Comparison of GRACE Satellite Data with Monitoring and Modeling Data

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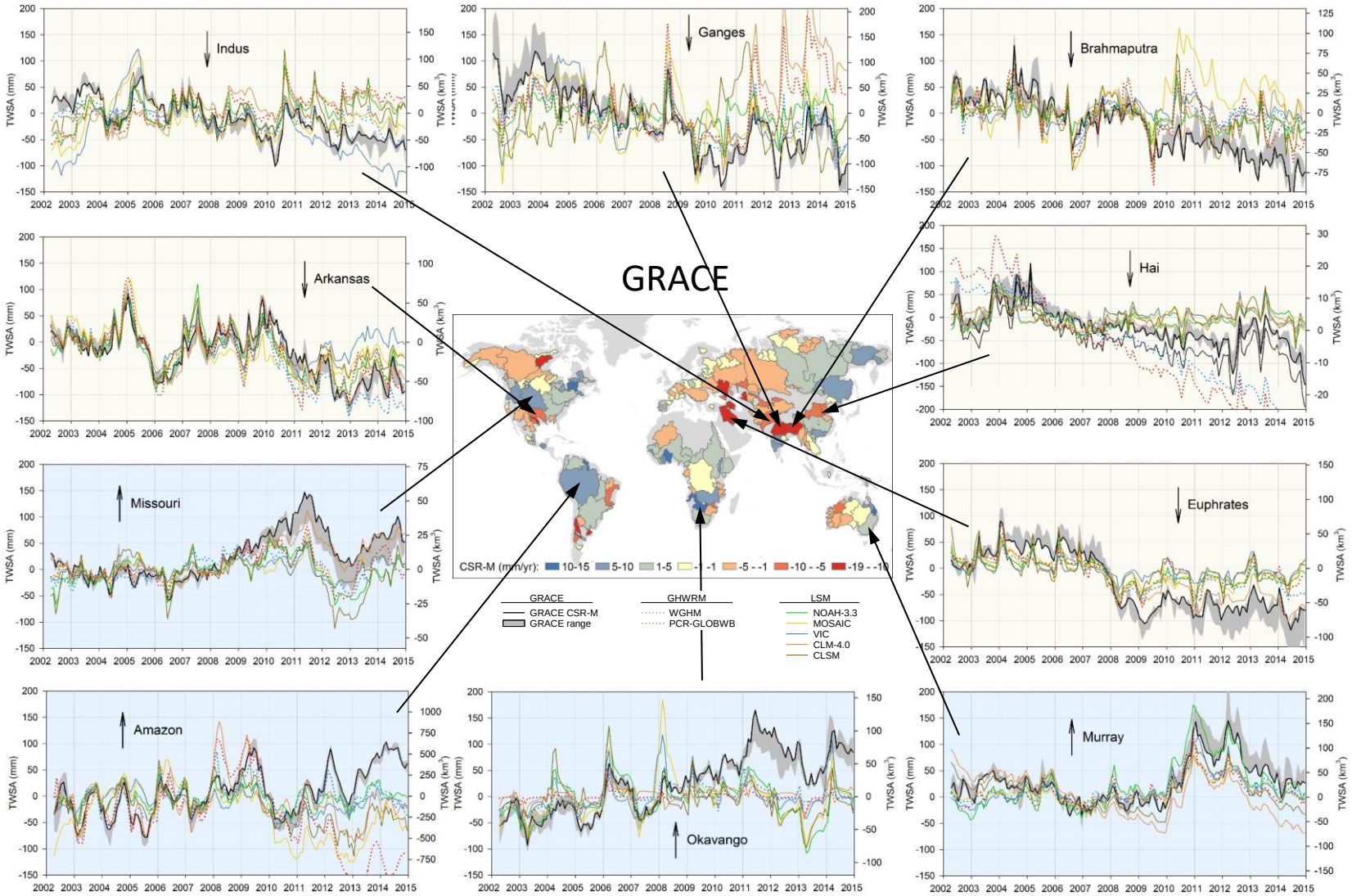
GRACE: The Big Picture, Comparison with Global Models Total Water Storage Trends (2002 – 2015)



