MIT EARTH RESOURCES LABORATORY
ANNUAL FOUNDING MEMBERS MEETING 2018

Earth Resources Laboratory

Surface deformations due to changes in terrestrial water storage across the contiguous United States

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Overview

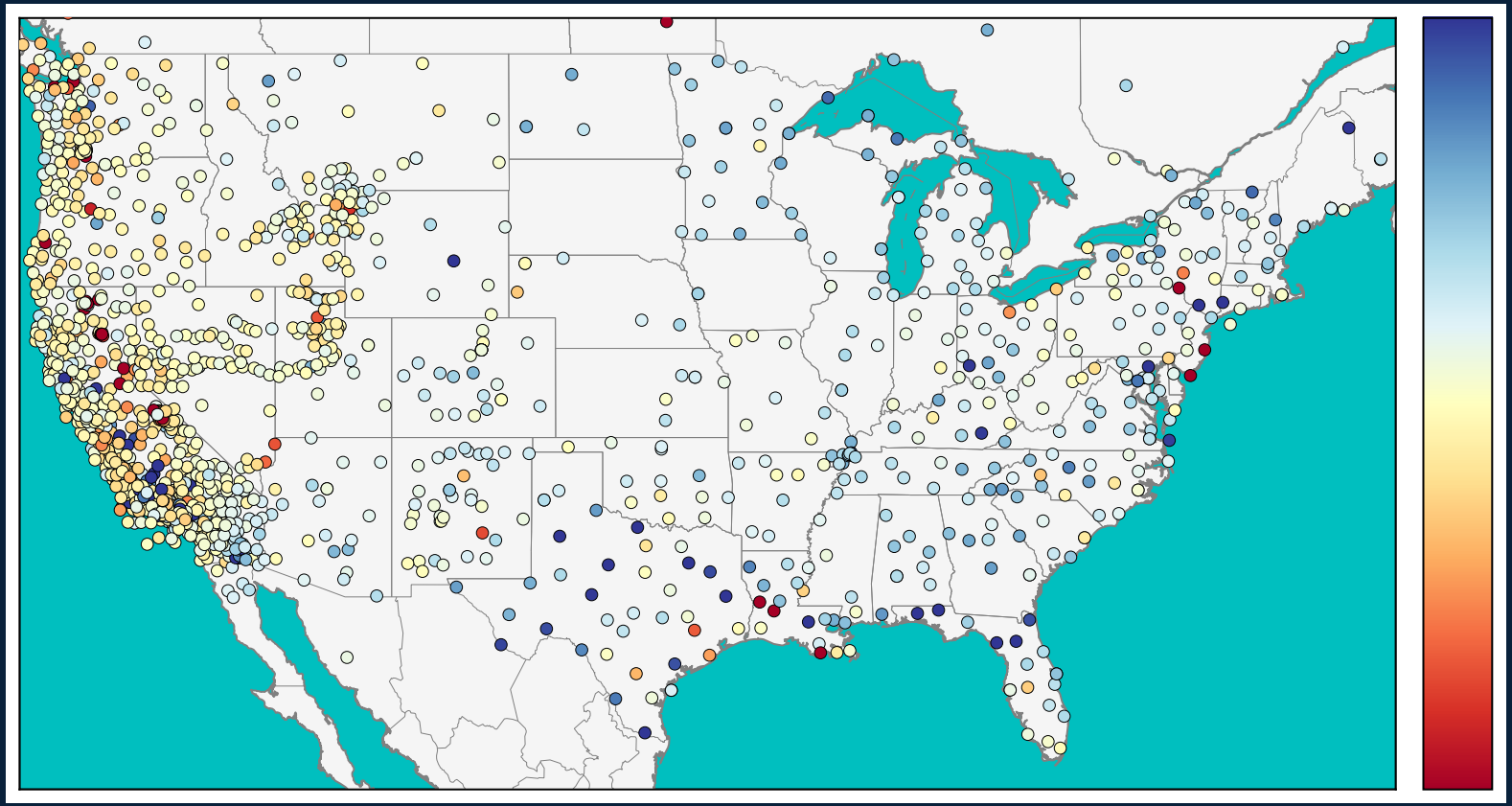
DUE TO THE GROWING SCARCITY OF WATER, KNOWLEDGE OF WATER RESOURCES IS BECOMING INCREASINGLY IMPORTANT FOR POLICY MAKERS AND RESIDENTS.

OPPORTUNITY:
CHANGES IN WATER LEVELS AFFECT THE SURFACE OF THE EARTH. THESE DEFORMATIONS CAN BE MEASURED IN GPS NETWORKS ALREADY DEPLOYED ACROSS THE UNITED STATES. GPS HAS A BETTER TEMPORAL RESOLUTION THAN GRACE. UNTIL 2017, GRACE WAS COMMONLY USED FOR TRACKING TERRESTRIAL WATER STORAGE

CHALLENGE:
THE RESPONSE OF EARTH'S SURFACE TO CHANGES IN WATER LEVELS DEPENDS ON THE MATERIAL. BEDROCK WILL FALL WITH AN INCREASE IN WATER AS IT RESPONDS ELASTICALLY TO CHANGES IN LOADING. HOWEVER, POROELASTIC AQUIFERS WILL RISE WHEN FILLED WITH WATER.

OUR APPROACH:

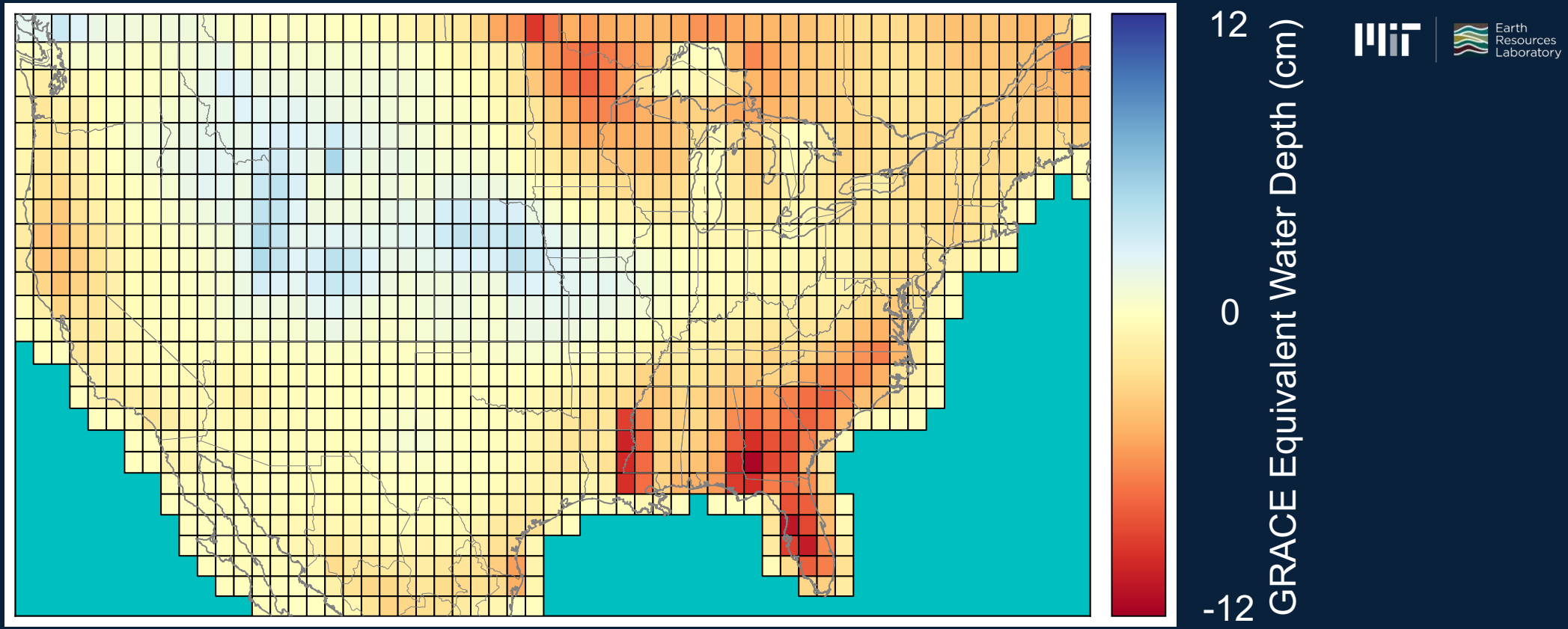
- WE CORRELATE TERRESTRIAL WATER STORAGE FROM GRACE WITH GPS VERTICAL POSITIONS ACROSS THE UNITED STATES
- WE EXPLORE THE RESULTS USING A VARIABLE RESOLUTION INTERPOLATION TECHNIQUE



