Application of GPS Vertical Positioning to Seasonal Water Variations in California and Postglacial Rebound in Antarctica

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TECHNICAL ADVANCES
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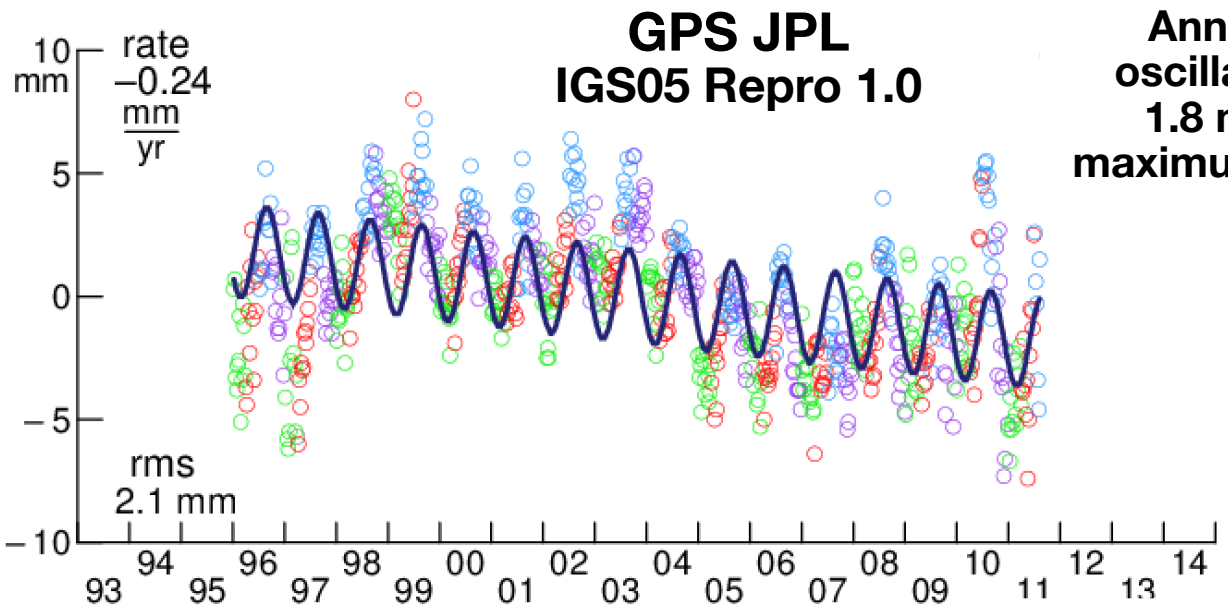
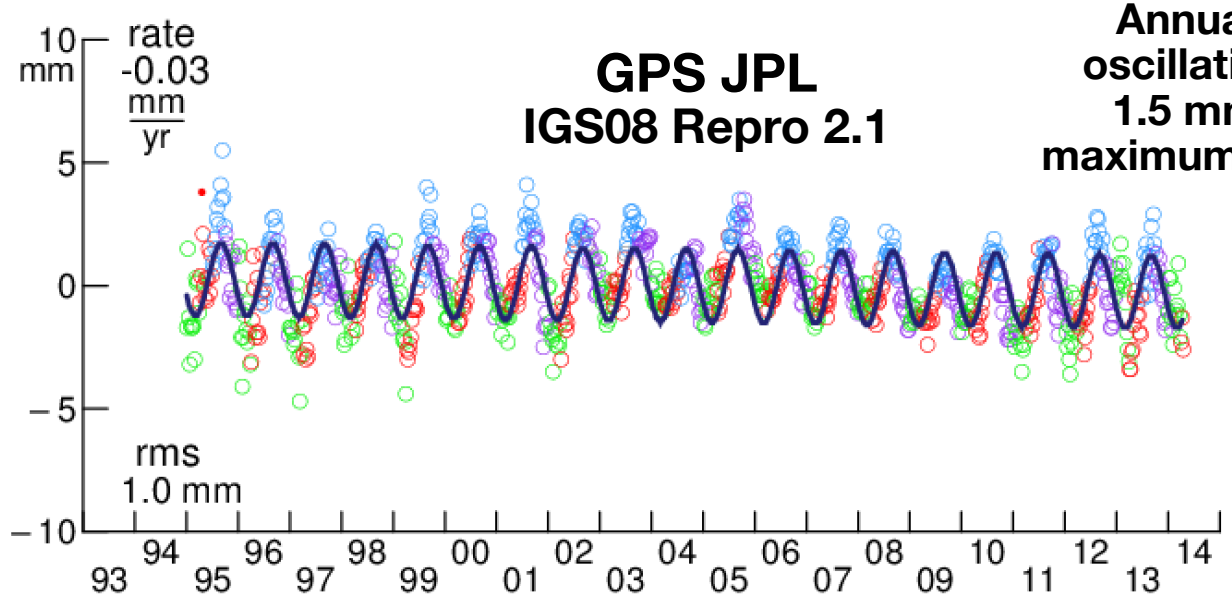
2014 IGS Workshop

PART 1
Technical Advances in GPS Vertical Positioning

Scale



Annual oscillation 1.8 mm maximum Aug



Annual oscillation 1.5 mm maximum Sep

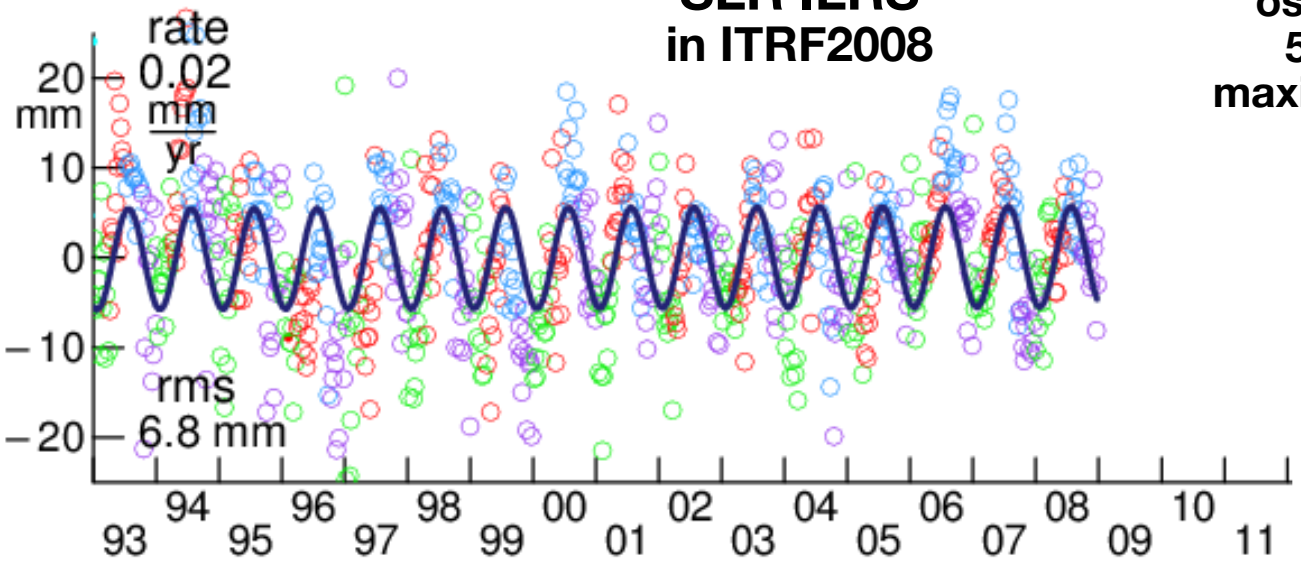
RESULT 1
Series for scale has become straighter.

Vertical positions on opposite sides of Earth are more accurate.

operational scale depend solar, phase, QC

Z

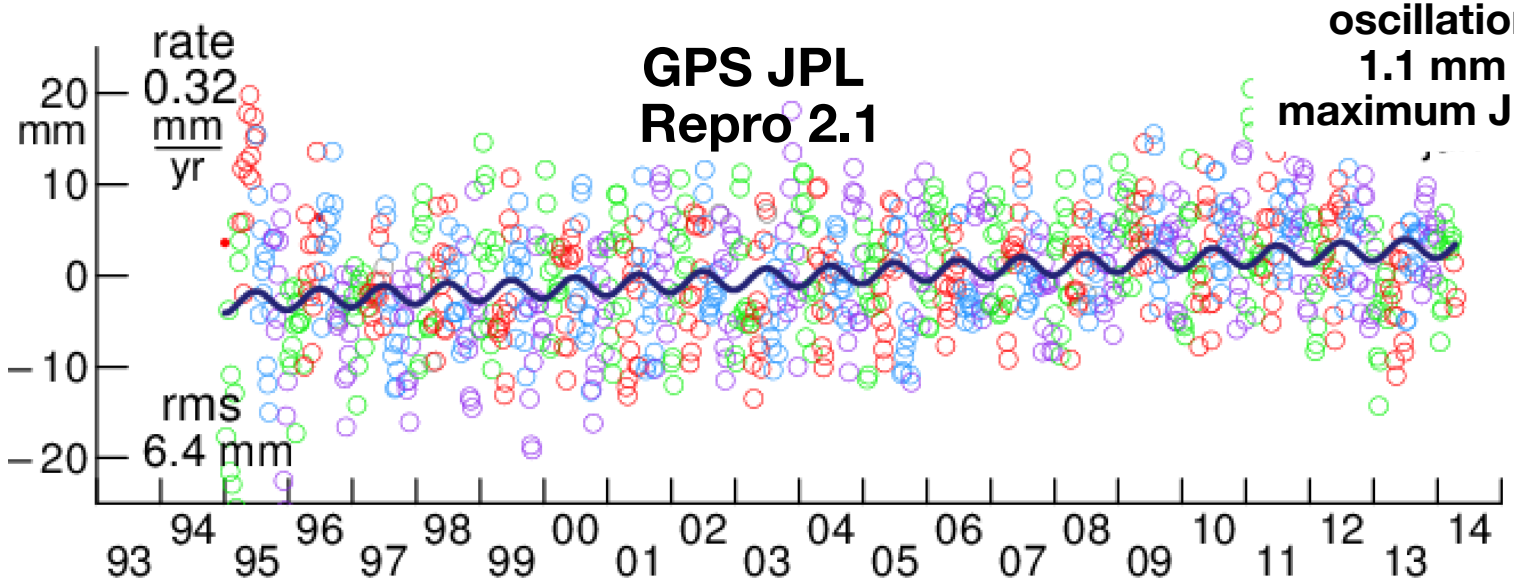
SLR ILRS in ITRF2008



Annual oscillation 5.6 mm maximum July

INFERENCE
GPS series for Z component of CM is straight, suggesting that GPS can be used to constrain the velocity of CM.

