Land Subsidence Monitoring, San Joaquin Valley

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U.S. Geological Survey
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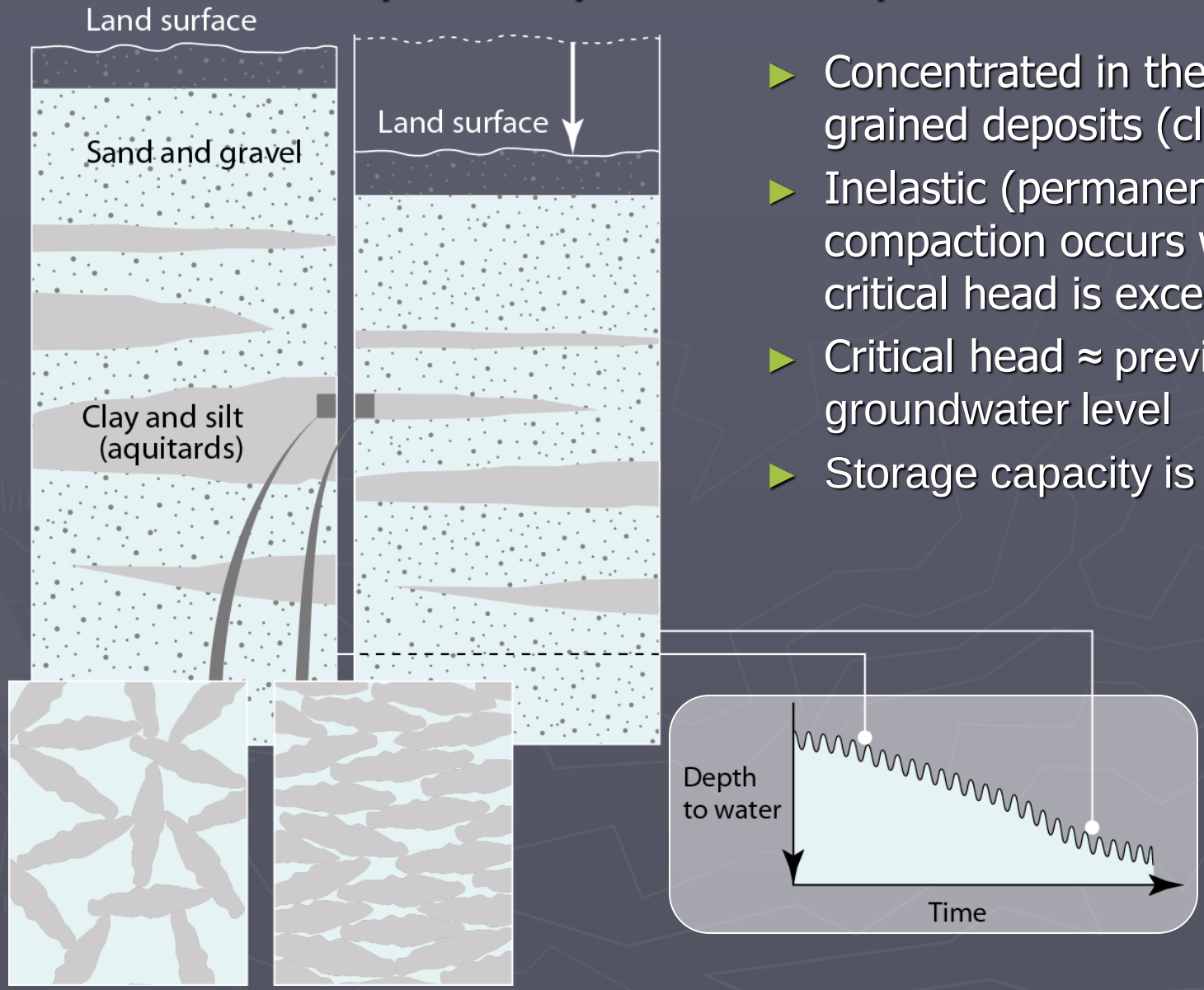
Land Subsidence in the San Joaquin Valley
Aquifer-System Compaction



- Concentrated in the fine-grained deposits (clays/silts)
- Inelastic (permanent) compaction occurs when the critical head is exceeded
- Critical head ≈ previous lowest groundwater level
- Storage capacity is reduced

Galloway and others (1999); USGS Circular 1182

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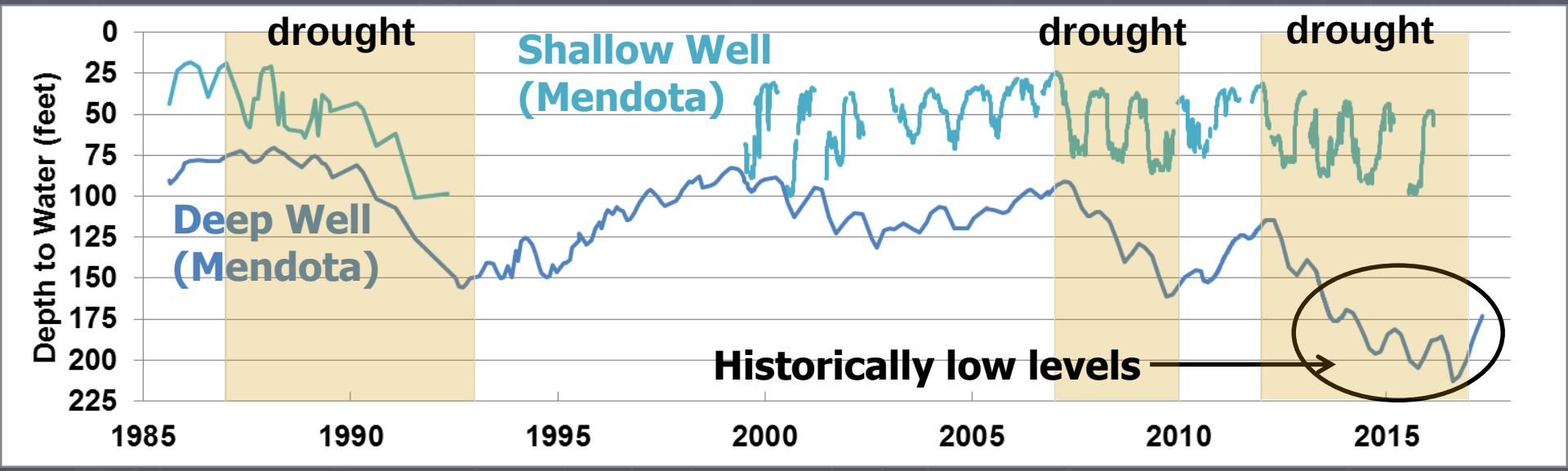
Groundwater Level Declines



Water level data from USGS and Luhdorff and Scalmanini Consulting Engineers; Preliminary and subject to revision