GPS Data

- GPS STATIONS FROM THE PLATE BOUNDARY OBSERVATORY
- VERTICAL POSITION AVERAGED OVER FEBRUARY, 2012

This material is based on data services provided by the Plate Boundary Observatory operated by UNAVCO for EarthScope (www.earthscope.org) and supported by the National Science Foundation No. EAR-0350028 and EAR-0732947.



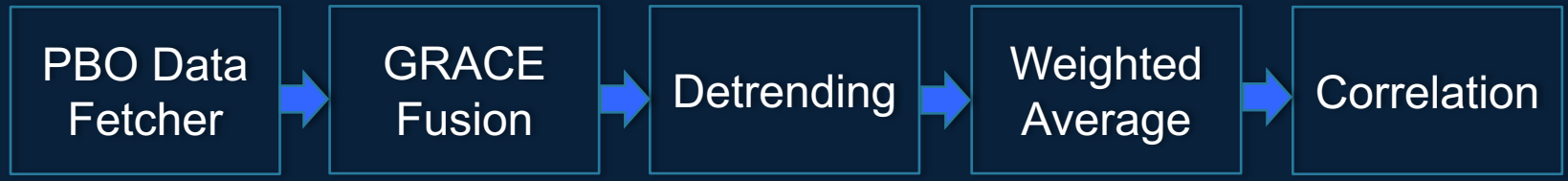
GRACE Data

- GRACE DATA FOR FEBRUARY 2012 AFTER PROCESSING
- EACH SQUARE REPRESENTS 1° × 1°

GRACE land datasets are available at http://grace.jpl.nasa.gov, supported by the NASA MEaSUREs Program

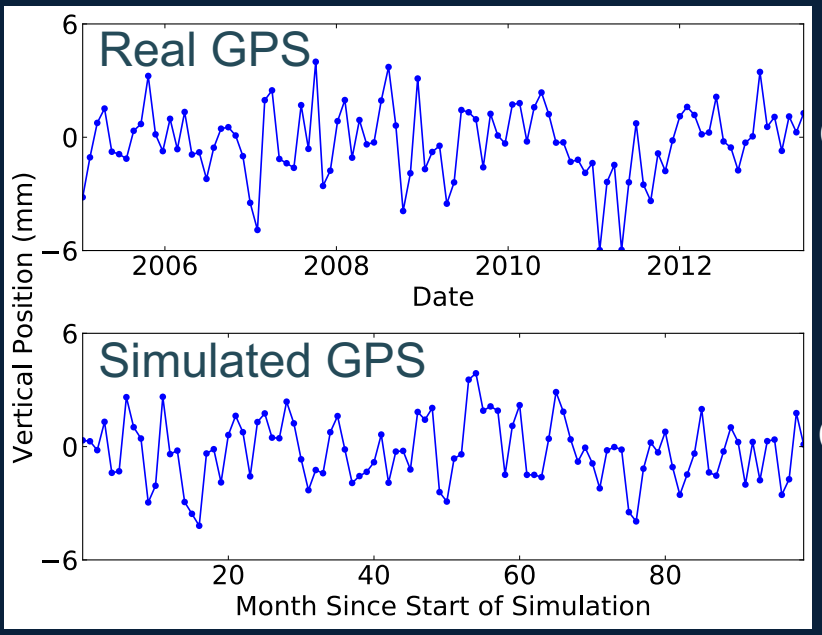
Processing Pipeline

Open access Jupyter notebooks available
github.com/MITHaystack/science-casestudies



- **PBO DATA FETCHER**
  RETRIEVES TIME SERIES OF VERTICAL POSITION WITH A DAILY TEMPORAL RESOLUTION
- **GRACE FUSION**
  LOCATES THE APPROPRIATE GRACE DATA FOR EACH GPS STATION
- **DETRENDING**
  REMOVES LINEAR, ANNUAL, AND SEMI-ANNUAL SIGNALS
- **WEIGHTED AVERAGE**
  SMOOTHS THE GPS DATA USING A WEIGHTED AVERAGE
- **CORRELATION**
  COMPUTES THE SPEARMAN AND PEARSON CORRELATION

