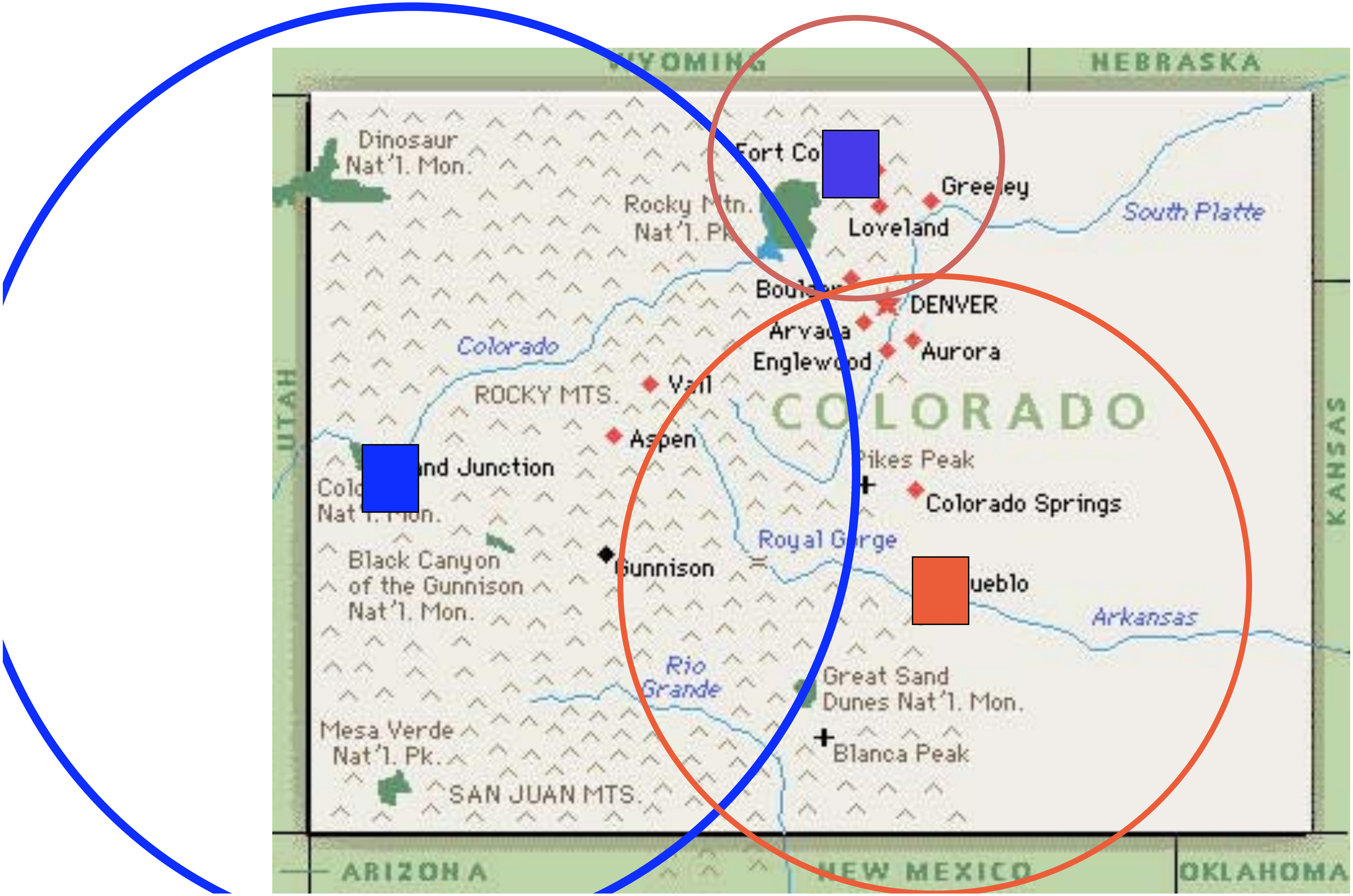
- Global positioning system
- Need 3 satellite signals to locate the receiver in 3D space
- 4th satellite used for time accuracy
- Calculate position within sub-centimeter

If the distance from the GPS transmitter is 250 miles, that means you are somewhere on a circle of radius 250 miles.

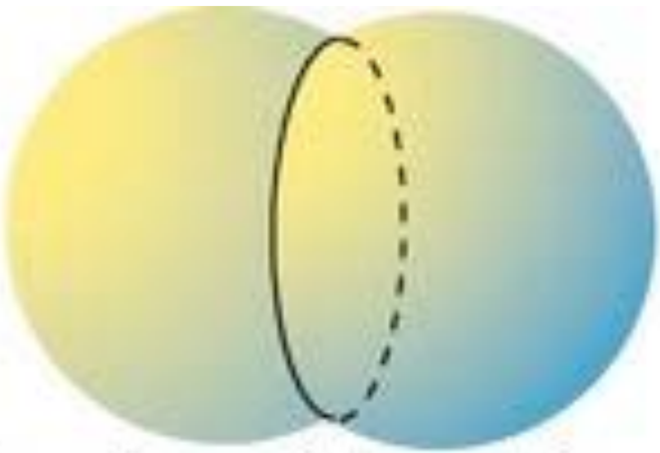
Now add a 2nd transmitter in Ft. Collins.