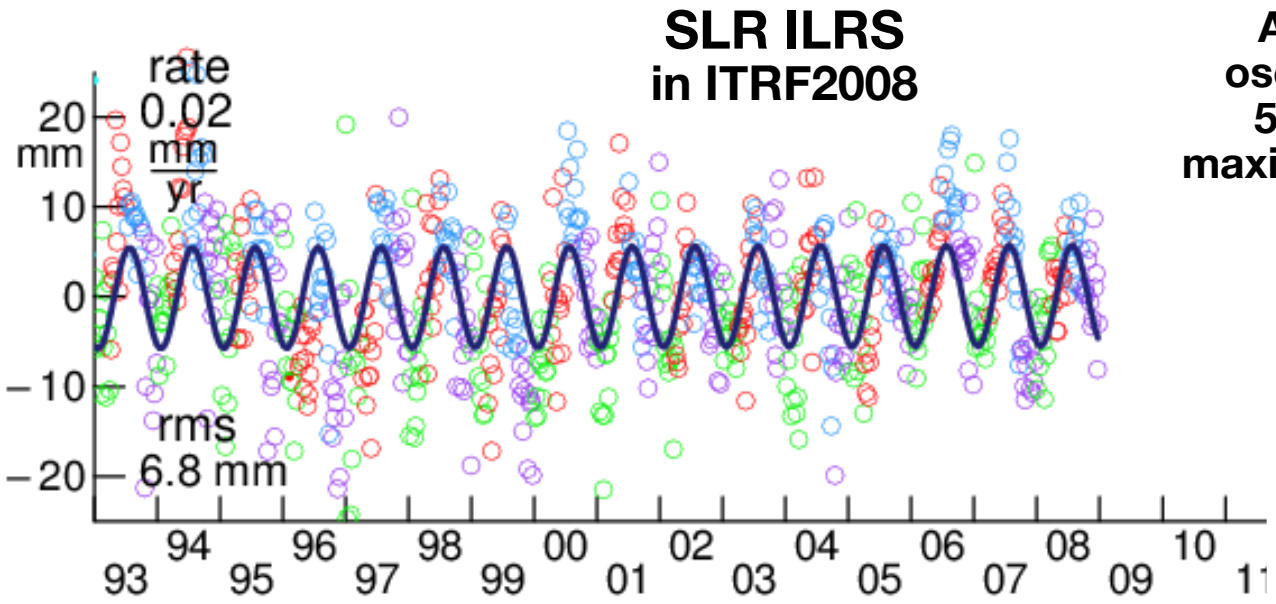
GPS JPL Repro 2.1



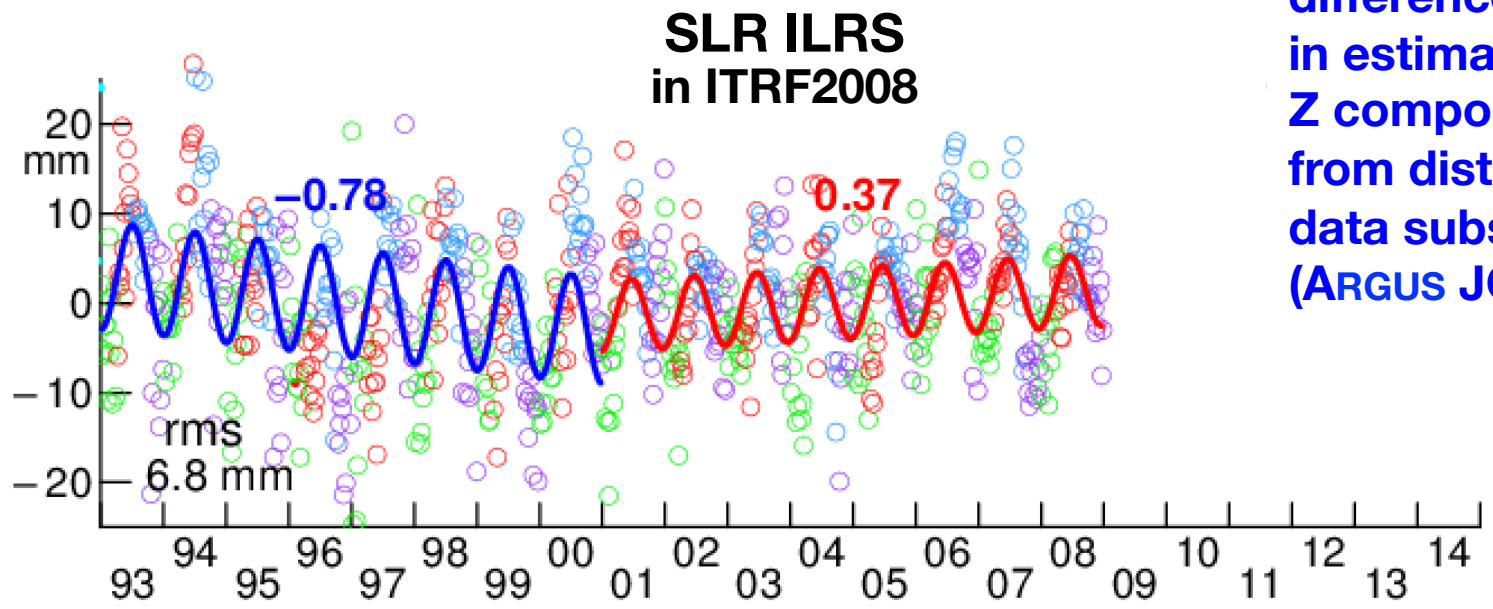
Annual oscillation 1.1 mm maximum June

Garcia–Fernandez & Desai 2nd order ionosphere

Z



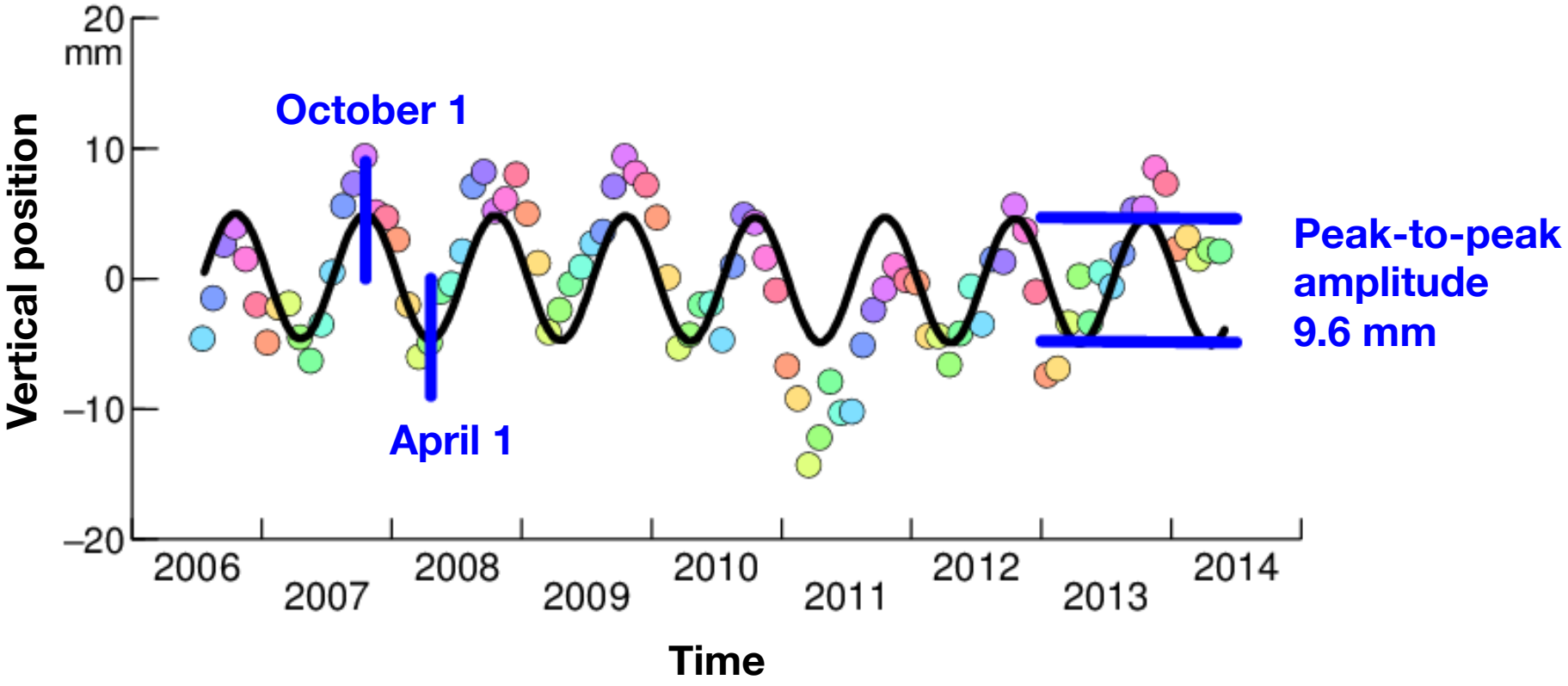
Annual oscillation 5.6 mm maximum July



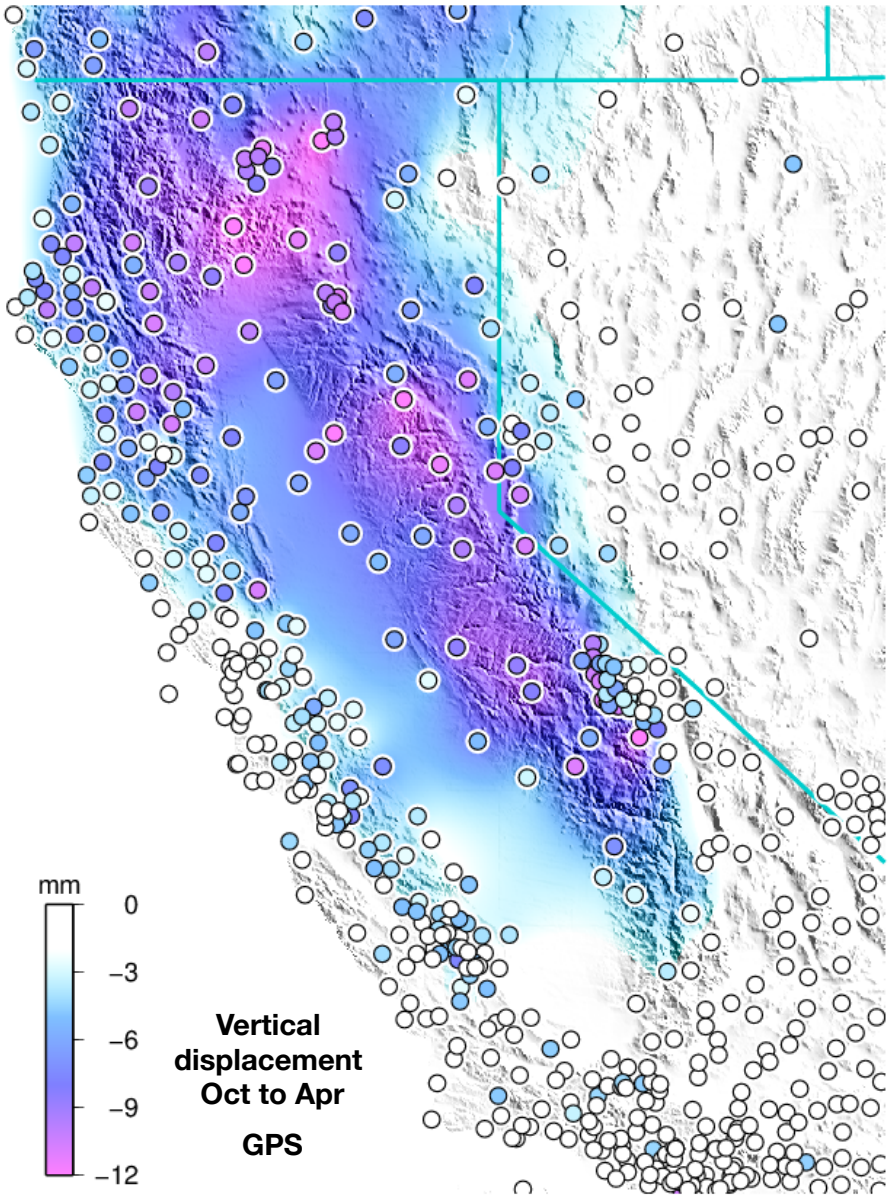
INFERENCE
SLR estimate of the velocity of CM is uncertain, as evident in the 1.15 mm/yr difference in estimates of Z component from distinct data subsets (ARGUS JGR 2012).

PART 2
