Low-degree gravity field coefficients from SLR data using the Bernese GNSS Software

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Overview

- Set-up for SLR solutions
- Quality of the solutions (station coordinates, ERPs):
  - Impact of estimating higher-degree terms on the other parameters
- Degree-1 / Geocenter
- Degree-2 coefficients:
  - Comparison with DGFI series
  - Comparison with CSR series
- Degree-3 coefficients:
  - Comparison with GRACE series
- Conclusions

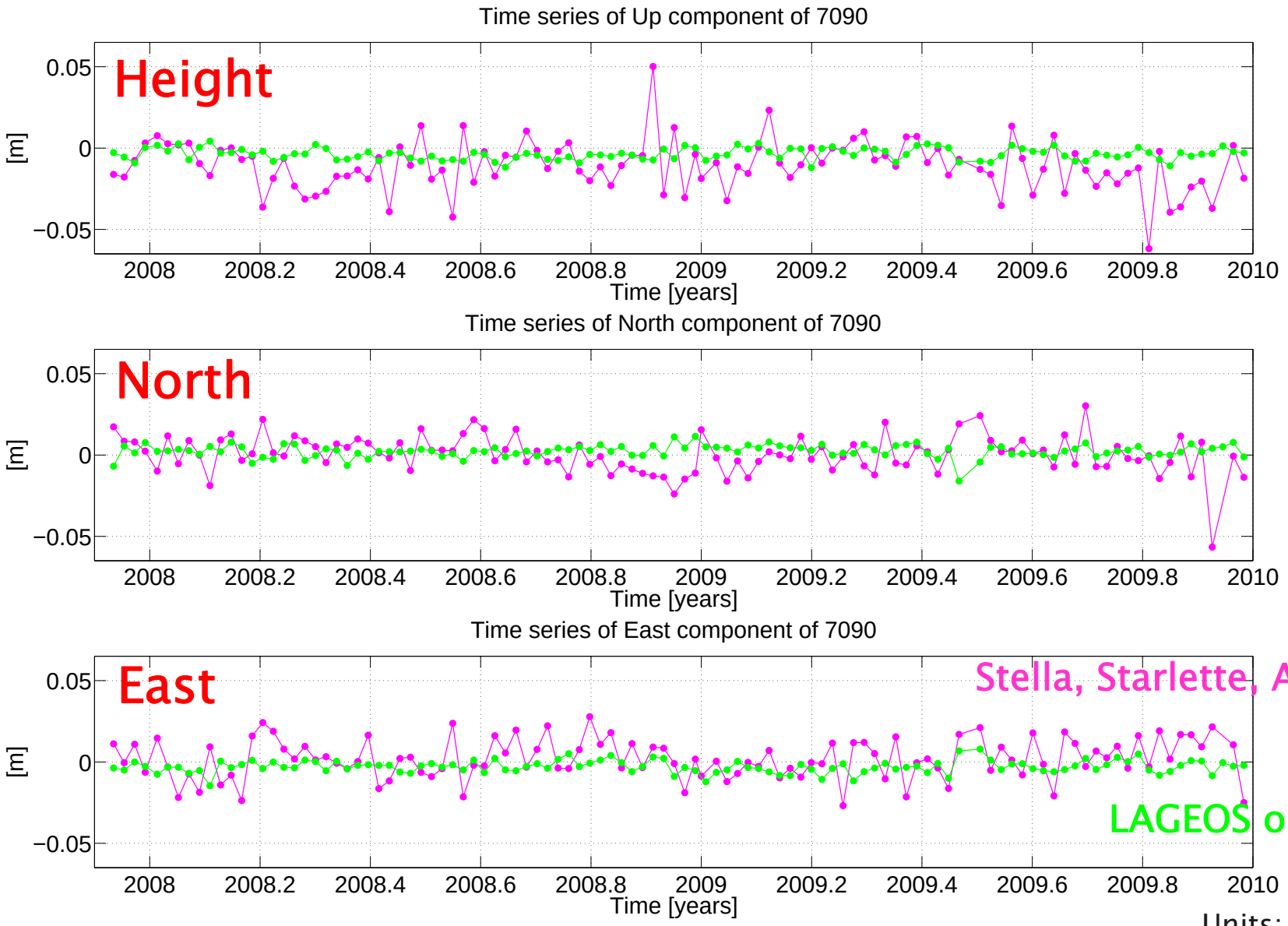
Solution set-up

- *Bernese GNSS Software* (+ SLR developments)
- IERS2010 Conventions
- SLRF2008 reference frame
- Weekly solutions
- Satellites used: LAGEOS-1 / -2
- Time span 2000.0 – 2012.0: 12 years, 626 weeks
- Parameters estimated:
  - Station coordinates
  - Earth Rotation Parameters
  - Satellite orbits (7-day arcs; S0, S_cos/S_sin)
  - Range biases (selected sites)
  - Gravity field coefficients of d/o 1, 2, and 3

Starlette / Stella / Ajisai

- Lower spherical satellites are more sensitive
- Similar modeling as for LAGEOS solutions
- Air drag model: MSIS-90 (scaling factor not estimated)
- Parameters estimated:
  - Station coordinates
  - Earth Rotation Parameters
  - Satellite orbits (7-day arcs, daily empirical parameters, stochastic pulses every revolution period)
  - Range biases (all sites)
  - Gravity field coefficients up to d/o 3
- First results for 2008 – 2009

Time series of station coordinates (Yarragadee)



Units: m

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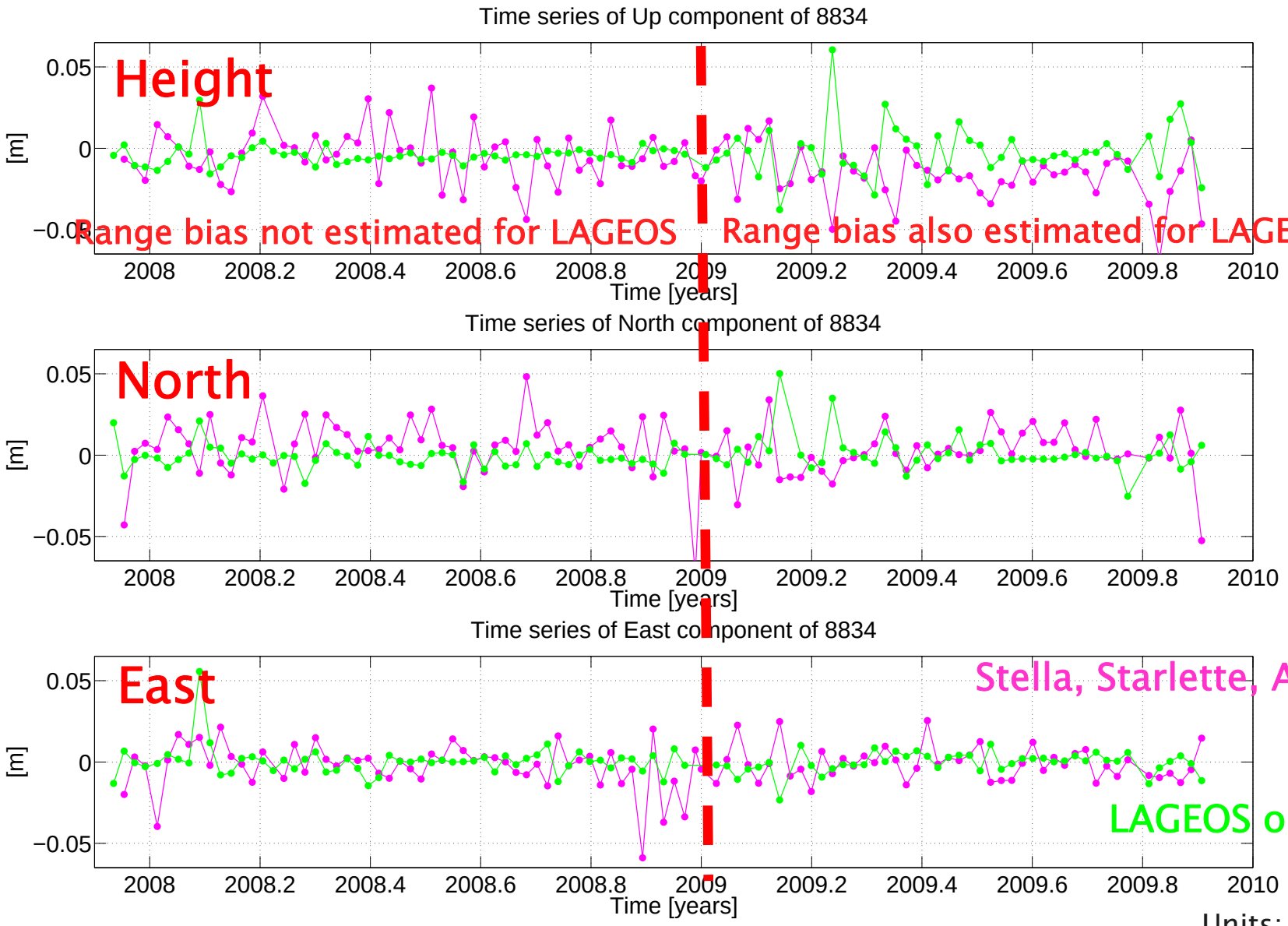
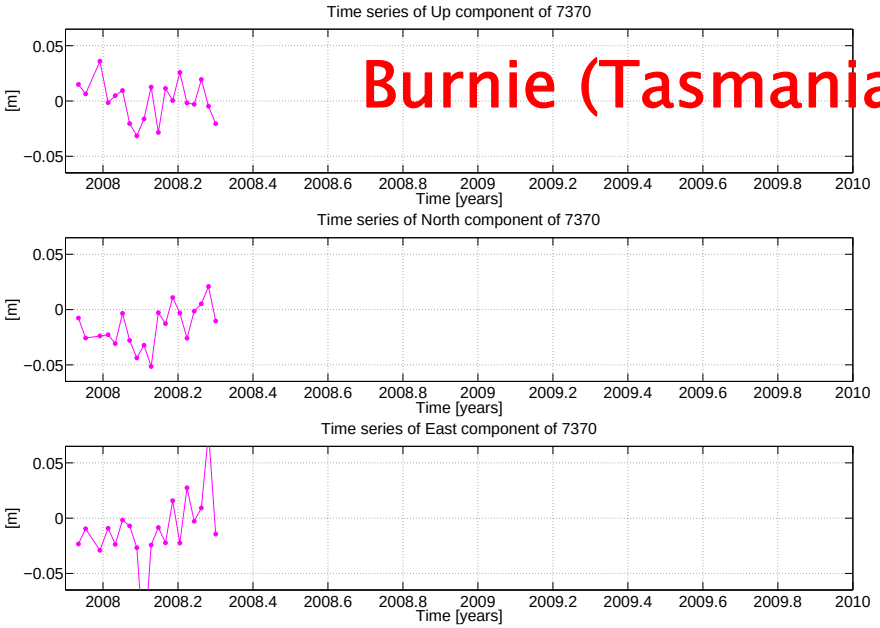
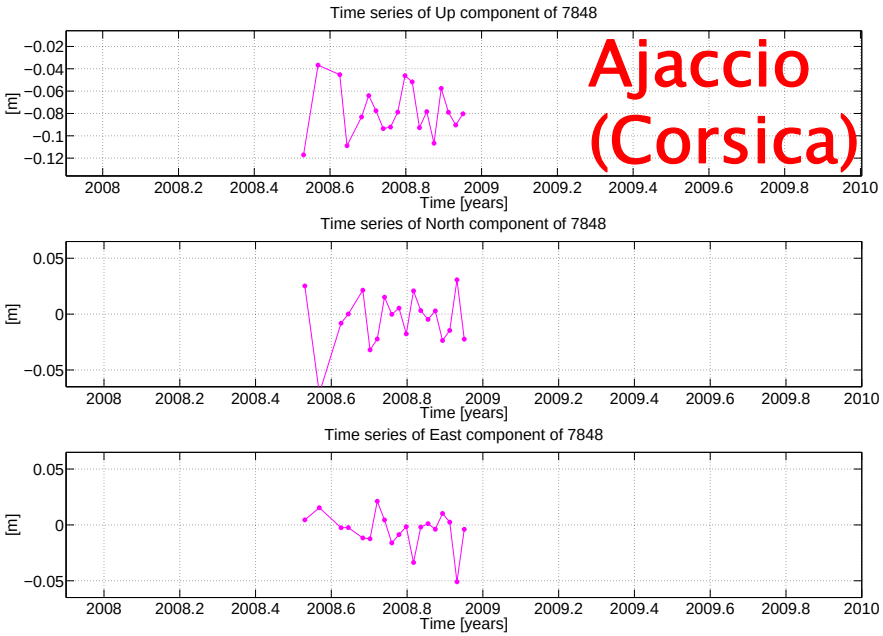
Time series of station coordinates (Wettzell)



Time series of station coordinates (FTLRS)





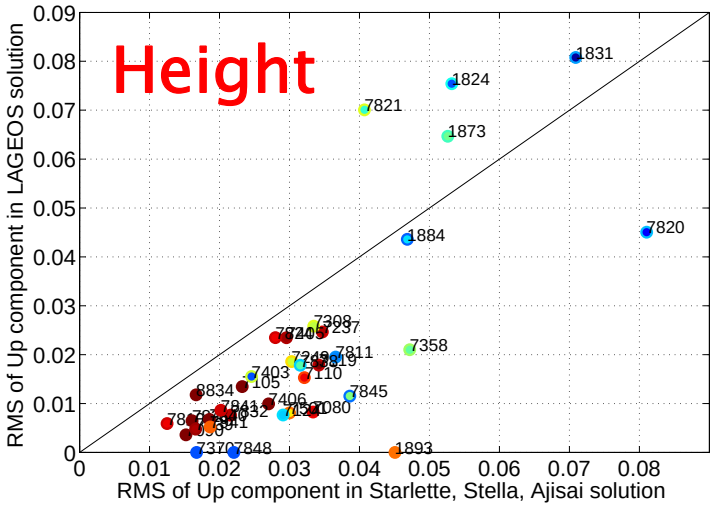
The French Transportable Laser Ranging Station (FTLRS)

