INFERRING LARGE-SCALE TERRESTRIAL WATER STORAGE THROUGH GRACE AND GPS DATA FUSION

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NEROC SYMPOSIUM
NOVEMBER 4TH 2016

INFERRING GROUNDWATER CHANGES WITH GPS

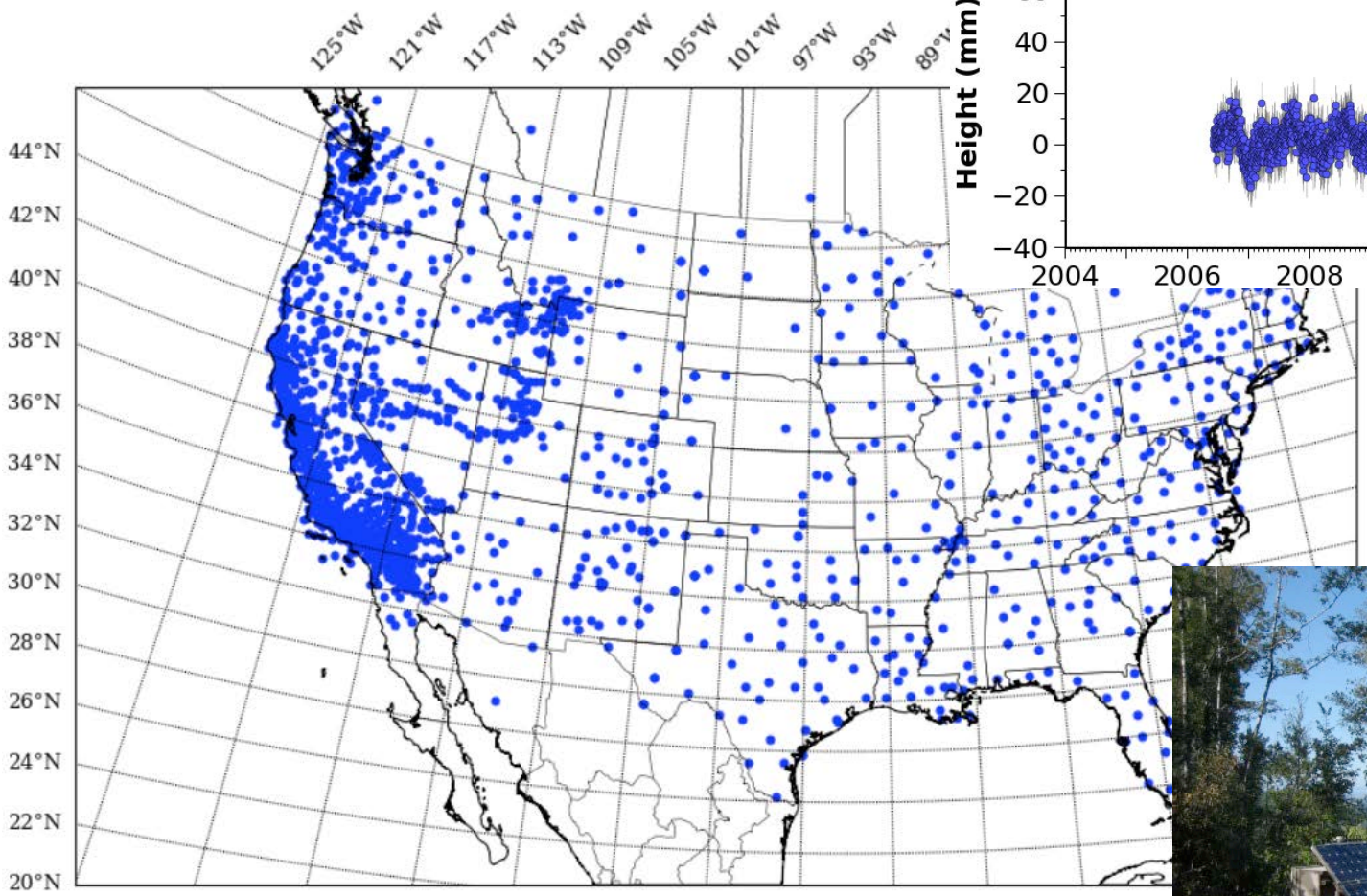
- Explore ability to monitor groundwater using GPS
- Utilize Computer-Aided Discovery system that allows offloading work to the cloud
- Correlate vertical position from GPS with measurements of equivalent water depth from the Gravity Recovery and Climate Experiment (GRACE)
- Compare GRACE measurements to direct groundwater wells

GROUNDWATER

- The load of water deforms the solid Earth and removing the water will cause Earth to rebound
- In an aquifer, water pressure supports the poroelastic material
- When the water is removed the material will compress
- When excessive amounts water is removed the compaction can be permanent
- The motion of the surface depends on whether elastic loading or poroelastic expansion dominates

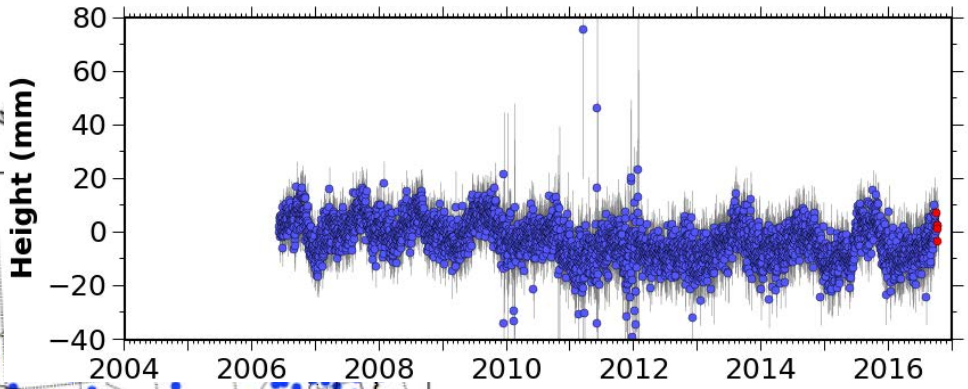
http://water.usgs.gov/edu/gallery/landsubsidence-poland.html

