A Simulation Study of Earth Gravity Field Model Inversion from SWARM Mission

H. Zhou (1), Z. C. Luo (1,2,3), B. Zhong (1,2) , and Q. Li(1)

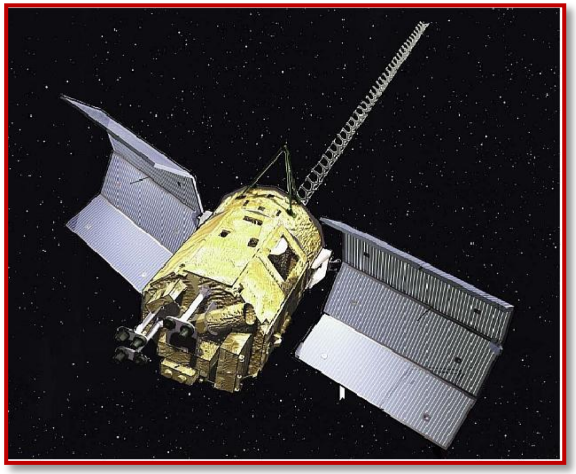
(1) School of Geodesy and Geomatics, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
(2) Key Laboratory of Geospace Environment and Geodesy, Ministry of Education, 129 Luoyu Road, Wuhan 430079, China
(3) State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, 129 Luoyu Road, Wuhan 430079, China

EGU General Assembly 2014

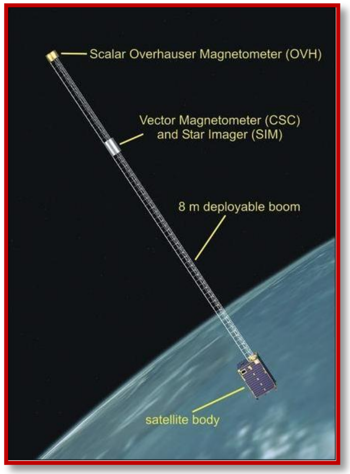
OUTLINE

- Brief introduction of SWARM Mission
- Closed-loop check of simulation software
- Numerical calculations and analysis
- Conclusions

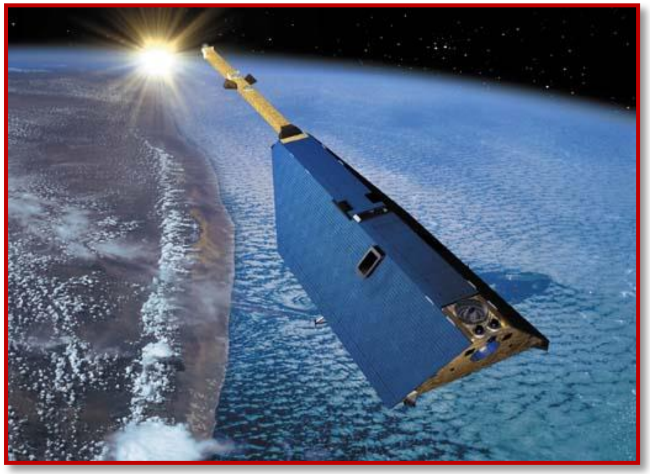
Brief introduction of SWARM Mission



SAC-C(2000~2013)



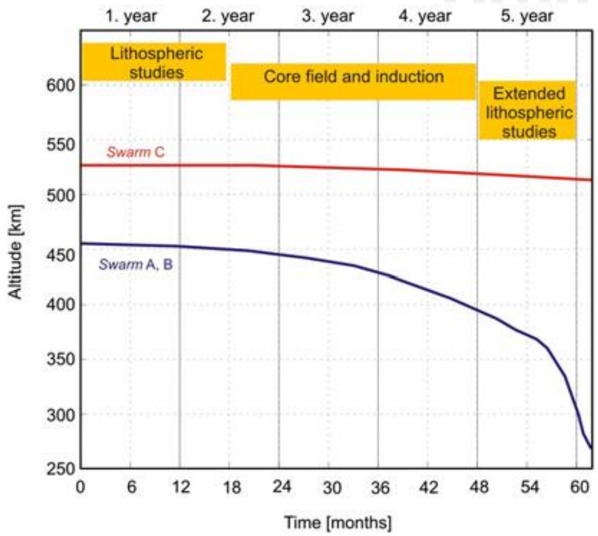
Ørsted(1999~)



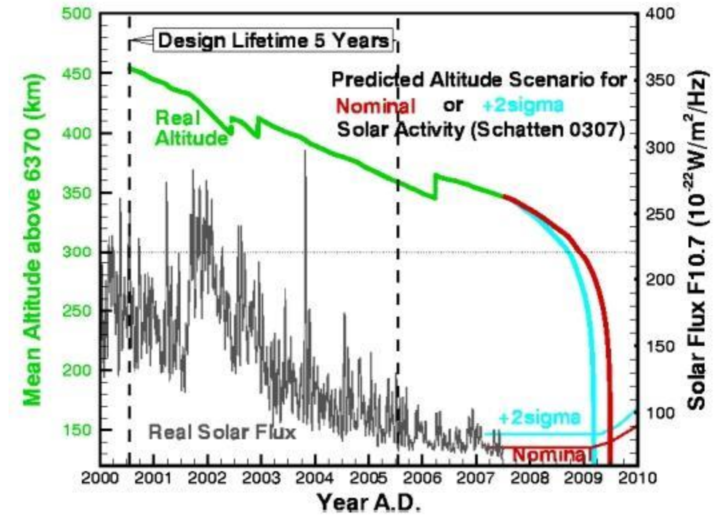
CHAMP(2000~2010)

SWARM 2013.11.22(12:02:29 UTC)