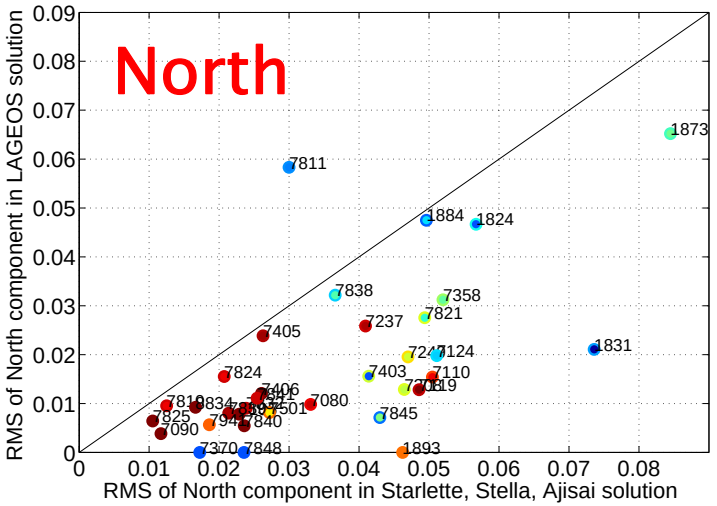
Stella, Starlette, Ajisai solution only

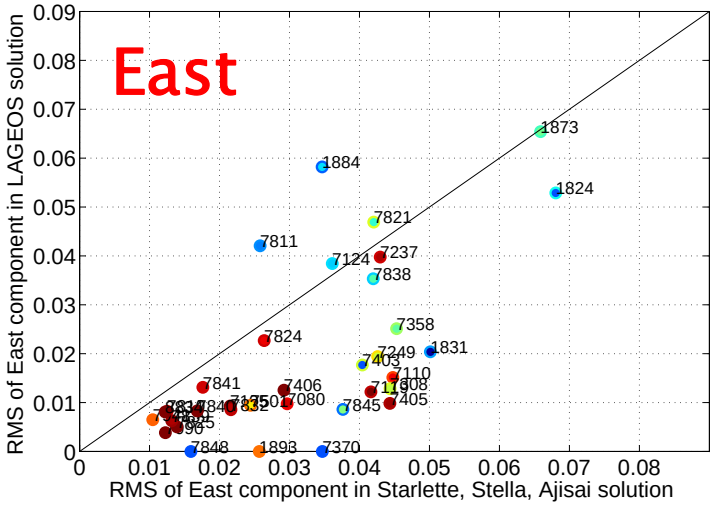
No LAGEOS solution

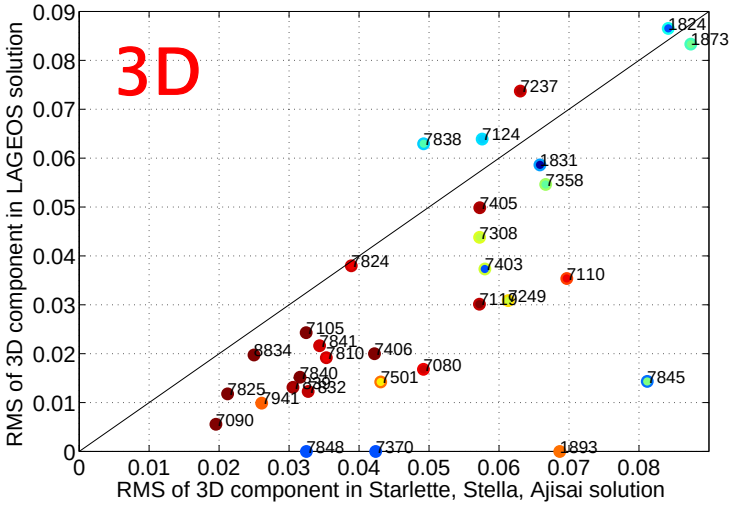
Repeatability of station coordinates

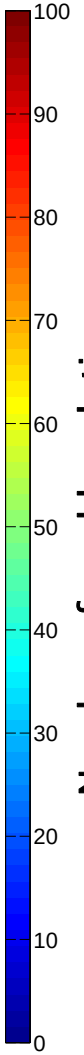
LAGEOS-only solution







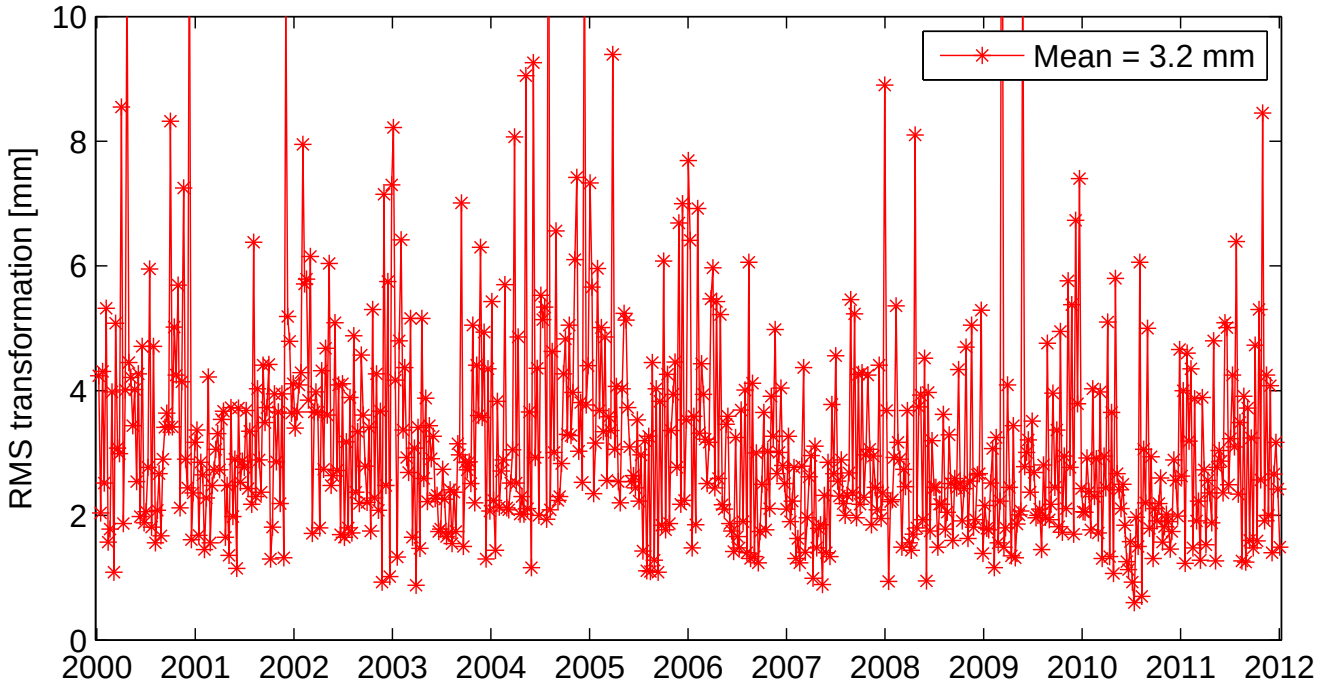




Stella-Starlette-Ajisai solution

Units: m

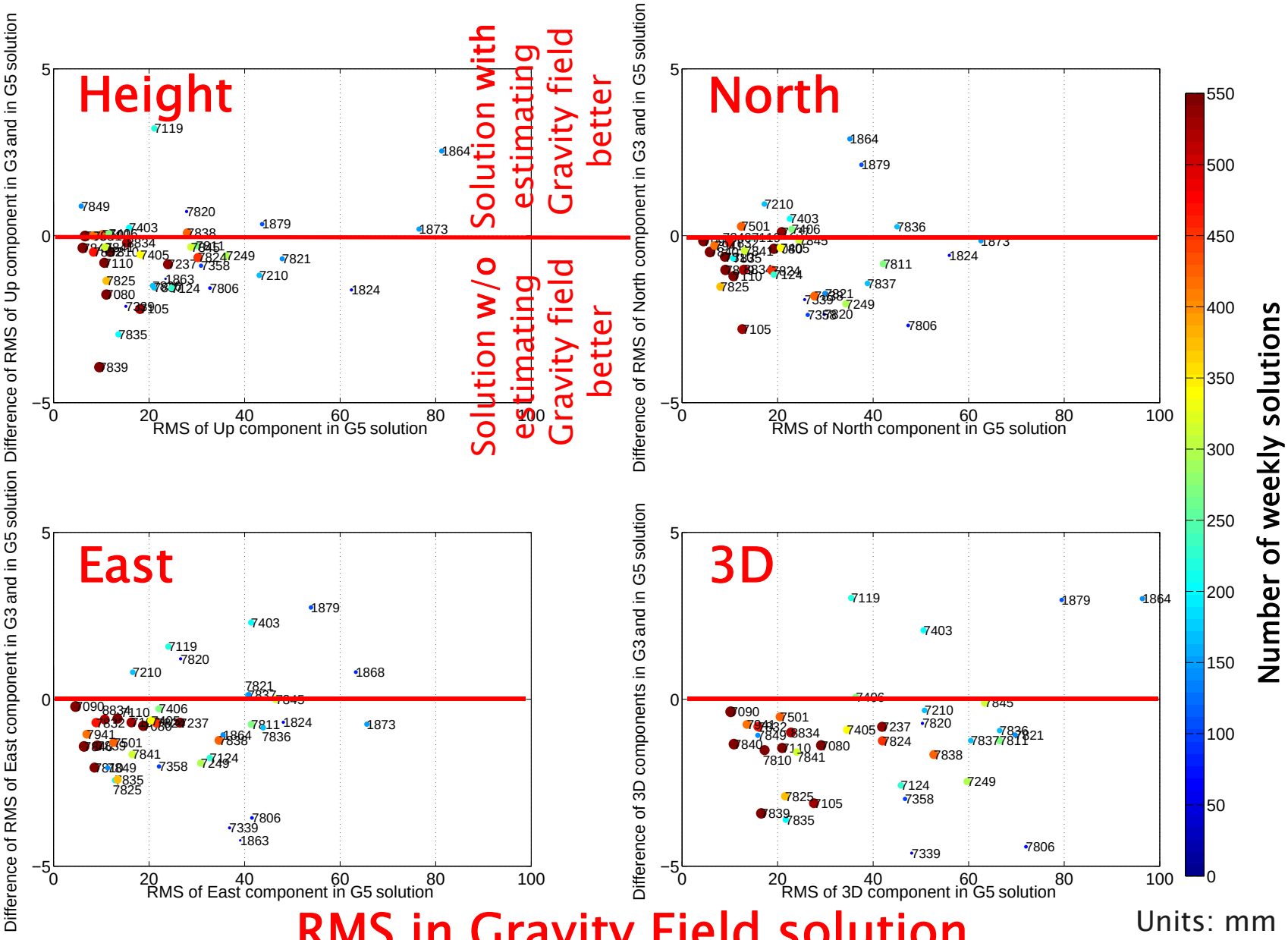
Impact on other parameters: Coordinates



- Impact of estimating higher degree terms is a few mm
- Scale differences < 0.3 ppb
- Translations: TX < 0.5 mm
  TY < 0.2 mm
  TZ < 1.0 mm

Impact on other parameters: Repeatability

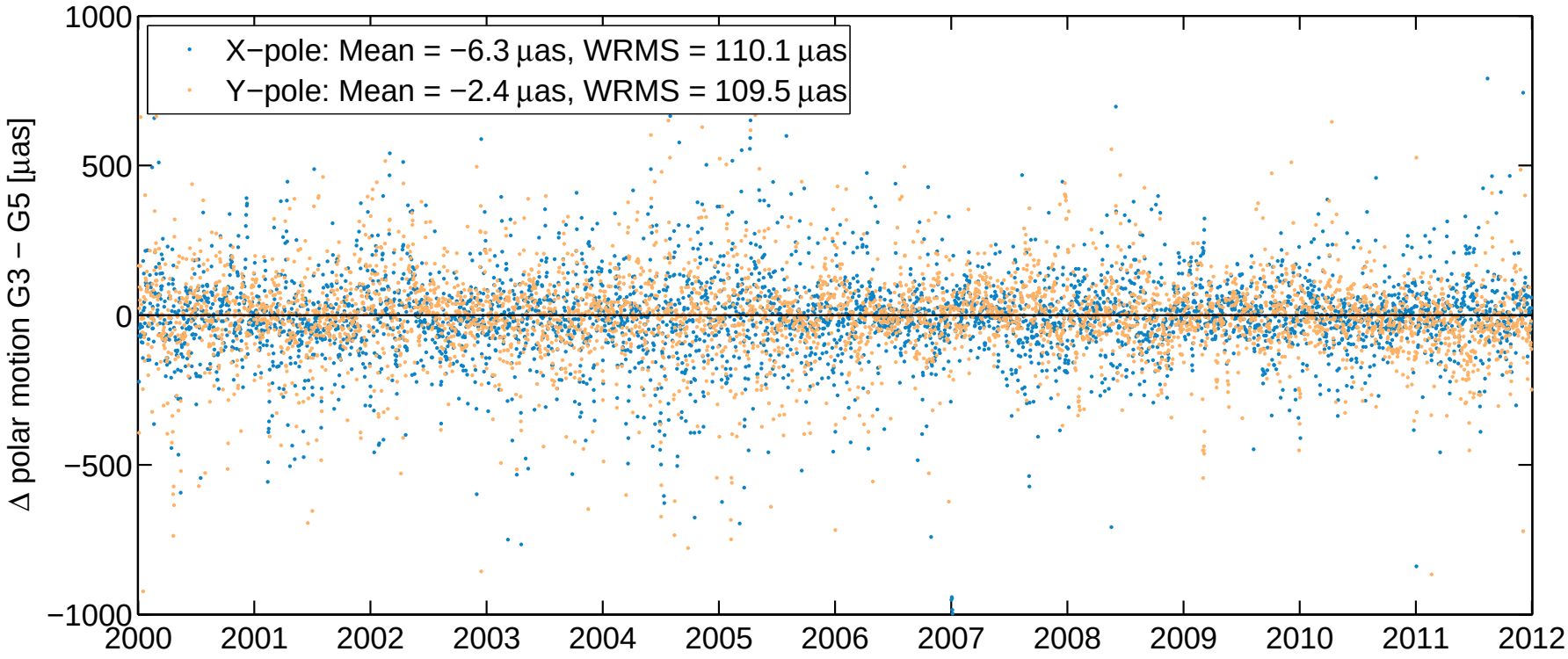
ΔRMS w/ vs. w/o Gravity Field



RMS in Gravity Field solution

Units: mm

Impact on other parameters: ERP



Impact of degree-2/-3 terms on polar motion: ~100 µas

Comparison with IERS-08-C04: No clearly preferred solution

	Mean XP	WRMS XP	Mean YP	WRMS YP
G3 (deg. 1)	40.8	167.9	-17.8	164.7
G5 (deg. 1-3)	33.9	203.1	-20.7	188.6

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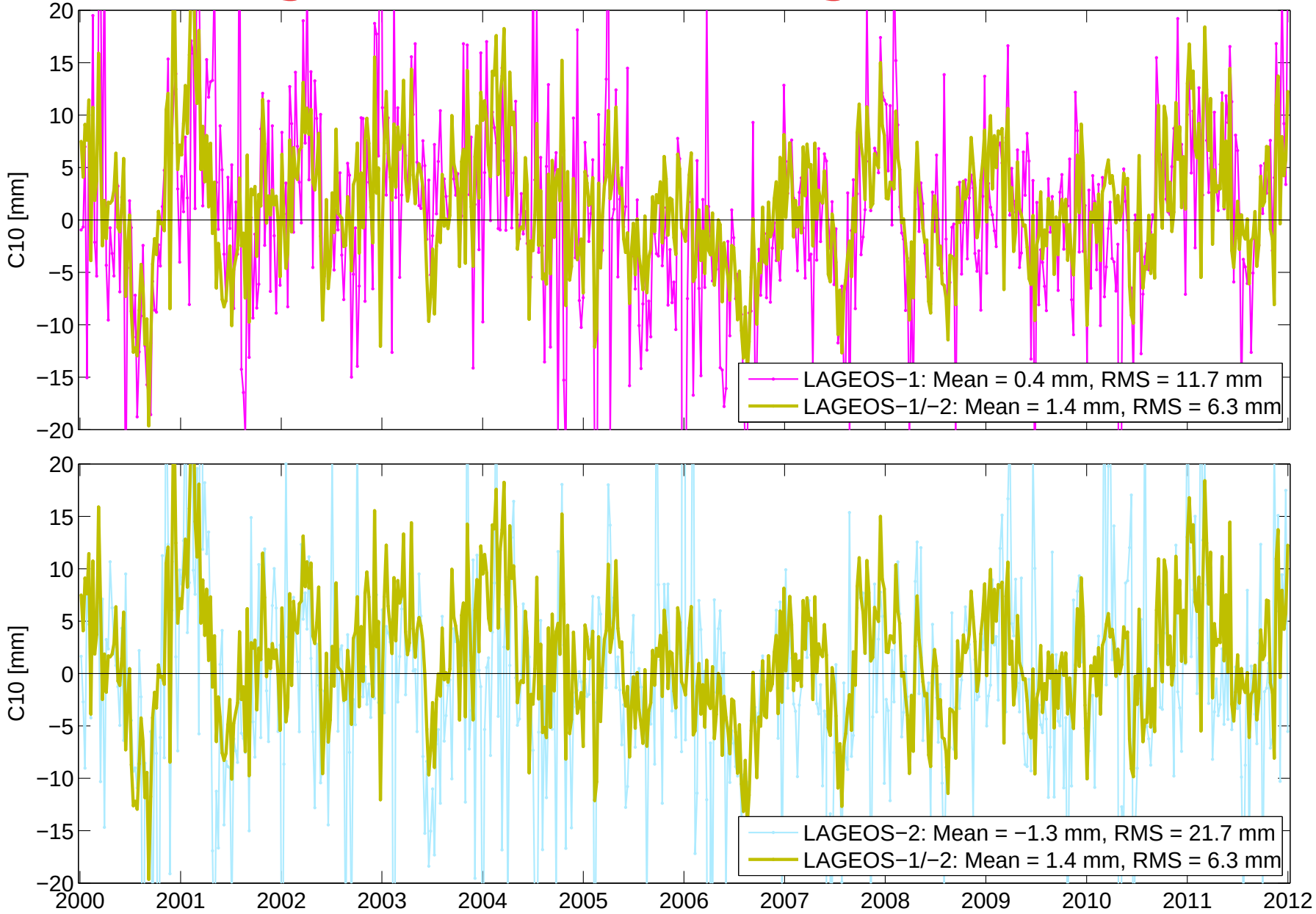
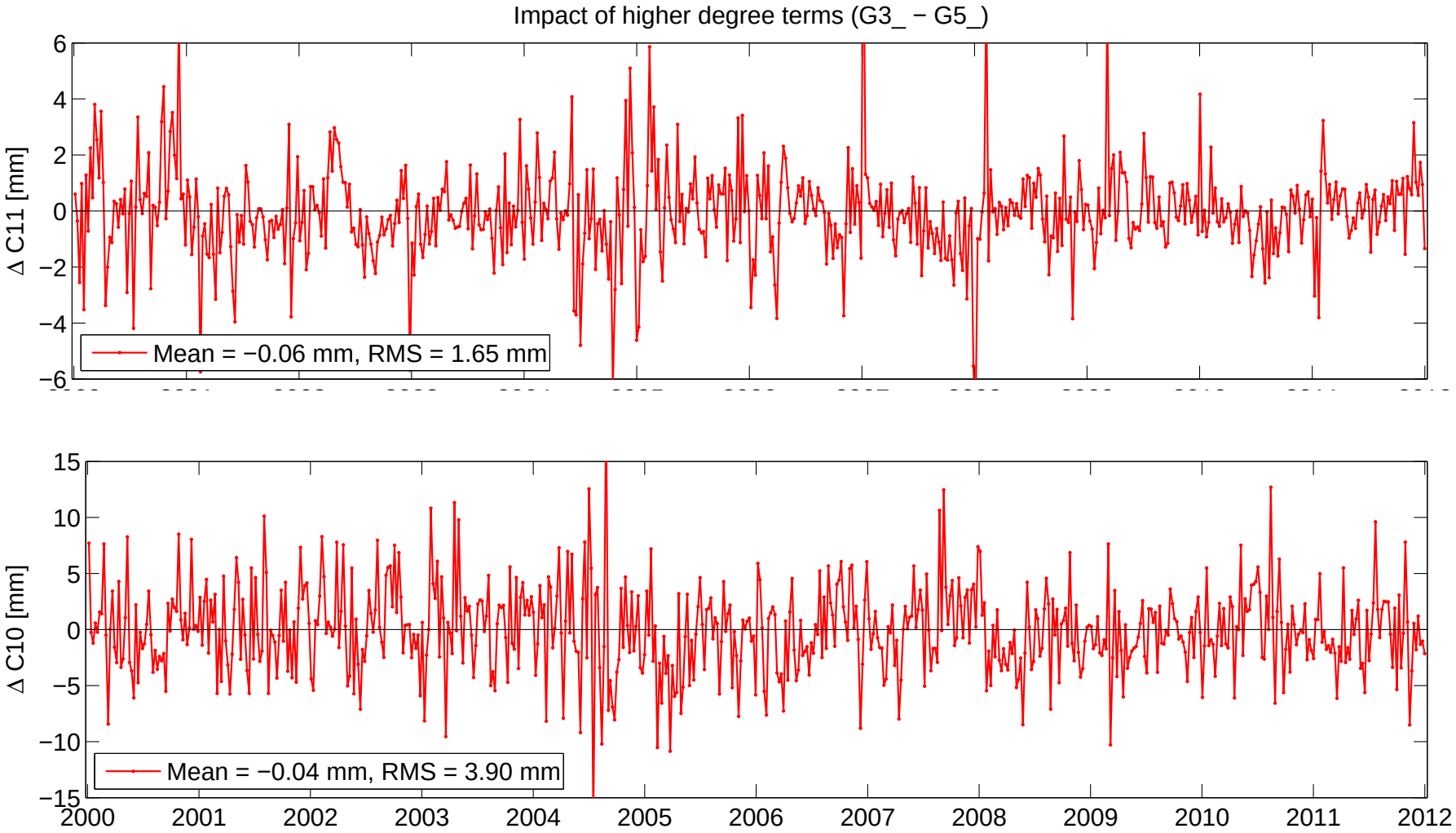
Degree-1 coefficients (geocenter)

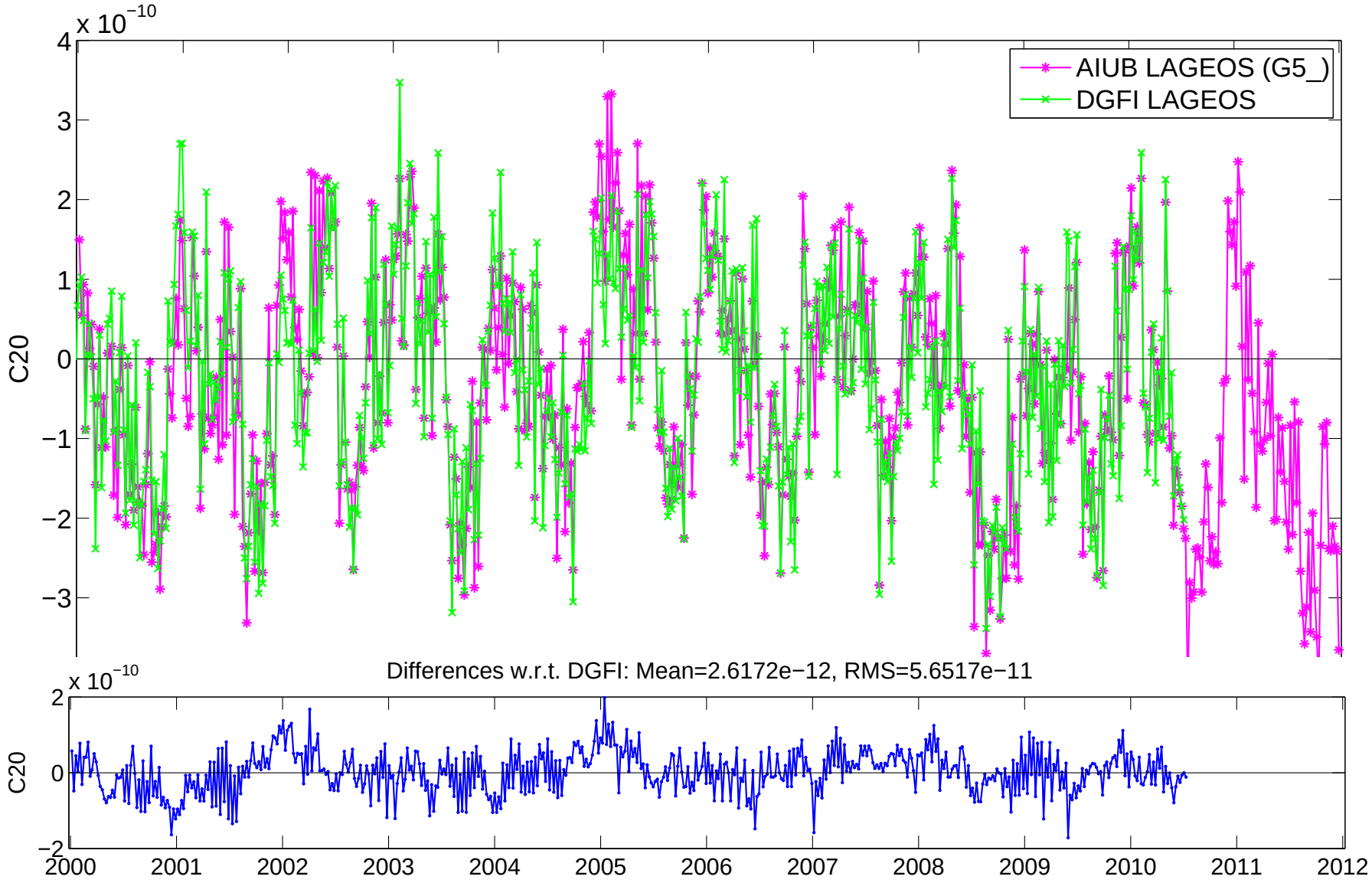


Degree-1 coefficients (geocenter)