PLATE BOUNDARY OBSERVATORY



Locations of PBO GPS stations around US

Vertical position time series

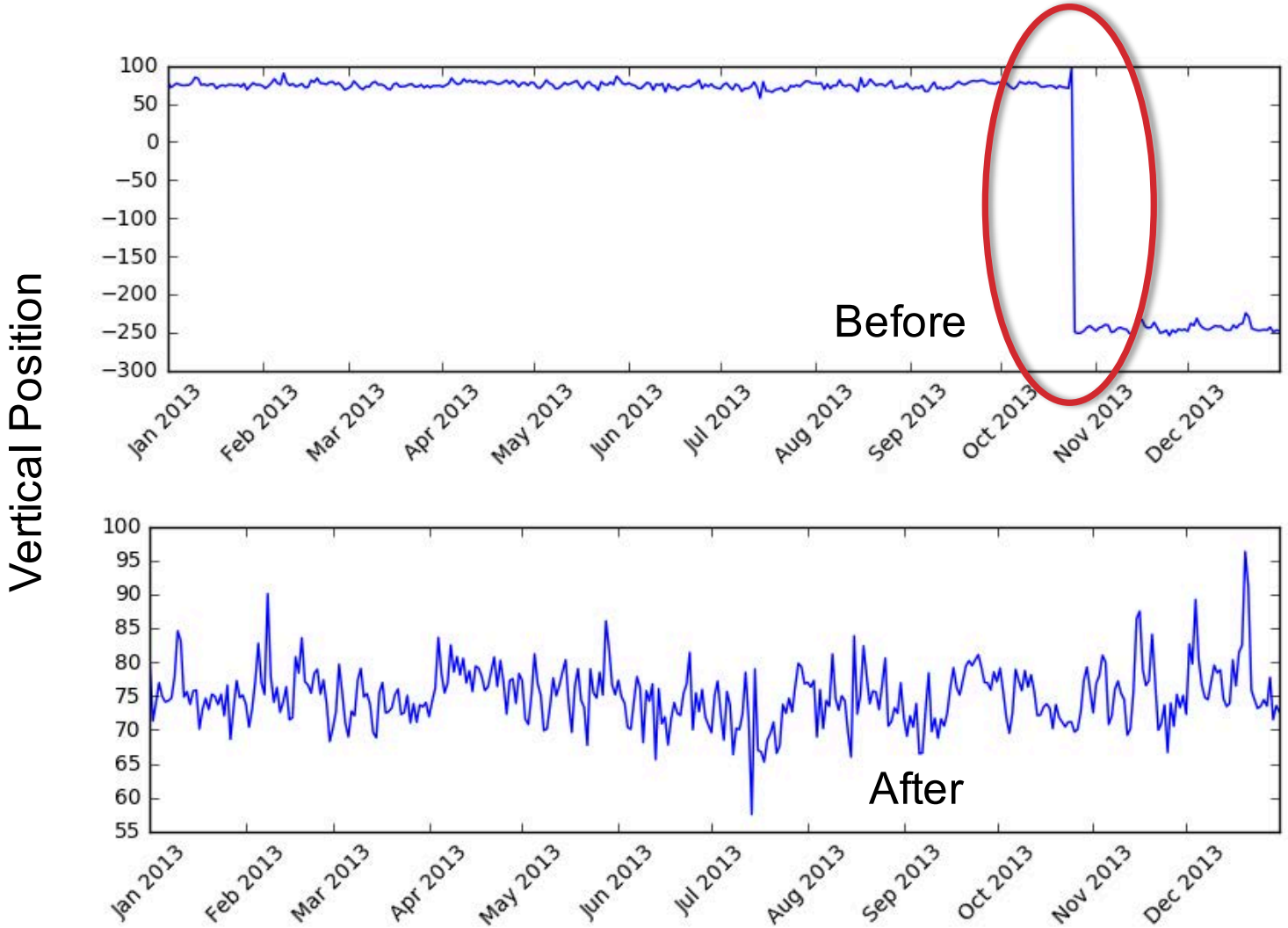


Example station P156

https://www.unavco.org/instrumentation/networks/status/pbo/overview/P156

ANTENNA FIXES

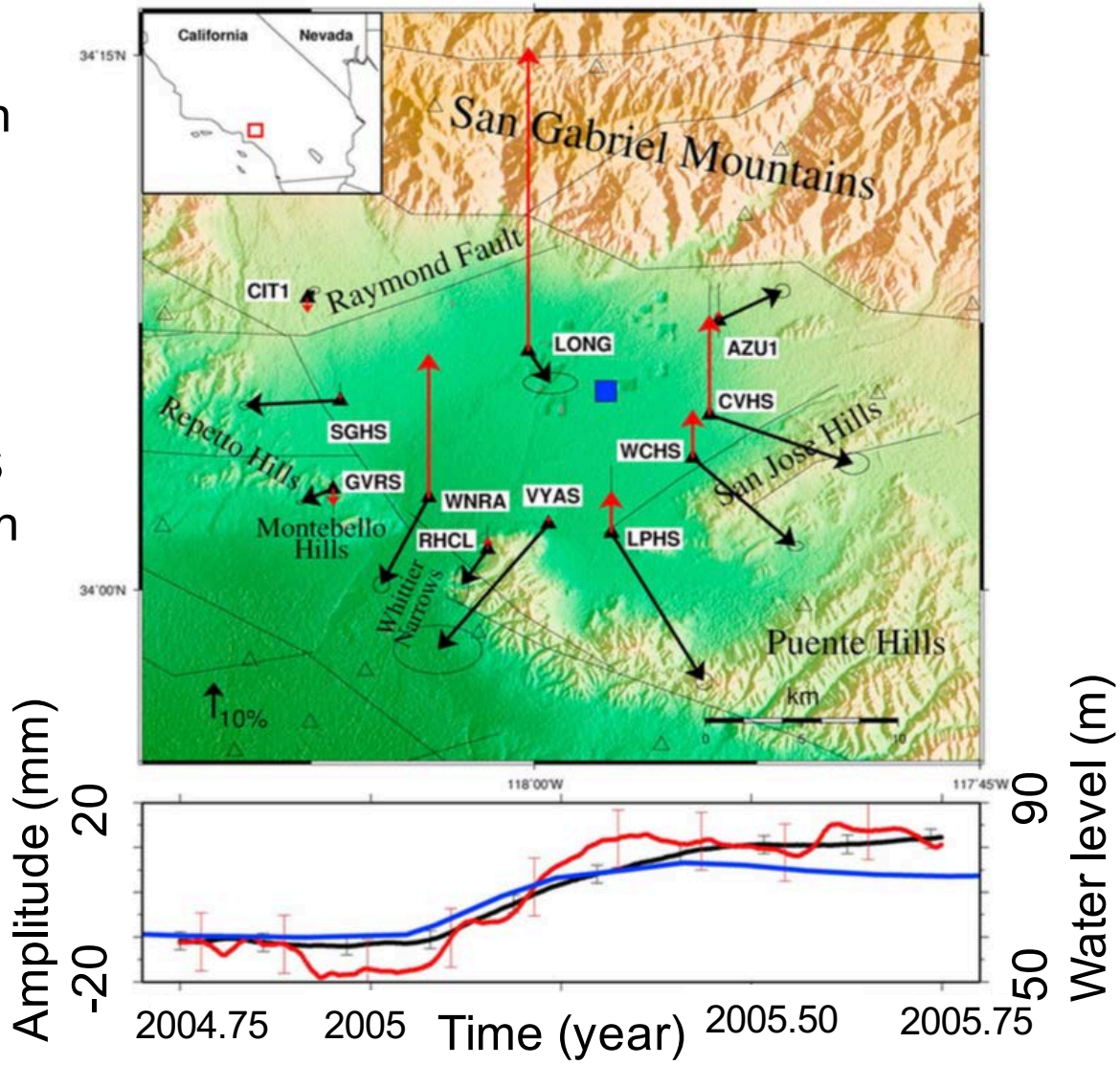
When a GPS receiver's antenna is changed, a break may occur in the time series



