CSR Level-2

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Center for Space Research

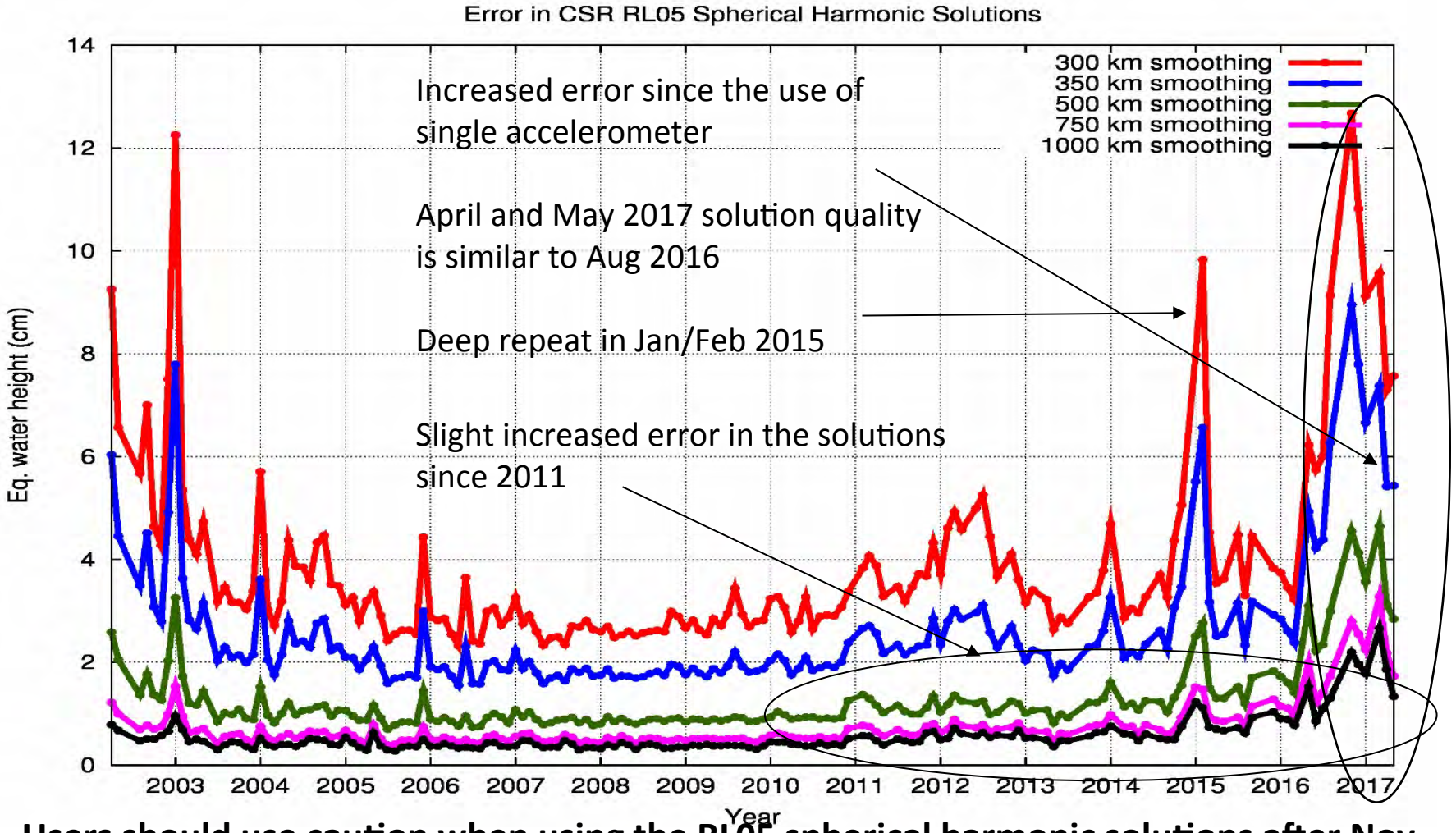
GRACE Science Team Meeting 2017

Austin TX

2016-2017 solutions

- Starting May 2016 the solutions show higher noise
  - May, June, July and Aug are dual accelerometer solution
- Aug 2016 data has a change in thermal character
  - Using heaters every rev for battery management
  - Due to loss of charge control
- Nov 2016 onwards
  - Single accelerometer
  - Using transplant accelerometer data for GRACE-B
- Zero pitch for Mar, Apr, May and Jun 2017
- Dual accelerometer data for May 2017

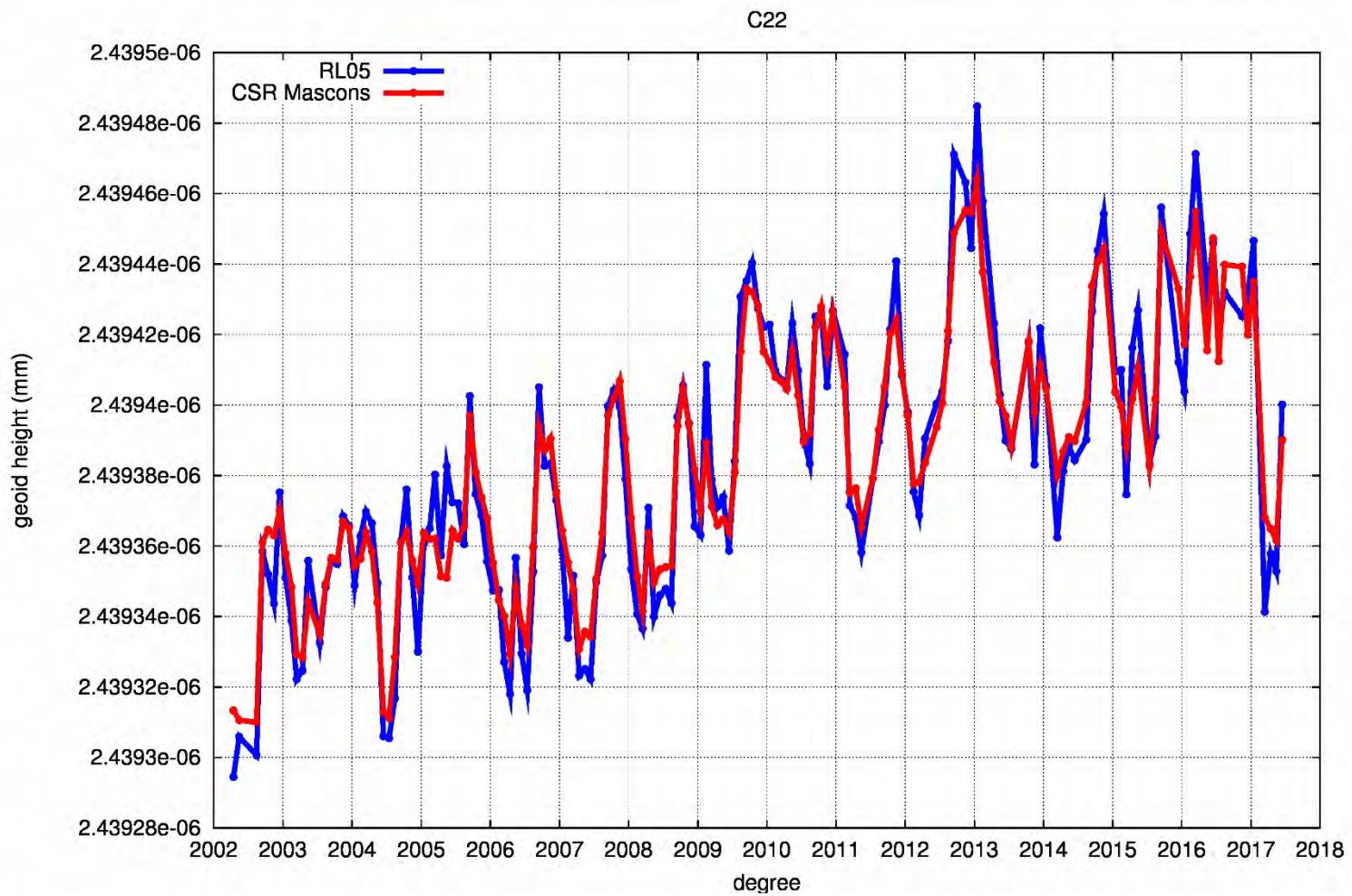
RL05 SHC error assessment



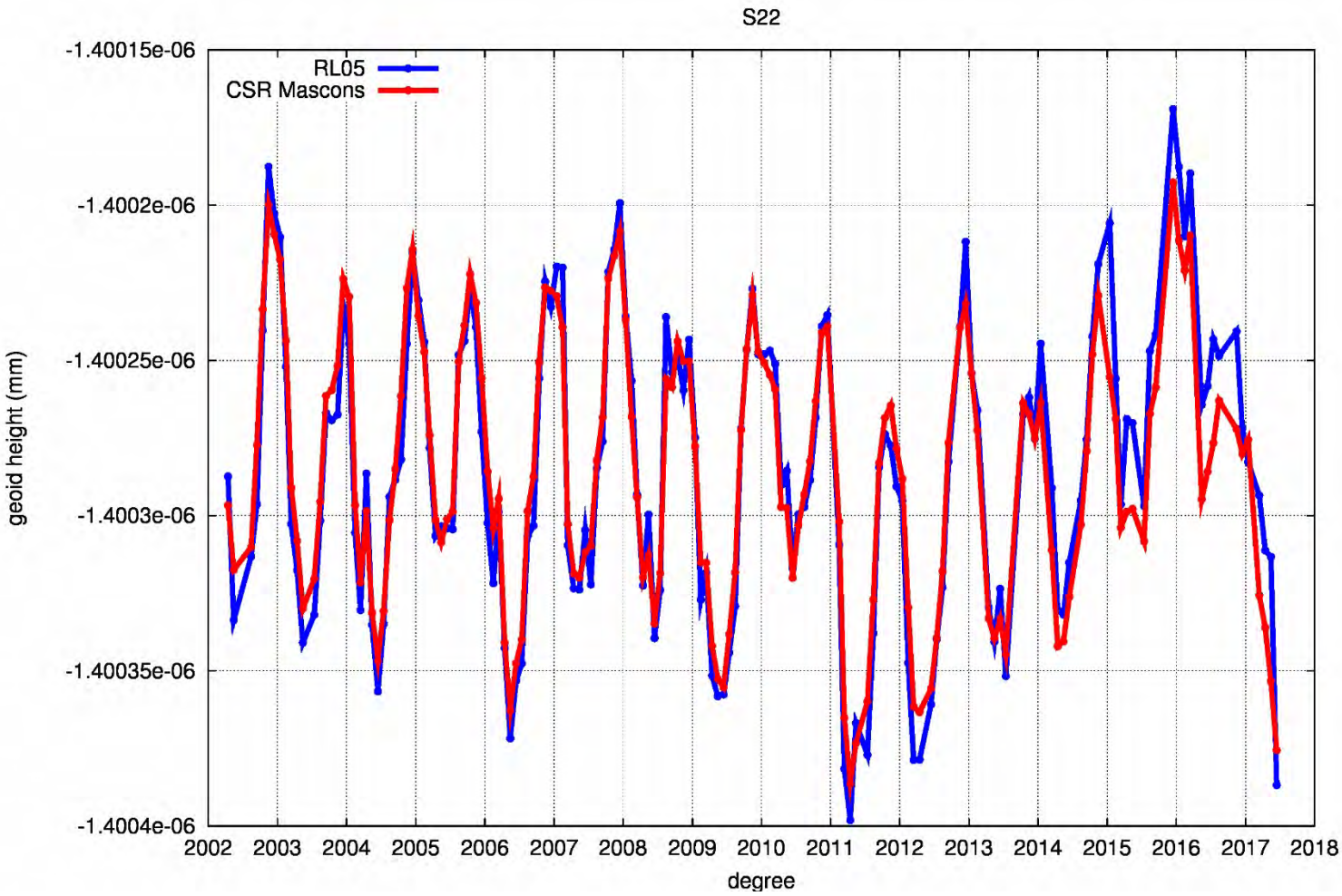
Users should use caution when using the RL05 spherical harmonic solutions after Nov 2016 for wavelengths shorter than 750 km. Mascon solutions may be more appropriate for shorter wavelengths

Possible low degree errors in 2016-2017 solutions

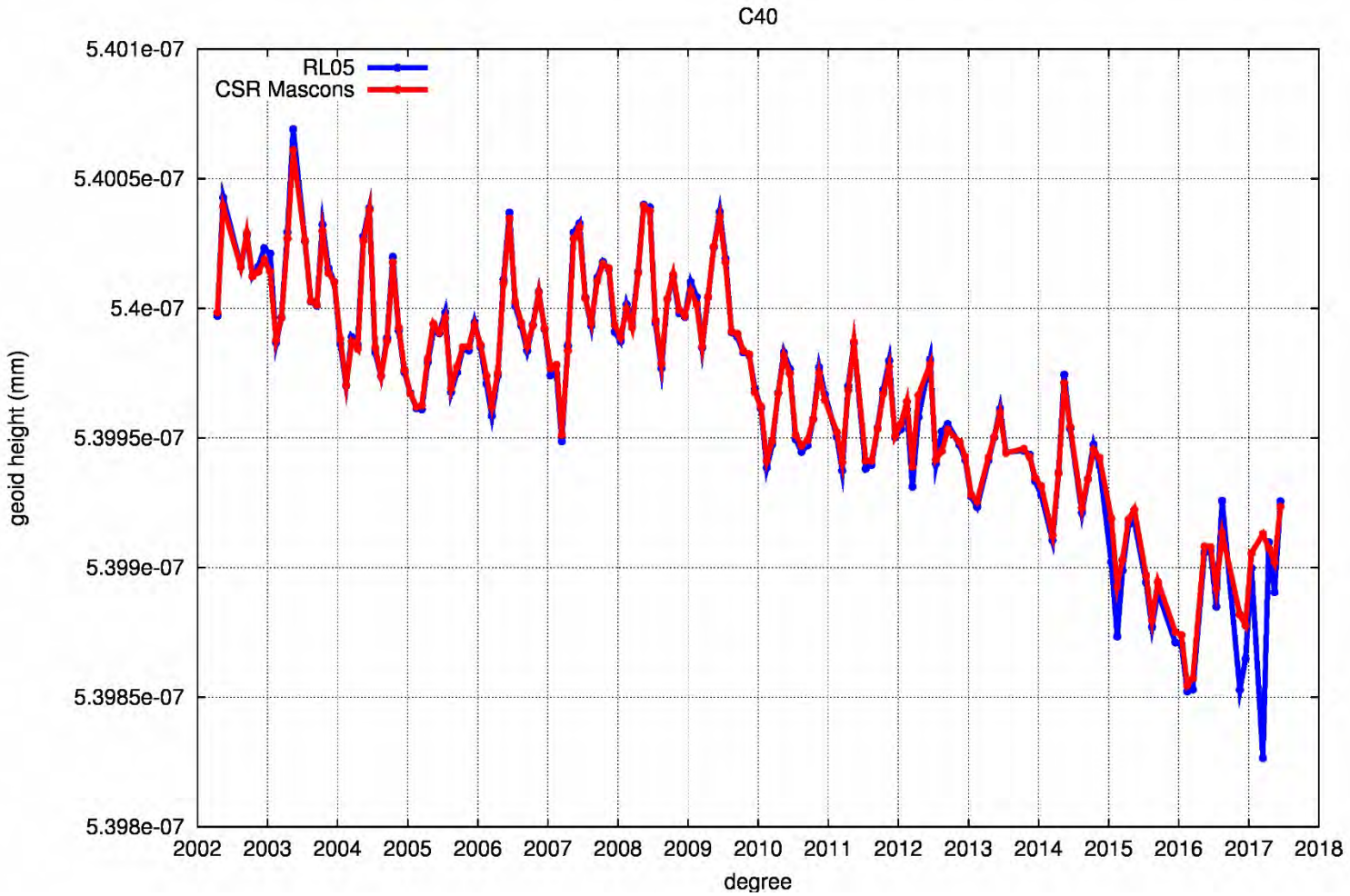
C22


C22
RL05
CSR Mascons
geoid height (mm)
2.4395e-06
2.43948e-06
2.43946e-06
2.43944e-06
2.43942e-06
2.4394e-06
2.43938e-06
2.43936e-06
2.43934e-06
2.43932e-06
2.4393e-06
2.43928e-06
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
degree