GRACE and GPS Correlations



Correlate

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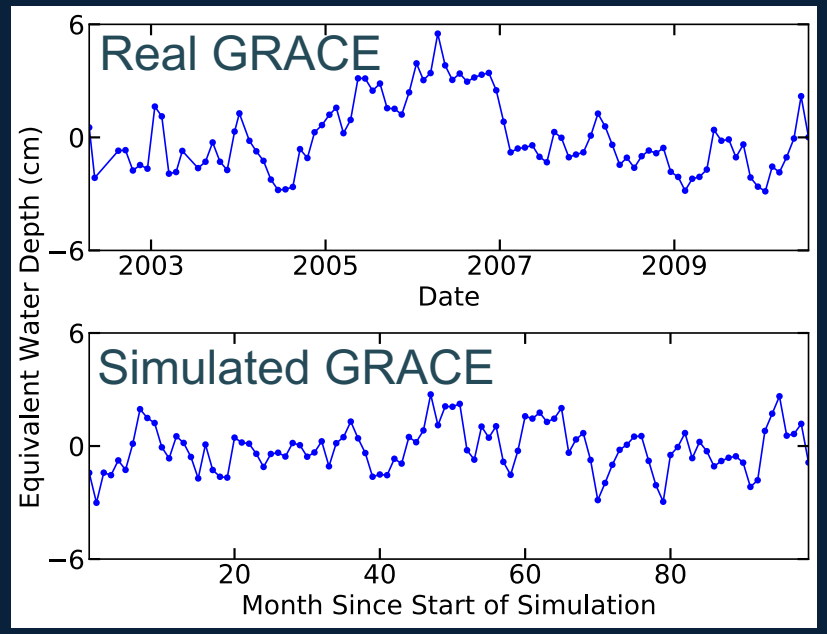
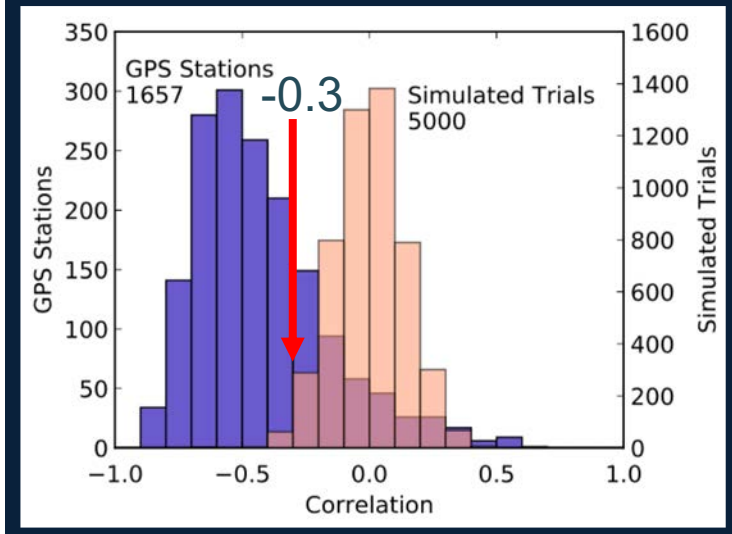
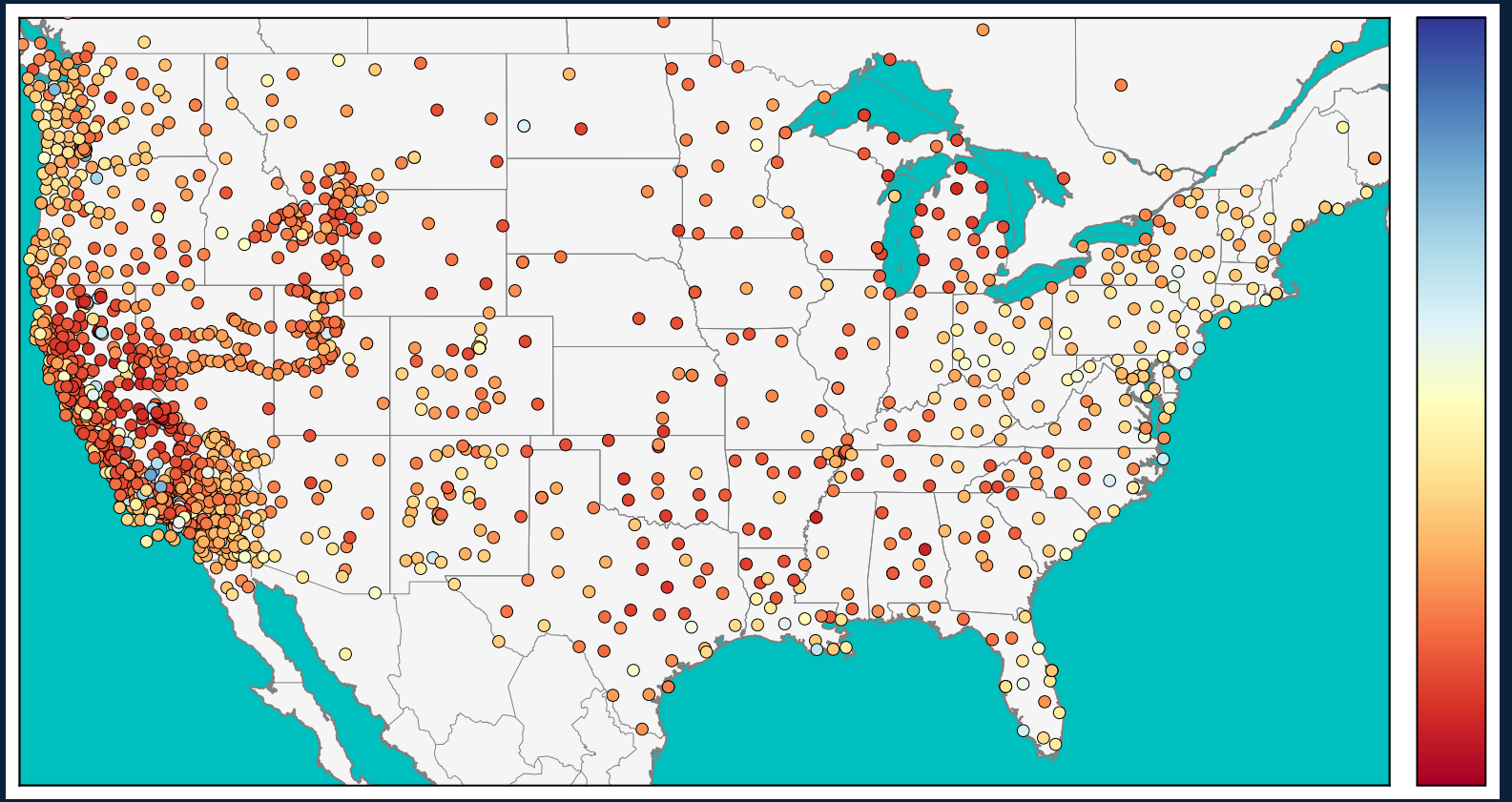