GROUNDWATER AND GPS

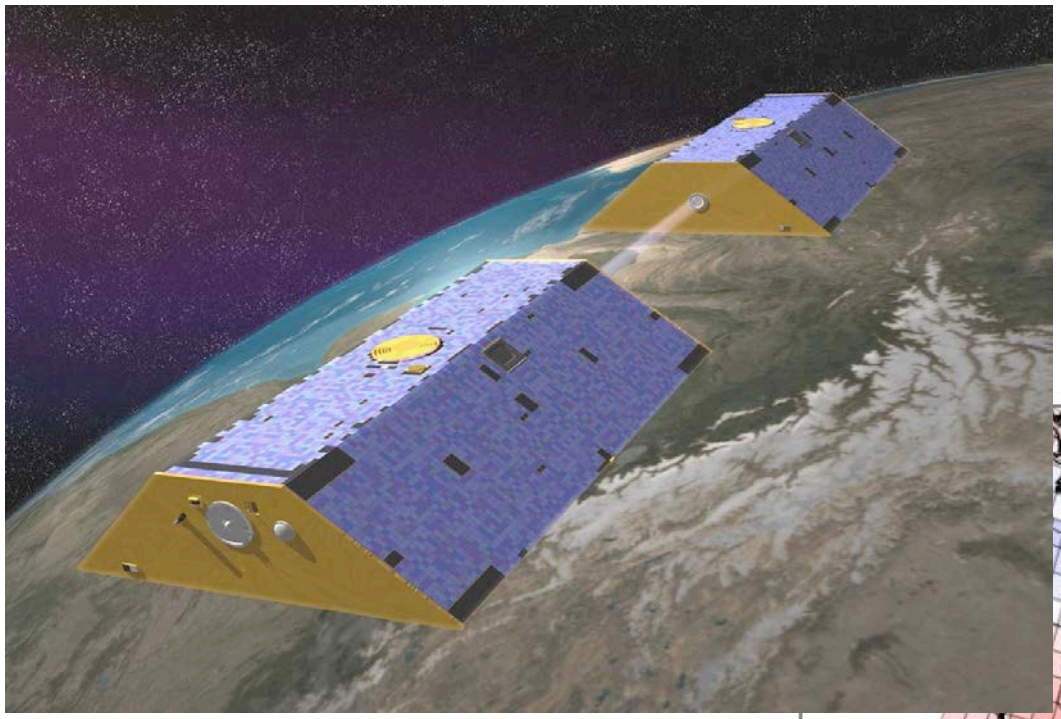
- Large amount of rain in San Gabriel Valley during 2005
- Comparison between groundwater well and GPS
- PCA decomposition of GPS stations revealed correlation with water level

Black arrows show horizontal PCA, red arrows show vertical PCA, and blue square is well location



Ji, K. H. and Herring, T., A., 2012, GRL, 39, L01301

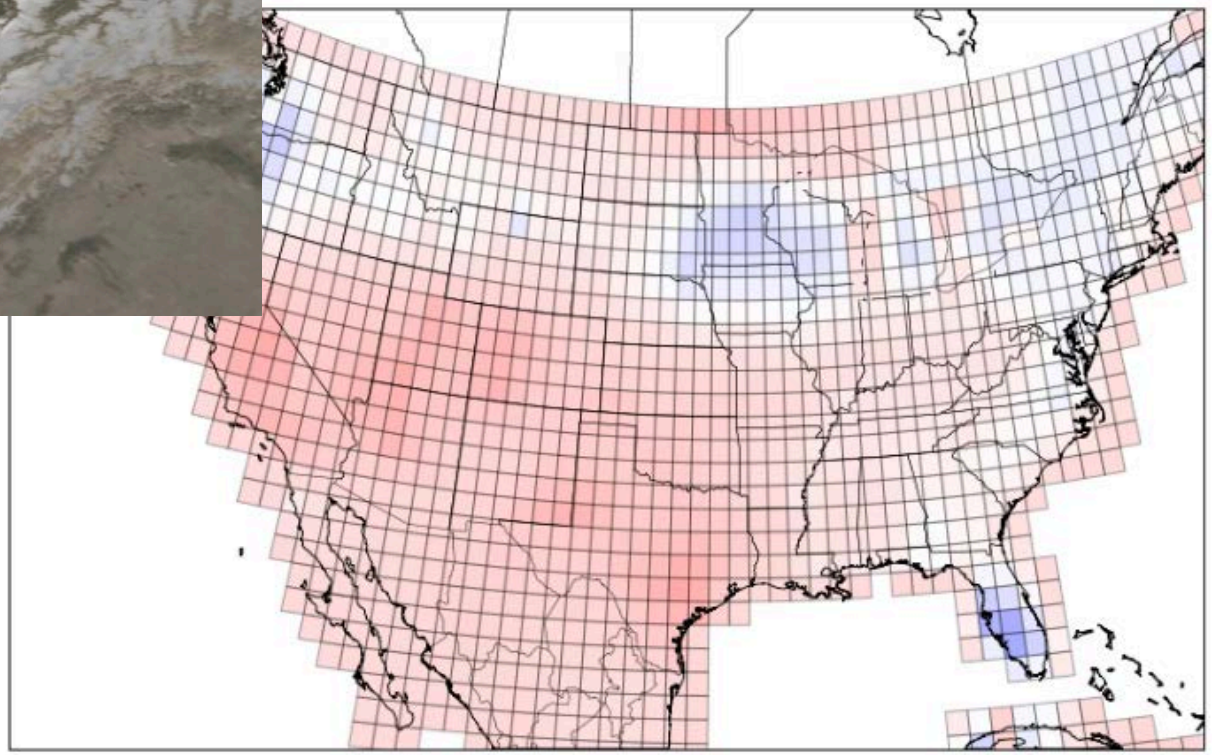
GRAVITY RECOVERY AND CLIMATE EXPERIMENT



Artist impression of GRACE

http://photojournal.jpl.nasa.gov/catalog/PIA04235

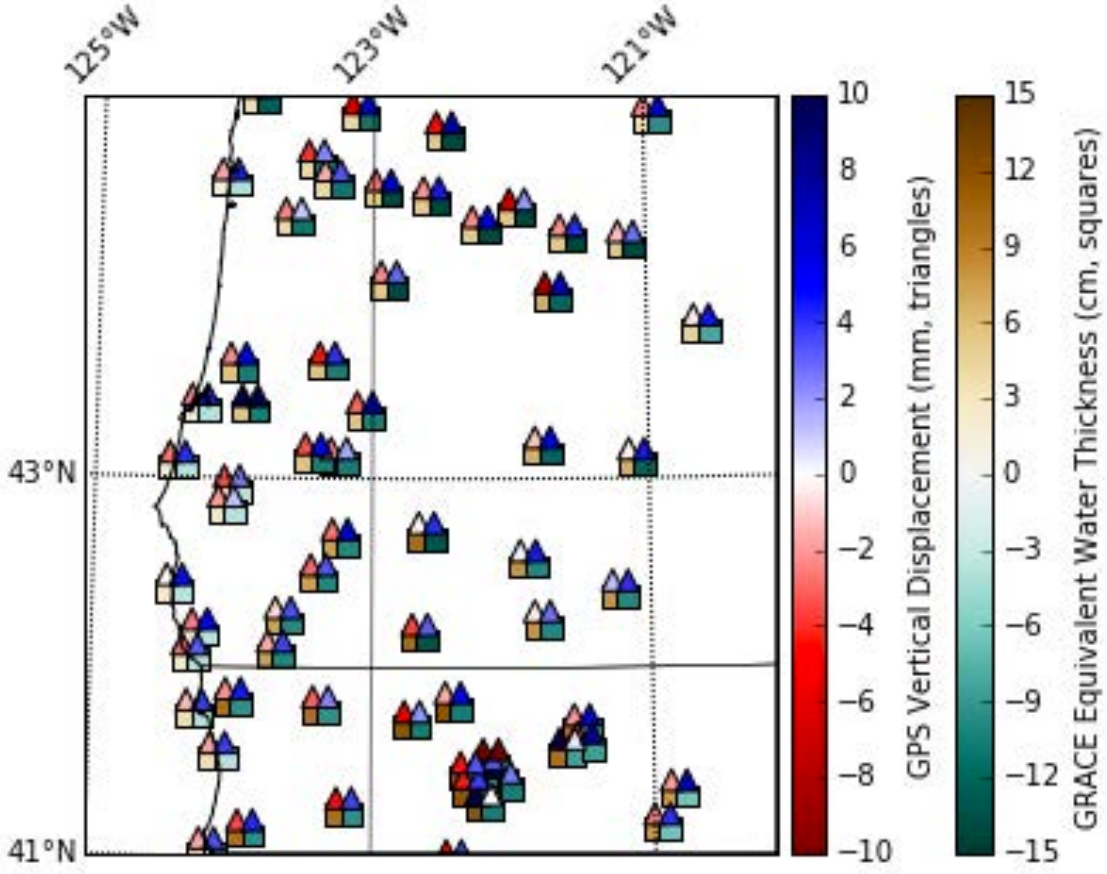
1x1 square degree GRACE terrestial water storage equivalent water depth measurements over US