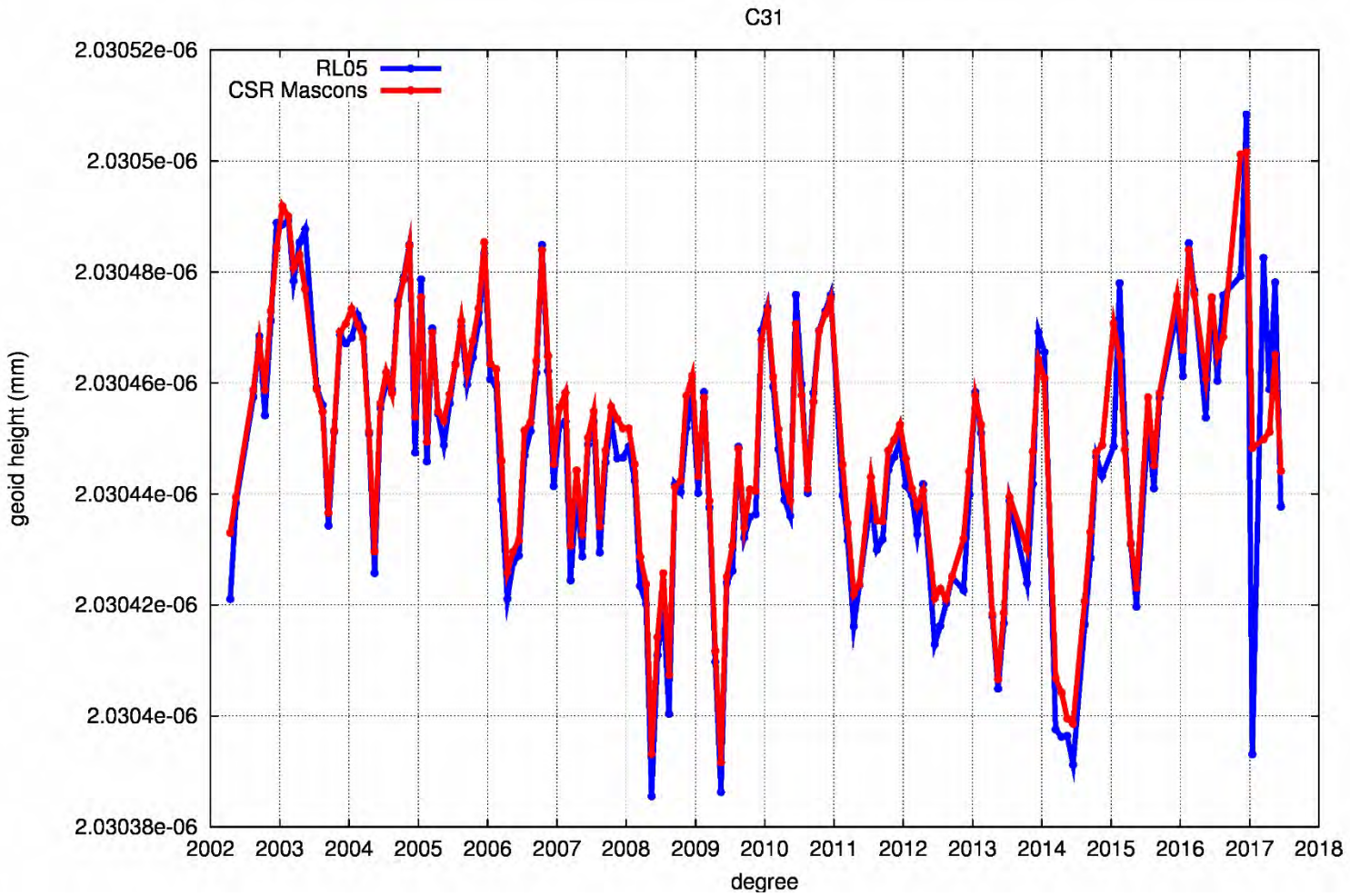
S22


S22
RL05
CSR Mascons
-1.40015e-06
-1.4002e-06
-1.40025e-06
-1.4003e-06
-1.40035e-06
-1.4004e-06
geoid height (mm)
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
degree

C30


C40
RL05
CSR Mascons
5.401e-07
5.4005e-07
5.4e-07
5.3995e-07
5.399e-07
5.3985e-07
5.398e-07
geoid height (mm)
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
degree

C31


C31
RL05
CSR Mascons
2.03052e-06
2.0305e-06
2.03048e-06
2.03046e-06
2.03044e-06
2.03042e-06
2.0304e-06
2.03038e-06
geoid height (mm)
2002
2003
2004
2005
2006
2007
2008
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2010
2011
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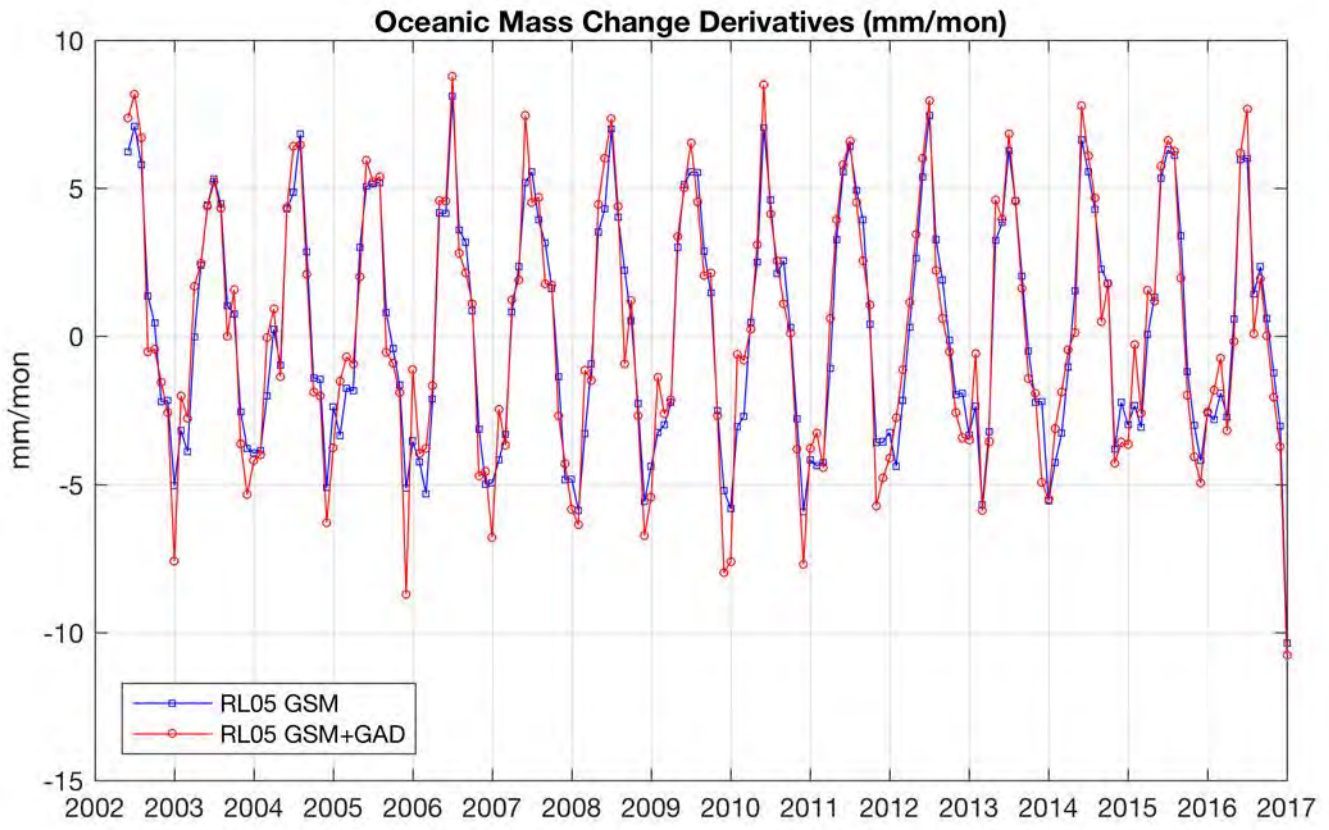
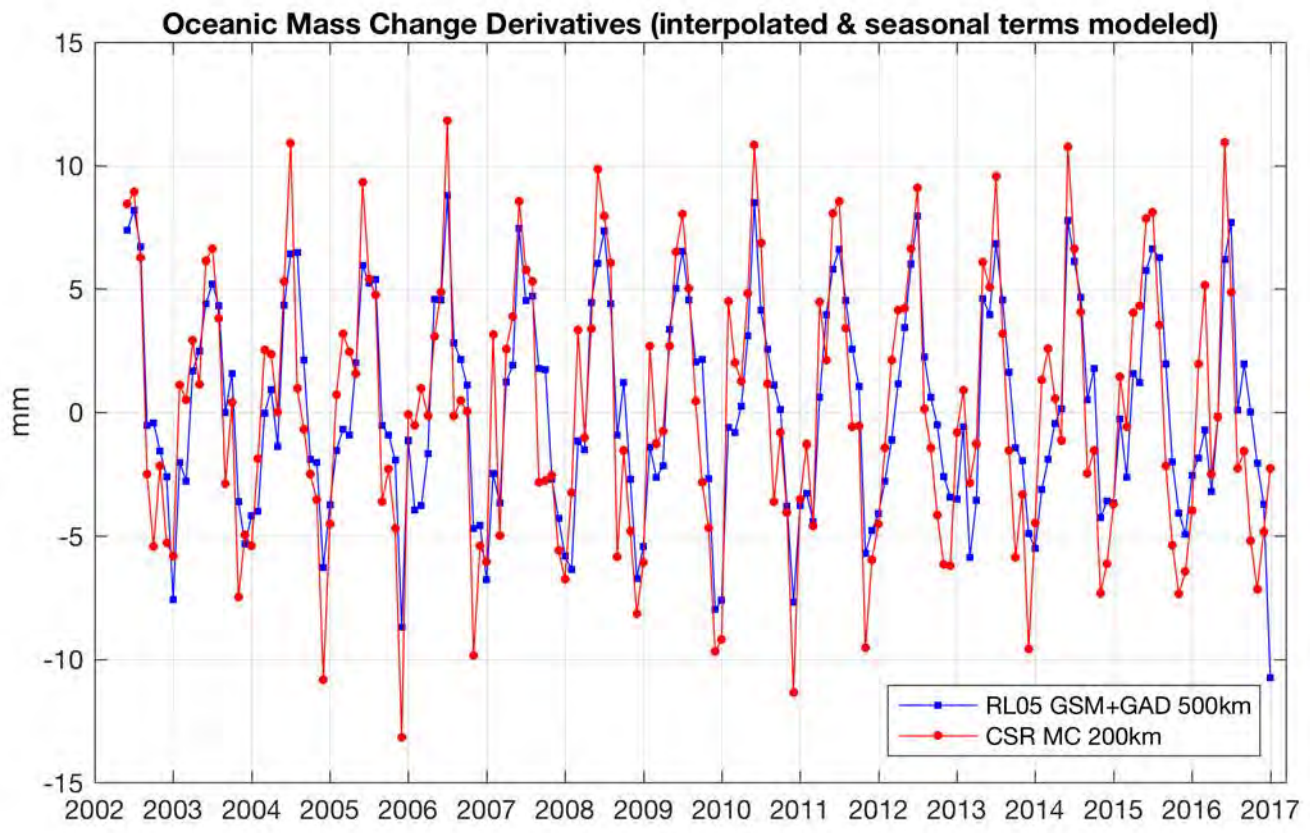
2014
2015
2016
2017
2018
degree