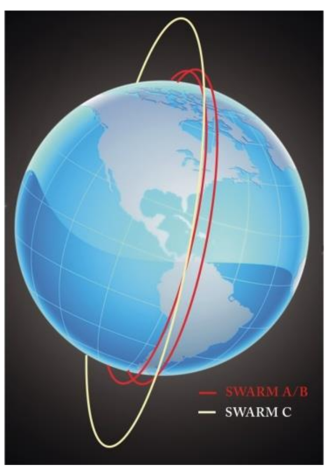
Orbit Configuration



(a)

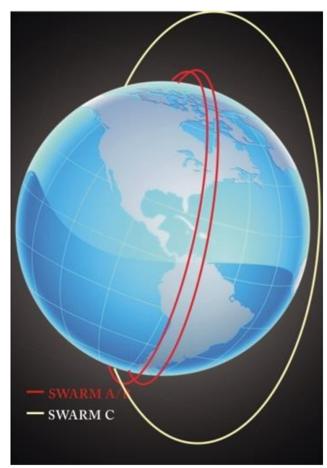


(b)



(c)

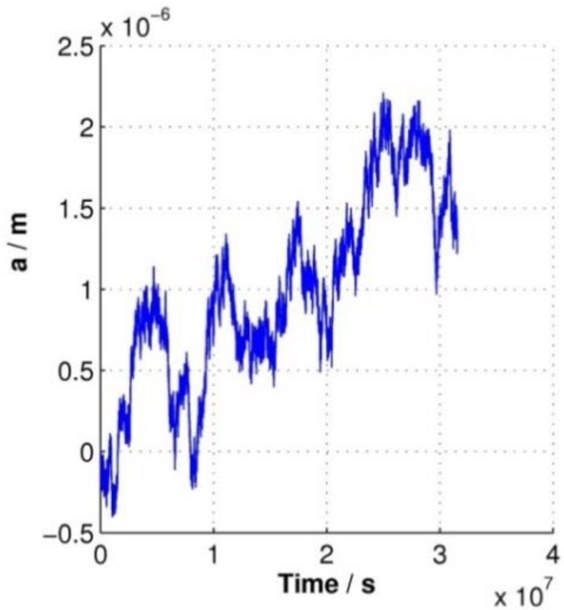
(d)



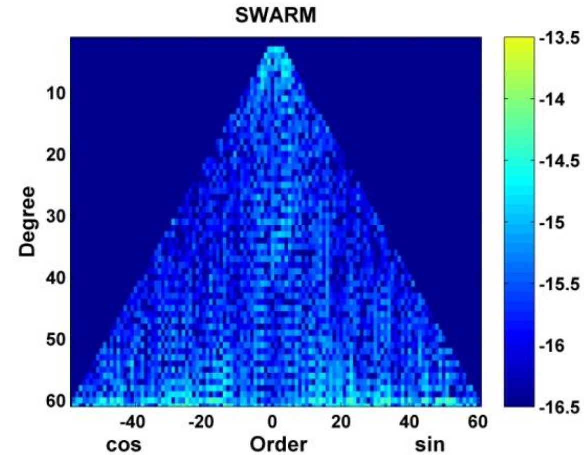
(e)

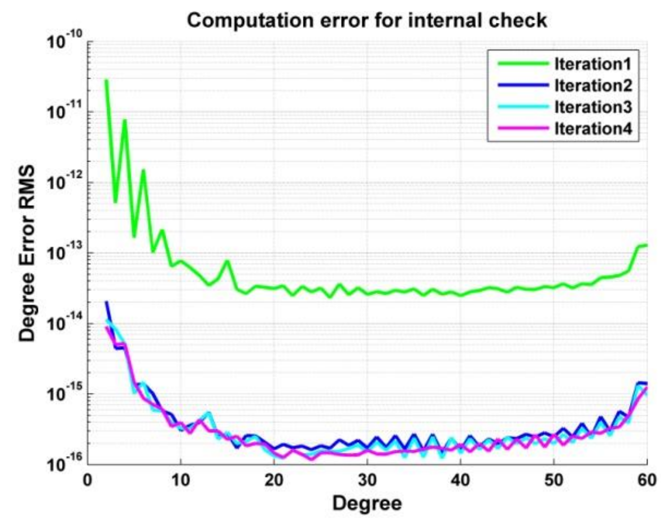
(a) Change in altitude versus time for SWARM mission, (b) Change in altitude versus time for CHAMP mission, (c, d, e) Spatial illustration of local time evolution

