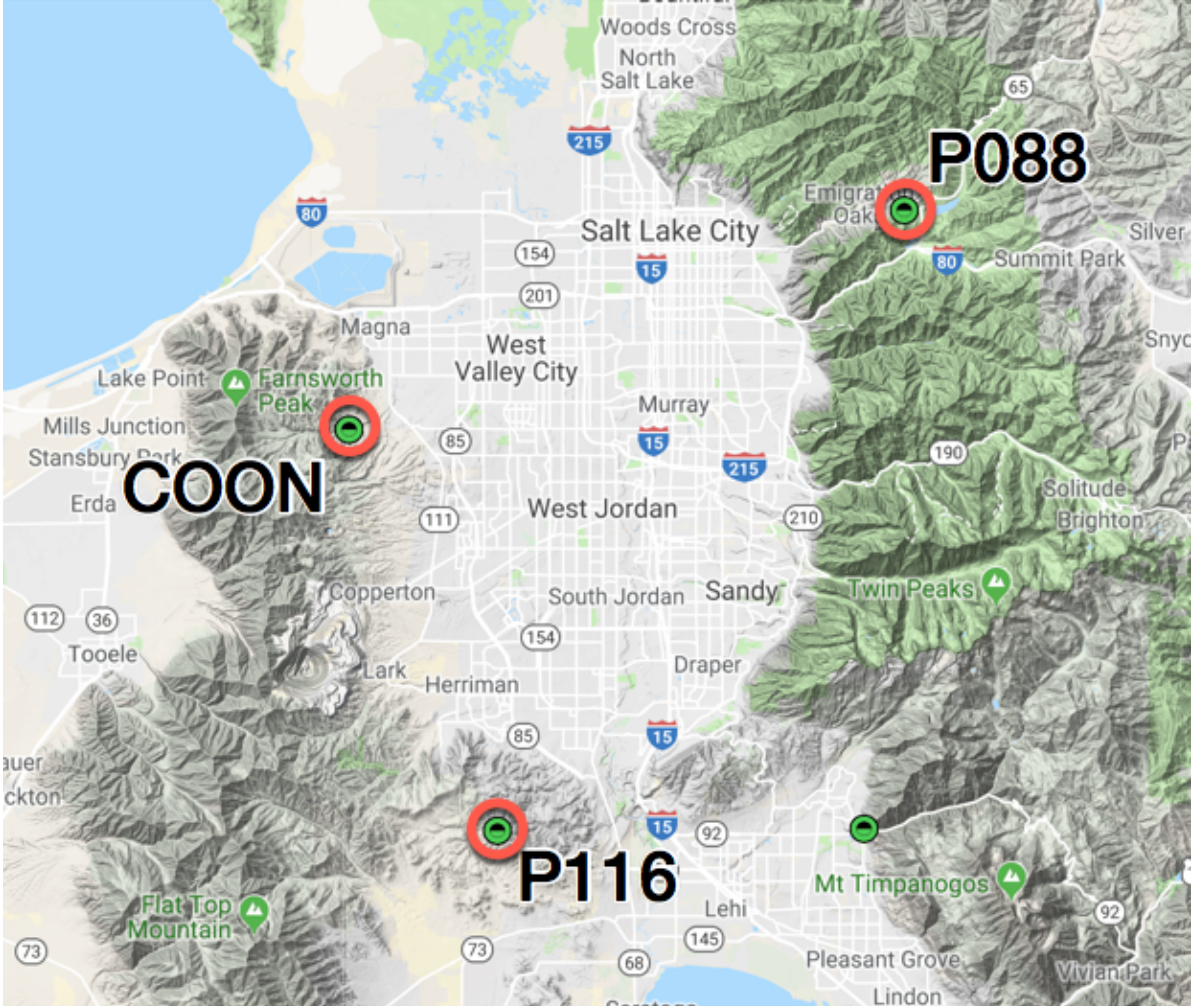
Your Turn:

Crustal strain across Salt Lake City, Utah



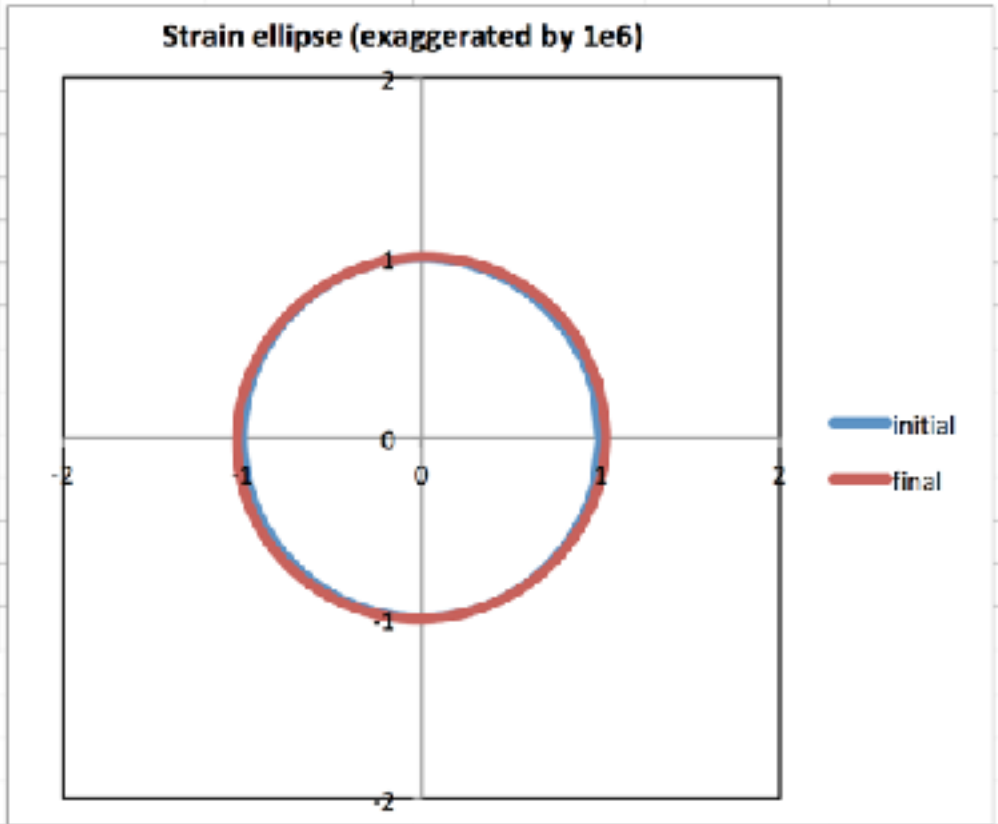
The handouts from this workshop are available via the workshop's web page —
http://croninprojects.org/GETSI-EER2018/

Don’t be shy. Ask for help when you need it.

	A	B	C	D	E	F	G	H
1	**Infinitesimal strain from GPS velocity data from sites in a triangular array**							October 18, 2012
2		Send corrections, suggestions, comments to Vince_Cronin@baylor.edu						
3								
4	**Instructions**							
5		(1) Input the name. location, and velocity data from three GPS sites in the yellow cells.						
6		(2) When the required data have been input, the answers will appear in the Output Data section (blue cells).						
7								
8	**Initial Input Data**							
9		**Site**	**Longitude**	**Latitude**	**E velocity**	**E vel uncert**	**N velocity**	**N vel uncert**
10		**Name**	**west is negative**	**south is negative**	**(mm/yr)**	**(mm/yr)**	**(mm/yr)**	**(mm/yr)**
11		P088	-111.722890000	40.771770000	-0.41	0.03	0.02	0.02
12		COON	-112.121010000	40.652590000	-1.72	0.03	0.04	0.04
13		P116	-112.014230000	40.434020000	-1.95	0.03	-0.08	0.02

