



Caspian Sea Level Change and Validation of GRACE and GRACE-FO

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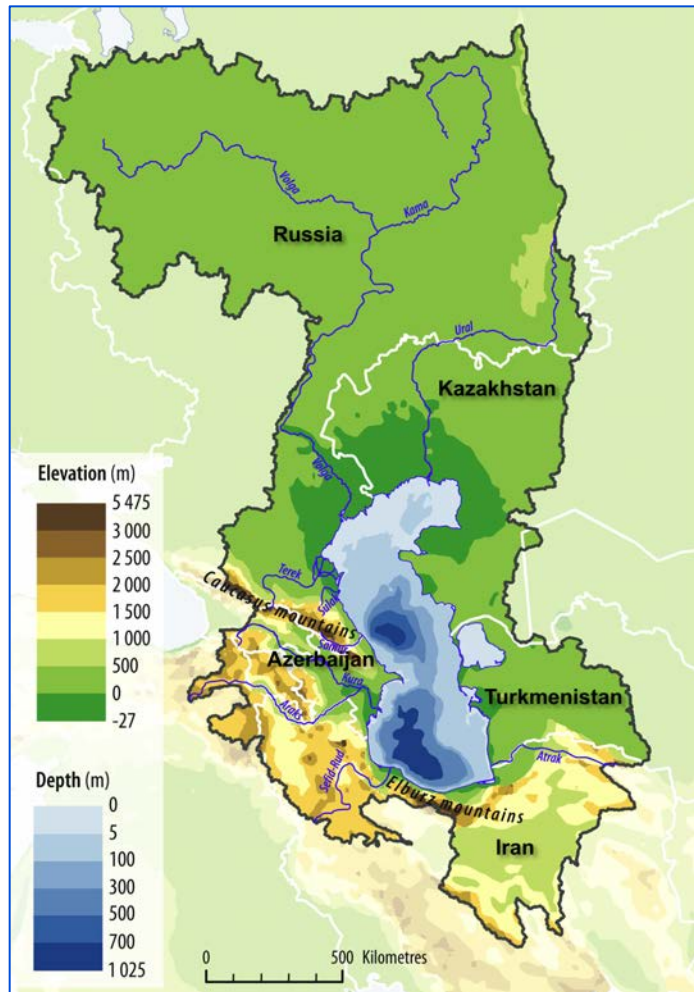
2017 GRACE Science Team Meeting 10/10-10/12, Austin, Texas

Limited Resources for Validating GRACE Observations

- ❑ **Satellite laser altimeter (ICESat) and other remote sensing data over polar ice sheets**
- ❑ **Satellite radar altimeter global mean sea level change + Argo steric**
- ❑ **Groundwater level observations from dense well network in limited regions**
- ❑ **Low-degree gravitational changes from satellite laser ranging (SLR) and Earth rotation observations**
- ❑ **“Invariable” terrestrial water storage in special regions (e.g. Sahara Desert)**
- ❑ **Water storage change in large lakes**
- ❑ **...**