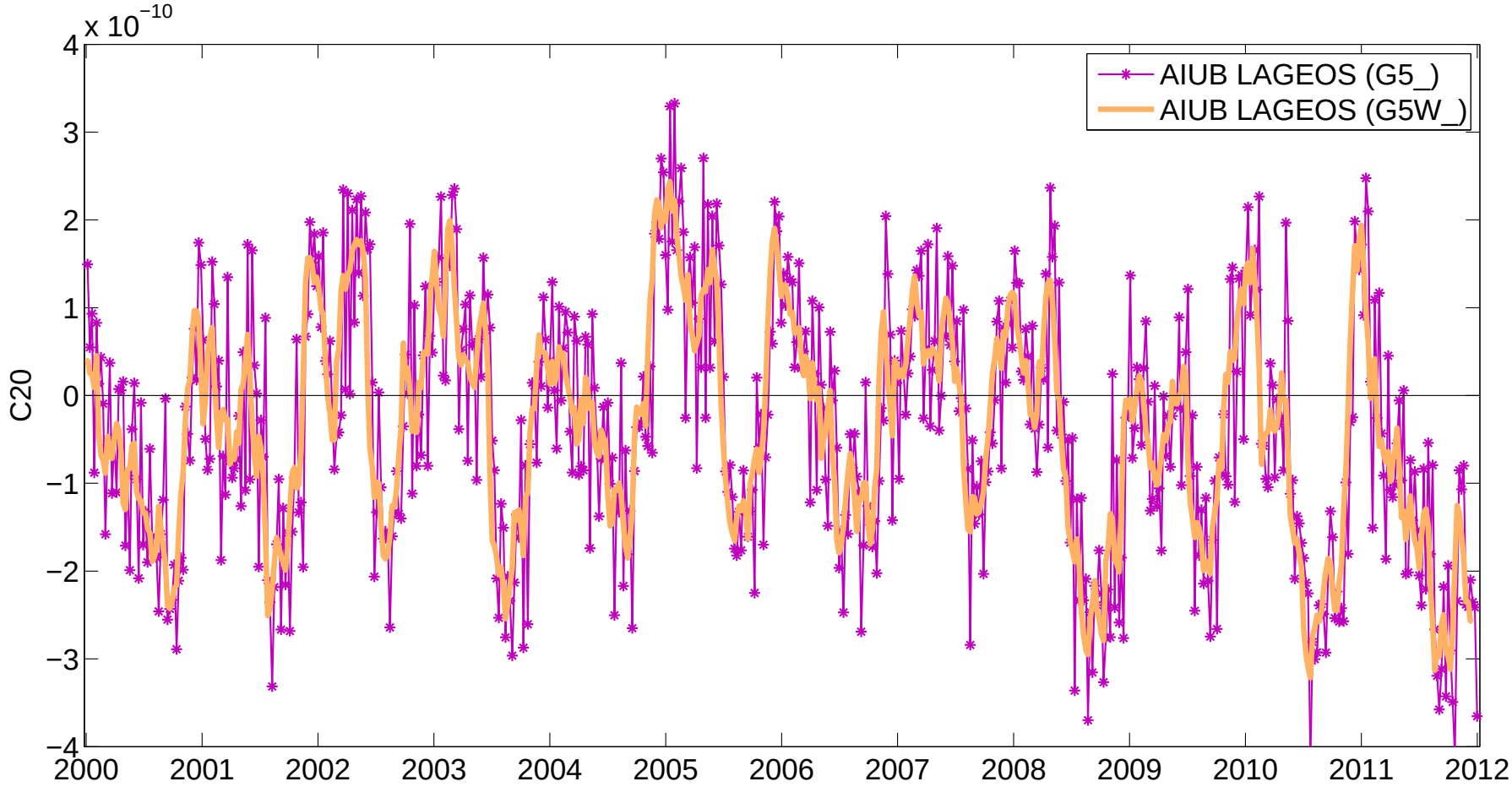


- Impact of estimating higher degree terms is a few mm

Coefficient C20: AIUB vs.DGFI

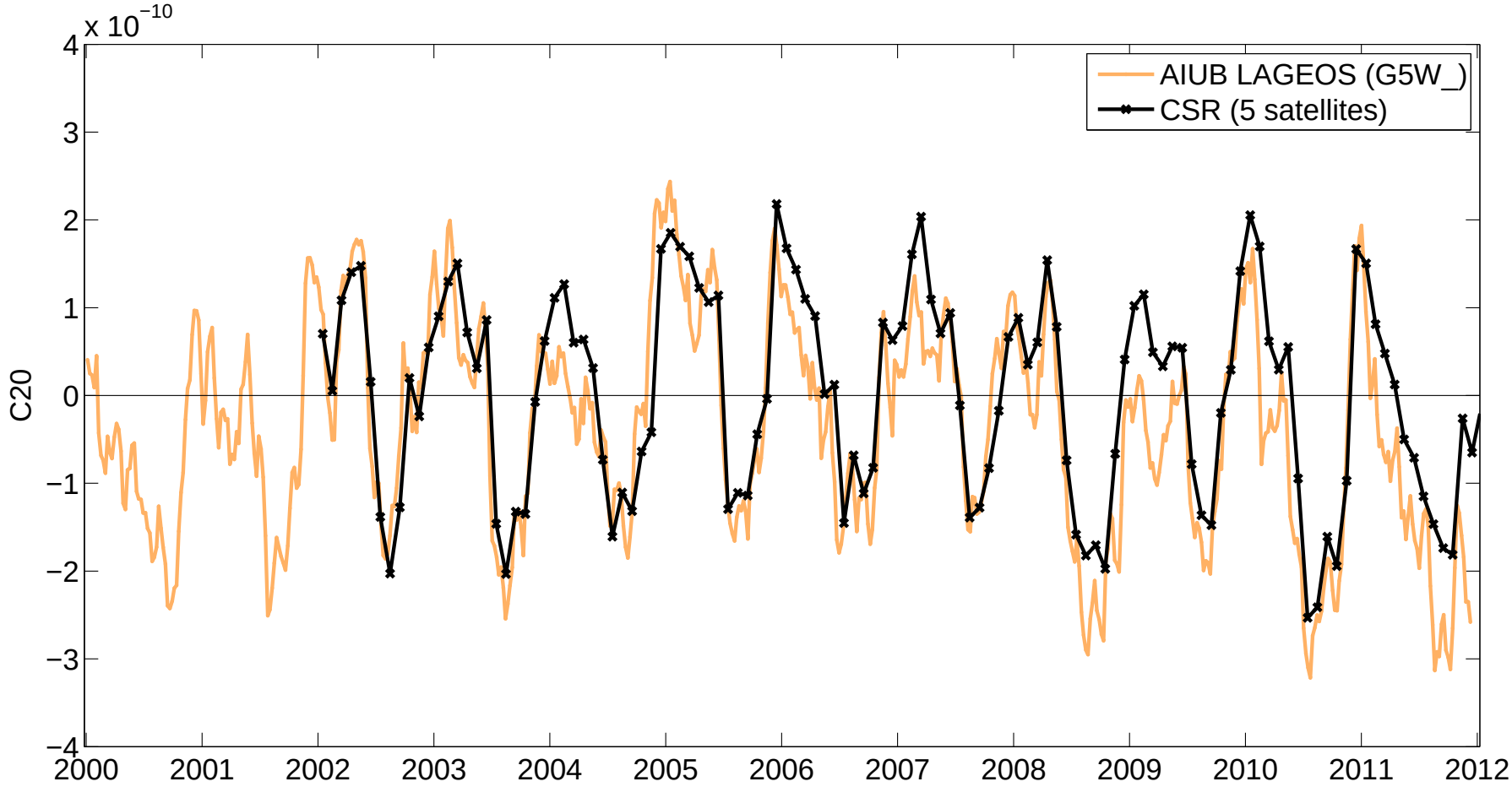


Coefficient C20: Weekly vs. monthly



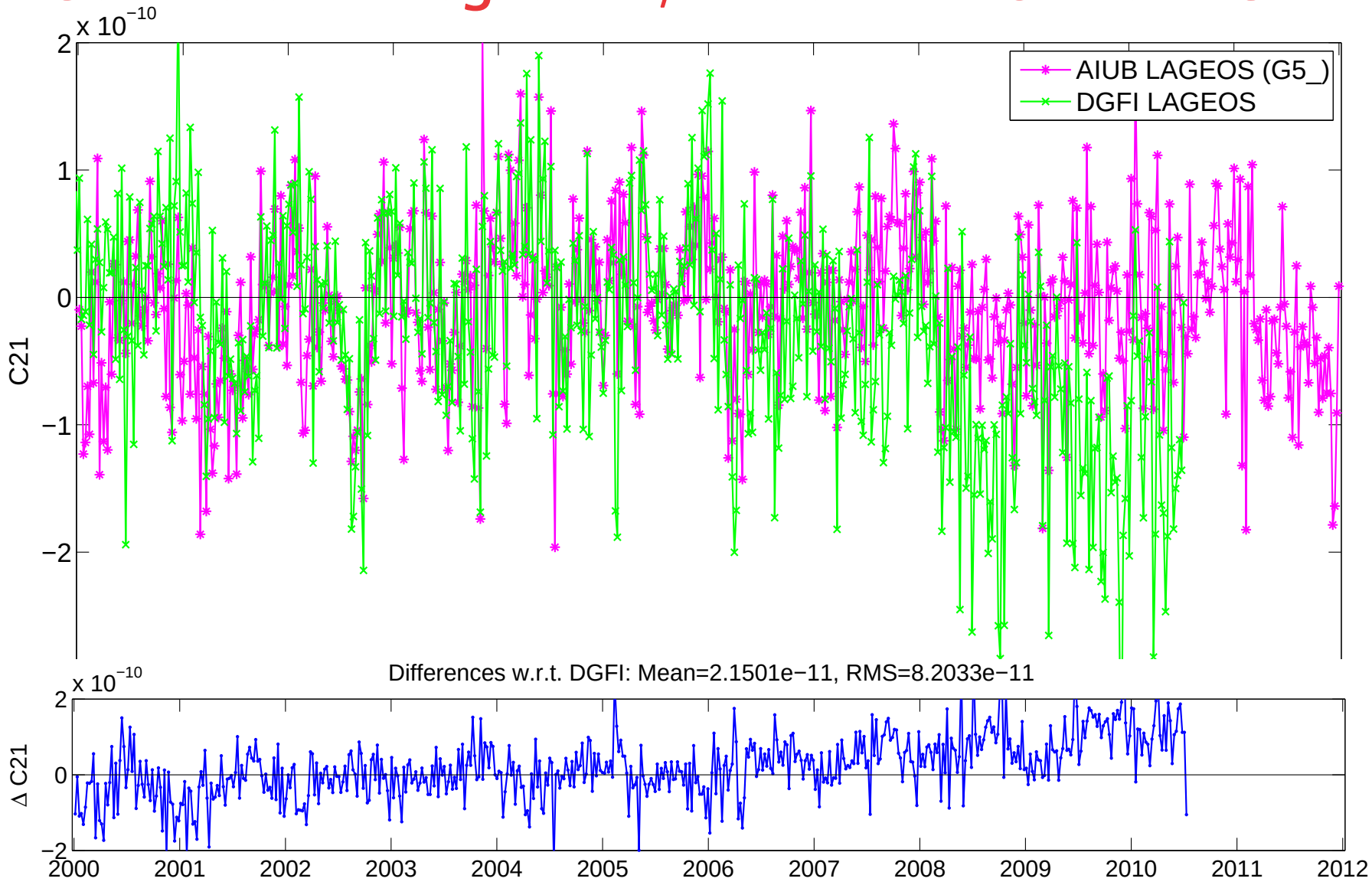
- «Monthly» series (4 weeks accumulated), shift by 1 week
- Orbits are kept as weekly arcs

Coefficient C20: AIUB vs. CSR

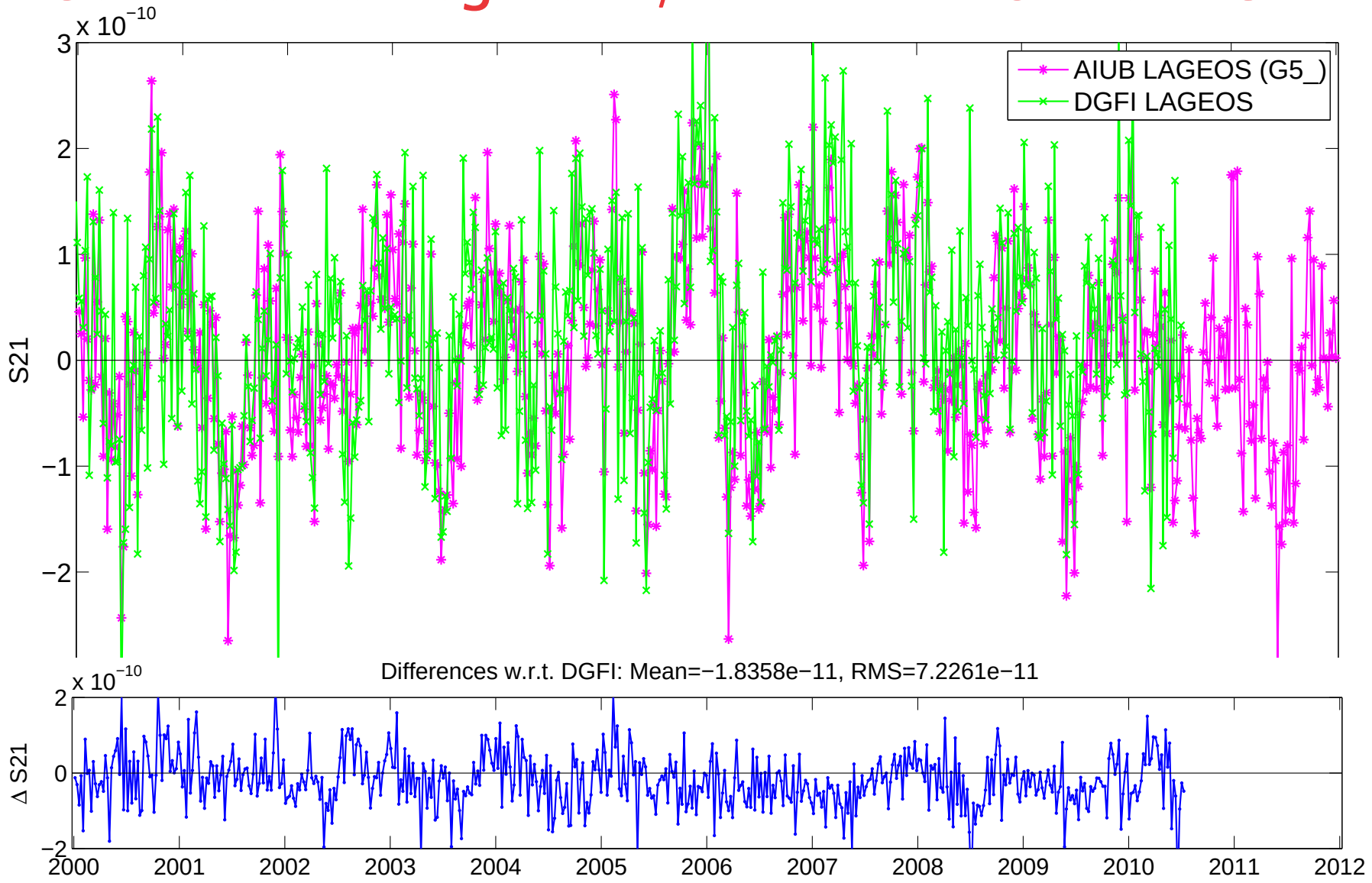


- Comparison with CSR **monthly** series:
- **5 satellites**: LAG-1, LAG-2, Stella, Starlette, Ajisai

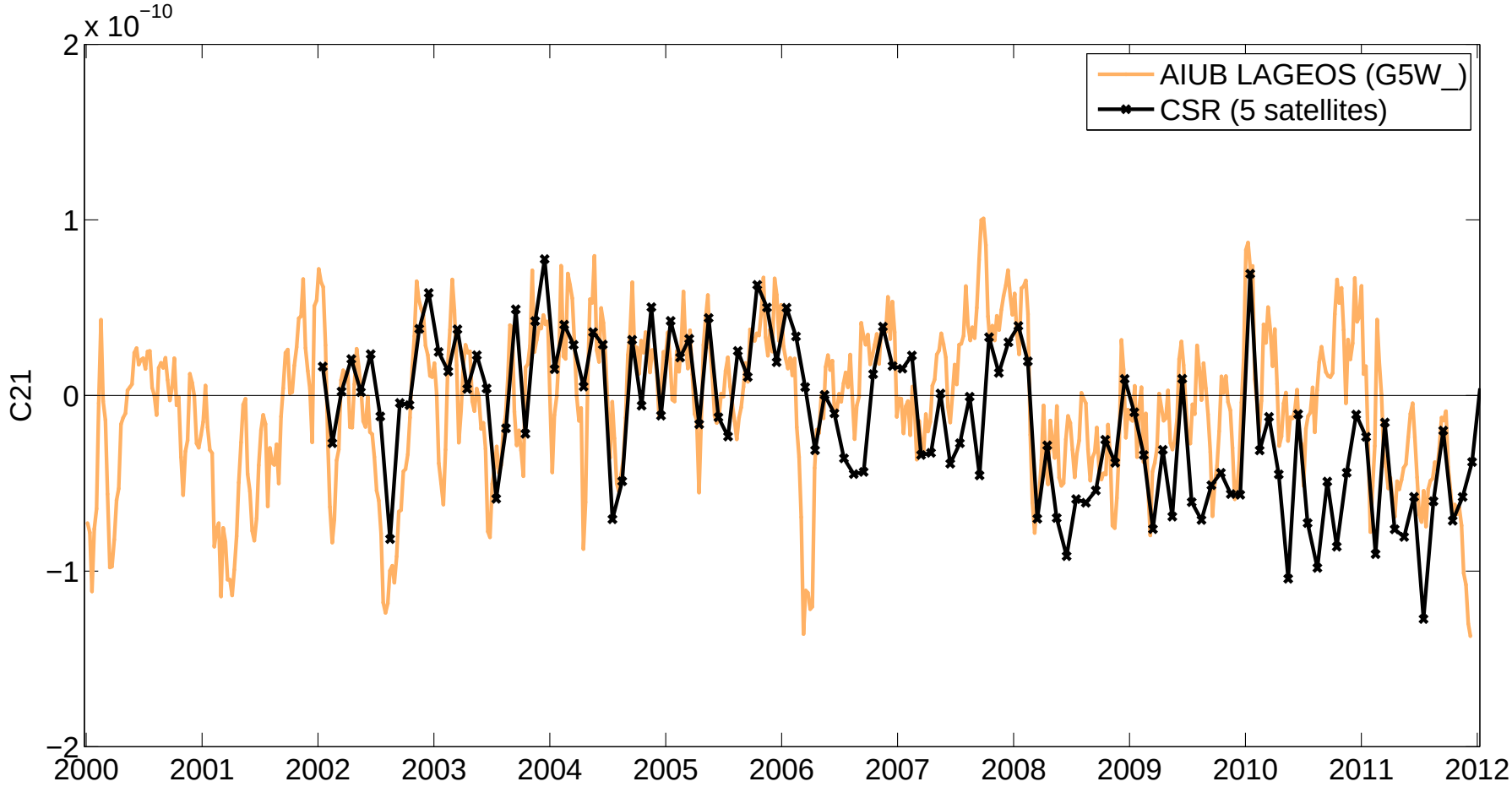
Coefficients degree 2 / order 1: AIUB vs. DGFI