Primary Output Data

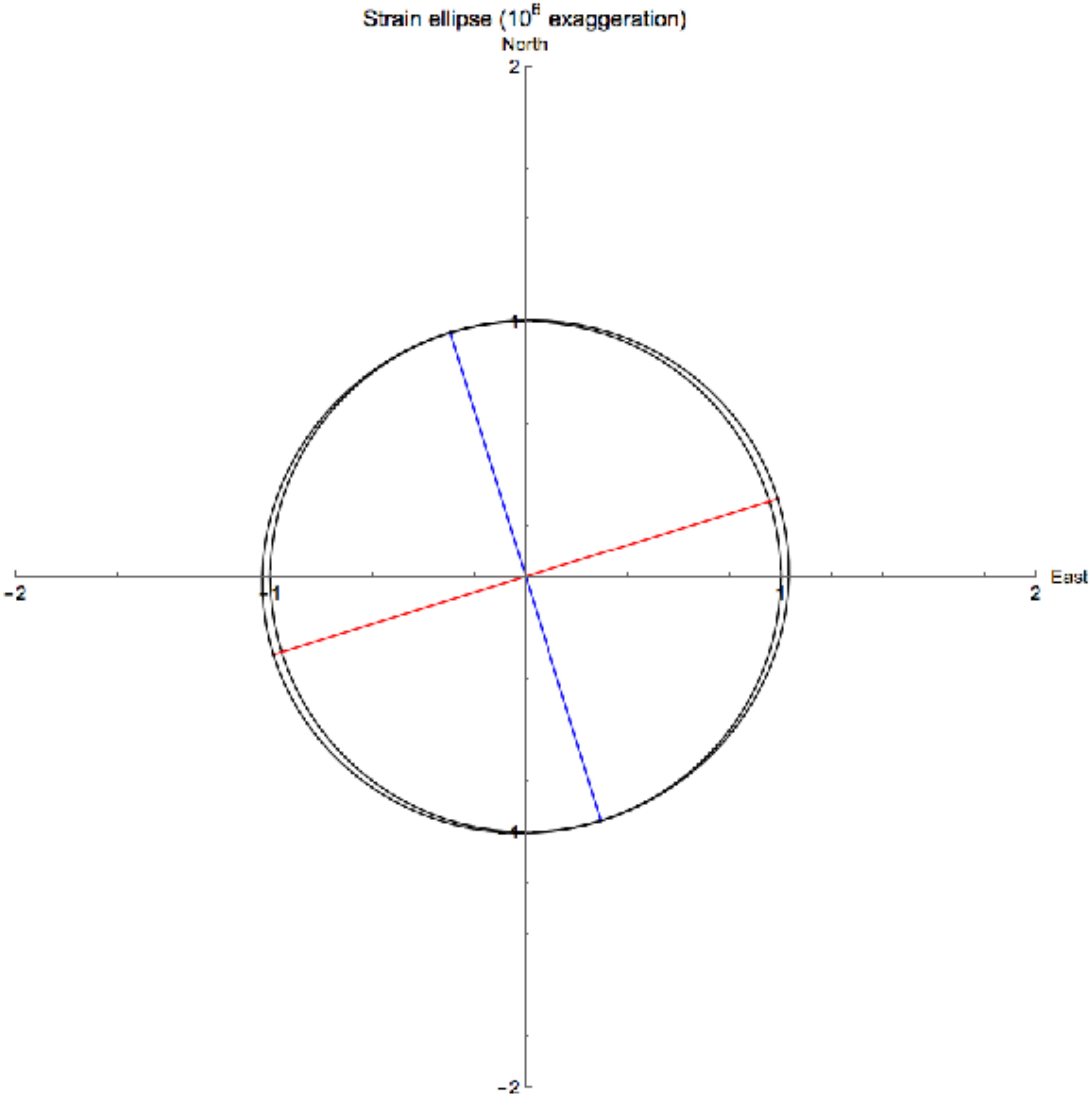
Translation Vector			
E component ± uncert (m/yr)	-0.0014	±	1.73205E-05
N component ± uncert (m/yr)	0.0000	±	1.63299E-05
Azimuth (degrees)	269.7		
Speed (m/yr)	0.0014		
Rotation ± uncertainty (degrees/yr)	-0.00000065	±	0.00000006
Rotation ± uncertainty (nano-rad/yr)	-11.3613	±	1.0929
Direction of rotation	clockwise		
Max horizontal extension (e1H) (nano-strain)	33.8051		
Azimuth of S1H (degrees)	72.7875	or	252.7875179
Min horizontal extension (e2H) (nano-strain)	1.2973		
Azimuth of S2H (degrees)	162.7875	or	342.7875179
Max shear strain (nano-strain)	32.5077		
Area strain (nano-strain)	35.1024		