GPS as a High-Resolution Technique for Evaluating Water Resources Available to California

Vertical position of GPS site P310



Seasonal vertical displacement
Fall & Winter

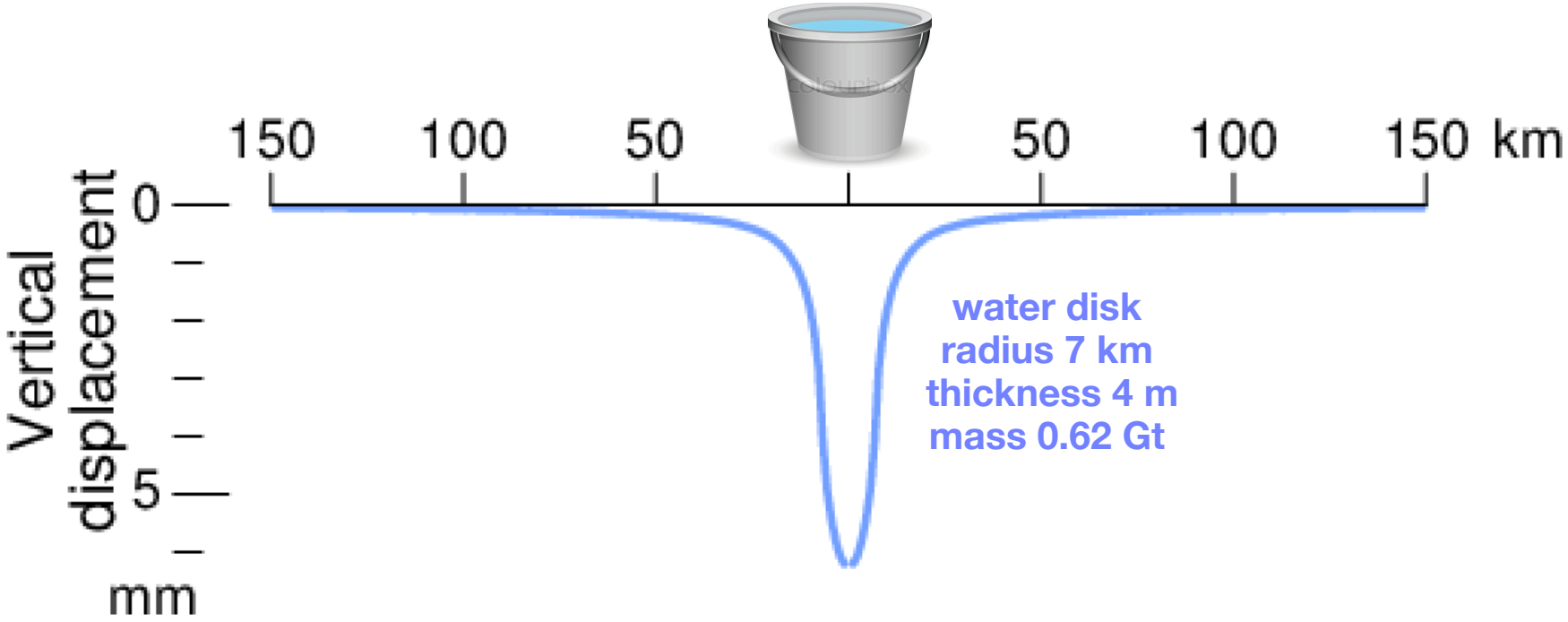


OPPORTUNITY

- **500 GPS sites deployed in California since 2007**
- **PBO built by UNAVCO and funded by NSF and NASA.**

Elastic response of Earth's surface to a mass load

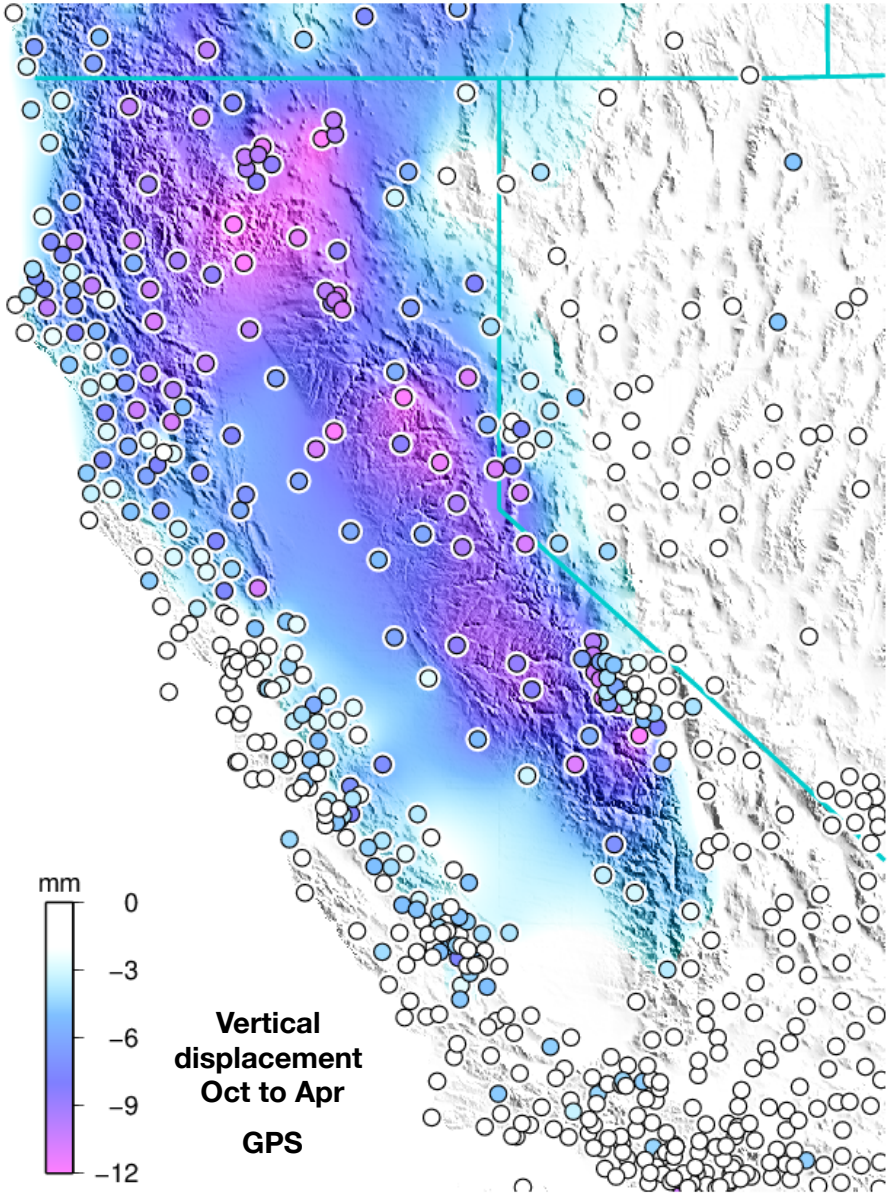
Well known,
Given by Green's functions, and
Insensitive to Earth structure