Closed-loop check of Dynamic approach software



Performance of Gauss-Jackson integrator

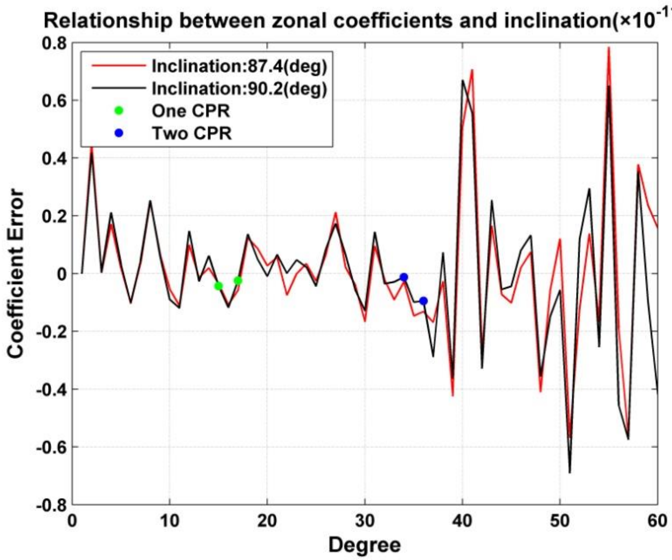


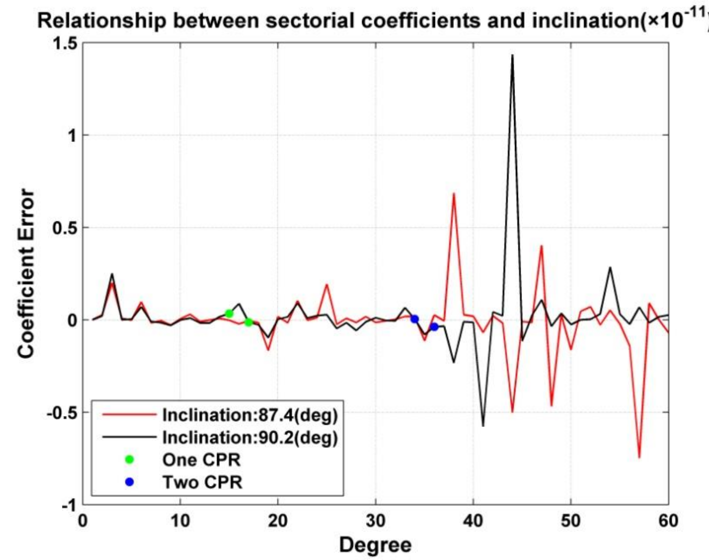


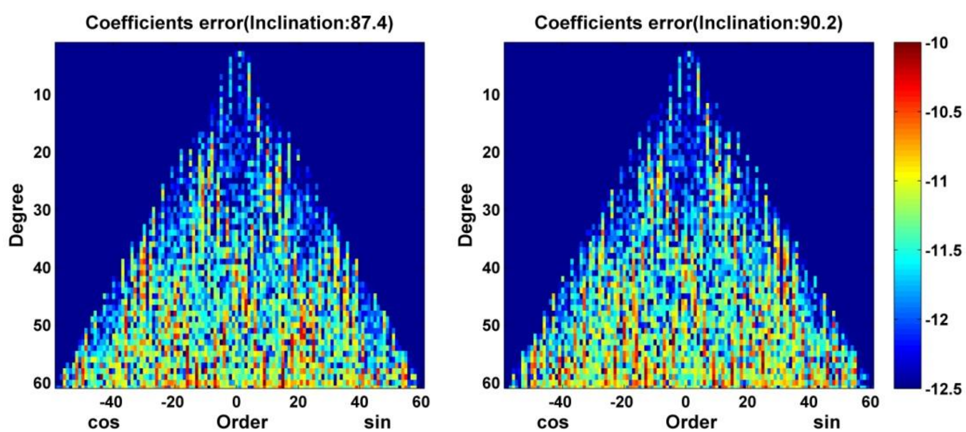
Performance of static signal inversion (rapidly converged in two iterations)

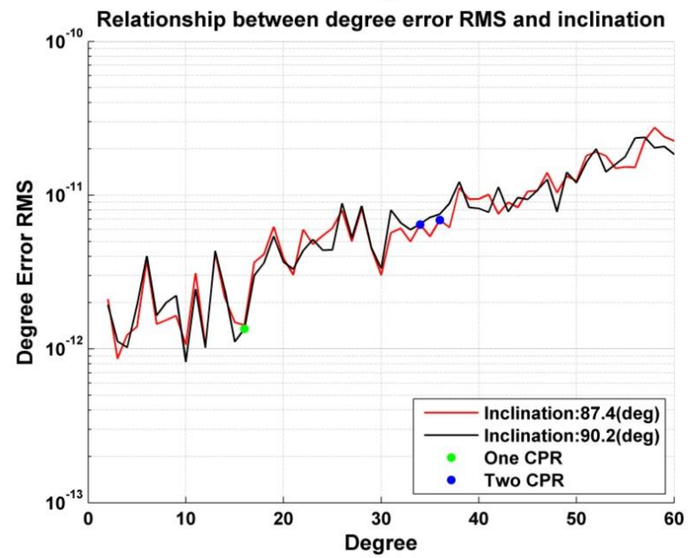
Wu Han University

Relationship between inclination and inversion accuracy (87.4 vs 90.2deg, Altitude:350km)