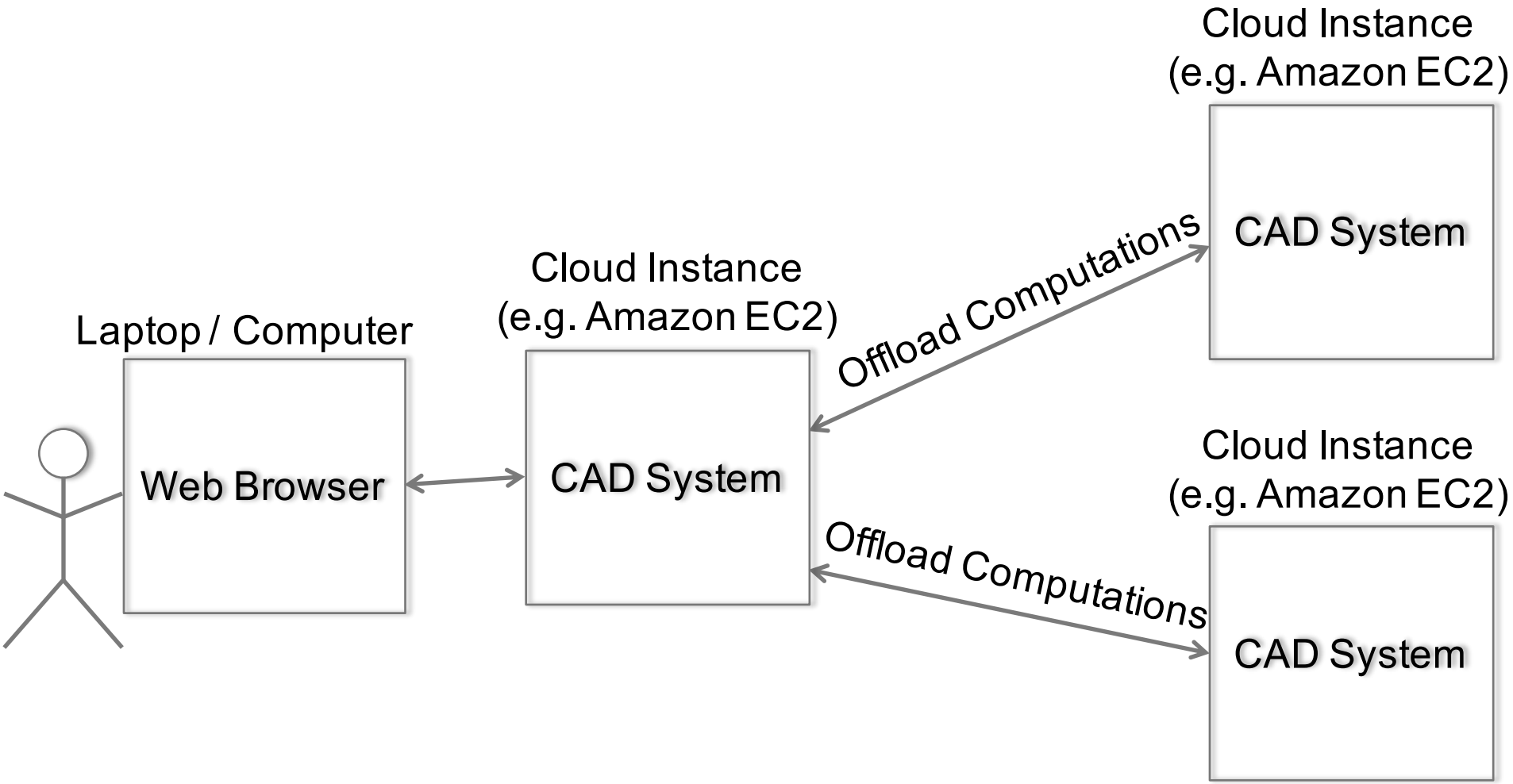
COMPARISON OF GRACE AND GPS

Vertical GPS position (triangles) and GRACE (squares) with linear detrending

Left symbols are from March 2010, and right symbols are from August 2010



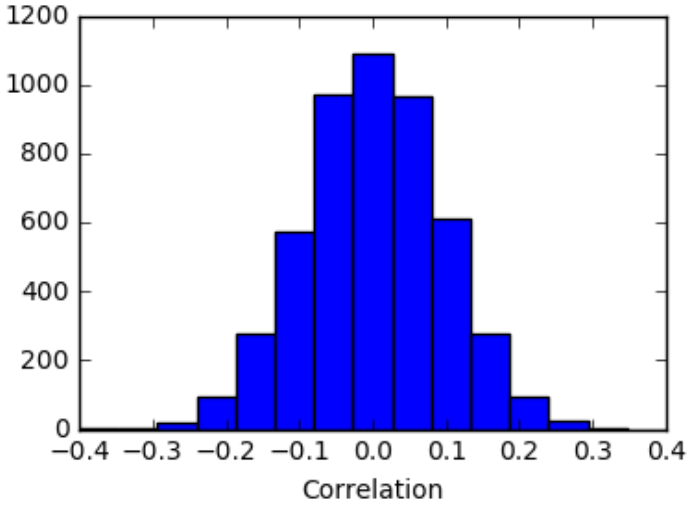
OFFLOADING CORRELATIONS



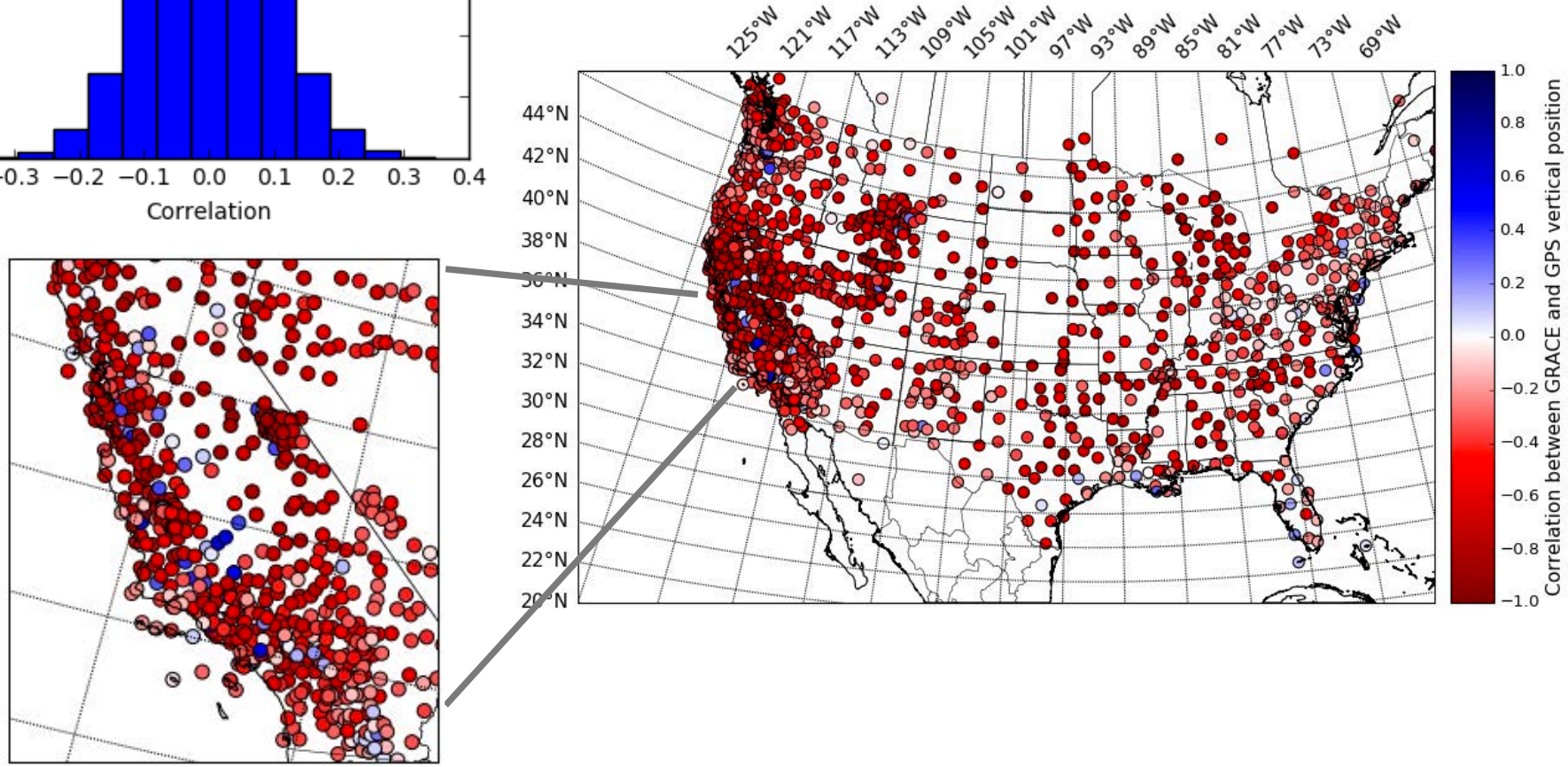
CORRELATIONS OF GPS AND GRACE ACROSS THE US (PEARSON)