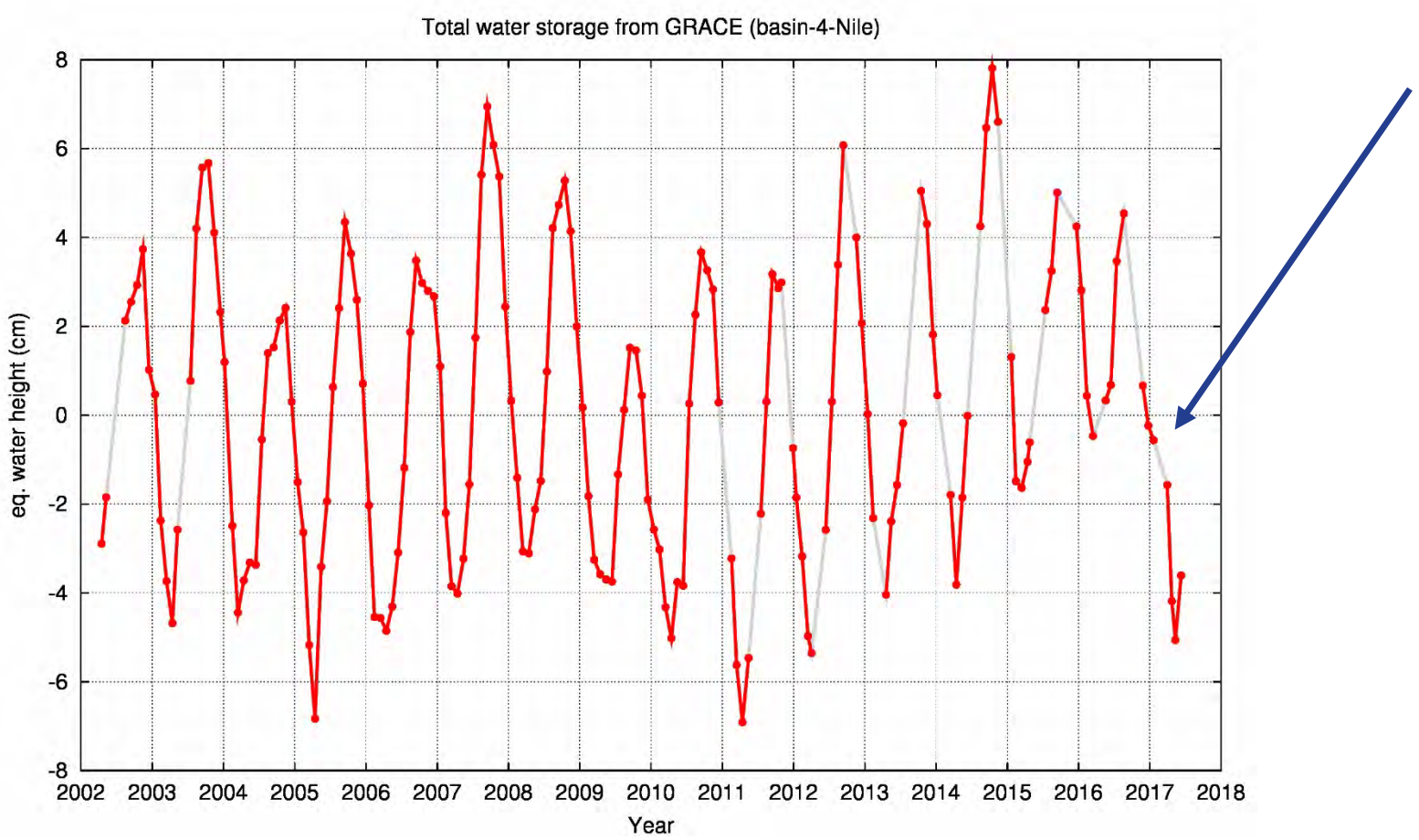
Ocean Mass Change Derivative



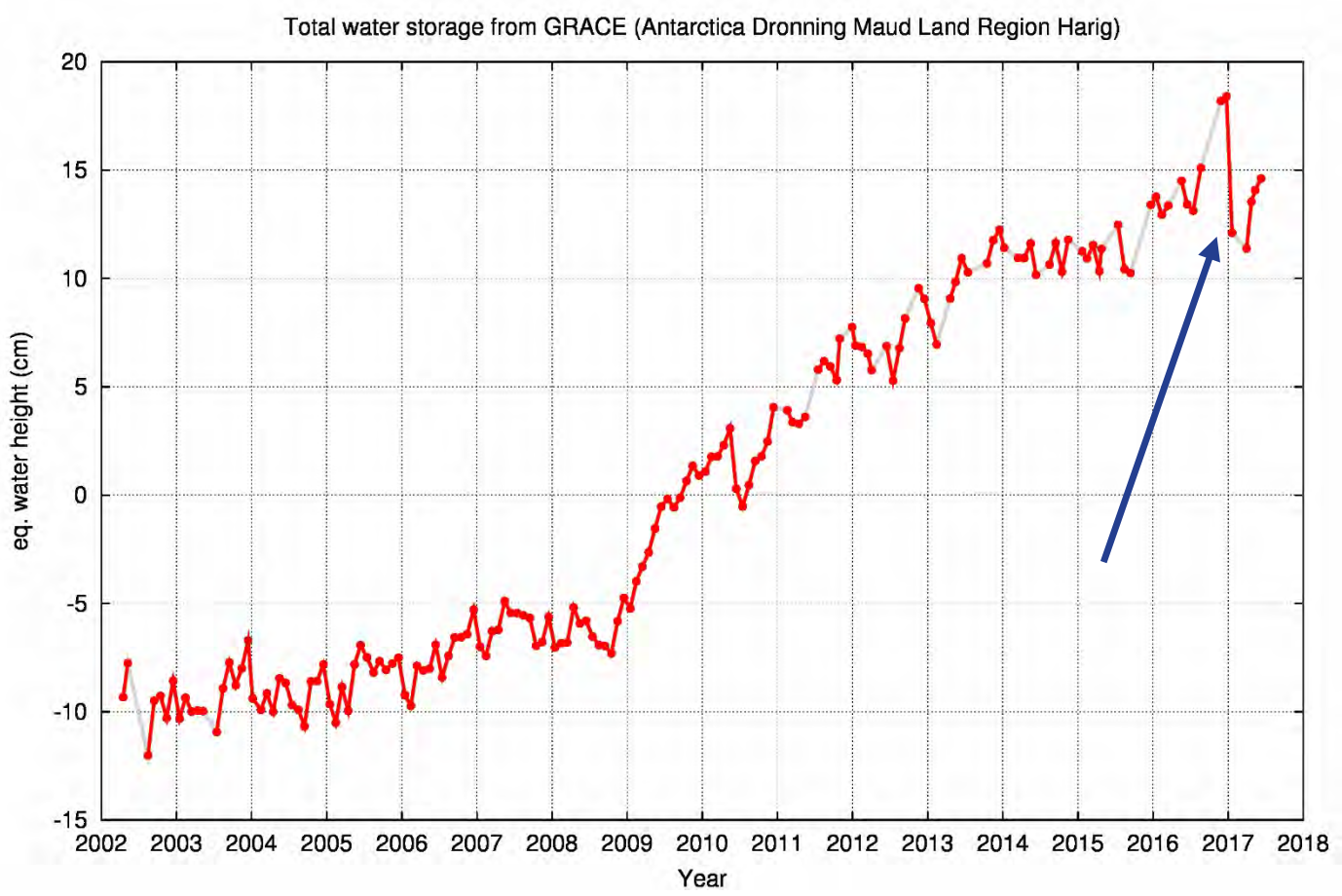
Ocean Mass Change Derivative



Basin average (Nile)



Dronning Maud Land

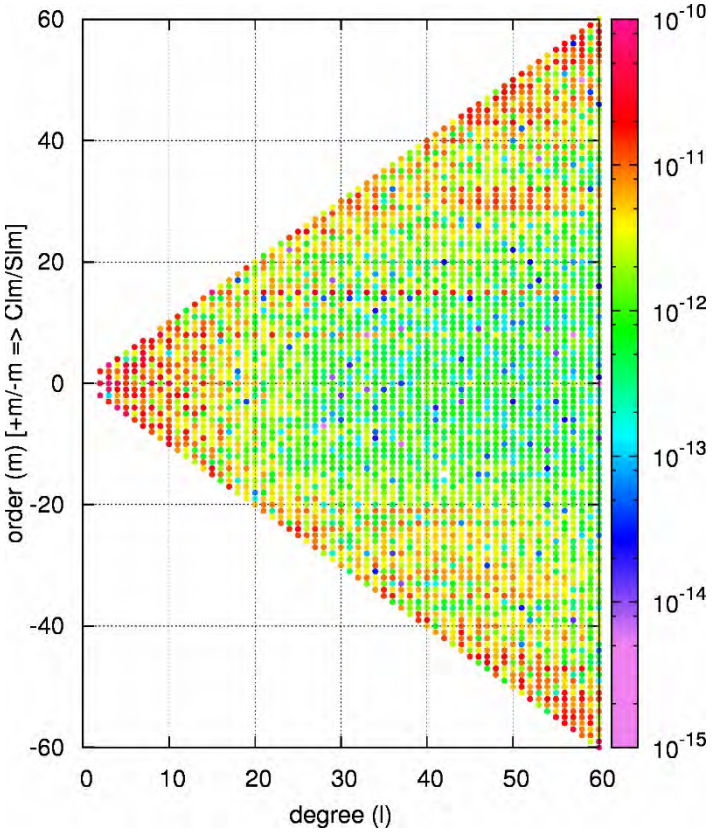


Pitch-bias introduced in 2017-03

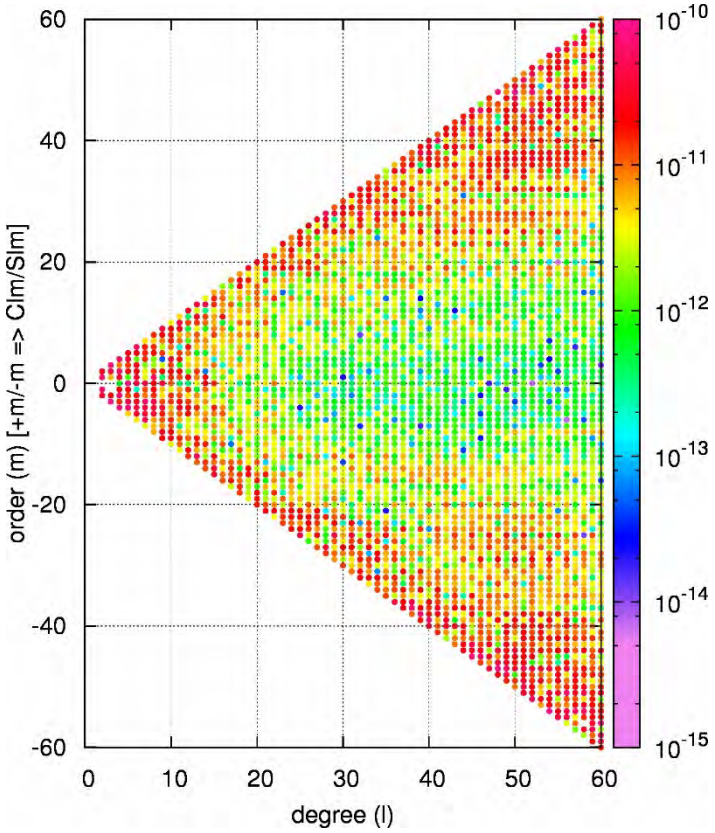
- Accelerometer data for Nov, Dec 2016 and Jan 2017
  - Transplanted from GRACE-A to GRACE-B
  - Approximate pitch correction is applied
  - One satellite nose-down and other nose-up
  - Introduces errors in the transplanted accelerometer data
- Operational need to reduce drag to conserve fuel
- Satellites flying LVLH since end of March
  - ACC data transplant does not require pitch correction
  - Increase in high frequency noise in KBR data

Zonal errors

2016 - 05



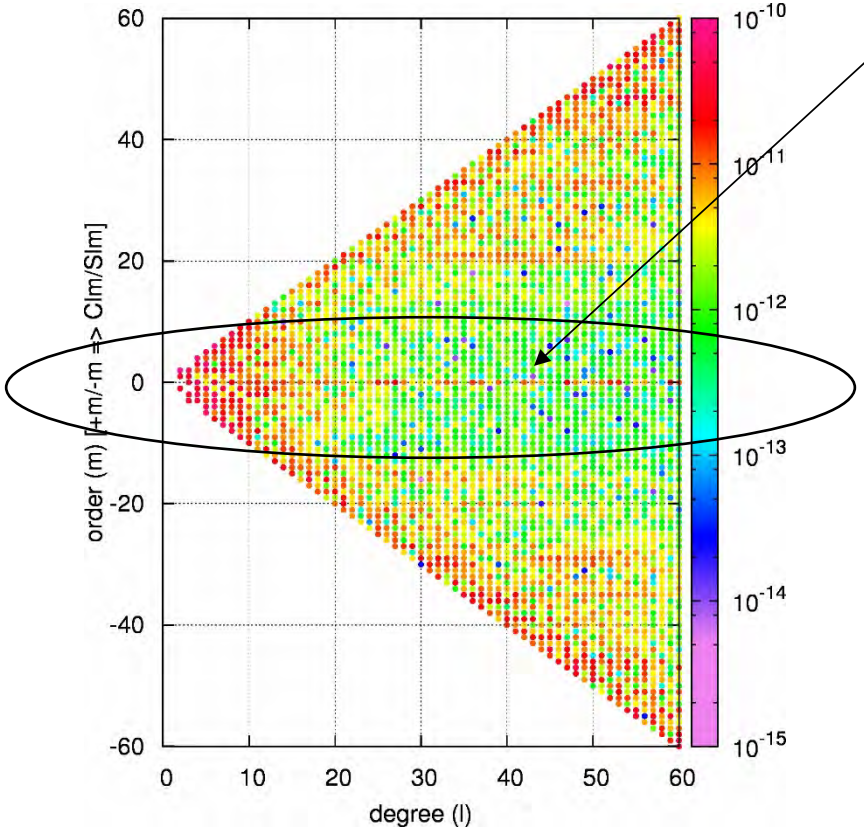
2016 - 11



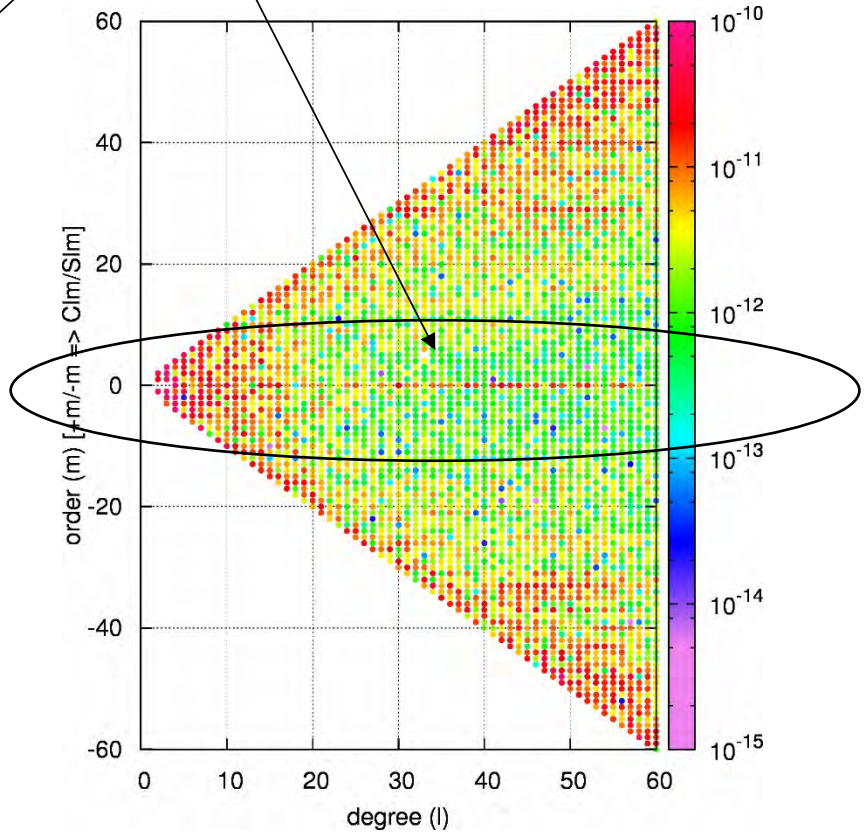
Zonal errors

Increase in zonal errors

2017 - 04



2017 - 06



Caution!!!