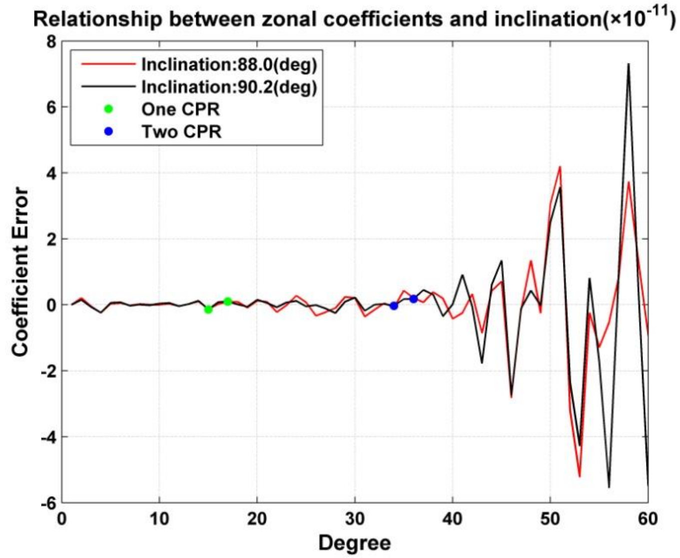


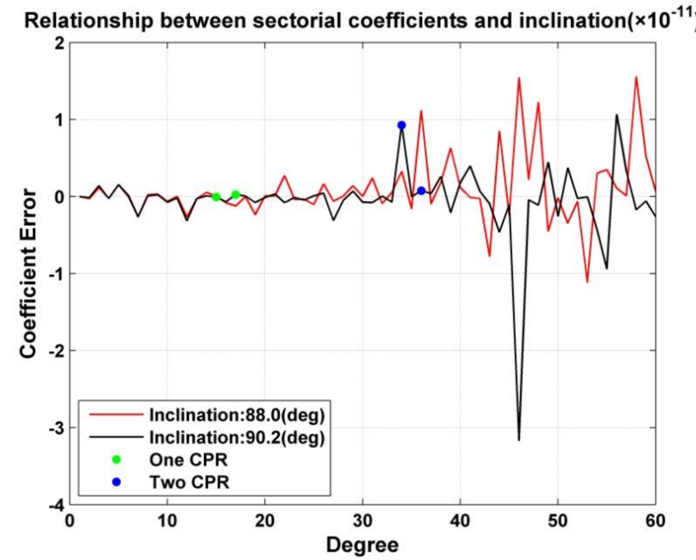


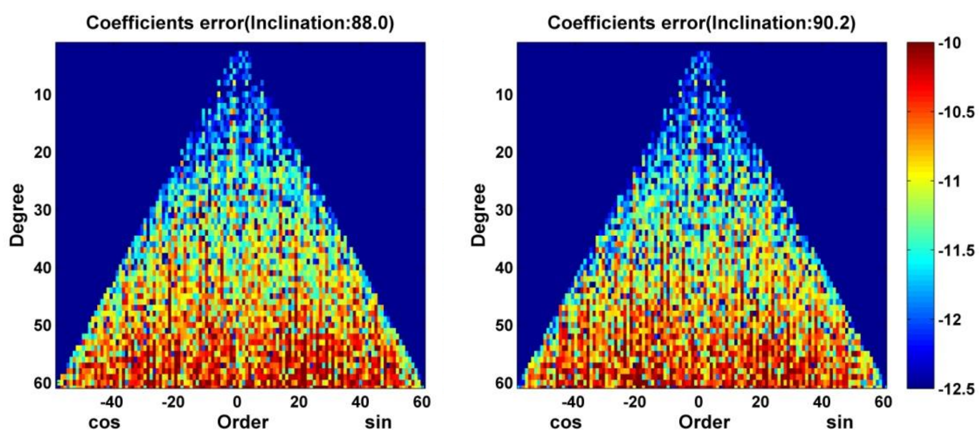


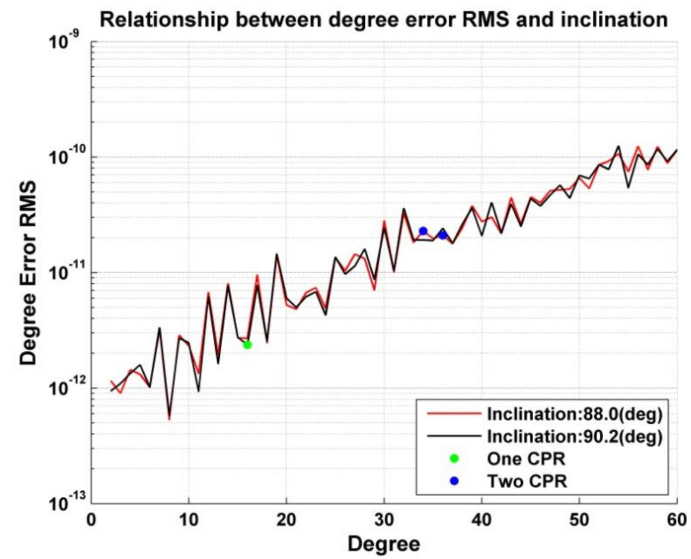


Relationship between inclination and inversion accuracy (88.0 vs 90.2deg,Altitude:530km)