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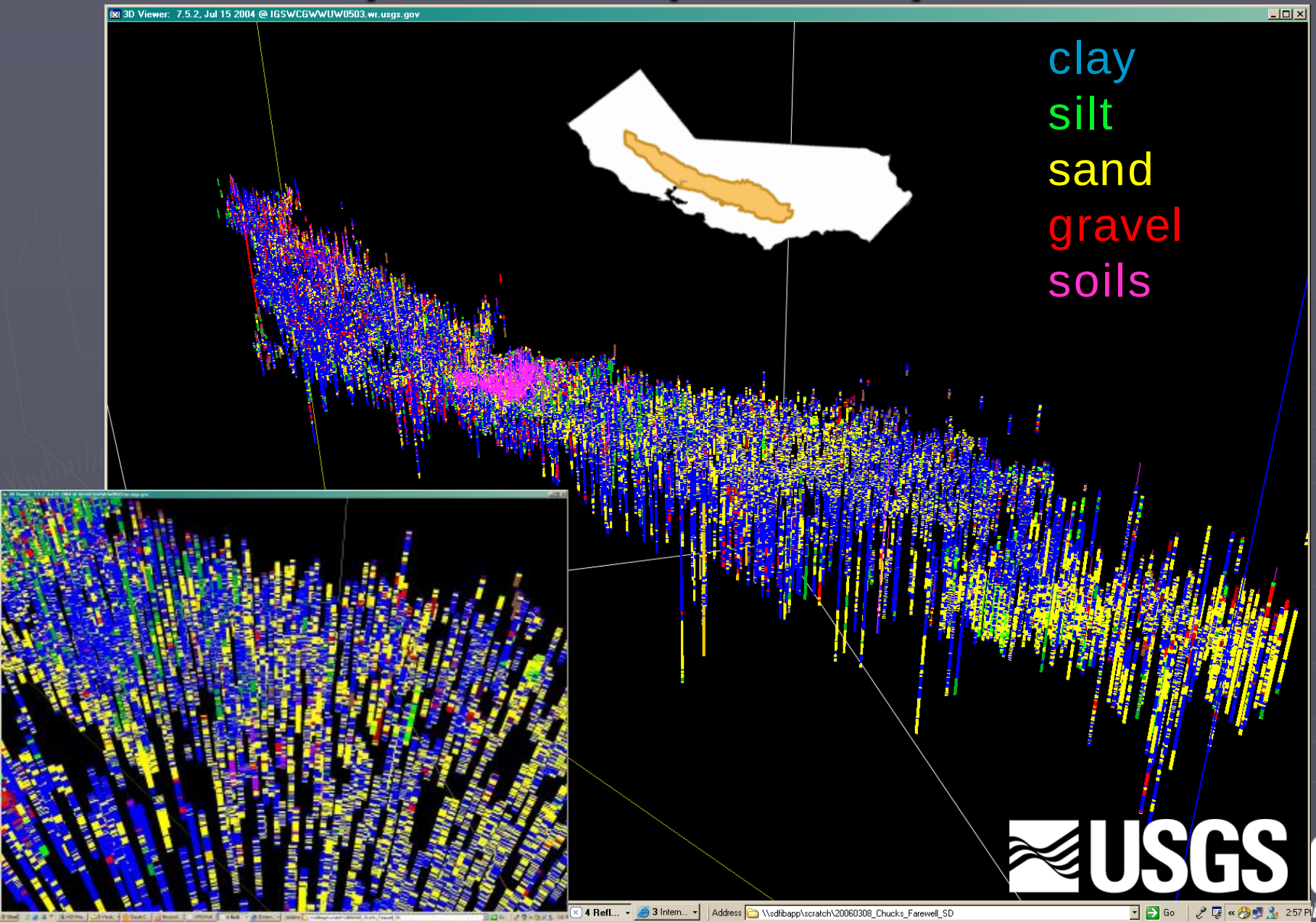
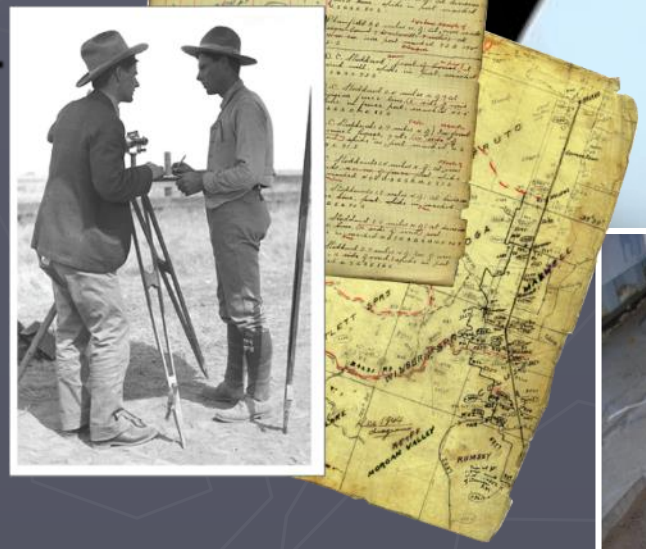
Clay-Rich Aquifer Systems



Subsidence Monitoring

- Can result in early detection
- Provides a measure of water-resources sustainability within relevant planning horizons
- Produces data needed for subsidence management



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Subsidence Measurements: Space and Time

Spatial Resolution

- One to Several Points
  - Borehole Extensometer*
- 10's of Points
  - Spirit Leveling
  - GPS (RTK/static/continuous)
- 1000's-1,000,000's of Points
  - InSAR (space and airborne)
  - LiDAR
  - Radar Altimetry

Temporal Resolution

- <Several measurements/year
  - Spirit Leveling
  - GPS (RTK, Static)
- Several measurements/year
  - InSAR (space and airborne)
  - LiDAR
  - Radar Altimetry
- 1000's measurements/year
  - Borehole Extensometer*
  - GPS (continuous)

* Measures aquifer-system compaction

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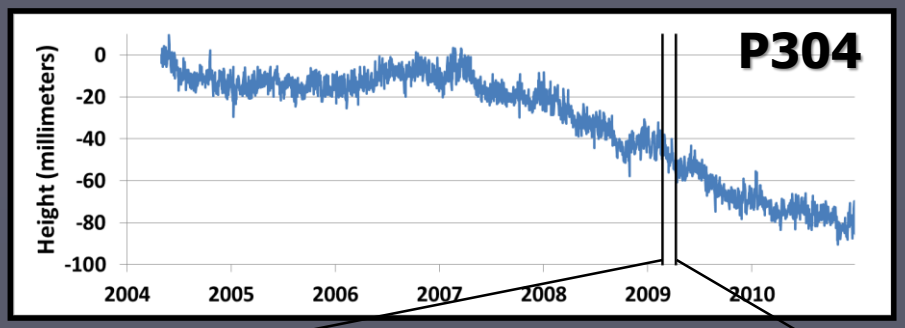
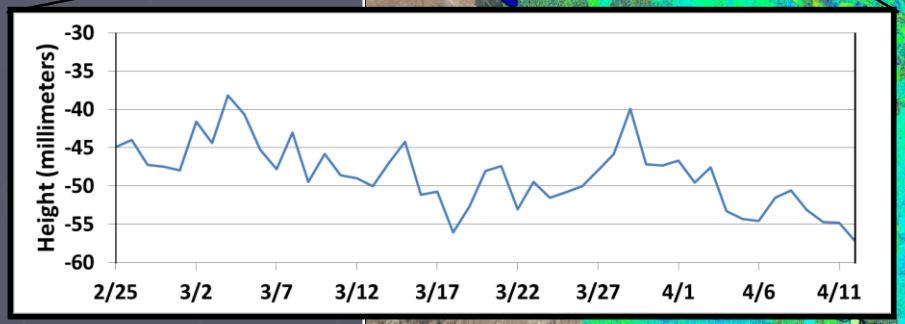


←CGPS: High Temporal Resolution



InSAR: High Spatial Resolution

Guide design of monitoring networks (like GPS)