- Please exercise caution when using the solutions from late 2016 through 2017.
- Possible problems with low degree harmonics
- The low degree issue likely also hurting the mascon solutions
- The error in the zonals for the solutions in March to June 2017
- Some of this signal may show up as spurious geophysical signals
- The SDS centers are looking for feedback with respect to the 2016 and 2017 solutions

Towards RL06 - summary

- GRACE data for the entire mission will be reprocessed with latest standards and processing improvements
- The signal definition of RL06 GRACE solutions will ***not*** change from RL05
  - The GSM-2 products will continue to represent primarily the Hydrology and Cryospheric variability; as well as corrections to tides, non-tidal ocean variability, and atmospheric pressure variations.
- GRACE-FO data will be processed with the same standards as GRACE RL06
  - GRACE RL06 will provide a starting point for GRACE-FO processing
  - Harmonizing the GRACE and GRACE-FO time series
- GRACE RL06 reprocessing will be done in the of Fall 2017
- GRACE RL06 solutions will be ready in time for GRACE-FO data processing using GRACE RL06 standards

Changes for RL06

- V03 Level 1 data

  Work by Bandikova and Sakumura @ JPL

  - SCA1B and KBR1B
    - SCA1B is reconstructed using star tracker and accelerometer data
    - High frequency V03 SCA1B noise significantly reduced
    - V02 Level 1 data for everything else
- Model Upgrades under evaluation
  - De-aliasing product candidate: AOD RL06
  - Mean Field candidate: GGM05C and new mean field w/ low altitude GRACE data
  - Ocean Tide Models candidate: FES2014 and GOT+GRACE model
- GPS handling for CSR RL06
  - IGS14 standards, JPL products for GPS clocks and orbits
  - Un-differenced phase instead of double difference
- Improved parameterization, arc structure and data editing

What is different?

Model	RL05	RL06
Mean Gravity	GIF48 (360)	GGM05C (360)
3rd Body Pert	DE 405	DE 430
Body Tides	IERS-2003	IERS-2010
Ocean Tides	GOT4.8 + SCEQ (d/o 180)	GOT4.8/FES2014/GOT+GRACE (d/o 180)
Pole Tide (Solid)	IERS-2010 (cubic mean-pole model)	IERS-2010 (new linear mean-pole model)
Pole Tide (Ocean)	IERS-2010 (cubic mean-pole model)	IERS-2010 (new linear mean-pole model)
Atmosphere + non-tidal Oceans	AOD1B_RL05 (ECMWF + OMCT)	AOD1B_RL06 (ECMWF+MPIOM)
L2 data	V02 for all Level-1 data	V03 for SCA1B and KBR1B V02 for everything else

Improved parameterization and processing

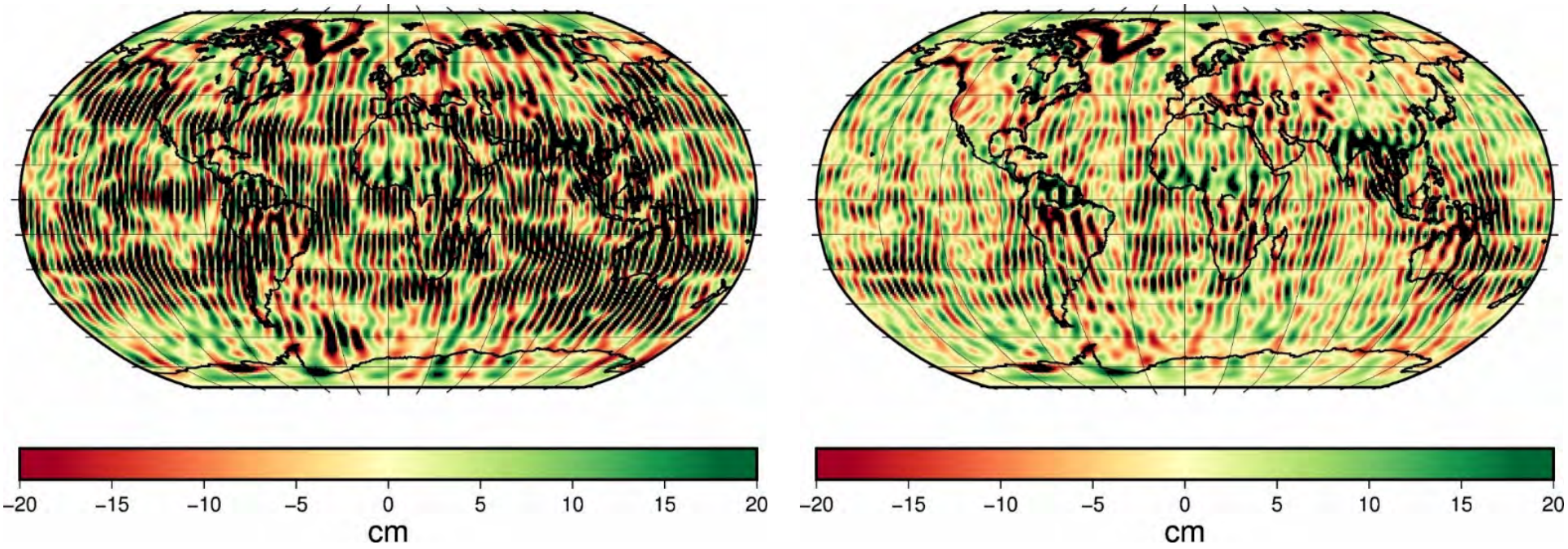
- Improve the estimation of orbit, accelerometer and other parameters in presence of the best known "state of the earth"
- Use the best estimate of the orbit, accelerometer and other parameters to compute the best unconstrained gravity field from GRACE

** manuscript in preparation*

Reduced errors in the gravity field

Aug 2008

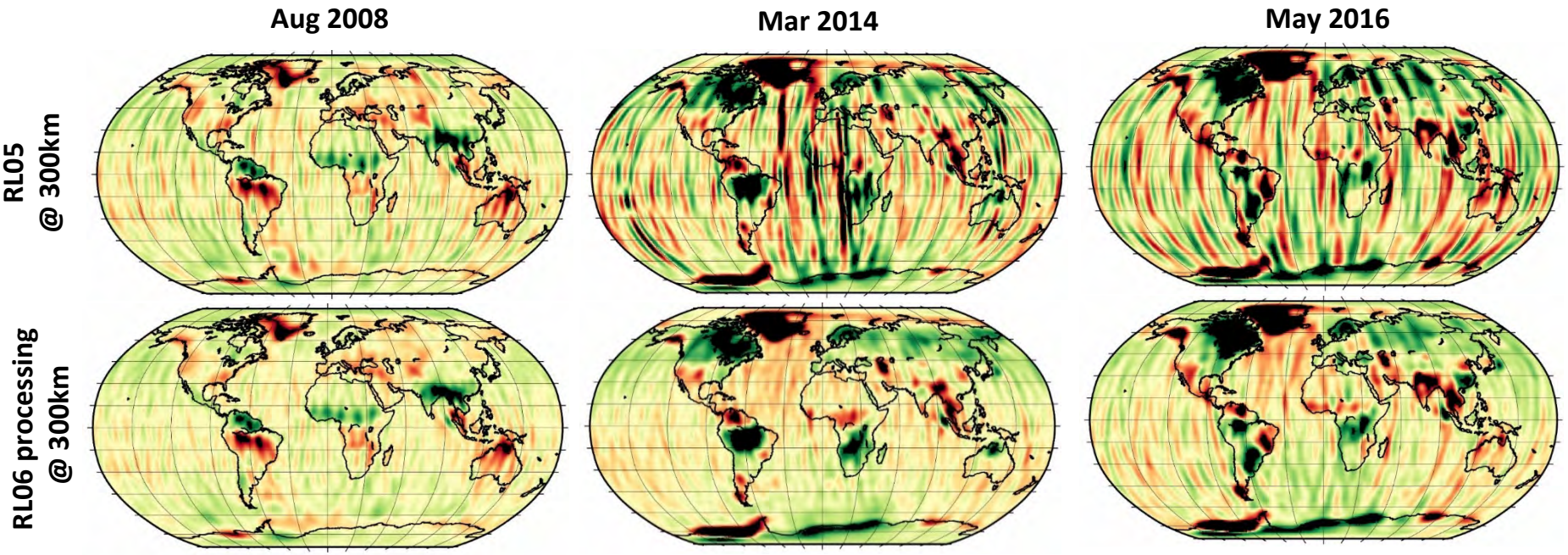
deg 60 – No smoothing



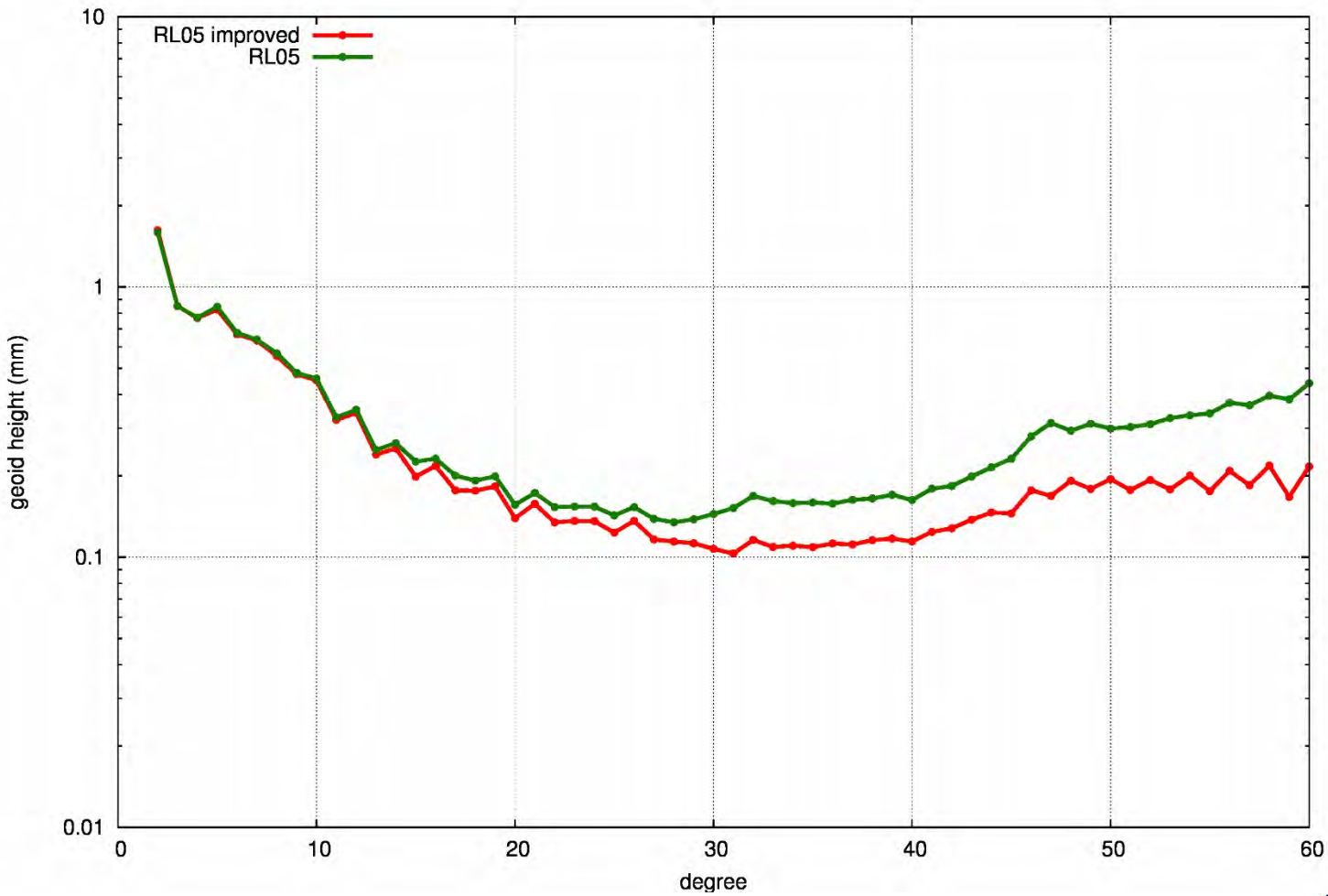
RL05

Improved RL05 two step estimation

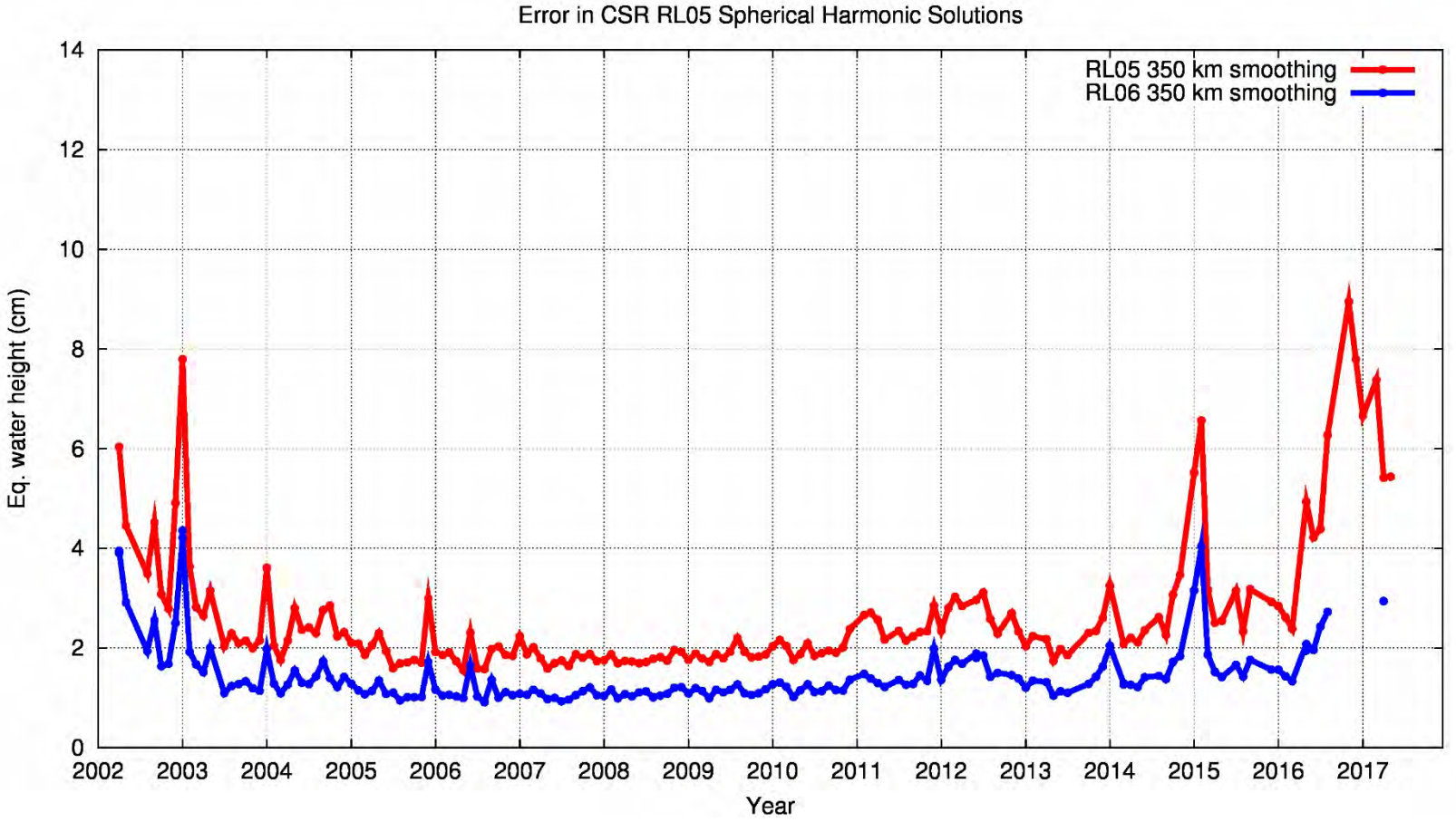
Uniform solution quality in RL06 time series?