Most global models underestimate TWS trends relative to GRACE data

Scanlon et al., 2018, PNAS

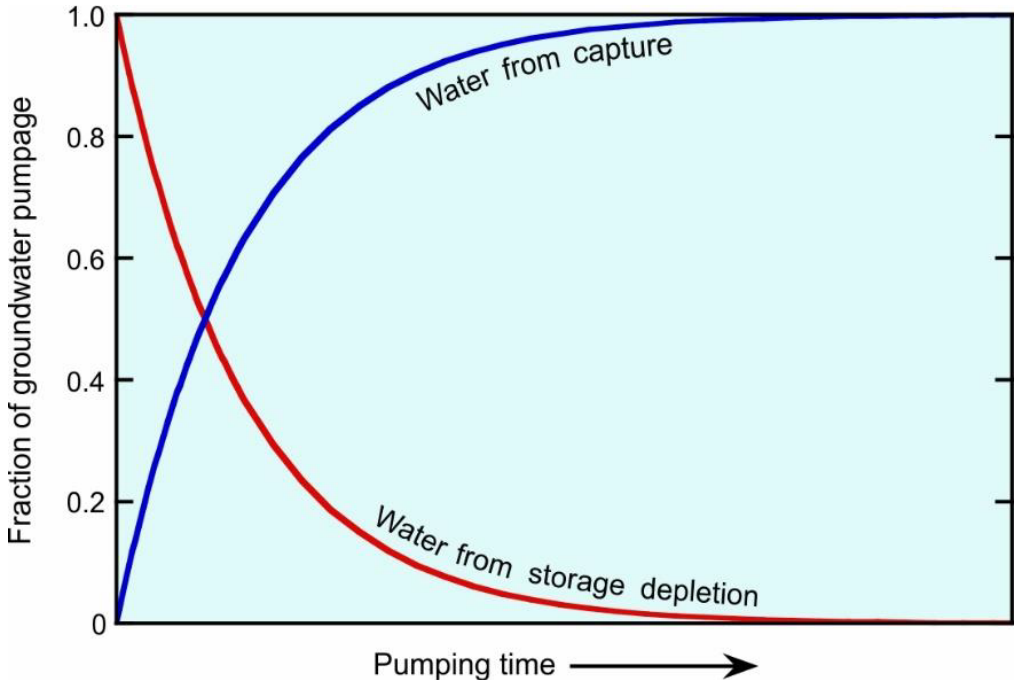
Water Storage

Input – Output = Change in Storage

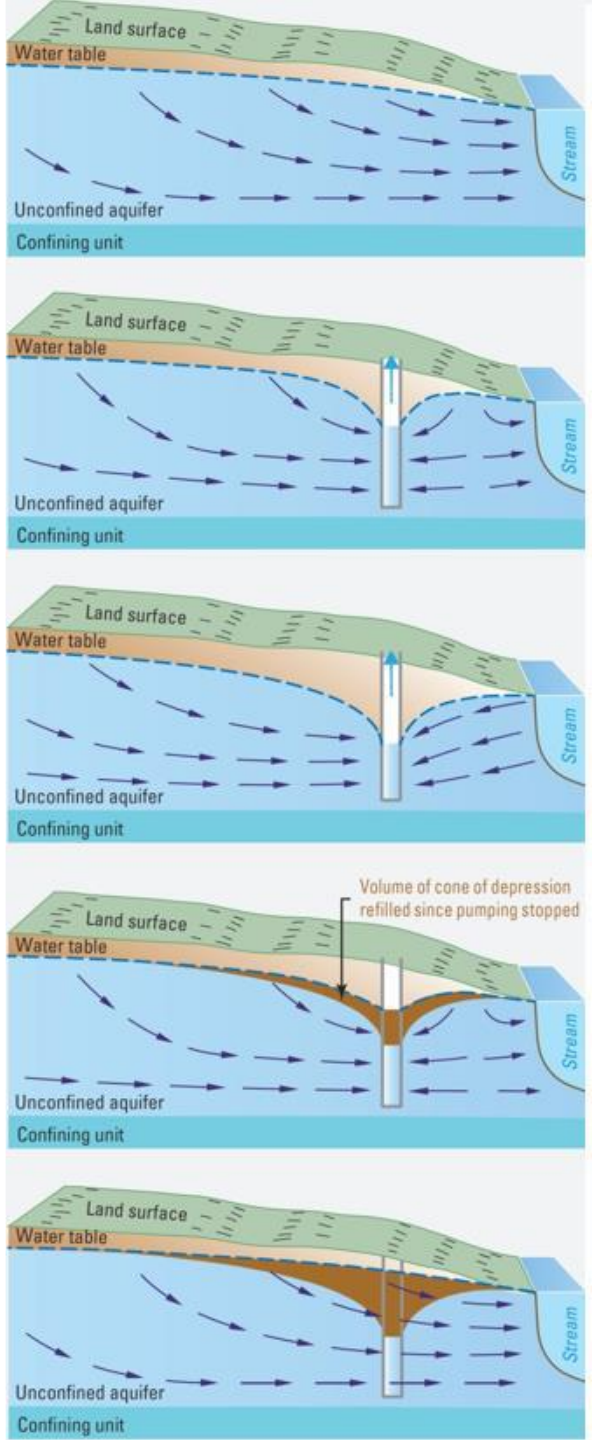
↓ ↑ ↓

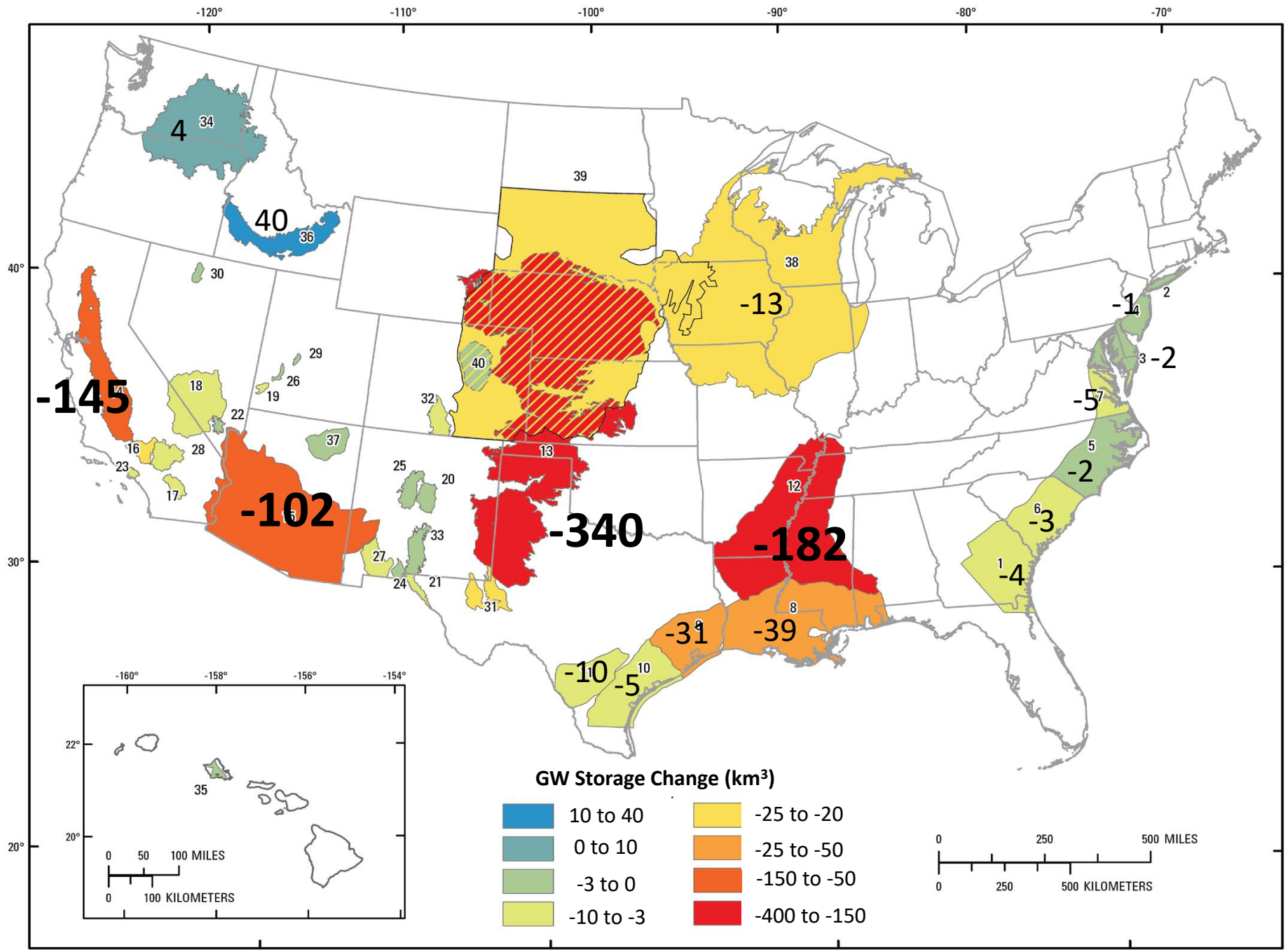
Change in GW Storage = change in **GW levels** x **Storage coefficient**

Change in Storage = Recharge – Discharge



Konikow and Bredehoeft, 2020





Base from U.S. Geological Survey digital data, 1972,1:2,000,000
Albers Equal-Area Conic Projection
Standard parallels 29° 30' N and 45° 30' N, central meridian 96° 00' W

Background

Groundwater storage trends from regional groundwater models and groundwater level monitoring

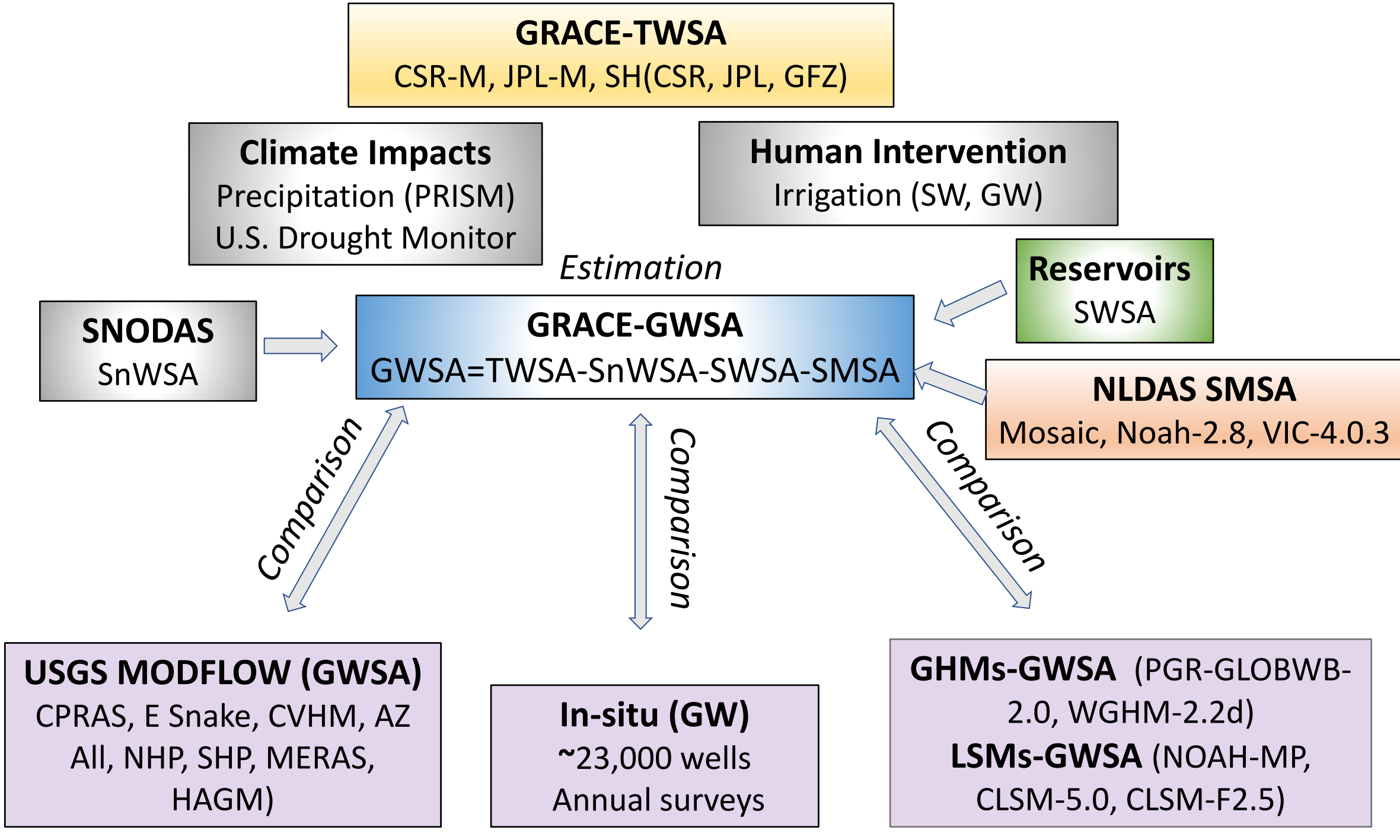
km^3 from 1900 - 2008

High Plains, AZ Alluvial, Upper Colorado, & Snake: unconfined
Columbia & Central Valley: semiconfined
All other aquifers: confined