CGPS data from UNAVCO; survey data from DWR

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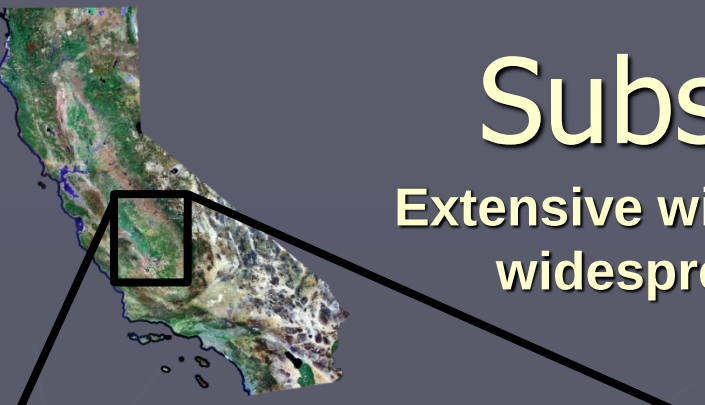
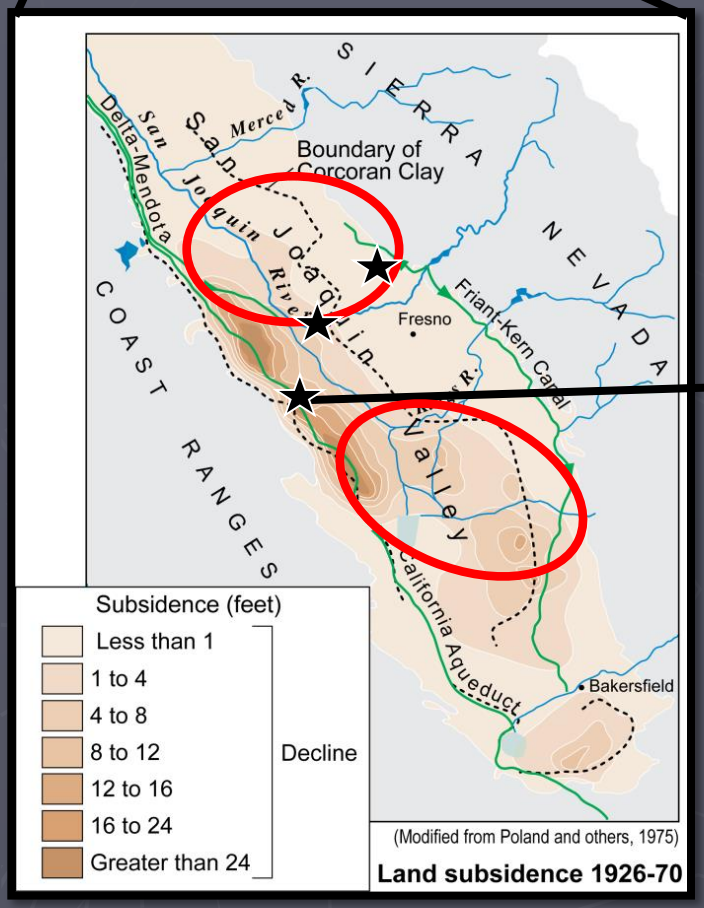
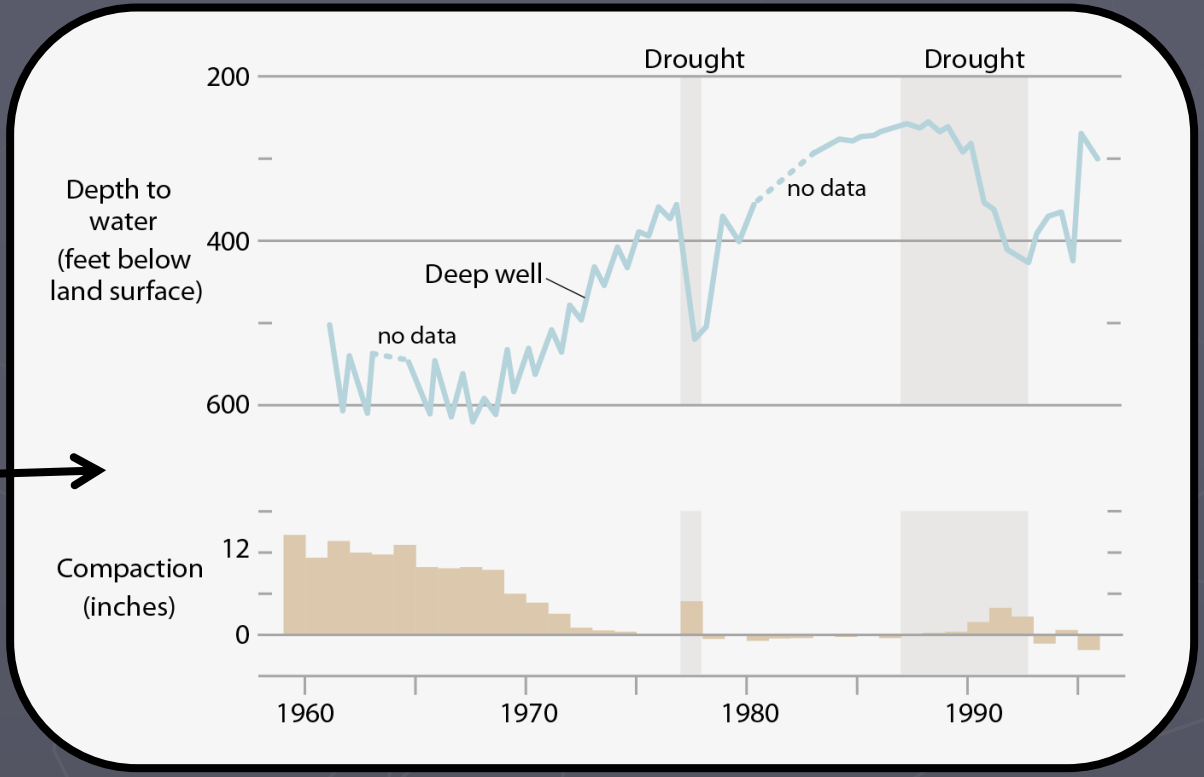
Subsidence History

Extensive withdrawal of groundwater caused widespread subsidence (1920s-1970)







Surface-water deliveries caused widespread recovery and slowing or cessation of subsidence, except when deliveries were curtailed and groundwater pumping increased to meet demand

Galloway and others, 1999; USGS Circular 1182

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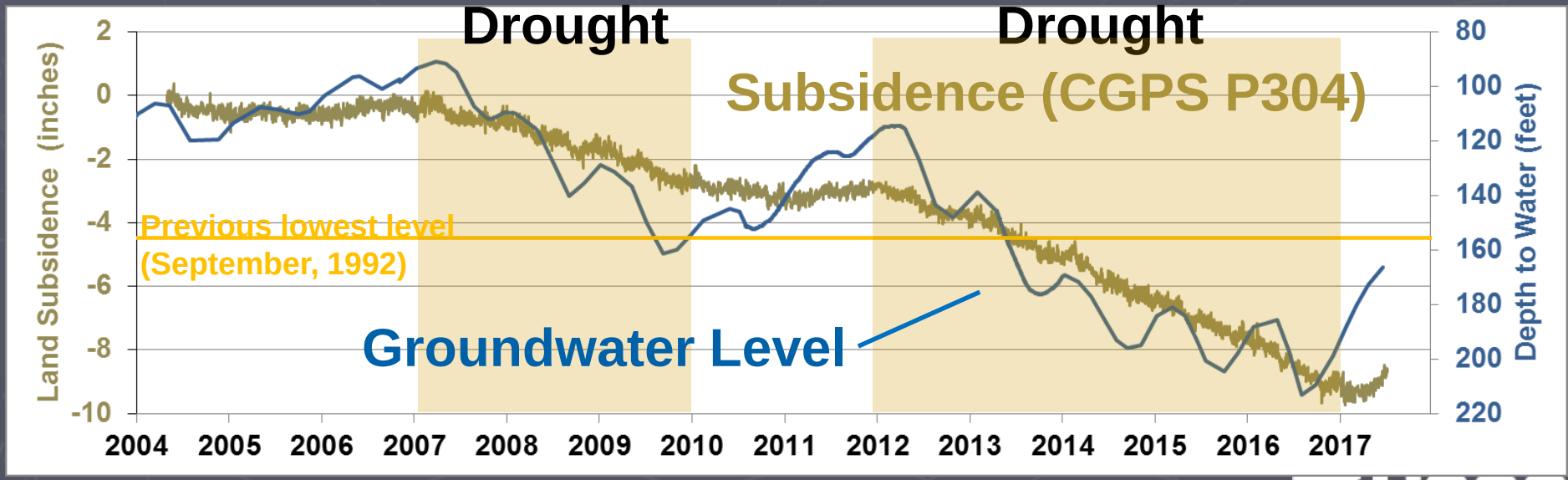
Recent Subsidence

- Renewed subsidence concern during the 2007-09 drought initiated investigations
  - Reduced surface water importation
  - More reliance on the groundwater resources
  - As it turns out…this is not just a problem during droughts for some areas with limited surface-water access



CGPS data from UNAVCO; water level data from DWR, USGS, and Luhdorff and Scalmanini Consulting Engineers

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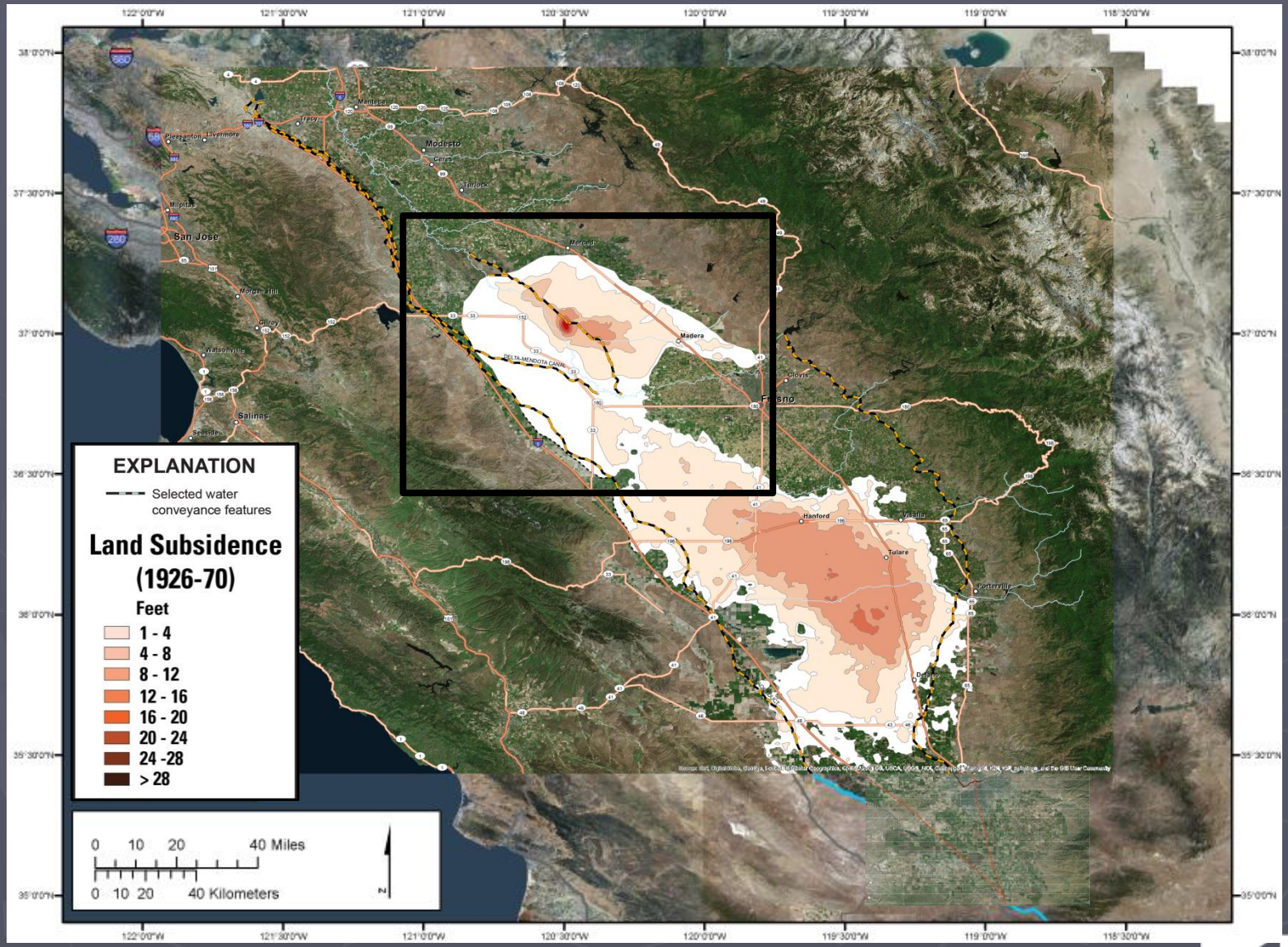
Historical Subsidence