- Linear, annual, and semi annual detrending
- Thirty-one day weighted average

Correlations from random signals

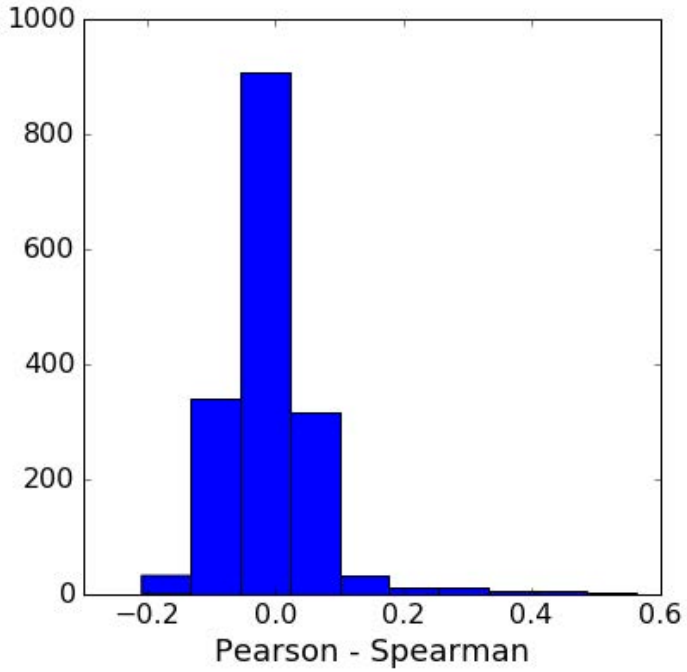


Pearson Correlations between GRACE and Vertical GPS Position

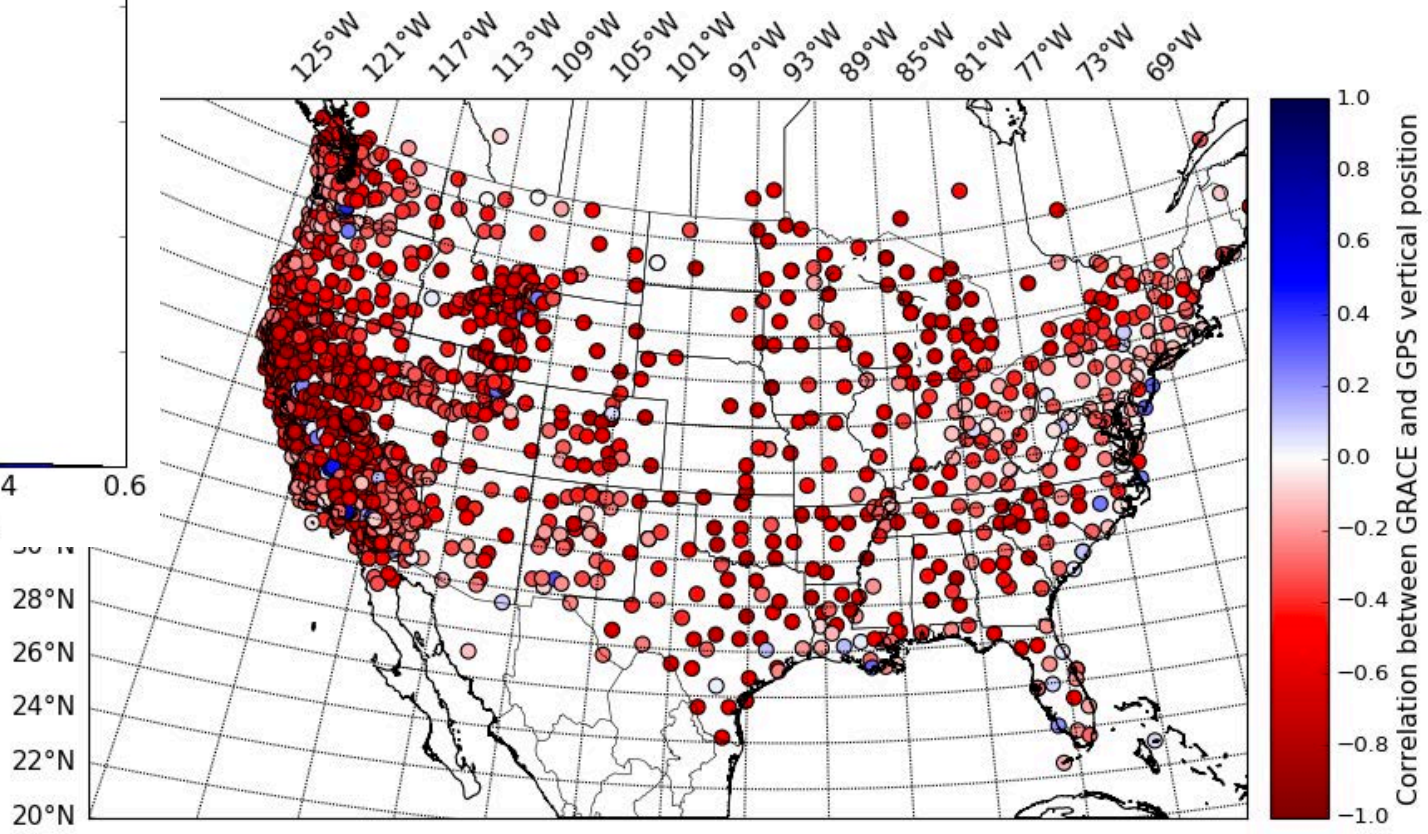


CORRELATIONS OF GPS AND GRACE ACROSS THE US (SPEARMAN)