Konikow, USGS SIR, 2013

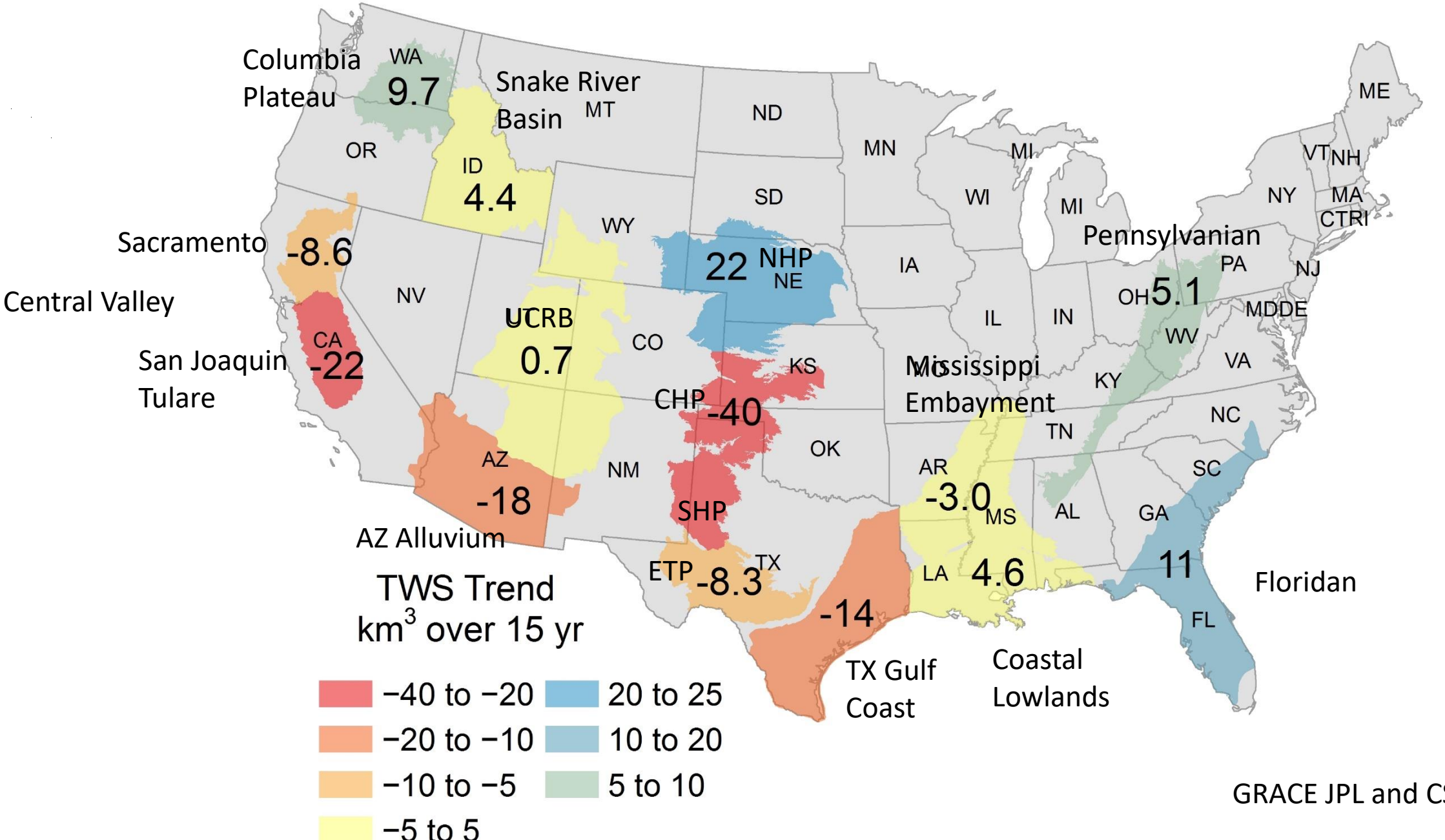
Basic Questions

1. How reliable are GRACE satellite data?
2. What is causing changes in water storage? Climate? Human intervention?
3. How can we use the results of these analyses to move towards more sustainable water resources management?


GRACE-TWSA
CSR-M, JPL-M, SH(CSR, JPL, GFZ)
Climate Impacts
Precipitation (PRISM)
U.S. Drought Monitor
Human Intervention
Irrigation (SW, GW)
Estimation
Reservoirs
SWSA
SNODAS
SnWSA
GRACE-GWSA
GWSA=TWSA-SnWSA-SWSA-SMSA
NLDAS SMSA
Mosaic, Noah-2.8, VIC-4.0.3
Comparison
Comparison
Comparison
USGS MODFLOW (GWSA)
CPRAS, E Snake, CVHM, AZ All, NHP, SHP, MERAS, HAGM)
In-situ (GW)
~23,000 wells
Annual surveys
GHMs-GWSA (PGR-GLOBWB-2.0, WGHM-2.2d)
LSMs-GWSA (NOAH-MP, CLSM-5.0, CLSM-F2.5)

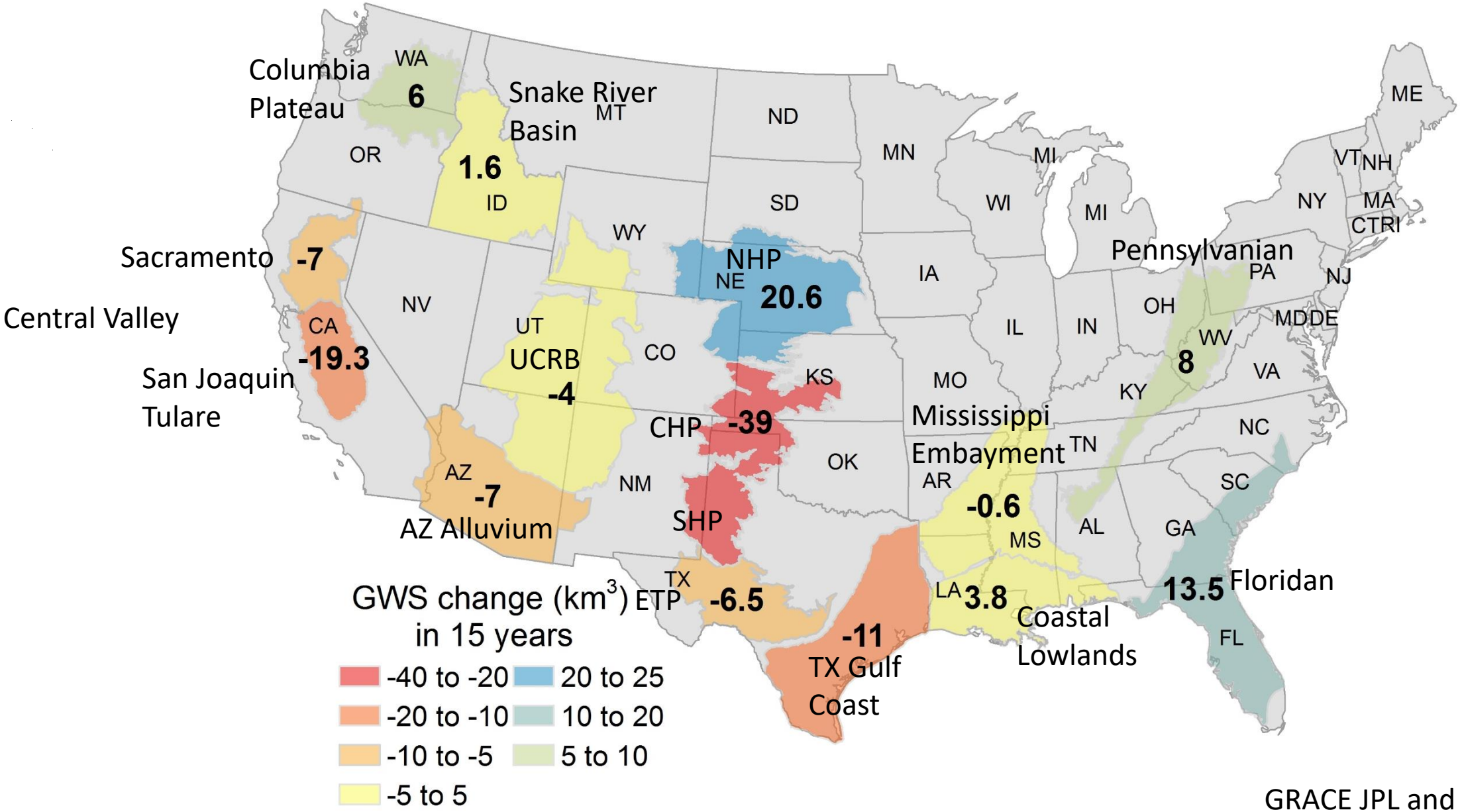
RESULTS

GRACE Trends in **Total Water Storage** (2002 – 2017)



GRACE JPL and CSR Mascons

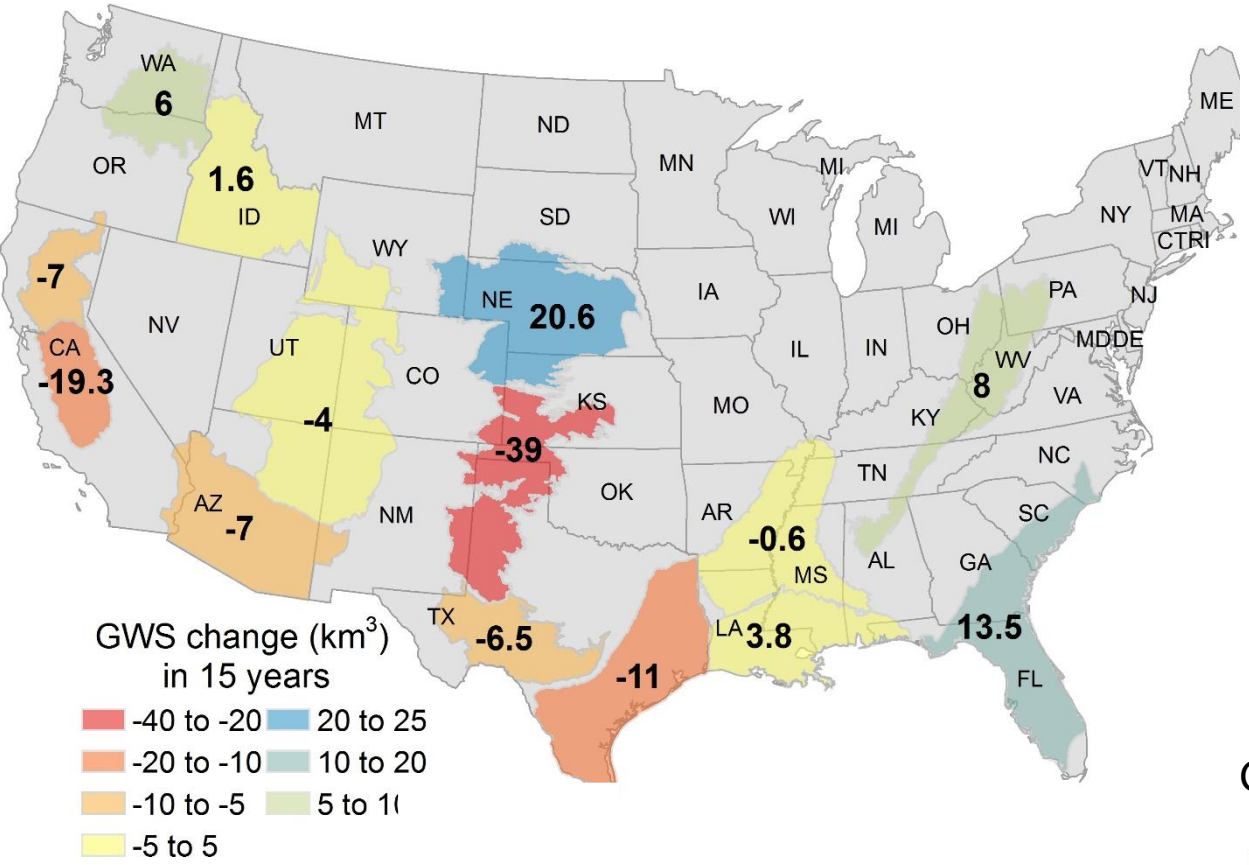
GRACE Trends in **Groundwater Storage** (2002 – 2017)