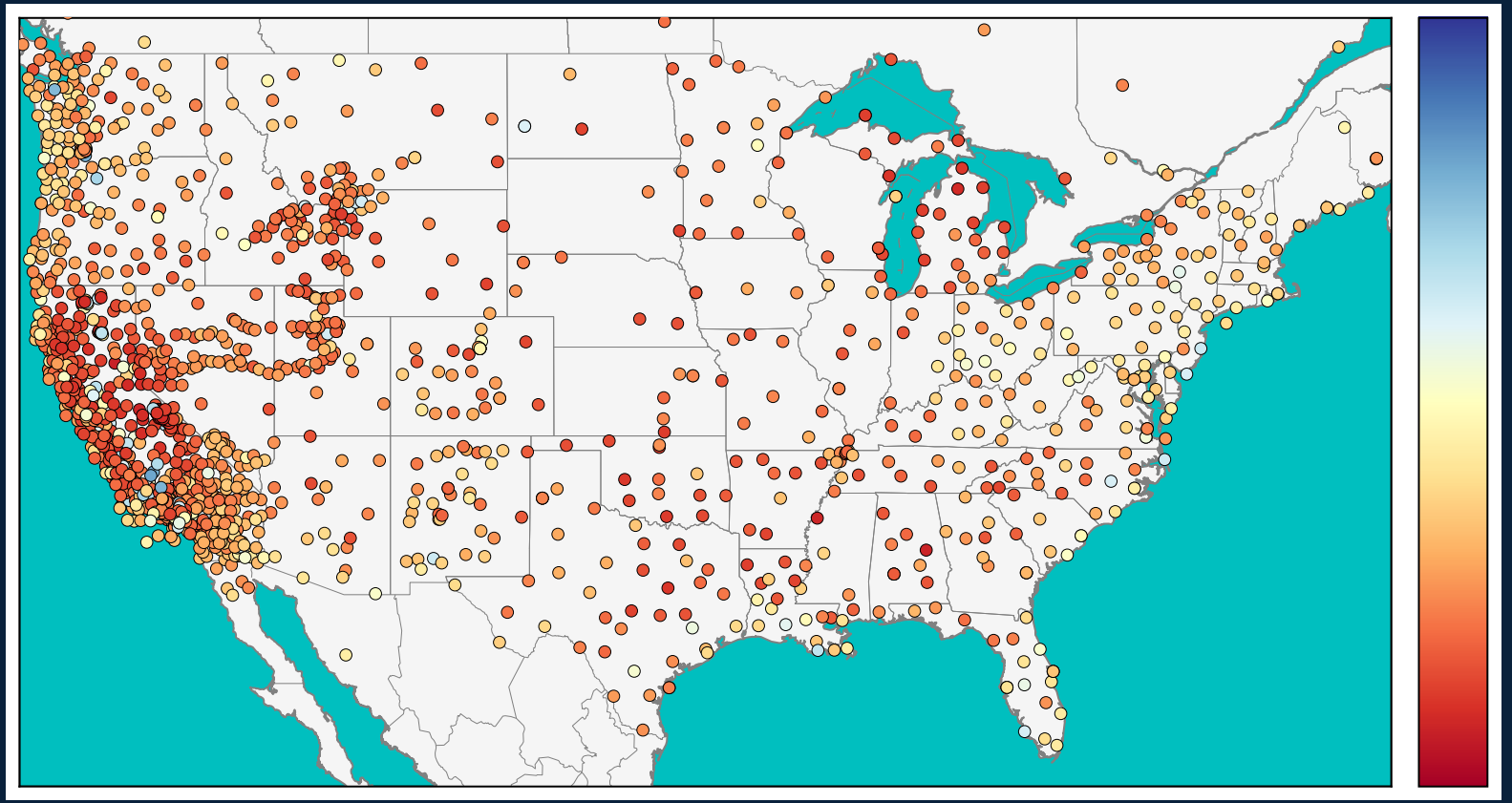
From April 2002 to April 2015



GRACE and GPS Correlations

- EACH DOT MARKS THE LOCATION OF A GPS STATION
- THE COLOR INDICATES THE CORRELATION BETWEEN GPS VERTICAL POSITION AND EQUIVALENT WATER THICKNESS FROM GRACE