Difference between Pearson and Spearman Correlations

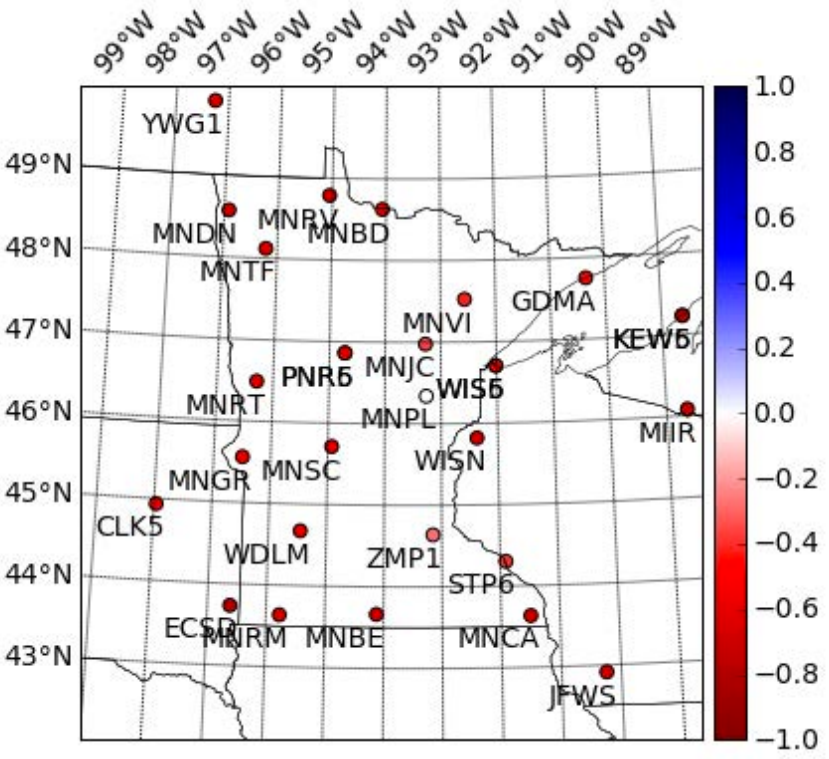


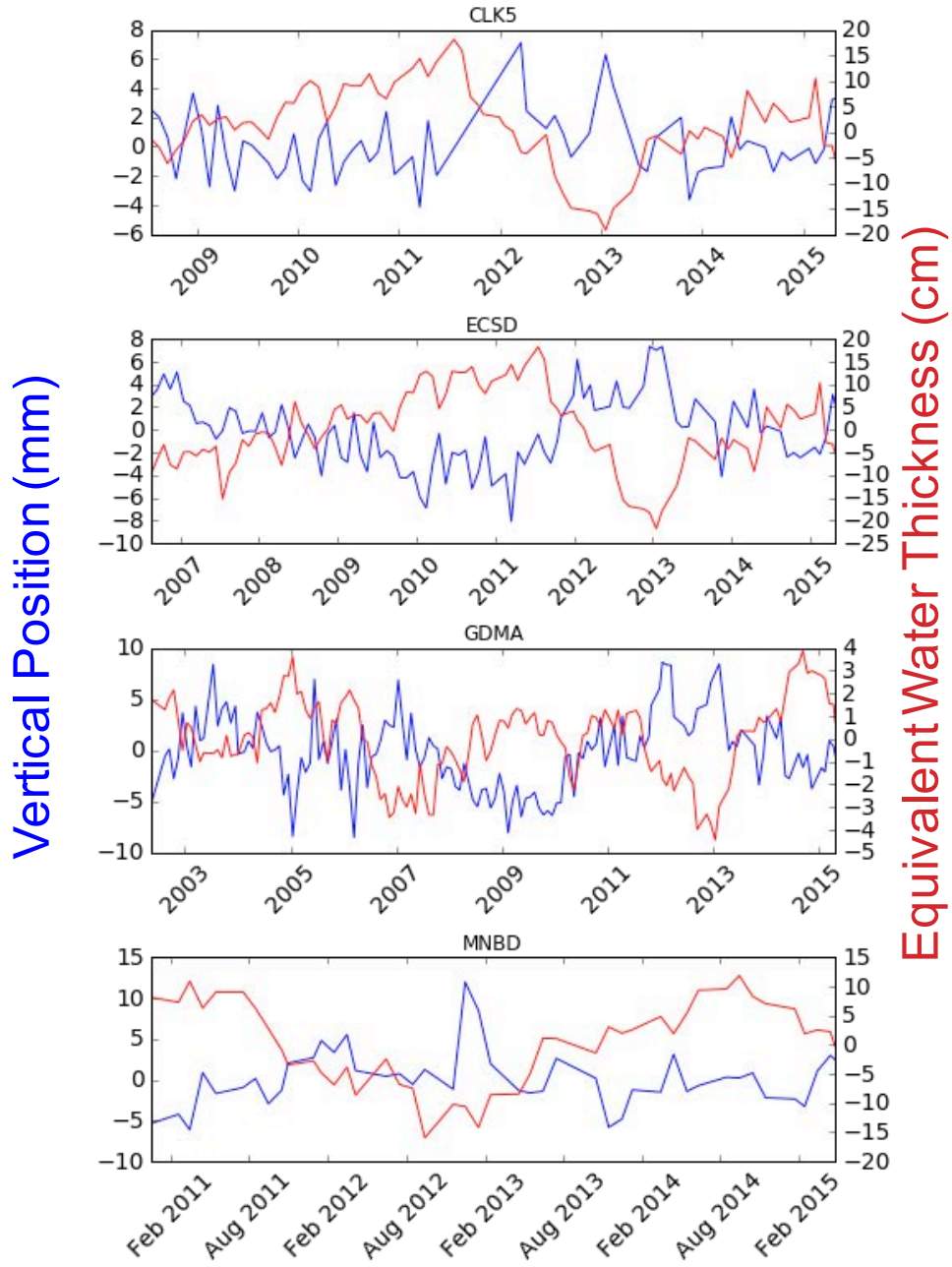
Spearman Correlations between GRACE and Vertical GPS Position



STATIONS AROUND MINNESOTA

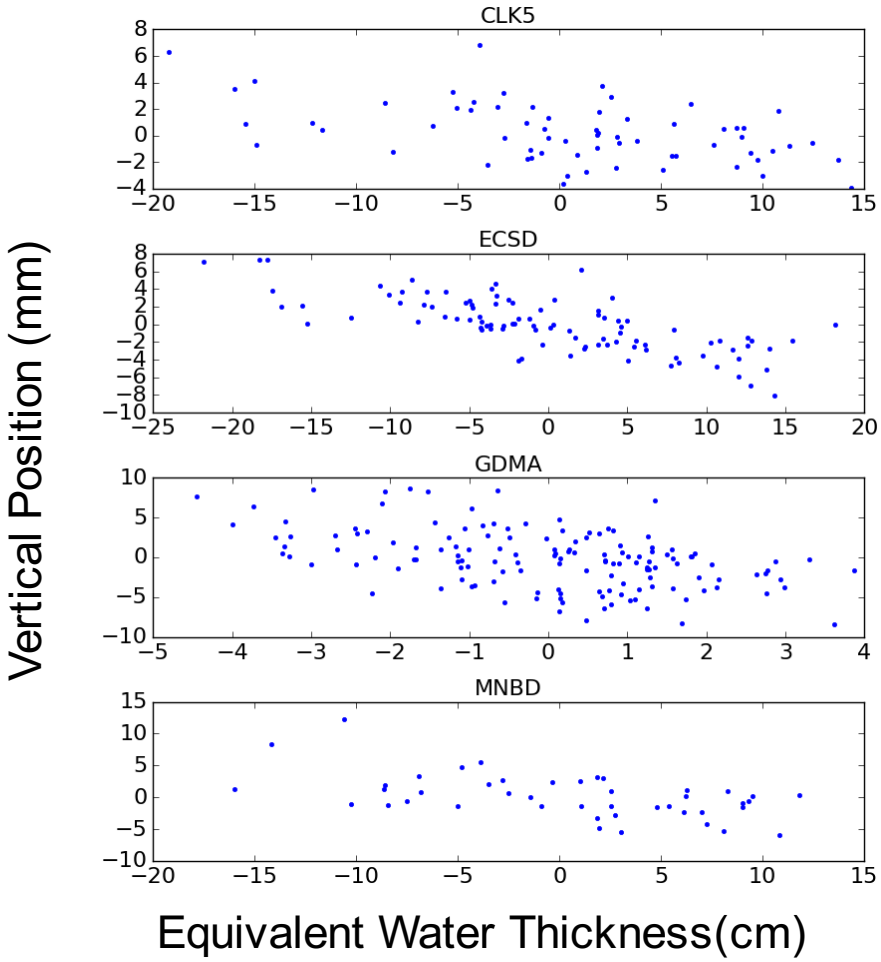
Correlations between GRACE and GPS around Minnesota