GRACE JPL and CSR Mascons

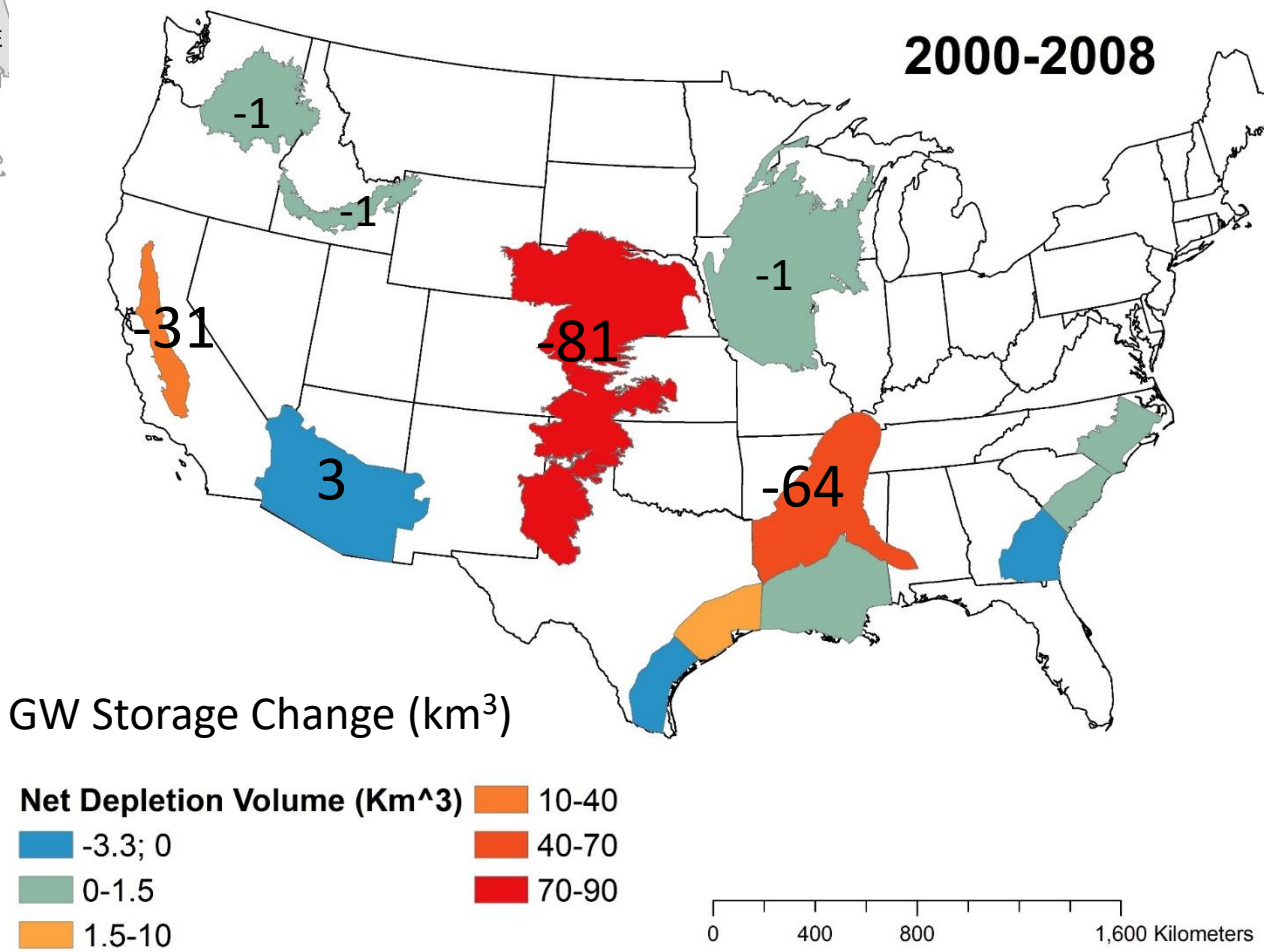
Rateb et al., 2020, WRR

GW Storage Change
GRACE (2002 – 2015)



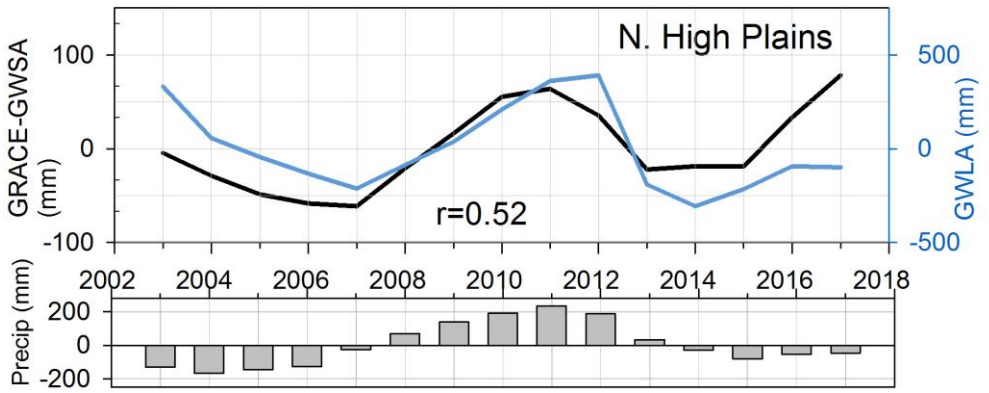
Rateb et al., 2020

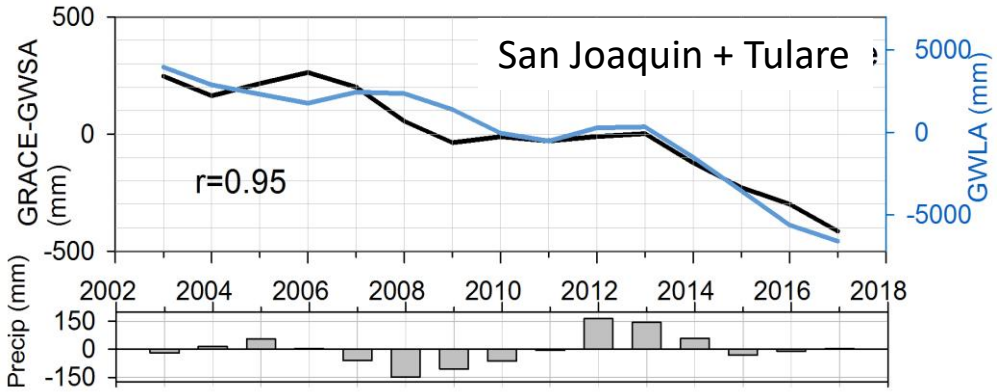
GW Storage Change
Regional Models and Monitoring