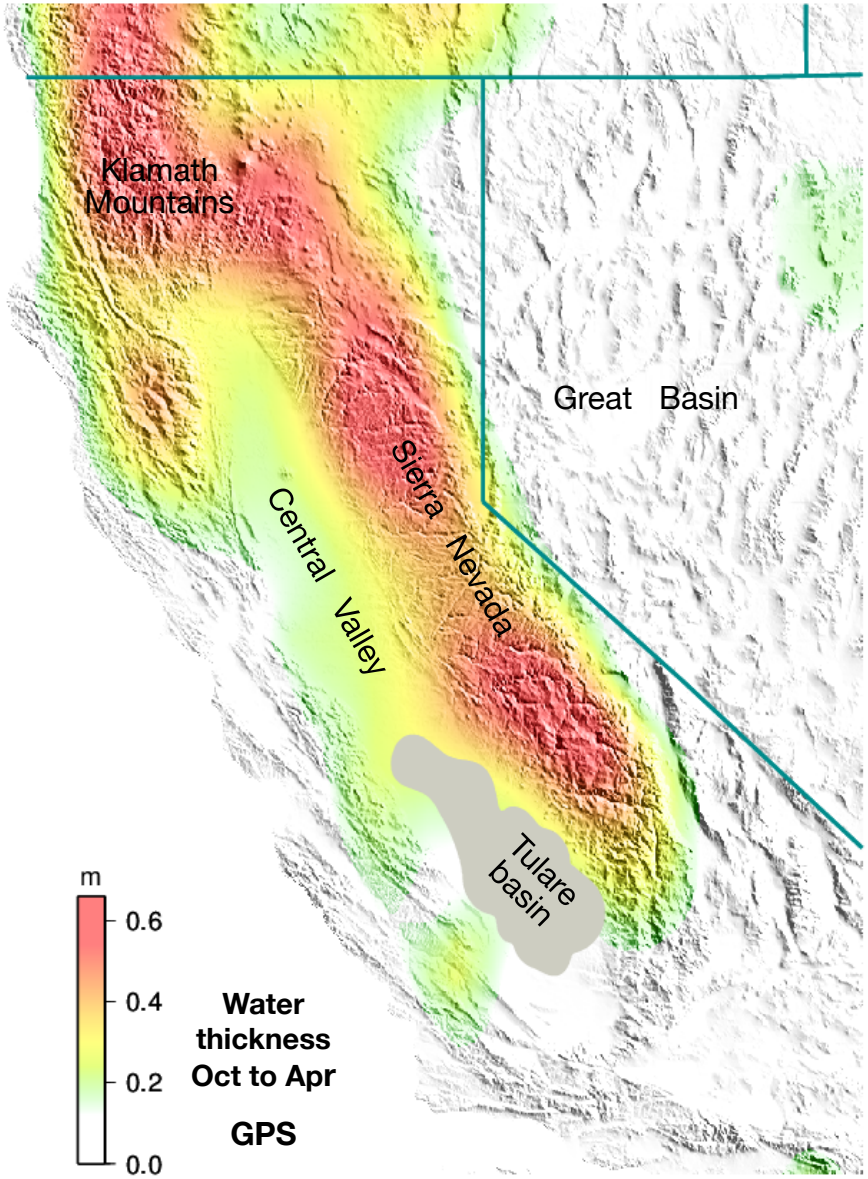
Elastic vertical displacement
resolves water storage
at very high spatial resolution.