Your location is at the intersection of the 3 circles

And a third transmitter in Pueblo

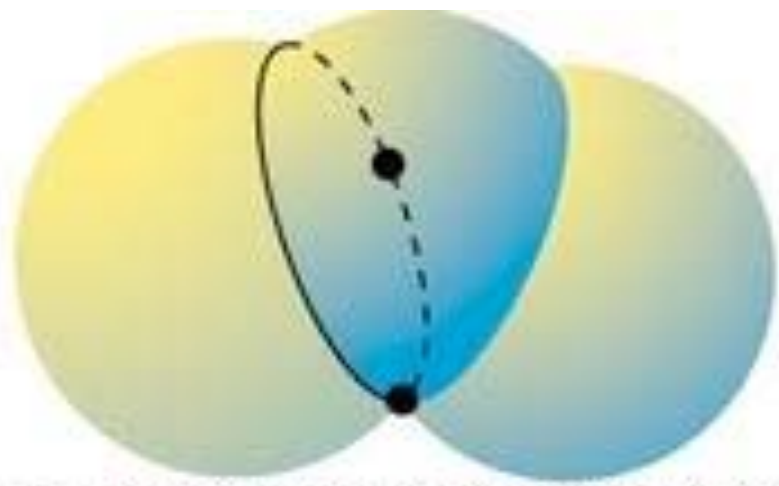


Intersecting Spheres



Two spheres intersect in a circle

But only 1 point is on the Earth



Three spheres intersect in two points

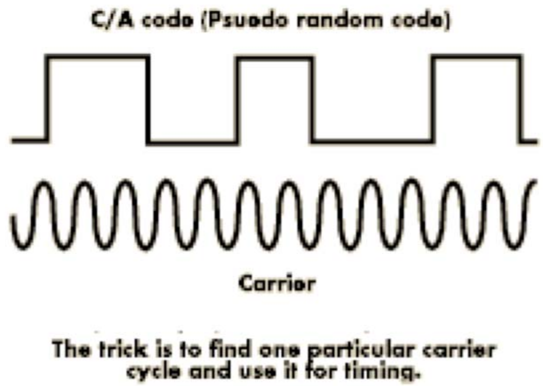
Handheld vs. High Precision GPS

- Better Equipment
  - Dual band receivers
  - Carrier frequency measurements
- Better job of modeling sources of error
  - Ionosphere, troposphere, orbits, antenna phase centers, tidal loading