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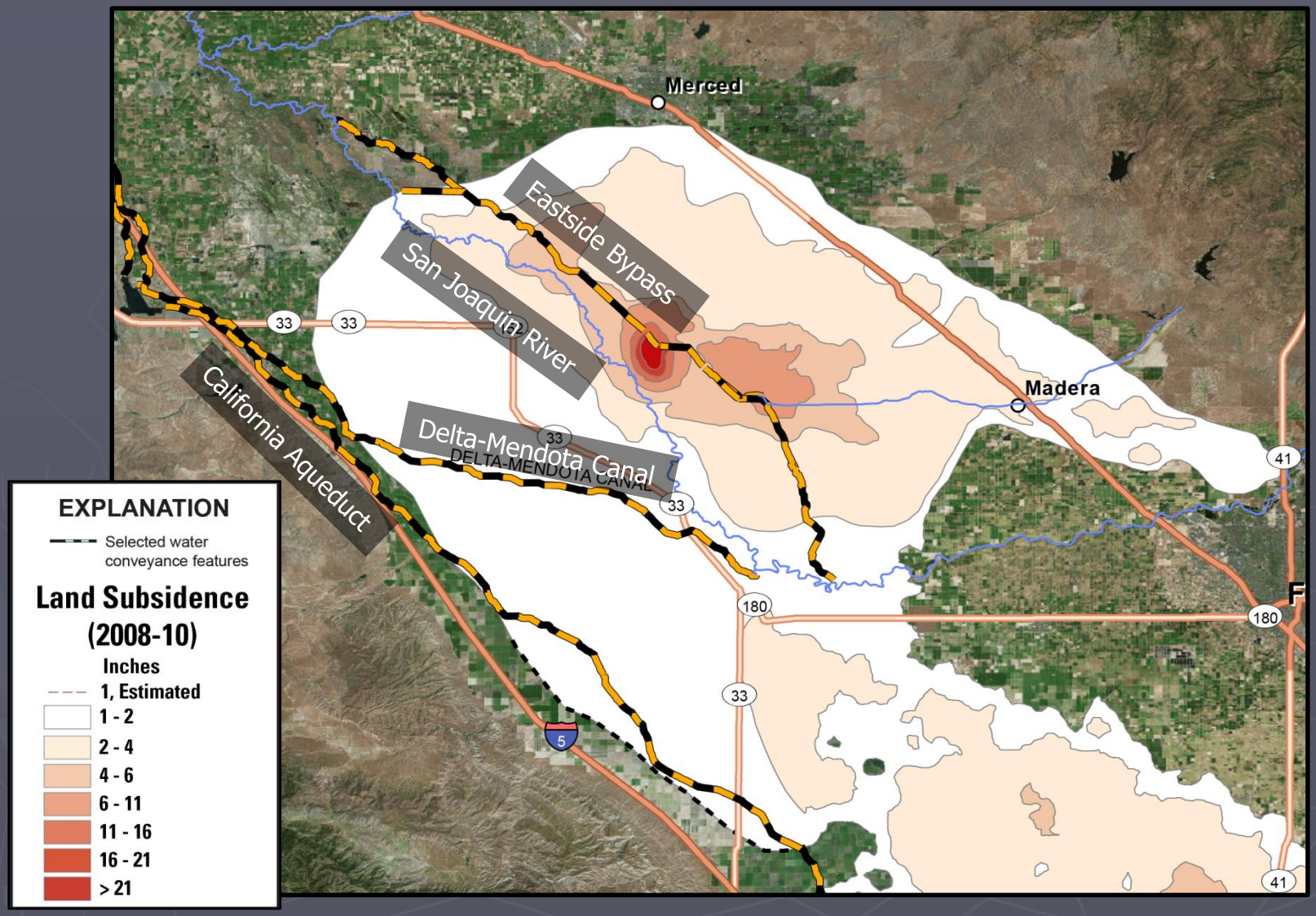
Water Conveyance Infrastructure



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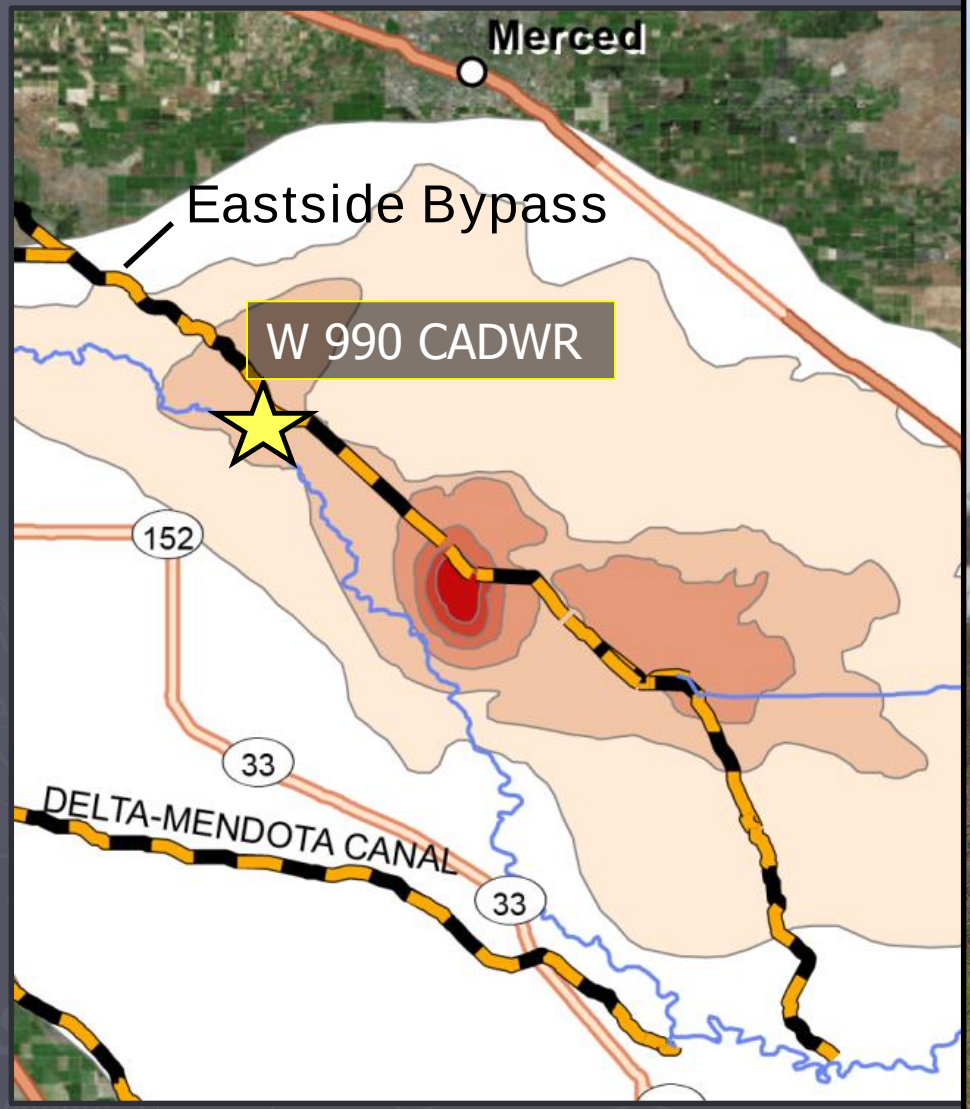
Periodic Leveling/GPS Surveys