Coefficients degree 2 / order 1: AIUB vs. DGFI

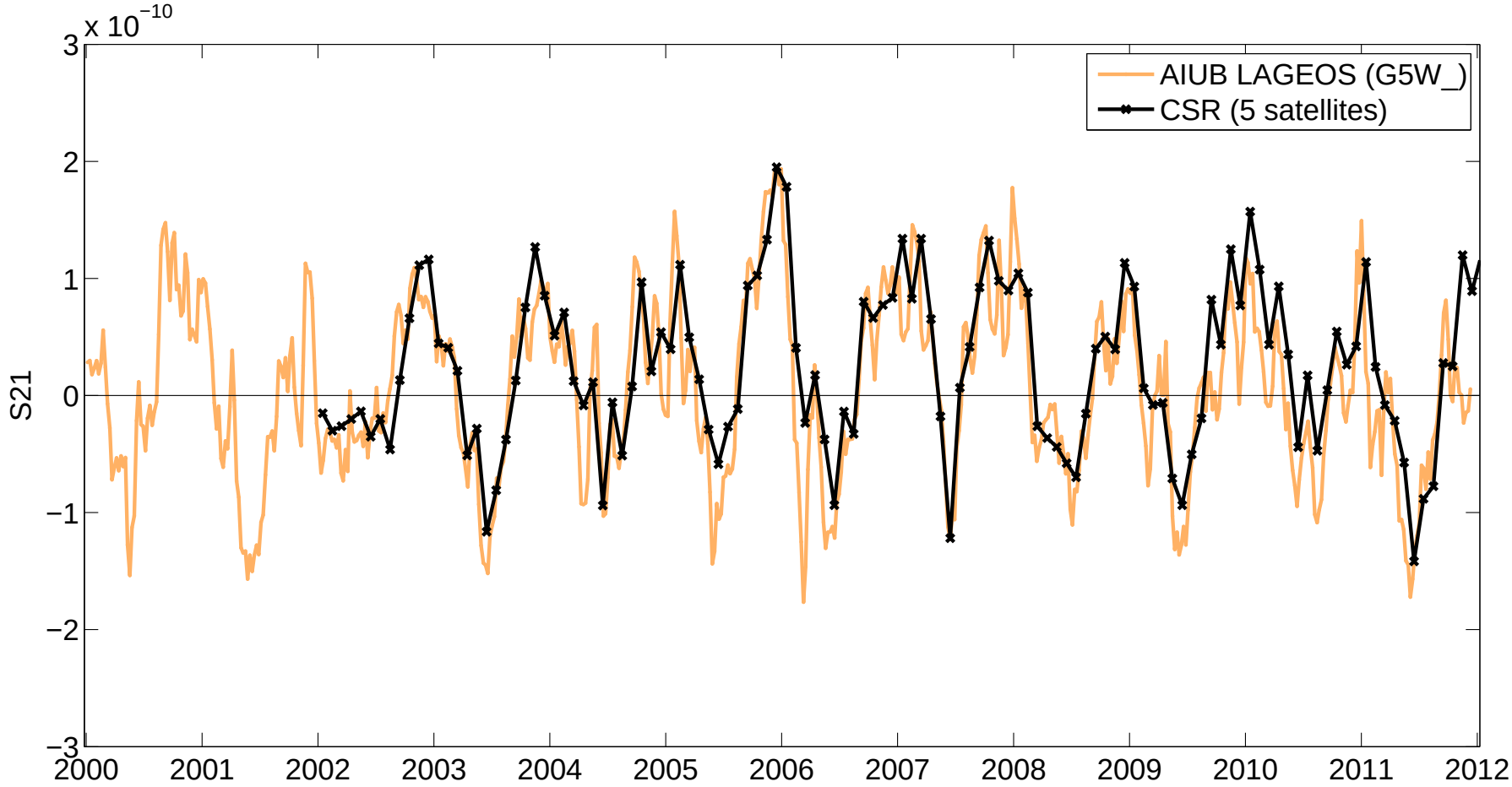


Coefficients degree 2 / order 1: Monthly



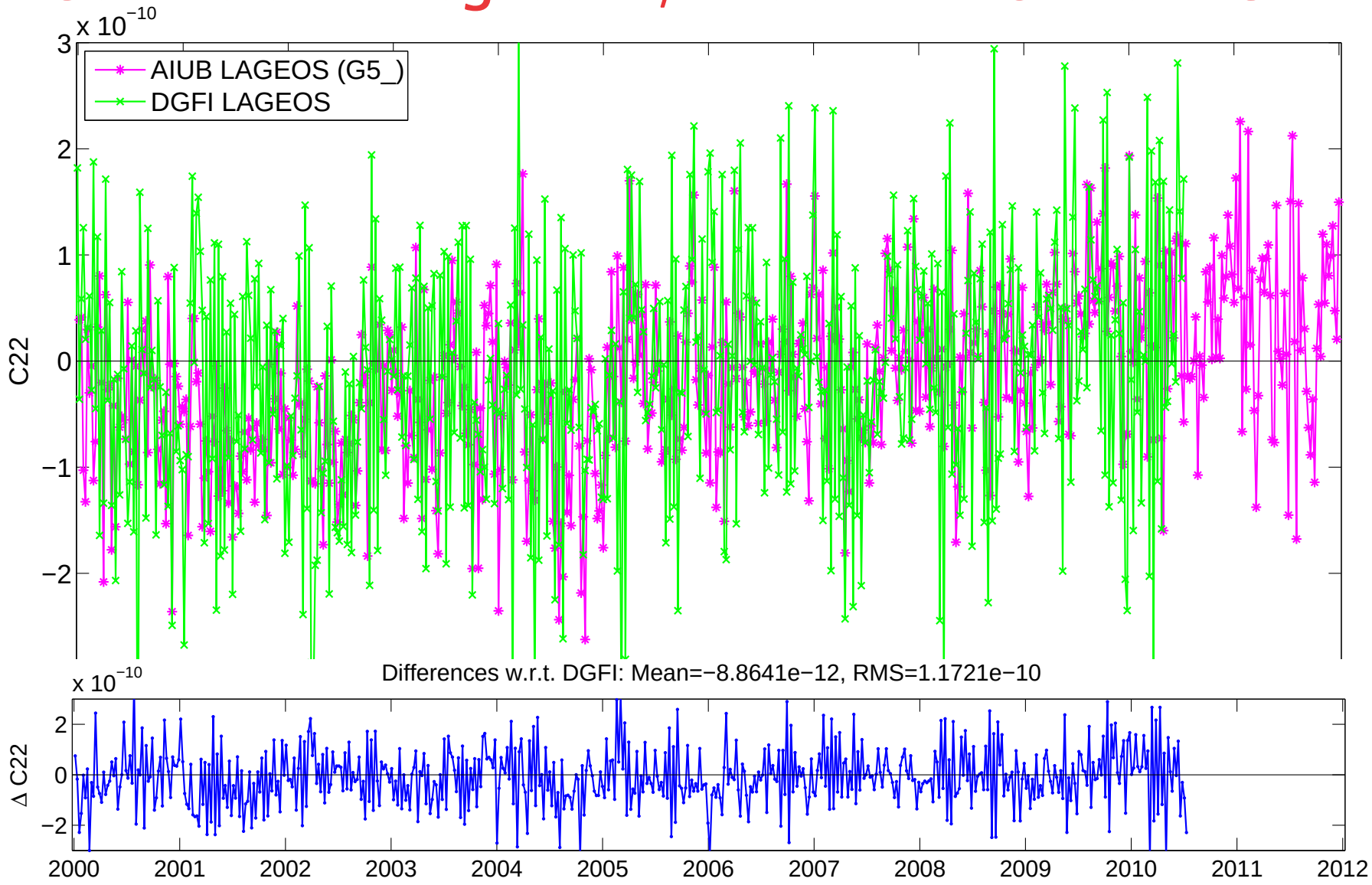
- Short-period variations agree well

Coefficients degree 2 / order 1: Monthly

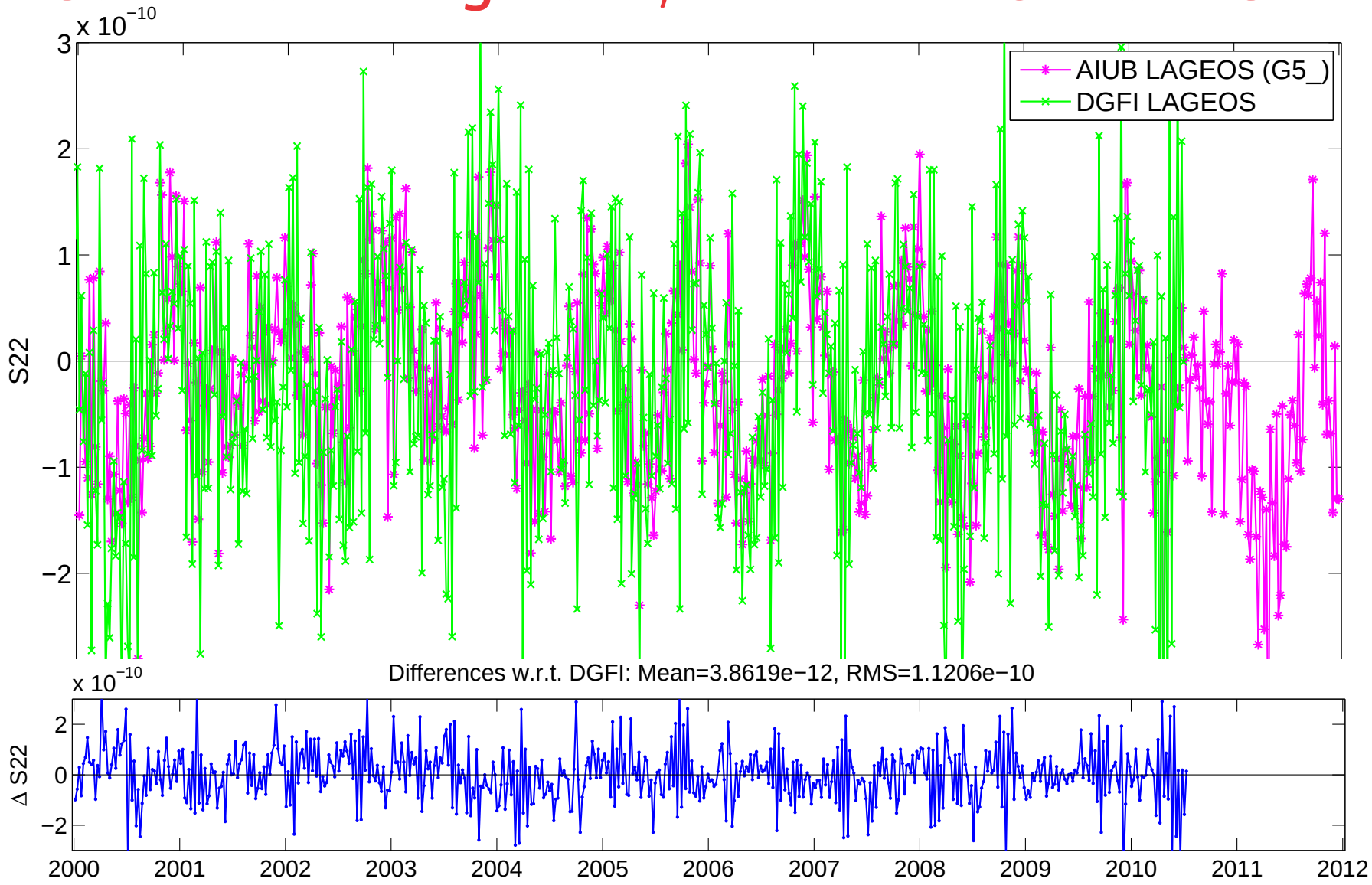


- Annual signal agrees well between both series
- Short variations traceable only with weekly resolution (AIUB)

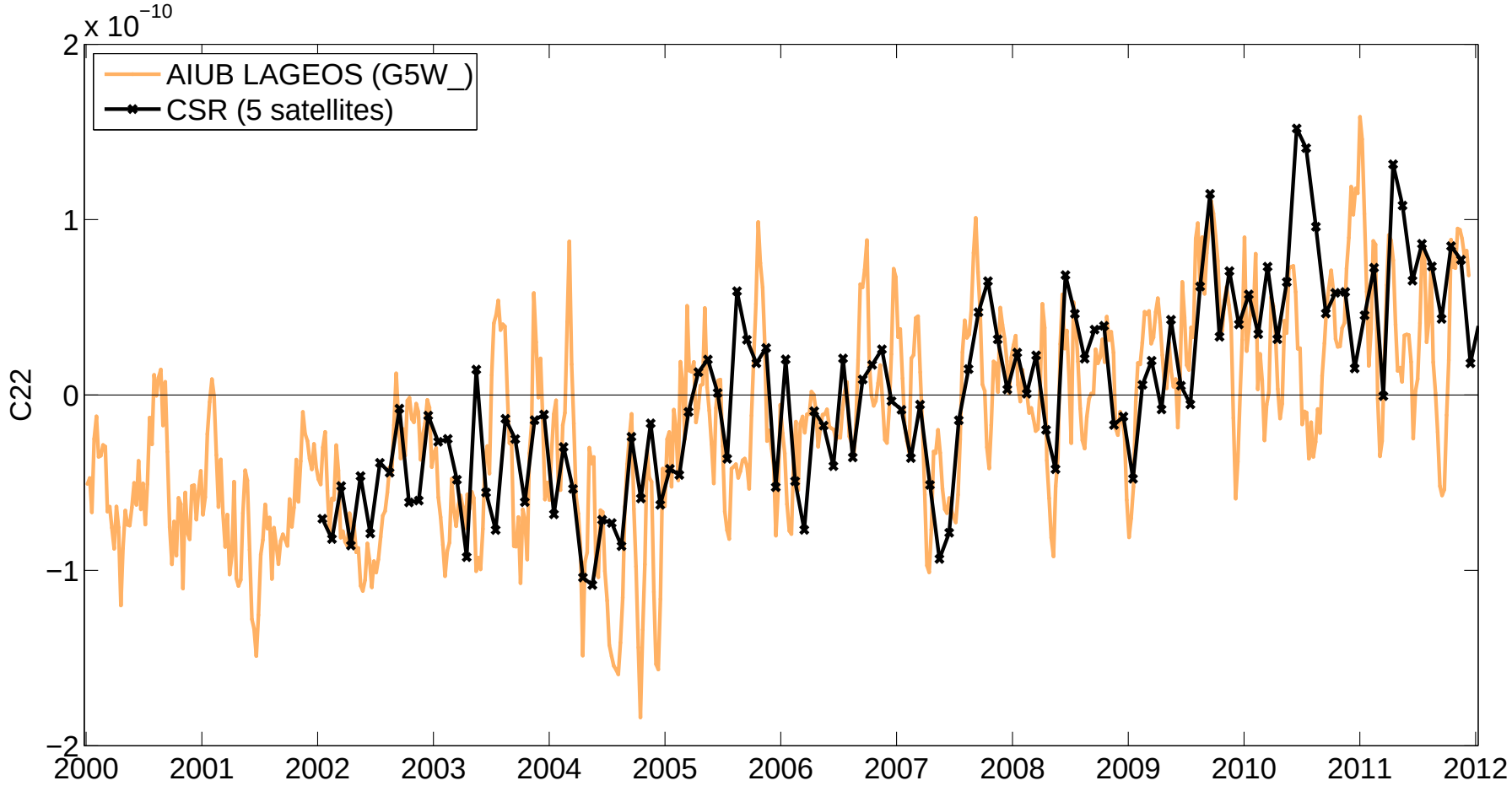
Coefficients degree 2 / order 2: AIUB vs. DGFI