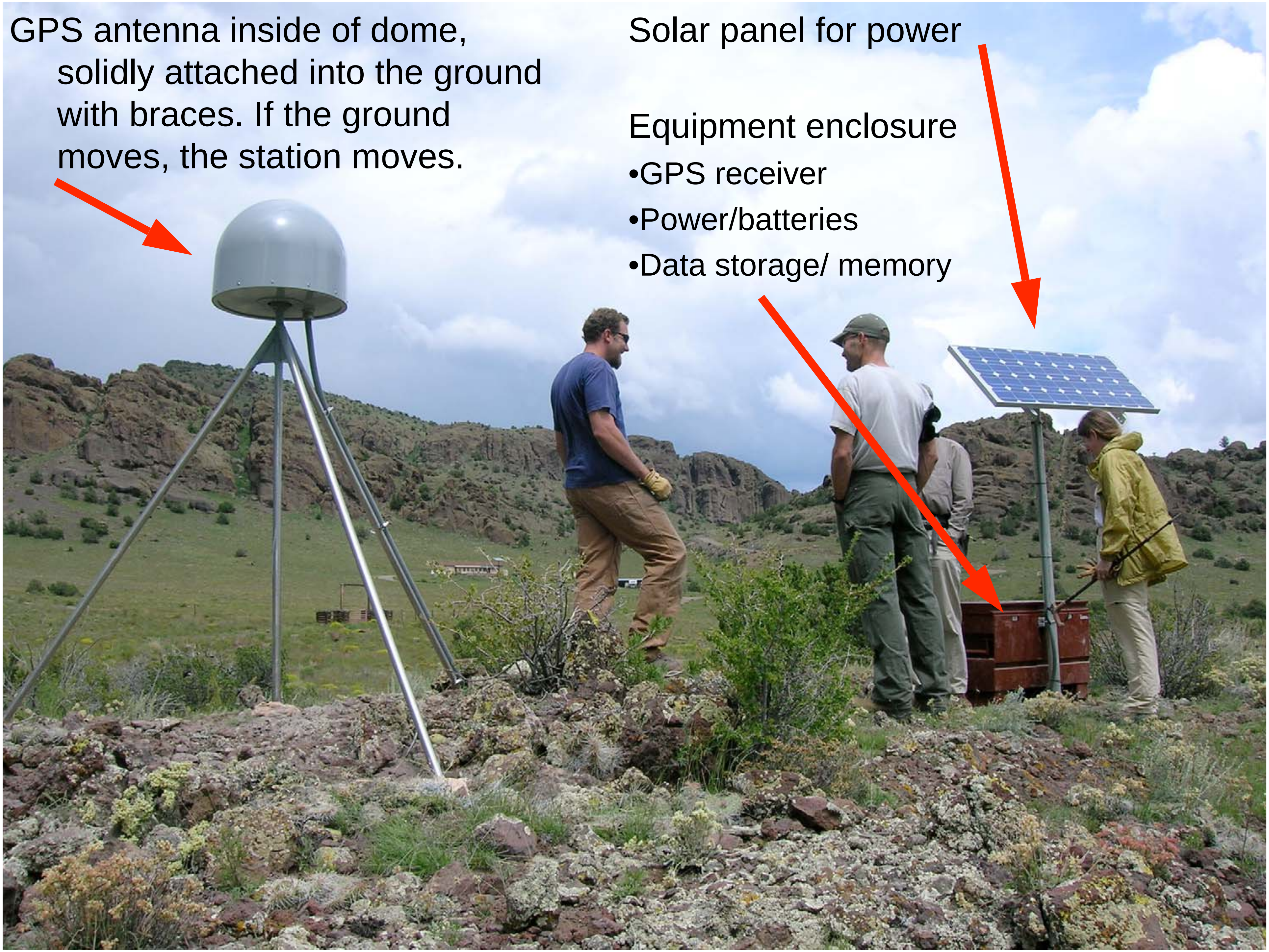
Dual Frequency

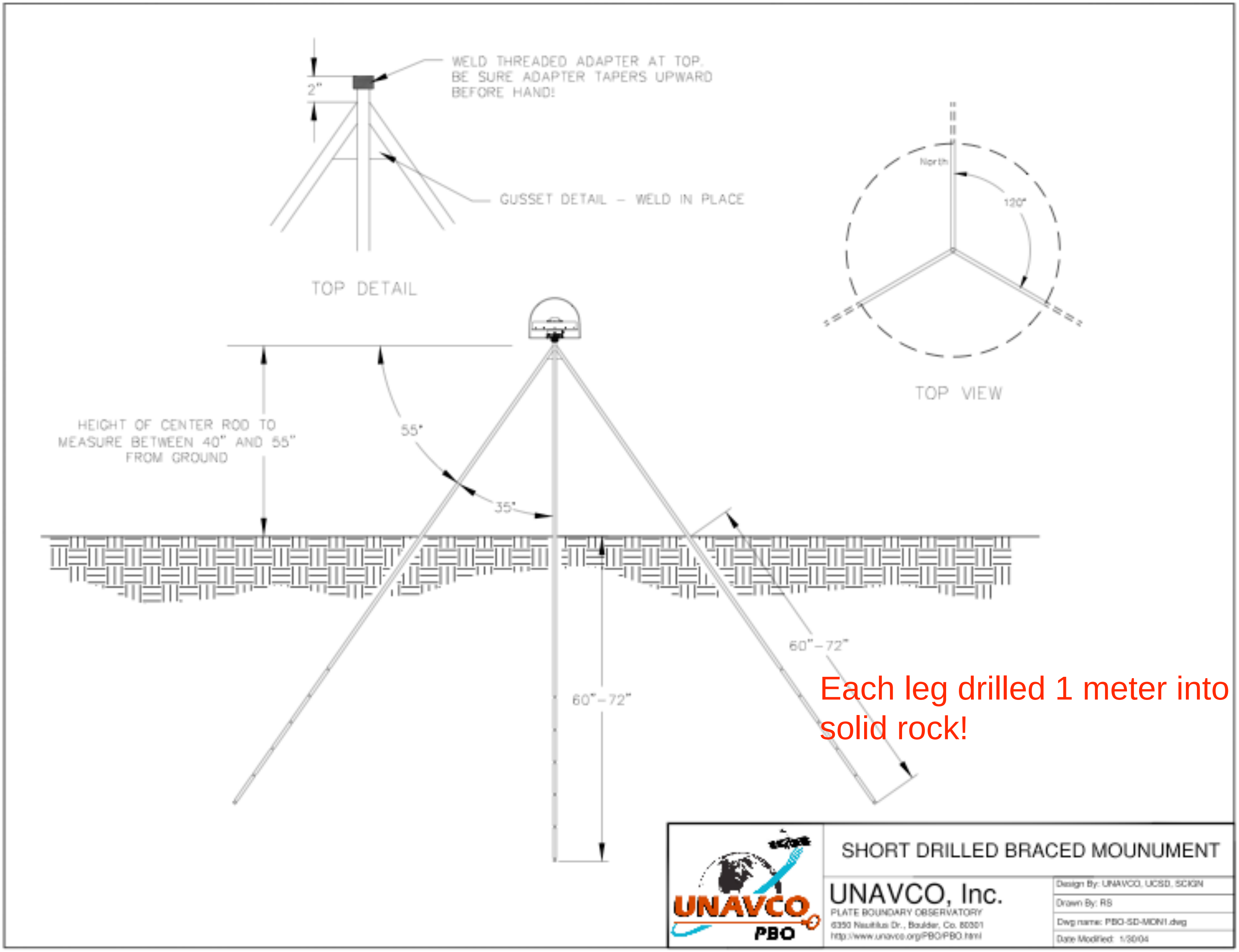
- Each GPS satellite broadcasts two separate frequencies
- If we use both frequencies we can correct for the ionospheric delay

Carrier Phase vs. Code Phase



- For the best measurement we need to use the highest frequency part of the signal.
- The carrier phase has a much higher frequency than the code phase.
- Handheld receivers use only the code phase.