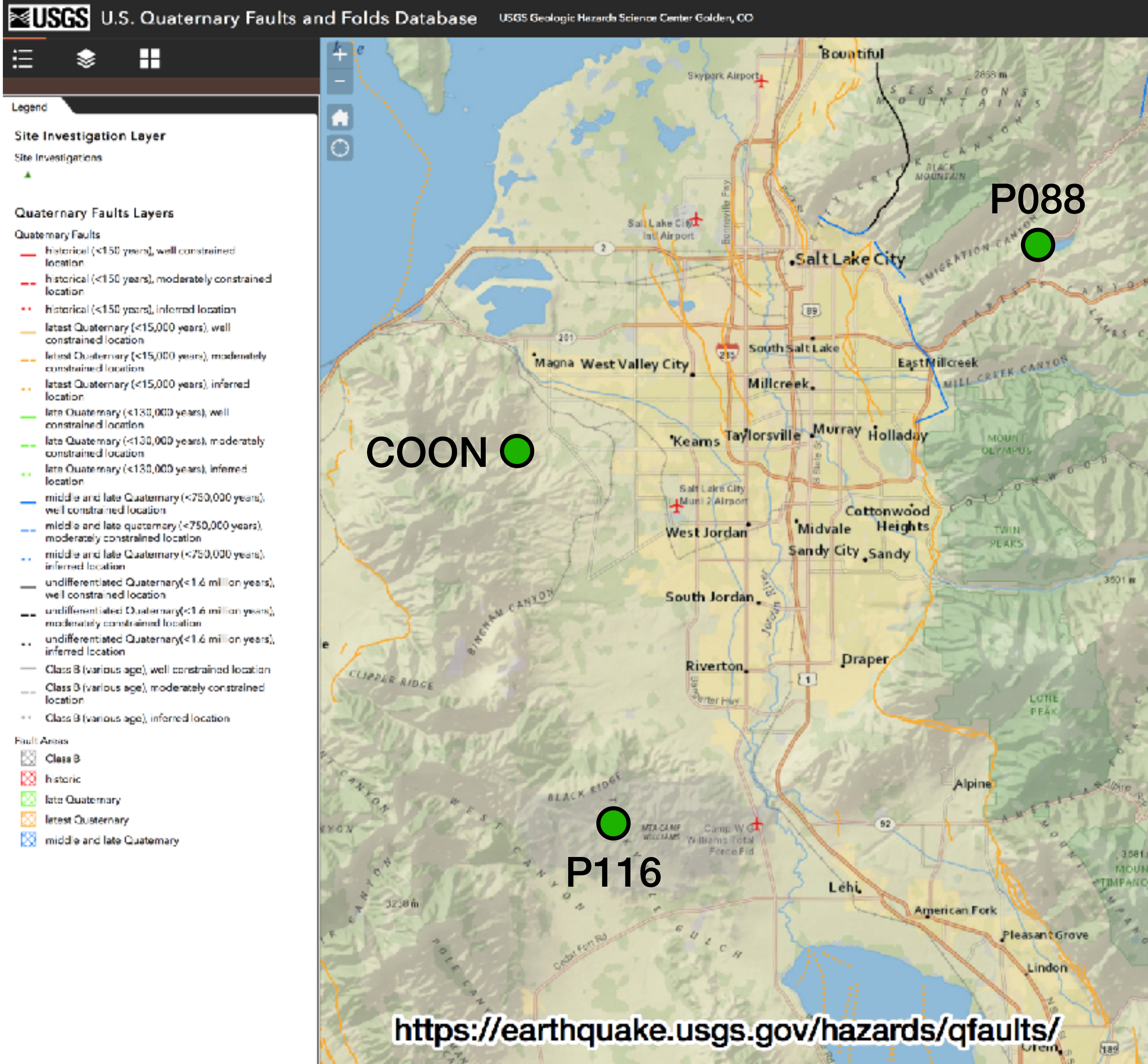
Other Output

Lagrangian strain-rate tensor			
εxx ± uncert (nano-strain)	30.9585	±	1.4858
εxy ± uncert (nano-strain)	9.1887	±	1.0929
εyy ± uncert (nano-strain)	4.1439	±	1.3039
First invariant of strain-rate tensor (nano-strain)	35.1024		
Second invariant of strain-rate tensor (nano-strain)	4.38564E-08		
Third invariant of strain-rate tensor (nano-strain)	4.38564E-08		