Survey data from Bureau of Reclamation

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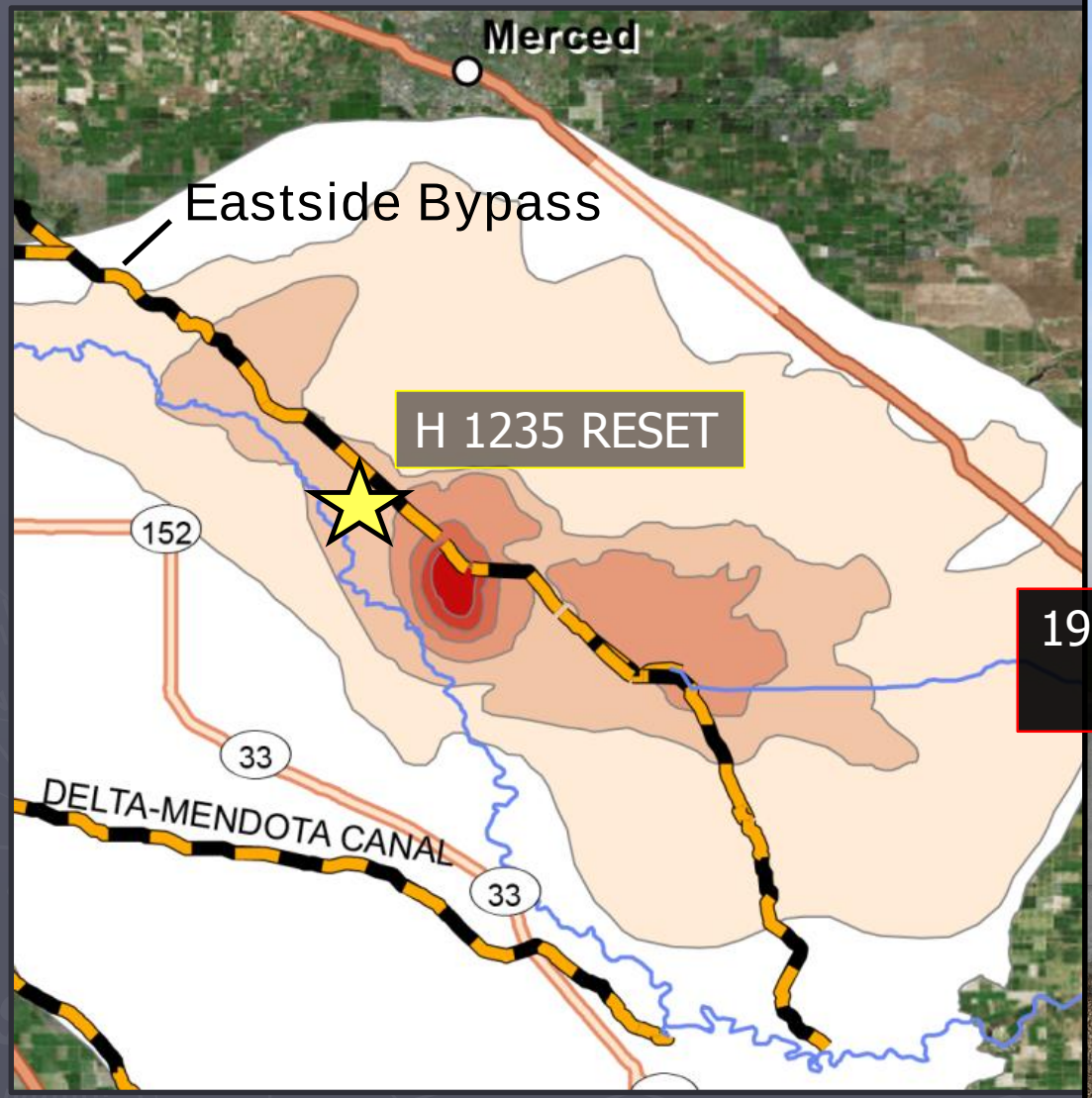
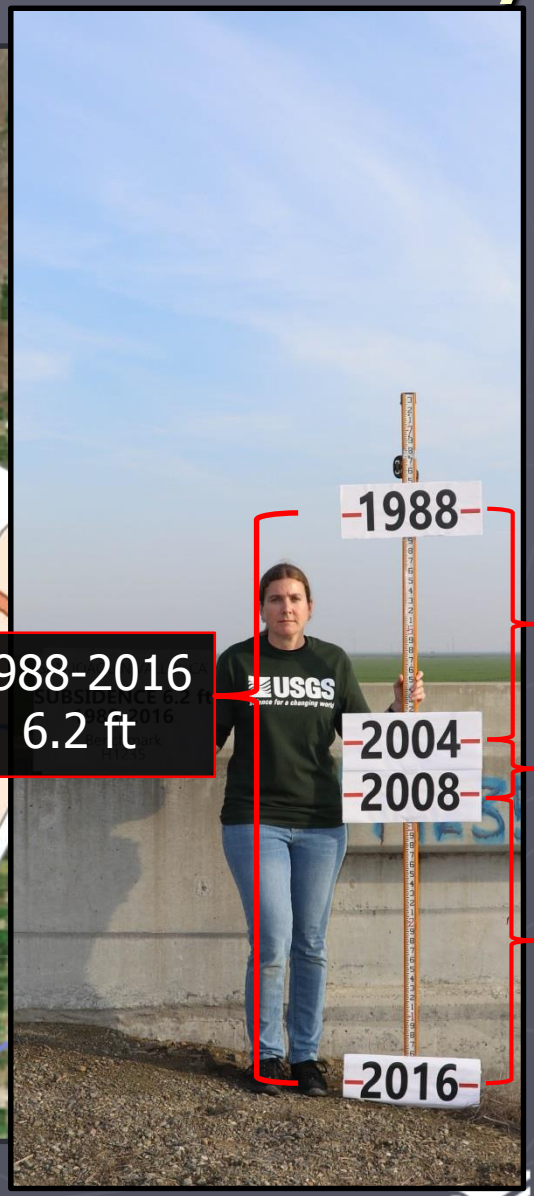
Periodic Leveling/GPS Surveys