GPS antenna inside of dome, solidly attached into the ground with braces. If the ground moves, the station moves.
Solar panel for power
Equipment enclosure
•GPS receiver
•Power/batteries
•Data storage/ memory



WELD THREADED ADAPTER AT TOP.
BE SURE ADAPTER TAPERS UPWARD
BEFORE HAND!
2"
GUSSET DETAIL – WELD IN PLACE
TOP DETAIL
North
120°
TOP VIEW
HEIGHT OF CENTER ROD TO
MEASURE BETWEEN 40" AND 55"
FROM GROUND
55°
35°
60"–72"
60"–72"
Each leg drilled 1 meter into solid rock!
SHORT DRILLED BRACED MOUNUMENT
UNAVCO, Inc.
PLATE BOUNDARY OBSERVATORY
6350 Nautilus Dr., Boulder, Co. 80301
http://www.unavco.org/PBO/PBO.html
Design By: UNAVCO, UCSD, SCIGN
Drawn By: RS
Dwg name: PBO-SD-MDN1.dwg
Date Modified: 1/30/04

Monument Time Series

RG16
Shadow Creek Ranch
N. Colorado

North Offset

+10 mm

-10 mm

Each blue dot tells you the position of a GPS receiver on a single day.

East Offset

+10 mm

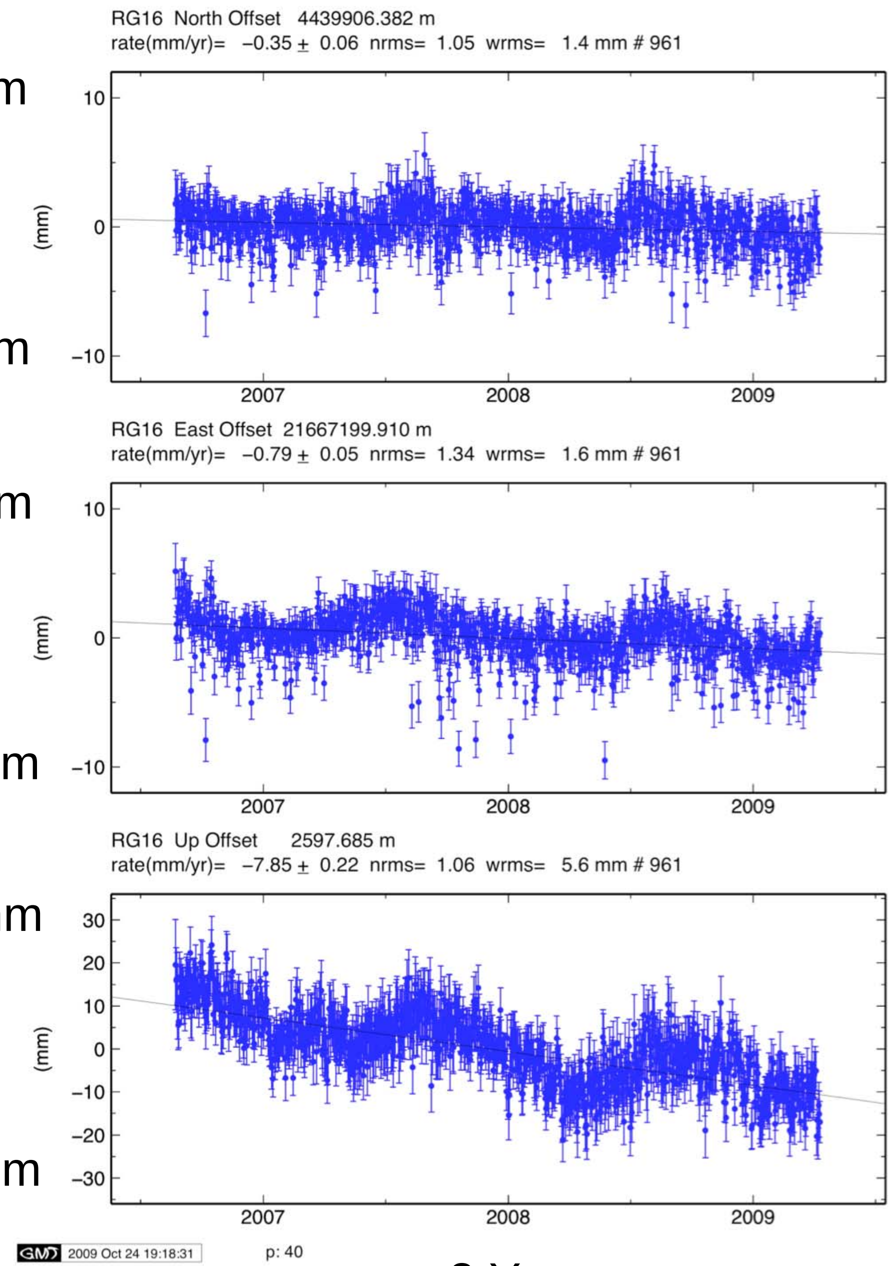
-10 mm

The blue bars indicate the formal uncertainty for each position.