Infinitesimal horizontal strain ellipse for P088-COON-P116 based on PBO GPS data accessed 11 July 2018



Output from the *Mathematica* strain calculator


USGS U.S. Quaternary Faults and Folds Database
USGS Geologic Hazards Science Center Golden, CO
Legend
Site Investigation Layer
Site Investigations
Quaternary Faults Layers
Quaternary Faults
historical (<150 years), well constrained location
historical (<150 years), moderately constrained location
historical (<150 years), inferred location
latest Quaternary (<15,000 years), well constrained location
latest Quaternary (<15,000 years), moderately constrained location
latest Quaternary (<15,000 years), inferred location
late Quaternary (<130,000 years), well constrained location
late Quaternary (<130,000 years), moderately constrained location
late Quaternary (<130,000 years), inferred location
middle and late Quaternary (<750,000 years), well constrained location
middle and late quaternary (<750,000 years), moderately constrained location
middle and late Quaternary (<750,000 years), inferred location
undifferentiated Quaternary(<1.6 million years), well constrained location
undifferentiated Quaternary(<1.6 million years), moderately constrained location
undifferentiated Quaternary(<1.6 million years), inferred location
Class B (various age), well constrained location
Class B (various age), moderately constrained location
Class B (various age), inferred location
Fault Areas
Class B
historic
late Quaternary
latest Quaternary
middle and late Quaternary
P088
COON
P116
Bountiful
Salt Lake City
South Salt Lake
Magna
West Valley City
Millcreek
East Millcreek
Kearns
Taylorsville
Murray
Holladay
Cottonwood Heights
Midvale
West Jordan
Sandy City
Sandy
South Jordan
Riverton
Draper
Alpine
Lehi
American Fork
Pleasant Grove
Lindon
Orem
https://earthquake.usgs.gov/hazards/qfaults/