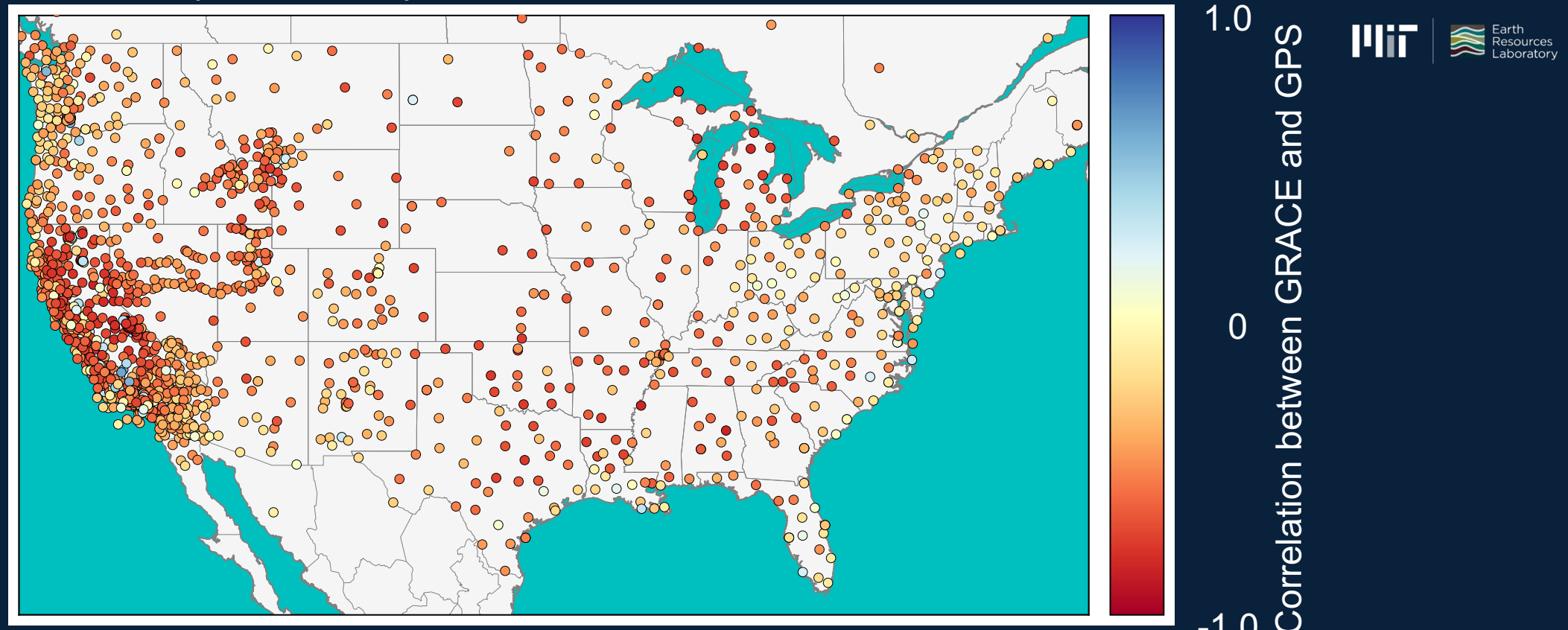
From April 2002 to April 2015



GRACE and GPS Correlations

- NEGATIVE CORRELATIONS ARE DOMINATED BY ELASTIC LOADING
- POSITIVE CORRELATIONS COULD INDICATE POROELASTIC EXPANSION

From April 2002 to April 2015



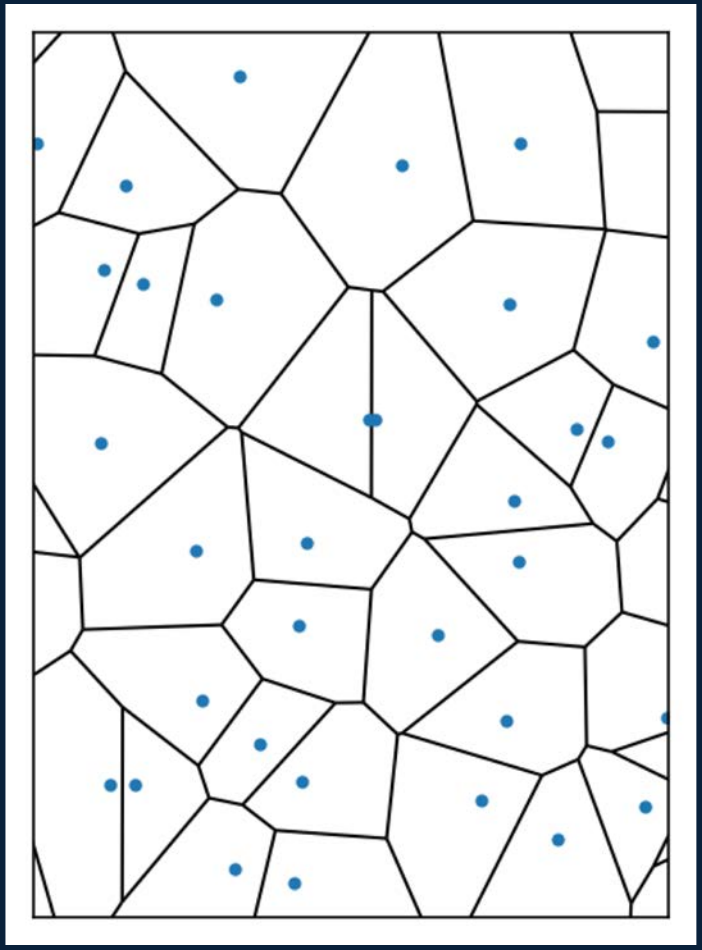
Interpretation difficult with many GPS Stations

- DATA OFTEN OVERLAPS
- POSSIBLY DIFFERENT INTERPRETATION BASED ON WHICH POINTS HAPPEN TO APPEAR ON TOP

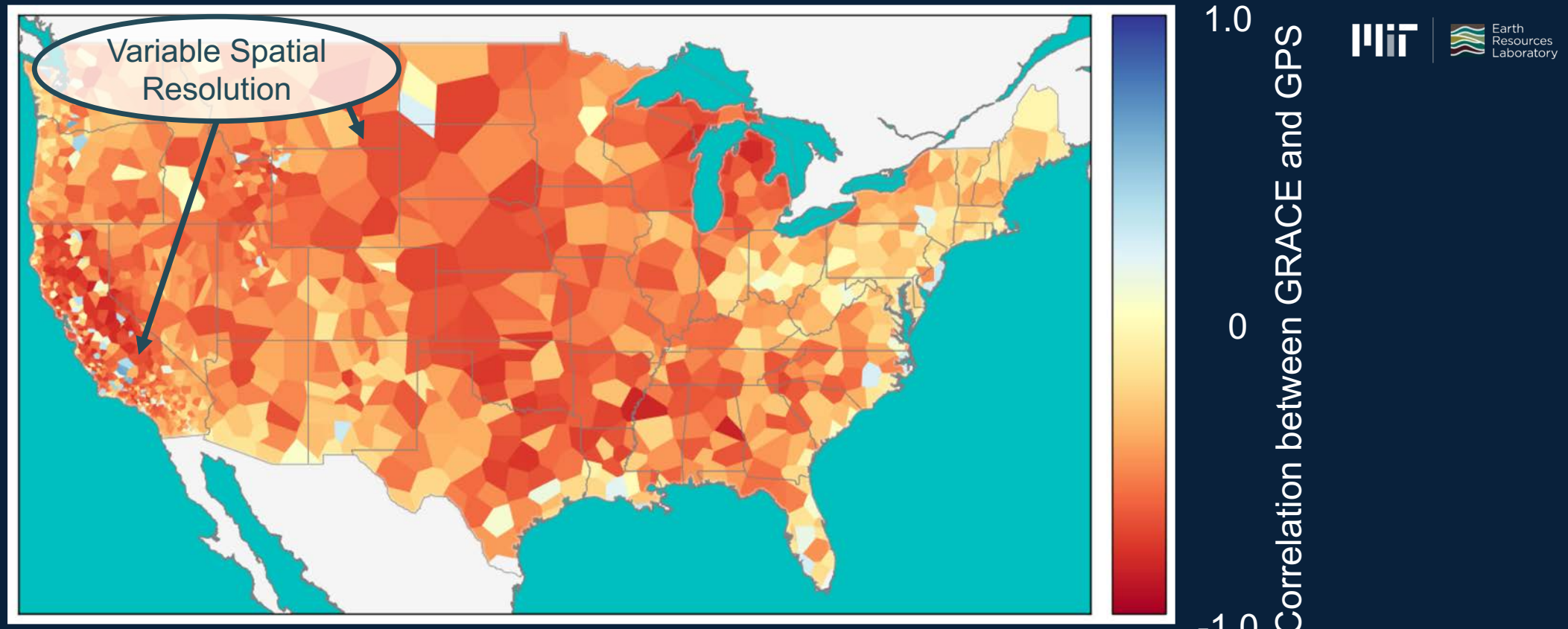
Visualization Approach

SPHERICAL VORONOI TESSELLATION

- **EACH POINT IS ENCLOSED IN A CELL**
- **REGION IN EACH CELL IS CLOSEST TO ENCLOSED POINT**
- **USED FOR ADAPTIVE RESOLUTION INTERPOLATION**



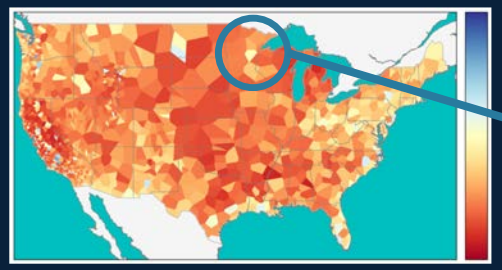
Hammond, W. C., Blewitt, G., & Kreemer, C. 2016, J Geophys Res Solid Earth, 2016JB013458