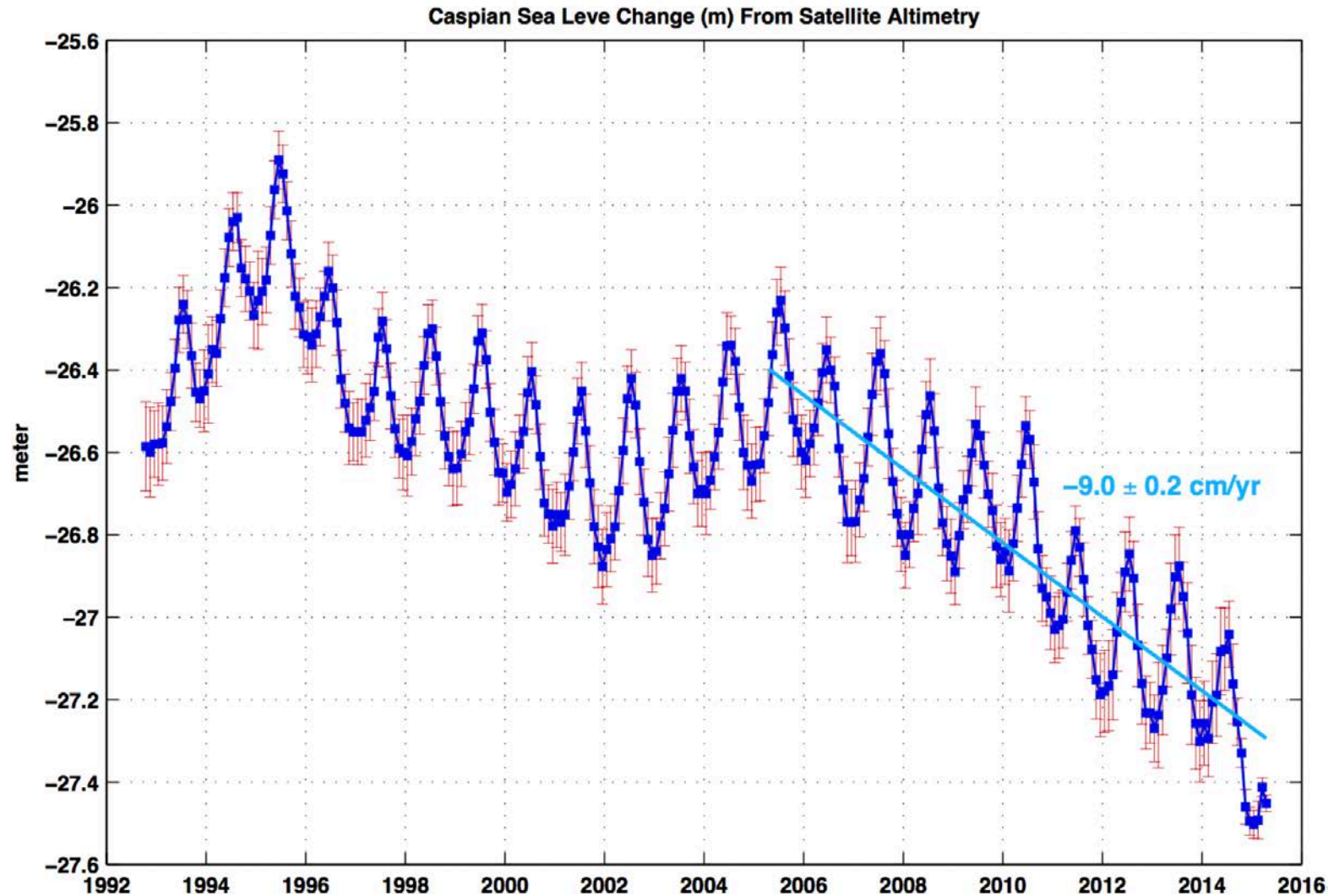


Caspian Sea Level Change and GRACE Validation

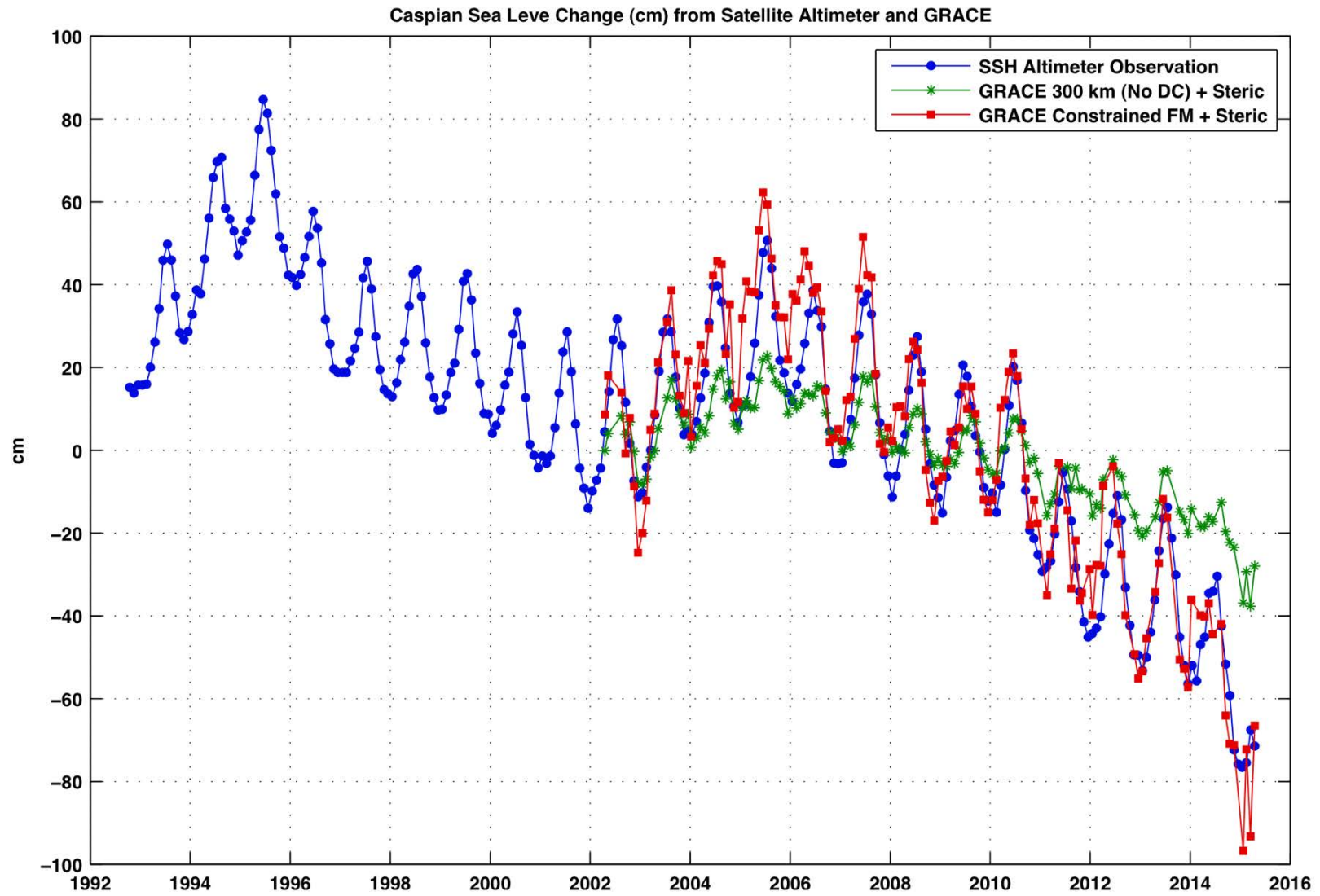


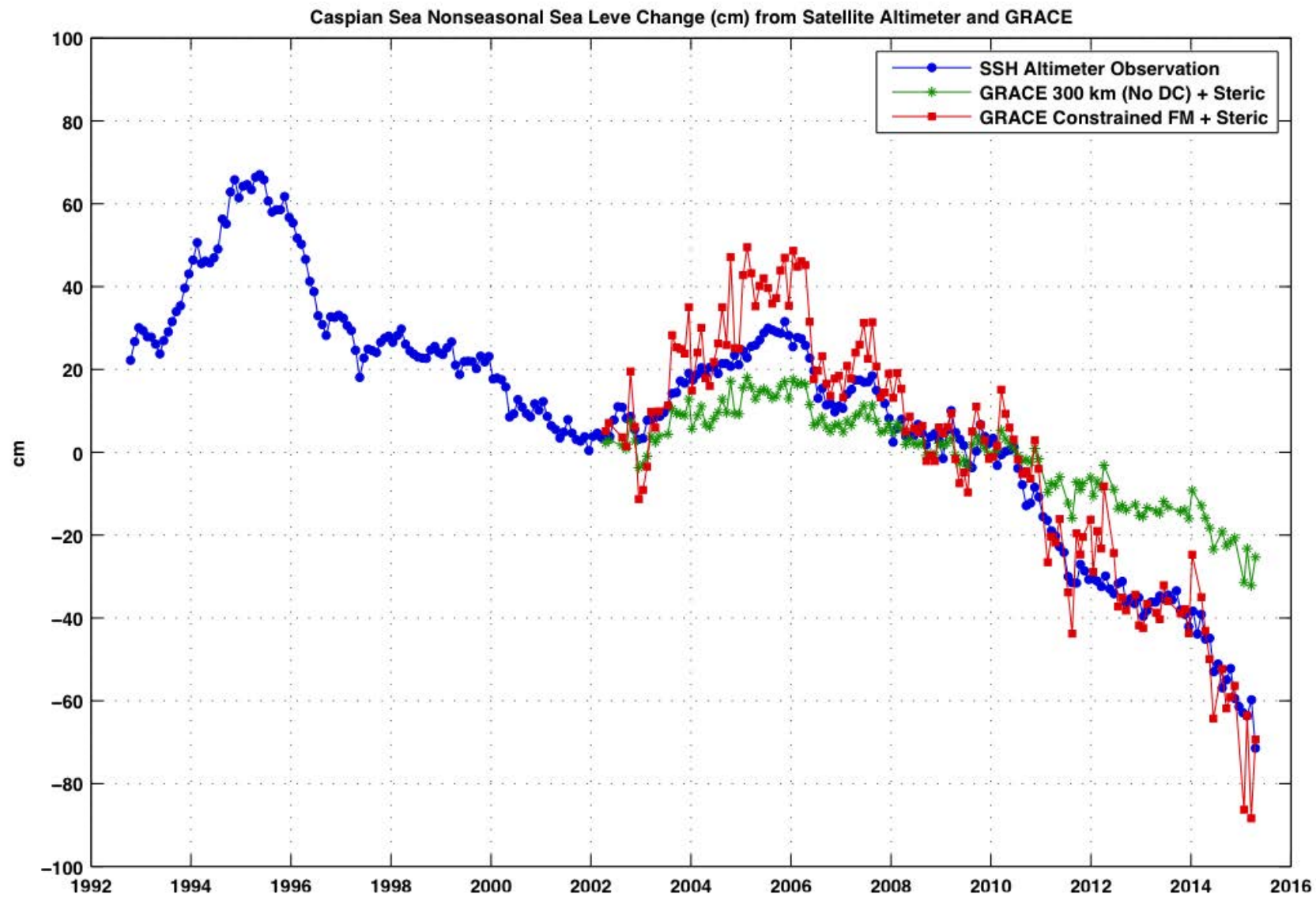
- ❑ The Caspian Sea is the largest enclosed inland body of water on Earth, with a surface area of $\sim 371,000 \text{ km}^2$.
- ❑ Average Caspian Sea level is currently about 27.5 m below mean sea level.
- ❑ Very large seasonal Caspian Sea level change ($\sim 40 \text{ cm}$ from peak-to-peak).
- ❑ Very large long-term Caspian Sea level change over the GRACE period ($\sim 9 \text{ cm/yr}$), almost 30 times larger than the global mean sea level rate.
- ❑ Caspian Sea level change is dominated by imbalanced water flux (precipitation, evaporation, and runoff).
- ❑ Surrounded by mostly arid regions (except for the very northern part).