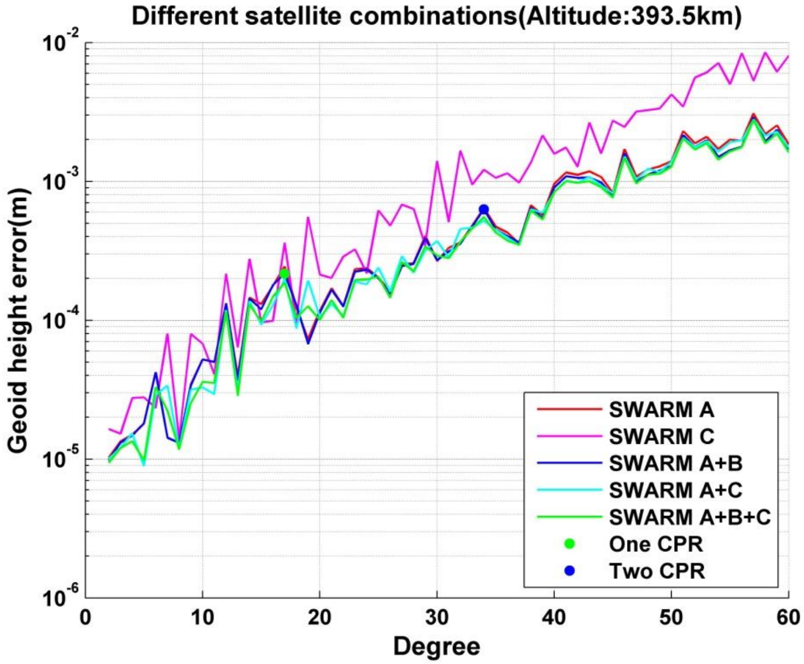






Different satellite scenarios' combinations

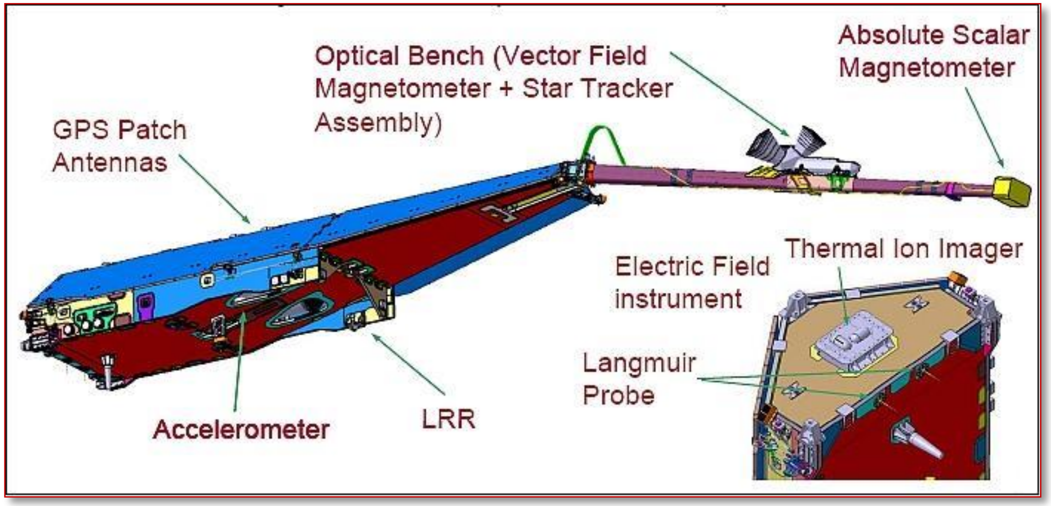
Inclination	Altitude	Alpha(day)	Beta(circles)	vacancy in equator(deg)	vacancy in equator(km)
87.4	383.5	15	233	1.55	172.00
	393.5	2	31	11.61	1292.74
88	**530**	**21**	**316**	**1.14**	**126.82**
	520	**25**	**377**	**0.95**	**106.30**

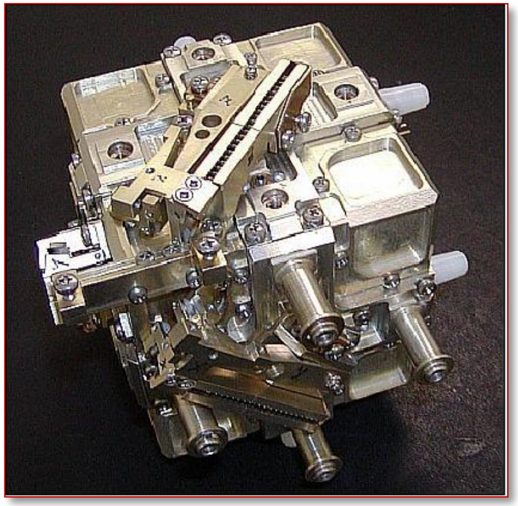


Cumulative geoid height errors(393.5km)

Degree	SWARM A	SWARM A+B	SWARM A+C	SWARM A+B+C
10	8.32E-5	8.27E-5	6.90E-5	6.46E-5
20	4.38E-4	4.19E-4	4.00E-4	3.73E-4
30	8.84E-4	8.58E-4	8.44E-4	7.94E-4
40	1.98E-3	1.90E-3	1.85E-3	1.78E-3
50	4.35E-3	4.07E-3	4.03E-3	3.85E-3
60	8.19E-3	7.56E-3	7.64E-3	7.20E-3