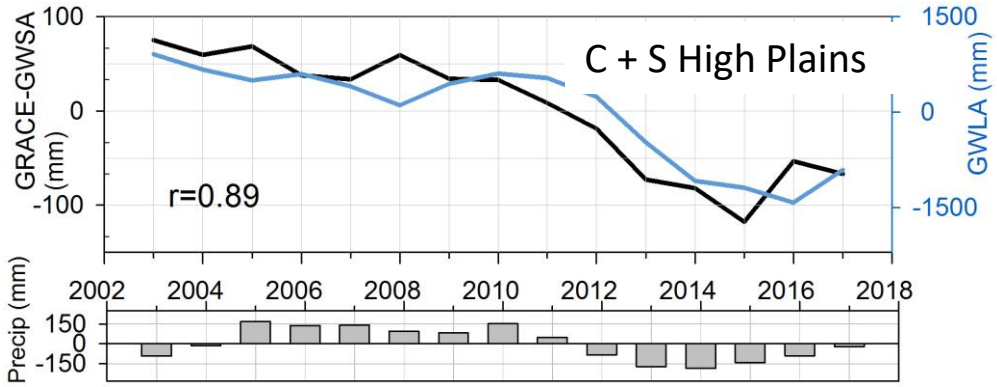


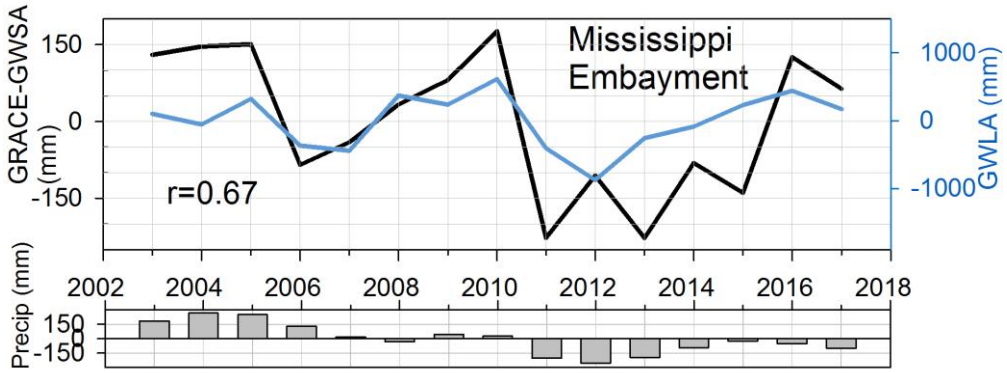
Konikow et al., 2011

Comparison of GRACE-derived GW Storage Change and GW Level Monitoring Data

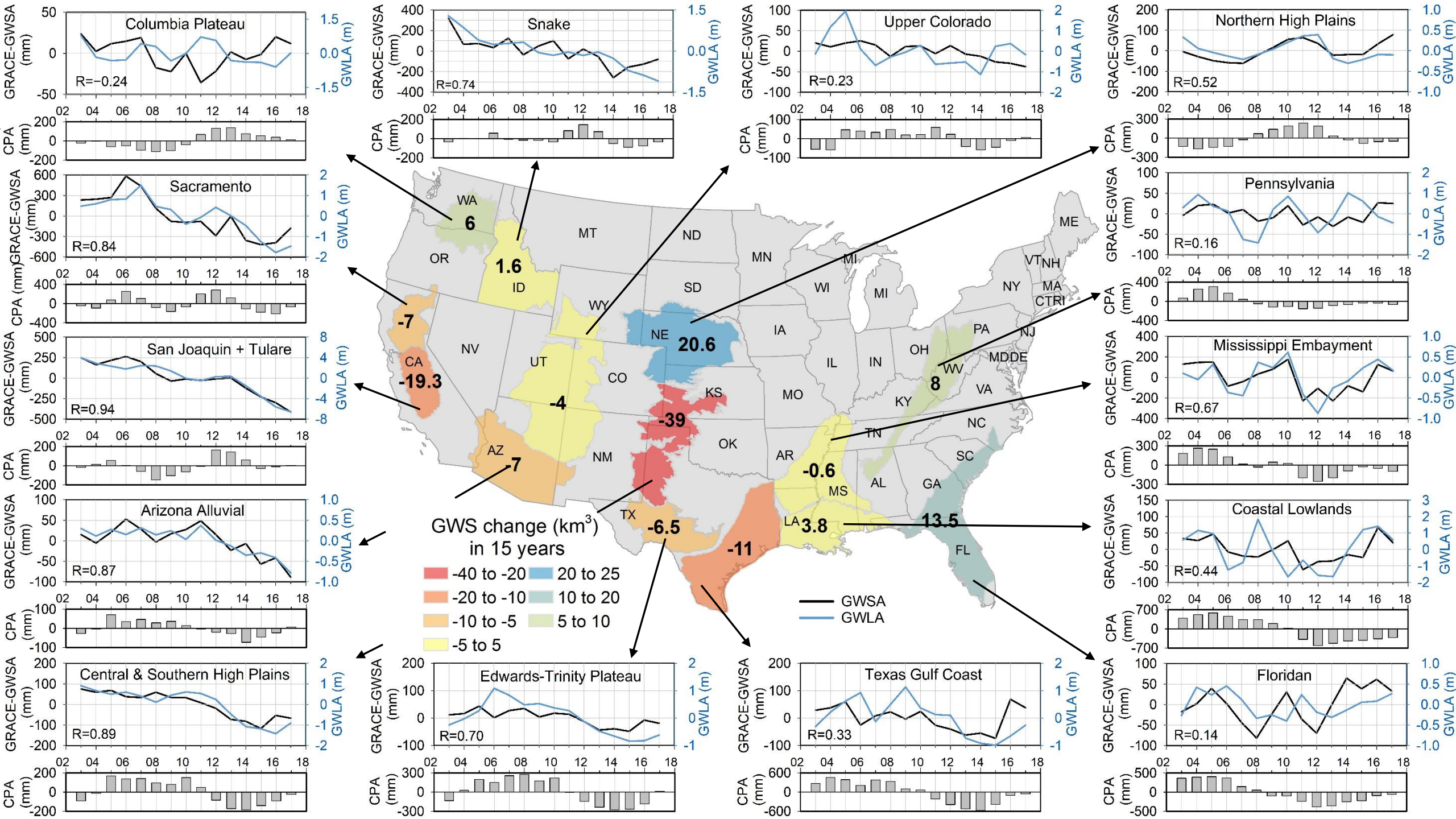




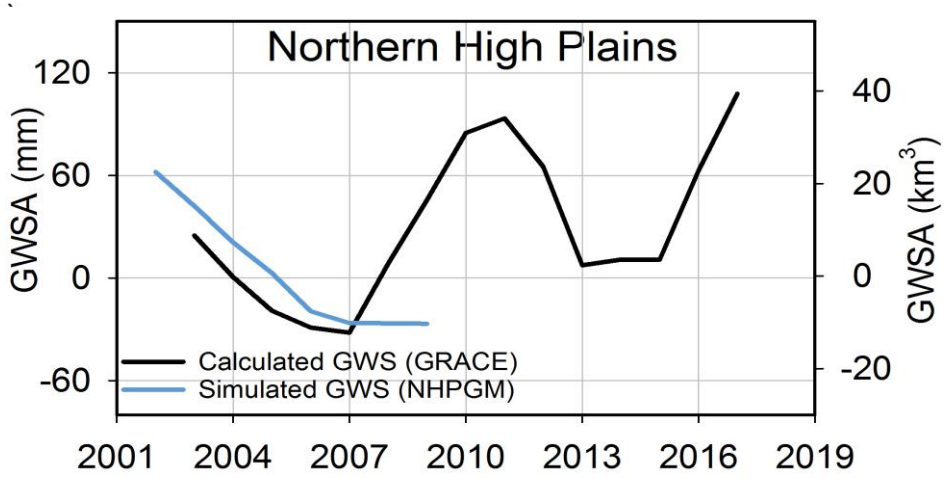


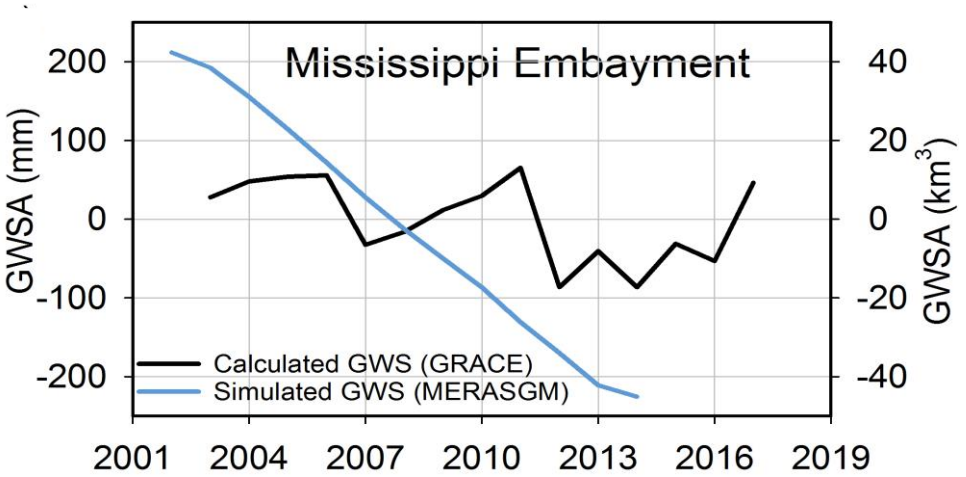


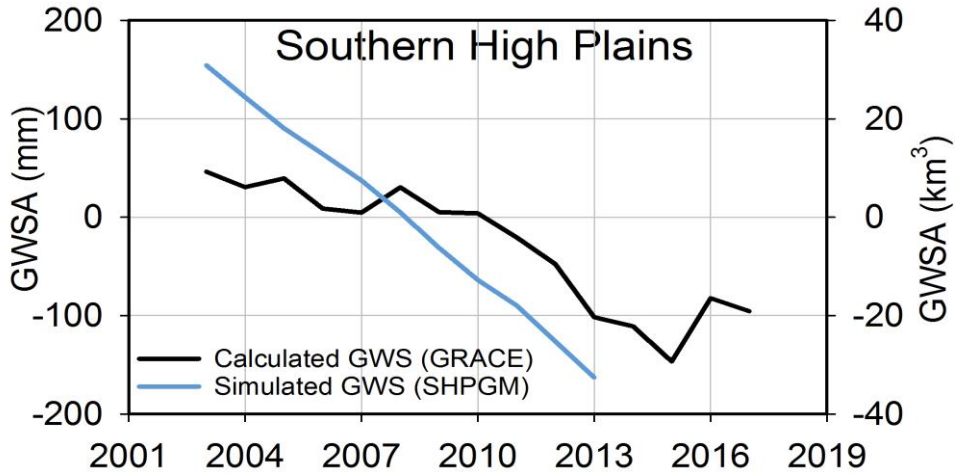
GRACE-GWSA
GWLA


Columbia Plateau
R=−0.24
Snake
R=0.74
Upper Colorado
R=0.23
Northern High Plains
R=0.52
Sacramento
R=0.84
Pennsylvania
R=0.16
San Joaquin + Tulare
R=0.94
Mississippi Embayment
R=0.67
Arizona Alluvial
R=0.87
Coastal Lowlands
R=0.44
Central & Southern High Plains
R=0.89
Edwards-Trinity Plateau
R=0.70
Texas Gulf Coast
R=0.33
Floridan
R=0.14
GRACE-GWSA (mm)
GWLA (m)
CPA (mm)
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
MDDE
NJ
VT
NH
ME
MA
CTRI
6
1.6
-7
-19.3
-4
20.6
-39
-7
-6.5
-11
3.8
-0.6
8
13.5
GWS change (km3) in 15 years
-40 to -20
-20 to -10
-10 to -5
-5 to 5
20 to 25
10 to 20
5 to 10
GWSA
GWLA