Vertical Offset

+30 mm

-30 mm



<---------- 2 Years -------->

Monument Time Series

RG16
Shadow Creek Ranch
N. Colorado

If we fit a line to our time series we can estimate the station's velocity

North Offset

+10 mm

-10 mm

East Offset

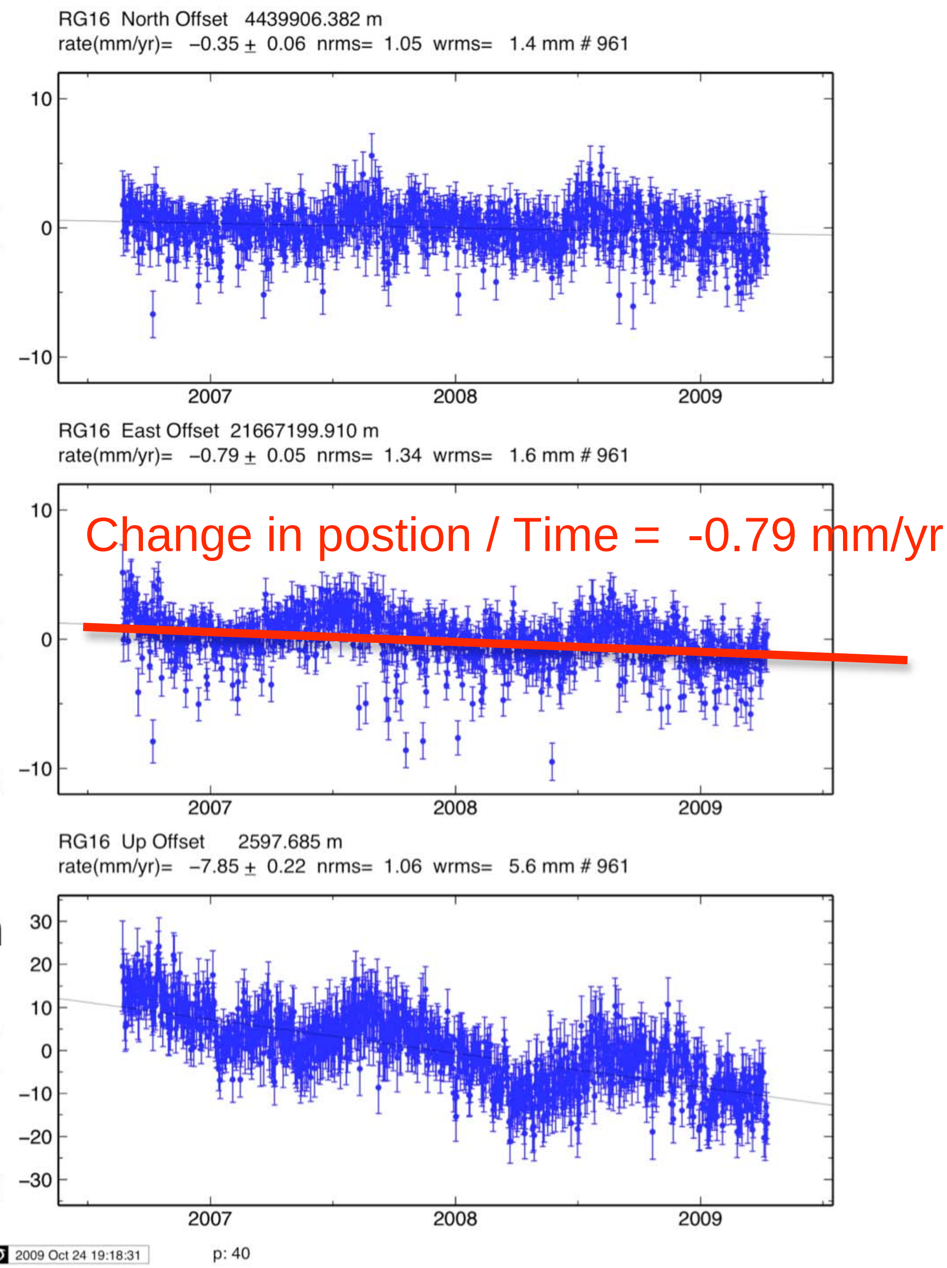
+10 mm

-10 mm

Vertical Offset

+30 mm

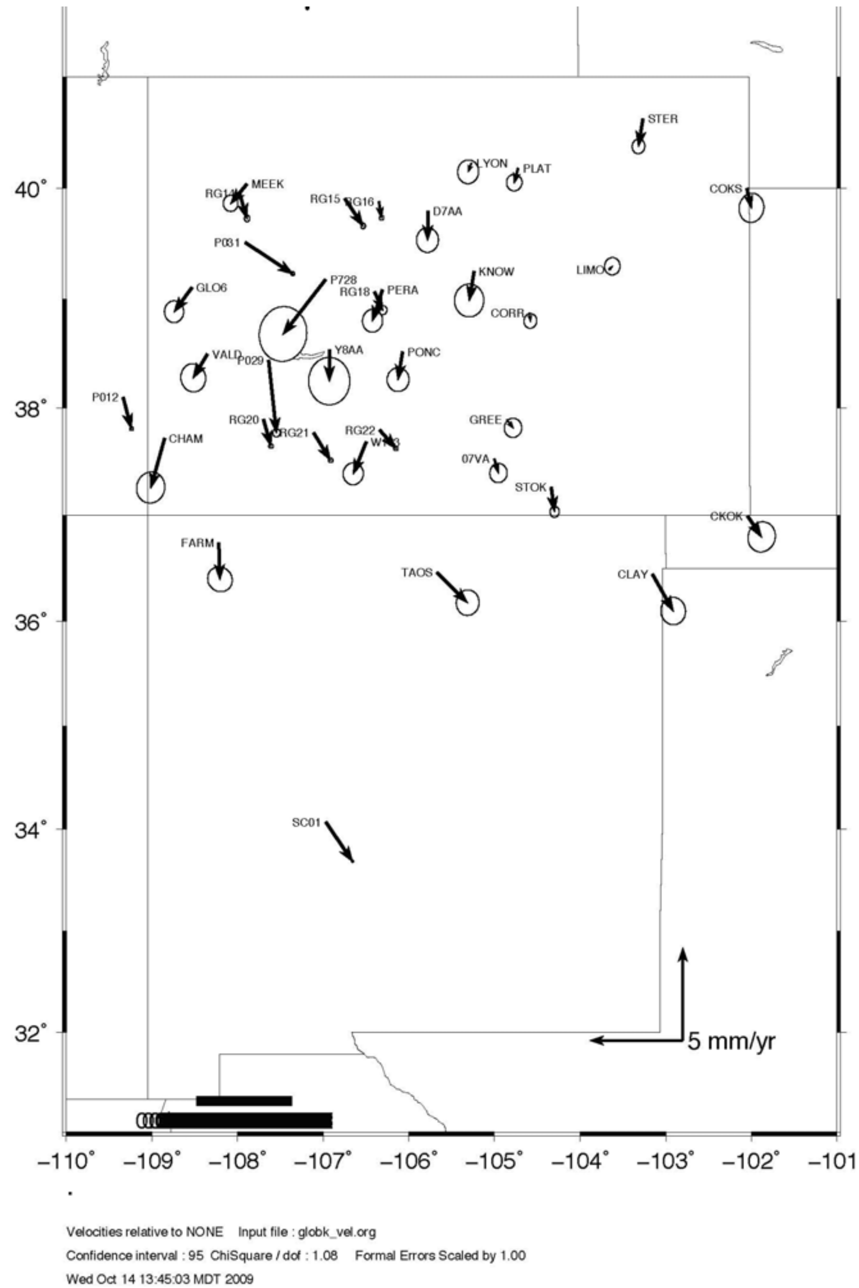
-30 mm



<---------- 2 Years -------->

Some Preliminary Results:

We can plot our velocity estimates and try to understand how they are distributed.



Computer models of plate stretching