Vertical displacement 20 km from load
Is half than 10 km from load

Seasonal vertical displacement
Fall & Winter

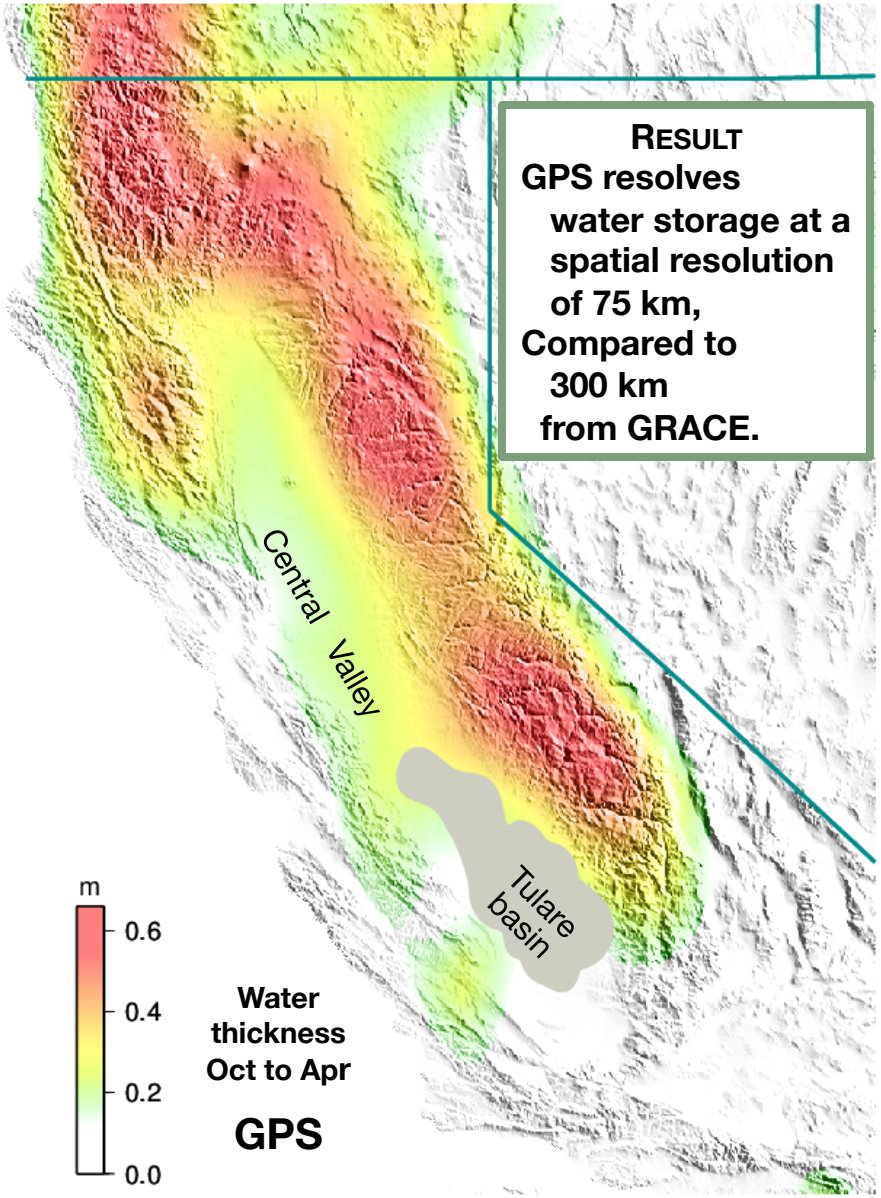


Seasonal water thickness GPS
Fall & Winter

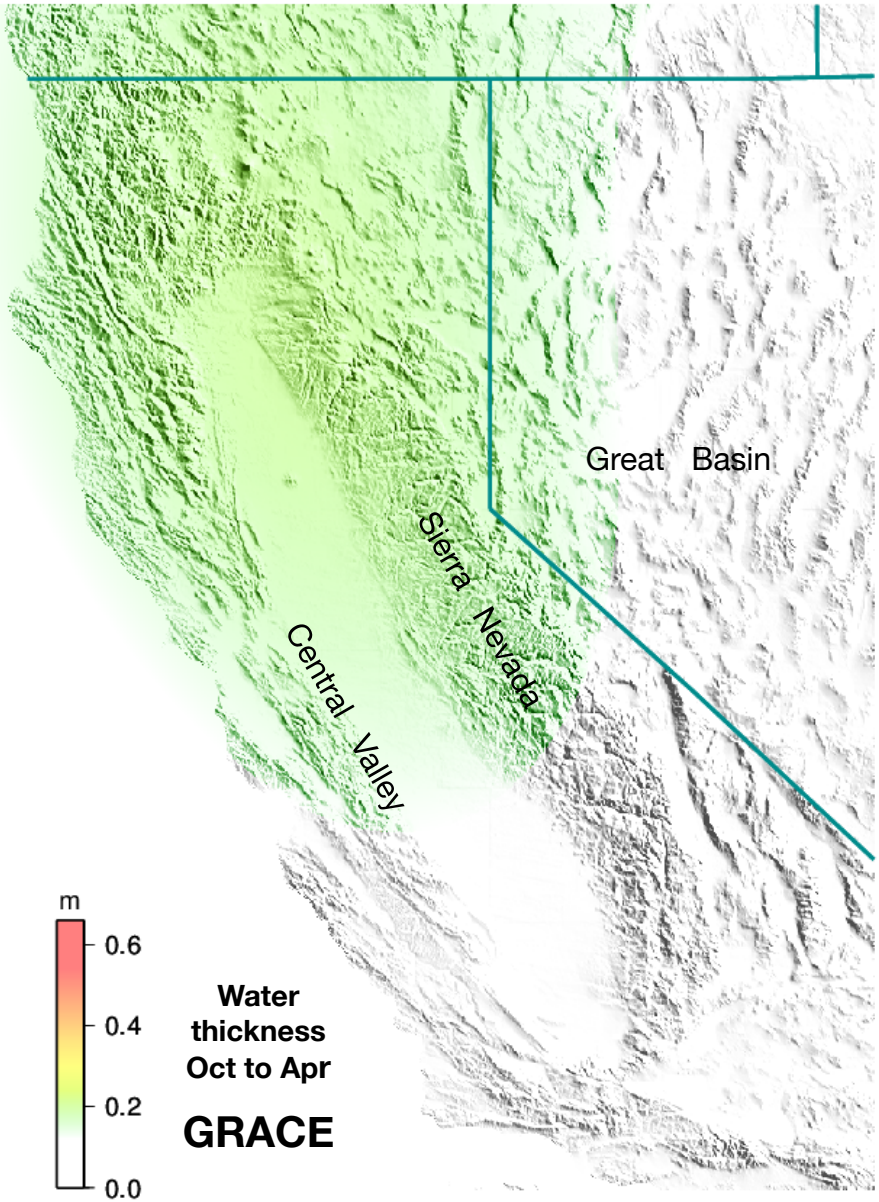


rigorous 1/4° Lapacian Fu

Seasonal water thickness change GPS Fall & Winter



Seasonal water thickness GRACE Fall & Winter

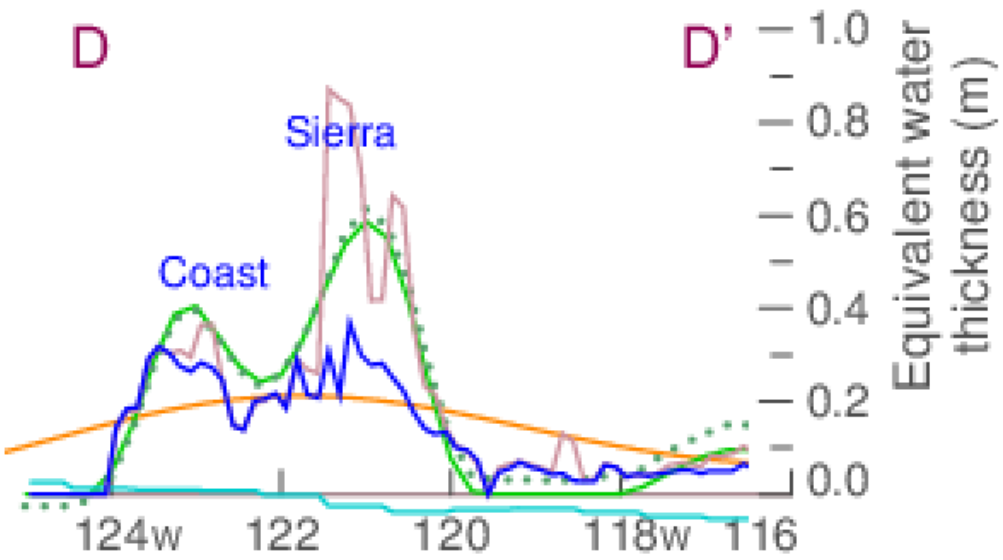


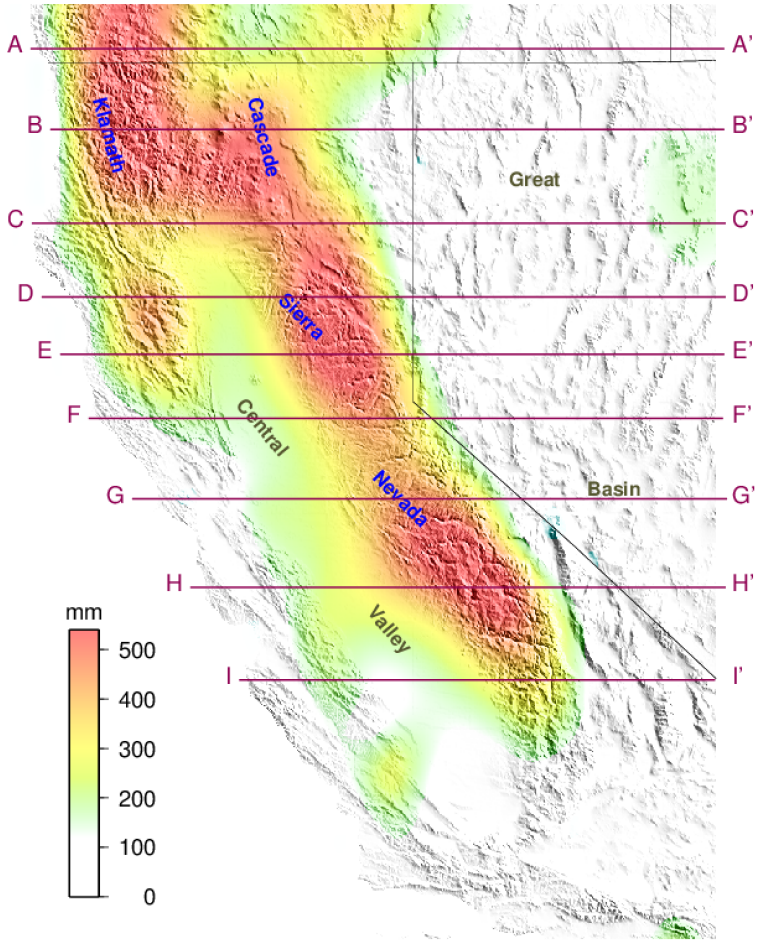
GPS resolves water storage at a spatial resolution of 75 km, compared to 300 km from GRACE.