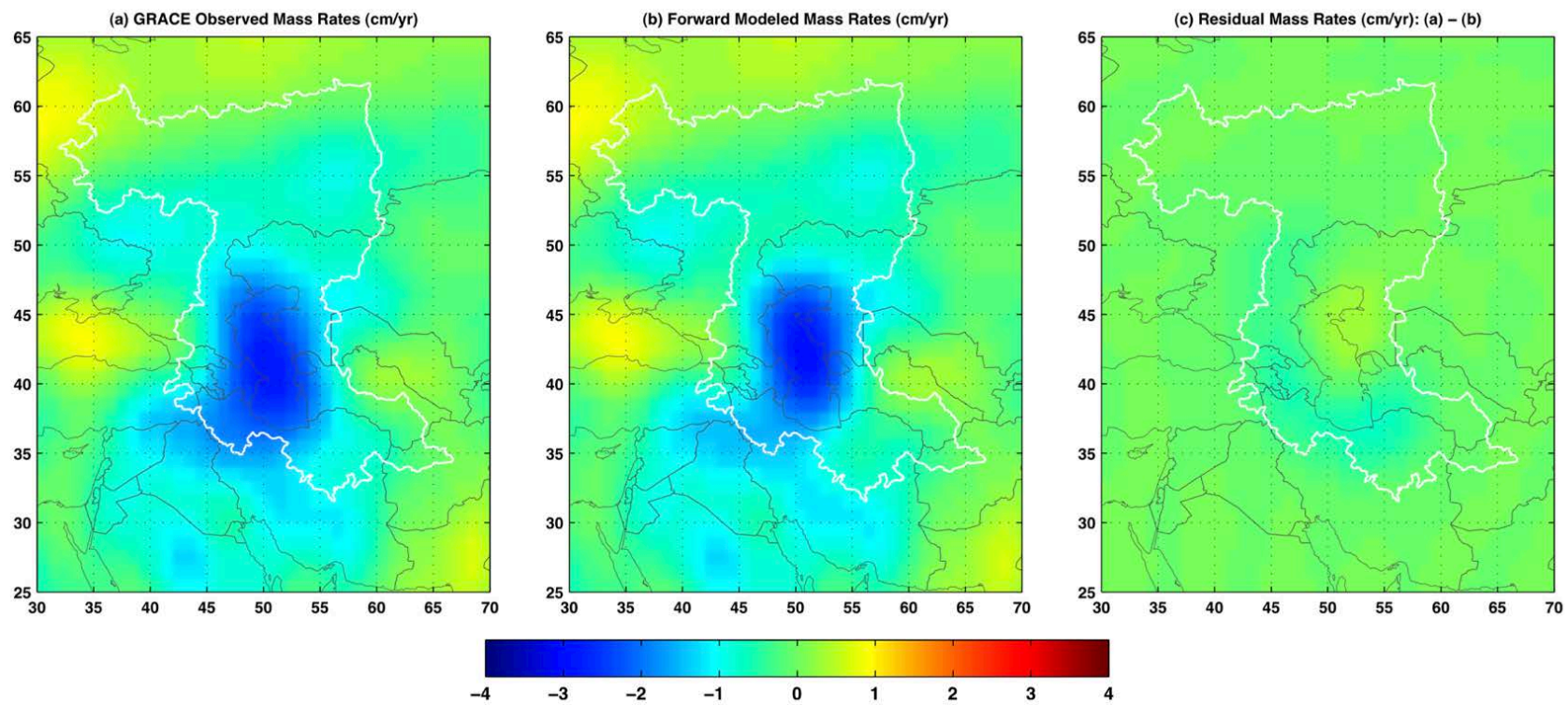
Caspian Sea Level Change From Satellite Altimetry (1992.10-2015.04)