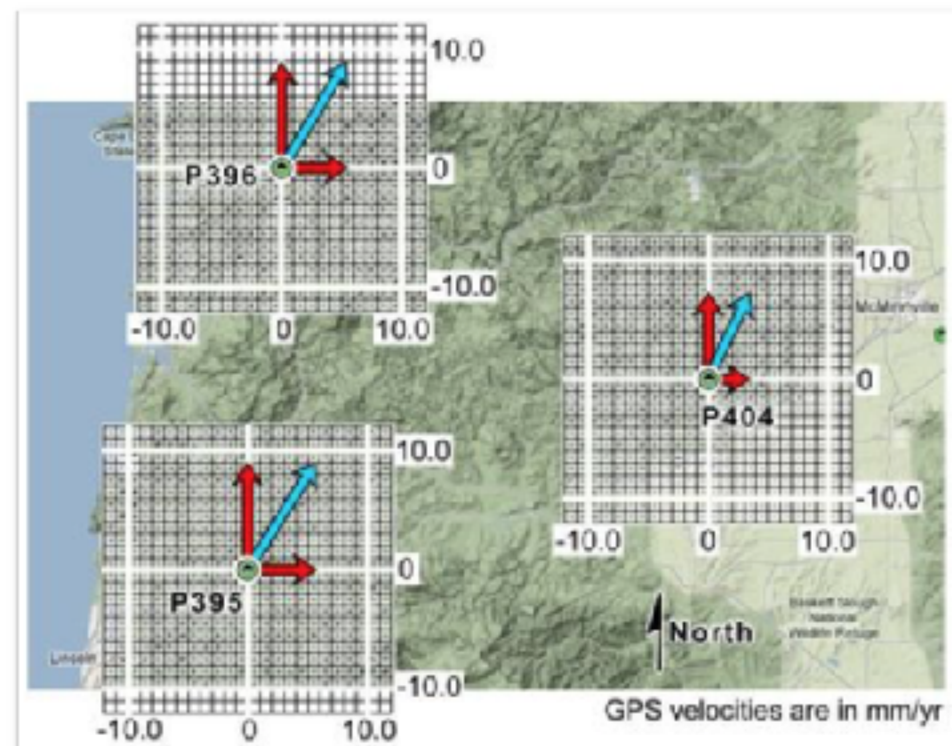
Summary

Students work with GPS velocity data from three stations in the same region that form an acute triangle. By investigating how the ellipse inscribed within this triangle deforms, students learn about strain, strain ellipses, GPS, and how to tie these to regional geology and ongoing hazards. This unit contains the primary infinitesimal strain analysis for the module. After the instructor demonstrates the method using data from Japan, students investigate three different GPS station triangles in three difference tectonic regimes: convergent (U.S. Pacific Northwest), extensional (Wasatch fault, Utah), and strike-slip (San Andreas Fault, California).

▶ *Show more information on GPS versus GNSS*

Learning Goals

Unit 4 Learning Outcomes



- Students will be able to use the GPS Strain Calculator to **compute** how a three-station triangle of GPS stations has rotated, translated, and or strained in relation to a stable reference frame (i.e., in relation to stable North America).
- Students will be able to **analyze** the tectonic and geological implications of the calculated strain, **connect** to regional earthquake risks, and **develop** mitigation strategy proposals.

  ▶ Show more info on how learning outcomes connect to science literacy principles and module goals

Unit 4 Teaching Objectives

- Behavioral: Provide an opportunity for students to learn to use the GPS Strain Calculator and Strain Ellipse Visualization tool.
- Cognitive: Facilitate students' ability to interpret the GPS Strain Calculator output for geologic and tectonic implications.
- Affective: Encourage reflection and analysis of societal impacts of earthquakes.

https://serc.carleton.edu/getsi/teaching_materials/gps_strain/unit4.html

UNAVCO

GPS Strain & Earthquakes Unit 4: GPS strain analysis examples – Student exercise

Example 1: Olympic Peninsula

Name:__________________________

Please complete the following worksheet to estimate, calculate, and interpret the strain for a triangle defined by three GPS stations at the tip of the Olympic Peninsula, just west of Seattle.

Step 1. Estimate the strain from the velocity field

Use your group's map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

	Approximate Magnitude (m/yr)	Approximate Azimuth
Translation:	______________	______________
Rotation direction (+ = counter clockwise, - = clockwise):		______________

Strain:

	Sign (+ = extension, - = contraction)	Approximate Azimuth
Max horizontal extension	______________	______________
Min horizontal extension	______________	______________

Step 2. Calculate the instantaneous deformation

Use the strain calculator provided by your instructor to find the following parameters that describe the complete deformation of the area.

https://d32ogoqmya1dw8.cloudfront.net/files/getsi/teaching_materials/gps_strain/unit_4_gps_infinitesimal.v5.pdf

Example 2: Wasatch Front **Name:__________________________**

Please complete the following worksheet to estimate, calculate, and interpret the strain for a triangle defined by three GPS stations that span the Wasatch Mountain Front in the Salt Lake City metropolitan area (Fig. WF.1).

Step 1. Estimate the strain from the velocity field

Use your map of the velocity field to hypothesize (infer) the instantaneous deformation for this set of stations.

	Approximate Magnitude (m/yr)	**Approximate Azimuth**
Translation:	______________	______________
Rotation direction (+ = counter clockwise, - = clockwise):		______________

Strain:

	Sign (+ = extension, - = contraction)	**Approximate Azimuth**
Max horizontal extension	______________	______________
Min horizontal extension	______________	______________

Step 2. Calculate the instantaneous deformation

Use the strain calculator provided by your instructor to find the following parameters that describe the complete deformation of the area.

	E component ± uncert (m/yr)	N component ± uncert (m/yr)
Translation Vector		

GETSI Module: GPS, Strain, and Earthquakes

Unit 1

Unit 2

Unit 3

Unit 4

Unit 5

Unit 6

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Unit 1 Why this is relevant and important, and why you should care

Unit 2

Unit 3

Unit 4

Unit 5

Unit 6

GETSI Module: GPS, Strain, and Earthquakes

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Unit 2 Building background about how materials deform — strain

Unit 3

Unit 4

Unit 5

Unit 6

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Unit 3 Building background about GPS and its use to measure crustal strain

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Unit 5

Unit 6

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Unit 6 Applying what you have learned

Check the time…