Sharon Schmidt and M. Roy, University of New Mexico

Basic question: what governs the distribution of GPS velocities at the surface in the Rio Grande Rift?

This will be better answered when we have more accurate time series, but for now here is a set of "numerical experiments" to see what the role of the lower crust is…

The lower crust may have the same strength as the upper crust, or it may be significantly weaker, making the plate into a "jelly sandwich"

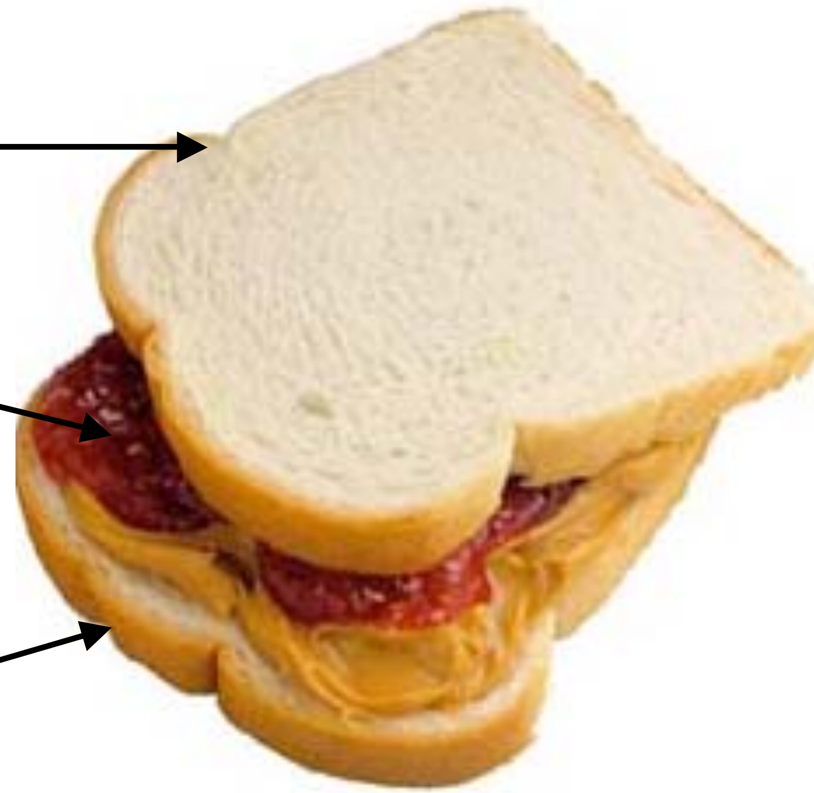
So… the upper crust might slide on the lower crust and move slightly differently than the mantle