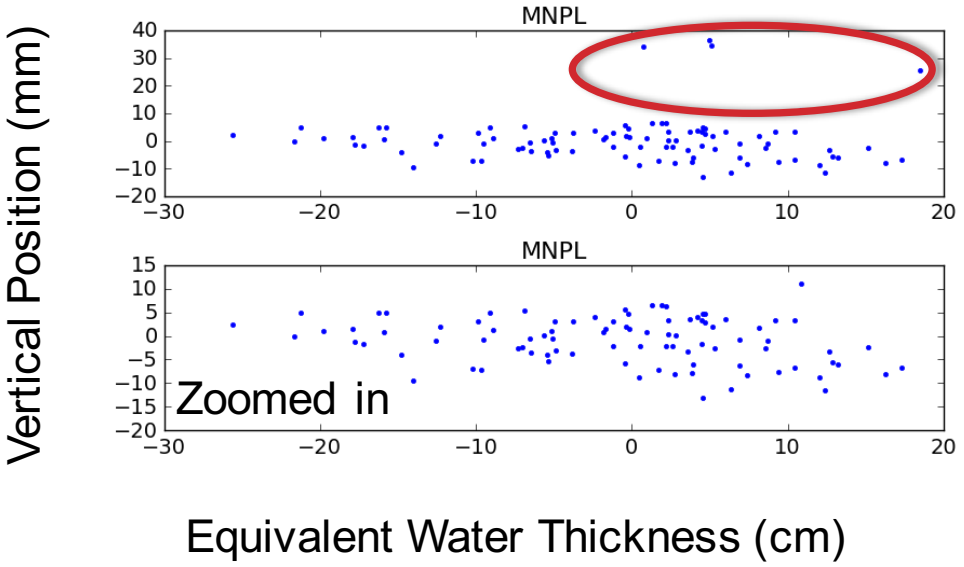


GPS VS GRACE

Vertical position versus equivalent water depth

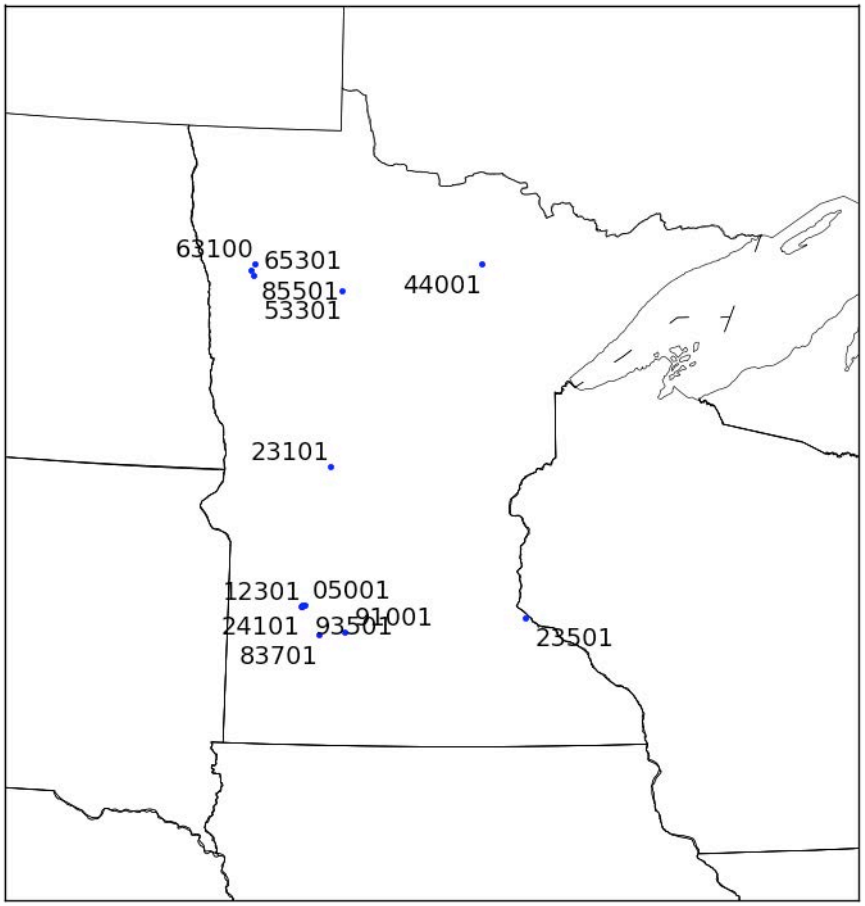


The one station with no correlation contains outliers

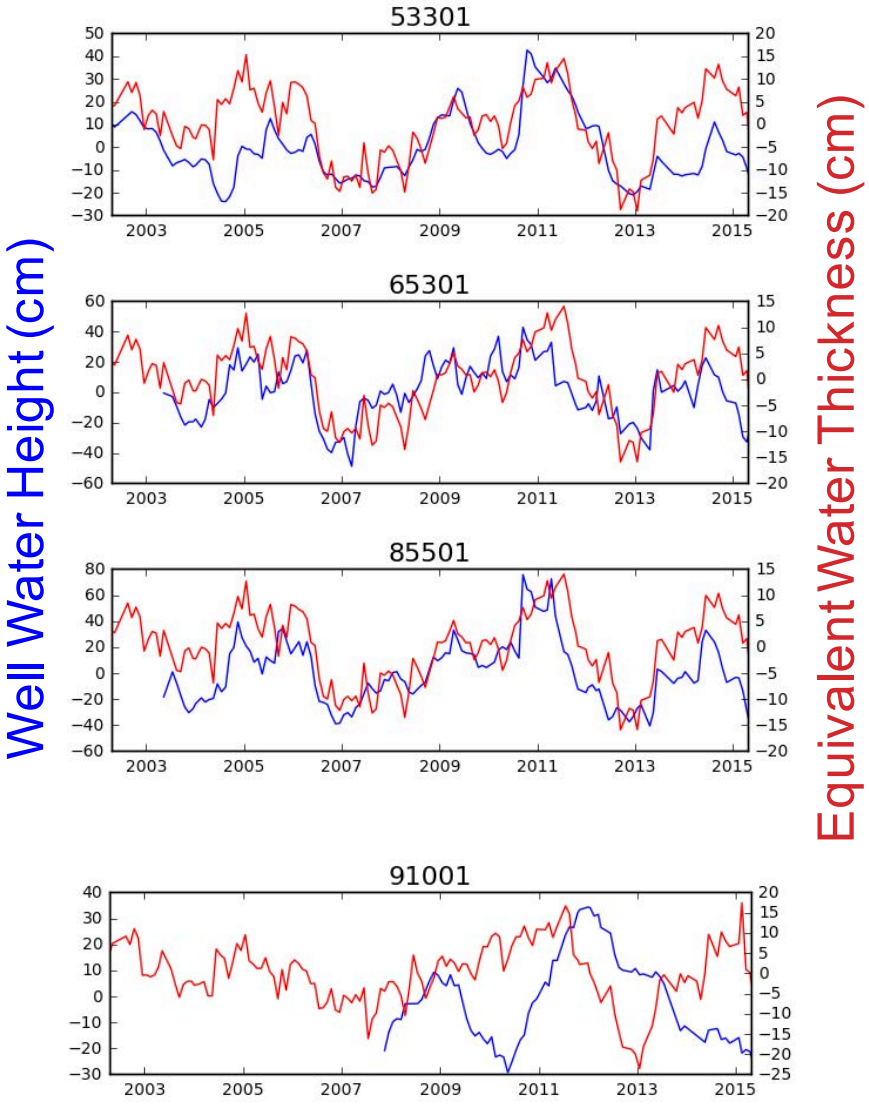


GRACE AND GROUNDWATER IN MINNESOTA

Locations of wells



Wells track local water changes



SUMMARY

- The response of GPS stations to changes in ground water depends on whether the motion is dominated by aquifer expansion or solid Earth deformation
- The majority of GPS stations across the US are negatively correlated with GRACE
- This result has been tested using two different correlation metrics