Payloads' nominal precision



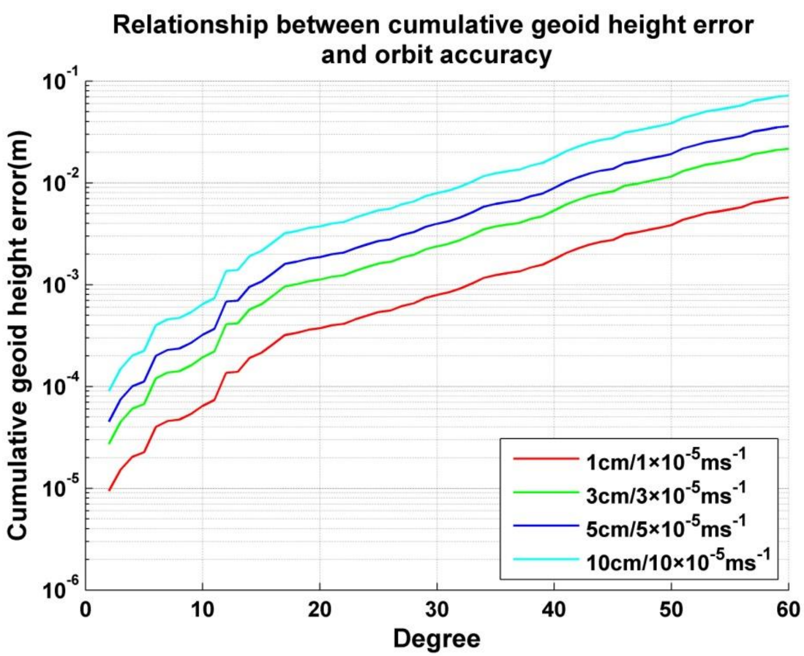


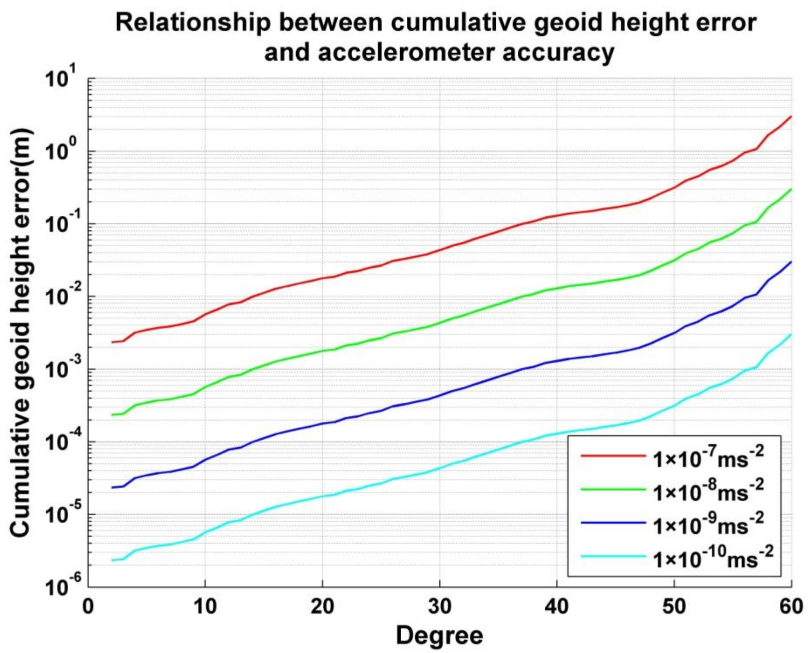
Mission	*Altitude (km)*	*Inclination (degree)*	*GPS receiver*	*Orbit error (cm)*	*Accelerometer*	*Non-gravitational force(m/s²)*
SWARM A/B	250~460	87.4	IGPS-A	10/1 ?	MAC-C	$5\times10^{-8}/1\times10^{-10}$?
SWARM C	520~530	88.0	IGPS-A	10/1 ?	MAC-C	$5\times10^{-8}/1\times10^{-10}$?
CHAMP	350~460	87.275	BlackJack	3~4	STAR	1×10^{-9}
GRACE	300~485	89.02	BlackJack	3~4	SuperSTAR	1×10^{-10}
GOCE	250~270	96.7	Lagrange	1~2	ONERA	DRAG FREE

Relationship between Mission Payloads and inversion accuracy

$$\delta^2\{N\}_{GPS}^{hl} = \frac{GM}{r^2\gamma_e}\left[\left(\frac{r}{a_e}\right)^{2n} + (n+1)^2 \times 1.6\times 10^{-10} n^{-3}\right]\frac{\delta_r^2}{N_{\max}}$$

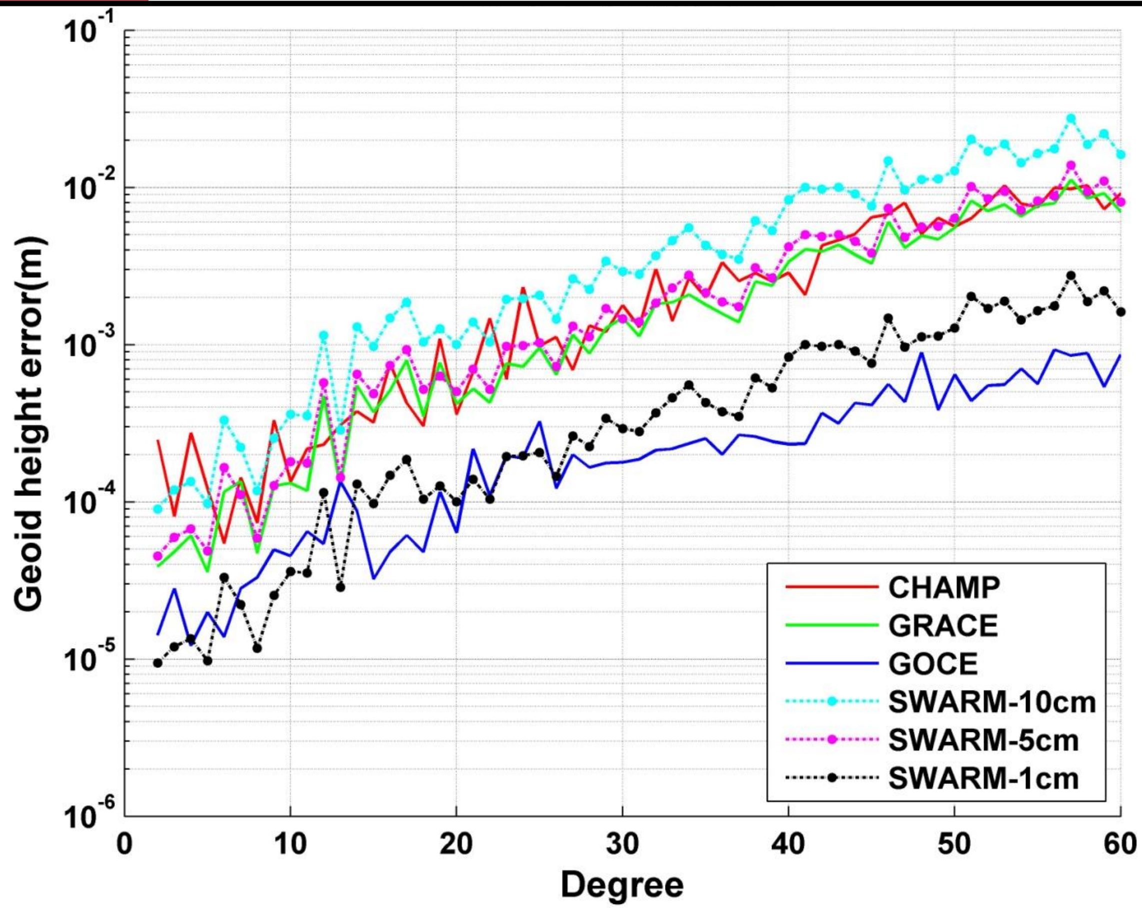
$$\delta^2\{N\}_{acc}^{hl} = \frac{T^2 r}{\gamma_e}\left(\frac{r}{a_e}\right)^{2n}\frac{\delta_{acc}^2}{N_{\max}}$$