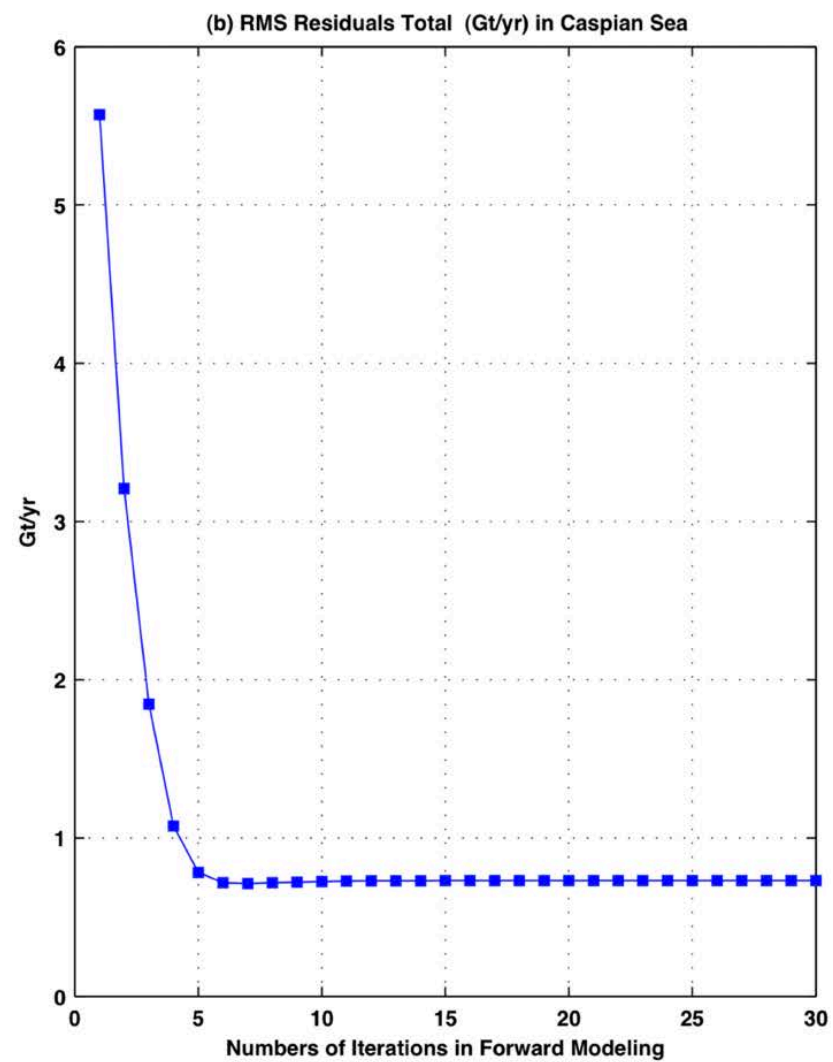
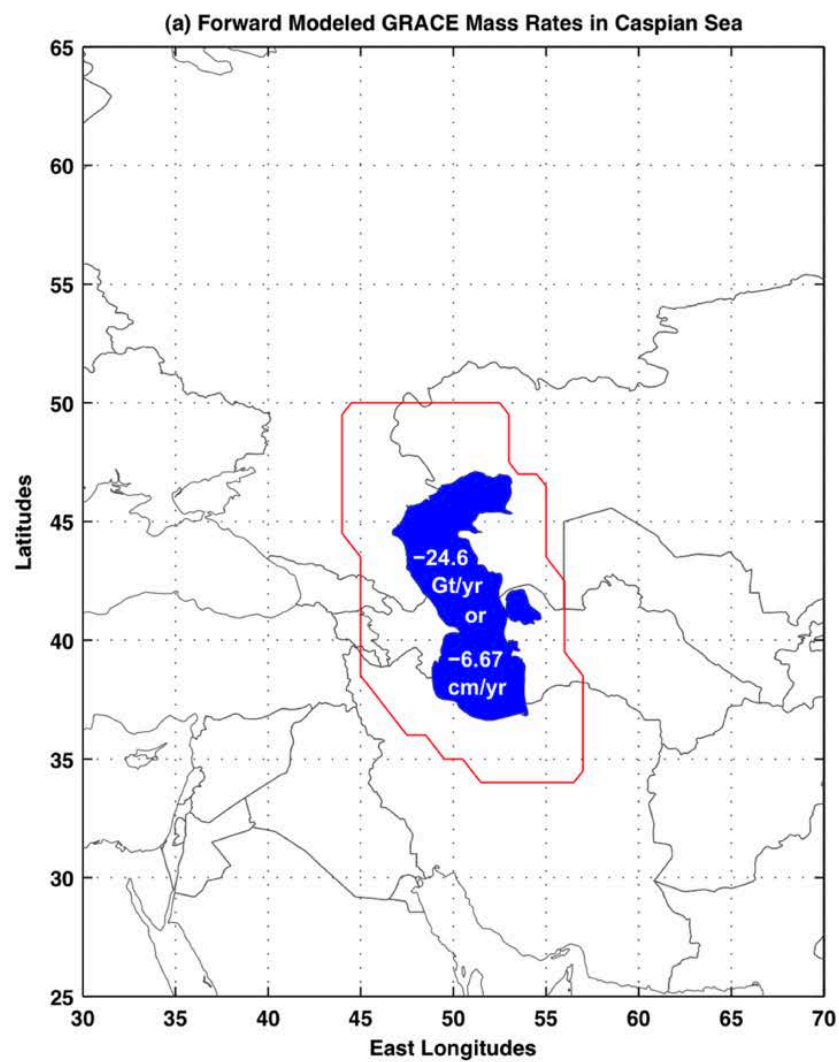