- The majority of GPS stations are measuring a response to surface loading and not aquifer expansion

WHAT'S NEXT

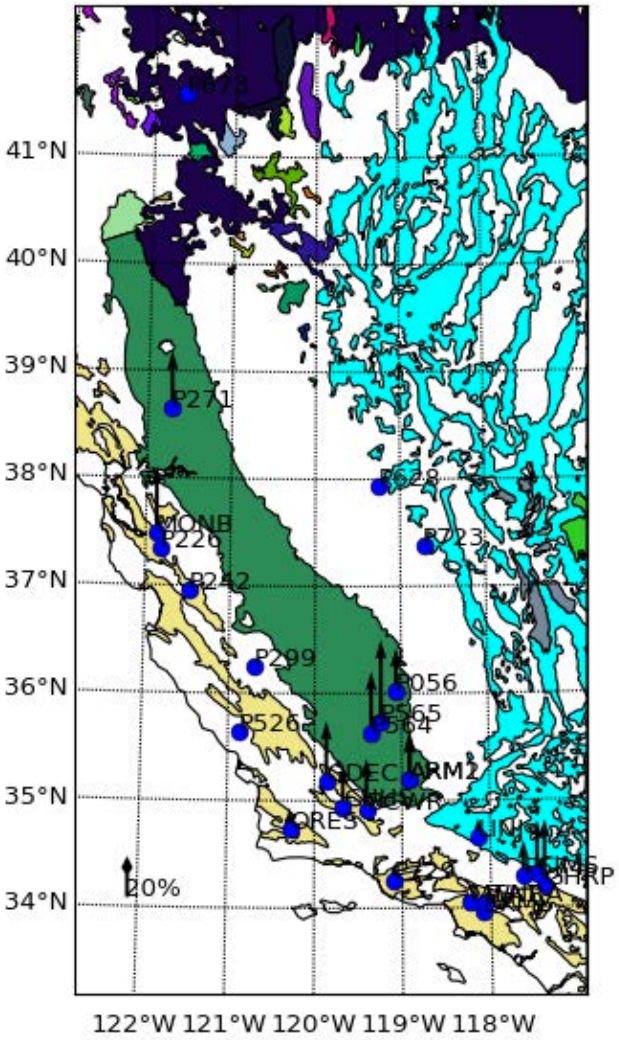
- Integrate additional GPS data
- Use "GPS imaging" techniques to provide a map of groundwater changes inferred from GPS measurements
- Compare GPS results to groundwater wells to determine response of local groundwater changes to GPS

THANK YOU

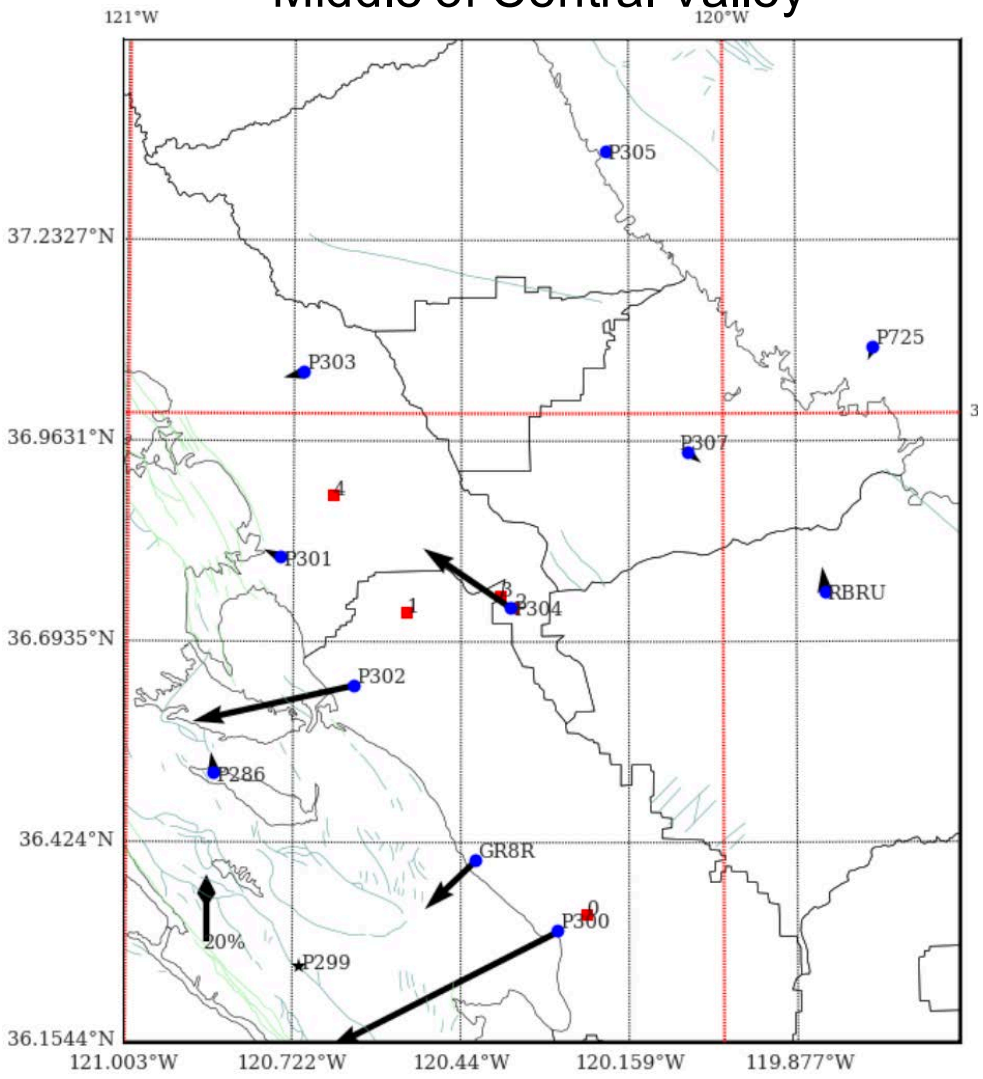
We acknowledge support from NASA AISTNNX15AG84G, NSF ACI1442997, and an Amazon Web Services Research Grant

BACKUP SLIDES

PCA of positively correlated GPS stations in California



Middle of Central Valley



Li, J. D., et al, in prep