Coefficients degree 2 / order 2: AIUB vs. DGFI

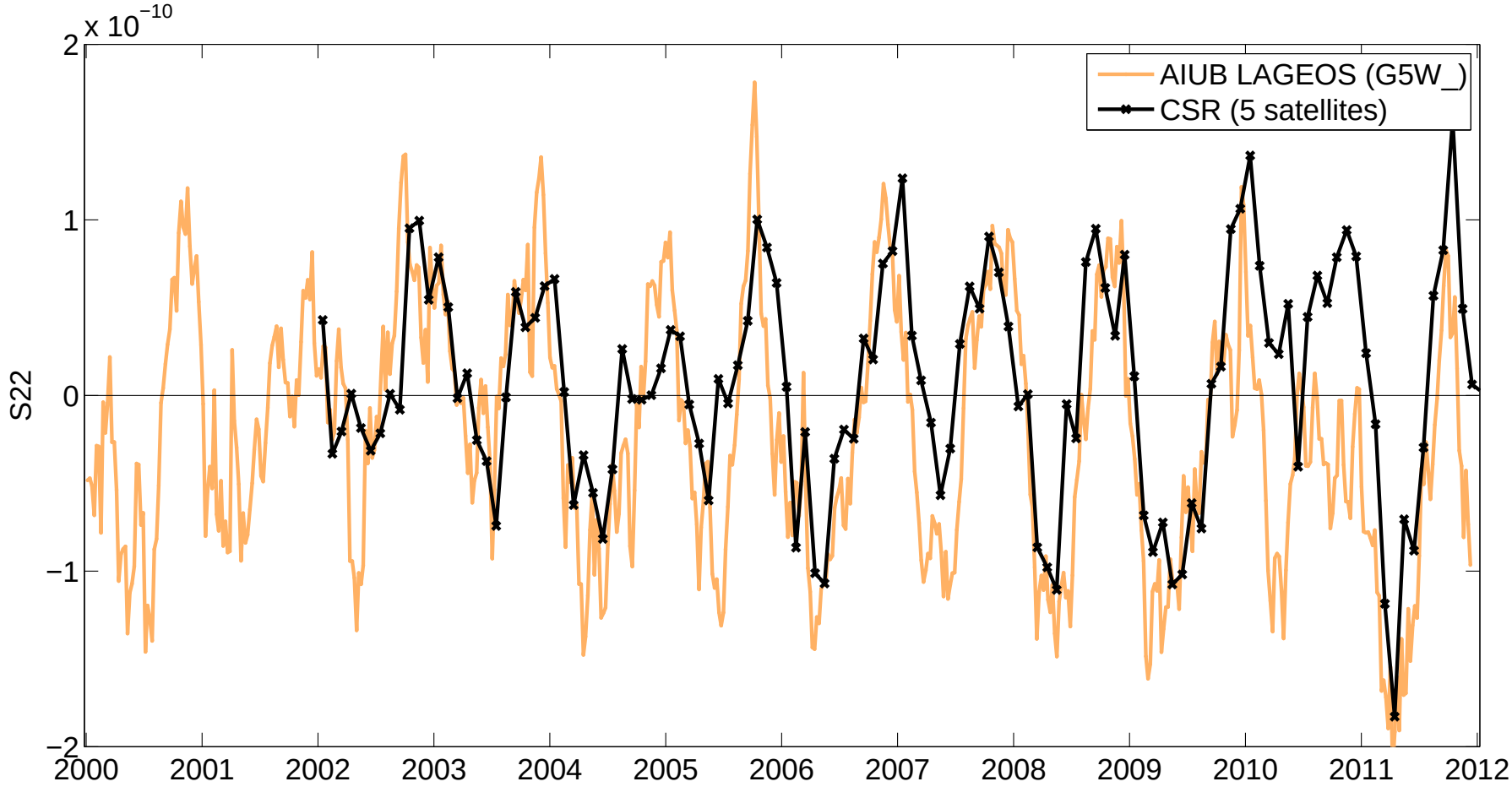


Coefficients degree 2 / order 2: Monthly



- Similar trend in both series visible
- Short-period variations agree well

Coefficients degree 2 / order 2: Monthly

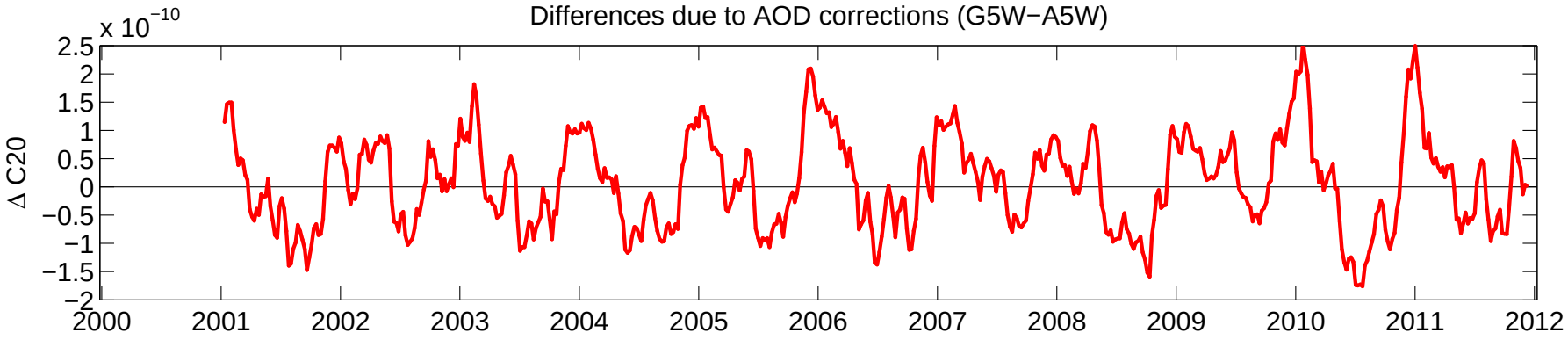


- Annual signal agrees well between both series
- Short variations traceable only with weekly resolution (AIUB)

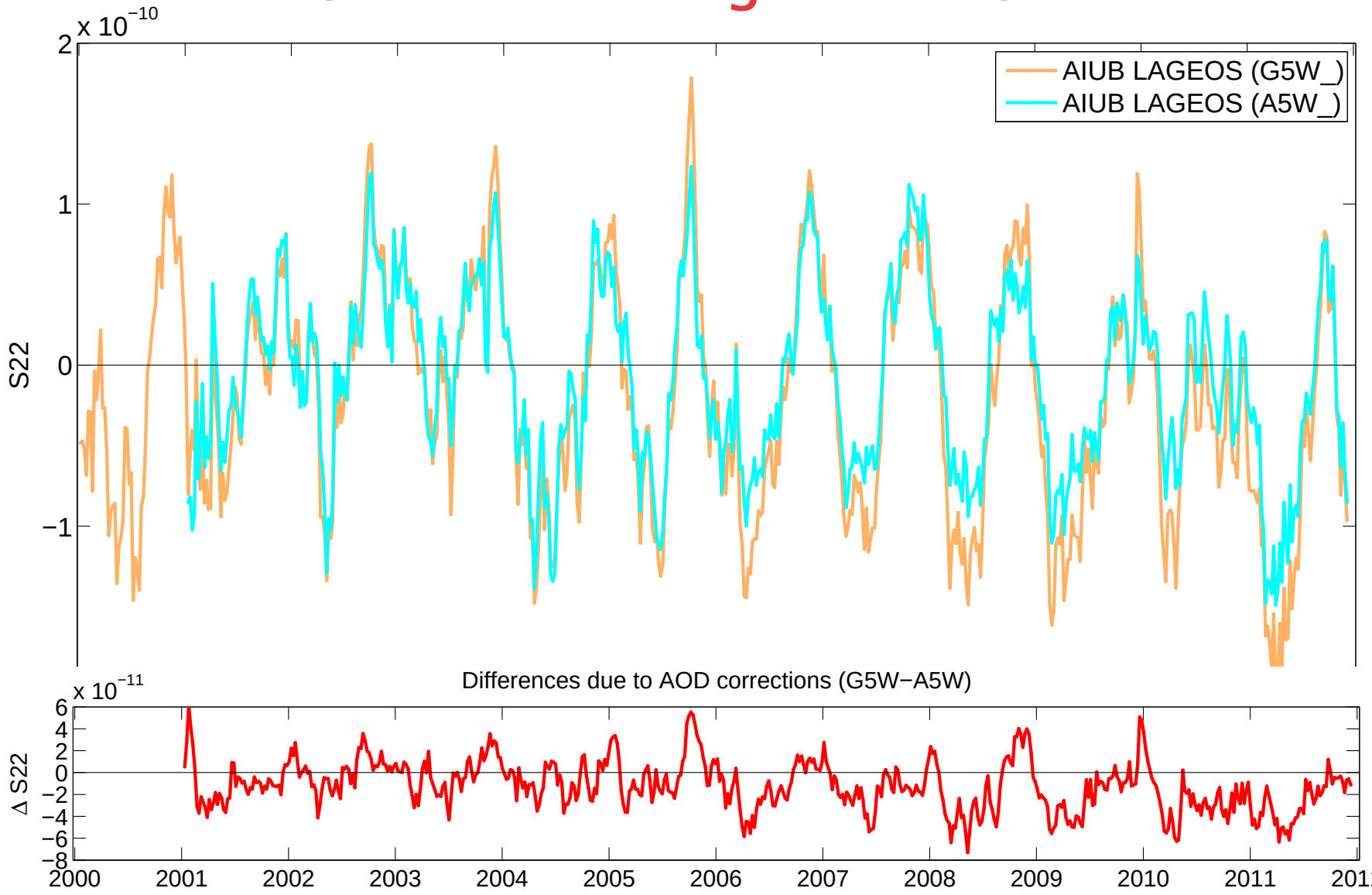
Coefficients degree 2: AOD

Atmosphere and Ocean De-aliasing (AOD) products from GRACE processing:

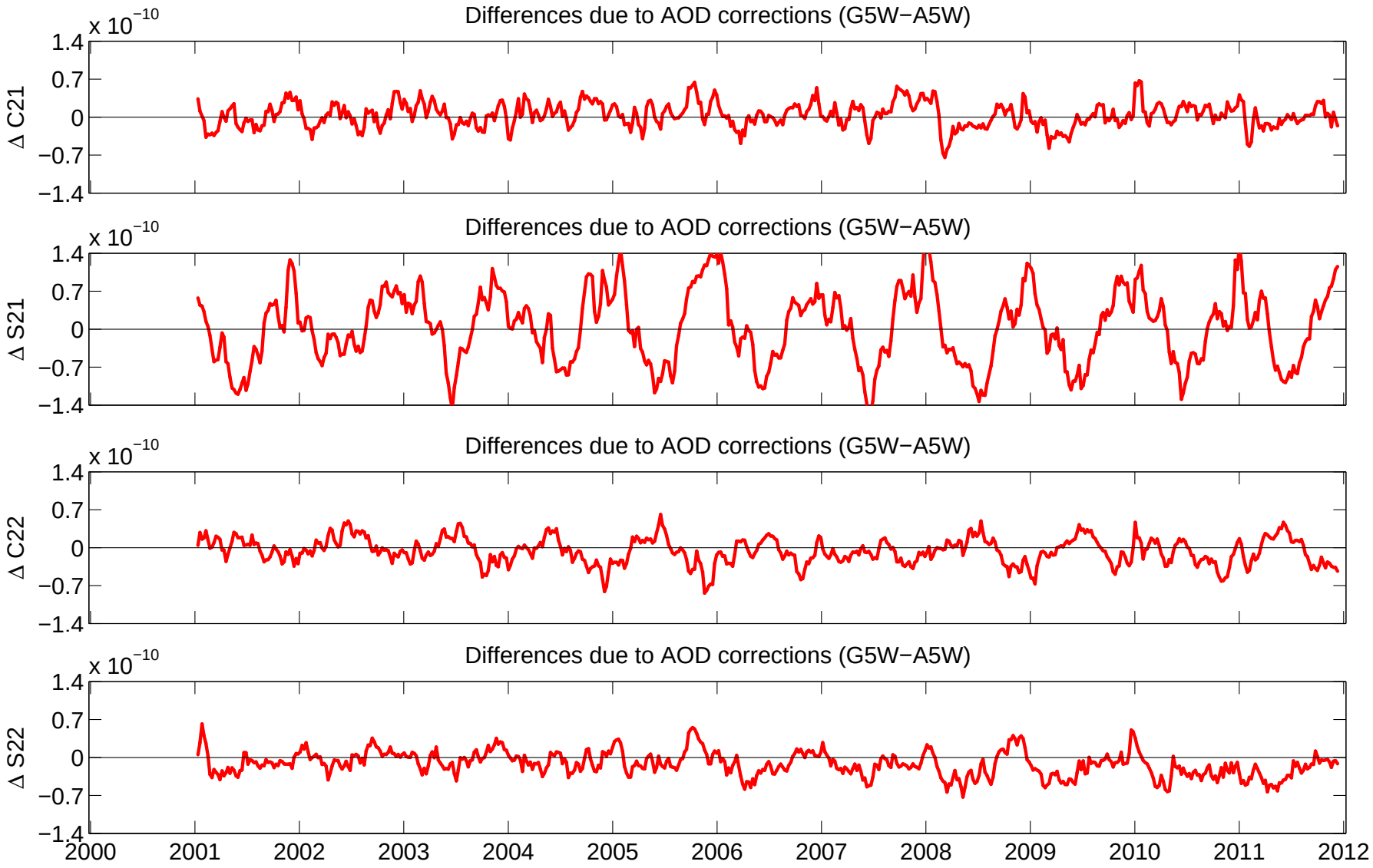
- Variations in gravity field coefficients can partly be explained by mass variations in atmosphere and oceans
- Correct for «known» variations by applying AOD products in SLR data analysis



Coefficients degree 2: AOD



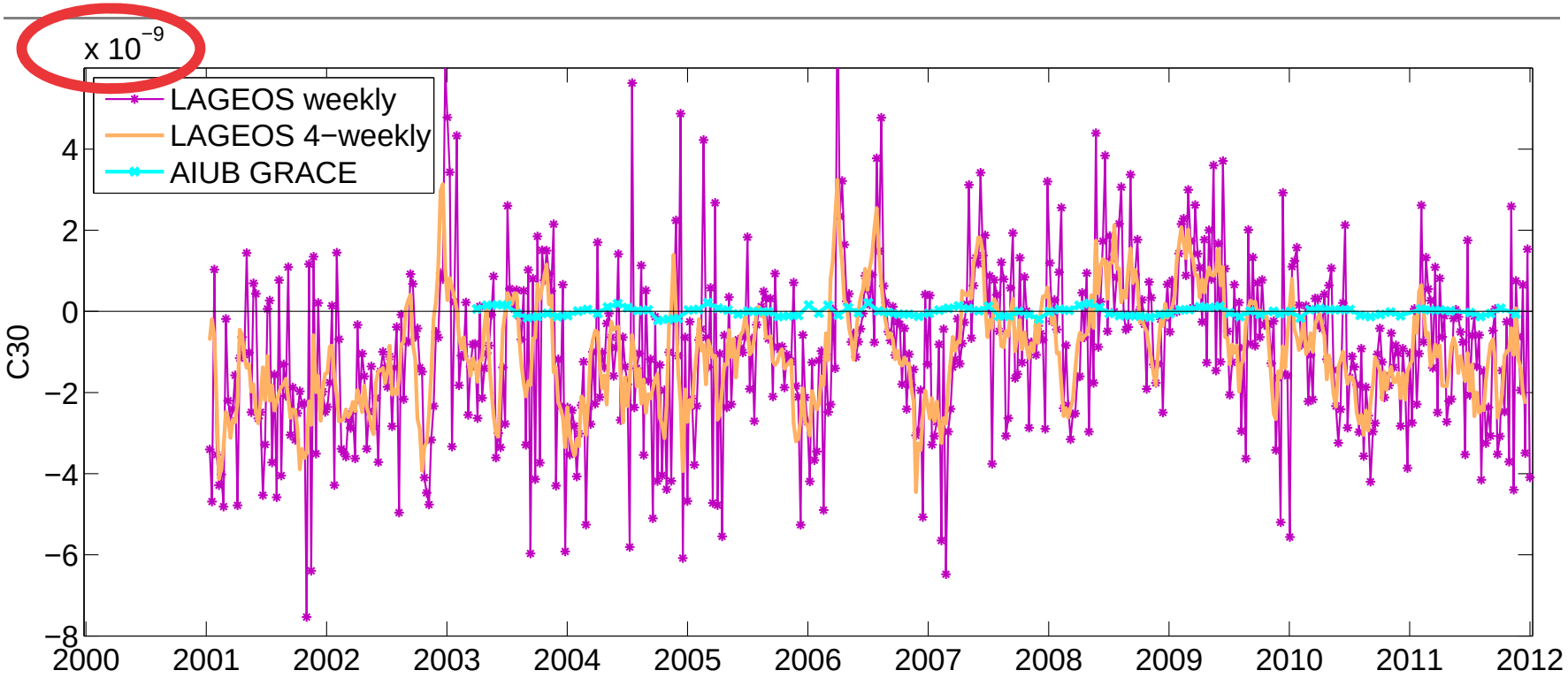
Coefficients degree 2: AOD



Coefficients degree 3

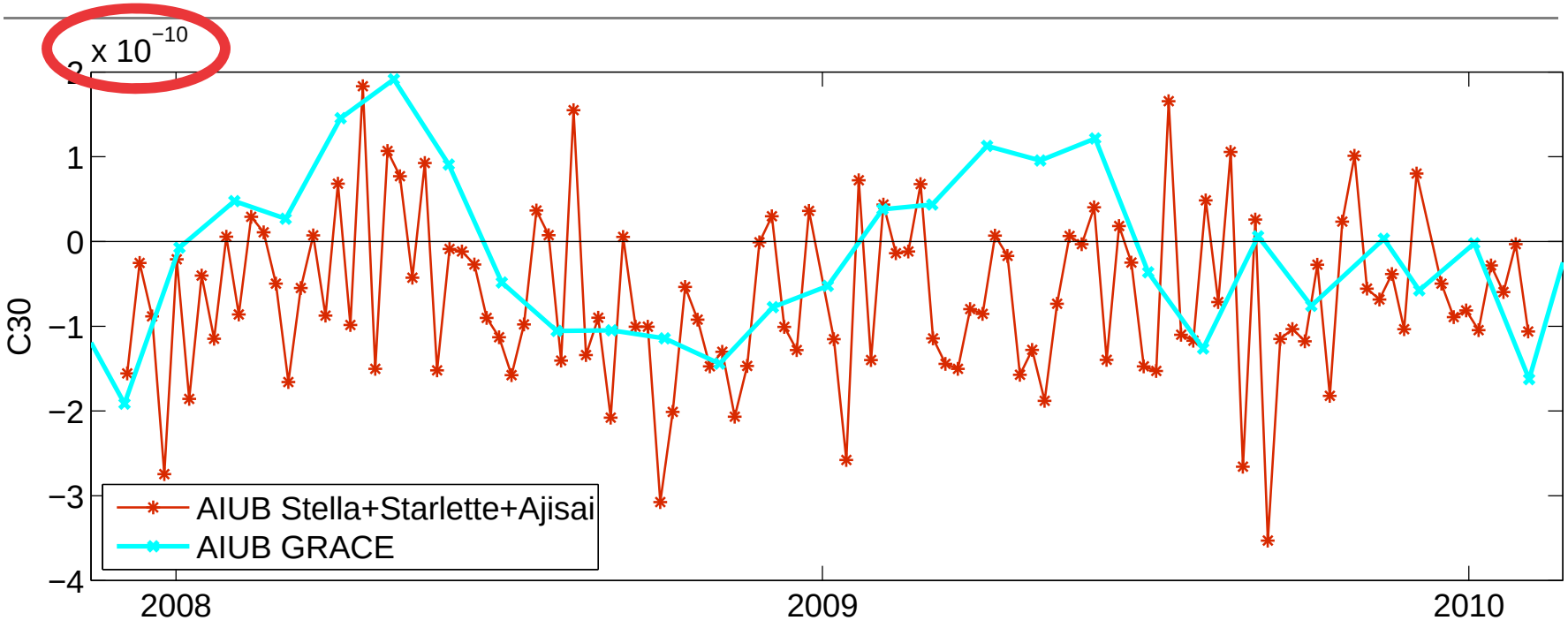
- Comparison with monthly GRACE solutions computed at AIUB:
  - Resolved up to degree 60 and order 45
  - Starting 2003
- C30 cannot be determined by LAGEOS in a reasonable way
- AOD corrections are reduced in LAGEOS and GRACE solutions (not in Stella-Starlette-Ajisai)