Observations
GPS
GRACE

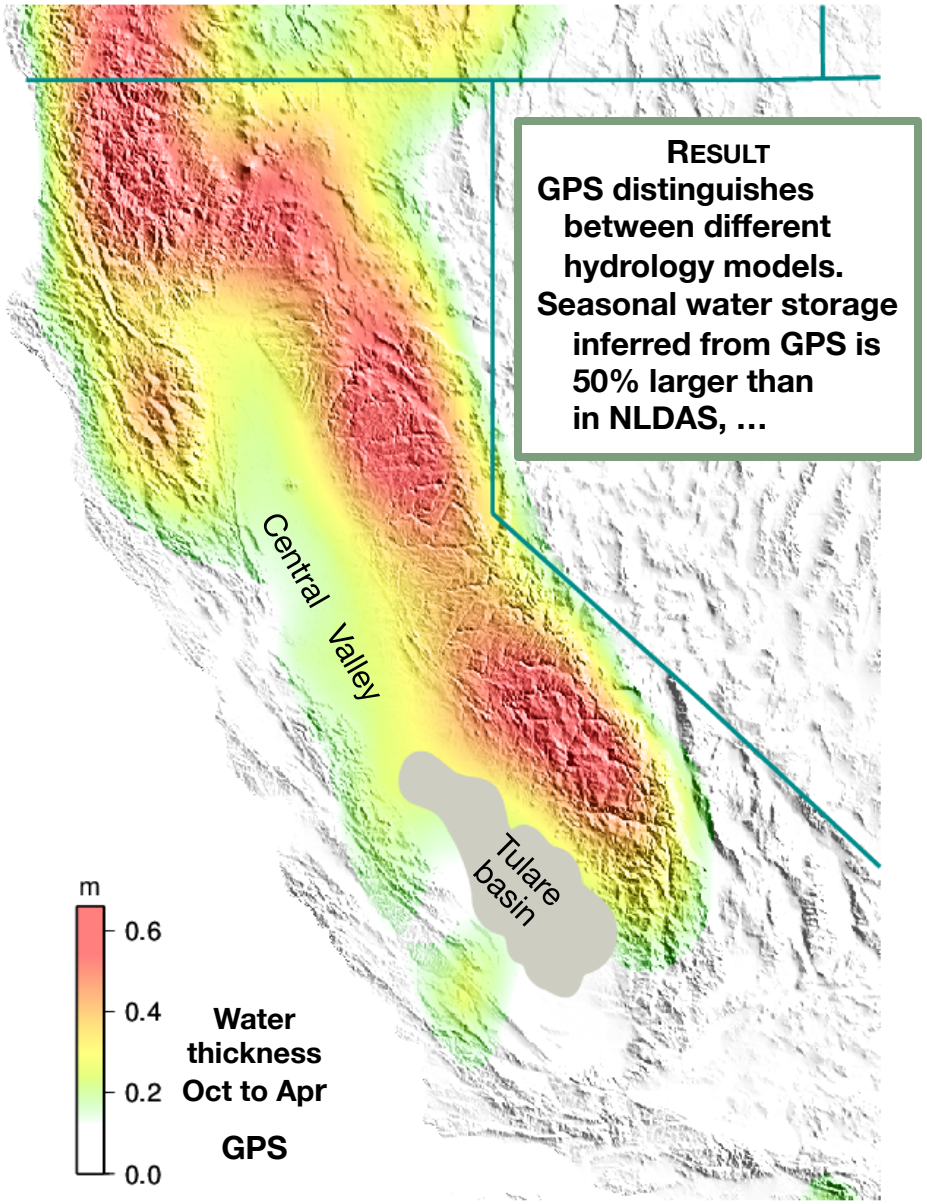
Hydrology models
NLDAS
Composite model

Atmosphere
EMCWF

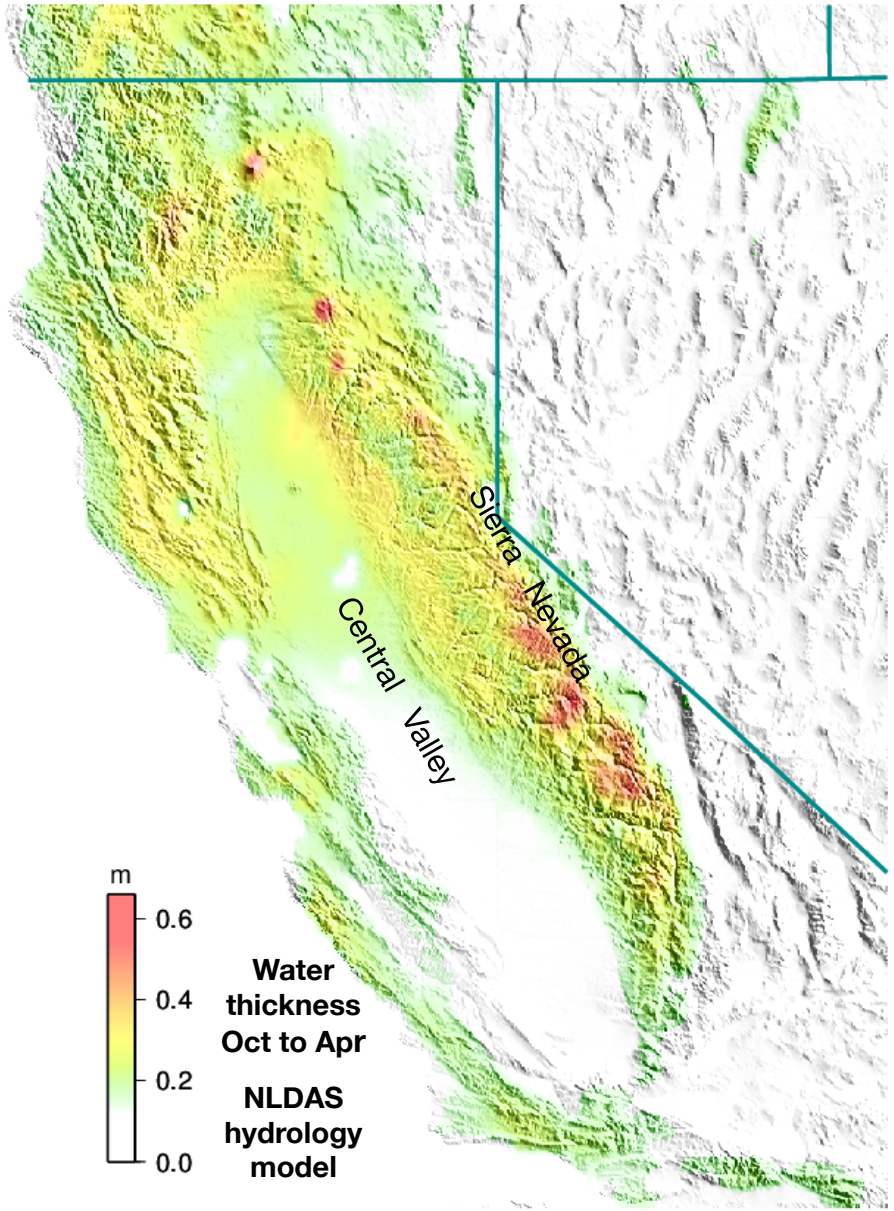




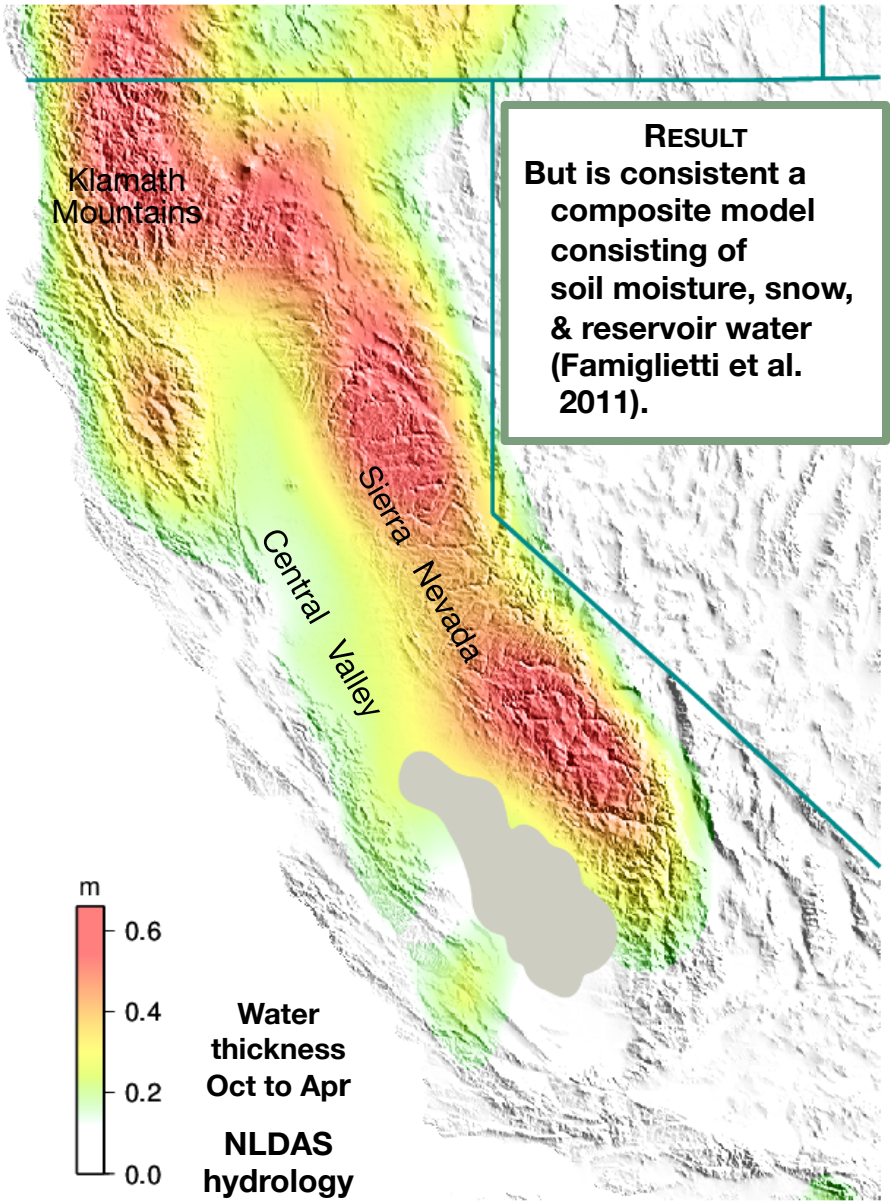
Seasonal water thickness GPS
Fall & Winter



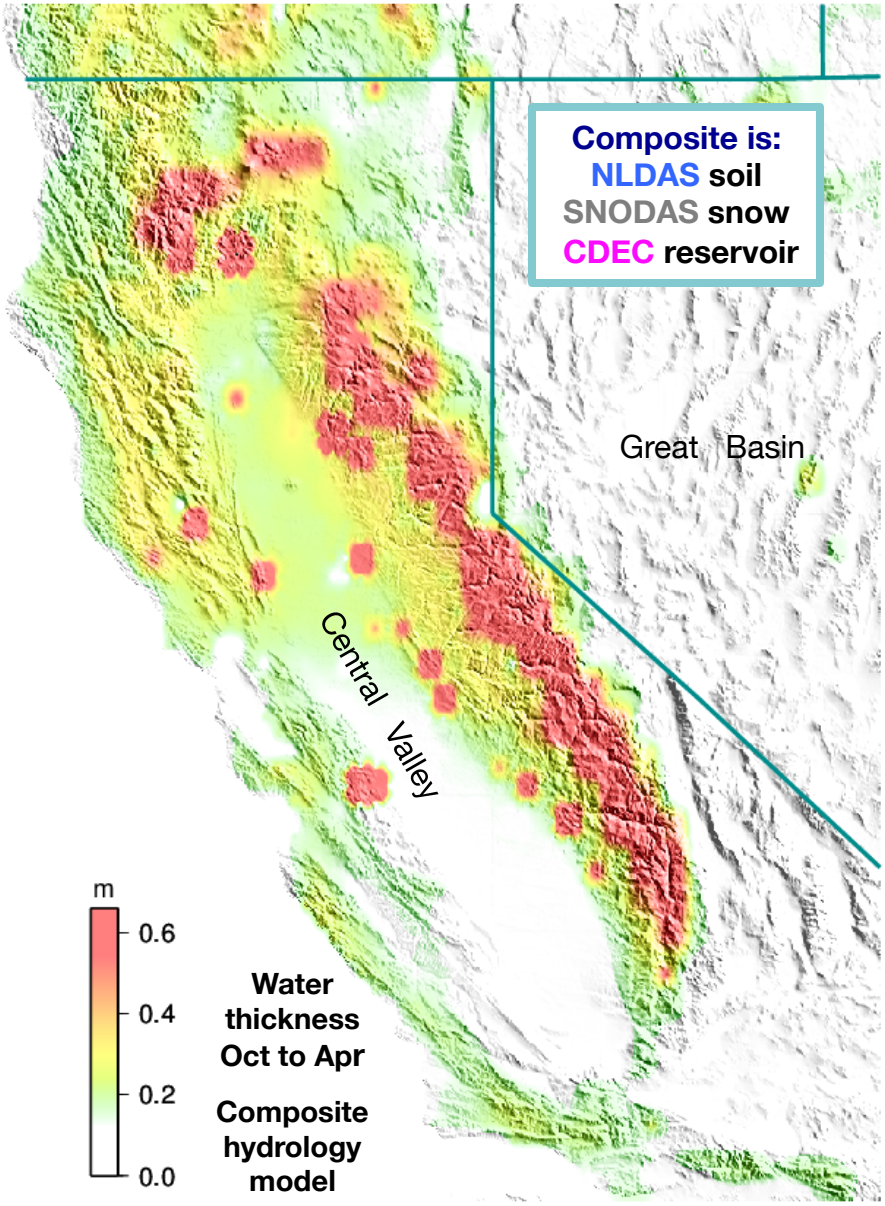
Seasonal water thickness
NLDAS hydrology model



Seasonal water thickness GPS Fall & Winter



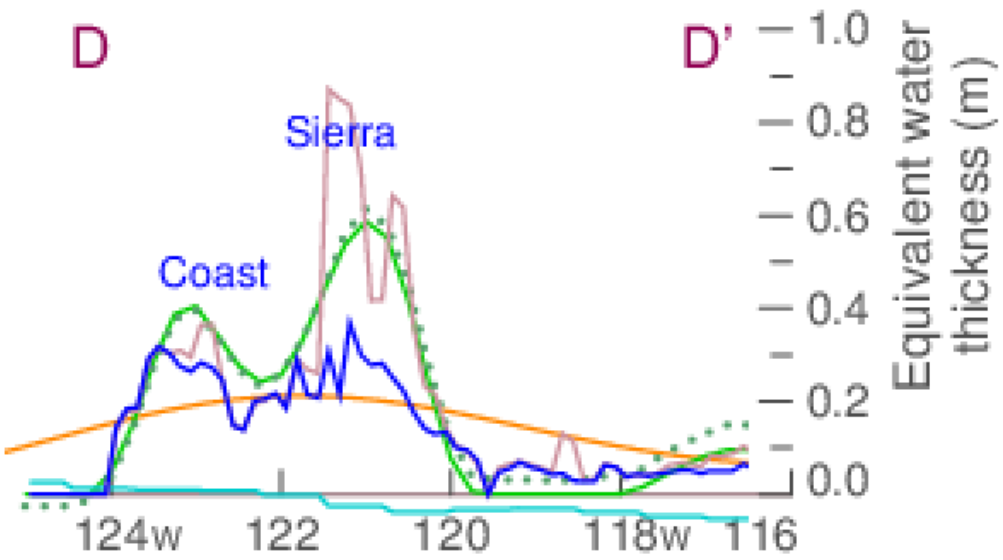
Seasonal water thickness Composite hydrology model