1988-2016
6.2 ft

16 years
2.3 ft

4 years
0.6 ft

8 years
3.3 ft

Survey data from Caltrans, Bureau of Reclamation, and DWR

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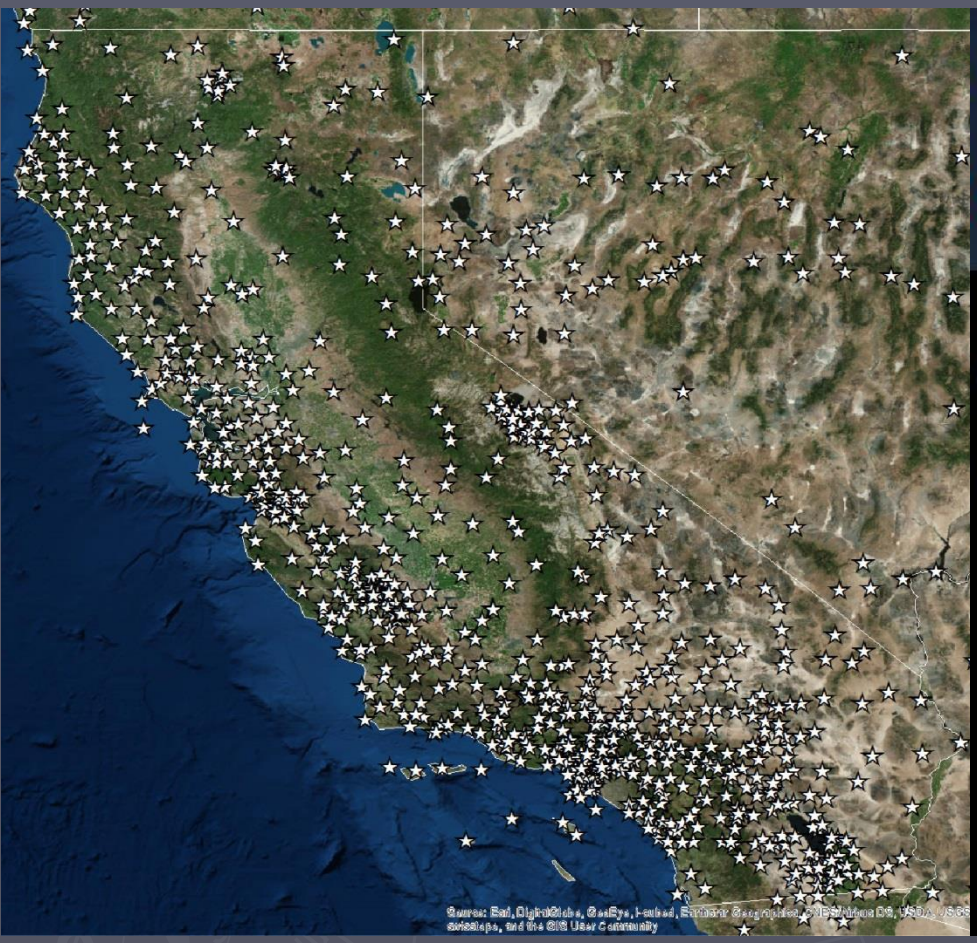
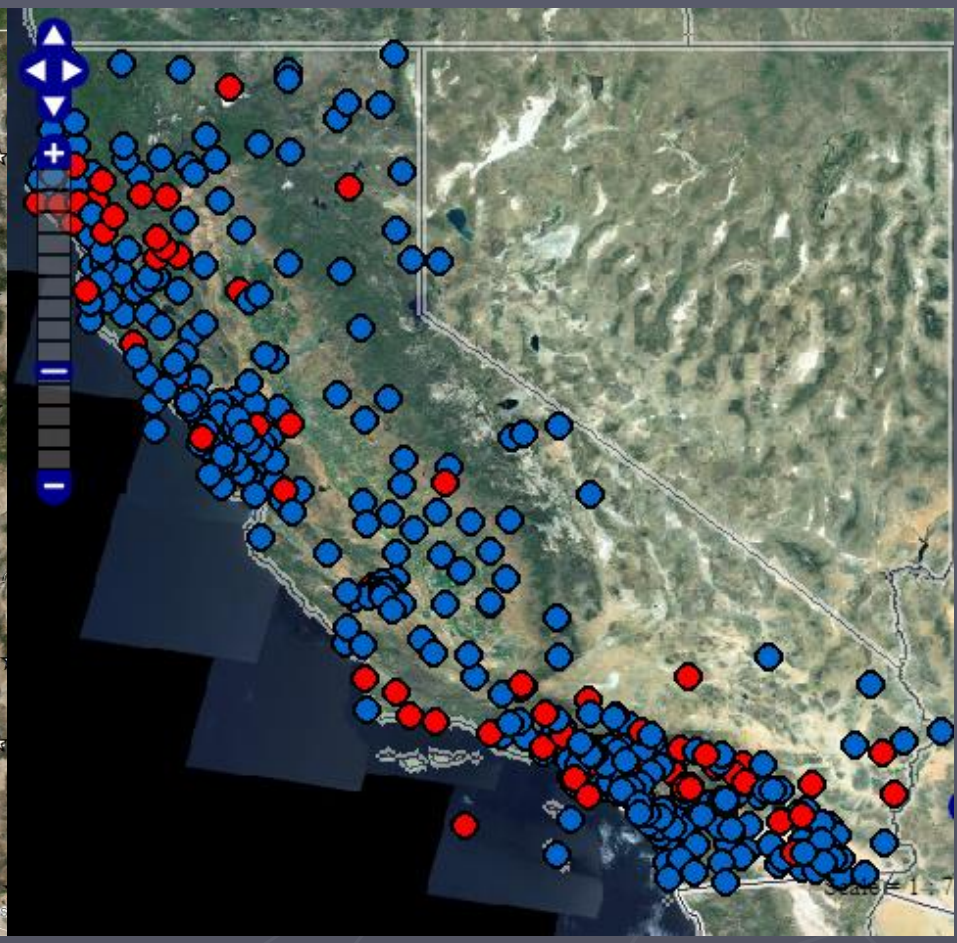
Continuous GPS Stations in CA





http://www.unavco.org/instrumentation/networks/status/pbo

http://sopac.ucsd.edu/map.shtml

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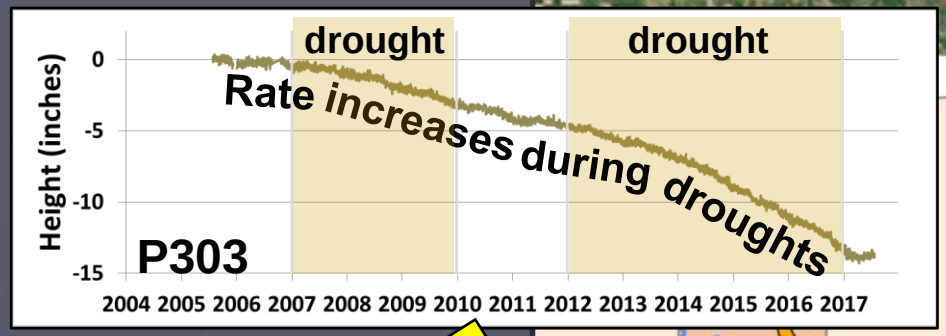
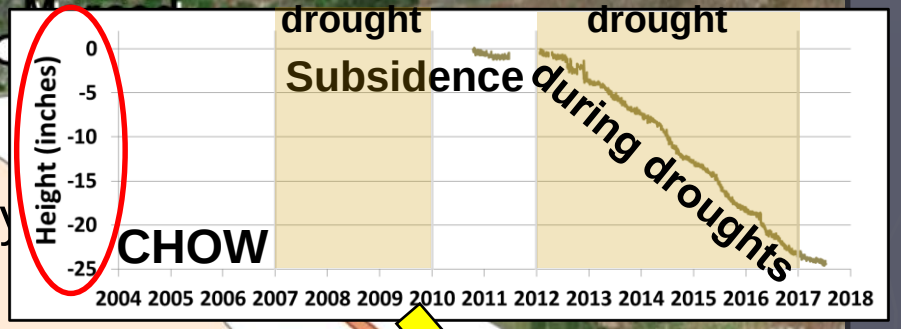
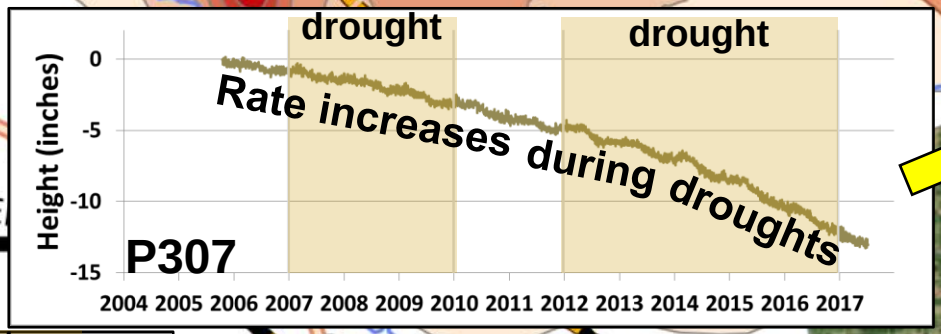
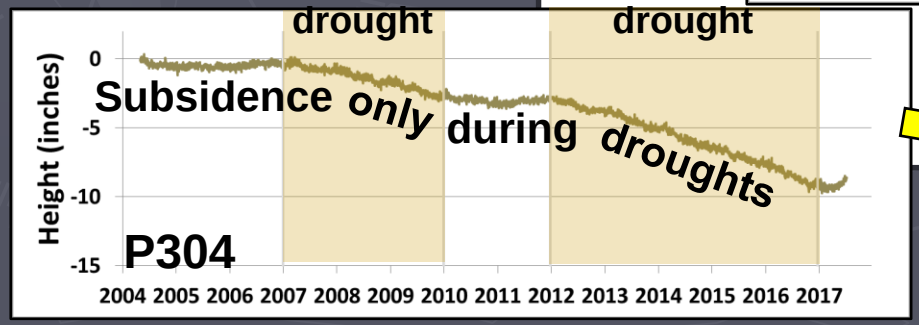
Continuous GPS Time Series