Coefficient C30



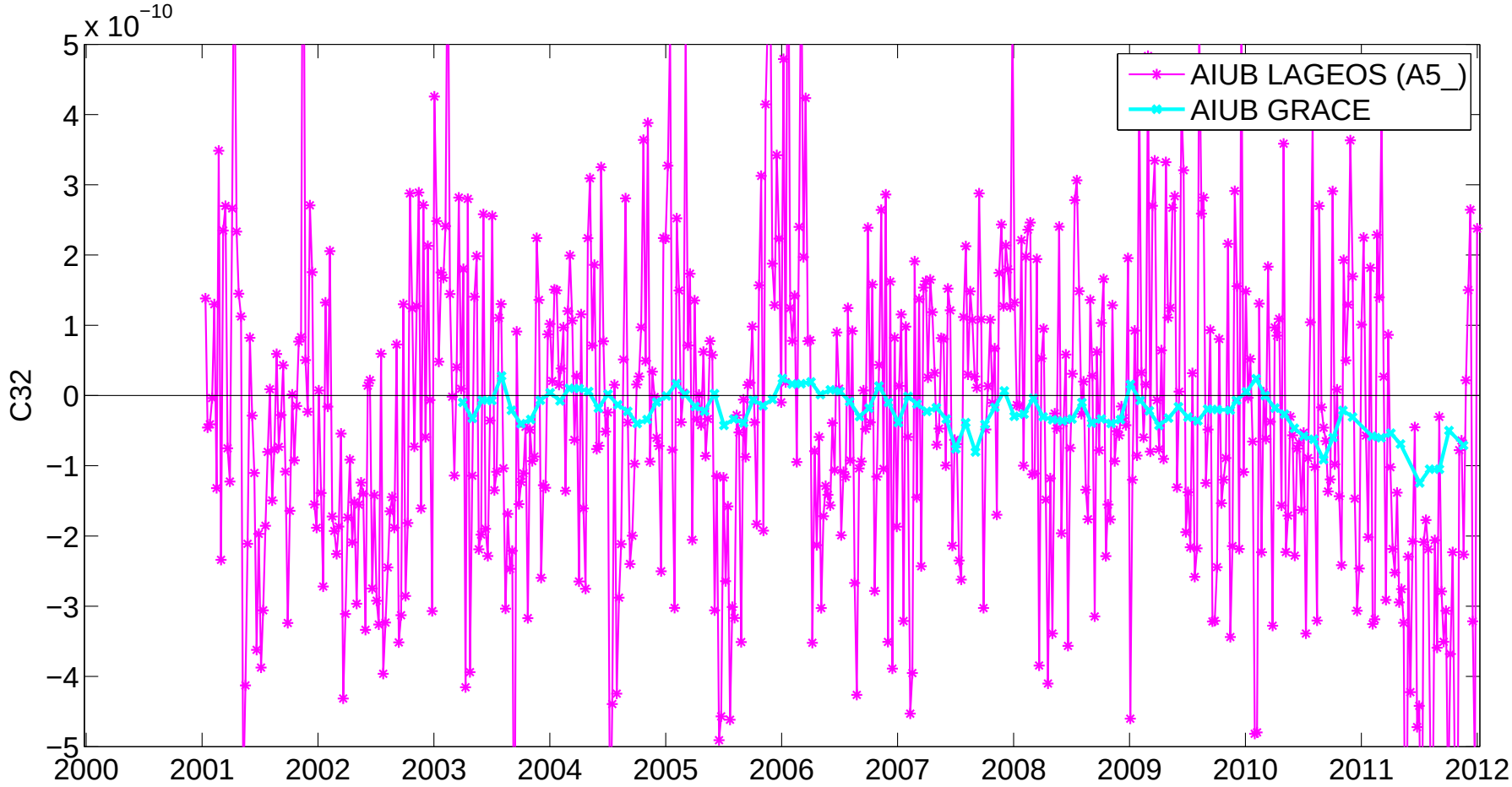
- LAGEOS is not suited for determining C30
- Even 4-weekly solution cannot determine C30

Coefficient C30



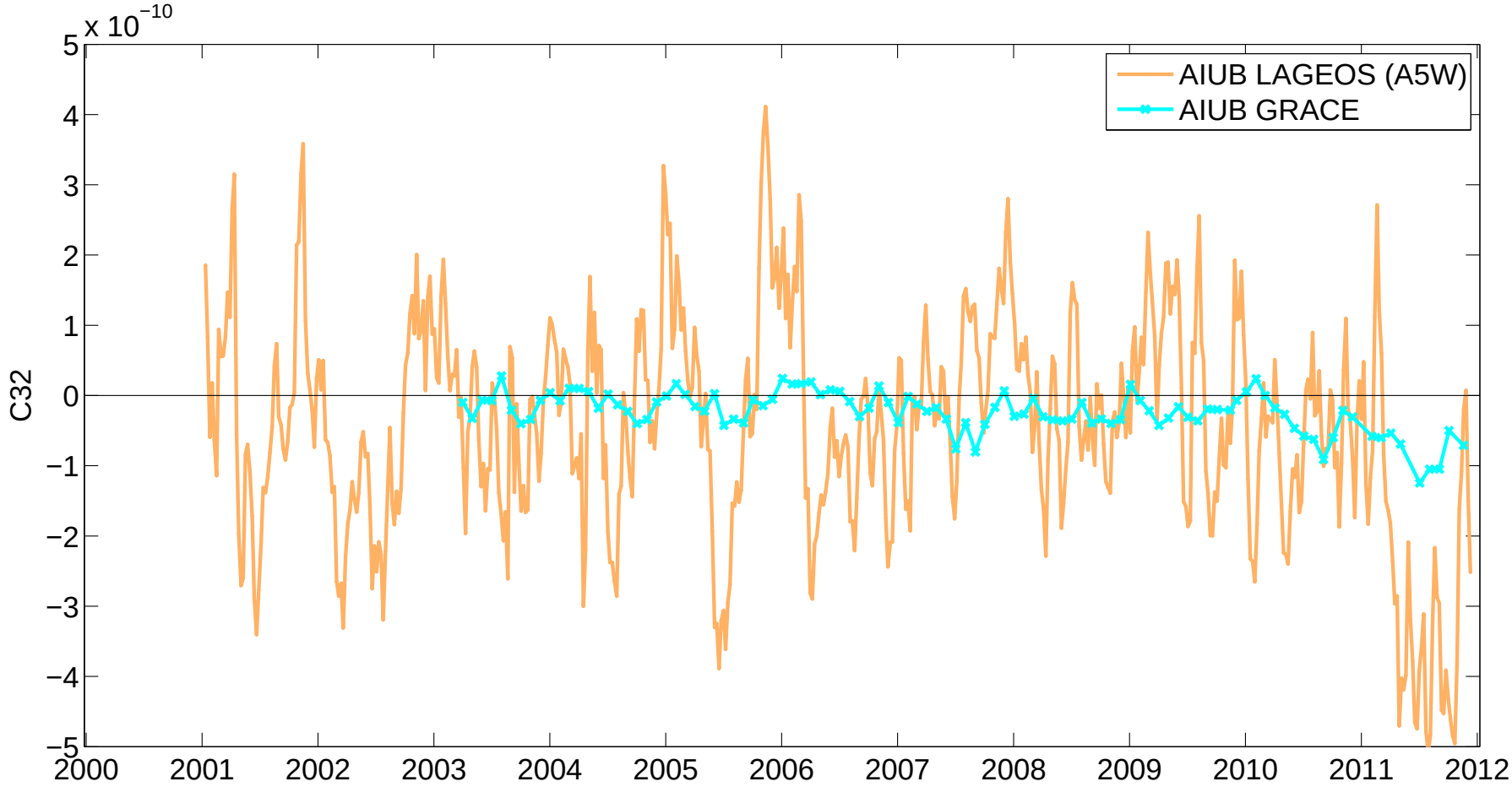
- Weekly series from **Stella-Starlette-Ajisai** agrees well with monthly series from GRACE
- Remaining differences probably due to AOD corrections

Coefficients degree 3 / order 2



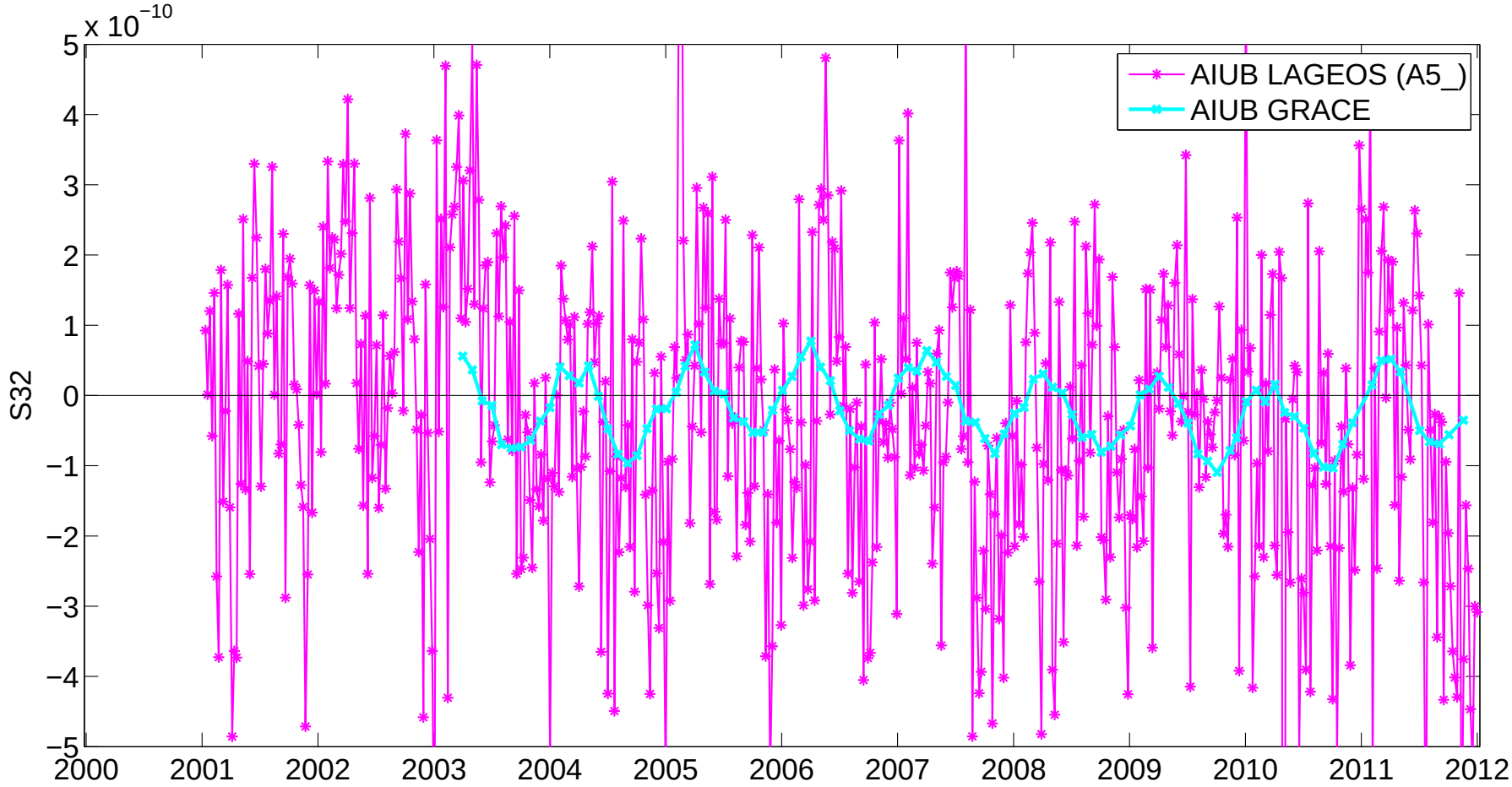
Weekly LAGEOS solutions

Coefficients degree 3 / order 2



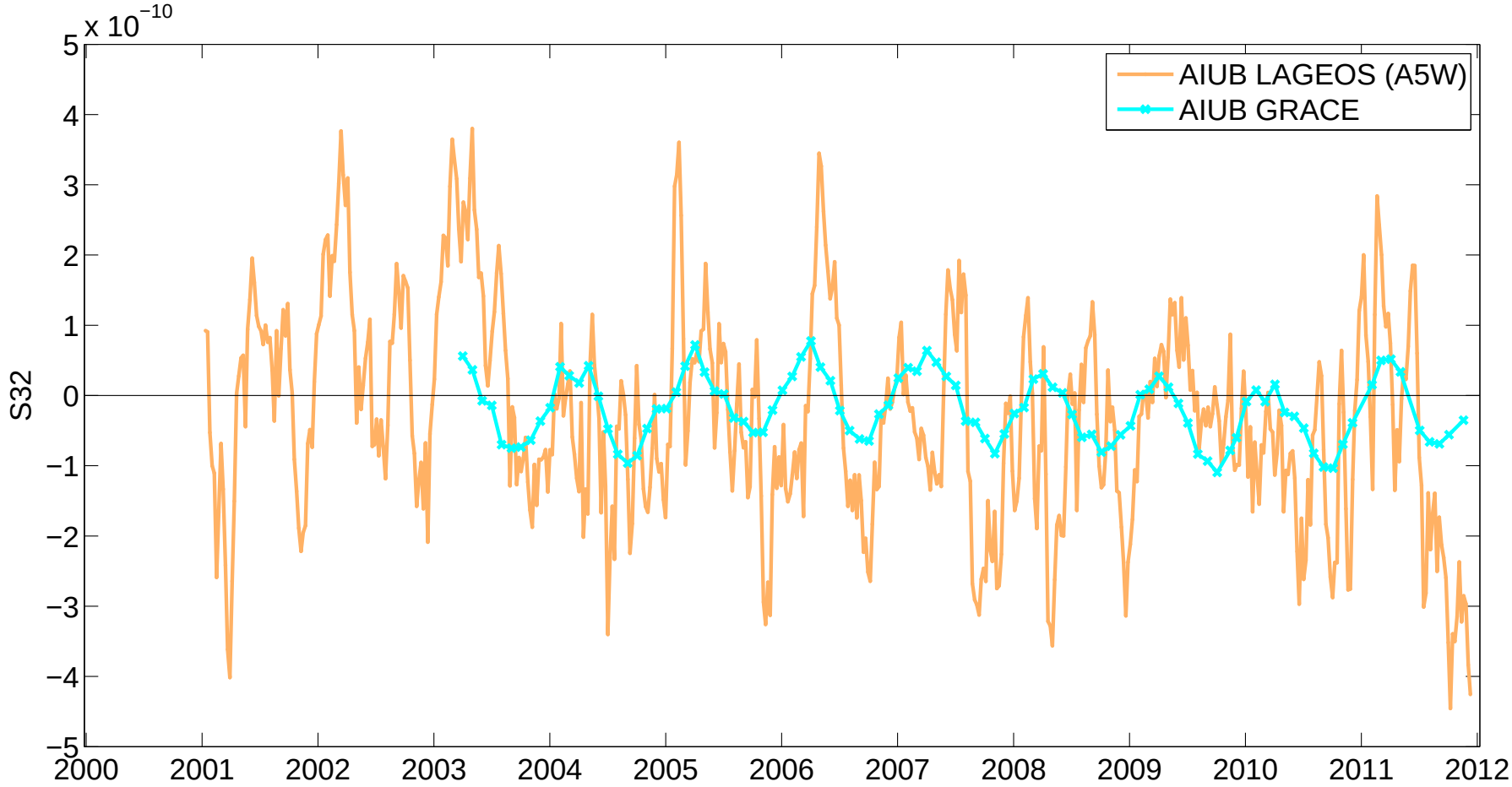
4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 2



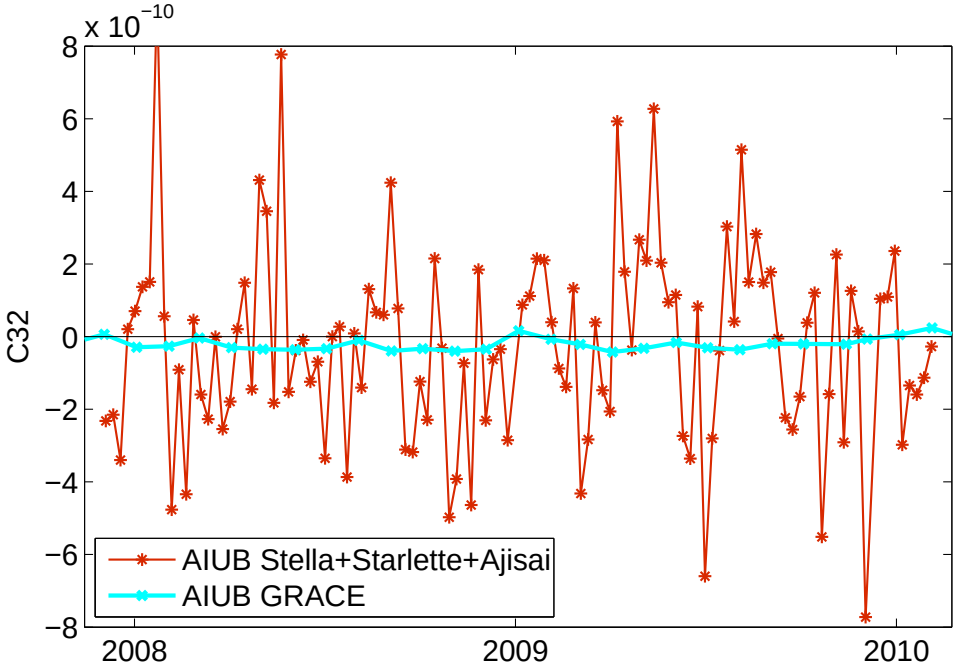
Weekly LAGEOS solutions

Coefficients degree 3 / order 2

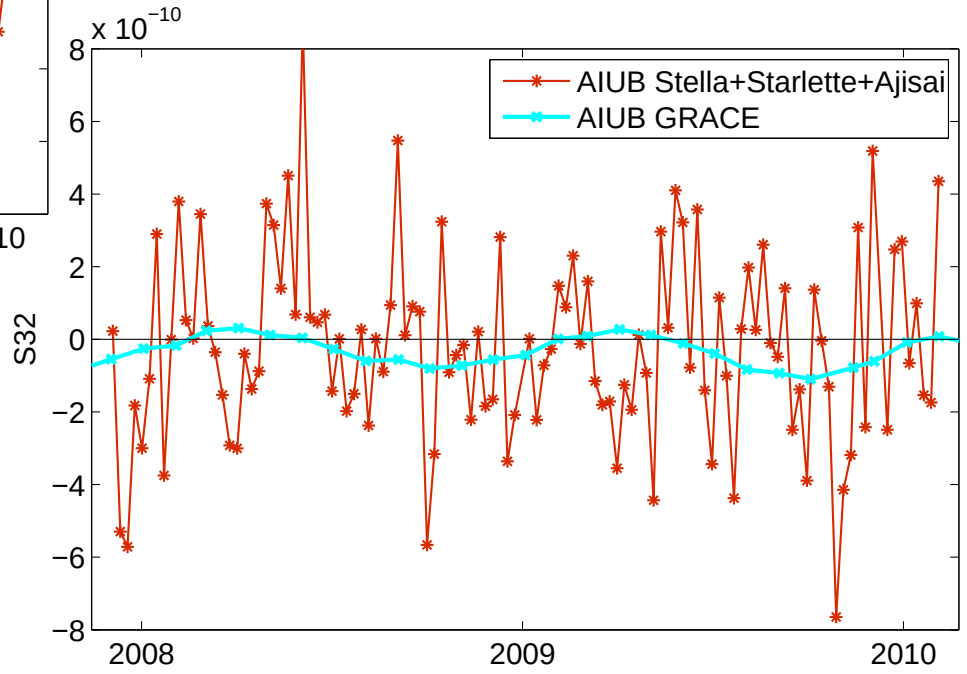


4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 2



Weekly solutions based on Starlette-Stella-Ajisai



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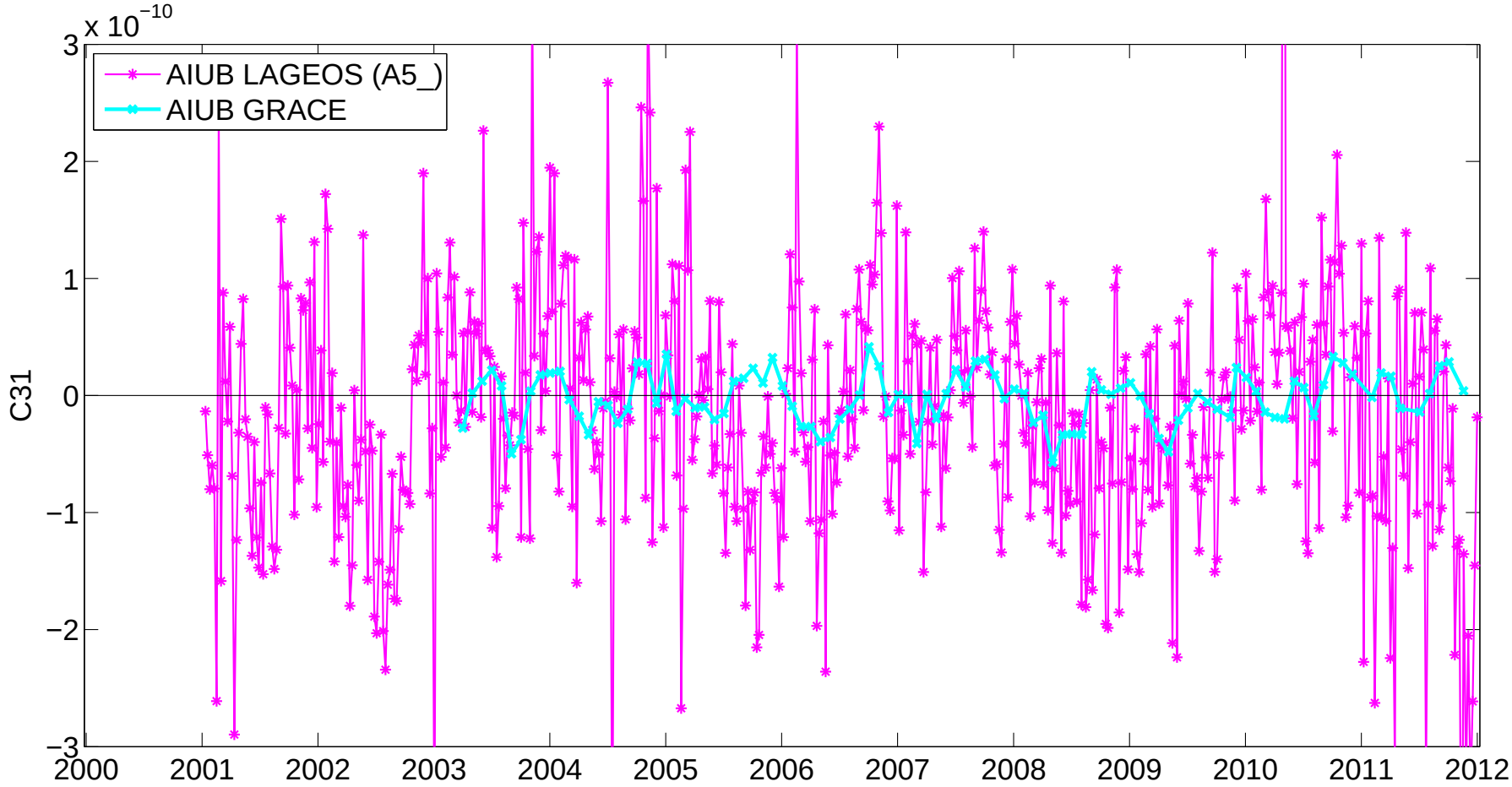
Conclusions