The whole thing is a “tectonic plate” or “lithosphere”

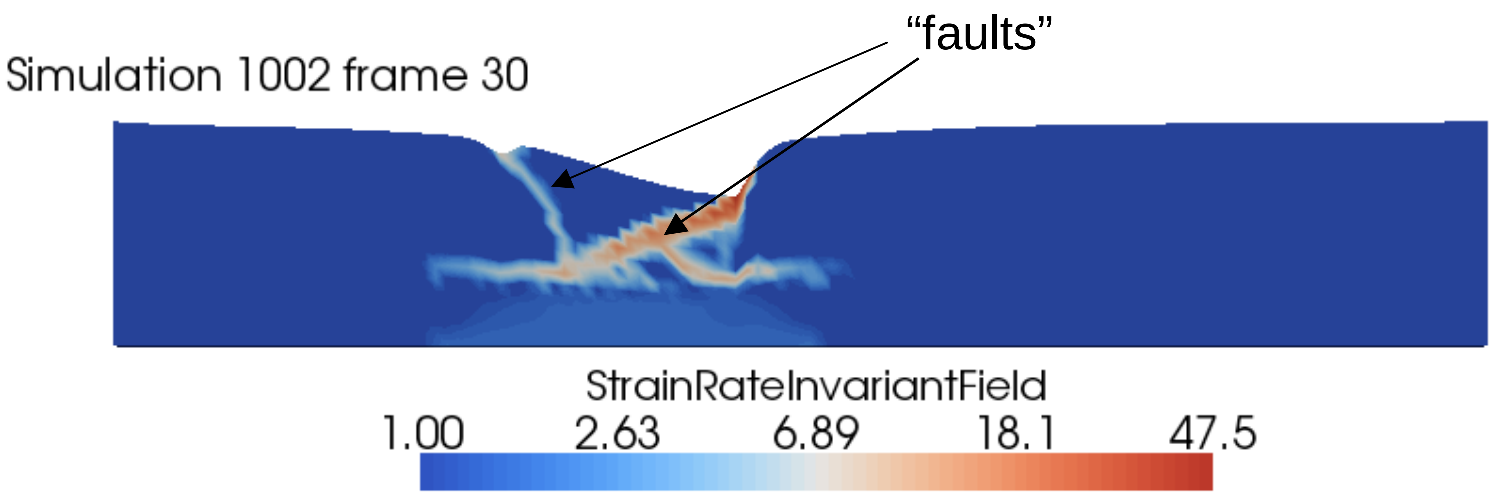
Upper crust

Lower crust

Upper mantle



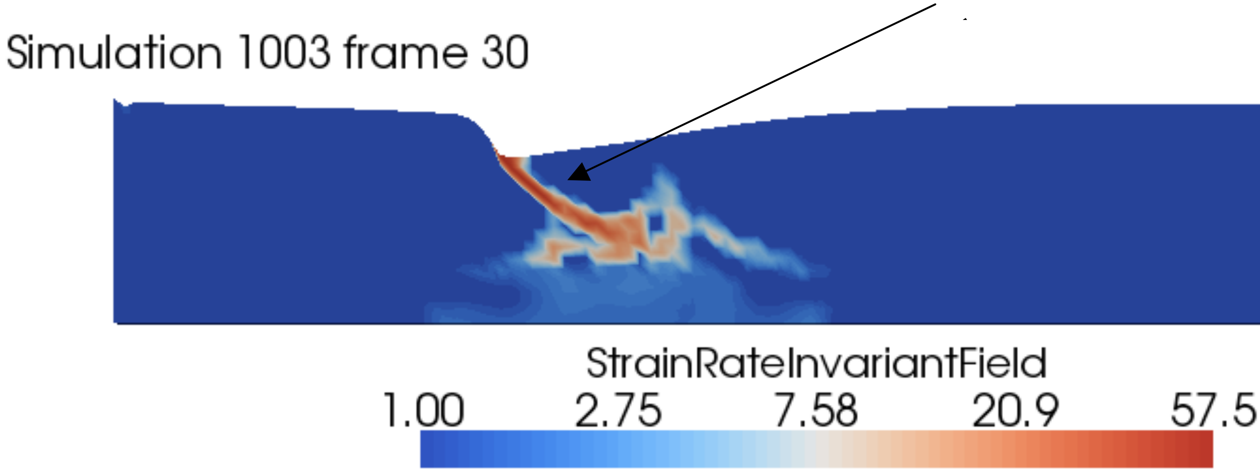
Start with equally “strong” (equal viscosity) upper and lower crust… allow faults to form in the upper crust and look at pattern of faulting as you pull the plate apart