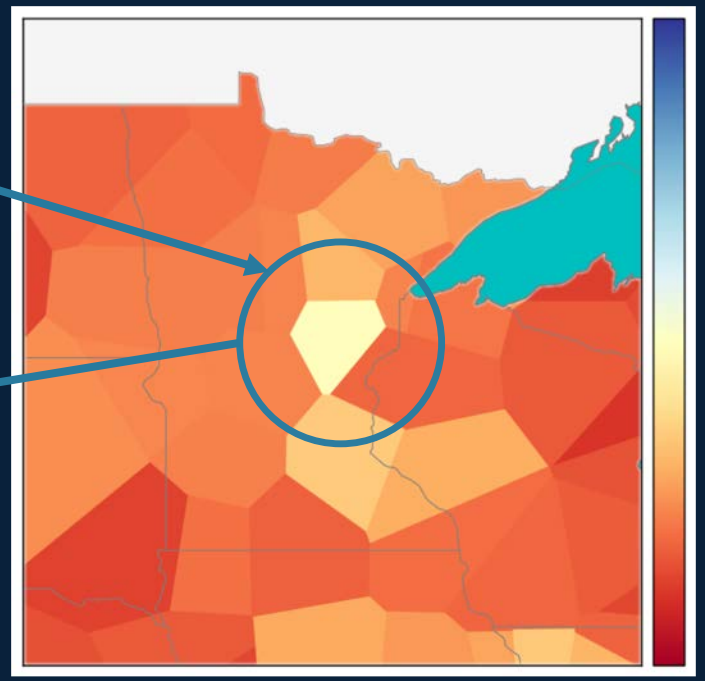


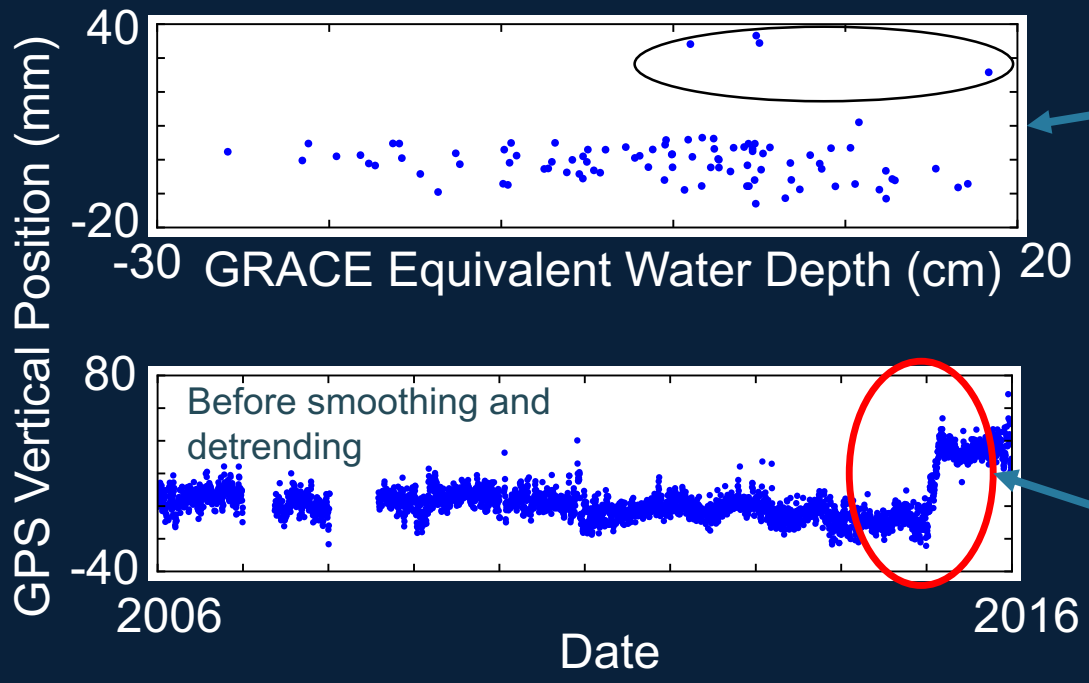
GRACE and GPS Correlations

- EACH CELL'S COLOR IS DETERMINED BY THE ENCLOSED GPS STATION
- CELLS WHOSE CORRELATION VALUE APPEARS TO BE AN OUTLIER MAY CONTAIN INTERESTING BEHAVIOR