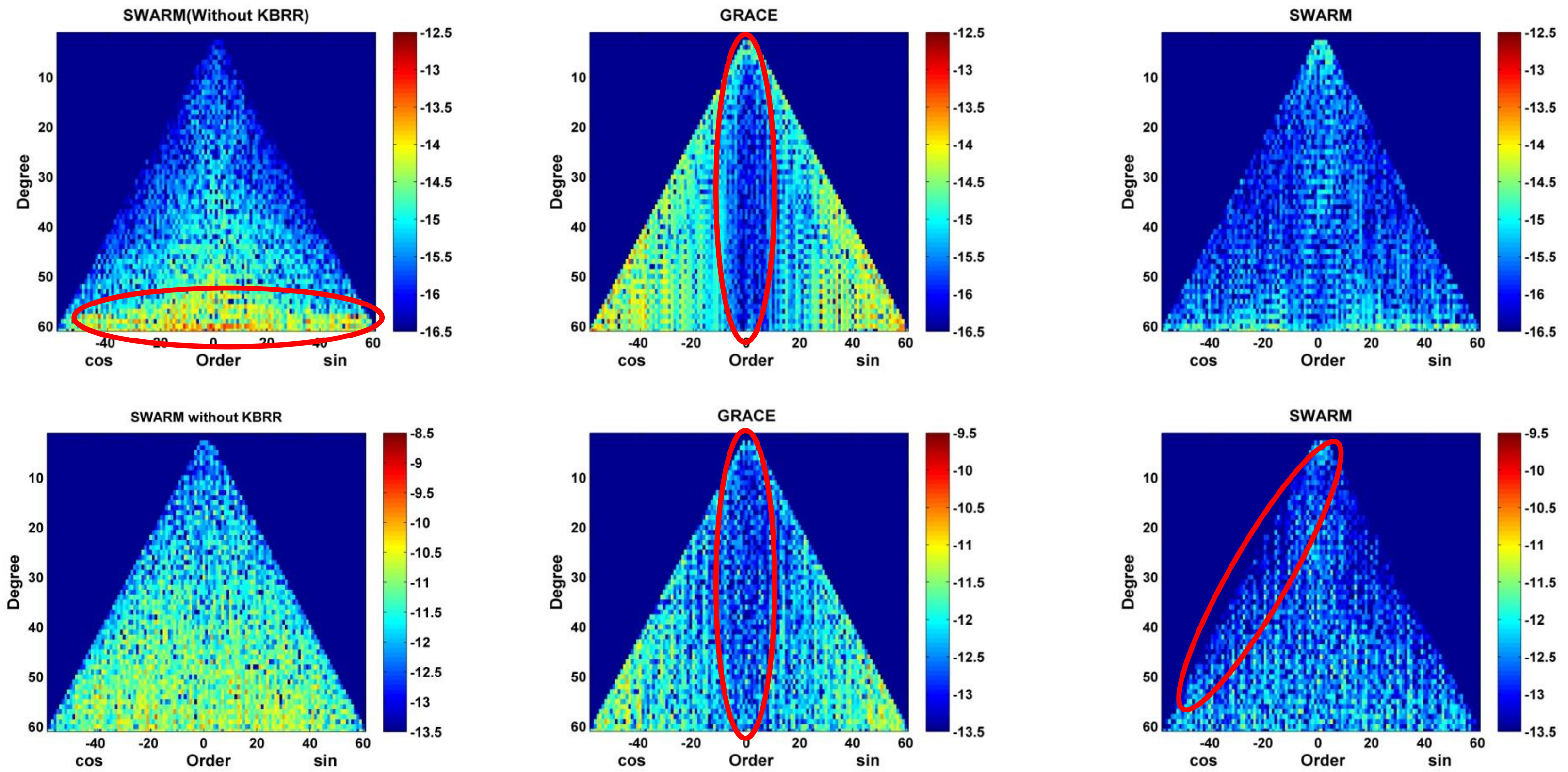


Inversion accuracy of different missions (HL-SST)

Inclination	*Altitude*	*Alpha(day)*	*Beta(circles)*	*vacancy in equator(deg)*	*vacancy in equator(km)*
87.4	383.5	15	233	1.55	172.00
88	**530**	**19**	**286**	**1.26**	**140.12**



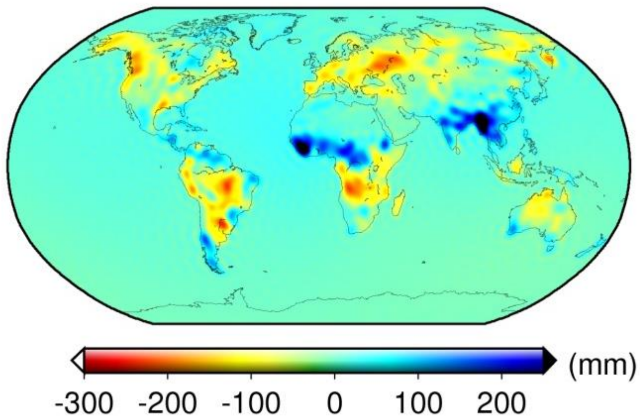
Spectral contribution of different satellite constellations



Noise free and white noise(1 cm for orbit and 1×10^{-7}m/s for KBRR, respectively)
(Altitude:450km)