CGPS data from UNAVCO

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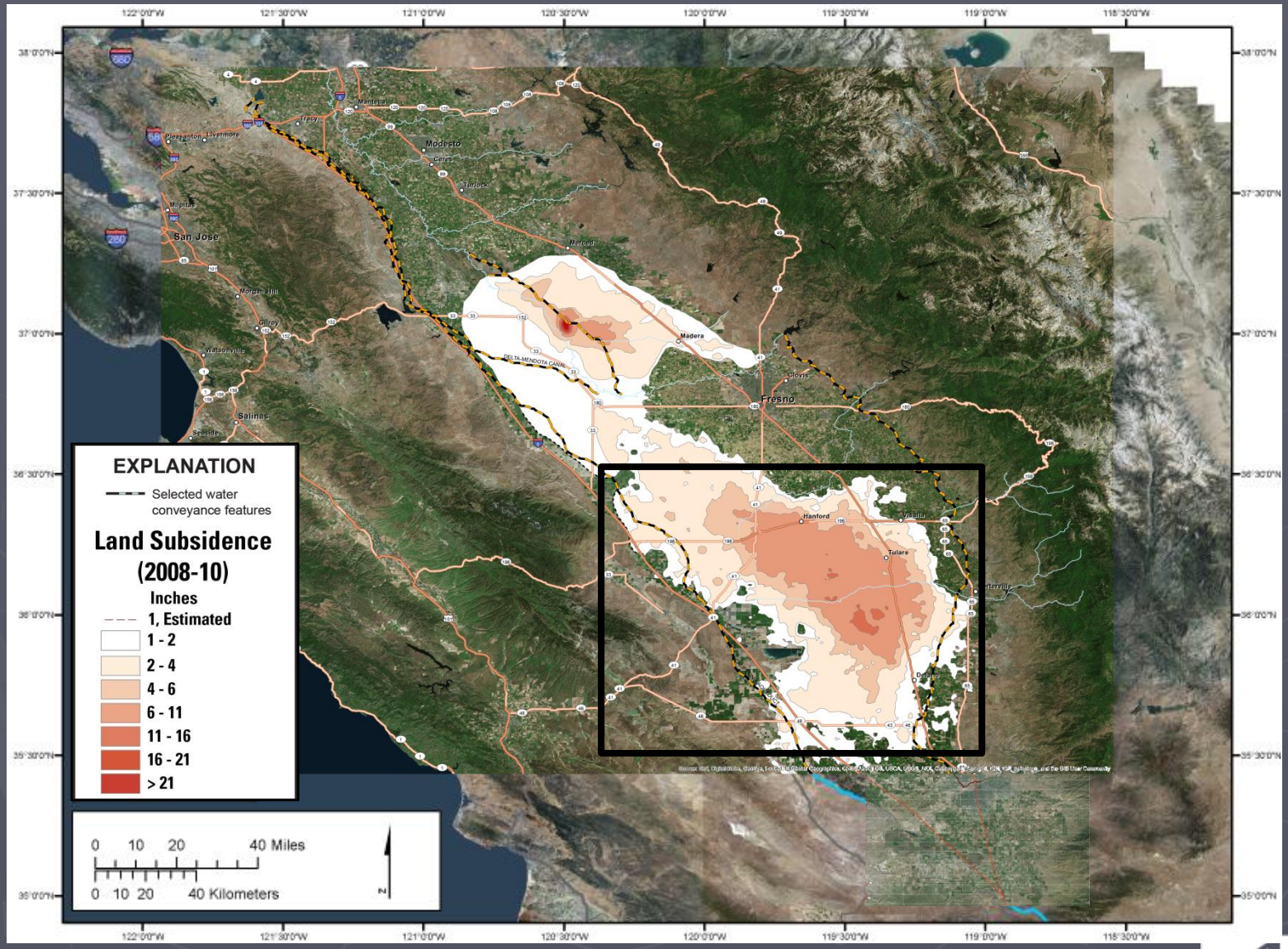
Recent Subsidence



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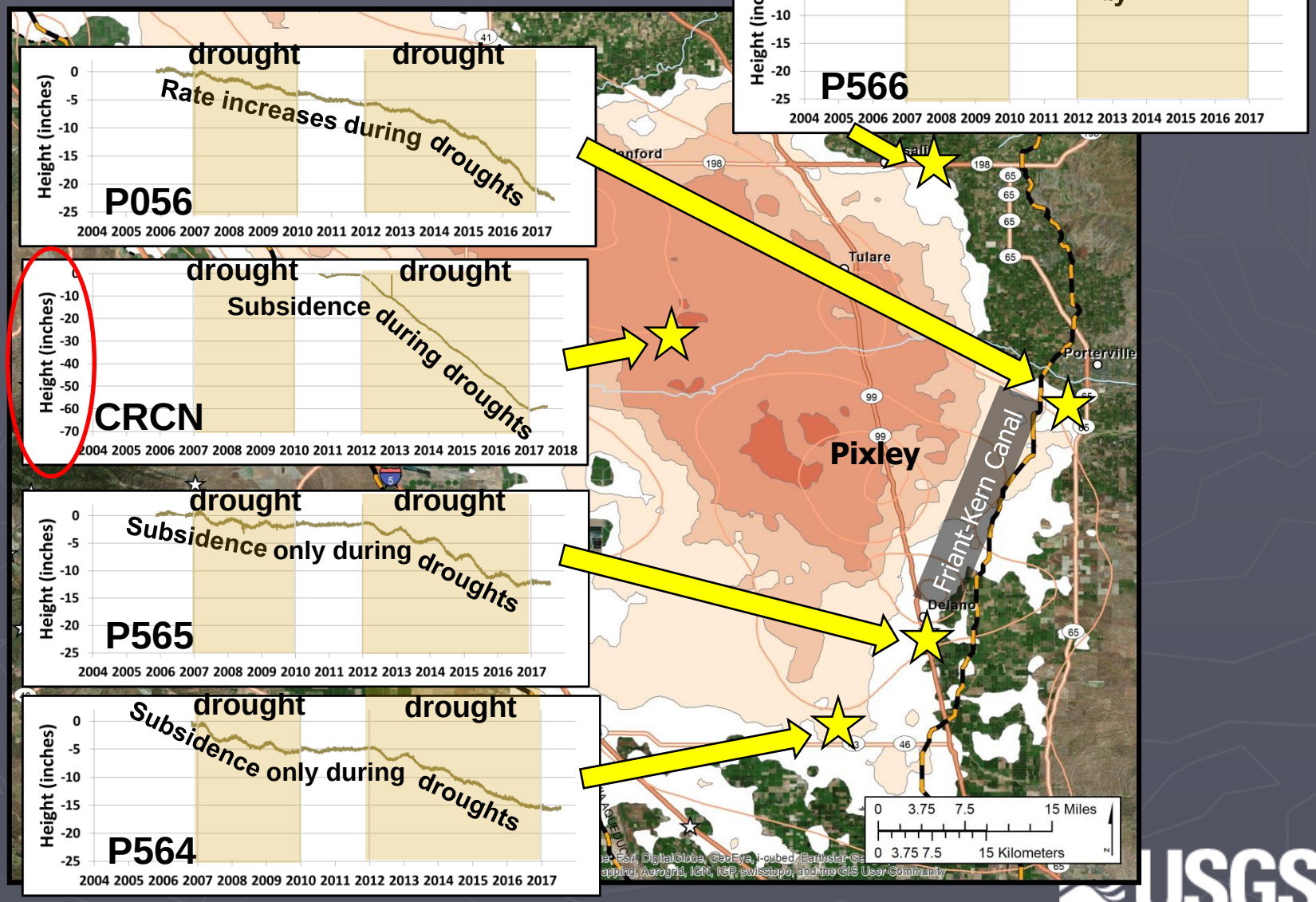
Continuous GPS Time Series