Lower crust is initially 10 km thick
Total crust is initially 35 km thick

Reduce the strength of the lower crust by a factor 10 (make it jelly-like)…

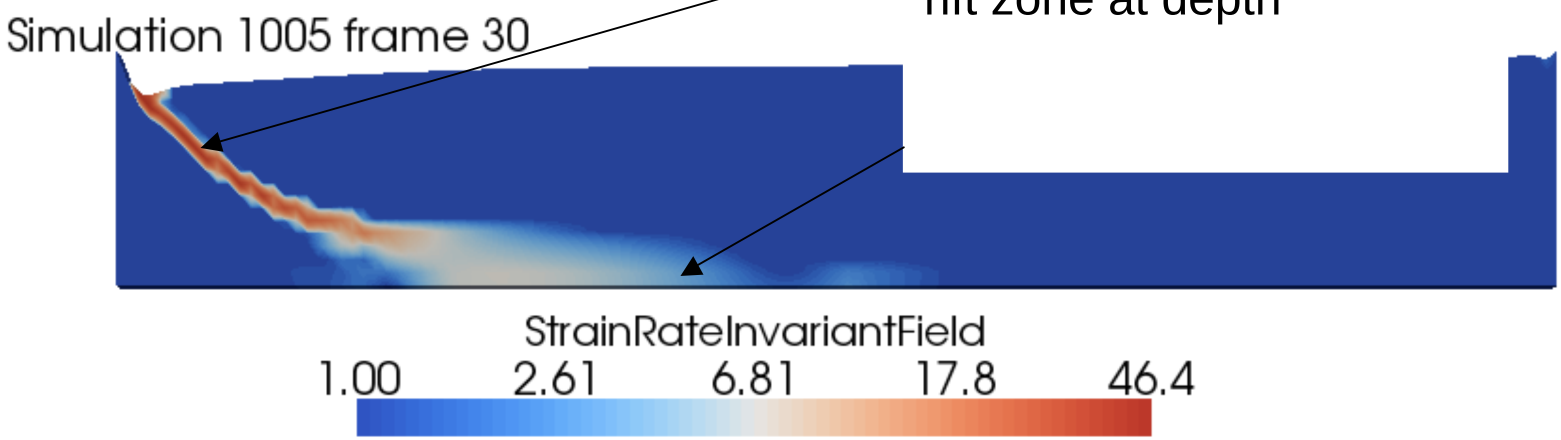
“fault” -- narrower rift zone at the surface



Lower crust is initially 10 km thick
Total crust is initially 35 km thick

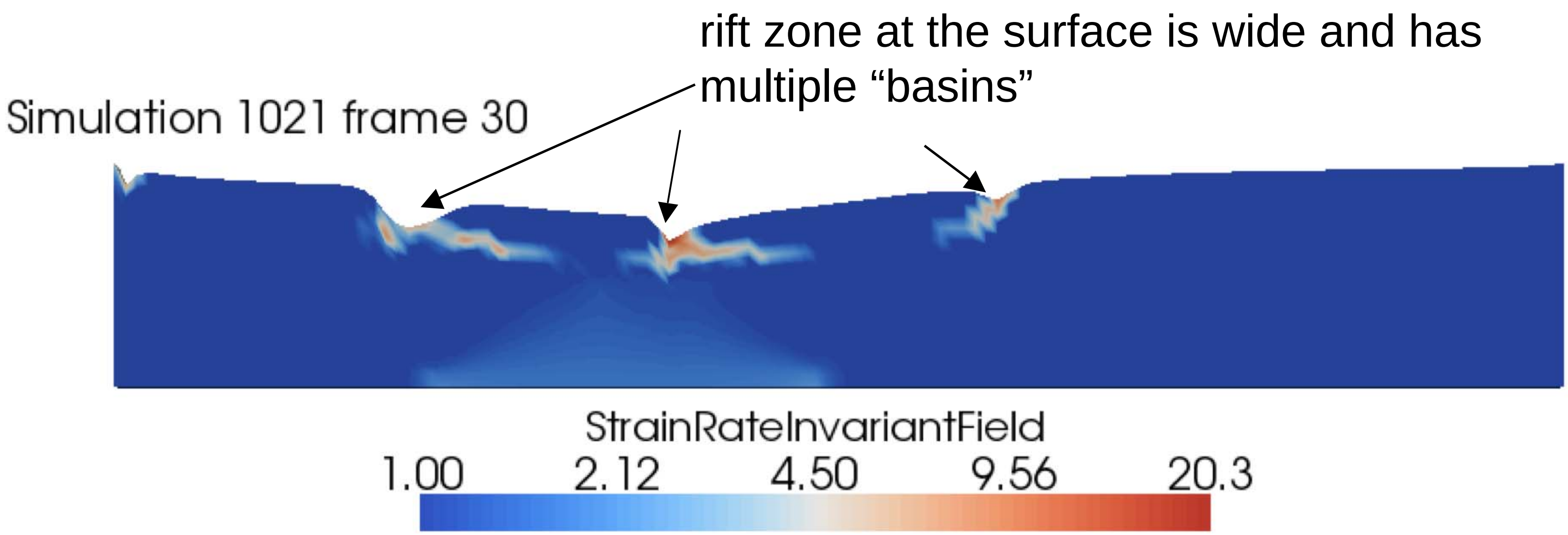
Reduce the strength of the lower crust by a factor 100 (make it very jelly-like!)…

“fault” -- rift zone at the surface is displaced from rift zone at depth



Lower crust is initially 10 km thick
Total crust is initially 35 km thick

How to make a very wide rift



Preliminary result: Start with a thick but not very weak lower crust… (weakening the crust localizes rifting, all other factors being equal)

Initial thickness of the lower crust here is 20 km…

How does this relate to the RGR?

- What causes the rift to be narrow in northern NM and CO, but wider in southern NM?
- The lower crust may be one of the possible reasons…