RL05 v RL05 Improved

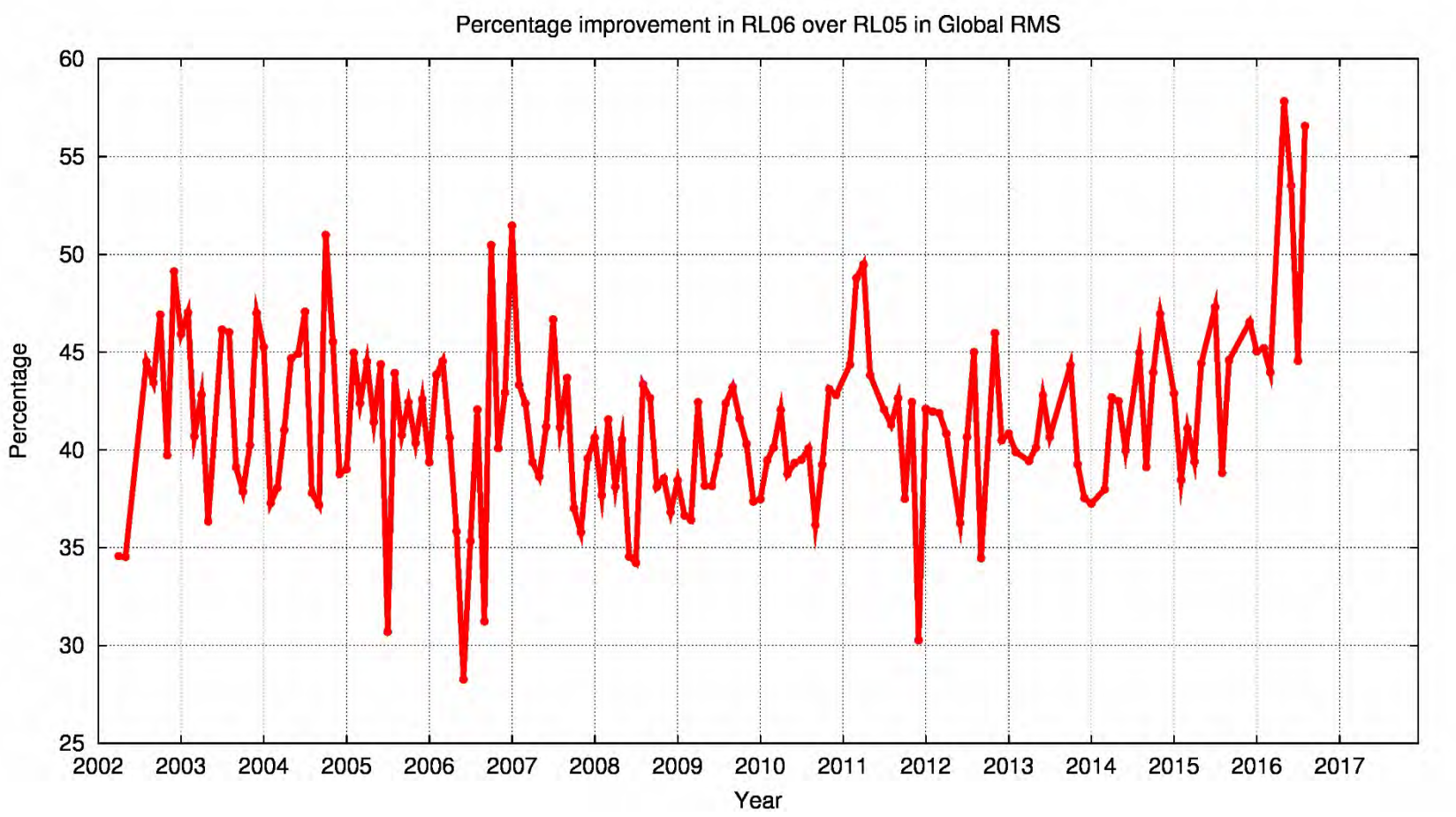


Expected improvement in RL06 error vs RL05

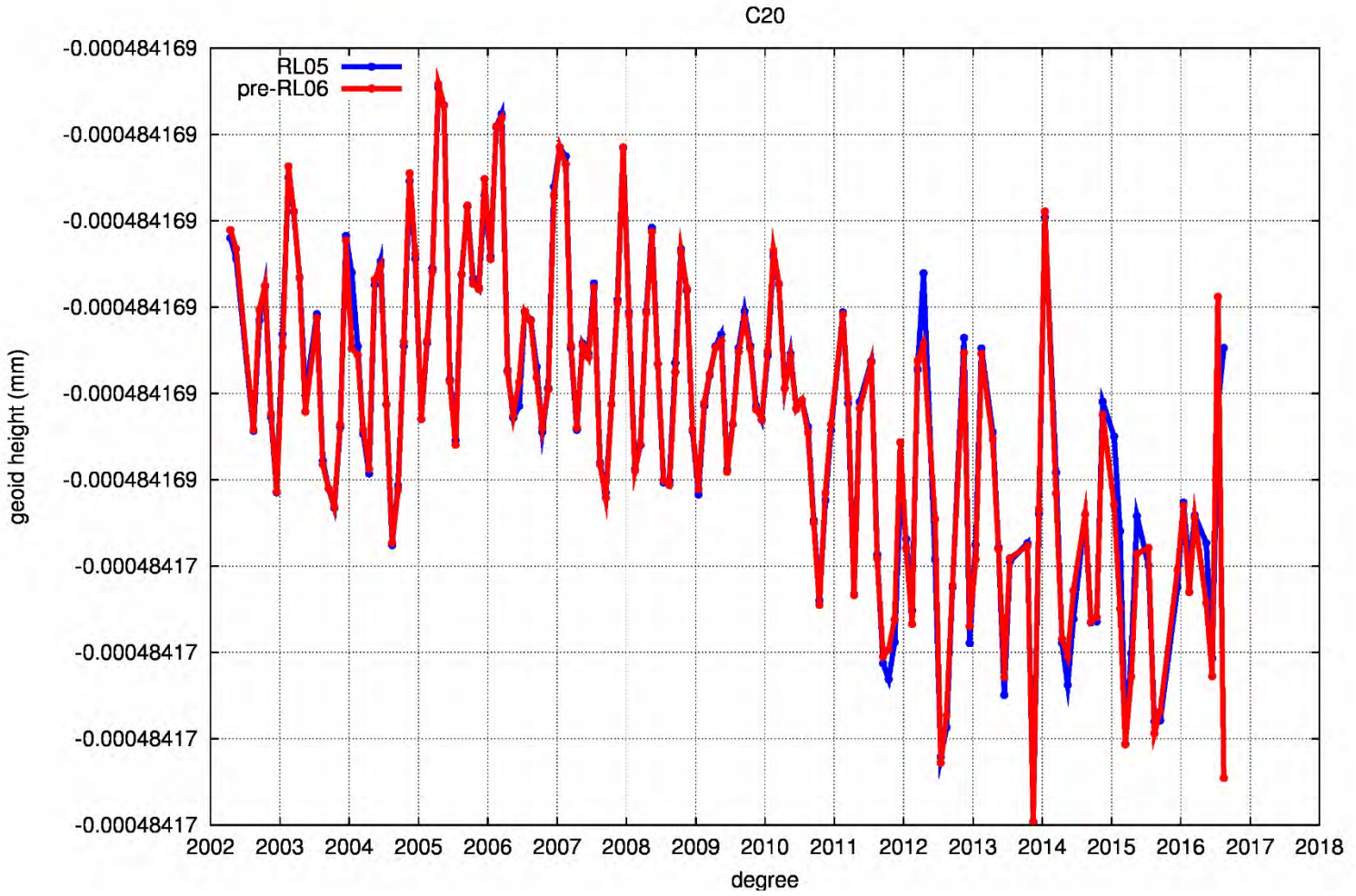


We expect to see an improvement of roughly 30% to 50% in global error RMS

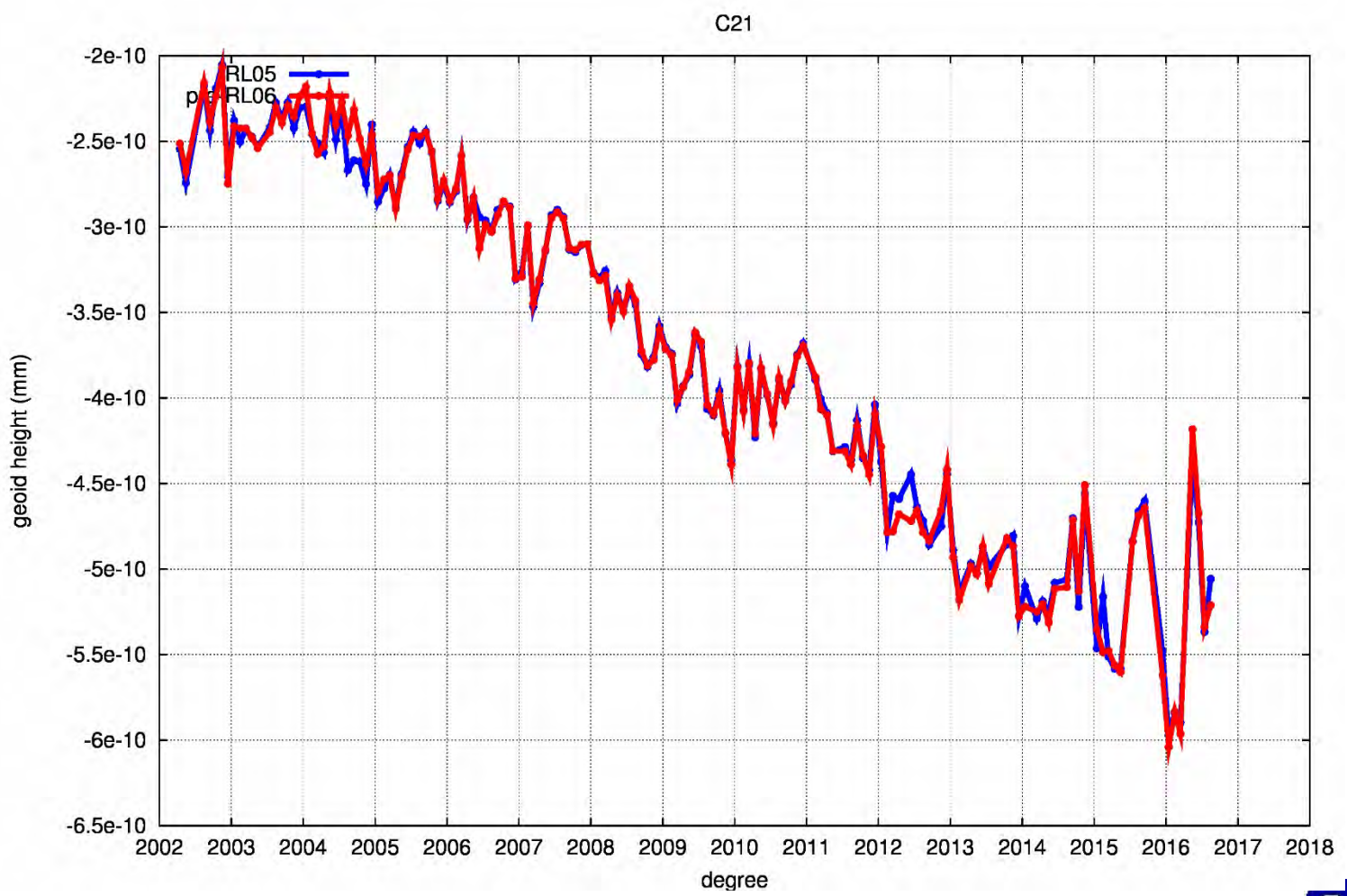
Roughly 30% to 50% improvement in global error RMS



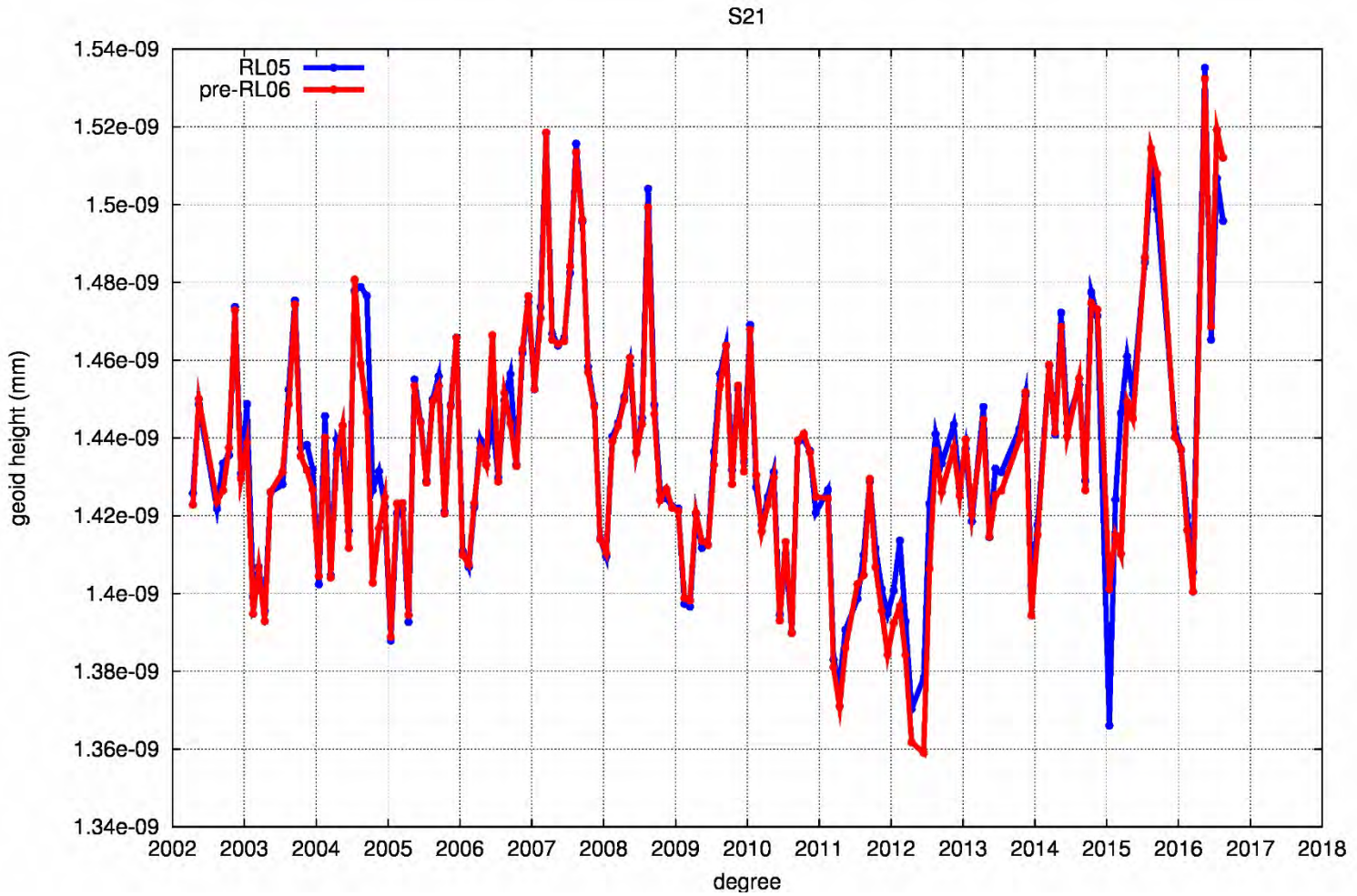
Low degree comparison (C20)