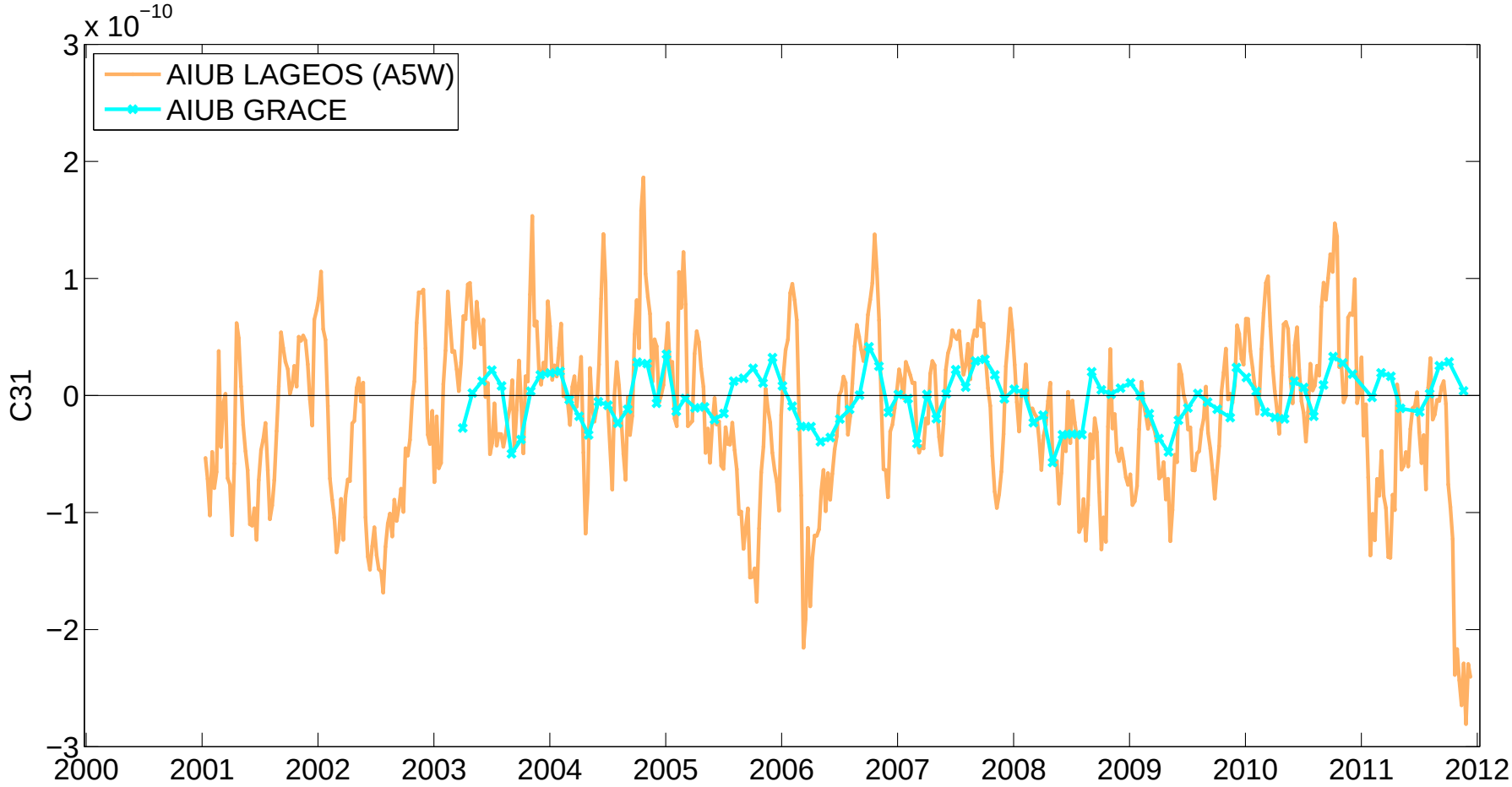
- 12 years time series of low-degree gravity field coefficients from SLR (LAGEOS-only)
- Degree 1, 2 and 3
- Weekly resolution needed to track short-period variations
- Weekly solutions are very noisy
- But 4-week solution series with sliding windows suitable to achieve weekly resolution
- AIUB and DGFI weekly series are comparable
- 4-week solution LAGEOS-only comparable with GRACE
- Promising solutions from Stella-Starlette-Ajisai

Coefficients degree 3 / order 1



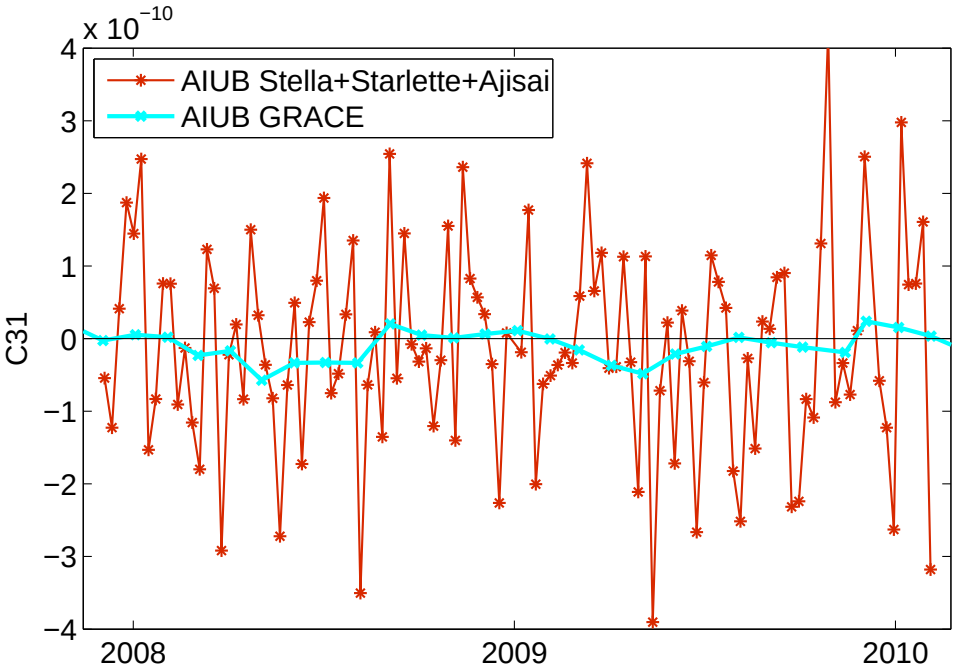
Weekly LAGEOS solutions

Coefficients degree 3 / order 1

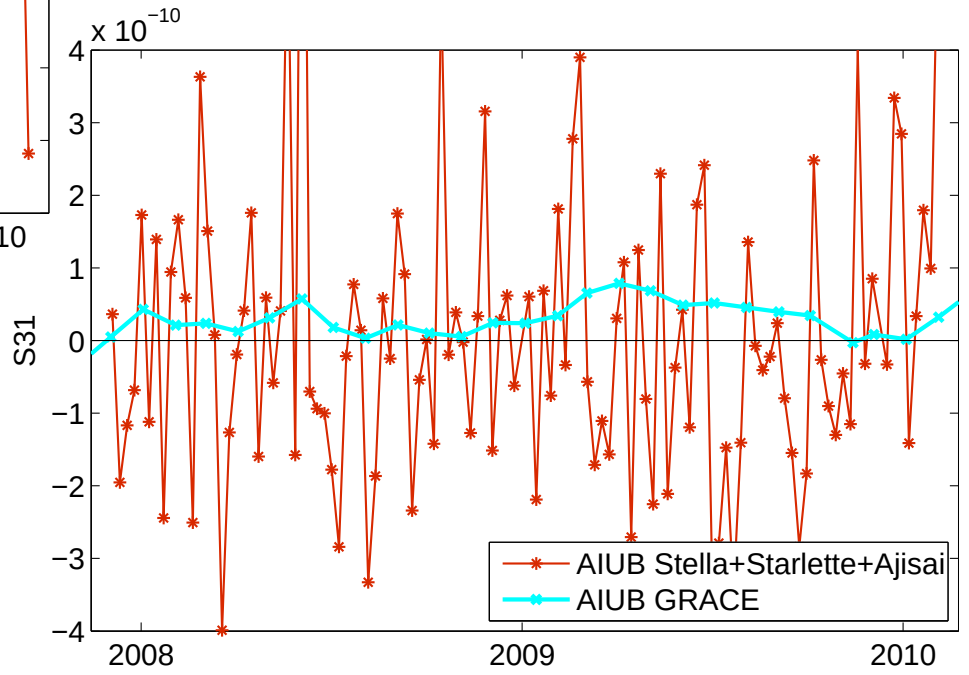


4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 1



Weekly solutions based on Starlette-Stella-Ajisai



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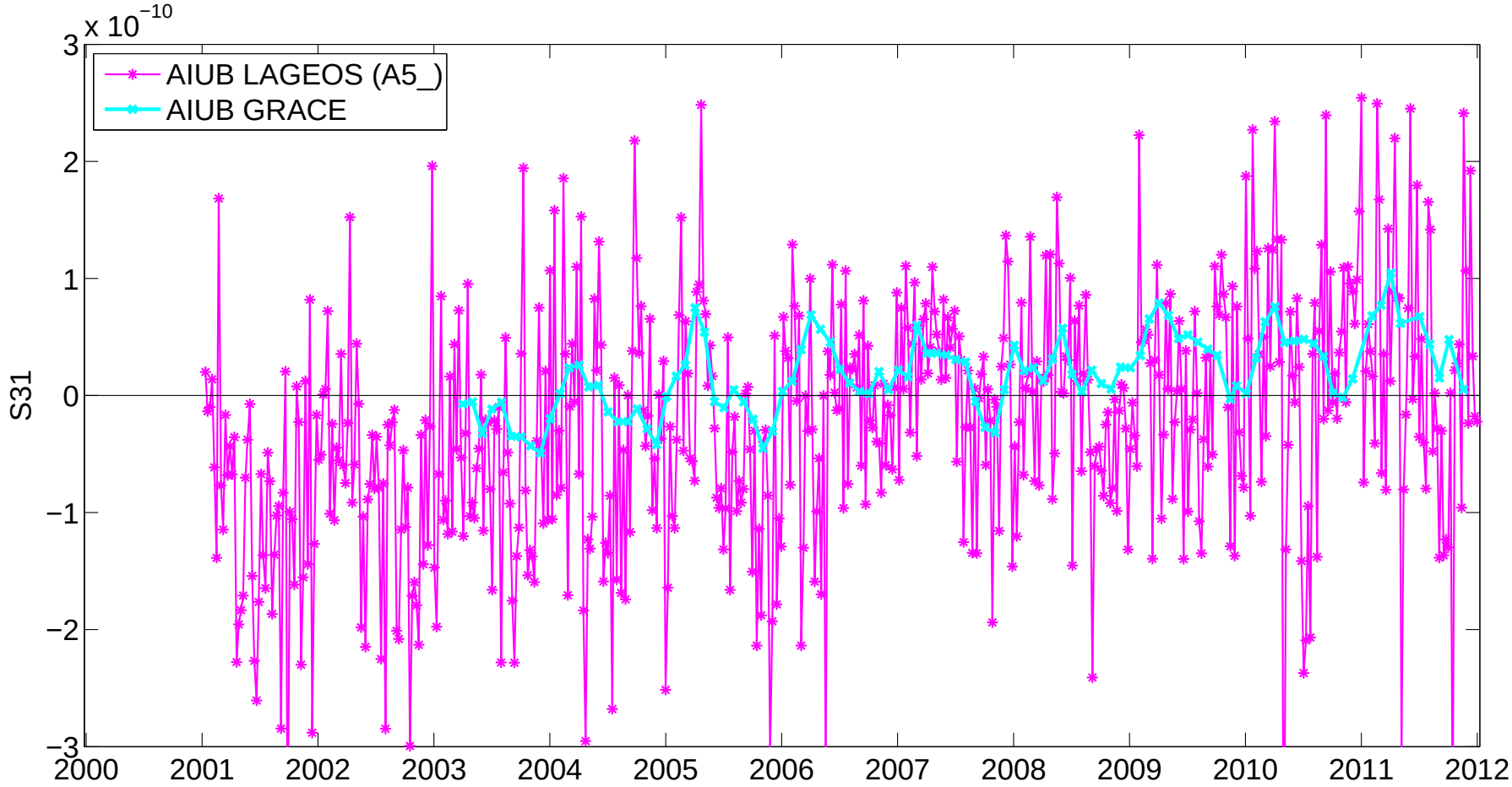
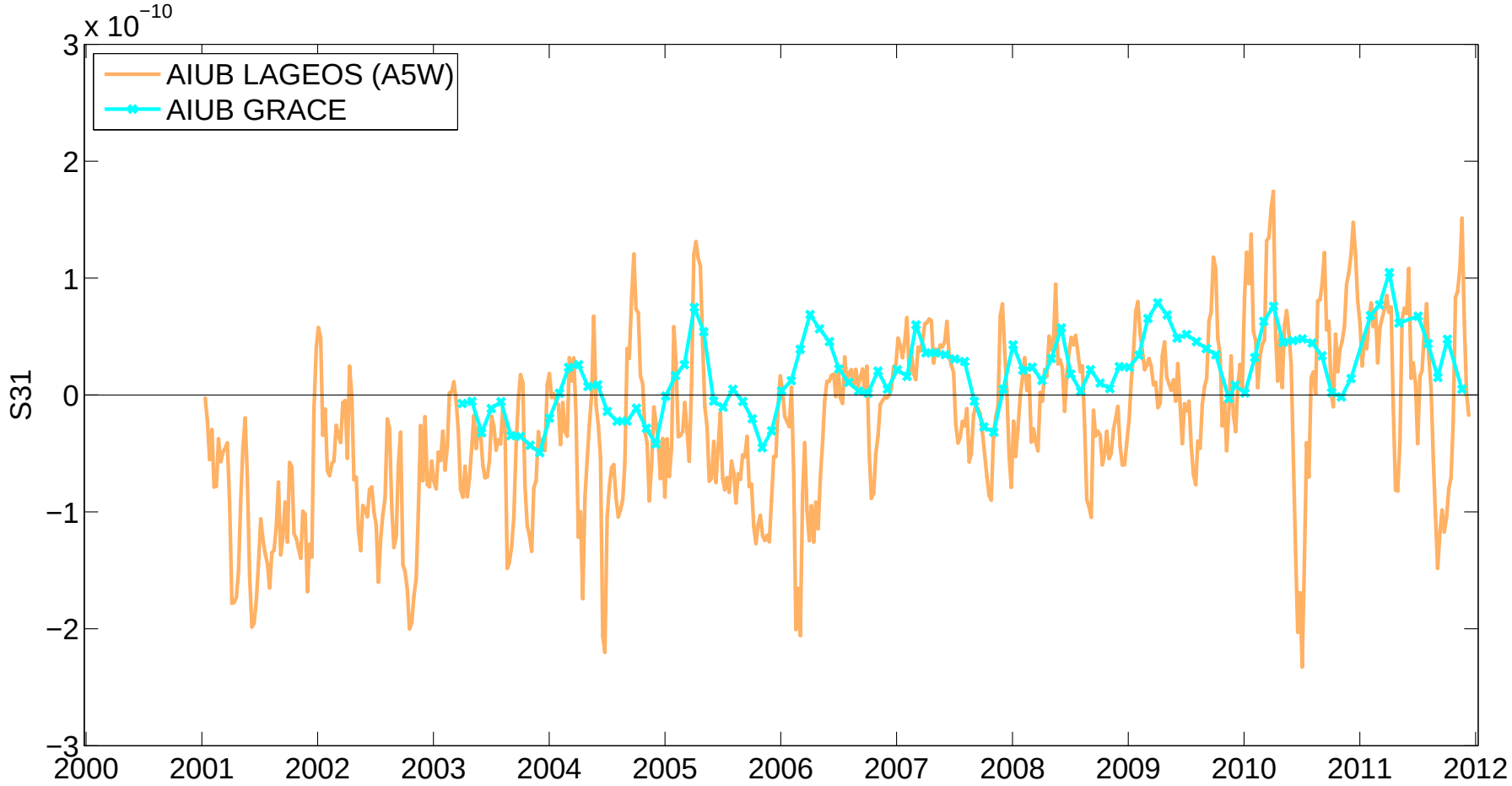
Coefficients degree 3 / order 1