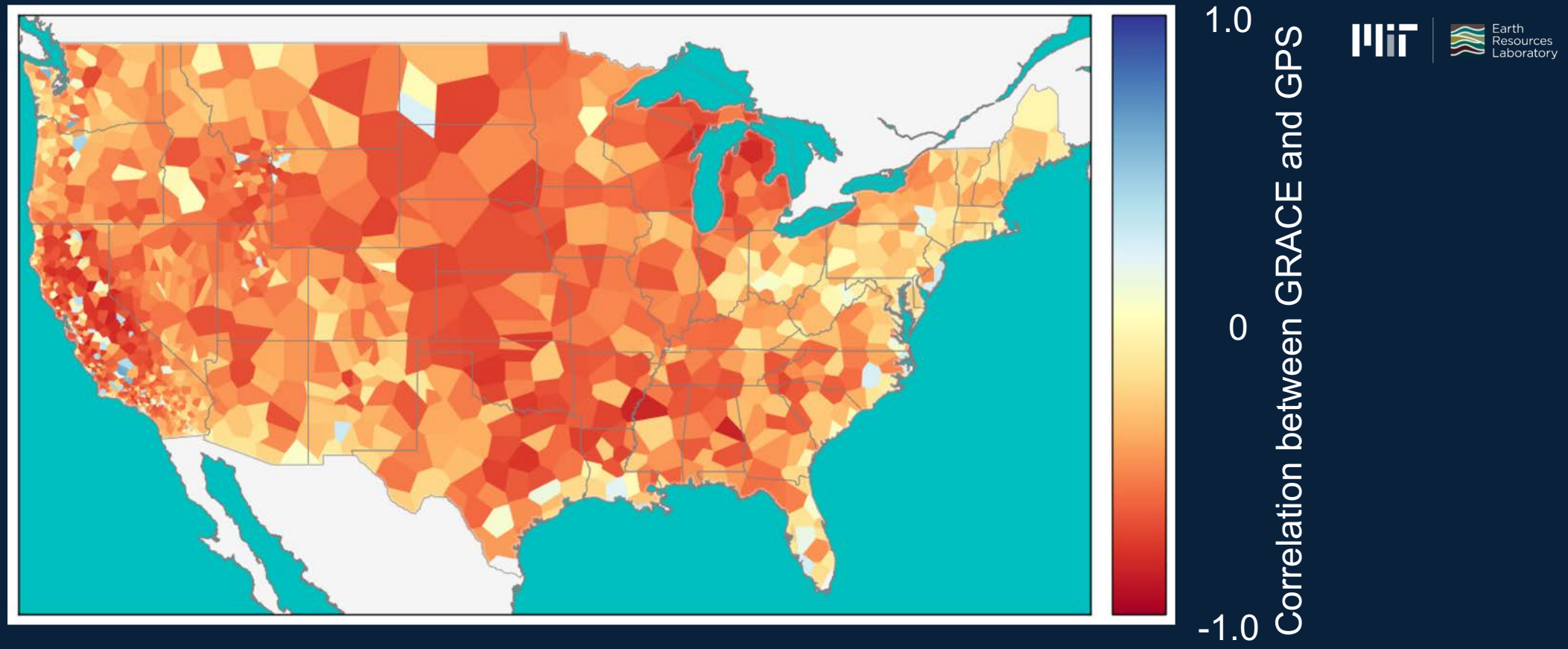
Example: Minnesota



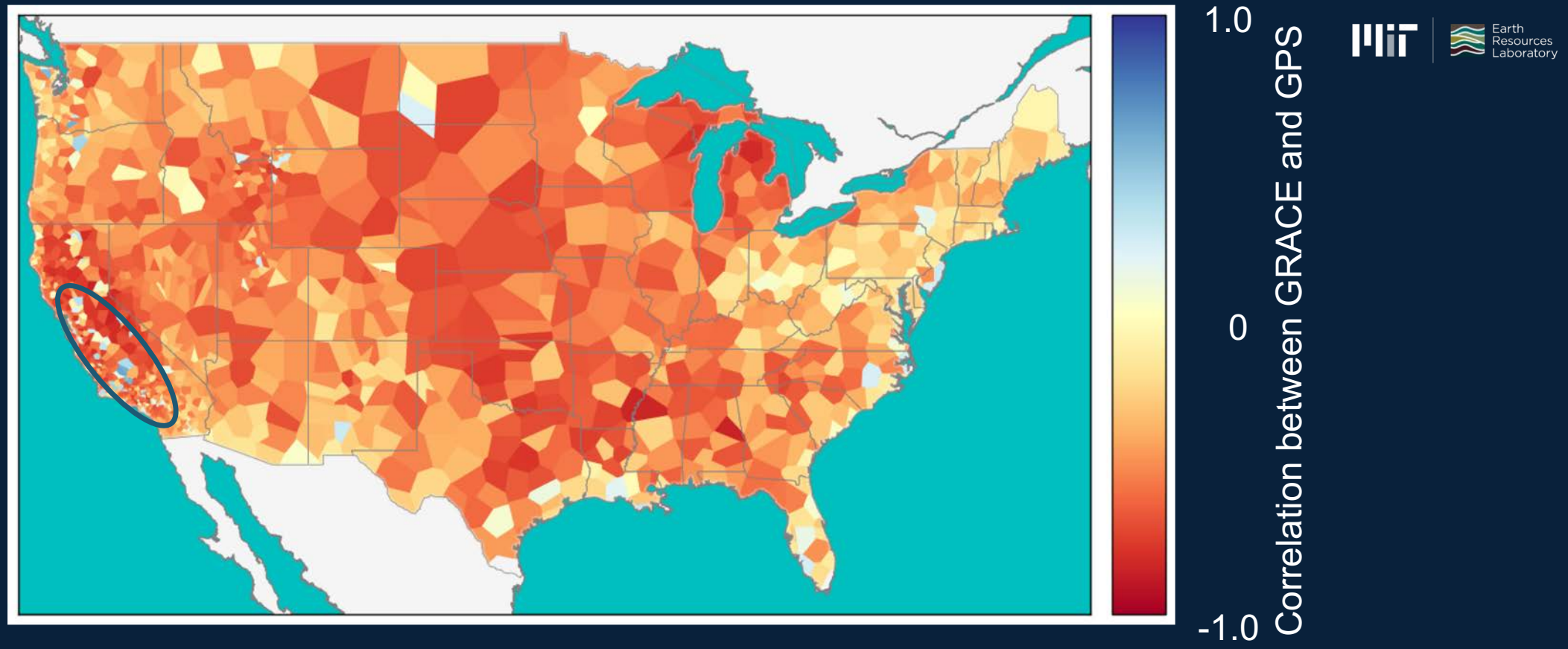




- Discovery of a transient event in GPS data
- Not due to a modification of equipment (i.e. antenna change)