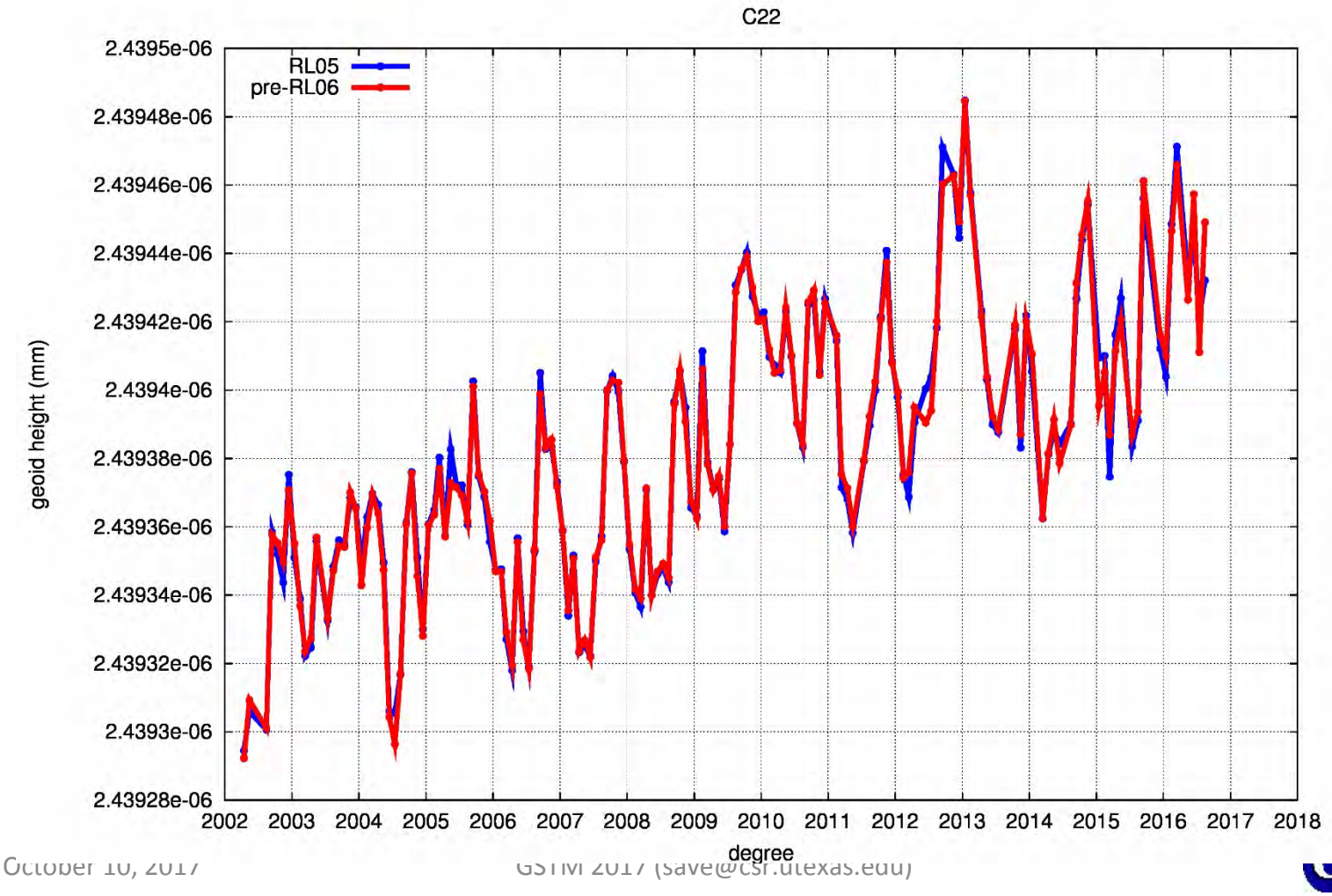
Low degree comparison (C21)



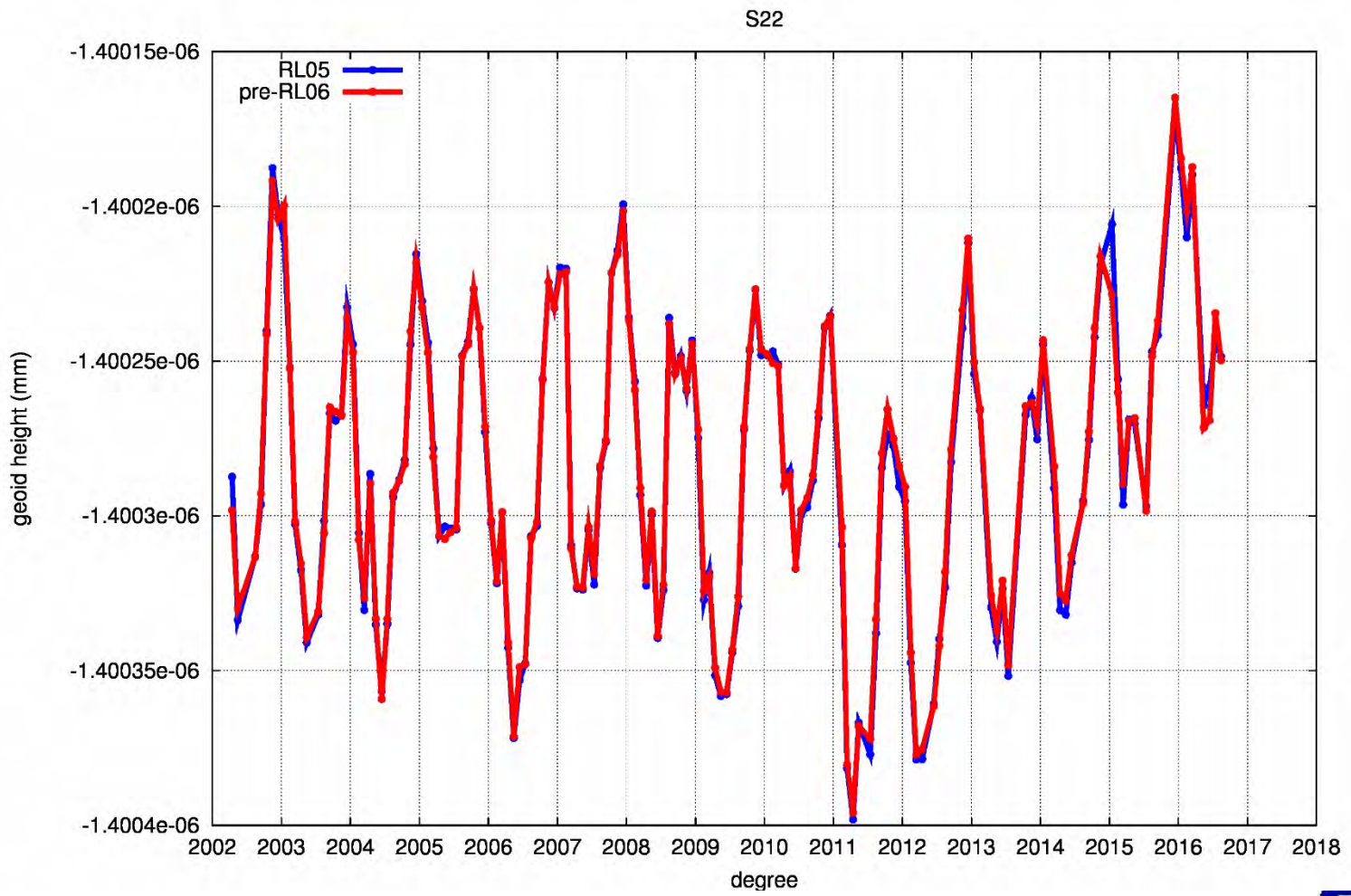
Low degree comparison (S21)



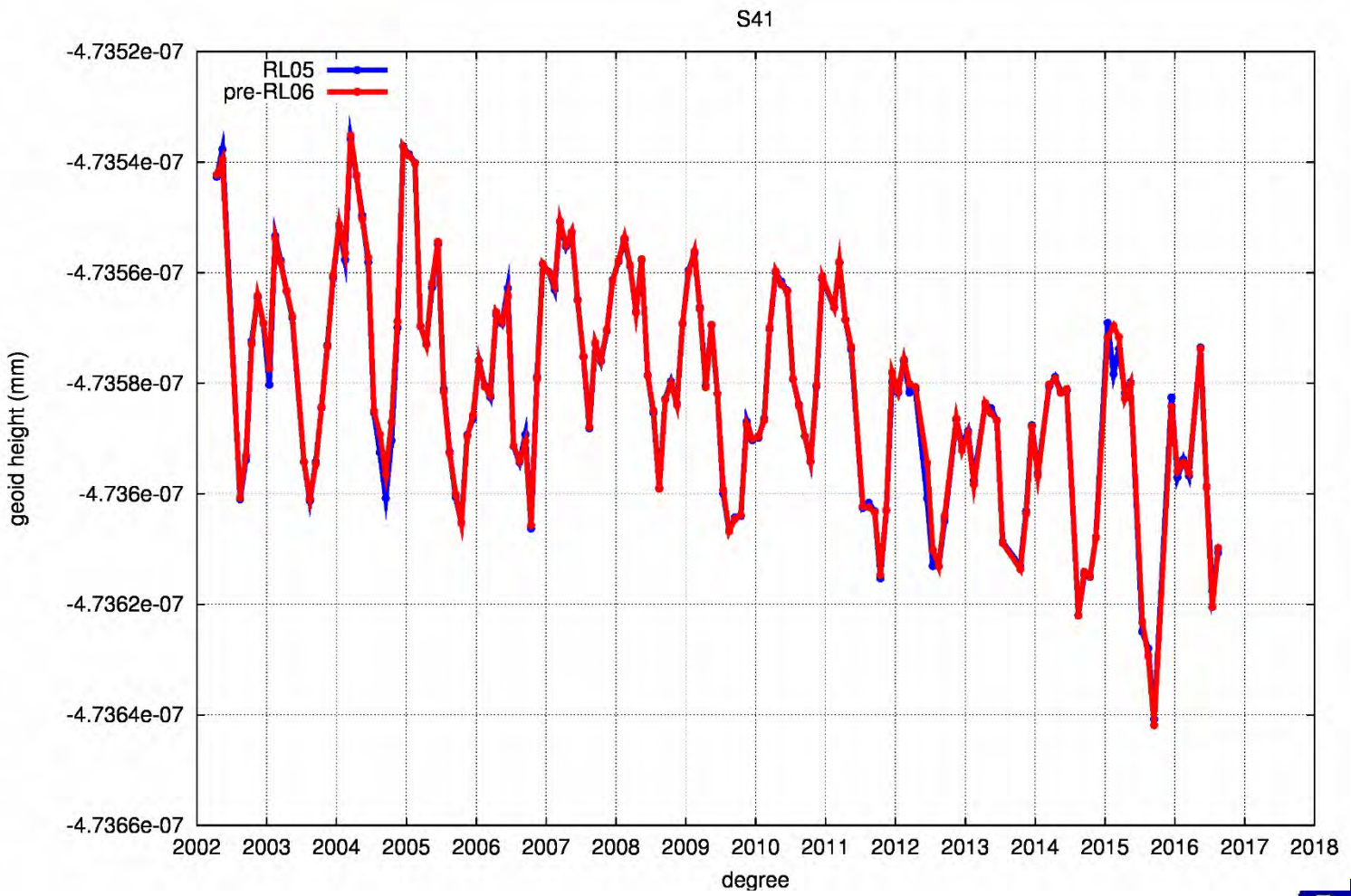
Low degree comparison (C22)