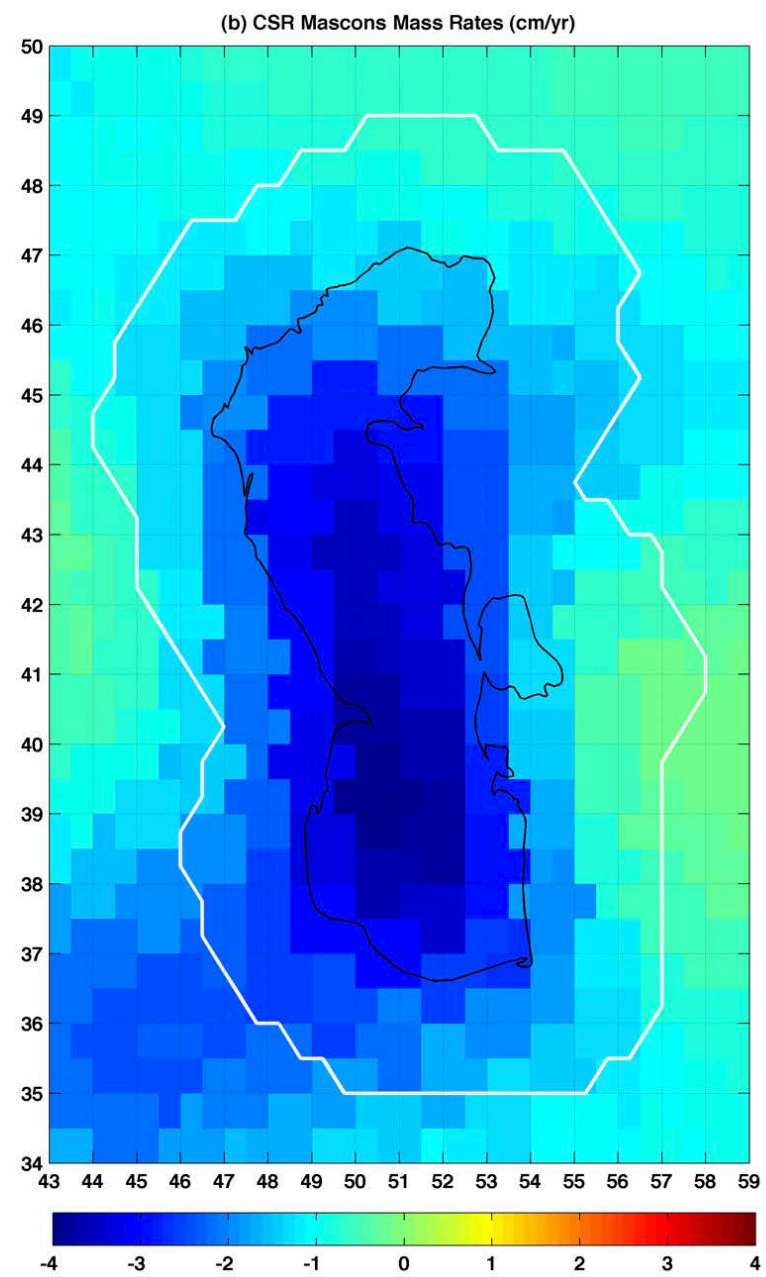
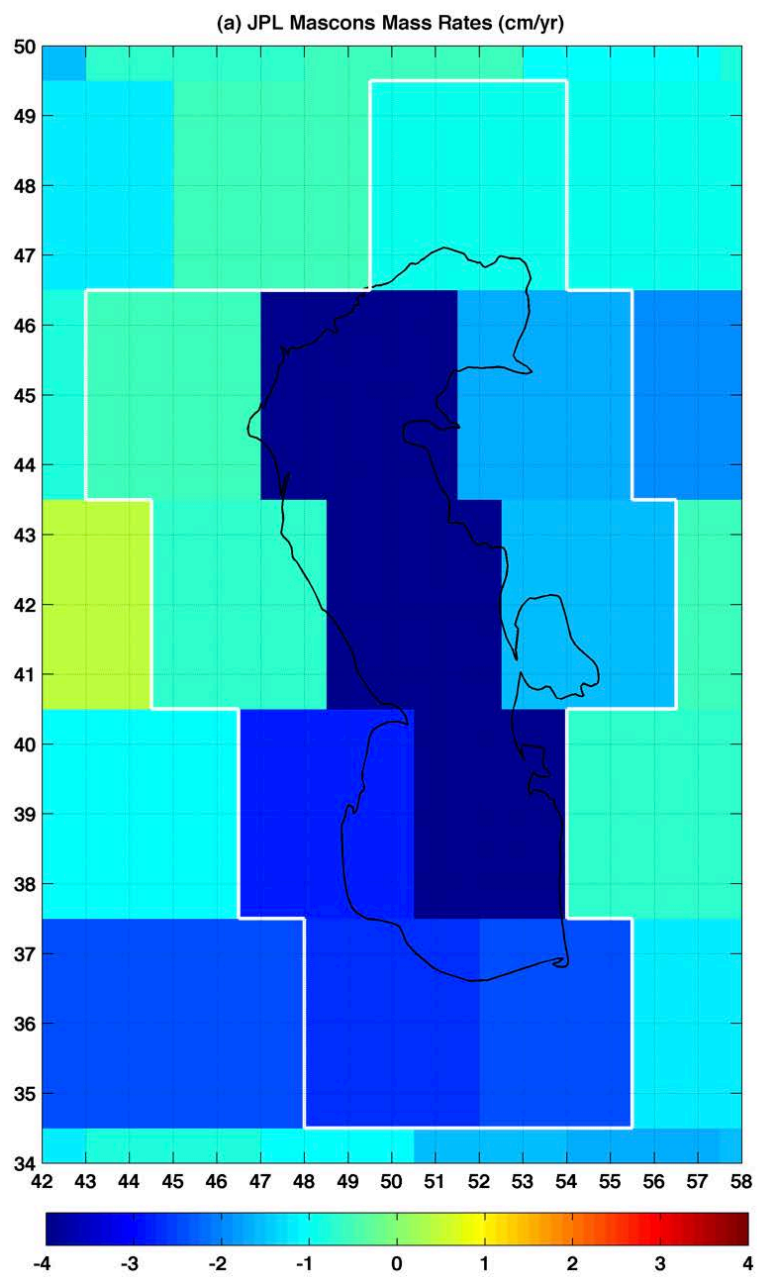
A Caspian Sea level rate of -9.0 cm/yr