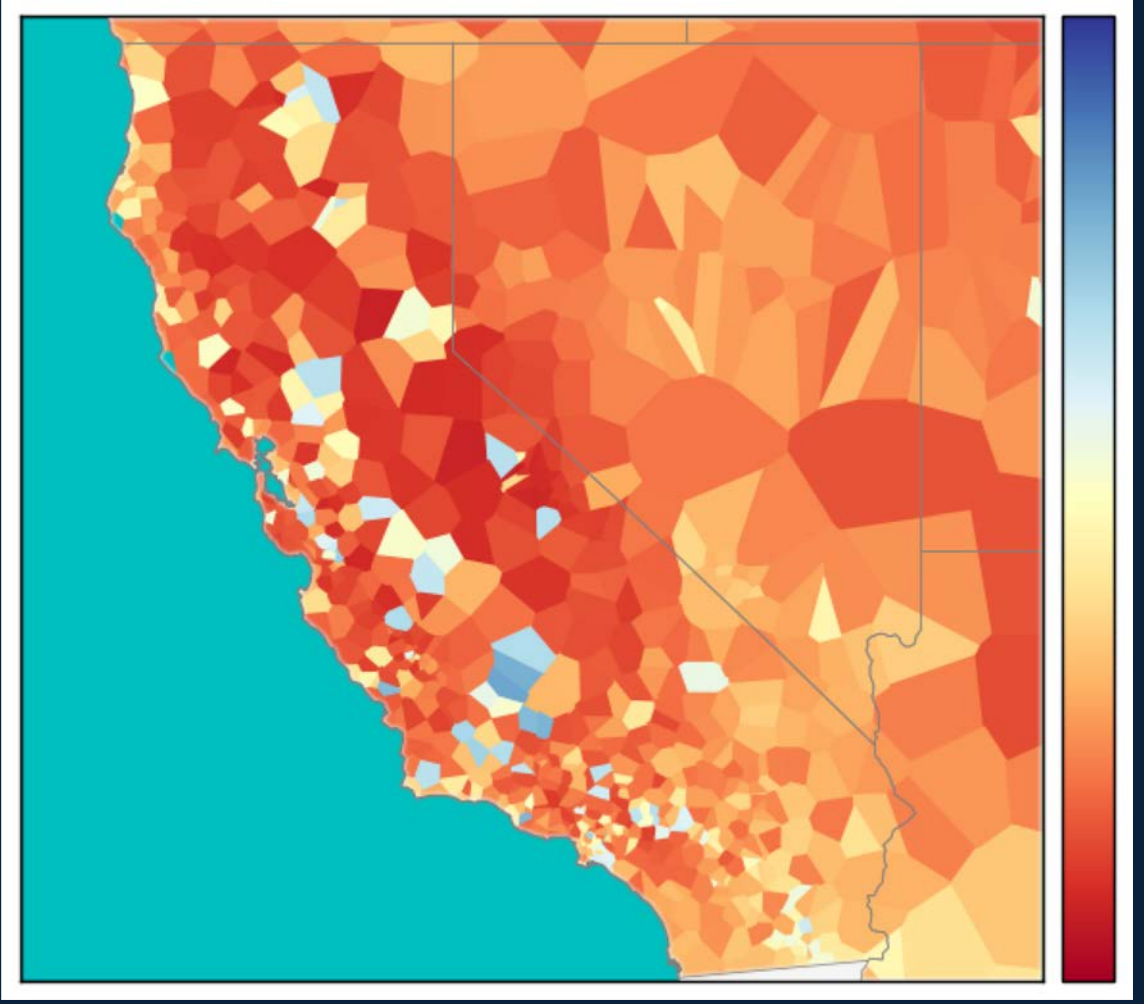


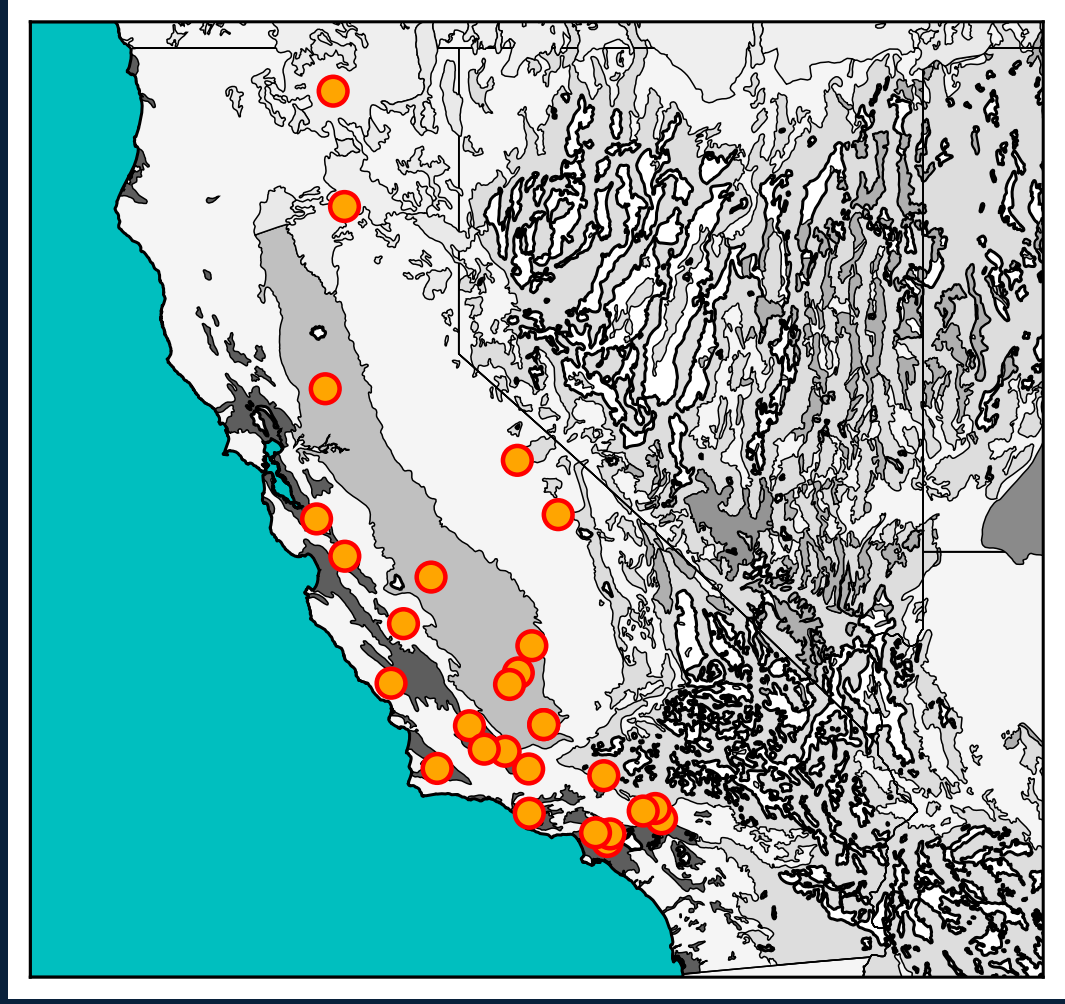
Example: Where are Positive Correlations (i.e. Poroelastic Expansion)?



Example: Where are Positive Correlations (i.e. Poroelastic Expansion)?

- SOME BLUE CELLS IN CALIFORNIA



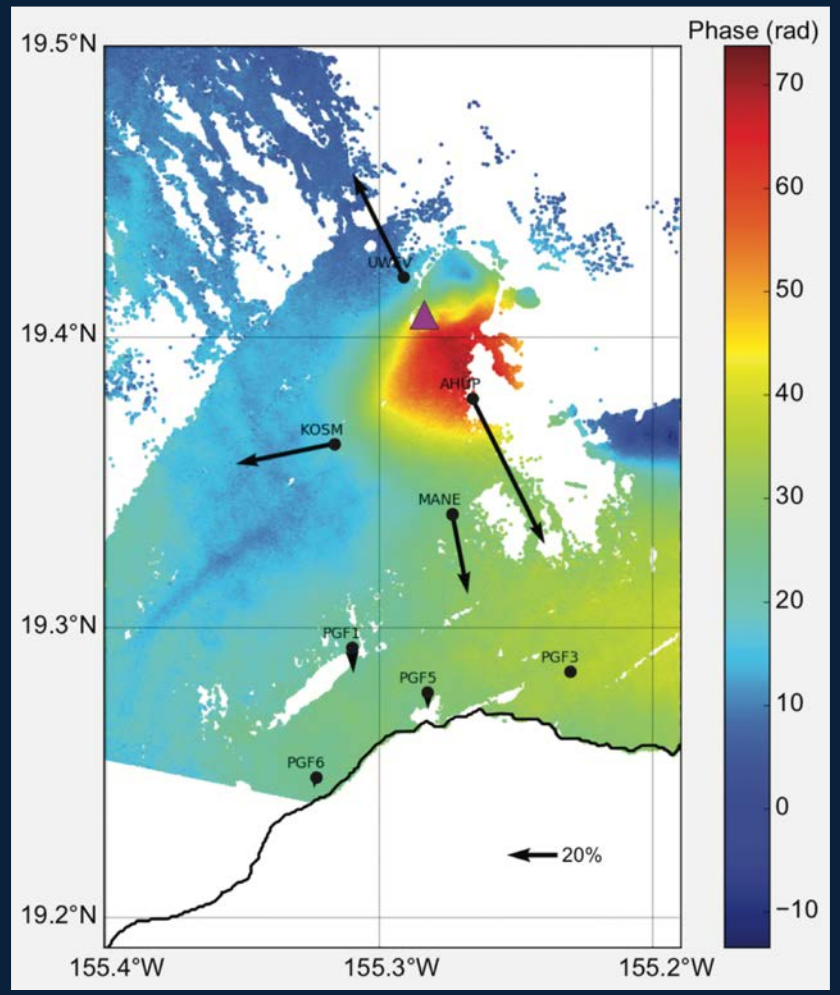


Example California

- CALIFORNIA CONTAINS SEVERAL GPS STATIONS WITH POSITIVE CORRELATIONS
- POSITIVE SITES COINCIDE WITH KNOWN AQUIFERS
- POSITIVE CORRELATION MAY BE DUE TO POROELASTIC EXPANSION

FUTURE WORK

- COMPARE WITH INSAR
- EXPLORE MACHINE LEARNING APPLICATIONS



Pankratius, V. *et al.* Computer-Aided Discovery Tools for Volcano Deformation Studies with InSAR and GPS. 16 *AGU Fall Meeting Abstracts* **23,** IN23B-1774 (2016).

SUMMARY

- MAJORITY OF GPS STATIONS SHOW THAT THE SURFACE HAS AN ELASTIC RESPONSE TO CHANGES IN WATER LOADING
- OUR VISUALIZATION APPROACH HELPS REVEAL A TRANSIENT EVENT IN MINNESOTA
- SEE EXAMPLE ON GITHUB.COM/MITHAYSTACK/SCIENCE-CASESTUDIES

Open Source Software Available

SCIKIT-data access
DATA INTERFACES FOR PYTHON

https://github.com/MITHaystack/scikit-dataaccess

SCIKIT-discovery
PYTHON TOOLKIT FOR COMPUTER-AIDED DISCOVERY

https://github.com/MITHaystack/scikit-discovery

SCIENCE CASE STUDIES
CODE FOR SCIENTISTS AND EDUCATORS

https://github.com/MITHaystack/science-casestudies

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Thank You

Questions?

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