CGPS data from UNAVCO

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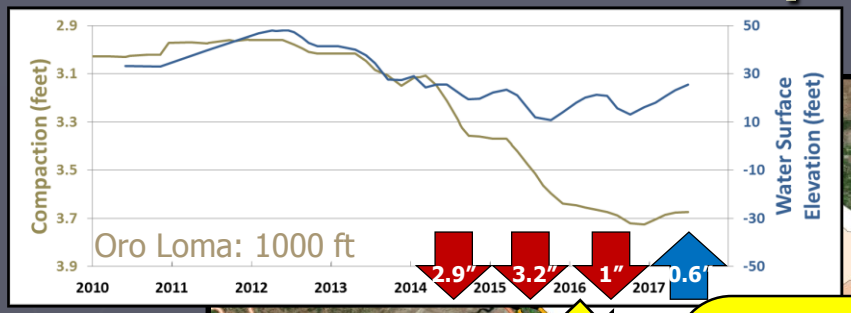
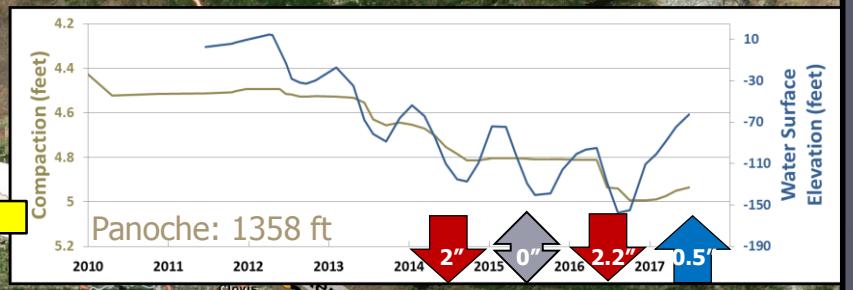
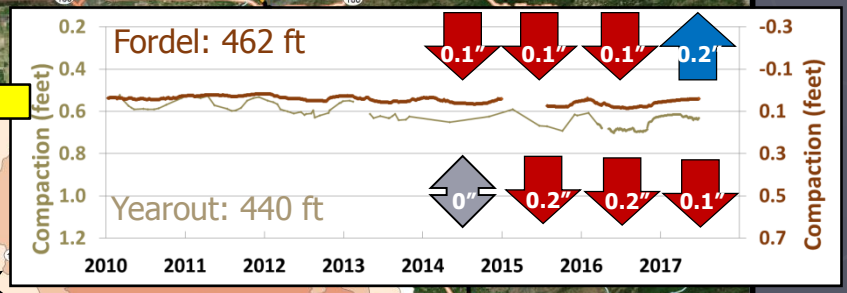
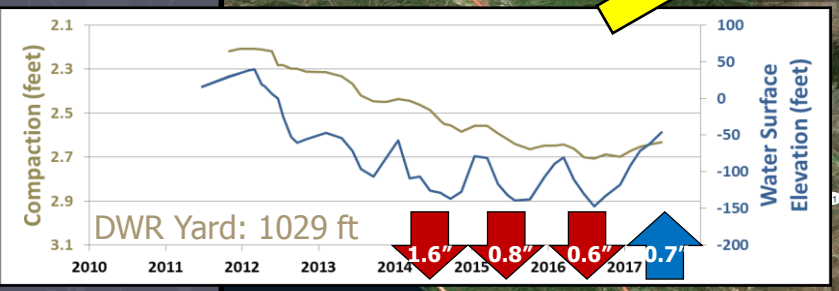
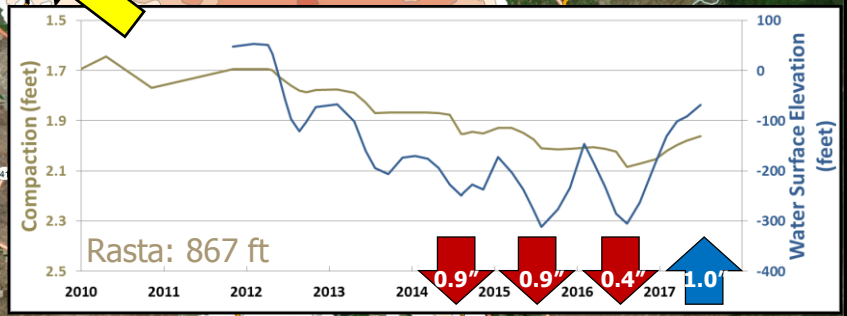
Continuous Compaction: Extensometers











Extensometer and water-level data from USGS and Luhdorff and Scalmanini Consulting Engineers

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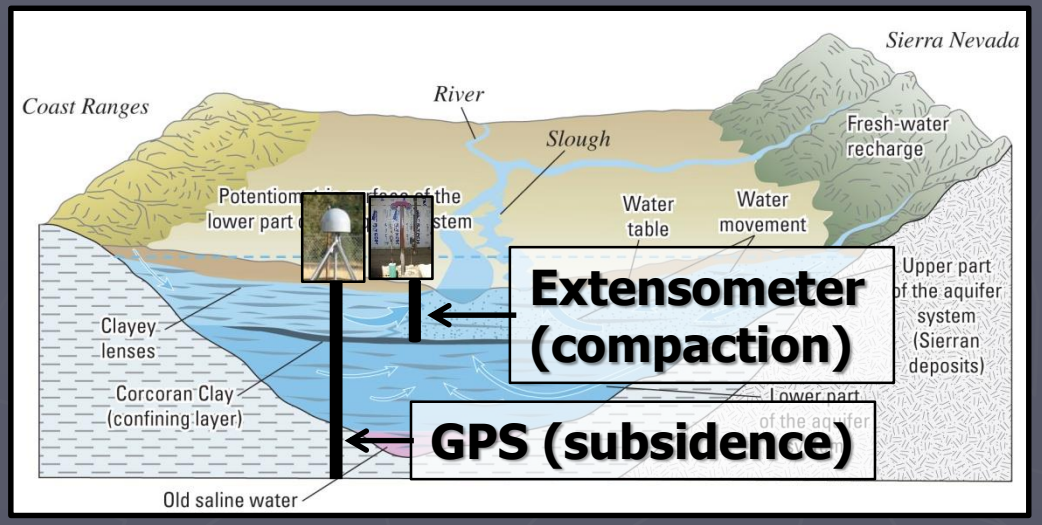
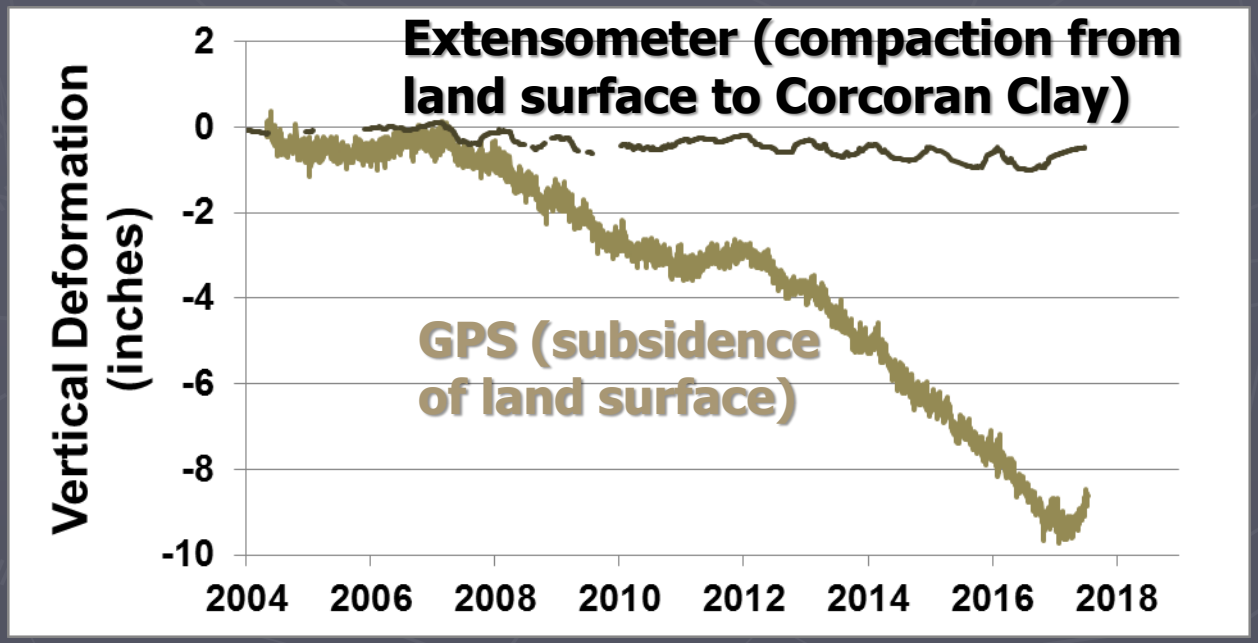
Compaction Depths (Mendota)

- Extensometer is anchored in the top of Corcoran Clay
- GPS reflects subsidence relative to the center of the Earth
- GPS measured much more deformation than the extensometer





- **Conclusion:** most of deformation is occurring below the top of the Corcoran Clay

CGPS data from UNAVCO; extensometer data from Luhdorff and Scalmanini Consulting Engineers and USGS

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Subsidence Monitoring Summary

- Measuring subsidence/compaction AND groundwater levels is essential to understanding aquifer-system behavior
  - Estimate critical head and aquifer-system storage properties (model input)
- High spatial resolution of subsidence provided by InSAR data can help focus monitoring resources
  - Design ground-based networks to improve temporal resolution
- High temporal resolution of subsidence provided by continuous GPS or extensometers can help managers determine how various management strategies affect subsidence (decision support)
- Extensometers are the only measurement technique that will indicate depth intervals of compaction
  - Understanding compacting intervals is critical in subsidence management

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Thanks!

For more information:

http://ca.water.usgs.gov/land_subsidence/

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