is equivalent to -33.4 km³/yr !

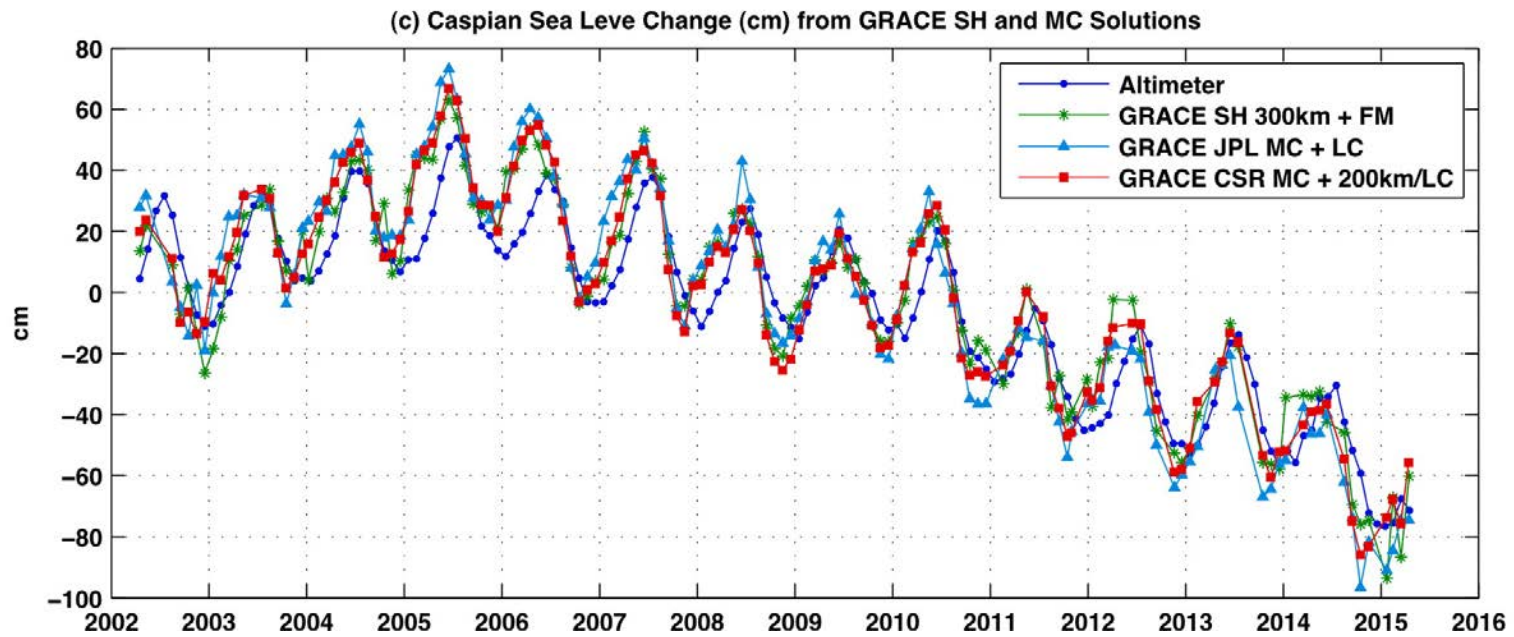
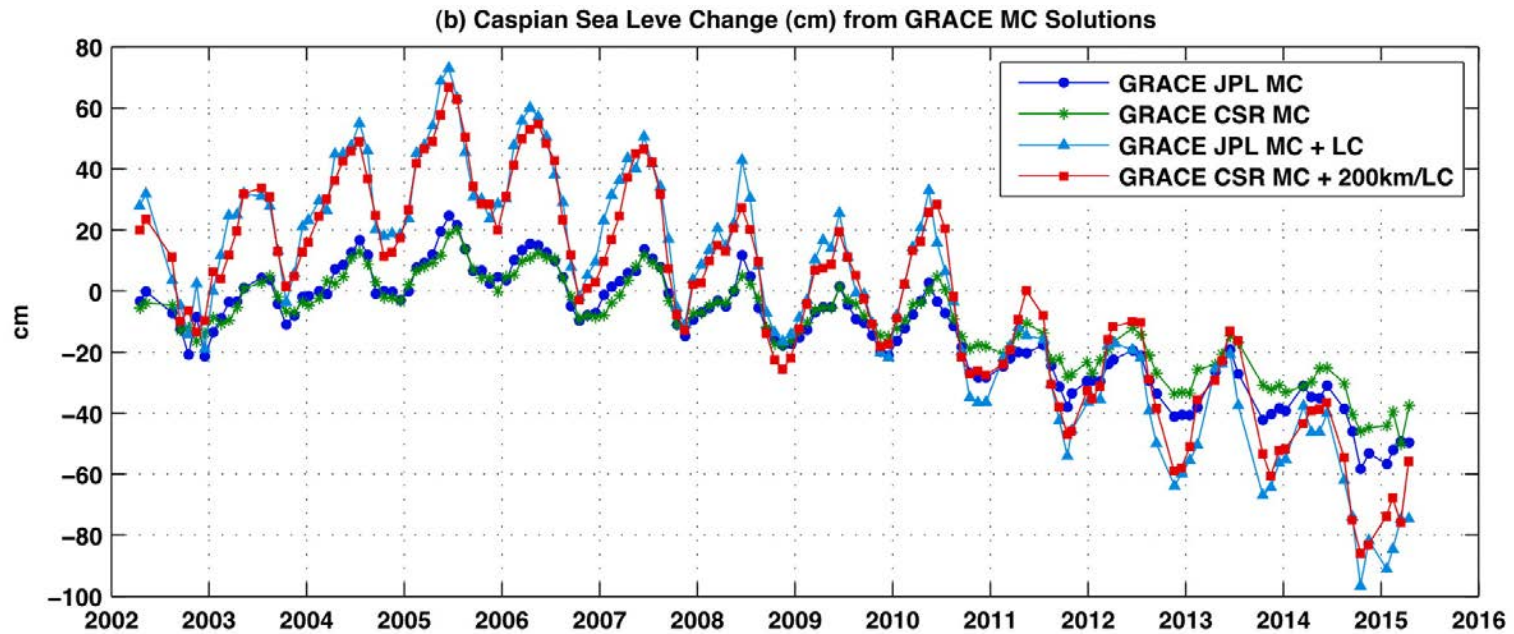