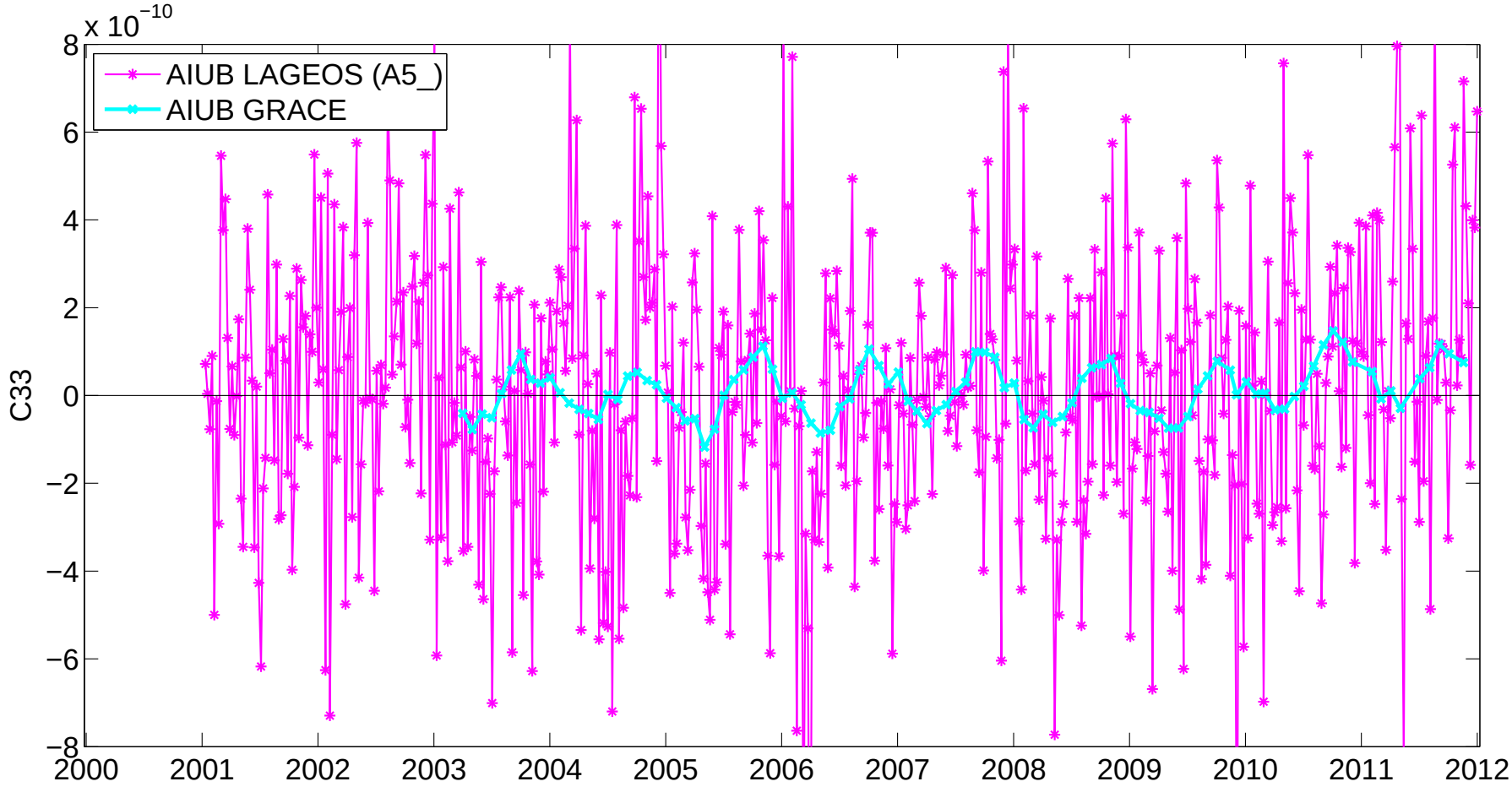
Weekly LAGEOS solutions

Coefficients degree 3 / order 1



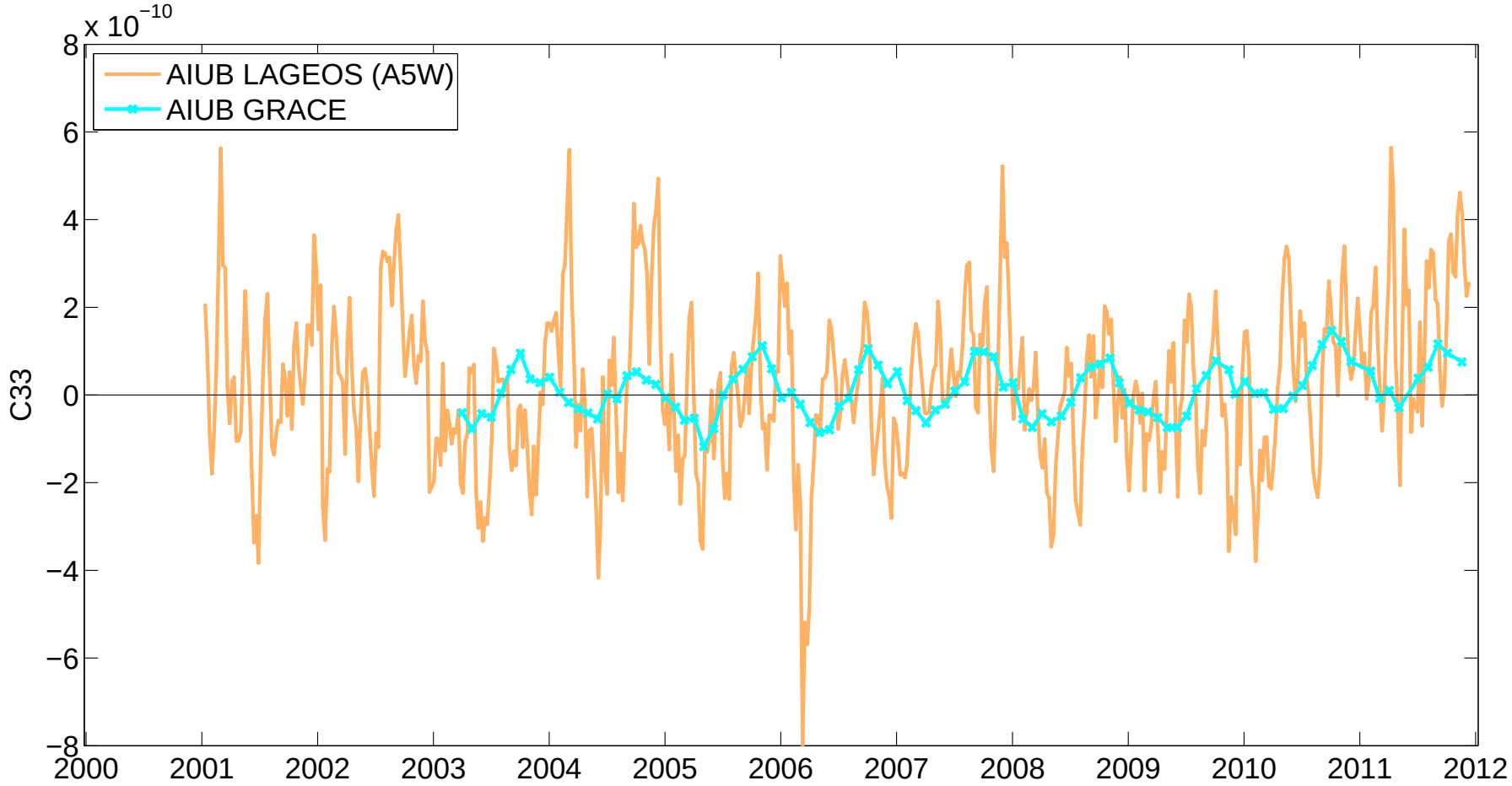
4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 3



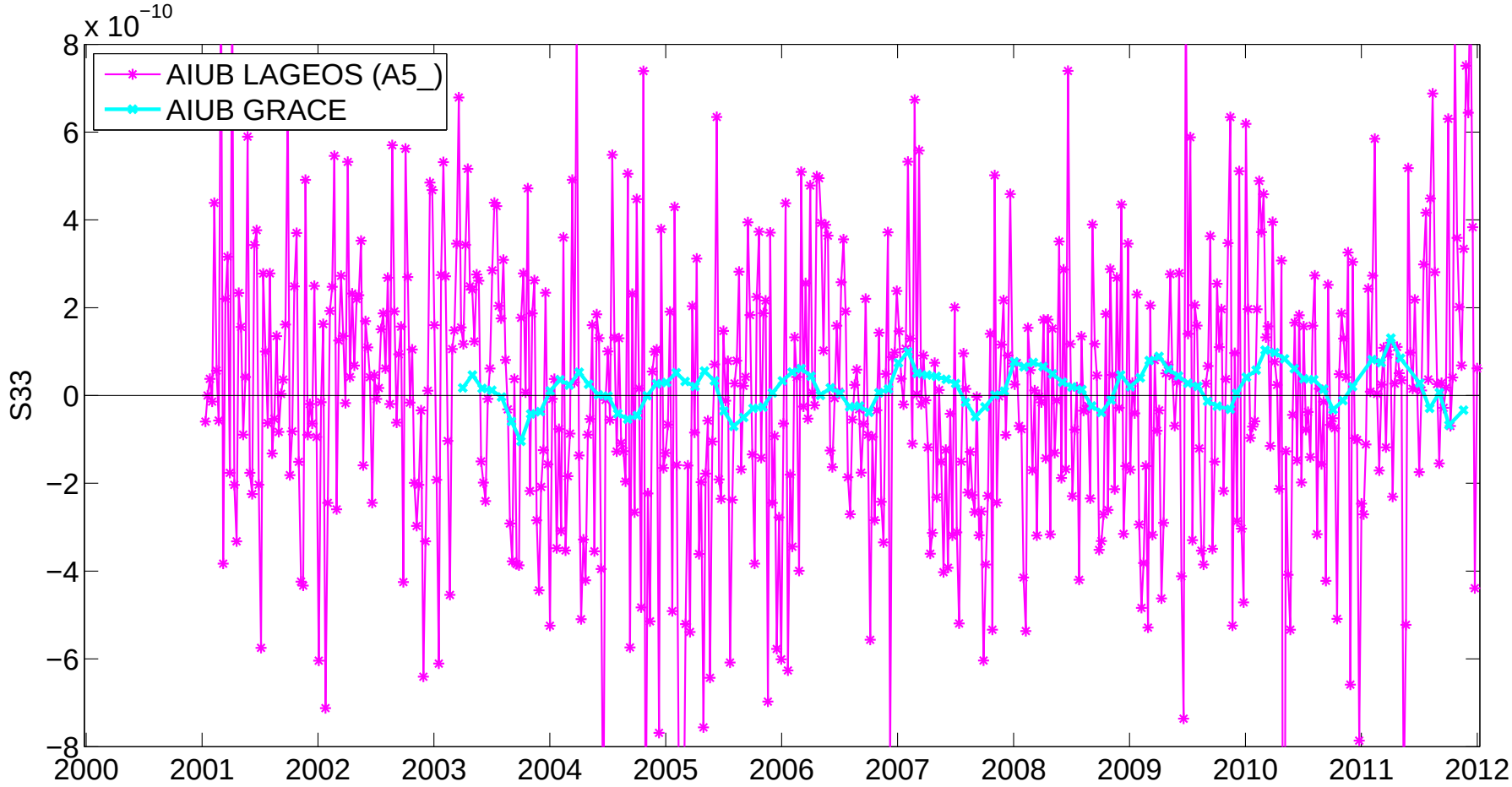
Weekly LAGEOS solutions

Coefficients degree 3 / order 3



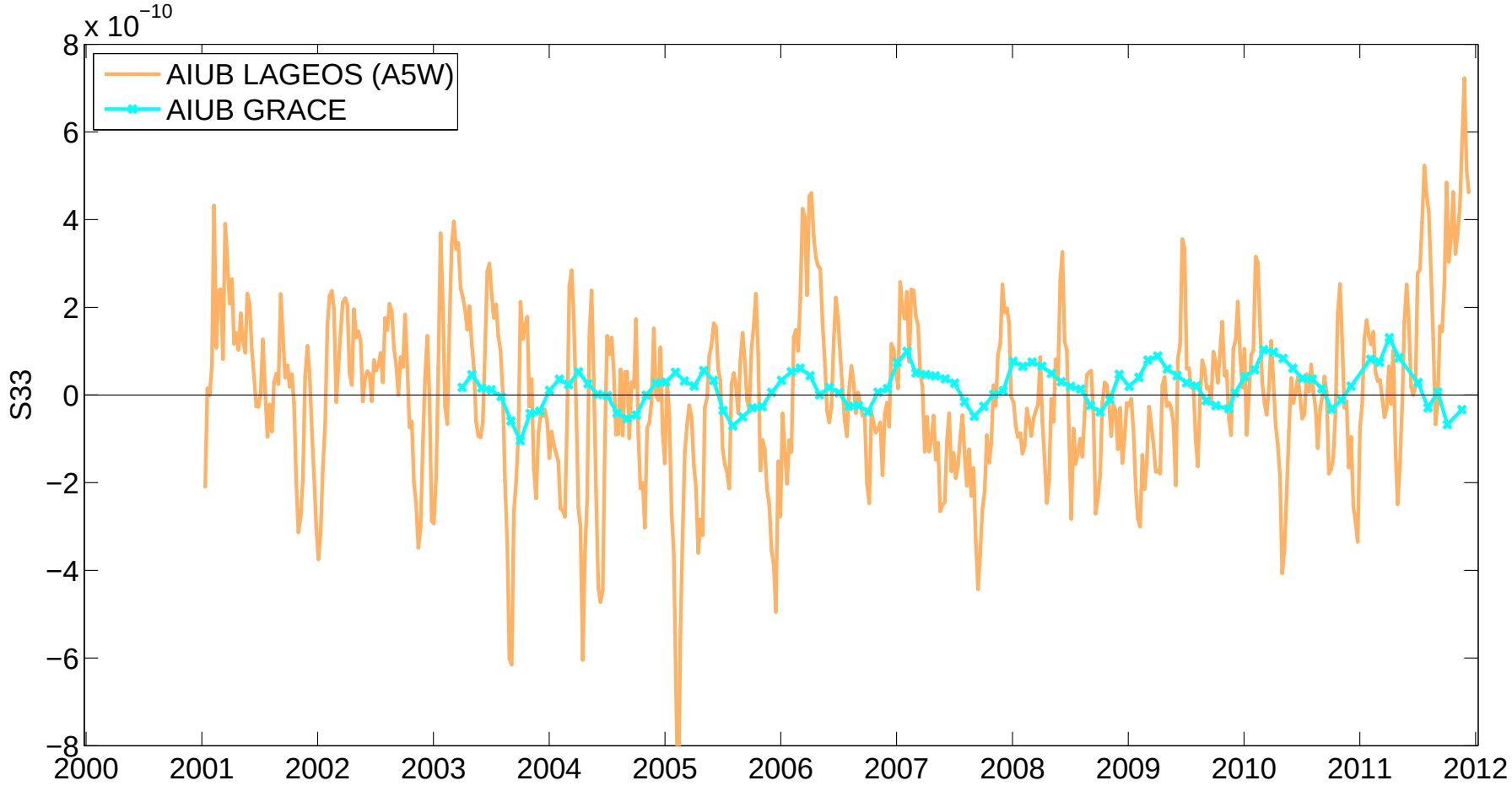
4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 3



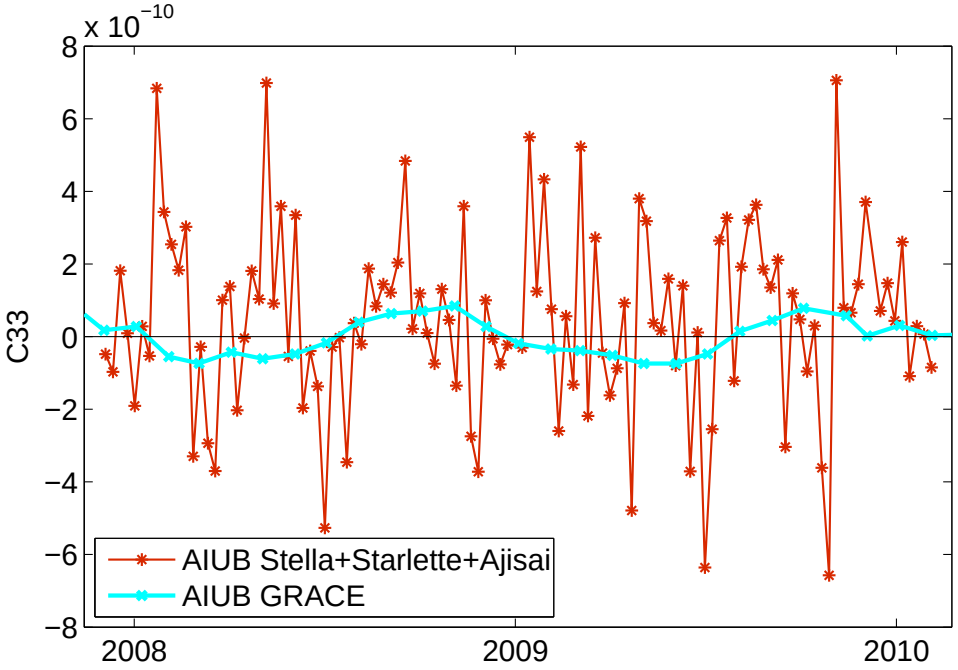
Weekly LAGEOS solutions

Coefficients degree 3 / order 3

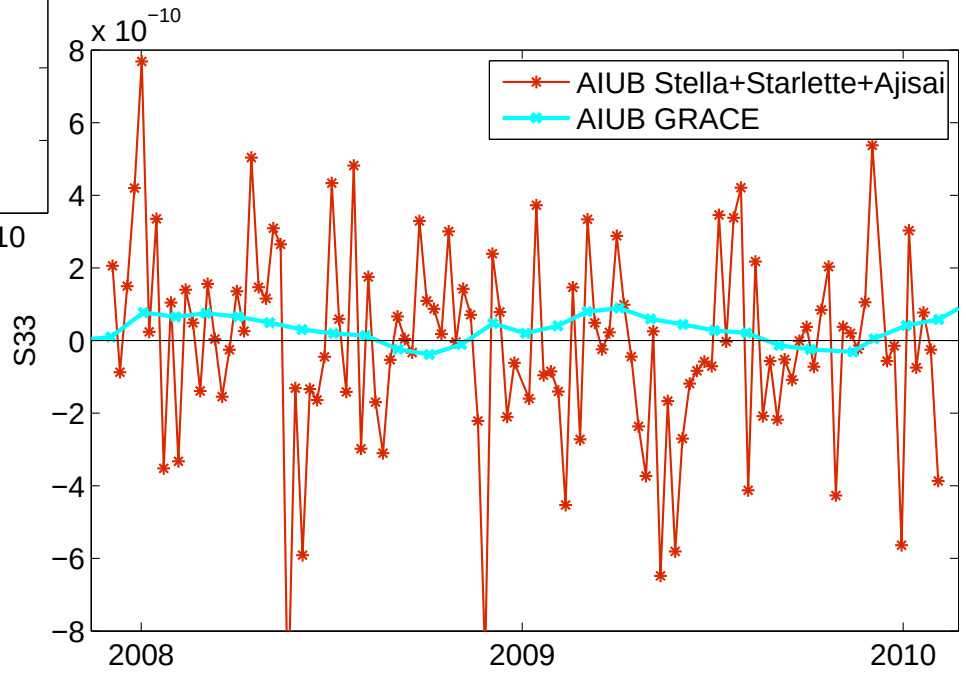


4-weekly LAGEOS solutions (sliding window):

Coefficients degree 3 / order 3



Weekly solutions based on Starlette-Stella-Ajisai



A. Jäggi et al.: Low-degree gravity field coefficients from SLR
COSPAR 2012