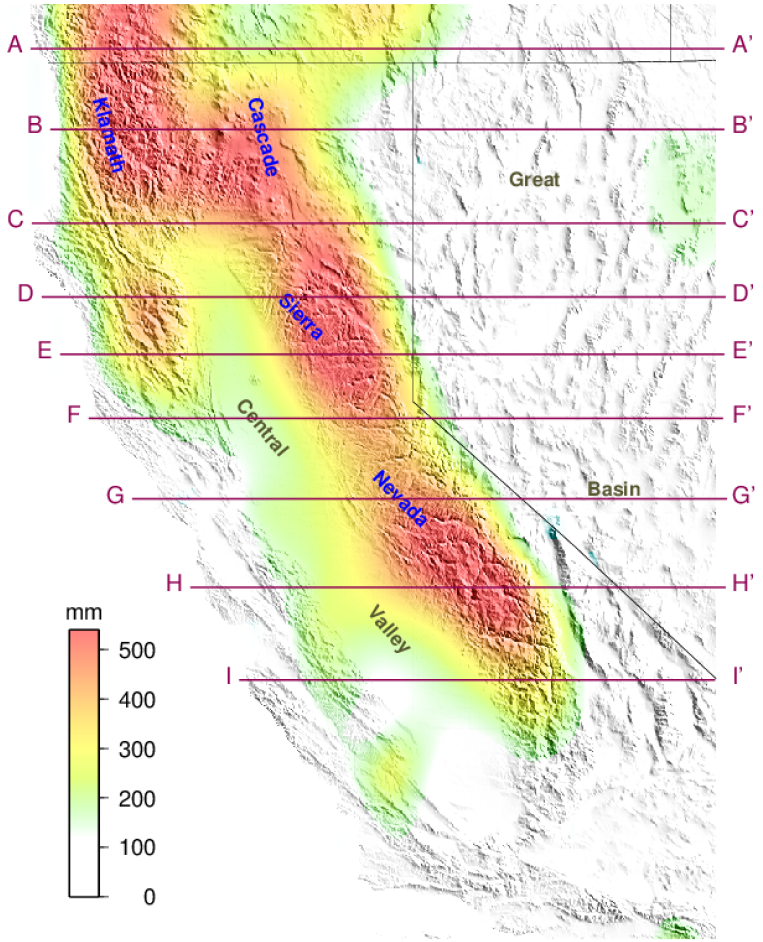


Observations
GPS
GRACE

Hydrology models
NLDAS
Composite model

Atmosphere
EMCWF





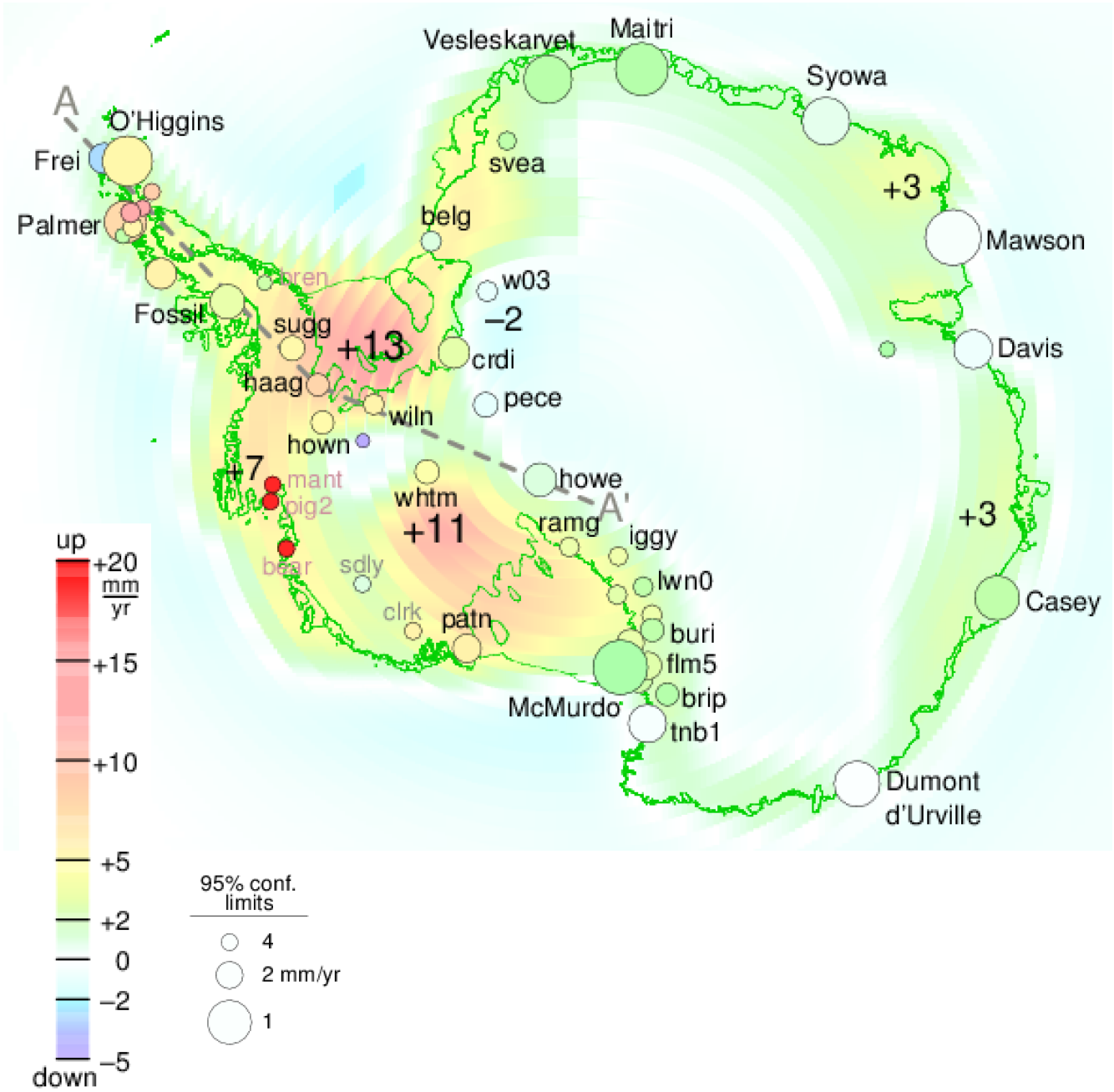
PART 3B

ICE-6G_C (VM5a)

in Antarctica

Fits all data:
GPS vertical rates,
ice thickness changes,
relative sea level histories.

GPS vertical rates



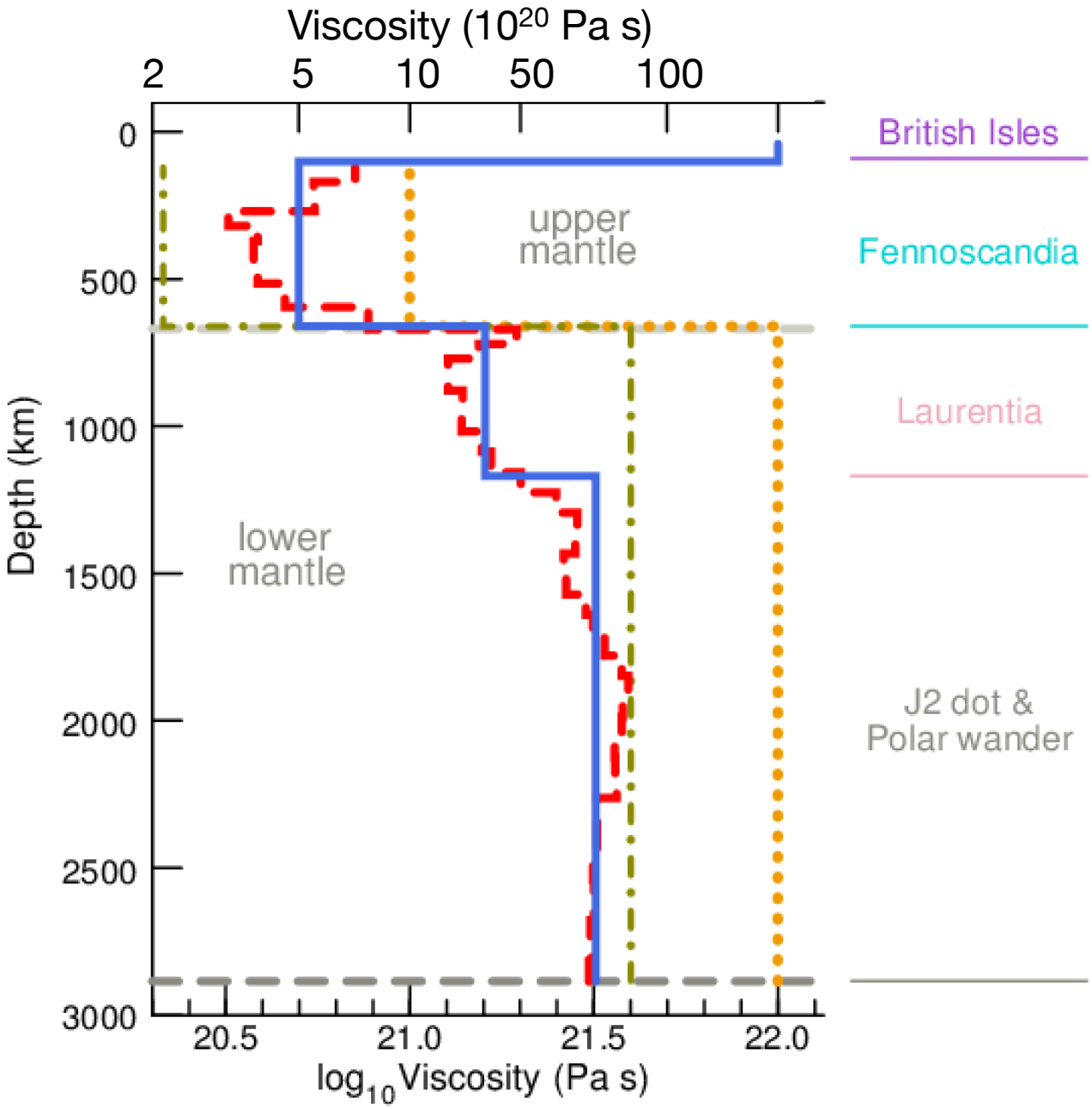
SITES USED TO CONSTRAIN PGR
25 East Antarctica
17 West Antarctica
——
42

SITES NOT USED
9 northern Antarctica Peninsula
7 Mount Erebus
1 South Shetland plate
——
17

An elastic model of current ice loss near Pine Island Bay & in northern Antarctica peninsula was constructed.

The 42 sites used are insignificantly affected by current ice loss.

Mantle viscosity profile



Key
- VM2
- VM5a
- Whitehouse 2012
- Ivins 2013

COMPARISON
UPPER MANTLE VISCOSITY
10^{20} Pa s

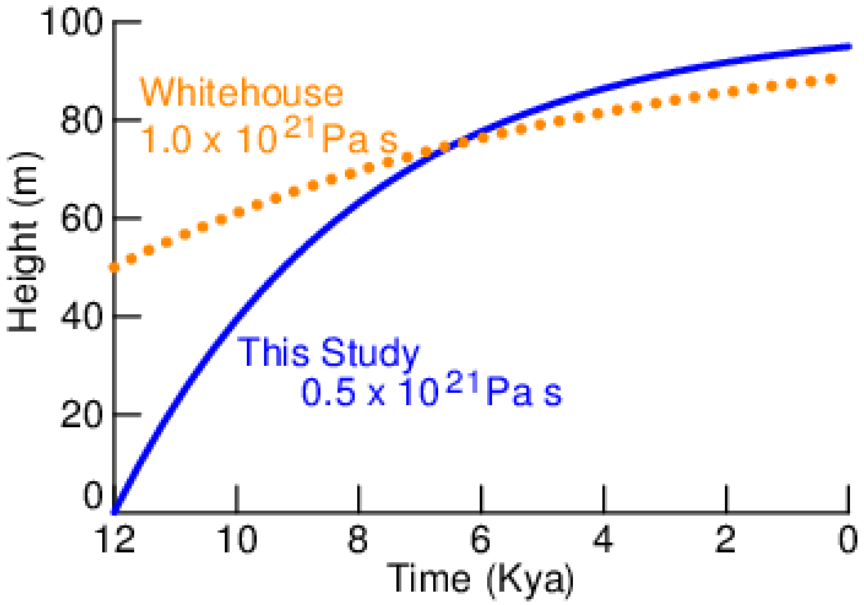
most of Antarctica
2 Ivins et al. 2013
5 Argus, Peltier, et al. 2014
10 Whithouse et al. 2012
10 Nield et al. 2014