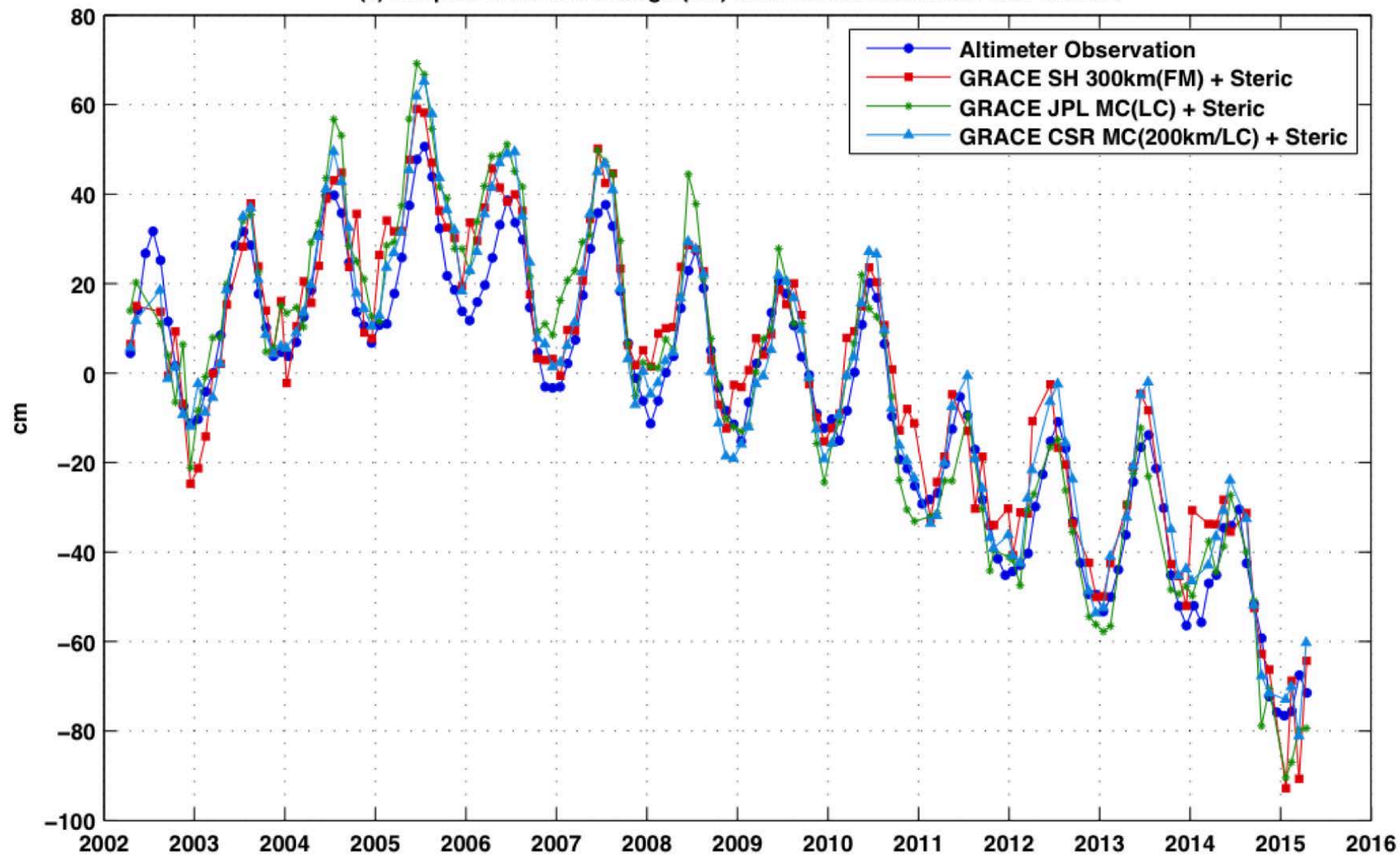




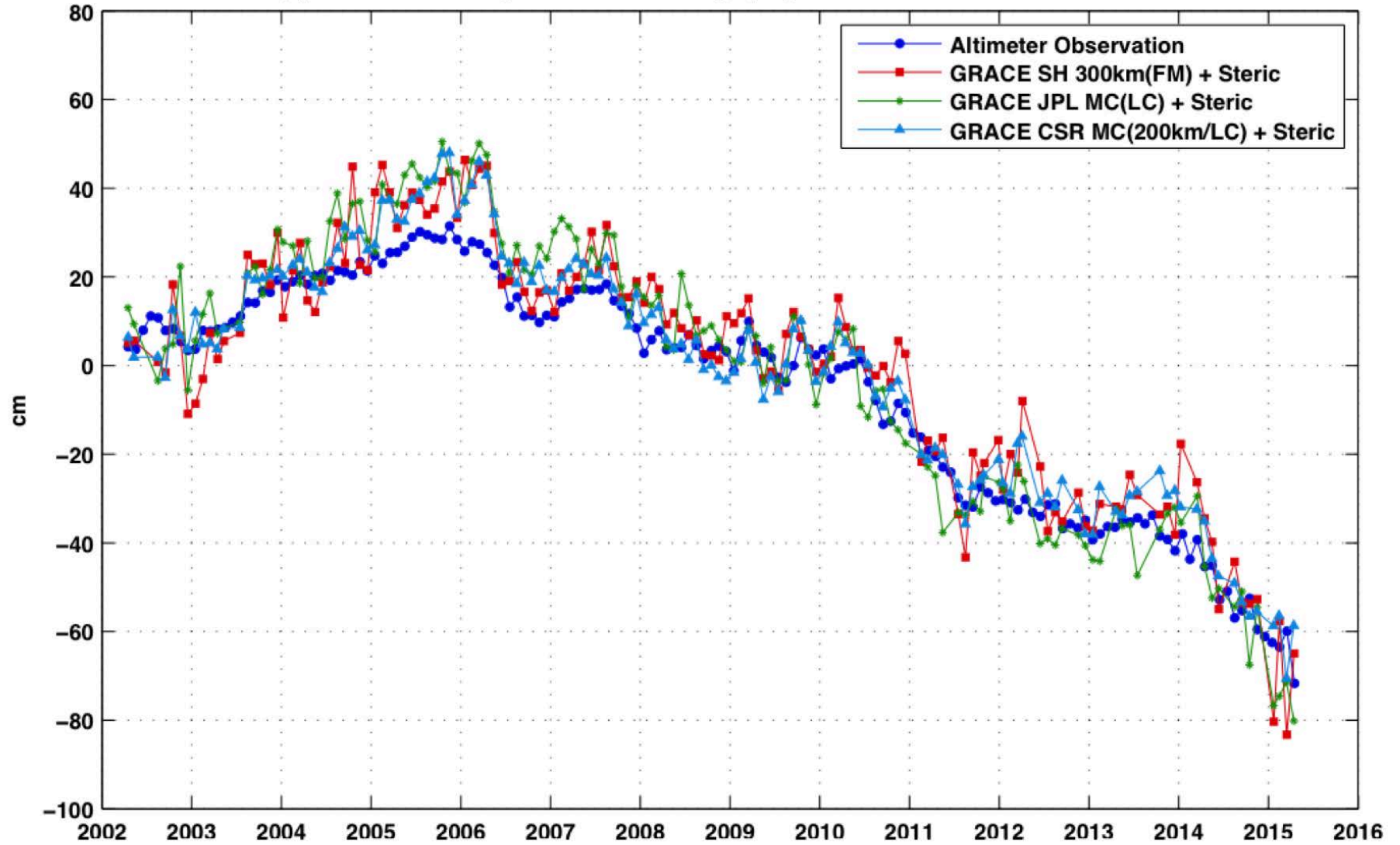




(a) Caspian Sea Leve Change (cm) from Satellite Altimeter and GRACE

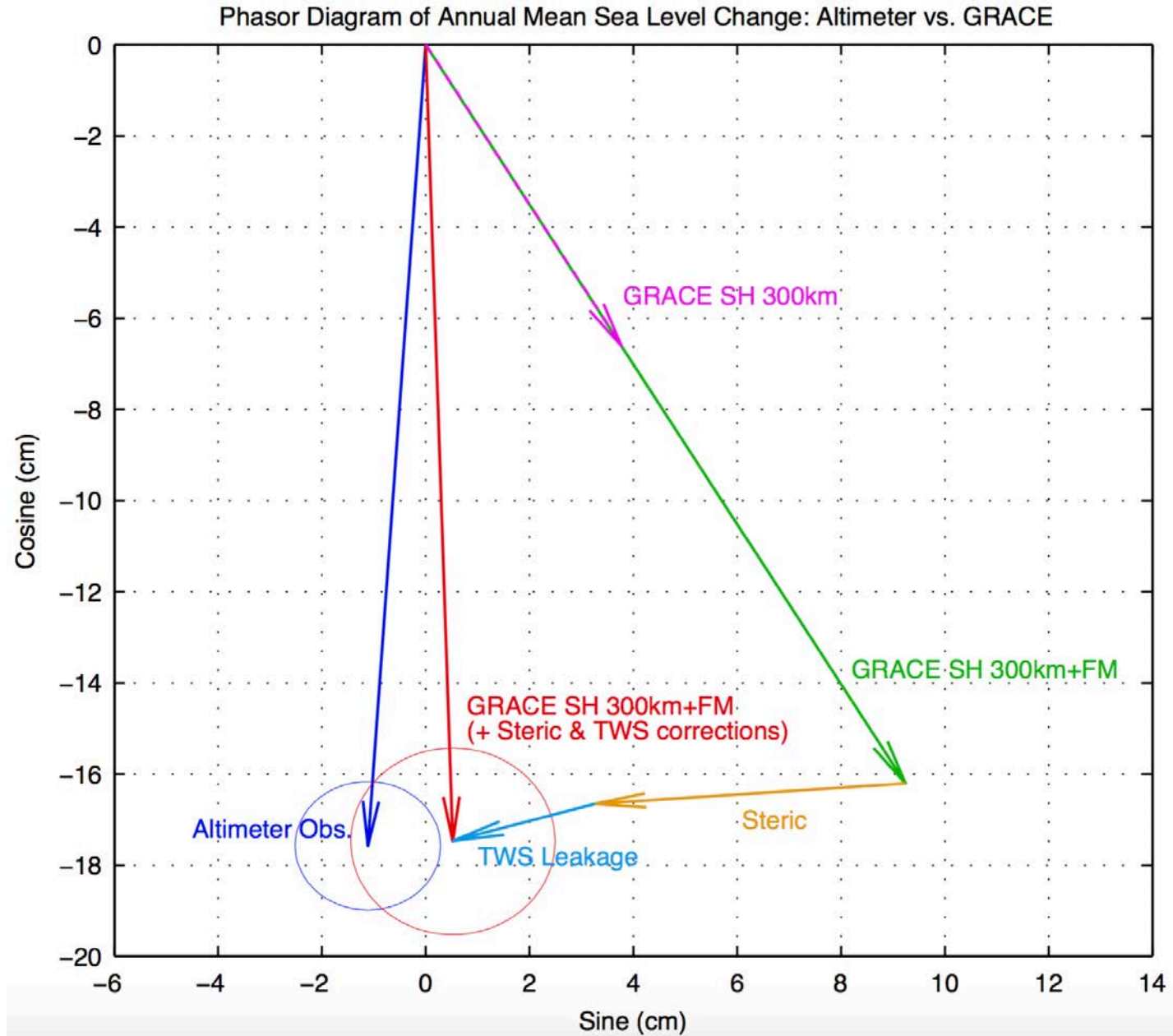


(b) Nonseasonal Caspian Sea Level Change (cm) from Satellite Altimeter and GRACE



Caspian Sea Level	Annual Amplitude (cm)	Phase (deg)	Semiannual Amplitude (cm)	Phase (deg)	Linear Trend (cm/yr)
Altimeter Observation	17.6 ± 1.4	266 ± 5	3.3 ± 1.4	69 ± 25	-6.07 ± 0.26
GRACE SH 300km+FM + Steric – TWS	17.5 ± 2.0	272 ± 6	4.2 ± 2.0	78 ± 27	-6.00 ± 0.39
GRACE JPL MC (+LC) + Steric – TWS	20.1 ± 2.0	274 ± 6	5.4 ± 2.0	81 ± 21	-7.19 ± 0.39
GRACE CSR MC (+SF/LC) + Steric	16.2 ± 1.9	270 ± 5	6.2 ± 1.8	80 ± 17	-6.29 ± 0.35
GRACE CSR MC (+200km/LC) + Steric–TWS	21.0 ± 1.9	270 ± 5	6.3 ± 1.8	79 ± 16	-6.08 ± 0.34
GRACE CSR MC (+100km/LC) + Steric – TWS	16.5 ± 1.5	264 ± 5	5.2 ± 1.5	79 ± 16	-5.06 ± 0.28
GRACE SH 300km+FM	18.7 ± 2.1	300 ± 6	4.5 ± 2.1	80 ± 26	-6.70 ± 0.40
GRACE SH 300km	6.7 ± 0.8	300 ± 6	1.6 ± 0.7	80 ± 26	-2.41 ± 0.14
GRACE SH 300km+DC+FM	14.7 ± 1.3	313 ± 5	3.4 ± 1.3	82 ± 22	-4.49 ± 0.25
GRACE SH 300km+DC	5.6 ± 0.5	313 ± 5	1.3 ± 0.5	82 ± 22	-1.69 ± 0.09
GRACE JPL MC+LC	21.2 ± 2.0	310 ± 6	5.2 ± 2.0	81 ± 23	-8.15 ± 0.40
GRACE JPL MC	9.6 ± 1.1	297 ± 6	3.0 ± 1.1	78 ± 20	-3.89 ± 0.21
GRACE CSR MC+200km/LC	20.9 ± 1.9	305 ± 5	6.1 ± 1.9	77 ± 17	-7.16 ± 0.36
GRACE CSR MC+SF/LC	16.9 ± 1.9	290 ± 6	6.2 ± 1.9	77 ± 17	-6.20 ± 0.35
GRACE CSR MC	8.2 ± 0.9	291 ± 6	3.0 ± 0.9	79 ± 17	-3.01 ± 0.17
Steric Effect	6.0 ± 0.0	184 ± 0	0.04 ± 0.0	155 ± 0	-0.09 ± 0.0
TWS Leakage (w/ FM)	2.9 ± 0.3	17 ± 6	0.3 ± 0.3	103 ± 47	-0.78 ± 0.05
TWS Leakage (w/o FM)	0.8 ± 0.1	17 ± 6	0.1 ± 0.1	103 ± 47	-0.21 ± 0.01
TWS Leakage (JPL MC+LC)	7.1 ± 0.3	28 ± 3	0.2 ± 0.3	237 ± 93	-1.05 ± 0.06