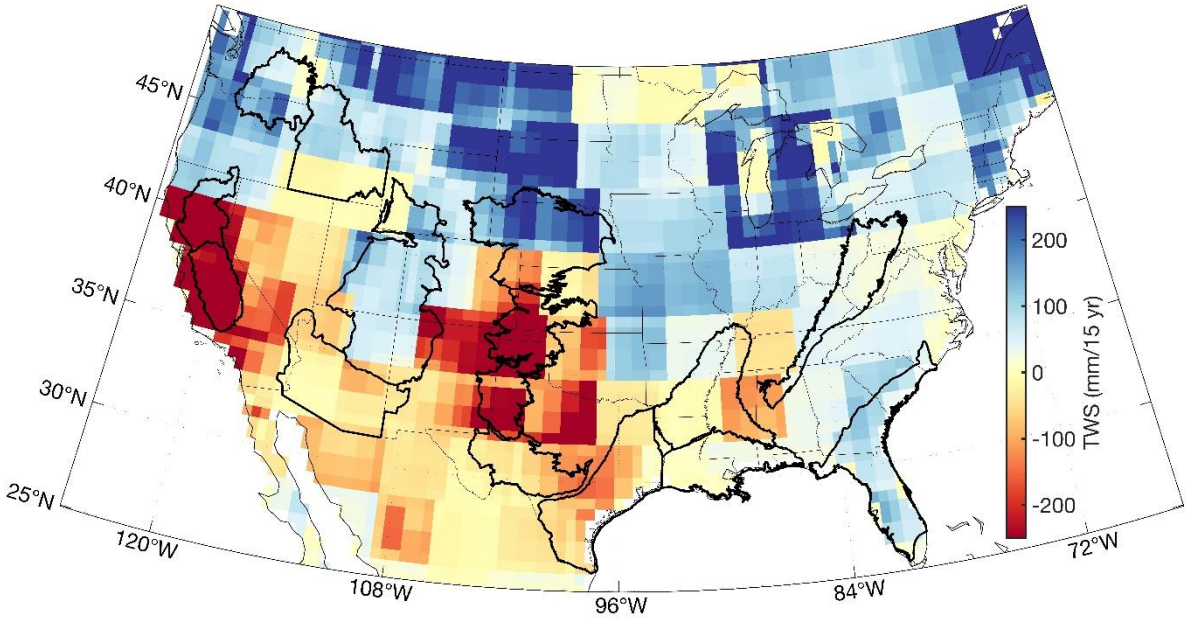
Comparison of GRACE-derived GW Storage Change and **Regional GW Models**



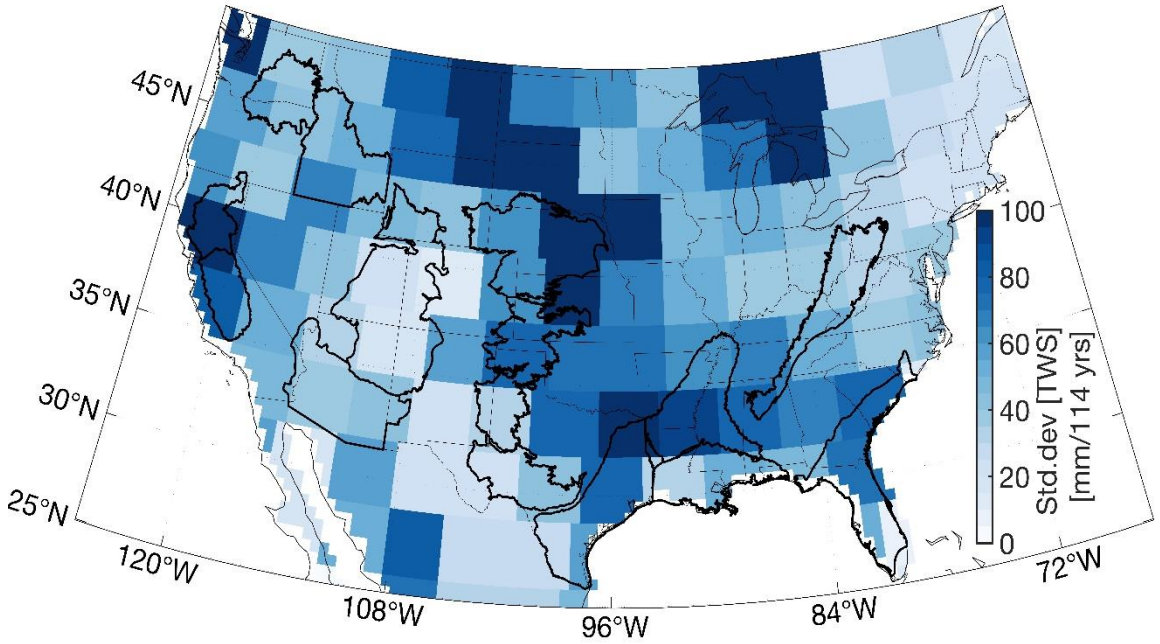


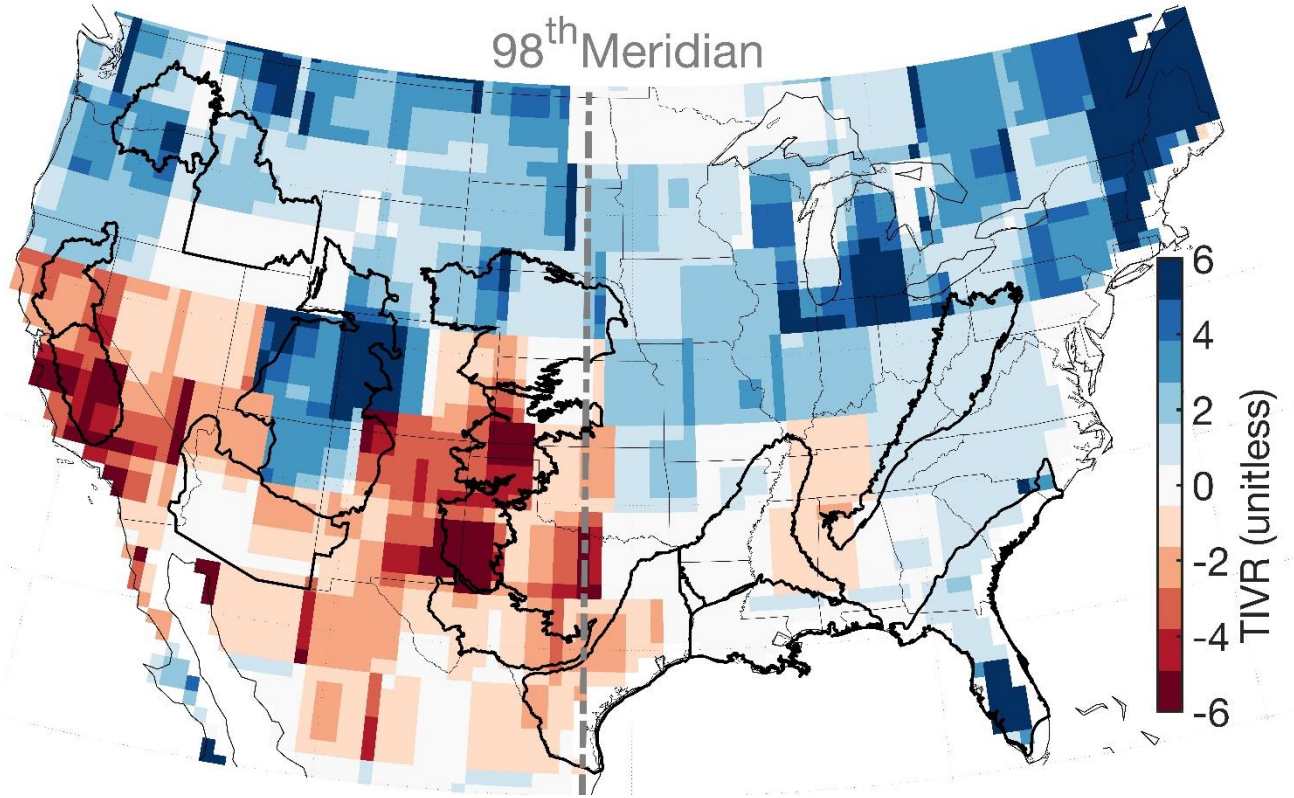


What is a TWS Trend?



$$\frac{\text{TWS trend (15.25 yrs)}}{\text{SD TWS. Rec 114 yrs (Interannual)}} =$$