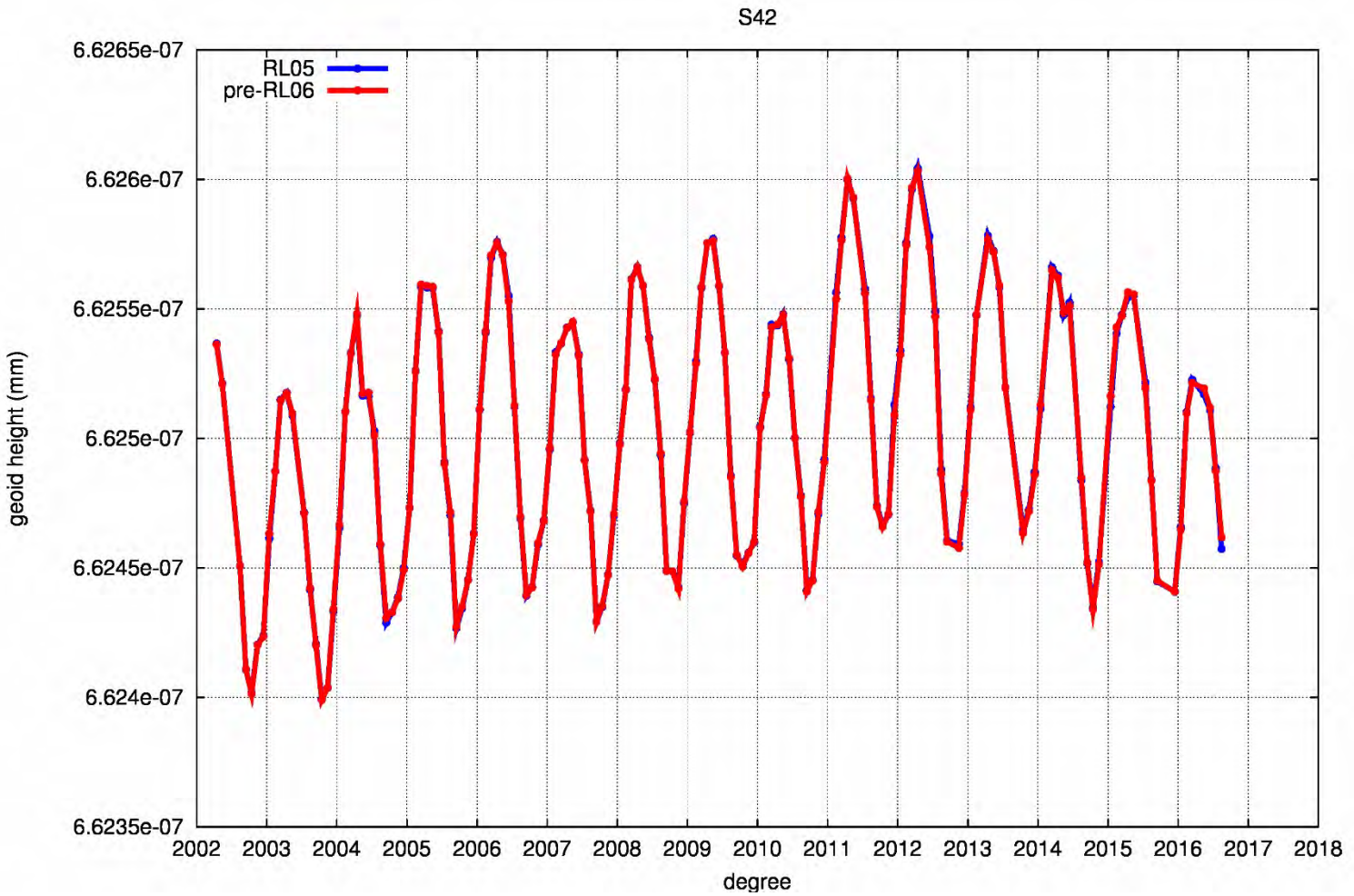
Low degree comparison (S22)



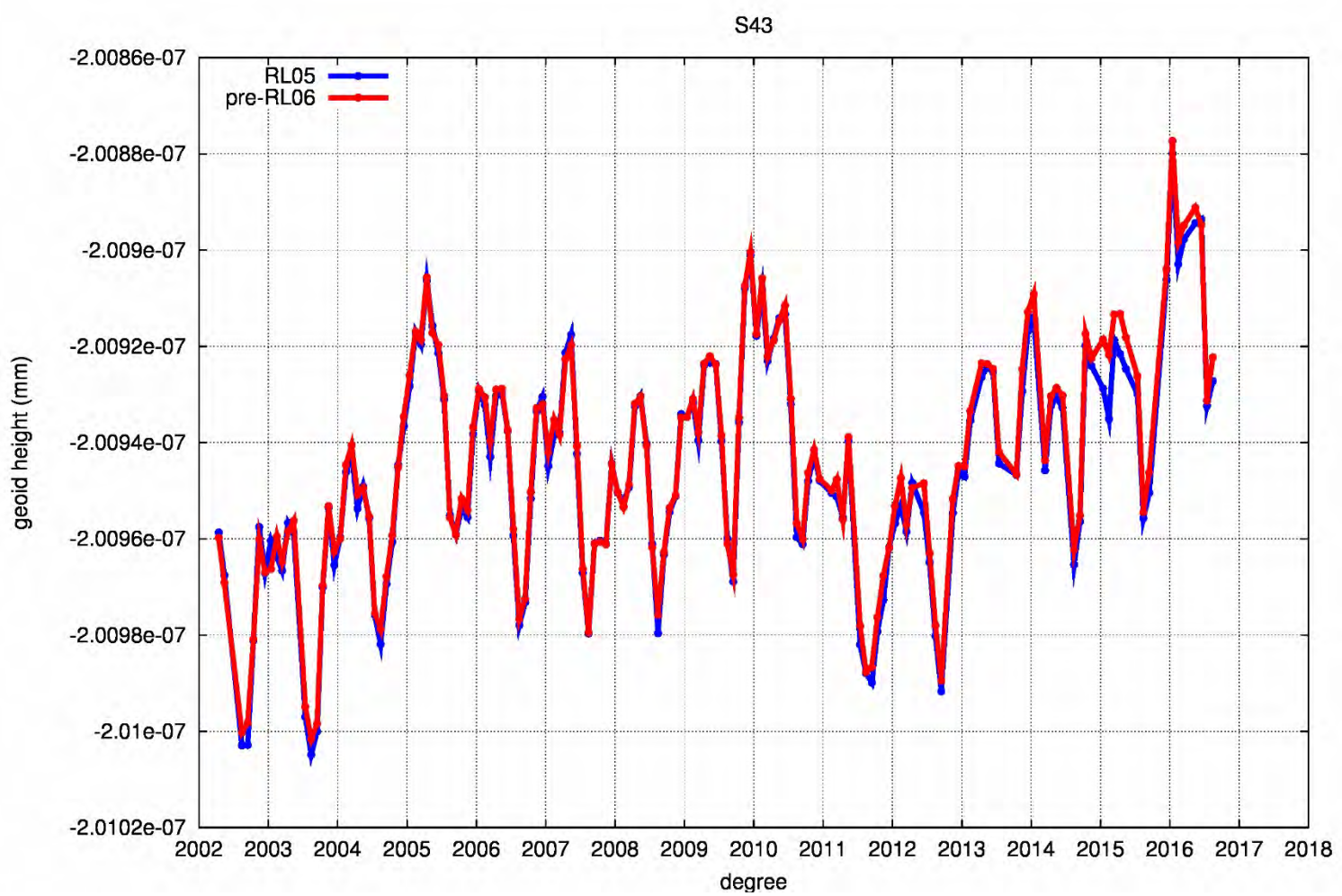
Low degree comparison (S41)



Low degree comparison (S42)



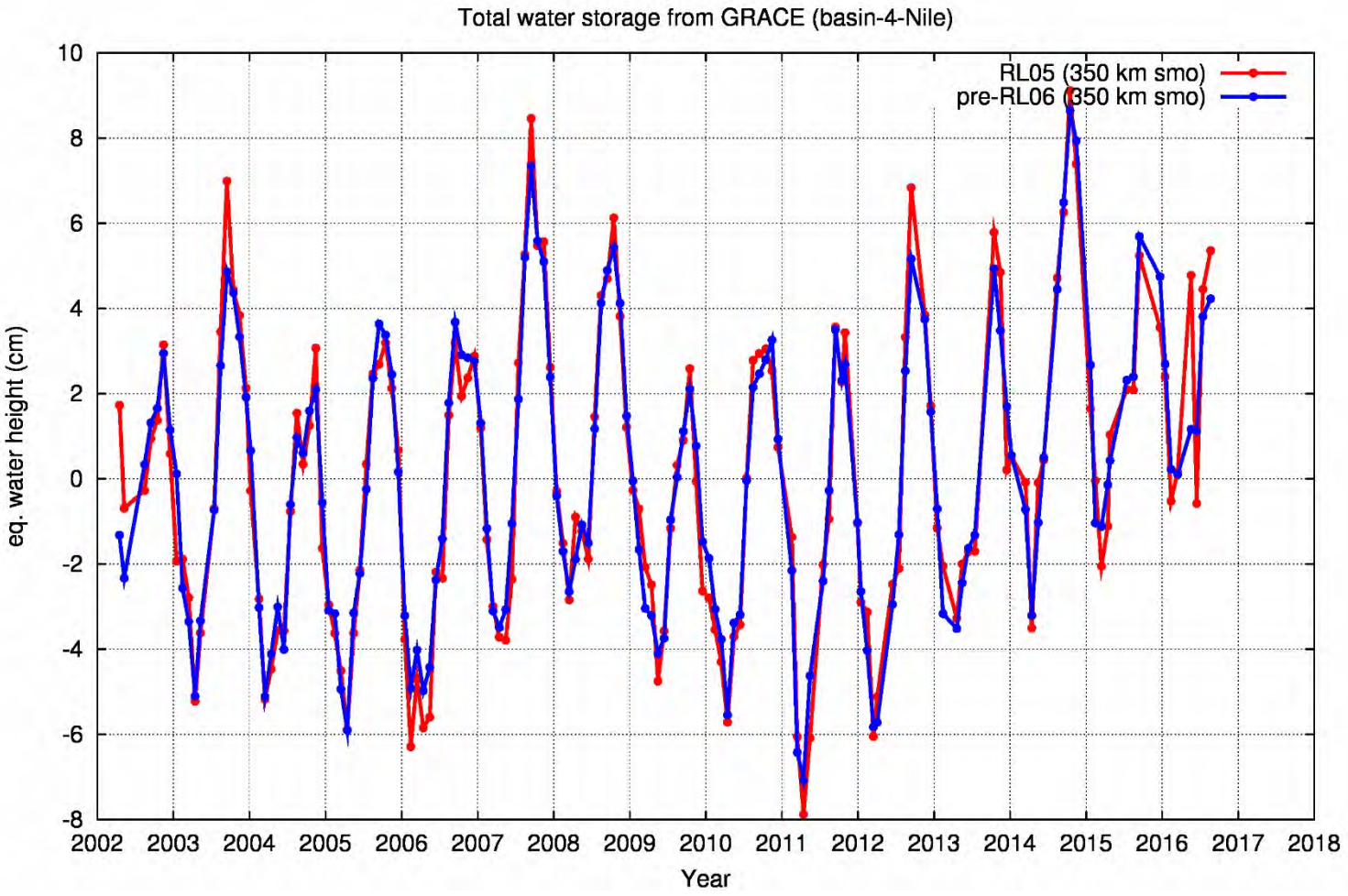
Low degree comparison (S43)



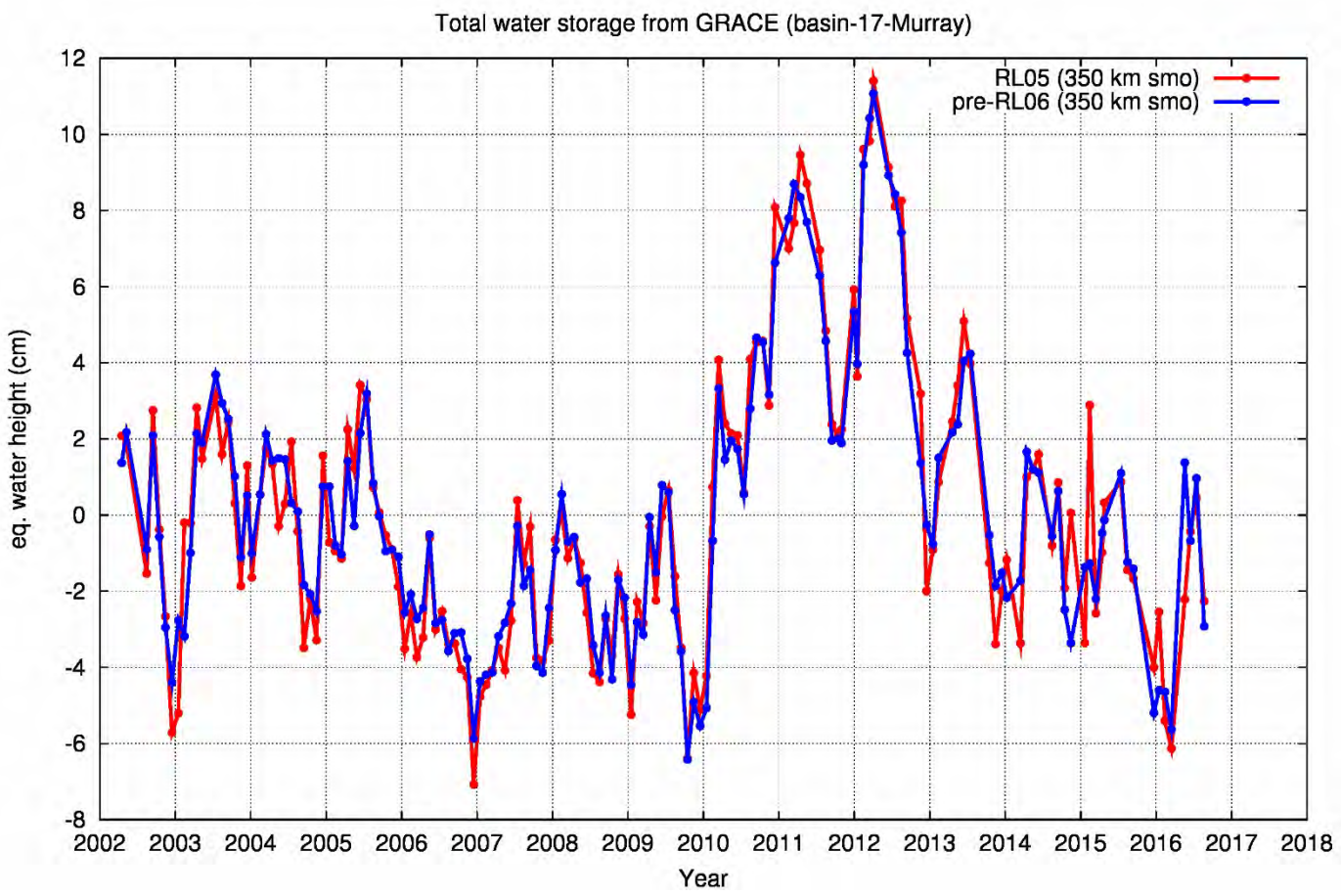
Basin average analysis

- Compare GSM from
  - RL05 and pre-RL06
- No de-striping or filtering is applied
- Only 350 km smoothing is applied
- No leakage correction is applied
- No scale factor is applied
- C20 is ignored
- Only to compare the two solutions