TWS Leakage (CSR MC+200km)	6.9 ± 0.3	30 ± 3	0.2 ± 0.3	299 ± 106	-1.17 ± 0.06
TWS Leakage (CSR MC+100km)	3.5 ± 0.2	34 ± 3	0.1 ± 0.2	311 ± 111	-0.54 ± 0.03

Caspian Sea Level	Annual Amplitude (cm)	Phase (deg)	Semiannual Amplitude (cm)	Phase (deg)	Linear Trend (cm/yr)
Altimeter Observation	17.6 ± 1.4	266 ± 5	3.3 ± 1.4	69 ± 25	-6.07 ± 0.26
CSR GSM SH 300km+FM + Steric – TWS	17.5 ± 2.0	272 ± 6	4.2 ± 2.0	78 ± 27	-6.00 ± 0.39
GFZ GSM SH 300km+FM + Steric – TWS	15.3 ± 2.8	284 ± 10	8.5 ± 2.7	73 ± 18	-5.46 ± 0.52
JPL GSM SH 300km+FM + Steric – TWS	17.9 ± 2.2	276 ± 7	5.6 ± 2.1	95 ± 21	-6.26 ± 0.41
JPL MC (+LC) + Steric – TWS	20.1 ± 2.0	274 ± 6	5.4 ± 2.0	81 ± 21	-7.19 ± 0.39
CSR MC (+SF/LC) + Steric	16.2 ± 1.9	270 ± 5	6.2 ± 1.8	80 ± 17	-6.29 ± 0.35
CSR MC (+200km/LC) + Steric–TWS	21.0 ± 1.9	270 ± 5	6.3 ± 1.8	79 ± 16	-6.08 ± 0.34



Conclusion



- ❑ Satellite radar altimeter observations show that Caspian Sea level has been declining at a rate of -6.07 ± 0.26 cm/yr with superimposed annual fluctuations of amplitude 17.6 ± 1.4 cm, over the period April 2002 – April 2015.
- ❑ These create a large mass change signal in a well-defined geographical location surrounded by mostly arid basins. Both signal amplitude and geography provide a unique opportunity to evaluate various GRACE solutions and processing methods.
- ❑ GRACE estimates show excellent agreement with altimeter results when GRACE spatial leakage error is corrected.
- ❑ With leakage correction, GRACE spherical harmonics solutions show better agreement with altimeter data than mascon solutions do.
- ❑ CSR GSM solutions show better agreements with altimeter data than GFZ and JPL GSM solutions do.
- ❑ Caspian Sea level change will be a useful data resource for validating upcoming GRACE-FO observations as well.



Thanks!