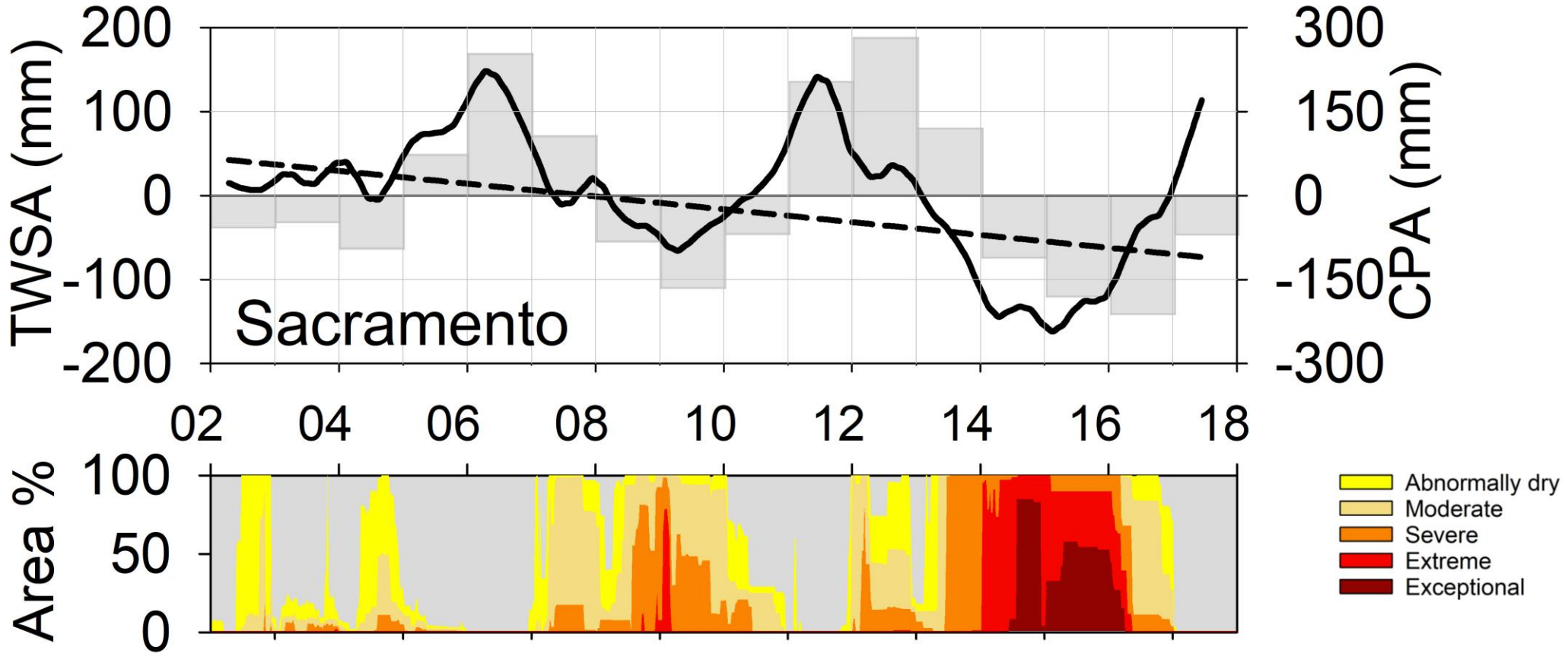




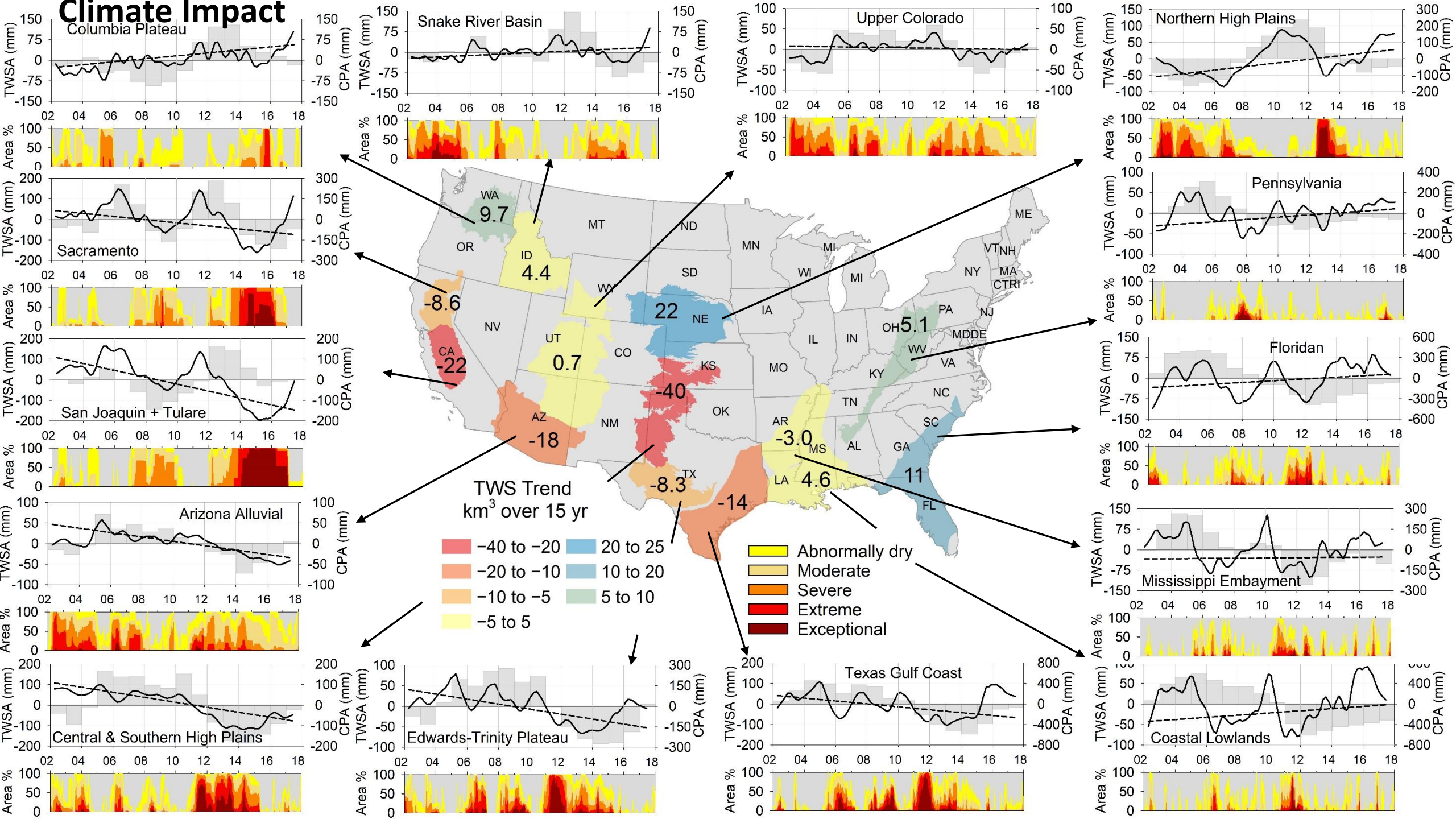
Trends > 2 – 3 SD of interannual variability