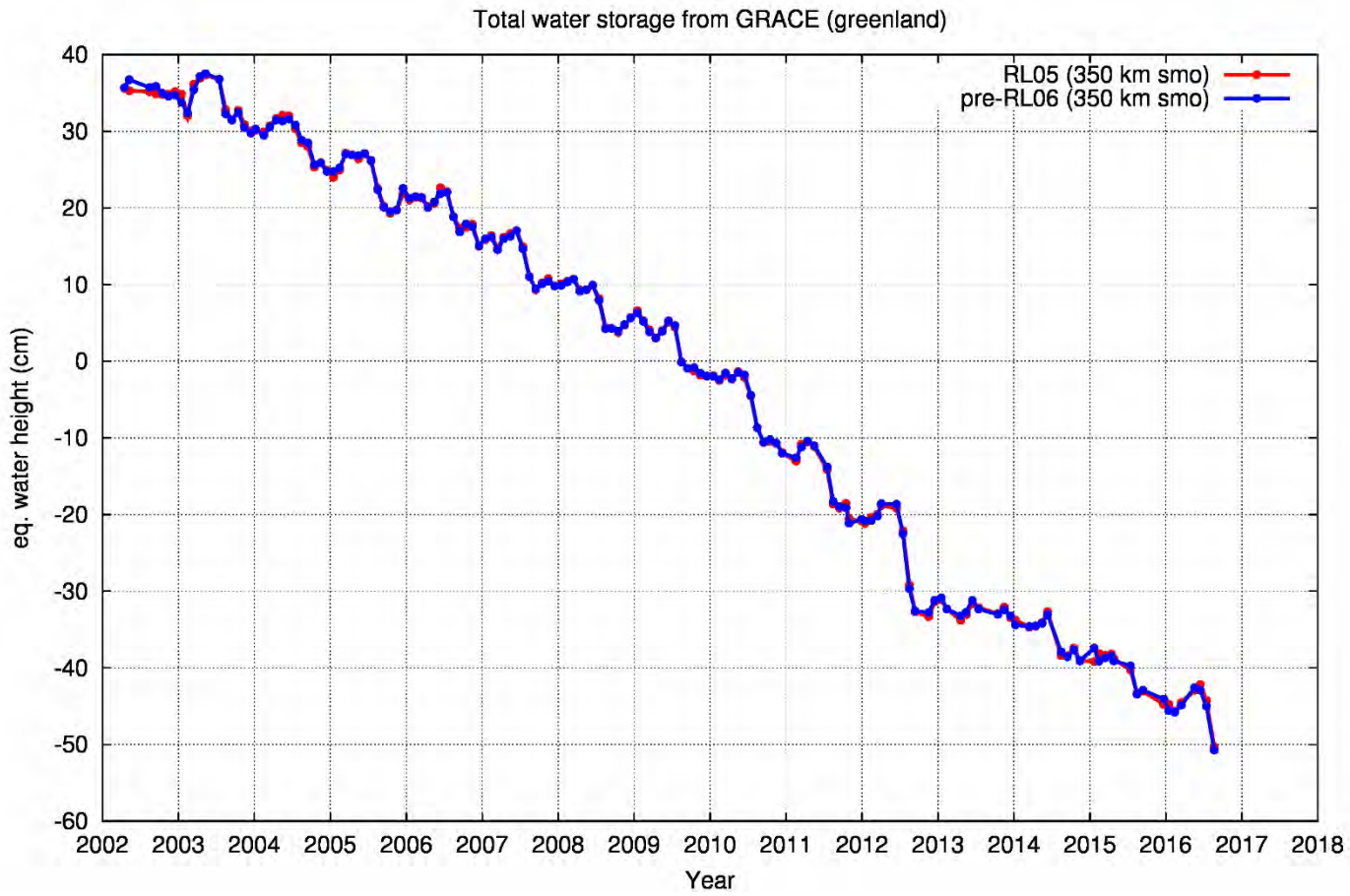
Basin average (Nile)



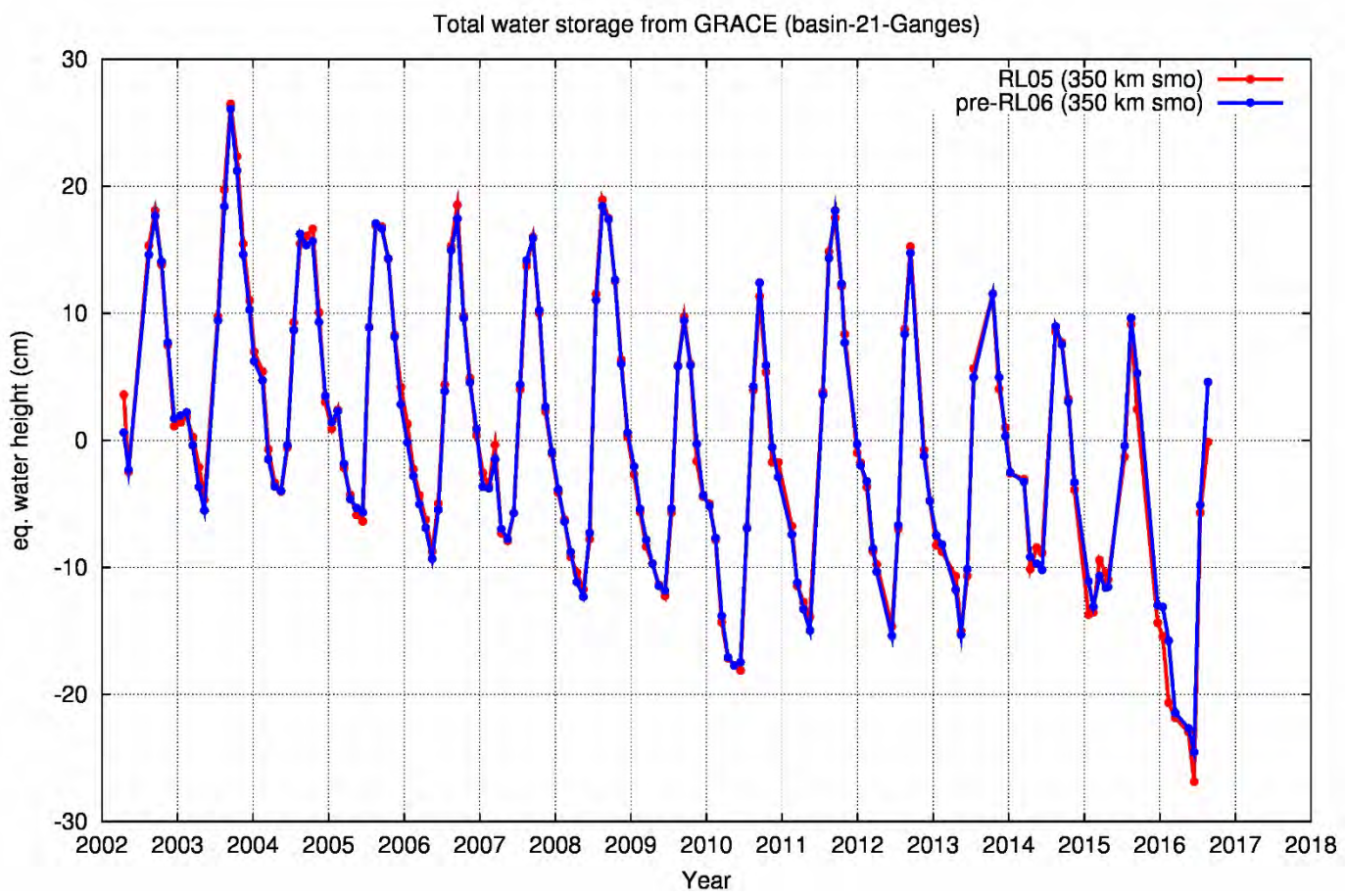
Basin average (Murray)



Basin average (Greenland)



Basin average (Ganges)



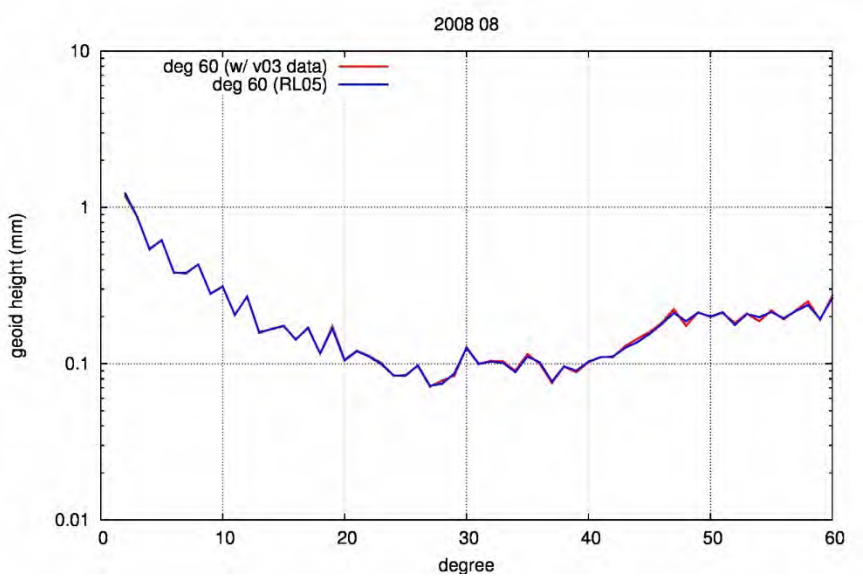
Caution

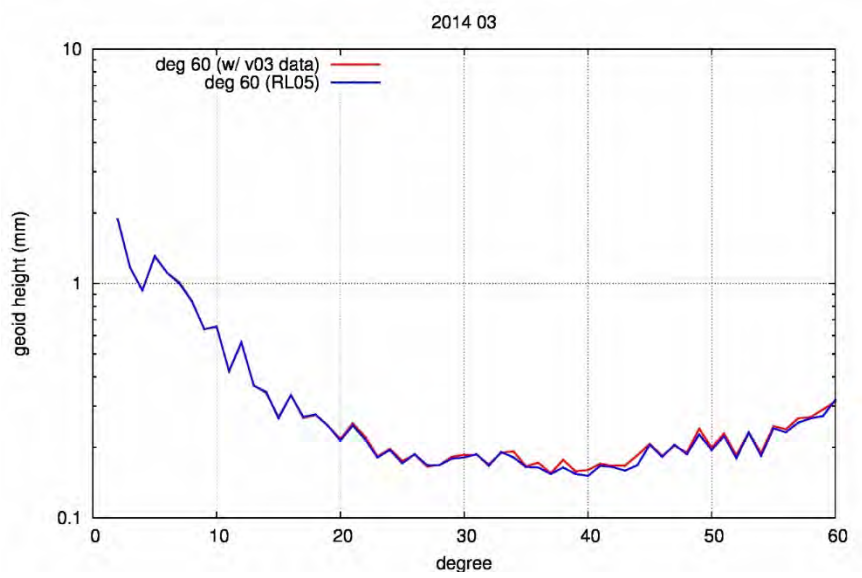
- We are evaluating a modified two-step approach that offers the advantage as seen
- But we have previously argued that two-step methods are tricky
  - chance that they bias may the solutions towards an a-priori
- So we are proceeding very carefully
  - Final decision at a later date
- Consider this a progress report

V03 SCA1B reprocessing

- What is new?
  - SCA1B is reconstructed using star tracker and accelerometer data
  - Star tracker and accelerometer data are processed using Kalman Filtering
  - Correct implementation of stellar aberration
  - Correct weighting for strong and weak axes of the star tracker
  - Detailed modeling of star tracker and accelerometer noise
  - SCA1B output at 1 Hz instead of 0.2 Hz (V02)
- Initial assessment:
  - High frequency V03 SCA1B noise significantly reduced
  - Improved attitude reconstruction for single camera operations
  - No appreciable change in the gravity field

Preliminary results from V03 data





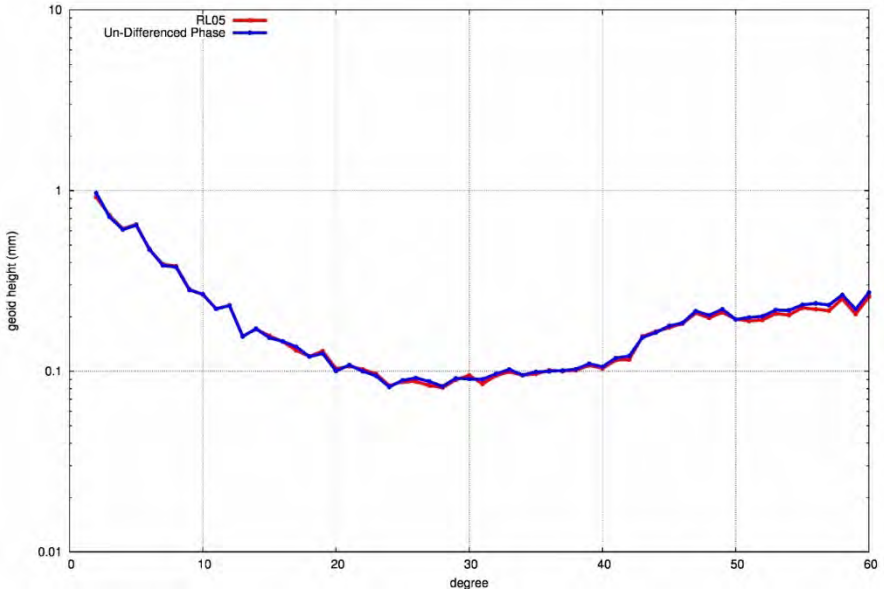
We see little or no difference in the gravity field

Double Difference v/s Un-differenced Phase

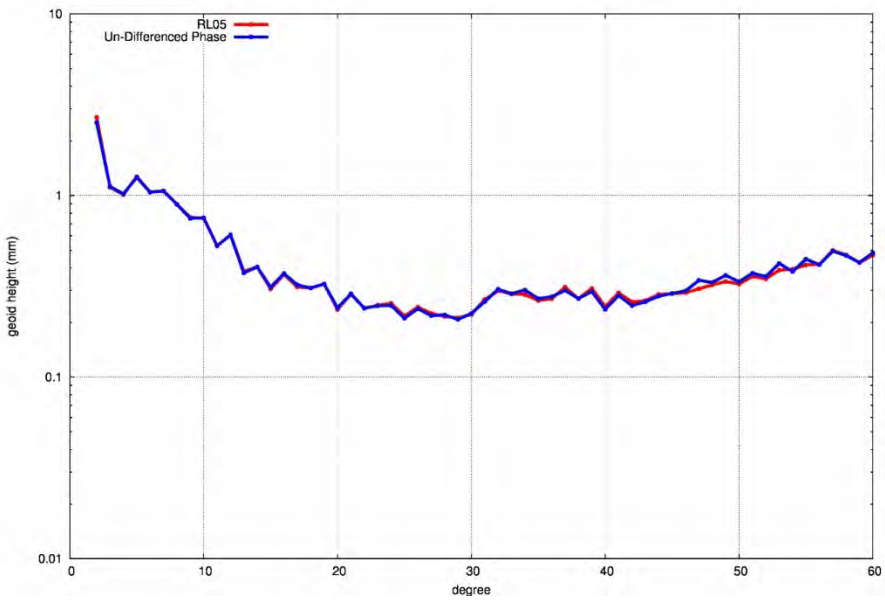
- CSR RL05 used double difference technique for handling the GPS data
  - Dependence on the IGS ground network
  - Required monitoring of the IGS ground station data quality
  - Required changes in L2 processing because of changes in the IGS core network due to reprocessing
- CSR RL06 will use un-differenced phase processing for handling the GPS data
  - In the gross, statistical sense, there is no difference between using the two obs-types
  - Improvement in the robustness due to less dependence on the ground segment
  - We will be looking closer at this to see if there are any other subtle differences.
- No change in the quality of the final L2 product because of this change

Double Difference v/s Un-differenced Phase

2008 – scatter w.r.t. GIF48



2015 - scatter w.r.t. GIF48



We do not expect a quality improvement in the final L2 product because of this change