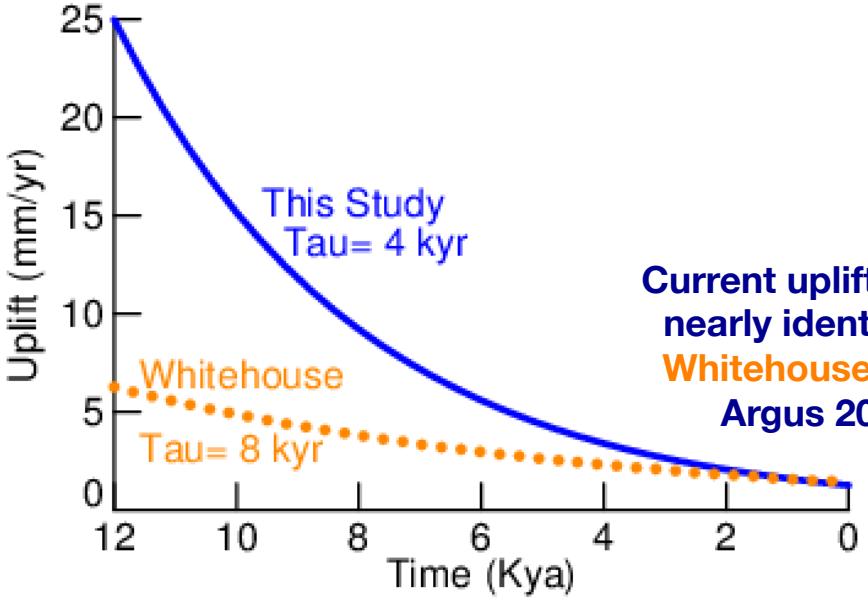
southern Antarctica peninsula
1 Nield et al. 2014

northern Antarcttica peninsula
0.1 Nield et al. 2014

Argus et al. 2014 ha twice the relaxation time as Whitehouse et al. 2012, Half the relaxation time as Ivins et al. 2013

Viscous relaxation time



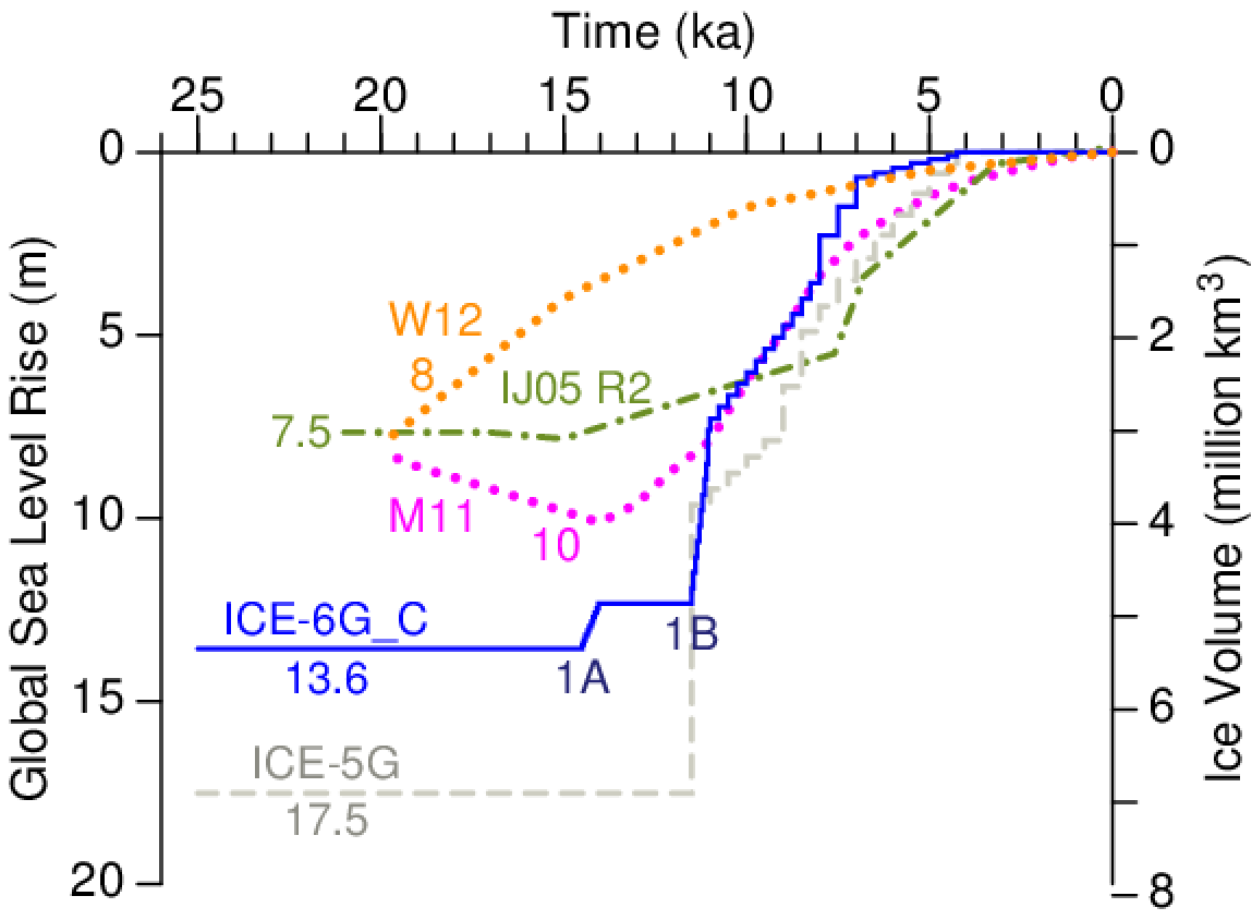


Current uplift rate is nearly identical in Whitehouse 2012, Argus 2014.

PGR MODEL
This straightfoward example illustrates differences between Whitehouse 2012, Argus 2014.

Whitehouse 2012 has twice the relaxation time, half the ice loss compared to Argus et al. 2014.

Deglaciation history



RESULTS

ICE-6G has nearly twice the ice loss as W12, IJ05 R2.

ICE-6G has fast ice loss at and after Meltwater Pulse 1B (11.5 ka – 7 ka)

INFERENCE

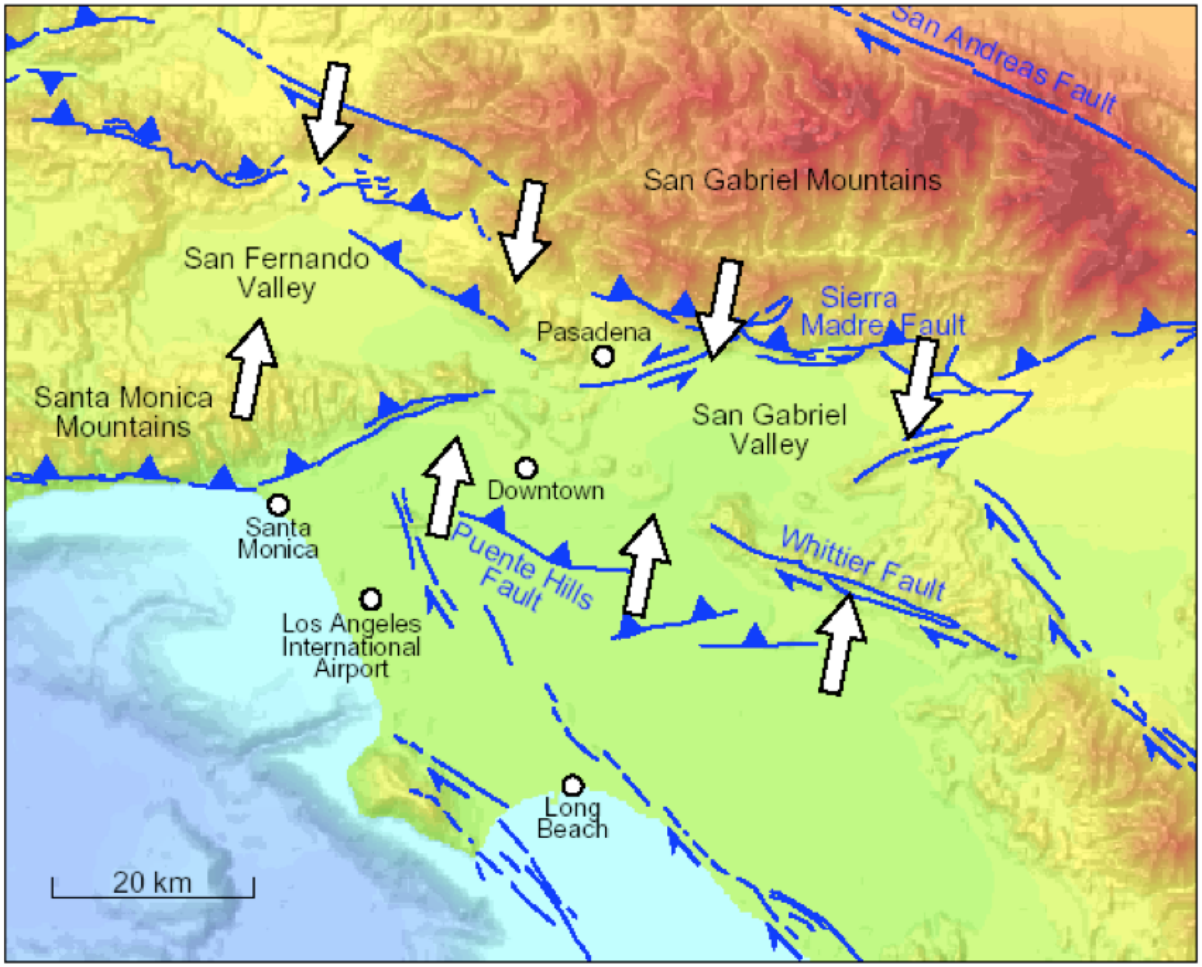
W12 ice loss is too early,
IJ05 R2 ice loss is too late.

CONCLUSION

Technical advances in GPS vertical positioning have improved our understanding of:

(1) Water changes in California and

(2) Postglacial rebound in Antarctica and North America.



ARGUS ET AL. JGR 2005
Northern metropolitan Los Angleles is shortening and thickening.

Puente Hills thrust
Slip rate 8 mm/yr
Locking depth 12 km