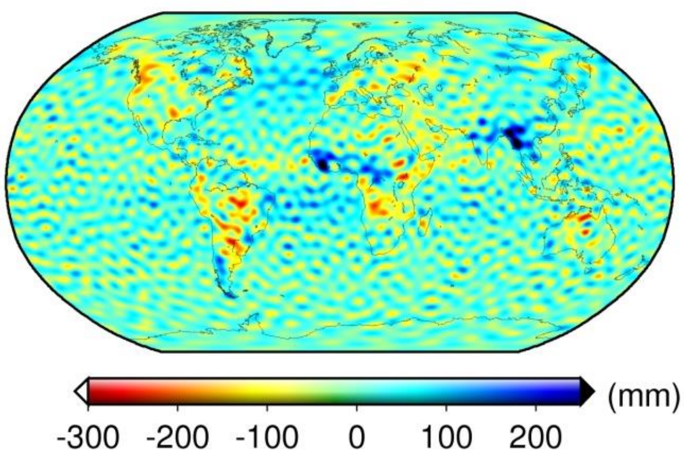
Inversion error of different satellite constellations(white noise)

GLDAS

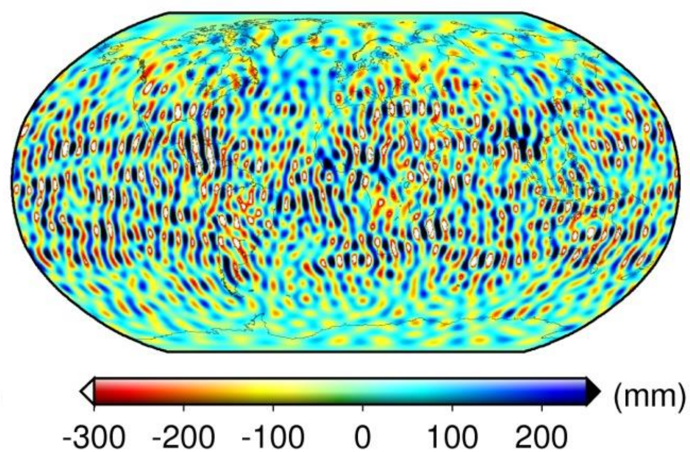


Ability to recover temporal gravity field model with 1 $\times 10^{-7}$ m/s KBRR white noise(Without filtering)

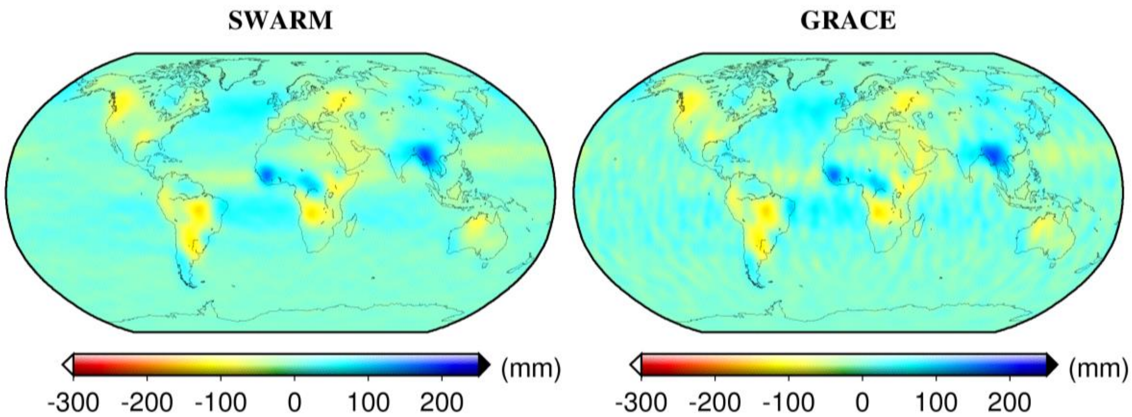
SWARM



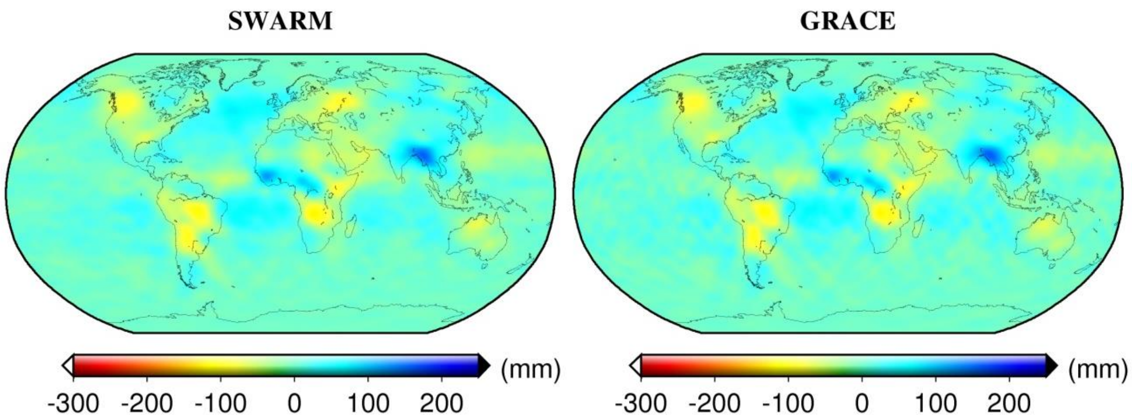
GRACE



Inversion error of different satellite constellations(filtered)



Ability to recover temporal gravity field model with 1×10^{-7}m/s KBRR white noise(Gauss filter)



Ability to recover temporal gravity field model with 1×10^{-7}m/s KBRR white noise(Gauss +P3M8)

Conclusions

- *On the basis of dynamic integral approach, a high performance software for Earth Gravity Field Model Inversion from SWARM Mission was built.*
- *Several essential factors about inverse accuracy was discussed:*
  - *Altitude(repeat period, ground track, signal attenuation)*
  - *Inclination(repeat period, polar gap)*
  - *Satellite combination(especially SWARM A+B versus SWARM A+C)*
  - *Satellite constellation(especially for temporal signal inversion)*
  - *Payload precision(GPS receiver, Accelerometer)*

Thanks for your attention!