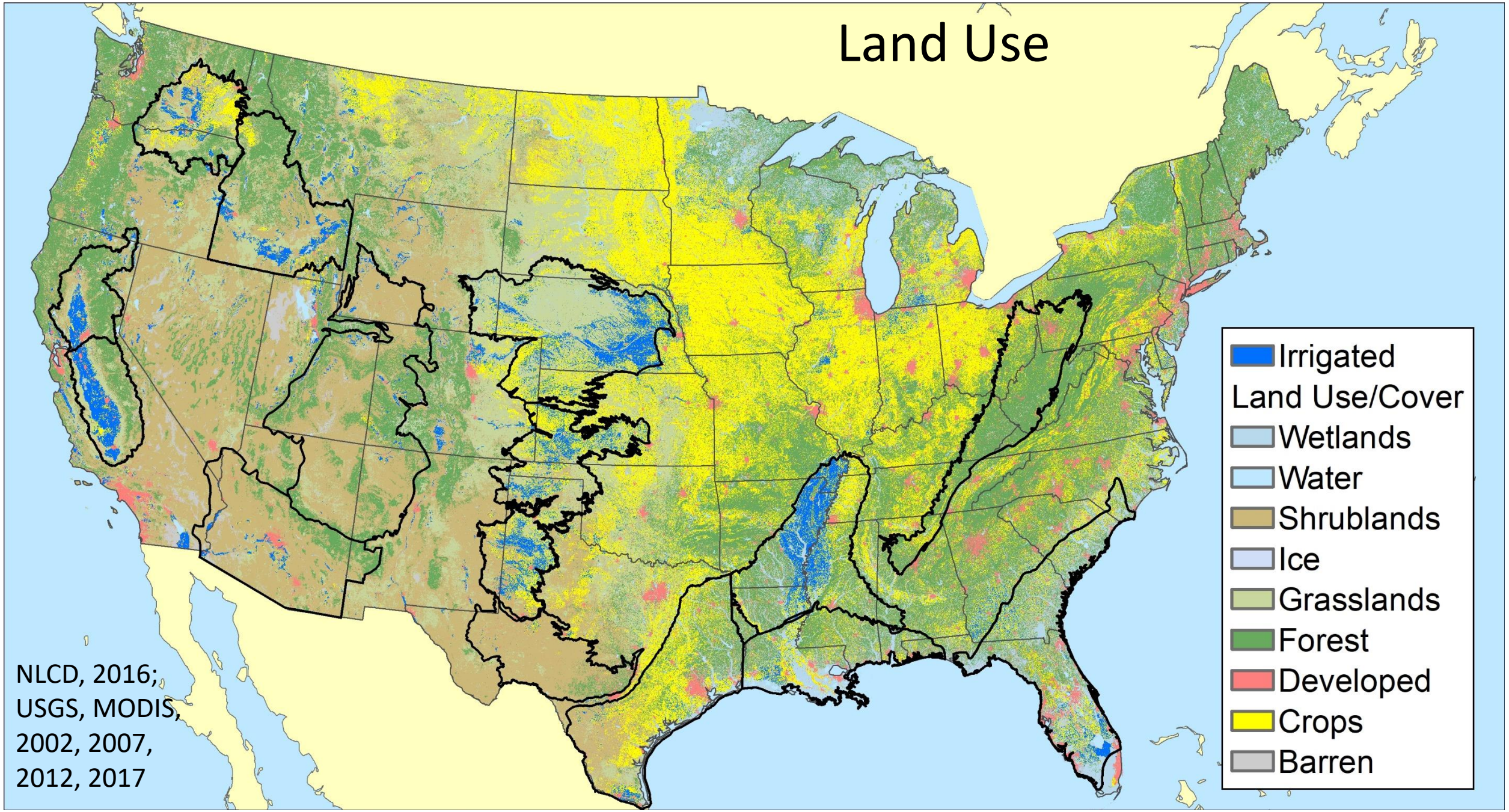
Vishwakarma et al., 2021, ERL

Causes of GRACE TWS Variations

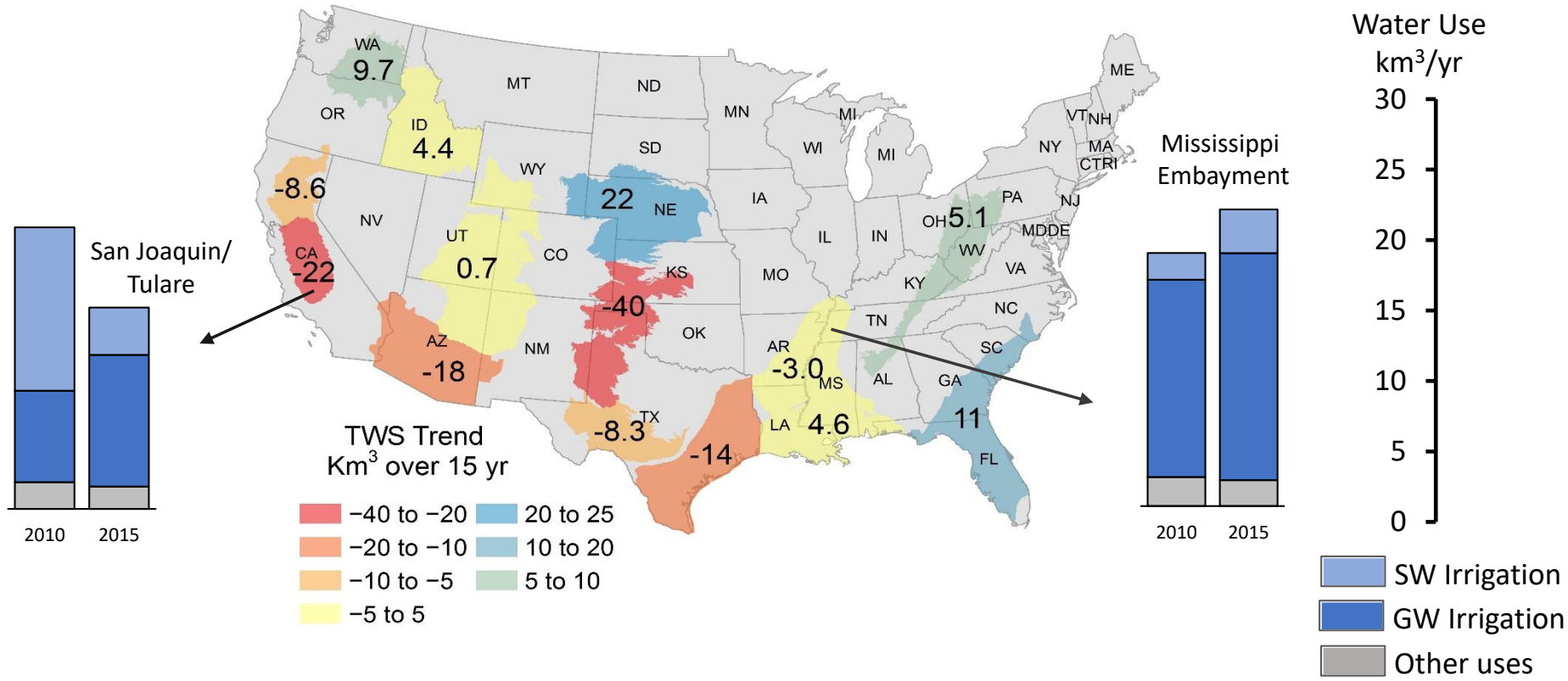


Climate Impact



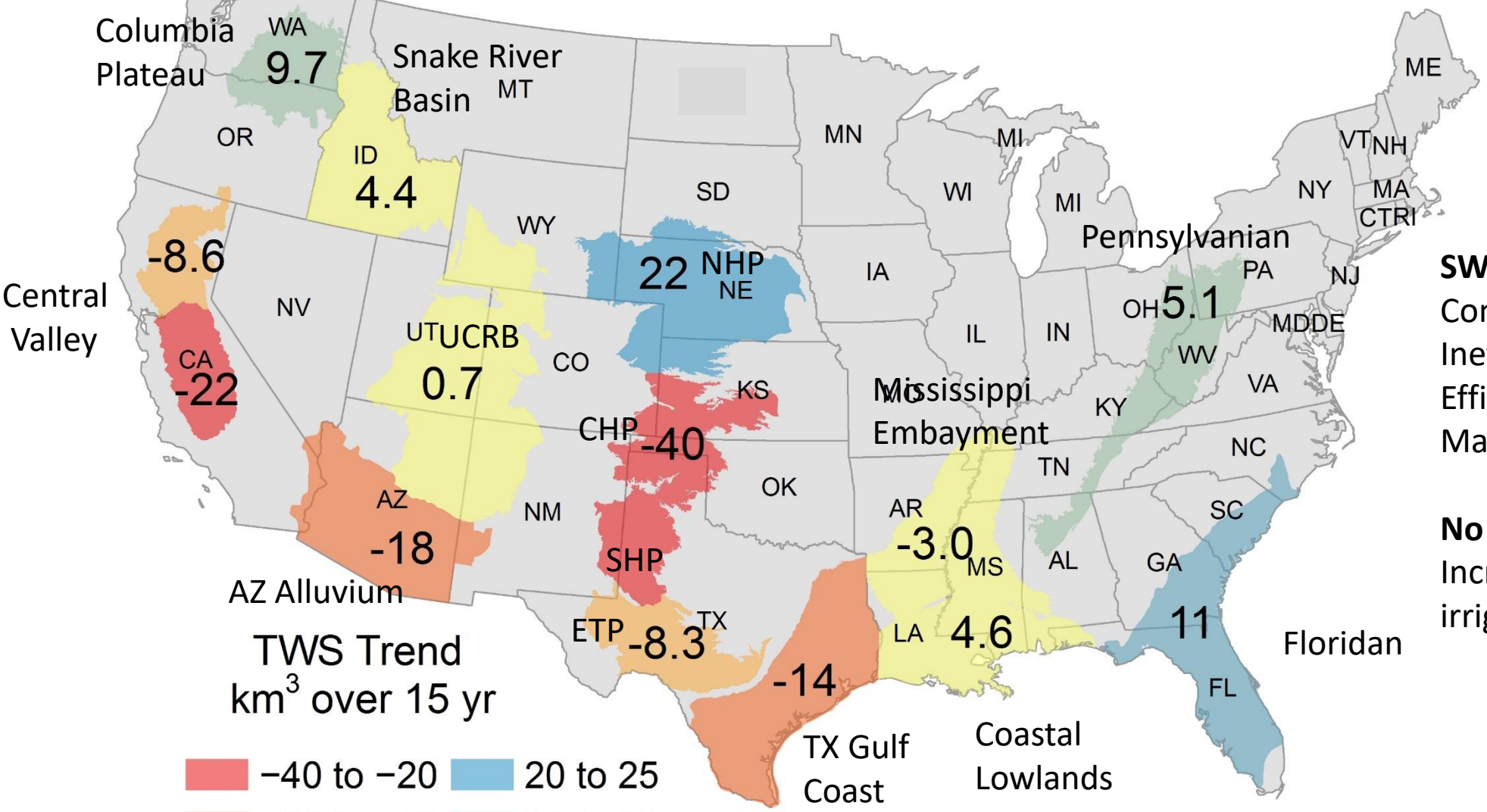

Land Use
Irrigated
Land Use/Cover
Wetlands
Water
Shrublands
Ice
Grasslands
Forest
Developed
Crops
Barren
NLCD, 2016;
USGS, MODIS,
2002, 2007,
2012, 2017

Human Intervention
Irrigation



Approaches toward more Sustainable Management

GRACE Trends in **Total Water Storage** (2002 – 2017)



SW Available:
Conjunctive use of SW and GW
Inefficient SW irrigation
Efficient GW irrigation
Managed Aquifer Recharge

No SW Available:
Increase efficiency of GW irrigation

GRACE JPL and CSR Mascons

Summary

1. How is total water storage changing in U.S. aquifers? (↑, ↓, →)

Stable or increasing in most aquifers but declining in southwest and southcentral U.S.

2. How reliable are GRACE satellite data?

Good comparison with GW level monitoring data in most aquifers and qualitatively agree with regional models, except Mississippi Embayment

3. What is causing changes in water storage? Climate? Human intervention?

Drought amplified by GW irrigation in southwest and southcentral U.S., conjunctive use of SW and GW in NW dampens climate impacts, less drought in N and E U.S.

4. How can we use the results of these analyses to move towards more sustainable water resources management?

Conjunctively use SW and GW, inefficient SW irrigation to recharge GW and efficient GW irrigation to minimize storage depletion.

USGS Powell Research Study

Collaboration among USGS, NASA, and academia

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